MSC-W Data Note 1/2005
Date: August 2005

METEOROLOGISK INSTITUTT
Norwegian Meteorological Institute

Transboundary air pollution by main pollutants (S, N, O_3) and PM

Spain

EMEP/MSC-W: Heiko Klein, Peter Wind, Maarten van Loon

Data Note 2005

ISSN 0804-2446

Contents

1 Introduction

This note is one of a series of country-specific reports, complementary to the EMEP Status Report 1/2005. It presents overview information on transboundary pollution of main pollutants, ground level ozone and PM relevant for Spain.

The transboundary contributions are based on source-receptor calculations using meteorological and emission data for the year 2003. These source-receptor calculations are based on the same version of the EMEP Unified Model as presented in the main report (rv 2.0.10).

Emissions The emissions for 2003 have been derived from the 2005 data submissions. The gridded distributions of 2003 emissions have been derived by scaling with respect to gridded data distributions in year 2000 (Base 2000 V5). The gridded emission data for 2003 will be available on `http://webdab.emep.int` in autumn 2005.

Trends The deposition data used for trends derive from different model versions.

- 1980 - 2000: Model rv 1.6.11. Data used in 2003 for the EMEP Assessment Report: `http://www.emep.int/index_assessment.html`
- 2001, 2002: Model rv 2.0beta. Data used for Country reports in 2004.
- 2003: Model rv 2.0.10. Data used throughout this report.

The emission data used for trends varies depending on the above mentioned model versions.

Transboundary data The data for the maps, pie and bar charts is generated by source-receptor calculations, where emissions for each emitter of one or more precursors are reduced by 15%. For oxidised sulphur, oxidised nitrogen and reduced nitrogen, the results have been scaled to present data corresponding to all emissions from a emitter. Due to non-linear effects, this is not possible for the other components.

The pie charts for depositions and PM give a picture of the relative contributions of the countries or regions to depositions over Spain.

For the O_3 related indicators bar charts are used because in some cases the effect of a reduction of emissions from a country can either increase or decrease O_3 levels elsewhere. The values in the bar charts for ozone indicators show the six most important contributors to AOT40 and SOMO35 in Spain. Since the contributions can be both positive or negative, the relative importance of the contributors has been determined by comparing the absolute value of the contributions.

BIC as used here includes anyway compounds which have undergone important changes due to man-made emissions, such as NO_x, CH_4 and CO. When reducing SO_x ”emissions” from BIC, the values of the boundary and initial conditions of both SO_2 and SO_4 are reduced. Similarly, for reducing NO_x ”emissions” all compounds containing nitrogen oxidized are reduced and for reducing NH_3 ”emissions” particulate ammonium is reduced, since boundary and initial conditions for NH_3 itself are zero. For NMVOC simply all boundary and initial conditions for the NMVOC species in the model are reduced. Ozone is excluded from BIC for these runs because of its special importance and known high contribution to indices such as AOT40 and SOMO35.

To give more intuitive pictures on the effect of pollution from a given country, we use positive scales for pollution reductions throughout this note.

Comparison with Observation The map of monitoring stations shows all stations of Spain in the EMEP measurement network. Not all stations have measured data in 2003. The frequency analysis plot compare 2003 observation results with the model results. The measurement data is available from CCC: `http://www.nilu.no/projects/ccc/emepdata.html`.

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

Country Codes

Many tables and graphs in this report make use of codes to denote countries and regions in the EMEP area. Table 1 provides an overview of these codes and lists the countries and regions included in the present 2003 source-receptor calculations.

Code	Country/Region	Code	Country/Region
AL	Albania	HR	Croatia
AM	Armenia	HU	Hungary
ASI	Remaining Asian areas	IE	Ireland
AT	Austria	IS	Iceland
ATL	Remaining N.E. Atlantic Ocean	IT	Italy
AZ	Azerbaijan	KZ	Kazakhstan
BA	Bosnia and Herzegovina	LT	Lithuania
BAS	Baltic Sea	LU	Luxembourg
BE	Belgium	LV	Latvia
BG	Bulgaria	MD	Republic of Moldova
BIC	Boundary and Initial Conditions	MED	Mediterranean Sea
BLS	Black Sea	MK	The FYR of Macedonia
BY	Belarus	MT	Malta
CH	Switzerland	NAT	Natural marine emissions
CS	Serbia and Montenegro	NL	Netherlands
CY	Cyprus	NO	Norway
CZ	Czech Republic	NOA	North Africa
DE	Germany	NOS	North Sea
DK	Denmark	PL	Poland
EE	Estonia	PT	Portugal
EMC	Land Areas	RO	Romania
ES	Spain	RU	Russian Federation
EU	European Community	SE	Sweden
FI	Finland	SI	Slovenia
FR	France	SK	Slovakia
GB	United Kingdom	TR	Turkey
GE	Georgia	UA	Ukraine
GL	Greenland	VOL	Volcanic emissions
GR	Greece		

Table 1: Country/Region codes used in the source-receptor calculations

Russian Federation means the part of the Russian Federation inside the EMEP domain of calculations. The same applies to the Remaining N.E. Atlantic region and natural marine emission area. North Africa and Asia refer to parts of them within the model domain. For North Africa this concerns parts of Morocco, Algeria, Tunisia, Libya and Egypt. With respect to Asia it includes Syria, Lebanon, Israel, parts of Uzbekistan, Turkmenistan, Iran, Iraq and Jordan. The European Union includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, The Netherlands, Portugal, Spain, Sweden, United Kingdom, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. BIC is boundary and initial, excluding ozone.

2 Definitions, statistics used

The following definitions and acronyms are used throughout this note:

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

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

$PM_{2.5}$ denotes fine particulate matter, defined as the integrated mass of aerosol with diameter up to 2.5 μm. In the Unified EMEP model $PM_{2.5}$ is calculated as the sum: $PM_{2.5}$ = SO_4^{2-} + NO_3^-(fine) + NH_4^+ + $PPM_{2.5}$

PM_{10} denotes particulate matter, defined as the integrated mass of aerosol with diameter up to 10 μm. In the Unified EMEP model PM_{10} is calculated as the sum: PM_{10} = $PM_{2.5}$ + NO_3^-(coarse) + PPM_{co}

SOMO35 - The Sum of Ozone Means Over 35 ppb is the new 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 ensures that only A_8^d values exceeding 35 ppb are included. The corresponding unit is ppb·days (abbreviated also as ppb·d).

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

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

where the $\max$ function ensures that only ozone values exceeding 40 ppb are included. The integral is taken over time, namely the relevant growing season for the vegetation concerned, and for daytime only. The corresponding unit are ppb·hours (abbreviated to ppb·h).

Although the EMEP model now generates a number of AOT-related outputs, these country reports present results for three "practical" definitions:

$\mathbf{AOT40}_f^{\mathbf{3m}}$ - AOT40 calculated over April-September from O_3 concentrations at 3 m height. This AOT40 is close to that derived from measurements. (Technically, the 3 m is above the displacement height, and so close to the top of a forest canopy, but well above a crop canopy).

