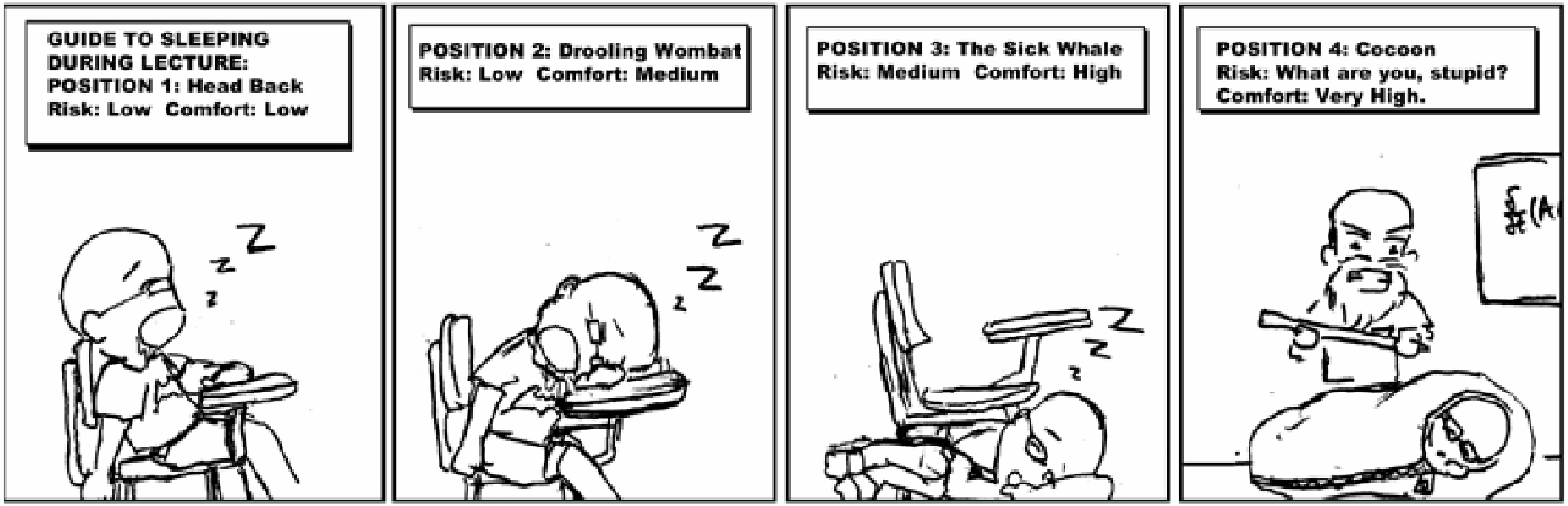
Overview of Enviro-HIRLAM

Ulrik Smith Korsholm
usn@dmi.dk
Research Department
Danish Meteorological Institute

Todays programme:

- Overview
- Model code structure
- Chemistry in Enviro-HIRLAM
- Exercises

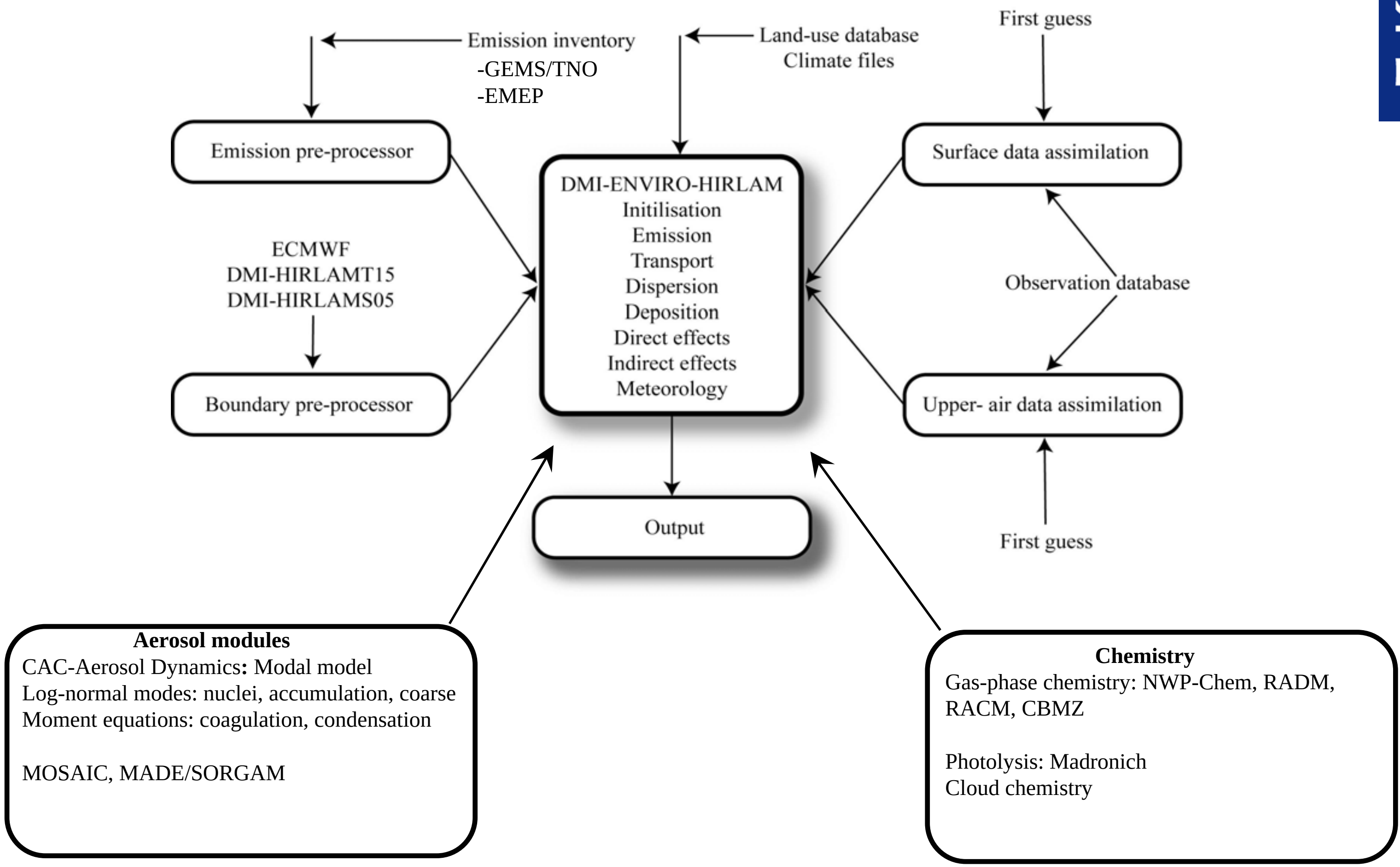


To come:

Model description
Emphasis on chemistry and aerosols
Some background and theory neccessary
How to compile and run the model
Examples of usage

After this course you should now how to use the model:
make changes, include new code, execute the model,
do experiments, have a general overview of the model
in terms of schemes and code

Execution of the model



Methodology of online modeling

Offline models: Chemical Transport Models (CTM's) which are seperated from their meteorological driver; coupling interval typically every one – three hours.

Online access models: Coupling interval every time step of the driver; feedbacks possible. CTM could be seperated or integrated in its driver.

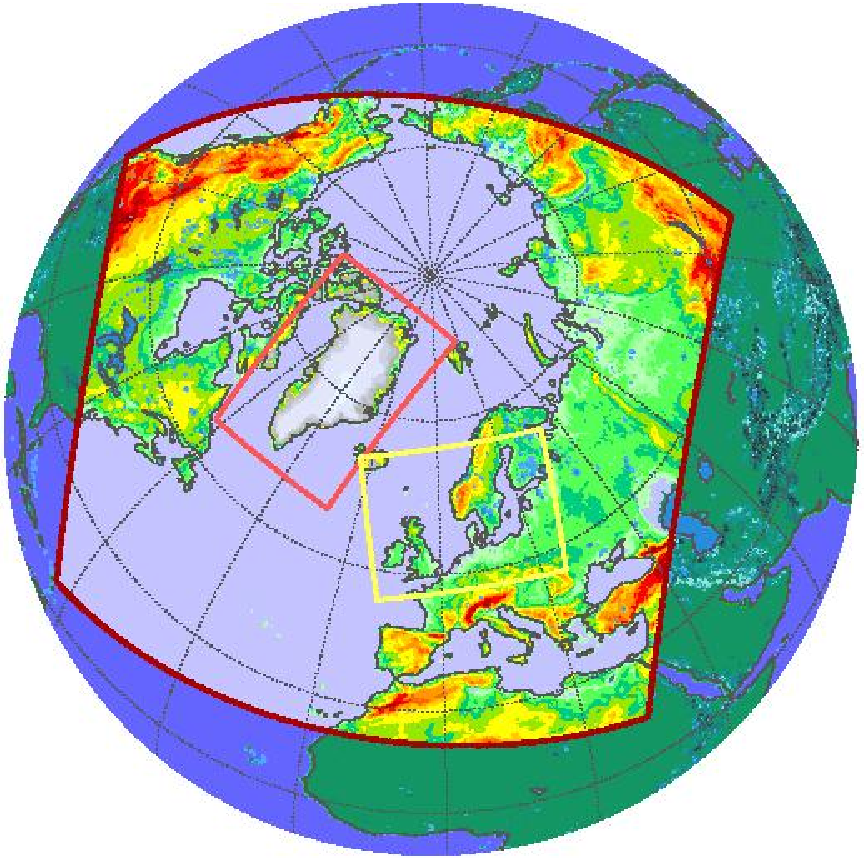
Online coupled models: CTM's integrated into their driver; coupling interval every time-step of the driver; feedbacks possible.

Methodology of online modeling

Advantages of online models:

- Only one grid; no interpolation in space
- No time interpolation
- Physical parameterizations are the same; no inconsistencies
- Possibility of feedbacks with meteorology
- All 3D meteorological variables are available at the right time (each time step); no restriction in variability of met. fields
- Does not need meteorological- pre/post-processors

