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

Enviro-HIRLAM development team

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Alexander Baklanov

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Sander Tijm on behalf of
Bent Hansen Sass on behalf of
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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. Smyshlyaev, 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 a 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

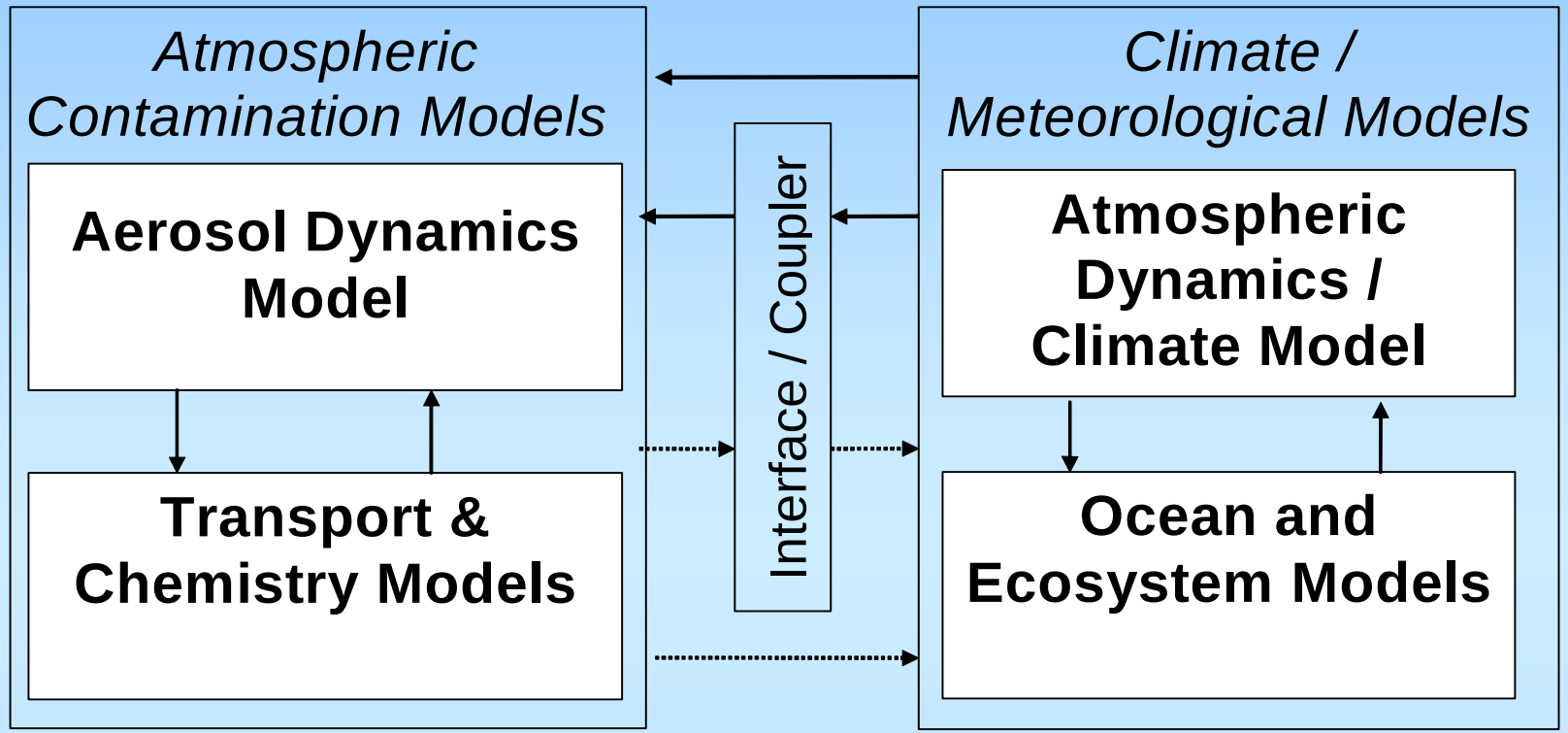
Four main stones for Atmospheric Environment modelling:

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 ACT 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)