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

$\mathbf{AOT40}_c^{\mathbf{uc}}$ - 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 the UNECE Mapping Manual, but using a default growing season of May-July, and a default crop-height of 1 m.

3 Emissions

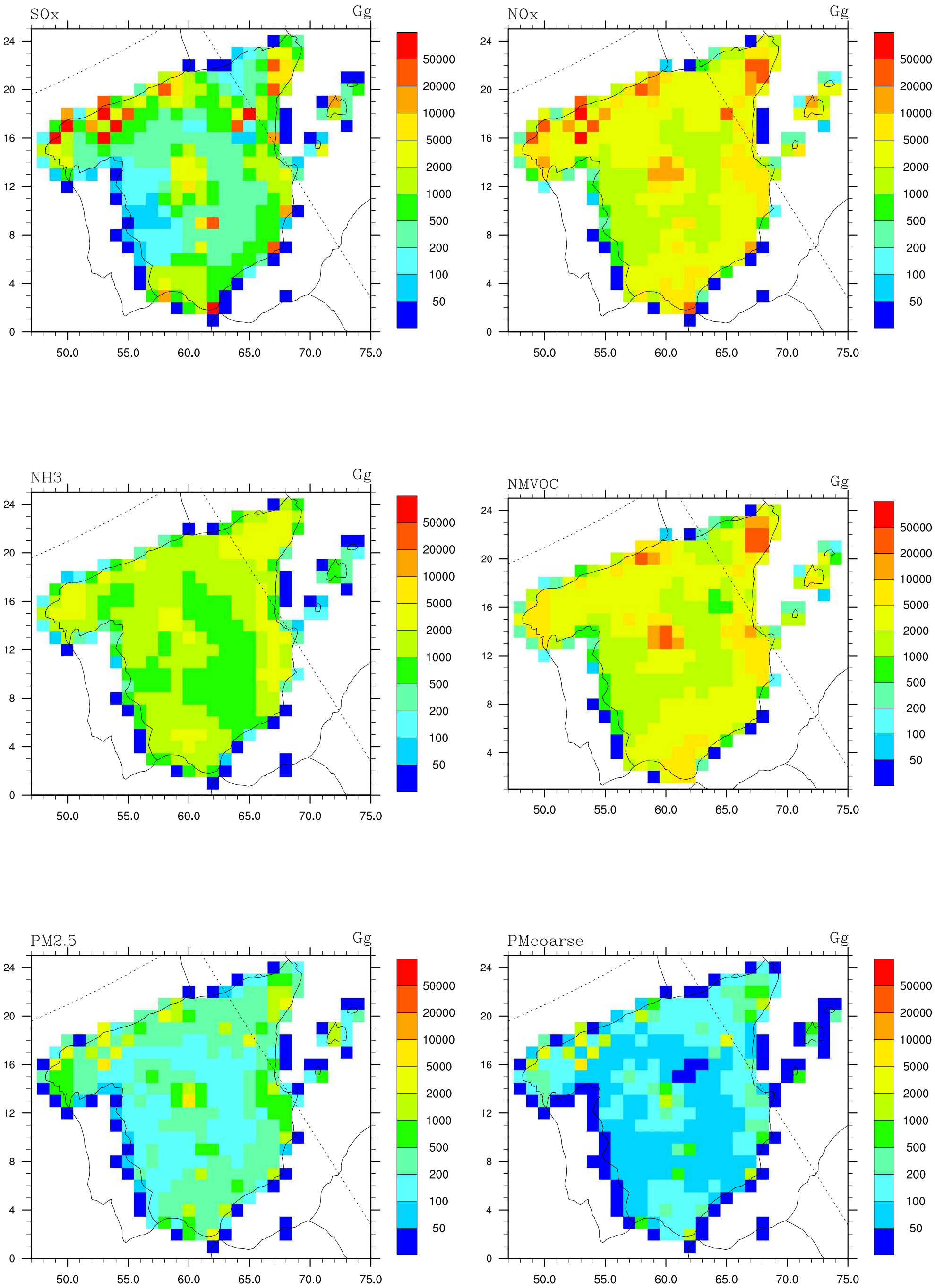


Figure 1: Spatial distribution of emissions from Spain in 2003.

4 Trends

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
SO_x	3013	2526	2167	1808	1577	1716	1601	1606	1488	1433	1507	1353
NO_x	1141	1045	1281	1357	1300	1332	1327	1314	1333	1305	1339	1411
NH_3	396	420	472	467	517	502	488	368	386	380	379	396
NMVOC	2279	2303	2511	2431	2394	2416	2462	1532	1496	1477	1459	1098
CO	3776	3549	3986	3569	3518	3359	3342	2876	2774	2743	2623	2285
$PM_{2.5}$								147	147	148	145	140

Table 2: Emissions from Spain for different years. Units: Gg.

	1980	1985	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003
S dep.	538	450	416	320	320	335	287	280	256	249	278	260
oxN dep.	169	161	200	176	180	184	165	168	153	170	182	178
redN dep.	172	187	204	181	218	215	187	182	163	163	176	180

Table 3: Estimated deposition of Sulphur(S) and Nitrogen(N) in Spain in 2003. Units: Gg(S) or Gg(N).

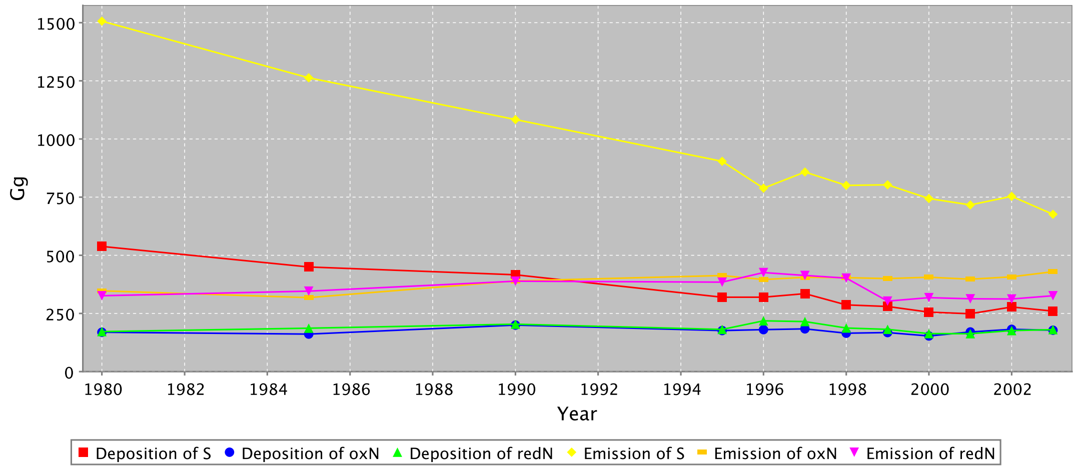


Figure 2: Trends in emissions and depositions of oxidised sulphur and the sum of oxidised and reduced nitrogen. Units: Gg(S) or Gg (N).

