# Tests with Liu-Penner ice microphysics in Hirlam

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# In this presentation:

- Short description of Liu-Penner parameterization of cloud ice and the reason for testing it.
- Differences between present Rasch-Kristjansson (RK) scheme and RK-scheme with Liu-Penner parameterization.
- 'Liu-Penner' changes of the radiation scheme.
- Some other updates of Kain Fritsch (KF) convection and of RK-scheme.
- Results of using Liu-Penner parmeterization + updates.
- Discussion and conclusions

# Short description of the Liu-Penner parametrization and the reason for testing it.

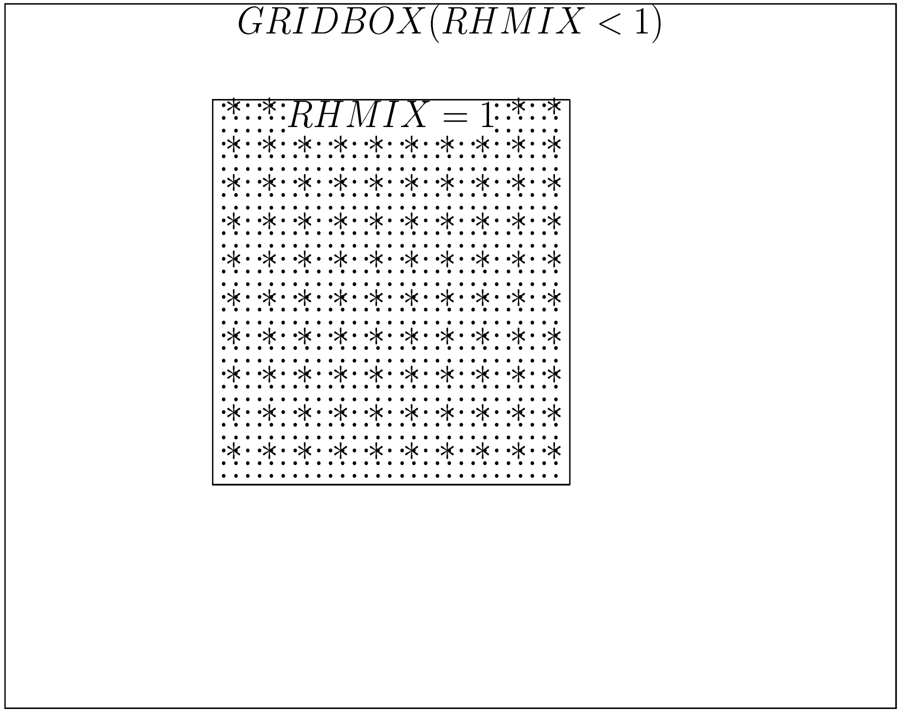
- Makes the parametrization of condensation and radiation for cloud ice processes more realistic, especially for 2-way coupling of chemistry modeling.
- Some parts are already included in the present RK-scheme:
- Prognostic equations of cloud water and -ice instead of a temperature dependent relation.
- The vapor deposition / evaporation for spherical ice crystals as in Rotstayn (2000), solved analytically:

$$\frac{dq_i}{dt} = 0.878 k_s q_i^{\frac{1}{3}} N_i^{\frac{2}{3}} f(T,P)(RH_i - 1)$$

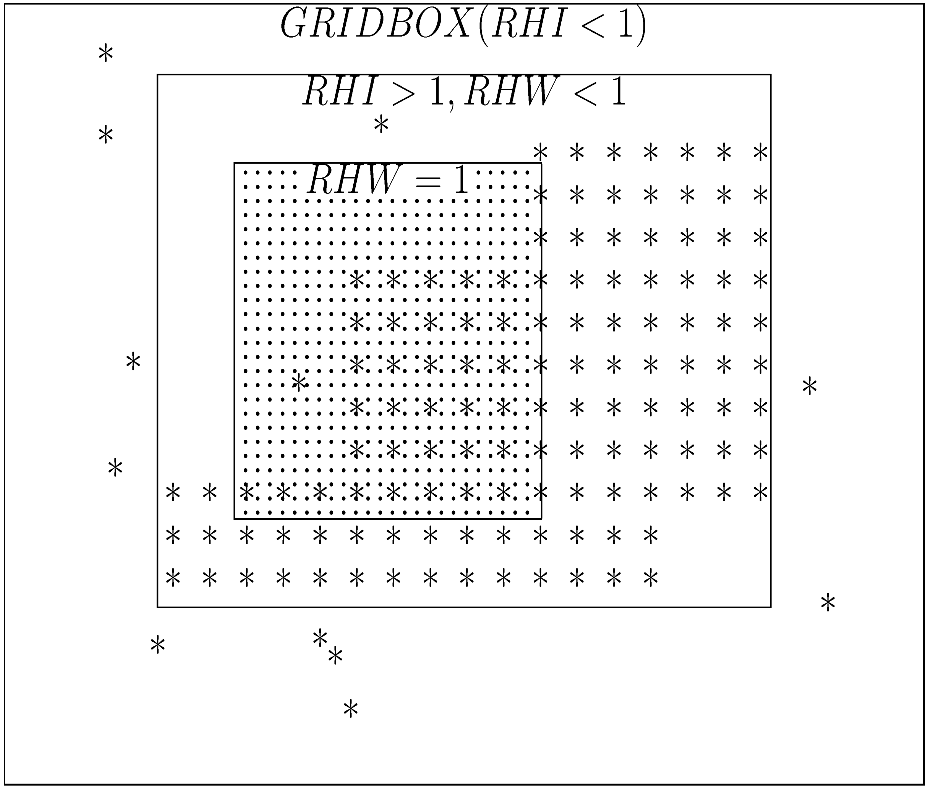
- Here, qi = cloud ice content, ks = temperature and relative humidity dependent crystal shape factor,Ni = ice crystal number concentration, f(T,P) = function dependent on temperature and pressure and RHi = relative humidity (ice).
- Meyers (1992) formulation of the ice nucleus concentration(IN) (mineral dust) :

  IN = K exp(12.96((esw -esi)/esi-0.639), esi= ice saturation pressure, esw = water s.p.

- New things from Liu-Penner (LP) parametrization:
- The CAM3 (Zhang et al ,2003) parametrization of cloud condensate is used for water only, instead of for both water and ice. The ice crystal growth equation is used for for conversion ice-vapor instead of ice-water, and thus replaces CAM3 parametrization of cloud condensate for ice.
- An important reason for splitting the two condensation processes is that the time-scale of cloud ice to reach some equilibrium with the environment is normally much larger (~ a few minutes to several hours) than for cloud water. ( order of a few seconds)
- The cloud fraction is a sum of one pure cloud-ice part based on relative humidity with respect to ice and cloud water part based on relative humidity with respect to water. The ice part of cloud fraction is also dependent on the cloud ice content. (The present cloud cover calculation is based on a mixed ice-water relative humidity, dependent on the cloud ice+water content)
- Modifications of IN concentration ( height dependence included)
- Not included:  prognostic formulations (including advection) for CCN and IN. Instead they are dependent on location and of height.