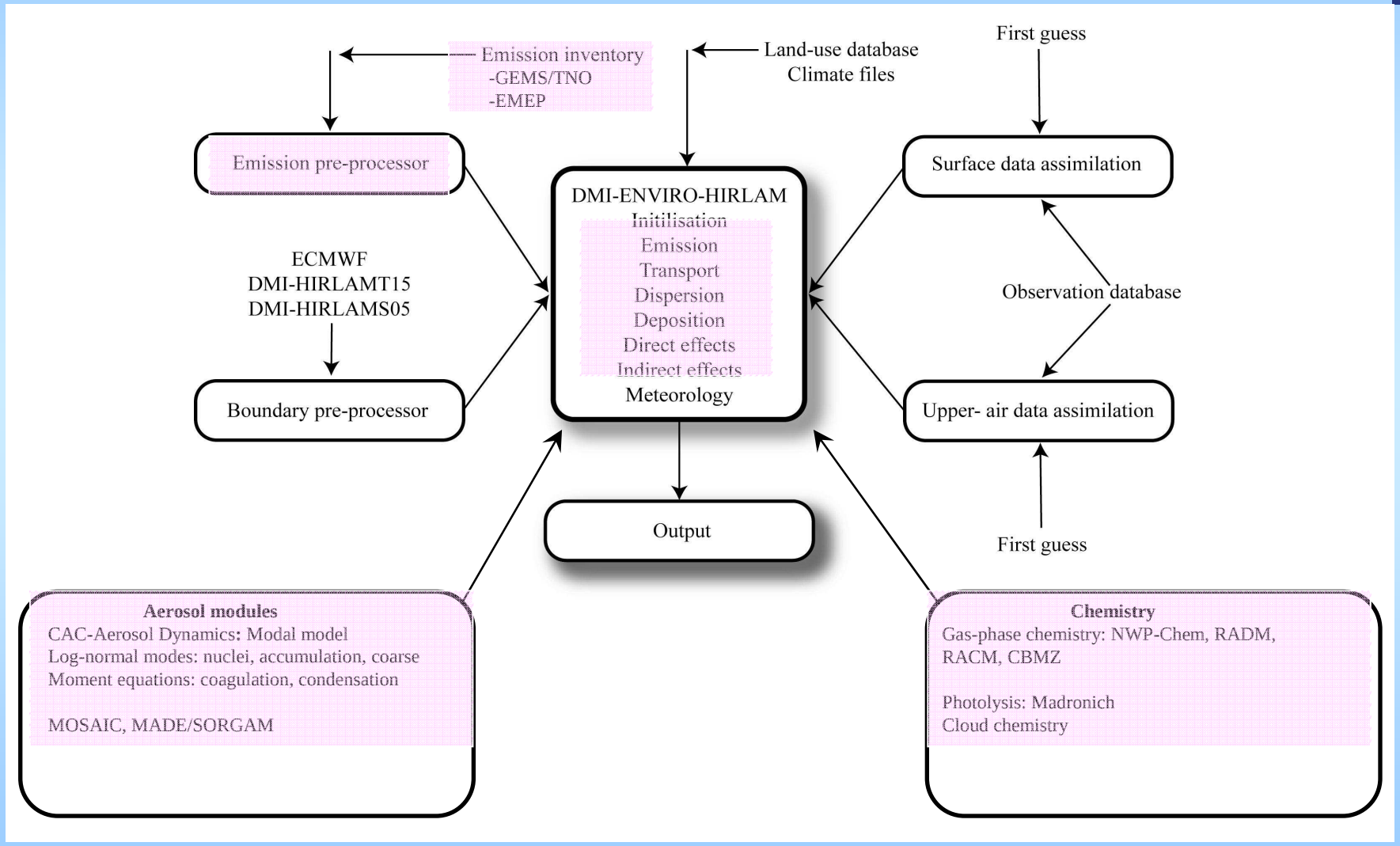
Two-way: 1. Driver + partly feedback NWP (data exchange via an interface with a limited time period);

