The Rasch Kristjansson large scale condensation. Present status and prospects

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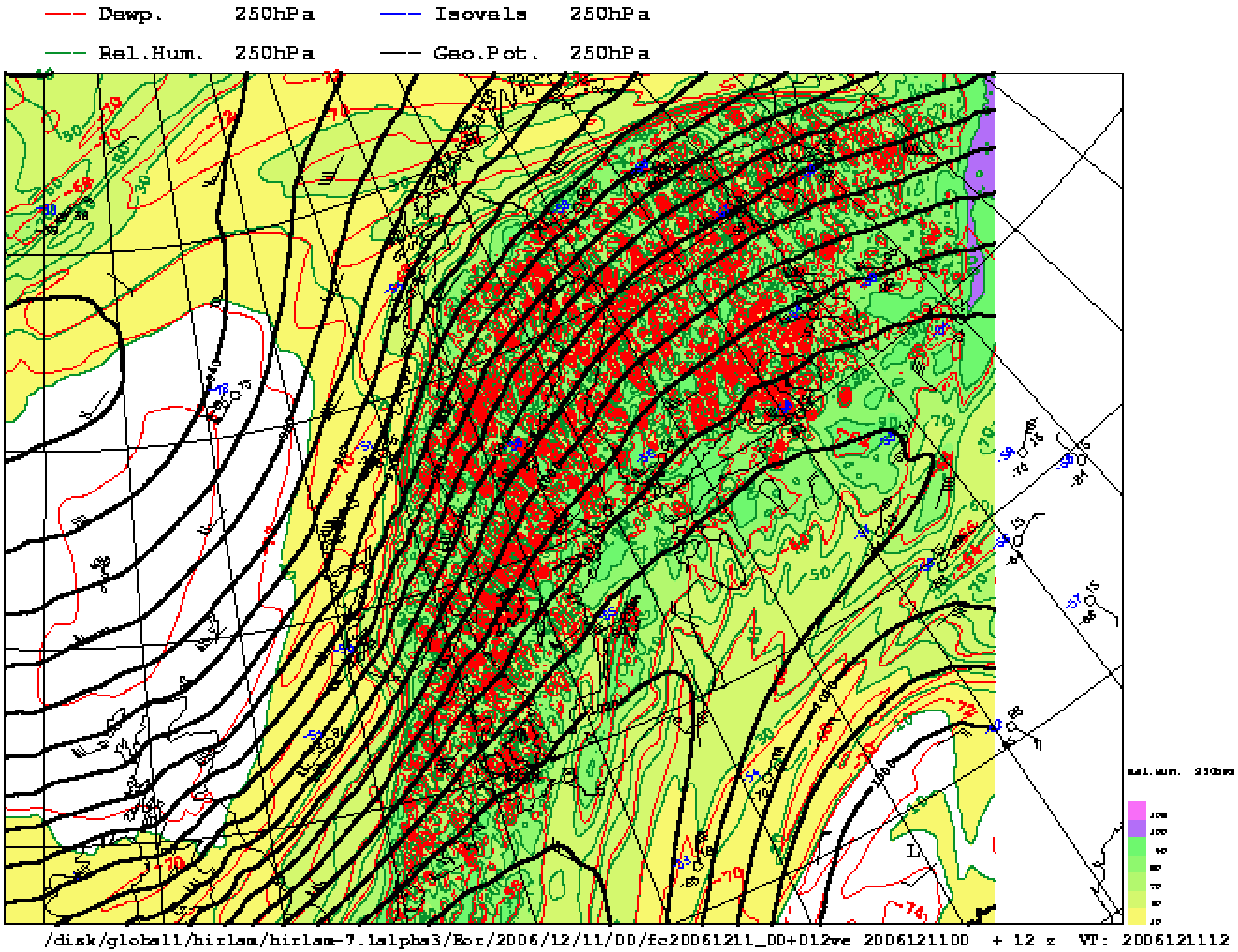
What is the Rasch-Kristjansson scheme ?

- The cloud condensate is determined from fluxes of humidity, cloud condensate and temperature and the current state of those variables (basically the same type of parameterization as in the Sundqvist scheme, but specific humidity is used instead of relative humidity, Rasch and Kristjansson 1998)
- Cloud fraction from Slingo (1980)
- Improved bulk micro-physic :
- Conversion of cloud water to rain by colliding cloud water drops
- Collection of cloud water by rain
- Conversion of cloud ice to snow by colliding cloud ice
- Collection of cloud ice by snow
- Collection of cloud water by snow

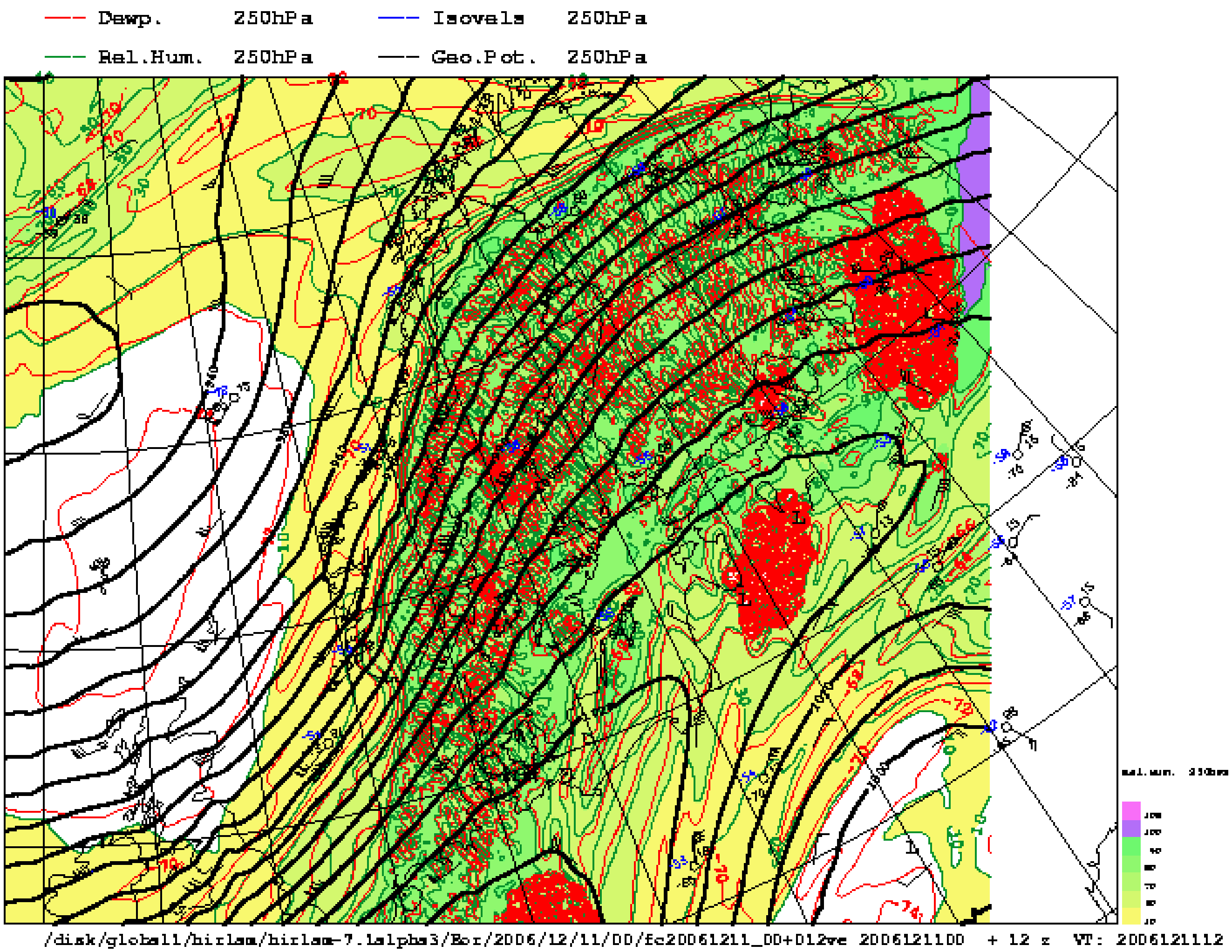
Known problems with the old version that have been solved or at least are not too big problems any more

- Small amount of precipitation too frequent. -partly solved
- Too much precipitation behind mountains. -solved
- To much low clouds in case of severe winter conditions. -partly solved, not a big problem with the new surface scheme
- Cooling due too snow melt not accounted for, poor parametrization of snow melt (rain too quickly) -solved
- Too much middle level clouds. -solved
- Noisy cirrus cloud field in case of strong jets, short time step may increase it. -partly solved

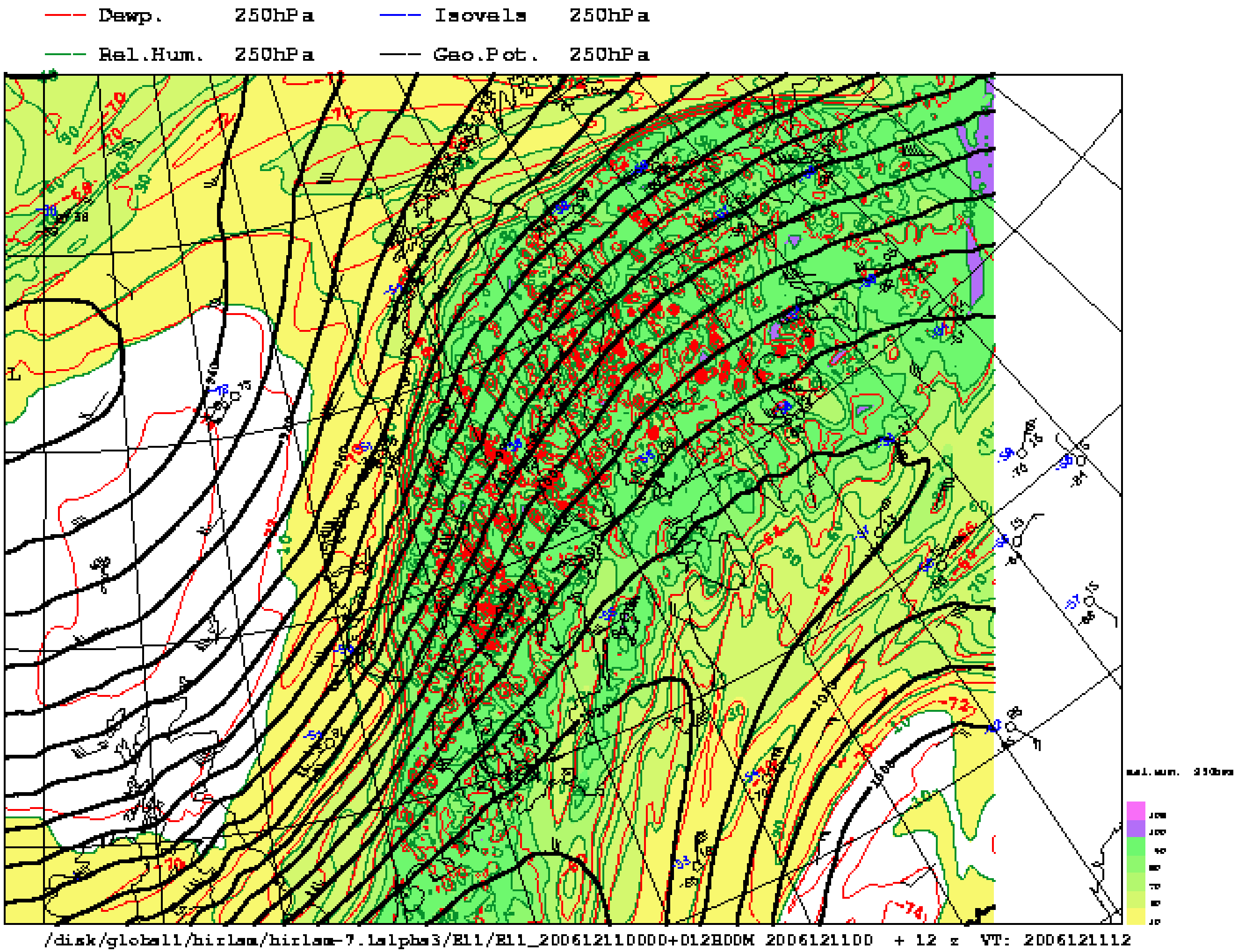
Noise at jet-level, old scheme 5min timestep



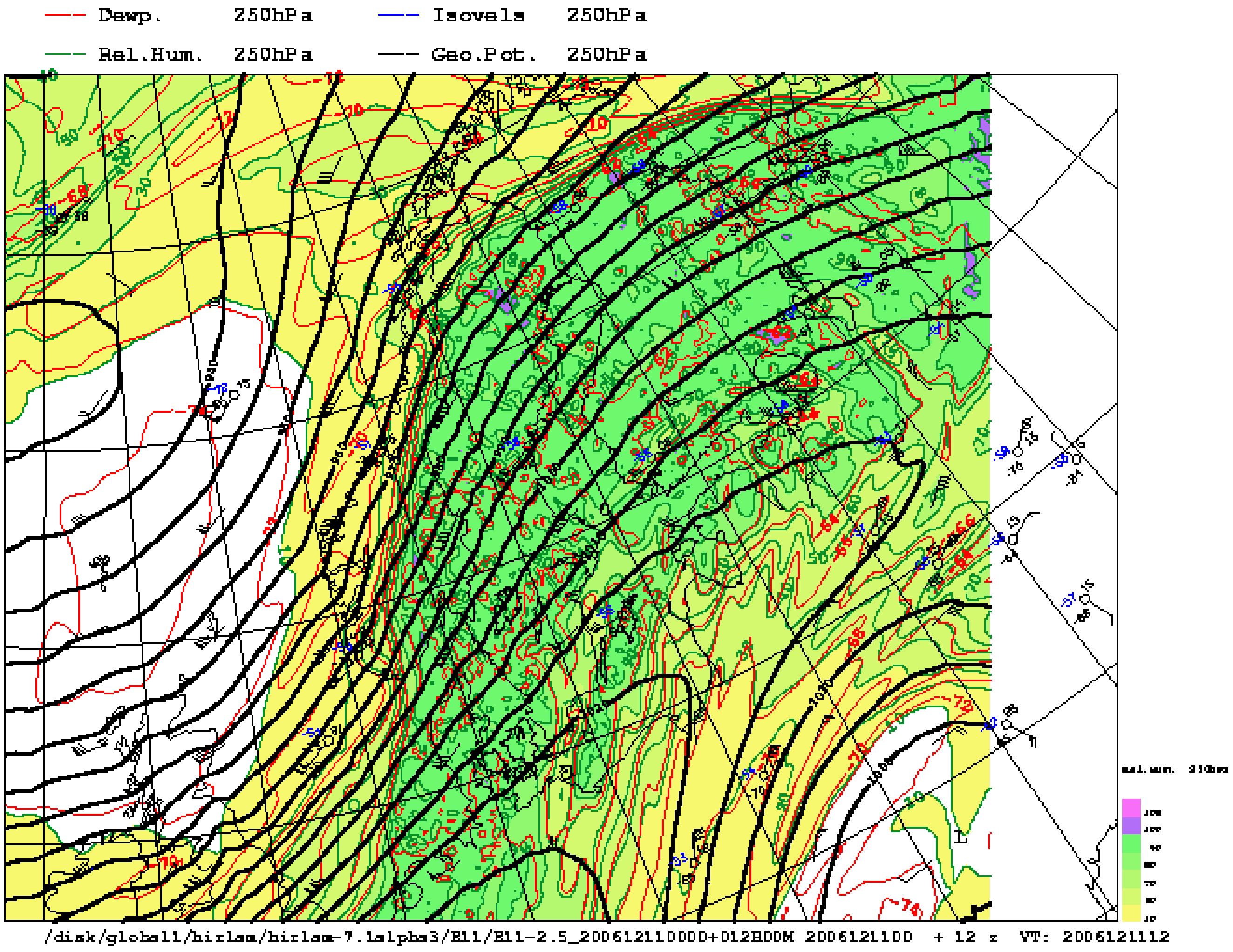
Noise at jet-level, old scheme 2.5min timestep



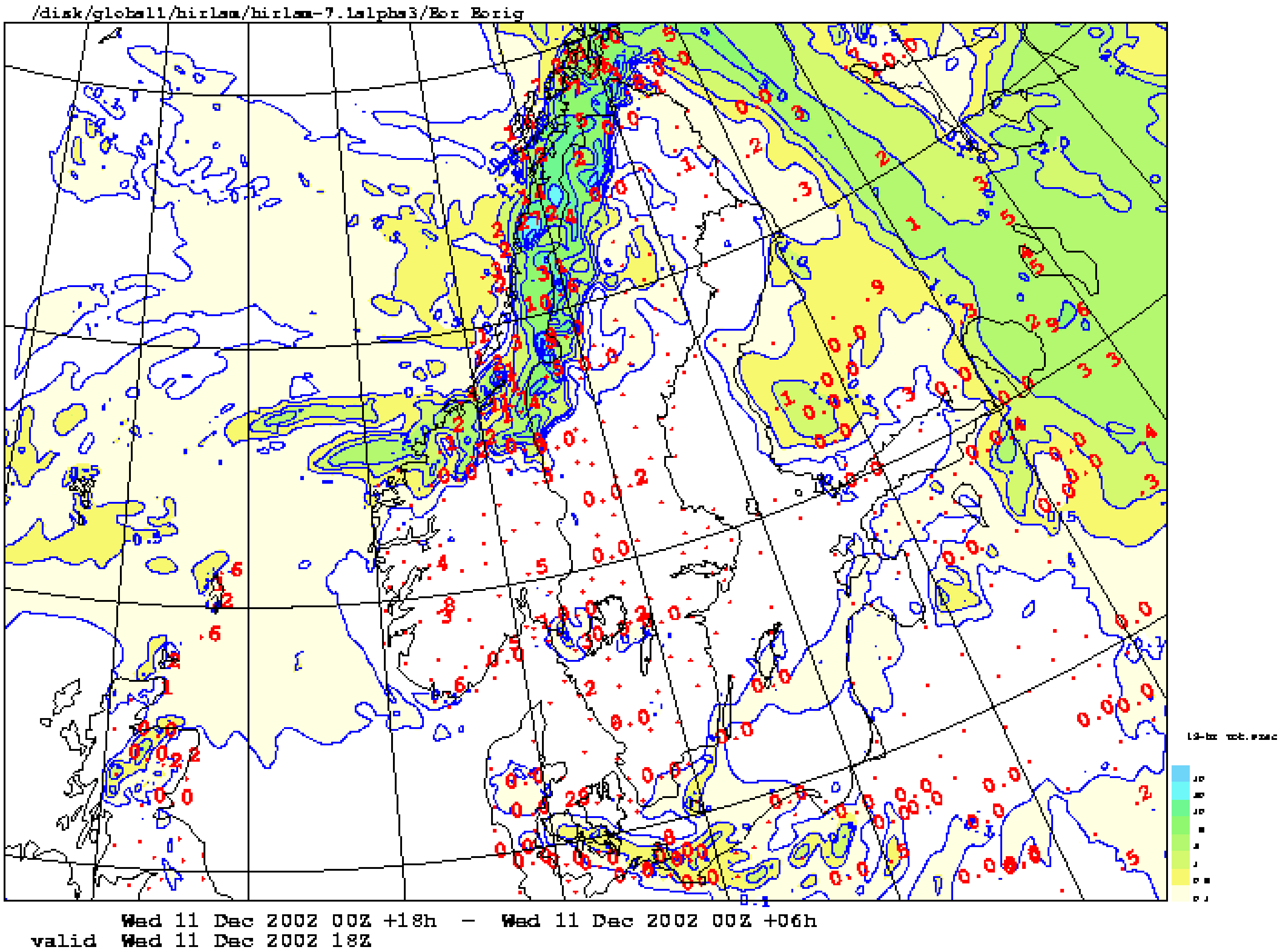
Present scheme: Revised precipitation release, lower critical relative humidity (5min timestep)



