Enviro-HIRLAM online integrated ACT-NWP modeling system with two-way interactions

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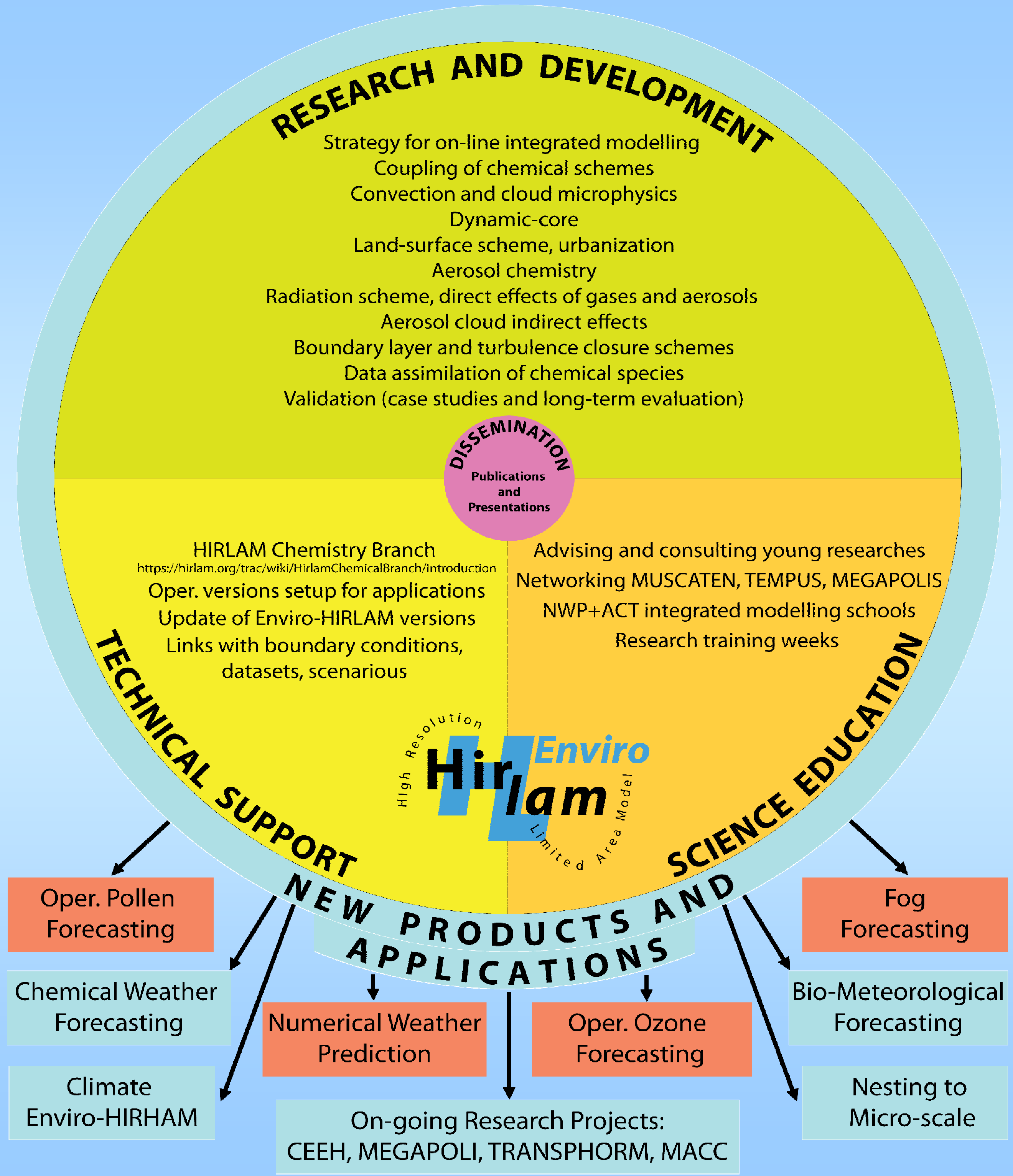
In cooperation with the HIRLAM consortium


RESEARCH AND DEVELOPMENT
Strategy for on-line integrated modelling
Coupling of chemical schemes
Convection and cloud microphysics
Dynamic-core
Land-surface scheme, urbanization
Aerosol chemistry
Radiation scheme, direct effects of gases and aerosols
Aerosol cloud indirect effects
Boundary layer and turbulence closure schemes
Data assimilation of chemical species
Validation (case studies and long-term evaluation)
DISSEMINATION
Publications and Presentations
HIRLAM Chemistry Branch
https://hirlam.org/trac/wiki/HirlamChemicalBranch/Introduction
Oper. versions setup for applications
Update of Enviro-HIRLAM versions
Links with boundary conditions, datasets, scenarious
TECHNICAL SUPPORT
Advising and consulting young researches
Networking MUSCATEN, TEMPUS, MEGAPOLIS
NWP+ACT integrated modelling schools
Research training weeks
SCIENCE EDUCATION
High Resolution Enviro HIRLAM Limited Area Model
NEW PRODUCTS AND APPLICATIONS
Oper. Pollen Forecasting
Chemical Weather Forecasting
Climate Enviro-HIRHAM
Numerical Weather Prediction
On-going Research Projects: CEEH, MEGAPOLI, TRANSPHORM, MACC
Oper. Ozone Forecasting
Fog Forecasting
Bio-Meteorological Forecasting
Nesting to Micro-scale

Enviro-HIRLAM overview

Enviro-HIRLAM can be seen as an extension to HIRLAM

Main components: Dynamical core Physical module Chemical module

Primitive equations

Radiation, clouds, precipitation, …

Semi-Lagrangian, Eulerian, semi-Lagrangian + Bott, CISL

Helmholtz equation, semi-implicit adjustmnent,
4th order diffusion

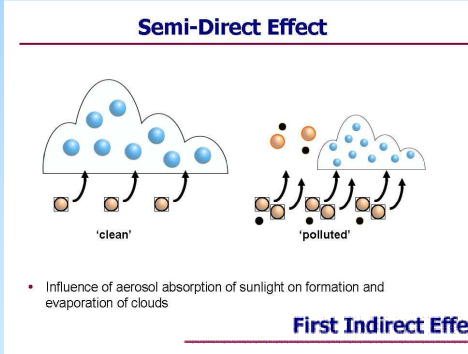
Gas chemistry
Aerosol chemistry
Aerosol equilibration
Aerosol dynamics
Deposition

Feedbacks between all modules

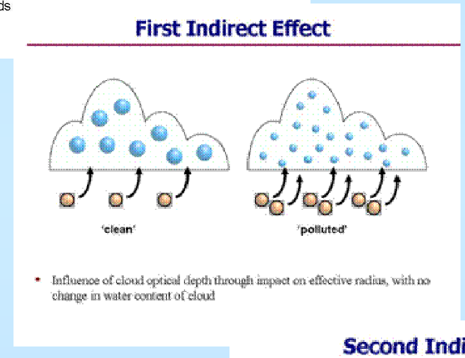
Prognostic equations: u, v, w, T, q, s, TKE, Ps, chemical and aerosol species

Motivation: Aerosol Effects on Atmospheric Processes

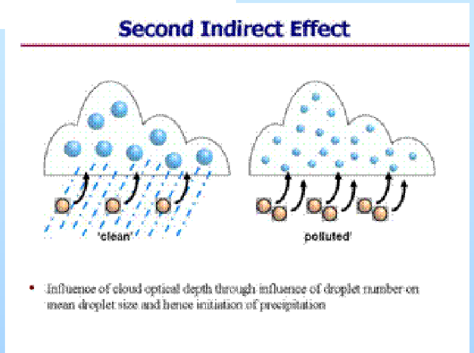
- Direct effect → decrease solar/ thermal-IR radiation and visibility;
  warming: GHGs, BC, OC, Fe, Al, polycyclic/nitrated aromatic compounds
  cooling: water, sulfate, nitrate, most OC
  (scattering, absorption, refraction, etc.)



