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. SO_2) and aerosols (e.g. sulfates) cause detrimental effect on living organisms;
- Aerosols can cause changes in meteorological parameters by influencing electromagnetic radiation.

Example of gaseous pollutants source (Pechenganikel` mining company, Kola Peninsula, Russia)

Aim

- To evaluate the aerosol effect on several meteorological parameters and environmental pollution by sulfur containing compounds using Enviro-HIRLAM online-integrated modelling system.

Sources of anthropogenic and natural aerosols

ENVIRO-HIRLAM MODELLING SYSTEM: SETUP AND CASE STUDIES

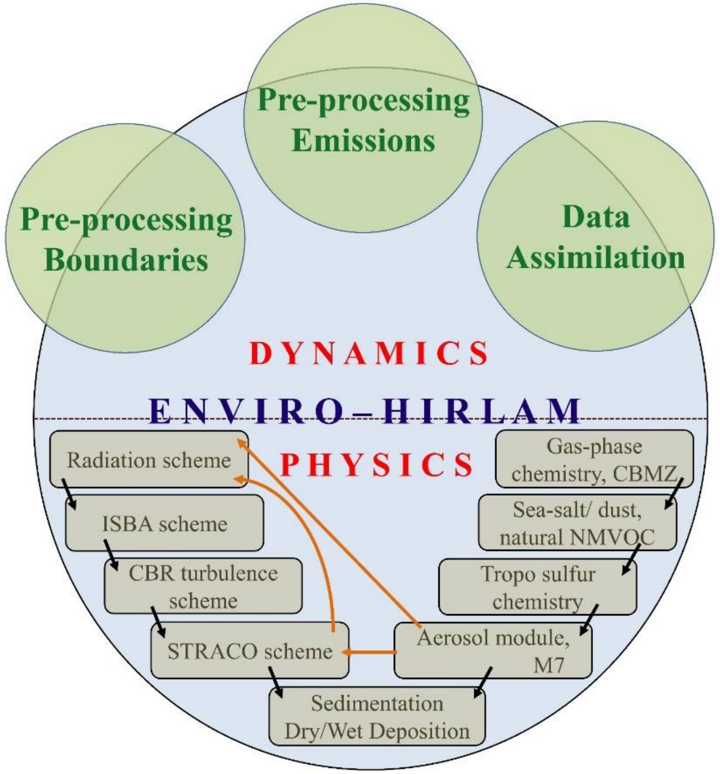
Period of research

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

Domain of interest

Enviro-HIRLAM

Model scheme (**center**) and setup options (**right**)



Orig.: A. Baklanov et al., 2017

- 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 MODELLING SYSTEM: AEROSOL EFFECTS

