Overview HIRLAM contents

Sander Tijm

Contents of lecture

- HIRLAM
- Equations used in HIRLAM
- Discretization
- Advection
- Input HIRLAM data
- Data assimilation
- Initialization
- Physics
- Output HIRLAM data

KNMI

Koninklijk Nederlands Meteorologisch Instituut

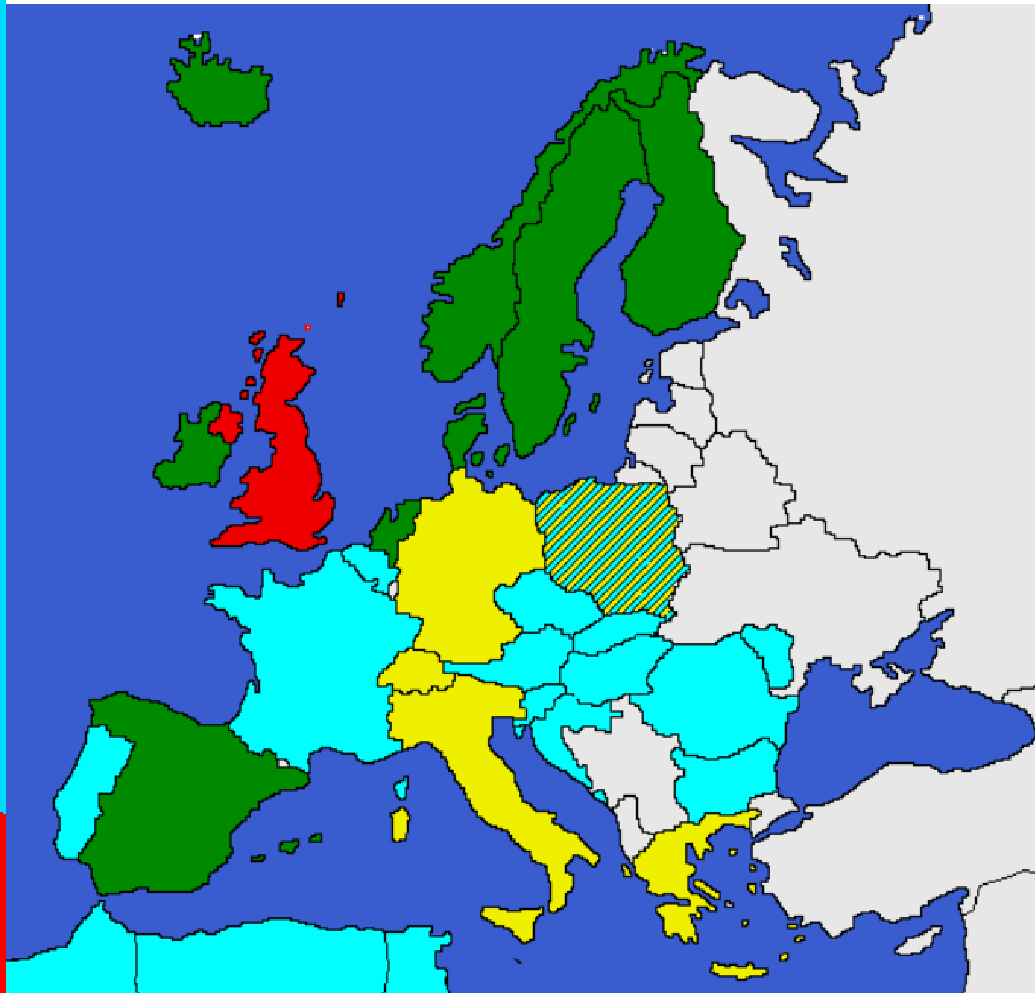
HIRLAM and ALADIN

KNMI

SRNWP Consortia in Europe

ALADIN
Algeria
Austria
Belgium
Bulgaria
Croatia
Czech Rep.
France
Hungary
Moldova
Morocco
Poland
Portugal
Romania
Slovakia
Slovenia
Tunisia

UKMO
United Kingdom



HIRLAM

Denmark
Finland
Iceland
Ireland
Netherlands
Norway
Spain
Sweden

COSMO

Germany
Greece
Italy
Poland
Switzerland

Koninklijk Nederlands Meteorologisch Instituut

HIRLAM and ALADIN

- HIRLAM: HIgh Resolution Limited Area Model
  - 9 countries, 2 acceding members
- HIRLAM started in Nordic countries in 1986
- Cooperation with ALADIN on mesoscale modeling, working on HARMONIE model (includes chemistry already!)
- HARMONIE: Hirlam Aladin Research on Mesoscale Operational NWP In Euromed

Equations used in HIRLAM

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

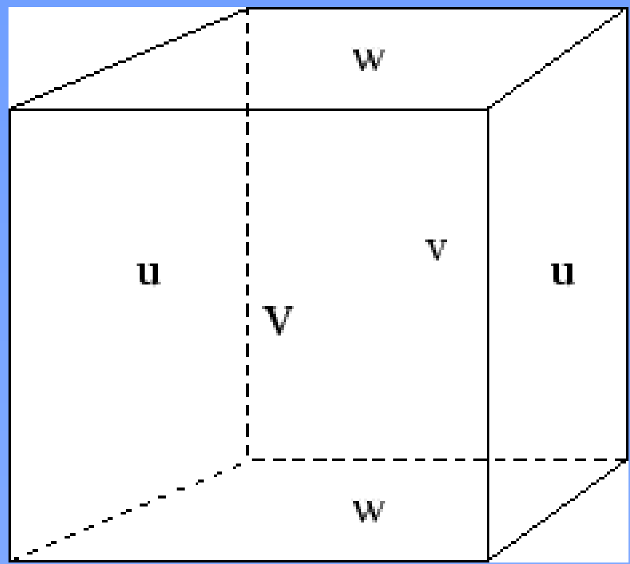
$$\frac{\partial p}{\partial z} = -\rho g$$

$$\frac{dT}{dt} = Pt + Kt$$ Similar for q, cw, ci

$$\frac{dU}{dT} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + fv + Pt + Kt$$ Similar for V

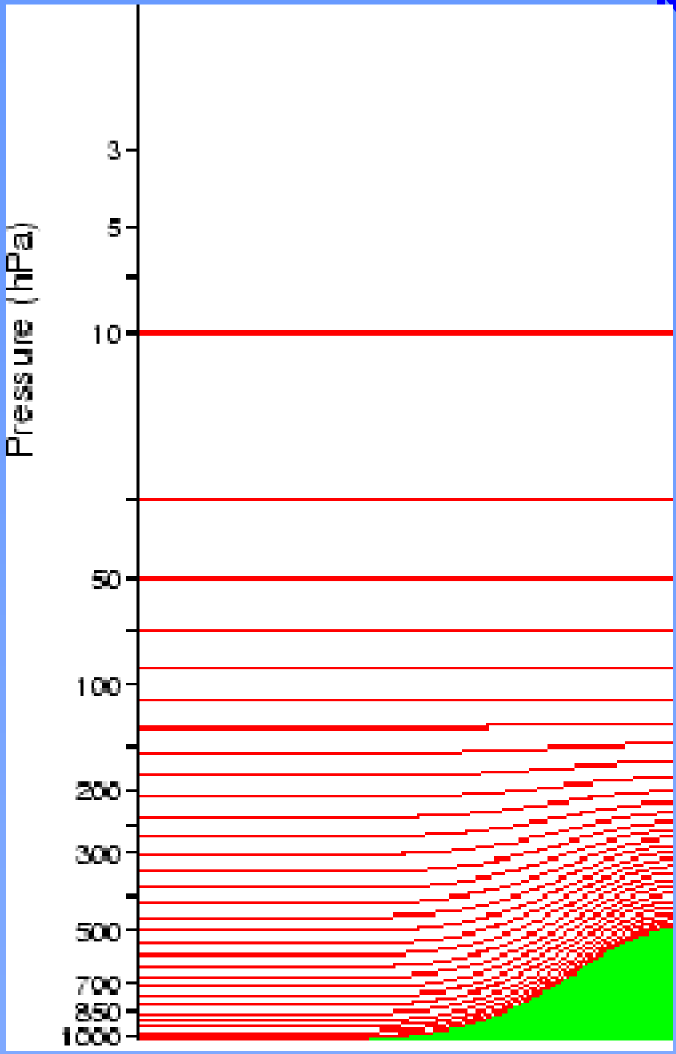
Discretization

- Arakawa C-grid
  - T, q, cw, ci, TKE at grid points
  - U (shifted half grid point distance east-west) and V (shifted half grid point distance north-south) staggered



Discretization

- Hybrid vertical coordinate system
  - Half levels and full levels
  - T, q, cw, ci, u, v, TKE at full levels
  - Omega at half levels (intermediate)
  - Terrain following near surface
  - Pressure levels high in atmosphere