Enviro-HIRLAM is an online coupled chemical weather model based on HIRLAM

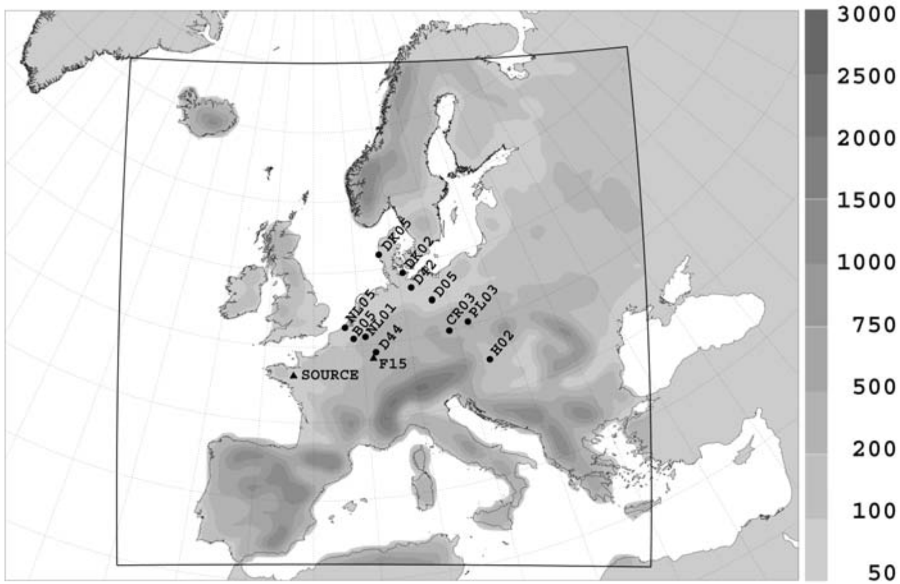


Model identification	**T15**	**S05**
grid points (mlon)	610	496
grid points (mlat)	568	372
number of vertical levels	40	40
horizontal resolution (deg)	0.15°	0.05°
time step (dynamics)	360s	120s
time step (physics)	360s	120s
host model	ECMWF	T15

HIRLAM 5, Scientific Documentation, December 2002

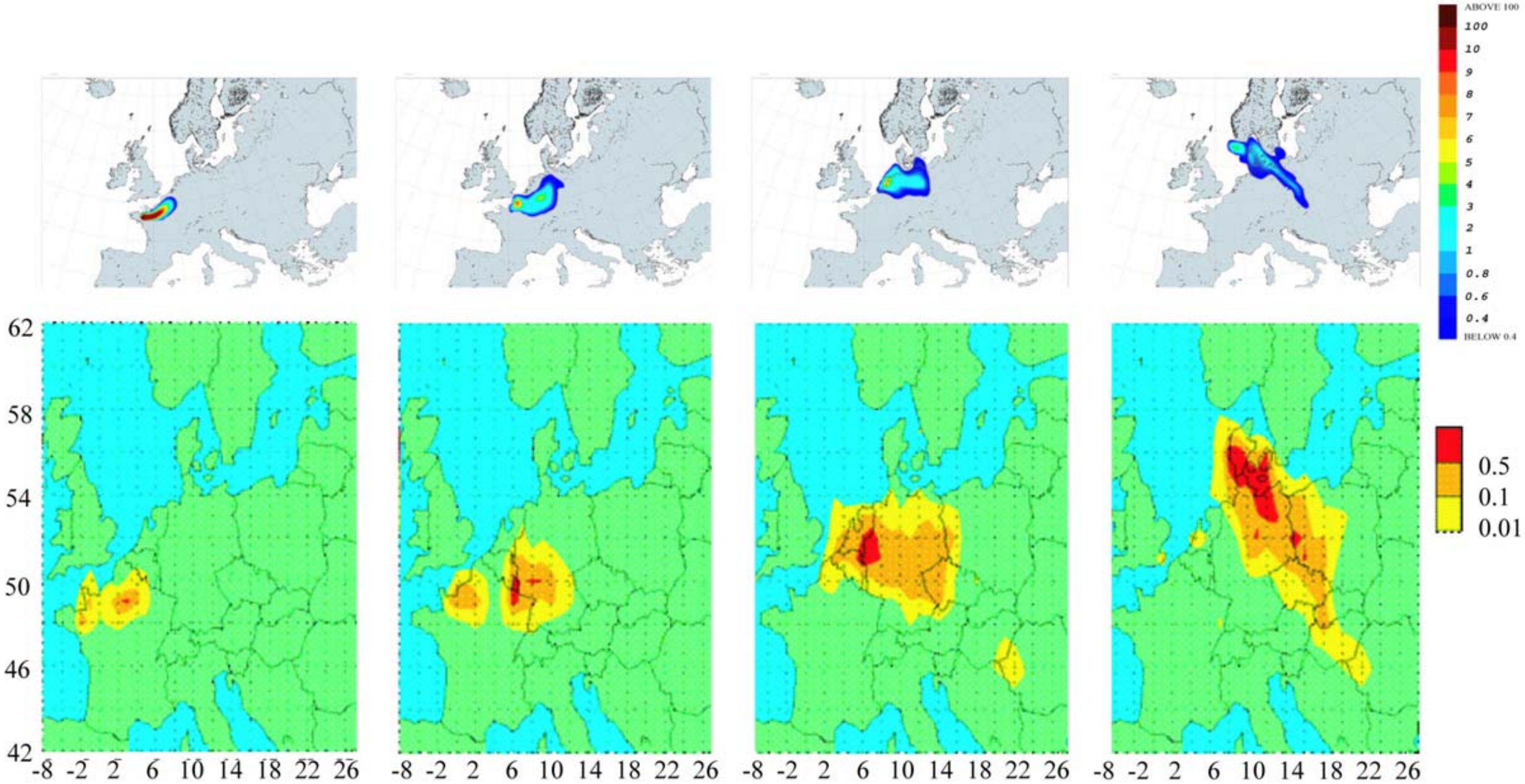
Importance of the offline coupling interval

The work presented here is also published as:
Korsholm, Baklanov, Gross, Sørensen, 2009. Atm. Env., doi: 10.1016/j.atmosenv.2008.11.0.17.



