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Transboundary particulate matter, photo-oxidants, acidifying and eutrophying components

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Executive Summary

This report presents the EMEP activities in 2019 and 2020 in relation to transboundary fluxes of particulate matter, photo-oxidants, acidifying and eutrophying components, with focus on results for 2018. It presents major results of the activities related to emission inventories, observations and modelling. The report also introduces specific relevant research activities addressing EMEP key challenges, as well as technical developments of the observation and modelling capacities.

Measurements and model results for 2018

In the first chapter, the status of air pollution in 2018 is presented, combining meteorological information and emissions with numerical simulations using the EMEP MSC-W model together with observed air concentration and deposition data.

Altogether 35 Parties reported measurement data for 2018, from 170 sites in total. Of these, 120 sites reported measurements of inorganic ions in precipitation and/or main components in air; 70 of these sites had co-located measurements in both air and precipitation. The ozone network consisted of 141 sites, particulate matter was measured at 68 sites, of which 44 performed measurements of both PM_{10} and $PM_{2.5}$. In addition, 56 sites from 21 Parties reported at least one of the components required in the advanced EMEP measurement program (level 2). However, very few sites provided a complete level 2 program, i.e. only 12 sites have implemented all the required aerosol parameters.

The mean daily max O_3, SOMO35 and AOT40 all show a distinct gradient with levels increasing from north to south, a well established feature for ozone reflecting the dependency of ozone on the photochemical conditions. The geographical pattern in the measured values is fairly well reflected by the model results for all these three metrics.

PM pollution was rather moderate in 2018, in particular in Central, Western and Southern Europe (10-30% lower compared to the 18-year average) due to the relatively mild winter and more precipitation. Only in Turkey, the Caucasus region, Ukraine, the Baltic countries and southern parts of Finland and Sweden, PM_{10} and $PM_{2.5}$ levels were higher. EMEP MSC-W model calculations and EMEP observations show a general increase of annual mean PM_{10} and $PM_{2.5}$ over land from north to south, with concentrations being below 2-5 μg m^{-3} in Northern Europe and increasing to 5-15 μg m^{-3} in the mid-latitudes and further south. The distribution of the regional background PM is fairly homogeneous over most of Central and

Western Europe, with somewhat elevated PM_{10} levels of 15-20 μg m^{-3} in the Po Valley and the Benelux. The observations also show elevated PM_{10} concentrations in Poland, Czechia and Hungary, while the model calculates high PM for the regions east of the Caspian Sea and over the southern Mediterranean (heavily influenced by Saharan dust).

There is good agreement between the modelled and observed PM_{10} and $PM_{2.5}$, with annual mean model biases of -22% and -14% and correlation coefficients of 0.66 and 0.81, respectively.

Model results and EMEP observational data show that the annual mean regional background PM_{10} concentrations were below the EU limit value of 40 μg m^{-3} in Europe in 2018, but some exceedances of the WHO recommended AQG of 20 μg m^{-3} occurred. The annual mean $PM_{2.5}$ concentrations in 2018 were below the EU limit value of 25 μg m^{-3} (except modelled $PM_{2.5}$ for the Po Valley). However, exceedances of the WHO AQG value of 10 μg m^{-3} by annual mean $PM_{2.5}$ were observed at seventeen sites.

Out of the 62 sites, days with PM_{10} exceedances of 50 μg m^{-3} were observed at 36, but in all cases with fewer than the upper EU-limit of 35 days per year registered. Still, 18 sites had more than 3 exceedance days (the upper limit recommended by the WHO AQGs). Daily mean $PM_{2.5}$ concentrations exceeded the WHO AQG recommended of value 25 μg m^{-3} at 31 out of 41 stations in 2018. Among those, at 21 sites the number of exceedance days were more than 3 (the recommended limit according to WHO AQG). The modelled numbers of exceedance days in 2018 show in general a good correspondence with the observations, with somewhat better agreement for PM_{10} than for $PM_{2.5}$. The model has a tendency of underestimating the frequency of exceedance days at some Central European sites and overestimating at some Mediterranean sites. The majority of PM exceedances occurred during the winter and autumn 2018 at Central European sites, whereas during the summer at the Mediterranean sites. Remarkably, the largest number of $PM_{2.5}$ exceedances at three out of four German sites occurred in spring, while much fewer occurred during the cold seasons.

The summer of 2018

During April/May-August parts of Europe experienced a persistent heat wave. Northern Europe and in particular the Nordic countries and the UK were most heavily affected, but also central parts of the continent experienced long-lasting heat and drought in summer. The heat and drought affected the atmospheric level of pollutants in many ways. Tropospheric ozone is strongly tied to the meteorological conditions, and hot, sunny and dry weather conditions can lead to increased ozone levels in many ways.

The continent experienced a series of ozone episodes during April/May-August. The most pronounced lasted from the last part of July to the first days of August when areas from Southern Italy to Scandinavia were affected and peak values exceeding 100 ppb were seen at several sites. Another marked ozone episode was seen one month earlier, from the end of June to the first week of July, mainly affecting Central Europe.

Long-term time series of EMEP ozone measurements show a downward trend in the metrics SOMO35 and AOT40 reflecting the reduced emission of precursors, whereas the levels in 2018 were clearly elevated. This is a clear message that an efficient abatement of surface ozone depends on future climate change as well as on the reduction of NO_x and VOCs emissions. The high levels of AOT40 in 2018 should, however, not be used directly to assess ozone effects on vegetation. The extreme drought likely reduced the uptake of ozone in the plants, leading to increased near-surface ozone.

PM_{10} and $PM_{2.5}$ levels in Northern Europe were generally increased all of summer 2018. The increase was mainly attributed to fine ($PM_{2.5}$) OC (organic carbon) and mineral dust, which formation and emission were governed by the favourable meteorological conditions. Some sites experienced a substantial 250-400 % increase in the mineral dust loading compared to the 2013-2017 period, with source regions both within and outside of Europe. Isoprene levels were elevated compared to previous years, as were 2-methyltetrols, which are oxidation products of isoprene partitioning to the particulate phase. Unchanged EC levels and reduced BB (biomass burning) and PBAP (primary biological aerosol particles) tracer levels point to BSOA (biogenic secondary organic aerosol) formation as the explanation of the increased level of fine OM in summer 2018.

Status of emission reporting

In 2020, 43 out of 51 Parties (84%) submitted emission inventories to the EMEP Centre on Emission Inventories and Projections (CEIP), and 40 Parties reported black carbon (BC) emissions, 38 of them for the year 2018. The quality of reported emission data differs significantly across countries, and the uncertainty of the data is considered to be relatively high.

2017 was the first year with reporting obligation of gridded emissions in $0.1°\times0.1°$ longitude/latitude resolution. Until June 2020, 32 of the 48 countries which are considered to be part of the EMEP area reported sectoral gridded emissions in this resolution. For remaining areas, missing emissions are gap-filled and spatially distributed using expert estimates. Emissions from international shipping in different European seas were estimated based on the CAMS global shipping emission dataset for the year 2018.

The 1999 Gothenburg Protocol lists emission reduction commitments of NO_x, SO_x, NH_3 and NMVOCs for most of the Parties to the LRTAP Convention for the year 2010. These commitments should not be exceeded in 2010 nor in subsequent years. When considering only reported data, approved adjustments and fuel use data of the respective countries, it can be seen that Czechia had not reduced its NMVOC emissions according to the Gothenburg Protocol requirements, and that Croatia, Denmark, Germany, Norway and Spain are above their Gothenburg Protocol ceilings for NH_3. In terms of NO_x emissions, Norway exceeded its ceilings. For SO_x all countries were below their individual ceilings.

Condensable organics: model evaluation and source receptor matrices for 2018

Estimates of PM emissions as currently provided by Parties have a number of major uncertainties, and there is a clear need for clarification and standardisation of the methods used to define and report PM emissions. Previous work has clearly shown that the definitions behind national emission estimates are inconsistent in their treatment of condensable organics: some countries explicitly do not include condensables in their PM inventories, some likely include condensables and for some it is mixed or unclear. In 2019 and 2020, Parties were asked to include a table with information on the condensable component in their reporting of PM emissions. This year, 21 Parties provided such information. The treatment of condensable organics in emission factors is best known for the emissions from the energy sector and road transport, while it is less clear for small-scale combustion, which is one of the sources where the largest impact on the emission factor occur.

In March 2020, MSC-W hosted an expert workshop on condensables (funded by the Nordic Council of Ministers (NMR)), which brought together experts in emissions, measure-

ments, inventories, and policy from Europe and North America, and created a much better understanding of the issues and possible approaches for dealing with this important class of compounds. Discussions at the NMR workshop confirmed that even when countries did include condensables, there were significant differences in the methodologies used. Furthermore, the workshop agreed that as a first step the TNO Ref2 emissions for GNFR[1] sector C (where condensables are added to small-combustion emissions in a harmonised way) is a good first no-regret step for describing condensable emissions in atmospheric dispersion modelling. The EMEP Bureaux decided that EMEP MSC-W should make use of the Ref2 emissions for condensable organics in order to produce more consistent model results.

Therefore, the assessment of the air quality situation in Europe and source receptor calculations for 2018 made this year, have been conducted with official EMEP emissions combined with TNO Ref2 emissions for the GNFR sector C for PM (EMEPwRef2C). These model results, and in addition model results using officially reported PM emissions, have been compared to EMEP and EEA observations - showing improved performance for $PM_{2.5}$, especially in wintertime, in the case where condensables are consistently included.

The improvement was seen for most countries, although as expected, the extent of the change depends on the country and location (and the methods used to define PM emissions in nearby countries). Although there is good evidence for the basic concepts which are applied here, many of the assumptions are very uncertain, even by the standards of organic aerosol modelling in general.

For some countries (e.g. Norway, Bulgaria, Italy), the EMEPwRef2C and EMEP estimates of $PM_{2.5}$ emissions are comparable, but for others (e.g. Austria, Estonia, France, Germany, the Netherlands and Switzerland) the EMEPwRef2C estimate is far higher than the reported emissions. For a few countries EMEPwRef2C is lower (e.g. Croatia, Hungary). In order to estimate the impact of such differences on source-receptor matrices we have calculated the changes in country-to-itself and import-to-country for $PM_{2.5}$ for all the Parties, using the two different emission estimates. The changes in $PM_{2.5}$ and especially $PPM_{2.5}$ were quite sensitive to the different emission setups, with differences in country-to-itself contributions up to a factor 5 for $PPM_{2.5}$, and up to a factor 2 for $PM_{2.5}$, but varying greatly from country to country.

It is clear that the current situation, in which some countries include and others exclude condensables, is very problematic, and leads to inconsistent and unfair source-receptor matrices. Recent activities to better document and understand the current situation have led to a greater understanding of the issues among different expert communities. One of the main conclusions of the NMR workshop is that although these initial calculations with the EMEPwRef2C data are a good first step towards a harmonised emission methodology, these expert estimates should be increasingly replaced by national estimates once procedures for dealing with condensables in a more harmonised way are agreed on and implemented. Such improvements will need detailed discussion among the emission inventory communities (e.g. TFEIP, TFTEI, national experts) as well as with modellers who will have to account for the complex volatility issues surrounding the condensables and associated issues.

[1]Gridded Nomenclature For Reporting, an aggregated version of NFR (Nomenclature For Reporting) sectors used by the Parties in reporting to the LRTAP Convention

Elemental carbon: model evaluation and source receptor matrices for 2018

It is well known that current reporting of black carbon (BC) to CLRTAP suffer from a number of critical deficiencies, and that the uncertainties in estimated BC emissions are large. In this report, we present model calculations for 2018 using both the reported EMEP BC emissions (assuming that the reported BC is elemental carbon (EC) for all countries) and an EC emission inventory which is partly derived from the TNO Ref2 bottom-up estimate (corresponding to EMEPwRef2C discussed in the previous section). The EMEP MSC-W model results were compared with EMEP observations of EC. Annual mean EC in $PM_{2.5}$ is underestimated by 26% in the model run based on officially reported emissions, whereas it is overestimated by 24% in the model run using EMEPwRef2C (with corresponding biases for the winter of -31% and +33%). From the model evaluation presented here it is not possible to judge which of the emission data sets is the most 'correct' one, but the results are very different for many countries.

Source-receptor calculations have been performed for both emission scenarios. We demonstrate that the differences in the emission estimates of EC lead to up to a factor of 2-4 differences in country-to-itself and import-to-country contributions to EC concentrations.

The EMEP Intensive Measurement Period (IMP) 2017/18: Equivalent Black Carbon (EBC) from fossil fuel and biomass burning sources

We present an overview of data from the EMEP IMP 2017/18 and source apportionment (fossil fuel and wood burning equivalent black carbon, EBC_{ff} and EBC_{bb}, respectively), using positive matrix factorization (PMF). The advantage of the PMF approach to EBC source apportionment is that an a priori knowledge of the aerosol Ångström exponent (AAE) is not required (rather, AAEs are an output derived from factor profiles). PMF consistently produced 2 factors with profiles of AAE_{ff} and AAE_{bb}. Time series of the PMF factors exhibit clear diurnal patterns for the urban sites, with AAE_{ff} showing a morning and an evening peak, while AAE_{bb} mainly peaks in the evening. For the background sites there is typically a low diurnal variation as they are likely more affected by long-range transported (LRT) emissions than local emissions. The EBC_{bb} contribution at sites that are mostly influenced by LRT (34 $\pm$ 10%) was marginally lower than at sites dominated by local emissions (39 $\pm$ 8%) and shows that biomass burning contributes significantly to background EBC, i.e. EBC_{bb} air pollution is a regional as well as a local problem. We also provide an overview of the data that are available to the community on request.

Downscaling of PM and NO_2 in Europe using uEMEP

Over the past four years EMEP MSC-W has been developing and implementing a downscaling methodology to enhance the capabilities of the EMEP MSC-W chemical transport model in Europe. This downscaling model is known as uEMEP (urban EMEP) and can achieve high resolution air quality modelling down to 100 m for entire countries. It is here applied to calculate annual mean NO_2, $PM_{2.5}$ and PM_{10} concentrations for all of Europe at 100 m resolution and is validated against all available EEA monitoring stations in Europe (including traffic stations) at 25 m resolution. The downscaling shows significant improvement in NO_2 concentrations where spatial correlation has been doubled for most countries and bias reduced from -46% to -17% for all stations in Europe. The downscaling of $PM_{2.5}$ and PM_{10}

does not show improvement in spatial correlation but does reduce the overall bias in the European calculations from -28% to -17% and -43% to -30% for $PM_{2.5}$ and PM_{10} respectively. Sensitivity tests in Norway show that improvements in the emission and emission proxy data used for the downscaling can significantly improve the PM results but more effort is required to improve PM downscaling across Europe. The downscaling development opens the way for improved exposure estimates, improved assessment of emissions as well as detailed calculations of source contributions to exceedances in a consistent way for all of Europe at high resolution.

Reduced nitrogen in Europe

EMEP-MSC-W model calculations for the years 2005, 2017 and 2030 have been performed, assuming official EMEP emissions for 2005 and 2017 and NEC Directive obligations for 2030. Emissions of ammonia have decreased from 2005 to 2017, and further reductions are projected for 2030. However, these reductions are much smaller than the corresponding reductions in SO_x and NO_x emissions. EMEP MSC-W model calculations predict that these differences in emission reductions lead to an increasingly smaller fraction of ammonia being converted to ammonium, likely impacting the ability of controlling $PM_{2.5}$ by additional reductions of ammonia emissions on top of NEC2030.

Following the emission reductions, depositions of reduced nitrogen are decreasing in Europe. As the reductions in NO_x emission are larger than for ammonia, the fraction of reduced versus total deposition of nitrogen is increasing and is projected to reach more than 70% in large parts of Europe by year 2030. Further reductions in ammonia emissions would thus efficiently reduce the deposition of reduced and also total nitrogen in the future.

Model improvements

The EMEP MSC-W model code has been upgraded in a number of ways. The Local Fractions method, which allows to track a large number of primary emission sources efficiently, has been generalized and can be used to track emissions from a list of countries. The chemical mechanisms have been updated, and the chemical pre-processing system and associated box-model (GenChem, boxChem) have been released as open-source. New default and country-specific emission speciations for NMVOC and $PM_{2.5}$ have been implemented, making use of new and more detailed emissions information from the TNO CAMS inventories.

Development in the monitoring programme

The two last chapters of the report present the implementation of the EMEP monitoring strategy and general development in the monitoring programme including data submission. There are large differences between Parties in the level of implementation, as well as significant changes in the national activities during the period 2000-2018. With respect to the requirement for level 1 monitoring, 40% of the Parties have had an improvement since 2010, while 33% have reduced the level of monitoring. For level 2 monitoring there has been a general positive development in recent years. However, only few sites have a complete measurement program.

The complexity of data reporting has increased in recent years, and it is therefore now mandatory for the data providers to use the submission and validation tool when submitting data to EMEP to improve the quality and timeliness in the data flow. There is a need for

improvements in the reporting, as only half of the data providers use the submission tool, and less than 60% report within the deadline of 31 July.

For the level 2 parameters, there have been large improvements in the data quality and measurement capabilities over the last decade resulting from development in ACTRIS (European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases) in co-operation with EMEP and the WMO Global Atmospheric Watch Programme (GAW). New routines for quality assurance for VOCs have been developed, including a digital tool (Atmospheric VOC Assessment Tool, @VOC@), which is presented briefly in this report. The tool will help streamline and harmonize the quality checks of VOC data in Europe.

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The work on condensable organics was partly funded by the Norwegian Ministry of Climate and Environment. In addition, the Nordic Council of Ministers funded an expert workshop on condensables in March 2020, which brought together experts in emissions, measurements, inventories, and policy from Europe and North America, and created a much better understanding of the issues and possible approaches for dealing with this important class of compounds.

The work of TNO was partly funded by the Copernicus Atmosphere Monitoring Service (CAMS), in particular the Contracts on emissions (CAMS_81) and policy products (CAMS_71).

The work presented in this report has benefited largely from the work carried out under the four EMEP Task Forces and in particular under TFMM.

A large number of co-workers in participating countries have contributed in submitting quality assured data. The EMEP centers would like to express their gratitude for continued good co-operation and effort. The institutes and persons providing data are listed in the EMEP/CCC's data report and identified together with the data sets in the EBAS database. Further, more than 50 participants have contributed with data to the winter 2017/2018 campaign and their co-operation is very much appreciated.

For developing standardized methods, harmonization of measurements and improving the reporting guidelines and tools, the close co-operations with participants in the European Research Infrastructure for the observation of Aerosol, Clouds, and Trace gases (ACTRIS) as well as with the Scientific Advisory Groups (SAGs) in WMO/GAW are especially appreciated.

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The computations were partly performed on resources provided by UNINETT Sigma2 - the National Infrastructure for High Performance Computing and Data Storage in Norway (grant NN2890k and NS9005k). IT infrastructure in general was available through the Norwegian Meteorological Institute (MET Norway). Furthermore, the CPU time granted on the supercomputers owned by MET Norway has been of crucial importance for this year's source-receptor matrices. The CPU time made available by ECMWF to generate meteorology has been important for both the source-receptor and status calculations in this year's report.

Contents

CHAPTER 1

Introduction

1.1 Purpose and structure of this report

The mandate of the European Monitoring and Evaluation Programme (EMEP) is to provide sound scientific support to the Convention on Long-range Transboundary Air Pollution (LRTAP), particularly in the areas of atmospheric monitoring and modelling, emission inventories, emission projections and integrated assessment. Each year EMEP provides information on transboundary pollution fluxes inside the EMEP area, relying on information on emission sources and monitoring results provided by the Parties to the LRTAP Convention.

The purpose of the annual EMEP status reports is to provide an overview of the status of transboundary air pollution in Europe, tracing progress towards existing emission control Protocols and supporting the design of new protocols, when necessary. An additional purpose of these reports is to identify problem areas, new aspects and findings that are relevant to the Convention.

The present report is divided into four parts. Part I presents the status of transboundary air pollution with respect to acidification, eutrophication, ground level ozone and particulate matter in Europe in 2018. Part II summarizes research activities of relevance to the EMEP programme, while Part III deals with technical developments going on within the centres.

Appendix A in Part IV contains information on the national total emissions of main pollutants and primary particles for 2018, while Appendix B shows the emission trends for the period of 2000-2018. Country-to-country source-receptor matrices with calculations of the transboundary contributions to pollution in different countries for 2018 are presented in Appendix C.

Appendix D describes the country reports which are issued as a supplement to the EMEP status reports.

Appendix E introduces the model evaluation report for 2018 (Gauss et al. 2020c) which is available online and contains time series plots of acidifying and eutrophying components (Gauss et al. 2020b), ozone (Gauss et al. 2020a) and particulate matter (Tsyro et al. 2020). These plots are provided for all stations reporting to EMEP (with just a few exclusions due to data-capture or technical problems). This online information is complemented by numerical

fields and other information on the EMEP website. The reader is encouraged to visit the website, `http://www.emep.int`, to access this additional information.

1.2 Definitions, statistics used

For sulphur and nitrogen compounds, the basic units used throughout this report are μg (S or N)/m^3 for air concentrations and mg (S or N)/m^2 for depositions. Emission data, in particular in some of the Appendices, is given in Gg (SO_2) and Gg (NO_2) in order to keep consistency with reported values.

For ozone, the basic units used throughout this report are ppb (1 ppb = 1 part per billion by volume) or ppm (1 ppm = 1000 ppb). At 20°C and 1013 mb pressure, 1 ppb ozone is equivalent to 2.00 μg m^{-3} .

A number of statistics have been used to describe the distribution of ozone within each grid square:

Mean of Daily Max. Ozone - First we evaluate the maximum modelled concentration for each day, then we take either 6-monthly (1 April - 30 September) or annual averages of these values.

SOMO35 - The Sum of Ozone Means Over 35 ppb is the indicator for health impact assessment recommended by WHO. It is defined as the yearly sum of the daily maximum of 8-hour running average over 35 ppb. For each day the maximum of the running 8-hours average for O_3 is selected and the values over 35 ppb are summed over the whole year.

If we let A_8^d denote the maximum 8-hourly average ozone on day d, during a year with N_y days (N_y = 365 or 366), then SOMO35 can be defined as:

$SOMO35 = \sum_{d=1}^{d=N_y} \max\left(A_8^d - 35 \text{ ppb}, 0.0\right)$

where the `max` function evaluates $\max(A-B, 0)$ to $A-B$ for $A > B$, or zero if $A \leq B$, ensuring that only A_8^d values exceeding 35 ppb are included. The corresponding unit is ppb.days.

POD$_Y$ - Phyto-toxic ozone dose, is the accumulated stomatal ozone flux over a threshold Y, i.e.:

$$\text{POD}_Y = \int \max(F_{st} - Y, 0)\, dt \qquad (1.1)$$

where stomatal flux F_{st}, and threshold, Y, are in nmol m^{-2} s^{-1}. This integral is evaluated over time, from the start of the growing season (SGS), to the end (EGS).

For the generic crop and forest species, the suffix gen can be applied, e.g. POD$_{Y,gen}$ (or $AF_{st}1.6_{gen}$) is used for forests. POD was introduced in 2009 as an easier and more descriptive term for the accumulated ozone flux. The definitions of AFst and POD are identical however, and are discussed further in Mills and Simpson (2010). See also Mills et al. (2011a,b) and Mills et al. (2018).

AOT40 - is the accumulated amount of ozone over the threshold value of 40 ppb, i.e..

$AOT40 = \int \max(O_3 - 40 \text{ ppb}, 0.0)\, dt$

where the `max` function ensures that only ozone values exceeding 40 ppb are included. The integral is taken over time, namely the relevant growing season for the vegetation concerned. The corresponding unit are ppb.hours (abbreviated to ppb.h). The usage and definitions of AOT40 have changed over the years though, and also differ between UNECE and the EU. LRTAP (2009) give the latest definitions for UNECE work, and describes carefully how AOT40 values are best estimated for local conditions (using information on real growing seasons for example), and specific types of vegetation. Further, since O_3 concentrations can have strong vertical gradients, it is important to specify the height of the O_3 concentrations used. In previous EMEP work we have made use of modelled O_3 from 1 m or 3 m height, the former being assumed close to the top of the vegetation, and the latter being closer to the height of O_3 observations. In the Mapping Manual (LRTAP 2009) there is an increased emphasis on estimating AOT40 using ozone levels at the top of the vegetation canopy.

Although the EMEP MSC-W model now generates a number of AOT-related outputs, in accordance with the recommendations of LRTAP (2009) we will concentrate in this report on two definitions:

AOT40$_f^{\mathbf{uc}}$ - AOT40 calculated for forests using estimates of O_3 at forest-top (uc: upper-canopy). This AOT40 is that defined for forests by LRTAP (2009), but using a default growing season of April-September.

AOT40$_c^{\mathbf{uc}}$ - AOT40 calculated for agricultural crops using estimates of O_3 at the top of the crop. This AOT40 is close to that defined for agricultural crops by LRTAP (2009), but using a default growing season of May-July, and a default crop-height of 1 m.

In all cases only daylight hours are included, and for practical reasons we define daylight for the model outputs as the time when the solar zenith angle is equal to or less than 89°. (The proper UNECE definition uses clear-sky global radiation exceeding 50 W m^{-2} to define daylight, whereas the EU AOT definitions use day hours from 08:00-20:00.). In the comparison of modelled and observed AOT40$_f^{\mathrm{uc}}$in chapter 2, we have used the EU AOT definitions of day hours from 08:00-20:00.

The AOT40 levels reflect interest in long-term ozone exposure which is considered important for vegetation - critical levels of 3 000 ppb.h have been suggested for agricultural crops and natural vegetation, and 5 000 ppb.h for forests (LRTAP 2009). Note that recent UNECE workshops have recommended that AOT40 concepts are replaced by ozone flux estimates for crops and forests. (See also Mills and Simpson 2010).

This report includes also concentrations of particulate matter (PM). The basic units throughout this report are μg m^{-3} for PM concentrations and the following acronyms are used for different components to PM:

POA - primary organic aerosol - which is the organic component of the PPM emissions (defined below). (POA is in this report assumed to be entirely in the particle phase, see Chap. 6.)

SOA - secondary organic aerosol, defined as the aerosol mass arising from the oxidation products of gas-phase organic species.

SIA - secondary inorganic aerosols, defined as the sum of sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+). In the EMEP MSC-W model SIA is calculated as the sum: SIA= SO_4^{2-} + NO_3^-(fine) + NO_3^-(coarse) + NH_4^+.

SS - sea salt.

MinDust - mineral dust.

PPM - primary particulate matter, originating directly from anthropogenic emissions. One usually distinguishes between fine primary particulate matter, $PPM_{2.5}$, with aerosol diameters below 2.5 μm and coarse primary particulate matter, PPM_{coarse} with aerosol diameters between 2.5 μm and 10 μm.

$PM_{2.5}$ - particulate matter with aerodynamic diameter up to 2.5 μm. In the EMEP MSC-W model $PM_{2.5}$ is calculated as $PM_{2.5}$ = SO_4^{2-} + NO_3^-(fine) + NH_4^+ + SS(fine) + MinDust(fine) + SOA(fine) + $PPM_{2.5}$ + 0.27 NO_3^-(coarse) + PM25water. (PM25water = PM associated water).

PM_{coarse} - coarse particulate matter with aerodynamic diameter between 2.5μm and 10μm. In the EMEP MSC-W model PM_{coarse} is calculated as PM_{coarse} = 0.73 NO_3^-(coarse)+ SS(coarse) + MinDust(coarse) + PPM_{coarse}.

PM_{10} - particulate matter with aerodynamic diameter up to 10 μm. In the EMEP MSC-W model PM_{10} is calculated as PM_{10} = $PM_{2.5}$ + PM_{coarse}.

In addition to bias, correlation and root mean square the statistical parameter, index of agreement, are used to judge the model's agreement with measurements:

IOA - The index of agreement (IOA) is defined as follows (Willmott 1981, 1982):

$$IOA = 1 - \frac{\sum_{i=1}^{N}(m_i - o_i)^2}{\sum_{i=1}^{N}(|m_i - \bar{o}| + |o_i - \bar{o}|)^2} \quad (1.2)$$

where $\bar{o}$ is the average observed value. Similarly to correlation, IOA can be used to assess agreement either spatially or temporally. When IOA is used in a spatial sense, N denotes the number of stations with measurements at one specific point in time, and m_i and o_i are the modelled and observed values at station i. For temporal IOA, N denotes the number of time steps with measurements, while m_i and o_i are the modelled and observed value at time step i. IOA varies between 0 and 1. A value of 1 corresponds to perfect agreement between model and observations, and 0 is the theoretical minimum.

1.3 The EMEP grid

At the 36th session of the EMEP Steering Body the EMEP Centres suggested to increase spatial resolution and projection of reported emissions from 50$\times$50 km^2 polar stereographic

grid to 0.1°×0.1° longitude-latitude grid in a geographic coordinate system (WGS84). The EMEP domain shown in Figure 1.1 covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude. This domain represents a balance between political needs, scientific needs and technical feasibility. Parties are obliged to report gridded emissions in this grid resolution from year 2017.

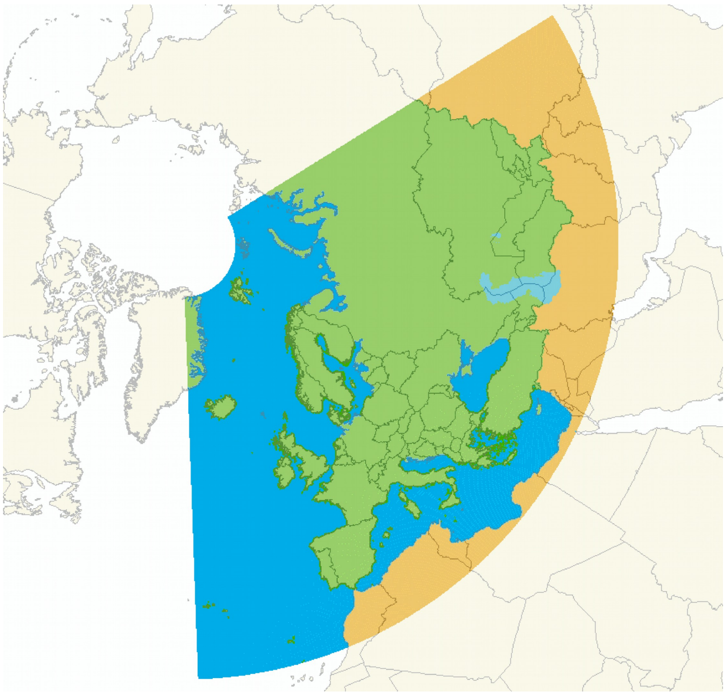

Figure 1.1: The EMEP domain covering the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

The higher resolution means an increase of grid cells from approximately 21500 cells in the 50×50 km^2 grid to 624000 cells in the 0.1°×0.1° longitude-latitude grid.

1.3.1 The reduced grid: EMEP0302

For practical purposes, a coarser grid has also been defined. The EMEP0302 grid covers the same region as the 0.1°×0.1° longitude-latitude EMEP domain (Figure 1.1), but the spatial resolution is 0.3° in the longitude direction and 0.2° in the latitude direction. Each gridcell from the EMEP0302 grid covers exactly 6 gridcells from the 0.1°×0.1° official grid.

1.4 Country codes

Several tables and graphs in this report make use of codes to denote countries and regions in the EMEP area. Table 1.1 provides an overview of these codes and lists the countries and regions included.

All 51 Parties to the LRTAP Convention, except two, are included in the analysis presented in this report. The Parties that are excluded of the analysis are Canada and the United States of America, because they lie outside the EMEP domain.

Code	Country/Region/Source
AL	Albania
AM	Armenia
AST	Asian areas
AT	Austria
ATL	N.-E. Atlantic Ocean
AZ	Azerbaijan
BA	Bosnia and Herzegovina
BAS	Baltic Sea
BE	Belgium
BG	Bulgaria
BIC	Boundary/Initial Conditions
BLS	Black Sea
BY	Belarus
CH	Switzerland
CY	Cyprus
CZ	Czechia
DE	Germany
DK	Denmark
DMS	Dimethyl sulfate (marine)
EE	Estonia
ES	Spain
EU	European Union (EU28)
EXC	EMEP land areas
FI	Finland
FR	France
GB	United Kingdom
GE	Georgia
GL	Greenland
GR	Greece
HR	Croatia
HU	Hungary
IE	Ireland

Code	Country/Region/Source
IS	Iceland
IT	Italy
KG	Kyrgyzstan
KZ	Kazakhstan
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MC	Monaco
MD	Moldova
ME	Montenegro
MED	Mediterranean Sea
MK	North Macedonia
MT	Malta
NL	Netherlands
NO	Norway
NOA	North Africa
NOS	North Sea
PL	Poland
PT	Portugal
RO	Romania
RS	Serbia
RU	Russian Federation
SE	Sweden
SI	Slovenia
SK	Slovakia
TJ	Tajikistan
TM	Turkmenistan
TR	Turkey
UA	Ukraine
UZ	Uzbekistan
VOL	Volcanic emissions

Table 1.1: Country/region codes used throughout this report.

1.5 Other publications

This report is complemented by a report on EMEP MSC-W model performance for acidifying and eutrophying components, photo-oxidants and particulate matter in 2018 (Gauss et al. 2020c), made available online, at `www.emep.int`.

A list of all associated technical reports and notes by the EMEP centres in 2020 (relevant for transboundary acidification, eutrophication, ozone and particulate matter) follows at the end of this section.

Peer-reviewed publications in 2019

The following scientific papers of relevance to transboundary acidification, eutrophication, ground level ozone and particulate matter, involving EMEP/MSC-W and EMEP/CCC staff, have become available in 2019:

Aas, Wenche; Mortier, Augustin; Bowersox, Van C.; Cherian, Ribu; Faluvegi, Greg; Fagerli, Hilde; Hand, Jenny; Klimont, Zbigniew; Galy-Lacaux, Corinne; Lehmann, Christopher M. B.; Myhre, Cathrine Lund; Myhre, Gunnar; Oliviè, Dirk Jan Leo; Sato, Keiichi; Quaas, Johannes; Rao, P.S.P.; Schulz, Michael; Shindell, Drew; Skeie, Ragnhild Bieltvedt; Stein, Ariel; Takemura, Toshihiko; Tsyro, Svetlana; Vet, Robert; Xu, Xiaobin. Global and regional trends of atmospheric sulfur. Scientific Reports , 9 , 2019. DOI: 10.1038/s41598-018-37304-0

Barregård, Lars; Molnar, Peter; Jonson, Jan Eiof; Stockfelt, Leo. Impact on Population Health of Baltic Shipping Emissions. International Journal of Environmental Research and Public Health 2019 ; 16.(11) DOI: 10.3390/ijerph16111954

Boy, Michael; Thomson, Erik S.; Acosta Navarro, Juan-Camilo; Arnalds, Olafur; Batchvarova, Ekaterina; Bäck, Jaana; Berninger, Frank; Bilde, Merete; Brasseur, Zoe; Dagsson-Waldhauserova, Pavla; Castarede, Dimitri; Dalirian, Maryam; de Leeuw, Gerrit; Dragosics, Monika; Duplissy, Ella-Maria; Duplissy, Jonathan; Ekman, Annica; Fang, Keyan; Gallet, Jean-Charles; Glasius, Marianne; Gryning, Sven-Erik; Grythe, Henrik; Hansson, Hans-Christen; Hansson, Margareta; Isaksson, Elisabeth; Iversen, Trond; Jónsdóttir, Ingibjörg Svala; Kasurinen, Ville; Kirkevåg, Alf. ; Korhola, Atte; Krejci, Radovan; Kristjansson, Jon Egill; Lappalainen, Hanna K.; Lauri, Antti; Leppäranta, Matti; Lihavainen, Heikki; Makkonen, Risto; Massling, Andreas; Meinander, Outi; Nilsson, E. Douglas; Ólafsson, Haraldur; Pettersson, Jan B. C.; Prisle, Nønne L.; Riipinen, Ilona; Roldin, Pontus; Ruppel, Meri; Salter, Matthew E.; Sand, Maria; Seland, Øyvind; Seppä, Heikki; Skov, Henrik; Soares, Joana; Stohl, Andreas; Ström, Johan; Svensson, Jonas; Swietlicki, Erik; Tabakova, Ksenia; Thorsteinsson, Throstur; Virkkula, Aki; Weyhenmeyer, Gesa A.; Wu, Yusheng; Zieger, Paul; Kulmala, Markku. Interactions between the atmosphere, cryosphere,and ecosystems at northern high latitudes. . Atmospheric Chemistry and Physics , 2019, p. 2015-2061. DOI: 10.5194/acp-19-2015-2019

Brasseur, Guy P.; Xie, Ying; Petersen, Anna Katinka; Bouarar, Idir; Flemming, Johannes; Gauss, Michael; Jiang, Fei; Kouznetsov, Rostislav; Kranenburg, Richard; Mijling, Bas; Peuch, Vincent-Henri; Pommier, Matthieu; Segers, Arjo; Sofiev, Mikhail; Timmermans, Renske; van der A, Ronald; Walters, Stacy; Xu, Jianming; Zhou, Guangqiang. Ensemble forecasts of air quality in eastern China-Part 1: Model description and implementation of the MarcoPolo-Panda prediction system, version 1. Geoscientific Model Development 2019 ; 12.(1) p. 33-67 DOI: 10.5194/gmd-12-33-2019

Christensen, Torben R.; Arora, Vivek K; Gauss, Michael; Hoglund-Isaksson, Lena; Parmentier, Frans-Jan W. Tracing the climate signal: mitigation of anthropogenic methane emissions can outweigh a large Arctic natural emission increase. Scientific Reports , 9 (1146) , 2019. DOI: 10.1038/s41598-018-37719-9

Ciarelli, Giancarlo; Colette, Augustin; Schucht, Simone; Beekmann, Matthias; Andersson, Camilla; Manders-Groot, Astrid; Mircea, Mihaela; Tsyro, Svetlana; Fagerli, Hilde; Ortiz, Alberto González; Adani, Mario; Briganti, Gino; Cappelletti, Andrea; D'Isidoro, Massimo; Cuvelier, Cornelis; Couvidat, Florian; Meleux, Frédérik; Bessagnet, Bertrand. Long-term health impact assessment of total PM2.5 in Europe during the 1990–2015 period. Atmospheric Environment: X 2019 ; 3. DOI: 10.1016/j.aeaoa.2019.100032

Ciarelli, Giancarlo; Theobald, Mark, R.; Vivanco, Marta García; Beekmann, Matthias; Aas, Wenche; Andersson, Camilla; Bergström, Robert; Manders-Groot, Astrid; Couvidat, Florian; Mircea, Mihaela; Tsyro, Svetlana; Fagerli, Hilde; Mar, Kathleen; Raffort, Valentin; Roustan, Yelva; Pay, Maria-Teresa; Schaap, Martijn; Kranenburg, Richard; Adani, Mario; Briganti, Gino; Cappelletti, Andrea; D'Isidoro, Massimo; Cuvelier, Cornelis; Cholakian, Arineh; Bessagnet, Bertrand; Wind, Peter; Colette, Augustin. Trends of inorganic and organic aerosols and precursor gases in Europe: insights from the EURODELTA multi-model experiment over the 1990–2010 period. Geoscientific Model Development 2019 ; 12.(12) p. 4923-4954 DOI: 10.5194/gmd-12-4923-2019

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Associated EMEP reports and notes in 2020

Joint reports

Transboundary particulate matter, photo-oxidants, acidification and eutrophication components. Joint MSC-W & CCC & CEIP Report. EMEP Status Report 1/2020

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CEIP Technical and Data reports

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Part I

Status of air pollution

CHAPTER 2

Status of transboundary air pollution in 2018

Svetlana Tsyro, Wenche Aas, Sverre Solberg, Anna Benedictow, Hilde Fagerli and Thomas Scheuschner

This chapter describes the status of transboundary air pollution in 2018. A short summary of the meteorological conditions for 2018 is presented and the EMEP network of measurements in 2018 is briefly described. Thereafter, the status of air pollution and exceedances in 2018 is discussed.

The summer of 2018 was unusually warm and dry in large parts of Europe; therefore a separate chapter is devoted to the effect of these meteorological conditions on air pollution (Chapter 4).

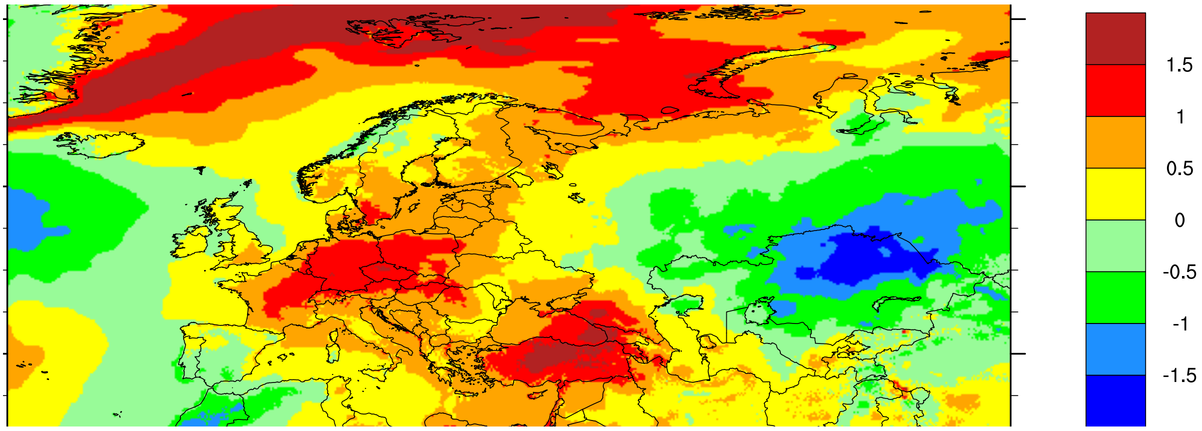
2.1 Meteorological conditions in 2018

Air pollution is significantly influenced by both emissions and weather conditions. Temperature and precipitation are particularly important factors. A short summary describing the situation in 2018 with respect to these two parameters, based on model results and as reported by the meteorological institutes in European and EECCA countries, is given below.

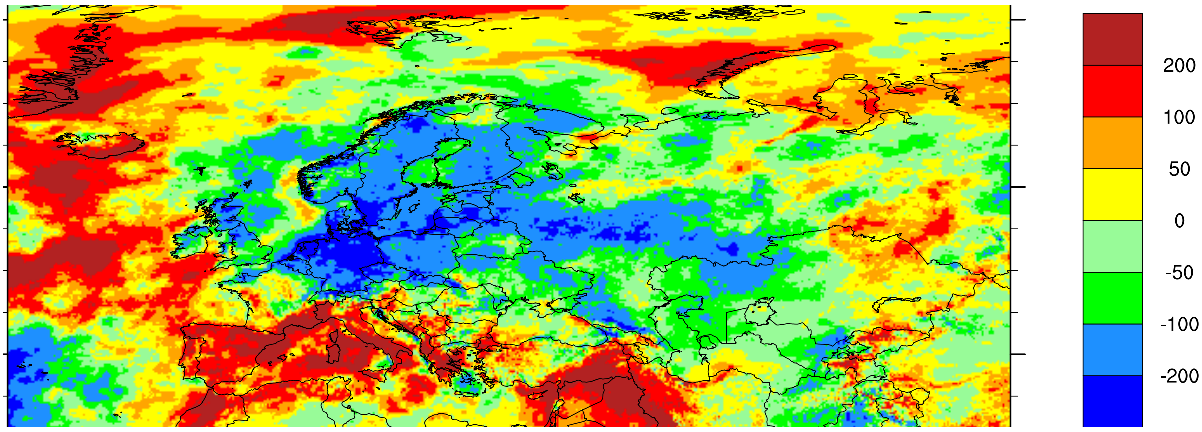
The meteorological data to drive the EMEP MSC-W air quality model have been generated by the Integrated Forecast System (IFS) model of the European Centre for Medium-Range Weather Forecasts (ECMWF), hereafter referred to as the ECMWF-IFS model. In the meteorological community the ECMWF-IFS model is considered state-of-the-art, and MSC-W has been using this model in hindcast mode to generate meteorological reanalyses for the year to be studied. IFS Cycle 40r1 is the version used for the year 2018 model runs. In the following section, temperature and precipitation in 2018 are compared to the 2000-2017 average based on the same ECMWF-IFS model setup.

2.1.1 Temperature and precipitation

The mean temperature in 2018 was reported by the World Meteorological Organisation (WMO 2019) as the fourth highest on record globally, and the third highest in Europe. In the Arctic, according to the Arctic Report Card 2018 (Overland et al. 2018), the period October 2017 to September 2018 was the second warmest 12-month period on record since 1900 (after 2015-2016). Global precipitation anomalies in 2018 were also reported by the WMO (WMO 2019) with above-average precipitation in south-west and south-east Europe, in contrast to rainfall deficits in central and northern Europe.



(a) Δtemperature at 2m (2018-climavg)



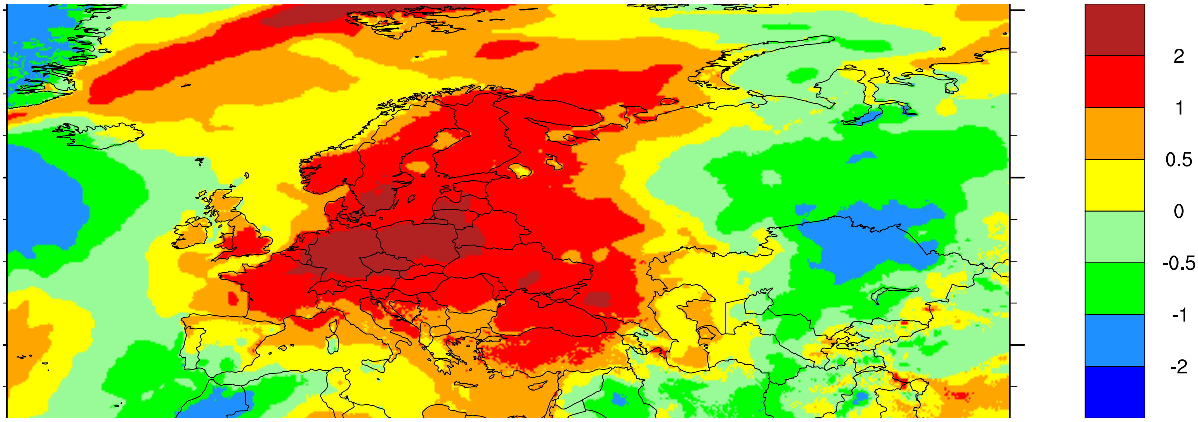
(b) Δprecipitation (2018-climavg)

Figure 2.1: Meteorological conditions in 2018 compared to the 2000-2017 average (climavg) for: a) Annual mean temperature at 2m [K] and b) Annual precipitation [mm]. The meteorological data have been calculated with the ECMWF-IFS model.

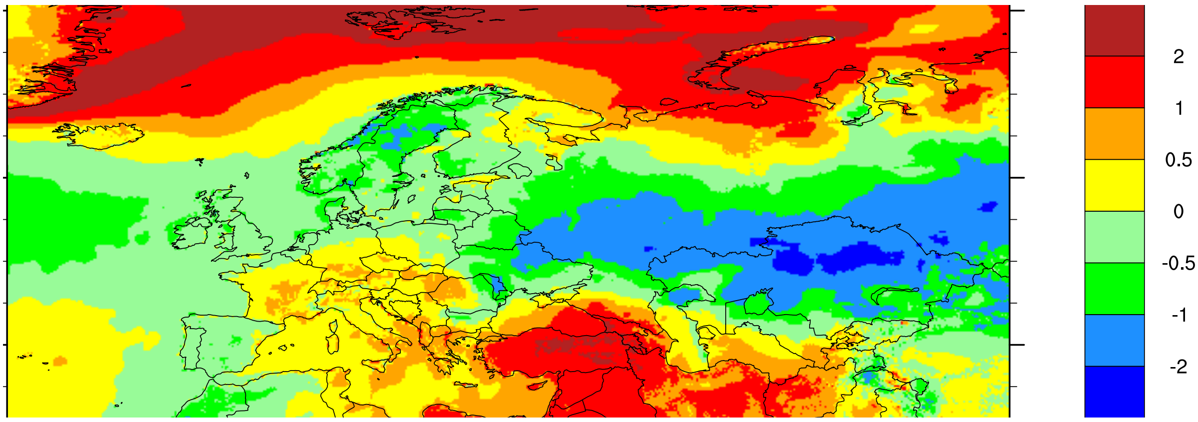
Compared to the 2000-2017 average, higher temperatures in 2018 are clearly seen in Figure 2.1 a) over the Arctic, central and south-eastern Europe, and slightly lower temperatures confined to limited parts of north-western and south-western Europe, Kazakhstan and southern Russia. Particularly, Turkey had abnormally high temperatures throughout the year with means above normal for all months (Sensoy et al. 2019). Svalbard recorded large positive temperature anomalies in 2018 (Overland et al. 2018), especially in the beginning with a record warm May and towards the end of the year.

Despite some local extreme precipitation events with heavy rainfall in short time, es-

pecially in western and south central Europe, 2018 was overall a dry year in much of Europe. Compared to the 2000-2017 average, precipitation in 2018 (Figure 2.1 b)) shows higher amounts than normal in south-west and south-east Europe, and below-normal precipitation in central and northern Europe. Iceland had more precipitation than the 2000-2017 average in 2018 with Reykjavik breaking a record with 261 rainy days.



(a) Δtemperature at 2m (AprSep 2018-climavg)

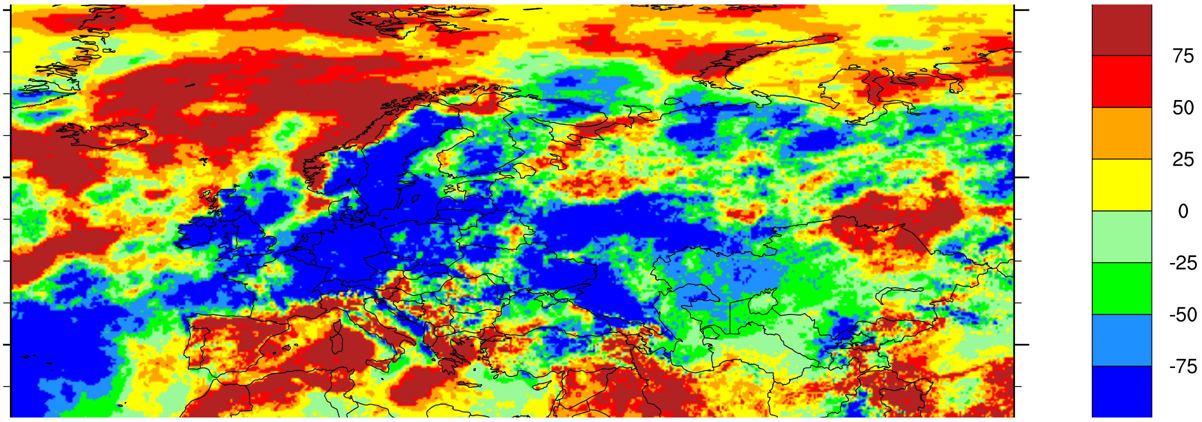


(b) Δtemperature at 2m (OctMar 2017-climavg)

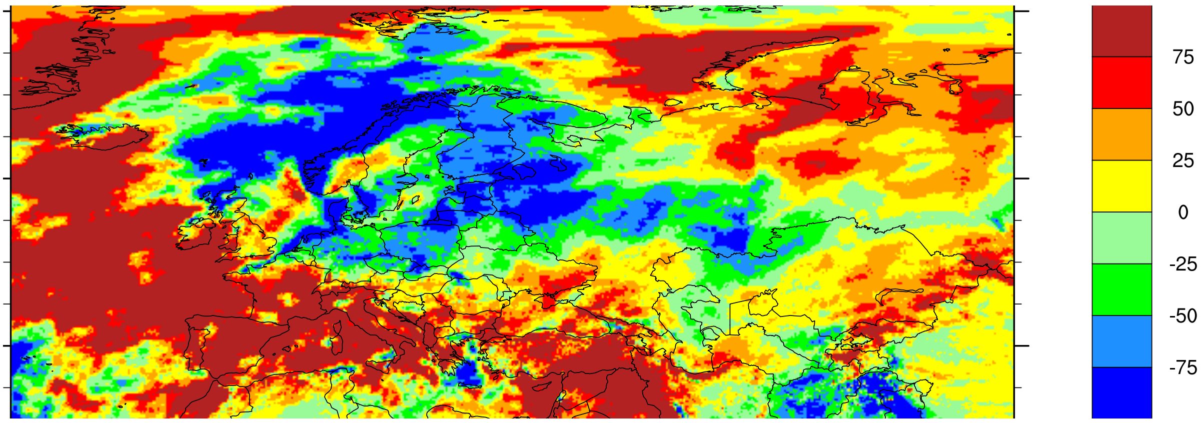
Figure 2.2: Meteorological conditions in 2018 compared to the 2000-2017 average (climavg) for: a) Summer (April-September) temperature [K], b) Winter (January-March and October-December) temperature [K]. The meteorological data have been calculated with the ECMWF-IFS model.

Figure 2.2 shows the temperatures in 2018 compared to the 2000-2017 average in Europe for the summer months (April through September) and the winter months (October through December and January through March). Characteristic of the year 2018 is the higher than average summer temperature in central Europe, as shown in Figure 2.2 a) with temperatures in 2018 compared to the 2000-2017 average. The heat wave during the summer of 2018 and its effect on air pollution levels are discussed in more detail in a separate chapter (Chapter 4). Spring, with an exceptionally warm May, was the warmest on record in Bosnia and Herzegovina, Bulgaria, Greece, Serbia and Turkey. May was also the warmest month on record in Svalbard, Scandinavia, the Baltic countries, Austria and Germany. Many of these regions continued breaking temperature records in the summer and autumn months. In Spain, the United Kingdom, Ireland and northern Scandinavia the winter was colder than normal, and close to normal in central Europe. Southeastern Europe experienced a milder than average

winter, see Figure 2.2 b). In February and March, easterly winds brought cold Siberian air to most countries in Europe. March was particularly cold in European parts of Russia with an anomaly of about -3°C. In April the weather changed from winter to summer conditions in only a few days for some areas in central and southeastern Europe. Bosnia and Herzegovina and Serbia had their warmest October on record.



(a) ∆precipitation (AprSep 2018-climavg)



(b) ∆precipitation (OctMar 2018-climavg)

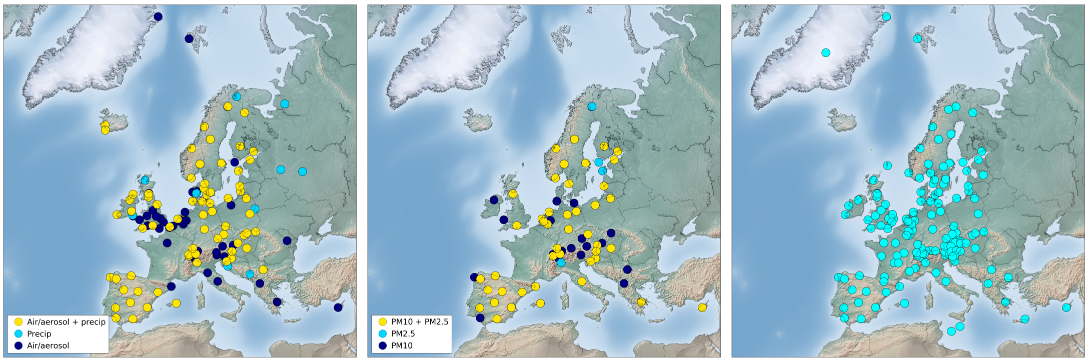
Figure 2.3: Meteorological conditions in 2018 compared to the 2000-2017 average (climavg) for: a) Summer (April-September) precipitation [mm], b) winter (January-March and October-December) precipitation [mm]. The meteorological data have been calculated with the ECMWF-IFS model.

Flooding affected central Europe in the beginning of the year, but the same area later experienced extremely dry conditions (see precipitation in winter and summer in 2018 compared to the 2000-2017 average in Figure 2.3). Precipitation for April through September in Figure 2.3 a) shows that northern and central Europe had much less precipitation than the 2000-2017 average, with the exception of northwestern coastal regions. Latvia reported its second driest spring, Ireland and the Netherlands its driest summer on record, and in Sweden a severe drought from May to July caused extensive forest fires in central parts of the country. Drought was also reported in the United Kingdom. Germany reported the second driest April-September period and Czechia its driest January-August period on record. However, above-average precipitation amounts were observed in south-west and south-east Europe in both the summer and winter months. In Figure 2.3 b) precipitation for the winter months (January-March and October-December) in 2018), compared to the 2000-2017 average, is

higher than average in western, central and southern Europe, and lower than average in north-eastern Europe. With the cold conditions in late February and early March some areas in western and southern Europe (Ireland, France, Italy and Portugal) experienced abnormal conditions with snow and freezing rain. And the year ended with above-average precipitation in December for most of central Europe, terminating the drought of the previous two seasons.

2.2 Measurement network 2018

In 2018, a total of 35 Parties reported measurement data of inorganic components, particulate matter and/or ozone to EMEP from altogether 170 sites, which are the relevant components for level 1 sites (UNECE 2019). All the data are available from the EBAS database (`http://ebas.nilu.no/`) and are also reported separately in technical reports by EMEP/CCC (Hjellbrekke 2020, Hjellbrekke and Solberg 2020). Figure 2.4 shows an overview of the spatial distribution of the sites reporting data for inorganic ions in air and precipitation, particulate matter and ozone in 2018.



(a) Inorganic compounds (b) PM mass concentration (c) Ozone

Figure 2.4: EMEP measurement network for level 1 components in 2018

120 sites reported measurements of inorganic ions in precipitation and/or main components in air. However, not all of these measurements were co-located, as illustrated in Figure 2.4. There were 70 sites with measurements in both air and precipitation. The number of sites is somewhat lower than in 2017, and this is mainly due to lack of most of the data from France, which have been delayed in their reporting. Ozone was measured at 141 EMEP sites.

There were 68 sites measuring either PM_{10} or $PM_{2.5}$ mass. 44 of these sites measured both size fractions, as recommended in the EMEP Monitoring strategy (UNECE 2019). The stations measuring EMEP level 2 variables are shown in Figure 12.2 in Chapter 12.1, along with a discussion on compliance with the monitoring obligations and the development of the programme during the last decade.

2.3 Setup for EMEP MSC-W model runs

The EMEP MSC-W model version rv4.35 has been used for the 2018 runs. The horizontal resolution is $0.1° \times 0.1°$, with 20 vertical layers (the lowest with a height of approximately 50 meters).

Meteorology, emissions, boundary conditions and forest fires for 2018 have been used as input. Meteorological data have been derived from ECMWF-IFS(cy40r1) simulations (see Section 2.1). The land-based emissions have been derived from the 2020 official data submissions to UNECE CLRTAP (Pinterits et al. 2020), as documented in Chapter 3. In the Base run for pollution assessments and the source-receptor runs included in this report, the officially submitted PM_{10} and $PM_{2.5}$ emissions from residential combustion (GNFR sector C) were substituted by an emission data set provided by TNO for 2017 (the so-called *Ref2* scenario used in the Copernicus Atmosphere Monitoring Service contract CAMS71). The data set by TNO represents the best-to-date available estimate of residential combustion emissions of PM, accounting for condensable organics in a consistent way. This run is henceforth referred to as **EMEPwRef2C**. To study the effect of condensable organics, another model run was performed using official emission data as prepared by CEIP, without any replacement (henceforth called **EMEP**), and the results are presented in this year's country reports (Klein et al. 2020) and discussed in Chapter 6.

Emissions from international shipping within the EMEP domain are derived from the CAMS global shipping emissions (Granier et al. 2019), developed by the Finnish Meteorological Institute (FMI). The forest fires emissions are taken from The Fire INventory from NCAR (FINN) (Finnigan et al. 1990), version 5. For more details on the emissions for the 2018 model runs see Chapters 3 and 5, and Appendix A.

Preliminary simulations for 2019 have been performed with the same EMEP MSC-W model version rv4.35, driven by 2019 meteorological input (derived from ECMWF-IFS cy46r1), using 2019 forest fire emissions (FINN) and else the same emissions as in the 2018 run. Climatological means were used for boundary conditions. No evaluation of the 2019 results have been made as EMEP observational data for 2019 are not yet available. The model data for 2019 can be downloaded from the EMEP webpage (`http://www.emep.int`).

2.4 Air pollution in 2018

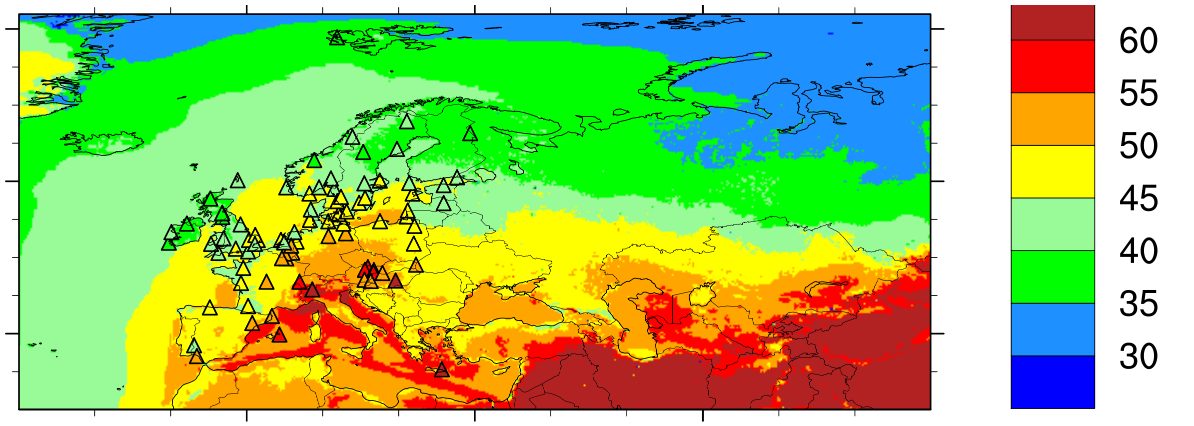
2.4.1 Ozone

The ozone observed at a surface station is the net result of various physio-chemical processes: surface dry deposition and uptake in vegetation, titration by nearby NO_x emissions, regional photochemical ozone formation and atmospheric transport of background ozone levels, each of which may have seasonal and diurnal systematic variations. Episodes with elevated levels of ozone are observed during the summer half year when certain meteorological situations (dry, sunny, cyclonic stable weather) promote the formation of ozone over the European continent.

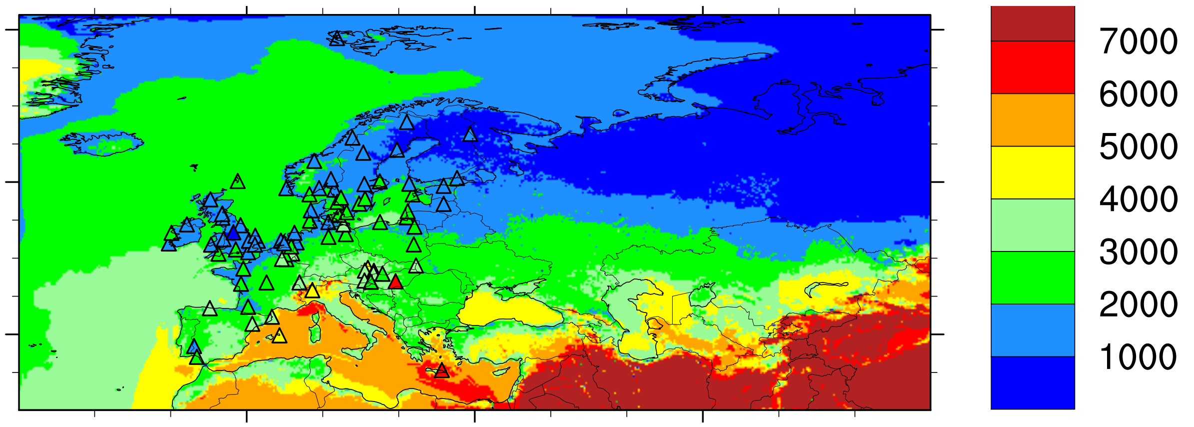
Due to the special meteorological conditions in 2018 with a remarkably hot and dry summer in large areas, most pronounced in northern parts of Europe, the ozone levels in 2018 are discussed in more detail at the separate Chapter 4 dealing with the prolonged heat wave.

Figure 2.5 shows various modelled ozone metrics for 2018 with the corresponding measured metrics based on the EMEP measurement sites plotted on top of the maps. Figure 2.6 shows similar plots with measurement data from EEA's air quality database (e-Reporting), but stations classified as urban or traffic sites were not used. Note that most of the EMEP sites are also included in e-Reporting and thus included in Figure 2.6 as well. Only stations located below 500 metres above sea level were used in this comparison to avoid uncertainties related

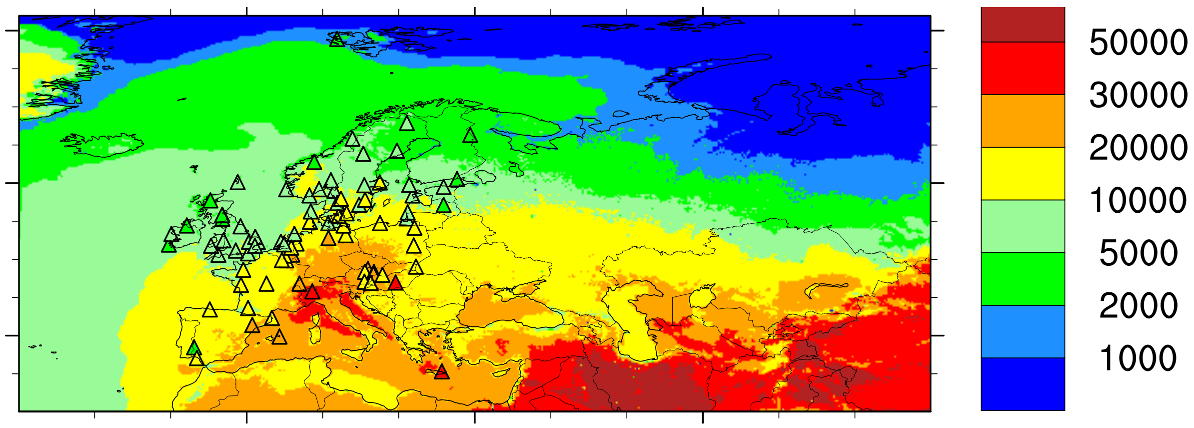
to the extraction of model data in regions with complex topography. Figure 2.7 shows only modelled POD_1 since measurements could not be calculated from the ozone monitoring data directly and could not be included.



(a) maxO3



(b) SOMO35

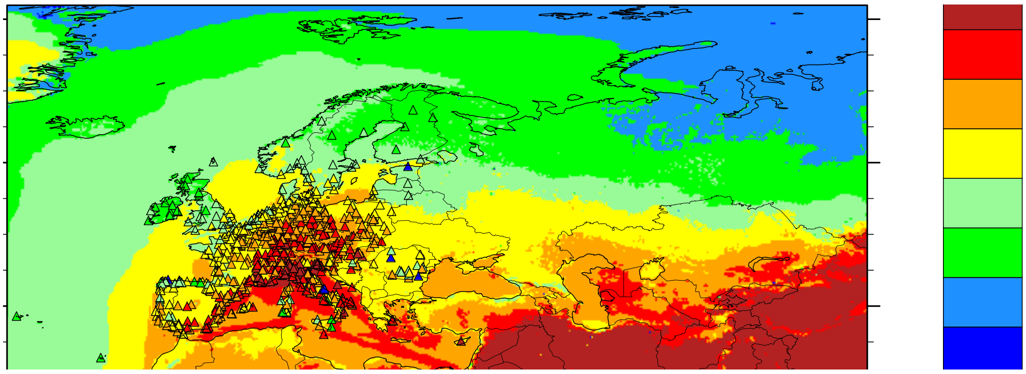


(c) AOT40

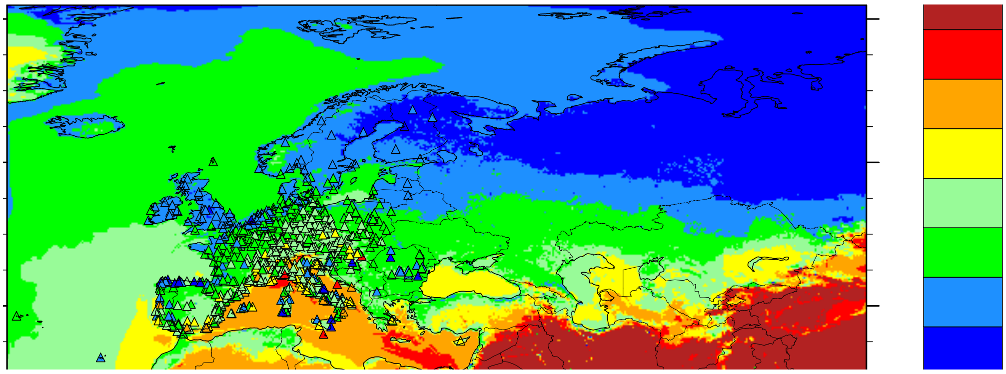
Figure 2.5: Model results and observations at EMEP stations (triangles) for mean of daily maximum ozone concentrations (a) ([ppb], Apr-Sep), SOMO35 (b) [$ppb.d$] and AOT40 for forests (c) [$ppb.h$]. Only data from measurement sites below 500 m a.s.l. are shown.

The Figures 2.5 and 2.6 show a) maxO3 (= mean of the daily max ozone concentration)

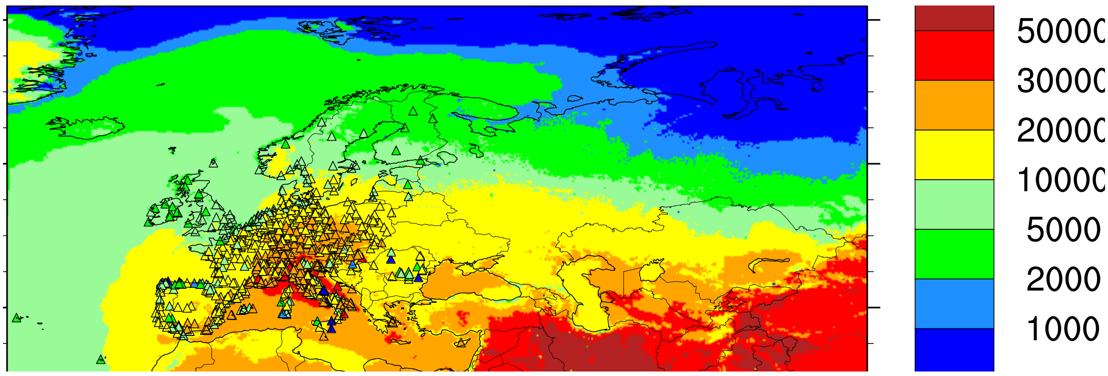
for the 6-month period April-September, b) SOMO35 (= Sum of Ozone Means Over 35 ppb), c) AOT40 for forests (= Accumulated Ozone exposure over a Threshold of 40 ppb) for the 6-month period April-September using the hours between 08 and 20, and Figure 2.7 shows POD_1 for forests (= Phytotoxic Ozone Dose above a threshold 1 mmol m^{-2}).



(a) maxO3



(b) SOMO35



(c) AOT40

Figure 2.6: Model results and observations at EEA's e-Reporting stations (triangles) for mean of daily maximum ozone concentrations (a) ([ppb], Apr-Sep), SOMO35 (b) [$ppb.d$] and AOT40 for forests (c) [$ppb.h$] in 2018. Only data from measurement sites below 500 m a.s.l. are shown. Urban and traffic stations are not included.

These plots indicate good agreement between the modelled and measured ozone metrics in general, although there are indications of a slight underestimation by the model in some areas, most visible for the mean of daily maximum. The number of stations included in EEA's

database (Figure 2.6) is, however, so large that it is difficult to see the underlying model fields in some areas.

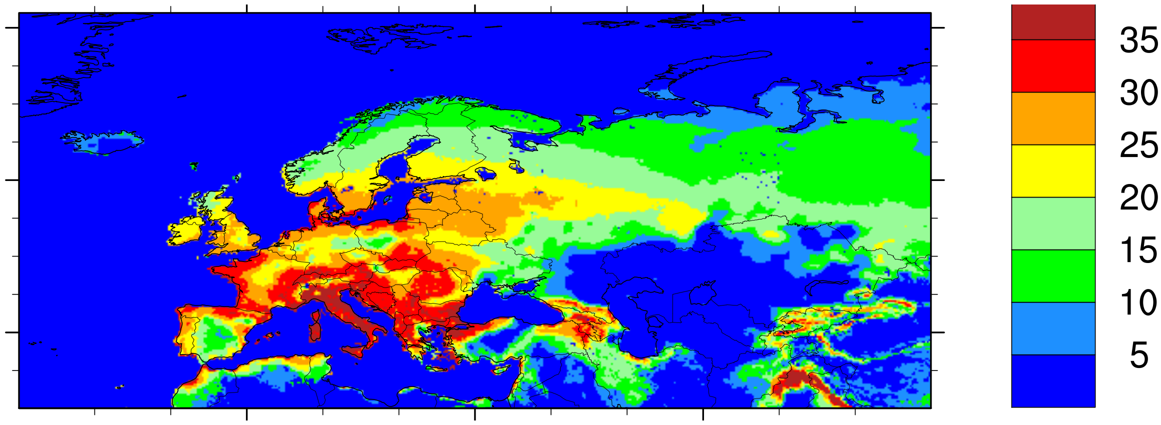


Figure 2.7: Model results of POD_1 for forests [$mmolm^{-}2$] in 2018

It should be noted that the O_3 metrics such as AOT40 are very sensitive to the calculation of vertical O_3 gradients between the middle of the surface layer and the 3m height used for comparison with measurements (Tuovinen et al. 2007) and thus more difficult to compare with measurement data than, e.g., the mean daily maximum. Indeed, the formulation we use (Simpson et al. 2012) is probably better suited to a lowest model layer of 90m thickness (since we equate the centre of this, ca. 45m, with a 'blending-height') than to a lowest model layer of 50m thickness (as used throughout this report). The modelled POD_1 pattern differs from the other metrics reflecting the influence of additional parameters such as plant physiology, soil moisture etc., and is a metric more indicative of the direct impact of ozone on vegetation than, e.g., AOT40. The POD_1 field could, however, not be validated by the EMEP ozone measurement data alone.

SOMO35 is an indicator for health impacts recommended by WHO, and the results given in Figures 2.5 and 2.6 indicate that the health risk associated with surface ozone increased towards southern Europe. Highest levels are seen in the Mediterranean area and Northern Italy. SOMO35 is a health risk indicator without any specific threshold or limit value.

AOT40 and POD_1 are indicators for effects on vegetation. UNECE's critical level for forests based on the 6-months AOT40 value is 5000 ppb hours, and the results shown in Figure 2.5 and Figure 2.6 indicate that this level was exceeded in most of Europe in 2018. In parts of central Europe (Germany, Czechia, Switzerland, Austria, etc.) the critical level was exceeded by a very large margin (20000 ppb hours). As discussed in Chapter 4 on the 2018 summer heat wave, AOT40 is probably a particularly poor indicator for effects on vegetation in 2018 due to the persistent drought over large areas. During dry periods, plants will reduce or close their stomata as a response to soil water deficit, which in turn will lead to reduced uptake of ozone. Parts of the reason for the elevated atmospheric concentrations of ozone (and the high AOT40 levels) could thus be explained by the reduced uptake in vegetation.

On the contrary, POD_1 takes into account this soil moisture deficit, giving an estimate of the actual flux of ozone into the plants. It is interesting to see the substantial difference in the geographical pattern of AOT40 and POD_1 in Figures 2.5 (c) and 2.7. Whereas AOT40 shows a north-south gradient with peak values over southern/central parts of the continent, POD_1 is highest along the coast and shows a minimum in central parts of Europe just where high values of AOT40 are seen. This reflects the importance of the soil moisture effect for

these two metrics for ozone damage to vegetation. For POD_1 the limit value depends on the species and Mills et al (2011) give a value of 4 mmol m^{-2} for birch and beech and 8 mmol m^{-2} for Norway spruce. The results in Figures 2.5 (c) and 2.7 indicate that both these limit values were exceeded in most of Europe. The modelled levels of POD_1 could, however, not be validated by observations.

A more detailed comparison between model and measurements for ozone for the year 2018 can be found in Gauss et al. (2020a).

2.4.2 Particulate matter

Maps of annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2018, calculated by the EMEP MSC-W model, are presented in Figure 2.8. The figures also show annual mean PM_{10} and $PM_{2.5}$ concentrations observed at the EMEP monitoring network, represented by colour triangles overlaying the contours of the modelled concentration fields.

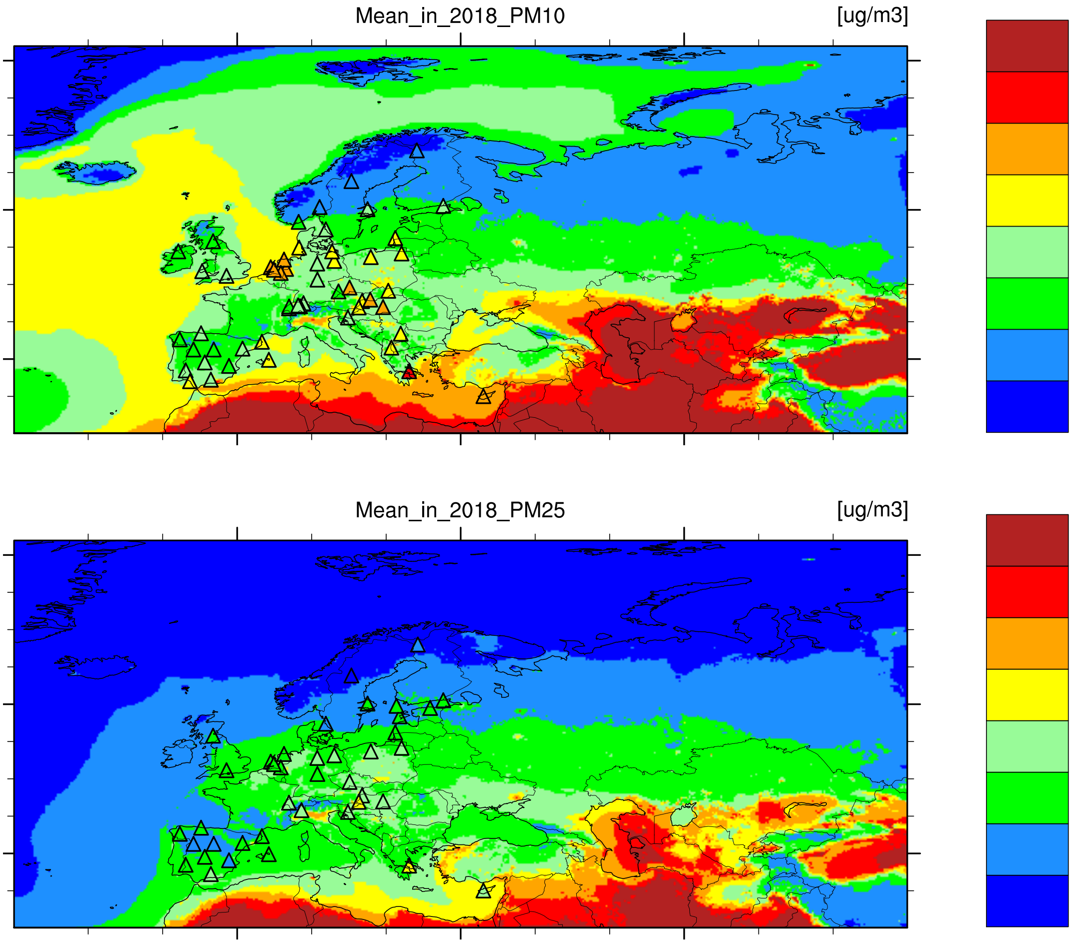


Figure 2.8: Annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2018: calculated with the EMEP MSC-W model (colour contours) and observed at EMEP monitoring network sites (colour triangles). *Note: Observations include hourly, daily and weekly data.*

The model results and the observations are well in agreement regarding the geographical distribution of the annual mean levels of PM_{10} and $PM_{2.5}$, showing their general increase over land from north to south. The concentrations are below 2-5 $\mu g\ m^{-3}$ in Northern Europe,

increasing to 5-15 μg m^{-3} in the mid-latitudes and further south, with $PM_{2.5}$ levels being somewhat lower than those of PM_{10}. Figure 2.8 displays fairly homogeneous levels of regional background PM over most of Central and Western Europe, with somewhat elevated PM_{10} levels of 15-20 μg m^{-3} in the Po Valley and the Benelux. The observations also show elevated PM_{10} concentrations in Poland, Czechia and Hungary, while the model calculates high PM for the regions east of the Caspian Sea (parts of Kazakhstan, Uzbekistan, Turkmenistan) and over the southern Mediterranean, with annual mean concentrations in excess of 50 μg m^{-3}. As explained in earlier EMEP reports, these high PM concentrations are due to windblown dust from the arid soils and deserts of Central Asia, though the accurateness of the calculated values still cannot be verified due to the lack of observations in these regions.

There is good agreement between the modelled and observed distributions of annual mean PM_{10} and $PM_{2.5}$, with correlation coefficients of 0.66 and 0.81, respectively. Overall, the model underestimates the observed annual mean of PM_{10} by 22% and $PM_{2.5}$ by 14%. A comprehensive model evaluation is provided in Tsyro et al. (2020).

In terms of meteorological conditions, the year 2018 was relatively warm across the EMEP area (except for Asian parts of Russia and Kazakhstan), particularly in Central Europe (Figure 2.1). The spring and summer were also notably warm in Fennoscandia, the Baltic countries and Eastern Europe. Mild winter conditions would mean less need for residential heating, resulting in lower emissions from this sector. Moreover, stagnant air conditions (with temperature inversion, low wind speed and thin mixing layer), causing elevated pollution levels, are less frequent in warm winters. In spring/summer time, higher temperatures would enhance evaporation of semi-volatile inorganic and organic aerosols (SIA and SOA), though the more efficient oxidation contributes to secondary aerosol formation. Furthermore, in Northern and Central Europe, the Baltic region and European Russia, the year 2018 was dry compared to the 2000-2017 average, especially in the spring and summer, which contributed to the photochemistry and secondary aerosol formation. On the other hand, it was a relatively wet year in Western and Southern Europe (Figure 2.1) and also in parts of Central, Northern and Eastern Europe in the winter (Tarrason et al. 2019), so that the pollutants were more efficiently removed from the air in those regions.

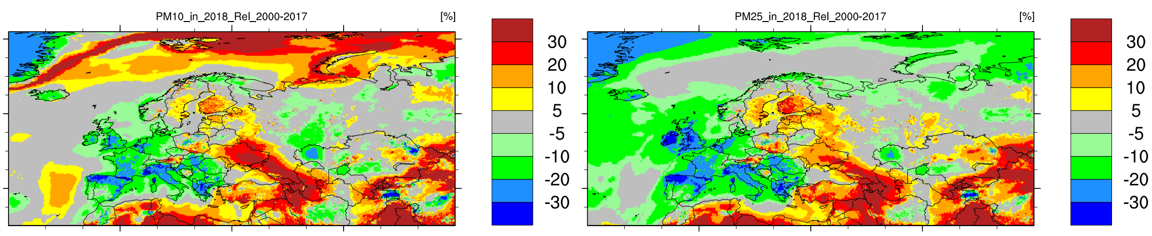


Figure 2.9: Relative anomalies of mean PM_{10} and $PM_{2.5}$ in 2018 from the 2000-2017 mean.

Figure 2.9 presents the relative anomalies of mean PM_{10} and $PM_{2.5}$ concentrations in 2018 relative to 2000-2017 averages simulated with a model version used for 2019 reporting and EMEP reported emissions. It shows that the PM pollution levels in 2018 were rather moderate, in particular in Central, Western and Southern Europe (10-30% lower compared to the 18-year average). Only in Turkey, the Caucasus region, Ukraine, the Baltic countries and southern parts of Finland and Sweden, PM_{10} and $PM_{2.5}$ levels were higher. The prolonged heat wave affected Central and Northern Europe during summer 2018 and caused enhanced aerosol levels; this is discussed in Chapter 4.

Exceedances of EU limit values and WHO Air Quality Guidelines in 2018

In this section we compare PM_{10} and $PM_{2.5}$ exceedances of EU critical limits and WHO recommended Air Quality Guidelines (WHO 2005), calculated by the EMEP MSC-W model, with those measured at EMEP sites. The EU limit values for PM_{10} (Council Directive 1999/30/EC) are 40 μg m^{-3} for the annual mean and 50 μg m^{-3} for the daily mean concentrations, with the daily limit not to be exceeded more than 35 times per calendar year (EU 2008). For $PM_{2.5}$, the annual mean limit value of 25 μg m^{-3} entered into force on 01.01.2015.

The Air Quality Guidelines (AQG) recommended by WHO (WHO 2005) are:

- for PM_{10}: 20 μg m^{-3} annual mean, 50 μg m^{-3} 24-hourly (99th perc. or 3 days per year)
- for $PM_{2.5}$: 10 μg m^{-3} annual mean, 25 μg m^{-3} 24-hourly (99th perc. or 3 days per year)

The EU limit values for protection of human health from particulate matter pollution and the WHO AQG for PM should apply to concentrations for zones or agglomerations, in rural and urban areas, which are representative for exposure of the general population. PM_{10} and $PM_{2.5}$ concentrations calculated with the EMEP MSC-W model on the $0.1° \times 0.1°$ grid cannot reproduce urban hotspot levels, but give a reasonable representation of PM levels occurring in rural and, to some extend, in urban background areas.

Model results and EMEP observational data show that the annual mean PM_{10} concentrations were below the EU limit value of 40 μg m^{-3} for all of Europe in 2018 (Figure 2.8). The model calculates annual mean PM_{10} above the WHO recommended AQG of 20 μg m^{-3} in only small regions in the Po Valley and western Turkey. The highest observed annual mean PM_{10} concentrations, exceeding the AQG of 20 μg m^{-3} , were registered in Slovakia (SK0007) with 26 μg m^{-3} , Greece (GR0001, but only 53% data coverage) with 25 μg m^{-3} , in Cyprus (CY0002) with 24 μg m^{-3} , in Czechia (CZ0003) with 23 μg m^{-3} , the Netherlands (NL0010R) with 21 μg m^{-3} and Hungary (HU0002) with 20 μg m^{-3} . Further, the observations and model results show that annual mean $PM_{2.5}$ concentrations (Figure 2.8) in 2018 were below the EU limit value of 25 μg m^{-3} (except in the Po Valley according to the model). However, there were observed cases of exceedance of the WHO AQG value of 10 μg m^{-3} by annual mean $PM_{2.5}$ at seventeen sites, with the highest values in Hungary (HU0003 with 16 μg m^{-3} and HU0002 with 15.5 μg m^{-3}) and in Austria (AT0002) and Czechia (CZ0003) both with 14.5 μg m^{-3} .

The maps in Figure 2.10 show the number of days with exceedances of 50 μg m^{-3} for PM_{10} and 25 μg m^{-3} for $PM_{2.5}$ in 2018: modelled values as colour contours and observed values as triangles.

Out of the 62 sites with daily or hourly PM_{10} measurements with data coverage above 75%, exceedance days were observed at 36 sites. No violations of the PM_{10} EU limit value (more than 35 exceedance days) were observed. Still, 18 sites had more than 3 exceedance days (according to WHO AQG recommendations). The highest numbers of days with observed exceedances of PM_{10} were 25 at CY0002 and SK0007, and 17 at CZ0003.

$PM_{2.5}$ concentrations exceeded the WHO AQG value at 31 out of 41 stations in 2018. Among those, at 21 sites the number of exceedance days were more than 3 (the recommended limit according to WHO AQG). The highest number of exceedance days registered were 50, which were observed at HU0002, IT0004 and PL0009, followed by 49 and 48 exceedance days at AT0002 and HU0003, respectively.

The modelled numbers of exceedance days in 2018 show in general a good correspondence with the observations, with somewhat better agreement for PM_{10} than for $PM_{2.5}$. For

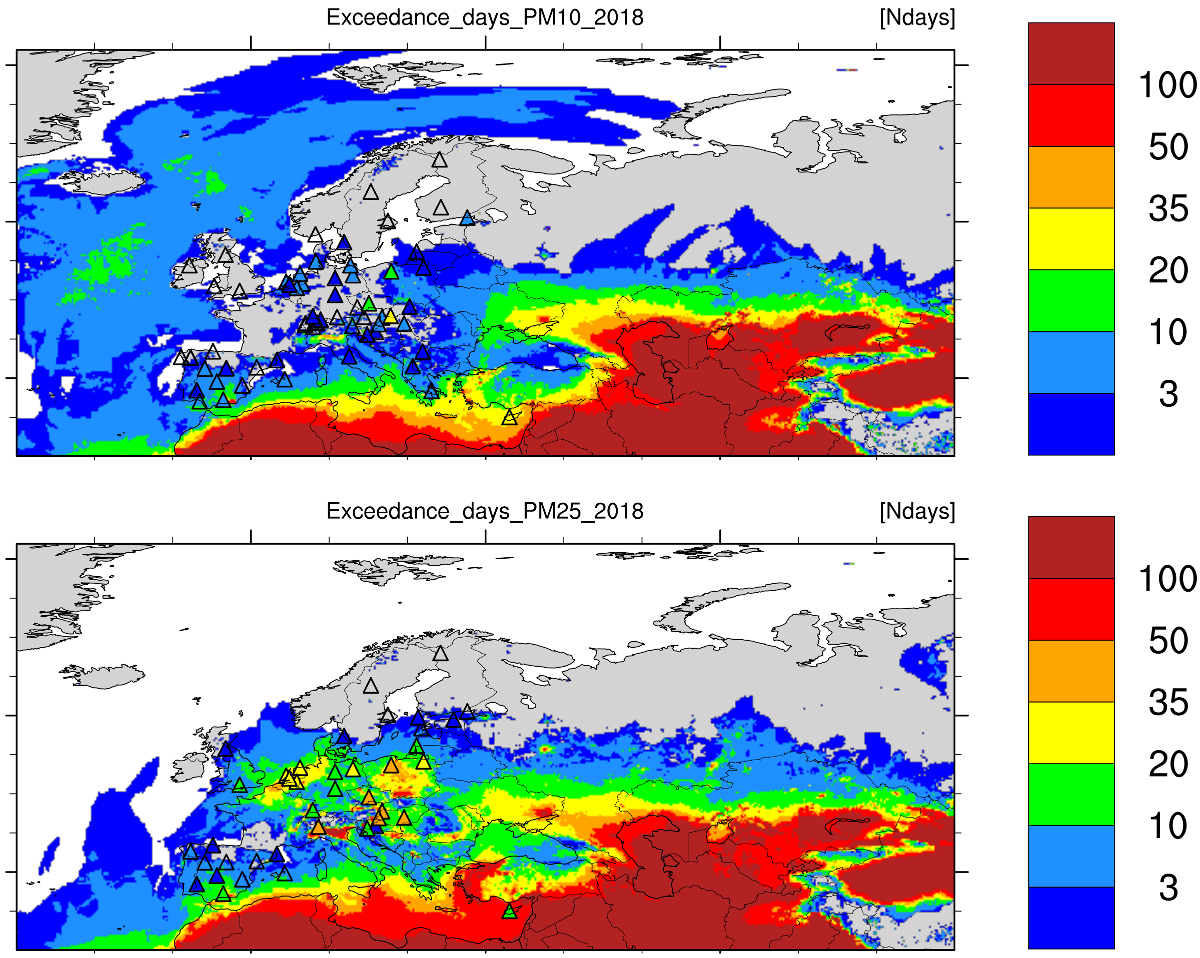
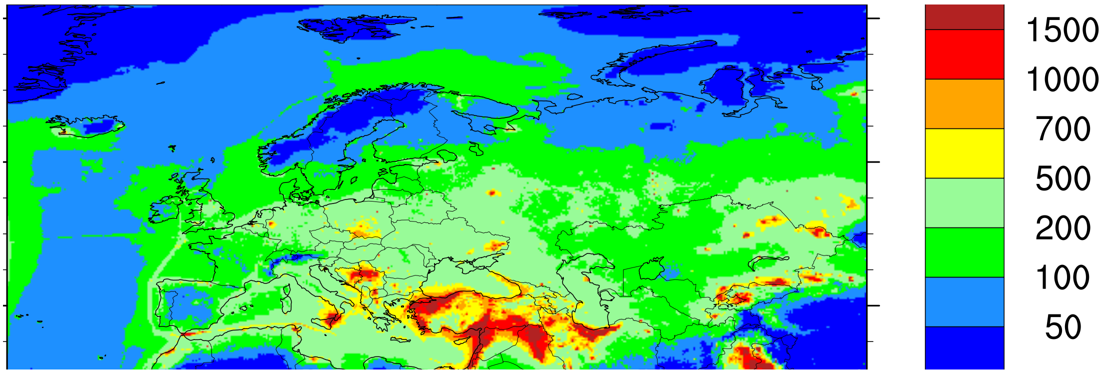


Figure 2.10: Calculated (with 0.1°resolution) and observed (triangles) number of days with exceedances in 2018: PM_{10} exceeding 50 μg m^{-3} (upper) and $PM_{2.5}$ exceeding 25 μg m^{-3} (lower panel). *Note: The EU Directive requires no more than 35 days with exceedances for PM_{10}, whereas WHO recommends no more than 3 days with exceedances for PM_{10} and $PM_{2.5}$ per calendar year.*

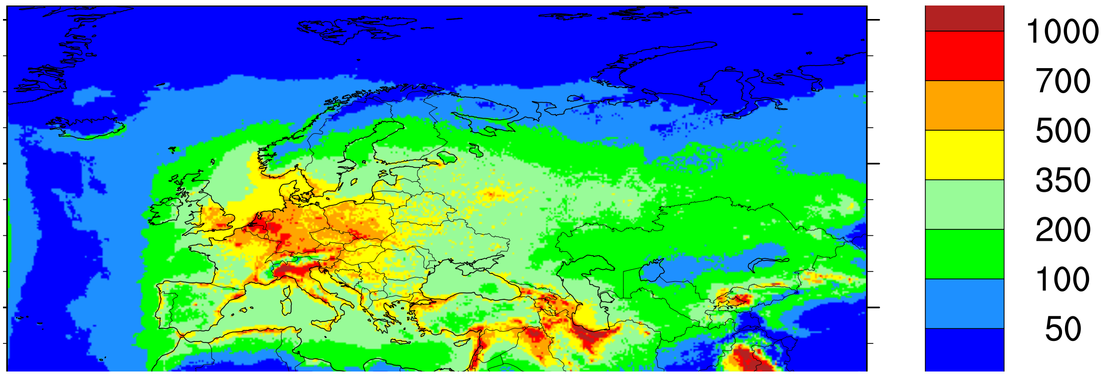
PM_{10}, the model underestimates the frequency of exceedances of the EU limit value of 50 μg m^{-3} for some central European sites, for instance at SK0007 and CZ0003 (no modelled exceedance days versus, respectively, 25 and 17 observed), PL0009 (1 exceedance day vs. 11 observed) and HU0002 (no exceedance day vs. 10 observed). On the other hand, the model tends to somewhat overestimate the number of exceedance days at some Mediterranean sites, influenced by Saharan dust, e.g. at the Cypriot site CY0002 (28 vs. 25 observed) and several Spanish sites (in particular ES0007 with 23 vs. 5 observed). Practically all the exceedances registered at the central European sites occurred during winter and autumn (and also in spring at e.g. Polish, Dutch, and Hungarian sites). By contrast, at the Mediterranean sites the exceedances were more frequent during summer.

For $PM_{2.5}$, the model calculates 17 exceedance days versus 50 observed at PL0009, 28 versus 49 observed at AT0002, 17 versus 48 observed at HU0003. At the Dutch sites, the model slightly underestimates observed $PM_{2.5}$ exceedance days at NL0009, but overestimates those at NL0010, NL0091 and NL0644. Also, the numbers of exceedance days are overestimated by the model at the Croatian site HR0002 (39 vs 2 observed) and at Ispra in Italy (IT0004, 64 vs 49 observed). As for PM_{10}, the model calculates a larger number of exceedance days

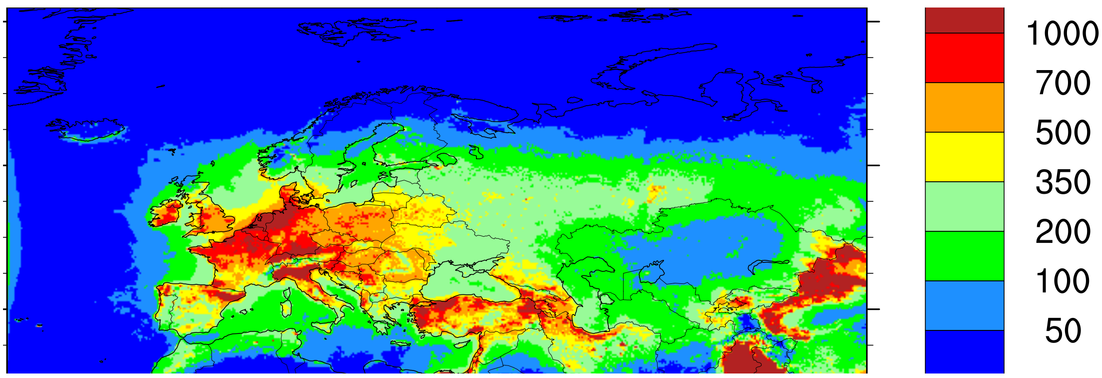
for $PM_{2.5}$ compared with observations at CY0002 and several Spanish sites, which is related to the uncertainties in windblown dust modelling. The seasonality of $PM_{2.5}$ exceedances is similar to that of PM_{10}, with most exceedance days at the Mediterranean sites in summer and at the other sites in winter, spring and autumn. The only difference is that the largest number of $PM_{2.5}$ exceedances at three of four German sites occurred in spring, while much fewer occurred during the cold seasons.



(a) oxidized S



(b) oxidized N



(c) Reduced N

Figure 2.11: Deposition of sulphur and nitrogen [mg(S)m^{-2}, mg(N)m^{-2}] in 2018.

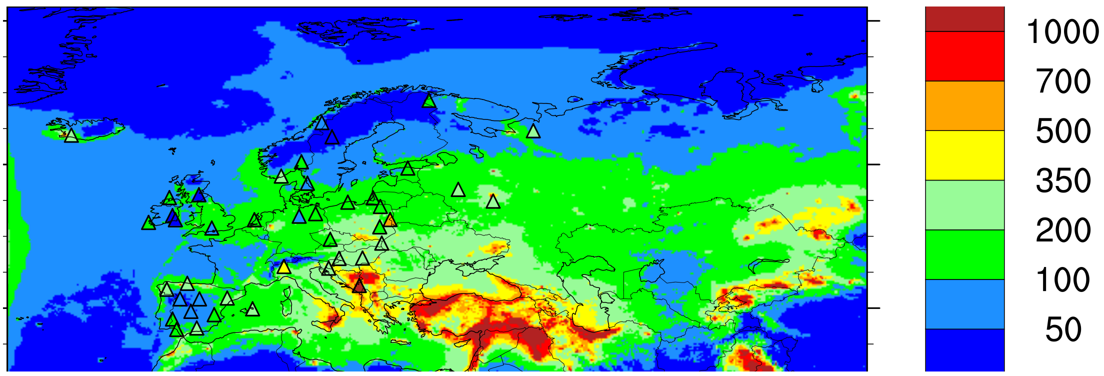
2.4.3 Deposition of sulphur and nitrogen

Modelled total depositions of sulphur and oxidised and reduced nitrogen are presented in Figure 2.11. For sulphur, many hot spots are found in the south-eastern part of the domain. In

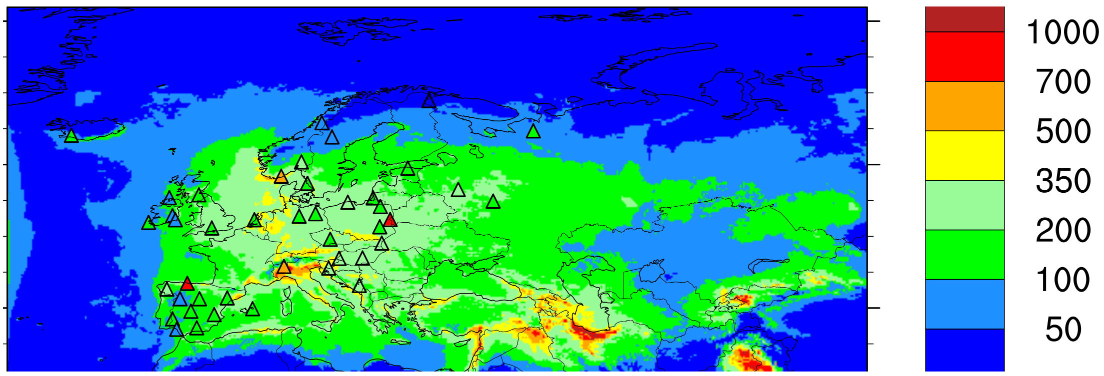
addition, volcanic emissions of SO_2 lead to high depositions in and around Sicily.

Oxidised nitrogen depositions are highest in northern Germany, the Netherlands, Belgium, Poland and northern Italy. These countries also have high depositions of reduced nitrogen, as do parts of the United Kingdom, France, Belgium in western Europe, and Turkey, Georgia, Armenia, Azerbaijan, Kyrgyzstan, Uzbekistan and Tajikistan in the east.

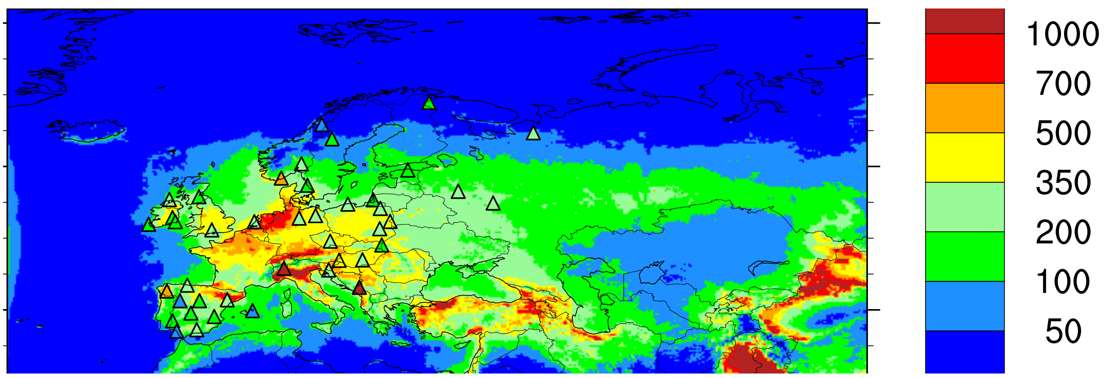
In Figure 2.12 wet depositions of nitrogen and sulphur compounds are compared to measurements at EMEP sites for 2018. Overall, the bias of the model with respect to measurements is around -36% to +5%, but higher for individual sites. A more detailed comparison between model and measurements for the year 2018 can be found in Gauss et al. (2020b).



(a) oxidized S



(b) oxidized N



(c) Reduced N

Figure 2.12: Modelled wet deposition of sulphur and nitrogen [mg(S)m^{-2}, mg(N)m^{-2}] in 2018, with EMEP observations on top (marked by triangles).

2.4.4 Exceedances of critical loads of acidification and eutrophication

The exceedances of European critical loads (CLs) are computed for the total nitrogen (N) and sulphur (S) depositions modelled on the 0.1°× 0.1° longitude-latitude grid (approx. 11 x 5.5 km^2 at 60°N). Exceedances are calculated for the European critical loads documented in Hettelingh et al. (2017), while a description of the methods is given in De Vries et al. (2015). The critical loads data for eutrophication by N (CL eut N) and for acidification by N and S (CL acid) are also used by the EMEP Centre CIAM (located at IIASA) in their integrated assessment modelling. The exceedance in a grid cell is the so-called 'average accumulated exceedance' (AAE), which is calculated as the area-weighted average of the exceedances of the critical loads of all ecosystems in this grid cell. The units for critical loads and their exceedances are equivalents (eq; same as *moles of charge*, molc) per area and time, making S and N depositions comparable on their impacts, which is important for acidity CLs.

Critical loads are available for about 4 million ecosystems in Europe covering an area of about 3 million km^2 (west of 42°E). The exceedances (AAE) of those critical loads are computed on a 0.1°× 0.1° longitude-latitude grid, and maps for the deposition in the years 2017 and 2018 are shown in Figures 2.13 and 2.14. As it can be seen from the maps, critical loads for eutrophication are exceeded in practically all countries in both years. The exceedance occurs on 63.3% (2017) and 64.8% (2018) of the ecosystem area. European average AAE is about 281 eq ha^{-1} yr^{-1} (2017) and 273 eq ha^{-1} yr^{-1} (2018). The highest exceedances of CLs are found in the Po Valley in Italy, the Dutch-German-Danish border areas and in north-eastern Spain. By contrast, critical loads of acidity are exceeded in a much smaller area. Hot spots of exceedances can be found in the Netherlands and its border areas to Germany and Belgium, and some smaller maxima in southern Germany and Czechia, whereas most of Europe is not exceeded (grey areas). Acidity exceedances occur on 5.5% (2017) and 5.2% (2018) of the ecosystem area, and the European average AAE is about 34 eq ha^{-1} yr^{-1} (2017) and 24 eq ha^{-1} yr^{-1} (2018).

