Convention on Long-range Transboundary Air Pollution

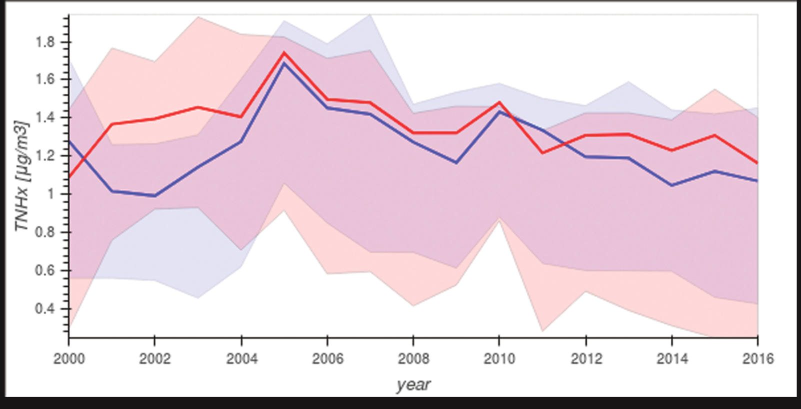
emep

Co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe

STATUS REPORT 1/2018

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

Status Report 1/2018



Modelled (red) and observed (blue) annual time series of air concentrations of total reduced nitrogen from 2000 to 2016 (25 and 75 percentiles are shown as shaded areas)

msc-w & ccc & ceip

EMEP Report 1/2018
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METEOROLOGISK INSTITUTT
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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 2017 and 2018 in relation to transboundary fluxes of particulate matter, photo-oxidants, acidifying and eutrophying components, with focus on results for 2016. It presents major results of the activities related to emission inventories, observations and modelling. The report also introduces specific relevant research activities addressing EMEP key challenges, as well as technical developments of the observation and modelling capacities.

Measurements and model results for 2016

In the first chapter, the status of air pollution in 2016 is presented, combining meteorological information with numerical simulations using the EMEP MSC-W model together with observed air concentration and deposition data.

Altogether 32 Parties reported measurement data for 2016, from 161 sites in total. Of these, 130 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 70 sites, of which 50 performed measurements of both PM_{10} and $PM_{2.5}$. In addition, 52 sites reported at least one of the components required in the advanced EMEP measurement program (level 2). A complete aerosol program was implemented at 12 sites, while only a few sites provided the required oxidant precursor measurements.

The mean daily max O_3, SOMO35 and AOT40 all show a distinct gradient with levels increasing from north to south, a well established feature for ozone in general reflecting the dependency of ozone on the photochemical conditions. The geographical pattern in the measured values are fairly well reflected by the model results for all these three metrics. In particular, the modelled mean daily max for the summer half year agrees very well with the measured values except for an underestimation in a few regions, mainly in the Mediterranean. Particularly high levels are predicted by the model in the southeast, but due to the lack of monitoring sites these levels could not be validated.

The modelling results and the observations show that the annual mean levels of PM_{10} and $PM_{2.5}$ in general increase over land from north to south. The concentration levels are below 2-5 μg m^{-3} in Northern Europe, increasing to 5-15 μg m^{-3} in the mid-latitude and further south. Elevated PM_{10} and $PM_{2.5}$ levels of 15-20 μg m^{-3} occurred in some areas (the Benelux countries and parts of Germany, Poland and East-European countries). A hot spot is seen in the Po Valley, with calculated $PM_{2.5}$ and PM_{10} exceeding 20-30 μg m^{-3}. There is good agreement between the modelled and observed distribution of mean PM_{10} and $PM_{2.5}$, with annual mean correlation coefficients of 0.78 and 0.71 respectively. Overall, the model underestimates the observed annual mean PM_{10} and $PM_{2.5}$ by 22% and 10% respectively.

Over most of the European part of the EMEP grid, mean concentrations of PM_{10} and $PM_{2.5}$ in 2016 were 10-30 % lower compared to mean PM levels in the 2000-2015 period, while they were 5-30 % higher in the very eastern and southern EMEP areas. This is consistent with the emission changes during that period (decrease in the western part, while increase in the eastern part of the EMEP domain). In addition, the precipitation anomaly distribution suggestes that enhanced wet removal of aerosols from the air contributed to lower PM pollution over large areas in 2016.

Exceedances and pollution episodes in 2016

In general, there were fewer high ozone episodes and lower O_3 levels in 2016 compared to 2015. An unusual event of high ozone levels in September occurred, with several monitoring sites having their annual peak ozone level during these days including levels above the EU information threshold of 180 μg m^{-3}. Record-high temperatures (well above 30°C) were recorded followed by record-high levels of ozone the following days. Our results indicate a very good agreement between the modelled and measured levels for this episode, both with respect to the location of the ozone plume and the concentration levels.

Model results and EMEP observational data show that in 2016, the annual mean PM_{10} and $PM_{2.5}$ concentrations were below the EU limit values for all of Europe. As far as daily concentrations are concerned, exceedance days for PM_{10} were observed at 34 out of 63 sites, but no violations of the PM_{10} EU limit value (more than 35 exceedance days) were registered (still 15 sites had more than 3 exceedance days, the recommended Air Quality Guidline (AQG) by WHO). $PM_{2.5}$ concentrations exceeded the WHO AQG value at 33 out of 46 stations in 2016 (on more than 3 days at 27 sites).

The major PM pollution episodes occurred in January, March and December 2016. The winter episodes, seen almost every year, are typically caused by a combination of stagnant air conditions and enhanced use of wood burning for residential heating during cold weather situations. On the other hand, agriculture and traffic emissions appear to be main contributors to the spring episodes. The different chemical composition of $PM_{2.5}$ at three selected sites confirms the diversity of the emission sources causing the episodes at different locations.

Critical loads (CL) for eutrophication were exceeded in virtually all countries in 2016, in about 61.7% of the ecosystem area (73% in the EU28) and the European average exceedance is about 217 eq ha^{-1}yr^{-1} (289 eq ha^{-1}yr^{-1} in the EU28). The highest exceedances are found in the Po Valley in Italy, the Dutch-German-Danish border areas and in north-eastern Spain.

In 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 maximum in southern Germany and the Czech Republic, whereas most of Europe in not exceeded. In Europe as a whole, acidity exceedances in 2016 occur in about 5.3% of the ecosystem area (6.6% in the EU28), and the European average exceedance is about 20 eq ha^{-1}yr^{-1} (28 eq ha^{-1}yr^{-1} in the EU28).

Model simulations for 2000-2016 in the new EMEP grid

This year, CEIP created a new set of emissions for 2000-2016 using the 0.1°× 0.1° resolution gridding system and updated emission data. The latest EMEP MSC-W model version has been used to calculate a consistent time series of air pollution. Furthermore, a new trend interface (http://aerocom.met.no/trends/EMEP/) has been developed at MSC-W. The interface allows visualization of the trends for different pollutants at all EMEP sites, and will be extended to include EMEP measurement data where these are available. Work is also in progress to include source categories as a part of this visualization tool.

Source receptor matrices in the new EMEP grid

Last year it was the first time Parties to the Convention reported emissions in the new grid in $0.1° \times 0.1°$ resolution and longitude-latitude projection. This year, these fine scale emissions are used in calculations of source receptor matrices (SRMs). In addition, the country border data set has been updated using high resolution information. The new country border data set is more accurate than the old $50\times50\text{km}^2$ data set and also consistent with what is used for emission distribution by CEIP.

As completing the SRMs calculations in the $0.1° \times 0.1°$ resolution is difficult within the current deadlines, a series of tests has been made to estimate the effect of the choice of the grid resolution on SRMs. For 5 selected countries, we compared SRMs calculated with 3 different resolutions ($0.1° \times 0.1°$, $0.3° \times 0.2°$ and $0.4° \times 0.3°$). For the country-to-itself contribution, the overall differences in SRMs due to different model resolutions are small for depositions (a few percent), but somewhat larger for PM and ozone (up to 11%). For the individual transboundary contributions, differences can be larger, especially when the pollution is transported across mountain areas and/or is very small. Based on this analysis, we decided to calculate SRMs for 2016 in $0.3° \times 0.2°$ resolution, as the $0.3° \times 0.2°$ results were somewhat closer to $0.1° \times 0.1°$ results than $0.4° \times 0.3°$.

In addition, we studied how the country border data set affects the SRMs. Overall, the differences due to using a new country border data set are as large as the differences due to the different model resolutions.

Status of emissions

Completeness and consistency of submitted emission data have improved significantly since EMEP started collecting information on emissions, and at least 45 Parties reported emission data to CEIP each year for the last seven years. In 2018, 45 out of 51 Parties (88%) submitted emission inventories. However, the quality of submitted data differs significantly across countries, and the uncertainty in the data is considered to be relatively large.

The reporting of CLRTAP inventories by EECCA countries to the Convention is still limited. In the last five years only Georgia, the Russian Federation and Ukraine provided annual submissions. CEIP conducts in-depth reviews of inventories, which support Parties in compiling and submitting high quality inventories and aims to increase confidence in the data used for air pollution modelling. In 2018, an in-depth review of the inventories of the Republic of Moldova, Armenia, Belarus, Ukraine and Azerbaijan will be made. In 2019, the Russian Federation and Georgia, and in 2020, Kyrgyzstan and Kazakhstan will be reviewed.

Last year was the first year with reporting obligation of gridded emissions in the new grid resolution of $0.1°\times0.1°$ longitude/latitude. 29 of the 48 countries which are part of the EMEP area did report sectoral gridded emissions in the new resolution until June 2018. One country reported only gridded national total values (instead of sectoral data).

The majority of gridded sectoral emissions in $0.1°\times0.1°$ longitude/latitude resolution have been reported for the year 2015 (28 countries). For the year 2016, gridded sectoral emissions have been reported by three countries. Two of the three countries reported too late, which is why data could not be used for preparing gridded emissions in 2018.

Reported gridded sectoral data cover less than 20% of the grid cells within the geographical EMEP domain. For remaining areas missing emissions are gap-filled and spatially distributed using expert estimates. This year CEIP also performed gap-filling and gridding for the whole time series from 2000 to 2016 in $0.1^{\circ}\times0.1^{\circ}$ longitude/latitude resolution on GNFR sector level.

Emissions from international shipping occurring in different European seas were updated for the period of 2000 to 2016 based on global shipping emissions from FMI (Finnish Meteorological Institute) for the year 2015 (and also for 2011 in case of NO_x and SO_x in the Baltic and the North Sea). For the year 2016 the FMI emission values for 2015 was used, while for historical shipping emissions the FMI data were adjusted according to trends from data developed within the EU Horizon2020 project MACC-III and the ICCT Report. NMVOC emissions from international shipping have been estimated to be 10.9% of the CO emissions.

The development in emissions in the eastern and western parts of the EMEP area seems to follow different patterns. While emissions of all pollutants in the western part of the EMEP domain are slowly decreasing, emissions of all pollutants in the eastern part of the EMEP domain have increased since the year 2000. The emissions in western parts of the EMEP area are mostly based on reported data, while the emissions in eastern parts often are based on expert estimates (with larger uncertainty). From 2000 to 2016, the total change in emissions for the EMEP area has been: NO_x (-6%), NMVOCs (-3%), SO_2 (-30%), NH_3 (+22%), $PM_{2.5}$ (+6%), PM_{coarse} (+17%) and CO (-17%).

Effect of ship traffic emissions

The contributions from ship traffic to air pollution in Europe have been calculated with a global version of the EMEP model. For ozone and ozone indicators, such as SOMO35 and POD_1 forest, the variability in the percentage contributions is large between countries and regions, with ship emissions resulting in reductions in several western European countries but substantial increases in other (mainly Mediterranean) countries. Regarding the effects of ship emissions from the Baltic Sea and the North Sea on adjacent countries, the percentage contributions to the ozone indicators SOMO35 and POD_1 forest are substantially larger (positive or negative) than to annually averaged ozone.

For a number of coastal countries, calculated contributions to $PM_{2.5}$ and depositions of sulphur and oxidized nitrogen from ships constitute 10% or more of the global anthropogenic total. The long-range transported contributions, calculated with a global version of the EMEP model, appear larger than in the regional model calculations. This may in part be explained by the different meteorological conditions in the different years (2015 for the global and 2014/2016 for the regional calculations), but also by the coarser resolution used in the global calculations. Nevertheless, all our calculations show large reductions in sulphur depositions and some reductions in $PM_{2.5}$ levels as a result of the implementation of SECA in the North Sea and the Baltic Sea, in countries bordering these two sea areas.

Equivalent Black Carbon (EBC) from fossil fuel and biomass burning sources

A joint EMEP/ACTRIS/COLOSSAL intensive measurement period was conducted in winter 2017-2018 (IMP Winter 2018), using multi-wavelength aethalometer measurements of equivalent black carbon (EBC) and a novel application of positive matrix factorisation (PMF) for source apportionment of EBC into fossil fuel (EBC_{ff}) and biomass burning (EBC_{bb}) origin.

The IMP aims to provide a harmonized European-wide data set of EBC_{ff} and EBC_{bb} applicable for model validation, to encourage initiation of regular monitoring of EBC_{ff} and EBC_{bb}, and reporting of such data to EMEP, and to substantially improve knowledge of carbonaceous aerosol sources in Europe. The 57 sites, situated in the 24 different countries participating in the IMP, underpin the great interest and knowledge requirement in this topic across Europe. Here, we report preliminary results from five of these sites, three urban sites in the Mediterranean region and two rural sites in Finland.

EBC_{ff} (45-74%) made a larger contribution to EBC than EBC_{bb} (26-55%) at all sites but one urban one. Diurnal variation was pronounced at the urban sites, and substantially different between EBC_{ff} and EBC_{bb}, clearly showing the influence of morning and afternoon traffic rush hours on EBC_{ff} and residential wood burning, commencing in early evening and continuing through the night, on EBC_{bb}. No diurnal variation was seen for the two rural sites, suggesting minor or no influence from local sources and that long-range atmospheric transport prevailed. Comparison between the biomass burning tracer levoglucosan and EBC_{bb} showed a very high degree of correlation (r^2 = 0.94 - 0.96), demonstrating the effectiveness of the novel PMF approach, as do the pronounced diurnal variations seen for the urban sites. Aerosol Angström exponents (AAE) derived from the PMF approach ranged from 0.92 - 1.08 for fossil fuel (AAE_{ff}) and from 1.27 - 1.51 for biomass burning (AAE_{bb}), which is in line with findings from the most recent and updated study discussing AAE in Europe.

Data from the participating sites will be analyzed according to the PMF approach as soon as possible after they are submitted to EMEP and found to have a sufficient data and metadata quality.

Model improvements

Most of the changes made in the EMEP MSC-W model since last year have been concerned with improvements to the model code and usability, and these have had little impact on model results. These improvements include several updates and bug-fixes to the chemical scheme, improved compatibility between the older SNAP and new GNFR emission sectors, updated land-cover database and improved handling of WRF and AROME meteorology. One major change did occur, however, and that concerns the treatment of photosynthetically active radiation (PAR) in the model, which impacts both biogenic VOC emissions and ozone flux estimates. The changed radiation scheme seems to mainly impact POD_1 estimates for forests (now reduced), with only small changes in POD_3 for crops or ozone concentrations.

Development in the monitoring network and database infrastructure

The last chapter of the report presents the implementation of the EMEP monitoring strategy and general development in the monitoring programme including data submission. There are large differences between Parties in the level of implementation, as well as significant changes in the national activities during the period 2000-2016. With respect to the requirement for level 1 monitoring, 42% of the Parties have had an improvement since 2010, while 30% have reduced the level of monitoring. For level 2 monitoring there has been a general positive development in recent years. However, in large parts of Europe the implementation of the EMEP monitoring strategy is still unsatisfactory.

The complexity of data reporting has increased in recent years. To improve the quality and timeliness of data reporting, the new online data submission and validation tool has been further developed to give better feedback when errors in the files occur, including automatic checks for inconsistency and outliers. The correctness of the data files submitted has improved significantly during the last years.

Acknowledgments

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The development of the local fraction method of the EMEP MSC-W model has been supported by the Norwegian Research Council project AIRQUIP.

The work presented here 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.

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

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The Working Group on Effects and its ICPs and Task Forces are acknowledged for their assistance in determining the risk of damage from air pollution. Maximilian Posch at the Centre for Integrated Assessment Modelling (CIAM) performed the calculations of the exceedances of critical loads based on the latest critical loads database.

This work has received support from the Research Council of Norway (Programme for Supercomputing) through CPU time granted at the supercomputers at NTNU in Trondheim, the University of Tromsø, and the University of Bergen through the EMEP project (grant NN2890K) for CPU, and the NorStore project European Monitoring and Evaluation Programme (grant NS9005K) for storage. 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 trend calculations. The CPU time made available by ECMWF to generate meteorology has been important for both the source-receptor and status calculations in this year's report.

Contents

CHAPTER 1

Introduction

1.1 Purpose and structure of this report

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

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

The present report is divided into four parts. Part I presents the status of transboundary air pollution with respect to acidification, eutrophication, ground level ozone and particulate matter in Europe in 2016. Part II summarizes research activities of relevance to the EMEP programme, while Part III deals with technical developments going on within the centres.

Appendix A in Part IV contains information on the national total emissions of main pollutants and primary particles for 2016, while Appendix B shows the emission trends for the period of 2000–2016. Country-to-country source-receptor matrices with calculations of the transboundary contributions to pollution in different countries for 2016 are presented in Appendix C.

Appendix E introduces the model evaluation report for 2016 (Gauss et al. 2018c) which is available online and contains time series plots of acidifying and eutrophying components (Gauss et al. 2018b), ozone (Gauss et al. 2018a) and particulate matter (Tsyro et al. 2018). These plots are provided for all stations reporting to EMEP (with just a few exclusions due to data-capture or technical problems). This online information is complemented by numerical fields and other information on the EMEP website. The reader is encouraged to visit the website, `http://www.emep.int`, to access this additional information.

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

1.2 Definitions, statistics used

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

PBAP - primary biological aerosol particles describes airborne solid particles (dead or alive) that are or were derived from living organisms, including microorganisms and fragments of all varieties of living things (Matthias-Maser (1998)).

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

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

SS - sea salt.

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

$PM_{2.5}$ denotes fine particulate matter, defined as the integrated mass of aerosol with dry diameters up to 2.5 μm. In the EMEP MSC-W model $PM_{2.5}$ is calculated as $PM_{2.5}$ = SO_4^{2-} + NO_3^-(fine) + NH_4^+ + SS(fine) + $PPM_{2.5}$ + 0.27 NO_3^-(coarse).

PM_{coarse} denotes coarse particulate matter, defined as the integrated mass of aerosol with dry diameters between 2.5μm and 10μm. In the EMEP MSC-W model PM_{coarse} is calculated as PM_{coarse} = 0.33 NO_3^-(coarse)+ SS(coarse) + PPM_{coarse}.

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

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

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

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

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 new 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 polar stereographic EMEP grid to 0.1°×0.1°longitude-latitude grid in a geographic coordinate system (WGS84). The new EMEP domain shown in Figure 1.1 will cover the geographic area between 30°N-82°N latitude and 30°W-90°E longitude. This domain represents a balance between political

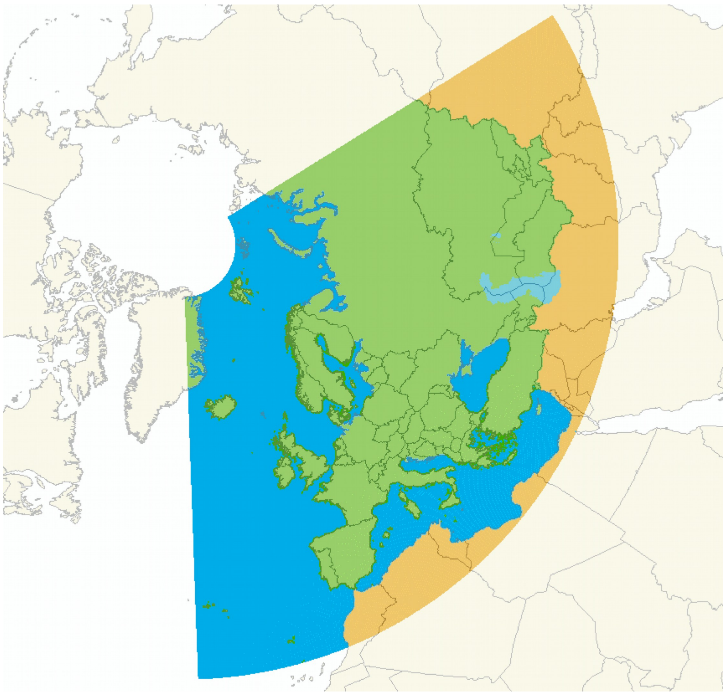

Figure 1.1: The new EMEP domain covering the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

needs, scientific needs and technical feasibility. Parties are obliged to report gridded emissions in the new 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 new longitude-latitude grid.

1.3.1 The reduced grid: EMEP0302

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

1.4 Country codes

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

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

Code	Country/Region	Code	Country/Region
AL	Albania	IS	Iceland
AM	Armenia	IT	Italy
AST	Remaining Asian areas	KG	Kyrgyzstan
AT	Austria	KZ	Kazakhstan
ATL	Remaining N.-E. Atlantic Ocean	LI	Liechtenstein
AZ	Azerbaijan	LT	Lithuania
BA	Bosnia and Herzegovina	LU	Luxembourg
BAS	Baltic Sea	LV	Latvia
BLS	Black Sea	MC	Monaco
BE	Belgium	MD	Republic of Moldova
BG	Bulgaria	ME	Montenegro
BIC	Boundary and Initial Conditions	MED	Mediterranean Sea
BY	Belarus	MK	The FYR of Macedonia
CH	Switzerland	MT	Malta
CY	Cyprus	NL	Netherlands
CZ	Czech Republic	NO	Norway
DE	Germany	NOA	North Africa
DK	Denmark	NOS	North Sea
EE	Estonia	PL	Poland
EXC	EMEP land areas	PT	Portugal
ES	Spain	RO	Romania
EU	European Union (EU28)	RS	Serbia
FI	Finland	RU	Russian Federation
FR	France	SE	Sweden
GB	United Kingdom	SI	Slovenia
GE	Georgia	SK	Slovakia
GL	Greenland	TJ	Tajikistan
GR	Greece	TM	Turkmenistan
HR	Croatia	TR	Turkey
HU	Hungary	UA	Ukraine
IE	Ireland	UZ	Uzbekistan

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

1.5 Other publications

This report is complemented by a report on EMEP MSC-W model performance for acidifying and eutrophying components, photo-oxidants and particulate matter in 2016 (Gauss et al. 2018c), made available online, at `www.emep.int`.

A list of all associated technical reports and notes by the EMEP centres in 2018 (relevant for transboundary acidification, eutrophication, ozone and particulate matter) follows at the end of this section.

Peer-reviewed publications

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 2017:

Backman, J., Schmeisser, L., Virkkula, A., Ogren, J. A., Asmi, E., Starkweather, S., Sharma, S., Eleftheriadis, K., Uttal, T., Jefferson, A., Bergin, M., Makshtas, A., Tunved, P., Fiebig, M. (2017). On Aethalometer measurement uncertainties and an instrument correction factor for the Arctic. Atmospheric Measurement Techniques, 10, 5039-5062. DOI:10.5194/amt-10-5039-2017

Baklanov, A., Brunner, D., Carmichael, G. R., Flemming, J., Freitas, S., Gauss, M., Hov, Ø., Mathur, R. R., Schlünzen, K. H., Seigneur, C., Vogel, B. Key Issues for Seamless Integrated Chemistry-Meteorology Modeling. Bulletin of The American Meteorological Society - (BAMS) , 2017. DOI: 10.1175/BAMS-D-15-00166.1

Bian, H., Chin, M., Hauglustaine, D. A., Schulz, M., Myhre, G., Bauer, S. E., Lund, M. T., Karydis, V. A., Kucsera, T. L., Pan, X., Pozzer, A., Skeie, R. B., Steenrod, S. D., Sudo, K., Tsigaridis, K., Tsimpidi, A. P., Tsyro, S. G. Investigation of global particulate nitrate from the AeroCom phase III experiment. Atmospheric Chemistry and Physics, 17 (21), p.12911-12940, 2017. DOI: 10.5194/acp-17-12911-2017

Colette, A., Andersson, C., Manders, A., Mar, K., Mircea, M., Pay, M.-T., Raffort, V., Tsyro, S. G., Cuvelier, C., Adani, M., Bessagnet, B., Bergström, R., Briganti, G., Butler, T., Cappelletti, A., Couvidat, F., D'Isidoro, M., Doumbia, T., Fagerli, H., Granier, C., Heyes, C., Klimont, Z., Ojha, N., Otero, N., Schaap, M., Sindelarova, K., Stegehuis, A. I., Roustan, Y., Vautard, R., Van Meijgaard, E., Garcia, V. M., Wind, P. A. EURODELTA-Trends, a multi-model experiment of air quality hindcast in Europe over 1990-2010. Geoscientific Model Development, 10 (9) p.3255-3276, 2017. DOI: 10.5194/gmd-10-3255-2017

Conen, F., Eckhardt, S., Gundersen, H., Stohl, A., Yttri, K. E. (2017). Rainfall drives atmospheric ice-nucleating particles in the coastal climate of southern Norway. Atmospheric Chemistry and Physics, 17, 11065-11073. DOI: 10.5194/acp-17-11065-2017

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Engardt, M., Simpson, D., Schwikowski, M., Granat, L. Deposition of sulphur and nitrogen in Europe 1900-2050. Model calculations and comparison to historical observations. Tellus. Series B, Chemical and physical meteorology, 69 (1), 2017. DOI: 10.1080/16000889.2017.1328945

Franz, M., Simpson, D., Arneth, A., Zaehle, S. Development and evaluation of an ozone deposition scheme for coupling to a terrestrial biosphere model. Biogeosciences, 14 (1), p. 45-71, 2017. DOI: 10.5194/bg-14-45-2017

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Jonson, J. E., Borken-Kleefeld, J., Simpson, D., Nyiri, A., Posch, M., Heyes, C. Impact of excess NOx emissions from diesel cars on air quality, public health and eutrophication in Europe. Environmental Research Letters, 12 (9), 2017. DOI: 10.1088/1748-9326/aa8850

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Associated EMEP reports and notes in 2018

Joint reports

Transboundary particulate matter, photo-oxidants, acidification and eutrophication components. Joint MSC-W & CCC & CEIP Report. EMEP Status Report 1/2018

EMEP MSC-W model performance for acidifying and eutrophying components, photo-oxidants and particulate matter in 2016. Supplementary material to EMEP Status Report 1/2018

CCC Technical and Data reports

Anne-Gunn Hjellbrekke. Data Report 2016 Particulate matter, carbonaceous and inorganic compounds. EMEP/CCC-Report 1/2018

Anne-Gunn Hjellbrekke and Sverre Solberg. Ozone measurements 2016. EMEP/CCC-Report 2/2018

Wenche Aas, Knut Breivik and Pernilla Bohlin Nizzetto. Heavy metals and POP measurements 2016. EMEP/CCC-Report 3/2018

Sverre Solberg, Anja Claude and Stefan Reimann. VOC measurements 2016. EMEP/CCC-Report 4/2018

CEIP Technical and Data reports

Mareckova, K., Pinterits, M., Ullrich, B., Burgstaller, J., Wankmüller, R., Tista, M. Inventory review. Review of emission data reported under the LRTAP Convention and NEC Directive. Stage 1 and 2 review. Status of gridded and LPS data. Joint CEIP/EEA Report. EMEP/CEIP Technical Report 1/2018

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Part I

Status of air pollution

CHAPTER 2

Status of transboundary air pollution in 2016

Svetlana Tsyro, Wenche Aas, Sverre Solberg, Anna Benedictow, Hilde Fagerli and Maximilian Posch

This chapter describes the status of transboundary air pollution in 2016. A short summary of the meteorological conditions for 2016 is presented and the EMEP network of measurements in 2016 is briefly described. Thereafter, the status of air pollution and exceedances in 2016 is discussed.

2.1 Meteorological conditions in 2016

Air pollution is significantly influenced by both emissions and weather conditions. Temperature and precipitation are important factors and therefore a short summary describing the situation in 2016 as reported by the meteorological institutes in European and EECCA countries is given first.

The meteorological data to drive the EMEP MSC-W air quality model have been generated by the Integrated Forecast System model (IFS) 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 as 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 (Cycle 40r1 is the model version used for the year 2016 model run). Next section show temperature and precipitation in 2016 compared to the 2000-2015 average based on the same ECMWF-IFS model hindcast setup.

2.1.1 Temperature and precipitation in 2016

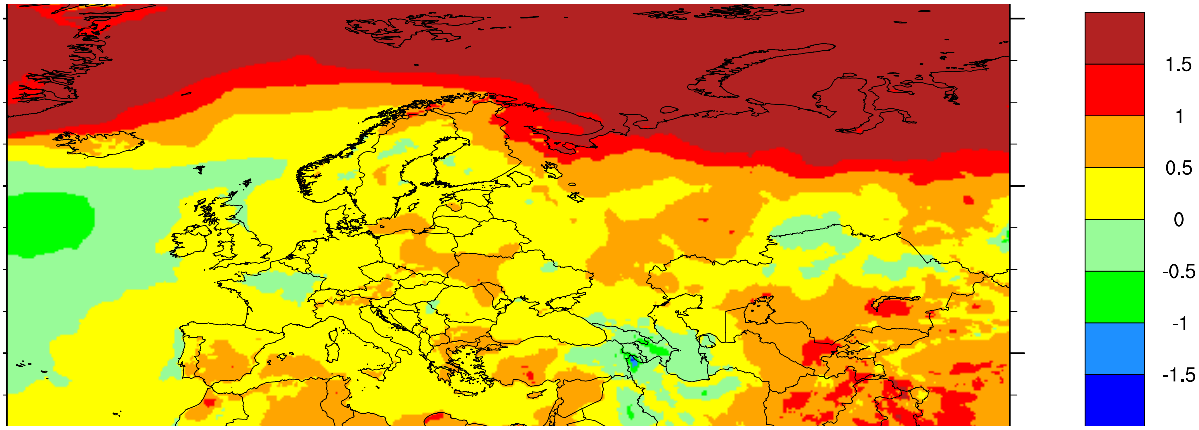
Globally the 2016 mean temperature was reported as the highest on record by the World Meteorological Organisation (WMO 2017). It was strongly influenced by the El Niño event, especially in the first half of the year. For the cold period (Jan-Mar and Oct-Dec) in 2016, NOAA reported extremely high temperatures due to advection of warm air into the Arctic from mid-latitudes explained by the Arctic and Mid-latitudes Connections (Overland et al. 2016). Year 2016 was the third warmest in Europe and the warmest on record in the European part of Russia (Blunden and Arndt 2017). For Europe, including the European part of Russia, 2016 was characterised by very high late summer and early autumn temperatures, but also exceptional high temperatures in the beginning of the year.

WMO reported that global precipitation was influenced by the transition from El Niño to La Niña halfway through the year 2016, with strong seasonal contrasts still resulting in annual totals close to average (WMO 2017). The global high temperatures were combined with extensive drought, and for any given month during 2016, 12% or more of the global land cover experienced severe drought conditions, the longest such recorded stretch, reported by NOAA (Blunden and Arndt 2017). However, the winter was very wet in western Europe, followed by a wet spring in central Europe. The summer was wet in eastern Europe and the autumn was wet in southern Europe, but very dry elsewhere. In Europe the year ended with extremely dry conditions everywhere in December.

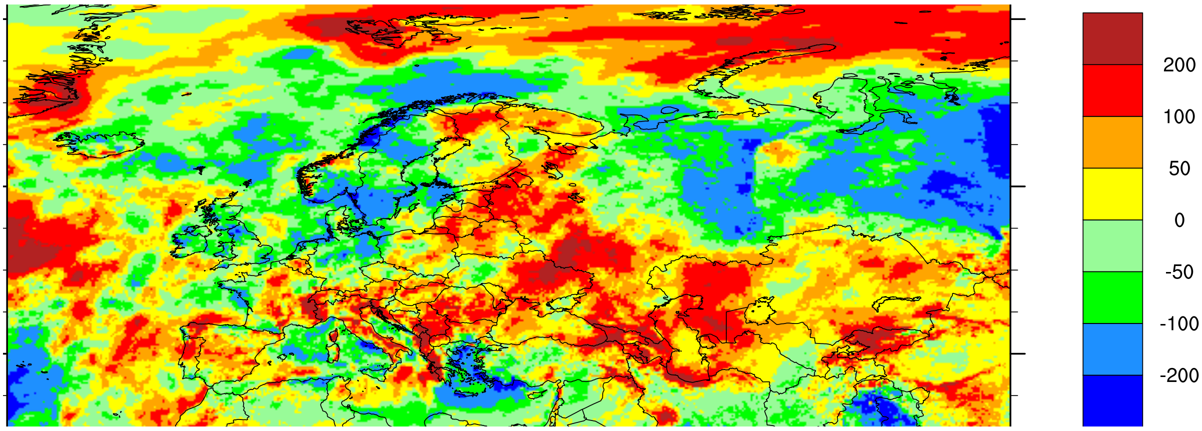
A well established Icelandic low and Azores high brought warm Atlantic air into large parts of Europe in the beginning of the year. France reported its warmest winter since measurements started, and Switzerland and the United Kingdom reported their second and third warmest winter on record. Caused by a lack of inflowing cold Arctic air and a weak winter blocking high over Russia, Belarus reported its warmest winter since 1891 and the second warmest in western Russia since 1936. Due to a warm winter, snow was replaced by above normal rain in central Europe, central and southern Russia, the Baltic countries, Azerbaijan and west Kazakhstan. The 2015/16 winter was the wettest recorded in Ireland and 2nd wettest since 1910 in the United Kingdom. Spain and France experienced record high temperatures in January, but Scandinavia had for a shorter period lower temperatures. The Mediterranean region was influenced by a positive temperature anomaly extending from Russia and the highest temperatures in 50 years were registered in Greece, and Austria had its second warmest February since 1858. In January the northwestern Iberian Peninsula received abundant rainfalls and France received more than normal precipitation. February was the wettest on record for Austria and 2nd wettest in Finland, while southern Europe had dry conditions.

In spring the warm Atlantic air entered into a more southerly path reaching the eastern Mediterranean. March was still warm in Belarus, western Kazakhstan, Germany and the Nordic countries, but the United Kingdom, France and Spain were colder than their climatological average. Spain and France remained colder than usual throughout the season. In April temperatures were still low in the United Kingdom and Ireland, but higher than normal in Iceland. A sudden late spring frost hit France, Germany, Switzerland and Poland in late April after higher than normal temperatures earlier in that month. May was the third warmest in Denmark since 1874, and in Finland since 1908, and also warmer than normal in Russia and Latvia. The recurring inflow of humid Atlantic air masses in spring, supported by low pressure systems over Scandinavia and the Mediterranean Sea caused strong rainfalls in France, Belgium, the Netherlands and the western Iberian Peninsula. France received more rain in spring than in the last 50 years with May being the wettest of the spring months. The Nordic countries and central Europe experienced a deficit in spring rainfall. During spring the cyclonic activity moved to the Black Sea and brought above normal precipitation to southern Italy, Malta, Greece, Bulgaria, northern Turkey and western Kazakhstan.

A high pressure system developed west of the Iberian peninsula in the summer as the Azores high strengthened during July and August. Subtropical air was transported to northeast



(a) Δtemperature at 2m (2016-climavg)

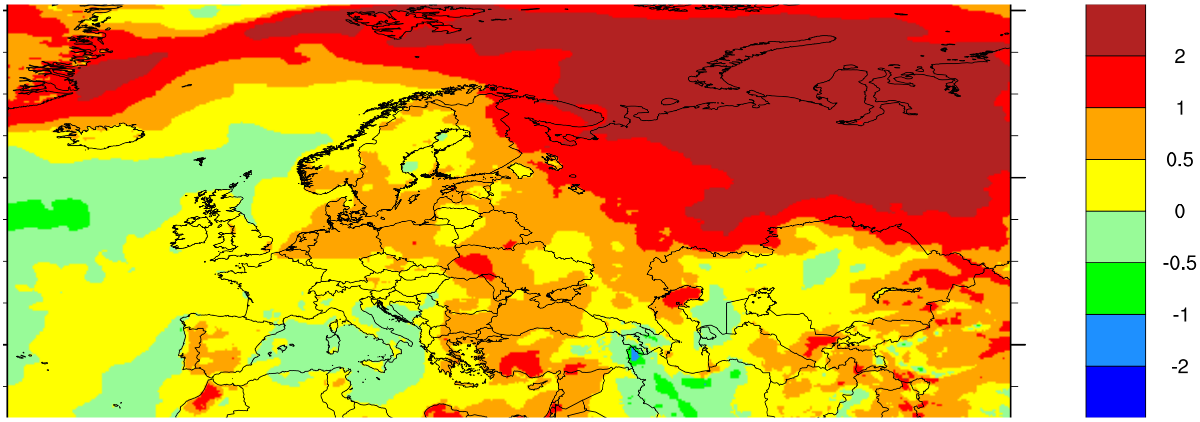


(b) Δprecipitation (2016-climavg)

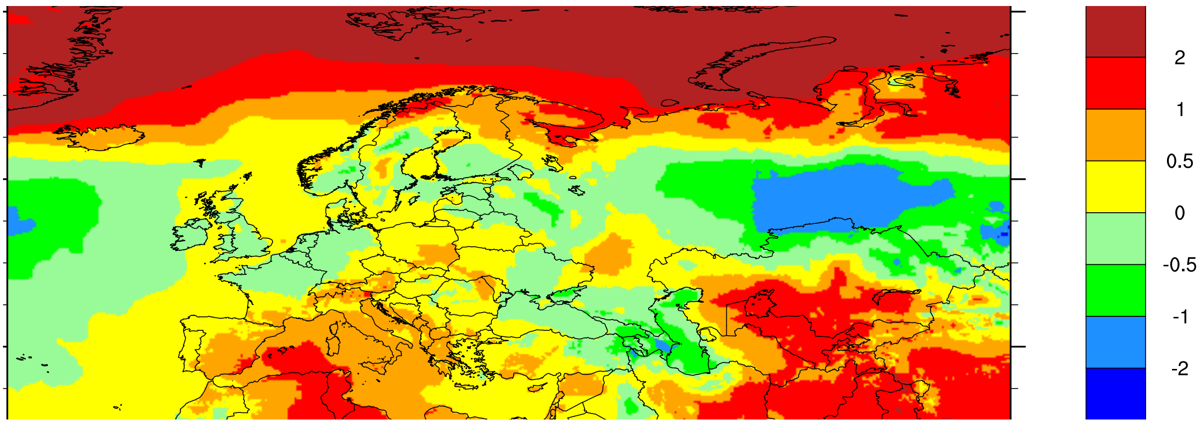
Figure 2.1: Meteorological conditions in 2016 compared to the 2000-2015 average (climavg) for: (a) Annual mean temperature at 2m [K] and (b) Annual precipitation [mm]. The meteorological data have been calculated with the ECMWF-IFS model.

Europe. Northwestern and southern Russia, northern Scandinavia and the Baltic countries had above average precipitation amounts, and the moist flows also reached Germany and Switzerland. Belgium registered its highest June precipitation since 1981. Summer rainfall in Finland was the 3rd highest ever recorded, and northern Switzerland registered its highest amount of precipitation in the first half of the year since 1864. Flooding was reported in northern France, Germany, Ireland, the United Kingdom and northern Switzerland, whereas southern France and the Iberian Peninsula suffered drought conditions. Portugal reported one of the five driest summers and the 2nd warmest summer since 1931. It was the 3rd warmest summer in Spain and the warmest on record in Russia. June was the 2nd warmest in the United Kingdom since 1910 and Cyprus was warmer than normal. The overall summer temperatures were close to normal in Scandinavia, central and eastern Europe. In the beginning of June a heatwave occurred in Denmark, and in July short heatwaves took place in the United Kingdom and in the European part of Russia. In June and July convective activity in the Mediterranean brought above normal rainfalls and floods to southern Italy, Macedonia, Greece and eastern Turkey. Temperatures were extremely high in western Kazakhstan, Armenia, Georgia, Azerbaijan, Turkey and Bulgaria in August. At the same time August was the warmest on record for Russia. An anticyclone over central Europe towards the end of August caused a heatwave in

Germany and higher than usual temperatures in France, Switzerland and the United Kingdom, whereas Hungary and Austria were colder than normal. A high pressure system over central Europe in July caused the driest August on record in France, whereas Germany, Ukraine, Bulgaria and western Turkey had precipitation deficits. Western Kazakhstan received large amounts of rain in June and July, but almost no rain in August.



(a) Δtemperature at 2m (AprSep 2016-climavg)



(b) Δtemperature at 2m (OctMar 2016-climavg)

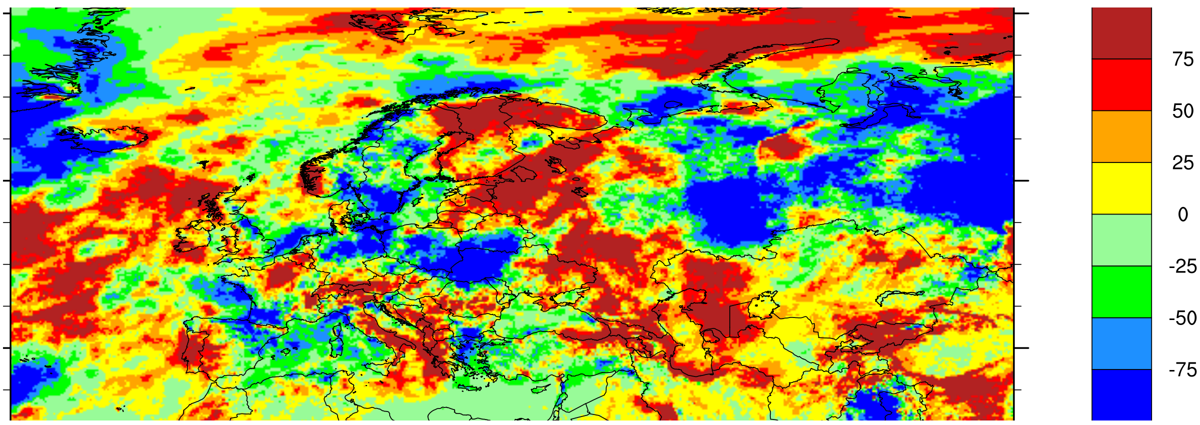
Figure 2.2: Meteorological conditions in 2016 compared to the 2000-2015 average (climavg) for: (a) Summer (April-September) temperature [K], (b) Winter (January-March and October-December) temperature [K]. The meteorological data have been calculated with the ECMWF-IFS model.

The beginning of the autumn was still affected by high pressure systems over Europe, the heat prevailed into the autumn in western and central Europe and dry conditions dominated most of Europe, northern Russia and Turkey. Spain and Portugal were experiencing heat-waves in the beginning of September. September was the warmest recorded in Denmark since 1874 and in Norway since 1900, the 2nd warmest in the United Kingdom since 1910, the 3rd warmest in France since 1900 and 4th warmest in Switzerland since 1864. Also Germany, Slovakia and the Czech Republic were unusually warm in the beginning of the autumn, but the conditions were cooler in October and November over most of Europe and Russia. Finland registered its driest October in 55 years, Norway its 4th driest. Conditions were also extremely dry in the United Kingdom and France. In the Balkans, eastern Europe and southern Italy the conditions were very wet, especially in October and November. In the middle of November storms formed over the Atlantic, bringing wet and windy weather to Europe with severe rainfalls in the United Kingdom, Spain and northern Italy, and heavy snowfall in Sweden.

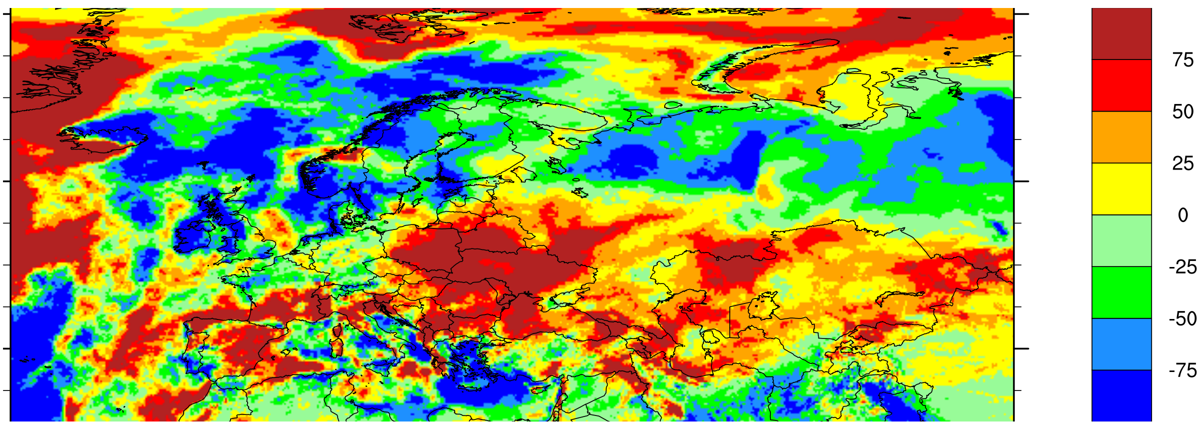
December was dry in Europe and Russia caused by an omega blocking pattern centred over central Europe. France and Austria registered their driest December on record, and drier than normal conditions were reported in Germany, Romania, Hungary, northern Spain, Italy, the Balkan countries, Greece and western Turkey. At the same time, heavy rainfall occurred in southern Spain, Crete, central Turkey, northwestern Russia and western Kazakhstan. The year ended with lower than average temperatures in countries around the Caspian Sea (West Kazakhstan, Armenia, Georgia and Azerbaijan) and central Europe, but warmer in northern and southern Europe influenced by the central Europe high. Denmark was warmer in December (6th warmest since 1874) than in November.

2.1.2 2016 compared to the 2000-2015 average

Calculations of meteorological data have been made with the ECMWF-IFS model with virtually the same model setup for the years 2000-2016, including also 2017. Here the 2000-2015 model calculated climatology is compared to 2016.



(a) Δprecipitation (AprSep 2015-climavg)



(b) Δprecipitation (OctMar 2015-climavg)

Figure 2.3: Meteorological conditions in 2016 compared to the 2000-2015 average (climavg) for: (a) Summer (April-September) precipitation [mm], (b) Winter (January-March and October-December) precipitation [mm]. The meteorological data have been calculated with the ECMWF-IFS model.

Compared to the 2000-2015 average, higher temperatures in 2016 are clearly seen in Figure 2.1 (a) especially over the Arctic region, but also over northern, eastern and southern Europe. The 2016 summer months (April-September) compared to the 2000-2015 average in Figure 2.2 (a) show higher temperatures in northern, southwestern and eastern Europe and lower temperatures in southern and western central Europe. Figure 2.2 (b) highlights that the 2016 cold period (January-March and October-December) differs from the 2000-2015 average, as it was strongly influenced by the exceptionally warm weather over the Arctic region, but also the relatively cold spring in western Europe had large effects on the annual temperature.

Figure 2.1 (b) shows that southern, eastern and northeastern Europe received larger amounts of precipitation than the 2000-2015 average, whereas central and western Europe received far less. Compared to the 2000-2015 average, the 2016 summer months (April-September) (Figure 2.3 (a)) in northeastern, eastern and south central Europe and the European part of Russia were wet, while northwestern and central Europe were very dry during the same period. Figure 2.3 (b) show that for the 2016 winter months (January-March and October-December) precipitation was higher in southeastern and southwestern Europe and lower in northern Europe and the northern European part of Russia compared to the 2000-2015 average.

2.2 Measurement network 2016

In 2016, a total of 32 Parties reported measurement data of inorganic components, particulate matter and/or ozone to EMEP from altogether 161 sites, which are the relevant components for level 1 sites (UNECE 2009). All data are available from the EBAS database (`http://ebas.nilu.no/`) and are also reported separately in technical reports by EMEP/CCC (Hjellbrekke 2018, Hjellbrekke and Solberg 2018). 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 2016.

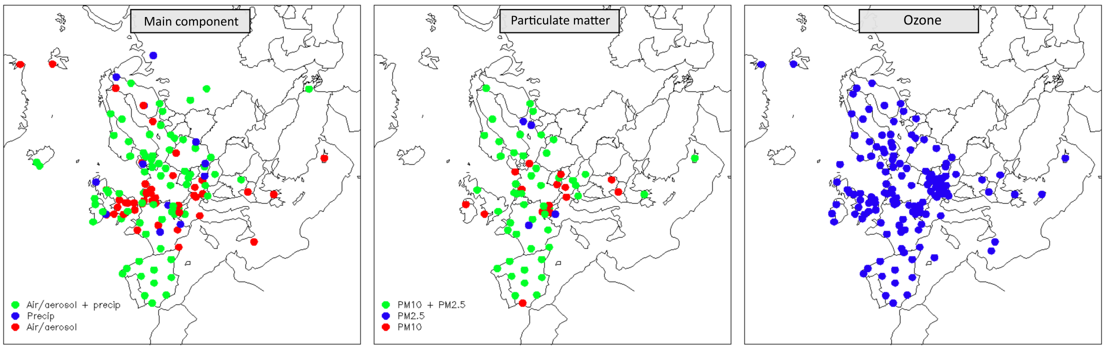


Figure 2.4: EMEP measurement network for main components (left), particulate matter (middle) and ozone (right) in 2016

130 sites reported measurements of inorganic ions in precipitation and/or main components in air. However, not all of these sites were co-located as illustrated in Figure 2.4. There were 73 sites with measurements in both air and precipitation. The network of ozone measurements in EMEP included 139 sites. There were 70 sites measuring either PM_{10} or $PM_{2.5}$ mass. 50 of these sites measured both size fractions, as recommended in the EMEP Monitoring strategy (UNECE 2009).

The stations measuring EMEP level 2 variables are shown in Figure 9.2. Compliance with the monitoring obligations, and the development of the programme during the last decade is discussed in Chapter 9.1.

2.3 Model setup for 2016 model runs

The EMEP MSC-W model version rv4.17a has been used for the 2016 model runs. The horizontal resolution is $0.1° \times 0.1°$, with 20 vertical layers (the lowest with a height of approximately 50 meters) as discussed in chapter 8.

Meteorology, emissions, boundary conditions and forest fires for 2016 have been used as input (for a description of these input data see Simpson et al. 2012). DMS emissions are created 'on-the-fly', e.g. they are meteorology dependent (see Chapter 9 in EMEP Status Report 1/2016). For international shipping emissions data from FMI (based on AIS data) for 2015 have been applied as 2016 data were not yet available (see Chapter 3).

2.4 Air pollution in 2016

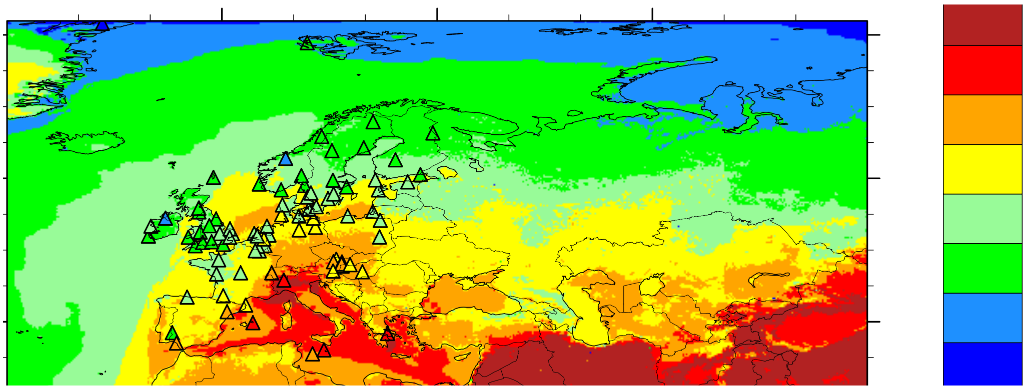
2.4.1 Ozone

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 baseline ozone levels, each of which may have seasonal and diurnal systematic variations. Episodes with elevated levels of ozone are observed during the summer half year when certain meteorological situations (dry, sunny, cyclonic stable weather) favour the formation of ozone over the European continent.

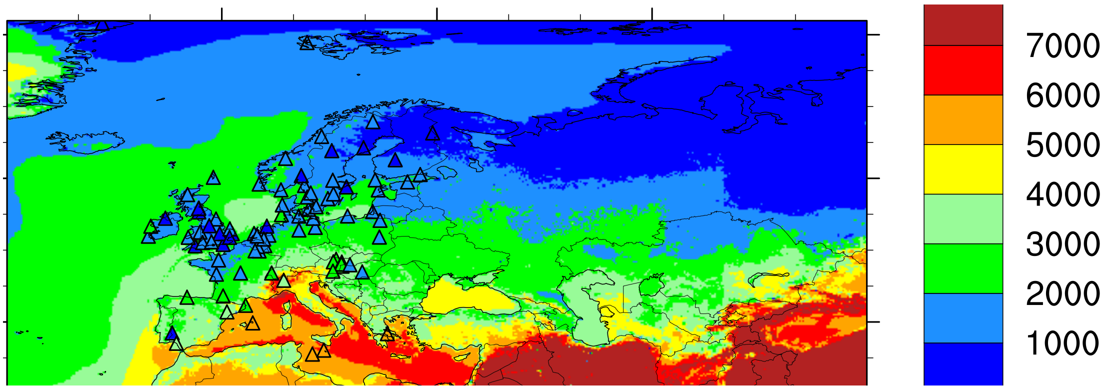
Figure 2.5 shows various modelled ozone metrics for 2016 with the corresponding metrics based on the EMEP measurement sites plotted on top of the maps. Figure 2.6 shows similar plots with data from Airbase measurement sites. Note that most of the EMEP sites are also classified as Airbase sites and thus included in Figure 2.6 as well. Only stations located below 500 m above see level (asl) were used in this comparison to avoid uncertainties related to the extraction of model data in regions with complex topography. The maps show a) the mean of the daily max concentration for the period April-September, b) SOMO35, c) 6-months AOT40 for forests (April-September) using the hours between 08 and 20 and d) POD_1 (only for Figure 2.5). POD_1 could not be calculated from the ozone monitoring data directly and are thus not given in Figure 2.6.

It can be noted that POD_1 values are substantially lower than those presented with model version rv4.15 in Status Report 1/2017, despite AOT40 levels being rather similar. The major reason for this difference is the change in radiation scheme, and discovery of a bug in the older scheme. As explained in Chapter 8, these changes seem to cause substantial impacts on POD_1 for forests but not on O_3 or even POD_3 for crops.

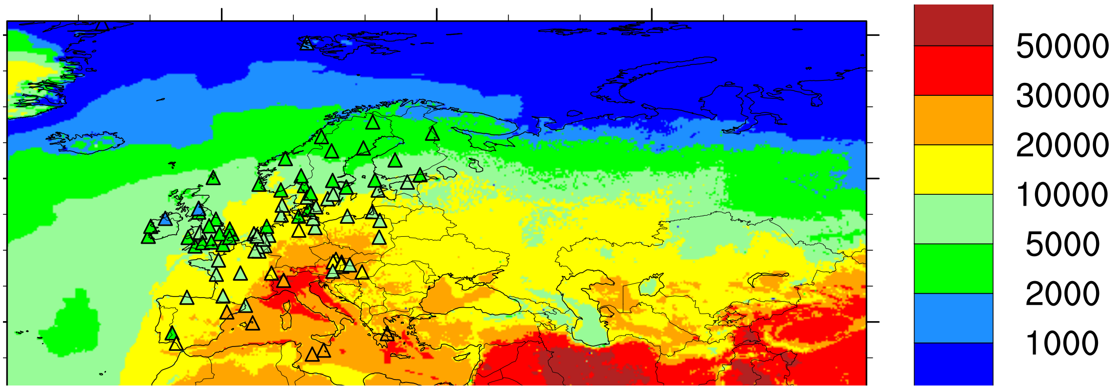
The mean daily max O_3, SOMO35 and AOT40 all show a distinct gradient with levels increasing from north to south, a well established feature for ozone in general reflecting the dependency of ozone on the photochemical conditions. Ozone formation is promoted by solar radiation and high temperatures. The highest levels of these ozone metrics are predicted over the Mediterranean Sea and in the southeast corner of the model grid.



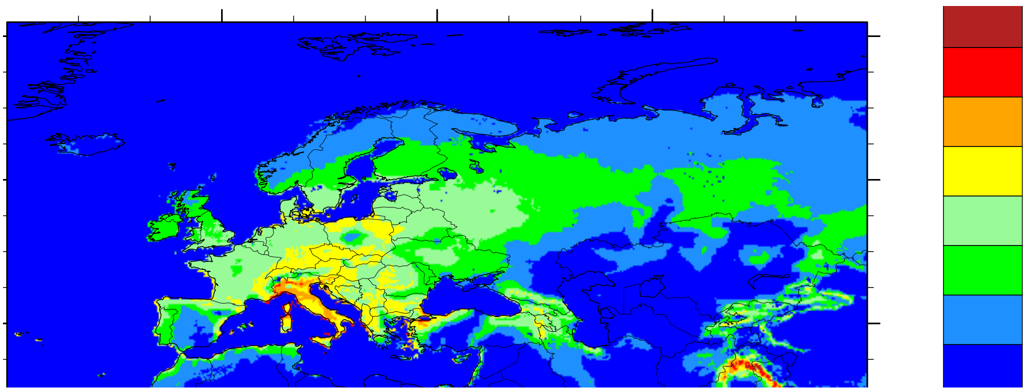
(a) Max. O_3



(b) SOMO35

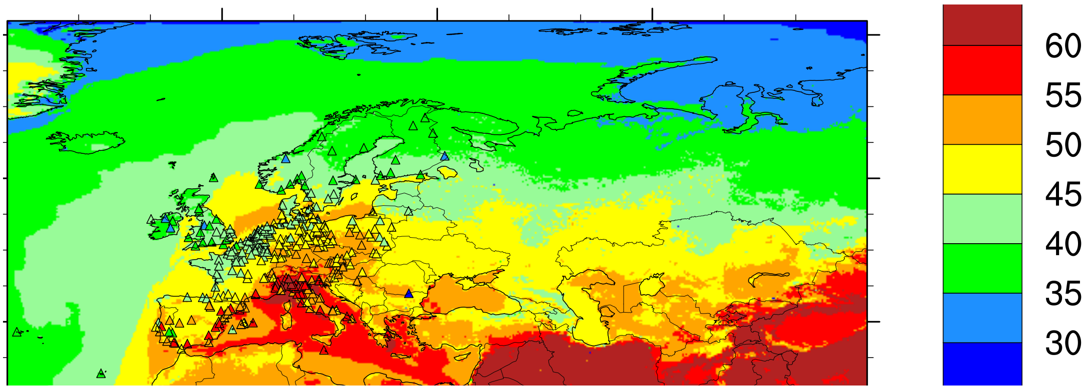


(c) AOT40

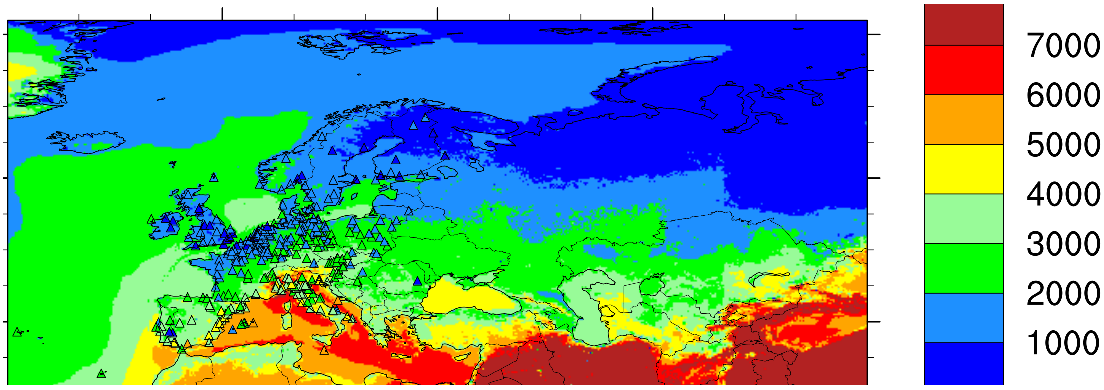


(d) POD1

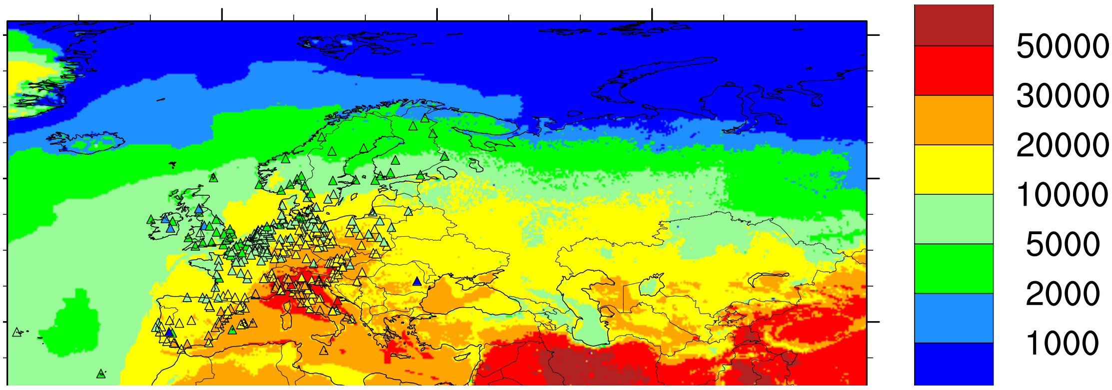
Figure 2.5: Model results and observations at EMEP stations (triangles) for mean of daily maximum ozone concentrations (ppb, April-September), SOMO35 [ppd.days], AOT40 [ppb.hours] for forests and POD_1 for forests [mmol m^{-2}] in 2016. Only data from measurement sites below 500 meter above sea level are shown.



(a) Max. O_3



(b) SOMO35



(c) AOT40

Figure 2.6: Model results and observations at Airbase stations (triangles) for mean of daily maximum ozone concentrations (ppb, April-September), SOMO35 [ppd.days], AOT40 [ppb.hours] for forests in 2016. Only data from measurement sites below 500 meter above sea level are shown.

The measurement network are limited to the continental western part of the model domain with no valid data in Belarus, Ukraine, Turkey or the area further east.

For the region covered by the monitoring sites, the pattern with increased levels to the south with maximum levels near the Mediterranean is seen in the measurement data as well as the model. The geographical pattern in the measured values is fairly well reflected by the model results for all these three metrics. In particular, the modelled mean daily max for the summer half year agrees very well with the measured values except for an underestimation in a few regions, mainly in the Mediterranean. Particularly high levels are predicted by the model in the southeast, but due to the lack of monitoring sites here these levels could not be validated.

A good agreement between modelled and observed levels of SOMO35 is also seen from Figure 2.5 and Figure 2.6. With respect to AOT40, the results shown in Figure 2.5 and Figure 2.6 indicate that the model tends to overestimate this metric in many regions compared to what is observed. It should be noted that the O_3 metrics such as AOT40 are very sensitive to the calculation of vertical O_3 gradients between the middle of the surface layer and the 3m height used for comparison with measurements (Tuovinen et al. 2007) and thus more difficult to compare with measurement data than e.g. the mean daily maximum. Indeed, the formulation we use (Simpson et al. 2012) is probably better suited to a first model layer of 90m height (since we equate the centre of this, ca. 45m, with a ‘blending-height’) than to a first level of 50m height (as used throughout this report), and probably needs reformulating for the new resolution. For this reason, it seems premature to compare the modelled AOT40 values with critical levels; this work will continue once the characteristics of the new resolution have been studied and accounted for in more detail.

The modelled POD_1 pattern differs from the other metrics reflecting the influence of additional parameters such as plant physiology, soil moisture, etc. and is a metric more indicative of the direct impact of ozone on vegetation than e.g. AOT40. The POD_1 field could however not be validated by the EMEP ozone measurement data alone.

SOMO35 is an indicator for health impact assessment recommended by WHO, and the results given in Figure 2.5 and Figure 2.6 indicates that the health risk associated with surface ozone increased from northern to southern Europe in 2016. SOMO35 is a health risk indicator without any specific threshold or limit value. AOT40 and POD_1 are indicators for effects on vegetation. UN-ECE’s limit values for forests is 5000 ppb hours, and the measurements given in Figure 2.5 and Figure 2.6 indicate that this level was exceeded in most of the European continent in 2016, whereas it was not exceeded in Scandinavia or the British Isles. As mentioned, the model predicts larger areas with exceedances than the measurements. For POD_1 the limit value depends on the species and Mills et al (2011) give a value of 4 for birch and beech and 8 for Norway spruce. The results in Figure 2.5 indicate that both these limit values were exceeded in most of Europe. The modelled levels of POD_1 can however not be validated by observations.

A more detailed comparison between model and measurements for ozone for the year 2016 can be found in Gauss et al. (2018a).

Ozone episodes in 2016

The CAMS interim annual assessment report for 2016 (Tarrason et al. 2016) presented various episodes of O_3 and PM and thus we don’t repeat these in the present report. In general, there were fewer episodes and lower O_3 levels in 2016 compared to 2015. Based on the EMEP observational data, we identified episodes of elevated ozone during 23-24 June, 18-21 July, 23-27 August and 11-14 September. In the following we present plots for the latter of these episodes.

11 - 14 September

Episodes of high ozone levels in September are rare, partly because the baseline level of O_3 is low at this time of the year. The period 11-14 September 2016 was thus an unusual event

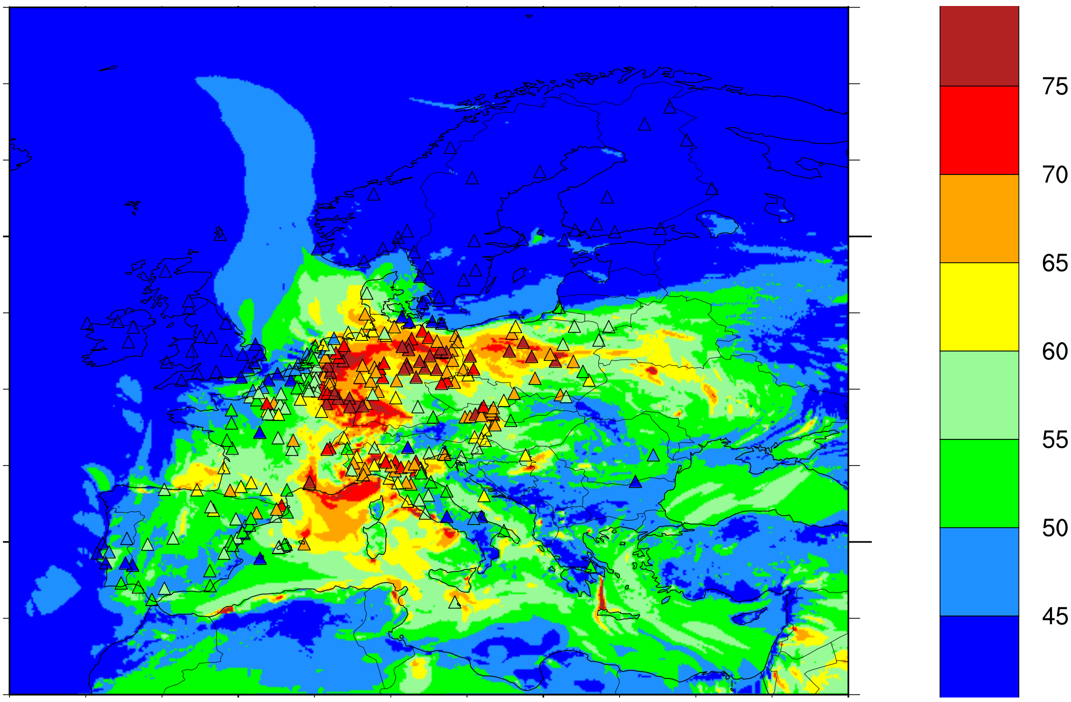


Figure 2.7: Modelled and measured daily max ozone (ppb) 12 September 2016. Data from EMEP and Airbase sites below 500 m asl are shown.

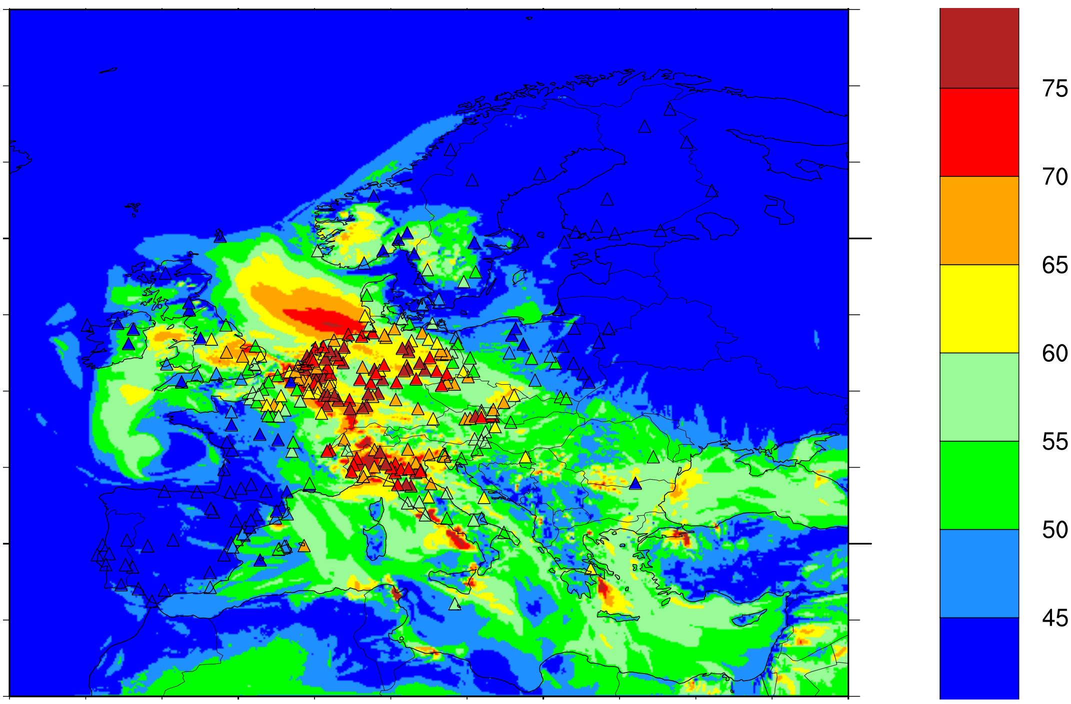


Figure 2.8: Modelled and measured daily max ozone (ppb) 14 September 2016. Data from EMEP and Airbase sites below 500 m asl are shown.

with several monitoring sites having their annual peak ozone level during these days including levels above the EU information threshold of 180 μg m^{-3}. By the start of the period a cold front was stretching from Spain over Ireland and into the North Sea, and a weak low was formed on the front just west of France. The frontal zone moved slowly to the east leading to the advection of very warm air masses from the south into central Europe. Record-high temperatures (well above 30°C) were recorded, as well as record-high levels of ozone the following days. The model results as well as the measurement data show the extent of the region with high ozone levels on 12 and 14 September (Figure 2.7 and Figure 2.8). These results indicate a very good agreement between the modelled and measured levels, both with respect to the location of the ozone plume and the concentration levels.

2.4.2 Particulate matter

Maps of annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2016, calculated by the EMEP MSC-W model are presented in Figure 2.9. The figures also show annual mean PM_{10} and $PM_{2.5}$ concentrations observed at EMEP monitoring network, represented by colour triangles overlaying the modelled concentration fields.

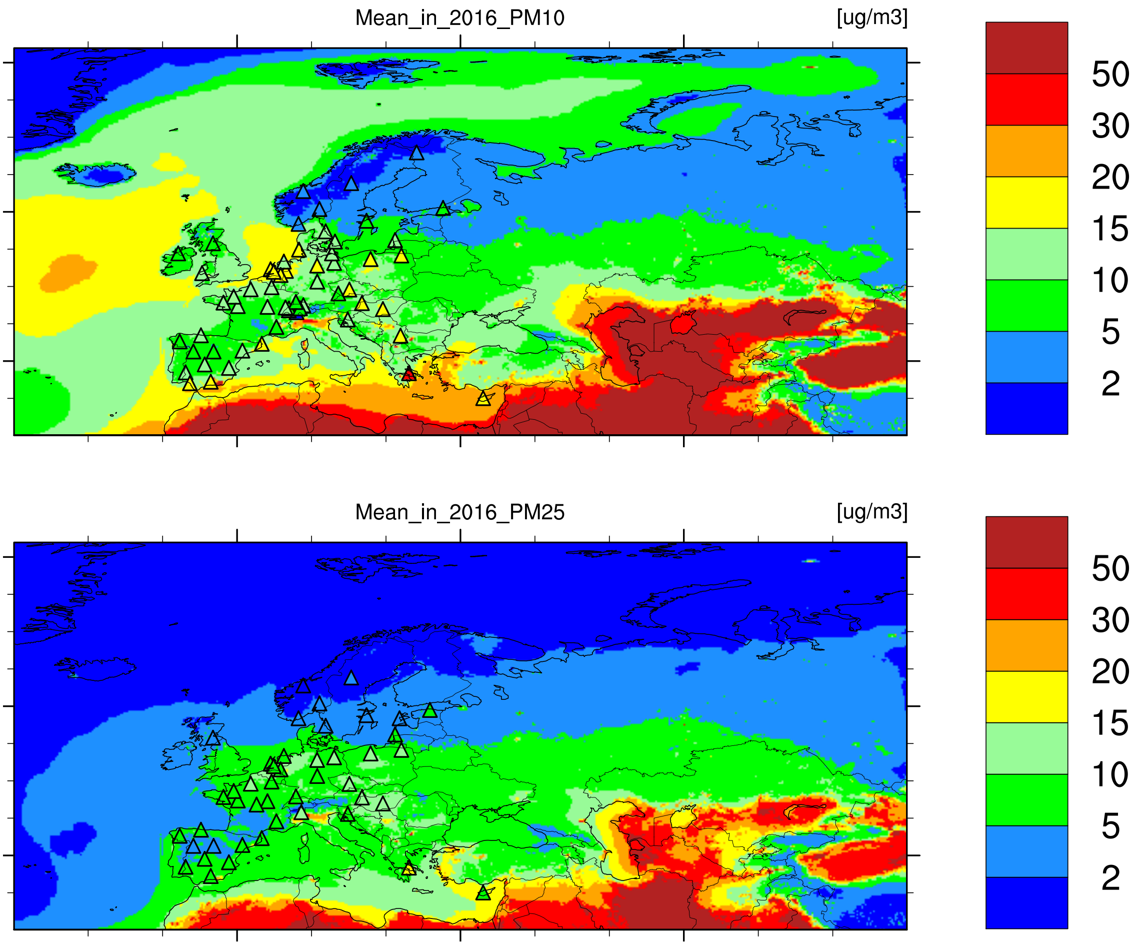


Figure 2.9: Annual mean concentrations of PM_{10} and $PM_{2.5}$ in 2016: calculated with the EMEP MSC-W model (colour contours) and observed at EMEP monitoring network (colour triangles). *Note: Observations include hourly, daily and weekly data.*

The modelling results and the observations show that the annual mean levels of PM_{10} and $PM_{2.5}$ in general decrease over the land from north to south. The concentration levels are below 2-5 μg m^{-3} in northern Europe, increasing to 5-15 μg m^{-3} in the mid-latitude and farther south. Figure 2.9 also reveals that elevated PM_{10} and $PM_{2.5}$ levels of 15-20 μg m^{-3} occurred in some areas (the Benelux countries and parts of Germany, Poland and East-European countries); and in most years a persistent hot-spot, with calculated $PM_{2.5}$ and PM_{10} exceeding 20-30 μg m^{-3}, is seen in the Po Valley. In the regions east from the Caspian Sea (parts of Kazakhstan, Uzbekistan, Turkmenistan) and in southern Mediterranean the model calculates annual mean PM levels in far excess of 50 μg m^{-3}. These high PM concentrations are due to windblown dust from the arid soils, though the accurateness of the calculated values cannot presently be verified due to the lack of observations in these regions.

There is quite a good agreement between the modelled and observed distribution of mean PM_{10} and $PM_{2.5}$, with annual mean correlation coefficients of 0.78 and 0.71 respectively, as documented in Tsyro et al. (2018). Overall, the model underestimates the observed annual mean PM_{10} and $PM_{2.5}$ by 22% and 10%, respectively. A comprehensive model evaluation is provided in Tsyro et al. 2018.