- Semi-direct effects → affect PBL meteorology and photochemistry;



- First indirect effect → affect cloud drop size, number, reflectivity, and optical depth via CCN;



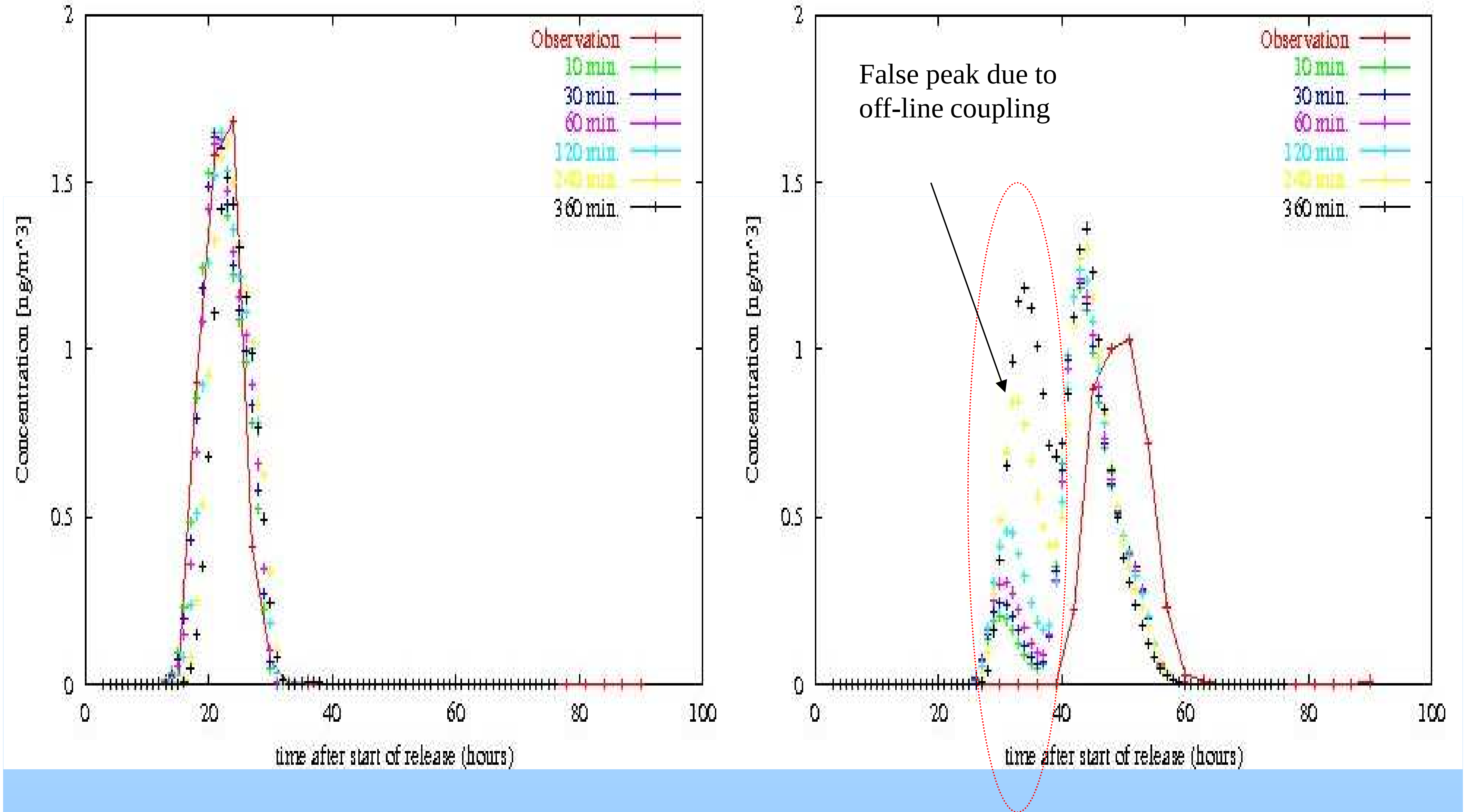
- Second indirect effect → affect cloud liquid water content, lifetime, and precipitation;

- Chain of all aerosol effects (nonlinear interaction)

⇒ High-resolution on-line models with a detailed description of the PBL structure are necessary to simulate such effects

⇒ On-line integrated models are necessary to simulate correctly the effects involved 2nd feedbacks

ETEX: On-line/Off-line Comparison



Top: concentration as function of time at F15 and DK02 for different coupling intervals: 30, 60, 120, 240, 360 minutes. Bottom: concentration after 36 hours with the same coupling intervals

Korsholm et al., AE, 2009

Chemistry and Aerosols in Enviro-HIRLAM

<u>GasChem module</u>: in the current version of Enviro-HIRLAM consist of:

A) The condensed CBM gas-phase mechanism based on CBMZ (*Zaveri et al., 1999*), which is simplified lumped structure photochemical mechanism and most fast chemical solver (The radical balance solution technique (*Sillman, 1991*).

The chemical module has 120 reactions and 23 advected species.

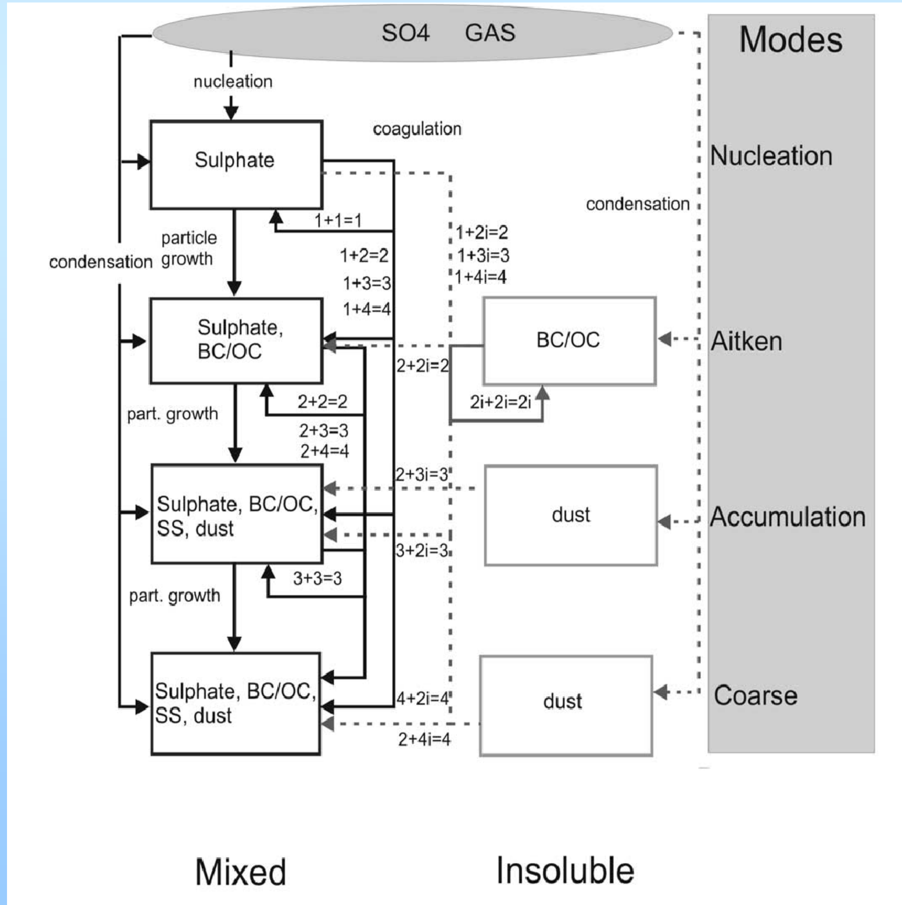
B) Photolysis rate: we setup a look-up table for J-values as a function of altitude, solar zenith angle, cloud optical depth. J-values were originally generated using programs supplied by Sasha Madronich.

<u>AeroChem module</u> in Enviro-HIRLAM consists of:

A) Thermodynamic equilibrium module HETV (Makar et al., 2003),

B) Cloud chemistry

C) Aerosol dynamics module M7 (Vignati et al., 2004).



Feedback parameterisations in Enviro-HIRLAM

• Enviro-HIRLAM contains parameterizations of the ***direct, semi-direct, first and second indirect effects of aerosols***.

• **Direct and semi-direct effects are realised by modification of Savijarvi scheme** with implementation of a new fast analytical SW and LW (2-stream approximation) transmittances, reflectances and absorptances

• Condensation, evaporation and autoconversion in warm clouds are considered fast relative to the model time step and are not treated prognostically.

• **The bulk convection and cloud microphysics scheme STRACO** (Sass, 1998) and the **autoconversion scheme by Rasch and Kristjansson (1998) forms the basis of the parameterisation of the second aerosol indirect effect.**

• **As aerosols are convected they may activate and contribute to the cloud droplet number concentration, thereby, decreasing the cloud droplet effective radius affecting autoconversion of warm cloud droplets into rain drops.**

• **Cloud radiation interactions are based on the cloud droplet effective radius** (Wyser *et al.*, 1998).