Discretization

$$P(lev) = A(lev) + B(lev) * Ps$$

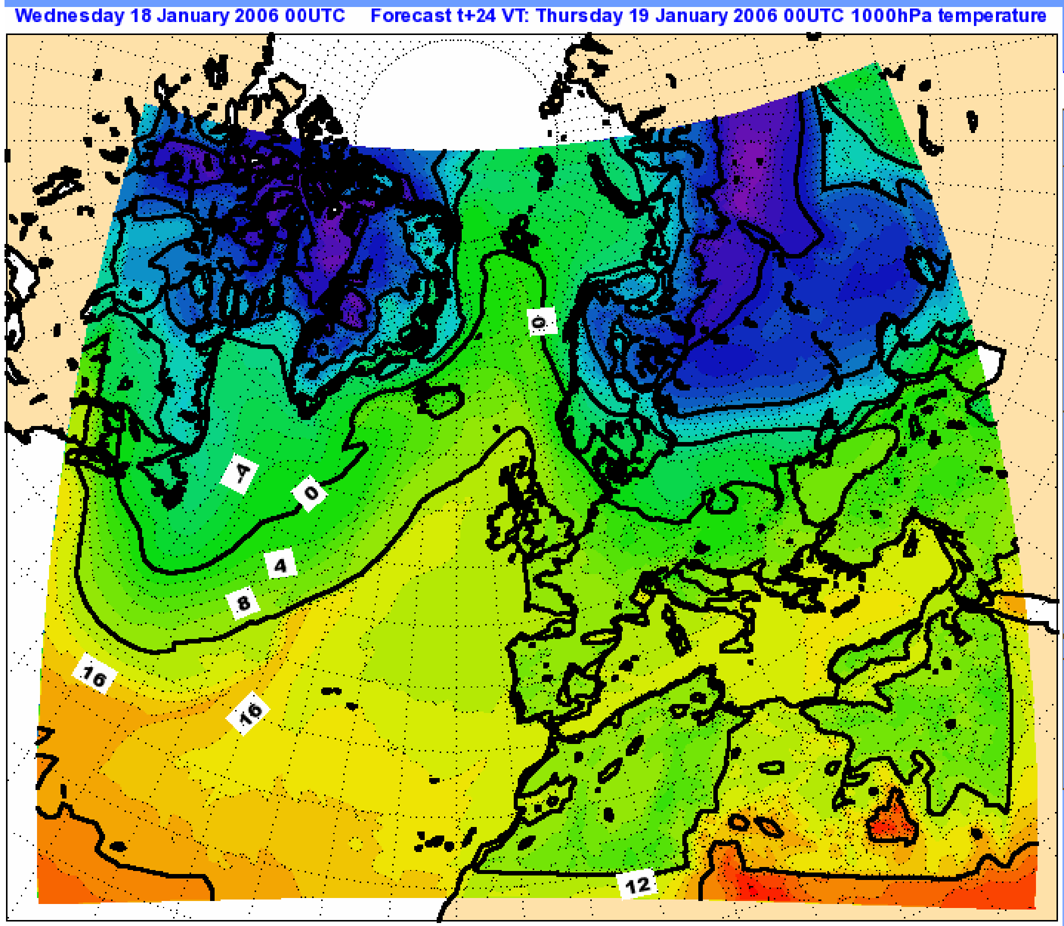
01	1000.0319824219	0.0000000000
02	3016.7302246094	0.0000001875
03	5053.9062500000	0.0001183500
04	9093.7656250000	0.0015856801
05	7087.0195312500	0.0005798100
55	174.2324371338	0.9554649591
56	65.5194854736	0.9646674395
57	12.3686571121	0.9731910229
58	0.0000000000	0.9811843634
59	0.0000000000	0.9888177514
60	0.0000000000	0.9962835312
	-----A----	-----B----

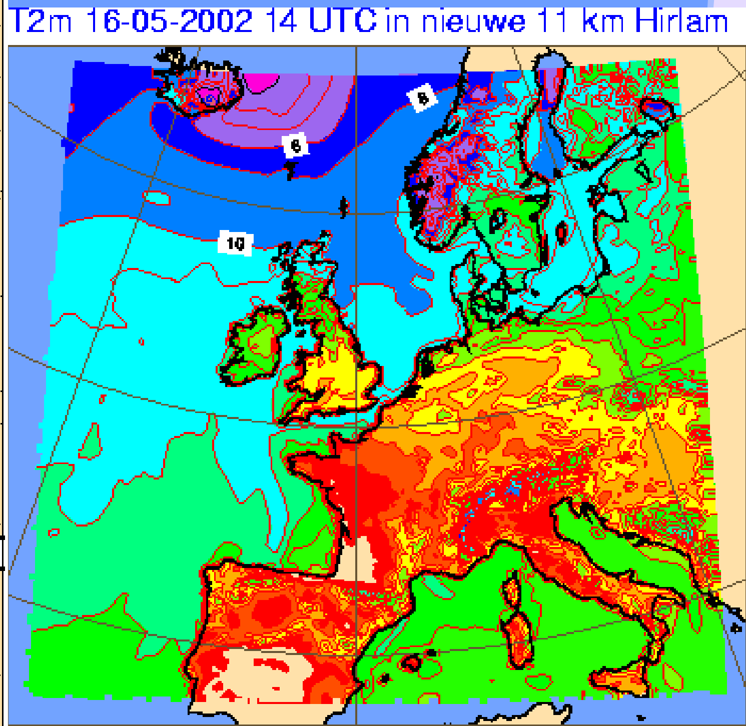
Discretization

lev	pres	winter	trans	summer
1	10.0	30170.5	30900.3	31794.9
2	30.2	23145.4	23792.9	24567.1
3	50.7	19847.4	20456.2	21173.9
4	71.5	17658.8	18242.0	18922.1
5	92.5	16013.6	16577.5	17229.4
55	969.6	341.9	361.0	380.1
56	977.9	276.0	291.5	306.9
57	986.0	211.7	223.5	235.3
58	993.9	148.8	157.1	165.4
59	1001.7	88.1	93.1	98.0
60	1009.2	29.2	30.8	32.5

Horizontal grid

- (Rotated) latitude longitude grid





Advection

- Semi-Lagrangian advection scheme
  - Not looking at next grid point only (maximum, as with Eularian advection, CFL criterium) for advection, but at values at departure point
  - Allows for much larger time step: example 10 km horizontal resolution, jet of 100 m/s, Eularian time step of 100 seconds, SL time step of 300 seconds or more possible
  - Reduces computing costs, allows for higher resolution or longer forecasts at same cost
  - Not conserving for tracers, not very suitable for ACT

HIRLAM input

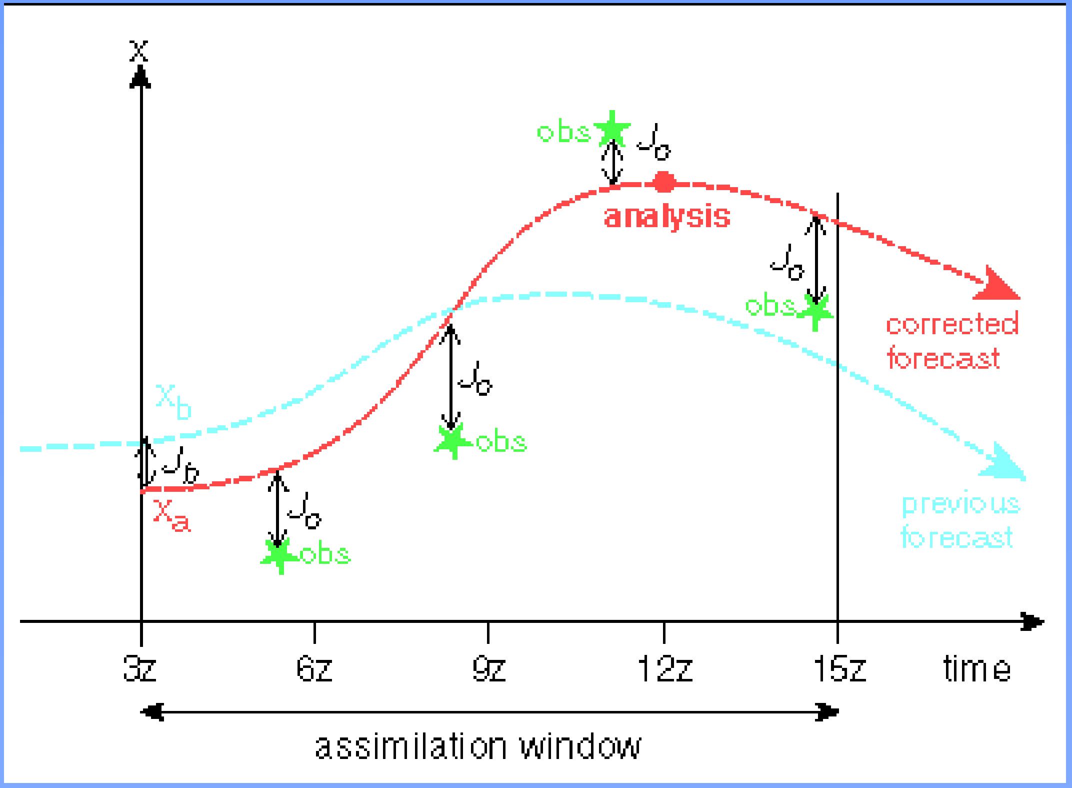
- Soil climate fields and surface description fields (fraction of land, surface height, vegetation type etc.)
- First guess, short forecast of previous cycle, or interpolated model state from boundary file, necessary for all model state parameters (soil parameters, U, V, T, q, cw, ci, TKE, Ps)
- Observations: SYNOP, TEMP, Buoy, AMDAR, SST from satellite (OSI-SAF), scatterometer, ATOV, wind profiler as input for data-assimilation
- Boundaries: model state parameters from ECMWF forecasts (operational use of HIRLAM), ECMWF analyses (in experiments) or HIRLAM forecasts (for nested runs).

Data assimilation

- Optimum interpolation, in old HIRLAM versions. Weight of observation dependent on observation error statistics. One solution based on interpolated analysis increments.
- 3D-Var: reference until HIRLAM 7.2. Uses background error (deviation from first guess, cost function J_b) and observation error (deviation from observations, J_o). J_o and J_b are determined for intermediate analysis and slope of J_o and J_b is used to determine if new analysis is better than previous step. Final analysis is reached through iteration procedure.

