

# INTEGRATED METEOROLOGICAL AND CHEMICAL TRANSPORT MODELLING: HIRLAM CHEMICAL BRUNCH, ENVIRO-HIRLAM STATUS AND AEROSOL FEEDBACK STUDIES

## Enviro-HIRLAM development team

*Danish Meteorological Institute,*

DMI, Research Department, Lyngbyvej 100, Copenhagen, DK-2100, Denmark  
alb@dm.dk, phone: +45 39157441

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Sander Tijm on behalf of  
Bent Hansen Sass on behalf of  
Alexander Baklanov

# Enviro-HIRLAM development team:

## Currently 4 institutions are working:

- Danish Meteorological Institute (A. Baklanov, U. Korsholm, A. Gross, A. Mahura, B.H. Sass, etc),
- University of Copenhagen (E. Kaas, etc),
- Tomsk State University (R. Nuterman, etc.),
- Russian State Hydro-Meteorological University (S. Smyshlyayev, etc.)
- HIRLAM-A program of the HIRLAM consortium (S. Tijm & HIRLAM Chemical branch).

## Teams willing to join the development team:

- University of Tartu, Estonia,
- Belgium Royal Meteorological Institute,
- Vilnius University, Lithuania,
- Odessa State Environmental University, Ukraine.

There is an initial working group (under COST728 and HIRLAM-A) for HIRLAM-ACTM integration work and a sub-program for the Enviro-HIRLAM/HARMONIE development cooperation.

Any HIRLAM and other teams are also welcome to join the team!

# Meteorology and Air Pollution: as a joint problem

- Meteorology is an important source of uncertainty in ACTMs => needs for urban- and meso-scale NWP model improvements
- Complex & combined effects of meteo- and pollution components (e.g., Paris, Summer 2003)
- Effects of pollutants/aerosols on meteo-processes (precipitation, thunderstorms, etc) and climate change

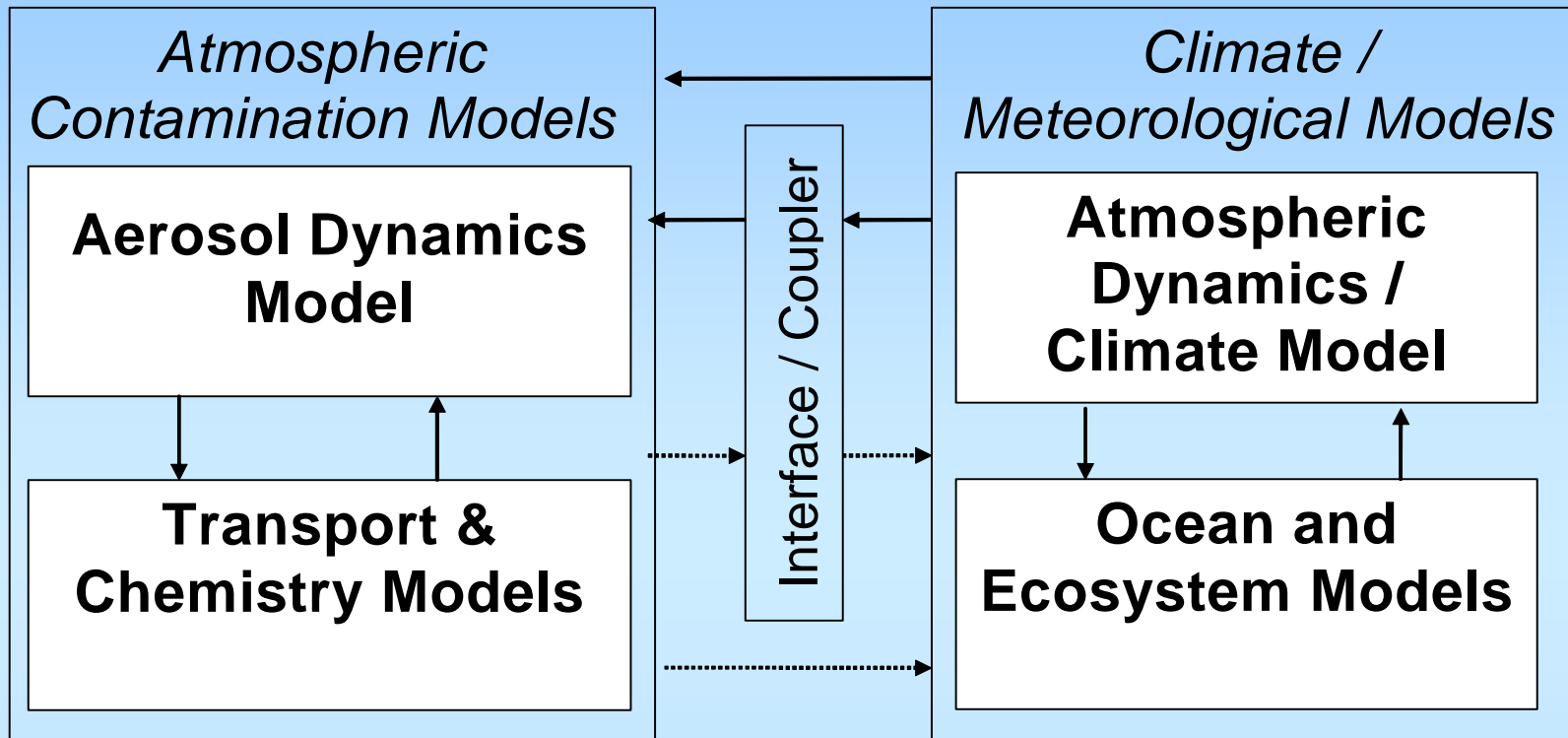
## Four main stones for Atmospheric Environment modelling:

1. Meteorology / ABL structure,
2. Chemistry,
3. Aerosol/pollutant dynamics (and emissions!)
4. Effects and Feedbacks

### => Integrated NWP & ACTM Approach:

In perspective, integrated NWP and ACTM have benefit for meteorological, environmental and “chemical weather” forecasting.

# Integrated Atmospheric System Model Structure



**One-way:** 1. HIRLAM meteo-fields as a driver for ACTM (off-line);

2. ACTM chemical composition fields as a driver for R/GCM (or for NWP)

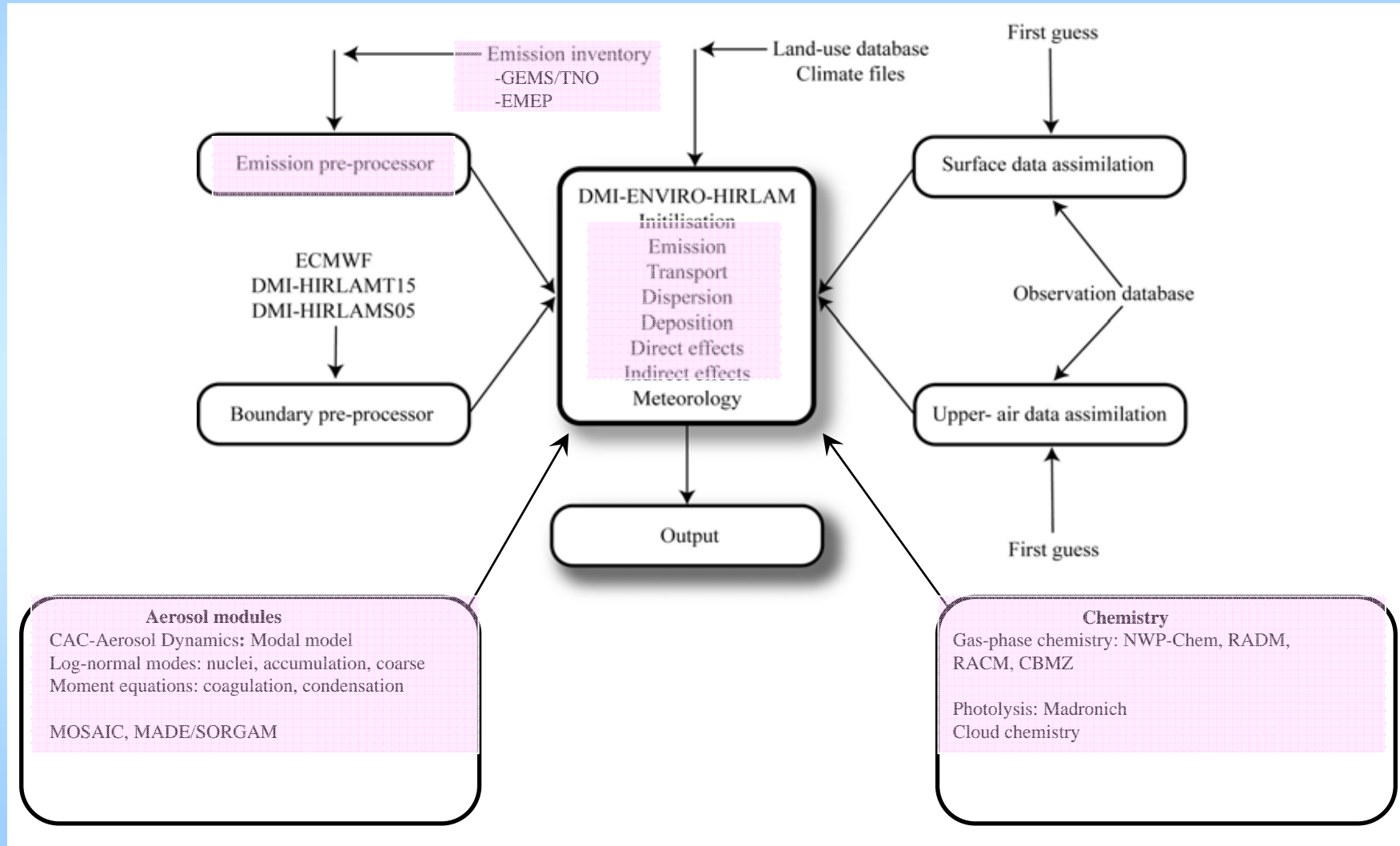
**Two-way:** 1. Driver + partly feedback NWP (data exchange via an interface with a limited time period);