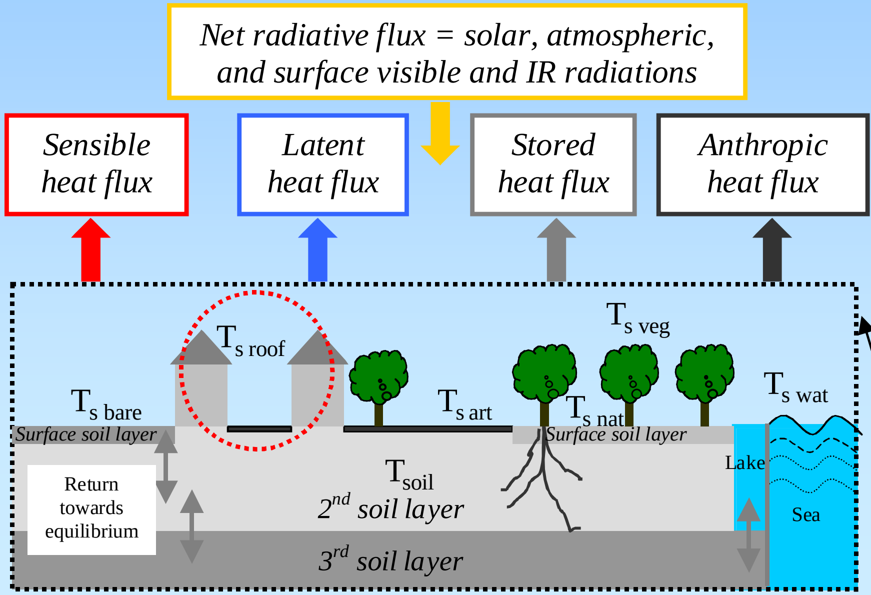
• **As it decrease warm clouds reflects more incoming short wave radiation, thereby, parameterising the first aerosol indirect effect.**

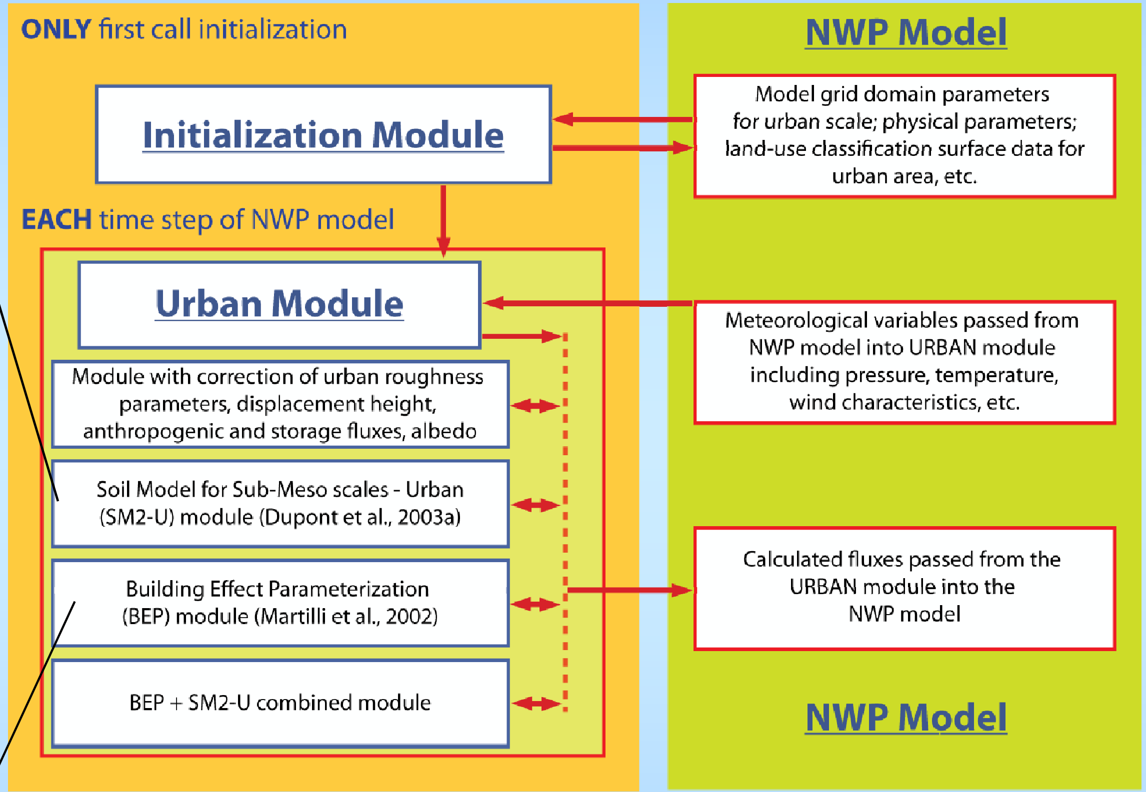
• A clean background cloud droplet number concentration is assumed and the anthropogenic contribution is calculated via the aerosol scheme.

