Enviro-HIRLAM modeling of atmospheric aerosols and pollution transport and feedbacks: North-West Russia and Northern Europe

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MOTIVATION AND AIM

Motivation
• Increase in anthropogenic pollution (aerosols and gases) due to growing urbanization level and natural pollution (volcanic eruptions, forest fires, sand storms, etc.);
• Gases (e.g. \( \text{SO}_2 \)) and aerosols (e.g. sulfates) cause detrimental effect on living organisms;
• Aerosols can cause changes in meteorological parameters by influencing electromagnetic radiation.

Aim
• To evaluate the aerosol effect on several meteorological parameters and environmental pollution by sulfur containing compounds using Enviro-HIRLAM online-integrated modelling system.
ENVIRO-HIRLAM MODELLING SYSTEM: SETUP AND CASE STUDIES

Period of research
- August 2010 (G. Nerobelov et al., 2018)
- January 2010

Domain of interest

Enviro-HIRLAM

Model scheme (center) and setup options (right)

- Model grid – 568x510;
- Horizontal res. – 0.15°;
- Vertical res. – 40 hybrid levels;
- Time step – 360 s;
- Forecast length – 3 and 6 h;
- Assim. period - 6 h;
- **4 model runs**—without aerosol effect included (CTRL), with direct (DAE), indirect (IDAE) and combined (COMB) effect.

Enviro-HIRLAM Model scheme (center) and setup options (right)

**Orig.**: A. Baklanov et al., 2017
ENVIRO-HIRLAM MODELLING SYSTEM: AEROSOL EFFECTS

Direct aerosol effect (I)

• Including the temporal variation of aerosol characteristics into short-wave and long-wave electromagnetic radiation schemes

Indirect aerosol effect (IIa & IIb)

• Account for aerosol characteristics effects (e.g. aerosol size, number, solubility, etc.) on cloud formation and microphysics

• Account for cloud droplets characteristics evolution in time

Main types of the aerosol effects
GIS INTEGRATION

- GIS integration of modeling results (SO$_2$ concentration and sulfate wet deposition) to QuantumGIS (QGIS)
- Reprojecting data to unique spatial grid
- Visualization and analysis of results
AEROSOL FEEDBACKS IN NORTH-WEST RUSSIA

5-6 Aug (left) and 13 Jan (right), air temperature at 2 m

5 Aug, 15 UTC
CTRL-DAE ↓14°C, ↑12°C

13 Jan, 0 UTC
CTRL-DAE ↓3°C, ↑12°C

6 Aug, 0 UTC
CTRL-DAE ↑8°C, ↓3°C

13 Jan, 0 UTC
CTRL-IDAE ↑8°C, ↓1°C

5 Aug, 6 UTC
CTRL-DAE ↓5g/kg, ↑2g/kg

13 Jan, 0 UTC
CTRL-DAE ↑10.5g/kg, ↑0.2g/kg

5 Aug, 12 UTC
CTRL-DAE ↓10g/kg, ↑7g/kg

13 Jan, 0 UTC
CTRL-IDAE ↑2g/kg, ↓10.2g/kg

*CTRL – without aerosol effects, DAE – direct aerosol effect, IDAE – indirect aerosol effect
AEROSOL FEEDBACKS IN NORTH-WEST RUSSIA

10 Aug (left) and 15 Jan (right),
total cloud cover

10 Aug, 12 UTC
CTRL-COMB ↓↑100%

15 Jan, 18 UTC
CTRL-DAE ↑60%, ↓40%

10 Aug, 12 UTC
CTRL-IDAE ↑60%, ↓40%

15 Jan, 18 UTC
CTRL-IDAE ↑60%, ↓40%

21 Aug, precipitation

21 Aug, 18 UTC
CTRL-IDAE ↓3 mm

CTRL – without aerosol effects, DAE – direct aerosol effect,
IDAE – indirect aerosol effect, COMB – DAE+IDAE effect
AEROSOL FEEDBACKS IN METROPOLITAN AREAS