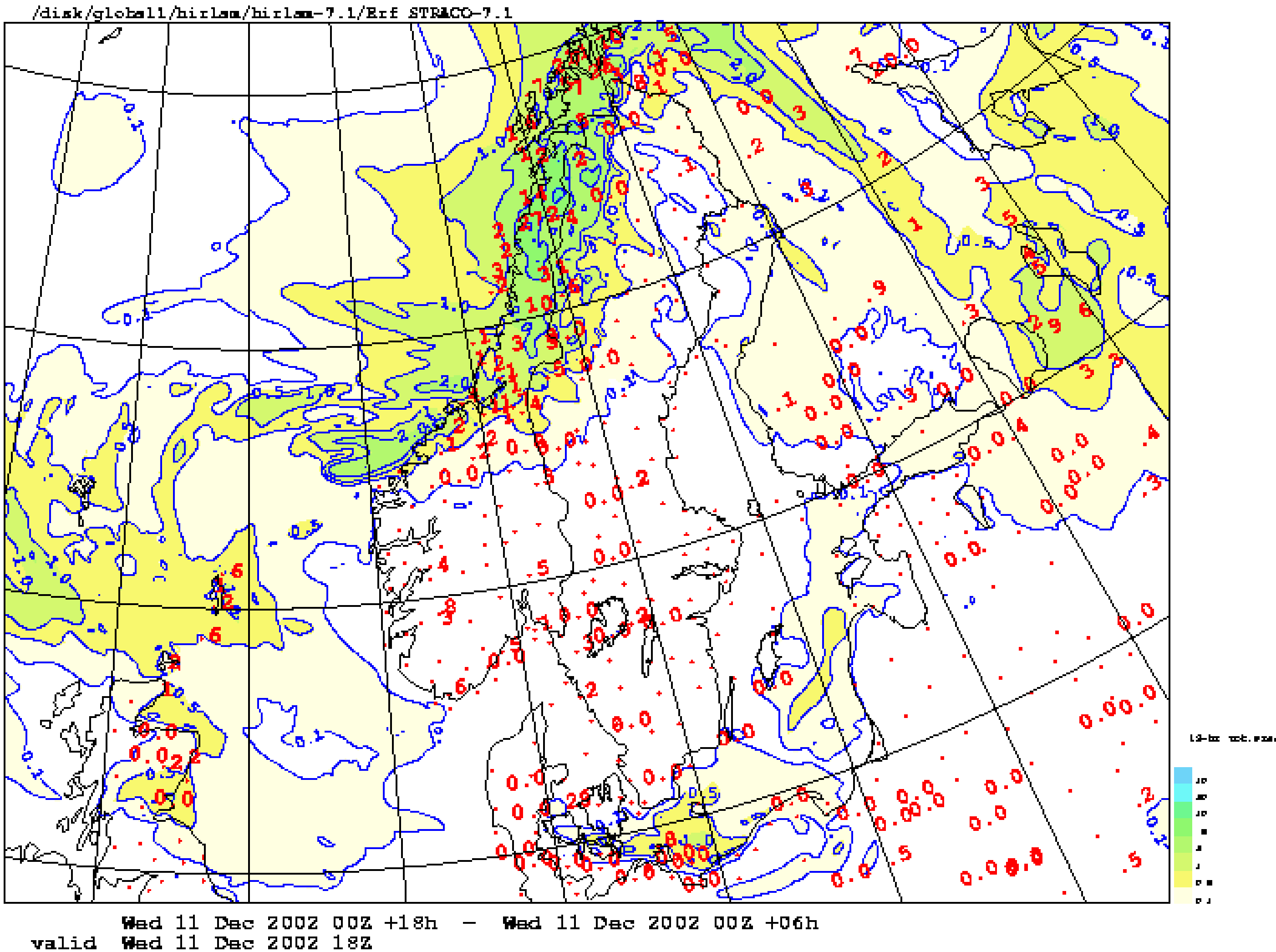
2.5 min timestep



Too much precipitation behind mountains, old scheme.



Straco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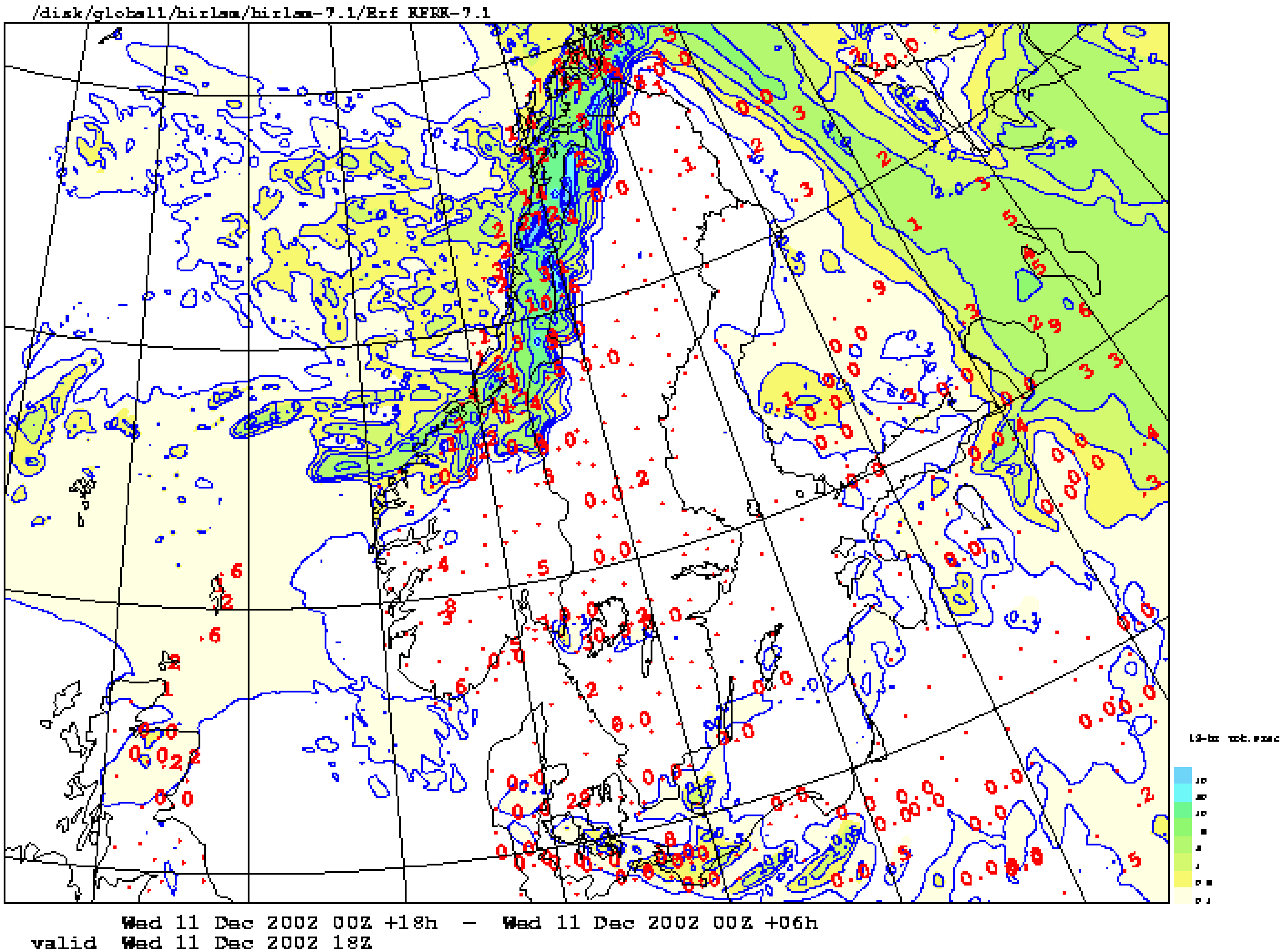
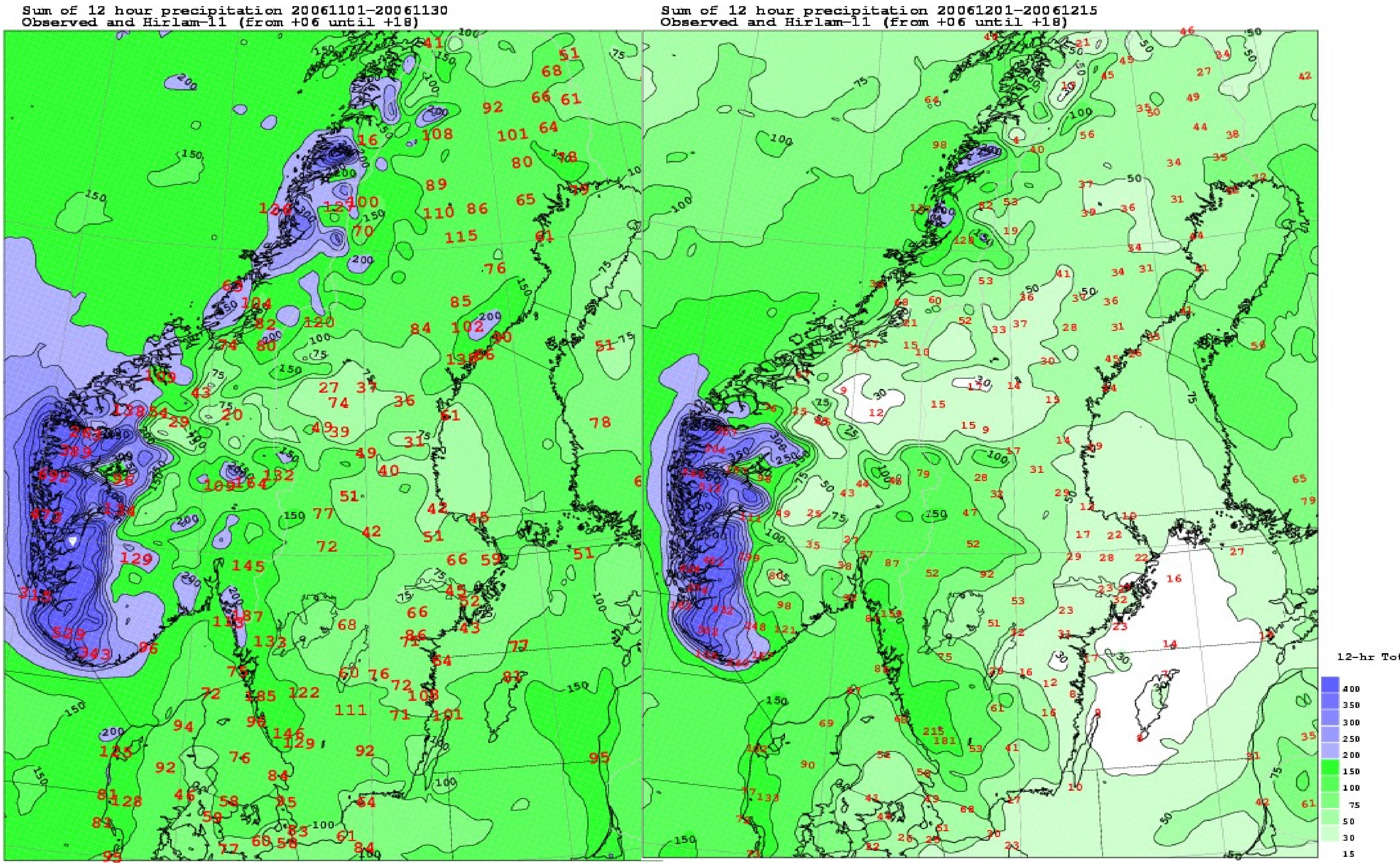
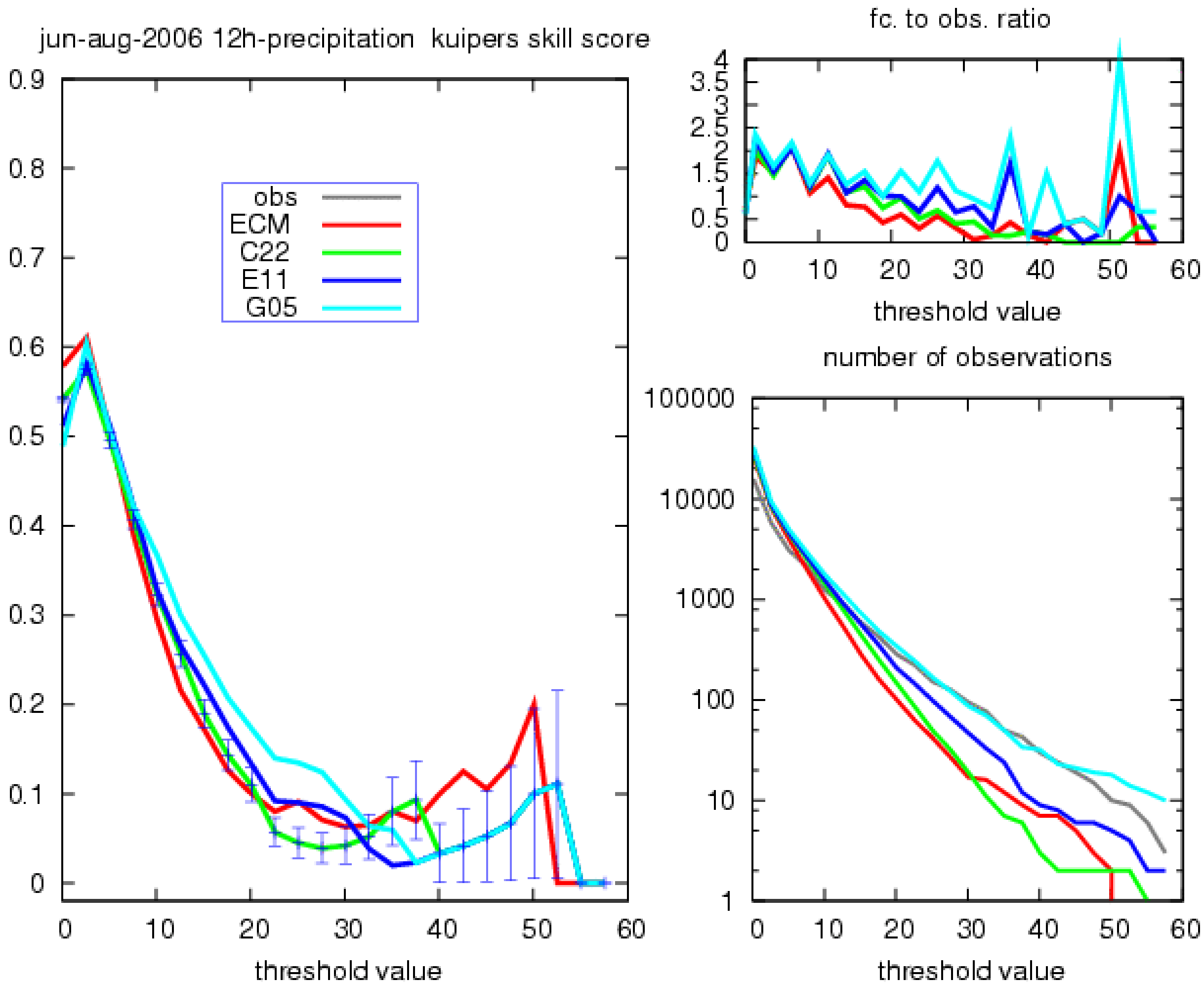
Present scheme : Kogan auto-conversion,adapted to current model resolution and orography,new critical relative humidity. Revised precipitation release



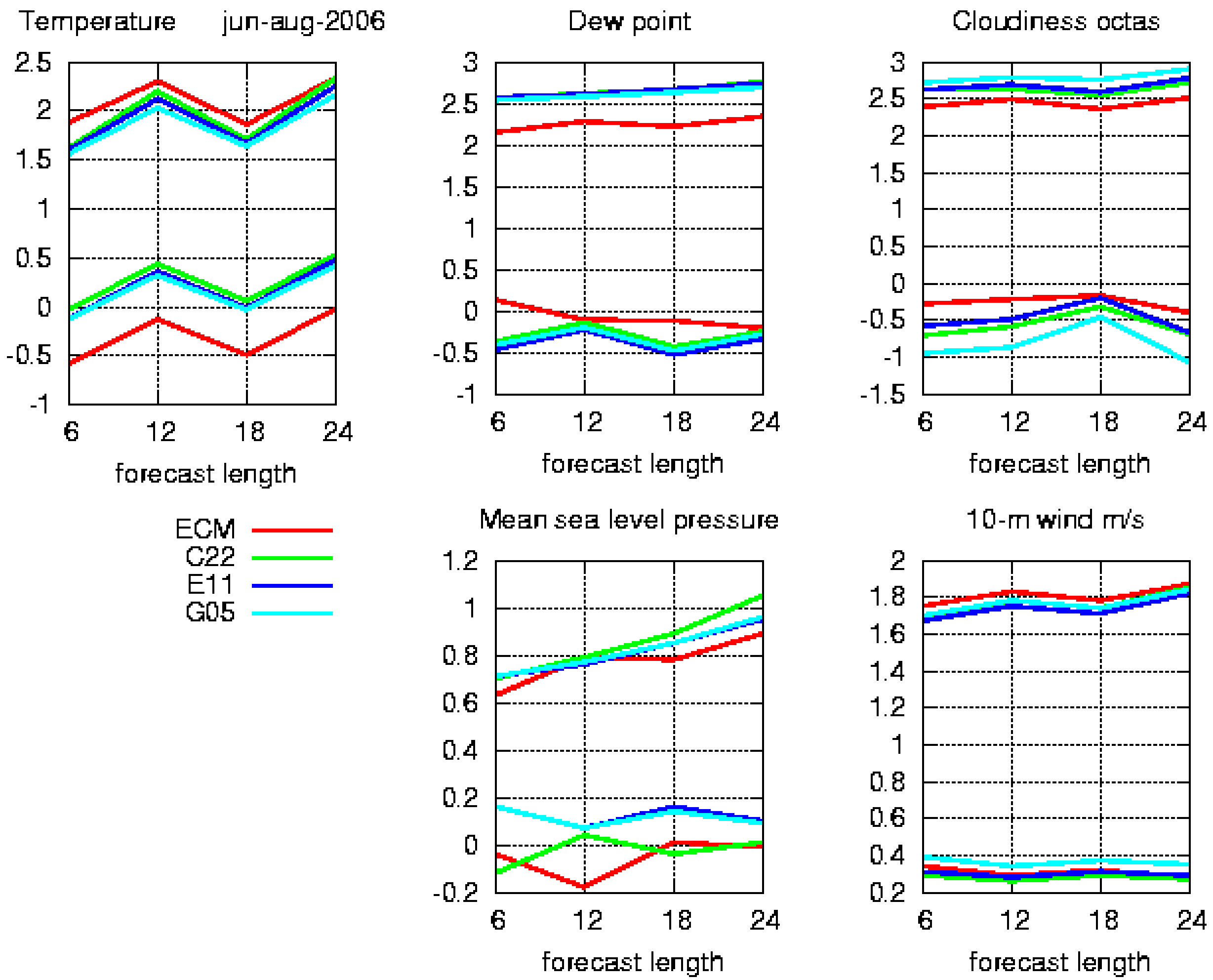
Is the scattered precipitation field over mountains (heterogeneous terrain) realistic or noise ?