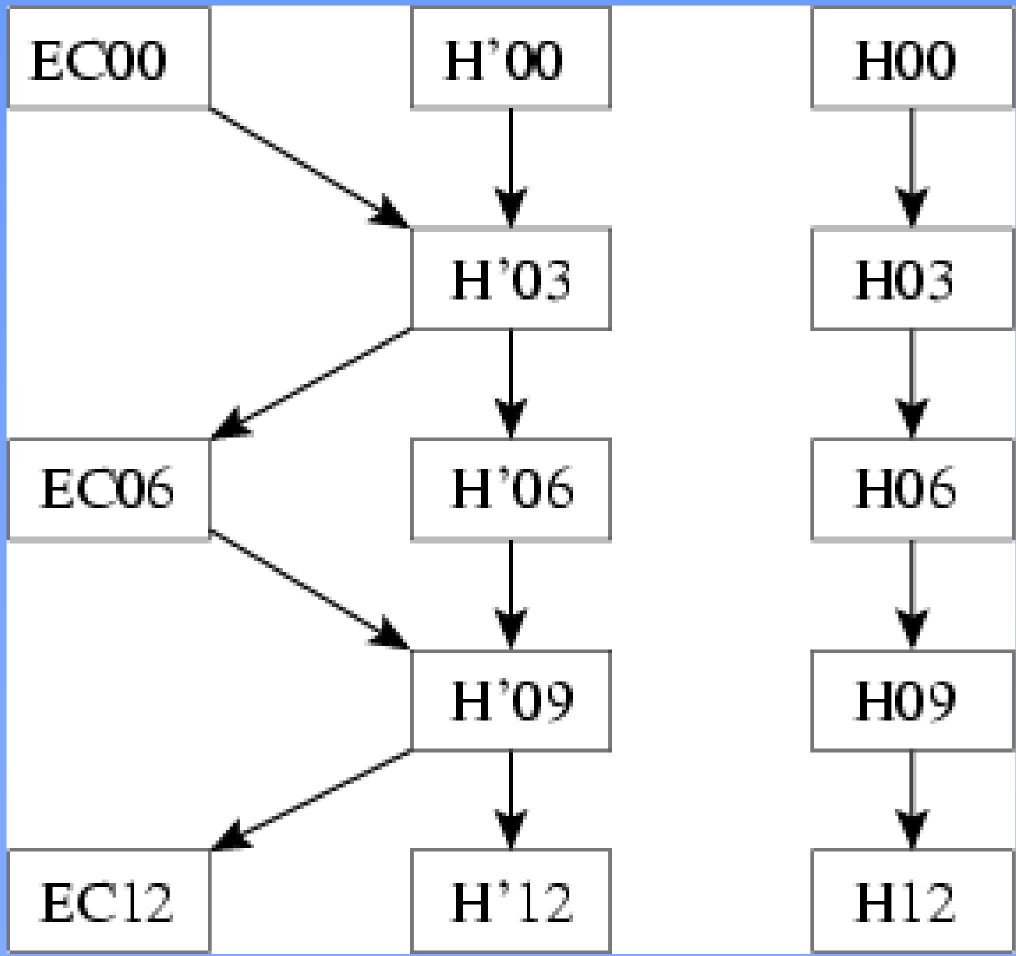
Data assimilation

- 4D-Var: Similar to 3D-Var, but now with J_o determined from deviation of model state trajectory from observations in large time window.



Data assimilation

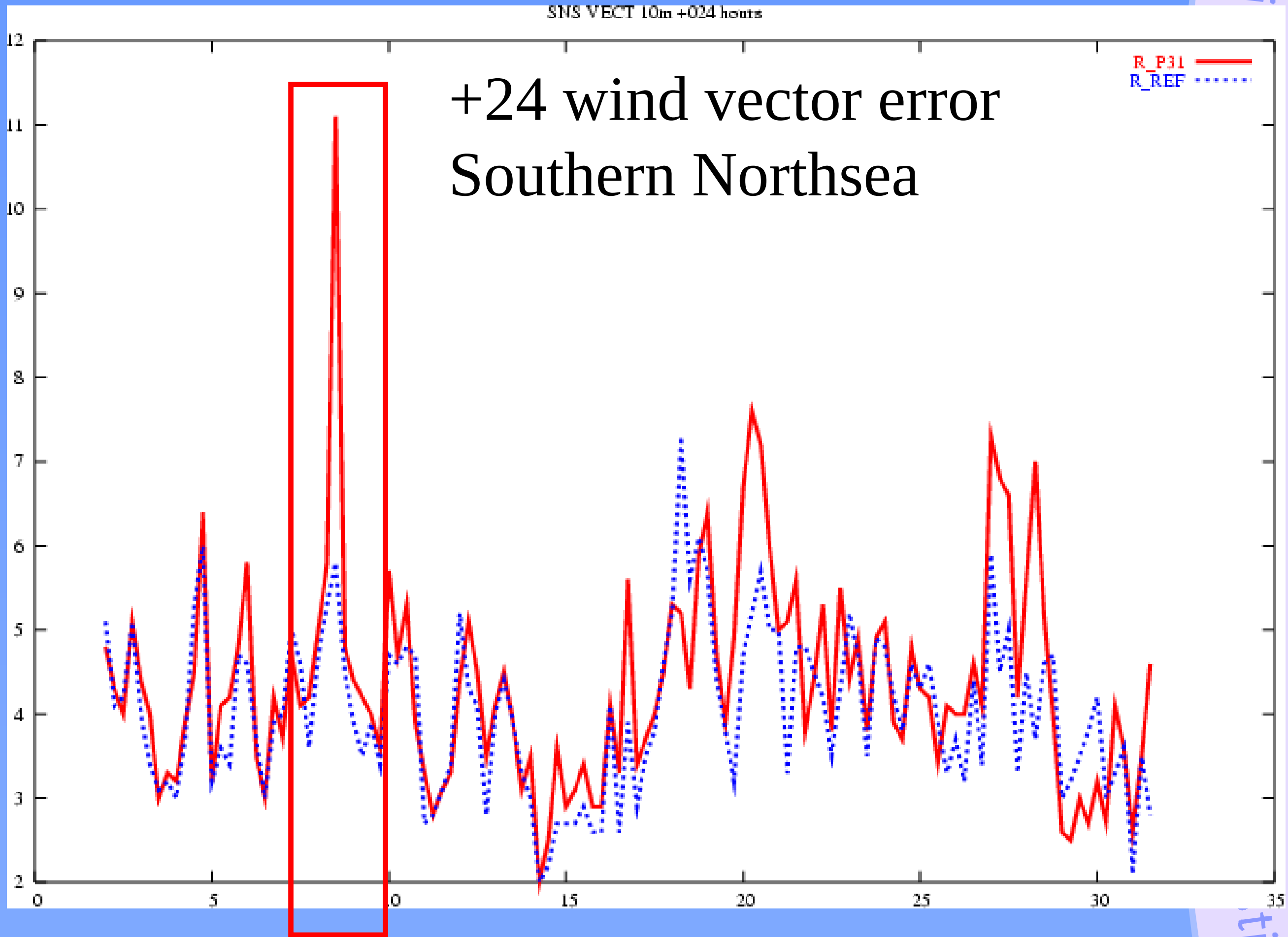
- Mixing in ECMWF analysis



Koninklijk Nederlands Meteorologisch Instituut

Mixing in ECMWF-analysis

- Experiment January 2005 shows that use of ECMWF analysis can reduce extreme errors



Storm 8 January 2005

Initialization

- Digital filtering: Digital filter consists of weight factors that determine filter characteristics:

$$\overline{\varphi} = \sum_{i=1}^{n} a_i \varphi_i$$

- Filter takes away quick oscillations, smoother start of forecast
- Cause of spinup in wind, clouds, precipitation etc.

Initialization

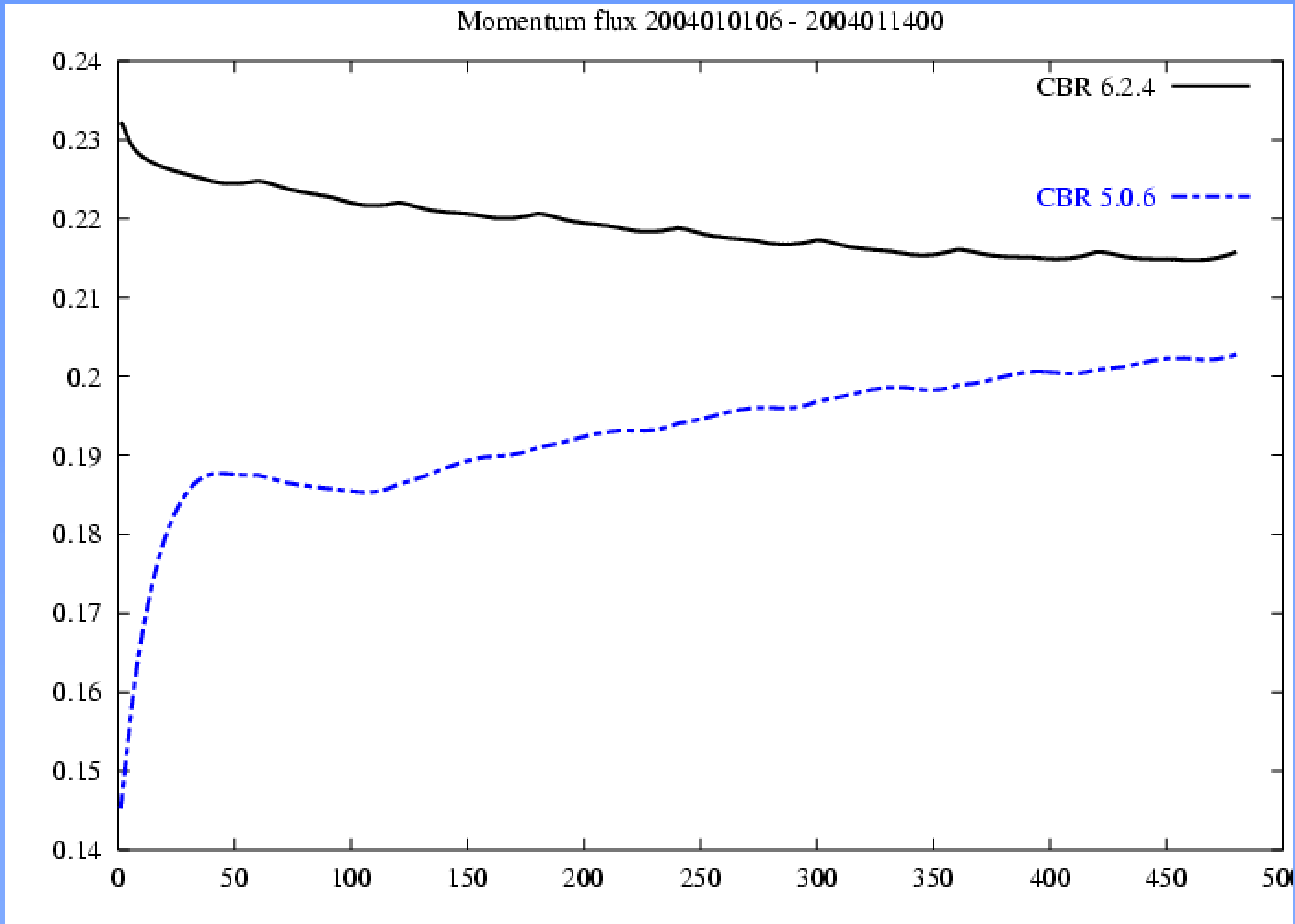
- Different options for DFI:
  - TDFI: -2 hours backward forecast with adiabatic model, filter (-1), two hours forward with full model, filter (0).
  - IDFI (current reference): perform TDFI on first guess and on analysis. Determine $(AN)_{DFI} – (FG)_{DFI} = I_{DFI}$
- IDFI more expensive (two DFI-runs necessary) than TDFI. Much less spinup with IDFI than TDFI

Initialization

- Spinup with TDFI:
  - Backwards forecast with adiabatic model (almost no physics), causes model to dry out and winds near surface to decrease. Filtered -1h forecast will have weaker winds and dry atmosphere where clouds were present
  - Forwards forecast with full model starts from too dry and weak wind conditions, which will be part of filtered state after second forecast. Real forecast (after DFI) will be too little cloud water and too weak winds.