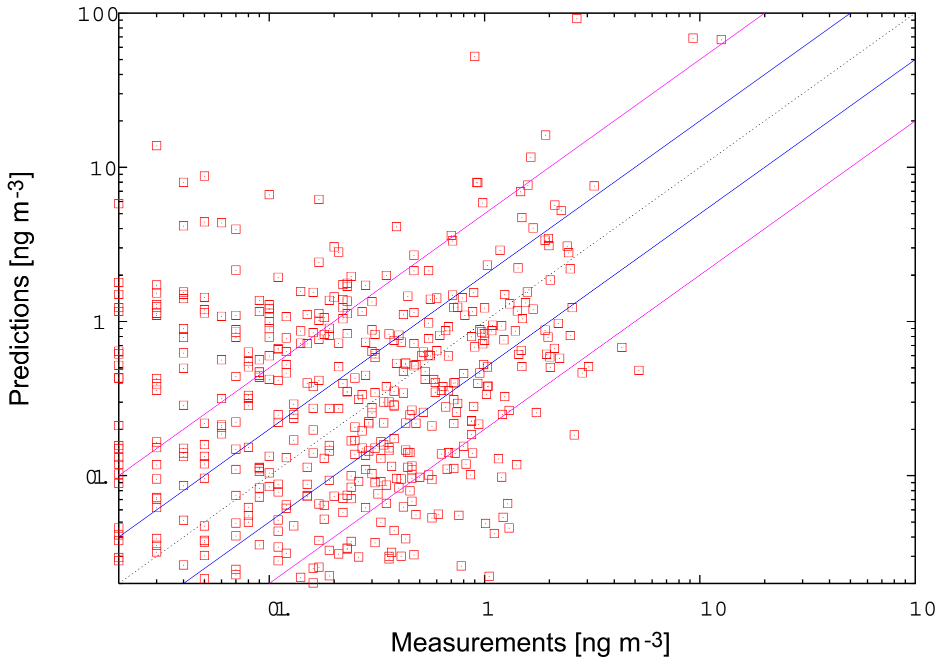
0.40 x 0.40 degrees
Passive tracer transport

Importance of the offline coupling interval



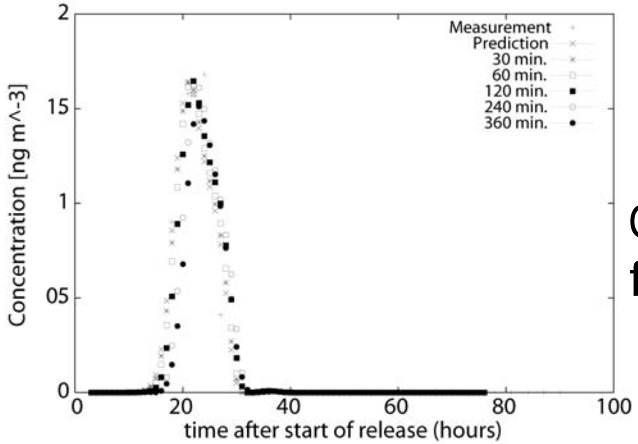
Top: concentration at lowest model level at 12, 24, 36 and 48 hours after release
Bottom: corresponding measured concentrations (Mosca *et al.*, 1998)

Importance of the offline coupling interval

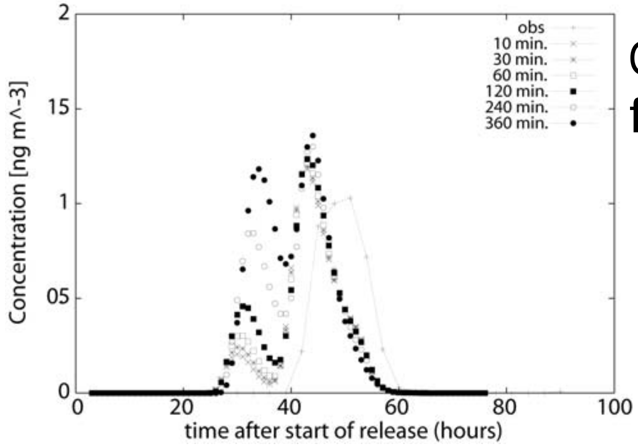


Number of points: 1243, FA2 = 20.84, FA5 = 36.52, Global BIAS = 0.39 ng m^{-3} , Global correlation = 0.57, Global NMSE = 104.59, Mean predicted = 0.26, Mean measured = 0.23.