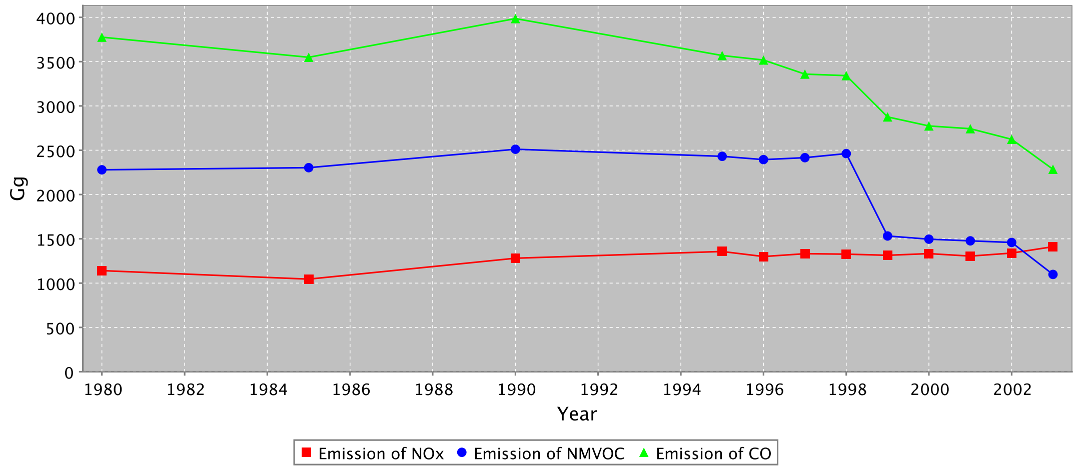


Figure 3: Trends in emissions of photo-oxidant pollution precursors. Units: Gg (note then that NO_x is here as NO_2).

5 Transboundary Fluxes in 2003

5.1 Oxidised sulphur deposition

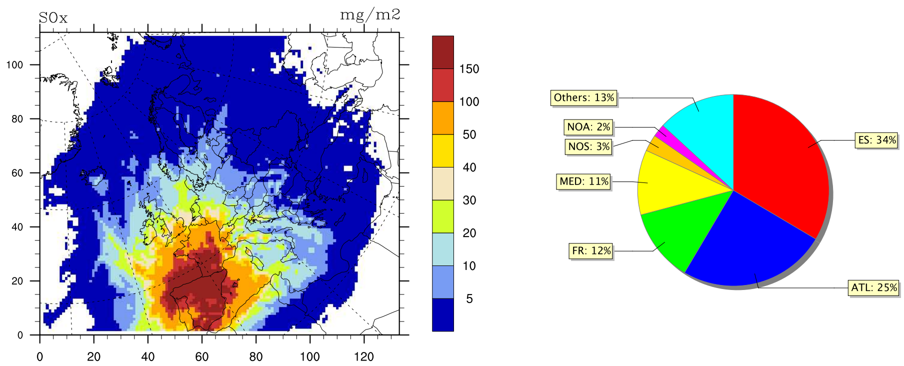


Figure 4: Contribution of emissions from Spain to oxidised sulphur deposition in the EMEP domain. Units: mg(S)/m^2. The pie chart shows the six main receptor areas of oxidised sulphur deposition from Spain. Units: (%).

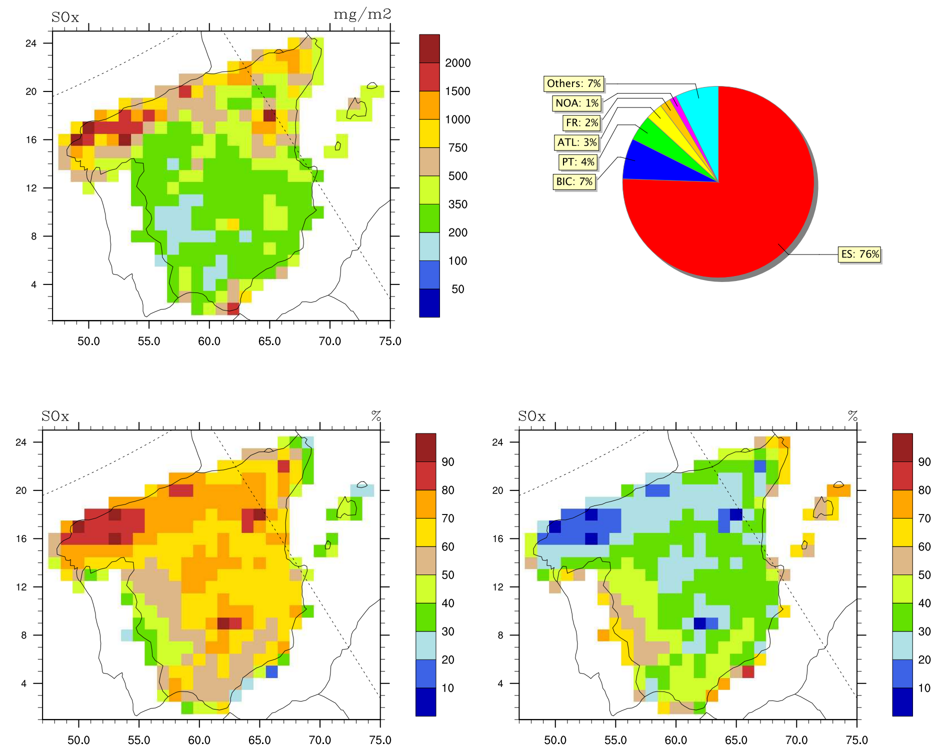


Figure 5: Oxidised sulphur deposition in Spain from: all countries (top left figure). Units: mg(S)/m^2. The pie chart shows the six main contributors to oxidised sulphur deposition in Spain. Units: (%). Fraction of sulphur deposition from indigenous deposition (lower left); and from others, transboundary contribution (lower right). Units: (%)

5.2 Oxidised nitrogen deposition

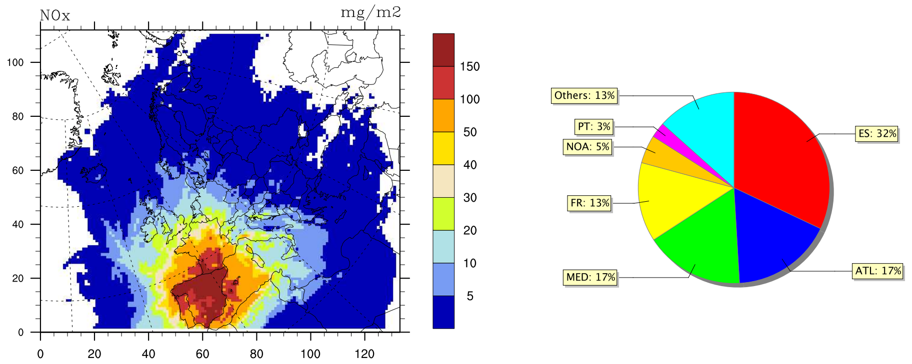


Figure 6: Contribution of emissions from Spain to oxidised nitrogen deposition in the EMEP domain. Units: mg(N)/m^2. The pie chart shows the six main receptor areas of oxidised nitrogen deposition from Spain. Units: (%).

