(Very) Last updates of the Liu-Penner parametrization in Hirlam.
(and of the KF -scheme)

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In this presentation:

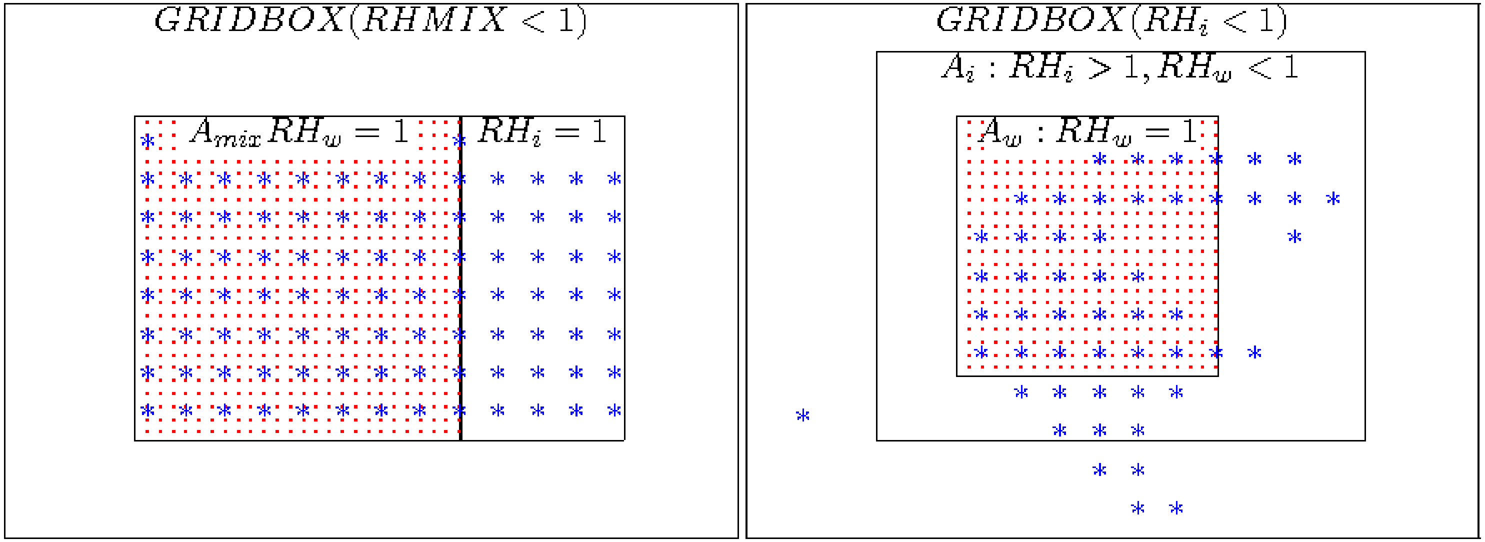
- Short description (repetition) of Liu-Penner parametrization of cloud ice.
- 'Liu-Penner' changes of the radiation scheme.
- Reduction of Kain Fritsch (KF) convection activity for high horizontal resolution.
- Test results with 7.3
- Discussion and conclusions

Short description of the Liu-Penner parametrization

- Makes the parametrization of condensation and radiation for cloud ice processes more realistic.
- More suitable for 2-way coupling of chemistry modeling.
- The RK-scheme is used for water phase only, instead of for both water and ice. The ice crystal growth equation below is used for conversion between ice and vapor instead of between ice and water.

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

- 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).
- Time-scale of cloud ice to reach some equilibrium with the environment is normally much larger (~ minutes to hours) for ice phase than for water. (~ seconds)
- The cloud fraction is a sum of one pure cloud-ice part based on relative humidity with respect to ice and cloud ice content and a cloud water part based on relative humidity with respect to water and the cloud liquid water content. (The present cloud cover calculation is based on a mixed ice-water relative humidity, dependent on the cloud ice+water content)
- Cloud scheme called only one time. (New , simpler → Alaro physics)



To the left is the Hirlam 7.3 parametrization and to the right is the new parametrization. RH_i is relative humidity with respect to ice, RH_w is with respect to water and $RHMIX$ is a mixture of those two. RHMIX and the size of the subgrid scale parts with water and ice depend on the fraction of the cloud condensate that is ice and of temperature. A_{mix} is the sum of the two cloudy part in the left figure. A '' means cloud ice and a '.' means cloud water.*

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

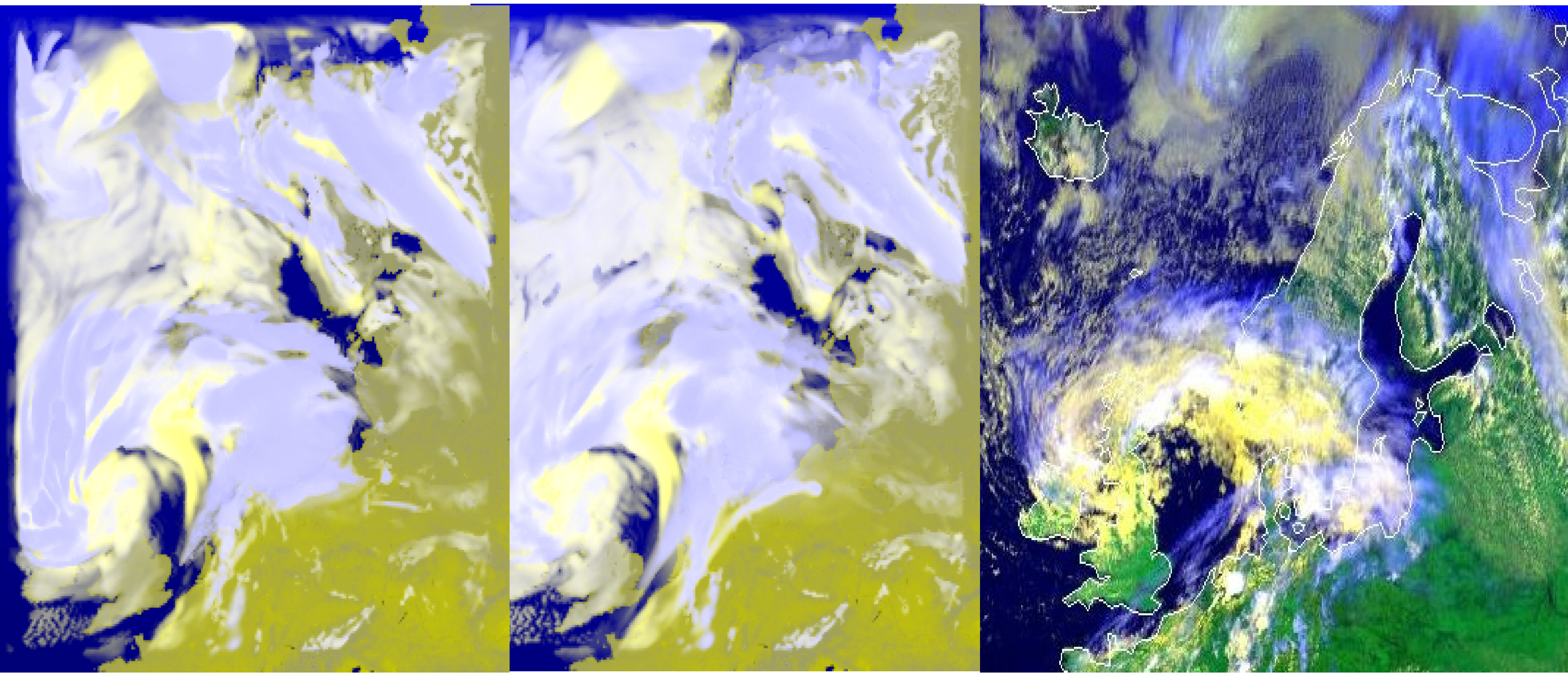
$$A_w = \max(0, 1 - \sqrt{1 - \frac{RH_w - RHLIM_w}{1 - RHLIM_w}}) \tag{2}$$

$$A_i = \min(1, 0.5(1 - e_{si}/e_{sw})/(1 - RHLIM_w)) \quad , A_w > 0 \tag{3}$$

$$A_i = \min(1, 0.5max(0, RH_i - RHLIM_i)/(1 - RHLIM_i)) \quad , A_w = 0 \tag{4}$$

$$RHLIM_i = 1 + e_{sw}/e_{si}(RHLIM_w - 1). \tag{5}$$

'Smoother' mixed-phase or ice clouds with LP-parametrization (Left: pseudo sat. picture without LP-param. Middle: with. Right: Sat. picture 20080621+036h. Note that this satellite picture underestimates cloudiness, but the psedo satellite pictures overestimates it)



'Liu-Penner' changes of the radiation scheme.

- The effective radius of ice crystals is a function of ice crystal concentration (which is dependent on the IN concentration and temperature) and the cloud ice content (qi).
- Only a function of temperature in the present scheme

$R^3 = k\, r^3$

$k = \exp(a + b(T-240) + c \ln(qi))$

- 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.

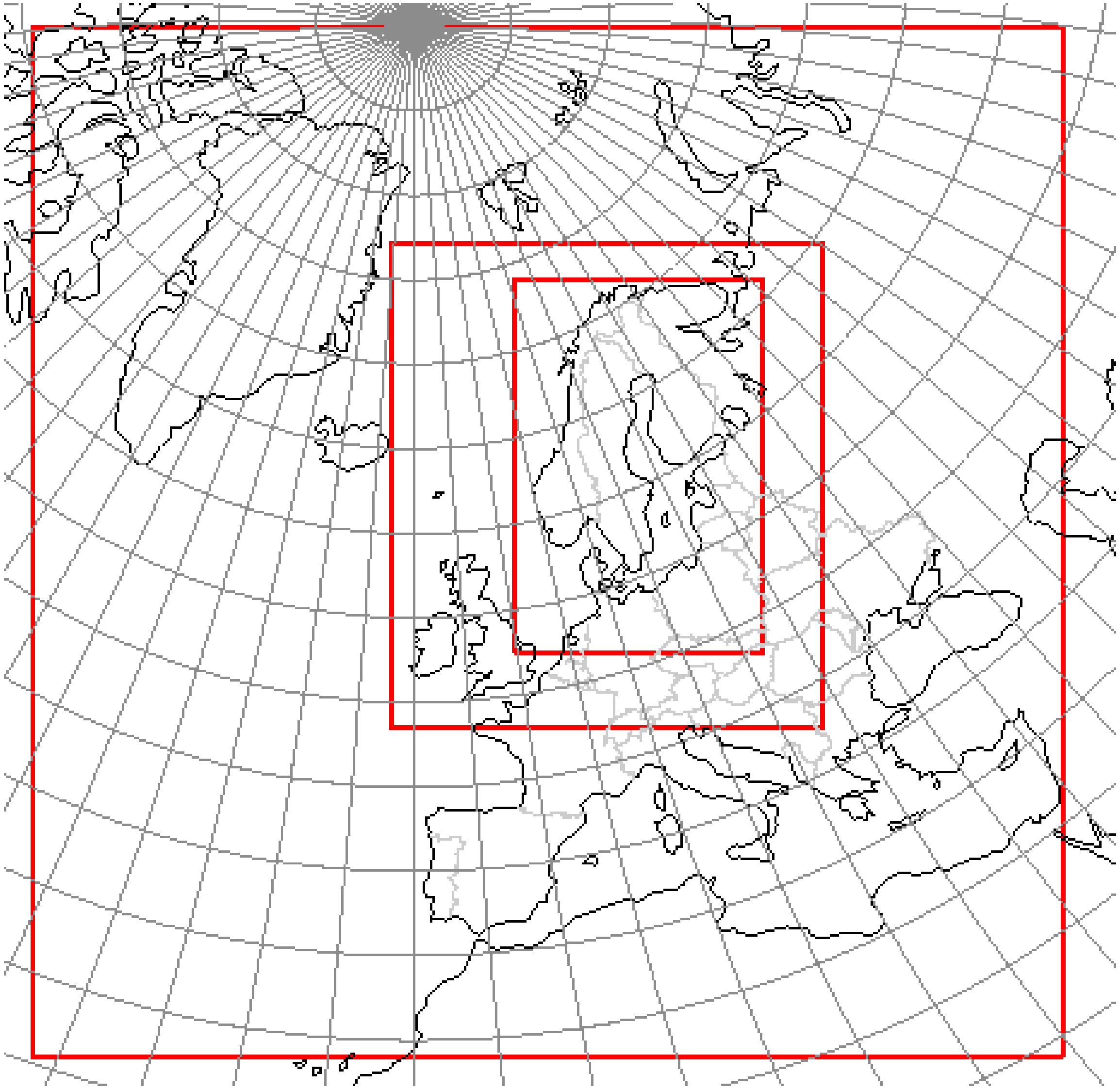
Reduction of Kain Fritsch (KF) convection activity for high horizontal resolution.

- Code in 7.3 but not activated. (Lisa Bengtssons param.)
- Method : Use longer timescale for convection for higher horizontal resolution if the ratio cloud height to updraft speed is high.
- Introduced below 0.15 degrees resolution.

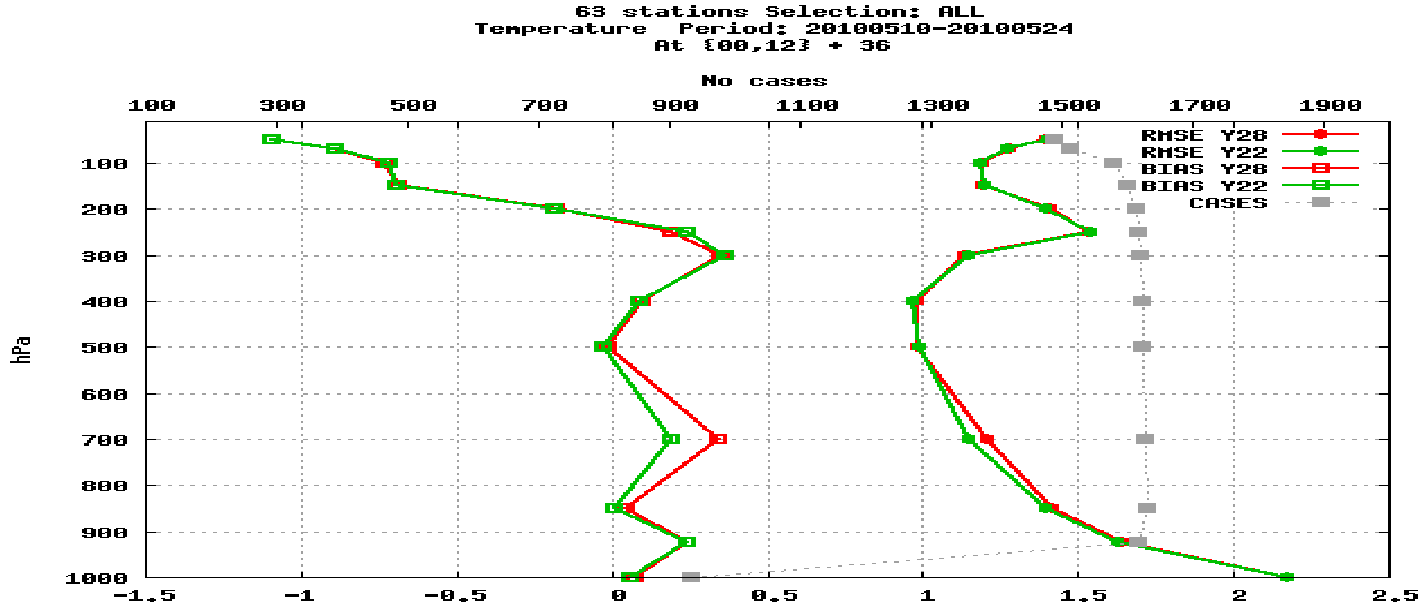
Results of reducing KF activity for high horizontal resolution

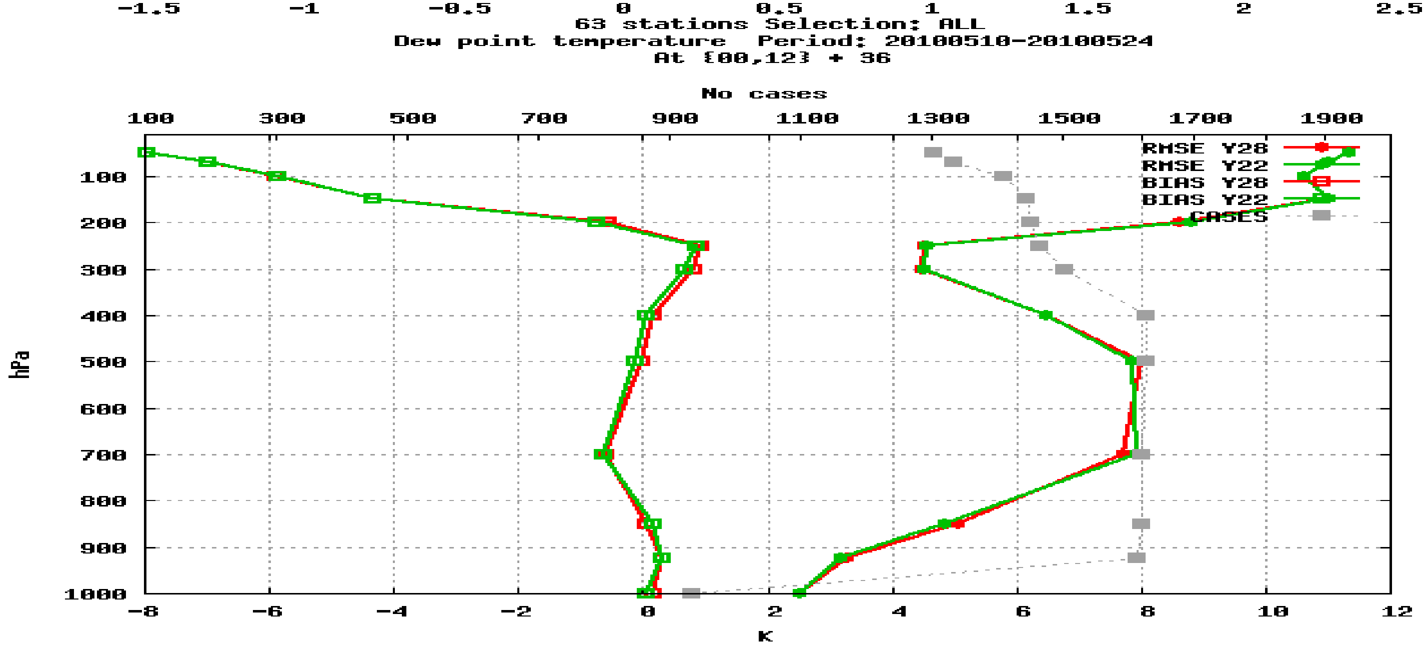
- Test: 5.5km resolution 60 levels. May 2010 SMHI E-area and 11km July 2007 SMHI C area
- Red   : no reduction
- Green : reduction

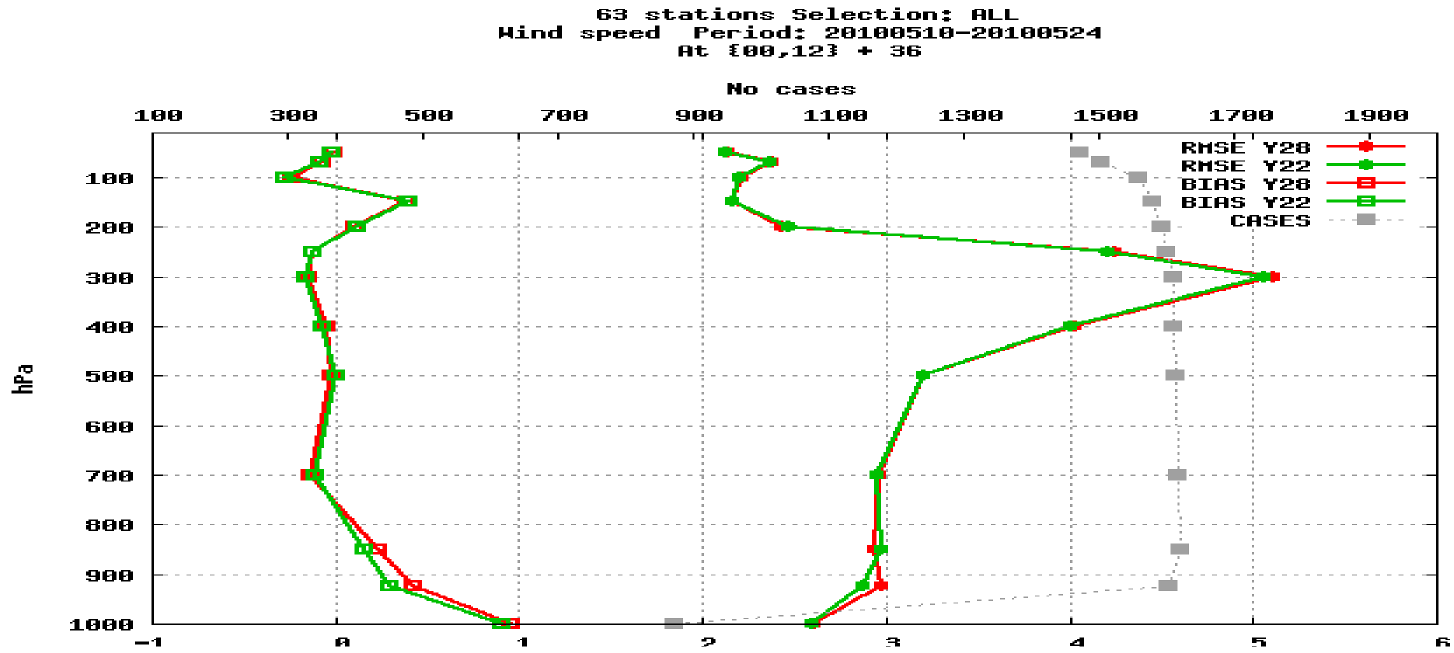
Model domains Big: C area, small: E-area, smallest: G-area

