Test of enhanced soil type determination in

Hirlam

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Introduction & Motivation

The HIRLAM climate generation includes processing of soil type (Bringfelt et al. 1995), and the data base it refers to is taken from the FAO-UNESCO soil database (FAO-UNESCO, 1987). This soil data classifies soil types into 10 categories:

1. sand
2. loam
3. clay
4. sand & loam
5. sand & clay
6. loam & clay
7. peat
8. ice
9. rock
10. missing data

The ISBA surface scheme in HIRLAM, however, does not make use of these 10 categories. Instead the ISBA preparation code for the climate files (steered by script Preps_ISBA) includes a remapping of the FAO soil types to 3 classes, which are a sub-set of the ISBA soil types (Bringfelt 1996, table A2.1). The three soili types are:

1. sand
5. loam
11. clay

They make up the sub-surface soil type soili used in HIRLAM (Bringfelt 1996, table A2.2). The representation of snow surface (SN) is hereby not used in recent HIRLAM versions.
Even though the remapping of the soil types and reduction to only three categories is a significant simplification, the proceduce has worked reasonably well.
One reason for this is that the three classes are good representatives of the soil characteristics. sand (1) and clay (11) represent two extremes, whereas loam (5) represents medium.

However, the limitations of the implemented soil type re-mapping became clear some years ago during spring time in the western part of Denmark, when HIRLAM's 2m temperature forecasts where found to grow too much during daytime compared to the observed values.
A significant contribution to this effect was found to come from the lack of soil water content, which in turn was found to be connected to the definition of the soil type in the low vegetation sub-surface tile of the HIRLAM grid, e.g. soil moisture initialization during a cold start depends strongly on the underlying soil type.
A large part of western Denmark (Jutland) was hereby found to be classified by soil type sand. Even though this soil type occurs at coastal locations, it cannot be seen as a major soil type over the area. The FAO soil type data base does not supply these details.

An experiment was then performed, where the soil type was set to loam instead of sand, in order to make HIRLAM *see* a medium soil type with medium soil water capabilities. The experiment showed an improvement of T2m by 1 to 2 degrees locally in Jutland. A quick fix was then applied in operational DMI-HIRLAM.

Refining soil type determination

Recently the issue of soil type definition for HIRLAM ISBA scheme was taken up again, when extreme surface temperatures were observed at the coast of Greenland. Even though these problems had other causes and were not related, they revealed a code bug concerning the no vegetation sub-surface tile. As a consequence, the potential insufficiencies of soil type definitions in the other two sub-surface tiles low vegetation and forest were discussed. These discussions took up the idea to refine the soil type determination by utilizing the sub-surface type vegi in addition to the FAO soil type not only under sub-surface tile no vegetation, but also under low vegetation and forest (As Table A2.2 in Bringfelt (1996) shows, vegi has been utilized in tile 3, but not in tiles 4 and 5).

The combination of using vegi and FAO soil type has the potential to refine the ISBA soil type determination, because the vegetation type may give an indication on the underlying soil type. This way the crude information on soil type in the FAO data can be enhanced by making use of information about the vegetation.