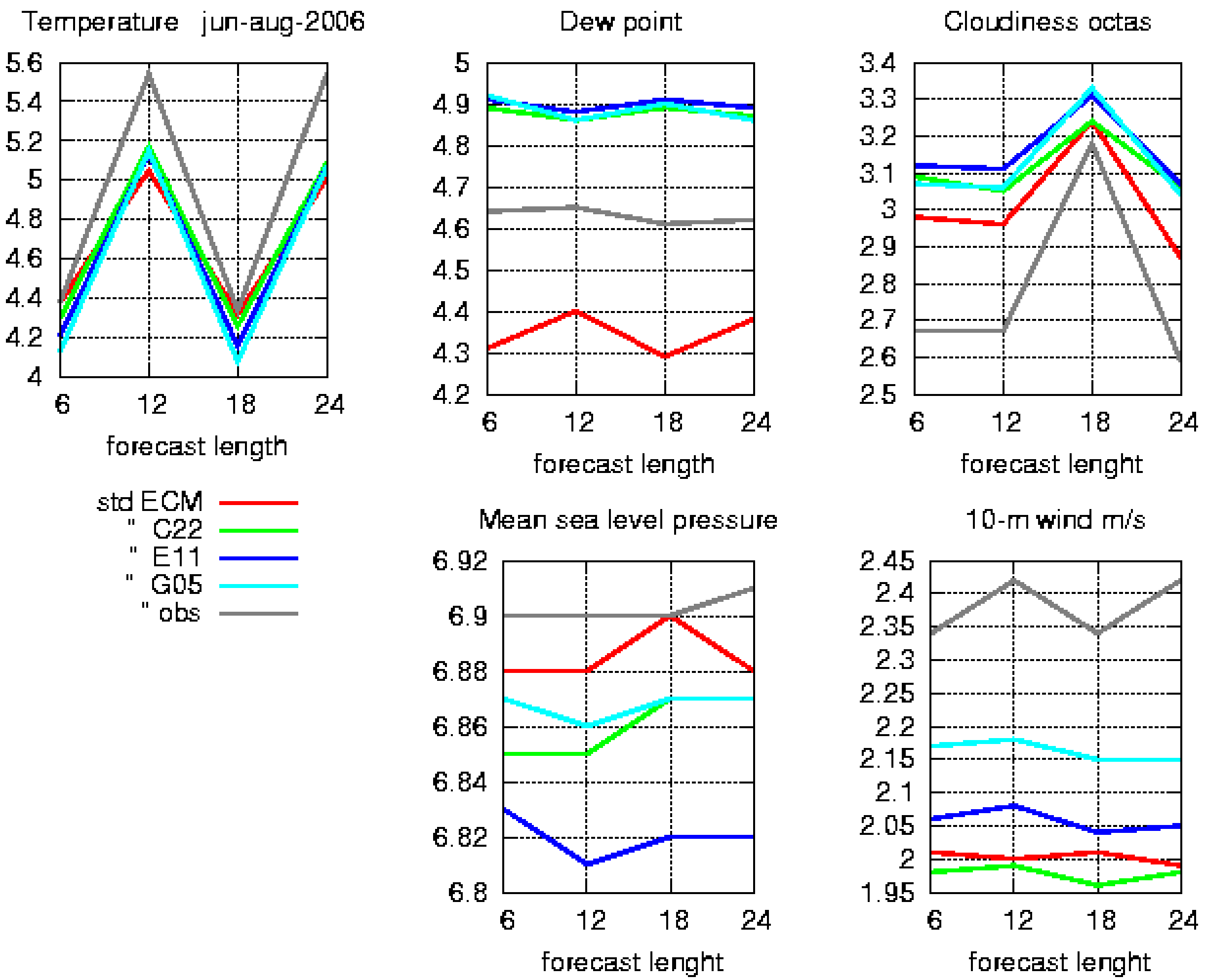
Precipitation summer 2006



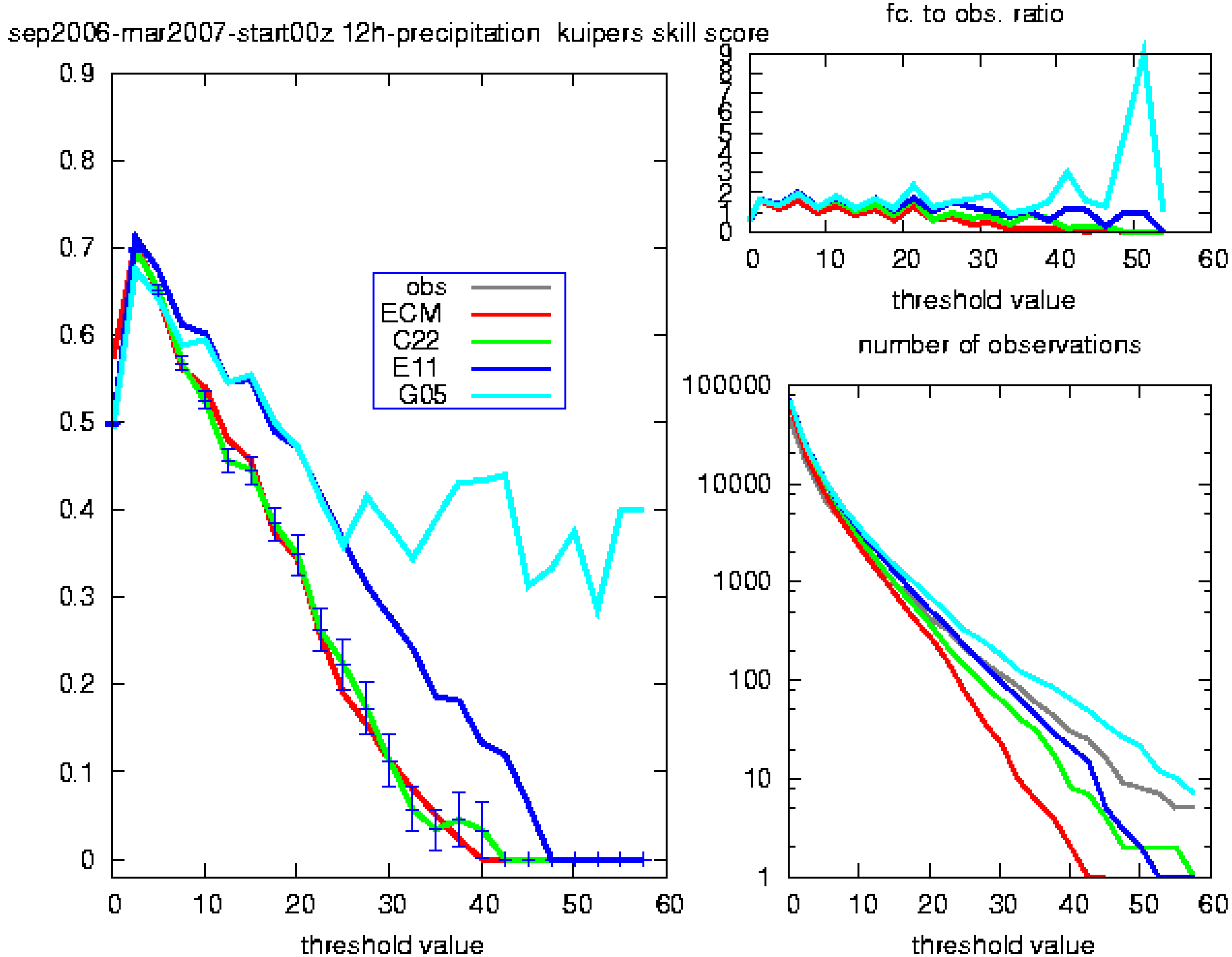
Surface parameters summer 2006



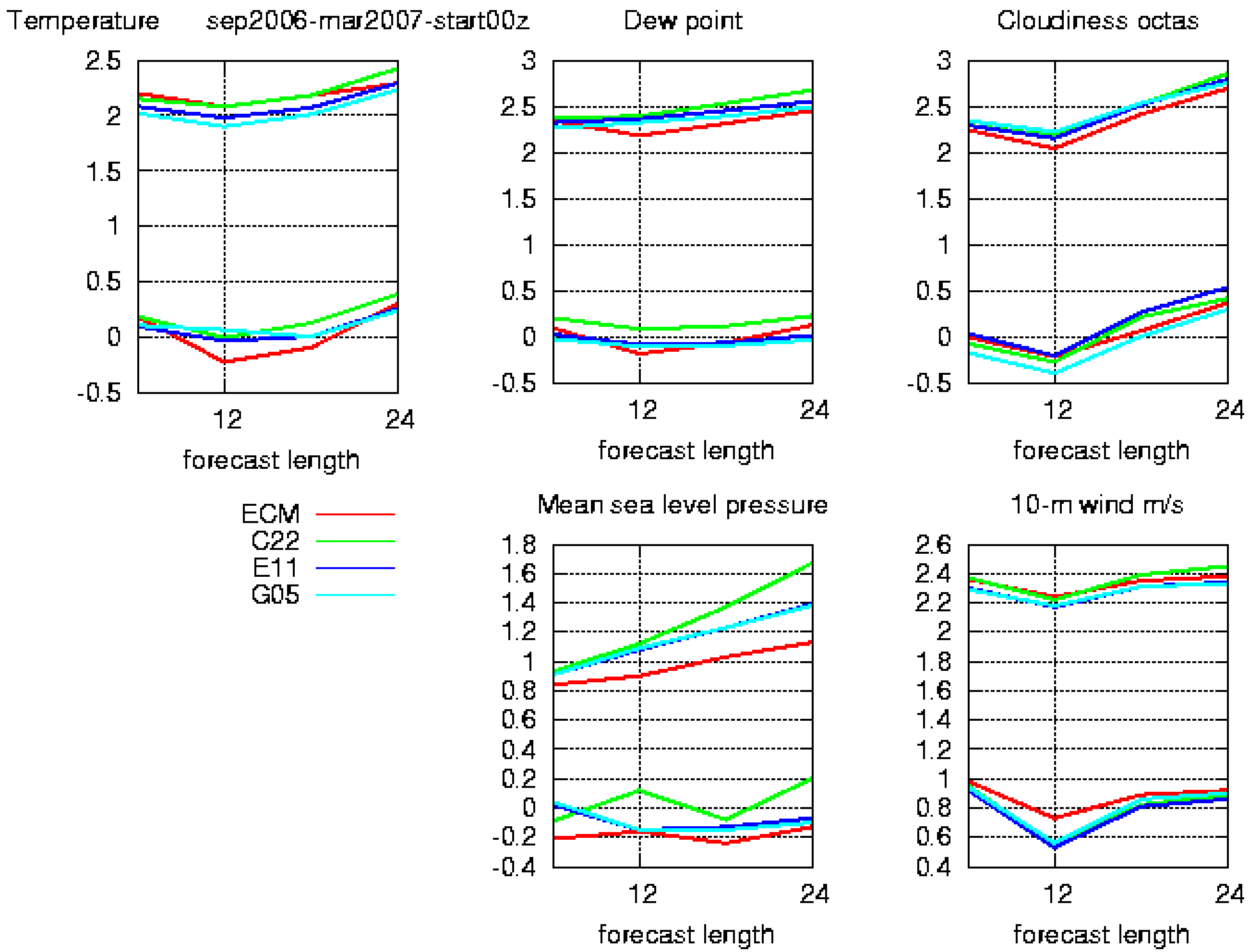
Surface parameters standard deviation summer 2006



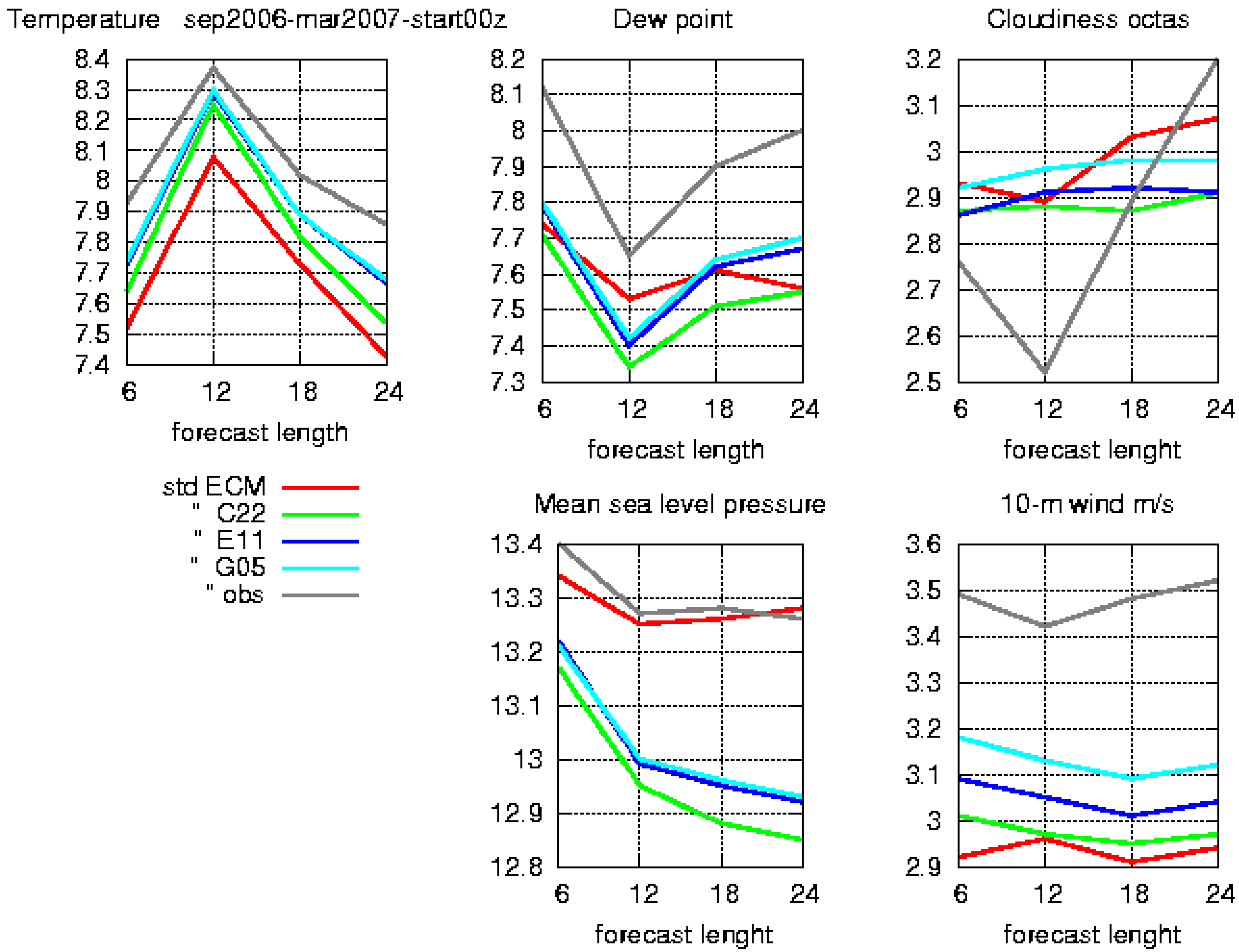
Precipitation Sept. 2006- March 2007



Surface parameters September 2006-March 2007



Standard deviation of Surface parameters September 2006-March 2007



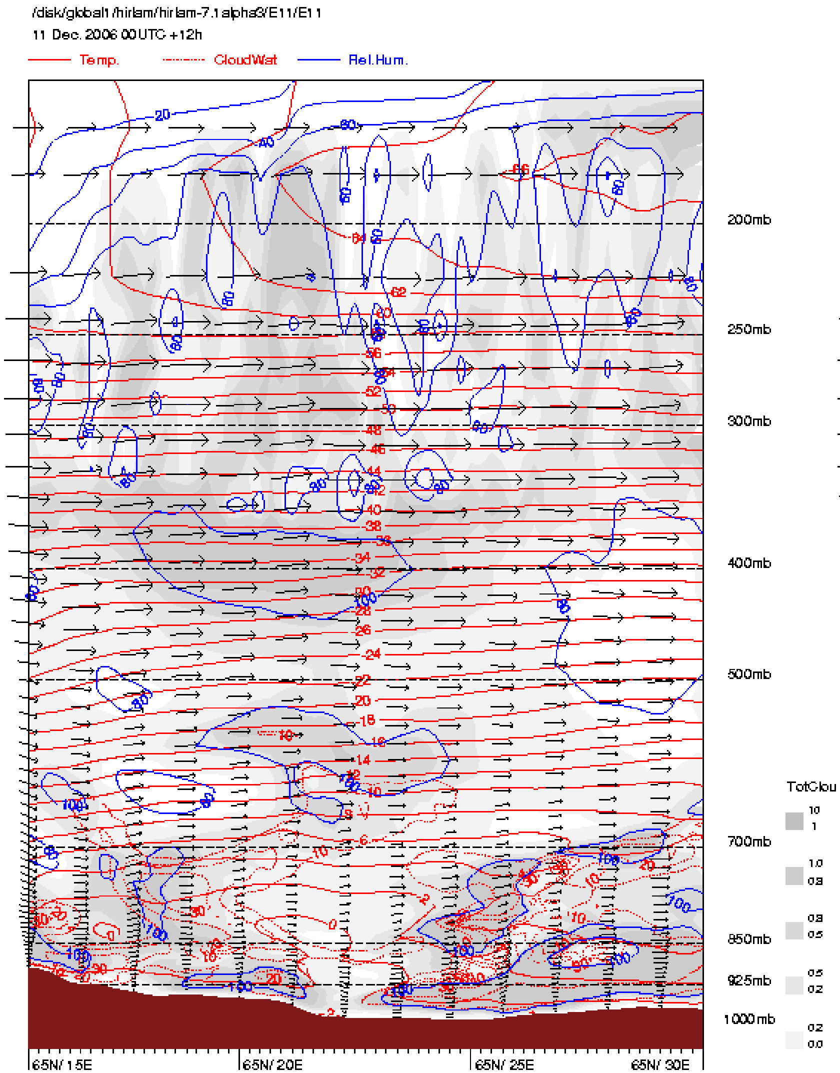
Tests with a new version of Rasch-Kristjansson scheme