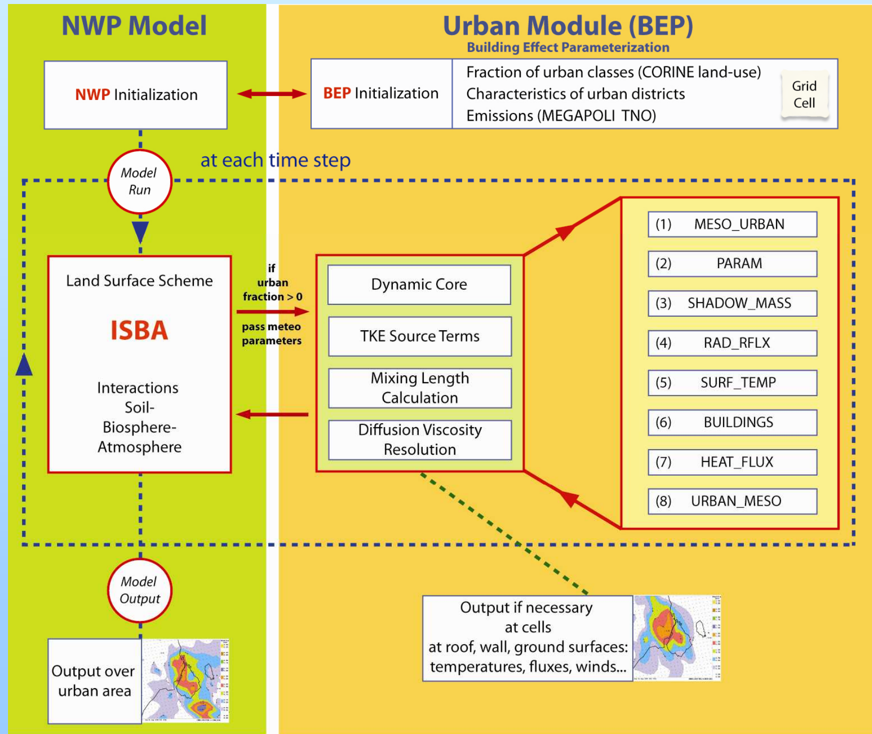
Application without chemistry

1) Urban case study

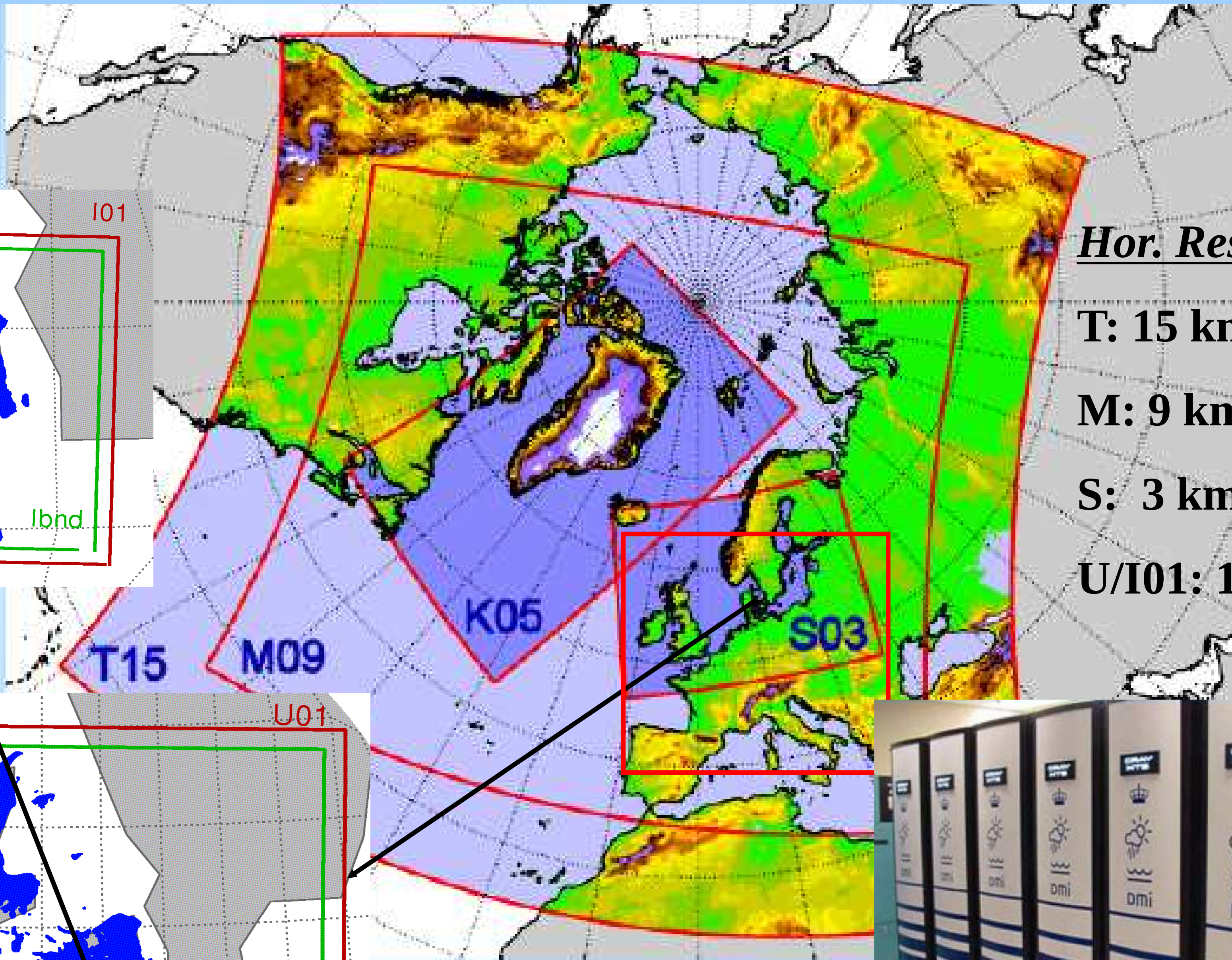
Enviro-HIRLAM Urbanization

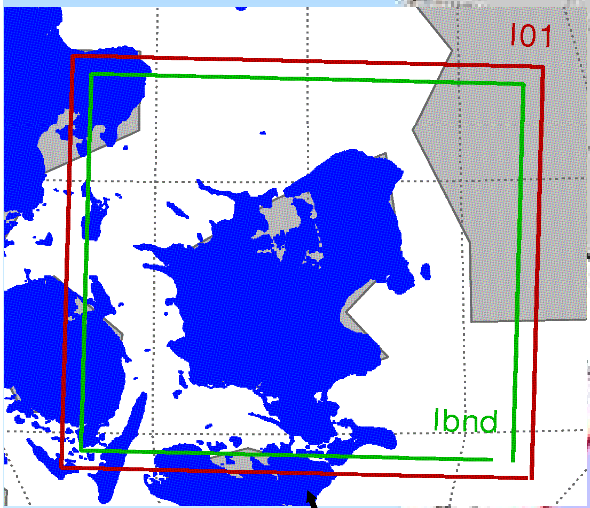


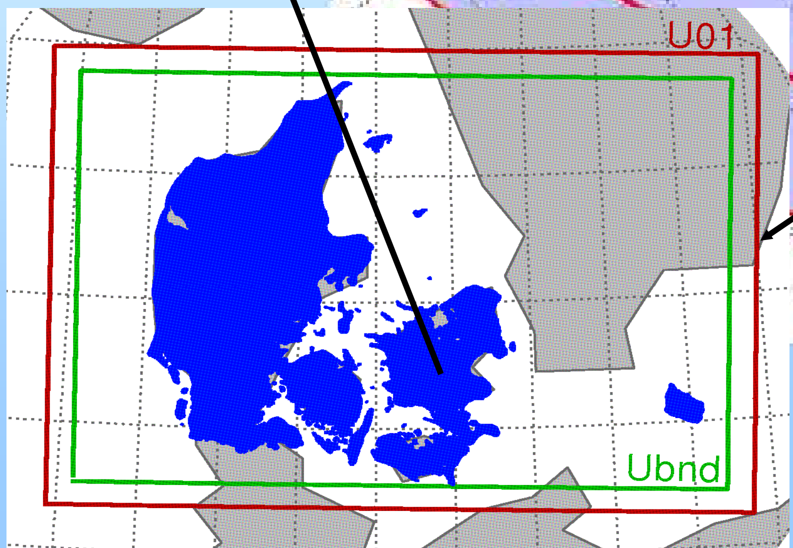




DMI NWP and Enviro-HIRLAM Modeling Domains







Hor. Resol.:

T: 15 km

M: 9 km

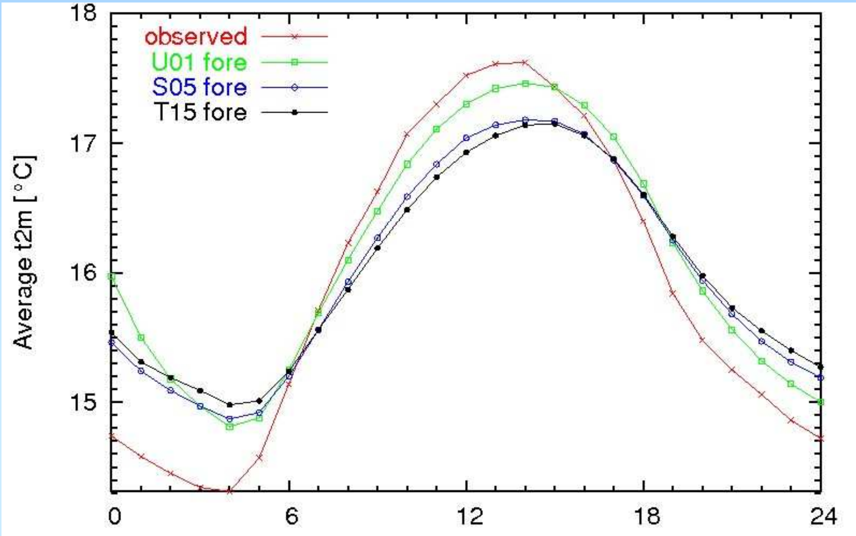
S: 3 km

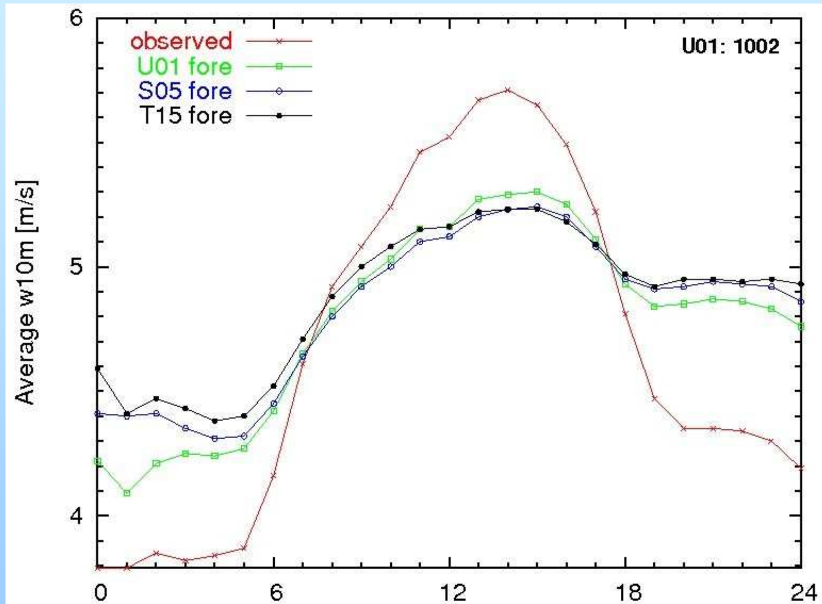
U/I01: 1.4 km

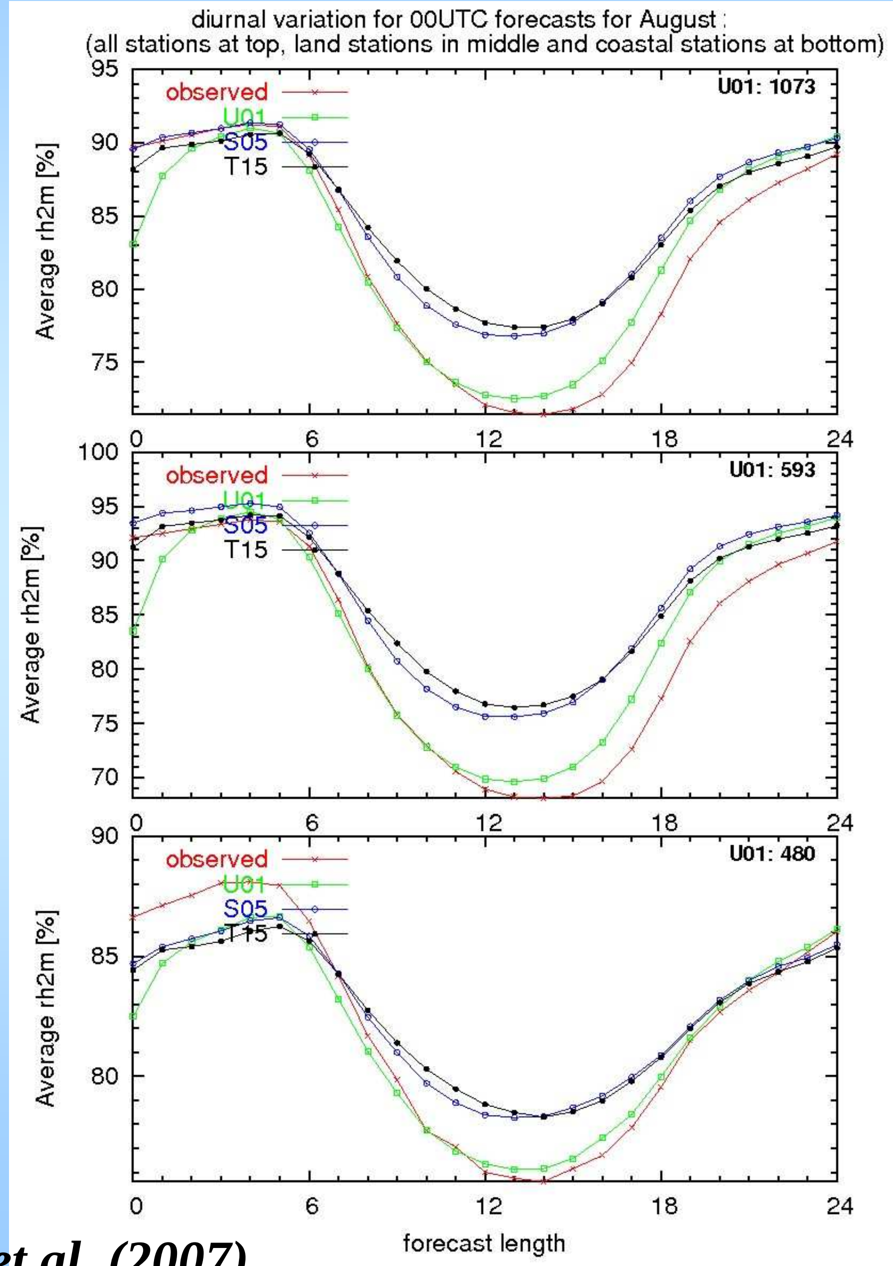
Urbanized Model Overall Performance

(for Denmark)

-------- all stations --------



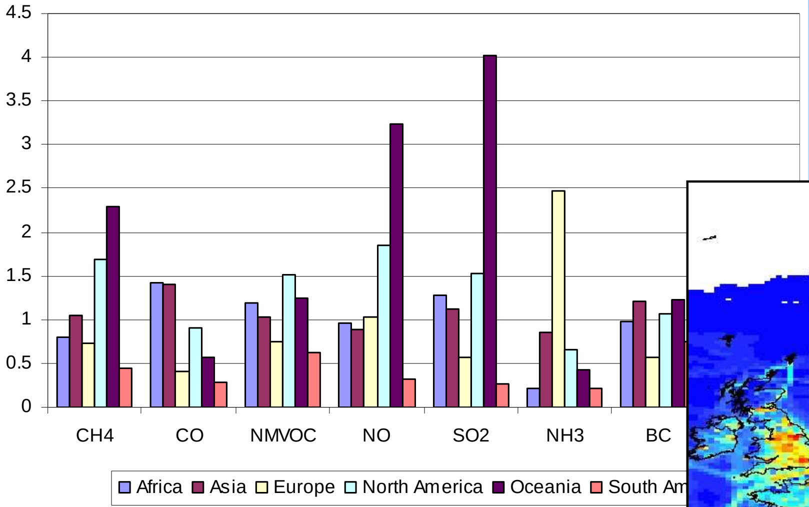




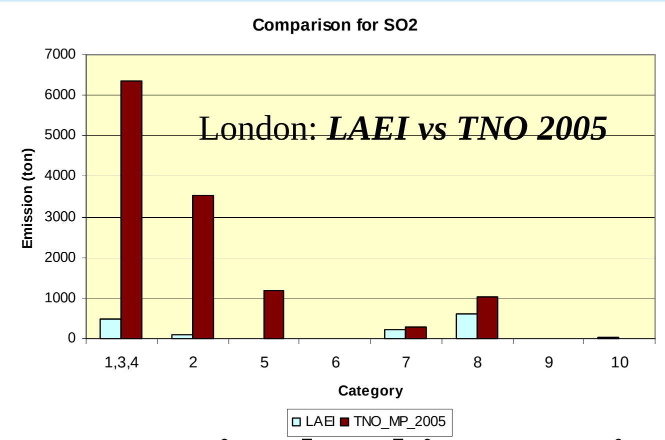
Mahura et al. (2007)

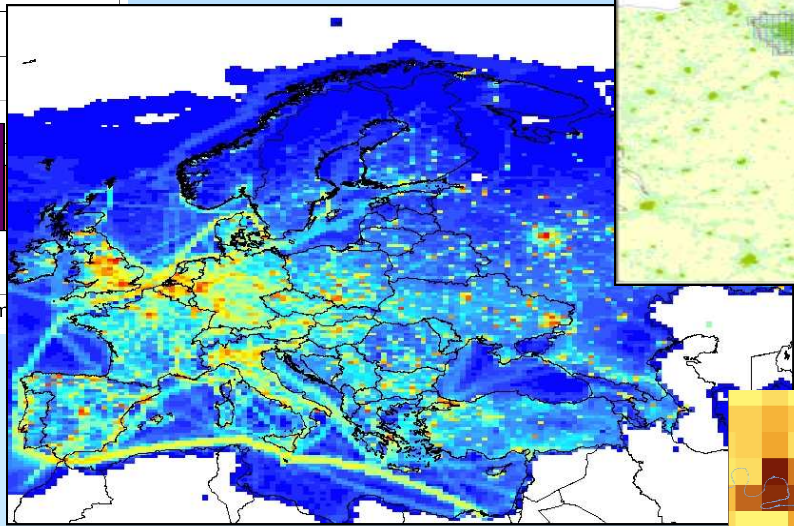
MEGAPOLI Emission Inventories

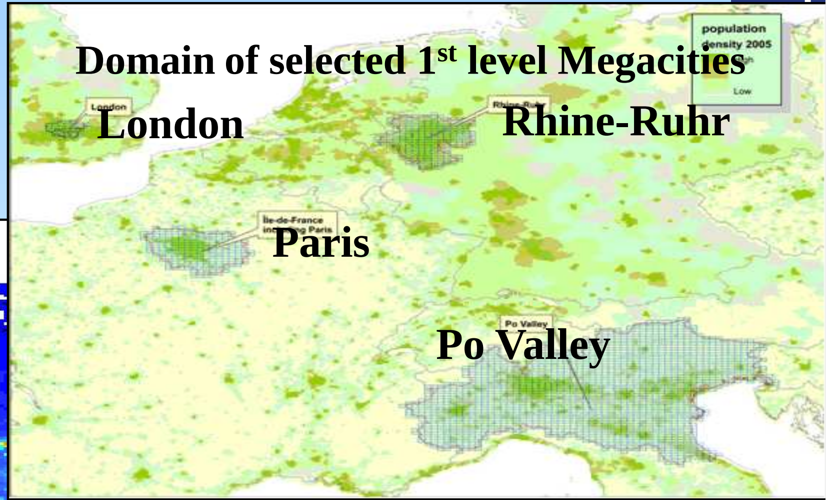
Lead by TNO Team: H. Denier van der Gone et al.