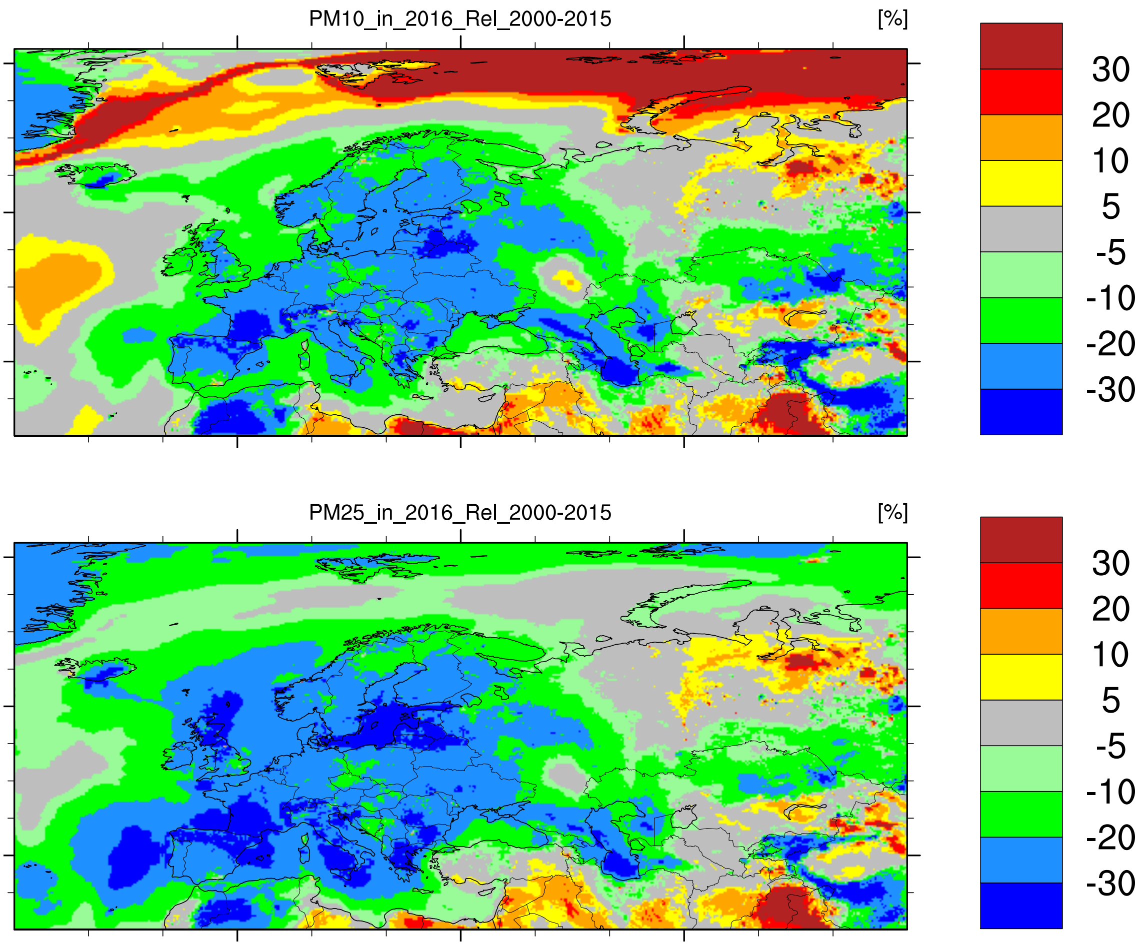


Figure 2.10: Relative anomaly of mean PM_{10} and $PM_{2.5}$ in 2016 from the mean in 2000-2015.

Figure 2.10 presents the relative anomaly of PM_{10} and $PM_{2.5}$ concentration levels in 2016 compared to the corresponding averages over the 2000-2015 period. Practically over all of the European part of the EMEP grid, the annual mean concentrations of PM_{10} and $PM_{2.5}$ were 10-30% lower compared to the mean PM levels in the 2000s (and more than 30% lower in the south-west of France, in the Pyrenees, parts of Italy, Greece, and also Scotland and the Baltic region). On the other hand, PM_{10} and $PM_{2.5}$ were in 2016 5-30% higher in the very eastern and southern EMEP areas. This is consistent with the emission changes during that period, namely emission decrease in the western part, while increase in the eastern part of the EMEP domain (Chapter 3). This distribution of high/low PM anomalies loosely resembles the pattern of the reciprocal of the precipitation anomaly in 2016, shown in Section 2.1 (Figure 2.1b), suggesting that the enhanced wet removal of aerosols from the air contributed to the lower PM pollution in many parts of Europe in 2016.

Exceedances of EU limit values and WHO Air Quality Guidelines in 2016

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

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

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

The EU limit values for protection of human health from particulate matter pollution and the WHO AQG for PM should apply to concentrations for so-called zones, or agglomerations, in rural and urban areas, which are representative for exposure of the general population. Prior to this report, operational EMEP MSC-W model calculations were performed on 50×50km^2 grid and provided regional background PM concentrations. PM_{10} and $PM_{2.5}$ concentrations calculated on $0.1° \times 0.1°$ grid are expected to offer a better representation of PM levels occurring in rural and to some extend in urban 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 2016 (Figure 2.9 (a)). The model calculates annual mean PM_{10} above the WHO recommended AQG of 20 μg m^{-3} in the Po Valley and the western parts of Turkey. The highest observed annual mean PM_{10} concentrations were seen in Greece (GR0001) with 34 μg m^{-3} , in Cyprus (CY0002) with 20 μg m^{-3} , and in the Po Valley (IT0004) with 18 μg m^{-3} .

Further, the observations and model calculations show that in 2016, $PM_{2.5}$ pollution did not exceed the EU limit value of 25 μg m^{-3} for annual mean level (except in the Po Valley according to the model). However, there were observed cases of exceedance of the WHO AQG value of 10 μg m^{-3} by observed annual mean $PM_{2.5}$ at ten sites, with the highest values in Greece (GR0001), the Po Valley (IT0004) and Hungary (HU0002) with concentrations above 14 μg m^{-3} , while some French, German, Austrian, Polish and Czech sites observed annual mean concentrations above 10 μg m^{-3} . This pattern is quite well reproduced by the model.

The maps in Figure 2.11 show the number of days with exceedances of 50 μg m^{-3} for PM_{10} and 25 μg m^{-3} for $PM_{2.5}$ in 2016: model calculated as colour contours and observed as triangles.

Compared to the previous year of 2015, PM limit value exceedances were registered at fewer sites and the number of exceedance days were in general lower in 2016. Out of 63 sites with PM_{10} measurements, exceedance days were observed at 34. No violations of the PM_{10}

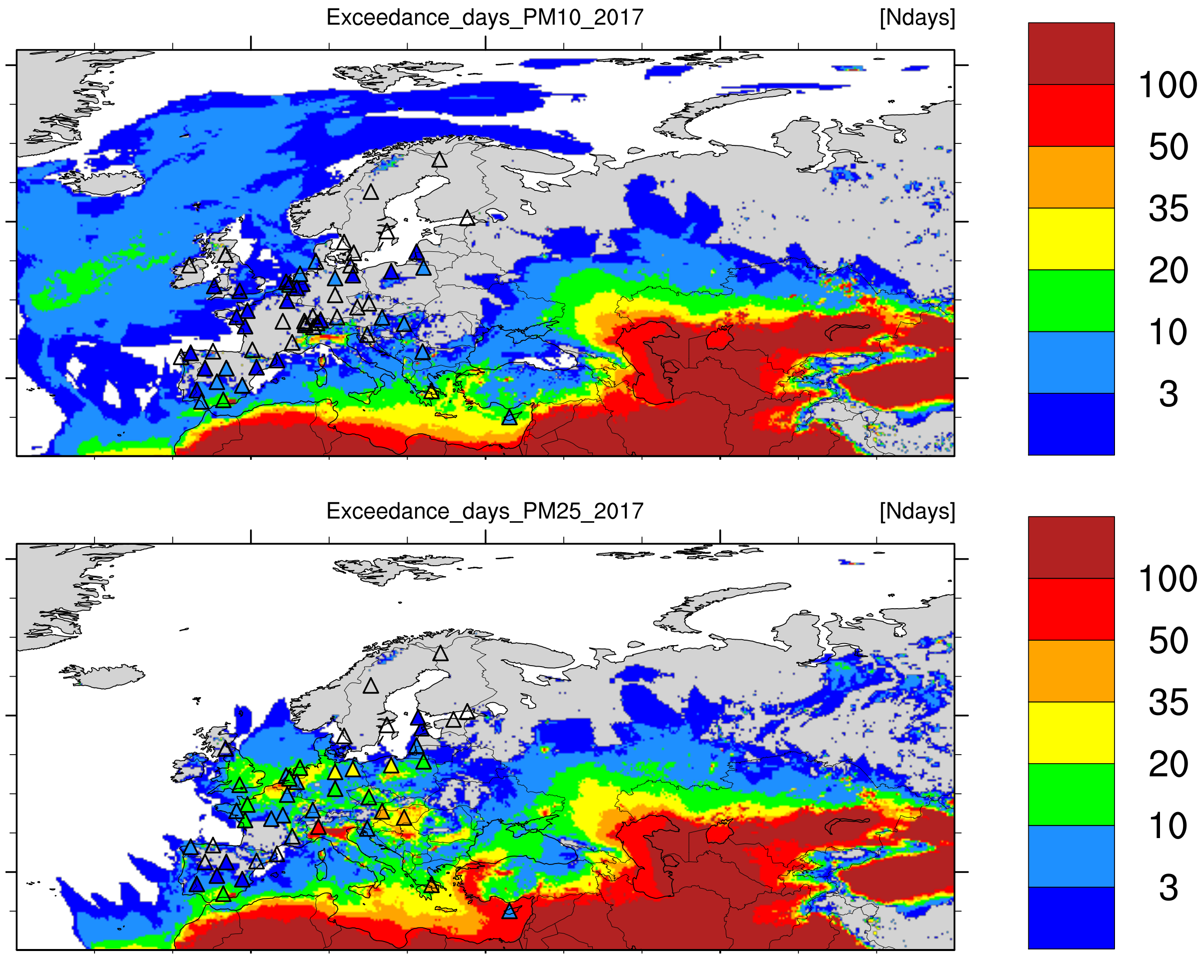


Figure 2.11: Calculated (with 0.1 °resolution) and observed (triangles) number of days with exceedances in 2016: PM_{10} exceeding 50 μg m^{-3} (upper) and $PM_{2.5}$ exceeding 25 μg m^{-3} (lower). *Note: EU Directive requires no more than 35 days with exceedances for PM_{10}, whereas WHO recommends no more than 3 days with exceedances for PM_{10} and $PM_{2.5}$ per a calendar year.*

EU limit value (more than 35 exceedance days) were observed, still 15 sites had more than 3 exceedance days (according to WHO AQG recommendations). The highest numbers of days with observed exceedances of PM_{10} were 32 at GR0001 and 11 at ES0007.

$PM_{2.5}$ concentrations exceeded the WHO AQG value at 33 out of 46 stations in 2016. Among those, at 27 sites the number of exceedance days were more than 3 (the recommended limit according to WHO AQG). The highest number of exceedance days are observed at IT0004 (55), GR0001 (44), HU0002 (41), AT0002 (38) and PL0009 (34).

The model calculated exceedance days in 2016 are in generally good agreement with the observations (especially for PM_{10}), though it shows a tendency towards overestimation of the frequency of exceedances in the Mediterranean region, i.e. at the sites severely affected by Saharan dust (CY0002 and GR0001). At those sites, and to a less degree at some Spanish and Dutch sites, the model overestimates the number of exceedance days, more pronounced for $PM_{2.5}$.

PM pollution episodes in 2016

Several PM pollution episodes were recorded in different parts of Europe in 2016. Among the major PM episodes identified in the CAMS Interim Annual Assessment Report on European air quality in for 2016 (Tarrason et al. 2017), is a PM_{10} episode 1-9 January (affected mainly Central Europe, with minor impacts on Western and Northern Europe) and two $PM_{2.5}$ episodes: 9-20 March and 4-9 December (covering Central, Western and Northern Europe).

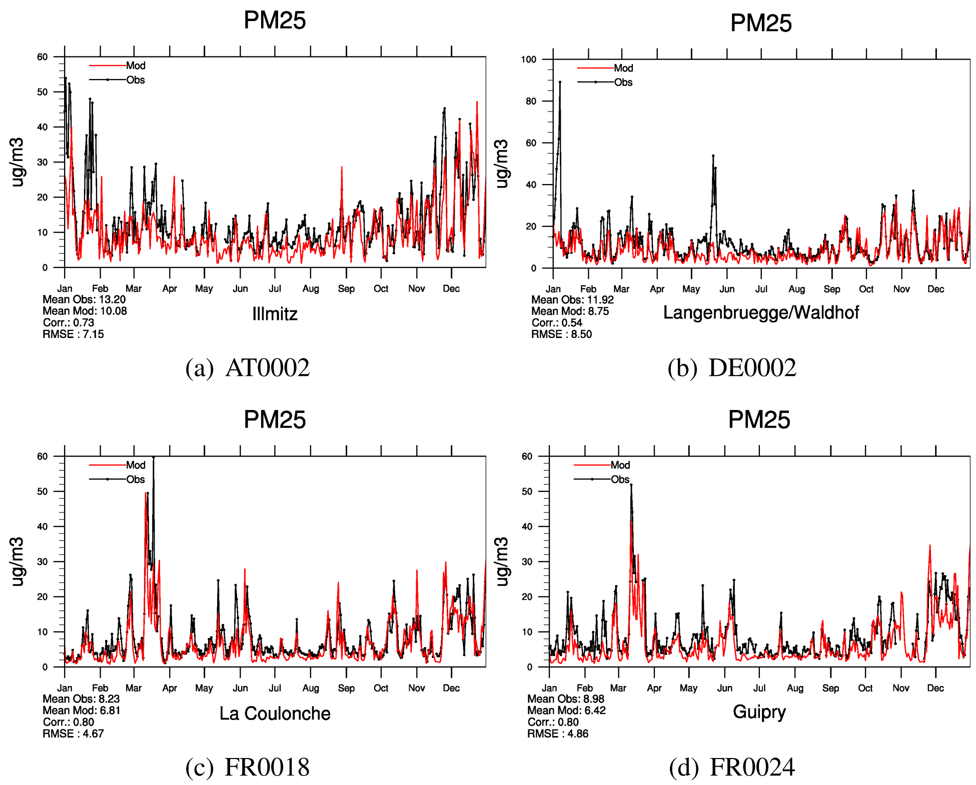


Figure 2.12: Modelled and observed timeseries of $PM_{2.5}$.

Winter episodes of particulate pollution in Central Europe were already discussed in a number of earlier EMEP Status Reports (e.g. 4/2013, 1/2014, 1/2016 and 1/2017). The meteorological situations favouring them are typically characterised by low temperatures and stagnant air conditions, and in addition enhanced use of wood burning for residential heating in cold weather leading to considerable increase of local PM emissions.

The PM episodes in 2016 described in Tarrason et al. (2017) are confirmed both by the EMEP MSC-W model and by observations (some examples are given in Figures 2.12 and 2.13). In addition to the 1-9 January episode, mainly seen in Central Europe (e.g. at AT0002 and DE0002 in Figure 2.12), our results also reveal an occurrence of elevated PM levels in the second part of January at a number of sites in a large part of Europe (AT0002 in Figure 2.12; PL0005, SI0008 and IT0004 in Figure 2.13). We find that the March episode is mostly prominent at French stations (examples for FR0018 and FR0024 are shown in Figure 2.12), but not so pronounced elsewhere. The reported 4-9 December episode in Tarrason et al. (2017) is embedded in a longer period with elevated PM_{10} and $PM_{2.5}$ concentrations, lasting from the end of November through almost end-December, as seen in Figures 2.12 and 2.13.

To facilitate a better understanding of the origin of the PM pollution, details on PM chemistry are also included in Figure 2.13 for three sites with available data (IT0004, SI0008 and

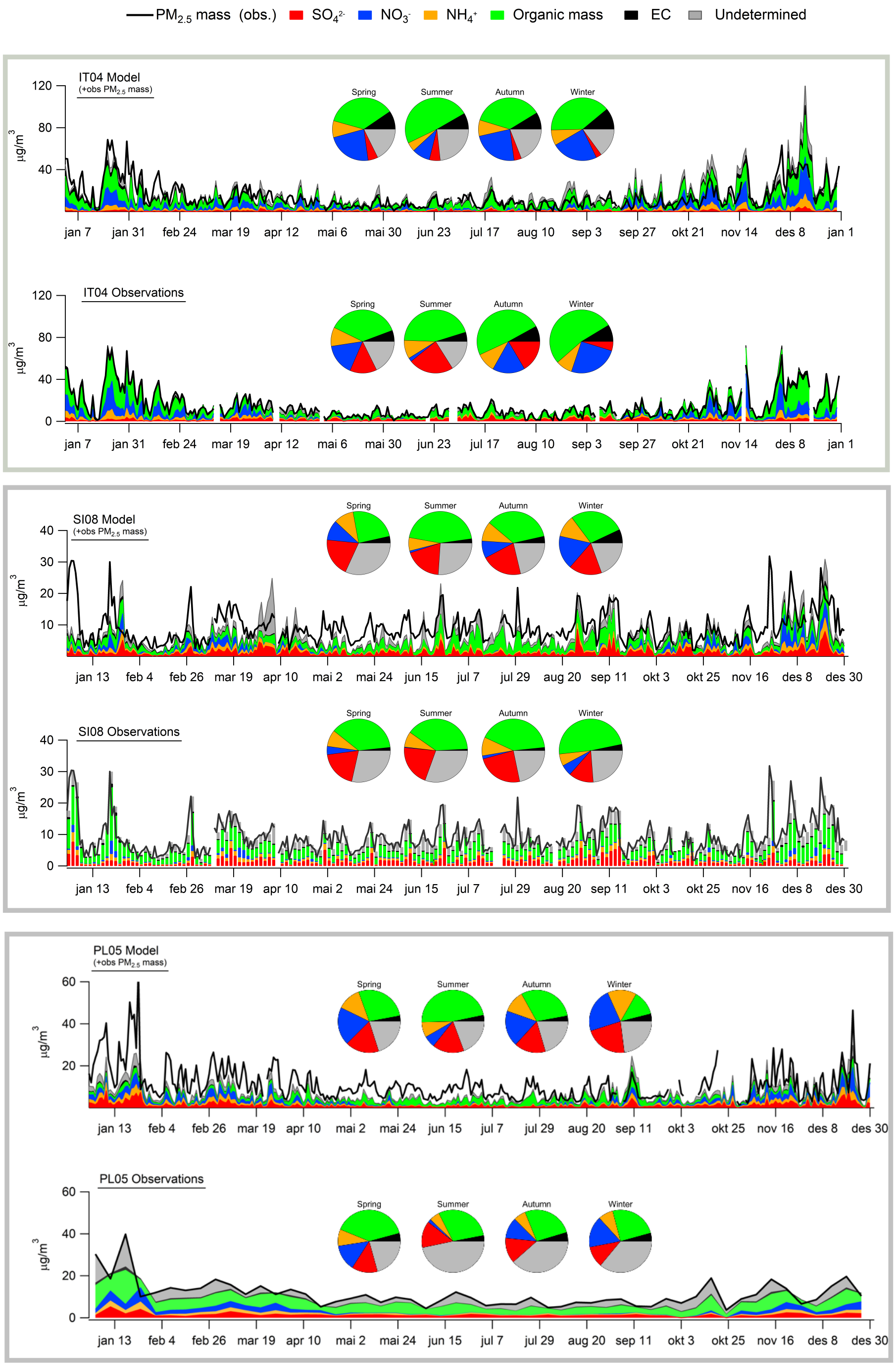


Figure 2.13: Chemical composition of $PM_{2.5}$ in 2016 observed and modelled at IT0004, SI0008 and PL0005 in 2016. Organic mass in the observations is calculated multiplying the observed OC with 1.5.

PL0005). Due to the limited observational data available we look at $PM_{2.5}$ only, since few sites have measurements of chemical composition in the coarse fraction. Further, several sites with chemical composition measurements in $PM_{2.5}$ have reduced sampling frequency, i.e. with one 24 hour sample per week, making it difficult to interpret.

The three sites, which all have highest concentrations both in model and observations during the winter months, show different chemical composition of the $PM_{2.5}$ mass. I.e at IT0004, the highest contribution is organic mass, while in Diabla Gora (PL0005) secondary inorganic aerosols (SIA) are most important. Iskrba (SI0008) is somewhat in-between. But also at the Slovenian site, organic mass is the most important contribution, though more important in observations than in the model. At Ispra the sulphate concentrations are relatively low compared to the other compounds and sites. These differences in chemical composition reflect the differences in PM sources. When comparing the winter season with summer, the EC and nitrate contributions are generally higher for all sites in winter, both for model and observations. For organic mass and sulphate, there are not that clear variations. However, even if organic mass can be equally high in summer as in winter, the source origins are quite different. In winter, contributions from residential heating is important, while in summer natural biological primary and secondary sources are more relevant (Bergström et al. 2012).

2.4.3 Deposition of sulphur and nitrogen

Modelled total depositions of sulphur and oxidised and reduced nitrogen are presented in Figure 2.14. For sulphur, many hot spot areas are found in the south-eastern part of the domain. In addition, volcanic emissions of SO_2 leads to high depositions in and around Sicily. Oxidised nitrogen depositions are highest in northern Germany, the Netherlands, Belgium and northern Italy. These countries also have high depositions of reduced nitrogen, as do parts of the United Kingdom, France, Belgium in western Europe, and Turkey, Georgia, Armenia, Azerbaijan, Kyrgyzstan, Uzbekistan and Tajikistan in the east.

In Figure 2.15 wet depositions of nitrogen and sulphur compounds are compared to measurements at EMEP sites for 2016. Overall, the bias between model and measurements are around -2 to -10%, but higher for individual sites. A more detailed comparison between model and measurements for the year 2016 can be found in Gauss et al. (2018b).

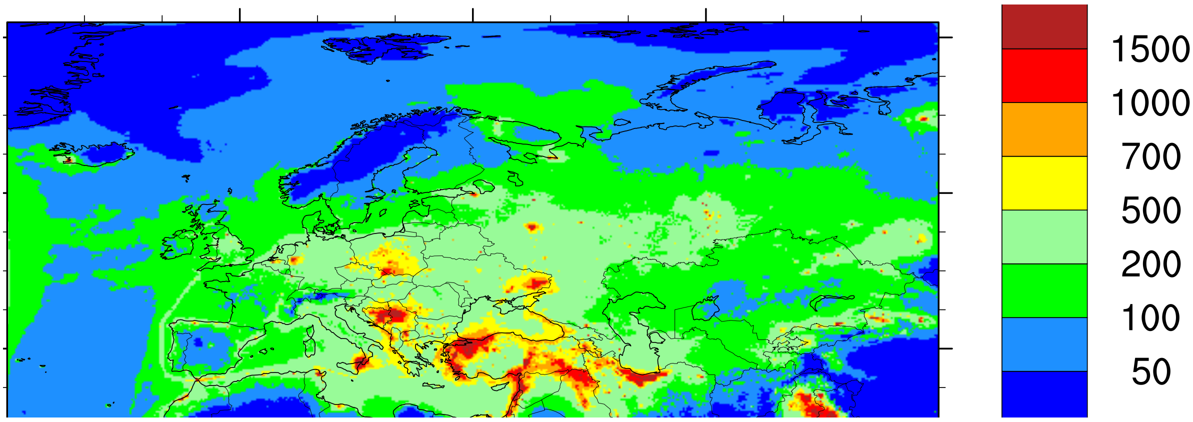
Exceedances of critical loads of acidification and eutrophication

The exceedances of European critical loads (CLs) are computed for the total nitrogen (N) and sulphur (S) depositions modelled on the $0.1° \times 0.1°$longitude-latitude grid (approx. 11×5.5 km^2 at 60°N).

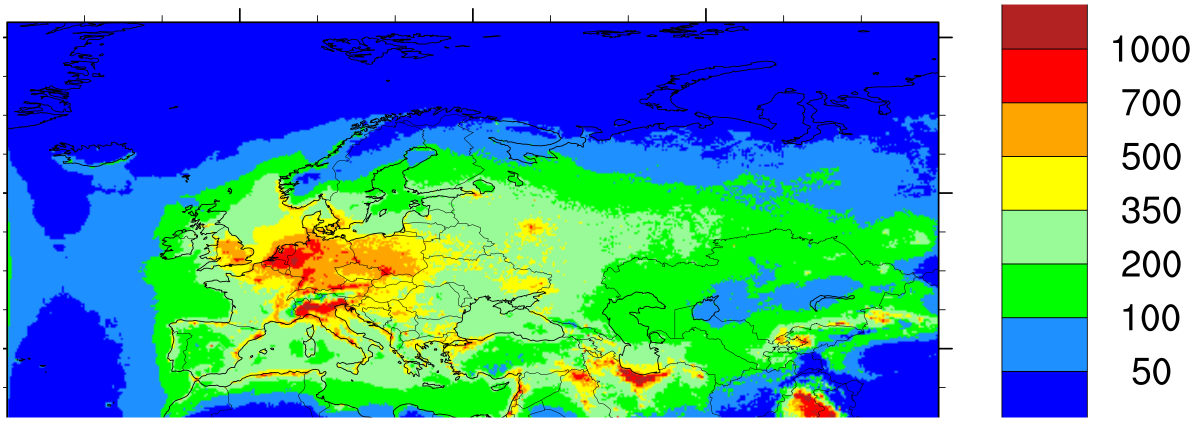
Exceedances are calculated for the European critical loads data documented in Hettelingh et al. (2017), whereas a description of the methodologies can be found in De Vries et al. (2015). The critical loads data for eutrophication by N (CLeutN) and for acidification by N and S are also used by the CIAM (located at IIASA) in integrated assessment modelling. The exceedance in a grid cell is the so-called 'average accumulated exceedance' (AAE), computed as the area-weighted mean of the exceedances of the critical loads of all ecosystems in that grid cell. The units for critical loads and their exceedances are equivalents (eq; same as moles of charge, mol_c) per area and time, making S and N depositions comparable on their impacts (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 $0.5° \times 0.25°$longitude-latitude grid, and maps thereof are shown in Figure 2.16 and 2.17.

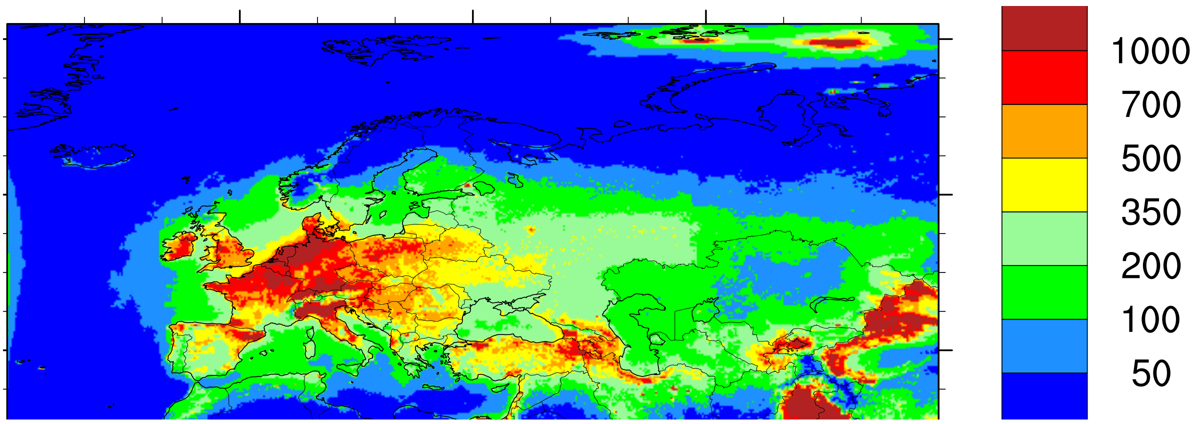
As it can be seen from the maps, critical loads for eutrophication are exceeded in virtually all countries in 2016, in about 61.7% of the ecosystem area (73% in the EU28) and the European average exceedance is about 217 eq $ha^{-1}yr^{-1}$ (289 eq $ha^{-1}yr^{-1}$ in the EU28). The



(a) oxidized S



(b) oxidized N

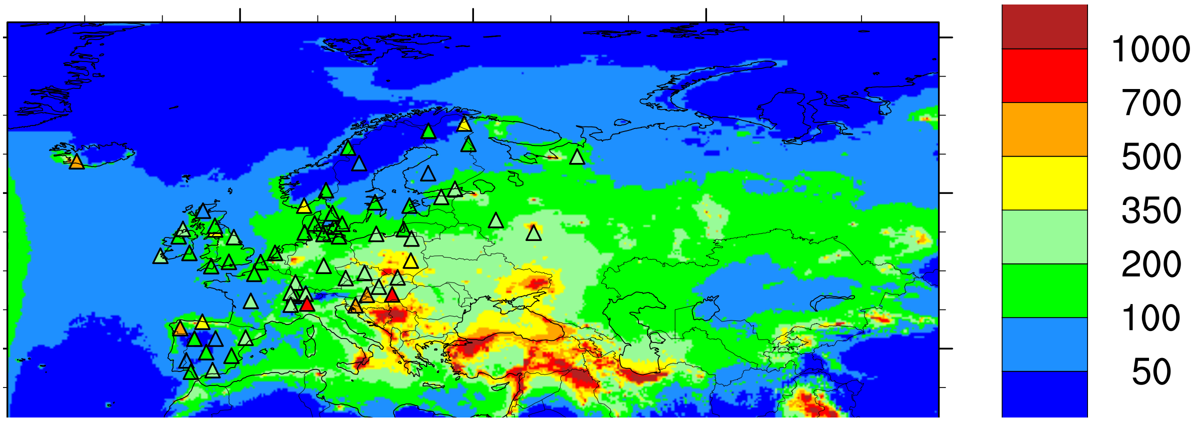


(c) Reduced N

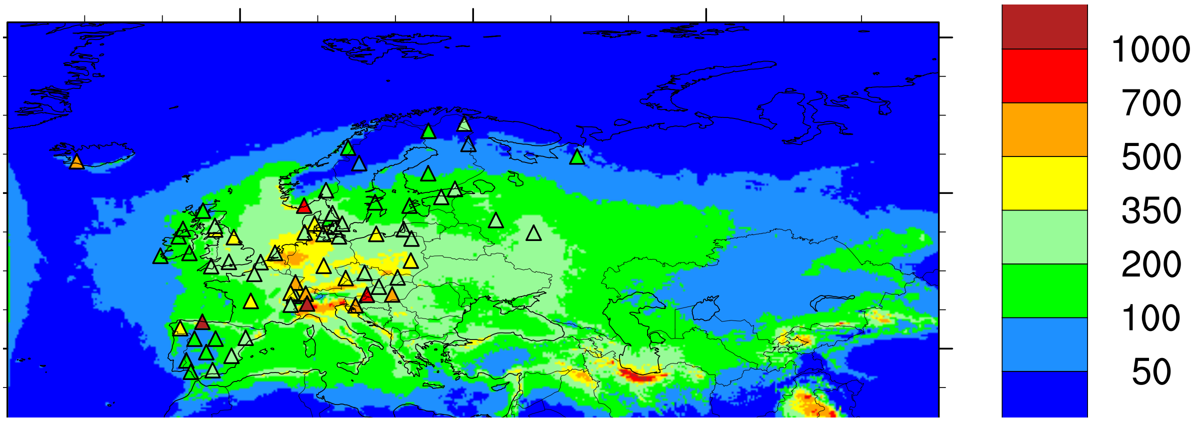
Figure 2.14: Deposition of sulphur and nitrogen [mgS(N)m^{-2}] in 2016.

highest exceedances are found in the Po Valley in Italy, the Dutch-German-Danish border areas and in north-eastern Spain.

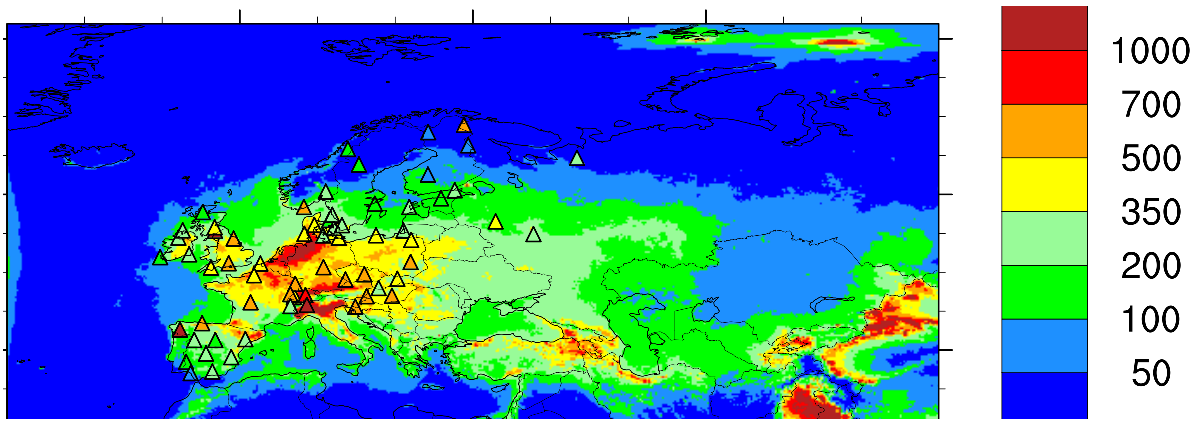
In contrast, critical loads of acidity are exceeded in a much smaller area. Hot spots of exceedances can be found in the Netherlands and its border areas to Germany and Belgium, and some smaller maxima in southern Germany and the Czech Republic, whereas most of Europe is not exceeded (grey areas). In Europe as a whole, acidity exceedances in 2016 occur



(a) oxidized S



(b) oxidized N

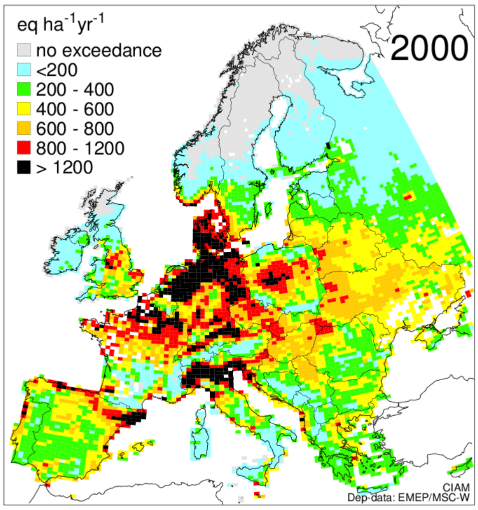


(c) Reduced N

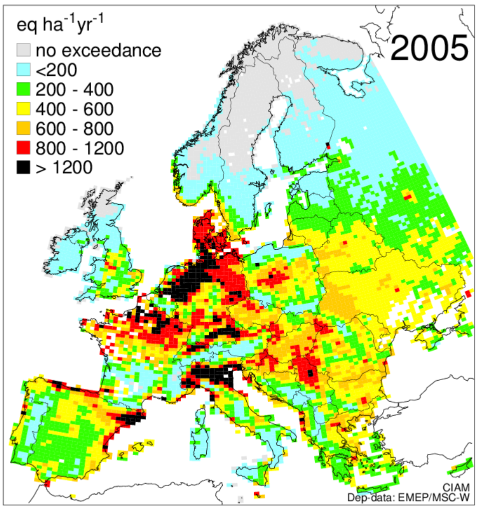
Figure 2.15: Wet deposition of sulphur and nitrogen [mgS(N)m^{-2}] in 2016. EMEP observations on top (triangles).

in about 5.3% of the ecosystem area (6.6% in the EU28), and the European average AAE is about 20 eq ha^{-1}yr^{-1} (28 eq ha^{-1}yr^{-1} in the EU28).

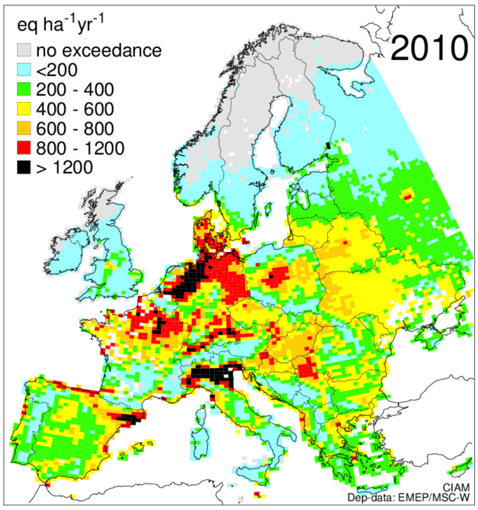
The depositions of total N and S on the $0.1° \times 0.1°$grid have not only been modelled for the year 2016, but also for the years 2000-2015. This enables us to compute consistent time series of exceedances for the period 2000-2016, and in Figure 2.18 such times series are shown for



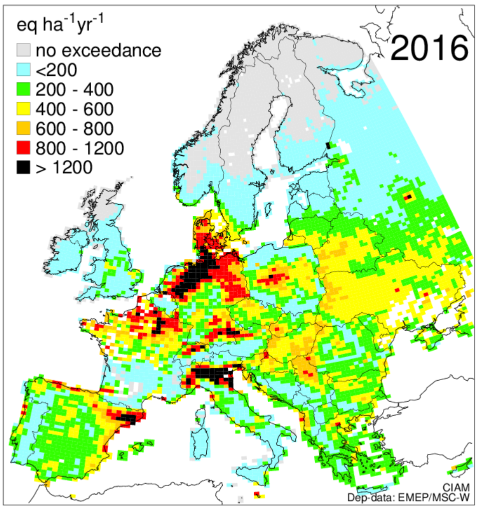
(a) Eutrophication, 2000



(b) Eutrophication, 2005



(c) Eutrophication, 2010



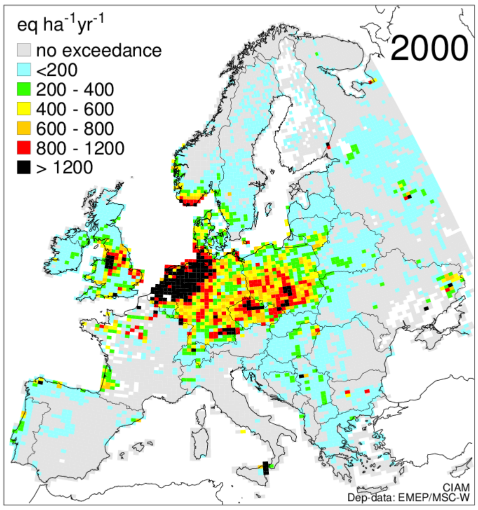
(d) Eutrophication, 2016

Figure 2.16: Exceedances of critical loads for eutrophication computed with the 2000, 2005, 2010 and 2016 N and S depositions simulated with the EMEP MSC-W model on a $0.1\times0.1°$longitude-latitude grid and mapped on a $0.5°\times0.25°$grid.

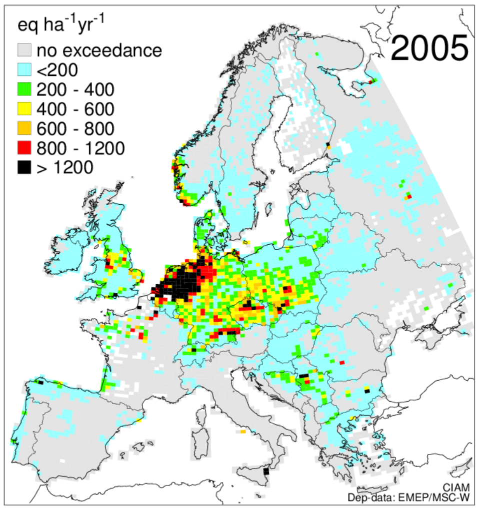
the whole of Europe.

Figure 2.18 shows that the general trend in Europe from the year 2000 onward is a decrease in average exceedances and in exceeded ecosystem area, both for eutrophication and acidification. While the decreases themselves are roughly comparable for both effects, acidification is a much smaller concern than eutrophication, as is also evident from the maps in Figure 2.16 and 2.17.

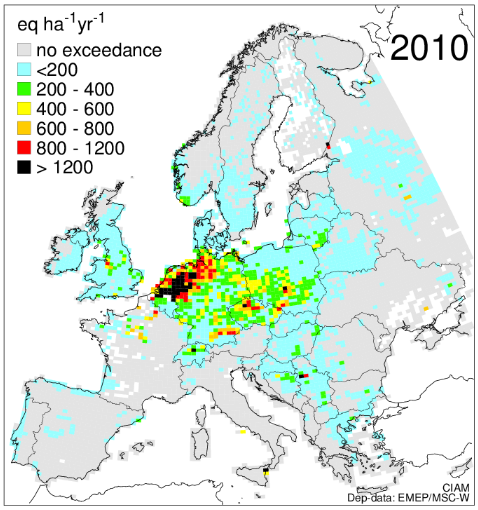
The decreases in exceedances (areas and amounts) are not always monotone, with some years showing an increase compared to the previous one, reflecting spatial and temporal meteorological fluctuations (as critical loads are identical for all years). There is a rather strong correlation between exceedances and exceeded area, which is not surprising for larger areas.



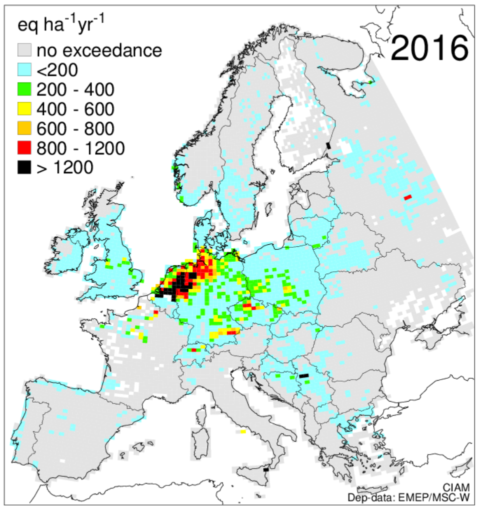
(a) Acidification, 2000



(b) Acidification, 2005



(c) Acidification, 2010



(d) Acidification, 2016

Figure 2.17: Exceedances of critical loads for acidification computed with the 2000, 2005, 2010 and 2016 N and S depositions simulated with the EMEP MSC-W model on a 0.1×0.1°longitude-latitude grid and mapped on a 0.5°×0.25°grid.

Nevertheless, this is not always the case: during the first 7-8 years the exceedances of eutrophication CLs decreased, whereas the exceeded area stayed almost the same, i.e. the N depositions decreased, but did not go below CLs in most of the exceeded areas.

Overall, the trends illustrated in Figures 2.17, 2.16 and 2.18 point in the 'right' direction, but a lot remains to be done in terms of emission reductions to achieve non-exceedance of critical loads everywhere.

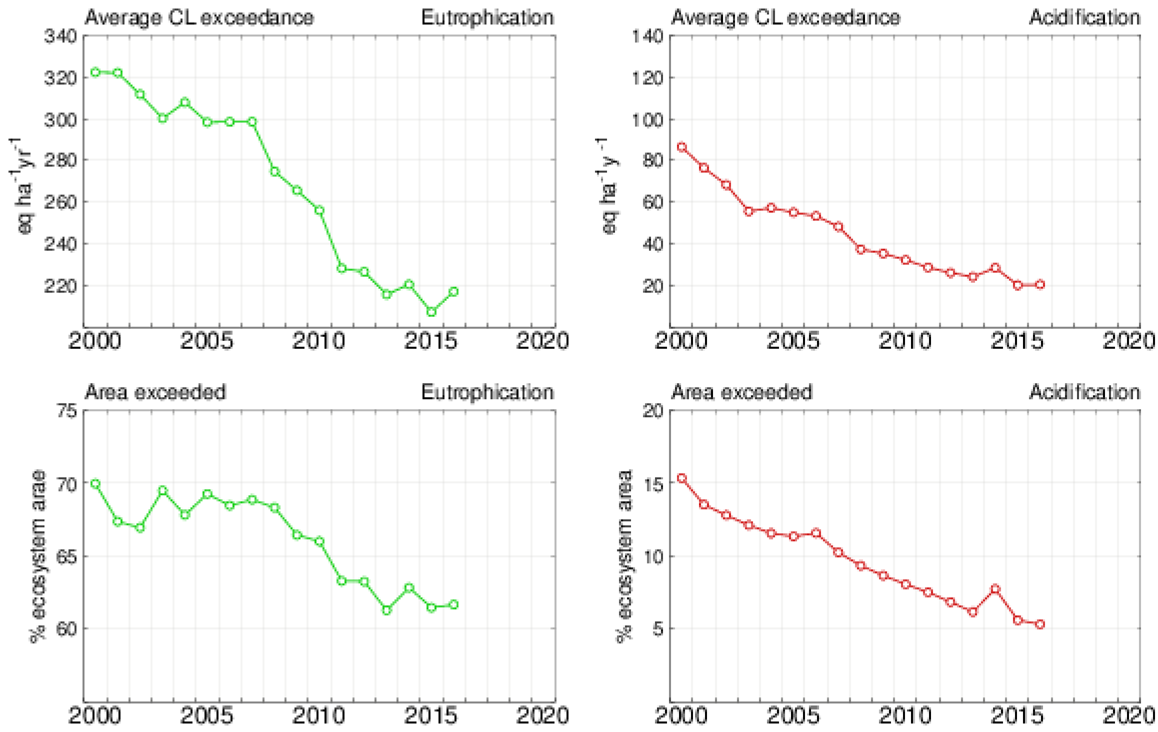


Figure 2.18: Temporal trends of the average European CL exceedance (in eq ha^{-1}yr^{-1}, top) and the ecosystem area exceeded (in percent of total, bottom), both for eutrophication (left) and acidification (right) for the years 2000 through 2016. Note that the ranges on the vertical axes for eutrophication and acidification are the same but differ in their absolute values.

2.4.4 Model calculations for 2017

Preliminary model calculations for 2017 has been performed. The meteorology for 2017 has been prepared the same way as for 2016, described in Chapter 2.3. The data for 2016 (same as in the status run) are used for emissions from anthropogenic sources and forest fires (FINN). Climatological means are used for boundary conditions. The EMEP MSC-W model version is the same as used for 2016 runs (rv4.17a).

As an example, 2017 results for nitrogen dioxide is shown in Figure 2.19. The data can also be download from the EMEP webpage (`http://www.emep.int`).

No analysis of the 2017 results has been attempted here, as the EMEP measurement data are not available until spring 2019.

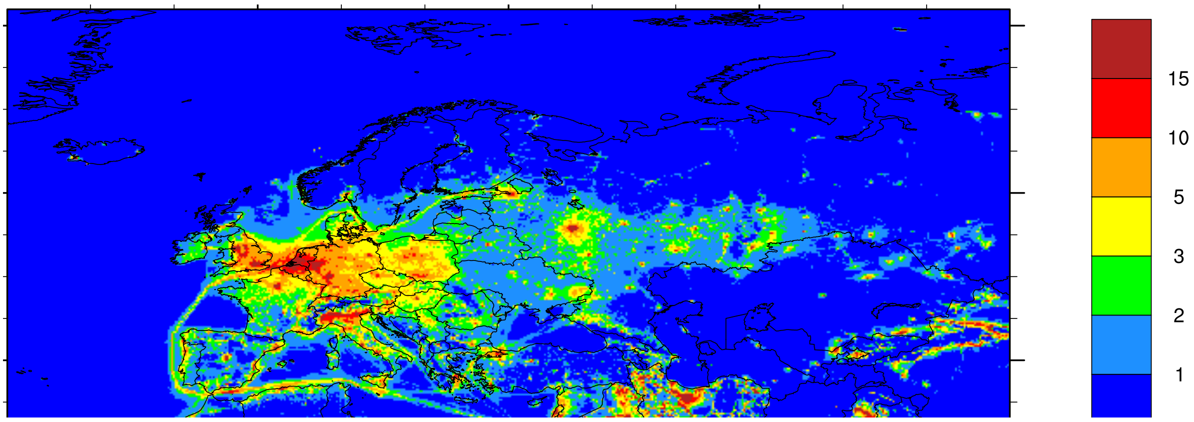


Figure 2.19: Example of 2017 results for NO_2 [μg m^{-3}]

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CHAPTER 3

Emissions for 2016

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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 2016 with respect to previous years are documented in the following sections.

3.1 Emissions for 2016

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

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

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

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

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

3.1.1 Reporting of emission inventories in 2018

Completeness and consistency of submitted data have improved significantly since EMEP started collecting information on emissions. Data from at least 45 Parties each year were submitted to CEIP for the last seven years (compare Figure 3.1). 45 Parties (88 %) submitted inventories[5] in 2018; six Parties[6] did not submit any data and 37 countries reported black carbon (BC) emissions (see section 3.1.2). Although 2018 was no reporting year for large point sources (LPS), gridded emissions and projections, four countries reported voluntary information on LPS, seven countries reported gridded data in the new resolution, and four countries reported projection data (Burgstaller et al. 2018).

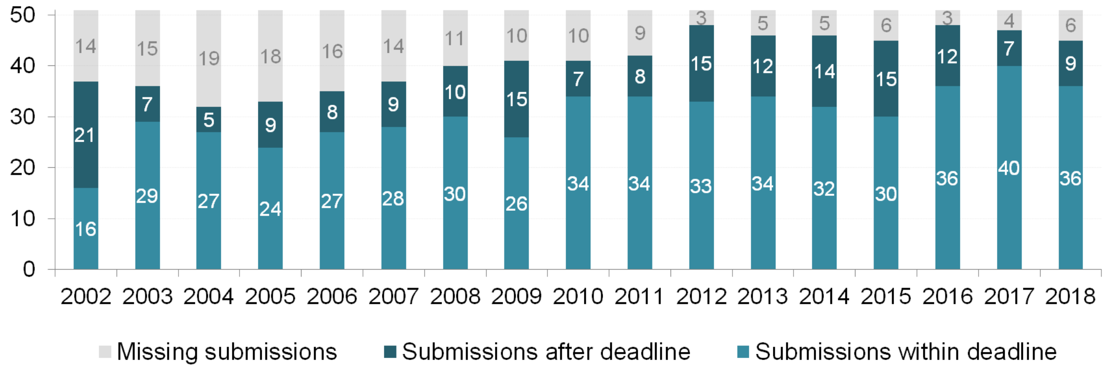


Figure 3.1: Parties reporting emission data to EMEP since 2002, as of 6 June 2018.

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

Detailed information on recalculations, completeness and key categories, plus additional review findings, can be found in the annual EEA & CEIP technical inventory review reports (Burgstaller et al. 2018) and its Annexes[7].

3.1.2 Black Carbon (BC) emissions

Over the last decade, black carbon (BC) has emerged as one of the most important anthropogenic air pollutants. According to the latest independent inventory estimates with the GAINs model, global total anthropogenic emissions of BC were 7.2 Tg BC in 2010, with 4.16 Tg BC and 1.35 Tg BC originating from residential combustion and road transport sectors, respectively (Klimont et al. (2017)). In their seminal review Bond et al. (2013) describe BC as “a distinct type of carbonaceous material, formed only in flames during combustion of

[5]The original submissions from the Parties can be accessed via the CEIP homepage on `http://www.ceip.at/status_reporting/2018_submissions`.

[6]Bosnia and Herzegovina, Kyrgyzstan, Liechtenstein, the Republic of Moldova, Monaco and Montenegro

[7]`http://www.ceip.at/review_proces_intro/review_reports`

carbon-based fuels". Black carbon is distinguished from other forms of carbon in atmospheric particulate matter (PM) e.g. organic carbon (OC) by its strong absorption of visible light, aggregate morphology, insolubility in water/common organic solvents, and that it is refractory (vaporization temperature ca. 4000K (Bond et al. (2013)). Due to these distinct physical properties and its potential toxicity (Janssen et al. (2012)) BC is a significant air pollutant in terms of both climate change and air quality. Given its absorption spectrum in the visible range, BC warms the atmosphere directly by absorbing solar radiation and, indirectly, by accelerating snow-/ice melt when deposited (Bond et al. (2013)). According to recent estimates, the direct radiative forcing effect of black carbon emissions during the first part of the industrial era may have been of the same magnitude as methane (CH_4) emissions (Bond et al. (2013), Wang et al. (2016)). Meanwhile, in terms of human health, epidemiological studies suggest that certain pulmonary and cardiovascular conditions are more strongly associated with exposure to BC rather than aggregate PM (e.g. Baumgartner et al. (2014)).

The emerging significance of BC is mirrored in developments in the international policy arena. Since the new National Emissions Ceilings (NEC) Directive (2016/2284/EU) was adopted in 2016, EU member states have been encouraged to submit BC emissions estimates as part of their mandatory NEC reporting obligations. Furthermore, in the context of the particularly acute impacts of BC in accelerating climate change in the Arctic (Sand et al. (2016)), ministers of the Arctic Council adopted the *Enhanced Black Carbon and Methane Emissions Reductions: An Arctic Council Framework Action* which committed the Arctic States (Canada, Denmark, Finland, Iceland, Norway, Russia, Sweden and United States of America) to develop and submit emissions inventories for BC and CH_4 to the Council. The EU is particularly keen to support further international policy development concerning BC and climate change in the Arctic (Romppanen (2018)), as demonstrated by the recent *EU initiative EU Action on Black Carbon in the Arctic* (EUA-BCA)[8]. The overall goal of the Action (2018–2020) is to contribute to the development of collective responses to reduce black carbon emissions in the Arctic and the action will examine *inter alia* current BC emissions reporting by the Parties to the LRTAP Convention. 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 since 2015 the reporting templates have been updated to include BC data. As per the reporting guidelines (ECE/EB.AIR/128), parties are encouraged to follow the methods described in the latest EMEP/EEA air pollutant emission inventory guidebook (EMEP/EEA 2016), where source level emissions are calculated as source-specific percentages of the respective $PM_{2.5}$ emissions. Below a brief overview of BC emissions estimates submitted by EMEP countries is given.

Twenty countries (out of 37) submitted a complete time series (1990-2016), 31 submitted a complete time series from 2000 onwards. Figure 3.2 shows the emission trends of 11 countries that submitted full time series and showed the highest absolute BC emissions in 2016. Although gridded BC data is requested by the modelers, the quality of the reported data is still not sufficient across most of the countries, therefore CEIP cannot provide these data. Figure 3.3 lists the national total BC emissions in 2016, and the percentage contribution of BC to total $PM_{2.5}$ for each country, which is 16% in mean (median). Compared to 2000, 23 countries reported a decrease of emissions and seven reported an increase.

For more detailed information on BC consult the annual EEA & CEIP technical inventory review report (Burgstaller et al. 2018).

[8] https://www.amap.no/eu-black-carbon-action

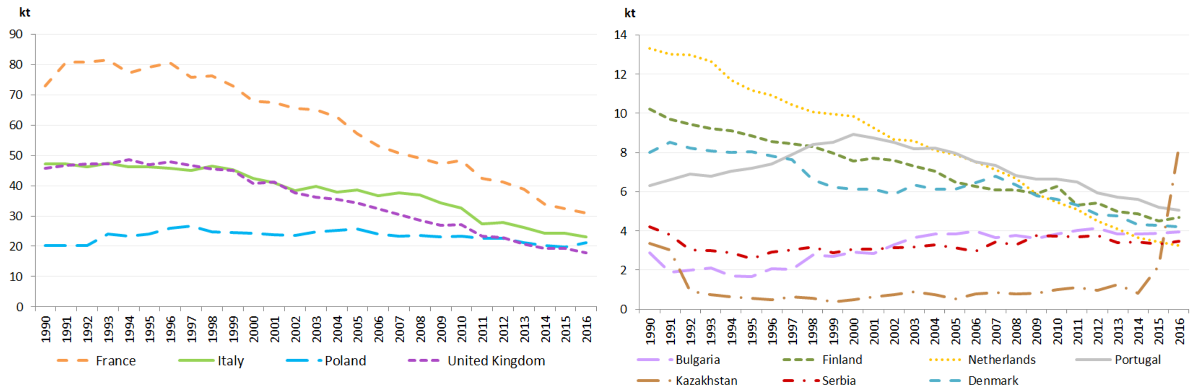


Figure 3.2: Black Carbon emissions trends of selected countries, 1990-2016 (based on reported data).

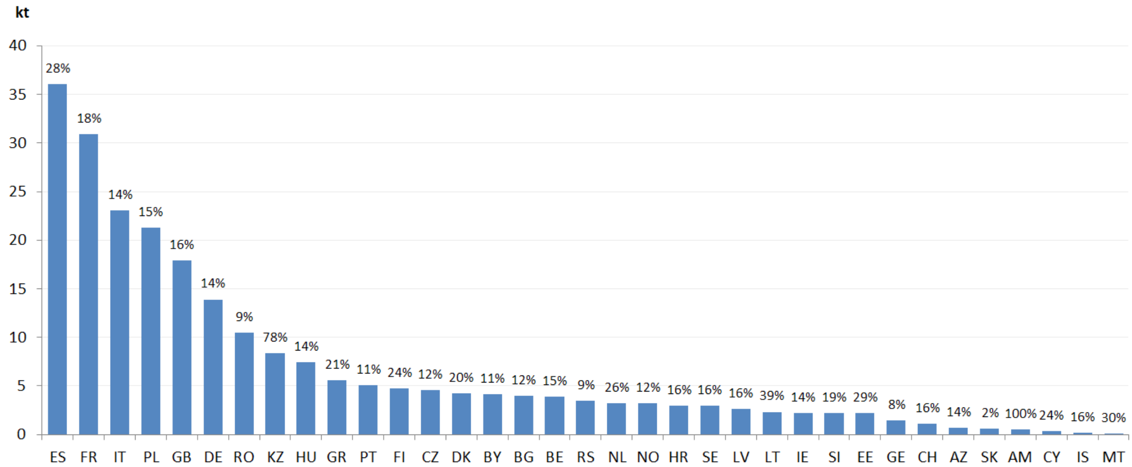


Figure 3.3: Black Carbon emissions for the year 2016 (based on reported data). 35 out of 37 reporting parties are included in this graph; not included: MK (incomplete reporting) and EU (sum of shown EU Member States). Percentage values indicate the amount of BC on $PM_{2.5}$.

3.1.3 EECCA countries – Status of reporting

The reporting of CLRTAP inventories by EECCA countries to the Convention is rather limited. In the last five years only Georgia, the Russian Federation and the Ukraine provided annual submissions. Submissions were often reported (long) after the deadline and/or lacking in completeness (see Table 3.1). There is not much improvement in the reporting, except that the number of submissions reported in time and/or up to the resubmission deadline is higher in the last three years than in the years before. Detailed information on the reporting of main pollutants and particulate matter in the EECCA countries is provided in Table 3.2 and 3.3.

CEIP conducts in-depth reviews of inventories, which supports Parties in compiling and submitting high quality inventories and aims to increase confidence in the data used for air pollution modelling. The aim is to conduct such a stage 3 (S3) review for every Party at least once in a five-year period. The plan for in-depth reviews for the period 2018-2020 is focusing on non-EU member states to minimise duplication of work and support EECCA countries. The plan will be modified if any listed Party does not submit the requested information within deadline. In 2018, an in-depth review of the inventories of the Republic of Moldova, Armenia,

Table 3.1: Overview of inventories submitted to CEIP by EECCA countries within the last five years. *Orange: reporting of some years or pollutants, reporting not complete (no complete time series). Light green: partly complete reporting (e.g. complete reporting for some pollutants). Green: reporting of complete time series.*

Reporting of the EECCA countries

	2014				2015				2016				2017				2018			
	Main pollutants	PMs, TSP, BC	HMs	POPs	Main pollutants	PMs, TSP, BC	HMs	POPs	Main pollutants	PMs, TSP, BC	HMs	POPs	Main pollutants	PMs, TSP, BC	HMs	POPs	Main pollutants	PMs, TSP, BC	HMs	POPs
Armenia	x	x	x		x	x	x		x	x	x	x					x	x	x	x
Azerbaijan					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Belarus	x	x	x	x	x	x	x	x									x	x	x	x
Georgia	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Kazakhstan									x	x	x	x	x	x	x	x	x	x	x	x
Kyrgyzstan	x	x	x	x					x	x	x		x	x	x					
Republic of Moldova	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
Russian Federation	x	x			x	x			x	x			x	x			x	x		
Ukraine	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x	x	x	

Table 3.2: Reporting of main pollutants (NO_x, NMVOCs, SO_x and NH_3) and CO of the EECCA countries within the last five years.

Reporting of NO_x, NMVOCs, SO_x, NH_3 and CO

EECCA countries	*2014*	*2015*	*2016*	*2017*	*2018*
Armenia	2006, 2008 - 2012	2008 - 2013	2014		2016
Azerbaijan		1990 - 2013 (not SO_x, CO)	1990-2014 (SO_x, CO: 1995-2014)	1990 - 2015 (SO_x, CO: 1995-2015)	1990 - 2016 (SO_x, CO: 1995 to 2016)
Belarus	2012	2013			2014-2016
Georgia	2012	2007 - 2013	2007-2014	2007 - 2015	2007-2016
Kazakhstan			2013-2014	1990, 2000, 2005, 2010 - 2015	1990 - 2016
Kyrgyzstan	2012		2014	2015	
Republic of Moldova	1990 - 2012	2013	1990-2014 (no emissions calculated for the waste sector)	1990 - 2015	
Russian Federation	2011, 2012	2013	2014	2010-2015	2010-2016
Ukraine	2012	2013	2014	2015	2016

Table 3.3: Reporting of main pollutants BC, $PM_{2.5}$, PM_{10} and TSP of the EECCA countries within the last five years.

Reporting of BC, $PM_{2.5}$, PM_{10} and TSP					
EECCA countries	**2014***	**2015**	**2016**	**2017**	**2018**
Armenia	2006, 2008 - 2012 (only TSP)	2008 - 2013 (only TSP)	2014		2016
Azerbaijan		1990 - 2013 (BC: 1995-2013)	1990-2014 (BC: 1995-2014)	1990 - 2015 (BC: 2014, 2015)	1990 - 2016 (BC: 2014-2016)
Belarus	2012	2013 (no BC)			2014-2016 (BC: 2016)
Georgia	2012	2007 - 2013 (no BC)	2007-2014	2007 - 2015	2007-2016
Kazakhstan			2013-2014	1990, 2000, 2005, 2010 - 2015	1990 - 2016
Kyrgyzstan	2012 (only PM10)		2014 (no TSP, no BC)	2015 (no BC)	
Republic of Moldova	1990 - 2012	2013	1990-2014 (no emissions calculated for the waste sector)	1990 - 2015	
Russian Federation	2011, 2012	2013 (no BC)	2014 (no BC)	2010-2015 (no BC)	2010-2016 (no BC)
Ukraine	2012	2013 (no BC)	2014 (no BC)	2015 (no BC)	2016 (no BC)

Belarus, Ukraine and Azerbaijan will be made. In 2019, the Russian Federation and Georgia, and in 2020, Kyrgyzstan and Kazakhstan will be reviewed.

3.1.4 Emission trends in the EMEP area

To provide a picture as complete as possible of the emission trends in the EMEP area[9], data as used for EMEP models (i.e. gap-filled data) were used for the calculations (see Section 3.3). The trend indicates that in the EMEP area total emissions of half of the reported pollutants have decreased overall since 2000 (Figure 3.4). The presented emission trends are based on gap-filled data as used in the EMEP models, therefore there is a certain uncertainty in the magnitude of this development. The decrease is significant for SO_x, CO, NO_x and NMVOCs. PM and NH_3 emissions increase, whereas NH_3 increased most (+22%) since the year 2000.

A more detailed assessment shows that emission developments in the eastern and western part of the EMEP area seem to follow strongly different patterns (see Figure 3.5)[10].

While emissions of all pollutants in the western part of the EMEP domain are slowly decreasing, emissions of all pollutants in the eastern part of the EMEP domain have increased since the year 2000. The emissions in the western parts of the EMEP area are mostly based

[9]The EMEP area is the new EMEP domain, which covers the geographic area between 30° N-82° N latitude and 30° W-90° E longitude.

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

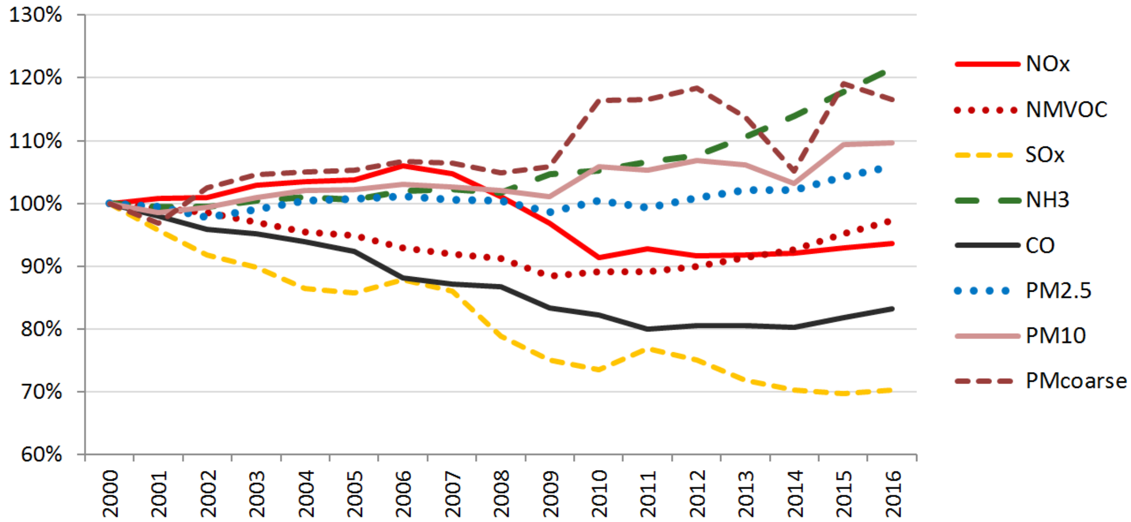


Figure 3.4: Emission trends 2000–2016 in the EMEP area (based on gap–filled data as used in EMEP models)

on reported data; the emissions in eastern parts are often expert estimates so the uncertainty is rather high. The significant increase in emissions (of all pollutants) in the 'EMEP east' area is mainly influenced by emission estimates made for the remaining Asian Areas in the EMEP domain. The new expert estimates for this area are based on grid emissions from EDGAR (JRC/PBL 2016) for 2000, 2005 and 2010, extrapolated with the GDP trend for China.

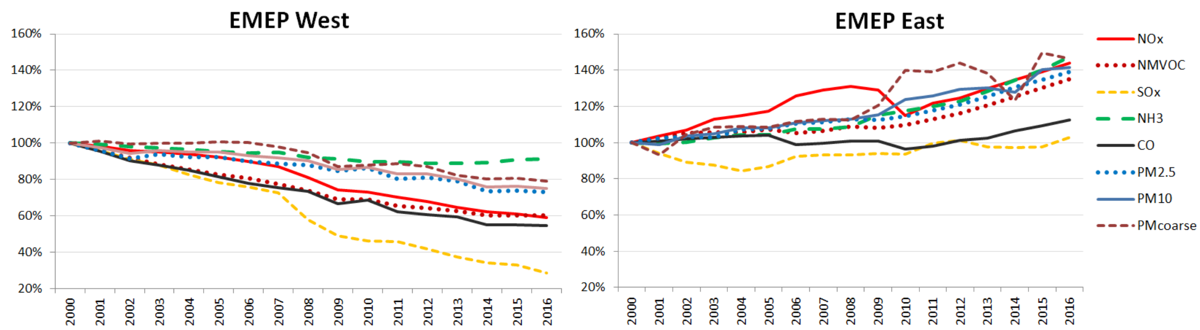


Figure 3.5: Emission trends 2000-2016 in the EMEP area (based on gap-filled data as used in EMEP models) divided in 2 areas 'EMEP West' (left), 'EMEP East' (right).

Trend analysis

Emission levels in the EMEP domain for 2016 of individual countries and areas are compared to 2000 emission levels for NO_x, NMVOCs, SO_x, NH_3, CO and PMs (see Tables 3.4-3.5). For this comparison, gap-filled data as used in the EMEP models were used (see Section 3.3). Overview tables with reported emission trends for individual countries have been published on the CEIP website at `http://www.ceip.at/status_reporting/2018_submissions`. Detailed information on the sectoral level can also be accessed in

WebDab[11].

The assessment of emission levels in individual countries and areas show an increase of emissions compared to 2000 emission levels in several countries or areas. In the case of PM_{coarse} as many as 29 countries/areas have emissions in 2016 higher than the year 2000 level, for PM_{10} and $PM_{2.5}$ 23 and 24 countries/areas showed increases, respectively. In the case of NO_x there are 17 countries/areas, NMVOCs 15, SO_x 16, NH_3 20 and CO 13 countries/areas with higher emissions in 2016 than in year 2000. Detailed explanatory information on emission trends should be provided in the informative inventory reports (IIRs).

NO_x emissions

Emissions decreased in 44 countries or areas and increased in 16 countries or areas (see Table 3.4) between 2000 and 2016. For the whole EMEP domain, emissions decreased by 6%. The strongest increase is shown for Georgia (+240%), followed by Kyrgyzstan (+191%).

NMVOC emissions

Emissions in the EMEP domain have decreased by 3% compared with 2000 levels. Compared with 2000, NMVOC emissions have decreased in 46 countries or areas and increased in 14 (see Table 3.4). The strongest NMVOC increases can be observed in Kyrgyzstan (+253%).

SO_x emissions

SO_x emissions decreased by 30% between 2000 and 2016 within the EMEP domain. Compared with 2000, SO_x emissions have decreased in 45 countries or areas and increased in 15 (see Table 3.4), among them Armenia (+361%), Montenegro (+275%) and Tajikistan (+272%).

NH_3 emissions

NH_3 emissions have increased in the EMEP domain by 22% compared with 2000 levels. Emissions have decreased in 35 countries or areas and increased in 19 (see Table 3.4). The strongest increases are shown for Turkmenistan (+152%) and Tajikistan (+124%).

CO emissions

The total decrease in emissions in the EMEP domain from 2000 to 2016 amounted to 17%. Compared with 2000 CO emissions have decreased in 48 countries or areas and increased in 12 (see Table 3.4), particularly in Kyrgyzstan (+256%).

$PM_{2.5}$ emissions

$PM_{2.5}$ emissions in the EMEP domain have increased by 6% compared with 2000 levels. Compared with the year 2000, $PM_{2.5}$ emissions have decreased in 38 countries or areas and increased in 22 countries or areas (see Table 3.4). The largest increase is seen in Kazakhstan (+220%), followed by Tajikistan (+204%).

[11] http://www.ceip.at/webdab_emepdatabase/reported_emissiondata and/or http://www.ceip.at/webdab_emepdatabase/emissions_emepmodels

Table 3.4: Differences between emissions for 2000 and 2016 (based on gap–filled data as used in EMEP models). Negative values mean that 2016 emissions were lower than 2000 emissions. Orange/red coloured data means that 2016 emissions were higher than 2000 emissions.

	Emission differences 2000-2016							
	NO_x	NMVOC	SO_x	NH_3	CO	$PM_{2.5}$	PM_{10}	PM_{coarse}
Albania	38 %	62 %	-55 %	-15 %	89 %	69 %	52 %	10 %
Armenia	76 %	127 %	361 %	80 %	-2 %	2 %	6 %	17 %
Asian Areas	121 %	73 %	79 %	69 %	59 %	82 %	81 %	79 %
Atlantic Ocean	-11 %	-22 %	-6 %		-22 %	0 %	0 %	0 %
Austria	-28 %	-22 %	-56 %	3 %	-24 %	-28 %	-21 %	-7 %
Azerbaijan	68 %	36 %	6 %	49 %	55 %	-13 %	46 %	106 %
Baltic Sea	-27 %	-22 %	-96 %		-22 %	-51 %	-50 %	-43 %
Belarus	-32 %	-32 %	-59 %	-9 %	-39 %	-36 %	-36 %	-37 %
Belgium	-44 %	-47 %	-75 %	-26 %	-61 %	-38 %	-37 %	-36 %
Black Sea	-10 %	-21 %	-3 %		-21 %	1 %	1 %	1 %
Bosnia and Herzegovina	-11 %	-35 %	-12 %	24 %	4 %	-12 %	-16 %	-21 %
Bulgaria	-15 %	-22 %	-88 %	-7 %	-29 %	24 %	2 %	-24 %
Caspian Sea	182 %	182 %	182 %		182 %	182 %	182 %	182 %
Croatia	-39 %	-34 %	-75 %	-14 %	-55 %	-45 %	-37 %	-2 %
Cyprus	-32 %	-40 %	-66 %	-12 %	-52 %	-51 %	-58 %	-67 %
Czech Republic	-44 %	-30 %	-51 %	-16 %	-16 %	-23 %	-26 %	-35 %
Denmark	-49 %	-40 %	-69 %	-22 %	-47 %	-13 %	-13 %	-13 %
Estonia	-30 %	-41 %	-69 %	28 %	-30 %	-51 %	-65 %	-78 %
Finland	-44 %	-50 %	-51 %	-8 %	-42 %	-31 %	-25 %	-13 %
France	-48 %	-62 %	-78 %	-5 %	-59 %	-48 %	-42 %	-23 %
Georgia	240 %	7 %	5 %	7 %	28 %	-38 %	-29 %	85 %
Germany	-37 %	-35 %	-45 %	2 %	-40 %	-38 %	-30 %	-18 %
Greece	-37 %	-37 %	-88 %	-9 %	-58 %	-43 %	-37 %	-28 %
Hungary	-36 %	-31 %	-95 %	-6 %	-45 %	10 %	-3 %	-26 %
Iceland	-15 %	-17 %	43 %	1 %	148 %	-2 %	4 %	31 %
Ireland	-36 %	-11 %	-90 %	1 %	-59 %	-36 %	-28 %	-17 %
Italy	-49 %	-43 %	-85 %	-16 %	-52 %	-17 %	-21 %	-36 %
Kazakhstan	107 %	75 %	56 %	58 %	110 %	220 %	256 %	425 %
Kyrgyzstan	191 %	253 %	113 %	40 %	256 %	65 %	53 %	30 %
Latvia	-15 %	-24 %	-80 %	16 %	-59 %	-29 %	-11 %	98 %
Liechtenstein	-21 %	-46 %	-57 %	-3 %	-24 %	-4 %	-8 %	-32 %
Lithuania	2 %	-25 %	-58 %	-1 %	-26 %	-19 %	-5 %	11 %
Luxembourg	-51 %	-18 %	-70 %	-9 %	-47 %	-37 %	-27 %	6 %
FYR of Macedonia	-49 %	-42 %	-45 %	-22 %	-49 %	-52 %	-51 %	-49 %
Malta	-40 %	-11 %	-91 %	-21 %	-58 %	1 %	-1 %	-5 %
Republic of Moldova	116 %	69 %	127 %	-3 %	195 %	173 %	90 %	17 %
Mediterranean Sea	-12 %	-23 %	-3 %		-23 %	2 %	2 %	0 %
Monaco	-35 %	-28 %	-86 %	-4 %	-62 %	-25 %	-25 %	-25 %
Montenegro	59 %	-14 %	275 %	-65 %	-25 %	11 %	53 %	97 %
Netherlands	-45 %	-44 %	-64 %	-27 %	-25 %	-57 %	-40 %	-6 %
North Africa	73 %	17 %	63 %	56 %	-5 %	52 %	54 %	58 %
North Sea	-20 %	-22 %	-93 %		-22 %	-50 %	-50 %	-47 %

Table 3.5: Table 3.4 continued. Differences between emissions for 2000 and 2016 (based on gap–filled data as used in EMEP models).

Norway	-28 %	-61 %	-43 %	0 %	-39 %	-35 %	-29 %	2 %
Poland	-14 %	2 %	-59 %	-16 %	-23 %	-14 %	-16 %	-18 %
Portugal	-44 %	-31 %	-82 %	-27 %	-52 %	-29 %	-35 %	-47 %
Romania	-20 %	-8 %	-78 %	0 %	8 %	17 %	21 %	37 %
Russian Federation (European part)	-4 %	5 %	-41 %	38 %	-5 %	-26 %	4 %	72 %
Russian Federation (Asian part)	-11 %	1 %	3 %	-6 %	-21 %	-1 %	9 %	25 %
Serbia	0 %	-13 %	-9 %	-16 %	-30 %	4 %	6 %	9 %
Slovakia	-41 %	-47 %	-78 %	-24 %	-36 %	-15 %	-23 %	-44 %
Slovenia	-38 %	-41 %	-95 %	-10 %	-40 %	17 %	12 %	-19 %
Spain	-45 %	-37 %	-84 %	-9 %	-42 %	-31 %	-30 %	-29 %
Sweden	-39 %	-29 %	-56 %	-11 %	-37 %	-33 %	-18 %	4 %
Switzerland	-40 %	-48 %	-60 %	-7 %	-58 %	-37 %	-18 %	2 %
Tajikistan	98 %	176 %	272 %	124 %	122 %	204 %	239 %	343 %
Turkey	20 %	0 %	0 %	28 %	-23 %	13 %	0 %	-13 %
Turkmenistan	58 %	-8 %	6 %	152 %	-13 %	128 %	133 %	163 %
Ukraine	-22 %	-6 %	-66 %	-7 %	-49 %	18 %	26 %	46 %
United Kingdom	-55 %	-50 %	-86 %	-7 %	-65 %	-28 %	-26 %	-23 %
Uzbekistan	-21 %	-39 %	-84 %	65 %	-35 %	50 %	65 %	112 %
Increase	***16***	***14***	***15***	***19***	***12***	***22***	***23***	***28***
Decrease	***44***	***46***	***45***	***35***	***48***	***38***	***37***	***32***

PM_{coarse} emissions

PM_{coarse} emissions in the EMEP domain have increased by 17% compared with 2000 levels. PM_{coarse} emissions have decreased in 32 countries or areas and increased in 28 (see Table 3.4). The largest increases are seen in Kazakhstan (+425%) and Tajikistan (+343%).

3.1.5 Gothenburg Protocol targets

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

In 2012, the Executive Body of the LRTAP Convention decided that adjustments to inventories may be applied in some circumstances (UNECE (2012)). From 2014 to 2017, adjustment applications of seven countries (Belgium, Denmark, Finland, France, Germany, Luxembourg and Spain) have been accepted and therefore these approved adjustments have to be subtracted for the respective countries when compared to the targets. Further, the reporting guidelines (UNECE (2014)) specify that some Parties within the EMEP region (i.e. Austria, Belgium, Ireland, Lithuania, Luxembourg, the Netherlands, Switzerland and the United Kingdom of Great Britain and Northern Ireland) may choose to use the national emission total calculated on the basis of fuels used in the geographic area of the Party as a basis for compliance with their respective emission ceilings. However, when considering only reported data, approved adjustments and fuel used data of the respective countries, Figure 3.6 indicates that Hungary could not reduce its NMVOC emissions with regard to the Gothenburg Protocol requirements, and that Croatia, Denmark, Germany, Norway and Spain are above their Gothenburg Protocol ceilings for NH_3.

