Modelling air quality in the Lake Baikal region

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1. Objectives

- Bilateral scientific co-operation between Russia (INM-RAS) and Flanders (VITO) with the aim:
  - *to mutually exchange expertise on transport-chemistry modelling and aerosol physics and chemistry in order to attain improved atmospheric modelling capabilities in both countries*
  - *to perform a joint validation study for simulation domains in Russia and Flanders*

Studying aerosol formation in the Antwerp area

Modelling air quality in the lake Baikal region

Contents

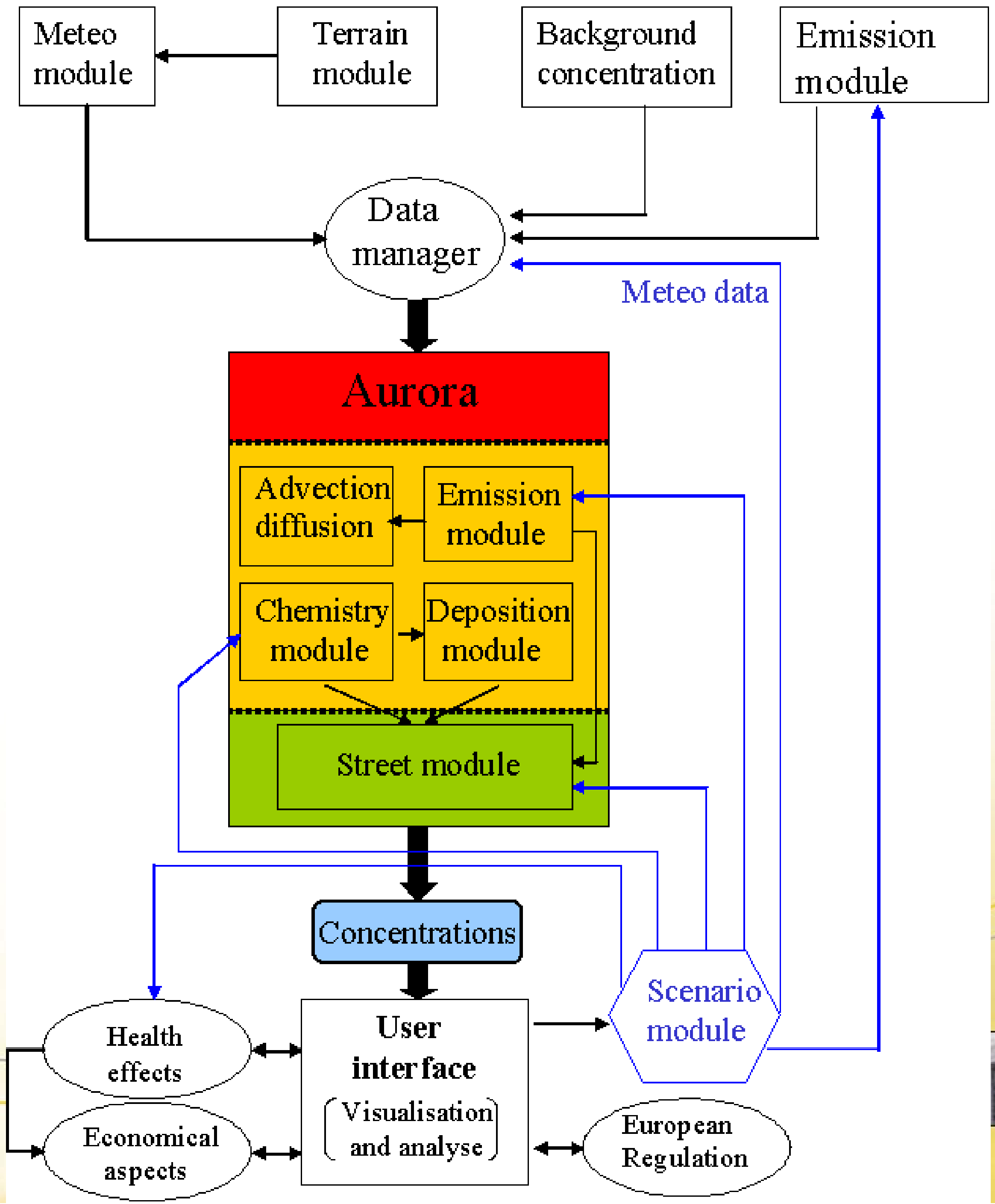
2. The AURORA model

Air quality modelling in **U**rban **R**egions using an **O**ptimal **R**esolution **A**pproach

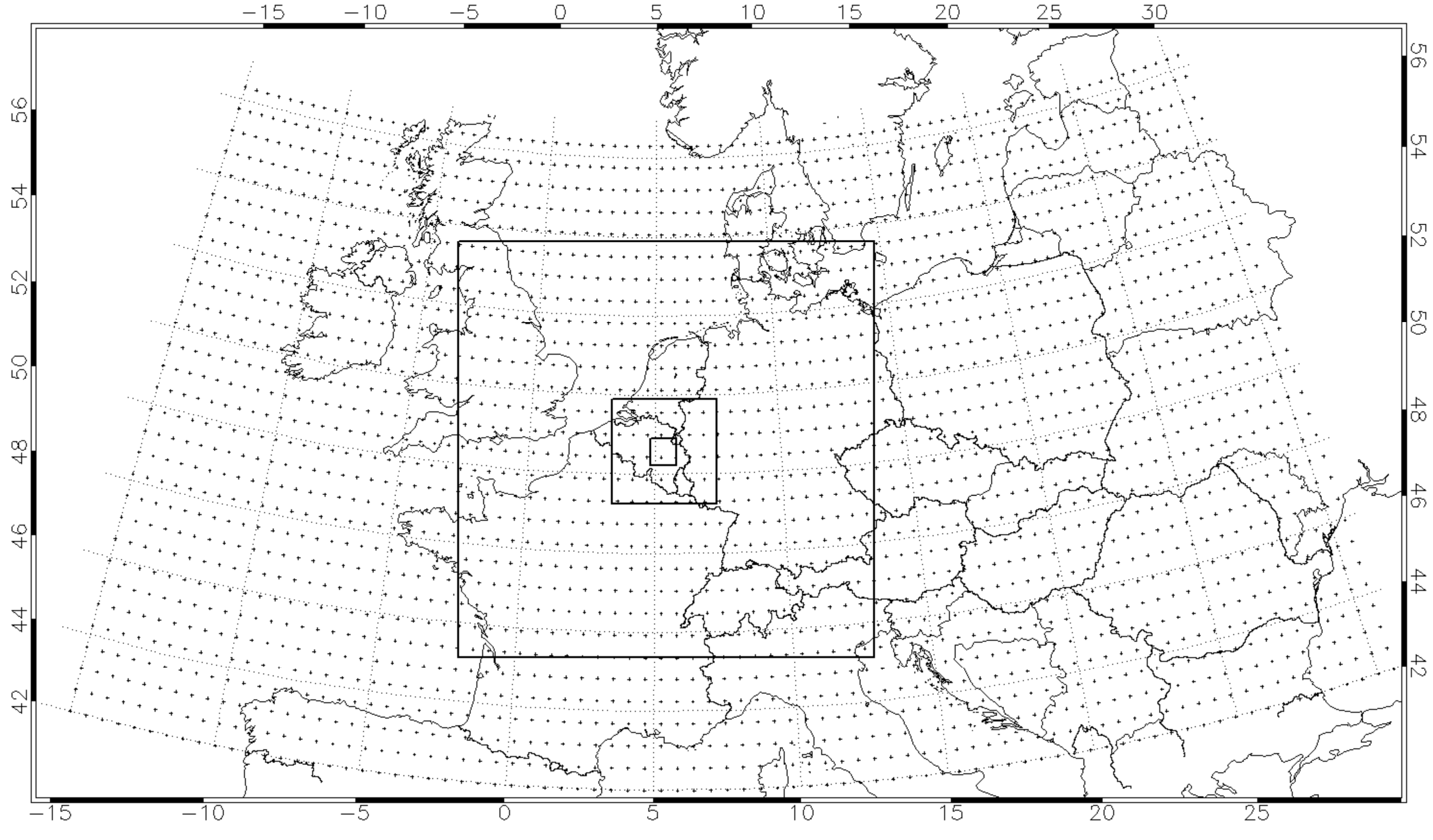
- 3-dimensional Eulerian grid model for meteorology-emissions-transport-chemistry
- different scales : regional -> urban scale, street-box sub-model
- meteorology from ARPS model (wind, turbulent diffusion, temperature, …)

2. The AURORA model

- emissions from various sectors : traffic, industry, domestic combustion, biogene emissions, …
- transport : Walcek advection, Crank-Nicholson diffusion
- chemistry :
  - Carbon-Bond IV gas-phase chemistry with isoprene, limited PM
  - CACM gas phase mechanism + MADRID2 aerosol module
  - PAH (Polycyclic Aromatic Hydrocarbon) version
- output : hourly gridded pollutant concentrations (O3, PM10, PM2.5, NO2, benzene, PAH, …)