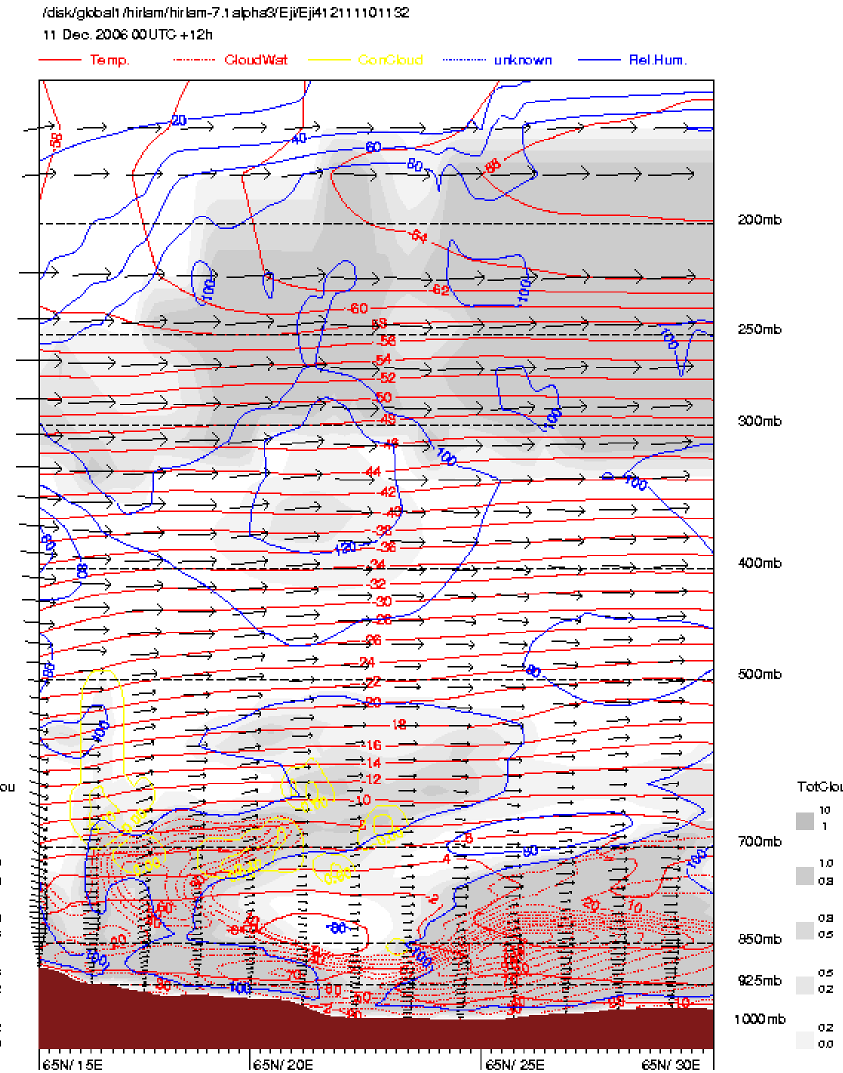
- Based on Zhang et al (2002)
- Sedimentation of cloud condensate
- Cirrus super saturation (Kärcher,Lohmann,2002)
- Prognostic cloud ice calculation (fraction of ice not only temperature dependent)
- Different parameterizations can be put on or off by using options (koption(n))

Why this new scheme?

- Try to solve the remaining problems:
- Small amount of precipitation too frequent
- Noisy cirrus cloud field in case of strong jets
- A little too much low clouds in very cold weather.
- Generally improve forecast quality by improved parameterizations :
- Better description of the life-cycle of mixed-phase clouds.
- Possible to forecast Ice super-saturation in cold conditions. (near tropopause)
- Noise reduction by filtering out “bad” tendencies. (tendencies towards negative cloud water amount or drier air but considerably increase of cloud water)

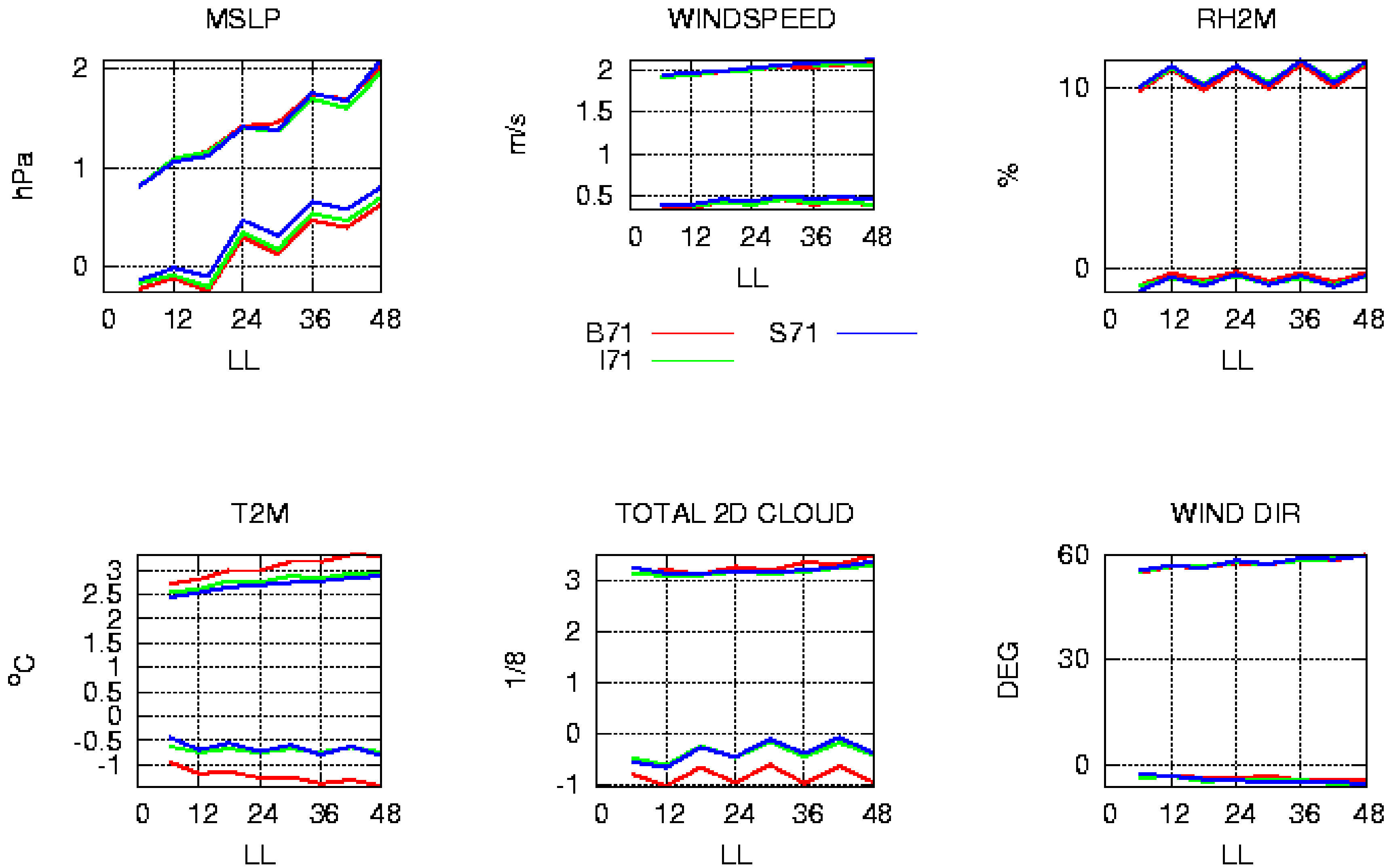
Present (left) Cam3, with ice super saturation (right) RK-scheme



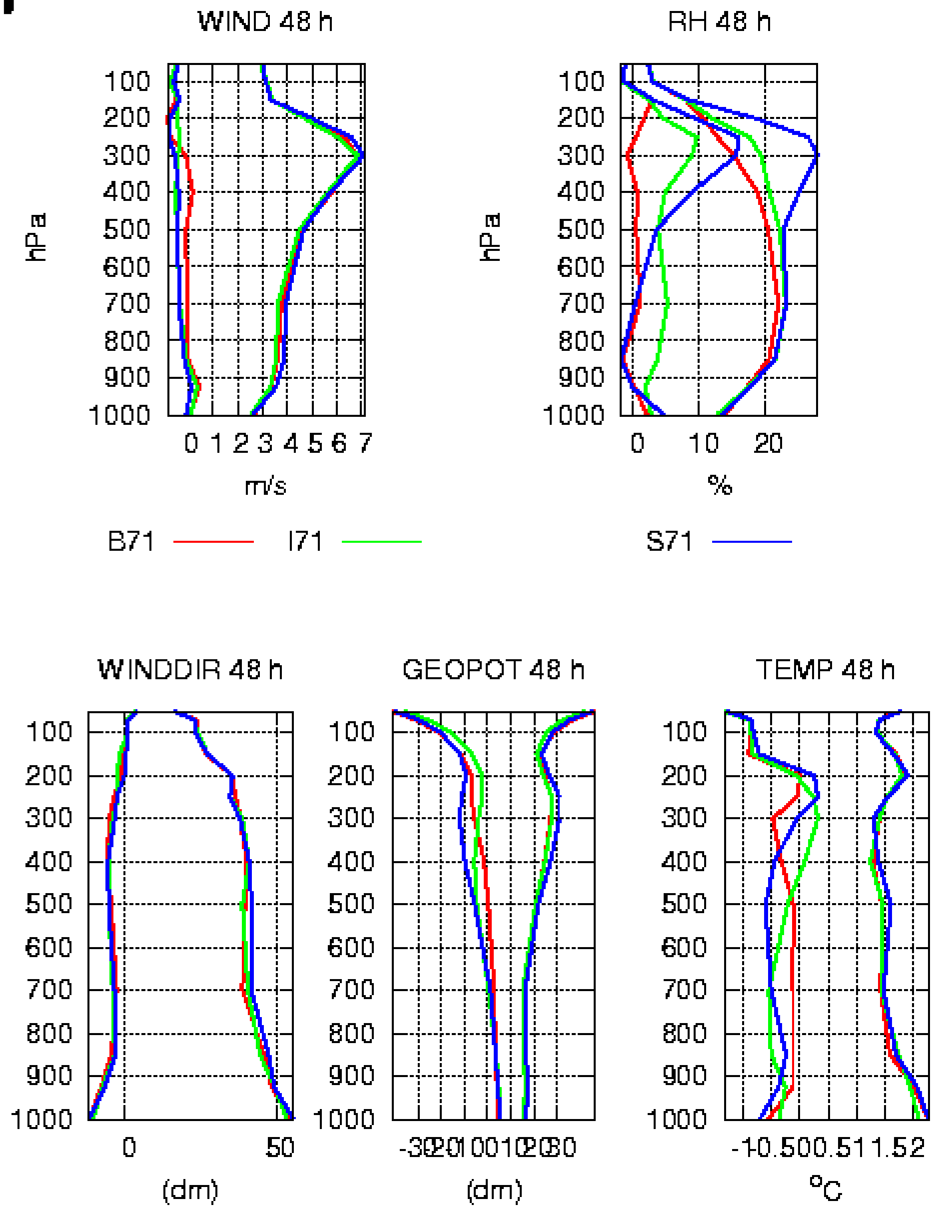


Jan. 4-15 2006

B71 = Kfrk ref.,S71 = straco ref ,I71= Kf-rk CAM3, supersaturation,sedimentation,kfeta (no prognostic ice)



Upper air :



WIND 48 h
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B71
I71
S71
WINDDIR 48 h
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50
(dm)
GEOPOT 48 h
(dm)
TEMP 48 h
°C

Use of separate prognostic treatment of cloud water and ice.

(Originally presented at the workshop on convection and cloud-micro physics at Tartu university, Estonia January 24-26 2005)

possible advantages :

- Simulate the life cycle of mixed-phase clouds
  (Initial supercooled water later ice)
- Better spatial distribution of the cloud field.
- No new clouds before reaching saturation with respect to water
  (down to about -35C)
- Spatial distribution of old clouds more related to
  saturation with respect to ice.
- Better use of detailed micro-physics.
- Modular : Conversion cloud water to ice in one small subroutine
  -portable to other condensation schemes.
- Option based: On may put it on or off just bye changing “koption” values.

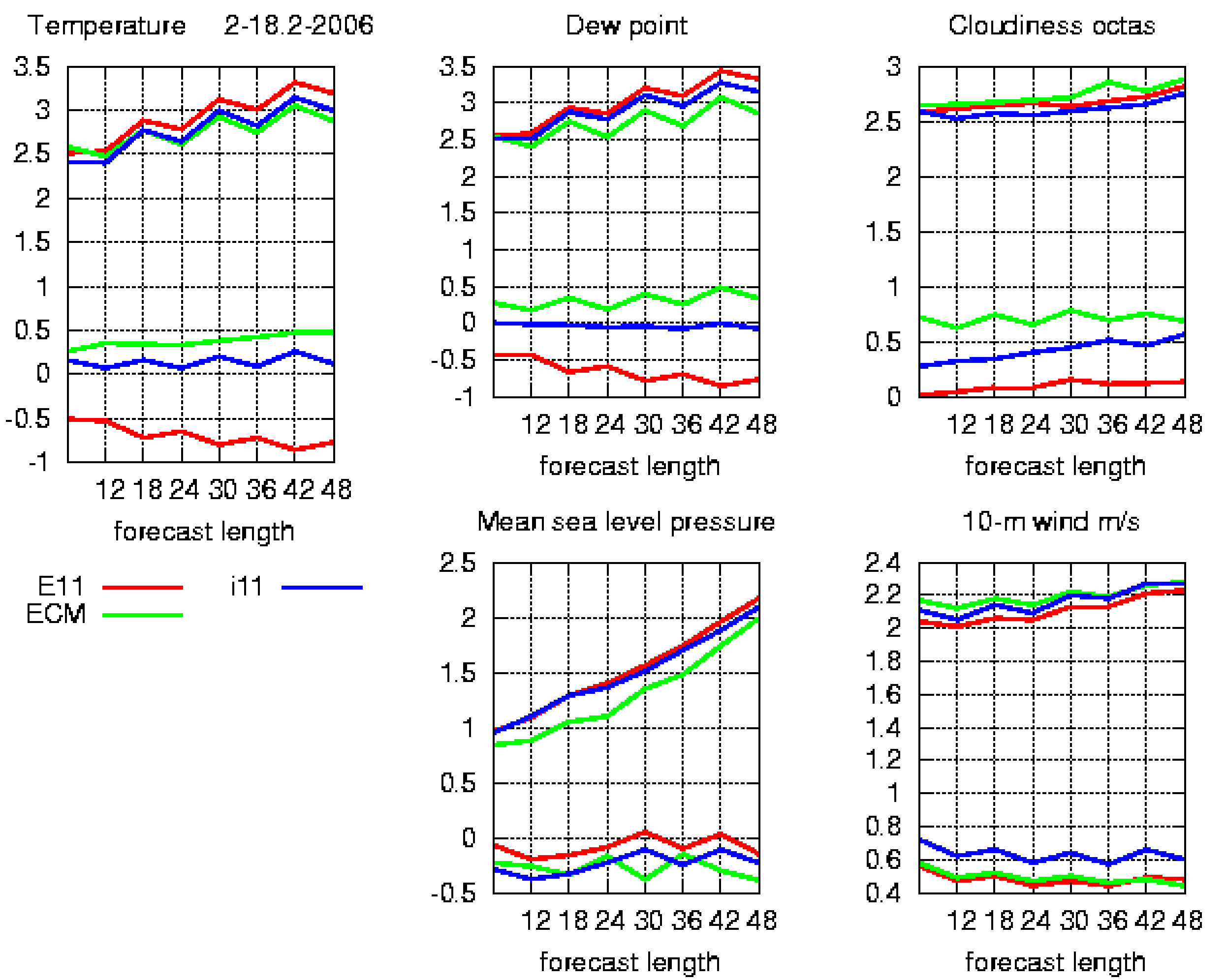
possible disadvantages :

- More expensive to run.
- Larger output files.
- Risk of numerical noise.