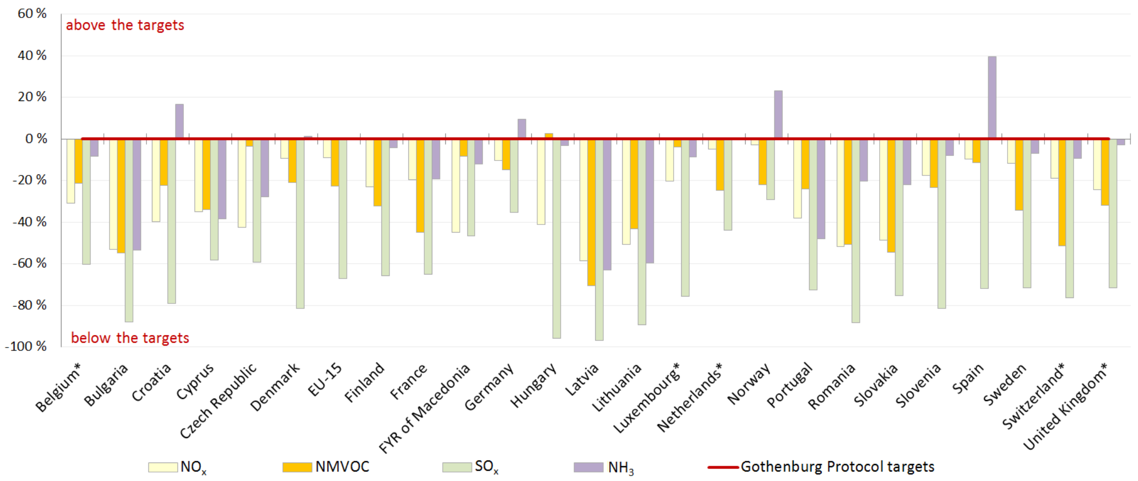


Figure 3.6: Distance to Gothenburg Protocol targets (based on reported data). Only Parties that ratified the Gothenburg Protocol are included. The United States and Canada have ratified the Gothenburg Protocol, but are not included here as the United States provided no data for 2016, and Canada did not submit their 2010 ceilings. * Emission data based on fuels used for road transport. Approved adjustments are considered for Belgium (NO_x), Denmark (NMVOCs, NH_3), Finland (NH_3), France (NO_x), Germany (NO_x, NMVOCs, NH_3), Luxembourg (NO_x, NMVOCs) and Spain (NO_x).

3.1.6 Contribution of individual sectors to total EMEP emissions

Figure 3.7 shows the contribution of each GNFR sector to the total emissions of individual air pollutants (SO_x, NO_x, CO, NMVOC, NH_3, $PM_{2.5}$ and PM_{coarse}). To provide a picture as complete as possible of the situation of the individual sectors to total EMEP emissions, data as used for the EMEP models (i.e. gap-filled data) were used for the calculations (see Section 3.3). Sea regions, North Africa and the remaining Asian areas were excluded for this analysis, as sectoral distributions are better reflected when only using country data.

It is evident that the combustion of fossil fuels is responsible for a significant part of all emissions. 47% of NO_x emissions are produced by transport (F, G, H, I) but 22% of NO_x also comes from large power plants (A).

NMVOC sources are distributed more evenly among the different sectors, such as 'E – Emissions from solvents' (26%), 'F – Road transport' (20%), 'D – Fugitive Emissions' (12%), 'B – Industry combustion' (11%), 'K – Manure management' (11%) and 'C – Other stationary combustion' (11%).

The main source of SO_x emissions are large point sources from combustion in energy and transformation industries (77%).

Ammonia arises mainly from agricultural activities (K and L), about 94%, while CO emissions originate primarily from 'F – Road transport' (37%) and 'C – Other stationary combustion' (30%).

The main sources of primary PM emissions are industry and other stationary combustion processes (up to 60%) and agriculture with a share of 12% to 36%.

Figure 3.8 illustrates the sector contribution for the sum of total emissions in the EMEP West region and the EMEP East region. The split between the EMEP West and EMEP East

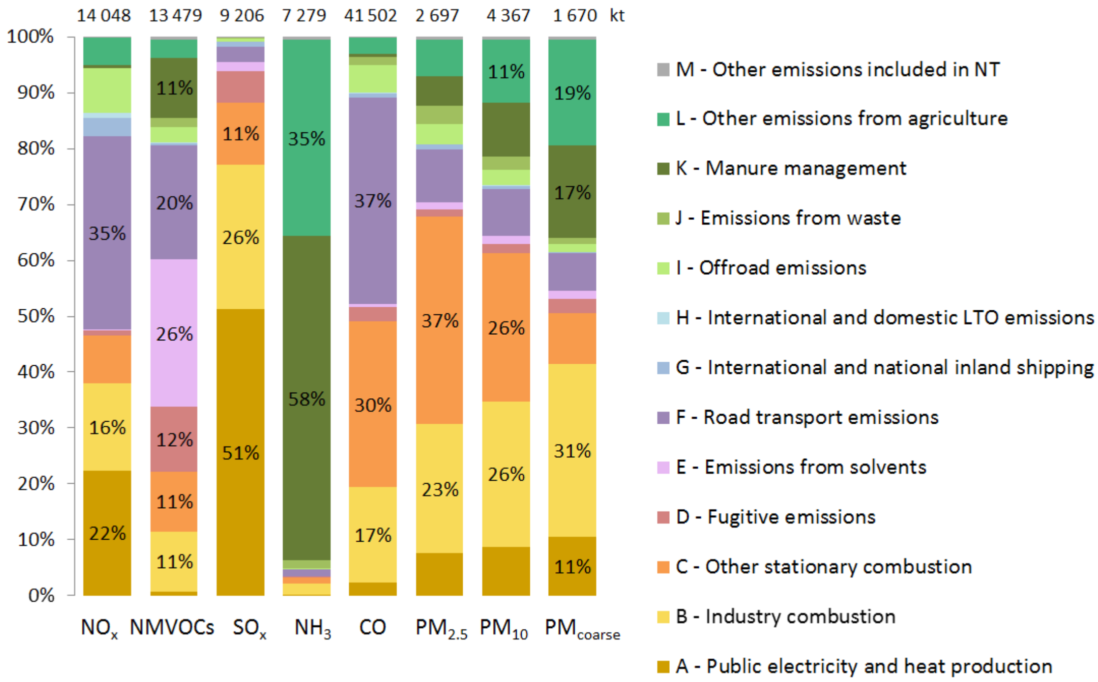


Figure 3.7: GNFR sector contribution to national total emissions in 2016 for the EMEP domain without sea regions, North Africa and remaining Asian areas (only percentages above 10% are shown).

regions is according to `http://www.ceip.at/emep_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 the EMEP West region the most important sector is 'F – Road transport emissions' (38%), whereas in the EMEP East region the sector 'A – Public electricity and heat production' is of higher importance (33%).

For NMVOC in the EMEP West region the most relevant sector is 'E – Emissions from solvents' with a share of 40%. In the EMEP East region the same sector has a considerable lower share (10%), whilst the sector 'F – Road transport emissions' is of high importance (34%).

The main source of SO_x are 'A – Public electricity and heat production' and and 'B – Industry combustion'. These two sectors together contribute to 77% of SO_x emissions within the EMEP West and EMEP East areas.

The main source of NH_3 emissions for both EMEP West and EMEP East is the agricultural sectors (K and L) with 92% and 95% respectively.

CO emissions arise mainly from 'F – Road transport emissions' (55%) in EMEP East. In the EMEP West region the main sector is 'C – Other stationary combustion' (42%).

For $PM_{2.5}$ and PM_{10} 'Other stationary combustion' (C) holds a significant share of the total emissions in the EMEP West area (53% and 38%, respectively), while for the EMEP East area the sector 'Industry combustion' (B) has the highest share, 31% and 30% of total $PM_{2.5}$ and PM_{10} emissions, respectively. For PM_{coarse} emissions 'Industry combustion' (B) is a major source for both the EMEP East (29%) and the EMEP West (33%) region.

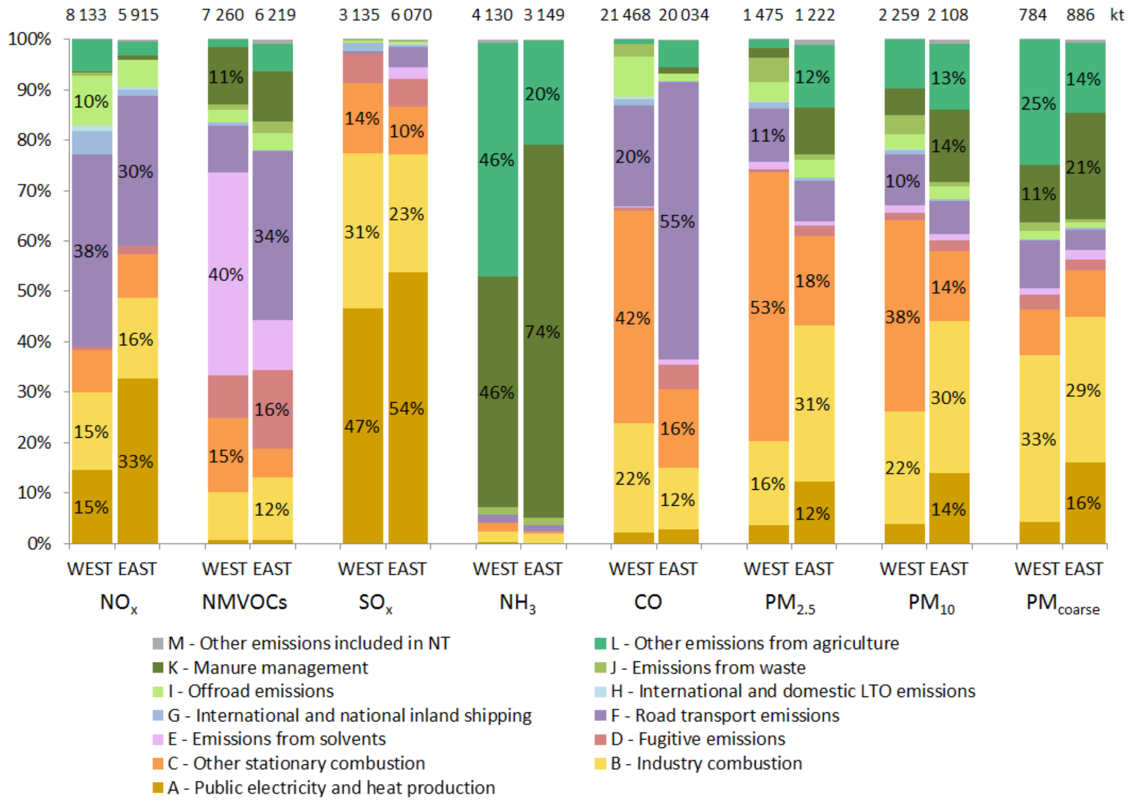


Figure 3.8: GNFR sector contribution to national total emissions in 2016 for the EMEP West and East regions (only percentages above 10% are visible).

3.2 Comparison of 2015 data (reported in 2017) and 2016 data (reported in 2018)

The comparison of 2015 emissions (reported in 2017) and 2016 emissions (reported in 2018) showed, that for 29 countries data changed by more than 15% for one or several pollutants (see Figure 3.9 and Table 3.6-3.7). These changes can be caused by real emission reductions or increases, or recalculations made by the respective country.

In five countries, both NO_x and CO emissions changed by more than 15%. For NMVOCs, emissions changed in seven countries by more than 15%. For SO_x, emissions changed by more than 15% in 14 countries, and for NH_3 in six countries. Of the PMs, emissions changed by more than 15% in nine countries for $PM_{2.5}$, in 11 countries for PM_{10} and in 19 countries for PM_{coarse} (see Figure 3.9 and Table 3.6-3.7). The largest changes occurred in Luxembourg, Georgia, Lithuania and Slovakia.

For Luxembourg, a huge change for PM_{coarse} (+1 445%) is mainly from the NFR category '3De – Cultivated crops' of $PM_{2.5}$ and PM_{10}. The change is caused by recalculations of the time series of $PM_{2.5}$ and PM_{10} made by Luxembourg in 2016.

Georgia showed a large change in SO_x emissions (+93%), especially in the sector '1A2f – Stationary combustion in manufacturing industries and construction: Non-metallic minerals'. This change is caused by recalculations of the time series made by Georgia in 2016, as well as by switching from coal with low sulphur content to high sulphur coal in the production of non-metallic minerals (mostly in cement production) (for more details see the IIR of Georgia

Table 3.6: Reported emission changes between 2015 (reported in 2017) and 2016 (reported in 2018) over 15% for main pollutants.

Pollutant	Country	2015 (kt)	2016 (kt)	Diff. (kt)	Diff. (%)
NO_x	ES	904.85	765.48	-139.37	-15%
NO_x	IE	79.54	112.28	32.73	41%
NO_x	MK	27.61	21.57	-6.04	-22%
NO_x	SK	86.21	66.97	-19.24	-22%
NO_x	TR	883.00	702.70	-180.30	-20%
NMVOCs	AT	112.89	137.62	24.73	22%
NMVOCs	CY	7.45	9.26	1.81	24%
NMVOCs	CZ	139.36	212.57	73.20	53%
NMVOCs	LU	9.74	12.92	3.18	33%
NMVOCs	PT	180.29	153.68	-26.61	-15%
NMVOCs	RO	313.14	258.42	-54.73	-17%
NMVOCs	SK	89.30	63.96	-25.34	-28%
SO_x	AZ	14.07	17.98	3.91	28%
SO_x	BG	142.06	104.92	-37.13	-26%
SO_x	CY	13.15	16.32	3.17	24%
SO_x	ES	273.29	217.99	-55.29	-20%
SO_x	GB	236.12	179.16	-56.95	-24%
SO_x	GE	4.98	9.61	4.63	93%
SO_x	IE	17.63	13.77	-3.86	-22%
SO_x	KZ	2091.94	1795.79	-296.15	-14%
SO_x	LT	18.23	15.44	-2.79	-15%
SO_x	LU	1.26	1.00	-0.26	-21%
SO_x	MK	76.41	58.67	-17.74	-23%
SO_x	PL	690.26	581.52	-108.74	-16%
SO_x	RO	151.87	107.67	-44.20	-29%
SO_x	SK	71.42	27.15	-44.28	-62%
NH_3	BG	33.62	50.29	16.67	50%
NH_3	CY	4.55	5.55	1.00	22%
NH_3	GE	45.35	35.85	-9.50	-21%
NH_3	HR	29.76	35.01	5.25	18%
NH_3	LT	28.85	34.03	5.17	18%
NH_3	LV	18.76	16.25	-2.51	-13%
NH_3	TR	907.00	713.32	-193.68	-21%
CO	AZ	174.43	136.67	-37.76	-22%
CO	BG	288.09	244.77	-43.32	-15%
CO	CZ	503.06	797.81	294.75	59%
CO	DK	326.99	244.03	-82.97	-25%
CO	PT	271.73	321.96	50.22	18%
CO	TR	2351.00	2002.55	-348.45	-15%

Table 3.7: Reported emission changes between 2015 (reported in 2017) and 2016 (reported in 2018) over 15% for PM.

Pollutant	Country	2015 (kt)	2016 (kt)	Diff. (kt)	Diff. (%)
$PM_{2.5}$	AZ	6.24	4.86	-1.37	-22%
$PM_{2.5}$	CY	1.00	1.32	0.32	32%
$PM_{2.5}$	CZ	23.73	39.30	15.56	66%
$PM_{2.5}$	EE	9.15	7.48	-1.67	-18%
$PM_{2.5}$	KZ	12.43	10.72	-1.71	-14%
$PM_{2.5}$	LT	17.86	6.01	-11.85	-66%
$PM_{2.5}$	LU	1.97	1.52	-0.45	-23%
$PM_{2.5}$	MK	18.89	14.22	-4.67	-25%
$PM_{2.5}$	RS	53.34	40.63	-12.71	-24%
PM_{10}	AZ	15.71	13.18	-2.52	-16%
PM_{10}	CY	1.72	2.06	0.34	20%
PM_{10}	CZ	36.41	51.53	15.13	42%
PM_{10}	EE	14.01	11.19	-2.82	-20%
PM_{10}	ES	168.16	200.17	32.01	19%
PM_{10}	GB	145.48	172.00	26.52	18%
PM_{10}	IE	23.90	29.06	5.15	22%
PM_{10}	LT	25.03	13.05	-11.98	-48%
PM_{10}	MK	28.00	21.13	-6.87	-25%
PM_{10}	RS	71.87	55.07	-16.80	-23%
PM_{10}	TR	829.00	715.45	-113.55	-14%
PM_{coarse}	BE	10.46	8.88	-1.58	-15%
PM_{coarse}	BG	21.21	15.94	-5.27	-25%
PM_{coarse}	DE	121.87	102.29	-19.58	-16%
PM_{coarse}	EE	4.85	3.70	-1.15	-24%
PM_{coarse}	ES	43.65	71.74	28.08	64%
PM_{coarse}	FI	10.16	13.51	3.35	33%
PM_{coarse}	FR	101.17	84.90	-16.27	-16%
PM_{coarse}	GB	40.71	63.04	22.33	55%
PM_{coarse}	HU	16.60	19.79	3.20	19%
PM_{coarse}	IE	9.99	13.59	3.59	36%
PM_{coarse}	IT	19.10	31.49	12.39	65%
PM_{coarse}	LU	0.05	0.74	0.69	1445%
PM_{coarse}	LV	5.68	7.78	2.10	37%
PM_{coarse}	MK	9.11	6.91	-2.20	-24%
PM_{coarse}	PL	96.55	113.66	17.11	18%
PM_{coarse}	PT	12.34	17.59	5.25	43%
PM_{coarse}	RO	38.82	30.54	-8.28	-21%
PM_{coarse}	RS	18.53	14.44	-4.09	-22%
PM_{coarse}	TR	829.00	715.45	-113.55	-14%

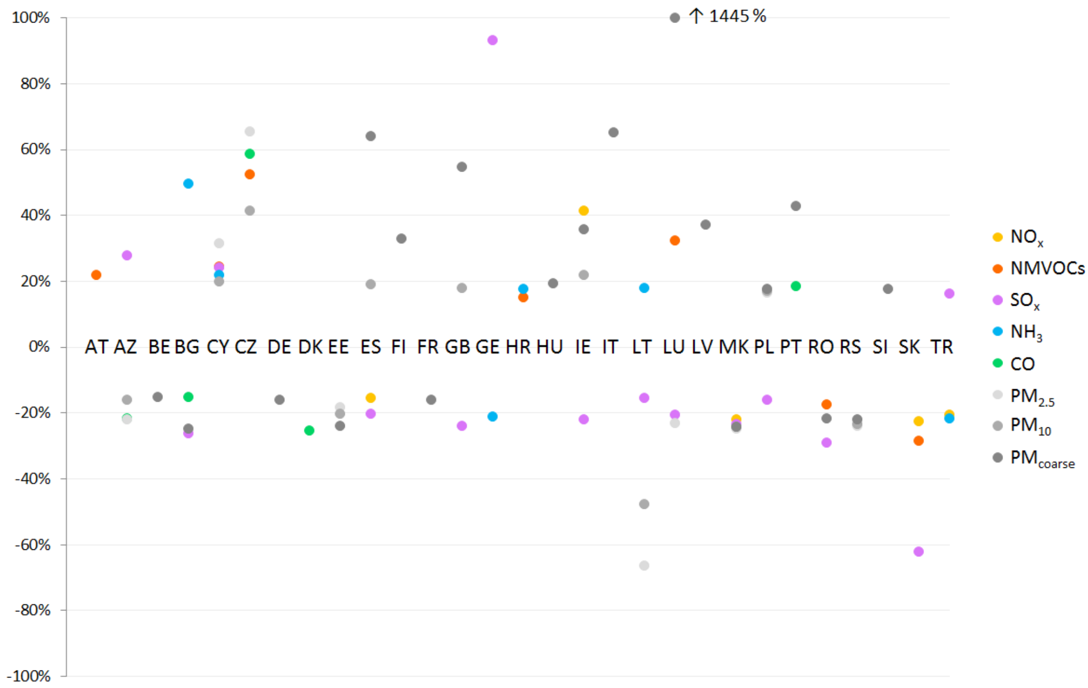


Figure 3.9: Emission changes between 2015 and 2016 in reported data (only changes larger than 15% are shown).

in 2018[12]).

For Lithuania, significant changes for $PM_{2.5}$ (-66%) and PM_{10} (-48%) originate mainly from the NFR category '1A4bi – Residential: Stationary'. These changes are caused by recalculations of the time series made by Lithuania in 2016 (for more details see the IIR of Lithuania in 2018[13]).

In Slovakia, data reveal a great change of SO_x emissions (-62%) between 2015 and 2016, mainly caused by the NFR category '1A1a – Public electricity and heat production'. These emissions originated from the source 'Slovenské elektrárne'. According to the records, this facility burnt twice the amount of brown coal in 2015 as in the previous year, and in 2016, emissions dropped again significantly (for more details see the IIR of Slovakia 2018[14]).

3.3 Data sets for modelers 2018

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

The sector data were aggregated to 13 GNFR sectors. In several cases, no data were submitted by the countries, or the reporting is not complete or contains errors. Before these emission data can be used by modelers, missing or erroneous information have to be filled in. To gap-fill those missing data, CEIP typically applies different gap-filling methods. The

[12] http://webdab1.umweltbundesamt.at/download/submissions2018/GR_IIR2018.zip?cgiproxy_skip=1
[13] http://cdr.eionet.europa.eu/lt/un/clrtap/iir/envwqqayw/
[14] http://cdr.eionet.europa.eu/sk/un/clrtap/iir/envwtcyiq/

gap-filling procedure in 2018 is fully documented in in a technical report (Technical report CEIP 01/2018), which can be downloaded from the CEIP website[15].

The countries where data were (partly) replaced in 2018 are Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Iceland, Ireland, Kazakhstan, Lithuania, Luxembourg, Malta, the Republic of Moldova, the Russian Federation, Slovakia, the Former Yugoslav Republic of Macedonia, Turkey and the Ukraine (see Appendix 3 or Technical report CEIP 01/2018).

After the gap-filling, sector emissions are spatially distributed over the EMEP grid. In 2018, data series for the years 2000 to 2016 were provided for the pollutants NO_x, NMVOCs, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10} and PM_{coarse}[16].

In cases, where data are in all probability erroneous, these data are replaced. If data in such cases will not be replaced, it is likely to get a wrong picture in the gridded maps. In 2018, data of 17 countries were (partly) replaced, including replacements of $PM_{2.5}$ and PM_{10} because of negative values for PM_{coarse}. Data for PM_{coarse} are calculated as the difference between PM_{10} and $PM_{2.5}$. In all cases, in a later step the National Totals were corrected (e.g. by the sum of the sectors).

3.3.1 Reporting of gridded data

2017 was the first year with reporting obligation of gridded emissions in the new grid resolution of $0.1°\times0.1°$ longitude/latitude. By June 2018, twenty-nine of the 48 countries which are considered to be part of the EMEP area reported sectoral gridded emissions in the new resolution. One country reported only gridded national total values (instead of sectoral data).

The majority of gridded sectoral emissions in $0.1°\times0.1°$ longitude/latitude resolution have been reported for the year 2015 (28 countries). For the year 2016, gridded sectoral emissions have been reported by three countries. Two of the three countries reported too late, which is why these data could not be used for preparing gridded emissions in 2018.

Only seven countries reported gridded emissions additionally for previous years (four countries for the years 1990, 1995, 2000, 2005 and 2010; one country for the whole time series from 1980 to 2016; one country for the whole time series from 1990 to 2015 and one country for the year 2014).

Reported gridded sectoral data in $0.1°\times0.1°$ longitude/latitude resolution, which can be used for the preparation of gridded emissions for modelers, covers less than 20% of the cells within the geographic EMEP area. For remaining areas missing emissions are gap-filled and spatially distributed by expert estimates. Reported grid data can be downloaded from the CEIP website[17].

An overview of reported gridded data available in the years 2017 and 2018 is provided in Table 3.8, while an example map of the gap-filled and gridded NO_x emissions in 2016 in $0.1°\times0.1°$ longitude-latitude resolution is shown in Figure 3.10.

[15] http://www.ceip.at/ms/ceip_home1/ceip_home/ceip_reports/
[16] http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/emissions_emepmodels/
[17] http://www.ceip.at/status_reporting

Table 3.8: Reported gridded emissions available in the years 2017 and 2018.

Country	2017	2018	Comments
Austria	2015	2015	
Belgium	2015	2015	
Bulgaria	2015	2015	
Croatia	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015	
Czech Republic	2015	2015	
Denmark	2015	2015	
Finland	2014, 2015	2014, 2015, 2016[a]	[a] Finland reported gridded emissions too late to be considered for the preparation of gridded data in 2018
France		2015	
FYR of Macedonia		2015	
Georgia		2015	
Germany	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015	
Greece		2015	
Hungary	2015[b]	2015	[b] Hungary reported gridded emissions too late to be considered for the preparation of gridded data in 2017
Ireland	2015	2015	
Italy		2015[c]	[c] Reported gridded data from Italy had to be replaced by EDGAR proxies
Latvia	2015	2015	
Lithuania	2015[d]	2015[d]	[d] Lithuania reported gridded emissions only on national total level, which could not be used for the gridding
Luxembourg	2005, 2010, 2015	2005, 2010, 2015	
Malta		2016[e]	[e] Malta reported gridded emissions too late to be considered for the preparation of gridded data in 2018
Monaco	2014, 2015	2014, 2015	
Netherlands		1990, 1995, 2000, 2005, 2010, 2015	
Norway	1990, 1995, 2000, 2005, 2010, 2015	1990, 1995, 2000, 2005, 2010, 2015	
Poland	2014, 2015	2014, 2015[f]	[f] For Poland, the spatial disaggregation of sector 'F – Road Transport' had to be replaced by EDGAR proxies
Portugal	2015	2015[g]	[g] For Portugal, the spatial disaggregation of sector 'F – Road Transport' had to be replaced by EDGAR proxies
Romania	2005	2005, 2015	
Slovakia	2015	2015	
Slovenia	2015	2015	
Spain	1990-2015	1990-2015	
Switzerland	1980-2015	1980-2016	
United Kingdom	2010, 2015	2010, 2015	

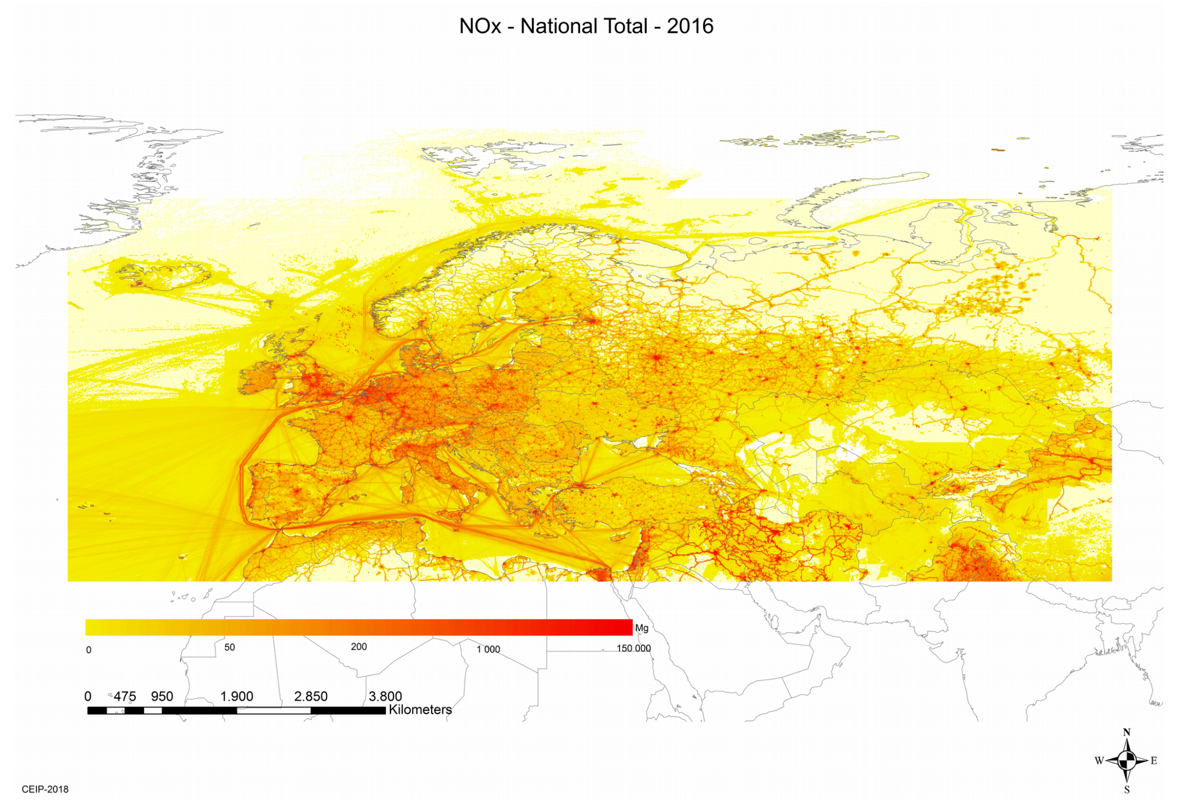


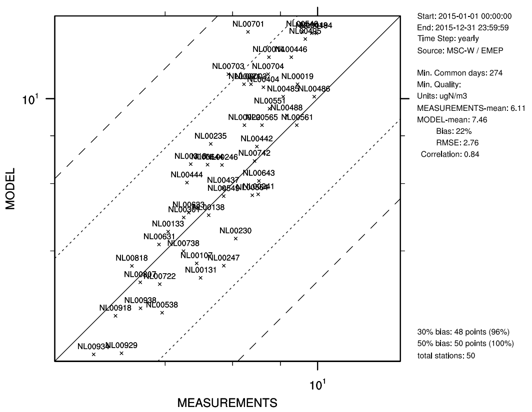
Figure 3.10: Visualized gap-filled and gridded NO_x emissions in 0.1°×0.1° long-lat resolution.

3.3.2 Model evaluation for countries that submitted gridded emissions in $0.1° \times 0.1°$ resolution for the first time in 2018

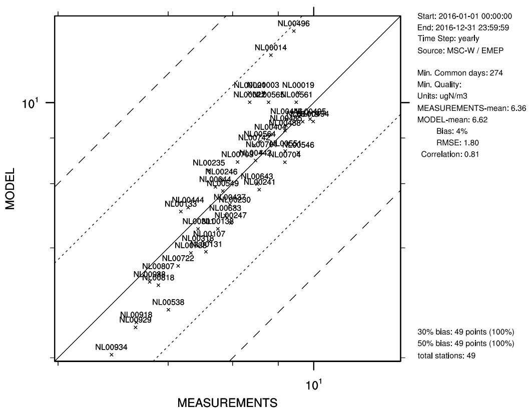
In 2017, 23 countries reported gridded emissions in $0.1° \times 0.1°$ resolution, 22 in time for being considered for the preparation of gridded data for the model runs. EMEP MSC-W model runs were performed using these new emissions and compared to model runs using emissions in the 'old' 50×50 km^2 resolution (but with the same national totals). Both sets of model runs were compared to AirBase data (excluding traffic stations). In general the model performance improved for the model runs using the finer resolution emissions, especially for NO_2 (Solberg et al. 2017).

This year, 7 additional countries reported gridded data (in addition to Hungary that reported too late in 2017). However, the data from Italy could not be used. Malta reported the gridded emissions too late to be taken into account this year. This means that in this year's model calculations, the emissions of the following countries have new gridding: France, Georgia, FYR Macedonia, Greece, the Netherlands and Hungary. For these countries, we have compared the performance of the status run for 2016 (see Chapter 2) to the performance of the model results for 2015 from last year's report. Both model data sets have been compared to AirBase observations for their respective years. Georgia did not report any measurements for NO_2 to AirBase in 2015 or 2016, and FYR Macedonia did only report NO_2 measurements for 2015, thus the comparison has been done for 4 countries.

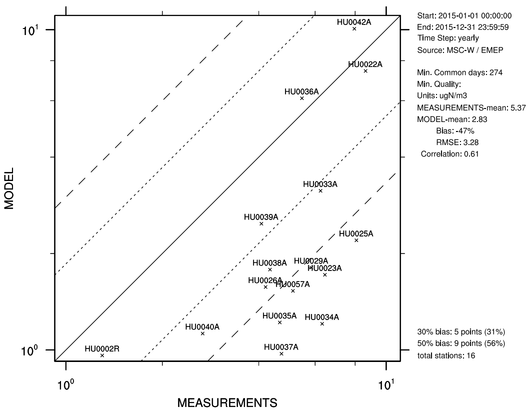
Clearly, this is not a consistent comparison, as the meteorological year is different, the national total emissions are different and the observations are different. Ideally 2016 should have been rerun with 2016 50×50 km^2 emission, or 2015 50×50 km^2 emissions. Nevertheless, the comparison indicates that for the Netherlands and Hungary, the model performance against AirBase NO_2 data is better using the new emissions (see Figure 3.11). For France and Greece, the number of measurements available in 2015 and 2016 is very different, thus it is difficult to interpret whether the new emissions improved the model results.



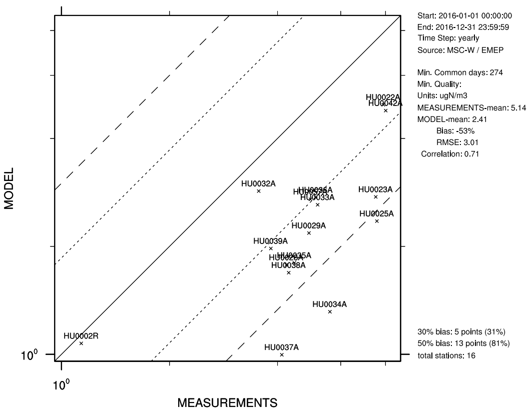
(a) Netherlands, NO_2, 2015



(b) Netherlands, NO_2, 2016



(c) Hungary, NO_2, 2015



(d) Hungary, NO_2, 2016

Figure 3.11: Model results for NO_2 ($0.1\times0.1°$) for 2015 (gridded by CEIP) and 2016 (gridded by country) versus AirBase observations for the respective years.

3.3.3 Time series from 2000 to 2016 in $0.1°\times0.1°$ longitude/latitude resolution

For this year it was agreed with the modelers to perform gap-filling and gridding for the whole time series from 2000 to 2016 in $0.1°\times0.1°$ longitude/latitude resolution on GNFR sector level.

The $0.1°\times0.1°$ GNFR grids of NO_x, NMVOCs, SO_x, NH_3, CO, $PM_{2.5}$, PM_{10} and PM_{coarse} were gridded based on the gridding system developed by CEIP. The system is module based and uses as a first step reported gridded emission data for each country and sector where it is available and usable. If no reported gridded data in the $0.1°\times0.1°$ longitude/latitude resolution is available, data from the Emission Database for Global Atmospheric Research (EDGAR) is used as proxy for spatial disaggregation, upgraded by point source information available under the European Pollutant Release and Transfer Register (E-PRTR). The system also uses data from FMI which is based on AIS tracking data for the spatial disaggregation of international shipping emissions.

Reported gridded data in 0.1°×0.1° longitude/latitude resolution was used from Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, France, Georgia, Germany, Greece, Hungary, Ireland, Latvia, Luxembourg, FYR of Macedonia, Monaco, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Switzerland and United Kingdom.

For Poland and Portugal the spatial disaggregation of sector 'F – Road Transport' had to be replaced by EDGAR proxies.

Finland and Malta reported their gridded emissions too late and therefore it could not be used for the preparation of spatial distributed emission data in 2018.

Reported gridded data from Italy had to be completely replaced by EDGAR proxies.

3.3.4 International shipping

Under this category emissions from international shipping occurring in different European seas are accounted (European part of the North Atlantic, Baltic Sea, Black Sea, Mediterranean Sea and North Sea). This year's update uses global shipping emissions from FMI (Finnish Meteorological Institute) for the year 2015 (and also for 2011 in case of NO_x and SO_x in Baltic and North Sea), based on AIS (Automatic Identification System) tracking data. For the year 2016 a copy of the FMI emission values for 2015 was used.

For historical shipping emissions the FMI data was adjusted regarding trends from data developed within the EU Horizon2020 project MACC-III (MACC-III 2015) and the ICCT Report (Olmer et al. 2017).

NMVOC emissions from international shipping have been estimated to be 10.9% of the CO emissions.

The new emission trends from international shipping in the EMEP area are shown in Figure 3.12. Due to the selective implementation of the Sulphur Emission Control Areas (SECAs) on the North Sea and Baltic Sea only, the emission trends differ between those seas and the other seas.

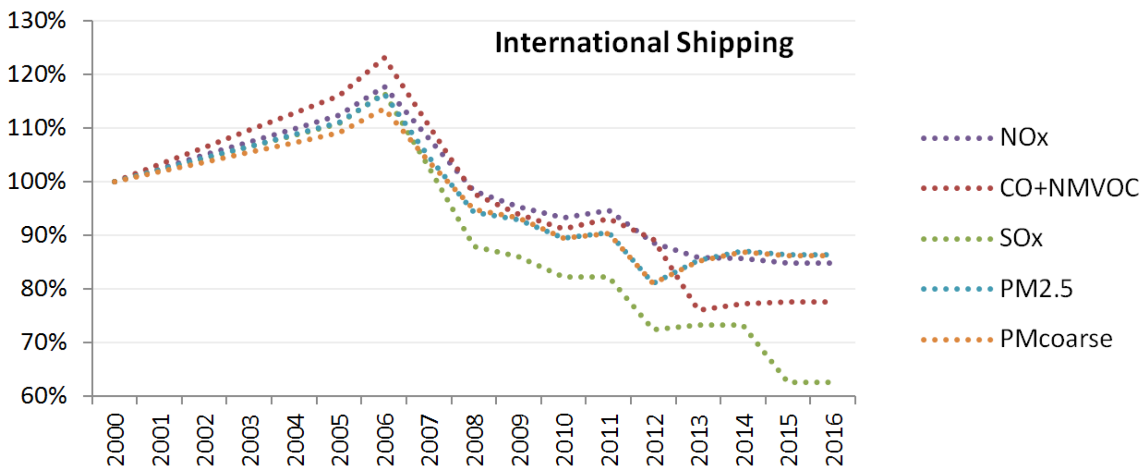


Figure 3.12: International shipping emission trends in the EMEP area based on FMI data (2015 and 2011), FMI data adjusted regarding MACC-III (2000-2011) and FMI data adjusted regarding ICCT (2012-2014).

Figure 3.13 illustrates the differences of NO_x and SO_x emissions from international shipping used until 2017 (MACC-III) and revised in 2018 (FMI data adjusted regarding MACC-III and ICCT trend) for the different sea areas.

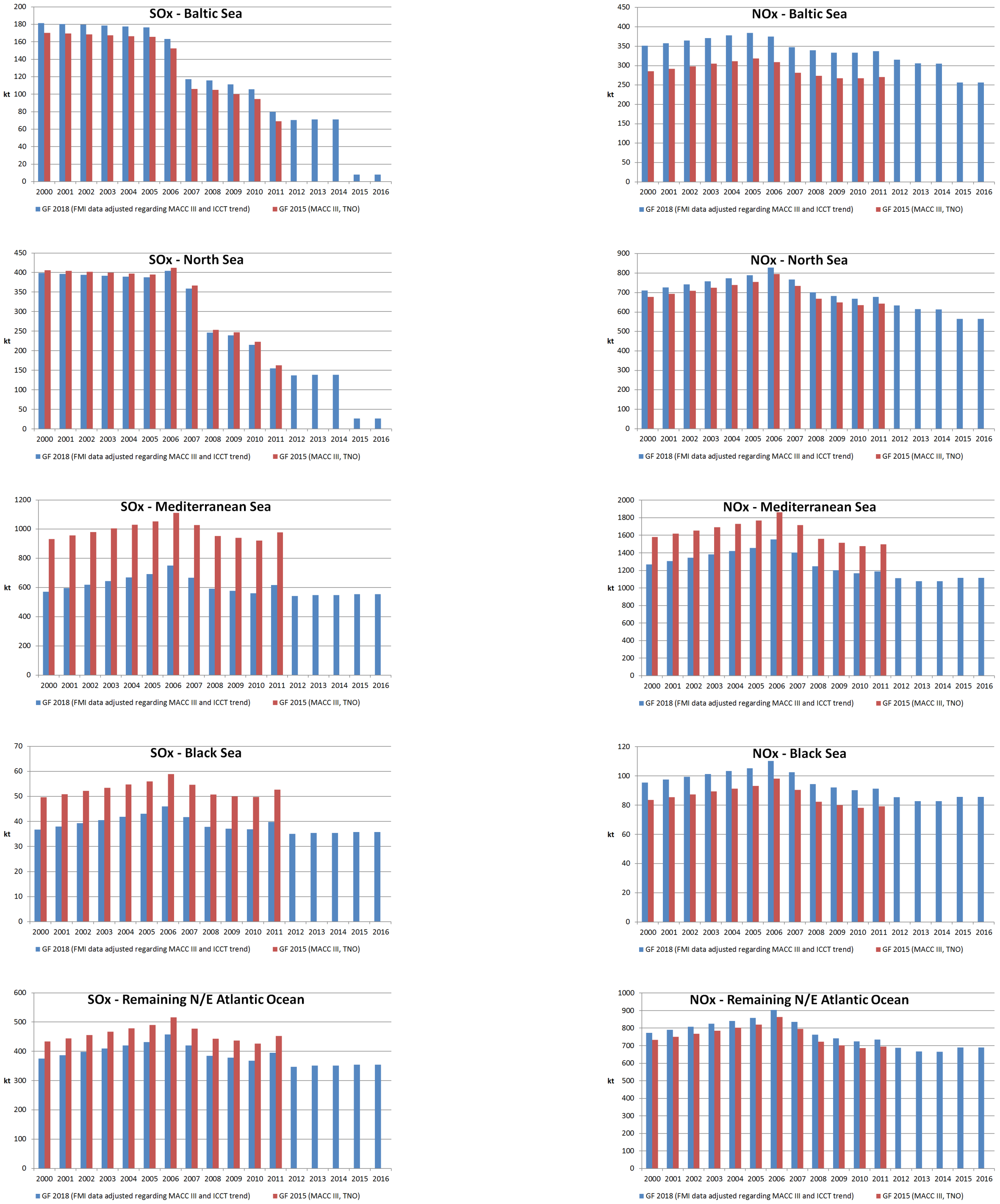


Figure 3.13: Example of comparisons between international shipping emissions used until 2017 (MACC-III) and revised in 2018 (FMI data adjusted regarding MACC-III and ICCT trend).

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CHAPTER 4

Model calculations in fine resolution for 2000-2016

Svetlana Tsyro and Augustin Mortier

The main purpose of this chapter is to introduce long-term modelling results obtained using a consistent time series for 2000-2016 of the new EMEP 0.1°× 0.1° emissions. The latest EMEP MSCW model version, set up at 0.1°× 0.1° resolution, is applied in those simulations, thus ensuring a consistent set of model results. Furthermore, we introduce a new trend interface under development at MSC-W. A profound trend analysis is beyond the scope of this chapter, still all the model data is made publically available at `www.emep.int`. The earlier EMEP TFMM trend analysis studies, performed within the Eurodelta-Trends exercise, can be found in (e.g. Colette et al. (2017); Theobald et al. (2018); and more in preparation)

4.1 Model setup

A series of runs has been performed with the EMEP MSC-W model (version rv4.17a) on the 0.1°× 0.1° grid for the period of 2000-2016. The runs were driven by ECMWF-IFS meteorology and used a consistent set of emissions provided by CEIP (see Chapter 3). Daily emissions from forest fires were from the Fire INventory from NCAR (FINN) for 2002-2016, whereas for 2000 and 2001 (unavailable from FINN), monthly averages over 2005-2015 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 the Mace Head correction has been used for ozone. 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.

4.2 Modelled and observed pollution levels for 2000-2016

Some examples of modelled annual time series and their comparison with observations are presented here. Figures 4.1 - 4.4 show annual series of pollutant concentrations in air and precipitation, averaged over a set of selected EMEP sites with appropriate data coverage over the 17-year period. The same suite of sites was used in the EMEP TFMM assessment (Colette et al. 2016), but here they are extended with data for additional years (2013-2016).

It should be noted that the number of the sites with observations are not necessarily exactly the same for each of the years, which brings some inconsistency in the shown trends (such as abrupt drops or peaks of pollutant levels in some years). This is a particular problem for PM_{10} and $PM_{2.5}$, for which just a few sites with measurements were available in 2000 and 2001, with the majority of the long term observations of these parameters starting in 2002. Thus consistent time series analysis for observations to be compared to the model results are not made. However, only the sites for which both observational and model data exist for any specific year are included in the time series plots in Figures 4.1- 4.4.

The figures show that there is a reasonable agreement between the modelled and observed 2000-2016 series of annual mean concentrations, averaged over the considered sites. The 25 and 75 percentiles, represented with shaded areas, show the spread in the modelled and observed concentrations at the considered sites.

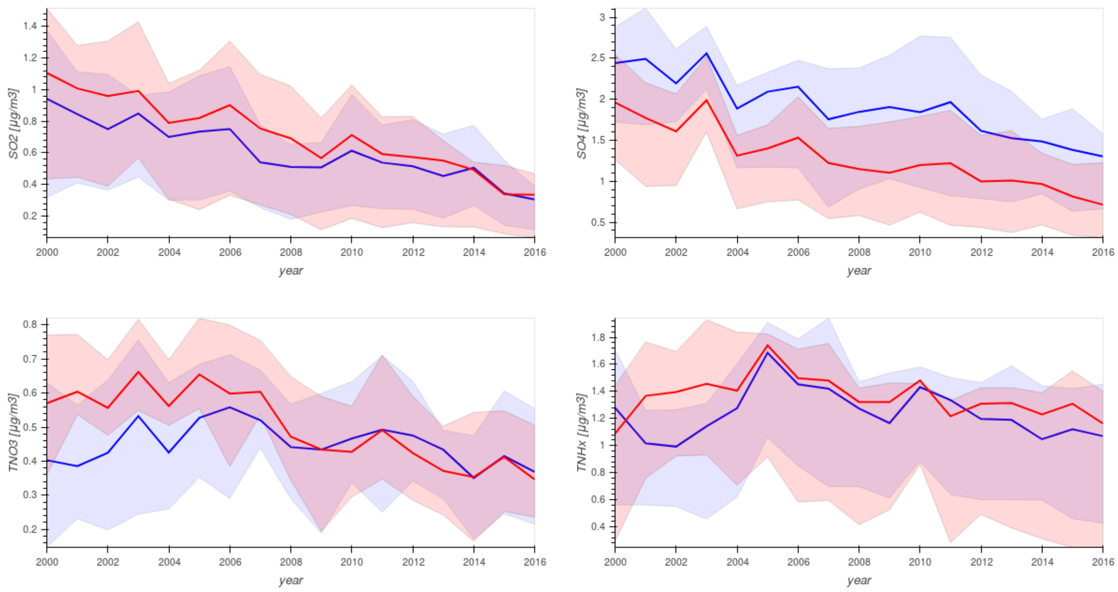

Figure 4.1: Modelled (red) and observed (blue) time series of annual mean concentrations in air for SO_2 (36 sites), SO_4^{2-} (34 sites), total NO_3^- and total NH_4 (34 sites) for the period 2000-2016. Shown are: mean concentrations (colour lines), 25 and 75 percentiles (shaded areas with corresponding colours)

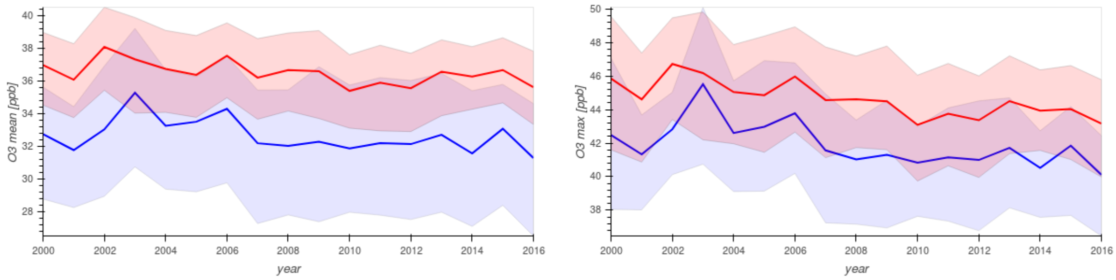

Figure 4.2: Same as in Figure 4.1, but for mean and max ozone (104 sites).

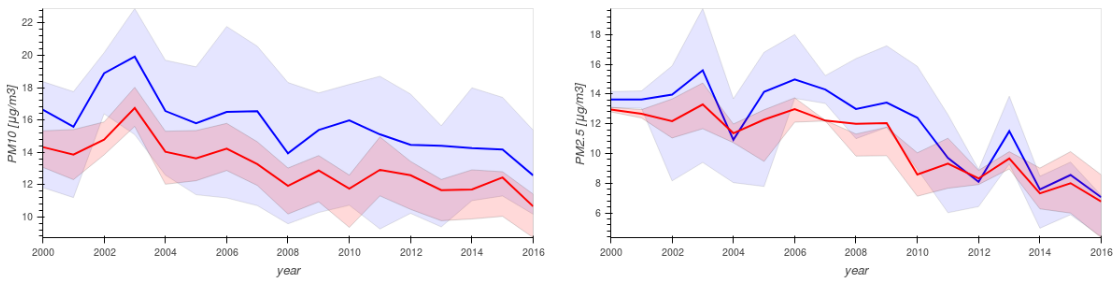

Figure 4.3: Same as in Figure 4.1, but for PM_{10} (27 sites) and $PM_{2.5}$ (17 sites).

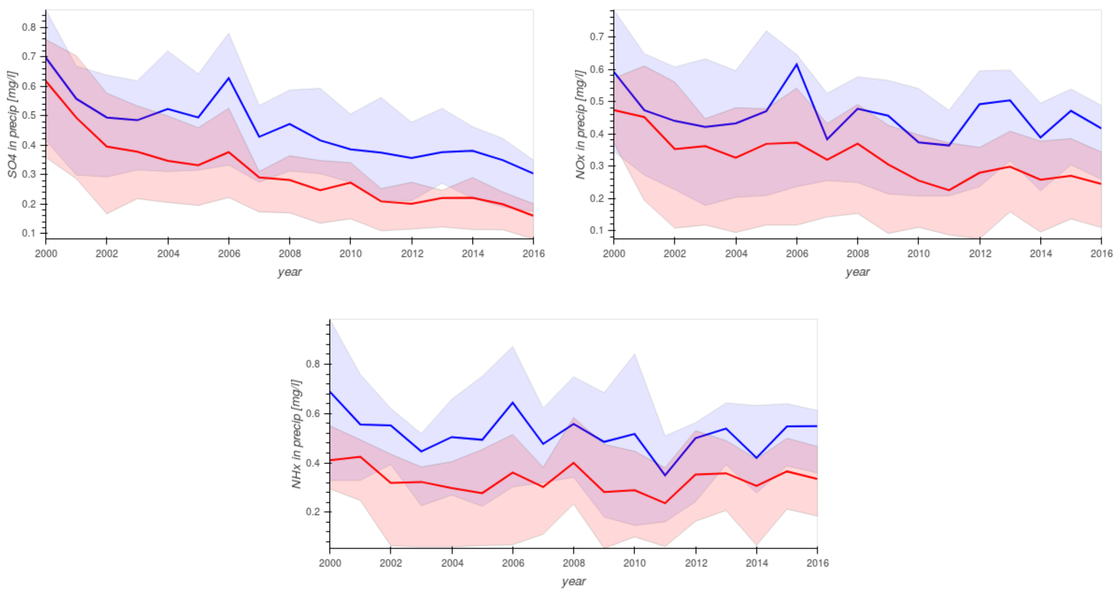

Figure 4.4: Same as in Figure 4.1, but for concentrations in precipitation of oxidised sulphur and oxidised and reduced nitrogen (64 sites).

4.3 EMEP trends interface

An online interface has been developed for the visualization of the model simulated trends (`http://aerocom.met.no/trends/EMEP/`). This tool is based on the "Aerosol Trends" development interface for the ACTRIS project, that allows the visualization of the trends for different aerosol parameters, observed or modeled, such as AOD, SO_4^{2-} deposition or aerosol number concentration (`http://aerocom.met.no/trends/index-dev.php`).

The EMEP trends interface is built in HTML/CSS and javascript and uses the highcharts visualization library. It provides a dynamic map that shows trends at all EMEP sites over Europe, as well as individual time series for each of the EMEP stations. The time series are also available for all individual countries, by averaging the concentrations over all sites within the country of interest. Note that all EMEP stations are shown in the map, meaning that not every single site has observations of all modelled components.

The overall map shows the trends at each station in three different colors: increase (red), decrease (blue) or no significant trend (green), as illustrated in Figure 4.5 for PM_{10}. The significance of the trend is determined with the Mann-Kendall test: if the p-value is smaller than 0.1, the trend is classified as significant. Then, the trend is quantified by calculating the Theil-Sen slope, which is less sensitive to the outliers than the linear regression, and converted to a relative trend (in percent per year) with respect to the first year of the series (2000 in this case).

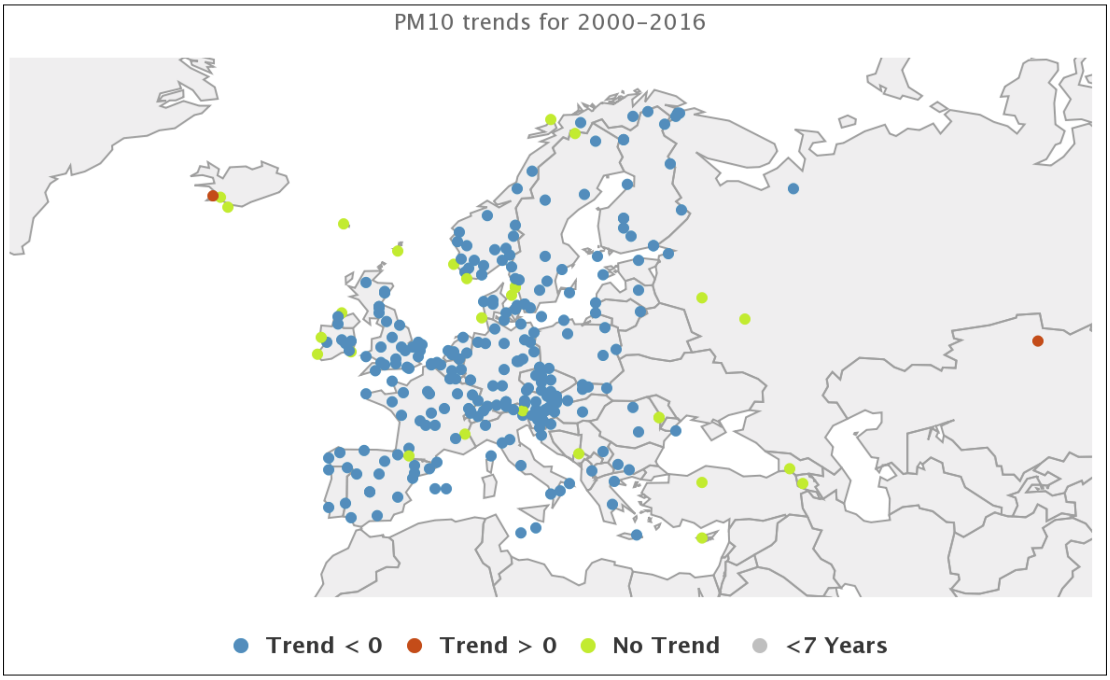

Figure 4.5: European PM_{10} trends computed at EMEP stations between 2000 and 2016.

The trend line is shown in a dynamic chart on the top of daily and monthly time series (Figure 4.6). The interface facilitates zooming-in, zooming-out, hiding/showing different elements of the chart. It also provides possibility to save the figure in various formats.

The yearly averages over all sites are also available in the bar-diagram just below the map (Figure 4.7). A click on a specific year in this window triggers a x-zoom in the previous chart, namely in Figure 4.6.

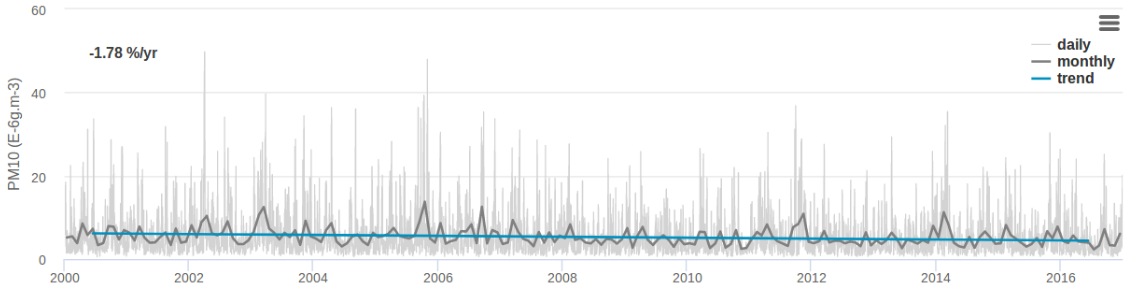

Figure 4.6: Daily and monthly total PM_{10} concentration at Birkenes between 2000 and 2016.

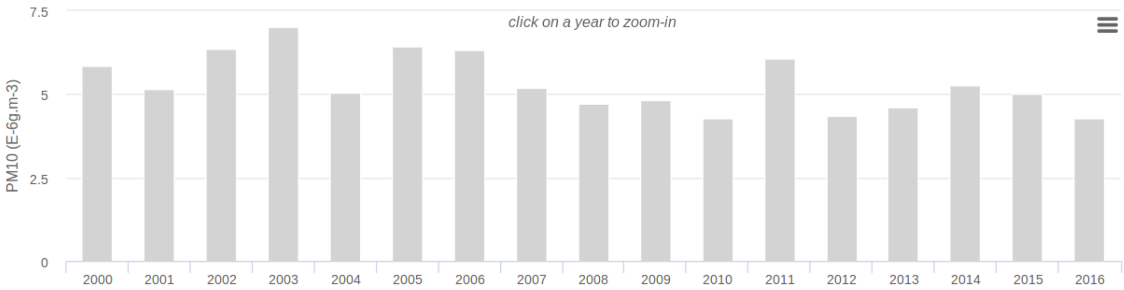

Figure 4.7: Yearly total PM_{10} concentration at Birkenes between 2000 and 2016.

The present version of the interface also allows visualization of the contribution of different species to the total PM_{10} with a stacked time series (Figure 4.8).

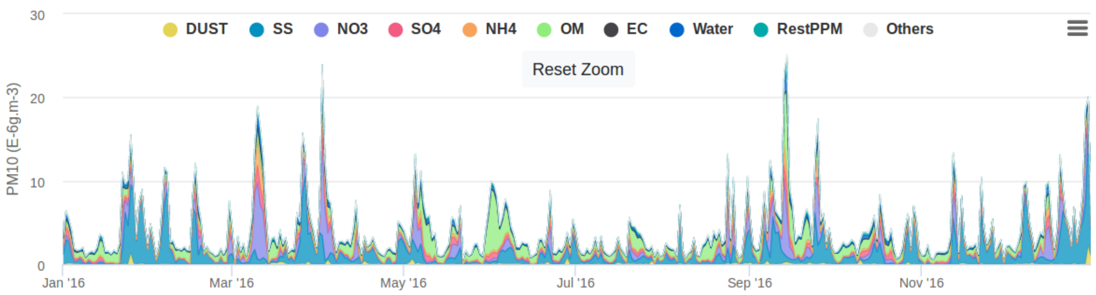

Figure 4.8: Chemical species contributing to total PM_{10} at Birkenes for the year 2016.

When the species tab on the top of the map is selected, the statistics table is replaced with a pie-chart showing the relative contribution of each species for the selected time period (Figure 4.9).

All of these charts are available both for individual station and as country averages (calculated as the average of the EMEP sites within every specific country). For now, only PM_{10} results are implemented, but the work is on-going to also incorporate other components (such as SIA aerosols, $PM_{2.5}$, SO_2, NO_2 etc.).

The interface will also be extended to include EMEP measurement data where these are available. Furthermore, we are working to include source categories in the interface. Model runs where emission sectors (traffic, industry, agriculture, residential heating) are reduced in separate runs have been performed for 2000-2016 - consistent with the setup described in 4.1. Some work remains to decide on how to interpret and visualize the results.

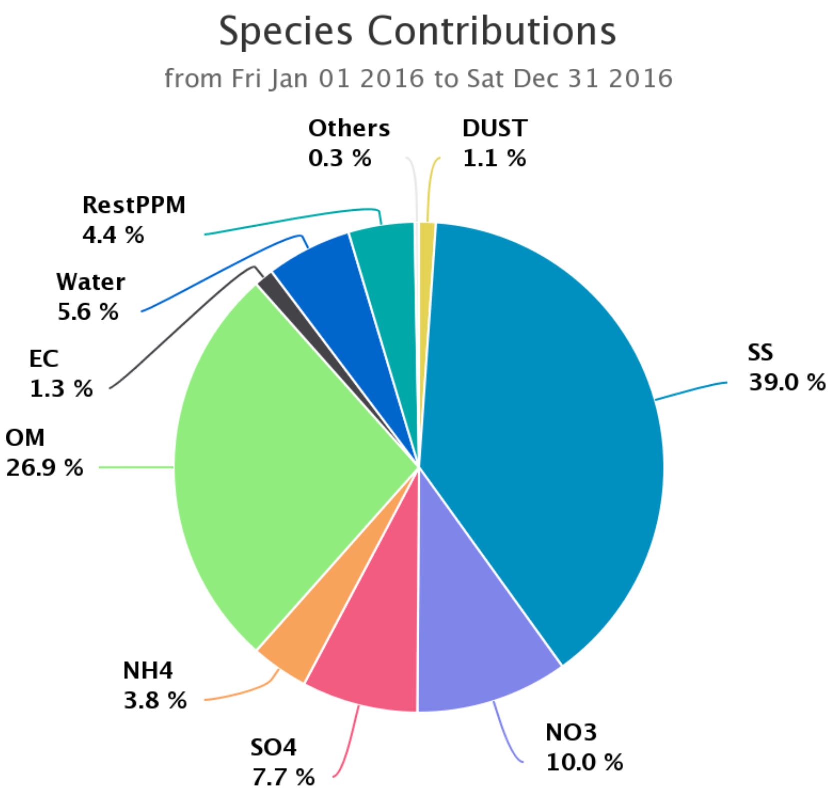

Figure 4.9: Relative contributions of the chemical species contributing to total PM_{10} at Birkenes for the year 2016.

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Part II

Research Activities

CHAPTER 5

Source receptor matrices in the new EMEP grid

Hilde Fagerli, Svetlana Tsyro, Anna Benedictow, Heiko Klein, Ágnes Nyíri and Alvaro Valdebenito

Last year it was the first time Parties to the Convention reported emissions in the new grid in $0.1^\circ \times 0.1^\circ$ resolution and longitude-latitude projection (see chapter 1.3). This year, these fine scale emissions are used in calculations of source receptor matrices (SRMs). Although status runs and trend runs are performed in the $0.1^\circ \times 0.1^\circ$ resolution (see chapter 2), it was planned from the beginning to calculate SRMs in a reduced resolution. Firstly, our assumption was that very fine resolution is less important for SRMs, as it is the country to country contribution that is most important. Secondly, a full set of SRMs in $0.1^\circ \times 0.1^\circ$ resolution requires an enormous amount of CPU hours and it would be difficult to finalize such model runs within the current timelines. (Emissions used for modelling are created by CEIP based on the reported data and delivered to MSC-W in June. In early August source receptor calculations has to be finalized and post-processed in order to present them to the Joint Session of the EMEP Steering Body and Working Group of Effects in September.)

In order to take full advantage of the high resolutions now available, we made another update at the same time: an update of the country border data set.

In this chapter we have selected some countries and analyzed (1) the effect of the choice of the resolution of the SRM calculations, and (2) how the country border data set affects the SRMs. The aim of this work was to make a choice of the resolution to be used for the SR calculations.

5.1 Experimental setup

We have performed SR calculations for 5 countries that represent different geographical parts of Europe, different sizes and different emission regimes: Bulgaria (BG), Italy (IT), The Netherlands (NL), Norway (NO) and Poland (PL).

All the calculations are performed using meteorological conditions for 2016, with 2015 emissions as they were reported last year in $0.1° \times 0.1°$ resolution (EMEP Status Report 1/2017 2017). The Mace Head correction (see Simpson et al. (2012)) for ozone boundary conditions came from a climatology, as 2016 was not yet available at that time, while other boundary conditions and forest fires were set for 2016.

Meteorological data were created in 3 resolutions: $0.1° \times 0.1°$ (0101), $0.3° \times 0.2°$ (0302) and $0.4° \times 0.3°$ (0403) longitude-latitude. The vertical levels were adapted to 20 vertical levels in correspondence with the original ECMWF meteorology, with the height of the lowest layer of approximately 50 meters. The same vertical structure has been used for all three meteorological data sets, and this is the same vertical structure which is used in the status runs throughout this report.

Emissions are interpolated on the fly to the same resolution as the meteorology, i.e. we used 3 sets of emissions (in $0.1° \times 0.1°$, $0.3° \times 0.2°$ and $0.4° \times 0.3°$ resolutions).

The EMEP MSC-W model version used here is rv4.17, which is a preliminary version of rv4.17a used for the status runs in chapter 2 (see also chapter 8). It can be noted that there have been many changes in chemistry, deposition, vertical resolution, and emissions in the current rv4.17 setup compared to the rv4.9 source receptor matrix calculations presented in EMEP Status Report 1/2016. For example, the increased NO_2 deposition rates discussed in Simpson et al. 2017 can lead to increased local-scale deposition in some regions. However, such changes are complex and beyond the scope of this chapter. Here we focus on changes associated with resolution and country border data.

For all 5 countries and 3 resolutions, 5 different reduction runs were performed (altogether 5×3×5 = 75 runs). In these 5 reduction runs, the respective country emissions of SO_x, NO_x, NH_3, NMVOC, and PPM_{fine}+PPM_{coarse} were reduced by 15%. The effect of these emission reductions on other countries have been calculated by subtracting the reduction run results from the model run with no reductions (the base run). The effect of emission reductions of the 5 different chemical compounds (SO_x, NO_x, NH_3, NMVOC, and PPM_{fine}+PPM_{coarse}) have then been added.

5.1.1 Country borders

The country borders that are used to establish how much of the emissions end up in the different countries have been updated this year. The 'old' country border data set was a manually created data set with country borders given in a 50×50km^2 polar stereographic grid. The new borders correspond to the grid definitions that CEIP has used for the emissions in the EMEP $0.1° \times 0.1°$ grid. The data source for the country borders is the ESRI maps "Europe Countries" for Europe and "World Countries 2008" for all countries/areas outside Europe (published in April 2008). The separation of the different sea areas is based on the 50×50km^2 polar stereographic grid.

5.2 Choice of model resolution for the source receptor matrices

An overview of the different data sets analyzed and their corresponding abbreviations are given in Table 5.1.

The source receptor matrices for the 3 resolutions (and different country border data) are compared in Figures 5.1 to 5.4. The contributions have been normalized, so that all contri-

Abbreviation	Model resolution	Country border resolution	Data set for country border
0101	$0.1° \times 0.1°$	$0.1° \times 0.1°$	New
0302	$0.3° \times 0.2°$	$0.3° \times 0.2°$	New
0302_0101	$0.1° \times 0.1°$	$0.3° \times 0.2°$	New
0403	$0.4° \times 0.3°$	$0.4° \times 0.3°$	New
50km_0101	$0.1° \times 0.1°$	50×50 km^2	Old

Table 5.1: Overview of the different data sets analyzed and their corresponding abbreviations.

butions are shown as relative to the total sum of contributions (except for ozone, where the absolute contribution is shown). The contribution to the country itself is presented, together with the contributions to the top 5 receptors (summed up for the 5 receptors that receive the highest contributions from that country, except the country itself. Note: it is the largest contribution in absolute numbers that is used; for ozone the contributions can be negative). In addition, the sum of the contributions to all other defined regions in the EMEP area is shown (that is: the rest of the countries plus the sea areas).

For the country-to-itself, the overall differences compared to the 0101 data set are small (see Table 5.2).

The difference only due to different resolution of the country borders of the receptor areas (Table 5.2, column 0302_0101) are in the order of 1-3%. However, differences to the results where the old country border data set is used (Table 5.2, column 50km_0101) are larger; up to 10%.

Comparing directly the 0302 and 0101 data sets using the same set of country border data, the difference is up to 11% (Table 5.2, column 0302). As expected, the difference between the 0403 and 0101 (Table 5.2, column 0403) is larger than the difference between 0302 and 0101. Overall, the smallest differences are found for depositions (only a few percent), while the differences for PM and ozone is somewhat larger.

The maximum differences between the different runs (for the 5 largest country-to-country contributions for each of the 5 countries) are also calculated (not shown). The maximum differences for the individual contributions to other countries are somewhat larger than for the country-to-itself contributions, and the largest differences are found for PM. Especially the Italy to Switzerland contribution differ between the different resolutions, up to almost

	0302	0403	0302_0101	50km_0101
S deposition	1.7 (IT)	3.0 (IT)	1.5 (IT)	8.7 (NO)
ox. N deposition	-3.1 (BG)	-2.9 (NL)	1.1 (IT)	-3.2 (NO)
red. N deposition	-1.6 (PL)	-1.5 (PL)	2.7 (NL)	8.2 (NL)
PM_{10}	-6.7 (IT)	-9.2 (NO)	1.8 (NL)	7.1 (NL)
$PM_{2.5}$	-6.7 (IT)	-9.9 (NO)	1.7 (NL)	6.4 (NL)
MAXO3_NOx	-10.9 (NL)	-10.6 (NL)	2.9 (NL)	9.7 (NL)
MAXO3_NMVOC	8.0 (BG)	10.2 (BG)	0.38 (NL)	2.7 (NO)

Table 5.2: Maximum difference (in percent) of the country-to-itself contribution due to different resolutions and country border data sets (see table 5.1). The 0101 model run is the reference. The country for which this maximum occurs is given in parenthesis.

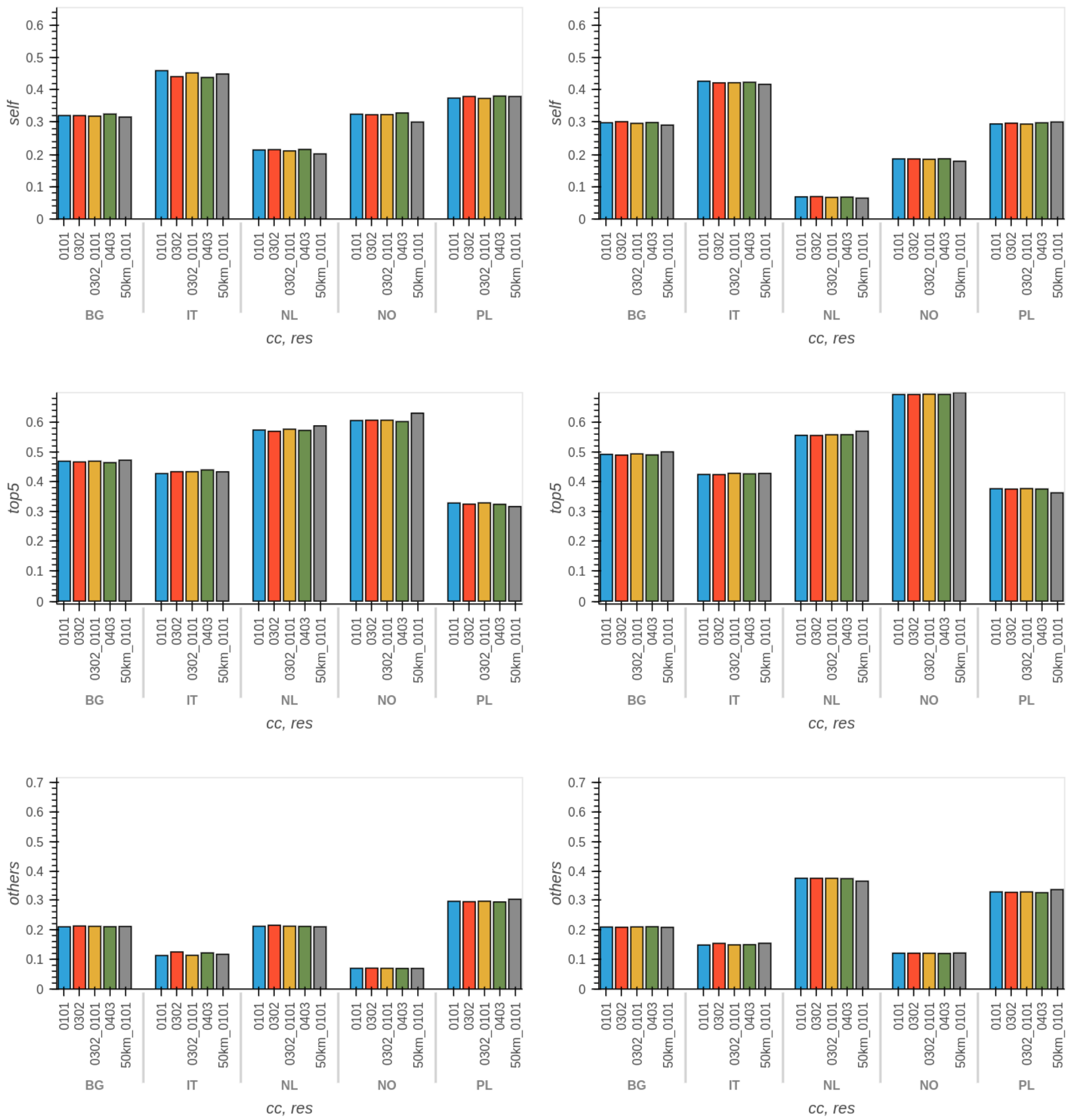

Figure 5.1: Relative contributions (based on 15% reductions) from one country to the country itself (self), to the 5 other countries receiving most of the pollution (top5) and to the rest of the countries/regions (others). Left column: oxidised sulphur deposition, right column: oxidised nitrogen deposition. The different colours define different resolutions, see table 5.1 for explanations.

30% for $PM_{2.5}$. This can probably be explained by the transport across the mountains towards Switzerland - which might be sensitive to the topography (which by definition would be better resolved in the finer resolution runs). However, this contribution is very small. Overall, the differences due to using a new country border data set is as large as the difference between 0302 and 0101, but the differences are not systematical (i.e. lower or higher). As expected, the 0302 model calculations are in closer agreement to 0101 than the 0403 model runs.

Based on these test calculations, we decided to run SRMs for 2016 in $0.3° \times 0.2°$ resolution, as the results were slightly closer to $0.1° \times 0.1°$ results than those from the $0.4° \times 0.3°$ resolution runs. The new country border data set is applied, as it is more accurate than the old $50{\times}50\text{km}^2$ data set and also consistent with what is applied for emissions by CEIP.

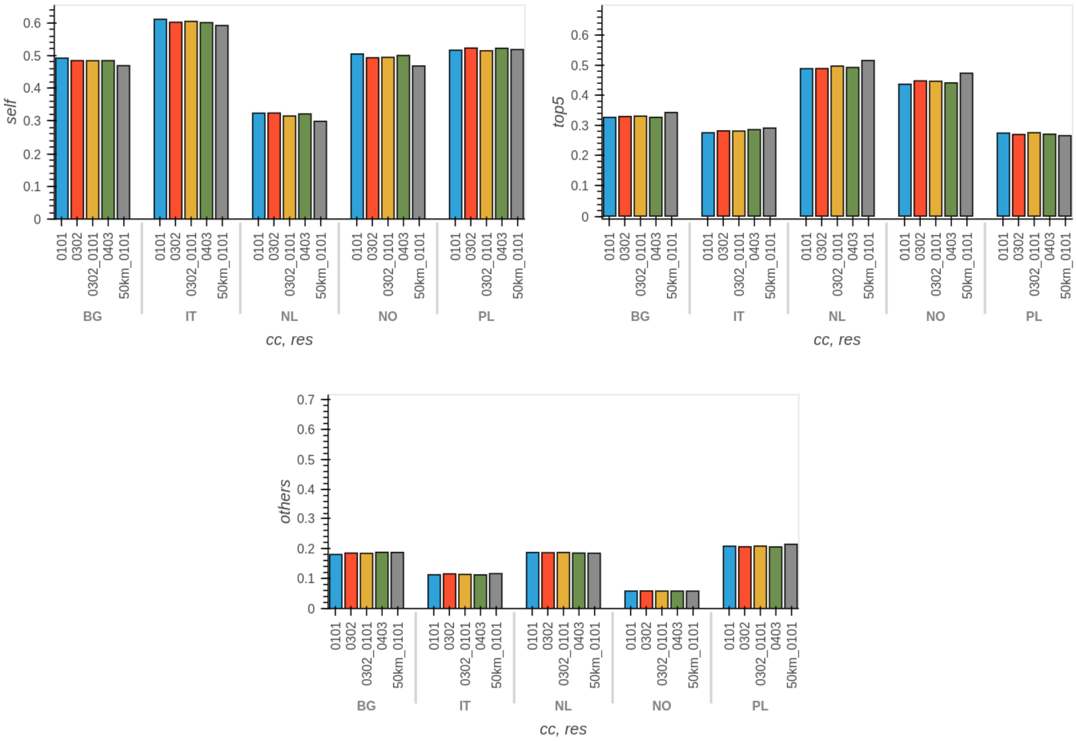

Figure 5.2: Relative contributions for reduced nitrogen deposition (based on 15% reductions) from one country to the country itself (self), to the 5 other countries receiving most of the pollution (top5) and to the rest of the countries/regions (others). The different colours define different resolutions, see table 5.1 for explanations.