*The two different sub-grib parts in the original parameterization. * means cloud ice and . means cloud water*




*The three different sub-grib parts in the LP-parameterization.*

$$A_{mix} = \max(0, 1 - \sqrt{1 - \frac{RHMIX - RHLIM}{1 - RHLIM}})$$

$$RHMIX = f(q_i, q_w, T)$$

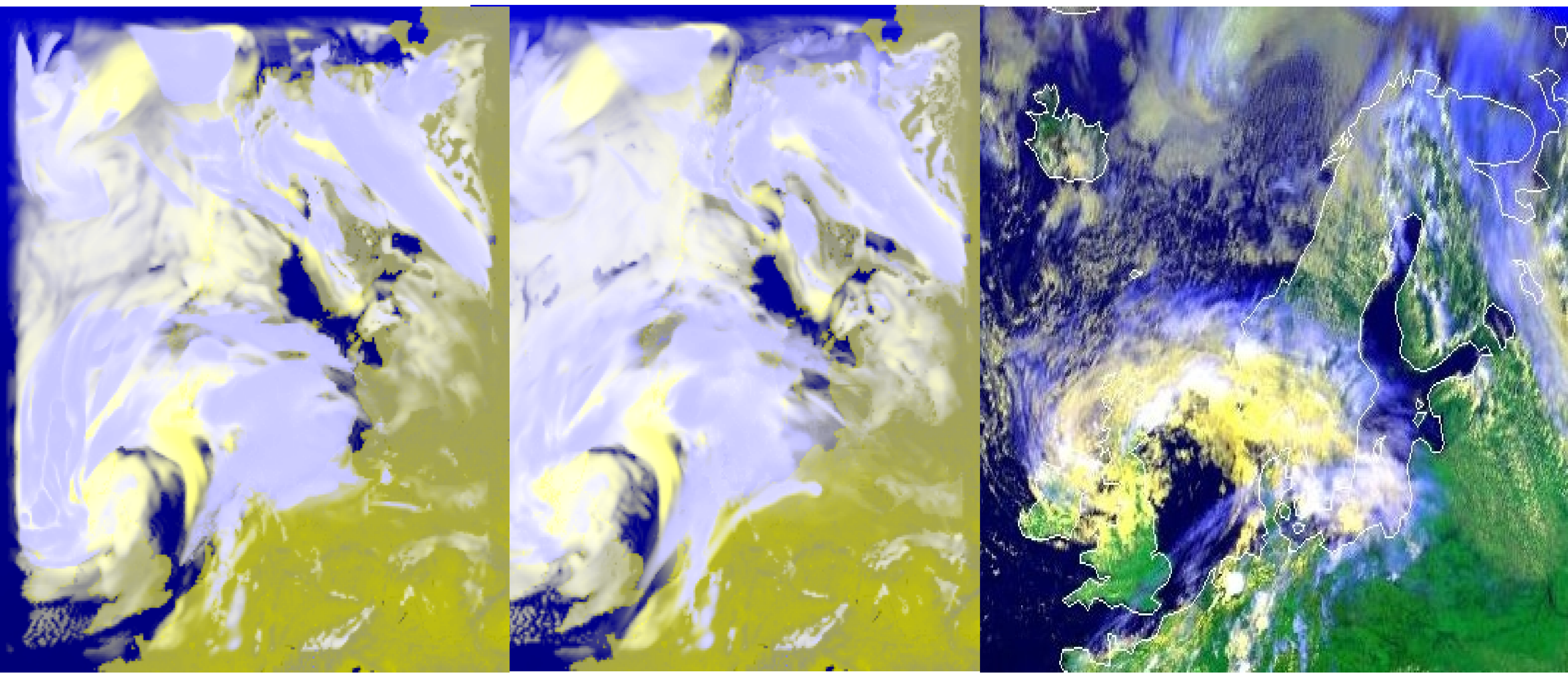
$$A_w = \max(0, 1 - \sqrt{1 - \frac{RHW - RHLIM}{1 - RHLIM}})$$

$$A_i = \min(1, 0.5(1 - e_{si}/e_{sw})/(1 - RHLIM))f(q_i), A_w > 0$$

$$A_i = \min(1, 0.5max(0, RHI - RHLIMI)/(1 - RHLIMI))f(q_i), A_w = 0$$

$$RHLIMI = 1 + e_{sw}/e_{si}(RHLIM - 1)$$

Less on-off behavior of mixed-phase or ice clouds with LP-parametrization ( Left: pseudo sat. picture without LP-param.Middle: with. Right: Sat. picture 20080621+036h)



# •'Liu-Penner' changes of the radiation scheme.

- Effective radius of ice crystals are a function of the number of ice crystal concentration ( which is dependent on the IN concentration) and the cloud ice content (qi)  This replaces the present scheme, in which it is only a function of temperature.

- $R^3 = k\, r^3$
- $k = \exp ( a + b(T-240) + c \ln(qi))$
- Ice crystals have a more or less infinity variation of shapes. Here, the volume mean radius, R, and the effective one, r  are assumed to be related to each other by k. The value of k has been determined by a linear regression expression.

## •Some other updates of Kain Fritsch (KF) convection and of RK-scheme.

- KF-eta instead of old KF.
- Reducing convective activity for high resolution ( Lisa Bengtssons param.) Shallow convection also reduced for low stratus.
- Increased precipitation release in the beginning of forecast for reducing spin-up.
- Condensate from convection are used in condensation scheme instead of being evaporated. Leads to more cloud condensate in convective clouds.

# Other updates ...

- Cloud drop dependence on collection of cloud water by falling rain and snow :

Collection of cloud water by snow, original :

Bulk formula:

$$P_{sacw} = C_{sac} E_{sw} q_w \tag{1}$$

Here, $C_{sac}$ = constant dependent on microphysics ( Lin et al ) $q_w$ = cloud-water content , $E_{sw}$ = collision efficiency , 0.1

New ( From Lohmann , 2004) :

$$E_{sw} = 0.939 St^{2.657} \tag{2}$$

Here, $St = \frac{2(V_t - v_t) v_t}{Dg}$ is the stokes number, $V_t$ = fall speed of snow ( currently just 0.9 m/s), $v_t$ = fall speed of cloud droplets (here comes CCN concentration in), $D$ = maximum dimension of snow crystal ( 5 mm ) and $g$ = gravity acceleration

Collection of cloud water by rain, original bulk formula :

$$P_{racw} = C_{racw} q_w \tag{3}$$

New ( Rogers and Yau , 1989 )

$$P_{racw} = 2 C_{racw} E_{rw} q_w \tag{4}$$

Here, $C_{racw}$ = constant dependent on microphysics, etc $E_{rw}$ = collision efficiency , function of drop radius :

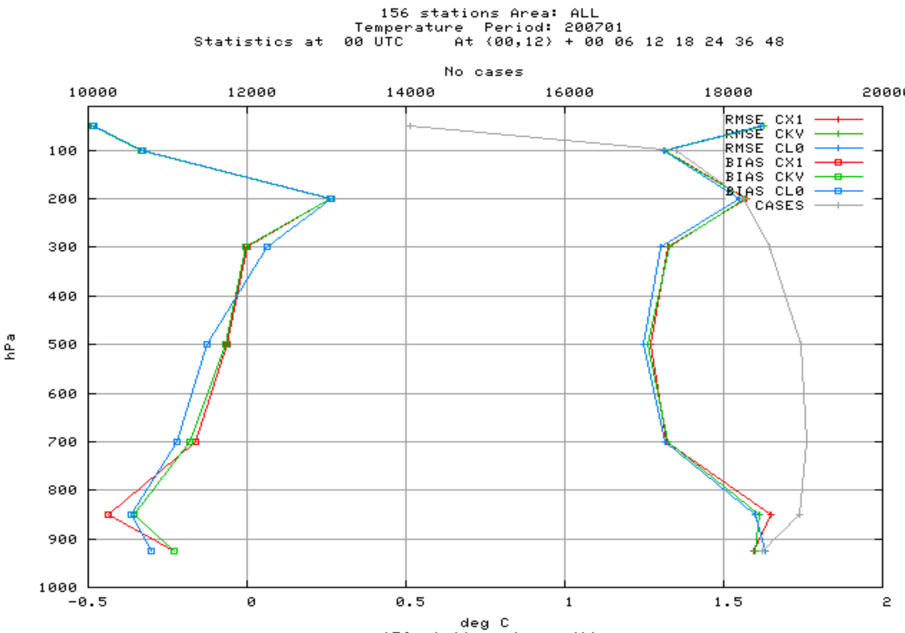
$$E_{rw} = \frac{e^{Ar} - 1}{e^{Ar} + 1} \tag{5}$$