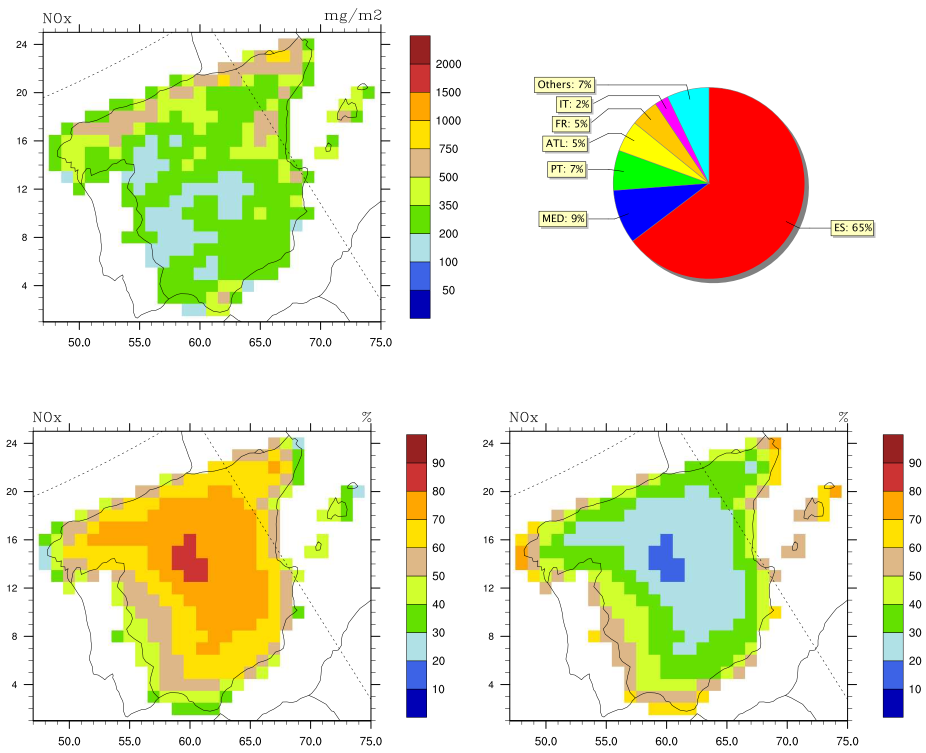


Figure 7: Oxidised nitrogen deposition in Spain from: all countries (top left figure). Units: mg(N)/m^2. The pie chart shows the six main contributors to oxidised nitrogen deposition in Spain. Units: (%). Fraction of oxidised nitrogen deposition from indigenous deposition (lower left); and from others, transboundary contribution (lower right). Units: (%)

5.3 Reduced nitrogen deposition

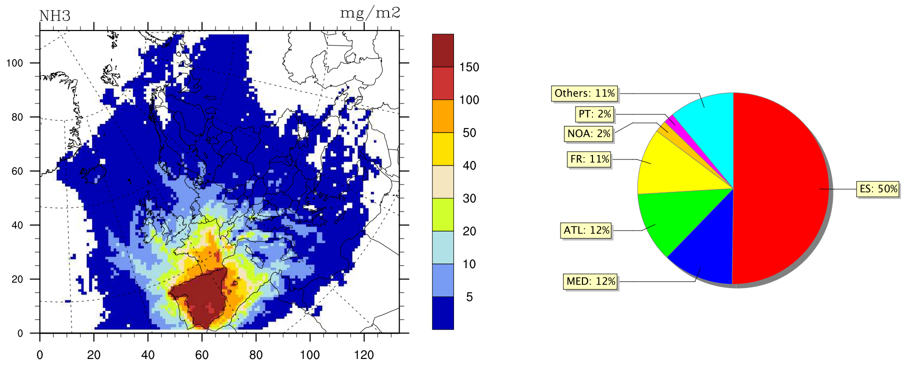


Figure 8: Contribution of emissions from Spain to reduced nitrogen deposition in the EMEP domain. Units: $mg(N)/m^2$. The pie chart shows the six main receptor areas of reduced nitrogen deposition from Spain. Units: (%).

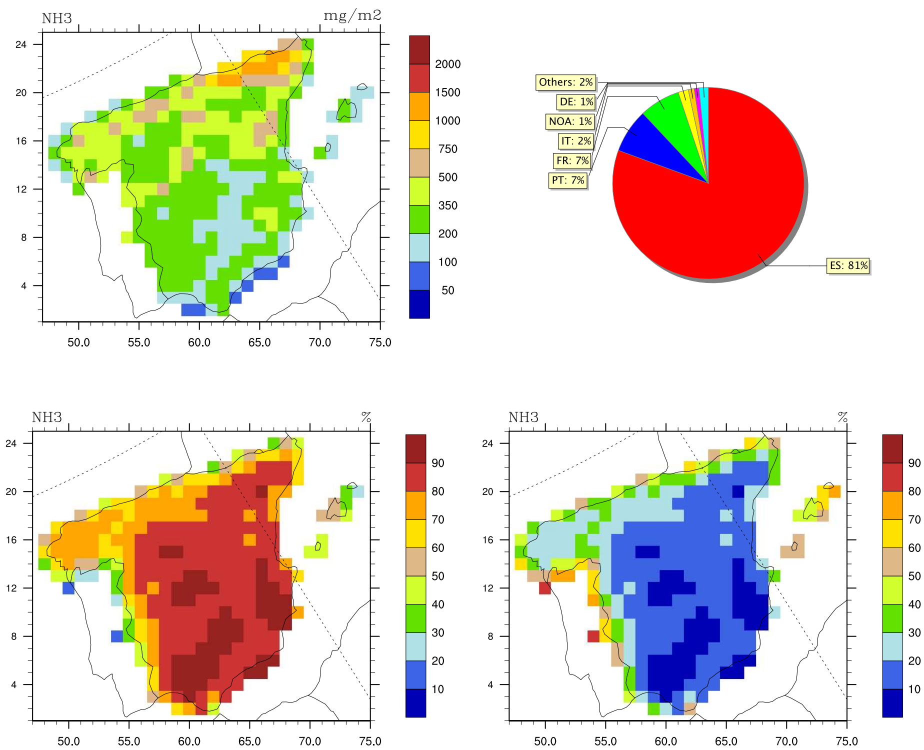


Figure 9: Reduced nitrogen deposition in Spain from: all countries (top left figure). Units: $mg(N)/m^2$. The pie chart shows the six main contributors to reduced nitrogen deposition in Spain. Units: (%). Fraction of reduced nitrogen deposition from indigenous deposition (lower left); and from others, transboundary contribution (lower right). Units: (%)

