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

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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 2021 and 2022 in relation to transboundary fluxes of particulate matter, photo-oxidants, acidifying and eutrophying components, with focus on results for 2020. It presents major results of the activities related to emission inventories, observations and modelling. This year, special attention has been given to chemical transport modelling of air pollution for present day and different scenarios for the coming decades, in support of the Gothenburg Protocol review. The impacts of the COVID-19 pandemic on particulate matter (PM) levels are also illustrated.

Measurements and model results for 2020

In the first chapter, the status of air pollution in 2020 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 33 Parties reported measurement data for 2020, from 173 sites in total. Of these, 140 sites reported measurements of inorganic ions in precipitation and/or main components in air; 73 of these sites had co-located measurements in both air and precipitation. The ozone network consisted of 139 sites. Particulate matter was measured at 81 sites, of which 54 performed measurements of both PM_{10} and $PM_{2.5}$. In addition, 57 sites from 18 Parties reported at least one of the aerosol components required in the advanced EMEP measurement program (level 2), while 20 sites from 9 Parties measured volatile organic compounds (VOCs), though only 4 sites with both hydrocarbons and carbonyls.

As in previous years, the mean daily maximum O_3, SOMO35 and AOT40 in 2020 all show a distinct gradient with levels increasing from north to south, reflecting the dependence of ozone on the photochemical conditions. The geographical pattern in the measured values is fairly well reproduced by the model results for all these three metrics. In connection with a heatwave in the north-west of Europe in late July/early August high ozone levels were observed in the Benelux countries and the south-east of UK.

EMEP MSC-W model simulations and EMEP observations for 2020 show a general increase of PM_{10} and $PM_{2.5}$ over land from north to south. PM_{10} concentrations are below 2-5 μg m^{-3} in Northern Europe, increasing to 5-15 μg m^{-3} in the mid-latitudes and further south. $PM_{2.5}$ follows in general the same spatial pattern, but with somewhat lower concentration compared to PM_{10}. The modelled levels of regional background PM are fairly ho-

mogeneous over most of Central and Western Europe, with PM_{10} in excess of 20 μg m^{-3} in the Po Valley, parts of Balkan and in the eastern Mediterranean region. The highest annual mean PM_{10} (just above 20 μg m^{-3}) was observed at Melpitz (south-eastern Germany). $PM_{2.5}$ concentrations are below 10 μg m^{-3} over most of the EMEP domain (except the most southern/southeastern regions), showing a few hot spots (between 10 and 15 μg m^{-3}) in the Po Valley, some parts of Balkan and Turkey. The same as for PM_{10}, the highest annual mean $PM_{2.5}$ (16.3 μg m^{-3}) was registered at Melpitz.

The model results indicate that due to the COVID-19 pandemic and dramatic restrictions on socio-economic activity, the annual mean PM levels in 2020 were 1-10% lower with respect to the "Business-as-Usual" scenario. The largest PM decreases, exceeding 10%, are simulated for the Po Valley and eastern parts of France.

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 2020. The model calculated annual mean PM_{10} is mostly below WHO Air Quality Guidelines Global Update 2021 (AQG-2021), which is 15 μg m^{-3}, except for small regions in the Po Valley, Serbia, Turkey and Central Asia. EMEP observations registered PM_{10} exeedances of the AQG-2021 limit value at 11 sites (out of 66). For daily PM_{10} exceedances of the EU limit value of 50 μg m^{-3} were observed at 38 (58%) sites, but nowhere on more than 35 days (required by EU Directive 2008/50/EC). The WHO AQG-2021 of 45 μg m^{-3} was exceeded at 49 (72%) sites, and 12 (18%) sites had more than 3 exceedance days.

Modelled and observed annual mean $PM_{2.5}$ concentrations in 2020 were mostly below the EU limit value of 20 μg m^{-3}, except in the Po Valley according to the model. However, there were observed cases of $PM_{2.5}$ exceedances of WHO AQG-2021 levels of 5 μg m^{-3} at 37 sites (out of 50). Daily $PM_{2.5}$ concentrations exceeded the AQG-2021 recommended limit of 15 μg m^{-3} at 44 (88%) sites, out of which 36 (72%) sites had more than 3 exceedance days.

Exceedances of critical loads

The average accumulated exceedances (AAE) of critical loads have been calculated for the years 2000, 2005, 2010, 2015 and 2020 based on the $0.1^\circ \times 0.1^\circ$ EMEP MSC-W calculations discussed in this report and updated data on critical loads. The critical loads for eutrophication are exceeded in practically all countries in all years. The share of ecosystems where the critical load for eutrophication is exceeded decreases relatively slowly, starting at 76.0% in 2000 and ending at 61.2% in 2020. The European average AAE is about 434 eq ha^{-1} yr^{-1} (in the year 2000) and 235 eq ha^{-1} yr^{-1} (in 2020). The highest exceedances of critical loads 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. Hotspots 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. Acidity exceedances occur on 14.1% (in 2000) and 3.6% (in 2020) of the ecosystem area and the European average AAE is about 145 eq ha^{-1} yr^{-1} (in 2000) and 22 eq ha^{-1} yr^{-1} (in 2020).

Status of emission reporting

In 2022, 47 out of 51 Parties (92%) submitted emission inventories to the EMEP Centre on Emission Inventories and Projections (CEIP), and 42 Parties reported black carbon (BC)

emissions.

After the first round of submissions in 2017, 2021 was the second year in which EMEP countries were obliged to report gridded emissions in $0.1^\circ \times 0.1^\circ$ longitude/latitude resolution. Until June 2022, 35 of the 48 countries which are considered to be part of the EMEP area reported sectoral gridded emissions in this resolution (one more than in 2021). For remaining areas, missing emissions are gap-filled and spatially distributed using expert estimates.

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 2022, CEIP organised an ad hoc review dedicated to the topic "Condensable component of PM emissions". Twenty-one experts participated in this review. For all Parties that had provided an informative inventory report, the residential heating and road transport sectors were reviewed, with a special focus on the condensable component of PM emissions. Based on the outcome of the review, CEIP, in co-operation with TNO, prepared a list of Parties where it could be assumed with a good degree of certainty that the condensable component is mostly included in PM emissions for GNFR sector C (small-scale combustion). For these Parties the reported PM emissions were used, while for other Parties updated TNO Ref2 (version v2.1) emission data were used. If no TNO Ref2 estimates were available, gap-filled data by CEIP was used for GNFR sector C. The resulting GNFR C dataset was combined with official EMEP emissions into the so-called EMEPwRef2_v2.1C emission dataset. This emission dataset has been used in the assessment of the air quality situation in Europe and the source receptor calculations for 2020 made this year.

The amended Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) entered into force on 7 October 2019 and sets out the emission reduction commitments for SO_x, NO_x, NH_3, NMVOCs and $PM_{2.5}$ for 2020 and beyond, expressed as percentage reductions from the 2005 emission level. In 2020 emissions from the following countries were above their respective Gothenburg Protocol requirements: NO_x: Lithuania and Romania; NMVOC: Denmark, France, Lithuania, the Netherlands and Norway; SO_x: Cyprus ; NH_3: Bulgaria, Denmark, Latvia, Lithuania, Luxembourg, Norway, Portugal, Spain, Sweden and the United Kingdom; $PM_{2.5}$: Romania.

uEMEP/EMEP modelling for the Gothenburg protocol review

In December 2019, the Executive Body launched the review of the Gothenburg Protocol as amended in 2012. In order to support the review and contribute to the assessment of the remaining risks for health, ecosystems and crops, uEMEP/EMEP MSC-W model calculations have been performed for present day (2015) and some future scenarios for the coming decades (2030, 2050). Three regions were addressed separately; the EECCA countries, Western Balkan countries and the EU including the EU27, EFTA and the UK. The emission scenarios for these calculations were developed and provided by CIAM; they include estimates for 2015, 2030, and 2050. Baseline scenario assumes implementation and enforcement of current and planned legislation while Maximum technically Feasible Reduction (MFR) scenario explores further (beyond Baseline) emission mitigation potential, applying proven and documented technological solutions to reduce emissions in 2030 and 2050. Emission estimates

for $PM_{2.5}$ consider a set of emission factors where the condensable fraction of PM is consistently included; these emission factors were developed by TNO within a Nordic Council of Ministers funded project. Modelling has been carried out with the EMEP MSC-W chemical transport model and further downscaled with the uEMEP (urban EMEP) model. The uEMEP model achieves resolutions of 25 m at station sites and 250 m for population exposure calculations across the entire EMEP domain. The results of the calculations, which include source contributions from local and long range transport, are used to assess the achievability of attaining the recent WHO guidelines for air quality in the three regions.

uEMEP calculations show that in 2015 most of the population in EU, Western Balkan and EECCA live in areas that have $PM_{2.5}$ values above current WHO annual mean guideline values of 5 μgm^{-3}. By 2030, the Baseline scenario indicates that 75% of the EU population will still be exposed to $PM_{2.5}$ levels above 5 μg m^{-3}. However, this number is reduced to 40% in the 2050 Baseline calculation. The additional implementation of MFR in 2050 will reduce this further to just 14% of the population above 5 μg m^{-3}. In this scenario, there is less than 1% of the population exposed to $PM_{2.5}$ levels above 10 μg m^{-3}. For the Western Balkan and EECCA countries, the baseline scenario shows much less improvement in the $PM_{2.5}$ levels. For the EECCA countries, the 2050 baseline scenario gives similar levels to 2015. Implementation of more stringent air quality policies, and especially the MFR scenario, would result in significant reduction of $PM_{2.5}$ concentrations in these countries. However, some EECCA countries are limited in achieving very low PM concentrations by high levels of wind-blown dust.

For NO_2, uEMEP calculations show that in 2015 around 65% of the population in the EU, 40% of Western Balkan and 50% of EECCA countries lived in areas above the WHO NO_2 guideline value of 10 μgm^{-3}. All the scenarios show that in 2050 less than 2% of the EU population are still exposed to levels above the recommended WHO exposure level of 10 μg m^{-3}. For the Western Balkan, 21% of the population is exposed to NO_2 above 10 μg m^{-3}. For the 2050 baseline, the EECCA countries show an increase in NO_2 concentrations, compared to 2015, with about 50% of the population exposed to levels above 10 μg m^{-3} and still with 13% of the population (33 million inhabitants) above the 40 μg m^{-3} level. It is only with the implementation of MFR that NO_2 concentrations approach, but do not achieve, the WHO guidance level. In summary, for almost all the EU and Western Balkan population, the Baseline scenario for NO_2 should bring exposure below the recommended WHO level of 10 μg m^{-3} by 2050. EECCA countries will need to implement Maximum technically Feasible Reductions to approach this level.

Contribution of biomass burning to total carbon across Europe during the 2017/2018 winter intensive measurement period

Emissions from residential wood combustion (RWC) are a major contributor to air pollution in wintertime Europe, but the magnitude of the emissions is associated with large uncertainty. The levoglucosan data set from the winter 2017/2018 EMEP intensive measurement period (IMP) provides an unprecedented opportunity to assess the magnitude of RWC emissions across Europe. The relative contribution of RWC to carbonaceous aerosol at 42 urban and rural background sites ranges from negligible (< 6%) to dominating (> 70%). We conclude that RWC is a large contributor (> 30%) at most sites (34/42), and likely dominating (> 40%) at more than 50% of the sites (24/42). With average wintertime carbonaceous aerosol levels as high as 15 μg(C) m^{-3}, there is a great potential to improve air quality in Europe by targeting

RWC.

The Local Fractions method and its application to trends in country-to-itself contributions to reduced nitrogen deposition

Reductions in sulphur and oxidised nitrogen emissions during the last decades are expected to have led to a decrease in the transport distance of reduced nitrogen in the atmosphere and thus to an increase in the contribution of a country (emitting reduced nitrogen) to deposition of reduced nitrogen within the country itself. This is because less particles are formed from ammonia when there is less sulphur and nitrogen oxides in the atmosphere. More ammonia then remains in the gaseous phase which is deposited to the ground more efficiently and thus closer to the emission source. Thanks to the highly efficient *Local Fractions* method, developed recently for the calculation of source-receptor relationships, we have been able to test this hypothesis based on a long-term (31-year) EMEP MSC-W model simulation. According to our results, there are statistically significant upward trends in the country-to-itself contribution to reduced nitrogen deposition during the 1990–2020 period in about half of the EMEP countries. We find trends of up to 5 – 8% per decade in some countries. The slopes of the linear regression of 1990-2020 country-to-itself contributions are upward in nearly all EMEP countries. These findings show that the transport distance of reduced nitrogen has indeed decreased over the last three decades (according to the EMEP MSC-W model), and more of it is deposited in the emitting country itself.

EMEP Trends in AeroVal

In last year's EMEP Status Report, we presented an assessment of the trends in air pollution in Europe for the period 2000–2019, based on long term observational data from the EMEP network as well as on EMEP MSC-W model calculations. This work was done to assess the progress made towards achieving the environmental and health objectives of the Gothenburg protocol. To make the data and the results more easily accessible, we have made all the results from the trend work available through a web interface. This interface also allows country representatives to understand, interpret and analyze data for their own area more easily.

The EMEP Trend Interface is available on the AeroVal webpage: https://aeroval.met.no/evaluation.php?project=emep-trends. The model data are the same as described in the trend chapter in the 2021 EMEP report, while the observations come from a newer extract of the EBAS dataset. Observed and modelled trends were processed with the pyaerocom software (https://github.com/metno/pyaerocom) for the period 2000–2019. In addition, several relevant sub-periods are distinguished, i.e. 2000-2010, 2005–2019, and 2010–2019.

Model improvements

The EMEP MSC-W model code has been upgraded in a number of ways. The landcover definitions and input files needed for phytotoxic ozone dose (POD) estimates were modified to better match the definitions given in the 2017 ICP-Vegetation Mapping Manual. New landcover and POD outputs were introduced for Mediterranean vegetation. An additional output option has been implemented to facilitate comparison of the EMEP simulations with satellite

data. The soil NO_x emissions were updated from v2.2 to v2.3. The Local Fractions capabilities were upgraded. New outputs for maximum daily eight-hour mean concentration (MDA8), and for 1st, 2nd, 3rd, 4th and 26th highest MDA8 ozone values were added for comparison with recent WHO health guidelines. In addition, improvements were made in memory and CPU usage when using netcdf emission inputs with large numbers of source categories.

Development in the monitoring programme

There are large differences between Parties in the level of implementation of the monitoring programme, as well as significant changes in the national activities during the period 2010–2020. With respect to the requirement for level 1 monitoring, 35% of the Parties have had an improvement since 2010, while 37% have reduced the level of monitoring. For level 2 monitoring there has been a general positive development, but only a few sites have a complete measurement program.

The complexity of data reporting has increased in recent years, and the data providers should use the submission and validation tool when submitting data to EMEP. Most of the Parties are now using the submission tool, which has significantly improved the quality and timeliness of the reporting.

Acknowledgments

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The work of TNO was partly funded by the Nordic Council of Ministers and partly by the Copernicus Atmosphere Monitoring Service (CAMS), in particular the Contracts on emissions (CAMS_81 and CAMS2_61) and policy products (CAMS2_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.

Chris Heyes, Gregor Kiesewetter and colleagues from EMEP CIAM/IIASA are acknowledged for provision of emission data and helpful discussions and advice.

The EMEP and uEMEP model application for the review of the Gothenburg protocol builds upon work carried out for the review of the European Ambient Air Quality Directives, a project funded by the European Commission DG-Environment: 'Service contract study to support the impact assessment for a revision of the EU Ambient Air Quality Directives Specific Contract under Framework Contract ENV/F1/FRA/2019/0001'.

The emission data used in the Gothenberg protocol review scenarios was firstly developed by IIASA in two earlier European Commission funded projects. The 9EAST project, 'Extension of the EU Energy and Climate Modelling Capacity to include the Energy Community and its Nine Contracting Parties': Service Contract ENER/A3/SER/2019-563/SI2.840866 - ENER/2020/OP/0005. The DG-CLIMA project, 'Non-CO2 greenhouse gas emissions in the EU27 from 2005 to 2070 with mitigation potentials and costs': Service Contract 340201/ 2019/ 813567/ CLIMA.C.1.

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The work of I. Gonzalez Fernandez in updating the EMEP model's ozone flux methodology was supported by the DGCEA-CIEMAT programme on atmospheric pollution and persistent organic pollutants (ACTUA-MITERD), Spanish Ministry of Ecological Transition.

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 and long-term calculations. Some computations were performed on resources provided by UNINETT Sigma2 - the National Infrastructure for High Performance Computing and Data Storage in Norway (grant NN2890k and NS9005k). 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. This year, special attention has been given to modelling of present and future air pollution scenarios (2015, 2030, 2050), supporting the review of the Gothenburg Protocol. The main goal of this work is to provide concentration and deposition data from the EMEP MSC-W model that can be used to estimate remaining risks for health, ecosystems and crops. In this report we document and present some EMEP/MSC-W model results for $PM_{2.5}$, PM_{10}, NO_2 and O_3 (the health indicator SOMO35). The EMEP/MSC-W model results have also been distributed to CCE, ICP Vegetation, ICP Materials and ICP Waters. These groups will use the model data to calculate effects of air pollution on vegetation, waters and materials in so-called 'ex-post analysis', but that will be presented elsewhere.

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 2020. The impact of the COVID-19 restrictions have been included (through total and temporal distribution of emissions), however, we do not attempt a major analysis of how the situation in 2020 would have been without COVID-19. Part II summarizes the assessment of future air pollution scenarios (2030, 2050) performed to support the review of the Gothenburg Protocol, as well as some recent research work on a new methodology to perform source-receptor calculations. 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 2020, while Appendix B shows the emission time series for the period of 1990-2020. Country-to-country source-receptor matrices with calculations of the transboundary contributions to pollution in different countries for 2020 are presented in Appendix C. Appendix D summarizes common statistical measures of model performance for 2020 with respect to EMEP observations, while model evaluation against all EMEP observations is visualized online at https://aeroval.met.no/evaluation.php?project=emep&exp_name=2022-reporting. Appendices E-H contain supplementary information to the chapters in Part I - Part III, while Appendix I describes the country reports which are issued as a supplement to the EMEP status reports.

The present report and the model evaluation web interface are 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 sulfur 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:

MDmaxO3 - 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.:

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

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).

In this report we work with the POD values which are intended for large-scale 'Integrated Assessment Modelling' (IAM), whereby generic crop, forest and other semi-natural species, and their characteristics, are as specified in the ICP-Vegetation Mapping Manual (LRTAP 2017). See also Mills et al. (2011a,b, 2018), LRTAP (2017) and Ch. 8.2.

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, and in some daytime period. 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 (2017) 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. In the EU approaches, O_3 concentrations are taken directly from observations (at typically ca. 3 m height), or grid-average 3 m modelled values. In the Mapping Manual (LRTAP 2009) approaches, there is a strong emphasis on estimating AOT40 using ozone levels at the top of the vegetation canopy. Since O_3 concentrations can have strong vertical gradients, this approach leads to lower AOT40 estimates than with the EU approach.

The EMEP MSC-W model now generates a number of AOT-related outputs,and in this report we will use:

EU-AOT40c - AOT40 calculated using EU criteria, from modelled (3 m) or observed ozone, for the assumed crop growing season of May–July. Here we use the EU definitions of day hours as 08:00–20:00.

EU-AT40f - AOT40 calculated using EU criteria from modelled 3 m ozone, or observed ozone, for the assumed forest growing season of April–September. Here we use the EU definitions of day hours as 08:00–20:00.

MM-AOT40f - AOT40 calculated for forests using estimates of O_3 at forest-top. This AOT40 is that defined for forests by LRTAP (2017), but using a default growing season of April-September.

MM-AOT40c - 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 (2017), but using a default growing season of May-July, and a default crop-height of 1 m.

For MM-AOT40f and MM-AOT40c only daylight hours are included, and for practical reasons we define daylight in 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).

In practice, it is very difficult to convert measured O_3 from an EMEP observation site to the MM-AOT40 values, since there are no data with which is to estimate the vertical gradient to get to upper-canopy O_3. Therefore, in the comparison of modelled and observed AOT40s in Ch 2, we have used the EU AOT definitions, since this approach is readily applicable to observed as well as modelled values. We do, however, present source-receptor calculations for the UNECE metrics MM-AOT40f and MM-AOT40c in Appendix C.

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 (MM-AOT40c) and natural vegetation, and 5 000 ppb.h for forests (MM-AOT40f) (LRTAP 2017). Note that the UNECE/ICP-vegetation recommendations are that AOT40 concepts are replaced by ozone flux estimates for crops and forests (see also LRTAP 2017).

Furthermore, this report includes 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 Fagerli et al. (2020).)

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 sulfate (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^+ + $SS_{2.5}$ + MinDust(fine) + SOA(fine) + $PPM_{2.5}$ + 0.13 · 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} = 0.87 · 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 $PM_{10} = PM_{2.5} + PM_{coarse}$.

SS_{10} - sea salt aerosol with diameter up to 10 μm.

$SS_{2.5}$ - sea salt aerosol with diameter up to 2.5 μm.

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):

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

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 50×50 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.

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.

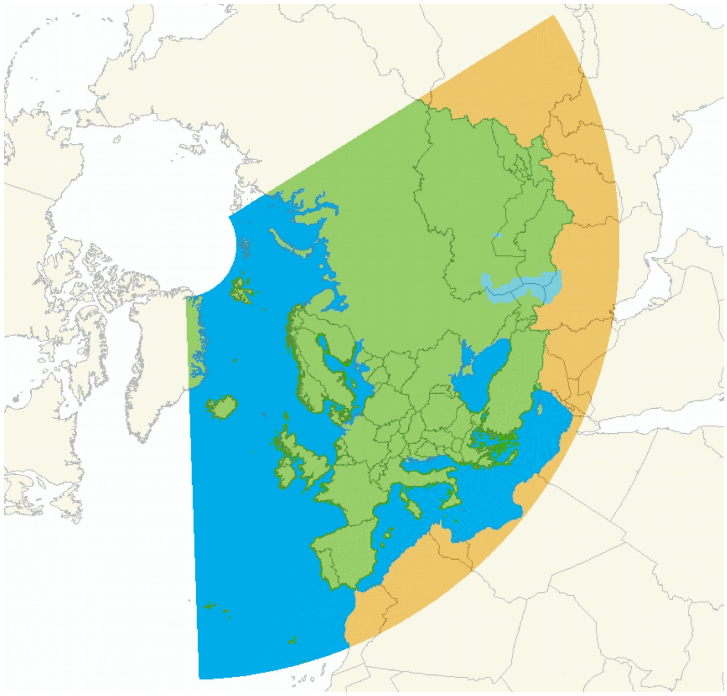

Figure 1.1: The EMEP domain covering the geographic area between 30° N-82° N latitude and 30° W-90° E longitude.

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.

1.5 Other publications

A list of all associated technical reports and notes by the EMEP centres in 2021 (relevant for transboundary acidification, eutrophication, ozone and particulate matter) follows at the end of this section.

Peer-reviewed publications in 2021

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 2021:

Barré, Jérôme; Petetin, Herve; Colette, Augustin; Guevara, Marc; Peuch, Vincent-Henri; Rouil, Laurence; Engelen, Richard J.; Inness, Antje; Flemming, Johannes; Garcia-Pando, Carlos Pérez; Bowdalo, Dene; Meleux, Frederik; Geels, Camilla; Christensen, Jesper Heile; Christensen, Jesper H.; Gauss, Michael; Benedictow, Anna Maria Katarina; Tsyro, Svetlana; Friese, Elmar; Joanna Struzewska, Joanna; Kaminski, Jacek W.; Douros, John; Timmermans, Renske; Robertson, Lennart A.; Adani, Mario; Jorba, Oriol; Joly, Mathieu; Kouznetsov, Rostislav. Estimating lockdown-induced European NO2 changes using satellite and surface observations and air quality models. Atmospheric Chemistry and Physics; 2021; 21 p. 7373-7394 DOI: https://doi.org/10.5194/acp-21-7373-2021

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

Code	Country/Region/Source	Code	Country/Region/Source
AL	Albania	IS	Iceland
AM	Armenia	IT	Italy
AST	Asian areas	KG	Kyrgyzstan
AT	Austria	KZ	Kazakhstan
ATL	N.-E. Atlantic Ocean	LI	Liechtenstein
AZ	Azerbaijan	LT	Lithuania
BA	Bosnia and Herzegovina	LU	Luxembourg
BAS	Baltic Sea	LV	Latvia
BE	Belgium	MC	Monaco
BG	Bulgaria	MD	Moldova
BIC	Boundary/Initial Conditions	ME	Montenegro
BLS	Black Sea	MED	Mediterranean Sea
BY	Belarus	MK	North Macedonia
CH	Switzerland	MT	Malta
CY	Cyprus	NL	Netherlands
CZ	Czechia	NO	Norway
DE	Germany	NOA	North Africa
DK	Denmark	NOS	North Sea
DMS	Dimethyl sulfate (marine)	PL	Poland
EE	Estonia	PT	Portugal
ES	Spain	RO	Romania
EU	European Union (EU27)	RS	Serbia
EXC	EMEP land areas	RU	Russian Federation
FI	Finland	SE	Sweden
FR	France	SI	Slovenia
GB	United Kingdom	SK	Slovakia
GE	Georgia	TJ	Tajikistan
GL	Greenland	TM	Turkmenistan
GR	Greece	TR	Turkey
HR	Croatia	UA	Ukraine
HU	Hungary	UZ	Uzbekistan
IE	Ireland	VOL	Volcanic emissions

M. Bressi, F. Cavalli, J.P. Putaud, R. Fröhlich, J.-E. Petit, W. Aas, M. Äijälä, A. Alastuey, J.D. Allan, M. Aurela, M. Berico, A. Bougiatioti, N. Bukowiecki, F. Canonaco, V. Crenn, S. Dusanter, M. Ehn, M. Elsasser, H. Flentje, P. Graf, D.C. Green, L. Heikkinen, H. Hermann, R. Holzinger, C. Hueglin, H. Keernik, A. Kiendler-Scharr, L. Kubelová, C. Lunder, M. Maasikmets, O. Makeš, A. Malaguti, N. Mihalopoulos, J.B. Nicolas, C. O'Dowd, J. Ovadnevaite, E. Petralia, L. Poulain, M. Priestman, V. Riffault, A. Ripoll, P. Schlag, J. Schwarz, J. Sciare, J. Slowik, Y. Sosedova, I. Stavroulas, E. Teinemaa, M. Via, P. Vodička, P.I. Williams, A. Wiedensohler, D.E. Young, S. Zhang, O. Favez, M.C. Minguillón, A.S.H. Prevot, A European aerosol phenomenology - 7: High-time resolution chemical characteristics of submicron particulate matter across Europe. Atmospheric Environment: X, 10,100108, 2021, https://doi.org/10.1016/j.aeaoa.2021.100108.

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Associated EMEP reports and notes in 2022

Joint reports

Transboundary particulate matter, photo-oxidants, acidification and eutrophication components. Joint MSC-W & CCC & CEIP Report. EMEP Status Report 1/2022

EMEP MSC-W model performance for acidifying and eutrophying components, photo-oxidants and particulate matter in 2020. Supplementary material to EMEP Status Report 1/2022

Assessment of heavy metals and POP pollution on global, regional and national scales. Joint MSC-E & CCC & CEIP & IMT & CIEMAT & INERIS &ENEA &FMI Report. EMEP Status Report 2/2022

CEIP Technical and Data reports

Bradly Matthews, Robert Wankmueller. Methodologies applied to the CEIP GNFR gap-filling 2022 Part I: Main pollutants, Particulate Matter and BC (NOx, NMVOCs, SOx, NH3, CO, PM2.5, PM10, PMcoarse, BC), Technical Report CEIP 1/2021

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Sabine Schindlbacher, Bernhard Ullrich. Methodology report, Technical Report CEIP 03/2022

Stephan Poupa. Methodologies applied to the CEIP GNFR gap-filling 2022 Part II: Heavy Metals and POPs (Pb, Cd, Hg, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, Total polycyclic aromatic hydrocarbons, Dioxin and Furan, Hexachlorobenzene, Polychlorinated biphenyls), Technical Report CEIP 04/2022

Sabine Schindlbacher, Bradly Matthews, Bernhard Ullrich. Uncertainties in emission inventories submitted under CLRTAP, Technical Report CEIP 05/2022

CCC Technical and Data reports

Anne-Gunn Hjellbrekke. Data Report 2020. Particulate matter, carbonaceous and inorganic compounds. EMEP/CCC-Report 1/2022

Anne-Gunn Hjellbrekke and Sverre Solberg. Ozone measurements 2020. EMEP/CCC-Report 2/2022

Wenche Aas and Pernilla Bohlin Nizzetto. Heavy metals and POP measurements 2020. EMEP/CCC-Report 3/2022

Sverre Solberg, Anja Claude and Stefan Reimann. VOC measurements 2020. EMEP/CCC-Report 4/2022

MSC-W Technical and Data reports

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Part I

Status of air pollution

CHAPTER 2

Status of transboundary air pollution in 2020

Svetlana Tsyro, Wenche Aas, Sverre Solberg, Anna Benedictow, Hilde Fagerli, Jan Eiof Jonson and Ágnes Nyíri

This chapter describes the status of transboundary air pollution in 2020. A short summary of the meteorological conditions is presented, the EMEP network of measurements and the EMEP MSC-W model set up is briefly described. Thereafter, the status of air pollution in 2020 is discussed.

2.1 Meteorological conditions in 2020

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 2020 with respect to these two parameters, based on NWP model results and as reported by the meteorological institutes in European and EECCA countries, is given below.

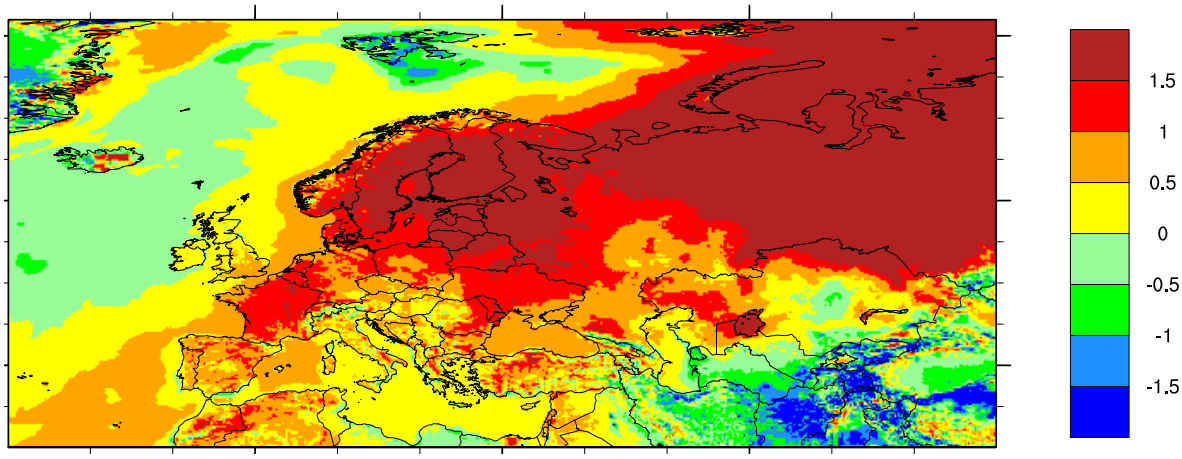
The meteorological data to drive the EMEP MSC-W air quality model have been generated by the Integrated Forecast System (IFS) model of the European Centre for Medium-Range Weather Forecasts (ECMWF), hereafter referred to as the ECMWF-IFS model. In the meteorological community, the ECMWF-IFS model is considered to be 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 46r1 is the version used for the year 2020 model runs. In the following section, temperature and precipitation in 2020 are compared to the 2000-2019 average based on the same ECMWF-IFS model setup. Meteorological data for the years 2000 to 2018 have been derived from the IFS Cycle 40r1 version and 2019 from IFS Cycle 46r1.

2.1.1 Temperature and precipitation

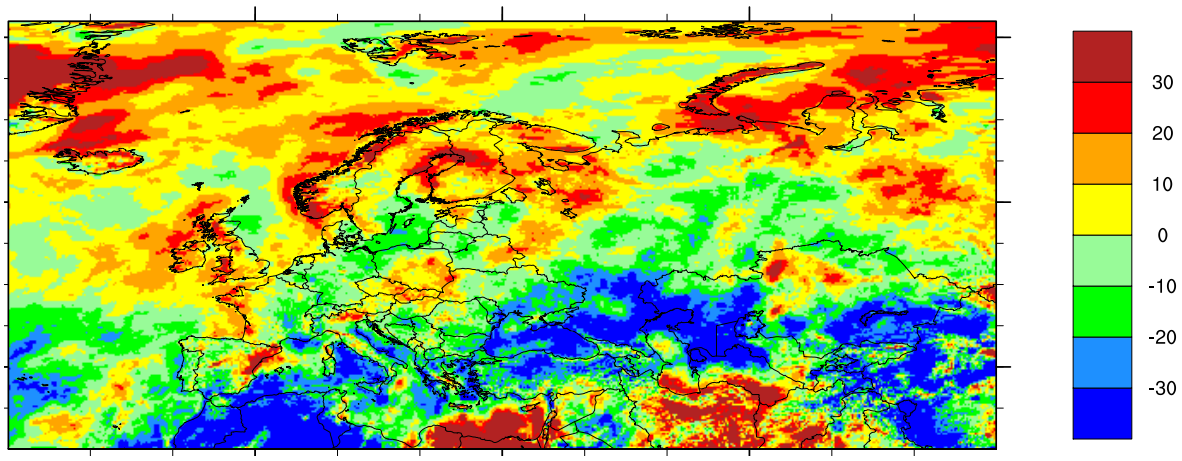
Globally, 2020 was reported by the World Meteorological Organisation (WMO 2021) as one of three warmest years on record. The annual temperature for Europe in 2020 was the high-

est on record according to Copernicus European State of the Climate 2020[1] and for Arctic lands, October 2019 to September 2020 was the second warmest period of the last century (Arctic Report Card 2020 Ballinger et al. 2020. Parts of Arctic and northern Siberia reported remarkably warm temperatures for the first half part of the year.

Global monitoring products reported in BAMS State of the climate 2020 (Regional climates 2020, Bissolli et al. 2021) indicate that global precipitation was near or above the 1981-2000 long-term average. Precipitation amounts across Europe were near normal, however with some seasonal local/regional extreme precipitation events or deficit as reported in the Copernicus and the BAMS climate reports.



(a) Δtemperature at 2m (2020-climavg)



(b) Δprecipitation (2020-climavg)

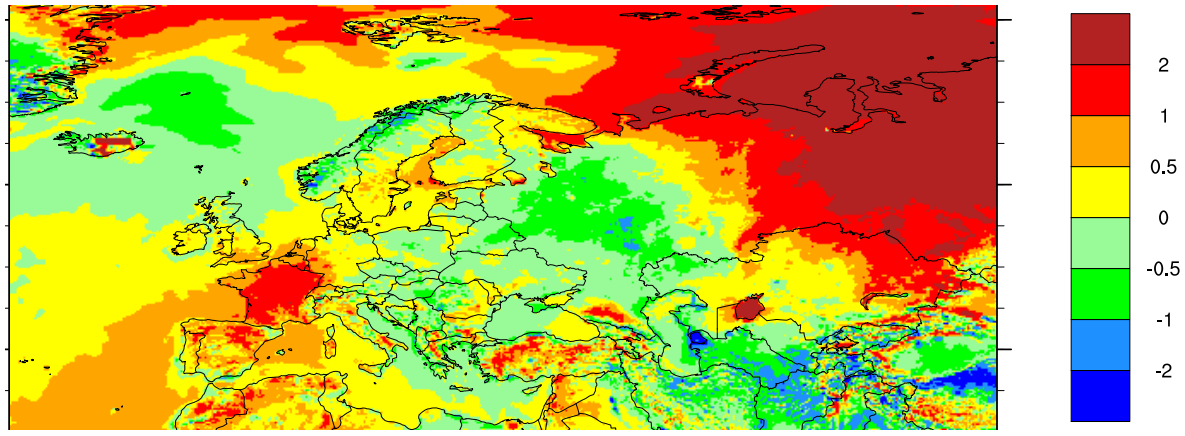
Figure 2.1: Meteorological conditions in 2020 compared to the 2000-2019 average (climavg) for: a) Annual mean temperature at 2m [K] and b) Annual precipitation [%]. The meteorological data have been calculated with the ECMWF-IFS model.

In Figure 2.1a) higher temperatures in 2020 compared to the 2000-2019 average are seen over all of Europe, with particularly high temperatures in northern Europe, most of Russia, and also in France, Benelux and eastern Europe. In fact, almost all European countries reported that 2020 was among the warmest years on record, except for Portugal, southern Spain, parts

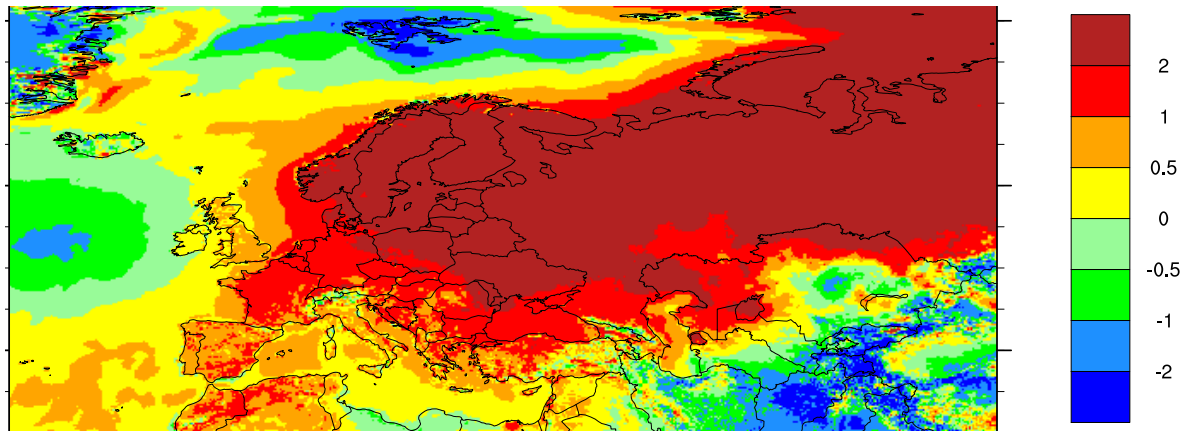
[1] https://climate.copernicus.eu/esotc/2020

of Italy, Ireland and northern United Kingdom. 2022 was the warmest year on record for Finland (since mid-19th century), Sweden (since 1860), Estonia (since 1866), France (since 1900), Netherlands (since 1901), Switzerland (together with 2018 since 1864) and for European Russia, as winter, spring and autumn were warmest for Russia, particularly in Arctic Siberia.

With respect to the 2000-2019 average, larger amount of precipitation in 2020 (Figure 2.1b) are seen in the northern and central parts of European Russia, the Nordic countries, Iceland, Ireland, the United Kingdom, in Central Europe (except from Germany), and also western France and eastern Spain. For Norway, 2020 was the second wettest year on record. The year of 2020 was particular dry in the east of Ukraine, southern parts of European Russia, Georgia, western parts of Central Asia, Turkey and Greece. The rest of Europe also received less precipitation relative to the mean during the reference period of 2000-2019.



(a) Δtemperature at 2m (AprSep 2020-climavg)



(b) Δtemperature at 2m (OctMar 2020-climavg)

Figure 2.2: Meteorological conditions in 2020 compared to the 2000-2019 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 2020 compared to the 2000-2019 average in Europe for the summer months (April through September) and the winter months (October through December and January through March). The summer period were warmest in western Europe, the Asian part of Russia and Kazakhstan, close to the 2000-2019 reference in central

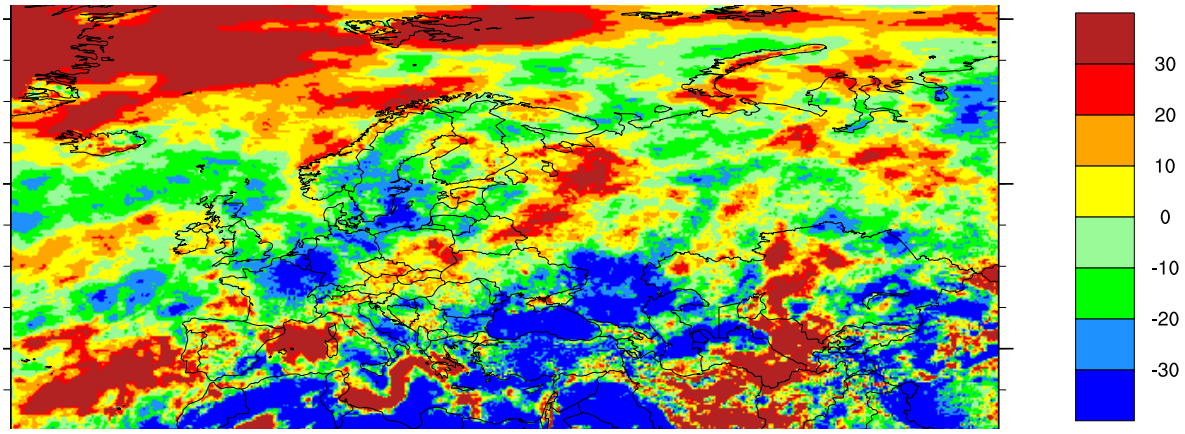
and southern Europe and relatively colder in the north of Scandinavia, eastern Europe, the European part of Russia, and Turkmenistan (see Figure 2.2a). Spring was warmer than usual in western Europe, particularly for France it was the second warmest on record and May was the warmest month on record for both Spain (since 1965) and Portugal, while central Europe had close to normal temperatures. The spring season ended with low temperatures and overall normal temperatures during summer were reported for eastern Europe and the European part of Russia. Though summer temperatures were overall near normal in most of Europe, some local periodical extremes occurred, as a heatwave over Scandinavia in June, whilst July was the warmest on record in Portugal and third warmest in Spain. France experienced its third warmest August (after 2003 and 1997) in a record dating back to 1900 and second warmest for Germany (since 1881). The average temperature at Uccle was the second warmest for the month in a similarly long record. Many countries experienced a lengthy heatwave during the last days of July and the first half of August. For example, the maximum temperature at Uccle exceeded 30°C for eight days in a row. The heatwave affected the Benelux countries, the south-east UK, and parts of France. It was characterized by very hot airmasses from the south moving into the area ahead of a cold front located west of the UK. The surface temperatures exceeded 35 C over a large region, with maxima of 36.4 C at Heathrow, London, on 7 August, 35.9 C at Uccle, Belgium and peaking at 38.2 C in Paris on 9 August. (See also https://climate.copernicus.eu/surface-air-temperature-august-2020 for a description of this heatwave). September was the warmest month in 50 years for Turkey (since 1971) and warmest on record for Belarus, Romania and Ukraine.

As shown in Figure 2.2b) winter temperatures were higher than the 2000-2019 average in virtually all of Europe, particularly in northern and eastern Europe including Russia. For the first months of 2020 most European countries reported their warmest winter on record, except for Iceland, Ireland and northern United Kingdom. Winter 2019/20 was the warmest on record for France (since 1900), Denmark (since 1874), Poland (since 1851) and Norway (since 1900). Spain reported its warmest February (together with 1990, since 1965) and second warmest for Germany (since 1881), Slovenia, Switzerland (since 1864). Autumn was reported as warmest for Turkey (since 1971), fourth warmest for Norway (since 1900) and Denmark (since 1874), and fifth for France since 1900. October was record warm for Romania (second warmest), European Russia, Belarus, Ukraine (fifth warmest), Moldova (fifth warmest) and Turkey (since 1971). For Sweden November was warmest since 1860, but also warm for Switzerland, Poland (fifth warmest), Estonia, Denmark (second warmest since 1874), Lithuania, Spain (third warmest since 1961), Italy, Albania and Montenegro. The year ended with record warm temperatures in central Siberia.

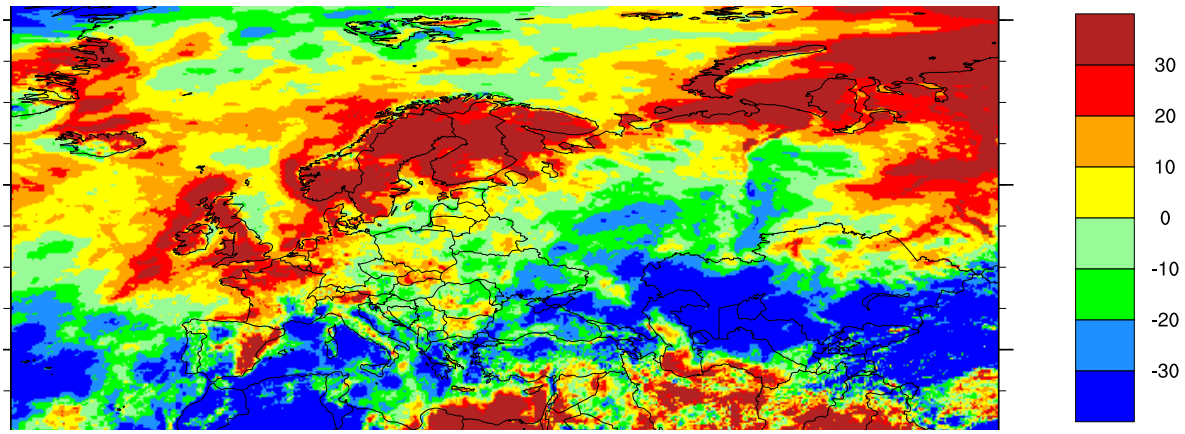
For the summer half-year, i.e. April through September, Figure 2.3a) shows that Europe in general had much less precipitation in 2020 relative to the 2000-2019 average, except for central European countries (apart from Germany), parts of Baltic countries, central Russia, Turkmenistan, Uzbekistan. Poland reported their second driest April in the last 55 years. Spring 2020 was rather dry in many areas. Many parts of the United Kingdom had less than 50 % of their climatological normal (i.e. 1981-2010 mean) spring rainfall and England had its driest May on record since 1896, contributing to the fifth driest springs on record for the UK overall. Furthermore, the spring 2020 was among the six driest since 1881 for Germany, and third driest in Hungary since the 20th century, but also very dry for Sweden, Denmark, Latvia, Lithuania, Estonia, Switzerland and France. Central European Russia reported their third wettest spring on record (since 1936). In summer, it was wetter than climatologically normal for the United Kingdom and Ireland, and June was reported as the second wettest

of the last 55 years for Poland, but July the driest for France (since 1959), second driest for Luxembourg and fifth driest on record for Belgium. Autumn was dry for France and particularly eastern Ukraine, southern European Russia and Turkey; also the South Caucasus was dry for the season.

As shown in Figure 2.3b), the 2020 winter period (January-March and October-December) was wetter than the 2000-2019 average for northern Europe and central/western European countries north of the Alps, while western Iberian Peninsula, eastern Europe, central/eastern Mediterranean and Balkan countries received less relative to the 2000-2019 average precipitation. Winter 2019/20 was second wettest for Germany (since 1881), Denmark (since 1874) and Norway (since 1900). Particularly February was the fourth wettest on record since 1924 for Latvia, second wettest for Ireland (since 1850) and for Germany (since 1881), and wettest for Denmark (since 1874) and the United Kingdom (since 1862). November was second wettest since 1956 for France, but very dry for Germany, Austria, Switzerland and Hungary. And December was very wet across most of western Europe, parts of northern Europe, in the south-east of Spain, in central Mediterranean areas and the wettest month on record since 1928 for Iceland, but very dry in south-western Iberia, parts of central Europe, much of eastern Europe and Turkey.



(a) Δprecipitation (AprSep 2020-climavg)

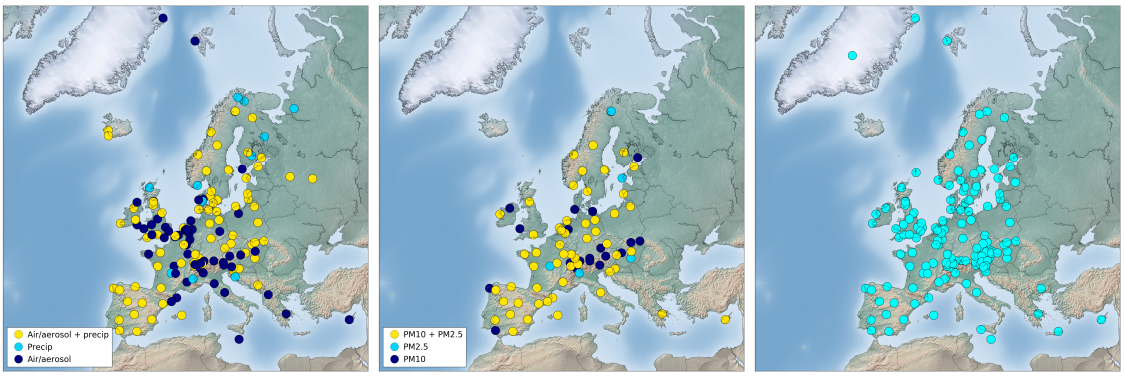


(b) Δprecipitation (OctMar 2020-climavg)

Figure 2.3: Meteorological conditions in 2020 compared to the 2000-2019 average (climavg) for: a) Summer (April-September) precipitation [%], b) winter (January-March and October-December) precipitation [%]. The meteorological data have been calculated with the ECMWF-IFS model.

2.2 Measurement network 2020

In 2020, a total of 33 Parties reported measurement data of inorganic components, particulate matter and/or ozone to EMEP from altogether 173 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 2022, Hjellbrekke and Solberg 2022). 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 2020.



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

Figure 2.4: EMEP measurement network for level 1 components in 2020.

140 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 73 sites with measurements in both air and precipitation. Ozone was measured at 139 EMEP sites.

There were 81 sites measuring either PM_{10} or $PM_{2.5}$ mass. 54 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 9.2 in Ch 9.1, along with a discussion on compliance with the monitoring obligations and the development of the programme during the last decade.

The number of sites is marginally higher compared to 2019.

2.3 Setup for EMEP MSC-W model runs

The EMEP MSC-W model version rv4.45 has been used for the 2020 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 2020 have been used as input. Meteorological data have been derived from ECMWF-IFS(cy46r1) simulations (see Ch 2.1). The land-based emissions have been derived from the 2022 official data submissions to UNECE CLRTAP (Schindlbacher et al. 2022), as documented in Ch 3. In model simulations for 2020 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 partly substituted by an emission dataset provided by TNO for 2019, the Ref2_v2.1 emission dataset, which is shortly described in Ch 3.3.1 and documented in more detail in Simpson et al. (2022) and Kuenen et al. (2022). The dataset by TNO represents the best-to-date available estimate of residential combustion emissions of PM, accounting for condensable organics in a consistent way. 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) (Wiedinmyer et al. 2011), version 5. For more details on the emissions for the 2020 model runs see Ch 3 and Appendix A.

The effects of socio-economic activity restrictions due to COVID-19 pandemic on emission temporal profiles in 2020 were accounted for based on estimates by Guevara et al. (2022b). Daily Adjustment Factors to 2020 emissions from the publicly available CAMS-REG_EAF-COVID19 dataset were combined with GENEMIS monthly and day-of-the-week emission time factors (Friedrich and Reis 2004) to create day-of-the-year emission time factors for 2020. For NH_3 emissions monthly time profiles from the LOTOS model were used instead of GENEMIS profiles. The adjustments to emission profiles were applied on a country and activity sector basis for each individual pollutant (for more details see Appendix H). The resulting day-of-the-year time profiles, accounting for COVID-19 effects, were used in Status (henceforth referred to as Base run) and Source-Receptor runs for 2020.

In order to make a quantitative estimate of the impact of COVID-19 restrictions on air pollution levels, in addition to the Base model run a "Business-As-Usual" (BAU) run have been performed for the meteorological conditions of 2020, in which 2019 emissions as reported in 2022 and GENEMIS time profiles were used. However, in order to take into account the global reduction of maximum sulphur content in ship fuels from 3.5% to 0.5%, which came into force on 1 January 2020, PM and SO_x emissions from international shipping were taken from the 2020 emission data set.

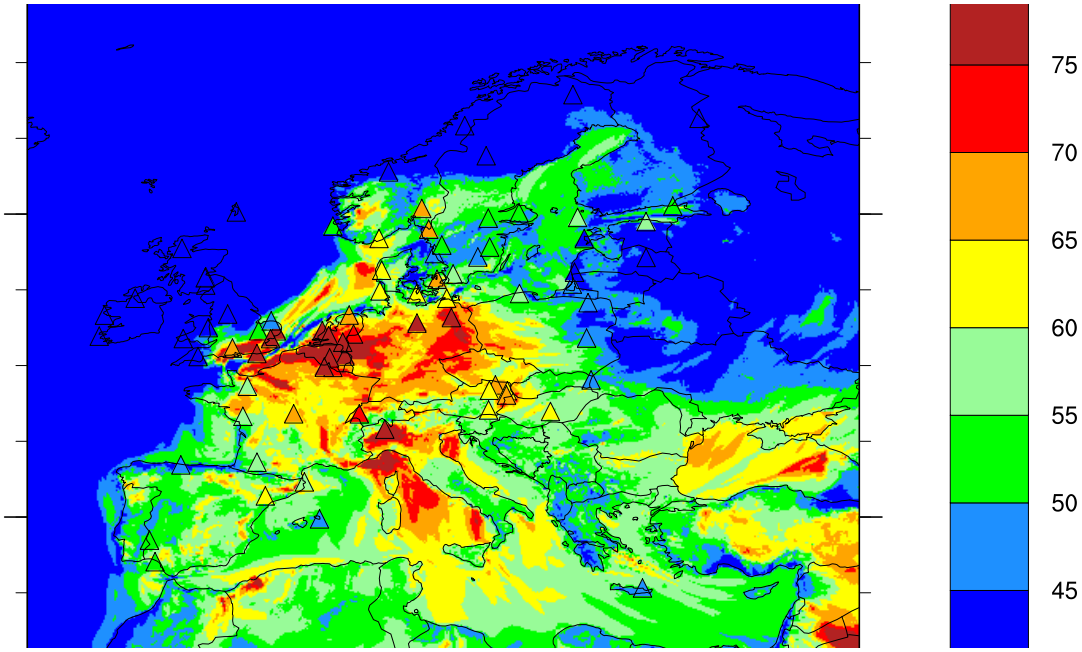
2.4 Air pollution in 2020

2.4.1 Ozone

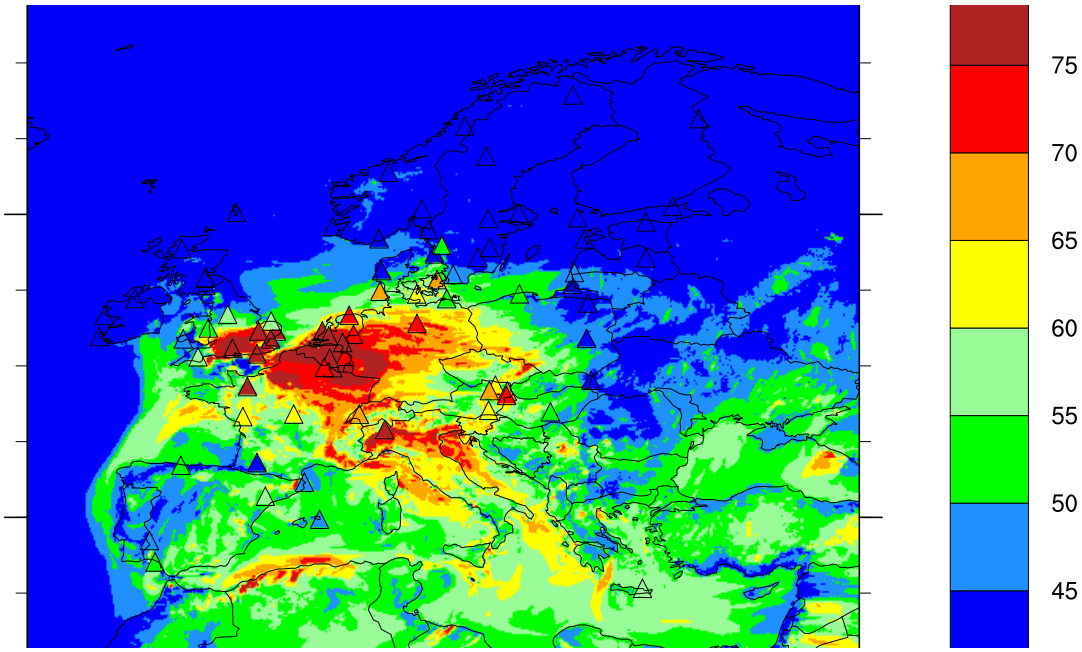
The ozone observed at a surface station is the net result of various physio-chemical processes: surface dry deposition and uptake in vegetation, titration by nearby NO_x emissions, regional photochemical ozone formation and atmospheric transport of background ozone levels, each of which may have seasonal and diurnal systematic variations. Episodes with elevated levels of ozone are mainly observed during the summer half year when certain meteorological situations (dry, sunny, cyclonic stable weather) promote the formation of ozone over the European continent. In particular there is a clear link between the increase in frequency and intensity of heatwaves in Europe and peak levels of surface ozone. Peak ozone episodes are now more frequent than in an otherwise stable climate (Solberg et al. 2008, Otero et al. 2016, Zhang et al. 2018).

The year 2020 was, however, a fairly modest year with regard to ozone episodes. Many metrics for high ozone levels were lower in 2020 compared to previous years, especially for the region of Austria, Switzerland, and Northern Italy. The most marked ozone episode in Europe occurred in the Benelux region and south-east UK at the end of July and in the first half of August. The August period coincided with the heatwave in this region described in

section 2.1.1. Surface ozone peaked at 112 ppb at De Zilk, the Netherlands on 7 August, 106 ppb at Vezin, Belgium, on 12 August and 109 and 108 ppb at St Osyth and Sibton in the UK, respectively, on 31 July. Figure 2.5 a) and b) shows the measured and modelled mean of daily max. ozone levels (MDmaxO3, see Ch. 1.2) on 8 and 10 August. The geographical distribution and the general concentration levels at the measurement sites are seen to be reproduced closely by the model for these two days, with the peak area over Benelux and south-east UK, even extending southwards into France, Germany and Northern Italy although at somewhat lower levels.



(a) Ozone Aug. 8 2020



(b) Ozone Aug. 10 2020

Figure 2.5: Modelled and measured MDmaxO3 [ppb] 8 August (a) and 10 August (b) 2020.

The covid-19 restrictions affected the emissions of ozone precursors in 2020. Based on the emission reductions between 2019 and 2020 (see Appendix A), a rough estimate indicates that in most European countries these reductions corresponded to the reductions achieved over the course of the last 3 to 4 years. However, most of these reductions were confined to the late Winter/Spring months. As noted in Chapter 3.5.2, an estimate of the emissions in 2020 was made using a combination of national reported annual emissions and daily emission reduction factors from Guevara et al. (2022a). Unfortunately, some inconsistencies were found when merging these data sets, which are particularly apparent in the summer months. Given the sensitivity of ozone concentrations (and especially peak-associated metrics such as SOMO35 or POD) to emissions in these summer months, we do not present a comparison of the Base model calculations (with covid-19 restrictions) to the BAU temporal emission scenario in this report.

Figure 2.6 shows three different model calculated ozone metrics with corresponding measured values (from the EMEP measurement sites) plotted on top for year 2020. Only measurement sites located below 500 metres above sea level are included, in order to avoid uncertainties related to the extraction of model data in regions with complex topography. The metrics shown in Figure 2.6 are (a) MDmaxO3 (= mean of the daily max ozone concentration) for the 6-month period April-September, SOMO35 (= Sum of Ozone Means Over 35 ppb, an indicator for health effects recommended by the World Health Organization), and EU-AOT40f (AOT40 for forests calculated using EU definitions). The EU definition of AOT40 is used since it is based upon O_3 at observational height, or from the model's 3 m (above the displacement height) concentrations, and these two levels are roughly comparable. (See also Ch. 1.2).

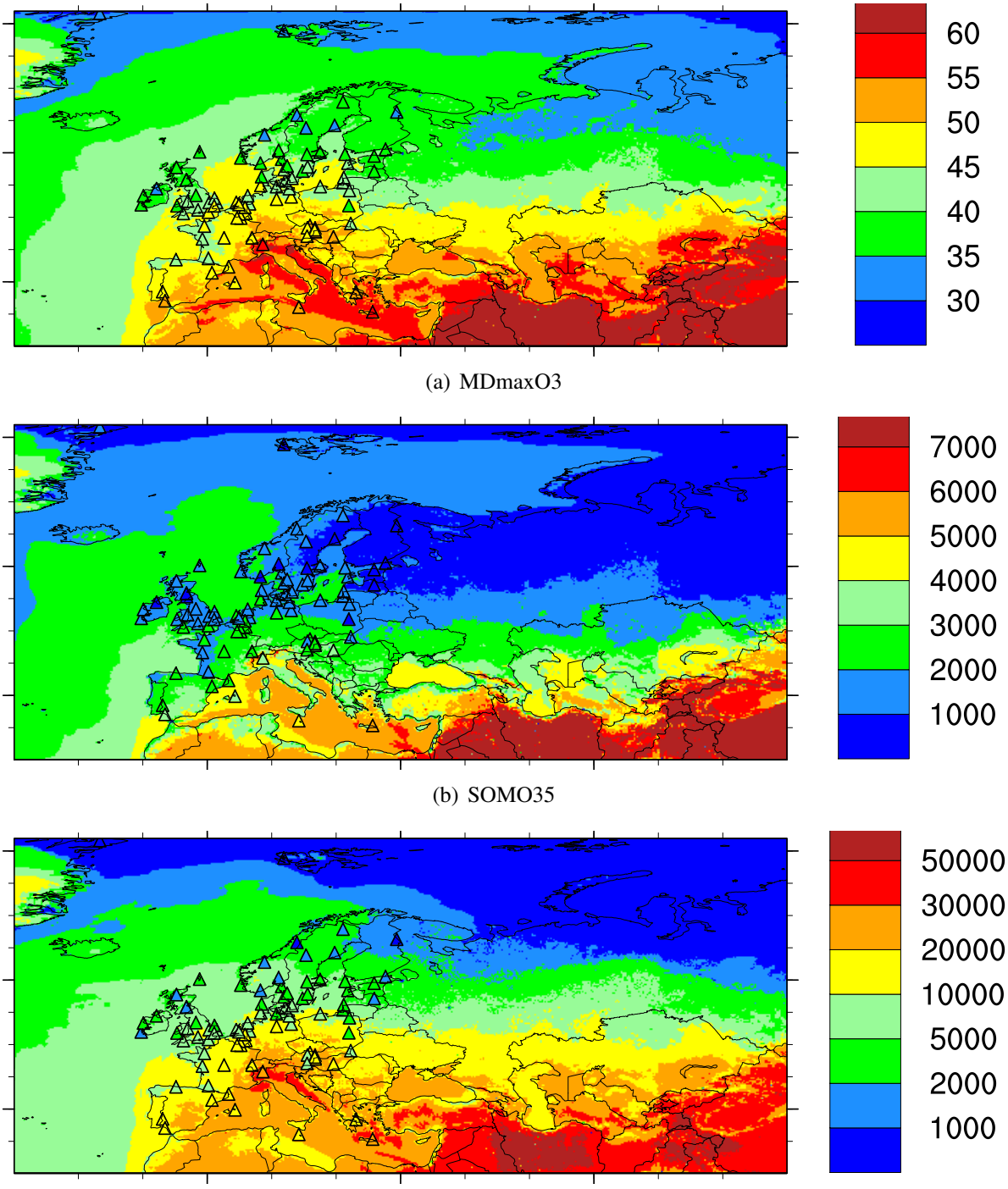
Figure 2.6 shows that the agreement between modelled and measured ozone metrics is generally good. The model and the measurements show an increasing gradient from north to the south-east as expected, which reflects the strong dependency between surface ozone, temperature and solar radiation.

Although AOT40 (especially using the Mapping Manual definition) has been used as an indicator of ozone damage vegetation in the past, the preferred metric in recent years has been phyto-toxic ozone dose, POD.

POD calculates the actual flux of ozone into the plants, by taking into account soil moisture deficit and other environmental factors. To control their water balance, plants regulate their stomata opening depending on the soil moisture. In dry conditions the plants tend to close the stomata opening, effectively also limiting the uptake of ozone. This is believed to give a more accurate description of how and when plants are damaged by ozone (Simpson et al. 2007, Mills et al. 2011, 2018). The biggest disadvantage of POD is that it cannot be verified by routine measurements. As noted on Ch. 1.2, POD_1 is the phyto-toxic ozone dose above a threshold 1 nmol m^{-2} s^{-1}.

Figure 2.7 shows POD_1 for forests (for the generic IAM_DF ecosystem, c.f. Ch. 8.2). For POD_1 the limit value depends on the species. For the generic IAM_DF ecosystem used here, the critical level is 5.7 mmole O_3 m^{-2} (PLA) s^{-1}, and this is exceeded almost everywhere. (See Ch. 8.2.6 for further examples).

Whereas AOT40 simply reflects the ozone concentrations in the selected months, resulting in 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 the central, dryer parts of Europe just where high values of AOT40 are seen - as expected from the impact of the soil moisture, humidity, and other environmental factors on POD as discussed above.



(a) MDmaxO3

(b) SOMO35

(c) EU-AOT40f

Figure 2.6: Model results and observations at EMEP stations (triangles) for (a) mean of daily maximum ozone concentrations (MDmaxO3, *ppb*), Apr-Sep), (b) SOMO35 (*ppb.d*) and (c) EU-AOT40f (*ppb.h*) in 2020. Only data from measurement sites below 500 m a.s.l. are shown.

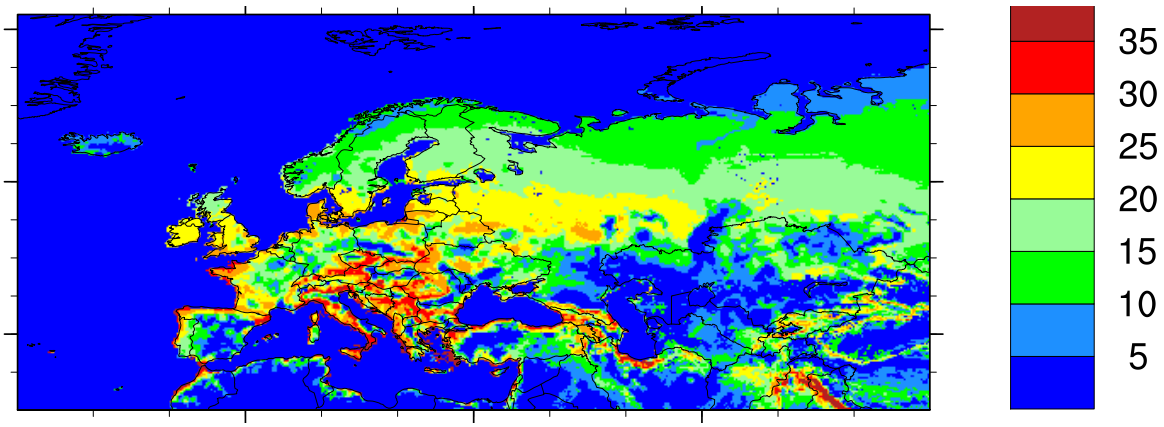


Figure 2.7: Model results of POD_1 for forests [mmol m^{-2}] in 2020.

2.4.2 Particulate Matter

Maps of annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2020, 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, which are represented by colour triangles overlaying the contours of the modelled concentration fields.

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. PM_{10} concentrations are below 2-5 μg m^{-3} in Northern Europe, increasing to 5-15 μg m^{-3} in the mid-latitudes and further south. $PM_{2.5}$ follows in general the same spatial pattern, with concentration levels being somewhat lower with respect to PM_{10}. Figure 2.8 displays fairly homogeneous modelled levels of regional background PM over most of Central and Western Europe, with PM_{10} in excess of 20 μg m^{-3} in the Po Valley, parts of Balkan and in the east of Mediterranean region. The highest annual mean PM_{10} (just above 20 μg m^{-3}) was observed at Melpitz (south-eastern Germany). $PM_{2.5}$ concentrations are below 10 μg m^{-3} over most of EMEP domain (except the most south/south-eastern regions), showing a few hot spots (between 10 and 15 μg m^{-3}) in the Po valley, some parts of Balkan and Turkey. Same as for PM_{10}, the highest annual mean $PM_{2.5}$ (16.3 μg m^{-3}) was registered at Melpitz. Furthermore, the model simulates 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}. These high PM concentrations are due to windblown dust from the arid soils and deserts of Central Asia, though the precision of the calculated values still cannot be verified due to the lack of observations in these regions.

There is a good agreement between the modelled and EMEP observed distributions of annual mean PM_{10} and $PM_{2.5}$, with correlation coefficients of 0.75 and 0.73, respectively. Overall, the model underestimates the observed annual mean of PM_{10} by 27% and $PM_{2.5}$ by 17%. Compared to observations at rural sites from the EEA AQ e-reporting database, the model's biases are -29 and -16 % and correlation coefficients are 0.68 and 0.86 for PM_{10} and $PM_{2.5}$ respectively. A more detailed comparison between model and measurements for the year 2020 can be found at https://aeroval.met.no/evaluation.php?project=emep&exp_name=2022-reporting.

The levels of PM air pollution are determined by the amount of emissions and meteorological conditions. Typically, the changes in national emissions are mostly small to moderate

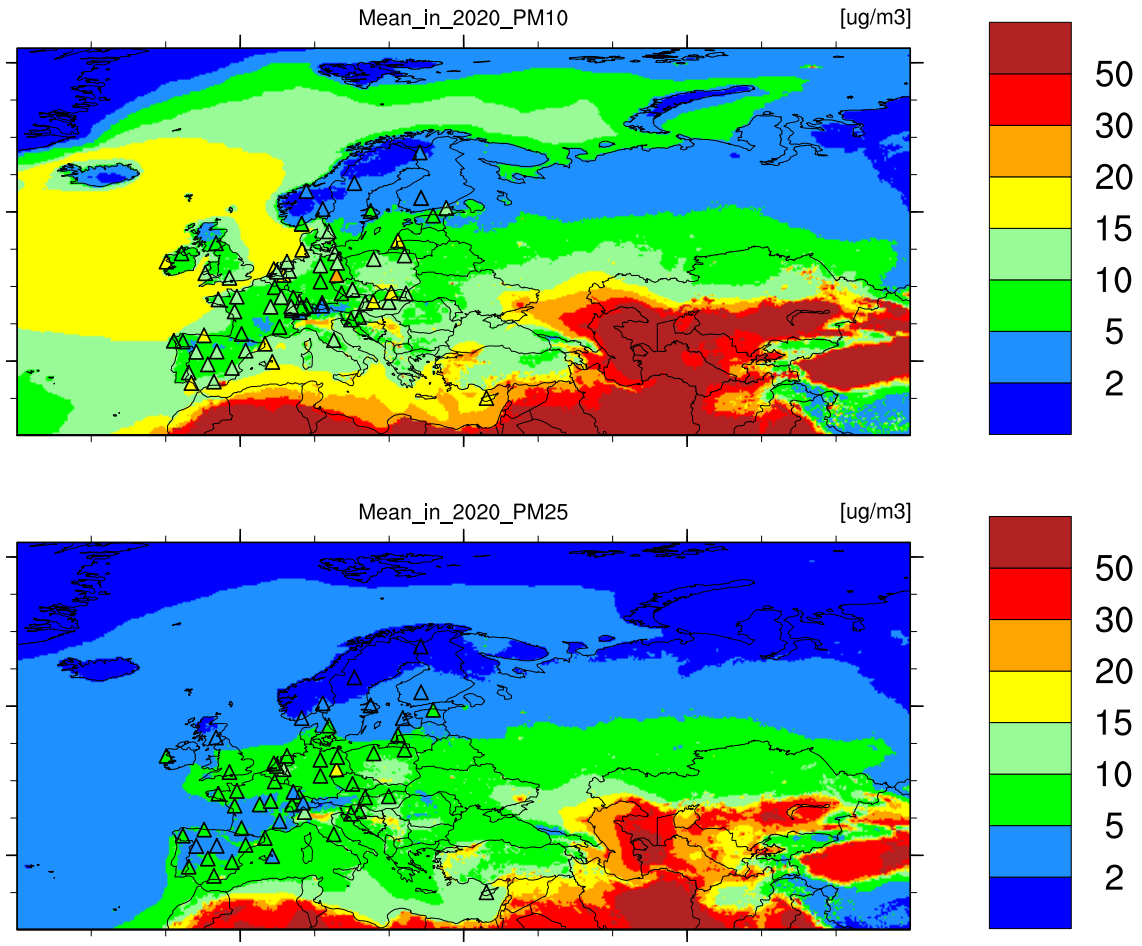


Figure 2.8: Annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2020: calculated with the EMEP MSC-W model (colour contours) and observed at EMEP monitoring network sites (colour triangles).

from year to year (with the exceptions of cases of major revisions in the reported values), thus the inter-annual variability in meteorology drives differences in PM concentrations. However, the year of 2020 was a special case due to COVID-19 pandemic and dramatic restrictions on socio-economic activity which brought about reductions in anthropogenic emissions (see 3). To make an estimate of the effect of emission reduction due to COVID-19 restrictions on PM pollution, we compare modelled PM concentrations obtained from the 2020 status run and Business-as-Usual (BAU) run (for 2020 meteorological conditions using 2019 emissions - assuming that most of the changes in emissions from 2019 to 2020 were due to COVID-19 restrictions). There is some inconsistency between the temporal variation of BAU emissions and COVID-19 adjusted 2020 emissions, as the COVID-19 adjustment factors were derived based on the different emission dataset (i.e. CAMS-REG_v5.1 2020).

The results indicate 1-10% lower annual mean PM_{10} due to COVID-19 restrictions over most of Europe (Figure 2.9), with the largest decreases exceeding 10% in the Po Valley and eastern parts of France. The pattern of COVID-19 restrictions impacts is similar for $PM_{2.5}$, with overall slightly larger concentration decreases (due to a larger contribution of anthropogenic vs. natural aerosols). The only country with higher modelled PM in 2020 despite COVID-19 restrictions is Serbia, which reported larger emissions in 2020 compared to 2019 (used in the BAU scenario) for SO_x, NH_3, and especially for PM_{10} and $PM_{2.5}$.

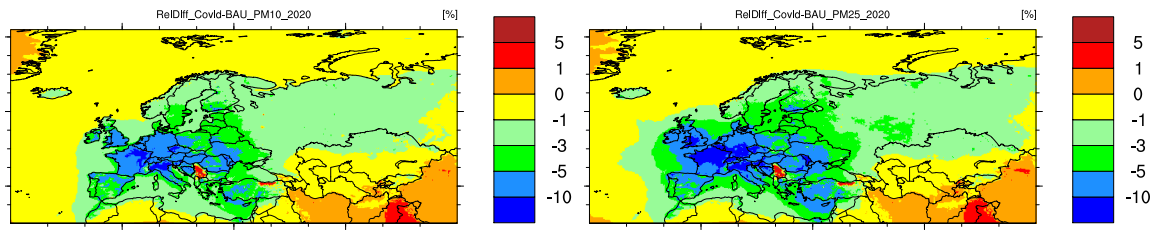


Figure 2.9: Relative differences in PM_{10} and $PM_{2.5}$ in 2020 due to COVID-19 restriction measures with respect to a BAU scenario (EMEP MSW-W model simulations with 2020 meteorology and 2019 emissions.

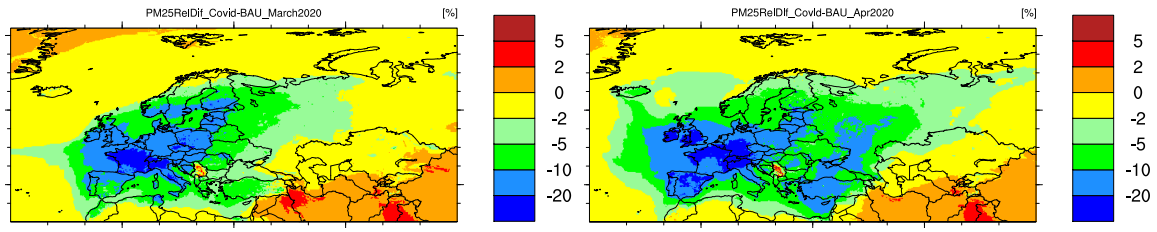


Figure 2.10: Relative differences in $PM_{2.5}$ due to COVID-19 restriction measures with respect to a BAU scenario for March and April 2020.

In most of EMEP countries, COVID-19 restrictions were imposed from middle/second part of March. Figure 2.10 shows COVID-BAU relative differences in monthly mean $PM_{2.5}$ concentrations for March and April. As the model results indicate that due lockdowns and other activity restrictions caused 10-20% lower $PM_{2.5}$ over most of western/central Europe and in the southern parts of Nordic countries. The largest reductions of $PM_{2.5}$, exceeding 20%, are modelled over France and northern Italy in March, and also for Switzerland, parts of Germany and Austria, southern half of the UK and Ireland. The effect of COVID-19 restrictions in March-April 2020 on PM levels (especially for PM_{10}) due to the drop in the anthropogenic emissions was masked to some extend in south-eastern Europe (due to mineral dust episodes) and in northern Europe (enhanced road dust levels due road salting/sanding and the use of studded tyres in wintertime) https://policy.atmosphere.copernicus.eu/reports/CAMS71_COVID_20200626_v1.3.pdf.

Exceedances of EU limit values and WHO Air Quality Guidelines in 2020

In this section, we present a brief discussion of the status of European air quality in 2020 for PM_{10} and $PM_{2.5}$ with respect to EU critical limits and WHO Air Quality Guidelines (AQG). Our assessment is based on PM concentrations from EMEP MSC-W model simulations and observations at EMEP sites. The new in this year report is that for annual mean $PM_{2.5}$ we apply a Stage 2 limit value of 20 μg m^{-3} (update from 25 μg m^{-3}), which was to be met as of 1 January 2020 (https://www.eea.europa.eu/ims/exceedance-of-air-quality-standards). Also in addition to WHO AQG Global Update 2005 (AQG-2005) (WHO 2005), we compare the modelled and observed PM with recently updated AQG, i.e. Global Update 2021 (AQG-2021) (WHO 2021). The WHO AQG offer health-based recommendations for air quality management, i.e. the lowest levels of exposure for which there is evidence of adverse health effects. Though not being legally binding standards, these guidelines provide WHO Member States with a valuable evidence-informed tool that they can use to inform legislation and

policy. Table 2.1 summarizes EU and WHO AQG limit values for PM_{10} and $PM_{2.5}$, relevant for air quality assessment for the year 2020.

Table 2.1: EU limit values and WHO Air Quality Guidelines Global Update 2005 (AQG-2005) and Global Update 2021 (AQG-2021) for PM_{10} and $PM_{2.5}$.

Limits	PM_{10} (μg m^{-3})		$PM_{2.5}$ (μg m^{-3})	
	Year	24-hour	Year	24-hour
EU	40	50[a]	20	-
AQG-2005	20	50[b]	10	25[b]
AQG-2021	15	45[c]	5	15[c]

[a] not more than 35 days per year
[b] 99th percentile (not more than 3 days per year)
[c] 99th percentile (i.e. 3–4 exceedance days per year)

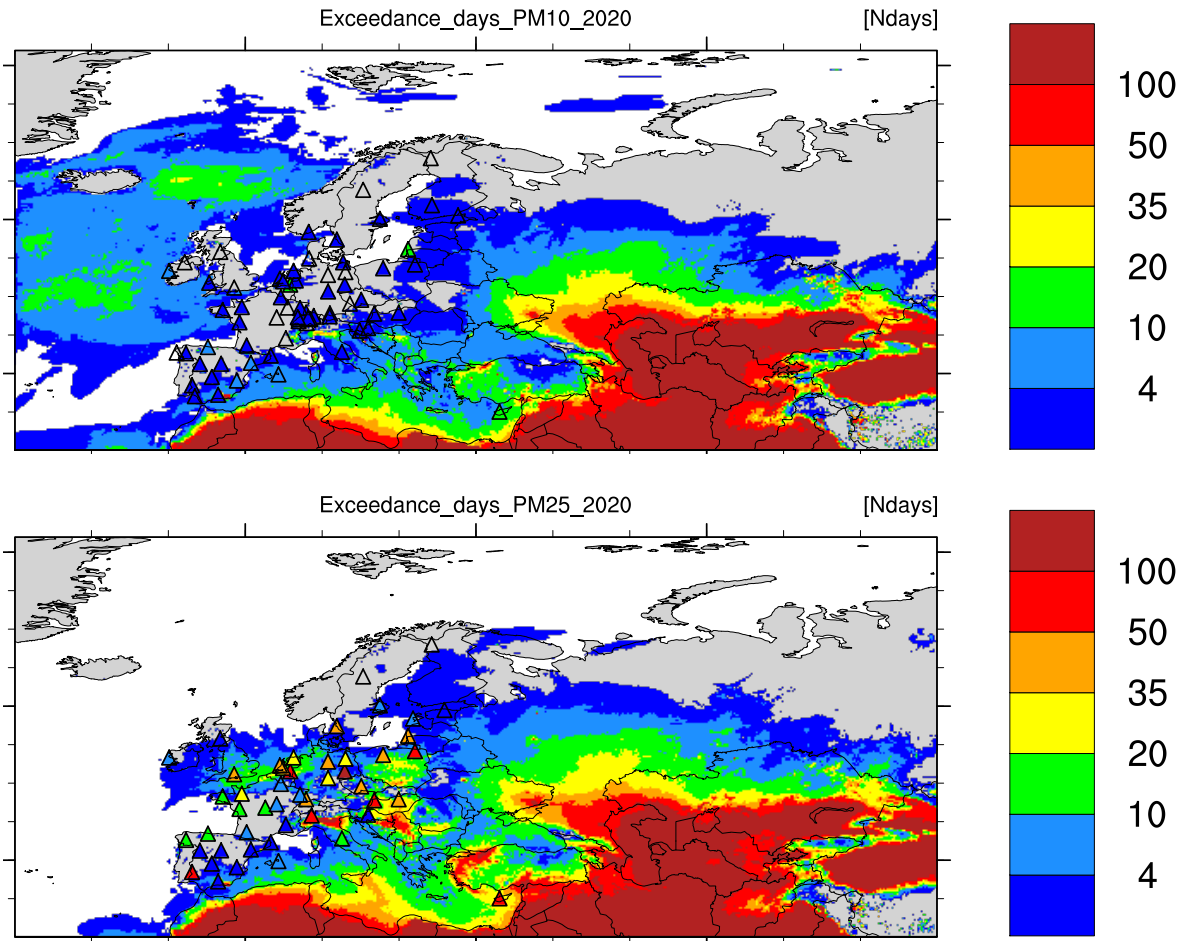


Figure 2.11: Modelled and observed (triangles) number of days with exceedances in 2020: PM_{10} exceeding 50 μg m^{-3} (upper) and $PM_{2.5}$ exceeding 25 μg m^{-3} (lower panel). *Note: The EU Directive requires no more than 35 days with exceedances for PM_{10}, whereas WHO Global Update 2005 recommended no more than 3 days with exceedances for PM_{10} and $PM_{2.5}$ per calendar 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 2020 (Figure 2.8). The model calculated annual mean PM_{10} is mostly below WHO AQG-2005 and AQG-2021, except for small regions in the Po Valley, Serbia, Turkey and Central Asia. The highest observed annual mean PM_{10} concentrations, exceeding the AQG-2005 of 20 μg m^{-3}, were registered at the Greek site GR0001 (21 μg m^{-3}, 58% data coverage only) and at the German site DE0044 (20 μg m^{-3}), whereas AQG-2021 were exceeded at 11 sites.

Further, the observations and model results show that annual mean $PM_{2.5}$ concentrations (Figure 2.8) in 2020 were mostly below the EU limit value of 20 μg m^{-3} (from 01.01.2020), except in the Po Valley according to the model. However, there were observed cases of exceedance by annual mean $PM_{2.5}$ of WHO AQG-2005 and AQG-2021 levels at 4 and 37 sites respectively, with the highest concentrations at DE0044 (16 μg m^{-3}) and IT0004 (13 μg m^{-3}).

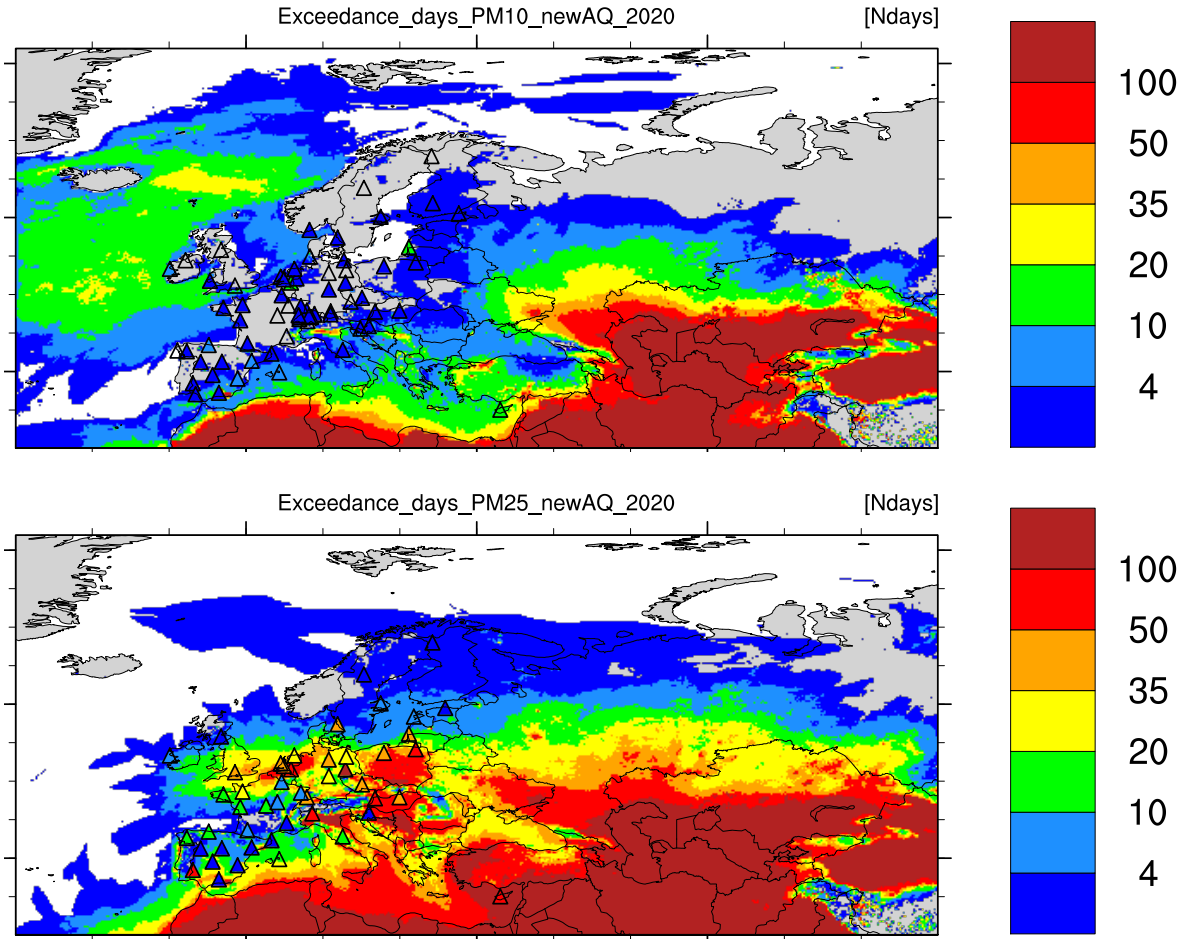


Figure 2.12: Modelled and observed (triangles) number of days with exceedances in 2020: PM_{10} exceeding 45 μg m^{-3} (upper) and $PM_{2.5}$ exceeding 15 μg m^{-3} (lower panel). *Note: WHO AQG Global Update 2021 recommends no more than 3-4 days with exceedances for PM_{10} and $PM_{2.5}$ per calendar year.*

The maps in Figure 2.11 and 2.12 show the number of days with PM_{10} and $PM_{2.5}$ ex-

ceedances in 2020 with respect to the limit values recommended by WHO AQG Global Update 2005 and Global Update 2021 respectively, according to EMEP MSC-W model simulations (colour contours) and EMEP observations (triangles). Out of 66 sites with daily or hourly PM_{10} measurements with data coverage above 75%, exceedance days were observed at 38 sites. No exceedances of the PM_{10} EU limit value (more than 35 exceedance days) were observed. Still, 9 sites had more than 3 exceedance days, as recommended by the WHO AQG, Global Update 2005. AQG from WHO Global Update 2021, were exceeded at 49 sites, and 12 sites had more than 3 exceedance days. The highest number of days with exceedances for PM_{10}, i.e. 11, was registered at LV0010 and NL0010.

Out of 50 sites with required data coverage in 2020, $PM_{2.5}$ concentrations exceeded AQG-2005 recommended limit of 25 μg m^{-3} at 38 sites, with more than 3 days with exceedances registered at 25 sites. The more stringent AQG-2021 limit of 15 μg m^{-3} was exceeded at 44 sites (36 sites with more than 3 $PM_{2.5}$ exceedance days). The largest number of exceedance days was registered at DE0044 (117 days with respect to AQG-2021).

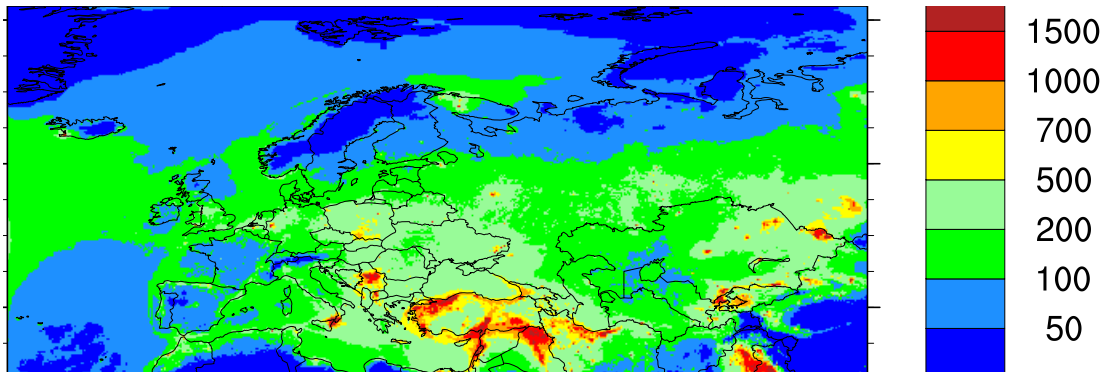
In general, there is a fair correspondence between modelled and observed numbers of days with PM_{10} exceeding the EU limit value of 50 μg m^{-3}, and the modelled number of exceedance days does not either exceed 35 at any site. The model under-counts the cases with exceedances for some sites, but the only considerable underestimations of observed exceedance days are for LV0011 and NL0010 (but the number of registered PM_{10} exceendances at NL0010 was mach higher compared to the other four Dutch sites). On the contrary, the number of exceedances are overestimated by the model for CY0002 in Cyprus and ES0007 in the south-eastern coast of Spain, for which the model simulated too many days with enhanced mineral dust pollution. Similar model performance compared to observations we see for PM_{10} exceedance days with respect to the AQG-2021 limit value of 45 μg m^{-3}.

For $PM_{2.5}$, the model simulates exceedances of AQG-2021 limit value of 15 μg m^{-3} on more than 3 days practically for all sites, except from 4. The largest numbers of $PM_{2.5}$ exceedance days are calculated for IT0004 (124 days) and CY0002 (114 days), whereas the modelled number of exceedance days for DE0044 is much lower than observed (i.e. 23 days).

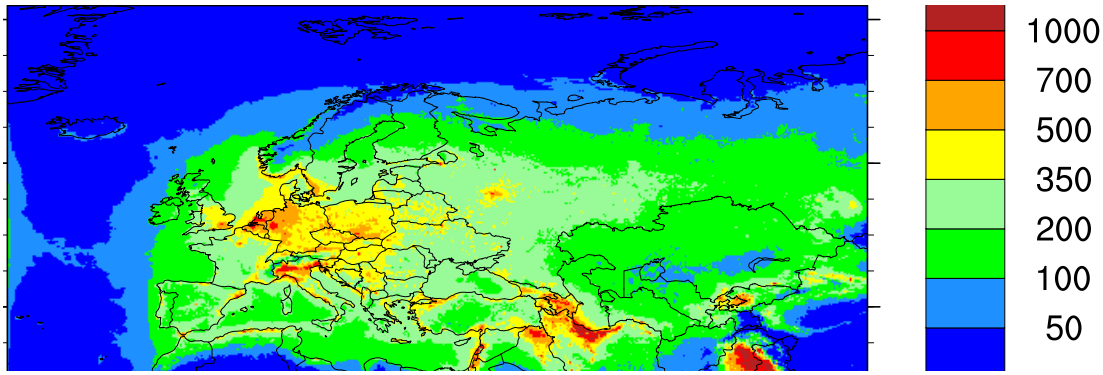
2.4.3 Deposition of sulfur and nitrogen

Modelled total depositions of sulfur and oxidised and reduced nitrogen are presented in Figure 2.13. For sulfur, 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.

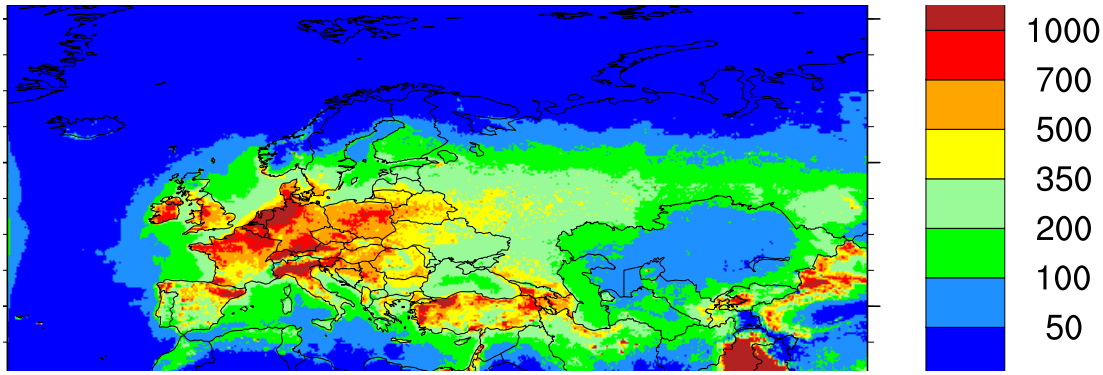
Oxidised nitrogen depositions are highest in northern Germany, the Netherlands, Belgium, Poland and northern Italy. These countries also have high depositions of reduced nitrogen, as do parts of the United Kingdom, France and Belgium in western Europe, and Turkey, Georgia, Armenia, Azerbaijan, Kyrgyzstan,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



(a) oxidized S



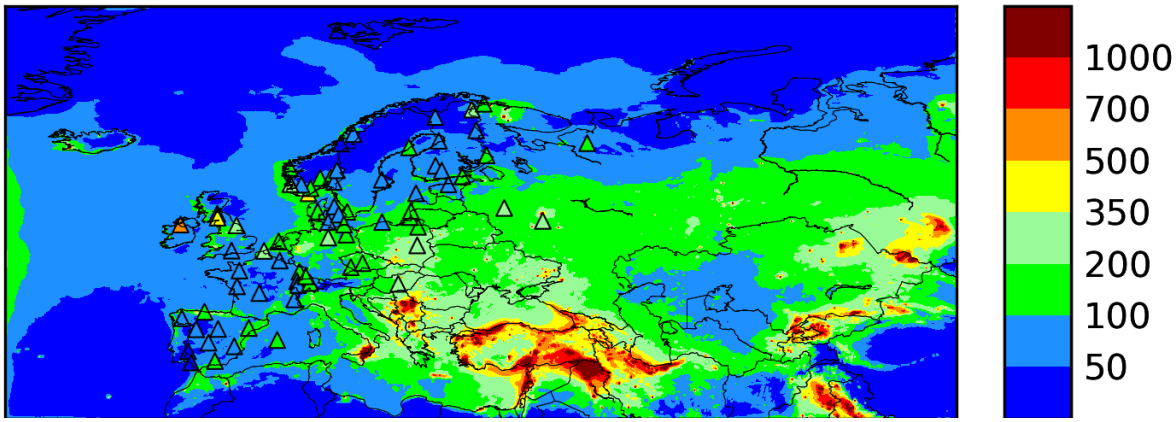
(b) oxidized N



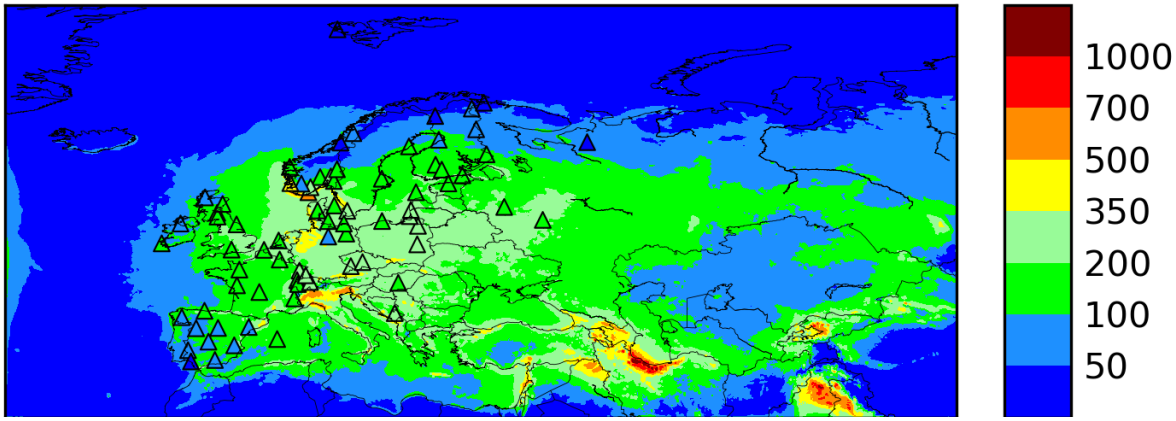
(c) Reduced N

Figure 2.13: Deposition of sulfur and nitrogen [mg(S)m^{-2}, mg(N)m^{-2}] in 2020.