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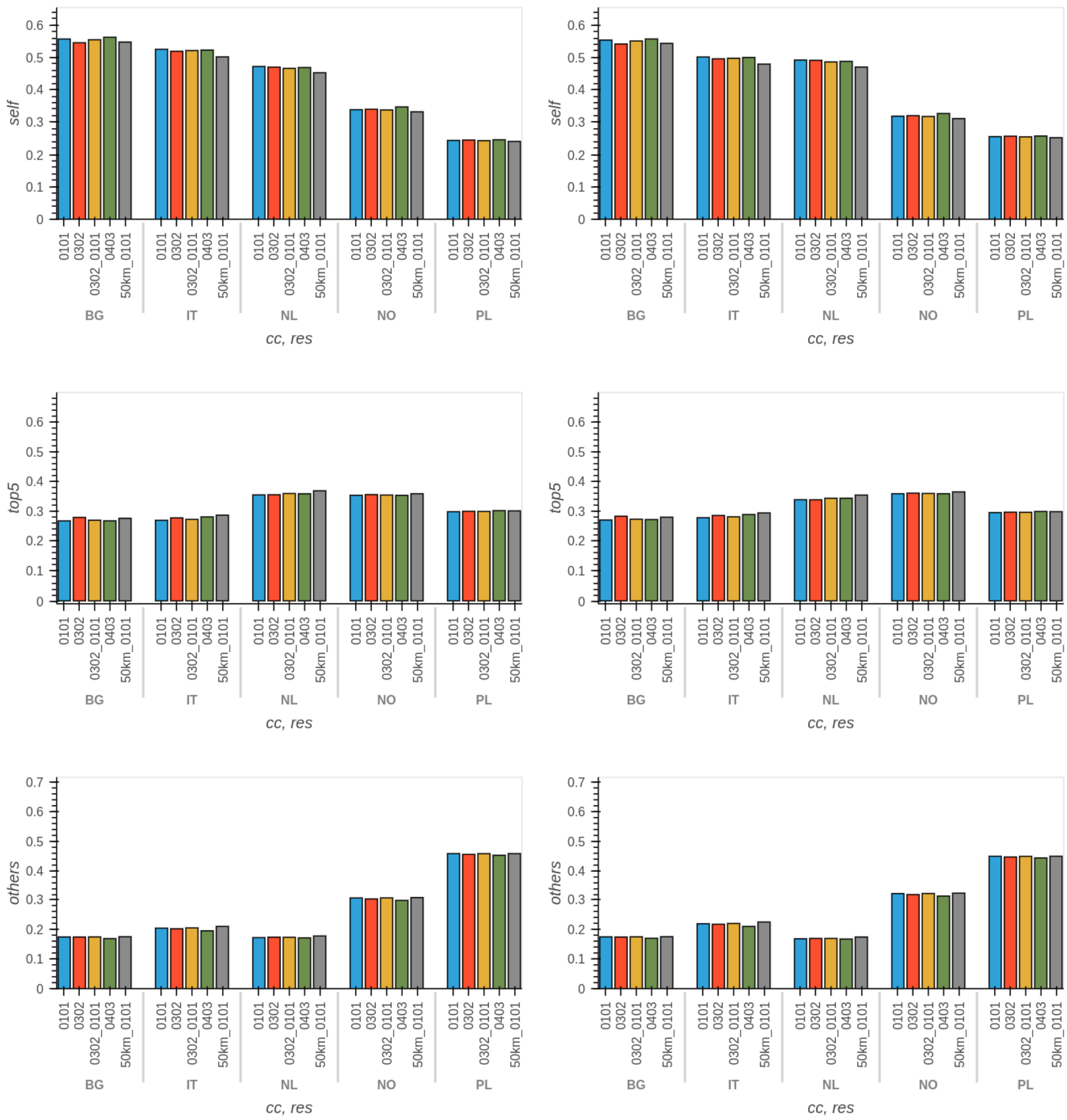


Figure 5.3: Relative contributions (based on 15% reductions) from one country to the country itself (self), to the 5 other countries receiving most of the pollution (top5) and to the rest of the countries/regions (others). Left column: $PM_{2.5}$, right column: PM_{10}. The different colours define different resolutions, see table 5.1 for explanations.

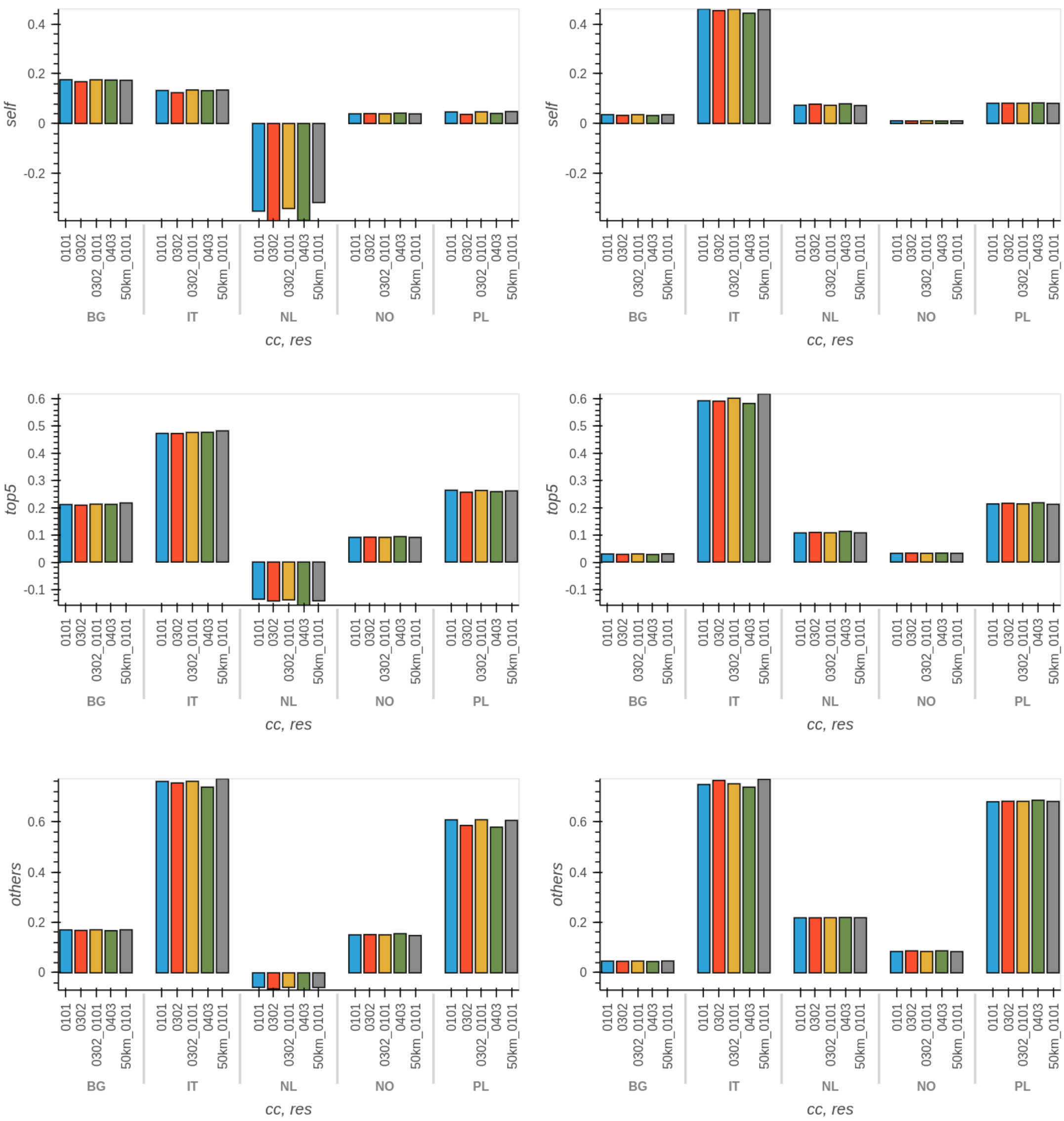


Figure 5.4: Contributions (ppb per 15% reductions) from one country to the country itself (self), to the 5 other countries receiving most of the pollution (top5) and to the rest of the countries/regions (others). Left column: Yearly average of daily maximum ozone from NO_x emission reductions, right column: Yearly average of daily maximum ozone from NMVOC emission reductions. The different colours define different resolutions, see table 5.1 for explanations.

CHAPTER 6

Effects of international shipping

Jan Eiof Jonson, Michael Gauss, Michael Schulz and Ágnes Nyíri

6.1 Background

The effects of international shipping on air pollution levels have been a subject in recent EMEP reports and papers, see Gauss and Jonson (2016), Gauss et al. (2017), Jonson et al. (2015, 2018). In Jonson et al. (2018) it was shown that the calculated contributions from European emissions to the ozone indicators SOMO35 and POD_1 forest were considerably higher than to annual mean ozone. On the other hand the calculated contributions from international shipping were similar for annual ozone and the ozone indicators. We suspected that this has to do with the location of ship emissions relative to the European continent, and that this result would vary, depending on the location of the emissions relative to the European continent. In order to test this assumption, separate source receptor relationships (SR) from global as well as from individual sea areas to European countries are calculated in this study. In addition to ozone and ozone indicators, SR relationships are calculated for $PM_{2.5}$ and depositions of nitrogen and sulphur. These results are compared to SR relationships calculated by the regional EMEP MSC-W model and reported in EMEP Status Report 1/2016 (2016), run with 2014 emissions/meteorology, and in Appendix C of this year's report, run with 2016 emissions/meteorology. Global model calculations enable us to calculate the percentage contribution of shipping to anthropogenic, and thus controllable, European pollution levels. It should be noted that these percentage contributions would be smaller if they were calculated with respect to *total* air pollution which is caused by both anthropogenic and natural (i.e. inherently uncontrollable) sources.

6.2 Emissions from shipping

Obtaining reliable data on emissions from international shipping has long been a challenge, but in recent years AIS (Automatic Identification System) positioning data have become available, continuously tracking the position of the vessels. This has resulted in substantial improvements in the reliability of the estimated ship emissions.

A number of IMO (International Maritime Organisation) and EU regulations have been implemented in recent years, or will be implemented in the near future, affecting ship emissions globally, and in European waters in particular. The most noteworthy change in the recent past is the SECA (Sulphur Emission Control Areas) regulation, limiting the sulphur content in marine fuels to 0.1% since 2015. Fuels with higher sulphur content may be used in combination with emission reduction technology reducing sulphur emission to levels corresponding to the use of low sulphur fuels. In European waters the North Sea and the Baltic Sea are designated as SECAs. These two sea areas are also designated as NECAs (NO_x Emission Control Areas) from 2021. Only gradual reductions of NO_x emissions are expected as the NECA regulation only applies to new ships or major modifications of existing ships. Furthermore, from 2020 a global cap on sulphur content in marine fuels of 0.5% will be implemented.

By courtesy of the Finnish Meteorological Institute (FMI) we have been granted access to a global ship emission data set for 2015 (Johansson et al. 2017). The implementation of these emissions in the EMEP MSC-W model was discussed in Gauss et al. (2017), comparing these emissions with previous estimates used in the EMEP MSC-W model. The same 2015 emissions are used here.

In Table 6.1 the FMI global emissions are listed for the Baltic Sea, the North Sea, the Mediterranean Sea and the Black Sea. In addition to the emissions listed in Gauss et al. (2017) the emissions from remaining sea areas outside Europe but within the EMEP domain ('Remaining Atl.'), as well as global emissions are listed. 'Remaining Atl.' corresponds to the ATL (Remaining N-E Atlantic Ocean) used in the regional SR calculations in the EMEP status report.

In the FMI 2015 emission data all PM emissions are assumed to be $PM_{2.5}$ (SO_4 is also emitted as particles). Emissions of ash are assumed to have a high content of metals with a weighted average molecular weight of 42.4, see Moldanová et al. (2009), thus making a non-negligible contribution to PM emissions by mass.

Table 6.1: Ship emissions from FMI in European sub Sea areas. Sulphur emissions are given as SO_2 and SO_4. PM emissions are sub-divided into Ash, EC and OC, all assumed emitted as $PM_{2.5}$.

	Sulphur Gg SO_2		**NOx** Gg NO_2	**CO** Gg CO	**$PM_{2.5}$** see caption		
	SO_2	SO_4			Ash	EC	OC
Global	9349	560	19571	1398	91	124	313
Remaining Atl.	478	28	996	73	4.7	6.5	16
Baltic Sea	10.3	0.8	321	22	1.5	2.0	5.0
North Sea	23.8	1.5	695	51	3.4	4.7	11.9
Mediterr. Sea	675	40	1353	94	6.4	8.8	22
Black Sea	68	3.9	172	13	0.9	1.2	3.0

6.3 Model results

The calculations have been made with the global EMEP rv4.14 version on a 0.5×0.5 degrees resolution for 2015. Land based 2015 emissions are from ECLIPSE version 5a. Traditionally the SR relationships calculated with the regional EMEP MSC-W model have been calculated reducing the emissions from the source regions (countries) separately for different species, or combination of species. Here we have taken a simpler approach reducing emissions in the sea areas by 15% for all species at the same time. We have also combined the North Sea and the Baltic Sea (both SECA areas) into one source area. Similarly, we have combined the Mediterranean Sea and the Black Sea. As it takes some time for the global model to adjust, the model simulations are preceded by a 5-month spin-up. The global model runs in this study are:

- Base: Model run with all emissions. Spin-up as Base.
- SR All: Model run with all anthropogenic emissions reduced by 15%. Spin-up as SR All.
- SR AllSh: Model run with all ship emissions reduced by 15%. Spin-up as SR AllSh.
- SR BALNOS: Model run with all ship emissions in the North Sea and the Baltic Sea reduced by 15%. Spin-up as Base.
- SR MEDBLS: Model run with all ship emissions in the Mediterranean Sea and the Black Sea reduced by 15%. Spin-up as Base.
- SR ATL: Model run with all ship emissions in the N-E Atlantic reduced by 15%. Spin-up as Base.

The motivation for the SR All model run is to relate the effects of ship emissions to the total global anthropogenic contributions to air pollution. The effects of global shipping and the effects of the individual sea areas are calculated subtracting the SR runs from the Base model run. For sea areas close to Europe the time lag for emission changes in these sea areas to affect European receptors is short, justifying the use of the spin-up from the Base run here. This is the same assumption also used in the regional source receptor calculations in Appendix C, where all model runs start from the same initial conditions.

Here we calculate the percentage contributions from shipping globally and in different sea areas relative to the global antropogenic contribution by letting Base - SR All represent 100% of the anthropogenic contribution. Thus the anthropogenic percentage contributions from shipping can be calculated as:

$$\frac{Base - SR\,x}{Base - SR\,All} \times 100$$

where SR x can be SR BALNOS, SR MEDBLS, SR ATL or SR AllSh. Below we also compare the source receptor relationships from shipping to selected countries calculated by the global model to previous (EMEP Status Report 1/2016 2016) and this year's (see Appendix C) regional model calculations. Differences in source receptor relationships can be caused by several factors such as interannual meteorological variability, model resolution and emissions. In particular ship emissions for 2014 differ substantially from 2015/2016 as documented in Gauss et al. (2017).

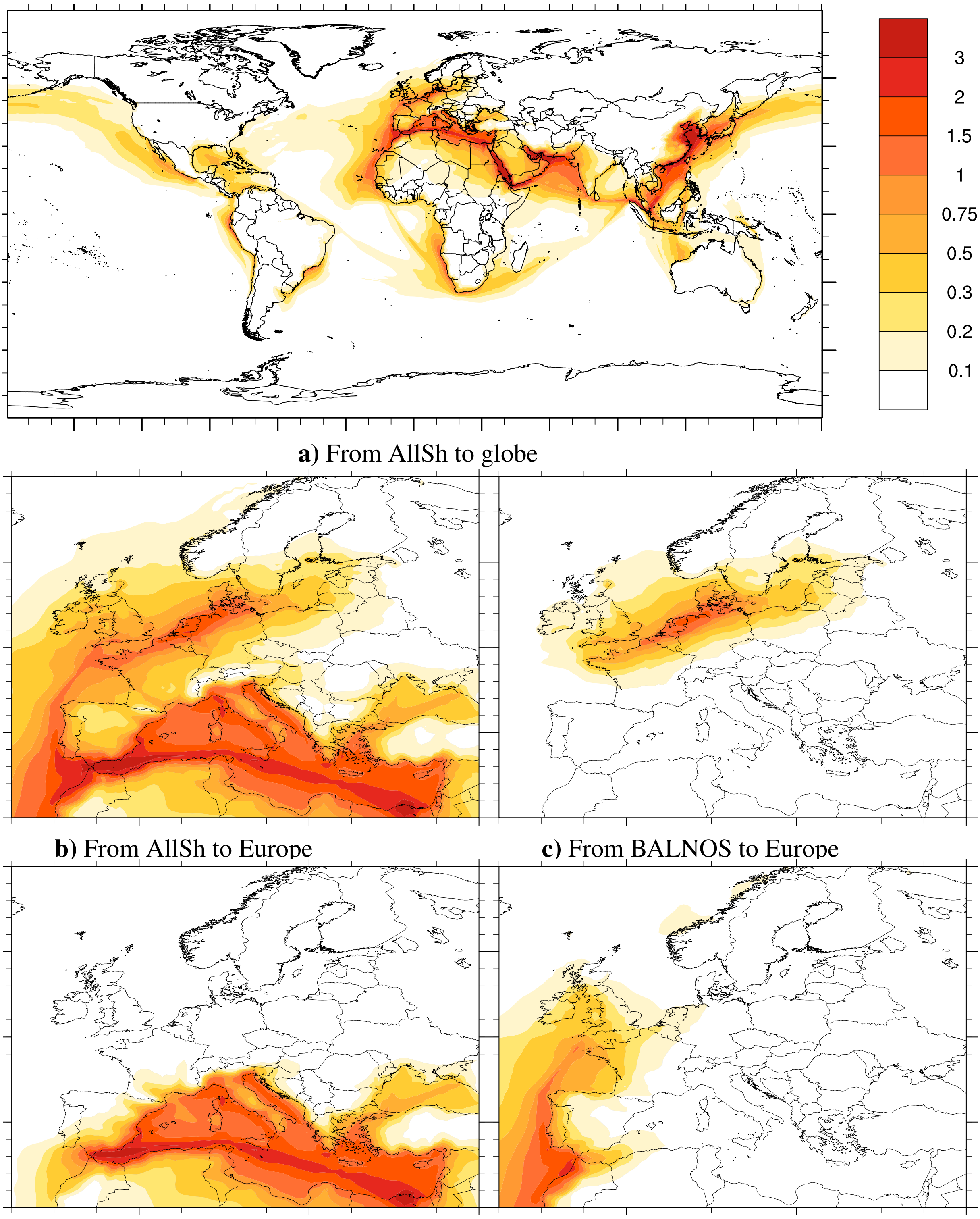
The effects of emissions from shipping on $PM_{2.5}$ from all ships (SR AllSh) and from the sea areas outside Europe (SR BALNOS, SR MEDBLS, SR ATL) on Europe are shown in Figure 6.1, supplemented by Figure 6.2a showing the percentage contributions from shipping in different sea areas to European countries relative to the global antropogenic contribution. The full length of the black bars in Figure 6.2a represents the total percentage contributions from shipping. The difference in the total length of the black bar and the stacked bars from other sea areas is a combination of ROW (Rest Of the World) shipping and non-linearities in the calculations. The largest effects from shipping are calculated for countries/regions bordering the Mediterranean Sea and the North Sea. The countries bordering the Mediterranean Sea have virtually no contributions from shipping outside the Mediterranean, whereas countries bordering other sea areas may have sizeable contributions (in percentage terms) also from more distant sea areas, as exemplified by the contributions from SR ATL to the Netherlands and Belgium. In Table 6.2 the contributions from ship emissions to $PM_{2.5}$ in European countries based on the global 2015 calculations (GL15) are compared to source receptor relationships for 2014 (EMEP Status Report 1/2016 2016) and for 2016 (extracted from Appendix C). The relative decreases in contributions from shipping to countries bordering the North Sea and the Baltic Sea between 2014 and GL15/2016 are much smaller than the decrease in sulphur emissions following the implementation of SECA, reflecting that $PM_{2.5}$ is also formed from NO_x as well as being emitted directly. For most countries the effects of ships is larger in the GL15 compared to the 2016 calculation. Source receptor relationships for different meteorological years will differ even if emissions are unchanged. Even so, parts of these differences may be caused by the coarse resolution in the global calculation.

The effects on European ozone levels of emissions from shipping from SR AllSh and from the sea areas outside Europe are shown in Figure 6.3. The largest effects are calculated for the North Sea region with ozone reductions, but also in and around the Mediterranean Sea where ship emissions result in an increase in ozone. In the North Sea region there are large emissions from land based sources as well, so that additional emissions from ships result in local ozone loss by NO_x titration. In and around the Mediterranean Sea high NO_x emissions occur in an environment with more sunlight and a NO_x to VOC ratio favourable for ozone production. This is also illustrated in Figures 6.2b (SOMO35) and 6.4a,b (annual average O_3 and POD_1 forest respectively) showing the percentage contributions from shipping in the sea areas relative to the global antropogenic contribution (SOMO35 and POD_1 forest are defined in section 1.2). As for $PM_{2.5}$ we let Base - SR All represent 100% of the anthropogenic contribution, but given the strong non-linear ozone chemistry, percentage contributions from individual sea areas are not added up, but displayed as separate bars. For several countries bordering the North Sea and the Baltic Sea (NO_x) emissions result in negative contributions to SOMO35. For Belgium and the Netherlands the resulting SR AllSh effects of ship emissions on ozone are negative for annually averaged ozone and for the two ozone indicators SOMO35 and POD_1 forest. In particular for countries bordering the Mediterranean countries ship emissions result in higher ozone levels. Ship emissions from distant sources relative to the European mainland as ATL (as well as ROW) result in higher ozone for all countries. This is also shown in the source receptor relationships listed in Table 6.3.

The percentage of the anthropogenic depositions of total sulphur and nitrogen originating from ship emissions are shown in Figure 6.5a,b. In particular for countries bordering the Mediterranean Sea a large percentage of the anthropogenic depositions are caused by ship emissions. Furthermore the calculated depositions here are almost entirely attributed to Mediterranean and Black Sea emissions. Also for countries bordering the North Sea and the

Table 6.2: Source receptor relationships for $PM_{2.5}$ from shipping (all emitted species) as calculated by the global model and as reported for year 2014. **Glob** is the contribution from all global shipping, **NOS + BAS** from the North Sea and Baltic Sea combined, **MED + BLS** the Mediterranean Sea and Black Sea combined and **ATL** is the North Atlantic. GL15 is from the global model calculations, 2014 is from EMEP Status Report 1/2016 (2016) and 2016 from Appendix C in this report. Only countries where shipping exceeds 5% of the antropogenic contribution are included here. Units: ng/m^3 per 15% emission reduction.

	Glob	**NOS + BAS**			**MED + BLS**			**ATL**		
Country	GL15	GL15	2014	2016	GL15	2014	2016	GL15	2014	2016
	Countries bordering the Baltic Sea									
EE	29	25	31	24	1	0	0	2	2	1
FI	10	8	13	8	0	0	0	2	2	2
DK	124	110	179	127	1	1	0	9	11	6
SE	19	15	27	17	0	0	0	3	3	3
	Countries bordering the North Sea									
BE	181	120	115	87	7	6	3	25	27	15
DE	108	76	68	52	4	5	2	10	10	5
LU	103	54	52	36	7	1	3	15	17	9
NL	255	198	193	155	6	5	2	23	27	16
NO	9	3	10	7	0	0	0	5	5	4
GB	75	37	56	48	1	1	1	34	43	27
	Countries bordering the Mediterranean Sea									
CY	197	1	0	0	194	209	112	1	1	0
ES	105	3	3	2	71	59	47	31	29	22
IT	145	3	1	1	136	123	88	3	3	2
FR	93	35	41	33	23	22	13	27	29	17
GR	116	1	0	0	113	122	74	1	1	1
MT	383	1	2	1	376	393	323	4	3	3
	Countries bordering the North Atlantic									
IE	62	23	17	21	1	0	0	36	54	32
IS	4	3	0	1	0	0	0	4	6	3
PT	112	1	2	1	22	10	14	87	93	57



a) From AllSh to globe

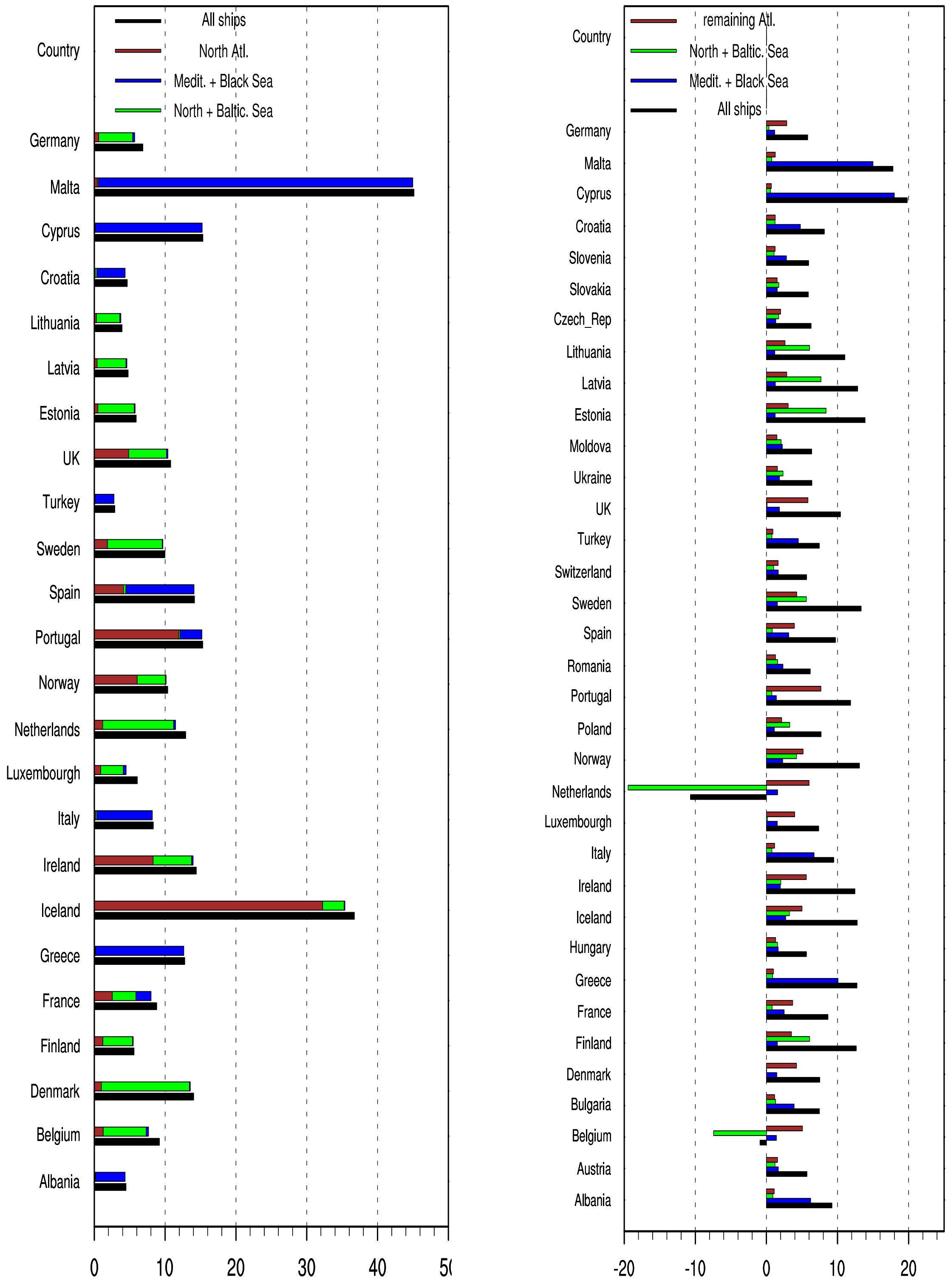
b) From AllSh to Europe

c) From BALNOS to Europe

d) From MEDBLS to Europe

e) From ATL to Europe

Figure 6.1: Percentage reduction in $PM_{2.5}$ that would result from a 15% reduction in the emissions of all emitted species from global shipping (a,b), and from the North Sea and the Baltic Sea (c) from the Mediterranean Sea and the Black Sea (d) and from the North Atlantic (e)



a) $PM_{2.5}$ **b)** SOMO35

Figure 6.2: Percentage contributions from shipping to $PM_{2.5}$ (left) and to SOMO35 relative to all global antropogenic emissions. For $PM_{2.5}$ the total length of the bars is the contribution from all shipping assuming linearity. For SOMO35 the contributions from all ships and from the individual sea areas are shown as separate bars. Contries with less than 5% contributions from shipping are not shown.

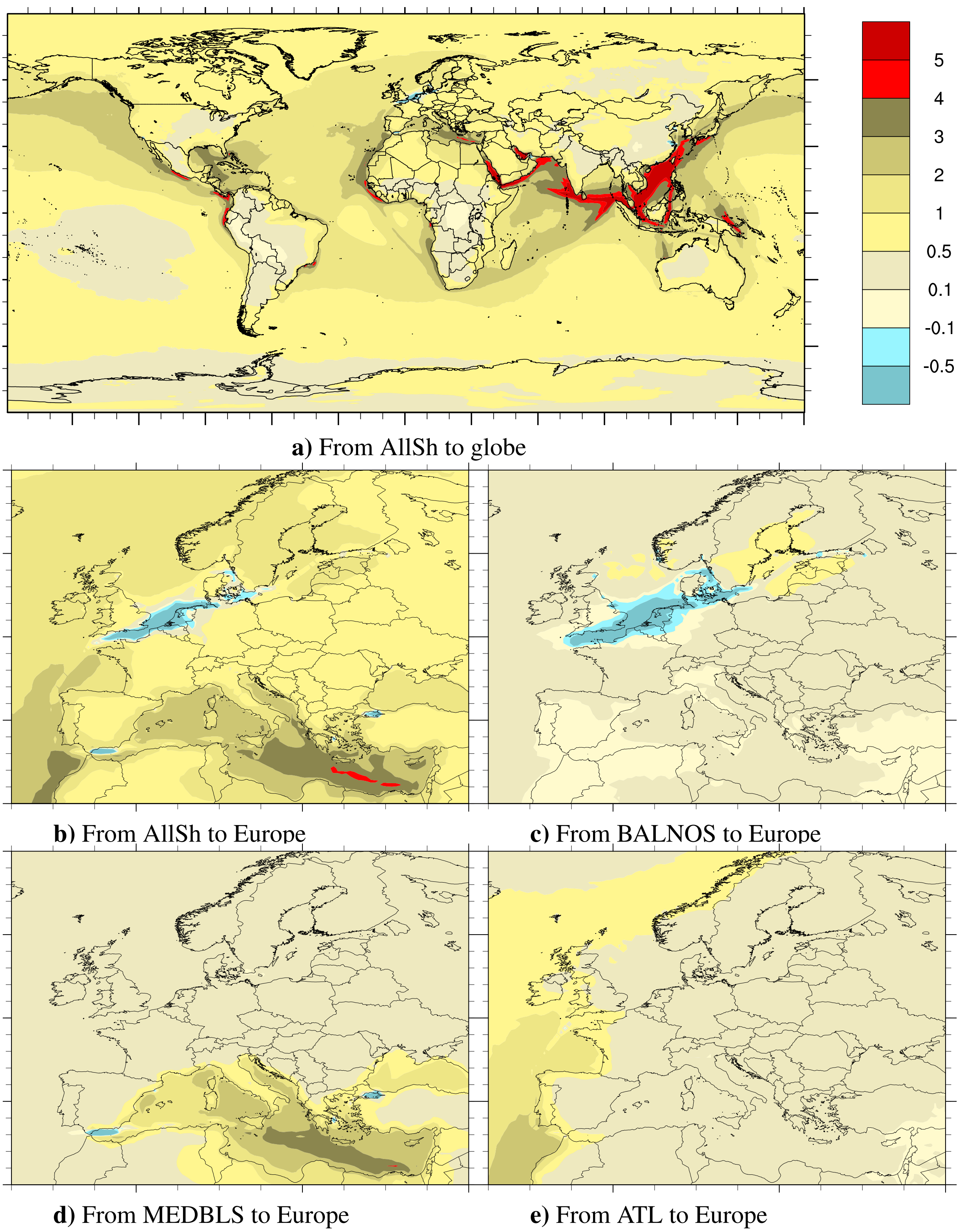
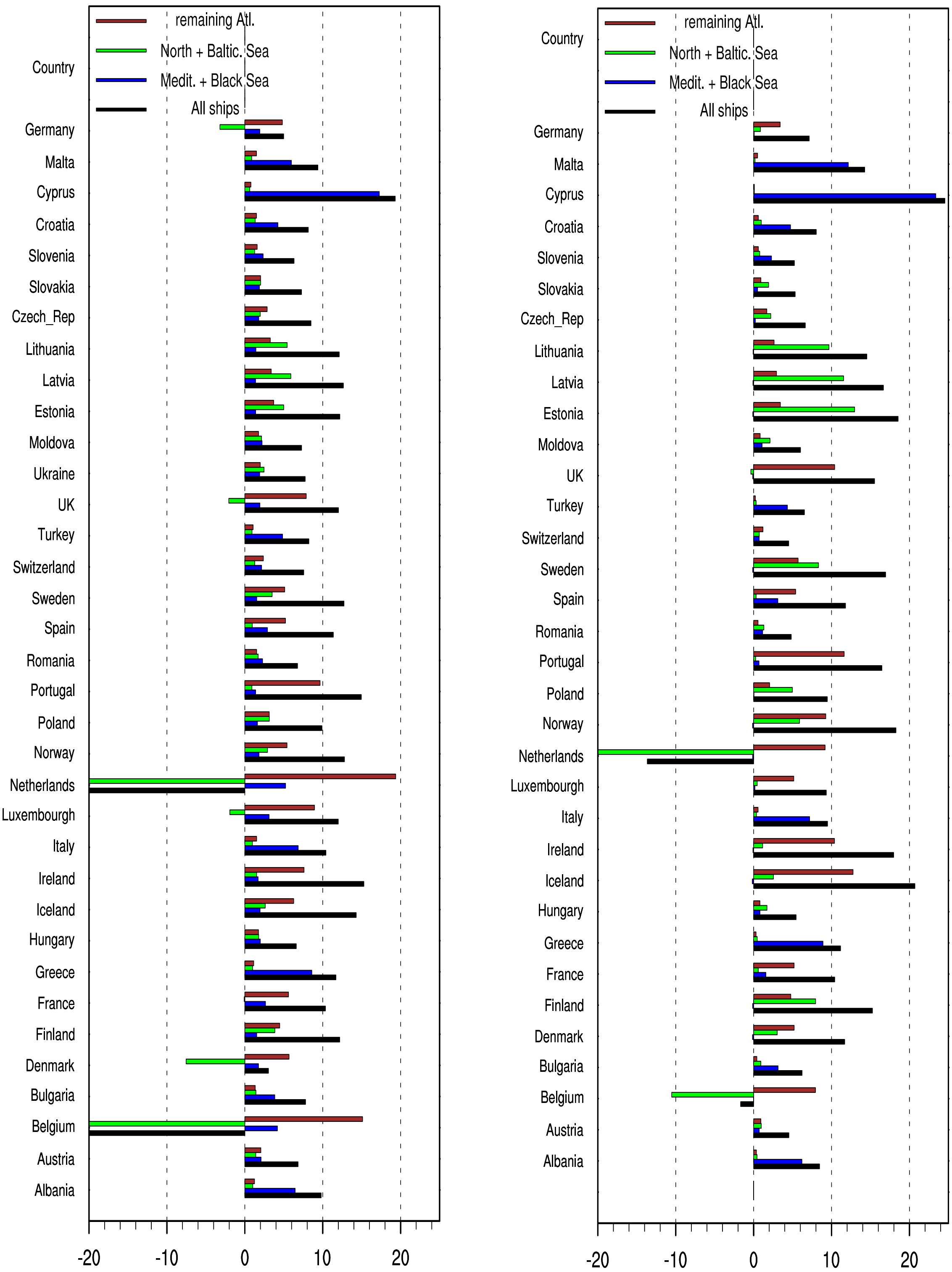


Figure 6.3: Percentage reduction in SOMO35 that would result from a 15% reduction in the emissions of all emitted species from global shipping (a,b), and from the North Sea and the Baltic Sea (c) from the Mediterranean Sea and the Black Sea (d) and from the North Atlantic (e)

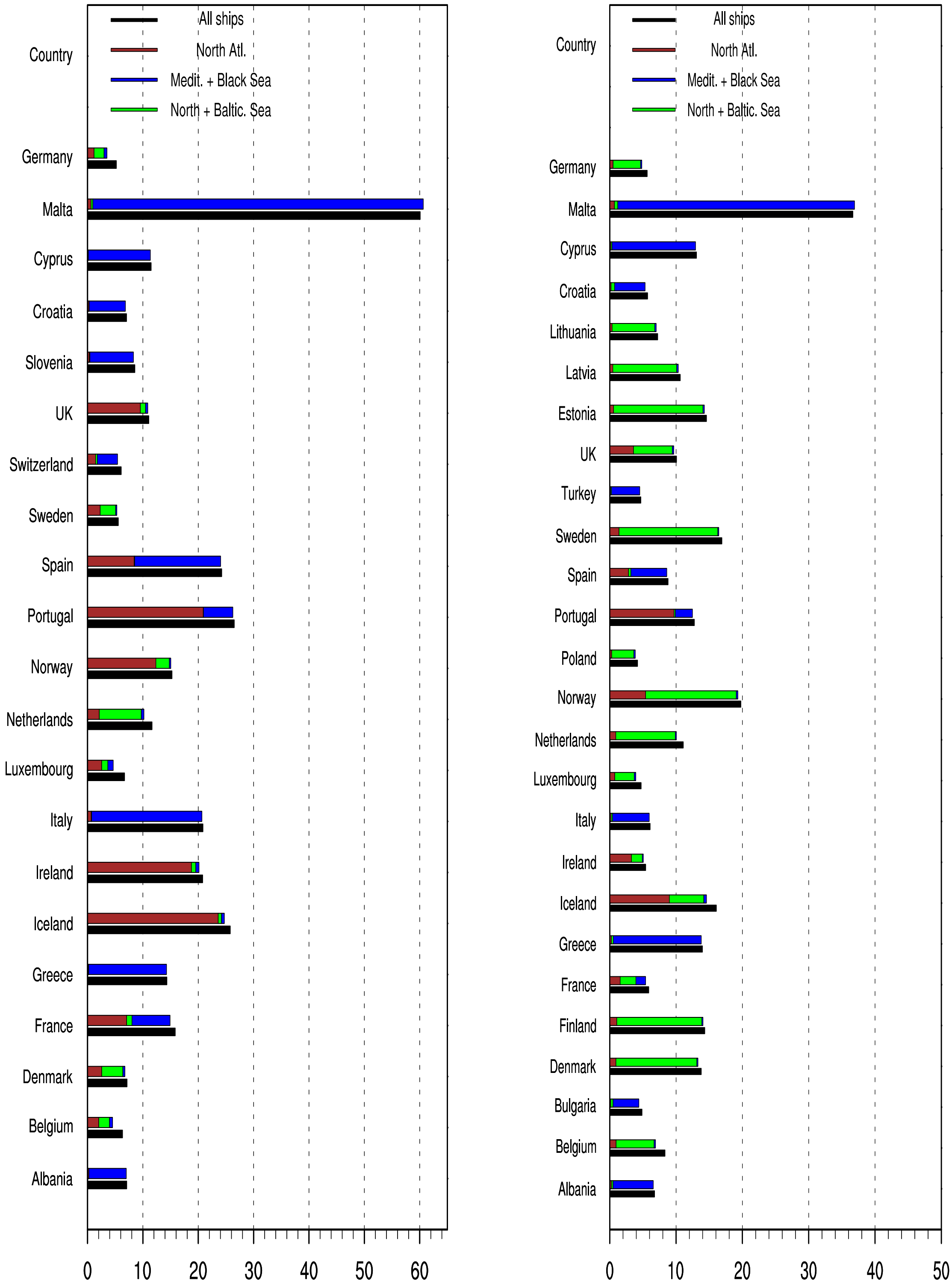


a) Annually averaged O_3 **b)** POD_1 forest

Figure 6.4: Percentage contributions from shipping to annually averaged O_3 (left) and POD_1 forest (right) relative to all global antropogenic emissions. The contributions are shown for all ships and for ships in different sea areas. The percentage contributions of annual average ozone to the Netherlands are -101% from the North Sea and Baltic Sea combined and from all ships -80%. For Belgium the percentage from the North Sea and Baltic Sea is -32% and from all ships 21%. Contribution to POD_1 forest in the Netherlands from the North Sea and Baltic Sea combined is 27%.

Table 6.3: Source receptor relationships for SOMO35 from shipping (all emitted species) as calculated by the global model and as reported for year 2014 and for 2016. **Glob** is the contribution from all global shipping, **NOS + BAS** from the North Sea and Baltic Sea combined, **MED + BLS** the Mediterranean Sea and Black Sea combined and **ATL** is the North Atlantic. GL15 is from the global model calculations, 2014 is from EMEP Status Report 1/2016 (2016) and 2016 from Appendix C in this report. Only countries where shipping exceeds 5% of the antropogenic contribution are included here. Units: ppb.days per 15% emission reductions.

	Glob	**NOS + BAS**			**MED + BLS**			**ATL**		
Country	GL15	GL15	2014	2016	GL15	2014	2016	GL15	2014	2016
Countries bordering the Baltic Sea										
EE	50	30	4	22	4	0	1	11	3	4
FI	34	16	3	12	4	0	0	10	3	4
DK	27	0	-13	7	5	0	0	15	9	6
LV	47	28	5	19	5	0	1	10	3	4
SE	42	18	2	12	5	0	0	13	5	6
PL	33	14	3	10	5	2	1	9	4	4
Countries bordering the North Sea										
BE	-3	-21	-14	-11	4	2	1	15	10	7
DE	25	2	-2	1	5	2	1	12	7	6
LU	25	0	-2	-1	5	2	2	13	9	6
NL	-27	-50	-27	-20	4	1	1	15	8	7
NO	38	12	2	8	7	0	0	15	5	7
GB	36	0	-9	0	6	1	0	20	13	8
Countries bordering the Mediterranean Sea										
AL	59	6	1	1	40	47	38	7	3	3
CY	143	4	0	1	130	97	78	5	2	1
ES	56	5	0	1	18	10	13	23	15	18
IT	64	5	1	2	45	34	39	8	5	5
FR	43	4	-1	3	12	7	7	18	14	11
GR	82	6	1	2	65	54	47	6	3	2
MT	125	5	1	2	105	65	37	9	7	6
TR	47	5	0	1	28	25	25	6	2	1
Countries bordering the Black Sea										
BG	41	7	2	2	21	19	17	6	2	2
RO	31	8	2	2	12	10	8	6	2	2
Countries bordering the North Atlantic										
IE	45	7	0	2	7	0	0	20	16	8
IS	39	10	1	2	8	0	0	15	10	6
PT	70	5	0	1	8	2	5	45	29	34



a) Dep. of S **b)** Total dep. of N

Figure 6.5: Percentage contributions from shipping to annual depositions of sulphur (left) and total nitrogen (right) relative to all global antropogenic emissions. The contributions are shown for all ships and for ships in different sea areas.

Table 6.4: Source receptor relationships for depositions of oxidised nitrogen from shipping (all emitted species) as calculated by the global model and as reported for year 2014 and for 2016.**Glob** is the contribution from all global shipping, **NOS + BAS** from the North Sea and Baltic Sea combined, **MED + BLS** the Mediterranean Sea and Black Sea combined and **ATL** is the North Atlantic. GL15 is from the global model calculations, 2014 is from EMEP Status Report 1/2016 (2016) and 2016 from Appendix C in this report. Only countries where shipping exceeds 5% of the antropogenic contribution are included here. Units: 100 Mg of S per 15% emission reductions.

	Glob	**NOS + BAS**			**MED + BLS**			**ATL**		
Country	GL15	GL15	2014	2016	GL15	2014	2016	GL15	2014	2016
	Countries bordering the Baltic Sea									
EE	35	32	19	22	0	0	0	1	1	1
FI	122	110	81	73	0	1	1	9	5	5
DK	72	65	50	42	1	1	0	4	3	2
SE	226	202	197	141	0	2	1	17	10	9
	Countries bordering the North Sea									
BE	43	29	21	24	1	6	0	5	4	3
DE	316	231	154	153	10	11	5	26	18	14
LU	2	1	1	1	0	0	0	0	0	0
NL	81	66	35	46	0	1	0	6	5	4
NO	134	98	98	87	0	1	0	31	15	19
GB	185	107	115	90	0	3	2	66	55	45
	Countries bordering the Mediterranean Sea									
AL	11	0	0	0	10	22	13	0	0	0
CY	6	0	0	0	6	4	3	0	1	0
ES	252	9	8	5	157	119	105	80	65	68
IT	203	6	4	4	186	212	173	6	4	5
FR	310	125	109	115	74	107	70	85	81	65
GR	91	2	0	1	87	92	69	2	1	1
MT	1	0	0	0	0	1	0	0	0	0
	Countries bordering the North Atlantic									
IE	25	7	11	9	1	0	0	15	16	11
IS	7	2	7	2	0	0	0	4	5	4
PT	55	1	1	0	11	4	6	42	41	34

Table 6.5: Source receptor relationships for depositions of oxidised sulphur from shipping (all emitted species) as calculated by the global model and as reported for year 2014 and for 2016.**Glob** is the contribution from all global shipping, **NOS + BAS** from the North Sea and Baltic Sea combined, **MED + BLS** the Mediterranean Sea and Black Sea combined and **ATL** is the North Atlantic. GL15 is from the global model calculations, 2014 is from EMEP Status Report 1/2016 (2016) and 2016 from Appendix C in this report. Only countries where shipping exceeds 5% of the antropogenic contribution are included here. Units: 100Mg of N per 15% emission reductions.

	Glob	**NOS + BAS**			**MED + BLS**			**ATL**		
Country	GL15	Glob	2014	2016	GL15	2014	2016	GL15	2014	2016
Countries bordering the Baltic Sea										
EE	2	1	7	1	0	0	0	1	0	0
FI	9	5	23	3	1	1	0	3	2	2
DK	7	4	29	2	0	1	0	2	2	1
SE	19	9	64	5	1	1	0	7	5	4
Countries bordering the North Sea										
BE	7	2	11	3	2	1	0	2	2	1
DE	59	19	64	7	6	8	3	13	9	6
LU	0	0	0	0	0	0	0	0	0	0
NL	16	11	33	4	1	1	0	3	2	2
NO	30	6	36	6	1	1	0	23	13	13
GB	55	4	50	5	2	3	1	48	56	28
Countries bordering the Mediterranean Sea										
AL	8	0	0	0	8	21	9	0	0	0
CY	3	0	0	0	3	4	1	0	0	0
ES	164	1	2	0	105	97	62	57	61	41
IT	134	1	1	0	127	202	101	5	3	3
FR	123	7	38	7	54	100	41	55	66	37
GR	64	0	0	0	62	79	43	1	0	0
MT	1	0	0	0	1	2	0	0	0	0
Countries bordering the North Atlantic										
IE	13	0	3	1	0	0	0	12	21	8
IS	4	0	1	0	0	0	0	3	5	2
PT	32	0	0	0	7	2	3	23	40	20

Baltic Sea there are large percentage contributions from shipping for nitrogen depositions, whereas contributions to sulphur depositions are much smaller. This can be attributed to the introduction of the stricter SECA regulations in the North Sea and the Baltic Sea in 2015. The effects of SECA is further illustrated comparing source receptor relationships for 2014, GL15 and 2016 in Table 6.5. For the depositions of nitrogen contributions from shipping are also large for countries bordering the North Sea and the Baltic Sea. as shown in Table 6.4 the calculated source receptor relationships are comparable for 2014, GL15 and 2016.

6.4 Discussions and conclusions

As shown here, the calculated anthropogenic contributions from shipping to air pollution and depositions in Europe are substantial. The contributions calculated with a global version of the EMEP MSC-W model appear larger than in the regional model calculations. This may in part be explained by the different meteorological conditions in different years, but also by the coarser resolution used in the global model calculations. Nevertheless, following the implementation of SECA in the North Sea and in the Baltic Sea, both the regional 2016 and the global GL15 calculations show large reductions in sulphur depositions in countries bordering these two sea areas. Reductions of $PM_{2.5}$ in the same countries are much smaller as $PM_{2.5}$ from non-sulphur primary particles and from NO_x are not directly affected by the SECA regulations.

Both SOMO35 and POD_1 forest are defined as exceedances above a certain threshold. Ozone levels/fluxes often fluctuate around the threshold values. As a result, changes in ozone levels will have larger impacts on the ozone indicators than on the average concentration. This applies both to shipping and land-based emissions.

Furthermore, in the high emissions region in around the North Sea and the Baltic Sea ozone titration events enhanced by ship emissions are frequent, but they occur more often in the winter months when ozone levels are low (and often lower than the 35 ppb threshold for SOMO35) and outside the growing season (thus without effect on POD_1 forest). The effects on ozone indicators are thus relatively low in winter, but much higher in the summer months when chemical activity is high and also the background ozone concentrations are high. The indicators will thus be more sensitive to emission changes than annual average ozone. In Jonson et al. (2018) it was shown that most of the anthropogenic ozone originates from sources outside Europe, but with considerable contributions from European sources in summer. As these two sea areas are located right next to major European source regions and emissions here affects ozone in the same way as European land-based emissions. This explains the larger effects on the percentage contributions (positive and negative) from these two sea areas compared to annually averaged ozone.

In the Mediterranean Sea and the Black Sea conditions favour net ozone production in most locations and throughout most of the year (more available sunlight and other ozone precursors), and ozone levels below the thresholds are less frequent. Here the percentage contributions from ship emissions to the ozone indicators are only marginally larger than to annually averaged ozone.

As the ozone chemistry is nonlinear, emissions in a clean environment have a higher potential for ozone production than in a polluted environment. Thus ship emissions from distant upwind sources relative to the European mainland, such as ATL (and ROW), result in higher ozone for all countries, often of similar magnitudes as for emissions in the North Sea and the

Baltic Sea.

As explained above, the anthropogenic percentage contribution to the ozone indicators are substantially higher than for annually averaged ozone when isolating the contributions from the North Sea and the Baltic Sea. On the other hand for ozone there are also marked contributions from ship emissions in distant sea areas as ATL and ROW with major contributions outside the summer months. Thus, as shown in Jonson et al. (2018), the contributions from all international shipping to Europe as a whole will not be substantially different for annual average ozone and the ozone indicators.

The motivation for the ozone indicators SOMO35 and POD_1 forest is that they are related to health and ecosystem damages. Ozone levels/fluxes below the thresholds are believed to cause less damage to health and Ecosystems. Related to this, the North Sea and Baltic Sea are now designated as NECAs from 2021, expected to (slowly) bring down emissions as older ships are replaced and thus likely to reduce the health and ecosystem relevant ozone indicators in Europe.

The model results documented here are based on calculations performed over the last six months. There are several unresolved issues that we will address in future work. In particular, we will include model runs calculating source receptor relationships for ROW (Rest of world) shipping. This will also enable us to further explore the non-linear nature of the calculations. For a better comparison with regional model calculations we also hope to repeat the calculations with the exact same model version (in global mode) and the same meteorology (2016) used in the source receptor calculations presented in Appendix C.

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CHAPTER 7

The winter 2018 intensive measurement period. A brief update

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7.1 Background

Carbonaceous matter is a major fraction of the ambient aerosol in Europe. It influences the atmospheric radiative balance and contributes to adverse health effects. Consequently, carbonaceous aerosol is a key species measured regularly in monitoring networks, such as EMEP. There are numerous anthropogenic and natural sources of carbonaceous aerosols, and it is important to identify and quantify these sources to develop efficient abatement strategies. Particularly, there is an interest in distinguishing between the contribution from fossil fuel and biomass combustion, which is possible by multi-wavelength determination of the absorption coefficient (Sandradewi et al. 2008), using the aethalometer manufactured by Magee Scientific. Being robust, easy to operate, available at relatively low cost, and widespread across Europe, this instrument holds the potential to be an important tool for source apportionment (SA) of carbonaceous aerosols.

In a study presented in last year's EMEP Status Report (1/2017), we separated equivalent black carbon (EBC) into a fossil fuel (EBC_{ff}) fraction and a biomass burning (EBC_{bb}) fraction at four EMEP sites, using a slight modification of the Sandradewi approach (Sandradewi et al. 2008), hereafter called the PMF (Positive Matrix Factorization) approach, whereas levoglucosan was used to validate the EBC_{bb} signal. Note that, unlike the Sandradewi approach, the PMF approach requires no a priori knowledge of the aerosol Angström exponents (AAE) for EBC_{bb} and EBC_{ff} (rather, these are derived as an output from PMF). Besides providing a snapshot of EBC_{ff} and EBC_{bb} for a few sites across Europe, this study was a pilot for the EMEP/ACTRIS/COLOSSAL intensive measurement period (IMP) conducted in Winter

2018, which demonstrated the feasibility of conducting an up-scaled study. Here we present a brief update for the IMP Winter 2018, as well as a selection of results from a few sites that has undergone the PMF approach to derive EBC_{ff} and EBC_{ff}. More information on the IMP Winter 2018 is found here:

- The objectives and setup: `https://www.nilu.no/projects/ccc/tfmm/Winter%20intensive%20measurement%20period.pdf`
- On aerosol filter sample collection routines for the campaign: `https://www.nilu.no/projects/ccc/tfmm/Guidlines_Filter_sampling.pdf`
- Laboratories offering analysis of OC/EC and levoglucosan: `https://www.nilu.no/projects/ccc/tfmm/Labs_offering_centralized_analysis.pdf`

7.2 Aim

The IMP Winter 2018 aim to use the PMF approach to separate EBC into EBC_{ff} and EBC_{bb} in the European rural background environment, including low concentration areas in Scandinavia and more polluted regions in Central Europe, and in areas likely differing in source composition, preferably also with an influence of coal combustion. Further, it should compare EBC_{ff} and EBC_{bb} apportioned by the PMF approach to filter based measurements of the biomass burning tracer levoglucosan for validation purposes, and to elemental carbon (EC) to derive site-specific Mass Absorption Coefficient (MAC) values. A desired outcome of the IMP is a harmonised European-wide data set with carbonaceous aerosol apportioned into EBC_{ff} and EBC_{bb}, which also is applicable for model validation. Finally, the IMP should encourage initiation of regular monitoring of EBC_{ff} and EBC_{bb}, and reporting of such data to EMEP.

7.3 Participation, partnership and co-benefit

All EMEP/ACTRIS sites performing absorption coefficient measurements with a multi- wavelength aethalometer were invited to participate in the EMEP/ACTRIS/COLOSSAL intensive measurement period. Participation also required off-line analysis of levoglucosan and OC/EC/TC on filter samples from a co-located filter sampler. A successful outcome of the IMP Winter 2018 depends on participants following the above mentioned guidelines. It also relies on the existing infrastructure of EMEP and ACTRIS, such as protocols for sampling and analysis, calibrated instruments and inter laboratory compared analytical methods. In addition, the IMP Winter 2018 greatly benefits from cooperation with the recently established COST action COLOSSAL (Chemical On-Line cOmpoSition and Source Apportionment of fine aerosol).

IMP winter 2018 was presented in various fora before the start up in December 2017, and we experienced a substantial interest in the initiative and requests to participate also outside EMEP/ACTRIS/COLOSSAL associated partners. Thus, urban background sites were included as well, as long as they fulfilled the measurement guidelines of participation. Inclusion of additional site categories adds value to the study in several ways, e.g. twin sites allow the study of incremental changes in pollution at urban locations or investigation of the influence of local sources at rural background sites.

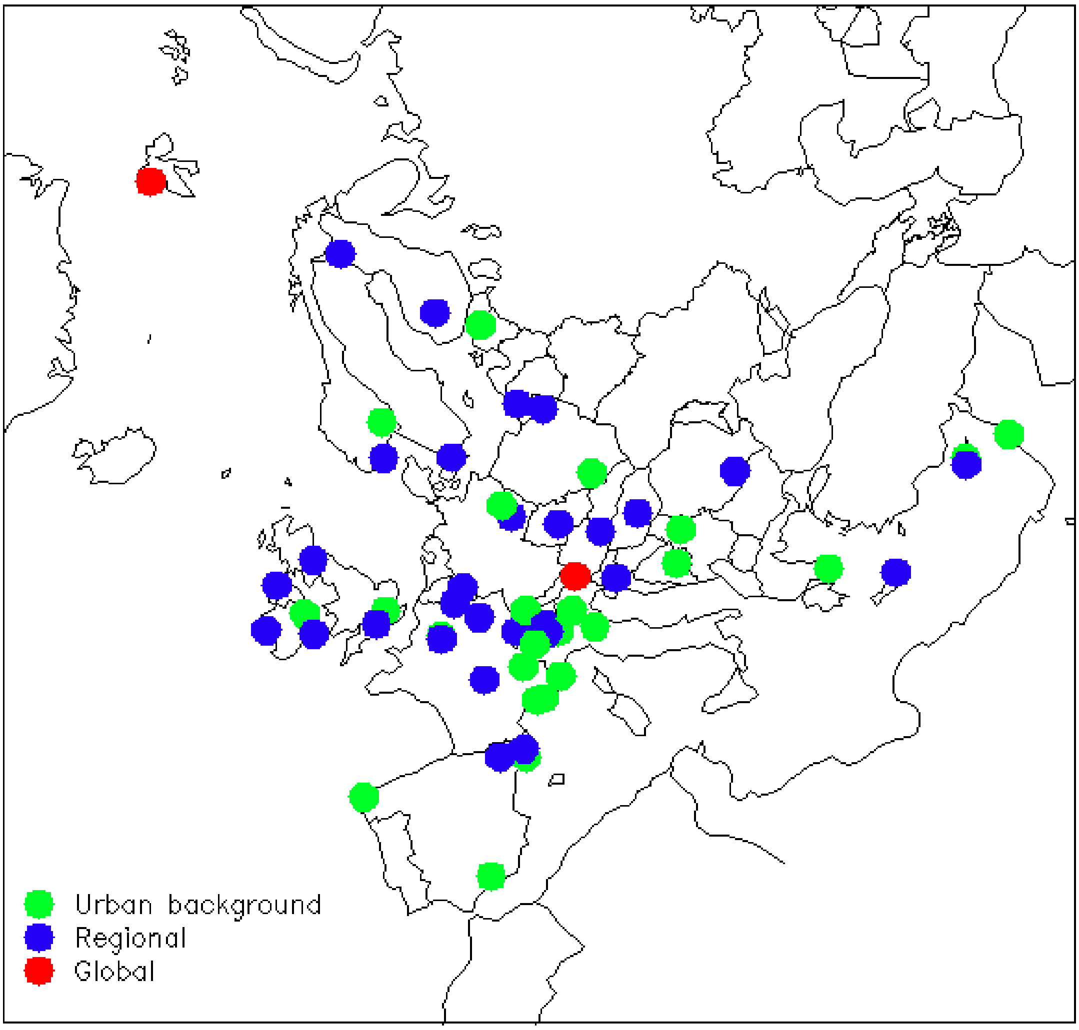

Figure 7.1: Location and category of sites participating in IMP Winter 2018.

Figure 7.1 shows the location of the 57 sites in 24 different countries that participated in the IMP Winter 2018, and their site category. This includes 2 global sites, 28 regional background sites and 27 urban sites, mostly located in background residential areas, but also traffic sites. The northernmost regional/global site is the Zeppelin Observatory at Svalbard (Norway), whereas Ayia Marina (Cyprus) in the Eastern Mediterranean Sea is both the southern- and easternmost regional site. Mace Head at the western coast of Ireland is situated furthest to the west. The sites that participated in IMP Winter 2018 cover a wider area than those sites regularly addressing carbonaceous aerosol by OC/EC measurements within EMEP. This extension is particular pronounced to the east, including several sites along a north to south transect from northern parts of Finland to Lebanon, and to the north-west by inclusion of seven sites in the British Isles.

Numerous variables relevant for air-quality and climate issues were measured at most of the sites participating in IMP Winter 2018, which also support our interpretation of the core variables, EBC_{ff} and EBC_{bb}. This includes on- and off-line variables monitored as part of long-term obligations within EMEP, but not exclusively; e.g. novel instrumentation such as the Total Carbon Analyzer (TCA-08) was tested at a selection of sites. Furthermore, additional funding was provided by one of the participants for ^{14}C-analysis of EC at selected sites, whereas some sites are considering adding ^{14}C-analysis at their own cost. ^{14}C-analysis provides a direct apportionment of EC from fossil and modern sources. Assuming that modern EC is from biomass burning, then ^{14}C-analysis yields a robust validation of the EBC_{ff} and EBC_{bb} fractions. This is an improvement compared to using levoglucosan tracer, which yields only EBC_{bb} concentrations via an a priori levoglucosan/EBC_{bb} emission ratio subject to uncertainties from variation with combustion conditions and the type of wood burned, and which might decrease as levoglucosan degrades in the atmosphere (likely a minor effect, particularly for northern sites in winter). A further advantage of ^{14}C-EC is that it allows assessment of this degradation via in situ measurement of modern EC/levoglucosan ratios. Finally, comparison of modern/fossil EC fractions to source apportioned biomass/fossil absorption coefficients yields source specific MAC values.

7.4 Data submission and quality control

The core variables (EBC, OC/EC and levoglucosan) asked for in IMP winter 2018, were to be reported by 1st June 2018, a deadline most participants failed to meet. As we write, absorption measurements from 20 sites and EC/OC and/or levoglucosan from 9 sites, have been submitted. Most sites have confirmed that they will report before the end of September.

Data are to be reported to EBAS via the EBAS submission tool (`https://ebas-submit-tool.nilu.no`), using predefined templates with substantial requirements for metadata and data quality control via flagging, thus ensuring all information required for complete data analysis is available to users in a consistent way, and which is also harmonised with other atmospheric data in EBAS. Even for an experienced user and submitter of aethalometer data, the level of sophistication asked for and needed for the analysis is profound, and several rounds of iteration has been necessary for some of the data to obtain the requested quality. In particular, zero readings needed to establish the Limit of Detection have frequently been left out from initial submitted data and, or when included, not flagged properly, as is the case with flagging of data in general.

7.5 Meteorology during IMP Winter 2018

The core sampling time of IMP Winter 2018 was 1 December 2017 - 1 March 2018. For certain sites, typically Scandinavia, northern Europe and European high altitude sites, there was an option to extend sampling to reflect the period when EBC was elevated, as well as to handle low ambient levels, which requires prolonged sampling time to cope with instrumental detection limits and the criteria of 25- 30 filter samples for OC/EC and levoglucosan analysis.

Overall, the winter 2017-2018 was characterised by windy, wet and rather mild conditions most of the time followed by a period at the end with extremely low temperatures associated with eastern air masses. In December 2017, low pressure activity lead to windy conditions with frequent precipitation and west and north-westerly winds over northern and central Europe. Although there were periods of cold Arctic air mass inflow, the mean temperatures were above normal in most of northern Europe, and precipitation was significantly above normal (180-200 % of the normal in some areas). An anticyclone located over southwestern Europe lead to drier and colder conditions in that area.

January 2018 started with strong westerly and north-westerly winds over central Europe, leading to precipitation and low temperatures, and continued with a period of cold winds from the north and northeast. By the middle of the month, the weather returned to the conditions with strong westerly winds and frequent low-pressure passages. Monthly mean temperatures were 2-3 degrees above normal in many areas and the precipitation was higher than normal in most areas. Paris received more than twice the normal precipitation and experienced severe flooding in the river Seine. A location in Switzerland received two meter snowfall during 24 hours.

February continued with westerly winds and precipitation the first part. From the middle of the month, a weak anticyclone was developing in central Europe that was gradually drifting to the northeast and intensifying. By the 24th an extensive high-pressure system was established over north-western Russia sending very cold air masses westwards over most of Europe leading to snowfall in the Mediterranean and freezing temperatures over large areas. This was named "the beast from the east" (or "the Siberian bear" in the Netherlands). The cold outbreak lasted until the 9th or 10th of March when milder air masses was entering from the south and west. Thus, IMP Winter 2018 provides an excellent opportunity to study changes in the relative share of biomass and fossil fuel to EBC under various winter time meteorological situations, in particular as a function of a wide range in the ambient temperature.

7.6 Results – Briefly on the Brenner and Hyytiälä sites

The winter (20 January - 12 March, 2018) EBC level (1.34 μg m^{-3}) calculated for the Brenner site supports previous findings of high EBC, EC and air pollution levels in general in the Italian Po Valley region (EMEP status Report 1/2017; Yttri et al. (2007)). The Brenner site is located in the alpine region of northern Italy, where biomass burning for domestic heating is common. In fact, biomass burning was the major fraction of EBC, accounting for 55%, whereas 45% was attributed to fossil fuel sources although the sampling station is placed in the close proximity of the highly trafficked A22, which is a major motorway connecting Italy and northern Europe. These figures show a slightly lower fossil fuel fraction than that observed at the Po Valley rural background site Ispra (EMEP status Report 1/2017), where the fossil fuel/biomass burning split was 50/50 in winter. As the IMP was conducted in winter, the biomass-burning signal was likely exclusively attributed to wood burning from residential heating. This is supported by the pronounced mean diurnal variation of EBC_{bb} (Figure 7.2A) with peak levels around midnight. After peaking, the concentration declined until the afternoon the next day except for a minor peak in the morning around 08:00. This cycle is identical to that observed at Ispra (EMEP Status Report 1/2017)) and suggests that biomass burning commences in early evening and continues to some extent through the night and early morning.

The pronounced diurnal variability suggests a strong influence from local sources. The EBC_{ff} diurnal cycle, clearly reveals the influence of the morning rush hours (07:00 - 09:00), whereas the afternoon (17:00 - 23:00) peak is broader. This reflects extensive vehicular traffic throughout the evening, but also wind direction change regularly occurring in this time frame has to be considered. Comparing the two diurnal cycles we find that EBC_{bb} is clearly higher than EBC_{ff} during night (18:00 - 06:00), whereas the two fractions equal each other during daytime. On a 24-hour basis, EBC_{bb} is the major fraction for approximately 80% of the cases.

An AAE_{ff} value of 0.98 and an AAE_{bb} value of 1.46 were derived from the PMF approach

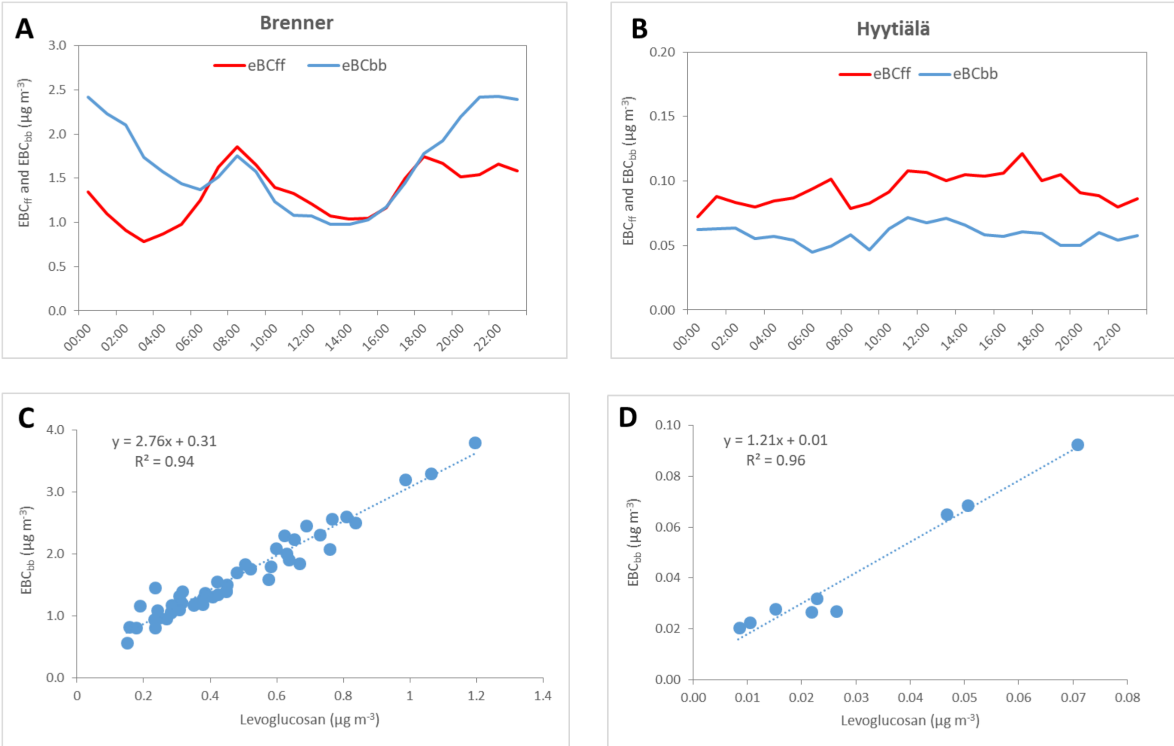

Figure 7.2: A) Diurnal variation of EBC_{bb} and EBC_{ff} determined via the PMF approach at the traffic site Brenner; B) Diurnal variation of EBC_{bb} and EBC_{bb} at the regional site Hyytiälä site; C) Scatterplot of EBC_{bb} versus levoglucosan for the Brenner site; D) Scatterplot of EBC_{bb} versus levoglucosan for the Hyytiälä site.

for the Brenner site, which reflects the range of AAE values obtained for the sites analyzed so far (Table 7.1). We note that the PMF approach provides $AAE_{ff} < 1.0$ at three of five sites, and AAE_{bb} ranging from 1.27 - 1.51, which is in line with the findings from the most recent and updated study discussing AAE values in Europe (Zotter et al. 2017), using ^{14}C-analysis of EC for validation of the AAE.

Table 7.1: Site specific absorption Angström exponents (AAE) for fossil fuel and biomass burning particles derived from the PMF approach, site specific MAC values and EBC relative share of fossil fuel (FF) and biomass burning (BB).

	Aosta Saint Christophe	Barcelona	Brenner	Hyytiälä	Matorova
Site category	Urban backgr.	Urban backgr.	Traffic	Rural backgr.	Rural backgr.
AAE_{ff}	0.96	1.08	0.98	0.96	1.01
AAE_{bb}	1.40	1.45	1.46	1.27	1.51
$MAC_{950\,nm}$ 1) ($m^2\,g^{-1}$)			3.17	5.35	
FF/BB (%)	67/33	74/26	45/55	57/43	61/39

1) Obtained by orthogonal distance regression

The output of the PMF approach is partly validated by the diurnal variations observed for the EBC_{ff} and EBC_{bb} factors, however, the quality of the EBC_{bb} signal is mainly validated using the biomass burning tracer levoglucosan. Figure 7.2C shows the very high level of agreement based on linear regression ($r^2 = 0.944$) for the PMF EBC_{bb} factor time series with the levoglucosan time series, implying that the PMF approach performs very well.

The EBC wintertime (13 December 2017 - 18 Februar 2018) level (0.141 $\mu g\ m^{-3}$) at the

Finnish rural background site Hyytiälä was one order of magnitude lower than that observed at the previously discussed Brenner site, a traffic site in northern Italy. These two sites represent the lower and the higher ends of the EBC concentration range analysed so far in the IMP Winter 2018, with biomass burning explaining the major fraction of EBC at the traffic site and fossil fuel at the rural one (Table 7.1). One major difference between the two sites is the total lack of a diurnal variation at the rural background site, which indicate no or minor local influence for both fossil fuel and biomass burning, and that long-range atmospheric transport prevails. Figure 7.2B shows that EBC_{ff} was higher than EBC_{bb} for all hours of the day. The AAE_{ff} value (0.96) obtained from the PMF-approach was highly similar to that derived for Brenner, whereas AAE_{bb} (1.27) was the lowest amongst the five sites assessed so far (Table 7.1).

Diurnal variation cannot be used to validate the Hyytiälä EBC_{bb} and EBC_{ff} signals since none is seen or expected. However, EBC_{bb} shows a very high correlation with levoglucosan (r^2 = 0.962) (Figure 7.2D). As for the Brenner site, this implies that the PMF approach performs very well.

Preliminary data from ongoing PMF analysis indicates a certain variability compared to sites presented in this chapter with respect to AAE and MAC, whereas the levels of correlation between the absorption coefficient and EC, and between EBC_{bb} and levoglucosan, are rather consistent. Our findings so far, although preliminary and for a few sites only, are promising with respect to reveal differences in the influence of fossil fuel (45-74%) and biomass (26-55%) to EBC at sites across Europe. We think that IMP Winter 2018 has the potential to extend greatly our current knowledge on this topic and that this joint effort will be successful.

7.7 Work ahead

The results presented provide only a snapshot of which information can be extracted from the core data collected in the IMP Winter 2018. In future, other issues will be addressed as well. The results should be considered preliminary, as adjustments to the PMF approach and the data treatment still is likely, but the PMF-approach as used here is close to a final version, and will be presented in a forthcoming paper (Platt et al., in prep.). Data will be analysed according to the PMF-approach as soon as possible after they are submitted to EMEP and found to have a sufficient data- and metadata quality.

There are several additional measurements connected to IMP winter 2018, including absorption measurements by MAAP (Multi Angle Absorption Photometer), chemical composition measurements by ACSM (Aerosol Chemical Speciation Monitor) and various organic tracer analysis. Further, there will be a possibility to select filter samples from some sites for ^{14}C-analysis of EC. Which sites to be selected for ^{14}C analysis, as well as ad hoc studies, will be discussed at the COLOSSAL COST action meeting in Bucharest 24-28 Sept.

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Part III

Technical EMEP Developments

CHAPTER 8

Updates to the EMEP MSC-W model, 2017-2018

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This chapter summarises the changes made to the EMEP MSC-W model since Simpson et al. (2017) and, along with changes discussed in Simpson et al. (2013, 2015, 2016) 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 rv4.17a, which is a slight update of the rv4.17 code released in February 2018. Table 8.2 summarises the changes made in the EMEP model since the version documented in Simpson et al. (2012).

Most of the changes made since last year have been concerned with improvements to the model code and usability, and these have had little impact on model results. One major change did occur, however, and that concerns the treatment of photosynthetically active radiation (PAR) in the model, which impacts both biogenic VOC emissions and ozone flux estimates. Section 8.1 briefly summarises changes to the model in general, and Sect. 8.2 addresses the change in PAR in more detail.

8.1 Overview of changes

8.1.1 Chemistry

Several corrections/improvements were made to the EmChem16 mechanism introduced in Simpson et al. (2017):

- Exclude the unimportant (see Stadtler et al. 2018) O_3-dust gas-aerosol reaction.
- Bug-fix for rv4.17a: removed duplicated gas-aerosol reaction of NO_3 to give HNO_3.
- bug-fixes - for HONO and OD+H2O rates, and for gamma (small effects).

8.1.2 Configuration

- Many small changes to make model configuration easier and more flexible; see the User Guide for further explanation of some new methods and possibilities. Some module names were also changed to reflect better the content (eg ModelConstant_ml is now Config_module).

- Alternative paths to all input files can be defined in the config files.

8.1.3 Deposition

- N_2O_5 is now given the same deposition rate as HNO_3. This has a small impact on deposition and concentrations of other species on the European scale, but is important for global scale studies such as Stadtler et al. (2018).

8.1.4 Emissions

- Improved compatibility between the older SNAP and new GNFR emission sectors. Can force SNAP or GNFR sectors, even when the emissions are defined in the other system. It is also possible to mix GNFR and SNAP emissions in the same run. So far the splits, timefactors and release heights have not yet been defined specifically for GNFR sectors and a simple mapping onto SNAP values is used.

- Now have option to use same monthly time series for NH_3 as the LOTOS model (Schaap et al. 2004, Hendriks et al. 2016) for European runs.

- The 'femis' file used to control emission changes per country and sector can now operate for an area defined by lon/lat.

- rv4.17a fixed a bug concerning CO emissions from biomass burning that had been introduced in rv4.17.

- A climatological mode was added for forest-fire emissions, sometimes needed when real data is not available for specific years.

8.1.5 Landcover

- A new file landcover file (glc2000xCLMf18) is now used, again a merge of GLC2000 and CLM as in Simpson et al. (2017). This change was made to fix a bug in treatment of deserts, to better distinguish them from bare soil.

8.1.6 Meteorology

- Radiation. The Weiss and Norman (1985) radiation scheme was introduced to give better estimates of diffuse versus direct radiation, which is important in modelling both ozone update and biogenic VOC emissions. This makes rather a large difference in some ozone update calculations, and is discussed further in Sect. 8.2 below.

- Improvements were made for compatibility with AROME meteorology.

Table 8.1: Definition of the vertical layer boundaries (A_k, B_k) used in this year's status runs. Example pressure levels and heights for a standard atmosphere (with $P_{surf} = 101325.0$ Pa) are also given. The pressure at each level boundary is defined by $P_k = A_k + B_k \cdot P_{surf}$.

k	A_k (Pa)	B_k	P_k^* (hPa)	h_k (m)
1	10000.00000	0.00000	100.00	16179.7
2	12077.44629	0.00182	122.61	14886.8
3	15379.80566	0.01114	165.09	13000.6
4	18045.18359	0.03412	215.03	11324.7
5	19755.10938	0.07353	272.06	9812.0
6	20429.86328	0.13002	336.04	8396.6
7	20097.40234	0.20248	406.13	7077.7
8	18864.75000	0.28832	480.79	5862.2
9	16899.46875	0.38389	557.97	4757.0
10	14411.12402	0.48477	635.31	3767.5
11	11632.75879	0.58617	710.26	2897.6
12	8802.35644	0.68327	780.35	2149.1
13	6144.31494	0.77160	843.26	1522.2
14	3850.91333	0.84737	897.11	1015.0
15	2063.77979	0.90788	940.55	623.5
16	855.36176	0.95182	972.99	340.7
17	467.33359	0.96765	985.14	236.7
18	210.39389	0.97966	994.75	155.2
19	65.88924	0.98827	1002.02	93.9
20	7.36774	0.99402	1007.26	49.9
21	0.00000	1.00000	1013.25	0.0

- Snow-depth from ECMWF is now multiplied by a factor 5 by default, as a simple conversion from water-equivalent to physical depth of snow. (bug-fix)

- Corrected bug in variable used for snow depth from WRF fields.