Importance of the offline coupling interval

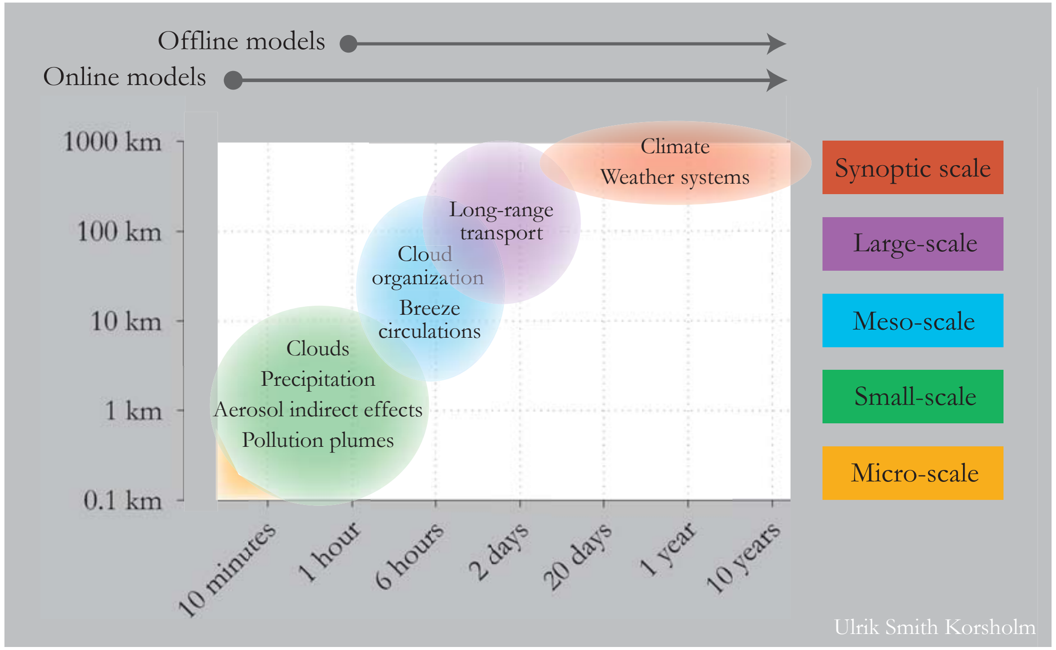


Concentration versus time at F15
for various coupling intervals and observations



Concentration versus time at DK02
for various coupling intervals and observations

Importance of the offline coupling interval



Enviro-HIRLAM overview

Enviro-HIRLAM can be seen as an extension to HIRLAM

Main components: Dynamical core | Physical module | Chemical module

Dynamical core → Primitive equations → Semi-Lagrangian, Eulerian, semi-Lagrangian + Bott → Helmholtz equation, semi-implicit adjustmnent, 4^{th} order diffusion

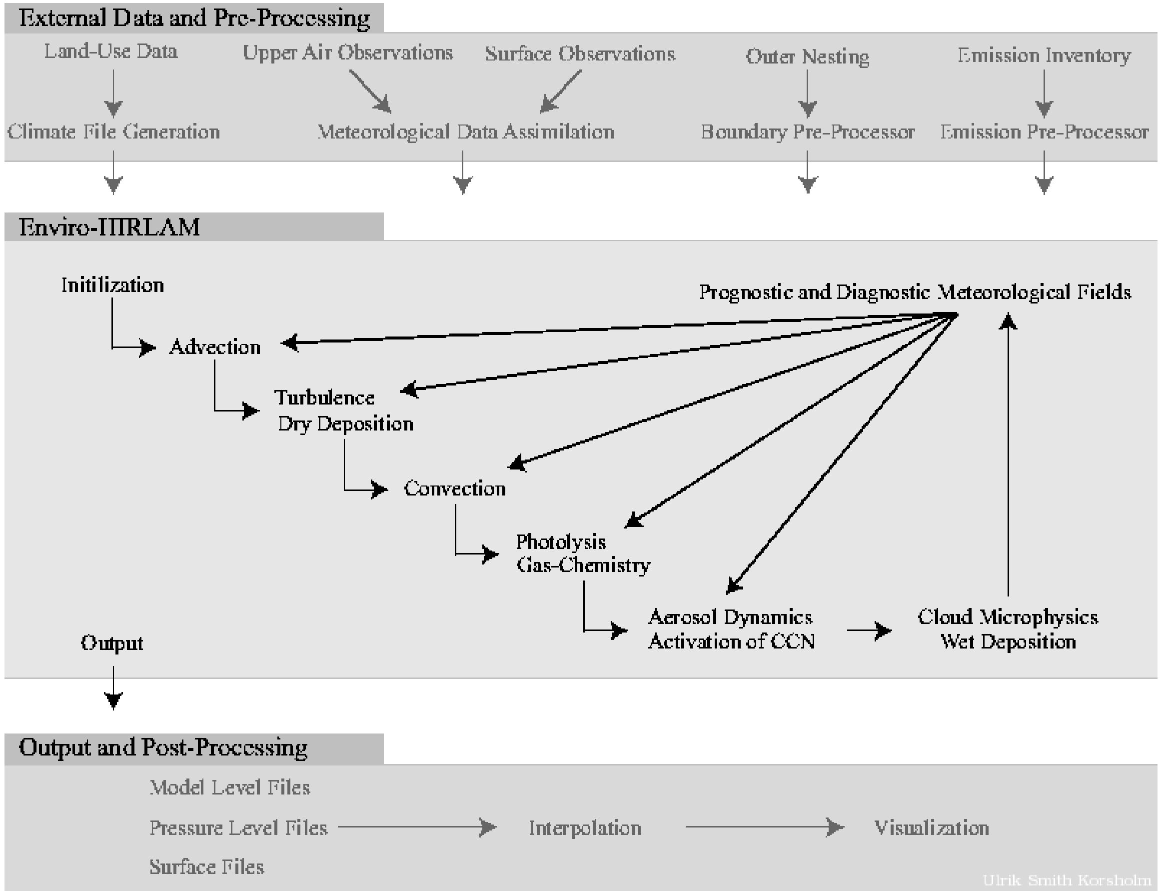
Physical module → Radiation, clouds, precipitation, ...