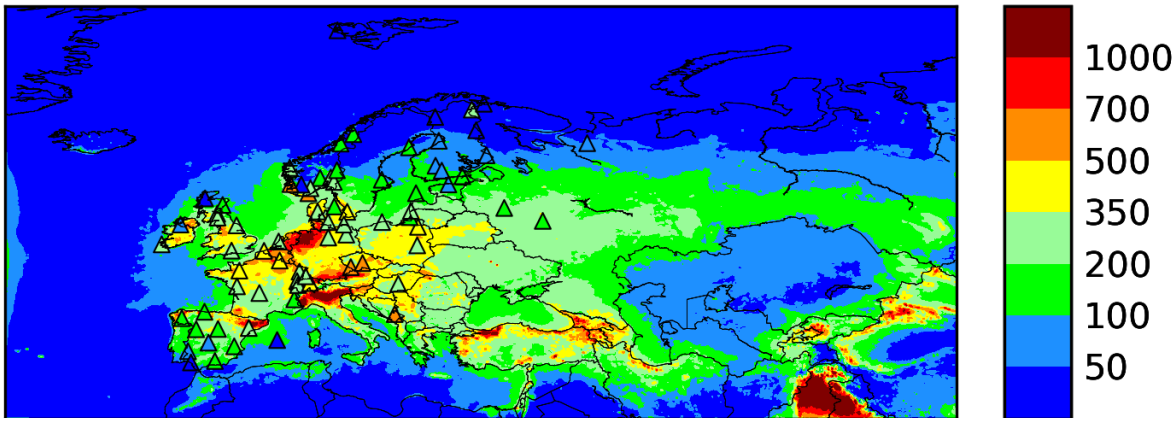
In Figure 2.14 wet depositions of nitrogen and sulfur compounds are compared to measurements at EMEP sites for 2020. Overall, the bias of the model with respect to measurements of wet depositions are around -30% to +15% (Appendix D), but higher for individual sites. A more detailed comparison between model and measurements for the year 2020 can be found at https://aeroval.met.no/evaluation.php?project=emep&exp_name=2022-reporting.



(a) oxidized S



(b) oxidized N



(c) Reduced N

Figure 2.14: Modelled wet deposition of sulfur and nitrogen [mg(S)m^{-2}, mg(N)m^{-2}] in 2020, 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 Geupel (in prep.), 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 theses exceedances based on the modelled deposition in the years 2000, 2005, 2010, 2015 and 2020 are shown in Figures 2.16 and 2.17. As indicated in the maps, the critical loads for eutrophication are exceeded in practically all countries in all years. The share of ecosystems where the critical load for eutrophication is exceeded decreases relatively slowly, starting at 74.0% in 2000 and ending at 61.2% in 2020. European average AAE is about 434 eq ha^{-1} yr^{-1} (2000) and 235 eq ha^{-1} yr^{-1} (2020). 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 14.1% (2000) and 3.6% (2020) of the ecosystem area, and the European average AAE is about 145 eq ha^{-1} yr^{-1} (2000) and 22 eq ha^{-1} yr^{-1} (2020). Overall statistics for the share of critical load exceedance and European average of AAE are shown in Figures 2.15.

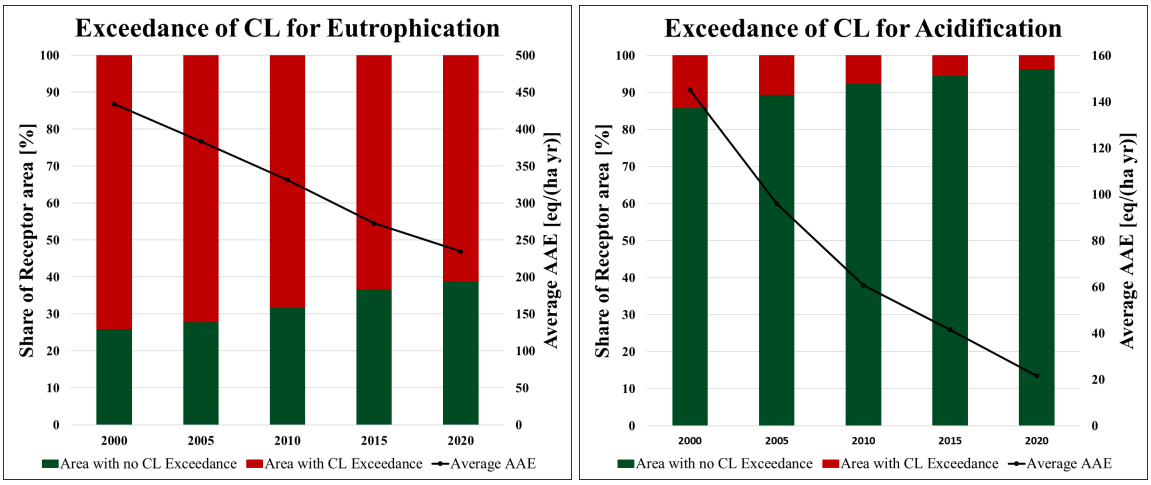


Figure 2.15: Statistics for Exceedance of Critical Load for Eutrophication (left) and Acidification (right).

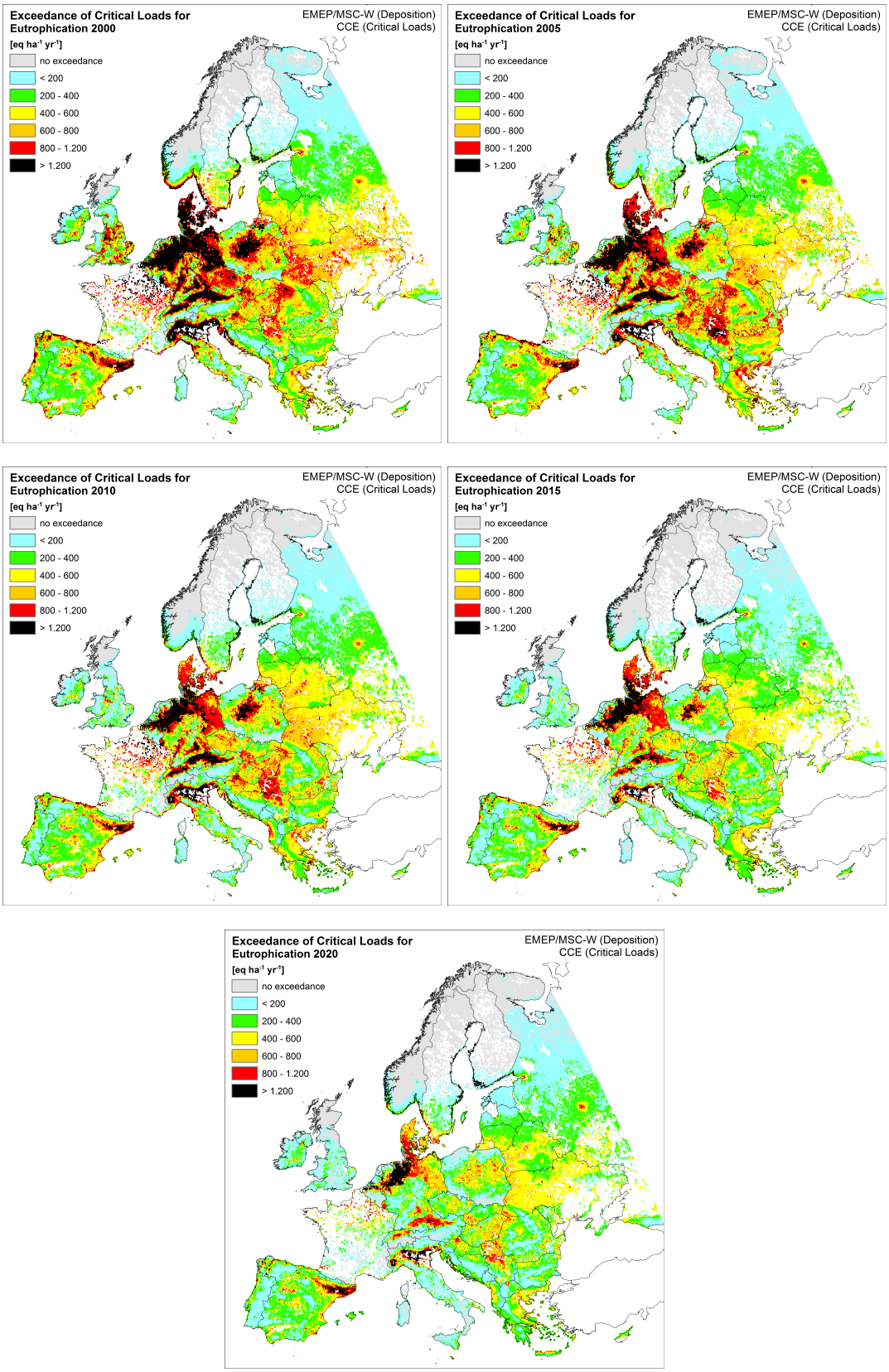


Figure 2.16: Exceedance of Critical Load for Eutrophication for the years 2000, 2005, 2010, 2015 and 2020.

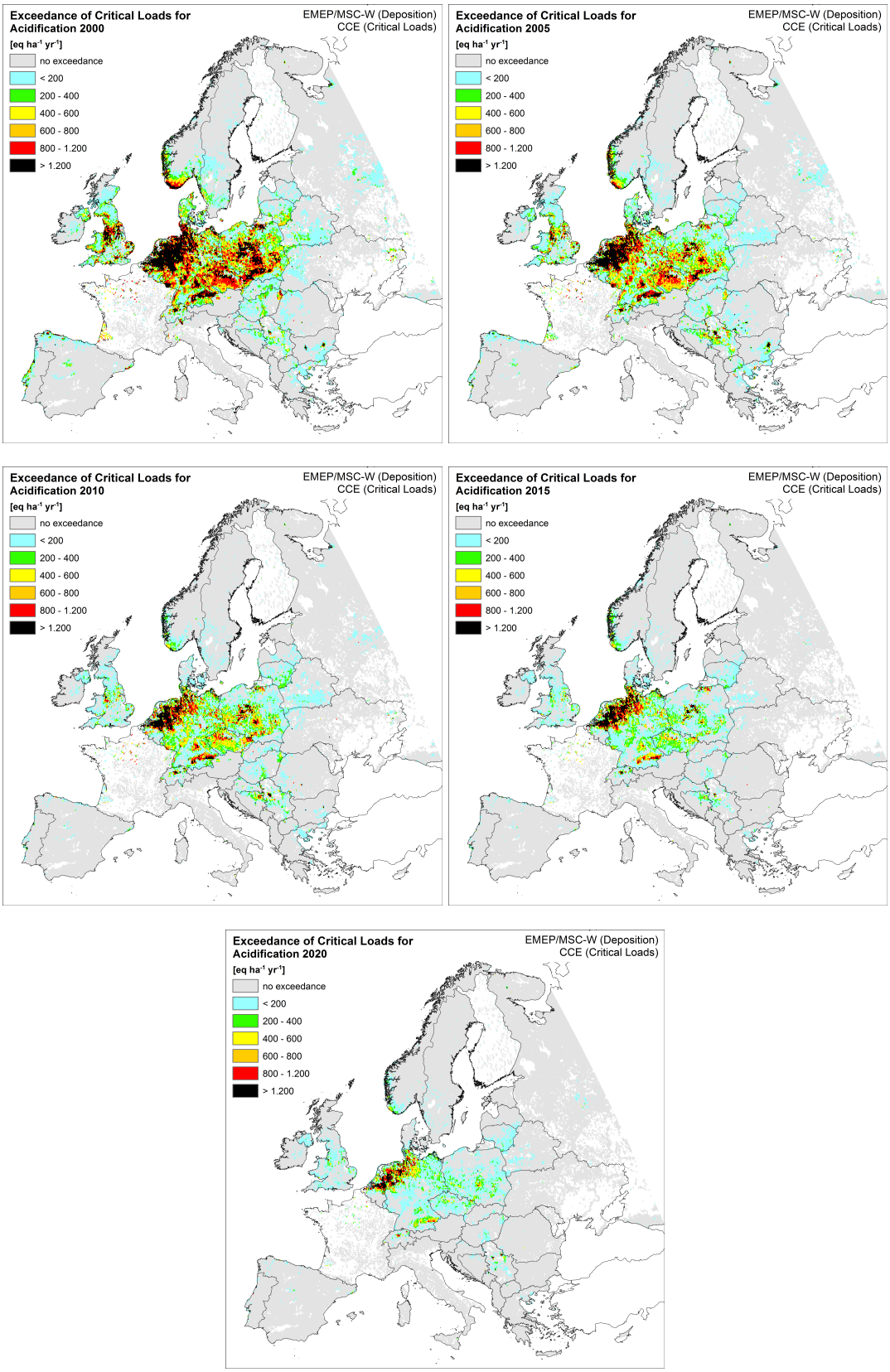


Figure 2.17: Exceedance of Critical Load for Acidification for the years 2000, 2005, 2010, 2015 and 2020.

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CHAPTER 3

Emissions for 2020

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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 2020 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 of air pollutants (SO_x[1], NO_2[2], CO, NMVOCs[3], NH_3, HMs, POPs, PM[4] and voluntary BC) and associated activity data. 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) every four years.

3.1 Reporting of emission inventories in 2022

Completeness and consistency of submitted data have improved significantly since EMEP started collecting information on emissions. Data of at least 47 Parties each year were submitted to CEIP since 2017 (see Figure 3.1). In 2022 (as of 1 June 2022), 47 Parties (92%)

[1]"sulfur oxides (SO_x)" means all sulfur compounds, expressed as sulfur dioxide (SO_2), including sulfur trioxide (SO_3), sulfuric acid (H_2SO_4), and reduced sulfur compounds, such as hydrogen sulfide (H_2S), mercaptans and dimethyl sulfides, 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], four Parties[6] did not submit any data and 42 Parties reported black carbon (BC) emissions for at least one year in the time series (see Ch 3.2). The year 2022 is not an obligatory reporting year for large point sources (LPS) and gridded emissions. Nevertheless, three Parties reported information on LPS and four Parties reported gridded data (Schindlbacher et al. 2022).

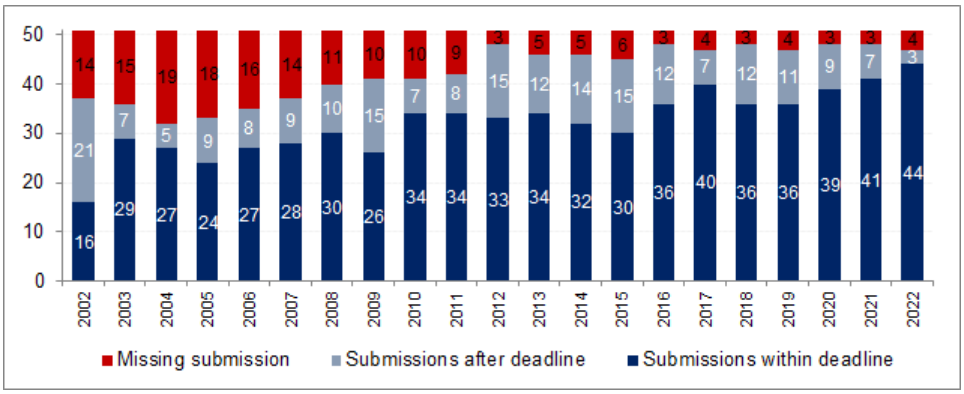


Figure 3.1: Parties reporting emission data to EMEP since 2002, as of 1 June 2022.

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*, currently the 2019 version (EMEP/EEA 2019). However, many countries still use the 2016 Guidebook (EMEP/EEA 2016) or older versions (e.g. EMEP/EEA (2013)). As analysed in a technical report (Schindlbacher et al. 2021), uncertainty of the reported data (national totals, sectoral data) is relatively high, e.g. the reported uncertainty estimates range from 6.9% to 56% for NO_x emissions reported in 2020. Furthermore, the completeness of reported data has not turned out satisfactory for all pollutants and sectors either.

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

Indeed, the issue of recalculations is highly relevant to users of EMEP emissions datasets. The aforementioned CEIP report on uncertainties in reported emissions highlighted how time series of reported emissions can vary significantly over subsequent rounds of submissions due to, inter alia, revisions in activity data, updates of methods and emissions factors and/or inclusion of previously overlooked sources of emissions (Schindlbacher et al. 2021).

The following sections summarise the inventory submissions in terms of three topics that are currently of high interest within the Convention:

- Reporting of black carbon emissions (Ch 3.2)
- Inclusion of the condensable component in particulate matter emissions (Ch 3.3)
- Comparison of reported Party emissions to respective reduction targets set out in the Gothenburg Protocol (Ch 3.4)

[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/2022-submissions.

[6]Azerbaijan, Bosnia and Herzegovina, Kyrgyzstan and Republic of Moldova

[7]https://www.ceip.at/review-of-emission-inventories/technical-review-reports

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.

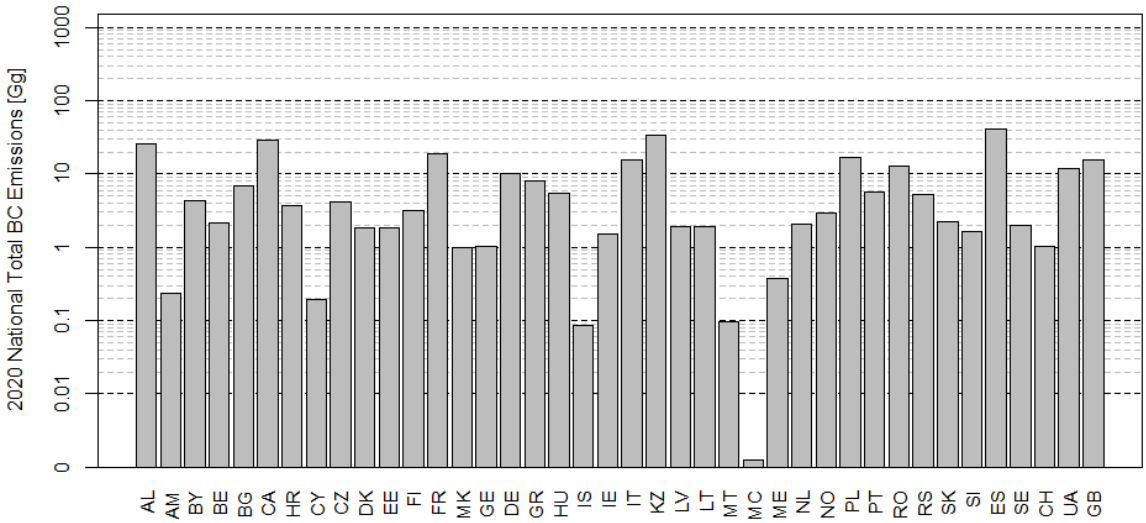


Figure 3.2: Black carbon emissions for the year 2020 as reported by CLRTAP Parties.

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.

While BC is not a mandatory pollutant to be reported under the Convention, 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 Parties in 2022 is given below.

Since enabling the reporting of BC, a total of 45 CLRTAP Parties have reported BC emissions estimates[8]. In this round of reporting, 28 CLRTAP Parties submitted a complete time series of national total BC emissions (1990-2020), while 36 CLRTAP Parties submitted a complete time series from 2000 onwards. Furthermore, 40 EMEP Parties have provided national total BC emissions estimates for the year 2020 (see Figure 3.2), while 42 Parties provided a national total emissions estimate for at least one year of the time series.

For more detailed information on BC one can 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 organic compounds of low volatility that may exist in equilibrium between the gas and particle phase. It is probably

[8]As of 1 June 2022 Austria, Bosnia and Herzegovina, Liechtenstein, Luxembourg, Russia and Turkey have yet to report estimates of national BC emissions.

the biggest single source of uncertainty in PM emissions. For more background information see Simpson et al. (2020). 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; however, much improvement has been made in the last update of the Guidebook. Various EMEP centres and task forces and other stakeholders jointly discuss the topic and work on progress in this area. An important activity in 2020 was the workshop organised by MSC-W that resulted in a comprehensive report by 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.

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 2020 the average contribution to the national total $PM_{2.5}$ emissions from this source category was 46%. 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). To improve the quality of the input data for air quality models, and following a decision of UNECE (2020), the group of experts that met at the workshop organised by MSC-W agreed on the following approach (for more details see Simpson et al. (2020)):

- In year one (2020) the Ref2 emission data provided by TNO, which include condensable organics, are used in an initial estimate for residential combustion emissions. The Ref2 data and their usage in the EMEP modeling work in 2020 are described in Denier van der Gon et al. (2020) and Fagerli et al. (2020).

- In subsequent years these top-down estimates should be increasingly replaced by national estimates once procedures for quantifying condensables in a more harmonized way are agreed on and implemented. Also, where replacement is necessary, the latest available version of the Ref2 type estimates should be used.

In 2022, CEIP organised an ad hoc review dedicated to the topic "condensable component of PM emissions". Twenty-one experts participated in this review. For all Parties that had provided an informative inventory report, the residential heating and road transport sectors were reviewed, with a special focus on the condensable component of particulate matter (PM) emissions. Based on the outcome of the review a list of Parties was prepared, where the conclusion was that the PM emission data reported by the Party should be used as the condensable component seemed to be included for $PM_{2.5}$ emissions from GNFR sector C. For other Parties updated TNO Ref2 emission data was used, or if no TNO Ref2 estimates were available, gap-filled data by CEIP was used (see Table 3.1).

The Ref2 dataset which was used in 2022 is described in Section 3.3.1. In this report, the emission dataset which combines Ref2 (version v2.1) estimates for $PM_{2.5}$ from GNFR C with EMEP estimates is referred to as the EMEPwRef2_v2.1C dataset (see Appendix A).

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 reporting under the CLRTAP Convention in 2022. This table has been added to the revised recommended structure for IIRs[9]. Twenty-

[9] https://www.ceip.at/reporting-instructions

Table 3.1: Data source for PM emissions in GNFR C used in the EMEP status runs and source-receptor calculations in 2022 (EMEPwRef2_v2.1C dataset).

Party Name	Data source for PM emission in GNFR C	Party Name	Data source for PM emission in GNFR C
Albania	Ref2	Latvia	CEIP - reported by Party
Armenia	Ref2	Liechtenstein	CEIP - gap-filled
Austria	Ref2	Lithuania	Ref2
Azerbaijan	Ref2	Luxembourg	Ref2
Belarus	Ref2	Malta	Ref2
Belgium	CEIP - reported by Party	Monaco	CEIP - reported by Party
Bosnia and Herzegovina	Ref2	Montenegro	Ref2
Bulgaria	CEIP - reported by Party	Netherlands	Ref2
Croatia	CEIP - reported by Party	North Macedonia	CEIP - reported by Party
Cyprus	CEIP - reported by Party	Norway	CEIP - reported by Party
Czechia	CEIP - reported by Party	Poland	CEIP - reported by Party
Denmark	CEIP - reported by Party	Portugal	CEIP - reported by Party
Estonia	Ref2	Republic of Moldova	CEIP - reported by Party
Finland	CEIP- reported by Party	Romania	Ref2
France	Ref2	Russian Federation	Ref2/CEIP
Georgia	Ref2	Serbia	CEIP - reported by Party
Germany	Ref2	Slovakia	CEIP - reported by Party
Greece	CEIP - reported by Party	Slovenia	CEIP - reported by Party
Hungary	CEIP - reported by Party	Spain	CEIP - reported by Party
Iceland	CEIP - reported by Party	Sweden	CEIP - reported by Party
Ireland	CEIP - reported by Party	Switzerland	Ref2
Italy	CEIP - reported by Party	Turkey	Ref2
Kazakhstan	CEIP - gap-filled	Ukraine	Ref2
Kyrgyzstan	CEIP - gap-filled	United Kingdom	CEIP - reported by Party

three Parties provided information on the inclusion of the condensable component in PM_{10} and $PM_{2.5}$ emission factors[10]. This reporting is a first step towards a better understanding of 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.

[10]Status as of 25 May 2022

3.3.1 Ref2 v2.1 emissions and changes compared to last year's Ref2 data

The Ref2 emission inventory provides a bottom-up database of PM emissions (both PM_{10} and $PM_{2.5}$) from small combustion activities (GNFR category C), taking into account activity data and consistent emission factors that include condensables, for both wood and solid fuel combustion. It was originally developed for the year 2010 (Denier van der Gon et al. 2015), which was later scaled to the year 2015. However, residential emissions vary from year to year, because of technological developments in the sector (replacement of stoves and boilers) but also because of the heating demand due to fluctuating temperatures. Given the increasing discussions around condensables in the last years, the Ref2 inventory has received increasing attention, and its methodology and underlying assumptions have been discussed multiple times within the UNECE LRTAP Task Forces as well as with individual country experts. As a consequence, in 2022 a completely updated version of the Ref2 emission dataset was developed for the 2005–2019 period, taking the aforementioned reasons for variability into account. Activity data, different appliance types, respective emission factors and the impact of user behaviour were all taken into account in this new Ref2 inventory, version 2.1 (Simpson et al. 2022, Kuenen et al. 2022).

A literature review showed that there are large uncertainties in many aspects of the inventory: the amount of fuel used (especially for solid biofuels), the different appliance types used, the related emission factors and the way the appliances are operated. To reflect these uncertainties, 3 scenarios were defined where the "typical" scenario is considered to be the most representative. An "ideal" scenario represents the situation without the user impact (i.e. assuming all users operate the combustion devices properly and with minimum emissions) and a "high EF" scenario assuming higher emission factors than the "typical" scenario but still in the range of literature values. The work was conducted in close collaboration with IIASA (Z. Klimont). This version 2.1 of the Ref2 inventory has been prepared in a project funded by the Nordic Council of Ministers in support of the review of the Gothenburg Protocol and was presented in a dedicated EC workshop on condensables and in multiple UNECE LRTAP Task Force meetings in Spring 2022. This new version which covers the latest available information is also used as the baseline for EMEP modelling in 2022. Given that 2020 was not yet included in this dataset, 2019 emissions have been used as best approximation for 2020. While this does not take into account the meteorological conditions of 2020, it does take into account the latest available estimates and knowledge of the fuel use, the appliance type park and appropriate emission factors in each country.

Figure 3.3 shows a comparison between the Ref2 inventory (v2.1) and the official reported emissions from the 2022 inventory submissions. While for some countries the two inventories match well, for others the differences are large. These differences are mostly related to the inclusion of condensables, however since Ref2 is an independent bottom-up emission inventory there are also other differences (e.g. fuel use, appliance types, emission factors).

Figure 3.4 shows a comparison between the Ref2_v2.1 presented here and an earlier Ref2 inventory that was used for the 2021 EMEP modelling (version 1.2). For most countries the difference is relatively small, however a significant reduction of emissions is shown for Denmark, Sweden and the Baltic States, but also for Russia, Turkey and Ukraine. For the latter countries, the uncertainty is large since actual estimates of real-world wood consumption in this region are scarce. On the other hand, emissions in some other countries increase, most notably the United Kingdom but also Italy and Bosnia/Herzegovina. All-in-all the Ref2 emissions in v2.1 for 2019 (used in the EMEP 2022 modelling) amount to 918 kt PM2.5, whereas

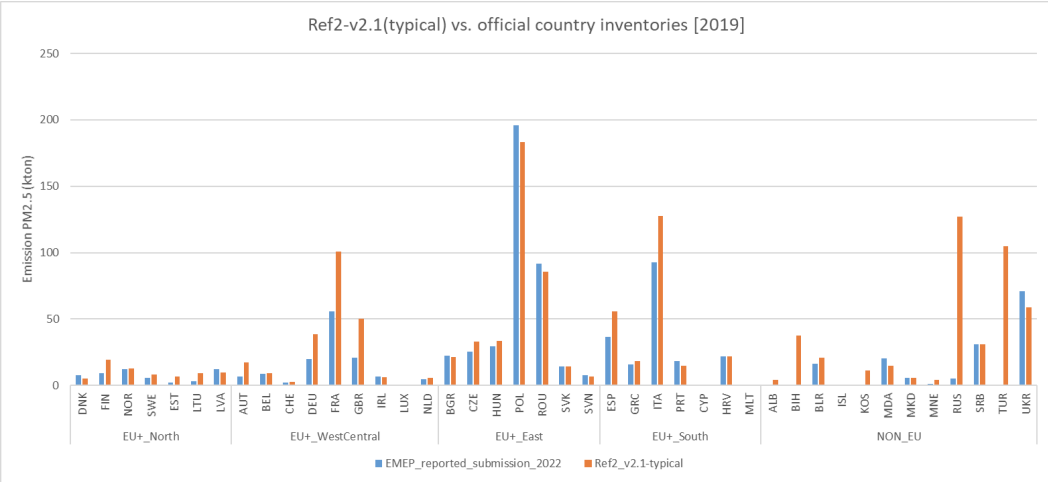


Figure 3.3: Reported $PM_{2.5}$ emissions for small combustion (GNFR C total), comparing the updated Ref2 (v2.1) inventory and the official reported emissions (submission in 2022) for the year 2019 for each Party for which Ref2 was calculated.

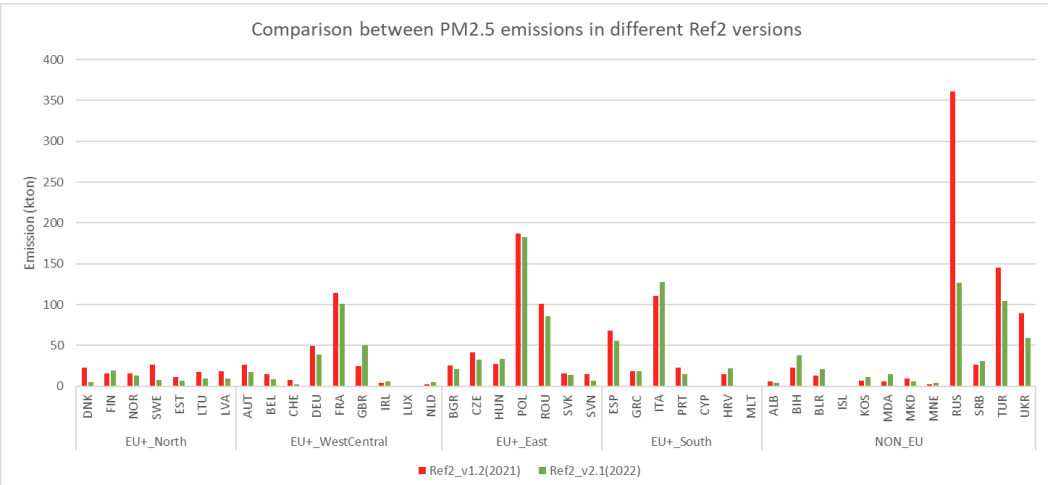


Figure 3.4: Comparison between the Ref2 dataset used in the 2022 EMEP modelling (Ref2_v2.1) and the Ref2 dataset used in last year (2021) modelling (Ref2_v1.2).

the Ref2_v1.2 (the version used for 2021 modelling) sum up to 1024 kt, which implies a reduction of around 10% in the new version. This reduction can be largely explained by the different base year (2019 vs. 2015), if the same comparison is made when taking the year 2015 (which is also part of the updated Ref2 set) the difference between the two versions is less than 2%.

While the similarity of these different versions may suggest that the emissions from this source are well understood, it should be highlighted that uncertainties in these emissions are significant. Fuel consumption (especially for wood), the distribution of fuel over different appliances, the emission characteristics of appliances and the way these appliances are operated are all uncertain factors in the calculation of emissions. Also the fuel type (what type of wood, wood or other types of biomass, in what form, etc.) contributes to this uncertainty. Moreover, while the difference in overall total European emissions is small, differences for individual countries can be substantially larger. Future work is needed to better understand the situation

in each country in Europe for all these parameters in order to improve our understanding of air pollution from small combustion installations.

3.4 Gothenburg Protocol targets

The amended Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) entered into force on 7 October 2019. Tables 2–6 of Annex II to the amended Protocol[11] set out the emission reduction commitments for SO_x, NO_x, NH_3, NMVOCs and $PM_{2.5}$ for 2020 and beyond, expressed as percentage reductions from the 2005 emission level. Of the thirty-four Parties that are currently listed in Tables 2–6, twenty-six have already ratified the amended Gothenburg Protocol.

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 2021, adjustment applications of ten countries (Belgium, Czechia, Denmark, Finland, France, Hungary, Germany, the Netherlands, Luxembourg, Spain and the United Kingdom) have been accepted by expert review teams. However, those previously approved adjustments have not been submitted in 2022 and therefore these adjustments were not subtracted for the respective countries when compared with the targets.

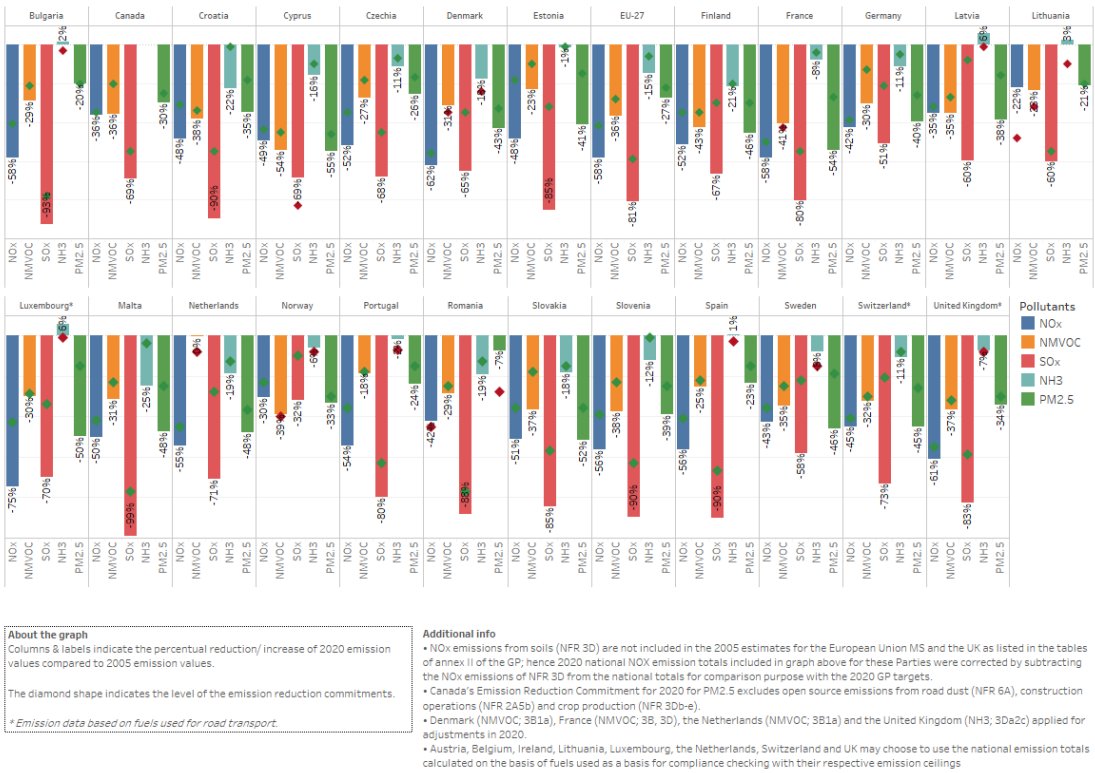


Figure 3.5: National total emissions vs emission reduction commitments for the year 2020 (based on data reported in 2022). Only Parties that ratified the Gothenburg Protocol are included.

[11] https://unece.org/sites/default/files/2021-10/Annex_II_and_III_updated_clean.pdf

In 2022, Denmark, France, the Netherlands and the United Kingdom submitted new adjustment applications. These adjustment applications were still under review in summer 2022 and were therefore not subtracted for the respective countries when compared with the targets in the figure below.

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. In 2022, Belgium, Switzerland and the United Kingdom used fuel used in the geographic area of the Party as a basis for compliance with their respective emission ceilings.

Figure 3.5 indicates that in the year 2020 Lithuania and Romania could not reduce their NO_x emissions below their respective Gothenburg Protocol requirements. For NMVOC, Denmark, France, Lithuania, the Netherlands and Norway were not able to achieve a reduction below the commitment level, whilst Cyprus could not reach the target for SO_x. Bulgaria, Denmark, Latvia, Lithuania, Luxembourg, Norway, Portugal, Spain, Sweden and the United Kingdom are above their emission reduction commitments concerning NH_3. For $PM_{2.5}$, Romania could not reduce the emissions below the reduction commitment level.

3.5 Datasets for modellers 2022

Under the Convention, CEIP is responsible for synthesizing the reported emissions data of the EMEP countries into complete gridded emissions datasets for the EMEP domain (covering the geographic area between 30° N-82° N latitude and 30° W-90° E longitude. These data are mainly used for modelling of air pollutant concentrations and depositions.

To compile these datasets each year, CEIP synthesizes and evaluates the most recent national sectoral emissions estimates and national gridded emissions data reported by the EMEP countries. CEIP strives to include, to the largest possible extent, the reported emissions data it receives from EMEP countries. However, due to cases of non-reporting or identified quality issues in the reported data, emissions need to be gap-filled or replaced. Furthermore, it should be noted how gridded and sectoral emissions totals are combined in compiling these datasets. National gridded emissions data, even if reported annually, are not directly utilized but are rather used to map out relative emissions, with which national sector emission totals are spatially distributed. If for a given year both national sector emissions totals and gridded estimates reported by a given country pass through the CEIP QA/QC checks, the generated gridded emissions will be identical to the gridded emissions reported by the country. The following subchapters describe important aspects of the 2022 EMEP datasets, summarising:

- The status of reporting of national gridded emissions data and the extent to which these are used to distribute emissions spatially (Ch 3.5.1)
- The extent to which sectoral emissions were gap-filled or replaced (Ch 3.5.2)
- The sectoral contributions (Ch 3.5.3) and temporal trends (Ch 3.5.4) in the emissions of carbon monoxide, nitrogen oxides, sulfur oxides, ammonia, non-methane volatile organic carbons, and particulate matter including black carbon. Trends in shipping emissions are discussed separately (Ch 3.5.5).

3.5.1 Reporting of gridded data

After the first round of submissions in 2017, 2021 was the second year for which EMEP countries were obliged to report gridded emissions in the grid resolution of 0.1°×0.1° longitude/latitude. As of June 2022, 35 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°×0.1° longitude/latitude resolution have been reported for the year 2015 (32 countries). For 2020 gridded sectoral emissions have been reported by 4 countries, for 2019 by 29 countries, for 2016 and 2017 by five countries and for 2018 by four countries. In comparison to reporting in 2017, reported gridded data were available for 11 more countries in 2021. In 2022 one more country was added.

Fifteen countries reported gridded emissions additionally for previous years (one country for the whole time series from 1980 to 2020; one country for the whole time series from 1990 to 2019; seven 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 2000, 2005 and 2010; one country for the year 2005; one country for the year 2010; and two 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 25% of the cells within the geographic EMEP area. For the remaining areas (or for EMEP countries that have no reported gridded data) missing emissions are gap-filled and spatially distributed by expert estimates. Reported grid data can be downloaded from the CEIP website[12]. The gap-filled gridded emissions are also available there[13].

An overview of gridded data in 0.1°×0.1° longitude/latitude resolution reported in 2017, 2021 and 2022 is provided in Table 3.2.

For compiling the 2022 EMEP emissions dataset, reported gridded data in 0.1°×0.1° longitude-latitude resolution was used from the following EMEP countries: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, 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.

3.5.2 Gap-filling of reported data in 2022

As described above, sectoral emissions reported by the EMEP countries are used, to the largest extent possible, to compile the gridded EMEP datasets. Each year the reported source-sector level data (NFR level) are aggregated into the 13 GNFR sectors and are then evaluated to identify countries for which emissions have not been reported or appear to exhibit implausible emission levels and/or trends. Based on this assessment, a procedure is then implemented to gap-fill missing emissions data and to replace data that have been identified as implausible. The sectoral emissions are then distributed spatially using, where available (and appropriate), the reported national gridded emissions as relative spatial proxies, or other independent datasets of spatial proxies.

Given the end of May deadline for compiling EMEP datasets, a cut-off date for incorporating reported emissions has to be set to allow necessary time for evaluating the reported

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

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

Table 3.2: Gridded emissions in $0.1^\circ \times 0.1^\circ$ longitude/latitude resolution reported until 2017, 2021 and 2022.

Country	2017	2021	2022	Comments
	Gridded data available for the years…	Gridded data available for the years…	Gridded data available for the years…	
Austria	2015	2000, 2005, 2010, 2015, 2019	2000, 2005,2010, 2015, 2019	
Belgium	2015	2015, 2019	2015, 2019	
Bulgaria	2015	2015, 2019	2015, 2019	
Croatia	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Cyprus		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Czechia	2015	2015, 2019	2015, 2019	
Denmark	2015	2015, 2019	2015, 2019	
Estonia		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Finland	2014, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017, 2019, 2020	
France		2015, 2019	2015, 2019	
North Macedonia		2015, 2019[a]	2015, 2019	(a) The submission of gridded emissions was too late to be considered for the preparation of gridded data for modelers in 2021
Georgia		2015	2015	
Germany	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2017, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2017, 2019	
Greece		2015, 2019	2015, 2019	
Hungary	2015[b]	2015	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, 2019[c]	2015, 2019	(c) The submission of gridded emissions was too late to be considered for the preparation of gridded data for modelers in 2021
Italy		2015,[d] 2019[d]	2015,[d] 2019[d]	(d) Reported gridded data was replaced by CAMS and EDGAR proxies
Latvia	2015	2015, 2019	2015, 2019	
Lithuania	2015[e]	2015[f], 2019[f]	2015[f], 2019[f]	(e) Reported gridded emissions only on national total level, which could not be used for the gridding, which is done on sectoral level f) Reported gridded data was replaced by CAMS and EDGAR proxies
Luxembourg	2015	2015, 2019	2015, 2019	
Malta		2016	2016	Grid reporting not in the defined 0.1°x0.1° coordinates
Monaco	2014, 2015	2014-2019	2014-2020	
Netherlands		1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Norway	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015, 2019	1990, 1995, 2000, 2005, 2010, 2015, 2019	
Poland	2014, 2015	2014, 2015, 2018, 2019	2014, 2015, 2018, 2019	
Portugal	2015	2015, 2019	2015, 2019	The spatial disaggregation of sector 'F – Road Transport' was replaced by CAMS proxies
Romania	2005	2005, 2015	2005, 2015	
Slovakia	2015	2015, 2019	2015, 2019	
Slovenia	2015	2015, 2019	2015, 2019	
Serbia			2020	The submission of gridded emissions was too late to be considered for the preparation of gridded data for modelers in 2022
Spain	1990-2015	1990-2019	1990-2019	The spatial disaggregation of sector 'F – Road Transport' was replaced by CAMS proxies
Sweden		1990, 2000, 2005, 2010, 2015, 2019	1990, 2000, 2005, 2010, 2015, 2019	
Switzerland	1980-2015	1980-2019	1980-2020	
United Kingdom	2010, 2015	2010, 2015, 2019	2010, 2015, 2019	
Russian Federation		2019	2019	Reported gridded data was replaced by EDGAR proxies

emissions and implementing the gap-filling procedure. This year, the sectoral emissions data reported by 07 April 2022 were evaluated and considered for use in the compilation of the 2022 EMEP datasets of gridded emissions.

The Parties for which data were (partly) replaced, corrected or gap-filled in 2022 are: Albania, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Cyprus, Denmark, Estonia, Georgia, Germany, Greece, Hungary, Italy, Kazakhstan, Kyrgyzstan, Liechtenstein, Lithuania, Luxembourg, Montenegro, the Republic of Moldova, the Russian Federation, Serbia, Slovenia, Spain, Sweden, Turkey and Ukraine. More Parties were gap-filled this year compared to the previous year due to the request for EMEP emission trends starting in 1990. For many countries, the complete reported time series of particulate matter emissions begins with the year 2000. The results of the quality control and gap-filling procedures are described in detail in the CEIP gap-filling report (Matthews and Wankmüller 2022).

Finally, it should be noted that the gap-filling and replacement procedure has been updated since 2020. The gap-filling/replacement of EMEP country emissions remains based on the independent estimates from the ECLIPSE v6b[14] dataset that has been compiled by IIASA using their GAINS model (Amann et al. 2011). However, the emissions for the areas 'North Africa', 'remaining Asian areas', and the part of Russia within the EMEP domain for which Russia does not report emissions (referred to as 'Russian Federation Asian part' further in this chapter), are now based on the updated EDGAR v5.0[15] dataset (Crippa et al. 2019) that was generated by the European Commission's Joint Research Centre (JRC). Previously, the emissions for these areas were based on a previous version (EDGAR v4.3.2) of the dataset (Crippa et al. 2018). Furthermore, gap-filling and/or replacement of 2020 emissions is often based on a 2020 projection from the ECLIPSE v6b dataset and represents a business as usual scenario and does not consider the impact of the COVID-19 pandemic on 2020 emissions. Where 2020 emissions of all or single sectors were replaced/gap-filled with the 2020 projections of GAINS, the emission value was corrected using pollutant- and GNFR sector-specific adjustment factors calculated by Guevara et al. (2022). More details can be found in the CEIP gap-filling report (Matthews and Wankmüller 2022).

3.5.3 Contribution of GNFR sectors to total EMEP emissions

Figure 3.6 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) in 2020. To clarify, the reader is reminded that these analyses are based on the emission data in the EMEP datasets for modellers i.e. data based largely on reported emissions, but also compiled with independent emissions estimates for countries and regions where data are not reported or the reported data have been omitted due to quality issues. The sea regions were excluded for this sectoral analysis.

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, 39%) and from large power plants (sector A, 22%).

NMVOC sources are distributed more evenly among the different sectors, such as 'E - Emissions from solvents' (21%), 'F - Road transport' (29%), 'D - Fugitive Emissions' (14%),

[14] https://iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv6.html

[15] https://edgar.jrc.ec.europa.eu/dataset_ap50

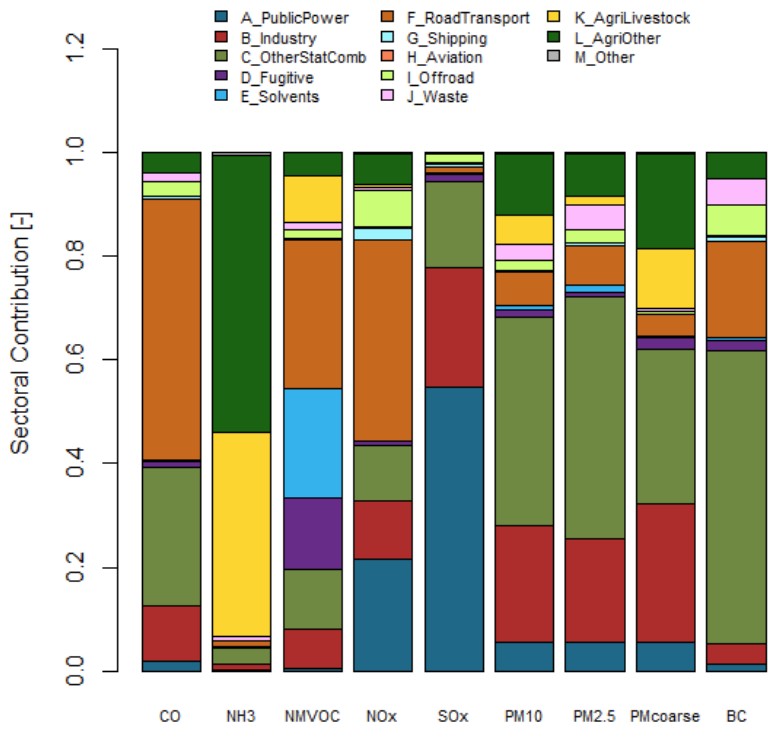


Figure 3.6: GNFR sector contribution to national total emissions in 2020 for the EMEP domain apart from the sea regions.

'B - Industry combustion' (7%), 'K - Manure management' (9%) and 'C - Other stationary combustion' (12%).

The main source of SO_x emissions are large point sources from combustion in energy and transformation industries (sector A, 55% and sector B, 23%).

Ammonia arises mainly from agricultural activities; about 93% combined contribution from sectors K and L. Emissions of CO originate primarily from 'F - Road transport' (50%) and 'C - Other stationary combustion' (27%).

The main sources of primary PM_{10} and $PM_{2.5}$ emissions are industry (22% and 20%) and other stationary combustion processes (40% and 47%). 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 (30% combined) together with significant contributions from 'B - industry combustion' (27%) and 'C - Other stationary combustion' (30%).

Finally, the most important contributors to BC emissions are 'F - Road transport' (19%) and 'C - Other stationary combustion' (56%).

Figure 3.7 illustrates the sector contributions to the total emissions in the EMEP West region and the EMEP East region, respectively. 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' (36% and 32%, respectively), although it is worth noting the higher contribution from 'A - Public electricity and heat production' in the East region (25% vs 12% in the West).

For NMVOC in the EMEP West region the most relevant sector is 'E - Emissions from

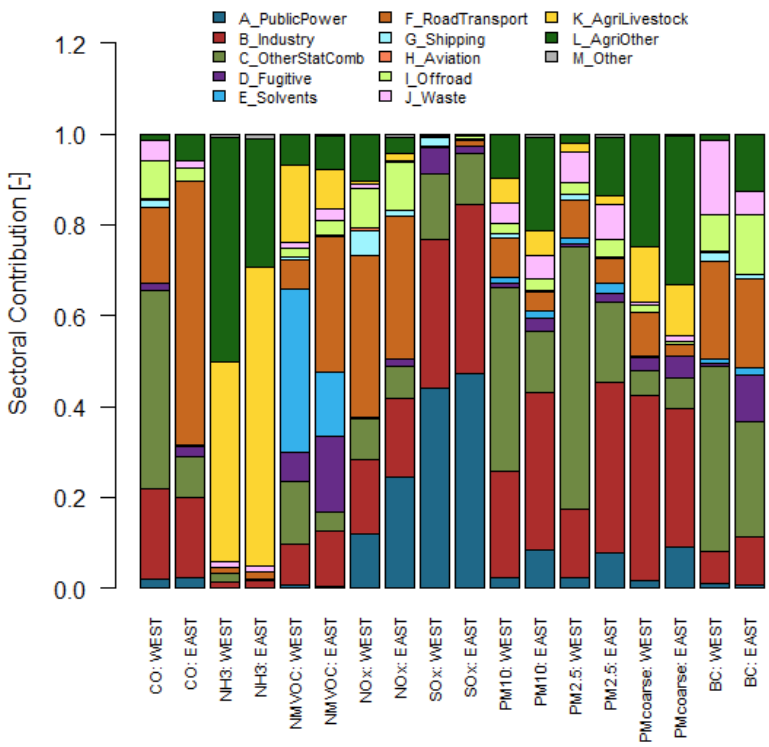


Figure 3.7: GNFR sector contribution to national total emissions in 2020 for the EMEP West and EMEP East areas. Asian areas, North Africa and the sea regions are not included.

solvents' with a share of 36%. In the EMEP East region the same sector has a considerable lower share (14%), whilst the sector 'F - Road transport' is of high importance (30%).

The main source of SO_x are 'A - Public electricity and heat production' and 'B - Industry combustion'. These two sectors together contribute to 77% and 84% of the SO_x 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 94%, 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' (44%).

For $PM_{2.5}$ and PM_{10} 'C - Other stationary combustion' holds a significant share of the total emissions in the EMEP West area (58% and 40%), compared to the EMEP East area (18% and 14%). 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 (44%). Finally, it is interesting to note the significant contribution to BC emissions in the EMEP East area from fugitive emissions (10% in EMEP East versus 1% in EMEP West).

3.5.4 Trends in emissions in the geographic EMEP domain

The following trend analyses are based on the emissions data in the EMEP datasets for modellers, i.e. data based largely on reported emissions, but also compiled with independent emissions estimates for countries and regions where data are not reported or the reported data have been omitted due to quality issues.

Excluding shipping emissions in the sea regions (these are summarised in Section 3.5.5),

the trend analyses of total emissions from the non-sea areas in the EMEP domain[16] in Figure 3.8 shows that emissions of seven of the nine pollutants have decreased overall since 2000. Only the 2020 PM_{coarse} and NH_3 emissions have increased (by 5 and 14%, respectively) since 2000. The 2020 emissions of SO_x are 67% of the respective 2000 emissions. While the 2020 emissions of CO, NMVOC, NO_x, $PM_{2.5}$, PM_{10} and BC are all lower than respective emissions in 2000 (2-14% lower), it is interesting to note that emissions of these pollutants have been increasing between 2014 and 2019. However, between 2019 and 2020, emissions of most pollutants, particularly NO_x, declined due to the COVID-19 pandemic and the resulting restrictions on socio-economic activity.

Despite these overall trends, the regional emission developments seem to follow strongly different patterns (Figure 3.9). While emissions of all the pollutants in the EMEP West countries are clearly decreasing, emissions of all pollutants in the EMEP East countries of the EMEP domain have been somewhat stable (albeit gradually decreasing for most pollutants) over the 2000-2019 period. Drops in emissions between 2019 and 2020 due to the COVID-19 pandemic are nonetheless visible for both the EMEP West and EMEP East regions. For the Other Land Areas (North Africa and the remaining Asian areas), emissions are clearly on the rise, albeit slowing between 2019 and 2020 as a result of the impacts of the COVID-19 pandemic.

Of course it is not just the emission trends that separate the three land regions. Whereas the emission trends of the EMEP West countries are based to a very large extent on the official national inventories reported to CEIP, the countries of the Other Land Areas within the EMEP domain (North Africa, remaining Asian areas) are not Parties to the Convention and thus are not obliged to report their emissions. For these regions, emissions are based completely on the independent gridded emission estimates of the EDGAR v5.0 dataset (Crippa et al. 2019). Furthermore, the recent trends should be viewed with caution as the last available year in the EDGAR v5.0 dataset is 2015 and emissions between 2016 and 2020 has to be extrapolated

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

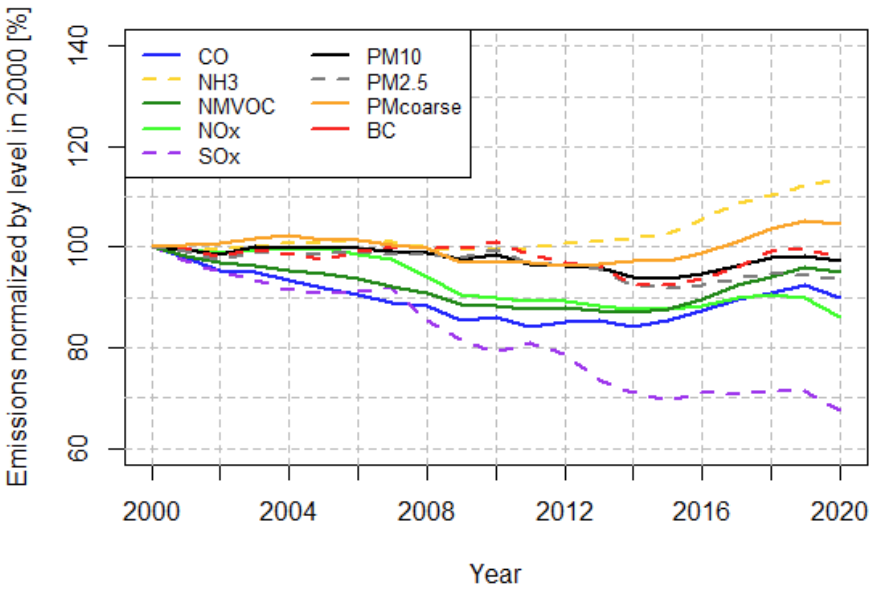
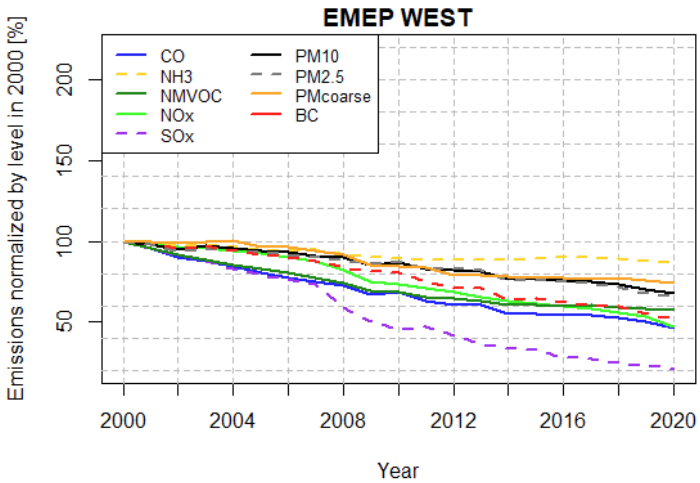
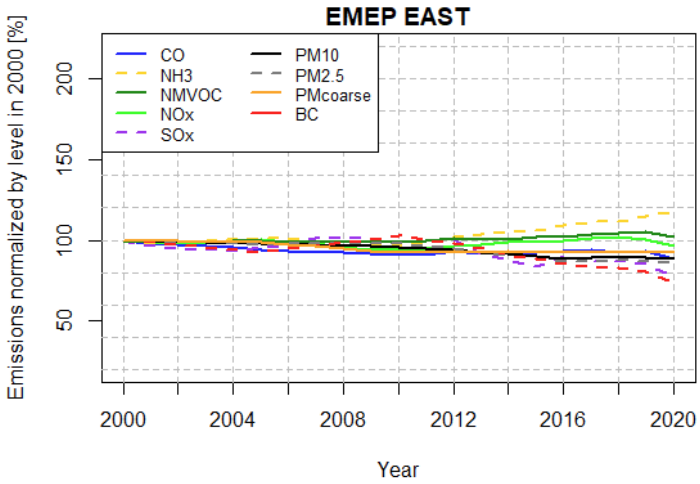


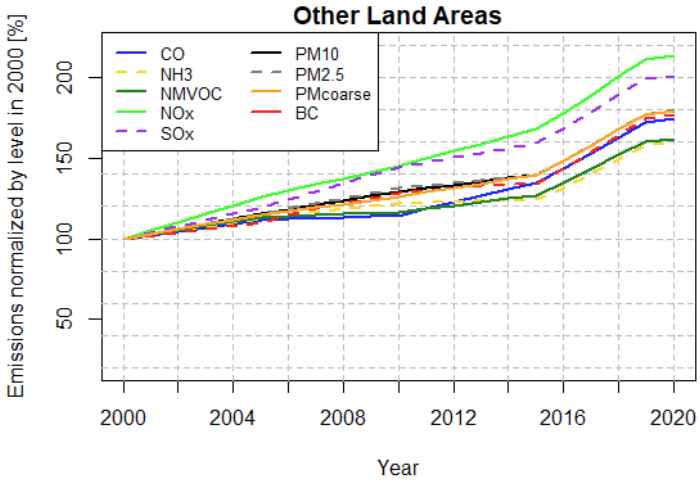
Figure 3.8: Emissions during the 2000–2020 period in the geographic EMEP area (emissions from international shipping in the sea regions are excluded).



(a) EMEP West



(b) EMEP East



(c) Other Land Areas

Figure 3.9: Emissions during the 2000–2020 period in the geographic EMEP domain (emissions from international shipping in the sea regions are excluded) divided into three areas: 'EMEP West' (top), 'EMEP East' (middle) and 'Other Land Areas' (bottom), that include the emissions from North Africa and the remaining Asian areas.

Table 3.3: Differences between emissions for 2000 and 2020 (based on gap-filled data as used in EMEP models). Negative values mean that 2020 emissions were lower than 2000 emissions. Red/blue coloured data indicates that 2020 emissions were higher/lower than 2000 emissions. Furthermore, the symbol in parentheses indicate whether the emissions times series are completely based on reported data (R), are partially based on reported data (r), or have been completely replaced/gap-filled (-).

Country	CO	NH3	NMVOC	NOx	SOx	PM10	PM2.5	PMcoarse	BC
Albania	-3.4 (-)	16.4 (-)	4.7 (-)	34.4 (-)	-28.5 (-)	40 (-)	39.9 (-)	40.3 (-)	0.3 (-)
Armenia	-47.4 (-)	62.9 (-)	-13.6 (-)	138.5 (-)	542.6 (-)	69.6 (-)	72.6 (-)	60.6 (-)	271 (-)
Asian Areas	80.9 (-)	63.7 (-)	70.4 (-)	127.8 (-)	113.9 (-)	86.4 (-)	86.8 (-)	85.8 (-)	77.4 (-)
Austria	-34.5 (R)	1.8 (R)	-38.6 (R)	-41.6 (R)	-66.6 (R)	-33.3 (r)	-44.8 (r)	-13.5 (-)	-52.5 (-)
Azerbaijan	77 (-)	60.5 (r)	194.8 (-)	202.7 (-)	-63.9 (-)	136.6 (-)	145.1 (-)	108.9 (-)	231.1 (-)
Belarus	-44.4 (-)	12.5 (-)	-29.2 (-)	-19.9 (-)	-59.7 (-)	-13.1 (-)	-8.6 (-)	-25.3 (-)	-10.2 (-)
Belgium	-73.3 (R)	-28.7 (r)	-51.8 (R)	-62.5 (R)	-85.9 (R)	-53.6 (r)	-58.1 (r)	-41.4 (-)	-75.3 (r)
Bosnia and Herzegovina	40.2 (-)	58.6 (-)	65.6 (-)	22.5 (-)	-78.2 (-)	46.7 (-)	123.3 (-)	-48 (-)	171.4 (-)
Bulgaria	-35.1 (r)	-2 (R)	-42.3 (R)	-44 (R)	-93.8 (R)	-29.1 (R)	-10.7 (R)	-52.7 (-)	45.6 (-)
Croatia	-54.2 (R)	-19.5 (R)	-32.6 (R)	-48 (R)	-89.8 (R)	7.8 (R)	-20.6 (R)	93.8 (-)	-31.5 (R)
Cyprus	-70.4 (R)	-16.4 (R)	-46.7 (R)	-48.9 (R)	-75.2 (R)	-59.2 (r)	-62.1 (r)	-55.9 (-)	-68.1 (r)
Czech Republic	-27.9 (R)	-16.7 (R)	-37.9 (R)	-50.3 (R)	-71.5 (R)	-36.8 (R)	-35.2 (R)	-41.3 (-)	-37.3 (R)
Denmark	-59.5 (R)	-26.5 (R)	-41.5 (R)	-59.8 (R)	-71.9 (R)	-31.2 (R)	-41 (R)	-14.3 (-)	-55.2 (r)
Estonia	-26.9 (R)	18.8 (R)	-31 (R)	-46.8 (R)	-88.6 (R)	-67.8 (r)	-50.9 (r)	-80.9 (-)	-30.1 (r)
Finland	-46.6 (R)	-14 (R)	-52.7 (R)	-56.3 (R)	-71.6 (R)	-37.5 (R)	-45.7 (R)	-24.6 (-)	-51 (R)
France	-67.3 (R)	-13.3 (R)	-54.4 (R)	-61.9 (R)	-85.3 (R)	-55.4 (R)	-64.3 (R)	-28.1 (-)	-73.5 (R)
Georgia	-15.8 (R)	-22.6 (r)	-8.8 (R)	64.4 (r)	113 (-)	-21.1 (-)	-26.8 (-)	29 (-)	65.1 (-)
Germany	-51.6 (R)	-13.9 (R)	-42.6 (R)	-48.2 (R)	-63.8 (R)	-39.6 (r)	-50.9 (r)	-25.6 (-)	-73.4 (r)
Greece	-57.8 (R)	-16.8 (R)	-57.1 (R)	-48.5 (R)	-88.9 (R)	-54 (r)	-48.1 (r)	-60.4 (-)	-28 (R)
Hungary	-60.4 (R)	-12.3 (R)	-40.9 (R)	-43.3 (R)	-96.2 (R)	-21.1 (r)	-23.1 (r)	-17 (-)	-31.4 (r)
Iceland	39.5 (R)	-4.6 (R)	-39.3 (R)	-40.5 (R)	45.6 (R)	-27.3 (R)	-30.1 (R)	-25 (-)	-62.1 (R)
Ireland	-62.6 (R)	2.8 (R)	-9.1 (R)	-47.8 (R)	-92.6 (R)	-24.2 (R)	-36 (R)	-11.6 (-)	-60.4 (R)
Italy	-60.6 (R)	-20.6 (R)	-45.7 (R)	-62.1 (R)	-89.2 (R)	-32 (r)	-30.3 (r)	-37.8 (-)	-62.6 (r)
Kazakhstan	-10.7 (-)	43.1 (-)	45.4 (-)	59.4 (r)	43.4 (-)	11.4 (-)	10 (-)	14 (-)	-17.2 (-)
Kyrgyzstan	47 (-)	35.5 (-)	55.7 (-)	98.6 (-)	34.4 (-)	56.5 (-)	64.3 (-)	39 (-)	21.6 (-)
Latvia	-63.4 (R)	17.5 (R)	-39 (R)	-23.7 (R)	-80.2 (R)	-17.3 (R)	-38.1 (R)	106.2 (-)	-42.9 (R)
Liechtenstein	-50.1 (R)	8.6 (R)	-45.8 (R)	-56.3 (R)	-87.4 (R)	-41.4 (R)	-50.9 (R)	-19.4 (-)	-69 (-)
Lithuania	-39.3 (R)	21.4 (R)	-25.1 (R)	-11.1 (R)	-71.6 (R)	3.2 (r)	-4.6 (R)	8.4 (-)	-13.6 (R)
Luxembourg	-64.4 (R)	-2.9 (R)	-33.9 (R)	-61.1 (R)	-78.3 (R)	-39.4 (R)	-47.8 (R)	-4.6 (-)	-77.2 (-)
Malta	-62.8 (R)	-37.3 (R)	-34.1 (R)	-49.7 (R)	-98.5 (R)	24.5 (R)	-49.3 (R)	164.1 (-)	-58.9 (R)
Monaco	-69 (R)	-82.9 (R)	-51.4 (R)	-77.2 (R)	-90.3 (R)	-51.2 (R)	-70.2 (R)	-6.3 (-)	-83.3 (R)
Montenegro	250.3 (-)	-42.5 (R)	279.4 (-)	547.6 (-)	28.4 (R)	242.8 (-)	301.1 (-)	74.3 (-)	459.2 (-)
Netherlands	-39.9 (R)	-27.9 (R)	-19.9 (R)	-56.4 (R)	-75 (R)	-44.2 (R)	-57.3 (R)	-14.3 (-)	-79 (R)
North Africa	27 (-)	32.4 (-)	24.1 (-)	57.9 (-)	57.9 (-)	39.1 (-)	36.5 (-)	42.6 (-)	77.4 (-)
Norway	-29.6 (R)	0.1 (R)	-63.1 (R)	-31.2 (R)	-41.8 (R)	-35 (R)	-41.1 (R)	-6.3 (-)	-40.8 (R)
Poland	-34.8 (R)	-9.7 (R)	-17.4 (R)	-32 (R)	-68.2 (R)	-18.4 (R)	-17.2 (R)	-21.8 (-)	-19.5 (R)
Portugal	-61.6 (R)	-17.4 (R)	-32.9 (R)	-55.1 (R)	-87 (R)	-32.2 (R)	-33.4 (R)	-27.5 (-)	-50.8 (R)
Republic of Moldova	128.8 (r)	-20.2 (r)	85 (r)	65.1 (r)	-0.6 (r)	262.6 (r)	352.7 (r)	94.9 (-)	454.2 (-)
Romania	-12.8 (R)	-12.5 (R)	-25.5 (R)	-35.3 (R)	-85.5 (R)	9.3 (R)	5 (R)	23.2 (-)	3.7 (R)
Russian Federation (European part)	-7.8 (r)	0.2 (r)	-4 (r)	-14.4 (r)	-53.1 (r)	-28.9 (r)	-40.9 (r)	-18.8 (-)	-42.9 (-)
Russian Federation (Asian part)	-21.2 (-)	18.5 (-)	3.6 (-)	-15.1 (-)	-43.7 (-)	-18.2 (-)	-32.8 (-)	13.9 (-)	-50.7 (-)

Table 3.3 cont. Differences between emissions for 2000 and 2020 (based on gap–filled data as used in EMEP models).

Country	CO	NH3	NMVOC	NOx	SOx	PM10	PM2.5	PMcoarse	BC
Serbia	-4.4 (R)	-24.4 (R)	-7.9 (R)	20.2 (R)	-9.8 (R)	35.6 (R)	41.3 (R)	17.4 (-)	48.7 (-)
Slovakia	-48.5 (R)	-19.5 (R)	-38 (R)	-49.1 (R)	-88.6 (R)	-55.4 (R)	-59.9 (R)	-36.2 (-)	-42.4 (R)
Slovenia	-57.7 (R)	-18.2 (R)	-45.3 (R)	-57.1 (R)	-95.7 (R)	-27.8 (r)	-29.7 (r)	-22.9 (-)	-36 (r)
Spain	-46.1 (R)	-7.1 (R)	-37.6 (R)	-53.1 (R)	-91.6 (R)	-31.5 (r)	-31.7 (r)	-31 (-)	-24.7 (r)
Sweden	-56 (R)	-10.8 (R)	-40.1 (R)	-46.9 (R)	-65.9 (R)	-33.3 (R)	-49.8 (R)	-3.9 (-)	-63.9 (r)
Switzerland	-63.7 (R)	-14.2 (R)	-50.8 (R)	-48.2 (R)	-77 (R)	-29.1 (R)	-49.6 (R)	3.4 (-)	-74 (R)
Tajikistan	635.3 (-)	62.2 (-)	285.3 (-)	463.7 (-)	380.1 (-)	467.9 (-)	485.5 (-)	415.5 (-)	429.4 (-)
The former Yugoslav Republic of Macedonia	-65.6 (R)	-37.2 (R)	-52.6 (R)	-54.4 (R)	-12.1 (R)	-69.2 (R)	-71 (R)	-65.2 (-)	-63.3 (R)
Turkey	-43.4 (r)	40.1 (R)	-10.9 (r)	19.1 (r)	-3.2 (R)	8.9 (-)	-0.4 (-)	38.3 (-)	-44.6 (-)
Turkmenistan	117.3 (-)	83.8 (-)	120.9 (-)	81.4 (-)	189.8 (-)	44 (-)	48.5 (-)	30.7 (-)	34.2 (-)
Ukraine	-24.3 (-)	-9.1 (-)	-40.6 (-)	-42.1 (-)	-76.1 (r)	-31.7 (-)	-31 (-)	-33.1 (-)	-32 (-)
United Kingdom	-74.9 (R)	-13.2 (R)	-55.7 (R)	-66.8 (R)	-89.5 (R)	-42.8 (R)	-46.5 (R)	-36.5 (-)	-63.5 (R)
Uzbekistan	8 (-)	61.3 (-)	38.4 (-)	-16.4 (-)	3.2 (-)	8.4 (-)	11.8 (-)	-1.6 (-)	1.2 (-)
Increase (no. countries/areas)	11	22	13	15	11	19	15	21	16
Decrease (no. countries/areas)	43	32	41	39	43	35	39	33	38

based on economic trends. In EMEP East region not all countries are Parties to the Convention (such as Turkmenistan, Tajikistan and Uzbekistan) and the reported Russian emissions do not cover the region of Russia within the EMEP domain that is ca. east of the Urals. The emissions for the eastern part of Russia have also been gap-filled using the independent gridded emission estimates of the EDGAR v5.0 dataset. Finally, it should be noted that many of the emissions time series for the EMEP East countries that are Parties to the Convention have been partially or fully replaced with independent estimates from the ECLIPSE v6b[17] dataset that has been compiled by IIASA using their GAINS model (Amann et al. 2011).

Non-sea emission levels in the geographic EMEP domain for 2020 of the individual countries and areas are compared to 2000 emission levels for each pollutant (see Tables 3.3-3.3 cont.). Again, the reader is reminded that the following trend analyses are based on the emissions data in the EMEP datasets for modellers, i.e. the data based largely on reported emissions, but also compiled with independent emissions estimates for countries and regions where data are not reported or the reported data have been omitted due to quality issues. Overview tables with reported emission trends for individual countries have been published on the CEIP website[18]. Detailed information on the sectoral level can also be accessed in WebDab[19].

The assessment of emission levels in individual countries and areas shows an increase of emissions in 2020 compared to 2000 emission levels in several countries or areas.

In case of PM emissions, 21 countries/areas have higher PM_{coarse} emissions in 2020 than in 2000, while PM_{10} and $PM_{2.5}$ emissions increased in 19 and 15 countries/areas, respectively. In case of NO_x there are 15 countries/areas, for SO_x 11, NMVOC 13, NH_3 22 and CO 11 countries/areas with higher emissions in 2020 than in year 2000. Detailed explanatory information on emission trends for the reporting countries should be provided in the respec-

[17] https://iiasa.ac.at/web/home/research/researchPrograms/air/ECLIPSEv6.html

[18] https://www.ceip.at/webdab-emission-database/reported-emissiondata

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

tive informative inventory reports (IIRs). Tables 3.3-3.3 cont. indicates whether the emissions were based completely (R) or partially (r) on reported data, or whether the data have been completely gap-filled/replaced (-)

3.5.5 Trends in emissions from international shipping

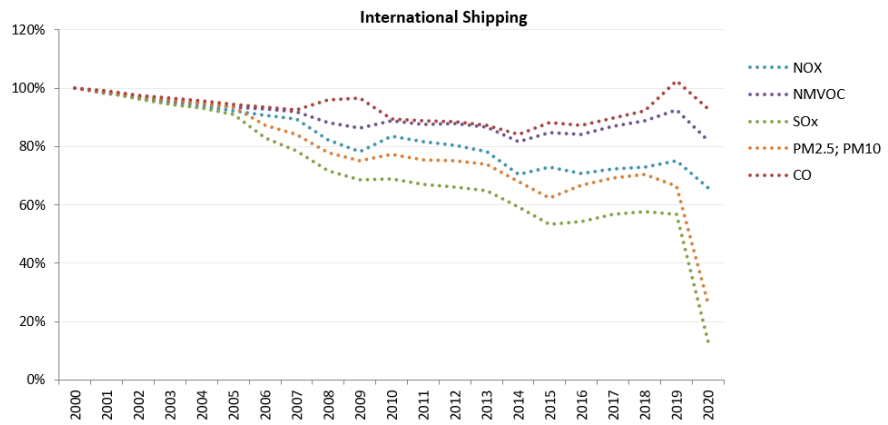


Figure 3.10: International shipping emissions during the 2000–2020 period in the EMEP area, extracted from the CAMS global shipping emission dataset developed by by the Finnish Meteorological Institute (FMI), and provided directly by FMI for the years 2014-2020 and via ECCAD (CAMS_GLOB_SHIP) for 2000-2013. These are the emissions which have been used for the most recent trend calculations with the EMEP model.

International shipping emissions are not reported by Parties. Gridded emissions for the sea regions (European part of the North Atlantic, Baltic Sea, Black Sea, Mediterranean Sea and North Sea) were calculated using the CAMS global shipping dataset (Granier et al. 2019) developed by by the Finnish Meteorological Institute (FMI) for the years 2000 to 2020 (Figure 3.10). For the years 2014 to 2020, the most up-to-date data was provided directly by FMI, while for earlier years (2000-2013) the trend from the CAMS-GLOB-SHIP v2.1 dataset was used as provided via ECCAD[20] (ECCAD 2019).

Shipping emissions from 1990 to 1999 were calculated by using the trend for global shipping from EDGAR v.4.3.2[21].

According to FMI the reason for the high emission reduction between 2019 and 2020 for PM and SO_x is the global reduction of maximum sulphur content in ship fuels from 3.5% to 0.5%[22]. This impacts directly the SO_x and particulate SO_4 emissions. The COVID-19 pandemic led to a reduction of all emissions in 2020, but the global sulphur cap impacted PM and SO_x emissions even more.

3.6 Summary

This chapter summarises the status of emissions reported by LRTAP Convention Parties and the extent to which these data have been incorporated into the 2022 EMEP emissions datasets

[20] https://eccad.aeris-data.fr
[21] https://edgar.jrc.ec.europa.eu
[22] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

for modellers. The chapter documents the historical improvement in reporting over time, noting the increasing extent of reporting emissions inventories for the mandatory pollutants and black carbon, as well as increased reporting of gridded emissions in 2021 compared to 2017. Despite these positive trends in terms of reporting, reporting is not yet complete. For some parties, emissions inventories and gridded data are not reported (or are reported late and/or incomplete). There is further room for improvement on the reporting of particulate matter emissions with respect to whether the condensable component has been included in the reported estimates.

The 2022 EMEP emissions datasets for modellers therefore need to be complied carefully and this chapter documents for which countries and pollutants the time series have been based fully or partially on reported inventories and gridded data, and for which countries and regions the datasets have been built using independent emissions data products.

Based on the complied datasets in 2022, it is worth noting that emissions from the land areas have decreased from 2000 to 2020 for most pollutants except for PM_{coarse} and NH_3. This appears to be driven by the emission changes in the EMEP West countries, for which the time series are based almost completely on reported data. In contrast, EMEP East as whole shows a rather stable trend in terms of emissions (emissions based partially on reported data), with notable emissions increases shown for the 'Other areas' (based completely on independent estimates). In addition to these long term trends, it should also be noted that the emissions of almost all pollutants for the EMEP domain as a whole (and the EMEP West, EMEP East and 'Other areas', respectively) demonstrated discrete decreases between 2019 and 2020 due to the COVID-19 pandemic impacts on socio-economic activity. An abrupt decrease in international shipping emissions has also been identified (Ch 3.5.5). However, in the case of PM and SO_x from international shipping, the much larger reductions were driven not only by the pandemic, but mainly by the introduction of the global sulphur cap on ship fuels.

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Part II

Assessment and Research Activities

CHAPTER 4

uEMEP/EMEP modelling for the Gothenburg protocol review

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4.1 Introduction

At its thirty-ninth session (Geneva, 9–13 December 2019), the Executive Body launched the review of the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (the Gothenburg Protocol) as amended in 2012.

In order to support the review and contribute to the assessment of the remaining risks for health, ecosystems and crops, uEMEP/EMEP MSC-W model calculations have been performed for present day (2015) and some future scenarios for the coming decades (2030, 2050).

In this chapter, we document the input, model setup and results (for $PM_{2.5}$, PM_{10} NO_2, O_3 and SOMO35) from EMEP MSC-W and uEMEP calculations based on emission scenario input from CIAM. We assess how current reduction plans will improve air quality in the coming decades for three different regions of the EMEP area. These regions are the EU (EU27 including the UK and the EFTA countries of Iceland, Liechtenstein, Norway and Switzerland), the Western Balkan countries and the EECCA countries. We also assess whether further technical (and non technical) measures would improve the situation.

The EMEP MSC-W model results have been distributed further to CCE, ICP Vegetation, ICP Materials and ICP Waters and will be used to calculate effects of air pollution on vegetation, waters and materials in so-called 'ex-post analysis', but this is not part of the work documented in this chapter.

4.2 Emissions

The EMEP Center for Integrated Assessment Modelling (CIAM) has developed three key emission scenarios including estimates for key air pollutants and methane for the UNECE area, including also North America. The scenarios were developed with the GAINS model (Amann et al. 2011) and cover the period from 1990 to 2050 but the focus of the analysis for the current calculations is on 2015, 2030 and 2050. Emission estimates for $PM_{2.5}$ consider a set of emission factors where the condensable fraction of PM is consistently included; these emission factors were developed by TNO within a Nordic Council of Ministers funded project (Simpson et al. 2022) and we chose to use the so called 'typical' emission factors.

4.2.1 The emission scenarios

Baseline scenario

The development of the baseline included an update of the historical data and comparison and validation with the emissions nationally reported (in 2021) within the Convention; the work was jointly performed with the Center for Emission Inventories and Projections (CEIP). The scenario includes the impact of implementing recently committed policies and measures (both international, e.g., EU, as well as national plans). The projections of emission generating activities originate from the PRIMES (Capros et al. 2018) and CAPRI (CAPRI 2021) models consistent with the Green Deal (Fit for 55) scenarios for the European Union (EU) and results of the 9EAST project for Western Balkan, Rep of Moldova, Georgia, and Ukraine. For EFTA, Turkey, and the remaining EECCA countries activity projections are based on the IEA World Energy Outlook (International Energy Agency 2021). Recent events in the Ukraine have not been considered in the scenarios.

Maximum technically Feasible Reduction scenario 'MFR'

The MFR scenario uses the same activity data (energy scenario, agriculture scenario) as Baseline and explores the potential for further emission mitigation applying technical measures which are characterized with lowest emission factors, attainable with reduction technologies for which experience exists. These include highly efficient end of pipe technologies in industry (filters, scrubbers, primary measures), transport sector (the so called EURO stages - up to Euro 7; and associated requirements for fuel quality), residential combustion (clean burning stoves, pellet stoves and boilers), measures in agriculture including: new low emission houses (including cleaning of ventilation air where applicable), covered storage of manures, immediate or efficient application of manures on land, urea use with inhibitors. For the solvent use sector and fossil fuel production and distribution, control of leaks, improved maintenance, incineration as well as substitution or low solvent products are applied.

The 'Low' scenario

This scenario explores further emission reduction opportunities, beyond pure technological solutions as used in the MFR case. Therefore, beyond MFR type of mitigation policy, the scenario also includes climate policies compatible with Paris goals (as in sustainable development scenario of the International Energy Agency 2021) resulting in significant decline of fossil fuel production and use, compared to the Baseline scenario. Additionally, developments

in the agricultural sector are driven by consideration of dietary changes and further improvements of nitrogen use efficiency, both of which result in lower livestock numbers and decline in use of mineral nitrogen fertilizers; the key assumptions behind this agricultural outlook originates from The Food and Land Use Coalition Growing better study (The Food and Land Use Coalition 2019)

In the Baseline, we estimate strong reductions of air pollutants in the EU, EFTA, UK, and Western Balkan countries (Figure 4.1), which is driven by the implementation of existing legislation and ambitious EU climate policy (Green Deal) for the EU while for the Western Balkan countries the implementation of the Energy Community agreements in the coming decades. EECCA countries have a distinctly different CO_2 trajectory (still increasing emissions) but even here, due to existing legislation, an ongoing decoupling of economic growth and air pollution emissions is taking place over time. Methane declines in the baseline only in the EU (Green Deal scenario). Primary $PM_{2.5}$ are expected to decline in all regions except EECCA. The decline is driven by legislation in industry, transport, and the residential sector which share declines slightly (e.g., due to reduced use of coal in the future) for the whole region with strong differences between regions. The estimates for $PM_{2.5}$ are associated with rather large uncertainties in fuel use and limited information on structure of installations, both of which are critical for the residential sector and total $PM_{2.5}$.

Figure 4.2 compares the relative change in emissions between the baseline and the two mitigation scenarios (MFR and Low). For SO_2 and NO_x most regions have significant reductions in the Baseline (EECCA countries less) and therefore further mitigation potential is limited (see MFR and Low). However, even in these cases, one needs to note that in relative terms moving from MFR to Low might halve emissions further. For NH_3 the picture is different, the Baseline shows no reduction, rather increase and there is significant further mitigation potential that increases further in the Low scenario where significant transformation in the agricultural sector is embedded (driven by assumed dietary changes). For the EU the baseline already assumes a strong decarbonization and rather strict emission limit values (Green Deal and ZPAP (zero pollution) strategy). Therefore, in both the Baseline and the Low scenarios the same underlying energy projections are used for the EU and consequently no further mitigation potential on top of MFR, apart from NH_3, are available.

Table 4.1: Emission scenarios applied in this study. See text for details,

Scenario name	Emission year	Description
Baseline	2015	Reference calculation for validation
Baseline	2030	Baseline for the year 2030
MFR	2030	Maximum technical feasible reduction for the year 2030
Baseline	2050	Baseline for the year 2050
MFR	2050	Maximum technical feasible reduction for the year 2050
Low	2050	As in maximum technical feasible reduction for the year 2050 but with additional behavioural changes in regard to diet and reductions compatible with other climate goals

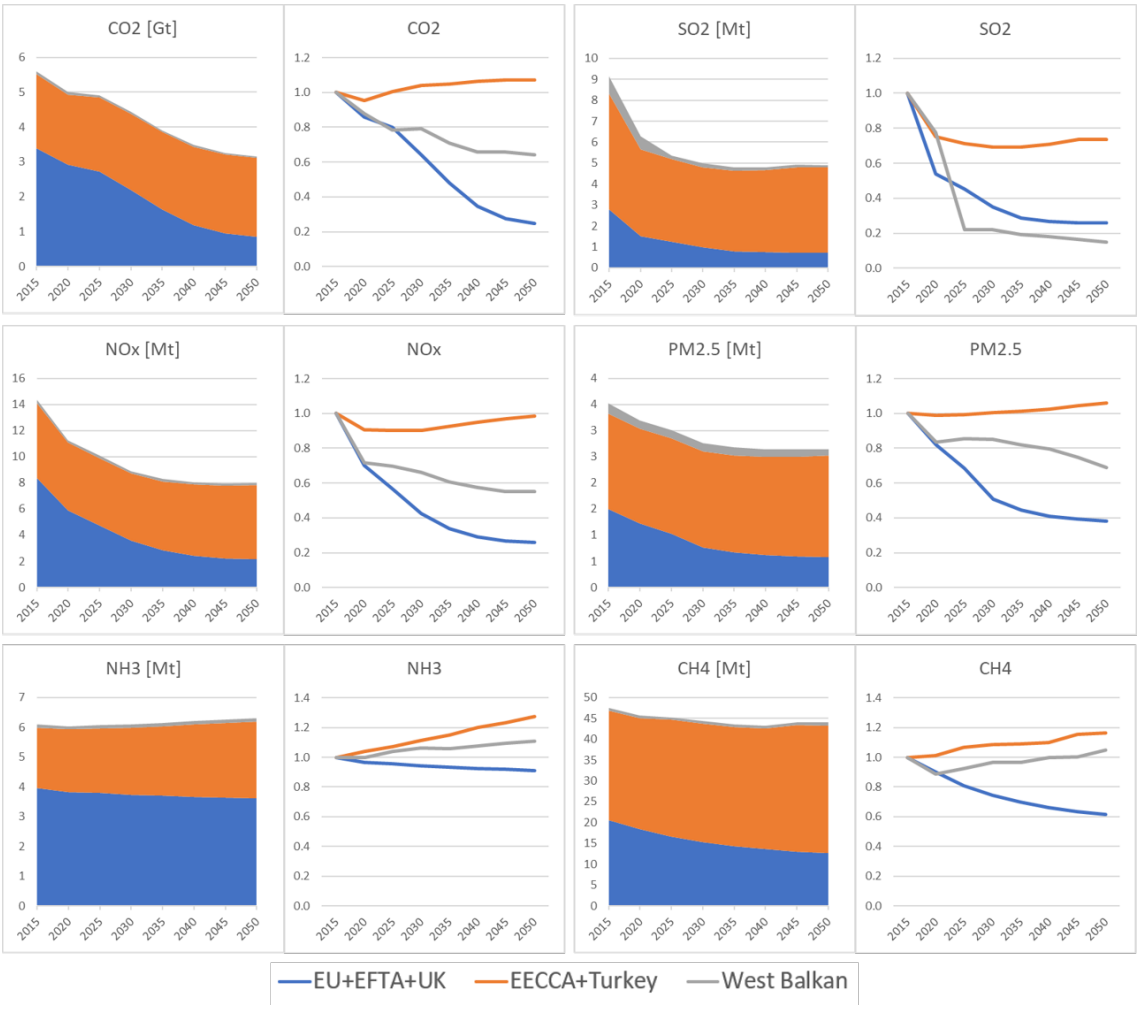

Figure 4.1: Baseline emissions of key air pollutants and greenhouse gases in the European, Western Balkan and ECCAA regions; 2015-2050

4.2.2 Implementation of the emissions in the EMEP model

For most emissions the national and sector total emissions for each GNFR sectors are provided by CIAM, while the spatial distribution of emissions are based on different sources:

- **EU27, Norway, Switzerland and the United Kingdom** - National and sector total emissions are provided by CIAM, spatial distribution from the gridded EMEP 2019 emissions on $0.1° \times 0.1°$resolution.
- **Western Balkan and EECCA countries** - Both national and sector total emissions and spatial distribution are provided by CIAM on $0.1° \times 0.1°$resolution.
- **International shipping** - Emission totals for the 5 sea regions (North Sea, Baltic Sea, Black Sea, Mediterranean Sea, North-East Atlantic Ocean) in the model domain are provided by CIAM and distributed spatially using the AIS based gridded shipping emissions from the EMEP 2019 data set.
- **Agricultural (fertilizer induced) soil NO_x and NO_x from agricultural waste burning** - Both national and sector total emissions and spatial distribution are provided by

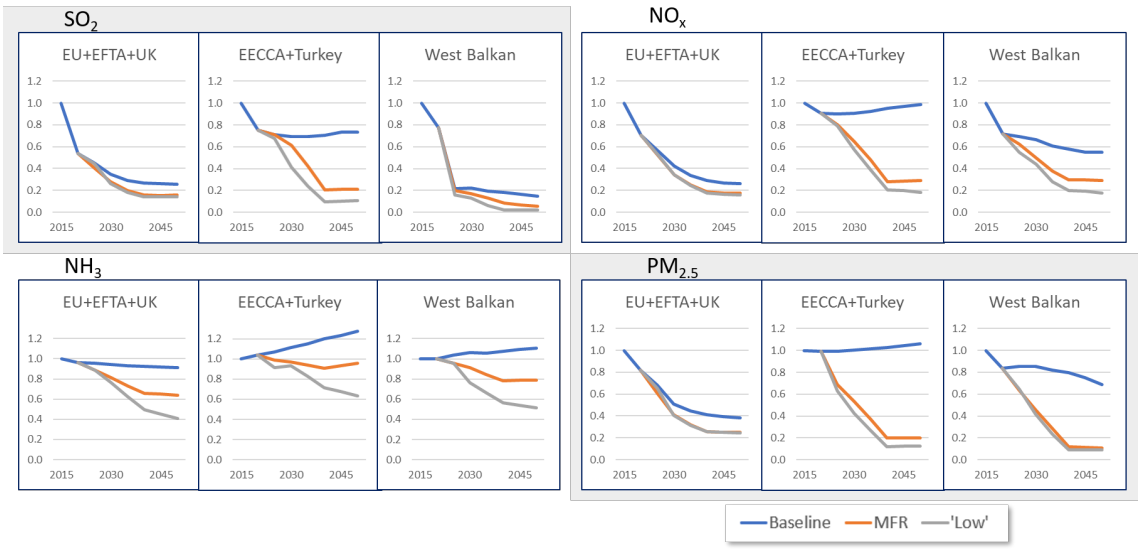

Figure 4.2: Relative changes of the emissions scenarios Baseline, MFR and Low for key air pollutants and greenhouse gases in Europe; 2015-2050

CIAM on $0.1° \times 0.1°$resolution for each scenario. Soil NO_x emissions from other sources, such as 'Biome' (a background emission rate for each landcover type, modified by temperature and soil moisture), 'Ndep' (emissions resulting from atmospheric N deposition) and 'Pulsing' (emissions resulting from rain and/or soil moisture changes after a dry period) are added from the CAMS-GLOB-SOIL v2.2 NO_x inventory (Simpson and Darras 2021).

- **North African and Asian areas** - Gridded emissions from the ECLIPSE v6b CLE scenario are used for North African and Asian areas which are within the model domain. The resolution is $0.5° \times 0.5°$.
- **NMVOC emissions from agriculture** - The NMVOC emissions provided by CIAM for the agricultural sectors contain only NMVOC from agricultural waste burning. In order to account for other sources, NMVOC emissions from agricultural sectors were added from the EMEP 2019 data set. These emissions were kept constant for each scenarios.

The monthly temporal profiles of emissions are based on global gridded emission data from the ECLIPSE v6b dataset.

4.3 Model setup

Modelling was carried out with the EMEP MSC-W model and the downscaling model uEMEP (urban EMEP).

4.3.1 EMEP MSC-W

The EMEP MSC-W model version rv4.44 has been used for the Gothenburg protocol review runs. The horizontal resolution is $0.1° \times 0.1°$, with 20 vertical layers (the lowest with a height of approximately 50 meters). Meteorological conditions for the year 2015 are used

in all scenario runs which are discussed here. The meteorological data have been derived from ECMWF-IFS(cy40r1) simulations. The forest fires emissions are taken from The Fire INventory from NCAR (FINN) (Wiedinmyer et al. 2011). In order to be consistent with the meteorological conditions, forest fires emissions for 2015 were used. Boundary conditions of ozone are developed from climatological ozone-sonde datasets, modified monthly against clean-air surface observations for 2015 (the so-called "Mace-Head" adjustment, see Simpson et al. 2012). The modeled geographic area is between 30° N-82° N latitude and 30° W-90° E longitude.

4.3.2 uEMEP

Downscaling of the $0.1° \times 0.1°$EMEP MSC-W model output was carried out using the uEMEP model. This model is a Gaussian plume based model that firstly redistributes EMEP MSC-W $0.1° \times 0.1°$gridded emissions to high resolution using appropriate emission proxies. Each sub-grid emission is then modelled with uEMEP to produce high resolution concentration fields. Dispersion is carried out on annual mean emissions using a rotationally symmetric Gaussian plume dispersion kernel. Downscaling occurs within a limited region. Each sub-grid will 'see' emissions only from within a $\pm$ 0.1^o moving window. The EMEP MSC-W contribution from the same region is calculated using the local fraction methodology (Wind et al. 2020) and this is removed before adding the uEMEP contribution. In this way double counting is avoided. When presenting source contributions then a combination of both uEMEP, out to $\pm$ 0.1^o, and EMEP local fractions, out to $\pm$ 0.4^o is used, see Figure 4.3. Only primary emissions are downscaled. A parameterised chemistry scheme is used to calculate NO_2 from NO_x and O_3.

Downscaling is carried out for 5 of the GNFR emissions sectors. These are listed in Table 4.2 along with the emission proxies used for redistribution. Two resolutions are used. For calculations at air quality station sites a resolution of 25 m is applied. For exposure calculations a resolution of 250 m is applied.

A description of the uEMEP model can be found in Denby et al. (2020) and Mu et al. (2022).

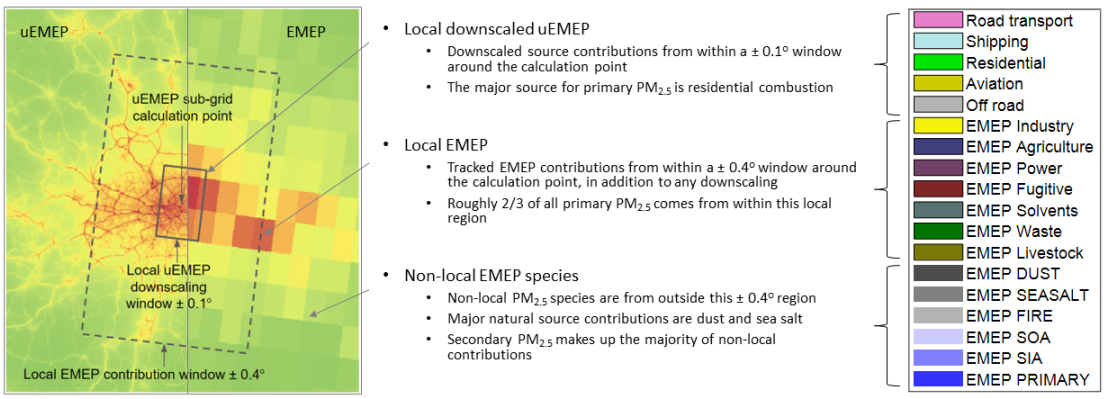

Figure 4.3: Explanation of how the local and non-local source contributions from uEMEP and EMEP MSC-W are combined

Table 4.2: Downscaling proxies used in the uEMEP calculations

GNFR	Sector name	Emission proxy	Comments
F	Road transport	Open Street Map (OpenStreetMap contributors 2020)	Weighting of emission distributions using the road type according to Mu et al. (2022).
G	Shipping	AIS based emission data provided by the Coastal authorities of Norway (Kystverket 2020)	
C	Residential combustion	Population density from Schiavina et al. (2019)	Alternative proxies were evaluated in Mu et al. (2022).
H*	Aviation	Corine land cover (Copernicus Land Monitoring Service 2018) 'airport' polygon	Only low level emissions included (0.5 of total).
I*	Off road	Corine land cover (Copernicus Land Monitoring Service 2018) polygons for urban, suburban, construction and road and rail	Weighted combination of these

* These sectors were not downscaled for the EECCA countries as suitable land cover data was not available

4.4 Results

The uEMEP/EMEP modelling system is applied to the 6 emission scenarios listed in Table 4.1. For 2015 a validation against Airbase stations is carried out for the annual mean concentrations of the pollutants $PM_{2.5}$, PM_{10}, NO_2 and O_3 and the O_3 health indicator SOMO35 (see Ch. 1.2). SOMO35 is not downscaled so these results come directly from the EMEP MSC-W model. Further to this, the result of the scenario calculations are provided in terms of concentration distributions at station sites for the pollutants NO_2 and $PM_{2.5}$ as well as the SOMO35 health indicator. Maps for each of the scenarios at 250 m resolution are made for NO_2 and $PM_{2.5}$ and at 0.1° for SOMO35. The maps produced with uEMEP are calculated on 2 separate domains, a Western domain that covers the EU27, EFTA, UK and Western Balkan regions and an Eastern domain to cover the EECCA countries. Exposure distributions are calculated for three separate regions; 1) The EU region which includes the EU27, EFTA countries and the UK; 2) The Western Balkan countries; 3) The EECCA countries. Population weighted concentrations for each region and each country are calculated along with the source contributions.

4.4.1 Validation for 2015

Calculated concentrations for 2015, using 2015 meteorology, are compared to measured annual mean concentrations at all available Airbase stations. The results are shown as scatter plots for NO_2 and $PM_{2.5}$ in Figures 4.4 and 4.5 and statistical parameters are provided for all 4 pollutants in Table 4.3.

There is an improvement for all statistical parameters when going from EMEP MSC-W to uEMEP. Particularly for NO_2 the bias is reduced from -42% to -8% and the spatial correlation

increases from $r^2 = 0.31$ to $r^2 = 0.56$. Smaller but significant improvements are found for PM and O_3.

The reason for improvement and change in bias is two fold. Firstly, with downscaling the positions of the emissions are better spatially resolved and gradients in pollutants will be improved. Secondly, downscaling also introduces a vertical profile to the concentrations so that near surface releases, such as road transport, result in higher ground level concentrations even without the horizontal redistribution. This change in bias is most evident for NO_2.

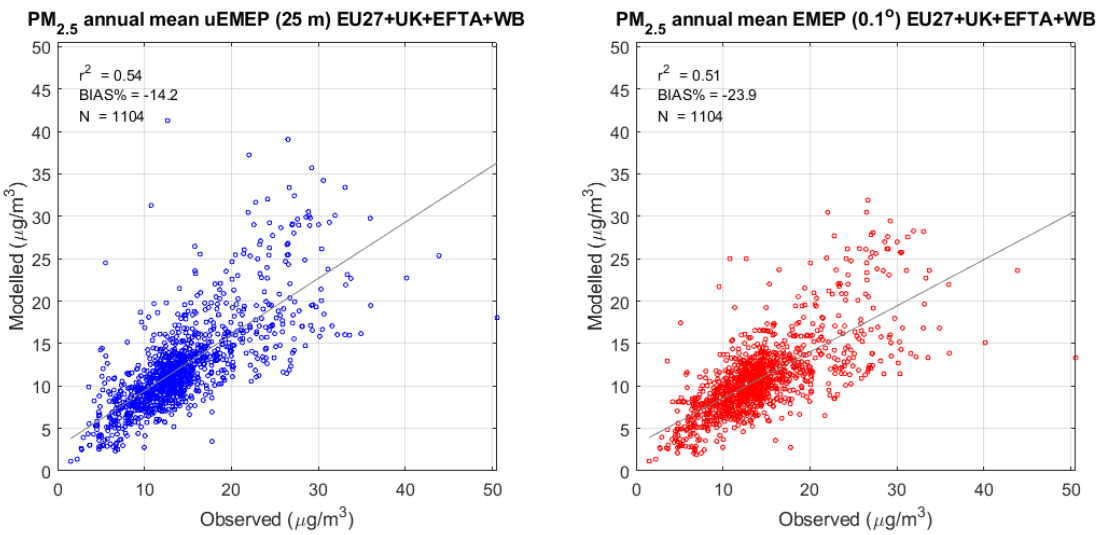

Figure 4.4: Scatter plots of annual mean $PM_{2.5}$ concentrations showing both the results of uEMEP/EMEP (left) and EMEP (right) calculations. All available Airbase stations are used in the validation.