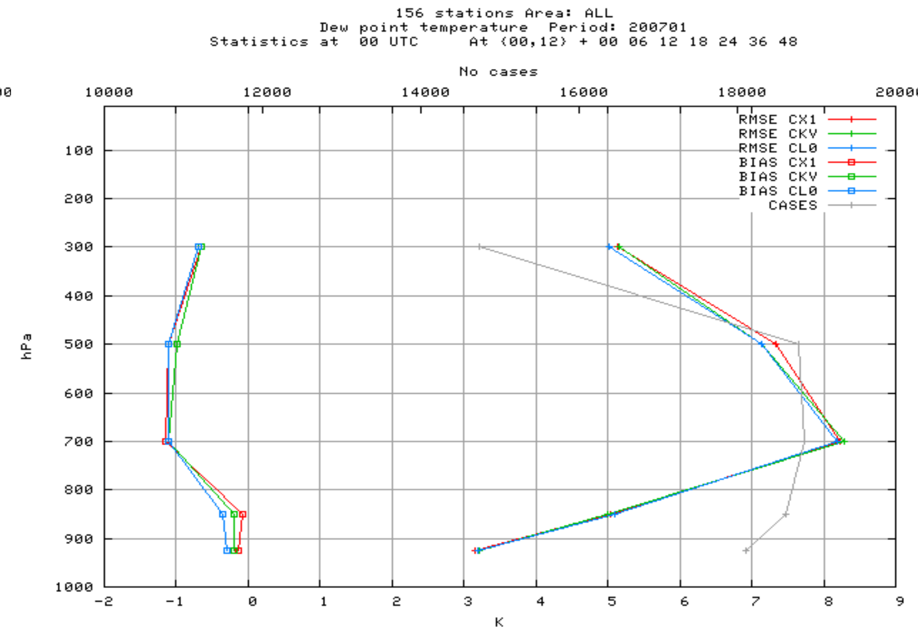
$A = 2.5x10^5$ , $r$ = mean cloud droplet radius, m

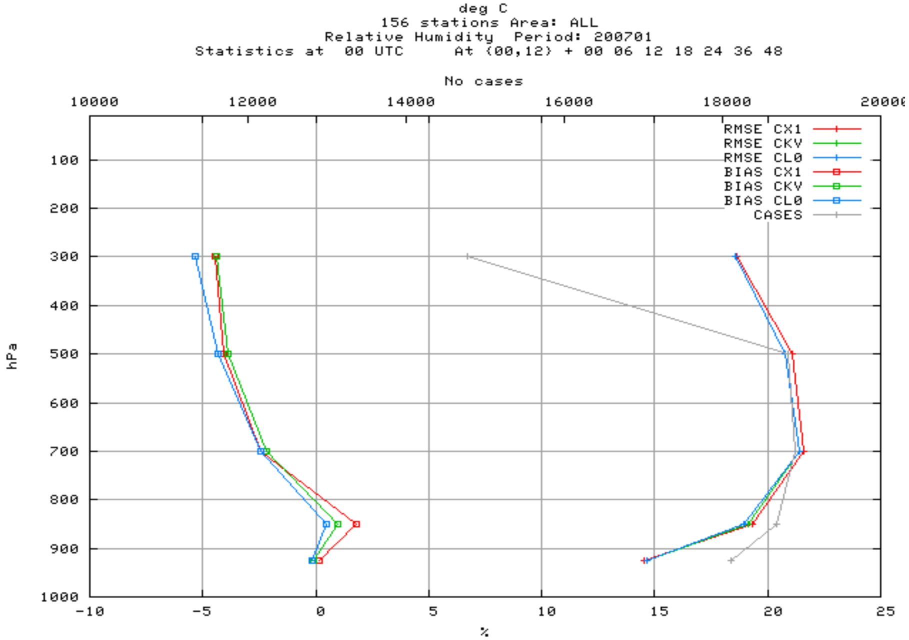
•Results of using Liu-Penner parametrization.

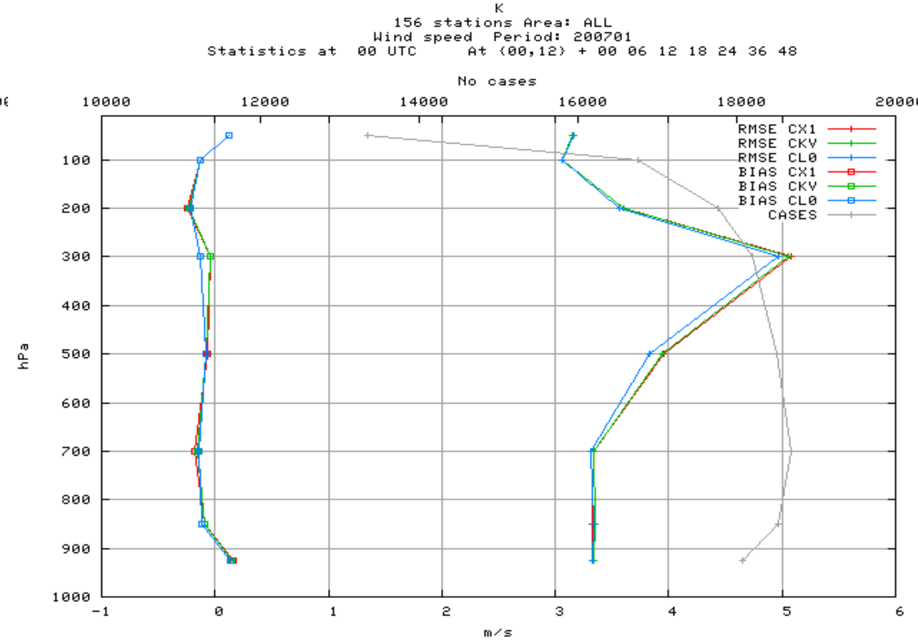
- Test: 22km resolution 40 levels. January 2006,2007 + July 2007. SMHI C22 area. Hirlam 7.3beta2 (='Newsnow' scheme)
- CX1 : 'Reference' Hirlam 7.3 beta2
- CKV : With KF-eta and a small modification of CBR
- CL0 : LP parametrization + CKV changes