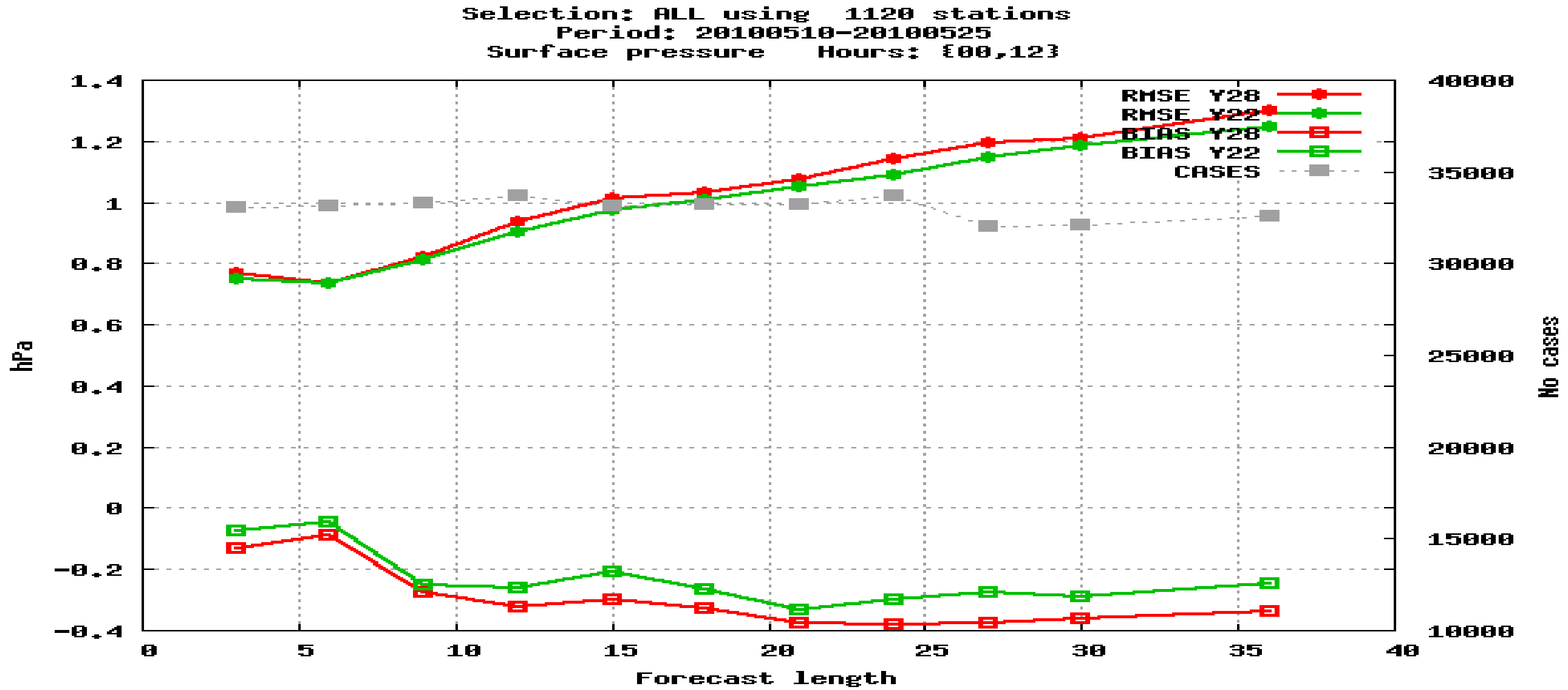


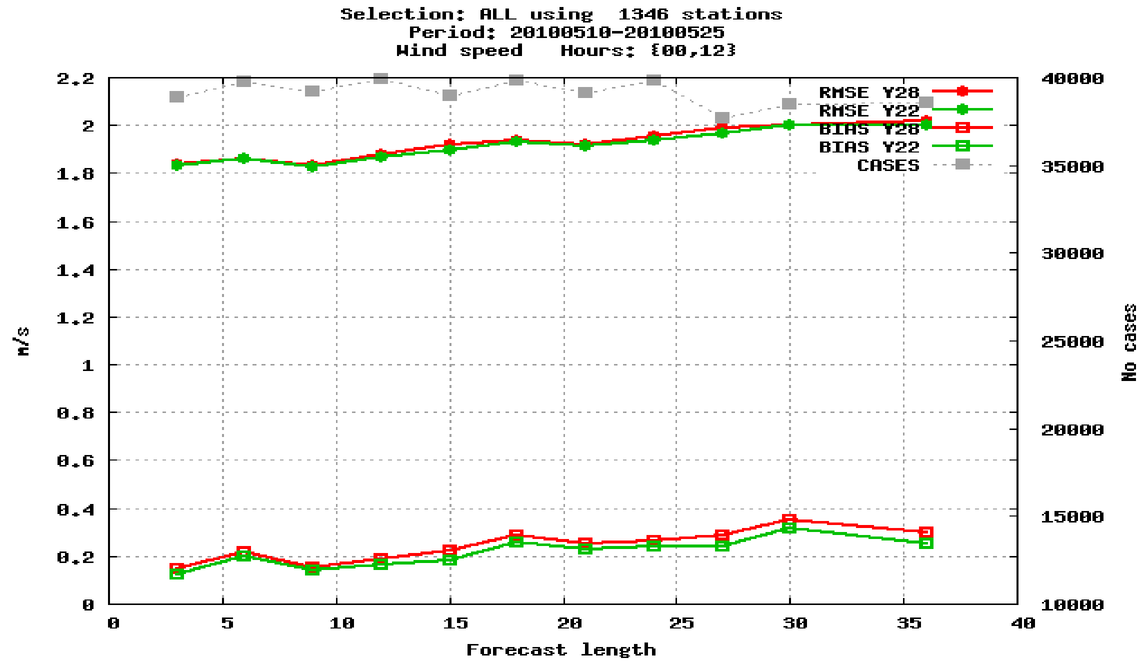
2010-05 (two weeks) 5.5km E-area

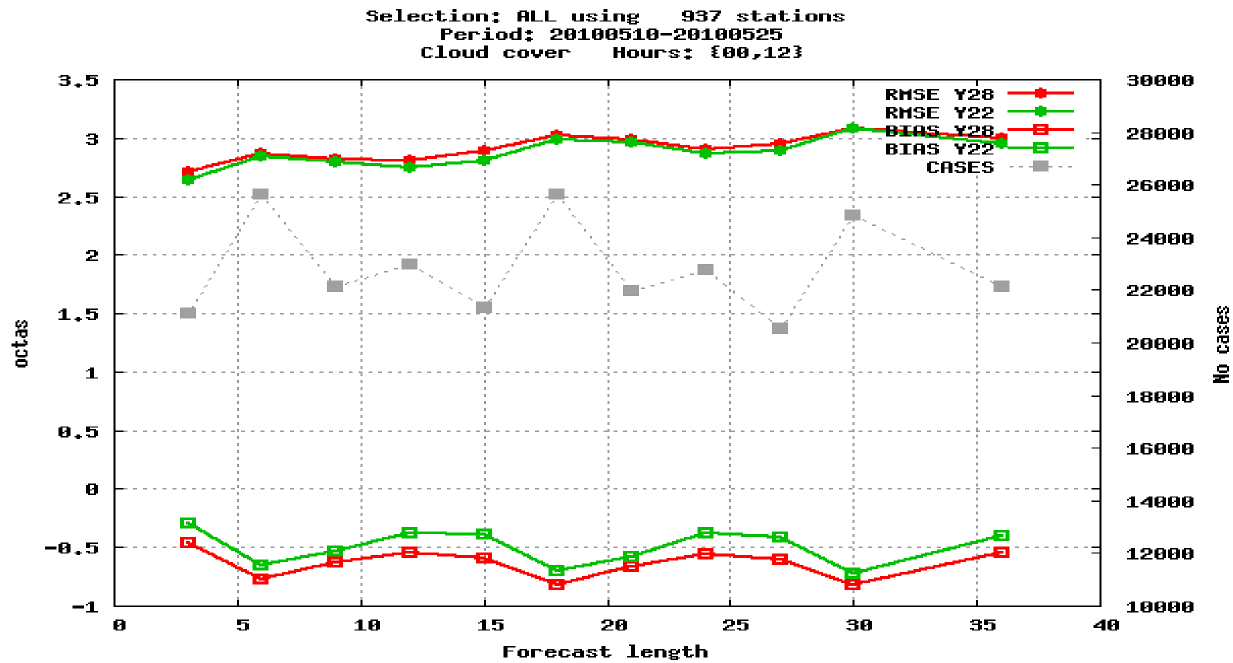




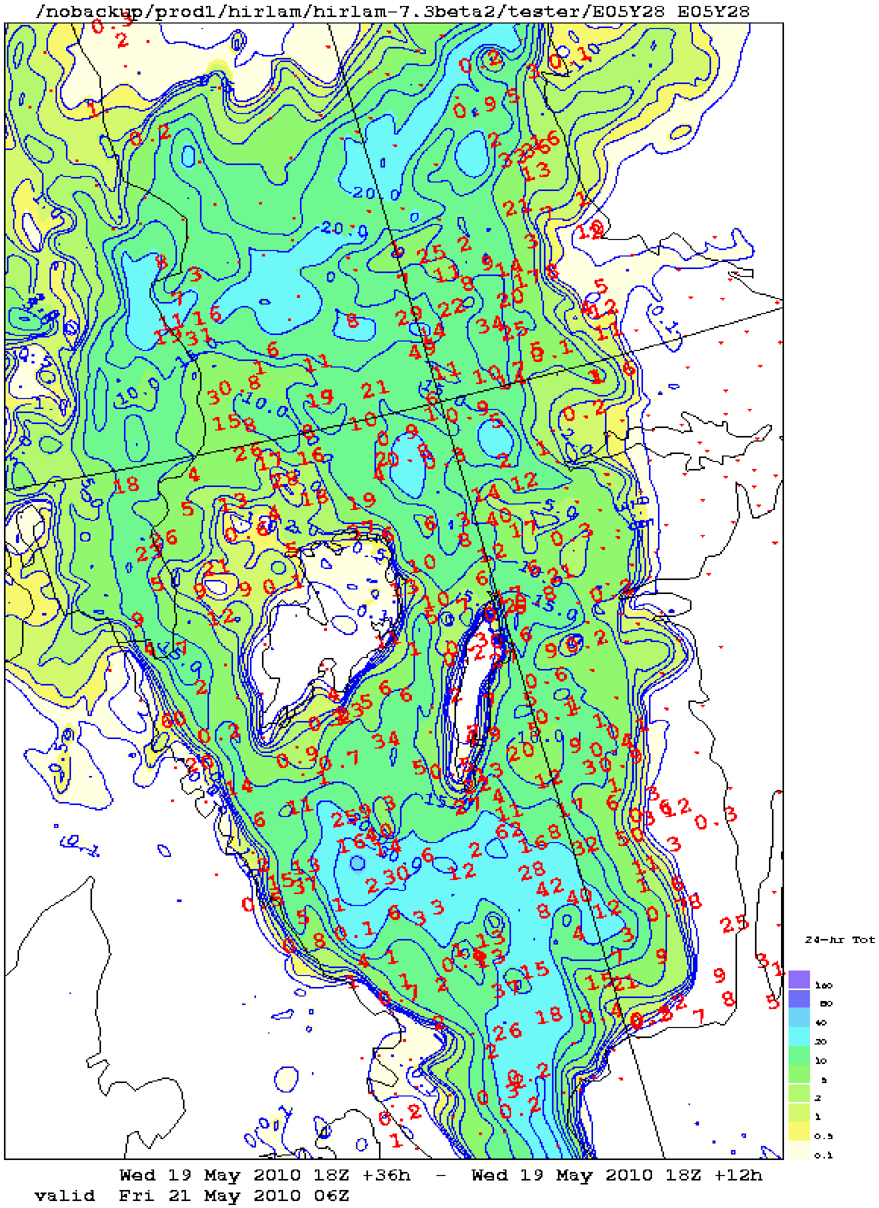

63 stations Selection: ALL
Wind speed Period: 20100510-20100524
At {00,12} + 36
No cases
100 300 500 700 900 1100 1300 1500 1700 1900
RMSE Y28
RMSE Y22
BIAS Y28
BIAS Y22
CASES
hPa
100 200 300 400 500 600 700 800 900 1000
-1 0 1 2 3 4 5 6

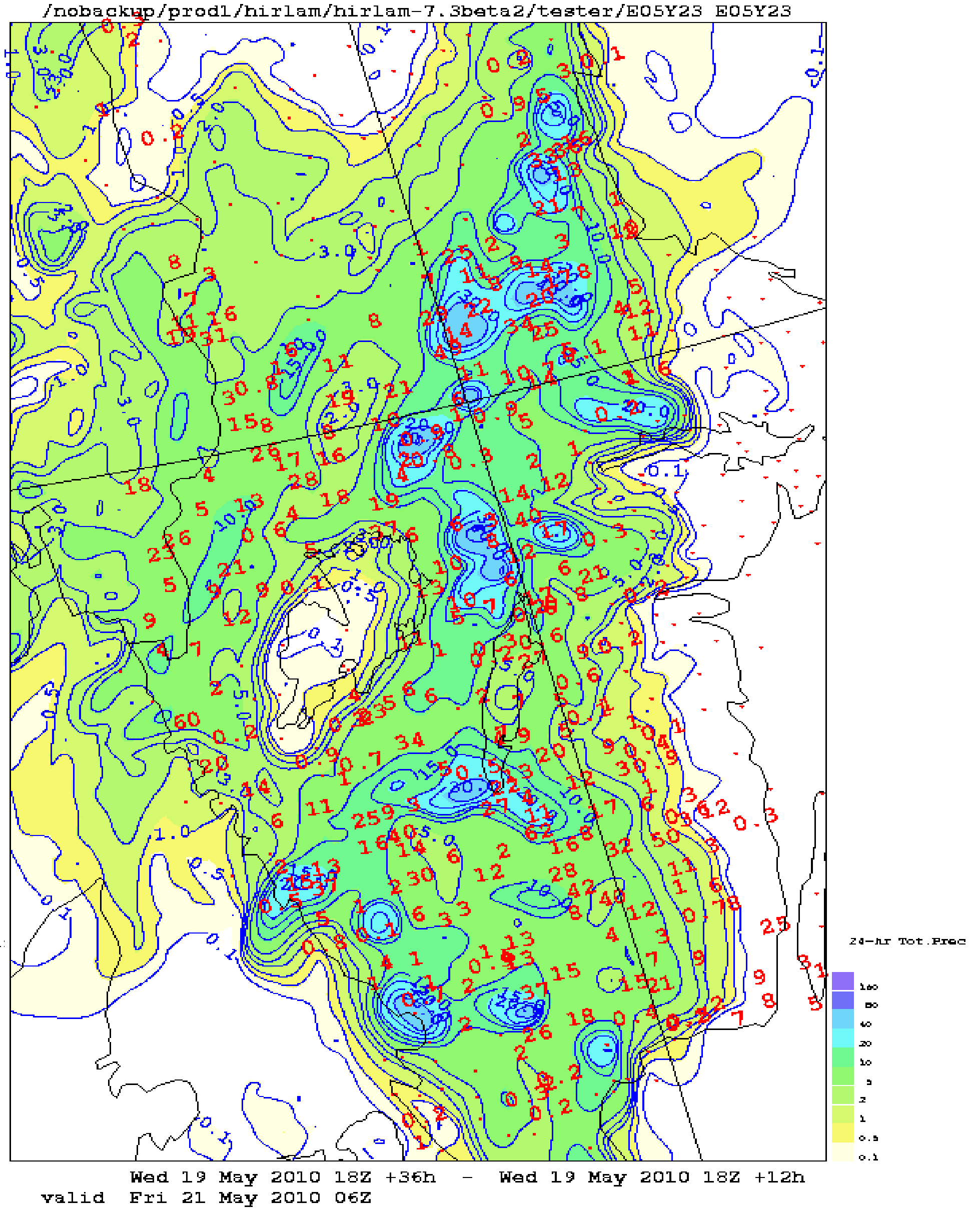

Selection: ALL using 1120 stations
Period: 20100510-20100525
Surface pressure Hours: {00,12}
RMSE Y28
RMSE Y22
BIAS Y28
BIAS Y22
CASES
hPa
1.4 1.2 1 0.8 0.6 0.4 0.2 0 -0.2 -0.4
40000 35000 30000 25000 20000 15000 10000
No cases
0 5 10 15 20 25 30 35 40
Forecast length

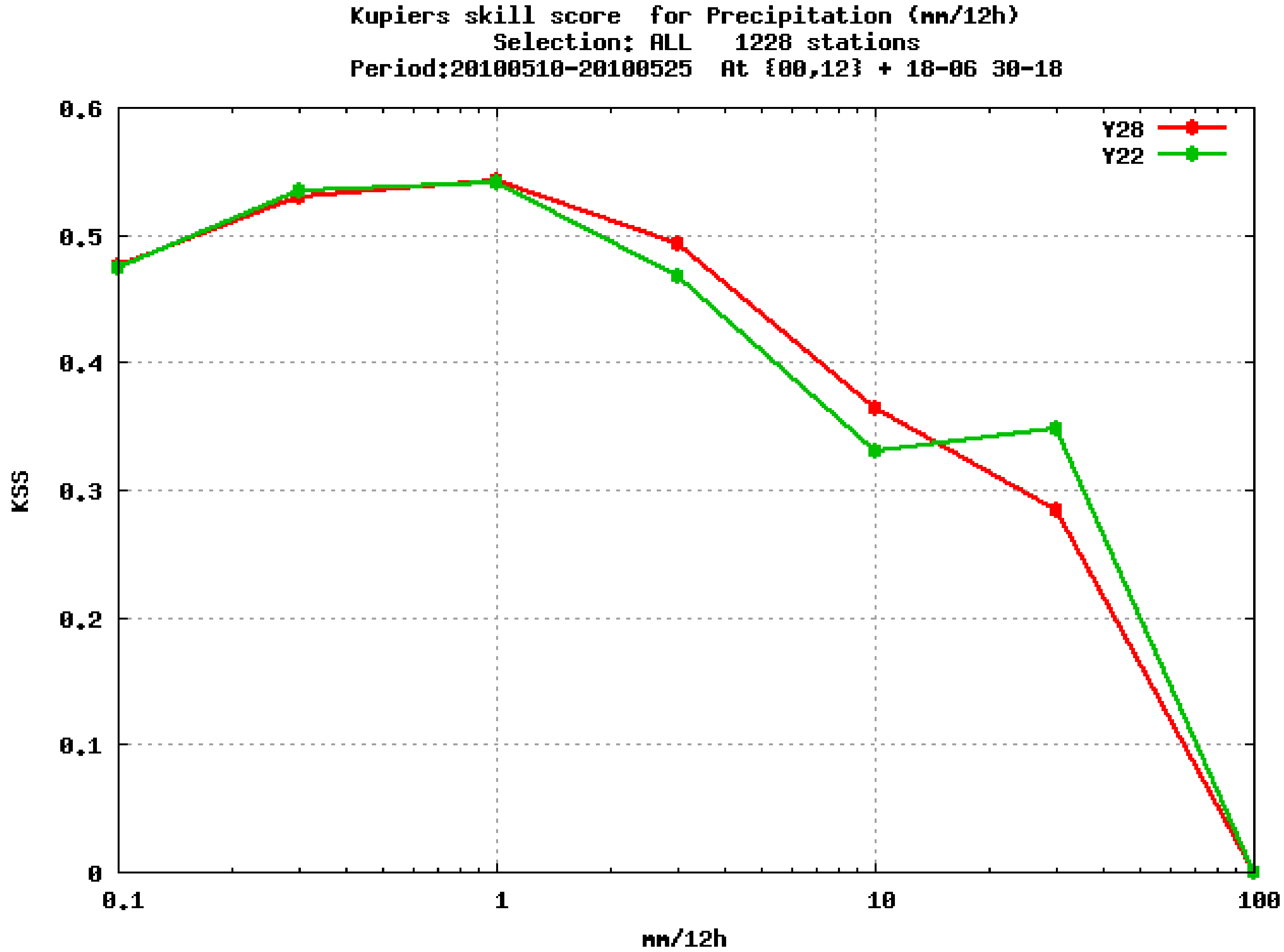

Selection: ALL using 1346 stations
Period: 20100510-20100525
Wind speed Hours: {00,12}
RMSE Y28
RMSE Y22
BIAS Y28
BIAS Y22
CASES
m/s
No cases
Forecast length
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
40000
35000
30000
25000
20000
15000
10000
0
5
10
15
20
25
30
35
40