2. Full feedbacks included on each time step (on-line coupling)

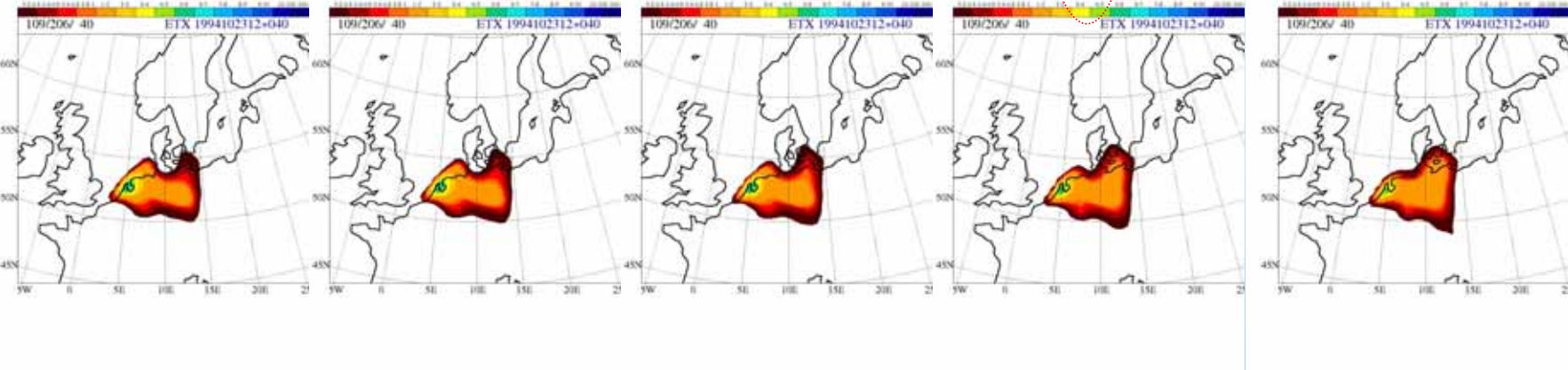
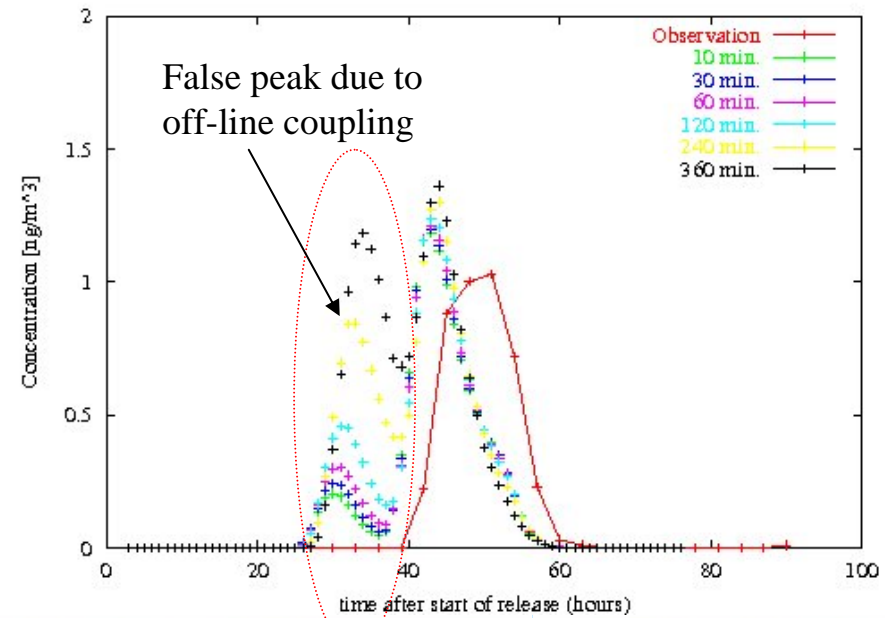
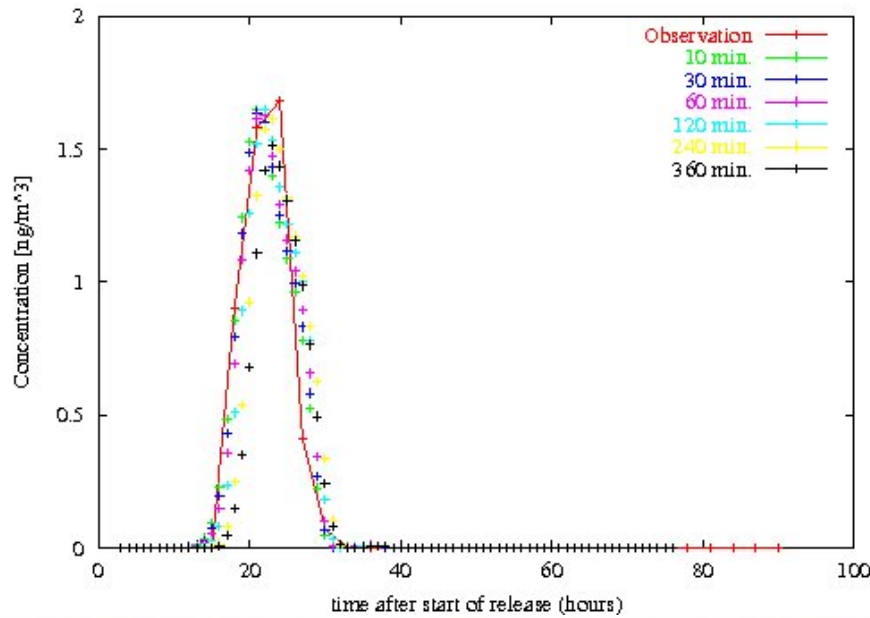
## Aerosol feedbacks to be considered