Initialization

- Model spinup



Koninklijk Nederlands Meteorologisch Instituut

Physics

- Radiation
- Surface processes
- Vertical diffusion
- (MSO)
- Condensation and convection

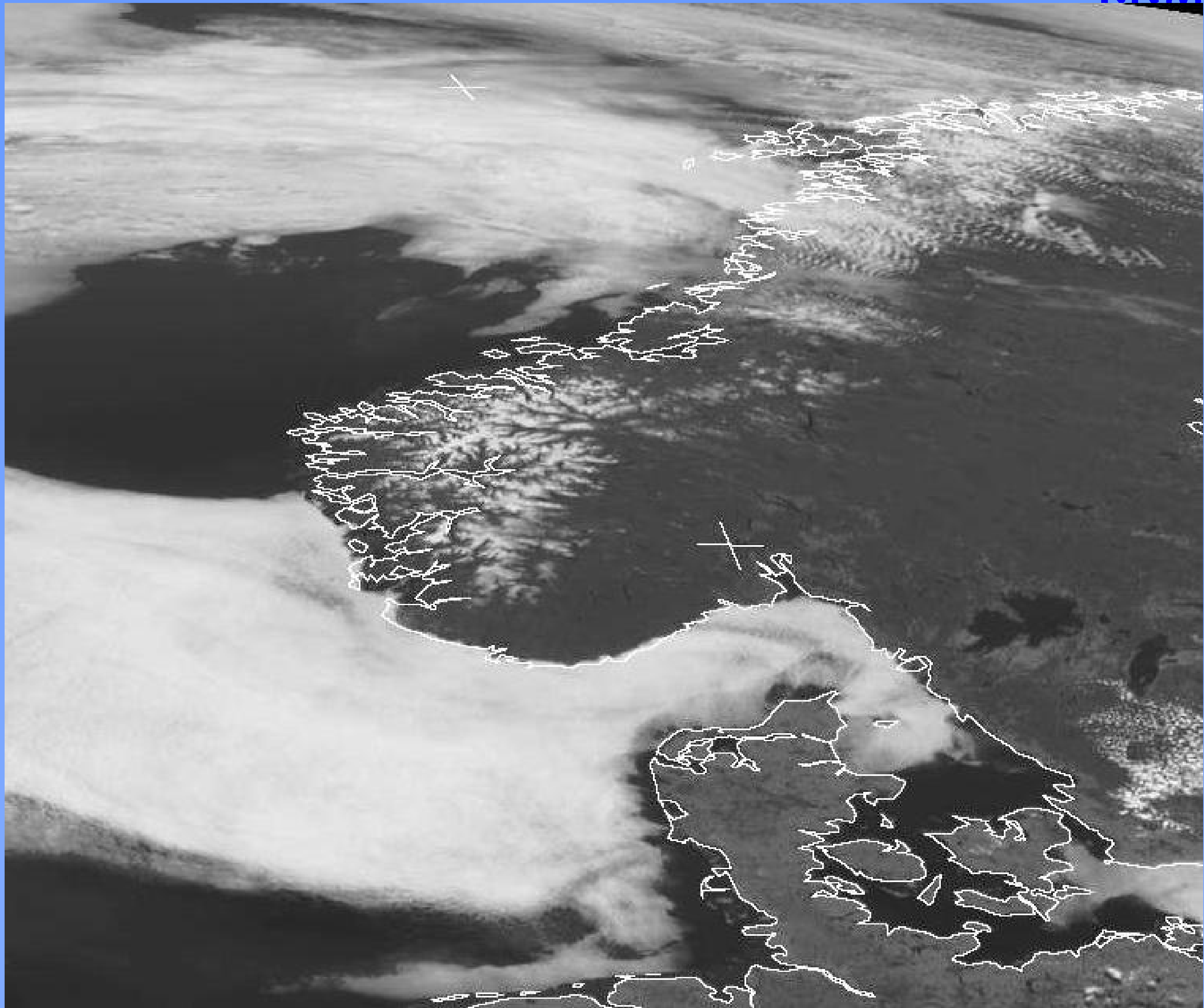
Physics

- Radiation:
  - Savijarvi scheme
  - Simple and quick, allows for calculation at every time step
  - Division in short wave and long wave calculations
  - Fixed reductions due to O_3, O_2, CO_2, WV and aerosol (dependent on angle)
  - Transmissivity of clouds dependent on cloud water and size distribution (empirical) of cloud droplets
  - Cloudy and clear contributions are linearly combined
  - LW part dependent on cloud water and water vapour
  - Sloping surfaces: important with mountains and high res.

Physics

- Surface processes
  - ISBA scheme
  - 5 tiles (water, sea ice, bare soil, low vegetation, high vegetation)
  - One grid box can have fractions from all 5 tiles
  - Blending height is around 60 metres, lowest model level at 30 metres
  - Fluxes calculated per tile and accumulated with fraction of tile as weight.
  - Development of new forest and snow scheme, to improve on Nordic temperature problems

Snow scheme



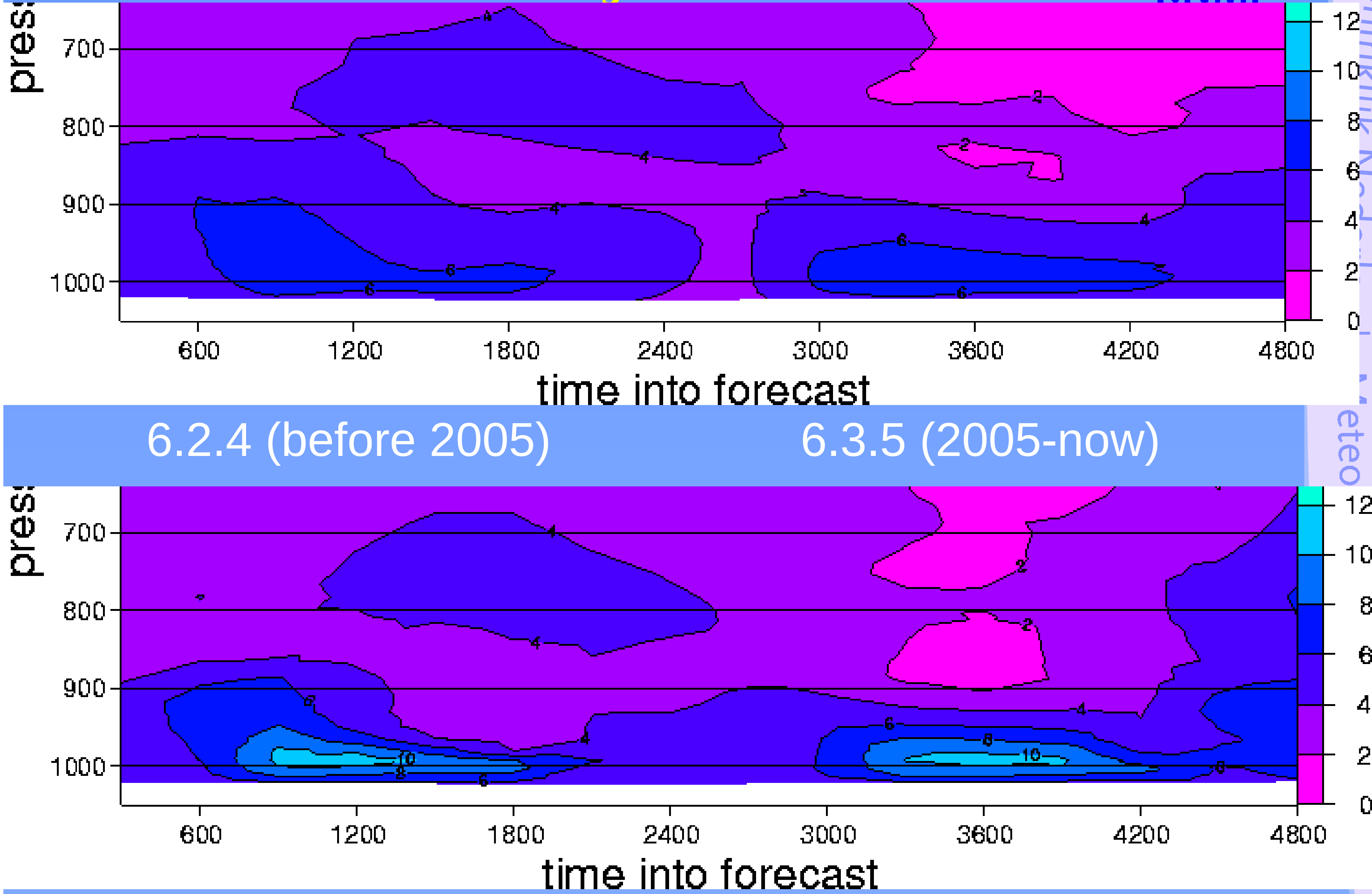
Physics

- Vertical diffusion
  - CBR scheme (Cuxart, Bougeault and Redelsperger)
  - TKE-l scheme

$$F_\phi = -K_\phi \frac{\partial \phi}{\partial z} \quad with \quad K_\phi = l_\phi \sqrt{E}$$

  - Very important for boundary layer development, transport in boundary layer and profiles of wind and temperature under stable conditions
  - Transition to moist scheme

•••• Low level jet in HIRLAM



6.2.4 (before 2005) 6.3.5 (2005-now)