Chemical module →
- 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

Enviro-HIRLAM overview



Enviro-HIRLAM overview

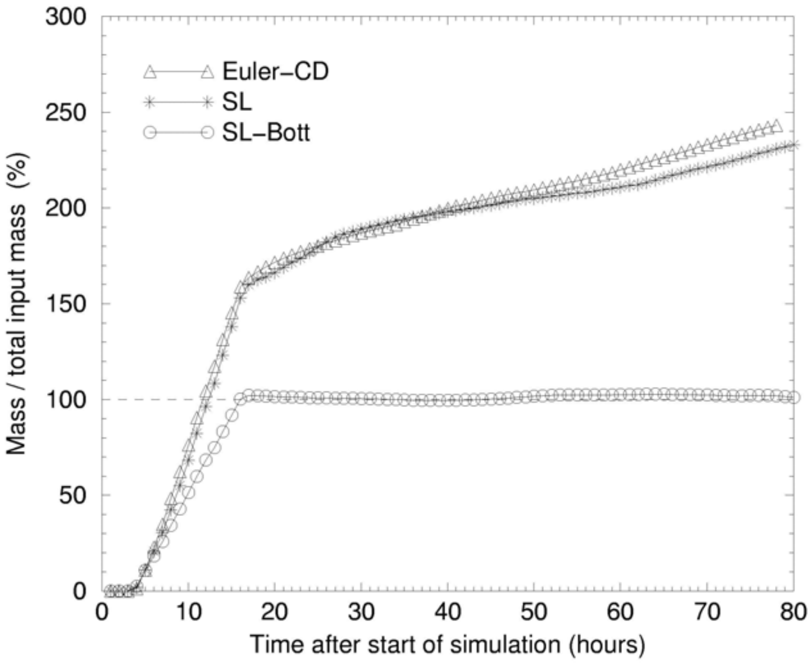
- Bott advection (*Bott, 1989*) + Easter update for tracers (*Easter, 1993*); 4th order polynomials in x and y; 2nd order polynomials in z; uses lower time step than meteorology.
- Semi-Lagrangian for meteorology
  - Mass-wind inconsistency

- Non-staggered finite differences (vertical)
- Hybrid coordinate η:

  $P = A(\eta) + B(\eta)\, P_{surface}$

  A=0; σ – coordinates

  B=0; P – coordinates
- Arakawa C grid
- Implicit 4th horizontal diffusion



Mass conservation test for ETEX release

(Chenevez 2000)

Enviro-HIRLAM overview

- **Vertical diffusion**: Cuxart, Bougeault, Redelsperger (CBR) – scheme (Cuxart et al., 2000)

  Eddy velocity scale: √TKE -> full TKE equation
  Eddy length scale: $l_{int}^{-1} = l_{min}^{-1} + l_{max}^{-1} + l_{stable}^{-1}$
  (*HIRLAM documentation*, *Cuxart, 2000*)

- **Horizontal diffusion**: Fourth order implicit

Enviro-HIRLAM overview

Convection: Modified STRACO (*Sass, 2002*)

$$\partial\psi/\partial t = (\partial\psi/\partial t)_{dyn} + (\partial\psi/\partial t)_{turb} + Q_\psi' F_\psi/F_\psi' + S_\psi$$

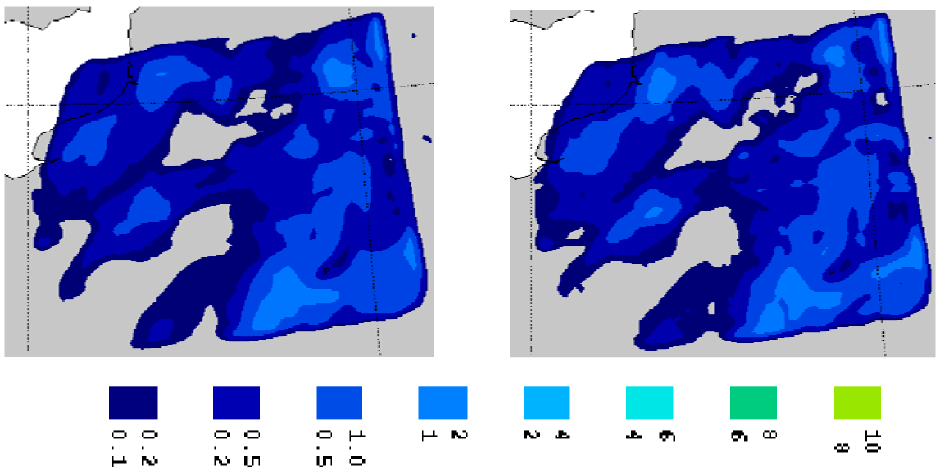
Ψ : species mass concentration
’ denotes a vertical average over the convective cell
S_ψ : entrainment through cloud top
Q_ψ : total concentration source
F_ψ : $\psi - \psi_e$; vertical redistribution function; lateral entrainment

Triggering: temperature perturbation, specific humidity perturbation

When triggered adiabatic lifting determines the height of the convective cell

Enviro-HIRLAM overview

Old STRACO New STRACO



Convective summer case; 24 hour accumulated rain

Enviro-HIRLAM overview

Emissions -> Eulerian point sources

Particle size dependent parameterizations for dry and wet deposition

Resistance approach for dry deposition (*Wesley, 1989; Zanetti, 1990*)

Terminal settling velocity in different regimes:

- Stokes' law
- non-stationary turbulence regime
- correction for small particles

Dependent on land use classification

Below-cloud aerosol scavenging (washout); precipitation rates (*Baklanov & Sørensen, 2001*)

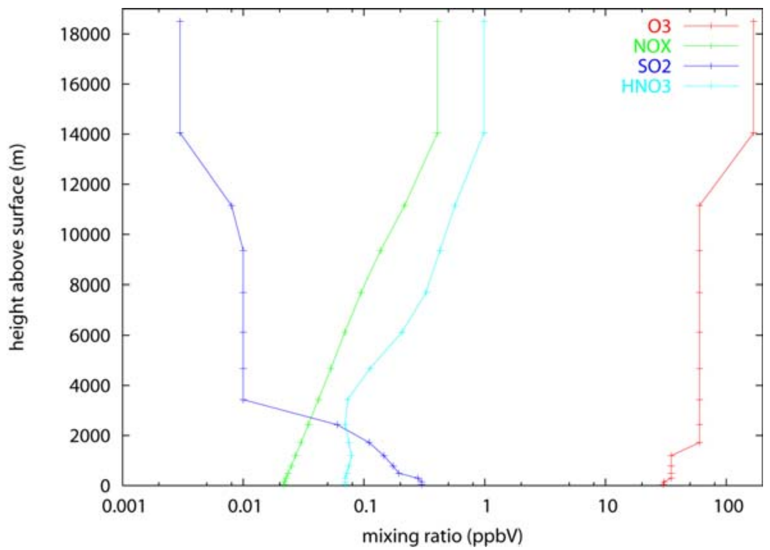
In and Below cloud gas scavenging follows Seinfeld and Pandis, 1998.