8.1.7 Vertical resolution

The EMEP model has had the ability to use a flexible number and definition of vertical levels for some years. Although not a change in the model code, this year's runs have used a new definition of these vertical layers. Unlike 'traditional' runs that used 20 layers and lowest level at around 90 m, and runs in EMEP Status Report 1/2017 (2017) that used 34 levels, the status runs this year use 20 levels and a lowest level at ca. 50m. Compared to the previously used sigma layers (e.g. Simpson et al. 2012) the layer boundaries have now been selected to match the original ECMWF-IFS layers. Table 8.1 summarises the coefficients used in these runs, and the associated pressure and height values for a standard atmosphere.

8.2 Radiation issues

As pointed out by Ferd Sauter and Roy Wichink Kruit (RIVM), the equations used to calculate direct and diffuse radiation (eqns. 12-13 of Simpson et al. 2012) result in incorrect scaling between the different components. For this reason, a new system was introduced into model version rv4.16 in late 2017. The new system uses the formulation of Weiss and Norman (1985). In investigating differences between the two schemes, we also found a bug in units scaling for the previous implementation. The radiation scheme used in newer code (rv4.16 onwards) therefore produces significantly lower PAR values than the rv4.15 and earlier schemes. Although this change has very limited impact on most results and pollutants, calculations of photo-toxic ozone dose (POD) were found to be rather large in some case, especially for forests. This is illustrated in Fig. 8.1, which compares results from two model runs using identical emissions and meteorology, but versions rv4.15 and rv4.17. It can be seen that ozone itself is hardly affected by this change, but POD1 values for deciduous forests are about 30% lower with rv4.17 than with rv4.15. In both cases the two model versions correlate extremely well.

At first sight, the lack of sensitivity of POD_3IAM to this problem seem surprising because higher thresholds (Y in PODY) tend to lead to greater sensitivity (Tuovinen et al. 2007). However, the light response coefficients used in the calculation of stomatal conductance (g_{sto}) are quite different for crops and forests, such that g_{sto} for forests is more likely to be limited by low PAR values than crops. Further, the accumulation season for POD_3IAM in crops is shorter (90 days for IAM_CR) and confined to the summer period when light levels are not limiting, whereas the accumulation season for POD1 extends into the spring and autumn and thus includes more periods when light-levels act to limit g_{sto}. The impacts of this change will be investigated in more detail in the coming months.

8.3 Acknowledgments

Thanks are due to Ferd Sauter and Roy Wichink Kruit from RIVM for first pointing out problems with the radiation formulation, to John Johansson (Chalmers) for spotting problems with snow fields in WRF, and to Massimo Vieno (CEH, Edinburgh) for pointing out various landcover and other issues with the model.

Table 8.2: Summary of major EMEP MSC-W model versions from 2012–2017. Extends Table S1 of Simpson et al. 2012

Version	Update	Ref$^{(a)}$
rv4.17a	Used for this report. Small updates	This report
rv4.17	Public domain (Feb. 2018)	This report
	Corrections in global land-cover/deserts; added 'LOTOS' option for European NH_3 emissions; corrections to snow cover	This report
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)	This report
rv4.15	EmChem16 scheme	R2017
rv4.14	Updated chemical scheme	R2017
rv4.12	New global land-cover and BVOC	R2017
rv4.10	Public domain (Oct. 2016) (Used for Mills et al. 2018a)	R2016
rv4.9	Updates for GNFR sectors, DMS, sea-salt, dust, S_A and γ, N_2O_5	
rv4.8	Public domain (Oct. 2015) ShipNOx introduced. Used for EMEP HTAP2 model calculations, see see acp special issue: `https://www.atmos-chem-phys.net/special_issue390.html`). Also for Jonson et al. (2017).	R2015
rv4.7	Used for reporting, summer 2015 : New calculations of aerosol surface area; ; New gas-aerosol uptake and N_2O_5 hydrolysis rates ; Added 3-D calculations pf aerosol extinction and AODs; ; Emissions - new flexible mechanisms for interpolation and merging sources ; Global - monthly emissions from ECLIPSE project ; Global - LAI changes from LPJ-GUESS model ; WRF meteorology (Skamarock and Klemp 2008) can now be used directly in EMEP model.	R2015
rv4.6	Used for Euro-Delta SOA runs Revised boundary condition treatments ; ISORROPIA capability added	R2015
rv4.5	Sixth open-source (Sep 2014) Improved dust, sea-salt, SOA modelling ; AOD and extinction coefficient calculations updated ; Data assimilation system added ; Hybrid vertical coordinates replace earlier sigma ; Flexibility of grid projection increased.	R2014
rv4.4	Fifth open-source (Sep 2013) ; Improved dust and sea-salt modelling ; AOD and extinction coefficient calculations added ; gfortran compatibility improved	R2014, R2013
rv4.3	Fourth public domain (Mar. 2013) ; Initial use of namelists ; Smoothing of MARS results ; Emergency module for volcanic ash and other events; Dust and road-dust options added as defaults ; Advection algorithm changed	R2013
rv4.0	Third public domain (Sep. 2012) As documented in Simpson et al. (2012)	R2013
v2011-06	Second public domain (Aug. 2011)	
rv3	First public domain (Sep. 2008)	

Notes: (a) R2015 refers to EMEP Status report 1/2015, etc.

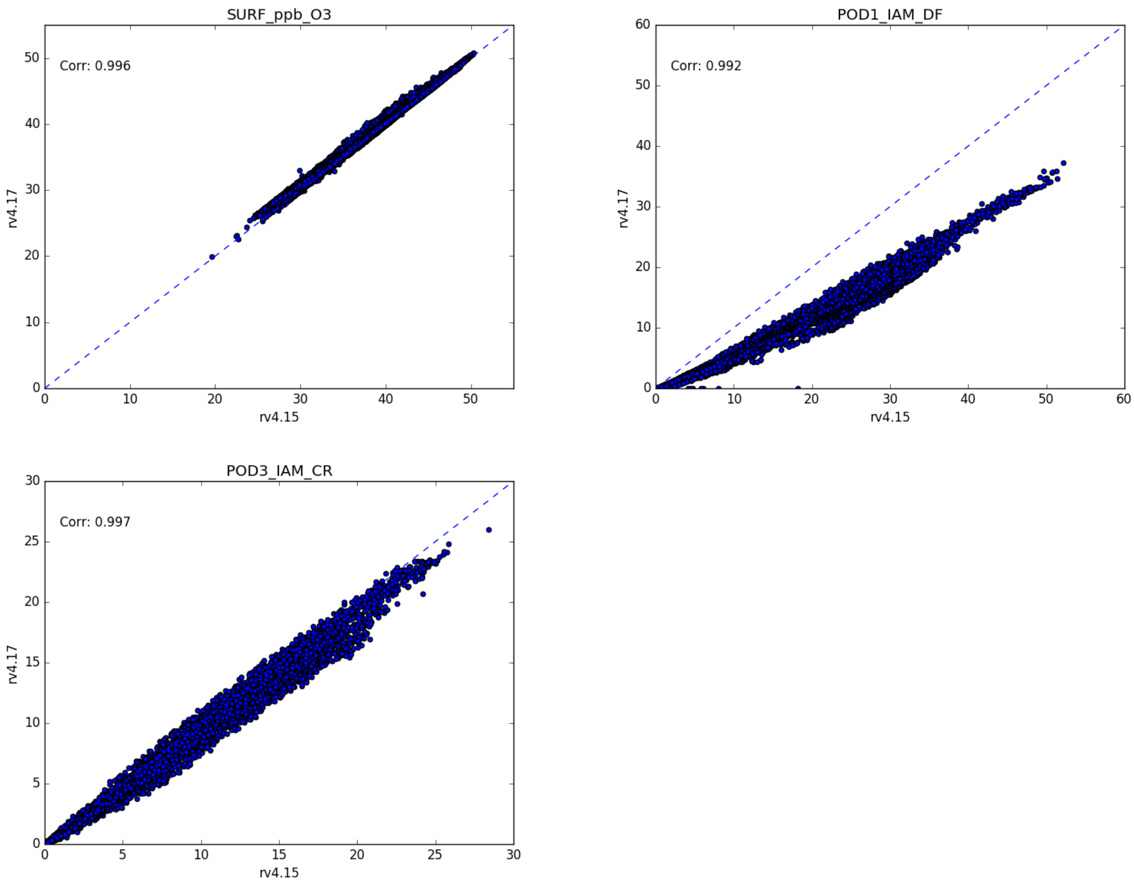

Figure 8.1: Comparison of model versions rv4.15 and rv4.17 for mean ozone (top-left), POD1 for IAM deciduous forests (top-right) and POD_3IAM for crops (bottom). The dashed line represents the 1:1 line. Calculations are for the year 2012, using the 50km version of the model.

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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 in EMEP are defined by the Monitoring Strategy for 2010-2019 (UNECE (2009), Tørseth et al. (2012)). The complexity in the monitoring program with respect to the number of variables and sites, whether parameters are a level 1 or level 2, and the required time resolution (hourly, daily, weekly), makes it challenging to assess whether a country is in compliance. CCC has developed an index to illustrate to what extent the Parties comply, how implementation compares with other countries, and how activities evolve with time.

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

Figure 9.1 summarises implementation in 2016 compared to 2000, 2005 and 2010. The countries are sorted from left to right with increasing index for 2016. Slovenia has a full score as they measure all the required parameters with satisfactory sampling frequency. Estonia, The Netherlands, Slovakia, Denmark, and Switzerland have almost complete program with

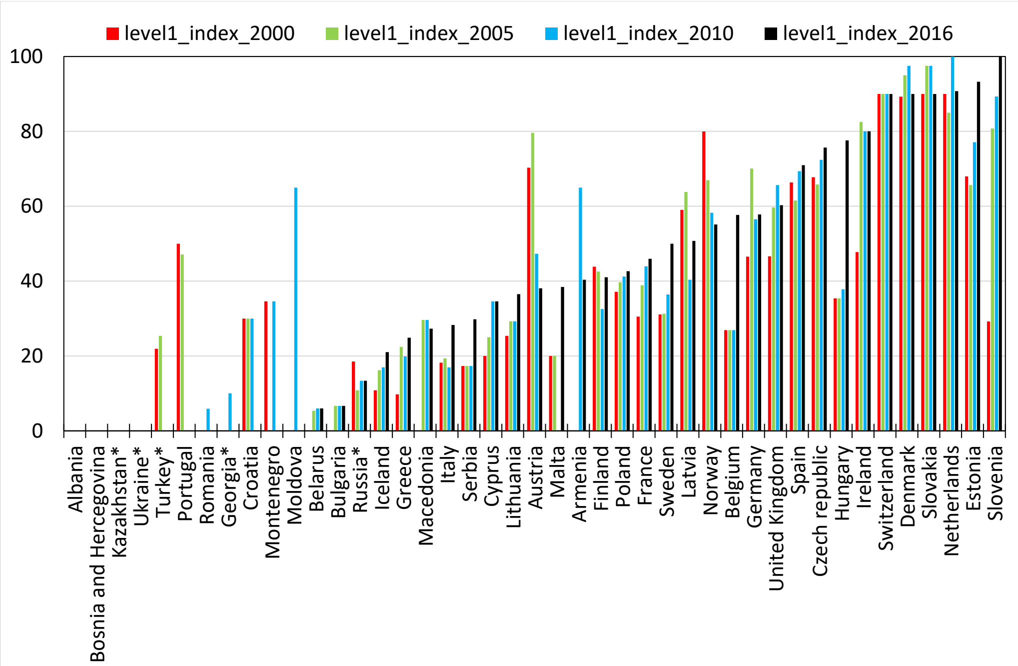

Figure 9.1: Index for implementation of the EMEP monitoring strategy, level 1 based on what has been reported for 2000, 2005, 2010 and 2016. * means adjusted land area

an index of 90% or higher. Small countries with requirements of less number of level 1 sites seem to comply easier than large countries. Since 2010, 42% of the Parties have improved their monitoring programme, while 30% have a decrease. Improvements are seen in e.g. Germany and Latvia. One Party, Malta, has reported data in 2016 and not in 2000 while Croatia, Georgia, Moldova, Montenegro and Romania have stopped reporting/measuring. In Figure 2.4 in Chapter 2.2, the geographical distribution of level 1 sites is shown for 2016. In large parts of Europe implementation of the EMEP monitoring strategy is far from satisfactory.

For the level 2 parameters, an index based system has not been defined, but mapping the site distribution illustrate the compliance to the monitoring strategy. 52 sites from 19 different Parties reported at least one of the required EMEP level 2 parameters relevant to this report (aerosols (47 sites), photo-oxidants (18 sites) and trace gases (5 sites)). The sites with measurements of POPs and heavy metals are covered in the EMEP status reports 2 and 3. Figure 9.2 shows that level 2 measurements of aerosols have better spatial coverage than oxidant precursors (VOC + methane) and trace gases. Few sites have a complete measurement program, and only 12 sites have a complete aerosol program. Nevertheless, regarding the aerosol monitoring, there have been large improvements in the spatial coverage and the data quality over the last decade. Standardization and reference methodologies have been developed, and the reporting has improved significantly with much more metadata information available. For oxidant precursors and trace gases, there are ongoing improvement in the measurement capabilities resulting from recent development in ACTRIS (Aerosols, Clouds, and Trace gases Research InfraStructure Network) and in co-operation with the WMO Global Atmospheric

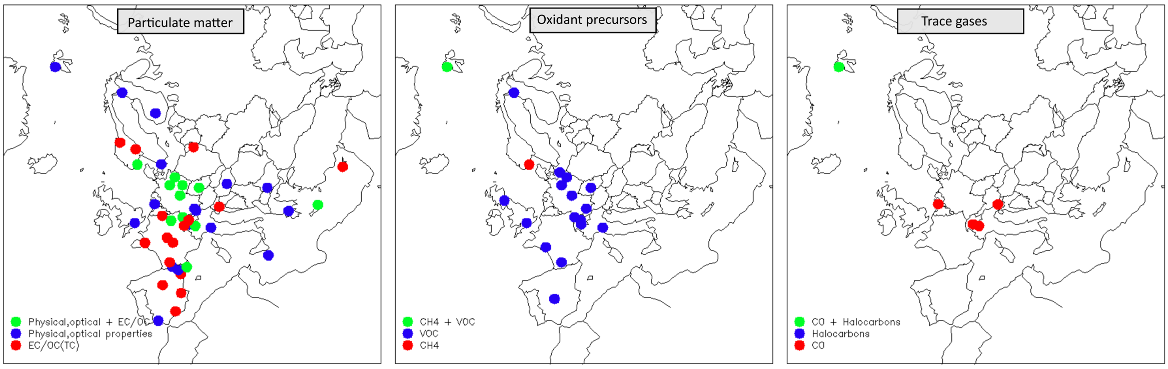

Figure 9.2: Sites measuring and reporting EMEP level 2 parameters for the year 2016

Watch Programme (GAW).

9.2 Updates in reporting templates and guidelines

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

Figure 9.3 shows the status of the submission of data for 2016 and to what extent the data were reported in time. It is obvious that large volumes of data are reported late and some not at all. Of the 32 Parties reporting either level 1 or level 2 data, less than 60% reported within the deadline of 31 July 2017.

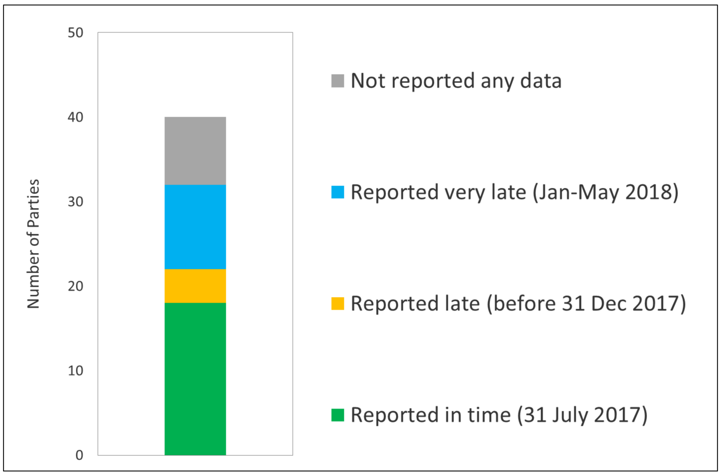

Figure 9.3: Submission of 2016 data to EMEP/CCC.

To improve the timelines and quality of the data reporting, an online data submission and validation tool was launched in spring 2016 (`http://ebas-submit-tool.nilu.no`) This tool gives data submitters a possibility to check and correct their files before submitting them. The tool gives information on how to best troubleshoot errors in the file, including information on how to format the data files, as well as offering the user a way to plot data.

The tool is designed to give the data submitters direct feedback on the formatted NASA Ames files and to deliver files through online data submission.

The format checker is directly linked to all (approx. 40) data format templates located at `http://ebas-submit.nilu.no/` and the ftp server designed for incoming data. EMEP data should be submitted using this submission tool, unless otherwise have been agreed upon. The requirement of checking the data files using the submission tool has significantly improved the correctness in the data files submitted.

The tool has been further developed to give better feedback when errors in the files occur. Automatic checks for inconsistency and outliers have been developed. In the coming year(s) there will be more focus on developing additional software tools for automatic creation of NASA Ames files directly from the output from various instruments for either regular annual reporting or Near-Real Time data submission, in addition to tools for checking the data based on requirements of consistency, completeness, data quality etc. defined by the different stakeholders i.e. EMEP, ACTRIS and WMO GAW.

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Part IV

Appendices

APPENDIX A

National emissions for 2016 in the EMEP domain

This appendix contains the national emission data for 2016 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 2016 source-receptor calculations. Results of these source-receptor calculations are presented in Appendix C.

The land-based emissions for 2016 have been derived from the 2018 official data submissions to UNECE CLRTAP (Burgstaller et al. 2018).

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 global shipping emissions from FMI (Finish Meteorological Institute) for the year 2015, which are calculated using the STEAM model (Jalkanen et al. 2016) based on real ship movements obtained from data collected through the Automatic Identification System (AIS). NMVOC emissions from international shipping have been estimated to be 10.9% of the CO emissions.

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

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

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

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Table A:1: National total emissions for 2016 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	$PM_{2.5}$	PM_{co}	PM_{10}
Albania	15	25	24	38	173	15	4	19
Armenia	39	18	19	36	107	4	2	6
Austria	14	154	68	138	565	18	13	31
Azerbaijan	18	80	74	91	137	5	11	16
Belarus	56	143	136	291	760	39	9	48
Belgium	42	193	68	114	368	25	9	34
Bosnia and Herzegovina	191	31	21	34	95	14	12	26
Bulgaria	105	125	50	84	245	32	16	48
Croatia	15	52	35	70	202	18	7	26
Cyprus	16	15	6	9	15	1	1	2
Czech Republic	115	165	73	213	798	39	12	52
Denmark	10	115	75	103	244	21	11	31
Estonia	30	31	12	22	140	7	4	11
Finland	40	131	31	88	324	20	13	33
France	140	842	630	608	2737	170	85	255
Georgia	13	38	36	40	168	17	4	22
Germany	356	1218	663	1052	2864	101	102	203
Greece	69	244	60	200	399	33	29	62
Hungary	23	117	87	141	450	53	20	73
Iceland	50	24	5	7	122	1	0	2
Ireland	14	112	117	108	103	15	14	29
Italy	116	761	382	904	2310	162	31	193
Kazakhstan	714	760	238	297	1313	172	61	232
Kyrgyzstan	53	62	36	70	319	12	5	17
Latvia	3	35	16	40	115	16	8	24
Liechtenstein	0	1	0	0	1	0	0	0
Lithuania	15	54	34	52	145	6	7	13
Luxembourg	1	20	6	13	22	2	1	2
Malta	2	5	1	3	6	1	1	1
Monaco	0	0	0	0	1	0	0	0
Montenegro	51	14	2	8	30	5	8	13
Netherlands	28	254	127	141	559	13	14	26
Norway	16	151	28	152	380	27	8	36
Poland	582	726	267	609	2506	146	114	259
Portugal	47	161	56	154	322	47	18	65
Republic of Moldova	9	27	23	49	81	11	5	16
Romania	108	211	167	258	742	110	31	141
Russian Federation	2080	3154	1196	3548	12163	389	373	762
Serbia	408	145	65	127	276	41	14	55
Slovakia	27	67	30	64	240	27	7	34
Slovenia	5	37	18	31	110	12	1	13
Spain	218	765	492	594	1661	128	72	200
Sweden	19	131	53	159	429	18	19	38
Switzerland	6	63	57	71	162	7	10	17
Tajikistan	18	10	51	18	112	5	2	7
TFYR of Macedonia	59	22	11	27	74	14	7	21
Turkey	2251	703	713	1071	2003	385	330	715
Turkmenistan	12	97	98	75	262	18	3	21
Ukraine	778	648	281	521	2130	143	70	213
United Kingdom	179	916	289	821	1536	109	63	172
Uzbekistan	29	177	248	112	478	22	10	32
North Africa	1602	1385	569	1244	2530	142	119	261
Asian areas (AST)	5720	6696	3987	9011	21551	1526	830	2356
Baltic Sea	8	257	0	2	17	8	1	8
Black Sea	36	86	0	1	6	6	0	6
Mediterranean Sea	554	1115	0	8	77	80	5	85
North Sea	26	565	0	5	42	19	1	20
Remaining N-E Atlantic Ocean	355	689	0	5	49	50	3	53
Natural marine emissions	2390	0	0	0	0	0	0	0
Volcanic emissions	943	0	0	0	0	0	0	0
TOTAL	20840	24841	11835	23755	65774	4527	2629	7155

APPENDIX B

National emission trends

This appendix contains trends of national emission data for main pollutants and primary particle emissions for the years 2000–2016 in the new EMEP domain, which covers the geographic area between 30°N-82°N latitude and 30°W-90°E longitude.

The land-based emissions for 2000–2016 have been derived from the 2016 official data submissions to UNECE CLRTAP (Burgstaller et al. 2018).

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 global shipping emissions from FMI (Finish Meteorological Institute) for the year 2015 (and also for 2011 in case of NO_x and SO_x in Baltic and North Sea), which is based on AIS (Automatic Identification System) tracking data. For the year 2016 a copy of the FMI emission values for 2015 was used. For the years 2000–2014 the FMI data was adjusted regarding trends from data developed within the EU Horizon2020 project MACC-III (MACC-III 2015) and the ICCT Report (Olmer et al. 2017). NMVOC emissions from international shipping have been estimated to be 10.9% of the CO emissions.

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

SO_x emissions from passive degassing of Italian volcanoes (Etna, Stromboli and Vulcano) are those reported by Italy. SO_x and PM emissions from volcanic eruptions of Icelandic volcanoes in the period 2000–2016 (Eyjafjallajökull in 2010 and Barðarbunga in 2014-2015) are reported by Iceland. Emissions from the eruption of Grímsvötn volcano in May 2011 are not included in the table, as the eruption event has not been included in the model simulations.

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

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Table B:1: National total emission trends of sulphur (2000-2007), as used for modelling at the MSC-W (Gg of SO_2 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	34	34	36	40	41	34	34	37
Armenia	8	4	8	10	14	18	22	26
Austria	32	33	32	32	27	26	26	23
Azerbaijan	17	16	15	15	15	16	15	16
Belarus	135	130	125	120	115	110	105	100
Belgium	172	167	157	151	155	142	133	124
Bosnia and Herzegovina	217	215	214	212	218	225	219	214
Bulgaria	862	828	758	827	791	778	765	820
Croatia	59	59	63	64	52	59	55	60
Cyprus	48	45	45	47	40	38	32	29
Czech Republic	233	229	223	218	215	208	207	212
Denmark	33	30	29	35	29	26	30	27
Estonia	97	91	87	100	88	76	70	88
Finland	82	96	90	101	84	70	83	81
France	625	565	524	498	479	458	429	419
Georgia	12	4	4	4	4	5	3	5
Germany	646	625	561	533	493	473	474	458
Greece	553	558	546	554	549	570	525	509
Hungary	427	346	272	246	150	41	39	36
Iceland	35	39	41	37	32	39	40	58
Ireland	140	134	101	79	72	72	61	55
Italy	756	704	623	524	487	409	387	345
Kazakhstan	457	477	503	542	574	634	640	668
Kyrgyzstan	25	25	25	25	25	25	27	30
Latvia	18	14	13	11	9	8	8	8
Lithuania	37	44	38	29	28	26	28	27
Luxembourg	3	4	3	3	2	2	3	2
Malta	24	26	25	27	11	11	11	12
Montenegro	14	11	15	15	14	13	14	12
Netherlands	78	79	71	66	69	67	67	63
Norway	27	25	23	23	25	24	21	20
Poland	1404	1379	1291	1273	1202	1164	1228	1166
Portugal	265	250	248	190	191	193	169	160
Republic of Moldova	4	4	5	6	5	5	5	3
Romania	493	515	509	589	552	605	649	518
Russian Federation	2867	2910	2952	2922	2747	2600	2657	2326
Serbia	448	439	462	484	497	429	445	457
Slovakia	126	131	103	104	96	89	88	71
Slovenia	94	63	63	60	50	40	17	16
Spain	1401	1341	1483	1224	1256	1215	1085	1053
Sweden	43	41	41	42	37	36	35	31
Switzerland	15	18	16	15	15	15	14	11
Tajikistan	5	7	8	7	9	8	10	13
TFYR of Macedonia	106	108	97	95	96	97	94	99
Turkey	2242	1983	1872	1791	1779	2003	2160	2523
Turkmenistan	12	12	12	13	12	12	11	12
Ukraine	2310	1844	1329	1252	1048	1192	1446	1363
United Kingdom	1286	1197	1077	1051	894	773	728	632
Uzbekistan	176	175	173	162	155	135	130	107
North Africa	982	1019	1056	1092	1129	1166	1187	1208
Asian areas (AST)	3193	3191	3188	3186	3183	3181	3345	3509
Baltic Sea	181	180	179	179	178	177	163	117
Black Sea	37	38	39	41	42	43	46	42
Mediterranean Sea	571	595	620	644	669	693	750	668
North Sea	399	396	394	392	390	388	405	359
Remaining N-E Atlantic Ocean	375	387	398	409	421	432	458	420
Natural marine emissions	2364	2318	2380	2232	2298	2338	2376	2352
Volcanic emissions	5746	4278	5300	3556	2701	1204	1308	840
TOTAL	33049	30476	30567	28201	26560	24937	25583	24661

Table B:2: National total emission trends of sulphur (2008-2016), as used for modelling at the MSC-W (Gg of SO_2 per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	29	29	27	25	23	21	19	17	15
Armenia	27	27	28	29	30	31	32	35	39
Austria	20	15	16	15	15	15	15	15	14
Azerbaijan	16	14	15	15	15	15	15	14	18
Belarus	84	80	59	63	68	61	53	57	56
Belgium	96	74	60	53	47	44	41	41	42
Bosnia and Herzegovina	208	203	201	199	198	196	195	193	191
Bulgaria	571	443	388	516	330	195	189	142	105
Croatia	54	56	35	29	25	17	14	16	15
Cyprus	22	18	22	21	16	14	17	13	16
Czech Republic	170	169	164	168	160	145	138	133	115
Denmark	21	15	15	14	12	13	11	10	10
Estonia	69	55	83	73	41	36	41	32	30
Finland	67	59	66	60	50	48	44	41	40
France	354	300	279	249	240	211	173	162	140
Georgia	6	12	12	11	11	11	12	12	13
Germany	455	398	411	401	382	374	359	364	356
Greece	439	367	219	158	133	119	103	99	69
Hungary	35	30	31	34	32	31	28	23	23
Iceland	74	69	74	73	84	70	63	56	50
Ireland	45	32	26	25	23	24	17	15	14
Italy	290	237	218	196	178	146	131	124	116
Kazakhstan	680	693	732	884	835	785	758	744	714
Kyrgyzstan	33	35	38	40	43	45	48	50	53
Latvia	7	6	4	4	4	4	4	4	3
Lithuania	24	21	20	23	20	18	16	16	15
Luxembourg	2	2	2	1	1	2	2	1	1
Malta	11	8	8	8	8	5	5	3	2
Montenegro	15	8	28	40	42	44	46	48	51
Netherlands	53	39	35	34	34	30	30	31	28
Norway	20	16	20	19	17	17	17	16	16
Poland	939	803	866	828	794	759	715	702	582
Portugal	112	77	68	62	57	51	46	47	47
Republic of Moldova	8	10	10	9	8	10	9	9	9
Romania	525	447	354	324	260	227	183	157	108
Russian Federation	2113	1992	1911	2077	2089	2064	2057	2027	2080
Serbia	468	426	392	442	408	427	333	405	408
Slovakia	70	64	69	68	58	53	45	68	27
Slovenia	15	12	11	13	12	14	10	6	5
Spain	391	292	250	287	286	226	250	267	218
Sweden	28	27	28	26	25	22	20	18	19
Switzerland	12	10	10	9	9	9	8	7	6
Tajikistan	13	13	13	14	15	16	17	18	18
TFYR of Macedonia	101	96	91	102	97	83	83	76	59
Turkey	2558	2662	2557	2638	2703	1940	2149	1949	2251
Turkmenistan	13	12	12	12	12	12	12	12	12
Ukraine	1386	1290	1241	1346	1366	1449	922	854	778
United Kingdom	529	432	450	415	459	396	322	253	179
Uzbekistan	93	84	84	75	66	56	47	38	29
North Africa	1229	1250	1271	1418	1410	1474	1514	1582	1602
Asian areas (AST)	3674	3838	4002	4223	4338	4675	5016	5361	5720
Baltic Sea	116	111	106	80	70	71	71	8	8
Black Sea	38	37	37	40	35	35	35	36	36
Mediterranean Sea	591	579	560	617	543	549	549	554	554
North Sea	246	239	215	155	136	138	138	26	26
Remaining N-E Atlantic Ocean	385	379	368	395	347	351	352	355	355
Natural marine emissions	2386	2356	2314	2446	2368	2434	2250	2454	2390
Volcanic emissions	973	950	1070	943	943	943	11823	2070	943
TOTAL	23007	22017	21698	22542	22032	21274	31610	21889	20840

Table B:3: National total emission trends of nitrogen oxides (2000-2007), as used for modelling at the MSC-W (Gg of NO_2 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	18	19	20	21	25	25	24	22
Armenia	10	13	13	15	17	19	21	24
Austria	215	226	232	240	237	240	226	216
Azerbaijan	47	56	55	55	57	57	61	68
Belarus	211	207	203	198	194	190	186	181
Belgium	344	334	322	320	332	318	304	295
Bosnia and Herzegovina	35	34	34	34	33	33	33	33
Bulgaria	147	151	172	177	175	183	179	163
Croatia	86	86	88	88	86	84	83	86
Cyprus	22	21	21	22	21	22	21	22
Czech Republic	295	304	291	292	290	281	276	273
Denmark	227	224	221	230	214	205	205	191
Estonia	45	47	47	48	45	42	41	45
Finland	234	236	236	244	233	205	221	209
France	1617	1580	1543	1498	1463	1417	1334	1275
Georgia	11	14	15	16	20	26	28	32
Germany	1929	1851	1773	1718	1652	1577	1568	1499
Greece	388	415	412	422	430	440	442	442
Hungary	183	183	176	180	177	174	167	163
Iceland	28	27	28	28	28	26	26	28
Ireland	175	174	166	166	167	169	164	160
Italy	1489	1457	1399	1383	1338	1281	1211	1160
Kazakhstan	366	436	448	470	515	548	581	612
Kyrgyzstan	21	22	23	24	25	26	30	33
Latvia	41	44	42	44	43	42	43	43
Lithuania	53	54	55	55	56	59	62	61
Luxembourg	41	42	42	45	53	55	48	43
Malta	9	9	9	10	10	9	9	9
Montenegro	9	7	7	7	8	8	8	8
Netherlands	464	452	435	430	415	406	398	380
Norway	209	207	202	202	203	204	200	204
Poland	846	821	790	809	831	859	877	878
Portugal	289	287	292	269	272	279	256	247
Republic of Moldova	13	16	15	20	20	21	19	20
Romania	263	271	277	288	294	318	314	295
Russian Federation	3349	3442	3536	3786	3769	3731	4260	4288
Serbia	144	149	158	161	180	167	169	176
Slovakia	113	114	108	104	107	112	104	103
Slovenia	60	60	59	57	55	56	57	55
Spain	1388	1347	1382	1373	1406	1387	1343	1338
Sweden	216	206	198	194	189	184	180	173
Switzerland	105	101	96	93	92	91	88	86
Tajikistan	5	5	5	5	6	6	7	8
TFYR of Macedonia	43	40	38	34	36	37	37	40
Turkey	585	568	546	528	621	659	677	731
Turkmenistan	61	62	65	72	73	75	77	84
Ukraine	828	835	851	954	874	883	892	913
United Kingdom	2026	1978	1874	1830	1774	1763	1693	1623
Uzbekistan	223	222	225	221	210	200	204	202
North Africa	803	827	852	876	901	926	967	1009
Asian areas (AST)	3029	3193	3358	3522	3686	3850	3975	4100
Baltic Sea	351	358	365	371	378	384	375	348
Black Sea	96	97	99	101	103	105	110	103
Mediterranean Sea	1270	1307	1345	1382	1420	1457	1552	1405
North Sea	711	726	742	757	773	789	828	767
Remaining N-E Atlantic Ocean	772	790	807	824	842	859	903	835
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	26556	26755	26815	27315	27476	27569	28167	27802

Table B:4: National total emission trends of nitrogen oxides (2008-2016), as used for modelling at the MSC-W (Gg of NO_2 per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	22	22	22	23	23	23	24	24	25
Armenia	23	23	23	23	22	22	22	20	18
Austria	200	185	185	176	171	172	162	159	154
Azerbaijan	84	69	74	80	87	93	95	87	80
Belarus	189	189	170	171	175	167	159	145	143
Belgium	269	241	246	228	215	212	202	202	193
Bosnia and Herzegovina	33	33	32	32	32	32	31	31	31
Bulgaria	164	148	138	158	141	126	132	132	125
Croatia	81	75	67	64	58	57	53	54	52
Cyprus	20	20	19	22	22	17	18	15	15
Czech Republic	254	235	226	213	199	185	179	174	165
Denmark	174	155	150	141	130	125	116	115	115
Estonia	42	37	43	41	38	35	35	32	31
Finland	191	171	184	169	160	156	148	134	131
France	1178	1092	1078	1015	987	970	900	875	842
Georgia	32	31	33	37	38	33	35	37	38
Germany	1427	1330	1357	1342	1304	1304	1265	1241	1218
Greece	420	413	343	314	275	261	255	253	244
Hungary	158	147	142	134	125	123	122	124	117
Iceland	26	26	24	22	22	22	21	22	24
Ireland	146	123	117	105	108	109	108	111	112
Italy	1075	990	972	934	876	818	804	783	761
Kazakhstan	625	622	642	648	727	738	737	773	760
Kyrgyzstan	36	39	43	46	49	52	55	59	62
Latvia	39	37	39	36	36	36	36	36	35
Lithuania	60	53	56	53	55	54	54	54	54
Luxembourg	38	34	33	33	31	27	25	22	20
Malta	9	9	8	8	9	7	6	5	5
Montenegro	9	7	10	13	13	13	13	14	14
Netherlands	371	337	334	318	302	292	270	268	254
Norway	194	185	189	185	180	169	160	154	151
Poland	842	831	858	841	810	774	726	705	726
Portugal	227	217	202	185	172	169	166	168	161
Republic of Moldova	22	22	25	25	24	24	26	26	27
Romania	292	248	234	244	241	224	217	214	211
Russian Federation	4347	4255	2897	2999	3094	3146	3167	3125	3154
Serbia	165	157	144	159	149	149	126	142	145
Slovakia	104	94	94	85	83	81	80	75	67
Slovenia	59	51	50	49	47	45	40	36	37
Spain	1132	1010	952	937	902	789	801	805	765
Sweden	165	154	157	150	143	140	139	134	131
Switzerland	84	79	77	73	73	72	69	65	63
Tajikistan	8	8	8	8	8	9	9	9	10
TFYR of Macedonia	39	39	38	41	38	38	29	28	22
Turkey	722	704	698	737	649	679	680	691	703
Turkmenistan	87	85	83	86	88	90	92	94	97
Ukraine	893	731	716	704	693	682	671	659	648
United Kingdom	1451	1265	1242	1154	1178	1118	1045	1010	916
Uzbekistan	199	195	194	191	188	185	182	179	177
North Africa	1051	1092	1134	1230	1220	1275	1309	1369	1385
Asian areas (AST)	4225	4349	4474	4926	5079	5473	5872	6277	6696
Baltic Sea	340	333	333	337	315	306	305	257	257
Black Sea	94	92	90	91	85	83	83	86	86
Mediterranean Sea	1248	1203	1168	1188	1112	1078	1076	1115	1115
North Sea	702	683	669	677	633	614	613	565	565
Remaining N-E Atlantic Ocean	762	741	725	735	687	666	665	689	689
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	26849	25718	24263	24635	24325	24362	24433	24679	24841

Table B:5: National total emission trends of ammonia (2000-2007), as used for modelling at the MSC-W (Gg of NH_3 per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	29	29	28	28	27	27	26	24
Armenia	11	12	12	15	15	16	16	17
Austria	66	66	66	65	65	65	65	67
Azerbaijan	50	51	54	58	61	63	66	66
Belarus	150	149	148	147	146	145	144	144
Belgium	92	88	85	81	77	75	75	71
Bosnia and Herzegovina	17	17	17	18	18	18	18	19
Bulgaria	54	51	50	52	53	52	51	52
Croatia	41	44	42	43	46	42	41	41
Cyprus	6	7	7	7	7	6	6	7
Czech Republic	87	88	86	84	80	78	78	79
Denmark	97	95	94	93	92	89	85	84
Estonia	9	10	10	11	11	11	11	11
Finland	34	34	35	36	36	37	36	35
France	662	657	643	635	629	625	615	622
Georgia	34	34	35	37	36	35	30	35
Germany	647	653	640	637	626	625	626	628
Greece	66	64	65	64	67	65	63	65
Hungary	93	92	92	94	90	86	86	86
Iceland	5	5	5	5	5	5	5	5
Ireland	115	115	115	114	113	113	112	109
Italy	455	458	446	444	440	424	419	422
Kazakhstan	150	150	160	170	178	195	194	200
Kyrgyzstan	26	26	27	27	27	28	29	29
Latvia	14	15	14	15	14	15	15	16
Lithuania	35	34	36	37	37	38	38	38
Luxembourg	7	7	7	6	7	6	6	6
Malta	2	2	2	2	2	2	2	2
Montenegro	6	5	6	6	5	4	3	3
Netherlands	175	169	162	158	157	153	156	152
Norway	28	28	29	30	30	30	30	29
Poland	319	323	322	304	292	300	321	320
Portugal	78	74	71	65	64	63	61	62
Republic of Moldova	23	24	25	24	23	24	24	19
Romania	168	164	172	174	188	206	205	201
Russian Federation	966	935	904	898	900	817	872	849
Serbia	77	75	80	75	82	82	79	81
Slovakia	40	41	40	39	36	36	34	33
Slovenia	20	20	21	20	19	19	19	20
Spain	540	528	521	542	532	500	490	499
Sweden	60	59	59	59	59	58	57	57
Switzerland	62	61	60	59	59	60	60	61
Tajikistan	23	21	27	28	29	31	32	33
TFYR of Macedonia	13	13	12	12	12	12	12	12
Turkey	559	505	506	552	551	564	589	552
Turkmenistan	39	50	47	55	63	64	69	68
Ukraine	302	292	282	273	263	253	253	252
United Kingdom	312	304	299	292	298	290	283	279
Uzbekistan	151	147	148	160	169	175	183	186
North Africa	365	380	394	409	423	438	448	458
Asian areas (AST)	2361	2416	2471	2525	2580	2635	2695	2755
Baltic Sea	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0
Remaining N-E Atlantic Ocean	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	9740	9688	9682	9784	9841	9799	9935	9960

Table B:6: National total emission trends of ammonia (2008-2016), as used for modelling at the MSC-W (Gg of NH_3 per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	24	24	24	24	24	25	25	25	24
Armenia	17	17	18	18	18	18	19	19	19
Austria	66	67	67	66	66	66	67	67	68
Azerbaijan	72	71	70	69	71	73	75	77	74
Belarus	147	150	151	154	157	149	141	143	136
Belgium	70	71	71	70	70	71	68	68	68
Bosnia and Herzegovina	19	19	19	19	19	20	20	20	21
Bulgaria	49	46	47	45	45	46	49	50	50
Croatia	38	38	38	39	38	34	32	35	35
Cyprus	6	6	6	6	6	5	5	5	6
Czech Republic	78	73	72	71	70	72	72	73	73
Denmark	83	79	80	78	76	74	74	74	75
Estonia	12	11	11	11	12	12	12	13	12
Finland	34	35	35	34	33	33	33	31	31
France	630	621	625	615	616	615	621	628	630
Georgia	36	36	36	37	39	44	37	37	36
Germany	633	646	626	656	644	660	662	670	663
Greece	62	60	64	63	62	62	61	60	60
Hungary	79	77	78	79	79	82	82	87	87
Iceland	5	5	5	5	5	5	5	5	5
Ireland	110	110	108	104	106	108	108	111	117
Italy	412	398	387	387	396	378	367	368	382
Kazakhstan	205	211	216	207	211	213	222	229	238
Kyrgyzstan	30	31	31	32	33	34	34	35	36
Latvia	15	16	15	15	16	16	17	16	16
Lithuania	36	37	37	36	35	35	35	35	34
Luxembourg	6	6	6	6	6	6	6	6	6
Malta	2	2	2	1	2	2	2	1	1
Montenegro	3	3	3	3	3	3	2	2	2
Netherlands	139	136	133	129	123	122	125	126	127
Norway	29	29	29	28	28	28	29	28	28
Poland	306	292	285	285	275	274	270	267	267
Portugal	60	58	57	58	56	54	56	57	56
Republic of Moldova	19	21	22	21	20	19	23	23	23
Romania	198	191	175	173	172	172	169	171	167
Russian Federation	841	1066	1088	1108	1127	1130	1145	1178	1196
Serbia	72	77	68	70	75	71	65	65	65
Slovakia	31	31	31	30	31	30	31	31	30
Slovenia	19	19	19	18	18	18	18	18	18
Spain	462	467	456	446	439	443	464	492	492
Sweden	57	54	55	54	53	54	54	54	53
Switzerland	61	60	60	59	58	58	58	57	57
Tajikistan	37	39	40	42	44	46	47	49	51
TFYR of Macedonia	12	11	11	12	11	11	11	11	11
Turkey	519	529	547	567	628	657	667	650	713
Turkmenistan	73	74	76	80	84	87	91	95	98
Ukraine	252	252	251	256	261	266	271	276	281
United Kingdom	263	265	270	271	268	264	276	280	289
Uzbekistan	193	203	212	218	224	230	236	242	248
North Africa	469	479	490	506	501	523	537	562	569
Asian areas (AST)	2815	2876	2936	3006	3024	3258	3496	3737	3987
Baltic Sea	0	0	0	0	0	0	0	0	0
Black Sea	0	0	0	0	0	0	0	0	0
Mediterranean Sea	0	0	0	0	0	0	0	0	0
North Sea	0	0	0	0	0	0	0	0	0
Remaining N-E Atlantic Ocean	0	0	0	0	0	0	0	0	0
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	9909	10193	10255	10389	10478	10773	11093	11463	11835

Table B:7: National total emission trends of non-methane volatile organic compounds (2000-2007), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	23	25	26	29	32	33	33	33
Armenia	16	28	14	28	30	32	33	35
Austria	176	173	169	168	163	160	155	150
Azerbaijan	67	70	72	75	77	82	92	96
Belarus	430	420	411	402	393	384	375	367
Belgium	217	213	198	190	180	176	171	162
Bosnia and Herzegovina	52	50	49	48	46	45	44	42
Bulgaria	107	94	102	107	94	96	97	90
Croatia	106	104	107	111	115	117	117	112
Cyprus	15	15	16	17	18	18	17	17
Czech Republic	302	299	295	291	279	267	267	260
Denmark	172	164	159	152	149	145	141	137
Estonia	38	37	37	35	35	33	32	29
Finland	176	173	168	161	156	145	141	137
France	1615	1540	1410	1331	1256	1164	1047	938
Georgia	38	38	38	38	38	38	38	38
Germany	1609	1507	1439	1368	1377	1324	1336	1270
Greece	319	314	335	317	321	308	307	304
Hungary	205	206	190	192	183	168	156	150
Iceland	9	9	9	9	9	8	8	8
Ireland	122	122	122	120	120	120	120	120
Italy	1590	1527	1439	1418	1324	1339	1300	1284
Kazakhstan	170	175	177	187	194	205	223	245
Kyrgyzstan	20	21	23	25	26	28	32	36
Latvia	53	55	54	54	53	52	51	50
Lithuania	70	68	67	68	69	67	67	67
Luxembourg	16	16	16	14	16	15	14	13
Malta	3	3	3	3	3	3	4	3
Montenegro	10	9	8	9	10	8	9	10
Netherlands	252	225	212	198	185	190	184	183
Norway	390	400	355	311	278	229	200	197
Poland	596	572	596	584	598	606	647	618
Portugal	224	221	218	208	203	193	187	183
Republic of Moldova	29	35	33	34	38	47	50	53
Romania	281	264	264	282	290	329	333	322
Russian Federation	3414	3584	3754	3629	3519	3566	3207	3178
Serbia	146	144	145	147	150	147	143	147
Slovakia	121	121	120	113	114	107	104	98
Slovenia	52	49	50	49	46	43	43	42
Spain	947	914	886	848	831	803	778	766
Sweden	224	219	218	218	213	212	208	202
Switzerland	135	127	116	107	98	95	92	88
Tajikistan	6	8	9	9	10	9	11	13
TFYR of Macedonia	48	40	39	39	39	37	39	39
Turkey	1072	987	997	1021	1027	1013	1013	1002
Turkmenistan	82	84	86	93	88	84	80	82
Ukraine	555	609	632	632	611	631	664	680
United Kingdom	1648	1565	1471	1352	1264	1184	1136	1098
Uzbekistan	183	180	174	181	148	144	141	138
North Africa	1059	1058	1057	1057	1056	1055	1058	1062
Asian areas (AST)	5200	5327	5454	5581	5708	5835	5935	6036
Baltic Sea	2	2	3	3	3	3	3	2
Black Sea	1	1	1	1	1	1	1	1
Mediterranean Sea	11	11	12	12	13	13	14	12
North Sea	6	6	6	6	6	7	7	6
Remaining N-E Atlantic Ocean	7	7	7	7	8	8	8	7
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	24437	24237	24065	23689	23309	23171	22709	22460

Table B:8: National total emission trends of non-methane volatile organic compounds (2008-2016), as used for modelling at the MSC-W (Gg of NMVOC per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	33	33	34	35	35	36	37	37	38
Armenia	35	35	34	34	34	34	34	35	36
Austria	147	143	144	139	139	141	135	138	138
Azerbaijan	102	104	108	112	116	119	114	103	91
Belarus	387	362	308	346	347	339	330	310	291
Belgium	154	142	142	130	127	124	117	115	114
Bosnia and Herzegovina	41	40	39	38	37	36	35	35	34
Bulgaria	90	89	90	91	89	83	82	83	84
Croatia	110	95	90	85	79	75	68	69	70
Cyprus	15	14	15	10	10	9	9	9	9
Czech Republic	252	247	242	230	224	223	216	216	213
Denmark	132	125	122	115	112	112	103	106	103
Estonia	28	25	24	24	24	23	23	23	22
Finland	123	113	116	104	101	96	94	88	88
France	857	772	771	709	684	670	628	615	608
Georgia	37	37	39	39	38	45	43	40	40
Germany	1213	1116	1230	1146	1120	1105	1029	1039	1052
Greece	271	257	255	240	223	205	203	208	200
Hungary	144	146	144	147	147	149	140	143	141
Iceland	8	8	7	7	7	7	7	7	7
Ireland	115	113	109	107	108	111	106	107	108
Italy	1257	1180	1117	1027	1019	992	927	918	904
Kazakhstan	254	267	277	259	290	280	312	300	297
Kyrgyzstan	39	43	47	51	55	58	62	66	70
Latvia	45	44	42	42	43	43	44	42	40
Lithuania	61	59	59	57	56	52	53	52	52
Luxembourg	14	13	12	12	12	13	12	13	13
Malta	3	3	3	3	3	3	3	3	3
Montenegro	10	10	8	9	8	8	8	8	8
Netherlands	175	165	175	170	166	158	152	149	141
Norway	164	149	150	144	144	147	157	157	152
Poland	633	617	636	616	611	603	591	591	609
Portugal	173	160	163	156	154	152	156	157	154
Republic of Moldova	65	60	42	44	46	43	48	48	49
Romania	334	295	288	280	285	271	266	260	258
Russian Federation	3281	3201	3339	3404	3505	3525	3528	3524	3548
Serbia	144	141	134	134	128	127	117	123	127
Slovakia	102	96	90	88	80	71	66	69	64
Slovenia	40	38	37	35	33	32	30	30	31
Spain	705	648	637	611	586	567	568	583	594
Sweden	191	185	184	177	167	163	161	162	159
Switzerland	87	84	83	80	78	77	74	72	71
Tajikistan	13	13	14	14	15	16	16	17	18
TFYR of Macedonia	43	43	36	39	37	37	33	33	27
Turkey	1015	1039	1060	1043	1104	1049	1046	1086	1071
Turkmenistan	87	80	78	77	77	77	76	76	75
Ukraine	682	559	534	532	530	528	525	523	521
United Kingdom	1022	928	903	890	878	850	842	837	821
Uzbekistan	138	141	139	134	130	125	121	116	112
North Africa	1066	1069	1073	1101	1095	1145	1176	1229	1244
Asian areas (AST)	6136	6237	6337	6652	6833	7363	7901	8446	9011
Baltic Sea	2	2	2	2	2	2	2	2	2
Black Sea	1	1	1	1	1	1	1	1	1
Mediterranean Sea	11	10	10	10	10	8	8	8	8
North Sea	6	6	5	5	5	4	5	5	5
Remaining N-E Atlantic Ocean	7	6	6	6	6	5	5	5	5
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	22305	21610	21785	21790	21993	22333	22647	23237	23755

Table B:9: National total emission trends of carbon monoxide (2000-2007), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	92	97	109	125	154	151	158	145
Armenia	110	104	106	120	118	116	114	112
Austria	743	722	696	702	692	672	659	622
Azerbaijan	88	97	95	99	100	106	117	120
Belarus	1245	1214	1184	1154	1123	1093	1063	1033
Belgium	931	884	867	842	804	756	701	655
Bosnia and Herzegovina	92	92	92	92	96	94	93	90
Bulgaria	347	301	347	353	313	297	309	277
Croatia	451	435	417	439	416	419	391	376
Cyprus	30	29	29	29	28	27	25	24
Czech Republic	948	958	923	930	917	844	857	864
Denmark	464	454	431	433	416	417	404	409
Estonia	199	200	190	183	174	155	142	158
Finland	562	558	542	518	503	475	465	447
France	6633	6271	6038	5728	5822	5304	4710	4539
Georgia	131	170	173	167	187	221	225	178
Germany	4812	4636	4361	4181	3944	3737	3642	3525
Greece	953	951	890	853	839	799	826	751
Hungary	825	836	690	816	750	679	585	543
Iceland	49	51	54	54	56	51	59	76
Ireland	248	244	233	223	219	218	201	188
Italy	4855	4500	3929	3986	3434	3448	3296	3367
Kazakhstan	625	631	616	663	671	720	853	1009
Kyrgyzstan	90	97	105	113	120	128	146	163
Latvia	280	285	269	268	253	222	220	198
Lithuania	195	189	192	183	181	181	191	194
Luxembourg	42	43	40	40	42	38	35	39
Malta	14	12	11	11	10	11	10	10
Montenegro	40	37	34	40	40	37	36	37
Netherlands	750	748	740	733	742	722	733	721
Norway	621	604	596	572	543	547	521	506
Poland	3252	3107	3136	3045	3069	3059	3220	2977
Portugal	667	608	594	572	545	513	483	460
Republic of Moldova	28	29	34	50	48	49	50	44
Romania	685	593	613	703	787	960	898	846
Russian Federation	13244	13587	13929	14007	14524	14660	12650	12854
Serbia	392	394	394	408	425	399	353	398
Slovakia	376	395	368	390	378	378	337	321
Slovenia	182	177	172	168	154	150	140	132
Spain	2877	2469	2359	2271	2217	2155	2031	2017
Sweden	679	645	612	607	568	559	529	528
Switzerland	386	366	342	333	317	304	282	266
Tajikistan	50	56	65	67	77	78	87	98
TFYR of Macedonia	145	113	115	116	121	115	118	113
Turkey	2605	2357	2420	2376	2376	2318	2350	2399
Turkmenistan	301	297	305	337	317	310	322	294
Ukraine	4154	4028	3901	3775	3420	3200	3025	2881
United Kingdom	4369	4385	3902	3543	3334	3090	2899	2688
Uzbekistan	740	724	704	740	594	594	580	573
North Africa	2677	2600	2524	2447	2370	2294	2275	2257
Asian areas (AST)	13567	13828	14089	14349	14610	14871	14970	15069
Baltic Sea	22	22	23	24	24	25	24	21
Black Sea	8	8	8	9	9	9	9	9
Mediterranean Sea	101	104	108	112	116	119	129	114
North Sea	53	55	56	58	60	61	65	59
Remaining N-E Atlantic Ocean	63	64	66	68	69	71	76	69
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	79089	77465	75841	75227	74241	73028	69690	68862

Table B:10: National total emission trends of carbon monoxide (2008-2016), as used for modelling at the MSC-W (Gg of CO per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	148	146	150	154	158	162	165	169	173
Armenia	111	110	109	108	107	106	105	106	107
Austria	603	572	585	570	574	592	546	568	565
Azerbaijan	138	143	153	167	183	188	191	174	137
Belarus	1063	990	870	880	878	860	843	767	760
Belgium	657	429	499	396	345	523	322	375	368
Bosnia and Herzegovina	86	94	94	94	94	95	95	95	95
Bulgaria	274	257	278	277	272	249	243	240	245
Croatia	324	316	300	273	255	232	203	217	202
Cyprus	22	20	19	17	16	15	15	14	15
Czech Republic	805	802	823	805	803	821	798	795	798
Denmark	387	355	345	306	288	274	250	253	244
Estonia	157	156	157	132	142	134	129	129	140
Finland	423	397	410	373	364	350	344	322	324
France	4321	3843	4225	3517	3204	3254	2735	2682	2737
Georgia	178	172	173	171	158	180	178	167	168
Germany	3417	2972	3337	3250	2878	2850	2744	2850	2864
Greece	705	638	575	515	543	453	458	433	399
Hungary	484	527	531	541	557	550	471	458	450
Iceland	114	118	117	115	116	119	117	119	122
Ireland	180	159	145	134	127	119	112	109	103
Italy	3497	3112	3075	2435	2670	2502	2268	2378	2310
Kazakhstan	1082	1149	1252	1097	1361	1196	1520	1354	1313
Kyrgyzstan	180	198	215	232	250	267	285	302	319
Latvia	181	190	152	158	164	147	141	118	115
Lithuania	185	176	158	175	168	162	153	146	145
Luxembourg	33	30	29	26	27	26	25	21	22
Malta	11	9	8	8	7	7	7	6	6
Montenegro	35	29	30	33	32	32	31	31	30
Netherlands	725	676	675	652	619	589	562	569	559
Norway	493	445	457	432	425	396	375	382	380
Poland	2986	2909	3069	2784	2798	2664	2419	2370	2506
Portugal	418	398	400	373	361	342	326	334	322
Republic of Moldova	47	46	50	52	51	52	78	78	81
Romania	949	873	868	792	814	762	766	744	742
Russian Federation	12998	12333	10737	11198	11699	11946	12006	11993	12163
Serbia	379	357	348	345	308	284	268	272	276
Slovakia	311	268	277	260	255	247	254	247	240
Slovenia	127	130	131	128	124	123	106	107	110
Spain	1887	1731	1802	1757	1694	1652	1663	1649	1661
Sweden	514	502	491	479	455	450	437	427	429
Switzerland	256	240	230	209	201	194	175	167	162
Tajikistan	88	92	89	93	97	100	104	108	112
TFYR of Macedonia	125	134	115	120	103	105	88	86	74
Turkey	2722	2933	2900	2597	2827	2044	1961	2185	2003
Turkmenistan	296	290	276	274	272	269	267	264	262
Ukraine	2669	3016	2889	2763	2636	2510	2383	2257	2130
United Kingdom	2542	2093	2016	1835	1818	1815	1726	1689	1536
Uzbekistan	568	594	576	560	544	527	511	494	478
North Africa	2239	2220	2202	2281	2227	2328	2391	2499	2530
Asian areas (AST)	15169	15268	15367	16047	16343	17611	18896	20199	21551
Baltic Sea	21	20	20	20	19	17	17	17	17
Black Sea	8	8	7	8	7	6	6	6	6
Mediterranean Sea	99	94	90	93	89	76	77	77	77
North Sea	52	51	49	50	48	41	41	42	42
Remaining N-E Atlantic Ocean	62	59	58	59	56	48	49	49	49
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0	0
TOTAL	68547	65888	65008	63221	63633	63665	63445	64715	65774

Table B:11: National total emission trends of fine Particulate Matter (2000-2007), 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
Albania	9	9	10	13	14	13	14	13
Armenia	4	4	4	4	4	4	4	4
Austria	25	25	24	24	24	23	23	22
Azerbaijan	6	6	6	5	5	5	5	6
Belarus	61	59	58	56	55	54	52	51
Belgium	41	39	37	37	37	35	36	34
Bosnia and Herzegovina	16	17	18	19	20	20	19	18
Bulgaria	26	24	29	31	31	31	32	31
Croatia	33	36	35	40	39	41	37	34
Cyprus	3	2	2	2	2	2	2	2
Czech Republic	51	52	49	49	48	45	46	43
Denmark	24	24	23	25	25	26	26	29
Estonia	15	16	17	14	15	14	10	13
Finland	29	30	30	30	29	28	28	27
France	329	317	295	294	281	260	235	222
Georgia	28	27	26	26	25	24	24	23
Germany	163	157	151	146	142	135	131	126
Greece	58	62	57	56	57	58	58	56
Hungary	48	52	37	46	42	40	40	40
Iceland	1	1	1	1	1	1	2	2
Ireland	24	24	23	23	23	24	23	22
Italy	195	187	157	176	151	173	178	202
Kazakhstan	54	71	60	66	73	81	68	125
Kyrgyzstan	7	8	8	8	8	8	9	9
Latvia	23	23	23	24	26	23	23	22
Lithuania	7	8	8	8	8	7	8	8
Luxembourg	2	3	2	3	3	2	2	2
Malta	1	1	1	1	1	1	1	1
Montenegro	4	4	5	5	5	5	5	5
Netherlands	29	28	27	25	24	22	22	21
Norway	42	42	43	40	39	39	37	37
Poland	170	170	169	168	169	169	172	165
Portugal	67	65	65	62	64	62	58	57
Republic of Moldova	4	4	4	5	4	4	5	4
Romania	94	74	77	92	104	123	118	118
Russian Federation	489	481	472	437	477	442	496	433
Serbia	39	39	40	40	41	39	36	40
Slovakia	31	33	29	27	29	38	33	29
Slovenia	10	11	11	11	11	12	11	11
Spain	185	157	159	160	158	157	154	155
Sweden	28	27	27	27	27	27	26	25
Switzerland	11	10	10	10	10	10	9	9
Tajikistan	2	1	2	2	2	3	3	3
TFYR of Macedonia	30	18	19	29	31	28	27	21
Turkey	340	343	345	348	351	354	357	360
Turkmenistan	8	8	10	12	12	12	15	12
Ukraine	121	138	140	137	152	153	147	146
United Kingdom	151	149	133	133	131	129	127	121
Uzbekistan	15	15	17	15	16	16	17	18
North Africa	93	95	98	100	102	104	107	109
Asian areas (AST)	839	864	889	914	939	964	988	1011
Baltic Sea	16	16	16	16	16	16	14	11
Black Sea	5	6	6	6	6	6	7	6
Mediterranean Sea	79	81	84	87	89	92	98	89
North Sea	38	38	38	38	38	38	40	34
Remaining N-E Atlantic Ocean	50	52	53	54	55	57	60	55
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	4271	4250	4176	4228	4292	4300	4322	4294

Table B:12: National total emission trends of fine Particulate Matter (2008-2016), as used for modelling at the MSC-W (Gg of $PM_{2.5}$ per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	13	14	14	14	14	15	15	15	15
Armenia	4	4	4	4	4	4	4	4	4
Austria	21	20	20	20	19	20	18	18	18
Azerbaijan	6	6	6	6	7	7	6	6	5
Belarus	53	52	45	49	51	47	43	39	39
Belgium	34	30	32	26	27	29	22	24	25
Bosnia and Herzegovina	17	16	15	15	15	15	14	14	14
Bulgaria	31	29	31	34	34	32	31	32	32
Croatia	32	31	31	28	26	24	20	21	18
Cyprus	2	2	2	2	1	1	1	1	1
Czech Republic	42	42	45	43	43	43	41	40	39
Denmark	27	25	25	23	21	21	19	21	21
Estonia	12	10	14	18	8	11	8	9	7
Finland	25	24	26	22	22	21	21	19	20
France	217	206	214	186	191	192	167	168	170
Georgia	22	22	21	21	20	19	19	17	17
Germany	120	114	121	116	110	109	104	103	101
Greece	56	53	46	40	40	34	34	35	33
Hungary	37	47	50	57	60	61	52	55	53
Iceland	2	2	1	1	1	1	1	1	1
Ireland	22	21	19	17	17	17	16	16	15
Italy	216	201	196	150	177	172	155	166	162
Kazakhstan	143	133	122	131	139	147	155	163	172
Kyrgyzstan	9	10	10	10	11	11	11	12	12
Latvia	21	23	19	19	20	18	18	16	16
Lithuania	8	7	7	7	7	7	7	6	6
Luxembourg	2	2	2	2	2	2	2	1	2
Malta	1	1	1	1	1	1	1	1	1
Montenegro	6	4	4	5	5	5	5	5	5
Netherlands	19	18	17	16	15	14	14	13	13
Norway	36	34	38	35	36	31	27	28	27
Poland	161	153	163	155	154	148	140	138	146
Portugal	54	51	51	53	53	48	48	48	47
Republic of Moldova	4	4	4	5	5	5	11	11	11
Romania	139	132	132	122	125	116	115	110	110
Russian Federation	399	392	429	436	448	435	433	410	389
Serbia	39	42	42	42	42	37	37	38	41
Slovakia	29	28	28	29	29	30	29	30	27
Slovenia	12	13	14	13	13	13	11	12	12
Spain	142	143	139	138	136	131	130	130	128
Sweden	24	23	23	23	22	22	19	18	18
Switzerland	9	8	8	8	8	8	7	7	7
Tajikistan	3	4	3	4	4	4	4	4	5
TFYR of Macedonia	25	19	24	29	28	27	22	20	14
Turkey	362	365	368	371	374	377	379	382	385
Turkmenistan	12	15	14	15	16	16	17	18	18
Ukraine	162	139	135	136	138	139	141	142	143
United Kingdom	119	114	122	111	116	118	112	113	109
Uzbekistan	17	19	19	20	20	21	21	22	22
North Africa	112	115	117	124	125	131	134	140	142
Asian areas (AST)	1034	1058	1081	1121	1157	1247	1338	1430	1526
Baltic Sea	12	11	10	8	7	8	8	8	8
Black Sea	6	6	5	6	5	5	6	6	6
Mediterranean Sea	81	79	77	84	75	79	81	80	80
North Sea	28	28	25	20	18	19	19	19	19
Remaining N-E Atlantic Ocean	51	51	50	53	47	50	51	50	50
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	1673	0	0	0	0	0	0
TOTAL	4292	4214	5960	4241	4306	4362	4362	4453	4527

Table B:13: National total emission trends of coarse Particulate Matter (2000-2007), as used for modelling at the MSC-W (Gg of PM_{coarse} per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	4	4	4	4	4	4	4	4
Armenia	1	1	1	1	1	1	1	1
Austria	14	14	14	14	14	14	13	13
Azerbaijan	6	6	6	6	7	8	8	9
Belarus	15	14	14	14	13	13	13	12
Belgium	14	14	13	13	13	11	11	10
Bosnia and Herzegovina	15	15	16	16	16	17	16	15
Bulgaria	21	21	19	22	23	26	27	31
Croatia	7	8	9	11	11	10	10	10
Cyprus	2	2	2	2	2	2	2	2
Czech Republic	19	18	17	16	16	16	16	17
Denmark	12	12	11	11	12	12	12	12
Estonia	17	16	11	10	9	8	7	10
Finland	15	15	15	16	16	15	16	15
France	110	108	105	107	106	101	99	97
Georgia	2	2	2	3	3	3	3	3
Germany	125	116	117	111	110	107	108	105
Greece	40	45	46	47	48	53	50	50
Hungary	27	26	25	28	30	28	24	22
Iceland	0	0	0	0	0	0	0	1
Ireland	16	18	17	18	19	19	20	20
Italy	49	51	49	48	47	44	43	41
Kazakhstan	12	16	13	14	17	18	16	40
Kyrgyzstan	4	4	3	3	3	3	4	4
Latvia	4	4	4	4	12	7	8	9
Lithuania	6	6	7	7	7	7	7	7
Luxembourg	1	1	1	1	1	1	1	1
Malta	1	1	1	1	1	1	1	1
Montenegro	4	3	5	5	4	3	4	3
Netherlands	15	14	14	13	13	14	13	14
Norway	8	8	8	8	8	9	9	9
Poland	139	144	146	145	138	152	152	143
Portugal	33	48	52	39	39	40	43	34
Republic of Moldova	5	5	2	5	5	5	5	5
Romania	22	23	22	25	27	34	35	39
Russian Federation	234	241	248	294	323	300	266	237
Serbia	13	13	13	13	14	14	14	14
Slovakia	12	12	10	9	9	9	8	7
Slovenia	2	2	2	2	2	2	2	2
Spain	101	100	103	105	106	107	107	106
Sweden	19	19	19	19	19	19	19	20
Switzerland	10	10	9	9	10	10	10	10
Tajikistan	1	1	1	1	1	1	1	1
TFYR of Macedonia	14	9	9	13	14	13	12	10
Turkey	379	274	393	371	335	337	388	390
Turkmenistan	1	1	1	2	2	2	2	2
Ukraine	48	47	49	53	51	53	59	60
United Kingdom	82	85	73	80	74	72	71	69
Uzbekistan	5	5	5	6	6	6	6	7
North Africa	75	77	79	80	82	84	87	89
Asian areas (AST)	463	476	488	500	512	524	538	553
Baltic Sea	1	1	1	1	1	1	1	1
Black Sea	0	0	0	0	0	0	0	0
Mediterranean Sea	5	6	6	6	6	6	7	6
North Sea	3	3	3	3	3	3	3	2
Remaining N-E Atlantic Ocean	3	3	3	3	3	3	3	3
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	2254	2183	2309	2358	2369	2373	2406	2399

Table B:14: National total emission trends of coarse Particulate Matter (2008-2016), as used for modelling at the MSC-W (Gg of PM_{coarse} per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	4	4	4	4	4	4	4	4	4
Armenia	1	1	1	1	1	2	2	2	2
Austria	14	13	13	13	13	13	13	13	13
Azerbaijan	10	13	11	10	10	11	11	13	11
Belarus	13	13	13	14	16	14	12	12	9
Belgium	10	8	9	8	8	9	8	8	9
Bosnia and Herzegovina	14	13	12	12	12	12	12	12	12
Bulgaria	27	22	22	23	22	20	21	24	16
Croatia	11	10	8	8	8	7	7	7	7
Cyprus	2	2	2	1	1	1	1	1	1
Czech Republic	16	14	14	13	13	13	13	12	12
Denmark	12	11	11	11	11	11	11	11	11
Estonia	7	6	9	16	5	7	5	5	4
Finland	14	14	15	14	13	13	13	13	13
France	95	90	91	92	91	90	88	88	85
Georgia	3	3	4	4	4	4	4	4	4
Germany	105	100	106	110	109	112	112	111	102
Greece	49	40	46	42	43	30	29	29	29
Hungary	30	28	19	23	16	18	22	24	20
Iceland	0	0	0	0	0	0	0	0	0
Ireland	20	18	18	13	13	13	13	13	14
Italy	39	35	34	33	32	32	31	31	31
Kazakhstan	43	38	38	41	45	49	53	57	61
Kyrgyzstan	4	4	4	4	4	4	4	4	5
Latvia	9	7	7	9	8	8	8	9	8
Lithuania	7	7	7	7	7	7	7	7	7
Luxembourg	1	1	1	1	1	1	1	1	1
Malta	1	1	1	1	1	1	1	1	1
Montenegro	4	3	4	7	7	7	8	8	8
Netherlands	14	14	13	14	13	13	14	14	14
Norway	8	8	8	8	9	8	8	8	8
Poland	137	131	137	126	127	121	112	110	114
Portugal	36	37	27	36	54	19	15	16	18
Republic of Moldova	5	5	5	5	5	5	5	5	5
Romania	35	33	34	34	34	32	33	32	31
Russian Federation	221	235	363	372	385	383	385	381	373
Serbia	14	13	13	14	13	13	13	14	14
Slovakia	7	7	7	7	7	7	7	7	7
Slovenia	2	2	2	2	2	2	1	1	1
Spain	91	82	77	74	70	67	67	67	72
Sweden	19	18	18	20	18	20	18	19	19
Switzerland	10	10	10	10	10	10	10	10	10
Tajikistan	1	2	2	2	2	2	2	2	2
TFYR of Macedonia	11	9	10	13	12	13	11	9	7
Turkey	382	448	533	493	509	397	165	418	330
Turkmenistan	2	2	2	3	3	3	3	3	3
Ukraine	61	60	61	63	64	65	67	68	70
United Kingdom	62	57	63	60	57	64	62	62	63
Uzbekistan	7	8	8	9	9	9	10	10	10
North Africa	92	95	98	103	104	109	112	117	119
Asian areas (AST)	567	581	596	612	629	678	728	778	830
Baltic Sea	1	1	1	1	1	1	1	1	1
Black Sea	0	0	0	0	0	0	0	0	0
Mediterranean Sea	6	5	5	6	5	5	6	5	5
North Sea	2	2	2	1	1	1	1	1	1
Remaining N-E Atlantic Ocean	3	3	2	3	2	3	3	3	3
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	4297	0	0	0	0	0	0
TOTAL	2364	2385	6920	2628	2668	2563	2372	2686	2629

Table B:15: National total emission trends of Particulate Matter (2000-2007), as used for modelling at the MSC-W (Gg of PM_{10} per year).

Area/Year	2000	2001	2002	2003	2004	2005	2006	2007
Albania	12	13	14	17	18	17	18	17
Armenia	5	5	5	5	5	5	5	5
Austria	39	39	38	38	37	37	36	35
Azerbaijan	11	11	12	12	12	13	14	15
Belarus	75	74	72	70	68	67	65	63
Belgium	55	52	50	51	50	46	47	44
Bosnia and Herzegovina	31	32	34	35	36	37	35	33
Bulgaria	47	44	48	54	54	57	59	62
Croatia	41	44	44	51	50	51	47	45
Cyprus	5	4	4	4	4	4	4	4
Czech Republic	70	70	65	65	65	61	62	60
Denmark	36	36	34	36	36	37	38	41
Estonia	32	32	28	24	25	22	16	23
Finland	44	45	45	46	45	43	44	42
France	439	425	400	401	387	361	334	320
Georgia	31	30	29	28	28	27	27	26
Germany	288	274	268	258	252	242	239	230
Greece	98	107	103	103	105	110	108	107
Hungary	75	78	62	75	72	68	64	62
Iceland	2	2	1	2	2	2	2	2
Ireland	40	41	40	41	42	43	43	42
Italy	245	237	206	224	198	218	220	244
Kazakhstan	65	86	73	80	90	100	84	164
Kyrgyzstan	11	11	11	11	12	12	12	13
Latvia	27	27	27	29	37	30	30	31
Lithuania	14	14	15	14	15	15	15	15
Luxembourg	3	3	3	4	3	3	3	3
Malta	1	2	2	2	2	2	2	2
Montenegro	8	7	9	10	10	8	9	8
Netherlands	44	42	41	38	37	36	35	35
Norway	50	50	51	48	47	48	46	47
Poland	309	314	315	312	307	321	324	308
Portugal	100	113	117	101	103	102	102	91
Republic of Moldova	9	9	6	9	9	10	10	9
Romania	117	97	99	116	132	157	153	157
Russian Federation	723	722	720	732	800	742	762	669
Serbia	52	51	53	54	55	53	50	54
Slovakia	44	45	39	36	38	47	41	36
Slovenia	12	12	13	13	13	14	13	13
Spain	286	257	262	265	264	264	261	261
Sweden	46	46	45	46	46	46	45	45
Switzerland	20	20	19	19	19	19	19	19
Tajikistan	2	2	3	3	3	4	4	4
TFYR of Macedonia	43	28	28	42	46	41	39	31
Turkey	719	616	739	719	687	691	745	750
Turkmenistan	9	9	11	13	14	14	17	14
Ukraine	169	185	189	190	203	207	205	206
United Kingdom	232	234	206	214	205	201	198	190
Uzbekistan	20	20	22	21	22	22	23	25
North Africa	169	172	176	180	184	188	193	199
Asian areas (AST)	1302	1339	1377	1414	1451	1488	1526	1564
Baltic Sea	17	17	17	17	17	17	15	12
Black Sea	6	6	6	6	6	7	7	6
Mediterranean Sea	84	87	90	93	95	98	105	95
North Sea	40	40	40	40	40	40	43	37
Remaining N-E Atlantic Ocean	53	54	56	57	58	59	63	58
Natural marine emissions	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	0	0	0	0	0	0
TOTAL	6526	6433	6485	6587	6661	6673	6728	6693

Table B:16: National total emission trends of Particulate Matter (2008-2016), as used for modelling at the MSC-W (Gg of PM_{10} per year).

Area/Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
Albania	17	18	18	18	18	19	19	19	19
Armenia	5	5	5	5	5	6	6	6	6
Austria	35	33	33	33	33	33	31	31	31
Azerbaijan	16	18	18	16	17	17	17	19	16
Belarus	66	65	58	63	68	61	55	51	48
Belgium	43	38	41	34	35	37	30	33	34
Bosnia and Herzegovina	31	29	27	27	27	26	26	26	26
Bulgaria	58	51	53	57	56	52	52	55	48
Croatia	43	41	39	36	34	31	27	28	26
Cyprus	4	4	3	3	2	2	2	2	2
Czech Republic	58	56	59	56	56	56	53	53	52
Denmark	39	36	36	34	32	32	30	31	31
Estonia	19	16	23	34	13	18	13	14	11
Finland	40	38	41	37	35	34	34	32	33
France	312	296	306	278	283	282	255	257	255
Georgia	26	25	25	24	24	23	23	22	22
Germany	225	214	227	226	219	221	216	214	203
Greece	104	93	91	82	83	63	63	64	62
Hungary	67	75	69	80	76	79	74	78	73
Iceland	2	2	2	2	2	2	2	2	2
Ireland	41	39	37	31	30	31	29	30	29
Italy	256	236	231	183	209	204	187	197	193
Kazakhstan	187	171	160	172	184	196	208	220	232
Kyrgyzstan	13	14	14	14	15	15	16	16	17
Latvia	30	29	25	28	28	26	26	26	24
Lithuania	15	14	14	14	14	14	14	13	13
Luxembourg	3	3	3	2	2	2	2	2	2
Malta	2	2	1	1	1	1	2	1	1
Montenegro	10	7	8	12	12	12	12	13	13
Netherlands	34	31	30	30	28	28	27	27	26
Norway	44	43	46	43	45	39	36	36	36
Poland	298	284	300	280	280	269	252	249	259
Portugal	90	88	79	89	107	67	63	64	65
Republic of Moldova	9	9	10	10	10	10	16	16	16
Romania	173	165	166	157	159	148	148	142	141
Russian Federation	620	628	792	808	833	818	818	791	762
Serbia	54	55	56	56	55	50	49	51	55
Slovakia	36	36	35	36	36	37	36	37	34
Slovenia	14	15	15	15	15	15	13	13	13
Spain	233	225	216	212	206	199	197	198	200
Sweden	43	41	41	43	39	41	37	37	38
Switzerland	19	18	18	18	18	18	17	17	17
Tajikistan	5	5	5	5	6	6	6	7	7
TFYR of Macedonia	36	28	34	41	40	40	33	29	21
Turkey	744	813	901	864	883	773	544	800	715
Turkmenistan	14	17	17	18	18	19	20	21	21
Ukraine	223	199	196	199	202	205	207	210	213
United Kingdom	181	170	185	171	174	181	173	175	172
Uzbekistan	24	27	28	28	29	30	31	32	32
North Africa	204	210	215	227	229	240	246	257	261
Asian areas (AST)	1601	1639	1677	1734	1786	1925	2065	2208	2356
Baltic Sea	12	12	11	9	8	8	8	8	8
Black Sea	6	6	6	6	5	6	6	6	6
Mediterranean Sea	86	85	83	89	80	84	86	85	85
North Sea	30	30	27	21	19	20	20	20	20
Remaining N-E Atlantic Ocean	54	53	52	55	49	52	53	53	53
Natural marine emissions	0	0	0	0	0	0	0	0	0
Volcanic emissions	0	0	5970	0	0	0	0	0	0
TOTAL	6657	6599	12880	6869	6975	6925	6733	7140	7155

APPENDIX C

Source-receptor tables for 2016

The source-receptor tables in this appendix are calculated for the meteorological and chemical conditions of 2016. The EMEP MSC-W model version rv4.17 has been used for the 2016 source-receptor model runs. The emissions used are the latest reported emissions for 2016 as shown in Appendix A.

It can be noted that there also have been many changes in chemistry, deposition, and vertical resolution in the current rv4.17 setup compared to the rv4.9 source-receptor matrix calculations performed in EMEP Report 1/2016. For example, the increased increased NO_2 deposition rates discussed in EMEP Report 1/2017 (Chapter 8) can lead to increased local-scale deposition in some region, and the calculations of POD_1 for forests have changed. For more details see Chapter 8.