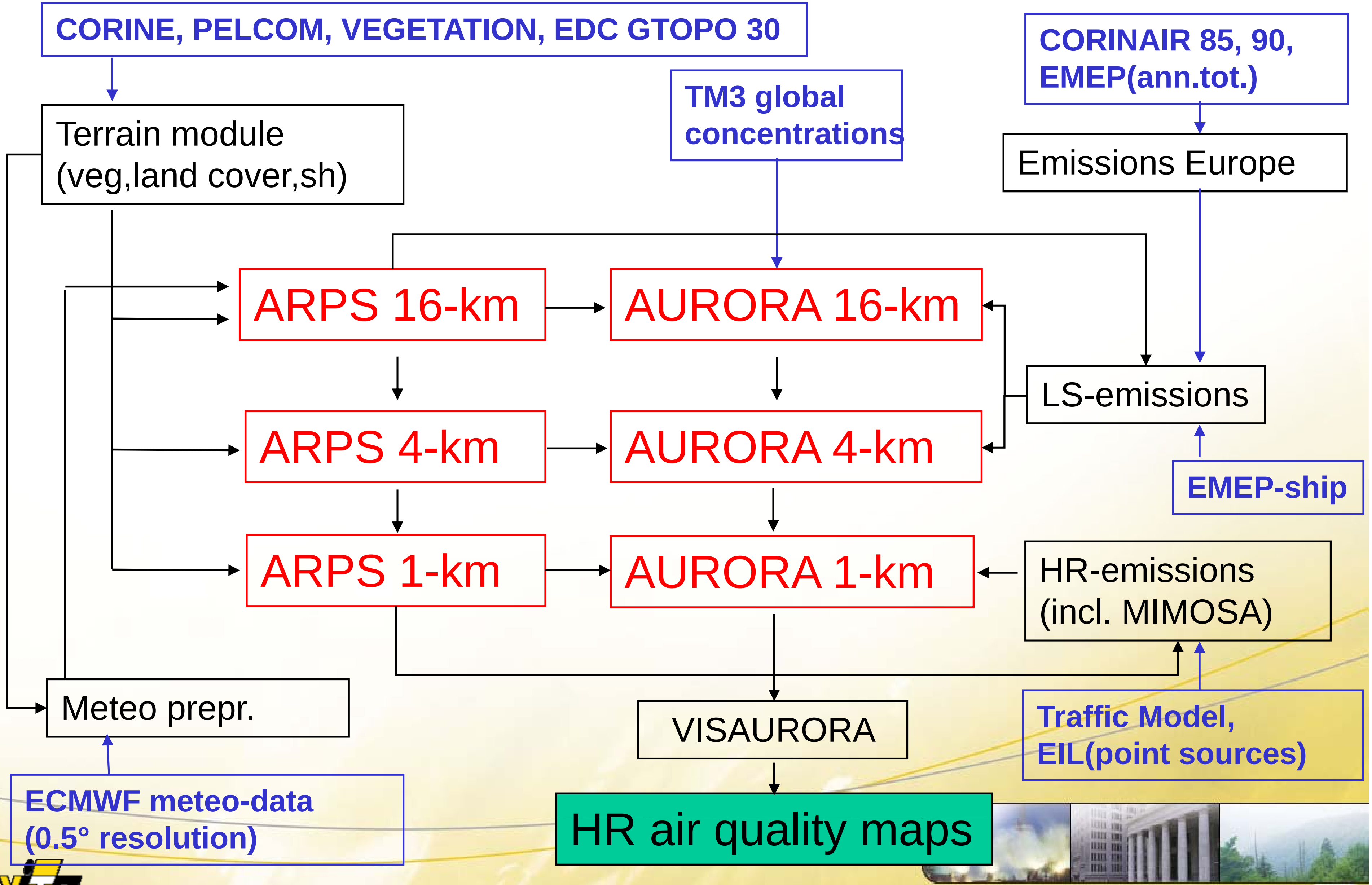

Meteo module
Terrain module
Background concentration
Emission module
Data manager
Meteo data
Aurora
Advection diffusion
Emission module
Chemistry module
Deposition module
Street module
Concentrations
Health effects
Economical aspects
User interface
Visualisation and analyse
Scenario module
European Regulation

principle of nesting

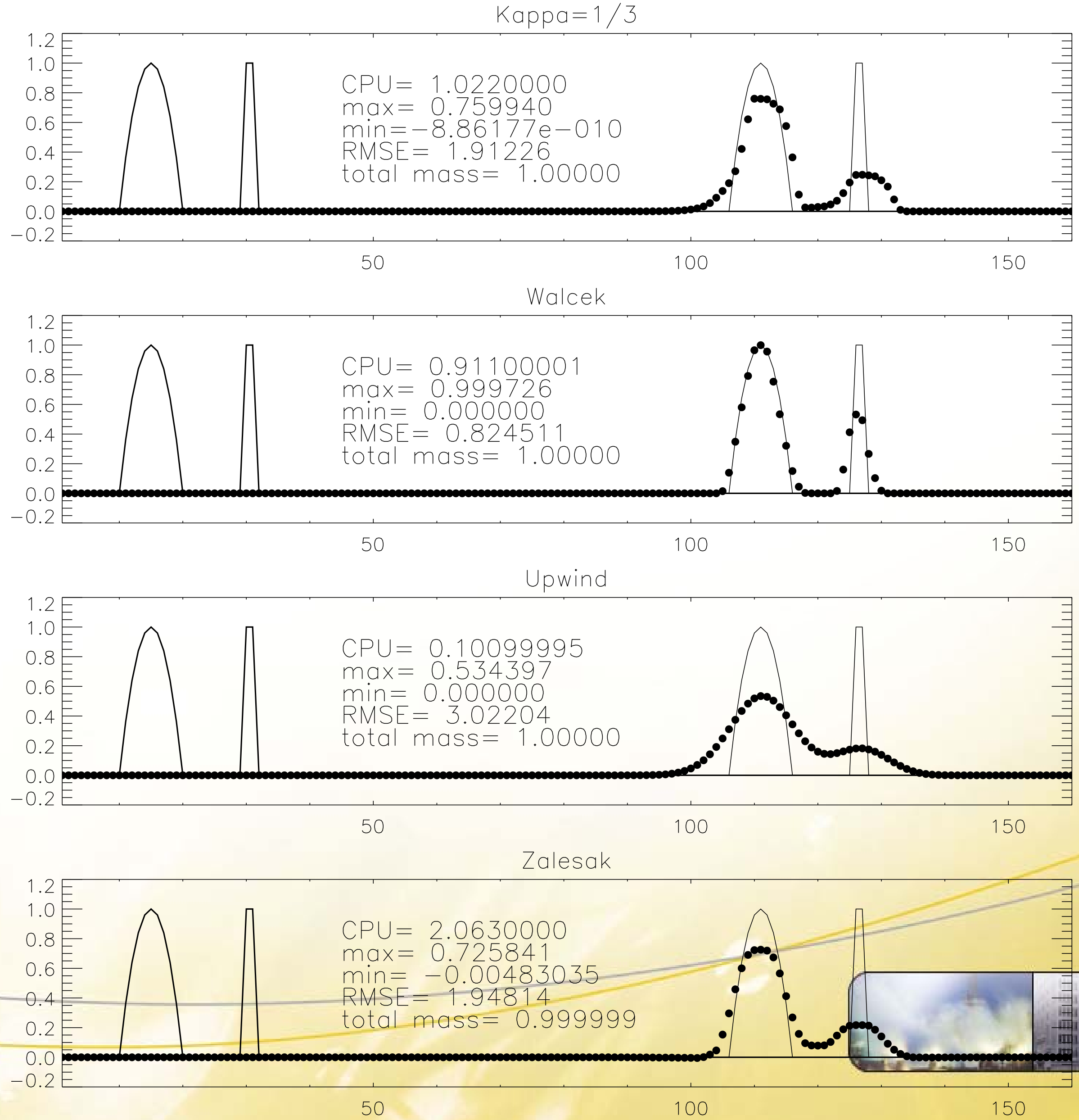


Multiple runs needed going from big domain at coarse resolution to domain of interest at high resolution

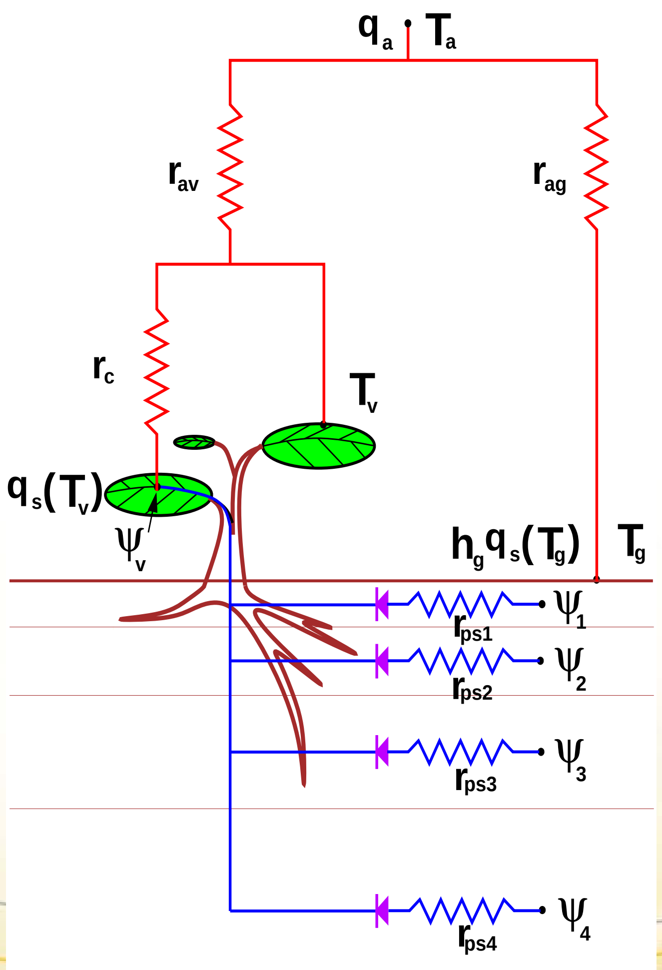
Software structure of nested AURORA-model