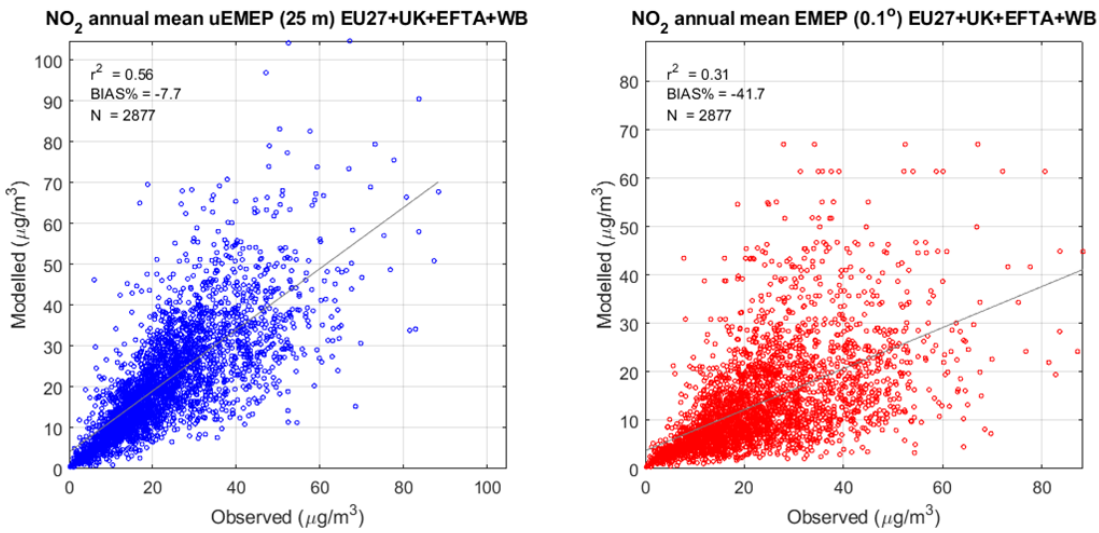

Figure 4.5: Scatter plots of annual mean NO_2 concentrations showing both the results of uEMEP/EMEP (left) and EMEP (right) calculations. All available Airbase stations are used in the validation.

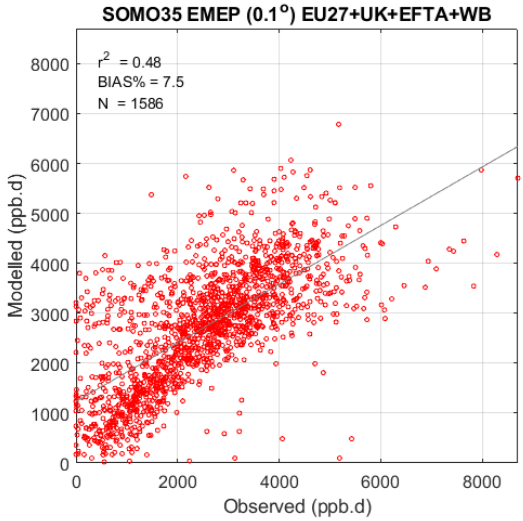

Figure 4.6: Scatter plots of the O_3 health indicator SOMO35 showing the results of EMEP MSC-W calculation. All available Airbase stations are used in the validation.

Table 4.3: Statistical parameters for the 2015 annual mean validation against Airbase stations for both uEMEP and EMEP calculations

Parameter	Bias(%)		r^2	
Pollutant	uEMEP	EMEP	uEMEP	EMEP
$PM_{2.5}$	-14	-24	0.54	0.51
PM_{10}	-31	-40	0.38	0.28
NO_2	-8	-42	0.56	0.31
O_3	+9	+18	0.39	0.30
SOMO35		+8		0.48

4.4.2 Station exceedances

Calculations are made at all station sites for all pollutants and for all scenarios. In Figures 4.7 and 4.8 the concentration distributions for observed and modelled scenario calculations are shown for $PM_{2.5}$ and NO_2. For 2015 the modelled concentrations have a negative bias and this can be seen in the concentration distribution. However, changes in the concentration distributions for the scenarios are much larger than this bias.

For $PM_{2.5}$ we see that by 2030, even with the Baseline scenario, that only a handful of stations remain above the 15 μg m^{-3} concentration level and only 10% of stations are above the 10 μg m^{-3}. By 2050 there are very few stations above 10 μg m^{-3} for all scenarios.

For NO_2 we see that by 2030 there are very few stations above the 30 μg m^{-3} concentration level and only around 3% of stations are above the 20 μg m^{-3}. By 2050 only 1% of stations are above 10 μg m^{-3} for all scenarios. There is only a small difference between the Baseline and the MFR scenarios for NO_2.

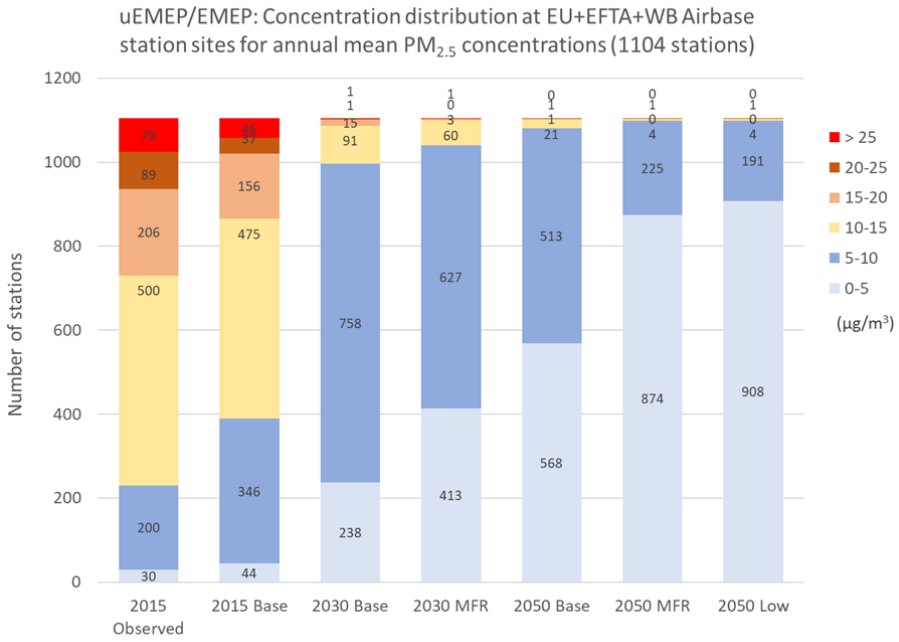

Figure 4.7: Number of stations within defined concentration ranges for annual mean $PM_{2.5}$. Shown are observed for 2015 and modelled for all scenarios. All available Airbase stations are used in the calculations.

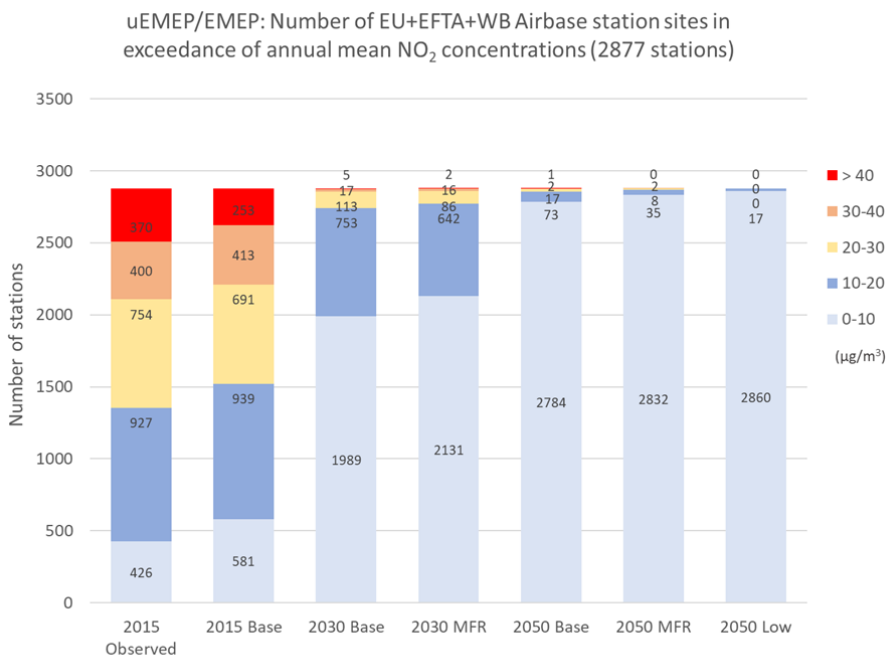

Figure 4.8: Number of stations within defined concentration ranges for annual mean NO_2. Shown are observed for 2015 and modelled for all scenarios. All available Airbase stations are used in the calculations.

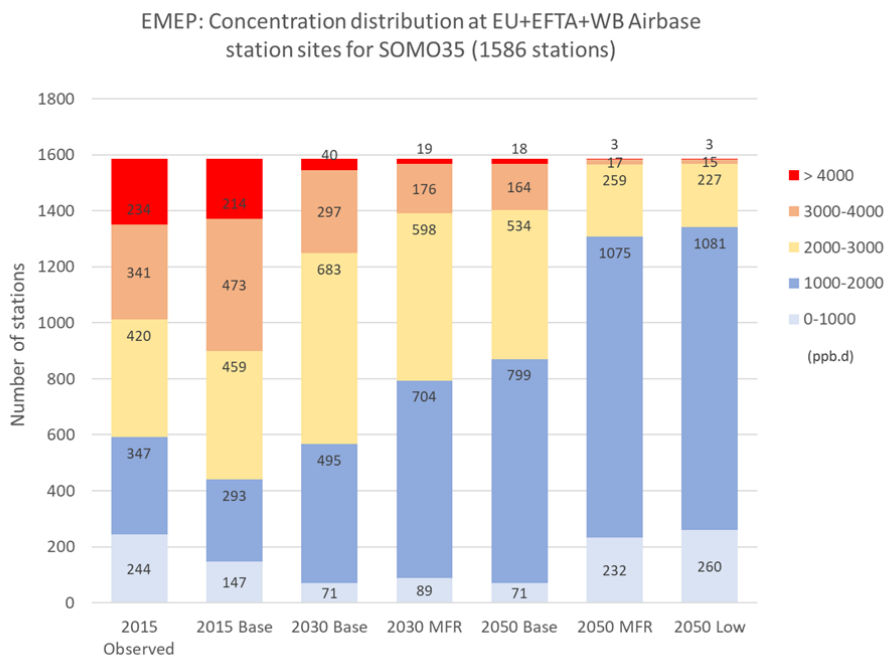

Figure 4.9: Number of stations within defined concentration ranges for SOMO35. Shown are observed for 2015 and modelled for all scenarios. All available Airbase stations are used in the calculations.

4.4.3 Maps

Calculations for each scenario are made using the uEMEP/EMEP modelling system. The final resolution of the maps is 250 m. The projection used is the European ETRS89-LAEA projection (EPSG: 3035) for the EU regions, centred in longitude at +10° E and a shifted region centred at +55° E to cover the EECCA countries. In Figures 4.10 to 4.13, 4 example maps are shown for the Western calculation domain and for a selected zoomed region for both NO_2 and $PM_{2.5}$. In Figure 4.14, SOMO35 is shown. Similar examples are also given for the Eastern domain and EECCA countries in Figures 4.15 to 4.18.

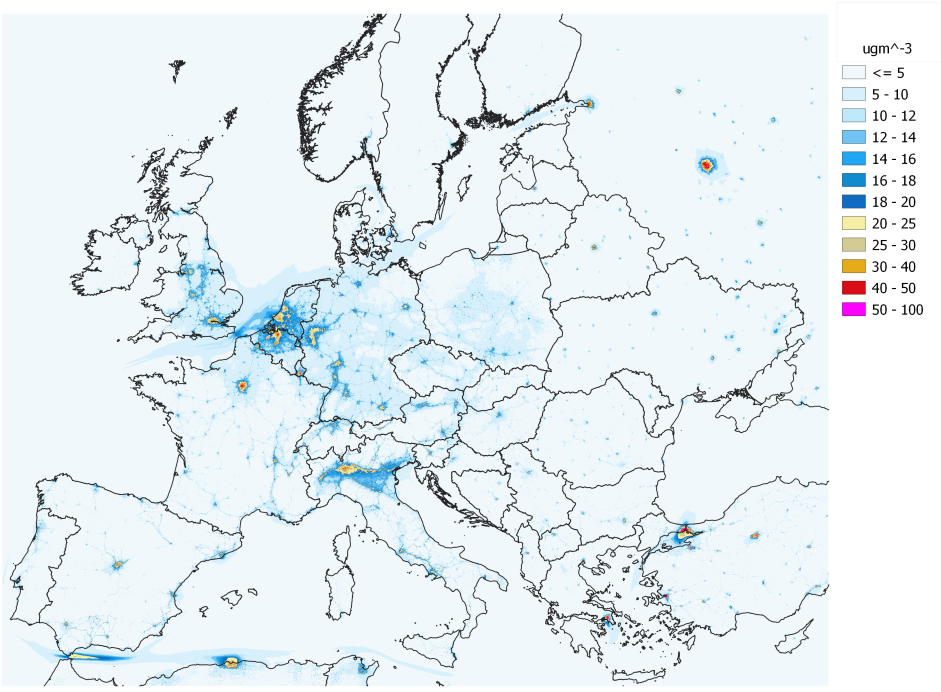

Figure 4.10: uEMEP Western calculation domain showing annual mean NO_2 concentrations for the 2015 Baseline scenario.

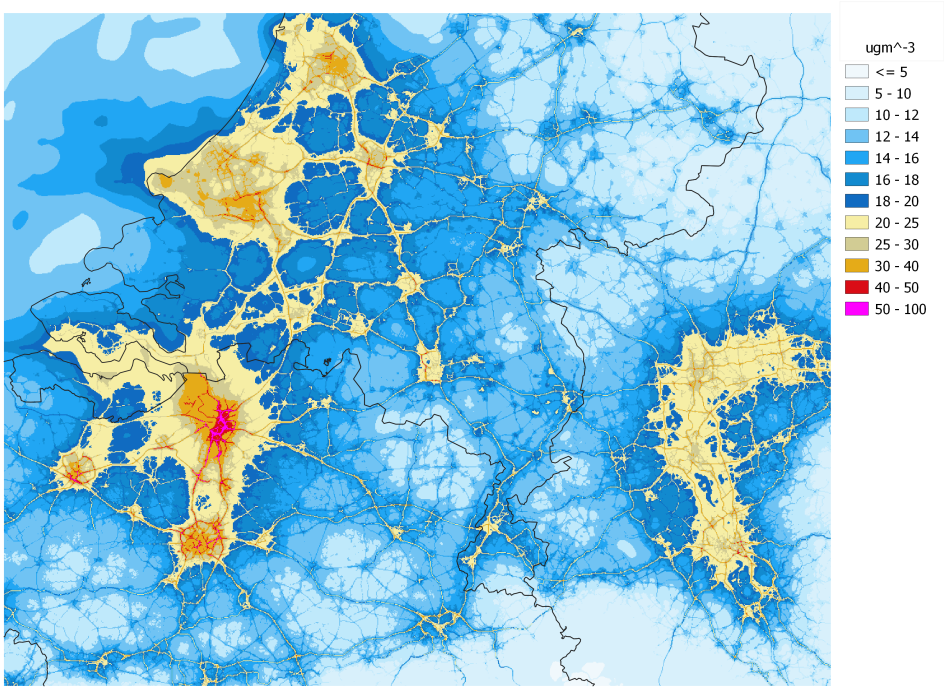

Figure 4.11: uEMEP zoom to The Netherlands, Belgium and Germany showing annual mean NO_2 concentrations for the 2015 Baseline scenario.

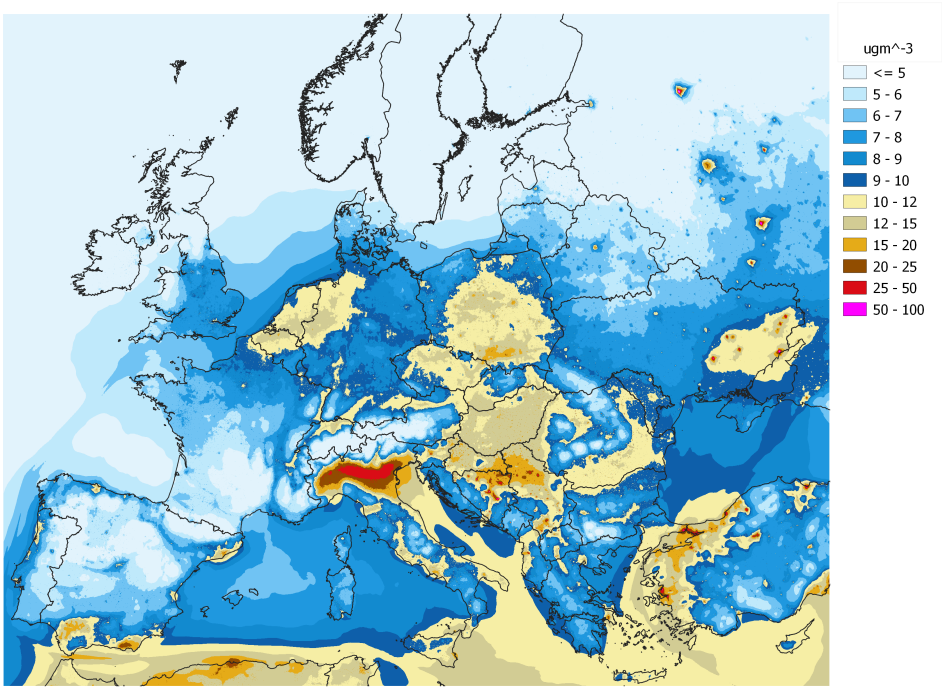

Figure 4.12: uEMEP Western calculation domain showing annual mean $PM_{2.5}$ concentrations for the 2015 Baseline scenario.

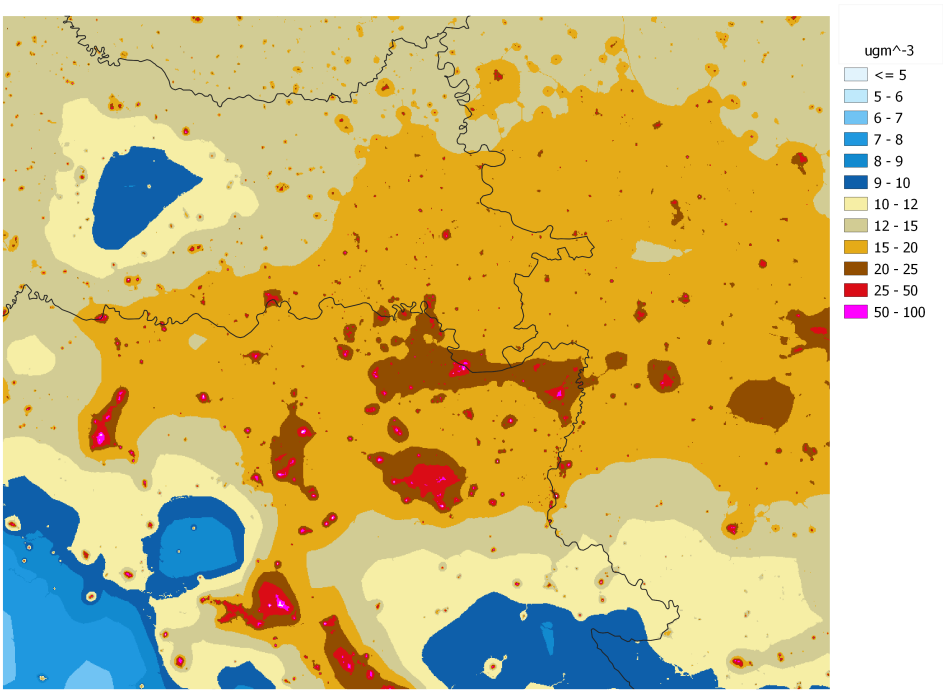

Figure 4.13: uEMEP zoom to the Western Balkan region including Croatia, Hungary, Serbia and Bosnia-Herzegovina showing annual mean $PM_{2.5}$ concentrations for the 2015 Baseline scenario.

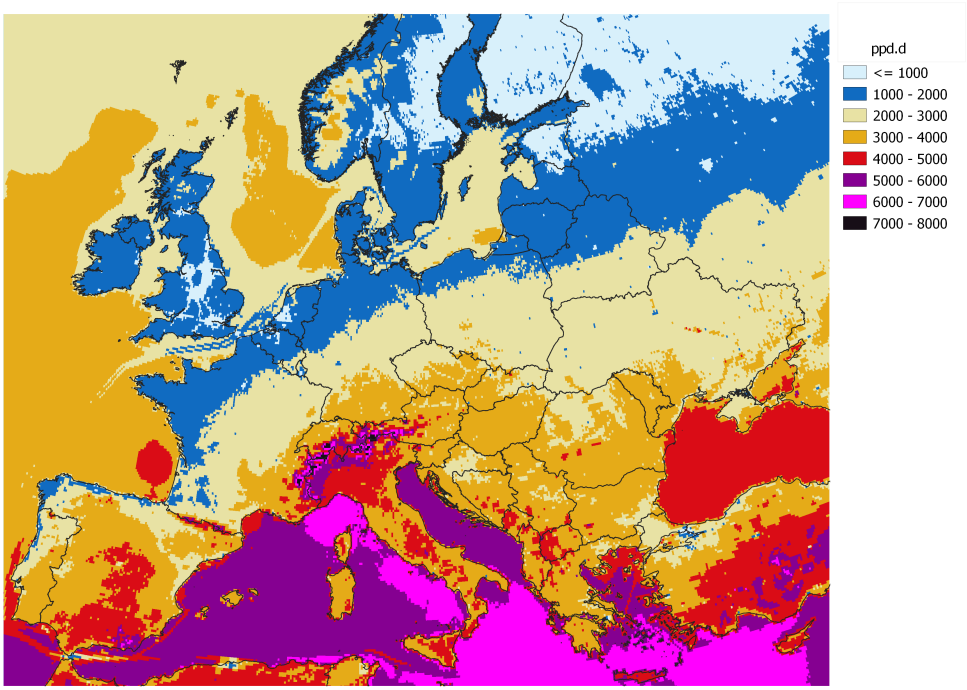

Figure 4.14: uEMEP Western calculation domain showing SOMO35 values for the 2015 Baseline scenario.

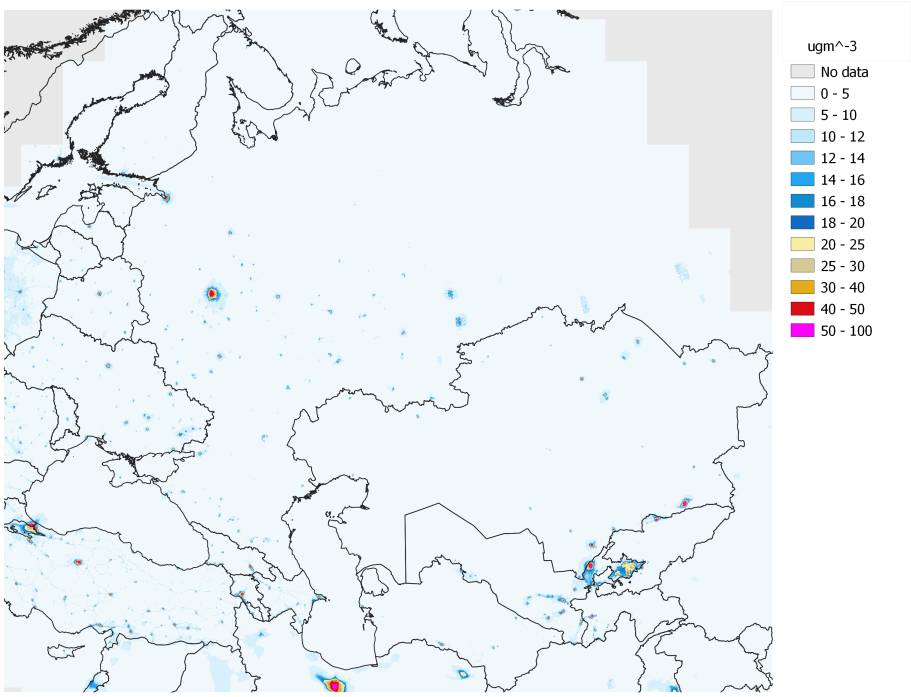

Figure 4.15: uEMEP Eastern calculation domain showing annual mean NO_2 concentrations for the 2015 Baseline scenario.

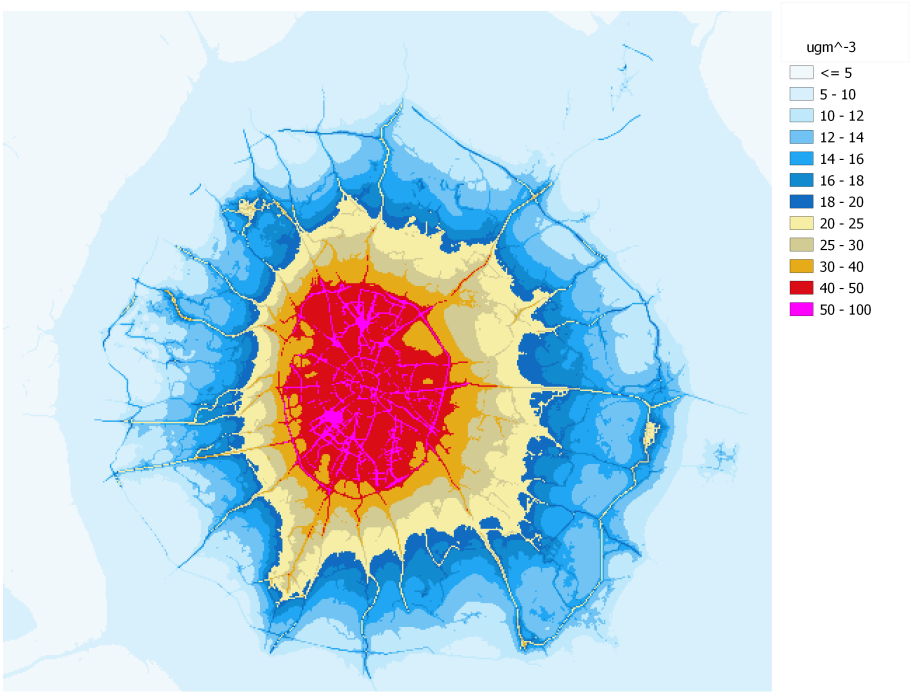

Figure 4.16: uEMEP zoom to Moscow showing annual mean NO_2 concentrations for the 2015 Baseline scenario.

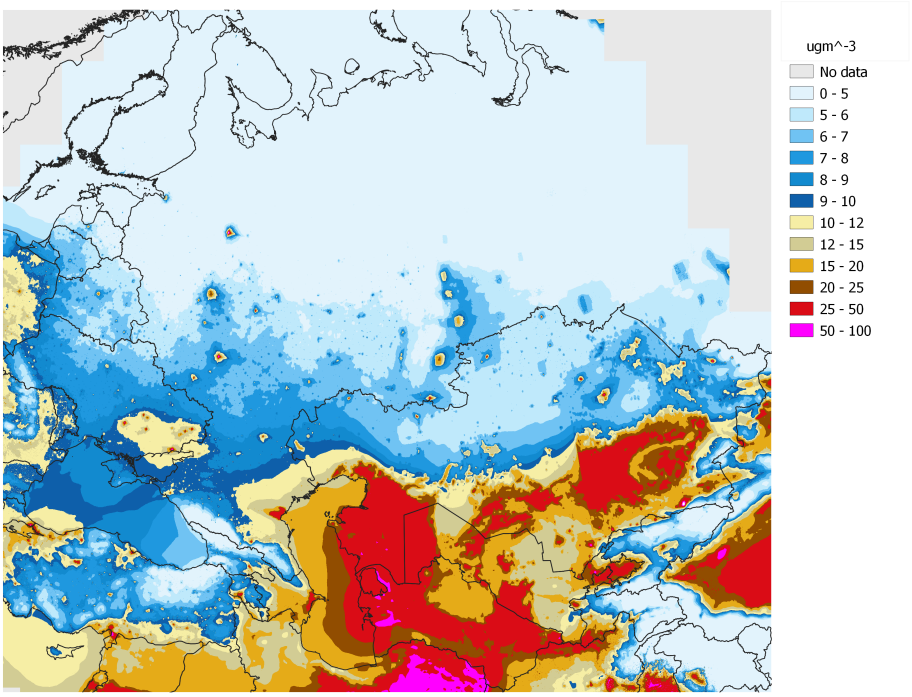

Figure 4.17: uEMEP Eastern calculation domain showing annual mean $PM_{2.5}$ concentrations for the 2015 Baseline scenario.

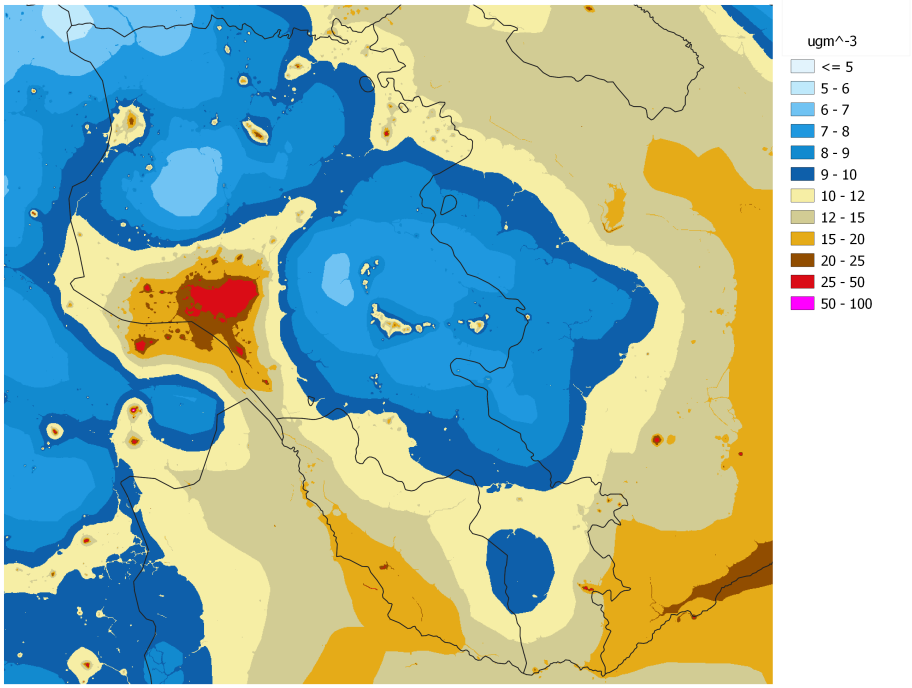

Figure 4.18: uEMEP zoom to the Armenia and surrounding countries showing annual mean $PM_{2.5}$ concentrations for the 2015 Baseline scenario.

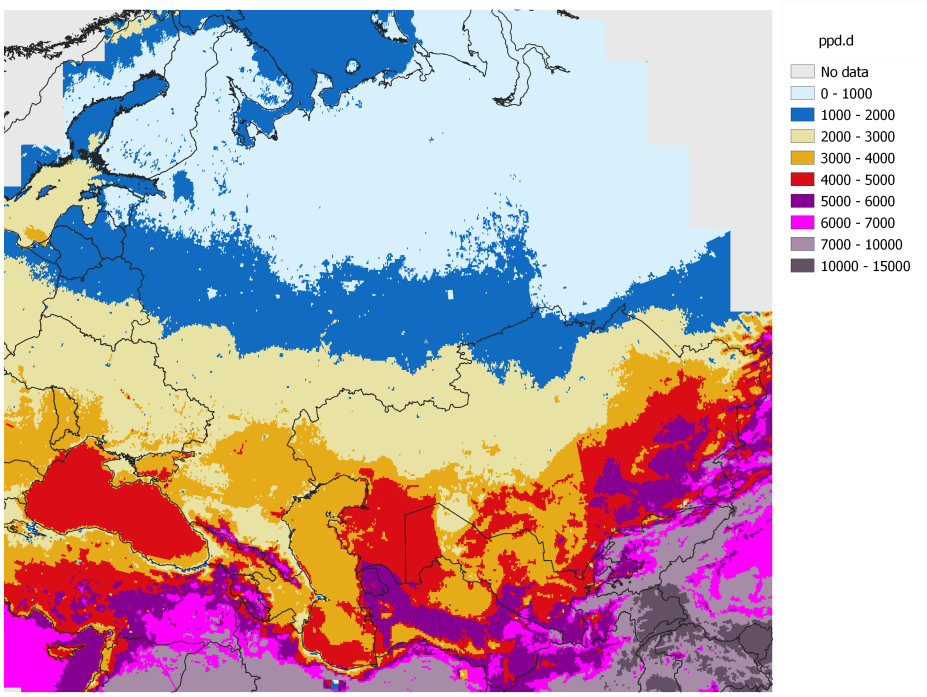

Figure 4.19: uEMEP Eastern calculation domain showing SOMO35 values for the 2015 Baseline scenario.

4.4.4 Exposure and source contributions

The maps shown in Section 4.4.3 are overlaid with population maps (Schiavina et al. 2019) provided at 0.0025^o resolution. The population maps remain unchanged for all the scenarios. From this the population exposure distribution is derived for the entire population in the countries considered, separated into the 3 regions of EU+EFTA (including the UK), Western Balkan and EECCA countries. In addition to the exposure distribution the population weighted concentration (PWC) is derived for each country individually. For both these calculations source contributions are determined and for PM the speciation is also provided. Section 4.3.2 explains how these source contributions are calculated.

EECCA countries

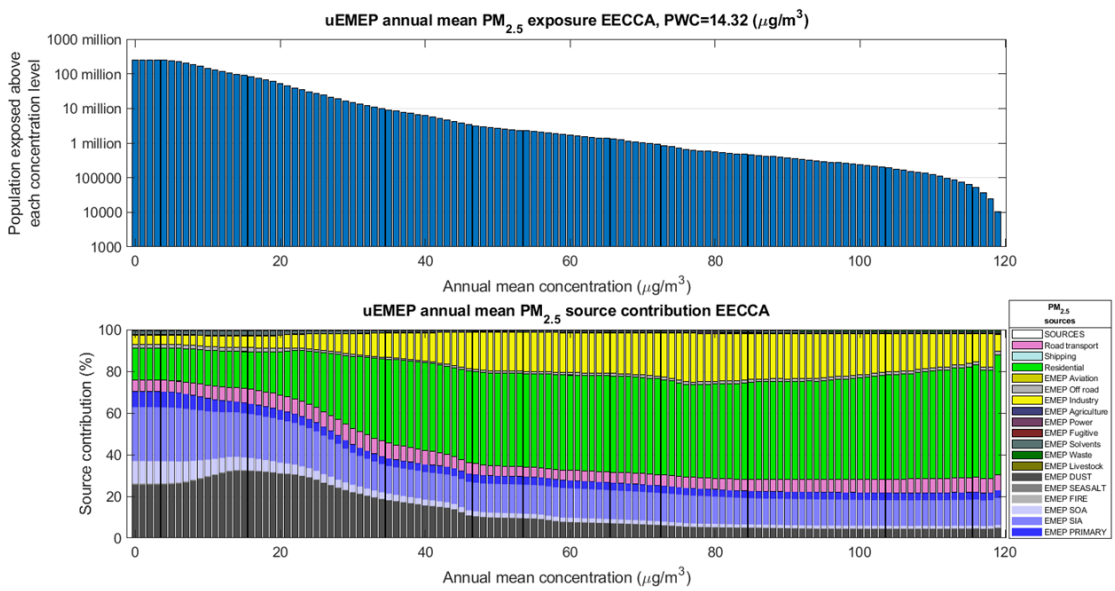

Figure 4.20: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2015 Baseline scenario in all EECCA countries. Shown are the number of inhabitants exposed above the given concentrations.

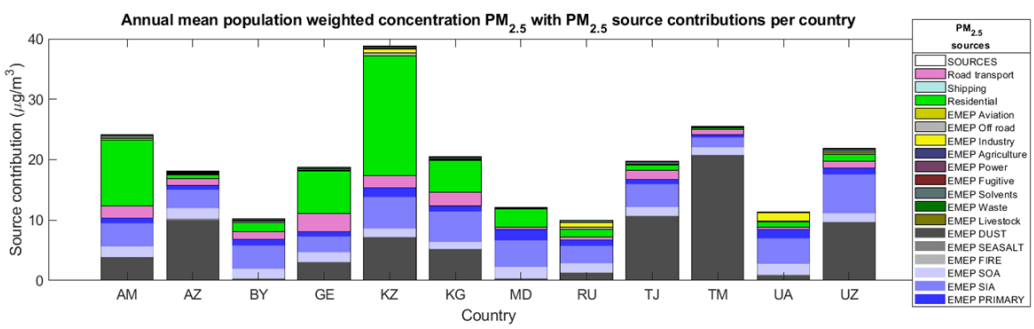

Figure 4.21: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2015 Baseline scenario in all EECCA countries.

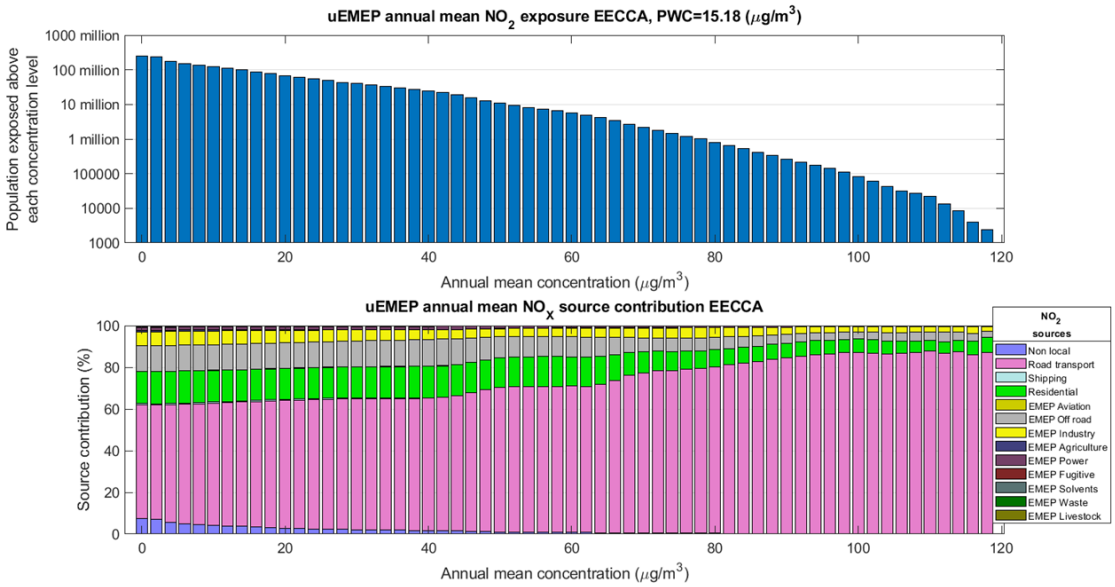

Figure 4.22: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2015 Baseline scenario in all EECCA countries. Shown are the number of inhabitants exposed above the given concentrations.

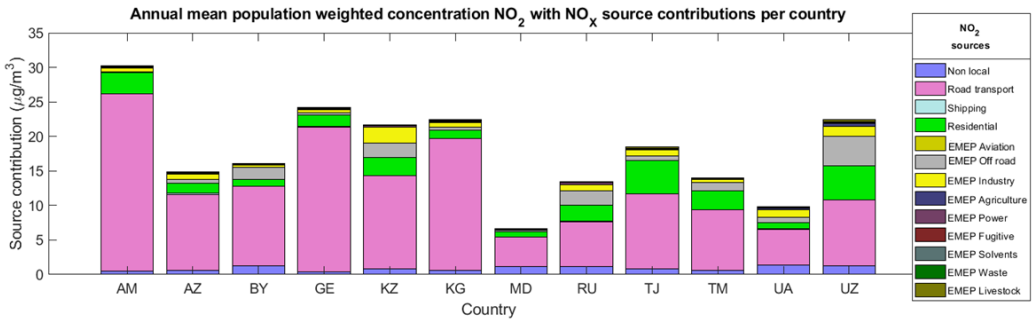

Figure 4.23: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2015 Baseline scenario in all EECCA countries.

The exposure distribution for annual mean $PM_{2.5}$ in EECCA countries is shown in Figure 4.20 for 2015. The dominant local source contribution for the higher concentrations is from the GNFR sector C, residential combustion. For the population as a whole, exposure to concentrations > 0 μg m^{-3}, then 35% of the exposure is from primary anthropogenic $PM_{2.5}$ emissions where 75% of this is from within the $\pm 0.4°$ local source contribution window, see Section 4.3.2. A large amount, 25%, of $PM_{2.5}$ is from natural sources and the rest, around 40%, is from secondary $PM_{2.5}$. The exposure to $PM_{2.5}$ per country varies significantly, Figure 4.21, with large contributions from wind blown dust in some countries. Kazakhstan (KZ) shows the highest exposure due to a large residential combustion contribution.

NO_2 exposure is dominated by the local contribution from road transport. More than 50% of the exposure is from this source and > 90% is from this and other local sources within the $\pm 0.4°$ local source contribution window.

Western Balkan countries

The exposure distribution for annual mean $PM_{2.5}$ in Western Balkan countries is shown in Figure 4.24 for 2015. As in the EECCA countries the dominant local source contribution for the higher concentrations is from the GNFR sector C, residential combustion. For the population as a whole, exposure to concentrations > 0 μg m^{-3}, then 65% of the exposure is from primary anthropogenic $PM_{2.5}$ emissions. Unlike EECCA countries there is little contribution from natural sources. Exposure in Western Balkan countries to $PM_{2.5}$ is higher than in EECCA countries. The exposure to $PM_{2.5}$ per country varies, Figure 4.25, with large contributions from residential combustion in all countries. Bosnia and Herzegovina (BA) shows the highest exposure due to a large residential combustion contribution.

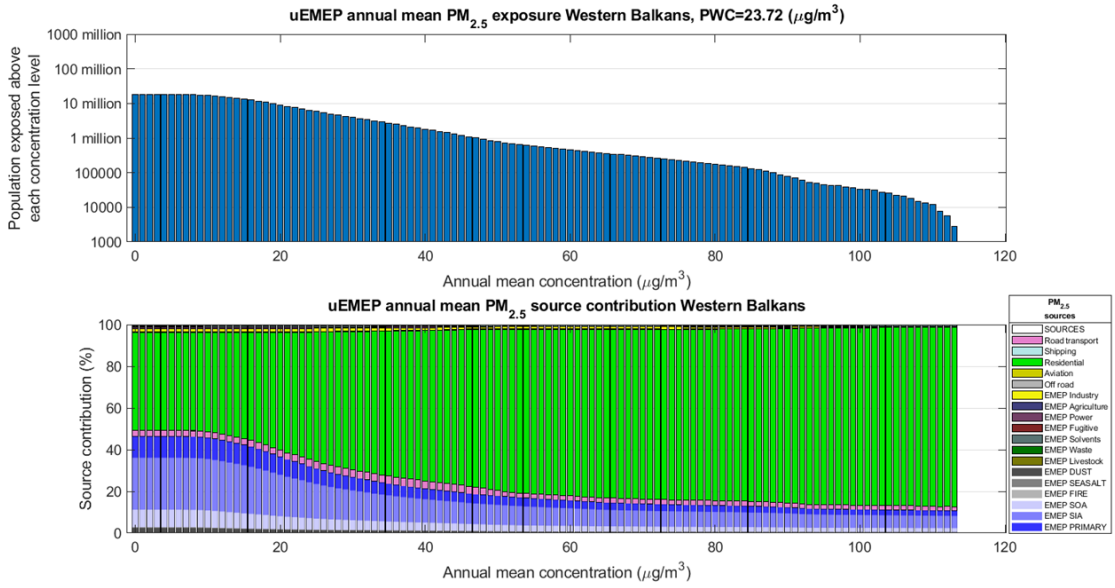

Figure 4.24: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2015 Baseline scenario in all Western Balkan countries. Shown are the number of inhabitants exposed above the given concentrations.

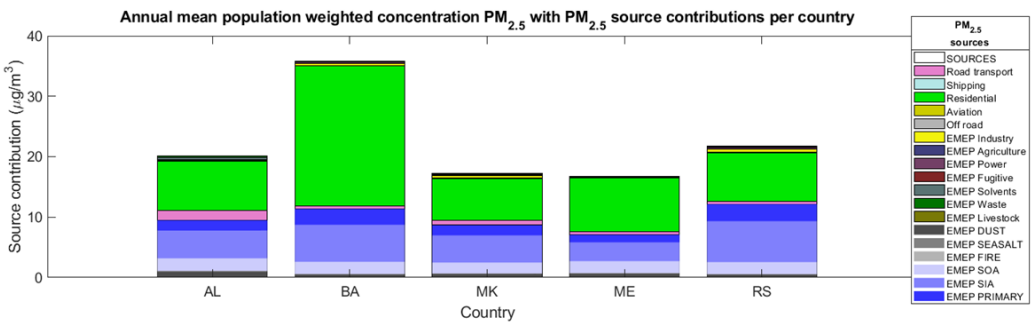

Figure 4.25: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2015 Baseline scenario in all Western Balkan countries.

As in EECCA countries NO_2 exposure is dominated by the local contribution from road traffic. More than 70% of the exposure is from this source and > 90% is from this and other local sources. Exposure to NO_2 is lower in the Western Balkan than in EECCA countries.

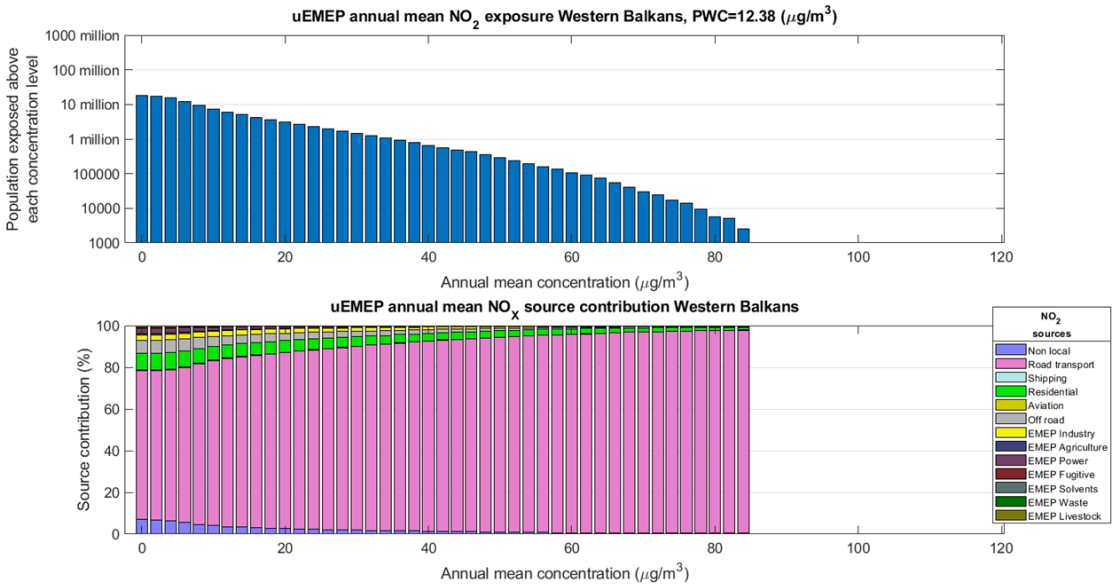

Figure 4.26: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2015 Baseline scenario in all Western Balkan countries. Shown are the number of inhabitants exposed above the given concentrations.

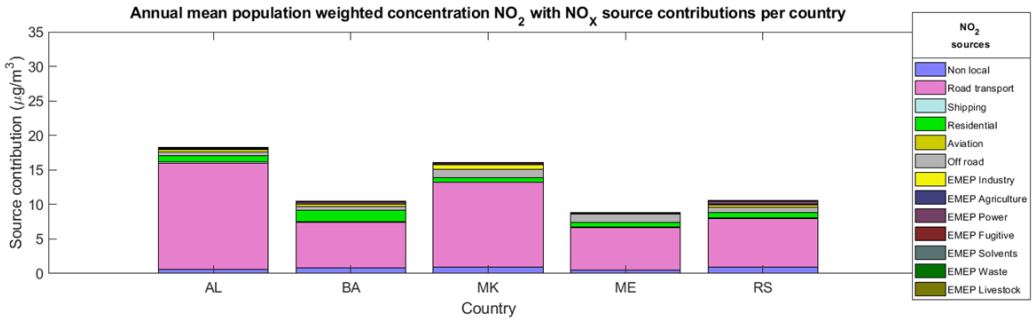

Figure 4.27: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2015 Baseline scenario in all Western Balkan countries.

EU and EFTA countries

The exposure distribution for annual mean $PM_{2.5}$ in EU and EFTA countries is shown in Figure 4.28 for 2015. Exposure to $PM_{2.5}$ is significantly less in these countries than in the other two regions, particularly the highest modelled concentrations are < 50 μg m^{-3} compared to over 100 μg m^{-3} in the EECCA and Western Balkan countries. The dominant local source contribution is from residential combustion but it is the secondary $PM_{2.5}$ that is responsible for > 50% of the exposure. Italy (IT) and Slovenia (SI) show the highest population exposures.

NO_2 exposure is higher in the EU countries compared to EECCA and the Western Balkan, dominated again by the local contribution from road transport. The highest exposure is modelled in Luxembourg (LU). Comparison with available Airbase stations in Luxembourg shows a large positive model bias, see Appendix E, Section E.1.

Similar plots for all 3 regions and all other scenarios have been made. For comparison the 2030 MFR scenario can be found in Appendix E, Section E.2.

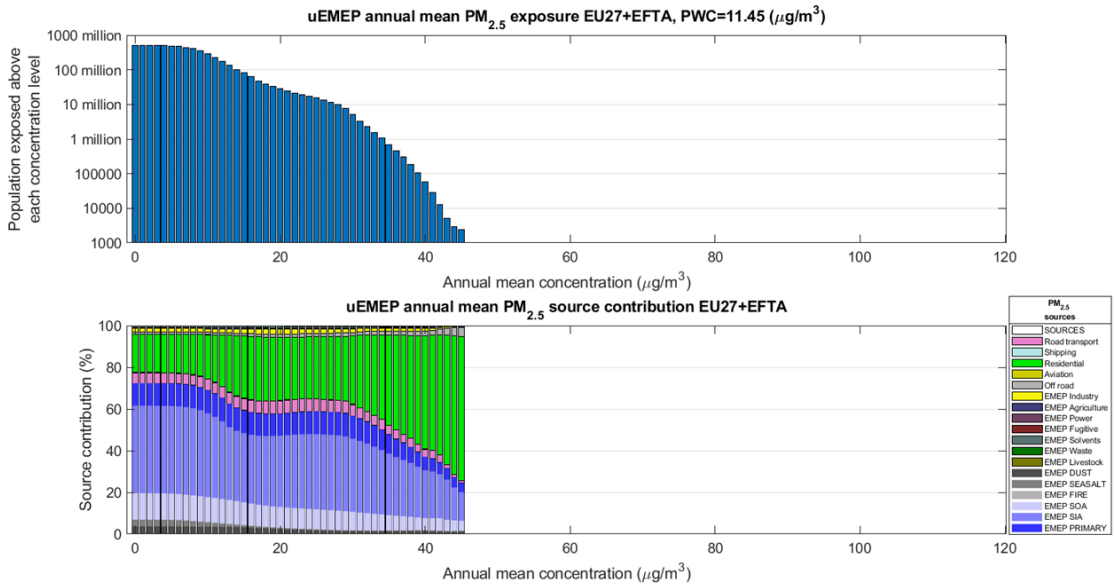

Figure 4.28: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2015 Baseline scenario in all EU and EFTA countries, including the UK. Shown are the number of inhabitants exposed above the given concentrations.

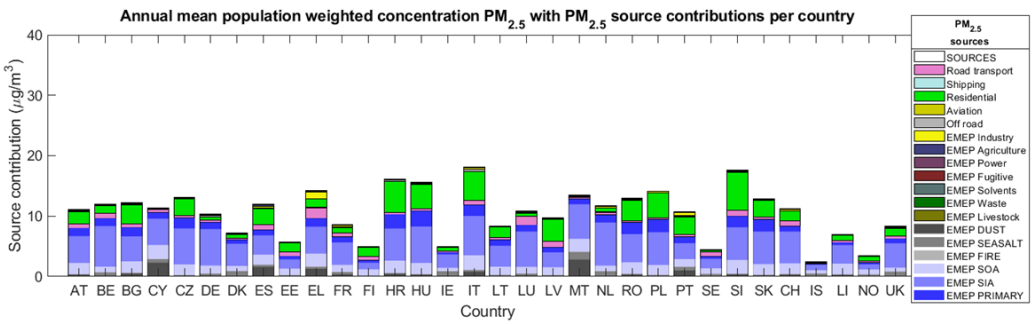

Figure 4.29: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2015 Baseline scenario in all EU and EFTA countries, including the UK.

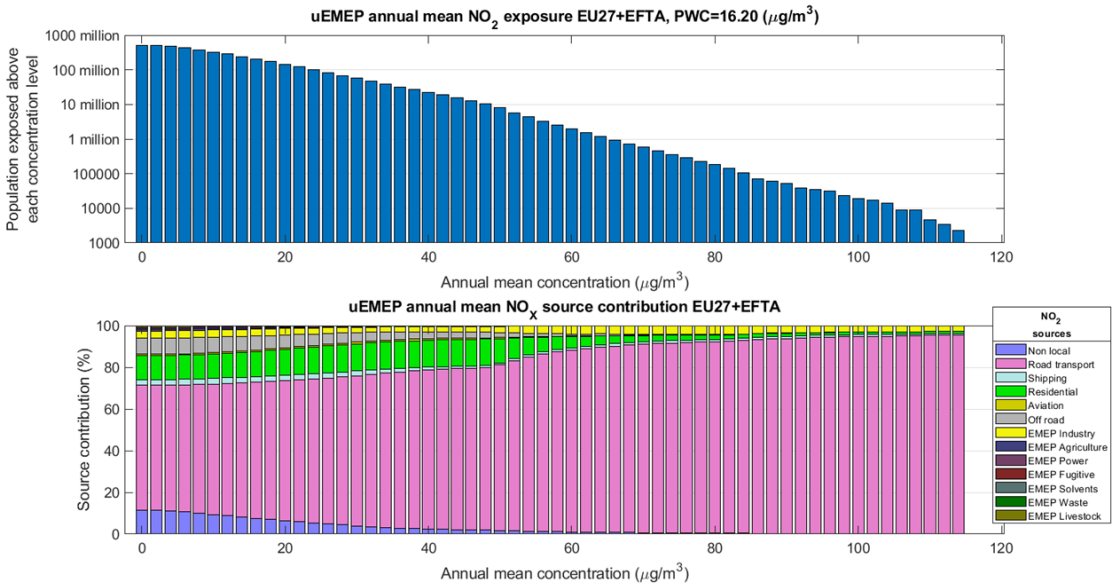

Figure 4.30: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2015 Baseline scenario in all EU and EFTA countries, including the UK. Shown are the number of inhabitants exposed above the given concentrations.

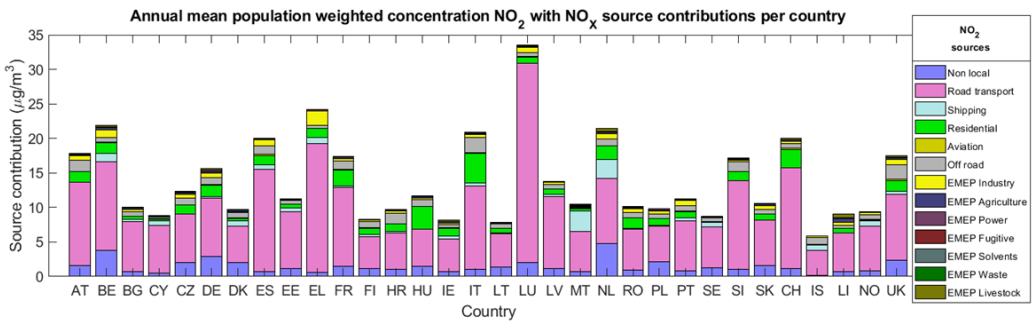

Figure 4.31: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2015 Baseline scenario in all EU and EFTA countries, including the UK.

4.4.5 Exposure and scenarios

To summarise the exposure distributions for $PM_{2.5}$, NO_2 and SOMO35 we show the number of people exposed within given concentration ranges for each of the scenarios and for each of the 3 regions individually.

$PM_{2.5}$ exposure

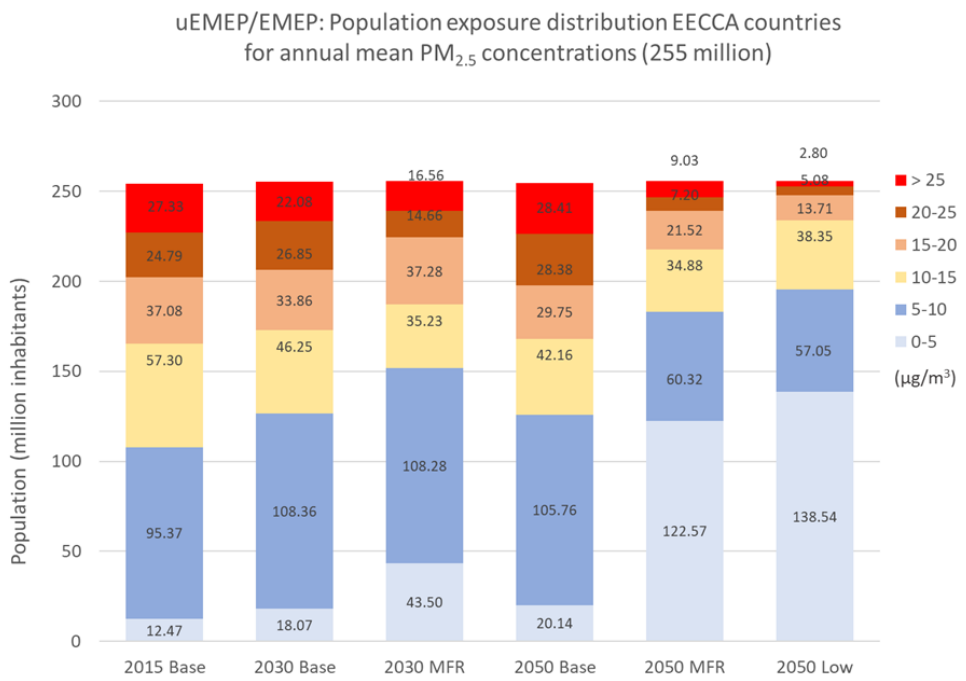

Figure 4.32: EECCA country population exposed to annual mean $PM_{2.5}$ concentrations within defined concentration ranges for all scenarios.

In Figures 4.32 to 4.34 the summarised scenario exposure calculations, presented in detail for the 2015 Baseline case in Section 4.4.4, are shown for $PM_{2.5}$. The selection of concentration ranges reflects current EU legislation and World Health Organisation guidelines (WHO 2021). Currently a limit value of 20 μg m^{-3} for $PM_{2.5}$ is in place for the EU, since 2020, but the latest guidance from the WHO recommends that a concentration level of 5 μg m^{-3} should be achieved for protection of human health. Though both the EU and Western Balkan countries approach this level of pollution with the strictest scenario in 2050 (2050 Low), this level of $PM_{2.5}$ is still not attained for over 60 million inhabitants. In the EECCA countries these low levels of $PM_{2.5}$ are far from attained with many countries well above 10 μgm^{-3}, of which a large part is from natural contributions (Figure 4.21).

The implementation of Maximum technically Feasible Reductions (MFR) has a significant impact in the Western Balkan in 2050, increasing the population exposed to < 10 μg m^{-3} from 5.7 million to 17 million. There is also a significant, but less pronounced impact of the MFR scenarios for EECCA and EU countries. For EECCA countries this reflects the high natural contribution to $PM_{2.5}$. It is also worth noting that for the Baseline scenarios in EECCA countries there is a slight reduction in 2030, but an increase in $PM_{2.5}$ concentrations in 2050. This follows the emission scenarios as outlined in Section 4.2

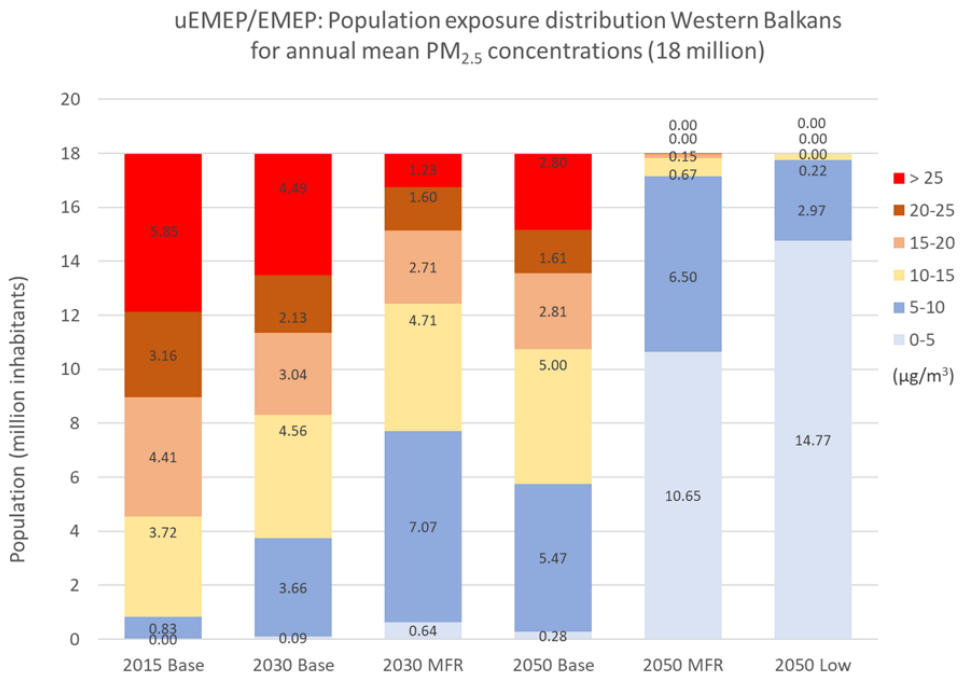

Figure 4.33: Western Balkan country population exposed to annual mean $PM_{2.5}$ concentrations within defined concentration ranges for all scenarios.

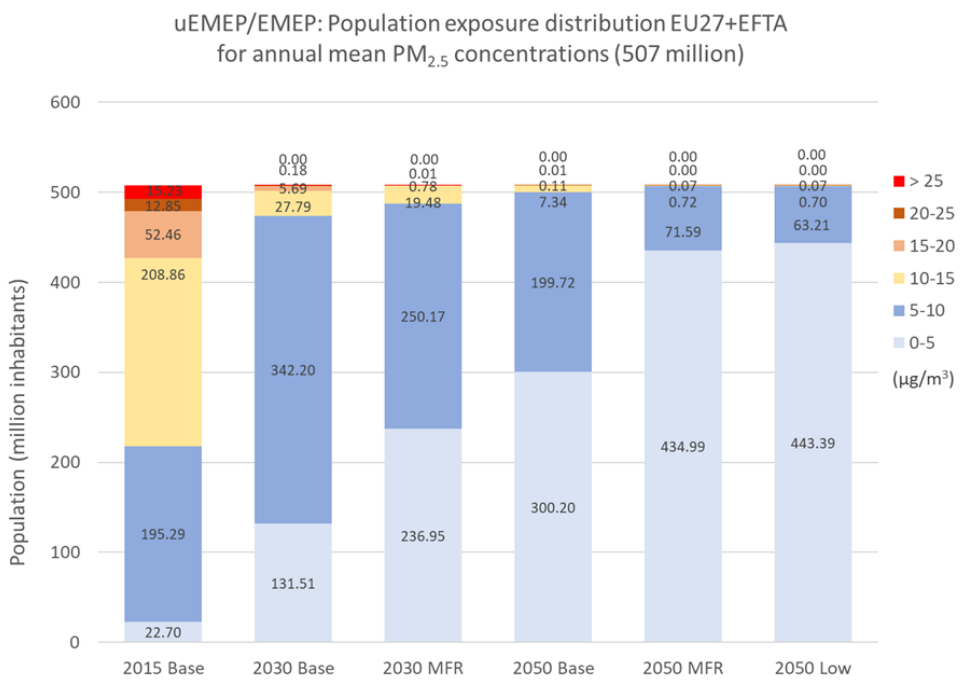

Figure 4.34: EU + EFTA country population exposed to annual mean $PM_{2.5}$ concentrations within defined concentration ranges for all scenarios.

NO_2 exposure

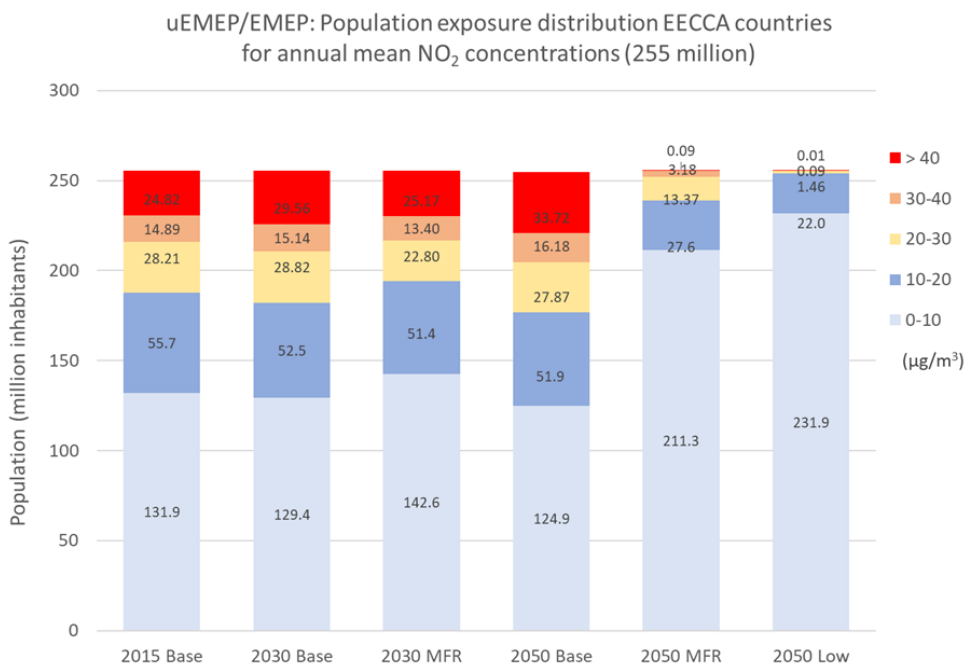

Figure 4.35: EECCA country population exposed to annual mean NO_2 concentrations within defined concentration ranges for all scenarios.

In Figures 4.35 to 4.37, the summarised scenario exposure calculations are shown for NO_2. The selection of concentration ranges reflects current EU legislation and World Health Organisation guidelines (WHO 2021). Currently a limit value of 40 μg m^{-3} is in place for the EU but the latest guidance from the WHO indicates a level of 10 μg m^{-3} should be achieved. The EU comes very close to achieving this goal by 2050 even with the Baseline scenario. For the Western Balkan 10 μg m^{-3} is only achieved in 2050 with the Low scenario. In the EECCA countries the Baseline scenarios show an increase in NO_2 concentrations in 2050, but the implementation of MFR has a significant impact in reducing these concentrations.

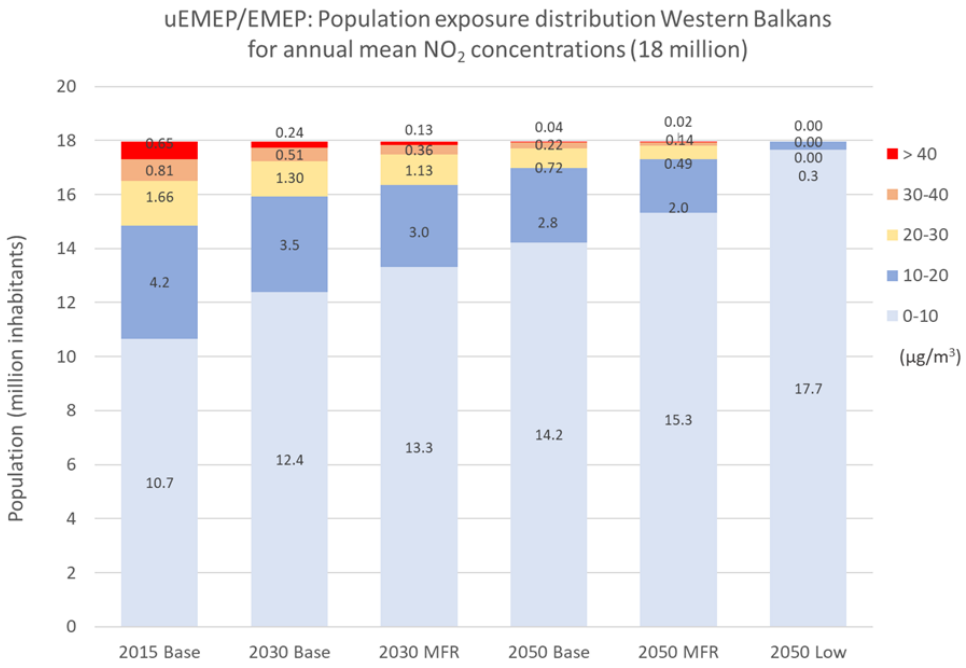

Figure 4.36: Western Balkan country population exposed to annual mean NO_2 concentrations within defined concentration ranges for all scenarios.

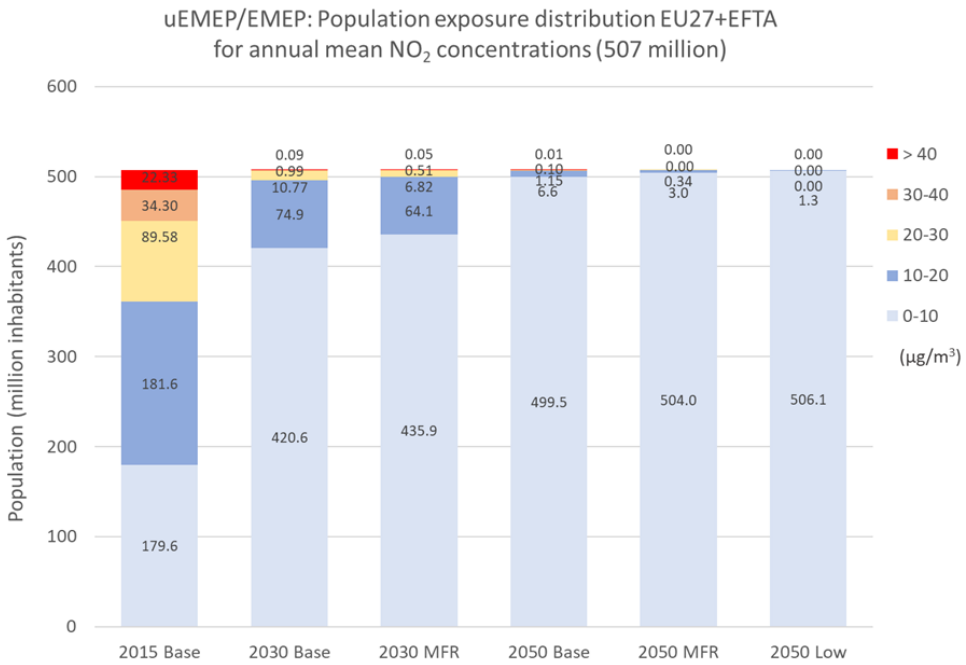

Figure 4.37: EU + EFTA country population exposed to annual mean NO_2 concentrations within defined concentration ranges for all scenarios.

SOMO35 exposure

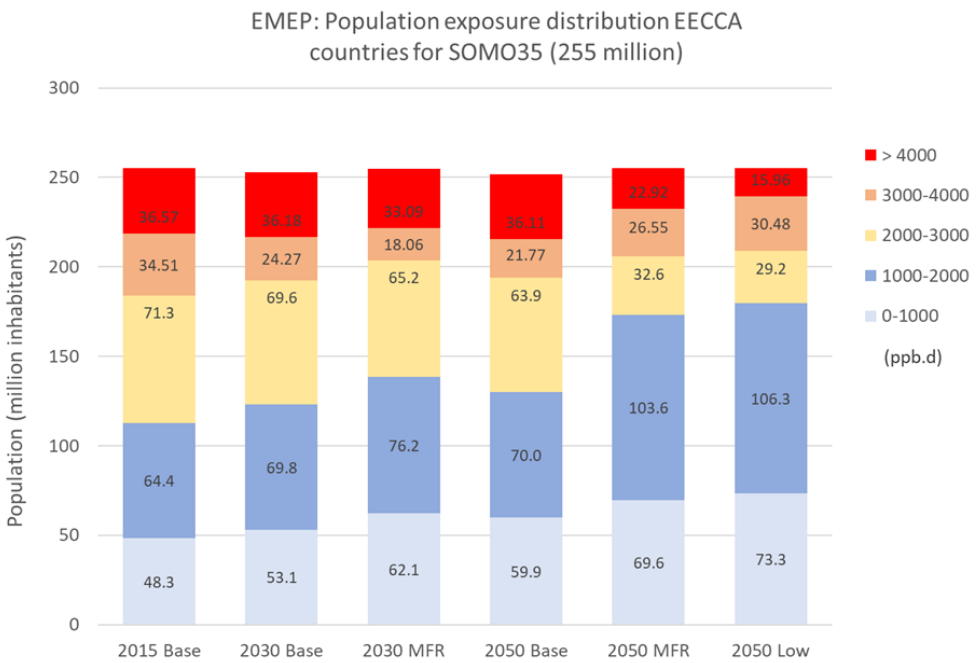

Figure 4.38: EECCA country population exposed to annual mean SOMO35 concentrations within defined concentration ranges for all scenarios.

In Figures 4.38 to 4.40, the summarised scenario exposure calculations are shown for SOMO35. SOMO35 is a health indicator, so there are no legislative limit values and the concentration ranges set are arbitrary. SOMO35 levels show very little change in the EECCA countries for both the Baseline and MFR scenarios. Contrary to this, there are improvements through the scenarios for both the Western Balkan and the EU countries.

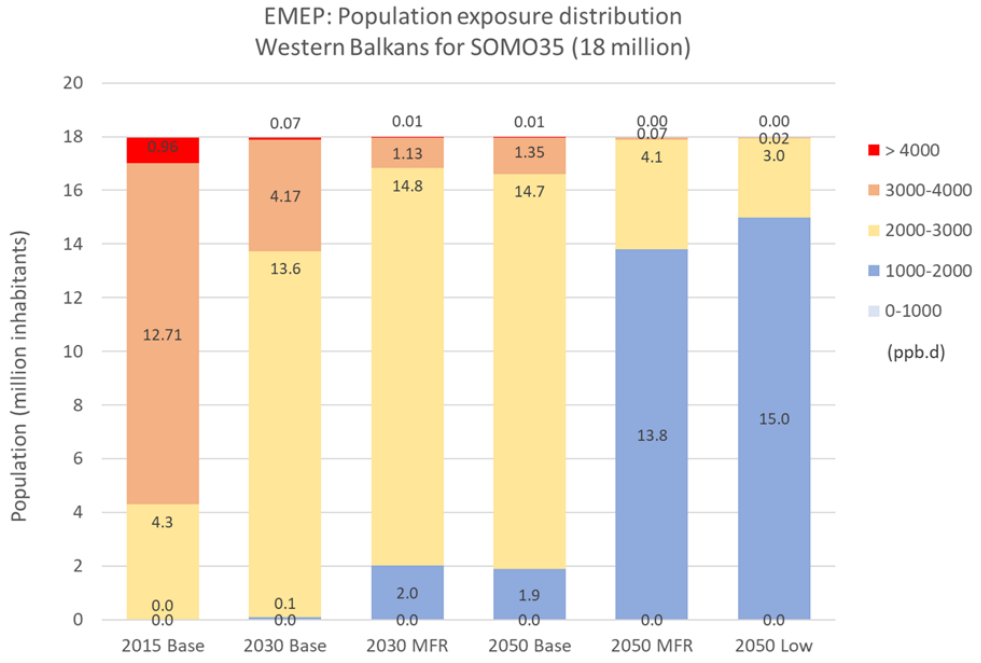

Figure 4.39: Western Balkan country population exposed to annual mean SOMO35 concentrations within defined concentration ranges for all scenarios.

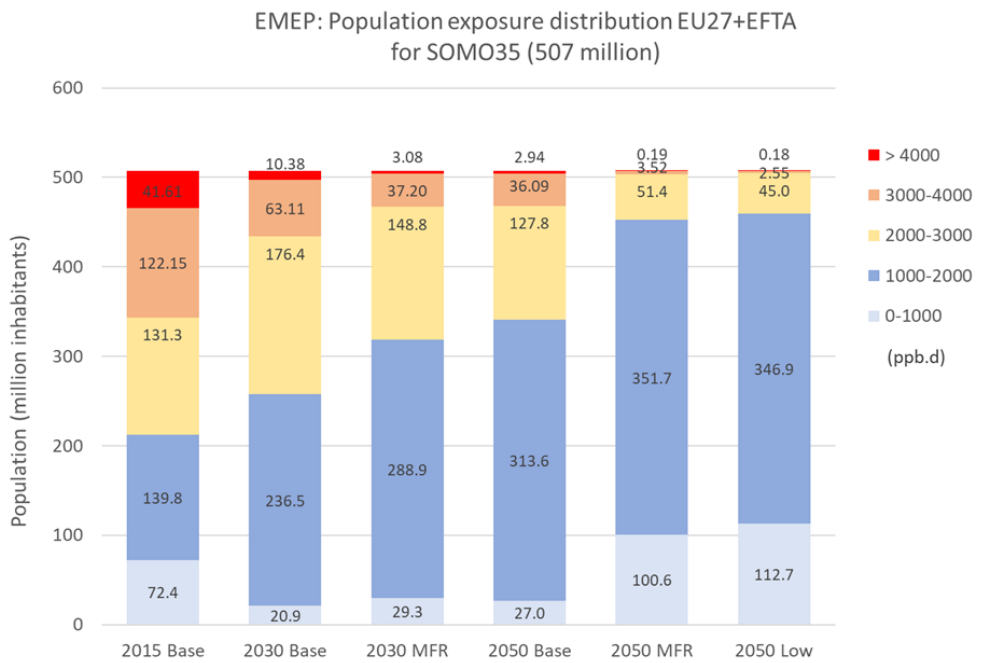

Figure 4.40: EU + EFTA country population exposed to annual mean SOMO35 concentrations within defined concentration ranges for all scenarios.

4.4.6 Comparison of uEMEP and EMEP for stations and exposure calculations

An alternative method for visualising the exposure and station site results is given in Figures 4.41 to 4.43. Here, the mean of all station and population weighted concentrations are show for each scenario and for both the uEMEP and EMEP calculations. In this case, the EU and Western Balkan regions are combined. EECCA countries are not shown since there are no measurement data available. Here we can more clearly see the general trend in the scenarios, the differences between the station and exposure calculations as well as the difference between the uEMEP and EMEP calculations. For $PM_{2.5}$, there are only small differences for all these 4 calculations indicating the homogeneous nature of $PM_{2.5}$ concentrations and the general applicability of using $PM_{2.5}$ measurement sites for exposure estimates. For NO_2, the differences are large for 2015, but reduce with time. By 2050, local sources are no longer dominating the NO_2 concentrations and background levels are more important. For SOMO35, there is a relatively constant negative offset for the exposure calculation in regard to the station sites. This would indicate that ozone stations are generally located in areas with higher ozone levels than in areas where people live.

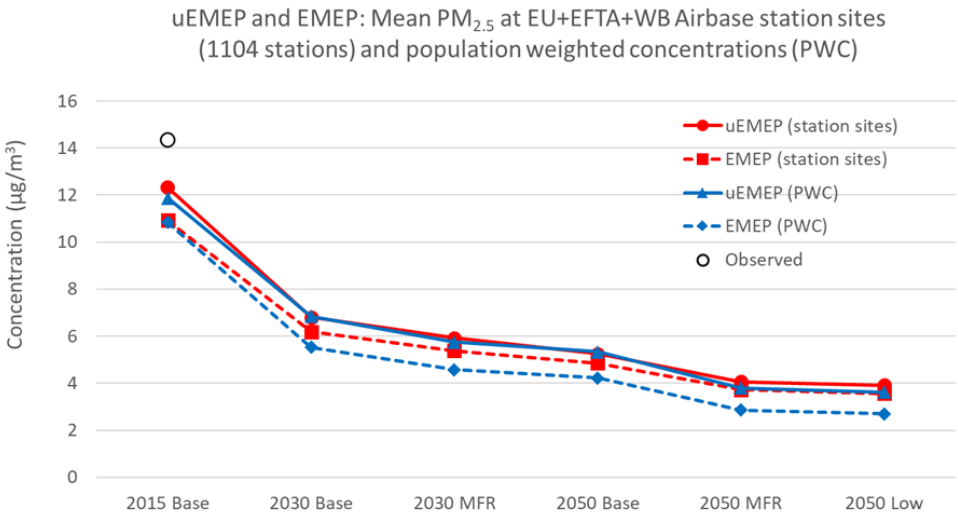

Figure 4.41: Calculated mean concentrations at all Airbase sites along with calculated population weighted concentrations (PWC) for all scenarios using uEMEP and the EMEP MSC-W model for $PM_{2.5}$. Also included is the observed mean concentration for $PM_{2.5}$ for 2015.

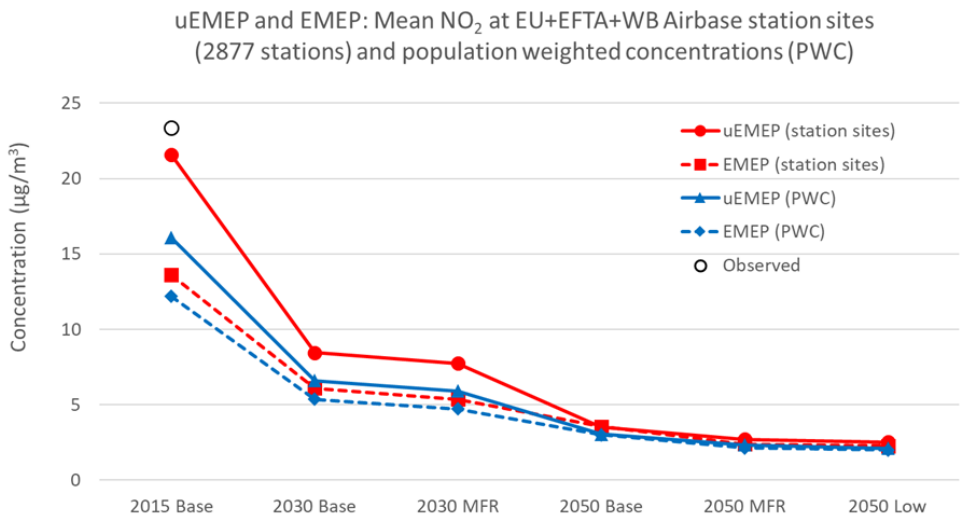

Figure 4.42: Calculated mean concentrations at all Airbase sites along with calculated population weighted concentrations (PWC) for all scenarios using uEMEP and the EMEP MSC-W model for NO_2. Also included is the observed mean concentration for NO_2 for 2015.

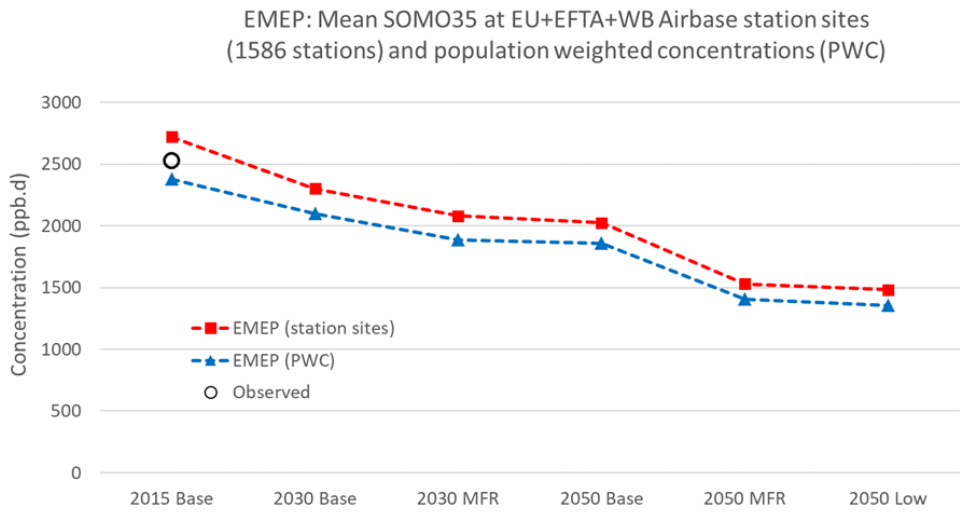

Figure 4.43: Calculated mean concentrations at all Airbase sites along with calculated population weighted concentrations (PWC) for all scenarios using the 0.1° EMEP MSC-W model for SOMO35. Also included is the observed mean concentration for SOMO35 for 2015.

4.4.7 Comparison of EECCA, Western Balkan and EU+EFTA exposure calculations

To summarise and compare the three regions discussed the population weighted concentration is calculated for each region and for each scenario. The results are shown in Figures 4.44 to 4.46.

For $PM_{2.5}$ the Western Balkan countries currently, and into the future, have the highest levels of pollution for the Baseline scenario. However, with MFR this can be reduced to average levels below 5 μg m^{-3}, similar to $PM_{2.5}$ in the EU and EFTA countries. The scope for reduction in the EECCA countries is limited by the high level of natural sources, particularly wind blown dust. Indeed, of the 6.8 μg m^{-3} shown for the 2050 Low scenario in Figure 4.44 more than half of this is attributable to natural sources. This result hides the fact that the MFR measures for $PM_{2.5}$ are also effective in EECCA countries for the anthropogenic emissions.

For NO_2 all three regions have similar exposure levels in 2015. However, in the 2030 and 2050 scenarios these diverge. The EU region sees a large decrease in NO_2 due mainly to existing plans for reducing road transport emissions. This decrease is also visible in the Western Balkan, but to a lesser extent. For the EECCA countries the baseline concentrations for NO_2 are expected to increase to 2050. However, with the implementation of the MFR and Low scenarios it is possible to reduce NO_2 concentrations to levels similar to those expected for the EU and the Western Balkan.

For SOMO35 there is a decrease with time in ozone levels for both the baseline and MFR scenarios. These changes are not as large as seen in the other pollutants.

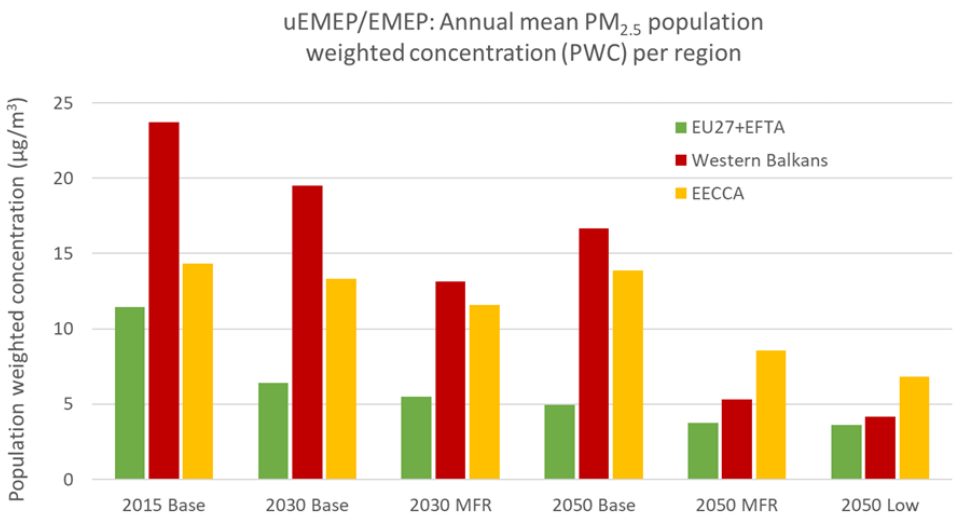

Figure 4.44: Calculated population weighted concentrations (PWC) for the 3 regions and for all scenarios using uEMEP for $PM_{2.5}$.

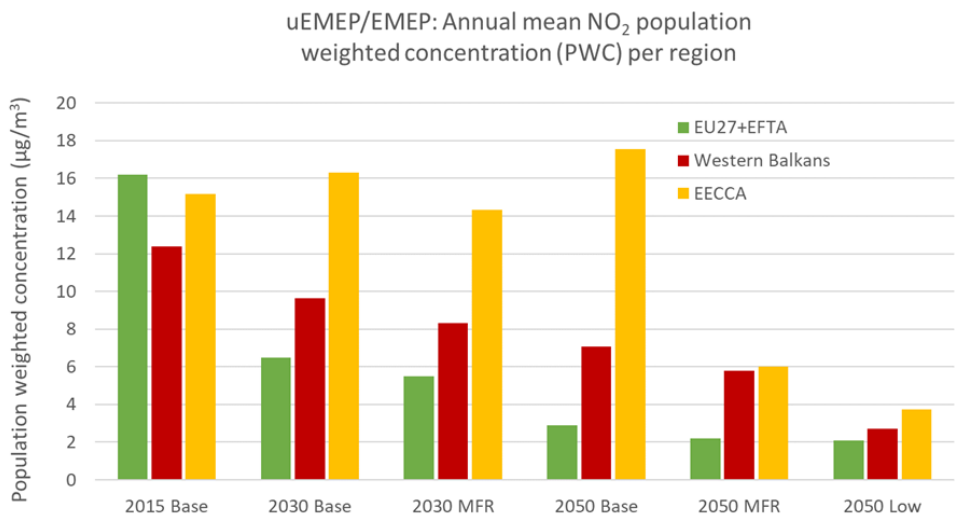

Figure 4.45: Calculated population weighted concentrations (PWC) for the 3 regions and for all scenarios using uEMEP for NO_2.

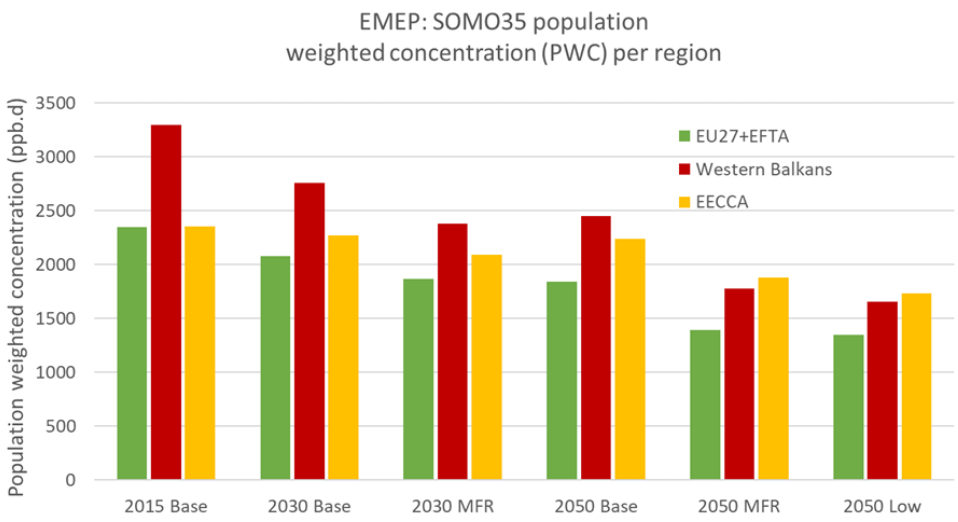

Figure 4.46: Calculated population weighted concentrations (PWC) for the 3 regions and for all scenarios using uEMEP for SOMO35.

4.5 Conclusions

The modelling carried out for this review is intended to show the impact of a number of mitigation strategies implemented across Europe, both through EU legislation and through individual efforts from many countries. Future scenarios for the Western Balkan and EECCA countries have also been implemented. The Baseline emissions used are intended to reflect the expected impact of existing or planned legislative changes and the Maximum technical Feasible Reduction (MFR) is provided to show what could be further achieved when going beyond the currently expected reductions. The Low scenario, based on MFR with additional nontechnical measures, is intended to reflect a significant transformation in the agricultural sector and the impact of achieving additional climate goals.

The analysis carried out here is aimed towards the health impacts of air pollution, with the

intention of reducing air pollution to levels recommended by the World Health Organisation (WHO) guidelines (WHO 2021). With this in mind the analysis has addressed exposure above and below a number of concentrations levels and has also addressed the concentrations levels, and eventual exceedance of any future limit values, at monitoring sites.

Whilst a model resolution of $0.1°$, as used in EMEP MSC-W, is likely sufficient for calculating urban and rural background exposure levels of $PM_{2.5}$, it is not sufficient for evaluation of near source concentrations such as road transport emissions. With these sources the horizontal and vertical gradients are much stronger than the grid sizes used in EMEP MSC-W. To address this the urban EMEP (uEMEP) model was developed and has been implemented in this analysis. A comparison between the $0.1° \times 0.1°$EMEP MSC-W calculation and the 250 m uEMEP calculations shows that the higher resolution for NO_2 increases the exposure by almost 60%. For $PM_{2.5}$, this increase is only 13% since $PM_{2.5}$ is a more homogeneously distributed pollutant.

The validation of the model against Airbase stations in 2015 indicates an underprediction of annual mean PM and NO_2, and a slight overprediction for O_3. The bias in the concentrations varies from country to country and some of this variability in bias is likely caused by the reporting of emissions, since the modelling method is consistent across all countries. The modelled bias for $PM_{2.5}$ and NO_2 is -14% and -8% respectively. This bias is significantly smaller than the impact of emission changes and we conclude the model is suitable for this assessment. Most of the monitoring stations in Airbase are from EU and EFTA countries. Only a handful of sites were available in 2015 for the Western Balkan and no monitoring data was available for the EECCA countries.

The calculations at station sites show that the current limit value for $PM_{2.5}$ of 20 μg m^{-3} (since 2020) should be achieved at all stations by 2030. More ambitious levels, such as those indicated by the WHO, are also achievable. By 2030, only 3 stations are above 15 μg m^{-3} and by 2050 only 5 stations are above 10 μg m^{-3} for the 2050 MFR scenario. Achieving levels below 5 μg m^{-3} seems less likely. Even for the 2050 MFR and the additional Low scenario there are still 17% of the current station sites above this 5 μg m^{-3} level. For NO_2, all the scenarios in 2050 showed just a few station sites above the recommended WHO exposure level of 10 μg m^{-3}.

The exposure calculations indicate similar trends for the different scenarios as for the station site calculations. For these calculations, the analysis looked at three different regions; the EECCA countries, the Western Balkan countries and the EU and EFTA countries, including the UK. These 3 regions showed different exposure levels and different future trends. By 2030 the Baseline scenario indicates that 75% of the EU population will still be exposed to $PM_{2.5}$ levels above 5 μg m^{-3}. However, this number is reduced to 40% in the 2050 Baseline calculation. The additional implementation of MFR in 2050 will reduce this further to just 14% of the population with exposure in excess of 5 μg m^{-3}. In this scenario, there is less than 1% of the population exposed to $PM_{2.5}$ levels above 10 μg m^{-3}. For the Western Balkan and EECCA countries, the baseline scenarios show much less improvement in the $PM_{2.5}$ levels. For the EECCA countries, the 2050 baseline scenario gives similar levels to 2015. It is only with the implementation of MFR that significant improvement in these countries can be attained. The EECCA countries are limited in achieving lower levels by high levels of wind blown dust.

For NO_2, all the scenarios in 2050 showed that below 2% of the EU population are still exposed to above the recommended WHO exposure level of 10 μg m^{-3}. For the Western Balkan 21% of the population is exposed to NO_2 above 10 μg m^{-3}. For the 2050 baseline,

the EECCA countries showed an increase in NO_2 concentrations compared to 2015, with about 50% of the population being exposed to above 10 μg m^{-3} level and still with 13% of the population (33 million inhabitants) above the 40 μg m^{-3} level. It is only with the implementation of MFR that NO_2 concentrations approach, but do not achieve, the WHO guidance levels.

In summary, the Baseline scenario for NO_2 should bring exposure for almost all the EU and Western Balkan population below the recommended WHO level of 10 μg m^{-3} by 2050. EECCA countries will need to implement Maximum technically Feasible Reductions to approach this level. However, reaching concentration levels for $PM_{2.5}$ below 5 μg m^{-3} by 2050 is difficult to achieve for all the population. More realistically, $PM_{2.5}$ levels below 10 μg m^{-3} may be achieved with additional mitigations beyond the expected Baseline.

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CHAPTER 5

The Local Fractions method and its application to trends in country-to-itself contributions to reduced nitrogen deposition

Krister S. Karlsen, Peter Wind, Heiko Klein and Michael Gauss

5.1 Introduction

Reductions in sulphur and oxidised nitrogen emissions during the last three decades are expected to have led to a decrease in the transport distance of reduced nitrogen in the atmosphere. This is due to the fact that less ammonium sulphate (or nitrate) particles are formed when there is less sulphur (or oxidised nitrogen) available in the atmosphere, leaving more reduced nitrogen in the gaseous form, which is more readily deposited to the ground than particles are. As a consequence, the contribution of a country (emitting reduced nitrogen) to deposition of reduced nitrogen within the country itself is expected to have *increased* over the same period. In this chapter we are testing this hypothesis.

Analysing long-term trends in source-receptor relationships is computationally demanding. However, during the last few years, a new method to calculate source-receptor relationships has been developed at EMEP MSC-W, the so-called "Local Fractions" (LF) method (Wind et al. 2020). Thanks to its high computational efficiency this method has recently been applied to study trends in the country-to-itself contributions to deposition of reduced nitrogen. By "country-to-itself contributions" in this context we mean the *fraction* of a country's reduced nitrogen emissions that is deposited within the country itself.

In this chapter, after a short review of the two computational methods, we compare their results in terms of country-to-itself contributions and transboundary transport. We then turn our attention to the temporal evolution in country-to-itself contributions to reduced nitrogen deposition, calculated with the Local Fractions method from the latest 1990–2020 trend sim-

ulation performed by EMEP MSC-W. In particular, we will test our hypothesis that, in the present-day situation, a larger fraction of reduced nitrogen emissions from a country is deposited to the country itself than was the case in the 1990s.

5.2 Methods to calculate source-receptor relationships

5.2.1 The two methods used at EMEP MSC-W

Two different methods are currently available for calculating source-receptor relationships with the EMEP MSC-W model: The LF method already mentioned above allows tracking the origin of a large amount of sources in a single run and at an affordable computational cost. By contrast, the direct approach which has traditionally been used by EMEP MSC-W (sometimes also referred to as *Brute Force* method and in this chapter abbreviated as BF), requires two runs - one with all emissions included and one where emissions from the source of interest are reduced. The difference between the two results is then assumed to be a measure of the contribution from the source of interest to air pollution or depositions in the receptor area. Common practice at EMEP MSC-W has been to reduce emissions from the source of interest by 15% in order to stay (at least to a reasonable extent) within the linear regime, and to mimic realistic emission reduction measures.