The tables are calculated for the new EMEP domain, which covers 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 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.

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 reduction in PPM means that PPM_{fine} and PPM_{coarse} are reduced together in one simulation. For year 2016, reductions in volcanic emissions are done for passive SO_2 degassing of Italian volcanoes (Etna, Stromboli and Vulcano). The boundary conditions for all gaseous and aerosol species were given as 5-year monthly average concentrations, derived from EMEP MSC-W global runs, kept invariable over the calculation period.

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

For the concentrations and indicator tables, the differences obtained by the 15% emission reduction of the relevant pollutants are given directly. Thus, the tables should be interpreted as estimates of this reduction scenario from the chemical conditions in 2016.

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.

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

Acidification and eutrophication

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

Ground Level Ozone

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

Particulate Matter

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

Fine Elemental Carbon

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

Coarse Elemental Carbon

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

Table C.1: 2016 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	34	0	0	0	5	0	1	0	0	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	5	0	0	0	0	0	0	4	AL
AM	0	68	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	-0	0	0	0	AM
AT	0	0	31	0	7	1	1	0	1	0	18	37	0	0	1	0	3	1	0	0	1	1	0	0	3	0	0	0	0	0	0	1	AT
AZ	0	21	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	0	0	0	0	0	AZ
BA	1	0	1	0	302	0	2	0	0	0	4	3	0	0	2	0	1	0	0	1	3	2	0	0	5	0	0	0	0	0	0	15	BA
BE	0	-0	0	-0	0	50	0	0	0	-0	0	17	0	0	1	0	15	6	-0	0	0	0	0	0	0	-0	0	0	0	0	0	0	BE
BG	2	0	0	0	11	0	181	1	0	0	2	2	0	0	1	0	0	0	0	18	0	1	0	0	2	0	1	0	0	0	1	6	BG
BY	0	0	1	0	9	1	5	103	0	0	11	22	1	3	1	2	2	3	0	1	0	1	0	0	1	0	3	6	0	1	1	3	BY
CH	0	0	0	0	0	0	0	0	14	0	1	7	0	0	2	0	8	1	0	0	0	0	0	0	3	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CY
CZ	0	0	3	0	6	1	1	0	0	0	158	48	0	0	1	0	3	2	0	0	1	2	0	0	1	0	0	0	0	0	0	1	CZ
DE	0	0	6	0	4	32	0	1	5	0	56	702	1	1	7	0	48	28	0	0	0	1	1	0	2	0	0	1	1	0	0	0	DE
DK	0	0	0	0	0	2	0	0	0	0	2	18	9	0	1	0	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	1	0	0	2	0	0	1	4	0	14	0	4	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0	EE
ES	0	0	0	0	1	1	0	0	0	0	1	4	0	0	371	0	7	2	-0	0	0	0	0	0	2	0	0	0	0	0	0	0	ES
FI	0	0	0	0	2	1	1	3	0	0	5	13	1	13	1	68	1	3	0	0	0	0	0	0	0	0	1	2	0	0	0	0	FI
FR	0	0	1	0	2	16	0	0	3	0	6	59	0	0	87	0	308	31	0	0	1	0	1	0	9	0	0	0	1	0	0	0	FR
GB	0	0	0	-0	0	4	0	0	0	0	2	17	0	0	7	0	12	286	-0	0	0	0	7	1	0	0	0	0	0	0	0	0	GB
GE	0	14	0	5	1	0	1	0	-0	1	0	0	0	0	0	0	0	0	34	1	0	0	0	0	0	0	2	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	2	0	0	0	7	0	23	0	0	0	1	2	0	0	2	0	1	0	0	92	0	1	0	0	6	0	1	0	0	0	0	3	GR
HR	1	0	2	0	61	0	1	0	0	0	6	5	0	0	3	0	2	0	0	1	23	3	0	0	9	0	0	0	0	0	0	4	HR
HU	1	0	3	0	45	0	5	0	0	0	12	9	0	0	1	0	1	1	0	2	4	48	0	0	3	0	0	0	0	0	0	8	HU
IE	0	0	0	0	0	1	0	0	0	-0	0	2	0	0	2	0	2	11	-0	0	0	0	22	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	0	2	0	0	0	0	0	53	0	0	0	0	0	0	0	0	IS
IT	1	0	2	0	29	1	3	0	1	0	5	7	0	0	21	0	23	1	0	2	8	1	0	0	211	0	0	0	0	0	0	5	IT
KG	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	119	39	0	-0	0	0	0	KG
KZ	0	25	0	9	6	0	6	4	0	1	3	5	0	2	1	1	1	1	3	3	0	0	0	0	1	92	1628	1	0	0	1	3	KZ
LT	0	0	0	0	2	1	1	6	0	0	4	10	1	1	0	1	1	2	0	0	0	0	0	0	0	0	0	18	0	1	0	1	LT
LU	0	-0	0	-0	0	0	0	0	0	-0	0	2	0	0	0	0	1	0	-0	0	0	0	0	0	0	0	0	0	1	0	0	0	LU
LV	0	0	0	0	2	0	1	5	0	0	3	7	1	2	0	2	1	2	0	0	0	0	0	0	0	0	0	9	0	7	0	0	LV
MD	0	0	0	0	2	0	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	9	1	MD
ME	2	0	0	0	9	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	35	ME
MK	2	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	1	0	0	0	0	0	0	1	MK
MT	0	-0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	-0	0	0	0	0	0	0	MT
NL	0	0	0	-0	0	25	0	0	0	-0	1	31	0	0	1	0	10	10	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	2	0	1	0	0	3	19	2	1	1	2	3	12	0	0	0	0	1	1	0	0	0	1	0	0	0	0	NO
PL	0	0	3	0	20	5	3	10	0	0	81	163	3	2	3	1	8	8	0	1	1	5	0	0	2	0	1	3	0	0	1	3	PL
PT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	2	0	1	0	47	0	53	2	0	0	9	11	0	0	2	0	1	1	0	8	2	8	0	0	5	0	2	0	0	0	4	17	RO
RS	3	0	1	0	69	0	13	0	0	0	4	4	0	0	1	0	1	0	0	6	2	4	0	0	3	0	0	0	0	0	0	44	RS
RU	1	23	2	14	44	4	33	79	0	1	32	75	4	69	5	49	7	14	8	11	1	4	1	1	4	8	1161	14	0	4	6	13	RU
SE	0	0	0	0	1	3	0	3	0	0	10	41	6	4	1	10	4	11	0	0	0	0	0	0	0	0	0	3	0	1	0	0	SE
SI	0	0	2	0	7	0	0	0	0	0	2	2	0	0	1	0	1	0	0	0	5	0	0	0	4	0	0	0	0	0	0	1	SI
SK	0	0	2	0	15	0	2	0	0	0	15	9	0	0	1	0	1	0	0	1	1	8	0	0	1	0	0	0	0	0	0	2	SK
TJ	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	3	7	0	-0	0	0	0	TJ
TM	0	6	0	3	0	0	0	0	-0	1	0	0	0	0	0	0	0	0	1	0	0	0	-0	0	0	0	25	0	0	0	0	0	TM
TR	1	19	0	1	11	0	22	1	0	13	2	3	0	0	3	0	1	0	1	19	0	1	0	0	7	0	3	0	0	0	1	4	TR
UA	1	1	2	1	33	1	28	30	0	0	29	38	1	3	4	2	3	3	1	8	2	9	0	0	5	0	14	3	0	0	11	9	UA
UZ	0	5	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	15	44	0	0	0	0	0	UZ
ATL	0	0	1	0	3	16	1	4	1	0	15	94	3	8	229	15	58	184	0	0	0	0	26	158	2	0	25	2	0	0	0	1	ATL
BAS	0	0	1	0	4	5	1	6	0	0	21	84	10	18	2	33	6	14	0	0	0	1	1	0	0	0	1	9	0	2	0	1	BAS
BLS	1	3	1	1	23	0	50	6	0	2	9	13	0	1	2	1	1	1	9	17	1	3	0	0	4	0	6	1	0	0	6	8	BLS
MED	19	1	3	0	153	2	58	1	2	24	17	28	0	0	178	0	81	5	0	90	14	3	0	0	234	0	1	0	0	0	1	41	MED
NOS	0	0	1	0	1	32	0	2	0	0	16	132	8	1	15	2	63	232	0	0	0	1	6	3	1	0	0	1	0	0	0	0	NOS
AST	0	28	0	26	2	0	3	1	0	9	1	1	0	0	1	0	0	0	4	4	0	0	0	0	1	25	244	0	0	0	0	1	AST
NOA	1	0	0	0	6	1	2	0	0	1	2	4	0	0	33	0	7	1	0	3	1	0	0	0	12	0	0	0	0	0	0	2	NOA
SUM	77	217	71	91	958	211	508	275	32	59	573	1760	51	146	1011	196	698	888	68	307	75	115	68	220	553	263	3217	77	5	17	44	239	SUM
EXC	56	184	64	64	765	153	393	255	29	23	492	1404	30	116	551	145	482	450	55	193	59	106	35	59	298	238	2940	63	4	15	36	187	EXC
EU	10	0	57	0	270	144	275	35	13	4	402	1224	23	38	529	88	454	415	0	126	49	82	34	3	262	0	6	39	4	10	7	54	EU
emis	77	194	69	90	957	212	525	279	31	82	575	1779	51	149	1090	199	702	896	64	345	74	115	69	248	582	264	3571	77	5	17	45	253	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.: 2016 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	11	0	0	0	1	0	0	14	0	0	0	0	0	0	6	2	0	0	0	0	9	0	0	12	7	3	50	172	90	15	AL
AM	0	0	0	0	0	0	0	0	1	0	0	0	0	0	44	0	0	0	0	0	1	0	90	3	14	0	5	231	118	1	AM
AT	0	0	0	0	23	0	1	19	1	0	2	2	0	0	2	2	0	0	0	0	2	0	0	3	6	1	5	181	163	128	AT
AZ	0	0	0	0	0	0	0	0	8	0	0	0	0	0	48	5	0	0	0	0	1	0	195	4	25	1	8	356	122	2	AZ
BA	1	0	0	0	10	0	3	109	1	0	0	2	0	0	4	5	0	0	-0	0	6	0	0	12	8	2	20	528	479	40	BA
BE	0	0	5	0	1	0	0	0	0	0	0	0	-0	-0	0	0	-0	1	0	0	0	2	0	1	2	3	0	106	98	97	BE
BG	20	0	0	0	9	0	25	63	8	0	0	1	0	0	82	30	0	0	0	3	10	0	3	14	17	2	43	560	468	244	BG
BY	2	0	1	0	140	0	9	25	68	1	0	3	0	0	46	106	-0	1	1	1	2	1	2	5	11	3	14	623	582	216	BY
CH	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	3	3	1	1	50	40	24	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1	0	4	2	2	1	2	32	19	4	CY
CZ	0	0	1	0	66	0	2	20	1	0	1	4	0	0	1	3	0	0	0	0	1	0	0	2	5	1	2	339	328	294	CZ
DE	0	0	22	0	89	1	1	11	4	0	0	2	0	0	1	4	-0	6	1	0	3	6	0	6	19	16	3	1096	1034	1005	DE
DK	0	0	2	0	12	0	0	1	2	0	0	0	0	0	0	1	-0	1	1	0	0	1	0	0	2	6	0	73	61	56	DK
EE	0	0	0	0	13	0	0	2	12	1	0	0	-0	0	1	4	-0	0	1	0	0	0	0	0	2	2	0	70	64	42	EE
ES	0	0	0	0	2	19	0	1	0	0	0	0	-0	-0	0	0	-0	41	0	0	62	0	0	79	54	28	4	683	415	412	ES
FI	0	0	1	2	31	0	1	5	87	9	0	1	0	0	5	12	-0	2	2	0	0	1	0	1	9	14	2	301	269	151	FI
FR	0	0	6	0	13	4	0	6	2	0	0	1	0	0	2	1	0	37	0	0	41	7	0	49	47	44	14	802	563	545	FR
GB	0	0	4	0	6	1	0	0	2	0	0	0	0	0	0	1	-0	28	0	0	1	5	0	1	19	37	0	445	353	348	GB
GE	0	0	0	0	1	0	1	2	7	0	0	0	0	0	121	8	0	0	0	2	2	0	89	5	20	1	12	329	198	4	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	8	2	0	12	2	0	GL
GR	20	0	0	0	5	0	5	34	4	0	0	1	0	0	114	15	0	0	0	2	41	0	6	46	31	11	100	580	342	140	GR
HR	1	0	0	0	12	0	3	82	1	0	2	2	0	0	4	5	0	0	0	0	14	0	0	14	9	4	21	298	235	76	HR
HU	5	0	0	0	35	0	21	134	2	0	1	15	0	0	8	10	0	0	0	0	4	0	0	8	8	1	14	413	376	163	HU
IE	0	0	0	0	1	0	0	0	0	0	0	0	-0	0	0	0	-0	8	0	0	0	1	0	1	7	17	0	76	42	41	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	0	6	12	0	78	57	3	IS
IT	3	0	0	0	12	1	2	37	2	0	2	1	0	0	13	8	0	3	0	0	101	0	1	90	46	24	286	955	404	304	IT
KG	0	0	0	0	0	-0	0	0	4	0	-0	0	12	1	13	1	28	0	0	0	0	0	169	1	68	0	6	466	220	0	KG
KZ	3	0	0	0	19	0	5	13	659	0	0	1	10	12	265	193	36	0	0	2	5	0	1074	16	352	4	67	4535	3013	50	KZ
LT	0	0	0	0	48	0	2	6	13	1	0	1	0	0	2	14	-0	0	0	0	0	0	0	1	3	2	2	148	138	93	LT
LU	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	5	LU
LV	0	0	0	0	27	0	1	4	13	1	0	1	0	0	3	9	0	0	1	0	0	0	0	1	3	3	1	111	102	66	LV
MD	1	0	0	0	8	0	6	5	5	0	0	0	0	0	16	32	0	0	0	1	1	0	0	2	2	0	3	101	91	20	MD
ME	1	0	0	0	1	0	0	14	0	0	0	0	0	0	2	1	0	0	-0	0	4	0	0	6	3	1	16	101	71	6	ME
MK	63	0	0	0	2	0	1	18	1	0	0	0	-0	0	12	3	0	0	0	0	2	0	0	4	4	1	14	148	122	20	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	32	0	3	0	0	0	0	0	0	0	-0	0	0	0	-0	2	0	0	0	4	0	1	2	5	0	129	115	113	NL
NO	0	0	2	25	12	0	0	0	17	3	0	0	0	0	0	3	0	13	1	0	0	5	0	0	18	48	0	197	111	63	NO
PL	2	0	3	1	1103	0	11	57	21	1	1	15	0	0	13	48	-0	2	0	0	3	0	1	7	17	9	13	1657	1604	1427	PL
PT	0	0	0	0	0	56	0	0	0	0	0	0	0	0	0	0	0	20	0	0	3	0	0	10	12	12	0	128	71	71	PT
RO	18	0	0	0	44	0	240	165	18	0	0	6	0	0	97	81	0	1	0	5	10	0	3	25	29	3	47	969	847	394	RO
RS	34	0	0	0	14	0	17	532	2	0	0	3	0	0	17	10	0	0	0	0	5	0	0	13	14	2	27	847	786	75	RS
RU	16	0	3	4	300	0	36	97	7142	11	1	9	2	4	797	1309	5	12	5	19	21	3	459	44	1307	122	163	13582	11427	695	RU
SE	0	0	3	6	58	0	1	2	33	32	0	1	0	-0	0	14	-0	4	3	0	0	2	0	1	15	21	1	296	248	188	SE
SI	0	0	0	0	4	0	1	14	0	0	8	1	0	-0	1	1	-0	0	0	0	4	0	0	2	2	1	4	67	54	30	SI
SK	1	0	0	0	47	0	7	44	1	0	0	34	0	0	4	6	0	0	0	0	2	0	0	3	4	1	6	220	203	129	SK
TJ	0	0	0	0	0	-0	0	0	2	0	-0	0	49	1	7	0	7	0	0	0	0	0	125	1	81	0	3	288	77	0	TJ
TM	0	0	0	0	1	0	0	1	17	0	0	0	2	20	49	8	5	0	0	0	1	0	765	6	190	1	13	1115	140	2	TM
TR	8	0	0	0	10	0	11	34	21	0	0	1	0	0	3954	45	0	1	0	13	80	0	1163	158	259	20	200	6093	4200	94	TR
UA	9	0	1	0	245	0	49	89	169	1	1	12	0	0	359	1245	0	1	0	13	16	1	29	32	48	6	63	2633	2423	448	UA
UZ	0	0	0	0	1	0	0	1	21	0	0	0	13	7	42	10	51	0	0	0	1	0	448	4	149	0	13	832	216	3	UZ
ATL	0	0	11	25	60	88	1	7	642	9	0	1	0	0	12	32	-0	1217	2	0	40	23	6	220	2437	3869	8	9559	1738	826	ATL
BAS	0	0	4	2	159	0	2	10	78	20	0	3	0	0	2	29	-0	3	17	0	1	3	0	2	20	39	3	621	532	397	BAS
BLS	14	0	0	0	62	0	49	80	105	0	0	4	0	0	1262	332	0	1	0	99	36	0	99	47	89	5	104	2562	2080	225	BLS
MED	41	6	1	0	59	7	22	191	13	0	2	5	0	0	1762	47	-0	29	0	8	1721	1	566	1475	503	546	1397	9364	3118	843	MED
NOS	0	0	35	12	77	1	1	4	16	3	0	2	0	0	1	11	0	41	2	0	2	64	0	4	58	208	1	1062	682	631	NOS
AST	2	0	0	0	5	0	2	7	108	0	0	0	11	10	504	65	10	0	0	2	26	0	10516	145	4637	12	100	16516	1079	30	AST
NOA	2	0	0	0	4	6	1	8	1	0	0	0	0	0	47	3	0	27	0	0	91	0	23	1335	392	34	53	2103	147	78	NOA
SUM	284	8	141	79	2855	186	544	1970	9336	96	26	137	99	54	9762	3772	143	1510	39	172	2385	131	15839	3929	11108	5214	2938	85847			SUM
EXC	224	1	88	40	2429	83	465	1664	8373	63	22	121	88	45	6171	3253	132	191	17	63	468	40	4630	700	2970	501	1273		33208	8350	EXC
EU	73	1	81	10	1664	82	325	709	227	46	20	89	0	0	368	269	0	159	10	10	307	30	19	369	372	271	572		8621	6566	EU
emis	293	10	140	78	2908	234	538	2041	10402	95	25	136	92	62	11255	3890	144	1773	40	179	2771	132	28600	8009	0	11950	4715	104197	46029	11698	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: 2016 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	18	0	0	0	1	0	1	0	0	0	0	1	0	0	2	0	1	0	0	8	1	1	0	0	12	-0	0	0	0	0	0	1	AL
AM	0	13	0	6	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	AM
AT	0	0	120	0	1	5	0	0	11	0	19	99	0	0	2	0	18	5	0	0	3	7	0	0	29	0	0	0	1	0	0	0	AT
AZ	0	5	0	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	4	0	0	0	0	0	AZ
BA	1	0	6	0	20	1	1	0	0	0	5	9	0	0	4	0	3	1	0	1	8	9	0	0	20	-0	0	0	0	0	0	2	BA
BE	0	0	1	0	0	48	0	0	1	0	1	29	1	0	2	0	38	25	0	0	0	0	1	0	1	0	0	0	2	0	0	0	BE
BG	2	0	3	0	2	1	103	1	0	0	3	8	0	0	2	0	2	1	0	29	1	5	0	0	6	0	0	0	0	0	2	1	BG
BY	0	0	4	0	1	5	3	77	1	0	10	56	7	2	2	4	9	12	0	2	1	6	1	0	6	0	2	15	0	5	3	0	BY
CH	0	0	3	0	0	2	0	0	52	0	1	23	0	0	3	0	34	3	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	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	24	0	1	6	0	1	4	0	83	116	1	0	2	0	20	9	0	0	2	9	1	0	7	0	0	0	1	0	0	0	CZ
DE	0	0	38	0	0	100	0	2	31	0	44	999	11	0	15	1	220	125	0	0	1	6	6	0	22	0	0	2	15	1	0	0	DE
DK	0	0	1	0	0	7	0	1	0	0	2	37	24	0	1	0	9	26	0	0	0	0	2	0	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	1	0	3	0	0	1	10	3	8	0	6	2	5	0	0	0	1	0	0	0	0	0	3	0	4	0	0	EE
ES	0	0	1	0	0	3	0	0	1	0	1	13	0	0	703	0	40	9	0	0	0	0	1	0	10	0	0	0	0	0	0	0	ES
FI	0	0	1	0	0	4	0	6	0	0	3	33	9	8	1	97	6	16	0	0	0	1	1	0	1	0	1	5	0	5	0	0	FI
FR	0	0	6	0	0	54	0	1	20	0	6	144	4	0	178	0	839	134	0	0	1	1	10	0	57	0	0	1	9	0	0	0	FR
GB	0	0	2	0	0	16	0	1	1	0	2	45	4	0	13	0	44	467	0	0	0	0	37	0	3	0	0	0	1	0	0	0	GB
GE	0	4	0	13	0	0	0	0	0	0	0	1	0	0	0	0	0	0	39	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	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	3	0	1	0	1	0	25	1	0	0	1	4	0	0	5	0	3	1	0	149	1	2	0	0	14	0	0	0	0	0	1	1	GR
HR	1	0	16	0	6	1	1	0	1	0	8	16	0	0	6	0	7	1	0	1	28	14	0	0	47	0	0	0	0	0	0	1	HR
HU	1	0	24	0	5	2	3	1	2	0	15	30	0	0	3	0	7	3	0	2	9	69	0	0	18	0	0	0	0	0	0	1	HU
IE	0	0	0	0	0	2	0	0	0	0	0	6	0	0	3	0	7	31	0	0	0	0	40	0	0	0	0	0	0	0	0	0	IE
IS	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	1	6	0	0	0	0	2	11	0	0	0	0	0	0	0	0	IS
IT	1	0	24	0	3	3	2	0	12	0	6	28	0	0	49	0	74	5	0	4	14	6	0	0	920	-0	0	0	0	0	0	1	IT
KG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	77	31	0	0	0	0	0	KG
KZ	0	6	2	25	0	2	3	9	1	0	3	16	1	1	4	4	6	6	8	5	1	2	0	0	7	52	999	2	0	1	1	0	KZ
LT	0	0	1	0	0	3	0	9	0	0	4	25	5	1	0	2	4	8	0	0	0	2	1	0	1	0	0	21	0	4	0	0	LT
LU	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	LU
LV	0	0	1	0	0	2	0	7	0	0	2	20	5	3	0	4	3	8	0	0	0	1	1	0	1	0	0	10	0	13	0	0	LV
MD	0	0	1	0	0	0	2	1	0	0	1	3	0	0	0	0	1	1	0	1	0	1	0	0	1	0	0	0	0	0	7	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	7	ME
MK	2	0	0	0	0	0	3	0	0	0	0	1	0	0	1	0	0	0	0	17	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	1	0	0	24	0	0	0	-0	1	37	1	0	2	0	24	43	0	0	0	0	2	0	1	0	0	0	1	0	0	0	NL
NO	0	0	1	0	0	9	0	2	0	0	2	47	16	1	2	4	13	51	0	0	0	0	4	0	0	0	0	1	1	1	0	0	NO
PL	0	0	25	0	2	26	2	16	4	0	74	336	19	1	6	3	46	42	0	1	5	24	3	0	14	0	0	9	3	3	2	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	41	0	2	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	PT
RO	2	0	12	0	5	3	34	4	2	0	10	34	1	0	5	1	8	5	0	12	5	27	0	0	19	0	1	1	0	0	8	3	RO
RS	4	0	6	0	8	1	10	1	1	0	5	13	0	0	3	0	3	2	0	10	4	16	0	0	13	-0	0	0	0	0	0	6	RS
RU	2	6	16	36	3	22	20	131	4	1	24	189	31	37	13	109	44	71	15	18	4	17	5	1	29	4	687	38	2	29	10	1	RU
SE	0	0	2	0	0	13	0	6	1	0	8	99	41	4	2	20	18	49	0	0	0	2	4	0	1	0	0	6	1	5	0	0	SE
SI	0	0	14	0	1	0	0	0	0	0	2	8	0	0	2	0	3	0	0	0	6	3	0	0	21	0	0	0	0	0	0	0	SI
SK	0	0	11	0	2	1	1	1	1	0	15	24	1	0	1	0	4	2	0	1	3	20	0	0	7	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	2	4	0	0	0	0	0	TJ
TM	0	2	0	10	0	0	0	1	0	0	0	1	0	0	1	0	1	0	2	1	0	0	0	0	1	0	19	0	0	0	0	0	TM
TR	1	5	3	4	1	1	18	2	1	7	2	10	0	0	9	0	6	2	4	43	1	3	0	0	16	0	2	0	0	0	2	1	TR
UA	1	0	15	3	3	8	20	40	3	0	28	100	7	2	8	4	19	15	2	13	5	30	1	0	22	0	9	8	1	4	18	1	UA
UZ	0	1	0	6	0	0	0	1	0	0	0	1	0	0	1	0	1	0	2	1	0	0	0	0	1	10	28	0	0	0	0	0	UZ
ATL	0	0	7	0	0	74	1	7	5	0	11	259	31	5	380	38	311	642	0	1	1	2	146	42	14	0	11	5	6	4	0	0	ATL
BAS	0	0	6	0	0	22	0	13	2	0	16	182	46	11	3	35	29	63	0	0	1	5	5	0	3	0	1	14	2	11	1	0	BAS
BLS	2	1	8	3	2	2	39	9	2	1	7	31	2	1	5	2	7	5	16	31	2	10	0	0	13	0	3	2	0	1	10	1	BLS
MED	20	0	36	1	17	13	51	3	14	14	18	95	2	0	439	1	284	29	0	228	34	21	2	0	742	0	1	1	2	0	3	9	MED
NOS	0	0	5	0	0	78	0	4	3	0	12	272	60	1	29	4	165	697	0	0	0	3	43	1	6	0	0	4	5	2	0	0	NOS
AST	1	7	1	64	0	1	3	3	1	7	1	6	0	0	5	1	4	2	9	12	1	1	0	0	8	20	198	1	0	0	1	0	AST
NOA	1	0	3	0	1	2	3	0	2	0	2	12	0	0	88	0	31	5	0	11	2	2	1	0	39	0	0	0	0	0	0	0	NOA
SUM	67	51	455	239	88	568	349	366	184	34	460	3537	336	88	2050	343	2425	2638	112	608	147	332	323	57	2184	165	2003	152	58	96	73	40	SUM
EXC	44	43	389	170	68	376	254	325	156	12	393	2680	195	70	1100	262	1595	1195	87	325	107	288	126	14	1359	145	1789	126	44	78	57	30	EXC
EU	11	0	330	1	29	325	173	60	93	3	311	2206	132	27	1045	136	1450	1024	1	204	81	201	111	1	1202	0	4	61	39	36	14	8	EU
emis	75	54	469	242	94	588	381	436	192	45	501	3708	350	95	2330	398	2561	2787	115	743	159	355	342	74	2317	188	2313	165	60	106	83	43	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.: 2016 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	5	0	0	0	0	-0	0	1	1	0	0	0	0	13	0	0	6	17	-0	0	97	60	31	AL
AM	0	0	0	0	0	0	0	0	1	0	0	0	0	0	7	0	0	0	0	0	1	0	48	1	16	-0	0	97	32	1	AM
AT	0	0	5	0	17	0	1	3	1	0	9	4	-0	0	0	1	0	1	1	0	4	5	0	1	19	-0	0	393	362	345	AT
AZ	0	0	0	0	0	0	0	0	11	0	0	0	0	1	8	2	0	0	0	1	1	0	128	1	32	-0	0	274	111	3	AZ
BA	0	0	1	0	8	0	3	18	1	0	1	3	-0	0	1	2	0	0	0	0	10	1	0	5	20	-0	-0	169	132	85	BA
BE	0	0	14	0	1	0	0	0	1	0	0	0	-0	0	0	0	0	3	1	0	0	23	0	0	11	0	0	205	167	165	BE
BG	4	0	1	0	8	0	28	24	9	0	0	2	0	0	28	17	0	0	1	6	16	1	1	7	40	-0	0	367	295	204	BG
BY	0	0	8	3	121	0	12	4	90	6	1	5	0	0	7	66	0	2	19	2	3	14	1	2	47	-0	0	649	559	304	BY
CH	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	2	0	1	11	-0	-0	162	144	92	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	3	0	2	1	3	-0	-0	19	9	5	CY
CZ	0	0	8	1	51	0	2	4	2	0	3	7	-0	0	0	2	0	1	2	0	2	9	0	1	18	-0	0	401	368	355	CZ
DE	0	0	116	4	77	2	1	1	7	3	2	4	0	0	0	3	0	14	21	0	5	132	0	3	98	0	0	2136	1863	1814	DE
DK	0	0	15	2	10	0	0	0	2	3	0	0	0	0	0	1	0	2	15	0	0	27	0	0	11	-0	-0	200	145	139	DK
EE	0	0	2	1	12	0	0	0	16	5	0	0	0	0	0	3	0	1	17	0	0	5	0	0	8	-0	0	119	88	64	EE
ES	0	0	2	0	2	65	0	0	1	0	0	0	0	0	0	0	0	68	0	0	105	5	0	48	173	-0	0	1255	855	853	ES
FI	0	0	8	9	26	0	1	1	80	30	0	1	0	0	1	5	0	5	55	0	1	18	0	0	51	-0	-0	494	365	261	FI
FR	0	0	40	2	10	12	1	1	3	1	1	1	0	0	0	1	0	65	4	0	68	111	0	27	178	-0	-0	1991	1538	1510	FR
GB	0	0	25	4	5	2	0	0	3	2	0	0	0	0	0	1	0	45	4	0	2	86	0	1	81	0	-0	897	679	669	GB
GE	0	0	0	0	1	0	1	0	6	0	0	0	0	0	18	2	0	0	0	3	2	0	39	2	28	-0	0	166	91	6	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	19	-0	0	24	3	2	GL
GR	5	0	1	0	4	0	7	10	5	0	0	1	-0	0	34	8	0	1	0	3	67	1	2	22	68	-0	0	454	290	220	GR
HR	0	0	1	0	9	0	3	15	1	0	6	4	0	0	1	2	0	1	0	0	22	1	0	7	22	-0	0	255	200	173	HR
HU	1	0	2	0	32	0	21	30	3	0	5	19	-0	0	2	6	0	1	1	0	7	3	0	4	26	-0	0	359	318	267	HU
IE	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	11	0	0	0	9	0	0	24	-0	0	142	96	95	IE
IS	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	2	0	0	18	-0	-0	49	25	13	IS
IT	1	0	3	0	9	3	2	6	2	0	17	2	-0	0	2	3	0	5	0	0	173	4	0	50	128	-0	0	1566	1205	1172	IT
KG	0	0	0	0	0	0	0	0	4	0	0	0	4	7	2	0	110	0	0	0	0	0	124	0	74	-0	0	436	237	1	KG
KZ	1	0	2	2	15	0	6	2	721	3	0	2	3	44	41	86	140	2	5	5	7	4	835	7	591	-0	0	3690	2234	94	KZ
LT	0	0	4	1	43	0	2	1	16	4	0	1	-0	0	0	8	0	1	15	0	0	8	0	0	13	-0	-0	213	174	138	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	1	0	0	15	13	13	LU
LV	0	0	4	2	26	0	1	1	19	6	0	1	0	0	0	6	0	1	19	0	0	8	0	0	13	-0	0	189	147	112	LV
MD	0	0	0	0	7	0	8	1	6	0	0	1	0	0	4	19	0	0	1	2	2	1	0	1	9	-0	0	83	69	30	MD
ME	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	3	8	-0	0	44	28	13	ME
MK	14	0	0	0	1	0	1	7	1	0	0	0	-0	0	3	1	0	0	0	0	4	0	0	2	10	-0	0	74	59	31	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	63	1	2	0	0	0	1	0	0	0	-0	0	0	0	0	4	1	0	0	45	0	0	14	0	-0	270	205	203	NL
NO	0	0	18	76	10	0	0	0	10	14	0	0	0	0	0	1	0	19	17	0	0	70	0	0	59	-0	-0	452	286	196	NO
PL	0	0	34	5	622	1	15	11	29	8	5	25	0	0	2	29	0	5	40	1	5	50	0	3	76	-0	0	1635	1455	1352	PL
PT	0	0	0	0	0	90	0	0	0	0	0	0	0	0	0	0	0	34	0	0	6	0	0	5	36	0	-0	219	137	137	PT
RO	3	0	4	1	40	0	218	42	21	1	2	10	0	0	22	52	0	1	2	9	16	4	1	12	79	-0	0	744	620	453	RO
RS	7	0	1	0	13	0	18	108	3	0	1	5	-0	0	3	5	0	1	1	1	8	1	0	6	33	-0	0	323	273	126	RS
RU	2	0	34	27	236	1	46	15	5689	50	3	13	1	16	117	618	23	26	142	35	30	69	318	17	1489	-0	0	10632	8508	1100	RU
SE	0	0	26	30	50	0	1	0	32	86	0	2	0	0	0	7	0	9	78	0	1	63	0	0	71	-0	-0	737	515	438	SE
SI	0	0	0	0	2	0	1	2	0	0	22	1	0	0	0	0	0	0	0	0	6	0	0	1	6	-0	-0	103	90	86	SI
SK	0	0	2	0	41	0	8	9	1	0	2	30	0	0	1	4	0	0	1	0	3	2	0	2	13	-0	0	216	195	176	SK
TJ	0	0	0	0	0	0	0	0	2	0	0	0	9	14	1	0	25	0	0	0	0	0	100	0	74	-0	0	234	59	1	TJ
TM	0	0	0	0	1	0	0	0	24	0	0	0	1	57	9	4	16	0	0	0	2	0	680	2	196	-0	0	1035	153	7	TM
TR	2	0	1	0	8	1	14	8	29	0	1	1	0	1	676	25	0	2	1	26	135	1	454	66	368	-0	0	1966	912	148	TR
UA	2	0	10	3	214	1	74	18	223	6	3	20	0	0	70	555	0	3	17	27	26	17	13	14	154	-0	0	1860	1590	637	UA
UZ	0	0	0	0	1	0	1	0	28	0	0	0	4	34	7	5	135	0	0	0	1	0	372	2	161	-0	0	807	269	8	UZ
ATL	0	0	94	139	48	151	2	1	299	37	1	2	0	0	2	12	0	1066	46	0	69	301	5	78	3731	5	-0	8092	2790	2270	ATL
BAS	0	0	39	14	119	0	2	1	71	48	1	4	0	0	0	14	0	7	160	0	1	75	0	1	58	0	0	1088	784	667	BAS
BLS	2	0	3	1	46	0	66	19	133	2	2	6	0	0	254	178	0	2	5	95	56	5	36	21	140	-0	0	1289	928	292	BLS
MED	9	10	15	1	39	23	30	39	22	1	16	9	0	0	352	28	0	50	4	17	1677	22	166	764	1118	1	3	6495	2674	2154	MED
NOS	0	0	128	74	58	3	1	0	16	22	1	3	0	0	0	5	0	80	51	0	4	458	0	2	192	2	0	2496	1707	1603	NOS
AST	1	0	1	1	5	1	4	2	131	1	0	1	4	61	113	28	40	1	1	4	56	1	7977	70	4392	-0	0	13252	749	66	AST
NOA	0	1	2	0	4	17	2	2	2	0	1	1	0	0	14	2	0	58	0	1	201	3	17	881	983	-0	0	2397	253	228	NOA
SUM	60	13	746	408	2058	378	605	415	7779	342	111	194	25	238	1806	1819	490	1608	749	241	2834	1670	11321	2154	15328	8	4	74030			SUM
EXC	47	2	464	178	1740	182	499	351	7105	230	90	168	21	176	1072	1551	450	343	482	123	770	806	3121	337	4712	-1	1		28227	14349	EXC
EU	15	1	384	66	1100	177	313	161	256	150	78	117	0	0	97	158	0	281	279	21	516	622	9	197	1280	0	0		12394	11419	EU
emis	66	16	774	461	2211	490	641	440	9598	398	113	204	29	294	2139	1973	537	2098	782	261	3394	1720	20379	4216	0			75601	42752	23307	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: 2016 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	89	0	0	0	0	0	1	0	0	0	0	1	0	0	4	0	1	0	0	6	1	1	0	0	9	-0	0	0	0	0	0	0	AL
AM	0	64	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	254	0	1	2	0	1	20	0	28	136	0	0	3	0	20	3	0	0	6	13	0	0	40	0	0	0	0	0	0	0	AT
AZ	0	20	0	302	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	0	0	0	0	0	1	0	0	0	0	0	AZ
BA	1	0	5	0	75	0	1	1	0	0	5	8	0	0	6	0	2	0	0	1	22	17	0	0	22	0	0	0	0	0	0	1	BA
BE	0	0	0	-0	0	160	0	0	1	0	0	27	1	0	3	0	88	15	-0	-0	0	0	2	0	1	0	0	0	5	0	0	0	BE
BG	6	0	2	0	1	0	183	3	0	0	2	5	0	0	3	0	1	0	0	23	1	8	0	0	5	0	0	0	0	0	4	0	BG
BY	0	0	4	0	1	2	3	489	1	0	9	46	6	2	3	2	9	6	0	1	2	10	1	0	6	0	2	23	0	6	6	0	BY
CH	0	0	2	0	0	1	0	0	273	0	1	29	0	0	6	0	40	1	0	0	0	0	0	0	32	-0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	CY
CZ	0	0	33	0	1	3	0	1	5	0	239	129	1	0	3	0	23	4	0	0	4	14	1	0	8	0	0	1	1	0	0	0	CZ
DE	0	0	37	0	0	71	0	4	57	0	36	2677	16	0	21	0	312	64	0	0	2	9	9	0	28	-0	0	2	14	1	0	0	DE
DK	0	0	1	0	0	4	0	1	0	-0	1	74	165	0	2	0	10	15	0	0	0	1	2	0	1	0	0	1	0	0	0	0	DK
EE	0	0	0	0	0	1	0	6	0	0	1	10	3	36	0	2	1	2	0	0	0	1	0	0	0	0	0	4	0	5	0	0	EE
ES	0	0	1	0	0	2	0	0	2	0	1	11	0	0	1917	0	67	5	0	0	0	0	2	0	10	0	0	0	0	0	0	0	ES
FI	0	0	1	0	0	2	0	13	0	0	3	30	10	6	1	133	5	7	0	0	0	2	1	0	1	0	1	6	0	4	0	0	FI
FR	0	0	5	0	0	48	0	1	41	0	4	102	4	0	287	0	2838	76	0	0	1	2	17	0	64	0	0	1	6	0	0	0	FR
GB	0	0	1	0	0	13	0	1	2	-0	2	49	5	0	20	0	79	907	0	0	0	1	99	0	4	-0	0	0	1	0	0	0	GB
GE	0	12	0	35	0	0	0	0	0	0	0	0	0	0	1	0	0	0	171	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	10	0	1	0	1	0	18	2	0	0	1	3	0	0	8	0	2	0	0	185	1	3	0	0	9	0	0	0	0	0	1	-0	GR
HR	1	0	14	0	14	0	1	1	1	0	8	14	0	0	10	0	5	1	0	1	105	32	0	0	54	0	0	0	0	0	0	0	HR
HU	1	0	26	0	6	1	4	2	2	0	13	25	1	0	5	0	5	1	0	1	24	265	0	0	20	0	0	0	0	0	1	0	HU
IE	0	-0	0	-0	0	2	0	0	0	-0	0	6	0	0	4	0	15	27	-0	-0	0	0	373	-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	3	0	0	0	0	2	17	0	0	0	0	0	0	0	0	IS
IT	3	0	16	0	4	1	2	1	15	0	5	20	0	0	73	0	44	2	0	3	13	10	0	0	1924	0	0	0	0	0	0	0	IT
KG	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	181	22	0	0	0	0	0	KG
KZ	1	15	1	50	1	1	3	12	1	0	2	8	1	1	3	1	4	1	12	2	0	2	0	0	4	43	1068	2	0	1	2	0	KZ
LT	0	0	1	0	0	1	0	28	0	0	3	24	5	1	1	1	4	4	0	0	0	2	1	0	1	0	0	101	0	6	1	0	LT
LU	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	9	1	0	0	0	0	0	0	0	0	0	0	10	0	0	0	LU
LV	0	0	1	0	0	1	0	18	0	0	2	18	5	3	1	1	3	4	0	0	0	2	1	0	1	0	0	21	0	51	0	0	LV
MD	0	0	0	0	0	0	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	43	0	MD
ME	4	0	0	0	2	0	0	0	0	0	0	1	0	0	2	0	0	0	0	1	0	1	0	0	5	0	0	0	0	0	0	6	ME
MK	7	0	0	0	0	0	4	0	0	0	0	1	0	0	2	0	0	0	0	9	0	1	0	0	2	0	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	MT
NL	0	0	0	-0	0	51	0	0	1	0	1	82	1	0	2	0	39	26	-0	-0	0	0	3	0	1	0	0	0	1	0	0	0	NL
NO	0	0	1	0	0	5	0	3	0	0	2	52	21	1	2	2	19	27	0	0	0	0	5	0	0	0	0	2	0	1	0	0	NO
PL	1	0	24	0	2	12	2	42	5	0	67	330	24	1	8	1	53	19	0	1	8	37	3	0	15	0	0	12	1	3	3	0	PL
PT	0	0	0	0	0	0	0	0	0	-0	0	1	0	0	61	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	5	0	10	0	5	1	36	10	1	0	8	26	1	0	7	0	5	2	1	8	8	56	0	0	22	0	1	1	0	0	22	0	RO
RS	9	0	4	0	8	0	14	2	1	0	4	10	0	0	5	0	2	1	0	5	10	32	0	0	13	0	0	0	0	0	1	1	RS
RU	3	15	10	70	6	9	16	241	4	1	19	148	28	24	17	49	38	28	32	10	5	20	5	0	24	5	437	42	1	26	17	1	RU
SE	0	0	2	0	0	6	0	12	1	0	8	118	59	3	2	10	20	24	0	0	1	3	4	0	2	0	0	7	0	4	0	0	SE
SI	0	0	14	0	1	0	0	0	1	0	2	7	0	0	3	0	2	0	0	0	9	5	0	0	27	0	0	0	0	0	0	0	SI
SK	0	0	14	0	2	1	1	1	1	0	16	21	1	0	2	0	4	1	0	0	6	39	0	0	8	0	0	0	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	6	0	0	0	0	0	TJ
TM	0	3	0	16	0	0	0	1	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	14	0	0	0	0	0	TM
TR	3	13	2	10	1	0	11	4	1	7	1	6	0	0	13	0	3	0	8	23	1	3	0	0	11	0	2	0	0	0	3	0	TR
UA	2	1	12	5	4	2	16	101	2	0	19	66	6	1	12	1	12	5	5	8	8	49	1	0	27	0	7	10	0	3	46	0	UA
UZ	0	3	0	11	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	19	45	0	0	0	0	0	UZ
ATL	0	0	5	0	0	45	0	11	7	0	10	217	28	3	418	14	608	439	0	0	1	2	325	22	11	0	7	4	4	2	0	0	ATL
BAS	0	0	5	0	1	10	0	25	2	0	14	272	111	11	4	25	31	30	0	0	2	8	6	0	3	0	0	20	1	12	1	0	BAS
BLS	3	2	5	7	3	1	30	19	1	1	5	18	1	0	6	1	4	1	38	18	3	11	0	0	12	0	3	3	0	1	19	0	BLS
MED	39	1	26	1	14	7	28	6	18	11	16	65	1	0	555	0	261	15	1	108	31	26	2	0	640	0	1	1	1	0	4	2	MED
NOS	0	0	4	0	0	72	0	8	4	-0	9	370	103	1	38	1	328	526	0	0	1	3	67	0	7	0	0	4	3	2	0	0	NOS
AST	0	12	0	116	0	0	2	4	0	4	0	2	0	0	4	0	1	0	12	4	0	1	0	0	3	30	130	1	0	0	1	0	AST
NOA	1	0	2	0	1	1	1	0	2	0	2	8	0	0	110	0	32	2	0	4	1	2	0	0	27	0	0	0	0	0	0	0	NOA
SUM	191	162	549	651	158	540	383	1079	473	33	573	5280	610	94	3660	246	5056	2297	308	428	279	694	936	41	3109	282	1750	271	51	130	179	14	SUM
EXC	146	147	501	527	139	405	322	1006	438	17	518	4329	365	79	2524	205	3792	1285	257	293	242	641	536	18	2405	252	1609	239	43	113	153	11	EXC
EU	26	0	458	1	40	384	250	148	155	7	455	3950	302	50	2446	149	3658	1212	1	225	191	503	521	0	2247	0	4	159	41	76	35	2	EU
emis	201	158	559	612	172	560	414	1121	471	46	600	5456	621	98	4053	256	5189	2384	295	494	288	717	961	44	3148	295	1957	280	54	134	187	16	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.: 2016 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	6	0	0	0	0	-0	0	1	1	0	0	0	0	0	0	0	3	5	0	-0	132	125	26	AL
AM	0	0	0	0	0	0	0	0	1	0	0	0	0	1	63	0	0	0	0	0	0	0	38	2	7	0	0	208	161	1	AM
AT	0	0	4	0	9	0	2	2	1	0	13	5	0	0	1	2	0	0	0	0	0	0	0	1	4	0	0	573	567	539	AT
AZ	0	0	0	0	0	0	0	0	22	0	0	0	0	2	51	2	2	0	0	0	0	0	90	3	13	0	0	528	422	2	AZ
BA	0	0	1	0	4	0	7	15	1	0	1	3	0	0	1	4	0	0	0	0	1	0	0	4	5	0	0	217	207	107	BA
BE	0	0	28	0	1	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	-0	0	-1	-0	0	0	-0	-0	333	334	332	BE
BG	8	0	0	0	4	0	63	22	10	0	0	2	-0	0	25	18	0	0	0	-0	1	0	1	6	10	0	-0	420	402	303	BG
BY	0	0	5	1	104	0	24	5	69	5	1	4	0	0	14	98	0	0	0	0	0	1	1	3	7	0	1	982	970	282	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	394	390	116	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	-0	0	1	1	1	-0	-0	14	11	7	CY
CZ	0	0	6	0	26	0	4	3	1	0	3	10	0	0	0	3	0	0	0	0	0	0	0	1	2	0	0	532	528	513	CZ
DE	0	0	186	1	57	1	2	2	3	3	2	4	-0	0	0	4	0	1	-2	0	1	-8	0	3	8	0	0	3631	3627	3557	DE
DK	0	0	13	1	8	0	0	0	1	4	0	0	0	0	0	1	0	0	-2	0	0	-1	0	0	1	-0	0	304	305	301	DK
EE	0	0	1	0	11	0	1	0	8	5	0	0	0	0	0	3	0	0	-0	0	0	0	0	0	1	0	0	105	104	86	EE
ES	0	0	2	0	2	57	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	-6	0	0	29	34	-1	-0	2135	2081	2078	ES
FI	0	0	5	3	24	0	2	1	70	22	0	1	0	0	1	6	0	0	0	0	0	1	0	0	5	0	0	371	364	267	FI
FR	0	0	31	0	8	10	1	1	2	1	1	1	0	0	1	1	0	-3	0	0	2	-7	0	22	26	-2	-0	3595	3558	3510	FR
GB	0	0	23	1	4	1	0	0	1	1	0	1	-0	0	0	1	0	-4	0	0	0	-5	-0	1	6	-3	0	1212	1217	1211	GB
GE	0	0	0	0	0	0	1	0	11	0	0	0	0	1	106	3	1	0	0	0	0	0	29	3	11	0	0	390	346	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	2	0	0	4	1	1	GL
GR	8	0	0	0	3	0	11	8	6	0	0	1	0	0	26	10	0	0	0	0	-1	0	1	13	20	-0	-1	352	320	247	GR
HR	0	0	1	0	3	0	6	13	1	0	12	5	0	0	1	4	0	0	0	0	1	0	0	5	5	0	0	322	311	274	HR
HU	1	0	1	0	10	0	42	29	2	0	7	31	0	0	2	12	0	0	0	0	0	0	0	3	5	0	0	549	541	483	HU
IE	0	0	3	0	1	0	0	0	0	0	0	0	-0	0	0	0	0	-2	-0	-0	0	-0	-0	0	1	-3	0	431	434	433	IE
IS	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	29	27	10	IS
IT	0	0	2	0	5	3	5	3	3	0	12	2	0	0	3	5	0	1	0	0	-3	0	0	30	33	0	-3	2240	2181	2144	IT
KG	0	0	0	0	0	0	0	0	5	0	0	0	50	9	10	1	176	0	0	0	0	0	199	1	36	0	0	694	458	1	KG
KZ	1	0	1	0	8	0	8	3	587	1	0	1	33	108	147	44	415	0	0	0	1	0	1251	9	143	0	1	4006	2599	56	KZ
LT	0	0	3	0	50	0	3	1	13	4	0	1	0	0	0	10	0	0	-0	0	0	0	0	0	1	0	0	275	273	219	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	27	27	27	LU
LV	0	0	2	1	23	0	2	1	11	6	0	1	0	0	1	7	0	0	-0	0	0	0	0	0	1	0	0	190	188	148	LV
MD	0	0	0	0	2	0	21	1	6	0	0	0	0	0	5	28	0	0	-0	-0	0	0	0	1	1	0	-0	122	120	34	MD
ME	0	0	0	0	0	0	1	4	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	2	0	0	34	30	13	ME
MK	31	0	0	0	1	0	2	8	1	0	0	0	0	0	3	2	0	0	0	0	0	0	0	1	3	0	-0	81	77	24	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	344	0	1	0	0	-0	0	0	0	0	0	0	-0	0	0	-0	-0	-0	0	-4	-0	0	-0	-0	0	549	553	552	NL
NO	0	0	12	117	9	0	0	0	5	14	0	0	0	0	0	1	0	0	1	0	0	1	0	0	7	0	0	313	303	175	NO
PL	0	0	23	2	1073	0	24	9	21	9	5	22	0	0	4	54	0	1	-1	0	1	1	0	3	9	1	0	1938	1923	1777	PL
PT	0	0	0	0	0	149	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	-0	0	-0	3	5	-1	-0	221	215	215	PT
RO	4	0	2	0	18	0	674	42	26	1	2	10	0	0	30	77	0	0	0	-0	1	0	1	10	18	0	-0	1155	1124	899	RO
RS	7	0	1	0	6	0	39	213	3	0	1	5	0	0	4	8	0	0	0	0	0	0	0	4	8	0	-0	421	408	152	RS
RU	3	0	19	7	180	1	68	19	6118	31	3	9	5	39	315	432	90	1	2	1	3	4	496	20	423	3	4	9649	8690	831	RU
SE	0	0	17	16	48	0	1	0	17	202	0	2	0	0	0	7	0	1	-1	0	0	1	0	1	7	0	0	607	598	544	SE
SI	0	0	0	0	1	0	1	1	0	0	58	1	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	138	135	131	SI
SK	0	0	1	0	15	0	13	8	1	0	3	82	0	0	1	7	0	0	0	0	0	0	0	1	2	0	0	259	255	231	SK
TJ	0	0	0	0	0	0	0	0	2	0	0	0	216	13	6	0	98	0	0	0	0	0	114	1	37	0	-0	498	347	0	TJ
TM	0	0	0	0	0	0	0	0	23	0	0	0	8	287	38	2	137	0	0	0	0	0	413	4	77	0	-0	1030	535	3	TM
TR	1	0	1	0	4	0	16	5	29	0	0	1	0	1	2980	22	1	0	0	-1	-3	0	261	74	140	-0	-5	3656	3189	106	TR
UA	2	0	4	1	116	1	144	17	225	4	4	15	0	1	117	1054	1	0	0	-0	2	1	11	16	26	1	1	2198	2139	548	UA
UZ	0	0	0	0	0	0	1	0	25	0	0	0	54	75	33	2	846	0	0	0	0	0	251	3	61	0	-0	1435	1120	4	UZ
ATL	0	0	68	41	39	121	2	1	1307	19	1	2	0	0	3	11	1	-23	3	0	0	9	9	41	527	-21	0	4348	3804	2388	ATL
BAS	0	0	28	6	115	0	4	2	36	80	1	4	0	0	0	15	0	0	-7	0	0	-2	0	1	6	-2	0	881	883	795	BAS
BLS	3	0	1	0	22	0	101	16	120	1	1	4	0	1	430	170	1	0	0	-5	2	0	26	20	40	0	1	1172	1087	250	BLS
MED	7	8	9	0	19	18	36	31	18	1	13	7	0	0	280	27	0	1	0	-0	-42	2	71	474	337	-8	-3	3188	2355	1905	MED
NOS	0	0	180	34	37	2	2	1	10	18	1	2	0	0	0	6	0	-1	-2	0	1	-15	0	2	21	-4	0	1847	1844	1781	NOS
AST	0	0	0	0	2	0	3	1	179	0	0	0	56	136	300	17	159	0	0	0	-1	0	18249	130	4459	-0	-4	24016	1183	29	AST
NOA	0	0	1	0	2	12	2	2	1	0	1	1	0	0	7	2	0	-3	0	-0	-11	0	4	1245	356	-2	-3	1815	229	212	NOA
SUM	80	10	1031	234	2080	383	1339	499	9009	432	149	241	423	674	5020	2183	1931	-30	-6	-4	-45	-18	21517	2203	6973	-38	-11	86765			SUM
EXC	69	1	744	152	1843	228	1190	446	7338	313	132	221	367	537	3998	1935	1769	-5	-1	1	5	-12	3159	290	1226	-1	-2		44839	23524	EXC
EU	23	1	698	26	1406	225	856	149	201	258	121	181	0	0	102	232	1	-8	-4	0	-2	-20	5	135	208	-7	-3		22175	21030	EU
emis	87	12	1049	233	2200	464	1378	532	9846	437	152	251	419	811	5874	2314	2043	0	0	0	0	0	32835	4682	0			97462	59945	32254	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: 2016 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	746	0	27	1	48	2	83	8	6	0	26	60	2	1	80	2	79	14	1	252	42	63	3	0	294	0	4	3	1	1	5	AL
AM	2	569	4	446	2	0	8	8	1	4	3	9	1	1	16	2	12	3	158	14	2	4	1	0	19	0	33	2	0	1	4	AM
AT	1	0	579	0	7	9	7	11	91	0	114	551	3	1	49	3	272	49	0	4	37	72	9	1	255	0	1	4	5	2	2	AT
AZ	1	51	3	740	1	0	7	11	1	1	3	9	1	1	11	4	10	5	147	10	2	4	1	0	13	0	83	3	0	1	3	AZ
BA	12	0	89	0	491	4	40	14	8	0	90	164	3	1	74	4	97	26	0	21	198	170	5	1	259	0	2	4	2	2	4	BA
BE	0	0	16	0	1	-544	1	7	9	0	11	50	6	1	33	4	308	47	0	1	2	6	24	4	17	0	1	4	15	2	0	BE
BG	24	0	21	2	19	3	650	37	3	0	26	64	5	2	29	7	34	15	3	143	16	70	3	1	64	0	8	8	1	4	31	BG
BY	0	0	6	0	1	4	2	335	2	0	23	100	25	15	5	33	33	39	0	1	2	12	9	2	7	0	8	71	1	27	4	BY
CH	1	0	49	0	2	14	2	3	614	0	9	177	2	0	76	1	740	46	0	3	7	7	10	1	415	0	1	2	6	1	1	CH
CY	8	2	8	4	7	2	33	9	3	456	6	20	1	0	44	2	45	5	5	247	7	11	2	0	84	0	5	2	0	1	6	CY
CZ	1	0	122	0	6	7	6	17	18	0	432	547	10	2	27	8	208	62	0	2	22	79	12	2	43	0	2	7	6	4	3	CZ
DE	0	0	43	0	1	-6	2	11	29	0	54	296	11	2	26	8	280	78	0	1	4	14	18	3	27	0	1	6	10	3	1	DE
DK	0	0	2	0	0	-13	1	17	1	0	7	84	-52	5	5	24	37	137	0	0	0	1	31	4	1	0	2	13	1	8	0	DK
EE	0	0	2	0	0	3	0	29	1	0	9	80	41	106	2	97	19	60	0	0	0	2	13	3	2	0	2	38	1	59	0	EE
ES	0	0	6	0	1	2	1	1	4	0	3	16	1	0	1280	1	159	24	0	1	2	2	11	1	32	0	0	0	0	0	0	ES
FI	0	0	1	0	0	2	0	9	0	0	3	38	18	14	1	165	11	33	0	0	0	1	7	3	1	0	1	9	0	10	0	FI
FR	0	0	11	0	1	1	1	4	23	0	7	63	4	1	160	3	904	69	0	2	4	5	26	2	86	0	1	2	3	1	0	FR
GB	0	0	2	0	0	-7	0	4	1	0	4	16	11	1	10	7	52	-140	0	0	1	2	47	4	7	0	1	3	1	2	0	GB
GE	2	50	4	260	2	0	14	13	1	2	3	11	2	1	16	3	13	5	603	18	2	5	1	0	20	0	33	4	0	2	6	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	1	0	0	0	0	0	0	0	GL
GR	58	0	16	1	18	2	294	20	4	0	17	45	3	1	59	4	63	13	2	855	17	38	3	1	172	0	7	4	0	2	17	GR
HR	6	0	180	0	132	5	24	12	11	0	112	223	3	1	75	4	132	35	0	13	468	242	6	1	311	0	2	5	2	2	3	HR
HU	3	0	133	0	26	6	21	25	9	0	124	232	8	2	37	8	92	37	0	6	78	555	6	2	104	0	3	9	2	3	7	HU
IE	0	0	2	0	0	-2	0	3	1	0	3	13	7	1	9	5	34	88	0	0	1	2	69	3	5	0	1	2	0	1	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	3	3	0	2	1	3	21	0	0	0	0	7	52	1	0	0	0	0	0	0	IS
IT	6	0	96	0	23	6	12	4	41	0	33	132	2	0	150	2	327	31	0	20	69	46	7	1	1173	0	1	2	2	1	1	IT
KG	1	4	3	10	1	0	3	3	1	0	2	6	0	0	17	1	10	1	5	4	1	2	0	0	12	684	222	1	0	0	1	KG
KZ	0	1	2	5	1	1	2	9	1	0	2	11	2	2	8	9	9	7	2	2	1	2	2	1	7	17	365	3	0	2	1	KZ
LT	0	0	6	0	1	5	1	100	1	0	20	123	44	20	5	43	30	69	0	0	2	7	15	3	5	0	4	198	1	46	1	LT
LU	0	0	23	0	1	19	1	7	11	0	17	254	3	1	43	4	468	76	0	1	2	7	20	3	22	0	1	4	-446	1	1	LU
LV	0	0	4	0	0	4	1	67	1	0	14	97	41	38	3	58	24	67	0	0	1	5	15	3	3	0	2	110	1	111	1	LV
MD	2	0	10	2	5	2	28	84	2	0	21	71	9	5	13	18	23	20	4	10	6	34	5	1	23	0	10	16	1	8	221	MD
ME	113	0	45	0	154	3	69	11	7	0	49	98	2	1	83	3	76	16	0	59	69	100	3	1	260	0	3	3	1	1	5	ME
MK	164	0	24	1	27	3	211	14	5	0	31	68	3	1	59	3	58	14	1	396	22	88	3	1	155	0	5	4	1	2	9	MK
MT	7	0	27	0	19	4	19	4	6	0	19	48	1	0	180	1	251	20	0	50	29	26	6	1	410	0	2	1	1	0	3	MT
NL	0	0	11	0	1	-91	1	8	3	0	16	-28	13	2	17	5	85	65	0	1	2	6	28	5	6	0	1	6	1	3	1	NL
NO	0	0	1	0	0	-0	0	6	0	0	2	23	15	3	3	20	12	52	0	0	0	0	10	3	1	0	0	5	0	3	0	NO
PL	0	0	21	0	2	5	3	54	4	0	80	289	28	7	10	22	80	56	0	1	7	38	12	3	15	0	5	24	3	12	4	PL
PT	0	0	2	0	0	1	1	1	1	0	1	9	1	0	722	1	60	19	0	1	1	1	11	1	10	0	0	0	0	0	0	PT
RO	7	0	22	1	16	3	92	47	3	0	31	84	7	3	23	10	34	20	2	16	17	100	4	1	51	0	7	12	1	5	48	RO
RS	49	0	47	0	82	4	128	19	5	0	61	119	4	1	46	6	58	21	1	44	54	188	4	1	131	0	4	6	1	2	9	RS
RU	0	0	1	4	0	1	1	18	0	0	2	13	4	5	3	19	6	9	2	1	0	1	2	1	3	0	55	6	0	4	1	RU
SE	0	0	1	0	0	1	0	8	0	0	5	48	34	5	2	41	16	61	0	0	0	1	11	3	1	0	1	8	0	7	0	SE
SI	2	0	413	0	23	6	12	11	19	0	99	304	2	1	62	3	167	40	0	7	263	143	7	1	401	0	1	4	2	2	2	SI
SK	1	0	87	0	12	6	10	29	9	0	191	264	11	2	26	10	88	40	0	3	38	260	7	2	65	0	3	10	2	4	8	SK
TJ	1	4	2	9	1	0	2	2	1	0	1	4	0	0	14	1	7	1	4	3	1	2	0	0	10	42	64	0	0	0	1	TJ
TM	1	6	3	27	1	1	3	7	1	0	2	10	1	1	13	4	11	4	10	5	1	3	1	0	10	2	145	2	0	1	1	TM
TR	6	19	7	20	5	1	37	17	2	10	6	20	2	1	32	3	28	6	25	67	5	11	1	0	50	0	11	4	0	2	10	TR
UA	1	0	9	3	3	2	14	104	2	0	19	68	11	6	11	19	23	22	3	7	5	26	5	1	18	0	22	20	1	9	25	UA
UZ	1	4	3	13	1	1	3	7	1	0	2	10	1	1	12	5	11	4	6	4	1	3	1	0	10	26	207	2	0	1	1	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	-1	0	7	0	0	3	35	14	9	1	31	9	36	0	0	0	1	8	1	0	0	1	8	0	9	0	BAS
BLS	0	0	1	2	1	0	10	9	0	0	2	6	1	1	2	2	3	2	8	5	1	3	0	0	4	0	4	2	0	1	5	BLS
MED	4	0	6	0	4	1	17	2	1	1	4	10	0	0	27	1	40	4	0	42	9	6	1	0	57	0	1	1	0	0	2	MED
NOS	0	0	0	0	0	-3	0	1	0	0	1	1	3	0	2	2	8	7	0	0	0	0	5	1	1	0	0	1	0	0	0	NOS
AST	1	3	2	13	1	0	4	2	1	5	1	5	0	0	10	1	7	1	4	10	1	2	0	0	10	14	61	1	0	0	1	AST
NOA	2	0	5	0	3	1	8	1	2	1	3	11	0	0	131	0	60	8	0	24	4	4	2	0	61	0	0	0	0	0	1	NOA
EXC	3	3	11	10	4	-0	12	21	5	1	12	42	6	4	54	17	60	17	6	14	6	13	5	2	38	11	89	7	1	4	4	EXC
EU	4	0	38	0	7	-3	33	16	12	1	35	118	12	5	204	24	214	38	0	33	19	38	15	2	124	0	2	11	2	7	5	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.: 2016 country-to-country blame matrices for $\mathbf{AOT40_f^{uc}}$.
Units: ppb.h per 15% emis. red. of NO_x. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	78	130	1	3	4	80	8	76	296	57	3	6	24	0	0	31	53	0	24	5	10	328	9	2	91	714	0	0	2703	1235	AL
AM	1	1	0	0	3	13	2	17	6	181	2	1	2	0	17	265	59	6	7	3	36	30	3	848	37	669	0	0	1908	144	AM
AT	1	1	0	0	7	96	7	29	15	35	6	71	33	0	0	3	23	0	40	8	1	43	23	0	18	575	0	0	2467	2268	AT
AZ	1	1	0	0	5	14	2	14	4	408	4	1	2	0	30	83	77	11	7	5	29	16	4	517	17	596	0	0	1789	128	AZ
BA	44	5	0	6	6	138	8	78	206	52	4	16	54	0	0	12	50	0	28	6	5	140	17	1	54	667	0	0	2463	1556	BA
BE	0	0	0	-129	23	39	6	3	2	27	11	2	5	0	0	1	7	0	65	10	0	7	-97	0	4	462	0	0	19	-63	BE
BG	11	28	0	3	7	126	4	354	170	220	7	5	28	0	0	51	258	0	16	12	74	63	12	3	32	652	0	0	2564	1688	BG
BY	0	0	0	5	29	275	1	16	4	403	43	1	11	0	0	3	94	0	26	77	2	2	38	2	1	571	0	0	1655	767	BY
CH	1	1	0	1	4	22	10	5	5	18	3	6	4	0	0	3	8	0	53	4	0	52	23	0	21	625	0	0	2281	1619	CH
CY	4	7	1	1	2	20	4	43	21	98	2	2	5	0	1	824	63	1	12	3	44	790	5	56	93	901	0	0	2122	1052	CY
CZ	1	1	0	5	18	264	4	37	19	58	14	16	74	0	0	2	40	0	42	18	1	15	40	0	5	587	0	0	2207	2019	CZ
DE	0	0	0	-34	25	115	4	9	4	44	20	3	11	0	0	1	14	0	61	18	0	8	25	0	4	556	0	0	1142	1005	DE
DK	0	0	0	-25	63	87	1	2	1	98	73	0	1	0	0	0	6	0	66	28	0	1	91	1	0	542	0	0	626	433	DK
EE	0	0	0	6	35	134	0	2	1	282	116	0	3	0	0	1	9	0	36	210	0	1	52	0	0	541	0	0	1162	798	EE
ES	0	0	0	1	3	8	193	2	1	8	2	2	1	0	0	1	2	0	184	2	0	155	11	0	111	964	0	0	1775	1752	ES
FI	0	0	0	4	36	37	0	1	0	160	93	0	1	0	0	0	4	0	34	93	0	0	29	0	0	428	0	0	666	452	FI
FR	0	0	0	-8	13	23	17	3	3	22	8	4	3	0	0	1	6	0	109	7	0	66	28	0	20	625	0	0	1480	1403	FR
GB	0	0	0	-17	42	22	1	2	1	29	19	1	2	0	0	1	4	0	78	14	0	3	13	0	2	450	0	0	136	48	GB
GE	2	2	0	0	5	21	3	29	8	321	5	1	2	0	16	171	101	6	9	6	114	28	5	213	30	616	0	0	1791	189	GE
GL	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	54	0	0	3	1	GL
GR	11	52	1	3	5	78	6	130	104	150	4	3	16	0	1	146	144	1	20	8	52	381	10	6	78	742	0	0	2592	1850	GR
HR	10	2	0	6	6	134	8	69	134	50	5	70	60	0	0	6	41	0	34	7	3	190	20	1	38	617	0	0	2614	2195	HR
HU	4	2	0	5	11	292	5	205	105	86	8	25	179	0	0	5	85	0	29	15	4	42	26	1	20	588	0	0	2557	2184	HU
IE	0	0	0	-7	24	23	1	2	0	20	12	1	2	0	0	0	5	0	61	10	0	2	21	0	1	383	0	0	330	272	IE
IS	0	0	0	1	11	3	2	0	0	4	4	0	0	0	0	0	0	0	41	3	0	0	11	0	0	298	0	0	120	52	IS
IT	5	3	1	3	4	44	13	22	28	25	3	42	15	0	0	7	17	0	46	4	2	384	16	1	86	648	0	0	2422	2253	IT
KG	0	1	0	0	1	5	2	5	2	107	1	1	1	60	65	29	12	586	4	1	3	9	1	595	18	854	0	0	1873	79	KG
KZ	0	0	0	1	7	13	1	6	2	706	8	0	1	1	8	9	28	24	8	7	3	4	5	73	5	944	0	0	1291	104	KZ
LT	0	0	0	9	33	273	1	6	3	286	66	1	8	0	0	1	27	0	36	145	0	2	52	1	1	563	0	0	1466	1005	LT
LU	0	0	0	-23	16	49	8	5	2	23	10	2	5	0	0	1	8	0	60	7	0	11	11	0	5	486	0	0	649	575	LU
LV	0	0	0	9	31	176	1	4	2	284	84	1	5	0	0	1	17	0	35	181	1	1	52	0	0	558	0	0	1287	876	LV
MD	2	2	0	4	16	203	2	235	20	321	17	2	19	0	0	31	491	0	17	28	38	17	21	4	11	659	0	0	2018	804	MD
ME	564	19	1	4	5	115	9	84	301	57	3	7	39	0	0	24	57	0	25	5	8	243	12	2	84	749	0	0	2524	1202	ME
MK	18	443	1	3	4	107	6	133	348	89	4	4	31	0	0	53	84	0	20	7	18	131	10	3	73	725	0	0	2701	1434	MK
MT	6	3	-559	3	4	33	15	25	25	18	2	11	9	0	0	19	18	0	47	3	4	366	13	1	192	708	0	0	766	631	MT
NL	0	0	0	-771	38	53	3	4	2	40	13	1	6	0	0	1	8	0	63	14	0	3	-149	0	1	458	0	0	-434	-541	NL
NO	0	0	0	-1	120	20	1	1	0	44	44	0	0	0	0	0	2	0	60	23	0	0	51	0	0	403	0	0	388	212	NO
PL	0	0	0	3	33	582	2	30	9	143	36	4	38	0	0	2	70	0	40	70	1	5	55	1	2	570	0	0	1743	1411	PL
PT	0	0	0	1	3	4	839	1	1	9	2	1	1	0	0	1	2	0	329	2	0	54	8	0	65	923	0	0	1711	1691	PT
RO	8	6	0	3	10	197	3	907	89	188	10	4	35	0	0	24	271	0	17	18	34	28	17	3	20	615	0	0	2422	1695	RO
RS	49	37	0	4	6	178	6	241	587	88	4	9	61	0	0	18	93	0	21	9	12	73	15	2	44	625	0	0	2477	1429	RS
RU	0	0	0	1	10	20	0	4	1	701	13	0	1	0	1	5	32	1	11	16	4	2	7	8	2	622	0	0	956	122	RU
SE	0	0	0	2	64	39	1	1	0	75	141	0	1	0	0	0	3	0	50	74	0	0	50	0	0	460	0	0	583	428	SE
SI	2	1	0	3	6	105	7	46	37	37	6	403	44	0	0	4	28	0	37	8	2	136	18	0	33	549	0	0	2727	2553	SI
SK	2	1	0	7	16	462	4	117	44	91	10	17	430	0	0	3	98	0	30	20	2	25	35	1	11	584	0	0	2492	2173	SK
TJ	0	0	0	0	1	4	2	4	2	79	1	0	1	244	172	31	10	306	3	1	2	7	1	698	18	909	0	0	1035	61	TJ
TM	1	1	0	1	3	11	2	7	3	319	4	1	2	4	143	29	33	103	6	4	5	9	3	401	12	840	0	0	945	104	TM
TR	3	5	0	1	4	32	4	56	20	231	4	1	5	0	3	803	116	1	12	6	94	148	6	287	68	912	0	0	1698	397	TR
UA	1	1	0	3	19	194	2	81	11	521	21	2	15	0	1	22	481	1	18	33	30	13	23	7	8	626	0	0	1836	612	UA
UZ	0	1	0	1	3	10	2	7	3	360	4	1	1	22	70	21	27	280	6	4	4	7	3	226	11	861	0	0	1154	100	UZ
ATL	0	0	0	-0	1	0	1	0	0	2	0	0	0	0	0	0	0	0	5	0	0	0	1	0	1	16	0	0	12	8	ATL
BAS	0	0	0	-1	19	43	0	1	0	51	57	0	1	0	0	0	2	0	20	35	0	0	27	0	0	203	0	0	347	265	BAS
BLS	0	0	0	0	2	14	0	21	3	123	3	0	2	0	0	27	76	0	2	4	58	6	2	3	3	103	0	0	348	86	BLS
MED	2	2	0	1	1	10	3	12	8	20	1	2	2	0	0	36	16	0	10	1	9	147	3	-3	25	136	0	0	359	259	MED
NOS	0	0	0	-10	9	5	0	0	0	6	5	0	0	0	0	0	1	0	16	3	0	1	-18	0	0	74	0	0	47	28	NOS
AST	0	1	0	0	1	4	1	6	3	79	1	0	1	5	42	74	13	32	3	1	5	29	1	1580	20	804	0	0	424	74	AST
NOA	1	1	1	0	1	6	31	6	5	7	1	1	2	0	0	19	6	0	73	1	2	180	4	-0	667	579	0	0	422	371	NOA
EXC	2	2	0	-2	14	50	11	28	12	452	17	3	7	3	10	44	52	22	27	18	10	29	12	59	13	678	0	0	1210	439	EXC
EU	2	3	0	-10	23	112	44	76	21	80	34	10	20	0	0	10	41	0	74	34	6	77	25	1	29	611	0	0	1485	1256	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.5: 2016 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	100	0	11	0	7	5	6	9	6	0	19	71	2	0	26	1	39	33	0	30	10	15	2	0	110	0	1	1	1	1	1	AL
AM	1	128	2	35	1	1	2	8	1	1	4	17	1	0	6	1	8	8	19	5	1	2	1	0	15	0	2	1	0	1	1	AM
AT	1	0	141	0	1	17	1	9	45	0	47	282	3	0	12	1	82	77	0	1	10	13	4	0	106	0	0	1	2	1	1	AT
AZ	1	11	2	93	1	1	2	12	1	0	5	19	1	1	6	2	9	11	22	5	1	2	1	0	14	0	4	1	0	1	1	AZ
BA	3	0	19	0	19	7	3	10	7	0	29	105	3	0	19	1	41	47	0	6	13	20	3	0	85	0	0	1	1	1	1	BA
BE	0	0	7	0	0	114	0	11	8	0	9	232	4	0	8	1	116	183	0	0	1	3	6	0	12	0	0	2	6	1	0	BE
BG	4	0	8	1	2	5	39	21	3	0	17	68	4	1	9	2	23	31	1	26	4	14	2	0	30	0	1	3	1	2	3	BG
BY	0	0	3	0	0	7	0	56	2	0	11	68	5	1	2	2	23	45	0	0	1	3	3	0	5	0	1	3	1	2	1	BY
CH	0	0	21	0	1	17	1	8	247	0	15	209	2	0	16	1	153	64	0	1	4	3	3	0	203	0	0	1	3	1	0	CH
CY	4	1	8	2	3	4	9	17	4	34	13	52	2	1	20	2	33	23	2	43	5	10	1	0	64	0	1	2	1	1	4	CY
CZ	0	0	28	0	1	17	1	11	12	0	131	235	5	1	8	2	65	86	0	1	4	13	4	0	27	0	0	2	2	1	1	CZ
DE	0	0	20	0	0	35	0	10	19	0	28	384	6	1	8	2	99	125	0	0	1	4	5	0	19	0	0	2	4	1	0	DE
DK	0	0	1	0	0	20	0	11	1	0	7	129	46	1	2	2	35	148	0	0	0	1	7	0	1	0	0	3	1	2	0	DK
EE	0	0	1	0	0	7	0	9	1	0	7	58	7	6	1	8	17	63	0	0	0	1	4	0	1	0	0	3	1	4	0	EE
ES	0	0	4	0	0	3	0	2	4	0	4	30	1	0	218	1	43	28	0	0	1	2	2	0	24	0	0	0	0	0	0	ES
FI	0	0	1	0	0	4	0	5	0	0	3	29	4	1	0	6	10	32	0	0	0	0	2	0	1	0	0	1	0	1	0	FI
FR	0	0	7	0	0	18	0	7	14	0	10	108	3	0	33	1	156	93	0	1	2	3	4	0	54	0	0	1	2	1	0	FR
GB	0	0	2	0	0	10	0	5	2	0	4	45	5	0	3	1	29	258	0	0	0	1	8	0	6	0	0	1	1	1	0	GB
GE	1	9	3	32	1	1	2	11	2	0	5	21	2	0	6	1	9	11	60	7	1	3	1	0	16	0	2	1	0	1	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	0	GL
GR	11	0	9	1	4	5	16	17	4	0	18	67	3	1	20	2	34	34	1	166	6	14	2	0	75	0	1	2	1	1	3	GR
HR	2	0	38	0	8	10	3	10	10	0	45	148	3	0	22	2	55	61	0	5	38	26	3	0	125	0	0	2	1	1	1	HR
HU	1	0	33	0	3	10	3	13	8	0	46	139	5	1	11	2	42	57	0	2	9	58	3	0	48	0	0	2	1	1	2	HU
IE	0	0	2	0	0	6	0	5	1	0	4	30	3	0	2	1	15	117	0	0	0	1	20	0	4	0	0	1	0	1	0	IE
IS	0	0	0	0	0	1	0	1	0	0	0	4	1	0	1	0	2	12	0	0	0	0	1	1	1	0	0	0	0	0	0	IS
IT	2	0	37	0	4	11	2	8	22	0	27	136	2	0	47	1	98	59	0	7	18	13	3	0	700	0	0	1	1	1	1	IT
KG	0	1	1	3	0	1	1	4	1	0	2	9	0	0	4	1	6	4	1	2	1	1	0	0	9	85	22	0	0	0	0	KG
KZ	0	0	1	1	0	1	1	7	1	0	3	15	1	0	3	1	6	11	1	1	0	1	1	0	6	6	19	1	0	1	1	KZ
LT	0	0	3	0	0	10	0	23	1	0	11	79	9	1	1	3	23	74	0	0	1	2	5	0	4	0	1	14	1	4	0	LT
LU	0	0	11	0	0	51	0	11	9	0	14	284	3	0	11	1	128	129	0	0	1	3	4	0	15	0	0	2	40	1	0	LU
LV	0	0	2	0	0	8	0	14	1	0	8	62	8	2	1	3	19	71	0	0	0	2	5	0	2	0	0	7	1	11	0	LV
MD	1	0	5	1	1	6	3	19	2	0	15	64	4	1	4	2	18	37	1	4	2	7	2	0	14	0	1	2	1	2	18	MD
ME	18	0	12	0	8	6	4	9	6	0	20	79	2	0	22	1	37	34	0	14	9	15	2	0	92	0	0	1	1	1	1	ME
MK	13	0	9	0	3	5	11	12	4	0	18	66	3	0	17	2	28	28	0	57	5	16	2	0	54	0	1	2	1	1	2	MK
MT	4	0	14	0	5	8	5	11	6	0	21	81	2	0	64	1	84	48	0	19	11	12	4	0	273	0	1	2	1	1	2	MT
NL	0	0	6	0	0	66	0	11	3	0	12	233	7	1	5	1	76	202	0	0	1	3	8	0	5	0	0	2	2	1	0	NL
NO	0	0	0	0	0	3	0	3	0	0	2	21	5	0	1	1	9	36	0	0	0	0	2	0	1	0	0	1	0	1	0	NO
PL	0	0	8	0	0	16	1	20	4	0	31	147	8	1	3	2	43	76	0	0	2	7	4	0	11	0	1	3	1	2	1	PL
PT	0	0	2	0	0	2	0	2	2	0	3	22	1	0	108	1	26	23	0	0	1	1	2	0	11	0	0	0	0	0	0	PT
RO	2	0	8	0	2	6	9	19	3	0	17	73	4	1	7	2	22	34	1	4	3	14	2	0	23	0	1	2	1	1	4	RO
RS	6	0	14	0	6	7	8	13	5	0	27	91	3	0	13	2	31	38	0	11	8	28	2	0	49	0	1	2	1	1	2	RS
RU	0	0	1	1	0	1	0	7	0	0	2	14	1	1	1	1	5	11	0	1	0	1	1	0	3	0	2	1	0	1	0	RU
SE	0	0	1	0	0	5	0	4	0	0	3	36	7	1	1	2	12	45	0	0	0	0	3	0	1	0	0	1	0	1	0	SE
SI	1	0	88	0	3	13	2	10	16	0	52	209	3	0	19	2	66	73	0	3	33	21	4	0	192	0	0	1	1	1	1	SI
SK	1	0	23	0	1	9	2	14	7	0	52	133	5	0	7	2	40	57	0	1	6	26	3	0	34	0	0	2	1	1	1	SK
TJ	0	1	1	3	0	0	1	3	1	0	2	8	0	0	3	0	4	3	1	1	0	1	0	0	8	10	7	0	0	0	0	TJ
TM	1	2	2	8	0	1	1	8	1	0	4	17	1	0	5	1	8	9	2	3	1	2	1	0	11	1	8	1	0	1	1	TM
TR	2	4	4	4	1	3	5	12	2	1	8	33	2	0	11	1	17	16	4	16	2	5	1	0	30	0	1	1	0	1	2	TR
UA	1	0	4	1	1	5	2	23	2	0	12	58	4	1	4	2	17	34	1	3	1	5	2	0	12	0	2	2	1	2	3	UA
UZ	0	1	2	4	0	1	1	7	1	0	3	16	1	0	4	1	8	8	1	2	1	1	1	0	10	15	12	1	0	1	1	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	5	0	4	0	0	3	35	8	2	0	4	9	37	0	0	0	0	2	0	0	0	0	2	0	2	0	BAS
BLS	0	0	1	1	0	1	1	4	0	0	2	9	1	0	1	0	3	5	2	2	0	1	0	0	3	0	0	0	0	0	1	BLS
MED	1	0	3	0	1	1	2	3	1	0	4	17	1	0	12	0	15	9	0	14	2	2	1	0	38	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	3	0	1	0	0	1	12	2	0	0	0	7	28	0	0	0	0	1	0	1	0	0	0	0	0	0	NOS
AST	1	1	1	4	0	1	1	4	1	1	2	9	0	0	4	0	5	4	1	4	1	1	0	0	9	3	5	0	0	0	1	AST
NOA	1	0	4	0	1	2	1	2	2	0	5	22	1	0	30	0	23	16	0	6	2	3	1	0	34	0	0	0	0	0	0	NOA
EXC	1	1	4	2	1	4	1	9	3	0	7	41	2	1	11	2	19	28	1	3	1	3	2	0	23	2	5	1	0	1	1	EXC
EU	1	0	12	0	1	13	2	9	8	0	17	110	5	1	38	2	57	76	0	7	4	7	4	0	72	0	0	2	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.: 2016 country-to-country blame matrices for $\mathbf{AOT40}_f^{\mathbf{uc}}$.
Units: ppb.h per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	
AL	9	10	0	9	3	50	4	15	42	42	3	3	7	0	0	14	19	0	0	0	0	1	0	2	31	106	0	0	740	477	AL
AM	0	0	0	2	2	13	1	6	3	77	2	0	1	0	1	29	20	1	0	0	0	0	0	304	10	82	0	0	433	103	AM
AT	0	0	0	26	4	53	2	7	5	29	4	14	11	0	0	2	10	0	0	0	0	0	1	0	7	77	0	0	1025	918	AT
AZ	0	0	0	3	3	16	1	6	3	138	2	0	1	0	2	21	31	1	0	0	0	0	0	226	7	116	0	0	460	114	AZ
BA	2	1	0	15	3	60	3	15	39	35	3	3	10	0	0	5	16	0	0	0	0	1	0	1	18	83	0	0	654	513	BA
BE	0	0	0	90	6	31	2	2	1	31	4	1	2	0	0	1	6	0	0	0	0	0	1	1	2	73	0	0	905	839	BE
BG	1	4	0	9	4	63	2	34	27	89	4	1	7	0	0	50	51	0	0	0	0	0	0	3	12	105	0	0	671	409	BG
BY	0	0	0	12	4	60	0	4	1	109	5	0	2	0	0	2	17	0	0	0	0	0	0	2	1	60	0	0	463	269	BY
CH	0	0	0	21	4	27	3	2	2	25	4	3	2	0	0	1	5	0	0	0	0	1	1	1	7	63	0	0	1074	780	CH
CY	1	3	0	7	3	34	3	23	13	99	3	2	5	0	0	319	45	0	0	0	0	1	0	57	37	191	0	0	927	405	CY
CZ	0	0	0	32	6	107	1	8	5	35	5	3	11	0	0	2	14	0	0	0	0	0	1	1	2	80	0	0	888	798	CZ
DE	0	0	0	60	7	55	1	3	2	32	6	1	4	0	0	1	7	0	0	0	0	0	1	1	2	76	0	0	955	875	DE
DK	0	0	0	50	13	40	0	1	0	52	22	0	1	0	0	0	4	0	0	1	0	0	1	1	0	65	0	0	604	521	DK
EE	0	0	0	16	4	45	0	1	0	64	9	0	1	0	0	1	4	0	0	0	0	0	0	0	0	49	0	0	346	262	EE
ES	0	0	0	5	2	10	28	1	1	11	2	1	1	0	0	1	2	0	0	0	0	1	0	0	28	54	0	0	435	411	ES
FI	0	0	0	8	3	17	0	0	0	31	6	0	0	0	0	0	2	0	0	0	0	0	0	0	0	21	0	0	169	127	FI
FR	0	0	0	28	5	27	4	2	1	28	4	2	2	0	0	1	6	0	0	0	0	1	1	1	7	62	0	0	631	566	FR
GB	0	0	0	25	8	15	0	1	0	24	5	0	1	0	0	1	4	0	0	0	0	0	1	0	1	41	0	0	468	423	GB
GE	0	1	0	3	3	18	1	9	4	105	2	1	1	0	1	28	31	0	0	0	0	0	0	100	9	87	0	0	417	126	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	-3	0	0	0	0	GL
GR	2	7	0	10	4	58	3	26	26	85	4	2	7	0	0	67	43	0	0	0	0	1	0	5	26	133	0	0	862	586	GR
HR	1	1	0	19	4	70	3	15	30	36	3	10	13	0	0	4	15	0	0	0	0	1	0	1	15	97	0	0	842	720	HR
HU	1	1	0	18	5	108	2	30	23	47	3	5	22	0	0	4	23	0	0	0	0	0	0	1	8	87	0	0	789	660	HU
IE	0	0	0	14	6	17	0	1	0	22	4	0	1	0	0	0	5	0	0	0	0	0	1	0	1	30	0	0	287	246	IE
IS	0	0	0	1	2	2	1	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-4	0	0	35	30	IS
IT	1	1	0	18	4	45	5	8	10	31	3	17	7	0	0	4	11	0	0	0	0	2	0	1	35	118	0	0	1368	1269	IT
KG	0	0	0	1	1	6	1	2	1	47	1	0	1	6	4	8	8	134	0	0	0	0	0	230	5	75	0	0	382	55	KG
KZ	0	0	0	2	2	11	0	2	1	107	2	0	1	0	1	4	11	6	0	0	0	0	0	35	2	74	0	0	244	75	KZ
LT	0	0	0	23	5	66	0	2	1	75	6	0	2	0	0	1	8	0	0	0	0	0	1	1	0	60	0	0	460	345	LT
LU	0	0	0	37	5	35	2	2	1	27	3	1	2	0	0	1	7	0	0	0	0	0	1	1	2	70	0	0	844	783	LU
LV	0	0	0	18	4	47	0	2	1	62	7	0	2	0	0	1	6	0	0	0	0	0	0	0	0	52	0	0	375	286	LV
MD	0	0	0	11	4	67	1	26	6	100	4	1	4	0	0	18	68	0	0	0	0	0	0	4	4	86	0	0	545	305	MD
ME	33	2	0	11	3	50	3	14	34	39	2	2	7	0	0	10	18	0	0	0	0	1	0	2	26	89	0	0	625	444	ME
MK	1	58	0	9	3	55	3	20	44	52	3	2	7	0	0	27	24	0	0	0	0	0	0	3	21	93	0	0	667	423	MK
MT	1	1	144	15	3	47	9	14	12	31	3	4	6	0	0	11	15	0	0	0	0	6	0	1	84	163	0	0	997	893	MT
NL	0	0	0	207	9	34	1	2	1	35	6	0	3	0	0	1	6	0	0	0	0	0	2	1	1	73	0	0	953	886	NL
NO	0	0	0	8	14	8	0	0	0	16	4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6	0	0	138	103	NO
PL	0	0	0	26	6	188	1	6	3	62	6	1	6	0	0	1	18	0	0	0	0	0	1	1	1	79	0	0	717	600	PL
PT	0	0	0	3	2	6	161	1	1	11	1	0	1	0	0	1	2	0	1	0	0	0	0	0	15	48	0	0	397	377	PT
RO	1	2	0	11	4	69	1	71	19	78	4	1	6	0	0	20	45	0	0	0	0	0	0	3	8	88	0	0	596	396	RO
RS	2	7	0	13	3	76	2	31	112	49	3	2	12	0	0	11	24	0	0	0	0	0	0	2	14	89	0	0	718	476	RS
RU	0	0	0	3	2	10	0	1	1	95	2	0	0	0	0	2	10	0	0	0	0	0	0	4	1	34	0	0	184	63	RU
SE	0	0	0	12	4	16	0	0	0	26	9	0	0	0	0	0	2	0	0	0	0	0	0	0	0	17	0	0	196	158	SE
SI	0	0	0	23	4	65	3	11	11	33	4	86	11	0	0	2	12	0	0	0	0	1	1	0	13	97	0	0	1080	986	SI
SK	0	0	0	18	5	143	1	18	10	45	4	3	35	0	0	3	20	0	0	0	0	0	0	1	5	77	0	0	736	627	SK
TJ	0	0	0	1	1	5	1	2	1	41	1	0	1	13	7	7	6	51	0	0	0	0	0	244	4	64	0	0	201	45	TJ
TM	0	0	0	2	2	12	1	4	2	95	2	0	1	1	11	12	15	8	0	0	0	0	0	246	6	115	0	0	268	90	TM
TR	0	1	0	5	3	24	2	13	7	89	2	1	3	0	0	174	33	0	0	0	0	0	0	114	18	97	0	0	547	208	TR
UA	0	0	0	9	4	56	1	12	4	136	4	1	3	0	0	12	98	0	0	0	0	0	0	6	4	85	0	0	545	257	UA
UZ	0	0	0	2	2	11	1	3	2	93	2	0	1	3	5	9	12	72	0	0	0	0	0	139	5	107	0	0	324	83	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	6	5	ATL
BAS	0	0	0	12	3	21	0	0	0	26	10	0	0	0	0	0	1	0	0	0	0	0	0	0	0	22	0	0	188	153	BAS
BLS	0	0	0	1	1	8	0	4	1	36	1	0	1	0	0	16	18	0	0	0	0	0	0	2	1	22	0	0	129	47	BLS
MED	0	0	0	3	1	9	1	4	3	14	1	1	1	0	0	26	7	0	0	0	0	1	0	6	16	30	0	0	201	142	MED
NOS	0	0	0	7	5	3	0	0	0	4	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	7	0	0	79	68	NOS
AST	0	0	0	1	1	6	1	3	2	39	1	0	1	0	3	24	9	5	0	0	0	0	0	773	6	97	0	0	163	59	AST
NOA	0	0	0	4	1	10	10	3	3	10	1	1	1	0	0	9	4	0	0	0	0	1	0	6	130	63	0	0	219	183	NOA
EXC	0	0	0	8	3	22	2	5	3	79	3	1	2	0	1	12	14	5	0	0	0	0	0	28	4	56	0	0	339	198	EXC
EU	0	1	0	22	5	48	8	9	5	37	5	3	4	0	0	6	11	0	0	0	0	0	1	1	9	64	0	0	616	530	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.6: 2016 country-to-country blame matrices for **SOMO35**.
Units: ppb.d per 15% emis. red. of NO_x. **Emitters** $\rightarrow$**, Receptors** $\downarrow$.