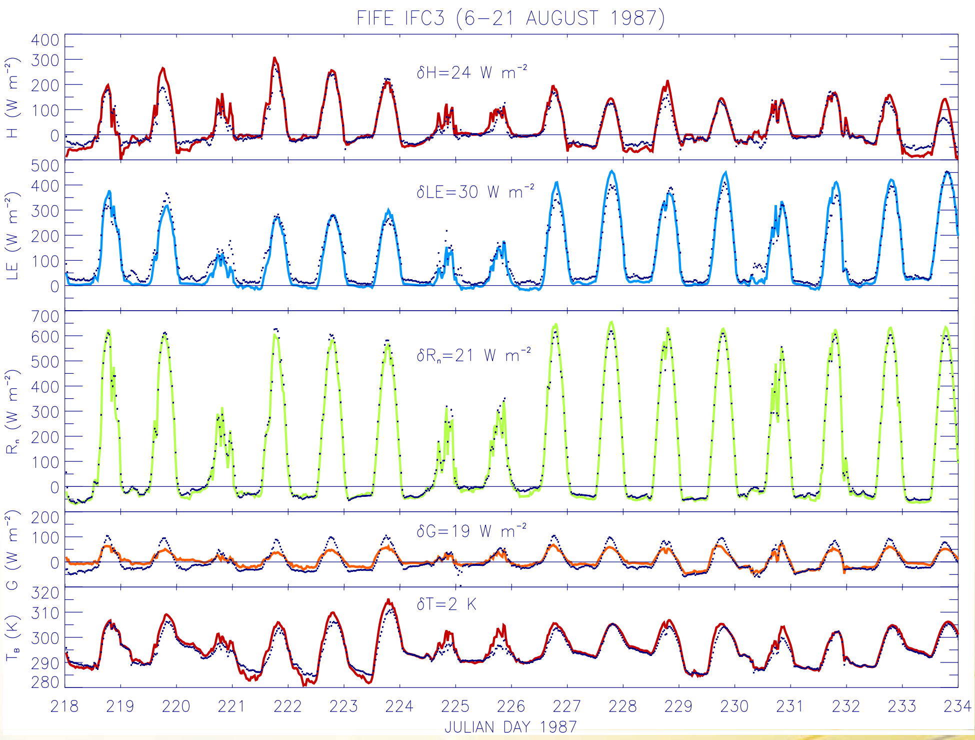


advection

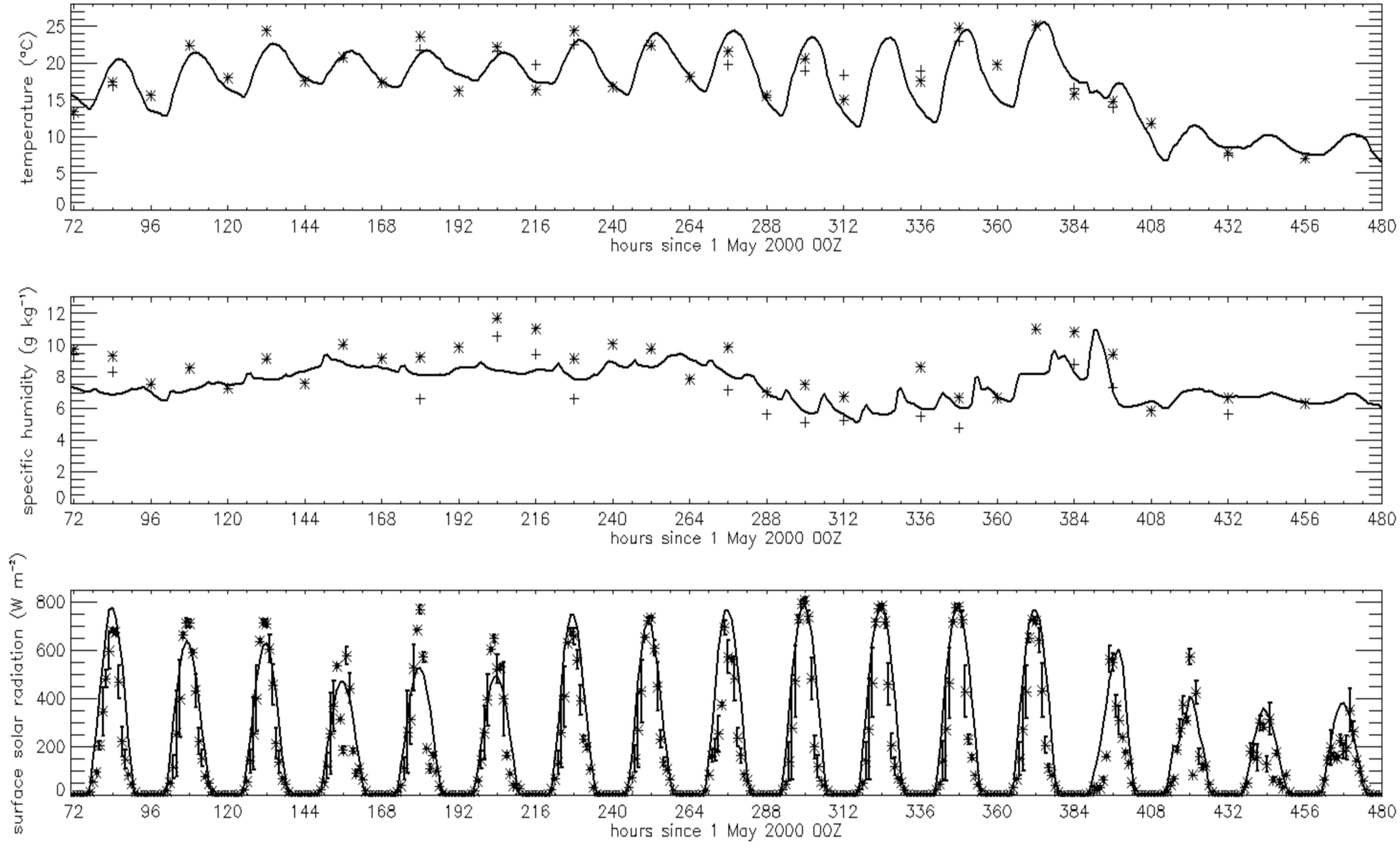

Kappa=1/3
CPU= 1.0220000
max= 0.759940
min=−8.86177e−010
RMSE= 1.91226
total mass= 1.00000
Walcek
CPU= 0.91100001
max= 0.999726
min= 0.000000
RMSE= 0.824511
total mass= 1.00000
Upwind
CPU= 0.10099995
max= 0.534397
min= 0.000000
RMSE= 3.02204
total mass= 1.00000
Zalesak
CPU= 2.0630000
max= 0.725841
min= −0.00483035
RMSE= 1.94814
total mass= 0.999999
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
50
100
150