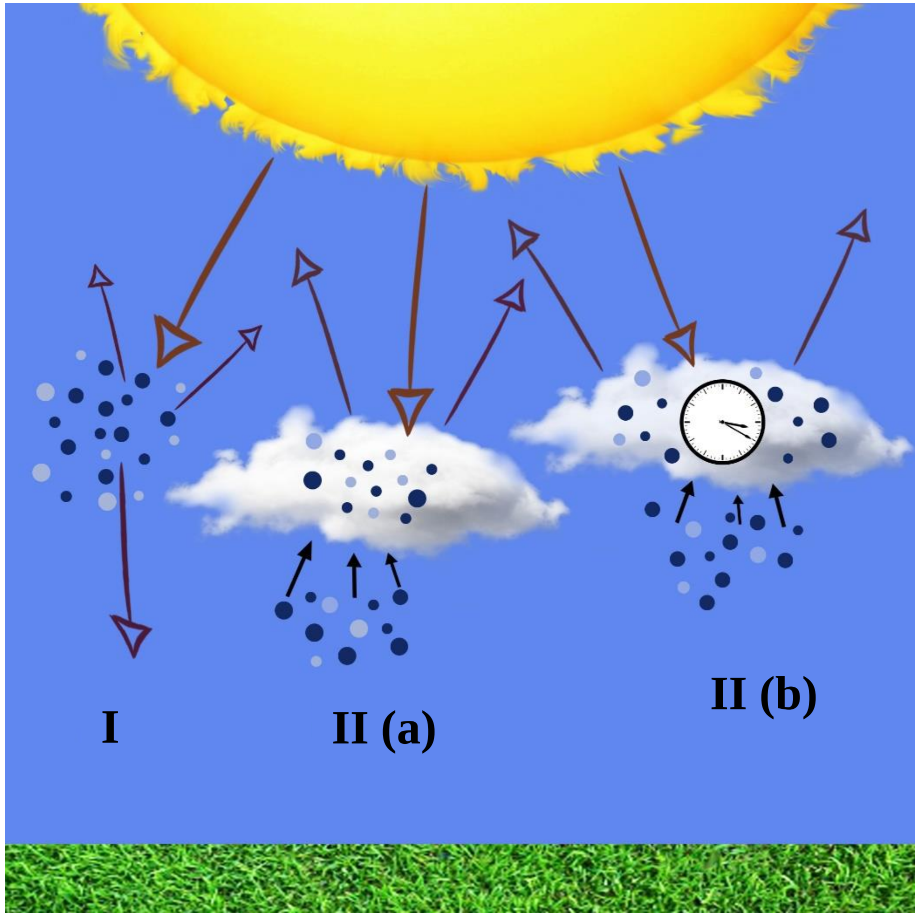
Direct aerosol effect (I)

- 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

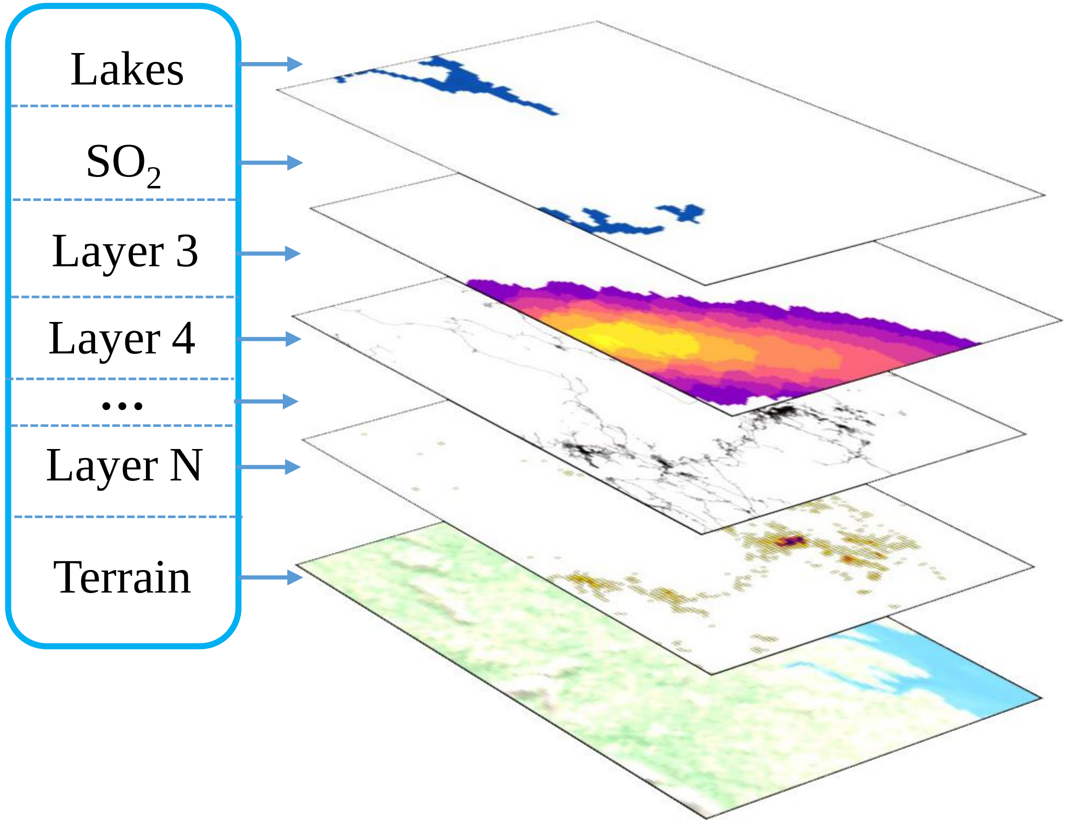
- Account for cloud droplets characteristics evolution in time