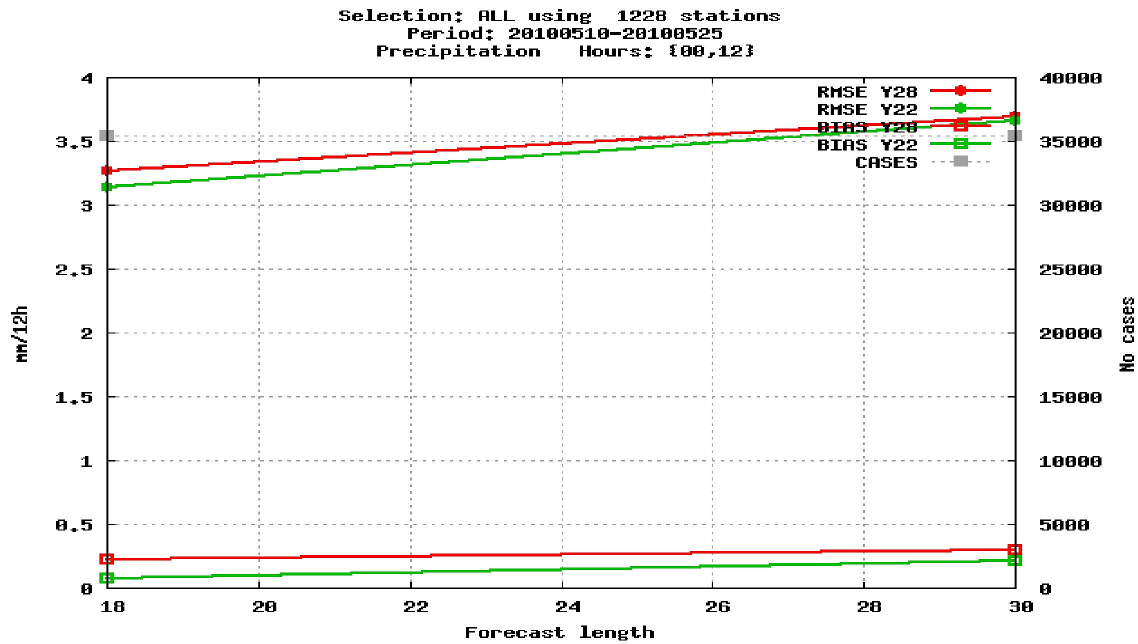

Selection: ALL using 937 stations
Period: 20100510-20100525
Cloud cover Hours: {00,12}
RMSE Y28
RMSE Y22
BIAS Y28
BIAS Y22
CASES
octas
No cases
Forecast length
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
30000
28000
26000
24000
22000
20000
18000
16000
14000
12000
10000
0
5
10
15
20
25
30
35
40

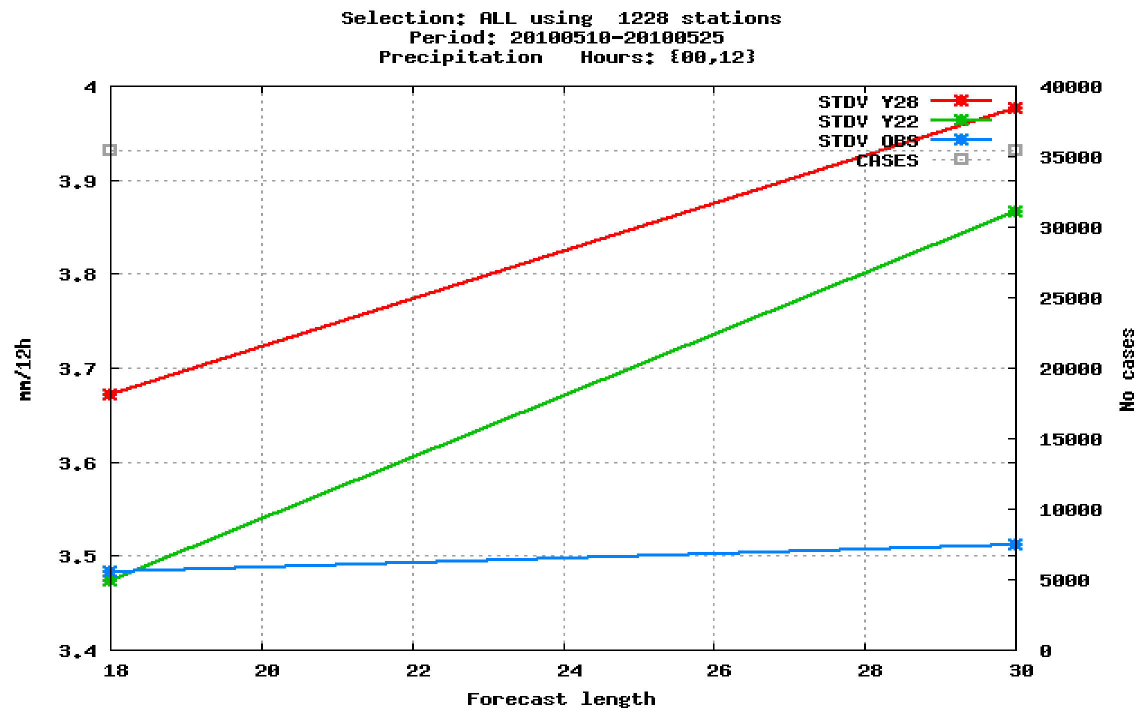
No reduction (left) , reduction (right) 5.5 km






Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 1228 stations
Period:20100510-20100525 At {00,12} + 18-06 30-18
Y28
Y22
KSS
0.6
0.5
0.4
0.3
0.2
0.1
0
0.1
1
10
100
mm/12h


Selection: ALL using 1228 stations
Period: 20100510-20100525
Precipitation Hours: {00,12}
RMSE Y28
RMSE Y22
BIAS Y28
BIAS Y22
CASES
mm/12h
No cases
Forecast length
4
3.5
3
2.5
2
1.5
1
0.5
0
18
20
22
24
26
28
30
40000
35000
30000
25000
20000
15000
10000
5000
0

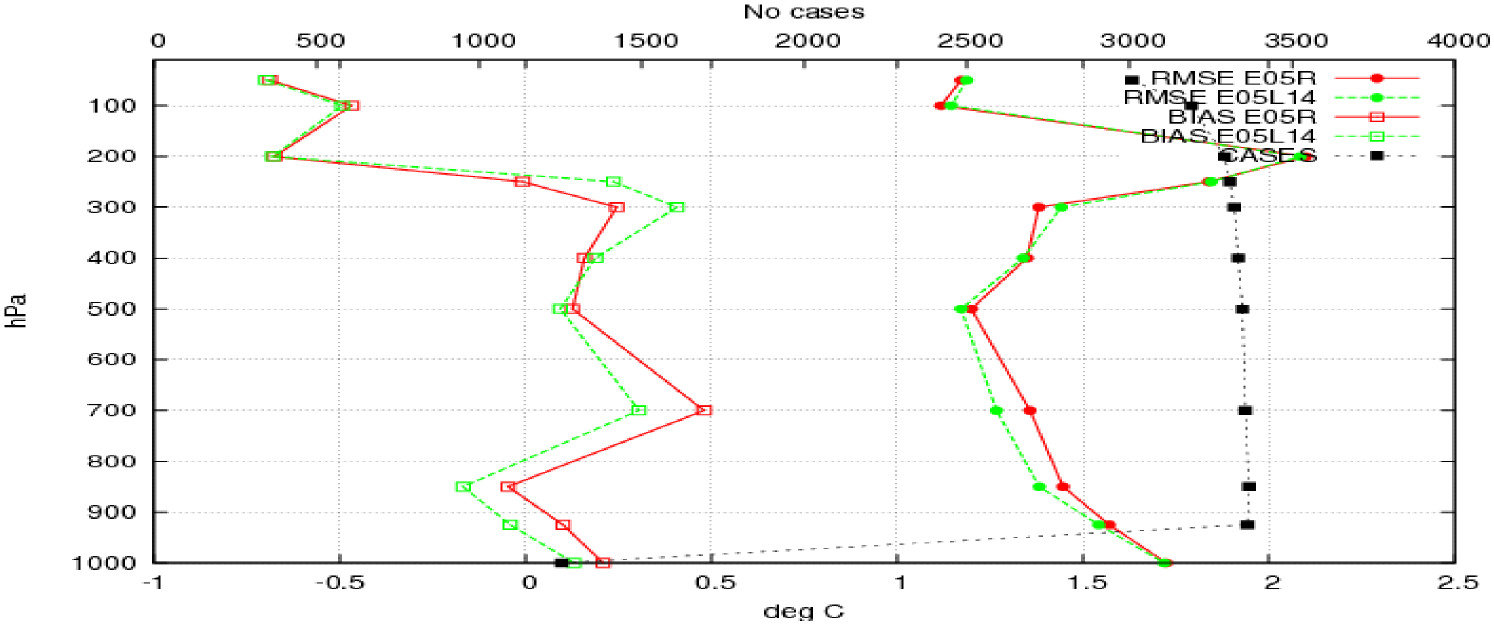

Selection: ALL using 1228 stations
Period: 20100510-20100525
Precipitation Hours: {00,12}
STDV Y28
STDV Y22
STDV OBS
CASES
mm/12h
No cases
Forecast length
4
3.9
3.8
3.7
3.6
3.5
3.4
18
20
22
24
26
28
30
40000
35000
30000
25000
20000
15000
10000
5000
0

Similar, but somewhat smaller changes for 11km resolution

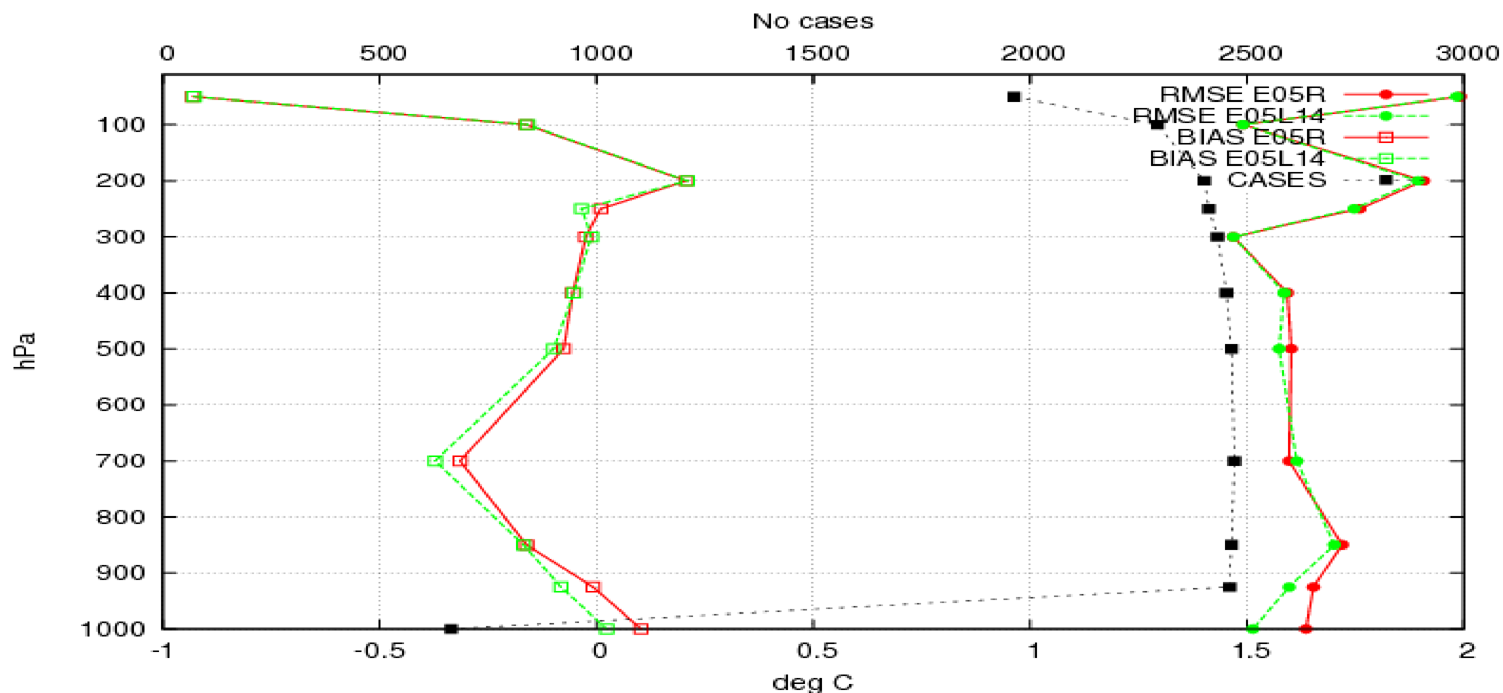
E-area 5.5 km 60 levels

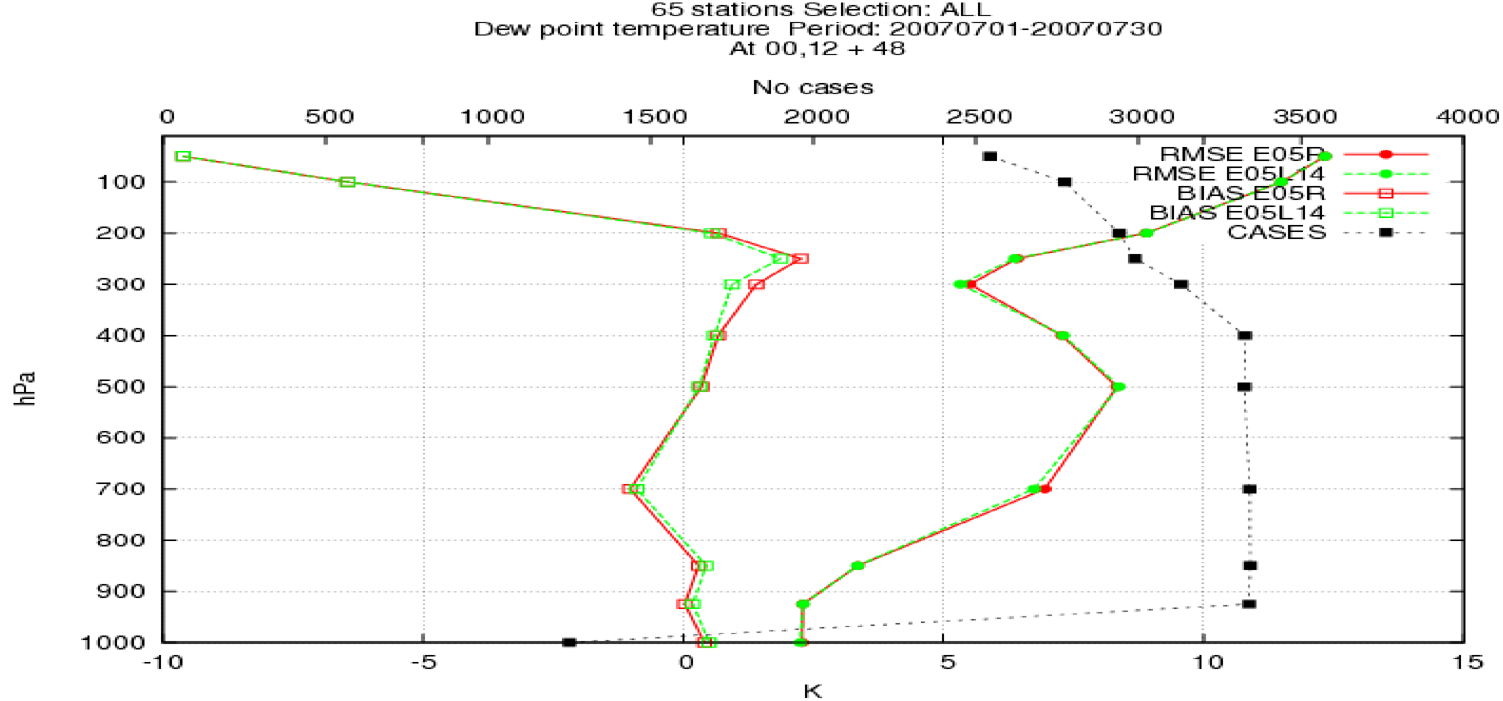
- Important that changes fit together. Here, test Liu-Penner changes together with reduction of KF activity (convective time scale) vs ref 7.3.
- Red : ref 7.3
- Green : 7.3 with Liu-Penner changes for radiation, condensation + KF.
- Top : Summer , bottom : winter

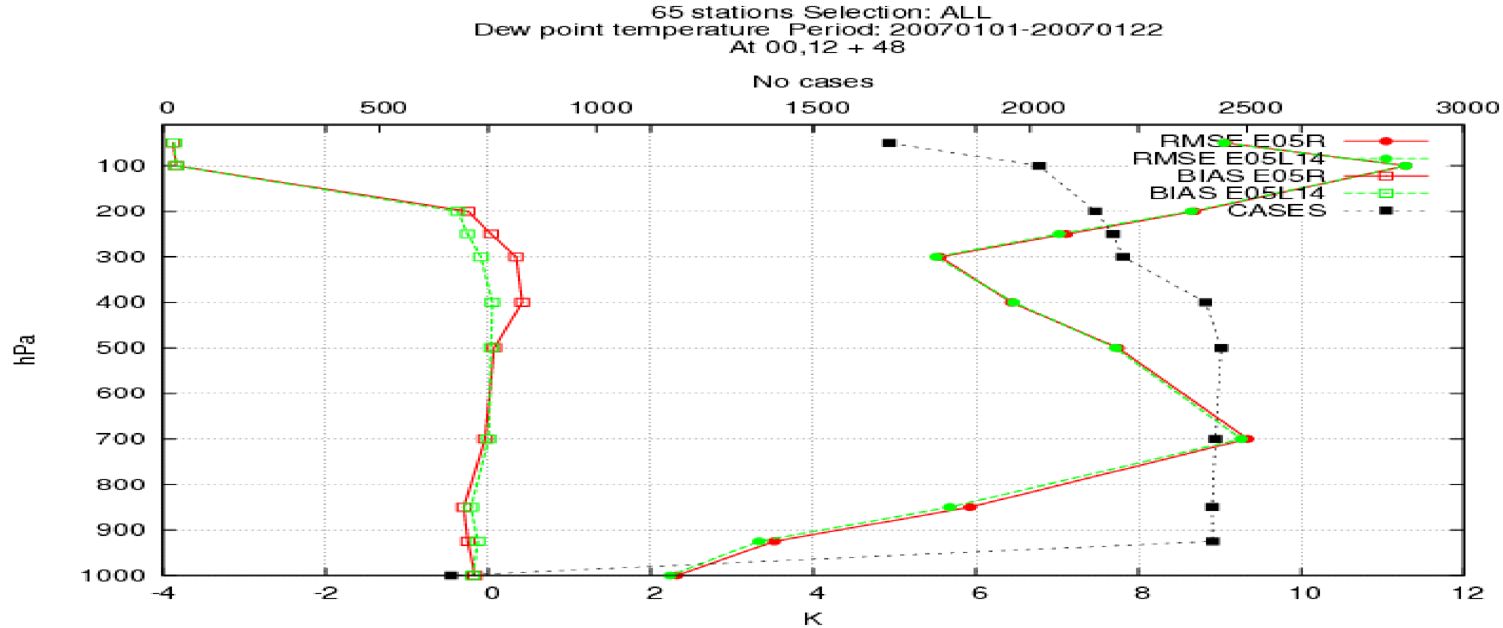
Temperature Period: 20070701-20070730
At 00,12 + 48