Surface module: LAICa

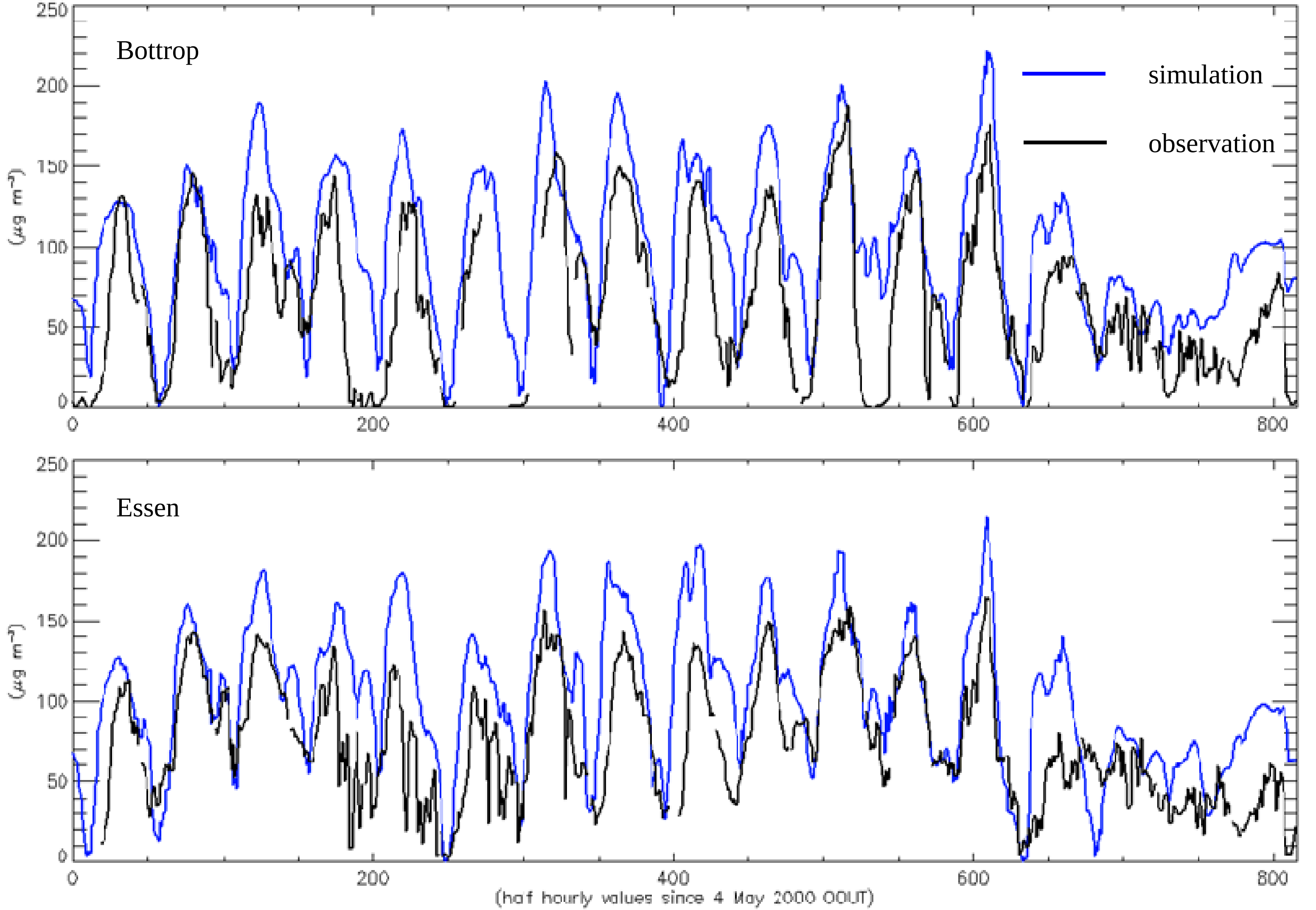




validation meteorology (T, q, R_s)



validation O_3 concentrations



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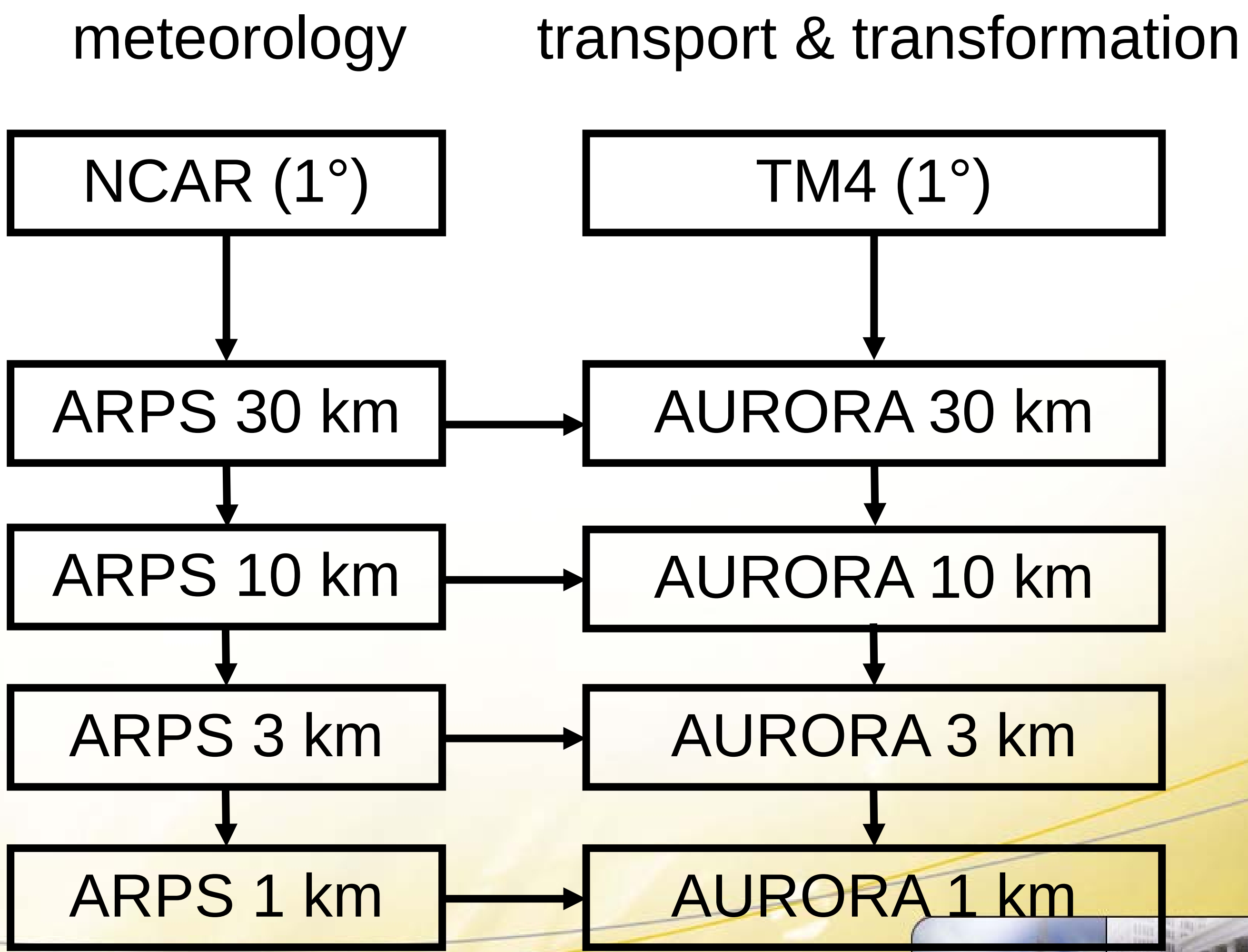
3. Results for lake Baikal

- Lake Baikal is the largest fresh water lake in the world
- The region is characterised by complex terrain, consisting of steep and densely forested hill slopes surrounding the lake

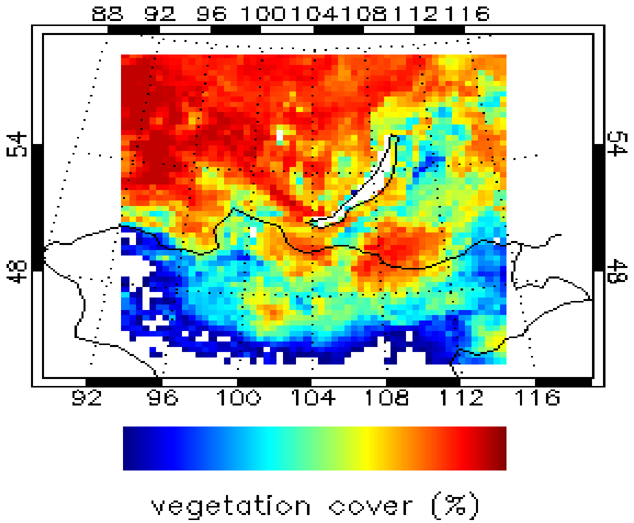
➢ A challenge with respect to the correct simulation of atmospheric dynamics and turbulence.

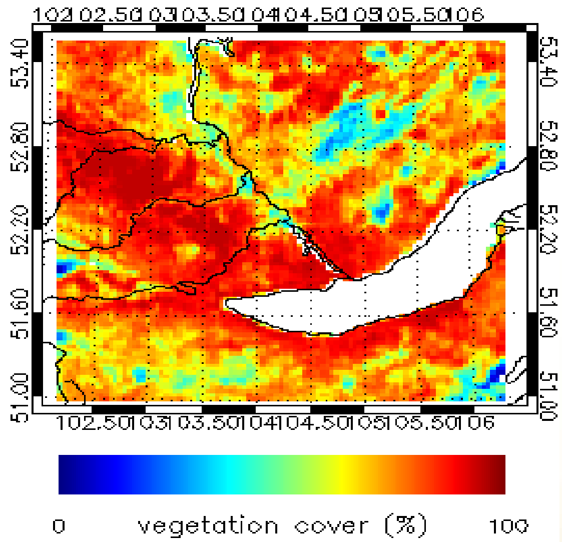
➢ Emissions: few large point sources, which are the dominant sources of air pollution in this area, but no information on other emissions in a wider area

ARPS – AURORA coupling and nesting



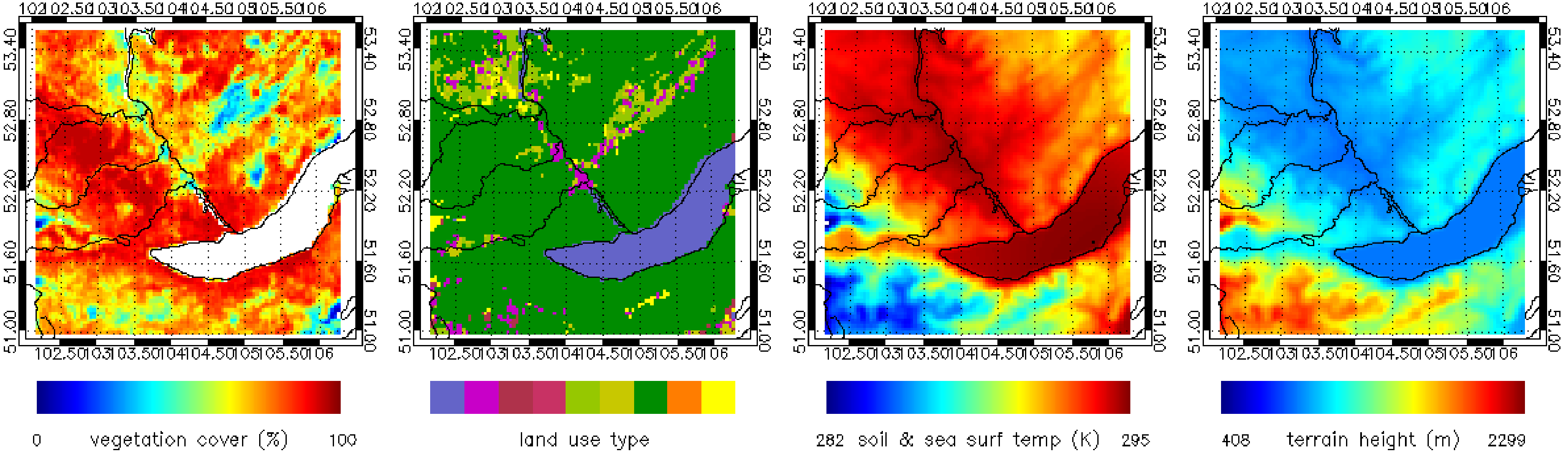
AURORA :: nesting levels





Number of grid points	60 x 60	100 x 100	50 x 50
Horizontal resolution	30km	10km	3km