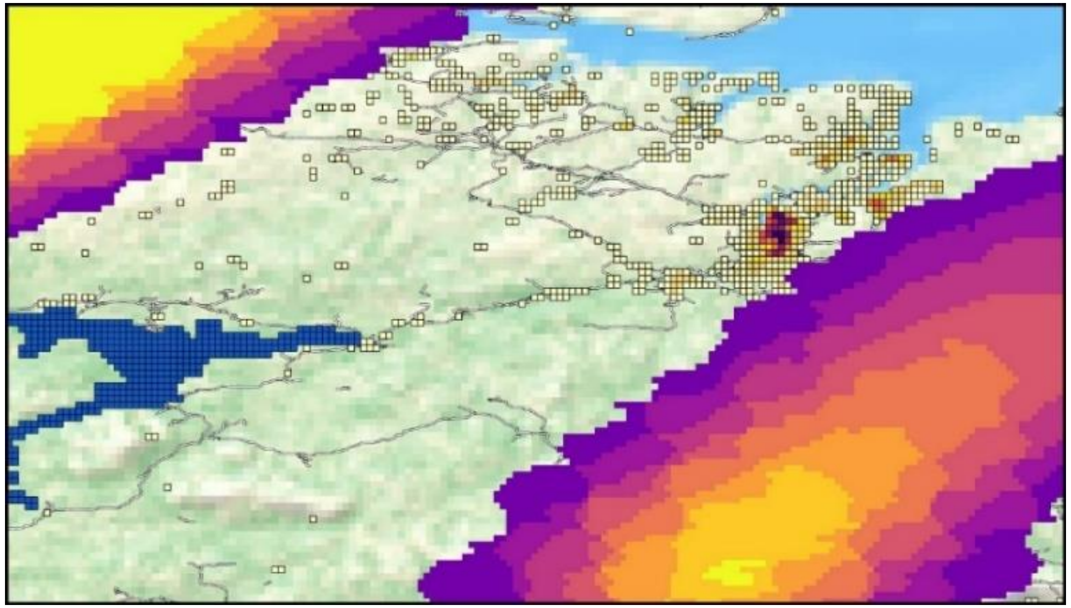


Main types of the aerosol effects

GIS INTEGRATION

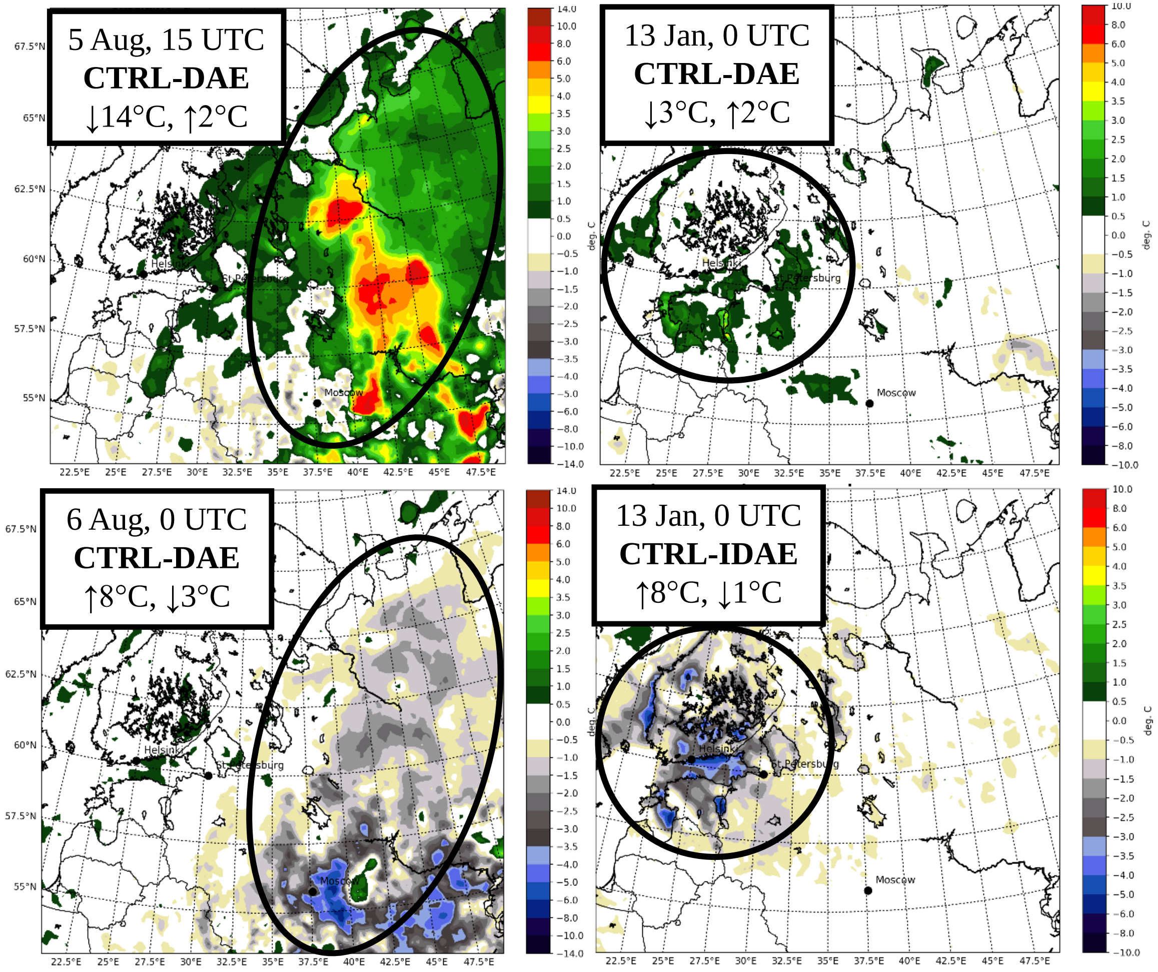
- GIS integration of modeling results (SO_2 concentration and sulfate wet deposition) to QuantumGIS (QGIS)
- Reprojecting data to unique spatial grid
- Visualization and analysis of results



