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

Slovenia

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

Data Note 2005
ISSN 0804-2446
## Contents

1 Introduction .................................................. 5
2 Definitions, statistics used ................................. 8
3 Emissions ..................................................... 10
4 Trends .......................................................... 11
5 Transboundary Fluxes in 2003 .............................. 12
   5.1 Oxidised sulphur deposition .......................... 12
   5.2 Oxidised nitrogen deposition .......................... 13
   5.3 Reduced nitrogen deposition .......................... 14
6 Transboundary ozone concentrations ...................... 15
   6.1 AOT40$^{3m}$ .............................................. 15
   6.2 SOMO35 – Risk of ozone damages in human health 16
7 Transboundary concentrations of particulate matter .... 17
8 Comparison with Observations .............................. 19
9 Risks from Ozone and PM in Slovenia in 2003 .......... 22
   9.1 Ecosystem-specific AOT40 values ...................... 22
   9.2 Health impacts from Ozone and PM .................... 22
   9.3 Regional PM$_{10}$ values ............................... 23
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 Slovenia.

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.

- 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 Slovenia.

For the O\textsubscript{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\textsubscript{3} levels elsewhere. The values in the bar charts for ozone indicators show the six most important contributors to AOT\textsubscript{40} and SOMO\textsubscript{35} in Slovenia. 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\textsubscript{x}, CH\textsubscript{4} and CO. When reducing SO\textsubscript{x} "emissions" from BIC, the values of the boundary and initial conditions of both SO\textsubscript{2} and SO\textsubscript{4} are reduced. Similarly, for reducing NO\textsubscript{x} "emissions" all compounds containing nitrogen oxidized are reduced and for reducing NH\textsubscript{3} "emissions" particulate ammonium is reduced, since boundary and initial conditions for NH\textsubscript{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 Slovenia 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](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.

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

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:

\[ SIA = SO_4^{2-} + NO_3^- \text{(fine)} + NO_3^- \text{(coarse)} + NH_4^+ \]

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 $\mu$m and coarse primary particulate matter, PPM$_{co}$ with aerosol diameters between 2.5$\mu$m and 10$\mu$m.

PM$_{2.5}$ denotes fine particulate matter, defined as the integrated mass of aerosol with diameter up to 2.5 $\mu$m. In the Unified EMEP model PM$_{2.5}$ is calculated as the sum:

\[ PM_{2.5} = SO_4^{2-} + NO_3^- \text{(fine)} + NH_4^+ + PPM_{2.5} \]

PM$_{10}$ denotes particulate matter, defined as the integrated mass of aerosol with diameter up to 10 $\mu$m. In the Unified EMEP model PM$_{10}$ is calculated as the sum:

\[ PM_{10} = PM_{2.5} + NO_3^- \text{(coarse)} + PPM_{co} \]

SOMO$_{35}$ - 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 SOMO$_{35}$ can be defined as:

\[ SOMO_{35} = \sum_{d=1}^{d=N_y} \max(A_8^d - 35 \text{ ppb, } 0.0) \]

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

AOT$_{40}$ - the accumulated amount of ozone over the threshold value of 40 ppb, i.e..

\[ AOT_{40} = \int \max(O_3 - 40 \text{ ppb, } 0.0) \, dt \]

where the $\max$ function ensures that only ozone values exceeding 40 ppb are included. The integral is taken over time, namely the relevant growing season for the vegetation concerned, and 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:
AOT40^{3m} - AOT40 calculated over April-September from O₃ 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).