AURORA input: terrain data for 3-km domain



Domain : 150km x 150km @ 3km resolution

Terrain data :

- vegetation information : VEGETATION / SPOT
- land use : GLC2000
- sea surface temperature : MODIS
- topography : Digital Elevation Model

AURORA input: emission data

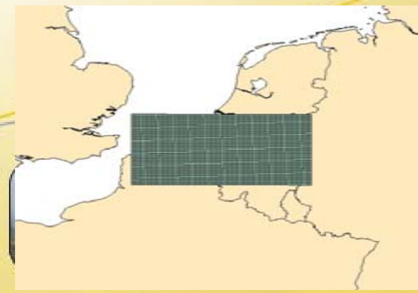
- Two approaches :
  - Bottom up
    - local emission = activity × activity factor
  - Top down
    - local emission = proportion of total emission

- Top down emission modeling :

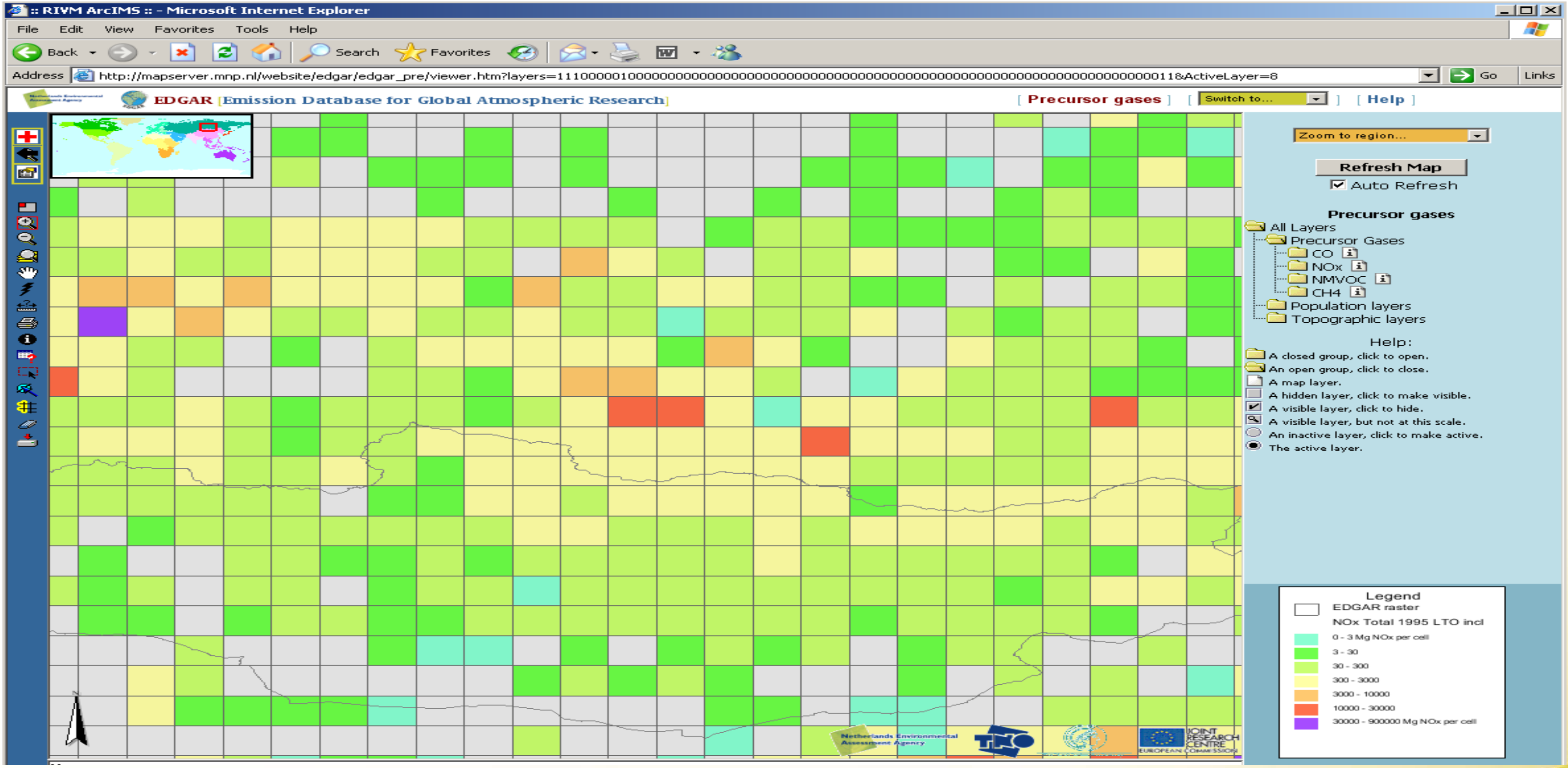
Emission inventory at low resolution

Geographical databases : land use, population density, road networks, large point sources, …

Gridded emission data at high resolution



Top down emission modelling :: NOx emissions from EDGAR database

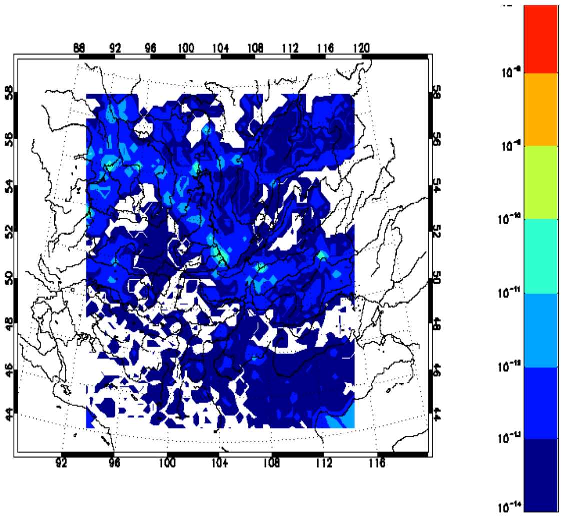


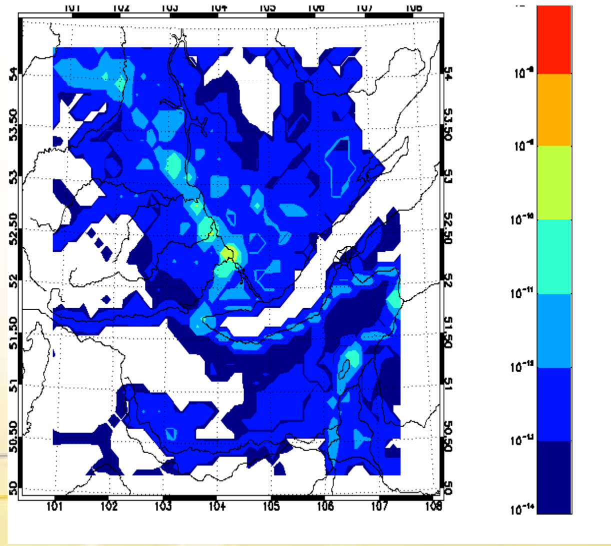
EDGAR 3.2 database provides emission data for 1995 :