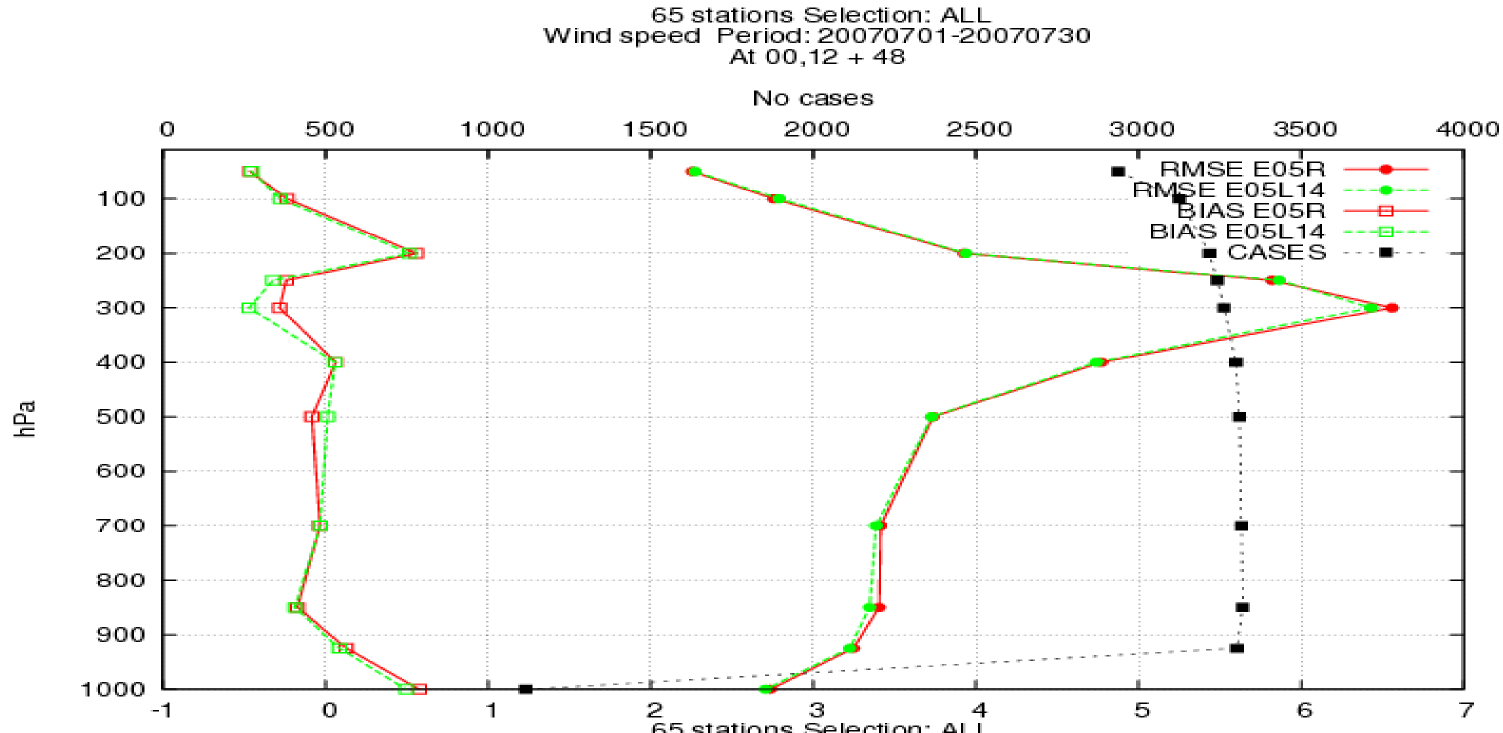


65 stations Selection: ALL
Temperature Period: 20070101-20070122
At 00,12 + 48

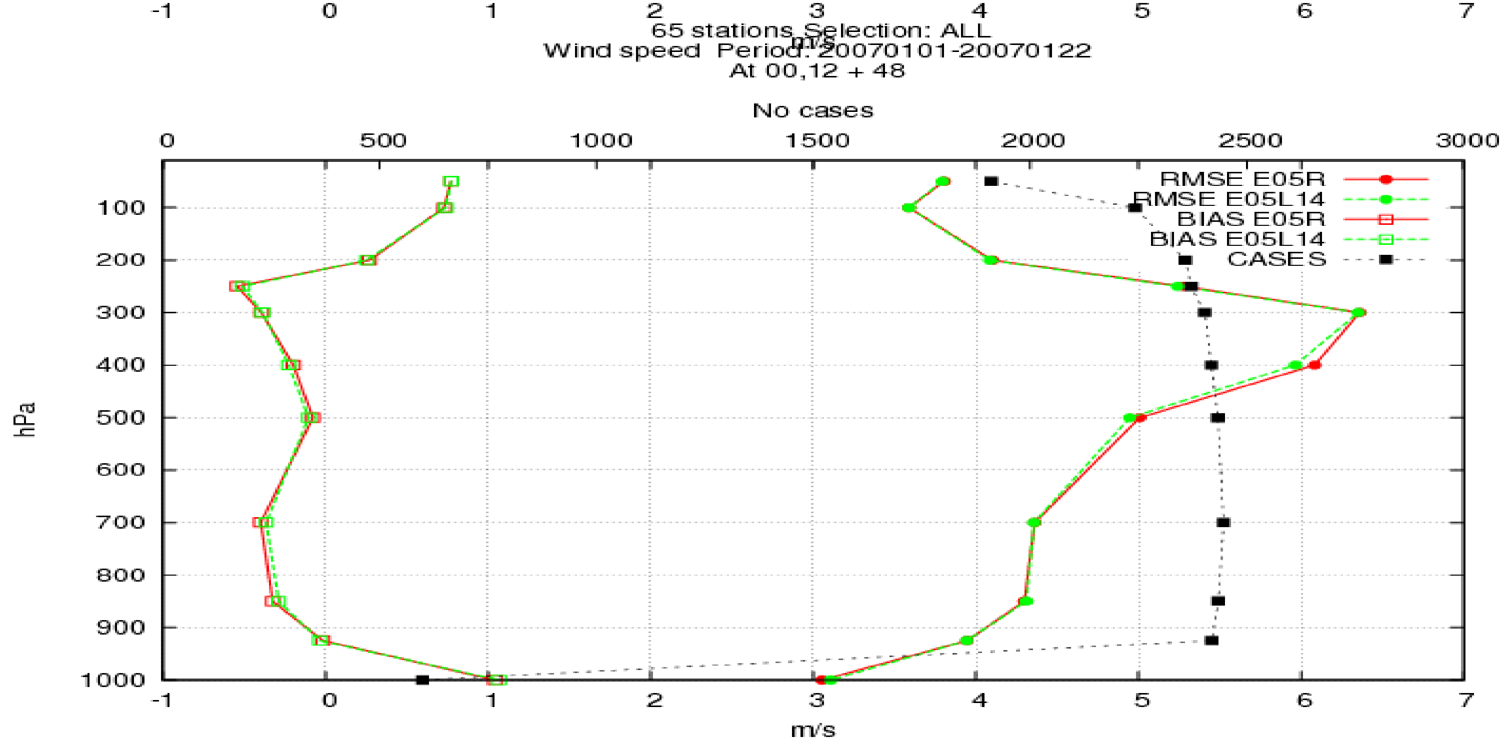



65 stations Selection: ALL
Dew point temperature Period: 20070701-20070730
At 00,12 + 48
No cases
hPa
K
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES

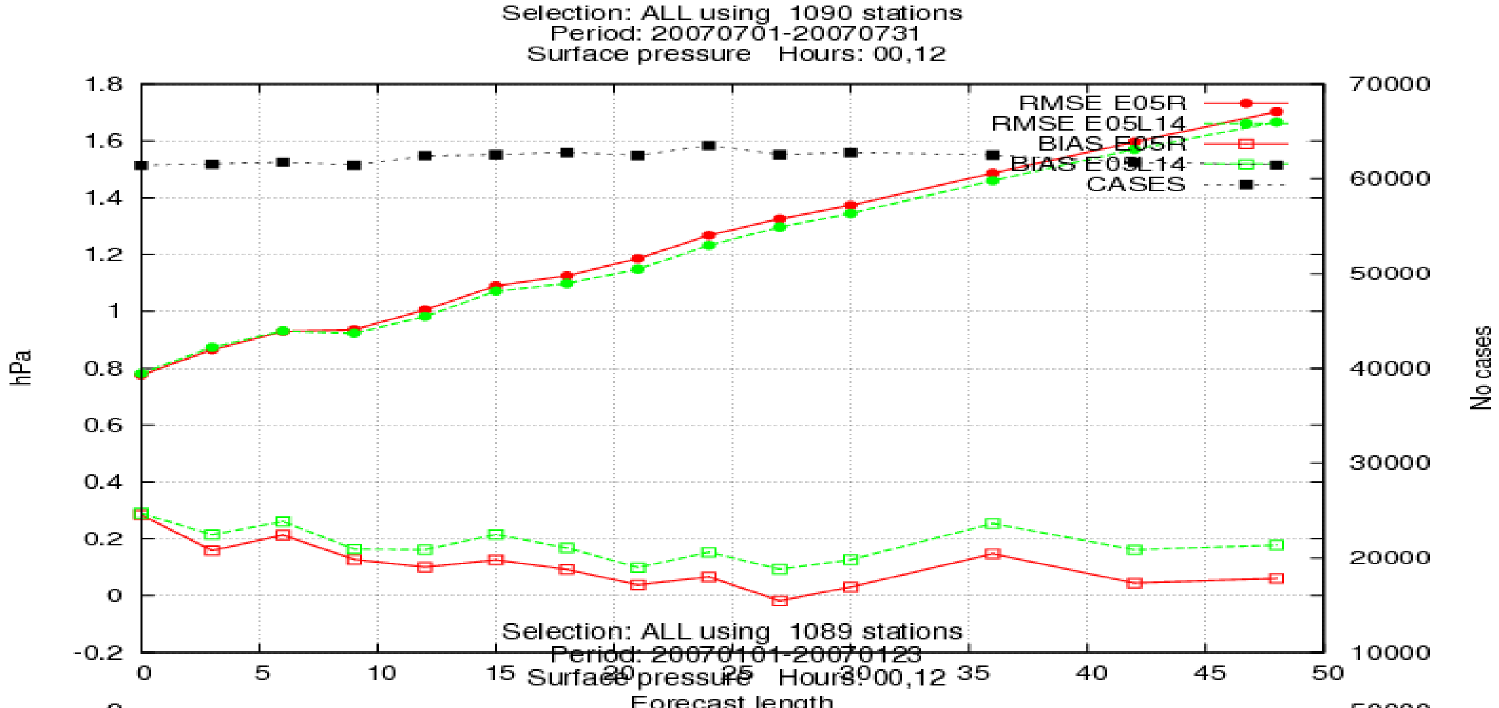

65 stations Selection: ALL
Dew point temperature Period: 20070101-20070122
At 00,12 + 48
No cases
hPa
K
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES

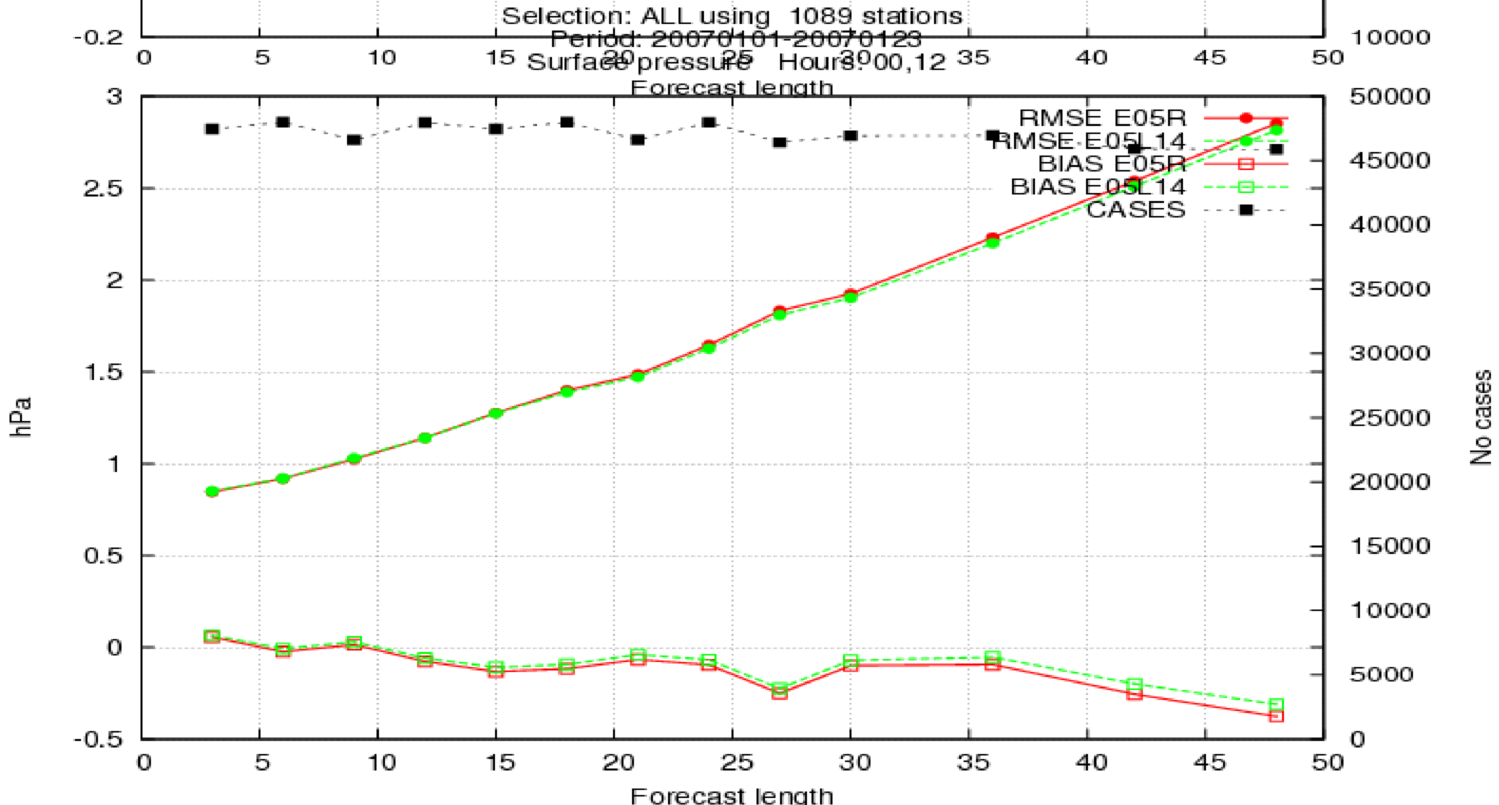


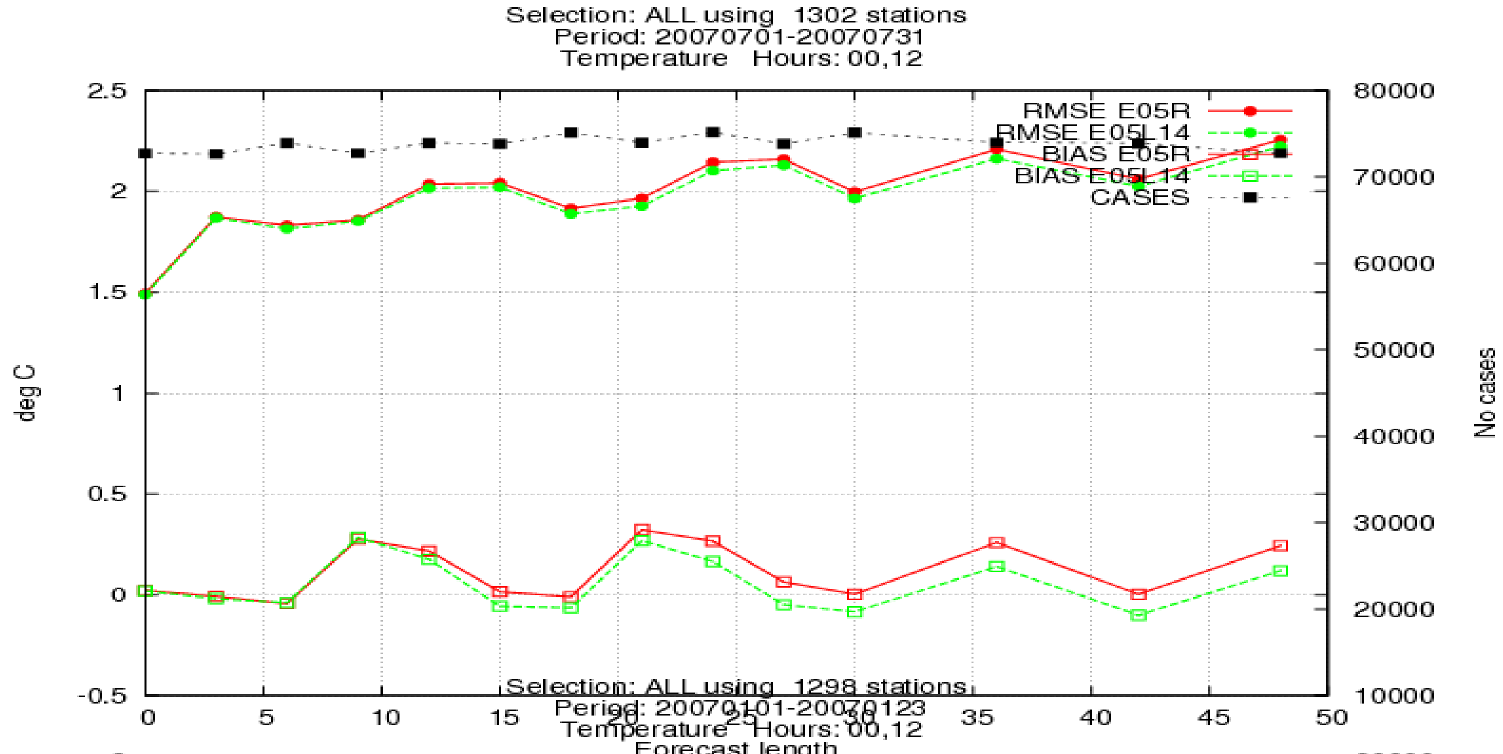
65 stations Selection: ALL
Wind speed Period: 20070701-20070730
At 00,12 + 48
No cases
hPa
m/s
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES

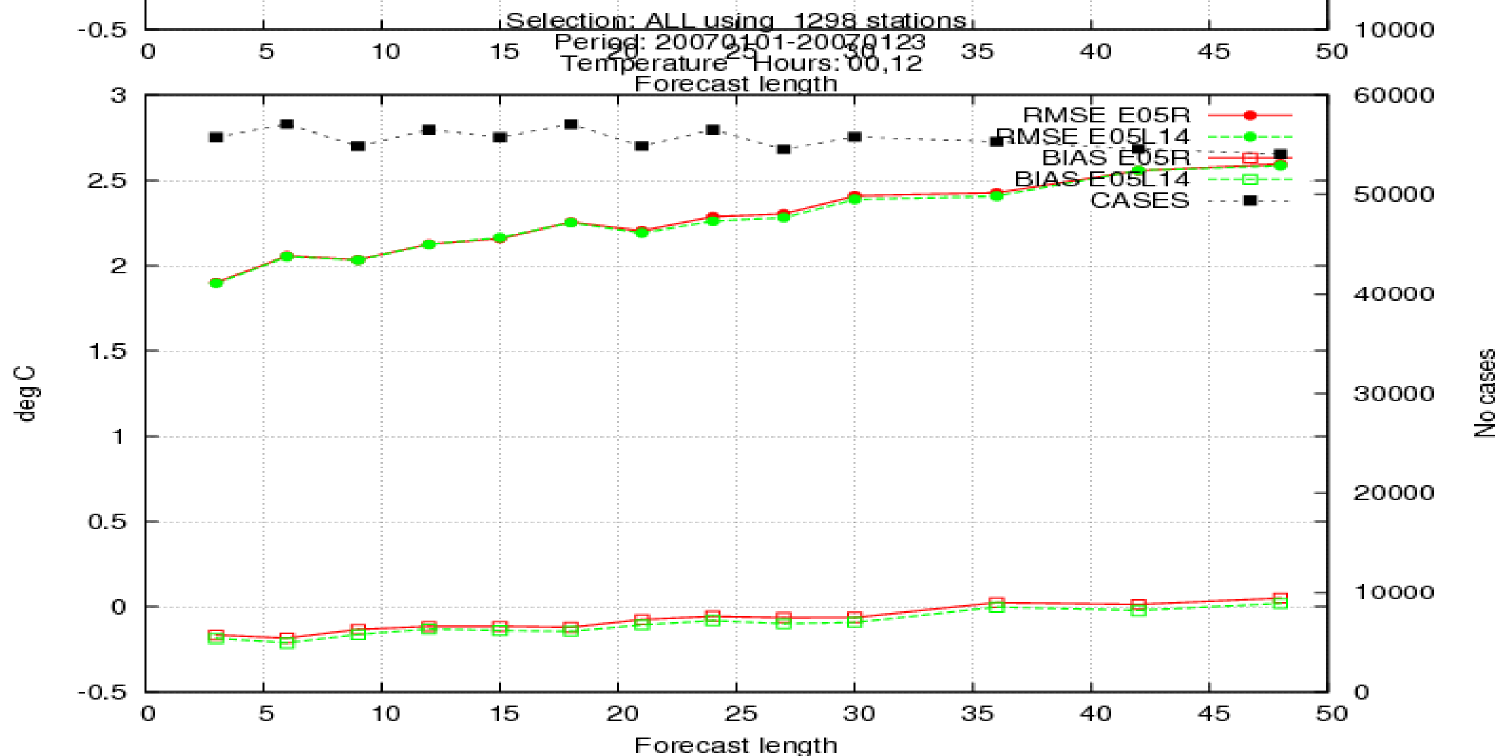


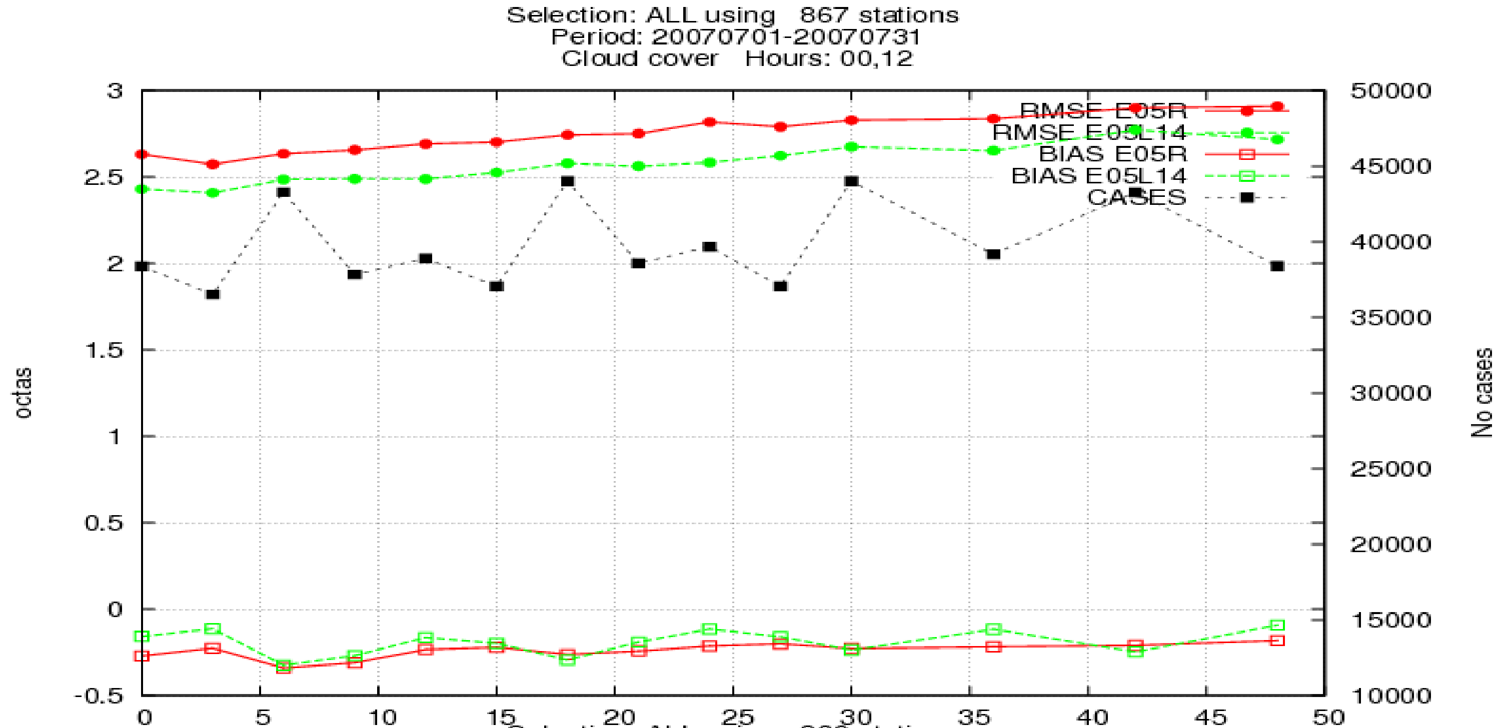
65 stations Selection: ALL
Wind speed Period: 20070101-20070122
At 00,12 + 48
No cases
hPa
m/s
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES


Selection: ALL using 1090 stations
Period: 20070701-20070731
Surface pressure Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
hPa
No cases
Forecast length

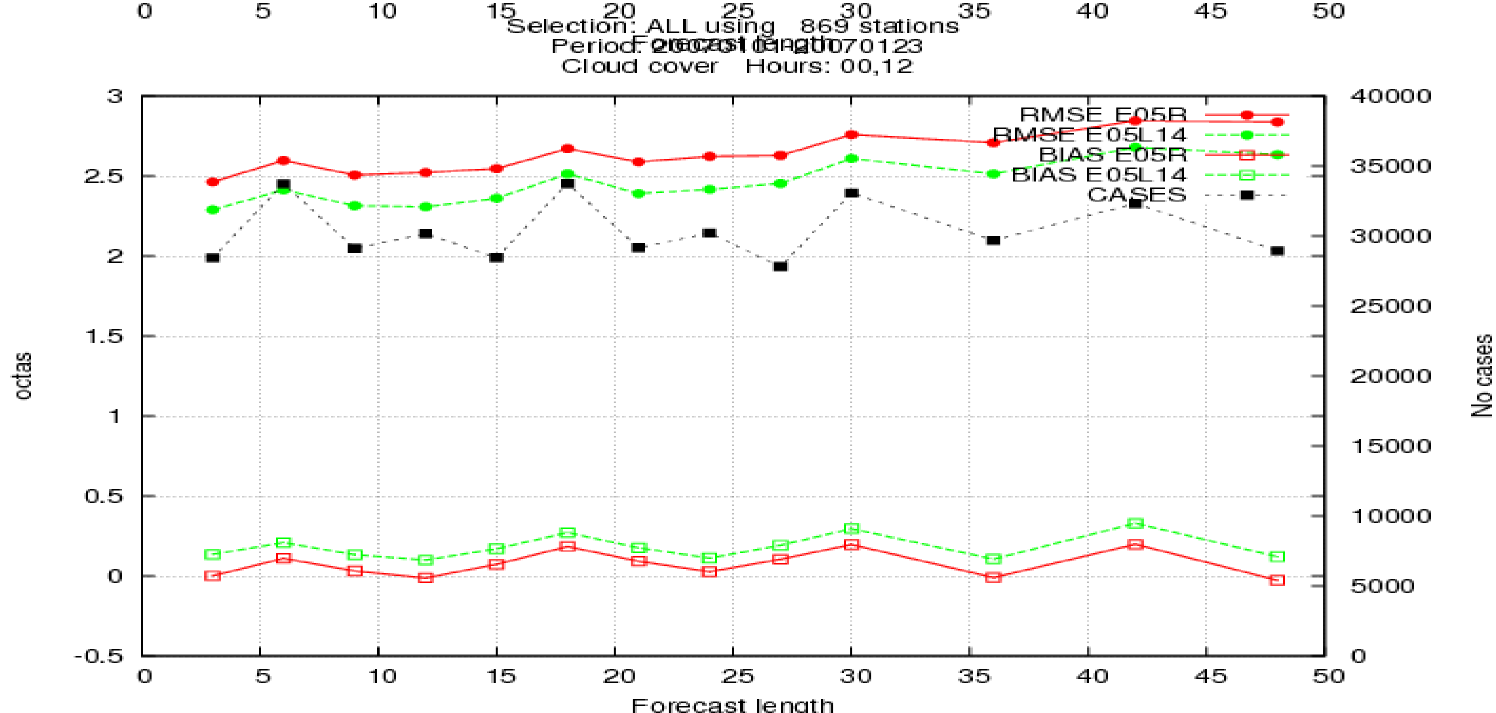

Selection: ALL using 1089 stations
Period: 20070101-20070123
Surface pressure Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
hPa
No cases
Forecast length


Selection: ALL using 1302 stations
Period: 20070701-20070731
Temperature Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
deg C
No cases
Forecast length

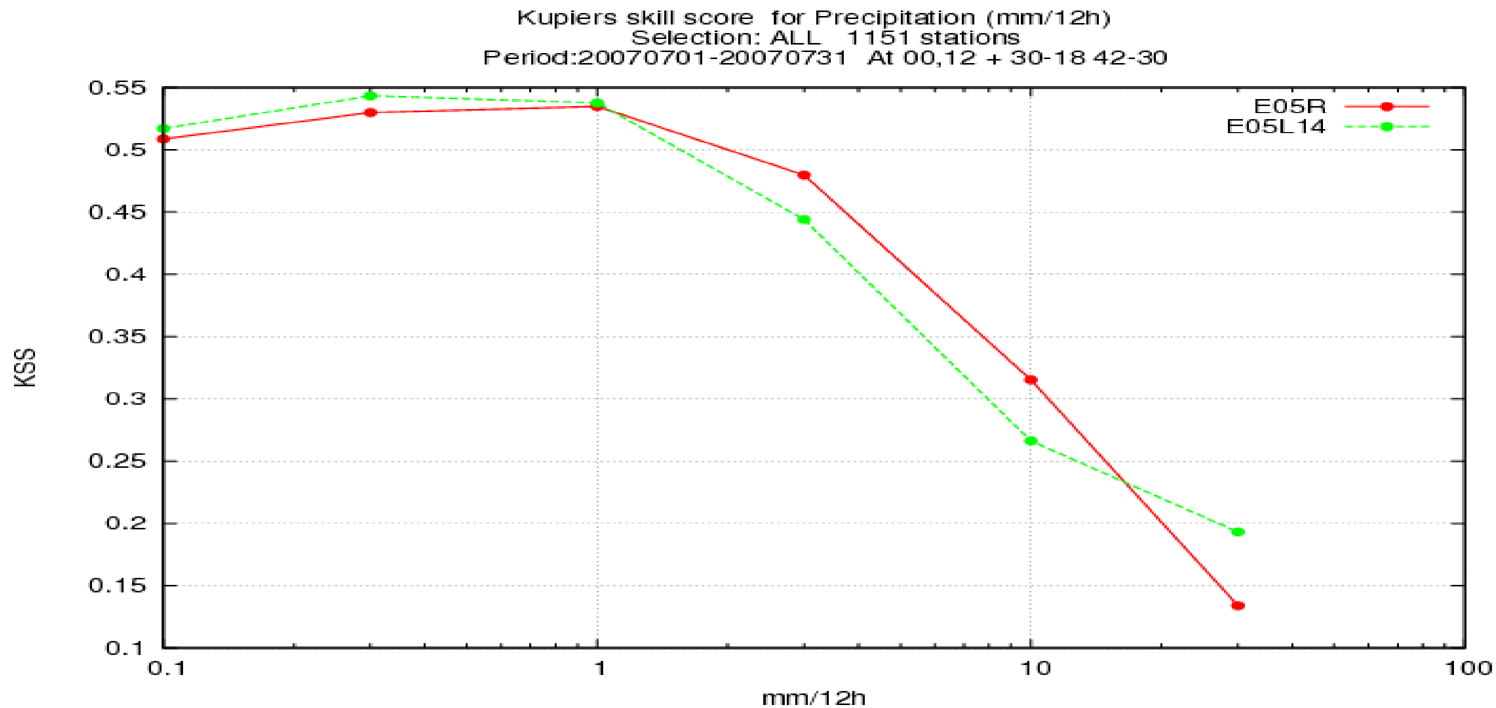

Selection: ALL using 1298 stations
Period: 20070101-20070123
Temperature Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
deg C
No cases
Forecast length

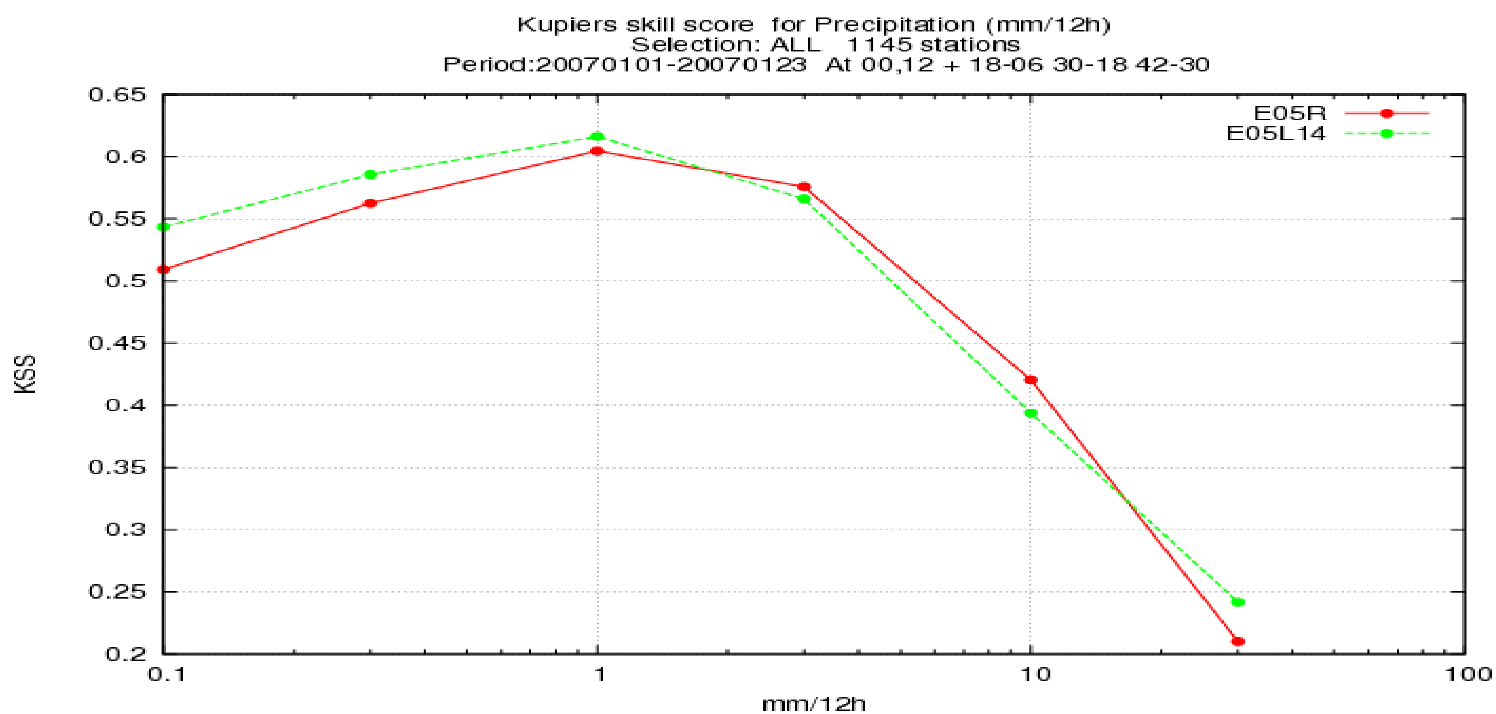


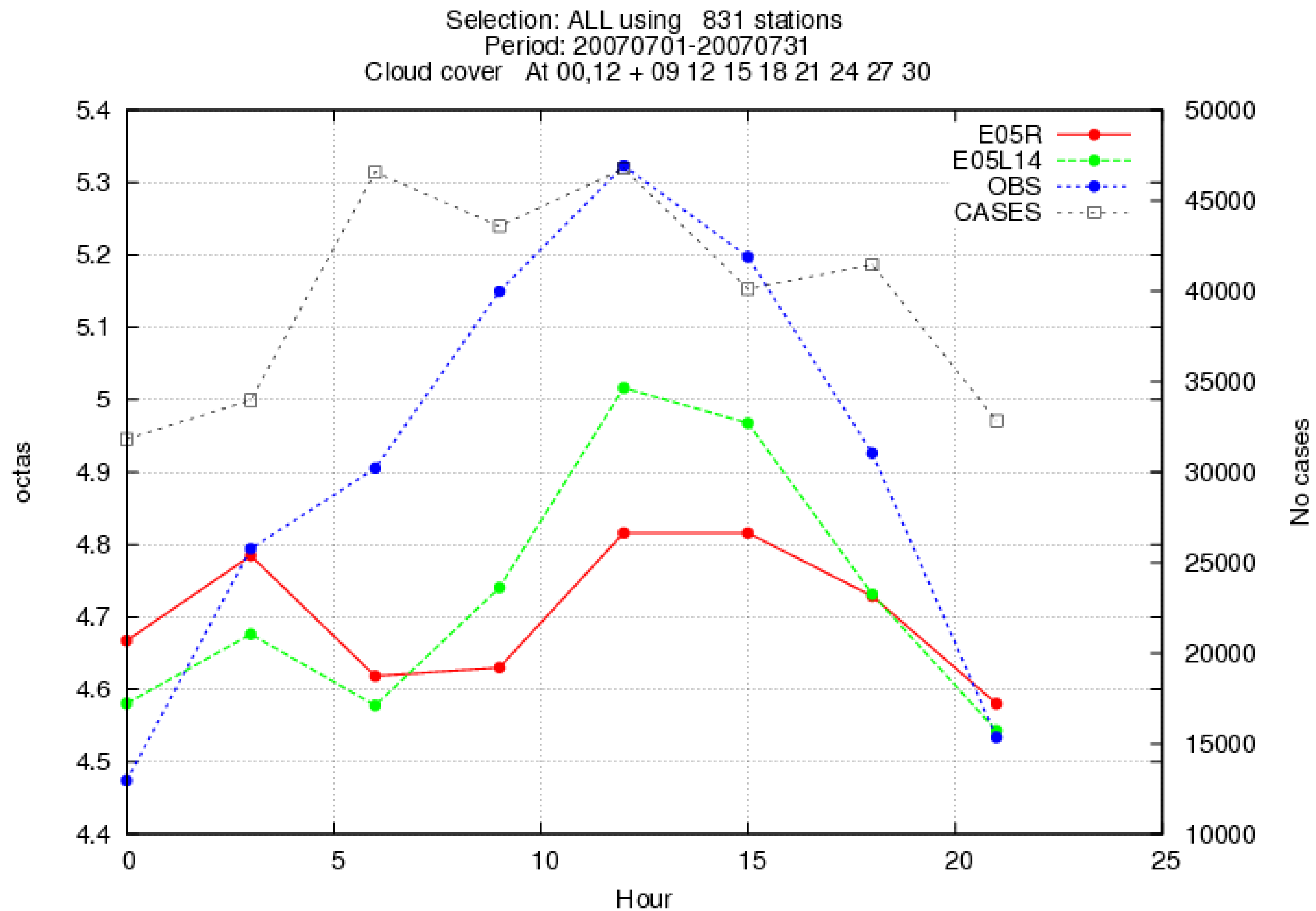
Selection: ALL using 867 stations
Period: 20070701-20070731
Cloud cover Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
octas
No cases
Forecast length



Selection: ALL using 869 stations
Period: 20070101-20070123
Cloud cover Hours: 00,12
RMSE E05R
RMSE E05L14
BIAS E05R
BIAS E05L14
CASES
octas
No cases
Forecast length


Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 1151 stations
Period:20070701-20070731 At 00,12 + 30-18 42-30
E05R
E05L14
KSS
mm/12h


Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 1145 stations
Period:20070101-20070123 At 00,12 + 18-06 30-18 42-30
E05R
E05L14
KSS
mm/12h


Selection: ALL using 831 stations
Period: 20070701-20070731
Cloud cover At 00,12 + 09 12 15 18 21 24 27 30
E05R
E05L14
OBS
CASES
octas
No cases
Hour
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
50000
45000
40000
35000
30000
25000
20000
15000
10000
0
5
10
15
20
25

Discussion and conclusions

- KF activity reduction for high horizontal resolution gives a little better temperatures at 700 Hpa in summer and a little lower RMSE of mslp pressure. Little lower wind speed near ground in summer.
- Liu-Penner parametrization for cloud ice microphysics lower RMS-error of cloudiness. Somewhat better diurnal cycle of cloudiness in summer. A little lower temperature over whole troposphere, except very near ground in winter. Other effect mainly small.
- Liu-Penner parametrization for radiation properties of cloud ice gives a little warmer temperatures over whole troposphere.
- Together, those temperature changes are counteracting each other.
- All three changes seems so far fit well together, at least for around 5 km resolution, 60 levels, so worth testing for 7.4. (65 levels)
- LP parametrization could have some potential to improve Alaro's ice microphysics, perhaps also the ICE3.

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

Extra slides follows ...