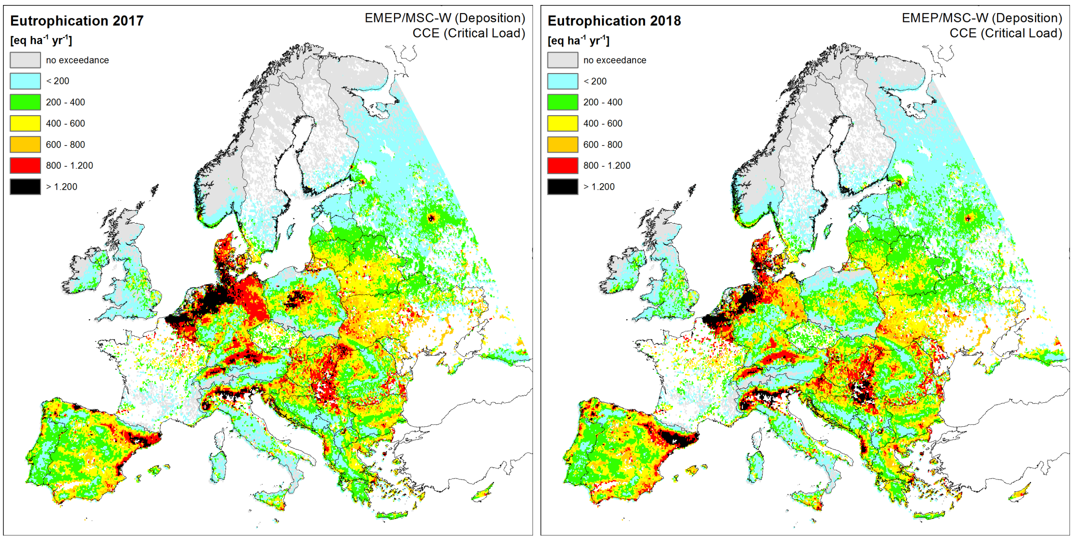


Figure 2.13: Exceedance of Critical Load for Eutrophication for the Year 2017 (left) and 2018 (right).

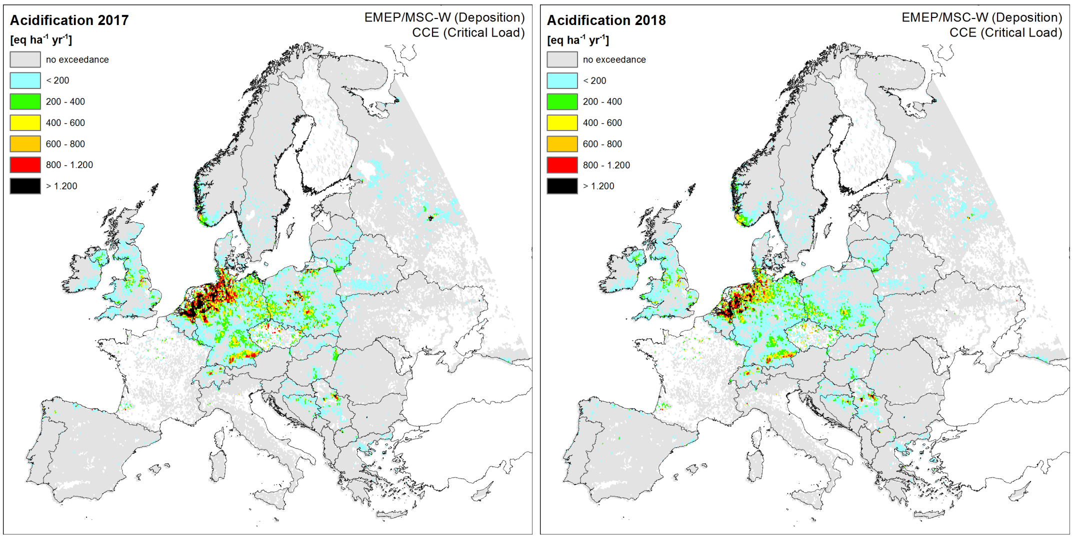


Figure 2.14: Exceedance of Critical Load for Acidification for the Year 2017 (left) and 2018 (right).

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CHAPTER 3

Emissions for 2018

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In addition to meteorological variability, changes in the emissions affect the inter-annual variability and trends of air pollution, deposition and transboundary transport. The main changes in emissions in 2018 with respect to previous years are documented in the following sections.

The EMEP Reporting guidelines (UNECE 2014) requests all Parties to the LRTAP Convention to report annually emissions and activity data of air pollutants (SO_x[1], NO_2[2], CO, NMVOCs[3], NH_3, HMs, POPs, PM[4] and voluntary BC). Further, every four years, projection data, gridded data and information on large point sources (LPS) have to be reported to the EMEP Centre on Emission Inventories and Projections (CEIP).

3.1 Reporting of emission inventories in 2020

Completeness and consistency of submitted data have improved significantly since EMEP started collecting information on emissions. Data of at least 45 Parties each year were submitted to CEIP for in years 2012-2019 (see Figure 3.1). As of 1 June 2020, 43 Parties (84%)

[1]"Sulphur oxides (SO_x)" means all sulphur compounds, expressed as sulphur dioxide (SO_2), including sulphur trioxide (SO_3), sulphuric acid (H_2SO_4), and reduced sulphur compounds, such as hydrogen sulphide (H_2S), mercaptans and dimethyl sulphides, etc.

[2]"Nitrogen oxides (NO_x)" means nitric oxide and nitrogen dioxide, expressed as nitrogen dioxide (NO_2).

[3]"Non-methane volatile organic compounds" (NMVOCs) means all organic compounds of an anthropogenic nature, other than methane, that are capable of producing photochemical oxidants by reaction with nitrogen oxides in the presence of sunlight.

[4]"Particulate matter" (PM) is an air pollutant consisting of a mixture of particles suspended in the air. These particles differ in their physical properties (such as size and shape) and chemical composition. Particulate matter refers to:
(i) "$PM_{2.5}$", or particles with an aerodynamic diameter equal to or less than 2.5 micrometers (μm);
(ii) "PM_{10}", or particles with an aerodynamic diameter equal to or less than 10 (μm).

submitted inventories[5] in 2020; eight Parties[6] did not submit any data and 40 Parties reported black carbon (BC) emissions (see section 3.2). Although 2020 was no reporting year for large point sources (LPS), gridded emissions and projections, seven Parties reported information on LPS, nine Parties reported gridded data, and five Parties reported projection data (Pinterits et al. 2020).

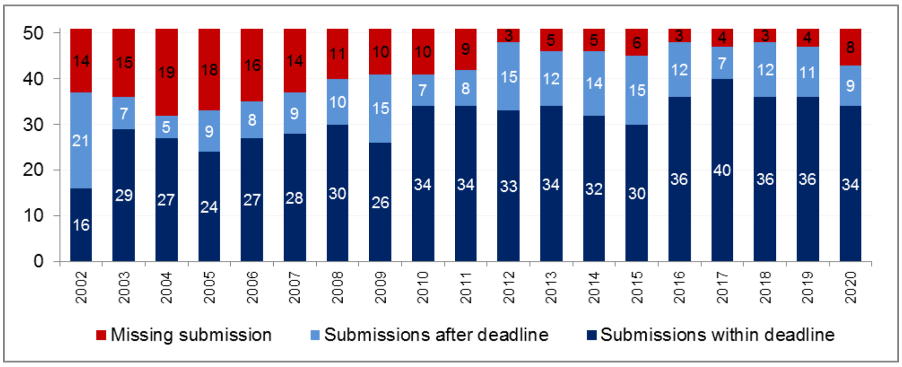


Figure 3.1: Parties reporting emission data to EMEP since 2002, as of 1 June 2020.

The quality of the submitted data across countries differs quite significantly. By compiling the inventories, countries have to use the newest available version of the *EMEP/EEA air pollutant emission inventory guidebook*, which is the version of 2016 (EMEP/EEA 2016). However, many countries still use the 2013 Guidebook (EMEP/EEA 2013) or older versions. Uncertainty of the reported data (national totals, sectoral data) is considered relatively high, the completeness of reported data has not turned out satisfactory for all pollutants and sectors either.

Detailed information on recalculations, completeness and key categories, plus additional review findings can be found in the annual CEIP technical country reports[7].

3.2 Black Carbon (BC) emissions

Over the last decade, black carbon (BC) has emerged as an important air pollutant in terms of both climate change and air quality.

The emerging significance of BC is mirrored in developments in the international policy arena with respect to emissions reporting. Since the Executive Body Decision 2013/04, Parties to the LRTAP Convention have been formally encouraged to submit inventory estimates of their national BC emissions, and in 2015 the reporting templates were updated to include BC data emissions.

In addition to reporting under CLRTAP, EU member states are also encouraged to submit BC emissions estimates as part of their emissions reporting under the National Emissions Ceilings (NEC) Directive (2016/2284/EU).

[5] The original submissions from the Parties can be accessed via the CEIP homepage on https://www.ceip.at/status-of-reporting-and-review-results/2020-submissions.

[6] Albania, Azerbaijan, Bosnia and Herzegovina, Georgia, Liechtenstein, Monaco, Russian Federation and USA

[7] https:www.ceip.at/status-of-reporting-and-review-results/2020-submissions

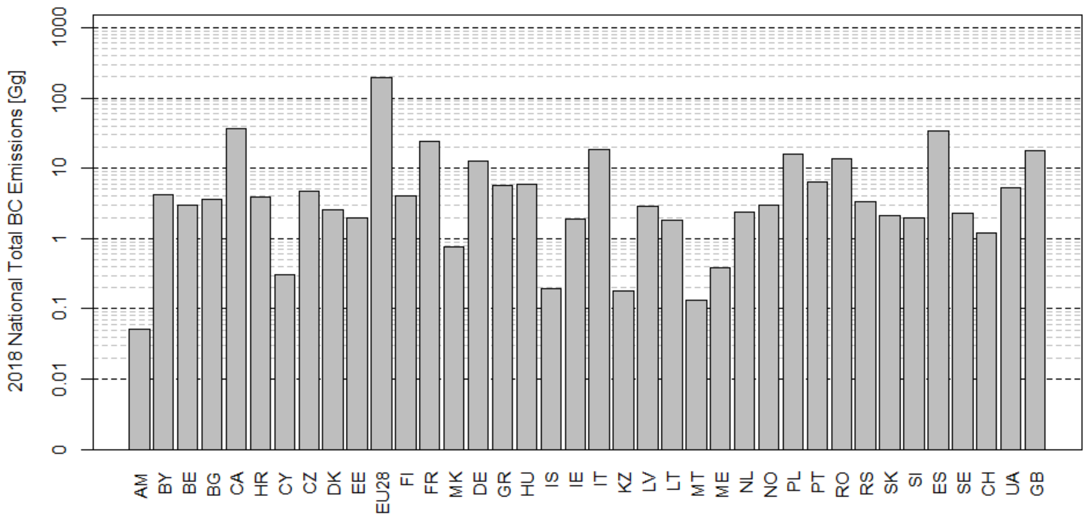


Figure 3.2: Black carbon emissions of the year 2018 as reported by CLRTAP Parties.

While BC is not a mandatory pollutant to be reported under CLRTAP, CEIP continues to monitor and review the level of BC reporting by the Convention's Parties. A brief overview of BC emissions estimates submitted by EMEP countries in 2020 is given in Figure 3.2 .

Since enabling the reporting of BC, a total of 44 CLRTAP Parties have reported BC emissions estimates[8]. In this round of reporting, 25 CLRTAP Parties submitted a complete time series of national total BC emissions (1990-2018), while 33 CLRTAP Parties submitted a complete time series from 2000 onwards. Furthermore, 38 EMEP Parties have provided national total BC emissions estimates for the year 2018.

For more detailed information on BC consult the annual CEIP technical inventory review report (Pinterits et al. 2020).

3.3 Inclusion of the condensable component in reported PM emissions

The condensable component of particulate matter is a class of compounds of low volatility that may exist in equilibrium between the gas and particle phase. It is probably the biggest single source of uncertainty in PM emissions. Currently the condensable component is not included or excluded consistently in PM emissions reported by Parties of the LRTAP Convention. Also in the EMEP/EEA Guidebook (EMEP/EEA 2019) the condensable fraction is not consistently included or excluded in the emission factors. Various EMEP centres and task forces and other stakeholders jointly discuss the topic and work on progress in this area. An important activity this year was the workshop organised by MSC-W that will result in a workshop report (Simpson et al. 2020). However, at the moment PM emissions reported by Parties to the LRTAP Convention are not directly comparable, which has implications on the modeling of overall exposure to PM.

Parties were asked to include a table with information on the inclusion of the condensable component in PM_{10} and $PM_{2.5}$ emission factors for the reporting under the CLRTAP conven-

[8]As of 1 June 2020 Albania, Austria, Bosnia and Herzegovina, Liechtenstein, Luxembourg, Russia, and Turkey have yet to report estimates of national BC emissions.

Table 3.1: Information on the inclusion of the condensable component in PM_{10} and $PM_{2.5}$ emission factors.

Party	NFR category	Source/sector name (according to Annex I, Reporting Guidelines, modified in selected cases)	Status of inclusion of PM emissions
Austria	1A4bi	Residential: Stationary	partially included + unclear status
Belgium	1A4bi	Residential: Stationary	Wood: included Other fuels: excluded
Croatia	1A4bi	Residential: Stationary	unclear status
Denmark	1A4bi	Residential: Stationary	Wood: included Other fuels: excluded
Estonia	1A4bi	Residential: Stationary	excluded
Finland	1A4bi	Residential: Stationary	partially included
France	1A4bi	Residential: Stationary	excluded
Germany	1A4bi	Residential: Stationary	excluded
Latvia	1A4bi	Residential: Stationary	partially included
Lithuania	1A4bi	Residential: Stationary	excluded
Luxemburg	1A4bi	Residential: Stationary	excluded
Netherlands	1A4bi	Residential: Stationary	included
Poland	1A4bi	Residential: Household and gardening (mobile)	solid fuels :included
Portugal	1A4bi	Residential: Stationary (wood combustion)	included
Romania	1A4bi	Residential	partially included + unclear status
Slovakia	1A4bi	Residential: Stationary	unclear status
Slovenia	1A4bi	Residential: Stationary	partially excluded + unclear status
Spain	1A4bi	Residential: Stationary	partially included + unclear status
Sweden	1A4bi	Residential: Stationary	included
Switzerland	1A4bi	Charcoal use Bonfire	included
United Kingdom	1A4bi	Residential: Stationary	partially included + unclear status

tion in 2019 and 2020. This table has been added to the revised recommended structure for informative inventory reports (IIRs)[9]. Twenty-one Parties provided information on the inclusion of the condensable component in PM_{10} and $PM_{2.5}$ emission factors (Austria, Belgium, Croatia, Denmark, Estonia, Germany, Finland, France, Latvia, Lithuania, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom)[10]. This reporting is a first step towards a better understanding of the reported PM data. The information that Parties provided on whether the condensable component is included in PM emissions was quite heterogeneous. The status of inclusion or exclusion is best known for emissions from the energy sector and road transport, for which many Parties submitted information. For example for *"1A3bi Road transport passenger cars"* 17 out of 18 Parties that provided condensable information for this source category report emissions to be included and only one Party states that the status of inclusion is unknown. For most other sectors, Parties either indicated that it is "unknown" whether the condensable component is included in the PM emissions or they did not provide any information.

Small-scale combustion sources make a notable contribution to total PM emissions. For all Parties that reported $PM_{2.5}$ emissions for *"1A4bi Residential: Stationary"* for the year 2018[11] emissions from this source category contributed 47% to the national total $PM_{2.5}$ emissions. Small-scale combustion is one of the sources where the inclusion of the condensable component has the largest impact on the emission factor. For example, for conventional woodstoves, one of the most important categories in Europe, the emission factors excluding and including the condensable fractions may differ by up to a factor of five (Denier van der Gon et al. 2015). Here the status of the inclusion was less clear. Of the twenty-one Parties that provided information for "1A4bi Residential: Stationary" four parties reported the condensable component to be included and five Parties to be excluded. The other Parties reported "unknown", "partially included" or provided information on a more detailed level with different status of inclusion (see Table 3.1).

For the modelling work this year, and following a decision of UNECE (2020), EMEP MSC-W has made use of the so-called 'Ref2' emissions provided by TNO, which include condensable organics. These data and their usage are described further in Chapter 5 and Chapter 6.

3.4 Comparison of 2017 data (reported in 2019) and 2018 data (reported in 2020)

The comparison of 2017 emissions (reported in 2019) and 2018 emissions (reported in 2020) showed, that for 32 countries data changed by more than 10% for one or several pollutants (see Figure 3.3 and Table 3.2-3.3). These changes can be caused by real emission reductions or increases, or recalculations made by the respective country.

In five countries, both NO_x and CO emissions changed by more than 10%. For NMVOCs, emissions changed in two countries by more than 10%. For SO_x, emissions changed by more than 10% in 14 countries, while for NH_3 the change of emission levels were less than 10% in each country. Of the PMs, emissions changed by more than 10% in ten countries for $PM_{2.5}$, in

[9] https://www.ceip.at/reporting-instructions/annexes-to-the-2014-reporting-guidelines
[10] Status 18 May 2020
[11] Status as of 7 May 2020.

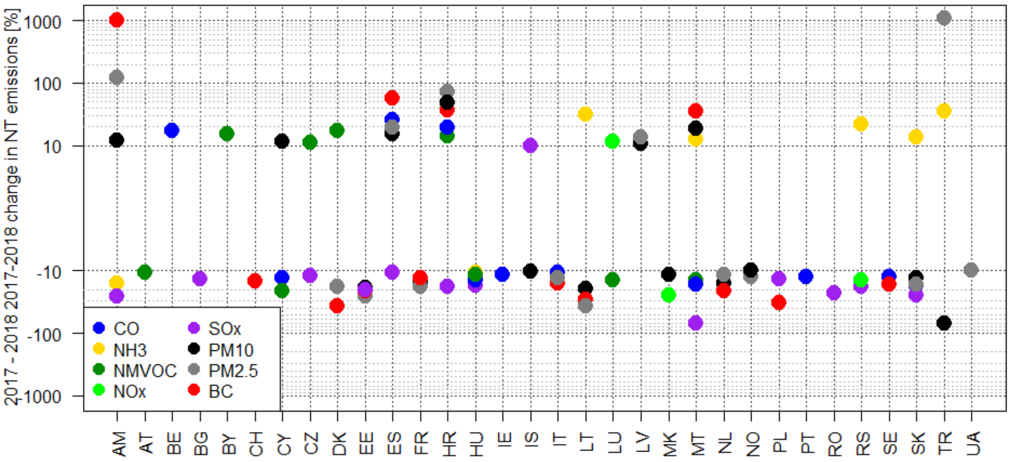


Figure 3.3: Emission changes between 2017 and 2018 in reported data (only changes larger than 10% are shown).

seven countries for PM_{10} and in nine countries for PM_{coarse}[12] (see Figure 3.5 and Table 3.2-3.3). The largest changes occurred in Belarus, Kyrgyzstan, Malta and Ukraine.

Reported emissions of NO_x were relatively stable, with 2017 to 2018 changes of more than 10% observed for three countries. For seven and ten countries respectively, NH_3 and NMVOC emissions changed by more than 10%. For CO and SO_x, 2017 to 2018 changes of more than 10% were observed for 12 and 13 countries, respectively. For emissions of particulate matter, more countries reported changes higher than 10%. In 16 countries, emissions of both $PM_{2.5}$ and PM_{10} changed by more than 10% from 2017 to 2018, while for BC 14 countries reported changes higher than 10%.

Changes above 50% were observed in Armenia, Croatia, Malta, Spain and Turkey. For Armenia, the 121% and 1000% increases in $PM_{2.5}$ and BC emissions were caused to a large extent by the increases in reported emissions from the sector *"1A4bi – Residential: Stationary"*. Such changes are likely due to a revision of the calculations. However, only estimates for the year 2018 were reported by Armenia in 2020 and new estimates of the previously reported years were not submitted.

For Croatia, the 72% increase in $PM_{2.5}$ was caused by an upward revision of the time series from 2005 onwards. This increase was mostly due to the revision of emissions from the sector *"1A4bi – Residential: Stationary"*.

For Malta, the 69% decrease in SO_x emissions mainly originates in the NFR category *"1A1a – Public electricity and heat production"*. Malta explained in its IIR that the decline in SO_x emissions mirrors the continued decrease in electricity generated from fuel combustion.

For Spain, the 56% increase in BC emissions was caused by an upward revision of the time series from 2000 onwards. The increase was mostly due to the upward revision of emissions from the sector *"5C2 – Open burning of waste"*.

[12] PM_{coarse} emissions are not reported by Parties but calculated as difference between PM_{10} and $PM_{2.5}$ emissions.

Table 3.2: Reported emission changes between 2017 (reported in 2019) and 2018 (reported in 2020) over 10% for main pollutants.

Pollutant	Country	2017 emissions (kt)	2018 emissions (kt)	Difference (kt)	Difference (%)
CO	BE	293.34	343.57	50.23	17.12
CO	CY	13.85	12.03	-1.82	-13.14
CO	ES	1309.37	1647.08	337.7	25.79
CO	HR	196.58	234.87	38.29	19.48
CO	HU	422.64	362.02	-60.62	-14.34
CO	IE	88.42	78.06	-10.36	-11.72
CO	IT	2331.32	2081.53	-249.78	-10.71
CO	MT	10.14	8.42	-1.71	-16.89
CO	PT	324.96	284.53	-40.43	-12.44
CO	SE	384.4	336.52	-47.87	-12.45
CO	SK	364.99	301.39	-63.6	-17.43
CO	UA	1128.56	1015.7	-112.86	-10
NH3	AM	19.35	16.25	-3.1	-16.02
NH3	HU	87.7	78.48	-9.22	-10.52
NH3	LT	29.55	38.89	9.34	31.62
NH3	MT	1.13	1.28	0.14	12.76
NH3	RS	64.91	78.97	14.05	21.65
NH3	SK	26.54	30.13	3.58	13.49
NH3	TR	739.7	996.82	257.11	34.76
NMVOC	AT	120.19	107.22	-12.97	-10.79
NMVOC	BY	143.3	165.51	22.21	15.5
NMVOC	CY	12.32	9.68	-2.64	-21.41
NMVOC	CZ	207.34	230.91	23.57	11.37
NMVOC	DK	102.26	119.67	17.41	17.03
NMVOC	HR	63.24	72.17	8.93	14.12
NMVOC	HU	141.52	125.31	-16.21	-11.45
NMVOC	LU	12.1	10.37	-1.73	-14.28
NMVOC	MT	3.45	2.97	-0.48	-14.02
NMVOC	UA	236.46	212.82	-23.65	-10
NOx	LU	18.31	20.46	2.15	11.74
NOx	MK	24.48	18.51	-5.96	-24.35
NOx	RS	147.64	127.15	-20.49	-13.88
SOx	AM	38.51	28.67	-9.84	-25.55
SOx	BG	103.07	88.78	-14.29	-13.86
SOx	CZ	109.96	96.51	-13.45	-12.23
SOx	EE	38.65	30.86	-7.79	-20.16
SOx	ES	220.44	196.71	-23.73	-10.77
SOx	HR	12.56	10.3	-2.26	-18.01
SOx	HU	27.72	22.95	-4.78	-17.23
SOx	IS	49.73	54.71	4.98	10.01
SOx	MT	0.63	0.19	-0.44	-69.22
SOx	PL	582.66	501.93	-80.72	-13.85
SOx	RO	106.93	82.47	-24.46	-22.87
SOx	RS	420.2	345.53	-74.67	-17.77
SOx	SK	27.04	20.35	-6.69	-24.73

Table 3.3: Reported emission changes between 2017 (reported in 2019) and 2018 (reported in 2020) over 10% for PM and BC.

Pollutant	Country	2017 emissions (kt)	2018 emissions (kt)	Difference (kt)	Difference (%)
PM10	AM	0.89	1	0.11	12.14
PM10	CY	2.05	2.29	0.24	11.46
PM10	EE	13.91	11.27	-2.64	-18.99
PM10	ES	172.1	198.26	26.16	15.2
PM10	FR	254.23	215.71	-38.52	-15.15
PM10	HR	25.38	37.81	12.43	49
PM10	IS	1.68	1.51	-0.17	-10.23
PM10	LT	14.2	11.4	-2.79	-19.69
PM10	LV	25.01	27.69	2.68	10.72
PM10	MK	16.12	14.27	-1.85	-11.46
PM10	MT	0.43	0.51	0.08	18.61
PM10	NL	26.93	22.71	-4.22	-15.66
PM10	NO	36.86	33.16	-3.7	-10.03
PM10	SK	22.59	19.62	-2.96	-13.12
PM10	TR	764.93	237.97	-526.96	-68.89
PM10	UA	114.37	102.93	-11.44	-10
PM2.5	AM	0.33	0.72	0.39	121.11
PM2.5	DK	20.06	16.39	-3.67	-18.3
PM2.5	EE	9.22	6.81	-2.41	-26.18
PM2.5	ES	105.1	125.31	20.21	19.23
PM2.5	FR	164.49	134.4	-30.09	-18.29
PM2.5	HR	16.73	28.73	12	71.76
PM2.5	HU	47.99	41.52	-6.47	-13.49
PM2.5	IS	1.28	1.15	-0.13	-10.34
PM2.5	IT	164.68	143.39	-21.28	-12.92
PM2.5	LT	9.08	5.78	-3.3	-36.3
PM2.5	LV	17.97	20.45	2.48	13.8
PM2.5	NL	14	12.36	-1.64	-11.73
PM2.5	NO	27.91	24.47	-3.44	-12.32
PM2.5	SK	18.07	15.12	-2.95	-16.32
PM2.5	TR	16.76	199.82	183.06	1092.18
PM2.5	UA	53.77	48.4	-5.38	-10
BC	AM	0	0.05	0.05	999.52
BC	CH	1.39	1.18	-0.21	-14.91
BC	DK	4.03	2.57	-1.46	-36.24
BC	EE	2.49	1.97	-0.52	-20.81
BC	ES	21.9	34.23	12.34	56.35
BC	FR	27.92	24.3	-3.62	-12.96
BC	HR	2.85	3.89	1.04	36.69
BC	HU	6.89	6	-0.89	-12.97
BC	IT	22.1	18.57	-3.53	-15.99
BC	LT	2.55	1.82	-0.73	-28.65
BC	MT	0.1	0.13	0.03	35.58
BC	NL	3.05	2.42	-0.63	-20.72
BC	PL	23.81	15.91	-7.91	-33.21
BC	SE	2.77	2.3	-0.46	-16.75

3.5 Gothenburg Protocol targets

The 1999 Gothenburg Protocol (GP) lists emission reduction commitments of NO_x, SO_x, NMVOCs and NH_3 for most of the Parties to the LRTAP Convention for the year 2010 (UNECE (1999)). These commitments should not be exceeded in 2010 and in subsequent years either.

In 2012, the Executive Body of the LRTAP Convention decided that adjustments to inventories may be applied in some circumstances (UNECE (2012)). From 2014 to 2020, adjustment applications of ten countries (Belgium, Denmark, Finland, France, Hungary, Germany, the Netherlands, Luxembourg, Spain and the United Kingdom) have been accepted and therefore these approved adjustments have to be subtracted for the respective countries when compared to the targets. In April 2020, Czechia submitted a new adjustment application, which will be approved most likely later this year.

Further, the reporting guidelines (UNECE (2014)) specify that some Parties within the EMEP region (i.e. Austria, Belgium, Ireland, Lithuania, Luxembourg, the Netherlands, Switzerland, the United Kingdom of Great Britain and Northern Ireland) may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance with their respective emission ceilings.

However, when considering only reported data, approved adjustments and fuel used data of the respective countries, Figure 3.4 indicates that Czechia could not reduce its NMVOC emissions with regard to the Gothenburg Protocol requirements, and that Croatia, Denmark, Germany, Norway and Spain are above their Gothenburg Protocol ceilings for NH_3. In terms of NO_x emissions, Norway exceeded their ceilings. For SO_x all countries were below their individual ceilings.

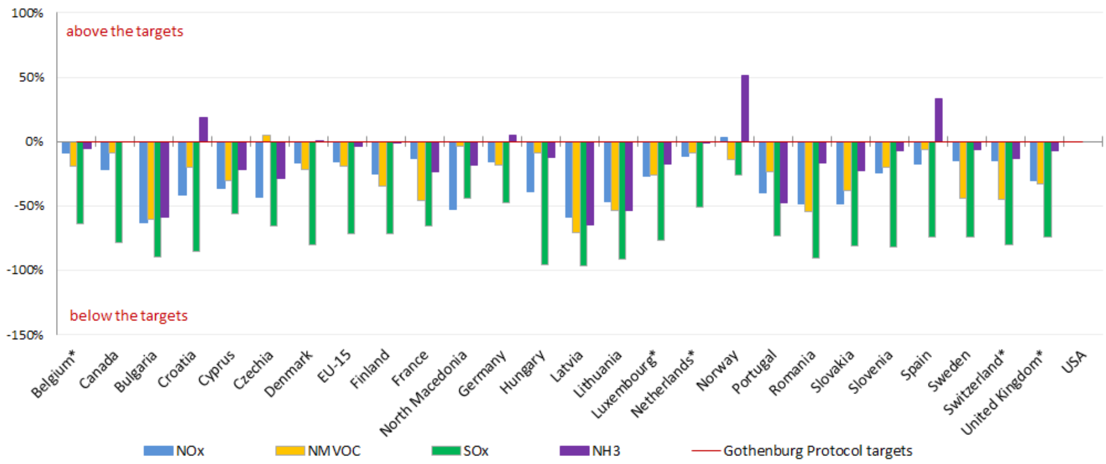


Figure 3.4: Distance to Gothenburg Protocol targets in 2020 (based on reported data). Only Parties that ratified the Gothenburg Protocol are included. * Emission data based on fuels used for road transport. Approved adjustments are considered for Denmark (NMVOCs, NH_3), Finland (NH_3), Germany (NO_x, NMVOCs, NH_3), Hungary (NMVOCs), Luxembourg (NO_x, NMVOCs), the Netherlands (NH_3, NMVOCs) and Spain (NO_x).

3.6 Emission trends in the EMEP area

To provide a picture as complete as possible of the emission trends in the EMEP area[13], data as used for EMEP models (i.e. gap-filled data) were used for the calculations (see Section 3.7).

The trend indicates that in the EMEP area total emissions of three of the reported pollutants have decreased overall since 2000 (Figure 3.5). Please note that PM_{coarse} is not reported but rather derived from the reported emissions of PM_{10} and $PM_{2.5}$. Nonetheless it is important to note that PM_{coarse} emissions have increased since 2000. The presented emission trends are based on gap-filled data as used in the EMEP models, therefore there is a certain uncertainty in the magnitude of this development. The observed decrease is significant for SO_x, CO, BC and NO_x; 75%, 91%, 92% and 94% of the respective 2000 emissions. In contrast, the 2018 emissions of NMVOC, $PM_{2.5}$, PM_{10}, PM_{coarse} and NH_3 have increased by 6%, 5%, 8%, 14% and 31%, respectively.

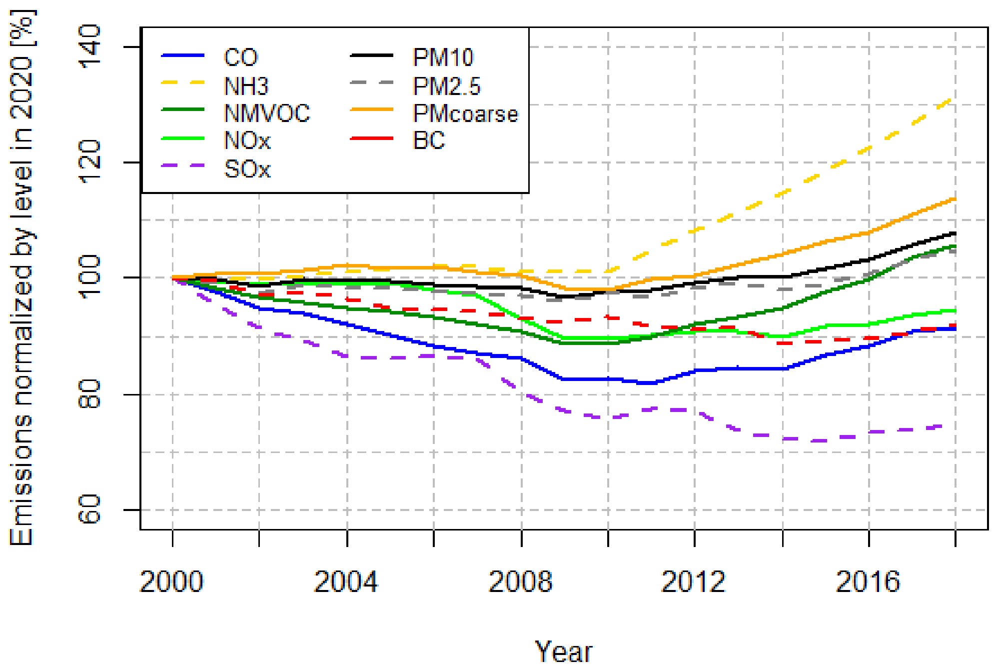


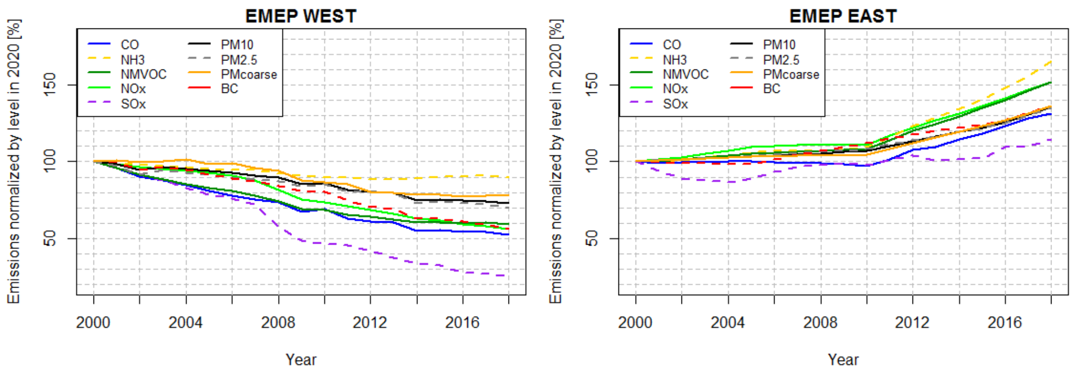
Figure 3.5: Emission trends 2000–2018 in the EMEP area (based on gap-filled data as used in EMEP models)

A more detailed assessment shows that emission developments in the eastern and western part of the EMEP area seem to follow strongly different patterns (see Figure 3.6)[14].

While emissions of all pollutants in the western part of the EMEP domain are slowly decreasing, emissions of all pollutants in the eastern part of the EMEP domain have increased since the year 2000. The emissions in the western parts of the EMEP area are mostly based on reported data, while the emissions in eastern parts are rather often expert estimates due to a lack of (plausible) reporting. One should thus keep this in mind when considering this comparison of emissions. The significant increase in emissions (of all pollutants) in the 'EMEP

[13]The EMEP domain covers the geographic area between 30° N-82° N latitude and 30° W-90° E longitude.

[14]The split between the EMEP West region and the EMEP East region according to `https://www.ceip.at/countries`. 'North Africa' and sea areas are not included and 'Asian Areas' are included in the EMEP East region.



(a) EMEP West (b) EMEP East

Figure 3.6: Emission trends 2000-2018 in the EMEP area (based on gap-filled data as used in EMEP models) divided in 2 areas 'EMEP West' (left), 'EMEP East' (right).

east' area is mainly influenced by emission estimates made for the remaining Asian Areas in the EMEP domain. These expert estimates are based on aggregated and interpolated gridded emissions from EDGAR (JRC/PBL 2016) for 2000, 2005 and 2010, extrapolated with the GDP trend for China.

3.6.1 Trend analysis

Emission levels in the EMEP domain for 2018 of individual countries and areas are compared to 2000 emission levels for NO_x, NMVOCs, SO_x, NH_3, CO and PMs (see Tables 3.4-3.4 continued). For this comparison, gap-filled data as used in the EMEP models were used (see Section 3.7). Overview tables with reported emission trends for individual countries have been published on the CEIP website[15]. Detailed information on the sectoral level can also be accessed in WebDab[16].

The assessment of emission levels in individual countries and areas show an increase of emissions in 2018 compared to 2000 emission levels in several countries or areas.

In case of PM emissions, 25 countries/areas have higher PM_{coarse} emissions in 2018 then in 2000, while PM_{10} and $PM_{2.5}$ emissions increased in 18 and 17 countries/areas, respectively. In case of NO_x and NMVOC there are 17 countries/areas, SO_x 14, NH_3 20 and CO 15 countries/areas with higher emissions in 2018 than in year 2000. Detailed explanatory information on emission trends should be provided in the informative inventory reports (IIRs).

3.7 Data sets for modelers 2020

Data used by CEIP were reported by the Parties to the LRTAP Convention as sectoral emissions (NFR14) and national total emissions according to the UNECE guidelines for reporting emissions and projections data under the LRTAP Convention, Annex I (UNECE (2014)).

The sector data were aggregated to 13 GNFR sectors. In several cases, no data were submitted by the countries, or the reporting is not complete or contains errors. Before these

[15] https://www.ceip.at/webdab-emission-database

[16] https://www.ceip.at/webdab-emission-database and/or https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models

Table 3.4: Differences between emissions for 2000 and 2018 (based on gap–filled data as used in EMEP models). Negative values mean that 2018 emissions were lower than 2000 emissions. Red/blue coloured data indicates that 2018 emissions were higher/lower than 2000 emissions.

	CO	NH_3	NMVOC	NO_x	SO_x	PM_{10}	$PM_{2.5}$	PM_{coarse}	BC
Albania	-5.7	-4.4	36.9	50.2	-35.9	53.9	64.9	27.3	58
Aral Lake	273	139.1	681.6	202.2	207.7	196.7	204.8	188.4	210.7
Armenia	-12.7	58.4	30.8	148.9	419	105.2	121	57.8	315
Asian Areas	100.9	120.6	116.2	161.8	122.2	128.4	128.7	127.9	119.5
Atlantic Ocean	-14.9		-15.7	-27.3	-25.7	-17	-17		-16.9
Austria	-32.1	6.7	-40.4	-28.5	-62.7	-30.2	-40.9	-11.3	-45.4
Azerbaijan	103.5	56.9	221.7	168.2	-64.9	112.8	121.1	85.6	191.2
Baltic Sea	-16.4		-16.7	-27.1	-96.1	-65.2	-65.2		-65.2
Belarus	-39.5	-8.8	-23.4	5.8	-78.1	-13.8	-10.2	-23.6	-11
Belgium	-60.7	-25.4	-50.2	-52.5	-77.7	-41.7	-45.1	-32.4	-64.7
Black Sea	-14.6		-17.2	-26.6	-24	-15.1	-15.1		-15
Bosnia and Herzegovina	56	48.8	82.3	47.1	-25.3	79.8	158	-16.8	197.3
Bulgaria	-28.4	-11.6	-29.8	-32.8	-89.7	2.6	19.4	-17.8	28
Caspian Sea	205.3		205.3	205.3	205.3	205.3	205.3	205.3	205.5
Croatia	-48.2	-13.2	-28.7	-41.9	-83	-9.8	-15.3	13.1	-19.2
Cyprus	-59.8	-4.3	-27.1	-32.9	-64.3	-52.2	-47.2	-58.2	-50.8
Czechia	-22.5	-19.6	-29.7	-42.4	-58.6	-22.7	-19.5	-32.2	-24.1
Denmark	-50.2	-22	-37.3	-53.2	-66.6	-17.4	-23.1	-8.2	-47
Estonia	-34.6	14.8	-38.6	-29	-68.2	-64.9	-55.6	-73.4	-42.6
Finland	-41.1	-7.7	-51.9	-47.5	-59.5	-26.9	-31.4	-19.9	-37.3
France	-61.5	-8.2	-63.9	-54	-78.3	-49	-58	-21.4	-65.3
Georgia	51	35	18.1	176.8	59.1	-16.7	-21.3	24.7	45.1
Germany	-43.9	-4.6	-38.1	-37.1	-55.6	-31.9	-44.4	-15.9	-68.4
Greece	-57.6	-18.8	-51.7	-40.1	-87.9	-53.6	-45.9	-61.1	-28.4
Hungary	-56.3	-7	-35.6	-35.7	-94.6	-13.9	-13.7	-14.3	-15
Iceland	46.5	-0.9	-37.6	-31.5	41.2	-8.2	-15.4	21.9	-43.8
Ireland	-68.3	3.7	-7.4	-37.7	-91.5	-28.5	-39.9	-16.1	-52.4
Italy	-56.2	-20.1	-42.9	-55.5	-85.4	-29.5	-27.1	-38	-55.7
Kazakhstan	76	42	64.8	98.2	46.2	20.4	22.7	15.9	24.1
Kyrgyzstan	141.8	33.1	119.3	134	74.9	75.5	88.7	45.9	98.8
Latvia	-52.9	10.8	-24.2	-17.9	-78.3	-10.3	-24.6	92.8	-16.2
Liechtenstein	-25.5	-6	-38.6	-22.6	-60.9	-9.7	-7.8	-13.9	-41.1
Lithuania	-23.8	21.4	-24.7	-5.8	-66.3	-21.7	-37.4	5.3	4.6
Luxembourg	-48.4	-16	-33.4	-49.1	-70.6	-30.8	-40.9	19.6	-68.3
Malta	-52.7	-29.6	-32.7	-34	-99.2	-49.8	-57.5	-27.3	-44.1
Mediterranean Sea	-12.8		-13.9	-26	-28.1	-18.3	-18.3		-18.3
Monaco	-45.2	-84.9	-34.8	-65.7	-78.7	-52.6	-59.6	-38	-71.4
Montenegro	-41.2	-16.7	3.3	42.7	22.9	267.5	303.9	162.2	436.3
Netherlands	-27.8	-26.1	-28.7	-47.5	-68.5	-45.5	-58	-15.5	-75.4
North Africa	8.5	76.8	33.7	86.4	70.7	68.3	65.6	71.5	66.8
North Macedonia	-61.1	-27.5	-39.7	-57.7	-42.7	-67.3	-71.3	-58.5	-71.5
North Sea	-18.1		-20.5	-29.7	-93.3	-61.7	-61.7		-61.7
Norway	-31.6	6	-60.8	-27.3	-40	-35.4	-42.2	-3.2	-39.3
Poland	-30.4	-4.4	-11.2	-11.2	-62.6	-8.2	-8.8	-7.4	5.8
Portugal	-58.3	-24.8	-34	-45.4	-84.6	-35.8	-31.2	-45.3	-38.4
Republic of Moldova	155.8	-23	92	53.1	103.8	200.8	277.5	60.7	463.5
Romania	3.8	-8.9	-10.4	-21.3	-83.3	7.3	6.1	11.4	14.5

Table 3.4 continued. Differences between emissions for 2000 and 2018 (based on gap–filled data as used in EMEP models).

Russian Federation (Asian part)	-17.3	9.2	4.8	-9.6	-45.3	-23.8	-37.5	-0.9	-57.9
Russian Federation (European part)	-3.7	-4.3	-2	-12	-45.5	-25.3	-32.5	-18.8	-32.9
Serbia	-37.5	-26.1	-19.7	-13.4	-25.4	-1.1	-3.6	6	-7.6
Slovakia	-44.8	-19.1	-50.9	-38.2	-82.6	-61.2	-64	-47.2	-32.2
Slovenia	-48	-14.2	-41.2	-42.9	-94.9	-9.9	-4.7	-26.7	-9.2
Spain	-37.3	-8.9	-34.2	-48.9	-85.8	-24	-23	-25.7	-25.5
Sweden	-49.9	-11	-39.3	-40.6	-61.7	-27.5	-44.2	1.7	-56.4
Switzerland	-60.7	-10.3	-47.9	-35.7	-68.8	-21.5	-40.2	7.3	-66.4
Tajikistan	235.5	39.3	144.5	78.3	534.8	123.5	130.5	105.4	303.5
Turkey	-50.5	55.7	-15.3	21.4	12.7	7.1	-2.2	36.7	-38.3
Turkmenistan	74.1	161.9	91.4	84	158.3	28.6	21.1	55.5	92.5
Ukraine	-22.6	-9.6	-34.8	-36.7	-71.7	-29.7	-29.5	-30.1	-27
United Kingdom	-65.5	-8.7	-50.6	-58.8	-87.6	-26	-27.3	-23.7	-56.8
Uzbekistan	32.4	42.3	45.3	-4.7	-16.5	25.3	32	6.3	-9.6
Increase (no. countries)	***15***	***20***	***17***	***17***	***14***	***18***	***17***	***25***	***19***
Decrease (no. countries)	***46***	***35***	***44***	***43***	***47***	***43***	***44***	***31***	***42***

emission data can be used by modelers, missing or erroneous information have to be filled in. To gap-fill those missing data, CEIP typically applies different gap-filling methods. The gap-filling procedure in 2020 is fully documented in a technical report (Technical report CEIP 01/2020), which can be downloaded from the CEIP website[17].

Where data were missing or deemed implausible, CEIP experts selected the most appropriate gap-filling/replacement option from a set of predefined methods:

- *Replacement* – where no data are available or no plausible data are available, the most appropriate option is to replace the time series with the respective estimates from the interpolated GAINS ECLIPSE v6b dataset. This option can be applied to either all GNFR sectors or in certain cases to a single GNFR sector.
- *Extrapolation* – where a significant portion of the data appears plausible, it is appropriate to extrapolate the missing/implausible years at the beginning and/or end of the time series. In this case the expert must decide the trend with which to extrapolate the national total:
  - Constant emissions are assumed; or where several years need to be extrapolated
  - Using the respective trends from GAINS estimates or even reported national totals (where national totals seem plausible)
  - Unlike replacement, this option can only be applied to all sectors. In this case, the national total is in fact extrapolated, and subsequently split between sectors based on a sector split of nearest year deemed plausible.
- *Ratio* – where the $PM_{2.5}$ emissions are plausible, yet BC has not been reported or appears implausible, this option is considered the most appropriate. For this option, the reported sector $PM_{2.5}$ emissions are multiplied by BC fractions (GNFR sector-specific)

[17] https://www.ceip.at/ceip-reports

derived from respective GAINS estimates of $PM_{2.5}$ and BC emissions. In most cases, the ratios from the respective country are taken; however, for small countries which are not resolved by GAINS, another country's BC fractions can be selected. Again this option can be applied to either all sectors or a single sector if e.g. there is a mass balance issue for the said GNFR sector.

- *Interpolation* – this option can be applied on its own or in combination with the extrapolation methods. In this case missing/implausible emissions for years in between periods of plausible data are simply replaced by linear interpolation.

The Parties where data were (partly) replaced, corrected or gap-filled in 2020 are Albania, Armenia, Austria, Azerbaijan, Belarus, Bosnia and Herzegovina, Denmark, Georgia, Kazakhstan, Kyrgyzstan, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, the Republic of Moldova, the Russian Federation, Serbia, Turkey and Ukraine.

For the countries, regions and sea regions of the EMEP domain for which there is no reporting obligation, emissions estimates from independent sources have been used to complete the EMEP dataset.

For the gap filled time series, significant changes in emissions from 2017 to 2018 were due to a recent update of the gap-filling procedure. As of this year, if reported emissions time series have been replaced, they have been replaced with estimates from the most recent GAINS ECLIPSE v6b dataset only. In previous years, emissions time series have been replaced with estimates from an older GAINS dataset, as well as from the EDGAR dataset.

After the gap-filling, sector emissions are spatially distributed over the EMEP grid. In 2020, gridded emissions of the pollutants NO_x, NMVOCs, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10}, PM_{coarse} and BC were provided to modelers for the year 2018[18].

3.7.1 Contribution of individual GNFR sectors to total EMEP emissions

Figure 3.7 shows the contribution of each GNFR sector to the total emissions of individual air pollutants (SO_x, NO_x, CO, NMVOC, NH_3, $PM_{2.5}$, PM_{10}, PM_{coarse} and BC). To provide a picture as complete as possible of the situation of the individual sectors to total EMEP emissions, data as used for the EMEP models (i.e. gap-filled data) were used for the calculations. Sea regions, North Africa and the remaining Asian areas were excluded for this analysis, as sectoral distributions are better reflected when only using country data.

It is evident that the combustion of fossil fuels is responsible for a significant part of all emissions. For NO_x emissions,the largest contributions come from transport (sector F, 33%) and from large power plants (sector A, 17%).

NMVOC sources are distributed more evenly among the different sectors, such as 'E – Emissions from solvents' (25%), 'F – Road transport' (20%), 'D – Fugitive Emissions' (13%), 'B – Industry combustion' (10%), 'K – Manure management' (11%) and 'C – Other stationary combustion' (9%).

The main source of SO_x emissions are large point sources from combustion in energy and transformation industries (sector A, 46% and sector B, 32%).

[18]https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models

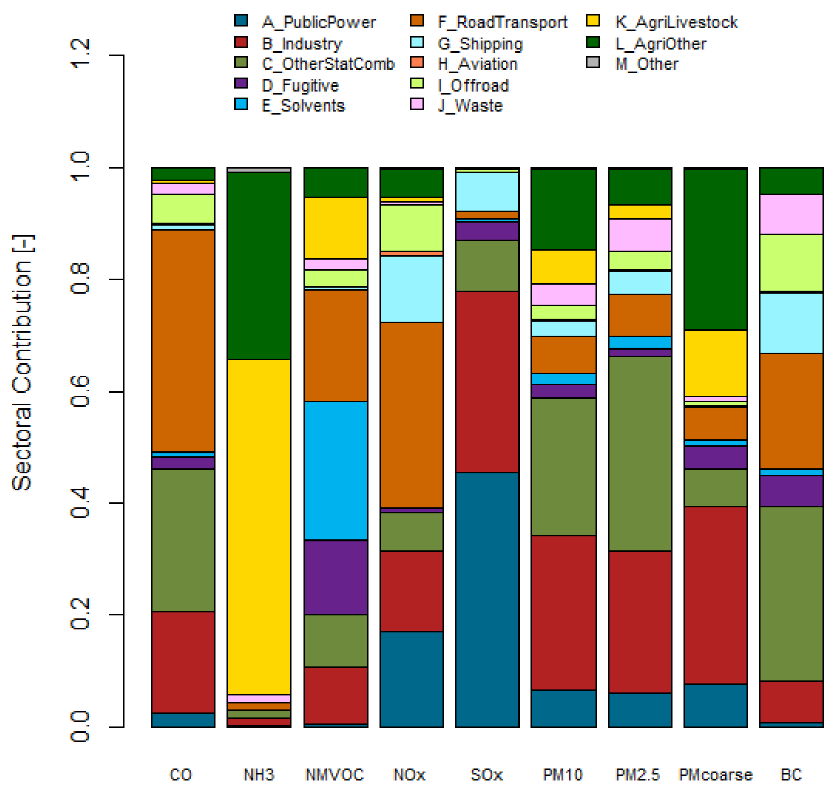


Figure 3.7: GNFR sector contribution to national total emissions in 2018 for the EMEP domain without sea regions, North Africa and remaining Asian areas.

Ammonia arises mainly from agricultural activities; about 93% combined contribution from sectors K and L. Emissions of CO originate primarily from 'F – Road transport' (40%) and 'C – Other stationary combustion' (26%).

The main sources of primary PM_{10} and $PM_{2.5}$ emissions are industry (28% and 25%) and other stationary combustion processes (25% and 35%). Due to the higher agricultural emissions of PM_{10} versus $PM_{2.5}$, sectors K and L make a much larger relative contribution to PM_{coarse} emissions (39% combined).

Finally, the most important contributors to BC emissions are 'F – Road transport' (20%) and 'C – Other stationary combustion' (31%).

Figure 3.8 illustrates the sector contributions to the sum of total emissions in the EMEP West region and the EMEP East region. The split between the EMEP West and EMEP East regions is according to `https://www.ceip.at/countries` (sea regions, North Africa and the remaining Asian areas are excluded). The comparison of both graphs highlights some significant differences between West and East.

For NO_x in both the EMEP West and EMEP East regions the most important sector is 'F – Road transport emissions' (38% and 34%, respectively), although it is worth noting the higher contribution from 'A – Public electricity and heat production' in the East region (25%).

For NMVOC in the EMEP West region the most relevant sector is 'E – Emissions from solvents' with a share of 37%. In the EMEP East region the same sector has a considerable lower share (12%), whilst the sector 'F – Road transport' is of high importance (33%).

The main source of SO_x are 'A – Public electricity and heat production' and and 'B – Industry combustion'. These two sectors together contribute to 78% and 85% of the SO_x

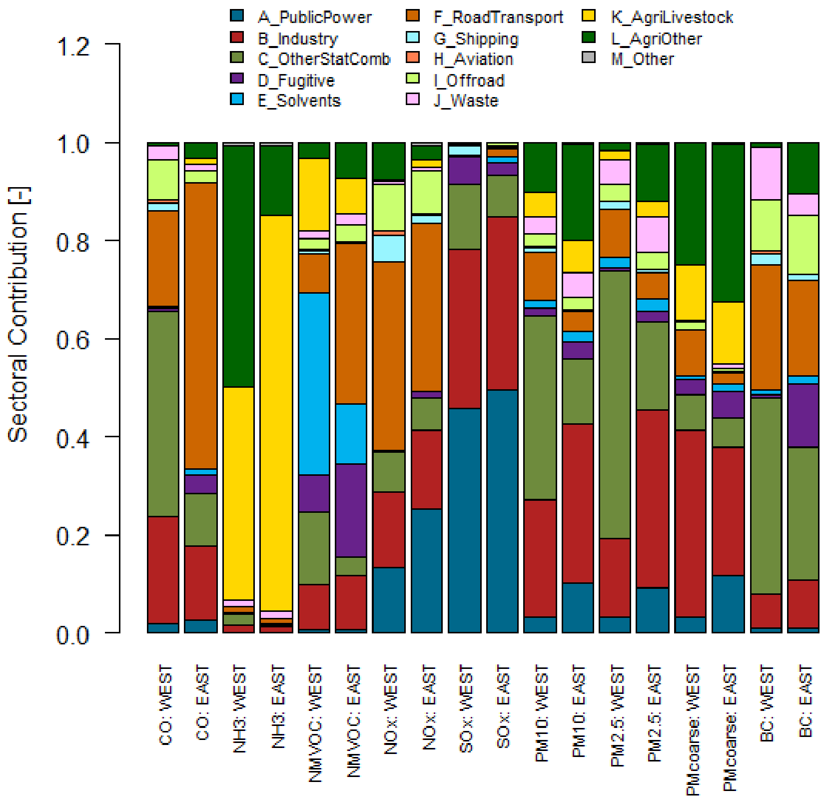


Figure 3.8: GNFR sector contribution to national total emissions in 2018 for the EMEP West and EMEP East areas. Asian areas are not included in the EMEP East region.

emissions within the EMEP West and EMEP East areas, respectively.

The main sources of NH_3 emissions for both EMEP West and EMEP East are the agricultural sectors (K and L) with 93% and 95%, respectively.

CO emissions arise mainly from 'F – Road transport emissions' (58%) in EMEP East. In the EMEP West region the main sector is 'C – Other stationary combustion' (42%).

For $PM_{2.5}$ and PM_{10} 'C – Other stationary combustion' holds a significant share of the total emissions in the EMEP West area (55% and 38%), compared to the EMEP East area (18% and 13%). For the EMEP East area sector 'B – Industry combustion' is of higher importance. For PM_{coarse} it is worth mentioning the higher contributions from agriculture in the EMEP East area (45%). Finally, it is interesting to note the significant contribution to BC emissions in the EMEP East area from fugitive emissions (13% in EMEP East versus 1% in EMEP West).

3.7.2 Reporting of gridded data

2017 was the first year with reporting obligation of gridded emissions in the grid resolution of $0.1° \times 0.1°$ longitude/latitude. Until June 2020, thirty-two of the 48 countries which are considered to be part of the EMEP area reported sectoral gridded emissions in this resolution.

The majority of gridded sectoral emissions in $0.1° \times 0.1°$ longitude/latitude resolution have been reported for the year 2015 (30 countries). For the year 2016, gridded sectoral emissions have been reported by three countries and for the year 2017 and 2018 by four countries.

Thirteen countries reported gridded emissions additionally for previous years (one country for the whole time series from 1980 to 2018; one country for the whole time series from 1990

Table 3.5: Gridded emissions reported until 2017 and 2020.

Country	2017	2020	Comments
	Gridded data available for the years…	Gridded data available for the years…	
Austria	2015	2015	
Belgium	2015	2015	
Bulgaria	2015	2015	
Croatia	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015	
Czechia	2015	2015	
Denmark	2015	2015	
Estonia		1990, 1995, 2000, 2005, 2010, 2015	
Finland	2014, 2015	2014, 2015, 2016, 2017, 2018[a]	[a] Gridded data for 2014, 2015 and 2018 could not be used for the preparation of spatial distributed emission data.
France		2015	
North Macedonia		2015	
Georgia		2015	
Germany	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2017	
Greece		2015	
Hungary	2015[b]	2015	[b]The submission of gridded emissions was too late to be considered for the preparation of gridded data for modelers in 2017
Ireland	2015	2015	
Italy		2015[c]	[c]Reported gridded data was replaced by CAMS and EDGAR proxies
Latvia	2015	2015	
Lithuania	2015[d]	2015	[d]Reported gridded emissions only on national total level, which could not be used for the gridding, which is done on sectoral level
Luxembourg	2005, 2010, 2015	2005, 2010, 2015	
Malta		2016	Grid reporting not in the defined 0.1°x0.1° coordinates
Monaco	2014, 2015	2014, 2015, 2016	
Netherlands		1990, 1995, 2000, 2005, 2010, 2015	
Norway	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015	
Poland	2014, 2015	2014, 2015, 2018	
Portugal	2015	2015[e]	[e]The spatial disaggregation of sector 'F – Road Transport' was replaced by CAMS proxies
Romania	2005	2005, 2015	
Slovakia	2015	2015	
Slovenia	2015	2015	
Spain	1990-2015	1990-2018	
Sweden		1990, 2000, 2005, 2010, 2015	
Switzerland	1980-2015	1980-2018	
United Kingdom	2010, 2015	2010, 2015	

to 2018; five countries for the years 1990, 1995, 2000, 2005 and 2010; one country for the years 1990, 2000, 2005 and 2010; one country for the years 2005 and 2010; one country for the year 2005; one country for the year 2010; and three countries for the year 2014).

Reported gridded sectoral data in 0.1°×0.1° longitude/latitude resolution, which can be used for the preparation of gridded emissions for modelers, covers less than 20% of the cells within the geographic EMEP area. For the remaining areas missing emissions are gap-filled and spatially distributed by expert estimates. Reported grid data can be downloaded from the CEIP website[19]. The gap-filled gridded emissions are also available there[20].

An overview of reported gridded data available in 2017 and until 2020 is provided in Table 3.5, while an example map of the gap-filled and gridded NO_x emissions in 2018 in 0.1°×0.1° longitude-latitude resolution is shown in Figure 3.9.

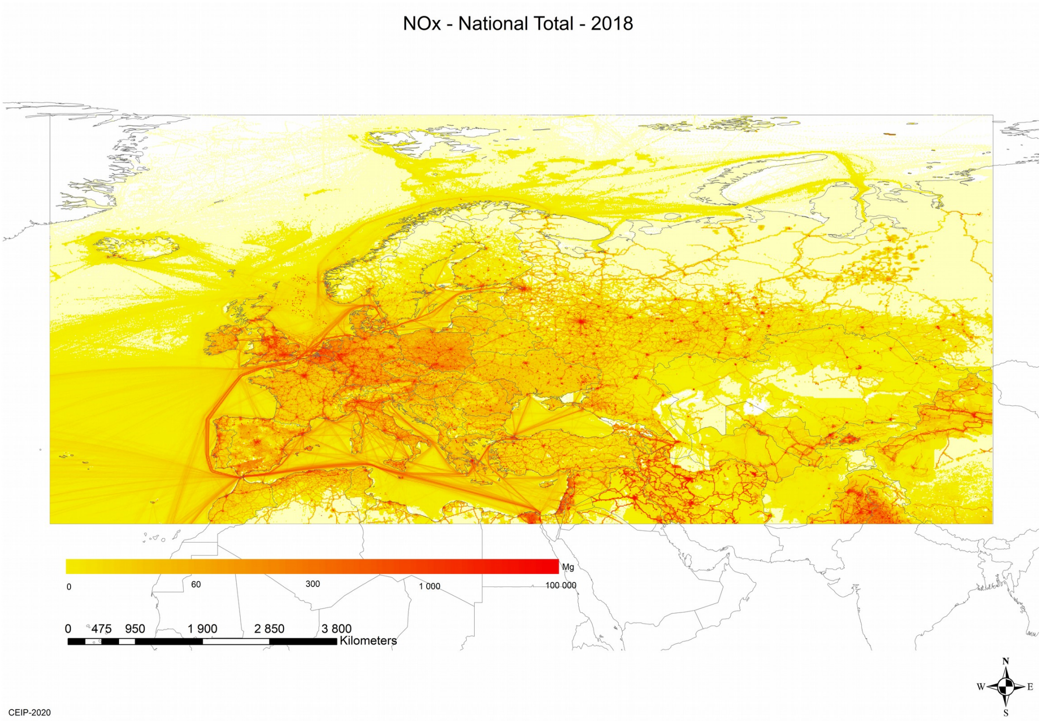


Figure 3.9: Visualized gap-filled and gridded NO_x emissions in 0.1°×0.1° long-lat resolution.

Reported gridded data in 0.1°×0.1° longitude-latitude resolution was used from Austria, Belgium, Bulgaria, Croatia, Czechia, Denmark, Finland, France, Georgia, Germany, Greece, Hungary, Ireland, Latvia, Luxembourg, Malta, Monaco, Netherlands, North Macedonia, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

3.7.3 International shipping

Under this category emissions from international shipping occurring in different European seas are accounted (European part of the North Atlantic, Baltic Sea, Black Sea, Mediterranean Sea and North Sea). International shipping emissions are not reported by Parties. Grid-

[19] https://www.ceip.at/status-of-reporting-and-review-results
[20] https://www.ceip.at/webdab-emission-database/emissions-as-used-in-emep-models

ded emissions for the sea regions were calculated using the CAMS global shipping emission dataset (Granier et al. 2019) for the years 2000 to 2018 (Figure 3.10), developed by the Finnish Meteorological Institute (FMI), and provided via ECCAD[21] the dataset *CAMS_GLOB_SHIP* (ECCAD 2019).

Due to the selective implementation of the Sulphur Emission Control Areas (SECAs) on the North Sea and Baltic Sea only, the emission trends differ between those seas and the other seas.

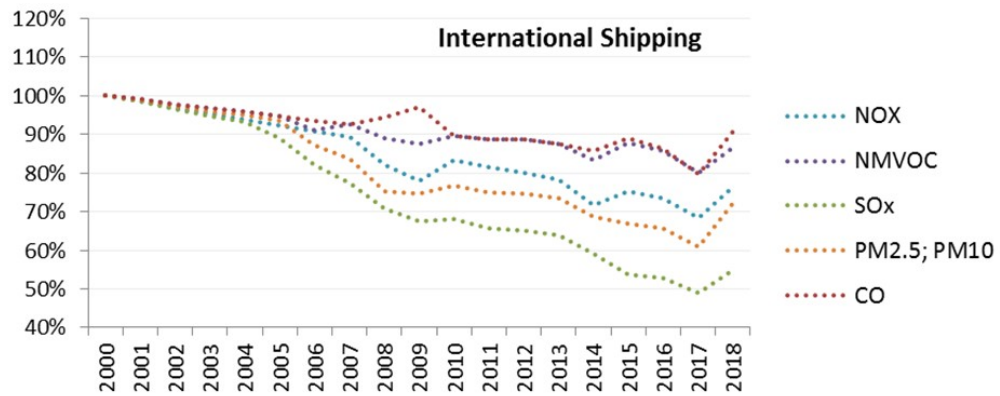


Figure 3.10: International shipping emission trends in the EMEP area, extracted from the CAMS global shipping emission dataset developed by FMI, and provided via ECCAD (*CAMS_GLOB_SHIP*) in April 2019 (for the years 2000 to 2017) and in November 2019 (for the year 2018). These are the emissions which have been used for the most recent trend calculations with the EMEP model.

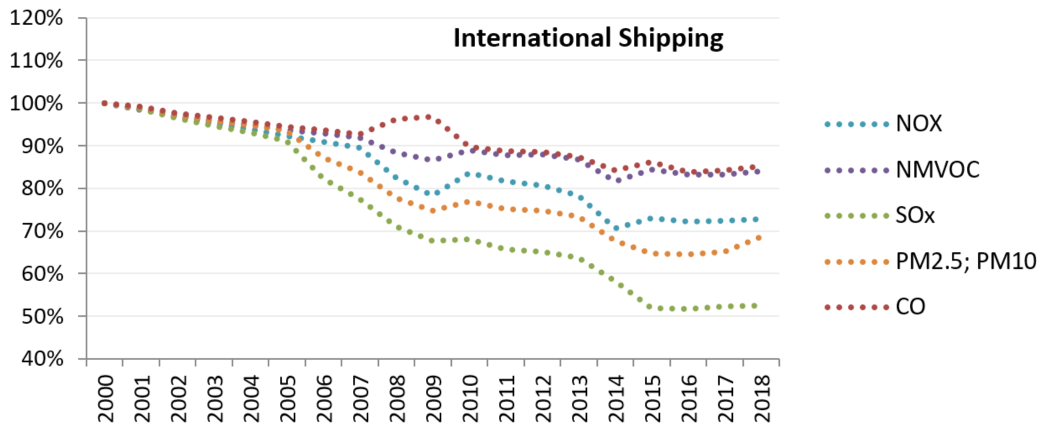


Figure 3.11: International shipping emission trends in the EMEP area, extracted from the CAMS global shipping emission dataset developed by FMI, and provided via ECCAD (*CAMS_GLOB_SHIP) in November 2019.*

The significant change in shipping emissions between 2017 and 2018 in the graph is partly because shipping data from the *CAMS_GLOB_SHIP* dataset have been adjusted since the preparation of gridded data for the years 2000 to 2017 in summer 2019. In 2020 only the year 2018 was added, but no re-gridding of the years 2000 to 2017 was carried out. Figure 3.11 shows the adjusted CAMS global shipping emissions for the full time series from 2000 to 2018, as of November 2019.

[21]https://eccad.aeris-data.fr

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CHAPTER 4

Air pollutant levels during the summer heat wave

Sverre Solberg, Karl Espen Yttri, Sabine Eckhardt, David Simpson and Wenche Aas

Climate change can influence air quality and potentially counteract the goal of reduced pollution levels aimed by emission abatement policies. This is called the "climate penalty" on air pollution. Warmer and dryer summers, as predicted by future climate scenarios, can affect the pollutant levels in many ways (e.g. Arneth et al. 2010, Colette et al. 2015, Simpson et al. 2014, Langner et al. 2012, Lin et al. 2020)

- Increased temperatures could speed up the photochemistry and increase the biogenic emissions of VOCs thereby leading to increased formation of ozone and biogenic secondary organic aerosols (SOA).
- Heat and drought could initiate wild fires leading to enhanced levels of PM and ozone.
- Reduced precipitation imply less removal of aerosols from the atmosphere.
- High-pressure situations with stagnant and stable weather conditions will trap the pollutants emitted at the ground in a shallow boundary layer.
- Drought can cause plants to close their stomata thereby reducing the uptake of ozone to vegetation leaving more ozone in the atmosphere.
- Drought could also lead to increased levels of wind-blown mineral dust in the atmosphere although reduced wind speeds typically experienced in high-pressure situations will imply less suspension of such aerosols.

The exceptional warm summer of 2003 and its consequences on air pollutant levels has been reported in detail through a large number of scientific studies (see e.g. Luterbacher et al. 2004, Vieno et al. 2010, Vautard et al. 2005, Solberg et al. 2008, Lin et al. 2020). The summer of 2018 was also unusually warm and dry in many parts of Europe, and thus we have briefly looked into the effects this may have had on the levels of surface ozone and aerosols.

4.1 The 2018 heat wave - "the endless summer"

For the year as a whole, 2018 was among the three warmest years on record in Europe with a temperature anomaly of around +1.2 °C. In summer, a prolonged heat wave affected Central Europe and in particular southern parts of the Nordic countries and the British Isles, as well as Poland, Germany, Czech Republic and eastern parts of France. Extreme drought followed the heat wave leading to substantial damage to agricultural crops, as well as extensive wild fires.

The most remarkable with the 2018 heat wave was the persistence and length of the period, and Hoy et al. (2020) use the phrase "the endless summer". Hoy et al. (2020) have compared the 2018 data to the well-known 2003 summer (Luterbacher et al. 2004) and found that the positive temperature anomalies for the summer half year (April-September) was even more pronounced in 2018 than in 2003, whereas the anomaly was slightly smaller than for 2003 for the 3-months summer season (JJA). They also found that the number of days with exceedance of certain temperature thresholds (20 and 25 °C) was extreme in Europe with about half the stations setting new records and often breaking the previous records with large margins.

All seasons were warmer than normal in 2018 in Europe but the main heat wave period started in April-May. In southeastern parts, the temperatures in April exceeded the normal with a record-high anomaly of more than 5 °C (Hoy et al. 2020). In mid-May the heat wave started in the Nordic countries and NW Europe. In parts of June, the positive temperature anomalies were reduced but from late June to mid July a strong contrasting pattern were seen with clear sky, drought and high temperatures in NW Europe and the Nordic countries, whereas parts of southern Europe (mainly Greece and Spain) experienced low temperatures, heavy precipitation and floodings (Drouard et al. 2019).

The most extreme and most extensive part of the heat wave occurred from mid July to the first week of August when large parts of the continent were affected and many stations, particularly in the Nordic countries, set new temperature records. From around 7 August the temperatures were reduced in the Nordic countries and the area of the heat wave moved southwards, causing a short and intense heat wave period in the Mediterranean.

Sweden was one of the countries that were most seriously affected by the prolonged heat wave with record-high summer mean temperatures corresponding to the high-emission “business as usual” climate scenario RCP8.5 for 2100, according to Johansson et al. (2020). The country experienced unprecedented drought, and the May-July precipitation at Lund in Southern Sweden was half the previous minimum in a timeseries dating back to 1748 (WMO 2019). As a consequence of the drought, extensive wildfires occurred and around 25 000 hectares were burned. Also Central Europe was affected by the drought, and Germany and several other countries experienced substantial losses of agricultural production (WMO 2019).

4.2 Surface ozone levels during the heat wave

Numerous episodes with elevated ozone levels were observed in the summer 2018 period. Figure 4.1 and Figure 4.2 gives examples for two of these episodes, 4 July and 4 August, respectively. Measurement data from both EMEP and EEA’s air quality database (e-Reporting) are included in these figures but EEA stations classified as traffic or urban were not included.

From the last part of June to the first few days of July, a marked high-pressure ridge over Scandinavia lead to easterly winds over large parts of central Europe. The high gradually weakened and left northern and central Europe inside a high-pressure area with very weak

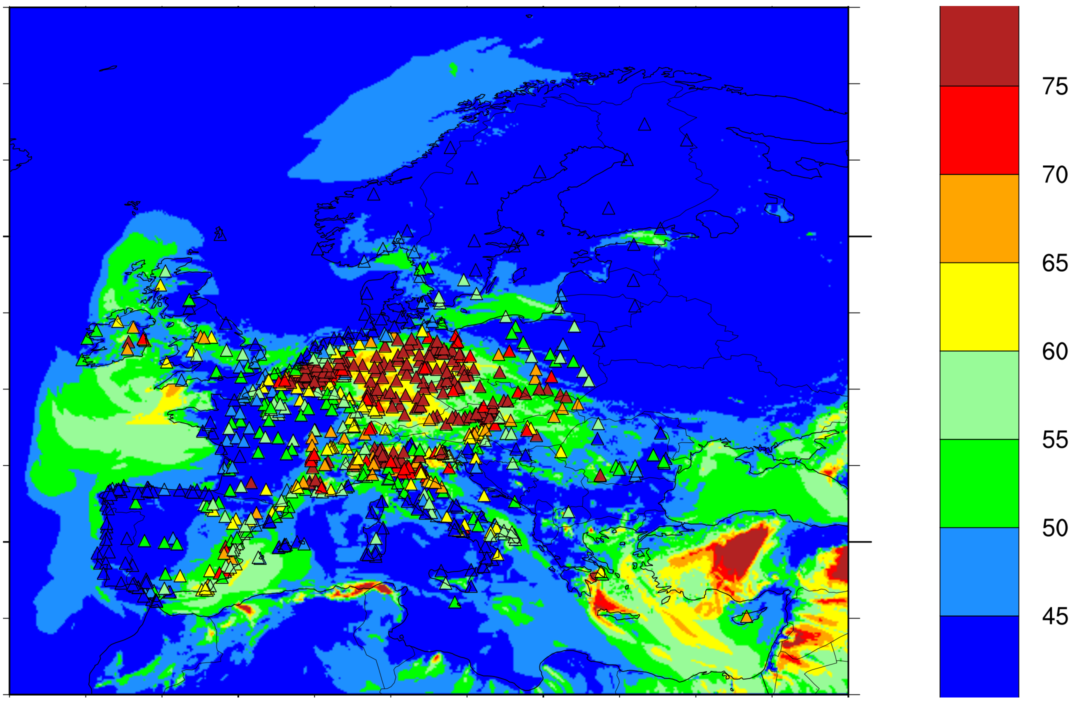

Figure 4.1: Modelled and measured daily max ozone [ppb] 4 July 2018. Data from EMEP and Airbase sites below 500 m asl are shown.

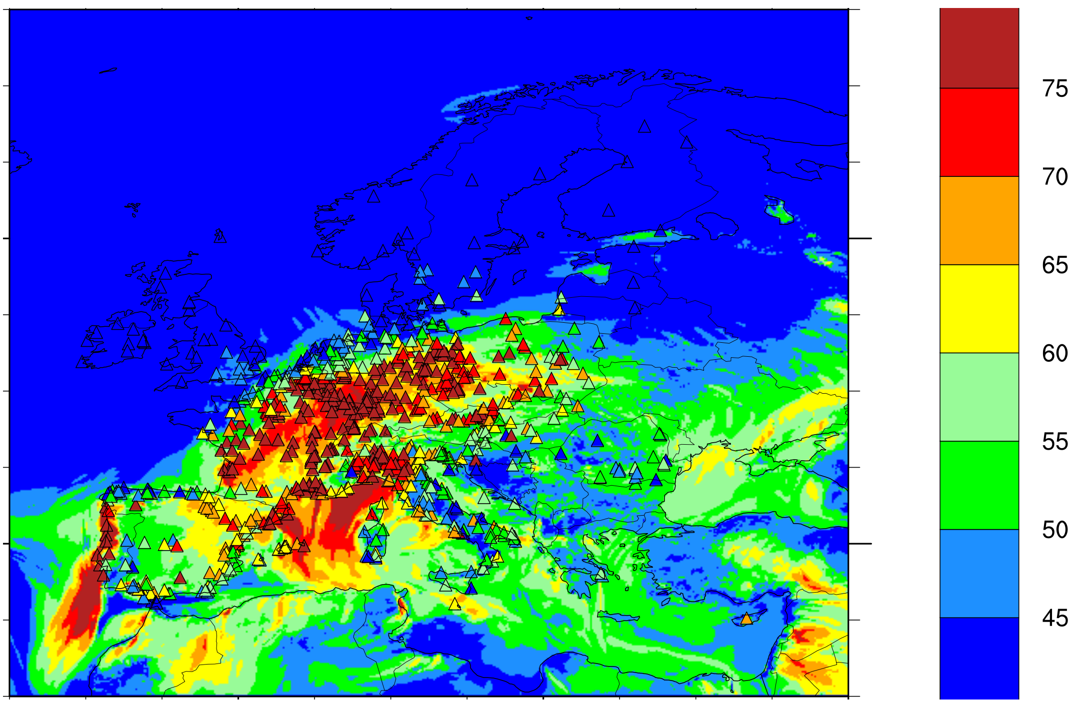

Figure 4.2: Modelled and measured daily max ozone [ppb] 4 August 2018. Data from EMEP and Airbase sites below 500 m asl are shown.

pressure gradients and gentle wind speed, whereas Spain and southwestern parts of France were influenced by a weak low-pressure system. The ozone measurements show an area of elevated ozone on 29 June that was increasing, then decreasing on 1 July and then intensifying

and moving slowly to the east, covering Germany, Belgium, the Netherlands, Austria and parts of Czech Republic and Poland on 4 July (Figure 4.1). The model calculations underestimate the daily peak ozone levels during this period.

The most extensive ozone episode occurred from the last part of July to the first days of August. A large low-pressure system with center south of Iceland set up southerly and easterly warm winds over central Europe. On the eastern side of the cold front elevated ozone levels were seen over an area stretching from southern Italy to southern parts of Scandinavia by 31 July. By 3 and 4 August (Figure 4.2) the low had weakened and most of central Europe were influenced by easterly winds associated with a high-pressure area centered west of UK. Strongly elevated ozone levels were seen over a large area from the Mediterranean to northern Europe with peak levels of more than 100 ppb. After weeks and months of high temperatures and little precipitation, the prolonged drought likely contributed to the extreme ozone levels observed during this episode.

Figure 4.3 shows the spread in three ozone metrics (SOMO35, 3-months AOT40 and 6-months AOT40) for the period 2000-2018 for the area north and south of 49°N, separately. Only sites with a certain data capture ($> 75\%$) each year are included, meaning that the data are consistent and comparable through the entire period. The number of sites used in each panel ranges from 22-28 depending on the metric. The geographical split at 49°N reflects a coarse separation between the northern and southern domain of the continent giving approximately the same number of ozone stations in each region. The 49°meridian follows a line from Paris to approximately the border between Austria and the Czech Republic and the border between Slovakia and Poland.

As seen by Figure 4.3, the ozone data in 2018 were clearly elevated for all three metrics in both regions, and the median levels have not been as high as this since 2006. For the southern domain, the 2003 levels were substantially higher than in 2018, though.

Based on a Mann-Kendall test of the annual medians, we found a significant downward trend in all three metrics for both domains. The associated Theil-Sen's slopes are of the order of 2-4% reduction per year relative to the overall mean (2000-2018), and the strongest relative decline is seen for the 3-months AOT40 in the northern domain.

The timeseries shown in Figure 4.3 illustrates two main features: firstly, a long-term significant reduction in ozone levels that certainly reflects the reduced emissions of ozone precursors in the last two decades, and secondly, that weather extremes like in 2018 (which seem to appear more frequently with time) clearly counteract the benefits of emission reductions. This gives a clear message that a combined action to reduce both climate change and the traditional LRTAP pollutants are needed in order to control surface ozone levels in the future.

The ozone levels in 2018, as shown by Figure 4.3, were clearly lower than in the extreme year 2003, and an unknown part of this difference could be explained by the lower levels of emissions in 2018 compared to 2003. It is an open question (to be answered by model calculations) how the 2018 situation would have been if the emission were as high as in 2003.

Whereas SOMO35 is an indicator for human health exposure, AOT40 has traditionally been used as an indicator for damage to vegetation. In recent years, it has become evident that the ozone flux, as calculated by the PODy metric, is much better suited for evaluation of effects on plants than AOT40 (Mills et al. 2011, 2018a). It is furthermore likely that AOT40 is a particularly poor metric for evaluating ozone effects on vegetation in 2018 since an important reason for the elevated ozone concentrations presumably was the long-term drought leading to closure of the plants' stomata, thereby reducing the ozone uptake and near-surface sink. In other words, trees and plants reducing their gas-exchange to a minimum during the dry period

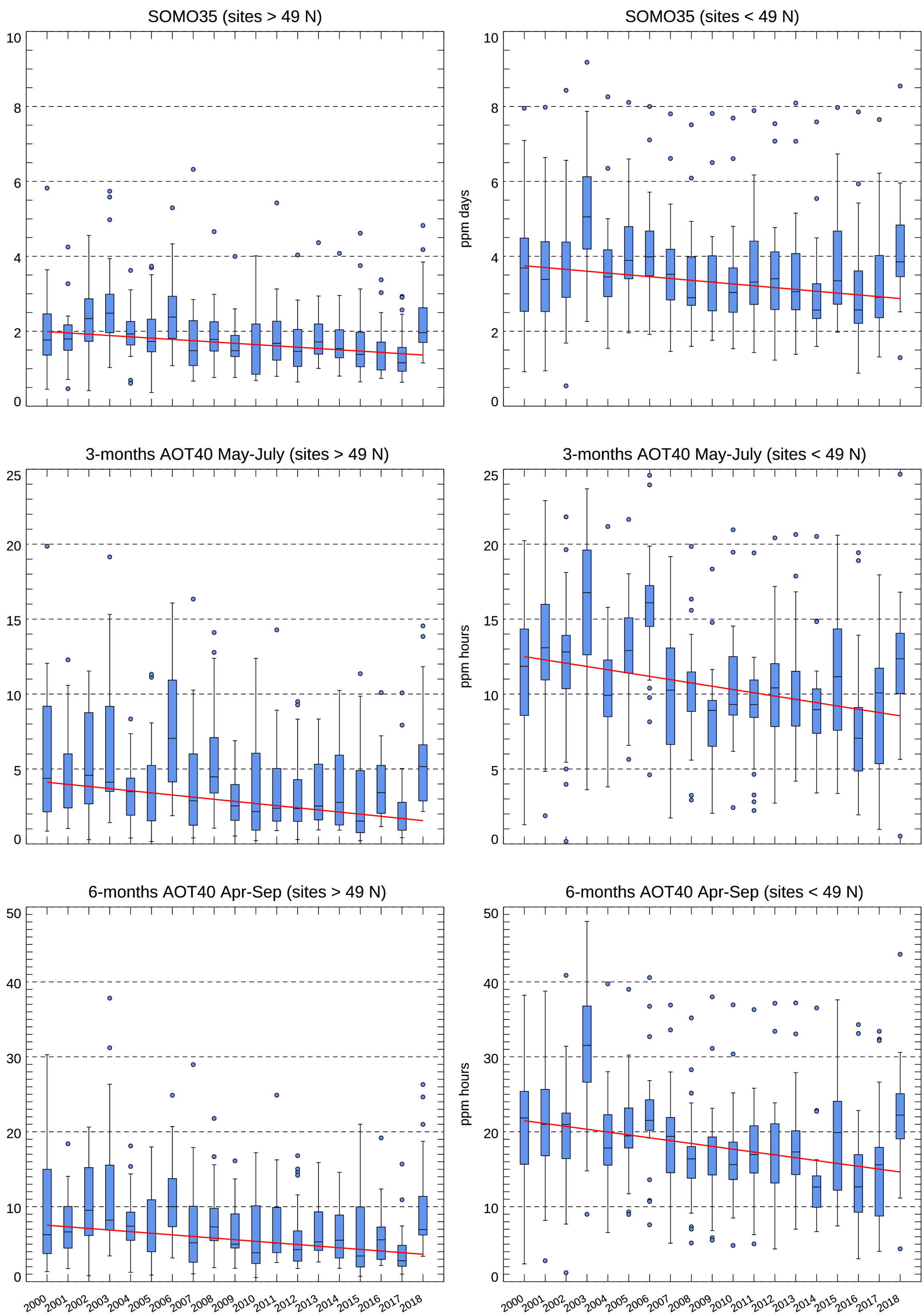

Figure 4.3: Annual spread in three ozone metrics during 2000-2018 for sites north (left) and south (right) of 49°N. The red line mark the Theil-Sen's slope of the annual median values

leads to higher ozone levels in the atmosphere, especially near the vegetation surface. The drought itself probably posed a much higher risk to the vegetation than the increased ozone levels in the atmosphere (see also Mills et al. 2018b).

4.3 Isoprene levels during the heat wave

During hot, dry and sunny periods in summer, the formation of ozone (and SOA) is promoted simply by the "speed-up" of the photochemical reactions. Additionally, increased biogenic emissions of VOCs from vegetation could add on to the increased formation of ozone and other secondary pollutants since these emissions increase with temperature and (for isoprene and some monoterpenes) also with solar radiation. Intuitively, one would think that the drought causing plants to close their stomata would also lead to reduced biogenic emissions. This is, however not necessarily true and for the more volatile species as isoprene and α-pinene, the emissions may in fact be more or less unchanged by the stomata opening, as discussed by Niinemets and Reichstein (2003) and others.

Figure 4.4 shows the measured isoprene data at six EMEP sites in 2018 compared to the data from the 2010-2017 period as a reference. Only data from the four summer months May-August were used and only measurements at daytime. These results indicate a marked increase in isoprene levels in the 2018 summer compared to the previous period, and the statistics show that the distribution of data values differs significantly (as given by the very low p values) from the distribution of values in the 2000-2017 period. It should be said, though, that there has been substantial changes in the instrumentation at the German UBA sites (Waldhof, Neuglobsow and Schmucke) during the period, and thus the data are not directly comparable.

Figure 4.5 shows the scatter plot between afternoon temperature, T (18 UTC) as given by gridded ECMWF interim data and the measured daytime mean concentration of isoprene at FI0050 and DE0043 and the grab samples of isoprene (at daytime) from FR0013 and FR0015. Only data from May-August were used in this plot. At the French sites, manual grab samples of VOCs were collected in canisters once per week with a filling time of around 15 minutes.At FI0050 an online PTR-MS system was applied giving hourly values, and at DE0043 an automated GC-MS were used giving values twice per day (day and night) with occasionally more frequent sampling. The ECMWF data was extracted from the Era-Interim (Berrisford et al. 2011) reanalysis dataset with a 6-hourly analysis (00:00, 06:00, 12:00, 18:00 UTC), retrieved on a 0.3°x 0.3°resolution. Note that the y-axis differs.

The scatter plots show a clear relationship between afternoon temperature and isoprene levels at all sites. The isoprene levels and the relationship to temperature is surprisingly similar at FI0050 and DE0043 even though they are located in very different regions and environments. Higher temperatures and substantially higher isoprene levels are seen at the two French sites as shown in Figure 4.5, although the temperature response is similar to the German site. The EMEP model uses an algorithm for isoprene emissions based on Guenther et al. (1993). For temperatures below 30°C this corresponds approximately to an exponential function with an exponent = 0.09 which is significantly lower than the exponents ranging from 0.14-0.19 for the relationship between temperature and observed isoprene concentration given in Figure 4.5. Other factors such as dispersion and chemical reactivity also affect these relationships of course, so whether these results reflect a real underestimation of the exponential dependency is an open question that needs further investigations.

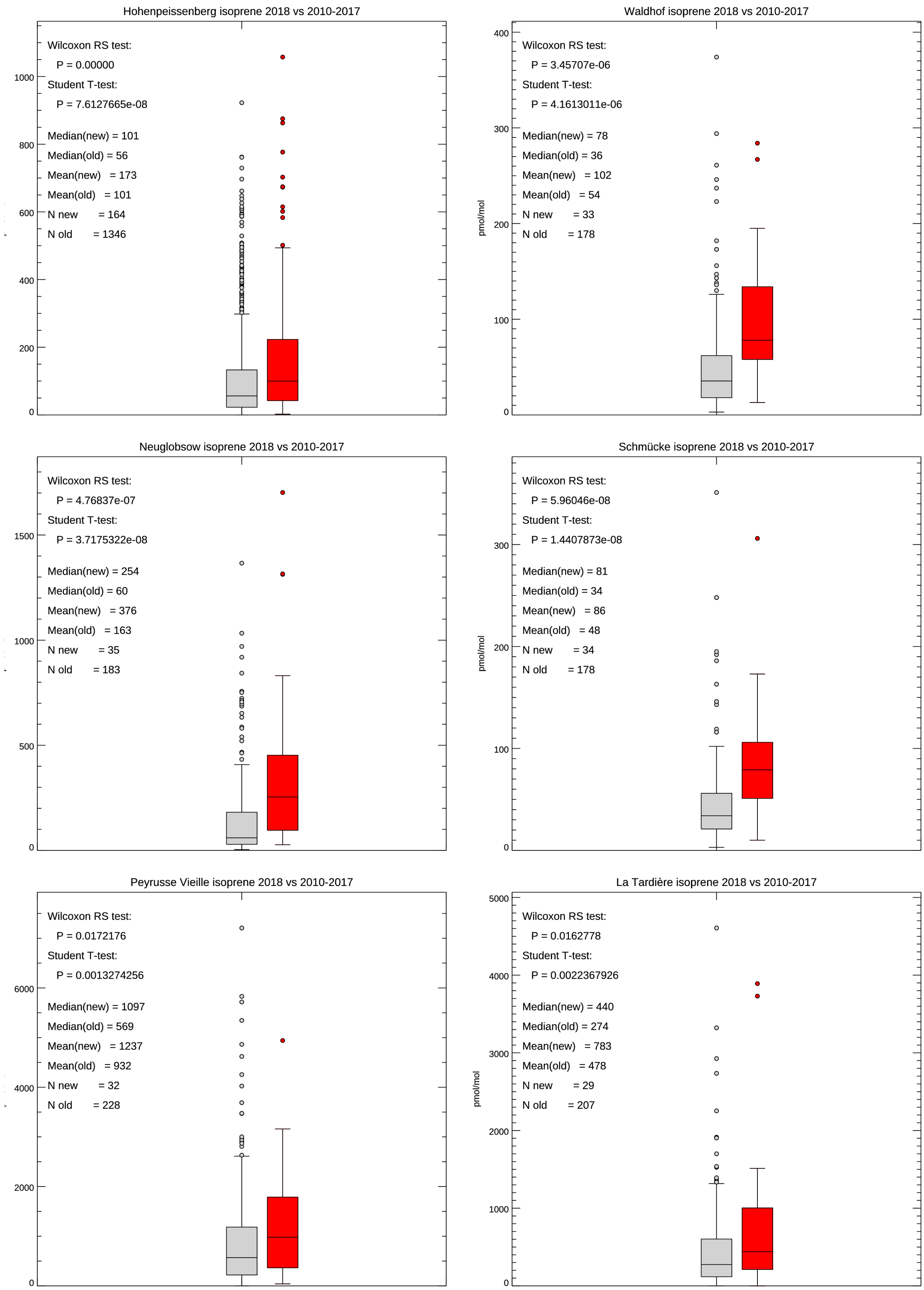

Figure 4.4: The spread in measured daily isoprene levels in 2018 (right bars) compared to the isoprene measurements 2010-2017 (left bars) at six EMEP stations. Only data from daytime during the months May-August were used. Mean and median levels are given as well as statistics for comparing the data distributions. Low p values indicate that the underlying probability distributions differ.

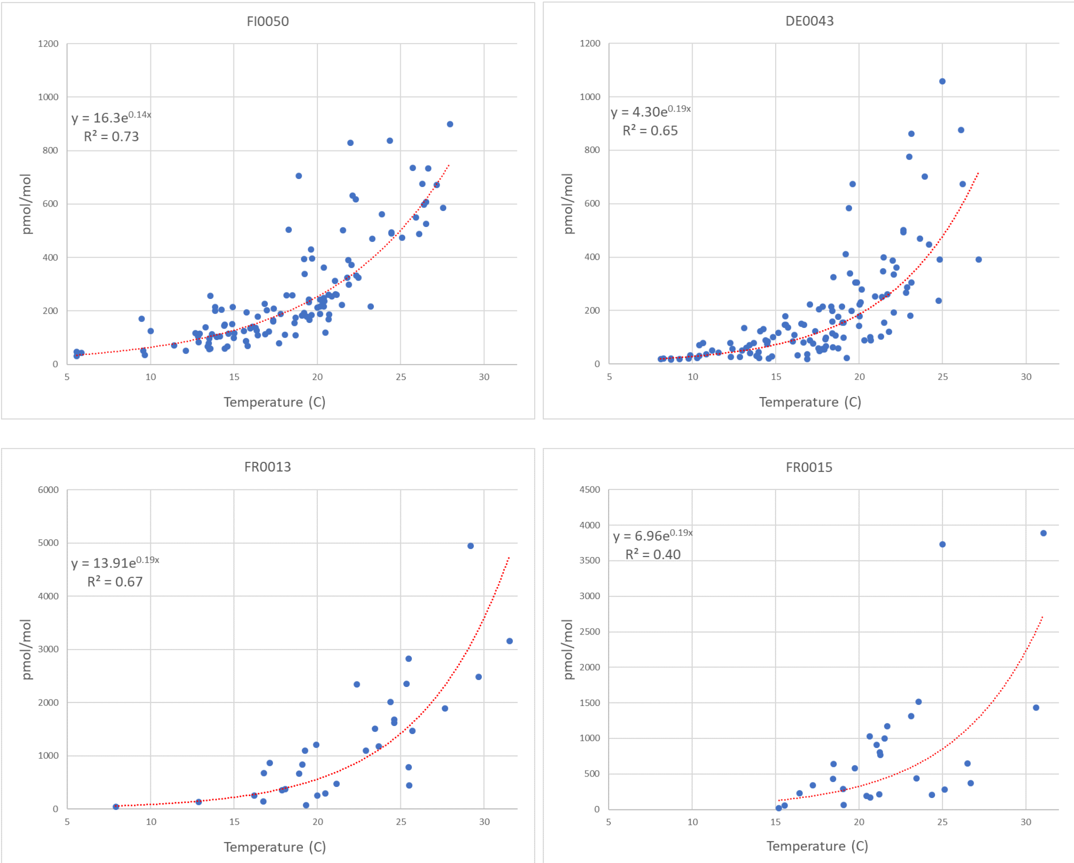

Figure 4.5: Scatter plots of measured daytime mean isoprene during May-August vs afternoon temperature, T (18 UTC) as retrieved from gridded ECMWF met data.

4.4 Aerosol levels during the heat wave

Figure 4.6 shows EMEP sites in northern Europe assessed when addressing the effect of increased temperature and reduced precipitation in summer 2018 on PM mass concentration level and composition. PM_{10} was measured at 28 and $PM_{2.5}$ on 22 of these sites. The major secondary inorganic aerosol (SIA) species SO_4^{2-} (30) and NO_3^- (26) were measured at about the same number of sites as PM but not necessarily on the same sites as PM. Measurements of carbonaceous aerosol [Organic Carbon (OC) and Elemental Carbon (EC)] (14) and iron (Fe) (12), a common mineral dust element, were less widespread but typically collocated with PM measurements. A selection of source specific organic tracers was measured at one of the sites (Birkenes, Norway) and is presented in chapter 4.5.

The median PM mass concentration in summer 2018 was higher than the median for the summers 2013 - 2017 at most sites both for PM_{10} (83%) and for $PM_{2.5}$ (63%), although more pronounced for PM_{10} (Figure 4.7). The median increase was comparable for the two (non-independent) size fractions, PM_{10} (17%) and $PM_{2.5}$ (19%), but more pronounced for $PM_{2.5}$ (35%) than for PM_{10} (25%) when only considering the sites experiencing an increase. One third of the sites experienced and increase > 30%, i.e. for both PM_{10} and $PM_{2.5}$. A substantial 68% increase in PM_{10} was observed for the Finnish site Virolahti III in southern Karelia. For $PM_{2.5}$, the largest increase (54%) was seen for the German site Schauinsland.

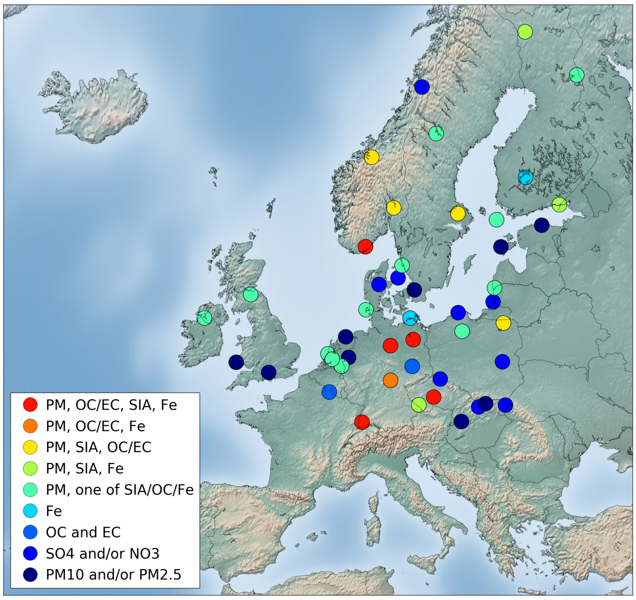

Figure 4.6: EMEP sites in Northern Europe assessed with respect to PM mass concentration level and composition in summer 2018.

No general increase in SO_4^{2-} and NO_3^- levels was observed in summer 2018 compared to the reference period (2013 - 2017), as seen for PM (Figure 4.7). However, SO_4^{2-} was substantially (17 - 97%) increased at some of the sites, i.e. those in the Czech Republic, Slovakia, and Norway, and at Vredepeel (The Netherlands) and Shauinsland (Germany), thus contributing to the increased PM level observed at these sites. Notably, all these sites experienced a decrease in NO_3^-. The very few sites that experienced a substantial (20 – 90%) increase in NO_3^- was scattered and located at the British Isles, in Finland, Sweden, and Poland. Of these sites, only the Swedish one performed PM measurements, experiencing a 25% increase in PM_{10}.

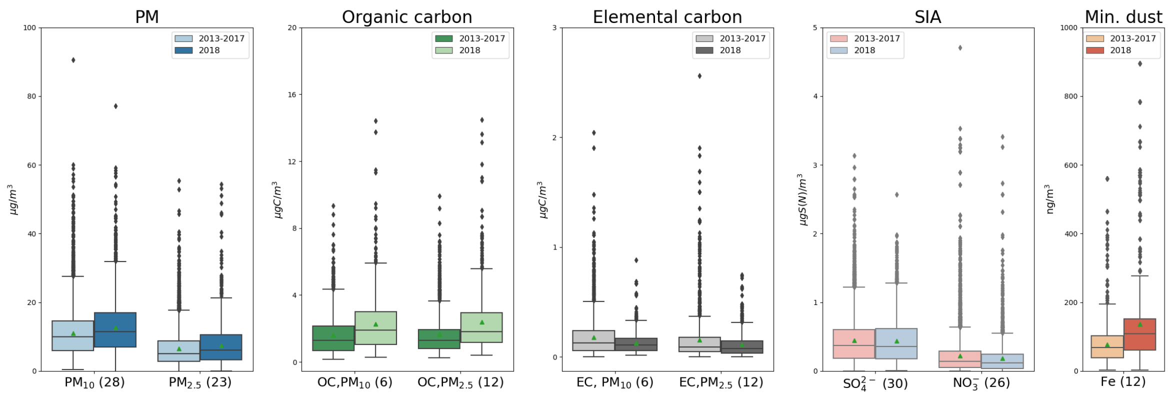

Figure 4.7: Levels of PM, OC, EC, SO_4^{2-}, NO_3^- and Fe in summer 2018 compared to summers 2013 – 2017 at northern European EMEP sites ((Figure 4.6). Boxes shows the 10th, 25th, 50th, 75th and 90th percentiles, and the arithmetic mean. The numbers in the brackets indicate the number of sites.

OC was increased at all sites measuring this variable. The median increase was similar for OC in PM_{10} (44%) as for OC in $PM_{2.5}$ (45%) (Figure 4.7), but at sites performing OC measurements in both size fractions the increase was substantially higher for $PM_{2.5}$ (69%)

than for PM_{10} (39%). For the majority (85%) of these sites, EC was decreased (median = -29%) or marginally increased (median = 6%), indicating that the increase in OC was not caused by anthropogenic combustion sources.

As for OC, Fe was increased at all sites measuring this variable and the median increase (60%) was even higher than for OC (Figure 4.7). Extreme increases at Birkenes (256%) in Southern Norway and at Virolahti III (418%) in Southern Karelia (Finland) were observed. All but the two sites in the Czech Republic report concentrations of Fe at a weekly time resolution, minimizing the influence of episodes. Further, Fe was elevated for the entire summer, thus the increase was not a result of a few extreme events but rather a prolonged period with mineral dust influence. The Fe time series for Birkenes and Virolahti III exemplifies this nicely and show that the increased Fe levels started already in April (Figure 4.8, left panel). The median Fe concentration at Virolahti III in summer 2018 exceeded 500 ng m^{-3} and was nearly four times higher than at Kosetice (140 ng m^{-3}), which observed the second highest median Fe concentration. We speculate that the very high level observed at Virolahti III could result from a local change in land use. Indeed, the Fe concentration for summer 2019 was also highly elevated at Virolahti III (288 ng m^{-3}), corresponding to a 192% increase compared to the summers 2013 – 2017.

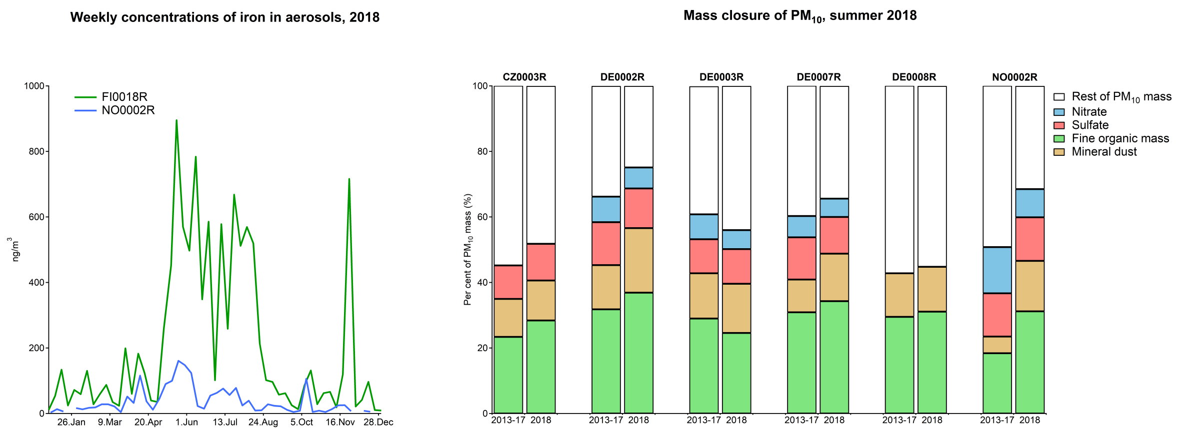

Figure 4.8: Left panel: Time series of Fe at the Birkenes Atmospheric Observatory (Norway) and at Virolahti III (Finland). Right panel: relative mass closure of PM_{10} at selected sites.

In order to investigate the source regions, we performed calculation with the Lagrangian transport model FLEXPART in backward mode for the two stations, Kosetice and Birkenes. The footprint for the week at which Fe peaked at Birkenes in 2018 (30 May - 6 June) shows no influence from the African continent but rather covers Eastern Europe and Scandinavia (Figure 4.9 (left)). Indeed, most of the Birkenes samples high in Fe had footprints that covered this area. A vast part of this region is arable land subject to agricultural activity, which could be a possible source, as can wind-blown dust from semi-arid and dry areas governed by the favorable meteorological conditions in summer 2018. To what extent new areas were recruited as mineral dust sources in summer 2018 ought to be explored. There were only minor differences in the mineral dust composition at Birkenes for all summer, which could indicate that most of the mineral dust had a common origin. In contrary, the highest Fe concentration measured at Kosetice (14 - 15 April) includes northern Africa as a likely source region but also large areas in Eastern Europe (Figure 4.9 (right)), as seen for Birkenes.