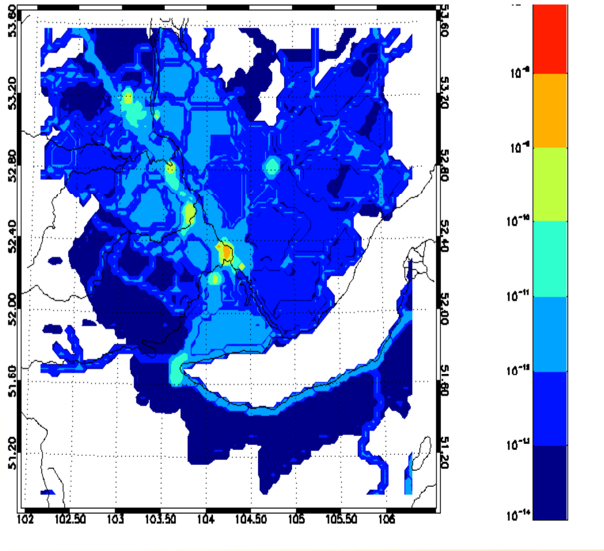
- on a 1x1 degree grid
- per country

AURORA: input emission data

NOx emissions for 30km, 10km and 3km resolution domains

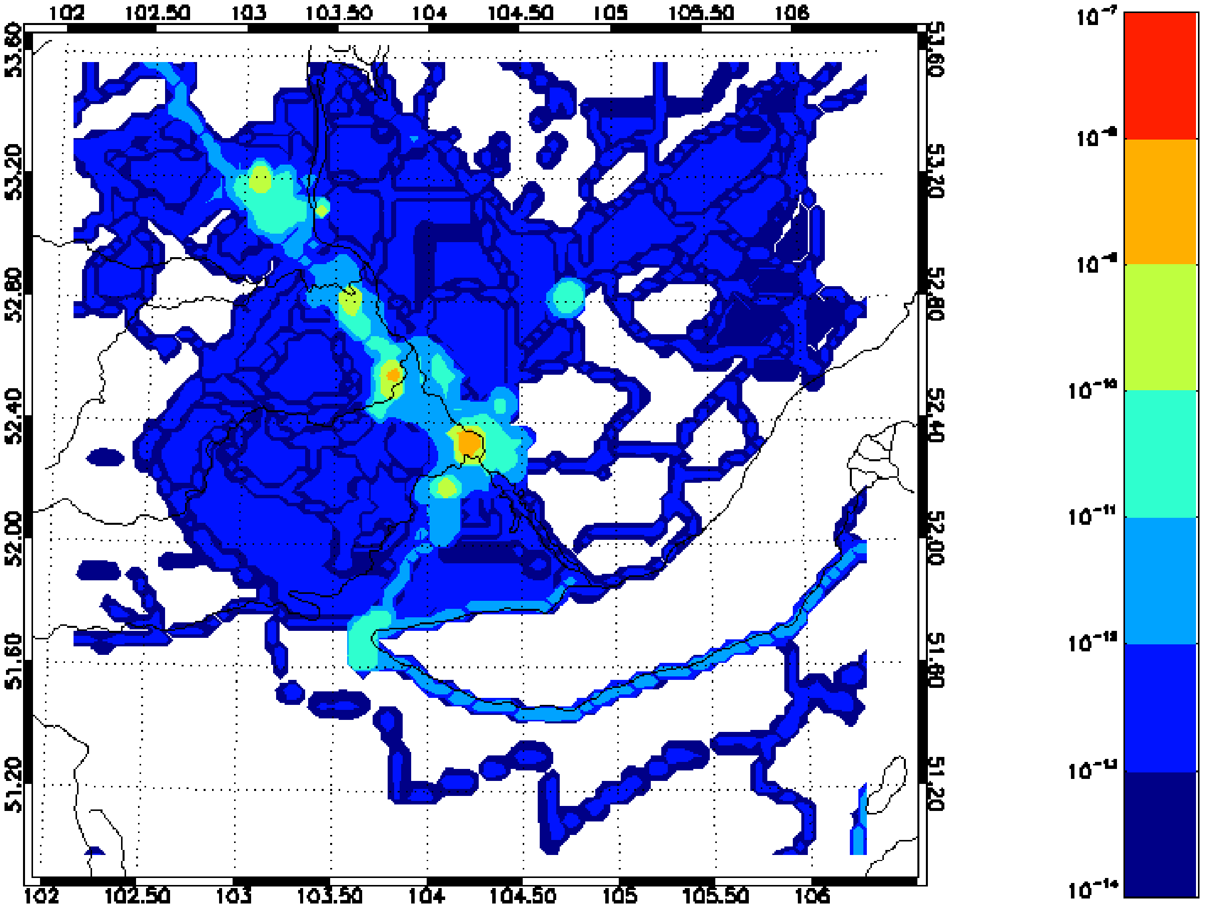




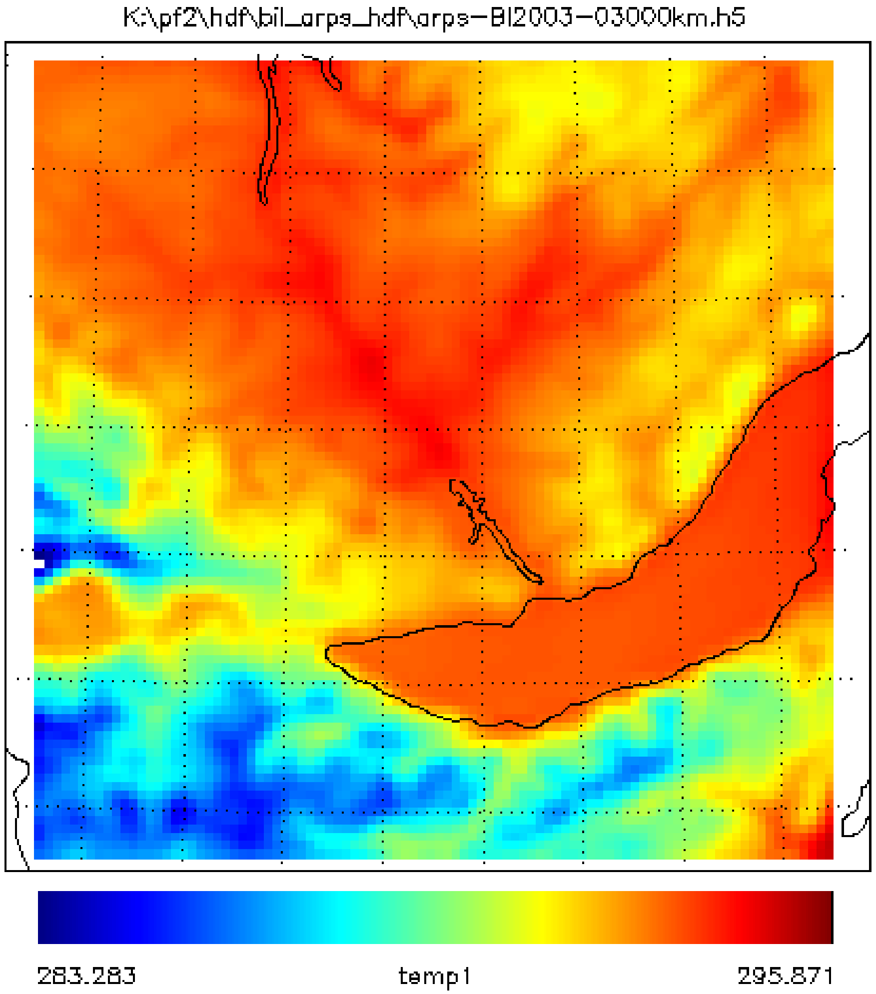


AURORA: input emission data

SO2 emissions for 3km resolution domains



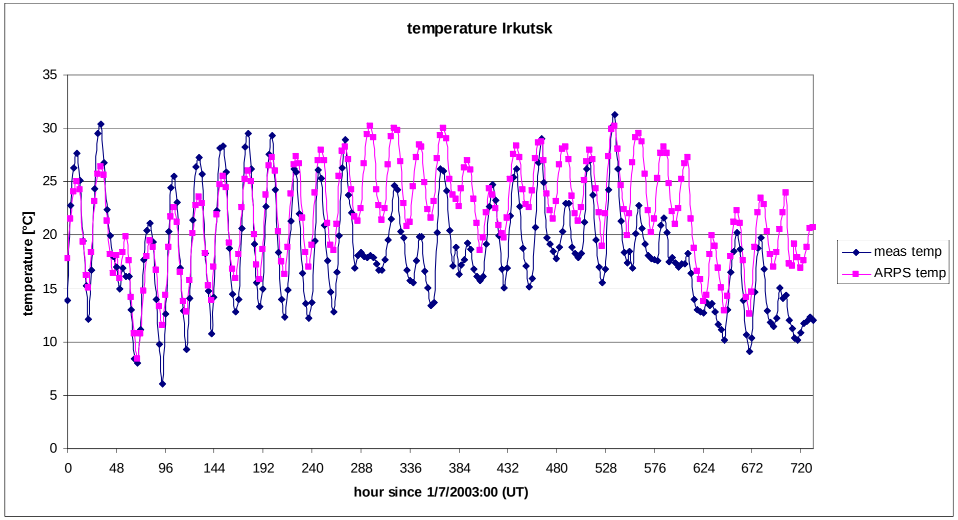
ARPS: meteo results

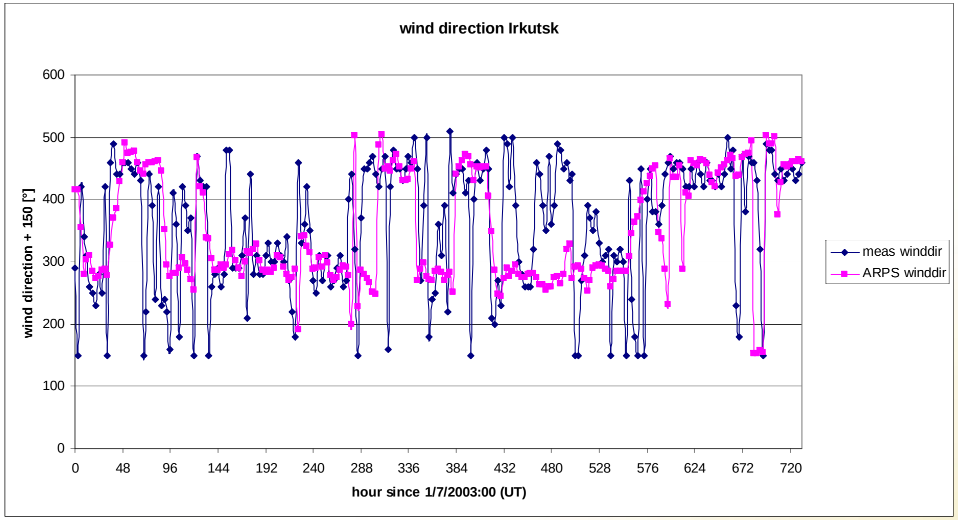


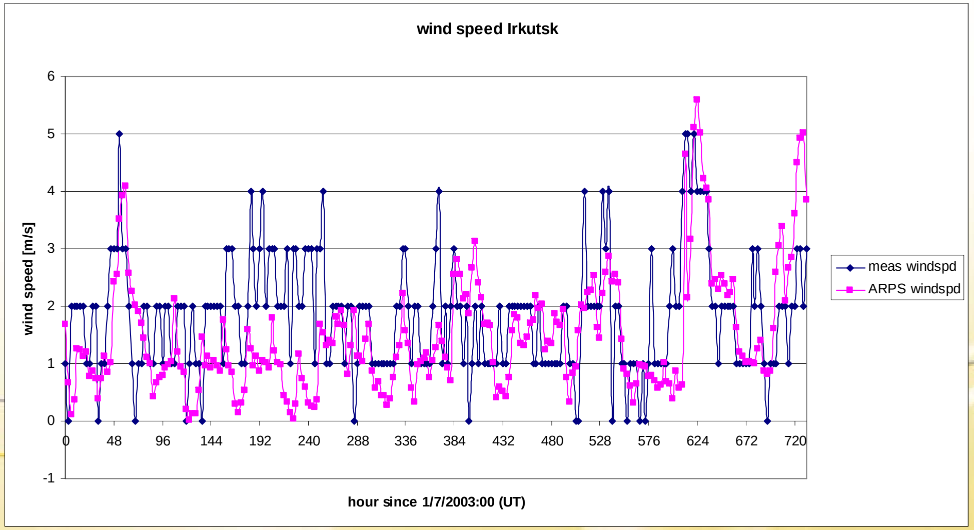
average temperature,
July 2003 :