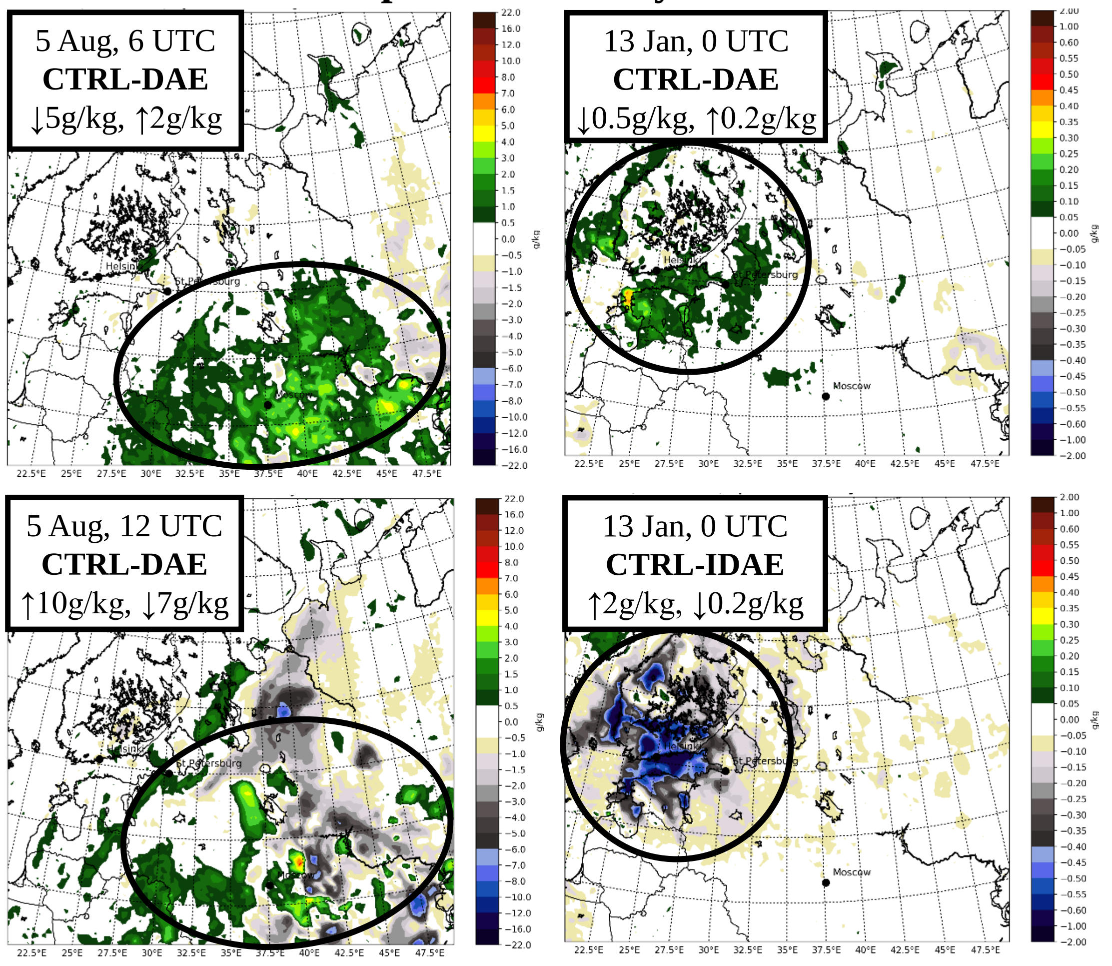


AEROSOL FEEDBACKS IN NORTH-WEST RUSSIA

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