Fine OM (OC x 1.9) was by far the most abundant fraction of PM_{10} at sites with concurrent

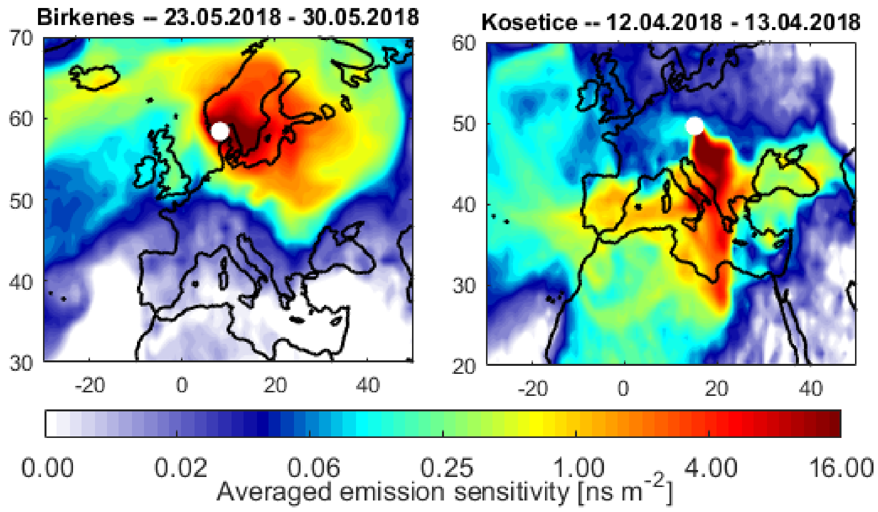

Figure 4.9: Footprint emission sensitivities calculated using the Flexpart model (Pisso et al. 2019)) for the period 30 May - 6 June 2018 at the Birkenes Atmospheric Observatory (Norway) (left)), and for 12-13 April at Kosetice (The Czech Republic) (right).

measurements of SO_4^{2-}, NO_3^-, fine OC and Fe (Mineral dust = Fe x 12; Factor derived from Alastuey et al. (2016)), except from Virolahti III, at which mineral dust was most abundant, thus reflecting the general increase in OC for summer 2018. Fine OM explained 34% (median) of PM_{10} and 52% (median) of $PM_{2.5}$, which was somewhat higher than for the summers 2013 – 2017, i.e. 32% (PM_{10}) and 47% ($PM_{2.5}$). As for OM, the mineral dust fraction of PM_{10} was increased in summer 2018 (15%, median) compared to summers 2013 – 2017 (13%, median), and for all sites but the Czech site Churanov. For Birkenes and Virolahti III the increase was considerable; i.e. from 5% to 15% (Birkenes) and from 15% to 53% (Virolahti III). At sites measuring both Fe and SO_4^{2-}, the calculated mineral dust concentration and thus the contribution to PM_{10}, was equally high or higher than SO_4^{2-} in summer 2018, whereas it was the other way around for the summers 2013 – 2017. For sites with both NO_3^- and mineral dust, mineral dust was typically more abundant both for 2018 and 2013 – 2017. Note that there are great uncertainties in both the Fe to mineral dust and the OC to OM conversion factors, hence mineral dust and concentrations, and their relative contributions to PM should be considered as estimates only.

Figure 4.8 (right panel) shows how fine OM and mineral dust are major fractions of PM_{10} in summer, not only for 2018 but also for 2013 – 2017. Previous studies have shown how fine OM is dominated by biogenic sources in summer (Simpson et al. 2007, Yttri et al. 2011, Bergström et al. 2012) and with mineral dust largely attributed to natural sources the data presented here suggest that the increased PM levels in 2018 largely is attributed to particles of natural origin.

4.5 Observed tracers of organic aerosols at Birkenes

Global isoprene emissions exceed 500 Tg yr^{-1} (Guenther et al. 2012) and its oxidation products account for up to 50% of the biogenic secondary organic aerosol (BSOA) budget (Henze and Seinfeld, 2006). In Norway, isoprene emissions are about 18% of anthropogenic emissions (Simpson et al. 2012), though in summer months the fraction of isoprene is much higher.

2-methyltetrols are well-known oxidation products of isoprene that partition to the particulate phase (Claeys et al. 2004). These species have been measured at Birkenes since 2016 and provide an excellent opportunity to assess organic carbon associated with BSOA (OC_{BSOA}) of isoprene origin and validation of model calculation of such.

2018 levels of 2-methyltetrols were clearly elevated compared to 2016 – 2017, i.e. by 46% when comparing the median (Figure 4.10). 2-methyltetrols and modelled concentrations of isoprene co-appear in May and were highly correlated (r^2 = 0.793). With the short atmospheric lifetime of isoprene (1 – 2 hours) this suggests that the observed 2-methyltetrols concentration at Birkenes originate from local isoprene emissions and thus is a measure of locally formed OC_{BSOA} (Yttri et al. in prep.). Birkenes is largely a recipient of long-range transported species, so also for BSOA (Yttri et al. in prep.). Nevertheless, r^2 equaled 0.652 for modelled BSOA (includes BSOA from all BSOA-forming BVOCs, not only isoprene) versus 2-methyltetrols for the period when 2-methyltetrols were elevated at Birkenes (23.05 – 17.10.2018).

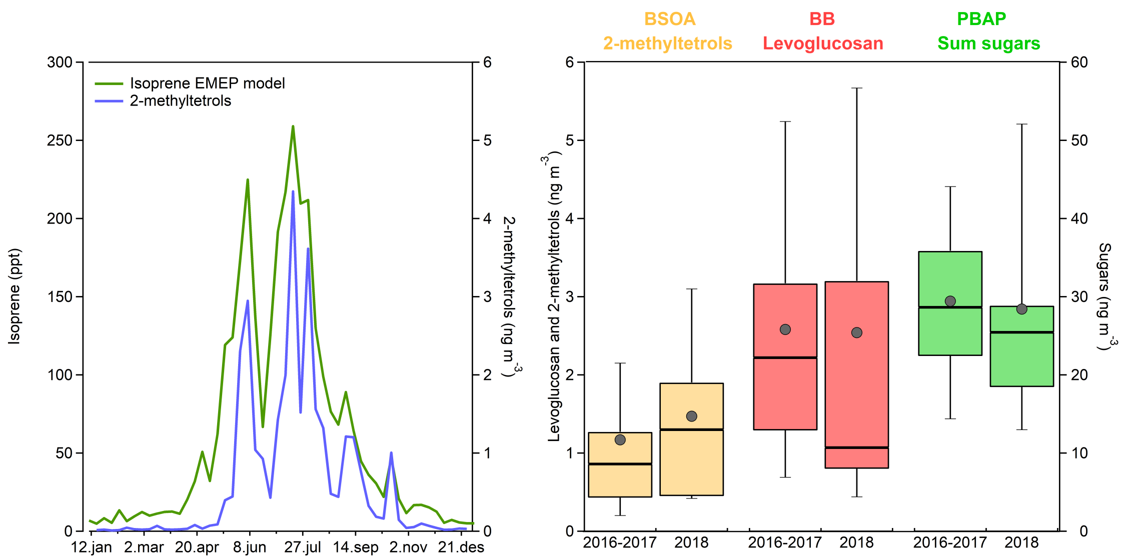

Figure 4.10: Times series of modelled concentrations of isoprene and observed 2-methyltetrols at Birkenes in 2018 (left panel) and box plot of 2-methyltetrols (BSOA = Biogenic Secondary Organic Aerosol), levoglucosan (Biomass Burning) and sugars (sum of arabitol, mannitol, glucose and trehalose) (PBAP = Primary Biological Aerosol Particles) for 2018 compared to 2016 – 2017 (right panel).

The fine ($PM_{2.5}$) OC level at Birkenes in May – September 2018 (1.0 μg(C) m^{-3}) was the second highest since measurements started in 2001. The median value was 98% higher than the median value of the previous 5 years. The relative contribution of 2-methyltetrols to observed fine OC was 15 – 20% lower for 2018 compared to 2016 – 2017. We can only speculate about the reason for this, such as other oxidation products of isoprene or mono/sesqui terpenes becoming more abundant, carbonaceous aerosol from other (non-BSOA) sources increasing more for 2018 than the 2-methyltetrols, or perhaps the most plausible explanation; a change in the BSOA fraction of local origin, represented by 2-methyltetrols, versus that of long range transported (LRT) origin. The median EC value appears unaltered (-14 - +9%) in 2018, whereas for levoglucosan there was a major decrease (-52%), excluding emissions

from anthropogenic primary carbonaceous aerosol sources. Primary Biological Aerosol Particles (PBAP) tracers at Birkenes in 2018 was also reduced (-11%) compared to 2016 – 2017. These findings point to BSOA as the explanation to the substantially increased fine OC levels at Birkenes in 2018, and LRT BSOA in particular. A certain increase in anthropogenic SOA cannot be excluded but is typically substantially less than BSOA regardless of season (Simpson et al. 2007).

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Part II

Research Activities

CHAPTER 5

The TNO CAMS inventories, and alternative (Ref2) emissions for residential wood combustion.

Hugo Denier van der Gon, Jeroen Kuenen, and Antoon Visschedijk

5.1 Introduction

Under the Copernicus Atmospheric Monitoring Service (CAMS) there is a specific project delivering gridded emissions data for air quality modelling (CAMS_81 Global and regional emissions). The CAMS regional anthropogenic emission inventory covers emissions for UNECE-Europe for the main air pollutants and greenhouse gases. The method starts from the reported emissions by European countries to UNFCCC (for greenhouse gases) and to EMEP CEIP (for air pollutants). TNO collects the data at the highest level of detail available and, using additional auxiliary data, compiled them into 246 different combinations of sectors and fuels which were also the basis in the earlier TNO_MACC-II and TNO_MACC-III inventories (Kuenen et al. 2014). A description of the process and previous versions of the CAMS-REG regional emissions data is presented in Granier et al. (2019) and can also be found at the Copernicus website [1]. An important added value of the CAMS-REG emission datasets is that a consistent spatial distribution methodology is applied for Europe. The spatial resolution of the emissions is $0.1° \times 0.05°$(lon $\times$ lat), in order to align with other emission inventories such as EDGAR and EMEP which have a resolution of $0.1° \times 0.1°$(lon $\times$ lat). The most recent version of the CAMS regional emissions dataset is version 4.2 (CAMS-REG-4.2) covering the years 2000-2017, its main characteristics are given in Table 5.1.

The sector classification follows GNFR, an aggregated version of the NFR (Nomenclature For Reporting) which is used by individual country emission reporting to EMEP and EU. More details on the sector classification can be found at the CEIP website. The dataset covers the entire European domain for the priority air pollutants (NOx, SO_2, NMVOC, NH_3,

[1] https://atmosphere.copernicus.eu/anthropogenic-and-natural-emissions

Table 5.1: Characteristics of the CAMS 2000-2017 regional European emissions (CAMS-REG_v4.2)

AP (Air Pollutants)	NOx (as NO_2), SO_2, NMVOC, NH_3, CO, PM_{10}, $PM_{2.5}$, CH_4
GHG (Greenhouse Gases)	$CO_{2,ff}$ (fossil fuel), $CO_{2,bf}$ (biofuel),CH_4
Resolution	0.1°x 0.05°(longitude latitude, 6x6 km over central Europe)
Period covered	2000-2017 (annual emissions for 18 individual years)
Domain	30°W – 60°E, 30°N – 72°N
Sector aggregation	GNFR (A to L), with GNFR F (Road Transport) split in F1 to F4 (total 16 sectors)
Emission unit	kg (both in CSV and NetCDF files)
Countries	42 countries + 13 sea regions Note: Emissions for other countries within the domain are added based on EDGAR v4.3.2

CO, PM_{10}, $PM_{2.5}$) and the greenhouse gases (CO_2 and CH_4). Next to adding the most recent reported emissions (2000-2017 as reported in 2019), several other improvements are implemented in this new CAMS-REG-4.2 version that make it different from previous versions, also for earlier years. These include an update of the point source emissions using the most recent E-PRTR data, use of AIS based shipping emissions for the years 2013-2017 based on the FMI STEAM model (Jalkanen et al. 2016), new distribution maps for agricultural NH_3 emissions, an updated road transport distribution map, and a change to using GFAS derived estimates for agricultural waste burning. The CAMS-REG_v4.2 is in line with emission reporting by the countries to EMEP and used as the reference emission scenario by EMEP.

Despite the efforts of the competent authorities reporting emissions to EMEP CEIP, significant uncertainties may still exist in the estimation of emissions. This is especially relevant for emissions from the residential heating sector which impacts the occurrence of particulate matter (PM) episodes in winter. The uncertainty can be visualized by looking at the country reported emissions for a base year (here 2010) but reported in different years (Fig. 5.1). Without going into details, Fig. 5.1 clearly illustrates that for many countries substantial adjustments occur over time, sometimes in the order of a factor 2 or more. Since the data are all for the year 2010, this is not driven by meteorology (e.g. a colder vs a milder winter) but due to changes in estimation methodology over time. The choice for the estimation methodology and accompanying emission factors may differ by country, introducing further uncertainty and lack of compatibility. The consequences for environmental studies can be severe, since environmental policies are based on the results of (modelling) studies using these inventories.

5.2 Ref2 - an alternative emission data set for residential wood combustion (RWC)

Denier van der Gon et al. (2015) demonstrated that current PM emission inventories in Europe do not account in a consistent and comparable manner for wood combustion emissions, and in particular that there is inconsistency in the emission factors used between countries. Therefore, a second reference scenario has been developed which includes a modification of the emission data for residential combustion. This scenario, referred to as "Ref2", is a further

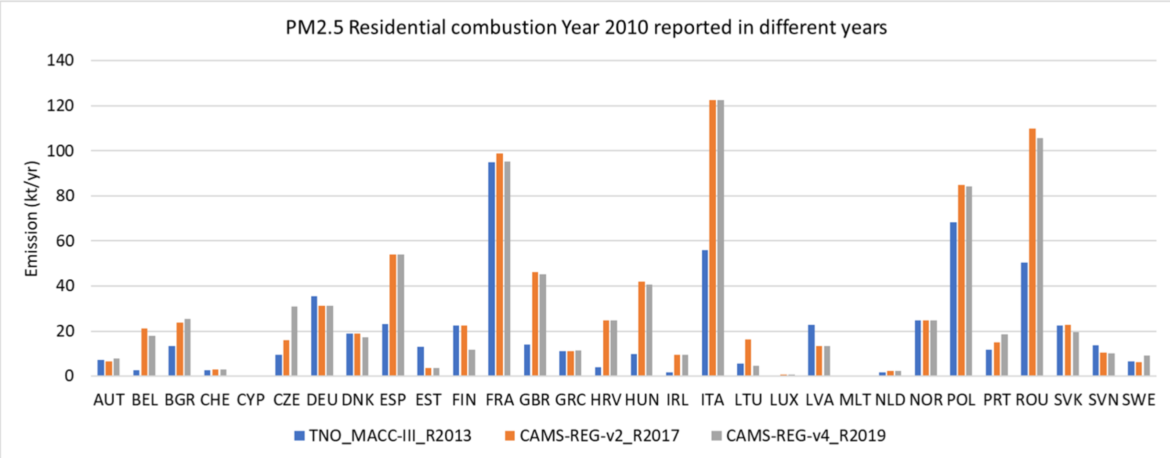

Figure 5.1: $PM_{2.5}$ emission from residential combustion by country for the year 2010, reported in the years 2013, 2017 and 2019.

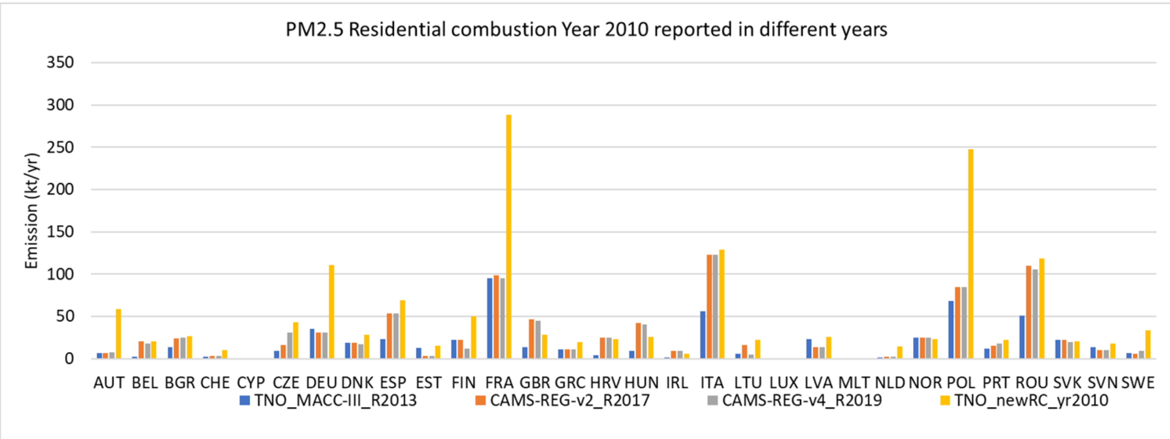

Figure 5.2: $PM_{2.5}$ emissions from residential combustion by country for the year 2010, reported in the years 2013, 2017 and 2019 and the TNO bottom-up calculation for the year 2010 (TNO_newRC_yr2010).

improvement of the alternative emission data set proposed by Denier van der Gon et al. (2015) and has been further developed partly under the CAMS policy support project (CAMS_713). The improvement of the dataset consist of a thorough review of the activity data for the base year 2010 including Eurostat data and available country reports and refinements of the spatial distribution. The latter included a reanalysis of high resolution population density maps to identify urban areas where most likely high rise buildings occur and therefore occurrence of fire places and woodstoves is unlikely. Based on the collected activity data (wood use) and the appliance type split by country from the IIASA GAINS model a bottom-up calculation was made where for all countries consistent emission factors were used. The result for the year 2010 (TNO_newRC_yr2010) is shown together with the country reported data (as shown in Fig.5.1) in Fig.5.2. It can be seen that for some countries the independent bottom-up estimate is equal or very close to the latest official country reported estimate (e.g. Belgium, Italy, Bulgaria, Norway, Romania) but for other countries the discrepancy is substantial (e.g. Austria, Germany, France, Netherlands, Poland). It should be noted that the TNO bottom-up estimate as shown in Fig. 5.2 includes substantial uncertainties for example concerning wood qual-

ity, appliance types in different countries, etc. but the merit is that it applies one consistent methodology to all countries.

The discrepancies as depicted in Fig. 5.2 are well-known and have been discussed in several UNECE-TFEIP meetings and workshops, most recently in an Nordic Council of Ministers (NMR) funded workshop in March 2020 (see also Chap. 6). The main underlying cause is the choice of using emission factors with or without including condensable organic particulate matter. (The concept of condensable particulate matter has been explained and discussed in detail in Robinson et al. (2010); see also Simpson et al. (2019) and chapter 6.

Until now this alternative reference scenario (and emission inventory), Ref2 corresponding to the current situation, but with revised emissions factors and activity data for the residential heating sector (GNFR C; PM_{10} and $PM_{2.5}$) has only been made for the year 2010. It is supposed to reflect new scientific understanding of emissions in this sector and, based on the intercomparison of modelling results with observations appears to be closer to real world emissions (see also Denier van der Gon et al. 2015, Simpson et al. 2019). However for assessing the current situation and/or analysing potential policy measures it is unsatisfactory to use a 2010 data set. This is relevant for the EMEP source-receptor matrices but also for the CAMS green scenarios toolbox (available through `https://policy.atmosphere.copernicus.eu/`). A complete update of activity data and appliance types by country is labour intensive and was not feasible at present. Therefore, an attempt is made to make a updated version of the woodburning 2010 emissions which could be used next to the most recent country reporting. These are the year 2017 emissions as reported in 2019 and used in the CAMS-REG_v4.2 dataset.

Woodburning emissions are subject to changes over the years due to meteorology, as heating demand will be higher during cold winters. The influence of climate will be erratic with cold and milder winters varying between years. Other trends that influence woodburning emissions are the promotion of wood as a climate-neutral biofuel to replace fossil fuels and the promotion of more advanced appliance types such as pellet stoves to reduce air pollution. To develop a more up-to-date Ref2 version, our assumption has been that all three of these autonomous developments are captured by the national emission registrations present in each country. While countries may use different estimation methodologies, as was shown above, within a country the methodology will be consistent for the timeseries reported in a particular year. Based on this assumption we can derive a country-specific scaling factor for the year 2010 to approximate the year 2017 emissions (Fig. 5.3).

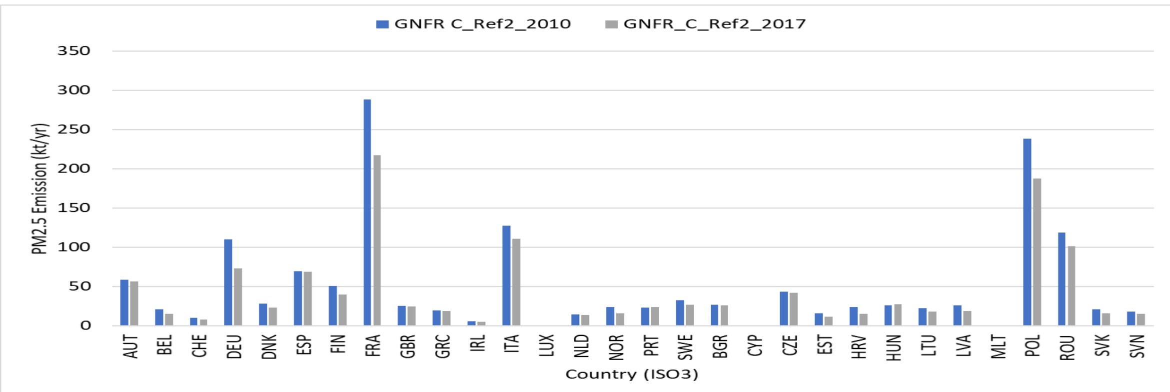

Figure 5.3: The TNO_newRC emissions (Ref2) for the residential combustion sector (GNFR C) for the years 2010 and 2017.

The scaling factor will account for climate variability, changes in wood consumption and changes in national shares of appliance types. The disadvantage is that the impact of these three different influences cannot be disentangled. The data in Fig. 5.3 show that the discrepancy between years can be substantial and can vary by country. While the use of biomass for heating in Europe has increased since 2010, the emissions in 2017 are generally lower. In general the winter of 2010 was relatively cold, creating a higher heating demand which is an important explaining variable. However as indicated it cannot be fully separated from the impact of promotion of new technologies or other emission reduction measures. A further detailed analysis of the trends in PM emissions from residential combustion is highly recommended. Nevertheless, the data in Fig. 5.3 show that using a Ref2 for the year of study (here 2017) is significantly better than using the year 2010 estimate.

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CHAPTER 6

Condensable organics: model evaluation and source receptor matrices for 2018

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6.1 Introduction

Condensable organic compounds (loosely denoted condensables hereafter), are a class of compounds of low volatility that may exist in equilibrium between the gas and particle (condensed) phase. Such compounds may or may not be included in current emission inventories for fine particulate matter ($PM_{2.5}$), and PM_{10}, with their treatment varying from country to country and from one emissions source to another (see also Sect. 3.3). The treatment of these compounds, first highlighted by Robinson et al. (2007b) and discussed in detail in Robinson et al. (2010), and for the EMEP situation in Bergström et al. (2012), Denier van der Gon et al. (2015), Simpson and Denier van der Gon (2015) and Simpson et al. (2019), has significant implications for the modelling of organic aerosol and therefore PM levels in the ambient atmosphere. Among other problems, the different definitions of PM emissions result in inconsistent source-receptor relationships between countries, as highlighted in Simpson et al. (2019). In addition, these problems with the organic carbon (OC) fraction of PM inventories are interlinked with those of elemental carbon (EC) through the common use of OC/EC ratios to derive one component from the other, and to 'intermediate volatility' organic compounds (IVOC) as discussed further in Simpson et al. (2019).

The issues are, however, complex, with emission factors for condensables being dependent on a large number of factors, including measurement methods, fuels, usage, and even ambient conditions (Robinson et al. 2010). It can be noted that the issues are not just "are condensables included or not?", but "how are they included?". As an example, in previous years Norway had much higher emission factors (EFs) than Sweden since Norway included and Sweden excluded condensables. Since 2019 Sweden has included condensables, but Norway still has

higher EFs since its methodology allows for poorer combustion conditions, designed to better reflect real-world usage of residential combustion appliances.

As discussed in Denier van der Gon et al. (2015) and Chap. 5, TNO have developed inventories for Europe in which the condensable components of $PM_{2.5}$ are included for all countries in a consistent manner. The latest such inventory is referred to as 'Ref2' (Chap. 5). In order to produce more consistent source-receptor relationships for EMEP, the EMEP Bureaux (UNECE 2020) decided that EMEP MSC-W should make use of the Ref2 emissions for condensable organics, and these results will be reported here. The merger of EMEP and Ref2 for Sector C is referred to as EMEPwRef2C – see also Chap. 3.

In March 2020 MSC-W hosted an expert workshop on condensables (funded by the Nordic Council of Ministers, Simpson et al. 2020), which brought together experts in emissions, measurements, inventories, and policy from Europe and North America, and created a much better understanding of the issues and possible approaches for dealing with this important class of compounds. A report from the workshop is currently in preparation, but the meeting endorsed the use of TNO Ref2 emissions for GNFR sector C as a good first no-regret step for describing condensable emissions in emission dispersion modelling. This inventory is to be considered as a gap-filling necessary to provide better match between air quality measurements and air quality modelling, but which will hopefully be increasingly replaced by national estimates once procedures for dealing with condensables in a more harmonised way are implemented.

For countries such as Norway where condensables were included in previous source-receptor calculations there will be little difference between the current results and previous ones, but for countries where the addition of condensables changes the PM emissions significantly there will of course be larger differences.

6.2 Model setup

In this work we have made use of two emission data sets; the one based only on the national reported emissions to EMEP for 2018 ('EMEP') and the other set where PM emissions from the Residential combustion sector (GNFR C) are replaced by a bottom-up TNO estimate (for 2017) using emission factors including condensable PM as described in Chapter 5 ('EMEP-wRef2C'), see Table 6.1.

Table 6.1: Notation for emissions scenarios used in this report

Scenario (this report)	Source
EMEP	Emissions based on national reported emissions to EMEP as of 2020 (for 2018), described in Chapter 3.
EMEPwRef2C	Based on the EMEP year 2018 emissions (as above) but the PM emissions from the Residential combustion sector (GNFR C) are replaced by a bottom-up TNO estimate (for 2017) using emission factors including condensable PM as described in Chapter 5. Gridded data provided by TNO.

The EMEP MSC-W model version, meteorological data and other inputs are the same

for both sets (described in Chapter 2). For both emission data sets a status run for 2018 has been performed, as well as source receptor calculations. The assessment of the year 2018, described in Chapter 2, has been based on the 'EMEPwRef2C' emissions.

In principle, use of condensable organics should also require a set of assumptions on their volatility distribution - since some of the semi-volatile compounds will evaporate once the emissions enter the atmosphere (Robinson et al. 2007a, 2010). Upon oxidation (via OH, O_3 or NO_3) these gas-phase SVOC compounds will relatively easily form compounds of even lower volatility and thus enter the particle phase as secondary organic compounds (SOA). As discussed in Simpson et al. (2012), by default the EMEP model used a so-called 'NPAS' scheme (No-Partitioning of POA +Aging of Secondary OA), in which POA emissions can be treated as non-volatile. In high-emission areas this NPAS scheme should lead to higher OA compared to a model that allows evaporation of some of the initially emitted POA. Calculations with the EMEP model (see SI, Sect. S6, of Simpson et al. 2012) showed that the two assumptions were generally comparable, within 0.2 μg m^{-3} over many parts of Europe, although differed for the Paris region by around 0.4 μg m^{-3} . Robinson et al. (2007a) also found that the total amount of PM formed when allowing for the evaporation and SOA-formation processes was rather similar to the amount produced when assuming that the PM emissions were inert. It should however be noted that both of these calculations made use of more complex assumptions concerning emissions and additional IVOC for the non-inert cases. Indeed, the so-called volatility basis set (VBS) schemes typically used to model SOA often postulate emissions of SVOC & IVOC which are supposed to be unaccounted for in the official emission inventories (Robinson et al. 2007a, Shrivastava et al. 2008, Bergström et al. 2012, Denier van der Gon et al. 2015, Jiang et al. 2019). This is likely more realistic, and provides a larger pool of VOC compounds from which partitioning to aerosol can occur, but it is also a large source of uncertainty.

In order to keep the use of EMEPwRef2C as simple as possible, and to avoid adding further assumptions on top of the inclusion of condensables in the PM inventories, we have retained the the assumption of inert emissions (NPAS approach) in the current calculations. (This assumption is further discussed in Sect. 6.4 below.)

The source receptor calculations using the EMEPwRef2C emissions have been performed using the 'brute force' methodology, e.g. separate reduction (15%) runs for each country and component (SO_x, NO_x, NH_3, NMVOC, PPM) have been performed, and the total effect is estimated by adding up the contribution from each of the runs. In addition, the contribution from primary PM emissions using the EMEP PPM emissions has been calculated using the LF methodology (see Chapter 11.2). The source receptor matrices for the EMEP emission data set is then calculated by adding up the contribution from SO_x, NO_x, NH_3 and NMVOC from the brute force methodology plus the PPM contribution using the EMEP PPM emissions and the LF methodology. In this report we will focus only on the changes in $PM_{2.5}$ concentrations, since these are most directly affected by the condensables issues.

6.2.1 Emissions

The different PM emission estimates used in this work have been compared in Figure 6.1. In addition, the officially reported national estimates for 2017 (reported in 2019) are included, since the TNO Ref2 bottom-up estimate including condensable organics is based on these emissions (as described in Chapter 5).

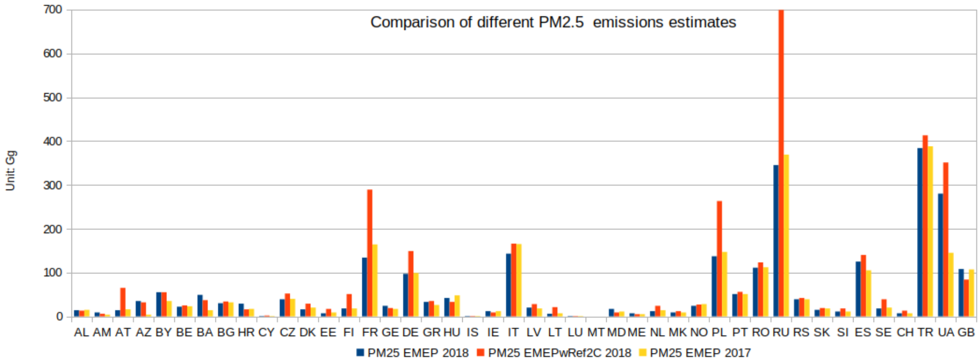


Figure 6.1: Emissions of primary PM in 3 different datasets: 1) Official EMEP estimates for 2018 (PM25 EMEP 2018), 2) EMEP estimates for 2018 where GNFR sector C has been replaced with TNO Ref2 estimates for 2017 and 3) Official EMEP estimates for 2017, reported in 2019 (PM25 EMEP 2017). Unit:Gg.

From the Figure it is clear that the EMEP emission estimates for some countries have changed substantially from 2017 to 2018. Changes above 50% in PM emissions are observed in Armenia, Croatia, Malta, Spain and Turkey (see also Chapter 3.4). For some countries, data are (partly) replaced, corrected or gap-filled in 2020 (for 2018), and the differences to 2017 are mainly due to different gap-filling for those countries in the EMEP estimates for 2017 and 2018.

The differences between EMEPwRef2C and EMEP for 2018 are largest for Austria, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Latvia, Lithuania, the Netherlands, Poland, Russia, Sweden, Switzerland and Ukraine. According to the UNECE inventory review (Juhrich 2020), Austria, Estonia, France, Germany, the Netherlands and Switzerland explicitly report PM emissions without condensable organics. Furthermore, for Lithuania, Poland and Russia the reporting method is mixed or unclear. For those countries, at least part of the differences can be attributed to the condensable organics issue. However, the Czech Republic, Denmark, Finland, Sweden and Latvia most likely include condensable organics in their emission estimates according to Juhrich (2020). As noted in the introduction, the issues are not just "are condensables included or not?", but "how are they included?". Therefore it is not possible to infer from such comparison of emission estimates which one is most correct, but hopefully increasing attention to these issues and better procedures for dealing with condensables in a more harmonised way will help improving consistency. Here we simply note that the emission estimates to a large extent are substantially different (for several reasons), and provide model results to show how this may affect calculations of concentrations, comparison to observations, source receptor matrices and calculation of $PM_{2.5}$ exceedances.

6.3 Results

6.3.1 Comparison to observations

As the effect of using TNO Ref2 emissions for residential combustion is larger for $PM_{2.5}$ than for PM_{10}, here we focus on evaluating the model performance for $PM_{2.5}$. The differences in 2018 annual mean $PM_{2.5}$ concentrations simulated in EMEPwRef2C and EMEP runs are shown on the upper map in Figure 6.2. The largest increases in $PM_{2.5}$ levels by 1.5-3 μg m^{-3} are seen in Poland, Austria, parts of France, Switzerland, Bulgaria and the Moscow

region. Some decreases of $PM_{2.5}$ concentrations in the EMEPwRef2C runs are found in much of the Balkans, countries south East of the Black sea, parts of Spain and Portugal, as well as the UK and parts of Norway.

Comparison to EMEP observations

The lower map in Figure 6.2 shows the annual mean $PM_{2.5}$ concentrations from the EMEP run and observations at EMEP sites (can be compared with Figure 2.8 for the EMEPwRef2C run).

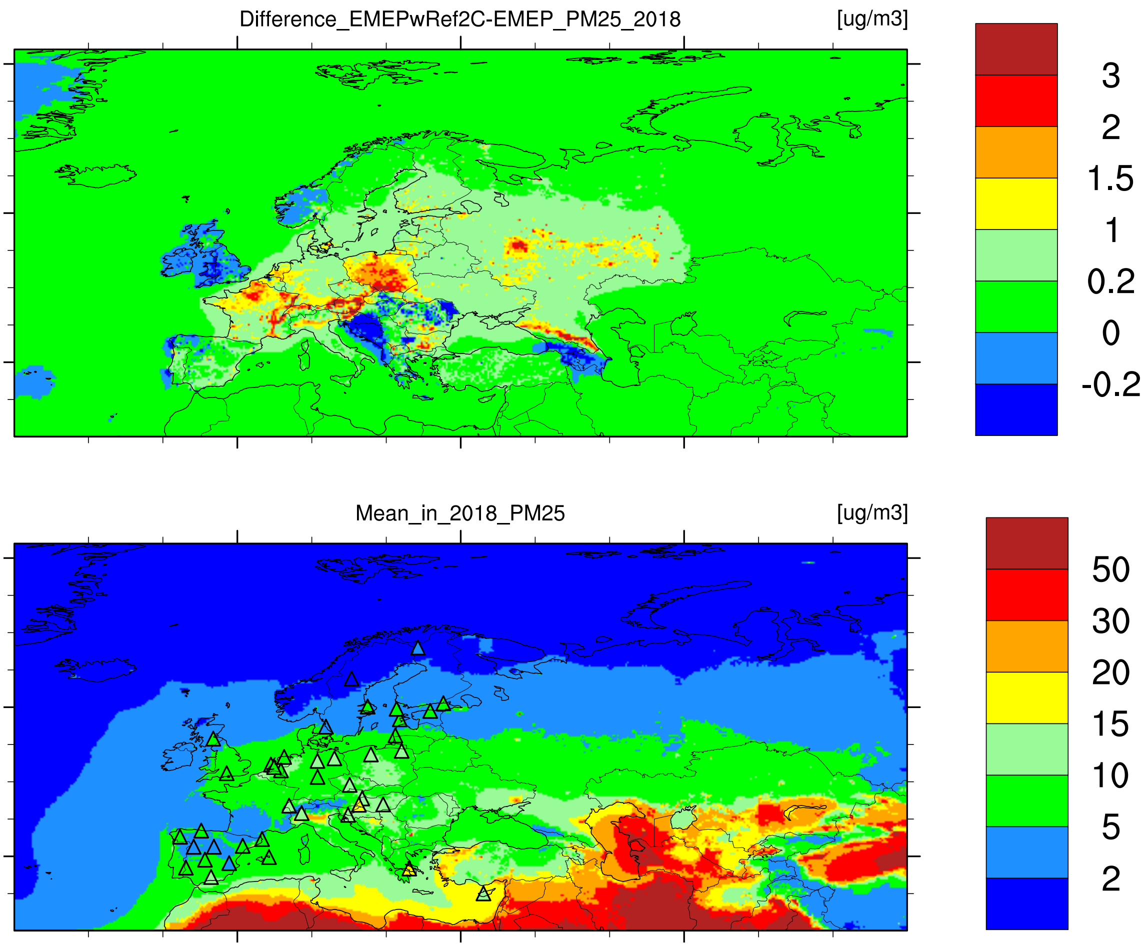
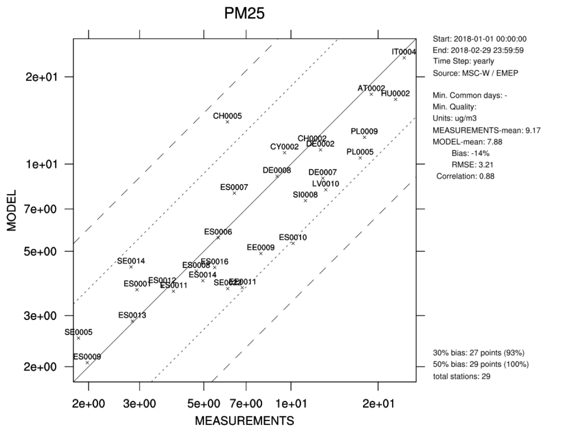


Figure 6.2: Difference between annual mean concentrations of $PM_{2.5}$ (upper) from EMEPwRef2C and EMEP runs and annual mean $PM_{2.5}$ (lower) from the EMEP run (colour contours) and observed at EMEP monitoring network (colour triangles) in 2018. Units $\mu g\ m^{-3}$

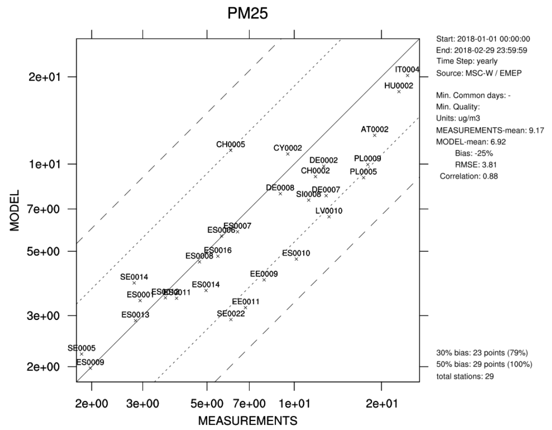
The model results have been compared to daily and hourly $PM_{2.5}$ measurements separately (two sets of sites using different measurement techniques, see Appendix (Tsyro et al. 2020)).

Compared to the EMEP run, the model bias for $PM_{2.5}$ in the EMEPwRef2C run is smaller, i.e. -14% versus -20% compared with daily observations and -6% versus -14% compared with hourly observations (not shown). We also find an improvement in the spatial correlation for $PM_{2.5}$ from the EMEPwRef2C than from EMEP run (0.81 vs 0.76) using the daily observations, but almost unchanged (0.80 vs 0.81) using the hourly observations.

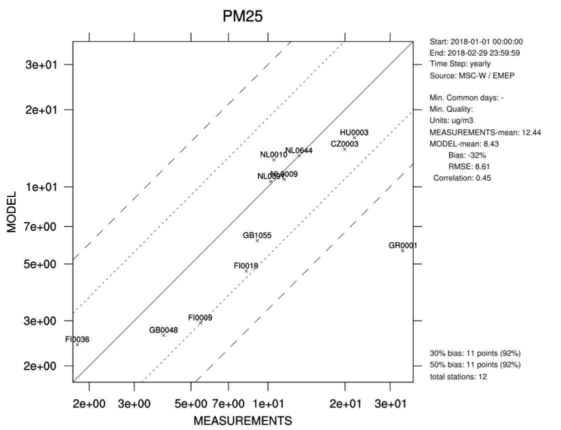
As expected, the bias improvements are more pronounced in the cold season, when the emissions from residential heating are the largest. The scatterplots for modelled versus observed $PM_{2.5}$ for January-February 2018 are shown in Figure 6.3. Compared to daily and hourly observations in January-February 2018, the model underestimation of $PM_{2.5}$ in the EMEPwRef2C run is smaller than in the EMEP run: 14% and 32% versus 25 and 41% respectively. The spatial correlation is almost unchanged.



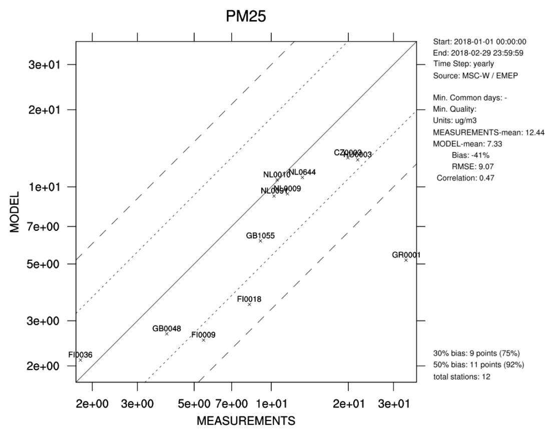
(a) EMEPwRef2C (daily observations)



(b) EMEP (daily observations)



(c) EMEPwRef2C (hourly observations)



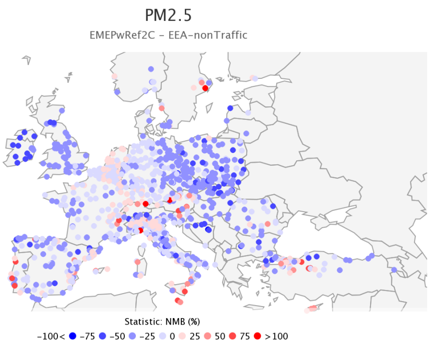
(d) EMEP (hourly observations)

Figure 6.3: Scatterplots for modelled vs observed $PM_{2.5}$ from EMEPwRef2C (a, c) and EMEP (b, d) runs. EMEP sites, daily (upper) and hourly (lower) observations, January-February 2018.

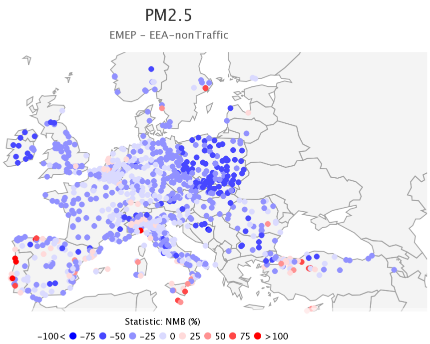
Comparison to EEA Observations

Modelled $PM_{2.5}$ concentrations from the EMEP and the EMEPwRef2C run have been compared to the European Environment Agency's (EEA) Air Quality e-Reporting Database for 2018 (loosely denoted 'EEA observations' herafter), downloaded 1/05/2020.

All the figures and statistics can be found on a dedicated web interface: `https://aerocom-evaluation.met.no/main.php?project=emep`. The user can select the classification of measurement data (rural, urban, non-traffic, or all stations) and view a large number of statistical parameters (bias, correlation, root mean square error, etc.).



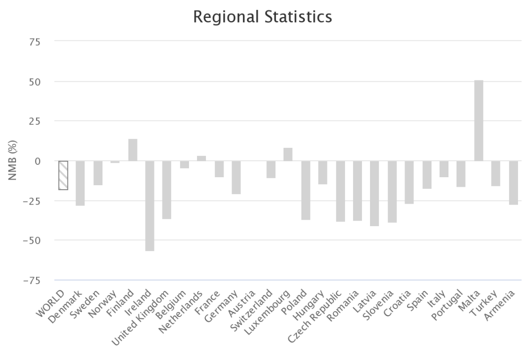
(a) EMEPwRef2C



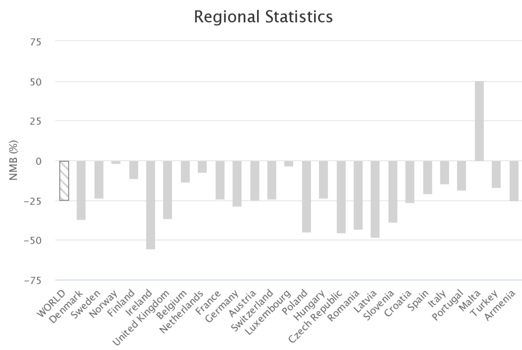
(b) EMEP

Figure 6.4: Normalized mean bias for $PM_{2.5}$ (Model runs versus non traffic EEA observation for 2018) using EMEPwRef2C and EMEP emissions. Units: %

In Figure 6.4, the normalized mean bias for the modelled versus observed concentrations of $PM_{2.5}$ are visualized on a map for non-traffic EEA observations. The bias for $PM_{2.5}$ concentrations is clearly lower in the EMEPwRef2C model run, especially for central European countries. Figure 6.5 show a similar picture when the model runs are compared to only rural background sites - a reduction in bias for a majority of countries. Overall, the bias improves from -29% to -22% when comparing the model runs to all non-traffic observations in Europe, and from -25% to -18% when comparing only to rural background sites (shown only in the web interface). At the same time the correlation coefficient (monthly data) improves from 0.57 to 0.62 (non-traffic sites) and from 0.72 to 0.74 (rural background sites).



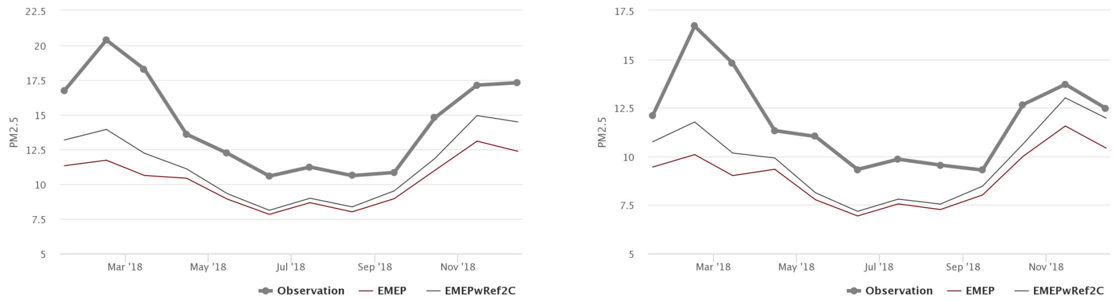
(a) EMEPwRef2C



(b) EMEP

Figure 6.5: Normalized mean bias for $PM_{2.5}$ concentration averaged per country (Model runs versus rural background EEA observation for 2018) using EMEPwRef2C and EMEP model runs. From left to right: nordic countries, central-west, central-east, southern countries. The statistics is based on monthly data. Units: % for $PM_{2.5}$

The improvement compared to observations is mainly seen in winter time (see Figure 6.6 for a comparison of monthly timeseries), when the magnitude of the residential heating emissions (the only difference between the two emission data sets) is largest.



(a) EEA non-traffic (b) EEA rural background

Figure 6.6: Monthly averaged timeseries (all non traffic EEA observations or all background rural EEA observations) against EMEPwRefC and EMEP model runs for $PM_{2.5}$. Units: $\mu g\ m^{-3}$.

6.3.2 Source receptor matrices

The largest impact on the source receptor (SR) calculations is in all cases to the emitter country itself. In Figure 6.8 and Figure 6.9 we present results of the country-to-itself calculations for all countries within the EMEP domain for primary $PM_{2.5}$ ($PPM_{2.5}$) and $PM_{2.5}$ concentrations, respectively. The impacts vary greatly among the countries, reflecting the changes in emissions to a large extent. For instance, Austria has more than 5 times larger country-to-itself contribution for $PPM_{2.5}$ and about twice as high contribution for $PM_{2.5}$ in EMEPwRef2C versus EMEP. Also France, Estonia, Lithuania, the Netherlands and Poland has contributions from country to itself that is more than double in EMEPwRef2C and around 20-30% for $PM_{2.5}$. On the other hand, for some countries the contribution is smaller (e.g. Croatia, Hungary, Great Britain) in EMEPwRef2C compared to EMEP. As seen in Figs. 6.10, 6.11, the imports (the sum of contributions from other than the country itself) increase or stay approximately the same for all countries - most likely due to a general increase in European emissions.

In some cases the ranking of contributions (e.g. which countries are the most important contributors) change for $PPM_{2.5}$, see an example in Figure 6.7 for Germany. Similar plots for all countries can be found in the respective country reports (Klein et al. 2020).

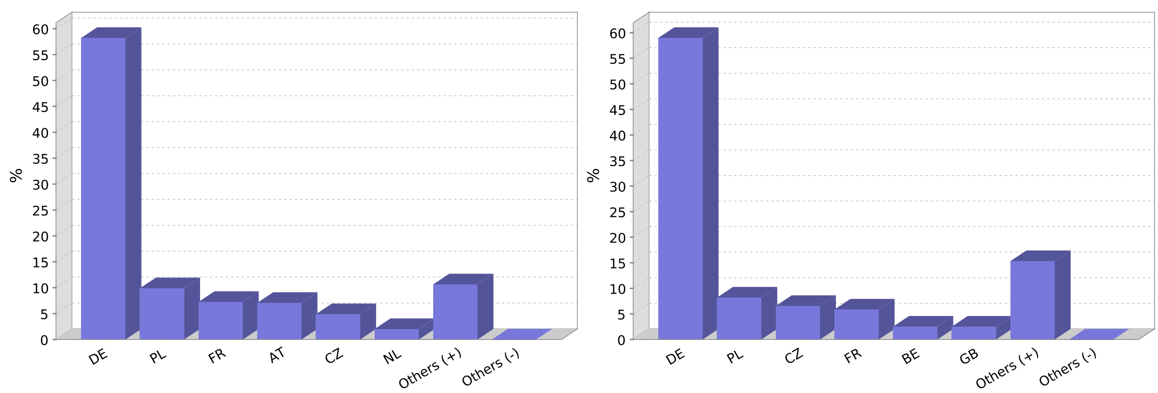


Figure 6.7: The six most important emitter countries or regions, with respect to their effects on $PPM_{2.5}$ (left: EMEPwRef2C emissions; right: EMEP emissions) in Germany that would result from reductions in emissions.

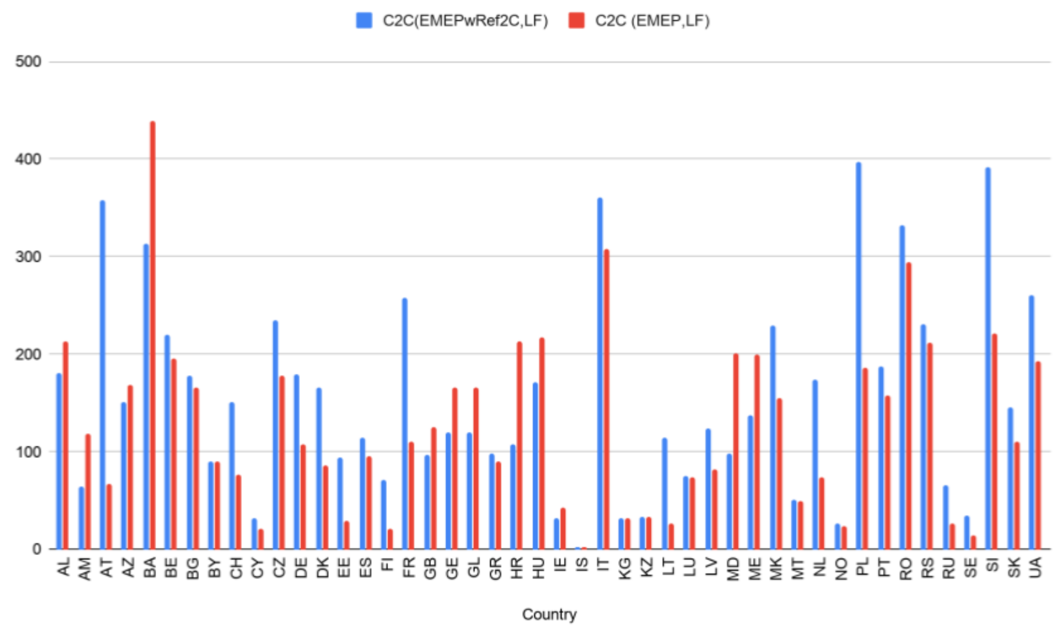


Figure 6.8: Contribution from the country to itself ($PPM_{2.5}$ concentrations) with two different emission estimates for PPM, EMEPwRef2C and EMEP. Units: ngm^{-3}

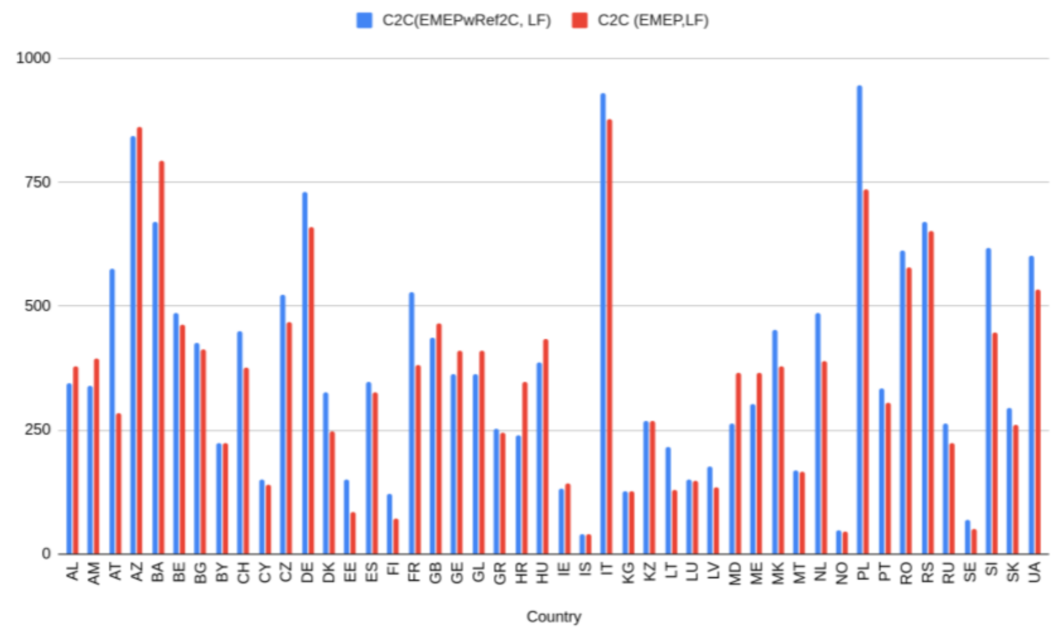


Figure 6.9: Contribution from the country to itself ($PM_{2.5}$ concentrations) with two different emission estimates for PPM, EMEPwRef2C and EMEP. Units: ngm^{-3}

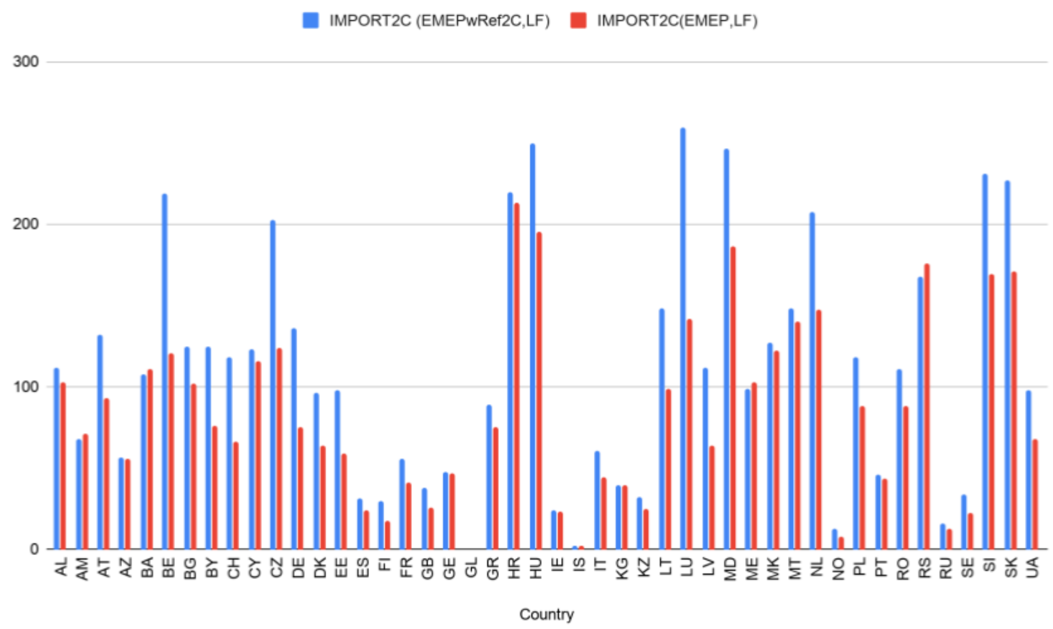


Figure 6.10: Import from other countries to the country ($PPM_{2.5}$ concentrations) on the x-axis (excluding country to itself) with two different emission estimates for PPM; EMEPwRef2C and EMEP. Units: ngm^{-3}

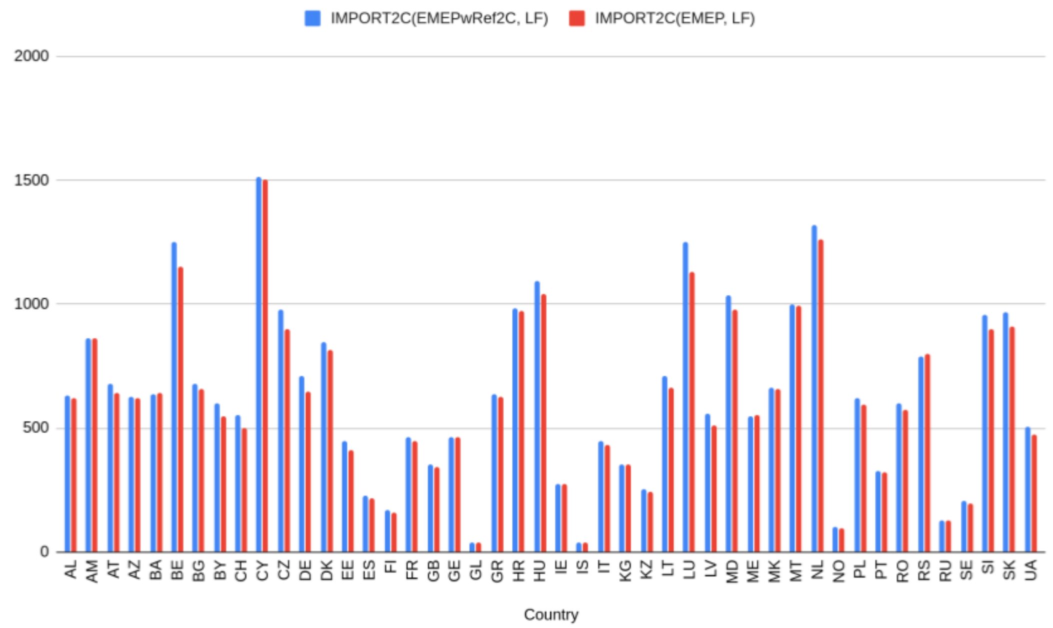


Figure 6.11: Import from other countries to the country ($PM_{2.5}$ concentrations) on the x-axis (excluding country to itself) with two different emission estimates for PPM; EMEPwRef2C and EMEP. Units: ngm^{-3}

6.3.3 $PM_{2.5}$ exceedances

As shown in Section 6.3.1 and Figure 6.2, the annual mean concentrations of $PM_{2.5}$ from EMEPwRef2C are higher by up to 25% compared to those from the EMEP run over most of Europe, with exception of the UK, Norway, north-west/west of the Balkans, parts of Romania and Hungary (where $PM_{2.5}$ is lower by 2-6 %). Here, we look at the effects on calculated daily $PM_{2.5}$ exceedances of the recommended by WHO value of 25μg m^{-3} .

Figure 6.12 shows a map of the number of days with $PM_{2.5}$ exceeding 25 μg m^{-3} in 2018 obtained in the EMEP run. Compared to those from the EMEPwRef2C run (Figure 2.10), the EMEP run produces a less frequent occurrence of $PM_{2.5}$ exceedance days. The number of EMEP sites with observed $PM_{2.5}$ exceedance days are represented by colour triangles. A better correspondence between calculated and observed $PM_{2.5}$ exceedance days (i.e. a better colour correspondence) can be seen for the EMEPwRef2C run compared to the EMEP run.

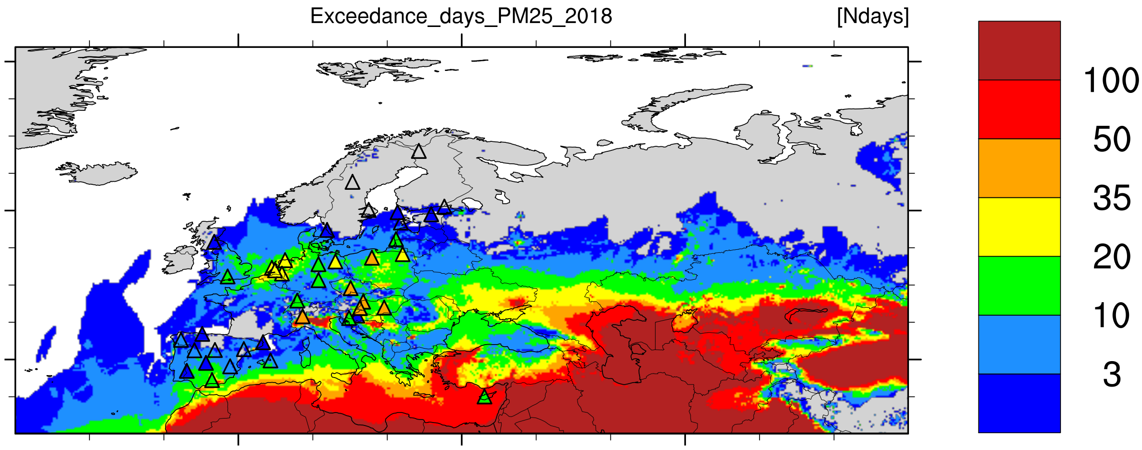


Figure 6.12: The number of days with $PM_{2.5}$ exceedances of 25 μg m^{-3} from the EMEP run (colour contours) and observed at EMEP monitoring network (colour triangles) in 2018.

Table 6.2 gives some examples for the sites with the largest differences between EMEPwRef2C and EMEP results. Compared with observations, there is a large improvement from EMEP to EMEPwRef2C results for AT0002, DE0002, DE0007, PL0009, HU0003 and NL0009 in terms of both the number of $PM_{2.5}$ exceedance days and the common days. On the other hand, EMEPwRef2C overestimates the number of days with observed $PM_{2.5}$ exceedance at IT0004, NL0010, NL0091 and NL0644. For the Croatian site HR0002, both runs greatly exaggerate the registered occurrence of $PM_{2.5}$ exceedances.

6.4 Discussion and Conclusions

Estimates of PM (and NMVOC) as currently provided by Parties have a number of major uncertainties, and there is a clear need for clarification and standardisation of the methods used to define and report PM emissions. The work of Denier van der Gon et al. (2015), Juhrich (2020) and CEIP (Chapter 3.3) clearly show that the definitions behind national emission estimates are inconsistent in their treatment of condensable VOCs; some countries explicitly do not include condensable organics in their PM inventories, some likely include condensables and for some it is mixed or unclear. Furthermore, discussions at the NMR workshop (Simp-

Table 6.2: Exceedance days for $PM_{2.5}$ (above 25μg m^{-3}) in 2018: observed (Obs) and from EMEP-wRef2C and EMEP runs (Model). Also shown are the number of coinciding observed and modelled exceedance days (Common). EMEP observations used are daily (upper part) and hourly (lower part)

		EMEPwRef2		EMEP	
	Obs	Model	Common	Model	Common
AT0002	49	28	18	11	7
DE0002	20	11	6	6	4
DE0007	25	7	5	2	1
HR0002	2	39	0	48	0
IT0004	49	64	38	46	28
PL0009	50	17	12	11	8
HU0003	48	17	7	10	4
NL0009	29	25	14	15	10
NL0010	25	34	13	24	11
NL0091	21	25	11	19	10
NL0644	23	40	16	23	11

son et al. 2020) confirmed that even when countries did include condensables, there were significant differences in the methodologies used.

As noted in the introduction, the NMR expert workshop on condensables (Simpson et al. 2020) agreed that as a first step the TNO Ref2 emissions for GNFR sector C (where condensables are added to small-combustion emissions in a harmonised way, see Chapter 5) is a good first no-regret step for describing condensable emissions in emission dispersion modelling. This was suggested by the Meteorological Synthesizing Centre-West and supported by the Bureaux and the Extended Bureaux to EMEP (UNECE 2020). Thus, the assessment for the air quality situation in Europe and source receptor calculations for 2018 done this year have used a bottom-up emission inventory for PM for the GNFR C emission sector (stationary combustion) that includes condensable organics. These model results, and in addition model results using officially reported PM emissions, have been compared to EMEP and EEA observations - showing improved performance for $PM_{2.5}$, especially in wintertime.

The improvement was seen for most countries, although as expected, the extent of the change depends on the country and location (and the methods used to define PM emissions in nearby countries), but for a few countries the results are somewhat worse. Although there is good evidence for the basic concepts which are applied here, many of the assumptions are very uncertain, even by the standards of organic aerosol modelling in general.

For some countries (e.g. Norway, Bulgaria, Italy) the TNO expert (EMEPwRef2C) and EMEP estimates of $PM_{2.5}$ emissions are comparable, but for others (e.g. Austria, Estonia, France, Germany, the Netherlands and Switzerland) the expert estimate is far higher than the reported emissions. For a few countries the expert estimate is lower (e.g. Croatia, Hungary). In order to estimate the impact of such differences on source-receptor matrices we have calculated the changes in country-to-itself and import-to-country for $PM_{2.5}$ for all the Parties, using the two different emission estimates. The changes in $PM_{2.5}$ and especially $PPM_{2.5}$ were quite sensitive to the different emission setup, with differences in country-to-itself contributions up to a factor 5 different for $PPM_{2.5}$, and up to a factor 2 for $PM_{2.5}$, but varying greatly from

country to country.

We can note some important caveats with this work:

1. The assumption that POA emissions are inert is a major simplification once condensables are included in this emission term. In principle some of these emissions should be allowed to evaporate and thus be available for gas-phase oxidation and SOA formation. A more realistic treatment would likely reduce the country-to-itself contributions, but increase the long-range influence of the condensables.

2. This work has focused on PM emissions, but not considered intermediate volatile compounds (IVOC) which are likely also missing from the emission inventories - being often too volatile to be shown in PM emissions measurements, but too massive and involatile to be found in NMVOC inventories. Upon gas-phase oxidation these IVOC can also form SOA, and are thus another source of potential $PM_{2.5}$ mass.

However, accounting for the above factors would have required a number of further (and not-well-founded) approximations, including likely additions of further mass to the emission inventories. Our focus on PM and condensables has been driven by the great differences in methodology between national estimates; something which affects the fairness of source-receptor calculations based upon these estimates. The issues surrounding IVOC may well be more important than those surrounding condensables, but IVOC are typically associated with the NMVOC inventories, and we are not aware of systematic country differences (except via different levels of important sources such as older diesel fleets, e.g. Jiang et al. 2019).

It is clear that the current situation, in which some countries include and others exclude condensables, is very problematic, and leads to inconsistent and unfair source-receptor matrices. Recent activities to better document and understand the current situation (Simpson et al. 2020, Juhrich 2020) have lead to a greater understanding of the issues among different expert communities. And one of the main conclusions of the NMR workshop is that although these initial calculations with the EMEPwRef2C data are a good first step at a harmonised emission methodology, these expert estimates should be increasingly replaced by national estimates once procedures for dealing with condensables in a more harmonised way are agreed and implemented. Such improvements will need detailed discussion among the emission inventory communities (e.g. TFEIP, TFTEI, national experts) as well as with modellers who will have to account for the complex volatility issues surrounding the condensable and IVOC issues.

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CHAPTER 7

Elemental carbon: model evaluation and source receptor matrices for 2018

Hilde Fagerli, Svetlana Tsyro, Ágnes Nyíri, Peter Wind and Heiko Klein

7.1 Introduction

The 2012 amendment of the Gothenburg Protocol to CLRTAP and the subsequent revision of the EU National Emission Ceilings Directive encourage Parties to prioritise emissions reductions of particulate matter in source sectors "known to emit high amounts of black carbon". Furthermore, in a potential revision of the Gothenburg protocol, it might be considered to include black carbon (BC). Clearly, if BC should be included in a revised protocol, or in an integrated assessment framework, well developed emissions inventories and relevant modelling results are needed. While the observed level of reporting is encouraging, the review conducted under the auspices of the EU Action on Black Carbon in the Arctic highlights a number of critical deficiencies in the current reporting systems (Matthews and Paunu 2019).

In this chapter, we present the EMEP MSC-W model results for concentrations of elemental carbon (EC), assuming that the reported BC emissions are EC. We analyze comparison to observations, as well as source receptor matrices using two different emission data sets:1) the officially reported EC emissions (ECgridded), and 2) an emission data set which partly is derived from a bottom-up TNO estimate (EMEPwRef2C). We demonstrate that uncertainties in the resulting modelled concentrations of EC, as well as source receptor matrices are large.

7.2 EMEP MSC-W model runs for EC

The EMEP-MSCW model has been run for 2018 with two different emission data sets (see section 7.2.1). The EMEP MSC-W model version, meteorological data and other inputs are

the same for both sets (described in Chapter 2). Source receptor calculations for EC have been performed using the Local Fraction method, described in 11.2, for both emission scenarios.

7.2.1 Emissions

Two different sets of emissions have been used in this work:

EMEPwRef2C: Based on the EMEP emissions for the year 2018, but the PM emissions from "Other stationary combustion" (GNFR C) are replaced by a bottom-up TNO estimate (for 2017) using emission factors which include condensable organic components, as described in Chapter 5. EC emissions are then derived from this data set with split factors per country and sector, consistent with a PM emission data set including condensables. This emission data set is the same as used in Chapter 2 for the assessment of the air quality situation in Europe in 2018 and Chapter 6 for source-receptor matrices.

ECgridded: Based directly on reported, gridded EC emission data for the year 2018 where available, otherwise gap-filled and spatially distributed by CEIP for areas where no EC emissions are reported. It is not always clear whether the emissions reported to EMEP are EC or BC (for most countries most likely EC). In the EMEP MSC-W model calculations, all emissions are assumed to be EC, and in the $EC_{2.5}$ fraction.

A comparison of the national total emissions of EC from the two data sets is shown in Figure 7.1, along with a comparison of contributions from small scale combustion (GNFR C) and road transport (GNFR F). Please note that only countries which reported EC emissions in 2020 and are within the boundaries of the EMEP domain are included in Figure 7.1.

The largest differences in total emissions are seen for France, Germany, Italy, Poland and Ukraine. As expected, the differences in GNFR C (small scale combustion) is much larger than in GNFR F (road transport). For GNFR sector F, the total $PM_{2.5}$ emissions are equal in the two data sets, but the EC to organic matter (OM) ratios are different.

The EC emissions reported to CLRTAP are often calculated by national experts as a fraction of PM emissions, and it is unclear to what extent countries take into account that the fraction should differ depending on whether emissions are reported with or without condensable organics. However, the issues regarding deficiencies in the reporting are complex, and there are many uncertainties, see Matthews and Paunu (2019) for a full discussion.

Among the countries mentioned above, according to Juhrich (2020), France and Germany report PM emissions without condensable organics, whilst Italy accounts for them. For Poland, emissions from coal combustion are including condensables, while emissions from biomass burning are excluding condensables. For Ukraine it is unknown. Also for Switzerland and the Netherlands (which according to Juhrich (2020) report PM emissions without condensable organics), officially reported EC emissions from GNFR sector C are much lower than EC emissions in EMEPwRef2C.

7.2.2 EC description in the model

Freshly emitted anthropogenic EC is mostly hydrophobic. As it ages in the atmosphere, EC becomes hydrophilic because of the acquired coating of more hygroscopic species. The EMEP MSC-W model accounts in a simplified way for the ageing and the associated changes of hygroscopical properties of EC. 80% of freshly emitted EC is assumed to be hydrophobic and

Figure 7.1: Comparison of EC emissions from EMEPwRef2C and EC emissions reported to EMEP (ECgridded). Only countries which reported EC to EMEP in 2020 are shown.

20% hydrophilic. The parameterization of EC ageing rate (and thus the rate of EC transformation from hydrophobic to hydrophilic) is based on the work by Riemer et al. (2004). Further, the hydrophobic fraction of EC does not get dissolved in cloud droplets and neither washed out from clouds, but only removed from the air by sub-cloud wet scavenging (more details regarding EC description in the EMEP MSC-W model can be found in Tsyro et al. (2007)).

7.2.3 Difference in model results for EC concentrations for 2018

Figure 7.2 presents a difference map between EC concentrations obtained in EMEPwRef2C and ECgridded runs. The EC concentrations in the EMEPwRef2C run are in general higher compared to those from the ECgridded run, with the largest differences seen over Poland, Germany, Bulgaria, Ukraine, and also in the Po Valley, north-west of France and central parts of European Russia, largely corresponding to the areas where the largest differences in emissions can be found (see Figure 7.1). Only in a few regions, namely in Moldova, Bosnia-Herzegovina, parts of Croatia, and to a smaller extend in Spain, the ECgridded simulation gives higher fine EC concentrations. Moldova and Bosnia-Herzegovina did not report EC emissions to EMEP, thus the differences are caused by the gap-filling done by CEIP and the estimates in EMEPwRef2C. EC emissions from international shipping are different because

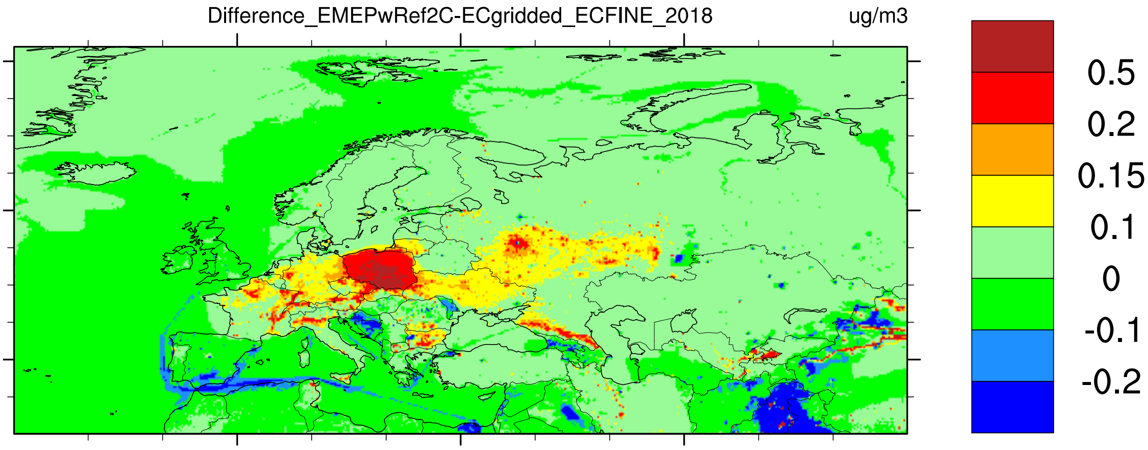


Figure 7.2: Difference between annual mean concentrations of fine EC from EMEPwRef2C and ECgridded model runs.

different fractions of the PPM emissions are assigned to EC in the ECgridded and EMEPwRef2C data sets.

7.3 Comparison with observations

7.3.1 EC in the EMEP monitoring network

Figure 7.3 shows maps of the annual mean concentrations of EC in $PM_{2.5}$ fraction from the EMEPwRef2C model run (upper map) and from simulations with the reported EC emissions (ECgridded, lower map). The observed concentrations of EC in $PM_{2.5}$ at EMEP stations are represented by coloured triangles. The corresponding scatterplots for modelled versus observed EC in $PM_{2.5}$ are presented in Figure 7.4.

Compared to the observations, annual mean EC in $PM_{2.5}$ is underestimated by 26% in the ECgridded run, whereas it is overestimated by 24% in the EMEPwRef2C run. The spatial correlation is 0.85 and 0.89 respectively. Among the countries with larger differences in the modelled EC, the correspondence of the EMEPwRef2C run with observations is considerably better at Polish and German sites. On the other hand, at French and Swiss sites and at Ispra in the Po Valley, EC is overestimated (or more overestimated) in the EMEPwRef2C run compared to the ECgridded run.

Since the most significant differences between the EMEPwRef2C and ECgridded data sets are in EC emissions from residential and commercial heating sector, the largest differences in model performance are not surprisingly found for the cold season, with biases of +33% and -31% respectively for the EMEPwRef2C and ECgridded, as compared to the summer months (+12% and -12%, respectively).

7.3.2 Aerosol Absorption coefficient

Surface in-situ measurements of aerosol light absorption coefficients facilitate additional evaluation of modelled elemental carbon. Black carbon (BC) is the most important light absorber, but also some oxidized organic aerosols ("brown carbon") and mineral dust contribute to the light absorption (Yang et al. 2009). The relationship between BC (i.e. light-absorbing carbon)

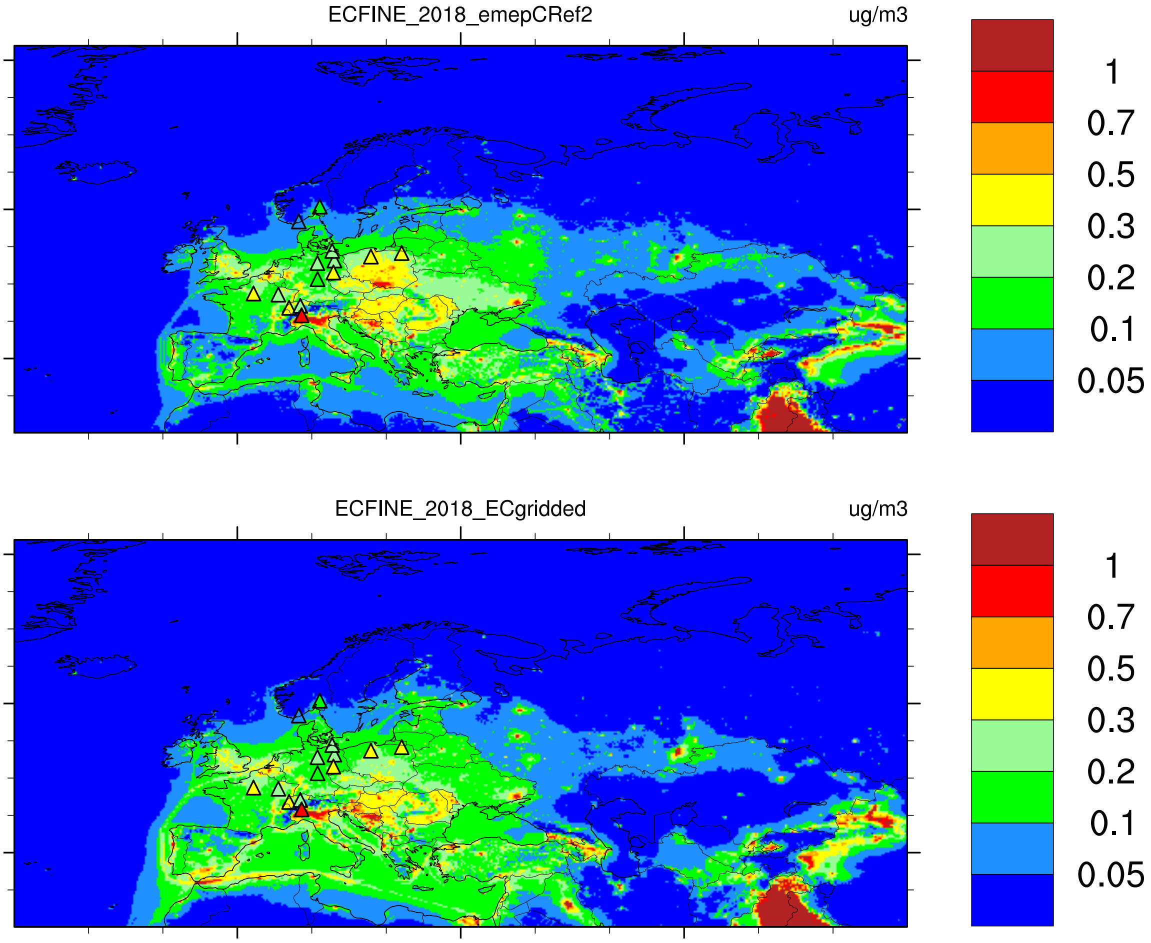
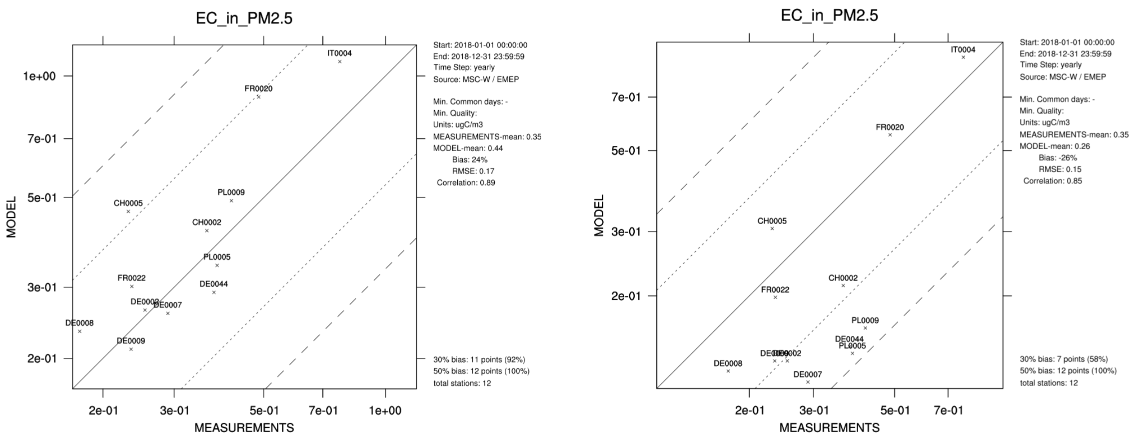


Figure 7.3: Annual mean concentrations of EC in $PM_{2.5}$ in 2018, calculated with the EMEP MSC-W model (colour contours) and observed at EMEP monitoring network (colour triangles) from EMEPwRef2C run (upper panel) and ECgridded run (lower panel).



(a) EMEPwRef2C

(b) ECgridded

Figure 7.4: Scatterplots for modelled vs observed EC in $PM_{2.5}$ from (a) EMEPwRef2C and (b) EC-gridded runs. EMEP sites, year 2018.

and EC (defined as substance containing only carbon) concentrations is not straightforward (Petzold et al. 2013, Genberg et al. 2013). For instance, in summer conditions in Vienna, the studies by Hitzenberger et al. (2006) found no significant differences between BC and EC derived from several methods for urban background aerosol predominantly from strong diesel traffic source. Whereas for winter conditions in Vienna, under significant contribution from biomass burning in residential heating, measured EC concentrations tended to be lower than BC due to considerable effect of brown carbon (Reisinger et al. 2008).

In the model, the absorption coefficient (AC) is calculated as the sum of absorption coefficients due to EC and mineral dust, using the mass absorption coefficients (MACs) of 8.5 m^2g^{-1} for freshly emitted EC, 11.5 m^2g^{-1} for aged EC, and 0.04 m^2g^{-1} for mineral dust (Bond et al. 2013, Utry et al. 2015 and Lack et al. 2009). The contribution to the AC from absorbing organic aerosols was not accounted for in these simulations.

We have used absorption coefficient observations accessed through the GAW-WDCA database EBAS (http://ebas.nilu.no/). For the in-situ absorption data used in this study, the measurements were performed at 530 or 673 nm wavelengths and converted to 550 nm assuming an absorption Angstrom exponent of 1 (Gliß et al. 2020). The comparison of the modelled AC with GAW-WDCA observational data can be found on a recently developed interactive web interface: `https://aerocom-evaluation.met.no/main.php?project=emep&par=ac550aer#` (info about web interface in Appendix E).

Figure 7.5 presents the overall results of evaluation of ACs from the EMEPwRef2C model run with observations in 2018 available from 21 sites: a map of the model bias at the sites (left panel) and a scatterplot (right panel). At most of the sites, the model underestimates AC, though some over-estimations are also seen, with the most pronounced cases found at French, Swiss and Austrian sites. On average, the model underestimates annual mean AC by 40% (can be found at "Overall Evaluation" tab on the aforementioned interface `https://aerocom-evaluation.met.no/main.php?project=emep&par=ac550aer#`), which can be partly explained by the model not accounting for contribution from absorbing organic aerosols. The correlation between the modelled and observed AC is however very good (R^2=0.92).

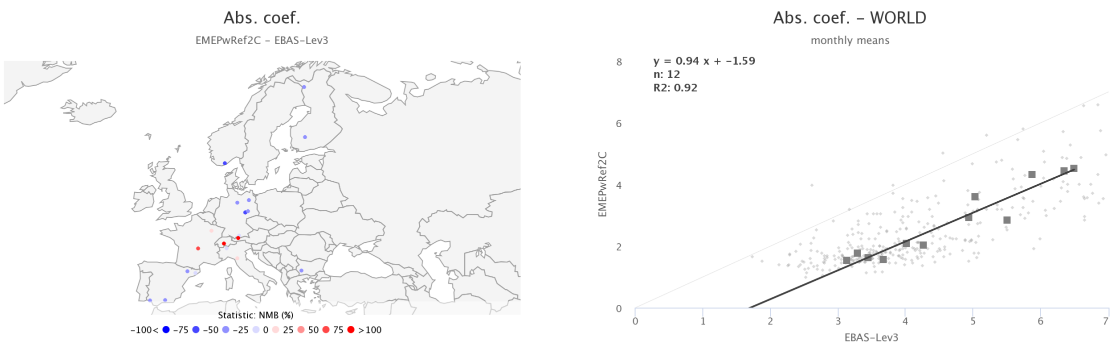
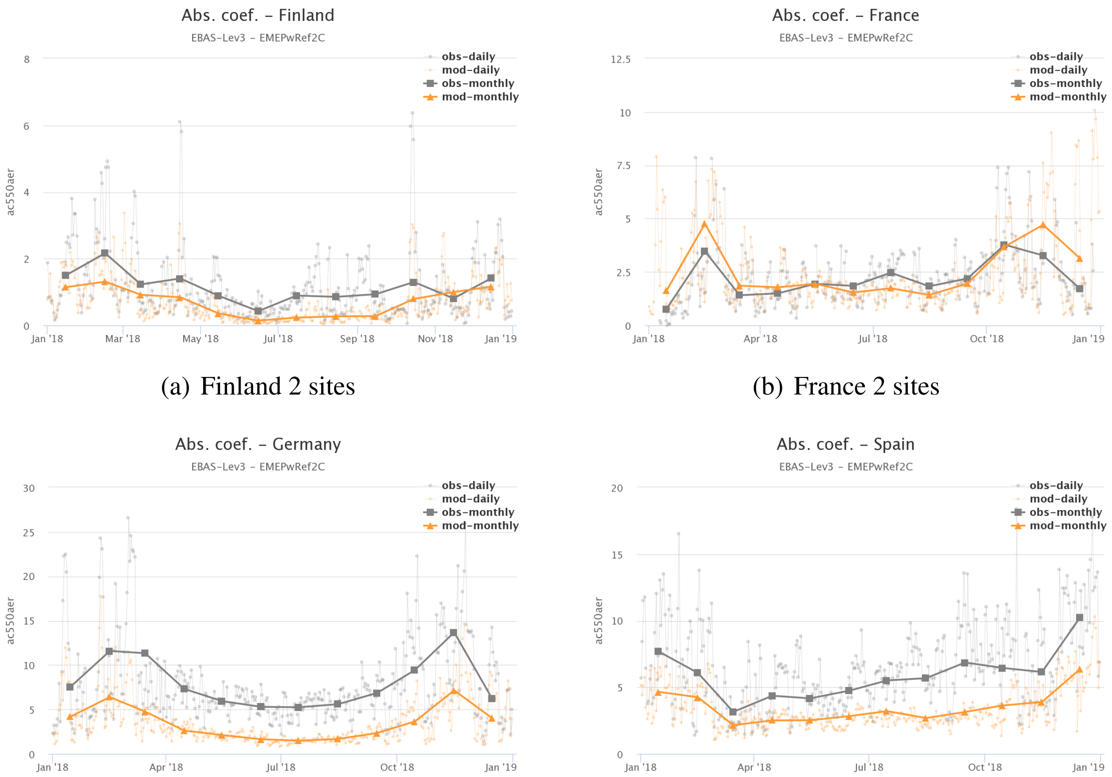


Figure 7.5: Evaluation of model calculated absorption coefficient (EMEPwRef2C run) with GAW/EBAS observations for 2018: model bias (left) and scatterplot (right). Units: Mm^{-1}

Several examples of model calculated and observed time-series of AC are presented in Figure 7.6. Shown here are the daily and monthly series at the sites in Finland, France, Germany and Spain. The modelled AC represents well the observed monthly variations. The calculated AC values are in a fairly good agreement with observations at French and Finnish



(a) Finland 2 sites

(b) France 2 sites

(c) Germany 6 sites

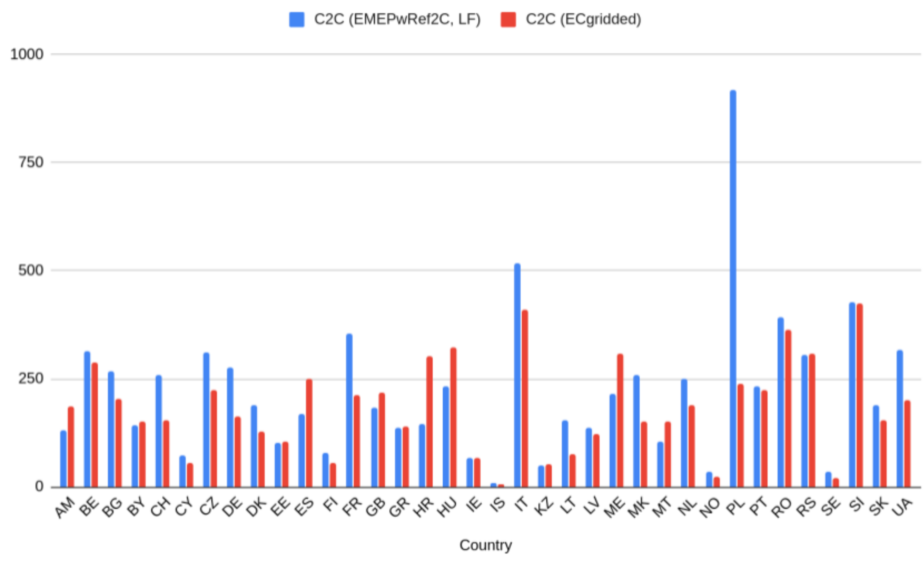
(d) Spain 4 sites

Figure 7.6: Timeseries of modelled (EMEPwRef2C run) and observed absorption coefficient in 2018 for Finland (a), France (b), Germany (c) and Spain (d). Units: Mm^{-1}

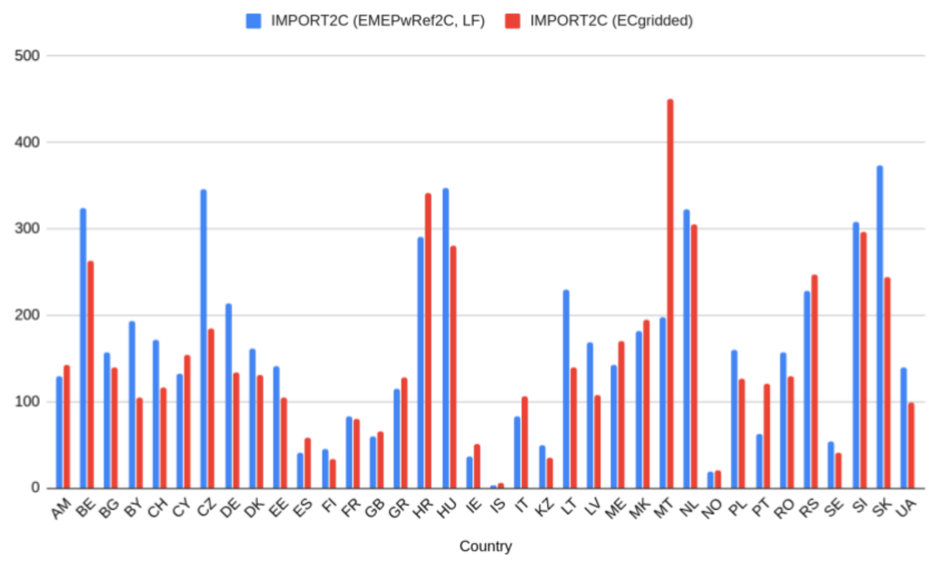
sites, showing somewhat larger underestimation at the German and Spanish ones. Given a rather crude approach to calculate the AC and uncertainties associated with EC vs BC concentrations, the evaluation of modelled absorption coefficients indicates a fairly good model representation of EC over Europe.

7.4 Source receptor calculations of EC

Indigenous (country to itself) contributions to EC concentrations for the individual European countries are presented in Figure 7.7 (a) for both the ECgridded and the EMEPwRef2C scenarios. As expected, the largest differences between those scenarios are found for countries where the differences between the two emission data sets are largest (e.g. France, Germany, Italy, Poland, Ukraine). Large differences are also seen for Switzerland and the Czech Republic, North Macedonia and Lithuania. For all those countries, calculated indigenous contributions are higher in the EMEPwRef2C run compared to ECgridded. Only a few exceptions can be seen: Spain, Hungary, Croatia and Montenegro, for which larger indigenous contributions were calculated using the ECgridded emissions. Out of the 36 countries, 22 have higher indigenous contributions based on EMEPwRef2C emissions, 7 are about the same as in the ECgridded run and 7 have lower country to itself contributions. The differences between the two scenario calculations are rather remarkable, with the indigenous contributions varying from around a factor two lower in EMEPwRef2C (Croatia) to almost a factor four higher



(a) Country to country SR



(b) Import SR

Figure 7.7: Country to country itself contribution (C2C) and import from all other countries (IMPORT2C) for $EC_{2.5}$ using ECgridded and EMEPwRef2C emissions, respectively. The local fraction methodology has been used for both calculations. Units: ngm^{-3}.

(Poland).

Figure 7.7 (b) presents the imported part of the annual mean EC concentrations (the domestic EC minus indigenous contribution) for the individual European countries, calculated with the two emission data sets (ECgridded and EMEPwRef2C). Also for EC import, large differences are seen. The largest difference is calculated for the Czech Republic, where the import of EC is doubled in the EMEPwRef2C scenario compared to the ECgridded scenario. On the other hand, for Spain, Greece, Croatia, Ireland, Italy, Montenegro, North Macedonia,

Portugal and Russia, the modelled import of EC is lower in the EMEPwRef2C than in the ECgridded scenario. Out of 36 countries, 21 have higher EC import in the EMEPwRef2C scenario, one has about the same as in the ECgridded scenario and 14 have lower import.

7.5 Conclusions

It is well known that current reporting of EC/BC to CLRTAP suffer from a number of critical deficiencies, and that the uncertainties in estimated EC emissions are large. Here we have presented model calculations for 2018 using both the reported EMEP EC emissions (ECgridded) and an emission inventory which is partly derived from a TNO bottom-up estimate (EMEPwRef2C).

The EMEP MSC-W model results were compared with EMEP observations of EC. Annual mean EC in $PM_{2.5}$ is underestimated by 26% in the ECgridded run, whereas it is overestimated by 24% in the EMEPwRef2C run (with corresponding biases for the winter of -31% and +33%). Among the countries with larger differences in the modelled EC (and emissions), the correspondence of the EMEPwRef2C run with observations is considerably better at Polish and German sites. On the other hand, at French and Swiss sites and at Ispra in the Po Valley, EC is overestimated (or more overestimated) in the EMEPwRef2C run compared to the ECgridded run. Furthermore, EC absorption from the EMEPwRef2C model run were compared with absorption coefficient observations (21 sites) accessed through the GAW-WDCA database EBAS (`http://ebas.nilu.no/`), and show fairly good agreement with R^2=0.92 and underestimations of 40% (partly due to unaccounted contributions from other aerosols to the absorption). From the model evaluation presented here it is not possible to judge which of the emission data sets that are most 'correct', however, the results are very different.

Source receptor calculations have been performed for both emission scenarios. We demonstrate that the differences in the emission estimates of EC lead to up to a factor of 2-4 differences in indigenous and import contributions to EC concentrations.

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CHAPTER 8

Downscaling of PM and NO_2 in Europe using uEMEP

Bruce Rolstad Denby, Qing Mu, Hilde Fagerli, Eivind Grøtting Wærsted

8.1 Introduction and background

Over the past four years the EMEP Meteorological Synthesizing Centre - West (EMEP MSC-W) at the Norwegian Meteorological Institute has been developing and implementing a downscaling methodology to enhance the capabilities of the EMEP MSC-W chemical transport model (Simpson et al. 2012). This downscaling model is known as uEMEP (urban EMEP) and can achieve high-resolution air quality modelling down to 100 m for entire countries. Even though the methodology is referred to as 'downscaling', uEMEP is actually an independent Gaussian plume modelling system which is added as post-processing to the EMEP MSC-W model. This makes the modelling similar to other local-scale air quality models and allows for a good physical representation of air quality concentrations.

uEMEP was first reported in the 2016 EMEP status report (Denby and Wind 2016). Since then uEMEP has been further developed and operationally implemented in the Norwegian Air Quality Forecasting System (***luftkvalitet.miljostatus.no***) as well as providing air quality data, maps and information to Norwegian municipalities through the Air Quality Expert Service (***miljodirektoratet.no/luftkvalitet-fagbruker***).

The uEMEP/EMEP modelling system is now established in Norway where access to good quality emission related data is available. However, the longer term aim of this model development is to extend uEMEP to the European level and additionally to other regions of the globe. Unfortunately the same quality of high resolution emission data that is available in Norway is not directly available for all of Europe. Many countries have suitable high resolution data but these are not readily accessible for use. In order to implement uEMEP for all of Europe then proxy data that can be used to redistribute emissions to fine scales are required. Three datasets are available for all of Europe, also globally, and have been used to enable the high-resolution modelling in Europe. These are:

- Open Street Maps (OSM) for redistributing road traffic emissions

- Population data from Global Human Settlement (GHS) gridded to 0.0025 degrees for redistributing residential heating emissions
- Automatic Identification System (AIS) data for shipping emissions gridded to 0.0025 degrees

This allows downscaling of the traffic, residential heating and shipping emission sources. All other sources are not included in the downscaling.

Results of the European modelling for NO_2, $PM_{2.5}$ and PM_{10} are presented as example maps in Section 8.3, validation against Airbase stations in Section 8.4 and results of a number of sensitivity studies are also reported in Section 8.5.

8.2 Methodology

Downscaling with uEMEP applies the following methodology:

- Calculations are made using EMEP for all of Europe in a similar way to the official EMEP calculations but with the additional output of the EMEP local fractions (EMEP Status Report 1/2017 2017, Wind et al. 2020)
- uEMEP is implemented as a post-processing routine to the annual mean output from EMEP. EMEP emission grids per sector and per compound are redistributed onto high resolution sub-grids using the emission proxies
- uEMEP then calculates the local dispersion from these sub-grid emissions using a dispersion kernel within a region defined by 2 x 2 EMEP grids
- uEMEP removes the local fraction contribution from the EMEP grid results and replaces these with the uEMEP sub-grid results
- Resolution of the sub-grids varies according to application and range from 250 m, the lowest resolution, to 25 m, used for calculating concentrations at monitoring sites

8.2.1 EMEP model implementation

Setup and inputs of the EMEP model follow those in Section 2.3 but with the additional output of the EMEP 'local fraction' used as part of the downscaling to remove double counting of emissions. Calculations have been made for both 2017 and 2018 using both the EMEP and EMEPwRef2C emission inventories, see Table 6.1 in Chapter 6. For the Norwegian sensitivity study presented in Section 8.5.3, alternative local Norwegian emissions for the traffic and residential heating sectors replace those in the European inventory.

8.2.2 uEMEP model implementation

The uEMEP model is described in a recent publication under review (Denby et al. 2020). In that article the Norwegian forecast application of uEMEP is described where hourly downscaling using bottom-up emission inventories is carried out. For the European application calculations are made on annual mean data creating air quality maps for Europe down to 100 m resolution and calculating concentrations at Airbase stations positions down to 25 m.

Downscaling is carried out in the following way. EMEP grid emissions per sector and per source are redistributed to uEMEP sub-grids using the proxy emission data described in Section 8.2.3. These emission sub-grids are dispersed using a rotationally symmetric Gaussian dispersion kernel (Denby et al. 2020), given an initial plume size and height. These parameters are provided in Table 8.1. The initial horizontal plume size is determined by the size of the sub-grid. The Gaussian dispersion parameters used are based on the K_z dispersion methodology described in Denby et al. (2020) but adapted to the rotationally symmetric dispersion kernel. The local fraction contribution from the EMEP model is removed and replaced with the sub-grid dispersion calculation from uEMEP, thus avoiding double counting of emissions.

Table 8.1: Initial dispersion (σ_{z0}) and emission height (h_{emis}) for the three downscaled sources

Source	Initial dispersion (σ_{z0})	emission height (h_{emis})
Traffic (GNFR6)	2 m	1 m
Residential heating (GNFR3)	10 m	15 m
Shipping (GNFR7)	15 m	70 m

Downscaling with uEMEP occurs only for primary emissions within a specified 'local' area surrounding each uEMEP sub-grid. This is referred to as the uEMEP 'moving window'. For these simulations this area corresponds to two EMEP grids, i.e. within an area that is ± 0.1^o in both latitude and longitude. NO_2 is calculated from NO_X using an empirical relationship based on European monitoring data (Denby et al. 2020).

To improve efficiency of the calculations, Europe is split into a number of tiles that cover the European land domain. For 250 m mapping calculations and 25 m station calculations there are 199 tiles, all 250 x 250 km^2. For the 100 m mapping calculations there are 1097 tiles, each of which is 100 x 100 km^2. These tiling regions are shown in Figure 8.1.

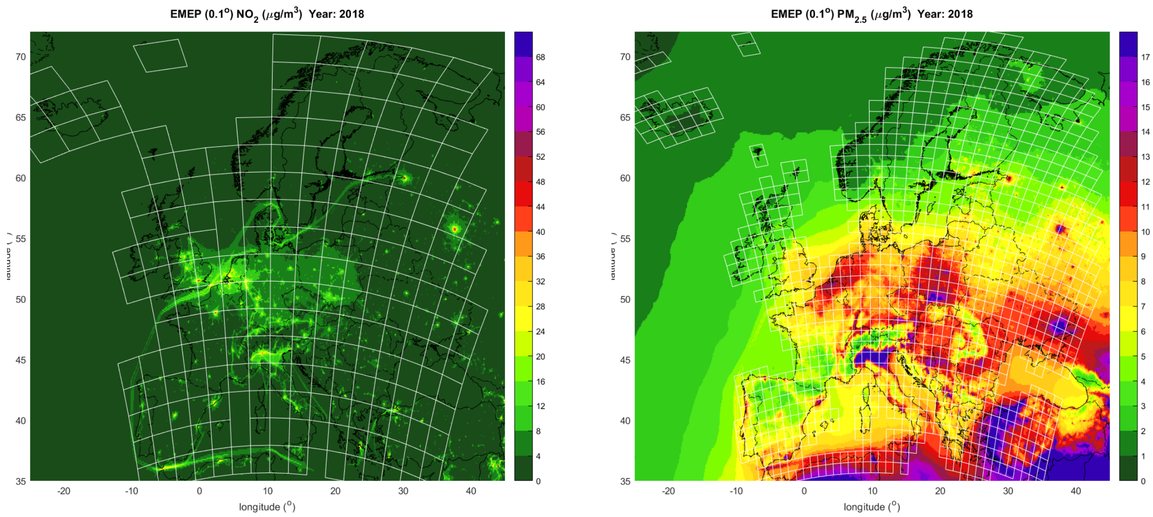

Figure 8.1: Annual mean NO_2 concentrations (left) and $PM_{2.5}$ concentrations (right) calculated with EMEP at 0.1^o for 2018. Also shown are the uEMEP tiling regions. 250 km tiles with 250 m resolution (left) and 100 km tiles with 100 m resolution (right).

8.2.3 uEMEP proxy data

We use road data from OSM (OpenStreetMap contributors 2020) to redistribute the traffic emissions. Though the spatial coverage of OSM is very good, it does not contain actual traffic data. Redistribution of the emission data is achieved by weighting the different road categories provided in OSM. The following road categories are considered: motorway, trunk, primary, secondary, tertiary, unclassified, residential. Each is weighted relative to the other so that emissions can be redistributed and attributed to the road links. Estimates of the weights are based on the representative average daily traffic (ADT) and heavy-duty vehicle (HDV) for different road categories for Norwegian average road situations. The weighting currently employed for the redistribution is shown in Figure 8.2. It is also worth noting that for major roads, such as motorways, OSM often represents these as dual carriageways, i.e. as two separate road links. In these cases the weighting of a motorway will be twice that indicated here. Sensitivity tests with alternative weighting, not discussed in this report, show the choice of weighting, within reasonable limits, does not have a strong impact on the results and that the current choice provides close to optimal statistical results.

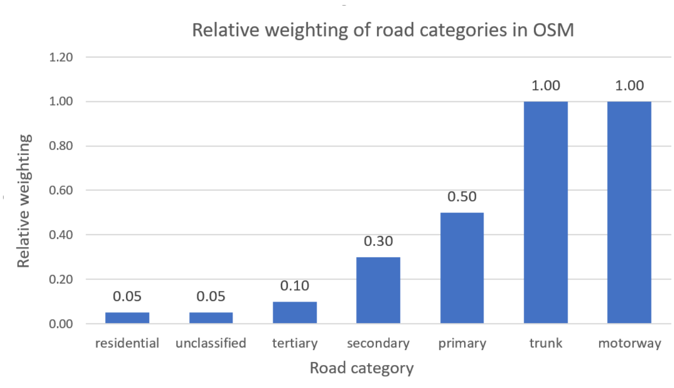

Figure 8.2: Weighting of the Open Street Map road categories used to redistribute EMEP emissions for downscaling.