Strictly speaking, the LF method emphasizes the question of *contributions* from each source, while the BF method assesses the effect of typical *emission reductions* from each source. Due to non-linearities in atmospheric chemistry, the most important sources with respect to the first question and the second question are not necessarily the same.

5.2.2 The Local Fractions method for reduced nitrogen

The original LF method as described in Wind et al. (2020) could only track inert pollutants. Reduced nitrogen, however, can be transformed between ammonia (NH_3) and ammonium (NH_4^+). The LF method in the EMEP MSC-W model has therefore been adapted to track the NH_3 and NH_4^+ also through their chemical transformations.

There are two possible approaches to track pollutants in the deposition process:

- One can consider that the ratio between NH_3 and NH_4^+ from different sources is different, and therefore the deposition rates will differ for different sources. (approach A)
- One can think of the nitrogen atoms being tagged. Depositions from different sources reflect the source distribution of the total NH_3 + NH_4^+ in air. The deposition rates (in units of fraction per time) from different sources are all equal. (approach B)

A reduction of emissions from a country will have an effect on the NH_3/NH_4^+ ratio and therefore the BF method is closer to the first approach.

The variables in the reduced nitrogen equilibrium module depend on the amount of nitrogen in the atmosphere. In the BF method, the nitrogen concentration will be changed, and thereby the equilibrium shifted. This gives an additional effect that is absent in the LF method. This effect is small but gives rise to a difference in results.

5.3 Comparison between the Local Fractions and Brute Force methods

The LF and the BF methods should in principle give almost the same results. The small differences can be understood by the difference in methodology: the LF method does not change the concentrations, but only tracks the relative contributions from the different sources in a model simulation where all emissions are included. The BF method requires two runs with different emissions, resulting in different *concentrations*. The transport scheme in the EMEP MSC-W model changes the transport patterns according to the concentration distribution. This will have a secondary (non-physical) effect when the BF method is used, an effect that is not present in the LF method. The differences are only local, and largest at places where there is a difference in the emission gradient (i.e. in our case at country borders). As described in more detail in Wind et al. (2020) this results in the contributions from a country to itself being slightly overestimated by the BF method as compared to the LF method.

To evaluate the performance of the new LF method more quantitatively, we compare the source-receptor matrices created with the LF method for reduced nitrogen deposition in 2019 with the results from the BF method. More specifically, we compare the source-receptor calculation that was done in 2021 for the year 2019 (using the BF method, see Appendix D in EMEP Status Report 1/2021 (2021)) with a corresponding LF calculation done specifically for this study. For the LF calculation, a model run was made for 2019 in a $0.3° \times 0.2°$ longitude-latitude projection, which is the same as was used to create the corresponding BF results in 2021. The runs are consistent also in terms of meteorological input data (ECMWF IFS cy46r1) and emission data (based on official data submissions of 2021). This approach allows for a proper comparison between the BF and LF methods for the year 2019.

5.3.1 Country-to-itself contributions

In regard to the *country-to-itself* contributions to reduced nitrogen deposition, the differences between the LF and BF methods are small for all countries shown in Figure 5.1. On average, the relative difference between LF approach A and the BF method is about 3% while the difference between LF approach B and the BF method is about 6%. These are very small differences and confirm that the two methods agree well for this parameter. In general, the BF method overestimates country-to-itself contributions compared to the LF method. The largest differences are probably due to the effect connected with the transport scheme mentioned above.

As for LF approaches A and B, they give very similar results. Nevertheless, approach B yields slightly smaller country-to-itself contributions than approach A in all countries considered. This could be because, close to emission sources (mainly agriculture), more reduced nitrogen is present as ammonia, which is more easily deposited. In approach B the nitrogen deposition rate at a given receptor point is the same for nitrogen from all countries, while for approach A the deposition rate is specific for each country, according to its NH_3/NH_4^+ ratio. In approach B, that ratio is thus shifted slightly more towards NH_4^+, since the average ratio effectively corresponds to less 'fresh' emissions. Nitrogen that has traveled over larger distances will on average have a smaller fraction of ammonia. In approach B, reduced nitrogen is thus somewhat less easily deposited *close* to the source and within the country itself. For *transboundary* contributions (next section) the reverse is true: approach A is likely to give

smaller contributions there than does approach B because more nitrogen has already been deposited in the emitting country itself.

In the remainder of this chapter (including the trend analysis of the next section) we will show results obtained with approach B, as this is a slightly more straightforward approach conceptually.

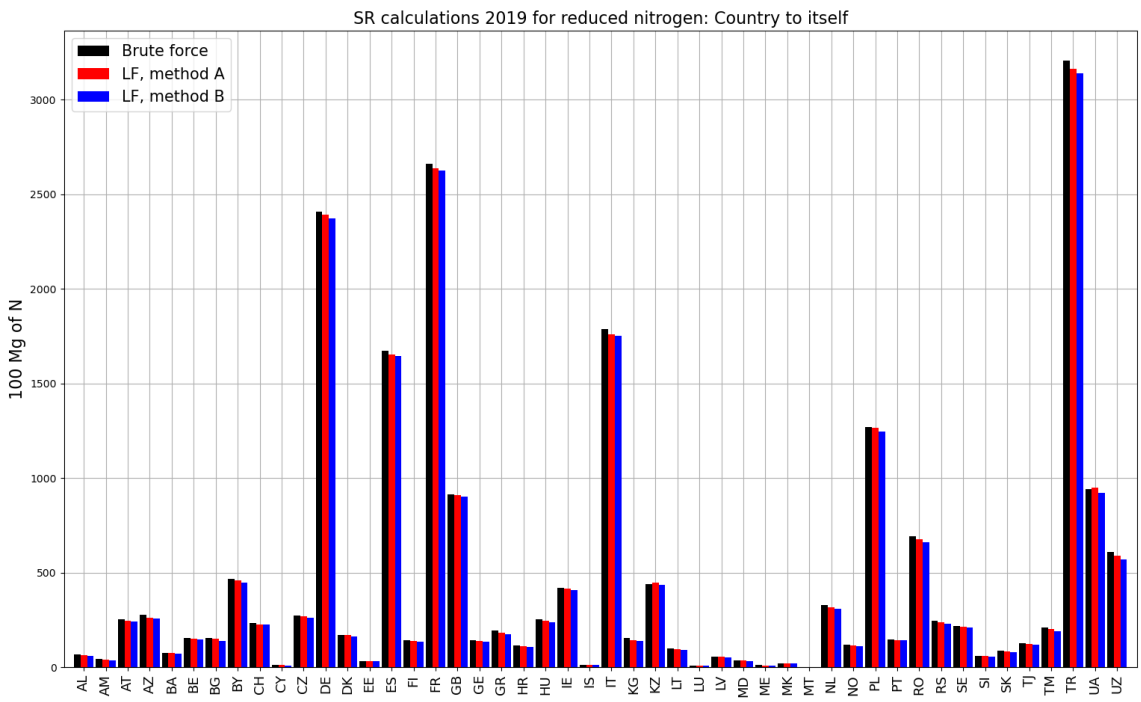

Figure 5.1: Country-to-itself contributions to reduced nitrogen in 2019 based on the "Local Fractions" method (approach A and approach B) and the "Brute Force" method. (Results for Russia are not shown because the country is not fully covered by the model domain, which has led to technical problems in this case that have yet to be resolved.)

5.3.2 Comparison for the largest contributors

When looking at the five largest contributions to long-range transported deposition (see Fig. 5.2 for a selection of countries) we see that the LF method gives slightly larger contributions than the BF method in most cases. This is in contrast to the *country-to-itself* contributions shown in the previous figure (5.1) and illustrates the fact that the change in methods affects indigenous and transboundary transport of air pollution differently. When the country-to-itself contributions are smaller, as tends to be the case in the LF method, more nitrogen is available to be transported across borders.

In any case, however, the differences between LF and BF with respect to the five largest contributions are very small.

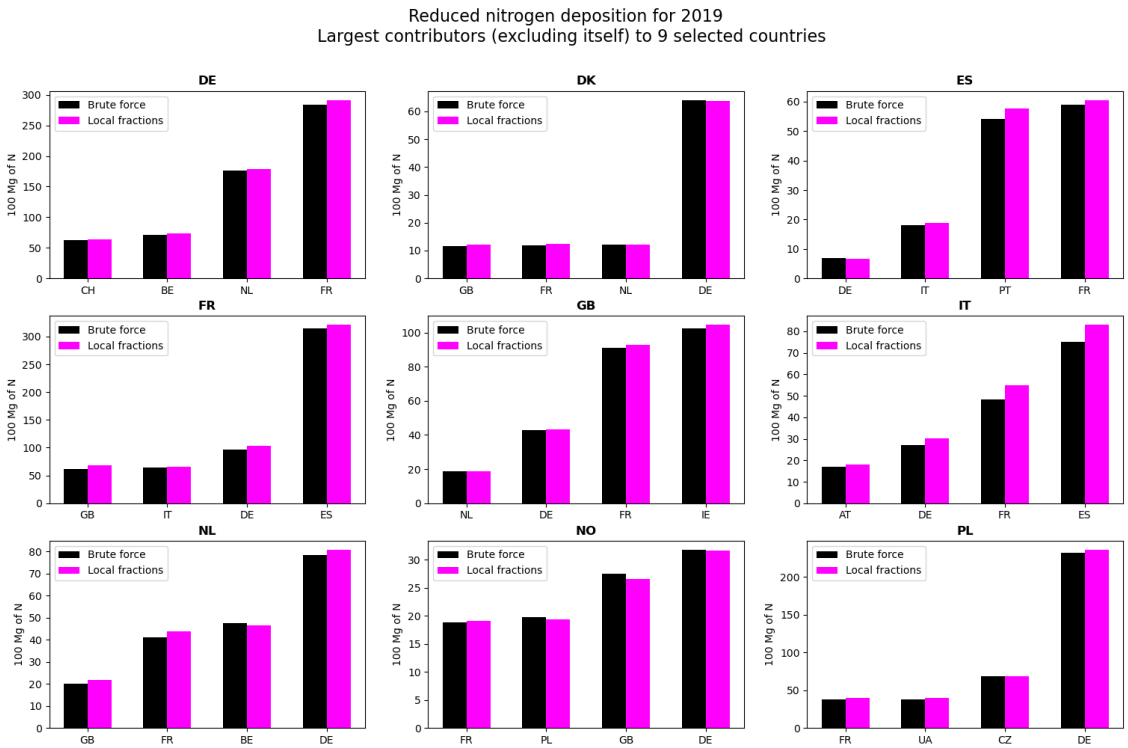

Figure 5.2: The five largest contributors (*excluding* country-to-itself) to reduced nitrogen deposition in nine selected countries for the year 2019. The results from the Local Fractions (LF) and Brute Force (BF) methods are compared.

5.4 Long-term trends in country-to-itself contributions to reduced nitrogen depositions

We now turn to the scientific question as to whether there have been any trends in the transport distance of reduced nitrogen, related to changes in the chemical regime during the last three decades.

As the LF method is relatively inexpensive, it is possible to run the same model consistently over many years and get full source-receptor results for each year. By "consistently" in this context we mean that the model is run with *the same* model version and on *the same* resolution for the entire trend period, and is fed with one consistent set of input data (most importantly meteorological data from the same numerical weather prediction model and emissions based on the same year's official data submissions). This is not the case for the BF results which are based on source-receptor calculations that have been done annually over the last two to three decades.

Figures 5.3 to 5.6 show country-to-itself contributions to reduced nitrogen deposition for the 1990–2020 period for most of the EMEP countries[1]. The thin lines show the results from the standard trend simulation described in Appendix F, which was run with the latest meteorological and emission data available for each respective year. The thick lines show results from an additional model experiment where the years 1990, 2000, 2010 were run

[1]Results for Russia are not shown because the country is not fully covered by the model domain, which has led to technical problems in this case that have yet to be resolved.

with the same meteorology as 2019 (i.e. 2019 meteorology). This additional experiment was designed to filter out the effects of meteorology and should thus better reflect chemical effects (due to the emission changes).

The curves slope slightly upward for nearly all countries, strongly supporting the hypothesis that transport distances for reduced nitrogen have indeed decreased over the period, although the variability from year to year is large. Table 5.1 lists all slopes and their p-values (Mann-Kendall test) for the time series of country-to-itself contributions in the standard trend simulation (with varying meteorology). The slope is positive in nearly all cases. It is statistically significant at the 90% level in most cases (indicated by a p-value lower than 0.1). The table also lists the average temporal changes, given as % per decade, derived from a linear regression analysis. The temporal evolution differs a lot between countries but in general shows an increase, with only few exceptions. The temporal evolution depends on many different factors such as the area of the country, its geographic location, the actual change in the emission mix within the country (but also in its neighboring countries), etc. A thorough investigation to explain these tendencies in detail has not been possible within the time frame of this report.

The table also lists the slopes for the constant-meteorology run. The statistical significance of these slopes (not shown) is lower because only four years could be run within the time frame of this study. The slopes are steeper in about half of the countries and less steep in the other half, but on average about the same as in the standard trend. This indicates that meteorology may not affect the *long-term* trends, if any, to a large degree although it does lead to considerable inter-annual variability.

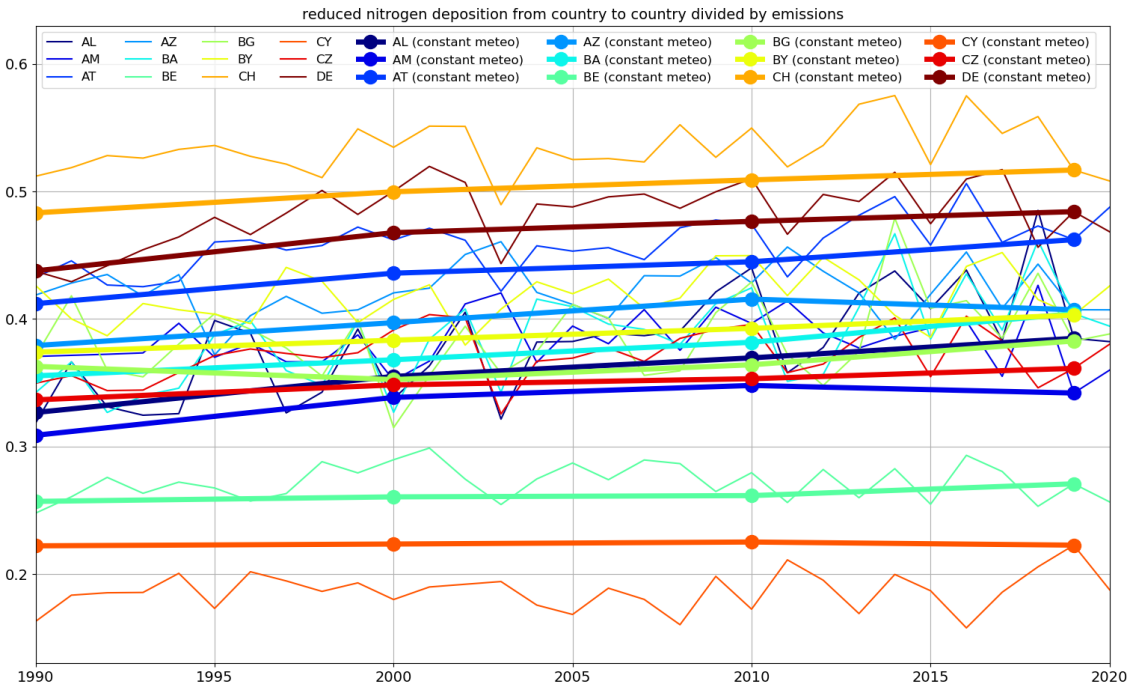

Figure 5.3: Country-to-itself contributions to reduced nitrogen deposition from 1990–2020 for countries fully included in the EMEP model domain, scaled by the emission of each country. For example a value of 0.3 means that 30% of the country's reduced nitrogen emissions is deposited within the country itself. Thin lines represent the results from the standard trend simulation (using meteorology for each respective year), while thick lines represent the four additional runs for 1990, 2000, 2010 and 2019 using constant meteorology (of 2019). For better visibility, the figure has been divided into separate figures. For other countries see the next figures.

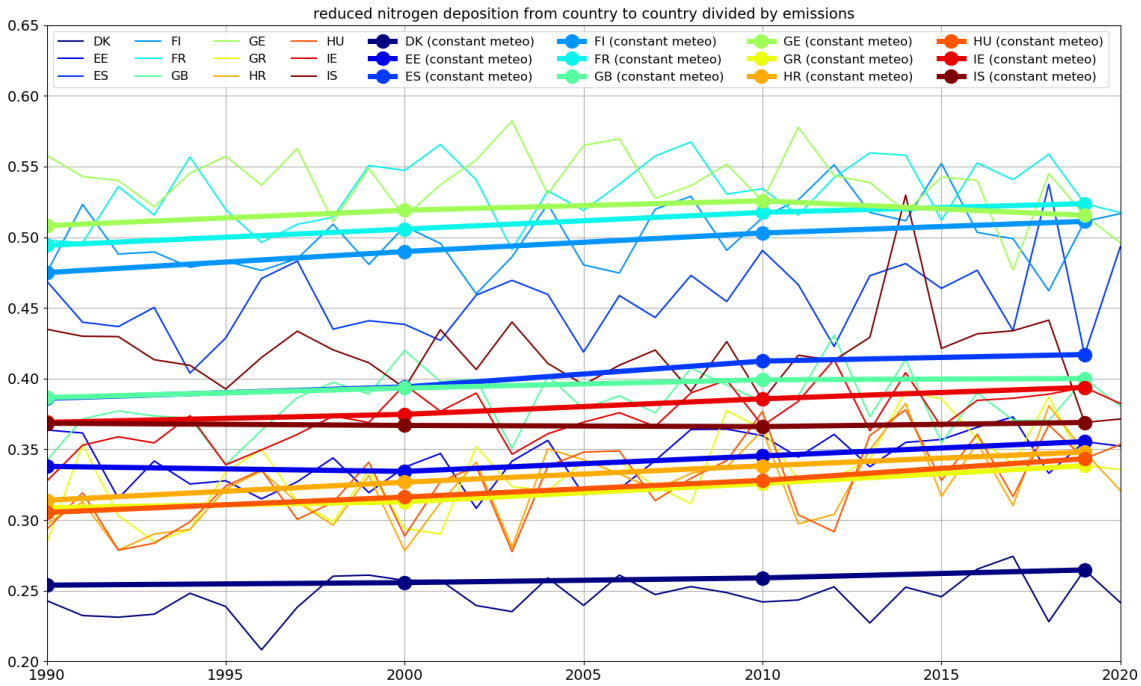

Figure 5.4: Same as Figure 5.4, but for a different set of countries.

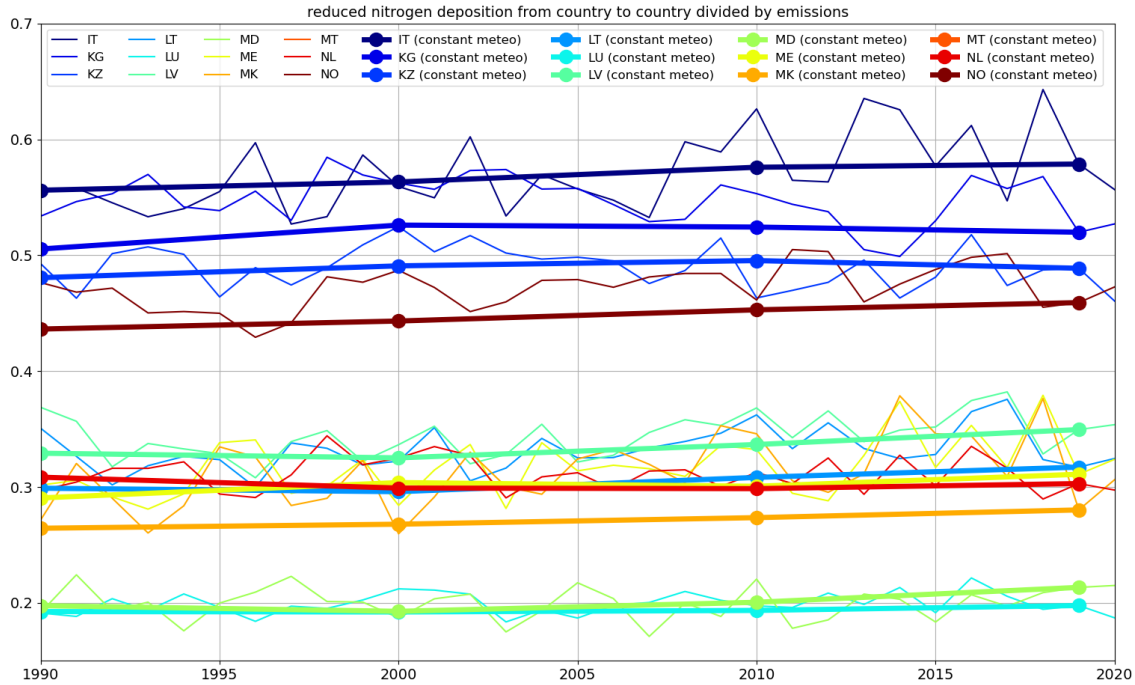

Figure 5.5: Same as Figure 5.5, but for a different set of countries.

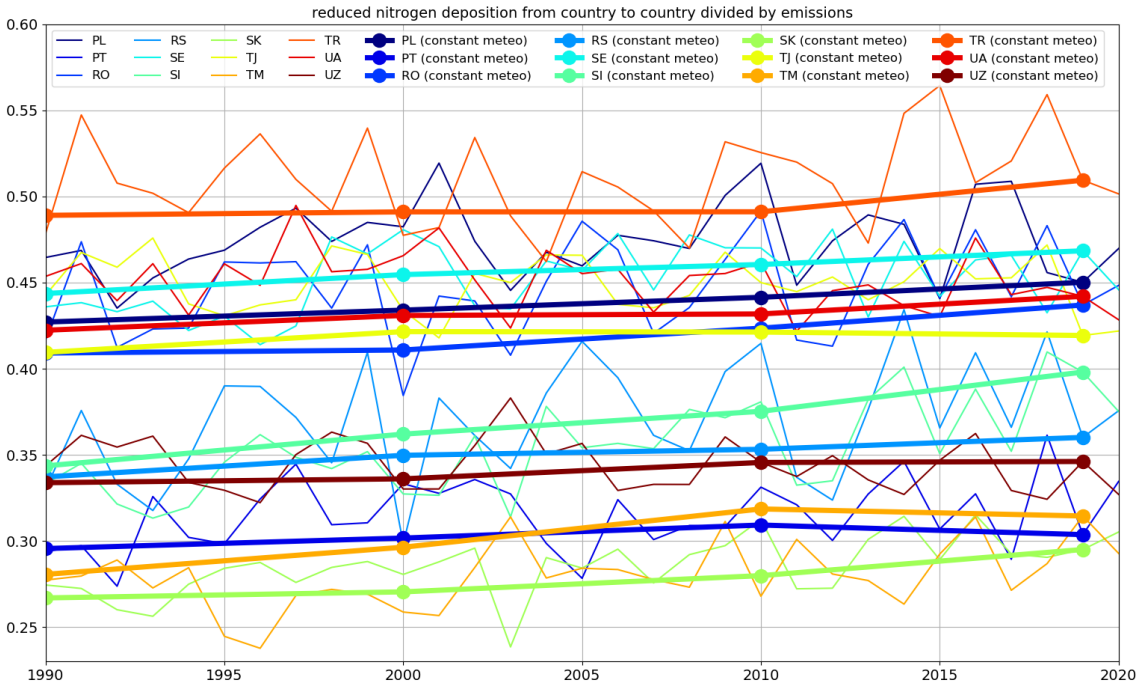

Figure 5.6: Same as Figure 5.6, but for a different set of countries.

Table 5.1: Slopes, average change per decade, and p-values for *country-to-itself* contributions to reduced nitrogen deposition for each country based on the LF method (approach B) in the standard trend simulation. Slopes are given in units of percentage points per year, changes in percent per decade. A p-value of less than 0.1 means that the trend is statistically significant at the 90% confidence level. The last column shows the slopes in the constant-meteorology experiment. (Results for Russia are not shown because the country is not fully covered by the model domain, which has led to technical problems in this case that have yet to be resolved.)

Country	slope	(%/decade)	p-val	slope 'const. meteo'
AL	0.27	8.01	0.00	0.19
AM	0.06	1.63	0.34	0.10
AT	0.14	3.18	0.00	0.17
AZ	0.01	0.33	0.69	0.14
BA	0.23	6.56	0.00	0.15
BE	0.01	0.49	0.81	0.04
BG	0.10	2.72	0.08	0.09
BY	0.07	1.62	0.08	0.10
CH	0.06	1.23	0.19	0.10
CY	0.03	1.46	0.40	0.01
CZ	0.08	2.11	0.10	0.08
DE	0.14	3.08	0.01	0.12
DK	0.05	2.12	0.08	0.04
EE	0.10	3.14	0.02	0.08
ES	0.13	2.85	0.07	0.11
FI	0.11	2.21	0.03	0.13
FR	0.09	1.68	0.07	0.11
GB	0.06	1.70	0.18	0.05
GE	-0.08	-1.38	0.15	0.05
GR	0.19	6.20	0.00	0.12
HR	0.20	6.76	0.00	0.12
HU	0.18	6.14	0.00	0.12
IE	0.14	3.87	0.00	0.09
IS	0.00	-0.11	0.84	0.00
IT	0.16	2.95	0.01	0.08
KG	-0.06	-1.03	0.15	0.02
KZ	-0.05	-1.09	0.14	0.04
LT	0.06	1.73	0.14	0.08
LU	0.02	0.91	0.34	0.02
LV	0.09	2.62	0.03	0.09
MD	0.02	1.22	0.50	0.07
ME	0.11	3.59	0.03	0.06
MK	0.14	4.82	0.01	0.06
MT	0.03	4.42	0.00	0.01
NL	-0.01	-0.43	0.74	-0.01
NO	0.08	1.77	0.02	0.08
PL	0.04	0.94	0.31	0.08
PT	0.05	1.73	0.13	0.04
RO	0.08	1.93	0.19	0.11
RS	0.13	3.80	0.08	0.08
SE	0.08	1.80	0.11	0.08
SI	0.21	6.46	0.00	0.19
SK	0.10	3.70	0.00	0.10
TJ	-0.01	-0.17	0.89	0.02
TM	0.07	2.50	0.05	0.14
TR	0.05	1.03	0.38	0.05
UA	-0.06	-1.22	0.04	0.06
UZ	-0.04	-1.02	0.12	0.05

5.5 Conclusions

The aim of this study was to investigate whether we could find long-term trends in country-to-itself contributions to reduced nitrogen deposition. To this end, results from the new "Local Fractions" (LF) method were used, as this method requires only one model run per year (i.e. 31 runs for the 1990–2020 period) to create a full set of source-receptor matrices. LF results were generated this year from the latest trend simulation described in Appendix F. To gain confidence in the LF method, it was first compared with output from the traditional "Brute Force" (BF) method, revealing only very small differences.

Looking at the country-to-itself contributions to reduced nitrogen deposition, we see an upward trend for about half of the countries (among which 15 countries above 3%/decade). In other words, the fraction of reduced nitrogen that ends up being deposited in the emitting country itself has increased noticeably in these countries. An additional simulation with constant meteorology gave similar results.

These findings support our hypothesis that the transport distance of reduced nitrogen has decreased over the 1990–2020 period, mainly due to changes in the chemical regime, related to the strong reductions in sulphur and oxidised nitrogen emissions.

The high computational efficiency of the LF method allows us to recalculate long time series of source-receptor relationships in a consistent way and to perform trend studies of this type for the first time. However, the method is not yet available for long-range transported oxidized nitrogen, so that this study has focused on reduced nitrogen deposition only. Development is underway to calculate country-to-country source-receptor relationships with the LF method also for oxidized nitrogen.

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CHAPTER 6

Relative contribution of biomass burning to TC across Europe - The 2017/2018 winter intensive measurement period

Karl Espen Yttri, Stephen Platt and Wenche Aas

6.1 The intensive measurement period in winter 2017-2018

The EMEP/COLOSSAL/ACTRIS intensive measurement period (IMP) in winter 2017-2018 (Platt et al. 2022) measured organic carbon (OC), elemental Carbon (EC), and total carbon (TC), along with levoglucosan and the absorption coefficient to:

- Quantify eBC_{ff} and eBC_{bb} across Europe, using measurements of the wood burning tracer levoglucosan (and Elemental Carbon (EC), Organic Carbon (OC), and Total Carbon (TC)) for validation of eBC_{ff} and eBC_{bb}.
- Provide a harmonized data set for model validation.
- Initiate regular monitoring of eBC_{ff} and eBC_{bb}, and reporting of such data to EBAS.

The IMP winter 2017/18 included 57 sites (4 global sites, 26 regional background sites, and 27 urban background sites) in 23 different countries and the data are made available by Platt et al. (2022). Levoglucosan and OC/EC/TC measurements were performed at most of the sites at a time resolution ranging from 12 - 168 h. In this brief pilot study including 42 of the sites (Table 6.1), we make a case that the OC/EC/TC and levoglucosan data are suited to address the winter-time levels of carbonaceous aerosol (TC/EC/OC) across Europe, and in particular provide an upper limit on the fraction coming from residential wood combustion (RWC), presenting preliminary results for TC_{bb} (TC_{bb} = TC from biomass burning).

Table 6.1: Sites with OC, EC, TC and levoglucosan measurements in IMP Winter 2017/2018 used in the present study.

Country	Site code*	Site name	Latitude	Longitude
Austria	AT02R	Illmitz	47.767	16.767
Bosnia-Herzegovina	BA29U	Sarajevo (Bjelave)	43.868	18.423
Belgium	BE07R	Vielsalm	50.304	6.001
Switzerland	CH02R	Payerne	46.813	6.945
Switzerland	CH10U	Zurich-Kaserne	47.378	8.530
Switzerland	CH33R	Magadino-Cadenazzo	46.160	8.934
Czech Republic	CZ03R	Kosetice	49.573	15.080
Cyprus	CY02R	Ayia Marina	35.039	33.058
Germany	DE44R	Melpitz	51.530	12.934
Germany	DE72U	Berlin (Nansenstrasse)	52.350	13.067
Germany	DE73U	Berlin - (Amrumerstrasse)	52.350	13.067
Germany	DE74T	Berlin - (Frankfurter Allee)	52.350	13.067
Spain	ES19U	Barcelona	41.390	2.116
Spain	ES20U	Granada	37.164	-3.605
Spain	ES24U	Coruna (IUMA)	43.336	-8.352
Finland	FI36R	Matorova	68.000	24.237
Finland	FI50R	Hyytiälä (SMEAR II)	61.850	24.283
France	FR09R	Revin	49.900	4.633
France	FR20R	SIRTA	48.709	2.159
France	FR22R	Perenne de l'Environnement (OPE)	48.562	5.506
France	FR35U	Marseille (Longchamp)	43.305	5.395
France	FR36U	Nice (Arson)	43.702	7.286
France	FR37I	Port de Bouc la Lècque	43.402	4.982
France	FR38U	Grenoble Les Frenes	45.189	5.725
France	FR39U	Passy	45.992	6.714
Greece	GR0XU	Athens (Thissio)	37.970	23.720
Greece	GR100U	Athens (Demokritos)	37.995	23.816
Hungary	HU02R	K-puszta	46.967	19.583
Italy	IT04R	Ispra	45.800	8.633
Italy	IT20U	Aosta (Saint-Christophe)	45.742	7.357
Italy	IT21U	Brenner (LEC)	45.865	11.003
Italy	IT22U	Bologna (ISAC II)	44.524	11.338
Italy	IT23U	Milan	45.510	9.211
Lebanon	LB01U	Beirut (Mansourieh)	33.858	35.568
Lithuania	LT15R	Preila	55.376	21.031
Norway	NO02R	Birkenes	58.389	8.252
Norway	NO73U	Oslo (Sofienbergparken)	59.967	10.756
Poland	PL05R	Diabla Gora	54.150	22.067
Poland	PL10U	Krakow (AGH Univ)	50.065	19.945
Romania	RO07R	Bucharest	44.348	26.029
Sweden	SE21R	Hyltemosa	56.017	13.150
Slovenia	SI08R	Iskrba	45.567	14.867

*: R = Rural background; U = Urban background; T = Traffic; I = Industrial

Table 6.2: EC/Levoglucosan and OC/Levoglucosan ratios for various European regions

Emission ratio	Switzerland[1] (North of the Alps)	Switzerland[1] (South of the Alps)	Austria[1]	Italy[1] (Po Valley)	Norway[2] (South NO)
OC_{nf}/Levo.[3]	12.6 ± 3.1	7.8 ± 2.7	7.24 ± 0.03	5.62 ± 0.30	
EC_{nf}/Levo.	1.72 ± 0.59	0.87 ± 0.27	1.31 ± 0.11	0.89 ± 0.06	
OC/Levo.					11.1 - 12.7
EC/Levo.					1.96

[1] Zotter et al. (2014) [2] Yttri et al. (2021) [3] nf denotes "non fossil"

Levolucosan is a cellulose combustion product commonly used to trace biomass burning (BB) aerosol in the atmosphere (e.g. Simoneit et al. (1999)). Estimates of the BB aerosol carbonaceous fraction can be obtained from Eq. 6.1 and Eq. 6.4, combining ambient aerosol concentration of levoglucosan with emission ratios (ER) from combustion studies (e.g. Fine et al. 2002). ER can also be derived from ^{14}C-EC, ^{14}C-OC and levoglucosan measurements performed on ambient aerosol samples collected in BB source regions (Zotter et al. 2014) or from positive matrix factorization (PMF) studies (Yttri et al. 2021).

$$OC_{bb} = [\text{Levoglucosan}] \times (\text{OC/Levoglucosan})_{bb} \tag{6.1}$$

$$EC_{bb} = [\text{Levoglucosan}] \times (\text{EC/Levoglucosan})_{bb} \tag{6.2}$$

$$OC_{bb} + EC_{bb} = TC_{bb} \tag{6.3}$$

$$\text{Fraction biomass burning} = TC_{bb}/TC_{Tot} \tag{6.4}$$

Combustion studies using European tree species are scarce and to some extent hampered by use of thermal analysis for OC/EC versus the currently used thermal-optical approach (e.g. Schmidl et al. 2008). ERs vary widely for EC/Levoglucosan (0.6 - 4.7) and OC/Levoglucosan (3.7 - 12.5) for the Austrian tree species (spruce, oak, beech, and larch) tested by Schmidl et al. (2008). Still, these ranges are comparable to the ratios derived from ambient aerosol samples presented by Zotter et al. (2014) for Switzerland, Austria, and the Po Valley and by Yttri et al. (2021) for Southern Norway. Ratios derived from ambient sampling provides a weighted average accounting for the various tree species used and for ER variability caused by varying combustion conditions, but also reflects differing degrees of atmospheric processing. We consider it the only way of providing a weighted average, as there are no tree species specific ER for most countries, nor inventories of tree species used for fuel.

Here we calculated OC/Levoglucosan and EC/Levoglucosan ratios for a selection of sites (n = 42) participating in the IMP winter 2017/2018, extracting the minimum and the 10th percentile values to be used as ER, assuming these represent conditions when RWC prevails. We aim to use the minimum ER (Min ER) to be as conservative as possible, using the 10 percentile ER (P10th ER) in case the minimum ER cannot be used. The most apparent limitations to this approach are degradation of levoglucosan and failing to include samples dominated by RWC (i.e., non-RWC sources dominate observed levels of OC and EC), leading to overestimation of the ER and thus an overestimation of the RWC source. However, any degradation of levoglucosan will lower the estimates of OC_{bb} and EC_{bb} in Eq. 6.1 and Eq. 6.2.

In our calculations, we assumed that the positive OC sampling artefact was 10% larger than the negative artefact. Uncertainties were estimated via a Monte Carlo simulation (n = 100000), including Gaussian errors estimated from variability of the observed levoglucosan

concentrations and 7.5% measurement uncertainty in Levoglucosan, EC, and OC concentrations used to determine EC/Levoglucosan and OC/Levoglucosan used as ER.

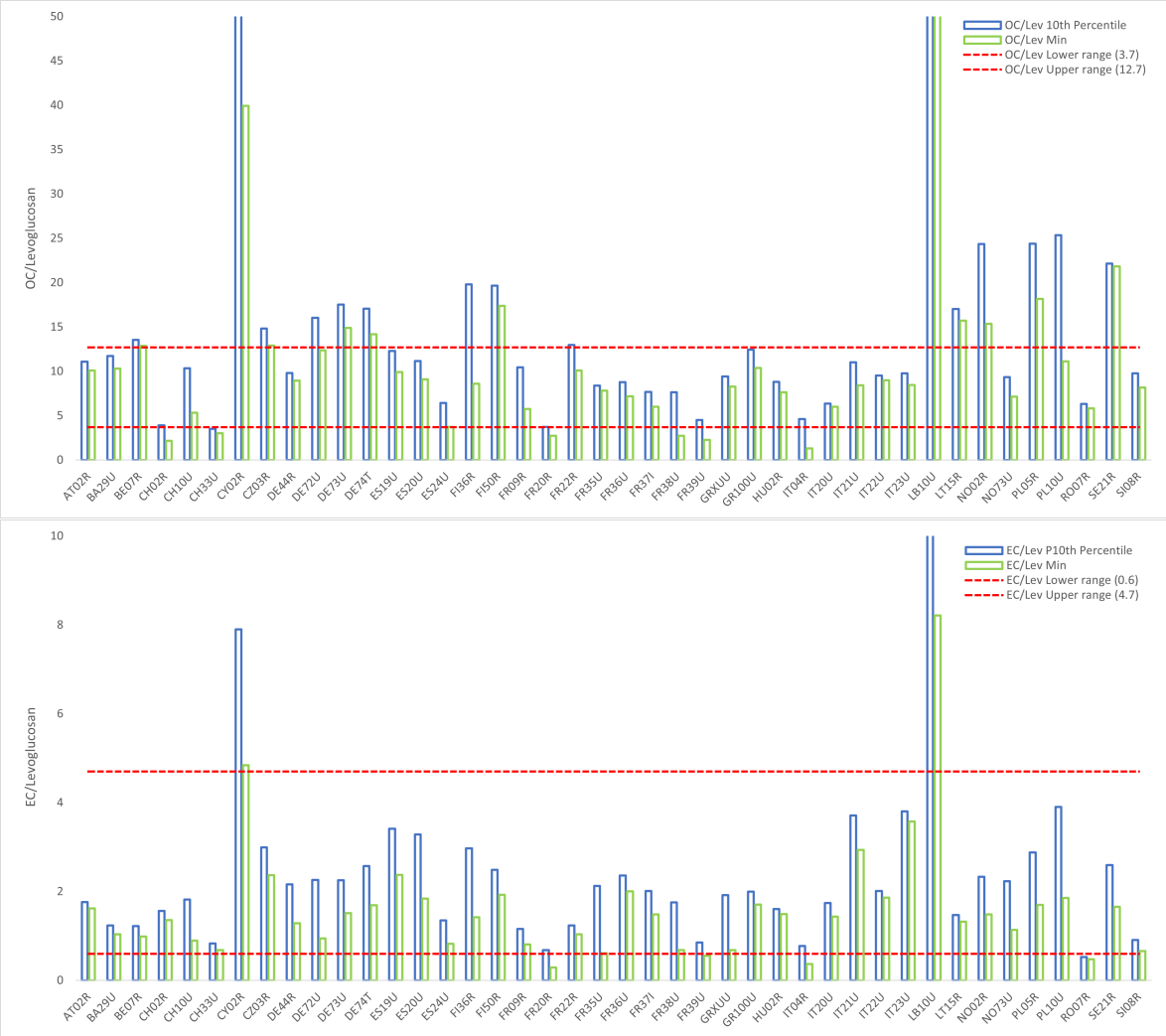

Figure 6.1: OC/Levoglucosan (upper) and EC/Levoglucosan (lower) ratios derived from ambient aerosol sampling.

Firstly, calculated ER were screened with respect to the range provided by ER reported by Schmidl et al. (2008), Zotter et al. (2014) and Yttri et al. (2021) (Table 6.2); i.e., 3.7 - 12.7 for OC/Levoglucosan and 0.6 - 4.7 for EC/Levoglucosan. 30 out of 42 sites had a calculated OC/Levoglucosan ratio (either Min ER, P10th ER, or both) within the provided range, whereas the corresponding number for EC/Levoglucosan was 39 of 42 (Fig. 6.1). ER outside this range were excluded, except for OC/Levoglucosan for BE07 (12.9), CH33 (3.5), and CZ03 (12.9) and EC/Levoglucosan for RO07 (0.5), which were close to the boundaries of the ranges given.

For the German urban sites DE72, DE73, DE74, the OC/Levoglucosan ratio exceeded the allowed range and were set to equal that of the rural site DE44, assuming substantial influence from other sources than RWC was the main explanation. For consistency, we also used the DE44 EC/Levoglucosan ratio for the German urban sites.

We used a similar approach for Spain, using the OC/Levoglucosan ratios for ES24 for all sites, despite that the ratios for ES19 and ES20 are within the allowed range. The Min

ER for ES24 is >2.5 times lower compared to ES19 (Barcelona) and ES20 (Granada), thus substantial influence from other sources is likely at these two sites. As a compromise, we used the P10th ER calculated for ES24 and not the Min ER, prioritizing a harmonized ER over potential site-specific ER. In compliance with the approach used for Germany we also used the ES24 EC/Levoglucosan ratio for all the Spanish sites.

For NO02 we used the same OC/Levoglucosan and EC/Levoglucosan ratios as for NO73, so also for SE21, as there are no other Swedish sites included. Similarly, we used the same ratios at FI50 as for FI36, whereas for PL05 and LT15 we used the ratios calculated for PL10. Following this approach, we ought to have used the ER derived from sites in Greece for CY02 an LB10, however we have used the average ratio for all sites (OC/Levoglucosan = 7.6; EC/Levoglucosan = 1.3) and thus consider the uncertainty higher for these two sites. Kaskaoutis et al. (2022) calculated an OC/Levoglucosan ratio of 4.05 for Ioanina (Greece), a site heavily influenced by RWC in winter (Mean levoglucosan conc. = 6044 ± 422 ng m^{-3}), being nearly 2 times lower than the ratios calculated for Greek sites in the present study (Fig. 6.1), indicating the level of uncertainty in the estimates presented.

6.2 Preliminary results

As shown in Fig. 6.2, calculated median concentrations of TC_{bb} ranged from 0.1 μg(C) m^{-3} to about 15 μg(C) m^{-3} across Europe. The sites experiencing the top ten highest median concentrations (4.4 - 15 μg(C) m^{-3}) were all urban sites or urban influenced sites, except the Hungarian site K-Puszta (HU02R), a site well-known to be influenced by RWC in winter (Gelencsér et al. 2007, Yttri et al. 2019, Salma et al. 2020). Five of the sites are situated in a geographically limited area, including the southern downslope of the Alps in France (FR38U and FR39U) and Italy, and the Po-Valley (IT04R, IT20U, IT21U, and IT22U). High particulate matter (PM) levels caused by RWC emissions in alpine Valleys in winter are well-known (Favez et al. 2010), as is RWC emissions contribution to the regional air pollution observed in the Po valley (e.g., (e.g. Gilardoni et al. 2011, Yttri et al. 2019). Notably, the first site (IT23U) missing the top ten list is also situated in the Po valley, thus the five Italian sites participating in the IMP Winter 2017/2018 all experienced high TC_{bb} concentrations. The BA29 (Sarajevo) and GRXUU (Athens) sites were the only two sites where TC_{bb} >10 μg(C) m^{-3} and thus greatly exceeded the other sites, confirming that Sarajevo, like several other cities in the Balkan region, experiences high levels of air pollution, particularly in winter. Recent studies have demonstrated that emissions from RWC can be high (Saffari et al. 2013) and even dominating ((Kaskaoutis et al. 2022) in certain parts of Greece and our results confirm this. However, TC_{bb} levels at GR100U, situated 8 km from the city center of Athens and 270 m asl, is more than one order of magnitude lower than at GR0XU, reflecting the importance of proximity to emission sources and the effect of local topography (Kalogridis et al. 2018). Indeed, this places GR100U amongst the ten sites with the lowest median TC_{bb} concentration (0.1 - 1.0 μg(C) m^{-3}), dominated by rural background sites, although in the higher end and noticeably higher than the four Nordic rural background sites (NO02R, FI36R, FI50R and SE21R). Considering the rural background sites only, the Nordic sites (0.1 - 0.3 μg(C) m^{-3}) stand out, having much lower TC_{bb} levels than continental Europe (0.8 - 7.2 μg(C) m^{-3}), likely reflecting diluted continental European emissions reaching this distant and less polluted region outskirts of Europe. Sites in eastern parts of France (FR09R and FR22R) and Belgium (BE07R) and in western parts of Switzerland (CH02R) are somewhat higher (0.8 - 1.3 μg(C) m^{-3}),

followed by eastern European sites (CZ03R, HU02R, LT15R, PL05R, and RO07R), and sites in Western (AT02R and DE44R) and Southern Europe (SI08R) situated far to the East (1.6 - 3.6 μg(C) m^{-3}). Two southern European sites hold the highest (IT04R; 7.2 μg(C) m^{-3}) and the lowest (CY02R; 0.1 μg(C) m^{-3}) level, indicating the wide variability natural for such large areas as considered here.

Median TC_{bb} concentrations ranged from a negligible contribution to TC at the two eastern Mediterranean sites CY02R (TC_{bb}/TC = 0.04) and LB10U (0.06) to totally dominating at IT22U (TC_{bb}/TC=0.71) in Bologna (Fig. 6.2). TC_{bb}/TC ratios exceeded 0.5 for 16 sites but it was likely the major contributor to TC at an even larger number of sites, as some biogenic secondary organic aerosol (BSOA) and primary biological aerosol particles (PBAP) are present alongside anthropogenic sources of TC even in winter. Indeed, TC_{bb}/TC > 0.3 at all but eight sites. High TC_{bb}/TC ratios were associated with high TC_{bb} levels, and eight of the top ten sites with respect to TC_{bb}/TC (0.57 - 0.71) also appeared on the TC_{bb} top ten list. In the other end of the range, seven of the lower ten sites with respect to TC_{bb}/TC (0.04 - 0.30) also appeared on the TC_{bb} lower ten list. Similarities in the rank comparing TC_{bb}/TC and TC_{bb} (Fig. 6.2) can be expected as two of three variables compared are identical, as indicated when correlating their ranked position (R^2 = 0.625). However, some sites differ by as much as 10 - 20 places (PL10U, ES20U, BE07R, GR100U, FR22R, IT23U, DE74T, and ES24U). Consequently, sites relatively most influenced by TC_{bb} belong to the urban category.

Considering only the rural background sites, the Nordic sites (TC_{bb}/TC 0.16 - 0.30) kept their lower ten position even on a relative basis, which might sound surprising given the widespread use of RWC in these countries. A turnover to cleaner combustion technology over the last decades could be added to the arguments made above to explain this, although there are indications that long-range atmospheric transport (LRT) dominates also for RWC, as seen for Birkenes (Yttri et al. 2021). Eastern European sites (TC_{bb}/TC 0.32 - 0.61) varied over an equally wide range as the Nordic sites, although not overlapping, experiencing two of the three highest relative contributions at RO07R (0.61) and HU02 (0.60). We are left to speculate about the relatively low fraction at the Polish site (PL05), indicating that it might be due to the rather widespread use of coal in this country. Also note that brown coal can emit levoglucosan (Fabbri et al. 2009), potentially further confounding the results shown in the present study. Finally, a higher minimum OC/Levoglucosan ratio (15.4) can be derived from Klejnowski et al. (2017), reporting measurements from a site in southern Poland, than for the northern Polish site in the present study. Neither the western European sites (0.31 - 0.51) nor the southern ones (0.41 - 0.54) (excluding CY02; 0.04) overlapped with the Nordic sites. Further, no obvious regional pattern could be observed for these sites.

In our further investigation of the IMP Winter 2017/2018 OC, EC, TC and levoglucosan data sets, we aim to extend upon the basic study presented here, demonstrating the importance of RWC as a source of carbonaceous aerosol air pollution in Europe. A comparison between EC_{bb}/EC_{ff} derived from levoglucosan measurements and eBC_{bb}/eBC_{ff} data derived from Positive Matrix Factorization (PMF) calculations (Platt et al., in prep.) is planned.

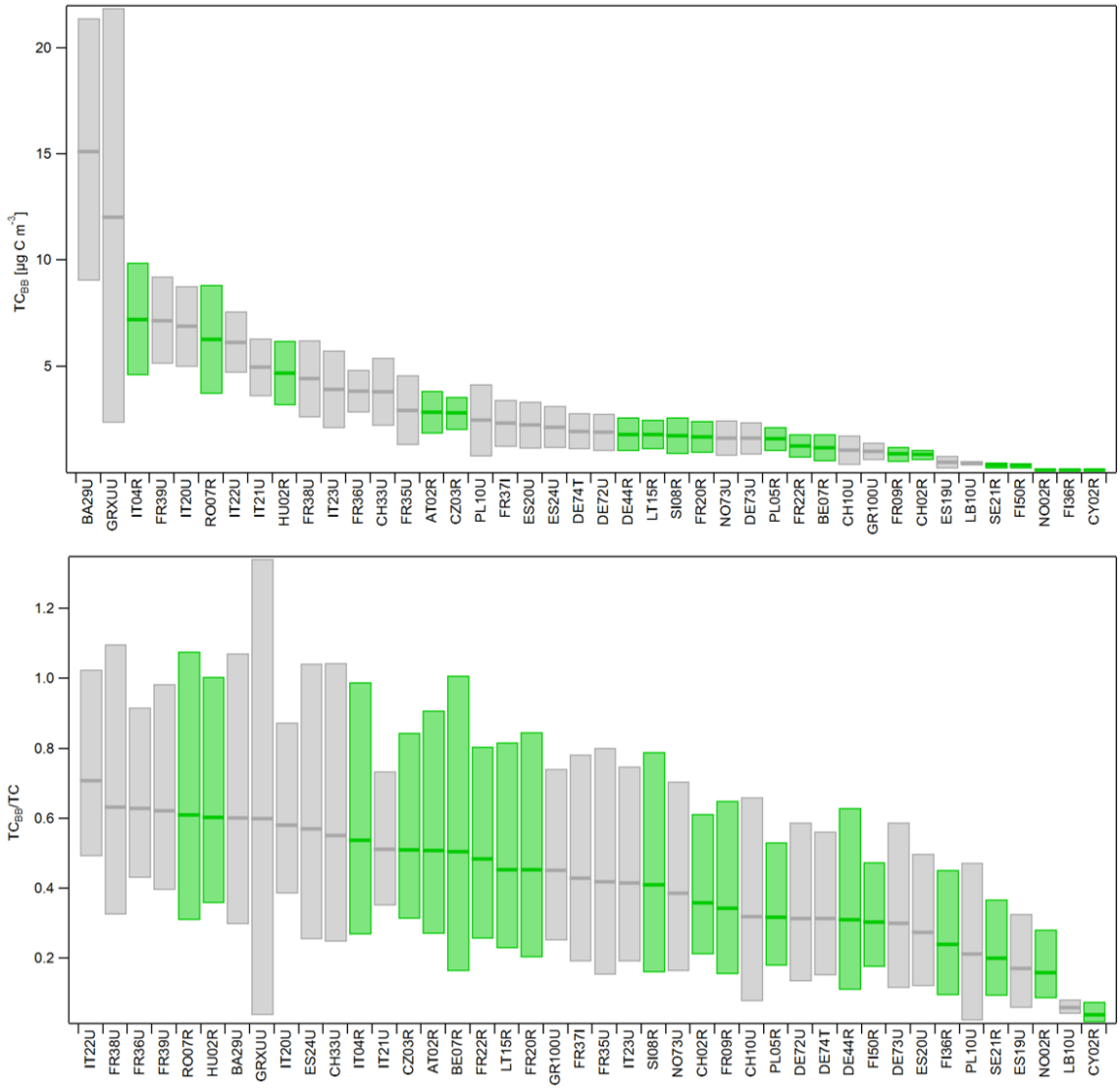

Figure 6.2: Median, 25th and 75th percentile for TC_{bb} (upper panel) and TC_{bb}/TC (lower panel) calculated based on ambient levoglucosan concentrations.

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Part III

Technical EMEP Developments

CHAPTER 7

EMEP trends in AeroVal

Daniel Heinesen and Augustin Mortier

This chapter presents the EMEP trends results in the AeroVal web interface, available at https://aeroval.met.no/evaluation.php?project=emep-trends. First we summarize the methods used to calculate the trends based on EMEP MSC-W model simulations and EMEP observations. We discuss how the data are processed and which constraints are put on the observations we use. We then move on to describe how the trends are calculated, explaining the two methods applied. Lastly, we look at some results and briefly discuss the differences between the two methods.

7.1 Observations and model data

7.1.1 Setup for EMEP MSC-W model calculations

For this trend interface the EMEP MSC-W model version rv4.42 has been used to perform model runs for years from 2000 through 2019. The horizontal resolution is $0.1° \times 0.1°$, with 20 vertical layers (the lowest with a height of approximately 50 meters). The model runs were documented in detail in last year's EMEP Status Report, see Aas et al. (2021).

7.1.2 Observations

The observations used have all been reported to EMEP and are openly available from the EBAS database (http://ebas.nilu.no). The database extract used here was downloaded on 18-03-2022.

Multiple sites were removed after visual inspection, either due to very high annual variability or/and inconsistent development. Sites which are situated higher than 1200 m.a.s.l. are often measuring above the boundary layer, which is not well represented by the model run. In

Aas et al. (2021) all sites above 1200 m.a.s.l. were removed automatically, but here all sites above this level were inspected and removed manually. An overview of the excluded sites can be found in appendix G in table G:1.

For more detail about EC and OC, and merging of sites in close proximity, see the 2021 EMEP Status Report (Aas et al. 2021).

7.2 Processing the data

Both observed and modelled trends were processed with the pyaerocom software (https://github.com/metno/pyaerocom) for the period 2000–2019. In addition, several sub-periods were distinguished, i.e. 2000-2010, 2005–2019 and 2010–2019. The first two compare the changes in pollution levels during the 1st and 2nd decades of the considered 20-year period; besides more observational data became available in the recent years. In particular, the 2010-2019 period was the only one when EC and OC observations were available for model evaluation. The 2005–2019 period was chosen for an individual analysis as 2005 is the base year of the Gothenburg Protocol. All observations were provided via the EBAS database.

Since sample temporal resolution and duration can vary between the sites and during the considered period, the lowest common resolution, i.e. monthly, was identified and higher resolution data (hourly and daily) were down-sampled to that resolution. For temporal re-sampling we required ca. 75% coverage in a hierarchical manner; that is, at least 18 hourly measurement values to retrieve a daily mean, and at least 21 daily values to retrieve a monthly mean. The coverage requirement for daily values was lowered for EC and OC because of a lower sampling frequency, i.e. at least 4 daily values to retrieve a monthly mean.

Trends are computed based on yearly averages, as described in more detail in section 7.3. To retrieve the yearly averages, at least one monthly value is required per each of the seasons. At least 75% of the years in a given period then have to be valid. Sites which did not meet this requirement were removed from the trend evaluation and analysis, so that all statistics are calculated only for sites where a sufficient number of valid years to calculate a trend was present. In addition to trends based on yearly averages, seasonal trends are computed for all pollutants only for valid years, as defined above (i.e. observations are available for all four seasons and at least for one month per season).

Model output at daily resolution was used for the trend analysis, including the daily maximum of O3 (calculated based on hourly values). To compute the model trends, the daily model output for each variable was co-located in space and time with the observations. Co-location in space was done by picking the nearest model grid to each site. Co-location in time was done by first re-sampling both model and observation data to the lowest common temporal resolution (i.e. monthly), then disregarding the model output at times when observations are missing, and finally calculating the monthly mean of both. Also precipitation (reported in units of mm) was colocated in time based on monthly aggregates, which were calculated independently for model and observations.

7.3 Computation of the trends

The same methodology, as described by Aas et al. (2019) and Mortier et al. (2020), has been used for calculating trends based on the model and observational time series. The significance

Trends in Europe for 2000-2019 (%/yr)				
	Median of Indiv. Stat.		Regional Time Series	
	EBAS	*EMEP*	*EBAS*	*EMEP*
NO2	-1.9	-2.2	-1.8	-2.3
O3max	-0.1	-0.1	-0.1	-0.1
SO2	-3.9	-5	-4.4	-5.2
CO	-0.4	-0.6	0.4	-0.9
PM2.5	-2.7	-2.4	-1.9	-2.2
PM10	-2	-2	-1.6	-1.6
SO4	-3.2	-3.7	-3	-3.9
tNO3	-1.7	-2	-1.1	-1.7
tNH4	-1.4	-1.2	-0.4	0.2
NH3	1.1	1.5	1.8	2.6
NH4	-2.5	-2.7	-2.9	-3.1
HNO3	-2	-2.6	-1.8	-2.6
NO3_PM2.5	-3.5	-3.3	-3.5	-3.3
NO3_PM10	-1.8	-2.7	-2	-2.3
SS_PM2.5	-2.7	-0.3	-2.7	-0.3
SS_PM10	-0.9	0.3	4.5	2.7
WetOXS	-3	-4.1	-3.6	-4.4
WetRDN	-0.8	-0.5	-0.9	-0.5
WetOXN	-1.6	-2.3	-1.8	-2.4
Precipitation	0.2	0	0.3	-0.1

Table 7.1: European trends computed with observational and model datasets for 2000-2019 using regional time series and individual stations methods.

of the trends is tested with the Mann-Kendall test (Hamed and Rao 1998), applying the probability level of 95% as a threshold for trend significance, i.e. if the related p-value is smaller than 0.05, the trend is identified as statistically significant (corresponding to 2σ confidence). The slope is calculated with the Theil-Sen estimator, which is less sensitive to outliers than standard least-squares methods (Sen 1968).

In order to ensure consistent comparisons, the trends are provided as relative trends (%/yr) with respect to the first year of the time period, i.e. the intercept of the time series.

The trends are provided for individual sites and "regions", i.e. EMEP countries and the whole EMEP area (referred to as "WORLD"). The regional trends have been derived with two different methods:

- The regional time series are computed by averaging the observations in the different regions, and the trends are computed based on those regional time series, as described in Mortier et al. (2020) - called "Regional time series" in the interface.
- The trends are computed at each individual sites and then averaged (mean or median) over the different regions - called "Individual stations" in the interface.

The European trends (i.e. over all available EMEP sites) calculated with these two methods are compared in Table 7.1.

Note that for the mean/median trends the standard deviation and p-values can't be calculated by the methods described above, and are instead calculated from the trends of the

individual sites in the region. The standard deviations are calculated as the standard deviation of the trends at the individual sites. The regional p-value is the harmonic mean of the p-values found at each site.

7.4 Visualizing the results in AeroVal

All results are available on the AeroVal webpage in the dedicated EMEP-trends project: https://aeroval.met.no/evaluation.php?project=emep-trends. This interactive web interface has been developed for the evaluation of climate and air quality models data processed with pyaerocom.

7.4.1 Quick overview of AeroVal

Before we go on to look at the results for the trend calculations, we will have a quick view at the AeroVal web interface. We will use Figure 7.1 to illustrate how to navigate the most important parts of the interface.

On the upper left, there is a list of different experiments referring to the different periods, introduced in Section 7.2.

The menu on the very top allows choosing different ways of visualizing the statistics. The most important tabs here are *Evaluation*, which is the page we can see in the figure, and *Overall Evaluation*, which summarizes all the statistics in compact heat maps.

Right below this menu is a row of five drop-down menus. The different pollutants can be chosen in the leftmost drop-down. The second and third drop-downs control the observations and models which have been evaluated. At present, EBAS and EMEP are the only possible choices. In the fourth drop-down we find the different seasons. Finally, the last drop-down (all the way to the right) is the statistics selection menu, where the user can choose which statistic to display.

The four panels in the center of the page constitute the main results of the evaluation:

- The upper left panel is a map of all the sites with valid data. The color of the dots on the map indicates the value of the chosen statistic at that site. The numerical value can be found by hovering over the dot.
- The upper right panel is a bar plot of the values of the statistic for the different regions (countries as well as Europe). Also here, it is possible to hover over the bars to get the numerical values.
- The bottom left panel shows the time series of the chosen model and observations, chosen by either clicking on one of the bar or on one of the sites on the map.
- The bottom right panel shows the scatterplot of model versus observations for a selected pollutant.

7.4.2 Trends in AeroVal

The observational and model data can be visualized for each site and aggregated for individual European countries. Trends for the different periods are available through a selection of different experiments, and the different methods for computing the trends (regional time series

or mean/median over individual sites) can be selected from a statistics selection menu. The trends at individual sites are visualized in a dynamic map according to a color scale ranging from blue, for negative trends, to red, for positive ones. Both observed and modelled trends can be visualized simultaneously (the squares being the model and the circles the observation) for the whole selected period, as well as for the different seasons, see Figure 7.1.

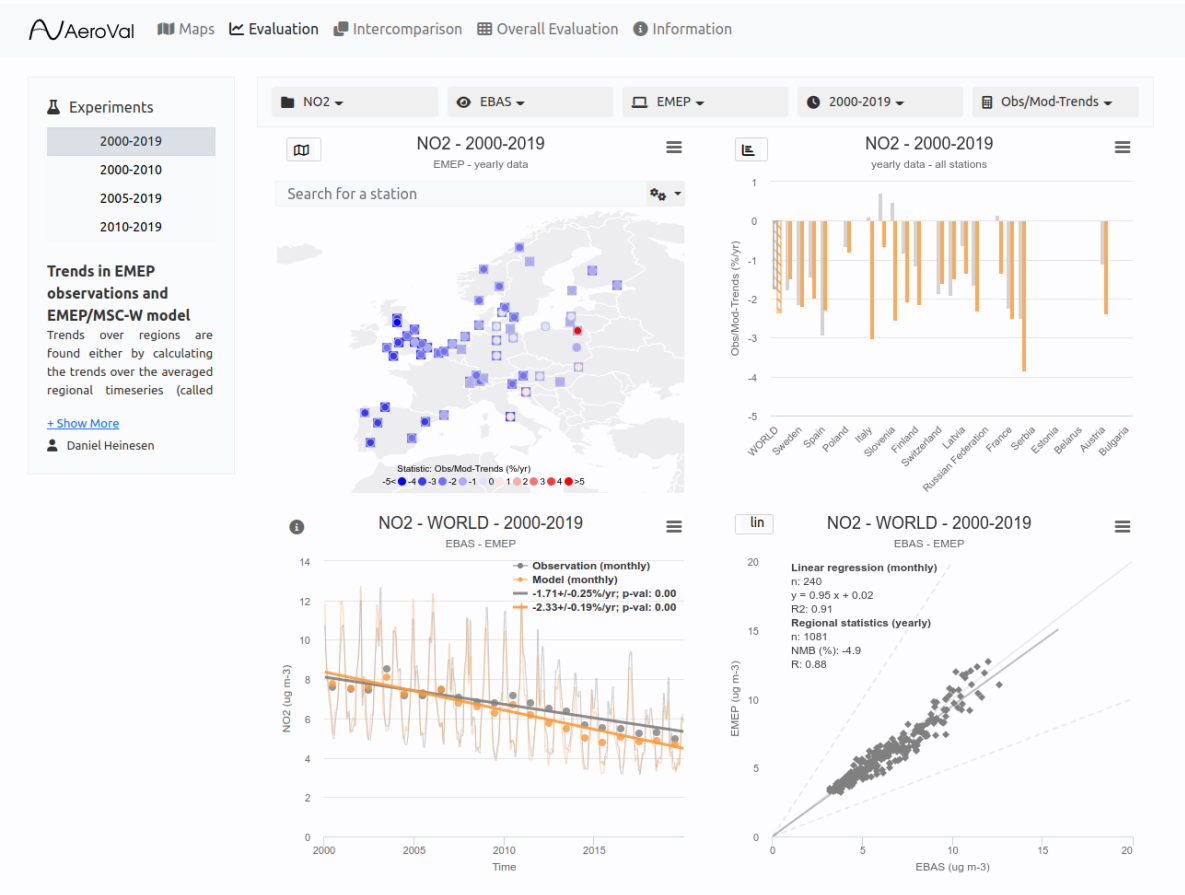
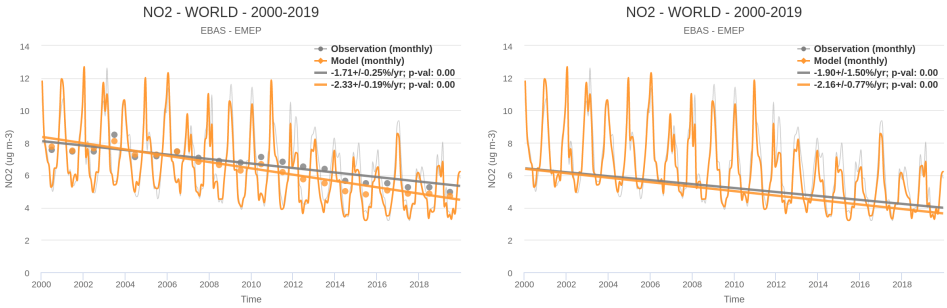


Figure 7.1: EMEP trends results in the AeroVal web interface - `https://aeroval.met.no/evaluation.php?project=emep-trends`. The description of the different parts of the web interface can be found in sec. 7.4.1

Note that in the graphs like those shown in Figure 7.2 for the individual countries and the whole of Europe, the same regional mean time series will always be displayed regardless which of the trend calculation method is chosen, e.g. the "regional time series" (Fig. 7.2a) or the "individual stations" (Fig. 7.2b). Therefore in the former case, the trend slope (computed on the basis of regionally averaged annual means, represented by dots) will correspond well with time series, while for the latter case, for either mean or median trend slopes, this will not be the case. This is because the trend line (as in Fig. 7.2b) is plotted using region mean/median trend slope and intercept values calculated based on time series at the individual sites.



(a) Regional trends (b) Median of individual trends

Figure 7.2: Time series for NO_2 in the period 2000-2019, and trends calculated from both the regional time series and the median of the individual sites. We see that the median trend corresponds poorly with the time series, as the time series is the regional average time series.

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CHAPTER 8

Updates to the EMEP MSC-W model, 2021–2022

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This chapter summarises the changes made to the EMEP MSC-W model since Simpson et al. (2021), and along with changes discussed in Simpson et al. (2013, 2015–2021) and Tsyro et al. (2014), updates the standard description given in Simpson et al. (2012). The model version used for reporting this year is denoted rv4.45, which has had some updates compared to the rv4.42 version reported in Simpson et al. (2021). Table 8.1 summarises the changes made in the EMEP model since the version documented in Simpson et al. (2012), and these changes are discussed in more detail in Ch 8.1-8.5.

8.1 Overview of changes

The major changes can be summarised:

- The landcover definitions and input files needed for phytotoxic ozone dose (POD) estimates were modified to better match the definitions given in the 2017 ICP-Vegetation Mapping Manual (LRTAP 2017). New POD outputs were introduced for Mediterranean vegetation. See Ch. 8.2.

- An additional output option has been implemented to facilitate comparison of the EMEP simulations with satellite data – see Ch. 8.3

- The soil NOx emissions were updated from v2.2 to v2.3 (Ch. 8.4.1).

- Upgraded Local Fractions (Wind et al. 2020) capabilities. Some primary particles are changing their deposition properties according to their age. This is now taken into account in the corresponding Local Fractions.

- Added new outputs for maximum daily eight-hour mean concentration (MDA8, e.g. Fleming et al. 2018, Lefohn et al. 2018), and for 1st, 2nd, 3rd, 4th and 26th highest MDA8 ozone values. These ozone indicators can be used for comparison to new EU target values (c.f. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:152:0001:0044:EN:PDF, annex VII page 24) which suggest 120 μg m^{-3} not to be exceeded on more than 25 days per calendar year averaged over three years. The 99% percentile is between the third and fourth highest MDA8 ozone values. The 26th highest MDA8 gives approximately the 93% percentile highest value.

8.2 Updated landcover/POD calculations

Here we first present the changes in the model and input parameters associated with the landcover update (Ch. 8.2.3–8.2.5), then briefly present results of POD calculations for the different land-covers (Ch. 8.2.6). Finally, we take the opportunity to present information on the current biogenic VOC (BVOC) emission factors associated with the full set of landcovers used in the EMEP model (Ch. 8.2.7).

8.2.1 Revised landcover categories

The EMEP model landcover classifications and parameters have been modified to reflect those of the most recent version of the ICP-Vegetation 'Mapping Manual' (LRTAP 2017), where now six classes of generic vegetation and POD levels are defined for use with chemical transport models and integrated assessment modelling (IAM). In EMEP notation, the vegetation classes are:

IAM_WH - specified in the Mapping Manual for wheat in Atlantic, Boreal, Continental, Steppic and Pannonian regions, but calculated for the full European domain in EMEP.

IAM_WH_MED - as IAM_WH, but for Mediterranean wheat.

IAM_DF - as IAM_WH, but for deciduous forests (Beech, birch, temperate oak, poplar).

IAM_DF_MED - as IAM_WH_MED, but for Mediterranean deciduous forests (Deciduous oak spp.)

IAM_SNL - as IAM_WH, but for seminatural vegetation (O_3-sensitive forbs, including legumes).

IAM_SNL_MED - as IAM_SNL, but for Mediterranean vegetation (O_3-sensitive legumes).

(The IAM_WH category above is identical to the IAM_CROP category used previously; it has just been renamed for better consistency with the latest Mapping Manual classes.) For completeness, Tables 8.2-8.3 provide the parameters used for the dry deposition scheme (Emberson et al. 2000, Simpson et al. 2012). All but one of the parameters are explained in Simpson et al. (2012). The only new variable in Tab. 8.2 is $\mathrm{SMI_{max}}$, which gives the value of the root-zone soil moisture index (SMI3, see Simpson et al. 2012) at which the soil water factor f_{SW} (*ibid.*) attains the value 1.0. Below $\mathrm{SMI_{max}}$ the f_{SW} factor is reduced linearly until it equals zero at SMI3=0. Above $\mathrm{SMI_{max}}$, f_{SW} = 1. In previous model versions $\mathrm{SMI_{max}}$

has been set to 0.5 for all vegetation, but as from rv4.43 the value is modified to 0.4 for the Mediterranean landcovers NF (Med. needle leaf) and MS (Med. scrublands), and to 0.9 for IAM_SNL_MED.

Finally, Tables 8.2-8.3 also contain two entries for IAM_WH_Irrig and IAM_WH_MED-_Irrig; these are identical to the IAM_WH and IAM_WH_MED classes, but with f_{SW} set to 1.0 always - an approximation to crops which are under constant irrigation. (The _Irrig suffix would trigger this behaviour for a land-cover category.)

8.2.2 Use of topography in setting growing season.

rv4.43 also introduced the use of topography in modifying the start and end of growing seasons (SGS, EGS) in the model. Following the Mapping Manual, we now delay SGS, and advance EGS, by 1 day for every 100 m elevation. These changes are limited to a maximum of 20 days.

8.2.3 Seminatural vegetation: g_{max} for IAM_SNL_MED

The EMEP model uses a two-step procedure to calculate POD values. First, a so-called big-leaf calculation is made to estimate O_3 at the top of the vegetation canopy from the O_3 values at the centre of the model's lowest layer. Second, a leaf-level calculation is made to estimate the flux of this ozone into the leaf stomata. These steps are discussed in more detail in Tuovinen et al. (2009) and Simpson et al. (2012). Although different resistance terms are used in the two steps, the default behaviour of the EMEP model is to use the same value of g_{max} (maximum stomatal conductance) for both the big leaf and leaf-level calculations.

The new Mediterranean seminatural vegetation category, IAM_SNL_MED, is unique in that the species-specific g_{max} value is very high (782 mmole O_3 m^{-2} (PLA) s^{-1}), and that this ozone-sensitive species should be assumed to be well mixed with other species belonging to the same vegetation category. Thus, although the high g_{max} is appropriate for leaf-level calculations, it would be inappropriate and excessive for the big-leaf calculations which represent fluxes to the community of species in the canopy. For IAM_SNL_MED we therefore use a lower g_{max} (550 mmole O_3 m^{-2} (PLA) s^{-1}) for the big-leaf calculations, and the higher g_{max} for the leaf-level.

8.2.4 Seminatural vegetation: time-windows

In the Mapping Manual a time-window of 1.5 months is suggested for POD calculations for Mediterranean seminatural vegetation (IAM_SNL_MED), and 3 months for POD for the general seminatural class (IAM_SNL). These windows are considered to be the periods when the vegetation is most sensitive to O_3 damage. However, as there are very large uncertainties associated with the start and end dates of such windows, we have elected to accumulate POD over the longer periods associated with the growing seasons (between SGS and EGS, c.f. Table 8.3). The growing season is assumed to be from 1st February to 30th June for IAM_SNL_MED, and from 1st April to 30th September for IAM_SNL. The scaling factors are thus1.5/5 (=0.3) for POD1_SNL_IAM_MED and 3/6 (=0.5) for POD1_SNL_IAM.

8.2.5 Mediterranean mask

In previous EMEP model versions we have calculated ozone fluxes and POD values for all grid cells which contain vegetation, even when the desired ecosystem type would not cover the full domain. As of v4.43 we have implemented a mask so that POD values over Mediterranean ecosystems can be provided without having to model the whole domain. The mask is based upon the biogeographical regions dataset of the European Environment Agency (https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3). A 0.5°×0.5° map was created to delineate the Mediterranean ecosystems for the EMEP model, though the border areas were extended by 1° to capture any small areas lying just outside the EEA map.

8.2.6 Revised POD calculations

Figure 8.1 shows the difference between POD estimates for the revised land-cover categories, and also illustrates the impact of the Mediterranean mask on the model outputs. These results will not be discussed in detail here, but we can note that POD values exceed the suggested critical levels for all land-cover types (5.7 mmol m^{-2} for IAM_DF, 13.7 mmol m^{-2} for IAM_DF_MED, 6.6 mmol m^{-2} for IAM_SNL, 10.8 mmol m^{-2} for IAM_SNL_MED, and 7.9 mmol m^{-2} for IAM_WH and IAM_WH_MED, LRTAP 2017).

8.2.7 BVOC emissions

Although BVOC emission rates have not changed in recent model versions, we here use Table 8.3 to update and complete earlier documentation. As discussed in detail in Simpson et al. (2012) the EMEP model requires the specification of standard emission potentials (valid at 30°C, 1000 μE photosynthetic active radiation, PAR) for isoprene and both light and pool-dependent monoterpene emissions, represented by the variables $\varepsilon_{\Lambda_{c,iso}}$, $\varepsilon_{\Lambda_{c,mtl}}$ and $\varepsilon_{\Lambda_{c,mtp}}$ in Table 8.3.

For Europe these BVOC emission potentials are built upon a complex system which utilises maps of 115 forest species from 30 countries (from Köble and Seufert 2001) together with species-specific emission potentials. Thus, the emission potential for a specific land-cover category (e.g. CF) can differ substantially from cell to cell, depending on the mix of tree species within the cells, and such potentials are read in as gridded maps for the model. The emission potentials of other landcover categories, or for the CF, DF, NF and BF forests which lie outside the Köble and Seufert maps, are simply specified with generic emission potentials as given in Table 8.3.

Simpson et al. (2017) and Simpson et al. (2018) discussed the inclusion of new global landcover datasets which are used outside of the EMEP/EECCA domain. The global dataset was based upon a merge of data from the Community Land Model (http://www.cgd.ucar.edu/models/clm/, Oleson et al. 2010, Lawrence et al. 2011) and the 'GLC-2000' land-cover dataset (http://bioval.jrc.ec.europa.eu/products/glc2000/glc2000.php). These more global categories (from 'NDLF_EVGN_TMPT_TREE' to 'BARE' in Table 8.3) were also assigned generic emission potentials, which were loosely based upon studies such as Guenther et al. (2012) and Messina et al. (2016). Table 8.3 now provides the various ε_Λ values for each land-cover.

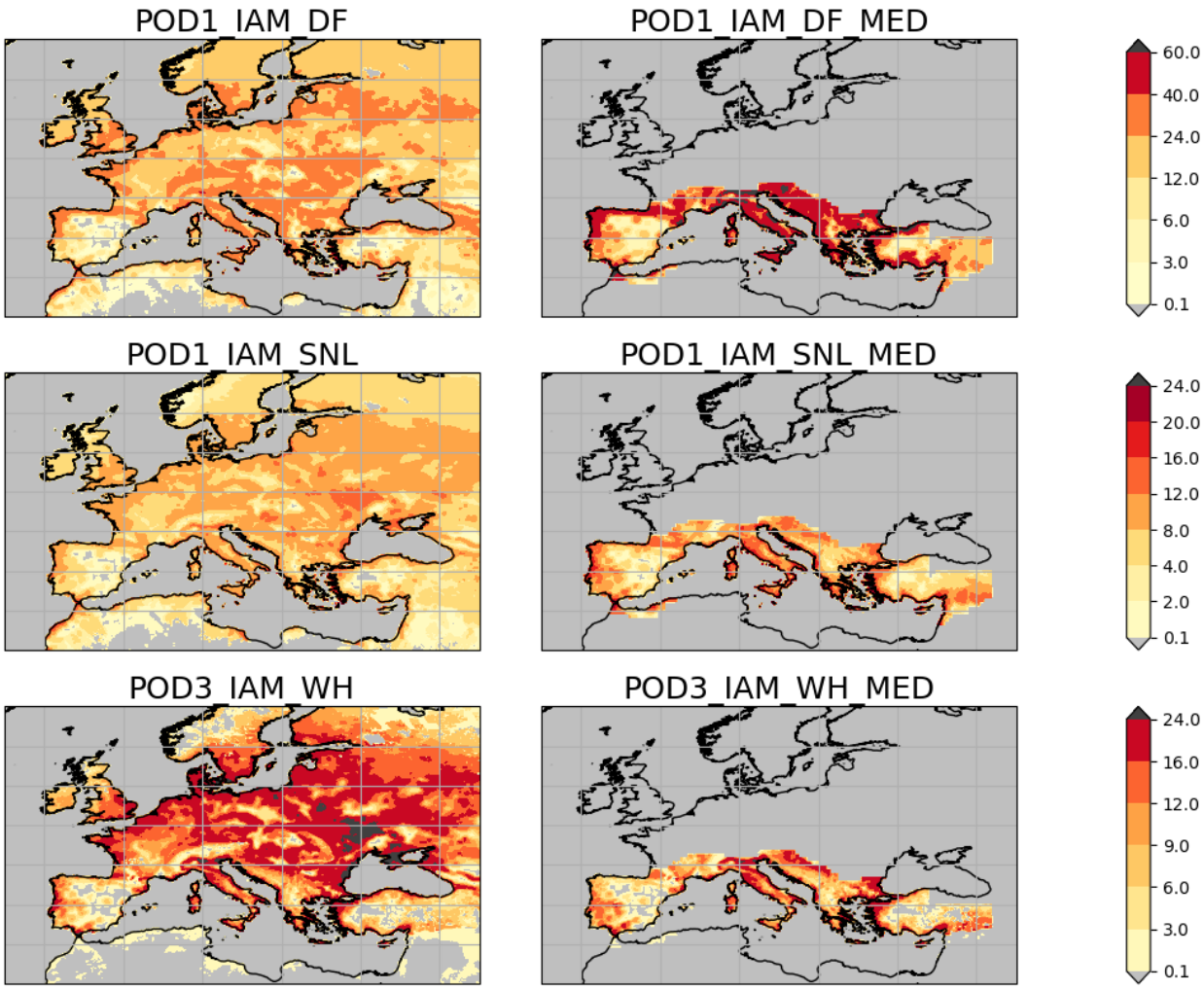

Figure 8.1: Comparison of POD values for the updated IAM ecosystems. Calculations for 2019. Units: mmol m^{-2}

As well as the inclusion of these global land-cover categories, it should be noted that the ε_{Λ_c} values given in Table 8.3 are now given as 'leaf'-level, rather than the 'branch'-level values used in Simpson et al. (2012). As discussed in Guenther et al. (1994) and Simpson et al. (2012) the ratio of leaf to branch level emissions is 1.75 for light-sensitive emissions ($\varepsilon_{\Lambda_{c,iso}}$, $\varepsilon_{\Lambda_{c,mtl}}$) and 1.0 for other emissions (thus $\varepsilon_{\Lambda_{c,mtp}}$).

8.3 Satellite toolbox

To facilitate comparison of the EMEP simulations with satellite data, an additional output option has been implemented based on the *CAMS Satellite Operator* (CSO) toolbox. The CSO toolbox is publicly available (`https://ci.tno.nl/gitlab/cams/cso`) and provides tools to download and prepare satellite data for simulation by a model, and to compare the simulations with the observations. An EMEP dedicated version *eCSO* of the toolbox has been created for use in the EMEP projects, and can be provided on request.

8.4 Updates in emission systems

- The time factors used to modulate emissions are normally divided into monthly, daily and hourly time factors. In order to be able to describe the special situation for 2020, it is now possible to define a daily time factor for each day of the year, instead of monthly+daily. The daily time factors must be provided by the user in an external file.

- The hourly time factors can now be given as gridded factors.

- In previous versions, reading of emissions could be relatively slow, or memory demanding on some computer systems. The emissions are now read much faster, even when a large number of countries/sectors are to be read. It is now easy to use emissions for all countries and sectors.

- The default time factors and emission release heights for GNFR_D has been changed from earlier SNAP 4 (Production processes), to SNAP 5 (Extraction and distribution of fossil fuels).

8.4.1 Soil NO emissions

As documented in Simpson et al. (2021), the EMEP model now makes uses of a new global dataset for soil NO emissions. Version v2.2 of this dataset was described in detail in Simpson and Darras (2021), and provided gridded monthly data and the corresponding 3-hourly weight factors at $0.5^\circ \times 0.5^\circ$ degrees horizontal resolution, over the period 2000-2018. The basic methodology merges methods from Yienger and Levy (1995), with various updates to reflect recent literature (especially Steinkamp and Lawrence 2011), and some simplifications which reflect lack of availability of some key data.

Version v2.3 was produced in 2021 to fix some issues found in v2.2, and to make use of updated inputs. From v2.2 to v2.3, the changes are:

1. The 'biome' emissions in the v2.2 sent to the web-site were erroneously set to be the same for all years. v2.3 restores the intended behaviour with year to year variation.

2. The 2008–2010 global meteorological data used as input for the calculations were found to have some errors. These data were re-generated.

3. Use of updated CEDS data. Although not used directly, in v2.2, soil-NO emissions from the CEDS database (Hoesly et al. 2018) were used to scale the Potter-based fertilizer induced emissions from our base-year of 2005 to other years in the range 1980–2018. The CEDS database has subsequently been updated (to v2021-04-21 McDuffie et al. (2020), O'Rourke et al. (2021), and large changes were found in the CEDS soil-NO emissions compared to the original data. These changes result in new scaling factors for the fertilizer-induced soil NO emissions in v2.3.

8.5 Other

A number of smaller changes have been made:

- the configuration options for emissions reading were expanded.
- The mass medium diameter of coarse sea-salt was changed to 4.0 μm (was 4.8). (This adjustment, based on typical size distribution of sea salt aerosols (available from literature), was made in order to better reconcile model results with observations.)
- Added the "RESTART" option for NEST in the configuration setup. This is to be used when one restarts a run without changing the domain size ("checkpoint-restart"). The difference with "START" is only that the boundary conditions (BC) are not overwritten. This is important in the case of restarting exactly at the start of a month (at time 00:00, the 1st), because the nest file will have the BC from preceding month. If using "START" and not "RESTART", it will use directly the values from the stored nest file BC, i.e. from the previous month. See the user guide at https://emep-ctm.readthedocs.io/en/latest/ for further details.
- Numerous small changes to make the code more flexible and/or to fix various bugs. Additionally, improvements were made in memory and CPU usage when using netcdf emission inputs with large number of sources categories.

Table 8.1: Summary of major EMEP MSC-W model versions from 2012–2022. Extends Table S1 of Simpson et al. 2012.

Version	Update	Ref[(a)]
v4.45	Improved and faster emissions handling; Updated soil NO to v2.3; New O_3 outputs	This report
v4.44	Changed MMD of SS to 4.0μm; Bug fix on f_{SW} usage; Added extension "ZD_EmCso" for simulation of satellite observations.	This report
v4.43	Updates to landcover and POD calculations; Much faster reading of netcdf emissions in new format.	This report
v4.42	19-sector emissions system (GNFR-CAMS) introduced; Emissions for soil NO, DMS, and aircraft updated using results from CAMS81 project; Modified various parameters concerning fine/coarse fractions for sea-salt and nitrate; Added RH limits on Gerber functions; 'rnr' emission split and EmChem19r introduced; Revised global monthly emission factors produced (and use of global time.zone map); Changed default Kz and Hmix schemes; upgraded local fraction methods; cleaned up various config options.	R2021
rv4.36	Public domain (Nov. 2020); Updated NO_3 photolysis; Allow physical height and topography settings in sites/sondes output; better time resolution on Hmix outputs; allow hourly time-factors per country and species; Various emission coding improvements	
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	R2020
rv4.34	Public domain (Feb. 2020); EmChem19a, EmChem19p	R2020
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; 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 of 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.

Table 8.2: Land-cover specific parameters for stomatal conductance (DO_3SE) calculations. For variable SMI_{max}, see Ch. 8.2. For explanation of other variables, see Simpson et al. (2012).

Code	g^m_{max} †	f_{min}	f_{phen} factors ϕ_a	ϕ_b	ϕ_c	ϕ_d	ϕ_e days	ϕ_f days	ϕ_{A_S} days	ϕ_{A_E} days	f_{light} α	f_T T_{min} °C	T_{opt} °C	T_{max} °C	f_D D_{max} kPa	D_{min} kPa	$\Sigma D_{Crit.}$ kPa	SMI_{max}
EMEP/EECCA-domain ecosystems:																		
CF	140	0.1	0.8	0.8	0.8	0.8	1	1	0	0	0.006	0	18	36	0.5	3	-1	0.5
DF	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
NF	200	0.13	1	1	0.2	1	130	60	80	35	0.013	8	25	38	1	3.2	-1	0.4
BF	200	0.02	1	1	0.3	1	130	60	80	35	0.009	1	23	39	2.2	4	-1	0.5
TC	300	0.01	0.1	0.1	1	0.1	0	45	0	0	0.0105	12	26	40	1.2	3.2	8	0.5
MC	300	0.019	0.1	0.1	1	0.1	0	45	0	0	0.0048	0	25	51	1	2.5	-1	0.5
RC	360	0.02	0.2	0.2	1	0.2	20	45	0	0	0.0023	8	24	50	0.31	2.7	10	0.5
SNL	60	0.01	1	1	1	1	1	1	0	0	0.009	1	18	36	1.3	3	-1	0.5
GR	270	0.01	1	1	1	1	0	0	0	0	0.009	12	26	40	1.3	3	-1	0.5
MS	200	0.01	1	1	0.2	1	130	60	80	35	0.012	4	20	37	1.3	3.2	-1	0.4
WE	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
TU	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
DE	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
W	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
ICE	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
U	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
Global (non-Euro-domain) ecosystems:																		
NDLF_EVGN_TMPT_TREE	140	0.1	0.8	0.8	0.8	0.8	1	1	0	0	0.006	0	18	36	0.5	3	-1	0.5
NDLF_EVGN_BORL_TREE	140	0.1	0.8	0.8	0.8	0.8	1	1	0	0	0.006	0	18	36	0.5	3	-1	0.5
NDLF_DECD_BORL_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_EVGN_TROP_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_EVGN_TMPT_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_DECD_TROP_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_DECD_TMPT_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_DECD_BORL_TREE	150	0.1	0	0	1	0	20	30	0	0	0.006	0	20	35	1	3.25	-1	0.5
BDLF_EVGN_SHRB	60	0.01	1	1	1	1	1	1	0	0	0.009	1	18	36	1.3	3	-1	0.5
BDLF_DECD_TMPT_SHRB	60	0.01	1	1	1	1	1	1	0	0	0.009	1	18	36	1.3	3	-1	0.5
BDLF_DECD_BORL_SHRB	60	0.01	1	1	1	1	1	1	0	0	0.009	1	18	36	1.3	3	-1	0.5
C3_ARCT_GRSS	270	0.01	1	1	1	1	0	0	0	0	0.009	12	26	40	1.3	3	-1	0.5
C3_NARC_GRSS	270	0.01	1	1	1	1	0	0	0	0	0.009	12	26	40	1.3	3	-1	0.5
C4_GRSS	270	0.01	1	1	1	1	0	0	0	0	0.009	12	26	40	1.3	3	-1	0.5
CROP	270	0.01	1	1	1	1	0	0	0	0	0.009	12	26	40	1.3	3	-1	0.5
BARE	-1	-1	-1	-1	-1	-1	0	-1	0	0	-1	-1	-1	-1	-1	-1	-1	0.5
IAM ecosystems:																		
IAM_WH	500	0.01	1	1	1	1	1	1	0	0	0.0105	12	26	40	1.2	3.2	8	0.5
IAM_WH_MED	430	0.01	1	1	1	1	1	1	0	0	0.0105	13	28	39	3.2	4.6	8	0.5
IAM_WH_Irrig	500	0.01	1	1	1	1	1	1	0	0	0.0105	12	26	40	1.2	3.2	8	0.5
IAM_WH_MED_Irrig	430	0.01	1	1	1	1	1	1	0	0	0.0105	13	28	39	3.2	4.6	8	0.5
IAM_DF	150	0.1	0	0	1	0	15	20	0	0	0.006	0	21	35	1	3.25	-1	0.5
IAM_DF_MED	265	0.13	0	0	1	0	20	50	0	0	0.006	0	22	35	1.1	3.1	-1	0.5
IAM_SNL	210	0.1	1	1	1	1	1	1	0	0	0.02	10	22	36	1.75	4.5	-1	0.5
IAM_SNL_MED	782/550‡	0.02	1	1	1	1	1	1	0	0	0.013	8	22	33	2.2	4.3	-1	0.9

Notes: † Units of g^m_{max} are mmole O_3 m^{-2} (PLA) s^{-1}; ‡ – IAM_SNL_MED has a special treatment for g^m_{max}, see Ch. 8.2.3.

Table 8.3: Default land-phenology data for EMEP deposition calculations. For BVOC parameters, see Ch.8.2.7.

Name	code	type	PFT	hveg	SGS50 day	DSGS days/d	EGS50 day	DEGS days/d	LAImin m2/m2	LAImax m2/m2	SLAIlen days	ELAIlen days	BiomasD g/m2	$\varepsilon_{\Lambda_{c,iso}}$ ug/g/h	$\varepsilon_{\Lambda_{c,mtl}}$ ug/g/h	$\varepsilon_{\Lambda_{c,mtp}}$ ug/g/h
EMEP/EECCA-domain ecosystems:																
temp_conif	CF	ECF	CF	20	0	0	366	0	5	5	1	1	1000	(1.7)	(0.85)	(2)
temp_decid	DF	EDF	DF	20	100	1.5	307	-2	0	4	20	30	320	(26)	(3.4)	(2)
med_needle	NF	ECF	NF	8	0	0	366	0	4	4	1	1	500	(6.8)	(0.3)	(4)
med_broadleaf	BF	EDF	BF	15	0	0	366	0	4	4	1	1	300	(0.2)	(17)	(0.2)
temp_crop	TC	ECR	NOLPJ	1	123	2.57	213	2.57	0	3.5	70	20	700	0.2	0.3	0.2
med_crop	MC	ECR	NOLPJ	2	123	2.57	237	2.57	0	3	70	44	700	0.2	0.3	0.2
root_crop	RC	ECR	NOLPJ	1	130	0	250	0	0	4.2	35	65	700	0.2	0.3	0.2
moorland	SNL	SNL	C3PFT	0.5	0	0	366	0	2	3	192	96	200	8.5	1.7	1
grass	GR	SNL	C3PFT	0.3	0	0	366	0	2	3.5	140	135	400	0.2	0.3	0.2
medscrub	MS	SNL	C4PFT	2	0	0	366	0	2	2	1	1	150	14	0.85	2
wetlands	WE	SNL	NOLPJ	0.5	0	0	366	0	-1	-1	-1	-1	150	3.4	0.85	0.5
tundra	TU	SNL	NOLPJ	0.5	0	0	366	0	-1	-1	-1	-1	200	8.5	0.85	0.5
desert	DE	BLK	NOLPJ	0	0	0	366	0	-1	-1	-1	-1	0	0	0	0
water	W	BLK	NOLPJ	0	0	0	366	0	-1	-1	-1	-1	0	0	0	0
ice	ICE	BLK	NOLPJ	0	0	0	366	0	-1	-1	-1	-1	0	0	0	0
urban	U	BLK	NOLPJ	10	0	0	366	0	-1	-1	-1	-1	50	0	0	0
Global (non-Euro-domain) ecosystems:																
NDLF_EVGN_TMPT_TREE	†	ECF	CF	17	0	0	366	0	4	5	1	1	1000	8	1.2	1.2
NDLF_EVGN_BORL_TREE	†	ECF	CF	17	0	0	366	0	4.5	4.5	1	1	700	8	1.2	1.2
NDLF_DECD_BORL_TREE	†	EDF	DF	14	100	1.5	307	-2	0	4.5	20	30	400	8	1.2	1.2
BDLF_EVGN_TROP_TREE	†	EDF	BF	35	100	1.5	307	-2	5	5	20	30	500	24	1.2	1.2
BDLF_EVGN_TMPT_TREE	†	EDF	BF	35	100	1.5	307	-2	5	5	20	30	375	24	1.2	1.2
BDLF_DECD_TROP_TREE	†	EDF	DF	18	100	1.5	307	-2	0	4	20	30	400	24	1.2	1.2
BDLF_DECD_TMPT_TREE	†	EDF	DF	20	100	1.5	307	-2	0	4.5	20	30	375	45	1.2	1.2
BDLF_DECD_BORL_TREE	†	EDF	DF	20	100	1.5	307	-2	0	4.5	20	30	375	45	1.2	1.2
BDLF_EVGN_SHRB	†	NOLPJ	0.5	0	0	366	0	0	3	192	96	200	16	1.2	1.2	
BDLF_DECD_TMPT_SHRB	†	SNL	C3PFT	0.5	0	0	366	0	0	2.5	192	96	200	16	1.2	1.2
BDLF_DECD_BORL_SHRB	†	SNL	C3PFT	0.5	0	0	366	0	0	3	192	96	200	16	1.2	1.2
C3_ARCT_GRSS	†	SNL	C3PFT	0.3	0	0	366	0	0	3.5	140	135	300	5	0.1	0.1
C3_NARC_GRSS	†	SNL	C3PFT	0.3	0	0	366	0	0	3.5	140	135	300	5	0.1	0.1
C4_GRSS	†	SNL	C4PFT	0.3	0	0	366	0	1	3	140	135	300	5	0.4	0.4
CROP	†	SNL	C3PFT	0.3	0	0	366	0	0	3	140	135	400	1	0.1	0.1
BARE	†	BLK	NOLPJ	0	0	0	366	0	-1	-1	-1	-1	0	0	0	0
IAM ecosystems:																
IAM_WH	†	ECR	NOLPJ	1	123	2.57	213	2.57	3.5	3.5	1	1	0	0	0	0
IAM_WH_MED	†	ECR	NOLPJ	1	123	2.57	213	2.57	3.5	3.5	1	1	0	0	0	0
IAM_WH_Irrig	†	ECR	NOLPJ	1	123	2.57	213	2.57	3.5	3.5	1	1	0	0	0	0
IAM_WH_MED_Irrig	†	ECR	NOLPJ	1	123	2.57	213	2.57	3.5	3.5	1	1	0	0	0	
IAM_DF	†	EDF	NOLPJ	20	105	1.5	297	-2	0	4	15	30	0	0	0	0
IAM_DF_MED	†	EDF	NOLPJ	20	105	1.5	297	-2	4	4	15	30	0	0	0	0
IAM_SNL	†	SNL	C3PFT	0.2	91	0	273	0	2.5	2.5	1	1	0	0	0	0
IAM_SNL_MED	†	SNL	C3PFT	0.2	32	0	181	0	2	2	1	1	0	0	0	0

Notes: † Codes are identical to name for these land-cover categories; BVOC parameters given for forests in parentheses are only used when gridded species-specific rates cannot be calculated (typically non-European areas) - see Simpson et al. (2012).

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CHAPTER 9

Developments in the monitoring network, data quality and database infrastructure

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9.1 Compliance with the EMEP monitoring strategy

The monitoring obligations of EMEP were updated in 2019 and are defined by the Monitoring Strategy for 2020-2030 (UNECE (2019)).

The complexity in the monitoring program with respect to the number of variables and sites, whether parameters are at 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 per 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 9.1 summarises implementation in 2020 compared to 2000, 2005 and 2010. The countries are sorted from left to right with increasing index for 2020. Slovakia, Estonia, The Netherlands, Denmark, and Switzerland have almost complete programs with an index of 90% or higher. Small countries generally comply better (due to more easily satisfying the site density requirements). Since 2010, 35% of the Parties have improved their monitoring

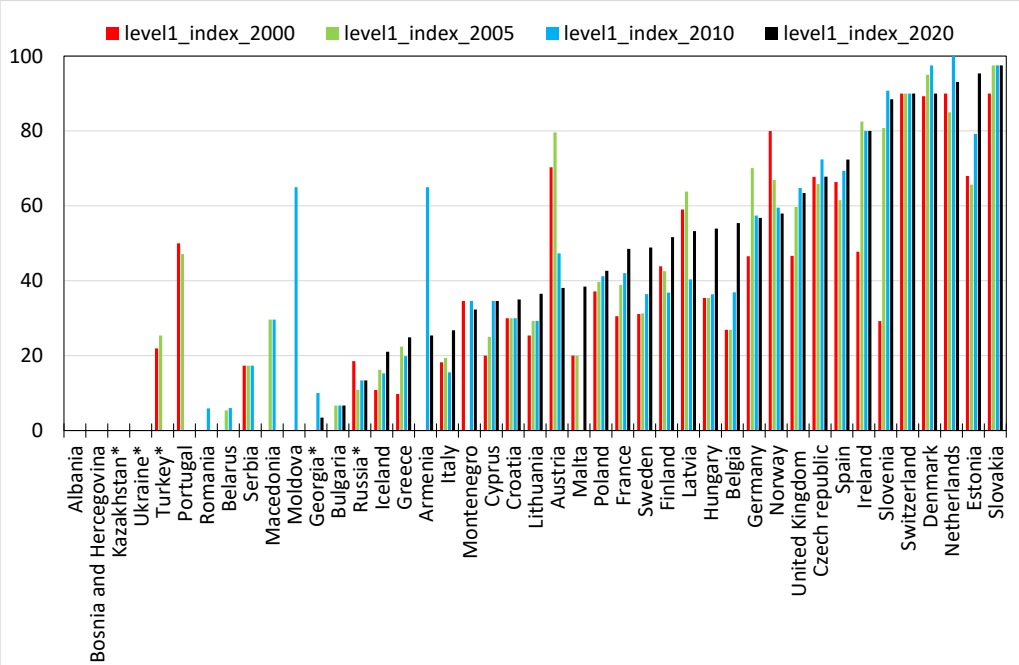


Figure 9.1: Index for implementation of the EMEP monitoring strategy, level 1 based on what has been reported for 2000, 2005, 2010 and 2019. * means adjusted land area.