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

Aerosol feedbacks to be considered

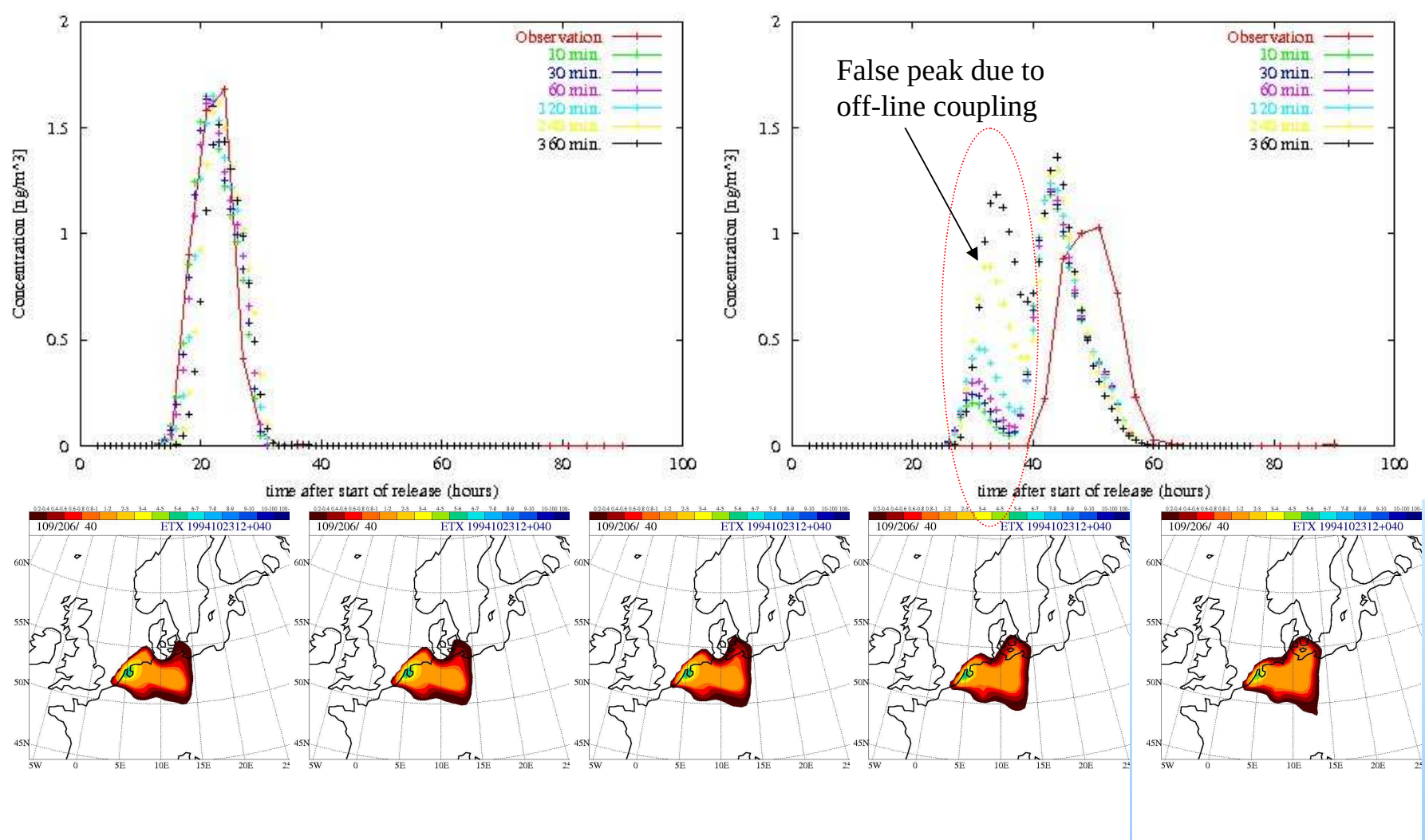
- **Direct effect - Decrease solar/thermal-IR radiation and visibility**
- **Semi-direct effect - Affect PBL meteorology and photochemistry**
- **First indirect effect – Affect cld drop size, number, reflectivity, and optical depth via CCN**
- **Second indirect effect - Affect cloud LWC, lifetime, and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

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



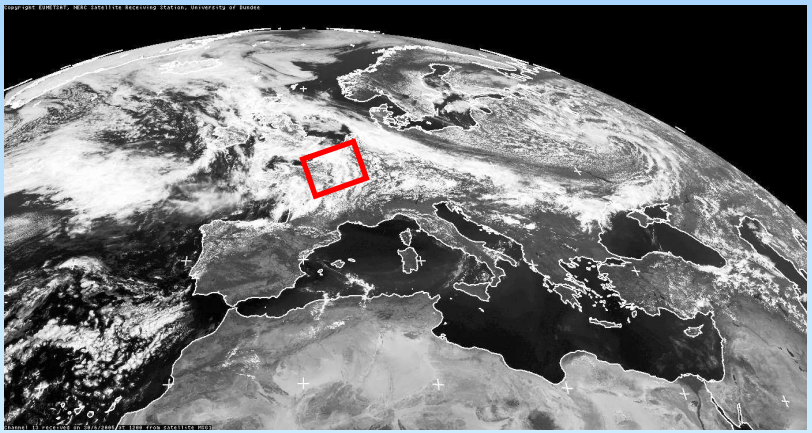
Korsholm, Baklanov, Gross, Mahura (2007)