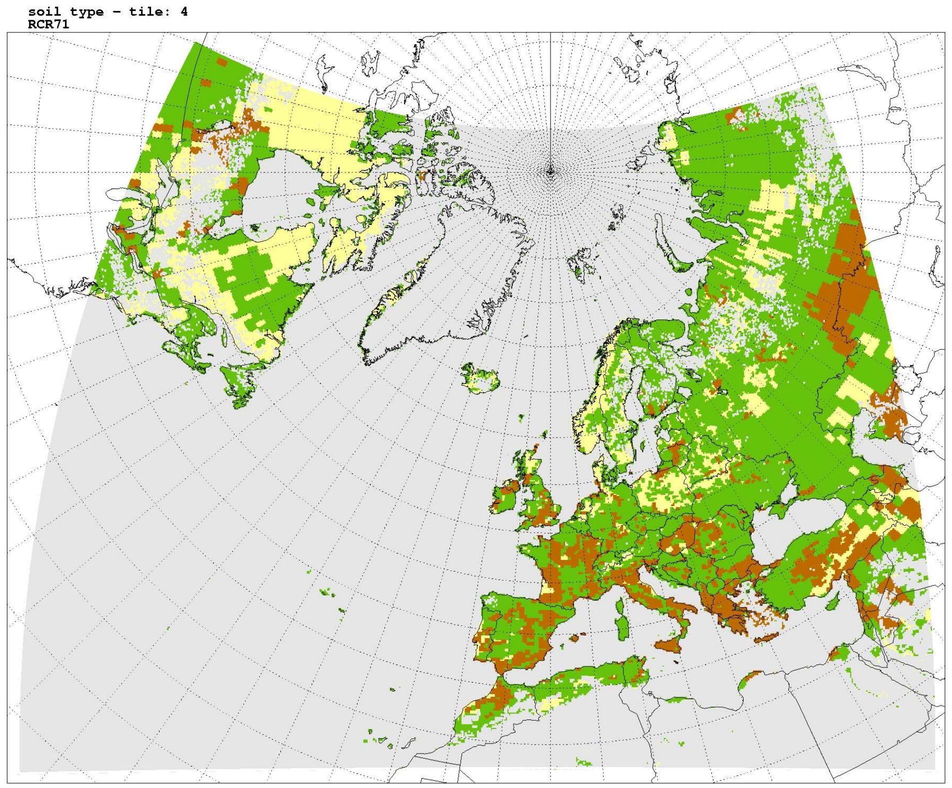
The new mapping of FAO soil type and vegi into ISBA sub-surface soil type is formulated in the list to the right, for each of the three sub-surface tiles no vegetation (3), low vegetation (4) and forest (5):

FAO soil type	1	4,7	2,6	5	3	8	9	0
Tile 3 no vegetation								
vegi = 8 (desert)	1	1	1	1	1	5	1	1
vegi = 12 (ice)	5	5	5	5	5	5	5	5
Tile 4 low begetation								
vegi = 1 (crop)	5	5	5	5	11	5	5	5
vegi = 2 (short grass)	1	5	5	11	11	5	1	5
vegi = 7 (tall grass)	1	5	5	11	11	5	1	5
vegi = 9 (tundra)	5	5	5	5	11	5	5	5
vegi = 10 (irrigated crop)	1	5	5	11	11	5	1	5
vegi = 11 (semi-desert)	1	5	5	11	11	5	1	5
vegi = 13 (bog/marsh)	5	5	11	11	11	5	5	11
vegi = 16 (evergreen shrub)	5	5	5	5	11	5	5	5
vegi = 17 (deciduous shrub)	5	5	5	5	11	5	5	5
Tile 5 forest								
vegi = 3 (evergreen needle tree)	1	1	1	5	5	5	1	5
vegi = 4 (deciduous needle tree)	1	1	1	5	5	5	1	5
vegi = 5 (deciduous broadleaf tree)	5	5	5	5	11	5	5	5
vegi = 6 (evergreen broadleaf tree)	5	5	5	5	11	5	5	5
vegi = 18 (mixed woodland)	5	5	5	5	11	5	5	5
vegi = 19 (forest/fields)	5	5	5	5	11	5	5	5

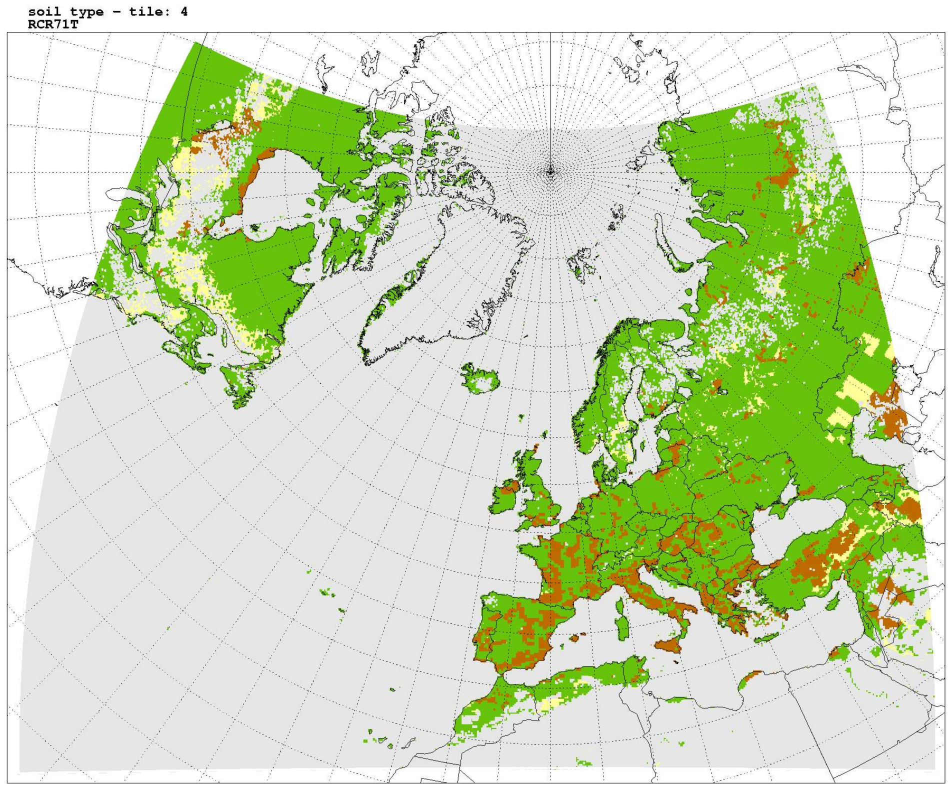
The difference between the current and the new ISBA soil type determination in HIRLAM can be seen from the pictures below.