6 Transboundary ozone concentrations

6.1 $AOT40_f^{3m}$

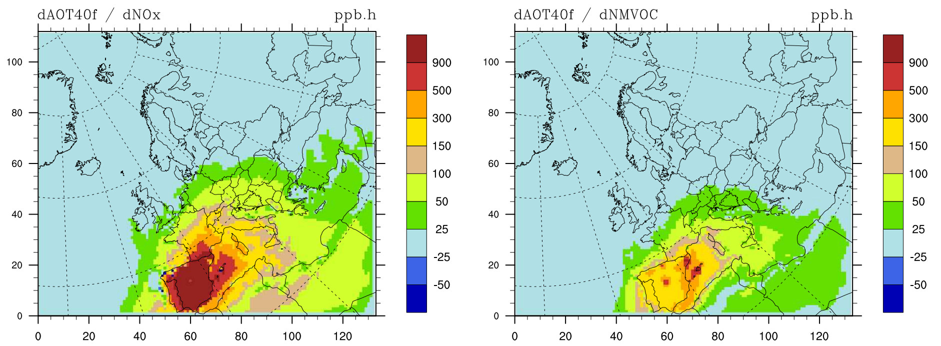


Figure 10: Change in $AOT40_f^{3m}$ due to 15% change in NO_x(left) and NMVOC (right) emission reductions from Spain. Units: ppb·h

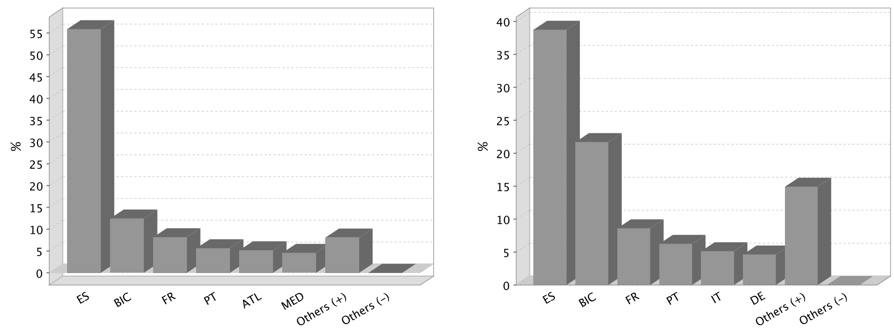


Figure 11: Six most important contributors to $AOT40_f^{3m}$ in Spain by NO_x(left) and NMVOC (right) emission changes (15% reduction). Units: (%)

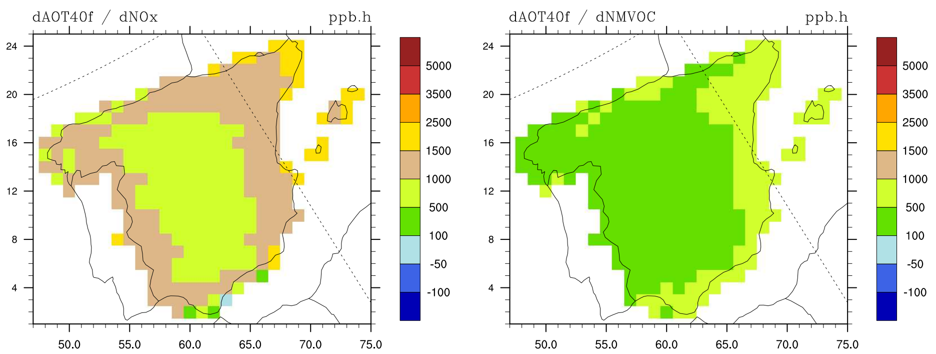


Figure 12: Change in $AOT40_f^{3m}$ due to 15% change in NO_x (left) and NMVOC emission reductions (right) from others, transboundary contribution. Units: ppb·h

6.2 SOMO35 – Risk of ozone damages in human health

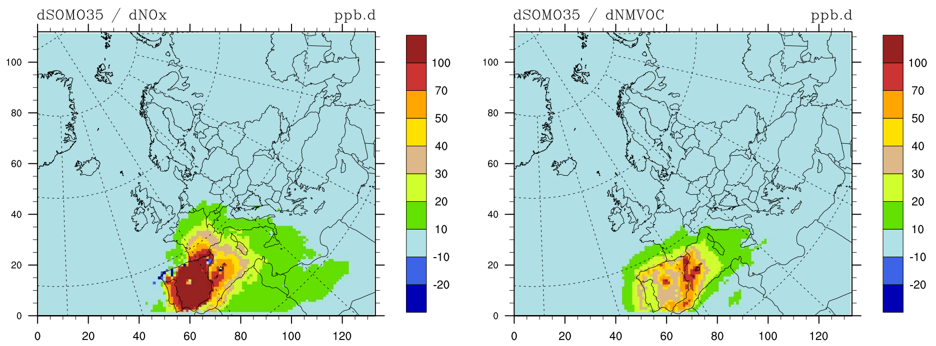


Figure 13: Change in SOMO35 due to 15% change in NO_x(left) and NMVOC (right) emission reductions from Spain. Units: ppb·day

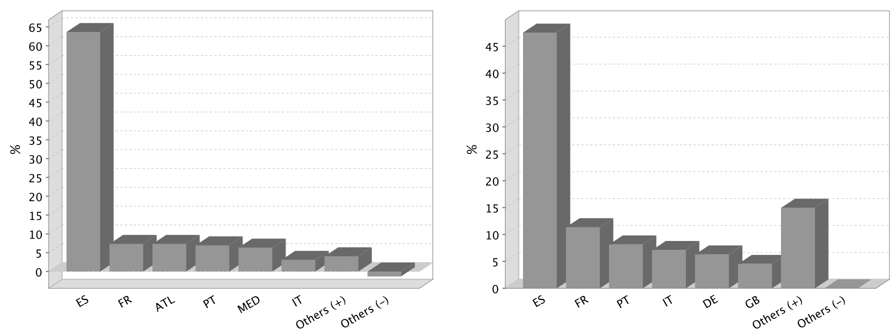


Figure 14: Six most important contributors to SOMO35 in Spain by NO_x(left) and NMVOC (right) emissions (15% reduction)

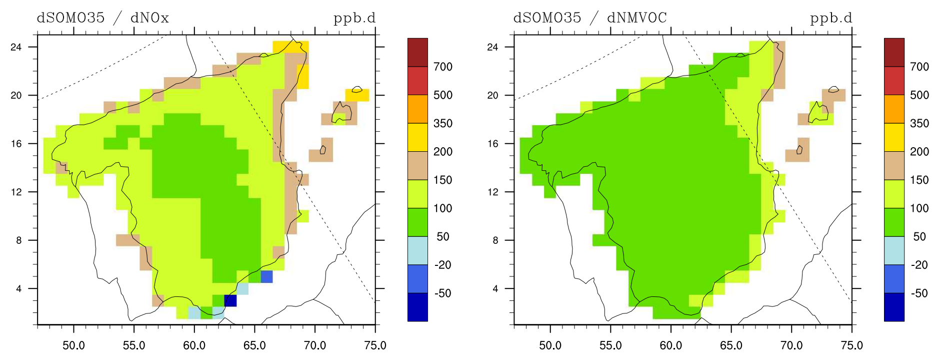


Figure 15: Change in SOMO35 due to 15% change in NO_x (left) and NMVOC emission reductions (right) from others, transboundary contribution. Units: ppb·day