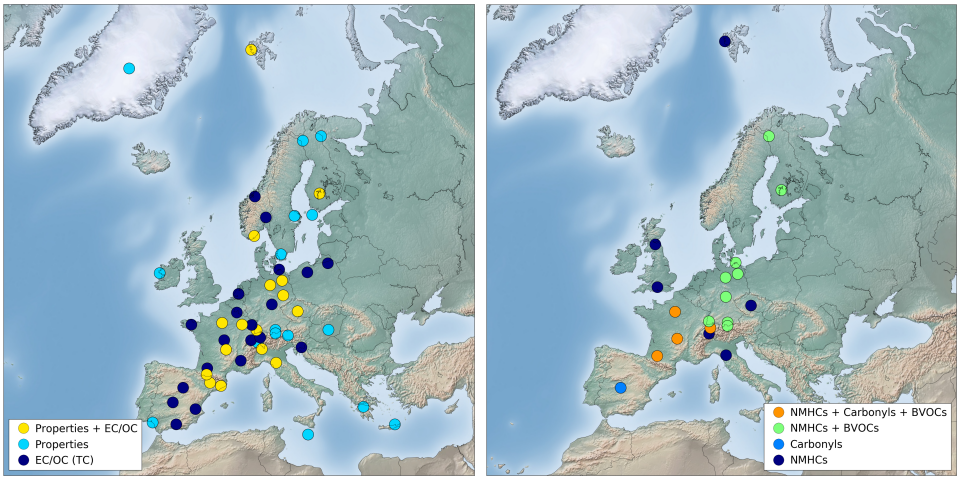
programme, while 37% have a decrease. Improvements are seen in e.g. Estonia, Finland, Italy and Hungary. One Party, Malta, has reported data in 2020 and not in 2010, while Belarus, Macedonia, Moldova, Romania and Serbia did not report data in 2020 but in 2010. In addition Albania, Bosnia and Herzegovina, Kazakhstan, Portugal, Turkey and Ukraine have not been reporting data for many years. In Figure 2.4 in Ch 2.2, the geographical distribution of level 1 sites is shown for 2020. In large parts of Eastern 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. 57 sites from 18 different Parties reported at least one of the required aerosol component, 20 sites from 9 Parties measured volatile organic compounds(VOC), though only four sites with both hydrocarbons and carbonyls.

One should note that some of these level 2 sites have been reporting data to ACTRIS (the European Research Infrastructure for the observation of Aerosol, Clouds and Trace Gases) and/or to the WMO Global Atmospheric Watch Programme (GAW) and not to EMEP. They have been included here in the overview since these 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 2/2022).

Figure 9.2 shows that level 2 measurements of aerosols have better spatial coverage than VOCs. For aerosols, mineral dust is also a required level 2 component, 19 sites reported Si, Al or Fe, which are used as tracers for mineral dust. Further, 7 sites reported measurements of organic and inorganic composition in non-refractory aerosols to EMEP and/or ACTRIS in

2020. In addition to various VOCs other oxidant precursors and gaseous short-lived climate pollutants are included as level 2 components in EMEP, i.e. methane and carbon monoxide. Data from 3 and 8 sites have reported respectively methane and carbon monoxide data to EMEP in 2020. However, there are much more measurement of these components conducted in Europe and data are available from ICOS, the European Integrated Carbon Observation System.



(a) Particulate matter (b) VOCs

Figure 9.2: Sites measuring and reporting EMEP level 2 parameters for the year 2020.

Even though VOCs together with NOx are critical components in ozone formation, the EMEP VOC network is not targeted specifically to study ozone episodes. It is particularly challenging that only a very few sites are measuring oxygenated VOCs (O-VOCs), and there is a need for more observations of aldehydes, and especially formaldehyde. Terpenes (i.e. α-pinene and limonene) has traditionally not been part of the EMEP VOC programme (but in GAW) and only one site has reported these compounds to EMEP the later years. Terpenes are especially important precursors for secondary organic aerosols (SOAs). Furthermore, the current monitoring of carbonyls includes only 1-2 samples per week. The Task Force of Measurement and Modelling (TFMM) has therefore conducted an intensive measurement period (IMP) during the summer of 2022 (and possibly in 2023) on high ozone episodes in Europe, focusing on widening and complementing existing VOC measurements to improve current understanding of these episodes as the primary goal. A secondary goal of the IMP is to assess the formation of SOA during these episodes, and that focus will be on biogenic SOA (BSOA), addressed by organic tracer analysis. For the summer 2022 around 30 sites across Europe are participating in the IMP. Results from this IMP will be presented at TFMM and in the report next year.

9.2 Development in data reporting and access

Figure 9.3 shows the status of the submission of data for 2020 and to what extent the data were reported in time. Of the 33 Parties reporting level1 and/or level2 data, about 67% reported within the deadline of 31 July 2021. Only 2 Parties reported very late. 10 Parties have not

reported data as also indicated in the discussion above regarding the implementation of the monitoring Strategy.

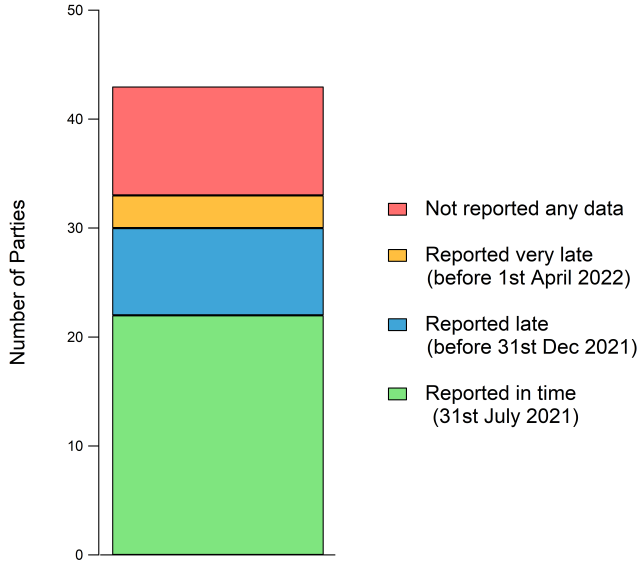


Figure 9.3: Submission of 2020 data to EMEP/CCC.

The time from reporting to available data in EBAS is usually 2-3 months depending on the quality of the data and the correctness of the data files submitted. Most of the Parties are now using the online data submission and validation tool (http://ebas-submit-tool.nilu.no) which has significantly improved the quality and timeliness of the reporting, though there are still a need for improvements for some Parties.

The EMEP data are extensively used. Figure 9.4 shows the access requests for EMEP data per year (about 250 thousand annual datasets in 2021). The number of accessed datasets include the sum of downloaded, displayed and plotted data. 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. The number of downloads decreased somewhat in 2021 compared to 2020.

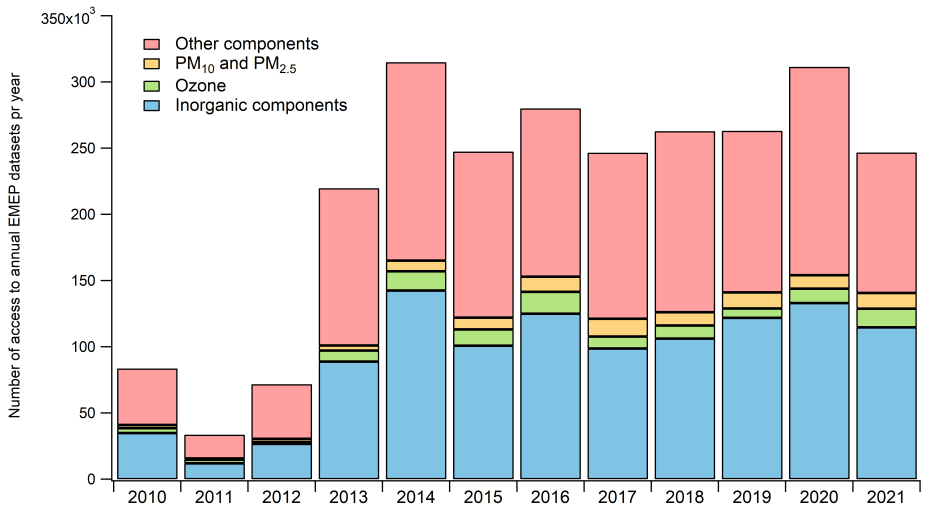


Figure 9.4: Access of EMEP data, number of annual dataset (compounds) per year.

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Part IV

Appendices

APPENDIX A

National emissions for 2020 in the EMEP domain

This appendix contains the national emission data for 2020 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 2020 source-receptor calculations. Results of these source-receptor calculations are presented in Appendix C.

The land-based emissions for 2020 have been derived from the 2022 official data submissions to UNECE CLRTAP (Schindlbacher et al. 2022). This year, two different estimates for primary PM emissions have been available for the modeling: 1) EMEP emissions as prepared by CEIP based on the official data submissions for 2020, 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 v2.1 dataset (Simpson et al. 2022, Kuenen et al. 2022) for the following countries: Albania, Armenia, Austria, Azerbaijan, Bosnia and Herzegovina, Belarus, Switzerland, Germany, Estonia, France, Georgia, Lithuania, Luxembourg, Montenegro, Malta, Netherlands, Romania, Russian Federation, Turkey and Ukraine.

In this report (1) is referred to as EMEP and (2) is referred to as EMEPwRef2_v2.1C. 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 sulfide (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 2020 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	26	20	35	76
Armenia	6	40	15	20	56
Austria	11	124	65	111	475
Azerbaijan	77	300	80	345	584
Belarus	68	178	114	168	416
Belgium	24	135	68	113	266
Bosnia and Herzegovina	42	46	22	95	228
Bulgaria	70	92	43	73	250
Croatia	6	46	32	70	217
Cyprus	12	12	8	7	9
Czechia	67	154	68	199	796
Denmark	9	89	76	107	192
Estonia	11	24	9	24	138
Finland	23	105	31	85	317
France	91	660	573	939	2162
Georgia	24	47	34	34	104
Germany	233	979	537	1036	2452
Greece	62	222	64	132	426
Hungary	16	107	75	112	339
Iceland	51	19	4	5	105
Ireland	11	95	123	113	122
Italy	82	571	363	885	1873
Kazakhstan	2149	646	109	535	1178
Kyrgyzstan	33	56	33	33	150
Latvia	4	32	16	34	101
Liechtenstein	0	0	0	0	0
Lithuania	11	54	38	47	107
Luxembourg	1	16	6	11	17
Malta	0	5	1	3	6
Moldova	4	31	19	58	127
Monaco	0	0	0	0	1
Montenegro	66	7	3	17	45
Netherlands	20	211	124	272	456
North Macedonia	93	20	8	22	50
Norway	16	148	29	153	415
Poland	432	594	321	671	2199
Portugal	38	135	63	160	262
Romania	71	204	157	239	914
Russian Federation	1288	3107	1252	3785	11764
Serbia	418	179	83	138	450
Slovakia	13	56	27	92	279
Slovenia	4	25	18	30	87
Spain	117	633	480	551	1432
Sweden	15	118	53	133	287
Switzerland	4	53	53	76	152
Tajikistan	43	48	34	85	520
Turkey	2169	904	904	1133	1853
Turkmenistan	115	256	74	185	892
Ukraine	350	579	247	362	2747
United Kingdom	136	697	259	784	1248
Uzbekistan	332	334	202	313	1160
Asian areas	5413	6806	3379	9588	34541
North Africa	1154	1188	382	1503	3041
Baltic Sea	9	262	0	3	24
Black Sea	13	83	0	1	7
Mediterranean Sea	145	1088	0	11	85
North Sea	23	607	0	7	63
North-East Atlantic Ocean	91	667	0	7	58
Natural marine emissions	3003	0	0	0	0
Volcanic emissions	943	0	0	0	0
TOTAL	19738	23921	10801	25747	78318

Table A:2: National total emissions of particulate matter for 2020 in the EMEP domain. Unit: Gg.

Area/Pollutant	BC	$PM_{2.5}$ EMEP	PM_{co} EMEP	PM_{10} EMEP	$PM_{2.5}$ EMEPwRef2_v2.1C	PM_{co} EMEPwRef2_v2.1C	PM_{10} EMEPwRef2_v2.1C
Albania	2	13	3	16	10	2	12
Armenia	1	7	2	9	6	2	8
Austria	4	13	12	25	24	12	36
Azerbaijan	9	39	10	49	34	9	43
Belarus	8	56	17	73	62	17	79
Belgium	2	17	9	26	17	9	26
Bosnia and Herzegovina	6	42	8	50	50	8	58
Bulgaria	6	32	13	45	32	13	45
Croatia	4	28	23	51	28	23	51
Cyprus	0	1	1	2	1	1	2
Czechia	4	32	10	42	32	10	42
Denmark	2	12	10	23	12	10	23
Estonia	2	6	3	9	10	3	13
Finland	3	14	13	27	14	13	27
France	19	113	74	187	163	76	239
Georgia	6	23	4	27	19	8	27
Germany	10	81	99	180	101	99	201
Greece	8	35	24	59	35	24	59
Hungary	6	37	20	57	37	20	57
Iceland	0	1	1	2	1	1	2
Ireland	2	12	16	28	12	16	28
Italy	16	138	37	175	138	37	175
Kazakhstan	13	127	69	197	127	69	197
Kyrgyzstan	1	13	5	18	13	5	18
Latvia	2	17	9	26	17	9	26
Liechtenstein	0	0	0	0	0	0	0
Lithuania	2	7	11	18	13	12	25
Luxembourg	0	1	1	2	1	1	2
Malta	0	0	1	2	0	1	2
Moldova	3	20	5	25	20	5	25
Monaco	0	0	0	0	0	0	0
Montenegro	1	7	1	8	7	1	8
Netherlands	2	14	13	27	15	13	28
North Macedonia	1	9	5	13	9	5	13
Norway	3	25	8	33	25	8	33
Poland	17	255	86	340	255	86	340
Portugal	6	47	14	61	47	14	61
Romania	13	112	41	152	105	41	146
Russian Federation	40	291	424	715	413	431	844
Serbia	10	65	17	82	65	17	82
Slovakia	2	17	6	24	17	6	24
Slovenia	2	10	4	14	10	4	14
Spain	41	120	58	179	120	58	179
Sweden	2	17	18	35	17	18	35
Switzerland	1	6	8	14	7	8	14
Tajikistan	5	32	9	41	32	9	41
Turkey	30	391	171	563	378	180	558
Turkmenistan	4	27	8	35	27	8	35
Ukraine	24	274	127	401	325	127	452
United Kingdom	16	80	56	136	80	56	136
Uzbekistan	9	66	19	85	66	19	85
Asian areas	270	1379	906	2285	1379	906	2285
North Africa	270	158	115	273	158	115	273
Baltic Sea	2	4	0	4	4	0	4
Black Sea	1	2	0	2	2	0	2
Mediterranean Sea	9	23	0	23	23	0	23
North Sea	4	10	0	10	10	0	10
North-East Atlantic Ocean	6	14	0	14	14	0	14
Natural marine emissions	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0
TOTAL	928	4393	2628	7021	4639	2649	7288

APPENDIX B

National emission trends

This appendix contains trends of national emission data for main pollutants and primary particle emissions for the years 1990–2020 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 1999–2020 have been derived from the 2022 official data submissions to UNECE CLRTAP (Schindlbacher et al. 2022). For primary PM in years 2005-2020, two different sets of emissions have been available: 1) EMEP emissions as prepared by CEIP based on the official data submissions for 2005-2020, 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 v2.1 emission dataset (Simpson et al. 2022, Kuenen et al. 2022) for the following countries: Albania, Armenia, Austria, Azerbaijan, Bosnia and Herzegovina, Belarus, Switzerland, Germany, Estonia, France, Georgia, Lithuania, Luxembourg, Montenegro, Malta, Netherlands, Romania, Russian Federation, Turkey and Ukraine. In this report 1) is referred to as EMEP and 2) is referred to as EMEP-wRef2_v2.1C. Please note that this year's trend calculations are based only on 2) EMEP-wRef2_v2.1C emissions, which are also used in the status run (Ch 2 and in source-receptor calculations (Appendix C). These are the emissions which are shown in the emission tables in this appendix.

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 2020, developed by the Finish Meteorological Institute using AIS (Automatic Identification System) tracking data. Shipping emissions from 1990 to 1999 were estimated using the trend for global shipping from EDGAR v.4.3.2[1].

Natural marine emissions of dimethyl sulfide (DMS) are calculated dynamically during

[1] https://edgar.jrc.ec.europa.eu

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 2000-2020 (Eyjafjallajökull in 2010, Grímsvötn in 2011 and Barðarbunga in 2014-2015) are reported by Iceland.

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 (1990-1999), as used for modelling at the MSC-W (Gg of SO_2 per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	69	58	46	35	23	12	11	11	10	9
Armenia	40	33	26	19	12	5	4	4	3	2
Austria	74	71	54	53	47	47	44	40	36	34
Azerbaijan	181	188	195	201	208	215	215	215	214	214
Belarus	762	673	583	494	404	315	286	256	227	198
Belgium	365	366	357	332	290	258	248	226	212	173
Bosnia and Herzegovina	493	405	316	228	140	51	79	107	135	163
Bulgaria	1448	1239	1113	1542	1718	1688	1639	1591	1454	1096
Croatia	171	100	105	112	100	77	62	77	95	95
Cyprus	32	33	38	40	42	40	42	44	47	50
Czechia	1755	1650	1382	1303	1159	1059	914	694	425	232
Denmark	178	239	184	149	151	145	176	104	81	60
Estonia	277	251	192	156	151	116	124	118	106	99
Finland	249	206	156	138	123	105	109	101	93	92
France	1287	1378	1227	1068	995	938	923	781	813	716
Georgia	276	235	195	154	113	73	60	48	36	24
Germany	5460	3964	3237	2902	2416	1742	1475	1225	977	798
Greece	507	502	517	508	524	517	514	546	571	556
Hungary	829	832	715	719	629	613	612	625	565	557
Iceland	23	22	25	24	23	22	24	24	23	30
Ireland	183	183	171	162	177	163	150	169	180	161
Italy	1784	1672	1574	1471	1389	1322	1214	1138	1004	903
Kazakhstan	2500	2369	2239	2108	1977	1846	1777	1708	1638	1569
Kyrgyzstan	145	119	94	69	43	18	19	21	22	23
Latvia	100	82	70	66	67	49	56	44	40	32
Lithuania	202	225	112	104	102	77	76	70	86	64
Luxembourg	16	17	16	17	16	9	9	6	3	3
Malta	13	11	11	15	13	10	10	10	10	11
Moldova	149	124	104	72	57	31	32	16	12	6
Montenegro	45	46	38	35	28	3	40	37	49	48
Netherlands	197	183	173	162	149	136	124	110	101	94
North Macedonia	112	91	88	91	90	97	91	95	109	99
Norway	49	42	37	35	35	34	34	31	30	29
Poland	2679	2613	2312	2273	2163	2097	2140	1939	1749	1567
Portugal	318	308	367	310	288	322	263	275	322	331
Romania	819	700	697	700	665	696	699	614	494	475
Russian Federation	5700	5160	4620	4080	3539	2999	2916	2833	2750	2667
Serbia	577	510	492	459	420	500	502	542	550	419
Slovakia	140	135	132	126	123	120	118	117	118	115
Slovenia	203	188	194	191	185	125	116	120	110	96
Spain	2051	2074	2056	1955	1905	1768	1556	1623	1495	1509
Sweden	103	101	94	84	82	71	69	60	57	47
Switzerland	37	36	34	29	26	26	25	21	22	19
Tajikistan	64	63	45	34	24	20	14	14	13	11
Turkey	1686	1776	1814	1685	1726	1809	1938	2108	2187	2098
Turkmenistan	82	70	72	45	45	37	36	34	37	41
Ukraine	4852	4387	3921	3456	2991	2525	2313	2100	1888	1676
United Kingdom	3574	3506	3414	3102	2820	2535	2155	1756	1754	1353
Uzbekistan	542	509	480	471	436	403	392	377	356	336
Asian areas	2279	2525	2772	3019	3266	3513	3317	3120	2924	2727
North Africa	757	761	766	771	775	780	770	760	751	741
Baltic Sea	144	150	162	158	162	168	171	175	180	189
Black Sea	37	38	41	40	41	43	43	45	46	48
Mediterranean Sea	660	688	740	722	741	766	782	801	824	864
North Sea	282	293	316	308	316	327	334	342	351	369
North-East Atlantic Ocean	438	456	491	479	492	508	519	531	546	573
Natural marine emissions	2899	2926	3042	2980	2969	2921	2898	2917	2880	2949
Volcanic emissions	8327	5119	6736	6226	5614	5266	5889	6739	6363	6000
TOTAL	59221	52704	51196	48286	45229	42180	41165	40255	38179	35464

Table B:2: 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	9	10	12	13	14	16	14	12	10	9
Armenia	1	1	1	1	1	1	2	2	2	2
Austria	32	32	31	31	27	26	27	23	20	15
Azerbaijan	214	194	173	153	133	112	97	82	67	53
Belarus	169	151	133	116	98	80	80	79	78	78
Belgium	171	165	157	152	155	143	134	123	95	74
Bosnia and Herzegovina	192	198	205	211	218	225	235	245	256	266
Bulgaria	1114	1046	940	1023	974	961	950	1040	727	571
Croatia	60	59	63	64	52	59	55	60	54	56
Cyprus	48	45	45	47	40	38	31	29	22	18
Czechia	234	229	223	218	215	208	207	212	170	169
Denmark	33	30	28	35	29	26	31	28	21	16
Estonia	98	92	87	100	89	77	70	88	69	55
Finland	82	96	90	101	84	70	83	81	67	59
France	616	560	516	498	476	458	425	404	346	292
Georgia	11	10	9	7	6	5	5	6	6	6
Germany	643	622	559	531	491	473	474	457	450	393
Greece	553	567	552	560	561	579	537	522	450	392
Hungary	427	346	272	246	151	43	39	36	36	30
Iceland	35	39	41	38	33	40	40	59	74	69
Ireland	144	142	107	83	73	73	61	55	46	33
Italy	756	705	623	526	489	411	389	348	294	241
Kazakhstan	1499	1565	1631	1696	1762	1828	1908	1989	2070	2150
Kyrgyzstan	25	25	25	25	25	26	28	31	33	36
Latvia	18	14	13	11	9	9	8	8	7	7
Lithuania	39	43	37	24	25	28	26	22	20	19
Luxembourg	4	4	3	3	3	3	3	2	2	2
Malta	9	11	11	12	12	12	12	13	10	7
Moldova	4	4	4	6	5	5	5	3	5	5
Montenegro	51	38	59	55	52	45	54	39	57	29
Netherlands	78	79	71	67	69	67	68	64	53	40
North Macedonia	106	108	96	95	96	95	93	98	76	103
Norway	27	25	23	23	25	23	21	19	20	15
Poland	1360	1324	1244	1214	1181	1160	1231	1141	913	797
Portugal	295	278	277	185	189	190	165	158	104	72
Romania	492	509	509	588	558	603	648	516	522	443
Russian Federation	2584	2580	2576	2572	2568	2564	2427	2290	2153	2016
Serbia	464	459	484	509	519	444	461	470	480	433
Slovakia	117	123	99	102	93	86	85	69	68	63
Slovenia	93	63	63	60	50	40	17	14	12	10
Spain	1388	1330	1474	1221	1252	1207	1076	1046	384	286
Sweden	45	42	42	42	38	36	36	32	29	27
Switzerland	16	17	15	15	15	14	13	12	12	10
Tajikistan	9	12	14	14	17	18	23	35	39	44
Turkey	2242	1982	1872	1791	1779	2003	2160	2522	2558	2662
Turkmenistan	40	38	39	41	42	44	45	54	60	60
Ukraine	1464	1416	1369	1321	1273	1226	1279	1333	1386	1290
United Kingdom	1292	1222	1098	1068	905	788	742	646	544	447
Uzbekistan	322	319	314	311	306	301	301	284	278	278
Asian areas	2531	2625	2720	2814	2908	3003	3151	3300	3448	3596
North Africa	731	764	796	829	861	894	910	926	942	958
Baltic Sea	204	199	197	195	191	186	125	98	90	87
Black Sea	54	53	53	52	51	50	50	49	45	43
Mediterranean Sea	952	939	917	902	885	866	852	839	763	726
North Sea	391	385	375	366	360	353	259	214	200	193
North-East Atlantic Ocean	598	591	576	565	558	547	538	527	482	460
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	33295	31125	31648	29336	28092	26429	26486	26046	24587	23613

Table B:3: National total emission trends of sulphur (2010-2020), 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	2019	2020
Albania	7	6	6	5	5	4	5	5	6	6	6
Armenia	2	2	2	3	3	3	3	4	5	6	6
Austria	16	15	15	14	15	14	13	13	12	11	11
Azerbaijan	38	43	49	54	59	65	68	72	75	79	77
Belarus	77	73	69	65	61	58	60	63	65	68	68
Belgium	61	53	47	43	41	41	34	32	32	30	24
Bosnia and Herzegovina	277	280	283	286	290	293	243	193	143	93	42
Bulgaria	329	656	329	169	160	137	101	101	85	73	70
Croatia	35	29	24	17	14	16	15	12	10	8	6
Cyprus	22	21	16	14	17	13	16	16	17	16	12
Czechia	164	168	160	145	134	129	115	110	97	80	67
Denmark	15	14	13	13	11	10	10	10	11	9	9
Estonia	83	73	43	42	44	36	35	39	31	19	11
Finland	66	60	50	48	44	41	40	35	33	30	23
France	269	222	219	202	159	152	136	131	123	100	91
Georgia	7	7	7	7	7	7	11	14	18	21	24
Germany	403	387	368	357	335	334	309	301	290	260	233
Greece	230	160	143	122	105	102	81	90	86	80	62
Hungary	30	34	30	29	26	24	23	28	23	17	16
Iceland	74	82	85	70	64	58	49	47	52	56	51
Ireland	27	25	23	23	17	16	15	15	14	11	11
Italy	222	199	179	148	132	126	120	117	109	105	82
Kazakhstan	2231	2213	2195	2177	2159	2141	2158	2175	2192	2210	2149
Kyrgyzstan	38	42	46	49	53	56	52	48	43	39	33
Latvia	4	4	4	4	4	4	3	4	4	4	4
Lithuania	18	19	17	14	13	15	15	13	13	12	11
Luxembourg	2	1	2	2	1	1	1	1	1	1	1
Malta	8	8	8	5	5	2	2	1	0	0	0
Moldova	4	5	4	4	4	4	3	4	4	5	4
Montenegro	52	60	56	59	58	62	54	56	64	62	66
Netherlands	36	35	35	30	30	31	28	27	25	23	20
North Macedonia	86	104	90	81	83	75	64	55	60	115	93
Norway	18	18	17	17	17	17	16	16	17	17	16
Poland	860	808	779	740	692	672	567	559	527	445	432
Portugal	63	57	52	48	44	46	46	47	45	44	38
Romania	356	326	261	210	183	151	101	81	76	91	71
Russian Federation	1878	1857	1775	1733	1719	1715	1804	1498	1411	1368	1288
Serbia	402	457	421	435	343	363	374	371	349	398	418
Slovakia	68	67	57	52	45	67	26	28	20	16	13
Slovenia	10	11	11	10	8	6	5	5	5	4	4
Spain	245	281	284	221	242	260	216	220	199	151	117
Sweden	29	26	26	23	21	18	18	18	17	16	15
Switzerland	10	8	9	8	7	6	5	5	5	4	4
Tajikistan	49	51	20	19	24	32	34	37	39	42	43
Turkey	2557	2623	2734	1955	2151	1942	2247	2354	2518	2525	2169
Turkmenistan	72	76	85	89	87	86	93	100	106	113	115
Ukraine	1216	1320	1339	1422	922	854	948	801	654	508	350
United Kingdom	455	427	461	398	324	262	191	187	174	156	136
Uzbekistan	267	256	274	267	259	248	267	286	306	325	332
Asian areas	3745	3814	3884	3954	4023	4093	4373	4676	4992	5289	5413
North Africa	974	1000	1026	1052	1078	1104	1116	1164	1200	1231	1154
Baltic Sea	80	68	67	66	65	9	14	14	15	10	9
Black Sea	46	45	44	44	42	41	41	44	43	45	13
Mediterranean Sea	732	725	717	702	634	666	669	702	718	710	145
North Sea	176	154	154	151	144	30	38	39	39	32	23
North-East Atlantic Ocean	484	479	474	464	415	429	432	449	453	451	91
Natural marine emissions	2314	2446	2368	2434	2250	2454	2390	2394	2440	2926	3003
Volcanic emissions	1070	1243	943	943	11823	2070	943	943	943	943	943
TOTAL	23109	23744	22900	21760	31715	21709	20858	20870	21054	21507	19738

Table B:4: National total emission trends of nitrogen oxides (1990-1999), as used for modelling at the MSC-W (Gg of NO_2 per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	20	18	17	16	15	14	15	16	17	18
Armenia	88	74	60	45	31	16	16	17	17	17
Austria	219	228	217	208	200	199	217	203	215	207
Azerbaijan	186	171	157	142	128	113	110	108	105	102
Belarus	422	386	351	315	280	244	240	236	231	227
Belgium	423	422	424	419	418	412	397	383	384	358
Bosnia and Herzegovina	71	60	49	38	28	17	21	25	29	33
Bulgaria	299	226	199	205	200	207	203	170	173	156
Croatia	106	80	75	75	77	79	84	87	89	93
Cyprus	18	18	20	21	21	21	21	22	22	22
Czechia	758	719	675	550	457	389	372	344	326	302
Denmark	297	347	303	302	305	286	319	273	253	234
Estonia	73	65	44	40	45	47	52	52	49	45
Finland	307	304	288	293	294	273	277	272	257	253
France	2088	2142	2108	2011	1944	1899	1859	1792	1828	1790
Georgia	91	72	59	51	39	37	34	30	28	28
Germany	2835	2614	2468	2368	2241	2184	2102	2029	2001	1967
Greece	409	409	416	407	415	402	409	424	450	444
Hungary	246	216	194	194	193	191	194	197	197	201
Iceland	30	29	31	33	32	34	34	34	33	33
Ireland	169	172	180	173	173	171	175	169	179	180
Italy	2124	2191	2230	2127	2027	1989	1916	1838	1724	1626
Kazakhstan	1158	724	673	588	503	579	439	408	383	324
Kyrgyzstan	136	115	94	73	52	30	30	30	29	29
Latvia	97	93	76	66	56	51	51	49	45	44
Lithuania	151	159	98	76	68	73	76	81	82	70
Luxembourg	41	47	47	44	41	35	35	35	35	37
Malta	8	8	9	10	11	10	10	11	11	10
Moldova	112	93	69	53	42	36	34	31	27	20
Montenegro	1	1	1	1	1	1	1	1	1	1
Netherlands	669	658	644	627	585	570	558	530	510	502
North Macedonia	45	38	39	41	37	39	39	38	43	40
Norway	197	191	195	201	205	216	226	234	235	228
Poland	1128	1117	1119	1125	1109	1087	1117	1058	963	932
Portugal	260	274	296	286	285	297	279	281	294	306
Romania	474	400	412	372	373	375	421	402	354	306
Russian Federation	5985	5611	5238	4864	4490	4116	4021	3925	3830	3734
Serbia	186	171	160	133	140	155	161	172	172	135
Slovakia	136	120	112	110	111	112	112	112	112	108
Slovenia	75	70	69	74	76	76	78	78	69	61
Spain	1326	1368	1388	1325	1331	1338	1323	1342	1338	1342
Sweden	289	293	279	266	269	258	253	241	232	225
Switzerland	145	141	135	123	120	116	110	106	106	105
Tajikistan	35	32	27	19	12	10	9	10	10	9
Turkey	552	581	618	626	656	691	713	731	743	731
Turkmenistan	176	137	117	109	120	114	108	108	115	134
Ukraine	2358	2155	1952	1750	1547	1344	1276	1207	1138	1069
United Kingdom	3100	3018	2972	2832	2777	2644	2560	2385	2303	2186
Uzbekistan	411	418	409	391	351	324	352	370	385	387
Asian areas	2010	2146	2281	2416	2551	2687	2746	2806	2866	2926
North Africa	562	582	601	620	639	659	678	696	715	734
Baltic Sea	267	279	300	292	300	310	317	324	334	350
Black Sea	74	77	83	81	83	86	88	90	92	97
Mediterranean Sea	1163	1212	1303	1272	1305	1349	1377	1410	1451	1522
North Sea	638	665	715	698	716	740	755	774	796	835
North-East Atlantic Ocean	777	809	870	849	872	901	920	942	969	1017
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	36026	34772	33969	32449	31401	30658	30341	29740	29396	28892

Table B:5: 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	19	22	25	27	30	33	32	32	31	31
Armenia	17	17	18	18	19	19	21	24	26	28
Austria	213	223	231	242	242	248	238	231	218	204
Azerbaijan	99	105	110	116	121	127	130	133	136	139
Belarus	223	223	224	224	224	225	226	228	230	231
Belgium	359	347	335	331	341	326	310	300	273	242
Bosnia and Herzegovina	37	42	47	52	56	61	64	66	69	72
Bulgaria	164	162	176	186	184	188	165	163	163	154
Croatia	88	88	91	90	88	86	86	88	85	77
Cyprus	23	23	22	23	22	22	22	21	20	20
Czechia	310	307	300	303	303	300	292	290	272	256
Denmark	221	218	216	225	210	202	201	188	172	153
Estonia	45	49	48	49	46	43	41	45	43	37
Finland	241	244	242	249	237	208	224	211	194	176
France	1730	1690	1650	1595	1551	1500	1411	1345	1262	1184
Georgia	28	24	24	25	25	27	29	33	30	34
Germany	1891	1835	1774	1728	1681	1632	1641	1591	1528	1433
Greece	430	456	451	461	464	483	483	481	455	435
Hungary	189	189	181	185	183	179	172	168	162	151
Iceland	32	29	31	31	32	28	27	30	28	27
Ireland	182	181	174	173	175	176	172	168	152	128
Italy	1504	1475	1418	1397	1348	1289	1238	1171	1052	965
Kazakhstan	405	374	397	431	478	562	525	532	503	517
Kyrgyzstan	28	29	30	31	32	33	38	43	48	52
Latvia	42	45	44	46	46	45	47	47	43	40
Lithuania	61	62	63	61	61	64	63	64	63	54
Luxembourg	41	43	44	46	55	57	51	46	43	39
Malta	10	9	9	9	9	10	10	10	10	9
Moldova	19	20	22	23	26	26	24	24	26	26
Montenegro	1	3	4	6	7	9	9	10	10	10
Netherlands	484	472	456	453	437	430	425	408	398	360
North Macedonia	44	41	41	36	37	35	35	37	34	35
Norway	215	213	208	210	208	209	209	213	206	196
Poland	874	848	813	821	836	862	874	866	838	822
Portugal	301	298	303	279	282	283	262	251	233	221
Romania	316	329	335	341	343	331	328	309	303	255
Russian Federation	3639	3611	3583	3556	3528	3500	3388	3275	3163	3051
Serbia	149	154	164	168	183	168	170	177	174	164
Slovakia	110	112	105	103	103	106	99	99	100	90
Slovenia	59	60	59	56	54	55	55	54	58	49
Spain	1349	1317	1341	1351	1367	1343	1313	1314	1121	1004
Sweden	222	212	205	201	197	194	192	187	179	166
Switzerland	103	100	95	94	93	94	92	91	91	86
Tajikistan	8	9	9	9	10	11	12	12	12	12
Turkey	759	731	704	711	722	771	795	854	853	890
Turkmenistan	141	140	147	160	169	177	176	183	185	188
Ukraine	1000	996	993	990	986	983	957	931	905	878
United Kingdom	2098	2042	1942	1904	1841	1817	1749	1670	1496	1304
Uzbekistan	400	401	393	380	370	361	357	345	340	333
Asian areas	2986	3153	3321	3488	3656	3823	3952	4080	4208	4336
North Africa	752	778	804	830	856	881	900	918	936	955
Baltic Sea	373	366	362	358	353	346	341	338	310	296
Black Sea	112	111	110	108	107	105	104	102	96	92
Mediterranean Sea	1689	1664	1631	1609	1584	1557	1533	1512	1386	1311
North Sea	877	865	847	830	820	806	795	779	726	695
North-East Atlantic Ocean	1060	1047	1024	1008	996	978	963	946	867	820
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	28774	28606	28399	28433	28434	28433	28065	27736	26565	25530

Table B:6: National total emission trends of nitrogen oxides (2010-2020), 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	2019	2020
Albania	30	30	30	30	30	30	30	29	29	28	26
Armenia	30	32	34	36	38	40	40	41	42	42	40
Austria	205	196	191	190	182	179	172	163	152	145	124
Azerbaijan	142	150	158	165	173	181	209	238	266	294	300
Belarus	233	230	228	225	223	220	213	205	198	190	178
Belgium	244	227	215	206	196	197	185	174	168	156	135
Bosnia and Herzegovina	74	73	71	69	68	66	62	59	55	51	46
Bulgaria	139	158	130	115	120	119	114	104	100	96	92
Croatia	69	66	58	57	54	54	54	55	50	49	46
Cyprus	19	21	21	15	16	14	14	14	13	14	12
Czechia	253	239	227	215	209	204	195	191	184	171	154
Denmark	148	139	128	123	114	112	112	110	104	97	89
Estonia	42	41	38	37	35	31	32	32	31	26	24
Finland	187	171	161	159	151	139	135	130	127	120	105
France	1150	1094	1071	1050	976	956	906	874	816	779	660
Georgia	36	38	39	41	47	49	49	47	53	48	47
Germany	1446	1420	1412	1412	1367	1345	1317	1267	1183	1109	979
Greece	364	326	285	274	269	263	262	268	259	250	222
Hungary	148	138	132	128	126	128	120	121	120	115	107
Iceland	26	23	23	22	22	23	21	21	22	21	19
Ireland	121	108	110	112	111	113	113	111	111	103	95
Italy	935	896	847	776	753	716	701	658	659	639	571
Kazakhstan	629	635	670	682	732	728	736	771	803	682	646
Kyrgyzstan	57	61	65	68	72	76	73	69	66	62	56
Latvia	41	39	39	38	38	37	35	35	36	35	32
Lithuania	57	56	56	53	56	57	57	56	57	56	54
Luxembourg	39	40	37	34	32	28	26	23	21	20	16
Malta	10	9	10	8	8	7	6	5	5	5	5
Moldova	28	30	28	29	30	29	32	34	36	36	31
Montenegro	11	10	10	9	9	8	8	8	8	8	7
Netherlands	355	341	322	311	286	284	268	257	250	235	211
North Macedonia	36	39	36	29	26	25	25	23	23	23	20
Norway	200	198	195	191	190	181	173	168	165	158	148
Poland	838	818	781	741	690	670	675	704	674	628	594
Portugal	204	187	174	170	167	170	163	166	161	155	135
Romania	241	250	246	227	221	220	211	220	222	217	204
Russian Federation	2938	2982	3043	3073	3083	3063	3110	3164	3142	3171	3107
Serbia	151	165	155	155	129	148	189	187	176	172	179
Slovakia	88	81	77	69	66	68	64	63	62	59	56
Slovenia	48	47	46	43	39	35	35	34	33	29	25
Spain	951	949	901	830	825	847	807	810	798	741	633
Sweden	170	164	157	153	150	146	144	138	134	126	118
Switzerland	85	81	81	81	77	73	71	68	64	61	53
Tajikistan	12	12	26	32	41	44	45	47	48	49	48
Turkey	893	910	946	937	968	1004	993	1023	1002	974	904
Turkmenistan	200	206	211	223	226	236	243	250	257	265	256
Ukraine	852	819	786	753	720	687	669	651	633	614	579
United Kingdom	1276	1184	1204	1136	1059	1023	933	898	857	801	697
Uzbekistan	316	323	315	309	309	308	317	327	336	346	334
Asian areas	4465	4602	4738	4874	5011	5147	5499	5881	6277	6651	6806
North Africa	973	1006	1039	1072	1104	1137	1149	1198	1236	1268	1188
Baltic Sea	317	306	301	293	275	274	278	281	285	299	262
Black Sea	96	95	93	90	87	84	83	89	85	90	83
Mediterranean Sea	1410	1382	1366	1328	1180	1242	1189	1229	1241	1281	1088
North Sea	728	709	703	684	626	645	630	635	642	642	607
North-East Atlantic Ocean	883	865	850	824	729	754	728	741	744	773	667
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0	0
TOTAL	25641	25416	25315	25010	24543	24666	24719	25166	25320	25273	23921

Table B:7: National total emission trends of ammonia (1990-1999), as used for modelling at the MSC-W (Gg of NH_3 per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	16	17	17	18	19	19	19	19	18	18
Armenia	11	10	10	10	10	9	9	9	9	9
Austria	69	70	68	68	68	68	67	67	67	66
Azerbaijan	45	44	44	43	42	42	43	44	45	47
Belarus	156	149	142	135	128	121	117	113	109	105
Belgium	105	106	106	106	106	106	104	102	100	97
Bosnia and Herzegovina	22	20	18	16	13	11	12	12	13	14
Bulgaria	106	92	98	69	60	51	52	49	42	45
Croatia	50	50	46	41	40	38	39	41	37	39
Cyprus	8	8	9	9	9	9	9	10	10	10
Czechia	150	140	123	110	99	93	95	92	87	85
Denmark	141	136	132	129	125	117	113	112	112	106
Estonia	20	18	16	11	11	9	8	8	8	7
Finland	36	34	33	33	34	34	35	37	36	39
France	664	664	652	648	642	647	653	648	650	650
Georgia	53	50	44	39	37	40	44	44	41	45
Germany	718	641	640	633	613	613	623	615	624	621
Greece	91	88	86	80	76	80	81	80	80	79
Hungary	136	112	94	84	79	80	80	78	81	82
Iceland	5	5	5	5	5	4	5	5	5	5
Ireland	110	112	115	114	115	116	120	123	128	125
Italy	469	475	463	468	459	454	448	459	459	465
Kazakhstan	151	149	147	145	144	142	129	116	103	90
Kyrgyzstan	31	30	28	27	26	24	24	24	24	24
Latvia	33	32	25	18	16	16	16	15	15	13
Lithuania	80	78	56	43	37	36	36	36	36	33
Luxembourg	6	6	6	6	6	6	6	6	6	6
Malta	2	2	2	2	2	2	2	2	2	2
Moldova	49	46	40	34	33	31	30	26	28	26
Montenegro	6	6	6	6	6	6	6	6	6	6
Netherlands	345	358	295	294	254	218	221	212	196	195
North Macedonia	16	15	15	15	15	15	14	14	13	13
Norway	30	29	30	28	27	28	29	28	29	29
Poland	500	439	416	385	389	381	360	364	372	368
Portugal	77	77	76	75	74	72	74	73	71	74
Romania	325	267	235	231	217	220	220	205	200	189
Russian Federation	2224	2091	1959	1826	1693	1561	1489	1417	1345	1273
Serbia	129	127	114	115	107	118	123	123	118	114
Slovakia	57	50	43	38	39	38	38	41	35	33
Slovenia	24	22	23	22	22	22	21	21	21	21
Spain	459	446	442	419	435	426	466	467	493	494
Sweden	60	58	59	61	62	61	61	62	62	60
Switzerland	69	68	67	66	66	66	64	62	62	62
Tajikistan	32	39	35	30	28	26	25	21	24	21
Turkey	617	638	816	665	633	606	623	603	643	661
Turkmenistan	32	29	28	31	30	29	30	24	34	37
Ukraine	644	602	561	519	477	436	403	370	337	304
United Kingdom	316	315	302	297	302	294	304	309	311	304
Uzbekistan	211	190	178	164	150	136	134	144	130	129
Asian areas	1629	1688	1748	1807	1866	1926	1953	1981	2009	2036
North Africa	229	232	235	238	241	244	253	262	271	280
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	11564	11175	10946	10474	10186	9949	9930	9801	9755	9657

Table B:8: 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	18	17	17	17	17	17	17	17	17	17
Armenia	9	10	10	10	11	11	11	12	12	13
Austria	64	64	63	63	63	63	63	65	64	66
Azerbaijan	50	51	54	58	61	63	66	66	67	69
Belarus	101	100	99	98	97	97	98	100	101	103
Belgium	95	93	90	86	81	80	79	77	74	74
Bosnia and Herzegovina	14	14	15	15	15	16	16	16	17	17
Bulgaria	44	40	40	42	43	42	42	41	41	40
Croatia	39	42	40	41	43	41	40	40	43	34
Cyprus	10	11	11	11	11	10	10	10	10	9
Czechia	82	83	82	81	78	77	76	76	74	70
Denmark	104	101	98	97	96	93	89	88	87	83
Estonia	8	8	8	8	9	9	10	10	10	10
Finland	36	36	37	38	38	39	38	38	37	37
France	661	656	641	632	625	620	611	617	623	615
Georgia	44	46	48	49	47	47	41	37	37	37
Germany	624	628	616	613	596	603	598	606	609	612
Greece	76	76	75	75	77	75	73	74	70	66
Hungary	85	84	85	86	83	79	78	78	71	68
Iceland	5	5	5	4	4	4	5	5	5	5
Ireland	120	120	121	121	118	120	121	115	117	117
Italy	457	456	445	444	439	421	416	418	407	392
Kazakhstan	76	80	84	88	92	96	98	99	101	102
Kyrgyzstan	24	24	25	25	26	26	27	28	28	29
Latvia	14	15	15	15	15	15	15	15	15	16
Lithuania	31	31	34	35	35	37	36	38	36	37
Luxembourg	6	6	6	6	6	6	6	6	6	6
Malta	2	2	2	2	2	2	2	2	2	2
Moldova	24	24	25	24	23	24	24	19	19	20
Montenegro	6	6	6	6	6	4	4	4	4	4
Netherlands	173	166	159	156	156	153	156	152	140	137
North Macedonia	13	13	12	12	12	11	11	11	11	10
Norway	29	29	29	30	30	30	31	31	31	31
Poland	355	344	338	325	315	333	338	344	332	319
Portugal	77	73	71	68	69	64	63	64	62	59
Romania	180	174	178	181	189	195	194	195	193	186
Russian Federation	1201	1199	1196	1194	1192	1190	1158	1127	1096	1064
Serbia	109	105	109	106	113	110	108	110	100	104
Slovakia	33	34	36	34	31	32	29	30	29	28
Slovenia	22	22	23	22	20	21	21	21	20	20
Spain	517	512	501	512	508	477	473	480	437	434
Sweden	60	59	59	59	59	58	57	57	57	54
Switzerland	62	62	61	60	59	60	60	61	60	58
Tajikistan	21	22	26	26	27	27	26	26	29	30
Turkey	646	585	578	602	620	638	650	616	580	582
Turkmenistan	40	49	54	61	65	75	80	77	78	77
Ukraine	271	262	252	243	233	224	227	230	233	236
United Kingdom	298	292	290	284	289	282	277	269	257	258
Uzbekistan	125	129	133	139	147	150	153	162	165	172
Asian areas	2064	2116	2169	2221	2273	2326	2369	2412	2455	2499
North Africa	289	296	304	312	319	327	329	331	332	334
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	9515	9474	9476	9537	9586	9619	9619	9620	9501	9462

Table B:9: National total emission trends of ammonia (2010-2020), 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	2019	2020
Albania	17	17	17	17	17	17	18	19	19	20	20
Armenia	13	13	14	14	14	14	14	15	15	15	15
Austria	66	65	65	65	66	67	68	68	67	66	65
Azerbaijan	70	71	72	73	74	75	76	77	78	79	80
Belarus	104	105	106	107	108	109	110	111	112	113	114
Belgium	75	74	74	73	71	72	72	70	70	68	68
Bosnia and Herzegovina	17	17	18	18	19	19	20	20	21	22	22
Bulgaria	39	39	40	41	42	42	44	43	43	42	43
Croatia	36	37	36	29	28	31	29	32	33	31	32
Cyprus	10	9	9	8	8	7	8	8	8	8	8
Czechia	68	68	68	71	72	79	80	79	74	72	68
Denmark	84	81	79	77	77	78	79	81	80	75	76
Estonia	10	10	10	11	11	11	10	10	10	10	9
Finland	38	36	36	36	36	34	34	33	33	32	31
France	618	608	609	607	611	618	618	614	609	596	573
Georgia	37	37	40	43	37	37	36	34	33	33	34
Germany	614	618	625	632	640	639	635	620	594	575	537
Greece	71	70	68	68	65	64	64	64	63	63	64
Hungary	69	69	68	70	70	74	75	75	74	74	75
Iceland	5	5	5	4	5	5	5	5	5	4	4
Ireland	115	111	117	118	114	120	125	129	135	125	123
Italy	379	379	387	370	357	357	370	364	351	349	363
Kazakhstan	104	105	105	106	106	107	108	108	109	109	109
Kyrgyzstan	30	30	30	31	31	31	31	32	32	32	33
Latvia	15	15	16	16	16	16	16	16	16	16	16
Lithuania	36	35	35	35	37	38	37	37	36	35	38
Luxembourg	6	6	6	6	6	6	6	6	6	6	6
Malta	2	2	2	2	2	2	1	1	1	1	1
Moldova	21	20	18	17	20	18	18	18	19	19	19
Montenegro	4	3	3	3	4	4	4	4	3	3	3
Netherlands	133	132	125	123	126	129	129	132	130	124	124
North Macedonia	11	11	10	10	10	10	10	10	10	9	8
Norway	31	30	30	31	30	30	30	30	31	29	29
Poland	310	308	299	303	299	298	299	313	324	311	321
Portugal	59	59	57	56	58	59	60	60	61	62	63
Romania	169	168	163	165	166	170	165	163	161	160	157
Russian Federation	1033	1056	1085	1088	1105	1151	1168	1194	1196	1246	1252
Serbia	95	96	98	95	90	89	88	88	82	77	83
Slovakia	28	28	28	29	29	28	29	30	30	30	27
Slovenia	20	19	19	19	19	19	19	19	19	18	18
Spain	431	421	418	422	442	450	453	472	471	467	480
Sweden	55	55	54	55	55	55	53	54	54	53	53
Switzerland	58	57	56	56	56	55	55	55	54	54	53
Tajikistan	31	31	31	32	32	33	33	33	34	34	34
Turkey	592	619	682	722	731	707	767	805	802	828	904
Turkmenistan	78	76	74	73	71	71	72	72	73	73	74
Ukraine	239	239	240	241	241	242	243	244	245	246	247
United Kingdom	260	258	255	253	261	263	267	271	270	266	259
Uzbekistan	177	181	185	188	192	194	195	197	199	200	202
Asian areas	2542	2544	2547	2549	2552	2554	2729	2919	3116	3301	3379
North Africa	336	342	348	354	360	366	370	386	398	408	382
Baltic Sea	0	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0	0
TOTAL	9461	9488	9586	9630	9690	9763	10045	10339	10506	10692	10801

Table B:10: National total emission trends of non-methane volatile organic compounds (1990-1990), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	42	42	42	42	42	43	41	39	37	35
Armenia	92	76	60	44	28	12	14	16	19	21
Austria	334	329	305	286	264	248	238	224	216	205
Azerbaijan	226	210	195	179	163	147	141	135	129	123
Belarus	421	388	356	323	291	258	254	250	246	241
Belgium	353	346	346	337	319	311	301	285	276	259
Bosnia and Herzegovina	139	129	119	109	99	89	83	77	70	64
Bulgaria	457	415	420	413	235	158	205	118	122	114
Croatia	172	137	104	102	99	120	122	109	108	107
Cyprus	13	13	13	13	14	14	14	14	13	14
Czechia	566	506	481	448	428	393	391	372	346	330
Denmark	213	221	221	213	215	211	212	200	191	184
Estonia	65	62	42	34	36	40	42	43	39	36
Finland	236	226	220	214	213	205	197	197	193	186
France	2893	2925	2845	2724	2577	2496	2428	2312	2256	2165
Georgia	54	54	51	56	32	39	52	45	39	38
Germany	3892	3380	3066	2884	2469	2342	2244	2190	2133	1971
Greece	317	318	312	312	315	303	309	307	313	315
Hungary	307	270	242	229	215	210	203	193	187	186
Iceland	10	10	10	10	10	10	10	9	9	9
Ireland	150	151	146	144	141	139	140	137	140	130
Italy	1993	2063	2133	2128	2077	2058	2007	1962	1874	1807
Kazakhstan	529	501	472	443	414	386	382	379	375	371
Kyrgyzstan	94	81	68	55	42	29	28	26	24	23
Latvia	89	85	77	71	66	65	65	62	59	57
Lithuania	128	131	107	95	87	86	76	87	80	71
Luxembourg	28	29	27	25	23	21	20	19	18	17
Malta	4	4	5	5	5	5	4	5	4	4
Moldova	106	89	67	54	50	48	49	47	40	34
Montenegro	15	15	15	15	15	15	13	11	9	7
Netherlands	607	571	526	503	469	437	409	376	379	359
North Macedonia	48	42	44	46	41	44	44	45	44	45
Norway	325	323	349	369	385	400	403	403	396	404
Poland	829	871	856	942	938	938	953	924	856	845
Portugal	249	251	257	244	244	239	239	244	247	238
Romania	404	337	310	286	301	308	357	361	335	306
Russian Federation	6365	5951	5536	5122	4707	4292	4205	4119	4032	3945
Serbia	192	168	163	149	148	146	148	153	157	139
Slovakia	258	239	226	201	185	174	168	155	155	148
Slovenia	65	63	61	62	63	63	66	63	59	56
Spain	1050	1051	1036	953	951	923	950	939	962	924
Sweden	368	352	333	300	294	279	274	253	241	233
Switzerland	302	288	265	237	222	206	194	182	171	164
Tajikistan	45	36	30	27	23	25	25	25	23	22
Turkey	1194	1244	1278	1307	1322	1343	1342	1327	1308	1280
Turkmenistan	95	78	80	67	62	64	71	67	76	82
Ukraine	1331	1203	1075	947	819	692	675	659	643	626
United Kingdom	2932	2889	2805	2685	2529	2390	2344	2243	2109	1908
Uzbekistan	242	251	238	238	229	209	209	219	219	221
Asian areas	4900	4951	5001	5051	5101	5151	5246	5341	5436	5531
North Africa	1073	1083	1094	1104	1115	1126	1143	1160	1177	1194
Baltic Sea	2	2	2	3	3	3	3	3	3	3
Black Sea	1	1	1	1	1	1	1	1	1	1
Mediterranean Sea	10	10	10	10	10	11	11	12	12	12
North Sea	6	6	6	7	7	7	7	7	8	7
North-East Atlantic Ocean	6	6	6	7	7	7	7	7	8	8
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	36840	35478	34157	32875	31158	29976	29783	29156	28621	27824

Table B:11: 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	33	34	34	34	35	35	35	34	34	33
Armenia	23	24	25	26	26	27	29	31	33	35
Austria	180	175	170	166	153	157	159	155	150	137
Azerbaijan	117	129	141	152	164	176	204	233	261	289
Belarus	237	237	237	236	236	236	236	237	238	238
Belgium	234	228	212	201	189	183	176	166	158	145
Bosnia and Herzegovina	57	55	52	49	46	43	43	44	44	44
Bulgaria	127	102	111	110	99	103	100	93	93	98
Croatia	104	102	105	108	113	114	114	110	108	94
Cyprus	13	13	14	15	15	16	15	16	14	13
Czechia	320	308	296	292	282	274	272	265	259	257
Denmark	182	173	167	164	160	155	150	148	144	134
Estonia	35	36	34	33	33	32	30	28	26	24
Finland	179	177	168	164	159	148	142	138	122	113
France	2061	1967	1839	1787	1671	1587	1486	1358	1281	1208
Georgia	37	37	38	38	38	32	31	33	32	31
Germany	1806	1711	1619	1538	1534	1487	1483	1421	1359	1245
Greece	308	306	319	331	341	334	310	288	261	250
Hungary	189	189	176	180	175	173	159	145	136	135
Iceland	9	8	8	8	8	7	7	7	7	6
Ireland	124	124	124	123	122	123	123	122	118	116
Italy	1630	1566	1471	1451	1349	1340	1304	1286	1264	1183
Kazakhstan	368	386	405	424	442	461	488	515	542	570
Kyrgyzstan	21	23	25	27	29	32	34	36	39	41
Latvia	55	58	57	56	56	52	51	51	46	44
Lithuania	63	61	62	62	62	62	64	63	63	58
Luxembourg	16	16	16	15	16	15	13	12	14	12
Malta	4	4	4	3	3	4	4	3	3	3
Moldova	32	36	40	42	45	50	44	40	42	40
Montenegro	4	7	9	11	13	16	16	16	17	17
Netherlands	339	310	295	288	268	273	268	271	267	267
North Macedonia	47	39	38	38	38	26	27	28	27	26
Norway	414	424	381	334	298	249	220	213	180	164
Poland	812	781	795	762	790	787	843	826	847	801
Portugal	238	231	225	214	207	196	188	181	171	158
Romania	321	307	308	323	332	335	336	315	332	289
Russian Federation	3858	3851	3845	3838	3831	3824	3764	3704	3644	3584
Serbia	149	147	148	152	154	149	147	151	146	145
Slovakia	148	149	136	135	136	144	138	132	128	121
Slovenia	55	56	52	51	49	48	46	46	44	40
Spain	882	854	828	795	775	738	708	689	639	586
Sweden	223	213	208	208	205	204	199	204	195	180
Switzerland	154	145	134	126	116	113	110	107	105	102
Tajikistan	22	23	24	24	27	28	30	32	33	34
Turkey	1272	1152	1126	1101	1097	1055	1048	1035	1043	1061
Turkmenistan	84	86	92	96	100	99	98	100	101	99
Ukraine	610	616	623	629	635	641	623	604	585	566
United Kingdom	1769	1673	1568	1467	1353	1262	1204	1158	1068	954
Uzbekistan	226	224	218	216	209	211	216	219	222	230
Asian areas	5626	5792	5958	6125	6291	6457	6492	6527	6562	6596
North Africa	1211	1228	1244	1261	1277	1294	1302	1311	1320	1328
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	13	13	13	13	13	12	12	12	12	11
North Sea	8	8	7	7	7	7	7	7	7	7
North-East Atlantic Ocean	8	8	8	8	8	8	8	8	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	27065	26625	26255	26061	25836	25637	25364	24978	24598	23976

Table B:12: National total emission trends of non-methane volatile organic compounds (2010-2020), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Albania	33	32	32	31	31	30	31	32	33	34	35
Armenia	37	38	40	41	43	44	40	35	30	26	20
Austria	137	133	130	124	118	113	111	112	109	109	111
Azerbaijan	318	329	340	351	361	372	374	375	376	378	345
Belarus	239	228	218	208	197	187	184	181	178	175	168
Belgium	144	132	128	125	118	117	116	114	113	112	113
Bosnia and Herzegovina	45	60	75	89	104	119	115	110	105	100	95
Bulgaria	90	93	91	87	83	85	82	82	76	76	73
Croatia	91	86	80	75	69	70	72	69	69	74	70
Cyprus	13	9	9	8	7	7	7	8	8	8	7
Czechia	253	242	236	234	230	230	227	228	228	219	199
Denmark	132	125	120	121	113	115	111	109	108	103	107
Estonia	23	23	23	22	22	22	22	23	23	23	24
Finland	114	105	102	97	95	90	90	88	86	85	85
France	1219	1149	1100	1092	1074	1047	1024	1012	990	973	939
Georgia	31	32	33	38	39	38	39	37	35	34	34
Germany	1361	1272	1257	1212	1174	1147	1141	1146	1099	1072	1036
Greece	215	200	193	176	172	165	157	151	146	146	132
Hungary	130	134	135	132	123	126	127	124	118	118	112
Iceland	6	6	5	5	5	6	6	6	6	6	5
Ireland	113	110	111	113	110	111	113	117	117	117	113
Italy	1116	1025	1032	996	924	897	881	921	894	888	885
Kazakhstan	597	605	614	623	631	640	629	617	606	595	535
Kyrgyzstan	44	47	51	55	59	63	57	52	47	42	33
Latvia	41	41	40	39	39	36	35	35	39	36	34
Lithuania	57	56	56	55	54	53	52	52	52	52	47
Luxembourg	12	12	12	12	11	11	11	11	11	11	11
Malta	4	3	3	4	3	3	3	3	3	3	3
Moldova	44	44	42	41	48	52	55	61	62	69	58
Montenegro	17	17	17	16	16	16	16	16	17	17	17
Netherlands	278	274	267	262	249	257	253	253	247	243	272
North Macedonia	27	27	27	27	26	26	25	25	25	23	22
Norway	167	158	159	158	169	164	162	160	157	141	153
Poland	769	765	746	698	690	710	736	737	700	668	671
Portugal	158	148	141	139	145	146	144	146	146	148	160
Romania	276	267	268	260	255	250	247	251	245	245	239
Russian Federation	3524	3577	3654	3661	3665	3697	3735	3808	3859	3896	3785
Serbia	137	137	131	130	119	126	131	128	124	124	138
Slovakia	121	118	116	111	94	109	108	106	98	95	92
Slovenia	40	37	36	35	32	32	33	32	32	31	30
Spain	585	566	543	531	526	540	545	565	579	571	551
Sweden	176	173	165	157	153	154	147	140	135	136	133
Switzerland	99	95	93	90	87	83	81	80	79	78	76
Tajikistan	36	38	47	50	57	59	66	72	79	86	85
Turkey	1075	1055	1115	1055	1048	1088	1065	1107	1083	1104	1133
Turkmenistan	107	111	111	118	124	127	142	157	172	187	185
Ukraine	547	526	504	483	461	440	426	412	398	384	362
United Kingdom	915	886	869	841	826	826	811	820	836	823	784
Uzbekistan	227	227	225	221	214	216	241	266	291	317	313
Asian areas	6631	6755	6878	7002	7125	7249	7745	8283	8842	9368	9588
North Africa	1337	1357	1377	1398	1418	1438	1454	1516	1563	1604	1503
Baltic Sea	3	3	3	3	3	3	3	3	3	3	3
Black Sea	1	1	1	1	1	1	1	1	1	1	1
Mediterranean Sea	12	12	12	12	11	11	11	12	12	12	11
North Sea	7	7	7	7	6	7	7	7	7	7	7
North-East Atlantic Ocean	7	7	7	7	7	7	7	7	7	8	7
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0	0
TOTAL	23936	23715	23824	23679	23585	23777	24251	25018	25503	26000	25747

Table B:13: National total emission trends of carbon monoxide (1990-1999), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	151	141	132	122	113	103	98	93	89	84
Armenia	495	405	315	225	135	45	57	69	82	94
Austria	1254	1261	1204	1142	1076	972	966	892	846	730
Azerbaijan	769	711	654	597	539	482	452	421	391	361
Belarus	1439	1302	1165	1028	892	755	753	752	751	749
Belgium	1508	1450	1453	1375	1312	1278	1231	1108	1051	983
Bosnia and Herzegovina	524	459	394	330	265	201	193	185	178	170
Bulgaria	840	503	591	653	575	593	543	413	473	420
Croatia	564	498	410	434	428	452	481	464	474	479
Cyprus	45	43	42	41	41	39	38	36	34	32
Czechia	2045	1942	1904	1694	1623	1547	1601	1479	1271	1143
Denmark	719	750	733	720	679	644	627	578	542	494
Estonia	251	240	149	141	175	221	259	256	222	205
Finland	764	736	715	700	687	662	657	651	646	630
France	10950	11315	10564	10039	9374	9188	8651	8034	7765	7278
Georgia	140	133	153	205	61	124	218	173	144	135
Germany	13046	10805	9320	8436	7434	7083	6528	6296	5795	5391
Greece	1237	1225	1166	1170	1155	1065	1066	1065	1068	1064
Hungary	1451	1335	1058	1124	1011	982	955	903	835	821
Iceland	72	71	69	66	65	65	64	64	71	76
Ireland	563	552	503	481	441	420	417	378	388	337
Italy	6797	7179	7281	7448	7035	7072	6785	6353	5922	5484
Kazakhstan	1878	1770	1663	1555	1447	1339	1335	1331	1326	1322
Kyrgyzstan	470	402	334	266	198	130	124	118	113	107
Latvia	469	431	384	385	364	339	342	316	300	294
Lithuania	373	420	239	215	190	211	227	226	220	195
Luxembourg	469	457	419	431	366	213	196	135	60	59
Malta	20	21	22	23	23	23	20	20	17	16
Moldova	367	301	182	112	109	105	110	115	94	71
Montenegro	33	33	33	33	34	34	30	25	21	17
Netherlands	1146	1049	1009	982	934	924	912	859	822	792
North Macedonia	132	112	123	133	121	125	123	126	129	132
Norway	793	746	711	717	708	688	665	652	632	606
Poland	3621	4277	4301	4963	4646	4724	4878	4493	3897	3919
Portugal	797	808	838	810	817	827	799	782	752	719
Romania	1208	954	815	756	758	747	1092	1240	1175	1018
Russian Federation	20802	19558	18313	17069	15824	14579	14283	13986	13690	13393
Serbia	609	553	505	447	485	434	450	477	512	457
Slovakia	1033	952	897	799	723	655	614	559	571	545
Slovenia	292	278	274	290	283	284	293	268	236	218
Spain	4133	4203	4219	3904	3640	3144	3568	3394	3268	3006
Sweden	1097	1144	1081	981	1000	942	915	833	784	721
Switzerland	817	779	719	628	575	532	511	479	459	444
Tajikistan	272	212	157	114	77	86	81	86	72	67
Turkey	3309	3433	3551	3603	3562	3732	3717	3738	3523	3287
Turkmenistan	479	345	364	283	257	286	336	300	354	399
Ukraine	11357	9888	8418	6949	5479	4010	3934	3858	3781	3705
United Kingdom	8393	8512	8228	7967	7362	6761	6850	6276	5864	5588
Uzbekistan	1172	1222	1115	1095	1015	835	859	960	989	1020
Asian areas	15252	15707	16162	16618	17073	17528	17842	18156	18470	18784
North Africa	2443	2464	2485	2506	2527	2548	2517	2486	2456	2425
Baltic Sea	21	21	23	22	22	22	22	23	23	24
Black Sea	6	6	6	6	6	6	6	6	6	6
Mediterranean Sea	77	79	83	80	81	82	83	83	84	87
North Sea	56	58	62	59	60	61	61	62	62	64
North-East Atlantic Ocean	49	50	53	51	52	53	53	53	54	56
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	129071	124307	117768	113029	105938	101003	100489	97190	93860	90728

Table B:14: 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	79	81	82	84	85	87	84	81	78	75
Armenia	106	106	107	107	107	108	109	111	112	113
Austria	725	698	666	669	651	626	626	603	584	564
Azerbaijan	330	350	369	388	408	427	450	474	497	520
Belarus	748	731	714	697	680	663	657	651	645	639
Belgium	995	921	958	912	858	798	739	612	617	423
Bosnia and Herzegovina	162	157	151	145	139	133	138	142	147	151
Bulgaria	385	350	393	410	362	348	364	341	331	304
Croatia	474	455	435	454	435	428	411	397	352	346
Cyprus	30	28	27	26	25	24	22	18	16	14
Czechia	1103	1068	1022	1040	1024	942	930	928	871	888
Denmark	474	465	440	442	425	425	411	415	394	358
Estonia	189	202	186	187	170	154	141	159	158	157
Finland	594	596	577	556	542	519	499	486	452	429
France	6608	6210	5997	5691	5753	5246	4657	4395	4201	3747
Georgia	123	130	131	132	129	85	90	102	94	92
Germany	5068	4878	4585	4262	4052	3828	3800	3762	3739	3199
Greece	1009	1014	965	928	916	869	884	827	761	695
Hungary	857	865	716	841	773	697	607	565	503	545
Iceland	75	72	70	70	72	51	57	71	108	111
Ireland	326	315	302	288	283	285	267	252	248	234
Italy	4751	4450	3855	3931	3394	3467	3323	3379	3510	3112
Kazakhstan	1318	1328	1337	1347	1356	1366	1521	1676	1831	1986
Kyrgyzstan	102	114	126	138	150	162	177	193	209	224
Latvia	276	286	275	273	263	235	236	218	200	205
Lithuania	177	176	175	172	169	173	178	177	174	164
Luxembourg	47	50	46	43	43	40	37	39	34	30
Malta	15	14	13	12	12	16	15	15	14	14
Moldova	56	58	56	66	65	67	67	61	68	61
Montenegro	13	28	44	59	74	90	83	76	69	63
Netherlands	759	758	748	744	755	741	756	743	751	703
North Macedonia	144	113	115	116	121	74	70	70	64	63
Norway	590	576	569	557	541	541	523	510	501	455
Poland	3371	3179	3180	3030	3048	3065	3302	3060	3155	3127
Portugal	683	636	615	591	561	523	490	464	425	403
Romania	1048	1019	1023	1078	1179	1202	1119	1108	1149	1036
Russian Federation	13096	12886	12675	12464	12253	12042	11768	11493	11218	10943
Serbia	470	488	483	501	525	495	450	498	464	455
Slovakia	542	554	476	501	508	549	504	500	462	405
Slovenia	206	217	184	186	173	183	162	167	159	143
Spain	2657	2510	2288	2435	2200	2028	2036	2005	1857	1890
Sweden	653	611	577	556	513	503	469	460	441	425
Switzerland	418	390	364	352	336	320	299	284	276	260
Tajikistan	71	80	90	90	120	121	140	163	149	157
Turkey	3272	2894	2852	2818	2727	2603	2608	2630	2928	3036
Turkmenistan	411	421	449	469	512	503	496	462	465	433
Ukraine	3629	3666	3704	3741	3778	3815	3640	3465	3290	3115
United Kingdom	4962	4640	4144	3756	3509	3220	2999	2802	2560	2032
Uzbekistan	1074	1057	1022	1006	936	947	945	965	985	1019
Asian areas	19098	19550	20001	20453	20905	21356	21507	21658	21809	21960
North Africa	2394	2443	2491	2539	2587	2635	2602	2569	2535	2502
Baltic Sea	25	25	24	24	24	23	23	23	24	24
Black Sea	7	7	7	7	7	7	7	7	7	7
Mediterranean Sea	97	96	95	94	93	92	91	90	94	95
North Sea	67	67	65	64	64	63	63	62	63	64
North-East Atlantic Ocean	58	58	57	56	56	55	55	54	56	57
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	87020	85136	83119	82599	81455	80071	78704	77542	76909	74275

Table B:15: National total emission trends of carbon monoxide (2010-2020), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Albania	72	71	70	70	69	69	71	73	75	77	76
Armenia	115	120	125	130	136	141	125	109	93	76	56
Austria	579	563	562	565	529	539	534	525	484	497	475
Azerbaijan	543	573	603	633	664	694	686	679	672	665	584
Belarus	633	604	575	547	518	489	475	462	449	435	416
Belgium	494	396	340	511	317	366	350	282	327	359	266
Bosnia and Herzegovina	156	182	209	235	261	288	276	265	253	242	228
Bulgaria	321	310	299	288	280	280	292	292	273	259	250
Croatia	336	311	293	282	249	270	260	254	232	219	217
Cyprus	14	13	12	12	12	11	11	11	10	10	9
Czechia	925	888	877	889	857	852	851	851	859	827	796
Denmark	349	307	289	276	252	256	247	237	221	206	192
Estonia	157	131	142	136	131	130	144	140	140	139	138
Finland	446	407	402	389	383	359	366	357	349	343	317
France	4141	3439	3149	3200	2682	2644	2673	2622	2501	2460	2162
Georgia	89	88	91	125	137	131	140	133	114	110	104
Germany	3506	3421	3168	3127	2958	3061	2942	2957	2849	2750	2452
Greece	616	598	641	552	559	538	481	493	469	461	426
Hungary	552	562	578	559	478	464	450	439	377	358	339
Iceland	109	107	108	109	108	111	109	113	112	106	105
Ireland	217	199	193	191	178	179	175	150	146	127	122
Italy	3073	2432	2696	2502	2256	2267	2192	2259	2050	2061	1873
Kazakhstan	2141	2129	2118	2107	2096	2084	1928	1771	1615	1458	1178
Kyrgyzstan	240	265	291	316	342	367	327	287	246	206	150
Latvia	164	165	163	144	136	112	109	116	119	114	101
Lithuania	158	150	147	137	129	122	120	118	119	113	107
Luxembourg	29	27	28	28	26	22	23	23	21	22	17
Malta	14	13	12	11	11	10	10	9	8	7	6
Moldova	65	70	64	66	90	96	100	123	173	157	127
Montenegro	56	53	51	48	45	43	43	44	44	45	45
Netherlands	706	685	651	617	586	582	565	561	543	525	456
North Macedonia	62	63	65	62	61	62	63	55	54	54	50
Norway	473	449	445	419	401	408	406	411	413	410	415
Poland	3377	3067	3089	2976	2714	2659	2772	2727	2563	2248	2199
Portugal	402	370	355	334	317	324	311	327	285	294	262
Romania	1036	988	973	953	956	912	934	941	943	948	914
Russian Federation	10669	10998	11438	11656	11706	11755	11961	12152	12373	12464	11764
Serbia	443	442	389	366	354	352	370	359	358	364	450
Slovakia	447	414	427	389	317	363	371	373	314	282	279
Slovenia	143	140	134	133	114	122	121	116	105	97	87
Spain	1906	1890	1586	1897	1642	1784	1637	1634	1848	1590	1432
Sweden	413	393	366	359	348	335	336	329	309	301	287
Switzerland	255	231	224	216	194	186	186	180	170	169	152
Tajikistan	169	158	256	271	321	346	391	436	481	526	520
Turkey	2996	2675	2962	2194	2114	2382	2201	2171	1668	1758	1853
Turkmenistan	486	517	493	547	572	594	671	748	826	903	892
Ukraine	2940	2898	2856	2813	2771	2729	2755	2782	2809	2835	2747
United Kingdom	1918	1746	1692	1679	1604	1551	1418	1415	1406	1358	1248
Uzbekistan	964	962	906	856	799	772	872	973	1074	1174	1160
Asian areas	22111	22912	23712	24512	25312	26112	27901	29839	31853	33748	34541
North Africa	2469	2557	2645	2734	2822	2910	2941	3066	3163	3245	3041
Baltic Sea	22	22	22	21	20	21	22	22	23	27	24
Black Sea	7	7	7	7	7	6	7	7	7	8	7
Mediterranean Sea	87	87	87	85	83	88	85	88	90	99	85
North Sea	60	59	59	59	55	58	59	60	60	63	63
North-East Atlantic Ocean	52	52	51	51	49	51	50	52	55	65	58
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0	0	0
TOTAL	74926	73379	74190	74394	73131	74460	75919	78016	79190	80470	78318

Table B:16: National total emission trends of fine particulate matter (1990-1999), as used for modelling at the MSC-W (Gg of $PM_{2.5}$ per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	23	21	18	16	14	12	11	11	10	10
Armenia	15	13	11	9	7	5	4	4	4	4
Austria	27	27	26	26	26	26	25	25	25	24
Azerbaijan	23	21	20	18	16	14	15	15	15	16
Belarus	101	94	86	79	72	64	64	63	62	62
Belgium	55	54	53	52	52	51	49	46	44	42
Bosnia and Herzegovina	94	81	69	57	45	33	30	28	25	22
Bulgaria	41	35	33	36	32	31	34	31	36	32
Croatia	40	43	37	38	36	38	42	40	40	39
Cyprus	2	2	2	2	3	3	3	3	3	3
Czechia	298	234	192	174	136	120	121	96	70	52
Denmark	24	25	25	25	24	24	24	23	21	20
Estonia	37	34	31	28	25	21	19	18	16	14
Finland	47	43	39	35	35	32	31	30	28	28
France	420	464	447	433	397	399	411	373	367	345
Georgia	36	35	35	34	34	34	33	32	32	31
Germany	428	383	338	293	247	202	190	189	179	174
Greece	75	74	73	71	70	67	70	71	73	76
Hungary	95	84	73	62	52	41	42	44	45	47
Iceland	1	1	1	2	2	2	2	2	2	1
Ireland	28	28	25	25	23	21	22	20	21	19
Italy	230	239	231	233	228	228	218	215	215	211
Kazakhstan	191	180	169	158	147	136	132	128	124	120
Kyrgyzstan	24	21	18	15	11	8	8	8	8	8
Latvia	26	28	26	27	27	28	30	29	29	29
Lithuania	15	16	9	9	8	7	8	8	8	7
Luxembourg	16	16	14	15	13	8	8	5	2	2
Malta	1	1	1	1	1	1	1	1	1	1
Moldova	24	18	12	7	7	6	7	6	5	5
Montenegro	6	6	6	6	6	6	5	4	4	3
Netherlands	56	54	52	49	46	44	41	38	36	35
North Macedonia	33	29	35	31	29	30	32	32	36	31
Norway	41	38	37	40	43	43	44	48	43	41
Poland	560	549	498	581	519	495	491	431	372	357
Portugal	69	70	72	68	67	68	69	70	78	72
Romania	77	64	62	65	68	73	111	131	117	109
Russian Federation	1121	1002	883	763	644	525	516	507	498	490
Serbia	62	54	49	48	46	41	43	45	48	44
Slovakia	96	87	81	66	58	51	47	41	42	40
Slovenia	16	15	15	14	14	13	14	14	14	14
Spain	213	209	205	200	196	192	189	185	182	179
Sweden	45	45	44	44	43	42	42	39	36	34
Switzerland	17	17	16	15	15	14	14	13	13	12
Tajikistan	28	20	17	11	6	5	4	6	5	5
Turkey	504	494	484	473	463	453	441	429	417	405
Turkmenistan	23	19	22	17	12	13	15	13	16	17
Ukraine	918	826	734	642	549	457	445	433	421	409
United Kingdom	251	250	243	224	215	195	189	180	170	166
Uzbekistan	83	83	72	73	71	59	60	61	59	59
Asian areas	626	644	662	679	697	714	719	724	729	734
North Africa	83	85	88	91	94	96	100	104	108	112
Baltic Sea	14	14	15	15	16	16	16	17	17	18
Black Sea	3	4	4	4	4	4	4	4	4	5
Mediterranean Sea	61	63	68	66	68	70	72	74	76	79
North Sea	29	30	33	32	33	34	35	35	36	38
North-East Atlantic Ocean	40	42	45	44	45	47	48	49	50	53
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	7515	7130	6655	6343	5854	5463	5457	5290	5138	5005

Table B:17: 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	10	10	10	11	12	12	12	12	12
Armenia	4	4	4	4	4	4	4	4	4	4
Austria	24	24	23	23	23	32	33	32	31	31
Azerbaijan	16	16	16	17	17	17	18	19	20	21
Belarus	61	61	61	61	61	65	64	64	63	63
Belgium	40	39	37	37	37	34	35	33	32	29
Bosnia and Herzegovina	19	20	21	22	23	51	52	52	52	53
Bulgaria	36	32	37	40	40	40	40	38	38	34
Croatia	36	39	38	44	42	44	40	38	38	37
Cyprus	3	2	2	2	2	2	2	2	2	2
Czechia	50	51	47	47	47	43	44	42	41	42
Denmark	21	21	20	21	21	22	22	24	23	21
Estonia	12	12	13	11	11	16	15	19	16	15
Finland	26	27	27	27	27	26	26	24	23	22
France	317	305	284	283	269	283	257	241	236	226
Georgia	31	29	27	25	23	15	16	17	17	17
Germany	165	159	153	146	141	162	163	161	160	144
Greece	67	71	69	68	69	69	68	68	64	62
Hungary	48	52	38	46	43	40	41	40	37	47
Iceland	2	2	1	2	2	2	2	2	2	2
Ireland	19	19	18	18	18	19	18	18	17	17
Italy	197	189	159	178	155	177	181	206	220	210
Kazakhstan	116	116	116	116	116	116	127	138	149	161
Kyrgyzstan	8	9	9	10	11	11	12	13	14	15
Latvia	27	28	28	29	30	27	27	26	25	27
Lithuania	7	7	7	7	7	17	18	17	17	17
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	5	5	5	5	6	5	5	5
Montenegro	2	3	5	7	9	11	11	10	10	10
Netherlands	34	32	31	30	29	28	27	26	24	22
North Macedonia	30	19	19	29	32	24	22	17	18	13
Norway	42	41	42	39	36	37	35	35	34	32
Poland	307	317	322	317	322	332	354	334	338	335
Portugal	71	67	67	64	65	62	59	58	56	52
Romania	106	87	90	106	119	125	119	117	135	127
Russian Federation	481	476	472	467	462	604	591	579	566	553
Serbia	46	47	48	49	50	47	44	49	45	51
Slovakia	44	43	32	32	30	36	32	28	26	23
Slovenia	14	16	14	15	14	16	15	16	16	14
Spain	176	169	163	179	163	157	162	162	149	155
Sweden	34	33	32	32	31	31	29	29	28	26
Switzerland	12	12	11	11	11	13	13	13	13	12
Tajikistan	5	5	6	8	8	9	9	11	10	11
Turkey	393	388	382	377	372	410	404	411	493	523
Turkmenistan	18	17	18	21	20	21	21	16	18	17
Ukraine	397	401	404	408	411	451	430	409	389	368
United Kingdom	149	146	129	128	125	123	121	112	103	95
Uzbekistan	59	60	58	53	53	52	52	55	55	56
Asian areas	738	761	785	808	831	854	880	907	933	959
North Africa	116	120	124	128	133	137	137	136	136	136
Baltic Sea	19	19	19	19	19	18	14	12	11	11
Black Sea	5	5	5	5	5	5	5	5	5	4
Mediterranean Sea	88	87	85	84	83	82	81	80	74	71
North Sea	40	40	39	38	38	37	31	28	26	25
North-East Atlantic Ocean	55	55	53	53	52	52	51	50	46	45
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	4850	4815	4731	4809	4779	5127	5093	5066	5116	5082

Table B:18: National total emission trends of fine particulate matter (2010-2020), 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	2019	2020
Albania	12	12	12	11	11	11	11	10	10	10	10
Armenia	4	4	5	5	5	5	5	6	6	6	6
Austria	33	31	31	31	27	28	27	27	25	25	24
Azerbaijan	22	23	23	24	25	25	28	30	32	34	34
Belarus	62	61	59	58	56	55	57	59	61	63	62
Belgium	30	25	25	25	21	22	22	20	19	18	17
Bosnia and Herzegovina	53	56	58	61	64	66	63	59	55	51	50
Bulgaria	36	39	38	35	35	35	32	32	31	30	32
Croatia	38	36	35	34	30	32	31	29	29	27	28
Cyprus	2	1	1	1	1	1	1	1	1	1	1
Czechia	45	43	43	44	41	41	40	41	39	35	32
Denmark	21	19	18	18	17	17	17	16	15	13	12
Estonia	20	23	14	16	14	12	11	12	11	10	10
Finland	23	20	20	20	19	17	18	17	17	16	14
France	236	199	211	218	186	190	192	184	175	171	163
Georgia	16	16	17	17	17	18	18	18	19	19	19
Germany	154	142	145	140	126	125	114	113	114	109	101
Greece	48	47	49	44	45	43	40	40	37	37	35
Hungary	50	56	58	58	49	51	49	47	41	38	37
Iceland	2	2	2	2	1	1	1	1	1	1	1
Ireland	16	14	14	14	13	14	14	13	13	12	12
Italy	202	154	182	178	159	163	159	166	148	143	138
Kazakhstan	172	169	166	164	161	158	153	147	142	137	127
Kyrgyzstan	16	17	17	17	17	18	17	16	15	14	13
Latvia	21	21	21	20	19	16	16	18	19	18	17
Lithuania	17	17	17	16	15	15	15	14	14	13	13
Luxembourg	2	2	1	1	1	1	1	1	1	1	1
Malta	1	1	1	0	1	0	0	0	0	0	0
Moldova	5	6	6	6	11	12	13	17	26	23	20
Montenegro	9	9	9	9	8	8	8	8	7	7	7
Netherlands	20	20	18	18	17	17	16	17	17	16	15
North Macedonia	16	22	21	24	17	15	13	9	9	9	9
Norway	34	32	32	28	26	26	25	25	25	24	25
Poland	368	345	347	336	309	306	318	310	293	256	255
Portugal	53	54	52	50	50	50	49	49	49	49	47
Romania	130	118	120	113	111	108	108	107	106	106	105
Russian Federation	540	530	531	517	510	487	455	446	438	427	413
Serbia	50	50	49	44	44	45	50	48	48	49	65
Slovakia	26	24	26	24	16	21	21	21	17	18	17
Slovenia	15	14	14	14	12	13	13	12	11	11	10
Spain	152	155	134	154	133	144	129	128	145	127	120
Sweden	26	26	24	23	20	19	19	19	18	17	17
Switzerland	12	11	11	10	10	9	9	8	8	7	7
Tajikistan	11	11	14	16	21	24	25	27	29	30	32
Turkey	523	495	495	442	423	414	411	405	375	372	378
Turkmenistan	18	19	20	20	19	20	22	23	25	26	27
Ukraine	347	338	328	318	309	299	306	313	320	327	325
United Kingdom	99	92	92	92	89	87	85	86	89	86	80
Uzbekistan	55	56	53	53	51	49	52	56	59	63	66
Asian areas	986	997	1008	1020	1031	1043	1114	1191	1272	1347	1379
North Africa	136	139	142	145	148	151	153	159	164	168	158
Baltic Sea	11	10	10	10	10	4	7	7	7	5	4
Black Sea	5	5	5	4	4	4	4	5	4	5	2
Mediterranean Sea	73	72	72	71	65	68	70	73	75	73	23
North Sea	25	23	23	23	22	11	14	15	15	11	10
North-East Atlantic Ocean	47	47	46	46	41	43	43	45	45	45	14
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	1673	13185	0	0	0	0	0	0	0	0	0
TOTAL	6820	18152	4987	4902	4704	4676	4703	4768	4786	4757	4639

Table B:19: National total emission trends of particulate matter (1990-1999), as used for modelling at the MSC-W (Gg of PM_{10} per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	33	29	25	21	17	14	13	13	12	12
Armenia	17	15	13	10	8	6	5	5	5	5
Austria	41	41	40	40	40	39	39	39	39	38
Azerbaijan	28	26	24	22	20	18	18	19	20	20
Belarus	146	135	125	115	105	95	93	90	88	86
Belgium	78	77	75	74	73	71	68	65	61	58
Bosnia and Herzegovina	172	146	119	93	67	41	40	39	37	36
Bulgaria	66	57	54	57	55	54	56	55	60	54
Croatia	60	60	50	53	53	55	60	59	58	54
Cyprus	5	5	5	5	5	5	5	5	5	5
Czechia	430	345	281	254	195	164	163	127	94	69
Denmark	36	37	36	36	35	35	35	34	32	32
Estonia	141	128	115	103	90	77	67	57	47	38
Finland	74	67	61	56	56	51	50	49	45	46
France	540	585	563	540	505	507	521	483	473	452
Georgia	48	46	43	41	39	37	36	36	35	35
Germany	873	767	661	555	448	342	326	331	319	313
Greece	163	157	152	145	140	131	133	135	136	137
Hungary	185	162	140	118	96	73	73	73	73	73
Iceland	3	3	3	3	3	3	3	3	3	3
Ireland	43	43	40	39	37	35	37	36	38	36
Italy	302	310	301	300	296	297	284	278	277	274
Kazakhstan	331	308	284	260	237	213	206	199	191	184
Kyrgyzstan	45	38	32	25	18	11	11	11	11	11
Latvia	31	34	31	32	31	33	34	34	34	34
Lithuania	44	43	33	30	26	22	22	22	21	19
Luxembourg	17	16	15	16	14	9	9	6	3	3
Malta	1	1	1	1	1	1	1	1	1	1
Moldova	32	25	18	12	11	9	10	9	8	7
Montenegro	7	7	7	7	7	7	6	5	4	3
Netherlands	79	75	73	69	65	61	57	53	50	48
North Macedonia	48	42	51	45	43	43	47	46	52	45
Norway	52	49	47	50	52	52	53	57	52	50
Poland	930	871	771	837	751	680	664	582	503	479
Portugal	87	89	90	86	86	87	86	90	157	113
Romania	133	108	101	106	108	115	153	169	153	141
Russian Federation	2292	2042	1793	1543	1293	1044	1033	1021	1010	998
Serbia	81	71	65	63	61	57	59	61	65	59
Slovakia	108	98	91	76	67	61	58	50	53	49
Slovenia	35	32	29	27	24	21	21	21	20	20
Spain	313	307	300	294	287	281	277	273	269	265
Sweden	66	66	64	64	64	63	62	58	56	53
Switzerland	25	25	25	24	23	22	22	21	20	20
Tajikistan	37	27	23	14	7	7	6	8	7	7
Turkey	758	730	702	673	645	617	597	577	557	537
Turkmenistan	31	26	30	22	16	17	19	17	21	23
Ukraine	1610	1437	1264	1091	918	745	713	682	650	619
United Kingdom	392	389	370	339	322	297	293	276	260	254
Uzbekistan	112	112	96	96	93	77	78	80	78	79
Asian areas	1037	1064	1092	1119	1147	1174	1185	1195	1205	1216
North Africa	141	146	150	155	160	165	171	177	184	190
Baltic Sea	14	14	15	15	16	16	16	17	17	18
Black Sea	3	4	4	4	4	4	4	4	4	5
Mediterranean Sea	61	63	68	66	68	70	72	74	76	79
North Sea	29	30	33	32	33	34	35	35	36	38
North-East Atlantic Ocean	40	42	45	44	45	47	48	49	50	53
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	12507	11671	10738	10020	9125	8312	8253	8009	7839	7595

Table B:20: 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	11	12	12	13	13	14	15	14	15	14
Armenia	5	5	5	5	5	5	5	5	6	6
Austria	38	38	37	37	36	46	46	45	45	43
Azerbaijan	21	21	21	22	22	22	23	26	27	28
Belarus	84	83	82	81	81	84	83	83	82	82
Belgium	55	53	50	51	50	46	46	43	42	38
Bosnia and Herzegovina	34	36	38	40	41	70	70	70	70	70
Bulgaria	63	54	64	67	67	69	67	62	60	51
Croatia	48	50	53	61	58	57	54	53	55	52
Cyprus	5	4	4	4	4	4	4	4	4	3
Czechia	67	67	62	62	62	58	59	57	55	55
Denmark	33	33	32	32	32	33	33	35	39	32
Estonia	28	27	23	21	19	23	21	29	22	21
Finland	43	44	44	45	44	42	43	41	38	37
France	421	407	383	383	368	379	351	332	325	310
Georgia	34	32	30	29	27	23	24	25	25	26
Germany	298	284	276	262	255	273	274	269	268	246
Greece	128	133	134	129	135	126	129	124	131	121
Hungary	73	79	62	73	75	73	64	62	65	76
Iceland	3	3	3	4	4	3	4	4	5	5
Ireland	37	38	37	38	39	40	40	40	38	36
Italy	257	249	218	235	213	232	234	258	269	256
Kazakhstan	177	177	177	178	178	178	192	206	219	233
Kyrgyzstan	11	12	13	14	14	15	17	18	19	21
Latvia	32	33	33	34	43	36	35	36	35	34
Lithuania	17	17	18	18	18	28	29	29	29	28
Luxembourg	3	3	3	4	3	3	3	3	3	2
Malta	1	1	1	2	2	2	2	2	2	1
Moldova	7	7	7	8	8	9	9	8	9	8
Montenegro	2	5	7	9	11	15	14	14	13	13
Netherlands	49	47	45	43	42	41	41	39	37	35
North Macedonia	44	28	28	42	46	37	34	28	28	22
Norway	51	50	51	47	45	46	44	45	43	40
Poland	417	425	428	423	425	437	464	441	443	437
Portugal	90	92	100	89	86	80	86	77	76	73
Romania	139	121	124	144	162	163	159	161	174	163
Russian Federation	987	982	977	972	967	1124	1098	1071	1044	1017
Serbia	60	61	62	63	65	62	60	64	60	65
Slovakia	54	53	42	42	39	45	41	36	33	31
Slovenia	20	22	20	21	21	23	22	24	24	18
Spain	261	253	250	269	254	248	255	255	225	223
Sweden	53	51	51	51	50	51	49	49	47	44
Switzerland	19	19	18	18	18	20	21	21	21	20
Tajikistan	7	7	8	10	11	12	12	14	14	15
Turkey	517	508	499	491	482	516	516	529	620	658
Turkmenistan	24	23	24	28	26	27	28	22	24	22
Ukraine	587	592	597	603	608	648	619	591	562	534
United Kingdom	238	241	212	224	208	203	197	182	166	154
Uzbekistan	79	80	77	71	71	69	69	74	73	74
Asian areas	1226	1262	1298	1334	1370	1406	1444	1483	1521	1560
North Africa	196	205	213	222	230	238	239	239	239	239
Baltic Sea	19	19	19	19	19	18	14	12	11	11
Black Sea	5	5	5	5	5	5	5	5	5	4
Mediterranean Sea	88	87	85	84	83	82	81	80	74	71
North Sea	40	40	39	38	38	37	31	28	26	25
North-East Atlantic Ocean	55	55	53	53	52	52	51	50	46	45
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	7362	7336	7261	7363	7349	7700	7667	7615	7650	7550

Table B:21: National total emission trends of particulate matter (2010-2020), 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	2019	2020
Albania	14	14	14	14	13	14	13	13	13	13	12
Armenia	6	6	6	7	7	7	7	8	8	8	8
Austria	46	44	44	43	40	40	40	40	37	37	36
Azerbaijan	29	30	31	32	33	34	36	38	41	43	43
Belarus	81	79	78	76	74	73	75	77	79	81	79
Belgium	39	33	33	34	29	31	31	29	28	27	26
Bosnia and Herzegovina	71	74	77	80	83	86	80	74	68	62	58
Bulgaria	50	57	53	48	51	52	44	44	44	45	45
Croatia	53	48	48	49	45	40	44	38	42	35	51
Cyprus	3	3	2	2	2	2	2	2	2	2	2
Czechia	57	55	55	56	53	52	51	52	51	46	42
Denmark	33	30	29	29	28	27	27	27	26	23	23
Estonia	29	39	20	24	20	16	16	16	16	14	13
Finland	38	36	34	34	34	31	32	31	31	30	27
France	322	284	296	302	267	271	273	268	257	254	239
Georgia	25	24	24	25	25	26	26	26	27	27	27
Germany	262	255	256	254	239	237	217	220	228	213	201
Greece	91	78	76	72	76	70	69	68	61	61	59
Hungary	72	75	74	77	72	73	70	66	62	60	57
Iceland	4	3	3	3	3	2	3	3	3	3	2
Ireland	34	27	28	28	27	28	28	28	28	28	28
Italy	247	197	224	219	200	202	198	205	187	186	175
Kazakhstan	247	243	239	235	231	227	222	217	213	208	197
Kyrgyzstan	22	22	22	23	23	23	22	21	20	19	18
Latvia	29	31	31	29	28	27	26	27	28	28	26
Lithuania	28	28	28	28	27	27	26	26	27	25	25
Luxembourg	2	2	2	2	2	2	2	2	2	2	2
Malta	1	1	1	1	1	1	1	1	2	2	2
Moldova	8	9	9	9	15	15	16	21	31	27	25
Montenegro	12	12	12	11	11	11	10	10	9	8	8
Netherlands	34	33	32	31	31	30	30	30	30	30	28
North Macedonia	28	35	34	37	27	22	20	14	14	14	13
Norway	43	41	42	37	34	34	34	34	33	33	33
Poland	473	447	447	433	402	399	411	405	386	343	340
Portugal	72	79	73	65	62	61	62	61	61	62	61
Romania	167	156	161	151	150	146	143	140	143	148	146
Russian Federation	990	981	986	964	958	928	891	883	872	858	844
Serbia	65	65	63	58	57	59	66	64	64	65	82
Slovakia	33	31	32	30	22	29	27	28	23	24	24
Slovenia	21	16	16	16	14	15	17	15	13	14	14
Spain	216	217	191	210	188	203	191	187	206	186	179
Sweden	44	45	42	43	39	37	38	39	38	37	35
Switzerland	20	19	19	18	18	17	16	16	16	15	14
Tajikistan	15	14	19	21	27	31	33	35	37	40	41
Turkey	663	645	659	609	598	602	600	595	550	551	558
Turkmenistan	24	25	26	27	25	27	28	30	32	34	35
Ukraine	505	491	477	463	448	434	440	447	453	460	452
United Kingdom	166	153	148	155	150	147	149	155	153	150	136
Uzbekistan	73	75	71	70	68	64	69	73	77	82	85
Asian areas	1599	1625	1650	1676	1702	1728	1846	1974	2107	2233	2285
North Africa	239	244	248	253	257	261	264	275	284	291	273
Baltic Sea	11	10	10	10	10	4	7	7	7	5	4
Black Sea	5	5	5	4	4	4	4	5	4	5	2
Mediterranean Sea	73	72	72	71	65	68	70	73	75	73	23
North Sea	25	23	23	23	22	11	14	15	15	11	10
North-East Atlantic Ocean	47	47	46	46	41	43	43	45	45	45	14
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	5970	47039	0	0	0	0	0	0	0	0	0
TOTAL	13577	54474	7440	7363	7176	7153	7222	7341	7408	7421	7288

Table B:22: National total emission trends of coarse particulate matter (1990-1999), as used for modelling at the MSC-W (Gg of PM_{coarse} per year).