Other updates (for condensation dependence of CCN , IN)

- 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

Collection of cloud water by rain, original bulk formula :

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

New (Rogers and Yau , 1989)

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

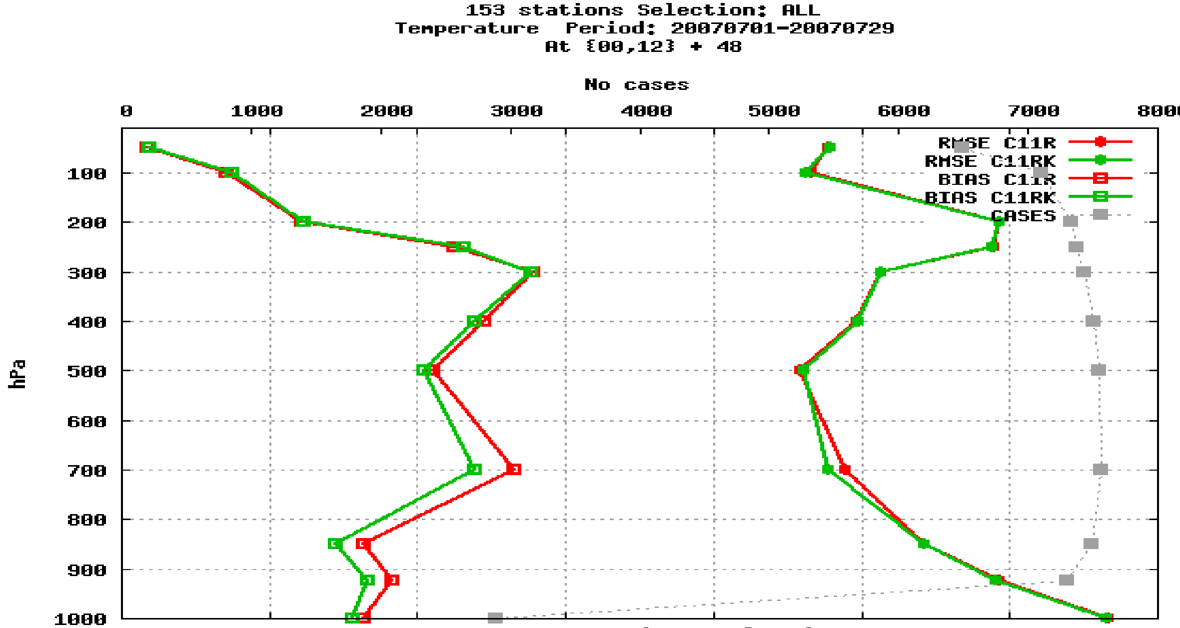
Here, C_{racw} = constant dependent on microphysics, etc E_{rw} = collision efficiency , function of drop radius :

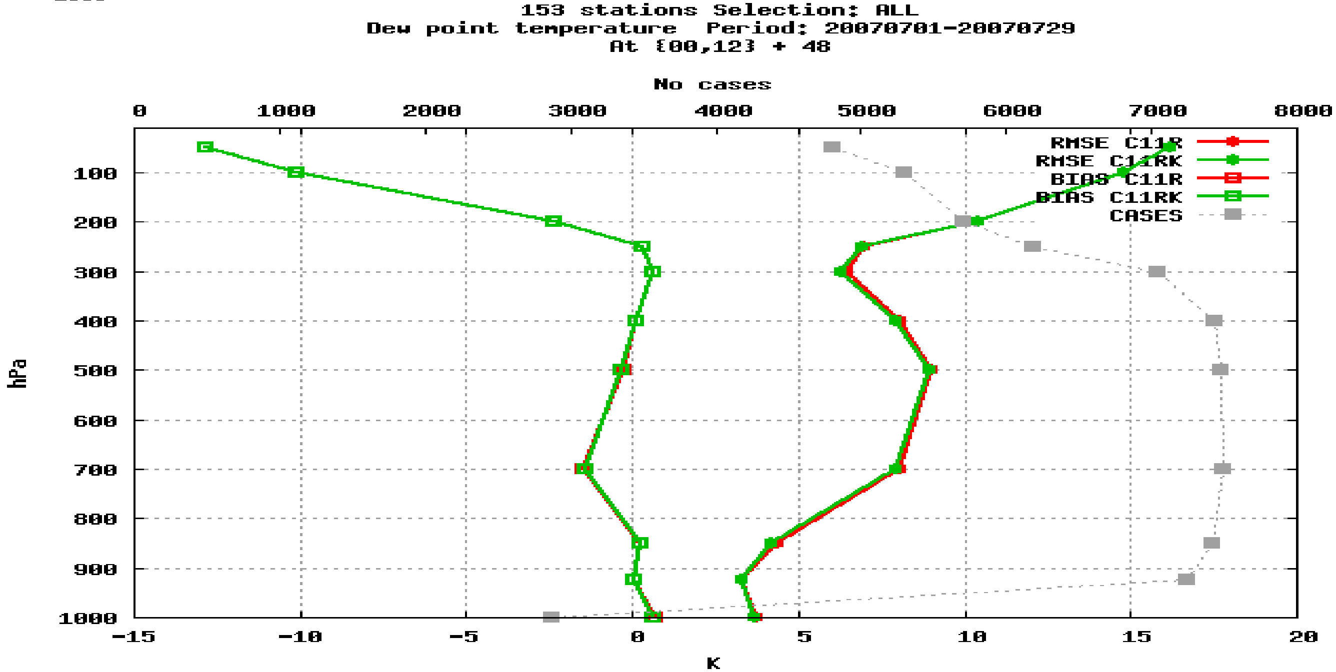
$$E_{rw} = \frac{e^{Ar} - 1}{e^{Ar} + 1} \tag{5}$$

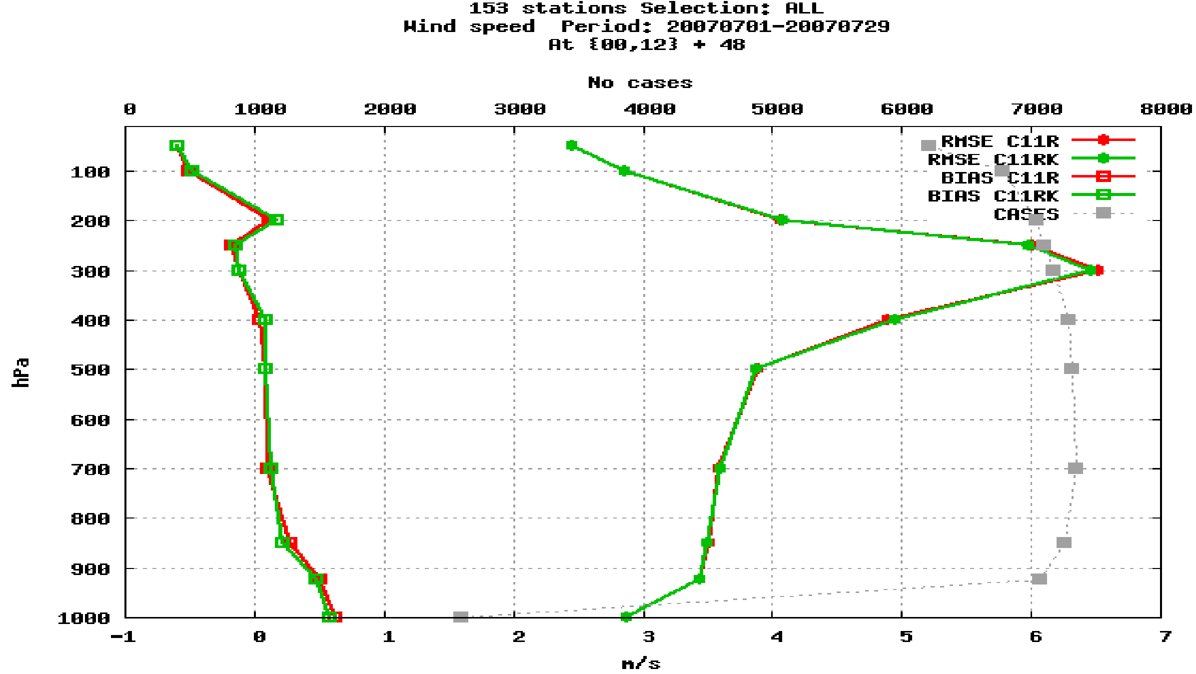
$A = 2.5x10^5$, r = mean cloud droplet radius, m

RK reduction 11 km

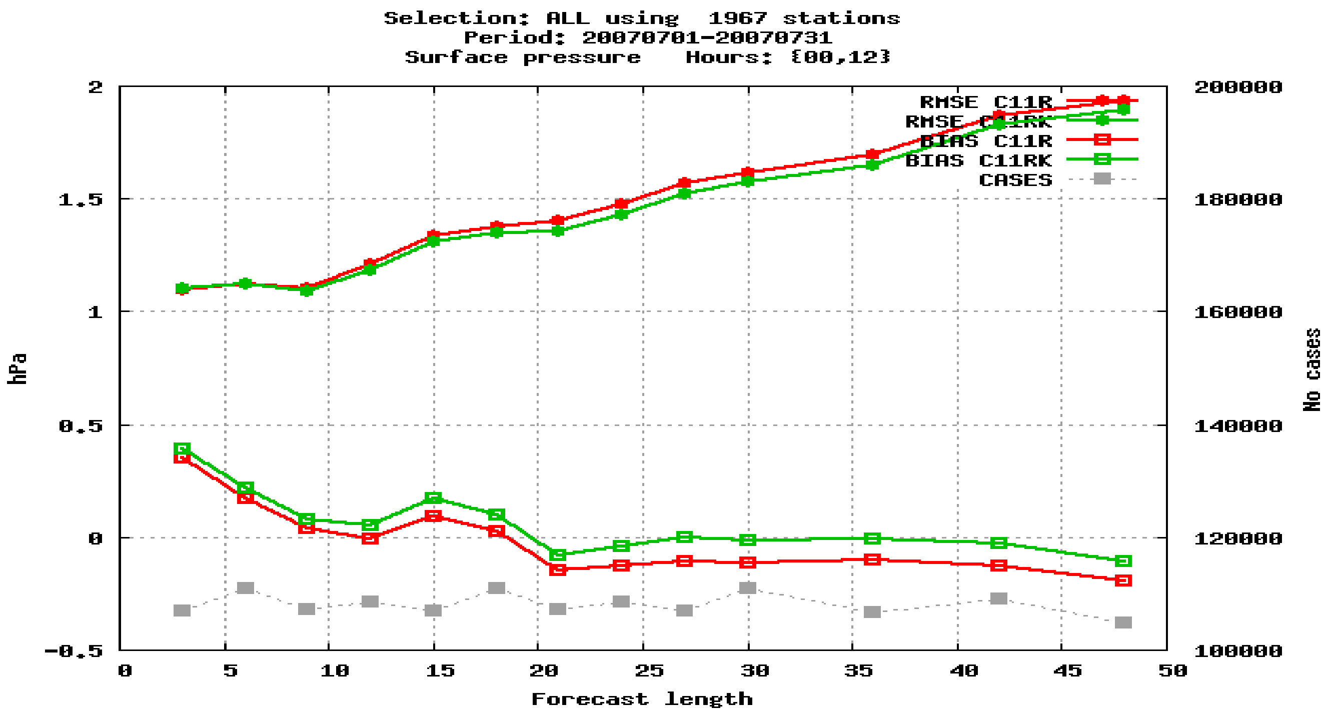
11 km 2007-07 C-area



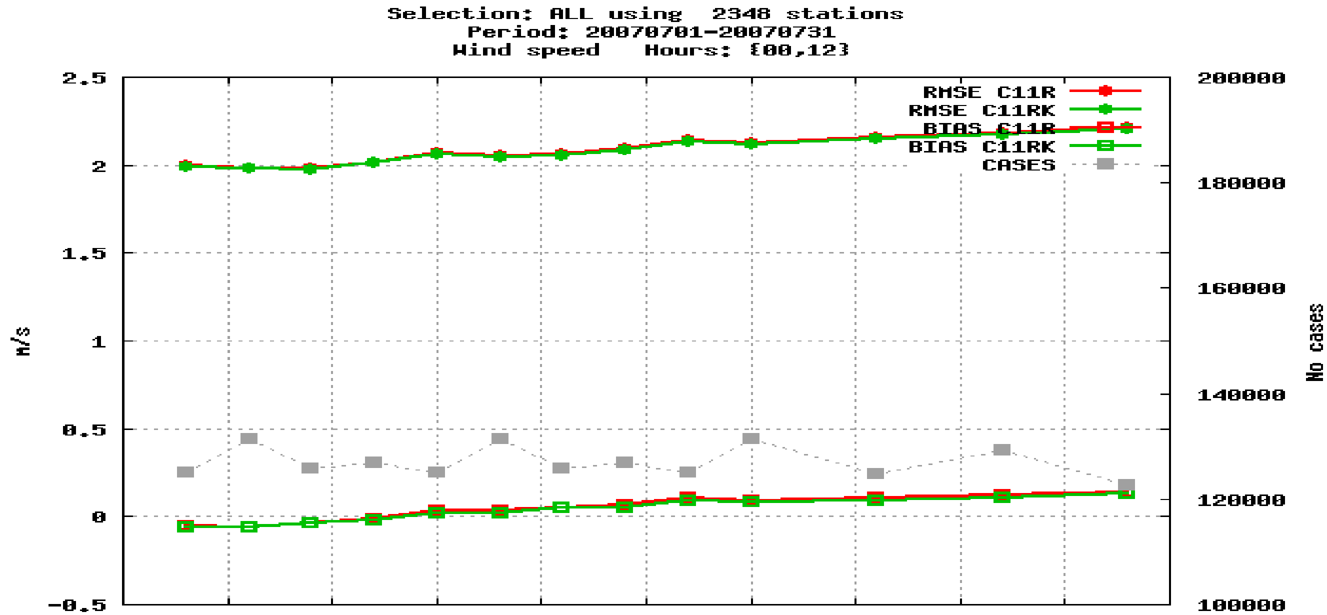




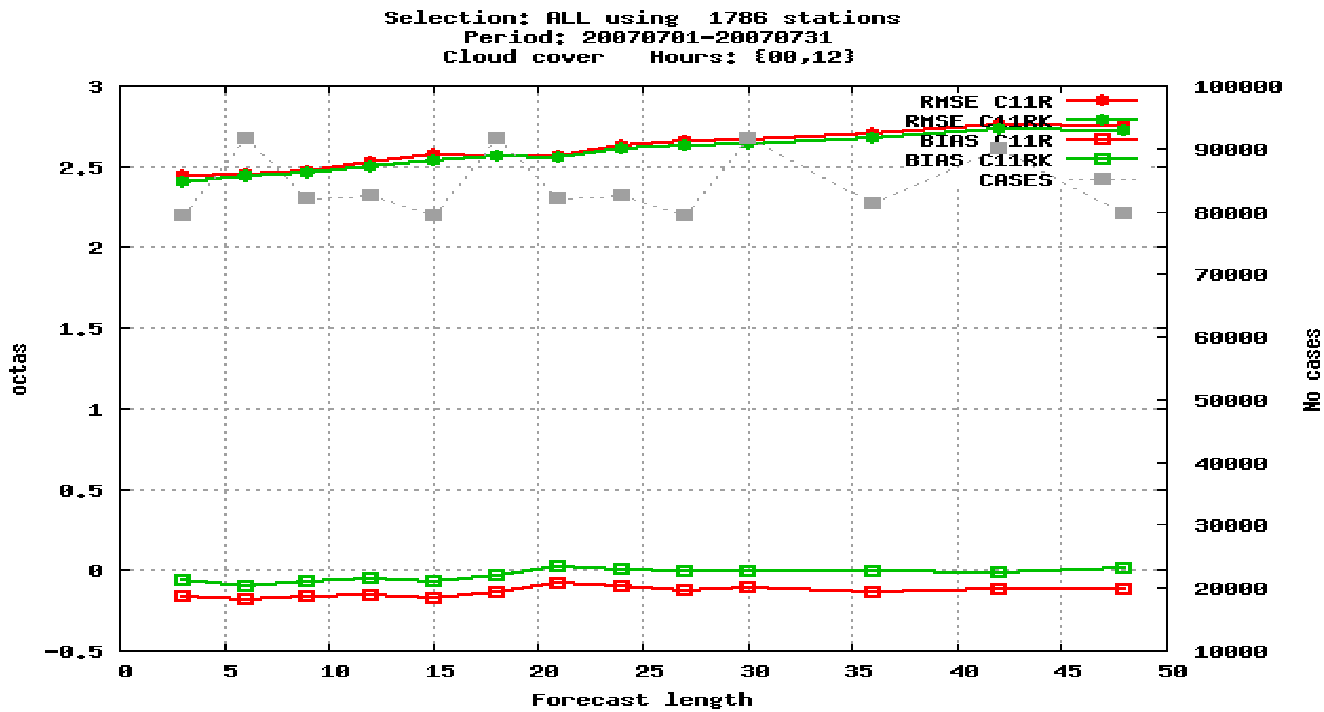
153 stations Selection: ALL
Wind speed Period: 20070701-20070729
At {00,12} + 48
No cases
0 1000 2000 3000 4000 5000 6000 7000 8000
RMSE C11R
RMSE C11RK
BIAS C11R
BIAS C11RK
CASES
100 200 300 400 500 600 700 800 900 1000
hPa
-1 0 1 2 3 4 5 6 7
m/s



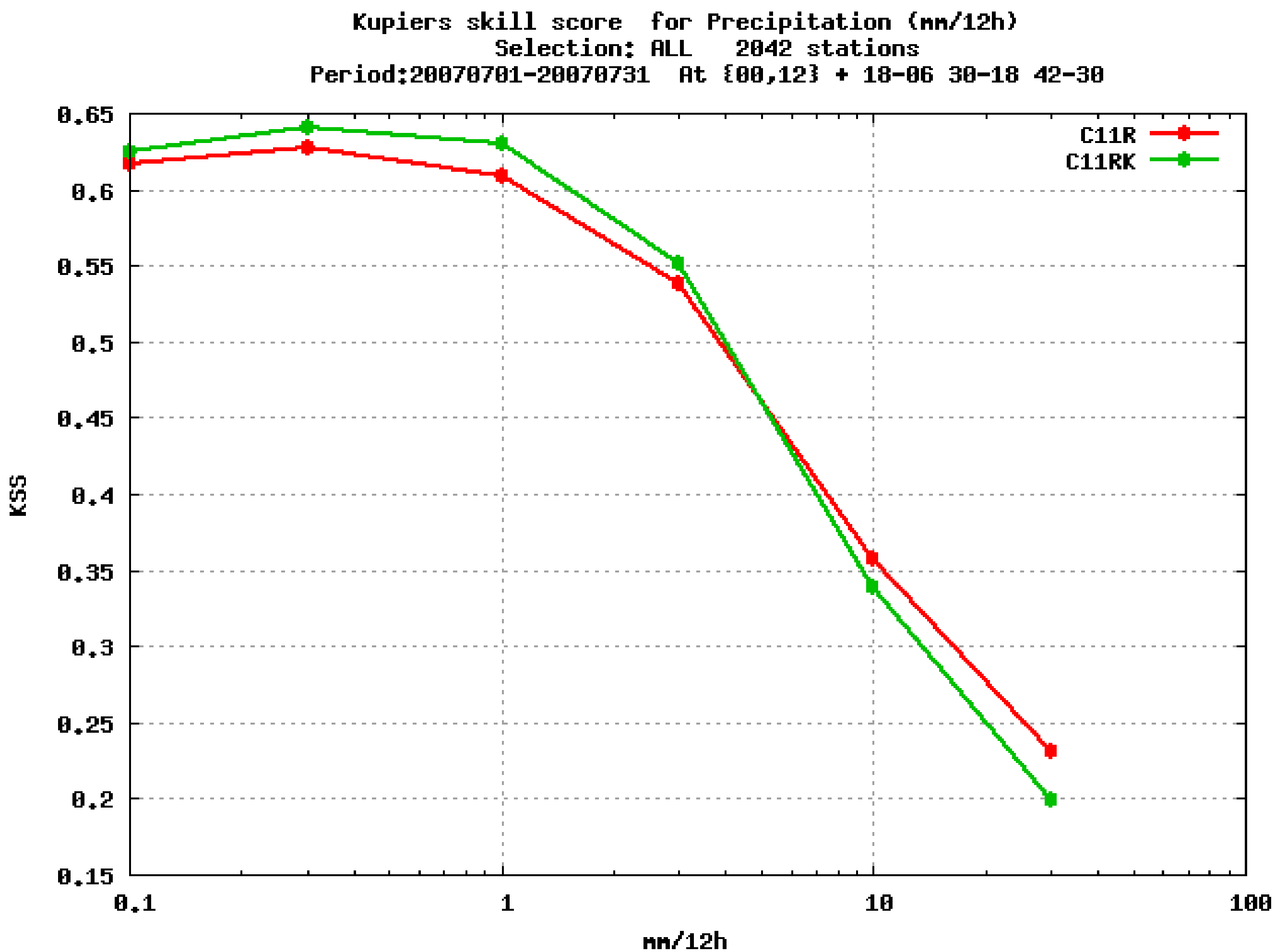
Selection: ALL using 1967 stations
Period: 20070701-20070731
Surface pressure Hours: {00,12}
RMSE C11R
RMSE C11RK
BIAS C11R
BIAS C11RK
CASES
2 1.5 1 0.5 0 -0.5
hPa
200000 180000 160000 140000 120000 100000
No cases
0 5 10 15 20 25 30 35 40 45 50
Forecast length