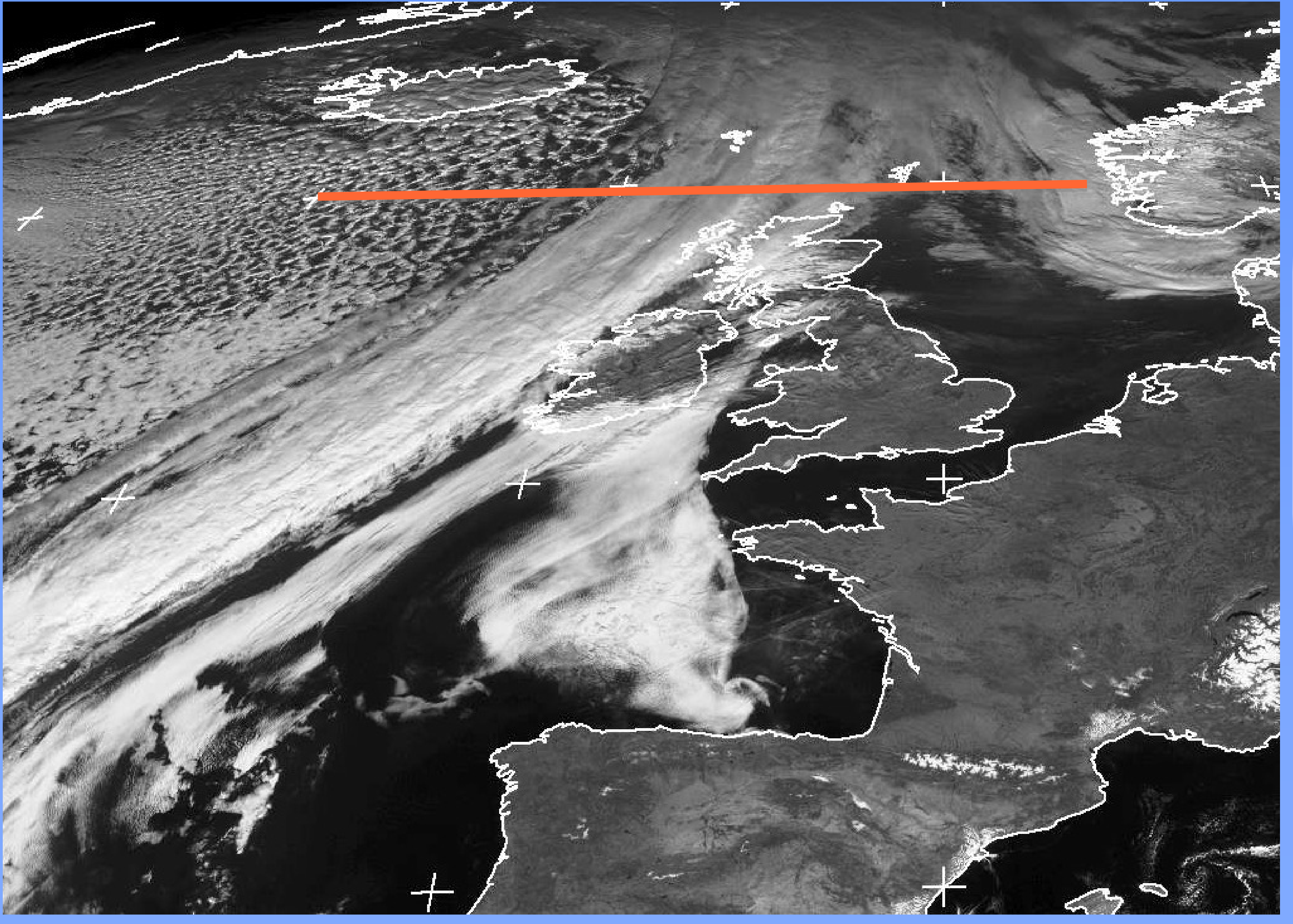
Physics

- MSO/SSO
  - MSO: applies the impact of mountains and mountain ridges on flow (flow blocking, mixing high in atmosphere due to breaking waves). Larger scales in orography. Decreasing importance with increasing resolution
  - SSO: represents the impact of subgrid scale orography on the turbulent characteristics of the flow. Smallest scales only have impact on turbulence.
  - Not yet in HIRLAM

Physics

- Convection and condensation: two possible options
  - STRACO (reference scheme until HIRLAM version 7.1, still current reference)
  - Kain-Fritsch Rasch-Kristjansson (HIRLAM reference from version 7.2)
  - Large differences in characteristics of both schemes
  - Significant impact on cloud water and precipitation distribution (and therefore important for ACT)
  - Small differences in meteorological scores.

