

Transboundary air pollution by
main pollutants (S, N, O₃) and PM

Latvia

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1 User guide

This report is one in a series of country-specific notes, complementary to the EMEP Status Report 1/2016. It presents an overview of transboundary pollution of main pollutants, ground level ozone and particulate matter (PM) for Latvia in 2014.

All model runs have been performed with the EMEP MSC-W model version rv4.9, using ECMWF-IFS meteorology. The transboundary contributions presented here are based on source-receptor calculations with the EMEP MSC-W model using meteorological and emission data for the year 2014.

As a basis for their correct interpretation, this section briefly explains what types of results are shown in this report and how they have been calculated.

1.1 The chapters of this report

Emissions (*Chapter 2*): The emissions for 2014 have been derived from the 2016 official data submissions to UNECE CLRTAP as of May 2016. The gridded distributions of the 2014 emissions have been provided by the EMEP Centre on Emission Inventories and Projections (CEIP).

The emissions for the period of 2000–2013 are the same as in the previous year's country report and have been derived from the data submissions to UNECE CLRTAP as of May 2015. Re-submissions of emission data in 2016 are not included since the gridded data set for 2000–2013 has not been updated by CEIP this year. The table showing total emissions also contains projections for 2020 from the revised Gothenburg Protocol (except CO emissions, as these are not projected for 2020 in the protocol).

The gridded emission data used in the model calculations this year are available on WebDab at:

http://www.ceip.at/webdab_emepdatabase/emissions_emepmodels.

In August 2014 a volcanic eruption started at the Barðarbunga fissure system in Iceland, and continued for 6 months until the end of February 2015. There was little ash released in the eruption, but large amounts of SO₂ were emitted into the atmosphere. In 2016 Iceland included SO₂ emissions from this eruption in the emission data reported under the LRTAP Convention. The total SO₂ emission from the Holuhraun eruption in 2014 was estimated to be 10,880 kt. This emission represents about one third of the total SO₂ emission within the EMEP domain in 2014 (including land-based anthropogenic, international shipping and natural emission sources). The volcanic eruption had a significant effect on SO₂ and SO₄²⁻ concentrations in air, as well as sulfur deposition in several countries, especially in Northern Europe.

Biogenic emissions of dimethyl sulphide (DMS) have been updated in the model. Rather than being prescribed, DMS emissions are now calculated dynamically during the model calculation and vary with current meteorological conditions. The new method yields DMS emissions about three times higher than in previous years, leading to changes in SO₂ and SO₄²⁻ concentrations and sulfur depositions in coastal countries.

Trends (*Chapter 3*): Trends in depositions and air concentrations are presented for the period of 2000–2014. The calculations are based on a consistent series of model runs, all using the EMEP MSC-W model version rv4.9. For the years 2000–2014, the meteorology of the respective year is used. Thus, interannual variability in the model results is due to changes in both emissions and meteorology. It should also be noted that the emission data and model version have changed since last year's report (see respective chapters on emissions and model updates in EMEP status report 1/2016), which may lead to differences between results reported here and in earlier reports. Most notably, changes have been

made in regard to the representation of sea salt, uptake rates of gaseous species on aerosol surfaces, and the calculation of DMS emissions.

Transboundary fluxes (*Chapter 4*): Data are presented in the form of maps and pie charts. The data are generated by source-receptor calculations, where emissions for each emitter of one or more precursors are reduced by 15%. The results have been scaled up to represent the entire emission from an emitter.

Transboundary concentrations (*Chapters 5 and 6*): Data are presented in the form of maps and bar charts. Ozone and particulate matter are subject to significant non-linearities in chemistry. Therefore we calculate the effect of 15% reductions in emissions only.

The horizontal maps show the reduction in concentrations when emissions are reduced by 15% in Latvia. By convention, reductions in concentrations are represented by positive values in the maps. Thus, any negative values mean that concentrations increase as a result of an emission reduction (due to non-linearities in chemistry).

The bar charts identify the six most important emitter countries in terms of their effects on concentrations in Latvia that would result from a 15% reduction in emissions. In the bar charts, the sum of the *absolute values* of these effects corresponds to 100%. The percentage values (vertical scale in the bar charts) thus give an indication of the relative importance of the various emitter countries that influence concentrations in Latvia (positive or negative, large or small contributions). Again, reductions are represented by positive values. Hence, a negative bar in the chart means that a *reduction* in emissions from an emitter country would lead to an *increase* in concentration in Latvia. In some countries this can occur because of strong non-linearities in chemistry.

In addition, for PM_{2.5} and PM₁₀ we show total concentration along with the contribution from natural sources (sea salt and natural dust) to the total concentration.

Comparison with observations (*Chapter 7*): The map of monitoring stations shows stations of Latvia in the EMEP measurement network with measurements in 2014 submitted to EMEP. The frequency analysis plots compare daily observation results with the model results. The measurement data are available from CCC: <http://www.nilu.no/projects/ccc/emepdata.html>. The table provides annual statistics of the comparison of model results with observations for each measured component. Comparison is done only for stations with a sufficiently consistent set of data available in weekly or higher time resolution.

Risks from ozone and PM (*Chapter 8*): The maps of ozone and PM values correspond to regional background levels and they are not representative of local point measurements, where these values can be much higher (i.e. in cities).

NOTE: In this series of country reports, trends are also presented for Kyrgyzstan, Uzbekistan, Turkmenistan and Tajikistan, although, as mentioned above, historical emission data before 2007 are not available. Emissions used for the years 2000–2006 are thus the same as for 2007 for these countries. The presented inter-annual changes of depositions and air concentrations are influenced by the emission changes in the old EMEP domain (132×111 grid cells) only.

For the Russian Federation and Kazakhstan, trends refer to the area of these countries inside the extended EMEP domain (132×159 grid cells), now covering all of Kazakhstan's territory and a larger part of the Russian Federation.

1.2 Country codes

Many tables and graphs in this report make use of codes to denote countries and regions in the EMEP area. Table 1 provides an overview of these codes and lists the countries and regions included in the source-receptor calculations for 2014.

Code	Country/Region	Code	Country/Region
AL	Albania	IE	Ireland
AM	Armenia	IS	Iceland
ASI	Remaining Asian areas (official)	IT	Italy
AST	Remaining Asian areas (extended)	KG	Kyrgyzstan
AT	Austria	KZ	Kazakhstan (official)
ATL	Remaining N.-E. Atlantic Ocean	KZT	Kazakhstan (extended)
AZ	Azerbaijan	LT	Lithuania
BA	Bosnia and Herzegovina	LU	Luxembourg
BAS	Baltic Sea	LV	Latvia
BLS	Black Sea	MD	Republic of Moldova
BE	Belgium	ME	Montenegro
BG	Bulgaria	MED	Mediterranean Sea
BIC	Boundary and Initial Conditions	MK	The FYR of Macedonia
BY	Belarus	MT	Malta
CH	Switzerland	NL	Netherlands
CY	Cyprus	NO	Norway
CZ	Czech Republic	NOA	North Africa
DE	Germany	NOS	North Sea
DK	Denmark	PL	Poland
EE	Estonia	PT	Portugal
EMC	EMEP land areas (official)	RO	Romania
EXC	EMEP land areas (extended)	RS	Serbia
ES	Spain	RU	Russian Federation (official)
EU	European Union (EU28)	RUE	Russian Federation (extended)
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

Table 1: Country/region codes used throughout this report: ‘official’ refers to the area of the country/region which is inside the official EMEP grid domain, while ‘extended’ refers to the area of the country/region inside the extended EMEP grid domain.

1.3 Definitions, statistics used

The following definitions and acronyms are used throughout this note:

SIA denotes secondary inorganic aerosol and is defined as the sum of sulphate (SO_4^{2-}), nitrate (NO_3^-) and ammonium (NH_4^+). In the EMEP MSC-W model SIA is calculated as $\text{SIA} = \text{SO}_4^{2-} + \text{NO}_3^-(\text{fine}) + \text{NO}_3^-(\text{coarse}) + \text{NH}_4^+$.

SOA - secondary organic aerosol.

SS - sea salt.

MinDust - mineral dust.

PPM denotes primary particulate matter, originating directly from anthropogenic emissions. One usually distinguishes between fine primary particulate matter, $\text{PPM}_{2.5}$ with aerosol diameters below $2.5 \mu\text{m}$ and coarse primary particulate matter, $\text{PPM}_{\text{coarse}}$ with dry aerosol diameters between $2.5 \mu\text{m}$ and $10 \mu\text{m}$.