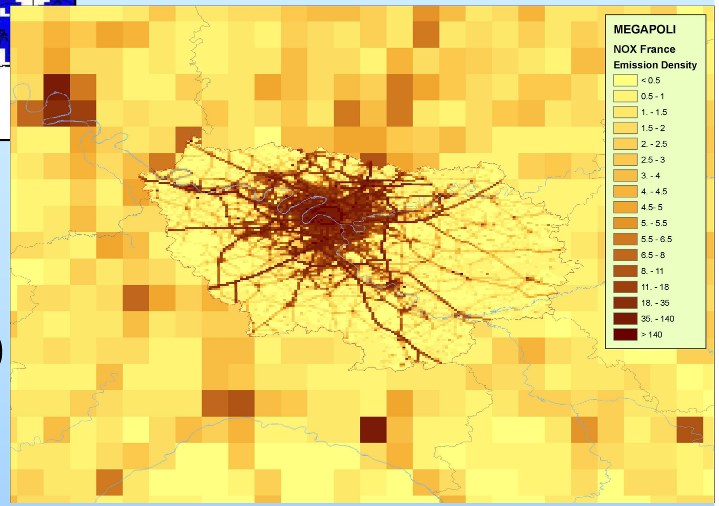


Emissions per capita in megacities (relative compared to all megacities)









- **Global emission inventory with all megacities mask**
- **2005 European emission inventory (6x6 km resolution)**
- **Natural emissions (e.g., fire, sea salt, pollen, volcano)**

- **Nesting local inventories for 4 megacities in focus (up to 1x1 km resolution)**
- **Comparison of city, national and European emissions**
- **Integration of nested emissions into multi-scale modelling chain**
- **European and megacity baseline scenarios for 2020, 2030 and 2050 (USTUTT)**

2) Study with anthropogenic aerosol emissions

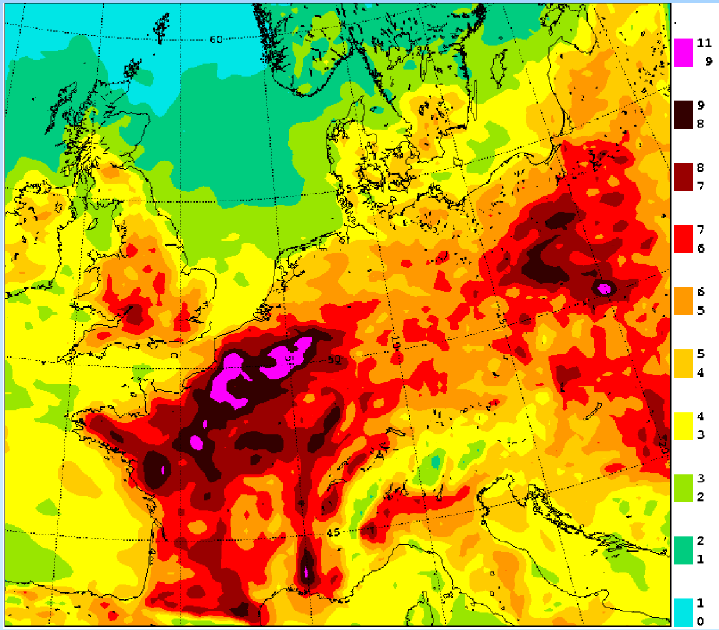
Monthly averaged changes in surface temperature due to aerosol indirect effects of primary sulfate aerosol emissions in Western Europe

Ulrik Smith Korsholm, Claus Petersen, Bent Hansen Sass,
Alexander Mahura, Alexander Baklanov

Comparing simulations with and without aerosol indirect effects for June 2009

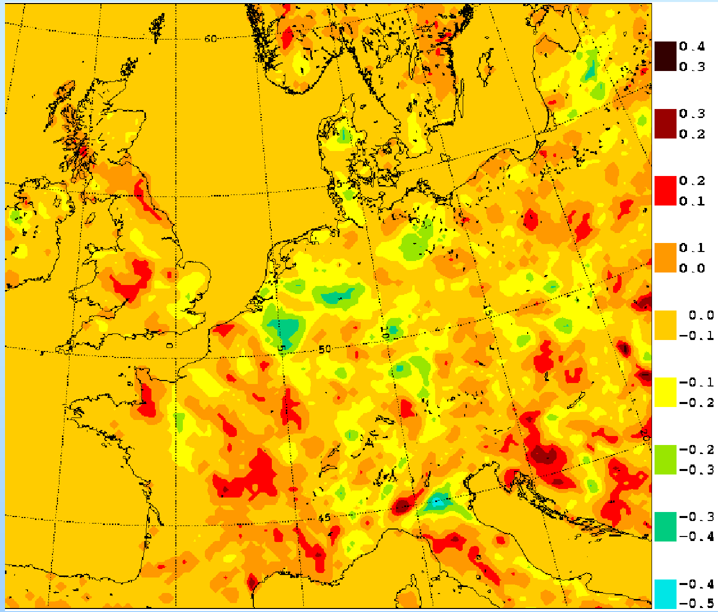
Cloud droplet effective radius modified by activated anthropogenic Aerosols → first indirect aerosol effect

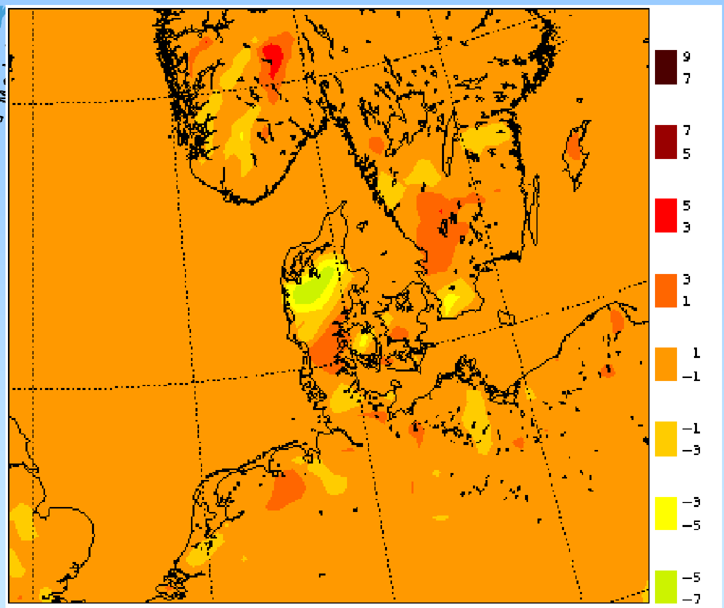
STRACO modified to include convection of passive aerosols
auto-conversion based on the Rasch-Kristjansson scheme
Dependent on number concentration of activated aerosols



Monthly averaged CCN number concentration ($x10^7$ m^{-3}) at 850 hPa.

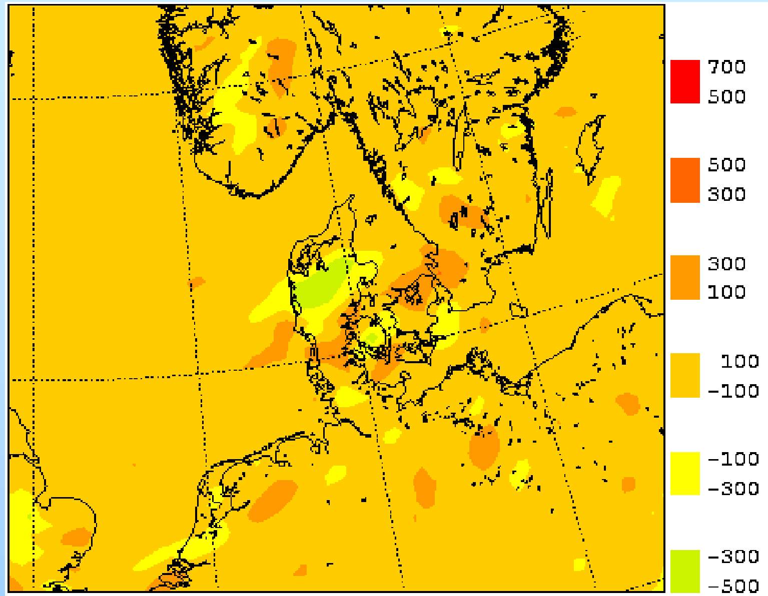
Monthly averaged difference in T_s (° C) (RUN - BASELINE)