	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	68	0	3	0	5	0	7	1	1	0	2	4	0	0	9	0	8	1	0	26	4	5	0	0	29	0	0	0	0	0	0	AL
AM	0	43	0	37	0	0	1	1	0	0	0	1	0	0	2	0	1	0	14	2	0	0	0	0	2	0	3	0	0	0	0	AM
AT	0	0	41	0	1	0	1	1	6	0	11	40	0	0	5	0	20	3	0	1	3	6	1	0	22	0	0	0	0	0	0	AT
AZ	0	6	0	74	0	0	1	1	0	0	0	1	0	0	1	0	1	0	15	1	0	0	0	0	2	0	8	0	0	0	0	AZ
BA	2	0	9	0	43	0	4	1	1	0	7	11	0	0	8	0	9	2	0	3	19	17	0	0	27	0	0	0	0	0	0	BA
BE	0	0	1	0	0	-70	0	1	1	0	1	-2	0	0	4	0	27	2	0	0	0	1	2	0	2	0	0	0	1	0	0	BE
BG	2	0	2	0	2	0	56	3	0	0	2	4	0	0	4	1	3	1	0	16	2	6	0	0	8	0	1	1	0	0	3	BG
BY	0	0	1	0	0	0	0	31	0	0	2	7	2	1	1	3	3	3	0	1	0	1	1	0	1	0	1	6	0	3	1	BY
CH	0	0	5	0	0	1	0	0	41	0	1	11	0	0	7	0	55	3	0	0	1	1	1	0	37	0	0	0	0	0	0	CH
CY	1	0	1	0	1	0	3	1	0	45	0	1	0	0	5	0	4	0	0	22	1	1	0	0	8	0	0	0	0	0	1	CY
CZ	0	0	10	0	1	-0	1	2	1	0	32	36	1	0	3	1	15	4	0	0	2	6	1	0	5	0	0	1	0	0	0	CZ
DE	0	0	3	0	0	-2	0	1	2	0	4	8	1	0	3	1	22	5	0	0	0	1	2	0	3	0	0	1	1	0	0	DE
DK	0	0	0	0	0	-2	0	1	0	0	1	3	-13	1	1	2	4	8	0	0	0	0	3	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	0	0	3	0	0	1	6	3	7	1	10	2	4	0	0	0	0	1	0	0	0	0	4	0	6	0	EE
ES	0	0	1	0	0	0	0	0	0	0	0	1	0	0	115	0	14	2	0	0	0	0	1	0	3	0	0	0	0	0	0	ES
FI	0	0	0	0	0	-0	0	2	0	0	0	3	2	2	0	18	1	3	0	0	0	0	1	0	0	0	0	1	0	1	0	FI
FR	0	0	1	0	0	-1	0	0	2	0	1	3	0	0	15	0	73	4	0	0	0	1	2	0	8	0	0	0	0	0	0	FR
GB	0	0	0	0	0	-1	0	0	0	0	0	-0	1	0	2	1	6	-35	0	0	0	0	5	0	1	0	0	0	0	0	0	GB
GE	0	5	0	24	0	0	2	1	0	0	0	1	0	0	2	0	2	0	59	2	0	1	0	0	3	0	3	0	0	0	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	0	GL
GR	5	0	2	0	2	0	25	2	0	0	1	3	0	0	7	0	6	1	0	80	2	3	0	0	18	0	1	0	0	0	1	GR
HR	1	0	16	0	12	0	2	1	1	0	9	15	0	0	8	0	11	2	0	2	38	23	1	0	30	0	0	0	0	0	0	HR
HU	0	0	12	0	3	0	2	3	1	0	11	15	1	0	4	1	8	2	0	1	7	49	1	0	10	0	0	1	0	0	1	HU
IE	0	0	0	0	0	-1	0	0	0	0	0	-0	0	0	1	0	3	5	0	0	0	0	-4	0	1	0	0	0	-0	0	0	IE
IS	0	0	0	0	0	-0	0	0	0	0	0	-0	0	0	1	0	1	1	0	0	0	0	1	6	0	0	0	0	0	0	0	IS
IT	1	0	8	0	2	0	1	0	3	0	3	9	0	0	14	0	26	2	0	2	6	4	1	0	83	0	0	0	0	0	0	IT
KG	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	1	1	0	0	0	0	1	55	20	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	2	36	0	0	0	0	KZ
LT	0	0	1	0	0	0	0	10	0	0	2	9	3	2	1	4	3	5	0	0	0	1	1	0	1	0	0	16	0	5	0	LT
LU	0	0	2	0	0	-2	0	1	1	0	1	19	0	0	5	0	40	5	0	0	0	1	2	0	3	0	0	0	-57	0	0	LU
LV	0	0	0	0	0	0	0	7	0	0	1	7	3	3	1	5	2	4	0	0	0	1	1	0	1	0	0	10	0	8	0	LV
MD	0	0	1	0	1	0	3	7	0	0	2	5	1	0	2	2	3	1	0	2	1	3	0	0	4	0	1	1	0	1	19	MD
ME	13	0	4	0	14	0	6	1	1	0	4	7	0	0	9	0	8	1	0	7	6	8	0	0	28	0	0	0	0	0	1	ME
MK	17	0	2	0	3	0	17	1	0	0	2	4	0	0	7	0	6	1	0	41	2	6	0	0	16	0	0	0	0	0	1	MK
MT	1	0	3	0	2	0	2	0	1	0	2	4	0	0	21	0	23	2	0	5	3	2	0	0	44	0	0	0	0	0	0	MT
NL	0	0	1	0	0	-13	0	1	0	0	1	-9	1	0	3	0	8	2	0	0	0	0	3	0	1	0	0	1	0	0	0	NL
NO	0	0	0	0	0	-0	0	1	0	0	0	1	1	0	1	3	2	4	0	0	0	0	1	0	0	0	0	0	0	0	0	NO
PL	0	0	2	0	0	-0	0	6	0	0	6	19	2	1	1	2	7	4	0	0	1	3	1	0	2	0	0	3	0	1	0	PL
PT	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	69	0	6	1	0	0	0	0	1	0	1	0	0	0	0	0	0	PT
RO	1	0	2	0	2	0	9	4	0	0	3	6	1	0	3	1	4	1	0	3	2	10	0	0	7	0	1	1	0	0	5	RO
RS	5	0	4	0	8	0	11	2	0	0	5	8	0	0	6	1	6	1	0	5	5	17	0	0	14	0	0	0	0	0	1	RS
RU	0	0	0	1	0	0	0	2	0	0	0	1	0	1	1	2	1	1	0	0	0	0	0	0	1	0	6	1	0	0	0	RU
SE	0	0	0	0	0	-0	0	1	0	0	1	3	3	1	1	5	2	5	0	0	0	0	1	0	0	0	0	1	0	1	0	SE
SI	0	0	34	0	2	-0	1	1	1	0	8	19	0	0	7	0	13	2	0	1	23	12	1	0	31	0	0	0	0	0	0	SI
SK	0	0	8	0	1	0	1	3	1	0	16	17	1	0	3	1	8	2	0	1	3	24	1	0	8	0	0	1	0	0	1	SK
TJ	0	0	0	1	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	1	3	6	0	0	0	0	TJ
TM	0	1	0	5	0	0	1	1	0	0	0	1	0	0	2	1	1	0	2	1	0	0	0	0	2	0	18	0	0	0	0	TM
TR	1	2	1	2	0	0	3	1	0	1	1	1	0	0	4	0	3	0	2	7	0	1	0	0	5	0	1	0	0	0	1	TR
UA	0	0	1	0	0	0	2	10	0	0	2	4	1	1	2	2	2	1	0	1	1	2	0	0	3	0	2	2	0	1	3	UA
UZ	0	1	0	2	0	0	0	1	0	0	0	1	0	0	2	1	1	0	1	1	0	0	0	0	2	2	24	0	0	0	0	UZ
ATL	0	0	0	0	0	-0	0	0	0	0	0	-0	0	0	4	1	3	2	0	0	0	0	1	1	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	-1	0	2	0	0	1	5	4	2	1	10	2	7	0	0	0	0	2	0	0	0	0	3	0	3	0	BAS
BLS	0	0	1	2	1	0	7	5	0	0	1	2	0	0	2	1	2	1	7	5	0	2	0	0	4	0	2	1	0	1	3	BLS
MED	2	0	3	0	2	0	5	1	1	1	2	4	0	0	20	0	26	2	0	18	4	3	1	0	37	0	0	0	0	0	1	MED
NOS	0	0	0	0	0	-3	0	1	0	0	0	-4	2	0	2	1	4	3	0	0	0	0	4	1	1	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	1	1	0	0	0	0	1	2	7	0	0	0	0	AST
NOA	0	0	1	0	0	0	1	0	0	0	0	1	0	0	18	0	8	1	0	4	1	1	0	0	9	0	0	0	0	0	0	NOA
EXC	0	0	1	1	0	-0	1	2	0	0	1	3	0	0	5	2	5	1	1	2	1	1	0	0	4	1	9	1	0	0	0	EXC
EU	0	0	3	0	1	-1	3	2	1	0	3	7	1	0	19	2	18	1	0	3	2	3	1	0	10	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.6 Cont.: 2016 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	BIC	DMS	VOL	EXC	EU	
AL	7	12	0	0	0	6	1	7	26	5	0	1	2	0	0	3	5	0	3	0	1	37	1	1	11	81	0	0	250	117	AL
AM	0	0	0	0	0	1	0	2	1	17	0	0	0	0	1	34	6	0	1	0	4	5	0	83	4	76	0	0	174	16	AM
AT	0	0	0	-0	1	8	1	3	1	3	1	6	3	0	0	0	2	0	4	1	0	6	1	0	3	60	0	0	191	174	AT
AZ	0	0	0	0	0	1	0	2	1	42	0	0	0	0	3	13	8	1	1	0	3	3	0	54	2	68	0	0	186	14	AZ
BA	4	1	0	0	1	11	1	8	20	5	0	2	5	0	0	1	5	0	3	1	1	18	1	1	8	76	0	0	230	145	BA
BE	0	0	0	-16	2	3	1	0	0	2	1	0	0	0	0	0	1	0	7	1	0	1	-12	0	1	52	0	0	-32	-39	BE
BG	1	3	0	0	1	10	0	32	15	19	1	0	2	0	0	5	21	0	2	1	7	10	1	1	5	71	0	0	228	151	BG
BY	0	0	0	-0	3	23	0	2	1	36	4	0	1	0	0	1	9	0	3	6	0	1	3	1	1	55	0	0	149	66	BY
CH	0	0	0	-0	0	2	1	1	1	2	0	1	0	0	0	0	1	0	5	0	0	6	1	0	4	65	0	0	174	128	CH
CY	0	1	0	0	0	2	0	4	2	8	0	0	0	0	0	76	6	0	1	0	4	74	0	10	8	96	0	0	199	100	CY
CZ	0	0	0	-1	1	20	0	3	1	5	1	1	6	0	0	0	3	0	4	1	0	2	2	0	1	58	0	0	164	149	CZ
DE	0	0	0	-5	2	9	0	1	0	3	2	0	1	0	0	0	1	0	6	1	0	1	0	0	1	56	0	0	72	61	DE
DK	0	0	0	-4	6	6	0	0	0	7	6	0	0	0	0	0	1	0	6	2	0	0	5	0	0	54	0	0	36	20	DK
EE	0	0	0	-0	4	12	0	1	0	26	11	0	0	0	0	0	1	0	4	18	0	1	4	0	0	53	0	0	106	70	EE
ES	0	0	0	-0	0	1	18	0	0	1	0	0	0	0	0	0	0	0	18	0	0	13	1	0	11	99	0	0	159	157	ES
FI	0	0	0	-0	4	4	0	0	0	21	10	0	0	0	0	0	1	0	4	9	0	0	3	0	0	49	0	0	76	47	FI
FR	0	0	0	-1	1	2	2	0	0	2	1	0	0	0	0	0	1	0	11	1	0	7	2	0	3	67	0	0	120	113	FR
GB	0	0	0	-2	3	2	0	0	0	2	1	0	0	0	0	0	0	0	8	1	0	0	-1	0	0	52	0	0	-13	-20	GB
GE	0	0	0	0	0	2	0	3	1	36	0	0	0	0	1	26	11	0	1	1	12	5	0	24	4	75	0	0	192	22	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	11	0	0	2	1	GL
GR	1	5	0	0	0	6	1	11	9	12	0	0	1	0	0	13	11	0	2	1	4	43	1	1	10	80	0	0	232	168	GR
HR	1	0	0	0	1	11	1	7	12	5	0	6	5	0	0	1	4	0	4	1	0	22	1	0	5	68	0	0	230	190	HR
HU	0	0	0	-0	1	24	1	19	9	8	1	3	16	0	0	1	8	0	3	1	0	6	2	0	3	60	0	0	224	189	HU
IE	0	0	0	-2	2	2	0	0	0	2	1	0	0	0	0	0	0	0	8	1	0	0	1	0	0	50	0	0	14	9	IE
IS	0	0	0	-1	2	0	0	0	0	2	1	0	0	0	0	0	0	0	6	1	0	0	1	0	0	50	0	0	16	6	IS
IT	1	0	0	0	0	4	1	2	3	2	0	3	1	0	0	1	2	0	5	0	0	39	1	0	10	70	0	0	190	173	IT
KG	0	0	0	0	0	0	0	0	0	9	0	0	0	6	6	4	1	49	1	0	0	2	0	75	2	89	0	0	160	8	KG
KZ	0	0	0	0	1	1	0	1	0	71	1	0	0	0	2	2	4	3	1	1	1	1	0	15	1	97	0	0	137	12	KZ
LT	0	0	0	0	3	24	0	1	0	24	6	0	1	0	0	0	3	0	3	11	0	1	4	0	0	53	0	0	126	84	LT
LU	0	0	0	-4	1	4	1	1	0	2	1	0	1	0	0	0	1	0	6	0	0	2	-1	0	1	53	0	0	29	22	LU
LV	0	0	0	0	3	16	0	1	0	25	8	0	0	0	0	0	2	0	4	15	0	1	4	0	0	53	0	0	112	73	LV
MD	0	0	0	0	1	16	0	23	2	27	2	0	2	0	0	3	43	0	2	2	4	4	2	1	2	66	0	0	181	74	MD
ME	47	2	0	0	0	9	1	8	28	5	0	1	3	0	0	3	5	0	3	0	1	28	1	1	10	85	0	0	229	110	ME
MK	2	39	0	0	0	8	1	12	31	8	0	0	2	0	0	5	7	0	3	1	2	17	1	1	9	80	0	0	244	129	MK
MT	1	0	-64	0	0	3	2	3	2	2	0	1	1	0	0	2	2	0	6	0	0	37	1	1	31	87	0	0	70	56	MT
NL	0	0	0	-102	3	4	1	0	0	3	1	0	1	0	0	0	1	0	7	1	0	1	-21	0	0	51	0	0	-86	-95	NL
NO	0	0	0	-1	13	2	0	0	0	7	6	0	0	0	0	0	0	0	7	3	0	0	5	0	0	53	0	0	45	22	NO
PL	0	0	0	-1	3	44	0	3	1	12	3	0	3	0	0	0	6	0	4	6	0	1	4	0	1	55	0	0	138	108	PL
PT	0	0	0	-0	0	0	79	0	0	1	0	0	0	0	0	0	0	0	34	0	0	5	1	0	7	99	0	0	161	159	PT
RO	1	1	0	0	1	16	0	82	9	17	1	0	3	0	0	3	24	0	2	1	3	5	1	1	4	66	0	0	223	155	RO
RS	5	4	0	0	1	14	1	22	50	8	0	1	5	0	0	2	8	0	2	1	1	11	1	0	6	69	0	0	223	127	RS
RU	0	0	0	0	1	2	0	1	0	71	1	0	0	0	0	1	4	0	1	2	1	1	1	2	0	60	0	0	101	14	RU
SE	0	0	0	-1	8	4	0	0	0	9	15	0	0	0	0	0	1	0	6	8	0	0	4	0	0	54	0	0	61	42	SE
SI	0	0	0	-0	0	8	1	5	3	4	0	23	4	0	0	1	3	0	4	1	0	15	1	0	5	59	0	0	210	194	SI
SK	0	0	0	-0	1	39	0	11	4	8	1	2	31	0	0	1	9	0	3	2	0	4	2	0	2	59	0	0	209	179	SK
TJ	0	0	0	0	0	0	0	0	0	7	0	0	0	24	15	3	1	24	1	0	0	1	0	92	2	95	0	0	93	6	TJ
TM	0	0	0	0	0	1	0	1	0	41	0	0	0	1	22	6	5	13	1	0	1	2	0	77	2	114	0	0	128	14	TM
TR	0	0	0	0	0	2	0	5	2	19	0	0	0	0	0	78	10	0	1	1	8	17	0	30	7	96	0	0	158	38	TR
UA	0	0	0	0	2	16	0	8	1	46	2	0	1	0	0	3	41	0	2	3	3	3	2	2	2	63	0	0	165	55	UA
UZ	0	0	0	0	0	1	0	1	0	45	1	0	0	3	9	4	4	25	1	0	1	2	0	42	2	109	0	0	135	13	UZ
ATL	0	0	0	-0	2	1	2	0	0	5	1	0	0	0	0	0	0	0	18	1	0	1	1	0	1	66	0	0	24	16	ATL
BAS	0	0	0	-2	6	10	0	0	0	16	17	0	0	0	0	0	1	0	6	8	0	0	6	0	0	64	0	0	92	66	BAS
BLS	0	0	0	0	1	7	0	15	2	74	1	0	1	0	0	17	45	0	2	2	45	7	1	4	3	75	0	0	217	56	BLS
MED	1	1	0	0	0	3	2	4	3	6	0	1	1	0	0	17	5	0	7	0	2	106	1	1	20	91	0	0	178	139	MED
NOS	0	0	0	-7	7	2	0	0	0	5	3	0	0	0	0	0	1	0	14	2	0	1	-16	0	0	73	0	0	25	10	NOS
AST	0	0	0	0	0	0	0	1	0	12	0	0	0	1	4	8	2	3	1	0	1	3	0	169	2	93	0	0	50	8	AST
NOA	0	0	0	0	0	1	4	1	1	1	0	0	0	0	0	3	1	0	9	0	0	26	1	0	94	100	0	0	61	53	NOA
EXC	0	0	0	-0	1	4	1	3	1	45	2	0	1	0	1	5	5	2	3	2	1	4	1	9	2	71	0	0	118	39	EXC
EU	0	0	0	-2	2	9	4	7	2	8	3	1	2	0	0	1	4	0	8	3	1	8	2	0	4	65	0	0	124	102	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.7: 2016 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	15	0	2	0	1	1	1	1	1	0	2	7	0	0	3	0	5	3	0	4	1	2	0	0	15	0	0	0	0	0	0	AL
AM	0	26	0	4	0	0	0	1	0	0	1	2	0	0	1	0	1	1	3	1	0	0	0	0	2	0	0	0	0	0	0	AM
AT	0	0	17	0	0	2	0	1	5	0	6	30	0	0	2	0	10	8	0	0	1	2	0	0	17	0	0	0	0	0	0	AT
AZ	0	3	0	13	0	0	0	1	0	0	1	2	0	0	1	0	1	1	5	1	0	0	0	0	2	0	1	0	0	0	0	AZ
BA	1	0	3	0	4	1	0	1	1	0	4	11	0	0	3	0	5	5	0	1	2	3	0	0	13	0	0	0	0	0	0	BA
BE	0	0	1	0	0	12	0	1	1	0	1	25	0	0	1	0	14	20	0	0	0	0	1	0	2	0	0	0	1	0	0	BE
BG	1	0	1	0	0	1	7	2	1	0	3	7	0	0	1	0	3	3	0	4	1	2	0	0	6	0	0	0	0	0	0	BG
BY	0	0	0	0	0	1	0	6	0	0	1	7	1	0	0	0	3	4	0	0	0	0	0	0	1	0	0	0	0	0	0	BY
CH	0	0	3	0	0	2	0	1	31	0	3	26	0	0	2	0	19	7	0	0	1	1	0	0	31	0	0	0	0	0	0	CH
CY	0	0	1	0	0	0	1	2	0	4	2	5	0	0	2	0	3	2	0	4	1	1	0	0	7	0	0	0	0	0	0	CY
CZ	0	0	4	0	0	2	0	2	2	0	17	26	1	0	1	0	8	8	0	0	1	2	0	0	5	0	0	0	0	0	0	CZ
DE	0	0	2	0	0	4	0	1	2	0	4	42	1	0	1	0	11	13	0	0	0	1	1	0	3	0	0	0	0	0	0	DE
DK	0	0	0	0	0	2	0	1	0	0	1	15	5	0	0	0	4	15	0	0	0	0	1	0	0	0	0	0	0	0	0	DK
EE	0	0	0	0	0	1	0	1	0	0	1	7	1	1	0	1	2	7	0	0	0	0	0	0	1	0	0	0	0	0	0	EE
ES	0	0	0	0	0	0	0	0	0	0	1	3	0	0	26	0	5	3	0	0	0	0	0	0	4	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	1	4	1	0	0	1	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	1	0	0	2	0	1	2	0	2	13	0	0	4	0	19	10	0	0	0	0	0	0	8	0	0	0	0	0	0	FR
GB	0	0	0	0	0	1	0	1	0	0	1	6	0	0	1	0	4	29	0	0	0	0	1	0	1	0	0	0	0	0	0	GB
GE	0	2	0	3	0	0	0	1	0	0	1	3	0	0	1	0	1	1	11	1	0	1	0	0	2	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	1	0	1	0	0	1	2	2	1	0	2	7	0	0	2	0	4	3	0	22	1	2	0	0	10	0	0	0	0	0	0	GR
HR	1	0	5	0	1	1	0	1	1	0	6	15	0	0	3	0	6	6	0	1	5	3	0	0	19	0	0	0	0	0	0	HR
HU	0	0	4	0	0	1	1	2	1	0	6	14	0	0	2	0	5	5	0	1	1	7	0	0	8	0	0	0	0	0	0	HU
IE	0	0	0	0	0	1	0	1	0	0	0	4	0	0	1	0	2	12	0	0	0	0	3	0	1	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	IS
IT	0	0	4	0	1	1	0	1	3	0	3	14	0	0	5	0	11	6	0	1	2	1	0	0	92	0	0	0	0	0	0	IT
KG	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	1	13	2	0	0	0	0	KG
KZ	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	1	3	0	0	0	0	KZ
LT	0	0	0	0	0	1	0	3	0	0	2	9	1	0	0	0	3	7	0	0	0	0	0	0	1	0	0	2	0	1	0	LT
LU	0	0	1	0	0	6	0	1	1	0	2	29	0	0	1	0	15	14	0	0	0	0	1	0	2	0	0	0	4	0	0	LU
LV	0	0	0	0	0	1	0	2	0	0	1	7	1	0	0	0	2	7	0	0	0	0	1	0	1	0	0	1	0	1	0	LV
MD	0	0	1	0	0	1	1	2	0	0	2	7	0	0	1	0	2	3	0	1	0	1	0	0	3	0	0	0	0	0	2	MD
ME	3	0	2	0	1	1	0	1	1	0	3	8	0	0	3	0	5	4	0	2	1	2	0	0	14	0	0	0	0	0	0	ME
MK	2	0	1	0	1	1	1	1	1	0	3	7	0	0	2	0	4	3	0	10	1	2	0	0	9	0	0	0	0	0	0	MK
MT	0	0	2	0	1	1	1	1	1	0	3	9	0	0	7	0	9	5	0	2	1	1	0	0	30	0	0	0	0	0	0	MT
NL	0	0	1	0	0	8	0	1	0	0	2	27	1	0	1	0	10	23	0	0	0	0	1	0	1	0	0	0	0	0	0	NL
NO	0	0	0	0	0	1	0	0	0	0	0	4	1	0	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	0	2	0	3	1	0	4	16	1	0	1	0	5	7	0	0	0	1	0	0	2	0	0	0	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	3	0	0	13	0	3	2	0	0	0	0	0	0	2	0	0	0	0	0	0	PT
RO	0	0	1	0	0	1	1	2	0	0	3	8	0	0	1	0	3	3	0	1	1	2	0	0	5	0	0	0	0	0	1	RO
RS	1	0	2	0	1	1	1	1	1	0	4	10	0	0	2	0	4	4	0	2	1	3	0	0	8	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	0	1	5	1	0	0	0	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	11	0	0	1	0	1	2	0	7	22	0	0	3	0	8	7	0	1	5	3	0	0	33	0	0	0	0	0	0	SI
SK	0	0	3	0	0	1	0	2	1	0	7	15	1	0	1	0	5	6	0	0	1	4	0	0	6	0	0	0	0	0	0	SK
TJ	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	2	1	0	0	0	0	TJ
TM	0	0	0	1	0	0	0	1	0	0	1	2	0	0	1	0	1	1	0	0	0	0	0	0	2	0	1	0	0	0	0	TM
TR	0	1	1	0	0	0	1	1	0	0	1	4	0	0	1	0	2	2	0	2	0	1	0	0	4	0	0	0	0	0	0	TR
UA	0	0	1	0	0	1	0	2	0	0	2	6	0	0	1	0	2	3	0	1	0	1	0	0	2	0	0	0	0	0	0	UA
UZ	0	0	0	1	0	0	0	1	0	0	1	2	0	0	1	0	1	1	0	0	0	0	0	0	2	3	2	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	2	0	0	1	0	2	3	0	0	0	0	0	0	1	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	2	0	0	1	12	2	0	0	1	3	12	0	0	0	0	1	0	1	0	0	1	0	1	0	BAS
BLS	0	0	1	1	0	1	2	3	0	0	2	7	0	0	1	0	3	3	2	2	1	1	0	0	4	0	0	0	0	0	1	BLS
MED	1	0	2	0	1	1	1	2	1	0	3	10	0	0	9	0	10	5	0	6	1	1	0	0	27	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	1	0	0	1	12	1	0	1	0	6	27	0	0	0	0	1	0	1	0	0	0	0	0	0	NOS
AST	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	1	1	0	0	0	0	0	0	1	0	1	0	0	0	0	AST
NOA	0	0	1	0	0	0	0	0	0	0	1	4	0	0	5	0	4	2	0	1	0	0	0	0	6	0	0	0	0	0	0	NOA
EXC	0	0	1	0	0	0	0	1	0	0	1	5	0	0	1	0	2	3	0	0	0	0	0	0	3	0	1	0	0	0	0	EXC
EU	0	0	2	0	0	1	0	1	1	0	2	12	1	0	5	0	7	8	0	1	1	1	0	0	10	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.: 2016 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	BIC	DMS	VOL	EXC	EU	
AL	1	2	0	1	0	5	0	2	5	5	0	0	1	0	0	2	2	0	0	0	0	0	0	1	4	14	0	0	93	58	AL
AM	0	0	0	0	0	2	0	1	0	9	0	0	0	0	0	6	3	0	0	0	0	0	0	54	2	12	0	0	67	14	AM
AT	0	0	0	3	0	7	0	1	1	4	0	2	1	0	0	0	1	0	0	0	0	0	0	0	1	11	0	0	125	111	AT
AZ	0	0	0	0	0	2	0	1	0	16	0	0	0	0	0	4	4	0	0	0	0	0	0	41	1	15	0	0	64	16	AZ
BA	0	0	0	1	0	7	0	2	5	5	0	1	1	0	0	1	2	0	0	0	0	0	0	1	3	12	0	0	86	66	BA
BE	0	0	0	10	1	4	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10	0	0	101	94	BE
BG	0	1	0	1	0	7	0	4	3	9	0	0	1	0	0	8	5	0	0	0	0	0	0	1	2	13	0	0	84	54	BG
BY	0	0	0	1	0	7	0	1	0	12	1	0	0	0	0	1	3	0	0	0	0	0	0	0	0	8	0	0	55	32	BY
CH	0	0	0	2	0	4	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	10	0	0	142	104	CH
CY	0	0	0	1	0	4	0	2	1	9	0	0	0	0	0	31	4	0	0	0	0	0	0	19	5	23	0	0	94	43	CY
CZ	0	0	0	3	1	15	0	1	1	4	1	1	1	0	0	0	2	0	0	0	0	0	0	0	1	11	0	0	111	99	CZ
DE	0	0	0	6	1	7	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10	0	0	108	99	DE
DK	0	0	0	6	2	5	0	0	0	5	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	0	0	68	60	DK
EE	0	0	0	2	1	6	0	0	0	8	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	6	0	0	45	33	EE
ES	0	0	0	1	0	1	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	8	0	0	52	49	ES
FI	0	0	0	1	0	3	0	0	0	5	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	0	0	26	18	FI
FR	0	0	0	3	1	4	0	0	0	3	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	8	0	0	77	69	FR
GB	0	0	0	3	1	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	55	50	GB
GE	0	0	0	0	0	2	0	1	1	13	0	0	0	0	0	5	4	0	0	0	0	0	0	15	1	11	0	0	59	18	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	1	1	GL
GR	0	1	0	1	0	6	0	3	3	9	0	0	1	0	0	9	4	0	0	0	0	0	0	1	4	16	0	0	100	69	GR
HR	0	0	0	2	0	9	0	2	3	5	0	2	1	0	0	1	2	0	0	0	0	0	0	0	2	13	0	0	105	89	HR
HU	0	0	0	2	0	13	0	4	3	5	0	1	3	0	0	1	3	0	0	0	0	0	0	0	1	11	0	0	94	79	HU
IE	0	0	0	2	1	2	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	4	0	0	35	30	IE
IS	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	0	11	8	IS
IT	0	0	0	2	0	5	1	1	1	4	0	2	1	0	0	1	1	0	0	0	0	0	0	0	5	15	0	0	167	154	IT
KG	0	0	0	0	0	1	0	0	0	4	0	0	0	1	1	1	1	16	0	0	0	0	0	34	1	10	0	0	46	6	KG
KZ	0	0	0	0	0	1	0	0	0	12	0	0	0	0	0	1	2	1	0	0	0	0	0	12	0	10	0	0	33	10	KZ
LT	0	0	0	2	1	9	0	0	0	8	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	7	0	0	55	41	LT
LU	0	0	0	4	1	5	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10	0	0	96	89	LU
LV	0	0	0	2	1	6	0	0	0	7	1	0	0	0	0	1	1	0	0	0	0	0	0	0	0	7	0	0	47	35	LV
MD	0	0	0	1	0	7	0	4	1	10	0	0	1	0	0	3	7	0	0	0	0	0	0	1	1	11	0	0	65	38	MD
ME	6	0	0	1	0	6	0	2	4	5	0	0	1	0	0	2	2	0	0	0	0	0	0	1	4	12	0	0	82	56	ME
MK	0	10	0	1	0	6	0	2	6	6	0	0	1	0	0	4	2	0	0	0	0	0	0	1	3	12	0	0	89	55	MK
MT	0	0	12	2	0	5	1	2	1	4	0	0	1	0	0	2	2	0	0	0	0	1	0	1	15	21	0	0	108	95	MT
NL	0	0	0	21	1	4	0	0	0	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	10	0	0	108	102	NL
NO	0	0	0	1	2	2	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	23	17	NO
PL	0	0	0	3	1	23	0	1	1	6	1	0	1	0	0	0	2	0	0	0	0	0	0	0	0	10	0	0	85	72	PL
PT	0	0	0	0	0	1	20	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	7	0	0	50	47	PT
RO	0	0	0	1	0	8	0	10	3	8	0	0	1	0	0	3	5	0	0	0	0	0	0	1	1	11	0	0	76	52	RO
RS	0	2	0	1	0	8	0	4	13	6	0	0	1	0	0	2	2	0	0	0	0	0	0	0	2	12	0	0	88	58	RS
RU	0	0	0	0	0	1	0	0	0	12	0	0	0	0	0	1	1	0	0	0	0	0	0	2	0	4	0	0	25	9	RU
SE	0	0	0	2	1	3	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	29	24	SE
SI	0	0	0	2	0	9	0	1	2	5	0	11	1	0	0	1	2	0	0	0	0	0	0	0	2	14	0	0	141	127	SI
SK	0	0	0	2	1	19	0	3	2	5	0	1	4	0	0	1	3	0	0	0	0	0	0	0	1	11	0	0	97	82	SK
TJ	0	0	0	0	0	1	0	0	0	4	0	0	0	2	1	1	1	7	0	0	0	0	0	33	1	7	0	0	23	5	TJ
TM	0	0	0	0	0	2	0	1	0	13	0	0	0	0	2	2	2	1	0	0	0	0	0	62	1	19	0	0	41	14	TM
TR	0	0	0	1	0	3	0	2	1	9	0	0	0	0	0	26	3	0	0	0	0	0	0	20	3	13	0	0	68	25	TR
UA	0	0	0	1	0	7	0	2	1	15	0	0	0	0	0	3	10	0	0	0	0	0	0	1	1	11	0	0	65	32	UA
UZ	0	0	0	0	0	2	0	1	0	12	0	0	0	1	1	2	2	11	0	0	0	0	0	29	1	16	0	0	48	12	UZ
ATL	0	0	0	1	0	1	1	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	18	14	ATL
BAS	0	0	0	4	1	9	0	0	0	9	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	9	0	0	66	53	BAS
BLS	0	0	0	1	1	7	0	4	2	26	1	0	1	0	0	21	11	0	0	0	0	0	0	4	2	18	0	0	111	43	BLS
MED	0	0	0	2	0	6	1	2	2	7	0	1	1	0	0	11	3	0	0	0	0	1	0	6	14	22	0	0	118	91	MED
NOS	0	0	0	5	3	4	0	0	0	4	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	8	0	0	76	65	NOS
AST	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	3	1	1	0	0	0	0	0	118	1	14	0	0	22	8	AST
NOA	0	0	0	1	0	2	1	1	1	2	0	0	0	0	0	2	1	0	0	0	0	0	0	2	21	12	0	0	36	30	NOA
EXC	0	0	0	1	0	3	0	1	0	10	0	0	0	0	0	2	2	1	0	0	0	0	0	7	1	8	0	0	44	25	EXC
EU	0	0	0	2	1	6	1	1	1	4	1	0	0	0	0	1	1	0	0	0	0	0	0	0	1	9	0	0	75	65	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.8: 2016 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	263	0	0	0	2	0	2	0	0	0	1	1	0	0	1	0	1	0	0	6	1	2	0	0	7	0	0	0	0	0	0	AL
AM	0	58	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	AM
AT	0	0	104	0	0	0	0	0	2	0	11	17	0	0	0	0	3	1	0	0	5	13	0	0	8	0	0	0	0	0	0	AT
AZ	0	4	0	29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	28	0	0	0	0	0	0	0	1	0	0	0	0	AZ
BA	1	0	2	0	130	0	1	0	0	0	3	2	0	0	1	0	1	0	0	0	19	11	0	0	7	0	0	0	0	0	0	BA
BE	0	-0	1	-0	0	260	0	0	1	-0	2	34	1	0	1	0	66	14	-0	0	0	0	1	0	1	-0	-0	0	4	0	0	BE
BG	1	0	1	0	1	0	191	1	0	0	1	1	0	0	0	0	0	0	0	6	1	5	0	0	2	0	0	0	0	0	1	BG
BY	0	0	0	0	0	0	0	76	0	0	1	2	1	1	0	1	1	1	0	0	0	2	0	0	0	0	0	3	0	3	1	BY
CH	0	0	4	0	0	1	0	0	97	0	1	20	0	0	0	0	24	1	0	0	0	0	0	0	16	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	1	0	0	24	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	9	0	1	1	0	0	1	0	233	25	1	0	0	0	6	1	0	0	2	16	0	0	2	0	0	0	0	0	0	CZ
DE	0	-0	6	-0	0	7	0	0	3	-0	11	140	2	0	0	0	18	4	0	0	0	2	0	0	1	0	0	0	1	0	0	DE
DK	0	-0	0	-0	0	2	0	0	0	-0	1	12	127	0	0	0	3	6	-0	-0	0	0	1	0	0	-0	0	0	0	1	0	DK
EE	0	0	0	0	0	0	0	2	0	0	0	1	1	36	0	5	0	1	0	0	0	0	0	0	0	0	0	1	0	9	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	110	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	0	1	1	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	0	0	0	5	0	0	2	0	1	10	0	0	3	0	172	6	0	0	0	0	0	0	5	0	0	0	1	0	0	FR
GB	0	-0	0	-0	0	2	0	0	0	-0	0	2	1	0	1	0	7	153	-0	-0	0	0	4	0	0	-0	0	0	0	0	0	GB
GE	0	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	136	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	5	0	0	0	1	0	7	0	0	0	1	0	0	0	1	0	1	0	0	86	1	2	0	0	4	0	0	0	0	0	0	GR
HR	1	0	6	0	25	0	1	0	0	0	6	3	0	0	1	0	2	0	0	0	170	29	0	0	19	0	0	0	0	0	0	HR
HU	0	0	11	0	3	0	2	1	0	0	11	6	0	0	0	0	2	1	0	0	23	364	0	0	6	0	0	0	0	0	0	HU
IE	-0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	2	19	-0	-0	0	0	63	0	0	-0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	IS
IT	1	-0	2	0	1	0	0	0	1	0	1	1	0	0	2	0	6	0	0	0	3	1	0	0	387	-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	46	0	0	0	0	KZ
LT	0	0	0	0	0	0	0	12	0	-0	2	3	2	1	0	1	1	1	0	0	0	1	0	0	0	0	0	33	0	11	0	LT
LU	0	0	1	0	0	34	0	0	1	0	3	58	0	0	1	0	70	7	0	0	0	0	0	0	1	0	-0	0	93	0	0	LU
LV	0	0	0	0	0	0	0	6	0	0	1	2	2	3	0	2	0	1	0	0	0	1	0	0	0	0	0	5	0	74	0	LV
MD	0	0	1	0	0	0	2	2	0	0	1	1	0	0	0	0	1	0	0	0	1	4	0	0	1	0	0	0	0	0	125	MD
ME	17	0	1	0	8	0	1	0	0	0	1	1	0	0	1	0	1	0	0	1	2	3	0	0	5	0	0	0	0	0	0	ME
MK	18	0	1	0	1	0	11	0	0	0	1	1	0	0	0	0	0	0	0	18	1	4	0	0	3	0	0	0	0	0	0	MK
MT	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3	0	5	0	0	1	1	1	0	0	19	0	0	0	0	0	0	MT
NL	0	-0	1	-0	0	60	0	0	0	-0	2	51	2	0	0	0	23	17	-0	-0	0	0	1	0	0	-0	-0	0	1	0	0	NL
NO	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	0	0	0	0	0	NO
PL	0	0	1	0	0	1	0	4	0	0	14	11	2	0	0	0	2	1	0	0	1	7	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	36	0	2	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	PT
RO	0	0	1	0	1	0	6	1	0	0	2	1	0	0	0	0	1	0	0	1	2	16	0	0	2	0	0	0	0	0	4	RO
RS	5	0	2	0	9	0	18	1	0	0	4	2	0	0	0	0	1	0	0	2	10	26	0	0	3	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	-0	0	1	3	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	22	0	2	0	0	0	0	0	5	4	0	0	1	0	2	0	0	0	47	13	0	0	40	0	0	0	0	0	0	SI
SK	0	0	6	0	1	0	1	1	0	0	20	6	0	0	0	0	2	1	0	0	4	78	0	0	3	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	0	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	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	0	0	0	0	1	4	0	0	1	1	0	0	0	0	0	0	0	0	0	3	0	0	1	0	1	0	0	1	4	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	8	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	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	1	0	-0	1	5	9	2	0	5	1	2	0	0	0	1	0	0	0	0	0	1	0	3	0	BAS
BLS	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	7	1	0	1	0	0	0	0	0	0	0	0	2	BLS
MED	2	0	0	0	1	0	1	0	0	0	0	1	0	0	7	0	7	0	0	5	1	1	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	3	0	0	0	-0	0	5	3	0	1	0	8	20	0	0	0	0	1	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	3	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	1	0	1	0	1	1	1	2	0	0	2	4	1	0	3	1	6	3	1	1	1	3	0	0	7	1	9	0	0	1	0	EXC
EU	0	0	4	0	1	4	6	1	1	0	7	16	2	1	14	2	26	11	0	3	4	11	1	0	29	0	0	1	0	2	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.8 Cont.: 2016 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	7	19	0	0	0	1	0	2	26	0	0	0	1	0	0	1	1	0	0	0	0	3	0	0	1	0	0	0	347	27	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	0	0	0	0	6	0	0	0	0	91	0	AM
AT	0	0	0	0	0	4	0	2	1	0	0	14	3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	192	187	AT
AZ	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	6	1	0	0	0	0	0	0	8	0	0	0	0	73	0	AZ
BA	4	0	0	0	0	5	0	3	16	0	0	1	3	0	0	1	1	0	0	0	0	1	0	0	1	0	0	0	213	58	BA
BE	0	0	0	14	0	2	0	0	0	0	0	0	0	-0	-0	-0	0	-0	1	0	0	0	12	-0	0	0	0	0	401	400	BE
BG	0	4	0	0	0	3	0	30	15	2	0	0	1	0	0	21	6	0	0	0	1	1	0	0	0	0	0	0	297	244	BG
BY	0	0	0	0	0	19	0	4	0	9	1	0	1	0	0	1	10	0	0	0	0	0	0	0	0	0	0	0	138	39	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	165	68	CH
CY	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	72	1	0	0	0	0	11	0	7	2	0	0	0	105	29	CY
CZ	0	0	0	0	0	31	0	3	2	0	0	2	13	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	352	347	CZ
DE	0	0	0	4	0	12	0	1	0	0	0	1	1	0	0	0	0	0	0	1	0	0	3	-0	0	0	0	0	215	211	DE
DK	0	0	0	2	3	7	0	0	0	1	4	0	0	-0	-0	-0	0	-0	0	5	0	0	4	-0	0	0	0	0	173	168	DK
EE	0	0	0	0	1	5	0	1	0	7	2	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0	76	64	EE
ES	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	2	0	0	4	0	0	1	0	0	0	125	125	ES
FI	0	0	0	0	1	1	0	0	0	4	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	41	35	FI
FR	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2	0	0	0	0	0	209	206	FR
GB	-0	-0	0	1	0	1	0	0	0	0	0	0	0	-0	0	0	0	0	2	0	0	0	4	-0	0	0	0	0	172	172	GB
GE	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	11	1	0	0	0	0	0	0	1	0	0	0	0	157	1	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	0	10	0	0	0	1	0	4	5	1	0	0	1	0	0	25	3	0	0	0	0	9	0	0	1	0	0	0	159	108	GR
HR	1	0	0	0	0	6	0	5	16	0	0	18	3	0	0	1	1	0	0	0	0	3	0	0	1	0	0	0	317	271	HR
HU	0	1	0	0	0	16	0	39	18	1	0	10	33	0	0	1	5	0	0	0	0	1	0	0	0	0	0	0	556	525	HU
IE	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	2	0	0	0	1	-0	0	0	0	0	88	88	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	0	0	0	3	1	IS
IT	0	0	0	0	0	1	0	0	1	0	0	5	0	-0	0	0	0	0	0	0	0	8	0	0	2	0	0	0	417	412	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	6	0	0	0	0	45	0	KG
KZ	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	1	1	0	0	0	0	0	6	0	0	0	0	60	1	KZ
LT	0	0	0	0	1	23	0	2	0	7	1	0	1	0	0	0	4	0	0	1	0	0	0	0	0	0	0	0	109	85	LT
LU	0	0	0	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-0	0	0	0	0	278	276	LU
LV	0	0	0	0	1	10	0	1	0	5	2	0	1	0	0	0	2	0	0	2	0	0	0	0	0	0	0	0	120	105	LV
MD	0	0	0	0	0	11	0	82	2	5	0	0	2	0	0	7	37	0	0	0	1	0	0	0	0	0	0	0	287	109	MD
ME	119	1	0	0	0	2	0	2	21	0	0	0	1	0	0	1	1	0	0	0	0	2	0	0	1	0	0	0	191	22	ME
MK	1	271	0	0	0	2	0	4	34	0	0	0	1	0	0	5	2	0	0	0	0	1	0	0	1	0	0	0	379	48	MK
MT	0	0	99	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	70	0	0	10	0	0	0	136	132	MT
NL	-0	-0	0	97	1	3	0	0	0	0	0	0	0	-0	-0	-0	0	-0	1	0	0	0	20	-0	-0	0	0	0	261	260	NL
NO	0	0	0	0	30	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	35	4	NO
PL	0	0	0	0	1	207	0	5	1	3	1	1	13	0	0	0	6	0	0	1	0	0	1	0	0	0	0	0	287	271	PL
PT	0	0	0	0	0	0	152	0	0	0	0	0	0	0	0	0	0	0	5	0	0	1	0	-0	1	0	0	0	191	191	PT
RO	0	1	0	0	0	6	0	327	11	2	0	1	3	0	0	4	10	0	0	0	1	0	0	0	0	0	0	0	404	369	RO
RS	5	14	0	0	0	6	0	24	268	1	0	1	4	0	0	2	3	0	0	0	0	1	0	0	0	0	0	0	412	104	RS
RU	0	0	0	0	0	1	0	0	0	30	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	41	3	RU
SE	0	0	0	0	6	2	0	0	0	1	15	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	33	26	SE
SI	0	0	0	0	0	4	0	3	2	0	0	311	2	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	462	456	SI
SK	0	0	0	0	0	35	0	15	4	1	0	3	250	0	0	1	5	0	0	0	0	0	0	0	0	0	0	0	439	425	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	21	1	0	0	6	0	0	0	0	0	15	0	0	0	0	31	0	TJ
TM	0	0	0	0	0	0	0	0	0	3	0	0	0	0	21	1	1	5	0	0	0	0	0	8	0	0	0	0	36	0	TM
TR	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0	228	1	0	0	0	1	3	0	5	0	0	0	0	239	5	TR
UA	0	0	0	0	0	12	0	15	1	12	0	0	2	0	0	5	99	0	0	0	1	0	0	0	0	0	0	0	167	41	UA
UZ	0	0	0	0	0	0	0	0	0	3	0	0	0	2	3	1	1	33	0	0	0	0	0	3	0	0	0	0	54	0	UZ
ATL	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	8	7	ATL
BAS	0	0	0	1	2	12	0	0	0	4	7	0	0	0	0	0	1	0	0	9	0	0	1	0	0	0	0	0	61	52	BAS
BLS	0	0	0	0	0	2	0	13	1	10	0	0	1	0	0	62	19	0	0	0	9	2	0	0	0	0	0	0	126	23	BLS
MED	0	1	0	0	0	1	1	1	1	0	0	1	0	0	0	23	1	0	0	0	0	28	0	3	9	0	0	0	78	49	MED
NOS	0	0	0	3	4	2	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	11	0	0	0	0	0	52	47	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	6	0	0	0	0	0	0	0	219	0	0	0	0	10	0	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	1	0	0	4	0	1	40	0	0	0	12	9	NOA
EXC	0	1	0	0	1	5	1	6	2	14	1	1	1	0	1	11	5	1	0	0	0	1	0	2	0	0	0	0	100	51	EXC
EU	0	0	0	2	1	19	4	20	2	1	2	3	5	0	0	2	2	0	1	0	0	2	1	0	0	0	0	0	208	197	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: 2016 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	84	0	1	0	39	0	5	0	0	0	3	4	0	0	3	0	1	0	0	14	1	1	0	0	10	0	0	0	0	0	0	AL
AM	0	219	0	8	0	0	0	0	0	1	0	0	0	0	0	0	0	0	5	0	0	0	-0	-0	0	0	6	0	0	0	0	AM
AT	0	0	24	0	6	1	1	0	2	0	20	43	0	0	1	0	4	2	0	0	2	3	0	0	5	0	0	0	0	0	0	AT
AZ	0	28	0	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	17	0	0	0	0	AZ
BA	1	0	2	0	310	0	3	1	0	0	10	12	0	0	2	0	2	1	0	1	3	3	0	0	6	0	0	0	0	0	0	BA
BE	0	-0	1	-0	0	78	0	0	1	-0	5	66	0	0	3	0	47	20	-0	0	0	0	1	0	1	-0	-0	0	1	0	0	BE
BG	2	0	1	0	13	0	92	2	0	0	4	5	0	0	1	0	1	0	0	11	1	2	0	0	2	0	1	0	0	0	1	BG
BY	0	0	0	0	1	1	1	37	0	0	3	10	1	3	0	3	1	2	0	0	0	1	0	0	0	0	1	6	0	1	1	BY
CH	0	0	2	0	1	1	0	0	36	0	4	28	0	0	2	0	15	1	0	0	0	0	0	0	6	0	0	0	0	0	0	CH
CY	0	1	0	0	3	0	4	0	0	33	1	1	0	0	1	0	0	0	0	8	0	0	0	0	3	0	1	0	0	0	0	CY
CZ	0	0	5	0	6	2	1	1	1	0	111	74	0	0	1	0	6	3	0	0	1	4	0	0	1	0	0	0	0	0	0	CZ
DE	0	-0	3	-0	1	8	0	1	2	0	18	144	1	1	1	0	14	9	0	0	0	1	0	0	1	0	0	1	0	0	0	DE
DK	-0	-0	0	-0	0	3	0	1	0	-0	4	34	20	1	1	1	3	15	-0	-0	0	0	1	0	0	0	0	1	0	0	0	DK
EE	0	0	0	0	0	0	0	2	0	0	1	7	1	15	0	12	0	3	0	0	0	0	0	0	0	0	0	3	0	2	0	EE
ES	0	0	0	0	0	0	0	0	0	0	1	3	0	0	103	0	6	2	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	1	0	0	1	3	0	2	0	21	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	FI
FR	0	0	0	0	1	5	0	0	2	0	3	22	0	0	11	0	57	10	0	0	0	0	1	0	3	0	0	0	0	0	0	FR
GB	0	-0	0	-0	0	1	0	0	0	-0	1	7	0	0	2	0	5	98	-0	0	0	0	4	1	0	-0	0	0	0	0	0	GB
GE	0	18	0	10	0	0	1	0	0	0	0	0	0	0	0	0	0	0	48	0	0	0	0	0	0	0	5	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	14	0	28	1	0	0	3	3	0	0	2	0	1	0	0	49	1	1	0	0	7	0	1	0	0	0	1	GR
HR	1	0	4	0	93	1	3	1	0	0	18	20	0	0	3	0	3	1	0	1	19	6	0	0	10	0	0	0	0	0	0	HR
HU	0	0	5	0	26	1	5	2	0	0	25	27	0	0	1	0	2	2	0	1	5	41	0	0	4	0	0	0	0	0	0	HU
IE	0	0	0	0	0	1	0	0	0	-0	0	4	0	0	1	0	2	29	-0	0	0	0	28	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	28	0	0	0	0	0	0	0	IS
IT	1	0	2	0	14	0	1	0	1	0	4	8	0	0	7	0	10	1	0	1	4	1	0	0	71	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	56	18	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	4	86	0	0	0	0	KZ
LT	0	0	0	0	1	1	0	11	0	0	3	13	1	4	0	4	1	4	0	0	0	0	0	0	0	0	0	24	0	2	0	LT
LU	0	-0	1	-0	1	25	0	0	1	0	8	85	0	0	2	0	46	13	0	0	0	0	1	0	1	0	-0	0	12	0	0	LU
LV	0	0	0	0	0	1	0	6	0	0	2	9	1	6	0	7	1	3	0	0	0	0	0	0	0	0	0	12	0	8	0	LV
MD	0	0	0	0	6	0	8	7	0	0	5	8	0	1	1	1	1	1	0	1	0	2	0	0	1	0	2	1	0	0	18	MD
ME	9	0	1	0	72	0	4	0	0	0	4	6	0	0	2	0	1	1	0	3	1	1	0	0	6	0	0	0	0	0	0	ME
MK	15	0	0	0	17	0	15	1	0	0	4	5	0	0	1	0	1	0	0	35	1	2	0	0	3	0	0	0	0	0	0	MK
MT	0	0	0	0	15	1	2	0	0	0	2	4	0	0	13	0	9	1	0	3	1	1	0	0	34	0	0	0	0	0	0	MT
NL	0	-0	0	-0	0	39	0	0	0	-0	6	82	1	1	2	0	24	24	-0	0	0	0	1	0	0	-0	0	1	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	1	0	3	2	1	5	0	0	16	42	1	2	0	1	3	3	0	0	0	2	0	0	1	0	0	2	0	0	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	2	0	0	64	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	1	0	1	0	14	0	16	3	0	0	6	9	0	1	1	0	1	1	0	2	1	5	0	0	2	0	1	0	0	0	2	RO
RS	5	0	1	0	56	0	17	1	0	0	10	12	0	0	1	0	1	1	0	6	2	6	0	0	3	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	0	1	6	2	1	0	3	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	SE
SI	0	0	10	0	16	1	1	1	0	0	17	23	0	0	2	0	3	1	0	1	18	4	0	0	14	0	0	0	0	0	0	SI
SK	0	0	3	0	9	1	2	2	0	0	30	29	0	1	1	0	2	2	0	1	2	16	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	5	9	0	0	0	0	TJ
TM	0	3	0	2	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	TM
TR	0	5	0	0	2	0	4	0	0	2	1	1	0	0	0	0	0	0	1	3	0	0	0	0	1	0	1	0	0	0	0	TR
UA	0	0	0	0	3	0	3	10	0	0	3	7	0	2	0	1	1	1	0	1	0	1	0	0	1	0	5	1	0	0	2	UA
UZ	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	9	45	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	2	0	0	2	15	3	3	0	8	1	6	0	0	0	0	0	0	0	0	0	2	0	1	0	BAS
BLS	0	2	0	1	3	0	8	3	0	0	2	3	0	1	0	0	0	0	4	3	0	1	0	0	1	0	4	0	0	0	1	BLS
MED	1	0	1	0	15	0	6	0	0	1	3	5	0	0	14	0	9	1	0	7	2	1	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	2	0	0	0	0	1	11	1	0	1	0	5	21	0	0	0	0	1	1	0	0	0	0	0	0	0	NOS
AST	0	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	10	0	0	0	0	AST
NOA	0	0	0	0	3	0	1	0	0	0	1	1	0	0	10	0	2	0	0	2	0	0	0	0	5	0	0	0	0	0	0	NOA
EXC	0	1	0	0	3	1	2	2	0	0	2	7	0	1	4	1	3	3	0	1	0	1	0	0	2	2	21	0	0	0	0	EXC
EU	0	0	1	0	5	3	4	1	0	0	8	26	1	1	16	2	11	10	0	2	1	2	1	0	6	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.9 Cont.: 2016 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	23	43	0	0	0	14	0	5	105	3	0	0	1	0	0	16	10	0	0	0	0	23	0	1	17	11	5	36	388	66	AL
AM	0	0	0	0	0	0	0	0	1	5	0	0	0	0	0	78	3	0	0	0	0	1	0	143	4	18	0	7	331	2	AM
AT	1	0	0	1	0	26	0	3	15	1	0	3	3	0	0	2	4	0	1	0	0	3	0	0	3	5	2	4	174	142	AT
AZ	0	0	0	0	0	1	0	0	1	23	0	0	0	0	0	37	10	0	0	0	0	0	0	133	2	10	0	4	169	2	AZ
BA	16	2	0	0	0	27	0	6	164	3	0	0	3	0	0	7	11	0	0	0	0	8	0	0	11	7	2	13	598	83	BA
BE	0	0	0	12	0	10	0	0	1	1	0	0	0	-0	-0	0	1	-0	7	0	0	1	6	-0	1	5	14	1	251	246	BE
BG	5	11	0	0	0	21	0	26	68	15	0	0	2	0	0	43	57	0	0	0	4	8	0	1	8	9	2	9	386	169	BG
BY	0	0	0	1	0	56	0	2	4	47	1	0	1	0	0	4	24	0	0	1	0	0	0	1	1	5	3	1	215	93	BY
CH	0	0	0	1	0	5	0	0	2	0	0	0	0	0	0	1	0	0	1	0	0	2	0	0	3	4	2	2	106	66	CH
CY	1	3	0	0	0	2	0	2	9	7	0	0	0	0	0	755	17	0	0	0	3	55	0	86	34	24	18	27	856	56	CY
CZ	0	0	0	1	0	81	0	4	18	3	0	1	6	0	0	2	7	0	1	0	0	1	1	0	2	5	4	2	344	305	CZ
DE	0	0	0	6	0	34	0	1	3	3	0	0	1	0	0	1	2	0	2	0	0	1	2	0	1	6	8	1	258	245	DE
DK	0	0	-0	3	2	21	0	0	0	9	2	0	0	-0	0	0	2	0	3	2	0	0	3	0	0	5	15	0	124	110	DK
EE	0	0	0	0	1	18	0	0	1	32	3	0	0	0	0	1	4	0	1	2	0	0	0	0	0	3	6	0	108	67	EE
ES	0	0	0	0	0	1	8	0	1	0	0	0	0	0	0	0	0	0	14	0	0	30	0	0	20	10	11	1	127	125	ES
FI	0	0	0	0	1	6	0	0	0	29	5	0	0	0	0	0	1	0	1	1	0	0	0	0	0	3	7	0	74	41	FI
FR	0	0	0	2	0	6	0	0	2	1	0	0	0	0	0	0	1	0	10	0	0	7	2	0	3	6	13	2	129	123	FR
GB	0	0	0	1	0	4	0	0	0	1	0	0	0	-0	0	0	1	0	14	0	0	0	3	0	0	6	22	0	128	125	GB
GE	0	0	0	0	0	1	0	1	1	13	0	0	0	0	0	51	9	0	0	0	3	1	0	40	2	7	0	5	160	4	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	6	2	0	0	0	GL
GR	5	22	0	0	0	12	0	9	48	9	0	0	1	0	0	86	32	0	0	0	2	42	0	3	19	12	7	40	343	118	GR
HR	5	2	0	1	0	37	0	8	117	3	0	3	5	0	0	7	12	0	1	0	0	16	0	0	10	7	3	12	384	142	HR
HU	3	2	0	1	0	76	0	25	79	5	0	2	15	0	0	8	22	0	1	0	0	5	0	0	6	8	2	6	388	240	HU
IE	0	0	0	1	0	3	0	0	0	1	0	0	0	-0	0	0	1	0	14	0	0	0	1	0	0	8	28	0	73	70	IE
IS	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	5	15	0	31	3	IS
IT	2	1	0	0	0	10	0	2	18	1	0	2	1	0	0	5	3	0	1	0	0	45	0	0	22	7	8	43	172	127	IT
KG	0	0	0	0	0	0	-0	0	0	2	0	-0	0	5	0	4	0	13	0	0	0	0	0	37	0	16	0	2	98	0	KG
KZ	0	0	0	0	0	1	0	0	0	65	0	0	0	0	0	3	11	1	0	0	0	0	0	23	0	19	0	1	176	3	KZ
LT	0	0	0	1	1	54	0	1	2	31	2	0	1	0	0	1	12	0	1	1	0	0	1	0	0	6	6	0	179	119	LT
LU	0	0	0	7	0	13	0	0	2	1	0	0	1	0	0	0	1	0	5	0	0	1	2	0	1	5	9	1	224	217	LU
LV	0	0	0	1	1	28	0	1	1	29	2	0	0	0	0	1	7	0	1	1	0	0	1	0	0	4	6	0	129	82	LV
MD	1	1	0	0	0	52	0	25	16	31	0	0	2	0	0	26	102	0	0	0	4	2	0	1	3	7	2	4	324	112	MD
ME	136	7	0	0	0	16	0	4	123	2	0	0	2	0	0	11	9	0	0	0	0	11	0	0	13	9	3	19	422	52	ME
MK	8	130	0	0	0	17	0	9	112	4	0	0	2	0	0	31	16	0	0	0	1	9	0	1	12	10	2	18	431	96	MK
MT	3	1	8	0	0	6	1	2	18	1	0	0	1	0	0	11	3	0	2	0	0	177	0	0	84	19	28	81	143	90	MT
NL	0	0	0	35	0	16	0	0	1	3	0	0	0	-0	0	0	1	-0	6	0	0	0	8	-0	0	5	16	1	240	233	NL
NO	0	0	0	0	6	3	0	0	0	8	2	0	0	0	0	0	1	0	3	0	0	0	1	0	0	5	14	0	29	13	NO
PL	0	0	0	1	0	186	0	3	9	12	1	0	4	0	0	2	14	0	1	1	0	1	1	0	1	6	5	2	320	272	PL
PT	0	0	0	0	0	1	44	0	0	0	0	0	0	0	0	0	0	0	37	0	0	10	0	0	14	12	19	1	117	117	PT
RO	4	4	0	0	0	41	0	81	50	14	0	0	4	0	0	20	53	0	0	0	2	3	0	0	5	8	1	6	338	173	RO
RS	22	23	0	0	0	37	0	24	300	6	0	0	5	0	0	16	23	0	0	0	1	6	0	0	9	9	2	13	582	130	RS
RU	0	0	0	0	0	4	0	0	0	109	0	0	0	0	0	2	13	0	0	0	0	0	0	2	0	46	4	0	151	9	RU
SE	0	0	0	1	3	7	0	0	0	10	7	0	0	0	0	0	1	0	2	1	0	0	1	0	0	3	8	0	49	33	SE
SI	1	0	0	1	0	28	0	5	36	2	0	23	3	0	0	4	7	0	0	0	0	13	0	0	8	5	3	8	223	154	SI
SK	1	1	0	1	0	106	0	12	30	4	0	1	34	0	0	5	18	0	0	0	0	3	0	0	3	6	2	4	317	246	SK
TJ	0	0	0	0	0	0	0	0	0	4	0	0	0	39	1	6	1	8	0	0	0	0	0	60	0	25	0	2	73	0	TJ
TM	0	0	0	0	0	1	0	0	0	30	0	0	0	2	6	13	11	3	0	0	0	0	0	122	1	23	0	3	105	2	TM
TR	1	1	0	0	0	3	0	3	7	10	0	0	0	0	0	498	18	0	0	0	4	13	0	81	12	20	3	15	563	18	TR
UA	1	1	0	0	0	42	0	8	8	52	0	0	2	0	0	18	135	0	0	0	2	2	0	2	2	6	2	3	310	76	UA
UZ	0	0	0	0	0	1	0	0	1	36	0	0	0	6	2	8	10	17	0	0	0	0	0	58	1	19	0	2	140	3	UZ
ATL	0	0	0	0	0	1	1	0	0	6	0	0	0	0	0	0	0	0	15	0	0	1	0	0	3	32	34	0	21	12	ATL
BAS	0	0	0	1	1	21	0	0	0	16	6	0	0	0	0	0	3	0	1	3	0	0	1	0	0	4	10	0	95	71	BAS
BLS	1	1	0	0	0	15	0	10	11	49	0	0	1	0	0	111	101	0	0	0	23	6	0	7	5	6	1	6	337	45	BLS
MED	4	3	1	0	0	8	1	3	22	4	0	0	1	0	0	162	12	0	3	0	1	123	0	24	61	19	23	78	308	83	MED
NOS	0	0	0	2	2	7	0	0	0	3	1	0	0	0	0	0	1	0	8	0	0	0	5	0	0	5	25	0	62	55	NOS
AST	0	0	0	0	0	0	0	0	1	7	0	0	0	0	1	45	3	0	0	0	0	2	0	323	4	120	1	5	73	2	AST
NOA	1	1	0	0	0	2	2	1	5	1	0	0	0	0	0	25	2	0	8	0	0	35	0	7	172	70	11	28	66	28	NOA
EXC	1	1	0	0	0	11	0	2	6	59	0	0	1	1	0	26	15	1	2	0	0	3	0	14	2	25	4	3	183	43	EXC
EU	1	1	0	2	1	29	2	7	13	8	1	0	2	0	0	7	9	0	6	0	0	10	1	0	6	6	9	6	187	140	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: 2016 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	60	0	1	0	3	0	2	0	0	0	1	2	0	0	1	0	1	0	0	12	2	2	0	0	11	0	0	0	0	0	0	AL
AM	0	62	0	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	1	0	0	0	0	AM
AT	0	0	120	0	1	3	0	0	10	0	21	95	0	0	1	0	11	4	0	0	7	11	0	0	29	0	0	0	0	0	0	AT
AZ	0	9	0	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24	0	0	0	0	0	0	0	3	0	0	0	0	AZ
BA	1	0	6	0	41	0	1	0	0	0	5	9	0	0	1	0	2	1	0	1	11	9	0	0	9	0	0	0	0	0	0	BA
BE	0	0	3	0	0	52	0	1	5	0	4	147	3	0	3	1	131	70	0	0	0	0	4	0	3	0	0	1	7	0	0	BE
BG	1	0	2	0	1	0	57	1	0	0	1	4	0	0	1	0	1	1	0	10	1	3	0	0	2	0	0	0	0	0	1	BG
BY	0	0	0	0	0	1	1	35	0	0	1	10	1	1	0	2	1	2	0	0	0	1	0	0	1	0	0	8	0	3	1	BY
CH	0	0	15	0	0	4	0	0	169	0	3	103	0	0	1	0	55	5	0	0	0	0	0	0	38	0	0	0	1	0	0	CH
CY	0	0	0	0	0	0	1	0	0	16	0	0	0	0	1	0	1	0	0	13	0	0	0	0	2	0	0	0	0	0	0	CY
CZ	0	0	34	0	1	4	0	1	4	0	97	112	1	0	1	0	16	5	0	0	3	14	0	0	5	0	0	0	1	0	0	CZ
DE	0	0	19	0	0	20	0	1	11	0	16	277	7	0	2	0	44	25	0	0	0	1	1	0	5	0	0	1	3	0	0	DE
DK	0	0	1	0	0	12	0	1	0	0	3	108	69	1	1	1	12	33	0	0	0	0	2	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	1	0	4	0	0	0	6	2	10	0	5	1	3	0	0	0	0	0	0	0	0	0	3	0	4	0	EE
ES	0	0	0	0	0	1	0	0	0	0	0	3	0	0	117	0	11	2	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	1	1	0	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	3	0	0	18	0	0	11	0	3	62	1	0	8	0	168	33	0	0	0	0	2	0	9	0	0	0	3	0	0	FR
GB	0	0	0	0	0	6	0	0	0	0	1	22	2	0	2	0	22	139	0	0	0	0	12	0	1	0	0	0	1	0	0	GB
GE	0	5	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	0	0	0	0	0	0	1	0	0	0	0	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	GL
GR	2	0	0	0	1	0	9	0	0	0	0	1	0	0	1	0	1	0	0	45	0	1	0	0	5	0	0	0	0	0	0	GR
HR	0	0	25	0	17	1	1	0	1	0	13	22	0	0	1	0	3	1	0	1	50	23	0	0	32	0	0	0	0	0	0	HR
HU	0	0	40	0	6	1	2	1	2	0	27	39	1	0	1	0	6	3	0	1	25	117	0	0	17	0	0	0	0	0	0	HU
IE	0	0	0	0	0	3	0	0	0	0	0	10	1	0	1	0	8	86	0	0	0	0	63	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	11	0	1	1	0	0	4	0	2	11	0	0	4	0	12	1	0	1	6	2	0	0	355	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	22	4	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	1	0	15	0	0	2	15	3	2	0	3	2	4	0	0	0	1	0	0	1	0	0	28	0	8	1	LT
LU	0	0	6	0	0	59	0	0	5	0	7	212	1	0	2	0	133	35	0	0	0	0	2	0	4	0	0	1	19	0	0	LU
LV	0	0	0	0	0	1	0	8	0	0	1	8	3	3	0	3	1	4	0	0	0	0	0	0	0	0	0	11	0	11	0	LV
MD	0	0	2	0	1	0	5	4	0	0	2	7	0	0	0	1	1	1	0	1	1	3	0	0	2	0	0	1	0	0	26	MD
ME	6	0	1	0	7	0	1	0	0	0	1	1	0	-0	1	-0	1	0	0	2	2	1	0	0	6	0	0	-0	0	-0	0	ME
MK	6	0	1	0	1	0	6	0	0	0	1	2	0	0	1	0	1	0	0	26	1	2	0	0	3	0	0	0	0	0	0	MK
MT	0	0	0	0	1	0	0	0	0	0	0	1	0	-0	6	0	6	1	0	2	1	1	0	0	22	0	0	0	0	-0	0	MT
NL	0	0	3	0	0	54	0	1	2	0	6	199	9	0	3	1	78	93	0	0	0	1	5	0	2	0	0	1	3	1	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	3	1	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	0	2	0	6	1	0	11	47	4	1	0	1	5	4	0	0	1	4	0	0	2	0	0	3	0	1	0	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	54	0	3	1	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	0	0	4	0	2	1	11	2	1	0	4	10	0	0	1	0	2	1	0	1	2	14	0	0	3	0	0	0	0	0	3	RO
RS	3	0	10	0	11	1	8	1	1	0	8	14	0	0	1	0	2	1	0	6	9	24	0	0	6	0	0	0	0	0	0	RS
RU	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	3	0	0	0	0	RU
SE	0	0	0	0	0	1	0	0	0	0	0	9	5	0	0	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	69	0	3	2	1	0	2	0	14	37	0	0	1	0	5	2	0	0	38	14	0	0	99	0	0	0	0	0	0	SI
SK	0	0	22	0	2	1	1	1	2	0	24	28	0	0	1	0	5	2	0	1	5	44	0	0	7	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	1	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	1	0	1	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	1	0	0	0	2	6	0	0	1	5	0	0	0	1	1	1	0	0	0	2	0	0	1	0	1	1	0	0	4	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	12	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	2	3	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	3	0	1	0	0	1	28	10	1	0	2	3	8	0	0	0	0	1	0	0	0	0	2	0	1	0	BAS
BLS	0	0	0	0	0	0	3	1	0	0	0	1	0	0	0	0	0	0	3	2	0	0	0	0	1	0	1	0	0	0	1	BLS
MED	1	0	1	0	1	0	1	0	0	0	0	1	0	0	7	0	6	1	0	6	1	0	0	0	21	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	6	0	0	0	0	1	35	6	0	1	0	19	36	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	3	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	0	2	0	0	2	0	0	0	0	4	0	0	0	0	0	0	NOA
EXC	0	0	2	1	0	1	1	1	1	0	2	12	1	0	4	0	8	5	0	1	1	2	1	0	7	1	5	0	0	0	0	EXC
EU	0	0	8	0	1	6	2	1	3	0	6	48	3	0	16	1	31	19	0	2	2	5	2	0	29	0	0	1	1	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.10 Cont.: 2016 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	9	0	0	0	2	0	2	18	1	0	0	1	0	0	1	1	0	0	0	0	14	0	0	3	16	0	0	141	41	AL
AM	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	19	1	0	0	0	0	1	0	61	1	14	0	0	123	2	AM
AT	0	0	0	3	0	13	0	2	3	1	0	14	4	0	0	0	1	0	1	1	0	3	3	0	1	14	0	0	356	340	AT
AZ	0	0	0	0	0	0	0	0	0	11	0	0	0	0	1	7	2	0	0	0	1	0	0	85	0	14	0	0	167	2	AZ
BA	3	0	0	1	0	6	0	3	13	1	0	1	3	0	0	0	2	0	0	0	0	4	1	0	2	14	0	0	130	69	BA
BE	0	0	0	59	2	7	0	0	0	2	1	0	0	0	0	0	1	0	8	4	0	2	66	0	0	40	0	0	510	500	BE
BG	0	2	0	0	0	5	0	22	16	6	0	0	1	0	0	9	11	0	0	1	4	4	1	0	1	15	0	0	160	111	BG
BY	0	0	0	2	1	30	0	3	1	33	2	0	1	0	0	1	15	0	0	6	0	0	3	0	0	10	0	0	158	71	BY
CH	0	0	0	3	0	4	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	2	4	0	1	16	0	0	406	235	CH
CY	0	0	0	0	0	1	0	1	1	3	0	0	0	0	0	67	2	0	0	0	2	41	0	12	6	31	0	0	111	37	CY
CZ	0	0	0	6	1	36	0	2	3	2	0	3	10	0	0	0	2	0	1	2	0	1	6	0	0	16	0	0	365	352	CZ
DE	0	0	0	35	2	23	0	0	0	2	2	1	1	0	0	0	1	0	3	11	0	1	35	0	0	26	0	0	500	483	DE
DK	0	0	0	28	8	17	0	0	0	4	11	0	0	0	0	0	1	0	3	52	0	0	61	0	0	19	0	0	319	304	DK
EE	0	0	0	2	1	7	0	0	0	14	4	0	0	0	0	0	3	0	0	15	0	0	3	0	0	6	0	0	71	49	EE
ES	0	0	0	1	0	0	8	0	0	0	0	0	0	0	0	0	0	0	6	0	0	13	1	0	4	16	0	0	146	146	ES
FI	0	0	0	1	1	2	0	0	0	4	3	0	0	0	0	0	0	0	0	5	0	0	2	0	0	4	0	0	27	21	FI
FR	0	0	0	13	0	3	0	0	0	1	0	0	0	0	0	0	0	0	6	1	0	4	28	0	1	19	0	0	340	328	FR
GB	0	0	0	14	2	2	0	0	0	1	1	0	0	0	0	0	0	0	11	2	0	0	40	0	0	20	0	0	229	226	GB
GE	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	8	1	0	0	0	2	0	0	10	0	9	0	0	81	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	4	0	0	0	1	0	3	4	3	0	0	0	0	0	10	4	0	0	0	1	18	0	1	3	16	0	0	98	69	GR
HR	1	0	0	2	0	13	0	6	23	1	0	12	6	0	0	0	2	0	0	1	0	9	2	0	2	16	0	0	261	215	HR
HU	1	1	0	2	0	33	0	36	35	2	0	12	30	0	0	1	6	0	1	1	0	3	3	0	1	22	0	0	451	395	HU
IE	0	0	0	7	1	2	0	0	0	1	1	0	0	0	0	0	0	0	15	1	0	0	17	0	0	14	0	0	185	183	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	2	0	0	3	2	IS
IT	0	0	0	1	0	3	0	1	2	1	0	9	1	0	0	0	1	0	1	0	0	35	1	0	4	24	0	0	432	422	IT
KG	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	22	0	0	0	0	0	13	0	6	0	0	50	0	KG
KZ	0	0	0	0	0	0	0	0	0	16	0	0	0	0	1	0	1	3	0	0	0	0	0	18	0	12	0	0	44	1	KZ
LT	0	0	0	3	1	37	0	1	1	21	4	0	1	0	0	0	8	0	1	15	0	0	5	0	0	10	0	0	165	118	LT
LU	0	0	0	32	1	9	0	0	0	1	1	0	0	0	0	0	0	0	4	2	0	2	30	0	0	28	0	0	534	525	LU
LV	0	0	0	2	1	13	0	1	0	18	4	0	0	0	0	0	5	0	0	13	0	0	4	0	0	7	0	0	99	66	LV
MD	0	0	0	1	0	23	0	50	3	16	1	0	2	0	0	5	48	0	0	2	5	1	1	0	1	13	0	0	210	105	MD
ME	24	1	0	0	0	1	0	1	11	1	-0	0	1	0	0	1	1	0	0	-0	0	6	0	0	2	13	0	0	70	20	ME
MK	1	31	0	0	0	2	0	3	18	1	0	0	1	0	0	3	2	0	0	0	0	5	0	0	2	14	0	0	113	48	MK
MT	0	0	5	0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0	0	76	0	0	17	21	0	0	50	46	MT
NL	0	0	0	119	3	13	1	0	0	3	3	0	1	0	0	0	1	0	10	11	0	1	115	0	1	48	0	0	605	595	NL
NO	0	0	0	1	5	1	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	0	4	0	0	3	0	0	17	11	NO
PL	0	0	0	5	1	118	0	3	1	9	2	1	4	0	0	0	6	0	1	9	0	1	7	0	0	14	0	0	247	222	PL
PT	0	0	0	0	0	0	58	0	0	0	0	0	0	0	0	0	0	0	14	0	0	4	0	0	3	15	0	0	118	118	PT
RO	1	1	0	1	0	14	0	107	16	6	0	1	4	0	0	3	16	0	0	1	3	2	1	0	1	15	0	0	232	182	RO
RS	4	7	0	1	0	13	0	22	82	3	0	2	6	0	0	1	4	0	0	1	1	3	1	0	2	19	0	0	256	138	RS
RU	0	0	0	0	0	1	0	0	0	31	0	0	0	0	0	0	2	0	0	1	0	0	0	1	0	8	0	0	42	4	RU
SE	0	0	0	2	3	3	0	0	0	1	7	0	0	0	0	0	0	0	1	8	0	0	6	0	0	4	0	0	39	35	SE
SI	0	0	0	2	0	12	0	3	7	1	0	105	3	0	0	0	1	0	0	1	0	12	2	0	1	17	0	0	424	409	SI
SK	0	0	0	1	0	26	0	13	8	1	0	4	47	0	0	0	5	0	0	1	0	2	2	0	0	13	0	0	255	235	SK
TJ	0	0	0	0	0	0	0	0	0	1	0	0	0	7	4	0	0	19	0	0	0	0	0	16	0	10	0	0	36	0	TJ
TM	0	0	0	0	0	0	0	0	0	8	0	0	0	0	13	1	1	6	0	0	0	0	0	43	0	17	0	0	40	1	TM
TR	0	0	0	0	0	1	0	1	1	5	0	0	0	0	0	82	3	0	0	0	3	9	0	18	2	22	0	0	106	12	TR
UA	0	0	0	0	0	16	0	11	1	29	1	0	1	0	0	3	51	0	0	2	3	1	1	0	0	11	0	0	145	49	UA
UZ	0	0	0	0	0	0	0	0	0	11	0	0	0	1	7	0	1	40	0	0	0	0	0	17	0	17	0	0	82	2	UZ
ATL	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	1	0	0	6	0	0	12	11	ATL
BAS	0	0	0	7	2	15	0	0	0	3	7	0	0	0	0	0	1	0	1	21	0	0	12	0	0	7	0	0	97	90	BAS
BLS	0	0	0	0	0	1	0	6	1	16	0	0	0	0	0	16	13	0	0	0	14	3	0	1	1	10	0	0	68	16	BLS
MED	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	13	2	0	1	0	1	46	0	1	11	20	0	0	70	50	MED
NOS	0	0	0	15	3	4	0	0	0	1	1	0	0	0	0	0	0	0	4	5	0	0	29	0	0	10	0	0	133	129	NOS
AST	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	4	0	1	0	0	0	2	0	168	1	39	0	0	15	2	AST
NOA	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	3	0	0	15	0	1	40	37	0	0	20	16	NOA
EXC	0	0	0	2	0	5	1	3	1	17	1	1	1	0	1	4	4	2	1	1	0	2	3	6	0	12	0	0	99	60	EXC
EU	0	0	0	8	1	16	2	8	3	3	2	2	2	0	0	1	2	0	3	4	0	6	13	0	1	16	0	0	240	224	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: 2016 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	69	-0	1	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	3	1	3	0	-0	4	0	-0	0	0	0	0	AL
AM	0	61	0	12	-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	103	0	0	1	0	1	4	0	15	47	0	0	0	0	4	1	0	0	3	8	0	0	13	0	0	0	0	0	0	AT
AZ	-0	4	0	53	-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	AZ
BA	1	0	5	-0	94	0	1	1	0	0	5	7	0	0	0	0	1	0	0	0	18	12	0	-0	7	-0	-0	0	0	0	0	BA
BE	0	-0	1	-0	0	185	-0	0	2	-0	2	92	2	0	1	0	66	36	-0	-0	0	0	3	0	2	-0	-0	0	7	0	0	BE
BG	1	0	3	0	1	0	97	1	0	0	2	4	0	0	0	0	0	0	0	6	2	7	0	-0	2	-0	-0	0	0	0	1	BG
BY	0	0	0	0	0	0	0	75	0	-0	2	11	1	0	0	0	2	1	0	0	0	2	0	0	0	0	0	4	0	1	1	BY
CH	-0	0	2	0	-0	1	-0	0	90	-0	1	27	0	0	1	0	15	1	0	-0	0	0	0	0	17	-0	-0	0	0	0	0	CH
CY	0	0	0	0	-0	-0	-0	-0	0	45	-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	20	0	1	2	0	1	2	0	188	93	2	0	1	0	10	3	0	0	3	17	0	0	3	0	-0	1	0	0	0	CZ
DE	0	-0	7	-0	0	14	0	1	4	0	13	270	2	0	1	0	25	12	0	0	1	2	1	0	2	-0	-0	0	1	0	0	DE
DK	0	-0	1	-0	0	5	0	1	0	-0	2	73	92	0	1	0	8	19	-0	-0	0	1	3	0	0	-0	-0	1	0	0	0	DK
EE	0	0	0	0	0	0	0	5	0	-0	1	10	3	34	0	4	1	2	0	0	0	1	0	0	0	-0	0	4	0	5	0	EE
ES	0	0	0	-0	-0	0	-0	0	0	-0	0	1	0	0	79	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	2	0	-0	0	4	1	1	0	15	0	0	0	0	0	0	0	-0	0	-0	0	1	0	0	0	FI
FR	0	0	1	0	-0	9	0	0	5	0	1	26	1	0	4	0	122	13	0	0	0	0	1	0	6	-0	-0	0	1	0	0	FR
GB	-0	-0	0	-0	-0	7	0	0	0	-0	1	17	2	0	2	0	19	172	-0	-0	0	0	7	0	1	-0	-0	0	0	0	0	GB
GE	-0	2	0	6	-0	-0	-0	0	0	-0	-0	-0	-0	-0	0	-0	-0	-0	26	-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	1	0	0	0	5	0	0	0	1	1	0	-0	0	0	0	0	0	54	0	2	0	-0	1	-0	-0	0	0	0	0	GR
HR	0	0	11	0	16	0	1	1	1	0	9	11	0	0	1	0	1	0	0	0	71	16	0	-0	26	-0	0	0	0	0	0	HR
HU	0	0	16	0	2	0	1	1	1	-0	17	22	1	0	1	0	2	1	0	0	10	117	0	0	8	0	0	1	0	0	0	HU
IE	-0	0	0	0	-0	3	-0	0	0	-0	0	8	1	0	0	0	8	43	0	-0	0	0	52	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	3	0	-0	-0	0	0	0	-0	IS
IT	0	0	3	0	0	0	0	0	2	0	1	3	0	0	2	0	2	0	0	0	2	1	0	-0	193	-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	18	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	34	0	0	0	0	KZ
LT	0	0	1	0	0	1	0	18	0	-0	3	19	4	1	0	1	2	2	0	0	0	2	0	0	1	-0	0	53	0	5	0	LT
LU	0	0	3	-0	0	47	0	0	2	0	5	137	1	0	1	0	58	17	0	0	0	0	2	0	2	0	-0	0	74	0	0	LU
LV	0	0	1	0	0	1	0	13	0	-0	2	14	3	4	0	1	1	2	0	0	0	1	0	0	0	-0	0	17	0	33	0	LV
MD	0	0	1	0	0	0	3	3	0	0	2	6	1	0	0	0	1	0	0	0	1	4	0	-0	1	0	0	1	0	0	62	MD
ME	10	-0	2	-0	6	0	0	1	0	0	1	4	0	0	0	0	0	0	-0	0	3	4	0	-0	5	0	-0	0	0	0	0	ME
MK	10	0	2	0	1	0	3	1	0	0	2	4	0	0	0	0	0	0	0	14	2	6	0	-0	2	-0	-0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	3	0	0	1	0	1	0	0	11	0	-0	0	0	0	0	MT
NL	-0	-0	1	-0	0	45	-0	0	1	-0	3	107	3	0	1	0	35	51	-0	-0	0	0	4	0	1	-0	-0	0	1	0	0	NL
NO	-0	-0	0	-0	-0	0	-0	0	0	-0	0	5	2	0	0	0	1	1	-0	-0	0	0	0	-0	0	-0	-0	0	0	0	0	NO
PL	0	0	4	0	0	2	0	5	1	0	22	61	4	0	1	0	6	3	0	0	1	10	0	0	1	0	-0	2	0	1	1	PL
PT	0	0	0	-0	-0	0	-0	0	0	-0	0	1	0	0	25	0	2	0	-0	-0	0	0	0	-0	0	0	-0	0	0	0	0	PT
RO	0	0	3	0	1	0	5	1	0	0	3	6	0	0	0	0	1	0	0	0	2	12	0	-0	2	0	0	0	0	0	2	RO
RS	2	0	6	0	5	0	5	1	1	0	6	10	0	0	0	0	1	0	0	1	7	19	0	-0	3	-0	-0	0	0	0	0	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	4	0	0	0	0	RU
SE	0	-0	0	-0	0	1	0	1	0	-0	0	13	6	0	0	1	1	2	-0	0	0	0	0	-0	0	-0	-0	1	0	0	0	SE
SI	0	0	28	0	1	0	0	1	1	-0	8	15	0	0	1	0	1	0	0	0	23	9	0	-0	64	0	0	0	0	0	0	SI
SK	0	0	12	0	1	1	1	2	1	0	29	29	2	0	1	0	3	1	0	0	4	45	0	0	4	0	0	1	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	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	TM
TR	0	0	0	0	0	0	1	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	0	0	-0	0	-0	-0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	8	0	0	2	6	1	0	0	0	1	0	0	0	0	4	0	-0	1	0	0	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	2	2	0	-0	0	0	UZ
ATL	-0	-0	0	-0	-0	0	-0	0	0	-0	0	1	0	0	2	-0	3	4	-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	2	49	17	2	0	3	3	5	0	0	0	1	1	0	0	-0	-0	4	0	2	0	BAS
BLS	0	0	1	0	0	0	5	1	0	0	0	1	0	0	0	0	0	0	2	2	0	1	0	-0	1	-0	-0	0	0	0	2	BLS
MED	1	0	0	0	-0	0	0	0	0	-0	0	1	0	-0	4	-0	2	0	0	-0	0	0	0	-0	7	-0	-0	0	0	-0	0	MED
NOS	0	-0	0	-0	0	12	0	0	0	-0	1	42	10	0	1	0	26	65	-0	0	0	0	5	-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	2	-0	0	0	0	-0	-0	-0	0	-0	-1	-0	-0	-0	0	-0	0	NOA
EXC	0	0	1	0	0	1	1	2	1	0	2	10	1	0	3	0	5	4	0	0	1	2	0	0	4	0	6	1	0	0	0	EXC
EU	0	0	5	0	0	5	3	1	1	0	8	40	3	1	11	1	21	15	0	2	2	6	2	0	16	-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.: 2016 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	1	-0	1	13	-0	0	0	0	0	-0	0	0	-0	0	0	0	0	0	-0	-0	1	0	0	105	19	AL
AM	-0	0	-0	-0	0	-0	-0	0	-0	-0	0	0	0	0	-0	23	-0	-0	0	0	0	0	0	21	0	1	0	0	98	0	AM
AT	0	0	-0	1	0	6	0	1	2	0	0	8	2	0	0	-0	0	0	0	0	0	0	0	0	-0	2	0	0	221	214	AT
AZ	-0	-0	-0	-0	-0	-0	-0	-0	-0	2	-0	0	-0	0	0	6	-0	0	0	0	0	0	0	19	-0	0	0	0	69	-0	AZ
BA	1	0	0	0	0	5	-0	3	16	0	0	1	2	0	-0	0	1	-0	0	0	0	0	0	0	0	1	0	0	182	69	BA
BE	-0	-0	-0	49	0	3	0	0	0	0	0	0	0	-0	-0	-0	0	-0	0	0	0	0	0	-0	-0	1	0	0	453	451	BE
BG	0	1	0	0	0	2	0	21	23	1	0	0	1	0	-0	12	3	0	0	0	0	0	0	0	0	1	0	0	193	149	BG
BY	0	0	0	1	0	37	0	2	1	14	1	0	1	0	0	1	18	0	0	0	0	0	0	0	0	1	0	0	179	70	BY
CH	-0	-0	-0	1	0	1	0	0	-0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	0	1	0	0	157	67	CH
CY	0	-0	0	-0	-0	-0	-0	-0	-0	-0	-0	0	-0	-0	0	3	-0	0	0	0	0	0	0	4	4	2	0	0	47	46	CY
CZ	0	0	-0	4	0	32	0	3	4	1	1	2	10	0	0	0	2	0	0	0	0	0	0	0	-0	3	0	0	407	396	CZ
DE	0	-0	-0	24	0	15	0	0	0	0	1	1	1	0	0	-0	1	-0	0	0	0	0	0	-0	-0	3	0	0	400	395	DE
DK	0	0	-0	17	1	14	0	0	0	1	6	0	0	-0	-0	-0	1	-0	0	0	0	0	0	-0	0	2	0	0	248	243	DK
EE	0	0	0	1	1	10	0	1	0	13	4	0	0	0	0	0	2	0	0	0	0	0	0	-0	0	0	0	0	104	82	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	90	90	ES
FI	0	0	-0	1	0	2	0	0	0	5	3	0	0	0	0	0	1	0	0	0	0	0	0	-0	0	0	0	0	38	30	FI
FR	0	-0	0	6	0	1	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	0	1	0	0	199	193	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	241	240	GB
GE	-0	-0	-0	-0	0	-0	-0	0	-0	1	0	0	0	0	-0	8	0	-0	0	0	0	0	0	2	-0	0	0	0	42	-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	-1	0	0	-0	-0	GL
GR	0	3	0	0	0	0	0	3	6	-0	0	0	0	-0	0	8	0	0	0	0	0	0	0	0	1	1	0	0	90	70	GR
HR	0	0	0	1	0	6	0	4	17	0	0	8	3	0	-0	0	1	0	0	0	0	0	0	0	0	1	0	0	206	171	HR
HU	0	0	0	1	0	15	0	17	19	1	0	4	17	0	0	0	4	0	0	0	0	0	0	0	-0	2	0	0	281	253	HU
IE	-0	-0	-0	4	0	1	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	0	0	0	0	122	121	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	5	2	IS
IT	0	0	0	0	0	1	0	0	1	-0	0	3	0	0	-0	-0	0	-0	0	0	0	0	0	-0	0	1	0	0	216	213	IT
KG	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	0	-0	1	0	-0	-0	5	0	0	0	0	0	3	-0	0	0	0	26	-0	KG
KZ	-0	-0	-0	0	0	0	-0	0	-0	17	0	0	0	0	0	0	1	2	0	0	0	0	0	9	-0	1	0	0	56	0	KZ
LT	0	0	0	2	0	52	0	2	1	9	3	0	1	0	0	0	5	0	0	0	0	0	0	0	0	1	0	0	190	155	LT
LU	0	-0	-0	18	0	5	0	0	0	0	0	0	0	0	0	-0	0	-0	0	0	0	0	0	-0	0	1	0	0	375	371	LU
LV	0	0	0	2	0	22	0	1	1	10	3	0	1	0	0	0	4	0	0	0	0	0	0	0	0	1	0	0	137	109	LV
MD	0	0	-0	0	0	12	0	33	2	7	0	0	1	0	0	4	43	0	0	0	0	0	0	0	-0	2	0	0	189	67	MD
ME	27	0	0	0	0	2	0	2	10	-0	0	0	1	0	-0	-0	0	-0	0	0	0	0	0	0	0	1	0	0	81	26	ME
MK	0	53	0	0	0	2	-0	4	33	-0	0	0	1	0	-0	1	1	-0	0	0	0	0	0	0	0	1	0	0	143	44	MK
MT	0	0	91	0	0	0	0	0	0	-0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2	1	0	0	114	113	MT
NL	-0	-0	-0	219	0	3	0	0	-0	0	1	0	0	-0	-0	-0	0	-0	0	0	0	0	0	-0	-0	1	0	0	479	477	NL
NO	-0	-0	-0	1	6	1	0	-0	-0	-0	1	0	0	-0	-0	-0	0	-0	0	0	0	0	0	-0	0	0	0	0	19	13	NO
PL	0	0	-0	4	0	223	0	5	2	3	2	1	7	0	0	0	8	0	0	0	0	0	0	0	0	2	0	0	378	359	PL
PT	-0	-0	-0	0	0	0	46	0	-0	-0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	-0	0	0	0	76	75	PT
RO	0	0	0	0	0	4	0	101	13	1	0	1	3	0	0	2	8	0	0	0	0	0	0	0	-0	1	0	0	174	145	RO
RS	1	4	0	0	0	5	-0	17	136	0	0	1	4	0	-0	1	1	-0	0	0	0	0	0	0	-0	1	0	0	238	87	RS
RU	0	0	0	0	0	1	-0	0	0	50	0	0	0	0	0	0	4	0	0	0	0	0	0	1	-0	0	0	0	64	4	RU
SE	0	0	0	2	1	4	0	0	0	1	13	0	0	-0	-0	0	1	-0	0	0	0	0	0	-0	0	0	0	0	49	45	SE
SI	0	0	0	1	0	4	0	2	4	0	0	114	1	0	0	-0	0	0	0	0	0	0	0	0	0	1	0	0	280	273	SI
SK	0	0	0	1	0	35	0	12	8	1	1	2	95	0	0	1	7	0	0	0	0	0	0	0	0	2	0	0	301	279	SK
TJ	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	-0	4	0	-0	-0	4	0	0	0	0	0	1	-0	0	0	0	8	-0	TJ
TM	-0	-0	-0	-0	-0	-0	-0	-0	-0	1	-0	0	-0	0	9	0	-0	2	0	0	0	0	0	10	0	0	0	0	14	-0	TM
TR	0	0	0	0	0	0	-0	1	0	-0	0	0	0	0	-0	109	0	-0	0	0	0	0	0	4	0	1	0	0	115	4	TR
UA	0	0	0	0	0	16	0	9	1	20	0	0	1	0	0	3	123	0	0	0	0	0	0	0	0	1	0	0	208	47	UA
UZ	-0	-0	-0	0	-0	-0	-0	-0	-0	1	0	-0	-0	1	1	-0	0	17	0	0	0	0	0	2	-0	0	0	0	24	-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	-2	0	0	12	12	ATL
BAS	0	0	0	6	1	28	0	1	0	5	13	0	0	0	0	0	2	0	0	0	0	0	0	-0	0	1	0	0	154	142	BAS
BLS	0	0	0	0	0	2	0	13	2	11	0	0	0	0	0	41	22	0	0	0	0	0	0	0	0	1	0	0	111	28	BLS
MED	-0	0	-0	0	0	-0	0	0	0	-0	0	0	-0	-0	0	-11	-0	0	0	0	0	0	0	1	0	0	0	0	4	15	MED
NOS	-0	-0	-0	28	2	4	0	0	0	0	1	0	0	-0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	200	197	NOS
AST	-0	-0	-0	-0	-0	-0	-0	0	-0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	62	1	6	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	8	0	0	0	1	NOA
EXC	0	0	0	2	0	7	0	2	1	23	1	0	1	0	0	5	6	1	0	0	0	0	0	2	0	0	0	0	98	49	EXC
EU	0	0	0	7	0	21	1	7	3	1	2	1	3	0	0	1	2	0	0	0	0	0	0	0	0	1	0	0	193	183	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: 2016 country-to-country blame matrices for **PM2.5**.
Units: ng/m^3 per 15% emis. red. of VOC. **Emitters →, Receptors ↓.**