$\text{PM}_{2.5}$ denotes fine particulate matter, defined as the integrated mass of aerosol with diameters up to $2.5 \mu\text{m}$. In the EMEP MSC-W model $\text{PM}_{2.5}$ is calculated as $\text{PM}_{2.5} = \text{SO}_4^{2-} + \text{NO}_3^-(\text{fine}) + \text{NH}_4^+ + \text{SS}(\text{fine}) + \text{MinDust}(\text{fine}) + \text{SOA}(\text{fine}) + \text{PPM}_{2.5} + 0.27 \text{NO}_3^-(\text{coarse}) + \text{PM}_{25\text{water}}$. (PM25water: PM associated water)

$\text{PM}_{\text{coarse}}$ denotes coarse particulate matter, defined as the integrated mass of aerosol with diameter between $2.5 \mu\text{m}$ and $10 \mu\text{m}$. In the EMEP MSC-W model $\text{PM}_{\text{coarse}}$ is calculated as $\text{PM}_{\text{coarse}} = 0.73 \text{NO}_3^-(\text{coarse}) + \text{SS}(\text{coarse}) + \text{MinDust}(\text{coarse}) + \text{PPM}_{\text{coarse}}$.

PM_{10} denotes particulate matter, defined as the integrated mass of aerosol with diameters up to $10 \mu\text{m}$. In the EMEP MSC-W model PM_{10} is calculated as $\text{PM}_{10} = \text{PM}_{2.5} + \text{PM}_{\text{coarse}}$.

SOx - group of oxidized sulphur components (SO_2 , SO_4^{2-}).

NOx - group of oxidized nitrogen components (NO , NO_2 , NO_3^- , N_2O_5 , HNO_3 , etc.).

redN - group of reduced nitrogen components (NH_3 and NH_4^+).

SOMO35 is the Sum of Ozone Means Over 35 ppb is an 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:

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

where the max function ensures that only A_8^d values exceeding 35 ppb are included. The corresponding unit is ppb·days (abbreviated also as ppb·d).

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

$$\text{AOT40} = \int \max(\text{O}_3 - 40 \text{ ppb}, 0.0) dt$$

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 for daytime only. The corresponding unit is ppb-hours (abbreviated to ppb·h).

Although the EMEP model generates a number of AOT-related outputs, in accordance with the recommendations of the UNECE Mapping Manual we will concentrate in this report on two definitions:

AOT40_f^{uc} - AOT40 calculated for forests using estimates of O₃ at forest-top (*uc*: upper-canopy). This AOT40 is that defined for forests by the UNECE Mapping Manual, but using a default growing season of April-September.

AOT40_c^{uc} - AOT40 calculated for agricultural crops using estimates of O₃ at the top of the crop. This AOT40 is close to that defined for agricultural crops by the UNECE Mapping Manual, but using a default growing season of May-July, and a default crop-height of 1 m.

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

$$\text{POD}_Y = \int \max(F_{st} - Y, 0) dt \quad (1)$$

where stomatal flux F_{st} , and threshold, Y , are in $\text{nmol m}^{-2} \text{s}^{-1}$, and the max function evaluates $\max(A - B, 0)$ to $A - B$ for $A > B$, or zero if $A \leq B$. This integral is evaluated over time, from the start of the growing season (SGS), to the end (EGS).

For the generic crop and forest species, the suffix “gen” can be applied, in this report e.g. $\text{POD}_{Y,gen}$ (or $AF_{st1.6gen}$) is used for forests and $\text{POD}_{3.0,gen-CR}$ (or AF_{st3gen}) is used for crops.

2 Emissions

2.1 Emissions used in the EMEP MSC-W model calculations

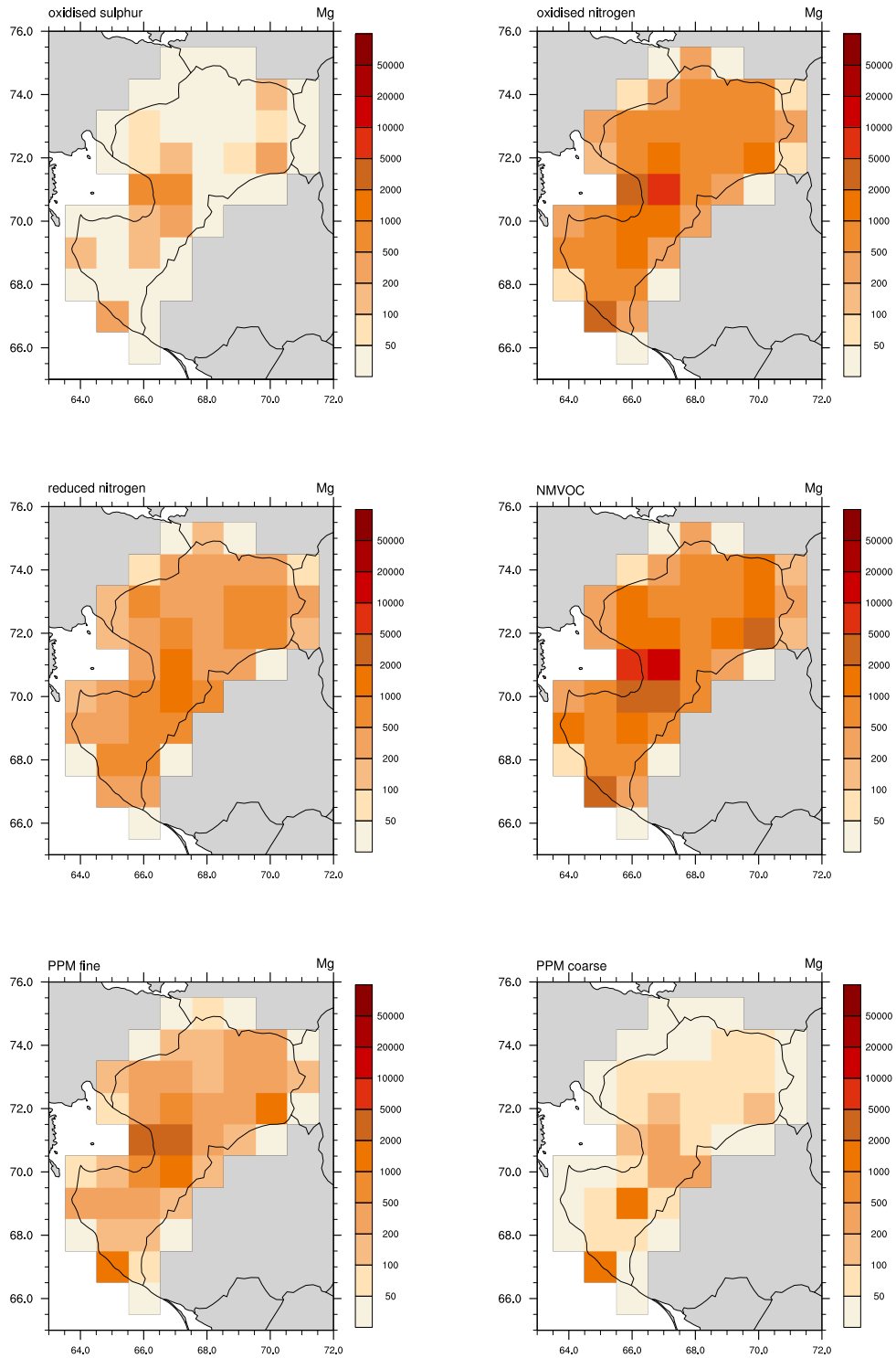


Figure 1: Spatial distribution of emissions from Latvia in 2014.

3 Trends

Important: For correct interpretation of the results shown in this chapter please read the paragraph on *Trends* in Section 1.1.

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2020
SO _x	15	6	6	5	4	4	3	2	2	2	4	6
NO _x	44	44	44	45	40	38	38	33	34	34	35	25
NH ₃	14	15	15	14	15	15	14	14	15	15	17	15
NMVOC	102	100	99	94	93	91	89	88	89	87	54	53
CO	236	204	198	187	174	186	154	158	165	149	136	
PM _{2.5}	25	29	29	28	28	30	24	25	26	24	18	23
PM ₁₀	29	35	35	35	35	35	30	31	33	30	24	27

Table 2: Emissions from Latvia. Unit: Gg.

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
SO _x dep.	34	23	24	22	25	19	24	18	18	16	20
NO _x dep.	28	26	28	27	29	23	26	25	25	23	22
redN dep.	19	18	21	20	22	19	22	20	22	19	21

Table 3: Estimated deposition of Sulphur (S) and Nitrogen (N) in Latvia. Unit: Gg(S) or Gg(N).