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

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

Figure 1: Spatial distribution of emissions from Slovenia in 2003.
4 Trends

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>234</td>
<td>241</td>
<td>196</td>
<td>125</td>
<td>112</td>
<td>118</td>
<td>123</td>
<td>104</td>
<td>99</td>
<td>68</td>
<td>71</td>
<td>66</td>
</tr>
<tr>
<td>NOₓ</td>
<td>51</td>
<td>53</td>
<td>63</td>
<td>67</td>
<td>70</td>
<td>71</td>
<td>64</td>
<td>58</td>
<td>58</td>
<td>57</td>
<td>58</td>
<td>56</td>
</tr>
<tr>
<td>NH₃</td>
<td>25</td>
<td>25</td>
<td>24</td>
<td>22</td>
<td>22</td>
<td>19</td>
<td>20</td>
<td>20</td>
<td>19</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
<tr>
<td>NMVOC</td>
<td>73</td>
<td>73</td>
<td>44</td>
<td>44</td>
<td>49</td>
<td>48</td>
<td>42</td>
<td>40</td>
<td>40</td>
<td>49</td>
<td>49</td>
<td>46</td>
</tr>
<tr>
<td>CO</td>
<td>68</td>
<td>68</td>
<td>81</td>
<td>91</td>
<td>95</td>
<td>93</td>
<td>77</td>
<td>70</td>
<td>68</td>
<td>93</td>
<td>89</td>
<td>81</td>
</tr>
<tr>
<td>PM₂.₅</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>S dep.</td>
<td>83</td>
<td>64</td>
<td>46</td>
<td>31</td>
<td>33</td>
<td>27</td>
<td>26</td>
<td>27</td>
<td>23</td>
<td>20</td>
<td>27</td>
<td>21</td>
</tr>
<tr>
<td>oxN dep.</td>
<td>21</td>
<td>20</td>
<td>19</td>
<td>16</td>
<td>17</td>
<td>15</td>
<td>15</td>
<td>15</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>redN dep.</td>
<td>20</td>
<td>20</td>
<td>17</td>
<td>15</td>
<td>15</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3: Estimated deposition of Sulphur(S) and Nitrogen(N) in Slovenia 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 NOₓ is here as NO₂).
5 Transboundary Fluxes in 2003

5.1 Oxidised sulphur deposition

Figure 4: Contribution of emissions from Slovenia 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 Slovenia. Units: (%).

Figure 5: Oxidised sulphur deposition in Slovenia from: all countries (top left figure). Units: mg(S)/m$^2$. The pie chart shows the six main contributors to oxidised sulphur deposition in Slovenia. 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 Slovenia 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 Slovenia. Units: (%).

Figure 7: Oxidised nitrogen deposition in Slovenia from: all countries (top left figure). Units: mg(N)/m^2. The pie chart shows the six main contributors to oxidised nitrogen deposition in Slovenia. 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 Slovenia to reduced nitrogen deposition in the EMEP domain. Units: mg(N)/m². The pie chart shows the six main receptor areas of reduced nitrogen deposition from Slovenia. Units: (%).

Figure 9: Reduced nitrogen deposition in Slovenia from: all countries (top left figure). Units: mg(N)/m². The pie chart shows the six main contributors to reduced nitrogen deposition in Slovenia. 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$^{3m}$

Figure 10: Change in AOT40$^{3m}$ due to 15% change in NO$_x$ (left) and NMVOC (right) emission reductions from Slovenia. Units: ppb·h

Figure 11: Six most important contributors to AOT40$^{3m}$ in Slovenia by NO$_x$ (left) and NMVOC (right) emission changes (15% reduction). Units: (%)

Figure 12: Change in AOT40$^{3m}$ 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 NOx (left) and NMVOC (right) emission reductions from Slovenia. Units: ppb·day

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

Figure 15: Change in SOMO35 due to 15% change in NOx (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 Slovenia. Units: $\mu g/m^3$

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

Figure 18: Changes in SIA and PPM2.5 concentrations in Slovenia 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 Slovenia. Units: $\mu g/m^3$

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

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

Figure 22: Location of stations in Slovenia

Figure 23: Frequency analysis of ozone in Slovenia at the stations that reported O$_3$ in 2003 (Model, Observations)
Figure 24: Frequency analysis of depositions in precipitation in Slovenia (Model, Observations)
Figure 25: Frequency analysis of air concentrations in Slovenia (Model, Observations)
9 Risks from Ozone and PM in Slovenia in 2003

9.1 Ecosystem-specific AOT40 values

(a) AOT40_{uc}^f (growing season: April-September): The critical level for forest damage is 5000 ppb-h.

(b) AOT40_{uc}^c (growing season: May-July): The critical level for agricultural crops is 3000 ppb-h.

Figure 26: AOT40_{uc}^f and AOT40_{uc}^c in Slovenia in 2003.

9.2 Health impacts from Ozone and PM

Figure 27: SOMO35 and PM_{2.5} in Slovenia in 2003.
9.3 Regional PM$_{10}$ values

(a) Daily mean of PM$_{10}$: The EU limit level is 40 µg/m$^3$.

(b) Days with PM$_{10}$ > 50 µg/m$^3$. The EU limit number is 35 days.

Figure 28: PM$_{10}$ in Slovenia in 2003