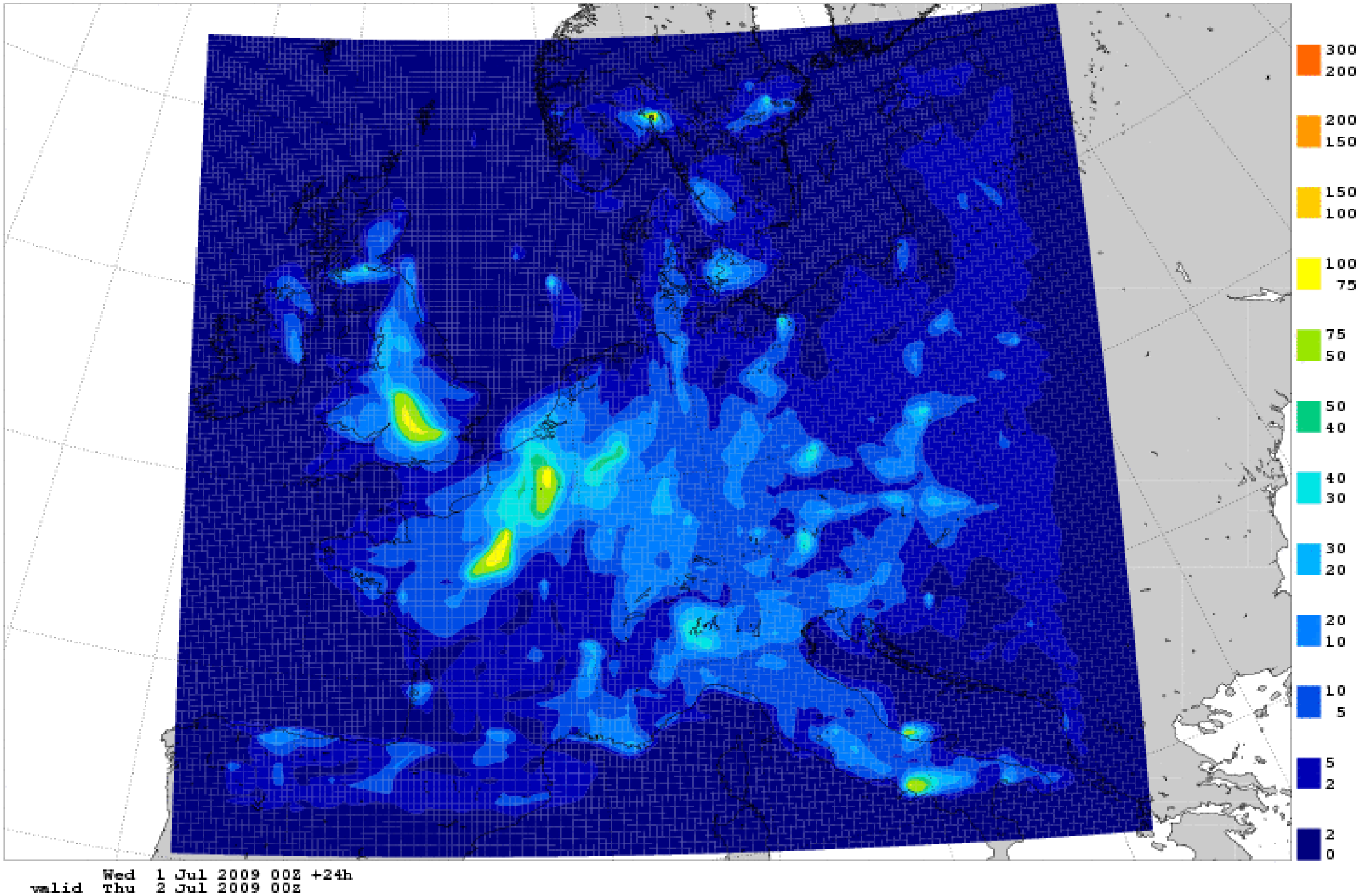
Change in T_s (° C) over Denmark on 8 June 2009 at 12 UTC (RUN - BASELINE)

Change in net SW radiation at the surface (W m^{-2}) on 8 June 2009 at 12 UTC (RUN - BASELINE)



3) Forecast example with chemistry

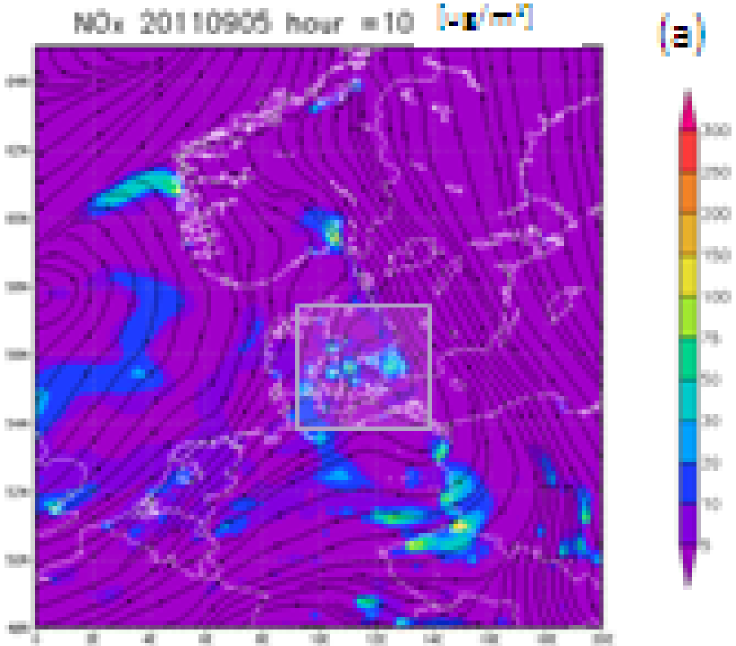
Enviro-HIRLAM NO2 concentration (µg m^{-3}) forecast



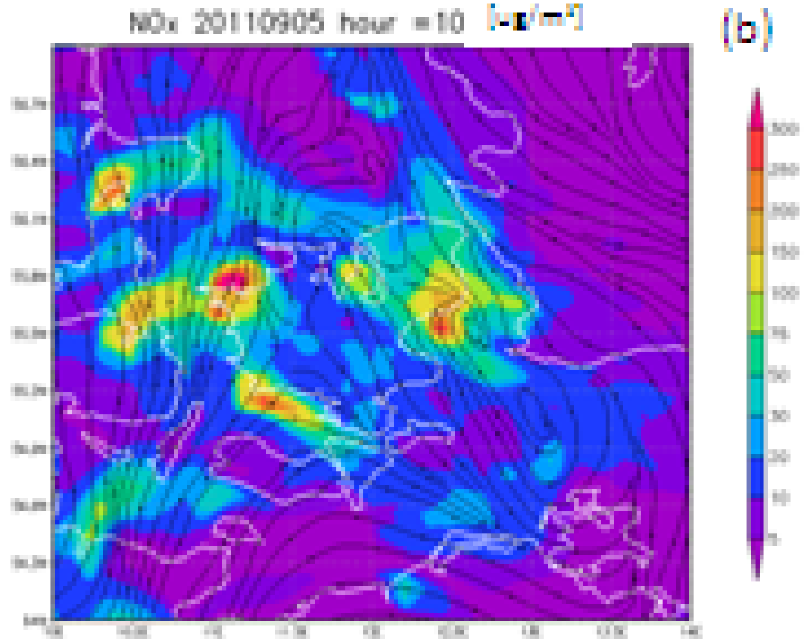
4) Example from MACC –project:

LAM forecast model chain ending with prediction on street scale level :

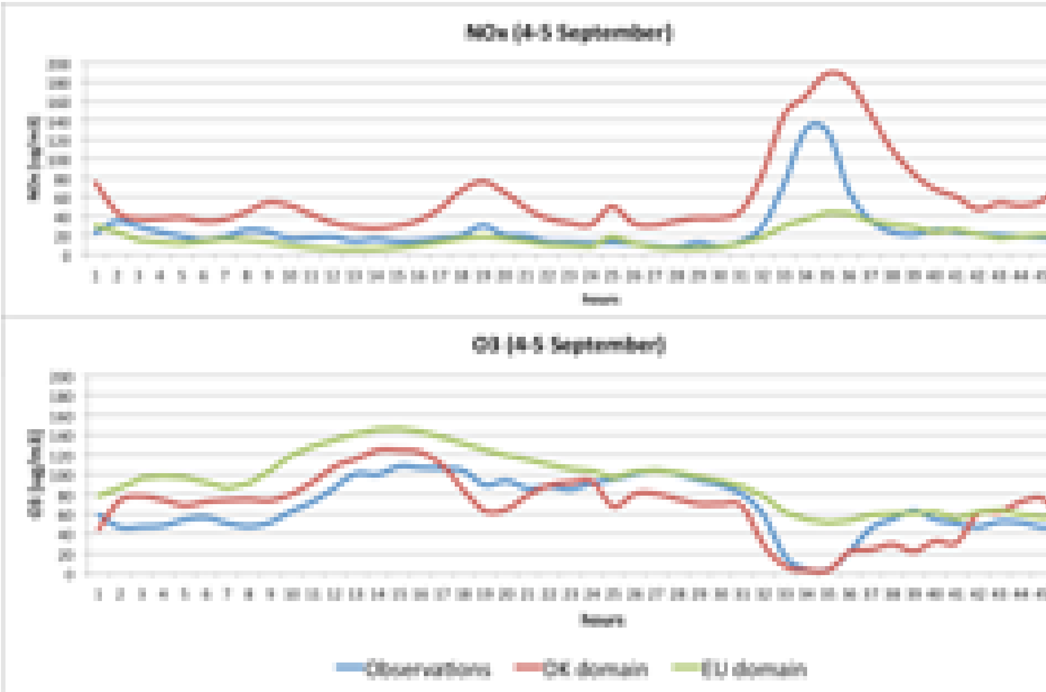
Modeling Results vs. Observations



(a)