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
mean ozone	30	31	32	30	32	30	30	31	30	31	30
max ozone	36	36	38	36	37	35	36	36	35	36	35
AOT40 _f ^{UC}	7896	7370	11816	7985	7534	5965	7030	5378	6108	6730	5140
SOMO35	1247	1250	1649	1274	1353	1073	1174	1066	992	1141	988
POD _{1.0,gen-DF}	26	27	27	26	27	26	26	26	26	27	24
PM _{2.5} anthrop.	6	6	7	6	5	5	7	5	5	6	6
PM ₁₀ anthrop.	7	8	8	7	7	6	8	7	6	7	8

Table 4: Estimated yearly mean values of air quality indicators averaged over Latvia. Unit: daily mean ozone (ppb), daily max ozone (ppb), AOT40_f^{UC} (ppb-h), SOMO35 (ppb-d), POD_{1.0,gen-DF} (mmol/m²), PM_{2.5} (μg/m³) and PM₁₀ (μg/m³).

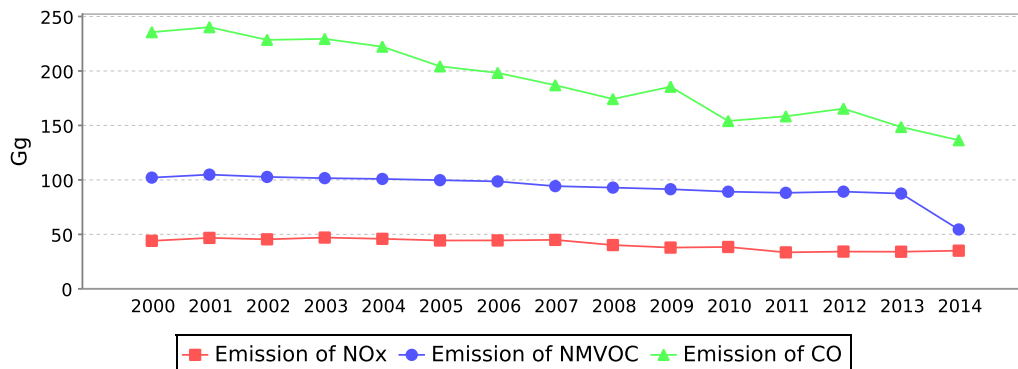


Figure 2: Trends in emissions of photo-oxidant pollution precursors. Unit: Gg (note that NO_x is here given as NO₂).

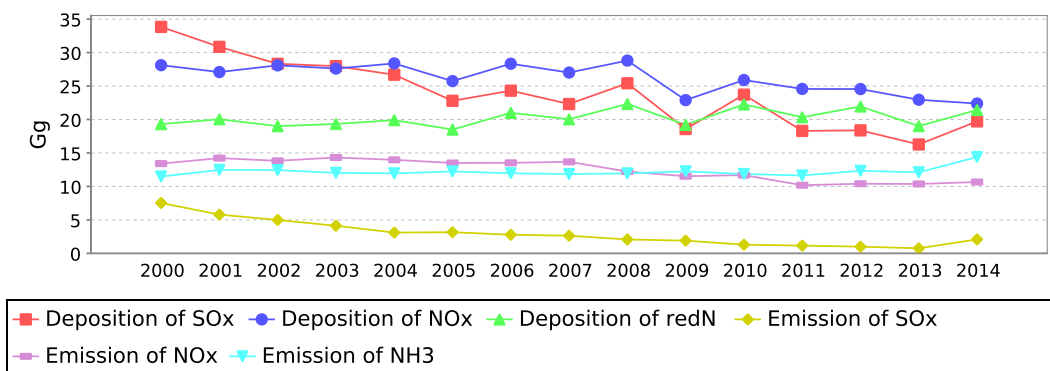


Figure 3: Trends in emissions and depositions of oxidised sulphur, oxidised nitrogen and reduced nitrogen. Unit: Gg(S) or Gg(N).

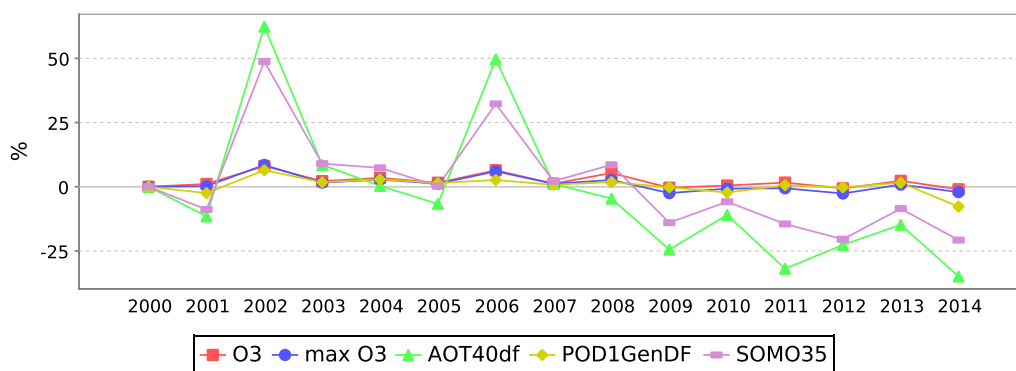


Figure 4: Changes in ozone related pollution relative to 2000. Unit: %. The large changes from year to year in some countries are mainly related to meteorological variability.

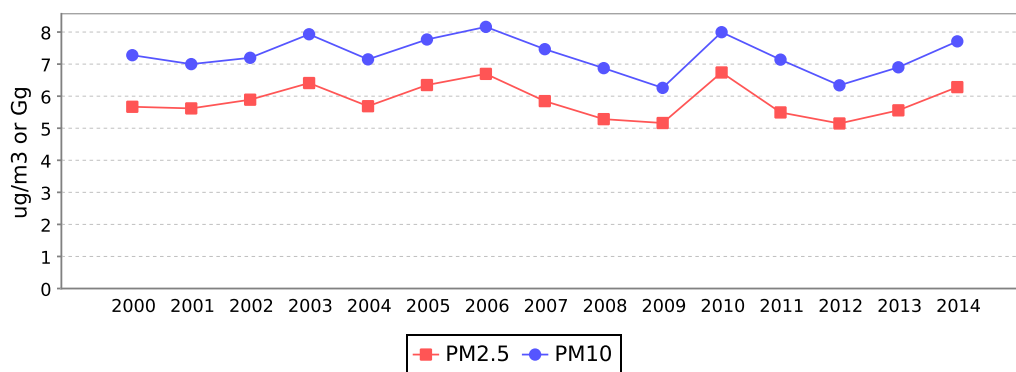


Figure 5: Trends in mean concentrations of particulate matter. Unit: $\mu\text{g}/\text{m}^3$.

4 Transboundary fluxes

4.1 Deposition of oxidised sulphur

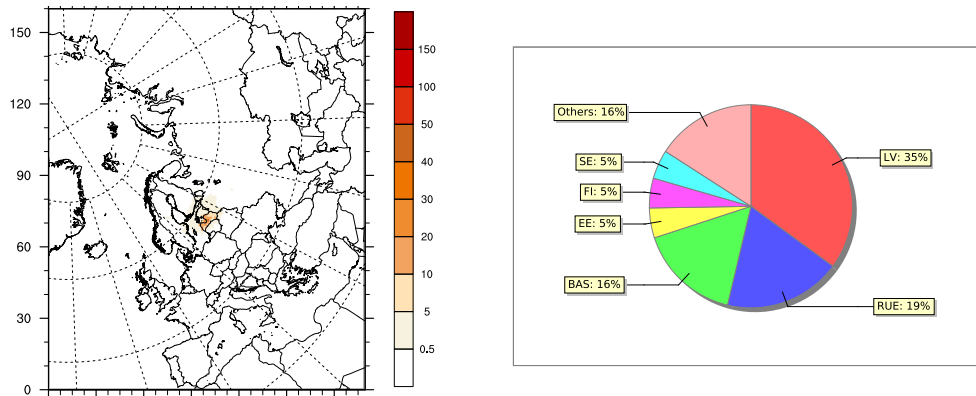


Figure 6: Contribution of emissions from Latvia to deposition of oxidised sulphur in the EMEP domain. Unit: mg(S)/m². The pie chart shows the six main receptor areas where oxidised sulphur from Latvia is deposited. Unit: %.