A global population dataset from the Global Human Settlement (Schiavina et al. 2019) is used as the proxy for redistributing residential heating emissions. We choose the highest available resolution of 9 arcsec (0.0025^o) from the year 2015. The coordinate system is WGS84. This dataset indicates the distribution of population as the number of people per cell.

Automatic Identification System (AIS) data for shipping emissions are provided by the Norwegian Coastal Administration (Kystverket 2020). The raw data, which contains a list of instantaneous point emissions, is averaged over the year 2017 and gridded to 0.0025^o. Though these data are actual emissions we still use them as proxy data to redistribute EMEP gridded emissions, to be consistent in the methodology.

8.3 Example maps

A variety of calculations have been made for mapping and validation and a range of sensitivity studies have been carried out. In this section we present example maps.

EMEP 0.1^o calculations are made on a latitude-longitude grid with a grid spacing of 0.1^o. The uEMEP calculations are made on an x-y projected map commonly used for European

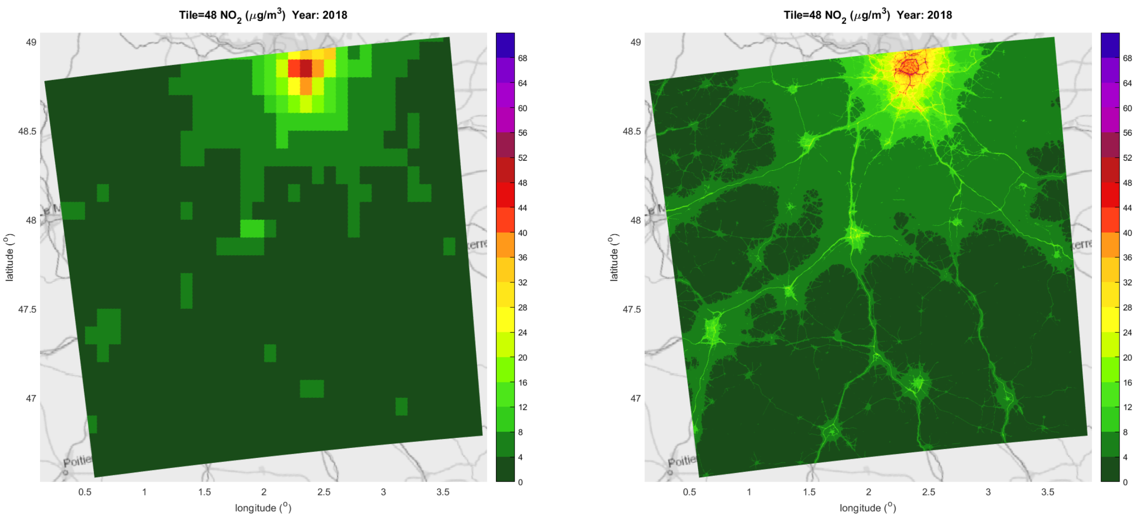

Figure 8.3: Calculated NO_2 concentrations in the 250 km tile (nr. 48) for 2018, part of the all European calculation at 250 m resolution. Left the EMEP calculation at 0.1^o and right the uEMEP calculation at 250 m resolution. The city in the North of this tile is Paris.

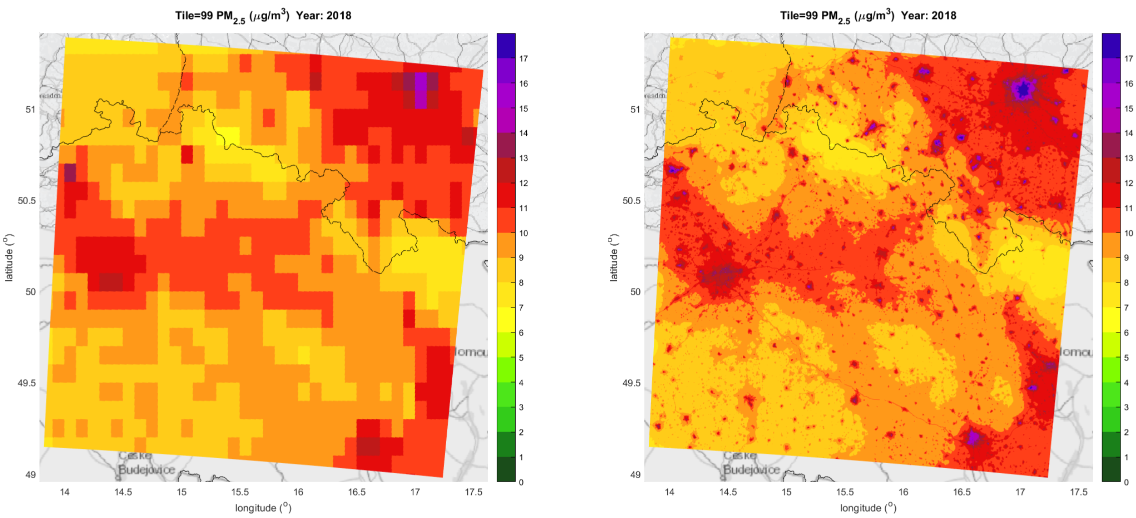

Figure 8.4: Calculated $PM_{2.5}$ concentrations in the 250 km tile (nr. 99) for 2018, part of the all European calculation at 250 m resolution. Left the EMEP calculation at 0.1^o and right the uEMEP calculation at 250 m resolution. This tile covers mostly the Czech Republic and the Southern part of Poland.

mapping. The projection used is the European ETRS89-LAEA projection (EPSG: 3035). Maps presented in this Section are shown on latitude and longitude which means that the projected uEMEP tiled maps do not necessarily follow the North-South direction. In Figure 8.1 the annual mean NO_2 and $PM_{2.5}$ calculation using the EMEP model on a lat-lon grid are shown. Not all of the EMEP domain is provided, only the region where uEMEP is applied. The colour scales used in Figure 8.1 are the same for all maps shown.

Four example tiles are shown in Figures 8.3 to 8.6, showing the original EMEP model

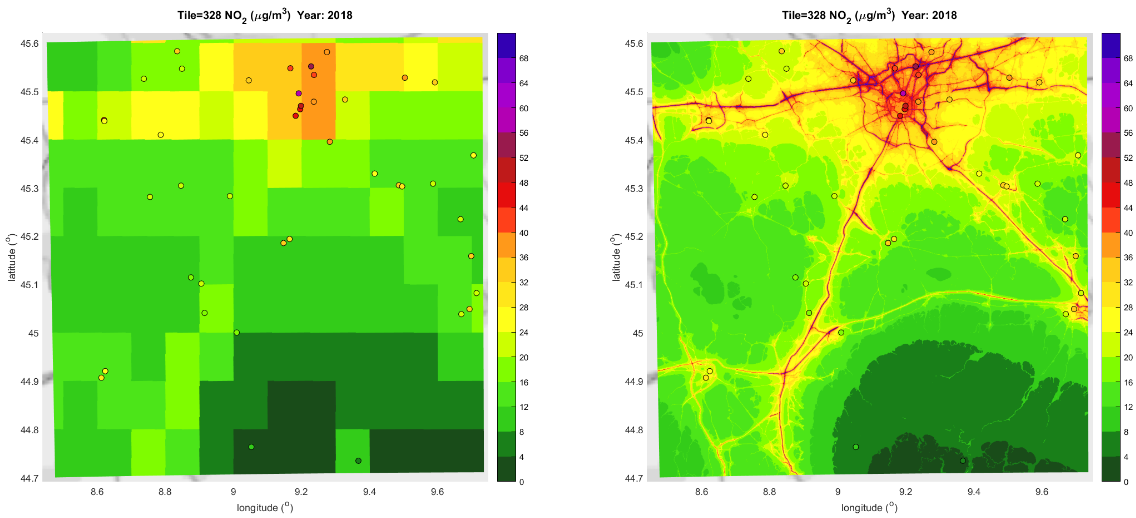

Figure 8.5: Calculated NO_2 concentrations in the 100 km tile (nr. 328) for 2018, part of the all European calculation at 100 m resolution. Left the EMEP calculation at 0.1^o and right the uEMEP calculation at 100 m resolution. The city in this tile is Milan. Airbase stations are shown as circles.

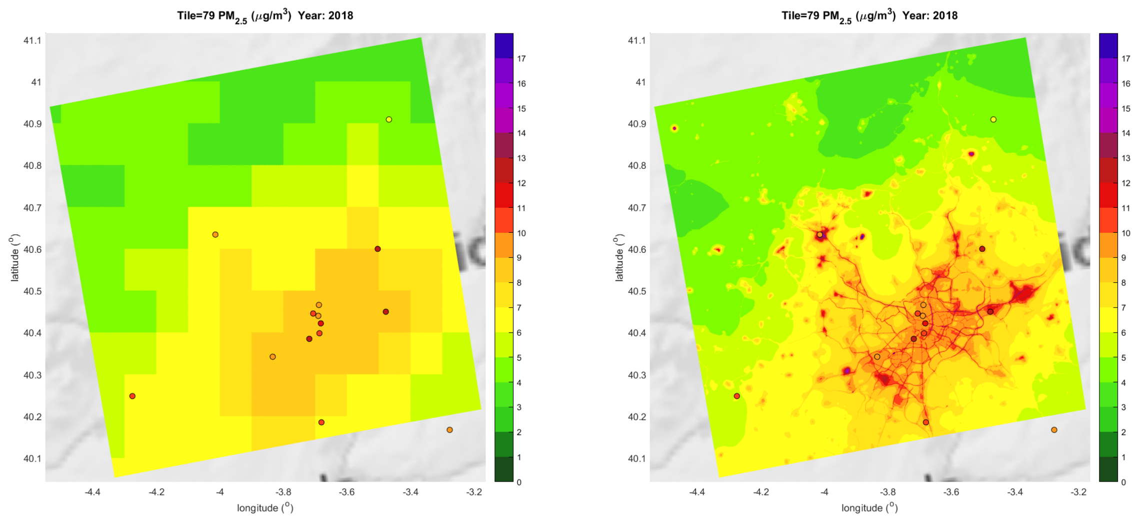

Figure 8.6: Calculated $PM_{2.5}$ concentrations in the 100 km tile (nr. 79) for 2018, part of the all European calculation at 100 m resolution. Left the EMEP calculation at 0.1^o and right the uEMEP calculation at 100 m resolution. The city in this tile is Madrid. Airbase stations are shown as circles.

calculations and the downscaled maps using uEMEP for NO_2 and $PM_{2.5}$. Both 250 km and 100 km tiles are given. In the 100 km example tiles, Figures 8.5 and 8.6, the Airbase stations are also included for comparison.

8.4 Validation

Observed annual mean concentrations of NO_2, $PM_{2.5}$ and PM_{10} from Airbase are used for comparison with both EMEP and uEMEP calculations. All valid Airbase stations are used in the validation, including traffic sites. Results for the 2018 calculations are shown but, where relevant, 2017 results will also be addressed. Results focus on the spatial correlation (r^2) and on the relative bias (Bias) with the use of uEMEP. For station sites the downscaling with uEMEP is performed on 25 m sub-grids, which is of sufficient resolution to spatially represent traffic sites. However, since the Gaussian model used does not take into account buildings or obstacles then traffic sites in street canyons or built up areas may be poorly represented.

8.4.1 NO_2

In Figures 8.14 and 8.15 scatter plots are shown for each country and Europe as a whole. These results are summarised in Figure 8.7 where the annual mean concentration and spatial correlation are shown.

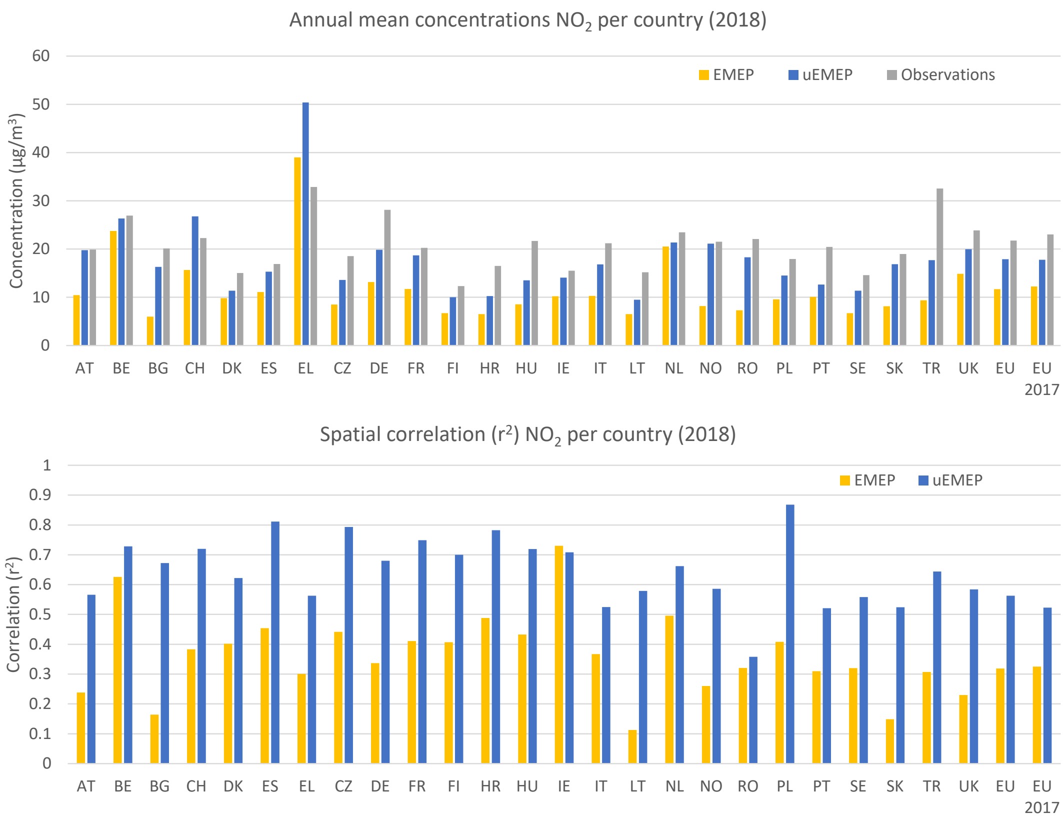

Figure 8.7: Annual mean NO_2 concentrations and spatial correlation (r^2) per country for 2018 calculated with EMEP and uEMEP compared to Airbase observations. Only countries with more than 10 stations are shown but all stations are included in the final EU result. For comparison the European calculation for 2017 is also shown. 3313 stations are included in the comparison.

In a majority of countries the spatial correlation for NO_2 is more than doubled when implementing uEMEP. The one exception is Ireland (IE) where the spatial correlation hardly

changes with the downscaling. The highest spatial correlation is for Poland (PL) with a remarkable $r^2 = 0.87$ and the poorest spatial correlation for Romania (RO) $r^2 = 0.36$.

The results for 2017 are quite similar to those presented here for 2018 but the overall spatial correlation for Europe was slightly less with $r^2 = 0.52$ for 2017 compared with $r^2 = 0.56$ for 2018. It is worth noting that the average spatial correlation per country is $r^2 = 0.65$ which is significantly higher than the spatial correlation when assessed for all stations in Europe ($r^2 = 0.56$). This indicates that a significant part of the variability occurs between countries and can be interpreted to reflect differences related to emission reporting from each country. If the NO_X emissions from individual countries have uncorrelated bias then this will reduce the overall spatial correlation.

The relative bias for EMEP is negative for all countries except Greece (EL) which has a positive bias of +18%. Only two countries have a negative bias higher than -20%, Belgium (BE) and The Netherlands (NL). On a European scale bias is improved from -46% for EMEP to -17% when using uEMEP. After downscaling only two countries, Romania (RO) and Switzerland (CH) have a positive bias. Of the 25 countries with more than 10 monitoring sites, 17 of these have an absolute bias less than 25% after downscaling. Turkey (TR) has the largest negative bias, after downscaling, of -45%.

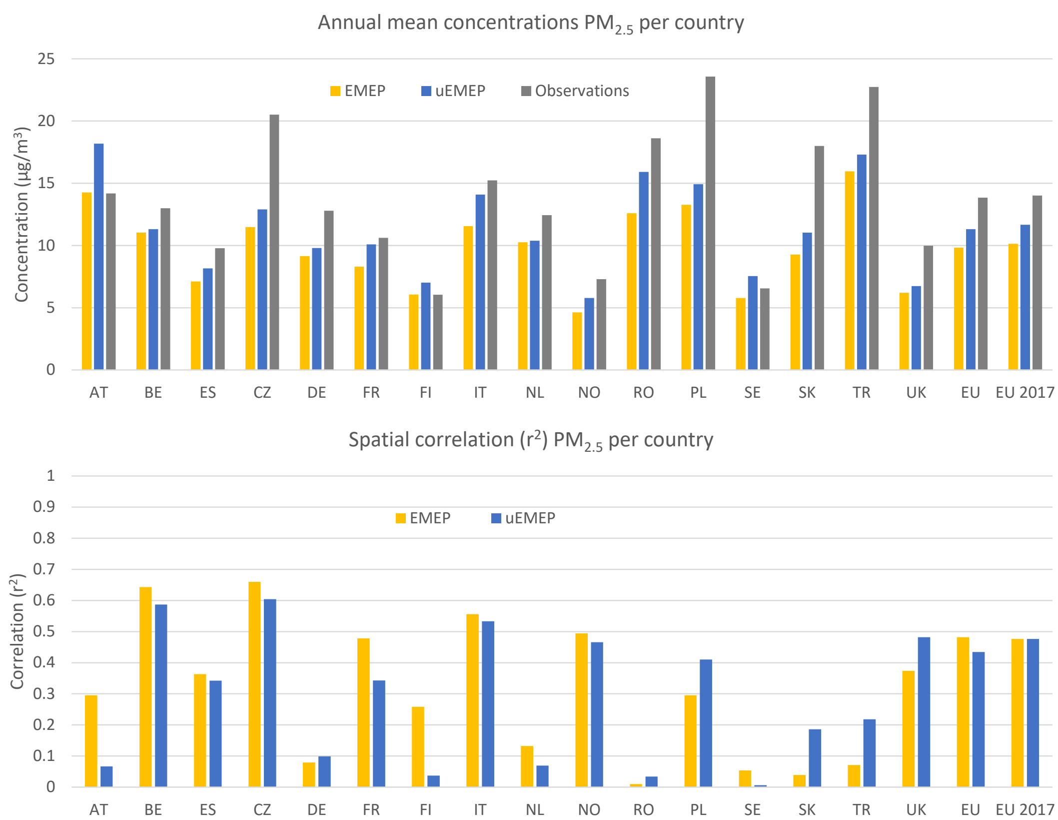

Figure 8.8: Annual mean $PM_{2.5}$ concentrations and spatial correlation (r^2) per country for 2018 calculated with EMEP and uEMEP compared to Airbase observations. Only countries with more than 10 stations are shown but all stations are included in the final EU result. For comparison the European calculation for 2017 is also shown. 1377 stations are included in the comparison.

8.4.2 $PM_{2.5}$

In Figures 8.16 and 8.17 scatter plots are shown for each country and Europe as a whole. These results are summarised in Figure 8.8 where the annual mean concentration and spatial correlation are presented.

Unlike the NO_2 downscaling there is generally no improvement in the spatial correlation when applying uEMEP for $PM_{2.5}$. Only 6 out of 16 countries show improved spatial correlation and overall for Europe there is a slight decrease, from $r^2 = 0.48$ for EMEP to 0.43 for uEMEP. For 2017 the uEMEP and EMEP calculations had the same spatial correlation, $r^2 = 0.48$. This result seems to indicate that population, at high resolution, is not a good proxy for residential heating emissions. This is further discussed in Section 8.6.

The relative bias is however improved for almost all countries. For Europe as a whole the relative bias increased from -28% for EMEP to -17% for uEMEP. Only the three countries Austria (AT), Sweden (SE) and Finland (FI), that had almost no bias with the EMEP calculation, achieved a positive bias with uEMEP.

8.4.3 PM_{10}

In Figures 8.18 and 8.19 scatter plots are shown for each country and Europe as a whole, summarised in Figure 8.9 since the scatter plots are similar to those for $PM_{2.5}$.

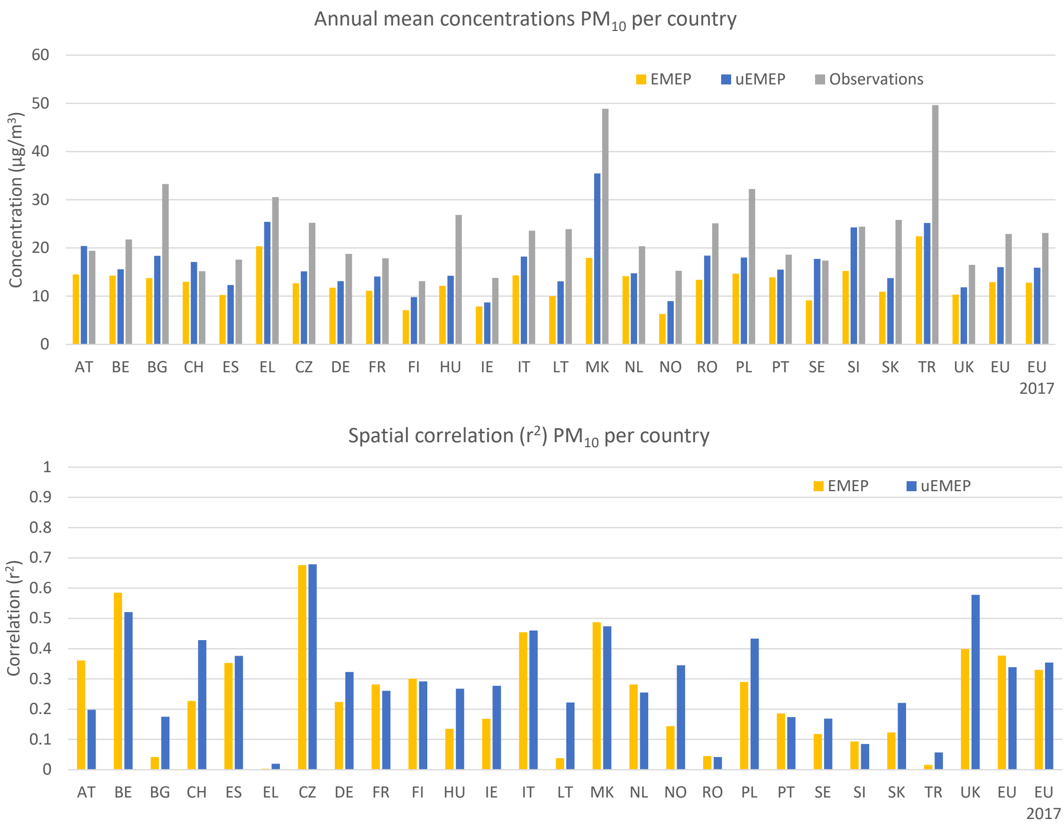

Figure 8.9: Annual mean PM_{10} concentrations and spatial correlation (r^2) per country for 2018 calculated with EMEP and uEMEP compared to Airbase observations. Only countries with more than 10 stations are shown but all stations are included in the final EU result. For comparison the European calculation for 2017 is also shown. 2891 stations are included in the comparison.

The results for PM_{10} are similar to those for $PM_{2.5}$. In this case though the majority of countries, 16 out of 26, have improved spatial correlation with the application of uEMEP. As with $PM_{2.5}$, the spatial correlation for all of Europe using uEMEP is slightly less than the EMEP calculation, 0.34 compared to 0.38 respectively. This is lower than the spatial correlation found for $PM_{2.5}$ by around 0.1.

As with $PM_{2.5}$ the relative bias is improved with the uEMEP downscaling. For Europe we see a decrease in relative bias from -43% for EMEP to -30% for uEMEP.

8.5 Sensitivity studies

In this Section we summarise the results of a number of sensitivity calculations using uEMEP. These include sensitivity to sub-grid resolution, to alternative residential heating emissions and sensitivity to alternative bottom up emissions in Norway.

8.5.1 Sensitivity to resolution

When calculating at station positions a grid resolution of 25 m is used. However, when mapping all of Europe lower resolutions of 100 and 250 m are employed. In Figure 8.10 we show the results of a change in resolution on the annual mean NO_2 calculations where the model calculations from 2017 have been used.

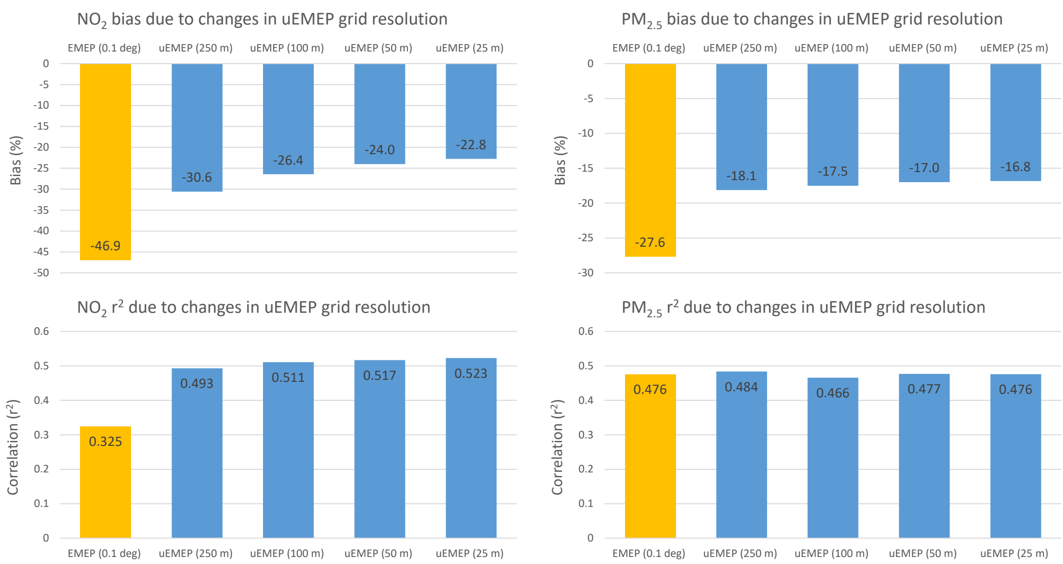

Figure 8.10: Change in bias (top) and correlation (bottom) as a result of changes in uEMEP resolution for the European calculations. Shown are the results for NO_2 (left) and $PM_{2.5}$ (right). Also included is the EMEP 0.1^o calculation in yellow. Calculation year is 2017.

For NO_2 both bias and correlation improve with increasing resolution. 100 m calculations are on average 3.6 % lower than the 25 m calculations. For $PM_{2.5}$ there is little change in bias between the different resolutions. Both shipping and residential combustion sources are only provided at 250 m so any further change in model results at lower resolutions will be due to the traffic contribution only. Spatial correlation is basically unchanged for all resolutions.

8.5.2 Comparison with residential heating emissions from the EMEP countries

The calculations presented in Section 8.4.2 include the $PM_{2.5}$ residential combustion emissions with condensables provided by TNO (EMEP-wRef2C emissions), see Chapter 5. EMEP and uEMEP were also applied to calculate $PM_{2.5}$ using the original EMEP emissions for residential combustion provided by the countries (EMEP emissions). A comparison of these two emission datasets is already provided in Chapter 6 for the EMEP model alone. Summary results for the uEMEP calculations is presented in Figure 8.11.

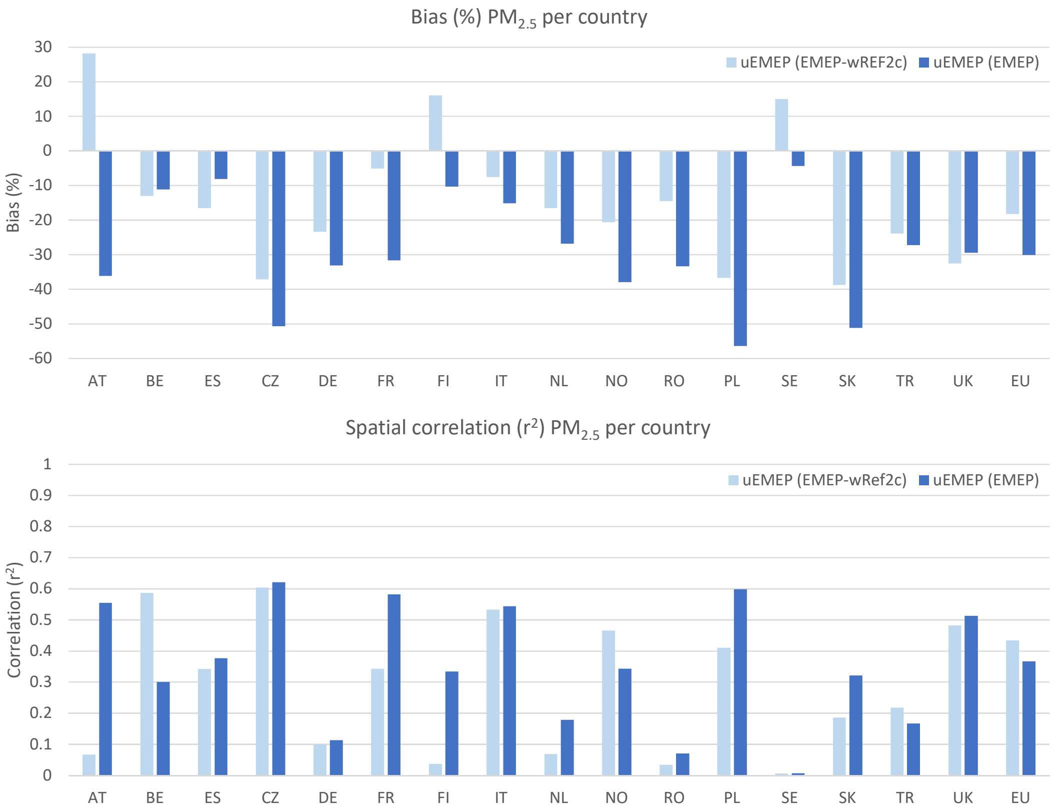

Figure 8.11: Annual mean $PM_{2.5}$ relative bias and spatial correlation (r^2) per country for 2018 calculated with uEMEP/EMEP using the two different residential emission data sets from TNO (EMEP-wRef2C) and from the countries (EMEP). Only countries with more than 10 stations are shown but all stations are included in the final EU result. 1377 stations are included in the comparison.

For many countries there is a significant difference in the results. The bias is generally less negative for the TNO emissions (-18%) compared to the EMEP emissions (-30%). This reflects the higher emissions in some countries due to the inclusion of the condensables. However, the spatial correlation per country is better for 12 out of the 16 countries shown when using the EMEP emissions. Despite this the spatial correlation for the whole of Europe is less when using the EMEP emissions. This likely reflects the variability in emissions per country, as in the NO_X emissions discussed previously. Whilst the EMEP emissions are provided independently by each country, the TNO emissions are made more consistently for the whole of Europe.

In Section 8.4.2 it was also reported that for all of Europe the uEMEP downscaling of the

EMEP-wRef2C emissions gave poorer spatial correlation for $PM_{2.5}$ than the EMEP model calculation. However, if we look at the average spatial correlation for individual countries then the best result is actually provided by the downscaling of the EMEP country emissions. The results for the average spatial correlation per country are summarised, along with the correlation when using all stations in Europe, in Table 8.2. These results will require further evaluation.

Table 8.2: Spatial correlation (r^2) for $PM_{2.5}$ using the two EMEP emission datasets (EMEP and EMEP-wRef2C) for 2018. Shown are just EMEP results and results when using the uEMEP downscaling results. Included is the average spatial correlation for individual countries and the correlation when all stations are taken individually in Europe.

Correlation (r^2) 2018	EMEP emissions	EMEP-wRef2C emissions
EMEP country average	0.32	0.30
uEMEP country average	0.35	0.28
EMEP all stations Europe	0.37	0.48
uEMEP all stations Europe	0.37	0.43

8.5.3 Results of improved emission data in Norway

Throughout the uEMEP downscaling simulations use has been made of the 0.1^o country reported emission data and redistributed using population, Open Street Map data and AIS shipping data for use as redistribution proxies for these emissions, Section 8.2.3. Many countries have more detailed emission datasets, including Norway, that could be used to improve the downscaling calculations. To test the impact of more realistic spatial distributions of emissions then emission and emission proxy data used in Norway are replaced in the EMEP and uEMEP calculations with the emission data currently used in the national air quality forecasting in Norway (EMEP-NO). Details surrounding these emissions can be found in Denby et al. (2020) and Grythe et al. (2019). The most important differences between the Norwegian and European emission and emission proxy data are:

- Traffic volume data from the Norwegian national road database is used instead of OSM weighting. Exhaust emissions are based on emission factors using a bottom up methodology
- The non-exhaust road dust emissions are calculated with the NORTRIP model (Denby et al. 2013b,a) which are a factor of 4 times larger than the current national estimates reported for Norway
- The total Norwegian residential heating emissions of PM are the same for both the Norwegian and the European emissions but the Norwegian emissions have been redistributed using the MetVed model (Grythe et al. 2019) using much more detailed information than just population to distribute the residential heating emissions at 250 m

Four separate calculations are made for Norway using the two EMEP emission data sets, EMEP-wRef2C and EMEP-NO, and the two high resolution proxy data sets, as used in Europe and as used in the Norwegian forecast system. Shipping is not changed in these simulations.

The results are shown in Figure 8.12 for NO_2 and Figure 8.13 for PM_{10} where the relative bias (%) and correlation (r^2) are shown.

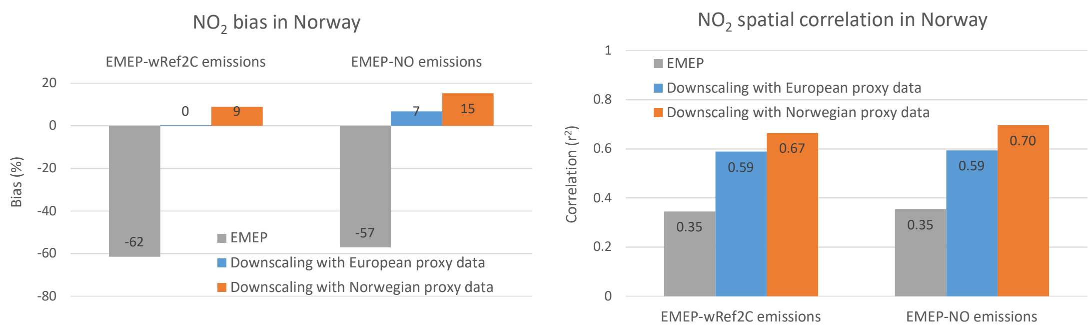

Figure 8.12: Change in bias and correlation as a result of changes in Norwegian emission and emission proxy data for the Norwegian NO_2 calculations. 'EMEP-wRef2C emissions' are the EMEP emissions used for all of Europe and 'EMEP-NO emissions' replaces these emissions for traffic and residential heating with alternative emissions used in the Norwegian air quality forecasting system. 'European' and 'Norwegian' proxy data is explained in the text. Calculation year is 2017.

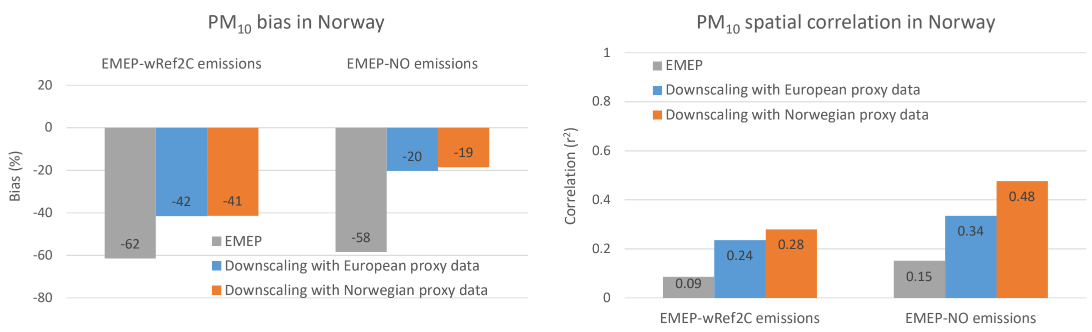

Figure 8.13: Change in bias and correlation as a result of changes in Norwegian emission and emission proxy data for the Norwegian PM_{10} calculations. 'EMEP-wRef2C emissions' are the EMEP emissions used for all of Europe and 'EMEP-NO emissions' replaces these emissions for traffic and residential heating with alternative emissions used in the Norwegian air quality forecasting system. 'European' and 'Norwegian' proxy data is explained in the text. Calculation year is 2017.

For NO_2 in Norway the large negative bias seen in EMEP is completely removed by the use of the traffic downscaling, using either the Norwegian or EMEP emission data. On a national level the local Norwegian (bottom up) traffic NO_X emissions are roughly 25% higher than the EMEP (top down) emissions. NO_2 concentrations are slightly overestimated when using the Norwegian proxy data for traffic. Spatial correlation is improved with the use of the Norwegian proxy data for traffic, compared to OSM data, from r^2 = 0.59 to 0.70. It is worth noting that in the complete Norwegian calculation reported in Denby et al. (2020) using hourly calculations and alternative NO_2 chemistry parameterisations that the spatial correlation is even higher at $r^2 = 0.78$.

For PM_{10} both bias and correlation are significantly improved with the implementation of the local emissions and proxies. This is to a large extent due to the improvement in the

road dust emission contribution but also due to an improvement in the residential heating distribution. For $PM_{2.5}$, not shown here, the correlation increases from r^2 = 0.49 to 0.55 when changing the residential heating proxy from population to the MetVed model.

These results indicate that some significant improvements can still be obtained in the downscaling if improved emissions and emission proxies are implemented. However, for traffic NO_X emissions in Norway, and in many other countries, the use of OSM proxy data already gives significant improvement and only limited improvements can be expected with the use of actual traffic volume data as a proxy.

8.6 Discussion

Downscaling only applies to emissions within a limited region surrounding each receptor subgrid, ± 0.1^o. Based on the uEMEP calculation, the local contributions to NO_X are significantly larger than for PM. The different source contributions at measurement sites are given in Table 8.3 and this shows that, on average in Europe, 58% of the NO_X contributions come from traffic within this limited region. In contrast only 19% of the $PM_{2.5}$ is attributable to residential heating, the largest downscaled contribution, from inside this region.

Table 8.3: Source contribution to all air quality stations in Europe calculated with uEMEP. uEMEP local contributions are from emissions within an region of ± 0.1^o in both latitude and longitude. Non-local EMEP contributions are all emissions from outside this region for the downscaled sources as well as other sources within this region that are not downscaled.

Source	NO_X ($\mu g/m^3$)	$PM_{2.5}$ ($\mu g/m^3$)	PM_{10} ($\mu g/m^3$)
Traffic (GNFR6)	13.9 (58%)	0.71 (6%)	1.1 (7%)
Residential heating (GNFR3)	1.8 (8%)	2.2 (19%)	2.6 (16%)
Shipping (GNFR7)	0.30 (1%)	0.01 (0.1%)	0.01 (0.1%)
Non-local EMEP	7.9 (33%)	8.4 (75%)	12.3 (77%)
Total	23.9 (100%)	11.3 (100%)	16.0 (100%)

NO_2 is well modelled with high spatial correlation for many countries, but there is significant variation in bias between countries that may be attributable to the methods used for generation of the national emissions. Though the problem remains that uEMEP does not take into account dispersion in street canyons, where a number of traffic site measurements are made, it is generally the case that the spatial representativeness of the uEMEP calculations is suitable for comparison with these measurements. Variation in bias between countries is then no longer a case of a mismatch in resolution but most likely reflects bias in the national emissions. uEMEP may be used to investigate this variability between countries further and to help harmonise future emission inventories across Europe.

There is a significant difference between the results achieved for the downscaling of NO_2 compared to PM. NO_2 is dominated by traffic emissions and this is spatially very well defined using OSM as a proxy. The largest contributor to PM is residential heating which uses population as a downscaling proxy, so it appears that this is not a good proxy for high resolution emission redistribution. Though clearly residential heating emissions occur where people live there can be large variation from city to city and from urban to suburban and to rural areas as heating practices vary significantly depending on housing type and on availability of alternative heating sources. To some extent this has been taken into account in the TNO emission

inventory at 0.1^o, Section 5, but this approach has not been further applied in the uEMEP downscaling proxy.

The Norwegian sensitivity tests show that when consistent emissions and emission proxies are used then spatial correlation can be significantly improved. For the application of uEMEP in Europe this was not the case since each country has there own methodology for calculating gridded EMEP emissions that may or may not make use of the downscaling proxies applied in uEMEP. A more consistent approach, as applied in Norway, would be to use the same spatial redistribution proxies in both the gridded EMEP emissions and the downscaling proxies. This would require additional interaction and cooperation between emission inventory developers and air quality modellers.

It is worth noting that no selection of the Airbase monitoring data was carried out. All available stations with more than 75% coverage were used. This includes mountain stations, all traffic stations as well as industrial sited stations. In comparisons with EMEP these types of sites are often removed. All stations were also assumed to be sited at 3 m above the surface. It is quite possible that different results would be obtained if a selection of stations was carried out. This will be assessed at a later time.

Downscaling can provide additional information concerning the contributions of local sources. This may be combined with EMEP source-receptor calculations to provide a more complete picture of local and long transported contributions and can lead to a better assessment of local verses regional measures for improving air quality.

8.7 Conclusions

Downscaling of annual mean concentrations from the EMEP-MSCW chemical transport model have been carried out for NO_2, $PM_{2.5}$ and PM_{10} using the uEMEP model. Downscaling redistributes EMEP gridded emission data, using suitable proxy data, to high resolution sub-grids and then calculates the sub-grid concentrations using a Gaussian dispersion model. These are then recombined with the EMEP-MSCW concentrations in a consistent way that avoids double counting of the emissions. Maps for all of Europe have been produced at a resolution of 100 m and concentrations at all Airbase measurement sites have been calculated at 25 m.

The results for NO_2 show significant improvement with a doubling of spatial correlation for many countries and a significant reduction in negative bias. For NO_2 the downscaling works very well and may be due to the fact that NO_X emissions are mainly attributable to traffic and these emissions are well defined spatially with the proxy data used.

Both $PM_{2.5}$ and PM_{10} do not show any improvement in spatial correlation with the downscaling, though the negative bias in PM concentrations is improved. The spatial distribution of PM emissions can be improved, as demonstrated for Norway, with improved proxy data but emissions of PM remain difficult to quantify properly at high resolutions and will require further effort. One way forward is to harmonise the proxies used for both the EMEP gridded emissions and the uEMEP downscaling. This has been shown to improve results in Norway.

The methodology shows good potential for further development and implementation and can be used to improve source contribution estimates, exposure estimates and assessment of local and non-local mitigation strategies for all of Europe at high resolution.

Scatter plots per country

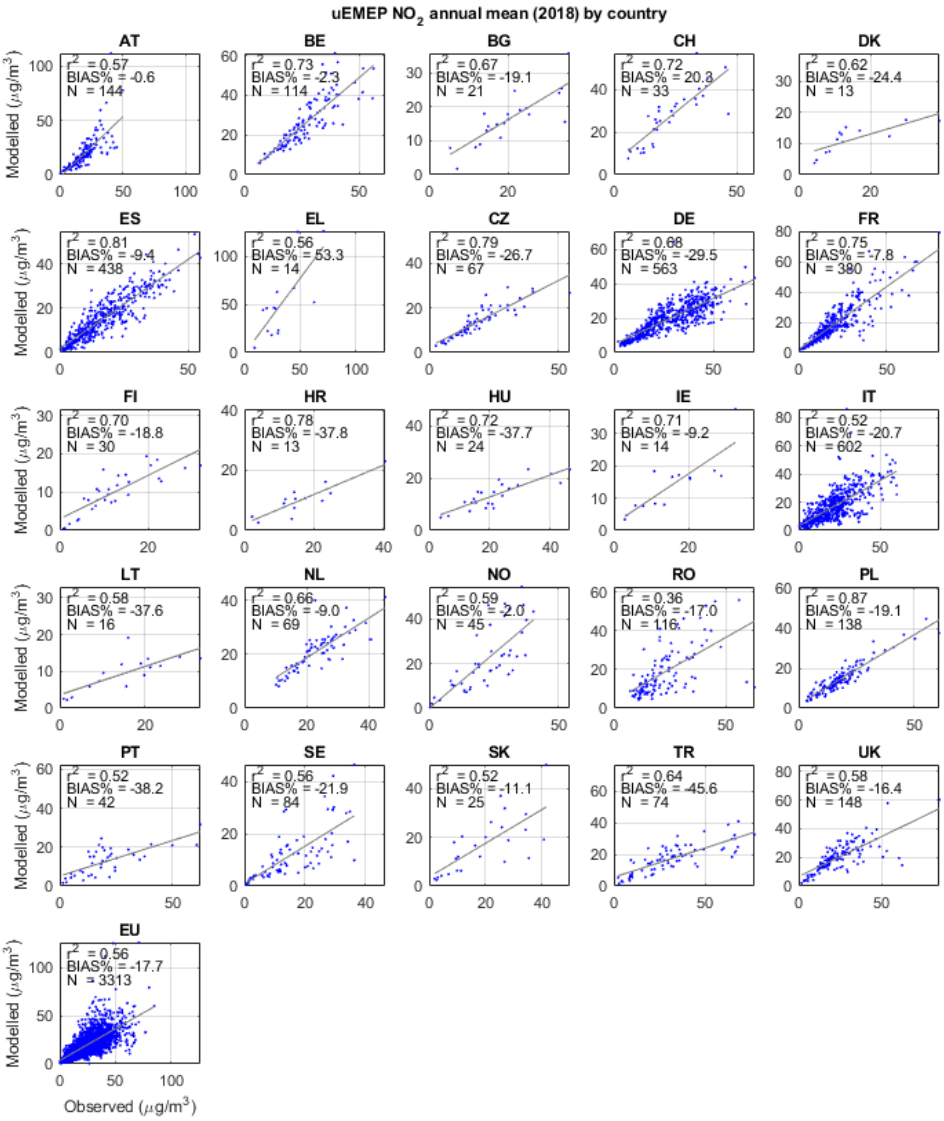

Figure 8.14: Scatter plots of annual mean NO_2 concentrations per country for 2018 calculated with uEMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

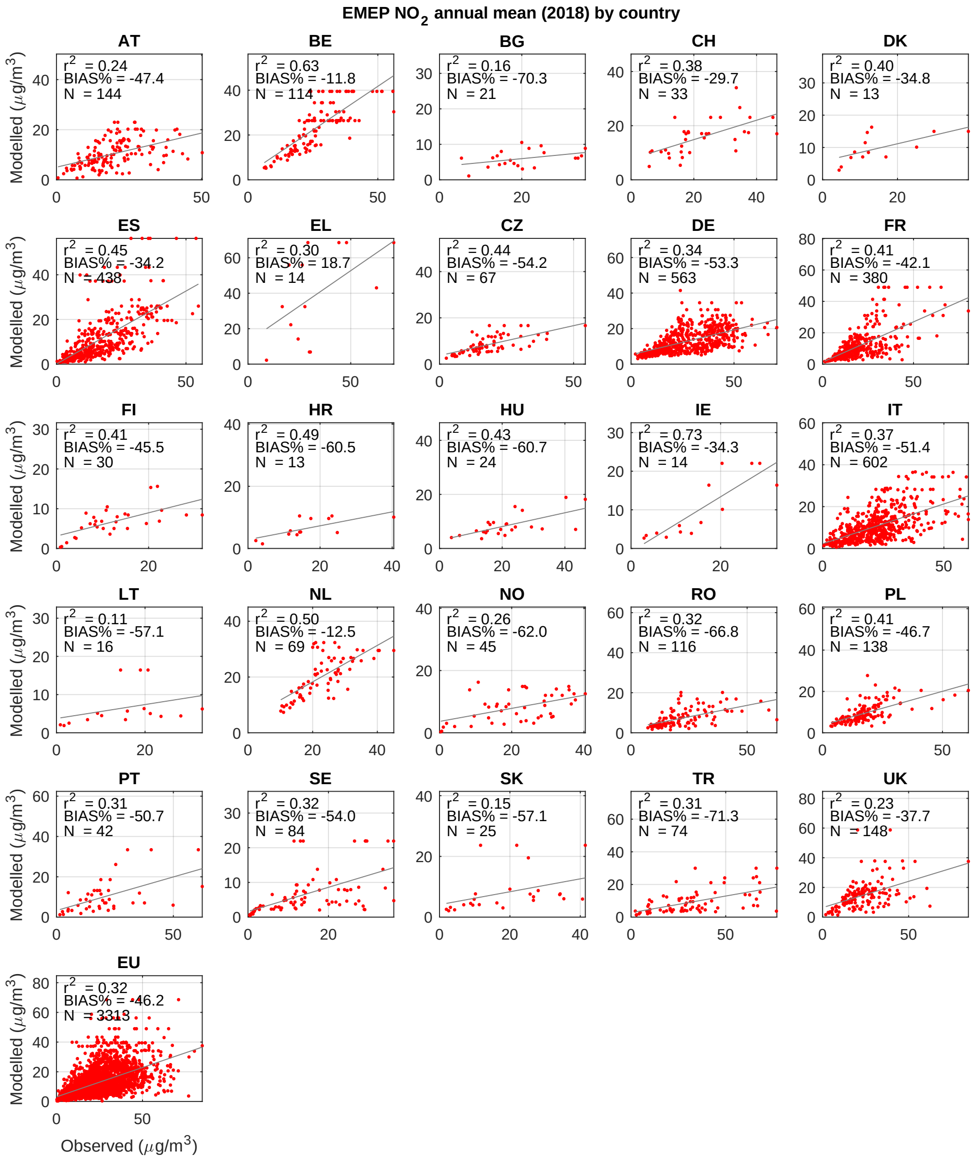

Figure 8.15: Scatter plots of annual mean NO_2 concentrations per country for 2018 calculated with EMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

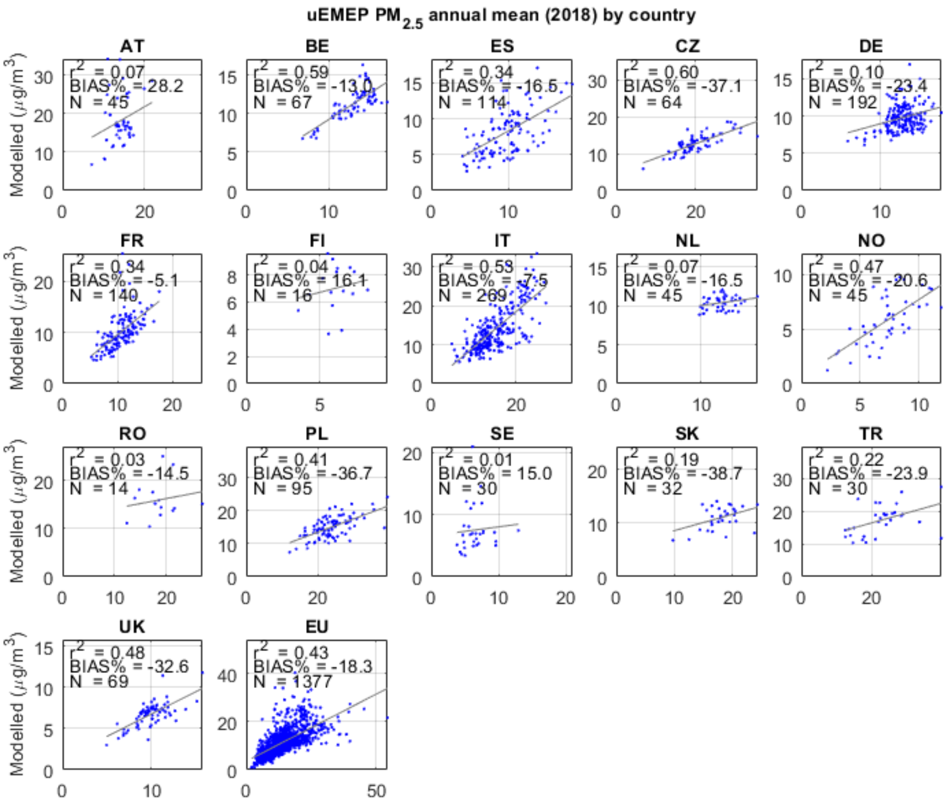

Figure 8.16: Scatter plots of annual mean $PM_{2.5}$ concentrations per country for 2018 calculated with uEMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

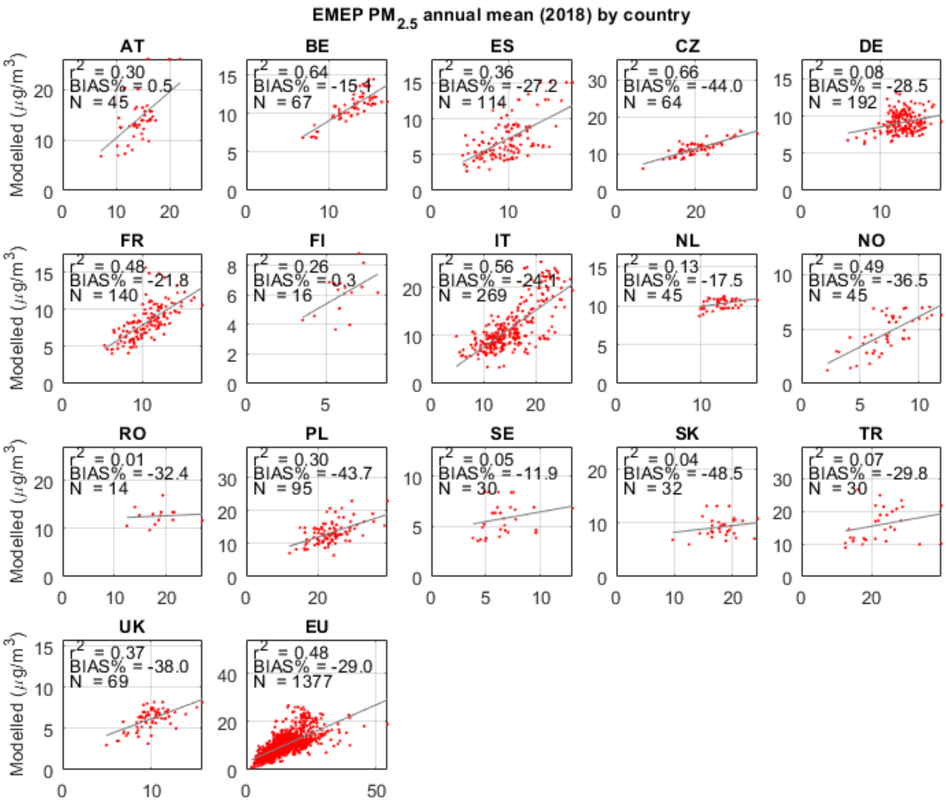

Figure 8.17: Scatter plots of annual mean $PM_{2.5}$ concentrations per country for 2018 calculated with EMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

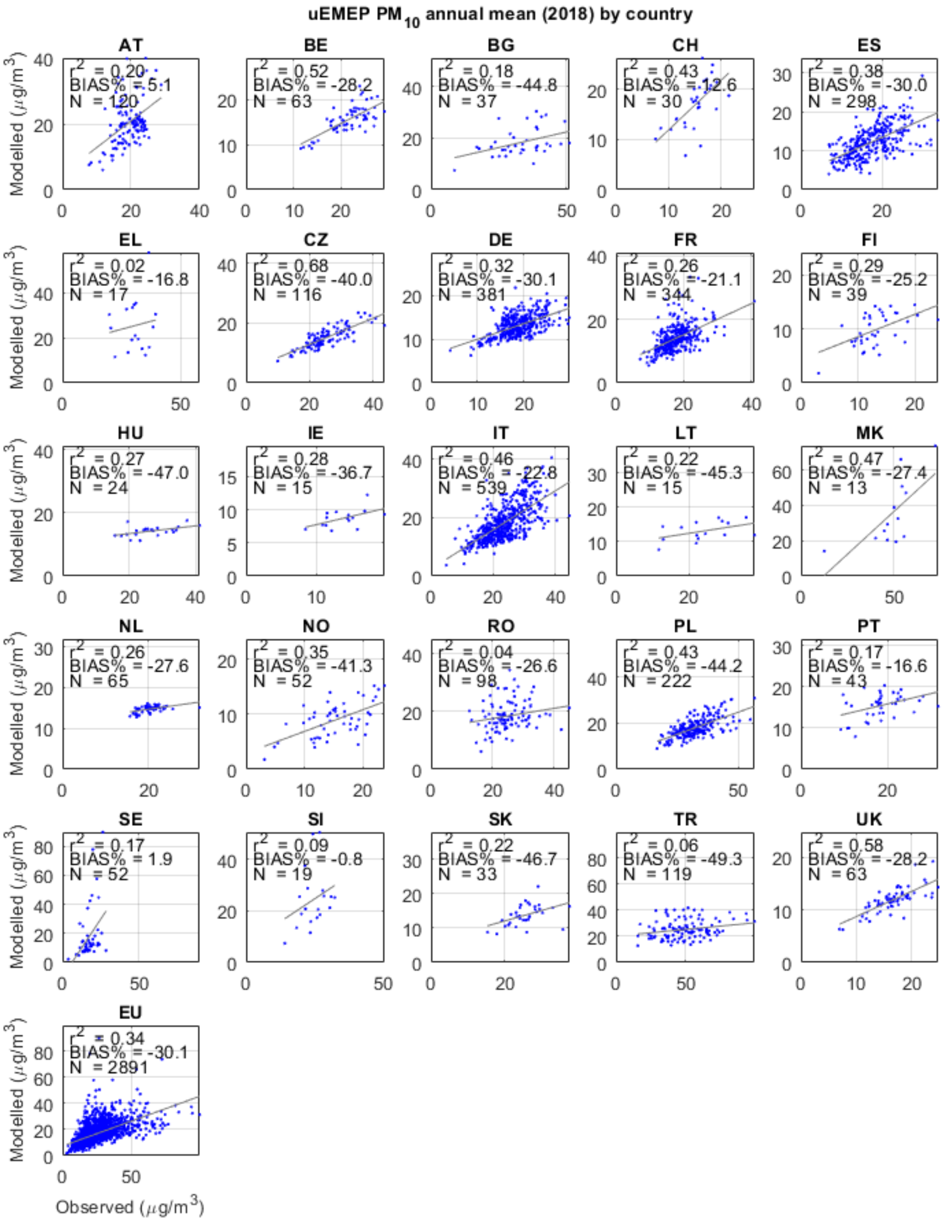

Figure 8.18: Scatter plots of annual mean PM_{10} concentrations per country for 2018 calculated with uEMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

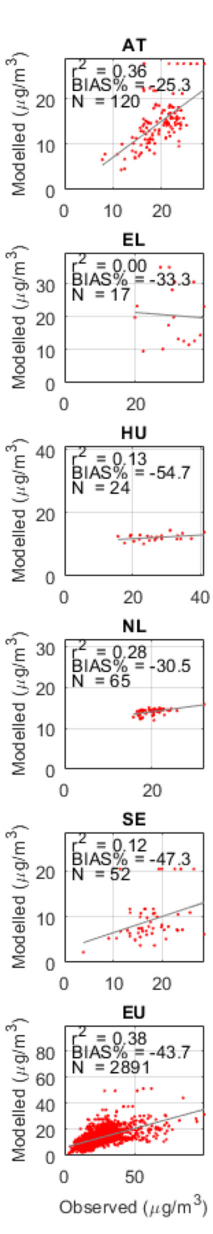

Figure 8.19: Scatter plots of annual mean PM$_{10}$ concentrations per country for 2018 calculated with EMEP. Only countries with more than 10 stations are shown individually but all stations are included in the final EU plot.

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CHAPTER 9

Reduced nitrogen in Europe in 2030

Jan Eiof Jonson, Hilde Fagerli and Svetlana Tsyro

9.1 Introduction

Concentrations of particles with a diameter of less than 2.5 μm ($PM_{2.5}$ have been decreasing in most of Europe since the turn of the century as a combined result of reductions in anthropogenic emissions of primary particles and their gaseous precursors SO_2, NO_x and ammonia. Emissions of ammonia play a central role in the secondary particle formation and are major contributors to the exceedances of critical loads for eutrophication (see chapter 2.4.4). In most of Europe, emissions of SO_2 and NO_x have been steadily decreasing in the past decades. At the same time, emissions of ammonia have changed much less (see chapter 3.6 and Appendix B in this report). Further reductions of SO_2, NO_x and ammonia emissions are required by the year 2030 according to the EU NEC2030 directive (`https://www.eea.europa.eu/themes/air/air-pollution-sources-1/national-emission-ceilings`), but the projected percentage reductions in ammonia emissions in NEC2030 are smaller than for SO_2 and NO_x.

In this chapter we apply the EMEP MSC-W model to investigate how $PM_{2.5}$ concentrations and deposition of reduced nitrogen have changed since 2005. Furthermore, model calculations for 2030, assuming that the NEC2030 will be met, are performed. In addition, we make a sensitivity study for $PM_{2.5}$ for post NEC2030, applying additional ammonia emission reductions on top of NEC2030 requirements.

9.2 Model runs

Model runs have been performed with the EMEP rv4.34 model version at $0.1° \times 0.1°$resolution for meteorological conditions of 2017. In these model runs, emissions representative for

year 2005, 2017 and year 2030 have been used. For the EU28 countries, the official EMEP emissions are used for both the 2005 model runs (as listed in appendix B) and for 2017 model runs (as listed in appendix A). For the 2030 model runs the emissions for the individual EU28 countries are scaled according to the NEC2030 obligations. For all other countries and regions the 2005 and 2030 emissions have been provided by the International Institute for Applied Systems Analysis (IIASA) within the European FP7 project ECLIPSE (`http://www.iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv5.html`). In this study we use ECLIPSE version 6a (hereafter referred to as 'ECLIPSEv6a'), which is a global emission data set widely used by the scientific community. Some of the methods used in ECLIPSE are described in the recent publication of Höglund-Isaksson et al. (2020). Ammonia emissions from all EU28 countries and selected European non-EU countries are listed in Table 9.1.

Table 9.1: Emissions (Em.) of ammonia and depositions (Dep.) of reduced nitrogen and the ratio of deposition to emissions (frac). Emissions and deposition are listed in 100 Mg of N. (Bosnia H. is Bosnia and Herzegovina and N. Macedonia is North Macedonia.

	2005			2017			2030		
Country	Em.	Dep.	frac.	Em.	Dep.	frac	Em.	Dep.	frac
28 EU countries									
Austria	516	589	1.14	569	597	1.05	454	487	1.07
Belgium	620	339	0.55	550	326	0.59	539	299	0.55
Bulgaria	425	444	1.04	407	462	1.14	374	408	1.09
Croatia	392	370	0.94	310	337	1.09	294	306	1.04
Cyprus	62	20	0.33	53	23	1.61	49	22	0.44
Czechia	636	587	0.92	552	567	1.03	496	465	0.94
Denmark	729	359	0.49	629	325	0.52	554	277	0.50
Estonia	84	108	1.28	84	106	1.26	84	95	1.14
Finland	307	351	1.14	256	355	1.39	246	281	1.14
France	4980	3423	0.69	4994	3434	0.69	4333	3054	0.70
Germany	5267	3943	0.75	5544	4081	0.74	3740	3039	0.81
Great Britain	2343	1177	0.50	2332	1167	0.50	1968	1042	0.53
Greece	533	337	0.63	459	343	0.75	479	336	0.70
Hungary	709	560	0.79	722	560	0.78	482	442	0.92
Ireland	933	392	0.42	976	416	0.42	887	379	0.43
Italy	3515	2215	0.63	3164	2037	0.64	2953	1923	0.65
Latvia	123	202	1.64	136	214	1.57	122	179	1.47
Lithuania	257	300	1.16	243	304	1.25	231	266	1.15
Luxembourg	48	26	0.53	48	26	0.54	38	22	0.58
Malta	12	1	0.12	9	1	0.11	9	1	0.13
Netherlands	1274	554	0.44	1088	554	0.51	1006	459	0.46
Poland	2671	2303	0.86	2533	2293	0.91	2217	1908	0.86
Portugal	516	242	0.47	474	235	0.50	439	219	0.50
Romania	1697	1265	0.74	1353	1188	0.88	1273	1062	0.83
Slovakia	312	303	0.97	219	274	1.25	219	236	1.08
Slovenia	166	136	0.82	153	149	0.97	119	112	0.93
Spain	4173	1699	0.41	4267	2064	0.48	3388	1570	0.46
Sweden	477	610	1.28	439	592	1.35	396	491	1.24
EU28	33777	23056	0.68	34896	22295	0.64	27389	19380	0.71
non EU countries									
Switzerland	497	343	0.69	454	377	0.83	446	302	0.68
Island	26	26	0.99	43	37	0.86	33	25	0.76
Norway	179	247	1.38	275	312	1.13	192	214	1.11
Albania	138	86	0.63	199	126	0.63	197	103	0.53
Turkey	2355	1626	0.69	6092	3894	0.64	3992	2555	0.64
Bosnia H.	130	225	1.73	175	246	1.41	205	215	1.05
N. Macedonia	65	69	1.06	84	77	0.92	8	65	1.12
Montenegro	19	39	2.09	17	35	2.06	16	37	2.29

In addition to base runs for the emission years 2005, 2017 and 2030, several sensitivity

model runs have been made to explore the effects of further emission reductions. The performed model runs are listed below:

- Base 2005: EU28 based on EMEP 2005 official emissions. Remaining land based emissions from ECLIPSEv6a.
- -10% 2005 NH_3: 2005 NH_3 emissions reduced by 10%. All other emissions as Base 2005.
- -20% 2005 NH_3: 2005 NH_3 emissions reduced by 20%. All other emissions as Base 2005.
- Base 2017: All emissions as reported in appendix A.
- Base 2030: EU28 as EMEP 2005 official emissions scaled to year 2030 in accordance to the NEC2030 obligations. Remaining land based emissions from Eclipse v6a.
- -10% 2030 NH_3: 2030 NH_3 emissions reduced by 10%. All other emissions as Base 2030
- -20% 2030 NH_3: 2005 NH_3 emissions reduced by 20%. All other emissions as Base 2030

9.3 Model results for 2005 versus 2030

9.3.1 $PM_{2.5}$

Figure 9.1, upper panel, shows concentration maps for $PM_{2.5}$ as calculated with 2005 emissions (Base2005, left) and 2030 emissions (Base2030, right). The high $PM_{2.5}$ levels over North Africa in both 2005 and in 2030 are caused by large natural sources of mineral dust there. This feature is also seen in the calculations for 2018 (Figure 2.8). From 2005 to 2030, as shown in Figure 9.1, there are substantial reductions in $PM_{2.5}$ concentrations due to reductions in ammonia emissions and even larger percentage reductions in SO_2 and NO_x emissions in Europe. In 2030, elevated $PM_{2.5}$ concentrations still persist in some areas, notably in the Po Valley in Italy and the BeNeLux countries. In these areas, high ammonia emissions are expected to remain also in 2030.

In the fine mode, ammonium sulphate particles are first formed from ammonia and H_2SO_4. Any excess ammonia can then form ammonium nitrate in thermodynamic equilibrium with HNO_3 (see Simpson et al. (2012)). When ammonia is in excess relative to both H_2SO_4 and HNO_3 concentrations, the formation of ammonium salts will slow down at some point (when there is less acids available to react with ammonia) and free ammonia will be present.

As a consequence, the fraction of ammonia in total reduced nitrogen in air (ammonia + ammonium) has been increasing, and is expected to increase further by 2030, as shown in Figure 9.2.

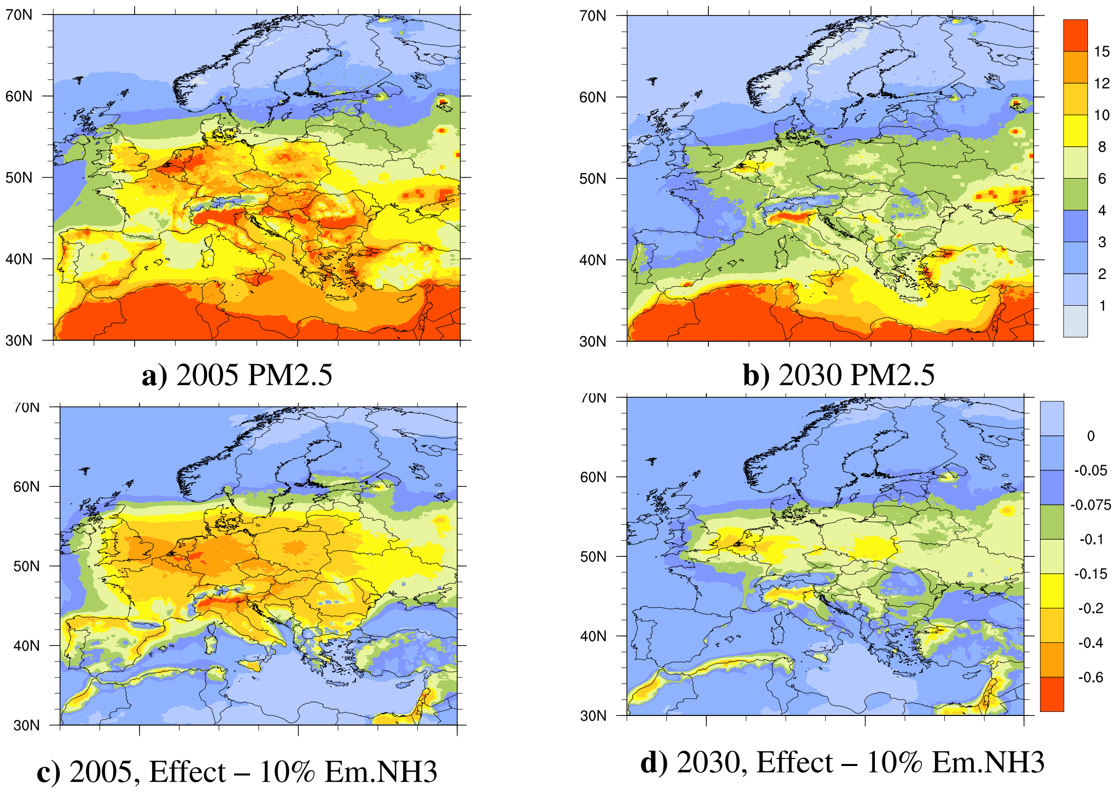


Figure 9.1: $PM_{2.5}$ in 2005 (a), and in 2030 (b). Effects of 10% further reductions in NH_3 emissions in 2005 (c) and in 2030 (d) [$\mu g\ m^{-3}$].

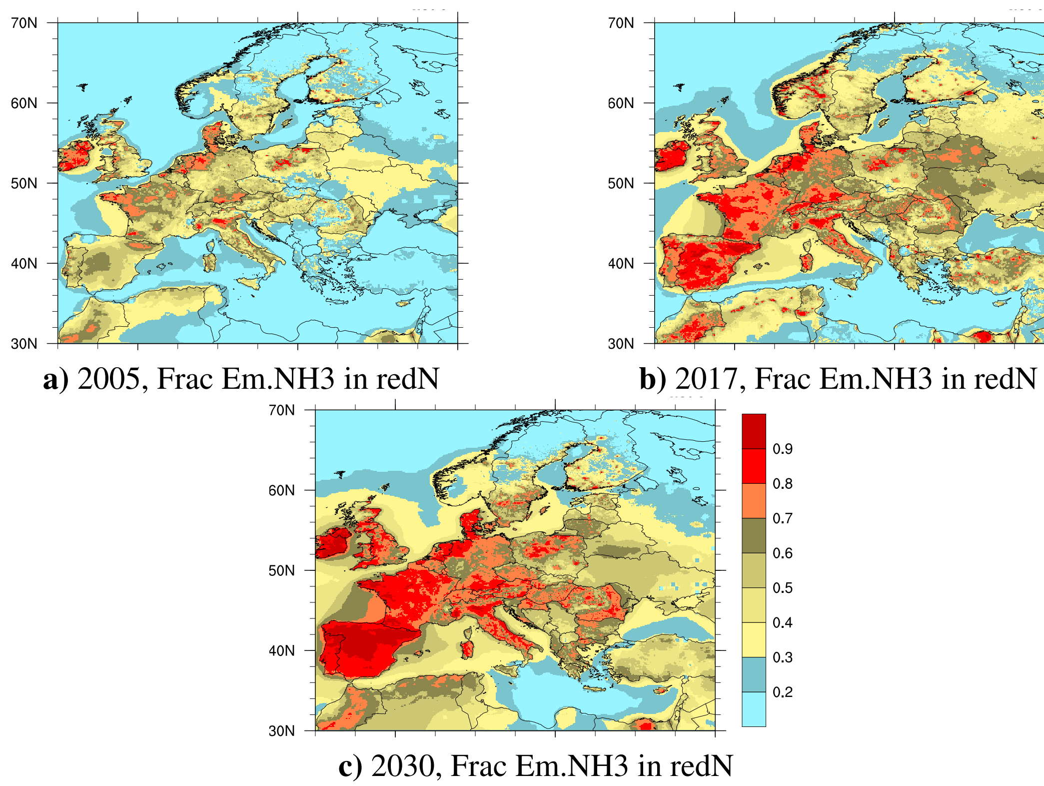
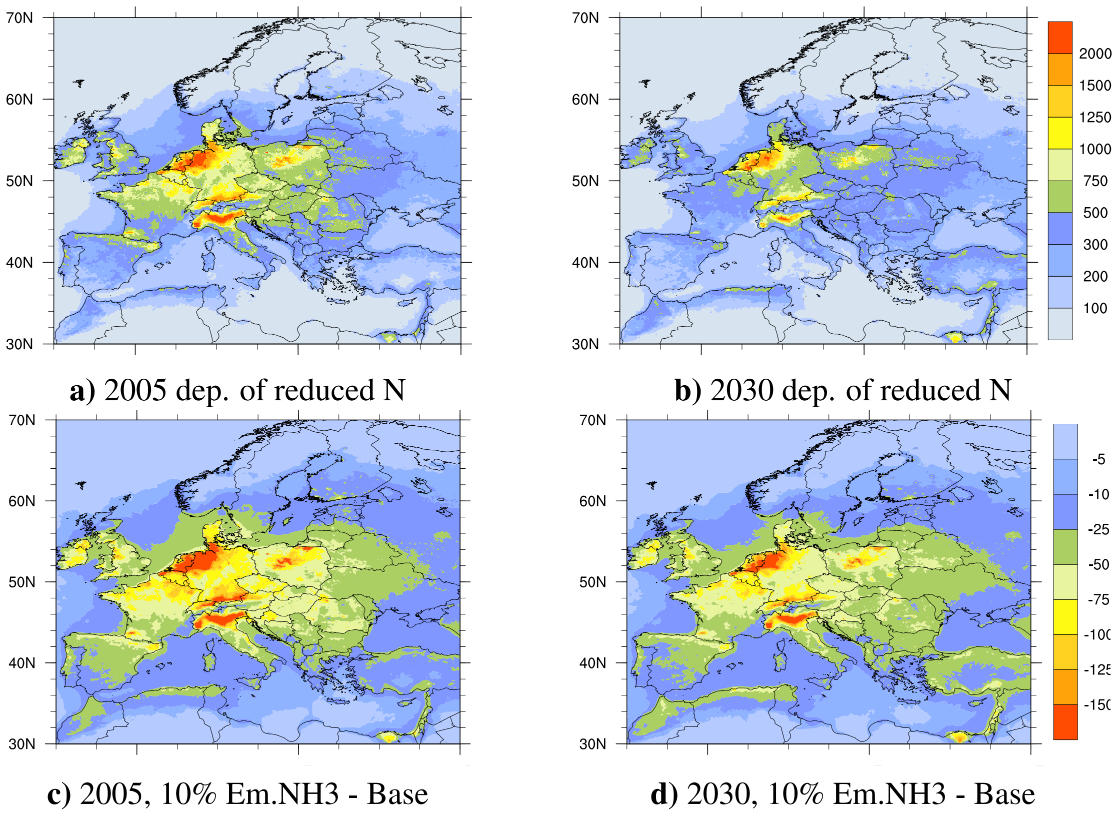


Figure 9.2: Fraction of NH_3 in reduced N (ammonia + ammonium) [mg(N)m^{-2}] in 2005, 2017 and 2030.



a) 2005 dep. of reduced N

b) 2030 dep. of reduced N

c) 2005, 10% Em.NH3 - Base

d) 2030, 10% Em.NH3 - Base

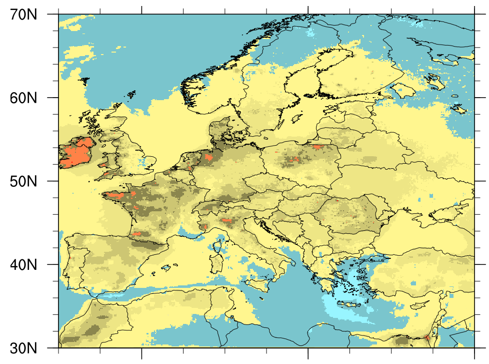
Figure 9.3: Deposition of reduced N in 2005 (a) and in 2030 (b) [mg(N)m^{-2}]. Difference with 10% further reductions of NH_3 emissions in 2005 (c) and in 2030 (d) [mg(N)m^{-2}].

9.3.2 Deposition of reduced nitrogen

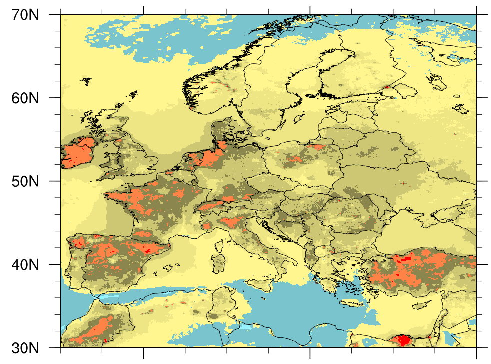
Figure 9.3, upper panel, shows the depositions of reduced nitrogen in 2005 (left) and in 2030 (right). As for $PM_{2.5}$, the Po valley and the BeNeLux countries stand out receiving large amounts of reduced nitrogen depositions in both 2005 and in 2030. The total amount of depositions per country in 2005, 2017 and 2030 are listed in Table 9.1 As shown in Tsyro et al. (2019), and in Figure 2.13 of this report, the critical loads for eutrophication were exceeded throughout most of Europe in 2017 and 2018. With the ambitions for further reductions towards 2030, as imposed by NEC2030, critical loads for eutrophication are likely to be exceeded in major parts of Europe also in 2030.

As shown in the lower panel in Figure 9.3, there are marked reductions in the expected depositions of reduced nitrogen in 2030 as compared to 2005. However, the ambitions for reductions by 2030 in ammonia emissions in NEC2030 are smaller compared to the reductions in SO_x and NO_x emissions. As a result, a larger portion of the total nitrogen deposition is expected to come from ammonia. This is illustrated in Figure 9.4 which shows the fraction of reduced nitrogen in the total nitrogen deposition calculated with 2005, 2017 and 2030 emissions. The Figure shows that this fraction increases significantly from 2005 to 2017, with a further increase expected from 2017 to 2030. By 2030 the percentage of the total nitrogen depositions resulting from ammonia emissions will exceed 70% in large parts of Europe.

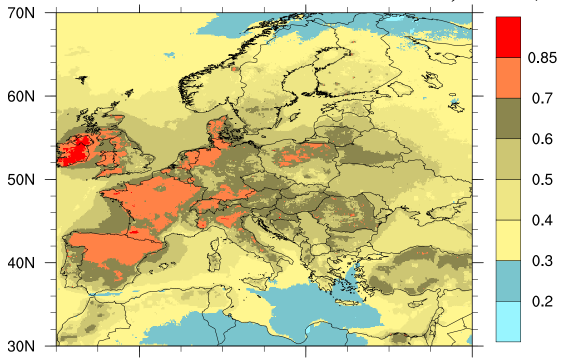
In Table 9.1 we also list the fraction of reduced nitrogen deposited domestically versus emitted ammonia for individual countries. For most central European high emitting countries this fraction is well below 1, meaning that these countries receive less deposition of reduced



a) 2005, Frac redN/totN



b) 2017, Frac redN/totN



c) 2030, Frac redN/totN

Figure 9.4: Fraction of reduced N deposition [mg(N)m^{-2}] relative to total N deposition with year 2005, 2017 and 2030 emissions.

nitrogen than they emit. Also, this is in particular the case for several countries facing the sea, with very few upwind sources, exemplified by Ireland and Portugal. For the European Union as a whole, this fraction is around 70% for all 3 emission years considered. The remaining 30% is either deposited at sea or in non-EU countries. A small portion is advected out of the model domain.

9.3.3 Effects of additional ammonia emission controls

Figures 9.1c) and d) show the effects of further 10% reductions of ammonia emissions on $PM_{2.5}$ concentrations in 2005 and 2030, respectively. Compared to 2005, the absolute effects of 10% further emission reductions in 2030 are smaller. Partially, this is because the percentage emission reductions in 2005 give a larger reduction in absolute numbers compared to percentage emission reductions based on the lower 2030 emissions. As an example, 10% of the emissions from EU in 2005 (3574Gg) will give a smaller reduction than 10% reductions in 2030 (2900Gg). However, these absolute changes in ammonia emissions are not large enough to explain a decrease of the magnitude seen in Figure 9.1c) versus Figure 9.1d). As seen in Figure 9.2, there is more 'free' ammonia (ammonia in excess of H_2SO_4 and HNO_3) in 2030 relative to 2005. Therefore, a 10% reduction in NH_3 emissions will make gradually smaller impact on the formation of ammonium in future years.

Furthermore, the dry deposition of ammonia is more efficient than that of ammonium. As the fraction of ammonia in total reduced nitrogen increases from 2005 to 2030 (as discussed in Section 9.3.1), it is expected that reduced nitrogen will be deposited closer to the source

regions. This is not readily seen based in the model calculations. As an example, the fraction of deposited versus emitted reduced nitrogen in EU28 (see Table 9.1) is close to 0.7 for all the three years. However, the reductions in ammonia emissions are in general larger in the strongly emitting central European countries than in other countries, potentially masking this effect.

About 90% of the ammonia emissions are from agriculture (Amman et al. 2017), with a minimum in emissions in winter and a maximum in spring, as opposed to NO_x and SO_x emissions peaking in winter. As a result, the excess of ammonia versus sulphate and HNO_3 is much smaller in winter than in other seasons. In Figure 9.5, we show that for $PM_{2.5}$ by far the largest effects of further reductions of ammonia emissions are modelled for the winter season, when the imbalance is smallest. Notably, most of $PM_{2.5}$ pollution episodes, including exceedances of the EU limits or WHO AQ guidelines, are most frequent in large parts of Europe during the winter period (see section 2.4.2). The smallest effects are calculated for the summer months when both SO_x and NO_x emissions are at a minimum. In summer, reductions are mainly confined to the southwestern parts of the North Sea, where ship emissions of NO_x are large.

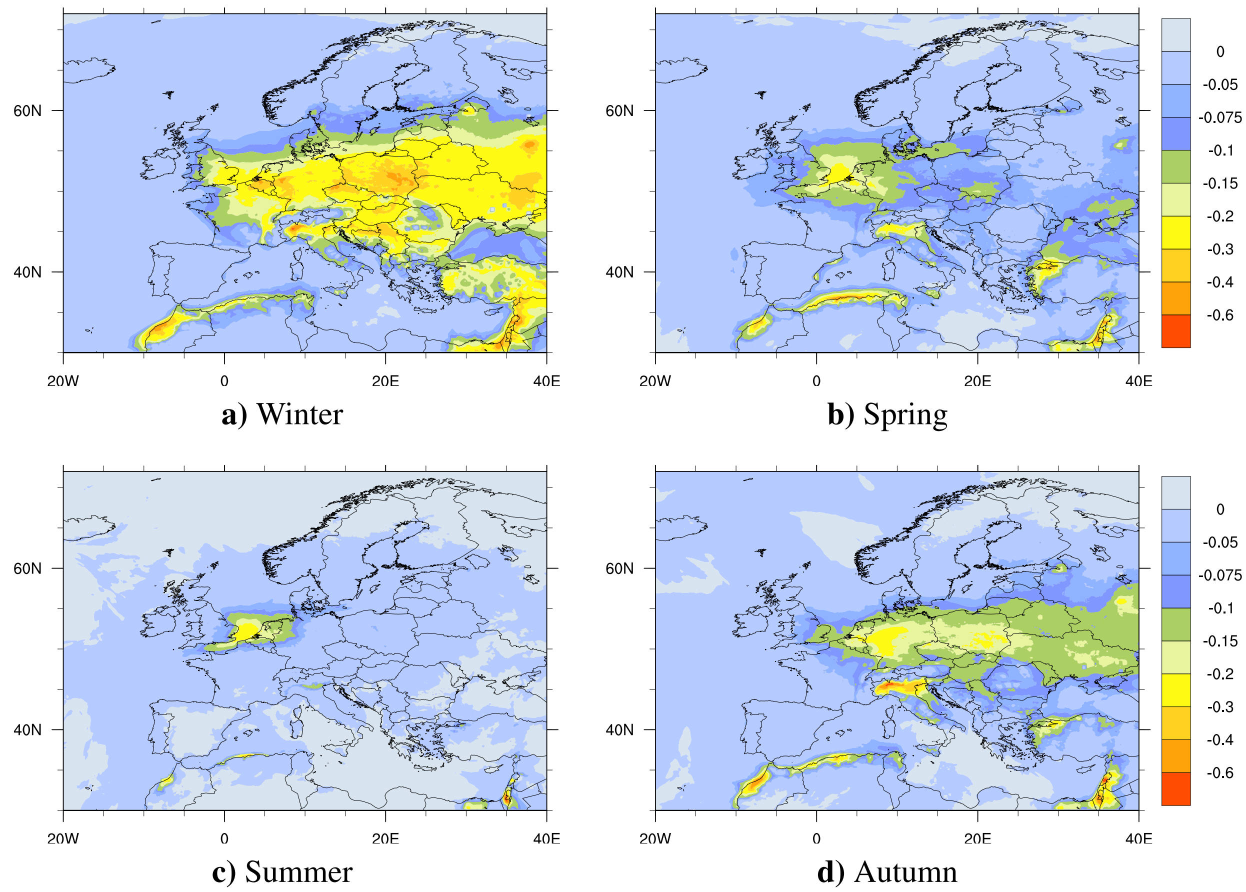
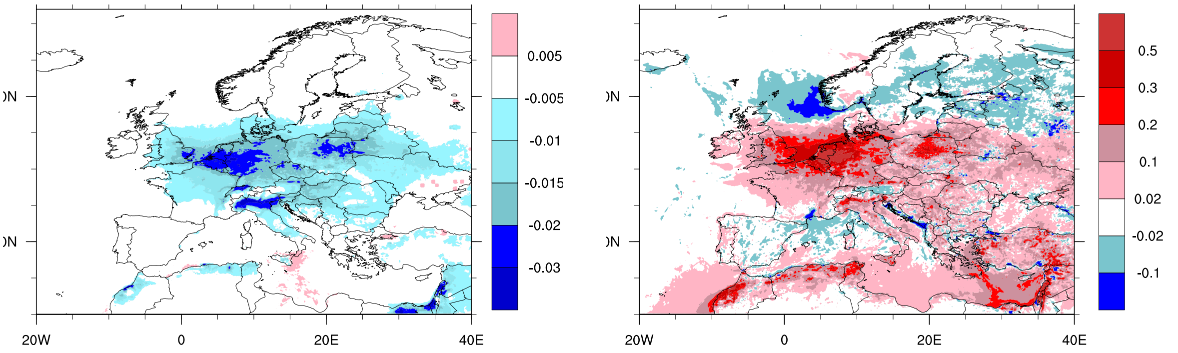


Figure 9.5: Effects of a 10% decrease in 2030 ammonia emissions on $PM_{2.5}$ [μg m^{-3}] split by season. Winter: December, January, February. Spring: March, April, May. Summer: June, July, August. Autumn: September, October, November.

Figure 9.6 compares the efficiency of ammonia emissions reductions on top of the NEC2030 requirements on $PM_{2.5}$ concentrations and reduced nitrogen depositions. The maps show the differences between the effects of two 10% versus one 20% reductions in ammonia emission

in 2030. If linear, doubling of the 10% reductions should equal the result of the 20% reductions. Although not perfectly linear, the differences seen in Figure 9.6 are small compared to the overall $PM_{2.5}$ and reduced nitrogen deposition levels (Figures 9.1 and 9.3). In general, the additional 20% reduction of ammonia emissions results in a slightly larger decrease of $PM_{2.5}$ levels compared to a doubling of the effects of the 10% additional emission reductions, likely due to a decreasing excess of ammonia.



a) $PM_{2.5}$ **b)** Dep. RDN

Figure 9.6: Difference between 2 × 10% reduction and 20% reduction in ammonia emissions on top of NEC 2030 for $PM_{2.5}$ concentrations [μg m^{-3}] (a) and deposition of reduced nitrogen [mg(N)m^{-2}] (b).

For depositions of reduced nitrogen the situation is reversed. Subtracting the effects of 20% additional reductions in 2030 from a doubling of the effects of 10% indicates that the amount of the dry deposition, at least near the source regions, decreases.This can be explained by a slightly larger portion of ammonium aerosol in the reduced nitrogen, which has a slower dry deposition rate than ammonia. Only a small portion of the reduced nitrogen is advected out of the model domain. As a result, the change in depositions seen in the source areas is compensated by a much smaller, but more widespread change in the opposite direction elsewhere.

9.4 Conclusions

In this chapter, we have investigated how $PM_{2.5}$ concentrations (with a focus on ammonium) and deposition of reduced nitrogen change from 2005 to 2030, assuming that NEC2030 will be met. In addition, we made a sensitivity study for $PM_{2.5}$ for post NEC2030, applying additional ammonia emission reductions on top of NEC2030 requirements.

Emissions of SO_2, NO_x and ammonia have decreased in most countries from year 2005 to present, and further emissions reductions are expected by year 2030. However, reductions in ammonia emissions are much smaller than reductions in SO_2 and NO_x emissions. Model calculations show that this difference in emission reductions leads to an increasingly smaller fraction of ammonia being converted to ammonium, with an increasingly larger portion of free ammonia. As a consequence, low-ambition measures to reduce the ammonia emissions will bring small effects on $PM_{2.5}$ levels, thus reducing the ability of controlling $PM_{2.5}$ by additional reductions of ammonia emissions on top of NEC2030.

Following the emission reductions, depositions of reduced nitrogen are decreasing in Europe. As the reductions in NO_x emission are larger than for ammonia, the fraction of reduced

versus total deposition of nitrogen is increasing and is expected to reach more than 70% in large parts of Europe by year 2030. Further reductions in ammonia emissions would thus efficiently reduce the deposition of reduced and also total nitrogen deposition in the future.

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CHAPTER 10

The winter 2017/2018 intensive measurement period. A brief update

Stephen Matthew Platt, Karl Espen Yttri, Wenche Aas

10.1 Summary

Here we present a short status update of the analysis of the ongoing work on the data from the EMEP intensive measurement period (IMP) in winter 2017/18. This analysis has comprised apportionment of equivalent black carbon (EBC) into fossil and biomass fractions (EBC_{ff} and EBC_{bb}, respectively), using the aethalometer model, and positive matrix factorization (PMF), as well as comparison to elemental carbon (EC) and levoglucosan.

10.2 Background

There are numerous anthropogenic and biogenic sources of carbonaceous aerosol, and it is important to identify and quantify these to develop efficient abatement strategies. Particularly, there is an interest in distinguishing between combustion sources using fossil fuels and biomass. This is usually possible by multi-wavelength measurements of the absorption coefficient using the *aethalometer model* (Sandradewi et al. 2008). EBC_{bb} tends to have a higher wavelength dependent absorption, expressed as higher aerosol Ångström exponents (AAEs) $\sim$1.7 (Zotter et al. 2017), while EBC_{ff} tends to have an AAE $\sim$1. Note that there are exceptions to this, e.g. biofuels are a biomass burning source, but combustion conditions in a vehicle engine are highly efficient and likely to produce EBC with an AAE$\sim$1, and the AAE of coal is not well defined, and is likely different in large centralized boilers compared to small domestic installations. Furthermore, uncertainty in the AAE for an individual source leads to large variation in the relative fractions of the EBC sources.

Here we present a new application of PMF to apportion EBC. Unlike the aethalometer model, the PMF approach requires no a priori knowledge of the aerosol Ångström exponents (AAEs) for EBC_{ff} and EBC_{bb} (rather, these are derived as output from the PMF). We provide an update on the data analysis and the status of data available as an output from the project.

Details regarding the background, methodology and meteorology during the period is described in last year EMEP Status Report (1/2019).

10.3 Aim

The IMP (Intensive Measurement Period) winter 2017/2018 aim to use the PMF approach to separate EBC into EBC_{ff} and EBC_{bb} in the European rural background environment, including low loading areas in Scandinavia and more polluted regions in Central Europe, and in areas likely differing in source composition, preferably also with an influence of coal combustion. Further, it should compare EBC_{ff} and EBC_{bb} apportioned by the PMF approach to filter-based measurements of the biomass burning tracer levoglucosan for validation purposes, and to elemental carbon (EC) to derive site-specific Mass Absorption Coefficients (MAC) values. A desired outcome of the IMP is a harmonised European-wide data set with apportioned into EBC_{ff} and EBC_{bb}, which is applicable for model validation. Finally, the IMP should encourage initiation of regular monitoring of EBC_{ff} and EBC_{bb}, and reporting of such data to EBAS, which then will pursue the EMEP monitoring strategy, as well as deliverables of ACTRIS (the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases).

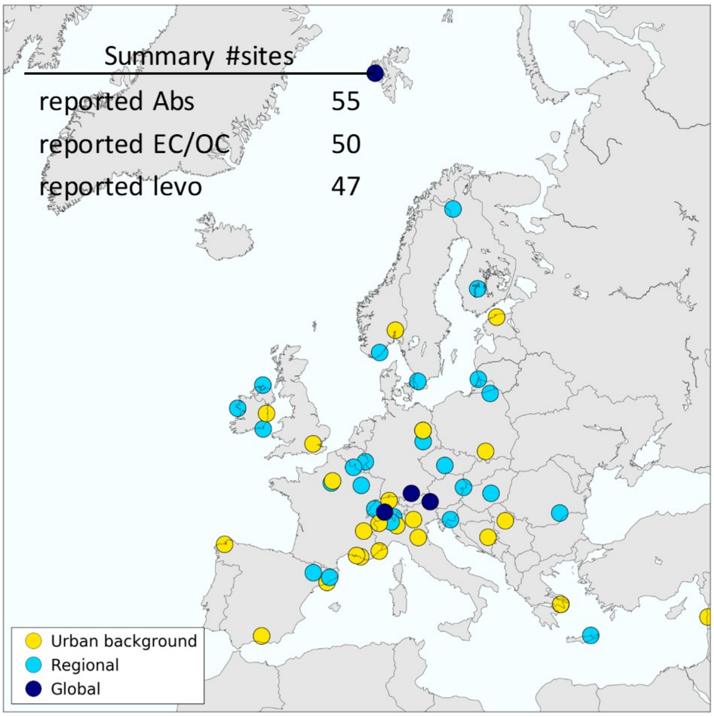

Figure 10.1: Location and category of sites participating in IMP Winter 2017/2018

Figure 10.1 shows the location of the 55 sites that reported data in the IMP Winter 2017/2018, and their site category. The northernmost site is the Zeppelin Observatory at Svalbard (Norway), whereas Beirut Mansourieh (Lebanon) in the Eastern Mediterranean Sea is both the

southern- and easternmost site. Mace Head at the Western coast of Ireland is situated furthest to the west. The sites that participated in IMP Winter 2017/2018 cover a wider area than those sites regularly addressing carbonaceous aerosol by OC/EC measurements within EMEP. This extension is particularly pronounced to the east, including several sites along a north to south transect from northern parts of Finland to Lebanon, and to the North-west by inclusion of sites in Ireland. The global sites Jungfraujoch and Hohenpeisenberg were added to the analysis despite not being part of the IMP because the wish for more global sites, and because absorption data was available for the time period.

Numerous variables relevant for air-quality and climate issues were measured at most of the sites participating in the IMP Winter 2017/2018, which also support our interpretation of the core variables, EBC_{ff} and EBC_{bb}.

10.4 Data submission and quality control

Data asked for in IMP Winter 2017/2018 were to be reported using predefined templates with substantial requirements for formatting, metadata and data quality control by flagging. This was to provide all the key meta data needed for the PMF analysis, for example: Information on invalid data, the multiple scattering parameter, and the zero readings needed for the error matrix.

The multiple scattering parameter depends on the tape used in the instrument and can take the value 1.39, 1.57, or 4.00 for the dual-spot aethalometer (AE33), and the calculated absorption/mass will scale linearly with this parameter. Not all sites reported the multiple scattering correction used and we have low confidence that all sites which reported it did so correctly, since the most recent tape type takes the value 4, and it is possible that not all participants updated their previous reporting templates. Furthermore, not all sites reported/collected zero data. Due to these challenges we accepted data from a number of sites not in the NASA aims format required for EBAS. This allowed us to expand the number of sites with data from 42 (last year's report) to 55. Nevertheless, we aim for all data collected as part of the IMP to be uploaded to EBAS. Data submission is now finished, and no more sites/additional data points will be added to the dataset. The data have been made available to the ongoing EURODELTA-CARB, EMEP/CAMS model experiment.

All sites have been analysed for absorption (Figure 10.3). We have excluded user invalid-flagged data, including zero data, from the analyses. Additionally, we have also excluded data where large variation in instrument flows was observed, even when not flagged by the data submitter, since this produces spikes in the data. Levoglucosan and EC, where reported, have also been analysed for these sites. Data coverage is not complete for a number of sites, and some lack levoglucosan and/or EC. Furthermore, levoglucosan and EC are reported for discrete sampling intervals at some sites, which further reduces coverage.

10.5 Data analysis

We calculated absorption coefficients in post-processing. Briefly, the aethalometer automatically generates absorption coefficients at 1-5 minute resolution. However, as discussed by Springston and Sedlacek_III (2007) and Backman et al. (2017), the time interval can be adjusted to any integer multiple of the base resolution and the absorption recalculated from the raw attenuation data. For the data from the 2017/2018 IMP we recalculated the absorption at

one hour intervals. The advantage of this technique is enhanced noise reduction, i.e. using the one-hour interval approach the noise reduction is proportional to as much as 1/n (where n are the measurement points), rather than 1/sqrt(n), attainable via signal averaging.

We determined the signal to noise for PMF analysis using the measurements of zero air, where submitted, for each site. Where zero data was not submitted, we used the average zero value from sites which did submit such data.

We observed overcompensation of the loading effect for several sites operating the AE33 aethalometer (clear jumps in the absorption after each tape advance). To correct for this artifact, we scaled the loading compensation parameter for each tape advance such that the average of the last two absorption coefficients at tape advance count number n was equal to the average of the first two absorption coefficients at tape advance count n+1. For consistency, and because error in the loading compensation parameter might be present but not easily observed, we corrected all AE33 data in this way. For the AE31/42 we used the Virkkula et al. (2007) compensation equation.

We performed repeated PMF runs on bootstrapped absorption/error matrix data to yield 2 factor profiles and time series from each site. An effective AAE was calculated using the PMF-derived factor profiles. This factor derived AAE was used to map the solutions such that factor 1 is defined as the profile with the lowest AAE (note that PMF yields factors in random order such that comparison of two or more solutions requires profiles that must be matched or 'mapped' to each other in order to calculate average results). Since factor 1 generally had AAE$\sim$1 and factor 2 had AAE$\sim$1.7 we assume these factors are equivalent to fossil fuel and biomass, respectively.

By binning the runs by the PMF-derived AAE (bin width = AAE $\pm$ 0.01) we could determine the modal AAEs and biomass burning/fossil contributions (e.g. Figure 10.2) out of the bootstrapped runs. The total number of bootstrap repeats was set in the analysis script to generate at least 10 runs in the modal bin at 880 nm for averaging purposes, or at least 300 total bootstrap runs, whichever gave the highest number of runs in the mode.

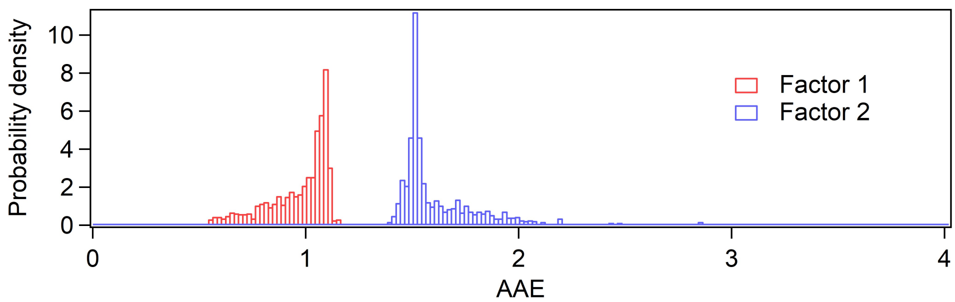

Figure 10.2: Positive matrix factorisation (2 factor solution) bootstrap runs binned by factor-derived aerosol Ångström exponent (AAE) for the Brenner site (Italy).

To convert absorption coefficients to EBC we used an effective mass absorption cross section (MAC) determined from the ratio of absorption coefficient to elemental carbon (EC). Since there is considerable uncertainty due to missing information about the tape types used (i.e. the multi scattering compensation parameter), the resulting MAC is not a true MAC value since it also compensates for this uncertainty. For sites which did not submit EC we used the standard MAC for each instrument type. Note that uncertainty in total concentrations does not influence the source apportionment, either by the PMF approach or by the aethalometer model.

10.6 Results and data output from the PMF source apportionment

We have run PMF for all IMP sites. PMF has consistently produced 2 factors with clear profiles. We have investigated 3 factor solutions for most sites, but no site yielded a clear separation into 3 factors.

Results from the source apportionment will be published in Platt et al. (in prep.), hence only a very brief overview is provided here. The mapped solutions yield a factor 1 with an AAE around 1 and an AAE around 1.5-2.0 (Figure 10.3), which is close to what is expected to correspond to AAE_{ff} and AAE_{bb}, respectively (Zotter et al. 2017).

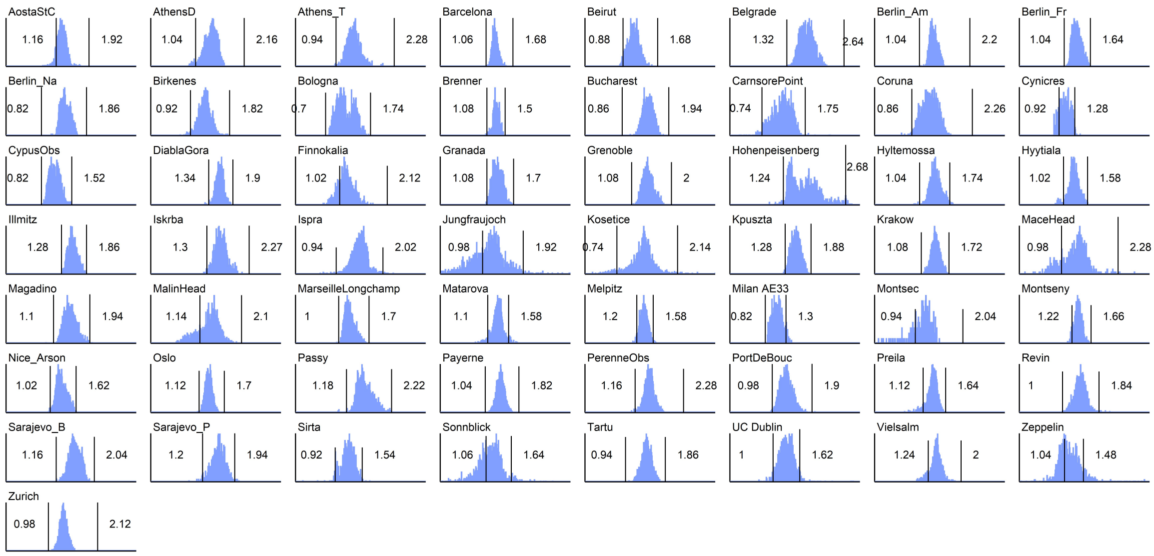

Figure 10.3: Absorption Ångström exponents (AAE) from PMF factor profiles (black lines) and the distributions of AAE values in the input data for all sites.

Time series of the PMF factors exhibit clear diurnal patterns for the urban sites, with factor 1 showing a morning and an evening peak, while factor 2 mainly peaks in the evening (Figure 10.4). For the background sites there is typically a lack of such a diurnal pattern. Generally, the observed diurnals lend credence to the PMF approach.