- Baikal lake :
  hotter water
- city of Irkutsk:
  urban heat island

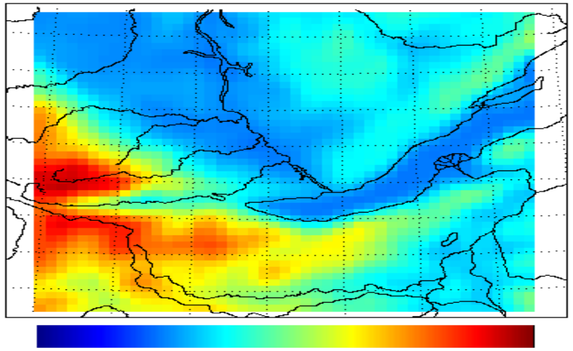
ARPS: validation meteo



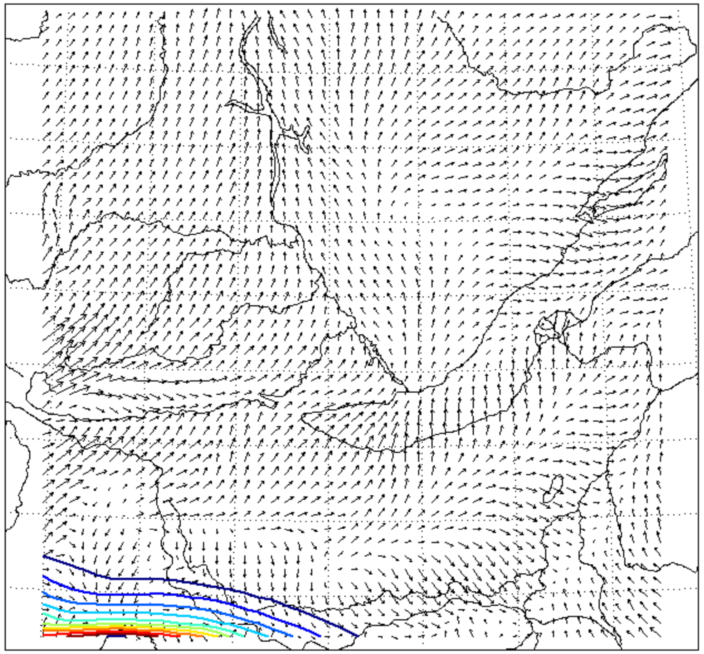




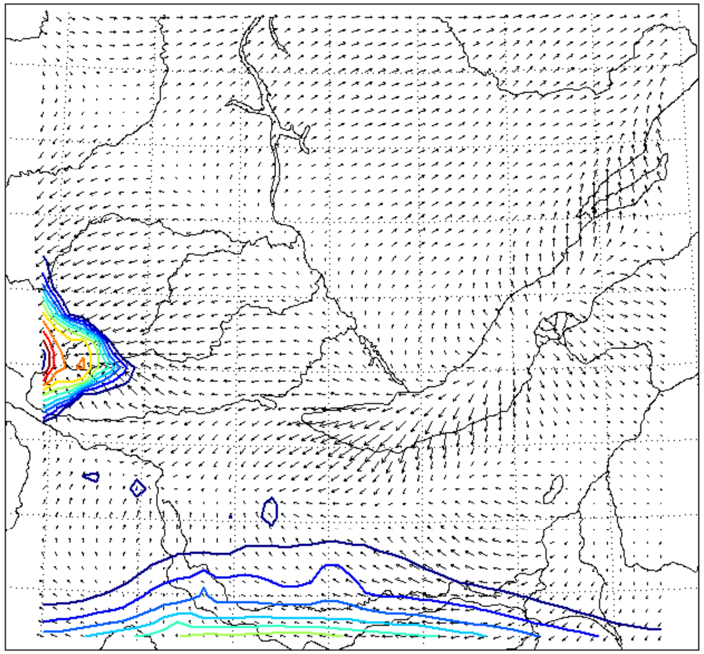
ARPS: day and night breezes



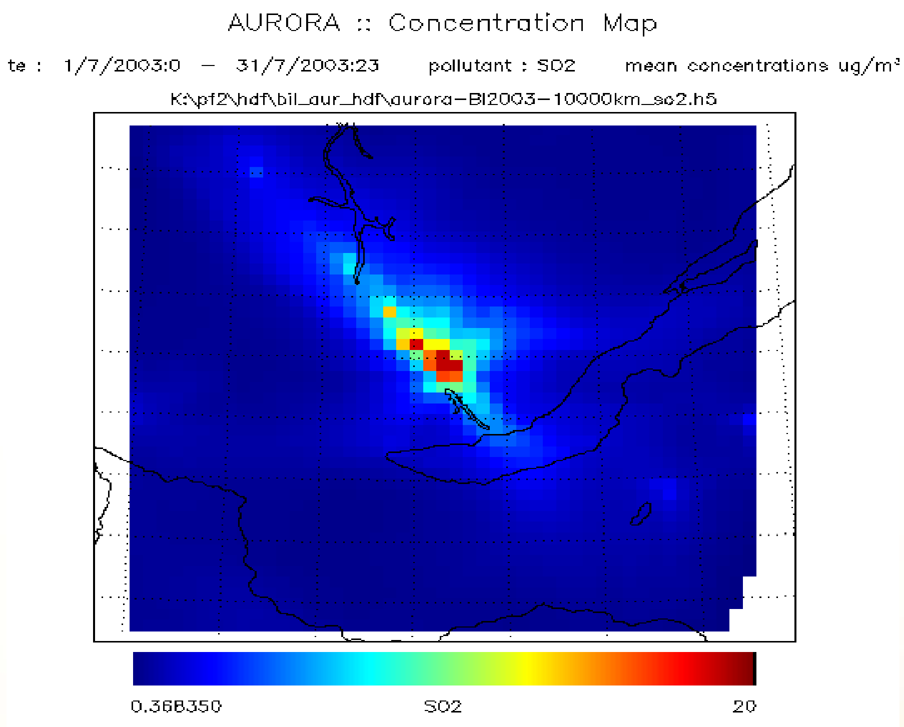
night breeze July 2, 4am LT

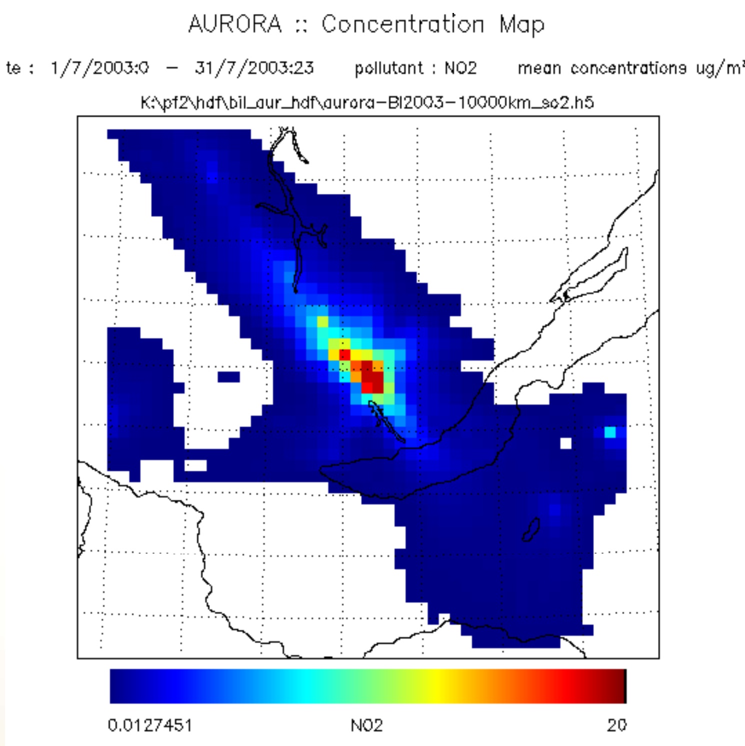


day breeze July 2, 3pm LT



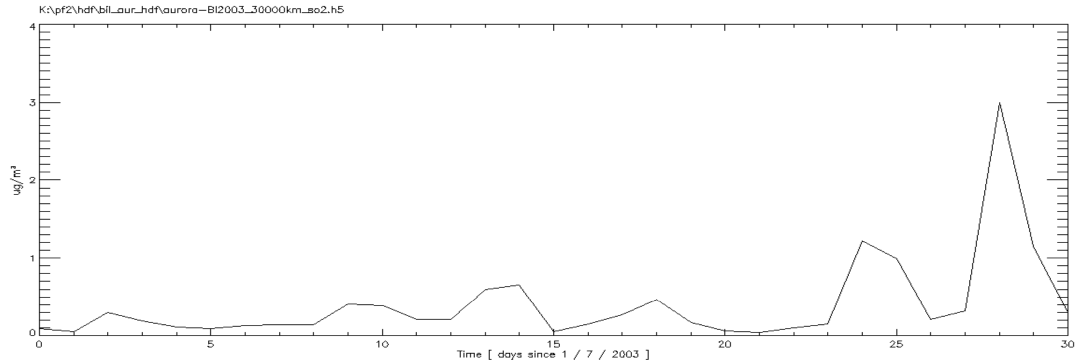
AURORA: average concentration fields





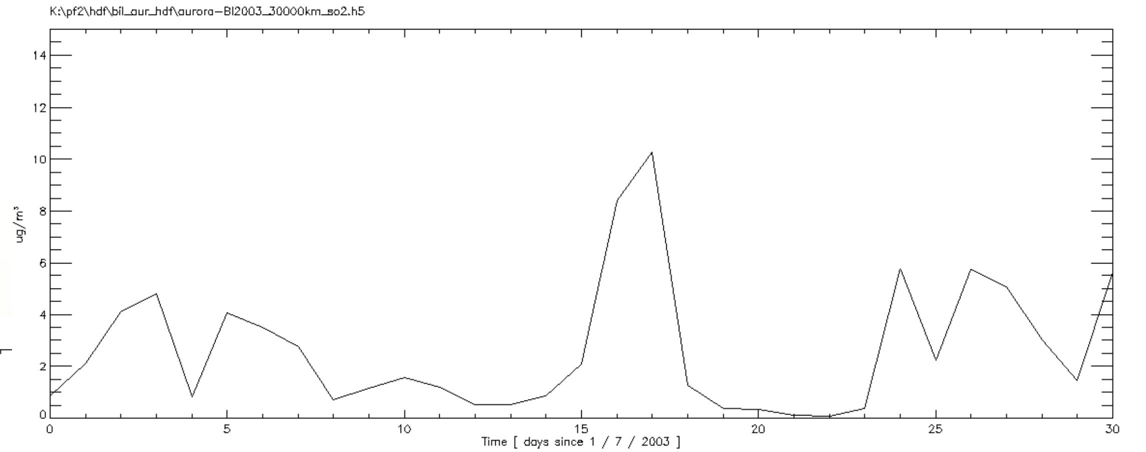
SO2 and NO2 concentration fields for the 10km resolution domain

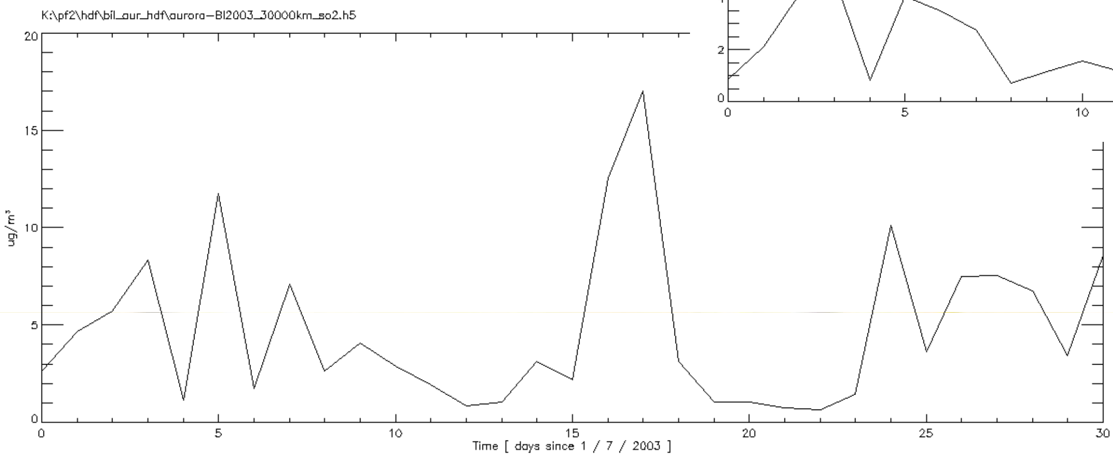
AURORA: modelled SO2 concentrations



Mondy :
meas mean July 2003 :