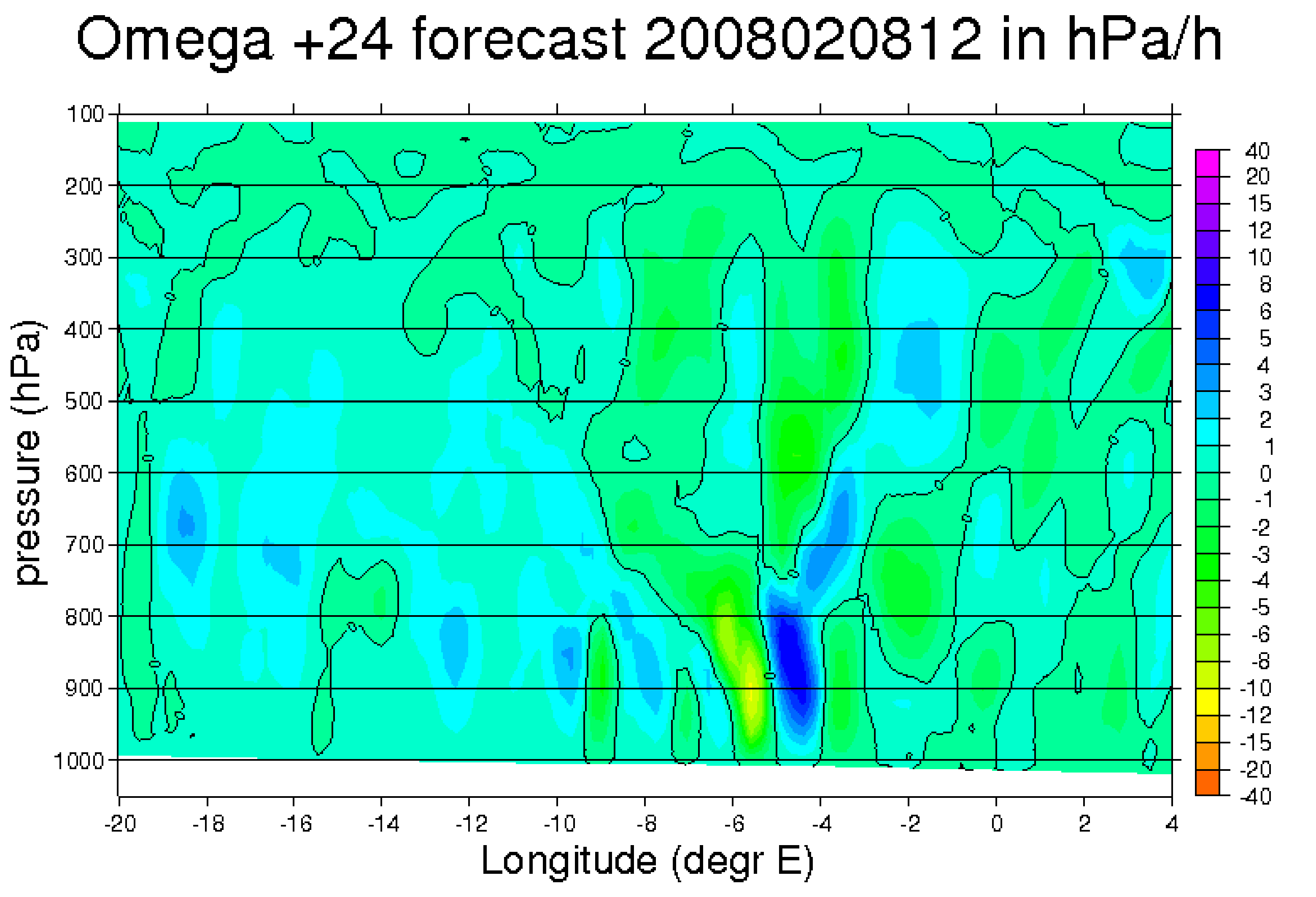
Two convections schemes: 13-02-2008



••••Influence convection on dynamics

KNMI

Koninklijk Nederlands Meteorologisch Instituut



Characteristics of model

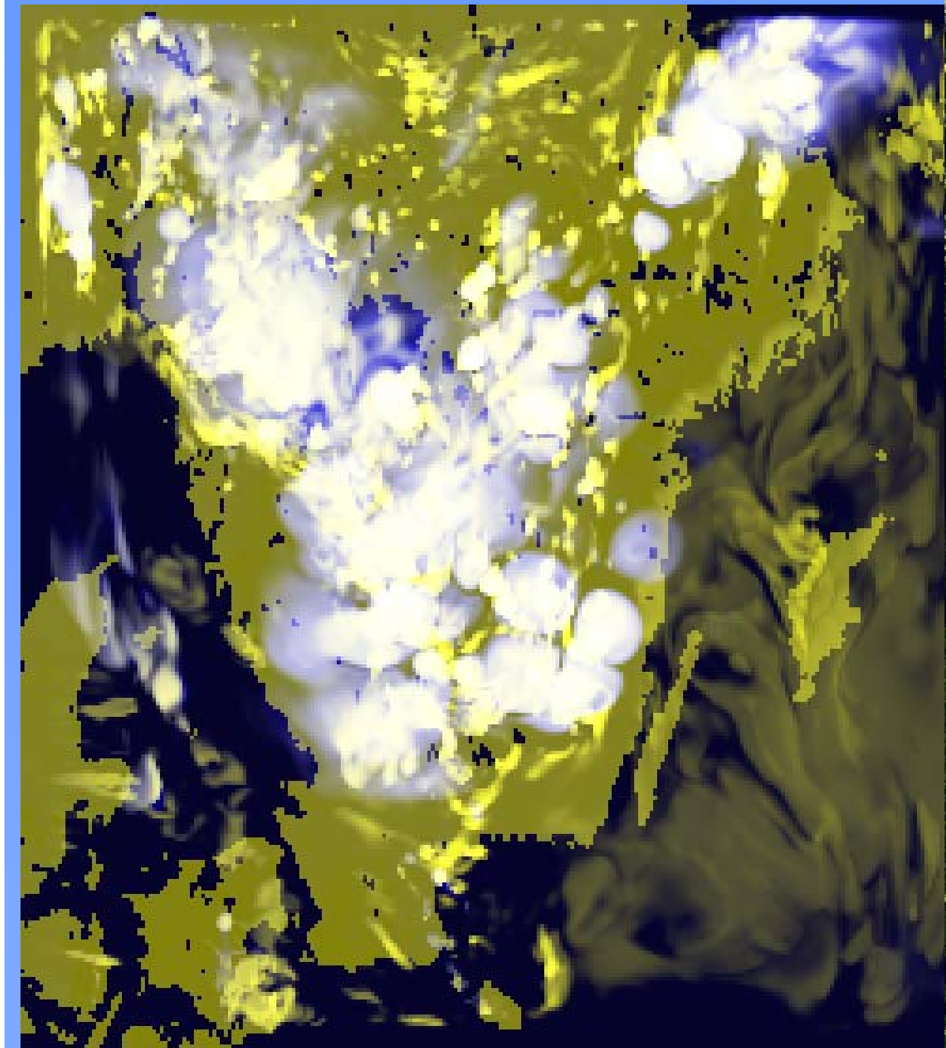
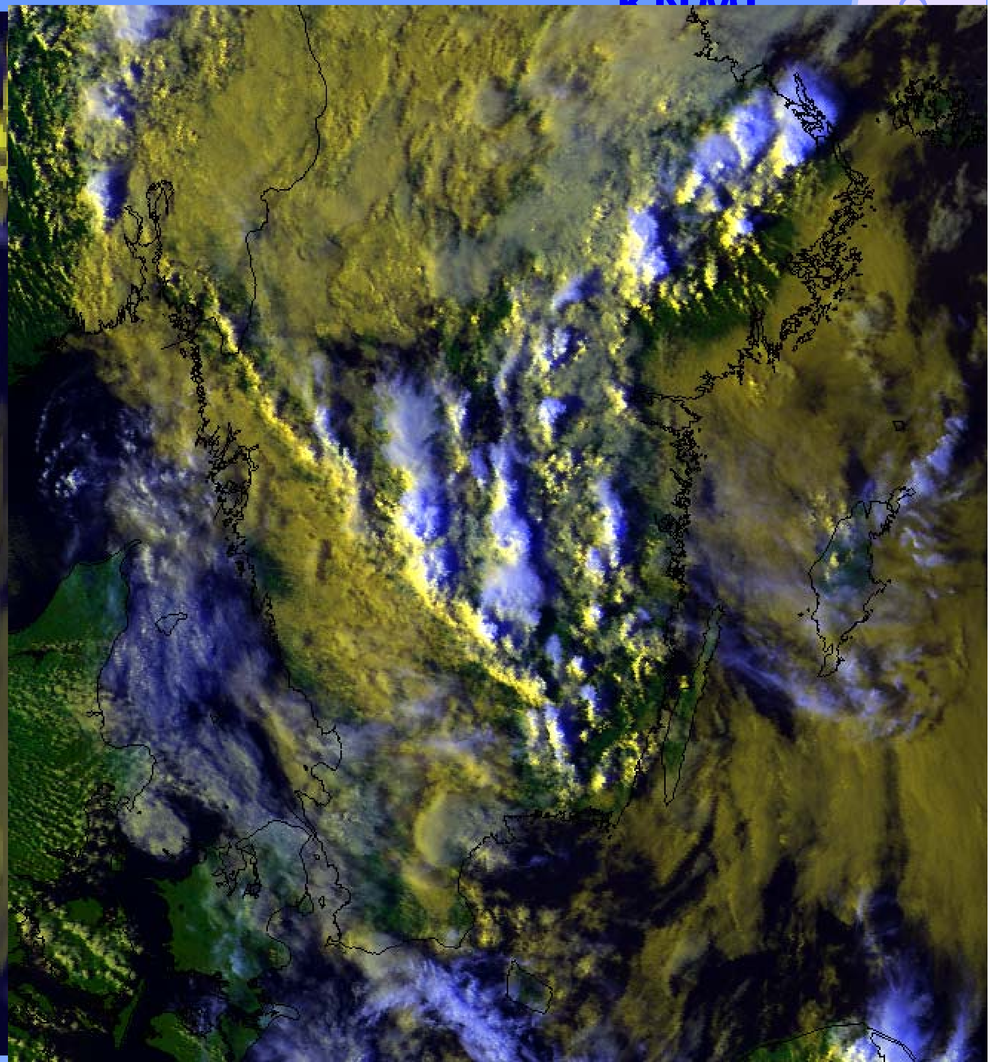
- Very important to know characteristics of model that is used for interpretation of ACT results
- How meteorological information is used also important!
- Examples:
  - Vertical diffusion too strong in stable conditions? Deeper stable boundary layer and too weak low level jets!
  - Too many light precipitation amounts? Too much rain out of chemical species
  - Too much fog over sea? Wet deposition of chemical species
  - Use of precipitation for rain out of entire column? Chemical species rain out from place without clouds!

KNMI

Koninklijk Nederlands Meteorologisch Instituut

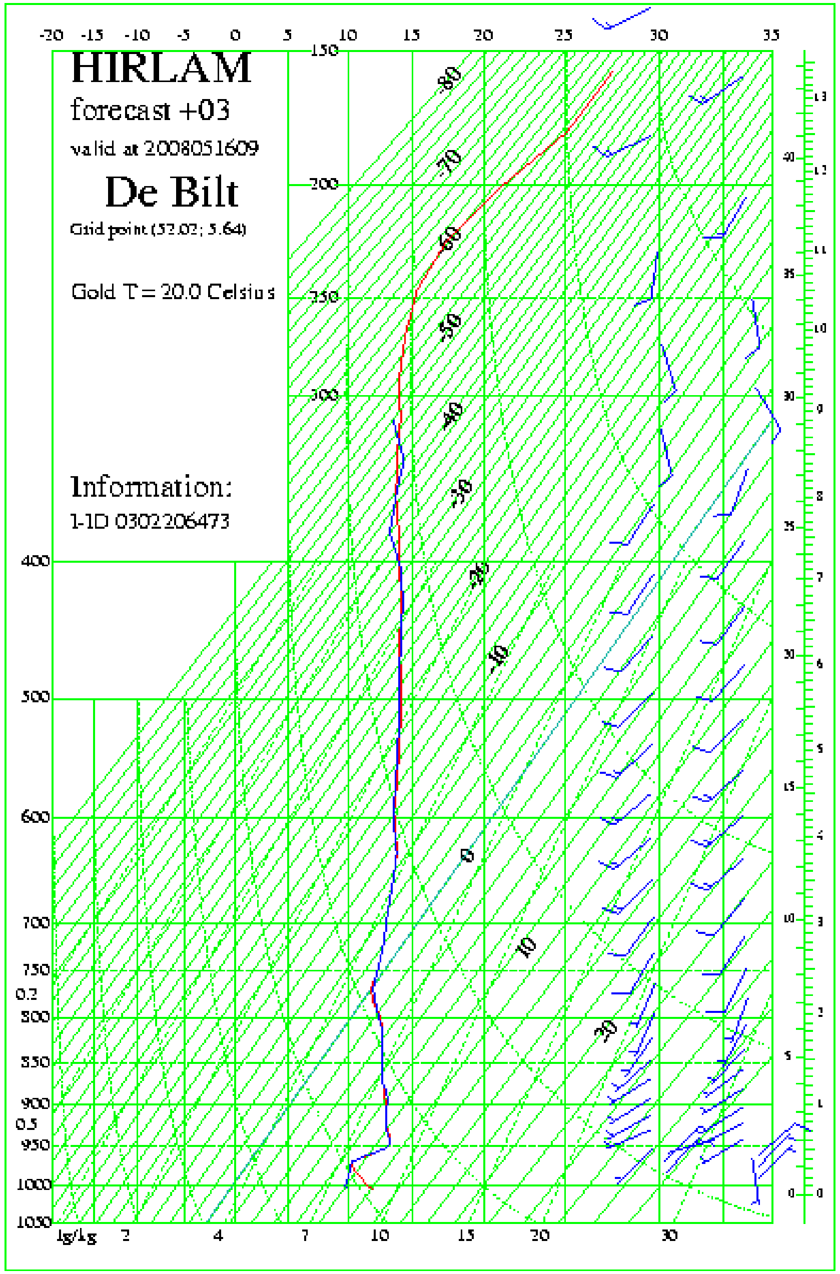
HIRLAM output

- Model state parameters (U,V, T, q, cw, ci, TKE, Ps, soil parameters)
- Postprocessing parameters, standard: PMSL, T2m, U10m, V10m, PBLH, l,m,h cloud cover, accumulated precipitation.
- Special parameters for postprocessing: pseudo satellite information (VIS, IR, WV), CAPE, CIN, LCL, LNB, accumulated fluxes of radiation, sensible and latent heat, wind gusts (instantaneous and accumulated over longer period), friction velocity, precipitation type
- Special for ACT (being implemented): L, accumulated flow characteristics

Output

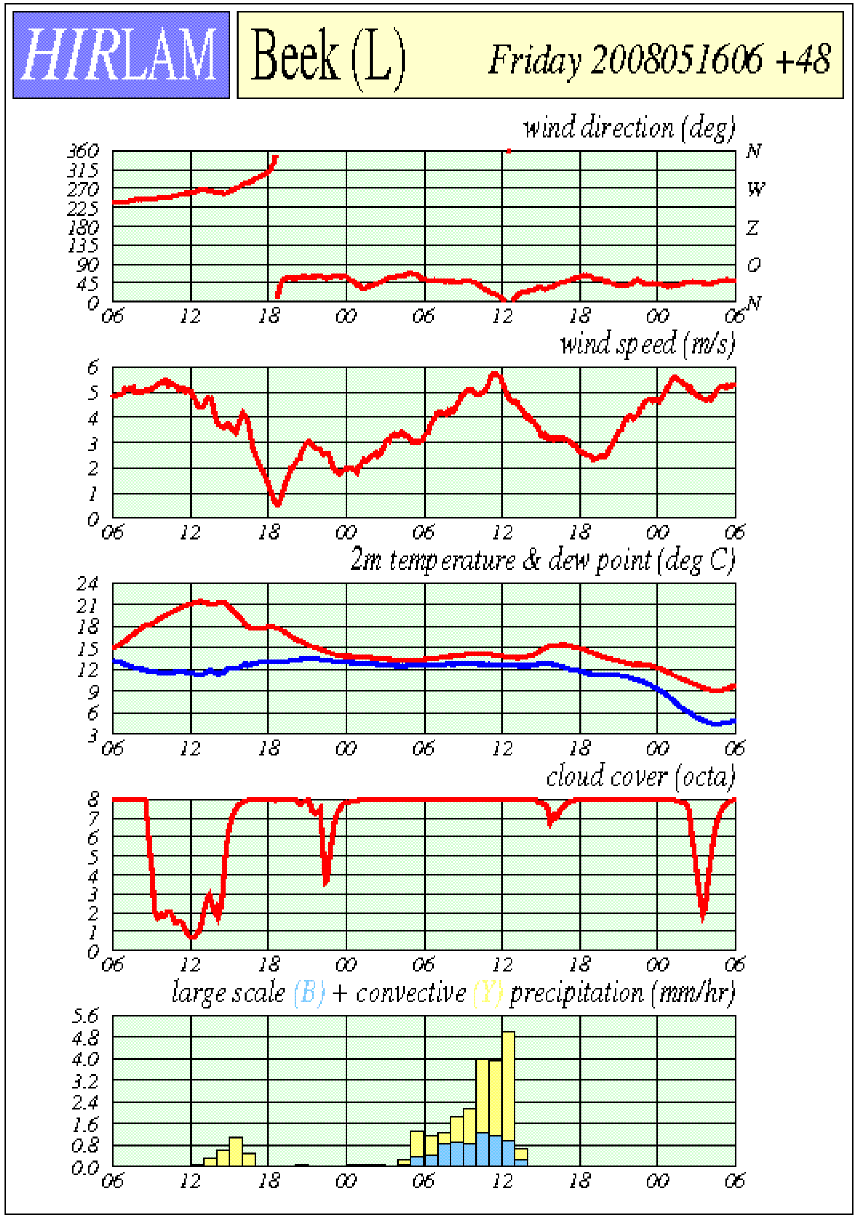
- Model profiles at specified times and specified points