- **Direct effect** - Decrease solar/thermal-IR radiation and visibility
- **Semi-direct effect** - Affect PBL meteorology and photochemistry
- **First indirect effect** – Affect cloud drop size, number, reflectivity, and optical depth via CCN
- **Second indirect effect** - Affect cloud LWC, lifetime, and precipitation

# Current version of Enviro-HIRLAM modelling systems, showing the components of a forecast

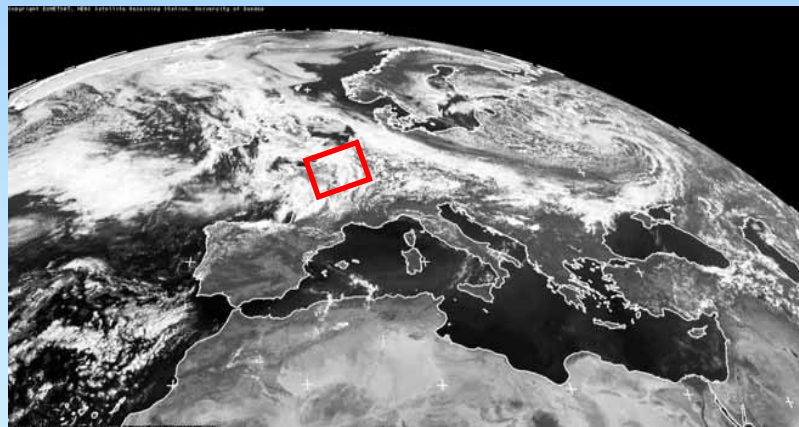


# ON-LINE/OFF-LINE COMPARISON



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

# ENVIRO-HIRLAM sensitivity study: First and Second indirect feedbacks of aerosols

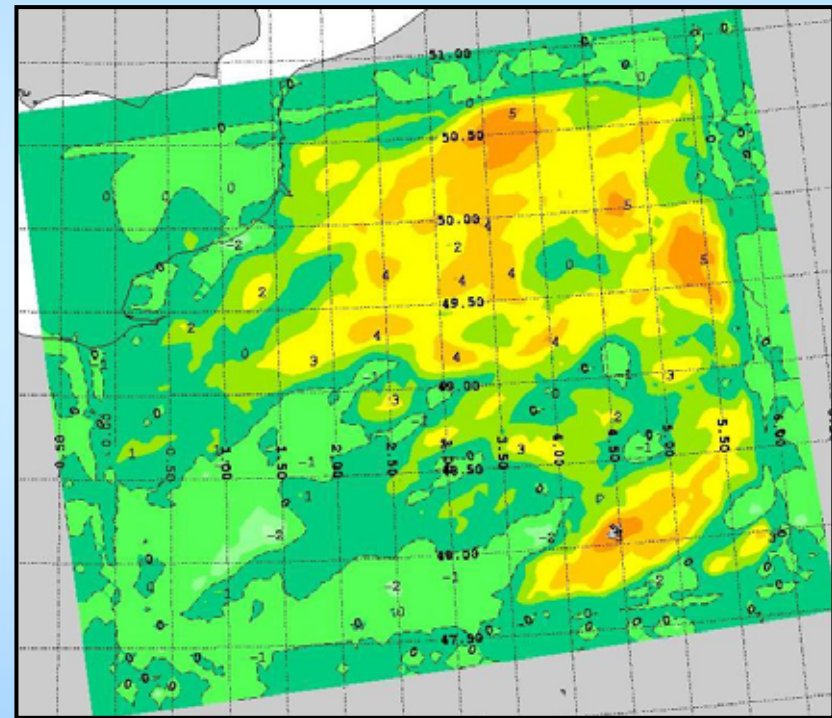
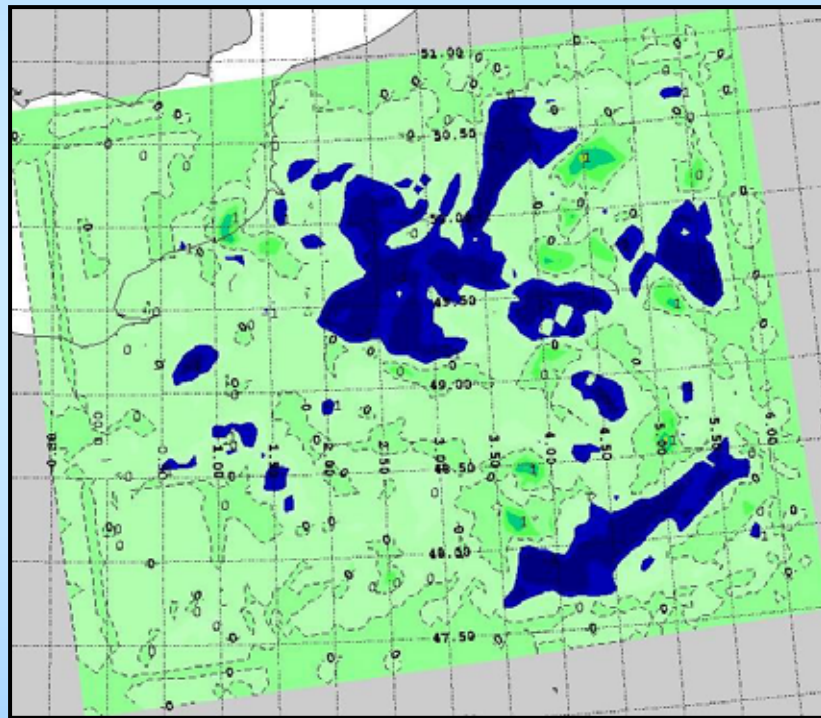


*Korsholm et al., EMS, 2008*

- Domain covering app. 500 x 400 km around **Paris, France**.
- 0.05 x 0.05 degrees horizontal resolution, 40 vertical levels, 300 s time step, NWP-Chem chemistry (18 species),
- CAC-aerosol mechanism: homogeneous nucleation, condensation, coagulation
- Aerosols consists of H<sub>2</sub>O, HSO<sub>4</sub><sup>-</sup>, SO<sub>4</sub><sup>--</sup>, two log-normal modes: nuclei, accumulation
- Accumulation mode aerosols used as CCN's
- Case with low winds, convective clouds, little precipitation
- Reference run without feedbacks, Perturbed run with first and second indirect effects.