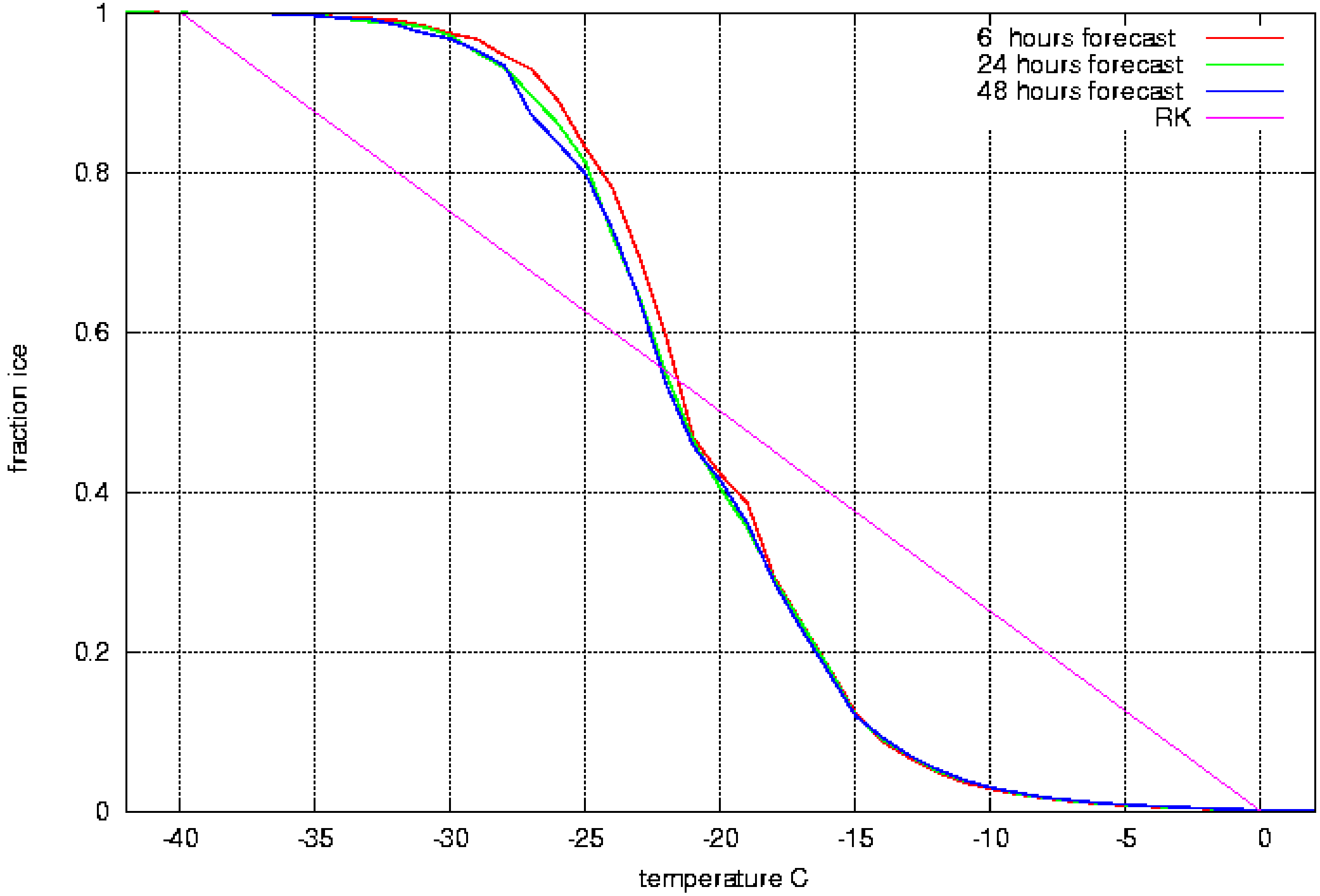
Status

- Works fairly well with older version (6.3.5,6.4.0)
- Problems with old surface scheme: Not good trying to compensate for errors in surface fluxes by changing critical relative humidity or other tuning parameters.
- Noise (?)
- A change in CBR left to do in 7.1 only.(?)
- Most relevant to test with the new surface scheme also in summer?

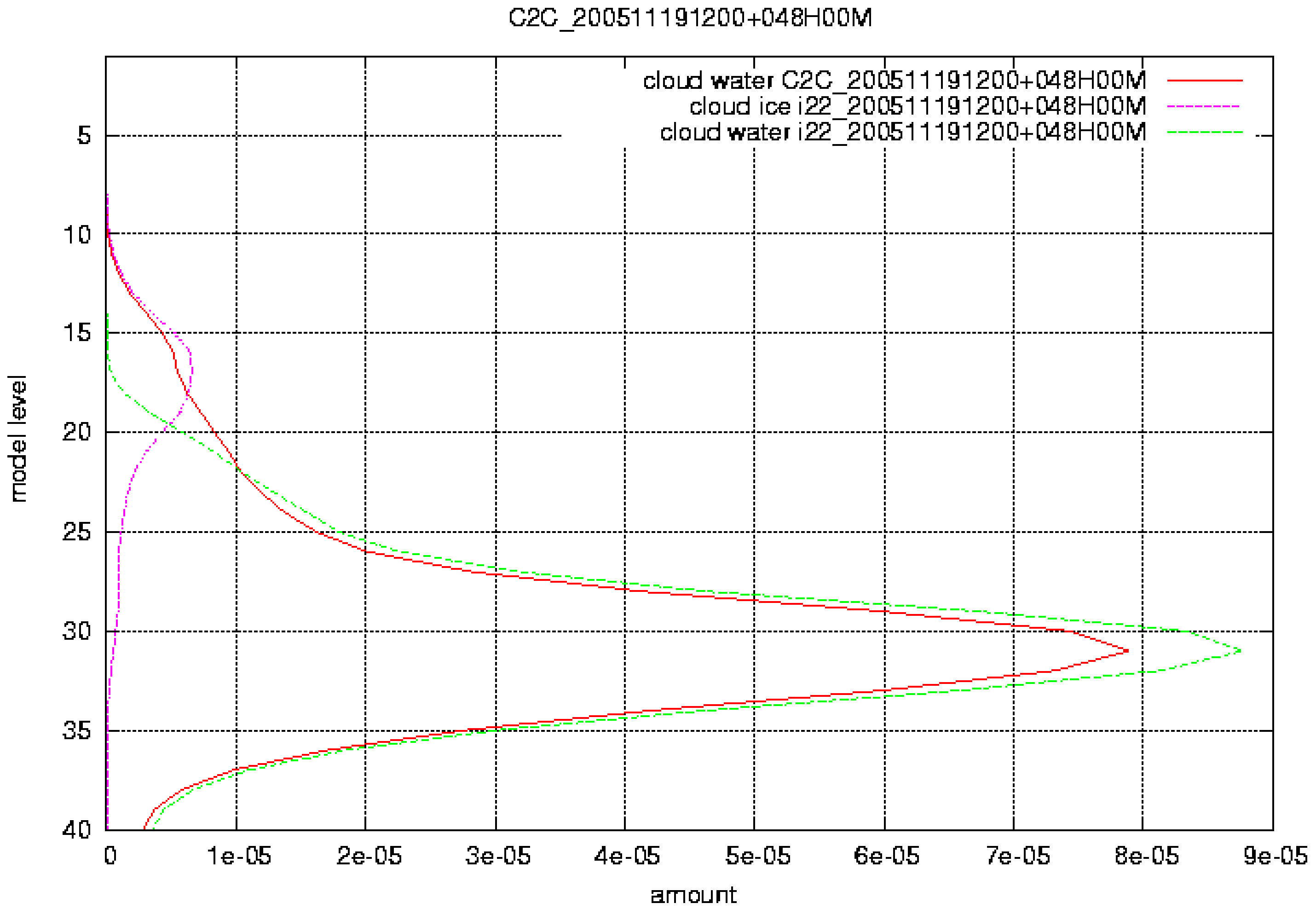
Some results with RK98 and H6.3.5 (11km,60 levels)



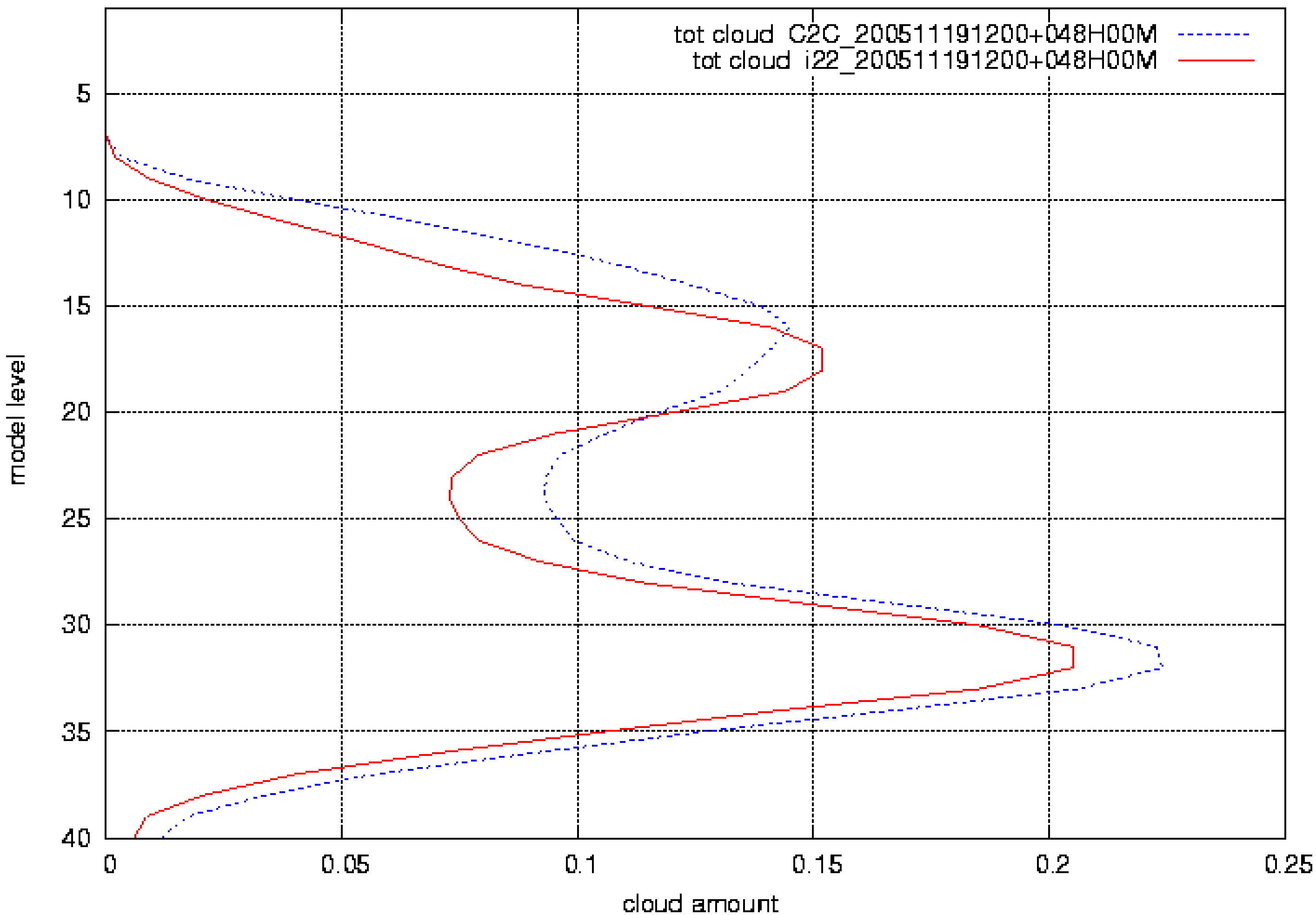
Fraction of ice



Cloud condensate at different levels (22 km , 40 levels Nov 9-19 2005



Cloud fraction (22 km 40 levels Nov 9-11 2005)



Conclusions

- Current RK scheme seems to work fairly well, but may be improved by CAM3 physics and some extensions as...
- Noise reduction by filtering tendencies
- Prognostic cloud ice
- New CAM3 version seems to fit better with new surface scheme (?)

References

- Rotstayn et al (2000): A Scheme for calculation of the liquid fraction in mixed-phase stratiform clouds in large scale models. Monthly weather review, p 1070-1088
- Meyers et al (1992): New primary ice-nucleation parameterization in an explicit cloud model. J. Appl. Meteor. 31 708-721
- Hsie et al (1980): Numerical simulation of ice-phase convective cloud seeding. J. Appl. Meteor. 19 1950-1977
- Lin et al (1983): Bulk parameterization of the snow field in a cloud model. J. of appl. Meteor. 22 1065-1092
- Miller and Young (1979): A numerical simulation of ice crystal growth from the vapor phase. J.A:S. 36 458-469
- Zhang et al: A modified formulation of fractional stratiform condensation rate in the NCAR Community atmospheric model J. Geophys. Res. 108(D1) 2003
- Rasch and Kristjansson : A comparison of the CCM3 model climate using diagnosed and predicted condensate parameterizations , J. Clim. 11 1587-1614 1998.
- Kärcher and Lohman 2002: A parmeterization of cirrus cloud formation: Homogeneous freezing of supercooled aerosols J. Geophys. Res. 107

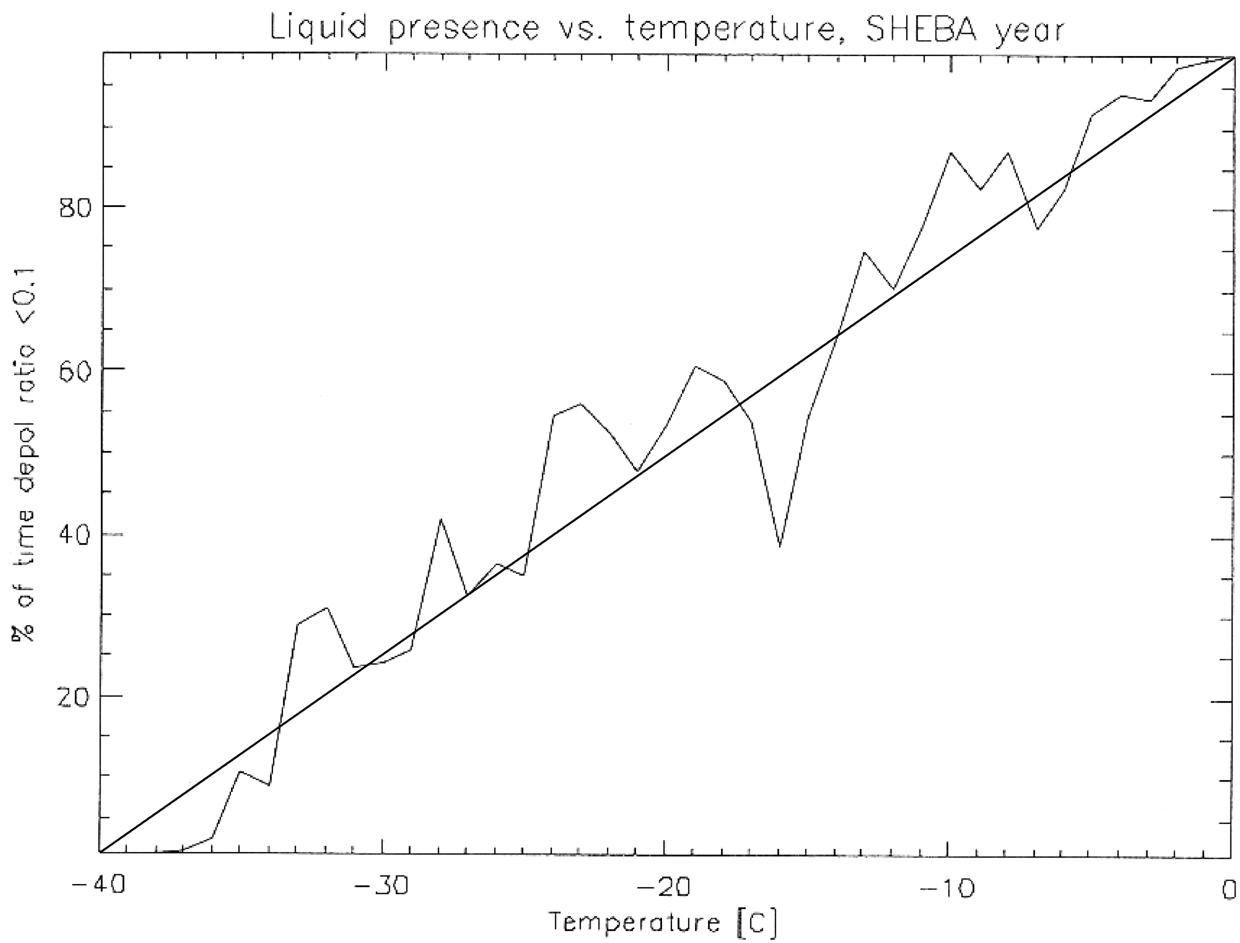
Extra ...

Some scientific/modelling questions

- What is cloud condensate and what is
- precipitation ?
- definition ?
- precipitation:
- - no horizontal advection in large scale models
- - falling down within each timestep
- - solid precipitation may exist for some time
- if T > 0 C
- cloud water and cloud ice :
- - often advected in models
- - no falling speed
- - cloud ice melts immediately if T > 0 C. (?)
-
- * What is known about the distribution of cloud ice
- and cloud water ?
- dependency of ...
- Temperature ? cloud type ? Part of the cloud ?

Janet Intrieri (2003)

This relation between the fraction of cloud-ice and temperature found here is used in current RK-scheme. (black line)



K.N. Bower el al. (1996)

For convective clouds, high amounts of cloudwater is found also for low temperatures. Since also larger iceparticles, than typicall for cloud ice are included, the relative amount of cloudwater may be even higher.

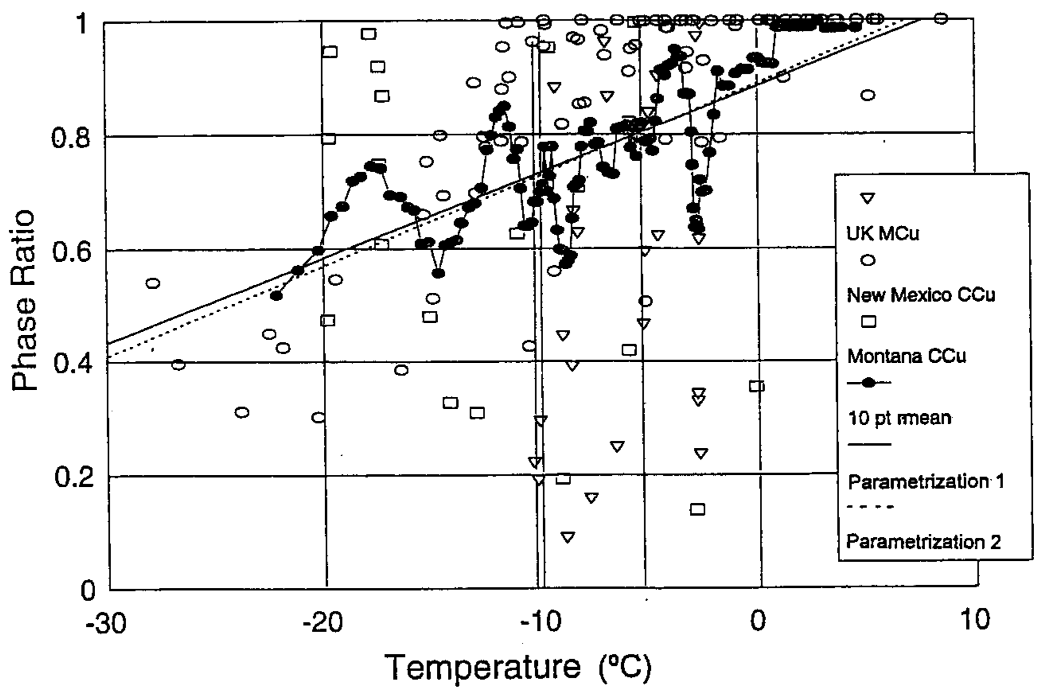


Figure 9. Combined plot of the pass-averaged phase-ratio values (the proportion of water to ice and water by mass) versus temperature for the convective clouds of New Mexico (circles), Montana (CCOPE) (squares) and the UK maritime cumulus clouds (triangles). Also shown is a ten-point running mean ratio (solid circles), and the best-fit lines (see text) to the running mean data (curve 1) and standard pass-averaged data (curve 2).