# 2007 -01 ,upper air

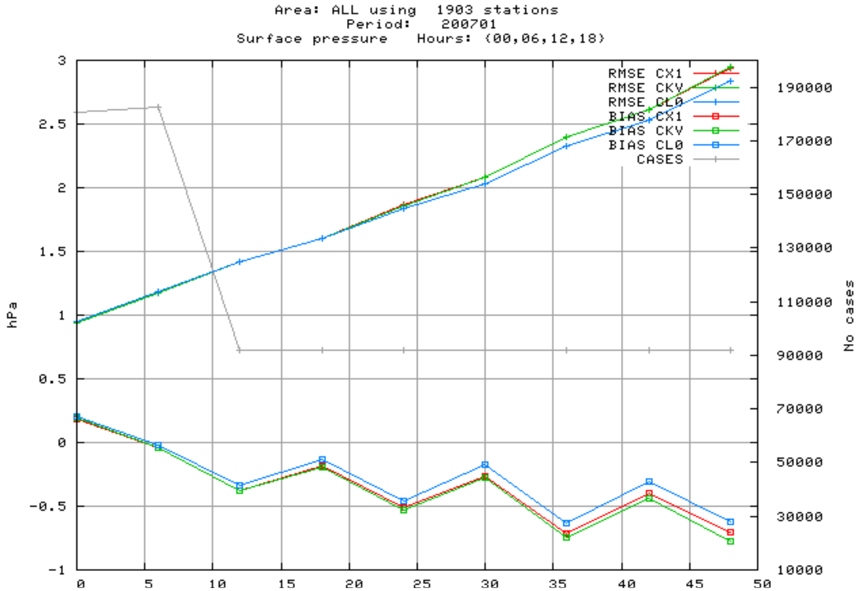


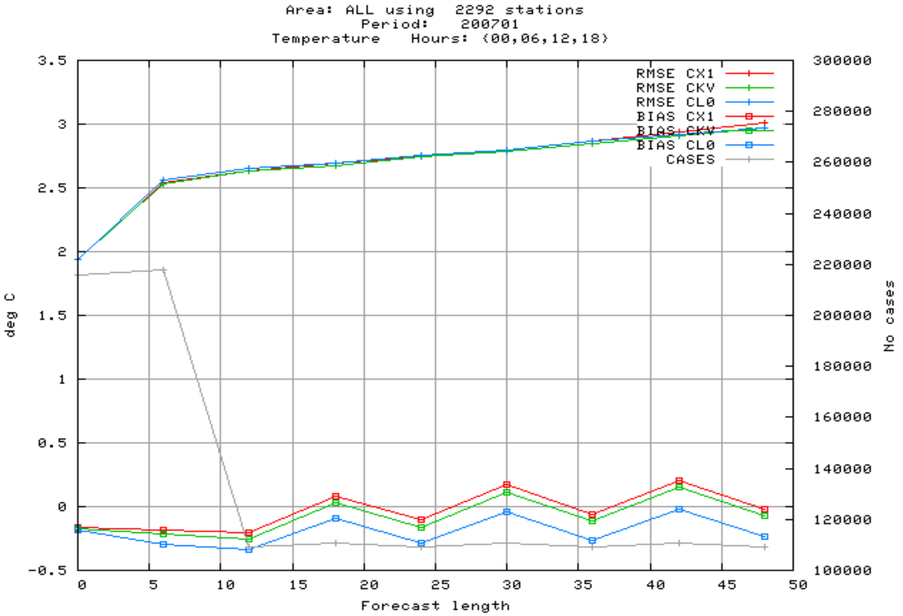



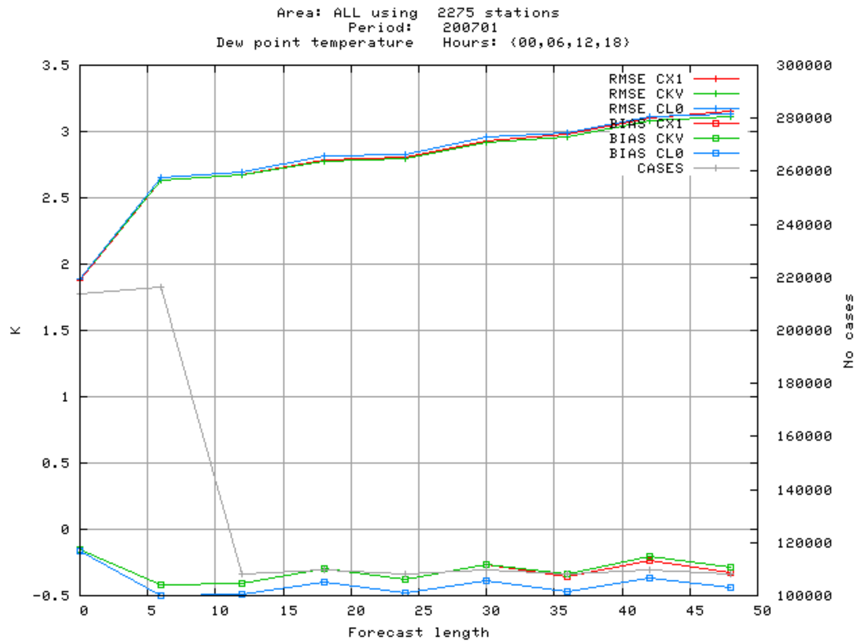



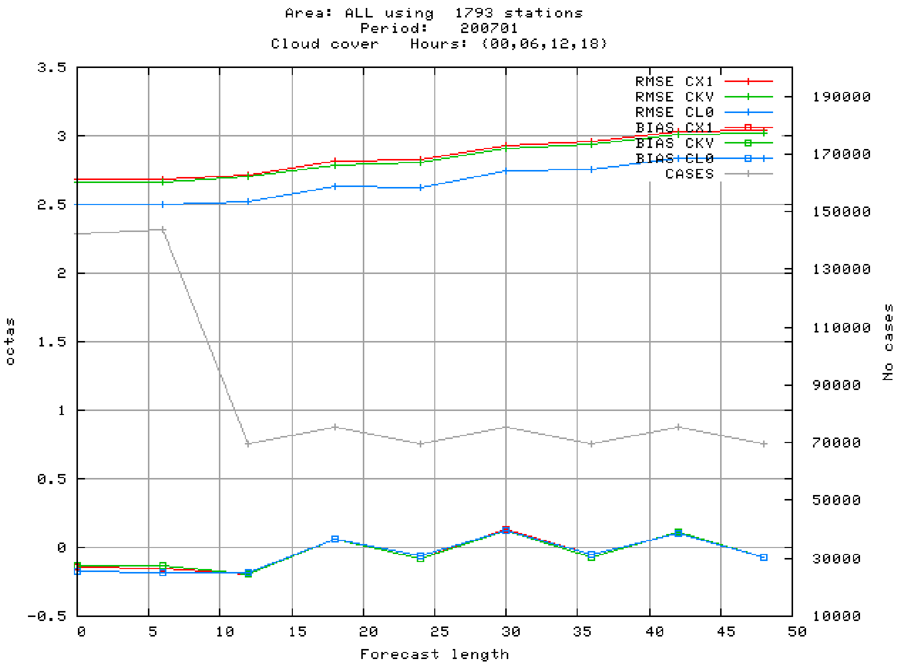



# 2007-01 surface

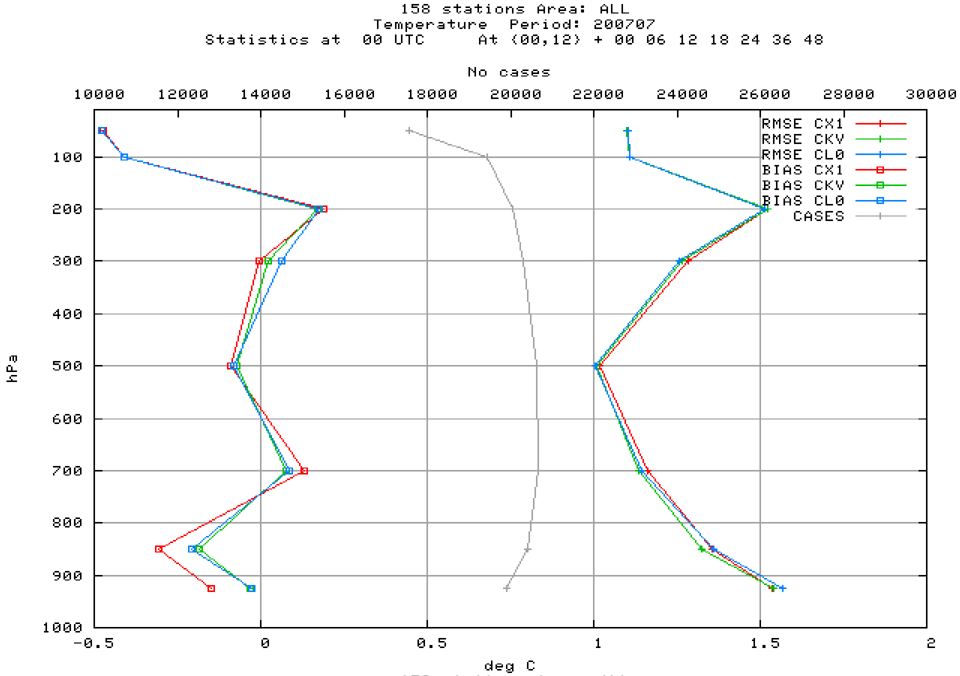


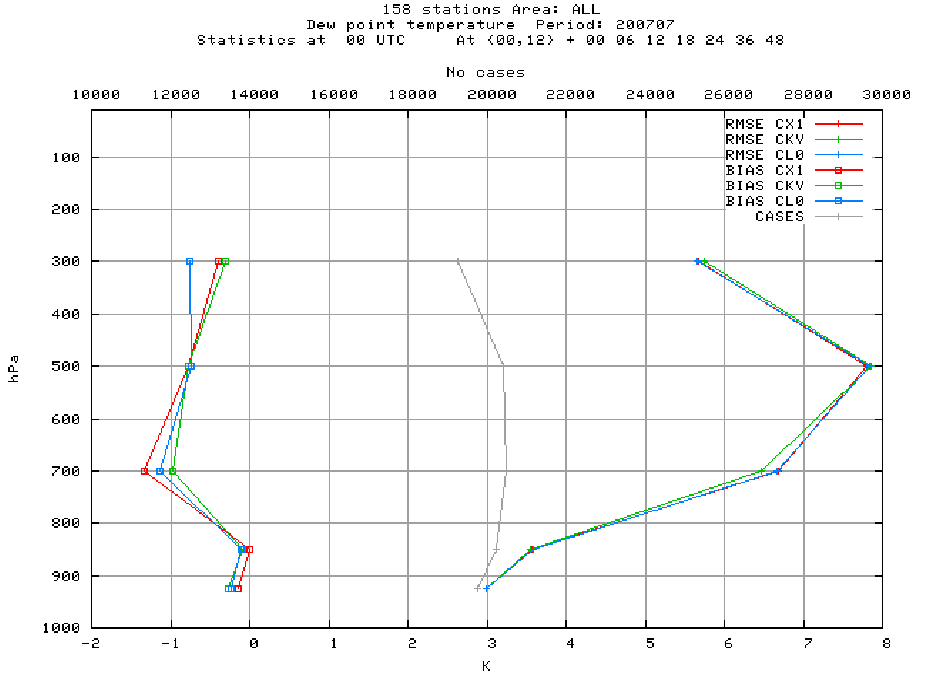



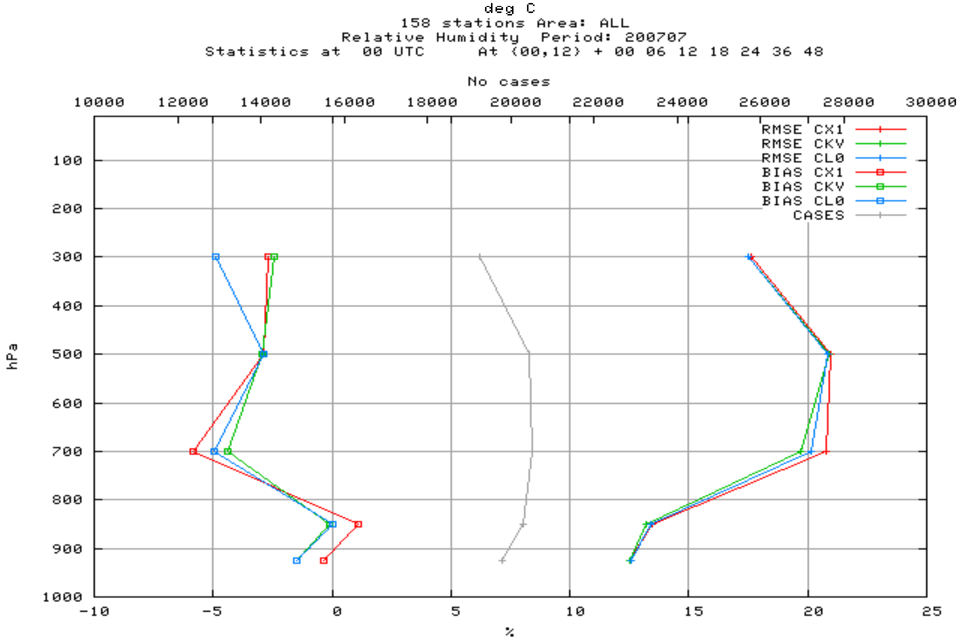



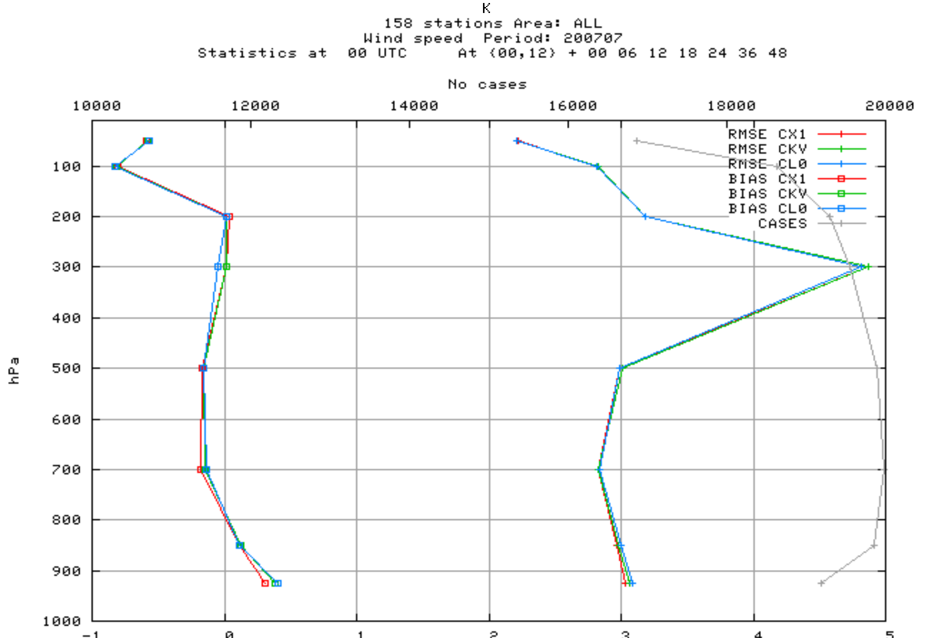



# 2007-07 upper air

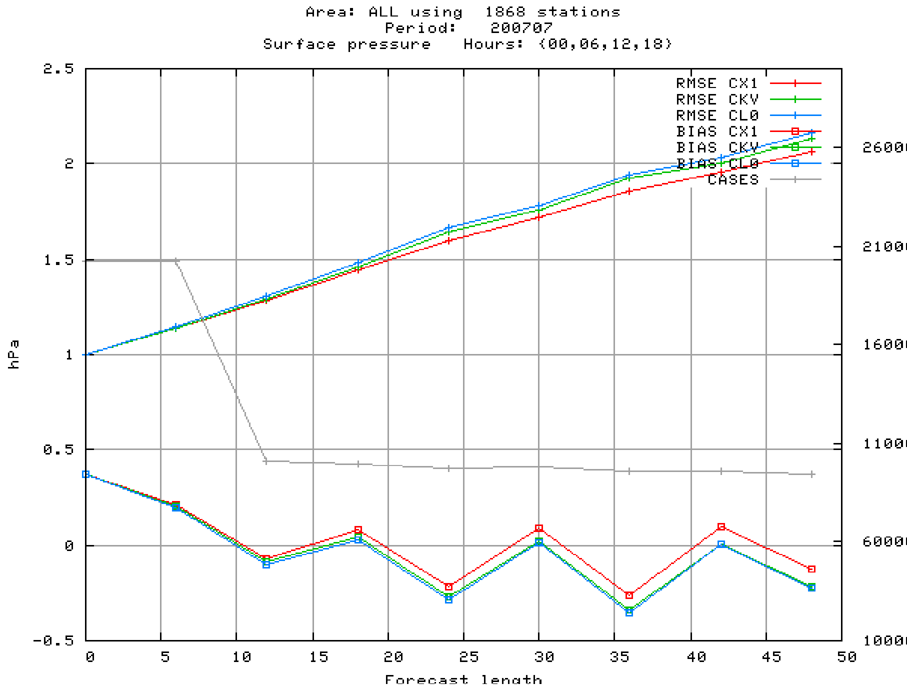


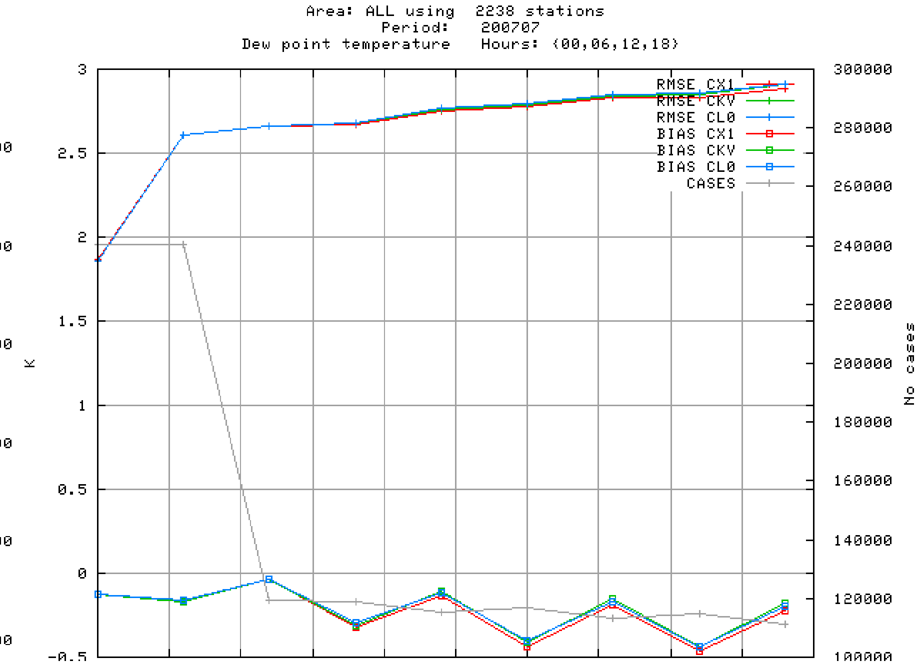



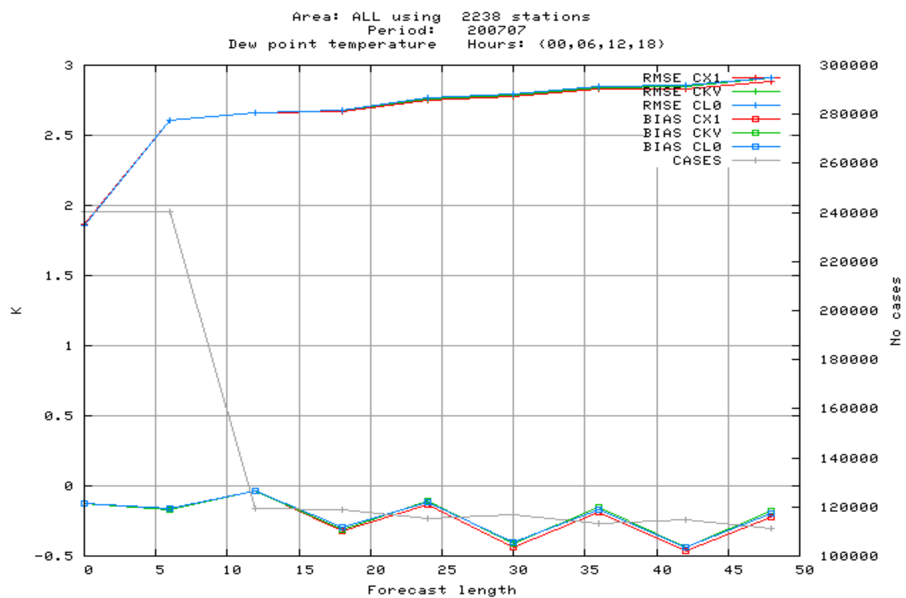



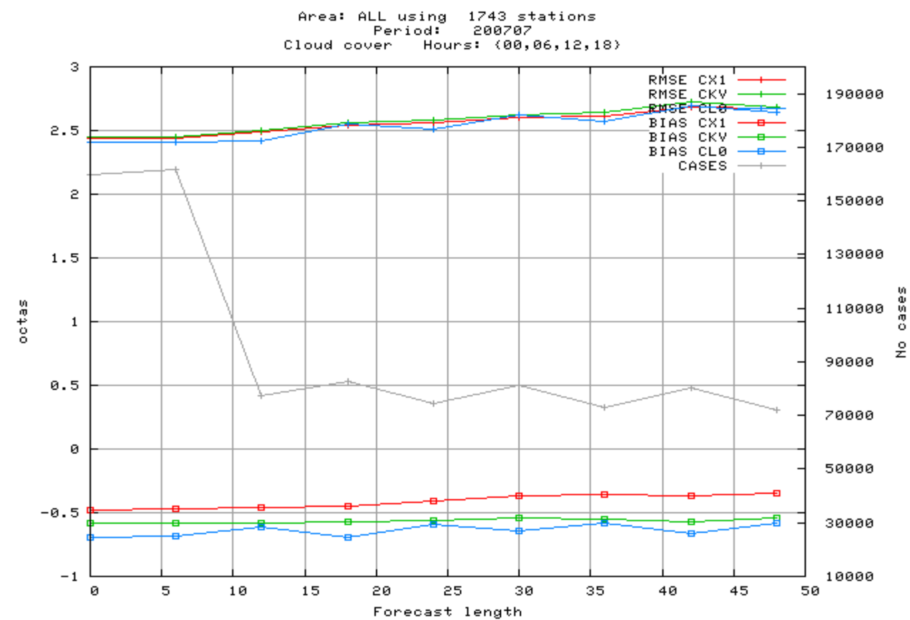



# 2007-07 surface

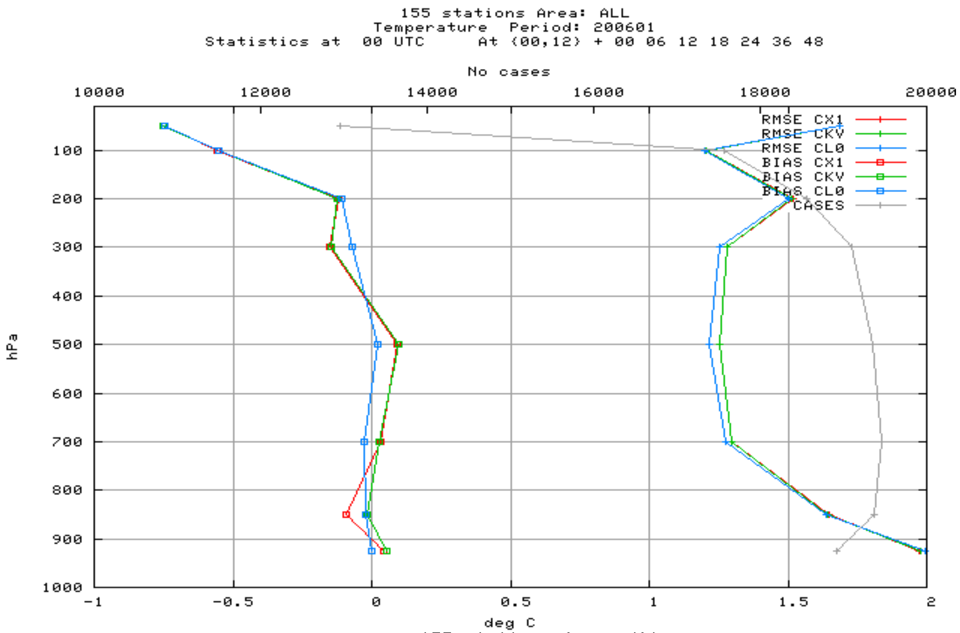