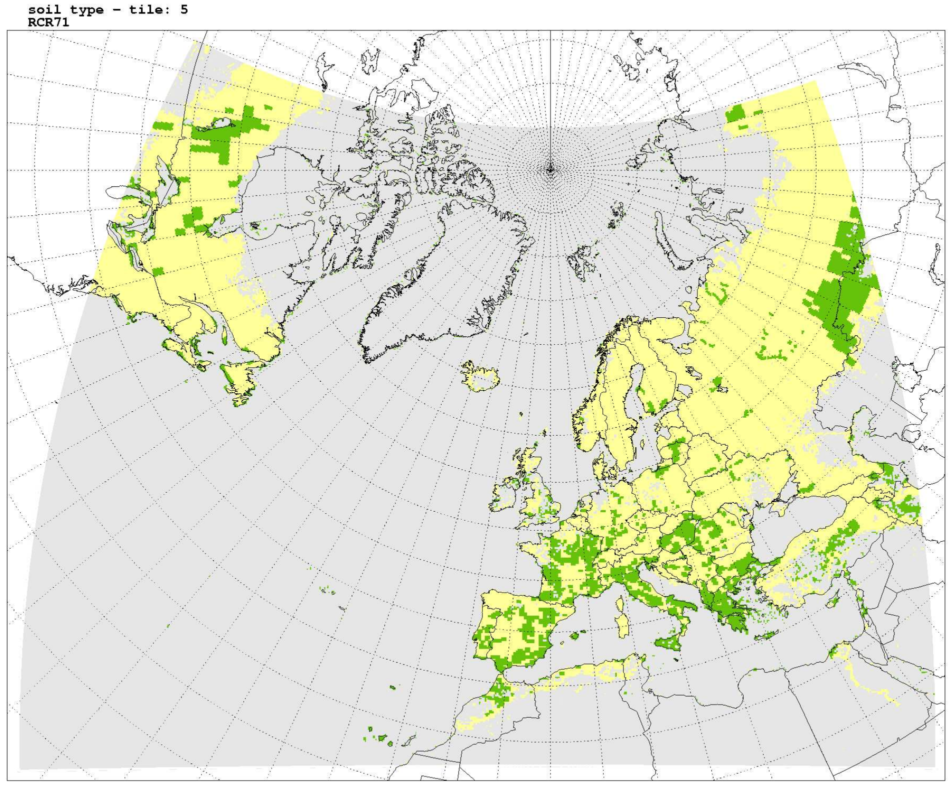
current

new

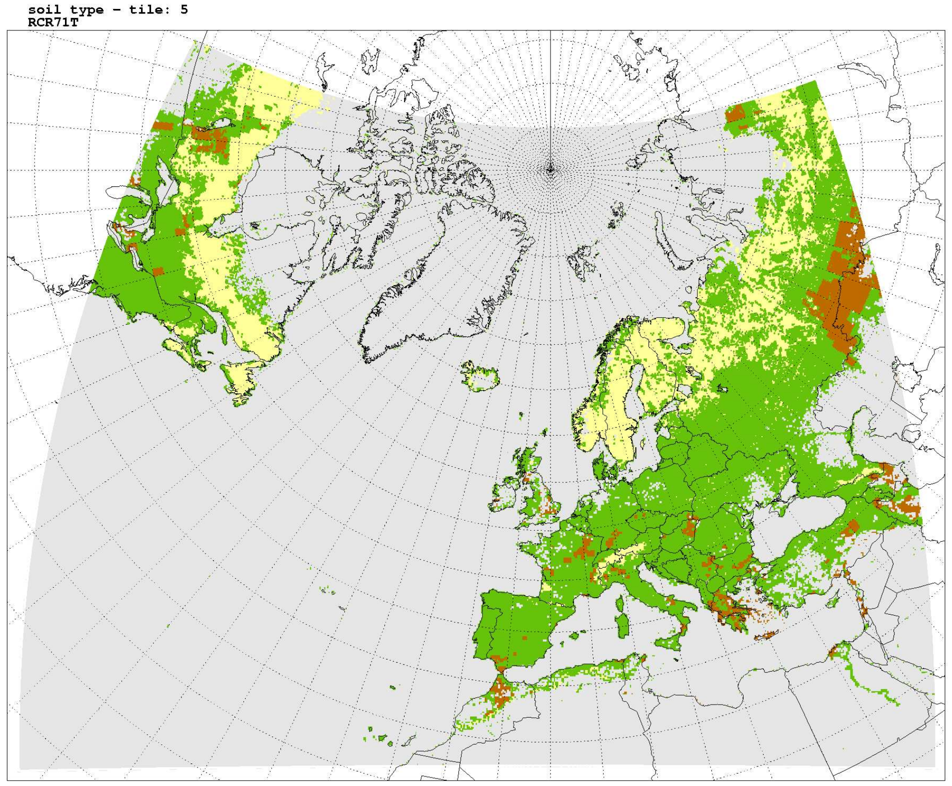

soil type - tile: 4
RCR71

⇒


soil type - tile: 4
RCR71T


soil type - tile: 5
RCR71

⇒


soil type - tile: 5
RCR71T