Koninklijk Nederlands Meteorologisch Instituut

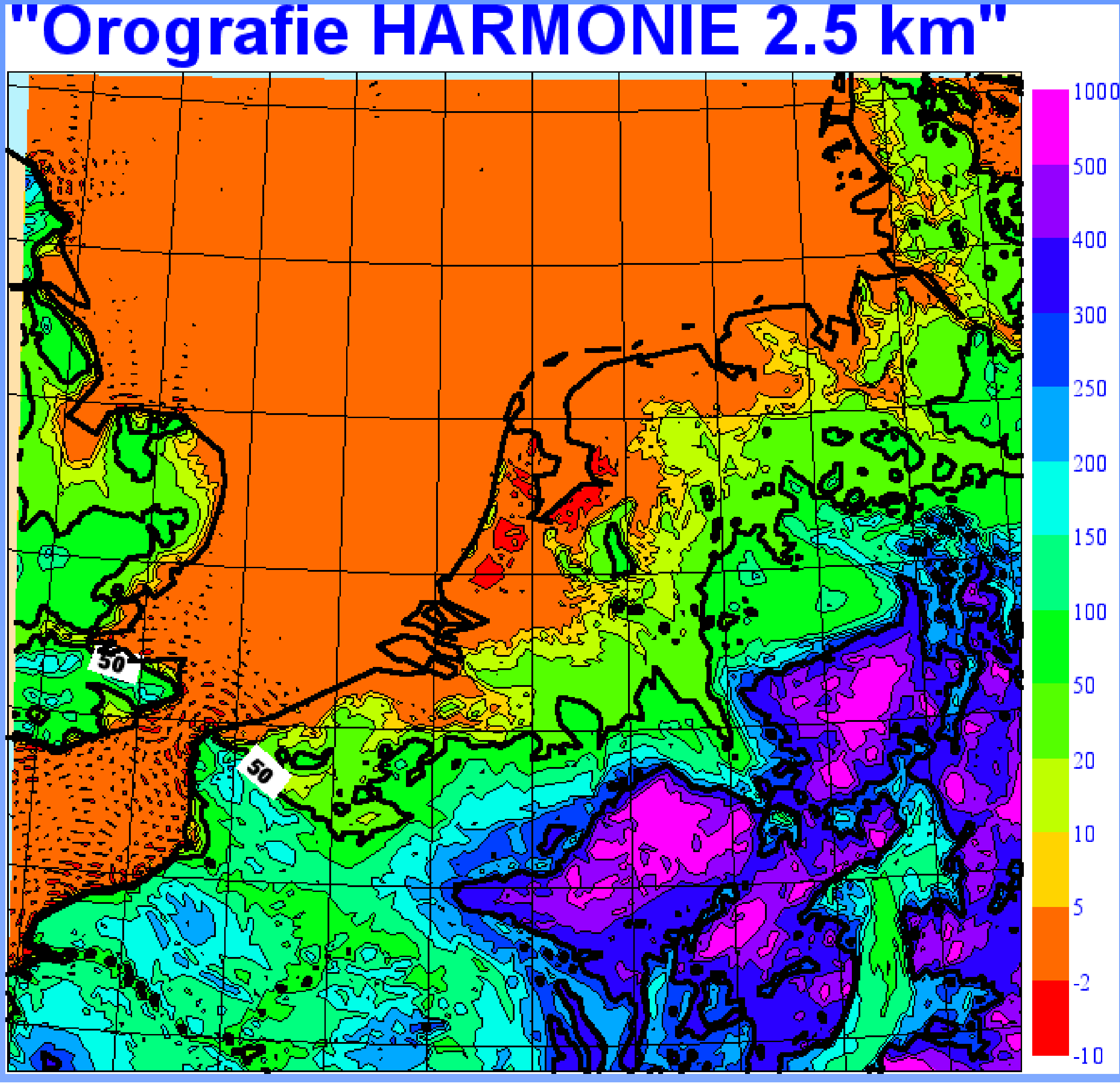
Output

- Time series, output of near surface parameters every time step of model



Koninklijk Nederlands Meteorologisch Instituut

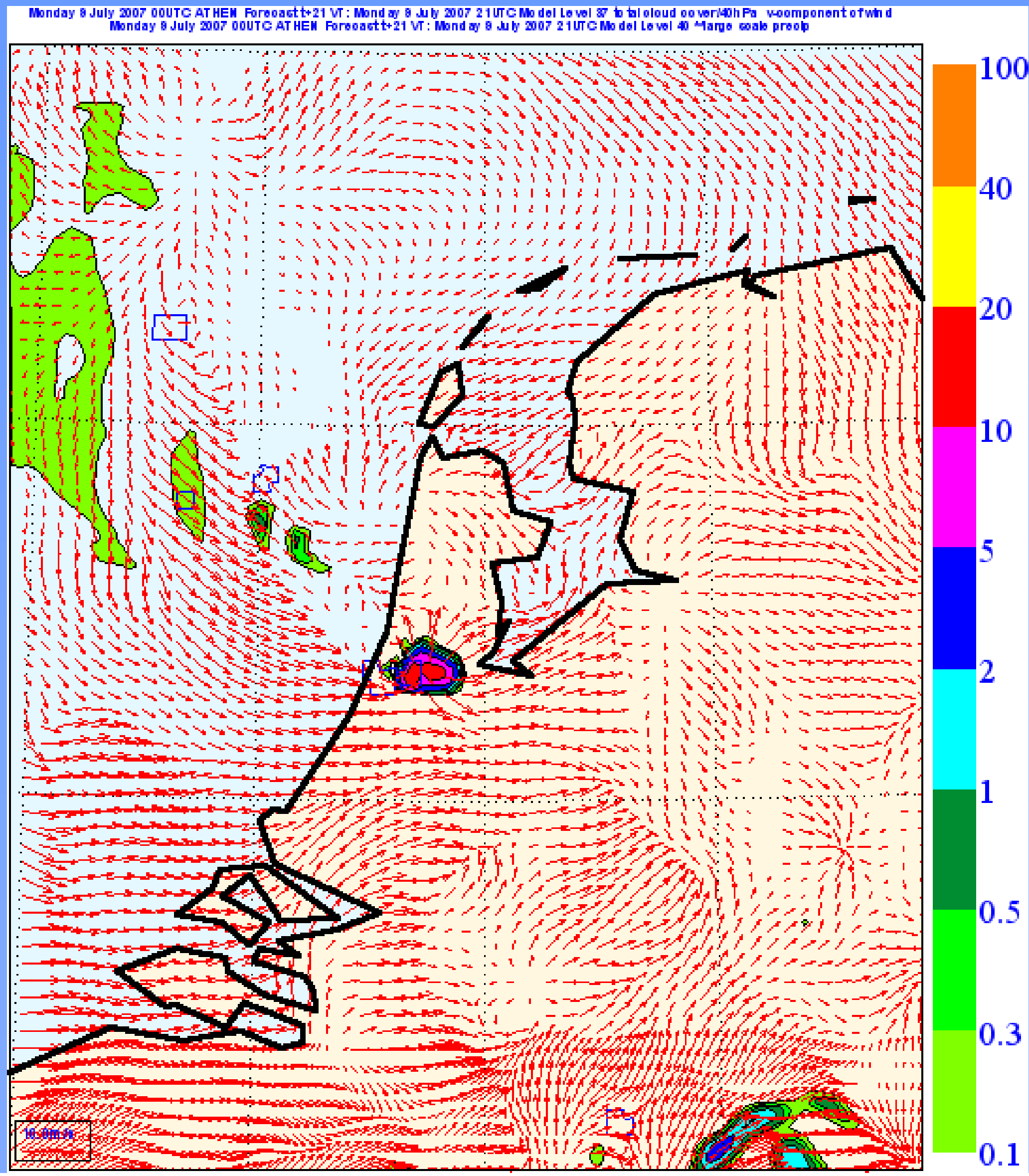
HARMONIE gebied



Koninklijk Nederlands Meteorologisch Instituut

Convergentie outflow

KNMI

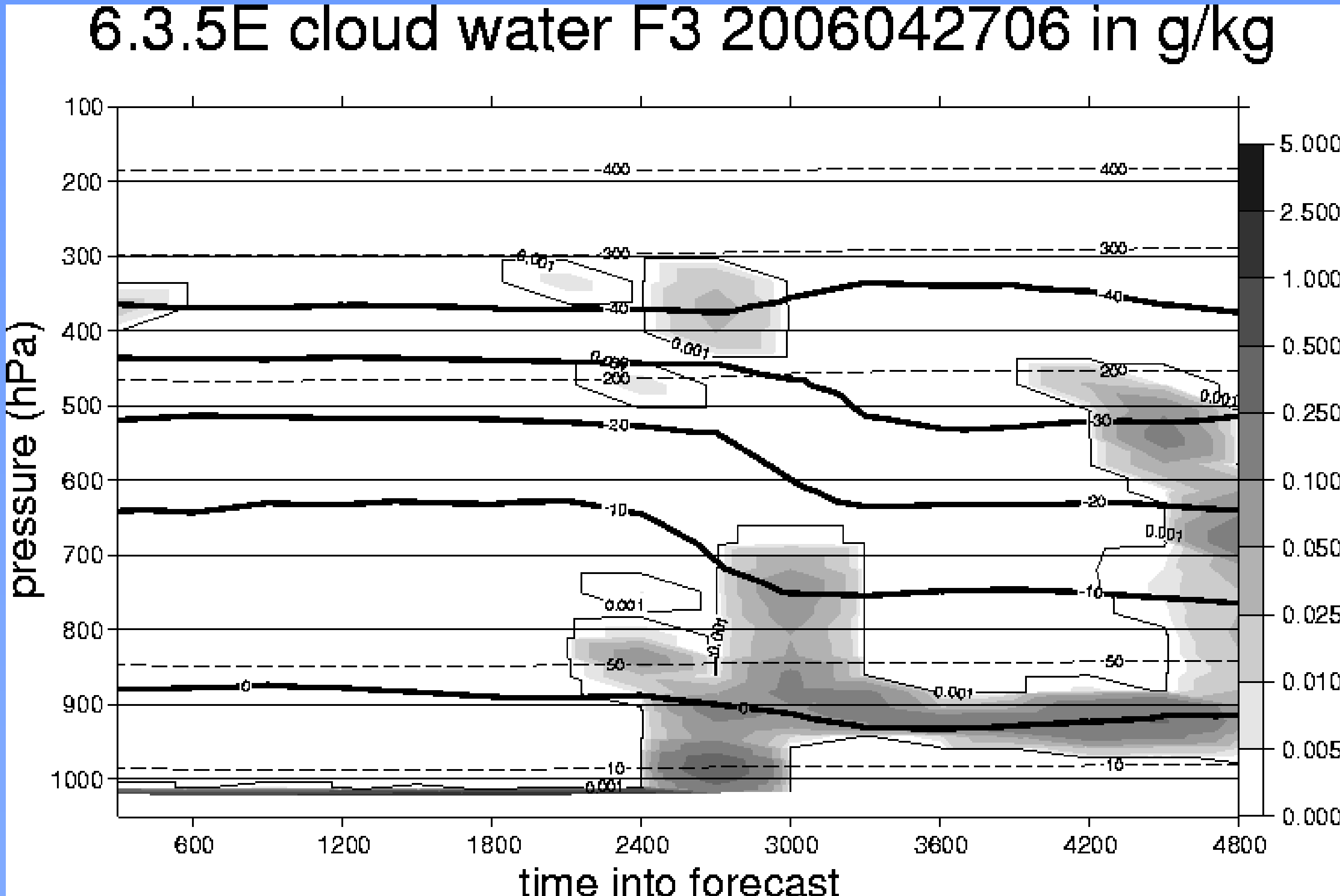