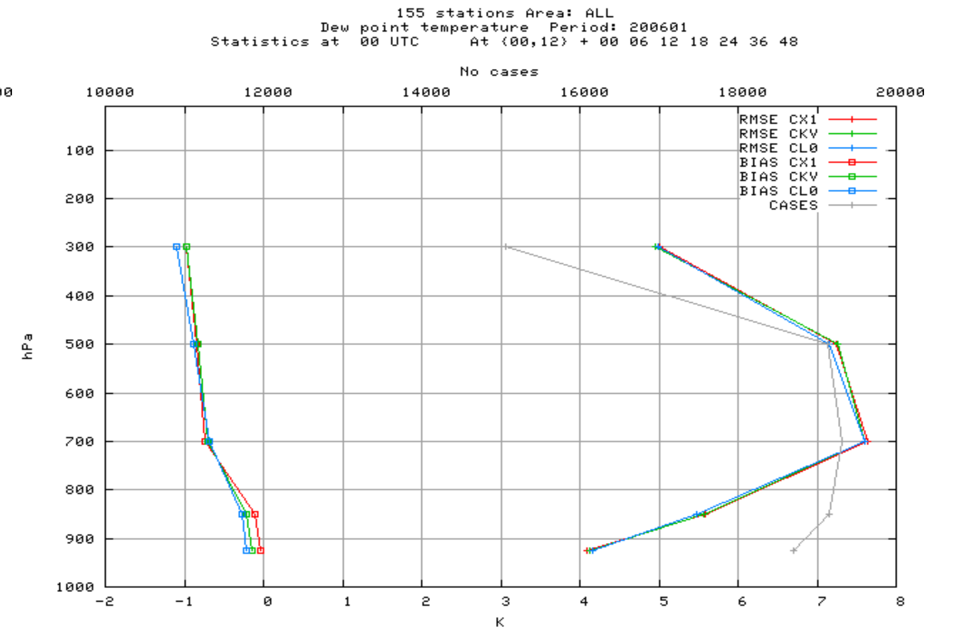



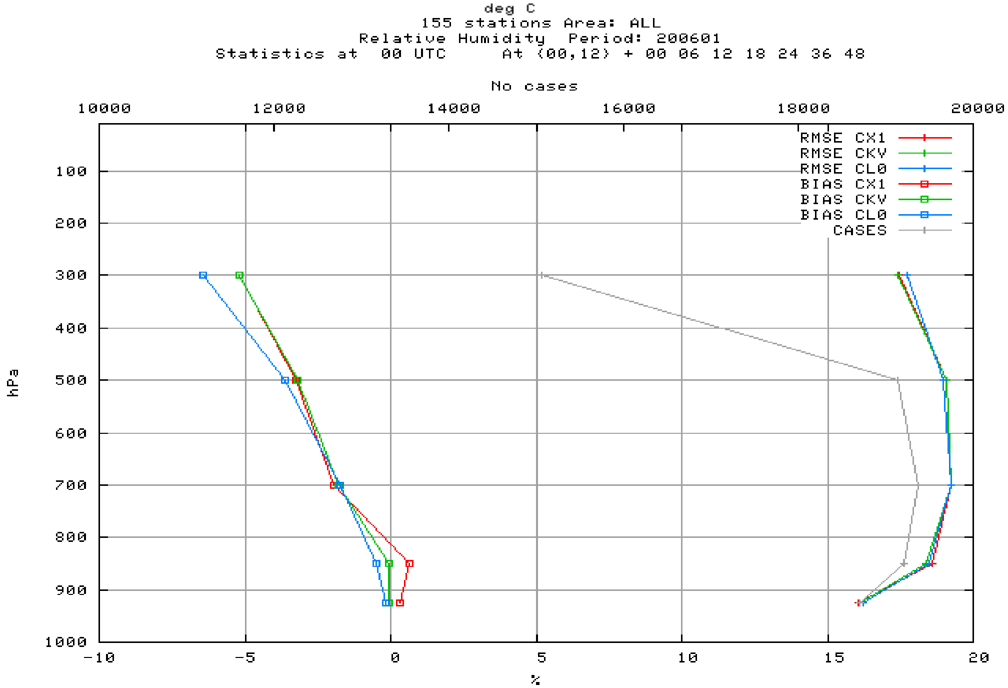



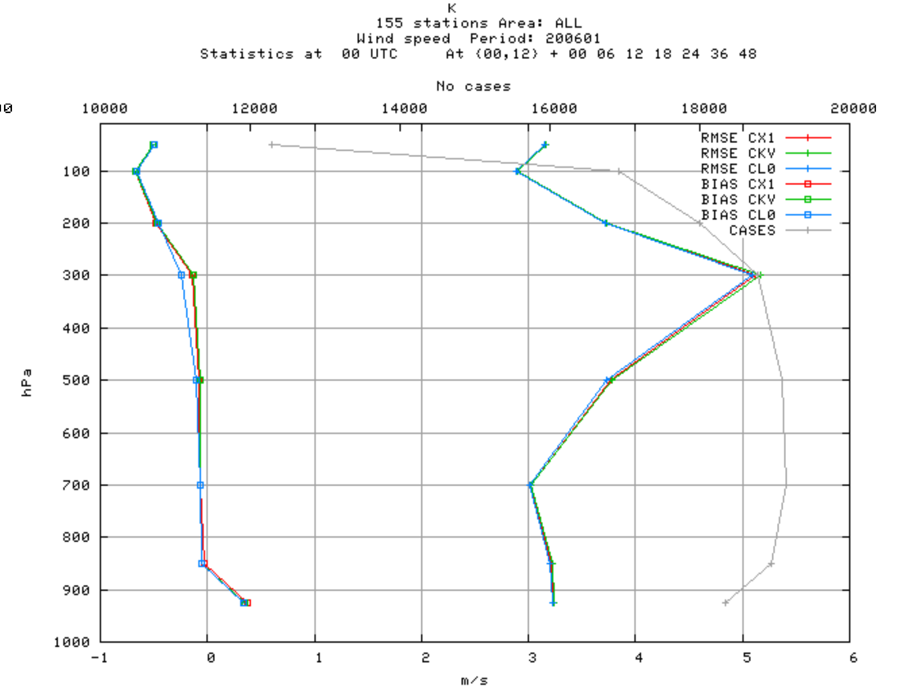



# 2006-01 upper air

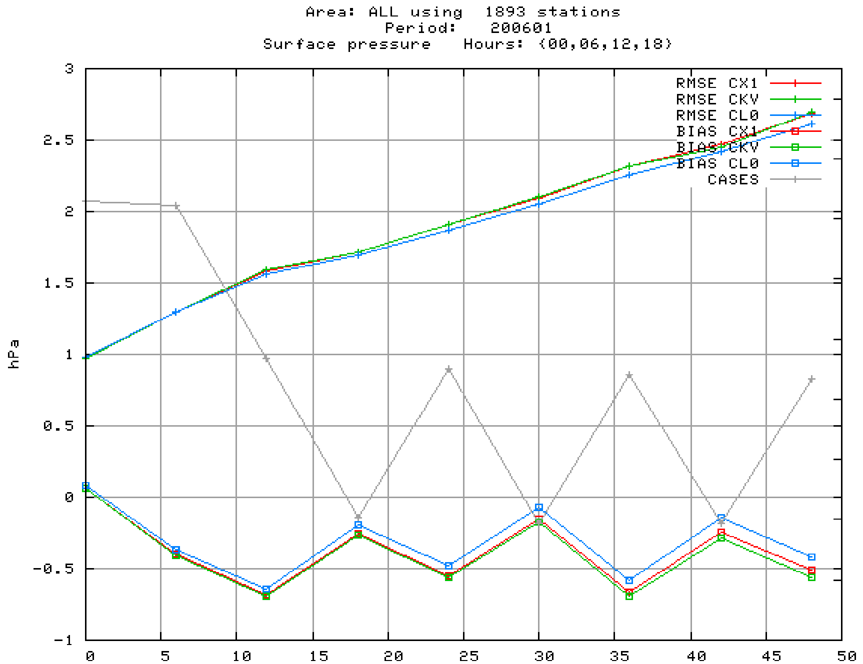


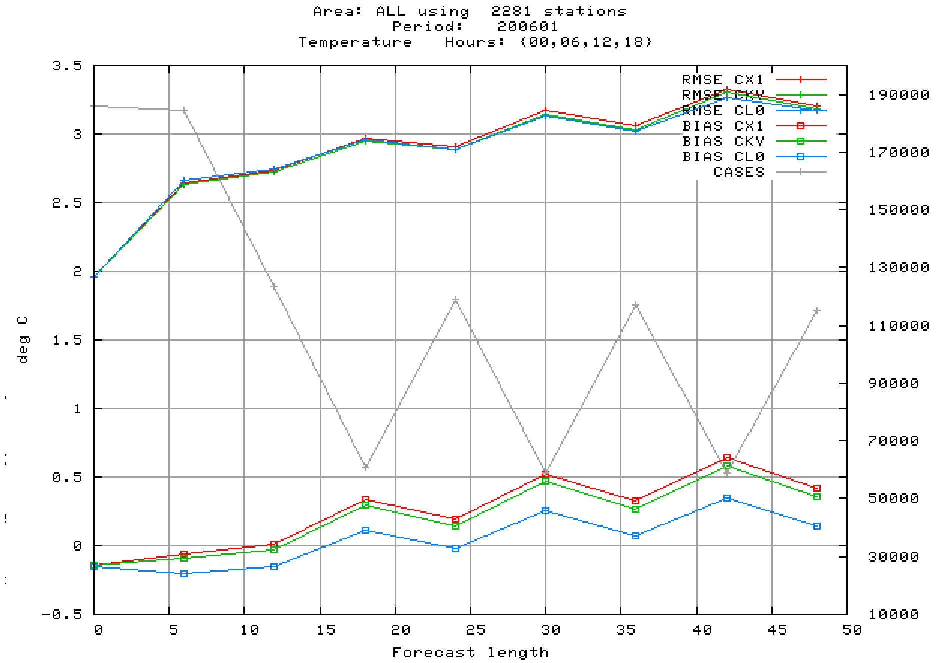



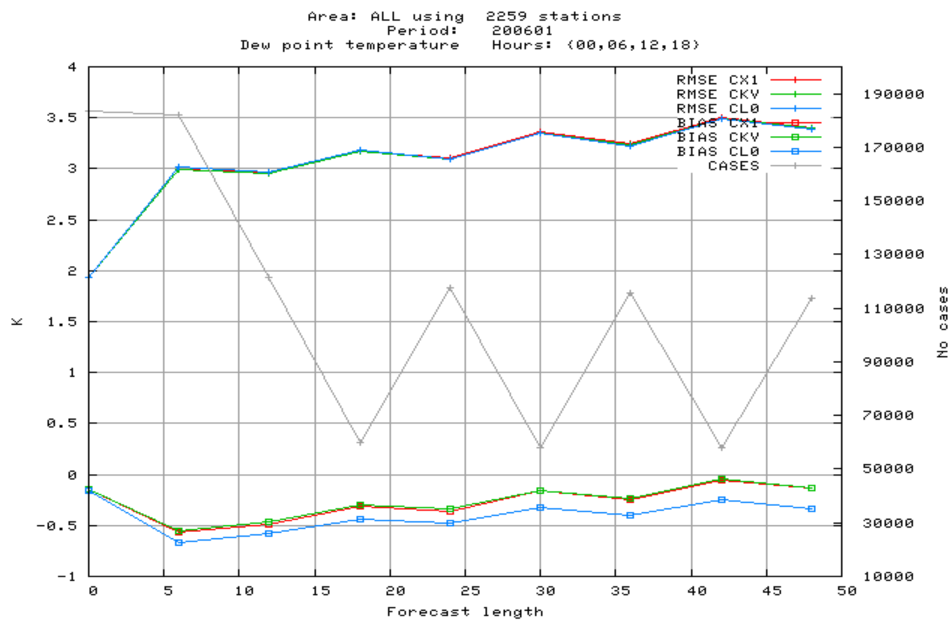



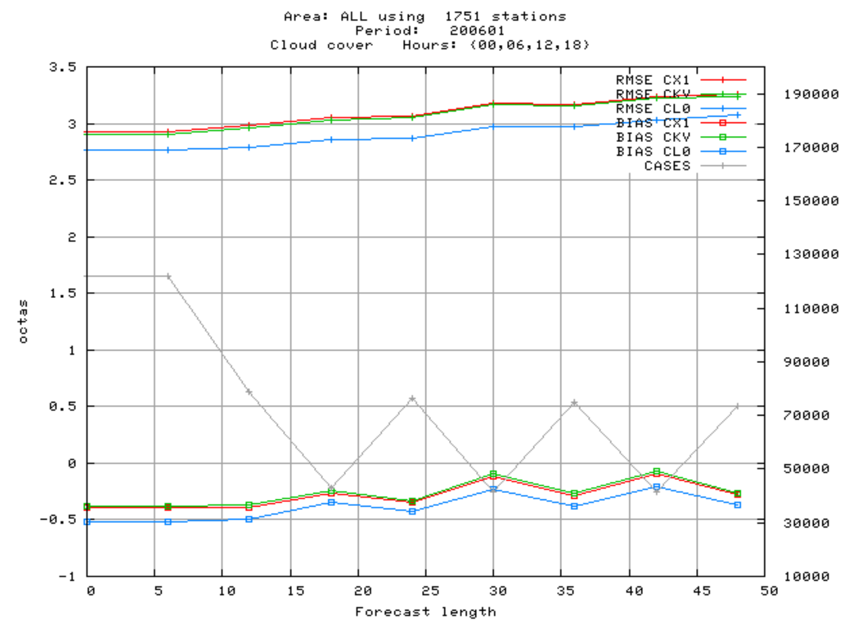



# 200601 surface



# •Discussion and conclusions

- With KF-eta  and mod. CBR: Reduced bias of temperature and humidity at upper levels, Mostly small impact in other respects
- With also including LP parametrization: Most forecast variables better in winter, but in summer neutral or a little worse.