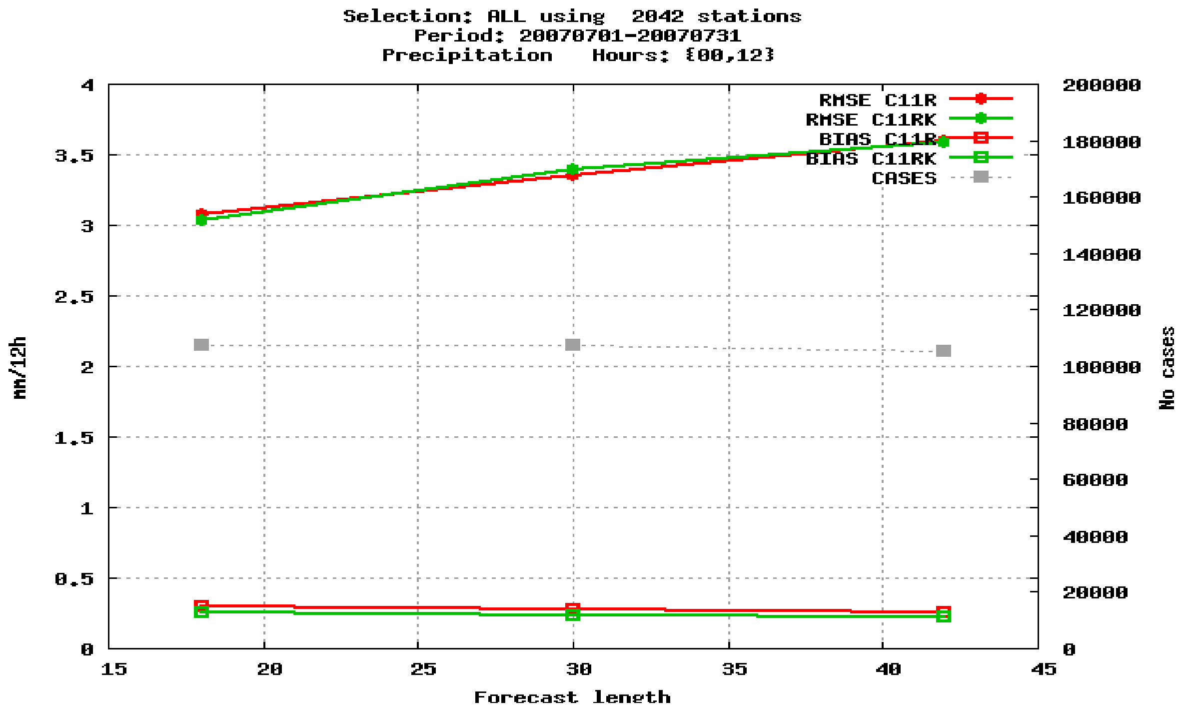


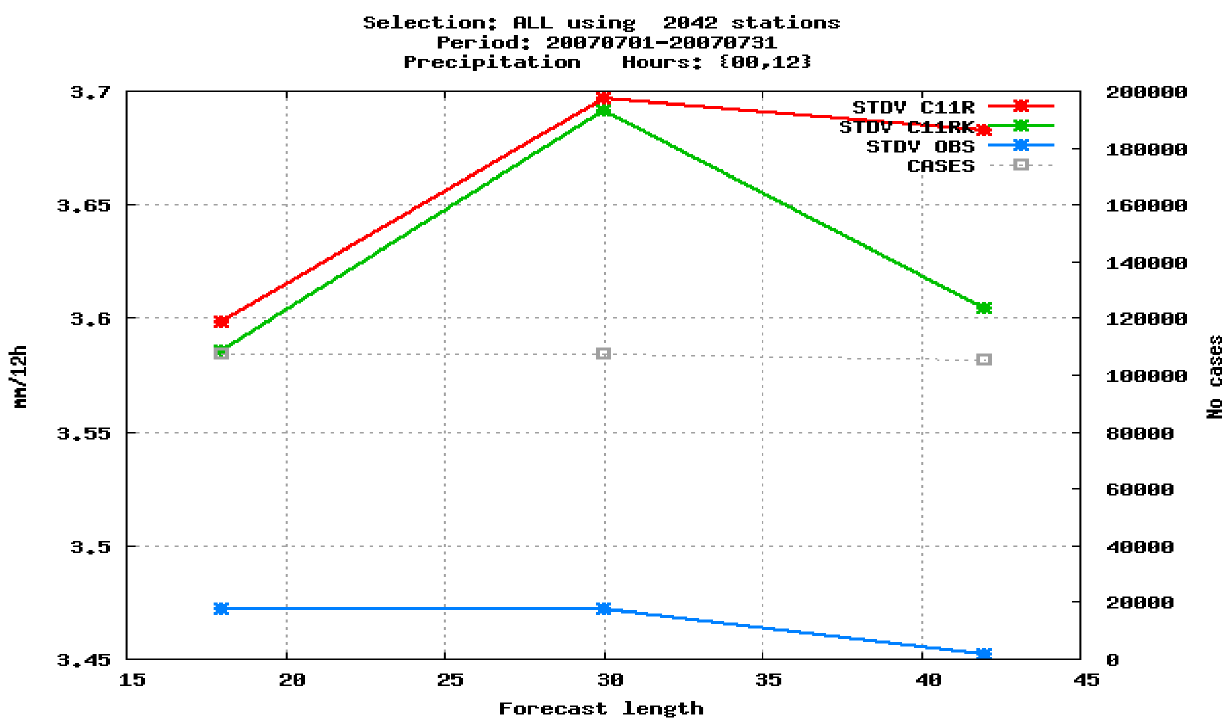
Selection: ALL using 2348 stations
Period: 20070701-20070731
Wind speed Hours: {00,12}
m/s
No cases
RMSE C11R
RMSE C11RK
BIAS C11R
BIAS C11RK
CASES
2.5
2
1.5
1
0.5
0
-0.5
200000
180000
160000
140000
120000
100000



Selection: ALL using 1786 stations
Period: 20070701-20070731
Cloud cover Hours: {00,12}
octas
No cases
RMSE C11R
RMSE C11RK
BIAS C11R
BIAS C11RK
CASES
3
2.5
2
1.5
1
0.5
0
-0.5
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
5
10
15
20
25
30
35
40
45
50
Forecast length

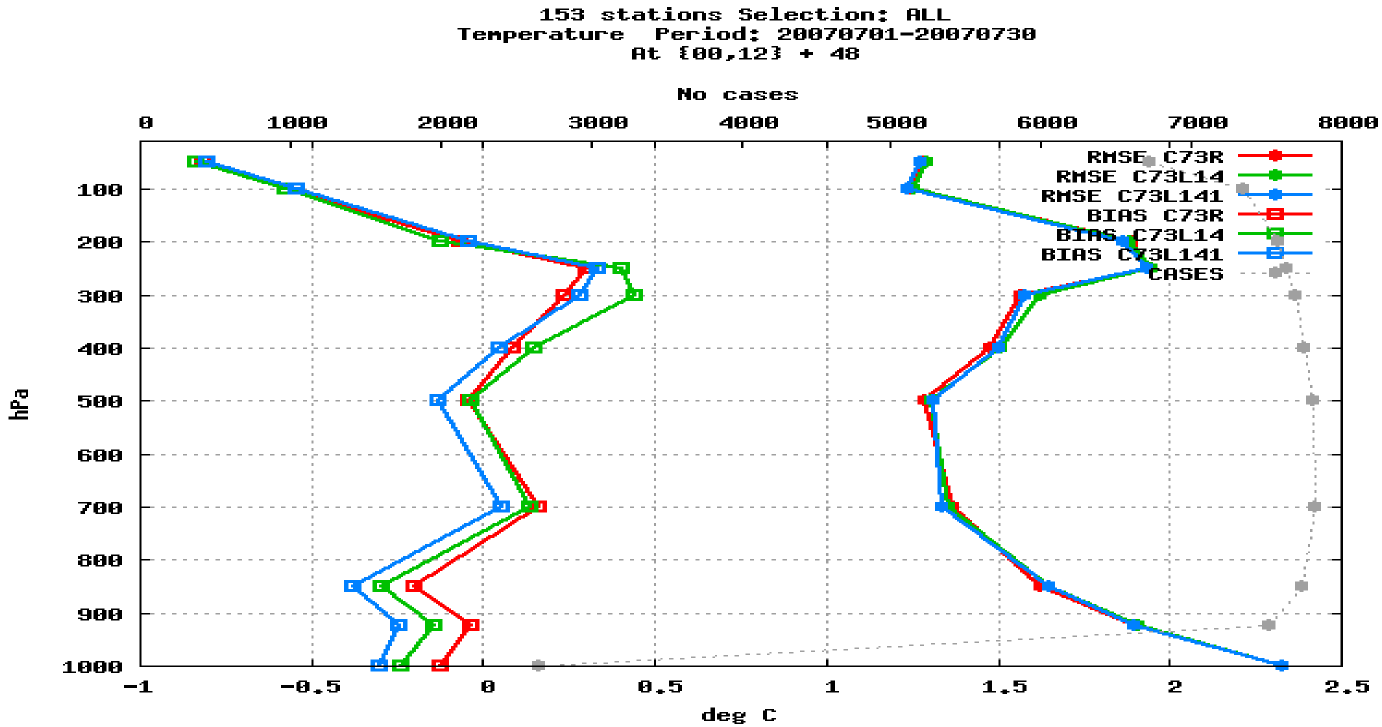

Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 2042 stations
Period:20070701-20070731 At {00,12} + 18-06 30-18 42-30
C11R
C11RK
KSS
mm/12h
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
1
10
100

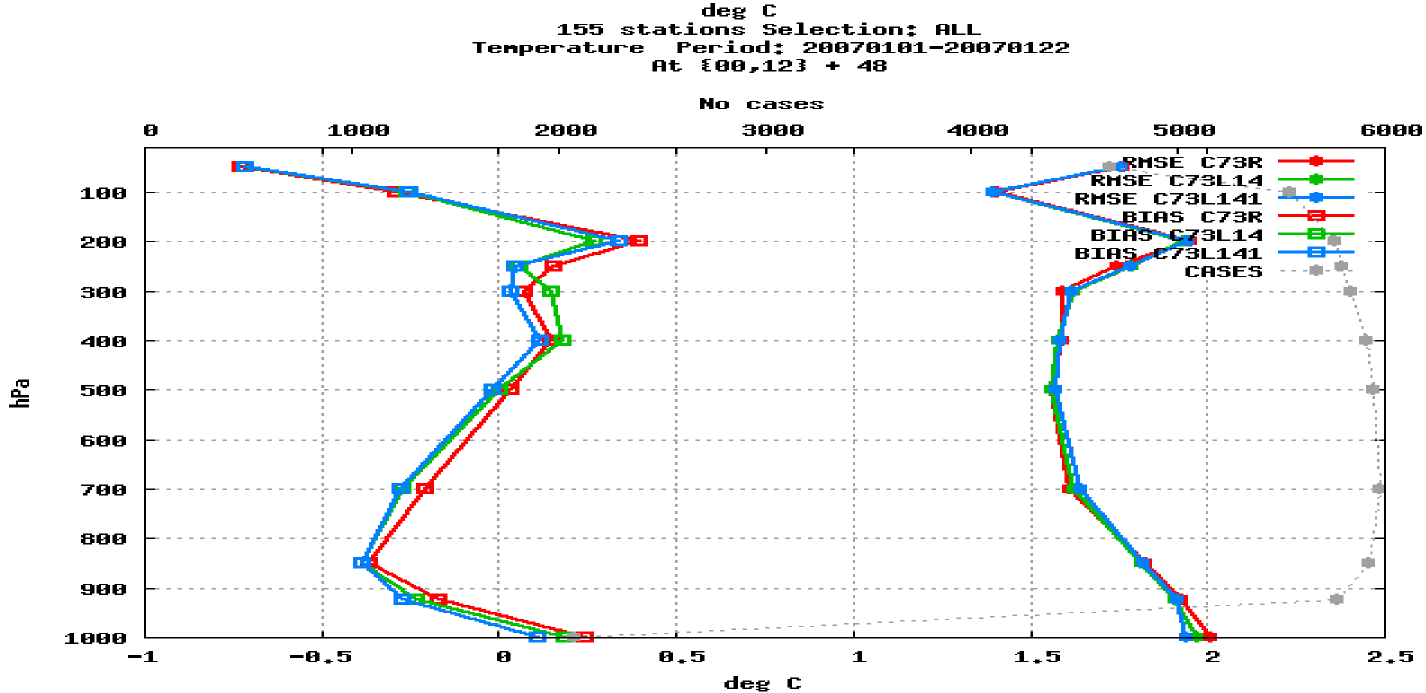

Selection: ALL using 2042 stations
Period: 20070701-20070731
Precipitation Hours: {00,12}
RMSE C11R
RMSE C11RK
BIAS C11R
BIAS C11RK
CASES
mm/12h
No cases
Forecast length


Selection: ALL using 2042 stations
Period: 20070701-20070731
Precipitation Hours: {00,12}
STDV C11R
STDV C11RK
STDV OBS
CASES
mm/12h
No cases
Forecast length

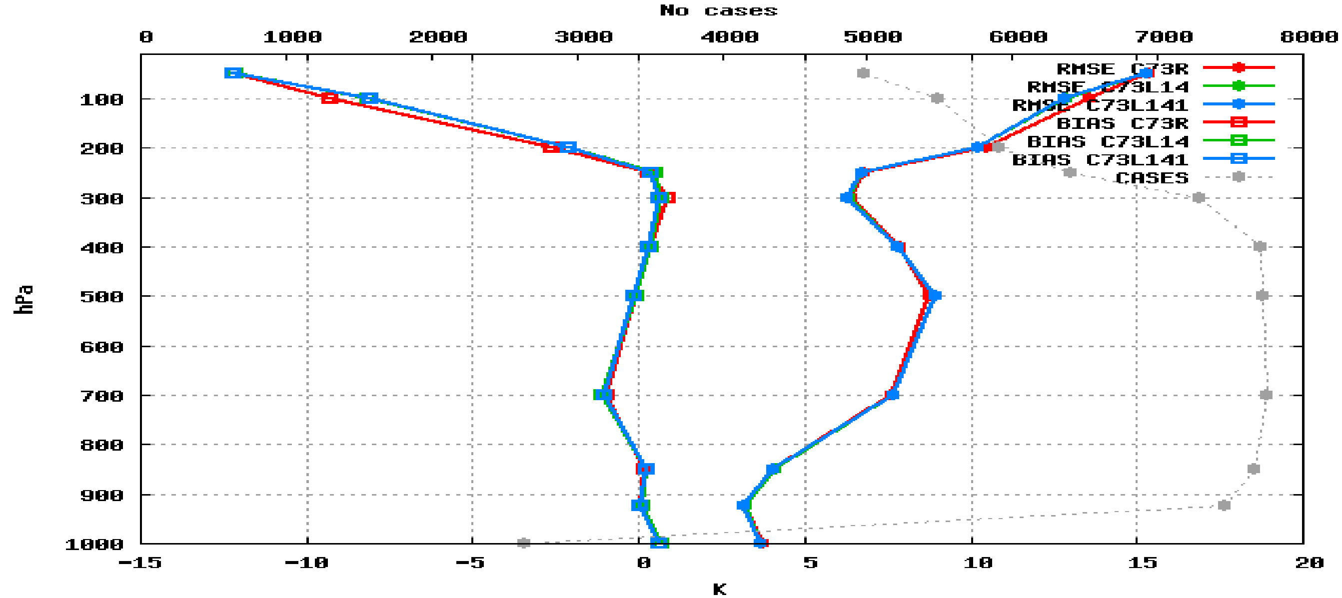
Liu-Penner tests C area 22km area 40 lev

- Red : Reference 7.3
- Green : 7.3, Liu-Penner. Both condensation and radiation
- Blue : 7.3, Liu-Penner condensation. 7.3ref for ice-crystal effects on radiation
- Top : Summer , bottom : winter

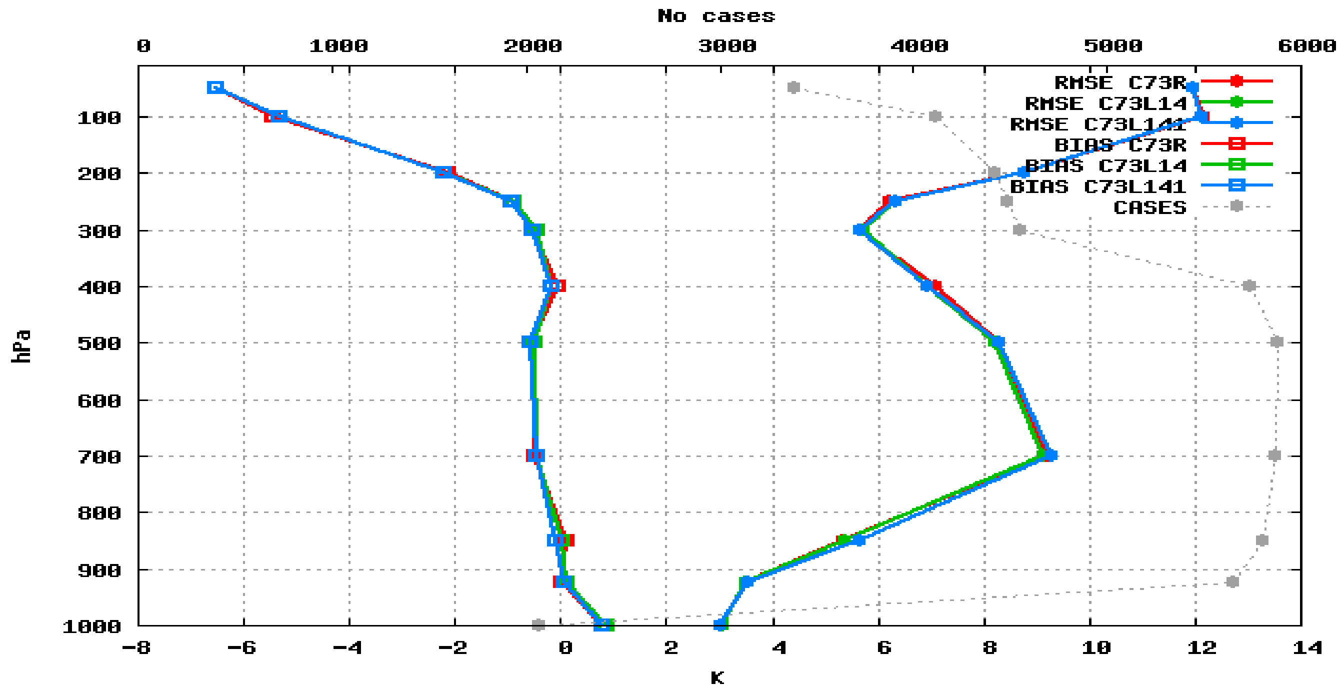

153 stations Selection: ALL
Temperature Period: 20070701-20070730
At {00,12} + 48
No cases
0
1000
2000
3000
4000
5000
6000
7000
8000
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
hPa
100
200
300
400
500
600
700
800
900
1000
-1
-0.5
0
0.5
1
1.5
2
2.5
deg C

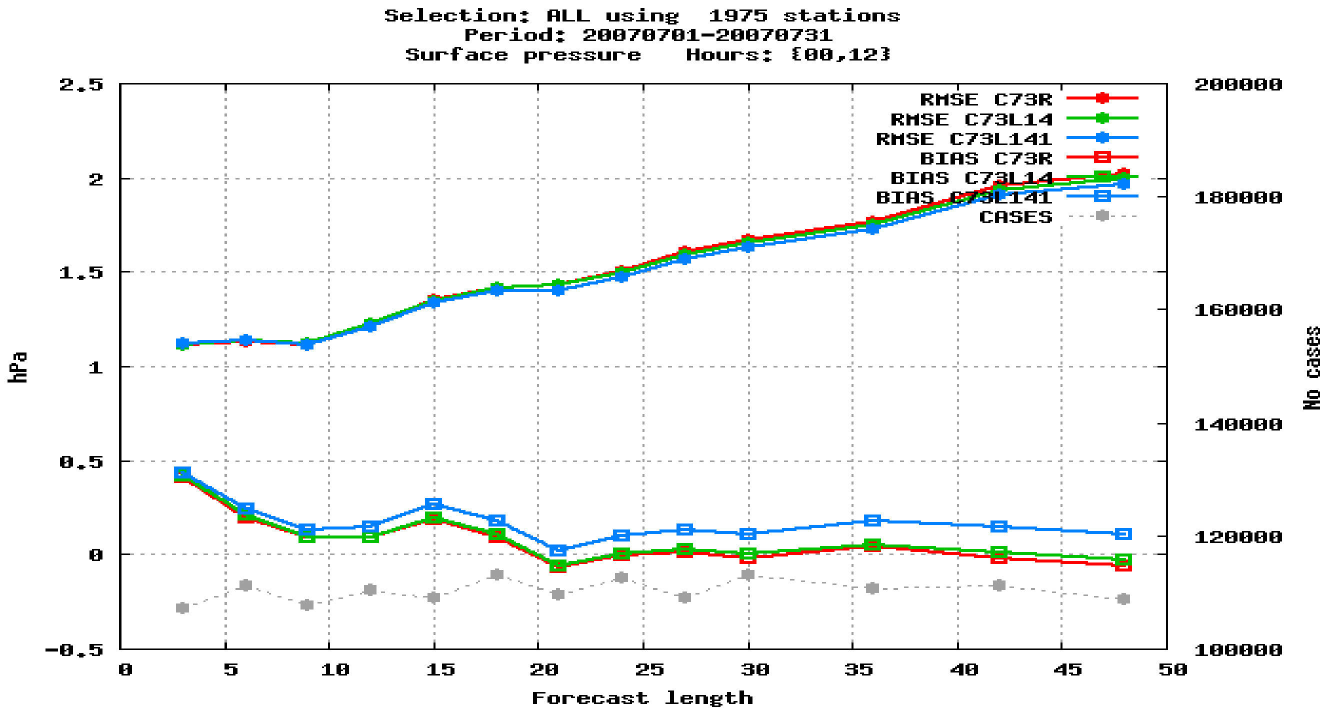

155 stations Selection: ALL
Temperature Period: 20070101-20070122
At {00,12} + 48
No cases
0
1000
2000
3000
4000
5000
6000
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
hPa
100
200
300
400
500
600
700
800
900
1000
-1
-0.5
0
0.5
1
1.5
2
2.5
deg C