# Results 1: Meteorology

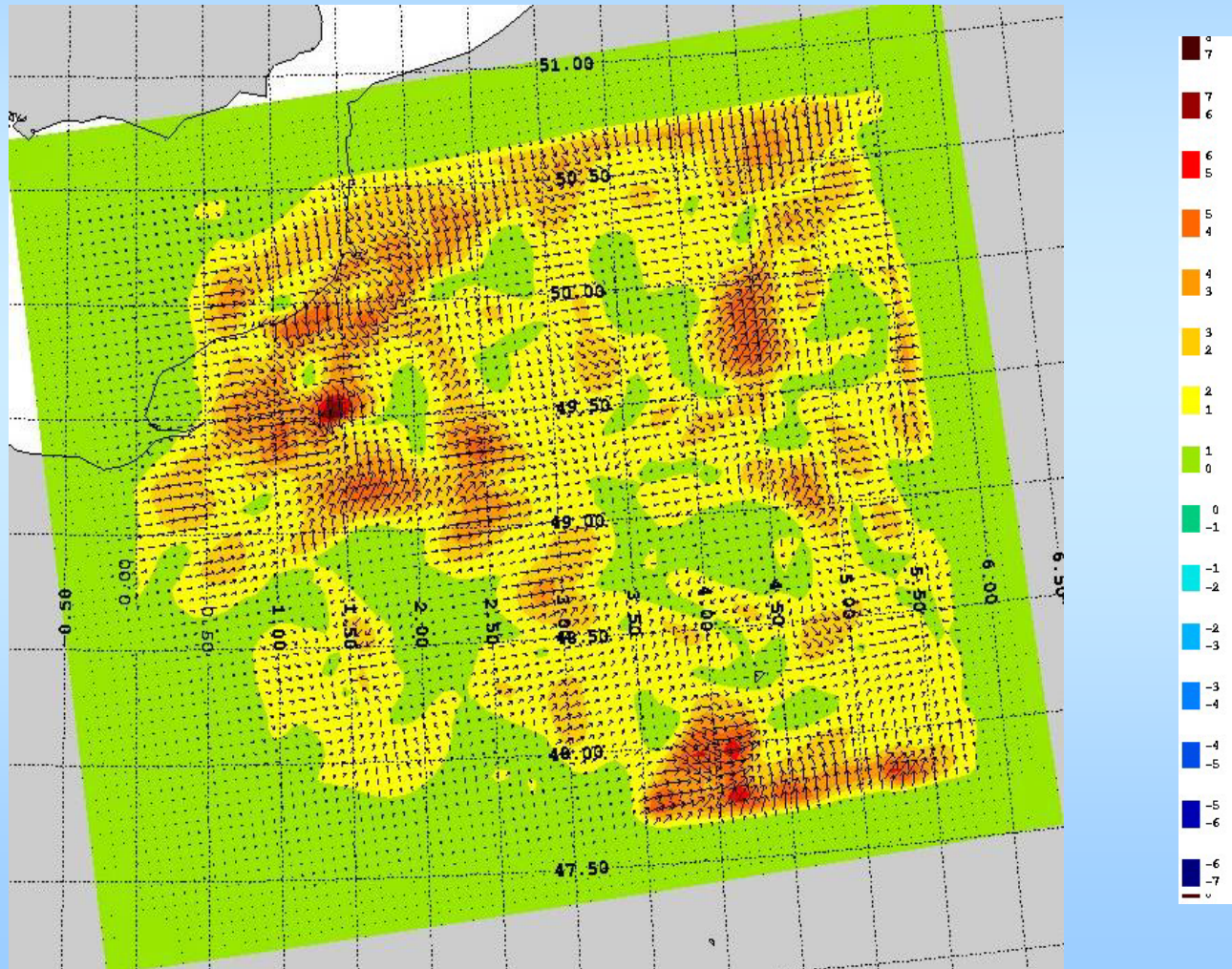
Day-time (2005-06-29 +036; 12 UTC) low cloud cover (left) and T2m (right) difference (reference - perturbation) with T2m in C.



Surface temperature changes are up to 4° C