Sites with an apparently low diurnal variation in EBC_{bb} in Figure 10.4 (Birkenes, CarnsorePoint, Cyprus Observatory (CyObs), Diabla Gora, Hohenpeisenberg, Hyltemossa, Hyytiala, Illmitz, Jungfraujoch, MaceHead, MalinHead, Matarova, Preila, Revin, Sonnblick, Vielsalm, Zeppelin) are likely more affected by transported, rather than local emissions. We find however only a small difference in the average EBC_{bb} contribution at sites with no apparent diurnal pattern in EBC_{bb} of 34 $\pm$ 10%, vs. 39 $\pm$ 8% for those with clear diurnal variation (Figure 10.4). This is likely explained by the number of competing factors influencing the EBC_{bb} contributions upwind of these sites (biomass source, temperatures etc.), and also suggests that biomass contributes significantly to background EBC, i.e. that EBC_{bb} air pollution is a regional, rather than a local problem. It is also clear that site classification is likely to have a weak influence on the EBC_{bb} fraction

Data from all sites are now available on request, including:

- Station name list
- Aethalometer time stamps (start/mid/end time, hourly over campaign)
- PMF output time series (absorption, Babs, 880nm)
- MAC 880nm values (conversion factor)
- Filter time stamps (start/end time)
- EC data
- Levoglucosan data
- Aethalometer model output time series
- Ångström exponents used in the aethalometer model
- Ångström exponents from PMF
- PMF/AE model splits to biomass/fossil (solid/ liquid fuel)
- A readme text

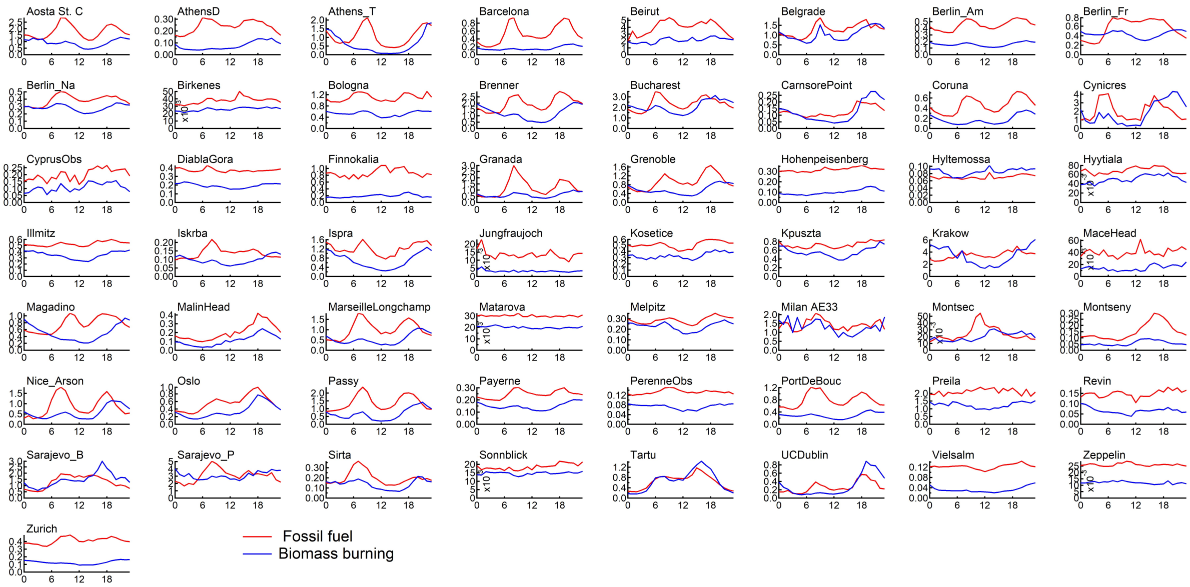

Figure 10.4: Diurnal variation in fossil fuel and biomass burning according to PMF during the IMP 2017/2018.

10.7 Continuation/Work ahead

The results presented provide only a snapshot of what is possible with the core data collected in the IMP Winter 2017/2018. In the future, other issues will be addressed as well. The results should be considered still preliminary, since the results shown are drawn from a subset of a large output dataset of many thousands of bootstrap replacement runs (i.e. the averaged modal bin) and other representations of the output are possible (for example boot strap runs drawn from the median, or via comparison to the levoglucosan and EC time series). Final results will be presented in a forthcoming paper (Platt et al., in prep.).

Further work will also be done on model intercomparisons, as was briefly presented in last year's report. Additionally, we will focus on combining data within the PMF, e.g. combined

absorptions from multiple sites/site classes with EC and levoglucosan. This would potentially allow us to constrain different numbers of factors (since there are more variables) and obtain representative AAEs, and source specific MACs for different site classes or geographical areas.

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Part III

Technical EMEP Developments

CHAPTER 11

Updates to the EMEP MSC-W model, 2019–2020

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This chapter summarises the changes made to the EMEP MSC-W model since Simpson et al. (2019), and along with changes discussed in Simpson et al. (2013), Tsyro et al. (2014), Simpson et al. (2015, 2016, 2017, 2019), updates the standard description given in Simpson et al. (2012). The model version used for reporting this year is denoted rv4.35, which has had some minor updates in the basic model since rv4.33 as documented in Simpson et al. (2019), major updates in the 'Local Fraction' methodology, and also in the emissions underlying some of the model runs. Table 11.1 summarises the changes made in the EMEP model since the version documented in Simpson et al. (2012), and Tables 11.3–11.4 compare the impacts of some of these changes.

11.1 Overview of changes

- Local Fractions: the Local Fractions method allows to track a large number of primary emission sources effectively. The details of the methodology are described in Wind et al. (2020). The method has been generalized and can be used to track emissions from a list of countries.

- The EMEP model's chemical pre-processing system and associated box-model (GenChem, boxChem) have been released as open-source. See Sect. 11.4.

- Chemical mechanisms: the three chemical mechanisms introduced in Simpson et al. (2019), EmChem19, CRI v2.2-emep, and CB6r2 have been updated for greater compatability and debugged, and are now denoted EmChem19a, CRIv2R5Em, CB6r2Em and EmChem19X (see Bergström 2020, in preparation). Additionally, EmChem19p, which is just EmChem19a plus code for four pollen species, has been introduced to the open-source code. See Sect. 11.3.

Table 11.1: Summary of major EMEP MSC-W model versions from 2012–2020. Extends Table S1 of Simpson et al. 2012

Version	Update	Ref[(a)]
rv4.35	Various updates, including heavy refactoring of local-fraction code, bug-fixes in MARS module, and updates in chemical mechanisms, default PM and NMVOC speciation and GenChem systems	This report
rv4.34	Public domain (Feb. 2020); EmChem19a, EmChem19p	This report
rv4.33	Public domain (June 2019); EmChem19, PAR bug-fix, EQSAM4clim	R2019
rv4.32	Used for EMEP course, April 2019	
rv4.30	Moved to new GenChem-based system	
rv4.17a	Used for R2018. Small updates	R2018
rv4.17	Public domain (Feb. 2018); Corrections in global land-cover/deserts; added 'LOTOS' option for European NH_3 emissions; corrections to snow cover	R2018
rv4.16	New radiation scheme (Weiss&Norman); Added dry and wet deposition for N_2O_5; (Used for Stadtler et al. 2018, Mills et al. 2018b)	R2018
rv4.15	EmChem16 scheme	R2017
rv4.14	Updated chemical scheme	R2017
rv4.12	New global land-cover and BVOC	R2017
rv4.10	Public domain (Oct. 2016) (Used for Mills et al. 2018a)	R2016
rv4.9	Updates for GNFR sectors, DMS, sea-salt, dust, S_A and γ, N_2O_5	
rv4.8	Public domain (Oct. 2015); ShipNOx introduced. Used for EMEP HTAP2 model calculations, see special issue: `www.atmos-chem-phys.net/special_issue390.html`, and Jonson et al. (2017).	R2015
rv4.7	Used for reporting, summer 2015; New calculations of aerosol surface area; New gas-aerosol uptake and N_2O_5 hydrolysis rates; Added 3-D calculations pf aerosol extinction and AODs; Emissions - new flexible mechanisms for interpolation and merging sources; Global - monthly emissions from ECLIPSE project; Global - LAI changes from LPJ-GUESS model; WRF meteorology (Skamarock and Klemp 2008) can now be used directly in EMEP model.	R2015
rv4.6	Used for Euro-Delta SOA runs Revised boundary condition treatments ; ISORROPIA capability added	R2015
rv4.5	Sixth open-source (Sep 2014); Improved dust, sea-salt, SOA modelling ; AOD and extinction coefficient calculations updated ; Data assimilation system added ; Hybrid vertical coordinates replace earlier sigma ; Flexibility of grid projection increased.	R2014
rv4.4	Fifth open-source (Sep 2013) ; Improved dust and sea-salt modelling ; AOD and extinction coefficient calculations added ; gfortran compatibility improved	R2014, R2013
rv4.3	Fourth public domain (Mar. 2013) ; Initial use of namelists ; Smoothing of MARS results ; Emergency module for volcanic ash and other events; Dust and road-dust options added as defaults ; Advection algorithm changed	R2013
rv4.0	Third public domain (Sep. 2012), as Simpson et al. (2012)	R2013

Notes: (a) R2018 refers to EMEP Status report 1/2018, etc.

- A 19-sector emission system, GNFR_CAMS, was introduced to take care of emissions provided by TNO as part of CAMS. This extended emissions system enables for example four road traffic sectors, F1–F4, with e.g. F1 representing exhaust emissions from gasoline vehicles.
- Emissions speciation. New default and country-specific emission speciations for NMVOC and $PM_{2.5}$ have been implemented. See Sect. 11.5.
- Numerous small changes to make the code more flexible and/or to fix minor bugs.

11.2 Local Fraction

The implementation of the method has been streamlined and generalized. New features include tracking of pollutants over the entire domain (the position of the source is then defined in a coarser resolution), tracking of pollutants by country of origin, tracking of single species, tracking of reduced nitrogen, tracking of sulfates and dry deposition. The development of secondary pollutants is still at an experimental stage.

The method is efficient and the cost of tracking pollutants from 100 countries in a single run is negligible (less than 5% additional runtime).

This new approach allows to compute an entire SR matrix for primary components (and with some preliminary implementation of groups such as reduced N). The interpretation of the contributions is slightly different than the results obtained by traditional scenario runs. The Local Fraction approach is essentially a tracking mechanism, and therefore only the first order effects of the change of emissions will be reflected. For primary particulate matter the differences between the two approaches are small.

It should be noted that primary particulate matter will have an influence on SOA through gas/particle partitioning impacts (Bergström et al. 2012), and also on gas-particle reaction rates which are dependent on aerosol surface area (Stadtler et al. 2018) and thereby on the total particulate matter concentrations. These secondary effects are not included in the Local Fraction method.

Another more subtle difference, is the effect on advection. In a scenario run, the concentrations of air pollutants will change. The 4th order Bott's scheme (Bott 1989) uses those concentrations to tune the advection parameters; the parameters are changed in a way that tend to keep the pollutants together (in order to reduce numerical diffusion). This spurious effect is not present in the Local Fraction method.

Table C.8 shows the blame matrix for PM_{fine} obtained by taking the differences of the result of a base run and a scenario with 15% reduction of primary PM_{fine} emissions for one country at a time. Table C.16.3 shows the corresponding numbers obtained using the Local Fraction method, i.e. obtained in a single run. Table C.16.2, similar to Table C.8, but shows the blame matrix for *primary* PM_{fine} from a scenario run. Differences between Table C.16.2 and Table C.16.3 are due to the "advection scheme effect". Figure 11.1 compares the results for each country. The differences are small, but the scenario runs slightly overestimate the contributions of countries to itself (order of magnitude 2-7% differences).

11.3 Chemical mechanisms – EmChem19a and EmChem19X

The EmChem19a scheme (Bergström 2020) is a small update of the EmChem19 scheme introduced in Simpson et al. (2019). EmChem19a is slightly simplified compared to EmChem19, including four fewer advected species and one less peroxy radical species. These simplifications were based on results from box model simulation tests at varying conditions and include the following:

- Simplified C5DICAROOH + OH chemistry leading to the removal of C5134CO2OH and C54CO from the scheme.

- Replacing PRRO2H by ACETOL.

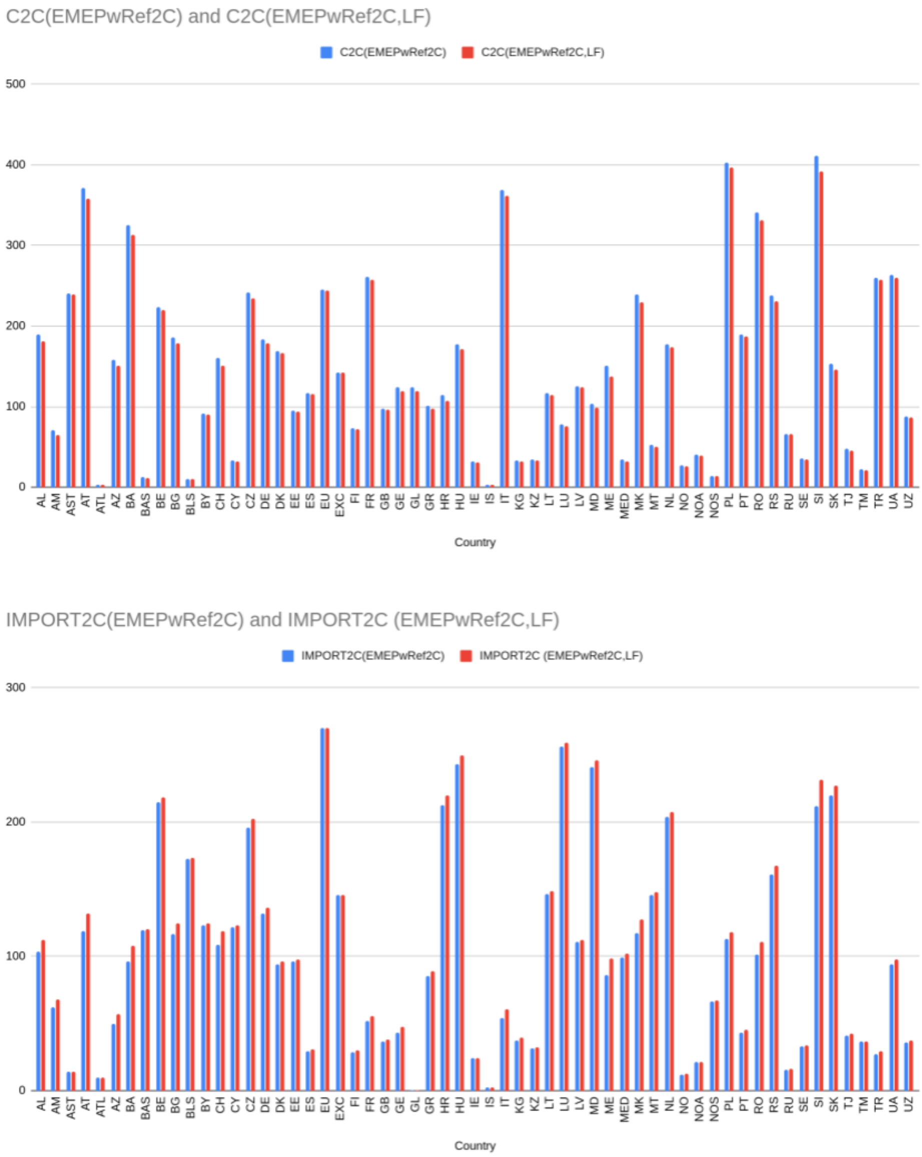

Figure 11.1: Country to country contribution (C2C) and import from all other countries (IMPORT2C) for $PPM_{2.5}$ using the brute force methodology and the local fraction methodology (LF), both with EMEPwRef2C emissions, see chapter 3.Units: ngm^{-3}

- Replacing methyl vinyl ketone (MVK) by the model species MACR in the simple monoterpene (APINENE) chemistry. This was made to be consistent with the isoprene chemistry, which already uses this simplification in EmChem19.

In addition, the following updates were made in EmChem19a:

- A bug in the wet deposition parameters for the gas phase fraction of volatility basis set (VBS) species, that was introduced in EmChem19, was corrected.
- Wet deposition of peroxy acetic acid (CH_3CO_3H) was added in EmChem19a.
- The reaction rates for α-pinene+OH and α-pinene+O_3 were updated to the latest IUPAC recommendations.

A much larger version of EmChem — denoted EmChem19X — has also been introduced. The EmChem19X has a more detailed description of aromatic chemistry and extended isoprene and monoterpene chemistries (including MVK as a separate species). It also includes more organic nitrates (including four additional peroxy acyl nitrates and a number of nitrate containing peroxy radicals) and a number of other additions. The EmChem19X is mainly intended for use in research projects and not for the regular EMEP source-receptor modelling.

A manuscript including a detailed description of the new chemical schemes (EmChem19a, EmChem19X, CRIv2R5Em, CB6r2Em), and evaluation of European and global scale EMEP model results against ambient measurements, and comparison to the GenChem version of the Master Chemical Mechanism (MCMv3.3Em) in box model simulations, is currently being prepared for submission (Bergström 2020).

11.4 GenChem

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The EMEP model's chemical pre-processor, GenChem (Simpson et al. 2020) includes the chemical pre-processor (GenChem.py), and a simple box-model (boxChem). GenChem provides scripts and input files for converting chemical equations into differential form for use in atmospheric chemical transport models (CTMs) and/or the boxChem system. Although GenChem is primarily intended for users of the EMEP MSC-W CTM and related systems, boxChem can be run as a stand-alone chemical solver, enabling for example easy testing of chemical mechanisms against each other.

The code needed to run the GenChem system is released as open-source code under the GNU license, (`https://github.com/metno/genchem`), with the user-guide provided at `https://genchem.readthedocs.io`. Simpson et al. (2020) presents an outline of the usage of the GenChem system, explaining input and output files, and along with Bergström (2020) presents some examples of usage.

11.5 Emission speciation

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The emissions speciation of NMVOC and primary PM (PPM) were updated for the EmChem19a scheme to reflect recent data available from the latest TNO/CAMS inventories (see chap. 5, also Granier et al. 2019). For NMVOC the main changes have been:

1. Use TNO NMVOC speciation

   TNO provided NMVOC speciation data for 25 compounds from each GNFR_CAMS category, as part of the CAMS-REG-v3.1.2 database, which were then mapped to the EmChem19a species.

2. Improve country-specific road transport estimates

   TNO provided country-specific fractions of the four road-traffic sectors in the CAMS-REG-AP_v2.2.1 inventory for 2015, specifically F1=gasoline exhaust, F2=diesel exhaust, F3=LPG exhaust, and F4=non-exhaust emissions. These were also aggregated to form country-specific NMVOC splits for the generic GNFR F category (road transport).

Table 11.2: Evaluation statistics for the model version used in this Report (rv4_35), run with 2017 emissions and meteorology (same setup as in Report 1/2019), against observations in 2017. Annual averages over all EMEP sites with measurements. N_{stat}= number of stations, wd=wet deposition, cp= concentration in precipitation, Corr. = spatial correlation coefficient, RMSE = root mean square error, IOA = index of agreement. The requirement for data completeness is 75 and 25% days with measurements for air concentrations and wet depositions/concentrations respectively.

Component	N_{stat}	Obs.	Mod.	Bias (%)	RMSE	Corr.	IOA
NO_2 (μg(N) m^{-3})	67	1.77	1.52	-14	0.81	0.84	0.91
SO_2 (μg(S) m^{-3})	59	0.41	0.33	-19	0.66	0.57	0.63
SO_4^{2-}, sea salt corrected (μg(S) m^{-3})	29	0.36	0.21	-40	0.23	0.76	0.74
SO_4^{2-}, including sea salt (μg(S) m^{-3})	34	0.46	0.29	-36	0.25	0.77	0.72
NO_3^- (μg(N) m^{-3})	26	0.26	0.28	9	0.12	0.81	0.89
HNO_3 (μg(N) m^{-3})	17	0.12	0.10	-17	0.08	0.54	0.68
NO_3^-+HNO_3 (μg(N) m^{-3})	37	0.42	0.42	-1	0.09	0.91	0.95
NH_3 (μg(N) m^{-3})	22	0.53	0.65	24	0.38	0.84	0.89
NH_4^+ (μg(N) m^{-3})	26	0.45	0.38	-16	0.25	0.67	0.81
NH_3+NH_4^+ (μg(N) m^{-3})	33	1.13	1.70	51	2.41	0.48	0.41
SO_4^{2-} wd (mg(S)m^{-2})	52	9116	6658	-27	100	0.63	0.75
SO_4^{2-} cp (mg(S)l^{-1})	52	0.25	0.16	-35	0.17	0.66	0.68
NH_4^+ wd (mg(N)m^{-2})	51	12646	15004	19	164	0.70	0.81
NH_4^+ cp (mg(N)l^{-1})	51	0.35	0.39	13	0.21	0.57	0.73
NO_3^- wd (mg(N)m^{-2})	53	10394	10401	0	87	0.79	0.89
NO_3^- cp (mg(N)l^{-1})	43	0.30	0.27	-12	0.24	0.46	0.58
Ozone daily max (ppb)	115	40.37	40.72	1	3.10	0.80	0.86
Ozone daily mean (ppb)	115	31.40	33.84	8	4.85	0.69	0.73
PM_{10} (μg m^{-3})	30	12.73	10.76	-15	3.54	0.74	0.81
$PM_{2.5}$ (μg m^{-3})	25	7.45	6.47	-13	2.36	0.76	0.84

For $PM_{2.5}$ and PM_{10}, we made use of country-data generated by TNO for the TFMM Euro-DeltaCarb simulations, which gave EC, OM (named OC in the files), Na, SO4 and other compounds, as well as the fraction of modern carbon in the GNFR-C categories. These data were aggregated to the EMEP models EC, OM, and remPPM compounds. Data were provided for both the Ref1 and Ref2 cases (see Chap. 5), and we assume that Ref1 data are appropriate for modelling with officially submitted emissions, and Ref2 data appropriate for modelling when Ref2 emissions are used (e.g. for the **EMEPwRef2C** simulations discussed in Chapters 2–6).

11.6 Emission inputs

The main change in emissions treatment has not been in the model code itself, but in the use of the Ref2 inventory as described in chapters 5.2 and 6.

Table 11.3: As Table 11.2, but for EMEP run (with officially reported emissions) for 2018 against EMEP observations in 2018.

Component	N_{stat}	Obs.	Mod.	Bias (%)	RMSE	Corr.	IOA
NO_2 (μg(N) m^{-3})	73	1.71	1.50	-13	0.68	0.87	0.92
SO_2 (μg(S) m^{-3})	57	0.30	0.26	-13	0.21	0.63	0.78
SO_4^{2-}, sea salt corrected (μg(S) m^{-3})	24	0.38	0.21	-44	0.24	0.87	0.69
SO_4^{2-}, including sea salt (μg(S) m^{-3})	32	0.48	0.29	-39	0.24	0.87	0.71
NO_3^- (μg(N) m^{-3})	25	0.27	0.31	14	0.12	0.78	0.87
HNO_3 (μg(N) m^{-3})	17	0.12	0.10	-18	0.08	0.54	0.68
NO_3^-+HNO_3 (μg(N) m^{-3})	34	0.42	0.42	0	0.08	0.94	0.97
NH_3 (μg(N) m^{-3})	20	0.64	0.68	7	0.29	0.91	0.95
NH_4^+ (μg(N) m^{-3})	26	0.50	0.42	-16	0.20	0.78	0.86
NH_3+NH_4^+ (μg(N) m^{-3})	31	1.28	1.59	24	1.47	0.70	0.69
SO_4^{2-} wd (mg(S)m^{-2})	43	9587	6149	-36	253	0.76	0.61
SO_4^{2-} cp (mg(S)l^{-1})	43	0.30	0.19	-38	0.27	0.60	0.55
NH_4^+ wd (mg(N)m^{-2})	42	11065	11623	5	185	0.62	0.78
NH_4^+ cp (mg(N)l^{-1})	42	0.38	0.38	0	0.20	0.62	0.78
NO_3^- wd (mg(N)m^{-2})	43	9003	8342	-7	156	0.58	0.73
NO_3^- cp (mg(N)l^{-1})	43	0.30	0.26	-12	0.24	0.46	0.58
Ozone daily max (ppb)	117	42.60	41.51	-3	3.00	0.82	0.85
Ozone daily mean (ppb)	117	33.00	34.41	4	4.15	0.72	0.76
PM_{10} (μg m^{-3})	31	14.09	10.49	-26	4.65	0.68	0.69
$PM_{2.5}$ (μg m^{-3})	26	8.28	6.66	-20	2.84	0.76	0.82

11.7 Documentation of model performance

In Tables 11.2-11.5 the changes in the model performance due to the model version and emission input updates, described in 2.3 and in Section 11.5, are documented. Table 11.2 provides the comparison statistics for model version rv4_35 run for the year 2017 (using the same setup - emissions and meteorology - as in EMEP Status Report 1/2019) with EMEP observations in 2017. Comparison with the evaluation results of rv4_33 model version for 2017, reported in 2019 ((Gauss et al. 2020b), (Gauss et al. 2020a), and (Tsyro et al. 2020)), shows that the differences due to the model version update are only minor. The main effects are due to bug correction in the MARS thermodynamic equilibrium module, which caused small (within few percent) changes in nitrogen and ammonium components. The largest effect (6-7% higher concentrations in rv4_35 run) is seen for PM and is due to the changes in ammonium nitrate and coarse nitrate.

Furthermore, Tables 11.3, 11.4 and 11.5 show the evaluation statistics of model results against EMEP 2018 observations for a series of model test runs for 2018: EMEP run (with officially submitted emissions), EMEPwRef2C run using old speciation for NMVOCs and EMEPwRef2C run using old speciation for PM emissions. The emission input updates appear to effect only limited number of components, and most of the changes in performance statistics are negligibly small. These statistics can be compared with the evaluation of the EMEPwRef2C run for 2018 (Appendix E), reported in 'Supplementary material to EMEP Status Report 1/2020' (Gauss et al. (2020b), Gauss et al. (2020a), and Tsyro et al. (2020)).

Table 11.4: As Table 11.3, but for EMEPwRef2C run with old NMVOC speciation

Component	N_{stat}	Obs.	Mod.	Bias (%)	RMSE	Corr.	IOA
NO_2 (μg(N) m^{-3})	73	1.71	1.49	-13	0.68	0.87	0.92
SO_2 (μg(S) m^{-3})	57	0.30	0.26	-13	0.21	0.63	0.78
SO_4^{2-}, sea salt corrected (μg(S) m^{-3})	24	0.38	0.21	-44	0.24	0.87	0.69
SO_4^{2-}, including sea salt (μg(S) m^{-3})	32	0.48	0.29	-39	0.24	0.87	0.71
NO_3^- (μg(N) m^{-3})	25	0.27	0.31	14	0.12	0.78	0.87
HNO_3 (μg(N) m^{-3})	17	0.12	0.10	-17	0.08	0.54	0.68
NO_3^-+HNO_3 (μg(N) m^{-3})	34	0.42	0.43	1	0.08	0.94	0.97
NH_3 (μg(N) m^{-3})	20	0.64	0.68	7	0.29	0.91	0.95
NH_4^+ (μg(N) m^{-3})	26	0.50	0.42	-16	0.20	0.78	0.86
NH_3+NH_4^+ (μg(N) m^{-3})	31	1.28	1.59	24	1.47	0.70	0.69
SO_4^{2-} wd (mg(S)m^{-2})	43	9587	6151	-36	253	0.76	0.61
SO_4^{2-} cp (mg(S)l^{-1})	43	0.30	0.19	-38	0.27	0.60	0.55
NH_4^+ wd (mg(N)m^{-2})	42	11065	11624	5	185	0.62	0.78
NH_4^+ cp (mg(N)l^{-1})	42	0.38	0.38	0	0.20	0.62	0.78
NO_3^- wd (mg(N)m^{-2})	43	9003	8363	-7	156	0.58	0.73
NO_3^- cp (mg(N)l^{-1})	43	0.30	0.27	-12	0.24	0.46	0.58
Ozone daily max (ppb)	117	42.60	41.57	-2	3.00	0.82	0.85
Ozone daily mean (ppb)	117	33.00	34.47	4	4.19	0.72	0.76
PM_{10} (μg m^{-3})	31	14.09	10.45	-26	4.68	0.68	0.69
$PM_{2.5}$ (μg m^{-3})	26	8.28	6.62	-20	2.86	0.76	0.82

Table 11.5: As Table 11.3, but for EMEPwRef2C run with old PM speciation

Component	N_{stat}	Obs.	Mod.	Bias (%)	RMSE	Corr.	IOA
NO_2 (μg(N) m^{-3})	73	1.71	1.50	-12	0.68	0.87	0.92
SO_2 (μg(S) m^{-3})	57	0.30	0.26	-13	0.21	0.63	0.78
SO_4^{2-}, sea salt corrected (μg(S) m^{-3})	24	0.38	0.21	-44	0.24	0.87	0.69
SO_4^{2-}, including sea salt (μg(S) m^{-3})	32	0.48	0.29	-39	0.24	0.87	0.71
NO_3^- (μg(N) m^{-3})	25	0.27	0.31	13	0.12	0.78	0.87
HNO_3 (μg(N) m^{-3})	17	0.12	0.10	-18	0.08	0.54	0.68
NO_3^-+HNO_3 (μg(N) m^{-3})	34	0.42	0.42	0	0.08	0.94	0.97
NH_3 (μg(N) m^{-3})	20	0.64	0.68	7	0.29	0.91	0.95
NH_4^+ (μg(N) m^{-3})	26	0.50	0.42	-16	0.20	0.78	0.86
NH_3+NH_4^+ (μg(N) m^{-3})	31	1.28	1.59	24	1.47	0.70	0.69
SO_4^{2-} wd (mg(S)m^{-2})	43	9587	6149	-36	253	0.76	0.61
SO_4^{2-} cp (mg(S)l^{-1})	43	0.30	0.19	-38	0.27	0.60	0.55
NH_4^+ wd (mg(N)m^{-2})	42	11065	11622	5	185	0.62	0.78
NH_4^+ cp (mg(N)l^{-1})	42	0.38	0.38	0	0.20	0.62	0.78
NO_3^- wd (mg(N)m^{-2})	43	9003	8339	-7	156	0.58	0.73
NO_3^- cp (mg(N)l^{-1})	43	0.30	0.26	-12	0.24	0.46	0.58
Ozone daily max (ppb)	117	42.60	41.52	-3	3.03	0.82	0.85
Ozone daily mean (ppb)	117	33.00	34.36	4	4.14	0.72	0.76
PM_{10} (μg m^{-3})	31	14.09	10.43	-26	4.69	0.68	0.69
$PM_{2.5}$ (μg m^{-3})	26	8.28	6.61	-20	2.88	0.76	0.81

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CHAPTER 12

Developments in the monitoring network, data quality and database infrastructure

Wenche Aas, Anne Hjellbrekke and Kjetil Tørseth

12.1 Compliance with the EMEP monitoring strategy

The monitoring obligations in EMEP were updated in 2019 and is defined in the Monitoring Strategy for 2019-2020 (UNECE (2019)).

The complexity in the monitoring program with respect to the number of variables and sites, whether parameters are a level 1 or level 2, and the required time resolution (hourly, daily, weekly), makes it challenging to assess whether a country is in compliance. CCC has developed an index to illustrate to what extent the Parties comply, how implementation compares with other countries, and how activities evolve with time.

The index is defined for level 1 parameters only, and is calculated based on the data reported in comparison with the expected. EMEP recommends one site pr 50.000 km^2, but this target number is adjusted for very large countries (i.e. KZ, RU, TR and UA). The components and number of variables to be measured in accordance to the strategy are as follows: major inorganic ions in precipitation (10 variables), major inorganic components in air (13 variables), ozone (1 variable), PM mass (2 variables) and heavy metals in precipitation (7 variables). For heavy metals, the sampling frequency is weekly, and for the other components it is daily or hourly (ozone). Based on the relative implementation of the different variables, the index has been given the following relative weights: Inorganics in precipitation: 30%, inorganics in air: 30%, ozone: 20%, PM mass: 10%, heavy metals: 10%.

Figure 12.1 summarises implementation in 2018 compared to 2000, 2005 and 2010. The countries are sorted from left to right with increasing index for 2018. Slovakia has a full score as they measure all the required parameters with satisfactory sampling frequency. Estonia, The Netherlands, Denmark, and Switzerland have almost complete program with an index of 90% or higher. Small countries generally comply better (due to more easily satisfying the

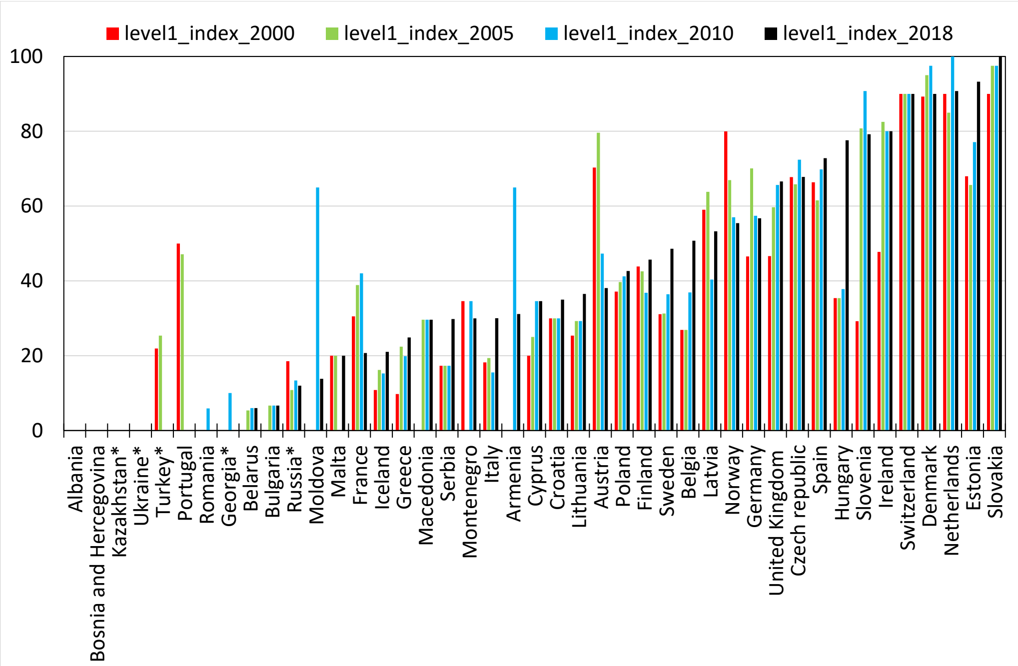
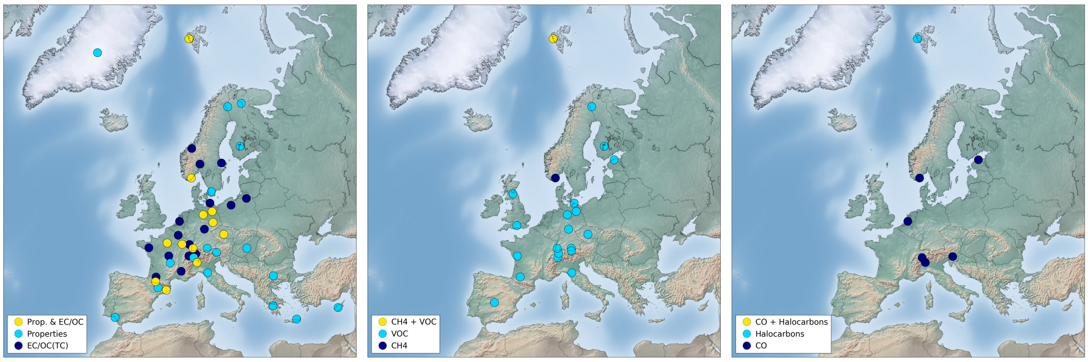


Figure 12.1: Index for implementation of the EMEP monitoring strategy, level 1 based on what has been reported for 2000, 2005, 2010 and 2018. * means adjusted land area.

site density requirements). Since 2010, 40% of the Parties have improved their monitoring programme, while 33% have a decrease. Improvements are seen in e.g. Italy, Sweden and Belgium. One Party, Malta, has reported data in 2018 and not in 2010, while Georgia and Romania have stopped reporting/measuring. In Figure 2.4 in Chapter 2.2, the geographical distribution of level 1 sites is shown for 2018. In large parts of Europe, implementation of the EMEP monitoring strategy is far from satisfactory.

For the level 2 parameters, an index has not been defined, but mapping the site distribution illustrate the compliance to the monitoring strategy. 56 sites from 21 different Parties reported at least one of the required EMEP level 2 parameters relevant to this report (aerosols (45 sites), photo-oxidants (21 sites) and atmospheric tracers (7 sites)). One should note that some of these sites have been reporting data to ACTRIS (the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases) and not to EMEP, but they have been included here in the overview since the observations are still comparable with those of EMEP. The sites with measurements of POPs and heavy metals are covered in the EMEP status report published by MSC-E (EMEP Status report 2/2020). Figure 12.2 shows that level 2 measurements of aerosols have better spatial coverage than oxidant precursors (VOC + methane) and atmospheric tracers. Few sites have a complete measurement program, and only 12 sites have a complete aerosol program. Nevertheless, regarding the aerosol monitoring, there have been large improvements in the spatial coverage and the data quality over the last decade, especially for the aerosol observations. For oxidant precursors and atmospheric tracers, there are ongoing improvement in the measurement capabilities resulting from development in ACTRIS in

co-operation with EMEP and the WMO Global Atmospheric Watch Programme (GAW), see more details in Chapter 13.



(a) Particulate matter (b) Oxidant precursors (c) Atmospheric tracers

Figure 12.2: Sites measuring and reporting EMEP level 2 parameters for the year 2018.

12.2 Updates in reporting templates and guidelines

In addition to the requirement that variables has to be measured as defined in the EMEP monitoring strategy discussed above, it is important that the data are reported in time to ensure that they can be quality assured and included in the database. This allows them to be included in the annual model validation, interpretations for the EMEP status reports, as well as other regional assessments and studies carried out beyond EMEP.

Figure 12.3 shows the status of the submission of data for 2018 and to what extent the data were reported in time. It is obvious that large volumes of data are reported late and some not at all. Of the 33 Parties reporting either level 1 or level 2 data, less than 60% reported within the deadline of 31 July 2019.

An online data submission and validation tool (`http://ebas-submit-tool.nilu.no`) was developed in 2016 improve the timeliness and quality of the data reporting. The tool is designed to give the data submitters direct feedback on the formatted NASA Ames files, and suggestions on how to correct the files. The format checker is directly linked to all (approx. 40) data format templates located at `http://ebas-submit.nilu.no/`, and it is continuously being improved and updated, after feedback from the users or when new templates are developed. Since last year there has been improvements in the testing for spikes (boundary check) and checks for flag consistency. There has also been improvement in the data curation tools and routines, i.e. a file tracking system and an issue tracker for keeping better control and trace all what is happening with the data from submission to being available in EBAS.

The requirement of checking the data files using the submission tool has significantly improved the correctness in the data files submitted, but still there are only 40% of the data, which are reported using the submission tool (or ftp), the rest is reported by e-mails. EMEP/CCC strongly encourage all the Parties to use the submission tool, which in fact is mandatory for submitting all the data to EMEP, unless otherwise have been agreed upon. In the coming years there will be further focus on improving the data submission tools to make it easier for the data provider to report correct and consistent data.

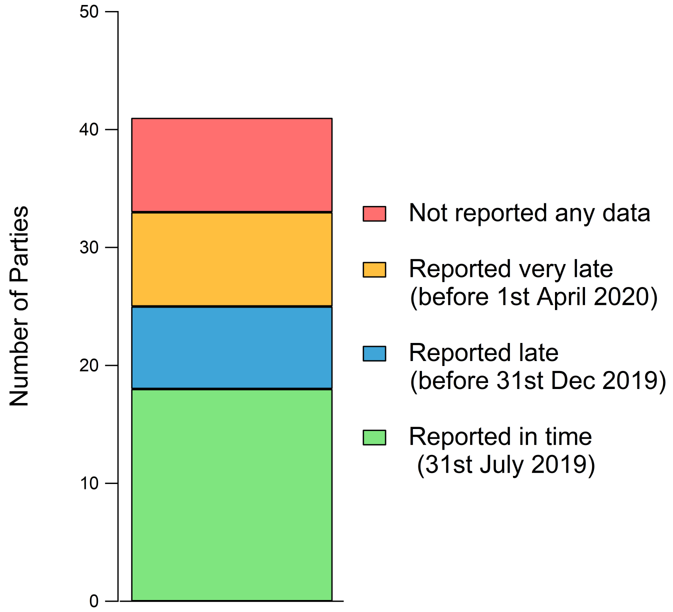


Figure 12.3: Submission of 2018 data to EMEP/CCC.

The EMEP data are extensively used. In 2009, a user statistic was implemented for the EBAS database infrastructure. The statistic counts how much data are downloaded, displayed or plotted. Figure 12.4 shows the access requests for EMEP data per year (about 300 thousand annual datasets). There was a big jump in 2013. This was the year when an automatic system for distributing all the data in EBAS to specific users was implemented.

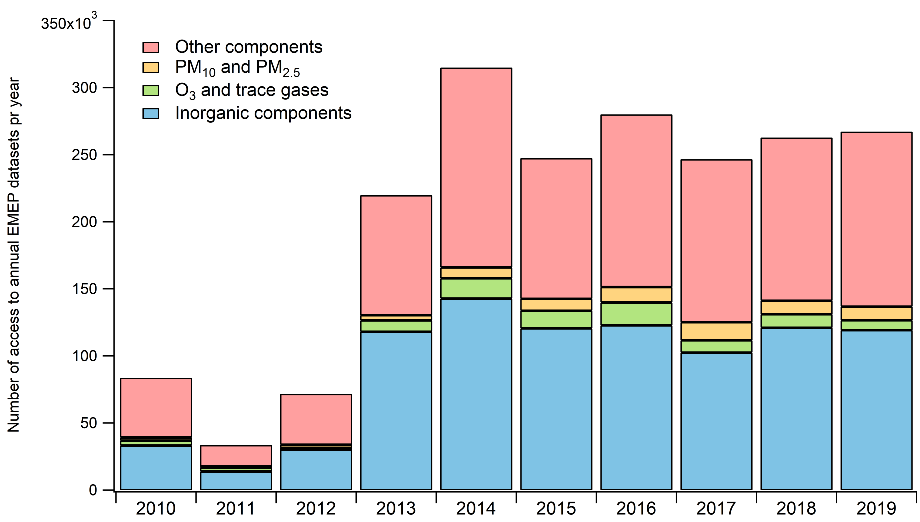


Figure 12.4: Access of EMEP data, number of annual dataset (compounds) per year.

There are ongoing work to make the access of data even more flexible to meet several of the user needs. In example using other platforms, like THREDDS (`https://thredds.nilu.no/thredds/catalog/ebas/catalog.html`) where NetCDF files are extracted from EBAS allowing faster access and the possibility to create more individual specific

defined outputs for plotting, statistics, aggregates etc. Further implementing primary DOI for data in EBAS are also being developed. The development of the database infrastructure are inline with the FAIR principles (findable, accessible,interoperable and reusable).

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CHAPTER 13

Recent Developments for Enhancing the Quality Assurance of VOCs in Europe

Stefan Reimann, Anja Claude, Matthias Hill, Sverre Solberg

13.1 Introduction

VOCs have been part of the EMEP monitoring program since the early 1990s (Solberg et al. 2019). These long-term measurements are used to track changes related to emissions and to assess the influence of VOCs on the production of secondary air pollutants, such as ozone and organic aerosols. EMEP has in recent years developed a very fruitful collaboration with ACTRIS (European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases) developing new routines for quality assurance for VOCs, resulting in improved VOC data quality. Major aspects were general improvements of the quality assurance and the development of a common measurement guideline. Furthermore, a newly developed digital tool (Atmospheric VOC Assessment Tool, @VOC@) streamlines and harmonizes the quality checks before submission. This is part of a procedure, which ensures the best possible quality for VOC data in Europe before publication at the data center.

13.2 Quality assurance principles of European VOC measurements under EMEP and ACTRIS

Since the 1950s, when VOCs were detected to act as precursors of secondary air pollutants, gas chromatography (GC) has always been the dominant analytical method for atmospheric VOCs. VOC concentrations, even in the most polluted atmosphere, are too low for direct detection with the often-used flame ionization detector (FID) or mass spectrometer (MS). Therefore, VOCs have to be preconcentrated, using adsorptive material, such as charcoal or

derivatives, often in connection with sub ambient cooling. Potential errors during sampling and analysis are many. To name a few: Adsorption on inlet lines, water interference during cold trapping, destruction due to heating when transferring the VOCs onto the GC system, non-linear behavior of the detector and last, the use of inappropriate standards for calibration. The EMEP Manual for Sampling and Analysis (EMEP 2014) provides general guidelines for performing measurements and quality checks based on statistics for measurement of VOC using off-line sampling with canisters and for oxygenated VOCs using DNPH samplers. As more and more on-line instruments are used at European measurement sites, a new guideline has been developed within ACTRIS (2014), which has been tested in an extensive intercomparison campaign, making use of both EMEP and ACTRIS sites (Hoerger et al. 2015). This work is ongoing and will be the basis for a new guideline for WMO to be published in 2020.

13.3 Recent Developments for Ensuring the Quality of VOC Data Before Submission to EBAS

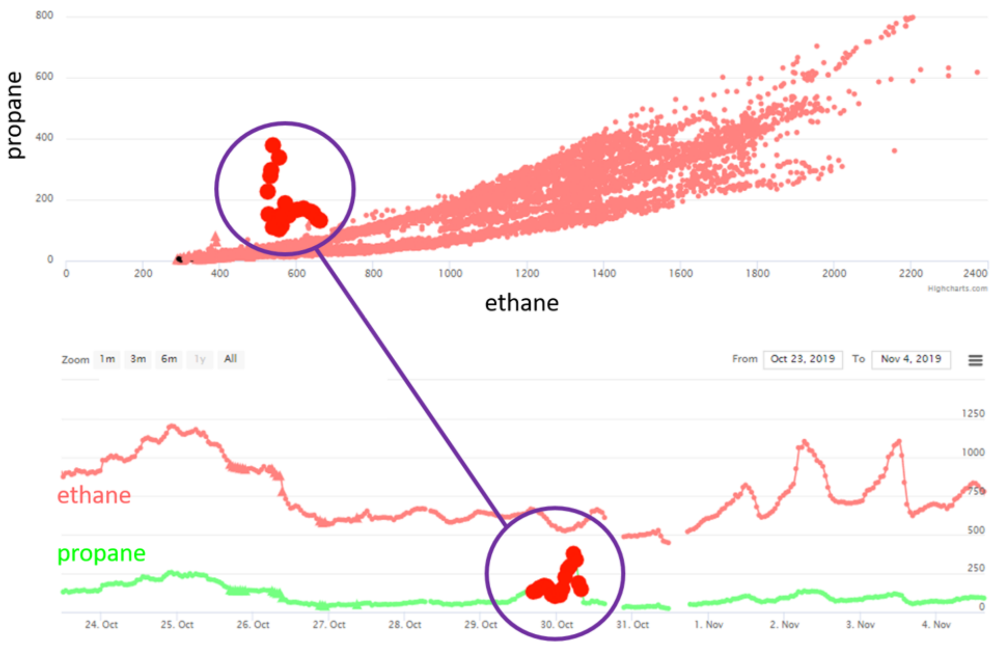

Figure 13.1: Propane vs. ethane in the @VOC@ tool. On 30 October, a local contamination lead to extraordinary behaviour in comparison to the rest of the year

Even when protocols and guidelines are followed, some erroneous data will still be present when the data is submitted for the first time. This can be due to unforeseen instrumental issues (e.g. leakage of potentially polluted indoor air, accumulation of VOCs in the lines after breakdowns and restarts) and local contamination outside of the measurement site (e.g. fires, usage of paints). In order to detect these inaccurate data, @VOC@ (ATmospheric VOC Assessment Tool; (ACTRIS 2019)), a digital tool has been developed in ACTRIS. @VOC@ makes use of the fact that during pollution events VOCs are normally highly correlated. This picks up an idea of Parrish et al. (1998), who extensively tested VOC from campaign data for consistency. @VOC@ uses these correlations to indicate obvious differences to the normal behavior of the

VOCs at a specific measurement site and also in comparison with other sites. In Figure 13.1 an example is shown, where a local pollution of propane occurs on 30 October (lower panel). By comparing propane with ethane (upper panel), the unusual behaviour becomes visible against one year of data. The propane data has subsequently been flagged as "local pollution".

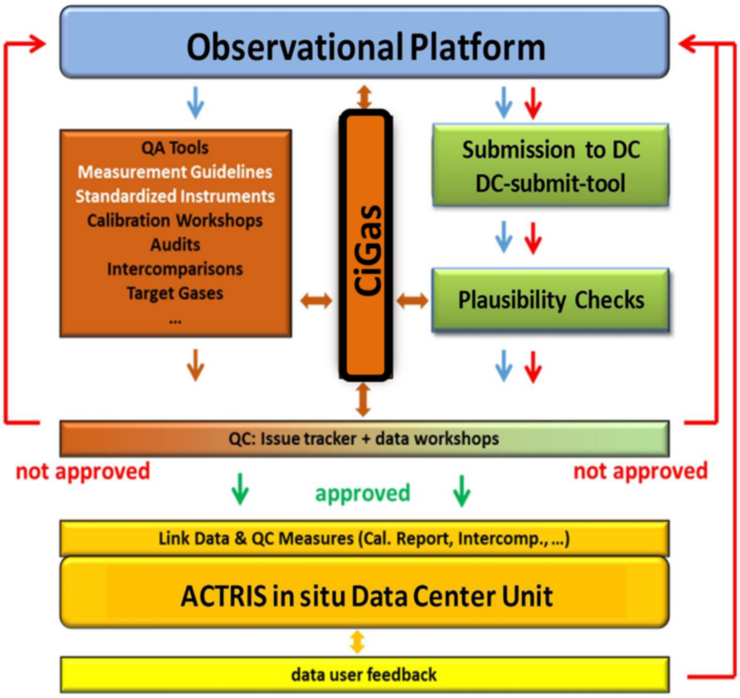

Figure 13.2: Procedure for quality checks and submission of VOC data within ACTRIS

These quality checks are a part of a wider procedure, developed within ACTRIS, to ensure a maximum of data consistency (Figure 13.2). Before the first submission, VOC data providers can already use @VOC@ for checking data. After the initial submission, members of the Centre for Reactive Trace Gases in Situ Measurements (CiGas) of ACTRIS perform the consistency checks as outlined above. Detected potential issues are reported in an "issue tracker", which automatically sends a message to the data provider, with suggestions for flagging and additional checks. After resubmission of the data, further discussions are held on-line and during a specific data quality meeting shortly before the final submission date. Finally, the commonly accepted data set is then transferred to the database.

The ACTRIS QA procedure is based on the VOC ratios in the new data. Complementary to that, the EMEP/CCC applies an additional data check routine which is based on a comparison of the concentration levels in the new data relative to data from previous years. This is done by statistical tools comparing the probability density functions of the new and old data sets and by visual inspection of plots. The aim of that routine is to detect shifts in the overall levels of the species and to identify individual outliers. One example from this check routine showing propane data at Hohenpeissenberg in 2018 compared to the previous 10 years is shown in Figure 13.3. The blue coloring indicates that the 2018 data do not differ significantly from the 2008-2017 data. When a shift in levels is found, the new data are given a red coloring. As for the ACTRIS checks, a feedback from this procedure is also given to each station via the issue tracker.

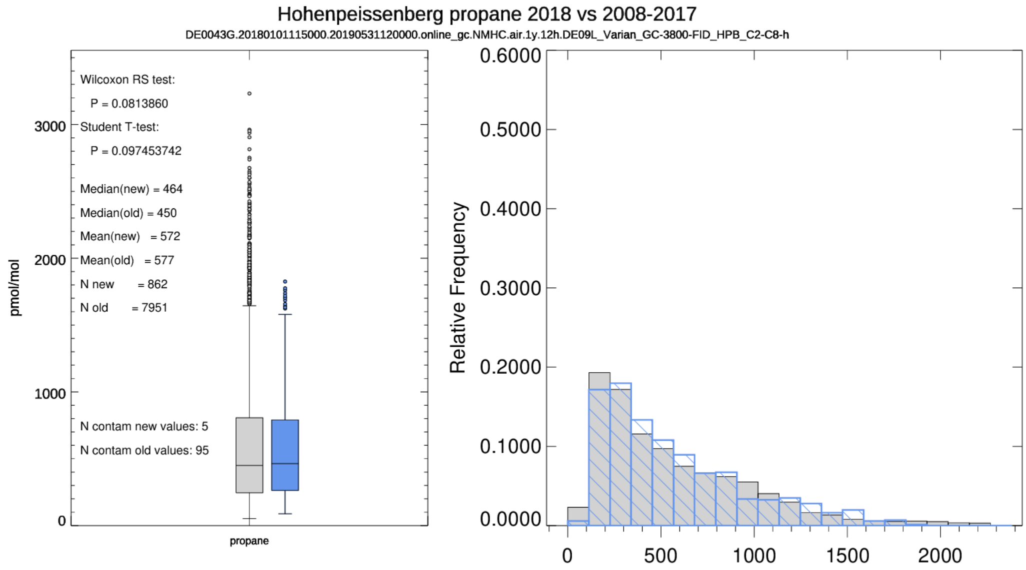

Figure 13.3: Comparison of propane from 2018 (blue) at Hohenpeissenberg with the previous 10 years of propane data (grey)

With the help of these procedures, the traceability of the data quality and the trust in the correctness of the data has been substantially increased. In the future, it is expected that also stations submitting VOC data in the framework of EMEP only could largely use the same procedure.

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Part IV

Appendices

APPENDIX A

National emissions for 2018 in the EMEP domain

This appendix contains the national emission data for 2018 used throughout this report for main pollutants and primary particle emissions in the new EMEP domain, which covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

These are the emissions that are used as basis for the 2018 source-receptor calculations. Results of these source-receptor calculations are presented in Appendix C.

The land-based emissions for 2018 have been derived from the 2020 official data submissions to UNECE CLRTAP (Pinterits et al. 2020). This year two different estimates for primary PM emissions have been used in the modeling: 1) EMEP emissions as prepared by CEIP based on the official data submissions for 2018, and 2) EMEP PM emissions where condensable organics from small-scale combustion are accounted for by using expert emission estimates for GNFR sector C from the TNO Ref2 data set. For more details please consult Chapter 6. In this report 1) is referred to as EMEP and 2) is referred to as EMEPwRef2C. National emission totals for both data sets are shown in Table A:2.

Emissions from international shipping occurring in different European seas within the EMEP domain are not reported to UNECE CLRTAP, but derived from other sources. This year's update uses the CAMS global shipping emissions (Granier et al. 2019) developed by FMI (Finnish Meteorological Institute).

Natural marine emissions of dimethyl sulphid (DMS) are calculated dynamically during the model run and vary with current meteorological conditions.

SO_x emissions from passive degassing of Italian volcanoes (Etna, Stromboli and Vulcano) are reported by Italy.

Note that emissions in this appendix are given in different units than used elsewhere in this report in order to keep consistency with the reported data.

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Table A:1: National total emissions of main pollutants for 2018 in the EMEP domain. Unit: Gg. (Emissions of SO_x and NO_x are given as $Gg(SO_2)$ and $Gg(NO_2)$, respectively.)

Area/Pollutant	SO_x	NO_x	NH_3	NMVOC	CO
Albania	6	29	27	32	75
Armenia	5	42	15	30	93
Austria	12	151	65	107	490
Azerbaijan	75	266	78	376	672
Belarus	47	143	130	281	717
Belgium	38	169	70	116	344
Bosnia and Herzegovina	143	55	21	105	253
Bulgaria	89	97	45	73	266
Croatia	10	51	36	72	235
Cyprus	17	15	7	10	12
Czechia	97	162	72	231	831
Denmark	11	106	77	120	237
Estonia	31	32	10	22	130
Finland	33	127	32	85	351
France	136	749	594	595	2514
Georgia	18	87	37	82	371
Germany	289	1202	636	1140	2938
Greece	65	255	63	150	396
Hungary	23	120	78	125	362
Iceland	55	22	5	6	110
Ireland	12	110	119	110	78
Italy	110	669	366	913	2082
Kazakhstan	2192	726	109	606	1100
Kyrgyzstan	43	66	32	47	246
Latvia	4	34	15	40	124
Liechtenstein	0	0	0	0	1
Lithuania	13	58	39	43	140
Luxembourg	1	20	6	10	21
Malta	0	6	1	3	8
Moldova	8	42	52	61	124
Monaco	0	0	0	0	1
Montenegro	27	13	6	5	12
Netherlands	25	244	129	240	549
North Macedonia	61	19	10	29	56
Norway	16	160	35	167	434
Poland	502	762	317	733	2339
Portugal	45	155	56	155	285
Romania	82	225	176	237	779
Russian Federation	1448	3243	1221	3720	12465
Serbia	346	127	79	120	250
Slovakia	20	67	30	86	301
Slovenia	5	34	19	32	99
Spain	197	698	470	624	1647
Sweden	17	126	53	134	337
Switzerland	5	66	55	80	157
Tajikistan	54	16	28	57	250
Turkey	2528	924	997	1078	1620
Turkmenistan	140	228	89	157	712
Ukraine	654	633	245	398	2809
United Kingdom	160	843	277	806	1541
Uzbekistan	257	397	189	329	1419
Asian areas	7097	7933	5207	11241	27258
North Africa	1677	1496	646	1416	2906
Baltic Sea	10	309	0	2	21
Black Sea	44	101	0	1	8
Mediterranean Sea	692	1366	0	10	94
North Sea	31	654	0	5	48
North-East Atlantic Ocean	442	848	0	6	60
Natural marine emissions	2440	0	0	0	0
Volcanic emissions	943	0	0	0	0
TOTAL	23549	27297	13171	27461	73776

Table A:2: National total emissions of particulate matter for 2018 in the EMEP domain. Unit: Gg.

Area/Pollutant	BC	$PM_{2.5}$ EMEP	PM_{co} EMEP	PM_{10} EMEP	$PM_{2.5}$ EMEPwRef2C	PM_{co} EMEPwRef2C	PM_{10} EMEPwRef2C
Albania	3	14	5	19	13	4	17
Armenia	1	9	2	11	6	2	8
Austria	5	14	12	26	65	12	77
Azerbaijan	8	35	9	44	32	9	41
Belarus	7	55	18	73	55	17	72
Belgium	3	22	10	32	25	10	35
Bosnia and Herzegovina	6	49	13	62	37	11	49
Bulgaria	4	30	17	48	34	17	51
Croatia	4	29	9	38	16	9	25
Cyprus	0	1	1	2	2	1	3
Czechia	5	39	11	51	52	11	63
Denmark	2	16	12	29	29	13	41
Estonia	2	7	4	11	17	5	21
Finland	4	18	13	31	51	13	63
France	24	134	81	216	289	84	373
Georgia	5	24	4	29	19	8	27
Germany	13	97	114	211	149	114	262
Greece	6	33	24	57	35	24	58
Hungary	6	42	21	62	33	20	54
Iceland	0	1	0	2	1	0	2
Ireland	2	12	16	28	9	15	25
Italy	19	143	34	177	166	36	202
Kazakhstan	20	142	71	213	142	71	213
Kyrgyzstan	2	15	5	20	15	5	20
Latvia	3	20	7	28	28	7	36
Liechtenstein	0	0	0	0	0	0	0
Lithuania	2	6	6	11	21	6	27
Luxembourg	0	1	1	2	1	1	2
Malta	0	0	0	1	0	0	1
Moldova	3	17	4	21	9	4	13
Monaco	0	0	0	0	0	0	0
Montenegro	1	7	2	9	5	2	7
Netherlands	2	12	10	23	24	10	35
North Macedonia	1	9	6	14	12	6	18
Norway	3	24	9	33	27	8	36
Poland	16	137	106	243	263	73	337
Portugal	6	51	20	71	56	20	75
Romania	13	111	36	146	123	35	158
Russian Federation	45	345	433	778	699	444	1143
Serbia	5	39	15	54	42	15	56
Slovakia	2	15	5	20	19	5	24
Slovenia	2	11	3	13	18	2	20
Spain	34	125	73	198	140	72	213
Sweden	2	18	19	38	39	19	58
Switzerland	1	7	8	15	13	8	21
Tajikistan	1	14	4	19	14	4	19
Turkey	34	384	169	553	413	142	555
Turkmenistan	8	24	7	31	24	7	31
Ukraine	25	280	133	413	351	133	484
United Kingdom	18	108	69	176	84	68	153
Uzbekistan	8	75	23	98	75	23	98
Asian areas	303	1918	1056	2974	1918	1056	2974
North Africa	24	155	129	284	155	129	284
Baltic Sea	4	10	0	10	10	0	10
Black Sea	3	6	0	6	6	0	6
Mediterranean Sea	40	98	0	98	98	0	98
North Sea	9	21	0	21	21	0	21
North-East Atlantic Ocean	25	63	0	63	63	0	63
Natural marine emissions	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0
TOTAL	795	5095	2858	7954	6064	2811	8875

APPENDIX B

National emission trends

This appendix contains trends of national emission data for main pollutants and primary particle emissions for the years 2000–2018 in the EMEP domain, which covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

The land-based emissions for 2000–2017 and 2018 have been derived from the 2019 and 2020 official data submissions to UNECE CLRTAP (Pinterits et al. 2019, 2020), respectively. For primary PM in 2018, two different sets of emissions have been used: 1) EMEP emissions, and 2) EMEP PM emissions where GNFR sector C are based on expert estimates including condensable organics (the TNO Ref2 data set). In this report 1) is referred to as EMEP and 2) is referred to as EMEPwRef2C.

Emissions from international shipping occurring in different European seas within the EMEP domain are not reported to UNECE CLRTAP, but derived from other sources. This year, emissions for the sea regions are based on the CAMS global shipping emission dataset (Granier et al. 2019, ECCAD 2019) for the years 2000 to 2018, developed by the Finish Meteorological Institute using AIS (Automatic Identification System) tracking data.

Natural marine emissions of dimethyl sulphid (DMS) are calculated dynamically during the model run and vary with current meteorological conditions.

SO_x emissions from passive degassing of Italian volcanoes (Etna, Stromboli and Vulcano) are those reported by Italy. SO_x and PM emissions from volcanic eruptions of Icelandic volcanoes in the period 2000–2018 (Eyjafjallajökull in 2010 and Barðarbunga in 2014-2015) are reported by Iceland. Emissions from the eruption of Grímsvötn volcano in May 2011 are not included in the table, as the eruption event has not been included in the model simulations.

Note that emissions in this appendix are given in different units than used elsewhere in this report in order to keep consistency with the reported data.

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Table B:1: National total emission trends of sulphur (2000-2009), as used for modelling at the MSC-W (Gg of SO_2 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	34	34	36	40	41	34	34	37	29	29
Armenia	8	4	8	10	14	18	22	26	27	27
Austria	32	33	32	31	27	25	26	23	20	15
Azerbaijan	20	18	18	17	17	18	17	17	17	15
Belarus	157	151	143	131	95	79	94	100	84	80
Belgium	172	167	157	152	155	143	134	124	96	74
Bosnia and Herzegovina	121	119	131	134	134	139	155	161	179	180
Bulgaria	863	829	759	826	791	779	766	825	576	442
Croatia	59	59	63	64	52	59	55	60	54	56
Cyprus	48	45	45	47	40	38	31	29	22	18
Czechia	233	229	223	218	215	208	207	212	170	169
Denmark	32	30	28	35	29	26	30	27	21	16
Estonia	97	91	87	100	88	76	70	88	69	55
Finland	82	96	90	101	84	70	83	81	67	59
France	626	565	524	499	481	460	431	414	353	297
Georgia	12	4	4	4	4	5	3	5	8	9
Germany	646	625	561	534	492	472	472	455	451	395
Greece	532	537	525	532	528	549	505	491	423	352
Hungary	427	346	272	246	152	43	39	36	36	30
Iceland	39	42	45	42	37	43	42	61	78	73
Ireland	144	142	107	83	73	73	61	55	45	32
Italy	756	704	623	524	487	409	387	345	290	237
Kazakhstan	457	477	503	542	574	634	640	668	680	693
Kyrgyzstan	25	25	25	25	25	25	27	30	33	35
Latvia	18	14	13	11	9	8	8	8	7	6
Lithuania	37	41	37	27	27	28	26	22	20	19
Luxembourg	3	4	3	3	2	2	3	2	2	2
Malta	10	11	10	11	11	12	12	12	10	7
Moldova	4	4	5	6	5	5	5	3	8	10
Montenegro	14	11	15	15	14	13	14	12	15	8
Netherlands	78	79	71	66	69	67	67	63	53	39
North Macedonia	106	108	97	95	96	97	94	99	101	96
Norway	27	25	23	23	25	24	21	19	20	15
Poland	1411	1386	1298	1268	1211	1172	1237	1174	947	811
Portugal	301	280	276	185	188	189	165	157	108	75
Romania	490	506	508	587	560	606	649	520	525	445
Russian Federation	2875	2918	2961	2931	2755	2608	2609	2270	2064	1927
Serbia	464	459	484	509	520	446	463	472	481	433
Slovakia	117	123	99	102	93	86	85	69	68	63
Slovenia	94	63	63	60	51	40	17	16	15	12
Spain	1389	1328	1470	1217	1249	1205	1074	1044	382	284
Sweden	43	41	41	42	37	36	35	31	28	27
Switzerland	16	17	15	15	15	14	13	12	12	10
Tajikistan	5	7	8	7	9	8	10	13	13	13
Turkey	2242	1982	1872	1791	1779	2003	2160	2522	2558	2662
Turkmenistan	19	17	18	19	19	19	19	20	21	21
Ukraine	2310	1844	1329	1252	1048	1192	1446	1363	1386	1290
United Kingdom	1286	1198	1077	1052	894	773	728	632	529	432
Uzbekistan	176	175	173	162	155	135	130	107	93	84
Asian areas	3193	3191	3188	3186	3183	3181	3345	3509	3674	3838
North Africa	982	1019	1056	1092	1129	1166	1187	1208	1229	1250
Baltic Sea	225	220	218	216	212	206	138	109	100	96
Black Sea	52	52	51	51	50	49	48	47	44	42
Mediterranean Sea	902	891	870	855	839	823	809	795	721	686
North Sea	450	443	432	421	415	363	300	248	231	224
North-East Atlantic Ocean	586	581	564	554	547	534	527	517	471	450
Natural marine emissions	2364	2318	2380	2232	2298	2338	2376	2352	2386	2356
Volcanic emissions	5746	4279	5300	3556	2701	1205	1308	840	973	950
TOTAL	33657	31006	31037	28558	26852	25077	25461	24660	23121	22069

Table B:2: National total emission trends of sulphur (2010-2018), as used for modelling at the MSC-W (Gg of SO_2 per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	27	25	23	21	19	17	15	13	6
Armenia	28	29	30	31	32	35	39	39	5
Austria	16	15	15	14	15	14	14	13	12
Azerbaijan	16	15	16	15	15	14	18	12	75
Belarus	59	63	68	55	53	57	56	48	47
Belgium	61	53	48	43	40	41	39	38	38
Bosnia and Herzegovina	180	178	176	174	172	171	170	170	143
Bulgaria	387	514	328	194	187	143	105	103	89
Croatia	35	29	25	17	14	16	15	13	10
Cyprus	22	21	16	14	17	13	16	16	17
Czechia	164	168	160	145	134	129	115	110	97
Denmark	15	14	13	13	11	10	10	10	11
Estonia	83	73	43	42	47	36	35	39	31
Finland	66	60	50	48	44	41	40	35	33
France	278	254	236	213	173	163	144	144	136
Georgia	11	15	14	3	6	7	10	11	18
Germany	409	395	375	366	346	343	320	315	289
Greece	205	146	120	106	89	84	72	57	65
Hungary	30	34	31	29	26	24	23	28	23
Iceland	77	84	86	72	66	61	52	50	55
Ireland	26	25	23	23	17	15	14	13	12
Italy	218	196	178	146	131	124	117	115	110
Kazakhstan	732	884	835	785	758	744	714	698	2192
Kyrgyzstan	38	39	41	42	44	45	47	48	43
Latvia	4	4	4	4	4	4	3	4	4
Lithuania	18	20	17	15	14	15	15	13	13
Luxembourg	2	1	1	2	2	1	1	1	1
Malta	8	8	8	5	5	2	2	1	0
Moldova	10	9	8	10	9	9	9	9	8
Montenegro	28	40	41	42	43	45	46	47	27
Netherlands	35	34	34	30	30	31	29	27	25
North Macedonia	91	102	96	83	83	77	65	56	61
Norway	19	19	17	17	17	17	15	15	16
Poland	875	836	803	768	724	711	591	583	502
Portugal	65	59	54	48	44	46	46	48	45
Romania	356	325	261	208	181	157	110	107	82
Russian Federation	1903	1915	1857	1828	1819	1795	1850	1663	1448
Serbia	403	458	421	436	343	416	423	420	346
Slovakia	68	67	57	52	44	67	26	27	20
Slovenia	11	13	12	14	10	5	5	5	5
Spain	244	280	279	221	243	260	217	220	197
Sweden	28	26	25	22	20	18	18	18	17
Switzerland	11	9	9	8	8	6	5	5	5
Tajikistan	13	14	15	16	17	18	18	19	54
Turkey	2557	2637	2703	1940	2149	1948	2250	2350	2528
Turkmenistan	22	23	26	26	26	26	26	27	140
Ukraine	1241	1346	1366	1449	922	854	948	839	654
United Kingdom	450	415	460	397	322	250	176	173	160
Uzbekistan	84	75	66	56	47	38	29	28	257
Asian areas	4002	4383	4728	5094	5466	5843	6235	6665	7097
North Africa	1271	1338	1378	1441	1479	1546	1564	1627	1677
Baltic Sea	89	75	75	74	73	9	9	9	10
Black Sea	45	44	44	43	43	42	41	40	44
Mediterranean Sea	696	689	682	669	614	661	648	603	692
North Sea	204	178	178	175	168	31	31	29	31
North-East Atlantic Ocean	473	469	464	455	413	449	441	403	442
Natural marine emissions	2314	2446	2368	2434	2250	2454	2390	2394	2440
Volcanic emissions	1070	943	943	943	11823	2070	943	943	943
TOTAL	21892	22632	22447	21638	31911	22267	21424	21554	23549

Table B:3: National total emission trends of nitrogen oxides (2000-2009), as used for modelling at the MSC-W (Gg of NO_2 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	18	19	20	21	25	25	24	22	22	22
Armenia	10	13	13	15	17	19	21	24	23	23
Austria	214	224	230	239	236	238	225	214	199	184
Azerbaijan	47	56	54	55	57	56	61	74	86	69
Belarus	135	135	137	140	148	171	187	181	189	189
Belgium	344	334	322	320	332	318	304	295	269	241
Bosnia and Herzegovina	35	34	34	34	33	33	33	33	33	33
Bulgaria	154	159	180	184	183	191	187	172	173	157
Croatia	88	88	91	90	89	87	87	89	84	79
Cyprus	21	21	21	22	21	21	21	21	20	20
Czechia	280	284	278	280	281	276	271	269	253	239
Denmark	227	225	222	230	214	206	205	190	174	155
Estonia	45	47	47	48	45	42	41	45	42	37
Finland	241	244	242	248	237	208	224	211	194	176
France	1618	1582	1546	1501	1465	1420	1336	1275	1178	1095
Georgia	11	14	15	16	20	26	28	32	32	31
Germany	1945	1868	1792	1736	1658	1584	1574	1504	1429	1331
Greece	412	439	436	447	451	470	474	470	447	436
Hungary	185	185	178	181	179	176	169	165	159	148
Iceland	33	30	32	31	32	29	28	31	29	28
Ireland	177	175	168	167	168	170	165	162	147	123
Italy	1487	1458	1398	1380	1335	1280	1211	1155	1069	984
Kazakhstan	366	436	448	470	515	548	581	612	625	622
Kyrgyzstan	21	22	23	24	25	26	30	33	36	39
Latvia	40	43	42	44	43	42	43	44	41	38
Lithuania	56	58	59	59	61	62	65	62	63	57
Luxembourg	41	43	43	45	54	55	48	43	39	34
Malta	9	9	9	10	10	10	10	10	10	9
Moldova	13	16	15	20	20	21	19	20	22	22
Montenegro	9	7	7	7	8	8	8	8	9	7
Netherlands	465	453	436	431	416	408	399	381	372	338
North Macedonia	43	40	38	34	36	37	37	40	39	39
Norway	224	222	217	217	215	217	216	217	211	201
Poland	852	829	798	818	840	869	890	893	863	856
Portugal	285	280	286	261	262	268	248	238	221	209
Romania	280	285	294	302	307	326	324	306	301	254
Russian Federation	3361	3455	3549	3801	3783	3745	3386	3304	3215	2953
Serbia	148	153	164	167	183	167	169	173	172	161
Slovakia	107	108	102	100	100	103	97	96	96	87
Slovenia	59	58	58	55	54	55	56	54	58	50
Spain	1356	1324	1360	1351	1383	1364	1315	1306	1098	978
Sweden	216	206	198	194	188	184	179	172	164	153
Switzerland	105	102	96	94	92	92	89	86	85	79
Tajikistan	5	5	5	5	6	6	7	8	8	8
Turkey	495	473	560	542	633	671	689	741	732	713
Turkmenistan	61	62	65	72	73	75	77	84	87	85
Ukraine	828	835	851	954	874	883	892	913	893	731
United Kingdom	2051	2000	1893	1849	1791	1777	1705	1637	1466	1273
Uzbekistan	223	222	225	221	210	200	204	202	199	195
Asian areas	3029	3193	3358	3522	3686	3850	3975	4100	4225	4349
North Africa	803	827	852	876	901	926	967	1009	1051	1092
Baltic Sea	408	400	397	392	385	378	372	369	339	323
Black Sea	122	121	120	119	118	115	113	112	104	99
Mediterranean Sea	1706	1682	1647	1625	1601	1573	1548	1524	1391	1315
North Sea	907	895	877	860	849	835	823	807	753	722
North-East Atlantic Ocean	1147	1133	1108	1090	1077	1057	1040	1023	936	885
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	27566	27633	27654	28020	28027	28001	27499	27266	26171	24778

Table B:4: National total emission trends of nitrogen oxides (2010-2018), as used for modelling at the MSC-W (Gg of NO_2 per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	22	23	23	23	24	24	25	25	29
Armenia	23	23	22	22	22	20	18	20	42
Austria	183	173	168	169	160	156	151	145	151
Azerbaijan	74	80	87	81	83	82	79	79	266
Belarus	170	171	175	166	159	145	143	143	143
Belgium	246	229	215	208	198	198	186	176	169
Bosnia and Herzegovina	32	32	32	32	31	31	31	31	55
Bulgaria	148	165	152	137	146	147	141	103	97
Croatia	71	67	62	61	57	57	56	55	51
Cyprus	19	21	22	16	17	15	15	15	15
Czechia	232	220	207	191	184	176	167	163	162
Denmark	150	141	130	125	116	114	115	112	106
Estonia	43	41	38	37	37	33	32	33	32
Finland	187	171	161	158	151	139	134	130	127
France	1077	1020	991	980	909	884	843	807	749
Georgia	33	37	39	35	36	37	37	38	87
Germany	1356	1340	1307	1309	1273	1250	1224	1188	1202
Greece	361	325	286	271	266	263	260	255	255
Hungary	145	135	127	125	123	124	117	119	120
Iceland	27	24	24	23	23	24	22	23	22
Ireland	117	105	108	109	109	112	112	110	110
Italy	967	929	871	818	800	775	751	709	669
Kazakhstan	642	648	727	738	737	773	760	756	726
Kyrgyzstan	43	44	46	48	50	51	53	55	66
Latvia	41	38	38	38	38	38	37	37	34
Lithuania	59	56	58	57	57	58	58	53	58
Luxembourg	34	34	31	28	26	22	20	18	20
Malta	9	8	9	7	7	6	6	5	6
Moldova	25	25	24	24	26	26	27	28	42
Montenegro	10	13	13	13	13	14	14	14	13
Netherlands	333	317	302	292	272	273	258	252	244
North Macedonia	38	41	40	38	29	27	27	24	19
Norway	206	207	203	196	189	178	170	163	160
Poland	888	872	836	796	747	725	742	804	762
Portugal	192	176	164	161	158	162	156	159	155
Romania	241	252	250	229	225	225	221	232	225
Russian Federation	2930	3023	3120	3172	3193	3153	3185	3239	3243
Serbia	150	163	151	153	129	146	149	148	127
Slovakia	85	77	75	73	73	72	67	66	67
Slovenia	48	48	46	44	39	35	36	35	34
Spain	921	904	870	757	774	777	741	739	698
Sweden	157	149	141	138	137	132	128	124	126
Switzerland	78	73	73	73	69	65	63	61	66
Tajikistan	8	8	8	9	9	9	10	10	16
Turkey	707	745	656	710	705	713	722	785	924
Turkmenistan	83	86	88	90	92	94	97	99	228
Ukraine	716	704	693	682	671	659	648	637	633
United Kingdom	1250	1161	1185	1125	1054	1018	928	893	843
Uzbekistan	194	191	188	185	182	179	177	174	397
Asian areas	4474	4901	5286	5695	6111	6532	6969	7450	7933
North Africa	1134	1194	1229	1285	1320	1379	1395	1452	1496
Baltic Sea	346	335	306	320	303	299	300	287	309
Black Sea	105	103	101	99	98	97	94	90	101
Mediterranean Sea	1420	1392	1377	1339	1210	1294	1258	1171	1366
North Sea	755	736	719	709	661	675	662	609	654
North-East Atlantic Ocean	953	934	928	891	799	863	840	773	848
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	24956	25127	25230	25313	25127	25577	25675	25921	27297

Table B:5: National total emission trends of ammonia (2000-2009), as used for modelling at the MSC-W (Gg of NH_3 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	29	29	28	28	27	27	26	24	24	24
Armenia	14	13	12	15	15	16	16	17	17	17
Austria	64	64	63	63	63	63	63	65	64	66
Azerbaijan	50	51	54	58	61	63	66	66	81	81
Belarus	142	137	128	120	121	135	134	144	147	150
Belgium	92	88	85	81	77	75	75	71	71	71
Bosnia and Herzegovina	17	17	17	18	18	18	18	19	19	19
Bulgaria	54	51	50	52	53	52	51	52	49	46
Croatia	45	48	46	46	49	48	45	45	42	41
Cyprus	7	8	8	8	8	7	8	8	7	7
Czechia	87	87	85	83	79	77	77	78	77	72
Denmark	97	95	94	93	92	89	85	84	83	79
Estonia	9	10	9	10	10	10	10	10	11	10
Finland	34	34	35	36	37	37	36	36	35	35
France	646	639	625	617	610	605	594	601	609	599
Georgia	34	34	35	37	36	35	30	32	33	33
Germany	662	669	654	651	640	640	642	646	649	661
Greece	66	65	65	64	67	65	63	65	62	61
Hungary	93	92	93	94	91	86	86	86	79	77
Iceland	5	5	5	5	5	5	5	5	5	5
Ireland	115	115	115	114	113	113	112	108	110	110
Italy	459	462	449	448	443	427	422	425	415	400
Kazakhstan	150	150	160	170	178	195	194	200	205	211
Kyrgyzstan	26	26	27	27	27	28	29	29	30	31
Latvia	14	15	15	15	14	15	15	16	15	16
Lithuania	27	27	29	30	30	31	32	31	30	32
Luxembourg	7	7	6	6	6	6	6	6	6	6
Malta	2	2	2	2	2	1	1	2	1	1
Moldova	23	24	25	24	23	24	24	19	19	21
Montenegro	6	5	6	6	5	4	3	3	3	3
Netherlands	176	170	163	160	158	155	158	154	140	138
North Macedonia	13	13	12	12	12	12	12	12	12	11
Norway	33	33	33	34	34	34	34	34	34	34
Poland	331	336	334	318	308	324	337	336	324	309
Portugal	77	73	71	64	64	63	61	62	60	57
Romania	186	182	187	190	203	206	205	201	198	191
Russian Federation	967	936	905	899	901	818	879	860	859	1082
Serbia	76	74	80	75	81	81	80	82	73	78
Slovakia	42	43	43	41	38	38	36	36	33	33
Slovenia	22	21	23	21	20	20	20	21	20	20
Spain	556	552	540	556	551	522	508	511	472	470
Sweden	60	59	59	59	59	58	57	57	57	54
Switzerland	60	59	58	57	57	58	58	59	59	58
Tajikistan	23	21	27	28	29	31	32	33	37	39
Turkey	557	521	479	526	518	554	566	580	541	571
Turkmenistan	22	28	26	31	34	47	54	54	56	56
Ukraine	358	378	270	242	225	260	227	213	206	187
United Kingdom	306	298	294	287	294	285	278	274	259	260
Uzbekistan	151	147	148	160	169	175	183	186	193	203
Asian areas	2361	2416	2471	2525	2580	2635	2695	2755	2815	2876
North Africa	365	380	394	409	423	438	448	458	469	479
Baltic Sea	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	9817	9811	9645	9714	9761	9810	9897	9969	9914	10190

Table B:6: National total emission trends of ammonia (2010-2018), as used for modelling at the MSC-W (Gg of NH_3 per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	24	24	24	25	25	25	24	24	27
Armenia	18	18	18	18	19	20	21	19	15
Austria	66	65	66	66	67	67	68	69	65
Azerbaijan	80	83	83	84	85	85	85	85	78
Belarus	151	154	157	149	141	143	136	138	130
Belgium	71	70	70	71	68	68	68	67	70
Bosnia and Herzegovina	19	19	19	20	20	20	21	21	21
Bulgaria	47	45	45	46	49	50	51	49	45
Croatia	41	42	42	36	34	39	37	38	36
Cyprus	7	7	7	6	6	6	6	6	7
Czechia	71	69	69	71	71	72	72	67	72
Denmark	80	78	77	74	75	75	75	76	77
Estonia	10	10	10	10	10	10	10	10	10
Finland	36	35	34	33	34	32	32	31	32
France	604	594	596	594	600	608	609	606	594
Georgia	33	33	36	41	35	34	33	31	37
Germany	641	671	659	677	679	689	681	673	636
Greece	64	64	62	62	60	57	57	56	63
Hungary	78	79	79	82	82	87	87	88	78
Iceland	5	5	5	5	5	5	5	5	5
Ireland	108	104	106	108	108	111	116	118	119
Italy	390	392	403	387	376	377	392	384	366
Kazakhstan	216	207	211	213	222	229	238	234	109
Kyrgyzstan	31	35	39	43	46	50	54	57	32
Latvia	16	16	16	16	17	16	16	17	15
Lithuania	31	31	31	30	31	31	30	30	39
Luxembourg	6	6	5	5	6	6	6	6	6
Malta	1	1	1	1	1	1	1	1	1
Moldova	22	21	20	19	23	23	23	23	52
Montenegro	3	3	3	3	3	2	2	2	6
Netherlands	134	131	125	124	128	129	128	132	129
North Macedonia	11	12	10	10	10	10	10	10	10
Norway	33	33	33	33	33	33	33	33	35
Poland	303	304	294	294	289	285	292	308	317
Portugal	57	57	55	53	56	57	57	58	56
Romania	175	173	172	172	169	172	168	164	176
Russian Federation	1053	1087	1120	1123	1137	1167	1180	1204	1221
Serbia	69	71	76	71	66	65	66	65	79
Slovakia	33	31	32	32	32	32	28	27	30
Slovenia	20	19	19	18	18	19	19	19	19
Spain	459	449	445	451	472	490	498	518	470
Sweden	55	54	53	54	54	54	53	53	53
Switzerland	58	57	56	56	56	56	55	55	55
Tajikistan	40	42	44	46	47	49	51	53	28
Turkey	606	643	713	755	704	673	683	740	997
Turkmenistan	56	56	57	57	57	57	59	61	89
Ukraine	251	256	261	266	271	276	281	286	245
United Kingdom	264	266	262	258	271	276	281	283	277
Uzbekistan	212	218	224	230	236	242	248	254	189
Asian areas	2936	3216	3468	3737	4010	4287	4574	4890	5207
North Africa	490	515	531	555	570	596	602	627	646
Baltic Sea	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	10284	10670	11043	11393	11685	12063	12422	12872	13171

Table B:7: National total emission trends of non-methane volatile organic compounds (2000-2009), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	23	25	26	29	32	33	33	33	33	33
Armenia	16	28	14	28	30	32	33	35	35	35
Austria	180	175	170	168	156	156	159	154	149	136
Azerbaijan	68	70	71	74	76	80	89	79	83	85
Belarus	225	215	229	308	324	349	358	367	387	362
Belgium	212	208	194	186	176	172	167	158	150	138
Bosnia and Herzegovina	52	50	49	48	46	45	44	42	41	40
Bulgaria	107	94	102	107	94	94	97	90	90	86
Croatia	104	103	106	109	114	116	116	112	109	94
Cyprus	18	19	18	20	22	22	21	21	21	19
Czechia	287	279	277	272	263	252	254	247	243	243
Denmark	169	161	156	151	147	143	140	137	133	124
Estonia	37	36	36	34	34	32	31	28	26	24
Finland	177	174	166	162	157	145	141	136	122	112
France	1644	1557	1432	1356	1268	1175	1065	966	891	801
Georgia	40	46	45	45	42	35	34	37	37	37
Germany	1638	1534	1467	1395	1402	1349	1369	1302	1242	1136
Greece	317	312	333	315	320	306	304	302	270	257
Hungary	197	199	185	188	182	172	159	155	150	150
Iceland	9	8	8	8	8	7	7	7	7	6
Ireland	122	122	122	120	120	120	120	120	116	113
Italy	1602	1537	1447	1427	1331	1348	1310	1294	1266	1188
Kazakhstan	170	175	177	187	194	205	223	245	254	267
Kyrgyzstan	20	21	23	25	26	28	32	36	39	43
Latvia	49	51	50	50	49	48	48	47	42	42
Lithuania	72	69	67	64	63	62	61	60	59	55
Luxembourg	16	15	15	14	16	15	13	12	14	12
Malta	5	5	5	5	5	4	4	4	4	4
Moldova	29	35	33	34	38	47	50	53	65	60
Montenegro	10	9	8	9	10	8	9	10	10	10
Netherlands	333	304	289	281	261	266	260	263	257	258
North Macedonia	48	40	39	39	39	37	39	39	43	43
Norway	406	416	370	326	293	243	214	210	176	160
Poland	732	705	723	702	708	721	761	733	748	748
Portugal	249	245	239	228	221	210	204	199	188	176
Romania	266	255	259	271	279	320	314	310	310	267
Russian Federation	3420	3590	3761	3635	3525	3572	3126	2948	2829	2715
Serbia	146	144	145	148	150	146	143	147	142	141
Slovakia	168	166	149	148	148	151	148	145	141	131
Slovenia	52	52	50	50	48	45	45	43	42	39
Spain	942	913	885	846	831	802	775	765	698	638
Sweden	224	218	216	217	210	209	204	198	187	182
Switzerland	147	140	128	119	110	107	104	101	99	96
Tajikistan	6	8	9	9	10	9	11	13	13	13
Turkey	1016	930	986	1009	1013	998	995	988	1002	1027
Turkmenistan	82	84	86	93	88	84	80	82	87	80
Ukraine	555	609	632	632	611	631	664	680	682	559
United Kingdom	1635	1558	1468	1351	1262	1179	1130	1089	1010	906
Uzbekistan	183	180	174	181	148	144	141	138	138	141
Asian areas	5200	5327	5454	5581	5708	5835	5936	6036	6136	6237
North Africa	1059	1058	1057	1057	1056	1055	1058	1062	1066	1069
Baltic Sea	3	3	3	3	3	3	3	3	3	3
Black Sea	1	1	1	1	1	1	1	1	1	1
Mediterranean Sea	11	11	11	11	11	11	11	10	10	10
North Sea	7	6	6	6	6	6	5	6	6	6
North-East Atlantic Ocean	8	8	7	7	7	7	7	7	7	7
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	24516	24302	24179	23890	23490	23396	22869	22507	22113	21365

Table B:8: National total emission trends of non-methane volatile organic compounds (2010-2018), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	34	35	35	36	37	37	38	39	32
Armenia	34	34	34	34	34	35	36	36	30
Austria	137	131	129	133	120	124	122	120	107
Azerbaijan	89	93	95	89	90	90	89	85	376
Belarus	308	346	347	334	330	310	291	143	281
Belgium	138	126	123	120	114	111	111	109	116
Bosnia and Herzegovina	39	38	37	36	35	35	34	33	105
Bulgaria	87	87	85	78	77	79	80	77	73
Croatia	90	84	78	73	67	68	68	63	72
Cyprus	20	14	14	13	12	12	12	12	10
Czechia	241	230	224	221	214	212	207	207	231
Denmark	122	115	112	112	104	107	103	102	120
Estonia	23	23	23	22	22	22	22	22	22
Finland	114	105	102	97	94	89	90	88	85
France	817	736	700	685	661	632	619	612	595
Georgia	38	38	37	44	42	41	41	41	82
Germany	1257	1148	1146	1102	1069	1042	1043	1069	1140
Greece	255	243	223	206	204	208	204	199	150
Hungary	146	150	152	151	141	144	142	142	125
Iceland	6	6	5	5	5	6	6	6	6
Ireland	110	107	108	111	107	107	109	113	110
Italy	1124	1033	1024	996	932	915	899	935	913
Kazakhstan	277	259	290	280	312	300	297	294	606
Kyrgyzstan	47	54	61	68	75	82	89	95	47
Latvia	40	41	42	41	42	40	38	38	40
Lithuania	55	53	53	50	49	47	46	46	43
Luxembourg	11	11	12	12	11	11	12	12	10
Malta	3	3	3	3	3	3	3	3	3
Moldova	42	44	46	43	48	48	50	51	61
Montenegro	8	9	8	8	8	8	8	8	5
Netherlands	268	265	261	257	245	253	251	252	240
North Macedonia	36	39	34	34	28	30	30	29	29
Norway	161	154	154	156	166	164	157	153	167
Poland	712	694	676	633	631	641	674	691	733
Portugal	178	169	166	165	170	170	167	168	155
Romania	261	257	255	246	242	237	237	240	237
Russian Federation	3424	3519	3624	3642	3646	3640	3665	3734	3720
Serbia	134	133	128	127	116	123	127	125	120
Slovakia	133	127	125	107	89	97	95	89	86
Slovenia	37	35	33	33	30	30	30	30	32
Spain	630	606	583	564	569	588	603	618	624
Sweden	181	174	164	160	156	154	145	147	134
Switzerland	93	90	88	86	83	80	78	78	80
Tajikistan	14	14	15	16	16	17	18	19	57
Turkey	1049	1034	1094	1039	1039	1077	1062	1099	1078
Turkmenistan	78	77	77	77	76	76	75	75	157
Ukraine	534	532	530	528	525	523	521	519	398
United Kingdom	880	861	845	818	813	815	801	809	806
Uzbekistan	139	134	130	125	121	116	112	109	329
Asian areas	6337	6941	7487	8068	8656	9254	9874	10555	11241
North Africa	1073	1129	1163	1216	1249	1305	1320	1374	1416
Baltic Sea	3	3	3	2	2	2	2	2	2
Black Sea	1	1	1	1	1	1	1	1	1
Mediterranean Sea	10	10	10	10	9	10	10	9	10
North Sea	6	6	6	6	5	6	6	5	5
North-East Atlantic Ocean	7	7	7	7	6	7	7	6	6
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	22090	22405	23006	23326	23751	24379	24975	25737	27461

Table B:9: National total emission trends of carbon monoxide (2000-2009), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	92	97	109	125	154	151	158	145	148	146
Armenia	110	104	106	120	118	116	114	112	111	110
Austria	730	710	685	693	683	618	610	579	558	538
Azerbaijan	104	112	109	112	112	118	128	130	147	152
Belarus	718	711	712	733	749	969	1070	1033	1063	990
Belgium	927	879	864	838	800	753	699	654	655	428
Bosnia and Herzegovina	181	167	153	92	96	94	93	90	86	94
Bulgaria	347	301	347	353	313	298	310	277	274	257
Croatia	451	435	417	439	416	419	391	376	324	316
Cyprus	30	29	28	29	28	27	25	24	22	20
Czechia	1075	1058	1018	1033	1020	934	939	939	886	903
Denmark	465	456	432	434	418	418	405	408	387	354
Estonia	199	200	190	183	174	155	142	158	157	156
Finland	595	595	579	556	541	509	500	481	463	440
France	6506	6146	5926	5635	5736	5240	4662	4496	4282	3816
Georgia	131	170	173	167	187	221	225	178	178	172
Germany	4833	4657	4382	4202	3964	3756	3660	3543	3434	2983
Greece	879	878	817	779	773	718	739	673	629	576
Hungary	830	839	691	817	750	682	582	540	481	521
Iceland	54	53	54	52	52	51	56	71	108	111
Ireland	246	242	230	221	216	215	198	185	177	156
Italy	4898	4575	3986	4038	3478	3510	3363	3423	3549	3155
Kazakhstan	625	631	616	663	671	720	853	1009	1082	1149
Kyrgyzstan	90	97	105	113	120	128	146	163	180	198
Latvia	261	267	254	253	241	221	218	197	180	189
Lithuania	183	182	184	178	174	176	187	192	182	174
Luxembourg	43	44	41	40	43	38	36	39	34	30
Malta	16	16	15	15	14	13	12	12	14	11
Moldova	28	29	34	50	48	49	50	44	47	46
Montenegro	40	37	34	40	40	37	36	37	35	29
Netherlands	762	760	750	744	754	735	746	734	738	687
North Macedonia	145	113	115	116	121	115	118	113	125	134
Norway	683	666	658	635	606	610	587	571	557	508
Poland	3356	3198	3194	3086	3090	3089	3228	2995	3009	2939
Portugal	690	625	600	576	546	510	479	455	417	395
Romania	750	675	703	774	864	1063	966	957	1008	906
Russian Federation	13299	13643	13988	14065	14586	14722	13201	13079	11736	10929
Serbia	401	403	404	419	436	404	359	403	367	360
Slovakia	546	563	483	509	514	557	510	506	470	412
Slovenia	188	182	178	177	166	163	154	147	143	132
Spain	2297	2102	1992	1891	1840	1757	1637	1604	1499	1353
Sweden	662	624	589	578	541	528	502	497	480	466
Switzerland	384	365	340	332	316	302	280	265	255	238
Tajikistan	50	56	65	67	77	78	87	98	88	92
Turkey	2605	2357	2420	2376	2376	2318	2350	2399	2722	2933
Turkmenistan	301	297	305	337	317	310	322	294	296	290
Ukraine	2531	2864	2888	2796	2955	2980	2841	2849	2940	2614
United Kingdom	4446	4468	3983	3628	3411	3163	2967	2754	2600	2128
Uzbekistan	740	724	704	740	594	594	580	573	568	594
Asian areas	13567	13828	14089	14349	14610	14871	14970	15069	15169	15268
North Africa	2677	2600	2524	2447	2370	2294	2275	2257	2239	2220
Baltic Sea	24	23	23	23	22	22	22	22	22	22
Black Sea	8	8	8	8	8	7	7	7	7	8
Mediterranean Sea	98	97	95	94	94	93	92	91	91	95
North Sea	57	56	56	55	54	54	53	53	54	54
North-East Atlantic Ocean	68	68	67	66	66	65	64	63	65	67
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	77023	76087	74517	73897	73465	72760	70003	69063	67535	64068

Table B:10: National total emission trends of carbon monoxide (2010-2018), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Albania	150	154	158	162	165	169	173	177	75
Armenia	109	108	107	106	105	106	108	112	93
Austria	553	525	526	566	522	540	535	529	490
Azerbaijan	161	174	183	132	134	135	127	124	672
Belarus	870	880	878	848	843	767	760	381	717
Belgium	497	395	345	519	319	372	361	293	344
Bosnia and Herzegovina	94	94	94	95	95	95	95	96	253
Bulgaria	278	276	272	250	243	240	245	242	266
Croatia	300	272	254	239	205	219	205	197	235
Cyprus	19	17	16	15	15	14	14	14	12
Czechia	927	897	883	883	843	825	820	819	831
Denmark	346	305	287	273	250	254	244	241	237
Estonia	157	132	142	134	129	129	140	138	130
Finland	454	414	407	389	383	361	368	359	351
France	4211	3535	3195	3259	2732	2688	2738	2695	2514
Georgia	173	171	158	184	183	169	177	177	371
Germany	3350	3262	2890	2862	2761	2868	2805	2832	2938
Greece	522	478	504	418	417	397	352	323	396
Hungary	523	530	546	538	460	445	437	423	362
Iceland	109	107	107	109	108	111	109	113	110
Ireland	143	131	124	118	111	108	102	88	78
Italy	3121	2477	2704	2535	2299	2344	2269	2331	2082
Kazakhstan	1252	1097	1361	1196	1520	1354	1313	1304	1100
Kyrgyzstan	215	262	310	357	404	452	499	546	246
Latvia	153	158	161	147	141	119	116	125	124
Lithuania	156	172	167	159	151	145	143	140	140
Luxembourg	29	26	27	26	25	21	22	22	21
Malta	11	10	7	7	7	6	6	6	8
Moldova	50	52	51	52	78	78	82	85	124
Montenegro	30	33	32	31	30	28	27	26	12
Netherlands	685	660	627	597	574	576	564	564	549
North Macedonia	115	120	89	90	62	65	65	57	56
Norway	520	493	485	453	433	438	434	437	434
Poland	3077	2782	2787	2658	2387	2343	2456	2543	2339
Portugal	395	363	349	329	312	320	308	325	285
Romania	897	828	835	794	796	774	779	783	779
Russian Federation	10783	11201	11705	11952	12012	11999	12172	12369	12465
Serbia	349	346	308	284	268	270	277	268	250
Slovakia	452	420	428	399	359	370	377	365	301
Slovenia	130	128	123	122	102	107	110	105	99
Spain	1421	1382	1317	1298	1313	1298	1292	1309	1647
Sweden	454	441	417	411	397	384	385	384	337
Switzerland	229	208	200	193	174	165	162	155	157
Tajikistan	89	93	97	100	104	108	112	116	250
Turkey	2900	2597	2827	2044	1961	2185	2050	2033	1620
Turkmenistan	276	274	272	269	267	264	262	259	712
Ukraine	2502	2499	2496	2493	2490	2487	2484	2481	2809
United Kingdom	2040	1855	1838	1837	1747	1707	1573	1555	1541
Uzbekistan	576	560	544	527	511	494	478	462	1419
Asian areas	15367	16833	18155	19564	20991	22440	23943	25595	27258
North Africa	2202	2318	2387	2496	2562	2678	2709	2819	2906
Baltic Sea	21	20	20	20	19	20	20	19	21
Black Sea	7	7	7	7	7	7	7	7	8
Mediterranean Sea	88	87	87	86	85	89	85	79	94
North Sea	51	50	50	50	48	50	49	45	48
North-East Atlantic Ocean	61	61	61	60	59	61	59	54	60
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	64651	63772	65408	65744	65720	67263	68606	70148	73776

Table B:11: National total emission trends of fine particulate matter (2000-2009), as used for modelling at the MSC-W (Gg of $PM_{2.5}$ per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	9	9	10	13	14	13	14	13	13	14
Armenia	4	4	4	4	4	4	4	4	4	4
Austria	25	25	24	24	24	22	21	20	20	19
Azerbaijan	5	5	5	5	5	5	5	7	6	6
Belarus	25	25	26	28	37	46	52	52	54	52
Belgium	41	39	37	37	37	35	36	34	34	30
Bosnia and Herzegovina	16	17	18	19	20	20	19	18	17	16
Bulgaria	26	24	29	31	31	31	33	31	31	29
Croatia	33	36	36	40	39	41	37	34	32	31
Cyprus	3	2	2	2	2	2	2	2	2	2
Czechia	49	50	47	47	46	43	44	42	41	42
Denmark	24	24	23	25	25	26	26	29	27	25
Estonia	15	16	17	14	15	14	10	13	12	10
Finland	26	27	27	27	26	25	25	24	23	22
France	328	316	294	294	280	260	235	222	216	206
Georgia	28	26	25	23	21	19	19	19	19	20
Germany	167	162	155	151	146	139	135	129	122	115
Greece	53	56	52	50	52	50	50	49	50	49
Hungary	48	52	37	46	43	40	40	40	36	47
Iceland	1	1	1	1	2	1	2	2	2	2
Ireland	20	20	19	19	19	19	19	18	18	17
Italy	196	189	159	177	152	175	179	203	217	202
Kazakhstan	54	71	60	66	73	81	68	125	143	133
Kyrgyzstan	7	8	8	8	8	8	9	9	9	10
Latvia	22	22	22	23	25	23	23	22	21	23
Lithuania	7	7	8	7	8	8	9	9	9	8
Luxembourg	2	3	2	3	3	2	2	2	2	2
Malta	1	1	1	1	1	1	1	1	1	0
Moldova	4	4	4	5	4	4	5	4	4	4
Montenegro	4	4	5	5	5	5	5	5	6	4
Netherlands	30	28	27	26	25	24	24	23	21	19
North Macedonia	30	18	19	29	31	28	27	21	25	19
Norway	43	42	43	40	39	39	37	37	36	35
Poland	159	159	159	157	161	160	164	158	155	148
Portugal	74	71	71	67	68	67	63	62	59	56
Romania	103	84	87	103	116	120	115	114	133	126
Russian Federation	492	483	475	438	478	442	517	530	423	412
Serbia	40	40	41	42	42	40	37	41	37	43
Slovakia	41	41	30	30	28	34	30	27	24	22
Slovenia	11	11	12	12	13	13	13	13	14	13
Spain	140	130	131	133	132	132	128	128	117	118
Sweden	33	32	31	32	31	31	29	29	27	26
Switzerland	11	10	10	10	10	9	9	9	9	8
Tajikistan	2	1	2	2	2	3	3	3	3	4
Turkey	384	372	359	348	351	354	357	360	362	365
Turkmenistan	8	8	10	12	12	12	15	12	12	15
Ukraine	121	138	140	137	152	153	147	146	162	139
United Kingdom	148	147	131	132	128	126	124	117	116	111
Uzbekistan	15	15	17	15	16	16	17	18	17	19
Asian areas	839	864	889	914	939	964	988	1011	1034	1058
North Africa	93	95	98	100	102	104	107	109	112	115
Baltic Sea	29	29	28	28	28	27	21	18	17	16
Black Sea	7	7	7	7	7	7	7	7	6	6
Mediterranean Sea	117	116	113	112	111	109	108	106	96	94
North Sea	61	60	59	58	57	57	47	42	39	39
North-East Atlantic Ocean	76	76	74	73	73	72	71	70	60	62
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	4350	4321	4219	4253	4317	4308	4331	4393	4310	4230

Table B:12: National total emission trends of fine particulate matter (2010-2018), as used for modelling at the MSC-W (Gg of $PM_{2.5}$ per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018 EMEP	2018 EMEPwRef2C
Albania	14	14	14	15	15	15	15	15	14	13
Armenia	4	4	4	4	4	4	4	4	9	6
Austria	19	18	18	18	16	16	16	16	14	65
Azerbaijan	6	6	7	6	6	6	4	4	35	32
Belarus	46	50	52	44	44	40	39	35	55	55
Belgium	33	26	27	29	22	24	25	23	22	25
Bosnia and Herzegovina	15	15	15	15	14	14	14	14	49	37
Bulgaria	31	34	34	32	31	32	32	32	30	34
Croatia	31	28	26	24	20	21	18	17	29	16
Cyprus	2	2	1	1	1	1	1	1	1	2
Czechia	45	43	43	44	41	40	39	40	39	52
Denmark	25	23	21	21	19	21	21	20	16	29
Estonia	14	18	9	12	9	10	8	9	7	17
Finland	24	21	21	20	19	18	18	18	18	51
France	215	189	192	194	168	170	170	164	134	289
Georgia	20	20	20	19	19	17	18	17	24	19
Germany	122	117	110	109	104	104	101	99	97	149
Greece	40	34	34	30	30	28	27	26	33	35
Hungary	49	55	58	59	49	52	50	48	42	33
Iceland	2	1	2	1	2	1	1	1	1	1
Ireland	16	15	14	15	14	14	13	12	12	9
Italy	196	150	177	172	155	161	157	165	143	166
Kazakhstan	122	131	139	147	155	163	172	180	142	142
Kyrgyzstan	10	11	12	13	15	16	17	18	15	15
Latvia	19	19	20	19	18	16	16	18	20	28
Lithuania	8	8	8	8	8	7	7	7	6	21
Luxembourg	2	2	2	2	2	1	2	1	1	1
Malta	0	0	0	0	0	0	0	0	0	0
Moldova	4	5	5	5	11	11	11	11	17	9
Montenegro	4	5	5	5	5	5	5	5	7	5
Netherlands	19	18	16	16	15	15	14	14	12	24
North Macedonia	24	29	22	24	17	16	13	9	9	12
Norway	38	35	36	31	28	28	27	28	24	27
Poland	157	150	149	144	136	136	142	147	137	263
Portugal	56	57	54	52	51	51	51	51	51	56
Romania	129	119	122	114	115	110	110	112	111	123
Russian Federation	427	424	429	416	413	390	369	369	345	699
Serbia	43	42	42	37	37	38	41	39	39	42
Slovakia	25	23	24	22	17	18	19	18	15	19
Slovenia	13	13	13	13	11	12	12	11	11	18
Spain	114	114	110	106	105	105	103	105	125	140
Sweden	26	26	24	24	21	20	20	20	18	39
Switzerland	8	8	8	8	7	7	7	7	7	13
Tajikistan	3	4	4	4	4	4	5	5	14	14
Turkey	368	371	374	377	379	382	385	388	384	413
Turkmenistan	14	15	16	16	17	18	18	19	24	24
Ukraine	135	136	138	139	141	142	143	145	280	351
United Kingdom	119	107	113	114	108	109	107	107	108	84
Uzbekistan	19	20	20	21	21	22	22	23	75	75
Asian areas	1081	1184	1277	1376	1477	1579	1685	1801	1918	1918
North Africa	117	123	127	133	136	143	144	150	155	155
Baltic Sea	16	15	15	15	14	9	9	9	10	10
Black Sea	7	7	6	6	6	6	6	6	6	6
Mediterranean Sea	97	96	96	94	87	94	92	86	98	98
North Sea	38	35	35	35	34	22	22	20	21	21
North-East Atlantic Ocean	65	65	64	63	58	63	62	57	63	63
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	1673	0	0	0	0	0	0	0	0	0
TOTAL	5972	4300	4425	4483	4473	4566	4650	4765	5095	6064