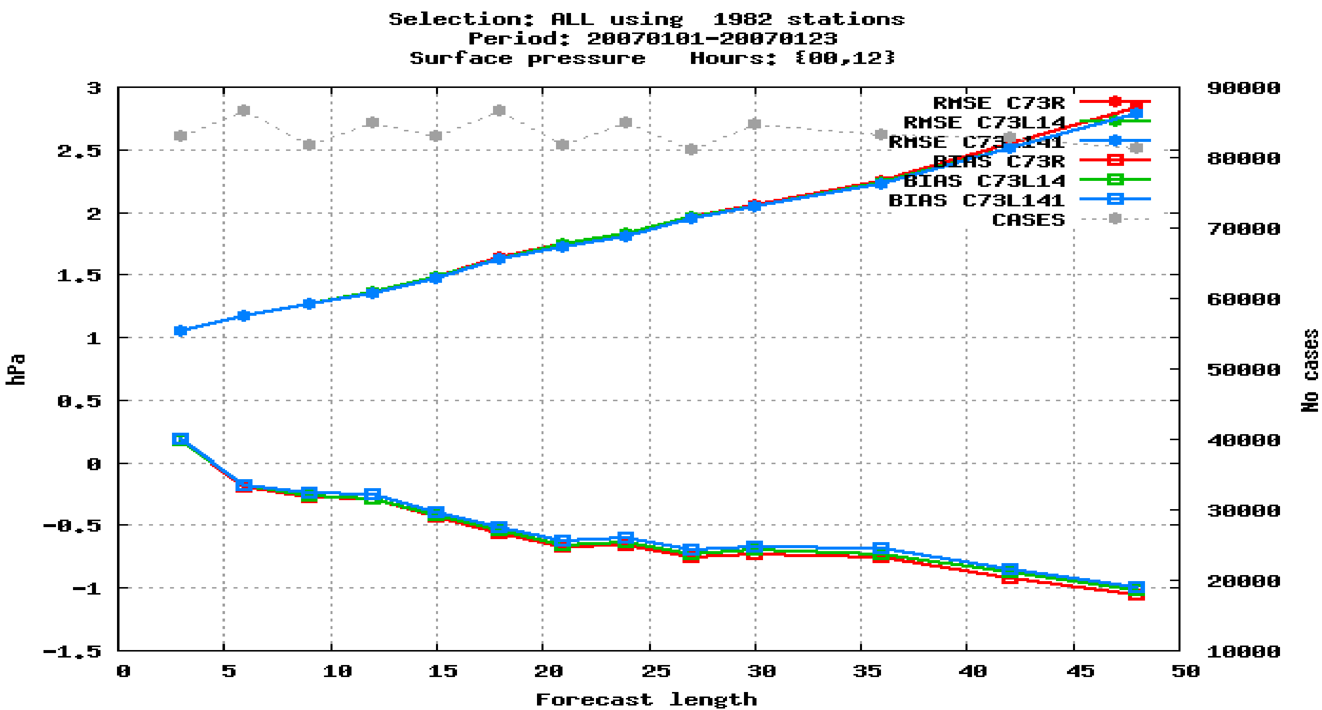
153 stations Selection: ALL
Dew point temperature Period: 20070701-20070730
At {00,12} + 48

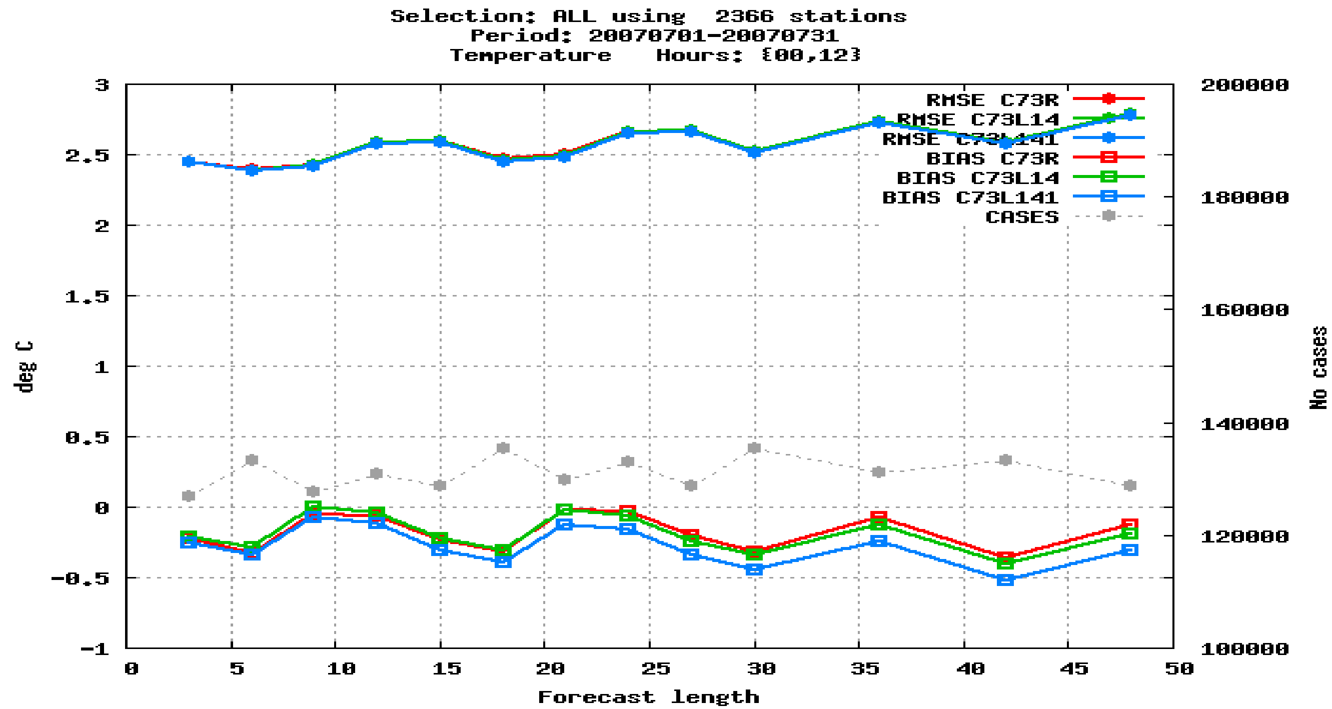


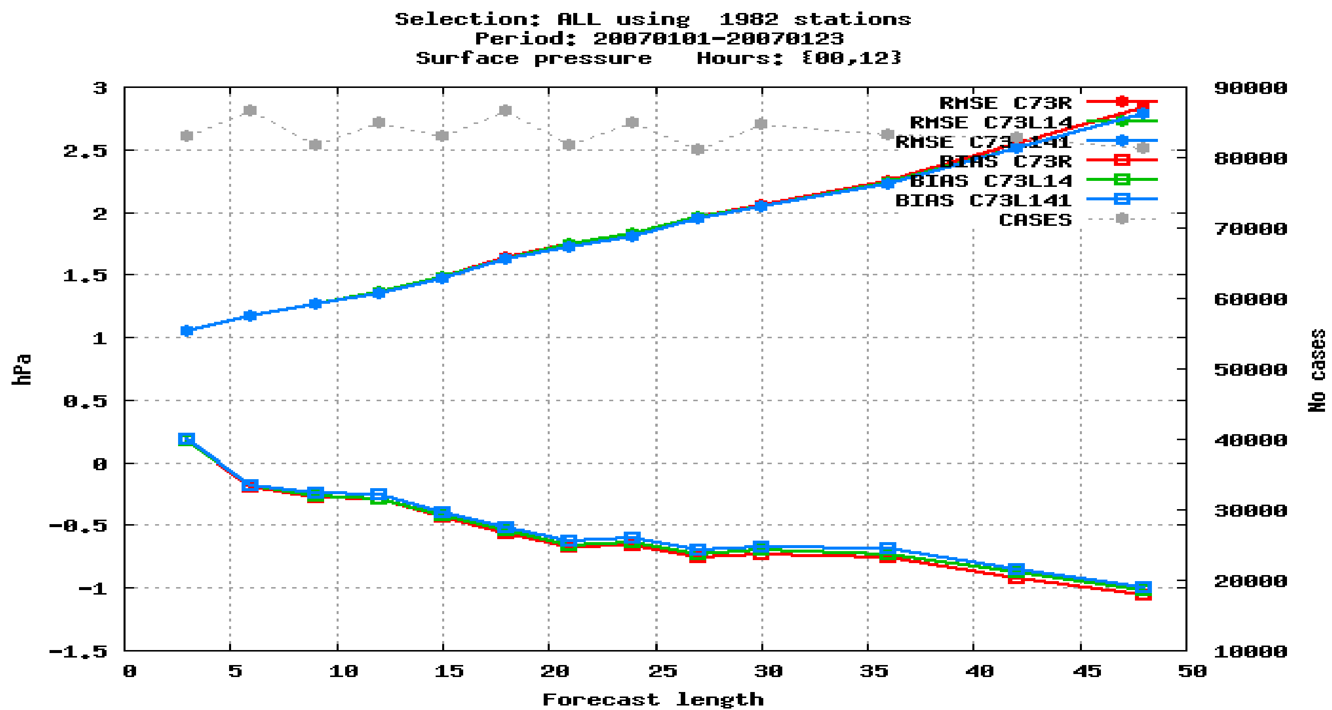
155 stations Selection: ALL
Dew point temperature Period: 20070101-20070122
At {00,12} + 48

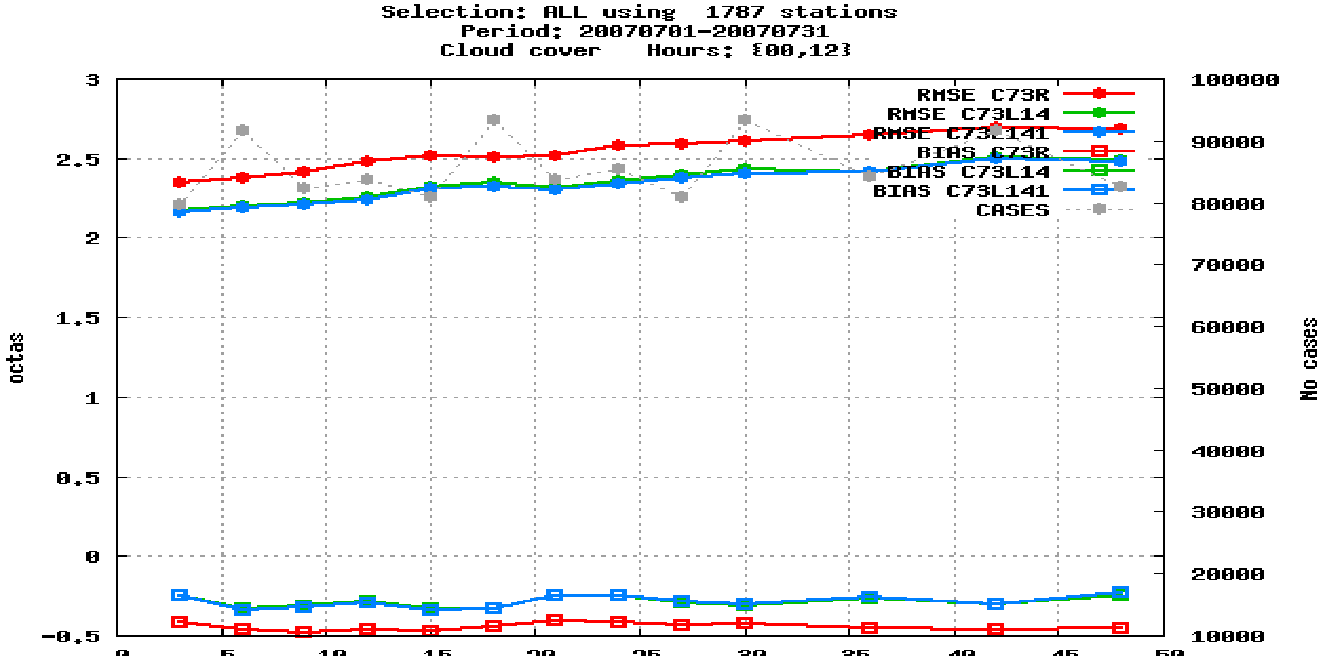



Selection: ALL using 1975 stations
Period: 20070701-20070731
Surface pressure Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
hPa
No cases
Forecast length

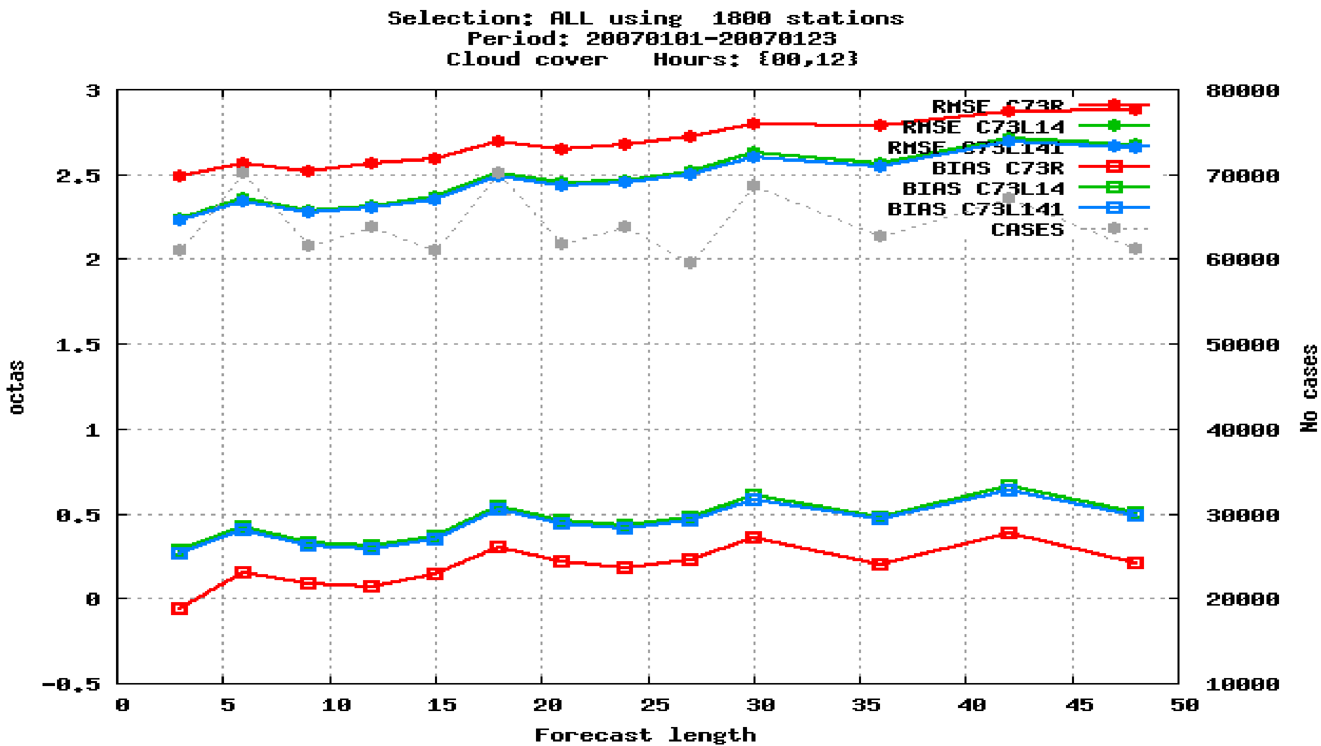

Selection: ALL using 1982 stations
Period: 20070101-20070123
Surface pressure Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
hPa
No cases
Forecast length


Selection: ALL using 2366 stations
Period: 20070701-20070731
Temperature Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
deg C
No cases
Forecast length

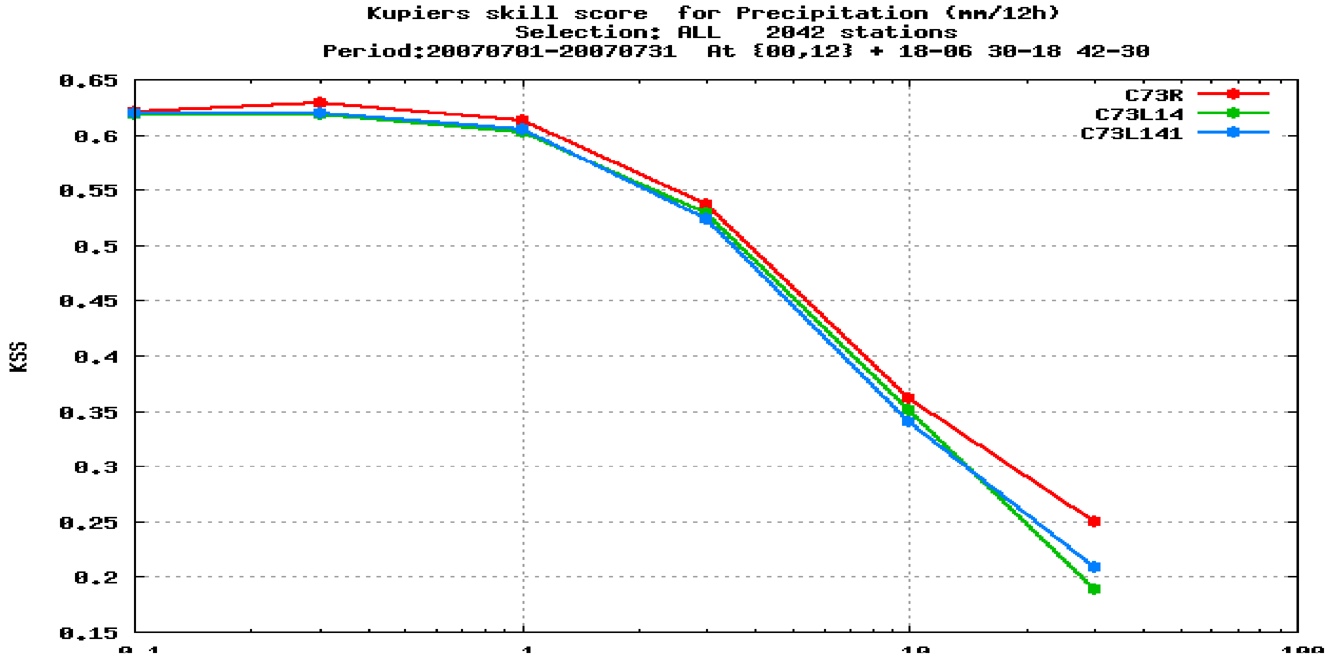

Selection: ALL using 1982 stations
Period: 20070101-20070123
Surface pressure Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
hPa
No cases
Forecast length



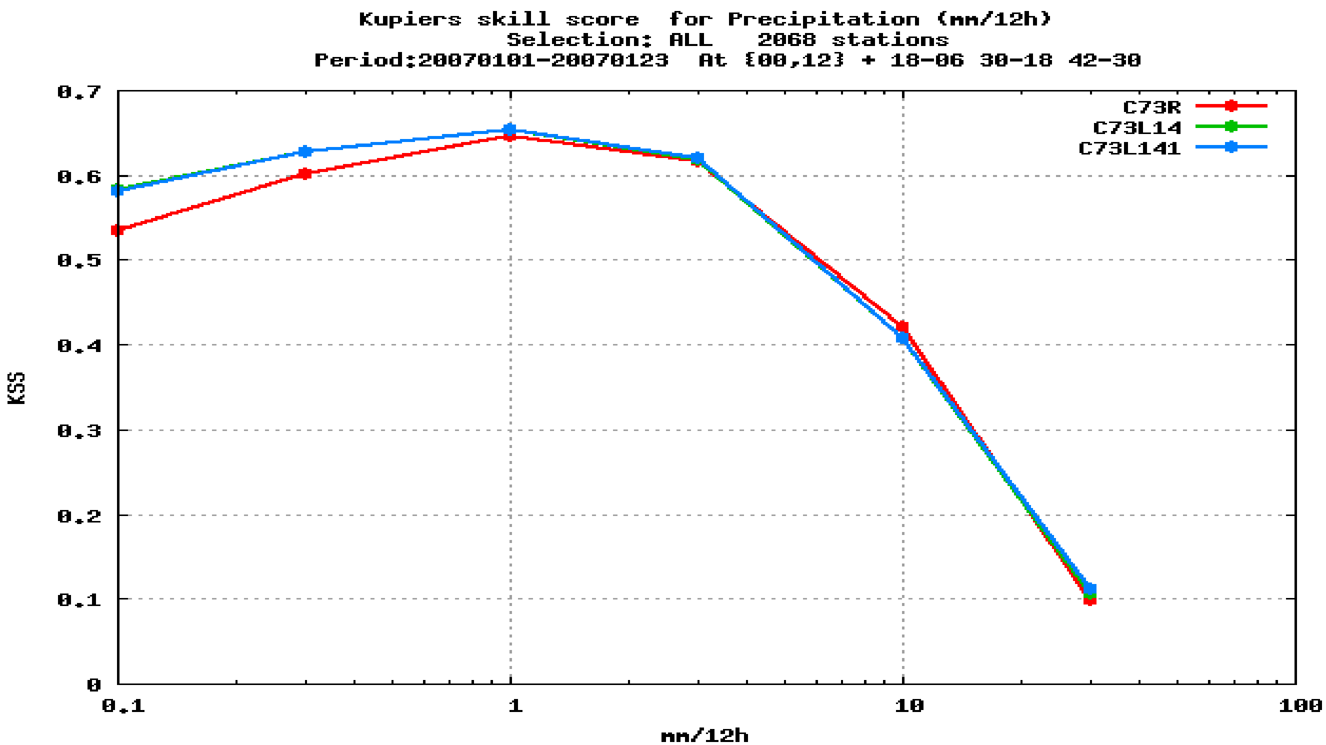
Selection: ALL using 1787 stations
Period: 20070701-20070731
Cloud cover Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
octas
No cases



Selection: ALL using 1800 stations
Period: 20070101-20070123
Cloud cover Hours: {00,12}
RMSE C73R
RMSE C73L14
RMSE C73L141
BIAS C73R
BIAS C73L14
BIAS C73L141
CASES
octas
No cases
Forecast length



Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 2042 stations
Period:20070701-20070731 At {00,12} + 18-06 30-18 42-30
KSS
C73R
C73L14
C73L141
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65



Kupiers skill score for Precipitation (mm/12h)
Selection: ALL 2068 stations
Period:20070101-20070123 At {00,12} + 18-06 30-18 42-30
KSS
C73R
C73L14
C73L141
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.1
1
10
100
mm/12h