# Results 2: Meteorology

Difference (reference-perturbation) in lowest level wind ( $\text{ms}^{-1}$ )



wind changes up to 3-6 m/s

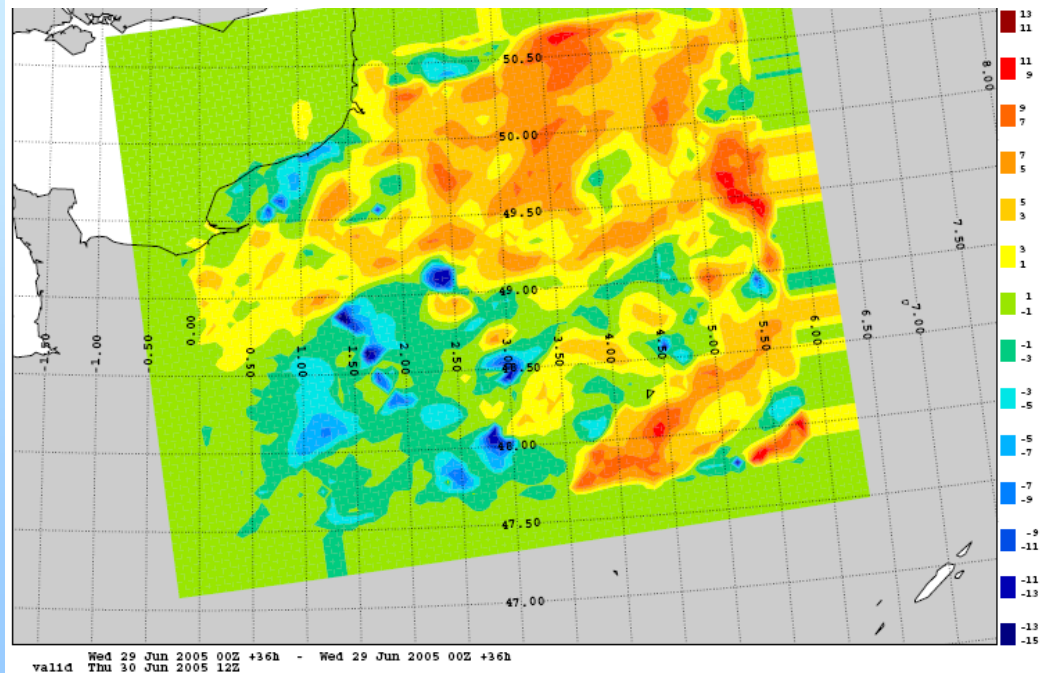
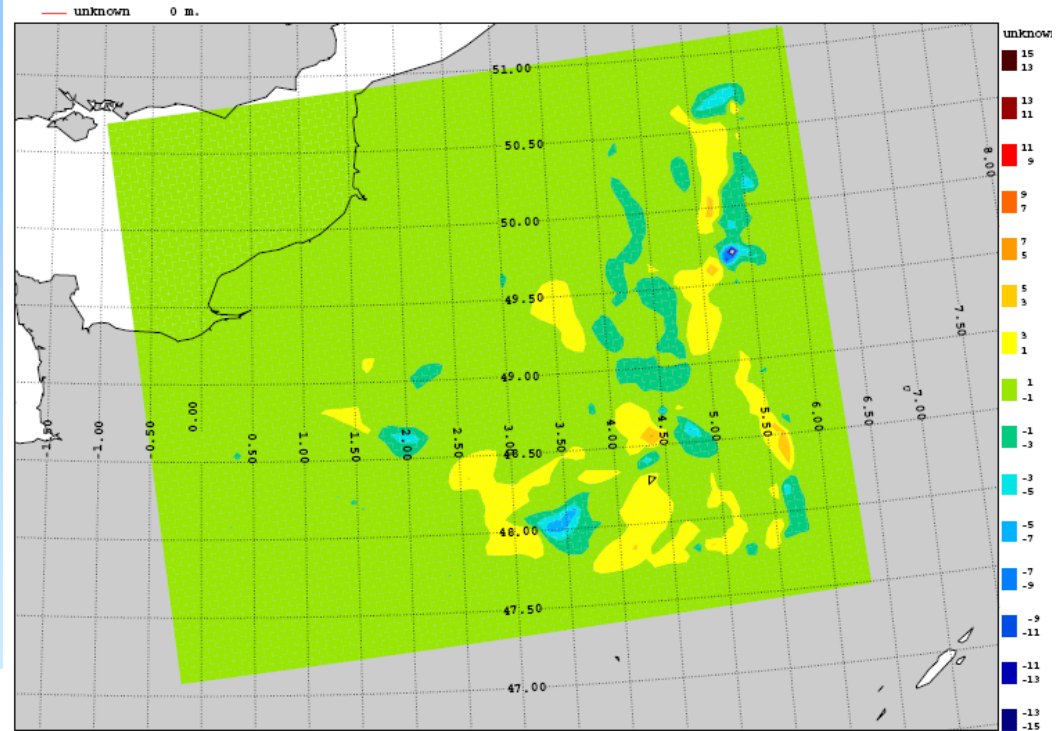
# Results 3: PBL height