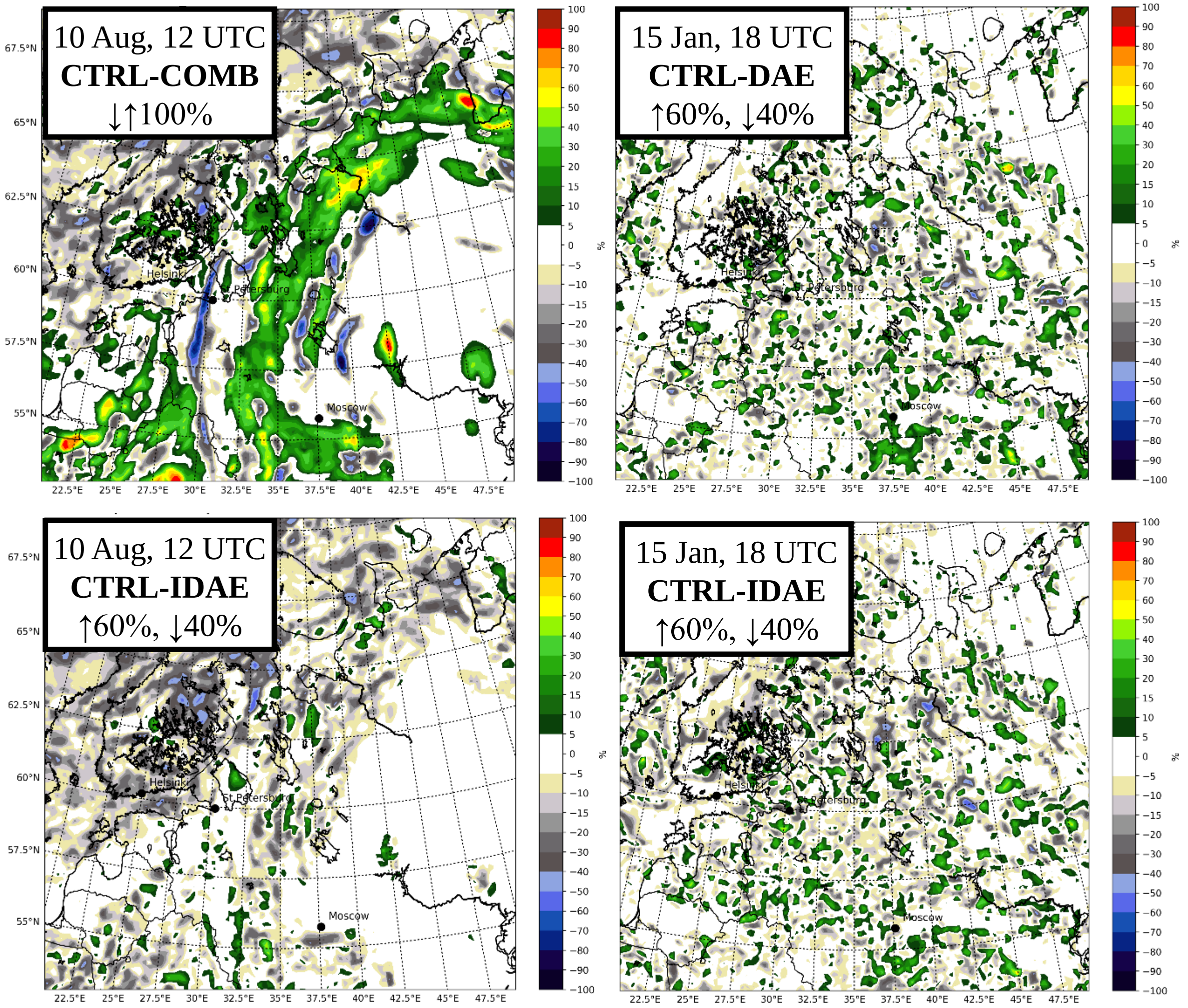
5 Aug (**left**) and 13 Jan (**right**),
specific humidity