Table B:13: National total emission trends of particulate matter (2000-2009), as used for modelling at the MSC-W (Gg of PM_{10} per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	12	13	14	17	18	17	18	17	17	18
Armenia	5	5	5	5	5	5	5	5	5	5
Austria	38	38	37	37	37	35	34	33	32	31
Azerbaijan	11	11	12	12	13	14	14	16	14	16
Belarus	37	36	36	38	48	54	61	63	66	65
Belgium	55	53	51	52	51	47	48	45	44	39
Bosnia and Herzegovina	31	32	34	35	36	37	35	33	31	29
Bulgaria	47	44	48	54	54	57	59	62	58	51
Croatia	41	44	45	52	51	52	48	46	44	42
Cyprus	5	4	4	4	4	4	4	4	4	3
Czechia	66	66	61	61	61	58	59	57	55	55
Denmark	36	36	34	36	36	37	38	41	39	36
Estonia	32	32	28	24	25	22	16	23	19	16
Finland	40	41	42	43	42	39	41	38	37	36
France	438	424	400	400	386	361	334	319	311	296
Georgia	33	31	29	27	25	23	23	23	23	24
Germany	294	279	273	263	257	246	243	234	228	215
Greece	115	120	117	111	118	107	111	106	117	108
Hungary	72	79	61	73	75	72	64	62	65	76
Iceland	2	2	2	2	2	2	2	3	2	2
Ireland	39	40	39	40	40	41	42	41	39	38
Italy	246	239	208	225	200	219	222	245	256	237
Kazakhstan	65	86	73	80	90	100	84	164	187	171
Kyrgyzstan	11	11	11	11	12	12	12	13	13	14
Latvia	25	26	26	28	36	30	30	32	30	29
Lithuania	13	13	14	14	14	15	16	15	16	15
Luxembourg	3	3	3	4	3	3	3	3	3	3
Malta	1	1	1	1	1	1	1	1	1	0
Moldova	9	9	6	9	9	10	10	9	9	9
Montenegro	8	7	9	10	10	8	9	8	10	7
Netherlands	44	42	41	39	38	37	36	36	34	32
North Macedonia	43	28	28	42	46	41	39	31	36	28
Norway	51	51	51	49	47	48	46	47	45	43
Poland	274	278	280	275	279	284	295	279	274	261
Portugal	109	121	125	108	109	108	108	97	97	94
Romania	135	116	119	139	155	157	153	154	170	159
Russian Federation	717	719	721	733	801	743	775	797	637	638
Serbia	53	53	55	55	56	54	51	55	51	56
Slovakia	50	49	38	37	34	40	36	32	29	27
Slovenia	13	13	14	14	15	15	15	15	16	15
Spain	237	226	232	235	236	235	234	232	207	199
Sweden	52	51	50	51	51	51	49	49	47	45
Switzerland	18	18	18	17	17	17	17	17	17	17
Tajikistan	2	2	3	3	3	4	4	4	5	5
Turkey	718	610	744	722	690	694	749	754	749	818
Turkmenistan	9	9	11	13	14	14	17	14	14	17
Ukraine	169	185	189	190	203	207	205	206	223	199
United Kingdom	236	242	213	226	210	203	197	188	178	169
Uzbekistan	20	20	22	21	22	22	23	25	24	27
Asian areas	1302	1339	1377	1414	1451	1488	1526	1564	1601	1639
North Africa	169	172	176	180	184	188	193	199	204	210
Baltic Sea	29	29	28	28	28	27	21	18	17	16
Black Sea	7	7	7	7	7	7	7	7	6	6
Mediterranean Sea	117	116	113	112	111	109	108	106	96	94
North Sea	61	60	59	58	57	57	47	42	39	39
North-East Atlantic Ocean	76	76	74	73	73	72	71	70	60	62
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	6542	6461	6513	6609	6694	6651	6708	6798	6654	6601

Table B:14: National total emission trends of particulate matter (2010-2018), as used for modelling at the MSC-W (Gg of PM_{10} per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018 EMEP	2018 EMEPwRef2C
Albania	18	18	18	19	19	19	19	19	19	17
Armenia	5	5	5	6	6	6	6	6	11	8
Austria	31	30	30	30	29	28	28	28	26	77
Azerbaijan	16	14	15	16	15	15	13	13	44	41
Belarus	58	63	68	55	55	51	48	59	73	72
Belgium	42	35	37	38	32	34	35	33	32	35
Bosnia and Herzegovina	27	27	27	26	26	26	26	26	62	49
Bulgaria	53	57	56	52	52	55	48	47	48	51
Croatia	40	37	35	32	28	29	27	25	38	25
Cyprus	3	3	2	2	2	2	2	2	2	3
Czechia	57	55	55	55	52	52	50	51	51	63
Denmark	36	34	32	32	30	31	31	31	29	41
Estonia	23	34	14	20	15	15	12	14	11	21
Finland	38	35	33	32	31	29	30	29	31	63
France	306	281	284	284	256	258	258	254	216	373
Georgia	24	24	24	23	23	22	22	22	29	27
Germany	229	228	220	222	217	214	203	206	211	262
Greece	85	65	62	59	61	56	57	56	57	58
Hungary	72	74	73	78	73	74	71	69	62	54
Iceland	2	2	2	2	2	2	2	2	2	2
Ireland	35	29	29	29	28	28	28	27	28	25
Italy	231	184	209	204	187	193	189	196	177	202
Kazakhstan	160	172	184	196	208	220	232	244	213	213
Kyrgyzstan	14	15	16	17	18	19	20	21	20	20
Latvia	25	28	28	26	26	26	24	25	28	36
Lithuania	15	15	15	15	15	14	14	14	11	27
Luxembourg	2	2	2	2	2	2	2	2	2	2
Malta	1	1	1	1	1	0	0	0	1	1
Moldova	10	10	10	10	16	16	16	17	21	13
Montenegro	8	12	12	12	12	12	12	12	9	7
Netherlands	31	31	29	29	28	28	27	27	23	35
North Macedonia	34	41	35	37	28	25	22	16	14	18
Norway	46	43	45	39	36	36	36	37	33	36
Poland	275	257	255	245	232	232	241	246	243	337
Portugal	88	93	85	74	68	69	71	73	71	75
Romania	164	155	158	149	150	145	144	143	146	158
Russian Federation	881	880	891	872	870	837	809	809	778	1143
Serbia	56	56	55	51	50	52	55	53	54	56
Slovakia	29	27	28	26	21	23	24	23	20	24
Slovenia	15	15	14	14	12	13	13	13	13	20
Spain	191	189	181	174	173	174	173	172	198	213
Sweden	45	46	42	44	40	39	40	40	38	58
Switzerland	17	16	16	16	15	15	15	15	15	21
Tajikistan	5	5	6	6	6	7	7	7	19	19
Turkey	907	870	889	779	551	807	721	765	553	555
Turkmenistan	17	18	18	19	20	21	21	22	31	31
Ukraine	196	199	202	205	207	210	213	216	413	484
United Kingdom	183	167	169	177	168	169	169	171	176	153
Uzbekistan	28	28	29	30	31	32	32	33	98	98
Asian areas	1677	1837	1981	2135	2291	2449	2613	2793	2974	2974
North Africa	215	226	233	244	250	262	265	275	284	284
Baltic Sea	16	15	15	15	14	9	9	9	10	10
Black Sea	7	7	6	6	6	6	6	6	6	6
Mediterranean Sea	97	96	96	94	87	94	92	86	98	98
North Sea	38	35	35	35	34	22	22	20	21	21
North-East Atlantic Ocean	65	65	64	63	58	63	62	57	63	63
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	5970	0	0	0	0	0	0	0	0	0
TOTAL	12962	7010	7177	7176	6986	7387	7429	7679	7954	8875

Table B:15: National total emission trends of coarse particulate matter (2000-2009), as used for modelling at the MSC-W (Gg of PM_{coarse} per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Albania	4	4	4	4	4	4	4	4	4	4
Armenia	1	1	1	1	1	1	1	1	1	1
Austria	14	14	13	13	13	13	13	12	13	12
Azerbaijan	6	6	7	7	7	9	9	10	8	11
Belarus	11	11	10	10	11	8	9	12	12	12
Belgium	15	15	14	14	14	12	12	11	11	9
Bosnia and Herzegovina	15	15	16	16	16	17	16	15	14	13
Bulgaria	21	21	19	22	23	26	27	31	27	22
Croatia	8	8	10	11	12	11	11	11	12	11
Cyprus	2	2	2	2	2	2	2	2	2	2
Czechia	17	16	15	14	14	15	15	15	14	13
Denmark	12	12	11	11	12	12	12	12	12	11
Estonia	17	16	11	10	9	8	7	10	7	6
Finland	14	15	15	16	15	14	15	14	14	13
France	110	108	105	106	106	101	99	97	95	90
Georgia	5	5	5	4	4	4	4	4	4	4
Germany	126	117	118	112	111	107	108	105	106	101
Greece	62	63	65	61	66	57	61	57	67	59
Hungary	24	27	24	27	32	32	24	22	29	29
Iceland	0	0	0	0	0	0	0	1	0	0
Ireland	18	20	19	21	22	22	23	23	21	21
Italy	49	51	49	48	47	45	43	41	40	35
Kazakhstan	12	16	13	14	17	18	16	40	43	38
Kyrgyzstan	4	4	3	3	3	3	4	4	4	4
Latvia	4	4	4	4	11	7	8	9	9	7
Lithuania	6	6	6	6	6	7	7	7	7	7
Luxembourg	1	1	1	1	1	1	1	1	1	1
Malta	1	1	1	1	1	0	0	0	0	0
Moldova	5	5	2	5	5	5	5	5	5	5
Montenegro	4	3	5	5	4	3	4	3	4	3
Netherlands	14	14	14	13	13	13	13	13	13	13
North Macedonia	14	9	9	13	14	13	12	10	11	9
Norway	8	8	8	8	8	9	9	9	8	8
Poland	114	119	121	118	119	124	130	121	119	113
Portugal	36	50	54	41	41	41	45	36	38	39
Romania	31	32	32	36	39	37	37	40	37	34
Russian Federation	225	236	247	295	323	300	258	266	214	226
Serbia	13	13	14	13	14	14	14	14	14	13
Slovakia	8	8	8	7	7	6	6	5	5	5
Slovenia	2	2	2	2	2	2	2	2	2	2
Spain	97	97	100	102	104	104	106	104	90	81
Sweden	19	19	19	19	20	20	20	20	19	18
Switzerland	8	8	8	8	8	8	8	8	8	8
Tajikistan	1	1	1	1	1	1	1	1	1	2
Turkey	334	238	385	374	339	340	392	394	386	452
Turkmenistan	1	1	1	2	2	2	2	2	2	2
Ukraine	48	47	49	53	51	53	59	60	61	60
United Kingdom	88	95	82	94	82	77	74	70	63	58
Uzbekistan	5	5	5	6	6	6	6	7	7	8
Asian areas	463	476	488	500	512	524	538	553	567	581
North Africa	75	77	79	80	82	84	87	89	92	95
Baltic Sea	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0
TOTAL	2192	2139	2294	2357	2377	2343	2377	2405	2344	2370

Table B:16: National total emission trends of coarse particulate matter (2010-2018), as used for modelling at the MSC-W (Gg of PM_{coarse} per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018 EMEP	2018 EMEPwRef2C
Albania	4	4	4	4	4	4	4	4	5	4
Armenia	1	1	1	2	2	2	2	2	2	2
Austria	12	12	12	12	12	12	12	12	12	12
Azerbaijan	9	8	8	10	10	9	9	8	9	9
Belarus	13	13	15	12	11	11	9	24	18	17
Belgium	10	9	9	10	9	10	10	10	10	10
Bosnia and Herzegovina	12	12	12	12	12	12	12	12	13	11
Bulgaria	22	23	22	20	21	24	16	15	17	17
Croatia	9	9	9	8	8	9	8	9	9	9
Cyprus	2	1	1	1	1	1	1	1	1	1
Czechia	13	12	12	12	12	12	11	11	11	11
Denmark	11	11	11	11	11	11	11	11	12	13
Estonia	9	16	5	8	6	5	4	5	4	5
Finland	14	14	13	12	12	12	12	11	13	13
France	91	92	91	91	88	88	88	90	81	84
Georgia	4	4	4	4	4	4	4	5	4	8
Germany	107	111	110	113	113	111	103	107	114	114
Greece	44	31	28	29	31	28	30	30	24	24
Hungary	22	19	15	19	23	22	21	21	21	20
Iceland	0	0	0	0	0	0	0	0	0	0
Ireland	19	15	15	15	14	15	15	15	16	15
Italy	34	34	32	32	31	31	31	31	34	36
Kazakhstan	38	41	45	49	53	57	61	64	71	71
Kyrgyzstan	4	4	4	4	4	3	3	3	5	5
Latvia	7	9	8	8	8	9	8	7	7	7
Lithuania	7	7	7	7	7	7	7	7	6	6
Luxembourg	1	1	1	1	1	1	1	1	1	1
Malta	0	0	0	0	0	0	0	0	0	0
Moldova	5	5	5	5	5	5	5	5	4	4
Montenegro	4	7	7	7	7	7	8	8	2	2
Netherlands	13	13	13	13	13	13	13	13	10	10
North Macedonia	10	13	12	13	10	9	9	7	6	6
Norway	8	8	9	8	8	8	8	9	9	8
Poland	118	107	106	101	96	96	99	99	106	73
Portugal	32	37	31	22	17	18	20	22	20	20
Romania	35	36	36	35	36	35	33	31	36	35
Russian Federation	454	456	462	456	457	447	440	441	433	444
Serbia	13	14	13	13	13	14	15	14	15	15
Slovakia	5	5	5	5	5	5	5	5	5	5
Slovenia	2	2	2	2	1	1	1	2	3	2
Spain	77	75	71	67	68	69	70	67	73	72
Sweden	19	20	18	20	19	19	20	20	19	19
Switzerland	8	8	8	8	8	8	8	8	8	8
Tajikistan	2	2	2	2	2	2	2	2	4	4
Turkey	539	499	515	403	171	424	336	377	169	142
Turkmenistan	2	3	3	3	3	3	3	3	7	7
Ukraine	61	63	64	65	67	68	70	71	133	133
United Kingdom	64	60	57	63	60	61	62	64	69	68
Uzbekistan	8	9	9	9	10	10	10	11	23	23
Asian areas	596	652	704	758	814	870	928	992	1056	1056
North Africa	98	103	106	111	114	119	120	125	129	129
Baltic Sea	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	4297	0	0	0	0	0	0	0	0	0
TOTAL	6989	2710	2752	2693	2513	2821	2779	2914	2858	2811

APPENDIX C

Source-receptor tables for 2018

The source-receptor tables in this appendix are calculated for the meteorological and chemical conditions of 2018, using the EMEP MSC-W model version rv4.35. The tables are calculated for the EMEP domain covering the geographic area between 30°N-82°N latitude and 30°W-90°E longitude, and are based on model runs driven by ECMWF-IFS(cy40r1) meteorology in $0.3° \times 0.2°$ longitude-latitude projection.

The source-receptor (SR) relationships give the change in air concentrations or depositions resulting from a change in emissions from each emitter country.

Some additional emphasis this year has been put on the emission of condensable organics, and most of the tables in this appendix are based on model calculations using the *EMEP-wRef2C* dataset. However, for tables related to primary particulate matter, additional tables are provided that are based on the *EMEP* emission dataset as provided by CEIP. Details about these emission datasets are given in Chapters 3 and 6, but for a quick overview, the national emission data for 2018 can be found in Appendix A, together with the expert estimates for 2018 for PPM. The expert estimates including condensable organics in GNFR sector C (EMEPwRef2C) are described in Chapter 5. The setup of the model for the source receptor model runs are described in Chapter 6.

For each country, reductions in five different pollutants have been calculated separately, with an emission reduction of 15% for SO_x, NO_x, NH_3, NMVOC or PPM, respectively. Here, a reduction in PPM means that $PPM_{2.5}$ and PPM_{coarse} are reduced together in one simulation. For year 2018, reductions in volcanic emissions are done for passive SO_2 degassing of Italian volcanoes (Etna, Stromboli and Vulcano). The boundary conditions for all gaseous and aerosol species were given as 5-year monthly average concentrations, derived from EMEP MSC-W global runs, kept invariable over the calculation period.

The deposition tables show the contribution from one country to another. They have been calculated adding the differences obtained by a 15% reduction for all emissions in one country multiplied by a factor of 100/15, in order to arrive at total estimates.

For the concentrations and indicator tables, the differences obtained by the 15% emission reduction of the relevant pollutants are given directly. Thus, the tables should be interpreted as estimates of this reduction scenario from the chemical conditions in 2018.

The SR tables in the following aim to respond to two fundamental questions about transboundary air pollution:

1. Where do the pollutants emitted by a country or region end up?
2. Where do the pollutants in a given country or region come from?

Each column answers the first question. The numbers within a column give the change in the value of each pollutant (or indicator) for each receiver country caused by the emissions in the country given at the top of the column.

Each row answers the second question. The numbers given in each row show which emitter countries were responsible for the change in pollutants in the country given at the beginning of each row.

A list of abbreviations of countries and regions is given in Table 1.1.

More information on aerosol components and SR tables in electronic format are available from the EMEP website `www.emep.int`.

Acidification and eutrophication

- Deposition of OXS (oxidised sulphur). The contribution from SO_x, NO_x, NH_3, PPM and VOC emissions have been summed up and scaled to a 100% reduction. Units: 100 Mg of S.
- Deposition of OXN (oxidised nitrogen). The contribution from SO_x, NO_x, NH_3, PPM and VOC emissions have been summed up and scaled to a 100% reduction. Units: 100 Mg of N.
- Deposition of RDN (reduced nitrogen). The contribution from SO_x, NO_x, NH_3, PPM and VOC emissions have been summed up and scaled to a 100% reduction. Units: 100 Mg of N.

Ground Level Ozone

- $AOT40_f^{uc}$. Effect of a 15% reduction in NO_x emissions. Units: ppb.h
- $AOT40_f^{uc}$. Effect of a 15% reduction in VOC emissions. Units: ppb.h
- SOMO35. Effect of a 15% reduction in NO_x emissions. Units: ppb.d
- SOMO35. Effect of a 15% reduction in VOC emissions. Units: ppb.d

For ozone, we do not include the contributions from areas that are outside the EMEP domain. Until last year these had been included in the tables as BIC (Boundary and Initial Conditions) and were calculated by reducing NOx and NMVOC at the model boundary. However, the most important contributor to ozone from areas outside the EMEP domain is ozone itself, transported hemispherically accross the model boundary. Including the BIC contribution that is due (only) to NOx and NMVOC only would be misleading.

Particulate Matter

- $PM_{2.5}$. Effect of a 15% reduction in PPM emissions. Units: ng/m^3
- $PM_{2.5}$. Effect of a 15% reduction in SO_x emissions. Units: ng/m^3
- $PM_{2.5}$. Effect of a 15% reduction in NO_x emissions. Units: ng/m^3
- $PM_{2.5}$. Effect of a 15% reduction in NH_3 emissions. Units: ng/m^3
- $PM_{2.5}$. Effect of a 15% reduction in VOC emissions. Units: ng/m^3
- $PM_{2.5}$. Effect of a 15% reduction in all emissions. The contribution from a 15% reduction in PPM, SO_x, NO_x, NH_3 and VOC emissions have been summed up. Units: ng/m^3

Fine Elemental Carbon

- Fine EC. Effect of a 15% reduction in PPM emissions. Units: 0.1 ng/m^3

Coarse Elemental Carbon

- Coarse EC. Effect of a 15% reduction in PPM emissions. Units: 0.1 ng/m^3

Source-receptor calculations with the 15% perturbation method used the EMEPwRef2C emission data set. Additional source-receptor calculations for PM, using the official EMEP emissions for PPM, were done only with the new *Local Fraction* method. For details about this method see Section 11.2. Since the *Local Fraction* method tracks all emissions, results have been scaled by a factor of 0.15 to give comparable results for concentrations and indicator tables. Unless stated otherwise in the captions of the tables, the results are given for the model calculations using EMEPwRef2C emissions.

For EC emissions, two different emission data sets have been used: 1) Official EMEP gridded EC emissions and 2) EC derived from the EMEPwRef2C emission data, using a set of PM-split files consistent with the TNO *Ref2* data set. For details see Chapter 7.

Table C.1: 2018 country-to-country blame matrices for **oxidised sulphur** deposition.
Units: 100 Mg of S. **Emitters →, Receptors ↓**.

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	
AL	14	0	0	0	4	0	3	0	0	0	0	0	0	0	1	0	0	0	0	8	0	0	0	0	3	0	0	0	0	-0	0	2	AL
AM	0	11	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3	0	0	0	0	0	AM
AT	0	0	24	0	7	1	1	0	1	0	15	28	0	0	0	0	2	1	0	0	1	2	0	0	2	0	0	0	0	0	0	1	AT
AZ	-0	2	0	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	16	0	0	0	0	0	AZ
BA	0	0	1	0	201	0	2	0	0	0	3	2	0	0	1	0	1	0	0	1	2	3	0	0	3	0	0	0	0	0	0	11	BA
BE	-0	0	0	-0	0	39	0	0	0	0	2	18	0	0	1	0	11	4	-0	0	0	0	0	0	0	-0	0	0	0	0	-0	0	BE
BG	0	0	0	0	9	0	172	1	0	0	1	2	0	0	0	0	0	0	0	11	0	1	0	0	1	0	2	0	0	0	1	2	BG
BY	0	0	0	0	7	1	4	79	0	0	8	13	0	2	0	1	1	2	0	1	0	2	0	0	1	0	10	3	0	1	2	1	BY
CH	0	0	0	0	0	0	0	0	11	0	1	8	0	0	1	0	6	0	-0	0	0	0	0	0	2	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	CY
CZ	0	0	3	0	7	1	1	1	0	0	113	33	0	0	0	0	2	1	0	0	0	3	0	0	1	0	1	0	0	0	0	1	CZ
DE	0	-0	7	0	5	22	1	2	4	0	62	521	2	1	4	1	35	23	0	0	0	2	1	0	1	0	1	1	1	0	0	0	DE
DK	0	0	0	0	1	2	0	0	0	0	2	15	9	0	0	0	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	1	0	0	2	0	0	1	3	0	14	0	3	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	EE
ES	0	0	0	0	1	1	0	0	0	0	1	6	0	0	374	0	10	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	ES
FI	0	0	0	0	3	1	1	4	0	0	4	11	1	15	0	54	1	3	0	0	0	0	0	0	0	0	5	2	0	1	0	0	FI
FR	0	0	1	0	3	21	0	0	4	0	11	76	0	0	75	0	309	21	0	0	1	0	1	0	10	0	0	0	1	0	0	0	FR
GB	0	-0	0	-0	0	5	0	1	0	0	4	19	0	0	5	0	15	251	-0	0	0	0	6	0	0	0	0	0	0	0	0	0	GB
GE	0	2	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	0	0	0	0	0	0	0	7	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	GL
GR	1	0	0	0	5	0	24	0	0	0	1	1	0	0	1	0	1	0	0	98	0	0	0	0	5	0	1	0	0	0	0	2	GR
HR	0	0	1	0	47	0	2	0	0	0	4	4	0	0	1	0	2	0	0	2	18	4	0	0	6	-0	0	0	0	0	0	3	HR
HU	0	0	2	0	32	0	7	1	0	0	8	6	0	0	0	0	1	0	0	2	2	41	0	0	2	0	1	0	0	0	0	4	HU
IE	0	0	0	0	0	0	0	0	0	0	1	2	0	0	1	0	1	10	0	0	0	0	20	0	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	0	0	0	0	0	63	0	0	0	0	0	0	0	0	IS
IT	1	0	2	0	32	0	3	0	1	0	6	9	0	0	12	0	17	1	0	5	6	2	0	0	219	0	0	0	0	0	0	5	IT
KG	-0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	96	143	0	0	0	0	0	KG
KZ	0	2	0	26	3	0	2	3	0	1	2	4	0	2	0	1	1	1	3	1	0	0	0	0	0	75	4491	0	0	0	0	1	KZ
LT	0	0	0	0	2	0	1	7	0	0	4	7	0	1	0	1	1	1	0	0	0	1	0	0	0	0	2	14	0	1	0	0	LT
LU	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	LU
LV	0	0	0	0	2	0	0	5	0	0	3	6	0	2	0	1	1	1	0	0	0	0	0	0	0	0	2	7	0	6	0	0	LV
MD	0	0	0	0	1	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	8	0	MD
ME	1	0	0	0	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	22	ME
MK	1	0	0	0	2	0	5	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	1	0	0	0	0	0	0	1	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	-0	0	0	0	0	19	0	0	0	0	2	29	0	0	1	0	7	8	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	NL
NO	0	0	0	0	1	2	0	1	0	0	5	20	2	1	1	2	3	12	0	0	0	0	1	1	0	0	1	0	0	0	0	0	NO
PL	0	0	2	0	16	3	4	11	0	0	53	93	2	2	1	1	5	6	0	1	1	6	0	0	1	0	6	3	0	0	1	2	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	14	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	1	25	0	38	2	0	0	6	7	0	0	1	0	1	1	0	7	1	7	0	0	2	0	10	0	0	0	6	5	RO
RS	1	0	1	0	67	0	16	0	0	0	3	3	0	0	0	0	1	0	0	8	1	5	0	0	2	0	1	0	0	0	0	21	RS
RU	0	2	2	51	33	4	20	60	0	1	25	59	3	67	3	40	7	12	9	8	1	5	0	1	3	9	3530	11	0	4	5	6	RU
SE	0	0	0	0	3	3	1	4	0	0	11	33	5	5	1	11	4	10	0	0	0	1	0	0	0	0	3	3	0	1	0	0	SE
SI	0	0	2	0	6	0	1	0	0	0	2	2	0	0	0	0	1	0	0	0	4	1	0	0	2	0	0	0	0	0	0	0	SI
SK	0	0	1	0	9	0	2	0	0	0	10	5	0	0	0	0	1	0	0	1	1	8	0	0	1	0	1	0	0	0	0	1	SK
TJ	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	0	0	2	19	0	0	0	0	0	TJ
TM	-0	1	0	10	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	1	0	0	0	-0	0	0	1	66	0	0	0	0	0	TM
TR	0	3	0	8	4	0	15	1	0	12	1	1	0	0	2	0	1	0	3	12	0	1	0	0	4	0	10	0	0	0	1	1	TR
UA	0	0	1	4	23	1	17	23	0	0	14	19	1	2	1	1	2	2	1	5	1	5	0	0	2	0	63	2	0	0	10	4	UA
UZ	-0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-0	0	0	12	103	0	0	0	0	0	UZ
ATL	0	0	1	0	6	19	2	6	1	0	23	106	4	9	208	13	57	191	0	1	0	1	24	176	2	0	72	3	0	1	0	1	ATL
BAS	0	0	1	0	6	4	1	8	0	0	20	68	10	20	2	30	5	14	0	1	0	2	1	0	1	0	5	9	0	3	0	1	BAS
BLS	0	1	0	8	9	0	27	2	0	2	3	5	0	1	1	0	1	1	14	9	0	1	0	0	2	0	26	0	0	0	4	2	BLS
MED	8	0	3	1	115	2	51	1	1	31	17	26	0	0	159	0	80	4	1	87	11	4	0	0	231	0	4	0	0	0	1	25	MED
NOS	0	0	1	0	4	34	1	3	1	0	22	138	11	2	12	2	69	195	0	0	0	1	5	3	1	0	1	2	0	0	0	1	NOS
AST	0	3	0	114	1	0	2	1	0	9	0	1	0	0	0	0	0	0	4	2	0	0	0	0	1	19	818	0	0	0	0	0	AST
NOA	0	0	0	0	5	0	2	0	0	0	2	4	0	0	35	0	7	1	0	4	0	0	0	0	12	0	0	0	0	0	0	1	NOA
SUM	29	28	60	394	720	189	435	231	26	65	479	1424	54	151	923	164	674	791	94	291	53	114	61	248	530	215	9428	63	5	19	41	130	SUM
EXC	20	25	53	271	573	129	349	210	23	23	391	1076	29	119	506	118	454	385	74	188	41	103	31	69	280	195	8502	49	4	15	35	99	EXC
EU	3	0	47	2	216	120	262	41	11	7	327	942	22	43	495	72	430	354	1	129	35	81	30	2	258	0	37	32	4	10	9	29	EU
emis	28	26	59	377	715	190	444	235	26	85	483	1445	54	154	984	166	679	799	89	323	51	115	61	274	551	216	10962	64	5	19	41	134	emis
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	

Table C.1 Cont.: 2018 country-to-country blame matrices for **oxidised sulphur** deposition.
Units: 100 Mg of S. **Emitters →, Receptors ↓.**

	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	
AL	20	0	0	0	1	0	0	12	1	0	0	0	0	0	10	3	0	0	0	0	9	0	2	13	6	2	41	155	82	17	AL
AM	0	-0	0	0	0	0	0	0	1	0	0	0	0	1	38	0	0	0	0	0	1	0	101	1	4	0	3	188	78	0	AM
AT	1	-0	0	0	26	0	2	23	2	0	2	3	0	0	4	5	0	0	0	0	2	0	1	2	8	1	5	177	158	113	AT
AZ	0	-0	0	0	0	0	0	0	6	0	0	0	0	4	40	3	1	0	0	0	1	0	216	2	7	0	3	426	196	1	AZ
BA	3	0	0	0	12	0	4	80	2	0	0	1	0	0	9	5	0	0	0	0	7	0	1	11	7	2	20	397	349	37	BA
BE	0	-0	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	3	1	0	91	84	83	BE
BG	12	-0	0	0	6	0	18	69	10	0	0	1	0	0	85	43	0	0	0	4	8	0	3	10	10	1	37	522	450	214	BG
BY	2	-0	0	0	86	0	7	21	62	1	0	3	0	0	19	100	0	0	0	1	2	0	2	3	13	2	8	475	442	137	BY
CH	0	-0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	5	0	1	44	34	22	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	23	0	0	0	0	0	3	0	19	3	1	1	2	59	31	7	CY
CZ	1	-0	0	0	61	0	3	27	2	0	1	4	0	0	2	6	0	0	0	0	1	0	0	1	6	1	4	291	277	229	CZ
DE	1	-0	15	0	102	0	2	17	6	0	0	2	0	0	2	8	0	5	1	0	2	4	0	3	29	11	5	913	852	806	DE
DK	0	-0	2	0	12	0	0	1	2	1	0	0	0	0	0	1	0	1	1	0	0	1	0	0	4	5	1	69	57	51	DK
EE	0	0	0	0	11	0	0	2	14	1	0	0	0	0	1	6	0	0	1	0	0	0	0	0	3	2	1	74	66	38	EE
ES	0	0	1	0	3	21	0	1	0	0	0	0	0	0	1	0	0	61	0	0	75	1	0	88	72	26	10	762	428	424	ES
FI	1	-0	1	1	33	0	1	7	70	6	0	1	0	0	3	15	0	2	2	0	1	1	1	1	21	14	2	289	246	137	FI
FR	1	-0	8	0	23	4	0	4	3	0	0	1	0	0	1	3	0	40	0	0	51	7	0	46	65	30	14	838	583	565	FR
GB	0	-0	4	0	18	1	0	1	2	0	0	0	0	0	0	1	0	30	0	0	1	6	0	2	32	32	0	440	338	331	GB
GE	0	-0	0	0	1	0	0	1	5	0	0	0	0	2	144	4	0	0	0	2	1	0	130	4	10	0	10	399	242	3	GE
GL	0	-0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	4	0	52	5	3	GL
GR	24	0	0	0	4	0	3	27	6	0	0	0	0	0	141	21	0	0	0	2	46	0	11	36	20	12	103	599	369	139	GR
HR	3	0	0	0	14	0	4	70	2	0	2	2	0	0	10	5	0	0	0	0	14	0	1	13	7	3	23	269	207	65	HR
HU	6	-0	0	0	32	0	18	120	4	0	1	12	0	0	8	16	0	0	0	0	3	0	1	5	6	1	12	360	330	137	HU
IE	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	0	0	10	0	0	0	1	0	0	11	16	0	78	40	38	IE
IS	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	21	15	0	112	70	6	IS
IT	6	0	0	0	20	1	2	39	3	0	3	2	0	0	26	8	0	3	0	0	118	0	3	110	45	22	390	1124	434	312	IT
KG	0	-0	0	0	0	-0	0	0	4	0	0	0	38	12	15	1	292	0	0	0	0	0	169	1	23	0	5	801	603	0	KG
KZ	2	-0	0	0	12	0	2	7	456	0	0	0	28	124	185	111	319	1	0	2	4	0	1158	11	145	4	50	7244	5868	31	KZ
LT	1	-0	0	0	40	0	1	6	12	0	0	1	0	0	2	12	0	0	0	0	0	0	0	1	4	2	2	130	120	75	LT
LU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	4	4	LU
LV	0	0	0	0	26	0	1	4	13	1	0	1	0	0	2	11	0	0	1	0	0	0	0	1	5	3	1	111	99	58	LV
MD	1	-0	0	0	4	0	3	3	5	0	0	0	0	0	13	33	0	0	0	1	1	0	1	1	2	0	2	87	80	12	MD
ME	2	0	0	0	1	0	0	11	0	0	0	0	0	0	3	1	0	0	0	0	3	0	1	5	2	1	10	79	56	6	ME
MK	70	-0	0	0	1	0	1	17	1	0	0	0	0	0	12	3	0	0	0	0	2	0	2	4	3	0	16	154	127	20	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	MT
NL	0	-0	24	0	6	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	3	3	0	110	99	97	NL
NO	0	-0	2	25	23	0	0	3	11	3	0	0	0	0	1	4	0	13	1	0	0	4	0	1	44	60	1	252	128	80	NO
PL	3	-0	2	0	887	0	10	55	26	1	1	10	0	0	8	50	0	1	1	0	2	0	2	4	20	8	10	1324	1275	1096	PL
PT	0	0	0	0	0	56	0	0	0	0	0	0	-0	0	0	0	0	29	0	0	4	0	0	9	15	10	1	142	74	73	PT
RO	12	-0	0	0	33	0	193	117	23	0	0	4	0	1	75	112	0	0	0	5	6	0	4	11	17	2	27	764	691	301	RO
RS	36	-0	0	0	13	0	18	452	4	0	0	2	0	0	17	15	0	0	0	1	4	0	2	8	8	1	25	736	688	74	RS
RU	14	-0	3	4	211	0	29	84	4927	10	1	7	5	55	665	1000	57	19	5	16	16	2	508	26	545	149	124	12465	11056	537	RU
SE	1	-0	2	5	70	0	2	10	33	30	0	1	0	0	2	14	0	4	4	0	1	2	1	1	31	19	2	337	273	197	SE
SI	0	-0	0	0	6	0	1	16	1	0	8	1	0	0	4	1	0	0	0	0	3	0	1	3	2	1	4	73	59	30	SI
SK	2	-0	0	0	40	0	6	34	2	0	0	24	0	0	2	10	0	0	0	0	1	0	0	2	4	0	4	175	163	101	SK
TJ	0	-0	0	0	0	-0	0	0	2	0	0	0	146	17	6	1	59	0	0	0	0	0	115	1	16	0	4	388	253	0	TJ
TM	0	-0	0	0	1	-0	0	0	10	0	0	0	6	163	43	6	38	0	0	0	1	0	643	4	27	0	8	1029	345	2	TM
TR	4	0	0	0	5	0	6	21	24	0	0	0	0	2	5201	47	0	1	0	20	89	0	1687	134	103	16	188	7628	5391	62	TR
UA	8	-0	1	0	135	0	32	64	165	1	0	5	0	5	244	1009	2	1	0	12	10	0	26	14	34	4	39	2014	1875	251	UA
UZ	0	-0	0	0	1	-0	0	0	13	0	0	0	46	61	33	5	383	0	0	0	1	0	366	3	23	0	9	1067	665	2	UZ
ATL	2	-0	12	29	113	83	2	14	364	9	0	2	0	0	11	29	1	1537	3	0	53	34	3	241	2967	4046	14	10495	1597	886	ATL
BAS	1	-0	4	2	181	0	3	19	71	16	0	3	0	0	4	28	0	3	22	0	2	3	1	2	28	39	4	649	545	399	BAS
BLS	8	0	0	0	23	0	22	44	102	0	0	1	0	2	1364	275	1	0	0	124	26	0	134	36	34	4	72	2392	1962	100	BLS
MED	47	1	1	0	53	7	12	135	21	0	3	4	0	0	2000	64	0	38	0	14	2283	1	1028	1714	323	540	1579	10733	3214	788	MED
NOS	1	-0	34	13	106	1	2	11	15	5	0	2	0	0	2	13	0	45	3	0	2	81	0	5	101	200	4	1158	716	648	NOS
AST	1	0	0	0	3	0	1	3	57	0	0	0	36	129	594	39	100	0	0	2	31	0	14376	160	823	11	83	17428	1942	22	AST
NOA	2	0	0	0	4	6	1	6	2	0	0	0	0	0	51	3	0	43	0	0	135	0	27	1642	270	42	83	2393	151	80	NOA
SUM	299	1	124	82	2473	181	414	1662	6570	87	24	102	306	580	11127	3153	1257	1895	47	209	3027	155	20748	4398	6077	5372	3069	91567			SUM
EXC	237	0	72	39	1990	84	371	1429	5939	57	20	90	270	448	7101	2701	1155	228	19	68	496	37	5180	599	1532	491	1229		36441	7026	EXC
EU	74	0	65	9	1479	84	267	652	238	41	19	70	0	2	403	349	1	190	12	13	344	29	50	352	443	228	661		7806	5724	EU
emis	305	1	123	81	2510	227	412	1728	7241	87	24	102	271	699	12639	3272	1286	2206	48	218	3460	157	35487	8387	0	12200	4717	117740	50860	10216	emis
	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	

Table C.2: 2018 country-to-country blame matrices for **oxidised nitrogen** deposition.
Units: 100 Mg of N. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	
AL	24	0	0	0	1	0	2	0	0	0	0	1	0	0	1	0	1	0	0	13	1	1	0	0	8	0	0	0	0	0	0	1	AL
AM	0	32	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	113	0	2	3	1	1	9	0	18	87	1	0	1	0	13	5	0	1	3	9	0	0	18	0	0	0	1	0	0	0	AT
AZ	0	10	0	226	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	3	0	0	0	0	0	AZ
BA	2	0	5	0	45	0	1	1	0	0	4	8	0	0	2	0	3	1	0	2	8	10	0	0	14	0	0	0	0	0	0	3	BA
BE	0	0	1	0	0	41	0	0	1	0	2	34	0	0	2	0	26	16	0	0	0	0	1	0	1	0	0	0	2	0	0	0	BE
BG	1	0	2	1	2	1	84	1	0	0	2	7	0	0	1	0	2	1	1	20	1	5	0	0	4	0	0	0	0	0	4	1	BG
BY	0	0	4	0	1	4	2	84	1	0	9	43	4	2	1	4	7	10	0	2	1	7	1	0	4	0	2	13	0	4	6	0	BY
CH	0	0	4	0	0	1	0	0	54	0	1	30	0	0	2	0	25	2	0	0	0	0	0	0	17	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	CY
CZ	0	0	20	0	2	4	1	1	3	0	69	88	2	0	1	0	12	6	0	1	3	12	0	0	4	0	0	0	1	0	0	0	CZ
DE	0	0	48	0	1	58	0	3	26	0	59	890	12	1	10	2	143	103	0	0	2	7	6	0	17	0	0	2	11	1	0	0	DE
DK	0	0	1	0	0	5	0	1	0	0	2	35	20	0	1	1	8	23	0	0	0	0	2	0	1	0	0	1	0	0	0	0	DK
EE	0	0	0	0	0	1	0	5	0	0	1	11	2	9	0	6	2	5	0	0	0	1	0	0	0	0	0	4	0	4	0	0	EE
ES	0	0	1	0	0	5	0	0	1	0	1	20	0	0	719	0	51	16	0	0	0	0	2	0	9	0	0	0	1	0	0	0	ES
FI	0	0	2	0	0	4	0	10	0	0	4	36	9	9	1	93	7	16	0	1	0	2	1	0	2	0	0	6	0	5	1	0	FI
FR	0	0	12	0	1	66	0	1	30	0	12	227	3	0	159	0	788	98	0	0	1	2	7	0	69	0	0	0	12	0	0	0	FR
GB	0	0	2	0	0	12	0	1	1	0	4	49	5	0	9	1	49	388	0	0	0	1	35	0	2	0	0	1	1	0	0	0	GB
GE	0	12	0	61	0	0	0	0	0	0	0	1	0	0	0	0	0	0	93	1	0	0	0	0	0	0	1	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	3	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	GL
GR	4	0	1	1	1	0	23	1	0	0	1	4	0	0	3	0	2	1	1	171	1	2	0	0	11	0	0	0	0	0	1	1	GR
HR	1	0	13	0	14	1	2	1	1	0	6	14	0	0	3	0	5	1	0	3	29	15	0	0	35	0	0	0	0	0	0	1	HR
HU	1	0	17	0	7	1	4	2	2	0	12	25	1	0	1	0	6	2	0	4	7	72	0	0	15	0	0	0	0	0	1	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	6	1	0	2	0	5	25	0	0	0	0	38	0	0	0	0	0	0	0	0	0	IE
IS	0	0	0	-0	0	1	0	0	0	-0	0	5	0	0	2	0	3	7	0	0	0	0	2	10	0	-0	0	0	0	0	0	0	IS
IT	3	0	31	0	9	2	2	1	14	0	9	36	1	0	32	0	54	4	0	9	16	10	0	0	846	0	0	0	0	0	0	1	IT
KG	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	31	0	0	0	0	0	KG
KZ	0	11	2	62	0	2	1	7	1	0	2	15	1	1	2	5	5	6	11	2	0	2	1	0	4	67	907	2	0	1	1	0	KZ
LT	0	0	2	0	0	2	0	10	0	0	4	23	3	1	0	2	3	6	0	0	0	2	1	0	1	0	0	23	0	4	1	0	LT
LU	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	LU
LV	0	0	1	0	0	2	0	9	0	0	3	19	3	3	0	3	3	7	0	0	0	1	1	0	1	0	0	10	0	12	1	0	LV
MD	0	0	0	0	0	0	1	1	0	0	0	2	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	13	0	MD
ME	2	0	0	0	2	0	1	0	0	0	0	1	0	0	1	0	1	0	0	2	0	1	0	0	4	0	0	0	0	0	0	7	ME
MK	2	0	0	0	1	0	4	0	0	0	0	1	0	0	0	0	0	0	0	17	0	1	0	0	2	0	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	0	0	1	0	0	16	0	0	0	0	2	41	1	0	2	0	18	29	0	0	0	0	2	0	1	0	0	0	1	0	0	0	NL
NO	0	0	2	0	0	9	0	2	1	0	4	62	15	1	3	5	16	54	0	0	0	1	5	0	1	0	0	1	1	1	0	0	NO
PL	0	0	19	1	4	16	2	21	4	0	54	222	18	2	2	3	29	37	0	2	4	24	2	0	10	0	1	9	2	3	2	0	PL
PT	0	0	0	0	0	1	0	0	0	0	0	2	0	0	45	0	4	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	PT
RO	2	0	9	2	5	2	22	5	1	0	9	30	1	0	1	1	6	4	1	12	3	24	0	0	12	0	1	1	0	0	16	1	RO
RS	4	0	5	0	13	1	12	1	1	0	5	13	0	0	1	0	3	1	0	12	4	17	0	0	9	0	0	0	0	0	1	4	RS
RU	2	13	17	113	4	19	11	125	5	0	28	196	26	37	9	114	38	66	34	13	4	22	6	1	21	6	647	44	2	30	17	1	RU
SE	0	0	5	0	1	12	1	8	1	0	11	101	32	5	2	27	18	54	0	1	1	5	4	0	3	0	0	7	1	5	1	0	SE
SI	0	0	15	0	1	0	0	0	1	0	3	8	0	0	1	0	2	0	0	1	6	4	0	0	15	0	0	0	0	0	0	0	SI
SK	0	0	7	0	2	1	1	1	1	0	11	19	1	0	0	0	4	2	0	1	3	18	0	0	5	0	0	0	0	0	1	0	SK
TJ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	4	0	0	0	0	0	TJ
TM	0	4	0	26	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4	0	0	0	0	0	0	1	17	0	0	0	0	0	TM
TR	1	19	2	22	1	1	13	1	1	6	2	7	0	0	5	0	4	1	13	37	1	2	0	0	9	0	2	0	0	0	3	0	TR
UA	1	1	10	8	4	6	11	39	2	0	17	68	5	2	2	4	13	12	5	10	3	18	1	0	12	0	12	7	1	3	25	1	UA
UZ	0	3	0	11	0	0	0	1	0	0	0	1	0	0	0	0	1	1	2	0	0	0	0	0	0	10	25	0	0	0	0	0	UZ
ATL	0	0	13	0	1	87	1	12	6	0	24	391	46	6	303	40	298	723	0	1	1	6	146	37	15	0	8	8	7	5	1	0	ATL
BAS	0	0	7	0	1	17	1	17	2	0	19	169	37	11	3	41	25	68	0	1	1	7	5	0	4	0	0	16	1	13	1	0	BAS
BLS	1	4	5	20	2	2	21	6	1	1	4	21	2	0	2	1	4	4	51	20	1	6	0	0	6	0	4	2	0	1	13	1	BLS
MED	29	1	43	3	30	11	46	3	17	16	22	108	2	0	434	1	270	22	4	281	37	27	2	0	708	0	1	1	2	0	4	10	MED
NOS	0	0	9	0	1	70	1	7	5	0	21	297	53	2	24	6	167	579	0	1	1	4	44	1	7	0	0	5	5	3	0	0	NOS
AST	0	17	1	215	1	1	2	2	0	6	1	5	0	0	3	1	3	2	18	10	0	1	0	0	6	19	175	1	0	0	1	0	AST
NOA	1	0	3	0	1	2	2	0	2	0	2	13	0	0	100	0	30	5	0	15	1	2	0	0	36	0	0	0	0	0	0	0	NOA
SUM	85	129	458	816	161	493	279	393	197	36	470	3499	310	93	1903	362	2179	2421	267	670	147	352	317	52	1972	179	1845	170	60	99	119	38	SUM
EXC	52	106	377	577	125	304	206	345	165	12	377	2495	170	74	1033	272	1382	1017	194	341	104	300	119	13	1190	160	1658	137	43	76	98	26	EXC
EU	14	1	323	6	53	258	146	82	99	5	302	2037	116	30	1000	139	1261	852	4	228	81	217	104	1	1082	0	5	67	38	37	31	8	EU
emis	88	127	459	809	168	514	295	434	201	44	492	3659	322	98	2126	385	2280	2565	264	775	154	365	335	68	2037	201	2210	177	62	104	128	38	emis
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	

Table C.2 Cont.: 2018 country-to-country blame matrices for **oxidised nitrogen** deposition.
Units: 100 Mg of N. **Emitters →, Receptors ↓.**

	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	
AL	3	0	0	0	1	0	1	6	1	0	0	0	-0	0	2	1	0	0	0	0	13	0	1	6	3	-0	0	95	71	31	AL
AM	0	0	0	0	0	0	0	0	1	0	0	0	0	1	10	0	0	0	0	0	1	0	64	1	2	-0	0	156	89	1	AM
AT	0	0	4	0	25	0	3	5	2	0	8	6	0	0	1	3	0	1	1	0	3	5	0	1	3	-0	-0	358	343	320	AT
AZ	0	0	0	0	0	0	0	0	12	0	0	0	0	4	11	1	2	0	0	0	1	0	167	1	4	-0	0	466	292	2	AZ
BA	0	0	1	0	11	0	5	20	2	0	1	3	-0	0	2	3	0	0	1	0	10	1	0	5	3	-0	0	180	159	82	BA
BE	0	0	16	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	20	0	0	3	0	-0	175	147	146	BE
BG	2	0	1	0	7	0	34	18	17	0	0	2	-0	0	26	29	0	0	1	9	13	1	2	4	5	-0	0	315	279	175	BG
BY	0	0	6	2	94	0	15	4	112	5	1	6	0	0	5	86	0	2	16	2	3	11	1	1	5	-0	0	595	554	249	BY
CH	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	2	0	1	2	-0	-0	150	142	87	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	5	0	8	1	1	-0	-0	29	13	6	CY
CZ	0	0	5	1	61	0	5	6	4	1	2	9	0	0	0	5	0	1	4	0	2	9	0	1	3	-0	0	349	330	307	CZ
DE	0	0	81	4	99	1	3	3	10	4	2	5	0	0	0	5	0	14	27	0	6	111	0	2	21	0	0	1804	1623	1568	DE
DK	0	0	11	2	12	0	0	0	2	3	0	0	0	0	0	1	0	2	18	0	0	27	0	0	2	0	0	182	132	126	DK
EE	0	0	2	1	12	0	1	0	24	4	0	0	0	0	0	4	0	1	18	0	0	5	0	0	2	0	0	127	101	65	EE
ES	0	0	5	0	3	72	0	0	1	0	0	0	0	0	0	0	0	98	1	0	136	11	0	57	45	-0	-0	1259	912	908	ES
FI	0	0	7	10	37	0	3	1	103	27	0	2	0	0	1	9	0	6	58	0	1	20	1	0	15	-0	-0	511	411	274	FI
FR	0	0	56	1	21	13	1	1	3	1	2	1	0	0	0	2	0	74	4	0	85	137	0	28	33	-0	-0	1955	1594	1554	FR
GB	0	0	22	3	15	2	0	0	4	2	0	1	0	0	0	1	0	48	7	0	1	102	0	1	25	0	0	797	612	601	GB
GE	0	0	0	0	1	0	1	0	8	0	0	0	0	2	36	2	1	0	0	3	2	0	72	1	5	-0	0	306	222	5	GE
GL	0	0	1	1	1	0	0	0	0	0	0	0	-0	0	0	0	0	1	1	0	0	2	0	0	30	-0	-0	45	11	9	GL
GR	5	0	0	0	4	0	7	8	10	0	0	1	-0	0	41	12	0	1	0	5	73	1	4	19	13	-0	0	438	321	235	GR
HR	0	0	1	0	15	0	6	17	2	0	5	5	-0	0	2	3	0	1	1	0	21	1	1	6	3	0	0	238	204	160	HR
HU	1	0	2	0	41	0	29	25	5	0	3	19	-0	0	2	16	0	1	2	1	6	3	1	2	3	-0	0	345	327	264	HU
IE	0	0	2	0	2	0	0	0	1	0	0	0	0	0	0	0	0	14	1	0	0	8	0	0	8	-0	0	116	85	84	IE
IS	0	0	2	1	1	0	0	0	0	0	0	0	-0	0	0	0	0	4	1	0	0	5	0	1	13	-0	-0	59	36	25	IS
IT	1	1	3	0	17	2	4	9	3	0	18	4	-0	0	4	4	0	5	1	0	199	4	1	59	23	-0	0	1445	1152	1103	IT
KG	0	0	0	0	0	0	0	0	5	0	0	0	6	11	3	0	227	0	0	0	0	0	136	0	11	-0	0	510	362	2	KG
KZ	0	0	2	3	15	0	5	1	813	3	0	1	5	111	40	47	295	5	6	4	6	5	934	5	92	-0	0	3520	2464	82	KZ
LT	0	0	4	1	40	0	3	1	20	3	0	2	0	0	1	10	0	1	14	0	1	7	0	0	2	-0	0	201	176	130	LT
LU	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	14	12	12	LU
LV	0	0	4	1	28	0	2	1	26	5	0	1	0	0	1	8	0	1	19	0	1	8	0	0	2	-0	0	189	157	110	LV
MD	0	0	0	0	5	0	7	1	9	0	0	0	-0	0	3	26	0	0	1	2	1	1	0	0	1	-0	-0	81	75	21	MD
ME	0	0	0	0	1	0	1	3	0	0	0	0	-0	0	1	1	0	0	0	0	4	0	0	2	1	-0	0	37	28	12	ME
MK	14	0	0	0	1	0	1	7	1	0	0	0	-0	0	3	2	0	0	0	0	3	0	1	2	2	-0	0	67	59	29	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	MT
NL	0	0	60	1	5	0	0	0	1	0	0	0	0	0	0	0	0	3	2	0	0	33	0	0	4	0	-0	226	183	180	NL
NO	0	0	16	76	22	0	1	0	9	19	0	1	0	0	0	3	0	20	24	0	1	71	0	0	26	-0	-0	474	332	240	NO
PL	1	0	24	5	589	0	18	12	43	9	3	22	0	0	2	46	0	5	53	1	4	43	1	2	13	-0	-0	1391	1270	1128	PL
PT	0	0	1	0	0	100	0	0	0	0	0	0	0	0	0	0	0	47	0	0	8	1	0	5	10	-0	-0	228	157	156	PT
RO	2	0	3	1	39	0	242	24	36	1	1	8	-0	1	20	92	0	1	3	9	11	4	2	5	8	-0	0	684	641	431	RO
RS	7	0	1	0	14	0	27	93	5	0	1	5	-0	0	4	10	0	0	1	1	7	2	1	4	4	-0	-0	297	276	133	RS
RU	2	0	32	35	239	1	54	15	5941	53	3	14	1	47	134	484	58	47	145	30	23	71	363	10	337	-1	0	9809	8784	1100	RU
SE	0	0	23	30	80	0	4	2	43	86	1	3	0	0	0	9	0	11	102	0	2	73	1	1	20	-0	-0	796	589	492	SE
SI	0	0	0	0	6	0	1	3	1	0	21	2	-0	0	1	1	0	0	0	0	5	1	0	1	1	-0	-0	101	93	85	SI
SK	0	0	1	0	44	0	10	8	4	0	2	28	-0	0	1	9	0	0	2	0	2	2	0	1	2	-0	0	195	186	159	SK
TJ	0	0	0	0	0	0	0	0	2	0	0	0	14	21	1	0	58	0	0	0	0	0	97	0	8	-0	0	212	105	1	TJ
TM	0	0	0	0	1	0	0	0	22	0	0	0	1	138	11	3	57	0	0	0	1	0	622	2	15	-0	0	931	289	6	TM
TR	1	0	1	0	6	1	14	4	46	0	0	1	0	1	1069	27	1	2	1	40	141	1	678	61	56	-0	0	2303	1324	113	TR
UA	1	0	8	3	153	0	67	13	277	5	2	12	0	4	59	597	3	3	17	26	16	14	13	5	18	-0	0	1621	1509	453	UA
UZ	0	0	0	0	1	0	0	0	28	0	0	0	8	64	8	3	275	0	0	0	1	0	329	1	15	-0	0	792	445	7	UZ
ATL	0	0	129	177	113	137	4	2	290	47	1	4	-0	0	2	17	1	1288	87	1	86	472	3	89	1883	3	-0	7023	3111	2556	ATL
BAS	0	0	34	14	148	0	6	4	84	49	1	5	0	0	1	19	0	9	187	0	2	80	1	1	12	0	0	1127	835	690	BAS
BLS	1	0	3	1	28	0	46	10	175	1	1	3	-0	2	294	160	1	1	5	117	40	5	47	15	10	-0	0	1172	932	186	BLS
MED	9	12	11	1	49	25	31	39	37	1	17	10	-0	0	444	39	0	71	5	29	2228	23	294	892	155	1	2	6561	2860	2188	MED
NOS	0	0	122	72	94	4	2	2	22	28	1	4	0	0	1	9	0	89	75	0	5	505	1	3	55	3	0	2410	1675	1554	NOS
AST	0	0	1	1	5	0	3	1	109	1	0	1	6	144	180	16	112	2	2	4	71	1	10077	80	525	-0	0	11835	1072	55	AST
NOA	0	1	2	0	4	19	2	2	3	0	1	1	0	0	16	3	0	88	1	1	284	4	17	1077	198	-0	-0	1942	272	242	NOA
SUM	54	15	712	451	2215	383	668	372	8381	362	103	195	41	553	2448	1829	1091	1973	915	290	3539	1916	13945	2463	3757	5	3	69247			SUM
EXC	42	2	410	184	1774	197	574	312	7661	235	81	167	35	406	1511	1565	978	425	554	138	822	825	3505	306	920	-2	1		29684	13470	EXC
EU	13	1	338	64	1204	193	374	145	365	149	72	123	0	2	109	271	1	338	340	28	585	638	23	197	268	-1	0		12053	10779	EU
emis	56	18	744	488	2318	473	686	387	9870	384	103	203	48	695	2811	1925	1208	2577	939	308	4157	1989	24145	4555	0			83071	44401	22177	emis
	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	

Table C.3: 2018 country-to-country blame matrices for **reduced nitrogen** deposition.
Units: 100 Mg of N. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	
AL	113	0	0	0	0	0	2	0	0	0	0	1	0	0	2	0	1	0	0	7	1	1	0	0	8	0	0	0	0	0	1	2	AL
AM	0	54	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	AM
AT	0	0	230	0	1	2	1	2	16	0	30	141	2	0	1	0	13	3	0	0	6	15	0	0	21	0	0	0	0	0	1	0	AT
AZ	0	15	0	299	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	1	0	0	0	0	0	AZ
BA	2	0	5	0	81	0	2	1	0	0	5	8	1	0	3	0	2	0	0	2	24	16	0	0	16	0	0	0	0	0	1	3	BA
BE	0	0	1	-0	0	145	0	0	1	0	1	37	1	0	2	0	69	11	0	0	0	0	2	-0	1	-0	0	0	5	0	0	0	BE
BG	2	0	2	1	1	0	172	3	0	0	2	5	1	0	2	0	1	0	1	17	1	6	0	0	4	0	1	0	0	0	11	0	BG
BY	1	0	3	0	1	2	3	446	1	0	7	31	5	1	1	1	7	4	0	1	2	10	1	0	5	0	1	21	0	5	15	0	BY
CH	0	0	3	0	0	1	0	0	253	0	1	46	0	0	2	0	31	1	0	0	0	0	0	0	18	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	CY
CZ	0	0	28	0	1	2	1	3	4	0	209	109	3	0	1	0	13	3	0	0	4	16	0	0	5	0	0	1	0	0	1	0	CZ
DE	0	0	50	0	1	57	1	8	47	0	58	2387	20	0	13	1	213	55	0	0	3	10	9	0	15	0	0	4	11	1	1	0	DE
DK	0	0	1	0	0	4	0	1	0	0	2	67	149	0	1	0	11	14	0	0	0	0	2	0	1	0	0	1	0	0	0	0	DK
EE	0	0	0	0	0	1	0	7	0	0	1	11	3	29	0	3	2	3	0	0	0	1	0	0	1	0	0	5	0	5	1	0	EE
ES	0	0	1	0	0	5	0	0	2	0	1	18	0	0	2080	0	91	10	0	0	0	0	3	0	9	0	0	0	0	0	0	0	ES
FI	0	0	1	0	1	3	0	11	1	0	3	39	10	5	1	124	9	9	0	0	1	2	2	0	2	0	1	7	0	4	1	0	FI
FR	0	0	9	0	1	74	0	2	57	0	10	200	4	0	249	0	2739	59	0	0	2	2	12	0	75	-0	0	1	8	0	0	0	FR
GB	0	0	2	0	0	13	0	2	1	0	4	63	6	0	12	0	102	851	0	0	0	1	99	0	3	-0	0	1	1	0	0	0	GB
GE	0	11	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	177	0	0	0	0	0	0	0	1	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	9	0	1	1	0	0	20	1	0	0	1	3	0	0	4	0	1	0	1	212	1	3	0	0	9	0	0	0	0	0	3	0	GR
HR	2	0	12	0	15	0	2	1	1	0	7	13	1	0	4	0	4	1	0	2	115	29	0	0	40	0	0	0	0	0	1	1	HR
HU	2	0	21	0	5	1	5	3	1	0	12	21	1	0	2	0	4	1	0	2	18	245	0	0	16	0	0	1	0	0	4	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	7	1	0	2	0	6	26	0	0	0	0	388	-0	0	-0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	1	0	0	0	0	0	4	0	0	1	0	3	4	0	0	0	0	2	19	0	0	0	0	0	0	0	0	IS
IT	4	0	23	0	6	1	3	2	18	0	10	38	1	0	46	0	36	2	0	5	18	13	0	0	1927	0	0	0	0	0	1	1	IT
KG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	160	17	0	0	0	0	0	KG
KZ	0	8	1	45	0	1	1	12	0	0	2	10	1	1	1	2	3	2	8	1	0	2	0	0	2	44	417	2	0	1	2	0	KZ
LT	0	0	1	0	0	1	1	32	0	0	3	20	4	1	1	1	3	3	0	0	1	3	1	0	1	0	0	105	0	6	2	0	LT
LU	0	0	0	-0	0	2	0	0	0	-0	0	5	0	0	0	0	7	0	0	0	0	0	0	0	0	-0	0	0	8	0	0	0	LU
LV	0	0	1	0	0	1	0	19	0	0	2	20	4	3	0	1	3	4	0	0	0	2	1	0	1	0	0	23	0	44	1	0	LV
MD	0	0	0	0	0	0	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	97	0	MD
ME	5	0	0	0	1	0	1	0	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0	0	4	0	0	0	0	0	0	20	ME
MK	6	0	0	0	0	0	5	0	0	0	0	1	0	0	1	0	0	0	0	10	0	1	0	0	2	0	0	0	0	0	1	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	0	-0	1	-0	0	42	0	1	0	0	2	105	1	0	2	0	35	20	-0	0	0	1	3	-0	1	-0	0	0	1	0	0	0	NL
NO	0	0	1	0	0	6	0	4	1	0	3	56	21	1	4	2	22	32	0	0	0	1	7	0	0	0	0	2	0	1	0	0	NO
PL	1	0	18	0	3	9	3	53	5	0	53	218	26	1	4	2	32	15	0	1	6	32	2	0	11	0	1	16	1	3	7	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	2	0	0	83	0	6	2	0	0	0	0	0	0	1	-0	0	0	0	0	0	0	PT
RO	3	0	7	1	3	1	25	10	1	0	8	20	2	0	3	0	3	1	1	8	5	47	0	0	12	0	2	2	0	0	61	1	RO
RS	8	0	5	0	9	0	14	2	0	0	5	11	1	0	2	0	1	1	0	6	9	33	0	0	8	0	0	0	0	0	4	6	RS
RU	3	9	12	82	6	11	11	242	5	1	23	171	28	22	10	57	42	31	32	7	5	24	5	0	19	5	229	56	1	28	43	2	RU
SE	0	0	4	0	1	8	1	13	1	0	9	110	50	3	3	14	23	31	0	0	1	5	6	0	2	0	1	9	1	4	1	0	SE
SI	0	0	15	0	1	0	1	0	1	0	3	9	0	0	1	0	2	0	0	0	10	6	0	0	19	0	0	0	0	0	0	0	SI
SK	0	0	10	0	2	1	2	2	1	0	13	15	1	0	1	0	3	1	0	1	5	31	0	0	5	0	0	0	0	0	2	0	SK
TJ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	TJ
TM	0	2	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	-0	0	0	1	0	0	0	0	0	TM
TR	1	13	1	14	0	0	10	2	0	7	1	4	1	0	6	0	2	0	14	19	1	3	0	0	8	0	2	0	0	0	6	0	TR
UA	2	1	7	5	3	3	11	86	2	0	13	50	7	1	4	1	11	4	4	6	4	25	1	0	11	0	6	10	0	2	95	1	UA
UZ	0	2	0	8	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	-0	0	17	11	0	0	0	0	0	UZ
ATL	0	0	8	0	2	57	1	18	6	0	17	297	40	3	390	14	602	523	0	1	2	5	352	22	13	0	5	9	3	4	2	0	ATL
BAS	0	0	6	0	1	11	1	26	2	0	15	241	103	11	5	35	29	36	0	1	2	7	7	-0	5	0	1	27	1	14	3	0	BAS
BLS	1	3	3	13	1	1	18	9	1	1	3	12	2	0	3	0	3	1	48	10	1	7	0	0	4	0	5	2	0	0	36	0	BLS
MED	51	1	29	2	17	7	31	5	18	15	21	78	2	0	528	0	236	11	3	138	41	27	2	0	669	0	1	1	1	0	9	8	MED
NOS	0	0	7	0	1	93	1	13	5	0	16	475	132	1	32	3	376	489	0	0	1	6	72	0	7	0	0	7	3	2	1	0	NOS
AST	0	9	0	128	0	0	1	3	0	5	0	2	0	0	2	0	1	0	10	4	0	0	0	0	2	27	21	1	0	0	1	0	AST
NOA	1	0	2	0	1	1	2	0	2	0	2	10	0	0	106	0	30	2	0	5	1	1	0	0	32	-0	0	0	0	0	0	0	NOA
SUM	222	129	532	697	169	573	355	1049	456	44	582	5195	635	84	3622	264	4834	2269	323	472	293	641	982	42	3013	256	732	317	48	126	418	50	SUM
EXC	167	116	477	552	146	402	300	974	421	22	507	4079	355	68	2557	211	3557	1206	261	314	244	588	549	20	2282	229	700	270	39	105	365	40	EXC
EU	26	1	438	4	42	376	238	176	159	13	445	3680	290	42	2518	147	3429	1125	4	252	197	470	532	0	2180	0	9	177	37	69	99	6	EU
emis	225	122	532	643	173	575	368	1067	452	58	591	5241	634	85	3872	265	4893	2279	307	519	294	646	983	44	3016	263	894	320	49	127	426	51	emis
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	ME	

Table C.3 Cont.: 2018 country-to-country blame matrices for **reduced nitrogen** deposition.
Units: 100 Mg of N. **Emitters →, Receptors ↓.**

	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	
AL	1	0	0	0	1	0	2	8	2	0	0	0	0	0	5	2	0	0	0	0	0	0	0	4	2	0	-0	165	159	26	AL
AM	0	0	0	0	0	0	0	0	2	0	0	0	0	1	62	0	0	0	0	0	0	0	52	1	2	0	0	208	153	1	AM
AT	0	0	3	0	19	0	6	6	3	0	12	7	0	0	2	4	0	0	0	0	0	0	0	1	3	0	0	553	548	514	AT
AZ	0	0	0	0	0	0	0	0	21	0	0	0	0	4	41	1	3	0	0	0	0	0	119	1	3	0	0	524	401	2	AZ
BA	0	0	0	0	11	0	9	26	3	0	1	4	0	0	5	4	0	0	0	0	1	0	0	4	3	0	0	247	239	110	BA
BE	-0	0	31	0	2	0	0	0	0	0	0	0	-0	0	0	0	0	-0	0	-0	0	-1	-0	0	1	-0	0	312	312	310	BE
BG	5	0	0	0	6	0	75	17	26	0	0	2	0	0	42	23	0	0	0	0	1	0	1	4	4	0	-0	439	429	296	BG
BY	1	0	4	1	89	0	26	6	99	4	1	4	0	0	11	95	1	0	-0	0	0	0	2	1	5	0	0	925	915	238	BY
CH	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	365	362	108	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	-0	0	4	2	0	-0	-0	27	21	13	CY
CZ	0	0	5	0	48	0	8	7	4	1	3	12	0	0	1	6	0	0	0	0	0	0	0	0	2	0	0	504	501	473	CZ
DE	0	0	152	1	89	1	5	5	8	4	3	5	-0	0	1	6	0	1	-1	0	0	-3	0	1	11	-0	0	3253	3244	3166	DE
DK	0	0	13	1	12	0	1	0	2	4	0	0	0	0	0	1	0	0	-1	0	0	-1	0	0	2	-0	0	290	291	284	DK
EE	0	0	2	1	10	0	2	1	13	4	0	0	0	0	1	4	0	0	-0	0	0	0	0	0	1	0	0	112	109	82	EE
ES	0	0	5	0	3	64	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	-4	1	0	47	26	-0	-1	2363	2297	2293	ES
FI	0	0	6	4	31	0	3	3	46	19	0	1	0	0	1	8	0	0	0	0	0	1	1	0	8	0	0	372	360	283	FI
FR	0	0	59	0	17	10	1	1	3	1	2	1	0	0	1	2	0	-1	0	0	3	-4	0	22	24	-1	0	3647	3603	3536	FR
GB	0	0	24	1	17	1	0	0	2	1	0	1	0	0	0	1	0	-3	0	0	0	-4	0	1	12	-2	0	1215	1211	1203	GB
GE	0	0	0	0	1	0	1	0	14	0	0	0	0	2	130	2	2	0	0	0	0	0	54	3	4	0	0	454	393	4	GE
GL	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	0	0	30	6	5	GL
GR	8	0	0	0	3	0	10	8	17	0	0	1	0	0	59	10	0	0	0	0	-1	0	3	14	8	-0	-1	411	387	269	GR
HR	1	0	1	0	12	0	9	23	3	0	12	5	0	0	6	4	0	0	0	0	1	0	0	5	3	0	0	335	326	269	HR
HU	1	0	1	0	24	0	56	41	6	0	6	30	0	0	4	17	0	0	0	0	0	0	0	2	2	0	-0	555	550	466	HU
IE	0	0	2	0	2	0	0	0	0	0	0	0	-0	0	0	0	0	-2	0	0	0	-0	0	0	4	-2	-0	437	436	435	IE
IS	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	49	39	19	IS
IT	1	0	3	0	15	2	7	11	5	0	15	5	0	0	13	5	0	1	0	0	-2	0	1	37	18	0	-2	2292	2239	2171	IT
KG	0	0	0	0	0	0	0	0	7	0	0	0	31	9	9	1	167	0	0	0	0	0	270	1	9	0	0	683	404	1	KG
KZ	0	0	1	0	12	0	5	2	754	1	0	1	20	97	118	32	316	0	0	0	1	0	1711	8	53	0	1	3706	1931	55	KZ
LT	0	0	3	0	46	0	5	2	17	3	0	2	0	0	2	10	0	0	-0	0	0	0	0	0	2	0	0	282	280	213	LT
LU	0	0	1	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	24	24	24	LU
LV	0	0	4	1	25	0	3	1	17	5	0	1	0	0	1	8	0	0	-0	0	0	0	0	0	2	0	0	202	199	149	LV
MD	0	0	0	0	3	0	18	1	11	0	0	0	0	0	5	28	0	0	-0	-0	0	0	0	0	1	0	0	175	174	29	MD
ME	0	0	0	0	1	0	2	6	1	0	0	0	0	0	2	1	0	0	0	0	0	0	0	1	1	0	0	51	48	12	ME
MK	31	0	0	0	1	0	3	8	2	0	0	0	0	0	6	2	0	0	0	0	0	0	0	1	1	0	-0	83	80	23	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	-0	0	0	0	0	-0	-0	1	1	1	MT
NL	0	0	311	0	5	0	0	0	0	0	0	0	-0	0	0	0	0	-0	-0	0	0	-2	-0	0	1	-0	0	530	532	530	NL
NO	0	0	13	133	16	0	1	1	5	15	0	1	0	0	0	3	0	1	0	0	0	1	0	0	18	0	0	375	354	206	NO
PL	1	0	18	2	1189	0	32	15	40	9	4	21	0	0	5	58	0	1	-0	0	0	1	1	1	8	0	0	1928	1916	1725	PL
PT	0	0	0	0	0	167	0	0	0	0	0	0	-0	0	0	0	0	-2	0	0	0	0	0	5	6	-0	0	270	262	261	PT
RO	2	0	1	0	29	0	715	33	50	1	1	10	0	1	27	90	1	0	0	-0	1	0	2	3	6	0	-0	1203	1190	902	RO
RS	7	0	0	0	11	0	52	275	9	0	1	5	-0	0	8	10	0	0	0	0	0	0	1	3	3	0	-0	511	505	167	RS
RU	3	0	25	12	216	1	82	24	7304	36	3	11	3	44	327	393	88	1	3	2	3	4	768	13	238	3	3	10834	9796	941	RU
SE	0	0	20	18	62	0	4	3	24	195	1	3	0	0	1	9	0	1	-1	0	0	2	1	0	12	0	0	657	641	567	SE
SI	0	0	0	0	4	0	2	4	1	0	63	2	0	0	2	1	0	0	0	0	0	0	0	1	1	0	0	152	149	138	SI
SK	0	0	1	0	28	0	17	10	4	0	2	77	0	0	1	11	0	0	0	0	0	0	0	1	1	0	0	252	250	215	SK
TJ	0	0	0	0	0	0	0	0	3	0	0	0	116	13	4	0	76	0	0	0	0	0	129	0	6	0	0	357	222	0	TJ
TM	0	0	0	0	1	0	0	0	23	0	0	0	3	223	32	1	99	-0	0	0	0	0	417	3	10	0	-0	836	406	3	TM
TR	1	0	1	0	5	0	18	4	70	0	0	1	0	2	4655	21	1	0	0	-1	-3	0	407	83	38	-0	-5	5418	4899	91	TR
UA	2	0	5	1	129	0	124	16	322	4	2	10	0	4	106	885	6	0	0	0	1	1	12	5	12	0	1	2023	1990	444	UA
UZ	0	0	0	0	1	0	0	0	25	0	0	0	24	46	22	1	536	-0	0	0	0	0	245	3	8	0	-0	953	698	4	UZ
ATL	0	0	92	58	86	121	5	5	107	24	1	3	0	0	4	15	1	-21	4	0	2	12	10	58	1400	-16	1	4369	2919	2674	ATL
BAS	0	0	32	7	150	0	9	5	49	74	1	5	0	0	2	16	0	0	-6	0	1	-1	1	1	10	-2	0	947	942	827	BAS
BLS	1	0	2	0	16	0	76	10	241	1	1	2	0	2	590	113	2	0	0	-6	1	0	35	20	12	0	1	1310	1246	169	BLS
MED	8	7	10	0	34	17	36	41	54	1	15	9	0	0	595	30	0	2	0	0	-43	2	140	624	125	-6	-3	3650	2809	1964	MED
NOS	0	0	214	48	83	3	5	4	13	29	1	3	0	0	1	12	0	-0	-1	0	1	-14	0	2	37	-4	0	2181	2161	2061	NOS
AST	0	0	0	0	3	0	2	1	141	0	0	0	33	140	318	11	152	-0	0	0	-1	0	23854	156	329	-0	-4	25356	1022	27	AST
NOA	0	1	2	0	3	13	2	2	3	0	1	1	-0	0	20	2	0	-4	0	0	-11	0	6	1607	112	-2	-3	1957	252	218	NOA
SUM	77	9	1071	292	2574	402	1441	636	9575	440	152	246	231	591	7259	1959	1454	-25	-0	-3	-44	-2	28250	2755	2640	-28	-13	91361			SUM
EXC	66	1	720	177	2198	248	1305	569	8967	312	133	223	198	448	5728	1761	1299	-2	3	3	7	-1	4203	287	616	1	-4		46480	23275	EXC
EU	21	1	666	30	1699	245	962	192	289	250	125	185	0	2	179	278	3	-5	-2	1	2	-8	16	150	166	-4	-3		22306	20787	EU
emis	81	11	1065	286	2610	462	1446	650	10058	438	153	248	230	730	8209	2018	1553	0	0	0	0	0	42885	5321	0			108468	60263	31779	emis
	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	SUM	EXC	EU	

Table C.4: 2018 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	664	1	21	3	59	1	122	9	3	0	20	40	2	1	37	2	38	5	3	247	37	57	1	0	158	0	3	3	0	1	11	AL
AM	0	242	2	695	1	0	4	3	1	2	2	7	1	0	9	2	6	2	185	4	1	2	0	0	6	0	31	1	0	1	2	AM
AT	3	0	346	1	18	5	9	11	47	0	131	446	7	1	33	7	137	15	1	9	34	66	3	1	147	0	3	5	4	2	3	AT
AZ	0	44	2	892	1	0	3	7	1	0	3	8	1	1	8	4	5	4	106	3	1	3	1	1	5	0	81	3	0	1	2	AZ
BA	21	0	71	1	637	2	40	12	3	0	65	107	5	2	28	6	49	8	2	39	166	141	2	1	130	0	3	5	1	2	10	BA
BE	1	0	8	0	1	-439	1	3	3	0	23	45	7	1	33	5	190	41	0	2	1	6	15	3	11	0	0	2	8	1	1	BE
BG	8	1	16	8	19	1	551	22	2	0	23	41	4	2	13	6	18	5	10	68	10	53	1	0	23	0	8	6	0	3	45	BG
BY	0	0	5	0	2	0	2	195	1	0	10	42	14	7	6	17	16	17	0	2	3	13	6	2	7	0	8	40	0	13	7	BY
CH	2	0	62	1	8	7	5	5	406	0	29	330	2	1	69	3	459	10	1	8	10	10	3	1	288	0	1	2	5	1	1	CH
CY	6	2	7	5	7	1	36	5	3	297	5	16	1	0	24	1	25	2	6	204	5	9	1	0	52	0	5	1	0	1	5	CY
CZ	1	0	69	1	10	3	9	23	7	0	239	373	17	3	19	12	94	23	1	5	16	67	5	2	24	0	4	10	4	5	4	CZ
DE	1	0	34	0	3	-2	2	12	13	0	57	190	15	3	28	9	147	39	0	2	4	15	13	2	21	0	2	9	6	5	1	DE
DK	0	0	1	0	0	0	0	10	0	0	3	43	-53	7	3	19	24	100	0	0	0	1	26	4	1	0	1	13	0	10	0	DK
EE	0	0	1	0	0	0	0	20	0	0	3	26	15	61	3	48	10	28	0	0	0	1	8	3	1	0	5	25	0	32	0	EE
ES	1	0	5	0	2	5	2	1	4	0	4	29	1	0	1196	1	203	26	0	5	3	2	8	0	31	0	0	0	1	0	0	ES
FI	0	0	1	0	0	0	0	6	0	0	2	13	6	9	1	76	4	16	0	0	0	1	4	2	0	0	2	6	0	5	0	FI
FR	1	0	10	0	3	16	2	3	25	0	13	125	4	0	141	3	785	33	0	4	4	5	11	1	67	0	0	1	8	1	0	FR
GB	0	0	1	0	0	-3	0	3	0	0	2	25	8	1	11	4	33	-152	0	0	0	1	41	3	2	0	0	2	0	1	0	GB
GE	1	57	3	486	1	0	6	6	1	0	4	10	1	1	9	3	7	3	705	4	1	4	1	0	6	0	31	3	0	1	5	GE
GL	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	64	1	15	5	24	1	270	14	3	1	14	33	2	1	34	3	32	5	7	714	14	35	1	0	95	0	6	4	0	2	18	GR
HR	14	0	134	2	193	3	28	14	4	0	86	161	6	1	31	7	64	11	2	26	397	206	2	1	156	0	2	5	1	2	7	HR
HU	3	1	73	3	23	2	37	29	3	0	89	145	10	3	16	14	41	11	2	14	38	383	3	1	33	0	5	10	1	5	15	HU
IE	0	0	0	0	0	1	0	3	0	0	1	18	4	1	8	3	21	95	0	0	0	0	62	2	2	0	0	2	0	1	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	2	1	0	1	1	2	12	0	0	0	0	5	6	0	0	0	0	0	0	0	IS
IT	11	0	97	1	39	3	15	5	34	0	40	126	2	1	104	3	216	10	1	31	61	42	2	0	921	0	1	2	2	1	2	IT
KG	0	3	2	13	1	0	1	2	1	0	2	10	1	0	14	2	10	3	4	2	1	2	1	0	7	467	226	1	0	0	1	KG
KZ	0	1	1	7	0	1	1	7	1	0	2	10	2	2	6	10	6	8	2	1	0	1	3	1	3	12	279	3	0	2	1	KZ
LT	0	0	3	0	1	1	1	95	1	0	8	50	24	10	5	23	16	32	0	1	1	5	10	2	3	0	5	109	0	36	2	LT
LU	1	0	14	0	2	37	2	4	7	0	29	307	7	1	51	5	285	41	0	2	2	7	13	2	17	0	0	3	-477	1	1	LU
LV	0	0	2	0	0	0	1	51	1	0	5	39	18	22	5	29	14	32	0	0	1	3	8	2	2	0	5	59	0	56	1	LV
MD	1	1	7	8	3	0	10	53	1	0	11	35	6	4	10	12	14	7	6	4	4	21	2	1	10	0	15	14	0	6	196	MD
ME	91	1	30	2	202	2	76	11	3	0	36	65	3	2	32	3	42	7	3	64	56	92	2	0	140	0	4	5	1	2	13	ME
MK	109	1	21	3	42	1	251	12	3	0	23	46	3	1	27	3	27	5	4	283	19	69	1	0	68	0	4	4	0	2	18	MK
MT	12	0	27	0	19	3	16	1	6	0	14	43	1	0	105	1	190	9	1	56	19	10	4	0	348	0	0	0	1	0	1	MT
NL	0	0	4	0	1	-49	1	6	1	0	16	16	12	1	13	6	65	47	0	1	1	6	19	3	7	0	0	5	1	2	1	NL
NO	0	0	1	0	0	1	0	3	0	0	2	21	10	1	1	7	8	36	0	0	0	1	9	3	0	0	0	3	0	2	0	NO
PL	1	0	11	1	3	-1	5	59	2	0	35	125	30	6	9	16	33	26	0	3	5	28	9	2	8	0	4	27	1	11	5	PL
PT	0	0	3	0	1	3	1	1	1	0	3	20	1	0	721	0	89	36	0	2	1	2	12	0	13	0	0	1	1	0	0	PT
RO	2	2	12	7	9	1	53	30	2	0	24	43	5	3	10	9	17	6	7	11	8	69	2	1	18	0	9	8	0	4	64	RO
RS	28	1	36	3	90	2	146	17	2	0	46	73	5	2	17	6	29	6	4	49	40	160	2	1	51	0	4	6	1	3	26	RS
RU	0	1	1	7	0	0	1	11	0	0	1	6	2	3	2	11	3	6	3	1	0	1	2	1	1	0	33	4	0	3	1	RU
SE	0	0	1	0	0	1	0	8	0	0	2	27	17	5	2	21	9	34	0	0	0	1	8	3	0	0	1	6	0	5	0	SE
SI	4	0	347	1	54	4	14	11	9	0	91	245	6	1	33	7	78	12	1	12	213	127	2	1	192	0	2	5	2	2	4	SI
SK	2	0	36	2	11	1	21	33	4	0	126	145	14	4	15	16	40	12	1	8	15	167	3	1	18	0	5	12	1	7	12	SK
TJ	0	3	2	15	1	0	1	2	1	0	2	10	0	0	13	1	9	3	5	2	1	1	1	0	5	37	84	1	0	0	1	TJ
TM	0	4	2	33	1	1	1	5	1	0	2	10	1	1	10	6	9	6	7	2	1	2	2	1	5	2	159	2	0	2	1	TM
TR	3	21	6	41	4	1	32	9	2	6	6	16	1	1	19	3	14	3	44	40	2	10	1	0	20	0	11	2	0	1	10	TR
UA	1	1	5	7	2	0	7	78	1	0	11	36	6	4	8	14	15	9	4	4	3	14	4	1	8	0	23	15	0	6	28	UA
UZ	0	2	1	11	1	1	1	5	1	0	2	10	1	1	9	6	8	6	4	1	0	1	2	1	4	14	206	2	0	1	1	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	-0	0	6	0	0	1	12	6	7	1	16	6	19	0	0	0	1	5	1	0	0	1	7	0	7	0	BAS
BLS	0	1	1	6	0	0	7	5	0	0	1	3	1	1	1	2	1	1	12	2	0	2	0	0	1	0	4	2	0	1	5	BLS
MED	5	0	5	1	6	1	16	2	1	1	3	9	0	0	20	0	30	2	1	35	8	5	1	0	44	0	1	0	0	0	2	MED
NOS	0	0	0	0	0	-1	0	1	0	0	0	3	1	0	1	1	4	1	0	0	0	0	4	1	0	0	0	1	0	0	0	NOS
AST	1	3	1	23	1	0	2	2	1	4	1	5	0	0	9	1	5	2	4	9	1	1	0	0	6	12	63	1	0	0	1	AST
NOA	3	0	5	0	4	1	6	1	2	1	3	12	0	0	110	0	54	5	1	22	4	4	2	0	55	0	0	0	0	0	1	NOA
EXC	3	2	8	15	5	0	10	14	3	0	9	30	4	3	48	10	46	9	8	10	5	10	4	1	25	8	69	5	1	3	4	EXC
EU	4	0	27	1	10	-1	29	14	9	1	27	88	9	4	185	14	169	16	1	29	15	29	10	2	90	0	2	9	2	5	7	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.4 Cont.: 2018 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	
AL	69	121	0	1	3	75	4	89	240	91	4	5	21	0	1	58	83	1	15	7	11	208	6	17	43	0	0	2416	993	AL
AM	0	0	0	0	2	10	2	9	2	149	2	0	2	0	41	257	31	18	7	3	18	12	2	870	12	0	0	1737	76	AM
AT	2	2	0	2	8	160	5	37	27	60	11	52	37	0	1	9	39	1	23	16	1	29	22	6	28	0	0	1948	1712	AT
AZ	0	0	0	0	5	15	1	9	2	382	4	0	2	0	80	66	46	36	10	6	14	7	3	444	7	0	0	1843	90	AZ
BA	43	8	0	2	6	159	2	111	143	71	6	15	53	0	1	26	68	1	18	13	5	81	12	10	34	0	0	2272	1217	BA
BE	0	0	0	-149	14	43	4	4	2	18	11	1	5	0	0	1	6	0	59	12	0	11	-104	1	9	0	0	-64	-119	BE
BG	5	10	0	1	6	76	2	311	101	278	8	3	20	0	3	55	301	2	14	14	69	24	7	17	15	0	0	2149	1266	BG
BY	0	0	0	0	19	125	1	20	4	359	28	1	8	0	1	2	113	1	23	52	2	3	19	1	2	0	0	1115	403	BY
CH	2	1	0	4	5	42	9	9	7	32	4	8	5	0	0	9	13	0	28	5	1	47	15	5	38	0	0	1880	1385	CH
CY	2	4	1	1	2	17	3	30	16	114	2	1	4	0	2	797	57	2	10	3	41	770	2	179	62	0	0	1785	748	CY
CZ	1	1	0	-1	14	346	3	48	28	102	20	8	55	0	1	5	58	1	28	34	1	10	35	4	10	0	0	1740	1475	CZ
DE	1	0	0	-17	17	130	3	11	6	50	20	4	10	0	0	2	18	0	42	24	0	9	20	2	8	0	0	888	759	DE
DK	0	0	0	-3	42	71	0	2	0	61	66	0	1	0	0	0	12	0	50	-31	0	1	43	0	1	0	0	467	336	DK
EE	0	0	0	0	25	41	0	1	0	331	49	0	1	0	0	0	14	0	26	80	0	0	27	1	0	0	0	756	356	EE
ES	0	0	0	2	1	9	175	2	2	8	1	1	1	0	0	4	3	0	172	1	0	137	13	2	100	0	0	1742	1713	ES
FI	0	0	0	1	22	22	0	0	0	115	40	0	1	0	0	0	5	0	20	40	0	0	16	1	0	0	0	362	208	FI
FR	1	1	0	-4	6	28	13	4	3	17	6	3	3	0	0	3	6	0	91	6	0	68	4	2	30	0	0	1356	1285	FR
GB	0	0	0	-10	17	18	2	1	0	12	12	0	1	0	0	0	3	0	60	12	0	2	-21	0	2	0	0	42	3	GB
GE	0	0	0	0	3	19	2	18	3	325	4	0	3	0	40	191	62	18	8	5	80	8	2	285	9	0	0	2048	112	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	GL
GR	10	47	0	1	4	57	4	102	84	201	5	3	13	0	2	149	172	1	15	8	55	262	6	23	52	0	0	2275	1463	GR
HR	13	5	0	3	7	187	3	96	124	60	8	56	55	0	1	17	58	1	21	16	3	124	17	7	28	0	0	2261	1736	HR
HU	3	3	0	1	10	309	2	241	84	125	14	11	144	0	1	11	165	1	19	29	5	20	18	8	14	0	0	2135	1647	HU
IE	0	0	0	3	8	14	1	1	0	9	8	0	0	0	0	0	2	0	69	9	0	2	20	0	2	0	0	271	247	IE
IS	0	0	0	0	3	1	0	0	0	2	3	0	0	0	0	0	0	0	19	2	0	0	6	0	0	0	0	41	28	IS
IT	7	4	0	2	4	63	11	22	27	29	3	40	18	0	0	15	21	0	32	5	2	384	12	6	80	0	0	2042	1839	IT
KG	0	0	0	0	2	8	2	3	1	150	2	0	1	62	62	26	11	685	8	2	1	6	2	454	14	0	0	1797	78	KG
KZ	0	0	0	1	10	10	1	3	1	651	8	0	1	1	14	5	22	35	18	9	1	2	6	58	4	0	0	1134	84	KZ
LT	0	0	0	0	23	118	1	5	2	248	47	1	4	0	0	1	37	0	26	92	1	1	31	1	1	0	0	934	516	LT
LU	0	0	0	-14	10	56	6	6	3	23	10	2	6	0	0	1	11	0	52	13	0	14	10	1	11	0	0	487	420	LU
LV	0	0	0	1	23	66	1	3	1	277	49	0	2	0	0	1	21	0	25	90	1	1	28	1	1	0	0	803	418	LV
MD	1	1	0	-1	10	156	2	124	7	350	13	1	13	0	4	10	607	4	17	26	27	8	9	11	5	0	0	1765	487	MD
ME	500	24	0	2	5	103	3	115	199	102	6	5	34	0	1	45	91	1	17	10	8	123	9	17	41	0	0	2224	927	ME
MK	19	354	0	1	4	73	3	128	267	127	5	3	22	0	1	72	127	1	13	9	18	61	6	19	32	0	0	2257	1090	MK
MT	6	5	-746	3	2	20	10	12	13	12	1	9	5	0	0	19	12	0	41	2	4	384	9	6	175	0	0	273	162	MT
NL	0	0	0	-625	22	59	2	4	2	23	16	0	4	0	0	0	5	0	50	17	0	5	-141	0	4	0	0	-301	-366	NL
NO	0	0	0	1	84	17	0	1	0	21	32	0	1	0	0	0	4	0	30	17	0	0	34	1	0	0	0	272	155	NO
PL	1	1	0	-4	23	371	1	32	10	166	34	2	24	0	1	3	100	1	27	73	1	3	33	3	3	0	0	1229	847	PL
PT	0	0	0	1	2	8	708	1	1	6	2	1	1	0	0	2	2	0	317	2	0	48	12	1	55	0	0	1650	1631	PT
RO	2	2	0	0	7	142	1	678	32	233	10	2	29	0	3	24	358	2	14	20	28	13	8	16	8	0	0	1961	1167	RO
RS	27	27	0	2	5	124	2	282	349	135	8	6	46	0	1	35	156	1	15	15	14	36	9	13	19	0	0	2059	1147	RS
RU	0	0	0	0	7	11	0	3	1	416	7	0	1	0	3	4	28	3	11	10	3	1	5	10	1	0	0	588	69	RU
SE	0	0	0	1	45	31	0	1	0	58	84	0	1	0	0	0	5	0	26	43	0	0	32	1	1	0	0	378	257	SE
SI	3	2	0	2	7	155	4	57	56	48	9	312	44	0	0	11	38	0	22	14	2	70	18	5	25	0	0	2232	1977	SI
SK	2	2	0	-0	13	480	2	134	35	143	17	6	268	0	2	7	162	1	20	38	3	10	22	7	9	0	0	2007	1569	SK
TJ	0	0	0	0	1	7	2	3	1	105	1	0	1	285	196	30	9	533	6	2	1	5	2	535	14	0	0	1379	68	TJ
TM	0	0	0	1	6	10	2	5	1	367	5	0	1	4	199	21	25	227	14	7	2	4	5	251	7	0	0	1152	88	TM
TR	2	2	0	1	3	25	3	51	12	246	4	1	5	0	6	1037	102	3	10	6	90	92	3	393	40	0	0	1832	273	TR
UA	1	1	0	0	13	140	1	58	5	513	16	1	9	0	6	11	500	6	20	28	20	7	11	13	5	0	0	1595	395	UA
UZ	0	0	0	1	7	9	1	3	1	396	5	0	1	25	70	13	20	303	14	6	2	3	5	130	7	0	0	1161	81	UZ
ATL	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	7	6	ATL
BAS	0	0	0	-1	12	24	0	0	0	48	26	0	1	0	0	0	4	0	14	-23	0	0	15	0	0	0	0	214	140	BAS
BLS	0	0	0	0	1	10	0	16	2	131	2	0	1	0	2	17	67	1	3	3	50	2	1	5	1	0	0	310	55	BLS
MED	2	1	-0	0	1	9	3	10	6	25	1	2	2	0	0	33	17	0	9	1	10	120	2	-0	19	0	0	312	209	MED
NOS	0	0	0	-8	4	4	0	0	0	3	3	0	0	0	0	0	1	0	11	1	0	0	-30	0	0	0	0	26	17	NOS
AST	0	0	0	0	1	5	1	4	2	90	1	0	1	6	70	87	10	71	5	2	3	30	1	1234	15	0	0	509	62	AST
NOA	1	1	0	1	1	6	26	5	4	11	0	1	2	0	0	19	7	0	79	1	2	175	3	1	581	0	0	381	325	NOA
EXC	1	2	0	-2	11	38	10	24	8	336	11	2	5	4	14	53	53	32	24	14	8	22	8	54	10	0	0	973	329	EXC
EU	2	3	-0	-8	15	93	38	64	16	83	23	8	16	0	1	12	54	0	60	24	6	67	13	4	27	0	0	1224	989	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	

Table C.5: 2018 country-to-country blame matrices for **AOT40$_f^{uc}$**.
Units: ppb.h per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	73	1	6	9	11	2	10	12	2	0	11	36	2	0	12	1	15	16	2	26	9	11	1	0	68	0	2	1	0	1	3	AL
AM	0	227	1	495	1	1	1	5	1	0	3	11	1	0	3	1	4	6	90	1	1	1	0	0	6	0	9	0	0	0	1	AM
AT	1	0	65	3	4	8	2	10	25	0	36	193	4	0	9	1	43	28	1	2	8	11	1	0	66	0	1	1	1	1	1	AT
AZ	0	15	1	721	1	1	1	8	1	0	4	14	1	0	3	1	5	9	59	1	1	2	1	0	7	0	15	1	0	1	1	AZ
BA	4	0	10	4	67	4	4	12	3	0	20	65	3	0	9	1	19	22	1	6	14	14	1	0	51	0	1	1	0	1	3	BA
BE	0	0	4	0	1	77	1	6	3	0	14	183	5	0	9	1	70	100	0	1	1	3	4	0	14	0	0	1	3	1	0	BE
BG	1	1	4	17	4	2	31	19	2	0	10	34	3	1	5	1	11	13	5	9	3	8	1	0	16	0	3	1	0	1	7	BG
BY	0	0	1	1	1	3	1	46	1	0	6	28	3	0	2	1	8	20	0	0	1	3	1	0	5	0	2	2	0	1	1	BY
CH	1	0	17	2	2	8	1	5	179	0	16	226	2	0	18	1	111	31	1	2	3	3	1	0	163	0	1	1	1	0	1	CH
CY	2	1	3	19	3	2	8	9	2	29	6	25	1	0	11	1	15	10	5	30	3	5	1	0	34	0	4	1	0	1	4	CY
CZ	0	0	13	2	2	10	2	16	5	0	86	149	7	1	6	1	31	37	0	1	4	11	2	0	19	0	2	1	1	1	2	CZ
DE	0	0	11	1	1	17	1	10	11	0	23	252	7	1	8	1	49	71	0	1	2	4	3	0	19	0	1	1	1	1	1	DE
DK	0	0	0	0	0	4	0	7	0	0	2	39	32	1	1	3	10	85	0	0	0	1	5	0	2	0	0	2	0	2	0	DK
EE	0	0	0	0	0	2	0	6	0	0	2	16	3	3	1	4	5	25	0	0	0	0	2	0	1	0	1	1	0	3	0	EE
ES	0	0	2	1	1	5	1	3	2	0	4	36	2	0	153	0	47	40	0	2	1	1	2	0	21	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	3	0	0	1	7	1	1	0	4	2	11	0	0	0	0	1	0	0	0	0	0	0	1	0	FI
FR	0	0	4	1	2	18	1	4	11	0	9	106	3	0	30	1	122	62	0	1	2	2	3	0	49	0	0	0	2	0	0	FR
GB	0	0	1	0	0	5	0	4	1	0	2	28	5	0	4	1	19	169	0	0	0	1	6	0	3	0	0	1	0	0	0	GB
GE	0	20	1	340	1	1	1	7	1	0	4	14	1	0	3	1	5	7	228	1	1	2	0	0	6	0	8	1	0	1	2	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	GL
GR	9	1	5	15	6	2	15	16	2	0	10	36	2	0	12	1	15	16	5	96	5	9	1	0	45	0	3	1	0	1	5	GR
HR	3	0	17	4	26	5	4	13	4	0	26	90	4	0	10	1	25	25	1	5	34	19	1	0	78	0	1	1	1	1	3	HR
HU	1	0	12	6	4	5	5	17	3	0	27	80	5	1	6	2	18	25	1	3	5	38	1	0	21	0	2	1	1	1	4	HU
IE	0	0	0	0	0	1	0	4	0	0	1	14	3	0	3	1	9	81	0	0	0	0	15	0	3	0	0	1	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	IS
IT	3	0	18	4	10	6	3	7	16	0	20	101	2	0	30	1	61	29	1	8	15	9	2	0	556	0	1	1	1	1	1	IT
KG	0	1	1	16	0	1	0	3	1	0	2	8	0	0	3	1	4	5	2	1	0	1	0	0	5	55	50	0	0	0	0	KG
KZ	0	0	0	6	0	1	0	5	0	0	1	8	1	0	2	1	3	8	1	0	0	1	1	0	3	3	34	0	0	0	0	KZ
LT	0	0	2	0	0	3	0	25	1	0	5	29	5	1	2	2	8	30	0	0	1	2	2	0	4	0	1	6	0	3	1	LT
LU	0	0	6	0	1	30	1	6	4	0	16	240	4	0	11	1	70	71	0	1	1	3	3	0	18	0	0	1	18	1	0	LU
LV	0	0	1	0	0	3	0	12	1	0	4	22	4	1	1	2	7	26	0	0	0	1	2	0	2	0	1	3	0	6	0	LV
MD	0	1	3	15	1	3	2	21	1	0	7	31	2	1	4	2	9	13	2	1	1	5	1	0	9	0	4	2	0	1	23	MD
ME	14	1	6	7	17	2	6	11	2	0	13	42	2	0	9	1	16	19	2	10	8	11	1	0	54	0	2	1	0	1	3	ME
MK	8	1	5	9	7	2	13	14	2	0	10	35	2	0	8	1	12	15	2	36	4	10	1	0	30	0	2	1	0	1	4	MK
MT	4	0	8	3	8	5	4	5	5	0	12	59	2	0	35	0	63	26	1	15	8	5	2	0	213	0	1	0	1	0	1	MT
NL	0	0	2	0	0	27	0	7	1	0	11	132	6	0	4	1	41	114	0	0	1	2	5	0	9	0	0	1	1	1	0	NL
NO	0	0	0	0	0	1	0	2	0	0	1	8	3	0	0	1	2	22	0	0	0	0	1	0	0	0	0	0	0	0	0	NO
PL	0	0	3	2	1	7	1	22	2	0	18	70	8	1	3	2	15	39	0	1	1	5	2	0	7	0	2	2	0	2	2	PL
PT	0	0	1	1	1	5	0	2	1	0	3	27	2	0	93	0	33	46	0	1	1	1	3	0	10	0	0	0	0	0	0	PT
RO	1	1	4	14	2	2	5	19	1	0	10	34	2	1	4	2	9	13	3	3	2	9	1	0	13	0	3	1	0	1	8	RO
RS	3	1	7	9	13	3	10	16	2	0	16	50	3	1	6	1	14	18	2	9	7	18	1	0	26	0	2	1	0	1	5	RS
RU	0	0	0	6	0	0	0	4	0	0	1	5	1	0	1	1	2	5	1	0	0	0	0	0	1	0	3	0	0	0	0	RU
SE	0	0	0	0	0	1	0	4	0	0	1	12	4	1	1	2	3	24	0	0	0	0	2	0	1	0	0	1	0	1	0	SE
SI	1	0	42	3	10	6	3	11	8	0	30	126	4	0	10	1	30	25	1	3	26	16	1	0	112	0	1	1	1	1	2	SI
SK	1	0	9	4	2	5	3	17	3	0	31	75	5	1	5	2	17	25	1	2	3	18	1	0	13	0	2	1	0	1	3	SK
TJ	0	1	1	20	0	1	0	3	1	0	1	8	0	0	3	0	3	4	2	1	0	1	0	0	4	6	21	0	0	0	0	TJ
TM	0	1	1	34	0	1	0	5	1	0	2	12	1	0	3	1	5	9	3	0	0	1	1	0	5	1	20	1	0	1	1	TM
TR	1	9	2	48	1	1	4	8	1	1	4	18	1	0	6	1	8	8	17	7	1	3	0	0	13	0	4	1	0	1	3	TR
UA	0	0	2	11	1	3	1	23	1	0	7	28	2	1	3	2	8	16	2	1	1	3	1	0	7	0	4	1	0	1	4	UA
UZ	0	1	1	13	0	1	0	4	1	0	2	10	1	0	3	1	4	8	2	0	0	1	1	0	4	8	27	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	3	0	0	1	10	5	1	0	2	3	19	0	0	0	0	1	0	0	0	0	1	0	1	0	BAS
BLS	0	0	0	9	0	0	1	3	0	0	1	4	0	0	1	0	1	2	6	0	0	1	0	0	1	0	1	0	0	0	1	BLS
MED	1	0	1	2	2	1	2	2	1	0	2	11	0	0	8	0	10	5	1	8	2	2	0	0	29	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	1	0	1	0	0	0	6	1	0	0	0	3	16	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	1	1	28	0	0	1	2	1	1	1	6	0	0	3	0	3	3	2	2	0	1	0	0	6	2	14	0	0	0	0	AST
NOA	1	0	2	2	1	2	1	2	2	0	3	18	1	0	23	0	18	12	1	4	2	2	1	0	31	0	0	0	0	0	0	NOA
EXC	0	1	2	13	1	2	1	7	2	0	4	24	2	0	8	1	11	16	3	2	1	2	1	0	16	1	9	1	0	1	1	EXC
EU	1	0	6	3	2	7	2	9	5	0	12	73	4	0	28	1	37	46	1	5	3	5	2	0	56	0	1	1	1	1	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.5 Cont.: 2018 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	
AL	4	15	0	5	2	46	2	17	39	56	2	2	7	0	0	25	22	0	0	0	0	1	0	21	17	0	0	587	308	AL
AM	0	0	0	2	1	11	1	4	2	71	1	0	1	0	7	51	11	4	0	0	0	0	0	537	5	0	0	1040	64	AM
AT	0	1	0	17	3	67	1	9	9	39	3	11	11	0	0	4	12	0	0	0	0	0	0	8	10	0	0	714	600	AT
AZ	0	0	0	3	2	16	1	4	2	117	2	0	2	0	10	18	15	5	0	0	0	0	0	329	4	0	0	1072	83	AZ
BA	1	2	0	8	3	61	1	19	30	47	3	3	9	0	0	13	18	0	0	0	0	0	0	12	12	0	0	562	351	BA
BE	0	0	0	126	4	34	1	2	2	15	4	1	3	0	0	1	3	0	0	0	0	0	2	1	8	0	0	695	659	BE
BG	0	2	0	6	3	39	1	37	17	104	3	1	5	0	1	28	45	1	0	0	0	0	0	20	6	0	0	507	247	BG
BY	0	0	0	7	3	32	0	5	2	89	3	0	2	0	0	1	15	0	0	0	0	0	0	2	1	0	0	299	137	BY
CH	0	0	0	18	2	31	3	3	3	23	2	4	3	0	0	4	5	0	0	0	0	0	0	7	15	0	0	901	671	CH
CY	0	2	0	4	2	25	2	15	10	84	2	1	4	0	1	314	27	1	0	0	0	2	0	263	27	0	0	729	237	CY
CZ	0	1	0	22	5	121	1	11	8	53	4	3	11	0	0	3	16	0	0	0	0	0	1	6	5	0	0	673	557	CZ
DE	0	0	0	39	4	53	1	4	3	31	4	2	4	0	0	1	7	0	0	0	0	0	1	3	6	0	0	651	580	DE
DK	0	0	0	17	9	30	0	1	0	29	15	0	1	0	0	0	4	0	0	1	0	0	1	1	1	0	0	303	252	DK
EE	0	0	0	7	3	13	0	0	0	83	4	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	191	94	EE
ES	0	0	0	11	1	12	22	1	1	12	1	1	1	0	0	4	2	0	1	0	0	1	0	4	34	0	0	399	369	ES
FI	0	0	0	2	2	7	0	0	0	30	3	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	81	43	FI
FR	0	0	0	37	3	23	3	2	2	14	3	2	2	0	0	2	3	0	0	0	0	0	1	3	14	0	0	532	488	FR
GB	0	0	0	17	4	12	1	1	0	11	4	0	1	0	0	0	2	0	0	0	0	0	1	0	2	0	0	302	279	GB
GE	0	0	0	3	2	16	1	5	2	103	2	0	2	0	6	31	15	3	0	0	0	0	0	210	4	0	0	848	79	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	1	9	0	5	3	42	2	20	22	90	2	2	6	0	1	64	34	0	0	0	0	1	0	27	19	0	0	638	352	GR
HR	1	2	0	11	4	72	1	21	30	46	3	9	11	0	0	10	17	0	0	0	0	1	0	10	12	0	0	645	477	HR
HU	0	1	0	11	4	100	1	37	17	68	4	3	20	0	0	7	30	0	0	0	0	0	0	10	6	0	0	598	432	HU
IE	0	0	0	5	3	9	0	1	0	10	3	0	0	0	0	0	2	0	0	0	0	0	0	0	2	0	0	170	150	IE
IS	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	8	IS
IT	1	2	0	13	3	44	4	9	12	28	2	15	7	0	0	10	10	0	0	0	0	2	0	10	38	0	0	1062	955	IT
KG	0	0	0	1	1	6	0	1	1	51	1	0	1	27	8	7	4	318	0	0	0	0	0	197	4	0	0	588	43	KG
KZ	0	0	0	2	1	7	0	1	1	83	1	0	1	1	2	2	5	13	0	0	0	0	0	31	2	0	0	201	43	KZ
LT	0	0	0	8	3	33	0	2	1	60	5	0	2	0	0	1	6	0	0	0	0	0	0	1	1	0	0	251	152	LT
LU	0	0	0	59	3	34	2	3	2	16	3	1	4	0	0	1	4	0	0	0	0	0	1	2	8	0	0	640	601	LU
LV	0	0	0	9	3	21	0	1	0	61	4	0	1	0	0	0	3	0	0	0	0	0	0	1	1	0	0	204	120	LV
MD	0	0	0	5	3	47	1	17	3	113	3	1	4	0	1	4	61	1	0	0	0	0	0	11	3	0	0	429	174	MD
ME	16	6	0	5	3	44	1	17	28	53	2	2	7	0	0	18	20	0	0	0	0	1	0	19	13	0	0	483	281	ME
MK	1	49	0	5	2	41	1	20	37	65	2	1	6	0	0	31	27	0	0	0	0	0	0	20	11	0	0	524	263	MK
MT	1	2	51	11	2	27	5	6	8	24	1	4	4	0	0	19	8	0	0	0	0	8	0	13	91	0	0	661	568	MT
NL	0	0	0	152	5	37	1	2	2	17	4	0	2	0	0	0	3	0	0	0	0	0	3	1	4	0	0	597	560	NL
NO	0	0	0	3	11	6	0	0	0	9	3	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	77	53	NO
PL	0	0	0	15	5	147	0	8	3	64	5	1	6	0	0	2	18	0	0	0	0	0	0	4	2	0	0	493	370	PL
PT	0	0	0	11	2	10	118	1	1	9	1	0	1	0	0	2	2	0	1	0	0	0	0	3	19	0	0	391	370	PT
RO	0	1	0	5	3	51	1	67	9	93	3	1	6	0	1	10	47	1	0	0	0	0	0	16	4	0	0	464	249	RO
RS	1	6	0	7	3	56	1	38	66	72	3	2	10	0	0	16	31	0	0	0	0	0	0	15	7	0	0	557	309	RS
RU	0	0	0	1	1	5	0	1	0	62	1	0	0	0	0	1	4	0	0	0	0	0	0	6	1	0	0	111	27	RU
SE	0	0	0	4	4	11	0	0	0	22	6	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	108	74	SE
SI	0	1	0	15	4	66	1	14	18	38	3	72	12	0	0	6	13	0	0	0	0	0	0	8	11	0	0	743	624	SI
SK	0	1	0	11	4	140	1	22	8	65	4	2	32	0	0	4	26	0	0	0	0	0	0	8	4	0	0	570	429	SK
TJ	0	0	0	1	1	5	1	1	1	43	1	0	1	43	16	7	4	130	0	0	0	0	0	207	4	0	0	337	38	TJ
TM	0	0	0	2	2	9	1	2	1	83	2	0	1	2	26	7	8	25	0	0	0	0	0	180	3	0	0	280	60	TM
TR	0	1	0	3	2	18	1	11	5	83	2	1	2	0	2	205	21	1	0	0	0	0	0	238	13	0	0	531	119	TR
UA	0	0	0	6	3	43	0	10	2	127	3	1	3	0	1	5	56	1	0	0	0	0	0	13	3	0	0	396	154	UA
UZ	0	0	0	2	2	7	0	2	1	78	1	0	1	13	9	4	6	157	0	0	0	0	0	90	3	0	0	376	50	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	ATL
BAS	0	0	0	4	2	11	0	0	0	26	5	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	100	67	BAS
BLS	0	0	0	1	1	5	0	3	1	38	1	0	1	0	0	9	10	0	0	0	0	0	0	6	1	0	0	105	24	BLS
MED	0	1	0	2	1	8	1	3	3	13	0	1	1	0	0	20	5	0	0	0	0	1	0	12	15	0	0	152	99	MED
NOS	0	0	0	5	2	3	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45	39	NOS
AST	0	0	0	1	1	5	0	2	1	34	1	0	1	2	9	26	4	14	0	0	0	0	0	815	6	0	0	183	40	AST
NOA	0	0	0	4	1	9	7	2	2	11	1	1	1	0	0	10	3	0	0	0	0	1	0	11	119	0	0	182	145	NOA
EXC	0	0	0	6	2	16	2	4	2	61	2	1	2	1	2	12	9	11	0	0	0	0	0	33	4	0	0	266	128	EXC
EU	0	1	0	18	3	40	6	9	5	36	4	2	4	0	0	6	10	0	0	0	0	0	1	6	11	0	0	457	373	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	