Scavenging by snow (*Maryon et al., 1996*)

Enviro-HIRLAM overview

Relaxation on lateral boundaries

Chemical initial conditions; all other fields have climatic values

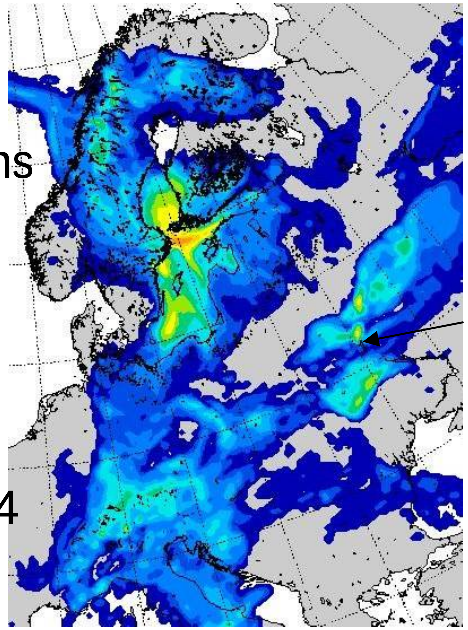


Enviro-HIRLAM examples

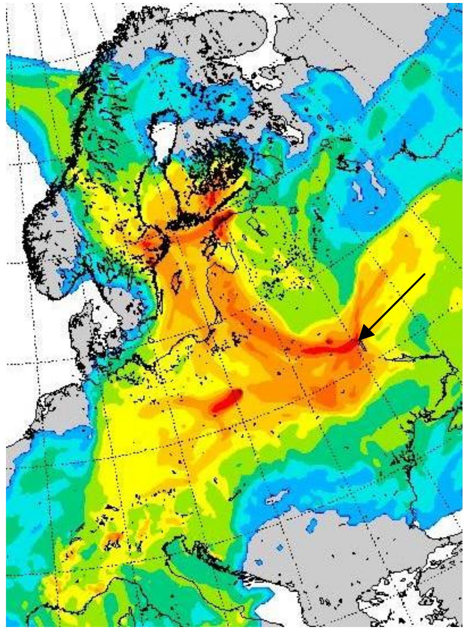
Simulation of Chernobyl accidental release

Mono-disperse point source emissions (*Devell et al., 1995, Persson et al., 1986*).Date: 1/5-1986 18:00 UTC