K.N. Bower el al. (1996)

For nimbostratus, high amounts of cloudice is found also for temperatures near 0 C. Also here, large iceparticles are included and the fraction cloudice content is assumed to be lower than the ice-water-content.

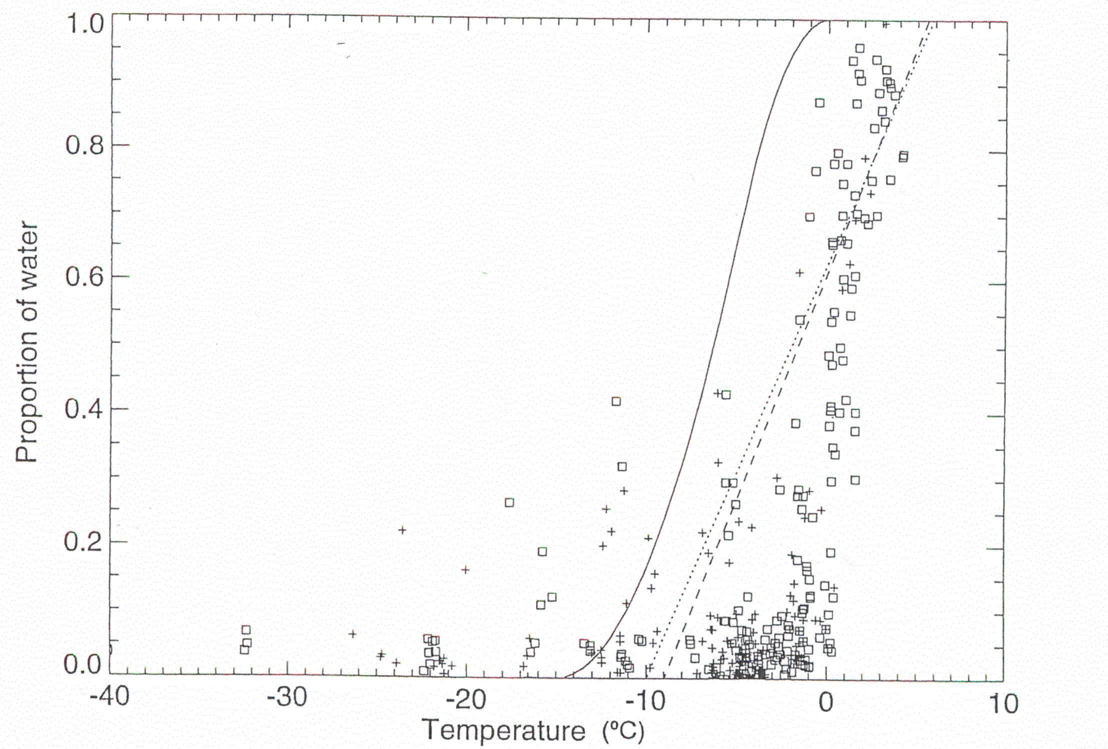
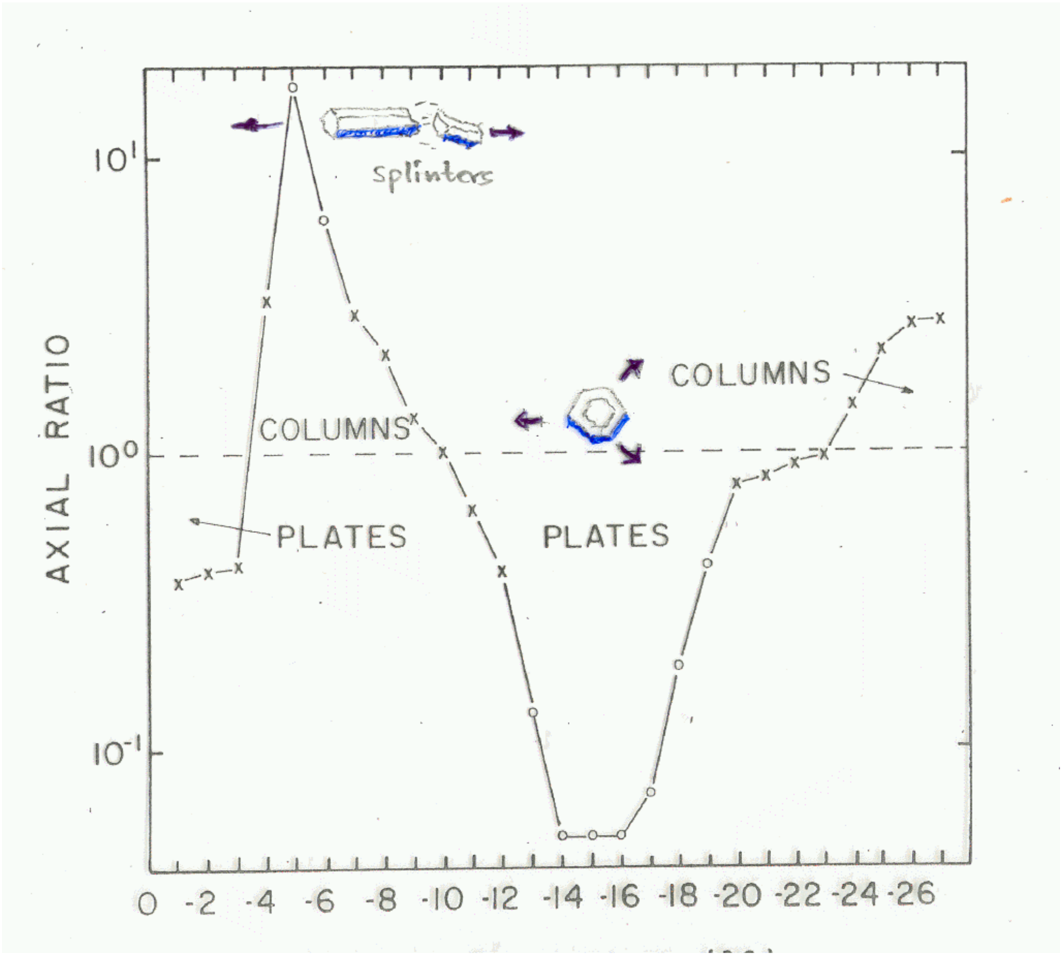


Figure 8. The phase ratio (the proportion of water to ice and water by mass) in cloud against temperature from the 11 frontal flights in Table 1. Each point represents the average value over a 2-minute horizontal leg in cloud. Crosses indicate clouds in continental airmasses and squares clouds in maritime airmasses. The dotted line is the best-fit line to the data for continental clouds and the dashed line for maritime clouds. The solid line is the current parametrization in the UK Meteorological Office atmospheric global-climate model.

Crystal habits

The growth of ice crystals is faster near -5C and -15C due to the shape of the ice crystals. Splinters may increse the number of ice crystals near -6C and to some extent also near -15C.



Crystal growth

Example of observed and simulated crystal growth. (Miller and Young, 1979)

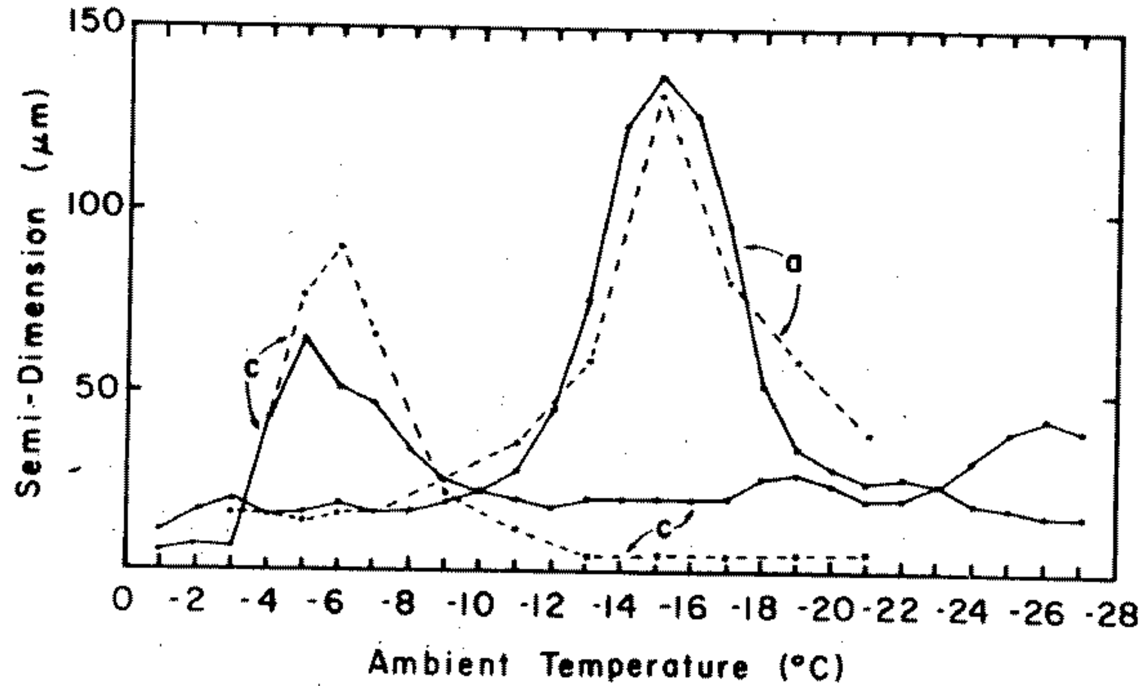


Fig. 6. Predicted crystal semi-dimensions after 120 s of growth at water saturation (solid lines). These are compared with those observed by Ryan *et al.* (1976), shown by the dashed lines.

Ice nucleus concentration (Rotstayn,2000)

The one proposed by Meyers (1992) is used in the experiment. Notice the large differences between the proposed concentrations.

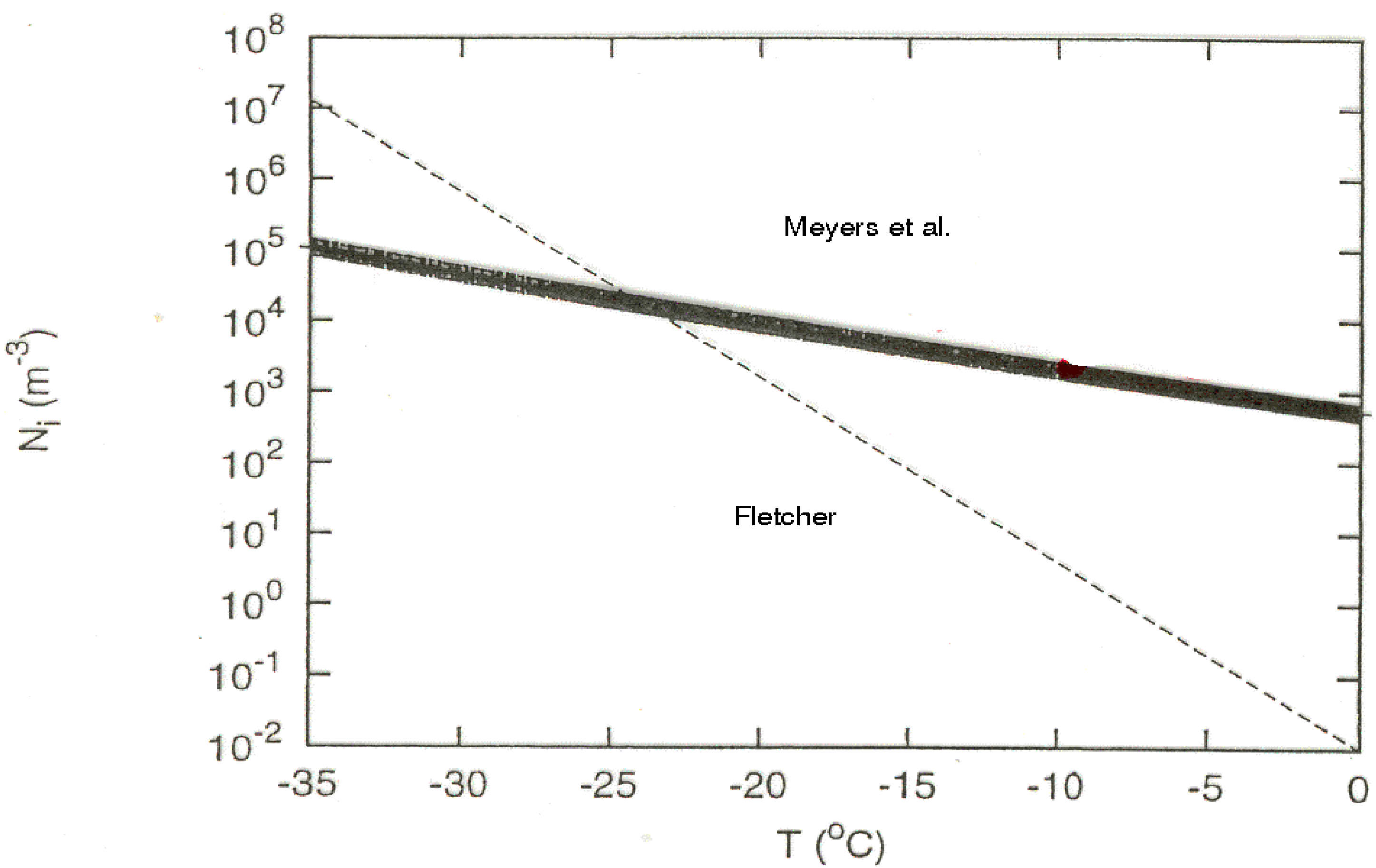
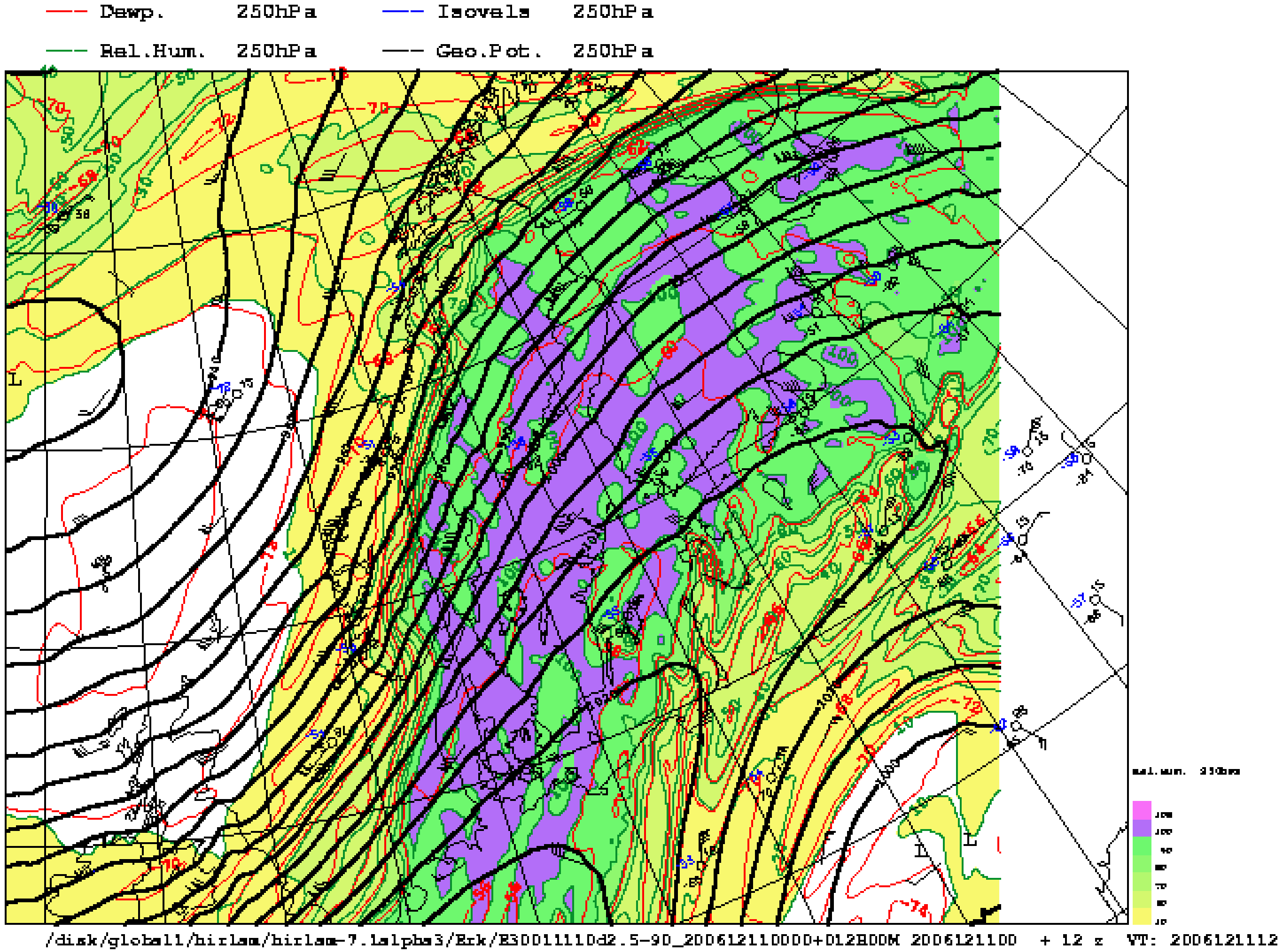
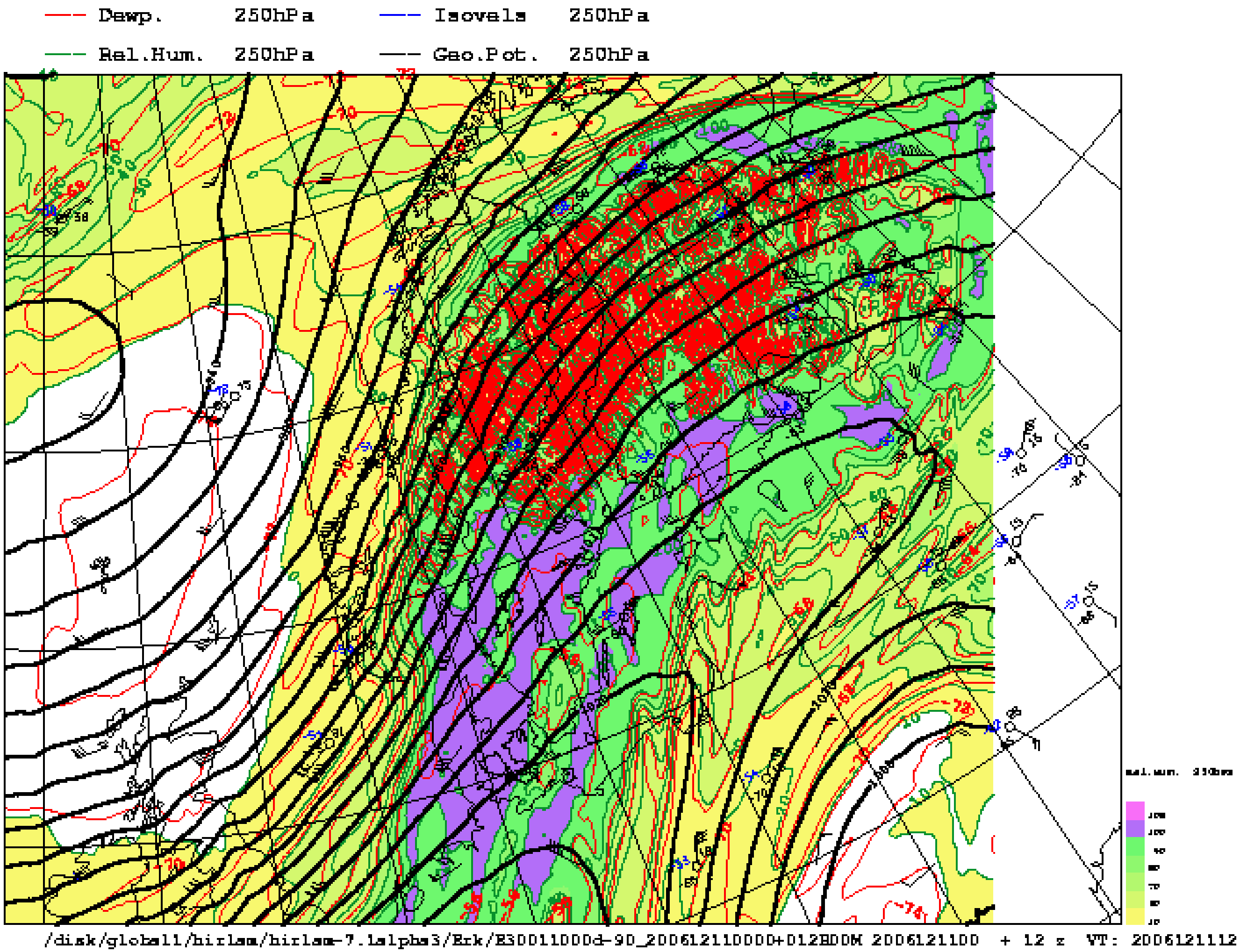