Reference - Perturbation  
(in 100 m)

00 UTC

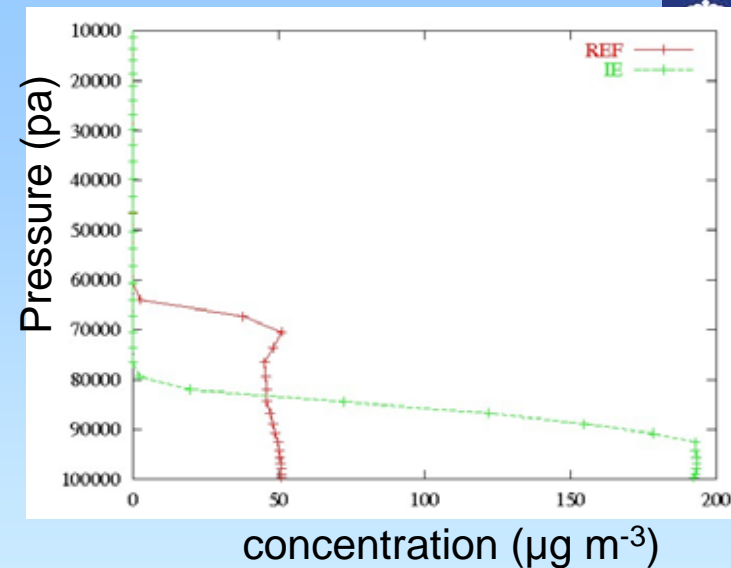
Changes in PBL height quite large  
(up to 900 m !)