0.5 ug/m3

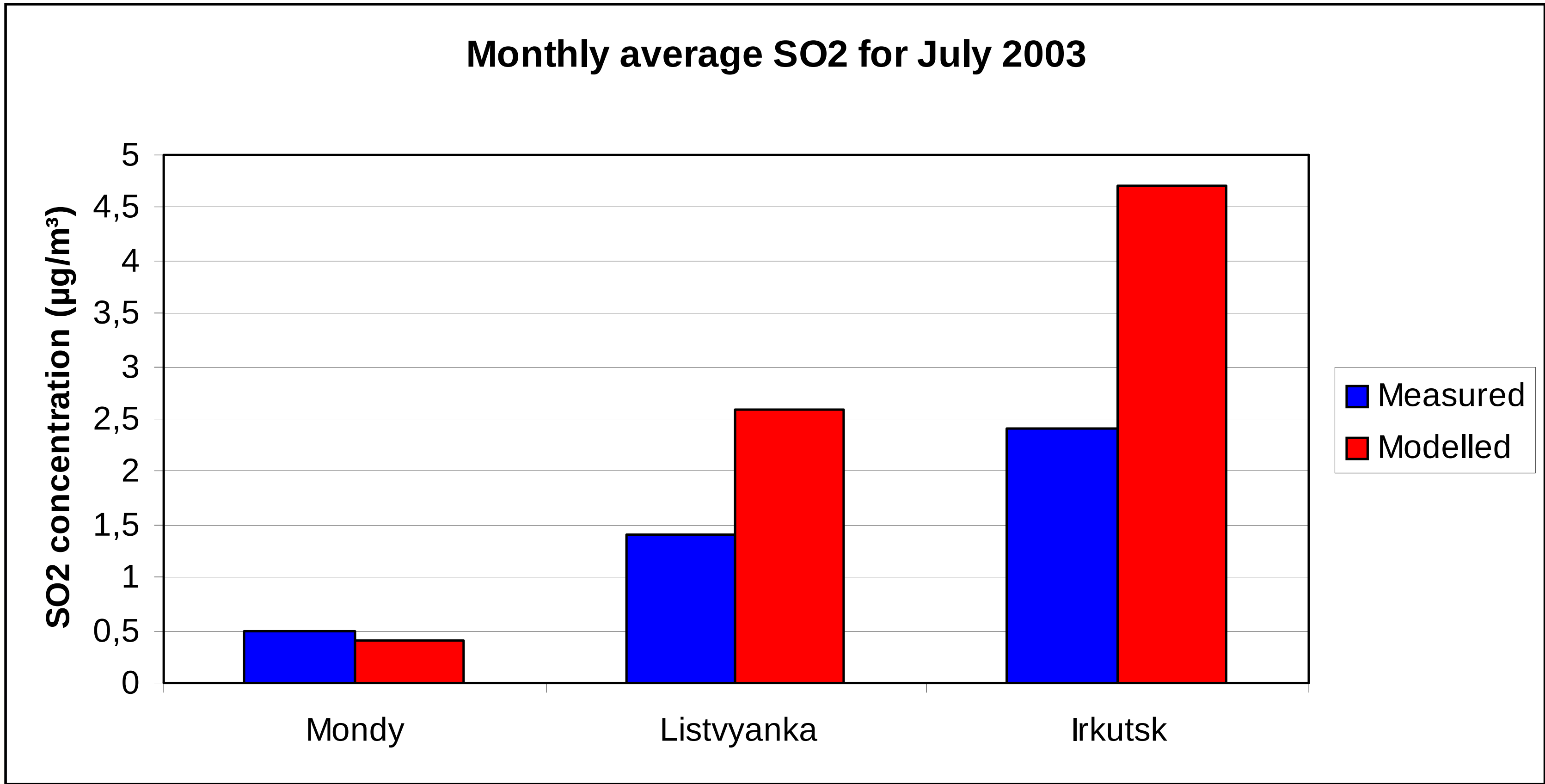
Listvyanka :
meas mean July 2003 :
1.4 ug/m3





Irkutsk :
meas mean July 2003 :
2.4 ug/m3

AURORA: validation SO2 concentrations



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4. Conclusions

- Modelling air quality in this part of the world is a challenge !
- The ARPS model can predict some part of the dynamics, especially in the first part of July.
- Emission data are difficult to obtain.
- Background SO_2 concentrations (Mondy) seem ok, but the SO_2 concentrations near the main sources are overestimated by +/- a factor of two.
- Further analysis of the results is needed

And… yes, this was also part of the bilateral co-operation…