7 Transboundary concentrations of particulate matter

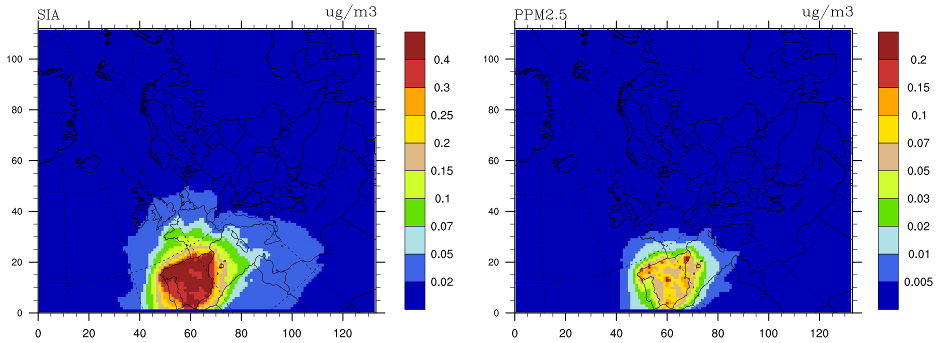


Figure 16: Changes in SIA and PPM2.5 concentrations due to 15% emission reduction from Spain. Units: μg/m^3

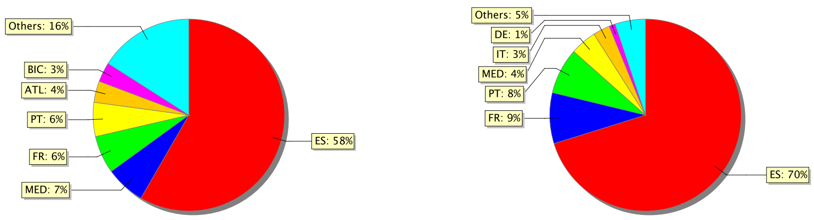


Figure 17: Main contributors to SIA (left) and PPM2.5 (right) concentrations in Spain. Units: (%)

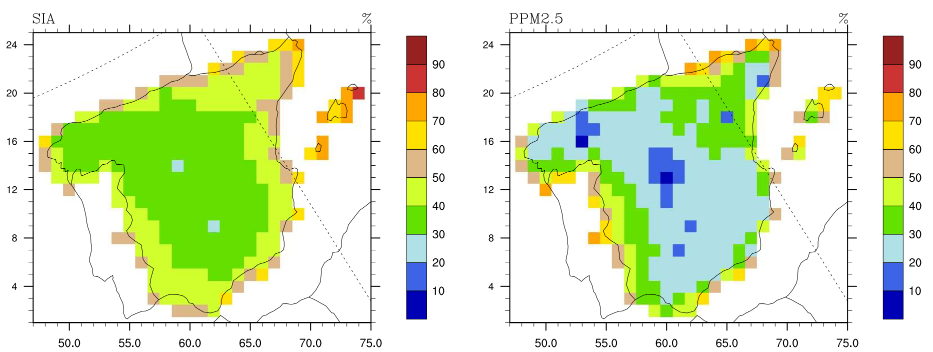


Figure 18: Changes in SIA and PPM2.5 concentrations in Spain due to 15% emission reductions from other countries, transboundary contribution. Units: (%)

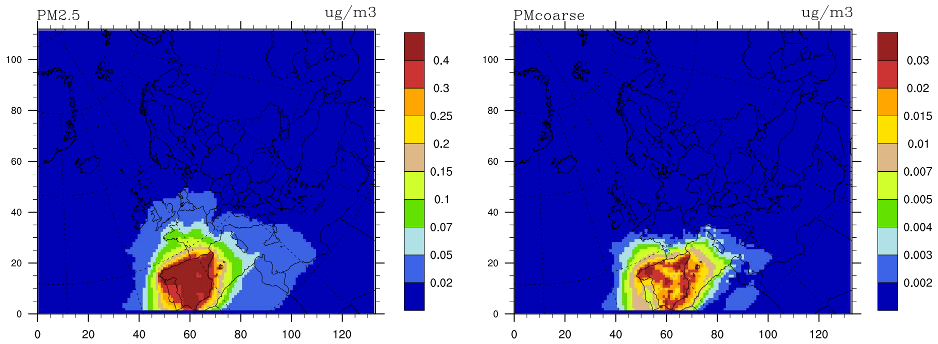


Figure 19: Changes in PM2.5 and PMcoarse concentrations due to 15% emission reduction from Spain. Units: μg/m^3

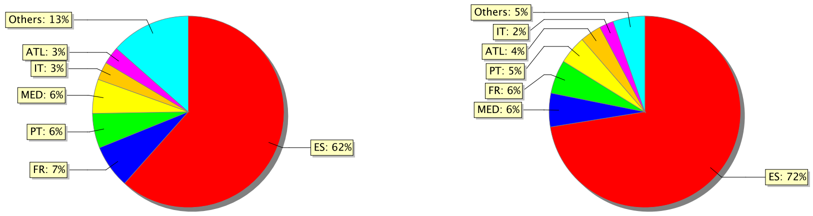


Figure 20: Main contributors to PM2.5 (left) and PMcoarse (right) concentrations in Spain. Units: (%)

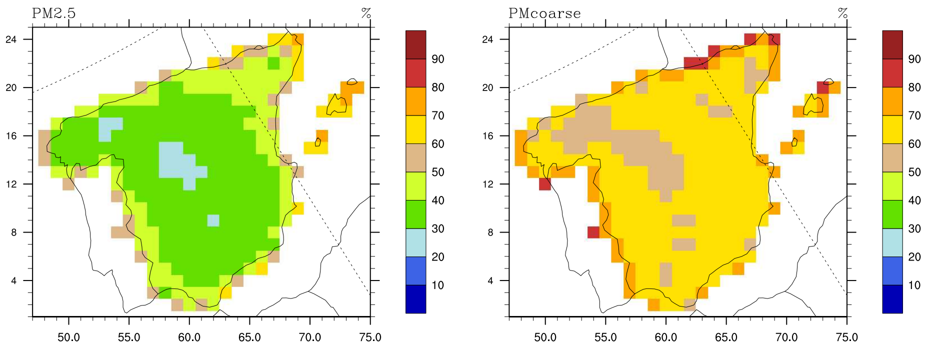


Figure 21: Changes in PM2.5 and PMcoarse concentrations in Spain due to 15% emission reductions from other countries, transboundary contribution. Units: (%)