FIG. 3. Variation with temperature of the ice crystal number concentration given by (9) (thick line) and (10) (dashed line).

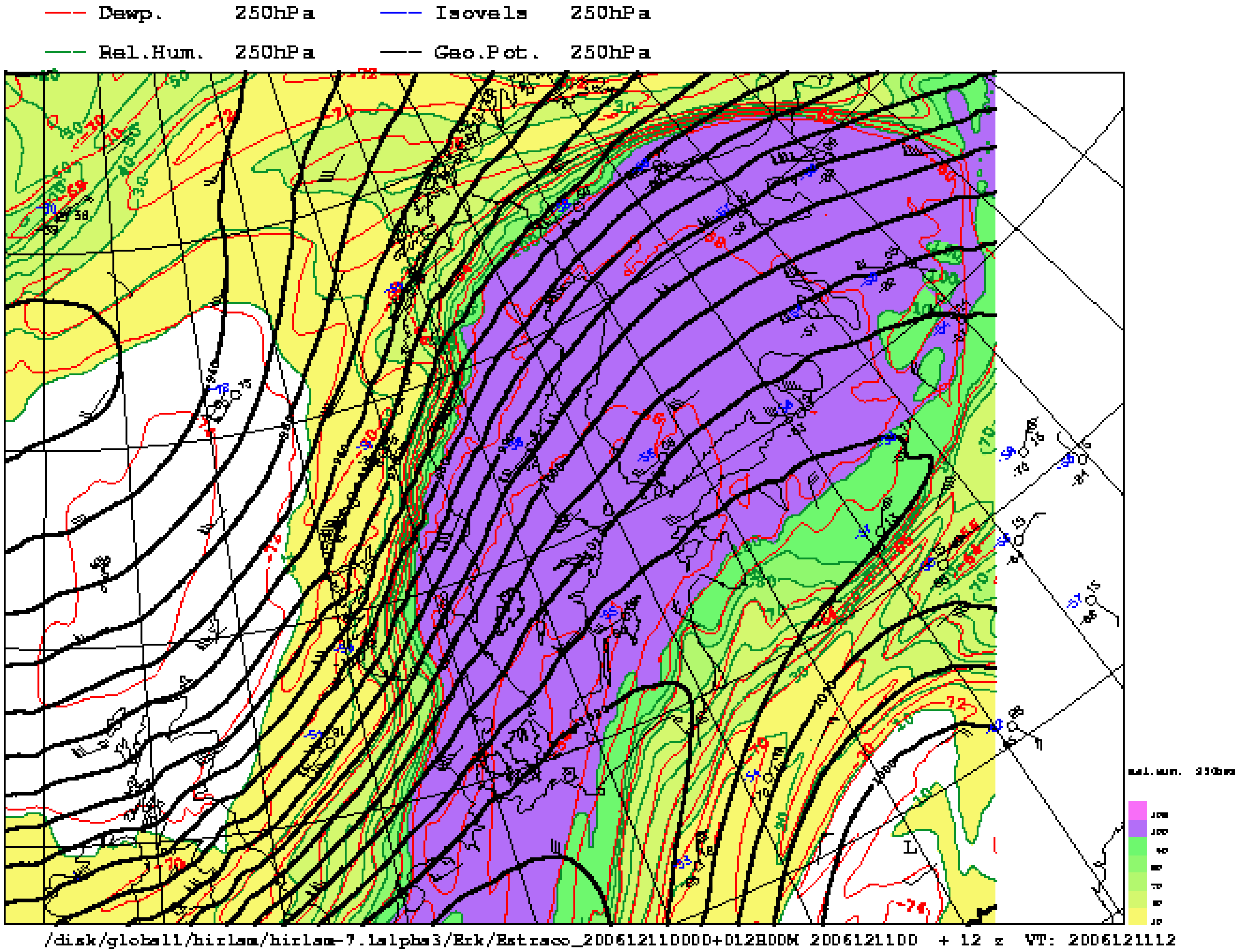
Experimental code (CAM3 RK-scheme +WRF-Kain-Fritsch) 2.5 min time step



Experimental code (CAM3 RK-scheme +WRF-Kain-Fritsch) 5 min time step



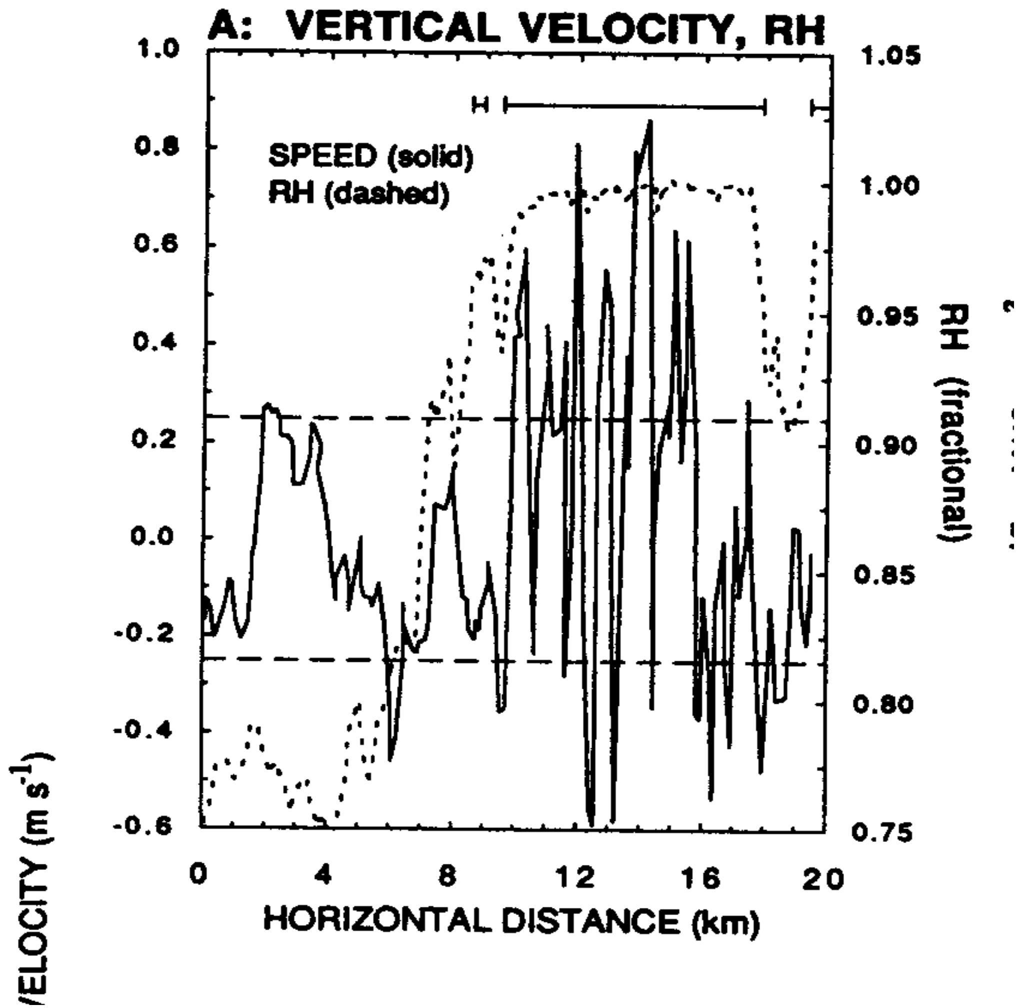
Straco 5 min time step



“Noise” always bad ?

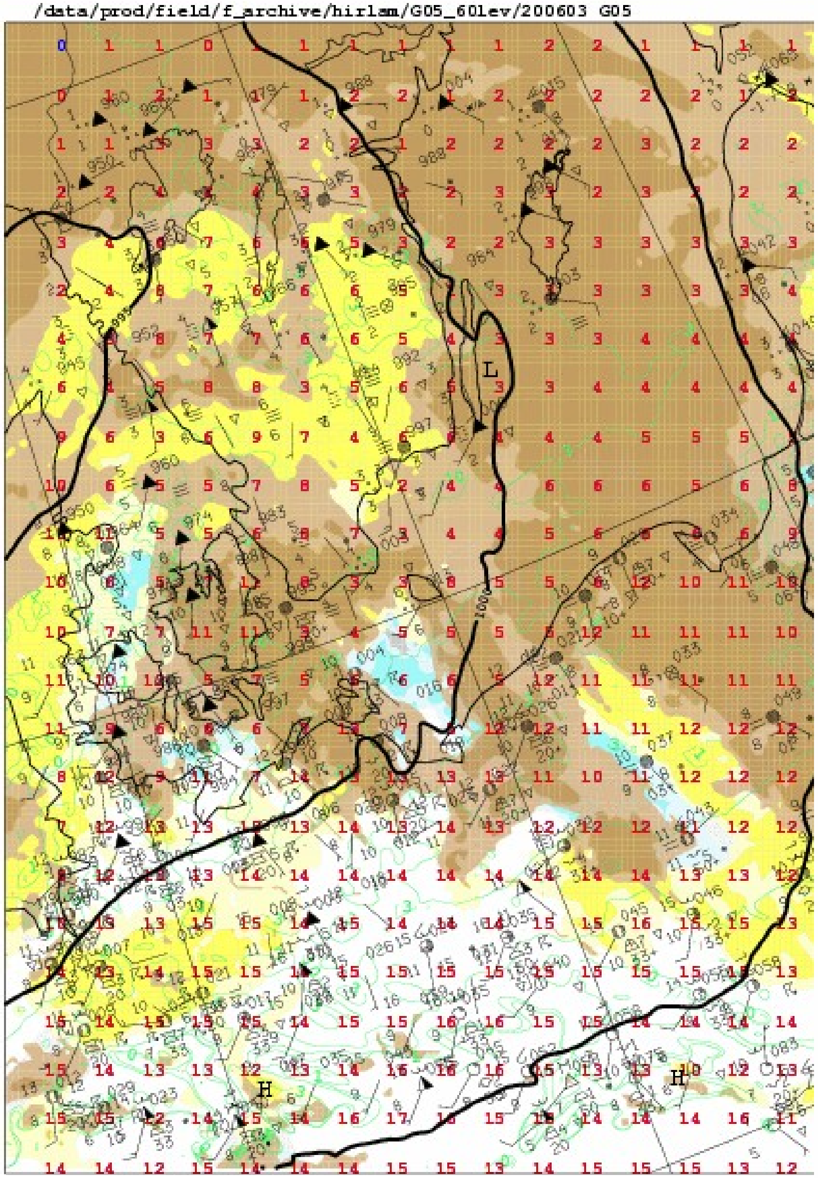
1 APRIL 1991

HEYMSFIE



Example of heavy convection Mars 27 2006.