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

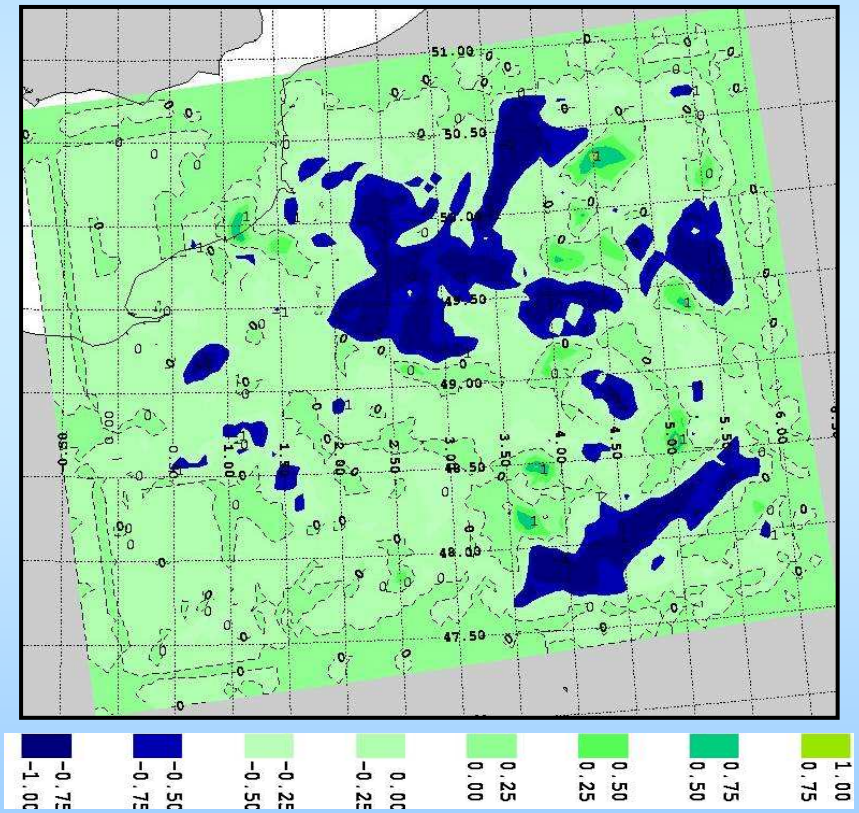


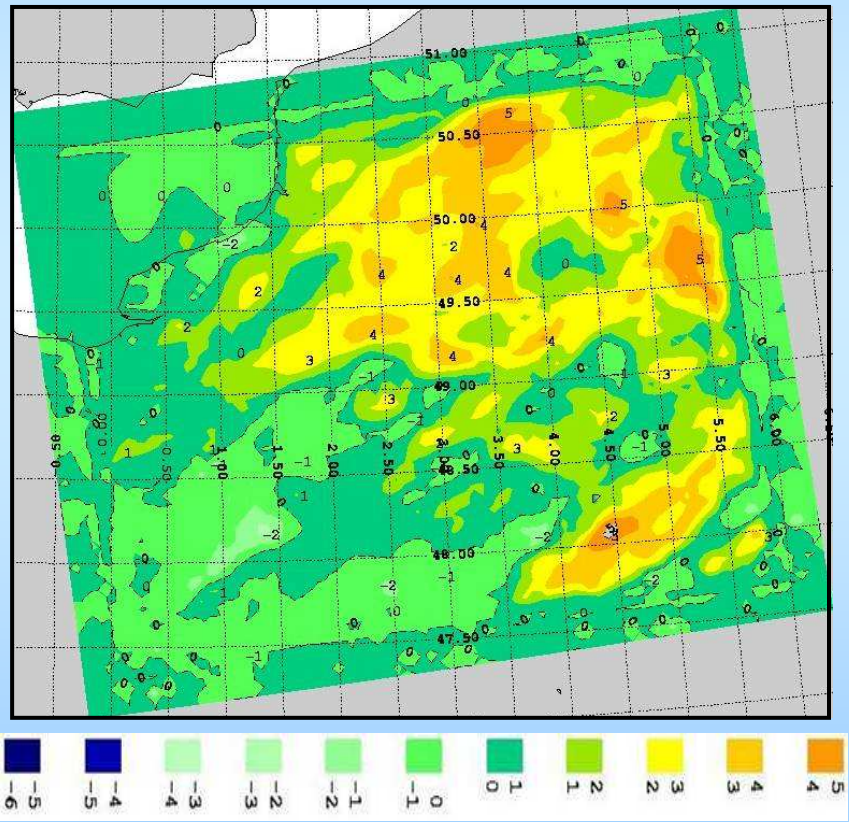
Korsholm et al., EMS, 2008

- 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 H2O, HSO4-, SO4--, 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.