8 Comparison with Observations

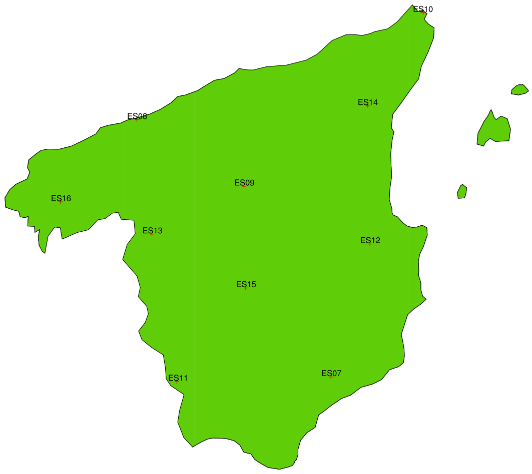


Figure 22: Location of stations in Spain

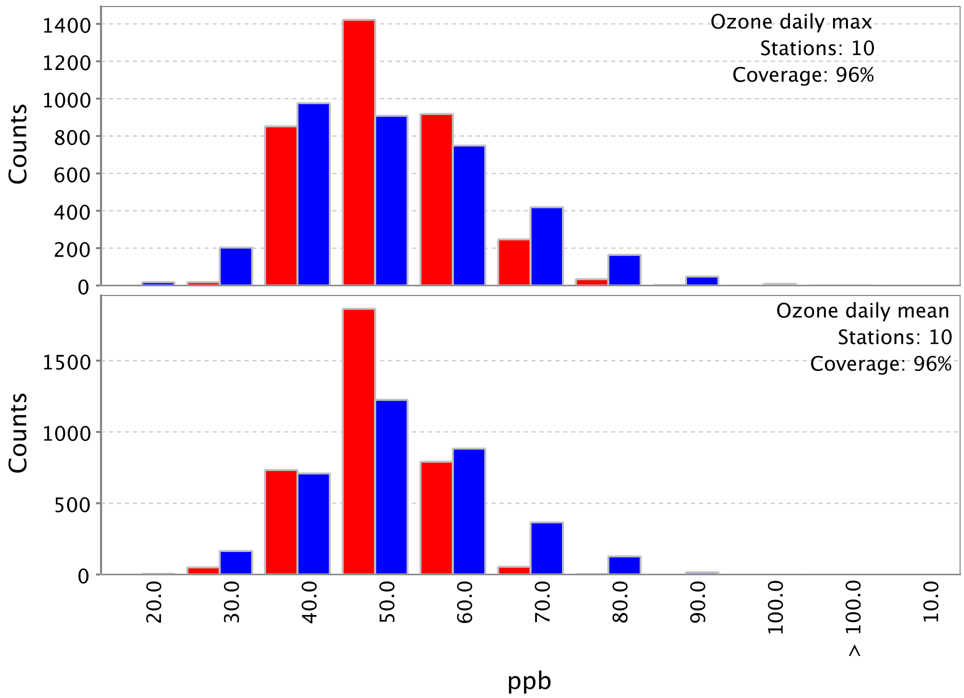


Figure 23: Frequency analysis of ozone in Spain at the stations that reported O_3 in 2003 (Model, Observations)

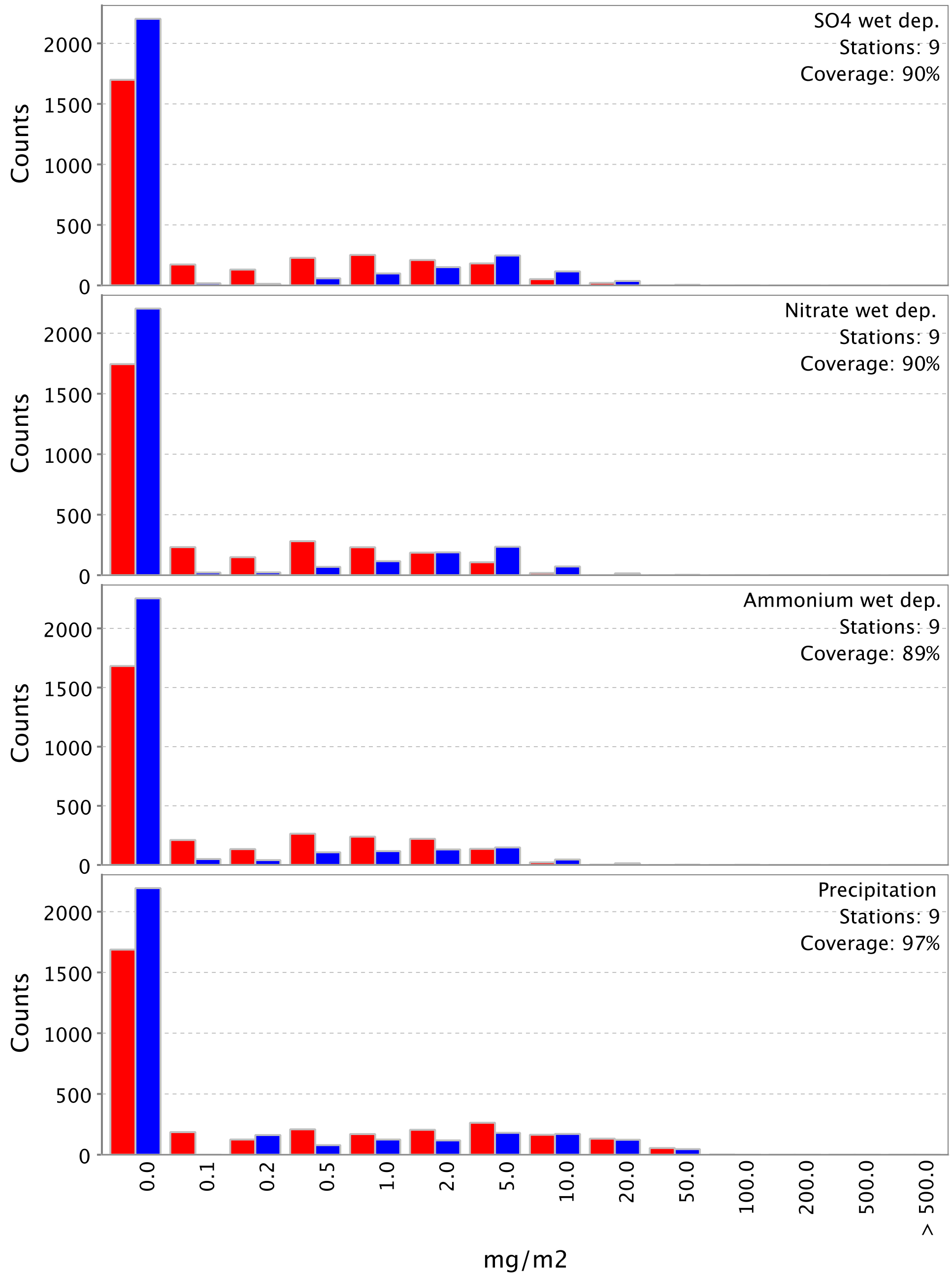


Figure 24: Frequency analysis of depositions in precipitation in Spain (Model, Observations)