Correlation: 0.59, predicted mean: 56.74 Bq/m^2, observed mean: 17.94 Bq/m^2

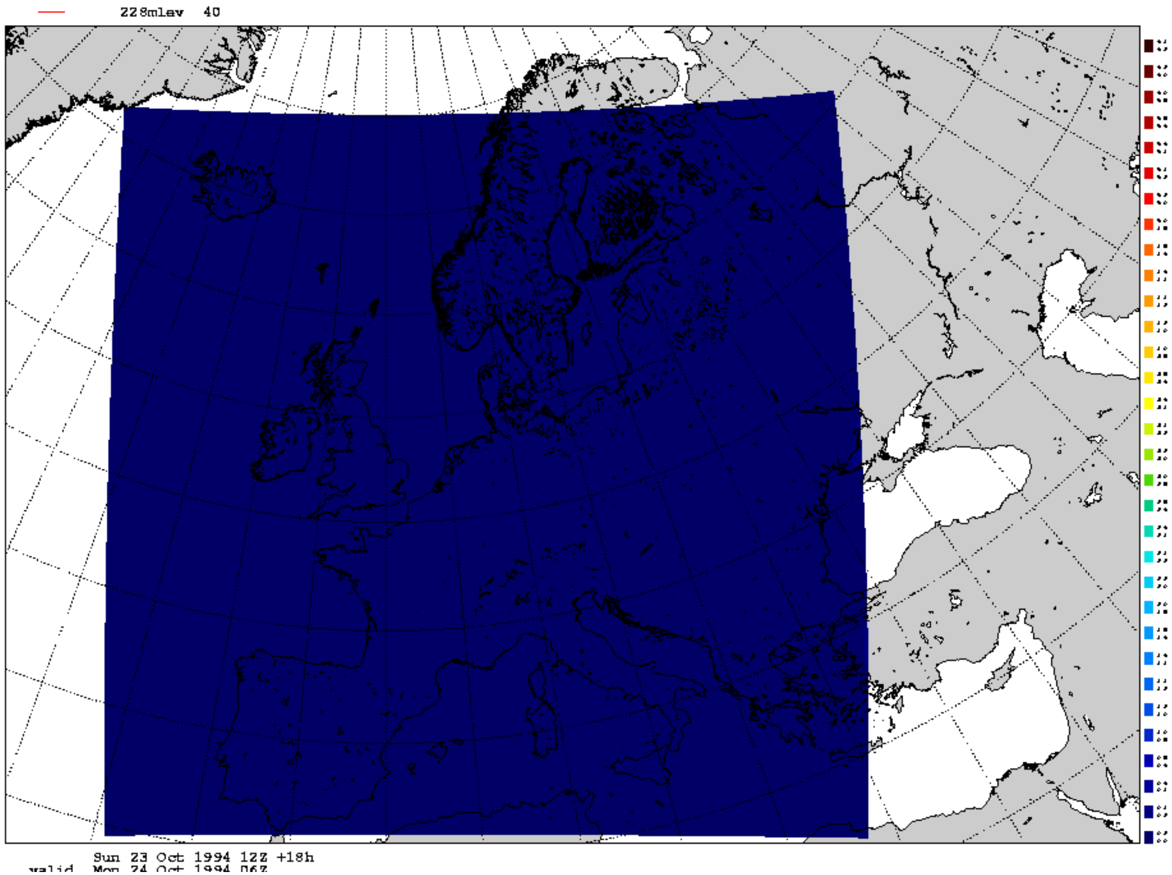


Cesium Wet deposition (KBq/m^2)



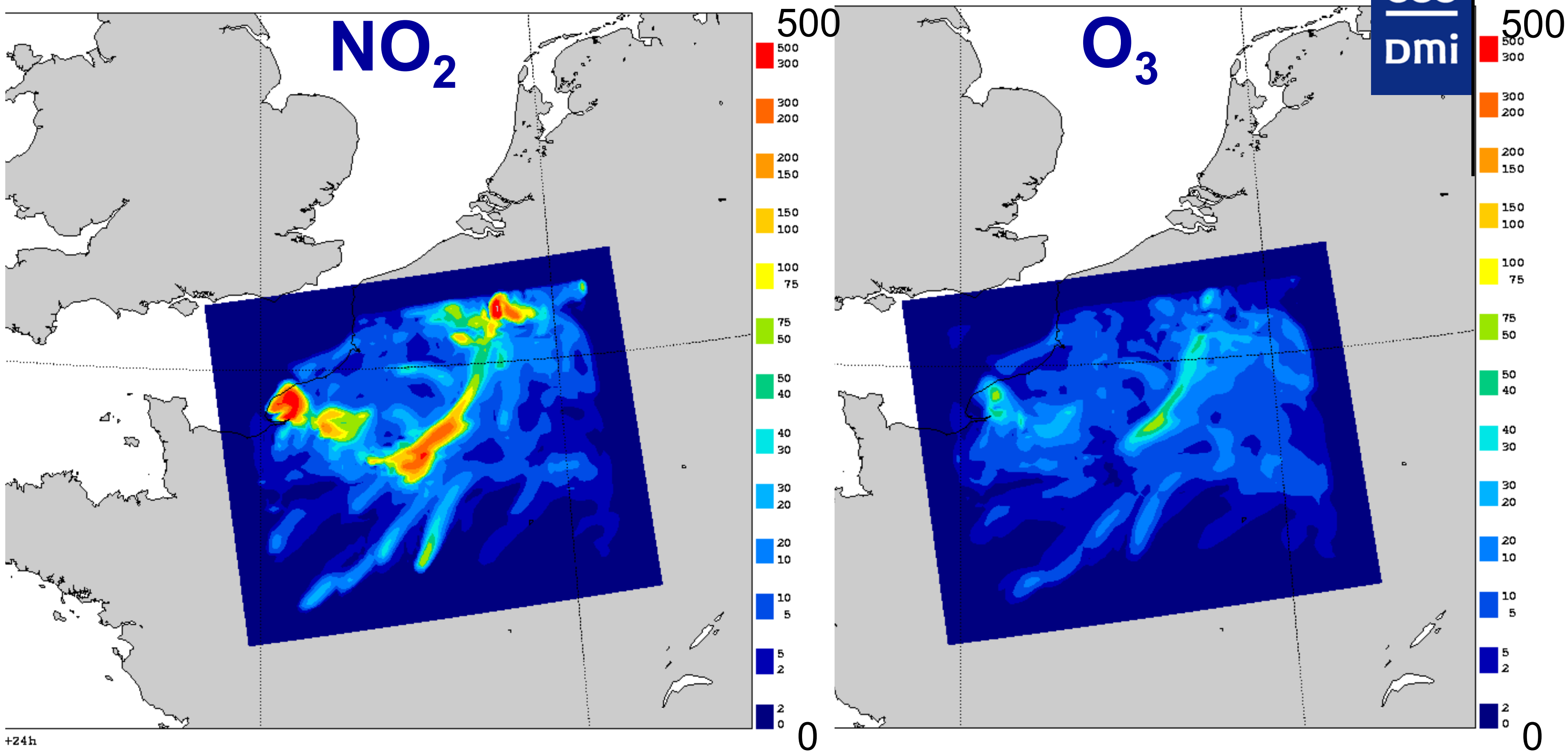
Cesium Dry deposition (KBq/m^2)

Enviro-HIRLAM examples



HO mixing ratio (ppb) as function of time (hours)

00 UTC June 29 – 00 UTC June 30, 2005.
Concentration (μg/m³)



Conclusions and outlook

Offline models cannot resolve fast mesoscale disturbances
and this may lead to forecast errors

Model tested in ETEX-1 and against Chernobyl data

Overestimation near source points:
- vertical redistribution of emissions
- emission model redistributing emissions on sub-gridscale

3D wet aerosol deposition
New aerosol model including aerosol ageing
New aerosol condensation scheme
Long term testing of predictive quality and feedbacks