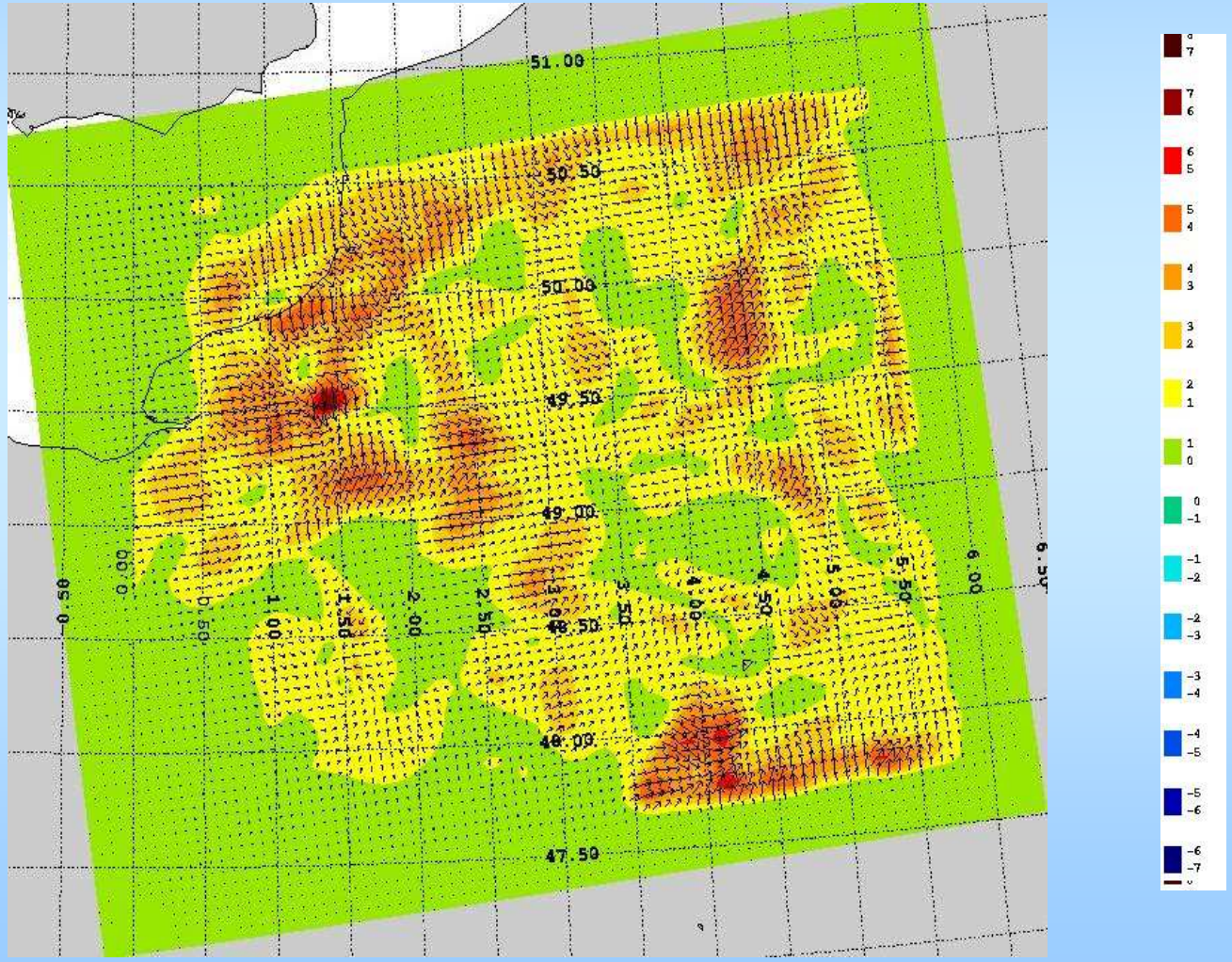




Surface temperature changes are up to 4º C

Results 2: Meteorology

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