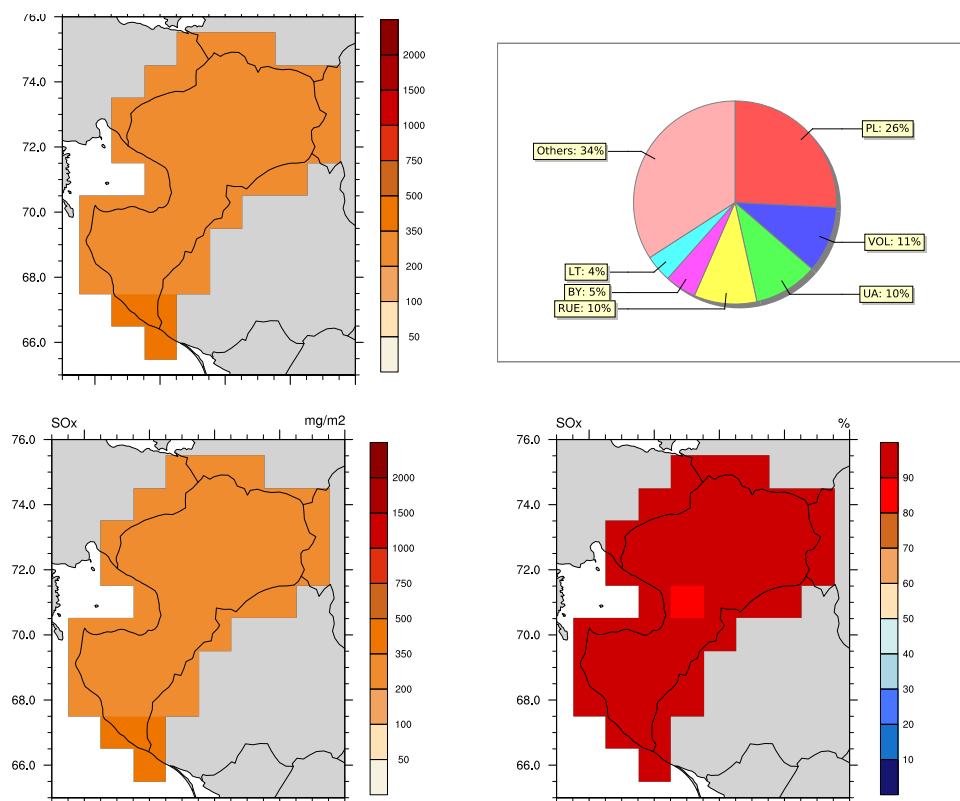


Figure 7: Top left: Deposition of oxidised sulphur in Latvia. Unit: mg(S)/m². Top right: The six main contributors to oxidised sulphur deposition in Latvia. Unit: (%). Bottom left: Oxidised sulphur deposition from transboundary sources. Unit: mg(S)/m². Bottom right: Fraction of transboundary contribution to total deposition. Unit: %.

4.2 Deposition of oxidised nitrogen

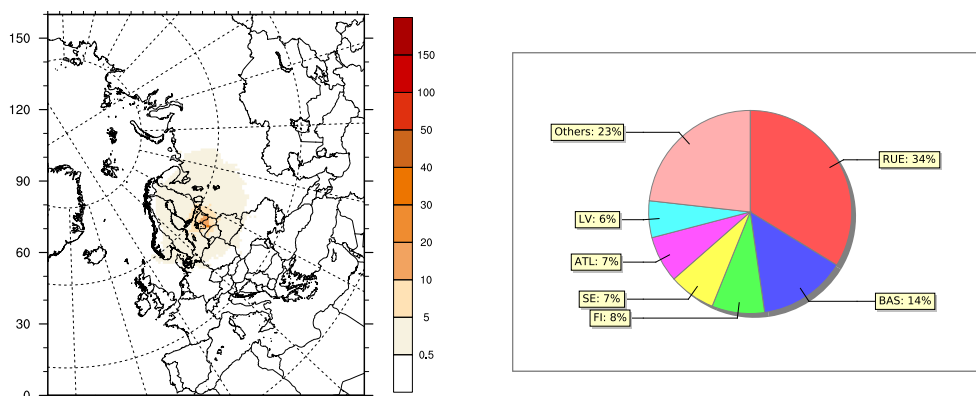


Figure 8: Contribution of emissions from Latvia to deposition of oxidised nitrogen in the EMEP domain. Unit: mg(N)/m². The pie chart shows the six main receptor areas where oxidised nitrogen from Latvia is deposited. Unit: %.

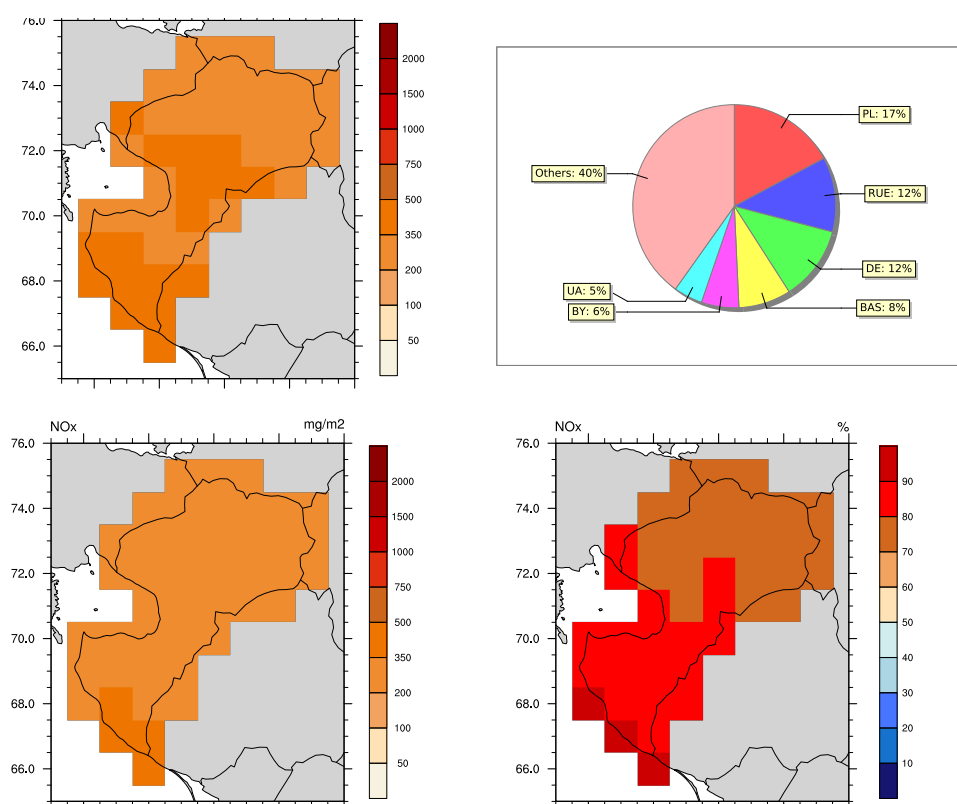


Figure 9: Top left: Deposition of oxidised nitrogen in Latvia. Unit: mg(N)/m². Top right: The six main contributors to oxidised nitrogen deposition in Latvia. Unit: %. Bottom left: Oxidised nitrogen deposition from transboundary sources. Unit: mg(N)/m². Bottom right: Fraction of transboundary contribution to total deposition. Unit: %.

4.3 Deposition of reduced nitrogen

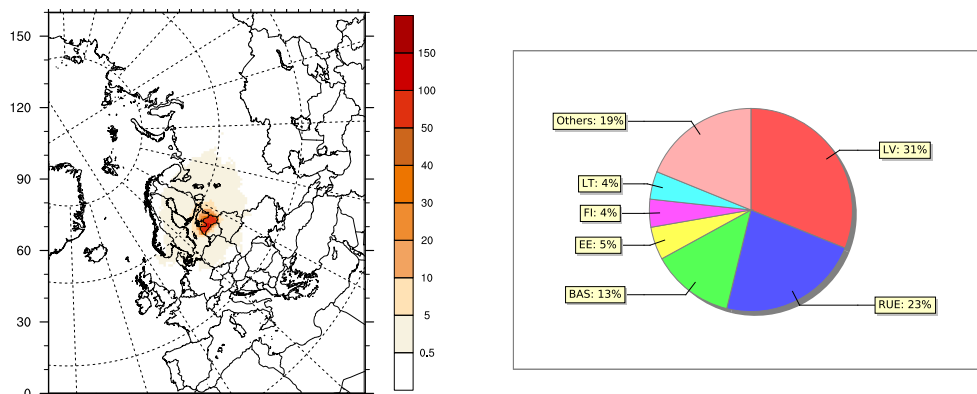


Figure 10: Contribution of emissions from Latvia to deposition of reduced nitrogen in the EMEP domain. Unit: mg(N)/m². The pie chart shows the six main receptor areas where reduced nitrogen from Latvia is deposited. Unit: %.