- Mixed phase clouds and pure ice clouds are more often closer to 4 octas with LP parametrization. Gives better RMSE of cloudiness. The difference is small when Kuipers skill score is used.
- The treatment of cloud ice is more 'explicit' and allow for more degrees of freedom with LP parametrization, since it not directly leads to some equilibrium state. Although more realistic, it also enhance the risk of numerical noise. So far some noise have been seen in case of high wind speed and long time steps, but seems generally to be much less nosier than the old RK-98 in Hirlam 7.2.
- Is interesting to test for Alaro, since Alaro's ice microphysics is fairly simple.

# References


- Meyers et al: New primary ice-nucleation parametrization in an explicit cloud model J. Appl. Metetor. 31, 708-721
- Kogan et al 2000: A new cloud physics parametrization in large-eddy simulation model of marine stratocumulus. Mon. wea. rev.,Vol 128 p 1070-1088.
- Lin et al 1983: Bulk parametrization of the snow field in a cloud model. J Appl. Meteor. 22 1065-1092
- Liu X et al. 2007: Inclusion of ice microphysics in the NCAR Community Atmospherical Model Version 3. (CAM3) Journal of Climate Vol 20 4526-4547
- Liu X, and Penner J.E. 2005 : Ice nucleation parametrization for global models. Meteorol. Z. 14 499-514
- Rogers R R , M K Yau. 1989 : A short course in cloud physics. 3D Pergamon 293 pp.
- Lohmann U. 2004: Can anthropogenic aerosols decrease the snowfall rate? J A S Vol 61 p 2457-2468
- Rasch P.J. and Kristjansson J.E. 1998: A comparison of the CCM3 model climate using diagnosed and predicted condensate parametrizations. Journal of Climate 1587 - 1614
- Rotstayn et al 2000: A Scheme for calculation of the liquid fraction in mixed-phase stratiform clouds in large scale models. Mon. wea. rev. 128 1070-1088
- Zhang et al 2003: A modified formulation of fractional stratiform condensation rate in the NCAR Community atmospheric model J. Geophys. Res. 108(D1) ACL 10 1-11