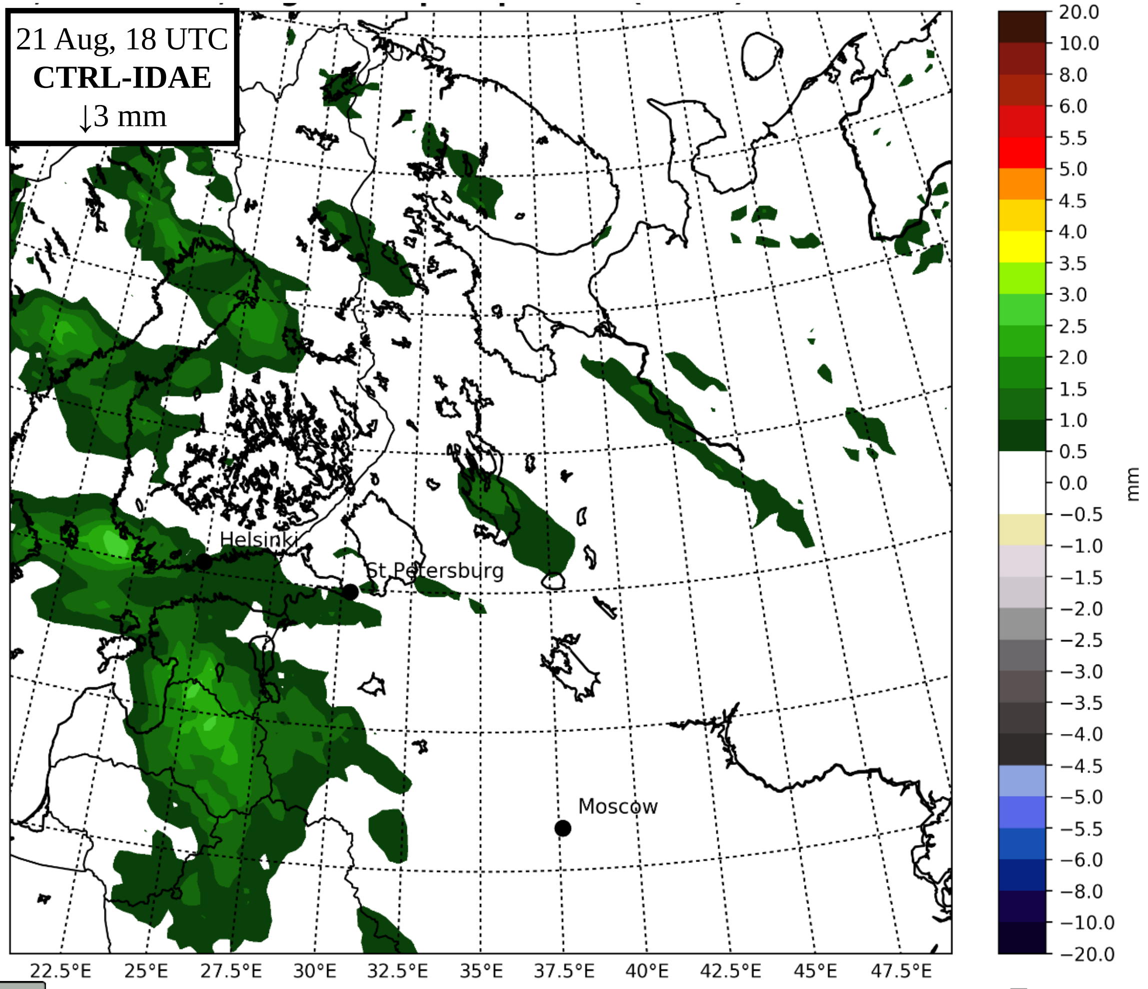
*CTRL – without aerosol effects, DAE – direct aerosol effect,
IDAE – indirect aerosol effect

AEROSOL FEEDBACKS IN NORTH-WEST RUSSIA

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



21 Aug, **precipitation**



*CTRL – without aerosol effects, DAE – direct aerosol effect, IDAE – indirect aerosol effect, COMB – DAE+IDAE effect