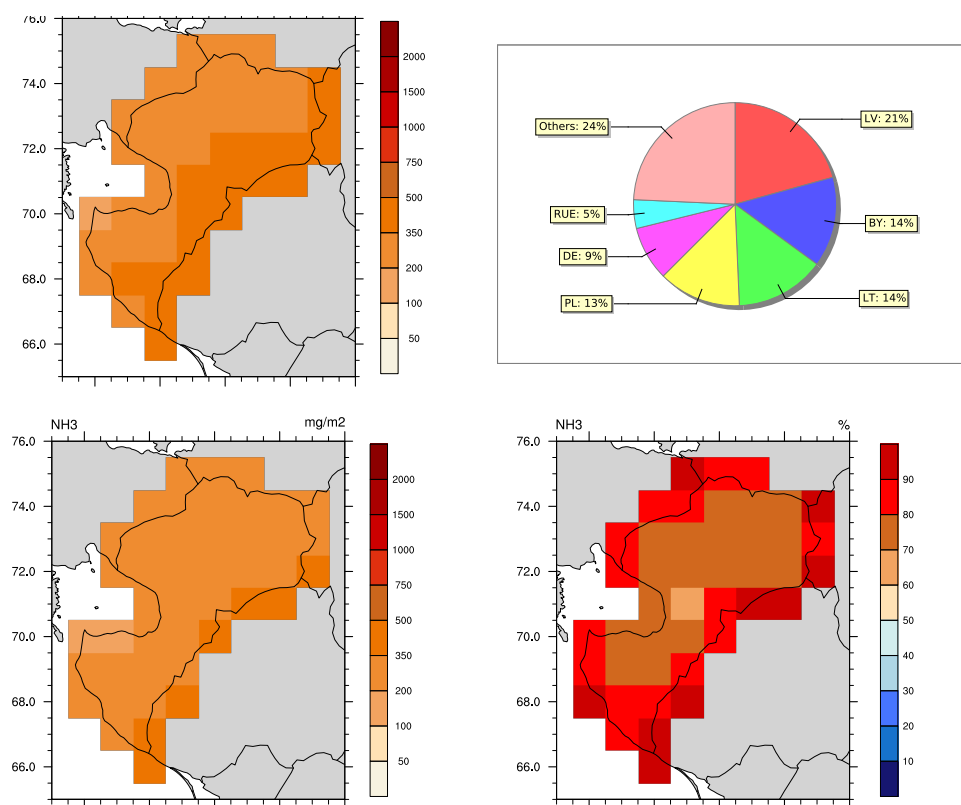


Figure 11: Top left: Deposition of reduced nitrogen in Latvia. Unit: mg(N)/m². Top right: The six main contributors to deposition of reduced nitrogen in Latvia. Unit: %. Bottom left: Deposition of reduced nitrogen from transboundary sources. Unit: mg(N)/m². Bottom right: Fraction of transboundary contribution to total deposition. Unit: %.

5 Transboundary concentrations of ozone

5.1 AOT40^{UC}_f

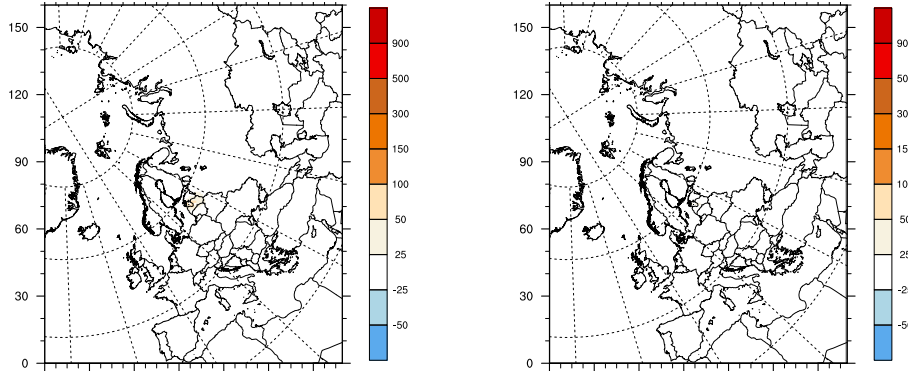


Figure 12: Reduction in AOT40_f^{UC} that would result from a 15% reduction in emissions of NO_x (left) and NMVOC (right) from Latvia. Unit: ppb·h.

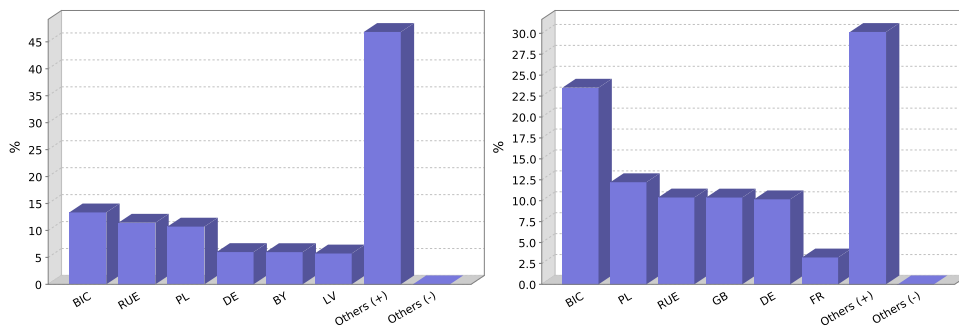


Figure 13: The six most important emitter countries or regions, with respect to their effects on AOT40_f^{UC} in Latvia that would result from reductions in NO_x emissions (left) or NMVOC emissions (right). The sum of the absolute values of the effects of all emitter countries corresponds to 100%. See Section 1.1 for more information.

5.2 POD_{1,0,gen-DF} – Ozone fluxes to deciduous forests

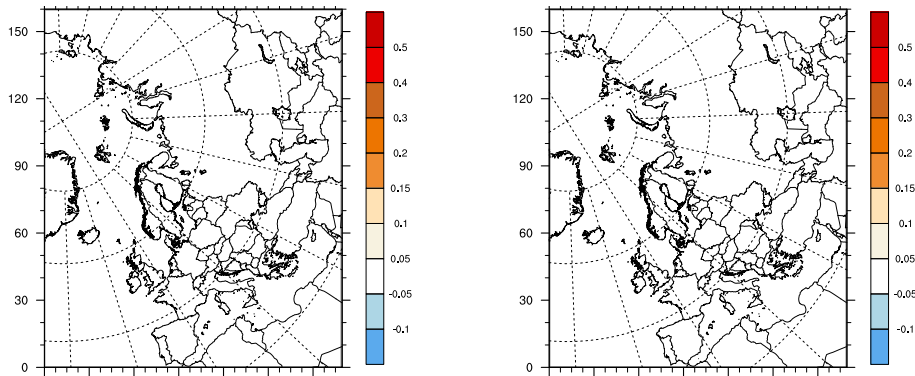


Figure 14: Reduction in POD_{1,0,gen-DF} that would result from a 15% reduction in emissions of NO_x (left) and NMVOC (right) from Latvia. Unit: mmol/m².

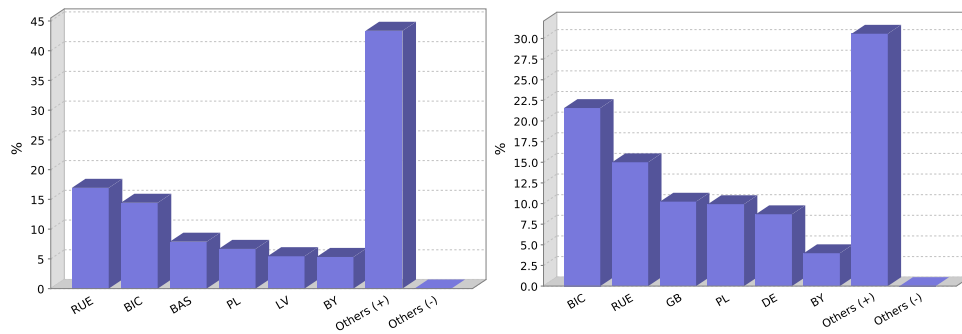


Figure 15: The six most important emitter countries or regions, with respect to their effects on POD_{1,0,gen-DF} in Latvia that would result from reductions in NO_x emissions (left) or NMVOC emissions (right). The sum of the absolute values of the effects of all emitter countries corresponds to 100%. See Section 1.1 for more information.