- Aerosol effects were more significant in **August** than in **January**;
- Changes in meteorological parameters more distinguishable:
  - in Moscow and St. Petersburg during **August**
  - in Helsinki during **January**

<table>
<thead>
<tr>
<th>Meteorological parameter</th>
<th>August 2010</th>
<th>January 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>St. Petersburg</td>
<td>Moscow</td>
</tr>
<tr>
<td>Air temperature on 2 m, °C</td>
<td>COMB</td>
<td>5</td>
</tr>
<tr>
<td>Total cloud cover, %</td>
<td>DAE &amp; COMB</td>
<td>100</td>
</tr>
<tr>
<td>Specific humidity, g/kg</td>
<td>COMB</td>
<td>6</td>
</tr>
<tr>
<td>Precipitation, mm</td>
<td>IDAE &amp; COMB</td>
<td>3</td>
</tr>
</tbody>
</table>
SO$_2$ TRANSPORT

August 2010

Cases of transboundary pollution, 25-26 Aug 2010

January 2010

Cases of transboundary pollution, 28-29 Jan 2010
## SULPHATES WET DEPOSITION

<table>
<thead>
<tr>
<th>Water body</th>
<th>Time</th>
<th>Deposited sulfates per whole water body area (kg)</th>
<th>Deposited sulfates per 1 km² (kg/km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper-Tuloma reservoir (Kola Peninsula, Russia)</td>
<td>6 UTC, 19 Aug</td>
<td>19734</td>
<td>22.5</td>
</tr>
<tr>
<td></td>
<td>0 UTC, 28 Jan</td>
<td>680</td>
<td>0.8</td>
</tr>
<tr>
<td>Lake Inari (Finland)</td>
<td>18 UTC, 21 Aug</td>
<td>49297</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>12 UTC, 31 Jan</td>
<td>2461</td>
<td>2.4</td>
</tr>
<tr>
<td>Lake Iešjávri (Norway)</td>
<td>12 UTC, 22 Aug</td>
<td>1674</td>
<td>24.5</td>
</tr>
<tr>
<td></td>
<td>12 UTC, 28 Jan</td>
<td>113.7</td>
<td>1.7</td>
</tr>
<tr>
<td>Lake Stora Lulevatten (Sweden)</td>
<td>12 UT, 24 Aug</td>
<td>1462</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>12 UTC, 4 Jan</td>
<td>160</td>
<td>0.6</td>
</tr>
</tbody>
</table>
CONCLUDING REMARKS

Aerosol influence on meteorological parameters

• Aerosol influence more significant during Aug 2010;
• Air temperature on 2 m:
  - Direct effect decreased (on 14°C in Aug, on 6 °C in Jan);
  - Indirect and Combined effects increased (on 6-10°C in Aug and Jan);
• Specific humidity:
  - Direct effect decreased in Jan (on 1 g/kg), increased in Aug (on 10 g/kg);
  - Indirect and combined effects decreased in Aug (on 4-12 g/kg),
    increased in Jan (on 2 g/kg);
• Three effects changed total cloud cover on 100% in both months;
• Three effects decreased precipitation on 2-20 mm in Aug and 0.6-2.5 mm in Jan;
• The changes of meteorological parameters were more significant:
  - in St. Petersburg and Moscow during Aug 2010;
  - in Helsinki during Jan 2010.
CONCLUDING REMARKS

Spatio-temporal distribution of SO$_2$ and sulfate wet deposition

- More cases (15 vs 9 days) of transboundary SO$_2$ pollution to the territory of Northern Europe in Aug 2010;

- Higher SO$_2$ concentrations over Kola Peninsula and Northern Europe in Jan 2010;

- Number of cases with wet deposition and amount of deposited sulfates were higher in Aug 2010.

- The max of sulfates wet deposition was observed in Finland (Lake Inari, 47 kg/km$^2$) and the min – in Sweden (Lake Stora Lulevatten, 5.6 kg/km$^2$) in Aug 2010.
REFERENCES


Thank you for your attention!