Table C.6: 2018 country-to-country blame matrices for **SOMO35**.
Units: ppb.d per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	56	0	2	0	6	0	10	1	0	0	2	3	0	0	6	0	4	0	0	24	4	5	0	0	17	0	0	0	0	0	1	AL
AM	0	-1	0	44	0	0	0	0	0	0	0	0	0	0	1	0	1	0	13	1	0	0	0	0	1	0	2	0	0	0	0	AM
AT	0	0	17	0	2	-0	1	1	3	0	9	30	0	0	4	0	11	0	0	1	3	6	0	0	12	0	0	0	0	0	0	AT
AZ	0	4	0	55	0	0	0	1	0	0	0	1	0	0	1	0	1	0	8	1	0	0	0	0	1	0	7	0	0	0	0	AZ
BA	2	0	6	0	50	0	4	1	0	0	5	8	0	0	4	0	5	0	0	5	15	13	0	0	14	0	0	0	0	0	1	BA
BE	0	0	1	0	0	-54	0	0	0	0	1	-3	1	0	5	0	17	2	0	0	0	0	1	0	2	0	0	0	-0	0	0	BE
BG	1	0	1	1	2	0	48	2	0	0	2	3	0	0	3	0	2	0	1	8	1	4	0	0	4	0	1	1	0	0	4	BG
BY	0	0	1	0	0	-0	0	14	0	0	1	3	1	0	1	1	2	1	0	0	0	1	1	0	1	0	1	3	0	1	1	BY
CH	0	0	4	0	1	0	0	0	18	0	1	18	0	0	7	0	36	0	0	1	1	1	0	0	21	0	0	0	0	0	0	CH
CY	1	0	1	0	1	0	3	0	0	29	0	1	0	0	4	0	3	0	1	18	0	1	0	0	6	0	0	0	0	0	0	CY
CZ	0	0	6	0	1	-0	1	2	0	0	12	24	1	0	3	1	8	1	0	1	1	5	0	0	3	0	0	1	0	0	0	CZ
DE	0	0	2	0	0	-1	0	1	1	0	3	-4	1	0	4	1	13	1	0	0	0	1	1	0	2	0	0	1	0	0	0	DE
DK	0	0	0	0	0	-1	0	1	0	0	-0	-0	-15	0	1	1	3	6	0	0	0	0	2	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	-0	0	2	0	0	0	2	1	2	1	4	1	2	0	0	0	0	1	0	0	0	1	2	0	3	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	2	0	0	101	0	15	2	0	0	0	0	1	0	3	0	0	0	0	0	0	ES
FI	0	0	0	0	0	-0	0	1	0	0	0	1	1	1	0	7	1	2	0	0	0	0	1	0	0	0	0	1	0	1	0	FI
FR	0	0	1	0	0	1	0	0	2	0	0	6	0	0	14	0	59	2	0	0	0	0	1	0	6	0	0	0	1	0	0	FR
GB	0	0	0	0	0	-1	0	0	0	0	0	-0	0	0	2	0	3	-35	0	0	0	0	3	0	0	0	0	0	-0	0	0	GB
GE	0	4	0	34	0	0	1	1	0	0	0	1	0	0	2	0	1	0	54	1	0	0	0	0	2	0	3	0	0	0	0	GE
GL	0	0	-0	0	0	-0	0	0	-0	0	-0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	GL
GR	6	0	1	0	2	0	23	1	0	0	1	2	0	0	5	0	4	0	1	60	1	3	0	0	11	0	0	0	0	0	1	GR
HR	2	0	11	0	18	0	3	1	0	0	6	11	0	0	4	0	6	1	0	3	31	18	0	0	15	0	0	0	0	0	1	HR
HU	0	0	6	0	3	-0	4	2	0	0	7	9	1	0	2	1	4	0	0	2	4	28	0	0	5	0	0	1	0	0	1	HU
IE	0	0	0	0	0	-0	0	0	0	0	-0	-1	0	0	1	0	2	4	0	0	0	0	-7	0	0	0	0	0	-0	0	0	IE
IS	0	0	0	0	0	-0	0	0	0	0	-0	-1	0	0	1	0	1	1	0	0	0	0	0	-0	0	0	0	0	-0	0	0	IS
IT	1	0	7	0	4	0	1	0	2	0	3	8	0	0	11	0	18	1	0	3	5	3	0	0	60	0	0	0	0	0	0	IT
KG	0	0	0	1	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	1	36	18	0	0	0	0	KG
KZ	0	0	0	1	0	0	0	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	0	1	1	28	0	0	0	0	KZ
LT	0	0	0	0	0	-0	0	8	0	0	1	3	2	1	1	2	2	2	0	0	0	1	1	0	1	0	1	5	0	2	0	LT
LU	0	0	1	0	0	-0	0	0	1	0	1	14	1	0	7	0	25	1	0	0	0	1	1	0	2	0	0	0	-58	0	0	LU
LV	0	0	0	0	0	-0	0	5	0	0	1	3	1	2	1	2	2	2	0	0	0	1	1	0	1	0	1	5	0	2	0	LV
MD	0	0	1	1	1	-0	1	4	0	0	1	2	0	0	2	1	2	0	1	1	1	2	0	0	2	0	2	1	0	1	14	MD
ME	9	0	2	0	18	0	7	1	0	0	3	4	0	0	6	0	5	0	0	7	5	8	0	0	15	0	0	0	0	0	1	ME
MK	11	0	2	0	4	0	23	1	0	0	2	3	0	0	5	0	3	0	0	27	2	5	0	0	8	0	0	0	0	0	2	MK
MT	1	0	3	0	2	0	2	0	1	0	1	3	0	0	13	0	17	1	0	5	2	1	0	0	37	0	0	0	0	0	0	MT
NL	0	0	0	0	0	-7	0	1	0	0	1	-6	1	0	3	0	7	1	0	0	0	1	2	0	1	0	0	0	-0	0	0	NL
NO	0	0	0	0	0	-0	0	0	0	0	0	0	1	0	1	1	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	1	-0	1	5	0	0	3	8	2	0	2	1	3	1	0	0	1	3	1	0	2	0	1	2	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	65	0	7	3	0	0	0	0	1	0	1	0	0	0	0	0	0	PT
RO	1	0	1	1	1	0	6	3	0	0	2	3	0	0	2	1	2	0	1	2	1	7	0	0	3	0	1	1	0	0	6	RO
RS	3	0	3	0	9	0	14	1	0	0	3	5	0	0	3	0	3	0	0	5	4	13	0	0	6	0	0	0	0	0	2	RS
RU	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	RU
SE	0	0	0	0	0	-0	0	1	0	0	0	2	1	1	1	3	1	3	0	0	0	0	1	0	0	0	0	1	0	1	0	SE
SI	0	0	27	0	5	0	1	1	1	0	6	16	0	0	4	0	7	0	0	1	19	10	0	0	15	0	0	0	0	0	0	SI
SK	0	0	3	0	1	-0	2	3	0	0	10	9	1	0	2	1	4	0	0	1	2	16	0	0	3	0	0	1	0	0	1	SK
TJ	0	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	3	7	0	0	0	0	TJ
TM	0	1	0	5	0	0	0	1	0	0	0	1	0	0	2	1	1	1	1	0	0	0	0	0	1	0	18	0	0	0	0	TM
TR	0	2	1	3	0	0	3	1	0	1	0	1	0	0	3	0	2	0	3	5	0	1	0	0	3	0	1	0	0	0	1	TR
UA	0	0	0	1	0	-0	1	6	0	0	1	2	0	0	1	1	2	1	0	1	0	1	0	0	1	0	2	1	0	1	3	UA
UZ	0	0	0	2	0	0	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	1	23	0	0	0	0	UZ
ATL	0	0	0	0	0	-0	0	0	0	0	-0	-0	0	0	3	0	3	2	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	-0	0	2	0	0	0	1	1	2	1	5	2	4	0	0	0	0	1	0	0	0	0	2	0	2	0	BAS
BLS	0	0	0	3	1	0	5	3	0	0	1	1	0	0	2	1	1	0	8	2	0	1	0	0	2	0	2	1	0	0	3	BLS
MED	2	0	2	0	3	0	5	0	1	1	1	3	0	0	16	0	20	1	0	15	3	2	0	0	28	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	-2	0	1	0	0	-0	-3	0	0	2	1	2	-2	0	0	0	0	4	1	0	0	0	0	-0	0	0	NOS
AST	0	0	0	3	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	1	7	0	0	0	0	AST
NOA	0	0	1	0	1	0	1	0	0	0	0	1	0	0	15	0	6	0	0	3	0	0	0	0	7	0	0	0	0	0	0	NOA
EXC	0	0	1	1	1	-0	1	1	0	0	1	2	0	0	5	1	4	0	1	1	0	1	0	0	2	1	7	0	0	0	0	EXC
EU	0	0	2	0	1	-0	3	1	1	0	2	4	0	0	17	1	13	-1	0	3	1	3	1	0	7	0	0	1	0	0	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.6 Cont.: 2018 country-to-country blame matrices for **SOMO35**.
Units: ppb.d per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	
AL	6	11	0	0	0	5	1	8	22	7	0	0	2	0	0	5	7	0	3	0	1	28	0	2	7	0	0	216	94	AL
AM	0	0	0	-0	0	1	0	1	0	11	0	0	0	0	3	30	3	1	1	0	2	4	0	65	2	0	0	117	9	AM
AT	0	0	0	-0	1	8	1	3	2	5	1	4	3	0	0	1	3	0	3	1	0	5	1	1	3	0	0	137	117	AT
AZ	0	0	0	-0	0	1	0	1	0	33	0	0	0	0	7	10	4	4	1	1	2	2	0	36	1	0	0	144	10	AZ
BA	4	1	0	0	0	11	0	10	13	6	0	1	4	0	0	3	6	0	3	1	1	13	1	1	5	0	0	195	107	BA
BE	0	0	0	-14	1	2	1	0	0	2	1	0	0	0	0	0	1	0	7	1	0	2	-10	0	1	0	0	-29	-35	BE
BG	1	1	0	0	0	6	0	29	10	23	1	0	2	0	0	4	25	0	2	1	7	6	0	1	3	0	0	192	115	BG
BY	0	0	0	-0	1	10	0	3	1	27	2	0	1	0	0	1	12	0	2	4	0	1	1	0	1	0	0	94	35	BY
CH	0	0	0	-0	0	1	1	1	1	3	0	1	0	0	0	1	1	0	5	0	0	6	1	1	4	0	0	122	96	CH
CY	0	0	0	0	0	1	1	2	1	9	0	0	0	0	0	66	4	0	2	0	3	79	0	11	8	0	0	158	72	CY
CZ	0	0	0	-1	1	20	0	4	2	8	1	1	4	0	0	1	5	0	3	2	0	2	2	0	2	0	0	121	99	CZ
DE	0	0	0	-3	1	7	0	1	1	4	1	0	1	0	0	0	2	0	5	1	0	2	0	0	1	0	0	46	35	DE
DK	0	0	0	-3	3	4	0	1	0	5	5	0	0	0	0	0	2	0	5	-5	0	1	-1	0	0	0	0	21	8	DK
EE	0	0	0	-0	3	4	0	1	0	28	5	0	0	0	0	0	2	0	3	5	0	0	2	0	0	0	0	67	30	EE
ES	0	0	0	0	0	0	15	0	0	1	0	0	0	0	0	0	0	0	18	0	0	12	1	0	8	0	0	144	141	ES
FI	0	0	0	-0	3	2	0	0	0	13	5	0	0	0	0	0	1	0	3	3	0	0	2	0	0	0	0	41	22	FI
FR	0	0	0	-1	1	1	1	0	0	1	0	0	0	0	0	0	1	0	11	0	0	7	-0	0	3	0	0	101	95	FR
GB	0	0	0	-2	1	1	0	0	0	1	1	0	0	0	0	0	0	0	7	1	0	1	-5	0	0	0	0	-20	-24	GB
GE	0	0	0	-0	0	1	0	2	0	29	0	0	0	0	3	26	6	2	1	0	8	4	0	24	2	0	0	176	14	GE
GL	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	1	-0	0	0	0	0	0	0	0	1	-0	GL
GR	1	4	0	0	0	4	1	9	7	15	0	0	1	0	0	13	13	0	3	1	5	33	0	2	8	0	0	196	129	GR
HR	1	0	0	0	1	12	0	9	11	5	1	4	5	0	0	2	5	0	3	1	0	16	1	1	4	0	0	191	143	HR
HU	0	0	0	-0	1	21	0	22	8	10	1	1	11	0	0	1	13	0	3	2	1	4	1	1	2	0	0	175	132	HU
IE	0	0	0	-1	1	0	0	0	0	1	1	0	0	0	0	0	0	0	9	0	0	1	-0	0	0	0	0	4	1	IE
IS	0	0	0	-0	1	-0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3	2	IS
IT	1	0	0	0	0	4	1	2	2	2	0	3	1	0	0	1	2	0	5	0	0	38	1	1	9	0	0	150	133	IT
KG	0	0	0	0	0	1	0	0	0	11	0	0	0	6	6	3	1	52	1	0	0	2	0	59	2	0	0	145	8	KG
KZ	0	0	0	0	1	1	0	1	0	65	1	0	0	0	2	1	3	5	2	1	0	1	1	6	1	0	0	119	10	KZ
LT	0	0	0	-1	2	10	0	1	0	17	4	0	1	0	0	0	4	0	3	7	0	1	2	0	0	0	0	73	39	LT
LU	0	0	0	-2	1	2	1	1	0	2	1	0	0	0	0	0	1	0	6	1	0	3	-0	0	2	0	0	5	-1	LU
LV	0	0	0	-0	2	6	0	1	0	21	4	0	0	0	0	0	3	0	3	7	0	1	2	0	0	0	0	67	34	LV
MD	0	0	0	-0	1	11	0	13	1	30	1	0	1	0	0	1	53	1	2	2	3	2	1	1	1	0	0	153	44	MD
ME	38	2	0	0	0	7	1	10	19	8	0	0	3	0	0	4	7	0	3	1	1	20	1	2	7	0	0	194	85	ME
MK	2	31	0	0	0	5	1	11	25	10	0	0	2	0	0	6	11	0	3	1	2	12	0	2	6	0	0	206	101	MK
MT	1	0	-92	0	0	1	1	1	1	1	0	1	0	0	0	2	1	0	6	0	0	26	1	1	23	0	0	11	-1	MT
NL	0	0	0	-76	2	3	0	0	0	2	1	0	0	0	0	0	1	0	6	1	0	1	-17	0	1	0	0	-61	-66	NL
NO	0	0	0	-0	8	1	0	0	0	3	4	0	0	0	0	0	1	0	5	1	0	0	2	0	0	0	0	27	13	NO
PL	0	0	0	-1	2	19	0	4	1	13	2	0	2	0	0	1	9	0	3	5	0	1	2	0	1	0	0	90	57	PL
PT	0	0	0	0	0	0	61	0	0	1	0	0	0	0	0	0	0	0	34	0	0	4	1	0	5	0	0	143	142	PT
RO	0	0	0	-0	1	11	0	59	4	19	1	0	3	0	0	2	31	0	2	1	3	4	1	1	2	0	0	177	106	RO
RS	3	3	0	-0	0	9	0	25	28	11	1	1	4	0	0	3	13	0	2	1	2	7	1	1	3	0	0	180	102	RS
RU	0	0	0	-0	1	1	0	0	0	40	1	0	0	0	0	1	3	0	2	1	0	0	0	1	0	0	0	59	7	RU
SE	0	0	0	-0	5	2	0	0	0	6	8	0	0	0	0	0	1	0	4	3	0	0	3	0	0	0	0	37	23	SE
SI	0	0	0	-0	1	8	1	5	5	4	1	16	3	0	0	1	4	0	3	1	0	10	1	1	4	0	0	166	144	SI
SK	0	0	0	-1	1	35	0	13	4	11	1	1	14	0	0	1	13	0	3	2	0	3	1	1	2	0	0	158	121	SK
TJ	0	0	0	0	0	1	0	0	0	8	0	0	0	28	17	3	1	40	1	0	0	1	0	80	2	0	0	116	7	TJ
TM	0	0	0	0	1	1	0	1	0	39	1	0	0	1	30	4	3	27	2	1	0	2	1	42	2	0	0	142	11	TM
TR	0	0	0	0	0	2	0	4	1	17	0	0	0	0	0	89	8	0	2	0	7	14	0	31	5	0	0	153	26	TR
UA	0	0	0	-0	1	10	0	6	1	42	1	0	1	0	1	2	39	1	2	2	2	2	1	1	1	0	0	134	35	UA
UZ	0	0	0	0	1	1	0	1	0	46	1	0	0	2	10	2	3	26	2	1	0	1	1	23	1	0	0	127	10	UZ
ATL	0	0	0	-0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	17	0	0	0	1	0	1	0	0	15	12	ATL
BAS	0	0	0	-1	4	4	0	1	0	14	8	0	0	0	0	0	2	0	6	-17	0	1	3	0	0	0	0	58	35	BAS
BLS	0	0	0	-0	1	5	0	11	1	76	1	0	1	0	1	11	39	1	2	1	42	5	0	3	3	0	0	188	37	BLS
MED	1	1	0	0	0	3	2	3	3	7	0	1	1	0	0	15	4	0	7	0	3	95	1	1	16	0	0	145	108	MED
NOS	0	0	0	-6	2	1	0	0	0	2	3	0	0	0	0	0	1	0	13	0	0	1	-32	0	0	0	0	9	1	NOS
AST	0	0	0	0	0	0	0	0	0	11	0	0	0	1	7	8	1	7	1	0	0	3	0	122	2	0	0	54	7	AST
NOA	0	0	0	0	0	1	3	1	1	1	0	0	0	0	0	3	1	0	10	0	0	24	0	0	82	0	0	50	42	NOA
EXC	0	0	0	-0	1	3	1	2	1	32	1	0	0	0	2	5	5	3	3	1	1	3	0	6	1	0	0	89	27	EXC
EU	0	0	0	-1	1	5	4	6	2	7	2	1	1	0	0	1	5	0	7	2	1	7	0	0	3	0	0	95	74	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	

Table C.7: 2018 country-to-country blame matrices for **SOMO35**.
Units: ppb.d per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	9	0	1	1	2	0	1	1	0	0	2	4	0	0	2	0	2	2	0	3	1	2	0	0	9	0	0	0	0	0	0	AL
AM	0	27	0	49	0	0	0	1	0	0	0	1	0	0	1	0	1	1	10	0	0	0	0	0	1	0	1	0	0	0	0	AM
AT	0	0	8	0	1	1	0	2	3	0	6	19	0	0	1	0	5	3	0	0	1	2	0	0	11	0	0	0	0	0	0	AT
AZ	0	2	0	88	0	0	0	1	0	0	1	2	0	0	0	0	1	1	9	0	0	0	0	0	1	0	2	0	0	0	0	AZ
BA	1	0	1	1	16	0	1	2	0	0	3	7	0	0	1	0	3	2	0	1	2	2	0	0	8	0	0	0	0	0	1	BA
BE	0	0	1	0	0	7	0	1	0	0	2	17	0	0	1	0	9	9	0	0	0	0	0	0	2	0	0	0	0	0	0	BE
BG	0	0	1	2	1	0	5	2	0	0	1	4	0	0	1	0	2	2	0	2	0	1	0	0	3	0	0	0	0	0	1	BG
BY	0	0	0	0	0	0	0	5	0	0	1	4	0	0	0	0	1	2	0	0	0	0	0	0	1	0	1	0	0	0	0	BY
CH	0	0	2	0	0	1	0	1	20	0	4	23	0	0	2	0	12	4	0	0	0	1	0	0	25	0	0	0	0	0	0	CH
CY	0	0	0	2	1	0	1	1	0	3	1	3	0	0	1	0	2	1	1	3	0	1	0	0	5	0	1	0	0	0	0	CY
CZ	0	0	2	0	1	1	0	2	1	0	11	15	1	0	1	0	4	4	0	0	1	2	0	0	3	0	0	0	0	0	0	CZ
DE	0	0	2	0	0	2	0	1	1	0	4	26	1	0	1	0	6	7	0	0	0	1	0	0	3	0	0	0	0	0	0	DE
DK	0	0	0	0	0	1	0	1	0	0	1	6	3	0	0	0	2	8	0	0	0	0	0	0	1	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	1	0	0	1	3	0	0	0	1	1	3	0	0	0	0	0	0	1	0	0	0	0	0	0	EE
ES	0	0	0	0	0	0	0	0	0	0	1	3	0	0	15	0	4	3	0	0	0	0	0	0	2	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	1	0	0	2	0	1	1	0	2	10	0	0	3	0	13	6	0	0	0	0	0	0	6	0	0	0	0	0	0	FR
GB	0	0	0	0	0	1	0	1	0	0	1	3	0	0	1	0	3	16	0	0	0	0	1	0	1	0	0	0	0	0	0	GB
GE	0	3	0	36	0	0	0	1	0	0	1	2	0	0	1	0	1	1	31	0	0	0	0	0	2	0	1	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	GL
GR	1	0	1	1	1	0	2	2	0	0	1	4	0	0	2	0	2	2	0	11	1	1	0	0	6	0	0	0	0	0	1	GR
HR	1	0	2	1	5	1	1	2	1	0	4	9	0	0	1	0	3	3	0	1	5	3	0	0	11	0	0	0	0	0	0	HR
HU	0	0	2	1	1	1	1	2	0	0	4	8	0	0	1	0	2	3	0	0	1	5	0	0	4	0	0	0	0	0	1	HU
IE	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	1	7	0	0	0	0	1	0	1	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	IS
IT	0	0	2	0	2	1	0	1	2	0	3	10	0	0	3	0	6	3	0	1	2	1	0	0	66	0	0	0	0	0	0	IT
KG	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	9	5	0	0	0	0	KG
KZ	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	1	5	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	3	0	0	1	4	0	0	0	0	1	3	0	0	0	0	0	0	1	0	0	1	0	0	0	LT
LU	0	0	1	0	0	3	0	1	1	0	3	22	0	0	1	0	9	7	0	0	0	0	0	0	3	0	0	0	2	0	0	LU
LV	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	1	3	0	0	0	0	0	0	1	0	0	0	0	1	0	LV
MD	0	0	0	2	1	0	1	3	0	0	1	4	0	0	1	0	1	2	0	0	0	1	0	0	2	0	1	0	0	0	4	MD
ME	2	0	1	1	4	0	1	1	0	0	2	5	0	0	2	0	2	2	0	1	1	2	0	0	8	0	0	0	0	0	0	ME
MK	1	0	1	1	2	0	2	2	0	0	2	4	0	0	1	0	2	2	0	5	1	2	0	0	5	0	0	0	0	0	1	MK
MT	0	0	1	0	1	1	0	1	1	0	2	7	0	0	4	0	7	3	0	2	1	1	0	0	24	0	0	0	0	0	0	MT
NL	0	0	0	0	0	3	0	1	0	0	1	14	1	0	1	0	6	11	0	0	0	0	0	0	1	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	0	1	0	3	0	0	3	8	1	0	1	0	2	4	0	0	0	1	0	0	2	0	0	0	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	3	0	0	9	0	3	4	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	0	0	1	1	1	0	1	3	0	0	2	4	0	0	1	0	2	2	0	1	0	1	0	0	3	0	1	0	0	0	1	RO
RS	1	0	1	1	3	0	1	2	0	0	2	5	0	0	1	0	2	2	0	1	1	3	0	0	4	0	0	0	0	0	1	RS
RU	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	5	0	3	1	0	2	1	0	5	12	0	0	1	0	3	3	0	0	4	3	0	0	16	0	0	0	0	0	0	SI
SK	0	0	1	1	1	1	0	2	0	0	5	8	1	0	1	0	2	3	0	0	1	3	0	0	3	0	0	0	0	0	0	SK
TJ	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	TJ
TM	0	0	0	7	0	0	0	1	0	0	0	2	0	0	0	0	1	1	1	0	0	0	0	0	1	0	3	0	0	0	0	TM
TR	0	1	0	4	0	0	0	1	0	0	1	2	0	0	1	0	1	1	2	1	0	0	0	0	2	0	0	0	0	0	0	TR
UA	0	0	0	1	0	0	0	3	0	0	1	3	0	0	0	0	1	2	0	0	0	1	0	0	1	0	1	0	0	0	1	UA
UZ	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	4	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	2	0	0	1	5	1	0	0	1	1	6	0	0	0	0	0	0	1	0	0	0	0	1	0	BAS
BLS	0	0	0	8	1	0	1	3	0	0	1	3	0	0	1	0	1	2	6	1	0	1	0	0	2	0	1	0	0	0	1	BLS
MED	1	0	1	1	2	1	1	1	1	0	2	7	0	0	6	0	7	3	0	4	1	1	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	1	0	1	0	0	1	5	1	0	1	0	3	15	0	0	0	0	1	0	1	0	0	0	0	0	0	NOS
AST	0	0	0	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	1	3	0	0	4	0	3	2	0	1	0	0	0	0	5	0	0	0	0	0	0	NOA
EXC	0	0	0	2	0	0	0	1	0	0	1	3	0	0	1	0	1	2	0	0	0	0	0	0	2	0	1	0	0	0	0	EXC
EU	0	0	1	0	0	1	0	1	1	0	2	8	0	0	3	0	4	5	0	1	0	1	0	0	7	0	0	0	0	0	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.7 Cont.: 2018 country-to-country blame matrices for **SOMO35**.
Units: ppb.d per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	
AL	0	2	0	1	0	5	0	2	5	7	0	0	1	0	0	3	3	0	0	0	0	0	0	2	3	0	0	74	39	AL
AM	0	0	0	0	0	1	0	1	0	7	0	0	0	0	1	10	1	0	0	0	0	0	0	85	2	0	0	116	9	AM
AT	0	0	0	2	0	8	0	1	1	6	0	2	2	0	0	1	2	0	0	0	0	0	0	1	1	0	0	91	75	AT
AZ	0	0	0	0	0	2	0	1	0	13	0	0	0	0	1	4	2	1	0	0	0	0	0	48	1	0	0	134	10	AZ
BA	0	0	0	1	0	8	0	3	4	7	0	0	2	0	0	1	3	0	0	0	0	0	0	1	2	0	0	84	47	BA
BE	0	0	0	11	0	4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	72	67	BE
BG	0	0	0	1	0	4	0	5	2	12	0	0	1	0	0	4	5	0	0	0	0	0	0	2	1	0	0	66	34	BG
BY	0	0	0	1	0	4	0	1	0	13	0	0	0	0	0	0	3	0	0	0	0	0	0	1	0	0	0	42	18	BY
CH	0	0	0	2	0	5	0	1	0	4	0	1	1	0	0	0	1	0	0	0	0	0	0	1	2	0	0	112	84	CH
CY	0	0	0	0	0	3	0	2	1	8	0	0	0	0	0	30	3	0	0	0	0	0	0	36	4	0	0	76	28	CY
CZ	0	0	0	2	1	13	0	1	1	8	0	0	2	0	0	0	2	0	0	0	0	0	0	1	1	0	0	83	66	CZ
DE	0	0	0	4	0	6	0	1	0	5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	75	65	DE
DK	0	0	0	3	1	4	0	0	0	5	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	43	33	DK
EE	0	0	0	1	0	2	0	0	0	12	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	30	15	EE
ES	0	0	0	1	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	39	35	ES
FI	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	8	FI
FR	0	0	0	3	0	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	58	52	FR
GB	0	0	0	2	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	31	GB
GE	0	0	0	0	0	2	0	1	0	12	0	0	0	0	1	7	2	0	0	0	0	0	0	29	1	0	0	107	11	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	GL
GR	0	1	0	1	0	4	0	2	2	9	0	0	1	0	0	6	4	0	0	0	0	0	0	3	3	0	0	71	41	GR
HR	0	0	0	1	0	9	0	3	3	7	0	1	2	0	0	1	3	0	0	0	0	0	0	1	2	0	0	85	60	HR
HU	0	0	0	1	0	12	0	5	2	10	0	0	3	0	0	1	4	0	0	0	0	0	0	1	1	0	0	80	56	HU
IE	0	0	0	1	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	18	IE
IS	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	5	IS
IT	0	0	0	1	0	5	0	1	1	4	0	2	1	0	0	1	1	0	0	0	0	0	0	1	5	0	0	125	111	IT
KG	0	0	0	0	0	1	0	0	0	4	0	0	0	3	1	1	0	36	0	0	0	0	0	37	1	0	0	68	5	KG
KZ	0	0	0	0	0	1	0	0	0	11	0	0	0	0	0	1	1	2	0	0	0	0	0	10	0	0	0	30	6	KZ
LT	0	0	0	1	0	5	0	1	0	10	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	0	0	38	22	LT
LU	0	0	0	5	0	4	0	0	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	69	63	LU
LV	0	0	0	1	0	3	0	0	0	10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	32	17	LV
MD	0	0	0	1	0	5	0	4	1	15	0	0	1	0	0	1	8	0	0	0	0	0	0	2	1	0	0	63	26	MD
ME	2	1	0	1	0	5	0	3	3	7	0	0	1	0	0	2	3	0	0	0	0	0	0	2	2	0	0	65	37	ME
MK	0	7	0	0	0	5	0	3	5	8	0	0	1	0	0	3	3	0	0	0	0	0	0	2	2	0	0	70	36	MK
MT	0	0	4	1	0	4	1	1	1	3	0	1	1	0	0	2	1	0	0	0	0	1	0	2	11	0	0	78	66	MT
NL	0	0	0	15	1	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	65	59	NL
NO	0	0	0	1	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	9	NO
PL	0	0	0	2	0	17	0	1	0	9	1	0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	63	45	PL
PT	0	0	0	1	0	1	13	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	39	36	PT
RO	0	0	0	1	0	6	0	11	1	12	0	0	1	0	0	2	6	0	0	0	0	0	0	2	1	0	0	66	37	RO
RS	0	1	0	1	0	7	0	5	8	9	0	0	2	0	0	2	4	0	0	0	0	0	0	1	1	0	0	73	40	RS
RU	0	0	0	0	0	1	0	0	0	9	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	17	4	RU
SE	0	0	0	1	1	2	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	12	SE
SI	0	0	0	2	0	9	0	2	2	7	0	9	2	0	0	1	2	0	0	0	0	0	0	1	2	0	0	99	80	SI
SK	0	0	0	1	1	17	0	3	1	10	0	0	5	0	0	1	4	0	0	0	0	0	0	1	1	0	0	79	58	SK
TJ	0	0	0	0	0	0	0	0	0	4	0	0	0	6	2	1	0	15	0	0	0	0	0	38	1	0	0	37	4	TJ
TM	0	0	0	0	0	1	0	0	0	11	0	0	0	0	6	2	1	5	0	0	0	0	0	52	1	0	0	46	9	TM
TR	0	0	0	0	0	2	0	1	1	8	0	0	0	0	0	23	2	0	0	0	0	0	0	35	2	0	0	58	14	TR
UA	0	0	0	1	0	5	0	2	0	18	0	0	1	0	0	1	8	0	0	0	0	0	0	2	1	0	0	56	21	UA
UZ	0	0	0	0	0	1	0	0	0	10	0	0	0	2	2	1	1	21	0	0	0	0	0	22	1	0	0	52	7	UZ
ATL	0	0	0	1	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	11	9	ATL
BAS	0	0	0	2	1	5	0	0	0	11	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	44	29	BAS
BLS	0	0	0	1	0	4	0	3	1	31	0	0	1	0	0	9	8	0	0	0	0	0	0	7	1	0	0	93	24	BLS
MED	0	0	0	1	0	5	1	2	1	7	0	1	1	0	0	9	2	0	0	0	0	1	0	9	13	0	0	95	68	MED
NOS	0	0	0	3	2	3	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	42	35	NOS
AST	0	0	0	0	0	1	0	0	0	4	0	0	0	0	1	3	1	2	0	0	0	0	0	125	1	0	0	25	5	AST
NOA	0	0	0	0	0	1	1	0	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	2	18	0	0	27	22	NOA
EXC	0	0	0	1	0	2	0	1	0	9	0	0	0	0	0	2	1	2	0	0	0	0	0	7	1	0	0	35	16	EXC
EU	0	0	0	2	0	5	1	1	1	5	0	0	1	0	0	1	1	0	0	0	0	0	0	1	1	0	0	55	43	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	DMS	VOL	EXC	EU	

Table C.8: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	202	0	1	0	4	0	3	0	0	0	1	1	0	0	0	0	1	0	0	10	1	1	0	0	4	0	0	0	0	0	0	AL
AM	0	78	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	401	0	2	0	0	1	3	0	18	19	0	0	0	0	4	0	0	0	5	8	0	0	10	-0	0	0	0	0	0	AT
AZ	0	6	0	170	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	17	0	0	0	0	0	-0	0	1	0	0	0	0	AZ
BA	2	0	6	0	340	0	1	0	0	0	4	3	0	0	0	0	1	0	0	1	16	6	0	0	4	-0	0	0	0	0	0	BA
BE	0	-0	3	-0	0	242	0	0	1	0	4	54	1	0	1	0	112	12	-0	0	0	0	0	0	1	-0	0	0	4	0	0	BE
BG	0	0	2	0	2	0	198	1	0	0	1	1	0	0	0	0	0	0	0	5	1	2	0	0	1	-0	0	0	0	0	1	BG
BY	0	0	1	0	0	0	0	98	0	0	1	2	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	7	0	5	1	BY
CH	0	0	22	0	0	0	0	0	179	0	2	31	0	0	0	0	36	0	0	0	0	0	0	0	20	-0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	35	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	-0	0	0	0	0	0	CY
CZ	0	0	31	0	3	1	1	1	1	0	258	28	1	0	0	0	7	1	0	0	3	11	0	0	2	-0	0	1	0	0	0	CZ
DE	0	0	26	0	0	6	0	1	4	0	17	204	2	0	0	0	26	4	0	0	0	2	0	0	2	-0	0	1	1	1	0	DE
DK	0	0	2	0	0	2	0	1	0	0	3	25	180	0	0	1	6	6	0	0	0	1	0	0	0	-0	0	1	0	1	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	2	1	103	0	10	1	1	0	0	0	0	0	0	0	0	0	5	0	21	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	127	0	8	1	0	0	0	0	0	0	1	-0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0	80	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	FI
FR	0	0	3	0	0	5	0	0	4	0	2	17	0	0	3	0	281	4	0	0	0	0	0	0	4	-0	0	0	1	0	0	FR
GB	0	0	0	-0	0	2	0	0	0	-0	1	5	1	0	0	0	14	106	-0	0	0	0	2	0	0	-0	0	0	0	0	0	GB
GE	0	6	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	133	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	GL
GR	4	0	1	0	1	0	11	0	0	0	1	1	0	0	0	0	0	0	0	110	0	1	0	0	3	-0	0	0	0	0	0	GR
HR	1	0	20	0	69	0	2	1	0	0	7	5	0	0	0	0	2	0	0	1	123	18	0	0	12	-0	0	0	0	0	0	HR
HU	0	0	29	0	11	0	3	1	0	0	13	7	0	0	0	0	2	0	0	1	12	192	0	0	4	-0	0	0	0	0	1	HU
IE	0	0	0	-0	0	1	0	0	0	0	0	2	0	0	1	0	4	11	0	0	0	0	34	0	0	-0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	IS
IT	0	0	9	0	2	0	0	0	2	0	1	2	0	0	2	0	7	0	0	0	2	1	0	0	404	-0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	6	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	36	0	0	0	0	KZ
LT	0	0	1	0	0	0	0	27	0	0	2	3	1	2	0	2	1	1	0	0	0	1	0	0	0	0	0	125	0	22	1	LT
LU	0	0	5	-0	0	30	0	0	1	0	6	97	1	0	1	0	118	5	0	0	0	0	0	0	1	0	0	0	83	0	0	LU
LV	0	0	0	0	0	0	0	14	0	0	1	2	1	8	0	3	1	1	0	0	0	0	0	0	0	0	0	22	0	134	0	LV
MD	0	0	1	0	1	0	5	3	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	1	112	MD
ME	15	0	2	0	17	0	2	0	0	0	1	1	0	0	0	0	1	0	0	1	1	2	0	0	3	-0	0	0	0	0	0	ME
MK	12	0	1	0	3	0	12	0	0	0	1	1	0	0	0	0	0	0	0	21	1	2	0	0	1	0	0	0	0	0	0	MK
MT	1	0	1	0	1	0	0	0	0	0	0	1	0	0	3	0	6	0	0	1	1	0	0	0	19	0	0	0	0	0	0	MT
NL	0	-0	2	-0	0	52	0	1	0	0	4	82	2	0	1	0	42	14	-0	0	0	0	0	0	0	-0	0	0	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	1	1	1	8	0	0	16	12	2	0	0	0	3	1	0	0	1	5	0	0	1	0	0	3	0	2	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	29	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	2	0	2	0	12	1	0	0	2	2	0	0	0	0	1	0	0	1	1	7	0	0	1	-0	0	0	0	0	4	RO
RS	4	0	5	0	24	0	14	1	0	0	4	3	0	0	0	0	1	0	0	3	6	13	0	0	2	-0	0	0	0	0	1	RS
RU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	1	2	3	1	0	4	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	SE
SI	0	0	94	0	7	0	1	1	0	0	7	6	0	0	0	0	2	0	0	0	36	9	0	0	28	-0	0	0	0	0	0	SI
SK	0	0	15	0	3	0	2	1	0	0	23	6	0	0	0	0	2	0	0	0	2	39	0	0	2	-0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	TJ
TM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	TM
TR	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	-0	0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	6	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	1	4	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	1	0	3	0	0	2	8	11	5	0	13	2	2	0	0	0	1	0	0	0	0	0	4	0	7	0	BAS
BLS	0	0	1	1	0	0	4	1	0	0	0	1	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1	BLS
MED	1	0	1	0	2	0	1	0	0	0	1	1	0	0	9	0	9	0	0	5	1	0	0	0	19	-0	0	0	0	0	0	MED
NOS	0	0	0	0	0	3	0	0	0	0	1	10	4	0	0	0	16	16	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2	0	0	1	0	0	0	0	2	-0	0	0	0	0	0	NOA
EXC	0	0	3	1	2	1	2	2	1	0	2	6	1	1	4	2	10	2	1	1	1	2	0	0	7	1	7	1	0	1	0	EXC
EU	0	0	13	0	2	4	6	2	1	0	9	23	3	2	16	7	42	8	0	4	3	6	1	0	29	0	0	3	0	3	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.8 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters** →, **Receptors** ↓.

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	9	21	0	0	0	2	0	2	34	1	0	0	0	0	0	2	4	0	0	0	0	3	0	0	0	0	0	0	305	27	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	27	0	0	0	0	0	0	0	8	0	0	0	0	135	0	AM
AT	0	0	0	0	0	17	0	2	3	1	0	20	5	-0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	525	512	AT
AZ	0	0	0	0	0	0	0	0	0	12	0	0	0	0	1	6	1	1	0	0	0	0	0	8	0	0	0	0	215	0	AZ
BA	5	1	0	0	0	7	0	5	20	1	0	2	2	-0	0	1	5	0	0	0	0	1	0	0	0	0	0	0	436	60	BA
BE	0	0	0	31	0	9	0	0	0	1	0	0	0	-0	-0	0	1	-0	1	0	0	0	8	-0	0	0	0	0	477	474	BE
BG	0	4	0	0	0	3	0	33	10	8	0	0	1	0	0	10	25	0	0	0	1	1	0	0	0	0	0	0	313	250	BG
BY	0	0	0	0	0	24	0	6	0	32	1	0	1	0	0	1	41	0	0	0	0	0	0	0	0	0	0	0	228	53	BY
CH	0	0	0	0	0	3	0	0	0	0	0	0	0	-0	-0	0	0	-0	0	0	0	0	0	0	0	0	0	0	297	117	CH
CY	0	0	0	0	0	0	0	1	0	2	0	0	0	-0	0	77	4	0	0	0	0	13	0	11	2	0	0	0	124	40	CY
CZ	0	0	0	1	0	79	0	5	4	3	0	3	11	-0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	463	444	CZ
DE	0	0	-0	7	0	34	0	1	1	2	1	1	1	-0	0	0	2	0	0	1	0	0	2	0	0	0	0	0	346	335	DE
DK	0	0	-0	4	2	20	0	1	0	2	8	0	0	0	0	0	2	0	0	7	0	0	5	0	0	0	0	0	272	263	DK
EE	0	0	0	0	1	10	0	1	0	26	3	0	0	0	0	0	7	0	0	3	0	0	0	0	0	0	0	0	202	160	EE
ES	0	0	0	0	0	1	10	0	0	0	0	0	0	-0	0	0	0	0	2	0	0	4	0	0	1	0	0	0	149	149	ES
FI	0	0	0	0	1	3	0	0	0	11	4	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	109	94	FI
FR	0	0	0	2	0	4	0	0	0	0	0	0	0	-0	-0	0	0	0	1	0	0	1	2	0	0	0	0	0	333	328	FR
GB	0	0	0	2	0	3	0	0	0	0	0	0	0	-0	-0	0	0	-0	2	0	0	0	4	-0	0	0	0	0	139	138	GB
GE	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	13	1	0	0	0	0	0	0	2	0	0	0	0	176	1	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	8	0	0	0	1	0	3	5	4	0	0	0	-0	0	17	10	0	0	0	1	8	0	0	1	0	0	0	184	133	GR
HR	1	1	0	0	0	13	0	6	22	2	0	25	3	-0	0	1	6	0	0	0	0	2	0	0	0	0	0	0	343	239	HR
HU	1	1	0	0	0	32	0	55	22	4	0	8	25	-0	0	1	21	0	0	0	0	0	0	0	0	0	0	0	449	387	HU
IE	0	0	0	1	0	2	0	0	0	0	0	0	0	0	-0	0	0	-0	3	0	0	0	1	0	0	0	0	0	56	55	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	IS
IT	0	0	0	0	0	3	0	1	1	0	0	7	1	-0	0	0	1	0	0	0	0	8	0	0	1	0	0	0	449	441	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	20	0	0	0	0	0	9	0	0	0	0	65	0	KG
KZ	0	0	-0	0	0	0	0	0	0	17	0	0	0	0	0	0	1	3	0	0	0	0	0	8	0	0	0	0	60	1	KZ
LT	0	0	0	0	0	42	0	4	0	20	2	0	1	0	0	0	17	0	0	1	0	0	0	0	0	0	0	0	278	212	LT
LU	0	0	0	5	0	9	0	0	0	1	0	0	1	0	-0	0	1	-0	0	0	0	0	2	0	0	0	0	0	367	363	LU
LV	0	0	0	0	1	19	0	2	0	20	3	0	0	0	0	0	12	0	0	2	0	0	0	0	0	0	0	0	248	201	LV
MD	0	0	0	0	0	12	0	74	1	19	0	0	1	0	0	4	120	0	0	0	1	0	0	0	0	0	0	0	362	100	MD
ME	162	2	0	0	0	2	0	3	24	1	0	0	1	-0	0	1	4	0	0	0	0	1	0	0	0	0	0	0	249	21	ME
MK	1	252	0	0	0	2	0	4	39	2	0	0	1	0	0	4	7	0	0	0	0	1	0	0	0	0	0	0	369	49	MK
MT	0	0	54	0	0	1	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	94	0	0	9	0	0	0	96	91	MT
NL	0	0	-0	195	0	16	0	0	0	1	1	0	0	-0	-0	0	1	-0	1	0	0	0	14	-0	0	0	0	0	418	414	NL
NO	0	0	0	0	30	1	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	41	9	NO
PL	0	0	0	1	0	428	0	9	2	9	1	1	7	0	0	0	24	0	0	1	0	0	1	0	0	0	0	0	545	498	PL
PT	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	0	0	1	0	0	0	235	235	PT
RO	0	1	0	0	0	8	0	361	7	8	0	0	2	-0	0	3	35	0	0	0	1	0	0	0	0	0	0	0	463	401	RO
RS	6	14	0	0	0	9	0	33	255	4	0	1	3	-0	0	2	13	0	0	0	0	0	0	0	0	0	0	0	420	98	RS
RU	0	0	0	0	0	1	0	0	0	72	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	88	4	RU
SE	0	0	0	0	4	7	0	1	0	3	40	0	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	72	63	SE
SI	0	0	0	0	0	12	0	3	5	1	0	439	2	-0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	660	641	SI
SK	0	0	0	0	0	70	0	25	5	4	0	3	164	-0	0	1	22	0	0	0	0	0	0	0	0	0	0	0	394	356	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	49	1	0	0	20	0	0	0	0	0	17	0	0	0	0	75	0	TJ
TM	0	0	0	0	0	0	0	0	0	4	0	0	0	1	24	1	1	16	0	0	0	0	0	8	0	0	0	0	53	0	TM
TR	0	0	0	0	0	0	0	1	0	3	0	0	0	-0	0	268	5	0	0	0	1	2	0	7	0	0	0	0	284	5	TR
UA	0	0	0	0	0	14	0	17	1	38	0	0	1	0	0	3	275	0	0	0	1	0	0	0	0	0	0	0	372	42	UA
UZ	0	0	0	0	0	0	0	0	0	5	0	0	0	6	5	0	1	94	0	0	0	0	0	4	0	0	0	0	127	0	UZ
ATL	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	9	8	ATL
BAS	0	0	0	1	1	32	0	2	0	12	15	0	1	0	0	0	5	0	0	14	0	0	1	0	0	0	0	0	128	106	BAS
BLS	0	0	0	0	0	3	0	10	1	35	0	0	0	0	0	45	57	0	0	0	11	1	0	0	0	0	0	0	174	22	BLS
MED	1	1	0	0	0	1	1	1	1	2	0	1	0	-0	0	22	3	0	1	0	0	35	0	4	9	0	0	0	85	53	MED
NOS	0	0	0	6	5	5	0	0	0	1	2	0	0	0	0	0	1	0	1	1	0	0	15	0	0	0	0	0	72	66	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5	1	1	0	0	0	0	0	249	0	0	0	0	13	0	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	-0	0	2	1	0	1	0	0	5	0	1	42	0	0	0	14	10	NOA
EXC	0	1	0	1	1	11	1	7	2	34	1	1	1	1	1	12	14	4	0	0	0	0	0	2	0	0	0	0	151	68	EXC
EU	0	0	0	3	1	41	5	23	2	4	5	4	4	0	0	1	7	0	1	1	0	2	1	0	0	0	0	0	285	265	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.9: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of SO_x. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	31	0	0	0	22	0	14	0	0	0	3	4	0	0	1	0	1	0	0	28	1	1	0	0	6	0	1	0	0	0	0	AL
AM	0	36	0	101	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	-0	0	0	14	0	0	0	0	AM
AT	0	0	21	0	10	1	2	1	1	0	18	34	0	0	0	0	3	1	0	1	2	4	0	0	4	-0	0	0	0	0	0	AT
AZ	0	3	0	183	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	-0	0	0	44	0	0	0	0	AZ
BA	1	0	1	0	192	0	5	1	0	0	7	9	0	0	1	0	1	1	0	3	3	4	0	0	4	0	1	0	0	0	0	BA
BE	0	0	1	-0	1	67	0	0	0	0	6	59	0	0	3	0	39	20	0	0	0	0	1	0	0	0	0	0	1	0	0	BE
BG	0	0	0	1	10	0	95	1	0	0	3	4	0	0	0	0	0	0	1	6	0	2	0	0	1	0	3	0	0	0	2	BG
BY	0	0	0	0	2	0	1	31	0	0	2	6	0	3	0	2	1	1	0	0	0	1	0	0	0	0	7	3	0	1	1	BY
CH	0	0	3	0	1	1	0	0	30	0	6	30	0	0	1	0	11	1	0	0	0	0	0	0	5	0	0	0	0	0	0	CH
CY	0	0	0	0	1	0	4	0	0	42	0	1	0	0	1	0	0	0	0	7	0	0	0	0	2	0	3	0	0	0	0	CY
CZ	0	0	4	0	10	2	3	2	0	0	80	54	1	0	1	0	5	3	0	1	1	5	0	0	1	0	1	0	0	0	0	CZ
DE	0	0	3	0	3	7	1	1	1	0	18	111	1	1	1	0	12	9	0	0	0	1	0	0	1	0	0	1	0	0	0	DE
DK	0	0	0	0	1	3	0	1	0	0	3	26	18	1	1	1	4	15	0	0	0	0	1	0	0	0	0	1	0	0	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	4	1	15	0	7	1	3	0	0	0	0	0	0	0	0	3	2	0	2	0	EE
ES	0	0	0	0	0	1	0	0	0	0	1	4	0	0	84	0	6	2	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	2	0	4	0	17	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	FI
FR	0	0	1	0	1	6	0	0	1	0	4	24	0	0	9	0	50	9	0	0	0	0	1	0	2	0	0	0	0	0	0	FR
GB	0	0	0	-0	0	1	0	0	0	0	1	7	0	0	1	0	6	87	0	0	0	0	4	1	0	0	0	0	0	0	0	GB
GE	0	3	0	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	0	0	0	0	-0	0	0	12	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	1	0	0	1	9	0	29	1	0	0	2	3	0	0	1	0	1	0	0	46	0	1	0	0	5	0	2	0	0	0	1	GR
HR	1	0	3	0	69	1	6	1	0	0	12	15	0	0	1	0	2	1	0	2	15	8	0	0	7	-0	1	0	0	0	0	HR
HU	0	0	3	0	19	1	10	2	0	0	16	18	0	0	1	0	2	1	0	2	2	32	0	0	3	0	2	0	0	0	1	HU
IE	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	2	23	0	0	0	0	22	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	36	0	0	0	0	0	0	0	IS
IT	0	0	2	0	12	0	1	0	1	0	4	7	0	0	4	0	8	1	0	1	3	1	0	0	69	-0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	39	58	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	207	0	0	0	0	KZ
LT	0	0	0	0	1	1	1	16	0	0	3	9	1	4	0	3	1	3	0	0	0	1	0	0	0	0	4	18	0	3	1	LT
LU	0	0	1	-0	1	20	0	0	1	0	8	81	0	0	3	0	36	13	0	0	0	1	0	0	1	0	0	0	9	0	0	LU
LV	0	0	0	0	1	0	0	11	0	0	2	6	1	6	0	4	1	3	0	0	0	0	0	0	0	0	4	9	0	6	0	LV
MD	0	0	0	1	3	0	7	6	0	0	3	6	0	1	0	1	1	1	0	1	0	2	0	0	0	0	11	1	0	0	29	MD
ME	4	0	0	0	63	0	8	0	0	0	3	5	0	0	1	0	1	1	0	5	1	2	0	0	4	0	1	0	0	0	0	ME
MK	5	0	0	0	17	0	30	1	0	0	3	4	0	0	0	0	1	0	0	34	0	1	0	0	2	0	1	0	0	0	1	MK
MT	1	0	1	0	11	1	2	0	0	0	2	5	0	0	9	0	9	1	0	3	1	0	0	0	39	0	0	0	0	0	0	MT
NL	0	-0	1	-0	1	32	0	1	0	0	8	66	1	1	2	0	20	22	-0	0	0	0	1	0	0	0	0	1	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	4	2	2	7	0	0	12	25	1	1	0	1	2	4	0	1	0	3	0	0	1	0	2	2	0	0	0	PL
PT	0	0	0	0	0	1	0	0	0	0	0	2	0	0	55	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	1	7	0	14	2	0	0	4	6	0	0	0	0	1	1	0	2	0	5	0	0	1	0	4	0	0	0	3	RO
RS	1	0	1	1	45	0	27	1	0	0	7	9	0	0	0	0	1	1	0	7	1	7	0	0	2	0	1	0	0	0	1	RS
RU	0	0	0	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	1	4	1	1	0	3	1	3	0	0	0	0	0	0	0	0	1	1	0	0	0	SE
SI	0	0	9	0	23	1	2	1	0	0	13	19	0	0	1	0	2	1	0	1	13	5	0	0	11	-0	0	0	0	0	0	SI
SK	0	0	1	0	9	1	6	2	0	0	19	18	0	0	0	0	2	2	0	1	1	13	0	0	1	0	1	0	0	0	1	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	25	0	0	0	0	TJ
TM	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	79	0	0	0	0	TM
TR	0	1	0	3	1	0	3	0	0	2	0	1	0	0	0	0	0	0	1	2	0	0	0	0	1	0	4	0	0	0	0	TR
UA	0	0	0	1	2	0	2	7	0	0	2	5	0	1	0	1	0	1	0	1	0	1	0	0	0	0	15	1	0	0	3	UA
UZ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	113	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	1	3	0	0	0	0	0	1	0	0	1	0	0	0	0	ATL
BAS	0	0	0	0	1	1	0	3	0	0	2	10	3	4	0	7	1	6	0	0	0	0	0	0	0	0	2	2	0	1	0	BAS
BLS	0	0	0	6	2	0	5	2	0	0	1	2	0	0	0	0	0	0	6	1	0	1	0	0	0	0	13	0	0	0	1	BLS
MED	1	0	1	0	10	0	5	0	0	1	2	5	0	0	12	0	8	1	0	7	1	1	0	0	21	0	1	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	1	9	1	0	1	0	5	21	0	0	0	0	1	1	0	0	0	0	0	0	0	NOS
AST	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	28	0	0	0	0	AST
NOA	0	0	0	0	2	0	1	0	0	0	1	1	0	0	8	0	2	0	0	2	0	0	0	0	4	0	0	0	0	0	0	NOA
EXC	0	0	0	2	2	1	2	1	0	0	2	6	0	1	3	1	2	2	0	1	0	1	0	0	1	1	51	0	0	0	0	EXC
EU	0	0	1	0	4	3	5	2	0	0	7	20	1	1	13	2	10	9	0	2	1	2	1	0	6	0	1	1	0	0	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.9 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of SO_x. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	10	62	0	0	0	10	0	4	71	5	0	0	1	0	0	27	15	0	0	0	1	21	0	4	7	6	4	22	319	75	AL
AM	0	0	0	0	0	0	0	0	0	4	0	0	0	0	4	77	2	1	0	0	0	1	0	181	2	6	0	4	247	2	AM
AT	1	1	0	1	0	33	0	3	29	3	0	3	3	-0	0	3	7	0	0	0	0	3	0	0	1	5	2	2	191	135	AT
AZ	0	0	0	0	0	1	0	0	0	17	0	0	0	0	9	29	9	3	0	0	0	0	0	157	1	5	0	2	310	2	AZ
BA	13	6	0	0	0	24	0	7	128	5	0	0	2	-0	0	14	15	0	0	0	0	7	0	2	4	6	2	7	450	74	BA
BE	0	0	0	14	0	16	0	0	1	1	0	0	0	0	-0	0	1	-0	7	0	0	1	5	0	1	9	12	0	237	230	BE
BG	2	7	0	0	0	12	0	18	72	23	0	0	1	0	0	41	73	0	0	0	6	5	0	3	2	7	1	5	382	146	BG
BY	0	0	0	0	0	34	0	3	6	47	1	0	1	0	0	5	43	0	0	0	0	1	0	1	0	7	3	1	207	63	BY
CH	0	0	0	1	0	12	0	0	2	1	0	0	0	0	0	1	1	0	1	0	0	2	0	0	1	5	1	1	110	73	CH
CY	0	1	0	0	0	2	0	1	6	8	0	0	0	0	0	725	15	0	0	0	4	74	0	176	27	10	20	34	823	60	CY
CZ	1	2	0	1	0	81	0	5	35	7	0	1	5	0	0	5	13	0	1	0	0	2	1	1	1	7	4	2	330	254	CZ
DE	0	0	0	5	0	39	0	1	8	4	0	0	1	0	0	2	5	0	2	1	0	1	2	0	1	8	8	1	241	216	DE
DK	0	0	0	3	1	23	0	1	3	7	3	0	0	0	0	1	5	0	4	3	0	0	3	0	0	8	15	0	127	107	DK
EE	0	0	0	0	1	13	0	1	2	39	2	0	0	0	0	1	13	0	1	2	0	0	0	0	0	6	5	0	120	53	EE
ES	0	0	0	0	0	2	9	0	0	0	0	0	0	0	0	1	0	0	20	0	0	30	0	0	15	11	9	3	113	110	ES
FI	0	0	0	0	1	5	0	0	1	32	3	0	0	0	0	0	3	0	2	1	0	0	0	0	0	5	7	0	75	34	FI
FR	0	0	0	3	0	9	0	0	1	1	0	0	0	0	0	1	1	0	10	0	0	7	3	0	2	8	10	2	125	118	FR
GB	0	0	0	1	0	7	0	0	0	1	0	0	0	0	-0	0	0	0	16	0	0	0	3	0	1	9	22	0	122	118	GB
GE	0	0	0	0	0	1	0	0	1	12	0	0	0	0	3	60	6	1	0	0	2	0	0	56	1	5	0	3	208	3	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	2	0	0	0	GL
GR	3	22	0	0	0	7	0	5	38	14	0	0	1	0	0	104	37	0	0	0	4	41	0	8	11	7	6	31	335	102	GR
HR	4	4	0	0	0	38	0	8	121	6	0	3	4	-0	0	10	15	0	0	0	0	15	0	1	4	6	3	7	359	127	HR
HU	3	5	0	1	0	67	0	27	83	11	0	1	12	-0	0	10	35	0	0	0	1	4	0	1	2	7	2	5	370	200	HU
IE	0	0	0	0	0	4	0	0	0	1	0	0	0	0	-0	0	0	0	17	0	0	0	1	0	1	11	27	0	61	59	IE
IS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	7	12	0	39	3	IS
IT	2	2	0	0	0	12	0	1	16	1	0	1	1	-0	0	5	3	0	1	0	0	51	0	1	14	5	7	41	161	119	IT
KG	0	0	0	0	0	0	-0	0	0	2	0	0	0	10	3	3	0	97	0	0	0	0	0	36	0	6	0	1	212	0	KG
KZ	0	0	0	0	0	1	0	0	0	44	0	0	0	1	3	2	6	9	0	0	0	0	0	23	0	10	1	0	277	2	KZ
LT	0	0	0	1	0	47	0	2	5	33	1	0	1	0	0	3	27	0	1	1	0	0	0	0	0	6	5	1	190	99	LT
LU	0	0	0	6	0	17	0	0	2	2	0	0	1	0	-0	1	2	-0	4	0	0	1	3	0	1	9	8	1	207	199	LU
LV	0	0	0	0	1	23	0	1	3	35	1	0	0	0	0	2	19	0	1	1	0	0	0	0	0	6	5	0	142	66	LV
MD	1	2	0	0	0	33	0	23	11	36	0	0	1	0	1	20	149	0	0	0	4	2	0	2	0	8	1	2	351	82	MD
ME	73	18	0	0	0	10	0	5	85	5	0	0	1	-0	0	19	16	0	0	0	1	9	0	3	5	6	2	11	331	47	ME
MK	4	141	0	0	0	10	0	6	87	9	0	0	1	0	0	41	27	0	0	0	2	8	0	6	4	6	1	11	427	94	MK
MT	2	4	5	0	0	6	1	1	8	1	0	0	0	0	0	14	2	0	2	0	0	242	0	4	84	8	23	149	130	86	MT
NL	0	0	0	28	0	28	0	0	3	3	0	0	0	0	-0	1	2	0	6	0	0	1	6	0	0	8	15	0	224	212	NL
NO	0	0	0	0	6	4	0	0	1	6	2	0	0	0	0	0	1	0	3	0	0	0	1	0	0	8	14	0	30	14	NO
PL	1	1	0	1	0	172	0	5	16	17	1	0	3	0	0	4	25	0	1	1	0	1	1	1	1	7	5	2	319	241	PL
PT	0	0	0	0	0	1	47	0	0	0	0	0	0	0	0	0	0	0	57	0	0	9	0	0	10	12	18	1	114	113	PT
RO	1	3	0	0	0	27	0	72	36	21	0	0	2	0	0	19	76	0	0	0	3	2	0	2	1	7	1	3	313	138	RO
RS	10	24	0	0	0	25	0	23	241	12	0	0	3	-0	0	23	41	0	0	0	2	4	0	3	3	7	1	7	518	116	RS
RU	0	0	0	0	0	2	0	0	0	74	0	0	0	0	1	2	10	0	1	0	0	0	0	3	0	9	5	0	131	7	RU
SE	0	0	0	0	3	9	0	0	1	10	7	0	0	0	0	0	2	0	2	1	0	0	1	0	0	6	8	0	54	34	SE
SI	1	1	0	0	0	34	0	4	62	4	0	24	3	-0	0	4	9	0	0	0	0	11	0	1	2	5	2	4	249	143	SI
SK	1	3	0	1	0	93	0	15	39	10	0	1	25	0	0	6	29	0	0	0	1	2	0	1	1	6	2	3	303	201	SK
TJ	0	0	0	0	0	0	-0	0	0	3	0	0	0	94	13	4	1	59	0	0	0	0	0	49	0	7	0	2	202	0	TJ
TM	0	0	0	0	0	1	0	0	0	18	0	0	0	5	52	8	7	25	0	0	0	0	0	105	0	10	0	1	201	2	TM
TR	0	1	0	0	0	2	0	2	6	10	0	0	0	0	0	583	17	0	0	0	6	13	0	117	9	9	2	12	640	13	TR
UA	0	1	0	0	0	27	0	7	7	48	0	0	1	0	1	13	138	0	0	0	2	1	0	3	0	8	2	1	288	51	UA
UZ	0	0	0	0	0	1	0	0	0	24	0	0	0	19	19	4	7	112	0	0	0	0	0	45	0	10	0	1	307	2	UZ
ATL	0	0	0	0	0	1	1	0	0	3	0	0	0	0	0	0	0	0	19	0	0	2	1	0	3	16	32	0	18	13	ATL
BAS	0	0	0	1	1	21	0	1	3	20	4	0	0	0	0	1	7	0	2	4	0	0	1	0	0	6	10	0	105	67	BAS
BLS	0	1	0	0	0	10	0	7	10	53	0	0	1	0	1	109	98	0	0	0	32	3	0	8	2	7	1	3	332	30	BLS
MED	2	4	0	0	0	7	1	2	15	5	0	0	1	0	0	146	12	0	5	0	2	151	0	38	57	9	22	88	273	76	MED
NOS	0	0	0	2	2	8	0	0	1	2	1	0	0	0	0	0	1	0	9	0	0	0	6	0	0	8	24	0	64	55	NOS
AST	0	0	0	0	0	0	0	0	0	5	0	0	0	1	7	50	2	4	0	0	0	3	0	350	4	14	1	4	103	2	AST
NOA	1	1	0	0	0	1	2	0	3	1	0	0	0	-0	0	23	2	0	10	0	0	41	0	9	166	17	10	28	57	24	NOA
EXC	0	1	0	0	0	10	1	2	6	42	0	0	0	2	3	29	14	6	2	0	1	3	0	15	1	9	4	2	199	37	EXC
EU	1	2	0	2	0	28	2	6	14	10	1	0	1	0	0	8	13	0	7	0	1	10	1	1	4	8	8	5	180	125	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.10: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	69	0	1	0	3	0	4	0	0	0	1	2	0	-0	1	-0	1	0	0	18	1	1	0	0	7	0	0	0	0	-0	0	AL
AM	0	83	0	86	0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	14	0	0	0	0	0	0	0	1	0	0	0	0	AM
AT	0	0	96	0	2	2	1	0	7	0	16	64	0	0	1	0	7	2	0	0	7	12	0	0	23	0	0	0	0	0	0	AT
AZ	0	13	0	293	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	27	0	0	0	0	0	0	0	4	0	0	0	0	AZ
BA	1	0	6	0	58	0	2	0	0	0	4	9	0	0	0	0	2	1	0	1	12	10	0	0	6	0	0	0	0	0	0	BA
BE	0	0	3	0	0	44	0	1	2	0	5	125	2	0	4	0	93	59	0	0	0	1	3	0	2	0	0	0	5	0	-0	BE
BG	0	0	1	1	1	0	62	1	0	0	1	3	0	0	0	0	1	0	1	7	0	2	0	0	1	0	0	0	0	0	3	BG
BY	0	0	1	0	0	1	0	38	0	0	2	9	1	1	0	2	1	2	0	0	0	2	0	0	1	0	1	7	0	2	3	BY
CH	0	0	18	0	0	2	0	0	156	-0	5	100	0	0	1	0	41	3	0	0	0	0	0	0	37	0	0	0	1	0	0	CH
CY	0	0	0	0	0	0	1	-0	0	22	0	0	0	-0	0	-0	0	0	0	10	0	0	0	0	1	0	0	-0	0	-0	0	CY
CZ	0	0	28	0	2	2	1	1	3	0	60	66	1	0	1	0	9	4	0	0	4	18	0	0	5	0	0	0	0	0	0	CZ
DE	0	0	20	0	0	13	0	1	9	0	18	209	4	0	2	0	30	21	0	0	1	2	1	0	5	0	0	1	2	0	0	DE
DK	0	0	2	0	0	12	0	2	1	0	6	109	46	1	1	2	17	34	0	0	0	2	2	0	1	0	0	2	1	1	0	DK
EE	0	0	0	0	0	1	0	8	0	0	1	7	2	8	0	5	1	3	0	0	0	1	0	0	0	0	0	6	0	6	1	EE
ES	0	0	0	0	0	1	0	0	0	-0	0	3	0	-0	82	-0	9	2	0	0	0	0	0	0	1	0	-0	0	0	-0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	2	1	1	0	11	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	FI
FR	0	0	3	0	0	15	0	0	8	0	3	52	1	0	6	0	111	22	0	0	0	0	2	0	5	0	0	0	2	0	0	FR
GB	0	0	0	0	0	4	0	0	0	0	1	18	2	0	1	0	22	107	0	0	0	0	11	0	0	0	0	0	0	0	0	GB
GE	0	11	0	59	0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	85	0	0	0	0	0	0	0	1	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	3	0	0	0	1	0	10	0	0	0	0	1	0	-0	1	-0	1	0	0	48	0	0	0	0	3	0	0	0	0	-0	0	GR
HR	1	0	20	0	26	1	2	0	1	0	9	17	0	0	1	0	3	1	0	1	47	25	0	0	17	0	0	0	0	0	1	HR
HU	0	0	21	0	8	1	4	1	2	0	13	24	0	0	1	0	4	2	0	1	12	85	0	0	9	0	0	0	0	0	1	HU
IE	0	0	0	0	0	2	0	0	0	0	0	8	1	0	1	0	5	45	0	0	0	0	41	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	-0	0	1	0	0	0	0	0	1	0	0	0	0	0	-1	0	0	-0	0	0	0	0	IS
IT	0	0	11	0	2	0	0	0	4	0	2	10	0	0	3	-0	8	1	0	1	5	3	0	0	267	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	-0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	19	1	0	0	-0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	11	0	0	0	0	KZ
LT	0	0	1	0	0	2	0	21	0	0	3	18	2	2	0	3	2	4	0	0	0	2	0	0	1	0	0	32	0	7	2	LT
LU	0	0	5	0	0	39	0	0	3	0	7	187	2	0	3	0	76	27	0	0	0	1	1	0	3	0	0	0	9	0	-0	LU
LV	0	0	1	0	0	1	0	14	0	0	2	10	2	2	0	3	1	3	0	0	0	1	0	0	0	0	0	17	0	9	1	LV
MD	0	0	1	1	1	1	8	6	0	0	2	9	0	0	0	1	2	1	0	1	0	3	0	0	1	0	1	1	0	0	62	MD
ME	7	0	1	0	9	0	2	0	0	0	1	3	0	-0	0	-0	1	1	0	3	2	2	0	0	5	0	0	0	0	0	0	ME
MK	6	0	1	0	2	0	11	0	0	0	0	1	0	-0	0	-0	1	0	0	28	0	1	0	0	2	0	0	0	0	-0	1	MK
MT	1	0	1	0	1	0	0	-0	0	0	0	1	0	-0	4	-0	5	0	0	2	1	0	0	0	22	0	-0	-0	0	-0	0	MT
NL	0	0	3	0	0	45	0	1	1	0	8	152	6	0	4	1	68	79	0	0	0	1	4	0	2	0	0	1	3	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	1	2	1	7	1	0	12	36	3	0	1	1	4	5	0	0	1	7	0	0	2	0	0	3	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	-0	0	1	0	-0	35	-0	2	1	0	0	0	0	0	0	0	0	0	-0	0	-0	-0	PT
RO	0	0	2	0	1	1	10	2	0	0	2	7	0	0	0	0	2	1	0	2	1	9	0	0	2	0	0	0	0	0	8	RO
RS	3	0	6	0	13	1	14	1	1	0	5	12	0	0	0	0	2	1	0	6	5	20	0	0	3	0	0	0	0	0	2	RS
RU	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	0	1	9	4	0	0	2	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	63	0	6	1	1	0	2	0	9	24	0	0	1	0	4	1	0	1	38	17	0	0	49	0	0	0	0	0	0	SI
SK	0	0	11	0	2	1	2	1	1	0	12	17	0	0	0	0	4	2	0	1	3	37	0	0	5	0	0	0	0	0	1	SK
TJ	0	0	0	0	0	0	0	-0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	0	0	1	2	-0	0	-0	0	TJ
TM	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	TM
TR	0	3	0	3	0	0	2	0	0	0	0	1	0	0	0	0	0	0	2	2	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	7	0	0	1	4	0	0	0	1	1	1	0	0	0	2	0	0	1	0	2	1	0	1	7	UA
UZ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	3	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	3	0	2	0	0	2	26	7	1	0	3	3	8	0	0	0	1	0	0	1	0	0	3	0	1	0	BAS
BLS	0	0	0	2	0	0	2	0	0	0	0	1	0	0	0	0	0	0	6	1	0	0	0	0	0	0	1	0	0	-0	2	BLS
MED	1	0	1	0	1	0	1	-0	0	0	0	1	0	-0	5	-0	5	0	0	6	1	0	0	0	16	0	0	-0	0	-0	0	MED
NOS	0	0	0	0	0	6	0	0	0	0	1	30	5	0	1	0	18	35	0	0	0	0	3	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	-0	0	0	0	0	0	-0	4	-0	1	0	0	1	0	0	0	0	2	0	0	-0	0	-0	0	NOA
EXC	0	0	2	2	1	1	1	2	1	0	1	10	1	0	3	1	5	4	1	1	1	1	0	0	5	0	4	1	0	0	1	EXC
EU	0	0	7	0	1	5	3	2	2	0	5	37	2	0	12	1	22	14	0	2	2	5	2	0	21	0	0	1	1	1	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.10 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of NO$_x$. **Emitters** $\rightarrow$, **Receptors** $\downarrow$.