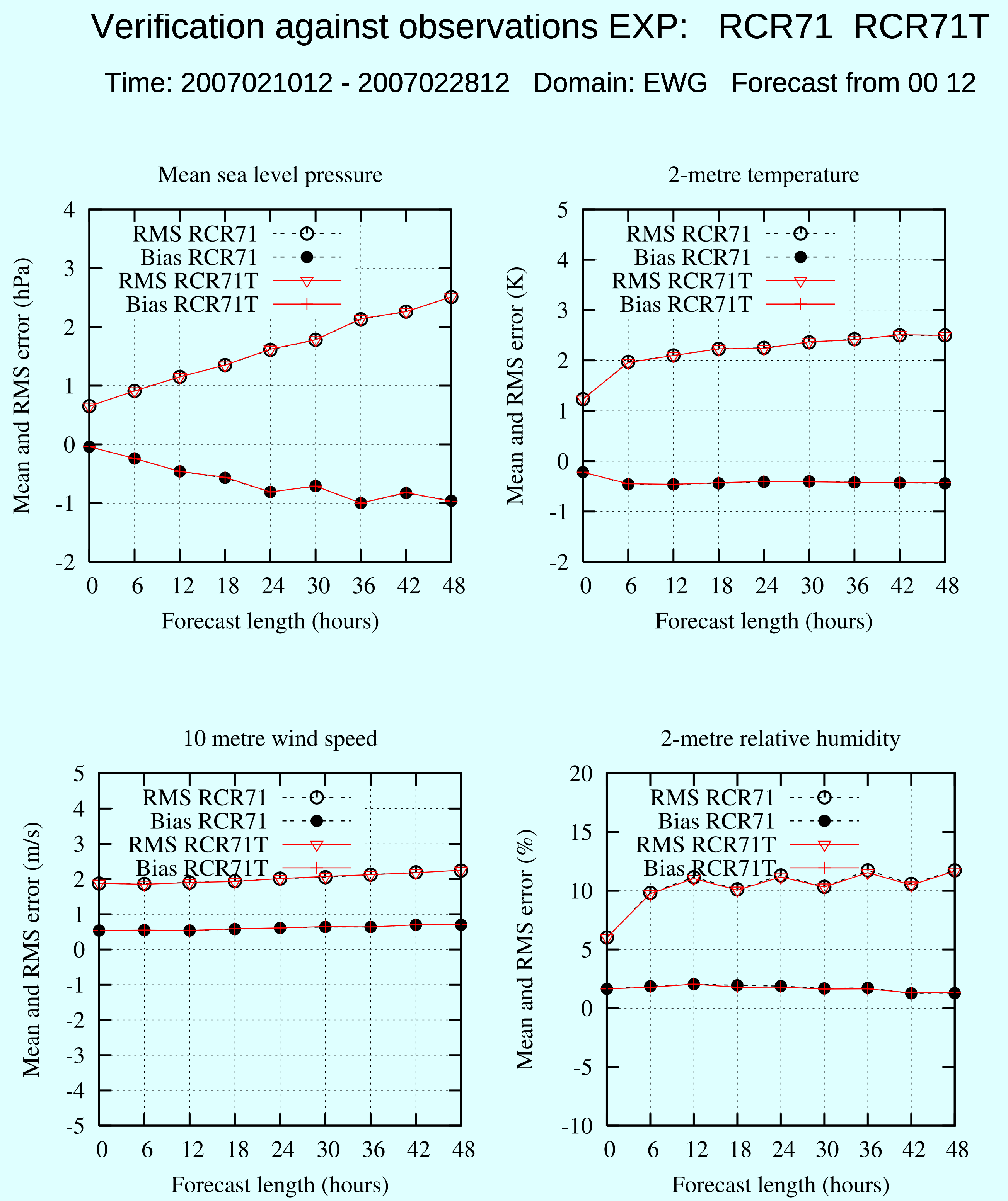
Impact on surface parameters

Overall scores

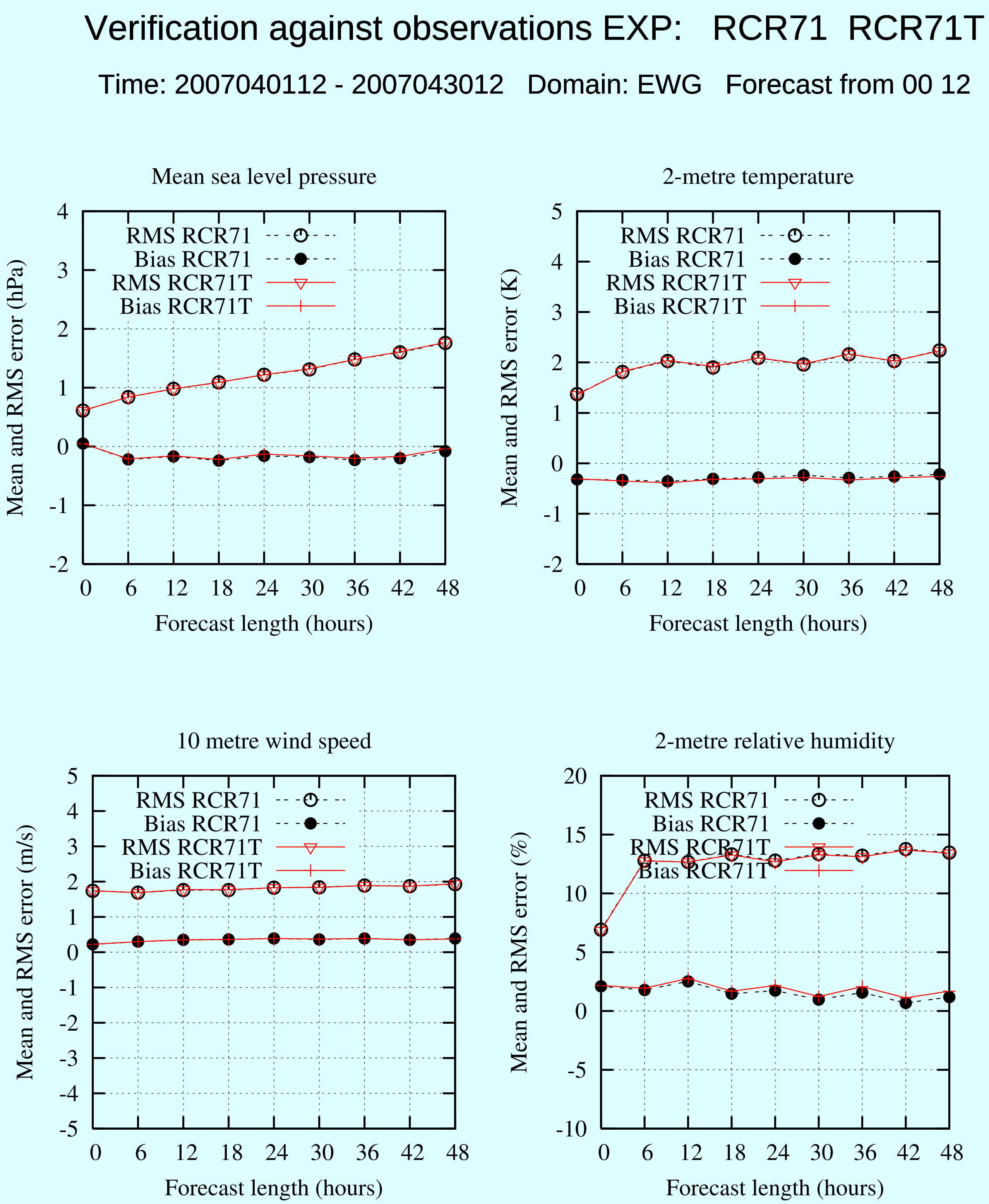
The impact of the refinement of ISBA soil type determination soili was tested in two experiments. The first experiment made use of the soil types as in the current HIRLAM system, and the second one used the newly defined soil types as described above.
Both experiments were run over the following three periods:

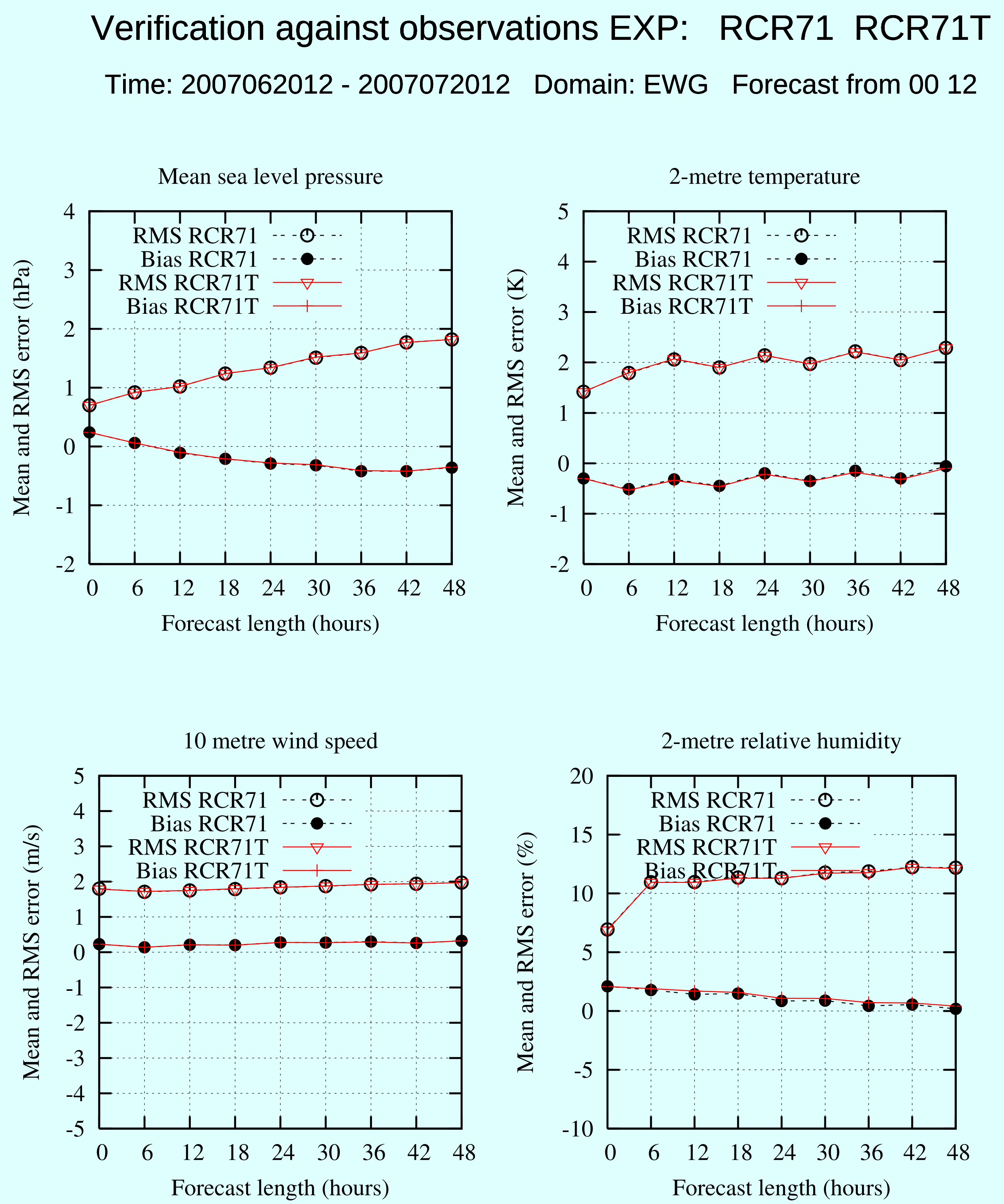
1. 2007-02-10 to 2007-02-28
2. 2007-04-01 to 2007-04-30
3. 2007-06-20 to 2007-07-20