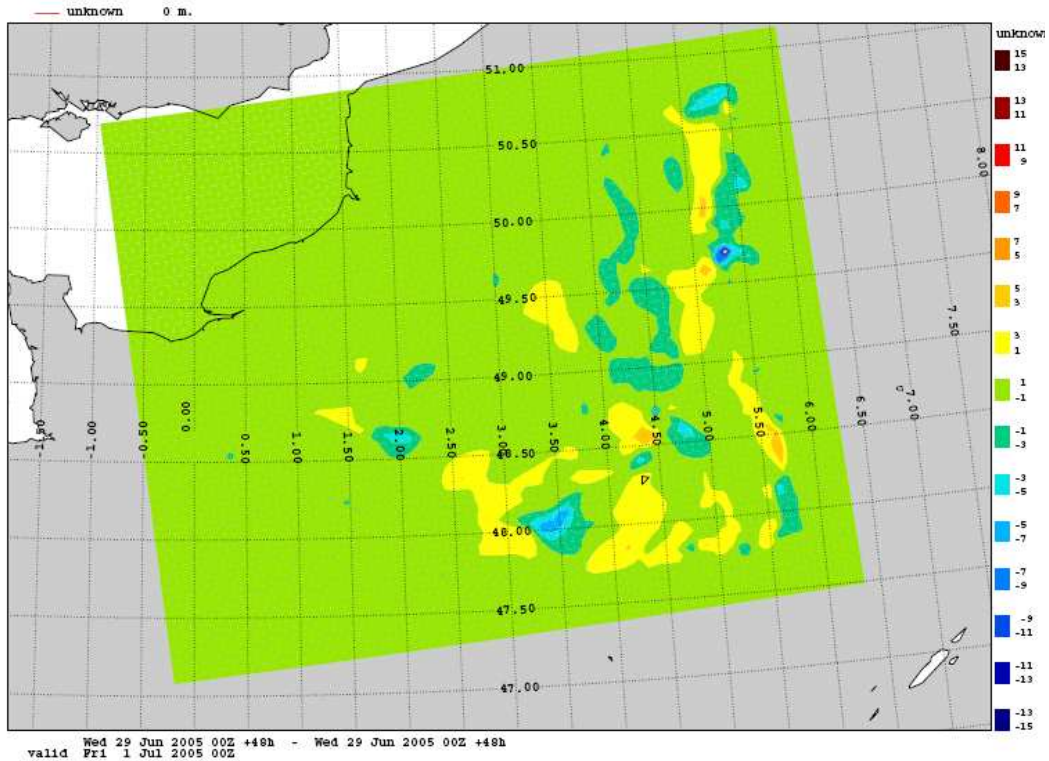


wind changes up to 3-6 m/s

Results 3: PBL height

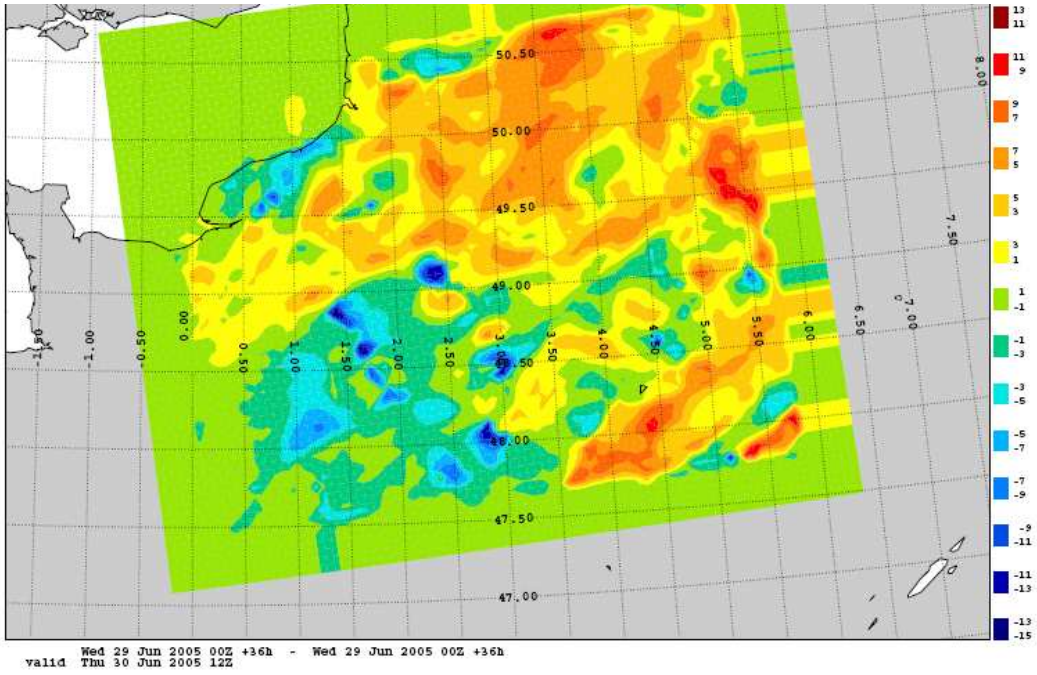
Reference - Perturbation
(in 100 m)