Area/Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Albania	10	8	7	5	4	2	2	2	2	2
Armenia	2	2	2	1	1	1	1	1	1	1
Austria	14	14	14	14	14	14	14	14	14	14
Azerbaijan	5	5	4	4	4	3	4	4	4	5
Belarus	45	42	39	36	33	30	29	27	26	24
Belgium	23	23	22	22	21	20	19	18	17	16
Bosnia and Herzegovina	78	64	50	36	22	8	10	11	12	14
Bulgaria	25	22	21	21	23	23	23	24	24	23
Croatia	19	17	13	14	17	17	19	19	17	15
Cyprus	2	2	2	2	2	2	2	2	2	2
Czechia	131	111	89	80	59	43	42	32	24	18
Denmark	12	12	11	11	11	12	11	11	11	11
Estonia	104	94	85	75	65	56	48	40	32	24
Finland	27	24	22	21	21	19	19	19	17	17
France	120	122	116	108	108	108	110	109	107	106
Georgia	12	10	9	7	5	3	3	3	3	3
Germany	446	385	323	262	201	140	136	142	140	139
Greece	88	83	79	74	70	65	63	63	63	62
Hungary	90	78	67	55	44	33	31	29	28	26
Iceland	2	1	1	1	2	2	2	2	2	2
Ireland	15	15	15	14	14	14	15	16	16	17
Italy	72	71	69	68	68	69	66	63	63	62
Kazakhstan	140	128	115	102	90	77	74	71	67	64
Kyrgyzstan	21	18	14	10	7	3	3	3	3	3
Latvia	6	5	4	4	4	4	4	5	5	5
Lithuania	29	27	24	21	18	15	14	14	13	12
Luxembourg	1	1	1	1	1	1	1	1	1	1
Malta	1	1	1	1	1	1	1	1	1	1
Moldova	8	7	6	5	4	4	3	3	3	3
Montenegro	1	1	1	1	1	1	1	1	1	1
Netherlands	23	22	21	20	18	17	16	15	14	13
North Macedonia	16	14	16	14	13	14	15	14	16	14
Norway	11	10	10	10	9	9	9	10	9	9
Poland	370	322	273	256	232	184	172	150	131	122
Portugal	18	18	19	18	19	20	17	20	80	41
Romania	56	45	39	41	40	41	42	39	36	32
Russian Federation	1171	1041	910	780	649	519	517	514	511	509
Serbia	19	17	16	15	15	15	16	16	17	14
Slovakia	11	11	10	10	10	10	11	10	11	10
Slovenia	19	17	15	12	10	8	8	7	6	6
Spain	100	98	96	93	91	89	88	87	86	86
Sweden	21	21	21	20	20	20	20	19	19	19
Switzerland	9	9	8	8	8	8	8	8	8	7
Tajikistan	10	7	6	4	2	2	1	2	2	2
Turkey	255	236	218	200	182	164	156	148	140	132
Turkmenistan	8	7	7	5	4	4	5	4	5	6
Ukraine	691	611	530	449	369	288	268	249	229	209
United Kingdom	141	139	127	116	107	102	104	96	90	88
Uzbekistan	29	28	24	24	22	18	18	19	19	20
Asian areas	410	420	430	440	450	460	465	471	476	482
North Africa	58	60	62	64	66	68	71	73	76	78
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	4992	4541	4083	3677	3271	2849	2796	2720	2701	2589

Table B:23: 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	2	2	2	2	2	2	2	2	2	2
Armenia	1	1	1	1	1	1	2	2	2	2
Austria	14	14	14	14	14	14	13	13	13	13
Azerbaijan	5	5	5	5	5	5	6	7	7	7
Belarus	23	22	22	21	20	19	19	19	19	19
Belgium	15	14	13	14	13	12	11	10	10	9
Bosnia and Herzegovina	15	16	17	17	18	19	18	18	18	18
Bulgaria	28	21	27	26	28	29	27	24	22	17
Croatia	12	11	15	17	16	13	14	15	17	14
Cyprus	2	2	2	2	2	2	2	2	2	2
Czechia	17	16	15	15	15	15	15	15	14	13
Denmark	12	12	11	10	11	11	11	11	16	11
Estonia	16	15	11	10	8	8	6	10	6	5
Finland	17	17	17	18	17	16	17	16	16	15
France	103	101	99	100	99	96	94	91	89	84
Georgia	3	3	3	3	3	8	8	8	8	8
Germany	133	124	124	116	114	111	111	108	108	103
Greece	62	63	65	61	65	57	61	56	66	59
Hungary	24	27	24	27	32	32	24	22	29	30
Iceland	2	2	2	2	2	2	2	2	3	3
Ireland	18	19	19	20	21	21	22	22	20	20
Italy	60	60	59	57	58	56	53	52	50	46
Kazakhstan	61	61	61	62	62	62	65	67	70	73
Kyrgyzstan	4	4	4	4	4	4	4	5	5	5
Latvia	5	5	5	5	12	8	9	10	10	8
Lithuania	10	10	11	11	11	11	11	11	11	11
Luxembourg	1	1	1	1	1	1	1	1	1	1
Malta	0	1	1	1	1	1	1	1	1	1
Moldova	2	3	3	2	3	4	4	4	4	3
Montenegro	1	1	2	2	3	4	3	3	3	3
Netherlands	15	14	15	14	14	13	13	14	14	13
North Macedonia	14	9	9	13	14	13	12	10	10	9
Norway	9	9	9	9	8	9	9	10	9	9
Poland	110	108	106	106	103	105	111	107	105	102
Portugal	19	26	33	25	21	18	27	19	21	21
Romania	33	34	34	38	43	39	40	43	39	36
Russian Federation	506	506	505	505	504	520	506	492	478	464
Serbia	14	14	15	14	15	15	15	15	15	14
Slovakia	10	10	10	9	9	9	8	8	8	7
Slovenia	5	6	6	6	6	7	7	8	8	4
Spain	85	84	87	90	91	91	93	93	77	68
Sweden	19	19	19	19	19	19	19	20	19	18
Switzerland	7	7	7	7	7	8	8	8	8	8
Tajikistan	2	2	2	3	3	3	3	4	4	4
Turkey	124	120	117	113	110	106	112	118	127	134
Turkmenistan	6	6	6	7	7	7	7	6	6	6
Ukraine	190	191	193	195	197	197	189	181	174	166
United Kingdom	89	96	83	96	83	79	75	70	63	59
Uzbekistan	20	20	19	18	18	17	17	18	18	19
Asian areas	488	500	513	526	539	552	564	576	588	601
North Africa	81	85	89	93	97	102	102	102	103	103
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	2512	2520	2530	2554	2570	2573	2574	2550	2534	2468

Table B:24: National total emission trends of coarse particulate matter (2010-2020), 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	2019	2020
Albania	2	2	2	2	2	2	2	2	2	2	2
Armenia	2	2	2	2	2	2	2	2	2	2	2
Austria	13	13	13	13	13	12	12	13	12	13	12
Azerbaijan	7	8	8	8	8	8	8	8	9	9	9
Belarus	19	19	18	18	18	18	18	18	18	18	17
Belgium	9	9	9	9	9	9	9	9	9	9	9
Bosnia and Herzegovina	18	18	18	19	19	20	17	15	13	10	8
Bulgaria	14	18	14	13	16	17	12	12	13	14	13
Croatia	14	12	13	14	15	8	13	9	14	8	23
Cyprus	2	1	1	1	1	1	1	1	1	1	1
Czechia	12	12	12	12	11	11	11	11	11	11	10
Denmark	12	11	11	11	12	10	10	11	11	10	10
Estonia	9	16	6	8	7	5	4	5	4	3	3
Finland	15	15	14	15	14	14	14	13	13	13	13
France	86	85	85	84	80	81	82	84	82	83	76
Georgia	8	8	8	8	8	8	8	8	8	8	8
Germany	108	112	111	114	113	112	103	107	113	104	99
Greece	43	31	27	28	31	27	30	28	23	24	24
Hungary	22	19	16	19	23	22	21	19	21	22	20
Iceland	3	2	1	1	1	1	1	1	1	1	1
Ireland	18	13	14	14	14	14	15	16	15	16	16
Italy	44	43	42	41	40	39	39	39	39	43	37
Kazakhstan	75	74	73	71	70	69	69	70	71	71	69
Kyrgyzstan	5	5	5	5	5	5	5	5	5	5	5
Latvia	8	10	10	9	9	11	9	9	9	9	9
Lithuania	11	12	12	12	12	13	12	11	12	12	12
Luxembourg	1	1	1	1	1	1	1	1	1	1	1
Malta	1	1	1	1	1	1	1	1	1	1	1
Moldova	3	3	3	3	4	3	3	4	5	5	5
Montenegro	3	3	3	3	2	2	2	2	2	1	1
Netherlands	13	14	13	13	14	14	14	13	13	13	13
North Macedonia	12	14	13	13	10	7	7	5	6	5	5
Norway	9	9	10	9	9	8	9	9	9	9	8
Poland	105	102	100	97	92	93	94	94	93	87	86
Portugal	19	24	21	14	12	11	13	12	12	13	14
Romania	37	39	41	38	39	38	35	33	37	42	41
Russian Federation	450	451	455	447	448	441	436	436	434	431	431
Serbia	14	15	14	14	14	15	16	16	16	17	17
Slovakia	7	6	6	6	6	8	6	7	6	6	6
Slovenia	6	2	2	2	2	2	4	2	2	3	4
Spain	64	62	57	55	55	59	62	59	61	59	58
Sweden	18	20	18	20	18	18	19	19	19	19	18
Switzerland	8	8	8	8	8	8	8	8	8	8	8
Tajikistan	4	4	5	5	7	8	8	8	9	9	9
Turkey	140	150	164	167	176	189	190	191	175	179	180
Turkmenistan	6	6	6	7	6	6	7	7	7	8	8
Ukraine	158	153	149	144	139	135	134	134	133	133	127
United Kingdom	67	62	56	63	61	60	64	69	64	64	56
Uzbekistan	19	19	18	17	16	16	16	17	18	19	19
Asian areas	613	627	642	656	671	685	732	783	835	885	906
North Africa	104	105	106	108	109	110	112	116	120	123	115
Baltic Sea	0	0	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0	0	0
North-East Atlantic Ocean	0	0	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0	0	0
Volcanic emissions	4297	33854	0	0	0	0	0	0	0	0	0
TOTAL	6758	36322	2453	2460	2472	2477	2519	2573	2622	2664	2649

APPENDIX C

Source-receptor tables for 2020

The source-receptor tables in this appendix are calculated for the meteorological and chemical conditions of 2020, using the EMEP MSC-W model version rv4.45. 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(cy46r1) 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.

All tables except one in this appendix are based on source-receptor calculations with the 15% perturbation method using the EMEPwREF2.1C emission data set as described in Chapter 3 and summarized in Appendix A.

The perturbation method means that 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 2020, reductions in volcanic emissions are done for passive SO_2 degassing of Italian volcanoes (Etna, Stromboli and Vulcano).

For EC emissions, two different emission data sets have been used: 1) EC derived from the EMEPwREF2.1C emission data, using a set of PM-split files consistent with the TNO *REF2.1* data set and 2) Official EMEP gridded EC emissions. Source-receptor calculations with the 15% *Perturbation Method* used EC derived from the EMEPwREF2.1C emission data set. Additional source-receptor calculations for EC, using the official EMEP gridded emissions for EC (BC), were done with the *Local Fraction* method described in Chapter 5. 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.

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 2020.

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

- MM-AOT40f. Effect of a 15% reduction in NO_x emissions. Units: ppb.h
- MM-AOT40f. 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

Fine Elemental Carbon

- Fine EC. Effect of a 15% reduction in primary EC emissions (using official gridded EMEP EC emissions) calculated with the Local Fractions method. 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