5.3 SOMO35 – Risk of ozone damages to human health

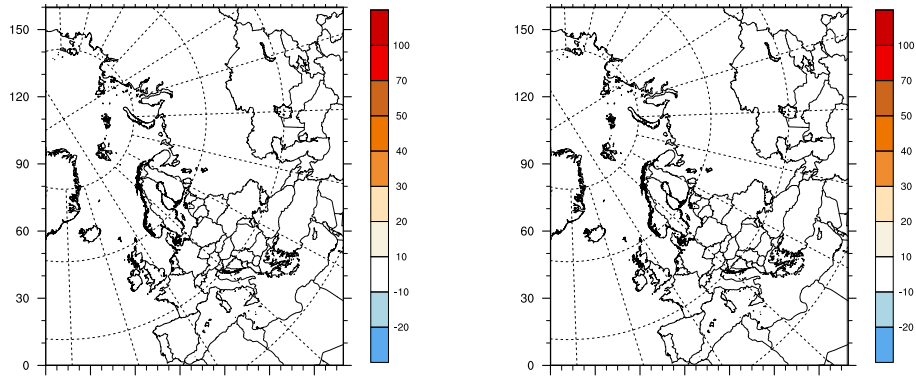


Figure 16: Reduction in SOMO35 that would result from a 15% reduction in emissions of NO_x (left) and NMVOC (right) from Latvia. Unit: ppb·day.

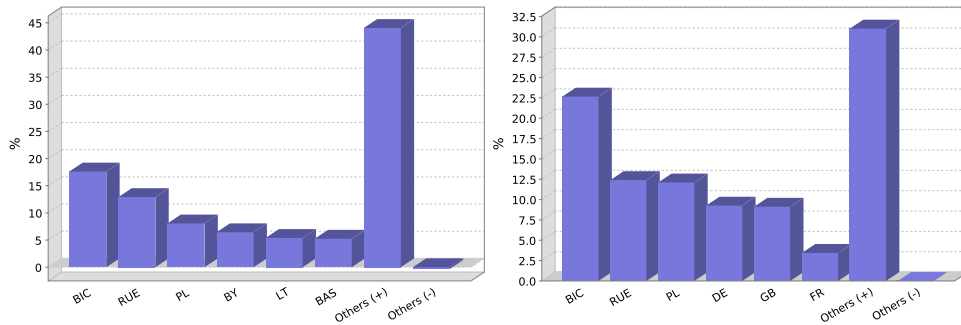


Figure 17: The six most important emitter countries or regions, with respect to their effects on SOMO35 in Latvia that would result from reductions in NO_x emissions (left) or NMVOC emissions (right). The sum of the absolute values of the effects of all emitter countries corresponds to 100%. See Section 1.1 for more information.

6 Transboundary concentrations of particulate matter

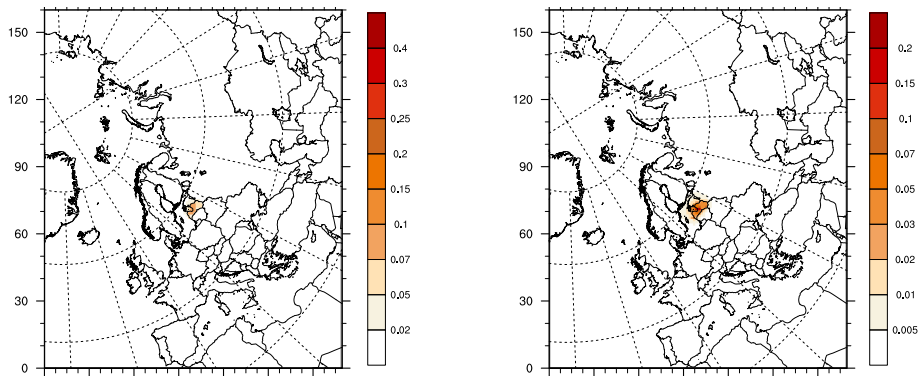


Figure 18: Reduction in concentrations of SIA (left) and $PPM_{2.5}$ (right) that would result from a 15% reduction in emissions from Latvia. Unit: $\mu\text{g}/\text{m}^3$. Note the difference in scales.

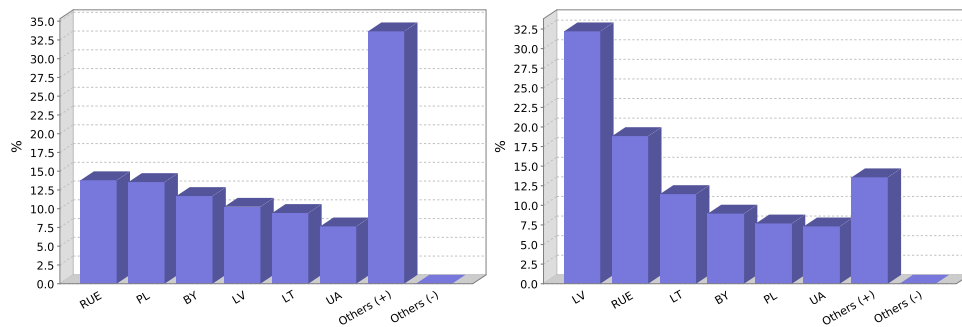


Figure 19: The six most important emitter countries or regions, with respect to their effects on SIA (left) or $PPM_{2.5}$ (right) in Latvia that would result from reductions in emissions. The sum of the absolute values of the effects of all emitter countries corresponds to 100%. See Section 1.1 for more information.

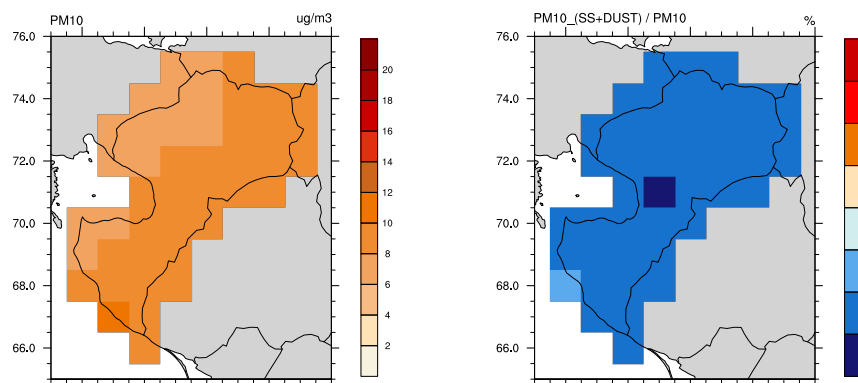


Figure 20: PM_{10} concentration (left) and fraction of natural contributions of PM_{10} (sea salt and natural dust) to total PM_{10} (right) in Latvia.

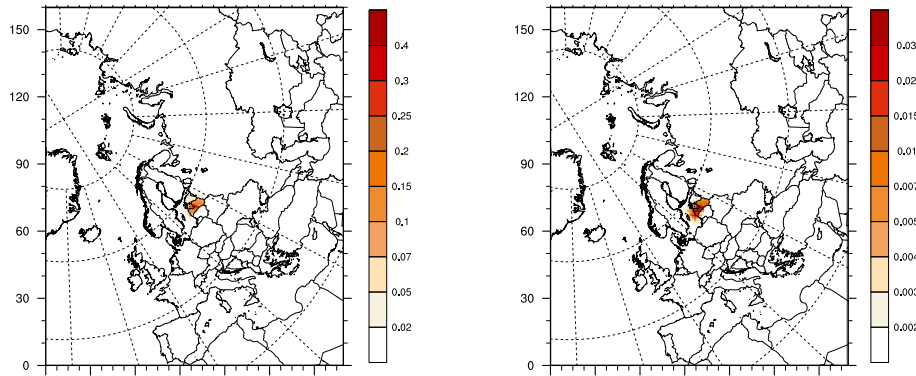


Figure 21: Reduction in $PM_{2.5}$ and PM_{coarse} concentrations that would result from a 15% reduction of emissions from Latvia. Unit: $\mu g/m^3$. Note the different color scales.