00 UTC



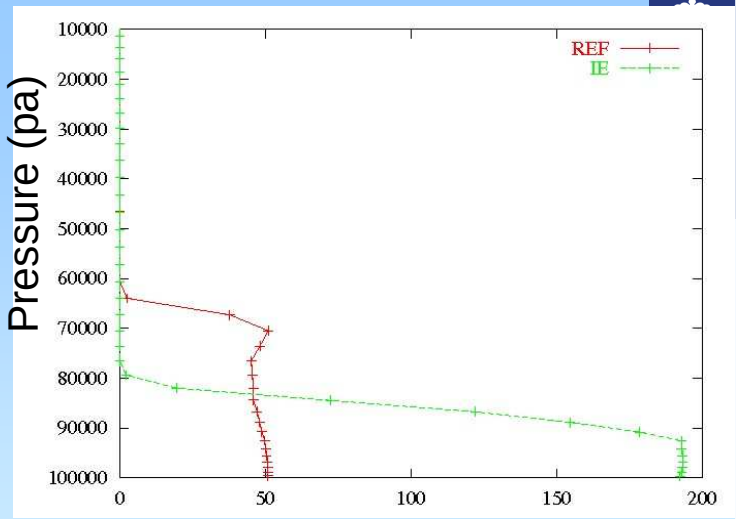
Changes in PBL height quite large
(up to 900 m !)

12 UTC

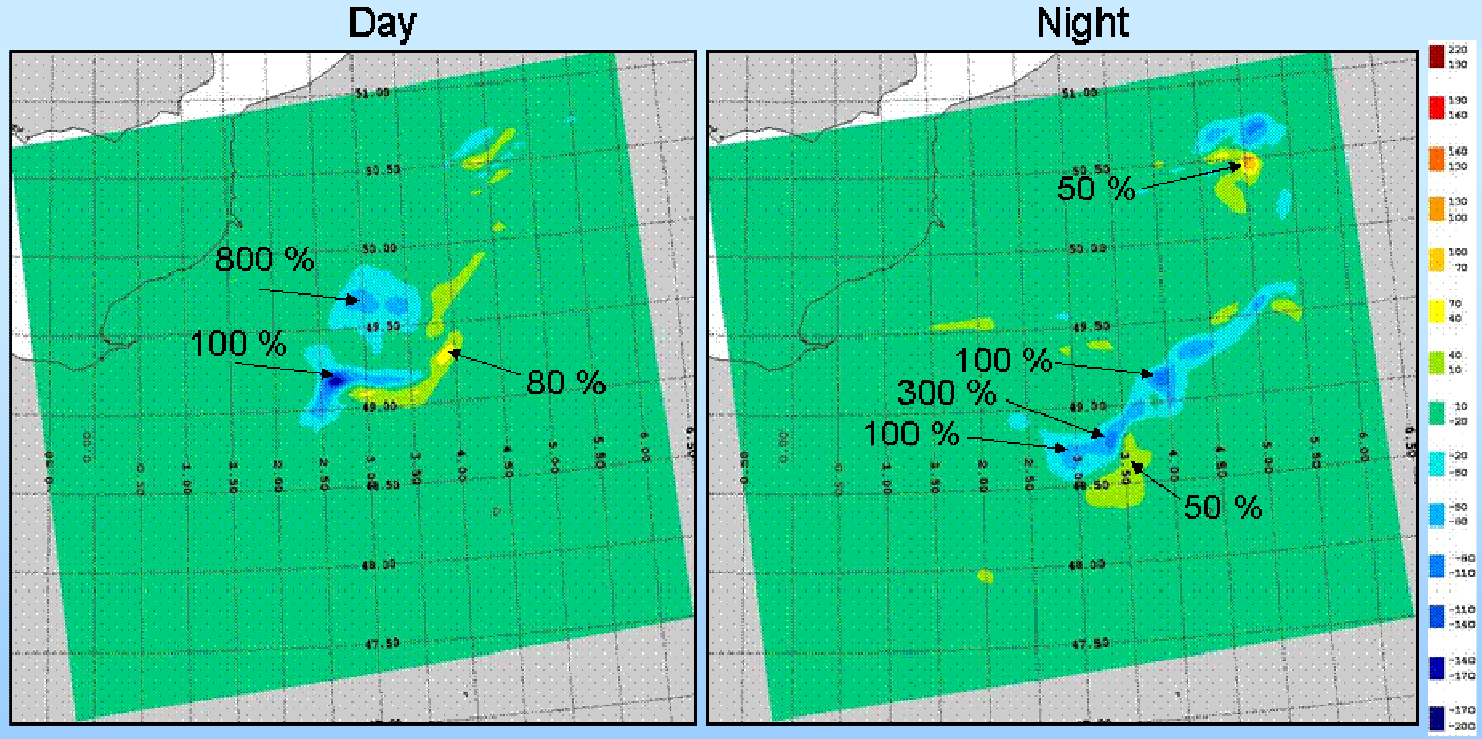


Results 4: NO2 concentrations

Vertical NO_2 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_2 concentration (µg m^{-3})