Primary Particulate Matter

- $PPM_{2.5}$. Effect of a 15% reduction in PPM emissions. Units: ng/m^3

Table C.1: 2020 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	1	0	1	0	0	0	0	0	0	0	1	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	5	AL
AM	0	12	0	17	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	AM
AT	0	0	21	0	1	0	0	0	1	0	9	23	0	0	1	0	3	1	0	0	0	1	0	0	3	0	0	0	0	0	0	1	AT
AZ	0	3	0	122	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	11	0	0	0	0	0	AZ
BA	0	0	1	0	62	0	1	0	0	0	2	2	0	0	1	0	1	0	0	0	1	1	0	0	4	0	1	0	0	0	0	14	BA
BE	0	0	0	0	0	21	0	0	0	0	0	8	0	0	1	0	11	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BE
BG	1	0	0	0	4	0	116	1	0	0	1	2	0	0	0	0	0	0	0	8	0	1	0	0	2	0	2	0	0	0	0	9	BG
BY	0	0	1	1	2	1	3	113	0	0	9	19	1	1	1	1	2	2	0	1	0	1	0	0	1	0	10	2	0	0	1	4	BY
CH	0	0	0	0	0	0	0	0	7	0	0	4	0	0	1	0	5	1	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	5	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	1	1	0	0	0	0	91	30	0	0	1	0	3	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	CZ
DE	0	0	5	0	1	18	0	1	3	0	27	433	1	0	5	0	35	21	0	0	0	0	1	0	1	0	1	0	1	0	0	0	DE
DK	0	0	0	0	0	1	0	0	0	0	1	12	8	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	0	0	0	3	0	0	1	4	0	5	0	1	1	1	0	0	0	0	0	0	0	0	1	2	0	1	0	0	EE
ES	0	0	0	0	1	0	0	0	0	0	1	3	0	0	214	0	5	1	0	0	0	0	0	0	3	0	0	0	0	0	0	1	ES
FI	0	0	0	0	1	1	1	5	0	0	4	14	1	5	1	47	2	3	0	0	0	0	0	0	0	0	4	2	0	1	0	1	FI
FR	0	0	1	0	1	7	1	0	2	0	3	31	0	0	54	0	180	17	0	0	0	0	1	0	8	0	0	0	1	0	0	1	FR
GB	0	0	0	0	0	3	0	0	0	0	1	12	0	0	3	0	8	225	0	0	0	0	6	1	0	0	0	0	0	0	0	0	GB
GE	0	3	0	25	0	0	1	0	0	0	0	0	0	0	0	0	0	0	59	0	0	0	0	0	0	0	4	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	1	0	0	0	0	0	GL
GR	1	0	0	0	2	0	15	0	0	0	1	1	0	0	1	0	1	0	0	65	0	0	0	0	4	0	2	0	0	0	0	6	GR
HR	0	0	1	0	10	0	1	0	0	0	3	3	0	0	2	0	2	0	0	0	10	2	0	0	7	0	0	0	0	0	0	4	HR
HU	0	0	2	0	8	0	2	1	0	0	6	6	0	0	1	0	1	0	0	1	2	31	0	0	3	0	1	0	0	0	0	8	HU
IE	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	1	8	0	0	0	0	19	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	1	0	0	0	0	0	49	0	0	0	0	0	0	0	0	IS
IT	1	0	2	0	6	0	2	0	1	0	3	5	0	0	11	0	12	1	0	1	3	1	0	0	138	0	1	0	0	0	0	8	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	76	127	0	0	0	0	0	KG
KZ	0	2	0	28	1	0	3	6	0	0	2	5	0	1	0	1	1	1	4	1	0	1	0	0	1	52	4093	1	0	0	0	3	KZ
LT	0	0	0	0	0	1	0	12	0	0	3	10	1	0	0	0	1	2	0	0	0	0	0	0	0	0	1	13	0	1	0	1	LT
LU	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	LU
LV	0	0	0	0	0	0	0	7	0	0	2	8	1	1	0	1	1	2	0	0	0	0	0	0	0	0	1	8	0	7	0	1	LV
MD	0	0	0	0	1	0	2	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	6	1	MD
ME	1	0	0	0	3	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	36	ME
MK	1	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	0	1	0	0	0	0	2	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	16	0	0	0	0	0	17	0	0	1	0	8	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	1	0	1	0	0	2	10	2	0	1	1	2	11	0	0	0	0	1	2	0	0	3	0	0	0	0	1	NO
PL	0	0	2	0	4	2	2	15	1	0	48	101	2	1	1	1	6	6	0	0	1	4	0	0	2	0	3	2	0	0	0	4	PL
PT	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	0	0	0	0	0	0	PT
RO	1	0	1	0	11	0	31	2	0	0	5	7	0	0	1	0	1	0	0	5	1	7	0	0	4	0	4	0	0	0	2	19	RO
RS	1	0	1	0	19	0	7	1	0	0	2	3	0	0	1	0	1	0	0	3	1	4	0	0	3	0	2	0	0	0	0	46	RS
RU	1	4	2	62	10	4	22	102	0	1	32	79	4	29	3	31	9	16	17	10	1	6	1	2	4	7	3417	12	0	4	2	21	RU
SE	0	0	0	0	1	3	1	4	0	0	5	32	6	1	1	6	5	11	0	0	0	0	0	1	0	0	5	2	0	0	0	2	SE
SI	0	0	1	0	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	2	0	0	0	4	0	0	0	0	0	0	1	SI
SK	0	0	1	0	3	0	1	0	0	0	8	6	0	0	0	0	1	0	0	0	1	5	0	0	1	0	0	0	0	0	0	3	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	3	25	0	-0	0	0	0	TJ
TM	0	1	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	68	0	0	0	0	0	TM
TR	1	4	0	6	2	0	14	2	0	7	1	2	0	0	2	0	1	0	4	18	0	0	0	0	4	0	3	0	0	0	0	6	TR
UA	1	0	2	6	8	1	19	27	0	0	14	24	1	1	1	1	2	2	3	7	1	6	0	0	3	0	31	1	0	0	4	14	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	125	0	0	0	0	0	UZ
ATL	0	0	1	1	1	10	1	6	0	0	8	54	2	3	116	9	36	131	0	0	0	1	19	176	3	0	76	1	0	0	0	3	ATL
BAS	0	0	1	0	2	4	2	11	0	0	16	75	9	6	2	14	8	13	0	1	0	1	0	1	1	0	7	6	0	2	0	3	BAS
BLS	0	1	1	8	5	0	27	5	0	1	3	6	0	0	1	0	1	1	16	8	0	1	0	0	2	0	12	0	0	0	2	10	BLS
MED	7	0	2	1	30	1	41	2	1	22	7	13	0	0	92	0	39	3	1	112	5	2	0	0	164	0	3	0	0	0	1	57	MED
NOS	0	0	1	0	1	19	1	1	0	0	8	75	6	0	8	1	52	176	0	0	0	0	4	6	1	0	2	0	0	0	0	1	NOS
AST	0	3	0	103	1	0	2	1	0	6	1	1	0	0	1	0	0	0	6	4	0	0	0	0	1	18	568	0	0	0	0	2	AST
NOA	0	0	0	0	2	0	2	0	0	0	1	2	0	0	19	0	4	1	0	4	0	0	0	0	9	0	0	0	0	0	0	3	NOA
SUM	32	34	54	397	208	120	325	332	19	45	333	1149	46	54	558	115	453	676	123	261	32	81	53	242	391	168	8618	55	4	17	20	302	SUM
EXC	23	29	49	284	166	85	249	306	18	15	290	923	28	45	319	91	313	351	100	132	26	76	29	59	211	151	7951	46	3	15	17	223	EXC
EU	4	0	42	2	55	74	174	53	9	5	222	760	20	14	304	56	281	92	1	83	21	55	22	3	182	0	27	30	3	10	3	68	EU
emis	32	32	53	387	209	121	348	341	19	59	333	1163	46	56	585	116	454	681	120	308	31	82	54	257	409	166	10747	55	4	18	20	331	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.: 2020 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	15	0	0	0	1	0	0	14	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	6	4	3	34	111	61	9	AL
AM	0	-0	0	0	0	0	0	0	1	0	0	0	0	0	38	0	0	0	0	0	0	0	74	1	5	1	4	157	72	0	AM
AT	1	-0	0	0	10	0	1	10	1	0	2	1	0	0	1	1	0	0	0	0	1	0	0	1	9	2	3	108	92	74	AT
AZ	0	-0	0	0	0	0	0	1	9	0	0	0	0	3	37	3	1	0	0	0	0	0	155	1	7	1	5	369	199	1	AZ
BA	1	0	0	0	6	0	2	56	1	0	0	1	0	0	3	1	0	0	0	0	2	0	1	5	6	3	22	202	164	24	BA
BE	0	-0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	4	3	0	58	48	44	BE
BG	27	0	0	0	6	0	18	106	4	0	0	1	0	0	57	9	0	0	0	1	2	0	2	5	9	5	29	429	377	156	BG
BY	3	-0	1	0	102	0	6	35	28	1	0	2	0	0	40	53	0	0	0	0	1	0	5	4	17	6	14	496	447	154	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	1	6	1	1	32	23	14	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	0	0	10	2	1	1	2	40	24	5	CY
CZ	1	-0	0	0	39	0	1	13	1	0	1	2	0	0	1	1	0	0	0	0	0	0	0	1	7	2	1	205	193	174	CZ
DE	0	-0	15	0	47	1	0	5	2	0	0	1	0	0	1	2	0	2	1	0	1	4	0	4	37	23	2	702	628	591	DE
DK	0	-0	2	0	6	0	0	2	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0	4	7	0	58	43	34	DK
EE	0	-0	0	0	12	0	0	2	4	1	0	0	0	0	2	3	0	0	1	0	0	0	0	0	4	3	1	56	47	30	EE
ES	1	0	0	0	2	15	0	4	0	0	0	0	0	0	1	0	0	11	0	0	18	0	0	101	67	37	14	504	255	244	ES
FI	1	-0	1	2	27	0	1	8	49	7	0	0	0	0	9	11	0	1	2	0	0	1	1	1	21	14	3	253	209	115	FI
FR	1	0	3	0	5	4	1	7	1	0	0	0	0	0	1	1	0	10	0	0	12	5	0	34	73	62	14	544	335	300	FR
GB	0	0	3	0	4	1	0	1	0	0	0	0	0	0	0	0	-0	7	0	0	0	5	0	2	34	58	0	378	271	43	GB
GE	1	0	0	0	1	0	1	3	7	0	0	0	0	1	144	4	0	0	0	1	0	0	101	3	10	4	12	385	255	3	GE
GL	0	-0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	42	3	0	48	3	0	GL
GR	35	0	0	0	4	0	3	43	4	0	0	0	0	0	102	6	0	0	0	1	9	0	2	17	14	15	75	430	298	95	GR
HR	1	0	0	0	6	0	2	44	1	0	1	1	-0	0	2	1	0	0	0	0	4	0	0	6	7	4	22	147	104	40	HR
HU	4	-0	0	0	22	0	10	109	1	0	1	7	0	0	3	3	0	0	0	0	1	0	0	3	7	2	14	261	233	95	HU
IE	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	13	23	0	71	32	24	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	20	19	0	92	52	1	IS
IT	7	0	0	0	7	1	2	33	2	0	2	1	0	0	6	3	0	1	0	0	26	0	1	48	38	35	256	666	259	190	IT
KG	0	-0	0	0	0	0	0	0	4	0	-0	0	39	12	11	1	304	0	0	0	0	0	110	0	21	0	2	709	575	0	KG
KZ	4	-0	0	0	22	0	4	16	421	0	0	1	24	75	148	91	449	0	0	1	1	0	726	7	123	7	37	6367	5465	45	KZ
LT	1	-0	1	0	41	0	1	6	5	0	0	1	0	0	5	6	0	0	0	0	0	0	0	1	5	4	2	125	113	73	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	3	3	2	LU
LV	0	-0	0	0	25	0	1	4	5	1	0	0	0	0	4	5	0	0	1	0	0	0	0	1	5	4	2	101	87	56	LV
MD	1	0	0	0	4	0	5	8	2	0	0	0	0	0	22	9	0	0	0	0	0	0	1	1	2	1	5	78	66	14	MD
ME	1	0	0	0	1	0	0	13	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	3	2	1	15	85	62	5	ME
MK	69	0	0	0	1	0	1	23	1	0	0	0	0	0	5	1	0	0	0	0	0	0	0	2	2	1	12	132	115	11	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	0	0	MT
NL	0	-0	22	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	4	7	0	89	74	66	NL
NO	1	0	1	25	13	0	1	5	20	2	0	0	0	0	5	3	0	4	1	0	0	4	1	1	41	64	3	236	117	39	NO
PL	3	-0	2	0	904	0	5	48	9	1	1	6	0	0	9	16	0	0	1	0	1	0	1	2	23	12	9	1264	1214	1095	PL
PT	0	0	0	0	0	46	0	0	0	0	0	0	0	0	0	0	0	6	0	0	1	0	0	9	11	12	1	96	55	54	PT
RO	23	0	0	0	27	0	159	202	7	0	1	3	0	0	84	21	0	0	0	1	3	0	4	10	19	7	49	725	632	255	RO
RS	34	0	0	0	9	0	10	489	2	0	0	1	0	0	7	3	0	0	0	0	1	-0	1	5	8	2	25	693	651	46	RS
RU	30	0	4	5	279	1	28	135	4379	11	1	7	5	40	846	618	75	4	5	7	7	3	549	32	545	134	149	11814	10378	584	RU
SE	2	-0	3	6	43	0	2	10	18	28	0	1	0	0	9	9	0	1	4	0	0	2	1	1	31	27	4	287	216	139	SE
SI	0	0	0	0	2	0	0	7	0	0	6	0	0	0	0	0	0	0	0	0	1	0	0	2	2	1	4	41	30	20	SI
SK	2	-0	0	0	33	0	3	41	1	0	1	18	0	0	1	2	0	0	0	0	0	0	0	1	4	1	4	145	134	80	SK
TJ	0	-0	0	0	0	0	0	0	2	0	-0	0	91	13	6	0	78	0	0	0	0	0	85	0	14	0	2	320	218	0	TJ
TM	0	-0	0	0	1	0	0	1	12	0	0	0	6	151	30	4	59	0	0	0	0	0	411	2	23	1	7	787	344	2	TM
TR	17	0	0	0	6	0	6	41	20	0	0	0	0	1	3881	28	0	0	0	4	18	0	1038	72	86	39	199	5536	4080	63	TR
UA	19	0	1	0	132	0	33	118	105	0	1	5	0	2	289	480	1	0	0	4	4	0	36	13	40	16	60	1541	1367	256	UA
UZ	0	-0	0	0	1	0	0	1	13	0	0	0	36	51	22	4	495	0	0	0	0	0	236	2	21	1	5	1032	768	2	UZ
ATL	3	0	7	25	42	73	2	14	438	7	0	1	0	0	18	18	0	310	2	0	13	19	3	160	2782	4655	20	9271	1308	397	ATL
BAS	3	0	4	2	142	0	3	22	22	15	0	2	0	0	13	18	0	1	21	0	1	3	1	2	29	52	5	546	431	314	BAS
BLS	19	0	0	0	22	0	22	73	90	0	0	1	0	1	1011	151	1	0	0	35	6	0	102	13	28	109	60	1856	1502	98	BLS
MED	85	0	1	0	26	6	15	185	14	0	2	2	0	0	1824	33	0	7	0	4	444	1	516	853	239	779	1297	6940	2799	551	MED
NOS	2	0	25	11	31	1	1	11	3	2	0	1	0	0	6	4	0	11	1	0	1	58	1	5	98	366	4	1005	461	237	NOS
AST	4	0	0	0	5	0	2	9	81	0	0	0	31	127	569	33	141	0	0	1	7	0	10415	120	687	19	87	13058	1722	25	AST
NOA	4	0	0	0	2	5	1	10	1	0	0	0	0	0	49	3	0	6	0	0	22	0	11	1006	156	46	74	1446	124	51	NOA
SUM	430	1	99	79	2126	155	355	1991	5790	76	21	67	232	478	9346	1667	1607	389	44	62	616	113	14604	2574	5516	6705	2674	73130			SUM
EXC	310	0	62	41	1854	70	308	1667	5141	53	18	61	200	349	5857	1407	1465	54	20	21	122	32	3554	415	1497	679	1126		31486	5371	EXC
EU	111	0	52	10	1269	68	211	707	114	38	15	43	0	0	319	102	0	37	12	3	82	19	24	251	418	315	513		5734	4053	EU
emis	467	1	98	78	2159	191	355	2091	6440	76	20	67	214	577	10847	1749	1661	453	44	65	723	113	27065	5770	0	15015	4717	98690	44726	7262	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: 2020 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	16	0	0	0	1	0	1	0	0	0	0	1	0	0	3	0	1	0	0	3	1	1	0	0	10	0	0	0	0	0	0	1	AL
AM	0	27	0	34	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	0	AM
AT	0	0	96	0	1	2	0	0	9	0	16	69	1	0	3	0	17	4	0	0	3	4	0	0	25	0	0	0	1	0	0	0	AT
AZ	0	11	0	247	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	3	0	0	0	0	0	AZ
BA	1	0	5	0	31	0	1	0	1	0	4	7	0	0	4	0	4	1	0	1	7	7	0	0	20	0	0	0	0	0	0	1	BA
BE	0	0	0	0	0	34	0	0	0	0	0	17	0	0	2	0	30	12	0	0	0	0	1	0	1	0	0	0	1	0	0	0	BE
BG	2	0	3	0	2	0	76	2	0	0	3	7	0	0	2	0	2	1	0	17	1	5	0	0	7	0	0	0	0	0	2	0	BG
BY	0	0	5	2	1	4	2	107	1	0	14	57	5	1	3	2	11	11	1	2	2	8	1	0	7	0	2	11	1	3	4	0	BY
CH	0	0	2	0	0	1	0	0	39	0	0	16	0	0	3	0	24	3	0	0	0	0	0	0	12	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	3	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	1	4	0	1	4	0	84	84	1	0	2	0	17	6	0	0	2	7	0	0	6	0	0	0	1	0	0	0	CZ
DE	0	0	28	0	0	64	0	1	25	0	34	771	8	0	18	1	173	86	0	0	1	3	5	0	13	0	0	1	12	0	0	0	DE
DK	0	0	1	0	0	5	0	0	0	0	1	28	18	0	1	0	9	22	0	0	0	0	1	0	1	0	0	0	0	0	0	0	DK
EE	0	0	1	0	0	1	0	4	0	0	2	14	2	6	1	3	3	5	0	0	0	1	0	0	1	0	0	4	0	4	0	0	EE
ES	0	0	1	0	0	2	0	0	1	0	1	8	0	0	600	0	31	6	0	0	1	1	1	0	12	0	0	0	0	0	0	0	ES
FI	0	0	2	0	0	5	1	11	1	0	5	43	9	8	2	82	11	18	0	0	0	2	1	0	1	0	1	7	1	6	0	0	FI
FR	0	0	6	0	1	29	0	0	17	0	4	103	2	0	155	0	618	74	0	0	1	2	9	0	42	0	0	0	5	0	0	0	FR
GB	0	0	1	0	0	11	0	0	1	-0	1	33	3	0	9	0	33	312	0	0	0	0	30	0	2	0	0	0	1	0	0	0	GB
GE	0	11	0	70	0	0	0	0	0	0	0	1	0	0	0	0	0	0	46	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	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	4	0	1	1	1	0	14	1	0	0	1	4	0	0	4	0	3	1	0	109	1	2	0	0	12	0	0	0	0	0	1	0	GR
HR	1	0	11	0	10	1	1	0	1	0	6	12	0	0	6	0	7	1	0	1	24	10	0	0	41	0	0	0	0	0	0	0	HR
HU	1	0	19	0	6	1	3	1	2	0	13	24	0	0	3	0	7	2	0	1	8	71	0	0	21	0	0	0	0	0	0	0	HU
IE	0	0	0	0	0	1	0	0	0	0	0	4	0	0	2	0	5	20	0	0	0	0	36	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	0	0	1	4	0	0	0	0	1	7	0	-0	0	0	0	0	0	-0	IS
IT	2	0	18	0	5	2	2	0	11	0	5	23	1	0	48	0	55	5	0	2	10	5	1	0	592	0	0	0	0	0	0	1	IT
KG	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	68	23	0	0	0	0	0	KG
KZ	0	10	2	72	1	1	2	14	1	0	3	16	2	1	3	4	4	7	6	2	1	2	1	0	5	53	706	3	0	2	2	0	KZ
LT	0	0	2	0	0	3	0	10	0	0	5	29	4	1	1	1	5	8	0	0	0	2	1	0	2	0	0	20	0	3	0	0	LT
LU	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	LU
LV	0	0	1	0	0	2	0	9	0	0	4	24	4	2	1	2	4	9	0	0	0	1	1	0	1	0	0	10	0	13	0	0	LV
MD	0	0	1	1	0	0	2	1	0	0	1	3	0	0	0	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	12	0	MD
ME	2	0	0	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1	0	1	0	0	6	0	0	0	0	0	0	4	ME
MK	2	0	1	0	1	0	2	0	0	0	0	1	0	0	1	0	1	0	0	8	0	1	0	0	3	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	0	0	0	16	0	0	0	0	1	24	1	0	2	0	20	26	0	0	0	0	2	0	0	0	0	0	0	0	0	0	NL
NO	0	0	1	0	0	7	0	2	0	0	3	36	14	1	3	4	13	52	0	0	0	1	5	1	1	0	0	1	0	1	0	0	NO
PL	0	0	21	0	3	16	2	16	5	0	68	234	10	1	6	2	40	34	0	1	4	20	2	0	14	0	0	8	2	3	1	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	32	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	PT
RO	2	0	10	1	7	2	30	4	1	0	10	25	1	0	4	0	8	3	1	12	5	26	0	0	21	0	1	1	0	0	8	1	RO
RS	4	0	6	0	10	1	8	1	1	0	5	11	0	0	4	0	4	1	0	5	5	14	0	0	15	0	0	0	0	0	0	2	RS
RU	2	17	19	149	5	22	14	203	5	1	41	226	33	30	17	103	53	88	25	18	5	24	7	1	30	6	631	51	2	34	13	1	RU
SE	0	0	3	0	1	14	1	6	1	0	8	108	34	2	4	18	27	54	0	1	1	3	4	0	2	0	1	5	1	3	1	0	SE
SI	0	0	10	0	1	0	0	0	1	0	2	5	0	0	2	0	3	0	0	0	5	2	0	0	22	0	0	0	0	0	0	0	SI
SK	0	0	9	0	2	1	1	1	1	0	12	19	0	0	1	0	5	2	0	0	3	19	0	0	8	0	0	0	0	0	0	0	SK
TJ	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	3	5	0	0	0	0	0	TJ
TM	0	3	0	25	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	1	20	0	0	0	0	0	TM
TR	2	15	2	19	1	1	11	3	1	4	2	7	0	0	7	0	5	2	5	43	1	2	0	0	13	0	1	1	0	0	2	0	TR
UA	2	2	13	15	5	5	15	54	3	0	23	75	4	1	5	2	16	14	5	14	5	24	1	0	20	0	9	5	1	2	19	1	UA
UZ	0	2	0	12	0	0	0	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	0	0	0	12	34	0	0	0	0	0	UZ
ATL	0	0	5	1	1	49	1	12	4	-0	11	185	25	4	267	38	207	457	0	1	1	3	109	34	14	0	9	6	4	4	1	0	ATL
BAS	0	0	7	0	1	21	1	15	3	0	22	197	33	7	6	23	42	66	0	1	1	6	4	0	4	0	1	14	2	9	1	0	BAS
BLS	1	4	5	21	2	1	22	11	1	1	5	19	1	0	3	1	6	4	23	18	2	6	0	0	10	0	2	2	0	1	8	0	BLS
MED	24	0	25	2	24	7	36	5	9	13	14	59	2	0	366	1	189	22	1	249	29	17	3	0	573	0	1	1	1	1	4	5	MED
NOS	0	0	6	0	1	49	1	2	3	0	11	180	34	0	28	2	138	543	0	0	1	3	41	2	7	0	0	1	3	1	0	0	NOS
AST	1	16	1	221	1	0	2	4	1	5	1	6	1	0	4	1	3	2	10	12	0	1	0	0	6	20	109	1	0	0	1	0	AST
NOA	1	0	2	0	2	1	3	0	1	0	1	7	0	0	76	0	19	3	0	16	1	2	0	0	32	0	0	0	0	0	0	0	NOA
SUM	72	119	374	901	132	389	254	506	157	27	452	2827	256	67	1715	295	1883	1993	142	547	133	310	268	47	1638	162	1563	155	47	92	84	20	SUM
EXC	44	98	323	654	101	261	189	457	134	9	387	2174	160	55	966	229	1281	896	106	250	98	273	111	11	993	142	1440	131	35	76	69	14	EXC
EU	13	1	265	4	42	207	131	68	81	3	287	1680	97	21	902	112	1107	399	2	148	71	186	66	1	846	0	5	58	30	33	16	4	EU
emis	79	121	378	913	140	410	279	543	162	35	468	2980	271	72	1927	321	2008	2120	143	675	139	326	289	59	1737	170	1967	164	49	98	94	21	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.: 2020 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	2	0	0	0	1	0	1	9	0	0	0	0	0	0	1	1	0	0	0	0	11	0	0	5	2	-0	0	74	55	24	AL
AM	0	0	0	0	0	0	0	0	1	0	0	0	0	1	9	0	0	0	0	0	1	0	46	0	2	-0	0	126	76	1	AM
AT	0	0	3	0	10	0	1	2	1	0	5	2	0	0	0	1	0	1	1	0	4	5	0	1	2	-0	0	296	281	261	AT
AZ	0	0	0	0	0	0	0	0	14	0	0	0	0	7	10	2	1	0	0	0	1	0	126	1	3	-0	0	438	307	2	AZ
BA	0	0	1	0	6	0	2	15	1	0	1	2	0	0	1	1	0	1	1	0	11	1	0	4	3	-0	-0	147	126	73	BA
BE	0	0	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	1	20	0	0	3	0	0	138	110	97	BE
BG	3	0	1	0	8	0	30	33	7	0	1	2	0	0	24	15	0	0	1	5	13	1	1	4	4	-0	0	287	259	165	BG
BY	0	0	7	2	104	0	13	7	61	4	1	5	0	1	9	79	0	2	16	2	4	15	3	3	7	-0	0	614	562	272	BY
CH	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	2	0	1	2	-0	0	113	104	61	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	3	0	5	1	0	-0	-0	21	11	4	CY
CZ	0	0	5	0	36	0	2	4	1	1	2	6	0	0	0	2	0	2	3	0	2	8	0	1	2	-0	0	320	302	283	CZ
DE	0	0	84	3	38	2	1	1	4	4	1	2	0	0	0	3	0	18	22	0	7	122	0	3	19	0	0	1580	1389	1264	DE
DK	0	0	12	1	6	0	0	0	1	2	0	0	0	0	0	1	0	3	12	0	0	30	0	0	2	0	0	162	114	87	DK
EE	0	0	3	2	14	0	1	0	11	5	0	1	0	0	1	4	0	1	17	0	0	7	0	0	1	0	0	120	94	66	EE
ES	0	0	2	0	1	51	1	1	1	0	0	0	0	0	0	1	0	70	0	0	120	5	0	68	44	-0	-0	1034	726	714	ES
FI	0	0	8	12	31	0	2	1	82	29	0	1	0	0	2	11	0	7	59	0	1	25	0	0	11	-0	-0	502	398	258	FI
FR	0	0	24	2	5	14	2	2	2	1	1	1	0	0	0	2	0	70	3	0	72	93	0	28	44	-0	0	1436	1126	1026	FR
GB	0	0	20	3	3	2	0	0	1	1	0	0	0	0	0	0	0	42	4	0	2	98	0	1	25	0	0	640	468	150	GB
GE	0	0	0	0	0	0	1	0	9	0	0	0	0	2	32	3	0	0	0	2	2	0	47	1	4	-0	0	238	181	5	GE
GL	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	-0	-0	36	4	1	GL
GR	6	0	0	0	4	0	7	15	6	0	0	1	0	0	40	8	0	1	0	4	57	1	1	13	8	-0	0	336	252	166	GR
HR	0	0	1	0	7	0	3	12	1	0	4	3	0	0	0	2	0	1	1	0	22	1	0	6	3	-0	0	201	167	138	HR
HU	1	0	2	0	29	0	17	28	2	0	4	16	0	0	1	6	0	1	1	0	8	3	0	3	3	-0	0	310	291	240	HU
IE	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	8	0	0	9	-0	0	101	73	53	IE
IS	0	0	1	1	0	0	0	0	0	0	0	0	-0	0	0	0	0	3	0	0	0	2	-0	0	12	-0	-0	34	17	4	IS
IT	1	1	2	0	7	4	4	9	3	0	10	2	0	0	2	3	0	6	1	0	165	4	1	46	23	-0	0	1082	835	793	IT
KG	0	0	0	0	0	0	0	0	5	0	0	0	22	8	2	0	168	0	0	0	0	0	92	0	9	-0	0	402	300	1	KG
KZ	0	0	3	4	23	0	8	3	717	4	0	2	16	91	36	66	234	4	9	4	5	8	672	5	79	-0	0	2918	2133	96	KZ
LT	0	0	5	1	40	0	2	1	11	3	0	2	0	0	1	9	0	1	14	0	1	10	0	0	2	0	0	203	174	131	LT
LU	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	10	9	9	LU
LV	0	0	5	2	28	0	1	1	14	5	0	1	0	0	1	7	0	1	18	0	1	11	0	0	2	0	0	190	155	111	LV
MD	0	0	0	0	5	0	9	2	4	0	0	1	0	0	6	16	0	0	0	2	2	1	1	1	1	-0	0	79	71	27	MD
ME	0	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	2	1	-0	0	36	26	13	ME
MK	12	0	0	0	1	0	1	13	1	0	0	0	0	0	2	1	0	0	0	0	3	0	0	1	1	-0	0	59	53	21	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	0	0	MT
NL	0	0	57	0	1	0	0	0	0	0	0	0	0	0	0	0	0	4	1	0	0	42	0	0	4	0	-0	205	153	125	NL
NO	0	0	13	74	12	0	1	1	12	15	0	1	0	0	1	4	0	20	19	0	1	74	0	0	23	-0	-0	420	281	134	NO
PL	0	0	25	3	492	1	12	11	20	6	3	21	0	0	2	29	0	6	38	0	6	44	1	2	8	-0	0	1244	1140	1013	PL
PT	0	0	0	0	0	81	0	0	0	0	0	0	0	0	0	0	0	39	0	0	8	1	0	5	9	-0	-0	182	120	119	PT
RO	3	0	2	1	34	0	217	48	13	1	2	8	0	0	29	45	0	1	2	7	18	4	1	8	7	-0	0	636	587	420	RO
RS	5	0	1	0	11	0	15	127	4	0	1	4	0	0	2	5	0	1	1	1	9	1	0	4	4	-0	-0	295	274	111	RS
RU	3	0	42	43	274	2	53	24	5926	63	4	17	3	61	189	507	56	44	170	33	35	108	390	20	313	-1	0	10253	9141	1183	RU
SE	0	0	27	32	44	0	4	2	29	85	0	2	0	0	2	11	0	13	88	0	2	81	1	1	17	-0	0	742	540	399	SE
SI	0	0	0	0	2	0	1	2	1	0	14	1	0	0	0	1	0	0	0	0	7	1	0	1	1	-0	0	84	74	69	SI
SK	0	0	1	0	34	0	6	10	1	0	2	26	0	0	0	4	0	1	1	0	3	2	0	1	1	-0	0	181	172	149	SK
TJ	0	0	0	0	0	0	0	0	2	0	0	0	42	10	1	0	46	0	0	0	0	0	74	0	6	-0	0	193	113	1	TJ
TM	0	0	0	0	1	0	0	0	23	0	0	0	4	196	8	3	60	0	0	0	1	0	441	1	11	-0	0	808	353	6	TM
TR	2	0	1	0	7	1	12	10	36	0	0	1	0	1	851	29	0	2	1	27	110	2	443	35	46	-0	0	1767	1101	121	TR
UA	2	0	9	3	143	0	69	26	164	3	3	14	0	4	86	516	2	4	13	26	24	18	22	10	18	-0	0	1539	1405	475	UA
UZ	0	0	0	0	1	0	0	0	25	0	0	0	22	50	6	4	252	0	0	0	1	0	220	1	14	-0	0	664	427	6	UZ
ATL	0	0	80	143	40	125	4	2	306	37	1	2	-0	1	3	18	0	971	52	1	81	335	2	70	1754	4	0	5486	2217	1224	ATL
BAS	0	0	38	14	112	1	6	4	45	45	1	5	0	0	3	22	0	11	153	1	4	91	1	2	8	1	-0	1056	787	610	BAS
BLS	2	0	2	1	25	0	44	17	145	1	1	3	0	1	253	148	1	1	4	90	34	5	43	8	6	0	0	1016	825	178	BLS
MED	11	9	8	2	29	22	33	60	27	2	10	6	0	0	504	40	0	52	5	23	1635	21	240	614	106	1	3	5146	2445	1704	MED
NOS	0	0	93	61	29	4	2	2	6	13	1	2	0	0	1	5	0	83	35	0	6	459	0	3	56	3	-0	1924	1277	649	NOS
AST	1	0	1	1	6	0	4	3	129	1	0	1	24	187	176	24	97	2	2	4	57	2	8635	56	414	-0	0	10255	1083	57	AST
NOA	1	1	1	0	3	13	3	4	3	0	1	1	0	0	20	3	0	55	0	1	201	2	15	790	123	-0	-0	1411	224	184	NOA
SUM	57	12	601	417	1713	331	595	520	7882	335	76	163	133	622	2325	1659	919	1561	772	237	2771	1776	11526	1835	3315	7	5	59790			SUM
EXC	42	2	379	193	1467	164	499	428	7221	235	62	144	109	433	1365	1399	820	386	521	117	753	861	2590	291	848	-1	1		27128	10951	EXC
EU	15	1	280	62	873	157	312	184	213	143	51	96	0	1	112	163	1	260	286	18	523	529	12	194	230	-0	0		9551	8163	EU
emis	61	15	641	450	1808	411	622	545	9457	359	77	171	145	779	2752	1763	1018	2027	798	252	3312	1847	20714	3616	0			72800	40232	16731	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: 2020 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	68	0	0	0	1	0	1	0	0	0	0	1	0	0	5	0	1	0	0	3	1	1	0	0	11	0	0	0	0	0	0	1	AL
AM	0	48	0	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	271	0	1	2	0	0	22	0	25	114	1	0	5	0	26	2	0	0	4	8	0	0	43	0	0	0	1	0	0	0	AT
AZ	0	16	0	284	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	1	0	0	0	0	0	AZ
BA	1	0	4	0	76	0	1	0	1	0	4	7	1	0	6	0	3	0	0	0	20	14	0	0	30	0	0	0	0	0	0	1	BA
BE	0	0	0	0	0	149	0	0	1	0	1	19	0	0	4	0	87	9	0	0	0	0	2	0	1	-0	0	0	4	0	0	0	BE
BG	3	0	2	0	3	0	147	2	1	0	2	6	0	0	3	0	2	0	0	18	3	8	0	0	9	0	-0	0	0	0	3	0	BG
BY	1	0	5	1	2	3	2	418	2	0	12	51	7	1	4	1	15	5	1	2	3	11	1	0	10	0	2	25	0	4	6	0	BY
CH	0	0	3	0	0	1	0	0	227	0	1	25	0	0	6	0	39	1	0	0	0	0	0	0	20	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	14	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	24	0	1	4	0	1	6	0	228	102	3	0	3	0	27	3	0	0	4	10	1	0	8	0	0	1	1	0	0	0	CZ
DE	0	0	41	0	0	81	0	3	57	0	32	2114	20	0	27	0	321	52	0	0	1	3	9	0	16	0	0	2	15	0	0	0	DE
DK	0	0	1	0	0	4	0	1	0	0	1	56	161	0	2	0	12	14	0	0	0	0	2	0	0	0	0	0	0	0	0	0	DK
EE	0	0	1	0	0	1	0	5	0	0	2	12	3	30	1	2	3	3	0	0	0	1	0	0	1	0	0	5	0	6	0	0	EE
ES	0	0	2	0	1	2	0	0	3	0	1	9	0	0	1986	0	59	4	0	0	1	1	2	0	20	0	0	0	0	0	0	0	ES
FI	0	0	1	0	0	3	0	9	1	0	4	34	10	5	2	137	13	8	0	0	0	2	2	0	1	0	1	7	0	4	0	0	FI
FR	0	0	8	0	1	41	1	1	44	0	5	97	2	0	290	0	2496	43	0	0	2	3	13	0	77	0	0	0	5	0	0	0	FR
GB	0	0	1	0	0	14	0	0	1	0	2	52	7	0	15	0	83	829	0	0	0	0	104	0	3	-0	0	0	1	0	0	0	GB
GE	0	12	0	53	0	0	0	0	0	0	0	1	0	0	1	0	0	0	148	1	0	0	0	0	1	0	1	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	0	GL
GR	10	0	1	1	1	0	14	1	0	0	1	3	0	0	7	0	2	0	0	191	1	3	0	0	14	0	0	0	0	0	1	0	GR
HR	1	0	10	0	13	0	1	0	1	0	6	10	0	0	10	0	6	1	0	0	89	22	0	0	61	0	0	0	0	0	0	0	HR
HU	1	0	17	0	6	1	3	2	2	0	11	21	1	0	5	0	7	1	0	1	20	235	0	0	32	0	0	1	0	0	1	0	HU
IE	0	-0	0	-0	0	2	0	0	0	0	0	7	0	0	4	0	13	32	-0	0	0	0	402	-0	1	-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	1	3	0	0	0	0	1	14	0	0	0	0	0	0	0	0	IS
IT	3	0	18	0	5	1	2	1	17	0	6	23	1	0	78	0	39	2	0	2	12	9	0	0	1701	0	0	0	0	0	1	0	IT
KG	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	159	18	0	0	0	0	0	KG
KZ	0	8	1	47	1	1	2	14	1	0	2	14	2	1	2	1	2	3	9	1	1	3	1	0	5	51	416	3	0	1	2	0	KZ
LT	0	0	1	0	0	2	0	23	1	0	3	27	6	0	1	1	6	4	0	0	1	2	1	0	2	0	0	111	0	5	1	0	LT
LU	0	0	0	0	0	3	0	0	0	0	0	3	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	8	0	0	-0	LU
LV	0	0	1	0	0	2	0	15	0	0	3	23	5	2	1	1	5	5	0	0	0	1	1	0	1	0	0	25	0	51	0	0	LV
MD	0	0	1	0	0	0	2	1	0	0	1	2	0	0	0	0	1	0	0	1	0	2	0	0	2	0	0	0	0	0	36	0	MD
ME	3	0	0	0	2	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	1	1	0	0	6	0	0	0	0	0	0	9	ME
MK	6	0	0	0	1	0	2	0	0	0	0	1	0	0	1	0	1	0	0	10	0	1	0	0	4	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	0	0	0	48	0	0	0	0	1	66	1	0	3	0	37	20	0	0	0	0	3	0	0	0	0	0	0	0	0	0	NL
NO	0	0	1	0	0	5	0	2	1	0	2	34	20	0	4	2	17	28	0	0	0	1	7	0	1	0	1	1	0	1	0	0	NO
PL	0	0	19	0	3	12	2	31	8	0	64	229	19	1	8	1	57	18	0	1	7	25	3	0	16	0	1	15	1	3	2	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	65	0	4	1	0	0	0	0	0	0	1	-0	0	0	0	0	0	0	PT
RO	3	0	9	1	7	2	31	6	2	0	9	24	1	0	5	0	8	1	1	9	8	53	0	0	30	0	0	1	0	0	15	1	RO
RS	6	0	5	0	13	0	9	1	1	0	5	8	0	0	6	0	3	0	0	5	11	30	0	0	21	0	0	0	0	0	1	2	RS
RU	4	14	15	105	6	14	18	240	6	1	35	201	41	20	21	52	54	40	40	15	7	31	8	0	36	7	234	64	1	32	19	2	RU
SE	0	0	2	0	0	10	1	7	1	0	6	111	61	1	4	10	32	28	0	0	1	2	5	0	2	0	1	6	1	2	1	0	SE
SI	0	0	14	0	1	0	0	0	1	0	3	6	0	0	3	0	3	0	0	0	7	5	0	0	41	0	0	0	0	0	0	0	SI
SK	0	0	10	0	2	1	1	1	2	0	14	19	1	0	2	0	6	1	0	0	6	34	0	0	11	0	0	1	0	0	0	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	3	0	0	0	0	0	TJ
TM	0	2	0	13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0	TM
TR	3	12	2	13	2	0	12	4	1	7	1	6	0	0	12	0	3	0	10	27	1	3	0	0	16	0	1	1	0	0	3	0	TR
UA	3	1	12	10	5	3	17	70	4	0	18	64	6	1	7	1	17	6	7	11	7	39	2	0	29	0	2	9	0	2	33	1	UA
UZ	0	1	0	7	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	24	11	0	0	0	0	0	UZ
ATL	0	0	5	1	1	54	1	10	8	0	11	199	32	2	459	15	588	436	1	1	1	3	361	20	24	0	8	4	4	2	1	0	ATL
BAS	0	0	5	0	1	15	1	18	4	0	15	249	115	9	7	21	47	34	0	0	1	6	6	0	4	0	1	20	1	12	1	0	BAS
BLS	2	3	4	14	3	1	24	13	1	1	4	15	1	0	4	1	4	1	40	12	2	7	0	0	12	0	1	2	0	1	12	0	BLS
MED	37	0	20	1	20	5	29	6	12	19	12	41	2	0	516	0	179	9	2	138	32	24	3	0	608	0	1	1	1	0	6	2	MED
NOS	0	0	4	0	1	70	1	3	4	0	8	287	94	0	38	1	323	479	0	0	1	3	71	1	8	0	1	2	2	1	0	0	NOS
AST	1	10	0	114	0	0	2	3	0	6	1	3	0	0	4	0	1	0	11	4	0	1	0	0	4	26	25	1	0	0	1	0	AST
NOA	2	0	1	0	1	1	2	0	1	0	1	4	0	0	79	0	18	1	0	5	1	2	0	0	28	0	0	0	0	0	0	0	NOA
SUM	160	128	545	696	180	559	330	917	444	52	563	4401	630	76	3721	250	4679	2132	292	463	259	611	1013	36	2972	272	731	311	50	130	148	22	SUM
EXC	117	114	504	566	154	414	270	863	414	25	511	3602	385	64	2614	212	3519	1171	238	302	220	566	571	15	2285	246	695	280	42	114	127	19	EXC
EU	23	1	453	3	46	371	203	109	170	15	427	3133	298	41	2520	154	3279	251	3	225	167	428	447	0	2089	0	4	175	38	73	26	3	EU
emis	168	126	539	658	184	560	352	936	440	68	564	4425	628	77	3955	253	4719	2133	281	524	260	617	1016	36	2986	268	900	315	51	131	154	27	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.: 2020 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	-0	0	0	0	1	0	1	7	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	3	2	0	-0	111	106	27	AL
AM	0	0	0	0	0	0	0	0	2	0	0	0	0	1	60	0	0	0	0	0	0	0	25	1	2	0	-0	171	142	1	AM
AT	0	0	3	0	11	0	2	2	2	0	12	3	0	0	1	2	0	0	0	0	0	0	0	1	3	0	0	570	565	533	AT
AZ	0	0	0	0	0	0	0	0	25	0	0	0	0	5	42	2	3	0	0	0	0	0	62	1	3	0	0	458	393	2	AZ
BA	0	0	0	0	7	0	5	19	2	0	1	3	0	0	2	2	0	0	0	0	0	0	0	3	2	0	0	219	213	108	BA
BE	0	0	23	0	1	0	0	0	0	0	0	0	-0	0	0	0	0	-0	0	0	0	-1	0	0	1	-0	0	300	299	290	BE
BG	6	0	1	0	7	0	65	28	11	0	1	2	0	0	34	16	0	0	0	0	0	0	0	3	4	0	-0	393	386	277	BG
BY	0	0	6	1	131	0	23	8	77	4	1	5	0	1	20	93	1	0	-0	0	0	0	2	2	7	1	1	982	968	329	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	330	327	98	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	-0	0	2	1	0	-0	-0	25	22	15	CY
CZ	0	0	5	0	41	0	2	3	2	1	3	8	-0	0	0	2	0	0	0	0	0	0	0	0	3	0	0	499	495	476	CZ
DE	0	0	176	1	54	2	2	1	4	4	1	2	0	0	1	5	0	0	-1	0	0	-5	0	2	14	1	0	3059	3048	2923	DE
DK	0	0	14	1	7	0	0	0	1	3	0	0	0	0	0	1	0	0	-1	0	0	-1	0	0	2	-0	0	282	282	264	DK
EE	0	0	2	1	14	0	1	1	8	5	0	0	0	0	1	3	0	0	-0	0	0	0	0	0	1	0	0	114	111	89	EE
ES	0	0	2	0	2	59	2	2	1	0	1	0	0	0	0	1	0	-1	0	0	-1	0	0	42	24	-1	-0	2224	2160	2148	ES
FI	0	0	6	4	27	0	3	2	33	21	0	1	0	0	3	8	0	0	0	0	0	1	0	0	9	0	0	366	355	285	FI
FR	0	0	25	0	7	13	4	2	2	1	2	1	0	0	1	2	0	-1	0	0	1	-3	0	18	27	-1	-0	3232	3192	3094	FR
GB	0	0	26	1	6	2	0	0	0	1	0	0	-0	0	0	1	0	-1	0	0	0	-3	0	1	13	-3	0	1157	1150	317	GB
GE	0	0	0	0	1	0	1	1	13	0	0	0	0	2	128	3	1	0	0	0	0	0	26	2	4	0	0	402	369	7	GE
GL	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	28	3	1	GL
GR	6	0	0	0	4	0	12	11	10	0	0	1	0	0	51	8	0	0	0	0	-0	0	1	8	6	-0	-2	372	359	256	GR
HR	0	0	1	0	6	0	5	14	2	0	11	3	0	0	1	2	0	0	0	0	0	0	0	4	3	0	0	287	280	244	HR
HU	1	0	1	0	18	0	33	34	4	0	8	26	0	0	2	8	0	0	0	0	0	0	0	2	3	0	0	509	503	443	HU
IE	0	0	3	0	1	0	0	0	0	0	0	0	-0	-0	0	0	0	-1	0	0	0	-0	-0	0	5	-3	0	468	466	434	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	9	0	0	32	23	5	IS
IT	0	0	1	0	8	4	8	7	4	0	12	2	0	0	4	5	0	0	0	0	-1	0	0	27	15	1	-4	2018	1979	1929	IT
KG	0	0	0	0	0	0	0	0	8	0	0	0	44	7	10	0	198	0	0	0	0	0	130	0	9	0	0	586	447	1	KG
KZ	1	0	2	1	23	0	11	4	724	2	0	1	28	71	104	48	325	0	0	0	0	0	730	5	47	1	1	2722	1939	84	KZ
LT	0	0	5	0	58	0	3	1	15	3	0	1	0	0	3	9	0	0	-0	0	0	0	0	0	2	0	0	301	298	241	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	25	25	25	LU
LV	0	0	4	1	31	0	2	1	12	6	0	1	0	0	2	7	0	0	-0	0	0	1	0	0	2	0	0	216	212	167	LV
MD	0	0	0	0	4	0	22	2	5	0	0	0	0	0	11	21	0	0	-0	-0	0	0	0	1	1	0	0	120	118	39	MD
ME	0	0	0	0	1	0	1	5	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	40	37	16	ME
MK	22	0	0	0	1	0	2	11	2	0	0	0	0	0	3	1	0	0	0	0	0	0	0	1	1	0	-0	73	71	25	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	320	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0	0	0	-3	0	0	1	-0	0	502	504	483	NL
NO	0	0	10	113	13	0	1	1	7	12	0	1	0	0	2	3	0	0	1	0	0	2	0	0	18	0	0	314	292	133	NO
PL	0	0	23	1	1290	0	16	11	23	7	5	19	0	0	5	35	0	0	-0	0	0	1	0	1	9	1	1	1995	1981	1842	PL
PT	0	0	0	0	0	173	0	0	0	0	0	0	-0	0	0	0	0	-1	0	0	0	0	0	3	4	-1	0	254	247	246	PT
RO	2	0	2	0	27	0	608	51	19	1	3	9	0	0	43	55	0	0	0	-0	1	0	1	5	7	0	0	1064	1049	841	RO
RS	3	0	1	0	9	0	32	264	7	0	2	5	0	0	4	6	0	0	0	0	0	0	0	3	3	0	-0	468	462	153	RS
RU	4	0	32	12	310	1	93	34	7712	44	4	15	5	52	453	443	119	1	3	1	2	5	379	19	246	6	4	11383	10716	1166	RU
SE	0	0	23	16	47	0	4	2	17	207	0	1	0	0	3	9	0	0	-0	0	0	2	1	1	12	0	0	641	624	537	SE
SI	0	0	0	0	2	0	1	1	1	0	59	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	154	152	146	SI
SK	0	0	1	0	25	0	9	11	2	0	3	74	0	0	1	5	0	0	0	0	0	0	0	1	2	0	0	248	245	219	SK
TJ	0	0	0	0	0	0	0	0	4	0	0	0	132	7	5	0	67	0	0	0	0	0	99	0	5	0	0	327	224	0	TJ
TM	0	0	0	0	1	0	0	0	27	0	0	0	6	199	21	2	105	0	0	0	0	0	251	1	8	0	-0	643	382	3	TM
TR	2	0	1	0	6	1	19	10	51	0	0	1	0	1	3794	24	1	0	0	-0	-1	0	167	36	33	-1	-5	4280	4050	120	TR
UA	2	0	7	1	134	0	129	26	232	3	3	14	0	4	152	899	6	0	0	0	1	1	13	7	16	1	1	2039	2000	536	UA
UZ	0	0	0	0	1	0	0	0	27	0	0	0	38	34	17	2	583	-0	0	0	0	0	139	1	7	0	0	899	752	4	UZ
ATL	0	0	79	41	46	158	6	5	113	19	1	2	0	1	8	16	1	-8	2	0	1	10	2	37	1362	-21	1	4135	2750	2078	ATL
BAS	0	0	38	7	142	0	7	4	33	78	1	3	0	0	4	18	0	0	-5	0	0	-1	1	1	11	-3	0	933	928	804	BAS
BLS	2	0	2	0	18	0	72	15	204	1	1	2	0	1	501	131	2	0	0	-3	0	0	23	6	11	-3	1	1174	1140	191	BLS
MED	5	8	5	0	24	22	50	38	38	1	11	6	0	0	588	38	0	1	0	0	-21	1	96	364	93	-20	-9	3064	2560	1757	MED
NOS	0	0	176	36	31	3	3	2	6	14	1	1	0	0	2	5	0	0	-1	0	1	-12	0	3	38	-5	0	1710	1686	1145	NOS
AST	0	0	0	0	5	0	4	3	198	0	0	0	39	132	346	16	150	0	0	0	0	0	16221	100	290	0	-4	17724	1115	39	AST
NOA	1	0	1	0	2	12	3	4	2	0	1	1	0	0	21	3	0	-1	0	0	-2	0	4	916	67	-3	-6	1176	201	164	NOA
SUM	61	10	1032	241	2607	459	1272	648	9694	441	150	218	293	517	6459	1964	1567	-8	-0	-1	-15	-2	18378	1634	2496	-45	-19	77820			SUM
EXC	52	1	731	156	2337	262	1127	578	9100	329	135	202	254	383	4989	1738	1412	-0	3	1	6	0	2030	208	625	10	-2		45024	21623	EXC
EU	17	1	644	26	1688	256	782	187	173	261	121	157	0	1	162	186	2	-1	-2	0	2	-6	7	120	161	2	-4		19841	18447	EU
emis	70	12	1024	236	2642	521	1294	681	10308	439	150	219	282	609	7449	2031	1661	0	0	0	0	0	27823	3149	0			88950	57977	28338	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: 2020 country-to-country blame matrices for **MM-AOT40f**.
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	515	0	40	1	83	3	62	15	7	0	33	71	4	1	71	4	94	20	0	132	53	54	5	1	241	0	2	4	1	2	7	AL
AM	1	84	3	497	2	1	5	6	1	2	2	8	1	1	13	3	9	2	105	9	1	2	1	0	12	0	17	1	0	1	2	AM
AT	0	0	469	0	7	11	2	6	88	0	126	527	9	1	42	5	265	36	0	1	23	39	11	1	169	0	1	3	7	2	2	AT
AZ	1	38	2	528	1	1	5	11	1	1	2	9	1	1	8	6	8	5	67	6	1	3	1	0	8	0	48	2	0	2	3	AZ
BA	10	0	97	0	532	6	18	13	11	0	73	152	8	2	63	6	119	26	0	6	167	116	7	1	229	0	2	6	2	3	6	BA
BE	0	0	4	0	0	-197	0	2	5	0	14	111	8	1	33	7	273	87	0	0	0	2	23	2	9	0	1	2	22	1	0	BE
BG	15	0	30	1	34	3	555	35	5	0	34	75	6	2	26	9	51	20	1	105	23	65	5	1	60	0	3	8	1	4	30	BG
BY	1	0	6	1	4	4	5	220	1	0	18	74	10	8	6	22	27	30	1	3	4	12	6	2	11	0	4	33	1	15	10	BY
CH	0	0	52	0	1	8	1	1	519	0	28	340	4	0	87	2	590	29	0	1	3	5	9	1	219	0	0	1	4	1	0	CH
CY	10	1	8	4	10	2	27	13	3	369	6	23	2	1	40	3	32	9	4	267	6	9	2	0	67	0	3	3	0	1	6	CY
CZ	0	0	86	0	6	12	3	17	16	0	289	460	16	2	22	10	162	54	0	1	14	41	13	3	24	0	1	8	7	5	2	CZ
DE	0	0	29	0	1	10	1	7	24	0	56	404	16	2	25	9	204	86	0	0	1	7	20	3	13	0	1	6	11	4	1	DE
DK	0	0	1	0	0	1	1	8	0	0	3	53	8	4	7	24	31	109	0	0	0	2	21	3	2	0	0	10	1	7	1	DK
EE	0	0	1	0	0	2	1	24	0	0	4	40	11	53	2	48	13	32	0	1	0	2	5	2	1	0	1	25	0	34	1	EE
ES	1	0	4	0	2	4	2	1	5	0	3	27	2	0	1099	2	181	27	0	2	3	3	8	1	41	0	0	0	1	0	0	ES
FI	0	0	0	0	0	1	0	4	0	0	1	15	5	5	1	65	5	15	0	0	0	1	2	1	0	0	0	5	0	4	0	FI
FR	1	0	14	0	3	12	2	1	29	0	11	152	4	1	147	3	786	65	0	1	4	5	18	1	63	0	0	1	7	1	0	FR
GB	0	0	1	0	0	2	0	2	1	0	4	55	13	1	10	8	63	53	0	0	0	0	28	3	2	0	0	2	2	1	0	GB
GE	2	49	4	431	2	1	9	15	2	1	3	13	1	1	12	6	11	4	450	11	2	4	1	0	12	0	18	3	0	2	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	66	0	23	2	30	3	199	24	6	0	22	54	4	1	55	6	68	19	1	594	20	35	5	1	144	0	3	5	1	3	16	GR
HR	4	0	168	0	156	7	11	11	14	0	99	222	10	1	58	5	141	30	0	4	368	171	8	1	291	0	2	5	3	3	5	HR
HU	2	0	123	1	35	7	18	26	10	0	115	237	11	3	30	10	101	33	0	5	65	357	8	1	95	0	2	11	3	6	6	HU
IE	0	0	1	0	0	5	0	1	1	0	3	41	7	1	9	6	43	111	0	0	0	0	75	2	1	0	0	1	1	1	0	IE
IS	0	0	0	0	0	1	0	0	0	0	0	3	1	0	0	1	4	15	0	0	0	0	2	5	0	0	0	0	0	0	0	IS
IT	5	0	93	0	32	6	11	5	39	0	40	134	5	1	138	2	287	27	0	8	53	35	8	1	858	0	1	2	2	1	3	IT
KG	0	3	2	15	1	0	2	3	1	0	1	6	0	0	10	1	9	2	4	3	1	1	1	0	6	402	143	1	0	0	1	KG
KZ	0	1	2	10	1	1	2	11	1	0	3	13	2	2	6	8	9	8	2	2	1	2	2	1	4	13	217	3	0	2	1	KZ
LT	1	0	3	1	2	5	5	95	1	0	10	79	21	10	7	30	27	48	0	3	2	7	9	2	6	0	2	117	1	36	4	LT
LU	0	0	9	0	1	81	1	3	6	0	23	289	8	1	45	6	377	94	0	0	1	4	23	2	15	0	1	2	-167	1	0	LU
LV	0	0	1	1	1	3	2	59	1	0	5	53	15	19	4	32	18	37	0	1	1	3	6	2	3	0	1	57	0	64	2	LV
MD	4	1	15	5	10	3	45	74	3	0	24	74	7	4	15	17	37	22	5	20	8	30	5	2	28	0	4	16	1	7	161	MD
ME	75	0	53	1	225	4	33	17	9	0	43	95	6	2	68	6	102	22	0	26	79	73	6	1	217	0	2	6	1	3	7	ME
MK	133	0	36	1	61	3	164	20	7	0	33	75	5	2	64	6	80	20	0	267	31	69	5	1	144	0	2	6	1	3	10	MK
MT	11	0	26	0	31	3	23	6	7	0	17	49	4	1	134	2	187	26	0	32	25	23	7	1	365	0	1	3	1	1	3	MT
NL	0	0	3	0	0	-20	0	4	1	0	15	105	12	1	16	8	96	91	0	0	0	1	23	3	3	0	0	4	3	2	0	NL
NO	0	0	0	0	0	1	0	3	0	0	1	15	9	2	2	15	10	32	0	0	0	0	5	1	1	0	0	2	0	2	0	NO
PL	1	0	16	0	5	6	6	55	4	0	64	204	18	7	14	19	69	56	0	2	7	27	13	3	17	0	1	29	3	13	4	PL
PT	0	0	2	0	0	3	0	0	2	0	2	22	2	0	533	1	86	30	0	0	1	1	10	0	10	0	0	0	1	0	0	PT
RO	7	0	30	1	20	4	90	42	5	0	42	89	7	3	22	12	47	20	1	25	16	90	4	1	47	0	3	10	1	5	31	RO
RS	30	0	60	0	115	5	86	23	7	0	63	124	7	2	42	7	78	23	0	35	58	148	6	1	113	0	2	7	2	4	9	RS
RU	0	1	1	8	1	1	2	14	0	0	2	11	2	2	2	9	6	6	3	1	0	1	1	1	2	0	28	3	0	2	1	RU
SE	0	0	1	0	0	2	0	6	0	0	2	28	14	4	3	26	14	32	0	0	0	1	5	2	1	0	0	6	0	4	0	SE
SI	1	0	366	0	27	9	3	6	26	0	101	299	8	1	52	4	168	30	0	2	192	103	9	1	400	0	1	3	4	2	3	SI
SK	2	0	75	1	19	7	12	32	10	0	176	236	12	4	24	12	94	37	0	4	29	181	8	2	57	0	1	14	3	8	5	SK
TJ	0	3	2	17	1	0	2	2	1	0	1	5	0	0	12	1	8	2	4	3	1	1	0	0	7	30	56	1	0	0	0	TJ
TM	0	5	2	42	1	0	2	8	1	0	2	9	1	1	9	5	8	5	7	3	1	2	1	0	6	4	120	2	0	1	1	TM
TR	6	15	8	35	7	1	28	19	3	7	6	23	2	1	26	5	24	7	22	64	5	9	2	0	32	0	4	4	0	2	9	TR
UA	2	1	10	9	6	2	20	86	2	0	19	63	7	5	10	18	27	23	5	11	5	22	5	2	17	0	13	16	1	8	24	UA
UZ	0	3	2	16	1	1	2	7	1	0	2	9	1	1	7	5	8	6	4	2	1	1	1	1	5	21	161	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	1	0	5	0	0	2	20	7	5	1	15	8	23	0	0	0	1	4	1	1	0	0	8	0	7	0	BAS
BLS	0	0	1	4	1	0	8	10	0	0	2	5	1	1	2	3	3	3	8	4	1	2	1	0	3	0	2	2	0	1	4	BLS
MED	4	0	6	0	6	1	10	3	1	1	4	11	1	0	24	1	31	4	0	28	8	5	1	0	35	0	0	1	0	0	2	MED
NOS	0	0	0	0	0	-1	0	0	0	0	1	4	2	0	1	2	8	12	0	0	0	0	3	0	0	0	0	0	0	0	0	NOS
AST	1	3	1	21	1	0	2	2	1	4	1	4	0	0	10	1	7	2	4	10	1	1	0	0	8	11	39	1	0	0	1	AST
NOA	3	0	5	0	5	1	8	2	3	1	3	14	1	0	110	0	50	5	0	24	4	4	2	0	52	0	0	0	0	0	1	NOA
EXC	3	2	10	13	6	2	10	17	5	1	11	44	4	2	47	10	55	17	5	11	5	10	4	1	29	7	53	5	1	3	3	EXC
EU	4	0	36	0	10	4	29	15	13	1	34	135	9	3	186	15	200	43	0	25	16	29	11	1	101	0	1	9	3	5	4	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.: 2020 country-to-country blame matrices for **MM-AOT40f**.
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	67	79	1	4	6	89	7	57	309	52	7	8	22	0	0	18	51	0	28	12	6	256	16	3	63	0	0	2303	1070	AL
AM	0	1	0	1	2	7	2	12	6	152	2	1	1	0	30	262	35	8	6	3	20	21	2	664	25	0	0	1315	100	AM
AT	0	0	0	6	11	108	4	12	6	27	13	49	28	0	0	1	25	0	43	22	0	39	29	1	16	0	0	2145	1933	AT
AZ	0	1	0	1	5	11	1	12	5	380	5	1	1	0	83	91	54	22	9	6	16	11	4	458	12	0	0	1443	100	AZ
BA	18	2	0	5	9	151	7	65	134	49	11	21	45	0	0	4	41	0	33	21	2	134	22	2	51	0	0	2242	1383	BA
BE	0	0	0	-88	22	23	5	1	1	22	13	0	4	0	0	1	4	0	66	15	0	8	-64	1	7	0	0	421	272	BE
BG	6	19	0	4	11	115	3	292	185	135	12	7	26	0	1	38	212	0	22	22	47	56	18	1	29	0	0	2273	1522	BG
BY	0	1	0	4	17	160	1	30	8	271	24	1	8	0	1	7	139	1	25	38	4	6	25	2	4	0	0	1211	495	BY
CH	0	0	0	4	7	22	8	3	2	10	7	4	3	0	0	1	4	0	48	9	0	45	24	0	25	0	0	1985	1407	CH
CY	3	8	1	2	4	25	4	27	28	99	4	2	4	0	1	768	64	0	15	7	33	722	8	90	93	0	0	1975	938	CY
CZ	0	0	0	8	19	285	3	15	8	48	24	10	48	0	1	1	38	0	48	38	1	12	46	1	7	0	0	1783	1568	CZ
DE	0	0	0	-6	24	109	3	4	2	34	23	1	8	0	0	1	13	0	59	31	0	8	36	0	5	0	0	1159	963	DE
DK	0	0	0	-10	49	73	2	3	1	54	55	0	2	0	0	1	13	0	53	21	0	1	74	0	1	0	0	539	299	DK
EE	0	0	0	5	22	44	0	6	1	183	40	0	1	0	0	2	13	0	21	83	0	1	32	0	1	0	0	623	340	EE
ES	0	1	0	2	4	6	155	3	4	7	3	2	1	0	0	2	4	0	147	3	1	152	16	0	100	0	0	1614	1554	ES
FI	0	0	0	3	15	13	0	1	0	75	32	0	0	0	0	0	4	0	13	35	0	0	14	0	0	0	0	277	162	FI
FR	0	0	0	-0	11	14	11	4	4	12	8	4	3	0	0	1	5	0	83	9	0	68	26	0	29	0	0	1410	1274	FR
GB	0	0	0	-9	24	21	2	1	0	17	18	0	1	0	0	0	2	0	62	19	0	2	-5	0	1	0	0	331	227	GB
GE	1	1	0	1	5	17	2	21	9	322	5	1	2	0	33	211	87	9	9	7	72	16	5	208	16	0	0	1801	146	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	9	46	1	3	7	74	6	105	142	109	8	5	15	0	1	121	134	0	25	14	38	301	16	4	60	0	0	2196	1459	GR
HR	5	1	0	6	11	157	6	59	82	43	12	68	47	0	0	2	41	0	38	23	1	181	27	1	38	0	0	2341	1933	HR
HU	2	1	0	7	14	290	4	123	72	61	18	23	149	0	1	3	91	0	34	34	2	48	31	1	18	0	0	2180	1819	HU
IE	0	0	0	2	19	15	2	0	0	11	15	0	0	0	0	0	2	0	60	13	0	1	34	0	1	0	0	380	232	IE
IS	0	0	-0	1	4	1	0	0	0	3	1	0	0	0	0	0	0	0	11	1	0	0	5	0	0	0	0	45	17	IS
IT	3	3	1	4	6	53	13	27	31	26	6	37	13	0	0	5	22	0	48	11	2	336	22	1	80	0	0	2048	1839	IT
KG	0	0	0	0	1	5	2	3	2	92	1	0	1	134	50	30	8	560	4	2	1	5	1	440	13	0	0	1509	57	KG
KZ	0	0	0	1	7	15	1	6	2	547	6	0	1	3	19	14	33	37	11	8	3	3	6	83	4	0	0	1022	93	KZ
LT	0	1	0	7	22	137	1	18	4	181	34	1	5	0	1	5	57	0	31	63	2	5	40	1	3	0	0	1005	579	LT
LU	0	0	0	6	20	27	7	2	1	25	14	1	5	0	0	1	6	0	66	16	0	12	50	1	10	0	0	943	781	LU
LV	0	0	0	6	20	69	1	8	2	175	31	0	2	0	0	4	33	0	24	71	1	2	33	1	1	0	0	746	407	LV
MD	2	4	0	3	17	170	2	211	32	235	18	3	17	0	2	45	470	1	25	31	45	23	21	4	12	0	0	1877	781	MD
ME	349	11	0	5	7	121	7	71	253	59	8	9	32	0	0	8	44	0	29	16	3	190	19	3	62	0	0	2168	1077	ME
MK	19	249	0	4	7	108	7	98	458	61	8	6	28	0	0	35	70	0	26	15	10	102	17	2	55	0	0	2406	1252	MK
MT	6	5	-610	2	6	39	11	23	38	28	5	8	8	0	0	16	32	0	47	9	5	501	19	3	228	0	0	604	388	MT
NL	0	0	0	-491	28	43	3	1	1	21	15	0	2	0	0	0	5	0	52	20	0	2	-115	0	2	0	0	3	-152	NL
NO	0	0	0	1	74	15	1	1	0	38	33	0	0	0	0	1	5	0	27	19	0	0	33	0	0	0	0	270	116	NO
PL	0	1	0	6	22	453	2	27	11	102	33	3	28	0	0	3	67	0	41	63	2	10	45	1	5	0	0	1423	1086	PL
PT	0	0	0	2	3	6	679	1	1	6	3	0	0	0	0	1	2	0	292	3	0	49	15	0	51	0	0	1414	1368	PT
RO	3	6	0	4	13	174	3	641	78	127	14	6	37	0	1	26	242	0	23	26	25	33	20	1	20	0	0	2053	1425	RO
RS	24	19	0	5	9	174	5	170	371	60	11	12	52	0	0	7	73	0	27	22	5	68	21	1	36	0	0	2050	1276	RS
RU	0	0	0	1	6	15	0	5	2	416	6	0	1	0	3	7	34	2	8	9	3	2	6	12	1	0	0	610	78	RU
SE	0	0	0	3	40	31	1	1	1	61	81	0	1	0	0	1	7	0	25	45	0	1	31	0	1	0	0	377	228	SE
SI	1	0	0	6	10	119	5	28	21	33	11	362	34	0	0	2	33	0	38	20	1	131	27	1	27	0	0	2488	2292	SI
SK	1	1	0	8	15	451	3	70	37	68	19	13	293	0	1	3	86	0	33	38	2	29	35	1	12	0	0	2136	1814	SK
TJ	0	0	0	0	1	4	2	3	2	75	1	0	1	470	116	33	7	408	4	1	1	7	1	626	16	0	0	1284	56	TJ
TM	0	0	0	1	5	9	1	5	2	279	4	0	1	9	274	30	29	187	9	5	4	7	4	332	9	0	0	1087	79	TM
TR	2	5	0	1	5	29	3	38	27	183	5	2	4	0	3	822	108	1	12	9	64	103	7	240	52	0	0	1615	333	TR
UA	1	2	0	3	17	150	2	74	17	371	19	2	13	0	6	32	423	3	24	31	28	15	21	10	7	0	0	1574	530	UA
UZ	0	0	0	1	5	9	1	4	2	278	4	0	1	41	77	22	24	300	9	5	2	5	4	178	7	0	0	1044	72	UZ
ATL	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	1	0	1	0	0	8	6	ATL
BAS	0	0	0	1	12	26	0	1	0	37	26	0	1	0	0	0	4	0	13	1	0	0	20	0	0	0	0	220	136	BAS
BLS	0	0	0	0	3	12	0	14	4	93	3	0	1	0	1	23	64	0	3	4	41	4	3	3	2	0	0	288	68	BLS
MED	1	2	0	1	1	10	3	10	9	17	1	2	2	0	0	26	16	0	10	2	7	116	3	-1	22	0	0	293	198	MED
NOS	0	0	0	-7	6	3	0	0	0	4	4	0	0	0	0	0	1	0	10	3	0	0	-22	0	0	0	0	47	24	NOS
AST	0	1	0	0	1	4	1	3	3	69	1	0	1	13	69	94	10	50	4	1	3	30	1	1234	21	0	0	457	63	AST
NOA	1	2	1	1	1	8	25	8	9	10	1	1	2	0	0	22	10	0	69	2	3	169	4	1	615	0	0	399	326	NOA
EXC	1	2	0	0	10	41	9	23	11	299	11	3	6	7	16	47	51	28	22	14	7	25	11	54	12	0	0	958	356	EXC
EU	1	3	0	-3	16	98	38	59	22	55	23	9	17	0	0	10	41	0	61	27	5	75	25	1	30	0	0	1337	1095	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: 2020 country-to-country blame matrices for **MM-AOT40f**.
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	71	0	10	1	20	5	5	4	4	0	18	59	5	1	17	1	38	27	0	12	12	14	4	0	103	0	1	2	1	1	2	AL
AM	0	86	1	315	1	1	1	3	1	0	2	10	1	0	3	1	6	5	23	2	1	1	1	0	8	0	7	1	0	0	1	AM
AT	0	0	67	1	2	10	0	2	21	0	35	152	5	0	8	1	58	33	0	0	5	7	5	0	74	0	0	1	1	0	1	AT
AZ	0	9	1	626	1	1	1	5	1	0	3	14	2	1	3	2	7	9	17	2	1	2	1	0	8	0	13	1	0	1	2	AZ
BA	2	0	15	1	74	6	2	3	5	0	24	72	5	1	12	1	38	27	0	1	15	15	4	0	82	0	1	1	1	1	2	BA
BE	0	0	2	0	0	83	0	1	3	0	14	154	6	0	7	1	77	69	0	0	0	1	7	0	7	0	0	1	2	0	0	BE
BG	3	0	7	2	9	5	36	8	3	0	18	56	5	1	7	2	28	23	0	14	6	14	3	0	34	0	1	2	0	1	6	BG
BY	0	0	2	2	1	3	1	23	1	0	8	31	3	1	2	2	12	19	0	1	1	3	2	0	7	0	1	2	0	1	2	BY
CH	0	0	13	0	1	9	0	0	106	0	12	140	4	0	13	1	86	32	0	0	2	2	4	0	114	0	0	0	1	0	0	CH
CY	3	0	5	9	5	3	6	7	3	22	7	35	4	1	13	1	28	19	1	30	4	6	3	0	47	0	2	2	0	1	3	CY
CZ	0	0	16	1	2	11	1	4	6	0	107	132	7	1	5	1	43	37	0	0	3	8	5	0	16	0	0	1	1	1	1	CZ
DE	0	0	9	0	0	20	0	2	9	0	23	220	8	1	5	1	53	56	0	0	1	2	6	0	10	0	0	2	1	1	0	DE
DK	0	0	1	1	0	8	0	3	0	0	4	52	34	1	2	2	20	51	0	0	0	1	4	0	2	0	0	2	0	1	0	DK
EE	0	0	0	1	0	2	0	3	0	0	2	17	3	3	1	3	6	15	0	0	0	1	2	0	1	0	0	2	0	3	0	EE
ES	0	0	2	0	1	4	1	0	2	0	2	29	2	0	119	0	41	23	0	0	1	1	3	0	23	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	1	0	0	1	6	1	1	0	2	2	6	0	0	0	0	1	0	0	0	0	1	0	1	0	FI
FR	0	0	4	0	1	14	0	1	8	0	7	80	3	0	22	1	97	44	0	0	1	2	5	0	32	0	0	0	1	0	0	FR
GB	0	0	1	0	0	11	0	1	1	0	4	57	8	0	2	1	31	118	0	0	0	0	4	0	2	0	0	1	0	1	0	GB
GE	0	11	2	284	1	1	2	5	1	0	3	14	2	0	3	1	7	7	52	2	1	2	1	0	9	0	7	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	10	0	7	3	10	5	13	7	3	0	16	53	5	1	14	2	35	27	0	86	7	11	4	0	68	0	1	2	0	1	5	GR
HR	1	0	25	1	26	8	2	3	8	0	32	104	6	1	13	1	48	33	0	1	37	19	5	0	142	0	1	1	1	1	2	HR
HU	1	0	21	1	8	7	3	5	5	0	37	106	6	1	7	1	37	30	0	1	9	48	4	0	54	0	1	2	1	1	2	HU
IE	0	0	0	0	0	7	0	1	1	0	3	43	5	0	2	1	19	64	0	0	0	0	14	0	2	0	0	1	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	2	6	0	0	0	0	1	0	0	0	0	0	0	0	0	IS
IT	1	0	18	1	7	7	2	2	12	0	18	86	5	0	28	1	70	35	0	1	11	8	5	0	478	0	1	1	1	1	1	IT
KG	0	1	1	15	0	1	0	2	0	0	1	6	1	0	2	1	4	4	1	1	0	1	0	0	4	34	49	0	0	0	0	KG
KZ	0	0	1	9	0	1	0	3	1	0	2	11	1	0	2	1	6	9	1	1	0	1	1	0	4	2	35	1	0	1	1	KZ
LT	0	0	1	1	1	4	1	9	1	0	5	33	5	1	2	2	12	25	0	1	1	2	2	0	5	0	1	8	0	3	1	LT
LU	0	0	4	0	0	29	0	1	4	0	14	156	5	0	8	1	63	51	0	0	0	1	6	0	10	0	0	1	17	0	0	LU
LV	0	0	1	1	0	3	0	6	0	0	3	23	4	1	1	2	8	17	0	0	0	1	2	0	3	0	0	4	0	6	1	LV
MD	1	0	5	9	4	4	6	11	2	0	14	48	4	1	5	2	23	22	1	5	3	8	2	0	21	0	2	2	0	1	31	MD
ME	11	0	9	1	26	5	2	4	4	0	17	56	5	1	12	1	34	25	0	3	10	12	4	0	79	0	1	1	0	1	2	ME
MK	12	0	8	1	13	5	11	5	3	0	19	54	4	1	12	1	30	24	0	27	6	15	3	0	57	0	1	2	0	1	3	MK
MT	3	0	11	1	12	5	4	3	5	0	14	62	6	1	37	1	64	41	0	6	10	10	5	0	235	0	1	1	1	1	2	MT
NL	0	0	2	0	0	40	0	2	1	0	11	154	8	1	4	1	56	70	0	0	0	1	7	0	4	0	0	1	1	1	0	NL
NO	0	0	0	0	0	1	0	1	0	0	1	9	3	0	1	1	5	12	0	0	0	0	1	0	1	0	0	0	0	0	0	NO
PL	0	0	5	1	2	7	1	8	2	0	25	71	7	1	4	2	25	33	0	1	2	6	4	0	11	0	0	3	0	2	2	PL
PT	0	0	1	0	0	4	0	0	1	0	1	24	2	0	67	0	31	24	0	0	0	0	3	0	8	0	0	0	0	0	0	PT
RO	2	0	7	3	7	5	10	8	3	0	20	57	4	1	5	1	25	21	0	5	4	15	2	0	27	0	1	2	0	1	6	RO
RS	5	0	12	1	26	6	8	5	4	0	27	74	5	1	9	1	32	26	0	5	10	24	4	0	53	0	1	2	1	1	3	RS
RU	0	0	0	7	0	1	0	2	0	0	1	7	1	0	1	1	4	5	0	0	0	1	1	0	2	0	4	1	0	0	0	RU
SE	0	0	0	0	0	2	0	1	0	0	2	16	4	0	1	1	6	13	0	0	0	0	1	0	1	0	0	1	0	1	0	SE
SI	0	0	41	1	6	9	1	2	13	0	34	126	5	0	12	1	54	32	0	1	22	14	5	0	236	0	0	1	1	1	1	SI
SK	1	0	14	1	5	7	2	6	5	0	44	91	6	1	6	1	30	29	0	1	5	22	3	0	30	0	0	2	1	1	2	SK
TJ	0	1	1	17	0	1	0	1	1	0	1	6	1	0	2	0	4	4	1	1	0	1	0	0	5	5	24	0	0	0	0	TJ
TM	0	1	1	39	0	1	1	3	1	0	2	11	1	0	3	1	6	8	2	1	1	1	1	0	6	1	27	1	0	0	1	TM
TR	1	3	3	29	3	2	4	6	2	1	5	23	2	0	7	1	15	11	4	10	2	4	2	0	21	0	2	1	0	1	3	TR
UA	1	0	3	13	2	3	3	11	1	0	10	37	4	1	3	2	14	19	1	3	2	5	2	0	13	0	3	2	0	1	5	UA
UZ	0	1	1	15	0	1	0	3	1	0	2	10	1	0	2	1	5	7	1	1	0	1	1	0	5	6	39	1	0	0	1	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	2	0	1	0	0	2	14	5	1	0	2	5	11	0	0	0	0	1	0	1	0	0	1	0	1	0	BAS
BLS	0	0	1	6	1	0	2	2	0	0	2	6	1	0	1	0	2	3	2	1	0	1	0	0	3	0	1	0	0	0	1	BLS
MED	1	0	2	1	2	1	1	1	1	0	3	12	1	0	7	0	11	6	0	7	2	2	1	0	30	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	2	0	0	0	0	1	9	1	0	0	0	6	11	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	1	1	24	1	1	1	1	1	0	1	6	1	0	3	0	4	3	1	2	0	1	0	0	6	1	12	0	0	0	0	AST
NOA	1	0	2	1	2	2	1	1	1	0	3	16	1	0	19	0	18	9	0	3	2	2	1	0	29	0	0	0	0	0	1	NOA
EXC	0	1	2	12	1	3	1	3	2	0	5	26	2	0	7	1	14	14	1	2	1	2	2	0	17	1	9	1	0	1	1	EXC
EU	1	0	7	1	3	8	3	3	4	0	14	70	5	0	24	1	41	30	0	4	3	5	4	0	55	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.5 Cont.: 2020 country-to-country blame matrices for **MM-AOT40f**.
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	15	8	0	12	3	47	2	14	55	28	4	3	9	0	0	5	11	0	0	0	0	1	0	2	18	0	0	654	399	AL
AM	0	0	0	2	1	8	1	4	2	72	1	0	1	0	8	63	10	3	0	0	0	0	0	392	8	0	0	660	58	AM
AT	0	0	0	21	3	44	1	3	2	11	3	8	9	0	0	1	5	0	0	0	0	0	0	1	5	0	0	599	518	AT
AZ	0	0	0	3	2	12	1	6	2	139	2	0	1	0	17	38	15	5	0	0	0	0	0	406	5	0	0	977	75	AZ
BA	2	0	0	13	3	54	2	13	24	22	3	4	11	0	0	2	8	0	0	0	0	1	0	2	14	0	0	571	395	BA
BE	0	0	0	101	5	20	1	1	0	8	4	0	2	0	0	1	2	0	0	0	0	0	2	1	3	0	0	582	492	BE
BG	1	3	0	12	3	56	1	43	30	45	4	2	10	0	0	16	26	0	0	0	0	0	0	1	10	0	0	546	366	BG
BY	0	0	0	9	3	37	0	7	3	58	3	1	3	0	0	4	16	0	0	0	0	0	0	3	2	0	0	276	142	BY
CH	0	0	0	18	3	13	2	1	1	5	2	2	2	0	0	1	1	0	0	0	0	0	0	0	7	0	0	592	441	CH
CY	1	2	0	8	3	27	2	14	12	66	3	1	4	0	0	265	21	0	0	0	0	2	0	82	30	0	0	702	278	CY
CZ	0	0	0	26	4	107	1	4	3	16	4	3	14	0	0	1	7	0	0	0	0	0	1	1	3	0	0	601	517	CZ
DE	0	0	0	54	5	44	1	1	1	12	4	1	4	0	0	1	4	0	0	0	0	0	1	1	2	0	0	564	474	DE
DK	0	0	0	34	9	30	0	1	0	17	10	0	1	0	0	1	4	0	0	1	0	0	2	0	1	0	0	299	211	DK
EE	0	0	0	7	2	17	0	2	1	33	4	0	1	0	0	1	3	0	0	0	0	0	0	1	1	0	0	139	79	EE
ES	0	0	0	10	2	6	18	2	1	4	1	1	1	0	0	1	1	0	0	0	0	1	0	1	26	0	0	307	268	ES
FI	0	0	0	3	1	6	0	0	0	14	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	55	30	FI
FR	0	0	0	26	3	12	2	2	1	6	2	1	1	0	0	1	2	0	0	0	0	0	1	1	9	0	0	386	319	FR
GB	0	0	0	37	5	17	0	0	0	6	3	0	0	0	0	0	1	0	0	0	0	0	2	0	1	0	0	317	183	GB
GE	0	0	0	3	2	12	1	6	3	102	2	0	1	0	7	45	17	2	0	0	0	0	0	152	6	0	0	626	77	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	0	GL
GR	2	6	0	12	3	47	2	24	30	47	4	2	8	0	0	29	22	0	0	0	0	2	0	4	17	0	0	635	427	GR
HR	1	0	0	17	4	61	2	12	18	19	4	11	12	0	0	2	8	0	0	0	0	1	0	1	12	0	0	691	565	HR
HU	1	0	0	19	3	99	1	23	19	24	4	4	28	0	0	2	13	0	0	0	0	0	0	1	6	0	0	641	525	HU
IE	0	0	0	23	4	13	1	0	0	5	3	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	0	214	138	IE
IS	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	10	IS
IT	1	1	0	15	3	30	4	8	7	16	4	10	6	0	0	2	6	0	0	0	0	2	0	1	24	0	0	915	819	IT
KG	0	0	0	1	1	4	0	1	1	43	1	0	0	47	8	11	3	243	0	0	0	0	0	169	3	0	0	495	31	KG
KZ	0	0	0	4	2	9	0	2	1	91	2	0	1	2	3	7	6	14	0	0	0	0	0	51	2	0	0	238	52	KZ
LT	0	0	0	11	3	36	0	5	2	36	4	0	2	0	0	3	9	0	0	0	0	0	0	2	1	0	0	239	147	LT
LU	0	0	0	49	5	18	1	1	1	9	3	0	2	0	0	1	2	0	0	0	0	0	1	1	4	0	0	466	393	LU
LV	0	0	0	9	2	24	0	2	1	30	3	0	1	0	0	2	5	0	0	0	0	0	0	1	1	0	0	171	104	LV
MD	1	1	0	10	4	56	1	36	10	71	3	1	6	0	1	25	42	0	0	0	0	0	0	4	6	0	0	506	269	MD
ME	40	1	0	12	3	45	2	12	33	27	3	2	8	0	0	3	9	0	0	0	0	1	0	2	18	0	0	526	337	ME
MK	3	33	0	11	3	51	2	20	63	27	3	2	10	0	0	6	13	0	0	0	0	0	0	2	15	0	0	566	355	MK
MT	2	1	59	12	4	34	5	11	14	23	4	4	6	0	0	8	9	0	0	0	0	8	0	3	81	0	0	735	607	MT
NL	0	0	0	198	5	35	1	1	0	9	4	0	2	0	0	0	2	0	0	0	0	0	3	0	1	0	0	626	534	NL
NO	0	0	0	4	9	5	0	1	0	8	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	68	36	NO
PL	0	0	0	19	3	157	1	7	4	27	4	1	8	0	0	3	11	0	0	0	0	0	1	1	2	0	0	469	372	PL
PT	0	0	0	10	1	7	113	1	0	3	1	0	0	0	0	1	1	0	1	0	0	0	0	0	14	0	0	308	275	PT
RO	1	1	0	12	3	63	1	81	20	42	3	2	11	0	0	17	26	0	0	0	0	0	0	2	7	0	0	527	367	RO
RS	4	5	0	14	3	70	2	30	102	26	4	3	16	0	0	2	13	0	0	0	0	0	0	1	11	0	0	639	412	RS
RU	0	0	0	2	1	7	0	2	1	66	1	0	1	0	1	3	5	0	0	0	0	0	0	8	1	0	0	130	33	RU
SE	0	0	0	8	3	11	0	1	0	12	5	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	96	62	SE
SI	0	0	0	18	3	48	2	6	6	15	4	49	10	0	0	1	7	0	0	0	0	1	0	1	9	0	0	787	699	SI
SK	0	0	0	18	3	141	1	14	10	24	4	3	42	0	0	3	11	0	0	0	0	0	0	1	4	0	0	591	490	SK
TJ	0	0	0	1	1	4	1	1	1	41	1	0	0	105	16	11	3	125	0	0	0	0	0	194	4	0	0	387	30	TJ
TM	0	0	0	3	2	9	1	3	1	87	2	0	1	6	46	18	8	41	0	0	0	0	0	231	4	0	0	349	57	TM
TR	0	1	0	5	2	20	1	10	7	67	2	1	3	0	1	165	19	0	0	0	0	1	0	106	15	0	0	472	146	TR
UA	0	1	0	8	4	44	1	15	5	94	3	1	4	0	1	16	48	1	0	0	0	0	0	9	3	0	0	411	185	UA
UZ	0	0	0	3	2	8	0	2	1	75	2	0	1	22	11	12	6	151	0	0	0	0	0	113	3	0	0	401	48	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	3	ATL
BAS	0	0	0	6	2	12	0	1	0	13	4	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	90	60	BAS
BLS	0	0	0	1	1	6	0	4	2	30	1	0	1	0	0	16	9	0	0	0	0	0	0	3	1	0	0	106	34	BLS
MED	0	0	0	2	1	7	1	3	3	9	1	1	1	0	0	14	3	0	0	0	0	1	0	4	14	0	0	141	97	MED
NOS	0	0	0	7	2	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47	32	NOS
AST	0	0	0	1	1	4	1	2	1	32	1	0	1	4	12	34	4	15	0	0	0	0	0	745	7	0	0	187	37	AST
NOA	0	0	0	4	1	8	6	3	3	8	1	1	1	0	0	8	3	0	0	0	0	1	0	4	114	0	0	164	124	NOA
EXC	0	0	0	7	2	17	2	5	3	56	2	1	2	2	3	12	8	11	0	0	0	0	0	31	4	0	0	264	122	EXC
EU	0	1	0	20	3	39	6	10	5	17	3	2	5	0	0	4	6	0	0	0	0	0	1	1	9	0	0	412	332	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: 2020 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	45	0	3	0	7	0	6	1	1	0	2	5	0	0	7	0	9	1	0	13	4	4	0	0	21	0	0	0	0	0	1	AL
AM	0	-15	0	35	0	0	1	1	0	0	0	1	0	0	1	0	1	0	9	1	0	0	0	0	1	0	2	0	0	0	0	AM
AT	0	0	38	0	1	1	0	1	8	0	11	44	1	0	5	0	21	2	0	0	2	4	1	0	15	0	0	0	0	0	0	AT
AZ	0	3	0	28	0	0	0	1	0	0	0	1	0	0	1	1	1	0	6	1	0	0	0	0	1	0	5	0	0	0	0	AZ
BA	1	0	8	0	42	0	2	1	1	0	6	11	1	0	7	1	11	1	0	1	15	10	1	0	20	0	0	0	0	0	1	BA
BE	0	0	1	0	0	-27	0	0	1	0	1	6	1	0	3	1	24	6	0	0	0	0	2	0	1	0	0	0	2	0	0	BE
BG	1	0	3	0	3	0	51	3	0	0	3	5	0	0	3	1	5	1	0	11	2	5	0	0	6	0	0	1	0	0	3	BG
BY	0	0	1	0	0	0	0	17	0	0	2	6	1	1	1	2	2	2	0	0	0	1	1	0	1	0	0	3	0	1	1	BY
CH	0	0	6	0	0	0	0	0	48	0	2	30	0	0	8	0	50	2	0	0	0	1	1	0	23	0	0	0	0	0	0	CH
CY	1	0	1	0	1	0	2	1	0	37	1	2	0	0	4	0	3	1	0	23	1	1	0	0	7	0	0	0	0	0	0	CY
CZ	0	0	7	0	1	1	0	1	1	0	24	36	1	0	2	1	13	3	0	0	1	4	1	0	2	0	0	1	1	0	0	CZ
DE	0	0	3	0	0	0	0	1	2	0	5	30	1	0	3	1	18	6	0	0	0	1	2	0	2	0	0	0	1	0	0	DE
DK	0	0	0	0	0	-0	0	1	0	0	0	4	-5	0	1	2	3	8	0	0	0	0	2	0	0	0	0	1	0	0	0	DK
EE	0	0	0	0	0	0	0	2	0	0	0	3	1	3	0	6	1	2	0	0	0	0	0	0	0	0	0	2	0	3	0	EE
ES	0	0	1	0	0	0	0	0	0	0	0	2	0	0	103	0	15	2	0	0	0	0	1	0	4	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	7	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	FI
FR	0	0	2	0	0	1	0	0	3	0	1	13	0	0	14	0	69	5	0	0	1	1	1	0	7	0	0	0	1	0	0	FR
GB	0	0	0	0	0	-0	0	0	0	0	0	3	1	0	1	1	7	-6	0	0	0	0	2	0	0	0	0	0	0	0	0	GB
GE	0	4	0	33	0	0	1	1	0	0	0	1	0	0	1	1	1	0	42	1	0	0	0	0	1	0	2	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	2	0	3	0	18	2	1	0	2	4	0	0	6	0	7	1	0	55	2	3	0	0	14	0	0	0	0	0	1	GR
HR	0	0	14	0	14	0	1	1	1	0	8	16	1	0	6	0	12	2	0	0	31	15	1	0	23	0	0	0	0	0	0	HR
HU	0	0	11	0	3	0	2	2	1	0	9	17	1	0	3	1	9	2	0	0	6	32	1	0	8	0	0	1	0	0	1	HU
IE	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	6	10	0	0	0	0	-2	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	1	3	0	0	0	0	1	-0	0	0	0	0	0	0	0	IS
IT	1	0	8	0	3	0	1	0	4	0	3	10	0	0	13	0	24	2	0	1	5	3	1	0	72	0	0	0	0	0	0	IT
KG	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	38	12	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	22	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	8	0	0	1	6	2	1	1	3	2	3	0	0	0	1	1	0	1	0	0	8	0	3	0	LT
LU	0	0	1	0	0	7	0	0	1	0	2	26	1	0	5	0	36	7	0	0	0	1	2	0	2	0	0	0	-22	0	0	LU
LV	0	0	0	0	0	0	0	5	0	0	1	4	1	2	0	3	1	3	0	0	0	0	1	0	0	0	0	4	0	3	0	LV
MD	0	0	1	0	1	0	4	6	0	0	2	5	1	0	2	1	3	2	1	2	1	3	0	0	3	0	0	1	0	1	16	MD
ME	8	0	4	0	19	0	4	1	1	0	3	7	0	0	7	0	10	1	0	3	7	6	1	0	19	0	0	0	0	0	1	ME
MK	12	0	3	0	5	0	15	2	1	0	2	5	0	0	6	0	7	1	0	26	2	5	0	0	13	0	0	0	0	0	1	MK
MT	1	0	2	0	3	0	2	1	1	0	1	4	0	0	17	0	19	2	0	4	2	2	1	0	39	0	0	0	0	0	0	MT
NL	0	0	0	0	0	-3	0	0	0	0	1	5	1	0	2	1	9	7	0	0	0	0	2	0	1	0	0	0	0	0	0	NL
NO	0	0	0	0	0	-0	0	0	0	0	0	1	1	0	1	2	1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	0	0	1	4	0	0	5	15	1	1	1	2	6	4	0	0	1	2	1	0	2	0	0	2	0	1	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	2	0	0	54	0	8	2	0	0	0	0	1	0	1	0	0	0	0	0	0	PT
RO	1	0	3	0	2	0	9	4	0	0	3	7	1	0	3	1	5	1	0	3	2	8	0	0	5	0	0	1	0	0	3	RO
RS	3	0	5	0	10	0	8	2	1	0	5	9	1	0	5	1	7	1	0	3	5	12	0	0	10	0	0	1	0	0	1	RS
RU	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	1	1	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	2	1	0	0	3	1	3	0	0	0	0	1	0	0	0	0	1	0	0	0	SE
SI	0	0	31	0	2	0	0	1	2	0	8	21	1	0	6	0	14	1	0	0	17	9	1	0	29	0	0	0	0	0	0	SI
SK	0	0	6	0	2	0	1	3	1	0	14	17	1	0	3	1	8	2	0	0	3	17	1	0	5	0	0	1	0	1	1	SK
TJ	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	1	2	5	0	0	0	0	TJ
TM	0	1	0	6	0	0	0	1	0	0	0	1	0	0	1	1	1	1	1	0	0	0	0	0	1	1	14	0	0	0	0	TM
TR	1	1	1	3	1	0	2	1	0	1	0	2	0	0	3	0	2	1	2	6	0	1	0	0	3	0	0	0	0	0	1	TR
UA	0	0	1	1	1	0	2	7	0	0	2	5	1	0	1	2	3	2	1	1	1	2	0	0	2	0	1	1	0	1	2	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	2	19	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	4	3	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	3	1	2	1	6	2	6	0	0	0	0	1	0	0	0	0	2	0	2	0	BAS
BLS	0	0	1	2	1	0	6	5	0	0	1	2	0	0	1	1	2	1	6	3	0	1	0	0	2	0	1	1	0	1	2	BLS
MED	2	0	3	0	3	0	4	1	1	1	2	5	0	0	17	0	20	2	0	14	3	2	1	0	27	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	-1	0	0	0	0	0	0	1	0	1	1	4	5	0	0	0	0	3	1	0	0	0	0	0	0	0	NOS
AST	0	0	0	2	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0	0	1	1	5	0	0	0	0	AST
NOA	0	0	1	0	1	0	1	0	0	0	0	2	0	0	16	0	7	1	0	4	1	1	0	0	8	0	0	0	0	0	0	NOA
EXC	0	0	1	1	1	0	1	2	0	0	1	3	0	0	5	1	5	1	1	1	0	1	0	0	3	1	6	0	0	0	0	EXC
EU	0	0	3	0	1	0	3	1	1	0	3	10	1	0	18	1	17	3	0	2	1	3	1	0	9	0	0	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.6 Cont.: 2020 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	8	0	0	1	7	1	5	27	5	1	1	2	0	0	2	5	0	3	1	1	26	1	1	8	0	0	205	95	AL
AM	0	0	0	0	0	1	0	1	1	13	0	0	0	0	3	31	3	1	1	0	2	3	0	66	3	0	0	94	10	AM
AT	0	0	0	0	1	9	0	2	1	3	1	5	3	0	0	0	3	0	4	2	0	4	2	0	2	0	0	182	162	AT
AZ	0	0	0	0	0	1	0	1	0	34	0	0	0	0	8	10	5	2	1	1	2	2	0	41	1	0	0	113	10	AZ
BA	2	0	0	0	1	11	1	6	13	5	1	2	4	0	0	1	5	0	4	2	0	14	1	0	5	0	0	192	118	BA
BE	0	0	0	-10	2	2	0	0	0	2	1	0	0	0	0	0	1	0	6	1	0	1	-9	0	1	0	0	23	10	BE
BG	1	2	0	0	1	9	0	26	16	12	1	1	2	0	0	3	18	0	2	2	4	7	1	0	4	0	0	200	135	BG
BY	0	0	0	0	2	14	0	3	1	22	2	0	1	0	0	1	11	0	2	4	0	1	2	0	0	0	0	100	43	BY
CH	0	0	0	0	1	2	1	1	0	1	1	1	0	0	0	0	1	0	5	1	0	5	2	0	3	0	0	182	128	CH
CY	0	1	0	0	0	2	0	2	3	9	0	0	0	0	0	68	5	0	2	0	3	67	1	13	8	0	0	178	88	CY
CZ	0	0	0	0	2	23	0	2	1	4	2	1	4	0	0	0	3	0	4	3	0	1	3	0	1	0	0	145	128	CZ
DE	0	0	0	-2	2	8	0	1	0	3	2	0	1	0	0	0	1	0	5	2	0	1	2	0	1	0	0	92	76	DE
DK	0	0	0	-1	5	6	0	0	0	4	5	0	0	0	0	0	1	0	5	-0	0	0	4	0	0	0	0	39	20	DK
EE	0	0	0	0	3	4	0	1	0	15	4	0	0	0	0	0	1	0	3	7	0	0	2	0	0	0	0	55	30	EE
ES	0	0	0	0	0	1	14	0	1	1	0	0	0	0	0	0	1	0	15	0	0	14	1	0	11	0	0	150	144	ES
FI	0	0	0	0	2	2	0	0	0	10	4	0	0	0	0	0	0	0	2	3	0	0	1	0	0	0	0	33	17	FI
FR	0	0	0	-0	1	1	1	1	1	1	1	0	0	0	0	0	1	0	8	1	0	7	2	0	3	0	0	127	115	FR
GB	0	0	0	-2	2	2	0	0	0	1	1	0	0	0	0	0	0	0	5	1	0	0	-2	0	0	0	0	17	19	GB
GE	0	0	0	0	0	1	0	2	1	31	0	0	0	0	3	26	8	1	1	1	7	3	0	27	2	0	0	169	14	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	0	GL
GR	1	4	0	0	1	6	1	9	12	9	1	0	1	0	0	12	11	0	3	1	3	31	1	1	7	0	0	194	131	GR
HR	0	0	0	0	1	12	1	6	9	4	1	6	4	0	0	0	4	0	4	2	0	17	2	0	4	0	0	197	159	HR
HU	0	0	0	0	1	23	0	12	7	6	1	2	13	0	0	0	9	0	3	3	0	4	2	0	2	0	0	187	154	HU
IE	0	0	0	-0	1	1	0	0	0	1	1	0	0	0	0	0	0	0	7	1	0	1	2	0	0	0	0	26	13	IE
IS	0	0	0	-0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	8	3	IS
IT	0	0	0	0	1	4	1	3	3	3	0	3	1	0	0	1	2	0	5	1	0	31	1	0	8	0	0	176	155	IT
KG	0	0	0	0	0	0	0	0	0	8	0	0	0	15	6	3	1	46	1	0	0	1	0	69	2	0	0	139	6	KG
KZ	0	0	0	0	1	1	0	1	0	54	1	0	0	0	3	2	3	4	1	1	0	1	1	10	1	0	0	105	10	KZ
LT	0	0	0	0	2	12	0	2	0	14	3	0	0	0	0	0	5	0	3	5	0	0	3	0	0	0	0	82	47	LT
LU	0	0	0	0	2	2	1	0	0	2	1	0	0	0	0	0	1	0	6	1	0	2	3	0	1	0	0	80	66	LU
LV	0	0	0	-0	2	6	0	1	0	14	3	0	0	0	0	0	3	0	2	6	0	0	2	0	0	0	0	61	33	LV
MD	0	0	0	0	1	13	0	20	3	20	2	0	1	0	0	4	41	0	2	3	4	3	2	0	2	0	0	164	67	MD
ME	30	1	0	0	1	9	1	7	25	6	1	1	2	0	0	1	5	0	3	1	0	20	1	1	7	0	0	194	94	ME
MK	2	23	0	0	1	8	1	9	40	6	1	1	2	0	0	3	7	0	3	1	1	11	1	1	6	0	0	212	108	MK
MT	1	1	-75	0	0	3	1	2	3	2	0	1	1	0	0	2	3	0	6	1	1	45	2	0	29	0	0	50	30	MT
NL	0	0	0	-64	2	3	0	0	0	2	1	0	0	0	0	0	1	0	5	1	0	0	-15	0	0	0	0	-26	-39	NL
NO	0	0	0	-0	7	1	0	0	0	5	4	0	0	0	0	0	0	0	4	2	0	0	2	0	0	0	0	30	12	NO
PL	0	0	0	-0	2	37	0	2	1	8	3	0	2	0	0	0	6	0	4	5	0	1	3	0	1	0	0	115	87	PL
PT	0	0	0	0	0	1	64	0	0	1	0	0	0	0	0	0	0	0	31	0	0	6	1	0	6	0	0	136	132	PT
RO	0	1	0	0	1	14	0	57	7	12	1	1	3	0	0	2	21	0	2	2	2	4	1	0	3	0	0	181	125	RO
RS	2	2	0	0	1	13	1	16	28	6	1	1	4	0	0	1	7	0	3	2	1	7	1	0	4	0	0	173	107	RS
RU	0	0	0	0	1	1	0	1	0	40	1	0	0	0	0	1	3	0	1	1	0	0	1	2	0	0	0	61	8	RU
SE	0	0	0	0	5	3	0	0	0	6	7	0	0	0	0	0	1	0	4	4	0	0	3	0	0	0	0	37	21	SE
SI	0	0	0	0	1	9	1	3	3	4	1	25	3	0	0	0	3	0	4	1	0	10	1	0	2	0	0	198	180	SI
SK	0	0	0	0	1	38	0	7	3	6	2	1	21	0	0	0	8	0	3	3	0	3	2	0	1	0	0	176	149	SK
TJ	0	0	0	0	0	0	0	0	0	6	0	0	0	50	11	4	1	32	1	0	0	1	0	96	2	0	0	120	6	TJ
TM	0	0	0	0	1	1	0	1	0	33	0	0	0	1	38	4	3	22	1	1	1	1	0	46	1	0	0	137	10	TM
TR	0	0	0	0	0	2	0	3	2	15	0	0	0	0	0	80	9	0	1	1	5	12	1	29	6	0	0	147	30	TR
UA	0	0	0	0	2	12	0	7	1	32	2	0	1	0	1	3	35	0	2	3	2	2	2	1	1	0	0	135	46	UA
UZ	0	0	0	0	1	1	0	1	0	35	1	0	0	5	11	3	3	27	1	1	0	1	0	29	1	0	0	121	9	UZ
ATL	0	0	0	-0	1	0	2	0	0	2	1	0	0	0	0	0	0	0	16	0	0	1	1	0	1	0	0	21	13	ATL
BAS	0	0	0	-0	5	7	0	1	0	12	9	0	0	0	0	0	1	0	5	-9	0	0	5	0	0	0	0	64	37	BAS
BLS	0	0	0	0	1	6	0	9	2	58	1	0	1	0	0	14	39	0	2	2	34	3	1	4	2	0	0	178	42	BLS
MED	1	1	0	0	1	4	2	4	5	6	1	1	1	0	0	14	5	0	7	1	2	89	1	0	18	0	0	156	114	MED
NOS	0	0	0	-4	4	2	0	0	0	3	3	0	0	0	0	0	1	0	10	2	0	0	-25	0	0	0	0	27	13	NOS
AST	0	0	0	0	0	0	0	0	0	10	0	0	0	2	7	10	1	5	1	0	0	3	0	120	2	0	0	52	7	AST
NOA	0	0	0	0	0	1	3	1	1	1	0	0	0	0	0	3	1	0	8	0	0	25	0	0	96	0	0	58	47	NOA
EXC	0	0	0	-0	1	3	1	2	1	29	1	0	0	1	2	5	5	3	3	1	1	3	1	7	1	0	0	91	32	EXC
EU	0	0	0	-1	2	8	4	5	2	5	2	1	1	0	0	1	4	0	6	2	0	7	2	0	3	0	0	117	95	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: 2020 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	0	2	0	1	0	0	0	2	6	0	0	2	0	4	3	0	2	1	1	0	0	11	0	0	0	0	0	0	AL
AM	0	13	0	36	0	0	0	0	0	0	0	1	0	0	0	0	1	1	3	0	0	0	0	0	1	0	1	0	0	0	0	AM
AT	0	0	7	0	0	1	0	0	2	0	3	16	0	0	1	0	6	3	0	0	1	1	0	0	10	0	0	0	0	0	0	AT
AZ	0	1	0	75	0	0	0	0	0	0	0	2	0	0	0	0	1	1	2	0	0	0	0	0	1	0	1	0	0	0	0	AZ
BA	0	0	2	0	10	1	0	0	1	0	2	8	0	0	1	0	4	3	0	0	2	2	0	0	11	0	0	0	0	0	0	BA
BE	0	0	0	0	0	9	0	0	0	0	1	17	1	0	1	0	9	7	0	0	0	0	1	0	1	0	0	0	0	0	0	BE
BG	0	0	1	0	1	0	4	1	0	0	2	5	0	0	1	0	3	2	0	2	1	1	0	0	4	0	0	0	0	0	1	BG
BY	0	0	0	0	0	0	0	2	0	0	1	3	0	0	0	0	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	BY
CH	0	0	2	0	0	1	0	0	14	0	1	15	0	0	2	0	10	3	0	0	0	0	0	0	17	0	0	0	0	0	0	CH
CY	0	0	0	1	1	0	1	1	0	2	1	3	0	0	1	0	3	2	0	3	0	1	0	0	5	0	0	0	0	0	0	CY
CZ	0	0	2	0	0	1	0	0	1	0	10	13	1	0	1	0	4	4	0	0	0	1	0	0	3	0	0	0	0	0	0	CZ
DE	0	0	1	0	0	2	0	0	1	0	2	23	1	0	1	0	6	5	0	0	0	0	1	0	1	0	0	0	0	0	0	DE
DK	0	0	0	0	0	1	0	0	0	0	1	6	3	0	0	0	2	5	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	2	0	0	0	0	1	2	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	3	0	0	14	0	4	2	0	0	0	0	0	0	3	0	0	0	0	0	0	ES
FI	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	FI
FR	0	0	1	0	0	1	0	0	1	0	1	8	0	0	3	0	10	4	0	0	0	0	0	0	5	0	0	0	0	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	0	6	1	0	0	0	4	12	0	0	0	0	1	0	0	0	0	0	0	0	0	GB
GE	0	2	0	32	0	0	0	1	0	0	0	2	0	0	0	0	1	1	7	0	0	0	0	0	1	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	0	1	0	2	1	0	0	2	5	0	0	1	0	3	2	0	10	1	1	0	0	7	0	0	0	0	0	0	GR
HR	0	0	3	0	3	1	0	0	1	0	3	10	1	0	2	0	5	3	0	0	4	2	0	0	17	0	0	0	0	0	0	HR
HU	0	0	2	0	1	1	0	0	1	0	4	10	1	0	1	0	4	3	0	0	1	5	0	0	6	0	0	0	0	0	0	HU
IE	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	3	7	0	0	0	0	2	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	0	0	0	0	0	0	0	0	IS
IT	0	0	2	0	1	1	0	0	1	0	2	8	0	0	3	0	7	3	0	0	1	1	0	0	54	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	7	5	0	0	0	0	KG
KZ	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	5	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	1	0	0	1	3	1	0	0	0	1	2	0	0	0	0	0	0	1	0	0	1	0	0	0	LT
LU	0	0	1	0	0	3	0	0	1	0	1	17	0	0	1	0	7	5	0	0	0	0	1	0	2	0	0	0	2	0	0	LU
LV	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	LV
MD	0	0	0	1	0	0	1	1	0	0	1	5	0	0	0	0	2	2	0	1	0	1	0	0	2	0	0	0	0	0	3	MD
ME	2	0	1	0	4	1	0	0	0	0	2	6	0	0	2	0	4	2	0	1	1	1	0	0	10	0	0	0	0	0	0	ME
MK	2	0	1	0	2	0	2	0	0	0	2	5	0	0	1	0	3	2	0	4	1	2	0	0	7	0	0	0	0	0	0	MK
MT	0	0	1	0	1	1	0	0	1	0	1	6	1	0	5	0	7	4	0	1	1	1	0	0	26	0	0	0	0	0	0	MT
NL	0	0	0	0	0	4	0	0	0	0	1	16	1	0	0	0	6	8	0	0	0	0	1	0	1	0	0	0	0	0	0	NL
NO	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	NO
PL	0	0	1	0	0	1	0	1	0	0	3	7	1	0	0	0	3	3	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	2	0	0	8	0	3	2	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	0	0	1	0	1	1	1	1	0	0	2	6	0	0	1	0	3	2	0	1	1	2	0	0	4	0	0	0	0	0	1	RO
RS	1	0	1	0	3	1	1	0	0	0	3	7	0	0	1	0	3	3	0	1	1	2	0	0	6	0	0	0	0	0	0	RS
RU	0	0	0	1	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	RU
SE	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	SE
SI	0	0	4	0	1	1	0	0	1	0	3	12	0	0	1	0	6	3	0	0	3	1	0	0	30	0	0	0	0	0	0	SI
SK	0	0	2	0	1	1	0	0	1	0	4	10	1	0	1	0	3	3	0	0	1	3	0	0	5	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	0	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	0	4	0	0	0	0	TM
TR	0	0	0	3	0	0	0	1	0	0	1	2	0	0	1	0	1	1	0	1	0	0	0	0	2	0	0	0	0	0	0	TR
UA	0	0	0	1	0	0	0	1	0	0	1	4	0	0	0	0	1	2	0	0	0	1	0	0	2	0	0	0	0	0	0	UA
UZ	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	1	5	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	0	0	0	1	6	2	0	0	1	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0	BAS
BLS	0	0	1	5	0	0	1	1	0	0	1	4	0	0	1	0	2	2	2	1	0	1	0	0	3	0	0	0	0	0	1	BLS
MED	1	0	1	0	1	1	1	0	1	0	2	7	1	0	6	0	7	4	0	3	1	1	1	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	1	0	0	0	0	1	6	1	0	0	0	4	11	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	1	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	0	2	0	0	3	0	3	1	0	1	0	0	0	0	5	0	0	0	0	0	0	NOA
EXC	0	0	0	2	0	0	0	0	0	0	1	3	0	0	1	0	2	1	0	0	0	0	0	0	2	0	1	0	0	0	0	EXC
EU	0	0	1	0	0	1	0	0	1	0	1	7	0	0	3	0	4	3	0	0	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.: 2020 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	2	1	0	1	0	5	0	2	7	3	0	0	1	0	0	1	1	0	0	0	0	0	0	0	3	0	0	72	42	AL
AM	0	0	0	0	0	1	0	1	0	8	0	0	0	0	1	9	1	0	0	0	0	0	0	80	1	0	0	82	8	AM
AT	0	0	0	2	0	4	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	65	56	AT
AZ	0	0	0	0	0	1	0	1	0	15	0	0	0	0	2	5	2	1	0	0	0	0	0	60	1	0	0	115	9	AZ
BA	0	0	0	1	0	5	0	2	3	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	66	45	BA
BE	0	0	0	11	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	63	53	BE
BG	0	0	0	1	0	5	0	5	3	4	0	0	1	0	0	2	2	0	0	0	0	0	0	1	1	0	0	57	39	BG
BY	0	0	0	1	0	4	0	1	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	27	15	BY
CH	0	0	0	2	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	72	53	CH
CY	0	0	0	1	0	2	0	1	1	6	0	0	0	0	0	25	2	0	0	0	0	0	0	23	4	0	0	66	26	CY
CZ	0	0	0	2	0	10	0	0	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	60	52	CZ
DE	0	0	0	5	0	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57	48	DE
DK	0	0	0	3	1	3	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	23	DK
EE	0	0	0	1	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	9	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	32	28	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	8	5	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	1	0	0	41	34	FR
GB	0	0	0	4	1	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33	19	GB
GE	0	0	0	0	0	1	0	1	0	11	0	0	0	0	1	6	2	0	0	0	0	0	0	29	1	0	0	73	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	0	0	1	0	GL
GR	0	1	0	1	0	4	0	3	3	4	0	0	1	0	0	3	2	0	0	0	0	0	0	1	2	0	0	66	45	GR
HR	0	0	0	2	0	6	0	1	2	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	74	60	HR
HU	0	0	0	2	0	9	0	2	2	2	0	0	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	63	52	HU
IE	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	23	15	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	4	2	IS
IT	0	0	0	1	0	3	0	1	1	2	0	1	1	0	0	0	1	0	0	0	0	0	0	0	3	0	0	99	89	IT
KG	0	0	0	0	0	0	0	0	0	4	0	0	0	7	1	1	0	31	0	0	0	0	0	33	0	0	0	63	4	KG
KZ	0	0	0	0	0	1	0	0	0	10	0	0	0	0	1	1	1	3	0	0	0	0	0	12	0	0	0	30	6	KZ
LT	0	0	0	1	0	4	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	24	15	LT
LU	0	0	0	5	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	50	42	LU
LV	0	0	0	1	0	3	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	12	LV
MD	0	0	0	1	0	5	0	4	1	6	0	0	1	0	0	2	4	0	0	0	0	0	0	0	1	0	0	48	27	MD
ME	6	0	0	1	0	5	0	2	4	3	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	63	39	ME
MK	0	5	0	1	0	5	0	2	8	3	0	0	1	0	0	1	1	0	0	0	0	0	0	1	2	0	0	65	39	MK
MT	0	0	4	1	0	3	1	1	2	2	0	0	1	0	0	1	1	0	0	0	0	1	0	0	12	0	0	76	63	MT
NL	0	0	0	20	1	4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	65	55	NL
NO	0	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	6	NO
PL	0	0	0	2	0	15	0	1	0	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	47	38	PL
PT	0	0	0	1	0	1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	34	31	PT
RO	0	0	0	1	0	6	0	9	2	4	0	0	1	0	0	2	2	0	0	0	0	0	0	0	1	0	0	57	40	RO
RS	1	1	0	1	0	7	0	3	11	3	0	0	2	0	0	0	1	0	0	0	0	0	0	0	1	0	0	67	42	RS
RU	0	0	0	0	0	1	0	0	0	8	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0	0	0	16	4	RU
SE	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	0	0	12	8	SE
SI	0	0	0	2	0	5	0	1	1	2	0	5	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	87	78	SI
SK	0	0	0	2	0	14	0	2	1	2	0	0	4	0	0	0	1	0	0	0	0	0	0	0	1	0	0	63	53	SK
TJ	0	0	0	0	0	0	0	0	0	4	0	0	0	23	2	1	0	15	0	0	0	0	0	37	0	0	0	55	3	TJ
TM	0	0	0	0	0	1	0	0	0	12	0	0	0	1	9	2	1	7	0	0	0	0	0	52	1	0	0	54	8	TM
TR	0	0	0	0	0	2	0	1	1	7	0	0	0	0	0	20	2	0	0	0	0	0	0	26	2	0	0	51	15	TR
UA	0	0	0	1	0	5	0	2	1	9	0	0	1	0	0	2	5	0	0	0	0	0	0	1	0	0	0	42	20	UA
UZ	0	0	0	0	0	1	0	0	0	10	0	0	0	3	2	2	1	20	0	0	0	0	0	23	0	0	0	56	7	UZ
ATL	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	10	7	ATL
BAS	0	0	0	2	1	5	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34	23	BAS
BLS	0	0	0	1	0	5	0	3	1	22	0	0	1	0	0	12	6	0	0	0	0	0	0	6	1	0	0	82	27	BLS
MED	0	0	0	1	0	4	1	2	2	4	0	1	1	0	0	7	2	0	0	0	0	1	0	5	12	0	0	84	61	MED
NOS	0	0	0	5	2	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	38	23	NOS
AST	0	0	0	0	0	1	0	0	0	5	0	0	0	1	2	4	1	2	0	0	0	0	0	132	1	0	0	26	5	AST
NOA	0	0	0	0	0	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	19	0	0	26	19	NOA
EXC	0	0	0	1	0	2	0	1	0	6	0	0	0	0	0	1	1	2	0	0	0	0	0	7	0	0	0	31	13	EXC
EU	0	0	0	2	0	4	1	1	1	2	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	44	35	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: 2020 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	163	0	1	0	8	0	2	0	0	0	1	1	0	0	1	0	1	0	0	6	3	2	0	0	8	0	0	0	0	0	0	AL
AM	0	80	0	22	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	AM
AT	0	0	160	0	3	0	0	0	2	0	9	14	0	0	0	0	4	0	0	0	7	7	0	0	13	-0	0	0	0	0	0	AT
AZ	0	6	0	203	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	AZ
BA	1	0	3	0	512	0	1	0	0	0	2	2	0	0	0	0	2	0	0	0	30	7	0	0	8	0	0	0	0	0	0	BA
BE	0	0	0	0	0	162	0	0	1	0	1	25	0	0	1	0	71	10	0	0	0	0	1	0	1	0	0	0	2	0	0	BE
BG	1	0	1	0	4	0	167	1	0	0	1	1	0	0	0	0	1	0	0	6	2	3	0	0	2	0	0	0	0	0	3	BG
BY	0	0	1	0	1	0	0	117	0	0	2	3	1	0	0	0	1	1	0	0	1	2	0	0	1	0	0	4	0	2	1	BY
CH	0	0	6	0	0	0	0	0	92	0	1	17	0	0	1	0	25	0	0	0	0	0	0	0	19	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	18	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	16	0	3	1	0	0	1	0	190	24	0	0	0	0	6	1	0	0	5	10	0	0	3	-0	0	0	0	0	0	CZ
DE	0	0	9	0	0	4	0	0	3	-0	7	149	1	0	1	0	19	4	0	0	0	1	0	0	2	-0	0	0	1	0	0	DE
DK	0	0	0	0	0	2	0	0	0	-0	1	15	74	0	0	0	5	6	0	0	0	1	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	5	0	0	1	2	1	55	0	2	1	1	0	0	0	0	0	0	0	0	0	3	0	11	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	108	0	4	0	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	1	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	3	0	0	2	0	1	8	0	0	4	0	158	3	0	0	0	0	0	0	4	-0	0	0	0	0	0	FR
GB	0	-0	0	-0	0	2	0	0	0	-0	0	3	0	0	0	0	6	99	-0	0	0	0	3	0	0	-0	-0	0	0	0	0	GB
GE	0	8	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	126	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	3	0	10	1	0	0	0	0	0	0	0	0	1	0	0	99	1	1	0	0	4	0	0	0	0	0	1	GR
HR	0	0	8	0	101	0	1	0	0	0	4	4	0	0	1	0	2	0	0	0	242	20	0	0	21	0	0	0	0	0	0	HR
HU	0	0	13	0	16	0	2	1	0	-0	7	5	0	0	0	0	2	0	0	0	27	245	0	0	7	-0	0	0	0	0	1	HU
IE	0	-0	0	-0	0	0	0	0	0	0	0	1	0	0	0	0	3	12	-0	0	0	0	51	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	3	0	4	0	0	0	1	0	1	1	0	0	2	0	6	0	0	0	5	2	0	0	327	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	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	1	33	0	0	0	0	KZ
LT	0	0	1	0	1	0	0	21	0	0	2	4	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0	70	0	8	1	LT
LU	0	0	1	0	0	19	0	0	1	0	2	50	0	0	1	0	87	4	0	0	0	0	0	0	2	0	0	0	61	0	0	LU
LV	0	0	0	0	0	0	0	11	0	0	1	3	1	3	0	1	1	1	0	0	0	1	0	0	0	0	0	13	0	75	0	LV
MD	0	0	1	0	1	0	3	3	0	0	1	2	0	0	0	0	0	0	0	1	1	2	0	0	1	0	0	0	0	0	272	MD
ME	11	0	1	0	27	0	1	0	0	0	1	1	0	0	0	0	1	0	0	1	4	3	0	0	5	0	0	0	0	0	0	ME
MK	11	0	1	0	5	0	9	0	0	0	1	1	0	0	0	0	1	0	0	15	2	3	0	0	3	0	0	0	0	0	1	MK
MT	1	0	0	0	3	0	1	0	0	0	0	0	0	0	3	0	4	0	0	1	1	1	0	0	23	0	0	0	0	0	0	MT
NL	0	0	0	0	0	37	0	0	0	0	1	45	1	0	1	0	26	14	0	0	0	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	2	0	2	1	0	4	0	-0	15	14	1	0	0	0	3	2	0	0	2	6	0	0	1	0	0	1	0	1	0	PL
PT	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	27	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	0	4	0	12	1	0	0	1	1	0	0	0	0	1	0	0	1	2	9	0	0	2	0	0	0	0	0	7	RO
RS	4	0	2	0	39	0	9	1	0	0	2	2	0	0	0	0	1	0	0	2	12	17	0	0	4	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	0	0	0	0	2	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	35	0	8	0	0	0	0	0	4	4	0	0	0	0	3	0	0	0	61	9	0	0	47	-0	0	0	0	0	0	SI
SK	0	0	9	0	6	0	1	1	0	-0	16	6	0	0	0	0	2	1	0	0	7	50	0	0	4	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	2	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	0	0	1	0	1	8	0	0	1	2	0	0	0	0	1	0	0	0	1	2	0	0	1	0	1	1	0	0	8	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	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	1	0	2	0	0	1	7	6	2	0	3	2	2	0	0	0	1	0	0	0	0	0	2	0	3	0	BAS
BLS	0	0	0	1	1	0	5	2	0	0	0	0	0	0	0	0	0	0	8	1	0	1	0	0	0	0	0	0	0	0	3	BLS
MED	1	0	1	0	4	0	1	0	0	0	0	1	0	0	7	0	6	0	0	6	3	1	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	0	5	2	0	0	0	8	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	1	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	0	0	1	1	2	1	1	2	0	0	2	4	0	0	3	0	6	2	1	1	1	2	0	0	6	1	6	0	0	1	1	EXC
EU	0	0	6	0	3	2	6	1	1	0	6	17	1	1	15	2	25	2	0	3	5	8	1	0	26	0	0	2	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.8 Cont.: 2020 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	16	13	0	0	0	3	0	4	46	0	0	0	1	0	0	0	2	0	0	0	0	1	0	0	1	0	0	0	282	32	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	21	1	0	0	0	0	0	0	8	0	0	0	0	134	1	AM
AT	0	0	0	0	0	7	0	2	2	0	0	10	2	-0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	244	235	AT
AZ	0	0	0	0	0	0	0	0	0	8	0	0	0	0	1	5	2	1	0	0	0	0	0	9	0	0	0	0	241	1	AZ
BA	5	0	0	0	0	6	0	5	27	0	0	1	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	621	71	BA
BE	0	0	0	17	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	6	0	0	0	0	0	299	287	BE
BG	1	2	0	0	0	5	0	35	22	2	0	0	1	0	0	6	13	0	0	0	0	0	0	0	0	0	0	0	279	224	BG
BY	0	0	0	0	0	40	0	3	1	8	0	0	1	0	0	1	31	0	0	0	0	0	0	0	0	0	0	0	225	63	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	164	70	CH
CY	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	83	4	0	0	0	0	3	0	9	2	0	0	0	116	26	CY
CZ	0	0	0	1	0	45	0	3	4	1	0	2	8	-0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	329	315	CZ
DE	0	0	0	5	0	13	0	0	0	0	0	0	0	-0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	223	214	DE
DK	0	0	0	3	2	12	0	0	0	1	2	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	0	0	127	116	DK
EE	0	0	0	0	1	12	0	1	0	7	2	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	112	91	EE
ES	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	0	124	123	ES
FI	0	0	0	0	1	3	0	0	0	5	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	36	26	FI
FR	0	0	0	1	0	1	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	190	183	FR
GB	0	0	0	2	0	2	0	0	0	0	0	0	0	-0	-0	0	0	-0	1	0	0	0	2	-0	0	0	0	0	118	18	GB
GE	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	11	2	0	0	0	0	0	0	2	0	0	0	0	171	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	6	0	0	0	3	0	6	10	1	0	0	0	0	0	9	7	0	0	0	0	2	0	0	1	0	0	0	171	128	GR
HR	1	0	0	0	0	9	0	6	30	0	0	15	2	-0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	473	336	HR
HU	0	0	0	0	0	24	0	38	39	1	0	6	20	-0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	465	397	HU
IE	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	70	58	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	3	0	IS
IT	0	0	0	0	0	2	0	2	2	0	0	4	0	0	0	0	1	0	0	0	0	2	0	0	2	0	0	0	365	355	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	17	0	0	0	0	0	10	0	0	0	0	65	0	KG
KZ	0	0	0	0	0	0	0	0	0	11	0	0	0	1	1	0	2	4	0	0	0	0	0	6	0	0	0	0	54	1	KZ
LT	0	0	0	0	1	49	0	2	1	8	1	0	1	0	0	0	11	0	0	1	0	0	0	0	0	0	0	0	189	145	LT
LU	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	236	230	LU
LV	0	0	0	0	1	22	0	1	0	6	1	0	1	0	0	0	8	0	0	1	0	0	0	0	0	0	0	0	153	125	LV
MD	0	0	0	0	0	15	0	70	3	5	0	0	1	0	0	4	63	0	0	0	0	0	0	0	0	0	0	0	453	100	MD
ME	212	1	0	0	0	4	0	4	33	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	315	28	ME
MK	1	172	0	0	0	4	0	6	61	0	0	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	303	47	MK
MT	1	0	38	0	0	1	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	21	0	0	11	0	0	0	85	76	MT
NL	0	0	0	132	0	6	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10	0	0	0	0	0	266	250	NL
NO	0	0	0	0	20	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	3	NO
PL	0	0	0	1	0	439	0	4	3	3	0	1	8	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	527	500	PL
PT	0	0	0	0	0	0	170	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	201	200	PT
RO	0	0	0	0	0	11	0	314	16	2	0	0	2	0	0	3	18	0	0	0	0	0	0	0	0	0	0	0	411	358	RO
RS	8	7	0	0	0	9	0	28	453	1	0	1	2	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	613	93	RS
RU	0	0	0	0	0	2	0	0	0	40	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	56	4	RU
SE	0	0	0	0	3	4	0	0	0	1	13	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	32	24	SE
SI	0	0	0	0	0	7	0	3	4	0	0	237	1	-0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	427	411	SI
SK	0	0	0	0	0	60	0	14	11	1	0	2	146	-0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	350	318	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	127	2	0	0	18	0	0	0	0	0	21	0	0	0	0	151	0	TJ
TM	0	0	0	0	0	0	0	0	0	4	0	0	0	3	34	1	2	15	0	0	0	0	0	6	0	0	0	0	65	1	TM
TR	0	0	0	0	0	1	0	2	1	2	0	0	0	0	0	229	6	0	0	0	0	1	0	6	0	0	0	0	246	6	TR
UA	0	0	0	0	0	22	0	14	2	15	0	0	1	0	0	4	251	0	0	0	0	0	0	0	0	0	0	0	339	48	UA
UZ	0	0	0	0	0	0	0	0	0	4	0	0	0	15	7	0	2	94	0	0	0	0	0	3	0	0	0	0	137	1	UZ
ATL	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7	6	ATL
BAS	0	0	0	1	1	25	0	1	0	5	6	0	0	0	0	0	3	0	0	5	0	0	1	0	0	0	0	0	76	62	BAS
BLS	0	0	0	0	0	4	0	9	2	17	0	0	0	0	0	72	48	0	0	0	3	0	0	1	0	0	0	0	178	22	BLS
MED	1	0	0	0	0	2	1	2	3	1	0	1	0	0	0	21	3	0	0	0	0	8	0	2	10	0	0	0	87	53	MED
NOS	0	0	0	3	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	47	26	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	8	1	1	0	0	0	0	0	235	0	0	0	0	16	0	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	47	0	0	0	15	11	NOA
EXC	0	0	0	1	1	11	1	6	3	19	0	1	1	2	1	10	13	4	0	0	0	0	0	2	0	0	0	0	121	51	EXC
EU	0	0	0	2	1	40	5	21	4	1	2	2	3	0	0	1	4	0	0	0	0	1	0	0	0	0	0	0	222	204	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: 2020 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	35	0	1	0	11	0	7	1	0	0	3	4	0	0	1	0	1	0	0	9	1	1	0	0	8	0	1	0	0	0	0	AL
AM	0	41	0	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0	0	0	0	10	0	0	0	0	AM
AT	0	0	28	0	2	1	0	1	1	0	11	29	0	0	1	0	4	1	0	0	2	2	0	0	5	0	0	0	0	0	0	AT
AZ	0	4	0	173	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	35	0	0	0	0	AZ
BA	1	0	2	0	87	0	3	1	0	0	7	10	0	0	1	0	2	1	0	0	3	3	0	0	6	0	1	0	0	0	0	BA
BE	0	0	0	0	0	41	0	0	0	0	3	41	0	0	3	0	35	15	0	0	0	0	1	0	1	0	0	0	1	0	0	BE
BG	1	0	1	0	4	0	76	3	0	0	3	4	0	0	0	0	1	0	0	6	0	2	0	0	2	0	3	0	0	0	1	BG
BY	0	0	0	0	1	0	1	35	0	0	3	10	1	1	0	1	1	2	0	0	0	1	0	0	0	0	6	2	0	0	0	BY
CH	0	0	2	0	0	1	0	0	22	0	2	19	0	0	1	0	11	2	0	0	0	0	0	0	8	0	0	0	0	0	0	CH
CY	0	0	0	0	1	0	3	1	0	34	0	1	0	0	0	0	0	0	0	13	0	0	0	0	2	0	1	0	0	0	0	CY
CZ	0	0	8	0	3	1	1	1	1	0	76	54	0	0	1	0	5	3	0	0	1	3	0	0	2	0	0	0	0	0	0	CZ
DE	0	0	5	0	0	5	0	1	2	0	10	100	1	0	1	0	12	9	0	0	0	0	0	0	1	0	0	0	0	0	0	DE
DK	0	0	0	0	0	3	0	1	0	0	2	26	12	0	1	0	4	12	0	0	0	0	0	1	0	0	1	0	0	0	0	DK
EE	0	0	0	0	0	0	0	5	0	0	1	5	1	4	0	3	1	2	0	0	0	0	0	0	0	0	3	2	0	1	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	2	0	0	63	0	3	1	0	0	0	0	0	0	2	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	2	0	1	0	9	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	FI
FR	0	0	1	0	0	3	0	0	1	0	2	15	0	0	9	0	31	7	0	0	0	0	0	0	3	0	0	0	0	0	0	FR
GB	0	-0	0	0	0	1	0	0	0	0	1	6	0	0	1	0	4	69	0	0	0	0	3	1	0	0	0	0	0	0	0	GB
GE	0	4	0	56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	81	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	2	0	0	0	4	0	22	1	0	0	2	3	0	0	1	0	1	0	0	39	0	1	0	0	6	0	1	0	0	0	0	GR
HR	0	0	4	0	28	0	2	1	0	0	10	16	0	0	1	0	3	1	0	0	13	4	0	0	11	0	1	0	0	0	0	HR
HU	0	0	4	0	9	1	3	2	0	0	13	19	0	0	1	0	2	1	0	0	3	27	0	0	5	0	1	0	0	0	0	HU
IE	0	0	0	0	0	1	0	0	0	0	0	4	0	0	1	0	2	18	0	0	0	0	20	1	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	33	0	0	0	0	0	0	0	IS
IT	0	0	2	0	5	0	1	0	1	0	3	6	0	0	4	0	6	1	0	0	2	1	0	0	53	0	1	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	57	0	-0	0	0	KG
KZ	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	2	208	0	0	0	0	KZ
LT	0	0	0	0	0	1	0	13	0	0	3	11	1	1	0	1	1	3	0	0	0	1	0	0	0	0	4	10	0	1	0	LT
LU	0	0	1	0	0	9	0	0	1	0	4	62	0	0	3	0	39	9	0	0	0	0	0	0	1	0	0	0	10	0	0	LU
LV	0	0	0	0	0	1	0	8	0	0	2	7	1	1	0	2	1	3	0	0	0	0	0	0	0	0	4	7	0	4	0	LV
MD	0	0	0	1	2	0	7	7	0	0	4	7	0	0	0	0	1	1	0	1	0	2	0	0	1	0	6	1	0	0	15	MD
ME	3	0	1	0	27	0	4	0	0	0	4	5	0	0	1	0	1	0	0	1	1	1	0	0	5	0	1	0	0	0	0	ME
MK	6	0	0	0	6	0	17	1	0	0	3	4	0	0	1	0	1	0	0	16	0	2	0	0	3	0	1	0	0	0	0	MK
MT	1	0	0	0	5	0	3	0	0	0	1	3	0	0	7	0	4	1	0	3	1	1	0	0	30	0	1	0	0	0	0	MT
NL	0	0	0	0	0	33	0	0	0	0	2	53	0	0	2	0	21	21	0	0	0	0	1	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	1	0	0	0	0	NO
PL	0	0	1	0	1	1	1	5	0	0	16	33	1	0	1	1	3	4	0	0	0	2	0	0	1	0	2	1	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	2	0	0	31	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	0	4	0	14	3	0	0	4	7	0	0	0	0	1	1	0	2	0	4	0	0	1	0	3	0	0	0	1	RO
RS	1	0	1	0	20	0	15	1	0	0	6	9	0	0	1	0	1	1	0	3	1	5	0	0	3	0	2	0	0	0	0	RS
RU	0	0	0	1	0	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	RU
SE	0	0	0	0	0	0	0	1	0	0	1	4	1	0	0	1	1	3	0	0	0	0	0	0	0	0	2	0	0	0	0	SE
SI	0	0	8	0	6	1	1	0	0	0	9	17	0	0	1	0	3	1	0	0	10	2	0	0	23	0	1	0	0	0	0	SI
SK	0	0	3	0	4	1	2	2	0	0	19	20	0	0	0	0	2	2	0	0	1	13	0	0	3	0	1	0	0	0	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	36	0	0	0	0	TJ
TM	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	96	0	0	0	0	TM
TR	0	1	0	3	0	0	3	1	0	1	0	1	0	0	0	0	0	0	2	3	0	0	0	0	1	0	1	0	0	0	0	TR
UA	0	0	0	2	1	0	3	9	0	0	3	7	0	0	0	0	1	1	1	1	0	1	0	0	1	0	12	1	0	0	1	UA
UZ	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	136	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	2	0	0	0	0	0	1	0	0	1	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	2	0	0	2	12	2	1	0	3	2	5	0	0	0	0	0	0	0	0	2	1	0	0	0	BAS
BLS	0	1	0	6	1	0	6	4	0	0	1	2	0	0	0	0	0	0	8	2	0	0	0	0	0	0	7	0	0	0	1	BLS
MED	1	0	0	0	4	0	5	1	0	1	2	3	0	0	9	0	5	1	0	8	1	1	0	0	17	0	1	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	1	7	1	0	1	0	4	17	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	26	0	0	0	0	AST
NOA	0	0	0	0	1	0	1	0	0	0	0	1	0	0	6	0	1	0	0	2	0	0	0	0	4	0	0	0	0	0	0	NOA
EXC	0	0	0	2	1	0	1	2	0	0	2	5	0	0	2	1	2	2	1	1	0	0	0	0	1	1	51	0	0	0	0	EXC
EU	0	0	2	0	2	2	4	1	0	0	6	19	1	0	10	1	7	4	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.: 2020 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	33	67	0	0	0	10	0	5	122	1	0	0	1	0	0	7	4	0	0	0	0	6	0	1	6	8	6	29	335	52	AL
AM	0	0	0	0	0	0	0	0	1	6	0	0	0	0	2	76	2	1	0	0	0	0	0	156	2	9	1	6	245	2	AM
AT	1	0	0	0	0	17	0	2	15	2	0	4	2	0	0	1	3	0	0	0	0	1	0	0	1	8	3	2	134	106	AT
AZ	0	0	0	0	0	1	0	0	1	26	0	0	0	0	7	31	7	2	0	0	0	0	0	150	1	8	1	3	303	2	AZ
BA	24	3	0	0	0	20	0	5	110	2	0	1	2	0	0	2	4	0	0	0	0	3	0	0	3	8	4	12	302	66	BA
BE	0	0	0	7	0	6	0	0	1	1	0	0	0	0	0	0	1	0	2	0	0	1	4	0	1	10	19	1	161	141	BE
BG	6	16	0	0	0	17	0	22	102	8	0	0	1	0	0	23	22	0	0	0	1	2	0	1	3	8	7	8	326	137	BG
BY	1	1	0	1	0	48	0	2	9	17	1	0	1	0	0	8	20	0	0	1	0	0	0	1	1	7	5	1	174	74	BY
CH	0	0	0	0	0	3	0	1	2	1	0	0	0	0	0	1	1	0	0	0	0	1	0	0	2	9	3	2	78	50	CH
CY	2	5	0	0	0	2	0	1	9	7	0	0	0	0	0	603	9	0	0	0	1	16	0	75	17	11	39	35	695	58	CY
CZ	1	1	0	1	0	49	0	2	24	2	0	2	5	0	0	1	3	0	0	0	0	1	1	0	1	8	6	1	255	213	CZ
DE	0	0	0	5	0	19	0	1	3	2	0	0	0	0	0	1	2	0	1	0	0	0	2	0	1	9	12	1	181	162	DE
DK	0	0	0	3	1	16	0	0	2	2	1	0	0	0	0	1	1	0	1	2	0	0	3	0	0	8	21	0	94	72	DK
EE	0	0	0	0	1	14	0	1	3	12	2	0	0	0	0	4	6	0	0	1	0	0	0	0	0	6	7	0	73	37	EE
ES	1	0	0	0	0	1	8	0	2	0	0	0	0	0	0	0	0	0	5	0	0	8	0	0	19	14	17	5	86	80	ES
FI	0	0	0	0	1	4	0	0	1	18	2	0	0	0	0	2	2	0	0	1	0	0	0	0	0	5	7	0	50	21	FI
FR	1	0	0	1	0	3	0	1	4	1	0	0	0	0	0	0	1	0	2	0	0	3	1	0	3	11	18	4	87	71	FR
GB	0	0	0	1	0	4	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	10	28	0	92	20	GB
GE	0	1	0	0	0	1	0	1	2	15	0	0	0	0	2	73	6	1	0	0	1	0	0	67	1	7	4	4	258	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	1	0	0	0	GL
GR	8	37	0	0	0	10	0	8	71	5	0	0	1	0	0	55	13	0	0	0	1	10	0	1	6	8	14	34	294	93	GR
HR	7	2	0	0	0	25	0	7	98	2	0	3	2	0	0	1	4	0	0	0	0	5	0	0	2	8	5	10	250	103	HR
HU	5	4	0	0	0	55	0	19	111	3	0	2	8	0	0	3	6	0	0	0	0	1	0	0	1	8	4	5	312	165	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	11	33	0	51	32	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	11	18	0	35	0	IS
IT	4	3	0	0	0	8	0	2	24	1	0	1	1	0	0	2	3	0	0	0	0	13	0	0	9	8	13	51	136	92	IT
KG	0	0	0	0	0	0	0	0	0	2	0	-0	0	13	3	3	0	121	0	0	0	0	0	42	0	7	0	1	240	0	KG
KZ	0	0	0	0	0	2	0	0	0	41	0	0	0	1	2	3	5	15	0	0	0	0	0	20	0	9	1	1	283	3	KZ
LT	1	1	0	1	1	47	0	1	6	12	1	0	1	0	0	5	9	0	0	1	0	0	1	1	0	7	8	1	139	84	LT
LU	0	0	0	3	0	7	0	0	1	1	0	0	0	0	0	1	1	0	1	0	0	1	2	0	2	9	13	1	156	140	LU
LV	0	0	0	1	1	23	0	1	4	11	1	0	0	0	0	5	8	0	0	1	0	0	0	0	0	6	8	1	98	53	LV
MD	3	3	0	0	0	36	0	21	25	15	0	0	1	0	0	29	46	0	0	0	2	1	0	1	1	9	5	4	239	84	MD
ME	131	12	0	0	0	11	0	4	114	1	0	0	1	0	0	4	3	0	0	0	0	3	0	1	3	8	4	16	339	41	ME
MK	15	164	0	0	0	12	0	8	151	2	0	0	1	0	0	10	5	0	0	0	0	2	0	1	4	8	4	13	430	69	MK
MT	7	6	2	0	0	5	1	2	25	1	0	0	0	0	0	3	3	0	1	0	0	51	0	0	43	10	48	171	116	64	MT
NL	0	0	0	28	0	11	0	0	0	1	0	0	0	0	0	0	1	0	2	0	0	0	6	0	1	9	21	0	179	154	NL
NO	0	0	0	0	5	3	0	0	0	6	1	0	0	0	0	1	1	0	1	0	0	0	1	0	0	7	14	0	24	7	NO
PL	1	1	0	1	0	155	0	3	17	5	1	0	3	0	0	3	6	0	0	1	0	0	1	0	1	8	8	1	270	225	PL
PT	0	0	0	0	0	1	47	0	0	0	0	0	0	0	0	0	0	0	13	0	0	3	0	0	13	15	25	2	86	84	PT
RO	5	7	0	0	0	32	0	64	67	7	0	0	2	0	0	18	20	0	0	0	1	1	0	1	2	8	4	6	270	134	RO
RS	28	28	0	0	0	27	0	18	344	3	0	0	2	0	0	4	7	0	0	0	0	2	0	0	3	8	3	10	536	95	RS
RU	0	0	0	0	0	4	0	0	1	63	0	0	0	0	0	4	7	1	0	0	0	0	0	3	0	8	4	0	119	7	RU
SE	0	0	0	0	3	6	0	0	1	6	4	0	0	0	0	1	2	0	1	1	0	0	1	0	0	5	9	0	38	21	SE
SI	1	1	0	0	0	20	0	4	38	2	0	25	2	0	0	1	4	0	0	0	0	4	0	0	1	7	4	6	182	126	SI
SK	3	2	0	1	0	75	0	8	52	3	0	1	21	0	0	3	5	0	0	0	0	1	0	0	1	7	4	3	248	172	SK
TJ	0	0	0	0	0	0	0	0	0	3	0	-0	0	79	13	5	0	91	0	0	0	0	0	50	0	9	0	1	232	0	TJ
TM	0	0	0	0	0	1	0	0	1	21	0	0	0	4	45	8	6	40	0	0	0	0	0	79	0	10	1	2	233	2	TM
TR	1	3	0	0	0	3	0	2	9	9	0	0	0	0	0	533	12	0	0	0	2	3	0	88	5	11	10	15	590	14	TR
UA	1	2	0	0	0	34	0	6	14	29	0	0	1	0	1	25	64	0	0	0	1	1	0	3	1	8	4	3	225	61	UA
UZ	0	0	0	0	0	1	0	0	0	22	0	0	0	14	15	5	5	161	0	0	0	0	0	35	0	10	1	1	371	2	UZ
ATL	0	0	0	0	0	1	1	0	0	4	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	17	34	0	15	7	ATL
BAS	0	0	0	1	1	18	0	0	3	8	3	0	0	0	0	2	3	0	0	3	0	0	1	0	0	6	12	0	75	48	BAS
BLS	1	3	0	0	0	11	0	5	13	40	0	0	0	0	1	134	49	0	0	0	9	1	0	12	1	7	18	5	298	30	BLS
MED	6	7	0	0	0	6	1	3	26	4	0	0	0	0	0	101	7	0	1	0	1	30	0	11	31	10	38	85	218	61	MED
NOS	0	0	0	2	1	4	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	4	0	0	9	30	0	45	22	NOS
AST	0	0	0	0	0	0	0	0	1	5	0	0	0	1	7	46	2	7	0	0	0	1	0	297	3	15	2	5	101	2	AST
NOA	2	2	0	0	0	1	2	1	7	1	0	0	0	0	0	17	2	0	2	0	0	9	0	3	121	18	17	33	52	19	NOA
EXC	1	1	0	0	0	9	0	2	8	35	0	0	0	1	2	28	8	9	0	0	0	1	0	13	1	9	6	3	184	30	EXC
EU	2	3	0	1	1	24	2	6	19	4	1	1	1	0	0	6	4	0	1	0	0	3	1	0	4	9	12	7	145	98	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: 2020 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	53	0	1	0	3	0	2	0	0	0	1	2	0	0	1	0	1	0	0	6	2	1	0	0	9	0	0	0	0	0	0	AL
AM	0	66	0	77	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	0	AM
AT	0	0	89	0	1	2	0	0	8	0	14	60	0	0	1	0	10	2	0	0	5	6	0	0	29	0	0	0	0	0	0	AT
AZ	0	11	0	219	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	0	0	0	0	2	0	0	0	0	AZ
BA	0	0	7	0	43	1	1	0	1	0	4	11	0	0	1	0	3	1	0	0	11	8	0	0	10	-0	0	0	0	0	0	BA
BE	0	0	1	0	0	42	0	0	3	0	3	87	2	0	5	0	102	42	0	0	0	0	3	0	3	0	0	0	3	0	0	BE
BG	0	0	1	0	1	0	41	1	0	0	1	2	0	0	0	0	1	0	0	4	1	2	0	0	1	0	0	0	0	0	2	BG
BY	0	0	1	0	0	1	0	33	0	0	3	13	1	0	0	1	2	3	0	0	0	2	0	0	1	0	0	5	0	1	1	BY
CH	0	0	11	0	0	2	0	0	125	0	2	64	0	0	1	0	36	4	0	0	0	0	0	0	33	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	20	0	0	0	-0	0	-0	0	0	0	9	0	0	0	0	1	0	0	0	0	-0	0	CY
CZ	0	0	31	0	1	3	0	1	5	0	73	86	1	0	1	0	14	5	0	0	4	11	0	0	7	0	0	0	1	0	0	CZ
DE	0	0	15	0	0	12	0	0	11	0	9	181	3	0	2	0	34	19	0	0	0	1	1	0	3	0	0	0	2	0	0	DE
DK	0	0	1	0	0	9	0	1	1	0	3	81	35	0	1	1	15	25	0	0	0	0	1	0	0	0	0	1	1	0	0	DK
EE	0	0	0	0	0	1	0	5	0	0	1	6	1	4	0	2	1	2	0	0	0	0	0	0	0	0	0	4	0	4	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	84	0	5	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	2	1	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	2	0	0	9	0	0	5	0	2	32	0	0	8	0	88	14	0	0	0	0	1	0	6	0	0	0	1	0	0	FR
GB	0	0	0	0	0	6	0	0	0	0	1	19	2	0	1	0	16	89	0	0	0	0	7	0	1	0	0	0	0	0	0	GB
GE	0	8	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	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	1	0	6	0	0	0	0	0	0	-0	0	-0	1	0	0	40	0	0	0	0	3	0	0	0	0	0	0	GR
HR	0	0	18	0	19	1	1	0	1	0	8	17	0	0	1	0	5	1	0	0	39	16	0	0	40	0	0	0	0	0	0	HR
HU	0	0	23	0	7	1	2	1	2	0	14	26	0	0	1	0	5	2	0	0	15	84	0	0	18	0	0	0	0	0	0	HU
IE	0	0	0	0	0	4	0	0	0	0	1	12	1	0	1	0	10	58	0	0	0	0	46	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	-0	0	0	0	0	0	0	0	IS
IT	0	0	9	0	2	1	0	0	4	0	2	9	0	0	3	0	9	1	0	0	4	2	0	0	246	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	24	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	9	0	0	0	0	KZ
LT	0	0	1	0	0	2	0	13	0	0	4	20	3	1	0	1	3	5	0	0	0	2	0	0	1	0	0	19	0	3	0	LT
LU	0	0	3	0	0	31	0	0	5	0	3	113	1	0	3	0	91	21	0	0	0	0	1	0	4	0	0	0	9	0	0	LU
LV	0	0	1	0	0	1	0	10	0	0	2	10	2	1	0	1	2	4	0	0	0	1	0	0	0	0	0	11	0	7	0	LV
MD	0	0	1	0	0	0	4	5	0	0	3	8	0	0	0	0	1	1	0	1	0	3	0	0	1	0	0	1	0	0	31	MD
ME	4	0	1	0	7	0	1	0	0	0	1	2	0	0	0	0	1	0	0	1	2	1	0	0	5	0	0	0	0	0	0	ME
MK	5	0	0	0	1	0	6	0	0	0	0	1	0	0	0	0	1	0	0	14	0	1	0	0	2	0	0	0	0	0	0	MK
MT	0	0	0	0	1	0	0	-0	0	0	0	0	0	-0	2	-0	3	0	0	1	1	0	0	0	18	0	-0	-0	0	-0	0	MT
NL	0	0	1	0	0	34	0	0	2	0	3	111	4	0	4	0	64	59	0	0	0	0	4	0	1	0	0	0	2	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	5	0	1	2	0	4	1	0	21	53	3	0	1	1	7	6	0	0	1	6	0	0	3	0	0	2	0	1	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	31	-0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	2	0	1	0	10	2	0	0	3	6	0	0	0	0	2	1	0	1	1	9	0	0	2	0	0	0	0	0	3	RO
RS	3	0	7	0	12	1	8	1	1	0	6	11	0	0	1	0	3	1	0	2	6	19	0	0	7	-0	0	0	0	0	1	RS
RU	0	0	0	1	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	0	0	0	0	9	3	0	0	1	2	3	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	49	0	4	1	0	0	3	0	9	24	0	0	1	0	7	2	0	0	29	9	0	0	118	0	0	0	0	0	0	SI
SK	0	0	14	0	2	1	1	1	1	0	17	22	0	0	0	0	5	2	0	0	5	35	0	0	9	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	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	7	0	0	0	0	TM
TR	0	3	0	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	3	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	1	1	0	0	1	7	0	0	2	7	0	0	0	0	1	1	0	0	0	3	0	0	1	0	1	1	0	0	4	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	13	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	2	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	2	0	1	0	0	2	23	5	0	0	1	4	6	0	0	0	0	0	0	0	0	0	1	0	1	0	BAS
BLS	0	0	0	1	0	0	2	1	0	0	0	0	0	0	0	-0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	1	BLS
MED	1	0	0	0	1	0	1	0	0	0	0	0	0	-0	4	-0	3	0	0	4	1	0	0	0	16	0	0	-0	0	-0	0	MED
NOS	0	0	0	0	0	5	0	0	0	0	1	21	3	0	1	0	14	23	0	0	0	0	1	0	0	0	0	0	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	2	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	1	0	0	0	0	2	0	-0	-0	0	-0	0	NOA
EXC	0	0	2	2	0	1	1	1	1	0	1	9	0	0	3	0	5	3	0	1	0	1	0	0	5	1	3	0	0	0	0	EXC
EU	0	0	6	0	1	4	2	1	3	0	6	34	2	0	13	1	19	7	0	2	2	4	1	0	22	0	0	1	1	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.10 Cont.: 2020 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 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	BIC	DMS	VOL	EXC	EU	
AL	5	7	0	0	0	1	0	2	25	0	0	0	0	0	0	1	1	0	0	0	0	11	0	0	1	4	0	0	125	29	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	19	1	0	0	0	0	0	0	50	0	4	0	0	175	1	AM
AT	0	0	0	2	0	8	0	1	1	1	0	9	2	0	0	0	1	0	1	1	0	2	3	0	0	4	0	0	255	239	AT
AZ	0	0	0	0	0	0	0	0	0	11	0	0	0	0	4	6	1	1	0	0	1	0	0	56	0	5	0	0	269	1	AZ
BA	2	0	0	1	0	6	0	3	11	1	0	1	2	0	0	0	2	0	0	1	0	4	1	0	1	4	0	0	131	70	BA
BE	0	0	0	52	2	5	0	0	0	1	1	0	1	0	0	0	1	0	6	2	0	2	57	0	0	11	0	0	360	310	BE
BG	0	1	0	0	0	4	0	23	11	3	0	0	1	0	0	5	9	0	0	0	3	2	0	0	1	4	0	0	116	81	BG
BY	0	0	0	2	1	38	0	3	1	18	1	0	2	0	0	1	19	0	1	5	0	0	4	0	0	3	0	0	156	78	BY
CH	0	0	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2	3	0	0	5	0	0	286	156	CH
CY	0	0	0	0	0	0	0	0	0	1	-0	0	0	0	0	43	1	0	0	0	1	30	0	9	2	6	0	0	78	32	CY
CZ	0	0	0	4	0	28	0	2	2	2	1	3	9	0	0	0	2	0	1	2	0	1	6	0	0	5	0	0	298	280	CZ
DE	0	0	0	26	1	10	0	0	0	2	2	0	1	0	0	0	1	0	3	7	0	1	30	0	0	7	0	0	339	305	DE
DK	0	0	0	22	5	12	0	0	0	2	6	0	0	0	0	0	1	0	3	31	0	0	59	0	0	6	0	0	224	189	DK
EE	0	0	0	1	1	9	0	0	0	12	3	0	0	0	0	0	2	0	0	9	0	0	3	0	0	2	0	0	61	37	EE
ES	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	6	0	0	12	1	0	3	5	0	0	100	99	ES
FI	0	0	0	1	1	2	0	0	0	4	2	0	0	0	0	0	1	0	0	4	0	0	1	0	0	1	0	0	23	16	FI
FR	0	0	0	8	0	1	0	0	0	1	0	0	0	0	0	0	0	0	5	1	0	4	20	0	1	5	0	0	182	161	FR
GB	0	0	0	14	1	3	0	0	0	1	1	0	0	0	0	0	0	0	9	3	0	0	41	0	0	6	0	0	163	72	GB
GE	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	11	1	0	0	0	1	0	0	11	0	3	0	0	124	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	5	0	0	0	0	GL
GR	0	4	0	0	0	1	0	2	5	1	-0	0	0	0	0	6	2	0	0	0	1	13	0	0	1	4	0	0	78	56	GR
HR	0	0	0	1	0	8	0	4	12	1	0	9	3	0	0	0	2	0	0	1	0	11	2	0	0	4	0	0	209	170	HR
HU	0	0	0	2	0	24	0	31	28	2	0	6	18	0	0	0	6	0	1	1	0	4	2	0	0	5	0	0	322	272	HU
IE	0	0	0	7	1	2	0	0	0	0	0	0	0	0	0	0	0	0	15	2	0	0	21	0	0	5	0	0	142	83	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	1	0	0	1	0	IS
IT	0	0	0	1	0	2	0	1	2	0	0	6	1	0	0	0	1	0	1	0	0	33	1	0	2	6	0	0	308	296	IT
KG	0	0	0	0	0	0	0	0	0	-0	-0	0	0	4	0	0	0	26	0	-0	0	0	0	18	0	2	0	0	57	0	KG
KZ	0	0	0	0	0	0	0	0	0	18	0	0	0	0	1	0	0	2	0	0	0	0	0	16	0	4	0	0	33	1	KZ
LT	0	0	0	4	1	47	0	1	0	13	3	0	2	0	0	0	7	0	1	14	0	0	7	0	0	3	0	0	160	118	LT
LU	0	0	0	20	1	2	0	0	0	1	1	0	0	0	0	0	0	0	4	1	0	2	25	0	0	7	0	0	314	286	LU
LV	0	0	0	2	1	19	0	1	0	11	2	0	1	0	0	0	4	0	1	10	0	0	5	0	0	3	0	0	95	64	LV
MD	0	0	0	1	0	19	0	48	3	9	0	0	2	0	0	4	57	0	0	1	4	1	1	0	0	4	0	0	207	95	MD
ME	25	0	0	0	0	1	0	2	14	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	1	4	0	0	72	19	ME
MK	1	18	0	0	0	1	0	3	25	0	0	0	0	0	0	2	1	0	0	0	0	3	0	0	1	4	0	0	84	30	MK
MT	0	0	1	0	0	0	0	0	1	-0	-0	0	0	0	0	0	0	0	1	-0	0	60	0	0	11	5	0	0	31	28	MT
NL	0	0	0	91	2	12	0	0	0	2	2	0	0	0	0	0	1	0	8	6	0	1	95	0	1	15	0	0	403	337	NL
NO	0	0	0	1	3	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	3	0	0	1	0	0	11	6	NO
PL	0	0	0	6	1	120	0	3	1	5	2	1	6	0	0	0	8	0	1	9	0	1	8	0	0	5	0	0	272	244	PL
PT	0	0	0	0	0	0	48	0	0	0	0	0	0	0	0	0	0	0	17	0	0	2	0	0	2	4	0	0	83	82	PT
RO	0	0	0	1	0	12	0	92	11	3	0	0	3	0	0	2	16	0	0	1	2	2	1	0	0	4	0	0	187	146	RO
RS	3	3	0	1	0	11	0	20	85	1	0	1	4	0	0	1	4	0	1	1	0	3	1	0	1	5	0	0	223	108	RS
RU	0	0	0	0	0	2	0	0	0	48	0	0	0	0	0	0	3	0	0	1	0	0	0	1	0	2	0	0	62	5	RU
SE	0	0	0	2	1	3	0	0	0	1	5	0	0	0	0	0	0	0	1	7	0	0	5	0	0	2	0	0	32	26	SE
SI	0	0	0	2	0	7	0	2	4	1	0	68	2	0	0	0	2	0	1	1	0	16	2	0	0	5	0	0	346	330	SI
SK	0	0	0	2	0	26	0	10	6	2	0	3	31	0	0	0	6	0	1	1	0	2	2	0	0	4	0	0	203	182	SK
TJ	0	0	0	0	0	-0	0	0	0	-0	-0	-0	0	36	3	0	0	23	0	-0	0	0	0	24	0	2	0	0	67	0	TJ
TM	0	0	0	0	0	0	0	0	0	5	-0	0	0	1	27	0	0	18	0	0	0	0	0	21	0	4	0	0	61	0	TM
TR	0	0	0	0	0	1	0	1	1	4	0	0	0	0	0	91	3	0	0	0	3	8	0	16	1	6	0	0	115	9	TR
UA	0	0	0	1	0	20	0	11	1	24	0	0	2	0	0	3	65	0	0	2	3	1	2	1	0	4	0	0	164	54	UA
UZ	0	0	0	0	0	0	0	0	0	7	0	0	0	5	7	0	0	46	0	0	0	0	0	9	0	5	0	0	85	1	UZ
ATL	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0	2	0	0	9	6	ATL
BAS	0	0	0	5	1	12	0	0	0	4	4	0	0	0	0	-0	1	0	1	14	0	0	10	0	0	3	0	0	77	64	BAS
BLS	0	0	0	0	0	1	0	4	1	15	0	0	0	0	0	19	10	0	0	0	13	3	0	1	0	3	0	0	62	10	BLS
MED	0	0	0	0	0	0	0	0	1	0	-0	0	0	0	0	5	1	0	1	0	0	31	0	1	5	4	0	0	41	32	MED
NOS	0	0	0	12	1	3	0	0	0	1	1	0	0	0	0	0	0	0	3	4	0	0	24	0	0	4	0	0	88	62	NOS
AST	0	0	0	0	0	0	0	0	0	1	-0	0	0	1	3	4	0	1	0	0	0	1	0	152	0	5	0	0	14	1	AST
NOA	0	0	0	0	0	0	1	0	0	0	-0	0	0	0	0	1	0	0	2	0	0	9	0	1	26	5	0	0	10	8	NOA
EXC	0	0	0	2	0	5	0	2	1	23	0	0	1	1	1	4	5	2	1	1	0	2	3	5	0	3	0	0	92	42	EXC
EU	0	0	0	6	1	15	2	7	2	2	1	1	2	0	0	1	3	0	3	3	0	6	10	0	1	4	0	0	174	153	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: 2020 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	66	0	1	0	1	0	1	0	0	-0	1	2	0	0	1	0	0	0	0	5	1	3	0	-0	5	0	-0	0	0	0	0	AL
AM	0	125	0	45	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	AM
AT	0	0	68	0	1	1	0	0	3	-0	8	21	0	0	1	0	3	1	0	0	4	8	0	0	11	-0	-0	0	0	0	0	AT
AZ	0	11	0	206	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	0	AZ
BA	1	0	4	0	89	0	1	0	1	0	3	7	0	0	1	0	2	1	0	0	15	9	0	0	8	-0	-0	0	0	0	0	BA
BE	-0	0	0	0	0	106	0	0	1	-0	1	38	1	0	2	0	38	17	0	-0	0	0	2	0	2	-0	-0	0	2	0	0	BE
BG	1	0	1	0	1	0	76	1	0	0	1	2	0	0	0	0	1	0	0	4	1	5	0	-0	3	0	-0	0	0	0	1	BG
BY	0	0	1	0	0	1	0	57	0	0	4	14	2	0	0	0	2	2	0	0	1	3	0	0	1	0	0	3	0	1	1	BY
CH	-0	0	2	0	0	1	0	0	62	-0	0	15	0	0	1	0	9	1	0	-0	0	0	0	-0	15	0	-0	0	0	0	0	CH
CY	0	0	0	0	-0	0	0	0	0	36	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	15	0	1	2	0	0	2	-0	97	51	2	0	1	0	8	3	0	0	4	15	0	0	5	-0	-0	0	0	0	0	CZ
DE	0	0	6	0	0	9	0	0	4	-0	9	154	2	0	1	0	19	9	0	0	0	1	1	0	2	0	0	0	1	0	0	DE
DK	0	0	1	0	0	4	0	0	0	-0	4	54	70	0	1	0	9	15	0	0	0	2	2	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	1	0	9	0	-0	2	10	2	18	0	1	2	2	0	0	0	1	0	0	0	0	0	7	0	7	0	EE
ES	-0	0	0	-0	-0	0	0	0	0	-0	0	0	0	0	53	0	3	0	0	0	0	0	0	0	1	-0	-0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	3	0	-0	0	4	1	1	0	13	1	1	0	0	0	0	0	-0	0	0	0	1	0	1	0	FI
FR	0	0	1	0	0	5	0	0	2	-0	1	11	0	0	5	0	60	6	0	0	0	0	1	0	5	-0	-0	0	0	0	0	FR
GB	0	-0	0	-0	0	6	0	0	0	-0	0	14	2	0	1	0	13	98	-0	-0	0	0	4	0	1	-0	-0	0	0	0	0	GB
GE	0	9	0	30	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	55	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	47	1	2	0	-0	2	0	-0	0	0	0	0	GR
HR	0	0	7	0	20	0	1	0	1	-0	5	9	0	0	1	0	2	1	0	0	69	14	0	-0	32	-0	-0	0	0	0	0	HR
HU	0	0	9	0	4	1	2	0	1	-0	10	14	1	0	1	0	2	1	0	0	14	124	0	0	12	-0	-0	0	0	0	0	HU
IE	0	-0	0	-0	0	2	0	0	0	0	0	7	1	0	0	0	9	23	-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	0	0	-0	0	-0	0	0	0	-0	0	-0	0	1	0	0	0	0	0	-0	0	IS
IT	0	0	3	0	1	0	0	0	1	-0	1	2	0	0	2	0	2	0	0	0	2	1	0	-0	140	-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	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	20	0	0	0	0	KZ
LT	0	0	1	0	0	2	0	16	1	-0	4	22	4	0	1	0	4	3	0	0	1	3	1	0	1	0	0	43	0	2	0	LT
LU	-0	0	1	0	-0	24	0	0	2	-0	1	67	1	0	2	0	42	8	0	-0	0	0	1	0	3	0	-0	0	37	0	0	LU
LV	0	0	1	0	0	1	0	14	0	-0	3	15	3	1	0	0	3	3	0	0	0	2	0	0	1	0	0	21	0	25	0	LV
MD	0	0	1	0	0	0	2	2	0	0	2	6	0	0	0	0	1	0	0	1	1	4	0	0	1	0	0	0	0	0	44	MD
ME	7	0	2	0	8	0	1	0	0	0	2	4	0	0	1	0	1	0	0	1	3	6	0	0	5	0	0	0	0	0	0	ME
MK	9	0	1	0	2	0	5	0	0	-0	2	3	0	0	1	0	1	0	0	15	2	7	0	0	4	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	1	0	0	0	0	1	0	0	12	0	-0	0	0	0	0	MT
NL	-0	0	0	0	-0	34	-0	0	1	-0	1	58	2	0	2	0	24	30	0	-0	0	0	3	0	1	-0	-0	0	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	-0	0	2	1	0	0	0	1	1	0	0	0	0	0	-0	0	0	0	0	0	0	0	NO
PL	0	0	4	0	1	2	0	2	1	-0	21	46	3	0	1	0	7	3	0	0	2	10	1	0	3	0	0	1	0	0	0	PL
PT	-0	-0	0	-0	-0	0	-0	0	0	-0	0	0	0	0	14	0	1	0	-0	-0	0	0	0	0	0	0	-0	0	0	0	0	PT
RO	0	0	1	0	1	0	5	1	0	0	2	4	0	0	0	0	1	0	0	1	1	9	0	-0	3	0	0	0	0	0	2	RO
RS	3	0	4	0	8	0	10	0	1	-0	4	7	0	0	1	0	1	0	0	2	7	19	0	0	6	-0	-0	0	0	0	1	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	2	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	-0	1	11	5	0	0	1	2	2	0	0	0	0	0	-0	0	0	0	0	0	0	0	SE
SI	0	0	18	0	2	0	0	0	1	-0	5	10	0	0	1	0	2	1	0	0	19	6	0	0	78	-0	-0	0	0	0	0	SI
SK	0	0	8	0	2	1	1	0	1	-0	18	21	1	0	1	0	3	1	0	0	6	54	0	0	9	-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	1	-0	0	-0	0	0	-0	0	0	0	0	0	0	0	-0	0	-0	0	0	0	-0	0	1	3	0	0	0	0	TM
TR	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	-0	0	0	-0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	5	0	0	3	9	1	0	0	0	1	1	0	0	1	4	0	0	1	0	1	1	0	0	3	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	8	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	-0	0	1	0	0	1	-0	2	2	0	0	0	0	1	-0	0	0	-0	0	0	0	0	ATL
BAS	0	0	1	0	0	2	0	3	0	-0	4	37	14	1	1	2	6	5	0	0	0	1	1	0	0	0	0	3	0	2	0	BAS
BLS	0	0	0	1	0	0	3	1	0	0	0	1	0	0	0	0	0	0	4	1	0	1	0	-0	1	0	0	0	0	0	1	BLS
MED	1	0	0	0	0	0	1	0	0	0	0	1	0	0	6	0	1	0	0	3	1	1	0	-0	9	0	-0	0	0	0	0	MED
NOS	0	0	0	0	0	9	0	0	0	-0	1	27	8	0	1	0	20	40	0	0	0	0	3	-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	0	0	0	1	0	0	0	0	0	0	0	0	-0	0	0	-0	0	0	0	0	NOA
EXC	0	0	1	1	0	1	1	2	0	0	1	7	1	0	2	0	3	2	0	0	1	2	0	0	3	1	4	1	0	0	0	EXC
EU	0	0	3	0	1	3	3	1	1	0	5	25	2	0	8	1	12	3	0	2	2	6	1	0	13	0	0	1	0	1	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.11 Cont.: 2020 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	1	2	0	0	0	2	0	3	26	0	0	0	1	-0	0	0	1	0	0	0	0	0	0	-0	0	0	0	0	126	27	AL
AM	0	0	-0	0	0	0	0	0	-0	1	0	0	0	-0	0	32	0	0	0	0	0	0	0	28	0	1	0	0	212	0	AM
AT	0	0	0	1	0	3	0	2	3	0	0	5	2	-0	-0	0	0	0	0	0	0	0	0	-0	0	0	0	0	148	139	AT
AZ	0	0	-0	0	0	0	-0	0	0	8	0	0	0	0	2	9	0	1	0	0	0	0	0	31	0	0	0	0	246	0	AZ
BA	2	0	0	1	0	4	0	6	39	1	0	1	2	-0	0	0	1	0	0	0	0	0	0	-0	-0	0	0	0	197	64	BA
BE	-0	-0	0	32	0	1	0	0	-0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	-0	-0	1	0	0	246	227	BE
BG	0	1	0	0	0	2	0	32	20	1	0	0	1	-0	0	10	5	0	0	0	0	0	0	0	0	0	0	0	175	133	BG
BY	0	0	0	2	0	41	0	3	1	11	1	0	2	0	0	1	21	0	0	0	0	0	0	1	0	0	0	0	178	82	BY
CH	-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	108	45	CH
CY	-0	-0	-0	0	0	-0	-0	0	-0	1	0	0	0	-0	0	47	0	-0	0	0	0	0	0	2	1	0	0	0	84	36	CY
CZ	0	0	0	4	0	20	0	4	7	1	0	3	9	-0	-0	0	1	0	0	0	0	0	0	0	0	1	0	0	258	242	CZ
DE	0	0	0	16	0	7	0	0	0	0	1	0	1	-0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	244	229	DE
DK	0	0	0	14	1	15	0	1	1	1	3	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	200	181	DK
EE	0	0	0	2	0	18	0	1	0	12	3	0	1	0	0	1	4	0	0	0	0	0	0	0	0	0	0	0	106	76	EE
ES	-0	-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	60	59	ES
FI	0	0	0	1	0	4	0	0	0	9	2	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	45	30	FI
FR	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	102	94	FR
GB	0	-0	0	11	0	1	0	0	0	0	0	0	0	-0	-0	-0	0	-0	0	0	0	0	0	-0	0	1	0	0	152	54	GB
GE	0	0	-0	0	0	0	0	0	0	4	0	0	0	0	0	16	0	0	0	0	0	0	0	4	0	0	0	0	115	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	1	0	5	6	1	0	0	0	0	0	16	2	0	0	0	0	0	0	0	0	0	0	0	95	65	GR
HR	0	0	0	1	0	5	0	7	36	1	0	6	2	-0	0	0	1	0	0	0	0	0	0	-0	0	0	0	0	224	164	HR
HU	0	0	0	2	0	17	0	30	40	0	0	4	13	-0	-0	1	2	0	0	0	0	0	0	0	0	0	0	0	307	255	HU
IE	0	-0	0	3	0	1	0	0	0	0	0	0	0	0	-0	-0	0	-0	0	0	0	0	0	-0	0	1	0	0	83	59	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	2	0	IS
IT	0	0	0	0	0	1	0	1	1	0	0	2	0	-0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	162	158	IT
KG	-0	-0	-0	0	0	0	0	0	-0	0	0	0	0	3	0	0	0	18	0	0	0	0	0	6	-0	0	0	0	56	0	KG
KZ	-0	-0	-0	0	0	0	0	0	-0	27	0	0	0	0	1	0	1	6	0	0	0	0	0	20	-0	0	0	0	57	1	KZ
LT	0	0	0	4	0	61	0	2	1	11	2	0	2	0	0	1	9	0	0	0	0	0	0	1	0	0	0	0	201	158	LT
LU	-0	-0	0	13	0	1	0	0	-0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	-0	0	0	0	0	203	192	LU
LV	0	0	0	3	0	31	0	1	1	10	3	0	1	0	0	1	6	0	0	0	0	0	0	1	0	0	0	0	152	116	LV
MD	0	0	0	1	0	11	0	30	2	8	0	0	2	0	0	4	39	0	0	0	0	0	0	1	0	0	0	0	165	64	MD
ME	33	0	0	0	0	3	0	4	32	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	119	35	ME
MK	0	50	0	0	0	3	0	7	45	0	0	0	2	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	162	52	MK
MT	0	0	59	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	80	79	MT
NL	-0	-0	0	156	0	2	0	0	-0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	-0	-0	1	0	0	315	283	NL
NO	0	0	0	1	4	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	13	7	NO
PL	0	0	0	4	0	158	0	5	4	2	1	1	8	0	0	1	6	0	0	0	0	0	0	0	0	1	0	0	302	281	PL
PT	-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	0	0	61	61	PT
RO	0	0	0	0	0	6	0	104	11	1	0	0	2	0	0	3	8	0	0	0	0	0	0	0	0	0	0	0	171	141	RO
RS	2	4	0	1	0	7	0	30	226	1	0	1	3	-0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	352	103	RS
RU	0	0	0	0	0	2	0	0	0	60	0	0	0	0	0	1	3	0	0	0	0	0	0	2	0	0	0	0	75	6	RU
SE	0	0	0	2	1	6	0	0	0	1	13	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	50	43	SE
SI	0	0	0	1	0	3	0	2	5	0	0	72	1	-0	-0	0	0	0	0	0	0	0	0	-0	0	0	0	0	229	220	SI
SK	0	0	0	2	0	39	0	18	18	1	0	3	81	-0	-0	1	4	0	0	0	0	0	0	0	0	1	0	0	298	267	SK
TJ	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	0	0	0	25	0	-0	-0	17	0	0	0	0	0	5	-0	0	0	0	46	-0	TJ
TM	-0	-0	-0	0	0	0	-0	0	-0	2	0	0	0	1	28	0	0	20	0	0	0	0	0	15	-0	0	0	0	56	0	TM
TR	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	160	1	0	0	0	0	0	0	4	0	0	0	0	170	4	TR
UA	0	0	0	1	0	21	0	9	2	25	0	0	2	0	0	6	95	1	0	0	0	0	0	1	0	0	0	0	196	57	UA
UZ	-0	-0	-0	0	0	0	-0	0	-0	4	0	0	0	5	2	0	0	72	0	0	0	0	0	6	-0	0	0	0	97	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	-1	0	0	9	7	ATL
BAS	0	0	0	6	1	32	0	1	1	6	10	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	145	125	BAS
BLS	0	0	0	0	0	2	0	9	1	20	0	0	0	0	0	57	15	0	0	0	0	0	0	1	0	0	0	0	123	21	BLS
MED	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	23	1	0	0	0	0	0	0	2	2	0	0	0	52	25	MED
NOS	0	0	0	22	2	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	138	96	NOS
AST	-0	-0	0	0	0	0	0	0	-0	1	0	0	0	0	1	4	0	0	0	0	0	0	0	91	1	1	0	0	8	0	AST
NOA	-0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	16	1	0	0	5	3	NOA
EXC	0	0	0	1	0	6	0	3	2	29	1	0	1	0	1	8	5	4	0	0	0	0	0	5	0	0	0	0	97	36	EXC
EU	0	0	0	5	0	17	1	9	4	2	2	1	2	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	142	127	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: 2020 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	1	0	0	0	1	0	0	0	0	0	1	2	0	0	1	0	1	1	0	1	1	1	0	0	5	0	0	0	0	0	0	AL
AM	0	5	0	6	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	AM
AT	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	1	0	0	0	3	0	0	0	0	0	0	AT
AZ	0	1	0	23	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	0	0	1	0	4	0	0	0	0	0	1	2	0	0	1	0	1	1	0	0	1	1	0	0	4	-0	0	0	0	0	0	BA
BE	0	0	0	0	0	3	0	0	1	0	1	9	0	0	1	0	4	4	0	0	0	0	0	0	2	0	0	0	0	0	0	BE
BG	0	0	0	0	1	0	1	0	0	0	1	2	0	0	0	0	1	1	0	1	0	0	0	0	2	0	0	0	0	0	0	BG
BY	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	-0	0	0	0	BY
CH	0	0	0	0	0	0	0	0	-1	0	0	-0	0	0	0	0	1	0	0	0	0	0	0	-0	2	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	1	4	0	0	0	0	1	1	0	0	0	1	0	0	2	0	0	0	0	0	0	CZ
DE	0	0	1	0	0	1	0	0	1	0	1	6	0	0	1	0	2	2	0	0	0	0	0	0	2	0	0	0	0	0	0	DE
DK	0	0	0	0	0	0	0	0	0	0	0	2	-0	0	0	0	1	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	1	0	0	0	0	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	1	0	0	4	0	1	1	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	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	0	0	0	0	0	0	2	0	0	1	0	1	1	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	1	2	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	1	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	1	0	0	0	1	2	0	0	1	0	1	1	0	3	0	0	0	0	3	0	0	0	0	0	0	GR
HR	0	0	1	0	2	0	0	0	0	0	1	3	0	0	1	0	2	1	0	0	2	1	0	0	7	0	0	0	0	0	0	HR
HU	0	0	1	0	2	0	0	0	0	0	1	4	0	0	0	0	1	1	0	0	1	2	0	0	3	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	-1	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	0	0	0	0	1	0	1	3	0	0	2	0	3	1	0	0	1	0	0	0	39	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	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	2	0	0	0	0	KZ
LT	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	LT
LU	0	0	1	0	0	0	0	0	1	0	1	7	0	0	1	0	3	1	0	0	0	0	0	0	2	0	0	0	-0	0	0	LU
LV	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	LV
MD	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	MD
ME	0	0	0	0	1	0	0	0	0	0	1	2	0	0	1	0	1	0	0	0	1	0	0	0	4	0	0	0	0	0	0	ME
MK	0	0	0	0	1	0	1	0	0	0	1	2	0	0	0	0	1	1	0	1	0	1	0	0	3	0	0	0	0	0	0	MK
MT	0	0	1	0	1	0	0	0	0	0	1	3	0	0	2	0	3	1	0	0	1	0	0	0	10	0	0	0	0	0	0	MT
NL	0	0	0	0	0	3	0	0	1	0	1	11	0	0	1	0	5	5	0	0	0	0	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	0	0	0	1	3	0	0	0	0	1	1	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	1	0	0	2	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	0	0	0	0	1	0	0	0	0	0	1	2	0	0	0	0	1	1	0	0	0	0	0	0	2	0	0	0	0	0	0	RO
RS	0	0	1	0	2	0	1	0	0	0	1	3	0	0	1	0	1	1	0	0	1	1	0	0	4	-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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	1	0	1	0	0	0	0	0	1	3	0	0	1	0	2	1	0	0	2	0	0	0	10	0	0	0	0	0	0	SI
SK	0	0	1	0	1	0	0	0	0	0	1	3	0	0	0	0	1	1	0	0	0	1	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	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	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	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	2	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	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	BAS
BLS	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	BLS
MED	0	0	0	0	1	0	0	0	0	0	1	2	0	0	2	0	2	1	0	1	1	0	0	0	8	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	1	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	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	0	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	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	EXC
EU	0	0	0	0	0	0	0	0	0	-0	0	2	0	0	1	0	1	1	0	0	0	0	0	0	4	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.: 2020 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	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-3	0	0	23	16	AL
AM	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	0	0	0	0	0	0	23	0	-2	0	0	20	2	AM
AT	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	-4	0	0	13	10	AT
AZ	0	0	0	0	0	1	0	0	0	10	0	0	0	0	1	1	1	1	0	0	0	0	0	38	0	1	0	0	45	4	AZ
BA	0	0	0	0	0	2	0	1	1	1	0	0	1	-0	0	0	0	0	0	0	0	0	0	0	1	-3	0	0	23	15	BA
BE	0	0	0	6	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	33	28	BE
BG	0	0	0	0	0	2	0	2	0	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	-3	0	0	20	13	BG
BY	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	11	5	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	-6	0	0	4	4	CH
CY	0	0	0	0	0	1	0	1	0	5	0	0	0	0	0	5	1	0	0	0	0	0	0	7	2	-3	0	0	24	10	CY
CZ	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-4	0	0	18	14	CZ
DE	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	20	16	DE
DK	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	9	6	DK
EE	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	6	3	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	12	10	ES
FI	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	-1	0	0	3	1	FI
FR	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	0	0	10	8	FR
GB	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	8	6	GB
GE	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	1	0	0	0	0	0	0	10	0	-2	0	0	16	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	1	3	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	-2	0	0	24	16	GR
HR	0	0	0	0	0	2	0	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	29	22	HR
HU	0	0	0	0	0	3	0	2	2	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	29	22	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	-3	0	0	-2	-1	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	IS
IT	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	-2	0	0	58	54	IT
KG	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	7	0	0	0	0	0	4	0	-2	0	0	13	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	3	0	-3	0	0	10	1	KZ
LT	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	-3	0	0	8	4	LT
LU	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	-2	0	0	20	16	LU
LV	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	-2	0	0	7	3	LV
MD	0	0	0	0	0	2	0	2	0	4	0	0	0	0	0	1	1	0	0	0	0	0	0	1	0	-4	0	0	19	10	MD
ME	-0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	-3	0	0	16	12	ME
MK	0	2	0	0	0	2	0	1	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	-3	0	0	22	14	MK
MT	0	0	1	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	-1	0	0	31	26	MT
NL	0	0	0	9	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	43	36	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	2	1	NO
PL	0	0	0	1	0	3	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	19	15	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	10	9	PT
RO	0	0	0	0	0	2	0	4	1	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	20	14	RO
RS	0	1	0	0	0	3	0	2	4	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	-3	0	0	31	19	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	1	0	-2	0	0	6	1	RU
SE	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	-1	0	0	3	2	SE
SI	0	0	0	0	0	1	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	0	0	28	24	SI
SK	0	0	0	0	0	3	0	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	21	16	SK
TJ	0	0	0	0	0	0	0	0	0	2	0	0	0	4	1	0	0	8	0	0	0	0	0	5	0	-2	0	0	17	0	TJ
TM	0	0	0	0	0	0	0	0	0	5	0	0	0	0	2	0	0	2	0	0	0	0	0	16	0	-2	0	0	15	2	TM
TR	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	-1	1	0	0	0	0	0	0	7	1	-5	0	0	10	5	TR
UA	0	0	0	0	0	1	0	1	0	5	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	-3	0	0	15	7	UA
UZ	0	0	0	0	0	0	0	0	0	4	0	0	0	2	1	0	0	16	0	0	0	0	0	9	0	-2	0	0	29	1	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	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	7	4	BAS
BLS	0	0	0	0	0	1	0	1	0	9	0	0	0	0	0	2	2	0	0	0	0	0	0	2	0	-2	0	0	24	7	BLS
MED	0	0	0	0	0	1	0	1	0	2	0	0	0	0	0	1	1	0	0	0	0	0	0	1	3	-1	0	0	29	22	MED
NOS	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	8	NOS
AST	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	1	0	0	0	0	0	46	0	-2	0	0	7	1	AST
NOA	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	-1	0	0	12	9	NOA
EXC	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	-2	0	0	11	5	EXC
EU	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	0	17	13	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: 2020 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	318	0	3	0	25	0	13	1	1	0	6	10	0	0	4	0	5	1	0	27	7	8	0	0	35	0	1	0	0	0	1	AL
AM	0	317	0	239	0	0	0	0	0	0	0	1	0	0	0	0	0	0	39	1	0	0	0	0	1	0	11	0	0	0	0	AM
AT	0	0	346	0	7	3	1	1	14	0	43	126	1	0	2	0	22	6	0	0	18	23	0	0	61	0	0	0	1	0	0	AT
AZ	0	33	0	823	0	0	1	1	0	0	0	1	0	0	0	0	0	0	46	0	0	0	0	0	1	0	39	0	0	0	0	AZ
BA	2	0	16	0	734	2	6	1	2	0	17	32	1	0	3	0	9	3	0	1	59	27	0	0	37	-0	1	0	0	0	1	BA
BE	0	0	3	0	0	354	0	1	6	0	9	201	4	0	11	1	250	88	0	0	0	1	6	0	9	0	0	0	9	0	0	BE
BG	2	0	3	0	11	1	361	6	1	0	6	11	1	0	1	0	3	2	0	21	4	12	0	0	9	0	3	1	0	0	7	BG
BY	0	0	3	1	2	2	1	244	1	0	13	41	4	2	1	2	6	7	0	1	2	7	1	0	4	0	7	15	0	4	3	BY
CH	0	0	21	0	0	3	0	0	301	0	6	114	0	0	4	0	82	7	0	0	1	1	0	0	77	0	0	0	1	0	0	CH
CY	1	0	0	1	1	0	4	1	0	107	1	2	0	0	2	0	2	1	1	27	0	1	0	0	7	0	1	0	0	0	1	CY
CZ	0	0	71	0	9	7	1	3	9	0	438	219	3	0	3	0	35	13	0	0	15	41	1	0	19	0	0	1	1	0	1	CZ
DE	0	0	36	0	1	31	0	1	21	0	35	590	7	0	6	1	86	42	0	0	1	3	3	0	9	0	0	1	4	0	0	DE
DK	0	0	3	0	1	18	0	2	2	0	11	177	191	0	3	1	34	58	0	0	1	3	4	1	1	0	1	1	1	1	0	DK
EE	0	0	1	0	0	2	0	24	0	0	4	23	5	82	1	8	5	8	0	0	0	2	1	0	1	0	4	15	0	24	1	EE
ES	0	0	0	0	1	1	0	0	0	0	1	5	0	0	312	0	17	3	0	0	0	0	0	0	6	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	6	0	0	1	9	2	3	0	44	2	3	0	0	0	0	0	0	0	0	3	2	0	2	0	FI
FR	0	0	4	0	1	20	0	0	11	0	5	69	1	0	27	0	337	31	0	0	1	1	3	0	19	0	0	0	2	0	0	FR
GB	0	0	1	0	0	15	0	0	1	0	2	43	4	0	3	0	40	357	0	0	0	0	17	1	2	0	0	0	1	0	0	GB
GE	0	30	0	162	0	0	1	1	0	0	0	1	0	0	0	0	0	0	306	1	0	0	0	0	1	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	2	0	8	0	44	3	0	0	4	6	0	0	3	0	3	1	0	228	3	5	0	0	18	0	1	0	0	0	3	GR
HR	1	0	37	0	170	2	5	1	3	0	28	49	1	0	4	0	14	4	0	1	366	55	0	0	111	0	1	0	0	0	1	HR
HU	1	0	50	0	38	3	9	3	3	0	46	68	2	0	2	0	13	6	0	1	59	482	1	0	44	0	1	1	0	0	2	HU
IE	0	0	0	0	0	7	0	0	0	0	1	23	2	0	2	0	23	109	0	0	0	0	151	1	1	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	2	0	0	0	0	0	37	0	0	0	0	0	0	0	IS
IT	1	0	17	0	11	1	2	1	9	0	7	22	0	0	13	0	26	3	0	1	13	6	0	0	805	0	1	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	131	67	0	0	0	0	KG
KZ	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	6	271	0	0	0	0	KZ
LT	0	0	4	0	2	4	1	64	1	0	13	59	10	3	1	3	9	14	0	0	2	6	1	0	3	0	4	142	0	14	1	LT
LU	0	0	6	0	0	84	0	1	10	0	10	299	2	0	9	0	261	44	0	0	0	1	4	0	13	0	0	0	117	0	0	LU
LV	0	0	2	0	1	3	0	43	1	0	7	36	7	7	1	4	6	11	0	0	1	3	1	0	2	0	4	52	0	112	1	LV
MD	1	0	3	1	4	1	17	18	1	0	11	24	1	1	1	1	4	3	1	4	2	11	0	0	5	0	7	2	0	1	363	MD
ME	26	0	5	0	71	1	7	1	1	0	8	14	1	0	3	0	5	2	0	4	11	12	0	0	24	0	1	0	0	0	1	ME
MK	33	0	3	0	15	0	38	2	1	0	6	10	0	0	3	0	4	1	0	63	5	12	0	0	16	0	1	0	0	0	1	MK
MT	2	0	2	0	9	1	4	0	1	0	3	7	0	0	18	0	15	2	0	5	4	3	0	0	93	0	1	0	0	0	0	MT
NL	0	0	3	0	0	140	0	1	4	0	7	277	7	0	10	1	140	129	0	0	0	0	9	1	5	0	0	1	4	0	0	NL
NO	0	0	0	0	0	1	0	1	0	0	1	6	2	0	0	1	2	5	0	0	0	0	0	0	0	0	1	0	0	0	0	NO
PL	0	0	14	0	5	7	2	15	3	0	74	149	8	1	3	1	21	16	0	0	6	25	1	0	10	0	2	5	1	2	1	PL
PT	0	0	0	0	0	1	0	0	0	0	0	4	0	0	106	0	7	4	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	1	0	6	0	11	1	41	7	1	0	10	20	1	0	1	0	5	2	0	4	5	32	0	0	11	0	3	1	0	0	15	RO
RS	11	0	15	0	80	1	43	3	2	0	19	31	1	0	3	0	8	3	0	9	26	61	0	0	24	-0	2	1	0	0	3	RS
RU	0	0	0	3	0	0	0	7	0	0	1	3	1	1	0	1	1	1	1	0	0	0	0	0	0	0	40	1	0	1	0	RU
SE	0	0	1	0	0	2	0	2	0	0	2	26	11	1	1	3	6	8	0	0	0	1	1	0	0	0	2	1	0	1	0	SE
SI	0	0	111	0	21	2	1	1	5	0	27	59	1	0	4	0	16	4	0	0	121	27	0	0	276	0	1	0	0	0	1	SI
SK	0	0	35	0	15	3	4	4	3	0	70	72	2	0	2	0	13	6	0	1	19	153	1	0	26	0	1	1	0	1	1	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	13	40	0	0	0	0	TJ
TM	0	1	0	11	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	3	110	0	0	0	0	TM
TR	0	5	0	7	1	0	6	2	0	2	1	2	0	0	1	0	1	1	3	8	0	1	0	0	3	0	2	0	0	0	1	TR
UA	0	0	3	4	3	1	6	30	1	0	10	25	2	1	1	1	4	4	2	2	2	11	0	0	4	0	15	3	0	1	16	UA
UZ	0	0	0	3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	23	168	0	0	0	0	UZ
ATL	0	0	0	0	0	1	0	0	0	0	0	3	0	0	6	0	6	7	0	0	0	0	2	1	0	0	1	0	0	0	0	ATL
BAS	0	0	2	0	1	6	1	8	1	0	9	81	27	5	2	8	14	19	0	0	1	2	1	0	1	0	2	7	0	6	0	BAS
BLS	0	2	1	11	2	0	17	8	0	0	2	6	0	0	1	0	1	1	24	5	1	2	0	0	2	0	8	1	0	0	6	BLS
MED	4	0	2	0	10	1	7	1	1	2	3	7	0	0	28	0	17	2	0	22	6	3	0	0	70	0	1	0	0	0	1	MED
NOS	0	0	1	0	0	18	0	1	1	0	3	62	14	0	3	0	47	98	0	0	0	0	6	1	2	0	0	0	1	0	0	NOS
AST	0	1	0	8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	2	29	0	0	0	0	AST
NOA	1	0	0	0	2	0	2	0	0	0	1	2	0	0	14	0	5	1	0	5	1	1	0	0	11	0	0	0	0	0	0	NOA
EXC	1	1	4	7	4	3	4	8	2	0	6	26	2	1	11	2	16	9	2	3	3	6	1	0	17	3	65	2	0	1	2	EXC
EU	1	0	18	0	7	11	14	5	5	0	23	97	5	2	46	4	66	16	0	8	10	20	4	0	71	0	1	4	1	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.13 Cont.: 2020 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	55	89	0	1	0	18	0	14	221	3	0	1	3	0	0	8	8	0	0	0	0	18	0	1	8	10	6	29	891	157	AL
AM	0	1	0	0	0	1	0	1	2	12	0	0	0	0	4	149	4	1	0	0	1	1	0	265	3	11	1	6	786	6	AM
AT	1	0	0	4	1	35	0	6	22	4	1	28	9	0	0	1	6	0	1	1	0	3	3	0	2	8	3	2	795	730	AT
AZ	0	0	0	0	0	2	0	1	2	62	0	0	0	0	16	52	12	6	0	0	1	1	0	284	2	14	1	3	1104	9	AZ
BA	33	4	0	2	0	39	0	20	189	5	1	4	7	0	0	3	9	0	0	1	0	8	1	1	5	9	4	12	1273	285	BA
BE	0	0	0	112	2	18	1	1	1	3	2	0	1	0	0	1	2	0	8	2	0	2	67	0	2	23	19	1	1099	993	BE
BG	7	21	0	1	0	30	0	114	155	16	0	1	4	0	0	45	50	0	0	1	4	4	1	1	4	8	7	8	915	587	BG
BY	1	1	0	5	1	168	0	11	12	58	3	1	5	0	0	11	91	1	1	6	0	1	4	2	1	7	5	1	743	302	BY
CH	0	0	0	3	0	5	0	2	2	2	0	1	1	0	0	1	2	0	1	1	0	3	3	0	2	8	3	2	640	325	CH
CY	2	5	0	0	0	4	0	4	10	15	0	0	0	0	0	780	15	0	0	0	2	49	0	103	24	15	39	35	997	162	CY
CZ	1	1	0	10	1	143	0	10	38	6	2	10	32	0	0	2	9	0	1	3	0	2	7	0	1	10	6	1	1157	1064	CZ
DE	0	0	0	52	2	49	1	2	4	5	3	1	2	0	0	1	4	0	4	7	0	2	33	0	2	14	12	1	1007	926	DE
DK	0	0	0	43	9	55	0	1	3	7	12	0	2	0	0	1	4	0	4	35	0	1	65	0	1	13	21	0	654	565	DK
EE	0	0	0	4	3	54	0	2	3	46	9	0	1	0	0	5	18	0	1	12	0	0	4	1	0	7	7	0	358	244	EE
ES	1	0	0	1	0	1	25	1	3	0	0	0	0	0	0	0	0	0	11	0	0	21	1	0	24	18	17	5	382	372	ES
FI	0	0	0	1	3	13	0	1	1	38	8	0	0	0	0	2	7	0	1	5	0	0	2	1	0	6	7	0	157	94	FI
FR	1	0	0	14	1	7	1	2	5	2	1	1	1	0	0	1	2	0	7	1	0	7	22	0	5	14	18	4	571	517	FR
GB	0	0	0	29	2	10	0	0	0	2	1	0	0	0	0	0	1	0	13	3	0	0	45	0	1	15	28	0	534	170	GB
GE	0	1	0	0	0	2	0	1	2	32	0	0	0	0	4	112	10	1	0	0	2	0	0	95	2	8	4	4	685	8	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	34	1	0	0	0	GL
GR	10	50	0	1	0	16	0	23	93	11	0	1	2	0	0	87	25	0	0	0	2	25	0	1	10	10	14	34	662	358	GR
HR	9	3	0	3	0	48	0	24	178	5	1	34	10	0	0	2	10	0	1	1	0	16	2	0	4	9	5	10	1185	795	HR
HU	6	5	0	5	1	124	0	120	220	8	1	18	60	0	0	5	24	0	1	2	0	6	3	1	2	10	4	5	1435	1112	HU
IE	0	0	0	11	1	6	0	0	0	1	1	0	0	0	0	0	0	0	19	2	0	0	23	0	0	13	33	0	344	231	IE
IS	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	12	18	0	41	2	IS
IT	5	3	0	1	0	14	1	6	30	3	0	15	2	0	0	2	5	0	1	0	0	48	1	0	15	12	13	51	1029	955	IT
KG	0	0	0	0	0	0	0	0	0	3	0	0	0	29	4	4	0	189	0	0	0	0	0	79	0	8	0	1	430	1	KG
KZ	0	0	0	0	0	3	0	0	1	101	0	0	0	2	4	4	9	28	0	0	0	0	0	66	0	10	1	1	436	7	KZ
LT	1	1	0	9	2	204	0	7	8	46	7	1	5	0	0	7	36	0	1	16	0	0	8	2	1	7	8	1	696	508	LT
LU	0	0	0	39	1	13	1	1	1	3	2	1	1	0	0	1	2	0	5	1	0	3	27	0	3	15	13	1	929	864	LU
LV	0	0	0	6	2	96	0	4	5	40	8	1	3	0	0	6	26	0	1	12	0	0	5	1	0	7	8	1	505	362	LV
MD	3	4	0	2	1	83	0	171	33	40	1	1	6	0	0	42	207	1	0	2	6	2	2	3	2	9	5	4	1083	353	MD
ME	400	14	0	1	0	21	0	14	193	4	0	1	4	0	0	5	7	0	0	0	0	8	0	1	5	9	4	16	861	135	ME
MK	17	405	0	1	0	21	0	24	282	4	0	1	4	0	0	14	11	0	0	0	1	5	0	1	6	9	4	13	1000	212	MK
MT	7	7	101	1	0	9	2	4	28	2	0	1	1	0	0	4	5	0	1	0	0	132	0	0	69	14	48	171	344	274	MT
NL	0	0	0	415	3	33	1	0	0	4	3	0	1	0	0	0	3	0	10	7	0	2	112	0	2	29	21	0	1205	1060	NL
NO	0	0	0	1	33	5	0	0	0	8	3	0	0	0	0	1	2	0	2	1	0	0	4	0	0	8	14	0	76	24	NO
PL	1	1	0	13	2	874	0	16	26	16	4	3	26	0	0	4	33	0	2	10	0	1	9	1	1	11	8	1	1390	1265	PL
PT	0	0	0	1	0	1	313	0	0	0	0	0	0	0	0	0	0	0	32	0	0	5	1	0	16	20	25	2	441	436	PT
RO	6	8	0	2	1	62	0	578	106	15	1	2	9	0	0	26	64	0	0	1	3	3	1	1	3	8	4	6	1059	793	RO
RS	41	43	0	2	0	56	0	99	1112	7	1	3	13	0	0	7	20	0	1	1	0	5	2	1	5	10	3	10	1753	418	RS
RU	0	0	0	0	0	9	0	1	1	215	1	0	0	0	1	5	19	2	0	1	0	0	0	7	0	9	4	0	319	23	RU
SE	0	0	0	5	8	19	0	1	1	10	36	0	0	0	0	1	4	0	1	8	0	0	5	0	0	6	9	0	155	117	SE
SI	2	1	0	3	1	38	0	12	50	5	1	404	6	0	0	1	9	0	1	1	0	21	3	0	2	7	4	6	1213	1112	SI
SK	3	2	0	5	1	203	0	51	88	8	1	9	280	0	0	4	27	0	1	1	0	3	3	1	1	9	4	3	1119	955	SK
TJ	0	0	0	0	0	0	0	0	0	5	0	0	0	272	18	6	1	157	0	-0	0	0	0	105	0	9	0	1	513	1	TJ
TM	0	0	0	0	0	2	0	0	1	36	0	0	0	10	136	10	9	95	0	0	0	0	0	137	1	13	1	2	430	5	TM
TR	1	3	0	0	0	5	0	6	11	21	0	0	0	0	0	1011	23	0	0	0	5	12	0	122	8	13	10	15	1132	38	TR
UA	2	2	0	2	1	99	0	40	18	98	1	1	6	0	1	38	477	1	0	2	4	2	2	6	2	9	4	3	939	227	UA
UZ	0	0	0	0	0	2	0	0	0	40	0	0	0	41	32	6	8	389	0	0	0	0	0	62	0	13	1	1	719	5	UZ
ATL	0	0	0	1	1	1	4	0	0	5	0	0	0	0	0	0	0	0	7	0	0	1	2	0	4	17	34	0	41	26	ATL
BAS	0	0	0	13	4	88	0	3	4	23	23	0	2	0	0	3	10	0	1	22	0	0	12	1	0	8	12	0	381	303	BAS
BLS	1	3	0	1	0	19	0	29	17	100	0	0	1	0	1	284	125	1	0	0	25	5	0	16	2	9	18	5	684	91	BLS
MED	7	8	0	1	0	9	2	8	31	8	0	2	1	0	0	150	12	0	2	0	1	69	0	16	52	13	38	85	427	192	MED
NOS	0	0	0	40	9	12	0	0	1	3	3	0	0	0	0	0	1	0	5	4	0	0	35	0	0	13	30	0	328	213	NOS
AST	0	0	0	0	0	1	0	0	1	10	0	0	0	3	12	62	3	11	0	0	0	2	0	821	5	19	2	5	147	5	AST
NOA	2	2	0	0	0	2	4	2	8	2	0	0	0	0	0	22	3	0	4	0	0	20	0	5	215	24	17	33	93	50	NOA
EXC	1	2	0	4	1	32	2	13	15	108	2	1	3	4	6	50	30	20	1	1	1	3	3	27	2	11	6	3	505	163	EXC
EU	2	3	0	14	2	96	10	44	29	11	6	5	9	0	0	9	13	0	4	4	0	9	11	1	6	12	12	7	700	594	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: 2020 country-to-country blame matrices for **fine 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	182	0	1	0	8	0	3	0	0	0	1	1	0	0	1	0	1	0	0	7	3	2	0	0	10	0	0	0	0	0	0	AL
AM	0	147	0	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	214	0	2	0	0	0	3	0	12	18	0	0	0	0	6	1	0	0	6	8	0	0	17	0	0	0	0	0	0	AT
AZ	0	12	0	554	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	1	0	5	0	405	0	1	0	0	0	3	4	0	0	1	0	2	0	0	0	29	8	0	0	11	0	0	0	0	0	1	BA
BE	0	0	1	0	0	211	0	0	1	0	2	29	0	0	2	0	94	11	0	0	0	0	1	0	1	0	0	0	2	0	0	BE
BG	1	0	1	0	4	0	179	1	0	0	1	1	0	0	0	0	1	0	0	7	1	3	0	0	2	0	0	0	0	0	3	BG
BY	0	0	1	0	1	0	0	146	0	0	2	4	1	0	0	0	1	1	0	0	1	2	0	0	1	0	0	6	0	2	1	BY
CH	0	0	7	0	0	0	0	0	134	0	1	21	0	0	1	0	33	1	0	0	0	0	0	0	21	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	41	0	0	0	0	1	0	0	0	0	5	0	0	0	0	2	0	0	0	0	0	0	CY
CZ	0	0	21	0	3	1	0	1	1	0	251	32	0	0	0	0	8	2	0	0	5	10	0	0	4	0	0	0	0	0	0	CZ
DE	0	0	11	0	0	5	0	0	4	0	9	200	1	0	1	0	26	5	0	0	0	1	0	0	2	0	0	0	1	0	0	DE
DK	0	0	1	0	0	2	0	1	0	0	2	20	84	0	0	0	6	7	0	0	0	1	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	3	1	55	0	2	1	1	0	0	0	0	0	0	0	0	0	4	0	10	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	147	0	6	0	0	0	0	0	0	0	2	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	3	0	0	2	0	1	10	0	0	5	0	198	4	0	0	0	0	0	0	5	0	0	0	0	0	0	FR
GB	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	7	128	0	0	0	0	3	0	0	0	0	0	0	0	0	GB
GE	0	8	0	53	0	0	0	0	0	0	0	0	0	0	0	0	0	0	226	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	1	0	3	0	11	1	0	0	1	1	0	0	1	0	1	0	0	112	1	1	0	0	5	0	0	0	0	0	1	GR
HR	1	0	11	0	83	0	1	0	0	0	6	6	0	0	1	0	4	1	0	0	223	20	0	0	27	0	0	0	0	0	1	HR
HU	0	0	17	0	14	0	2	1	0	0	10	7	0	0	0	0	3	1	0	0	23	248	0	0	9	0	0	0	0	0	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	4	13	0	0	0	0	62	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	6	0	0	0	0	0	0	0	IS
IT	0	0	4	0	4	0	0	0	2	0	1	2	0	0	3	0	8	0	0	0	4	2	0	0	365	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	44	6	0	0	0	0	KG
KZ	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	37	0	0	0	0	KZ
LT	0	0	1	0	0	1	0	18	0	0	3	6	1	1	0	1	2	2	0	0	0	1	0	0	1	0	0	92	0	7	1	LT
LU	0	0	1	0	0	24	0	0	1	0	2	62	0	0	2	0	114	5	0	0	0	0	0	0	2	0	0	0	63	0	0	LU
LV	0	0	0	0	0	0	0	12	0	0	2	4	1	3	0	1	1	2	0	0	0	1	0	0	0	0	0	17	0	70	0	LV
MD	0	0	1	0	1	0	4	4	0	0	2	2	0	0	0	0	1	0	1	1	1	2	0	0	1	0	0	1	0	0	290	MD
ME	13	0	2	0	25	0	2	0	0	0	2	2	0	0	1	0	1	0	0	1	4	3	0	0	7	0	0	0	0	0	0	ME
MK	14	0	1	0	5	0	11	0	0	0	1	1	0	0	1	0	1	0	0	18	2	3	0	0	4	0	0	0	0	0	1	MK
MT	1	0	1	0	3	0	1	0	0	0	1	1	0	0	6	0	6	0	0	1	2	1	0	0	29	0	0	0	0	0	0	MT
NL	0	0	0	0	0	44	0	0	0	0	1	54	1	0	1	0	32	16	0	0	0	0	1	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	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	2	1	0	4	0	0	19	18	1	0	0	0	4	2	0	0	2	6	0	0	2	0	0	1	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	0	4	0	13	2	0	0	2	2	0	0	0	0	1	0	0	1	2	9	0	0	3	0	0	0	0	0	8	RO
RS	5	0	4	0	33	0	11	1	0	0	4	3	0	0	1	0	2	0	0	2	10	18	0	0	5	0	0	0	0	0	1	RS
RU	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	3	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	47	0	7	0	0	0	1	0	5	6	0	0	1	0	4	0	0	0	56	9	0	0	60	0	0	0	0	0	0	SI
SK	0	0	12	0	5	0	1	1	0	0	21	8	0	0	0	0	3	1	0	0	6	52	0	0	5	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	2	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	0	6	0	0	0	0	TM
TR	0	2	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	1	1	1	0	1	10	0	0	2	2	0	0	0	0	1	1	1	0	1	3	0	0	1	0	1	1	0	0	9	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	13	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	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	2	0	0	2	10	7	3	0	3	3	3	0	0	0	1	0	0	0	0	0	2	0	3	0	BAS
BLS	0	1	0	4	1	0	5	2	0	0	0	1	0	0	0	0	0	0	16	1	0	1	0	0	0	0	0	0	0	0	3	BLS
MED	2	0	1	0	4	0	2	0	0	0	1	1	0	0	11	0	8	0	0	9	3	1	0	0	28	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	3	0	0	0	0	0	6	2	0	0	0	10	21	0	0	0	0	1	0	0	0	0	0	0	0	0	NOS
AST	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	2	0	0	0	0	AST
NOA	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6	0	2	0	0	1	0	0	0	0	3	0	0	0	0	0	0	NOA
EXC	0	0	2	4	2	1	2	3	1	0	2	6	0	0	4	1	8	2	1	1	1	2	0	0	7	1	7	1	0	1	1	EXC
EU	0	0	7	0	3	3	6	1	1	0	8	23	1	1	20	2	32	2	0	4	5	8	1	0	30	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.14 Cont.: 2020 country-to-country blame matrices for **fine 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	15	10	0	0	0	5	0	3	53	0	0	0	1	0	0	1	3	0	0	0	0	1	0	0	1	0	0	0	313	41	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	23	1	0	0	0	0	0	0	15	0	0	0	0	256	1	AM
AT	0	0	0	0	0	11	0	1	2	0	0	12	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	320	310	AT
AZ	0	0	0	0	0	0	0	0	0	7	0	0	0	0	2	6	3	1	0	0	0	0	0	19	0	0	0	0	612	1	AZ
BA	6	0	0	0	0	11	0	4	26	1	0	2	2	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	527	84	BA
BE	0	0	0	20	0	5	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	14	0	0	0	0	0	381	368	BE
BG	1	2	0	0	0	9	0	30	22	2	0	0	1	0	0	6	17	0	0	0	0	0	0	0	0	0	0	0	298	239	BG
BY	0	0	0	0	0	60	0	3	1	9	0	0	1	0	0	1	40	0	0	1	0	0	0	0	0	0	0	0	288	87	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	224	88	CH
CY	0	0	0	0	0	1	0	1	1	2	0	0	0	0	0	70	5	0	0	0	0	4	0	11	2	0	0	0	131	52	CY
CZ	0	0	0	1	0	71	0	2	4	1	0	3	10	0	0	0	3	0	0	0	0	0	1	0	0	0	0	0	435	420	CZ
DE	0	0	0	7	0	18	0	0	0	0	0	0	1	0	0	0	1	0	0	1	0	0	3	0	0	0	0	0	296	284	DE
DK	0	0	0	4	2	17	0	0	0	1	2	0	0	0	0	0	2	0	0	6	0	0	7	0	0	0	0	0	153	140	DK
EE	0	0	0	0	1	18	0	1	0	8	2	0	0	0	0	0	7	0	0	3	0	0	1	0	0	0	0	0	124	99	EE
ES	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	166	165	ES
FI	0	0	0	0	1	4	0	0	0	5	2	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	42	31	FI
FR	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	237	230	FR
GB	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0	0	151	22	GB
GE	0	0	0	0	0	0	0	0	0	4	0	0	0	0	1	13	3	0	0	0	0	0	0	4	0	0	0	0	310	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	5	0	6	11	1	0	0	0	0	0	10	9	0	0	0	0	3	0	0	1	0	0	0	194	146	GR
HR	1	0	0	0	0	14	0	5	27	1	0	19	2	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	458	340	HR
HU	0	0	0	0	0	40	0	32	35	1	0	7	22	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	489	423	HU
IE	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	85	72	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	6	0	IS
IT	0	0	0	0	0	4	0	1	2	0	0	5	1	0	0	0	2	0	0	0	0	3	0	0	2	0	0	0	414	403	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	13	1	0	0	24	0	0	0	0	0	13	0	0	0	0	88	0	KG
KZ	0	0	0	0	0	1	0	0	0	10	0	0	0	1	1	0	3	5	0	0	0	0	0	8	0	0	0	0	61	1	KZ
LT	0	0	0	1	1	72	0	2	1	12	1	0	1	0	0	1	13	0	0	2	0	0	1	0	0	0	0	0	242	193	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	287	280	LU
LV	0	0	0	1	1	32	0	1	0	7	1	0	1	0	0	0	10	0	0	2	0	0	1	0	0	0	0	0	171	138	LV
MD	0	0	0	0	0	24	0	54	3	5	0	0	2	0	0	4	86	0	0	0	0	0	0	0	0	0	0	0	492	97	MD
ME	189	1	0	0	0	6	0	3	33	0	0	0	1	0	0	0	3	0	0	0	0	1	0	0	1	0	0	0	301	36	ME
MK	1	136	0	0	0	7	0	6	65	0	0	0	1	0	0	1	4	0	0	0	0	0	0	0	1	0	0	0	288	58	MK
MT	1	0	111	0	0	2	0	1	2	0	0	1	0	0	0	0	2	0	0	0	0	24	0	0	15	0	0	0	172	163	MT
NL	0	0	0	207	0	8	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	27	0	0	0	0	0	369	351	NL
NO	0	0	0	0	22	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	29	4	NO
PL	0	0	0	1	0	660	0	4	2	4	0	1	9	0	0	0	15	0	0	1	0	0	1	0	0	0	0	0	768	736	PL
PT	0	0	0	0	0	0	173	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	213	213	PT
RO	0	0	0	0	0	18	0	251	15	2	0	1	2	0	0	3	26	0	0	0	0	0	0	0	0	0	0	0	369	308	RO
RS	8	6	0	0	0	16	0	26	419	1	0	1	3	0	0	1	7	0	0	0	0	0	0	0	0	0	0	0	588	106	RS
RU	0	0	0	0	0	3	0	0	0	40	0	0	0	0	0	0	7	0	0	0	0	0	0	1	0	0	0	0	59	5	RU
SE	0	0	0	0	4	6	0	0	0	1	12	0	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	36	28	SE
SI	0	0	0	0	0	11	0	3	4	0	0	300	1	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	520	504	SI
SK	0	0	0	0	0	98	0	12	10	1	0	3	163	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	422	387	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	167	3	1	0	25	0	0	0	0	0	25	0	0	0	0	201	0	TJ
TM	0	0	0	0	0	1	0	0	0	4	0	0	0	4	43	1	2	23	0	0	0	0	0	11	0	0	0	0	88	1	TM
TR	0	0	0	0	0	1	0	1	1	2	0	0	0	0	0	226	7	0	0	0	0	1	0	10	1	0	0	0	251	8	TR
UA	0	0	0	0	0	34	0	11	2	14	0	0	2	0	0	4	292	0	0	0	0	0	0	0	0	0	0	0	396	60	UA
UZ	0	0	0	0	0	1	0	0	0	4	0	0	0	25	12	0	2	132	0	0	0	0	0	4	0	0	0	0	197	1	UZ
ATL	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	9	6	ATL
BAS	0	0	0	1	2	36	0	1	0	6	7	0	0	0	0	0	4	0	0	14	0	0	2	0	0	0	0	0	98	81	BAS
BLS	0	0	0	0	0	6	0	8	2	17	0	0	0	0	0	48	57	0	0	0	4	0	0	1	0	0	0	0	176	25	BLS
MED	1	0	0	0	0	3	1	2	3	1	0	1	0	0	0	17	4	0	0	0	0	10	0	2	14	0	0	0	105	72	MED
NOS	0	0	0	4	5	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18	0	0	0	0	0	59	32	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	7	1	2	0	0	0	0	0	293	0	0	0	0	21	1	AST
NOA	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	2	1	0	0	0	0	1	0	1	71	0	0	0	20	15	NOA
EXC	0	0	0	1	1	17	1	5	3	18	0	1	1	2	2	10	15	5	0	0	0	0	0	3	0	0	0	0	143	63	EXC
EU	0	0	0	3	1	60	5	17	4	2	2	3	4	0	0	1	5	0	0	1	0	1	1	0	1	0	0	0	270	250	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: 2020 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 primary EC. **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	316	0	1	0	10	0	5	0	0	0	1	1	0	0	3	0	1	0	0	10	4	4	0	0	10	0	0	0	0	0	1	AL
AM	0	150	0	57	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	228	0	3	0	0	0	3	0	11	15	0	0	1	0	5	1	0	0	8	10	0	0	23	0	0	0	0	0	0	AT
AZ	0	13	0	515	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	2	0	6	0	597	0	2	0	0	0	3	3	0	0	2	0	2	1	0	1	37	12	0	0	12	0	0	0	0	0	1	BA
BE	0	0	1	0	0	205	0	0	1	0	1	19	0	0	4	0	70	16	0	0	0	0	1	0	1	0	0	0	3	0	0	BE
BG	2	0	1	0	5	0	261	1	0	0	1	1	0	0	1	0	1	0	0	10	2	4	0	0	3	0	0	0	0	0	5	BG
BY	0	0	1	0	1	0	0	156	0	0	2	3	1	1	1	1	1	2	0	0	1	2	0	0	1	0	0	6	0	2	2	BY
CH	0	0	8	0	0	0	0	0	129	0	1	16	0	0	3	0	27	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	46	0	0	0	0	1	0	0	0	0	8	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	25	0	4	1	0	1	2	0	216	24	1	0	2	0	8	2	0	0	6	13	0	0	4	0	0	0	0	0	0	CZ
DE	0	0	11	0	0	5	0	0	4	0	7	146	1	0	3	0	21	7	0	0	1	1	0	0	2	0	0	0	1	0	0	DE
DK	0	0	1	0	0	2	0	1	0	0	1	13	106	0	1	0	5	11	0	0	0	1	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	2	1	81	0	4	1	2	0	0	0	1	0	0	0	0	0	3	0	12	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	314	0	5	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	39	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	3	0	0	3	0	1	7	0	0	12	0	160	6	0	0	0	0	0	0	5	0	0	0	1	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	6	172	0	0	0	0	4	0	0	0	0	0	0	0	0	GB
GE	0	13	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	420	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	3	0	17	1	0	0	1	1	0	0	2	0	1	0	0	149	1	2	0	0	5	0	0	0	0	0	2	GR
HR	1	0	14	0	114	0	2	0	1	0	5	5	0	0	3	0	4	1	0	0	295	28	0	0	27	0	0	0	0	0	1	HR
HU	1	0	20	0	20	0	3	1	1	0	9	6	0	0	1	0	3	1	0	1	31	324	0	0	10	0	0	0	0	0	1	HU
IE	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	0	3	20	0	0	0	0	56	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	1	0	5	0	5	0	1	0	2	0	1	2	0	0	8	0	8	0	0	0	6	2	0	0	324	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	26	4	0	0	0	0	KG
KZ	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	36	0	0	0	0	KZ
LT	0	0	1	0	1	1	0	19	0	0	2	4	2	2	1	1	2	3	0	0	1	2	0	0	1	0	0	88	0	9	1	LT
LU	0	0	1	0	0	23	0	0	1	0	2	40	0	0	4	0	81	7	0	0	0	0	0	0	2	0	0	0	165	0	0	LU
LV	0	0	1	0	0	0	0	12	0	0	1	3	1	6	0	2	1	2	0	0	0	1	0	0	0	0	0	16	0	87	1	LV
MD	0	0	1	0	2	0	5	4	0	0	2	2	0	0	1	0	1	1	1	1	1	4	0	0	1	0	0	1	0	0	409	MD
ME	17	0	2	0	31	0	3	0	0	0	2	1	0	0	2	0	1	0	0	1	6	5	0	0	8	0	0	0	0	0	1	ME
MK	21	0	1	0	7	0	17	0	0	0	1	1	0	0	2	0	1	0	0	27	2	5	0	0	5	0	0	0	0	0	1	MK
MT	1	0	1	0	3	0	1	0	0	0	0	1	0	0	14	0	5	0	0	2	2	1	0	0	24	0	0	0	0	0	0	MT
NL	0	0	0	0	0	40	0	0	0	0	1	35	1	0	3	0	26	24	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	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	4	0	2	1	1	4	0	0	16	14	1	0	1	0	4	3	0	0	2	8	0	0	2	0	0	2	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	1	0	2	0	5	0	19	2	0	0	2	2	0	0	1	0	1	0	0	2	3	13	0	0	3	0	0	0	0	0	11	RO
RS	8	0	4	0	47	0	16	1	0	0	3	3	0	0	2	0	2	1	0	4	14	25	0	0	6	0	0	0	0	0	2	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	3	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	44	0	10	0	0	0	1	0	5	6	0	0	3	0	4	1	0	0	69	13	0	0	57	0	0	0	0	0	0	SI
SK	0	0	14	0	7	0	1	1	1	0	18	7	0	0	1	0	4	1	0	0	9	66	0	0	6	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	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	5	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	3	0	0	0	0	0	0	0	0	0	0	1	TR
UA	0	0	1	1	1	0	2	10	0	0	2	2	0	0	0	0	1	1	1	1	1	3	0	0	1	0	1	1	0	1	12	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	11	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	1	0	2	0	0	2	7	7	4	1	5	2	4	0	0	0	1	0	0	0	0	0	2	0	4	0	BAS
BLS	0	1	0	4	1	0	7	2	0	0	0	1	0	0	0	0	0	0	26	2	0	1	0	0	1	0	0	0	0	0	5	BLS
MED	3	0	1	0	4	0	2	0	0	0	1	1	0	0	24	0	7	0	0	12	3	1	0	0	23	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	2	0	0	0	0	0	4	2	0	1	0	8	30	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	1	0	0	0	0	AST
NOA	0	0	0	0	1	0	1	0	0	0	0	0	0	0	14	0	2	0	0	2	0	0	0	0	3	0	0	0	0	0	0	NOA
EXC	1	0	2	3	3	1	2	3	1	0	2	4	0	0	10	1	6	3	2	1	2	3	0	0	6	1	7	1	0	1	2	EXC
EU	0	0	8	0	3	3	9	1	1	0	7	17	2	1	43	3	26	3	0	5	7	11	1	0	27	0	0	2	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.15 Cont.: 2020 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 primary EC. **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	19	13	0	0	0	2	0	5	73	0	0	1	1	0	0	1	2	0	0	0	0	4	0	0	14	0	0	0	486	50	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	1	0	0	0	0	0	0	20	3	0	0	0	268	1	AM
AT	0	0	0	0	0	4	0	2	2	0	0	14	4	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	340	329	AT
AZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	11	2	1	0	0	0	0	0	27	2	0	0	0	587	1	AZ
BA	8	0	0	0	0	5	0	6	40	0	0	2	2	0	0	0	2	0	0	0	0	2	0	0	9	0	0	0	749	97	BA
BE	0	0	0	18	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	18	0	2	0	0	0	346	328	BE
BG	1	3	0	0	0	4	0	39	32	0	0	1	1	0	0	5	10	0	0	0	1	1	0	0	7	0	0	0	396	331	BG
BY	0	0	0	0	0	26	0	4	1	0	1	0	1	0	0	1	24	0	0	1	0	0	1	0	2	0	0	0	244	55	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	3	0	0	0	206	75	CH
CY	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	54	3	0	0	0	0	10	0	12	27	0	0	0	121	60	CY
CZ	0	0	0	1	0	26	0	3	5	0	0	4	9	0	0	0	2	0	0	0	0	0	1	0	2	0	0	0	361	345	CZ
DE	0	0	0	6	0	7	0	1	0	0	0	0	1	0	0	0	1	0	0	1	0	0	4	0	2	0	0	0	230	216	DE
DK	0	0	0	3	2	7	0	0	0	0	2	0	0	0	0	0	1	0	0	8	0	0	9	0	1	0	0	0	162	146	DK
EE	0	0	0	0	1	8	0	1	0	0	2	0	0	0	0	0	4	0	0	4	0	0	1	0	0	0	0	0	134	120	EE
ES	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	2	0	0	5	0	0	28	0	0	0	334	332	ES
FI	0	0	0	0	1	2	0	0	0	0	2	0	0	0	0	0	1	0	0	2	0	0	0	0	0	0	0	0	54	49	FI
FR	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	2	3	0	7	0	0	0	204	195	FR
GB	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	8	0	1	0	0	0	192	19	GB
GE	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	20	2	0	0	0	0	0	0	7	2	0	0	0	508	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	7	0	0	0	2	0	8	18	0	0	0	1	0	0	8	5	0	0	0	0	8	0	0	17	0	0	0	245	191	GR
HR	2	0	0	0	0	6	0	7	38	0	0	22	3	0	0	0	2	0	0	0	0	4	0	0	8	0	0	0	582	422	HR
HU	1	0	0	0	0	17	0	43	49	0	0	9	24	0	0	0	7	0	0	0	0	1	0	0	4	0	0	0	587	505	HU
IE	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	1	0	0	0	84	64	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	3	0	IS
IT	1	0	0	0	0	1	0	2	3	0	0	6	1	0	0	0	1	0	0	0	0	9	0	0	35	0	0	0	382	368	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	12	1	0	0	18	0	0	0	0	0	17	0	0	0	0	61	0	KG
KZ	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2	5	0	0	0	0	0	12	0	0	0	0	48	1	KZ
LT	0	0	0	1	1	30	0	2	1	0	1	0	1	0	0	0	8	0	0	2	0	0	1	0	1	0	0	0	185	151	LT
LU	0	0	0	3	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	0	3	0	0	0	337	327	LU
LV	0	0	0	1	1	14	0	1	1	0	2	0	1	0	0	0	6	0	0	3	0	0	1	0	0	0	0	0	162	138	LV
MD	0	0	0	0	0	11	0	81	4	0	0	0	2	0	0	3	52	0	0	0	1	1	0	0	3	0	0	0	593	115	MD
ME	308	1	0	0	0	3	0	4	44	0	0	1	1	0	0	0	2	0	0	0	0	2	0	0	9	0	0	0	446	40	ME
MK	3	187	0	0	0	3	0	8	99	0	0	1	1	0	0	1	3	0	0	0	0	1	0	0	11	0	0	0	400	77	MK
MT	1	0	193	0	0	1	1	1	3	0	0	1	0	0	0	0	1	0	0	0	0	74	0	0	243	0	0	0	258	247	MT
NL	0	0	0	183	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	36	0	1	0	0	0	322	296	NL
NO	0	0	0	0	18	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	24	4	NO
PL	0	0	0	1	0	259	0	5	3	0	1	1	10	0	0	0	9	0	0	1	0	0	1	0	2	0	0	0	358	334	PL
PT	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	8	0	0	1	0	0	16	0	0	0	289	288	PT
RO	1	1	0	0	0	8	0	346	22	0	0	1	3	0	0	2	15	0	0	0	1	1	0	0	5	0	0	0	465	404	RO
RS	13	7	0	0	0	7	0	32	603	0	0	2	3	0	0	1	4	0	0	0	0	1	0	0	8	0	0	0	810	124	RS
RU	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	1	0	0	0	0	16	5	RU
SE	0	0	0	0	3	3	0	0	0	0	16	0	0	0	0	0	1	0	0	2	0	0	1	0	0	0	0	0	35	28	SE
SI	0	0	0	0	0	4	0	4	5	0	0	348	2	0	0	0	2	0	0	0	0	3	0	0	5	0	0	0	580	560	SI
SK	0	0	0	0	0	38	0	16	14	0	0	4	166	0	0	0	9	0	0	0	0	0	0	0	3	0	0	0	388	353	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	146	3	1	0	22	0	0	0	0	0	23	0	0	0	0	176	0	TJ
TM	0	0	0	0	0	0	0	0	0	0	0	0	0	4	43	1	1	24	0	0	0	0	0	15	0	0	0	0	84	1	TM
TR	0	0	0	0	0	1	0	2	1	0	0	0	0	0	0	223	4	0	0	0	1	3	0	11	8	0	0	0	246	10	TR
UA	0	0	0	0	0	14	0	16	2	0	0	0	2	0	0	3	183	0	0	0	1	0	0	0	3	0	0	0	265	49	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	27	14	1	1	134	0	0	0	0	0	7	0	0	0	0	195	1	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	7	0	0	0	10	8	ATL
BAS	0	0	0	1	2	15	0	1	1	0	7	0	0	0	0	0	2	0	0	17	0	0	2	0	0	0	0	0	73	61	BAS
BLS	0	0	0	0	0	3	0	11	3	0	0	0	0	0	0	43	33	0	0	0	11	1	0	2	4	0	0	0	147	28	BLS
MED	1	1	0	0	0	1	1	3	4	0	0	1	0	0	0	14	2	0	0	0	0	30	0	3	188	0	0	0	114	83	MED
NOS	0	0	0	4	5	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	23	0	0	0	0	0	63	26	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	6	1	2	0	0	0	0	0	445	4	0	0	0	18	1	AST
NOA	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	1	1	0	1	0	0	5	0	1	885	0	0	0	28	24	NOA
EXC	0	0	0	1	1	7	1	6	5	0	1	1	1	2	2	10	9	5	0	0	0	1	1	4	3	0	0	0	120	60	EXC
EU	0	0	0	3	1	24	6	23	5	0	2	3	4	0	0	1	3	0	1	1	0	2	2	0	9	0	0	0	261	240	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: 2020 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	8	0	0	0	1	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	AL
AM	0	7	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	13	0	0	0	0	0	2	0	1	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	AT
AZ	0	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	0	0	0	0	47	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	BA
BE	0	0	0	0	0	18	0	0	0	0	0	8	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	1	0	14	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	5	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	BY
CH	0	0	0	0	0	0	0	0	131	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	6	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	1	0	0	0	0	0	1	0	20	6	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	CZ
DE	0	0	1	0	0	0	0	0	2	0	2	39	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	0	4	4	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	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	EE
ES	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	ES
FI	0	0	0	0	0	0	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	FI
FR	0	0	0	0	0	0	0	0	2	0	0	2	0	0	0	0	10	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	11	0	0	0	0	0	0	0	0	0	0	0	0	0	GB
GE	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	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	1	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	GR
HR	0	0	1	0	14	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	23	1	0	0	1	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	3	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	4	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	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	9	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	14	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	16	0	0	0	LT
LU	0	0	0	0	0	2	0	0	0	0	0	11	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	10	0	0	LU
LV	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	6	0	3	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	13	MD
ME	0	0	0	0	5	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	1	0	0	0	1	0	1	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	1	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	0	13	0	0	0	0	1	1	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	3	4	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	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	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	0	0	RO
RS	0	0	0	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	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	1	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	0	0	0	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	0	1	0	0	0	0	0	0	0	0	8	0	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	1	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	1	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	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	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	BAS
BLS	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	BLS
MED	0	0	0	0	1	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	1	0	0	0	0	0	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	1	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	0	0	0	1	0	0	0	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	1	0	2	0	0	1	1	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.16 Cont.: 2020 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	2	0	0	0	1	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	4	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	1	0	0	0	0	15	0	AM
AT	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	21	AT
AZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	29	0	AZ
BA	0	0	0	0	0	1	0	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	64	8	BA
BE	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	35	33	BE
BG	0	0	0	0	0	1	0	3	3	1	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	30	21	BG
BY	0	0	0	0	0	5	0	0	0	2	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	22	8	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	138	6	CH
CY	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	28	1	0	0	0	0	0	0	1	1	0	0	0	37	7	CY
CZ	0	0	0	0	0	14	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	48	46	CZ
DE	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	49	46	DE
DK	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	12	11	DK
EE	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	12	8	EE
ES	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	8	8	ES
FI	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	7	5	FI
FR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	13	FR
GB	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	2	GB
GE	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	41	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	1	0	1	1	1	0	0	0	0	0	5	1	0	0	0	0	0	0	0	0	0	0	0	32	23	GR
HR	0	0	0	0	0	2	0	1	4	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	50	31	HR
HU	0	0	0	0	0	6	0	3	5	0	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	39	30	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	6	5	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	0	0	0	0	15	12	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	2	0	0	0	0	10	0	KG
KZ	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	18	0	KZ
LT	0	0	0	0	0	5	0	0	0	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	29	24	LT
LU	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	31	30	LU
LV	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	18	14	LV
MD	0	0	0	0	0	3	0	4	0	2	0	0	0	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	34	8	MD
ME	10	0	0	0	0	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	3	ME
MK	0	23	0	0	0	1	0	1	6	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	40	9	MK
MT	0	0	25	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	30	29	MT
NL	0	0	0	16	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	35	NL
NO	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	0	3	0	NO
PL	0	0	0	0	0	64	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	77	73	PL
PT	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	8	8	PT
RO	0	0	0	0	0	2	0	24	2	1	0	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	37	29	RO
RS	0	1	0	0	0	2	0	5	48	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	70	12	RS
RU	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	13	1	RU
SE	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	5	SE
SI	0	0	0	0	0	2	0	0	1	0	0	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	29	SI
SK	0	0	0	0	0	17	0	1	2	0	0	0	12	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	44	39	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	2	0	0	0	0	0	2	0	0	0	0	19	0	TJ
TM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	0	0	2	0	0	0	0	0	1	0	0	0	0	11	0	TM
TR	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	85	1	0	0	0	0	0	0	1	0	0	0	0	88	1	TR
UA	0	0	0	0	0	4	0	1	0	8	0	0	0	0	0	1	45	0	0	0	0	0	0	0	0	0	0	0	62	6	UA
UZ	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	11	0	0	0	0	0	0	0	0	0	0	20	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	0	ATL
BAS	0	0	0	0	0	3	0	0	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	11	9	BAS
BLS	0	0	0	0	0	1	0	1	0	9	0	0	0	0	0	10	9	0	0	0	0	0	0	0	0	0	0	0	33	3	BLS
MED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0	1	3	0	0	0	15	5	MED
NOS	0	0	0	0	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	3	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	88	0	0	0	0	4	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	18	0	0	0	2	1	NOA
EXC	0	0	0	0	0	2	0	0	0	5	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	22	6	EXC
EU	0	0	0	0	0	6	0	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	25	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.17: 2020 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	152	0	1	0	8	0	2	0	0	0	1	1	0	0	1	0	1	0	0	6	3	2	0	0	8	0	0	0	0	0	0	AL
AM	0	74	0	21	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	0	AM
AT	0	0	143	0	3	0	0	0	2	0	8	13	0	0	0	0	4	0	0	0	6	7	0	0	12	0	0	0	0	0	0	AT
AZ	0	6	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	1	0	3	0	491	0	1	0	0	0	2	2	0	0	1	0	2	0	0	0	29	7	0	0	8	0	0	0	0	0	0	BA
BE	0	0	0	0	0	149	0	0	0	0	1	21	0	0	1	0	64	8	0	0	0	0	0	0	1	0	0	0	2	0	0	BE
BG	1	0	1	0	4	0	155	1	0	0	1	1	0	0	0	0	1	0	0	5	2	3	0	0	2	0	0	0	0	0	3	BG
BY	0	0	1	0	1	0	0	109	0	0	2	3	0	0	0	0	1	1	0	0	1	2	0	0	1	0	0	4	0	2	1	BY
CH	0	0	5	0	0	0	0	0	82	0	1	15	0	0	1	0	22	0	0	0	0	0	0	0	18	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	17	0	0	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	14	0	3	1	0	1	1	0	174	22	0	0	0	0	6	1	0	0	5	9	0	0	3	0	0	0	0	0	0	CZ
DE	0	0	8	0	0	4	0	0	3	0	6	134	1	0	1	0	17	3	0	0	0	1	0	0	1	0	0	0	1	0	0	DE
DK	0	0	0	0	0	1	0	0	0	0	1	13	69	0	0	0	4	5	0	0	0	1	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	0	0	5	0	0	1	2	1	50	0	2	1	1	0	0	0	0	0	0	0	0	0	2	0	10	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	99	0	4	0	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	1	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	3	0	0	2	0	1	7	0	0	4	0	144	3	0	0	0	0	0	0	4	0	0	0	0	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	5	92	0	0	0	0	3	0	0	0	0	0	0	0	0	GB
GE	0	8	0	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	119	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	3	0	9	1	0	0	1	0	0	0	1	0	1	0	0	91	1	1	0	0	4	0	0	0	0	0	1	GR
HR	0	0	7	0	96	0	1	0	0	0	4	4	0	0	1	0	2	0	0	0	227	19	0	0	20	0	0	0	0	0	0	HR
HU	0	0	11	0	15	0	2	1	0	0	6	5	0	0	0	0	2	1	0	0	25	227	0	0	7	0	0	0	0	0	1	HU
IE	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	11	0	0	0	0	48	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	3	0	4	0	0	0	1	0	1	1	0	0	2	0	6	0	0	0	5	2	0	0	297	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	33	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	1	32	0	0	0	0	KZ
LT	0	0	1	0	1	0	0	20	0	0	2	4	1	1	0	0	1	1	0	0	0	1	0	0	0	0	0	64	0	7	0	LT
LU	0	0	1	0	0	17	0	0	1	0	2	44	0	0	1	0	78	4	0	0	0	0	0	0	2	0	0	0	58	0	0	LU
LV	0	0	0	0	0	0	0	10	0	0	1	3	1	3	0	1	1	1	0	0	0	1	0	0	0	0	0	12	0	69	0	LV
MD	0	0	1	0	1	0	3	3	0	0	1	2	0	0	0	0	1	0	0	1	1	2	0	0	1	0	0	0	0	0	256	MD
ME	11	0	1	0	26	0	1	0	0	0	1	1	0	0	0	0	1	0	0	1	4	3	0	0	6	0	0	0	0	0	0	ME
MK	11	0	1	0	5	0	8	0	0	0	1	1	0	0	0	0	1	0	0	15	2	3	0	0	3	0	0	0	0	0	1	MK
MT	1	0	0	0	3	0	1	0	0	0	0	1	0	0	4	0	4	0	0	1	2	1	0	0	23	0	0	0	0	0	0	MT
NL	0	0	0	0	0	32	0	0	0	0	1	38	1	0	1	0	22	12	0	0	0	0	1	0	1	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	2	0	2	1	0	4	0	0	13	13	1	0	0	0	3	1	0	0	2	5	0	0	2	0	0	1	0	1	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	1	0	4	0	11	1	0	0	1	1	0	0	0	0	1	0	0	1	2	8	0	0	2	0	0	0	0	0	7	RO
RS	4	0	2	0	37	0	9	1	0	0	2	2	0	0	0	0	1	0	0	2	11	16	0	0	4	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	0	0	0	0	2	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	31	0	8	0	0	0	0	0	3	4	0	0	1	0	3	0	0	0	57	8	0	0	44	0	0	0	0	0	0	SI
SK	0	0	8	0	6	0	1	1	0	0	14	5	0	0	0	0	2	1	0	0	6	46	0	0	4	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	2	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	0	0	1	0	1	8	0	0	1	2	0	0	0	0	1	0	0	0	1	2	0	0	1	0	1	1	0	0	8	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	1	0	2	0	0	1	7	5	2	0	2	2	2	0	0	0	0	0	0	0	0	0	2	0	3	0	BAS
BLS	0	0	0	1	1	0	5	2	0	0	0	0	0	0	0	0	0	0	8	1	0	1	0	0	0	0	0	0	0	0	3	BLS
MED	1	0	1	0	4	0	1	0	0	0	0	1	0	0	7	0	6	0	0	6	3	1	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	0	4	1	0	0	0	7	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	1	0	0	0	0	0	0	0	0	0	3	0	1	0	0	1	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	0	0	1	1	2	1	1	2	0	0	1	4	0	0	3	0	5	2	1	1	1	2	0	0	6	1	6	0	0	1	1	EXC
EU	0	0	5	0	3	2	5	1	1	0	6	16	1	1	13	1	23	2	0	3	5	8	1	0	24	0	0	1	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.17 Cont.: 2020 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	15	12	0	0	0	3	0	4	44	0	0	0	1	0	0	1	2	0	0	0	0	1	0	0	1	0	0	0	269	33	AL
AM	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	19	1	0	0	0	0	0	0	8	0	0	0	0	126	1	AM
AT	0	0	0	0	0	7	0	2	2	0	0	9	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	222	213	AT
AZ	0	0	0	0	0	0	0	0	0	7	0	0	0	0	1	5	3	1	0	0	0	0	0	9	0	0	0	0	227	1	AZ
BA	5	0	0	0	0	7	0	5	27	0	0	1	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	598	70	BA
BE	0	0	0	13	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	267	258	BE
BG	1	2	0	0	0	5	0	33	21	2	0	0	1	0	0	6	13	0	0	0	0	0	0	0	0	0	0	0	265	211	BG
BY	0	0	0	0	0	37	0	3	1	8	0	0	1	0	0	1	29	0	0	0	0	0	0	0	0	0	0	0	211	59	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	147	64	CH
CY	0	0	0	0	0	1	0	1	1	2	0	0	0	0	0	87	4	0	0	0	0	3	0	9	2	0	0	0	120	25	CY
CZ	0	0	0	1	0	42	0	2	4	1	0	2	8	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	303	290	CZ
DE	0	0	0	5	0	12	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	201	192	DE
DK	0	0	0	2	2	11	0	0	0	1	1	0	0	0	0	0	1	0	0	2	0	0	2	0	0	0	0	0	117	107	DK
EE	0	0	0	0	1	12	0	1	0	7	2	0	0	0	0	0	5	0	0	1	0	0	0	0	0	0	0	0	104	84	EE
ES	0	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	0	115	114	ES
FI	0	0	0	0	1	3	0	0	0	5	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	33	24	FI
FR	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	174	168	FR
GB	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	109	16	GB
GE	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	11	2	0	0	0	0	0	0	2	0	0	0	0	164	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	6	0	0	0	3	0	6	10	1	0	0	0	0	0	9	7	0	0	0	0	2	0	0	1	0	0	0	163	120	GR
HR	1	0	0	0	0	9	0	6	29	1	0	14	2	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	448	317	HR
HU	0	0	0	0	0	24	0	36	37	1	0	5	18	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	435	370	HU
IE	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	66	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	3	0	IS
IT	0	0	0	0	0	2	0	2	2	0	0	4	0	0	0	0	1	0	0	0	0	2	0	0	2	0	0	0	335	325	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0	0	0	17	0	0	0	0	0	10	0	0	0	0	64	0	KG
KZ	0	0	0	0	0	0	0	0	0	10	0	0	0	1	1	0	2	4	0	0	0	0	0	6	0	0	0	0	53	1	KZ
LT	0	0	0	0	1	45	0	2	1	8	1	0	1	0	0	1	10	0	0	1	0	0	0	0	0	0	0	0	176	134	LT
LU	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	215	209	LU
LV	0	0	0	0	1	20	0	1	0	6	1	0	1	0	0	0	8	0	0	1	0	0	0	0	0	0	0	0	143	116	LV
MD	0	0	0	0	0	15	0	65	3	5	0	0	1	0	0	4	60	0	0	0	0	0	0	0	0	0	0	0	429	95	MD
ME	200	1	0	0	0	4	0	4	32	0	0	0	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	302	28	ME
MK	1	163	0	0	0	4	0	6	58	0	0	0	1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	291	46	MK
MT	1	0	37	0	0	1	0	1	2	0	0	0	0	0	0	0	1	0	0	0	0	20	0	0	11	0	0	0	86	77	MT
NL	0	0	0	119	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	234	220	NL
NO	0	0	0	0	19	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	3	NO
PL	0	0	0	1	0	411	0	4	3	3	0	1	8	0	0	0	12	0	0	0	0	0	0	0	0	0	0	0	495	469	PL
PT	0	0	0	0	0	0	161	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	190	190	PT
RO	0	0	0	0	0	11	0	293	15	2	0	0	2	0	0	3	18	0	0	0	0	0	0	0	0	0	0	0	388	336	RO
RS	8	7	0	0	0	9	0	27	430	1	0	1	2	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	585	91	RS
RU	0	0	0	0	0	2	0	0	0	37	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	53	4	RU
SE	0	0	0	0	3	4	0	0	0	1	12	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	30	23	SE
SI	0	0	0	0	0	7	0	3	4	0	0	217	1	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	395	380	SI
SK	0	0	0	0	0	57	0	14	10	1	0	2	136	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	328	297	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	122	2	0	0	17	0	0	0	0	0	20	0	0	0	0	146	0	TJ
TM	0	0	0	0	0	0	0	0	0	4	0	0	0	3	31	1	2	14	0	0	0	0	0	6	0	0	0	0	63	1	TM
TR	0	0	0	0	0	1	0	2	1	2	0	0	0	0	0	223	6	0	0	0	0	1	0	6	0	0	0	0	242	6	TR
UA	0	0	0	0	0	21	0	13	2	14	0	0	1	0	0	4	240	0	0	0	0	0	0	0	0	0	0	0	325	46	UA
UZ	0	0	0	0	0	0	0	0	0	4	0	0	0	14	6	0	2	89	0	0	0	0	0	3	0	0	0	0	131	1	UZ
ATL	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	7	5	ATL
BAS	0	0	0	1	1	23	0	1	0	4	6	0	0	0	0	0	3	0	0	5	0	0	0	0	0	0	0	0	71	57	BAS
BLS	0	0	0	0	0	4	0	9	2	17	0	0	0	0	0	72	48	0	0	0	3	0	0	1	0	0	0	0	176	22	BLS
MED	1	0	0	0	0	2	1	2	3	1	0	1	0	0	0	21	3	0	0	0	0	8	0	2	10	0	0	0	88	52	MED
NOS	0	0	0	3	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	42	23	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	8	1	1	0	0	0	0	0	224	0	0	0	0	17	1	AST
NOA	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	2	1	0	0	0	0	1	0	1	45	0	0	0	15	11	NOA
EXC	0	0	0	0	1	10	1	5	3	17	0	0	1	2	1	10	12	3	0	0	0	0	0	2	0	0	0	0	115	48	EXC
EU	0	0	0	2	1	38	5	20	4	1	2	2	3	0	0	1	4	0	0	0	0	1	0	0	0	0	0	0	206	188	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