(b)



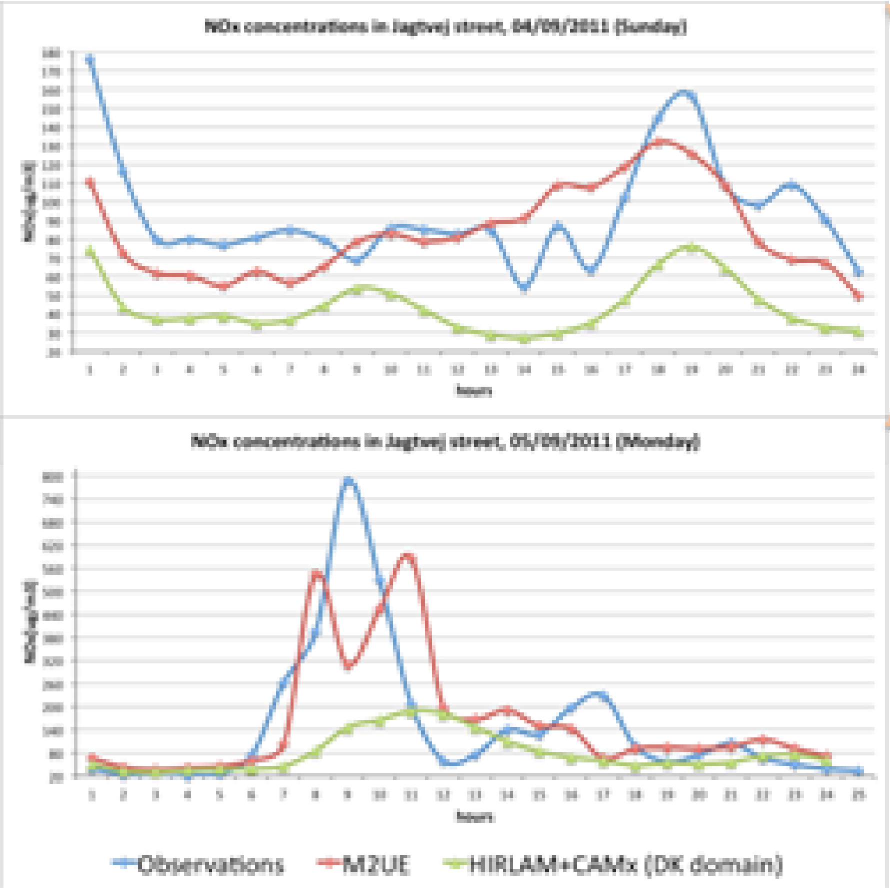
(c)

(a) HIRLAM+CAMx at European scale – EU resolution 0.2° x 0.2°

(b) HIRLAM+CAMx at Denmark scale – DK resolution 0.04° x 0.04°

(c) Observations at building roof level vs. modeling results for domains EU and DK (observations from http://www2.dmu.dk/atmosphericenvironment/byer/forside.htm)

Observations vs. Modeling Results



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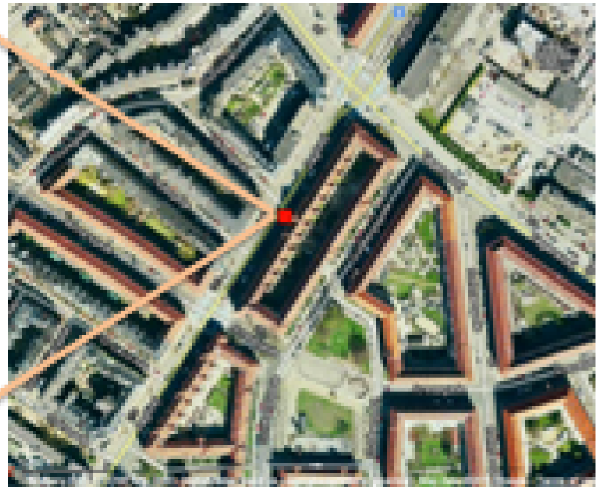
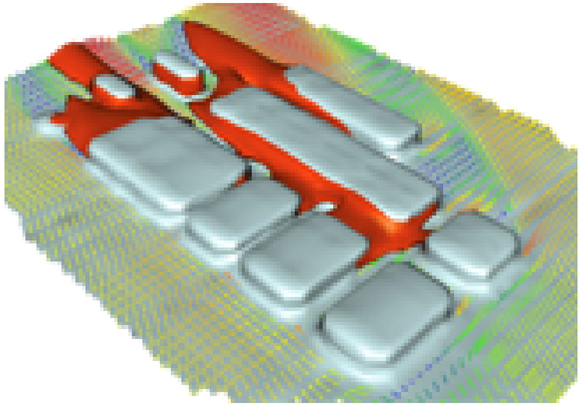
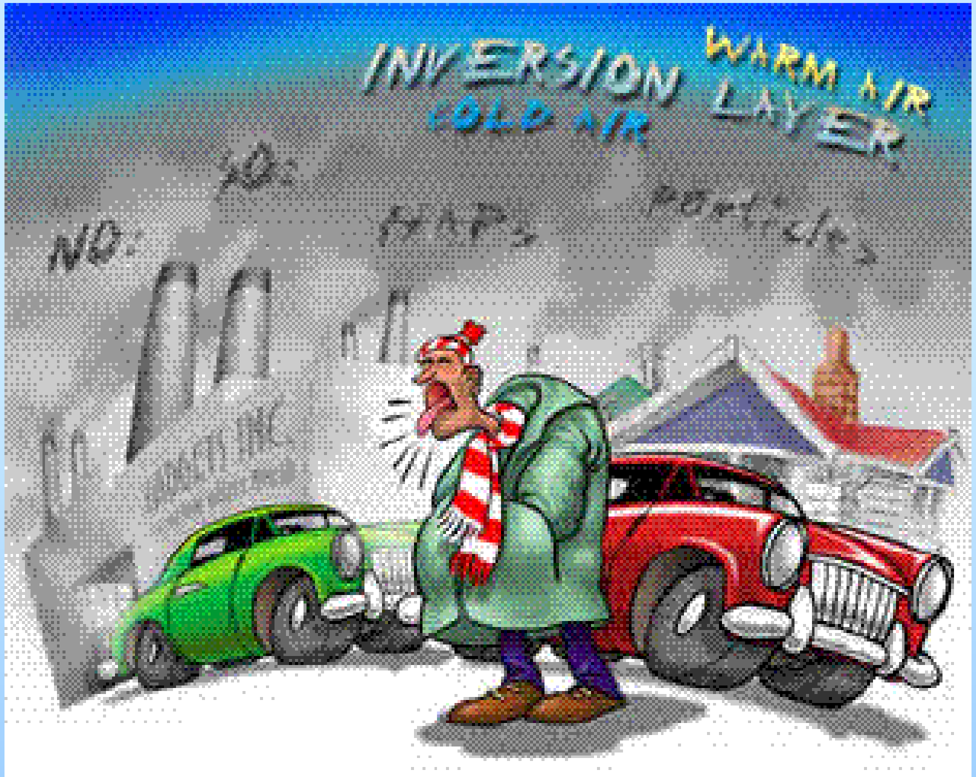




NOx concentration in the street canyon on 5 Sep 2011, 15:00 LST

Thank You !

Photochemical Smog
VOCs
NOx



INVERSION
COLD AIR
WARM AIR LAYER
NO
HAPs
Particles