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	5	11	0	0	0	1	0	2	19	1	-0	0	0	0	0	2	2	0	0	0	0	12	0	0	1	4	0	0	154	41	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	27	0	0	0	0	0	1	0	70	0	4	0	0	216	2	AM
AT	0	0	0	2	0	16	0	3	6	1	0	12	5	0	0	0	2	0	1	1	0	3	3	0	0	4	0	0	291	271	AT
AZ	0	0	0	0	0	0	0	0	0	11	0	0	0	0	4	9	1	2	0	0	1	1	0	72	0	5	0	0	365	2	AZ
BA	3	1	0	1	0	7	0	6	13	1	0	1	3	0	0	1	3	0	0	0	0	3	1	0	1	3	0	0	153	71	BA
BE	0	0	0	74	1	11	0	0	0	1	1	0	1	0	0	0	0	0	8	4	0	2	72	0	1	14	0	0	442	435	BE
BG	0	1	0	0	0	2	0	24	9	10	0	0	1	0	0	9	18	0	0	0	5	3	0	0	1	4	0	0	161	106	BG
BY	0	0	0	2	1	30	0	5	1	42	2	0	1	0	0	1	34	0	1	5	1	0	2	0	0	4	0	0	192	72	BY
CH	0	0	0	2	0	5	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	2	4	0	1	5	0	0	378	220	CH
CY	0	0	0	0	0	-0	0	0	0	2	-0	0	0	0	0	51	1	0	0	-0	2	49	0	15	5	8	0	0	91	36	CY
CZ	0	0	0	4	0	45	0	5	6	2	0	3	10	0	0	0	3	0	1	2	0	2	6	0	0	5	0	0	288	270	CZ
DE	0	0	0	25	1	28	0	1	1	2	1	1	2	0	0	0	1	0	3	9	0	2	29	0	1	8	0	0	406	390	DE
DK	0	0	0	29	5	25	0	1	1	5	11	0	1	0	0	0	2	0	4	50	0	1	65	0	0	9	0	0	322	306	DK
EE	0	0	0	2	1	15	0	1	0	23	3	0	1	0	0	0	6	0	1	12	0	0	3	0	0	3	0	0	101	62	EE
ES	0	0	0	1	0	0	7	0	0	-0	-0	0	0	0	0	0	0	0	7	0	0	10	1	0	3	5	0	0	107	106	ES
FI	0	0	0	0	1	3	0	0	0	6	3	0	0	0	0	0	1	0	1	5	0	0	1	0	0	2	0	0	32	24	FI
FR	0	0	0	12	0	5	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	3	29	0	1	6	0	0	250	240	FR
GB	0	0	0	9	1	4	0	0	0	1	1	0	0	0	0	0	0	0	11	3	0	0	38	0	0	8	0	0	186	183	GB
GE	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	12	1	0	0	0	2	0	0	13	0	3	0	0	177	2	GE
GL	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	GL
GR	0	3	0	0	0	0	0	2	3	5	-0	0	0	0	0	11	5	0	0	0	2	17	0	1	2	4	0	0	99	67	GR
HR	1	0	0	1	0	13	0	8	24	1	0	10	6	0	0	1	4	0	0	0	0	8	2	0	1	4	0	0	242	181	HR
HU	1	1	0	2	0	30	0	47	30	4	0	5	22	0	0	1	15	0	1	1	0	3	3	0	1	5	0	0	349	285	HU
IE	0	0	0	3	1	2	0	0	0	0	0	0	0	0	0	0	0	0	13	2	0	0	11	0	0	5	0	0	111	109	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	3	IS
IT	0	0	0	1	0	4	0	1	2	0	0	8	1	0	0	0	1	0	1	0	0	36	1	0	3	5	0	0	336	327	IT
KG	0	0	0	0	0	0	0	0	0	0	-0	0	0	1	1	0	0	31	0	0	0	0	0	16	0	2	0	0	54	0	KG
KZ	0	0	0	0	0	0	0	0	0	19	0	0	0	0	1	0	0	3	0	0	0	0	0	20	0	5	0	0	37	1	KZ
LT	0	0	0	3	1	58	0	4	1	29	4	0	2	0	0	0	17	0	1	16	0	0	5	0	0	4	0	0	223	151	LT
LU	0	0	0	29	1	8	0	0	0	1	0	0	1	0	0	0	0	0	5	2	0	2	27	0	0	9	0	0	406	400	LU
LV	0	0	0	2	1	26	0	2	0	23	3	0	1	0	0	0	11	0	1	12	0	0	4	0	0	3	0	0	139	87	LV
MD	0	0	0	1	0	18	0	53	2	31	0	0	1	0	0	8	116	0	0	2	8	2	1	0	0	5	0	0	335	107	MD
ME	36	2	0	0	0	1	0	3	10	1	0	0	1	0	0	1	2	0	0	0	0	5	0	0	1	3	0	0	95	26	ME
MK	1	31	0	0	0	1	0	4	15	2	-0	0	0	0	0	4	4	0	0	0	1	4	0	1	1	4	0	0	117	51	MK
MT	0	0	-5	0	0	0	0	0	0	-0	-0	0	0	0	0	1	0	0	1	0	0	75	0	0	16	5	0	0	36	32	MT
NL	0	0	0	92	2	25	0	0	0	3	2	0	1	0	0	0	0	0	9	10	0	2	107	0	1	18	0	0	507	498	NL
NO	0	0	0	1	6	1	0	0	0	1	2	0	0	0	0	0	0	0	1	1	0	0	4	0	0	2	0	0	21	13	NO
PL	0	0	0	4	1	145	0	7	2	11	2	1	7	0	0	0	17	0	1	11	0	1	7	0	0	5	0	0	292	250	PL
PT	0	0	0	0	0	0	48	0	0	-0	-0	0	0	0	0	0	0	0	16	0	0	3	1	0	2	5	0	0	89	89	PT
RO	0	0	0	1	0	10	0	106	7	10	0	0	3	0	0	4	32	0	0	1	4	2	1	0	0	4	0	0	227	161	RO
RS	4	6	0	1	0	13	0	30	61	4	0	1	5	0	0	2	10	0	0	1	1	2	1	0	1	4	0	0	233	127	RS
RU	0	0	0	0	0	1	0	0	0	48	0	0	0	0	0	0	3	0	0	1	0	0	0	1	0	3	0	0	63	4	RU
SE	0	0	0	2	2	5	0	0	0	2	8	0	0	0	0	0	1	0	1	9	0	0	6	0	0	2	0	0	46	40	SE
SI	0	0	0	1	0	14	0	5	11	1	0	91	5	0	0	0	3	0	1	1	0	10	2	0	1	4	0	0	352	327	SI
SK	0	0	0	1	0	31	0	21	8	2	0	2	36	0	0	0	11	0	0	1	0	2	2	0	0	4	0	0	216	189	SK
TJ	0	0	0	0	0	0	0	0	0	0	-0	0	0	14	6	0	0	24	0	0	0	0	0	14	0	3	0	0	49	0	TJ
TM	0	0	0	0	0	0	0	0	0	8	0	0	0	1	29	1	0	26	0	0	0	0	0	37	0	6	0	0	79	1	TM
TR	0	0	0	0	0	0	0	2	1	6	0	0	0	0	0	116	3	0	0	0	6	10	0	24	2	6	0	0	145	10	TR
UA	0	0	0	1	0	14	0	12	1	43	1	0	1	0	0	3	82	0	0	2	3	1	1	1	0	4	0	0	192	45	UA
UZ	0	0	0	0	0	0	0	0	0	11	0	0	0	3	11	0	0	60	0	0	0	0	0	16	0	6	0	0	109	1	UZ
ATL	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	3	0	0	10	10	ATL
BAS	0	0	0	6	1	24	0	1	0	6	6	0	1	0	0	0	3	0	1	18	0	0	11	0	0	4	0	0	115	101	BAS
BLS	0	0	0	0	0	1	0	5	1	27	-0	0	0	0	0	19	19	0	0	0	20	3	0	1	0	4	0	0	92	13	BLS
MED	0	0	0	0	0	0	0	0	1	1	-0	0	0	0	0	10	1	0	1	-0	1	46	0	-0	9	5	0	0	54	37	MED
NOS	0	0	0	13	3	5	0	0	0	1	2	0	0	0	0	0	0	0	4	6	0	0	31	0	0	5	0	0	125	121	NOS
AST	0	0	0	0	0	0	0	0	0	2	-0	0	0	0	3	5	0	2	0	0	0	2	0	167	1	6	0	0	21	1	AST
NOA	0	0	0	0	0	0	1	0	0	0	-0	0	0	0	0	2	0	0	3	0	0	15	0	1	35	7	0	0	14	11	NOA
EXC	0	0	0	2	0	6	0	3	1	25	1	0	1	0	1	6	6	3	1	1	1	2	3	7	0	4	0	0	105	50	EXC
EU	0	0	0	7	1	19	2	9	2	4	2	2	2	0	0	1	5	0	4	4	0	5	12	0	1	5	0	0	204	185	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.11: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of NH_3. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	62	0	1	0	0	0	1	0	0	0	1	2	0	-0	0	0	0	0	0	5	1	2	0	0	2	0	-0	0	0	0	0	AL
AM	0	149	0	52	-0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	11	0	0	0	0	-0	0	-0	-0	0	0	0	0	AM
AT	0	0	97	0	1	1	0	2	4	0	16	39	0	0	0	0	3	1	0	0	4	7	0	0	10	-0	0	0	0	0	0	AT
AZ	-0	11	0	198	-0	0	-0	0	0	0	-0	0	0	0	0	-0	0	-0	11	-0	-0	0	0	-0	-0	-0	0	0	0	0	0	AZ
BA	1	0	4	0	103	0	1	1	0	0	5	7	0	0	0	0	1	0	0	0	18	12	0	0	4	-0	0	0	0	0	1	BA
BE	0	-0	2	-0	-0	150	-0	1	1	0	5	89	2	0	1	0	48	33	-0	0	0	0	2	0	1	-0	0	0	5	0	0	BE
BG	1	0	2	0	1	0	89	1	0	0	2	4	0	0	0	0	0	0	0	5	1	4	0	0	1	-0	0	0	0	0	4	BG
BY	0	0	0	0	0	0	0	64	0	0	1	6	1	1	0	0	1	1	0	0	0	2	0	-0	1	0	0	3	0	1	3	BY
CH	0	0	4	-0	-0	1	0	0	106	-0	2	35	0	0	0	0	12	1	0	0	0	0	0	0	17	-0	0	0	0	0	0	CH
CY	0	0	0	0	-0	0	0	0	0	53	0	0	0	-0	0	-0	0	-0	0	1	0	0	-0	-0	-0	-0	-0	0	0	0	0	CY
CZ	0	0	15	0	1	2	1	4	1	0	145	63	1	0	0	0	7	3	0	0	4	14	0	-0	3	0	0	1	0	0	1	CZ
DE	0	0	8	-0	0	10	0	2	4	0	17	218	2	0	1	0	19	11	0	0	1	2	1	0	2	0	0	1	1	0	0	DE
DK	0	0	1	0	0	5	0	2	0	0	4	72	96	0	0	0	11	21	0	0	0	1	2	-0	0	0	0	1	0	0	0	DK
EE	0	0	0	0	0	0	0	11	0	0	1	9	2	33	0	7	1	2	0	0	0	1	0	-0	0	0	0	8	0	8	1	EE
ES	0	-0	0	-0	-0	0	-0	0	0	-0	0	2	0	0	60	0	7	1	0	-0	0	0	0	0	0	-0	-0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	2	0	-0	0	3	1	1	0	22	1	1	0	0	0	0	0	-0	0	0	0	1	0	1	0	FI
FR	0	-0	1	-0	-0	9	0	0	5	-0	3	31	1	0	4	0	104	11	0	-0	0	0	1	0	4	-0	0	0	1	0	0	FR
GB	0	0	0	-0	0	6	0	0	0	-0	1	22	2	0	1	0	21	141	0	0	0	0	6	0	0	-0	0	0	0	0	0	GB
GE	0	8	0	34	-0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	88	0	0	0	0	-0	0	-0	-0	0	0	0	0	GE
GL	-0	0	0	-0	-0	0	-0	-0	0	-0	-0	0	0	-0	0	-0	0	0	-0	-0	-0	-0	0	-0	0	-0	-0	-0	0	-0	-0	GL
GR	2	0	0	0	0	0	5	0	0	0	1	1	0	-0	0	-0	0	0	0	57	0	1	0	0	1	-0	-0	0	0	0	1	GR
HR	1	0	10	0	15	0	1	1	1	0	8	11	0	0	0	0	1	0	0	0	69	17	0	-0	15	-0	0	0	0	0	1	HR
HU	0	0	11	0	2	1	2	2	1	0	13	17	1	-0	0	0	2	1	0	0	7	97	0	-0	5	-0	0	0	0	0	2	HU
IE	0	0	0	-0	0	2	0	0	0	0	0	9	1	0	1	0	6	25	0	0	0	0	36	0	0	-0	0	0	0	0	0	IE
IS	0	0	0	0	-0	0	-0	0	0	-0	0	1	0	0	0	0	0	1	0	0	0	0	1	3	0	0	0	0	0	0	0	IS
IT	0	0	4	0	0	0	0	0	2	0	1	3	0	0	2	0	2	0	0	0	2	2	0	-0	183	-0	0	0	0	0	0	IT
KG	-0	0	0	0	-0	0	-0	0	0	0	0	0	0	-0	-0	-0	0	-0	0	-0	0	0	-0	-0	0	34	2	0	0	-0	0	KG
KZ	0	0	0	0	-0	0	-0	0	0	-0	0	0	0	0	-0	0	0	-0	0	-0	0	0	-0	-0	0	1	15	0	0	0	0	KZ
LT	0	0	1	0	0	1	0	23	0	0	2	14	2	1	0	1	2	2	0	0	0	2	0	-0	0	0	0	52	0	6	3	LT
LU	0	-0	3	-0	-0	34	0	1	2	0	7	141	1	0	1	0	39	14	-0	0	0	0	1	0	1	0	0	0	56	0	0	LU
LV	0	0	0	0	0	1	0	19	0	0	1	12	2	4	0	2	1	2	0	0	0	1	0	-0	0	0	0	24	0	36	2	LV
MD	0	0	1	0	0	0	3	4	0	0	1	5	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	1	0	0	73	MD
ME	7	0	2	0	8	0	1	0	0	0	2	4	0	0	0	0	1	0	0	0	2	5	0	0	3	-0	-0	0	0	0	0	ME
MK	8	0	1	0	1	0	6	0	0	0	2	3	0	0	0	0	0	0	0	18	1	4	0	0	1	0	-0	0	0	0	1	MK
MT	1	0	0	0	-0	0	0	0	0	0	0	1	0	0	3	0	3	0	0	1	0	0	0	-0	15	0	-0	0	0	0	0	MT
NL	0	-0	1	-0	0	33	0	1	1	-0	5	103	3	0	1	0	27	44	-0	0	0	0	4	0	0	-0	0	1	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	-0	0	5	2	0	0	0	1	2	0	0	0	0	0	-0	0	-0	-0	0	0	0	0	NO
PL	0	0	3	0	0	2	1	9	0	0	15	36	3	0	0	0	4	3	0	0	2	8	0	-0	1	0	0	3	0	1	1	PL
PT	-0	-0	0	-0	-0	0	-0	0	0	-0	0	1	0	-0	20	0	3	1	-0	-0	-0	0	0	0	0	0	-0	0	0	0	0	PT
RO	0	0	1	0	0	0	5	1	0	0	2	5	0	0	0	0	1	0	0	1	1	7	0	0	1	-0	0	0	0	0	7	RO
RS	2	0	3	0	6	0	8	1	0	0	5	8	0	0	0	0	1	0	0	2	5	15	0	0	2	-0	-0	0	0	0	2	RS
RU	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	3	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	0	1	11	5	0	0	2	2	3	0	0	0	1	0	-0	0	0	-0	1	0	0	0	SE
SI	0	0	31	0	2	0	1	2	1	0	8	13	0	0	1	0	1	0	0	0	23	9	0	-0	39	-0	0	0	0	0	0	SI
SK	0	0	7	0	1	1	1	4	0	0	21	21	1	0	0	0	2	1	0	0	3	35	0	0	3	-0	0	1	0	0	2	SK
TJ	-0	0	-0	0	-0	0	-0	-0	0	-0	-0	0	0	-0	-0	-0	-0	-0	0	-0	-0	-0	-0	-0	-0	3	0	-0	-0	-0	-0	TJ
TM	-0	0	-0	1	-0	0	-0	0	0	-0	-0	0	0	-0	-0	-0	0	-0	0	-0	-0	-0	-0	-0	-0	0	2	0	0	0	-0	TM
TR	0	1	0	0	0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	1	0	0	0	0	-0	0	-0	-0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	7	0	0	1	4	0	0	0	0	1	0	0	0	0	2	0	-0	1	0	0	1	0	0	7	UA
UZ	-0	0	-0	0	-0	0	-0	0	0	-0	-0	0	0	0	-0	0	0	-0	0	-0	-0	0	-0	-0	-0	5	6	0	0	0	0	UZ
ATL	0	0	0	-0	-0	0	0	0	0	-0	0	2	0	0	2	0	4	4	0	0	0	0	1	-0	0	-0	-0	0	0	0	0	ATL
BAS	0	0	1	0	0	2	0	5	0	0	3	39	17	2	0	8	4	7	0	0	0	2	1	-0	0	0	0	6	0	3	1	BAS
BLS	0	0	0	1	0	0	4	1	0	0	0	1	0	0	0	0	0	0	6	1	0	1	0	-0	0	0	0	0	0	0	4	BLS
MED	1	0	0	0	0	0	0	0	0	0	0	1	0	-0	5	0	1	-0	0	2	1	0	-0	-0	4	-0	-0	0	0	0	0	MED
NOS	0	0	1	0	0	11	0	1	0	0	1	48	13	0	1	0	27	64	0	0	0	0	5	-0	0	-0	0	1	0	0	0	NOS
AST	-0	0	0	2	-0	0	-0	0	0	0	-0	0	0	0	0	0	0	-0	0	0	-0	0	-0	-0	0	0	0	0	0	0	0	AST
NOA	0	0	0	0	-0	0	0	0	0	-0	0	0	0	-0	2	-0	0	0	0	0	-0	0	0	-0	-1	-0	-0	0	0	0	0	NOA
EXC	0	0	1	1	0	1	1	2	1	0	2	9	1	0	2	1	5	3	0	1	1	1	0	0	3	1	3	1	0	0	1	EXC
EU	0	0	4	0	0	4	3	2	1	0	7	33	2	1	8	2	19	12	0	2	2	5	1	-0	14	0	0	2	0	1	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.11 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of NH_3. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	2	2	0	0	0	1	-0	2	16	0	0	0	0	0	-0	1	0	-0	0	0	0	0	0	0	0	0	0	0	103	18	AL
AM	0	-0	-0	0	0	0	0	0	-0	1	0	0	0	0	0	38	0	-0	0	0	0	0	0	39	0	0	0	0	251	1	AM
AT	0	0	0	1	0	17	0	2	4	1	0	8	3	-0	-0	0	2	0	0	0	0	0	0	0	0	0	0	0	226	212	AT
AZ	-0	-0	-0	0	-0	0	-0	0	-0	4	0	0	-0	0	1	10	0	1	0	0	0	0	0	34	0	0	0	0	235	0	AZ
BA	5	0	0	0	0	7	0	7	34	1	0	1	3	-0	-0	1	2	0	0	0	0	0	0	0	0	0	0	0	219	71	BA
BE	0	-0	0	58	0	9	0	0	0	1	0	0	0	-0	-0	0	0	-0	0	0	0	0	0	-0	-0	1	0	0	409	406	BE
BG	0	1	0	0	0	2	0	23	21	5	0	0	1	0	-0	13	7	0	0	0	0	0	0	-0	0	0	0	0	191	136	BG
BY	0	0	-0	1	0	22	0	4	1	25	1	0	1	0	0	1	26	0	0	0	0	0	0	1	0	0	0	0	170	49	BY
CH	0	-0	-0	1	0	1	-0	0	0	0	0	0	0	-0	-0	0	0	0	0	0	0	0	0	-0	-0	0	0	0	183	77	CH
CY	-0	0	-0	0	0	-0	-0	0	-0	1	0	0	0	-0	0	55	-0	0	0	0	0	0	0	11	4	0	0	0	110	54	CY
CZ	0	0	0	4	0	73	0	5	8	3	0	2	9	-0	-0	0	5	0	0	0	0	0	0	0	0	1	0	0	379	356	CZ
DE	0	0	-0	17	0	31	0	1	1	2	1	1	1	-0	-0	0	2	0	0	0	0	0	0	0	-0	1	0	0	356	345	DE
DK	0	0	-0	17	1	27	0	1	1	2	7	0	1	-0	-0	0	2	0	0	0	0	0	0	0	0	1	0	0	279	270	DK
EE	0	0	0	2	0	17	0	2	0	28	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	145	98	EE
ES	-0	-0	-0	0	0	1	2	0	-0	0	0	0	0	-0	-0	-0	0	0	0	0	0	0	0	-0	0	0	0	0	75	75	ES
FI	0	0	0	1	0	4	0	1	0	10	2	0	0	0	-0	0	1	-0	0	0	0	0	0	0	0	0	0	0	54	40	FI
FR	0	-0	-0	8	0	5	0	0	0	0	0	0	0	-0	-0	-0	0	0	0	0	0	0	0	-0	0	0	0	0	188	182	FR
GB	0	-0	0	10	0	4	0	0	0	0	0	0	0	-0	-0	0	0	0	0	0	0	0	0	-0	0	1	0	0	219	218	GB
GE	0	-0	-0	0	0	0	0	0	-0	3	0	0	0	0	0	18	0	-0	0	0	0	0	0	4	0	0	0	0	152	1	GE
GL	-0	-0	-0	0	-0	0	-0	-0	-0	-0	-0	-0	0	-0	-0	-0	-0	-0	0	0	0	0	0	-0	0	7	0	0	0	0	GL
GR	0	2	0	0	0	0	-0	3	5	2	0	0	0	-0	-0	21	1	-0	0	0	0	0	0	0	0	0	0	0	105	71	GR
HR	1	0	0	1	0	11	0	5	23	1	0	8	3	-0	-0	0	2	0	0	0	0	0	0	-0	0	0	0	0	209	163	HR
HU	0	0	0	1	0	30	0	23	20	2	0	2	17	-0	-0	0	9	0	0	0	0	0	0	-0	0	0	0	0	270	232	HU
IE	0	0	0	3	0	2	0	0	0	0	0	0	0	-0	-0	0	0	0	0	0	0	0	0	-0	0	1	0	0	88	87	IE
IS	-0	-0	-0	0	0	0	0	0	-0	0	0	0	0	-0	-0	0	0	0	0	0	0	0	0	-0	0	0	0	0	7	3	IS
IT	0	0	0	0	0	2	-0	1	1	0	0	3	0	-0	-0	0	0	0	0	0	0	0	0	-0	0	0	0	0	209	205	IT
KG	-0	-0	-0	0	-0	0	-0	0	-0	0	0	0	0	2	0	0	-0	17	0	0	0	0	0	6	0	0	0	0	54	0	KG
KZ	-0	-0	-0	0	0	0	-0	0	-0	28	0	0	0	0	1	0	0	5	0	0	0	0	0	22	-0	0	0	0	50	0	KZ
LT	0	0	0	2	0	50	0	4	1	15	2	0	1	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	199	146	LT
LU	0	0	0	23	0	9	0	0	0	1	0	0	1	-0	-0	0	1	-0	0	0	0	0	0	-0	-0	1	0	0	336	332	LU
LV	0	0	0	2	0	29	0	3	0	20	3	0	1	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	173	122	LV
MD	0	0	0	0	0	10	0	27	2	18	0	0	1	0	-0	7	52	0	0	0	0	0	0	0	0	0	0	0	209	53	MD
ME	57	0	0	0	0	2	0	3	22	0	0	0	1	-0	-0	1	0	-0	0	0	0	0	0	0	0	0	0	0	124	28	ME
MK	0	51	0	0	0	2	0	4	35	1	0	0	1	0	-0	2	1	-0	0	0	0	0	0	0	0	0	0	0	146	45	MK
MT	0	0	114	0	0	0	0	0	0	0	0	0	0	0	-0	1	0	-0	0	0	0	0	0	-0	2	0	0	0	141	139	MT
NL	0	-0	-0	185	0	14	0	0	0	1	1	0	0	-0	-0	0	1	-0	0	0	0	0	0	-0	-0	1	0	0	429	424	NL
NO	0	0	-0	1	8	1	0	0	0	0	1	0	0	-0	-0	0	0	-0	0	0	0	0	0	-0	0	-0	0	0	24	15	NO
PL	0	0	0	4	0	227	0	7	4	6	1	1	7	-0	-0	0	13	0	0	0	0	0	0	0	0	0	0	0	364	329	PL
PT	-0	-0	-0	0	0	0	49	0	-0	-0	0	0	0	0	-0	-0	0	-0	0	0	0	0	0	-0	0	1	0	0	75	75	PT
RO	0	0	0	0	0	7	0	100	9	5	0	0	2	-0	-0	3	13	0	0	0	0	0	0	-0	0	0	0	0	175	134	RO
RS	2	4	0	1	0	8	0	22	137	1	0	1	3	-0	-0	1	3	-0	0	0	0	0	0	0	0	0	0	0	244	85	RS
RU	0	0	-0	0	0	1	0	0	0	71	0	0	0	0	0	0	3	0	0	0	0	0	0	4	-0	0	0	0	83	4	RU
SE	0	0	0	2	1	10	0	1	0	2	19	0	0	-0	-0	0	1	-0	0	0	0	0	0	0	0	0	0	0	66	60	SE
SI	0	0	0	1	0	11	0	3	7	1	0	106	2	-0	-0	0	2	0	0	0	0	0	0	-0	0	0	0	0	265	250	SI
SK	0	0	0	2	0	72	0	18	12	3	0	1	87	-0	-0	0	12	0	0	0	0	0	0	0	0	1	0	0	313	277	SK
TJ	-0	-0	-0	0	-0	-0	-0	-0	-0	-0	-0	0	-0	15	0	0	-0	17	0	0	0	0	0	4	0	0	0	0	36	-0	TJ
TM	-0	-0	-0	0	-0	0	-0	-0	-0	2	0	0	-0	0	18	0	0	13	0	0	0	0	0	15	0	0	0	0	36	0	TM
TR	0	0	0	0	0	0	-0	1	0	2	0	0	0	-0	-0	181	0	-0	0	0	0	0	0	9	1	0	0	0	190	3	TR
UA	0	0	0	0	0	13	0	9	1	43	0	0	1	0	0	5	121	0	0	0	0	0	0	1	0	0	0	0	223	37	UA
UZ	-0	-0	-0	0	-0	0	-0	-0	-0	3	0	0	-0	3	3	0	0	65	0	0	0	0	0	9	0	0	0	0	86	0	UZ
ATL	0	0	-0	1	0	0	0	0	0	-0	0	0	0	-0	-0	-0	0	-0	0	0	0	0	0	-0	-0	-1	0	0	14	14	ATL
BAS	0	0	0	6	1	49	0	3	1	12	15	0	1	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	193	168	BAS
BLS	0	0	0	0	0	2	0	10	2	27	0	0	0	0	0	49	18	0	0	0	0	0	0	0	0	0	0	0	132	22	BLS
MED	0	0	-0	0	0	0	-0	1	0	1	0	0	0	-0	0	22	0	0	0	0	0	0	0	1	1	-0	0	0	42	17	MED
NOS	0	0	0	29	3	7	0	0	0	1	2	0	0	-0	-0	0	1	0	0	0	0	0	0	-0	0	0	0	0	217	211	NOS
AST	-0	-0	-0	0	-0	-0	-0	0	-0	1	-0	0	-0	-0	0	3	0	0	0	0	0	0	0	83	2	0	0	0	7	0	AST
NOA	-0	-0	-0	0	0	-0	0	0	-0	0	0	0	-0	-0	-0	1	0	-0	0	0	0	0	0	0	20	1	0	0	3	2	NOA
EXC	0	0	0	2	0	8	0	3	2	34	1	0	1	0	1	8	6	3	0	0	0	0	0	6	0	0	0	0	111	45	EXC
EU	0	0	0	6	0	27	1	8	3	3	3	1	2	0	-0	1	3	0	0	0	0	0	0	0	0	0	0	0	187	171	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.12: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	2	0	0	0	1	0	0	1	0	0	1	2	0	0	1	0	1	1	0	1	1	1	0	0	3	0	0	0	0	0	0	AL
AM	0	8	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	3	0	1	0	0	1	1	0	2	8	0	0	0	0	2	1	0	0	1	1	0	0	3	0	0	0	0	0	0	AT
AZ	0	2	0	19	0	0	0	1	0	0	0	1	0	0	0	0	0	0	7	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	0	0	0	0	4	0	0	1	0	0	1	3	0	0	0	0	1	1	0	0	1	1	0	0	2	0	0	0	0	0	0	BA
BE	0	0	1	0	0	4	0	1	1	0	2	16	0	0	1	0	7	9	0	0	0	0	0	0	2	0	0	0	0	0	0	BE
BG	0	0	0	0	0	0	1	1	0	0	1	2	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	0	BG
BY	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	BY
CH	0	0	2	0	0	0	0	0	8	0	2	10	0	0	1	0	5	1	0	0	0	0	0	0	5	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	1	0	-0	0	1	0	0	1	0	1	0	0	2	0	0	0	0	2	0	0	0	0	0	0	CY
CZ	0	0	1	0	1	0	0	1	0	0	4	7	0	0	0	0	2	2	0	0	0	1	0	0	1	0	0	0	0	0	0	CZ
DE	0	0	1	0	0	1	0	1	1	0	3	14	0	0	1	0	4	3	0	0	0	1	0	0	3	0	0	0	0	0	0	DE
DK	0	0	0	0	0	1	0	0	0	0	1	5	1	0	1	0	2	2	0	0	0	0	0	0	1	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	2	0	0	6	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	0	0	0	1	0	0	1	0	1	6	0	0	1	0	6	2	0	0	0	0	0	0	2	0	0	0	0	0	0	FR
GB	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	5	0	0	0	0	0	0	1	0	0	0	0	0	0	GB
GE	0	1	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	0	0	0	1	0	0	1	0	0	1	2	0	0	1	0	1	1	0	4	0	0	0	0	3	0	0	0	0	0	0	GR
HR	0	0	1	0	2	0	0	1	0	0	2	5	0	0	0	0	1	1	0	0	2	1	0	0	4	0	0	0	0	0	0	HR
HU	0	0	1	0	1	0	0	1	0	0	2	4	0	0	0	0	1	1	0	0	1	2	0	0	2	0	0	0	0	0	0	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-0	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	IS
IT	0	0	1	0	1	0	0	0	1	0	2	6	0	0	2	0	4	1	0	0	1	1	0	0	52	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	LT
LU	0	0	1	0	0	1	0	0	1	0	2	15	0	0	1	0	5	3	0	0	0	0	0	0	2	0	0	0	0	0	0	LU
LV	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	LV
MD	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	MD
ME	1	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	1	1	0	0	0	1	0	0	2	0	0	0	0	0	0	ME
MK	0	0	0	0	1	0	0	1	0	0	1	2	0	0	0	0	1	1	0	2	0	1	0	0	2	0	0	0	0	0	0	MK
MT	0	0	1	0	1	0	0	0	0	0	1	4	0	0	3	0	5	1	0	1	1	0	0	0	16	0	0	0	0	0	0	MT
NL	0	0	1	0	0	4	0	1	0	0	3	17	0	0	1	0	7	9	0	0	0	1	0	0	2	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	0	0	0	0	0	2	0	0	2	4	0	0	0	0	1	2	0	0	0	1	0	0	1	0	0	0	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	RO
RS	0	0	0	0	1	0	0	1	0	0	1	3	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	3	0	1	0	0	1	0	0	2	7	0	0	1	0	2	1	0	0	2	1	0	0	8	0	0	0	0	0	0	SI
SK	0	0	0	0	1	0	0	1	0	0	2	4	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	TJ
TM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	TM
TR	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	BAS
BLS	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	BLS
MED	0	0	0	0	0	0	0	0	0	0	1	3	0	0	3	0	3	1	0	1	1	0	0	0	9	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	1	0	0	0	0	0	0	3	0	0	0	0	0	0	NOA
EXC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	EXC
EU	0	0	0	0	0	0	0	1	0	0	1	4	0	0	1	0	2	2	0	0	0	0	0	0	5	0	0	0	0	0	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.12 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	0	0	0	0	0	2	0	1	0	3	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	-2	0	0	23	14	AL
AM	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	20	0	-2	0	0	28	2	AM
AT	0	0	0	1	0	3	0	1	0	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	34	28	AT
AZ	0	0	0	0	0	1	0	0	0	8	0	0	0	0	1	2	1	1	0	0	0	0	0	25	0	1	0	0	46	4	AZ
BA	0	0	0	0	0	3	0	1	-0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	27	17	BA
BE	0	0	0	8	0	4	0	1	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	8	0	0	63	57	BE
BG	0	0	0	0	0	2	0	2	0	6	0	0	0	0	0	1	2	0	0	0	0	0	0	1	0	-3	0	0	25	12	BG
BY	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	15	6	BY
CH	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	39	29	CH
CY	0	0	0	0	0	1	0	1	0	6	0	0	0	0	0	12	1	0	0	0	0	0	0	11	1	-2	0	0	34	11	CY
CZ	0	0	0	1	0	5	0	1	0	4	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	36	28	CZ
DE	0	0	0	2	0	4	0	1	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	45	38	DE
DK	0	0	0	1	0	2	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	22	18	DK
EE	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	10	4	EE
ES	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-1	0	0	15	14	ES
FI	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	6	2	FI
FR	0	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	26	23	FR
GB	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	17	15	GB
GE	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	2	1	0	0	0	0	0	0	7	0	-1	0	0	26	2	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	0	0	0	0	2	0	1	0	5	0	0	0	0	0	1	1	0	0	0	0	0	0	1	1	-2	0	0	28	16	GR
HR	0	0	0	1	0	3	0	1	0	3	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	33	25	HR
HU	0	0	0	0	0	5	0	3	0	5	0	0	1	0	0	1	2	0	0	0	0	0	0	1	0	-3	0	0	37	26	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	4	3	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	1	0	IS
IT	0	0	0	1	0	3	0	1	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	83	77	IT
KG	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7	0	0	0	0	0	3	0	-1	0	0	14	0	KG
KZ	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	-3	0	0	11	1	KZ
LT	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	14	7	LT
LU	0	0	0	2	0	3	0	0	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	43	38	LU
LV	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	11	5	LV
MD	0	0	0	0	0	2	0	2	0	8	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	-5	0	0	23	9	MD
ME	0	0	0	0	0	2	0	1	0	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	-2	0	0	19	11	ME
MK	0	1	0	0	0	2	0	1	-0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	-2	0	0	23	13	MK
MT	0	0	4	1	0	2	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	2	2	0	0	48	42	MT
NL	0	0	0	10	0	5	0	1	0	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	10	0	0	71	63	NL
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	3	2	NO
PL	0	0	0	1	0	7	0	1	0	5	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	-1	0	0	35	24	PL
PT	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	14	14	PT
RO	0	0	0	0	0	2	0	4	0	6	0	0	0	0	0	1	2	0	0	0	0	0	0	1	0	-3	0	0	25	13	RO
RS	0	0	0	0	0	3	0	2	-0	5	0	0	1	0	0	1	2	0	0	0	0	0	0	1	0	-3	0	0	29	17	RS
RU	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	7	1	RU
SE	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	6	4	SE
SI	0	0	0	1	0	3	0	1	0	2	0	4	1	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	44	37	SI
SK	0	0	0	0	0	5	0	2	0	4	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	-2	0	0	31	21	SK
TJ	0	0	0	0	0	0	0	0	0	1	0	0	0	-0	0	0	0	8	0	0	0	0	0	6	0	-1	0	0	12	1	TJ
TM	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	1	0	0	0	0	0	13	0	-2	0	0	11	2	TM
TR	0	0	0	0	0	1	0	1	0	4	0	0	0	0	0	5	1	0	0	0	0	0	0	8	1	-4	0	0	19	6	TR
UA	0	0	0	0	0	2	0	1	0	7	0	0	0	0	0	0	2	0	0	0	0	0	0	1	0	-4	0	0	19	7	UA
UZ	0	0	0	0	0	0	0	0	0	4	0	0	0	1	1	0	0	16	0	0	0	0	0	7	0	-2	0	0	28	2	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	2	2	ATL
BAS	0	0	0	0	0	2	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	15	9	BAS
BLS	0	0	0	0	0	1	0	1	0	12	0	0	0	0	0	3	2	0	0	0	0	0	0	2	0	-2	0	0	30	8	BLS
MED	0	0	0	1	0	2	0	1	0	3	0	0	0	0	0	2	1	0	0	0	0	0	0	4	2	-0	0	0	37	28	MED
NOS	0	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	16	14	NOS
AST	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	35	0	-2	0	0	7	2	AST
NOA	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	-1	0	0	13	11	NOA
EXC	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	-2	0	0	14	7	EXC
EU	0	0	0	1	0	2	0	1	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-1	0	0	27	22	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.13.1: 2018 country-to-country blame matrices for **PM2.5 with EMEP PPM emissions**.
Units: ng/m^3 per 15% emis. red. of PPM, SO_x, NO_x, NH_3 and VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	378	0	2	1	32	1	25	1	0	0	6	10	0	0	2	0	3	2	1	62	5	7	0	0	23	0	1	0	0	0	1	AL
AM	0	394	0	266	0	0	0	0	0	0	0	1	0	0	0	0	0	0	47	0	0	0	0	0	1	0	15	0	0	0	0	AM
AT	1	0	285	0	17	4	3	4	14	0	63	158	1	0	2	0	18	6	0	2	22	33	0	0	49	0	1	1	1	0	1	AT
AZ	0	38	0	861	0	0	0	1	0	0	0	1	0	0	0	0	0	0	75	0	0	0	0	0	1	0	50	0	0	0	0	AZ
BA	6	0	14	0	795	1	11	3	1	0	20	31	1	0	2	0	6	3	0	6	64	36	0	0	21	0	1	0	0	0	2	BA
BE	0	0	7	0	1	462	0	3	5	0	21	318	5	0	10	1	227	134	0	0	1	2	7	1	6	0	0	1	15	0	0	BE
BG	2	0	4	3	16	1	413	5	1	0	7	13	1	1	1	0	2	2	2	25	4	11	0	0	4	0	4	1	0	0	12	BG
BY	0	0	2	0	3	2	2	224	0	0	7	24	2	5	0	5	3	5	0	1	1	6	0	0	2	0	8	15	0	8	8	BY
CH	0	0	31	0	2	4	0	1	376	0	16	195	0	0	4	0	87	7	0	0	1	1	1	0	82	0	0	0	1	0	0	CH
CY	0	0	0	1	2	0	5	1	0	139	1	2	0	0	2	0	2	1	1	22	0	1	0	0	7	0	3	0	0	0	1	CY
CZ	1	0	55	0	17	8	6	9	5	0	467	209	4	1	3	1	27	13	0	2	13	49	1	0	13	0	1	2	1	1	2	CZ
DE	0	0	37	0	4	36	1	5	17	0	68	660	9	1	5	1	75	48	0	1	2	8	3	0	12	0	1	2	4	1	0	DE
DK	0	0	5	0	2	22	1	7	1	0	17	226	247	2	3	4	36	80	0	1	1	4	6	0	3	0	0	4	1	2	1	DK
EE	0	0	1	0	1	2	1	32	0	0	3	22	5	86	0	22	3	9	0	0	0	2	1	0	1	0	4	18	0	29	3	EE
ES	0	0	1	0	1	3	0	0	0	0	2	12	0	0	328	0	28	6	0	0	0	0	1	0	4	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	5	0	0	1	8	2	6	0	71	2	3	0	0	0	1	0	0	0	0	2	3	0	3	0	FI
FR	0	0	6	0	1	35	0	1	18	0	12	123	2	0	23	0	382	48	0	0	1	1	4	0	17	0	0	0	4	0	0	FR
GB	0	0	1	0	0	14	0	1	1	0	4	52	5	0	5	1	57	466	0	0	0	0	25	1	1	0	0	1	1	0	0	GB
GE	0	32	0	158	0	0	0	1	0	0	0	1	0	0	0	0	0	0	409	0	0	0	0	0	0	0	13	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	11	0	1	2	12	0	50	2	0	0	3	7	0	0	3	0	2	1	2	244	2	4	0	0	15	0	2	0	0	0	3	GR
HR	4	0	39	1	203	2	12	4	2	0	36	52	1	0	3	0	9	4	1	5	346	73	0	0	56	0	1	1	0	0	2	HR
HU	2	0	42	1	47	3	21	8	3	0	52	69	2	0	2	1	11	6	1	5	43	434	0	0	23	0	2	1	0	0	5	HU
IE	0	0	0	0	0	4	0	1	0	0	2	22	3	0	4	0	15	106	0	0	0	0	142	0	1	0	0	1	0	0	0	IE
IS	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	1	3	0	0	0	0	1	41	0	0	0	0	0	0	0	IS
IT	2	0	21	0	18	1	2	1	9	0	11	27	0	0	13	0	27	3	0	3	15	8	0	0	879	0	0	0	0	0	0	IT
KG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	69	0	0	0	0	KG
KZ	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	269	0	0	0	0	KZ
LT	0	0	2	0	2	4	1	85	1	0	9	45	7	8	1	7	6	11	0	1	1	6	1	0	2	0	5	129	0	28	6	LT
LU	0	0	11	0	1	117	0	2	7	0	29	473	4	0	9	1	198	64	0	0	1	3	3	0	8	0	0	1	147	0	0	LU
LV	0	0	1	0	1	2	1	58	0	0	6	31	5	15	1	10	4	10	0	0	1	3	1	0	1	0	5	55	0	134	4	LV
MD	1	0	3	3	6	1	21	20	1	0	7	22	2	1	1	2	3	3	1	4	1	8	0	0	3	0	13	3	0	1	365	MD
ME	37	0	4	1	105	1	15	1	1	0	8	14	1	0	2	0	3	2	1	10	8	12	0	0	18	0	1	0	0	0	2	ME
MK	33	0	3	1	24	1	63	2	0	0	6	11	0	0	2	0	2	2	1	101	3	10	0	0	8	0	1	0	0	0	3	MK
MT	3	0	3	0	14	1	3	0	1	0	4	12	0	0	22	0	25	3	0	7	3	1	0	0	111	0	0	0	0	0	0	MT
NL	0	0	6	0	2	156	1	5	3	0	26	378	12	1	9	1	138	170	0	1	1	3	10	1	6	0	0	2	5	1	0	NL
NO	0	0	0	0	0	1	0	1	0	0	1	11	4	1	0	2	3	7	0	0	0	0	1	0	0	0	0	1	0	0	0	NO
PL	0	0	8	1	8	6	4	33	1	0	52	109	10	2	2	2	13	16	0	2	5	24	1	0	7	0	3	9	0	3	4	PL
PT	0	0	0	0	0	2	0	0	0	0	1	6	0	0	143	0	12	6	0	0	0	0	1	0	1	0	0	0	0	0	0	PT
RO	2	0	5	2	12	1	36	8	1	0	11	21	1	1	1	1	4	3	1	5	4	30	0	0	6	0	5	1	0	1	28	RO
RS	11	0	12	1	96	1	79	4	1	0	21	34	1	0	1	0	5	3	1	20	22	58	0	0	10	0	2	1	0	0	6	RS
RU	0	0	0	2	0	0	0	5	0	0	0	2	0	1	0	2	0	1	0	0	0	0	0	0	0	0	46	1	0	1	0	RU
SE	0	0	1	0	1	3	0	4	0	0	3	26	12	2	1	8	5	12	0	0	0	2	1	0	1	0	1	2	0	2	0	SE
SI	1	0	123	0	42	2	5	4	4	0	37	67	1	0	3	0	10	4	0	2	139	44	0	0	134	0	1	1	0	0	1	SI
SK	1	0	23	1	19	3	11	9	2	0	67	64	2	1	2	1	10	6	0	3	12	132	0	0	13	0	2	1	0	0	4	SK
TJ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	0	0	0	0	TJ
TM	0	1	0	9	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	95	0	0	0	0	TM
TR	0	7	1	8	1	0	6	1	0	2	1	3	0	0	1	0	1	0	6	6	0	1	0	0	2	0	4	0	0	0	1	TR
UA	0	0	2	2	3	1	5	29	0	0	6	16	1	2	1	2	3	3	1	2	1	6	0	0	2	0	18	3	0	2	25	UA
UZ	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	21	145	0	0	0	0	UZ
ATL	0	0	0	0	0	1	0	0	0	0	0	5	0	0	8	0	8	11	0	0	0	0	2	1	0	0	1	0	0	0	0	ATL
BAS	0	0	2	0	1	6	1	13	1	0	9	82	34	9	1	23	9	25	0	0	1	5	2	0	2	0	2	12	0	10	2	BAS
BLS	0	1	1	12	3	0	13	6	0	0	3	6	0	1	1	1	1	1	29	3	1	3	0	0	2	0	14	1	0	0	11	BLS
MED	4	0	2	1	14	1	8	1	1	2	4	10	0	0	32	0	23	2	1	20	5	2	0	0	66	0	1	0	0	0	1	MED
NOS	0	0	1	0	0	22	0	2	1	0	5	96	22	1	4	1	57	143	0	0	0	1	10	1	1	0	0	1	1	1	0	NOS
AST	0	1	0	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	33	0	0	0	0	AST
NOA	0	0	0	0	3	0	2	0	0	0	1	3	0	0	20	0	6	1	0	4	1	0	0	0	10	0	0	0	0	0	0	NOA
EXC	1	1	4	7	5	4	5	8	2	0	7	28	2	1	11	3	17	12	3	3	3	5	1	0	17	3	66	2	0	1	3	EXC
EU	1	0	15	0	9	15	16	8	5	0	26	108	6	2	46	7	70	46	0	9	9	19	5	0	69	0	1	4	1	4	3	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.13.1 Cont.: 2018 country-to-country blame matrices for **PM2.5 with EMEP PPM emissions**.
Units: ng/m^3 per 15% emis. red. of PPM, SO_x, NO_x, NH_3 and VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	30	89	0	1	0	15	0	11	131	10	0	1	3	0	0	33	22	0	1	0	1	37	1	5	9	8	4	22	911	180	AL
AM	0	0	0	0	0	1	0	1	1	9	0	0	0	0	5	173	3	2	0	0	1	2	0	320	3	7	0	4	921	6	AM
AT	1	1	0	5	0	77	0	11	41	8	1	35	15	0	0	4	15	0	1	1	0	6	3	1	2	8	2	2	901	792	AT
AZ	0	0	0	0	0	2	0	1	0	43	0	0	0	0	15	58	12	6	0	0	1	1	0	298	2	11	0	2	1169	9	AZ
BA	28	8	0	2	0	44	0	27	196	11	0	4	10	0	0	17	25	0	1	0	1	12	1	3	6	7	2	7	1398	304	BA
BE	0	0	0	167	2	43	1	1	2	6	2	0	2	0	0	1	3	0	16	4	0	3	85	1	2	32	12	0	1459	1435	BE
BG	2	11	0	1	0	19	0	94	110	49	0	1	3	0	0	74	122	0	0	0	13	9	1	4	3	9	1	5	1024	608	BG
BY	0	1	0	3	1	100	0	18	8	133	4	1	4	0	0	9	131	0	1	6	1	1	3	2	0	7	3	1	749	220	BY
CH	0	0	0	5	0	21	0	1	3	2	0	2	1	0	0	1	3	0	2	0	0	4	4	1	2	9	1	1	851	462	CH
CY	0	2	0	0	0	3	0	3	7	18	0	0	0	0	0	918	22	0	1	0	6	136	0	226	39	16	20	34	1167	189	CY
CZ	1	2	0	11	1	242	0	21	53	16	2	9	32	0	0	6	27	0	2	2	0	4	7	1	2	11	4	2	1333	1190	CZ
DE	0	1	0	52	2	117	1	4	11	12	3	2	5	0	0	2	10	0	6	10	0	3	33	1	2	17	8	1	1229	1162	DE
DK	0	0	0	52	10	86	1	4	5	16	25	1	3	0	0	2	11	0	8	59	0	1	72	0	1	16	15	0	890	834	DK
EE	0	0	0	4	3	50	0	6	3	106	10	0	2	0	0	2	30	0	2	16	0	0	4	1	0	7	5	0	461	277	EE
ES	0	0	0	2	0	4	27	0	1	0	0	0	0	0	0	1	0	0	30	0	0	44	2	0	20	16	9	3	421	417	ES
FI	0	0	0	1	3	14	0	2	1	55	10	0	0	0	0	0	6	0	2	6	0	0	2	0	0	7	7	0	205	130	FI
FR	0	0	0	25	1	21	1	1	2	2	1	1	1	0	0	1	2	0	18	1	0	11	34	0	3	14	10	2	737	709	FR
GB	0	0	0	23	2	17	1	0	1	3	2	0	0	0	0	0	1	0	29	4	0	1	45	0	1	18	22	0	688	677	GB
GE	0	0	0	0	0	2	0	1	1	27	0	0	0	0	5	106	9	2	0	0	4	1	0	84	1	7	0	3	773	9	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	2	0	0	0	GL
GR	4	33	0	1	0	11	0	13	51	28	0	0	2	0	0	156	54	0	1	0	7	66	0	10	15	10	6	31	721	362	GR
HR	8	6	0	3	0	72	0	30	188	12	1	37	16	0	0	13	27	0	1	1	1	25	2	2	5	7	3	7	1267	797	HR
HU	5	7	0	4	1	149	0	145	152	23	1	14	70	0	0	13	74	0	1	1	1	8	3	2	3	9	2	5	1439	1097	HU
IE	0	0	0	7	1	9	1	0	0	2	1	0	0	0	0	0	1	0	32	2	0	1	13	0	1	14	27	0	325	319	IE
IS	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	8	12	0	53	11	IS
IT	2	2	0	2	0	22	1	4	20	3	0	18	4	0	0	6	6	0	2	0	0	95	1	1	20	12	7	41	1132	1062	IT
KG	0	0	0	0	0	0	0	0	0	4	0	0	0	17	4	3	1	171	0	0	0	0	0	70	0	8	0	1	396	1	KG
KZ	0	0	0	0	0	1	0	0	0	105	0	0	0	1	5	2	8	21	0	0	0	0	0	75	0	11	1	0	426	5	KZ
LT	0	1	0	7	2	176	0	13	7	89	9	1	5	0	0	4	67	0	2	18	1	1	6	1	0	8	5	1	749	479	LT
LU	0	0	0	63	1	41	1	1	2	5	1	1	3	0	0	1	3	0	9	2	0	3	31	0	2	19	8	1	1205	1180	LU
LV	0	0	0	5	2	88	0	8	4	91	9	0	2	0	0	3	47	0	2	14	0	1	4	1	0	7	5	0	609	393	LV
MD	1	2	0	2	1	69	0	171	16	101	1	1	4	0	1	39	398	1	1	2	13	4	2	3	1	9	1	2	1304	334	MD
ME	365	22	0	1	0	17	0	15	140	10	0	1	4	0	0	24	23	0	0	0	1	16	1	4	7	8	2	11	868	136	ME
MK	6	379	0	1	0	16	0	19	172	17	0	1	3	0	0	53	40	0	0	0	3	13	0	7	6	8	1	11	986	253	MK
MT	3	5	167	2	0	9	2	2	10	3	0	2	1	0	0	18	3	0	4	0	0	410	1	4	113	15	23	149	442	381	MT
NL	0	1	0	389	3	79	1	2	4	11	4	1	2	0	0	1	5	0	16	11	0	3	125	1	2	37	15	0	1439	1404	NL
NO	0	0	0	2	45	7	0	0	1	7	6	0	0	0	0	0	2	0	5	2	0	0	6	0	0	9	14	0	107	49	NO
PL	1	2	0	10	2	736	0	28	25	43	5	2	25	0	0	5	72	0	2	13	1	2	8	1	1	12	5	2	1283	1082	PL
PT	0	0	0	1	0	2	305	0	0	0	0	0	0	0	0	0	0	0	81	0	0	13	1	0	14	18	18	1	482	480	PT
RO	2	5	0	2	0	50	0	577	59	46	1	1	9	0	0	29	149	0	1	1	8	4	1	3	1	8	1	3	1122	771	RO
RS	24	46	0	2	0	54	0	103	651	24	1	3	14	0	0	29	67	0	1	1	3	7	2	4	4	9	1	7	1411	447	RS
RU	0	0	0	0	0	6	0	1	1	223	1	0	0	0	1	3	20	1	1	1	0	0	0	9	0	10	5	0	322	19	RU
SE	0	0	0	5	10	28	0	2	2	16	49	0	1	0	0	1	5	0	3	11	0	0	7	0	0	8	8	0	206	165	SE
SI	1	2	0	3	0	70	0	16	85	9	1	447	13	0	0	5	19	0	1	1	0	23	2	1	4	8	2	4	1299	1123	SI
SK	2	4	0	4	1	236	0	77	65	20	1	6	261	0	0	8	66	0	1	1	1	4	3	1	2	8	2	3	1144	939	SK
TJ	0	0	0	0	0	0	0	0	0	4	0	0	0	169	22	5	1	128	0	0	0	0	0	90	0	9	0	2	371	1	TJ
TM	0	0	0	0	0	1	0	0	0	34	0	0	0	7	122	10	9	80	0	0	0	0	0	179	1	14	0	1	375	5	TM
TR	0	1	0	0	0	4	0	7	7	24	0	0	0	0	1	1117	26	0	0	0	12	26	0	166	13	12	2	12	1241	36	TR
UA	1	1	0	1	1	62	0	45	9	157	1	1	4	0	1	24	535	1	1	2	6	2	1	5	1	9	2	1	981	171	UA
UZ	0	0	0	0	0	1	0	0	0	46	0	0	0	32	39	6	9	339	0	0	0	0	0	81	1	15	0	1	646	5	UZ
ATL	0	0	0	2	1	2	4	0	0	4	0	0	0	0	0	0	0	0	26	0	0	2	3	0	4	17	32	0	52	45	ATL
BAS	0	0	0	14	5	111	0	7	5	48	32	0	3	0	0	2	18	0	3	34	0	1	13	1	0	10	10	0	497	400	BAS
BLS	0	1	0	1	0	16	0	33	13	132	0	0	1	0	2	222	187	1	0	0	62	6	0	11	3	9	1	3	724	89	BLS
MED	3	4	0	1	0	10	2	5	18	12	0	2	1	0	0	202	18	0	7	0	4	230	1	46	78	13	22	88	481	200	MED
NOS	0	0	0	48	11	23	1	1	1	5	5	0	1	0	0	0	3	0	15	7	0	1	51	0	1	15	24	0	471	446	NOS
AST	0	0	0	0	0	1	0	0	0	9	0	0	0	2	12	65	3	8	0	0	0	5	0	874	7	19	1	4	150	5	AST
NOA	1	1	0	0	0	2	4	1	3	2	0	0	0	0	0	28	3	0	15	0	0	61	0	12	263	24	10	28	101	57	NOA
EXC	1	2	0	4	2	29	2	13	10	118	2	1	3	3	6	54	37	17	3	2	1	6	4	33	2	11	4	2	528	181	EXC
EU	1	2	0	17	2	95	10	43	21	21	7	6	9	0	0	12	26	0	11	5	1	17	14	2	6	12	8	5	777	664	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.13.2: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of PPM, SO_x, NO_x, NH_3 and VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	367	0	3	1	30	1	22	1	0	0	6	10	0	0	2	0	3	2	1	62	4	7	0	0	22	0	1	0	0	0	1	AL
AM	0	353	0	267	0	0	0	0	0	0	0	1	0	0	0	0	0	0	44	0	0	0	0	0	1	0	15	0	0	0	0	AM
AT	1	0	619	0	15	4	3	4	16	0	70	164	1	0	2	0	20	6	0	1	19	32	0	0	50	0	1	1	1	0	1	AT
AZ	0	34	0	863	0	0	0	1	0	0	0	1	0	0	0	0	0	0	72	0	0	0	0	0	1	0	50	0	0	0	0	AZ
BA	5	0	18	0	696	1	10	3	1	0	20	31	1	0	2	0	6	3	0	6	50	33	0	0	21	0	1	0	0	0	2	BA
BE	0	0	10	0	1	508	0	3	6	0	22	343	6	0	10	1	299	133	0	0	0	2	7	1	6	0	0	1	16	1	0	BE
BG	2	0	5	3	15	1	445	5	1	0	7	14	1	1	1	1	3	2	2	25	3	10	0	0	4	0	4	1	0	0	11	BG
BY	0	0	2	0	3	2	2	232	0	0	7	24	3	6	0	5	4	5	0	1	1	6	0	0	2	0	8	20	0	9	8	BY
CH	0	0	49	0	2	4	0	1	479	0	17	205	0	0	3	0	106	7	0	0	1	1	1	0	85	0	0	0	1	0	0	CH
CY	0	0	1	1	2	0	5	1	0	153	1	2	0	0	2	0	2	1	1	22	0	1	0	0	7	0	3	0	0	0	1	CY
CZ	1	0	79	0	16	8	6	9	5	0	546	219	4	1	2	1	30	13	0	2	11	48	1	0	13	0	1	2	1	1	1	CZ
DE	0	0	58	0	4	38	1	5	20	0	73	756	10	1	5	1	90	48	0	1	2	8	3	0	12	0	1	3	4	1	0	DE
DK	0	0	6	0	1	22	1	7	1	0	18	238	341	2	3	5	39	78	0	1	1	4	5	0	3	0	0	5	1	3	1	DK
EE	0	0	1	0	1	2	1	32	0	0	4	23	6	160	0	28	3	8	0	0	0	2	1	0	1	0	4	22	0	37	2	EE
ES	0	0	1	0	1	3	0	0	0	0	2	12	0	0	359	0	32	6	0	0	0	0	1	0	4	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	5	0	0	1	8	3	8	0	130	2	3	0	0	0	1	0	0	0	0	2	3	0	3	0	FI
FR	0	0	8	0	1	36	0	1	20	0	12	129	2	0	23	0	552	47	0	0	1	1	4	0	18	0	0	0	4	0	0	FR
GB	0	0	1	0	0	14	0	1	1	0	4	55	6	0	4	1	65	446	0	0	0	0	24	1	1	0	0	1	1	1	0	GB
GE	0	29	0	158	0	0	0	1	0	0	0	1	0	0	0	0	0	0	376	0	0	0	0	0	0	0	13	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	10	0	2	1	12	0	55	2	0	0	3	7	0	0	3	0	3	1	1	264	2	4	0	0	15	0	2	0	0	0	2	GR
HR	3	0	55	1	181	2	11	4	2	0	38	53	1	0	3	0	9	4	0	5	256	68	0	0	56	0	1	1	0	0	2	HR
HU	2	0	65	1	41	3	20	8	3	0	57	71	2	1	2	1	12	5	1	5	34	408	0	0	22	0	2	1	0	0	5	HU
IE	0	0	1	0	0	4	0	1	0	0	2	23	3	0	4	0	17	104	0	0	0	0	133	0	0	0	0	1	0	0	0	IE
IS	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	1	3	0	0	0	0	1	41	0	0	0	0	0	0	0	IS
IT	1	0	28	0	17	1	2	1	10	0	11	27	0	0	13	0	29	3	0	3	13	7	0	0	974	0	0	0	0	0	0	IT
KG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	129	69	0	0	0	0	KG
KZ	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	271	0	0	0	0	KZ
LT	0	0	3	0	2	4	1	88	1	0	10	46	7	9	1	8	7	11	0	1	1	5	1	0	2	0	5	228	0	37	6	LT
LU	0	0	15	0	1	124	0	2	8	0	30	521	4	0	9	1	275	63	0	0	0	3	3	0	7	0	0	1	157	0	0	LU
LV	0	0	1	0	1	2	1	59	0	0	6	32	6	20	1	12	5	9	0	0	0	3	1	0	1	0	4	72	0	186	4	LV
MD	1	0	4	3	5	1	23	20	1	0	7	22	2	1	1	2	3	3	1	3	1	7	0	0	3	0	13	3	0	1	275	MD
ME	33	0	5	0	98	1	13	1	1	0	8	14	1	0	2	0	3	2	0	10	7	11	0	0	17	0	1	0	0	0	1	ME
MK	30	0	4	1	23	1	59	2	0	0	6	11	0	0	2	0	2	2	1	103	3	10	0	0	8	0	1	0	0	0	3	MK
MT	3	0	4	0	14	1	3	0	1	0	4	12	0	0	22	0	28	3	0	7	3	1	0	0	112	0	0	0	0	0	0	MT
NL	0	0	8	0	2	165	1	5	3	0	27	420	13	1	9	2	164	169	0	1	1	3	10	1	5	0	0	2	5	1	0	NL
NO	0	0	0	0	0	1	0	1	0	0	1	12	4	1	0	2	3	7	0	0	0	0	1	0	0	0	0	1	0	1	0	NO
PL	0	0	11	1	7	6	4	33	2	0	57	114	11	3	2	3	14	15	0	1	4	24	1	0	6	0	3	11	0	4	4	PL
PT	0	0	0	0	0	2	0	0	0	0	1	6	0	0	143	0	13	6	0	0	0	0	1	0	1	0	0	0	0	0	0	PT
RO	1	0	7	2	11	1	41	8	1	0	11	22	1	1	1	1	4	3	1	5	3	28	0	0	5	0	5	1	0	1	23	RO
RS	10	0	16	1	89	1	64	4	1	0	22	35	1	0	1	0	6	3	1	20	17	56	0	0	10	0	2	1	0	0	5	RS
RU	0	0	0	2	0	0	0	5	0	0	0	2	0	2	0	3	0	1	0	0	0	0	0	0	0	0	46	1	0	1	0	RU
SE	0	0	1	0	1	3	0	4	0	0	3	27	13	3	0	10	5	11	0	0	0	1	1	0	0	0	1	2	0	2	0	SE
SI	1	0	200	0	39	2	5	4	4	0	39	68	1	0	3	0	11	4	0	2	112	41	0	0	135	0	1	1	0	0	1	SI
SK	1	0	34	1	16	3	11	8	2	0	77	66	3	1	1	1	11	6	0	3	10	126	0	0	12	0	2	1	0	0	4	SK
TJ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	30	0	0	0	0	TJ
TM	0	1	0	9	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	95	0	0	0	0	TM
TR	0	6	1	8	1	0	6	1	0	2	1	3	0	0	1	0	1	0	5	6	0	1	0	0	2	0	4	0	0	0	1	TR
UA	0	0	2	2	3	1	6	29	0	0	6	16	1	2	1	2	3	3	1	2	1	6	0	0	2	0	18	4	0	2	22	UA
UZ	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	22	146	0	0	0	0	UZ
ATL	0	0	0	0	0	1	0	0	0	0	0	5	0	0	8	0	9	10	0	0	0	0	2	1	0	0	1	0	0	0	0	ATL
BAS	0	0	3	0	1	6	1	13	1	0	10	85	38	13	1	31	10	24	0	0	1	4	2	0	1	0	2	15	0	12	2	BAS
BLS	0	1	1	12	2	0	15	6	0	0	3	6	0	1	1	1	1	1	27	3	1	2	0	0	2	0	14	1	0	0	10	BLS
MED	4	0	3	1	14	1	8	1	1	2	4	10	0	0	33	0	27	2	1	21	4	2	0	0	68	0	1	0	0	0	1	MED
NOS	0	0	2	0	0	23	0	2	1	0	6	101	24	1	4	1	67	140	0	0	0	1	10	1	1	0	0	1	1	1	0	NOS
AST	0	1	0	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1	33	0	0	0	0	AST
NOA	0	0	1	0	2	0	2	0	0	0	1	3	0	0	20	0	7	1	0	4	0	0	0	0	10	0	0	0	0	0	0	NOA
EXC	1	1	7	7	5	4	5	8	2	0	8	31	2	2	12	4	23	11	2	3	2	5	1	0	19	3	66	2	0	2	2	EXC
EU	1	0	26	0	8	16	17	8	6	0	29	118	8	3	49	12	94	44	0	10	7	18	5	0	75	0	1	7	1	5	2	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.13.2 Cont.: 2018 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of PPM, SO_x, NO_x, NH_3 and VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	26	96	0	1	0	16	0	11	139	11	0	1	3	0	0	33	21	0	1	0	1	36	1	5	9	8	4	22	903	176	AL
AM	0	0	0	0	0	1	0	1	1	9	0	0	0	0	5	171	3	2	0	0	1	2	0	318	3	7	0	4	876	6	AM
AT	1	1	0	5	0	86	0	11	41	8	1	44	17	0	0	4	15	0	1	1	0	6	3	1	2	8	2	2	1266	1157	AT
AZ	0	0	0	0	0	2	0	1	0	52	0	0	0	0	15	55	12	6	0	0	1	1	0	295	2	11	0	2	1171	9	AZ
BA	26	8	0	2	0	46	0	27	195	11	0	5	10	0	0	17	25	0	1	0	1	12	1	3	6	7	2	7	1286	294	BA
BE	0	0	0	184	2	48	1	1	2	6	2	1	2	0	0	1	3	0	16	4	0	3	86	1	2	32	12	0	1628	1603	BE
BG	2	13	0	1	0	21	0	100	111	53	0	1	4	0	0	75	126	0	0	0	13	9	1	4	3	9	1	5	1071	649	BG
BY	0	1	0	3	1	112	0	19	8	152	4	1	4	0	0	8	145	0	1	6	1	1	3	2	0	7	3	1	812	243	BY
CH	0	0	0	5	0	23	0	1	3	2	0	2	1	0	0	1	3	0	2	0	0	4	4	1	2	9	1	1	1007	515	CH
CY	0	2	0	0	0	3	0	3	7	18	0	0	0	0	0	920	22	0	1	0	6	136	0	224	39	16	20	34	1181	202	CY
CZ	1	2	0	11	1	282	0	22	54	17	2	10	37	0	0	6	29	0	2	2	0	4	7	1	2	11	4	2	1496	1351	CZ
DE	0	1	0	57	2	136	0	4	11	13	3	3	6	0	0	2	10	0	5	10	0	3	33	1	2	17	8	1	1395	1325	DE
DK	0	0	0	54	10	97	1	4	5	17	30	1	3	0	0	2	11	0	8	60	0	1	73	0	1	16	15	0	1022	964	DK
EE	0	0	0	4	3	55	0	6	3	121	12	0	2	0	0	2	32	0	2	16	0	0	4	1	0	7	5	0	577	376	EE
ES	0	0	0	2	0	4	29	0	1	0	0	0	0	0	0	1	0	0	29	0	0	44	2	0	20	16	9	3	459	455	ES
FI	0	0	0	1	3	15	0	1	1	61	12	0	0	0	0	0	7	0	2	7	0	0	2	0	0	7	7	0	276	195	FI
FR	0	0	0	26	1	23	1	1	2	2	1	1	1	0	0	1	2	0	18	1	0	11	34	0	3	14	10	2	923	892	FR
GB	0	0	0	24	2	19	1	0	1	3	2	0	0	0	0	0	1	0	29	4	0	1	46	0	1	18	22	0	683	672	GB
GE	0	0	0	0	0	2	0	1	1	32	0	0	0	0	5	104	9	2	0	0	4	1	0	82	1	7	0	3	739	9	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	2	0	0	0	GL
GR	3	36	0	1	0	11	0	13	51	30	0	1	2	0	0	155	55	0	1	0	7	66	0	10	15	10	6	31	751	388	GR
HR	7	6	0	3	0	77	0	29	191	13	1	46	17	0	0	12	28	0	1	1	1	25	2	2	5	7	3	7	1187	735	HR
HU	4	7	0	4	1	165	0	154	155	25	1	17	78	0	0	12	82	0	1	1	1	8	3	2	3	9	2	5	1476	1128	HU
IE	0	0	0	7	1	10	1	0	0	2	1	0	0	0	0	0	1	0	33	2	0	1	13	0	1	14	27	0	319	313	IE
IS	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	8	12	0	53	11	IS
IT	2	2	0	2	0	23	1	4	19	3	0	21	4	0	0	6	6	0	2	0	0	95	1	1	20	12	7	41	1238	1168	IT
KG	0	0	0	0	0	0	0	0	0	4	0	0	0	17	4	3	0	171	0	0	0	0	0	70	0	8	0	1	399	1	KG
KZ	0	0	0	0	0	1	0	0	0	112	0	0	0	1	5	2	8	21	0	0	0	0	0	76	0	11	1	0	435	5	KZ
LT	0	1	0	7	2	198	0	14	7	100	10	1	5	0	0	4	72	0	2	18	1	1	6	1	0	8	5	1	903	614	LT
LU	0	0	0	65	1	46	1	1	2	5	1	1	3	0	0	1	4	0	9	2	0	3	31	0	2	19	8	1	1359	1333	LU
LV	0	0	0	5	2	98	0	8	4	103	10	0	3	0	0	3	50	0	2	14	0	1	4	1	0	7	5	0	713	482	LV
MD	1	2	0	2	1	74	0	179	16	111	1	1	4	0	1	39	439	1	1	2	13	4	2	3	1	9	1	2	1280	351	MD
ME	328	22	0	1	0	17	0	15	141	10	0	1	4	0	0	23	23	0	0	0	1	15	1	4	7	8	2	11	817	133	ME
MK	6	476	0	1	0	17	0	19	176	18	0	1	3	0	0	52	40	0	0	0	3	12	0	7	6	8	1	11	1081	252	MK
MT	3	5	171	2	0	10	2	2	10	3	0	2	1	0	0	17	3	0	4	0	0	412	1	4	112	15	23	149	450	390	MT
NL	0	1	0	510	3	88	1	1	4	12	4	1	3	0	0	1	6	0	16	11	0	3	128	1	2	37	15	0	1649	1612	NL
NO	0	0	0	3	51	8	0	0	1	8	8	0	0	0	0	0	2	0	5	2	0	0	6	0	0	9	14	0	117	53	NO
PL	1	2	0	10	2	978	0	30	25	48	6	3	25	0	0	5	80	0	2	13	1	2	8	1	1	12	5	2	1555	1342	PL
PT	0	0	0	1	0	2	347	0	0	0	0	0	0	0	0	0	0	0	81	0	0	13	1	0	13	18	18	1	526	525	PT
RO	2	5	0	2	0	54	0	644	59	49	1	1	9	0	0	29	158	0	1	1	8	4	1	3	1	8	1	3	1203	847	RO
RS	21	49	0	2	0	58	0	110	694	25	1	3	15	0	0	29	68	0	1	1	3	7	2	4	4	9	1	7	1444	443	RS
RU	0	0	0	0	0	6	0	1	1	269	1	0	0	0	1	2	21	1	1	1	0	0	0	9	0	10	5	0	371	21	RU
SE	0	0	0	6	11	32	0	2	2	18	75	0	1	0	0	1	5	0	3	12	0	0	7	0	0	8	8	0	244	200	SE
SI	1	2	0	4	0	75	0	16	85	9	1	664	13	0	0	5	19	0	1	1	0	22	2	1	4	8	2	4	1570	1397	SI
SK	2	4	0	4	1	270	0	81	65	22	1	7	313	0	0	8	76	0	1	1	1	4	3	1	2	8	2	3	1257	1045	SK
TJ	0	0	0	0	0	0	0	0	0	4	0	0	0	172	22	5	1	128	0	0	0	0	0	90	0	9	0	2	374	1	TJ
TM	0	0	0	0	0	1	0	0	0	35	0	0	0	7	124	10	9	82	0	0	0	0	0	178	1	14	0	1	380	5	TM
TR	0	1	0	0	0	4	0	7	7	25	0	0	0	0	1	1153	26	0	0	0	12	26	0	165	13	12	2	12	1277	36	TR
UA	1	1	0	2	1	69	0	46	9	179	2	1	4	0	1	24	618	1	1	2	6	2	1	5	1	9	2	1	1094	182	UA
UZ	0	0	0	0	0	1	0	0	0	48	0	0	0	32	39	5	10	346	0	0	0	0	0	80	1	15	0	1	656	5	UZ
ATL	0	0	0	2	1	2	4	0	0	4	0	0	0	0	0	0	0	0	26	0	0	2	3	0	4	17	32	0	54	46	ATL
BAS	0	0	0	14	5	128	0	7	5	53	40	0	3	0	0	2	19	0	3	36	0	1	13	1	0	10	10	0	555	451	BAS
BLS	0	1	0	1	0	17	0	34	13	154	1	0	1	0	2	226	195	1	0	0	63	6	0	11	3	9	1	3	759	94	BLS
MED	3	4	0	1	0	10	2	5	18	13	0	2	1	0	0	202	18	0	7	0	4	232	1	46	77	13	22	88	491	211	MED
NOS	0	0	0	51	12	26	1	1	1	5	6	0	1	0	0	0	3	0	14	7	0	1	53	0	1	15	24	0	494	467	NOS
AST	0	0	0	0	0	1	0	0	0	10	0	0	0	2	12	65	3	8	0	0	0	5	0	884	7	19	1	4	151	5	AST
NOA	1	1	0	0	0	2	4	1	3	2	0	0	0	0	0	28	3	0	15	0	0	61	0	12	265	24	10	28	102	59	NOA
EXC	1	2	0	5	2	35	3	15	10	139	3	2	3	3	6	56	41	17	3	2	1	6	4	33	2	11	4	2	580	207	EXC
EU	1	2	0	18	2	117	11	47	21	23	10	7	10	0	0	12	28	0	11	5	1	17	15	2	6	12	8	5	883	766	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.14.1: 2018 country-to-country blame matrices for **fine EC**
using official gridded EMEP EC emissions calculated with the *Local Fractions* method.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	556	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	AL
AM	0	265	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	329	0	0	0	0	0	1	0	11	10	0	0	0	0	0	0	0	0	5	12	0	0	4	0	0	0	0	0	0	AT
AZ	0	12	0	507	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	0	AZ
BA	0	0	1	0	775	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	3	0	0	0	0	0	0	0	0	0	BA
BE	0	0	0	0	0	380	0	0	0	0	0	19	0	0	0	0	61	4	0	0	0	0	0	0	0	0	0	0	7	0	0	BE
BG	0	0	0	0	0	0	281	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	1	BG
BY	0	0	0	0	0	0	0	221	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	2	1	BY
CH	0	0	7	0	0	0	0	0	205	0	0	18	0	0	0	0	22	0	0	0	0	0	0	0	16	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	141	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CY
CZ	0	0	16	0	0	0	0	0	0	0	330	12	0	0	0	0	1	0	0	0	1	8	0	0	0	0	0	0	0	0	0	CZ
DE	0	0	9	0	0	3	0	0	2	0	10	239	1	0	0	0	8	1	0	0	0	0	0	0	0	0	0	0	1	0	0	DE
DK	0	0	0	0	0	0	0	0	0	0	0	11	195	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	3	0	0	0	0	0	158	0	4	0	0	0	0	0	0	0	0	0	0	0	2	0	22	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	289	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	76	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	0	0	0	3	0	0	2	0	0	4	0	0	1	0	269	1	0	0	0	0	0	0	1	0	0	0	1	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	254	0	0	0	0	2	0	0	0	0	0	0	0	0	GB
GE	0	10	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	470	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	6	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	GR
HR	0	0	5	0	122	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	432	23	0	0	2	0	0	0	0	0	0	HR
HU	0	0	13	0	8	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	26	469	0	0	0	0	0	0	0	0	0	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	0	91	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	IS
IT	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	474	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	73	5	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	79	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	29	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	142	0	17	0	LT
LU	0	0	0	0	0	44	0	0	0	0	1	58	0	0	0	0	64	1	0	0	0	0	0	0	0	0	0	0	252	0	0	LU
LV	0	0	0	0	0	0	0	12	0	0	0	0	0	7	0	1	0	0	0	0	0	0	0	0	0	0	0	17	0	181	0	LV
MD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	539	MD
ME	30	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	ME
MK	26	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	MT
NL	0	0	0	0	0	56	0	0	0	0	0	47	0	0	0	0	11	6	0	0	0	0	0	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	0	0	0	0	0	5	0	0	9	3	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	13	RO
RS	5	0	0	0	34	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	10	13	0	0	0	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	49	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	83	10	0	0	16	0	0	0	0	0	0	SI
SK	0	0	6	0	1	0	0	0	0	0	14	1	0	0	0	0	0	0	0	0	2	69	0	0	0	0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	TJ
TM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	TM
TR	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	TR
UA	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	13	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	11	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	0	0	1	0	0	0	4	10	6	0	12	0	0	0	0	0	0	0	0	0	0	0	3	0	8	0	BAS
BLS	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	3	BLS
MED	2	0	0	0	1	0	0	0	0	1	0	0	0	0	9	0	3	0	0	8	2	0	0	0	13	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	0	4	4	0	0	0	8	24	0	0	0	0	0	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NOA
EXC	1	1	2	3	3	1	2	3	1	0	2	5	1	1	8	2	8	4	2	2	2	3	0	0	8	1	13	1	0	1	2	EXC
EU	0	0	8	0	2	4	8	1	1	0	8	21	2	2	34	6	35	15	0	6	7	12	2	0	33	0	0	2	0	3	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.14.1 Cont.: 2018 country-to-country blame matrices for **fine EC using official gridded EMEP EC emissions** calculated with the *Local Fractions* method.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	18	10	0	0	0	0	0	0	27	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	621	9	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	1	0	0	0	0	328	0	AM
AT	0	0	0	0	0	2	0	0	0	0	0	16	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	395	393	AT
AZ	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	542	0	AZ
BA	8	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	845	46	BA
BE	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	498	498	BE
BG	0	2	0	0	0	0	0	31	8	0	0	0	0	0	0	6	1	0	0	0	4	1	0	0	0	0	0	0	336	318	BG
BY	0	0	0	0	0	7	0	1	0	3	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	255	14	BY
CH	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	269	63	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	53	0	3	0	0	0	0	151	141	CY
CZ	0	0	0	0	0	27	0	0	0	0	0	1	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	408	407	CZ
DE	0	0	0	5	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	0	0	0	287	285	DE
DK	0	0	0	1	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	28	0	0	12	0	0	0	0	0	214	213	DK
EE	0	0	0	0	0	1	0	0	0	6	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	197	188	EE
ES	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	3	0	0	9	0	0	0	0	0	0	296	296	ES
FI	0	0	0	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	83	79	FI
FR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	3	0	0	0	0	0	283	281	FR
GB	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	12	0	0	0	0	0	261	261	GB
GE	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	504	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	6	0	0	0	0	0	31	0	0	0	0	0	0	229	213	GR
HR	2	0	0	0	0	0	0	1	17	0	0	27	1	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	634	493	HR
HU	0	0	0	0	0	4	0	32	17	0	0	6	21	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	604	574	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	1	0	0	0	0	0	106	106	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	8	0	IS
IT	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	484	482	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	9	0	0	0	0	0	6	0	0	0	0	88	0	KG
KZ	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	85	0	KZ
LT	0	0	0	0	0	16	0	0	0	4	0	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	212	177	LT
LU	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	423	423	LU
LV	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	224	209	LV
MD	0	0	0	0	0	1	0	54	0	0	0	0	0	0	0	0	52	0	0	0	1	0	0	0	0	0	0	0	646	55	MD
ME	395	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	473	3	ME
MK	0	241	0	0	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	344	33	MK
MT	0	0	203	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	398	0	0	2	0	0	0	208	208	MT
NL	0	0	0	278	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	0	0	0	0	0	399	399	NL
NO	0	0	0	0	33	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	35	2	NO
PL	0	0	0	0	0	322	0	1	0	1	0	0	6	0	0	0	8	0	0	2	0	0	0	0	0	0	0	0	361	346	PL
PT	0	0	0	0	0	0	295	0	0	0	0	0	0	0	0	0	0	0	16	0	0	1	0	0	0	0	0	0	326	326	PT
RO	0	0	0	0	0	0	0	452	6	0	0	0	0	0	0	0	8	0	0	0	2	0	0	0	0	0	0	0	491	464	RO
RS	11	7	0	0	0	0	0	21	431	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	556	68	RS
RU	0	0	0	0	0	0	0	0	0	52	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	59	1	RU
SE	0	0	0	0	3	1	0	0	0	0	42	0	0	0	0	0	0	0	0	7	0	0	1	0	0	0	0	0	51	48	SE
SI	0	0	0	0	0	0	0	0	0	0	0	554	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	717	715	SI
SK	0	0	0	0	0	27	0	6	2	0	0	1	261	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	399	388	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	81	0	0	0	14	0	0	0	0	0	37	0	0	0	0	99	0	TJ
TM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	0	0	11	0	0	0	0	0	5	0	0	0	0	131	0	TM
TR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	298	0	0	0	0	1	6	0	3	0	0	0	0	301	1	TR
UA	0	0	0	0	0	3	0	9	0	4	0	0	0	0	0	0	262	0	0	0	2	0	0	0	0	0	0	0	297	14	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	130	0	0	0	0	0	1	0	0	0	0	157	0	UZ
ATL	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	0	0	0	0	0	0	6	5	ATL
BAS	0	0	0	0	0	15	0	0	0	7	11	0	0	0	0	0	0	0	0	85	0	0	1	0	0	0	0	0	77	69	BAS
BLS	0	0	0	0	0	0	0	7	0	8	0	0	0	0	0	33	28	0	0	0	109	1	0	0	0	0	0	0	98	9	BLS
MED	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	1	0	0	205	0	3	13	0	0	0	47	36	MED
NOS	0	0	0	5	7	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	90	0	0	0	0	0	55	48	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	443	0	0	0	0	8	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	6	0	0	107	0	0	0	1	1	NOA
EXC	0	0	0	1	1	6	2	7	2	21	1	1	1	1	3	13	10	4	0	0	0	1	1	1	0	0	0	0	153	69	EXC
EU	0	0	0	3	0	25	7	26	1	1	4	4	4	0	0	0	1	0	1	2	0	4	2	0	0	0	0	0	291	283	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.14.2: 2018 country-to-country blame matrices for **fine EC**
calculated with the *Local Fractions* method.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	397	0	2	0	5	0	5	0	0	0	1	2	0	0	1	0	1	0	0	17	1	2	0	0	8	0	0	0	0	0	0	AL
AM	0	130	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	416	0	3	1	1	1	5	0	23	31	0	0	0	0	8	1	0	0	6	11	0	0	16	0	0	0	0	0	0	AT
AZ	0	12	0	416	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	2	0	0	0	0	AZ
BA	3	0	8	0	363	0	3	1	0	0	5	5	0	0	0	0	2	0	0	1	22	10	0	0	8	0	0	0	0	0	0	BA
BE	0	0	3	0	0	315	0	0	1	0	5	66	1	0	1	0	145	18	0	0	0	0	1	0	1	0	0	0	3	0	0	BE
BG	1	0	2	1	3	0	268	2	0	0	2	2	0	0	0	0	1	0	1	8	1	3	0	0	2	0	0	0	0	0	2	BG
BY	0	0	1	0	0	0	1	141	0	0	2	3	1	1	0	1	1	1	0	0	0	1	0	0	1	0	1	9	0	5	1	BY
CH	0	0	23	0	0	1	0	0	258	0	3	46	0	0	1	0	56	1	0	0	0	0	0	0	29	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	73	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	34	0	3	2	1	2	2	0	310	42	1	0	0	0	12	2	0	0	3	12	0	0	4	0	0	1	0	0	0	CZ
DE	0	0	25	0	1	8	0	1	6	0	20	277	3	0	1	0	37	6	0	0	1	2	0	0	3	0	0	1	1	1	0	DE
DK	0	0	2	0	0	3	0	1	0	0	4	34	190	0	0	1	9	10	0	0	0	1	1	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	0	0	8	0	0	1	3	1	102	0	11	1	1	0	0	0	0	0	0	0	0	0	7	0	21	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	2	0	0	169	0	11	1	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	1	1	2	0	79	1	1	0	0	0	0	0	0	0	0	0	1	0	2	0	FI
FR	0	0	3	0	0	7	0	0	6	0	3	22	0	0	5	0	356	6	0	0	0	0	0	0	6	0	0	0	1	0	0	FR
GB	0	0	1	0	0	2	0	0	0	0	1	7	1	0	1	0	18	185	0	0	0	0	4	0	0	0	0	0	0	0	0	GB
GE	0	8	0	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	245	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	9	0	1	0	2	0	16	1	0	0	1	1	0	0	1	0	1	0	1	136	1	1	0	0	5	0	0	0	0	0	0	GR
HR	2	0	24	0	76	0	3	1	1	0	10	8	0	0	1	0	4	1	0	1	145	23	0	0	19	0	0	0	0	0	0	HR
HU	1	0	31	0	13	1	5	2	1	0	16	11	0	0	0	0	4	1	0	1	13	231	0	0	7	0	0	0	0	0	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	3	0	0	1	0	5	16	0	0	0	0	66	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	0	0	0	0	0	0	0	IS
IT	1	0	11	0	3	0	0	0	4	0	2	4	0	0	3	0	13	0	0	1	4	2	0	0	516	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	7	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	49	0	0	0	0	KZ
LT	0	0	1	0	0	0	0	27	0	0	3	6	2	2	0	2	2	2	0	0	0	1	0	0	1	0	0	154	0	22	1	LT
LU	0	0	6	0	0	40	0	0	2	0	7	118	1	0	1	0	159	8	0	0	0	1	0	0	2	0	0	0	72	0	0	LU
LV	0	0	1	0	0	0	0	17	0	0	2	4	2	8	0	4	2	2	0	0	0	1	0	0	0	0	0	26	0	137	0	LV
MD	0	0	1	1	1	0	6	5	0	0	2	2	0	0	0	0	1	0	0	1	0	2	0	0	1	0	1	1	0	1	133	MD
ME	30	0	2	0	22	0	3	0	0	0	2	2	0	0	0	0	1	0	0	3	3	3	0	0	6	0	0	0	0	0	0	ME
MK	26	0	2	0	4	0	21	1	0	0	2	2	0	0	0	0	1	0	0	29	1	3	0	0	3	0	0	0	0	0	0	MK
MT	2	0	2	0	2	0	1	0	0	0	1	1	0	0	6	0	9	0	0	1	1	0	0	0	35	0	0	0	0	0	0	MT
NL	0	0	3	0	0	61	0	1	1	0	5	102	2	0	1	0	53	22	0	0	0	1	1	0	1	0	0	1	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	5	0	2	1	1	9	0	0	20	19	2	1	0	1	5	2	0	0	1	6	0	0	2	0	0	4	0	2	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	41	0	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	1	0	3	0	3	0	18	2	0	0	3	3	0	0	0	0	1	0	1	1	1	9	0	0	2	0	0	0	0	0	6	RO
RS	8	0	6	0	26	0	21	1	0	0	5	5	0	0	0	0	2	0	0	5	6	17	0	0	4	0	0	0	0	0	1	RS
RU	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	1	3	4	1	0	4	1	2	0	0	0	0	0	0	0	0	0	1	0	1	0	SE
SI	1	0	105	0	9	0	1	1	1	0	10	10	0	0	1	0	5	1	0	0	48	14	0	0	44	0	0	0	0	0	0	SI
SK	1	0	17	0	5	1	3	2	1	0	29	11	1	0	0	0	4	1	0	1	3	48	0	0	4	0	0	1	0	0	1	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	TJ
TM	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	TM
TR	0	2	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	TR
UA	0	0	1	1	1	0	2	9	0	0	1	2	0	0	0	1	1	0	0	0	0	2	0	0	1	0	1	1	0	1	5	UA
UZ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	15	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	1	0	3	0	0	3	12	12	5	0	14	3	4	0	0	0	1	0	0	0	0	0	5	0	7	0	BAS
BLS	0	1	1	3	1	0	6	2	0	0	1	1	0	0	0	0	0	0	15	1	0	1	0	0	0	0	1	0	0	0	2	BLS
MED	3	0	2	0	2	0	2	0	0	0	1	2	0	0	14	0	14	0	0	8	2	1	0	0	27	0	0	0	0	0	0	MED
NOS	0	0	1	0	0	4	0	0	0	0	1	13	5	0	1	0	20	26	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	3	0	0	1	0	0	0	0	3	0	0	0	0	0	0	NOA
EXC	1	0	4	3	2	1	2	3	1	0	3	8	1	1	5	2	13	3	1	1	1	2	0	0	9	1	10	1	0	1	1	EXC
EU	1	0	14	0	2	5	9	2	2	0	11	32	3	2	21	7	54	13	0	5	3	8	1	0	38	0	0	3	0	3	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.14.2: 2018 country-to-country blame matrices for **fine EC** calculated with the *Local Fractions* method.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	14	24	0	0	0	5	0	3	45	2	0	0	1	0	0	3	5	0	0	0	0	4	0	0	1	0	0	0	547	50	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	43	0	0	0	0	0	0	0	12	0	0	0	0	246	1	AM
AT	0	0	0	1	0	39	0	3	3	2	0	22	8	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	607	588	AT
AZ	0	0	0	0	0	0	0	0	0	15	0	0	0	0	2	12	1	1	0	0	0	0	0	15	0	0	0	0	493	1	AZ
BA	8	1	0	0	0	17	0	8	26	2	0	2	3	0	0	2	7	0	0	0	0	1	0	0	0	0	0	0	511	97	BA
BE	0	0	0	36	0	19	0	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	17	0	0	0	0	0	620	616	BE
BG	0	5	0	0	0	8	0	43	13	12	0	0	1	0	0	11	29	0	0	0	1	1	0	0	0	0	0	0	422	343	BG
BY	0	0	0	0	0	53	0	7	1	40	1	0	1	0	0	1	56	0	0	1	0	0	0	0	0	0	0	0	333	90	BY
CH	0	0	0	0	0	7	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	428	169	CH
CY	0	0	0	0	0	1	0	1	0	3	0	0	0	0	0	84	4	0	0	0	0	16	0	9	2	0	0	0	177	83	CY
CZ	0	0	0	1	0	175	0	6	5	4	0	4	14	0	0	1	9	0	0	1	0	0	1	0	0	0	0	0	653	626	CZ
DE	0	0	0	9	0	69	0	1	1	3	1	1	2	0	0	0	3	0	0	2	0	0	5	0	0	0	0	0	483	468	DE
DK	0	0	0	5	3	41	0	1	0	3	8	0	1	0	0	0	3	0	0	14	0	0	10	0	0	0	0	0	326	315	DK
EE	0	0	0	0	1	22	0	2	0	38	3	0	0	0	0	0	10	0	0	6	0	0	1	0	0	0	0	0	235	177	EE
ES	0	0	0	0	0	1	12	0	0	0	0	0	0	0	0	0	0	0	3	0	0	5	0	0	2	0	0	0	200	199	ES
FI	0	0	0	0	1	6	0	0	0	17	4	0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	120	98	FI
FR	0	0	0	3	0	9	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	5	0	0	0	0	0	431	423	FR
GB	0	0	0	2	0	7	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	9	0	0	0	0	0	231	230	GB
GE	0	0	0	0	0	1	0	0	0	8	0	0	0	0	0	21	2	0	0	0	0	0	0	3	0	0	0	0	322	2	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	1	9	0	0	0	4	0	4	6	6	0	0	0	0	0	19	11	0	0	0	1	10	0	0	2	0	0	0	237	172	GR
HR	2	1	0	0	0	29	0	10	25	3	0	26	5	0	0	1	8	0	0	0	0	3	0	0	0	0	0	0	431	311	HR
HU	1	1	0	1	0	74	0	60	26	5	0	8	30	0	0	1	29	0	0	0	0	1	0	0	0	0	0	0	577	496	HU
IE	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	0	0	0	97	96	IE
IS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3	IS
IT	0	0	0	0	0	7	0	1	2	1	0	8	1	0	0	1	2	0	0	0	0	10	0	0	2	0	0	0	587	574	IT
KG	0	0	0	0	0	0	0	0	0	1	0	0	0	8	0	0	0	35	0	0	0	0	0	12	0	0	0	0	103	0	KG
KZ	0	0	0	0	0	0	0	0	0	22	0	0	0	0	1	0	2	6	0	0	0	0	0	15	0	0	0	0	84	1	KZ
LT	0	0	0	1	1	91	0	4	1	27	2	0	1	0	0	0	23	0	0	3	0	0	1	0	0	0	0	0	379	298	LT
LU	0	0	0	7	0	20	0	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	4	0	0	0	0	0	450	444	LU
LV	0	0	0	1	1	42	0	3	0	28	3	0	1	0	0	0	16	0	0	4	0	0	1	0	0	0	0	0	300	237	LV
MD	0	0	0	0	0	28	0	82	2	24	0	0	1	0	0	5	163	0	0	0	1	0	0	0	0	0	0	0	467	132	MD
ME	214	3	0	0	0	6	0	4	35	2	0	1	1	0	0	2	5	0	0	0	0	2	0	0	1	0	0	0	353	39	ME
MK	1	259	0	0	0	6	0	6	51	4	0	0	1	0	0	5	8	0	0	0	0	1	0	0	0	0	0	0	437	78	MK
MT	0	0	106	0	0	3	1	0	1	0	0	1	0	0	0	1	1	0	0	0	0	110	0	0	16	0	0	0	176	168	MT
NL	0	0	0	251	0	32	0	0	0	2	1	0	1	0	0	0	2	0	1	1	0	0	28	0	0	0	0	0	543	537	NL
NO	0	0	0	0	34	3	0	0	0	2	3	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	50	13	NO
PL	0	0	0	1	0	920	0	10	2	14	1	1	8	0	0	1	31	0	0	3	0	0	1	0	0	0	0	0	1075	1014	PL
PT	0	0	0	0	0	1	234	0	0	0	0	0	0	0	0	0	0	0	10	0	0	2	0	0	1	0	0	0	285	284	PT
RO	0	1	0	0	0	21	0	392	9	11	0	1	3	0	0	3	48	0	0	0	1	0	0	0	0	0	0	0	547	460	RO
RS	9	16	0	0	0	22	0	41	304	5	0	1	4	0	0	3	15	0	0	0	0	1	0	0	0	0	0	0	531	141	RS
RU	0	0	0	0	0	2	0	0	0	89	0	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	110	6	RU
SE	0	0	0	1	5	15	0	1	0	4	35	0	0	0	0	0	1	0	0	4	0	0	1	0	0	0	0	0	84	72	SE
SI	0	0	0	0	0	29	0	5	6	2	0	427	4	0	0	1	6	0	0	0	0	2	0	0	0	0	0	0	732	705	SI
SK	0	1	0	1	0	162	0	26	8	5	0	3	188	0	0	1	30	0	0	0	0	0	1	0	0	0	0	0	560	505	SK
TJ	0	0	0	0	0	0	0	0	0	1	0	0	0	78	3	0	0	36	0	0	0	0	0	20	0	0	0	0	124	0	TJ
TM	0	0	0	0	0	0	0	0	0	6	0	0	0	2	40	1	1	32	0	0	0	0	0	11	0	0	0	0	92	1	TM
TR	0	0	0	0	0	1	0	2	0	5	0	0	0	0	0	308	5	0	0	0	1	3	0	6	1	0	0	0	333	8	TR
UA	0	0	0	0	0	33	0	19	1	47	0	0	1	0	0	3	316	0	0	0	1	0	0	0	0	0	0	0	453	68	UA
UZ	0	0	0	0	0	0	0	0	0	8	0	0	0	13	10	1	1	162	0	0	0	0	0	6	0	0	0	0	220	1	UZ
ATL	0	0	0	0	1	1	2	0	0	1	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	0	0	0	13	11	ATL
BAS	0	0	0	1	2	64	0	2	1	18	14	0	1	0	0	0	6	0	0	28	0	0	2	0	0	0	0	0	181	150	BAS
BLS	0	0	0	0	0	7	0	13	1	43	0	0	0	0	0	47	58	0	0	0	12	1	0	0	0	0	0	0	206	33	BLS
MED	1	1	0	0	0	3	1	1	2	2	0	1	0	0	0	23	4	0	1	0	0	38	0	3	13	0	0	0	119	80	MED
NOS	0	0	0	6	7	10	0	0	0	1	2	0	0	0	0	0	1	0	2	1	0	0	33	0	0	0	0	0	101	92	NOS
AST	0	0	0	0	0	0	0	0	0	2	0	0	0	1	2	7	1	2	0	0	0	0	0	274	0	0	0	0	20	1	AST
NOA	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	2	1	0	1	0	0	6	0	1	47	0	0	0	21	17	NOA
EXC	0	1	0	1	1	24	2	7	2	42	1	1	1	1	2	14	16	6	0	0	0	1	1	4	0	0	0	0	204	96	EXC
EU	0	1	0	4	1	88	6	26	3	6	4	4	4	0	0	1	9	0	1	1	0	2	2	0	1	0	0	0	396	368	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.15: 2018 country-to-country blame matrices for **coarse EC**.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	13	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	AL
AM	0	9	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	14	0	0	0	0	0	1	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AT
AZ	0	0	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	AZ
BA	0	0	0	0	43	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	BA
BE	0	0	0	0	0	18	0	0	0	0	1	16	0	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	BE
BG	0	0	0	0	0	0	23	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	BG
BY	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BY
CH	0	0	1	0	0	0	0	0	171	0	0	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CY
CZ	0	0	1	0	1	0	0	0	0	0	33	6	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	CZ
DE	0	0	1	0	0	0	0	0	2	0	4	45	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DE
DK	0	0	0	0	0	0	0	0	0	0	1	5	5	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	0	0	0	0	0	0	2	0	0	3	0	0	1	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	FR
GB	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	14	0	0	0	0	1	0	0	0	0	0	0	0	0	GB
GE	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	0	GR
HR	0	0	1	0	7	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	12	1	0	0	0	0	0	0	0	0	0	HR
HU	0	0	1	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	12	0	0	0	0	0	0	0	0	0	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	8	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	IS
IT	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	LT
LU	0	0	0	0	0	3	0	0	1	0	1	18	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	7	0	0	LU
LV	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	LV
MD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	MD
ME	1	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ME
MK	0	0	0	0	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	MT
NL	0	0	0	0	0	3	0	0	0	0	1	23	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RO
RS	0	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	3	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	4	1	0	0	1	0	0	0	0	0	0	SI
SK	0	0	1	0	1	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	TJ
TM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	TM
TR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	TR
UA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BAS
BLS	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	BLS
MED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NOA
EXC	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	EXC
EU	0	0	0	0	0	0	1	0	1	0	1	5	0	0	4	0	2	1	0	1	0	0	0	0	1	0	0	0	0	0	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.15 Cont.: 2018 country-to-country blame matrices for **coarse EC**.
Units: 0.1 ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	1	3	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	5	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	16	0	AM
AT	0	0	0	0	0	8	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	29	AT
AZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	26	0	AZ
BA	1	0	0	0	0	3	0	1	3	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	56	7	BA
BE	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44	43	BE
BG	0	0	0	0	0	1	0	4	2	2	0	0	0	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	40	29	BG
BY	0	0	0	0	0	4	0	0	0	5	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	26	6	BY
CH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	9	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	1	1	0	0	0	35	5	CY
CZ	0	0	0	0	0	38	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	85	82	CZ
DE	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	61	58	DE
DK	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	17	DK
EE	0	0	0	0	0	2	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	16	9	EE
ES	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	31	31	ES
FI	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	FI
FR	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	18	FR
GB	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	17	GB
GE	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	65	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	1	0	0	0	0	0	0	1	1	0	0	0	0	0	6	2	0	0	0	0	0	0	0	1	0	0	0	36	24	GR
HR	0	0	0	0	0	5	0	1	5	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	37	23	HR
HU	0	0	0	0	0	10	0	5	6	1	0	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	46	34	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	11	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	IS
IT	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	17	15	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	2	0	0	0	0	9	0	KG
KZ	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	22	0	KZ
LT	0	0	0	0	0	7	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	25	18	LT
LU	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	37	LU
LV	0	0	0	0	0	3	0	0	0	4	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	16	10	LV
MD	0	0	0	0	0	2	0	3	0	4	0	0	0	0	0	1	19	0	0	0	0	0	0	0	0	0	0	0	36	7	MD
ME	14	1	0	0	0	1	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	25	3	ME
MK	0	29	0	0	0	1	0	1	2	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	46	10	MK
MT	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	21	20	MT
NL	0	0	0	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	37	NL
NO	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	NO
PL	0	0	0	0	0	94	0	1	0	2	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	109	102	PL
PT	0	0	0	0	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	31	PT
RO	0	0	0	0	0	2	0	23	1	2	0	0	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	37	27	RO
RS	1	2	0	0	0	3	0	6	36	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	60	14	RS
RU	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	18	1	RU
SE	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	6	SE
SI	0	0	0	0	0	5	0	1	1	0	0	10	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	29	26	SI
SK	0	0	0	0	0	28	0	2	1	1	0	0	7	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	51	45	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	3	0	0	0	0	0	3	0	0	0	0	10	0	TJ
TM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	2	0	0	0	0	0	1	0	0	0	0	10	0	TM
TR	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	57	1	0	0	0	0	0	0	1	0	0	0	0	59	1	TR
UA	0	0	0	0	0	3	0	1	0	8	0	0	0	0	0	1	45	0	0	0	0	0	0	0	0	0	0	0	60	5	UA
UZ	0	0	0	0	0	0	0	0	0	2	0	0	0	1	1	0	0	13	0	0	0	0	0	1	0	0	0	0	22	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	ATL
BAS	0	0	0	0	0	5	0	0	0	3	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	15	12	BAS
BLS	0	0	0	0	0	1	0	1	0	8	0	0	0	0	0	7	9	0	0	0	0	0	0	0	0	0	0	0	30	2	BLS
MED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	1	0	0	0	0	0	0	1	14	0	0	0	17	5	MED
NOS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	91	0	0	0	0	3	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	31	0	0	0	2	1	NOA
EXC	0	0	0	0	0	3	0	0	0	7	0	0	0	0	0	3	2	0	0	0	0	0	0	1	0	0	0	0	25	8	EXC
EU	0	0	0	0	0	9	1	2	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	33	30	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.16.1: 2018 country-to-country blame matrices for **PPM2.5 using EMEP PPM emissions** calculated with the *Local Fractions* method.
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	213	0	0	0	5	0	5	0	0	0	1	1	0	0	0	0	0	0	0	10	2	2	0	0	5	0	0	0	0	0	0	AL
AM	0	118	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	67	0	4	0	1	1	1	0	11	13	0	0	0	0	2	1	0	0	8	9	0	0	9	0	0	0	0	0	0	AT
AZ	0	9	0	168	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	2	0	2	0	439	0	2	1	0	0	3	2	0	0	0	0	1	0	0	1	30	9	0	0	5	0	0	0	0	0	0	BA
BE	0	0	1	0	0	196	0	0	1	0	3	29	0	0	1	0	40	13	0	0	0	0	0	0	1	0	0	0	3	0	0	BE
BG	1	0	0	0	3	0	166	1	0	0	1	1	0	0	0	0	0	0	1	5	1	2	0	0	1	0	0	0	0	0	2	BG
BY	0	0	0	0	1	0	0	90	0	0	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	2	0	3	2	BY
CH	0	0	4	0	0	0	0	0	76	0	2	20	0	0	0	0	17	1	0	0	0	0	0	0	17	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	22	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	7	0	4	1	1	1	0	0	178	18	0	0	0	0	4	1	0	0	5	11	0	0	2	0	0	0	0	0	0	CZ
DE	0	0	4	0	1	5	0	1	2	0	12	108	1	0	0	0	11	5	0	0	1	2	0	0	2	0	0	0	1	0	0	DE
DK	0	0	0	0	0	2	0	1	0	0	2	13	86	0	0	0	3	7	0	0	0	1	0	0	0	0	0	0	0	1	0	DK
EE	0	0	0	0	0	0	0	6	0	0	0	1	1	29	0	4	0	1	0	0	0	0	0	0	0	0	0	1	0	13	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	96	0	4	1	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	4	0	0	2	0	2	10	0	0	3	0	111	5	0	0	0	0	0	0	4	0	0	0	1	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	1	3	0	0	1	0	6	125	0	0	0	0	3	0	0	0	0	0	0	0	0	GB
GE	0	10	0	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	166	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	4	0	0	0	2	0	6	0	0	0	0	1	0	0	0	0	0	0	0	90	1	1	0	0	3	0	0	0	0	0	1	GR
HR	1	0	5	0	91	0	2	1	0	0	5	4	0	0	0	0	1	0	0	1	214	22	0	0	13	0	0	0	0	0	0	HR
HU	1	0	6	0	16	0	4	1	0	0	8	5	0	0	0	0	1	1	0	1	21	218	0	0	5	0	0	0	0	0	1	HU
IE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	13	0	0	0	0	42	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	IS
IT	0	0	2	0	3	0	0	0	1	0	1	2	0	0	2	0	5	0	0	0	4	2	0	0	308	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	6	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	33	0	0	0	0	KZ
LT	0	0	0	0	1	0	0	25	0	0	1	2	1	1	0	1	1	1	0	0	0	1	0	0	0	0	0	27	0	13	1	LT
LU	0	0	1	0	0	23	0	0	1	0	4	49	0	0	1	0	42	6	0	0	0	0	0	0	1	0	0	0	74	0	0	LU
LV	0	0	0	0	0	0	0	13	0	0	1	2	1	3	0	1	0	1	0	0	0	1	0	0	0	0	0	6	0	82	1	LV
MD	0	0	0	0	1	0	3	4	0	0	1	1	0	0	0	0	0	0	0	1	1	2	0	0	1	0	0	0	0	0	201	MD
ME	19	0	0	0	24	0	4	0	0	0	1	1	0	0	0	0	0	0	0	2	3	2	0	0	4	0	0	0	0	0	0	ME
MK	15	0	0	0	4	0	17	0	0	0	1	1	0	0	0	0	0	0	0	19	1	2	0	0	2	0	0	0	0	0	1	MK
MT	1	0	0	0	2	0	0	0	0	0	0	1	0	0	3	0	3	0	0	1	1	0	0	0	18	0	0	0	0	0	0	MT
NL	0	0	1	0	0	43	0	1	0	0	3	41	1	0	1	0	16	16	0	0	0	0	1	0	1	0	0	0	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	2	1	1	8	0	0	11	8	1	0	0	0	2	2	0	0	2	5	0	0	1	0	0	1	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	1	0	1	0	3	0	7	2	0	0	1	1	0	0	0	0	0	0	0	1	1	9	0	0	1	0	0	0	0	0	9	RO
RS	5	0	1	0	31	0	29	1	0	0	3	2	0	0	0	0	1	0	0	3	10	15	0	0	2	0	0	0	0	0	1	RS
RU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	SE
SI	0	0	18	0	10	0	1	1	0	0	5	5	0	0	0	0	1	0	0	0	63	12	0	0	27	0	0	0	0	0	0	SI
SK	0	0	3	0	6	0	2	1	0	0	14	5	0	0	0	0	1	1	0	1	5	45	0	0	3	0	0	0	0	0	1	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	TJ
TM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	TM
TR	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	TR
UA	0	0	0	0	1	0	1	6	0	0	1	1	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1	0	0	1	7	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	0	0	3	0	0	1	5	6	2	0	5	1	3	0	0	0	1	0	0	0	0	0	1	0	5	0	BAS
BLS	0	1	0	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	10	1	0	1	0	0	0	0	0	0	0	0	2	BLS
MED	2	0	0	0	2	0	1	0	0	0	0	1	0	0	7	0	5	0	0	5	2	1	0	0	16	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	3	0	0	0	0	1	5	2	0	0	0	6	19	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	0	0	1	1	2	1	1	2	0	0	2	3	0	0	3	1	4	2	1	1	1	2	0	0	6	1	7	0	0	1	1	EXC
EU	0	0	2	0	3	3	5	2	1	0	6	13	1	0	12	2	17	9	0	3	4	7	1	0	23	0	0	1	0	2	1	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.16.1 Cont.: 2018 country-to-country blame matrices for **PPM2.5 using EMEP PPM emissions** calculated with local fraction method.
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	13	15	0	0	0	1	0	2	26	1	0	0	0	0	0	3	4	0	0	0	0	3	0	0	1	0	0	0	312	31	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	29	0	0	0	0	0	0	0	10	0	0	0	0	179	0	AM
AT	0	0	0	0	0	9	0	2	2	1	0	11	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	159	147	AT
AZ	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	8	1	1	0	0	0	0	0	11	0	0	0	0	213	0	AZ
BA	7	1	0	0	0	4	0	6	21	1	0	1	1	0	0	1	5	0	0	0	0	1	0	0	0	0	0	0	548	70	BA
BE	0	0	0	14	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	7	0	0	0	0	0	309	307	BE
BG	0	2	0	0	0	2	0	27	9	5	0	0	1	0	0	10	22	0	0	0	1	1	0	0	0	0	0	0	265	209	BG
BY	0	0	0	0	0	12	0	5	0	13	0	0	1	0	0	1	27	0	0	0	0	0	0	0	0	0	0	0	165	30	BY
CH	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	142	64	CH
CY	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	75	4	0	0	0	0	13	0	13	2	0	0	0	110	27	CY
CZ	0	0	0	0	0	39	0	5	3	1	0	2	7	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	301	283	CZ
DE	0	0	0	3	0	15	0	1	1	1	0	1	1	0	0	0	2	0	0	1	0	0	2	0	0	0	0	0	180	173	DE
DK	0	0	0	2	2	9	0	1	0	1	3	0	0	0	0	0	1	0	0	6	0	0	4	0	0	0	0	0	139	133	DK
EE	0	0	0	0	1	5	0	1	0	11	2	0	0	0	0	0	5	0	0	3	0	0	0	0	0	0	0	0	85	61	EE
ES	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	1	0	0	0	112	112	ES
FI	0	0	0	0	1	1	0	0	0	5	2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	38	29	FI
FR	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	148	144	FR
GB	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	144	143	GB
GE	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	14	1	0	0	0	0	0	0	3	0	0	0	0	210	1	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	1	5	0	0	0	1	0	3	4	2	0	0	0	0	0	18	9	0	0	0	1	8	0	0	1	0	0	0	154	106	GR
HR	2	1	0	0	0	7	0	7	19	1	0	16	2	0	0	1	5	0	0	0	0	3	0	0	0	0	0	0	424	301	HR
HU	1	1	0	0	0	16	0	46	19	2	0	5	17	0	0	1	13	0	0	0	0	1	0	0	0	0	0	0	412	355	HU
IE	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	62	61	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	IS
IT	0	0	0	0	0	2	0	1	1	0	0	4	0	0	0	0	1	0	0	0	0	8	0	0	2	0	0	0	343	335	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	20	0	0	0	0	0	9	0	0	0	0	62	0	KG
KZ	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	1	3	0	0	0	0	0	8	0	0	0	0	51	0	KZ
LT	0	0	0	0	0	20	0	4	1	8	1	0	1	0	0	0	12	0	0	1	0	0	0	0	0	0	0	0	124	77	LT
LU	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	213	210	LU
LV	0	0	0	0	1	9	0	2	0	8	1	0	0	0	0	0	8	0	0	1	0	0	0	0	0	0	0	0	144	112	LV
MD	0	0	0	0	0	6	0	66	1	9	0	0	1	0	0	4	79	0	0	0	1	0	0	0	0	0	0	0	386	83	MD
ME	200	2	0	0	0	2	0	3	24	1	0	0	0	0	0	2	4	0	0	0	0	2	0	0	0	0	0	0	300	24	ME
MK	1	155	0	0	0	2	0	4	34	2	0	0	1	0	0	4	7	0	0	0	0	1	0	0	0	0	0	0	275	51	MK
MT	0	0	50	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	92	0	0	10	0	0	0	87	81	MT
NL	0	0	0	75	0	7	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	12	0	0	0	0	0	209	206	NL
NO	0	0	0	0	24	1	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	31	5	NO
PL	0	0	0	0	0	186	0	7	2	5	1	1	6	0	0	0	16	0	0	1	0	0	1	0	0	0	0	0	273	238	PL
PT	0	0	0	0	0	0	158	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	0	0	1	0	0	0	191	190	PT
RO	0	1	0	0	0	5	0	295	7	4	0	0	2	0	0	3	26	0	0	0	1	0	0	0	0	0	0	0	382	326	RO
RS	8	10	0	0	0	5	0	26	212	2	0	1	2	0	0	2	11	0	0	0	0	1	0	0	0	0	0	0	387	102	RS
RU	0	0	0	0	0	1	0	0	0	26	0	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	39	2	RU
SE	0	0	0	0	4	3	0	0	0	1	14	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	34	27	SE
SI	0	0	0	0	0	7	0	3	4	1	0	222	2	0	0	1	4	0	0	0	0	2	0	0	0	0	0	0	389	367	SI
SK	0	1	0	0	0	36	0	21	6	2	0	2	111	0	0	1	12	0	0	0	0	0	0	0	0	0	0	0	281	250	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	46	2	0	0	20	0	0	0	0	0	17	0	0	0	0	71	0	TJ
TM	0	0	0	0	0	0	0	0	0	2	0	0	0	1	22	1	1	15	0	0	0	0	0	9	0	0	0	0	48	0	TM
TR	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	232	5	0	0	0	1	2	0	8	1	0	0	0	248	4	TR
UA	0	0	0	0	0	7	0	16	1	16	0	0	1	0	0	3	193	0	0	0	1	0	0	0	0	0	0	0	259	31	UA
UZ	0	0	0	0	0	0	0	0	0	3	0	0	0	6	5	1	1	86	0	0	0	0	0	4	0	0	0	0	116	0	UZ
ATL	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	8	7	ATL
BAS	0	0	0	0	1	15	0	2	0	6	7	0	0	0	0	0	3	0	0	12	0	0	1	0	0	0	0	0	69	55	BAS
BLS	0	0	0	0	0	2	0	9	1	14	0	0	0	0	0	41	49	0	0	0	10	1	0	0	0	0	0	0	138	16	BLS
MED	1	0	0	0	0	1	1	1	1	1	0	1	0	0	0	22	3	0	1	0	0	32	0	4	9	0	0	0	76	42	MED
NOS	0	0	0	3	4	2	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	14	0	0	0	0	0	49	44	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	5	1	1	0	0	0	0	0	239	0	0	0	0	13	0	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	1	0	0	5	0	1	40	0	0	0	13	9	NOA
EXC	0	0	0	0	1	5	1	6	2	13	1	1	1	1	1	11	10	3	0	0	0	1	0	2	0	0	0	0	99	42	EXC
EU	0	0	0	1	1	18	4	19	2	2	2	2	3	0	0	1	5	0	1	1	0	2	1	0	0	0	0	0	179	162	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

Table C.16.2: 2018 country-to-country blame matrices for **PPM2.5**
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	190	0	1	0	4	0	3	0	0	0	1	1	0	0	0	0	1	0	0	10	1	1	0	0	4	0	0	0	0	0	0	AL
AM	0	71	0	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	371	0	2	0	0	1	2	0	16	18	0	0	0	0	4	0	0	0	4	8	0	0	10	0	0	0	0	0	0	AT
AZ	0	5	0	158	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	2	0	6	0	325	0	2	1	0	0	4	3	0	0	0	0	1	0	0	1	15	6	0	0	4	0	0	0	0	0	0	BA
BE	0	0	3	0	0	224	0	0	1	0	3	46	1	0	1	0	101	10	0	0	0	0	0	0	1	0	0	0	3	0	0	BE
BG	0	0	2	0	2	0	187	1	0	0	1	1	0	0	0	0	1	0	0	5	1	2	0	0	1	0	0	0	0	0	1	BG
BY	0	0	1	0	0	0	0	92	0	0	1	2	1	1	0	1	1	0	0	0	0	1	0	0	0	0	0	6	0	5	1	BY
CH	0	0	20	0	0	0	0	0	161	0	2	28	0	0	0	0	33	0	0	0	0	0	0	0	19	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	28	0	3	1	1	1	1	0	242	26	1	0	0	0	7	1	0	0	2	10	0	0	2	0	0	1	0	0	0	CZ
DE	0	0	22	0	0	5	0	1	4	0	15	184	2	0	0	0	23	3	0	0	0	1	0	0	2	0	0	1	1	1	0	DE
DK	0	0	1	0	0	2	0	1	0	0	3	22	169	0	0	1	5	6	0	0	0	1	0	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	2	1	96	0	9	1	1	0	0	0	0	0	0	0	0	0	5	0	19	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	117	0	8	1	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	1	0	2	0	73	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	FI
FR	0	0	3	0	0	5	0	0	4	0	2	15	0	0	3	0	261	4	0	0	0	0	0	0	4	0	0	0	1	0	0	FR
GB	0	0	0	0	0	2	0	0	0	0	1	5	1	0	0	0	13	98	0	0	0	0	2	0	0	0	0	0	0	0	0	GB
GE	0	6	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	124	0	0	0	0	0	0	0	0	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	4	0	1	0	1	0	10	0	0	0	1	1	0	0	0	0	1	0	0	102	0	1	0	0	3	0	0	0	0	0	0	GR
HR	1	0	19	0	66	0	2	1	0	0	7	5	0	0	0	0	2	0	0	1	115	17	0	0	11	0	0	0	0	0	0	HR
HU	0	0	26	0	10	0	3	1	0	0	12	7	0	0	0	0	2	0	0	1	11	178	0	0	4	0	0	0	0	0	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	3	10	0	0	0	0	32	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	IS
IT	0	0	9	0	2	0	0	0	2	0	1	2	0	0	2	0	7	0	0	0	2	1	0	0	369	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	6	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	34	0	0	0	0	KZ
LT	0	0	1	0	0	0	0	25	0	0	2	3	1	2	0	2	1	1	0	0	0	1	0	0	0	0	0	117	0	20	1	LT
LU	0	0	4	0	0	27	0	0	1	0	5	84	1	0	1	0	107	5	0	0	0	0	0	0	1	0	0	0	78	0	0	LU
LV	0	0	0	0	0	0	0	13	0	0	1	2	1	8	0	3	1	1	0	0	0	0	0	0	0	0	0	20	0	126	0	LV
MD	0	0	1	0	1	0	4	3	0	0	1	1	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	1	104	MD
ME	15	0	2	0	16	0	2	0	0	0	1	1	0	0	0	0	1	0	0	1	1	2	0	0	3	0	0	0	0	0	0	ME
MK	11	0	1	0	3	0	11	0	0	0	1	1	0	0	0	0	0	0	0	20	1	2	0	0	2	0	0	0	0	0	0	MK
MT	1	0	1	0	1	0	0	0	0	0	1	1	0	0	4	0	6	0	0	1	1	0	0	0	20	0	0	0	0	0	0	MT
NL	0	0	2	0	0	44	0	1	0	0	4	69	2	0	1	0	35	12	0	0	0	0	0	0	0	0	0	0	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	1	1	1	8	0	0	15	11	2	0	0	1	3	1	0	0	1	4	0	0	1	0	0	3	0	2	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	28	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	2	0	2	0	11	2	0	0	2	2	0	0	0	0	1	0	0	1	1	6	0	0	1	0	0	0	0	0	4	RO
RS	3	0	5	0	23	0	14	1	0	0	4	3	0	0	0	0	1	0	0	3	5	12	0	0	2	0	0	0	0	0	1	RS
RU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	1	2	3	1	0	3	1	1	0	0	0	0	0	0	0	0	0	1	0	1	0	SE
SI	0	0	86	0	7	0	1	1	0	0	7	6	0	0	0	0	2	0	0	0	34	9	0	0	27	0	0	0	0	0	0	SI
SK	0	0	13	0	3	0	2	1	0	0	22	6	0	0	0	0	2	1	0	0	2	36	0	0	2	0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	TJ
TM	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	TM
TR	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	6	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	0	0	0	1	1	0	1	4	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	9	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	0	0	3	0	0	2	7	10	5	0	12	2	2	0	0	0	1	0	0	0	0	0	4	0	6	0	BAS
BLS	0	0	1	1	0	0	4	1	0	0	0	1	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1	BLS
MED	1	0	1	0	2	0	1	0	0	0	1	1	0	0	8	0	9	0	0	5	1	1	0	0	18	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	3	0	0	0	0	1	8	4	0	0	0	14	15	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	2	0	0	1	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	0	0	3	1	1	1	2	2	1	0	2	5	1	1	3	2	9	2	1	1	1	2	0	0	6	1	7	1	0	1	0	EXC
EU	0	0	12	0	2	3	6	2	1	0	8	21	2	1	15	6	39	7	0	3	2	6	1	0	27	0	0	3	0	3	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.16.2 Cont.: 2018 country-to-country blame matrices for **PPM2.5**
Units: ng/m^3 per 15% emis. red. of PPM. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	9	20	0	0	0	2	0	2	32	2	0	0	0	0	0	2	4	0	0	0	0	3	0	0	0	0	0	0	290	28	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	25	0	0	0	0	0	0	0	7	0	0	0	0	126	1	AM
AT	0	0	0	0	0	17	0	2	3	1	0	18	5	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	490	477	AT
AZ	0	0	0	0	0	0	0	0	0	12	0	0	0	0	1	5	2	1	0	0	0	0	0	8	0	0	0	0	201	1	AZ
BA	5	1	0	0	0	7	0	5	19	2	0	2	2	0	0	1	5	0	0	0	0	1	0	0	0	0	0	0	420	59	BA
BE	0	0	0	26	0	8	0	0	0	1	0	0	0	0	0	0	1	0	1	0	0	0	7	0	0	0	0	0	431	428	BE
BG	0	4	0	0	0	3	0	31	9	9	0	0	1	0	0	10	26	0	0	0	1	1	0	0	0	0	0	0	301	237	BG
BY	0	0	0	0	0	22	0	6	0	30	1	0	1	0	0	1	39	0	0	0	0	0	0	0	0	0	0	0	215	50	BY
CH	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	269	107	CH
CY	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	82	4	0	0	0	0	13	0	11	2	0	0	0	128	39	CY
CZ	0	0	0	1	0	75	0	5	4	3	0	3	10	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	437	417	CZ
DE	0	0	0	6	0	31	0	1	1	2	1	1	1	0	0	0	2	0	0	1	0	0	2	0	0	0	0	0	312	302	DE
DK	0	0	0	3	2	19	0	1	0	2	7	0	0	0	0	0	2	0	0	6	0	0	4	0	0	0	0	0	252	244	DK
EE	0	0	0	0	1	10	0	1	0	25	3	0	0	0	0	0	7	0	0	3	0	0	0	0	0	0	0	0	189	149	EE
ES	0	0	0	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	1	0	0	0	139	139	ES
FI	0	0	0	0	1	3	0	0	0	11	3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	101	86	FI
FR	0	0	0	2	0	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	309	305	FR
GB	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	0	0	0	128	127	GB
GE	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	12	2	0	0	0	0	0	0	2	0	0	0	0	165	1	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	8	0	0	0	2	0	3	5	5	0	0	0	0	0	18	11	0	0	0	1	8	0	0	1	0	0	0	177	125	GR
HR	1	1	0	0	0	13	0	7	21	2	0	23	3	0	0	1	6	0	0	0	0	2	0	0	0	0	0	0	325	225	HR
HU	1	1	0	0	0	31	0	51	20	4	0	8	23	0	0	1	20	0	0	0	0	0	0	0	0	0	0	0	421	360	HU
IE	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	53	52	IE
IS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	IS
IT	0	0	0	0	0	3	0	1	1	0	0	7	1	0	0	0	1	0	0	0	0	8	0	0	1	0	0	0	413	405	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	19	0	0	0	0	0	8	0	0	0	0	63	0	KG
KZ	0	0	0	0	0	0	0	0	0	16	0	0	0	0	0	0	1	3	0	0	0	0	0	8	0	0	0	0	58	1	KZ
LT	0	0	0	0	0	39	0	4	0	19	2	0	1	0	0	0	17	0	0	1	0	0	0	0	0	0	0	0	261	198	LT
LU	0	0	0	5	0	9	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	332	329	LU
LV	0	0	0	0	1	18	0	2	0	19	3	0	0	0	0	0	11	0	0	1	0	0	0	0	0	0	0	0	234	188	LV
MD	0	0	0	0	0	12	0	69	1	19	0	0	1	0	0	4	114	0	0	0	1	0	0	0	0	0	0	0	343	96	MD
ME	151	2	0	0	0	2	0	3	23	1	0	0	1	0	0	1	4	0	0	0	0	1	0	0	0	0	0	0	235	21	ME
MK	1	240	0	0	0	3	0	4	37	3	0	0	1	0	0	4	8	0	0	0	0	1	0	0	0	0	0	0	355	48	MK
MT	0	0	53	0	0	1	0	0	1	0	0	1	0	0	0	1	1	0	0	0	0	93	0	0	9	0	0	0	96	91	MT
NL	0	0	0	177	0	14	0	0	0	1	1	0	0	0	0	0	1	0	1	0	0	0	12	0	0	0	0	0	368	364	NL
NO	0	0	0	0	27	1	0	0	0	1	2	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	38	9	NO
PL	0	0	0	1	0	403	0	8	2	9	1	1	6	0	0	0	23	0	0	1	0	0	0	0	0	0	0	0	514	469	PL
PT	0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	0	0	1	0	0	0	224	223	PT
RO	0	1	0	0	0	9	0	341	6	8	0	0	2	0	0	3	35	0	0	0	1	0	0	0	0	0	0	0	442	380	RO
RS	6	13	0	0	0	9	0	31	239	4	0	1	3	0	0	2	13	0	0	0	0	0	0	0	0	0	0	0	398	94	RS
RU	0	0	0	0	0	1	0	0	0	66	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	81	4	RU
SE	0	0	0	0	4	7	0	1	0	3	36	0	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	67	58	SE
SI	0	0	0	0	0	12	0	3	5	1	0	412	2	0	0	0	4	0	0	0	0	2	0	0	0	0	0	0	622	602	SI
SK	0	1	0	0	0	67	0	24	5	4	0	2	153	0	0	1	21	0	0	0	0	0	0	0	0	0	0	0	373	335	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	48	1	0	0	19	0	0	0	0	0	16	0	0	0	0	73	0	TJ
TM	0	0	0	0	0	0	0	0	0	4	0	0	0	1	23	1	1	15	0	0	0	0	0	8	0	0	0	0	51	1	TM
TR	0	0	0	0	0	0	0	1	0	3	0	0	0	0	0	260	5	0	0	0	1	2	0	7	0	0	0	0	277	5	TR
UA	0	0	0	0	0	13	0	16	1	36	0	0	1	0	0	3	264	0	0	0	1	0	0	0	0	0	0	0	357	41	UA
UZ	0	0	0	0	0	0	0	0	0	5	0	0	0	6	5	0	1	88	0	0	0	0	0	4	0	0	0	0	120	1	UZ
ATL	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	9	8	ATL
BAS	0	0	0	1	1	29	0	2	0	11	13	0	1	0	0	0	5	0	0	13	0	0	1	0	0	0	0	0	119	98	BAS
BLS	0	0	0	0	0	3	0	10	1	34	0	0	0	0	0	44	57	0	0	0	11	1	0	0	0	0	0	0	172	22	BLS
MED	1	1	0	0	0	1	1	1	1	2	0	1	0	0	0	22	4	0	1	0	0	34	0	4	9	0	0	0	86	52	MED
NOS	0	0	0	5	4	5	0	0	0	1	1	0	0	0	0	0	1	0	1	1	0	0	14	0	0	0	0	0	65	59	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	6	1	1	0	0	0	0	0	240	0	0	0	0	13	0	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	1	0	0	5	0	1	40	0	0	0	14	11	NOA
EXC	0	1	0	1	1	10	1	6	2	31	1	1	1	1	1	12	13	3	0	0	0	0	0	2	0	0	0	0	142	63	EXC
EU	0	0	0	3	1	38	5	22	2	4	4	3	3	0	0	1	7	0	1	1	0	2	1	0	0	0	0	0	266	246	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

APPENDIX D

Explanatory note on country reports for 2018

The country reports issued by EMEP MSC-W (Klein et al. 2020) focus on chemical species that are relevant to eutrophication, acidification and ground level ozone, but also information on particulate matter is given. More specifically, these country reports provide for each country:

- horizontal maps of emissions, and modelled air concentrations and depositions in 2018;
- emission trends for the years 2000 to 2018;
- modelled trends of air concentrations and depositions for the years 2000 to 2018;
- maps and charts on transboundary air pollution in 2018, visualizing the effect of the country on its surroundings, and vice versa;
- comparison charts and maps concerning emissions of condensable organics (see Chapter 6);
- frequency analysis of air concentrations and depositions, based on measurements and model results for 2018, along with a statistical analysis of model performance;
- maps on the risk of damage from ozone and particulate matter in 2018.

EMEP MSC-W issues these country reports for 47 Parties to the Convention, and for Tajikistan, Turkmenistan and Uzbekistan. For the Russian Federation the country report includes only the territory which is within the EMEP domain (see Figure 1.1).

All 50 country reports are written in English. For the 12 EECCA countries, the reports are made available also in Russian. All country reports can be downloaded in pdf format from the MSC-W report page on the EMEP website:
`https://emep.int/mscw/mscw_publications.html#2020`

This year, the country reports are found under the header 'MSC-W Data Note 1/2020 Individual Country Reports'. The reports for each country can be selected from a drop-down menu.

References

Klein, H., Gauss, M., Tsyro, S., Nyiri, A., Fagerli, H., and Wind, P.: Transboundary air pollution by sulphur, nitrogen, ozone and particulate matter in 2018, Country Reports, Tech. Rep. EMEP MSC-W Note 1/2020 Individual Country Reports, The Norwegian Meteorological Institute, Oslo, Norway, available for 49 countries, at www.emep.int/mscw/mscw_publications.html, 2020.

APPENDIX E

Model Evaluation

The EMEP MSC-W model is regularly evaluated against various kinds of measurements, including ground-based, airborne and satellite measurements. As the main application of the EMEP MSC-W model within the LRTAP Convention is to assess the status of air quality on regional scales and to quantify long-range transboundary air pollution, the focus of the evaluation performed for the EMEP status reports is on the EMEP measurement sites.

Only parts of this evaluation are included in the printed version of the EMEP status report. A more comprehensive collection of maps, graphs and statistical analyses, including a more detailed discussion of model performance, are freely available as supplementary material from the MSC-W report page on the EMEP website:
`https://emep.int/mscw/mscw_publications.html`

This year, the evaluation report is found under the link 'Supplementary material to EMEP Status Report 1/2020'. It contains a comprehensive evaluation of the EMEP MSC-W model for air concentrations and depositions in 2018. The report is divided into three chapters, dealing with pollutants responsible for eutrophication and acidification (Gauss et al. 2020b), ground level ozone and nitrogen dioxide (Gauss et al. 2020a), and particulate matter (Tsyro et al. 2020), respectively.

The agreement between model and measurements in 2018 is visualized as:

- scatter plots for the EMEP MSC-W model domain;
- time series for individual EMEP stations;
- horizontal maps combining model results and EMEP measurement data.

Tables summarize common statistical measures of model score, such as bias, root mean square error, temporal and spatial correlations and the index of agreement (see Chapter 1).

This type of model evaluation is performed on an annual basis and can be downloaded from the same web page also for previous years.

A major effort this year has been put into the development of a web interface that presents a detailed evaluation against measurements from the European Environment Agency's (EEA) Air Quality e-Reporting Database:
https://aerocom-evaluation.met.no/main.php?project=emep
On that page the user can select the classification of measurement data (rural, urban, non-traffic, or all stations) and view a large number of statistical parameters (bias, correlation, root mean square error, etc.).

The web interface displays the co-located observational and model data sets and contains:

- daily and monthly time series for each station, or averaged per country (or the whole area covered by the model and the measurement network);
- seasonal- and annual-mean diurnal variation for each of the seven days of the week;
- statistics and scatter plots calculated for each station and country;
- an overall evaluation of the results using statistics calculated for each country or the whole area covered by the model and the measurement network.

In all cases the statistics are calculated using monthly resolution by default. Daily statistics are available by adding &stats=daily to the site URL given above.

Evaluation is made for the following chemical species and indicators: NO_2, O_3, $PM_{2.5}$ and PM_{10}, and O_3max (maximum daily ozone). Different types of visualization (bar charts, line charts, tables, etc.) are available for viewing and for download. The measurement data have been retrieved from the validated *E1a* stream of EEA and further harmonized and quality controlled by the GHOST tool (Globally Harmonised Observational Surface Treatment) developed at the Barcelona Supercomputing Center (BSC).

For supplemental evaluation of Elemental Carbon (EC), the modelled absorption coefficient (mainly due to EC) is compared to surface *in-situ* observations of the aerosol light absorption coefficient, accessed through the Global Atmospheric Watch - WDCA database EBAS (http://ebas.nilu.no/). More details about this can be found in Chapter 7.

References

Gauss, M., Hjellbrekke, A.-G., Aas, W., and Solberg, S.: Ozone, Supplementary material to EMEP Status Report 1/2020, available online at www.emep.int, The Norwegian Meteorological Institute, Oslo, Norway, 2020a.

Gauss, M., Tsyro, S., Fagerli, H., Hjellbrekke, A.-G., and Aas, W.: Acidifying and eutrophying components, Supplementary material to EMEP Status Report 1/2020, available online at www.emep.int, The Norwegian Meteorological Institute, Oslo, Norway, 2020b.

Tsyro, S., Gauss, M., Hjellbrekke, A.-G., and Aas, W.: PM10, PM2.5 and individual aerosol components, Supplementary material to EMEP Status Report 1/2020, available online at www.emep.int, The Norwegian Meteorological Institute, Oslo, Norway, 2020.

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