	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	
AL	2	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	0	1	0	0	0	0	3	0	0	0	0	0	0	AL
AM	0	6	-0	0	-0	-0	-0	0	0	0	-0	-0	-0	-0	-0	-0	-0	-0	0	0	-0	-0	-0	-0	0	-0	0	-0	-0	-0	-0	AM
AT	0	0	5	0	0	0	0	0	1	0	1	2	0	0	0	0	1	0	0	0	1	1	0	0	-0	-0	0	0	0	0	0	AT
AZ	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	-0	0	0	0	0	-0	AZ
BA	0	0	1	0	-1	0	0	0	0	0	1	2	0	0	0	0	1	1	0	0	0	1	0	0	2	0	0	0	0	0	0	BA
BE	0	0	1	0	0	8	0	1	1	0	2	26	1	0	1	0	10	12	0	0	0	0	1	0	2	0	0	0	0	0	0	BE
BG	0	0	0	0	0	0	2	1	0	0	1	1	0	0	0	0	0	0	0	1	0	1	0	0	1	-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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BY
CH	0	0	1	-0	0	0	0	-0	6	0	-0	2	0	-0	0	-0	1	0	0	0	0	0	0	0	0	-0	0	-0	0	-0	-0	CH
CY	0	0	0	0	0	0	0	1	0	-0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	CY
CZ	0	0	2	0	0	0	0	1	1	0	7	5	0	0	0	0	1	1	0	0	0	1	0	0	1	0	0	0	0	0	0	CZ
DE	0	0	2	0	0	2	0	0	2	0	3	15	0	0	1	0	5	3	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	1	2	1	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	0	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	0	0	0	5	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	ES
FI	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	FI
FR	0	0	0	0	0	1	0	0	1	0	0	3	0	0	1	0	7	1	0	0	0	0	0	0	2	0	0	0	0	0	0	FR
GB	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	2	10	0	0	0	0	0	0	1	0	0	0	0	0	0	GB
GE	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	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	1	0	0	0	0	0	1	1	0	0	1	1	0	0	1	0	1	0	0	4	0	0	0	0	3	0	0	0	0	0	0	GR
HR	0	0	1	0	0	0	0	0	0	0	1	2	0	0	1	0	1	0	0	0	3	1	0	0	4	-0	0	0	0	0	0	HR
HU	0	0	2	0	0	0	0	1	0	0	2	2	0	0	0	0	1	0	0	0	2	5	0	0	1	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	0	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	4	1	0	0	1	0	0	0	67	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	3	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	1	0	0	0	0	KZ
LT	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	LT
LU	0	0	2	0	0	3	0	0	1	0	2	17	0	0	1	0	7	3	0	0	0	0	0	0	2	0	0	0	1	0	0	LU
LV	0	0	0	-0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	-0	0	0	0	-0	LV
MD	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	MD
ME	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	2	-0	0	0	0	0	0	ME
MK	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	2	0	1	0	0	2	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3	0	3	1	0	1	0	0	0	0	10	0	0	0	0	0	0	MT
NL	0	0	1	0	0	7	0	1	1	0	4	26	1	0	1	0	12	14	0	0	0	0	1	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	1	0	0	2	4	0	0	0	0	1	1	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	0	0	0	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	RO
RS	0	0	1	0	0	0	0	1	0	0	1	2	0	0	0	0	1	1	0	1	1	2	0	0	1	-0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	RU
SE	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	SE
SI	0	0	2	0	0	0	0	0	0	0	1	2	0	0	0	0	1	0	0	0	3	1	0	0	3	0	0	0	0	0	0	SI
SK	0	0	2	0	0	0	0	1	0	0	3	3	0	0	0	0	1	1	0	0	1	3	0	0	1	0	0	0	0	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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	0	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	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	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	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	BLS
MED	0	0	0	0	0	0	0	0	0	0	1	2	0	0	2	0	3	1	0	2	0	0	0	0	7	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	3	0	0	0	0	0	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	NOA
EXC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	EXC
EU	0	0	1	0	0	0	0	0	0	-0	1	3	0	0	1	0	2	1	0	0	0	0	0	0	6	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.: 2016 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	1	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	-3	0	0	17	11	AL
AM	-0	-0	0	-0	-0	-0	-0	-0	-0	1	-0	-0	-0	-0	0	-0	-0	0	-0	0	-0	0	0	9	0	-5	0	0	7	-0	AM
AT	0	0	0	0	0	1	0	0	0	1	0	1	0	-0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	14	12	AT
AZ	0	0	0	0	-0	0	0	-0	0	3	0	0	0	-0	0	0	0	0	0	0	0	0	0	10	0	-4	0	0	6	0	AZ
BA	0	0	0	0	0	2	0	0	1	1	0	0	0	-0	0	0	1	0	0	0	0	0	0	0	1	-3	0	0	15	12	BA
BE	0	0	0	9	1	3	0	0	0	4	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	87	78	BE
BG	0	0	0	0	0	1	0	1	1	3	0	0	0	-0	0	3	2	0	0	0	0	0	0	0	0	-3	0	0	20	11	BG
BY	0	0	0	0	-0	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	7	4	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	-3	0	0	11	5	CH
CY	0	0	0	0	0	1	0	1	0	4	0	0	0	0	0	9	2	0	0	0	0	0	0	6	2	-5	0	0	23	7	CY
CZ	0	0	0	0	0	4	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	29	25	CZ
DE	0	0	0	2	0	2	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	43	38	DE
DK	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	10	7	DK
EE	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	5	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	-2	0	0	10	9	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	1	0	0	0	-0	0	0	0	0	0	0	0	0	0	0	0	-3	0	0	18	16	FR
GB	0	0	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	21	19	GB
GE	0	0	0	0	0	0	0	0	0	2	0	0	0	-0	0	0	0	0	0	0	0	0	0	3	0	-2	0	0	8	1	GE
GL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	GL
GR	0	0	0	0	0	1	0	1	1	3	0	0	0	0	0	2	2	0	0	0	0	0	0	0	1	-3	0	0	24	15	GR
HR	0	0	0	0	0	1	0	1	1	1	0	1	0	-0	-0	0	1	0	0	0	0	0	0	0	1	-3	0	0	21	17	HR
HU	0	0	0	0	0	3	0	2	1	1	0	1	1	-0	0	0	1	0	0	0	0	0	0	0	0	-4	0	0	30	24	HU
IE	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	-2	0	0	3	2	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	-1	0	0	88	85	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	3	0	-1	0	0	6	0	KG
KZ	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	7	1	KZ
LT	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	-3	0	0	5	3	LT
LU	0	0	0	3	0	1	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-2	0	0	48	43	LU
LV	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	5	3	LV
MD	0	0	0	0	0	2	0	1	0	3	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	-4	0	0	13	6	MD
ME	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	-2	0	0	14	10	ME
MK	0	3	0	0	0	2	0	1	1	2	0	0	0	-0	0	1	1	0	0	0	0	0	0	0	1	-2	0	0	21	11	MK
MT	0	0	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	-2	0	0	29	27	MT
NL	0	0	0	14	0	4	0	0	0	4	1	0	0	0	0	0	1	0	0	0	0	0	0	0	1	2	0	0	99	91	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	1	0	NO
PL	0	0	0	0	0	6	0	1	0	2	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	22	18	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	-2	0	0	9	8	PT
RO	0	0	0	0	0	2	0	4	1	2	0	0	0	-0	0	1	2	0	0	0	0	0	0	0	0	-4	0	0	18	11	RO
RS	0	1	0	0	0	2	0	1	4	2	0	0	1	-0	0	1	1	0	0	0	0	0	0	0	1	-3	0	0	25	16	RS
RU	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	-1	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	2	1	SE
SI	0	0	0	0	0	1	0	1	1	1	0	5	0	-0	-0	0	1	0	0	0	0	0	0	0	0	-3	0	0	22	20	SI
SK	0	0	0	0	0	5	0	1	0	2	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0	-3	0	0	29	24	SK
TJ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	7	0	-1	0	0	4	0	TJ
TM	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0	-2	0	0	7	1	TM
TR	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	5	1	0	0	0	0	0	0	4	1	-4	0	0	13	3	TR
UA	0	0	0	0	0	1	0	0	0	5	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	-3	0	0	14	5	UA
UZ	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	4	0	0	0	0	0	7	0	-2	0	0	11	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	-2	0	0	7	5	BAS
BLS	0	0	0	0	0	1	0	1	0	9	0	0	0	0	0	4	3	0	0	0	0	0	0	1	0	-2	0	0	25	7	BLS
MED	0	0	0	0	0	1	0	0	0	2	0	0	0	0	0	2	1	0	0	0	0	0	0	2	3	-3	0	0	26	20	MED
NOS	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	12	11	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	32	0	-3	0	0	4	1	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	1	5	-2	0	0	10	8	NOA
EXC	0	0	0	0	0	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	-2	0	0	11	6	EXC
EU	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	23	20	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: 2016 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	478	0	4	0	44	1	9	2	1	0	6	10	0	0	5	0	4	1	0	36	6	9	0	0	35	0	0	0	0	0	0	AL
AM	0	406	0	51	0	0	1	0	0	1	0	0	0	0	0	0	0	0	24	1	0	0	0	0	0	0	8	0	0	0	0	AM
AT	0	0	355	0	8	6	2	2	17	0	68	203	1	0	3	0	22	7	0	1	18	36	1	0	55	0	0	1	1	0	0	AT
AZ	0	46	0	228	0	0	0	1	0	0	0	0	0	0	0	0	0	0	68	0	0	0	0	0	0	0	22	0	0	0	0	AZ
BA	4	0	15	0	573	1	6	2	1	0	23	31	1	0	4	0	6	3	0	3	51	36	0	0	31	0	0	1	0	0	0	BA
BE	0	0	7	0	1	582	0	2	10	0	15	364	6	1	9	1	319	152	0	0	0	1	9	0	9	0	0	2	20	1	0	BE
BG	4	0	6	0	16	1	438	5	1	0	10	16	1	0	2	1	3	2	1	33	5	18	0	0	8	0	1	1	0	0	5	BG
BY	0	0	1	0	2	2	2	224	0	0	8	33	4	5	1	6	4	6	0	0	1	5	1	0	2	0	2	21	0	9	3	BY
CH	0	0	24	0	1	7	0	1	397	0	8	179	0	0	4	0	110	8	0	0	1	1	1	0	78	0	0	0	2	0	0	CH
CY	1	1	1	1	4	0	6	1	0	118	1	2	0	0	3	0	2	0	0	26	0	1	0	0	7	0	1	0	0	0	0	CY
CZ	0	0	70	0	8	10	2	3	8	0	636	310	4	1	3	1	38	13	0	1	10	52	1	0	12	0	0	2	1	1	0	CZ
DE	0	0	37	0	2	51	0	3	20	0	60	845	13	1	5	1	105	53	0	0	2	6	4	0	10	0	0	2	6	1	0	DE
DK	0	0	2	0	0	22	0	4	1	-0	11	229	309	2	2	3	27	74	0	0	0	1	6	0	1	0	0	4	1	2	0	DK
EE	0	0	1	0	0	2	0	13	0	0	3	23	7	95	0	27	3	9	0	0	0	1	1	0	1	0	1	11	0	20	1	EE
ES	0	0	1	0	0	2	0	0	1	0	1	7	0	0	415	0	28	5	0	0	0	0	1	0	6	0	0	0	0	0	0	ES
FI	0	0	0	0	0	1	0	4	0	0	1	10	3	4	0	73	1	3	0	0	0	0	0	0	0	0	0	2	0	2	0	FI
FR	0	0	5	0	1	37	0	1	21	0	8	123	2	0	28	0	526	62	0	0	1	1	4	0	26	0	0	0	5	0	0	FR
GB	0	0	1	0	0	17	0	1	1	0	3	51	5	0	7	1	54	571	0	0	0	0	26	1	2	0	0	0	1	0	0	GB
GE	0	30	0	34	0	0	1	1	0	0	0	0	0	0	0	0	0	0	255	1	0	0	0	0	0	0	7	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	13	0	2	0	16	0	50	2	0	0	4	7	0	0	5	0	3	1	0	240	2	5	0	0	20	0	1	0	0	0	1	GR
HR	3	0	46	0	151	2	6	3	2	0	47	59	1	0	6	0	10	4	0	3	312	76	0	0	92	0	0	1	0	0	0	HR
HU	1	0	74	0	37	3	11	6	4	0	82	96	2	1	4	1	13	6	0	3	65	643	0	0	37	0	0	2	0	1	1	HU
IE	0	0	0	0	0	7	0	1	0	0	1	22	3	0	3	0	21	178	0	0	0	0	206	1	1	0	0	0	0	0	0	IE
IS	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	4	0	0	0	0	1	33	0	0	0	0	0	0	0	IS
IT	2	0	20	0	17	2	2	1	9	0	10	26	0	0	18	0	34	3	0	2	15	6	0	0	1073	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	132	30	0	0	0	0	KG
KZ	0	1	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	7	187	0	0	0	0	KZ
LT	0	0	2	0	1	4	1	56	0	0	10	51	10	8	0	9	5	12	0	0	1	5	1	0	2	0	1	139	0	26	2	LT
LU	0	0	14	0	1	168	0	2	11	0	24	509	3	1	7	1	314	74	0	0	1	2	5	0	10	0	0	1	200	0	0	LU
LV	0	0	1	0	1	2	1	33	0	0	6	33	9	16	0	13	3	11	0	0	1	2	1	0	1	0	1	45	0	126	1	LV
MD	0	0	4	0	7	1	18	17	1	0	11	23	1	2	2	2	4	2	1	3	2	13	0	0	5	0	3	3	0	1	232	MD
ME	43	0	4	0	94	1	7	2	1	0	8	14	0	0	4	0	4	2	0	6	8	11	0	0	24	0	0	0	0	0	0	ME
MK	50	0	4	0	20	1	35	2	1	0	8	12	0	0	3	0	3	1	0	95	4	15	0	0	13	0	0	0	0	0	1	MK
MT	1	0	2	0	16	1	3	1	1	0	4	9	0	0	29	0	26	3	0	6	3	3	0	0	95	0	0	0	0	0	0	MT
NL	0	0	6	0	0	205	0	3	4	0	20	465	15	1	8	1	172	199	0	0	1	2	12	0	6	0	0	2	5	1	0	NL
NO	0	0	0	0	0	1	0	1	0	0	1	12	4	1	0	2	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	9	0	4	7	2	20	2	0	65	164	11	3	2	3	16	13	0	1	3	24	1	0	5	0	0	8	1	3	2	PL
PT	0	0	0	0	0	1	0	0	0	0	1	5	0	0	181	0	10	4	0	0	0	0	1	0	2	0	0	0	0	0	0	PT
RO	2	0	10	0	17	1	38	8	1	0	15	27	1	1	2	1	5	2	0	4	7	48	0	0	10	0	1	1	0	0	11	RO
RS	15	0	20	0	81	2	48	5	2	0	29	40	1	0	3	1	6	3	0	16	29	78	0	0	17	0	0	1	0	0	1	RS
RU	0	0	0	1	0	0	0	5	0	0	1	2	0	2	0	2	0	1	0	0	0	0	0	0	0	0	26	1	0	1	0	RU
SE	0	0	0	0	0	2	0	2	0	0	2	30	16	2	0	5	4	9	0	0	0	0	1	0	0	0	0	2	0	1	0	SE
SI	1	0	131	0	22	3	2	2	4	0	45	81	1	0	5	0	12	4	0	1	128	41	0	0	220	0	0	0	0	0	0	SI
SK	1	0	45	0	13	3	5	6	4	0	107	95	3	1	3	1	13	6	0	2	16	187	0	0	17	0	0	2	0	1	1	SK
TJ	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	10	12	0	0	0	0	TJ
TM	0	3	0	5	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	43	0	0	0	0	TM
TR	1	8	1	1	2	0	7	1	0	2	1	2	0	0	1	0	1	0	2	7	0	1	0	0	3	0	2	0	0	0	1	TR
UA	0	0	3	1	4	1	7	28	1	0	9	20	2	2	1	2	3	3	1	2	1	11	0	0	3	0	7	3	0	2	14	UA
UZ	0	1	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	22	67	0	0	0	0	UZ
ATL	0	0	0	0	0	1	0	0	0	0	0	4	0	0	9	0	8	11	0	0	0	0	3	1	0	0	0	0	0	0	0	ATL
BAS	0	0	1	0	0	6	0	8	0	0	7	98	40	8	1	18	9	22	0	0	0	2	2	0	1	0	0	9	0	8	0	BAS
BLS	1	2	1	2	4	0	20	7	0	0	3	6	0	1	1	1	1	1	16	7	1	4	0	0	3	0	5	1	0	0	6	BLS
MED	4	0	2	0	16	1	8	1	1	2	4	9	0	0	35	0	27	3	0	20	5	2	0	0	77	0	1	0	0	0	0	MED
NOS	0	0	1	0	0	24	0	1	1	0	4	95	20	1	5	1	60	146	0	0	0	0	10	1	1	0	0	1	1	1	0	NOS
AST	0	2	0	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	14	0	0	0	0	AST
NOA	1	0	1	0	3	0	2	0	0	0	1	3	0	0	21	0	7	1	0	4	1	0	0	0	12	0	0	0	0	0	0	NOA
EXC	1	2	5	2	4	4	5	7	2	0	8	35	2	1	14	3	23	14	2	3	3	7	2	0	21	3	41	2	0	1	1	EXC
EU	1	0	18	0	7	18	16	5	6	0	30	132	8	2	58	7	92	55	0	9	9	25	6	0	85	0	0	4	2	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.: 2016 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	36	73	0	1	0	19	0	11	162	4	0	1	3	0	0	19	13	0	1	0	0	40	0	2	22	25	5	36	997	165	AL
AM	0	0	0	0	0	1	0	1	1	9	0	0	0	0	1	142	4	0	0	0	1	2	0	241	5	28	0	7	650	5	AM
AT	1	0	0	6	0	50	0	8	21	3	0	40	12	0	0	3	6	0	1	1	0	6	4	0	4	18	2	4	957	895	AT
AZ	0	0	0	0	0	1	0	1	1	41	0	0	0	0	2	56	13	1	0	0	1	1	0	256	2	20	0	4	484	5	AZ
BA	25	2	0	2	0	45	0	15	210	5	0	4	11	0	0	9	15	0	1	0	0	14	1	0	14	20	2	13	1138	291	BA
BE	0	0	0	144	3	25	1	1	1	8	3	1	1	0	0	0	2	0	15	4	0	3	83	0	1	47	14	1	1703	1674	BE
BG	5	18	0	1	0	31	0	100	124	26	1	1	6	0	0	87	79	0	0	1	9	13	1	2	11	23	2	9	1056	684	BG
BY	0	0	0	4	2	143	0	11	6	105	5	0	4	0	0	6	68	0	1	7	1	1	3	1	1	13	3	1	696	277	BY
CH	0	0	0	6	0	10	0	0	2	1	0	1	1	0	0	1	1	0	2	0	0	4	4	0	4	17	2	2	844	440	CH
CY	1	3	0	0	0	4	0	4	11	14	0	0	0	0	0	905	22	0	0	0	5	107	0	116	47	51	18	27	1142	175	CY
CZ	1	1	0	12	1	183	0	12	27	6	2	9	39	0	0	3	12	0	2	2	0	3	7	0	2	21	4	2	1497	1425	CZ
DE	0	0	0	70	3	86	0	2	4	8	4	2	4	0	0	1	5	0	5	12	0	2	40	0	2	32	8	1	1417	1372	DE
DK	0	0	0	50	14	59	0	1	0	17	25	0	1	0	0	0	4	0	6	59	0	0	68	0	0	23	15	0	874	833	DK
EE	0	0	0	4	4	40	0	2	1	67	14	0	1	0	0	1	11	0	1	20	0	0	4	0	0	8	6	0	364	265	EE
ES	0	0	0	1	0	2	25	0	1	0	0	0	0	0	0	0	0	0	22	0	0	47	2	0	27	25	11	1	498	496	ES
FI	0	0	0	2	4	11	0	0	0	44	13	0	0	0	0	0	3	0	2	6	0	0	2	0	0	6	7	0	183	127	FI
FR	0	0	0	22	1	12	1	0	2	2	1	1	1	0	0	0	1	0	17	1	0	13	32	0	4	22	13	2	896	866	FR
GB	0	0	0	29	3	8	1	0	0	4	2	0	0	0	0	0	1	0	27	2	0	1	46	0	1	26	22	0	792	781	GB
GE	0	0	0	0	0	1	0	1	1	22	0	0	0	0	1	78	11	0	0	0	5	1	0	56	3	14	0	5	448	7	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	6	2	0	0	0	GL
GR	6	39	0	0	0	16	0	20	64	16	0	1	2	0	0	131	41	0	1	0	4	70	0	4	25	27	7	40	714	381	GR
HR	7	3	0	3	1	63	0	24	174	5	1	42	17	0	0	9	17	0	1	1	0	27	2	0	13	20	3	12	1190	816	HR
HU	4	4	0	4	1	142	0	120	152	10	1	28	97	0	0	11	37	0	1	2	1	9	3	0	8	28	2	6	1706	1437	HU
IE	0	0	0	12	1	6	1	0	0	2	1	0	0	0	0	0	1	0	32	2	0	0	19	0	0	21	28	0	471	464	IE
IS	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	1	0	0	7	15	0	43	8	IS
IT	3	1	0	2	0	17	1	3	21	3	0	20	3	0	0	5	5	0	2	0	0	88	1	0	30	31	8	43	1325	1259	IT
KG	0	0	0	0	0	0	0	0	0	3	0	0	0	7	1	4	1	47	0	0	0	0	0	61	0	21	0	2	226	1	KG
KZ	0	0	0	0	0	2	0	0	0	111	0	0	0	1	2	3	13	8	0	0	0	0	0	57	0	30	0	1	343	6	KZ
LT	0	0	0	7	3	166	0	6	4	69	10	1	4	0	0	2	29	0	1	17	0	0	6	0	0	13	6	0	647	480	LT
LU	0	0	0	63	1	31	1	1	3	5	1	1	2	0	0	1	2	0	9	2	0	3	34	0	2	32	9	1	1458	1433	LU
LV	0	0	0	5	3	73	0	3	2	63	11	0	2	0	0	2	19	0	1	16	0	0	5	0	0	9	6	0	491	366	LV
MD	2	2	0	1	1	101	0	191	23	62	2	1	8	0	0	41	232	0	1	2	10	4	1	1	4	18	2	4	1024	400	MD
ME	307	9	0	1	0	22	0	9	165	4	0	1	4	0	0	12	12	0	1	0	0	19	0	1	16	20	3	19	779	131	ME
MK	9	488	0	1	0	24	0	21	199	8	0	1	5	0	0	41	21	0	1	0	1	15	0	1	15	23	2	18	1088	248	MK
MT	4	2	206	1	0	8	2	4	20	1	0	1	1	0	0	15	4	0	3	0	0	323	1	1	114	39	28	81	472	407	MT
NL	0	0	0	485	5	39	1	1	1	11	5	1	2	-0	0	0	3	0	16	12	0	2	143	0	2	57	16	1	1684	1656	NL
NO	0	0	0	3	48	5	0	0	0	9	4	0	0	0	0	0	1	0	4	1	0	0	6	0	0	7	14	0	101	42	NO
PL	1	1	0	11	2	739	0	16	14	29	5	2	28	0	0	3	35	0	2	11	0	1	8	0	1	19	5	2	1254	1142	PL
PT	0	0	0	1	0	1	302	0	0	0	0	0	0	0	0	0	0	0	57	0	0	14	1	0	19	25	19	1	511	510	PT
RO	5	5	0	2	1	67	0	621	92	25	1	2	14	0	0	30	87	0	1	1	6	5	1	1	7	20	1	6	1166	880	RO
RS	32	48	0	2	1	63	0	89	789	11	1	4	19	0	0	21	32	0	1	1	1	9	2	1	12	26	2	13	1512	474	RS
RU	0	0	0	0	0	7	0	1	1	225	1	0	0	0	0	3	21	0	0	1	0	0	0	5	0	53	4	0	305	21	RU
SE	0	0	0	5	13	17	0	0	0	14	43	0	0	0	0	0	3	0	3	10	0	0	7	0	0	6	8	0	174	141	SE
SI	1	1	0	4	0	48	0	14	50	4	0	559	9	0	0	5	10	0	1	1	0	27	2	0	10	20	3	8	1411	1311	SI
SK	2	2	0	4	1	207	0	54	50	8	1	10	428	0	0	7	36	0	1	1	0	5	2	0	4	19	2	4	1339	1210	SK
TJ	0	0	0	0	0	0	0	0	0	5	0	0	0	72	6	7	1	39	0	0	0	0	0	99	1	34	0	2	153	1	TJ
TM	0	0	0	0	0	1	0	0	0	45	0	0	0	3	49	16	13	17	0	0	0	0	0	197	1	39	0	3	202	5	TM
TR	1	2	0	0	0	5	0	7	9	18	0	0	1	0	0	923	23	0	0	0	7	24	0	112	15	38	3	15	1035	42	TR
UA	1	1	0	1	1	88	0	43	11	117	2	1	7	0	0	30	410	0	1	2	6	3	1	3	3	16	2	3	843	217	UA
UZ	0	0	0	0	0	2	0	0	1	54	0	0	0	10	14	9	12	112	0	0	0	0	0	87	1	35	0	2	311	6	UZ
ATL	0	0	0	1	1	1	4	0	0	7	0	0	0	0	0	0	0	0	21	0	0	2	2	0	4	37	34	0	54	43	ATL
BAS	0	0	0	16	6	76	0	2	1	29	33	0	1	0	0	0	7	0	2	34	0	0	15	0	0	10	10	0	413	360	BAS
BLS	1	2	0	0	0	21	0	44	16	94	0	0	2	0	0	234	158	0	0	0	46	11	0	9	6	15	1	6	666	119	BLS
MED	5	4	1	1	0	10	2	6	25	7	0	2	1	0	0	188	15	0	5	0	3	198	1	31	83	36	23	78	486	217	MED
NOS	0	0	0	48	11	17	0	0	0	5	4	0	0	0	0	0	2	0	13	6	0	1	45	0	0	15	25	0	460	439	NOS
AST	0	0	0	0	0	1	0	0	1	12	0	0	0	1	3	58	4	2	0	0	0	4	0	804	7	162	1	5	107	5	AST
NOA	1	1	0	0	0	2	4	1	5	1	0	0	0	0	0	29	3	0	11	0	0	54	0	10	275	112	11	28	108	63	NOA
EXC	1	2	0	5	2	29	2	13	11	117	2	2	3	1	2	46	30	5	3	2	1	6	4	26	3	35	4	3	491	208	EXC
EU	1	2	0	19	3	86	10	43	21	14	7	7	12	0	0	11	15	0	10	5	1	18	15	1	8	21	9	6	850	763	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: 2016 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	621	0	2	0	3	0	4	0	0	0	2	2	0	0	1	0	2	0	0	10	4	4	0	0	15	0	0	0	0	0	0	AL
AM	0	51	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	0	1	0	0	0	0	AM
AT	0	0	350	0	1	1	0	1	4	0	25	43	0	0	1	0	8	2	0	0	12	21	0	0	18	0	0	0	0	0	0	AT
AZ	0	4	0	49	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26	0	0	0	0	0	0	0	2	0	0	0	0	AZ
BA	3	0	6	0	223	0	1	1	0	0	7	5	0	0	1	0	3	1	0	1	51	18	0	0	15	0	0	0	0	0	0	BA
BE	0	0	2	0	0	539	0	0	1	0	3	74	1	0	2	0	159	30	0	0	0	0	1	0	2	0	0	0	10	0	0	BE
BG	3	0	3	0	2	0	361	2	0	0	3	2	0	0	1	0	1	0	0	9	3	8	0	0	3	0	0	0	0	0	2	BG
BY	0	0	1	0	0	1	0	218	0	0	3	5	1	1	0	2	1	1	0	0	0	3	0	0	1	0	0	6	0	4	1	BY
CH	0	0	11	0	0	1	0	0	246	0	2	49	0	0	1	0	64	1	0	0	0	0	0	0	34	0	0	0	0	0	0	CH
CY	1	0	0	0	0	0	1	0	0	82	0	0	0	0	1	0	1	0	0	4	0	0	0	0	2	0	0	0	0	0	0	CY
CZ	0	0	28	0	1	2	1	1	2	0	526	61	1	0	1	0	14	3	0	0	6	27	0	0	4	0	0	0	0	0	0	CZ
DE	0	0	17	0	0	13	0	1	5	0	23	378	3	0	1	0	43	10	0	0	1	3	1	0	3	0	0	0	2	0	0	DE
DK	0	0	0	0	0	4	0	1	0	0	3	28	193	0	0	1	6	15	0	0	0	1	1	0	0	0	0	1	0	1	0	DK
EE	0	0	0	0	0	0	0	6	0	0	1	3	2	57	0	12	1	2	0	0	0	1	0	0	0	0	0	2	0	11	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	1	0	0	256	0	12	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	1	1	1	0	68	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	FI
FR	0	0	1	0	0	9	0	0	5	0	2	23	0	0	8	0	439	12	0	0	0	0	1	0	10	0	0	0	2	0	0	FR
GB	0	0	0	0	0	3	0	0	0	0	0	5	1	0	2	0	15	376	0	0	0	0	7	0	1	0	0	0	0	0	0	GB
GE	0	5	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	168	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	12	0	1	0	1	0	13	1	0	0	1	1	0	0	1	0	1	0	0	148	2	3	0	0	9	0	0	0	0	0	1	GR
HR	2	0	18	0	43	1	2	1	0	0	15	9	0	0	2	0	4	1	0	1	454	47	0	0	37	0	0	0	0	0	0	HR
HU	1	0	32	0	5	1	4	2	1	0	25	14	1	0	1	0	5	1	0	1	59	588	0	0	13	0	0	0	0	0	0	HU
IE	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	5	37	0	0	0	0	137	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	8	0	0	0	0	0	0	0	IS
IT	1	0	7	0	1	0	0	0	3	0	2	4	0	0	5	0	16	1	0	0	7	3	0	0	789	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	66	8	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	2	65	0	0	0	0	KZ
LT	0	0	1	0	0	1	0	30	0	0	4	7	3	1	0	2	2	3	0	0	1	2	0	0	1	0	0	82	0	13	1	LT
LU	0	0	4	0	0	71	0	0	2	0	6	141	1	0	1	0	174	15	0	0	0	1	1	0	3	0	0	0	289	0	0	LU
LV	0	0	0	0	0	1	0	16	0	0	2	4	3	5	0	4	1	3	0	0	0	1	0	0	0	0	0	12	0	100	0	LV
MD	0	0	2	0	1	0	3	7	0	0	3	3	0	0	0	0	1	1	0	1	1	6	0	0	2	0	0	1	0	0	208	MD
ME	44	0	2	0	13	0	2	1	0	0	2	2	0	0	1	0	2	0	0	1	6	6	0	0	11	0	0	0	0	0	0	ME
MK	45	0	2	0	2	0	20	1	0	0	3	2	0	0	1	0	1	0	0	24	3	7	0	0	6	0	0	0	0	0	0	MK
MT	1	0	1	0	1	0	0	0	0	0	1	1	0	0	8	0	13	1	0	1	2	1	0	0	43	0	0	0	0	0	0	MT
NL	0	0	1	0	0	107	0	1	1	0	4	111	2	0	1	0	52	36	0	0	0	1	2	0	1	0	0	0	1	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	3	0	0	2	1	10	0	0	31	28	3	0	0	1	6	3	0	0	2	12	0	0	2	0	0	2	0	1	1	PL
PT	0	0	0	0	0	0	0	0	0	0	0	1	0	0	79	0	5	1	0	0	0	0	0	0	1	0	0	0	0	0	0	PT
RO	1	0	3	0	2	0	11	3	0	0	4	4	0	0	1	0	2	0	0	1	5	26	0	0	4	0	0	0	0	0	6	RO
RS	13	0	7	0	14	0	32	1	0	0	8	5	0	0	1	0	2	1	0	3	27	42	0	0	7	0	0	0	0	0	0	RS
RU	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	RU
SE	0	0	0	0	0	1	0	1	0	0	1	3	5	0	0	2	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	SE
SI	0	0	72	0	2	1	0	1	1	0	12	12	0	0	1	0	4	1	0	0	122	22	0	0	81	0	0	0	0	0	0	SI
SK	0	0	19	0	1	1	2	2	1	0	44	15	1	0	1	0	5	1	0	0	10	127	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	2	2	0	0	0	0	TJ
TM	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	5	0	0	0	0	TM
TR	0	1	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	TR
UA	0	0	1	0	0	0	1	12	0	0	3	3	0	0	0	1	1	1	0	0	1	6	0	0	1	0	1	1	0	1	7	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	12	0	0	0	0	UZ
ATL	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	0	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	ATL
BAS	0	0	0	0	0	1	0	3	0	0	3	13	15	3	0	10	3	5	0	0	0	1	0	0	0	0	0	2	0	4	0	BAS
BLS	0	0	1	0	0	0	5	3	0	0	1	1	0	0	0	0	1	0	8	2	1	2	0	0	1	0	1	0	0	0	3	BLS
MED	4	0	1	0	1	0	2	0	0	0	1	2	0	0	16	0	18	1	0	8	4	2	0	0	44	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	6	0	0	0	0	1	11	4	0	1	0	19	45	0	0	0	0	2	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	3	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	4	0	0	1	0	0	0	0	4	0	0	0	0	0	0	NOA
EXC	1	0	3	0	1	2	3	4	1	0	4	10	1	0	8	2	16	6	1	1	3	5	1	0	14	1	12	1	0	1	1	EXC
EU	1	0	11	0	1	8	11	2	1	0	16	42	3	1	33	6	65	26	0	5	9	19	3	0	59	0	0	2	1	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.14 Cont.: 2016 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	13	34	0	0	0	3	0	3	50	0	0	1	1	0	0	2	1	0	0	0	0	8	0	0	2	0	0	0	778	54	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	37	0	0	0	0	0	0	0	13	0	0	0	0	104	1	AM
AT	0	0	0	1	0	8	0	3	2	0	0	21	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	527	519	AT
AZ	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	11	0	0	0	0	0	0	0	16	0	0	0	0	96	1	AZ
BA	7	0	0	0	0	9	0	5	33	0	0	2	3	0	0	1	1	0	0	0	0	3	0	0	1	0	0	0	399	129	BA
BE	0	0	0	33	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	27	0	0	0	0	0	864	862	BE
BG	0	6	0	0	0	5	0	49	29	2	0	1	2	0	0	21	5	0	0	0	2	3	0	0	1	0	0	0	525	453	BG
BY	0	0	0	0	0	38	0	6	1	11	1	0	2	0	0	1	9	0	0	1	0	0	1	0	0	0	0	0	318	77	BY
CH	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	412	166	CH
CY	0	1	0	0	0	0	0	1	1	1	0	0	0	0	0	80	1	0	0	0	1	26	0	13	5	0	0	0	179	94	CY
CZ	0	0	0	1	0	59	0	4	3	1	0	3	15	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	768	758	CZ
DE	0	0	0	10	0	22	0	1	0	1	1	1	1	0	0	0	0	0	1	1	0	0	6	0	0	0	0	0	541	533	DE
DK	0	0	0	4	3	13	0	0	0	2	9	0	0	0	0	0	0	0	1	11	0	0	9	0	0	0	0	0	287	281	DK
EE	0	0	0	0	1	9	0	1	0	8	4	0	0	0	0	0	1	0	0	7	0	0	1	0	0	0	0	0	126	109	EE
ES	0	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	4	0	0	10	0	0	3	0	0	0	286	286	ES
FI	0	0	0	0	1	2	0	0	0	4	5	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	89	82	FI
FR	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	3	4	0	0	0	0	0	518	513	FR
GB	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	9	0	0	0	0	0	416	415	GB
GE	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	19	0	0	0	0	1	0	0	2	0	0	0	0	201	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	15	0	0	0	2	0	7	11	1	0	0	1	0	0	24	2	0	0	0	1	22	0	0	3	0	0	0	262	193	GR
HR	2	1	0	0	0	11	0	8	31	0	0	28	4	0	0	1	1	0	0	0	0	7	0	0	1	0	0	0	726	643	HR
HU	0	1	0	0	0	29	0	62	34	1	0	14	38	0	0	1	5	0	0	0	0	1	0	0	1	0	0	0	940	887	HU
IE	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	2	0	0	0	0	0	187	186	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	0	0	0	10	2	IS
IT	0	0	0	0	0	2	0	1	1	0	0	8	1	0	0	0	0	0	0	0	0	19	0	0	4	0	0	0	854	846	IT
KG	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6	0	0	0	0	0	12	0	0	0	0	82	0	KG
KZ	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	0	1	1	0	0	0	0	0	9	0	0	0	0	81	1	KZ
LT	0	0	0	1	1	47	0	3	1	13	3	0	1	0	0	0	3	0	0	3	0	0	1	0	0	0	0	0	227	178	LT
LU	0	0	0	6	0	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	722	719	LU
LV	0	0	0	1	1	19	0	2	0	8	4	0	1	0	0	0	2	0	0	4	0	0	1	0	0	0	0	0	192	164	LV
MD	0	0	0	0	0	22	0	128	3	5	0	0	2	0	0	7	36	0	0	0	2	1	0	0	0	0	0	0	446	180	MD
ME	234	2	0	0	0	4	0	3	42	0	0	1	1	0	0	1	1	0	0	0	0	6	0	0	1	0	0	0	383	45	ME
MK	1	496	0	0	0	4	0	7	67	1	0	1	1	0	0	4	1	0	0	0	0	3	0	0	1	0	0	0	700	82	MK
MT	0	0	392	0	0	1	1	1	1	0	0	1	0	0	0	1	0	0	0	0	0	171	0	0	23	0	0	0	475	468	MT
NL	0	0	0	291	0	5	0	0	0	1	1	0	0	0	0	0	0	0	2	1	0	0	45	0	0	0	0	0	621	619	NL
NO	0	0	0	0	29	1	0	0	0	1	2	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	39	9	NO
PL	0	0	0	1	1	437	0	8	2	8	1	1	14	0	0	0	5	0	0	2	0	0	1	0	0	0	0	0	586	559	PL
PT	0	0	0	0	0	0	257	0	0	0	0	0	0	0	0	0	0	0	13	0	0	3	0	0	2	0	0	0	345	345	PT
RO	0	1	0	0	0	12	0	530	21	2	0	1	4	0	0	4	10	0	0	0	1	1	0	0	1	0	0	0	661	610	RO
RS	8	23	0	0	0	11	0	39	517	1	0	2	5	0	0	2	2	0	0	0	0	2	0	0	1	0	0	0	777	194	RS
RU	0	0	0	0	0	2	0	0	0	34	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	49	5	RU
SE	0	0	0	1	5	4	0	0	0	1	34	0	0	0	0	0	0	0	0	3	0	0	1	0	0	0	0	0	63	56	SE
SI	0	0	0	0	0	7	0	4	5	0	0	505	2	0	0	0	1	0	0	0	0	5	0	0	1	0	0	0	859	848	SI
SK	0	1	0	1	0	68	0	24	8	1	0	4	295	0	0	1	5	0	0	0	0	1	0	0	0	0	0	0	645	624	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	26	1	1	0	6	0	0	0	0	0	30	0	0	0	0	38	0	TJ
TM	0	0	0	0	0	0	0	0	0	3	0	0	0	1	19	2	0	5	0	0	0	0	0	17	0	0	0	0	37	1	TM
TR	0	0	0	0	0	1	0	3	1	1	0	0	0	0	0	364	1	0	0	0	1	7	0	10	1	0	0	0	380	10	TR
UA	0	0	0	0	0	24	0	24	1	10	0	0	3	0	0	5	83	0	0	0	2	1	0	0	0	0	0	0	195	74	UA
UZ	0	0	0	0	0	0	0	0	0	3	0	0	0	2	2	1	0	35	0	0	0	0	0	7	0	0	0	0	63	1	UZ
ATL	0	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	7	0	0	0	0	0	1	0	0	0	16	14	ATL
BAS	0	0	0	2	2	23	0	1	0	5	15	0	0	0	0	0	1	0	0	21	0	0	2	0	0	0	0	0	113	101	BAS
BLS	0	0	0	0	0	4	0	22	3	9	0	0	1	0	0	67	15	0	0	0	21	4	0	0	1	0	0	0	153	42	BLS
MED	1	1	1	0	0	1	1	2	2	1	0	1	0	0	0	24	1	0	1	0	0	68	0	5	20	0	0	0	142	106	MED
NOS	0	0	0	7	5	3	0	0	0	0	1	0	0	0	0	0	0	0	3	1	0	0	26	0	0	0	0	0	108	102	NOS
AST	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	7	0	0	0	0	0	1	0	423	1	0	0	0	14	1	AST
NOA	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	2	0	0	2	0	0	10	0	1	98	0	0	0	24	20	NOA
EXC	0	1	0	1	1	11	2	9	4	16	1	1	2	0	1	17	4	1	0	0	0	1	1	3	0	0	0	0	175	107	EXC
EU	0	1	0	4	1	39	7	33	4	2	4	4	6	0	0	2	2	0	2	1	0	4	3	0	1	0	0	0	434	418	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: 2016 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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AL
AM	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-0	0	0	0	0	0	0	0	AM
AT	0	0	4	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	AT
AZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AZ
BA	0	0	0	0	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BA
BE	0	0	0	0	0	7	0	0	0	0	0	3	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	BE
BG	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	0	0	0	BG
BY	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	0	0	0	0	BY
CH	0	0	0	0	0	0	0	0	23	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CH
CY	0	0	0	0	0	0	0	0	0	1	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	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	CZ
DE	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0	1	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	1	3	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	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EE
ES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	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	0	0	0	1	0	0	0	0	3	1	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	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	GB
GE	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	-0	0	0	0	0	0	0	0	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	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	GR
HR	0	0	0	0	4	0	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	HR
HU	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	HU
IE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	IS
IT	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	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	1	0	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	LT
LU	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	9	0	0	LU
LV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	MD
ME	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	ME
MK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MK
MT	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MT
NL	0	0	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	NL
NO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NO
PL	0	0	0	0	0	0	0	0	0	0	0	1	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	PT
RO	0	0	0	0	0	0	0	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	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	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	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	SI
SK	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	0	0	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	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	0	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	0	0	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BAS
BLS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	BLS
MED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	MED
NOS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	NOA
EXC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	EXC
EU	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	EU
	AL	AM	AT	AZ	BA	BE	BG	BY	CH	CY	CZ	DE	DK	EE	ES	FI	FR	GB	GE	GR	HR	HU	IE	IS	IT	KG	KZ	LT	LU	LV	MD	

Table C.15 Cont.: 2016 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	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	2	1	AL
AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	4	0	0	0	0	9	0	AM
AT	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	AT
AZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	7	0	0	0	0	1	0	AZ
BA	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	34	2	BA
BE	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	0	14	14	BE
BG	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	5	3	BG
BY	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	7	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	25	2	CH
CY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	0	0	2	0	4	1	0	0	0	10	1	CY
CZ	0	0	0	0	0	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	17	CZ
DE	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	21	20	DE
DK	0	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	7	7	DK
EE	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	3	3	EE
ES	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	2	2	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	5	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	5	5	FR
GB	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	30	30	GB
GE	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	4	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	0	0	0	0	0	7	4	GR
HR	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	0	0	0	10	6	HR
HU	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	9	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	4	4	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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	4	4	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	3	0	0	0	0	2	0	KG
KZ	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	3	0	KZ
LT	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	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	17	17	LU
LV	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	LV
MD	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	6	4	MD
ME	1	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	3	1	ME
MK	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	MK
MT	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17	0	0	2	0	0	0	25	24	MT
NL	0	0	0	5	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	14	14	NL
NO	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	NO
PL	0	0	0	0	0	86	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	88	88	PL
PT	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	3	3	PT
RO	0	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	4	3	RO
RS	0	0	0	0	0	1	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	2	RS
RU	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	RU
SE	0	0	0	0	0	1	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	SE
SI	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7	SI
SK	0	0	0	0	0	12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	14	SK
TJ	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	7	0	0	0	0	2	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	6	0	0	0	0	1	0	TM
TR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	1	0	3	0	0	0	0	51	0	TR
UA	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	7	4	UA
UZ	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1	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	ATL
BAS	0	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	7	7	BAS
BLS	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	8	0	0	0	0	1	0	0	0	0	0	0	0	10	1	BLS
MED	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	6	0	2	3	0	0	0	4	1	MED
NOS	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	5	4	NOS
AST	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	169	0	0	0	0	1	0	AST
NOA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	18	0	0	0	0	0	NOA
EXC	0	0	0	0	0	2	0	0	0	3	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	0	9	4	EXC
EU	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	14	EU
	ME	MK	MT	NL	NO	PL	PT	RO	RS	RU	SE	SI	SK	TJ	TM	TR	UA	UZ	ATL	BAS	BLS	MED	NOS	AST	NOA	BIC	DMS	VOL	EXC	EU	

APPENDIX D

Explanatory note on country reports for 2016

The country reports issued by EMEP MSC-W focus on chemical species that are relevant to eutrophication, acidification and ground level ozone, but also information on particulate matter is given. More specifically, these country reports provide for each country:

- horizontal maps of emissions, and modelled air concentrations and depositions in 2016
- emission trends for the years 2000 to 2016
- modelled trends of air concentrations and depositions for the years 2000 to 2016
- maps and charts on transboundary air pollution in 2016, 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 2016, along with a statistical analysis of model performance
- scatter plots for different species, including available stations within the country
- maps on the risk of damage from ozone and particulate matter in 2016

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 the territory of the Russian Federation, which is covered by the extended 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 `http://emep.int/mscw/mscw_publications.html`

This year, the country reports are found under the header ’MSC-W Data Note 1/2018’. The reports for each country can be selected conveniently from a drop-down menu.

APPENDIX E

Model Evaluation

The EMEP MSC-W model is regularly evaluated against various kinds of measurements, including ground-based, airborne and satellite measurements. As the main application of the EMEP MSC-W model within the LRTAP Convention is to assess the status of air quality on regional scales and to quantify long-range transboundary air pollution, the focus of the evaluation performed for the EMEP status reports is on the EMEP measurement sites.

Only parts of this evaluation are included in the printed version of the EMEP status report (see Chapter 2). A more comprehensive collection of maps, graphs and statistical analyses, including a more detailed discussion of model performance, are freely available as supplementary material from the MSC-W report page on the EMEP website `http://emep.int/mscw/mscw_publications.html`

This year, the evaluation report is found under the link 'Supplementary material to EMEP Status Report 1/2018'. It contains a comprehensive evaluation of the EMEP MSC-W model for air concentrations and depositions in 2016. The report is divided into three chapters, dealing with pollutants responsible for eutrophication and acidification (Gauss et al. 2018b), ground level ozone and nitrogen dioxide (Gauss et al. 2018a), and particulate matter (Tsyro et al. 2018), respectively.

The agreement between model and measurements in 2016 is visualized as:

- scatter plots for the EMEP MSC-W model domain
- time series for individual EMEP stations
- horizontal maps combining model results and EMEP measurement data

Tables summarize common statistical measures of model score, such as bias, root mean square error, temporal and spatial correlations and the index of agreement (see Chapter 1).

This type of model evaluation is performed on an annual basis and can be downloaded from the same web page also for previous years.

References

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Tsyro, S., Gauss, M., Hjellbrekke, A.-G., and Aas, W.: PM10, PM2.5 and individual aerosol components, Supplementary material to EMEP Status Report 1/2018, available online at www.emep.int, The Norwegian Meteorological Institute, Oslo, Norway, 2018.

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Modelled (red) and observed (blue) annual time series of air concentrations of total reduced nitrogen from 2000 to 2016 (25 and 75 percentiles are shown as shaded areas)

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