12 UTC

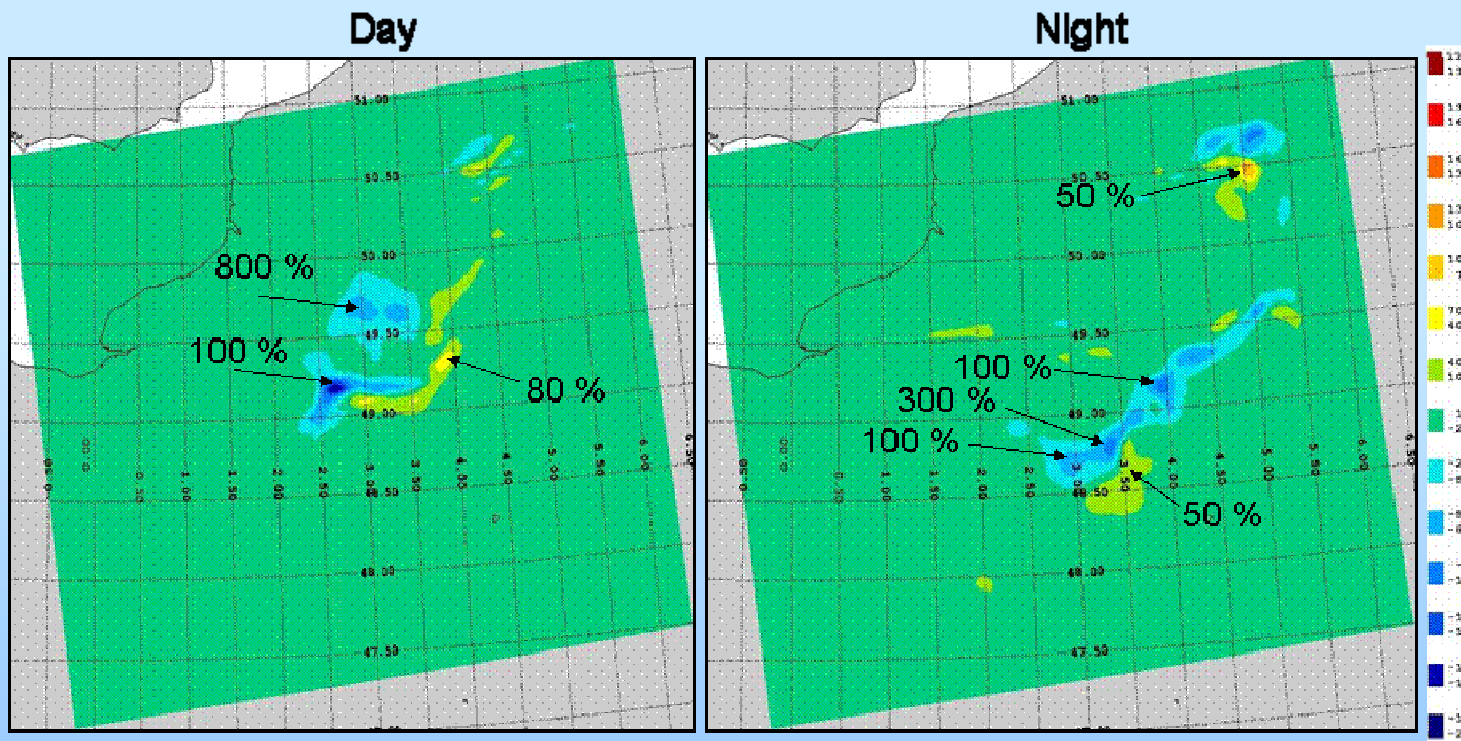


# Results 4: NO<sub>2</sub> concentrations

Vertical NO<sub>2</sub> profile in point of maximum increase (49.2N;2.7E) during daytime 2005-06-29 +036; 12 UTC for the reference simulation (red) and the simulation including the indirect effects (green)



## Reference – Perturbation



Day-time (2005-06-29 +036; 12 UTC) and night-time (2005-06-29 +048; 00 UTC) reference - perturbation NO<sub>2</sub> concentration ( $\mu\text{g m}^{-3}$ )

# Conclusions

In this particular case:

- Indirect effects induce large changes in  $\text{NO}_2$
- Changes mediated through changes in dynamics
- Residual circulation induced by temperature changes
- Redistribution both vertically and horizontally
- Also applies for night-time conditions
- Chem vs dynamics
- First indirect effect is much smaller than second one
- Large non-linear component

## Further work with Enviro-HIRLAM development

There are a number of outstanding issues which will be dealt with in the future, e.g.:

- Enviro-HIRLAM currently runs on the NEC-SX6 super-computer at DMI, but will be ported and optimized to the new CRAY-XT5 at DMI (this work is going),
- the model will be updated to HIRLAM version 7.1 / 7.2,
- will be implemented and available on the chemical branch of HIRLAM,
- improvement and validation of the direct and indirect aerosol effects,
- implementation of the gas feedback mechanisms,
- implementation and parallelization of a new advection scheme,
- updates for the gas-phase chemistry and aerosol modules,
- in MEGAPOLI it is planned to test EnviroHIRLAM with the aerosol model from University of Helsinki,
- improved representation of PBL and SL, further ‘urbanization’ of the model,
- a new mass conservative horizontal diffusion scheme will be implemented,
- heterogeneous chemistry will be expanded and implemented,
- data assimilation for the chemical compounds to be implemented,
- expansion of the HARMONIE system to include the Enviro-HIRLAM chemistry and aerosol features and feedbacks,
- Climate version of the Enviro-HIRLAM => Enviro-HIRHAM (based on newest HIRLAM version)
- .....

These would be a joint effort for the Enviro-HIRLAM developers and the HIRLAM consortium.

# Thank You !