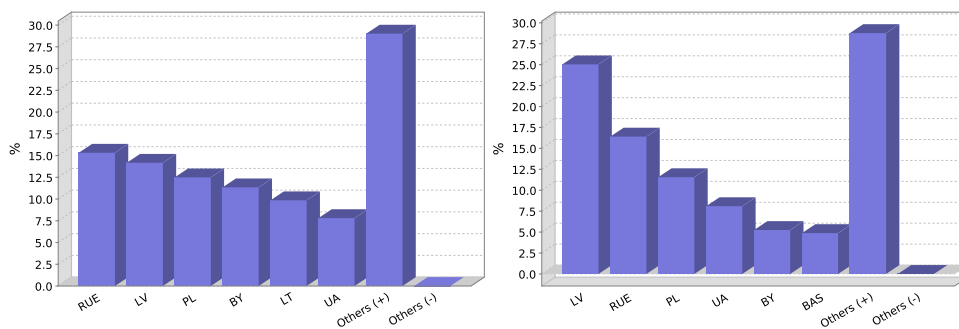


Figure 22: The six most important emitter countries or regions, with respect to their effects on $PM_{2.5}$ (left) or PM_{coarse} (right) in Latvia that would result from reduction in emissions. The sum of the absolute values of the effects of all emitter countries corresponds to 100%. See Section 1.1 for more information.

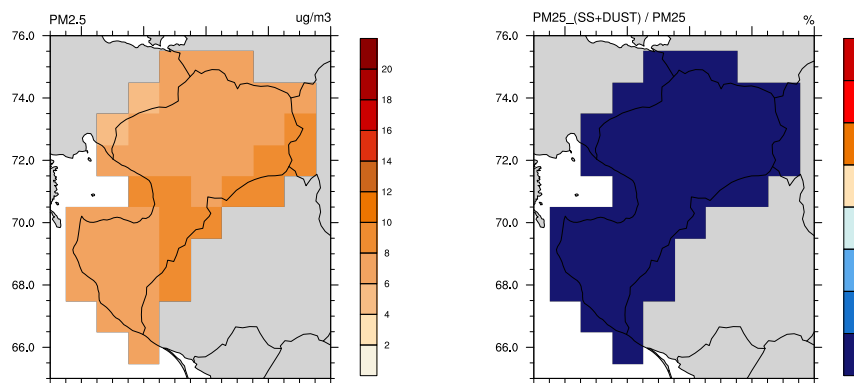


Figure 23: $PM_{2.5}$ concentration (left) and fraction of natural contributions of $PM_{2.5}$ (sea salt and natural dust) to total $PM_{2.5}$ (right) in Latvia.

7 Comparison with observations



Figure 24: Location of stations in Latvia.

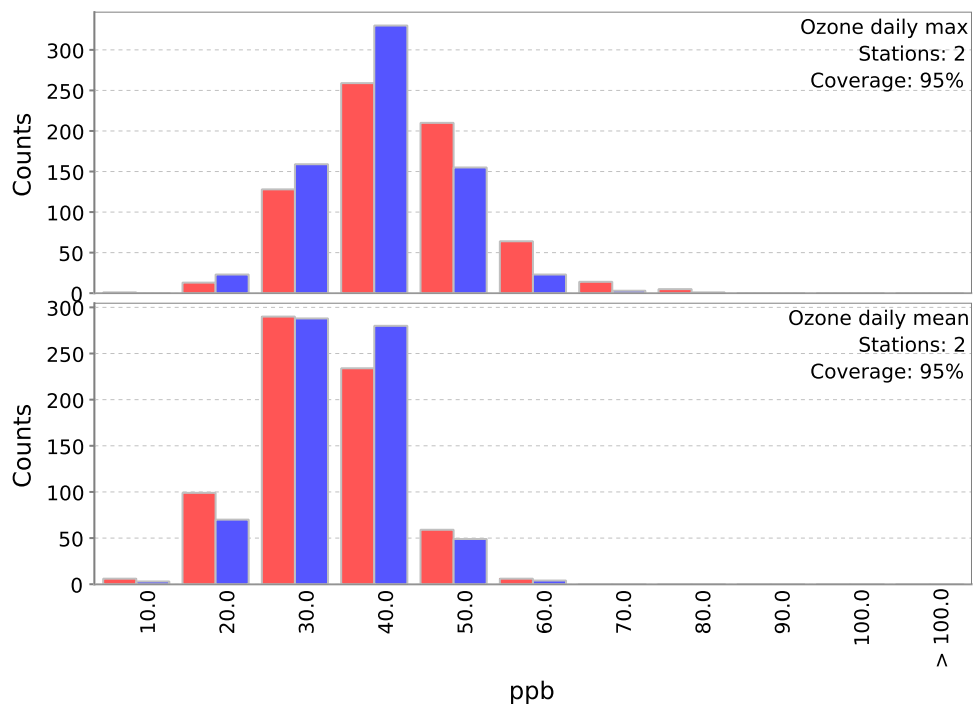


Figure 25: Frequency analysis of ozone in Latvia at the stations that reported O₃ for 2014 (Model, Observations).

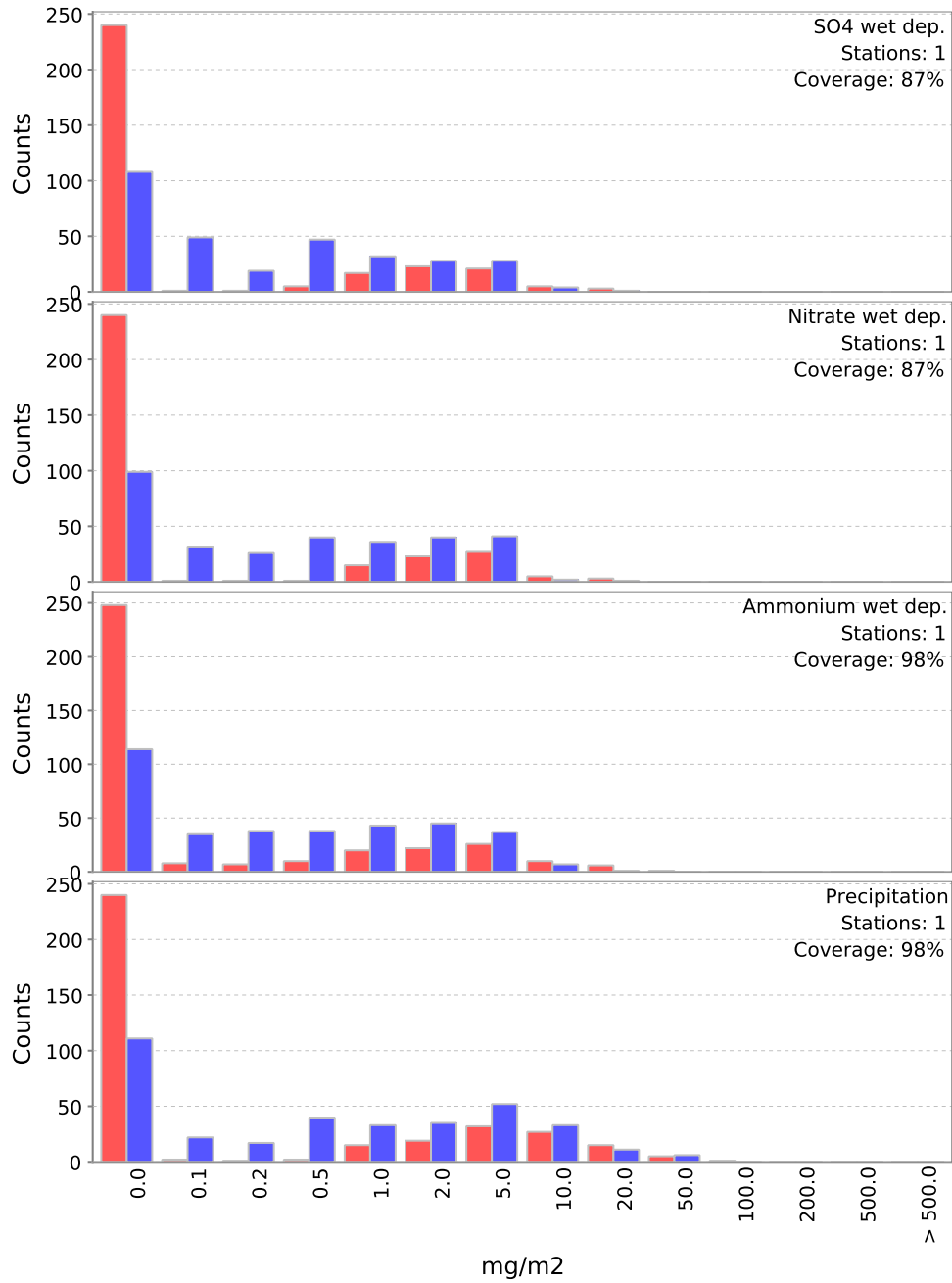


Figure 26: Frequency analysis of depositions in precipitation in Latvia (Model, Observations).