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 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 emphasis of the evaluation performed for the EMEP status reports has traditionally been put on the EMEP measurement sites.

However, a more detailed evaluation against measurements from both the EMEP network (available from the EBAS data base as described in Section 2.2 and Chapter 9) and the European Environment Agency's (EEA) Air Quality e-Reporting Database can be found at the AeroVal webpage that has been developed for the evaluation of EMEP MSC-W model output:

https://aeroval.met.no/evaluation.php?project=emep&exp_name=2022-reporting

On this page, the user can select the set of measurement data, the station or country of interest, and view a large number of statistical parameters (bias, correlation, root mean square error, etc.). AeroVal is flexible and allows using all available observations, including irregular and non-standard-frequency measurements. For temporal averaging, 75% data coverage in a hierarchical manner is required for most of components, i.e. at least 18 hourly measurement values to calculate a daily mean, at least 21 daily values to calculate a monthly mean, and at least 9 months for an annual mean. The coverage requirement for daily values was lowered for size-resolved aerosols (in $PM_{2.5}$ and PM_{10}) because of a lower sampling frequency (e.g. every 4th or 6th day); for these components at least 4 daily values are required for calculating a monthly mean. Most of the observational data is collocated with model results on a daily basis (EBAS-d dataset), then monthly, seasonally and yearly mean statistics are calculated. The dataset EBAS-m is based on monthly averaged data in order to incorporate observations with coarser resolutions (e.g. weekly, 15-daily, monthly) and thus, included more sites than the EBAS-d. For NO_2 and ozone, model results are also evaluated with hourly observations from both EMEP and EEA Air Quality e-Reporting Database. Note that only rural EEA observations are used for EMEP model evaluation in the AeroVal.

The web interface displays co-located observational and model datasets and contains:

- daily and monthly time series for each station, averaged per country, or the whole area covered by the model and the measurement network (labeled 'ALL');
- 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 (so-called Heatmaps and Taylor Diagrams).

Evaluation is made for O_3, $PM_{2.5}$, PM_{10}, SO_2, SO_4, NO_2, and several other nitrogen-containing species. The different types of visualization (bar charts, line charts, tables, etc.) are available both for viewing and for download.

Table D:1 summarizes common statistical measures of model performance for 2020 with respect to EMEP observations. The flexibility of AeroVal allows including more observational data with different sampling resolution and duration with respect to what was included in the earlier EMEP reports. The statistics provided in Table D:1 are based on EBAS-m dataset.

Table D:1: Comparison of model results and observations for 2020. Annual averages over all EMEP sites with measurements. N_{stat}= number of stations, wd=wet deposition, Corr. = spatial correlation coefficient, RMSE = root mean square error. The numbers are taken from AeroVal (last updated 20 August 2022).

Component	N_{stat}	Obs.	Mod.	Bias (%)	RMSE	Corr.
NO_2 (μg(N) m^{-3})	75	1.35	1.20	-11	0.62	0.83
PM_{10} (μg m^{-3})	63	11.53	8.39	-27	4.09	0.77
$PM_{2.5}$ (μg m^{-3})	49	6.65	5.64	-15	2.2	0.75
Ozone daily max (ppb)	122	39.93	41.16	3	4.45	0.87
Ozone daily mean (ppb)	122	31.43	33.21	6	4.21	0.67
SO_2 (μg(S) m^{-3})	60	0.21	0.17	-18	0.15	0.66
HNO_3 (μg(N) m^{-3})	23	0.06	0.06	-6	0.04	0.64
NO_3^- +HNO_3 (μg(N) m^{-3})	38	0.32	0.31	-2	0.13	0.73
NH_3 (μg(N) m^{-3})	43	0.93	1.13	21	1.06	0.73
NH_3 +NH_4^+ (μg(N) m^{-3})	34	1.03	0.90	-12	0.70	0.77
SO_4^{2-}, including sea salt (μg m^{-3})	53	1.04	0.63	-40	0.68	0.75
SO_4^{2-}, sea salt corrected (μg m^{-3})	39	0.88	0.59	-33	0.58	0.84
SO_4^{2-} in PM_{10} (μg m^{-3})	59	0.94	0.62	-35	0.47	0.83
SO_4^{2-} in $PM_{2.5}$ (μg m^{-3})	27	0.83	0.63	-25	0.25	0.80
NO_3^- in PM_{10} (μg m^{-3})	54	1.02	1.21	18	0.52	0.80
NO_3^- in $PM_{2.5}$ (μg m^{-3})	27	0.71	1.12	57	0.50	0.90
NH_4^+ in PM_{10} (μg m^{-3})	50	0.50	0.48	-4	0.20	0.79
NH_4^+ in $PM_{2.5}$ (μg m^{-3})	27	0.46	0.54	17	0.16	0.87
EC in PM_{10} (μg(C) m^{-3})	7	0.17	0.15	-13	0.05	0.92
EC in $PM_{2.5}$ (μg(C) m^{-3})	21	0.22	0.18	-16	0.07	0.94
EC in $PM_{2.5}$ EMEP BC emis (μg(C) m^{-3}) $\star$	21	0.22	0.17	-25	0.16	0.80
OC in PM_{10} (μg(C) m^{-3})	7	1.59	0.92	-43	0.93	0.65
OC in $PM_{2.5}$ (μg(C) m^{-3})	21	1.76	1.10	-37	0.81	0.81
Sea salt in PM_{10} (μg(C) m^{-3})	41	2.42	2.29	-8	1.34	0.90
Sea salt in $PM_{2.5}$ (μg(C) m^{-3})	29	0.43	0.49	13	0.49	0.34
SO_4^{2-} wd (mg(S)m$^{-2}d^{-1}$)	71	0.37	0.25	-32	0.44	0.46
NO_3^- wd (mg(N)m$^{-2}d^{-1}$)	74	0.42	0.47	13	0.31	0.75
NH_4^+ wd (mg(N)m$^{-2}d^{-1}$)	74	0.62	0.67	7	0.59	0.64
Precipitation (mm)	92	2.61	2.86	10	1.36	0.90
AOD	98	0.13	0.13	4	0.02	0.94

$\star$ Based on BC emissions data officially submitted to LRTAP, see Section 3.2

APPENDIX E

Gothenburg protocol review

E.1 Validation per country

The following figures show scatter plots comparing calculated and observed pollutants for the year 2015. All available Airbase stations are used. Countries without stations return values of NaN for the statistics.

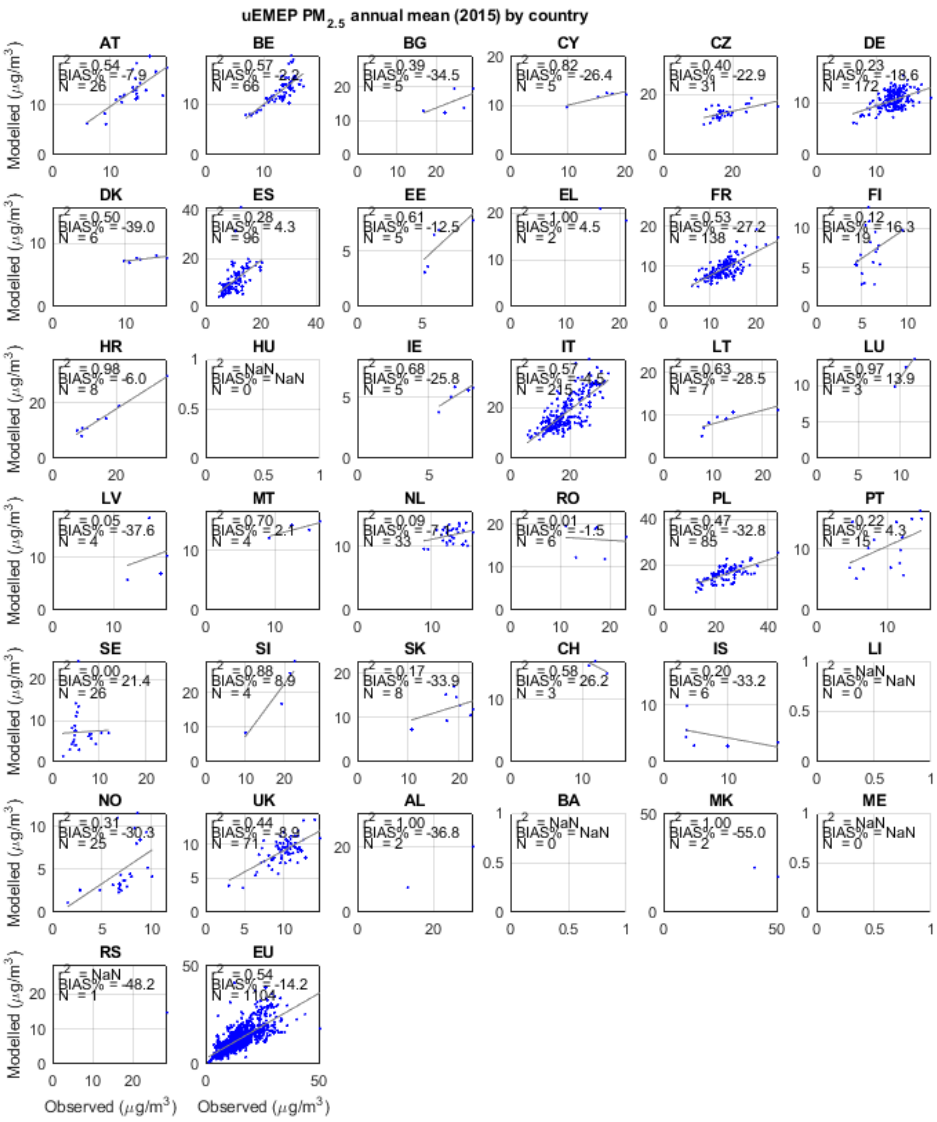

Figure E.1: Individual country scatter plots of annual mean $PM_{2.5}$ concentrations for the uEMEP/EMEP calculations. All available Airbase stations are used in the validation.

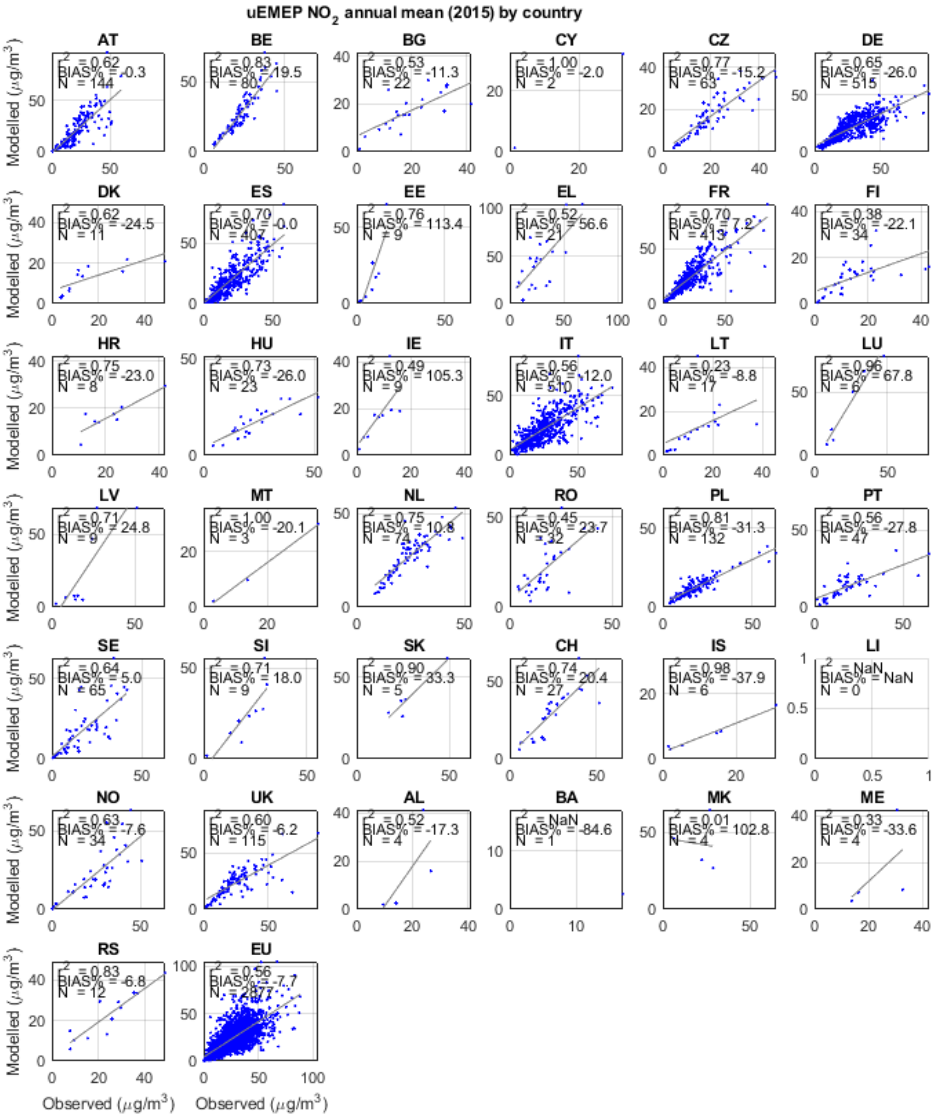

Figure E.2: Individual country scatter plots of annual mean NO_2 concentrations for the uEMEP/EMEP calculations. All available Airbase stations are used in the validation.

E.2 Exposure calculations for the 2030 MFR scenario

In Section 4.4.4 exposure distributions and population weighted concentrations with source contributions for each country are presented for the 2015 Baseline scenario. These calculations were made for all regions and scenarios and are presented in summary form in Section 4.4.5. As an additional example we provide the same plots but for the 2030 MFR scenario. These figures can be directly compared to those presented in Section 4.4.4.

EECCA countries

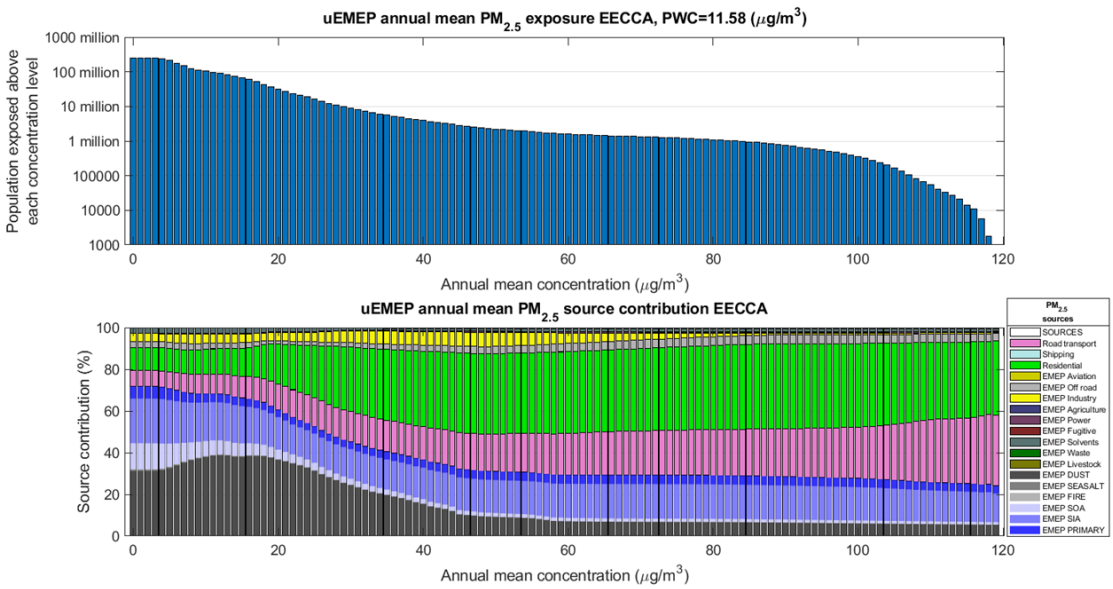

Figure E.3: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2030 MFR scenario in all EECCA countries. Shown are the number of inhabitants exposed above the given concentrations.

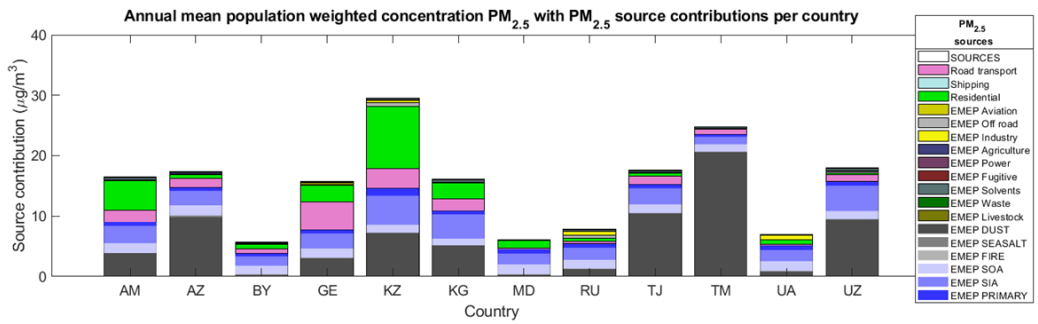

Figure E.4: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2030 MFR scenario in all EECCA countries.

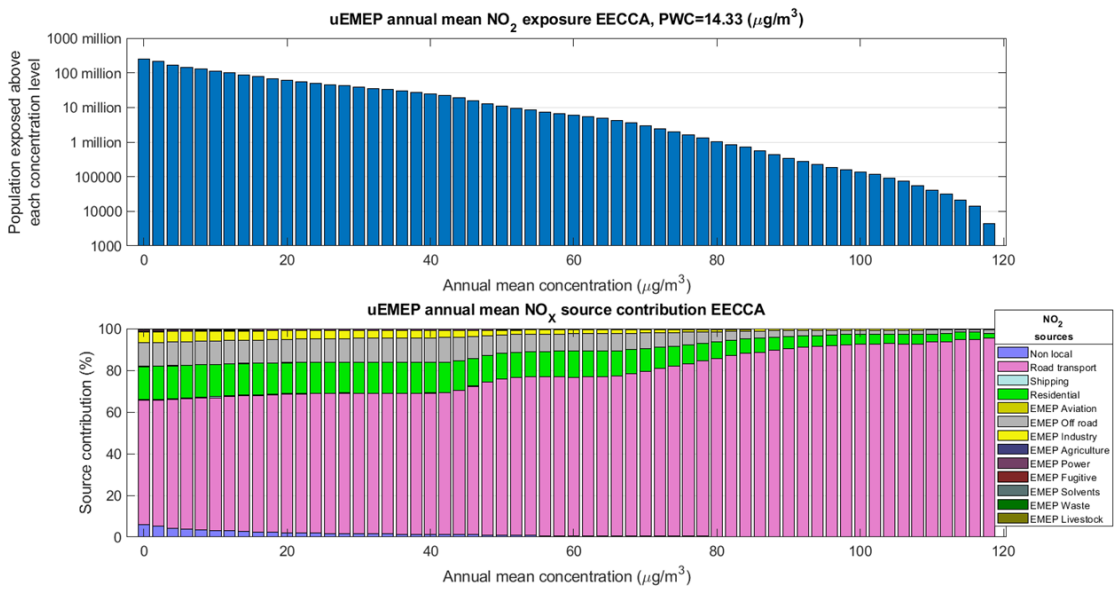

Figure E.5: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2030 MFR scenario in all EECCA countries. Shown are the number of inhabitants exposed above the given concentrations.

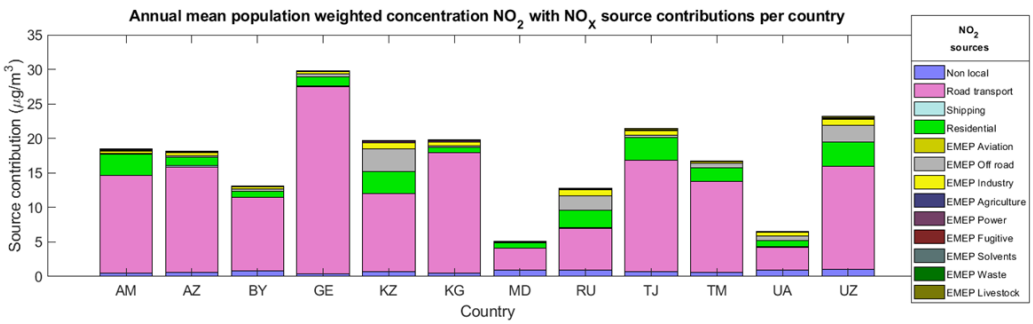

Figure E.6: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2030 MFR scenario in all EECCA countries.

Western Balkan countries

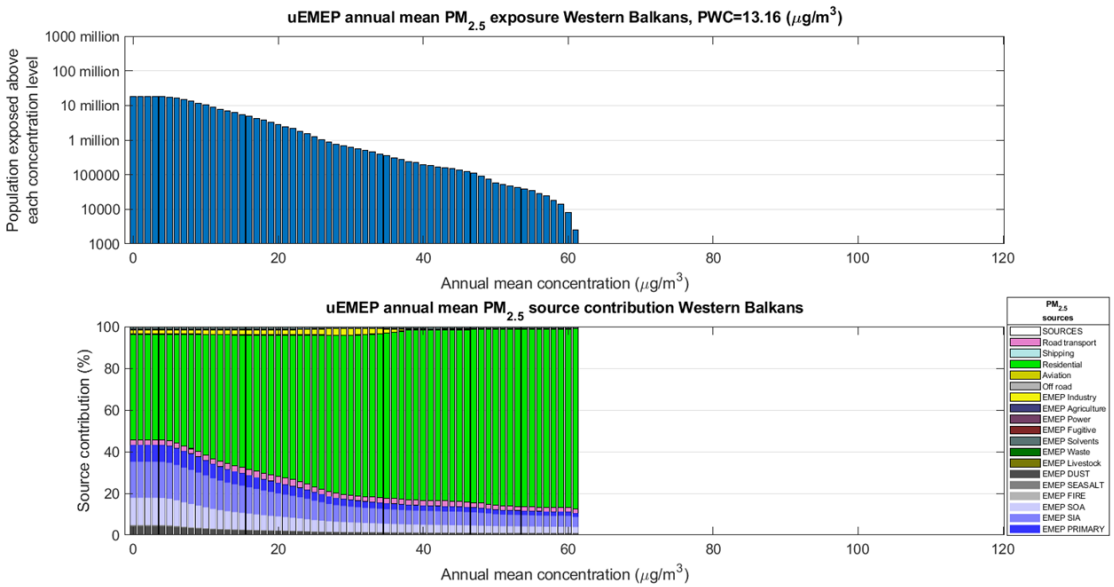

Figure E.7: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2030 MFR scenario in all Western Balkan countries. Shown are the number of inhabitants exposed above the given concentrations.

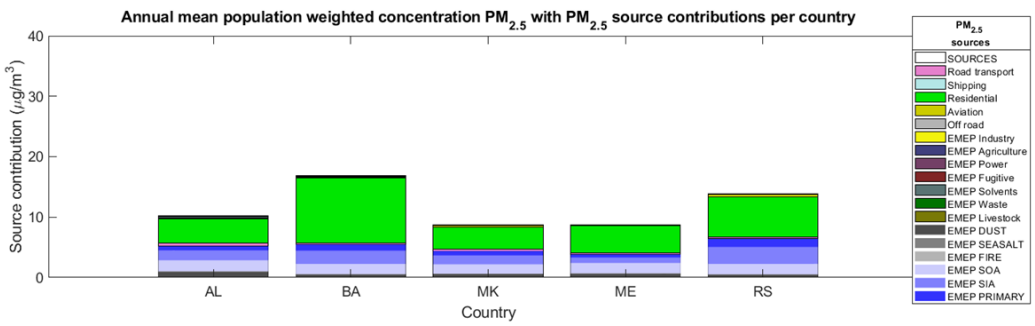

Figure E.8: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2030 MFR scenario in all Western Balkan countries.

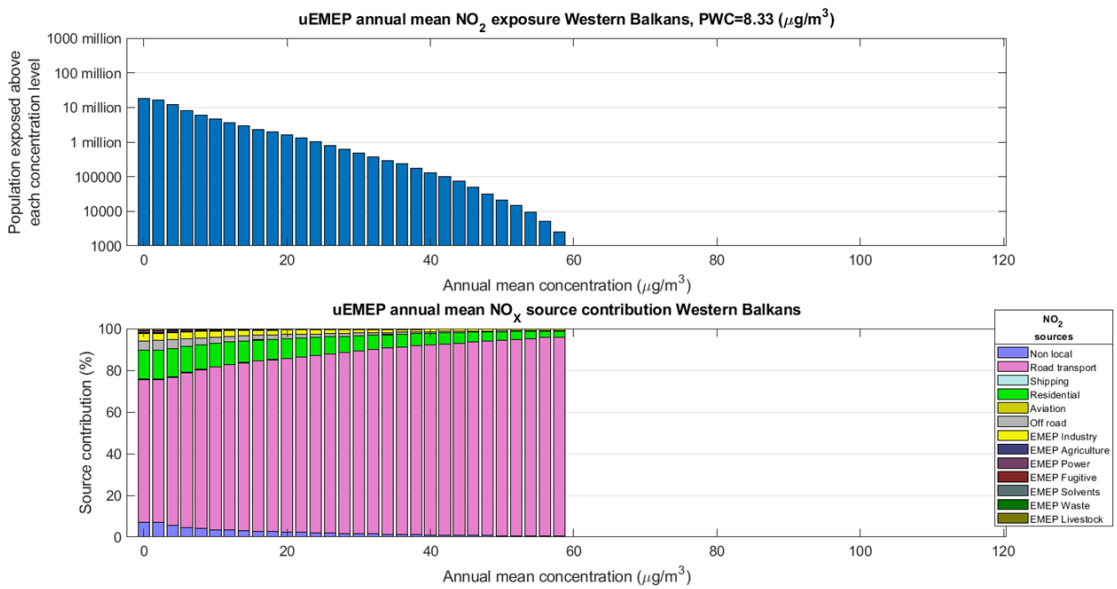

Figure E.9: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2030 MFR scenario in all Western Balkan countries. Shown are the number of inhabitants exposed above the given concentrations.

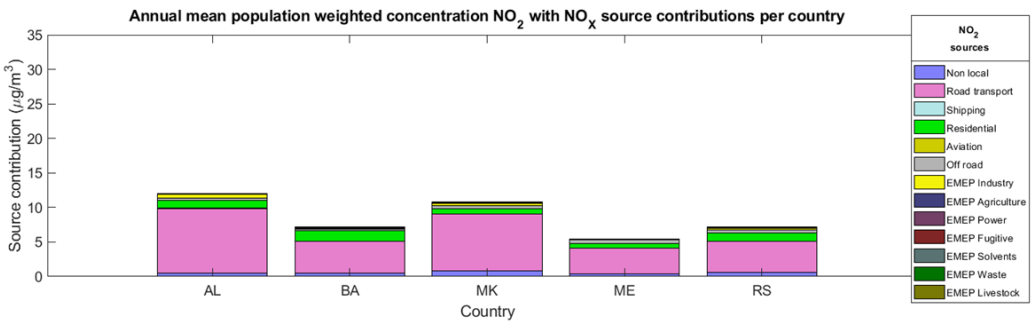

Figure E.10: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2030 MFR scenario in all Western Balkan countries.

EU and EFTA countries

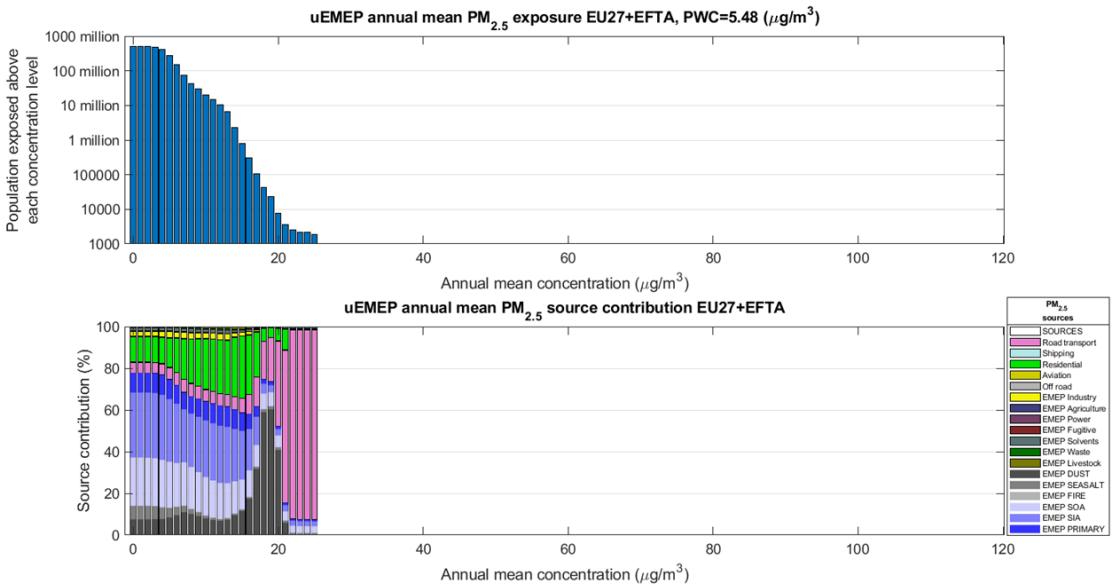

Figure E.11: Annual mean $PM_{2.5}$ population exposure distribution and source contributions for the 2030 MFR scenario in all EU and EFTA countries, including the UK. Shown are the number of inhabitants exposed above the given concentrations.

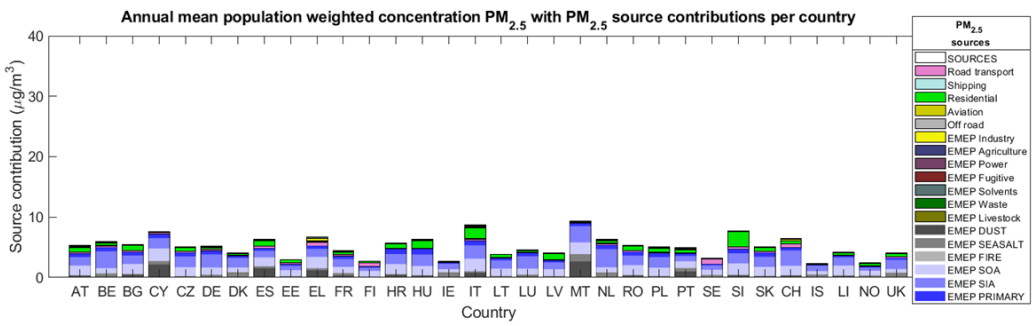

Figure E.12: Annual mean $PM_{2.5}$ population weighted concentrations and source contributions for the 2030 MFR scenario in all EU and EFTA countries, including the UK.

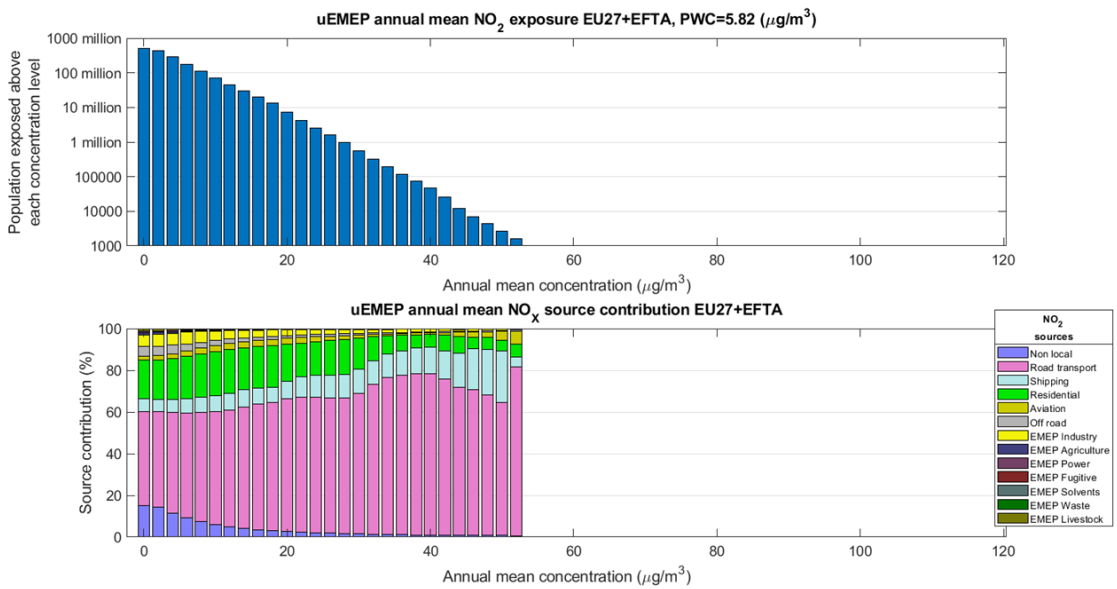

Figure E.13: Annual mean NO_2 population exposure distribution and source contributions (NO_x) for the 2030 MFR scenario in all EU and EFTA countries, including the UK. Shown are the number of inhabitants exposed above the given concentrations.

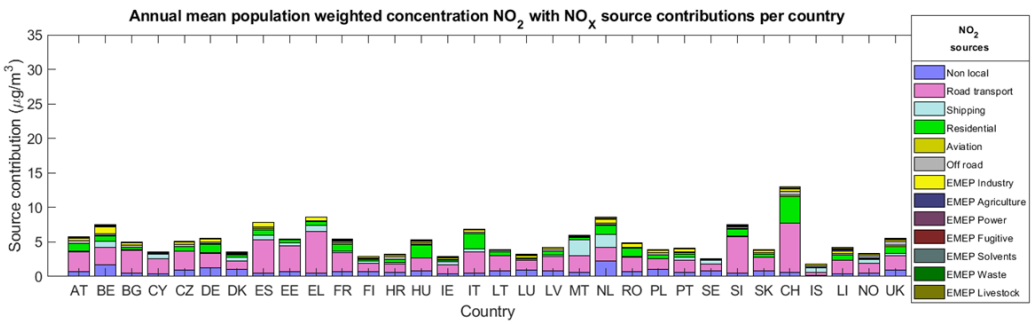

Figure E.14: Annual mean NO_2 population weighted concentrations and source contributions (NO_x) for the 2030 MFR scenario in all EU and EFTA countries, including the UK.

APPENDIX F

Trend simulation done in 2022

Trend runs with the EMEP MSC-W model version rv4.45 have been performed in $0.1^\circ \times 0.1^\circ$ longitude/latitude resolution for the period 1990–2020, using meteorological data and emissions for the respective years (IFS version cy40r1 for 1990–2018 and cy46r1 for 2019 and 2020).

The land-based emissions for 1990–2020 were derived from the 2022 official data submissions to UNECE CLRTAP (Schindlbacher et al. 2022) and the international shipping emissions were derived from the CAMS global shipping emission dataset (Granier et al. 2019, ECCAD 2019), produced by FMI using AIS (Automatic Identification System) tracking data (see also Appendix B).

Daily emissions from forest fires were from the Fire INventory from NCAR (FINNv5, Wiedinmyer et al. 2011) for 2002-2020, whereas for 1990 through and 2001 (unavailable from FINN), monthly averages over the 2005-2015 period were used.

The boundary conditions for the main gaseous and aerosol species were based on climatological observed values with prescribed trends in trans-Atlantic fluxes, while ozone levels have been corrected based on measurements at Mace Head in Ireland (c.f. Simpson et al. 2012). The boundary conditions for natural particles of sea salt and mineral dust were the same as in the status run, namely 5-year monthly average concentrations, derived from EMEP MSC-W global runs, kept invariable over the calculation period.

Condensables (for PM emissions) were taken into account only back to 2005, as reliable information on condensable emissions before that is not available.

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Simpson, D., Benedictow, A., Berge, H., Bergström, R., Emberson, L. D., Fagerli, H., Hayman, G. D., Gauss, M., Jonson, J. E., Jenkin, M. E., Nyíri, A., Richter, C., Semeena, V. S., Tsyro, S., Tuovinen, J.-P., Valdebenito, A., and Wind, P.: The EMEP MSC-W chemical transport model – technical description, Atmos. Chem. Physics, 12, 7825–7865, doi:10.5194/acp-12-7825-2012, 2012.

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APPENDIX G

Sites excluded from trend calculations

This appendix contains information of which EMEP sites have been excluded for the trend analysis for the different components presented in Chapter 7.

Table G:1: Sites excluded in the trend calculation for different components. Excluded sites are marked with "x". All sites not included here are used for all components. Components not shown here use all available sites. NO0042R is excluded for all components.

Code	SO_2	SO_4	SO_4wet	NO_2	totNO_3	HNO_3	NO_3pm_{10}	$NO_3pm_{2.5}$	NO_3wet	totNH_4	NH_4	NH_3	NH_4dep	PM_{10}	$PM_{2.5}$	EC	OC
AM0001R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
AT0001R	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
AT0002R	-	-	-	-	x	-	x	x	-	-	-	-	x	-	-	-	-
AT0034R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
BE0001R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
BE0032R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
BE0035R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
BY0004R	-	-	x	-	-	-	-	-	x	-	-	-	x	-	-	-	-
CH0001R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
CH0002R	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
CY0002R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
CZ0003R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
DE0001R	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
DE0003R	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
DE0043G	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
DE0044R	-	x	-	-	-	-	x	x	-	-	-	-	-	-	-	x	x
DK0010R	x	x	-	-	-	-	x	x	-	-	x	x	-	-	-	-	-
DK0022R	-	-	x	-	-	-	-	-	x	-	-	-	x	-	-	-	-
EE0009R	x	x	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
EE0011R	x	-	-	x	-	-	-	-	-	-	-	-	x	-	-	-	-
ES0001R	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
ES0005R	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ES0006R	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ES0007R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
ES0008R	-	-	-	-	x	-	-	-	x	x	-	x	-	-	-	-	-
ES0009R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
ES0010R	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
ES0011R	-	-	-	-	x	-	-	-	-	x	-	-	-	-	-	-	-
ES0013R	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
ES0014R	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
ES0015R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
ES0016R	-	-	-	-	-	-	-	-	x	x	-	-	x	-	-	-	-
ES0017R	-	-	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-
ES1778R	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
FI0022R	-	-	-	x	-	-	x	x	-	-	-	-	-	-	-	-	-
FI0050R	-	-	-	-	-	-	-	-	-	-	-	-	-	x	x	-	-
FI0096G	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
FR0008R	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FR0009R	-	x	-	-	x	-	-	-	-	x	-	-	-	-	-	-	-
FR0010R	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
FR0012R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
FR0013R	-	x	-	x	x	-	-	-	-	x	-	-	-	-	-	-	-
FR0014R	-	x	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-
FR0015R	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
FR0016R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
FR0030R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
GB0006R	-	-	-	-	x	-	x	x	-	-	x	-	-	-	-	-	-
GB0013R	-	-	-	-	x	-	x	x	x	-	-	-	x	-	-	-	-
GB0014R	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
GB0036R	-	x	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
GB0045R	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
GB0054R	-	-	-	-	-	-	x	x	-	x	-	x	-	-	-	-	-
GR0001R	x	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-
HR0004R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
IE0001R	-	-	-	x	-	-	-	-	x	-	-	-	-	-	-	-	-
IE0008R	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
IS0002R	x	x	x	-	-	-	-	-	x	-	-	-	-	-	-	-	-
IS0091R	-	x	x	-	-	-	-	-	x	-	-	-	x	-	-	-	-

Table : C:1 Cont.: Sites excluded in the trend calculation for different components. Excluded sites are marked with "x". All sites not included here are used for all components. Components not shown here use all available sites. NO0042R is excluded for all components.

Code	SO_2	SO_4	SO_4wet	NO_2	totNO_3	HNO_3	NO_3pm_{10}	$NO_3pm_{2.5}$	NO_3wet	totNH_4	NH_4	NH_3	NH_4dep	PM_{10}	$PM_{2.5}$	EC	OC
IT0001R	-	-	x	-	-	x	-	-	-	-	-	x	x	-	-	-	-
IT0004R	-	-	-	x	-	-	-	-	-	-	-	-	-	x	-	-	-
LV0010R	-	-	-	-	-	-	x	x	x	-	-	-	-	-	-	-	-
LV0016R	-	x	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
MD0013R	-	x	-	x	x	x	x	x	-	-	x	x	-	x	-	-	-
ME0008R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
MK0007R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
NL0008R	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NL0009R	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
NL0010R	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
NL0091R	-	-	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
NO0015R	-	-	-	-	x	x	x	x	-	x	x	x	-	-	-	-	-
NO0039R	-	-	-	-	x	x	x	x	-	x	x	x	-	-	-	-	-
NO0042R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
NO0055R	-	-	x	x	x	x	x	x	x	x	x	x	-	-	-	-	-
NO0056R	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
PL0003R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
PL0005R	-	-	-	-	x	x	x	x	-	-	-	-	-	-	-	-	-
RS0005R	x	-	x	x	-	-	-	-	x	-	-	-	x	-	-	-	-
RU0001R	-	x	x	-	-	-	x	x	x	-	x	-	x	-	-	-	-
RU0013R	-	-	x	-	-	-	-	-	x	-	-	-	x	-	-	-	-
RU0018R	x	x	-	-	-	-	x	x	-	-	-	-	-	-	-	-	-
RU0020R	-	x	x	-	-	-	x	x	-	-	-	-	-	-	-	-	-
SE0005R	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
SK0002R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-
SK0004R	-	-	x	x	-	-	-	-	x	-	-	-	-	-	-	-	-
SK0005R	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
SK0006R	-	-	-	-	-	x	x	x	-	-	-	x	-	-	-	-	-
TR0001R	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	-	-

APPENDIX H

Temporal profiles for 2020

The effects of socio-economic activity restrictions due to COVID-19 pandemic on emission temporal profiles in 2020 were accounted for based on estimates by Guevara et al. (2022). Daily Adjustment Factors to 2020 emissions from the publicly available CAMS-REG_EAF-COVID19 dataset were combined with GENEMIS monthly and day-of-the-week emission time factors (Friedrich and Reis 2004) to create day-of-the-year emission time factors for 2020.

The CAMS-REG_EAF-COVID19 dataset contains day-of-the-year, country-, sector- and pollutant-dependent emission adjustment factors for 2020. The adjustment factors are expressed as % of emission changes compared to a business-as-usual scenario for the same year. The contents of the dataset are summarised on Table H:1 and Table H:2. Note no temporal profile adjustments were made for the countries not included in Table H:2, for which GENEMIS temporal factors were used.

Table H:1: Adjustment factors by pollutant and sector provided by the CAMS-REG_EAF-COVID19 dataset, Guevara et al. 2022.

GNFR Sector	CO	NH_3	NMVOC	NOx	PM10	PM2.5	SO_2	CH_4	CO_{2bf}	CO_{2ff}
A - PublicPower				same profile for all species						
B - Industry	X	X	X	X	X	X	X	X	X	X
C - OtherStationaryComb	X	X	X	X	X	X	X	X	X	X
D - Fugitive	X	X	X	X	X	X	X	X	X	X
E - Solvents	X	X	X	X	X	X	X			
F1 - RoadTranspExhGas				same profile for all species						
F2 - RoadTranspExhDis	X	X	X	X	X	X	X	X	X	X
F3 - RoadTranspExhLPG				same profile for all species						
F4 - RoadTranspNonExh		X			X	X				
G - Shipping				same profile for all species						
H - Aviation				same profile for all species						
I - OffRoadTransp	X	X	X	X	X	X	X	X	X	X

Table H:2: Adjustment factors by country and sector provided by the CAMS-REG_EAF-COVID19 dataset, Guevara et al. 2022.

GNFR Sector	Countries
A - PublicPower	AT, BE, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LV, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
B - Industry	AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IT, LT, LU, LV, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, TR
C - OtherStationaryComb	AT, BA, BE, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LU, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
D - Fugitive	AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IT, LT, LU, LV, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, TR
E - Solvents	AT, BE, BG, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IT, LT, LV, NL, NO, PL, PT, RO, SE, TR
F1 - RoadTransp	AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LU, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
F2 - RoadTransp	AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LU, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
F3 - RoadTransp	AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LU, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
F4 - RoadTransp	AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IT, LT, LU, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, SK, TR, UA
G - Shipping	ATL, BAR, BAS, BLS, CAS, ENC, GRS, IRC, KAR, MED, NOS, NWS, PSG
H - Aviation	AL, AM, AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IL, IT, LT, LU, LV, MA, MD, ME, MT, NL, NO, PL, PT, RO, RS, SE, SK, TR, UA
I - OffRoadTransp	AT, BA, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IT, LT, LU, LV, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, TR

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Guevara, M., Petetin, H., Jorba, O., and Pérez García-Pando, C.: CAMS-REG_EAF-COVID19 emission adjustment factors, doi:10.24380/k966-3957, URL https://doi.org/10.24380/k966-3957, 2022.

APPENDIX I

Explanatory note on country reports for 2020

The country reports issued by EMEP MSC-W (Klein et al. 2022) focus on chemical species that are relevant to eutrophication, acidification and ground level ozone, but information on particulate matter is given as well. The country reports provide for each country:

- horizontal maps of emissions, and modelled air concentrations and depositions in 2020;
- emission trends for the years 1990 to 2020;
- modelled trends of air concentrations and depositions for the years 1990 to 2020;
- maps and charts on transboundary air pollution in 2020, visualizing the effect of the country on its surroundings, and vice versa;
- frequency analysis of air concentrations and depositions, based on measurements and model results for 2020, along with a statistical analysis of model performance;
- maps on the risk of damage from ozone and particulate matter in 2020.

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#2022

This year, the country reports are found under the header *MSC-W Data Note 1/2022 Individual Country Reports*. The reports for each country can be selected from a drop-down menu.

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