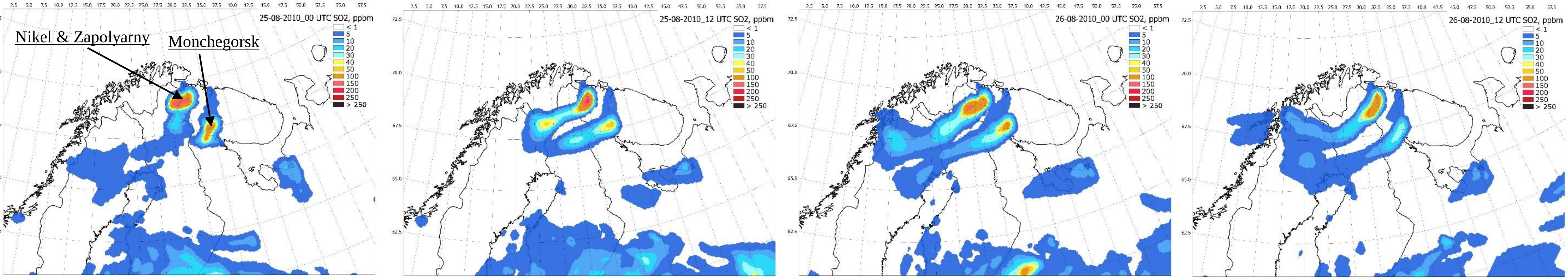
AEROSOL FEEDBACKS IN METROPOLITAN AREAS

- 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**

	August 2010						**January 2010**		
	St. Petersburg			Moscow			Helsinki		
Meteorological parameter	Aerosol effect	Max increase	Max decrease	Aerosol effect	Max increase	Max decrease	Aerosol effect	Max increase	Max decrease
Air temperature on 2 m,°C	COMB	**5**	**10**	DAE & COMB	**8**	**14**	COMB	**8**	**3**
Total cloud cover, %	DAE & COMB	**100**	**100**	DAE & COMB	**100**	**100**	All effects	**100**	**90**
Specific humidity, g/kg	COMB	**6**	**6**	DAE & COMB	**6**	**6**	IDAE & COMB	**2**	**0.2**
Precipitation, mm	IDAE & COMB	**3**	**10**	DAE & COMB	**1.5**	**2.5**	IDAE & COMB	**0.15**	**0.6**

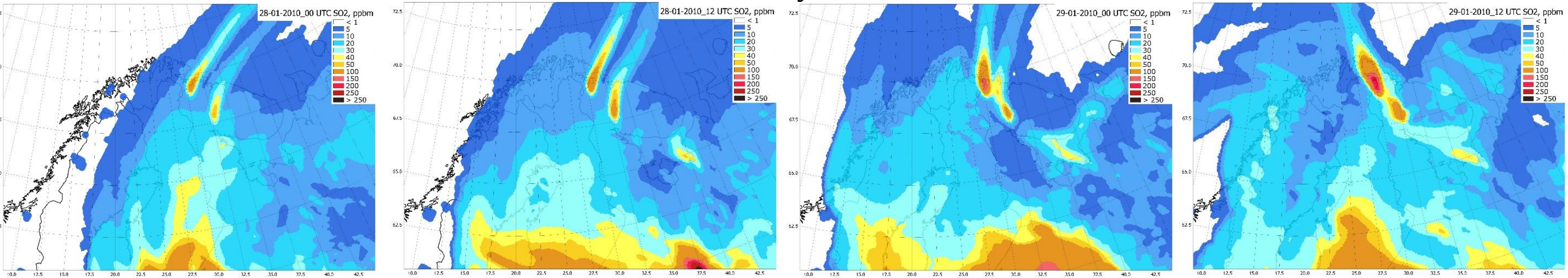
SO_2 TRANSPORT

August 2010



Cases of transboundary pollution, 25-26 Aug 2010

January 2010



Cases of transboundary pollution, 28-29 Jan 2010

SULPHATES WET DEPOSITION

Water body	Time	Deposited sulfates per whole water body area (kg)	Deposited sulfates per 1 km^2 (kg/km^2)
Upper-Tuloma reservoir (Kola Peninsula, Russia)	6 UTC, 19 Aug	19734	22.5
	0 UTC, 28 Jan	680	0.8
Lake Inari (Finland)	18 UTC, 21 Aug	49297	47
	12 UTC, 31 Jan	2461	2.4
Lake Iešjávri (Norway)	12 UTC, 22 Aug	1674	24.5
	12 UTC, 28 Jan	113.7	1.7
Lake Stora Lulevatten (Sweden)	12 UT, 24 Aug	1462	5.6
	12 UTC, 4 Jan	160	0.6

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

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2. Nerobelov G., Sedeeva M., Mahura A., Nuterman R., Mostamandi S., Smyshlyaev S. Online integrated modeling on regional scale in North-West Russia: evaluation of aerosols influence on meteorological parameters. Geography, Environment, Sustainability. 2018;11(2):73-83. https://doi.org/10.24057/2071-9388-2018-11-2-73-83

Thank you for your attention!