Twee problemen:
-Te sterke koude uitstroom uit bui
-Te hoge neerslag-intensiteit

Koninklijk Nederlands Meteorologisch Instituut

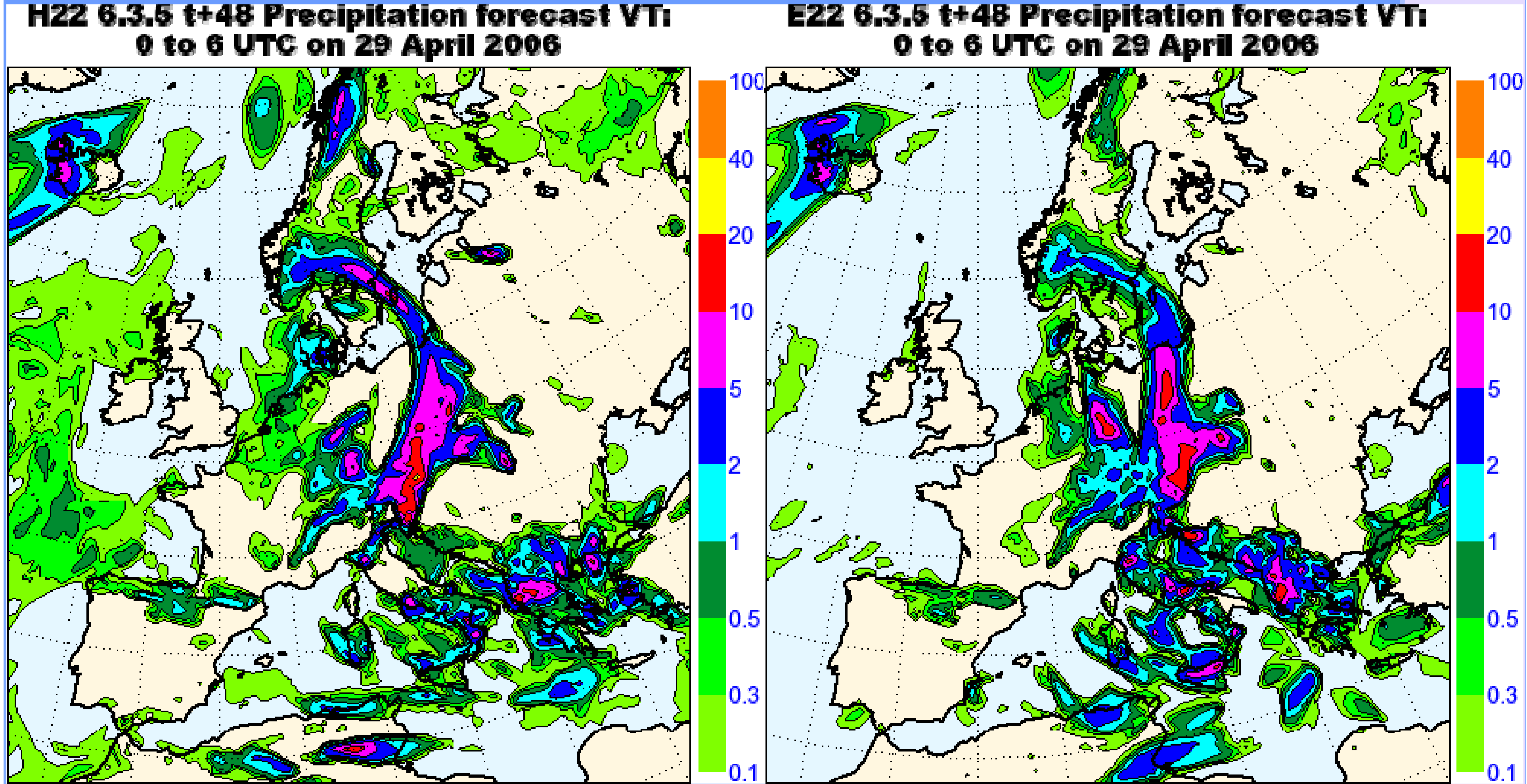
Moist CBR

- Impact on cloud water profiles

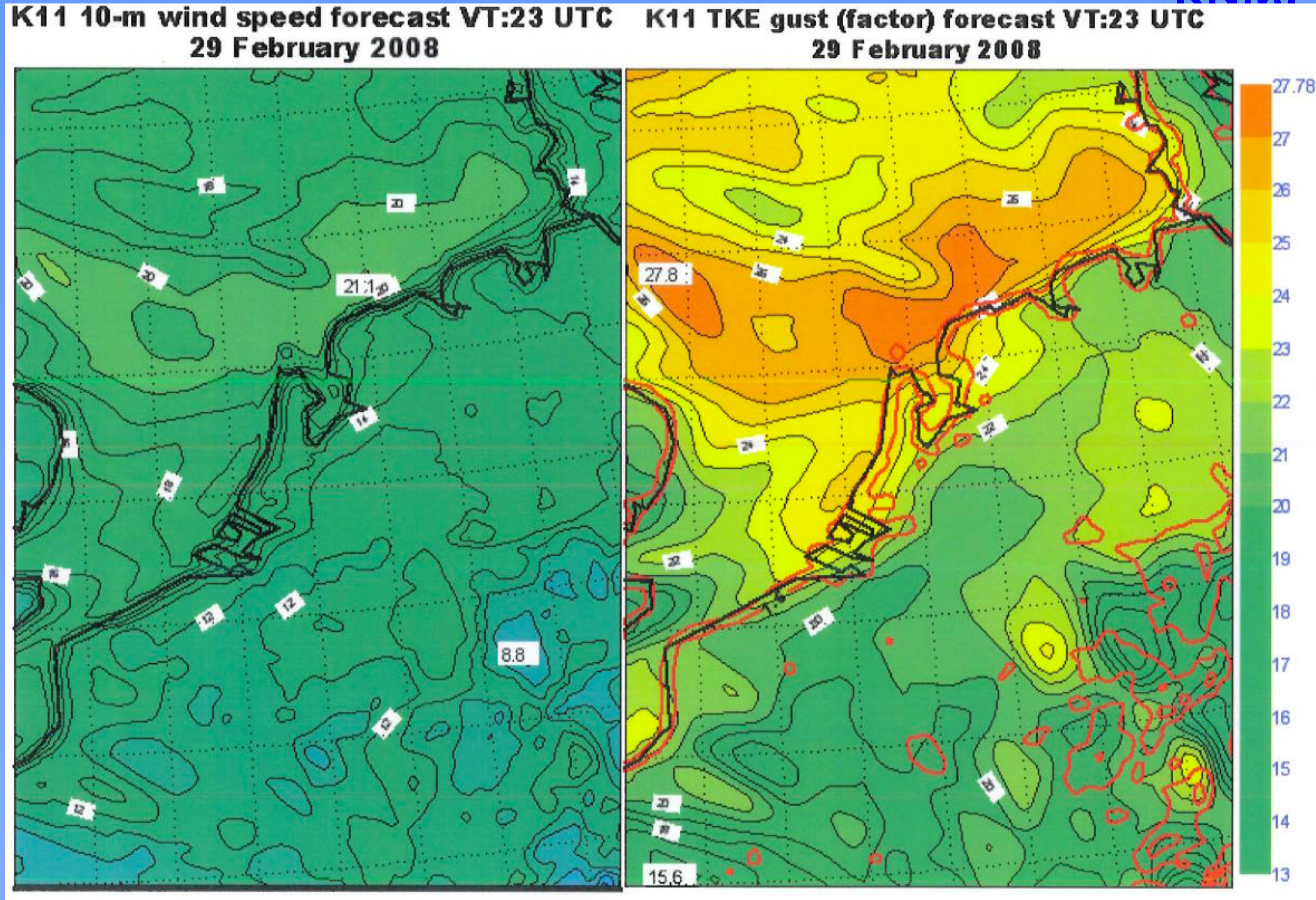


•••• Moist CBR

- Impact on precipitation



Influence convection on wind



Koninklijk Nederlands Meteorologisch Instituut