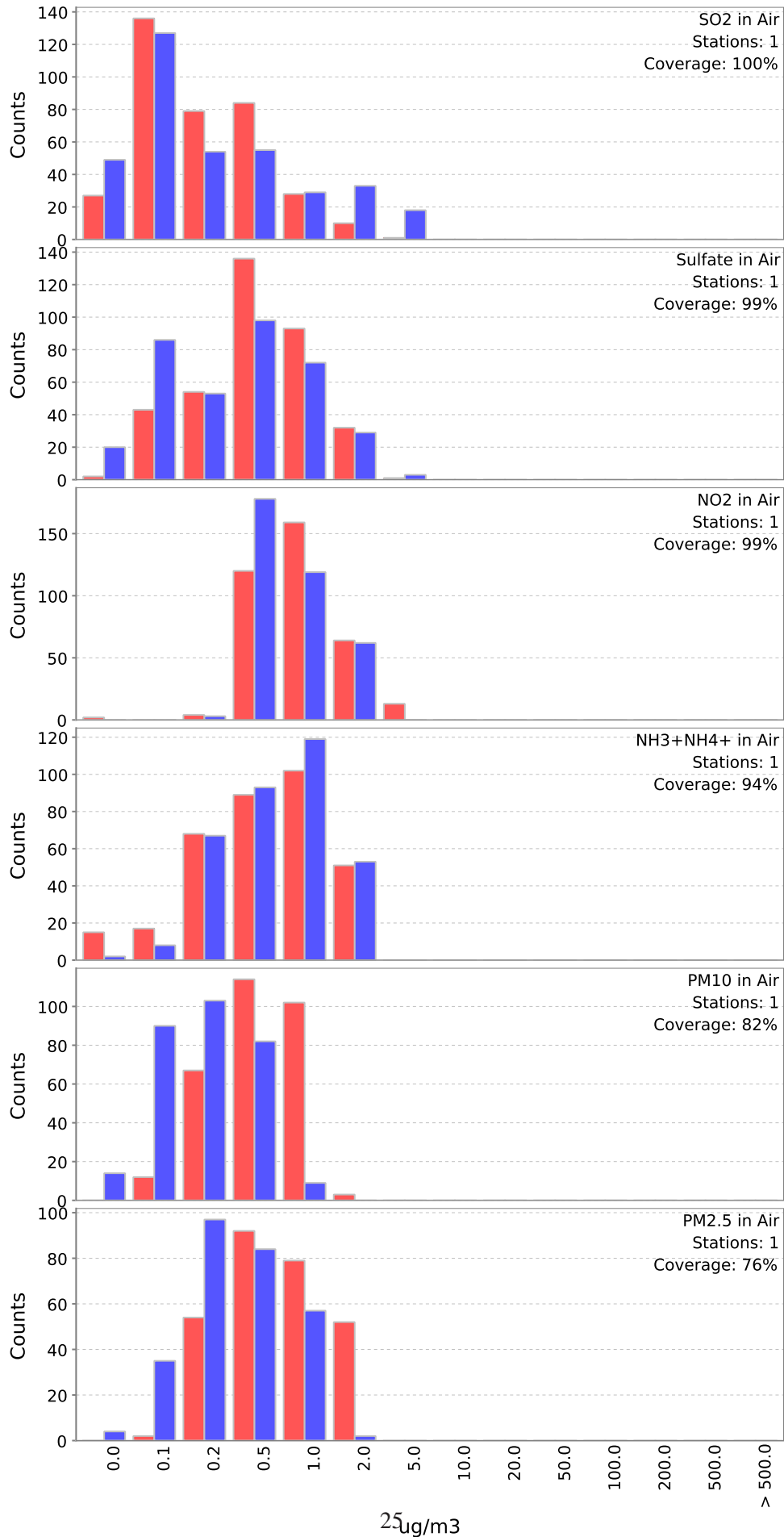


Figure 27: Frequency analysis of air concentrations in Latvia (Model, Observations).

Component	No.	Bias	Correlation	RMSE
SO2 in Air	1	69%	0.72	0.47
Sulfate in Air	1	-12%	0.81	0.19
NO2 in Air	1	28%	0.78	0.39
NO3- in Air	1	-92%	0.00	0.39
NH3+NH4+ in Air	1	10%	0.75	0.39
PM10	1	-51%	0.57	11.56
PM2.5	1	-39%	0.80	5.79
Ozone daily max	2	-9%±3%	0.88±0.00	5.40±1.51
Ozone daily mean	2	2%±1%	0.83±0.07	3.97±0.61
SO4 wet dep.	0			
Nitrate wet dep.	0			
Ammonium wet dep.	0			
Precipitation	0			

Table 5: Annual statistics of comparison of model results with observations in Latvia for stations with a sufficiently consistent set of data available in weekly or higher time-resolution. Standard deviations provide variability ranges between stations.

8 Risk of damage from ozone and particulate matter in Latvia

8.1 Ecosystem-specific AOT40 values

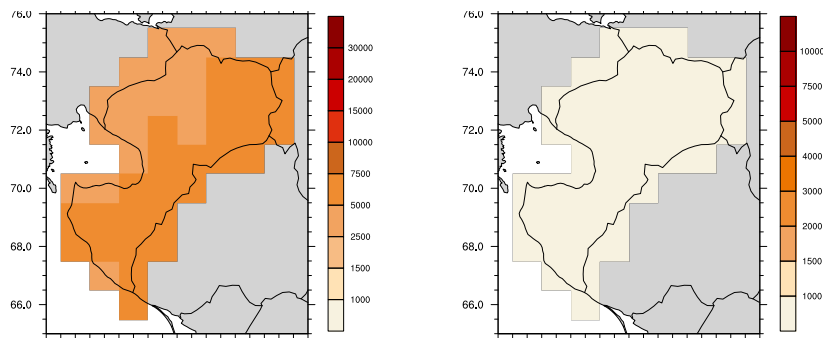


Figure 28: $AOT40_f^{uc}$ and $AOT40_c^{uc}$ in Latvia in 2014. ($AOT40_f^{uc}$: growing season April-Sept., critical level for forest damage = 5000 ppb·h; $AOT40_c^{uc}$: growing season May-July, critical level for agricultural crops = 3000 ppb·h.)

8.2 Ecosystem-specific ozone fluxes

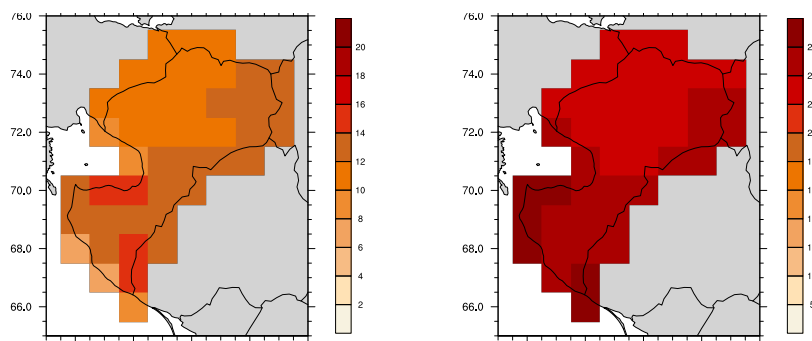


Figure 29: $POD_{3.0,gen-CR}$ and $POD_{1.0,gen-DF}$ in Latvia in 2014.

8.3 Health impacts from ozone and particulate matter

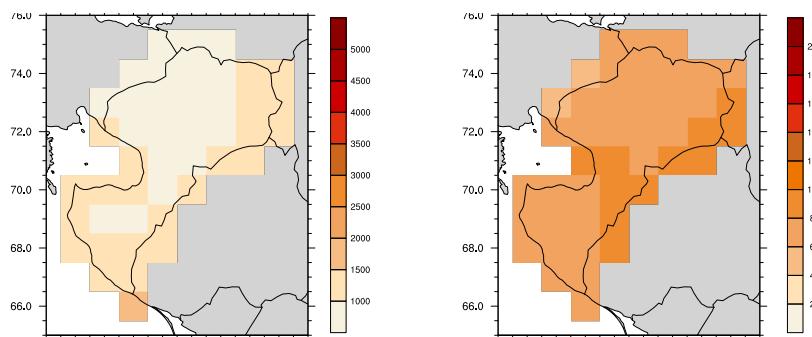


Figure 30: Regional scale SOMO35 and $PM_{2.5}$ in Latvia in 2014.

emep

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