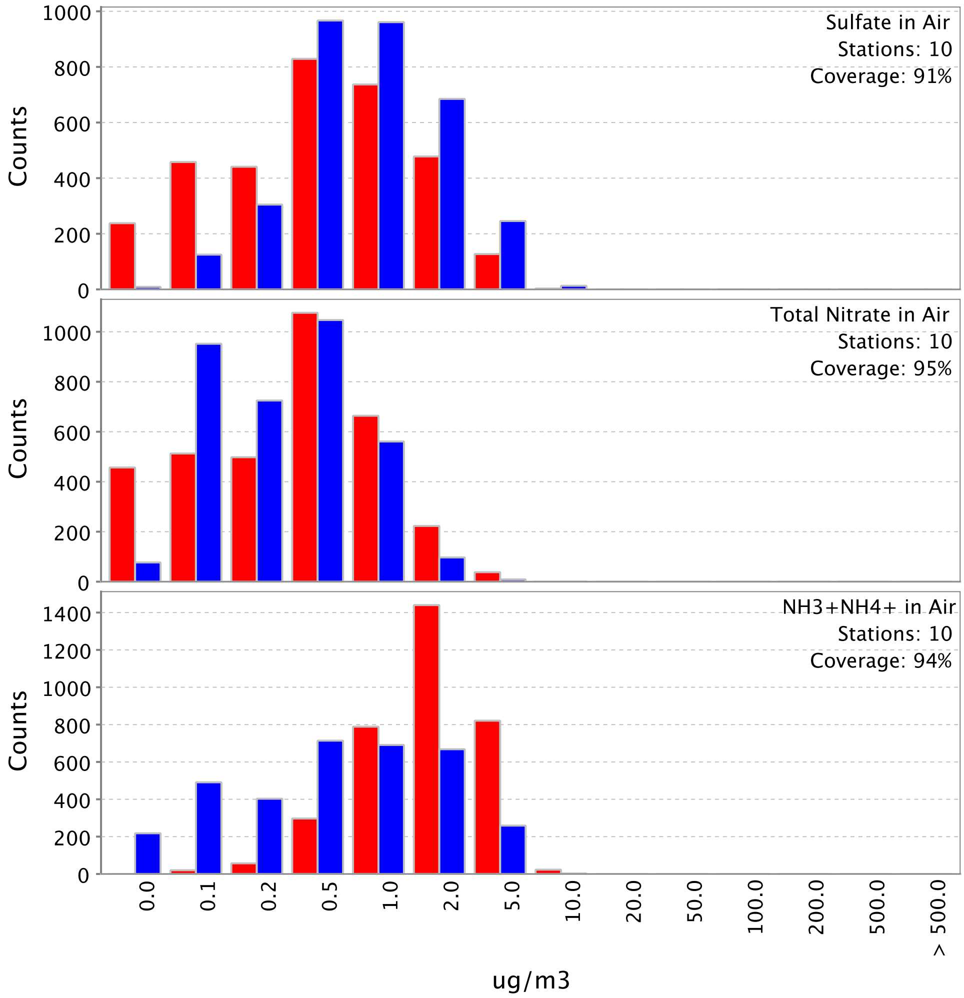
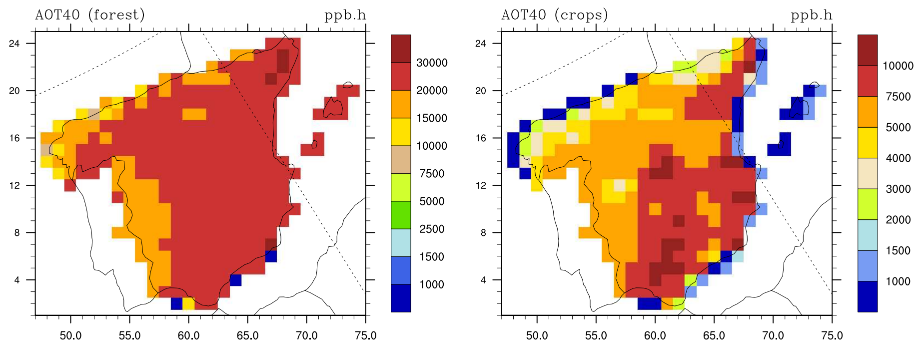


Figure 25: Frequency analysis of air concentrations in Spain (Model, Observations)

9 Risks from Ozone and PM in Spain in 2003

9.1 Ecosystem-specific AOT40 values



(a) $AOT40_f^{uc}$(growing season: April-September): The critical level for forest damage is 5000 ppb·h.

(b) $AOT40_c^{uc}$(growing season: May-July): The critical level for agricultural crops is 3000 ppb·h.

Figure 26: $AOT40_f^{uc}$ and $AOT40_c^{uc}$ in Spain in 2003.

9.2 Health impacts from Ozone and PM

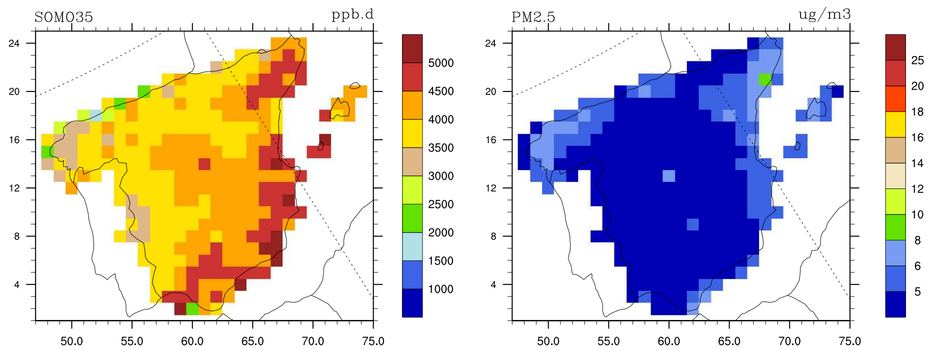
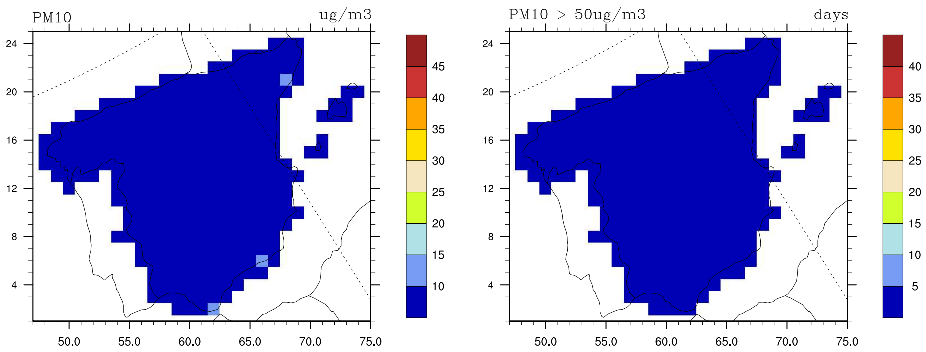


Figure 27: SOMO35 and $PM_{2.5}$ in Spain in 2003.

9.3 Regional PM_{10} values



(a) Daily mean of PM_{10}: The EU limit leve is $40\mu g/m^3$.

(b) Days with $PM_{10} > 50\mu g/m^3$. The EU limit number is 35 days.

Figure 28: PM_{10} in Spain in 2003