Conclusions

In this particular case:

- **Indirect effects induce large changes in 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**
- **Fist indirect effect is much smaller than second one**
- **Large non-linear component**

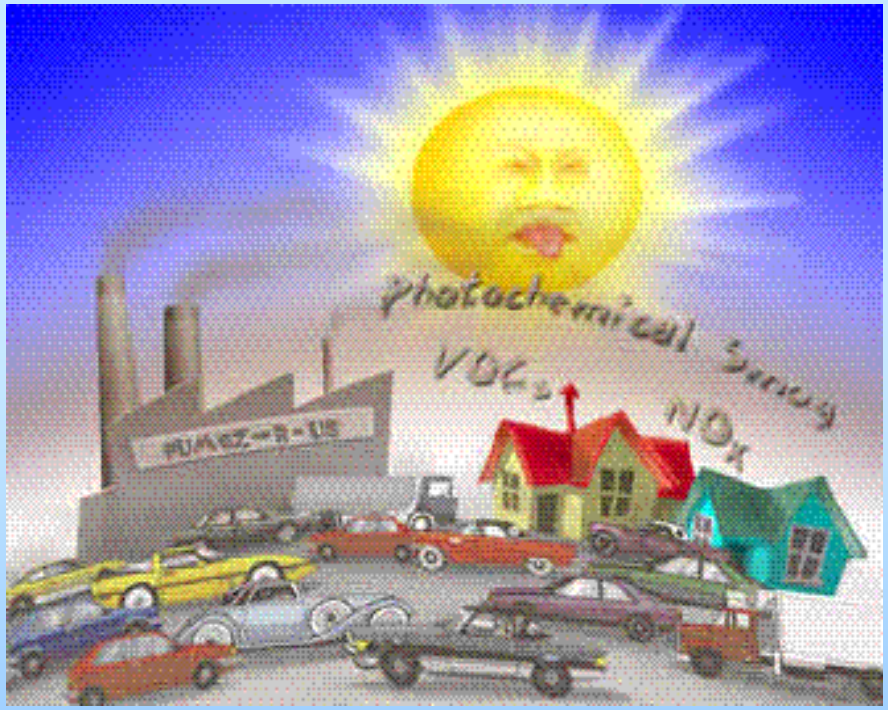
Further work with Enviro-HIRLAM development

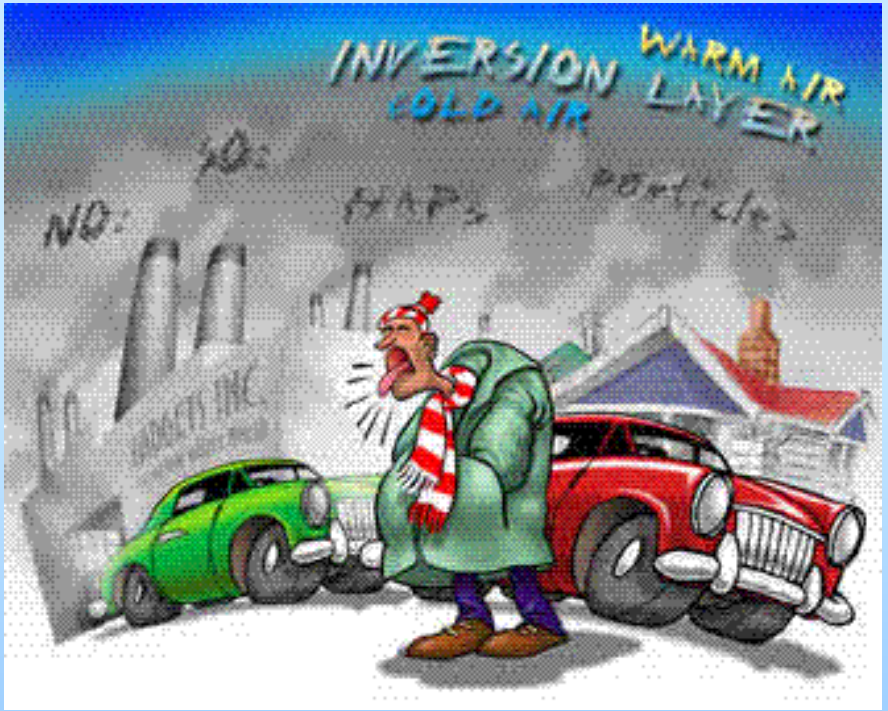
There are a number of outstanding issues which will be dealt with in the future, e.g.:

- 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 planed 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 !


Photochemical Smog
VOCs
NOx


INVERSION
COLD AIR
WARM AIR
LAYER
NO2
NO
Particles