- About 40mm rain / 12 h forecasted (11km/5.5km) over Bornholm , about 10mm reported (Less amount in the 22km run)
- Tornadoes reported over northern Germany, 20 mm/ 12h observed.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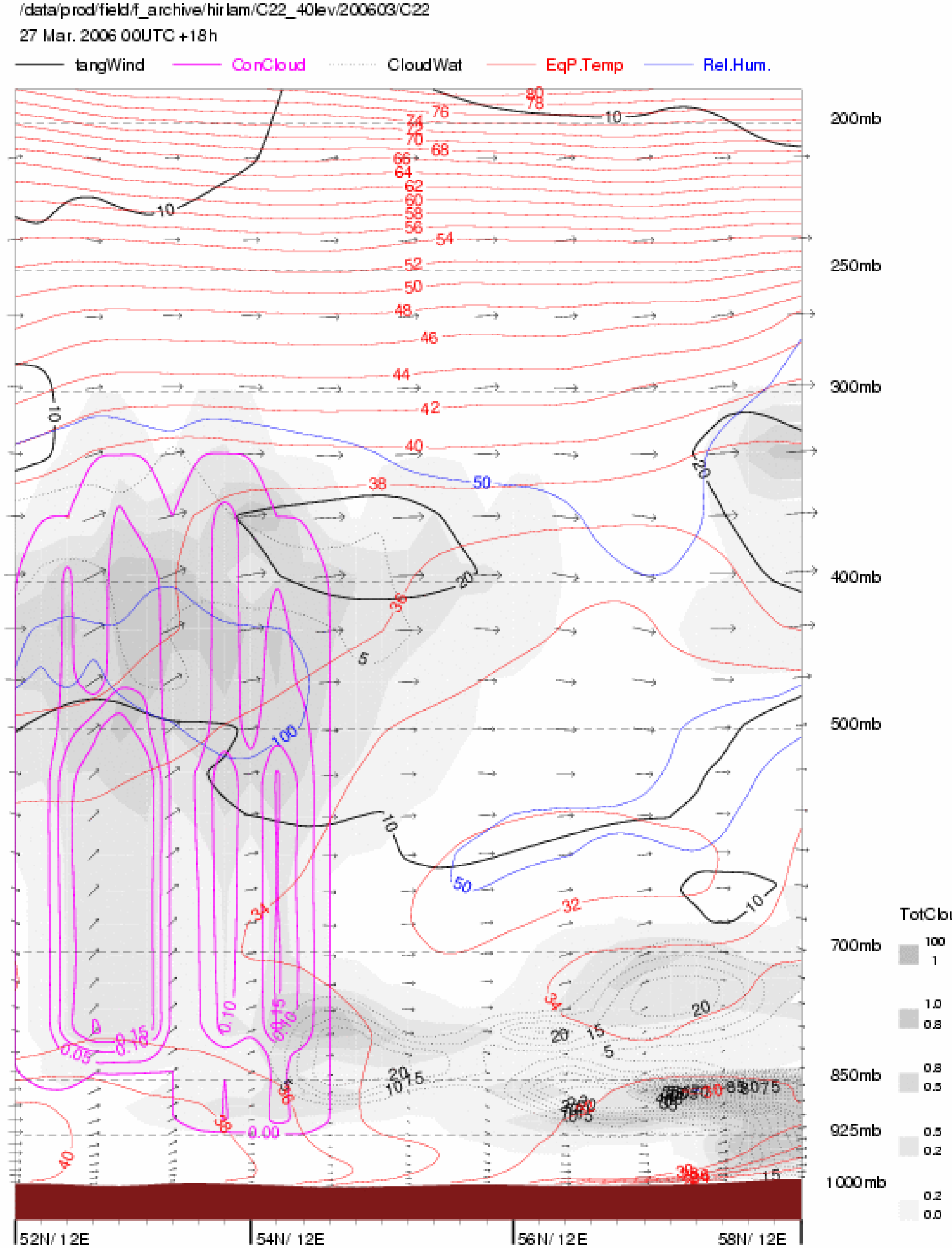
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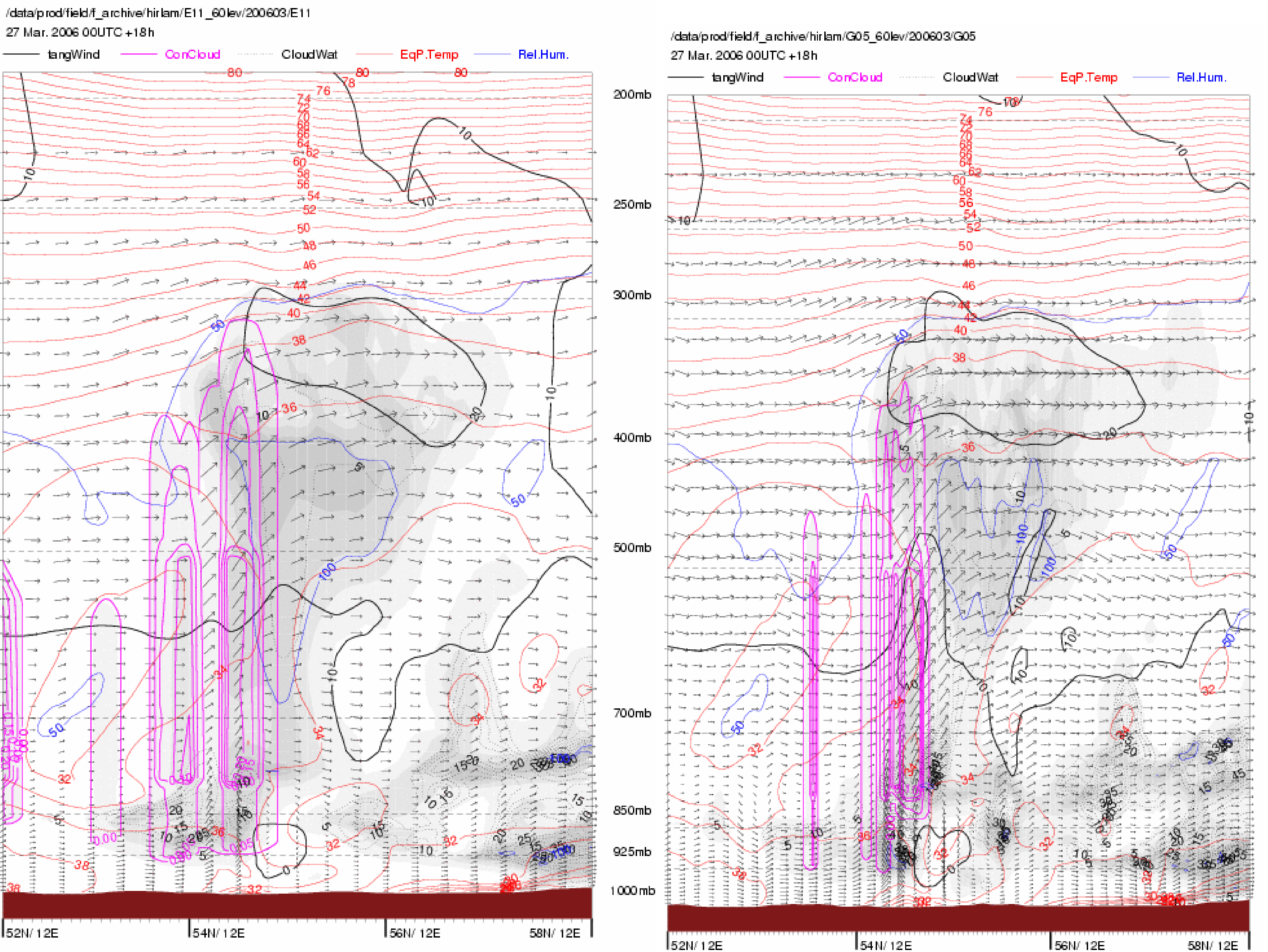
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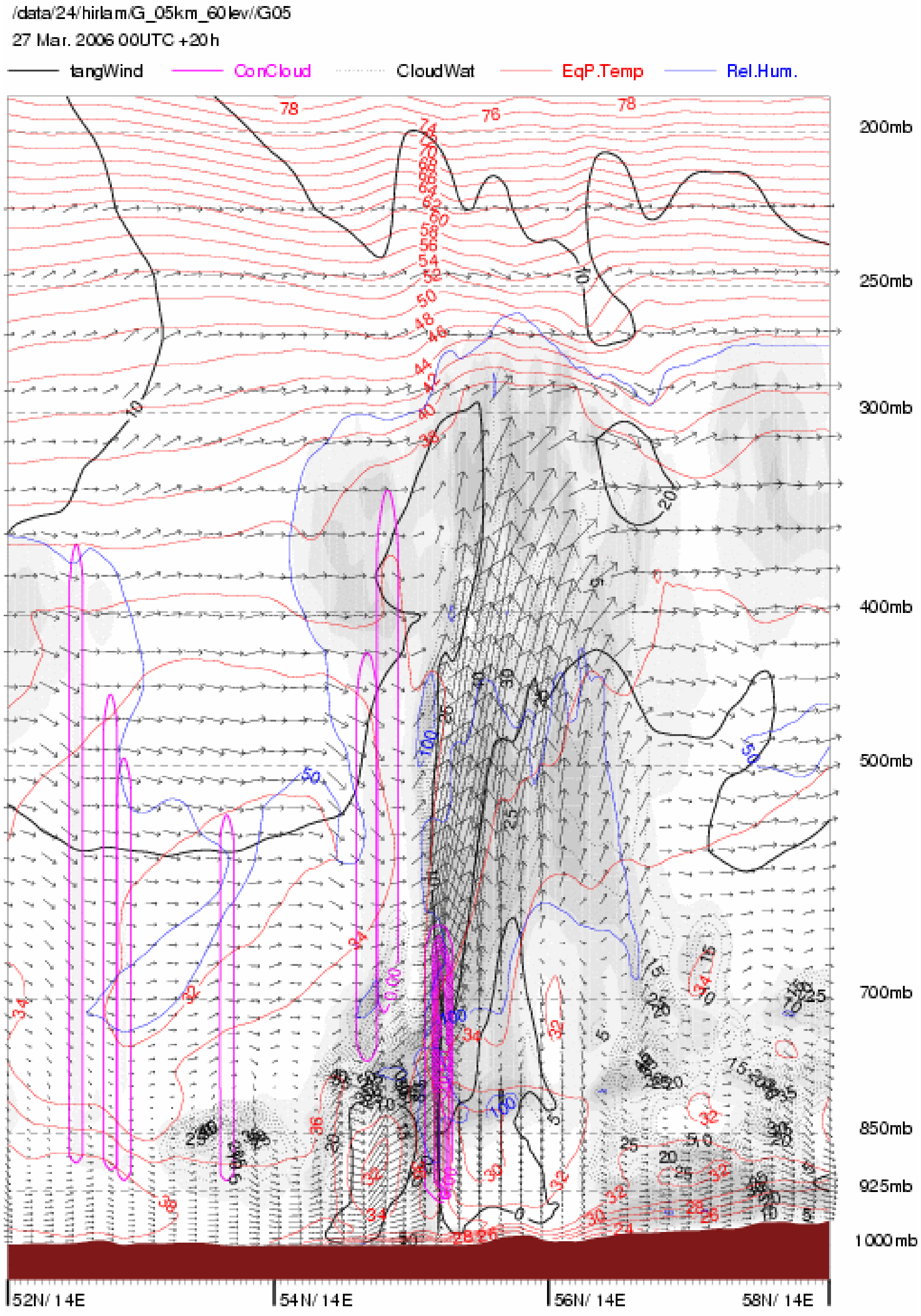
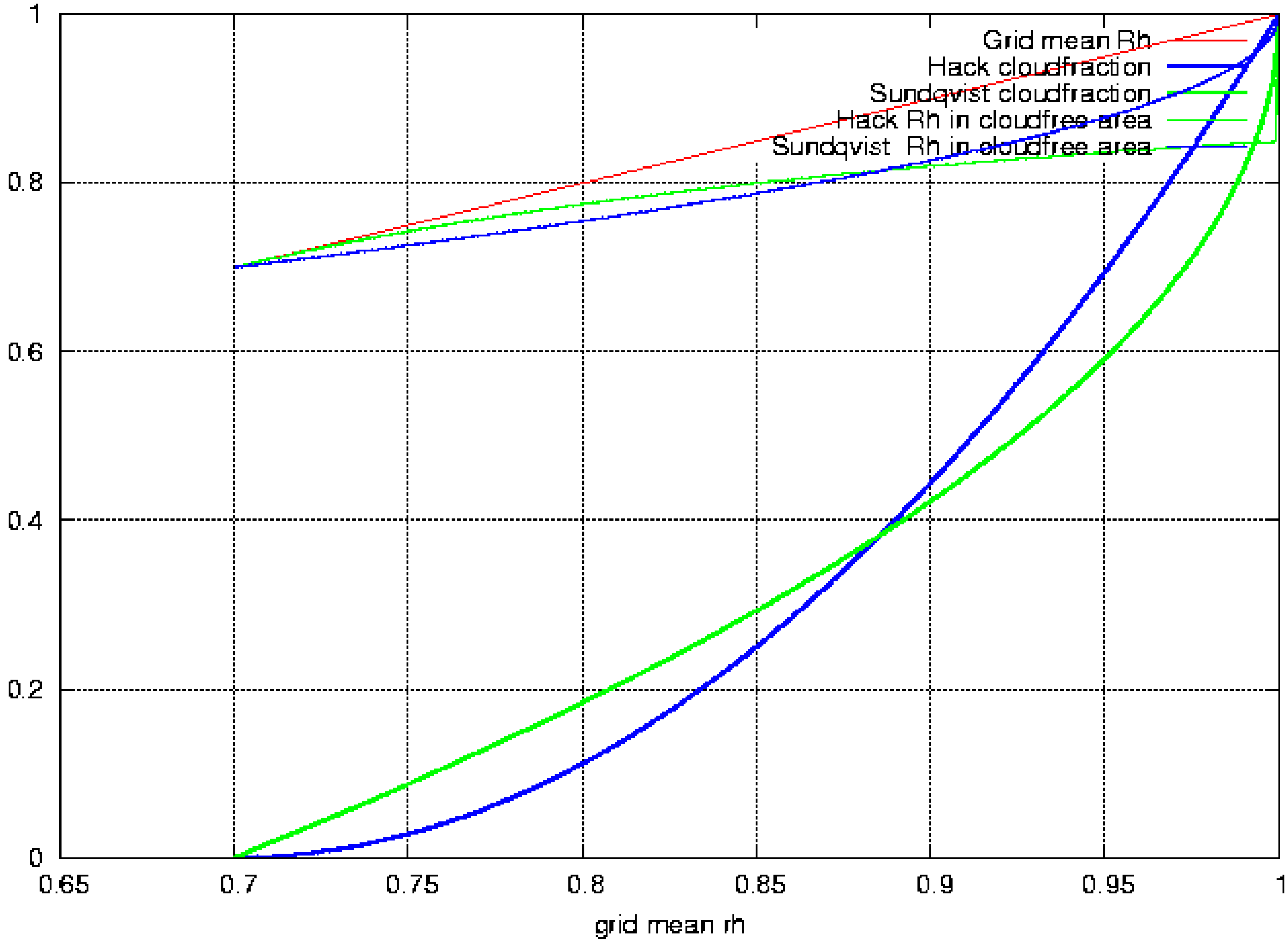


2hours later in the forecast

Hack or Sundqvist cloud cover ?



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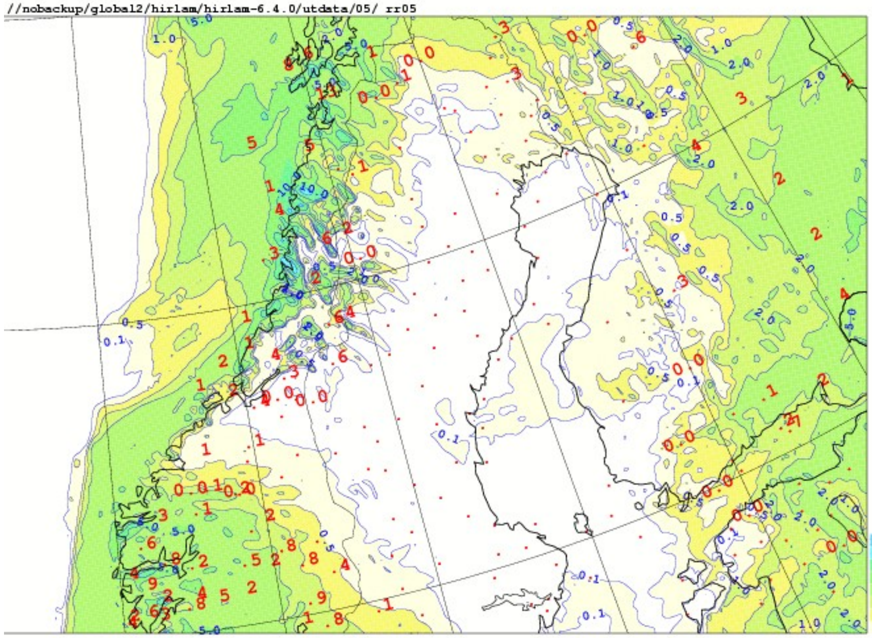

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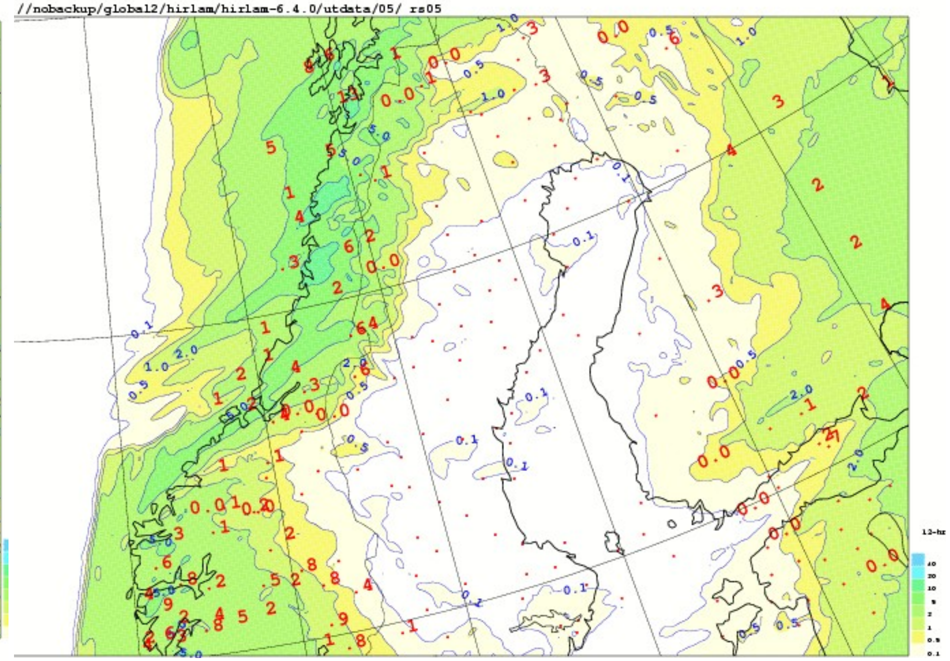

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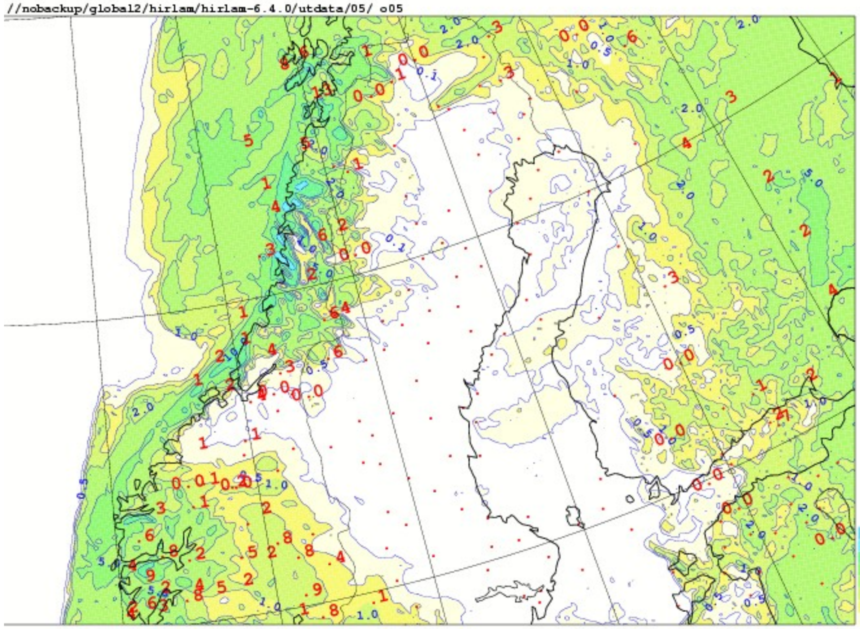

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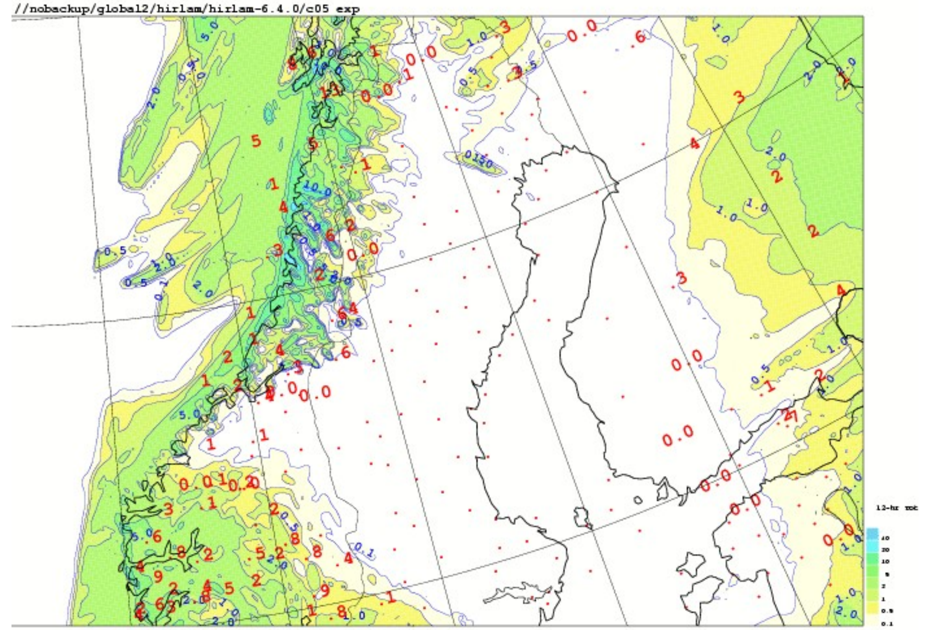

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1 New maximum-random overlap

May be everywhere between pure maximum overlap and pure random dependent on r

$$c_{lev} = c_{rand}(1 - r) + \max(c_{lev-1}, c_{lev})r$$

Here, $c_{rand} = 1 - (1 - c_{lev-1})(1 - c_{lev})$ r is the correlation in case of $c_{lev-1} = c_{lev}$
Exemple: of difference between the old and the new one $r = 0.5$:
Clodiness 0.5 , 0 , 0.5 gives 0.75 with the old algroritm , 0.625 with the new
Clodiness 0.5 , 0.5 , 0.5 gives 0.5 with the old algroritm , 0.656 with the new