The first period is to represent winter conditions, and the second period includes shifting weather condition, which include sunny high pressure situations over Europe. The third period contains a summer period with many thunderstorms.
Both experiments are based on HIRLAM trunk version as of changeset [5673], still including the fix of changeset [5692]. The experiments were configured to run on the RCR-7.1 domain, and using 3DVAR analysis. Else default specifications were used.
HIRLAM standard verification was applied to the experiment runs. Overall impact of the soili refinement on surface parameters MSLP, T2m, RH2m and W10m is shown in the following figures (EWGLAM station list).



Impact on surface parameters



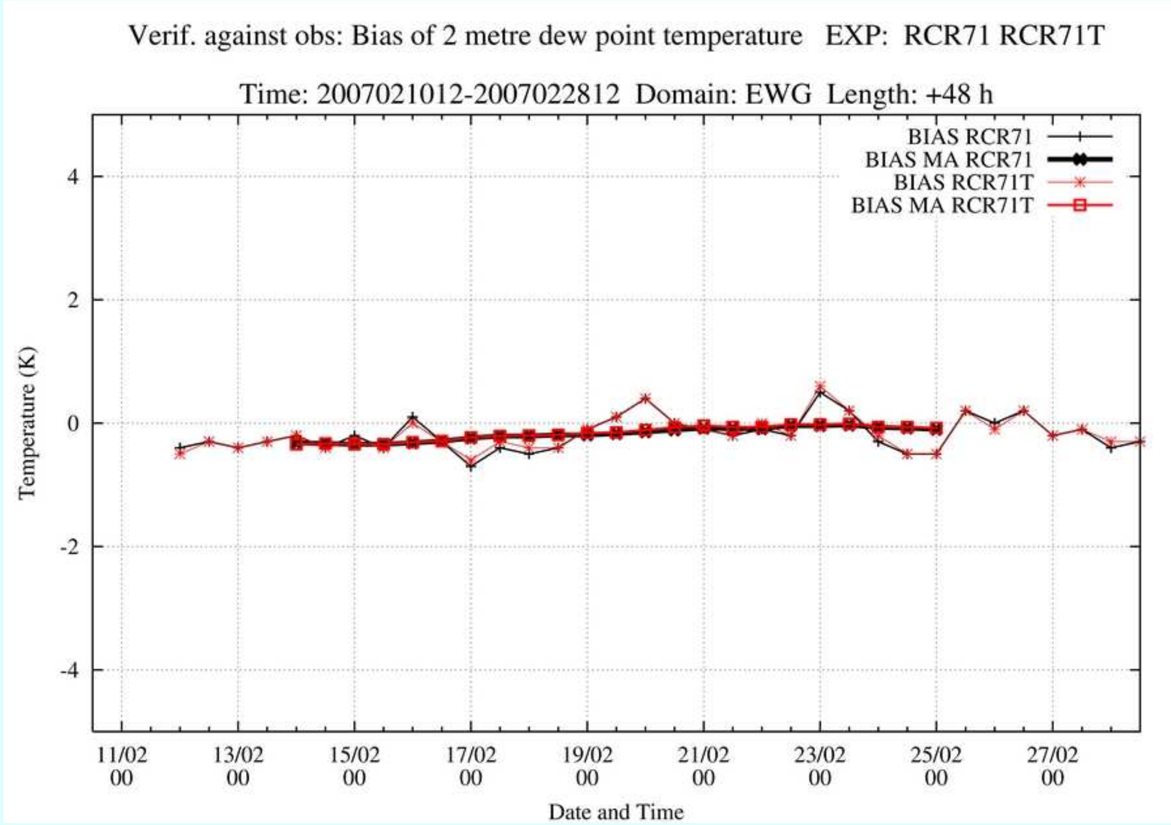


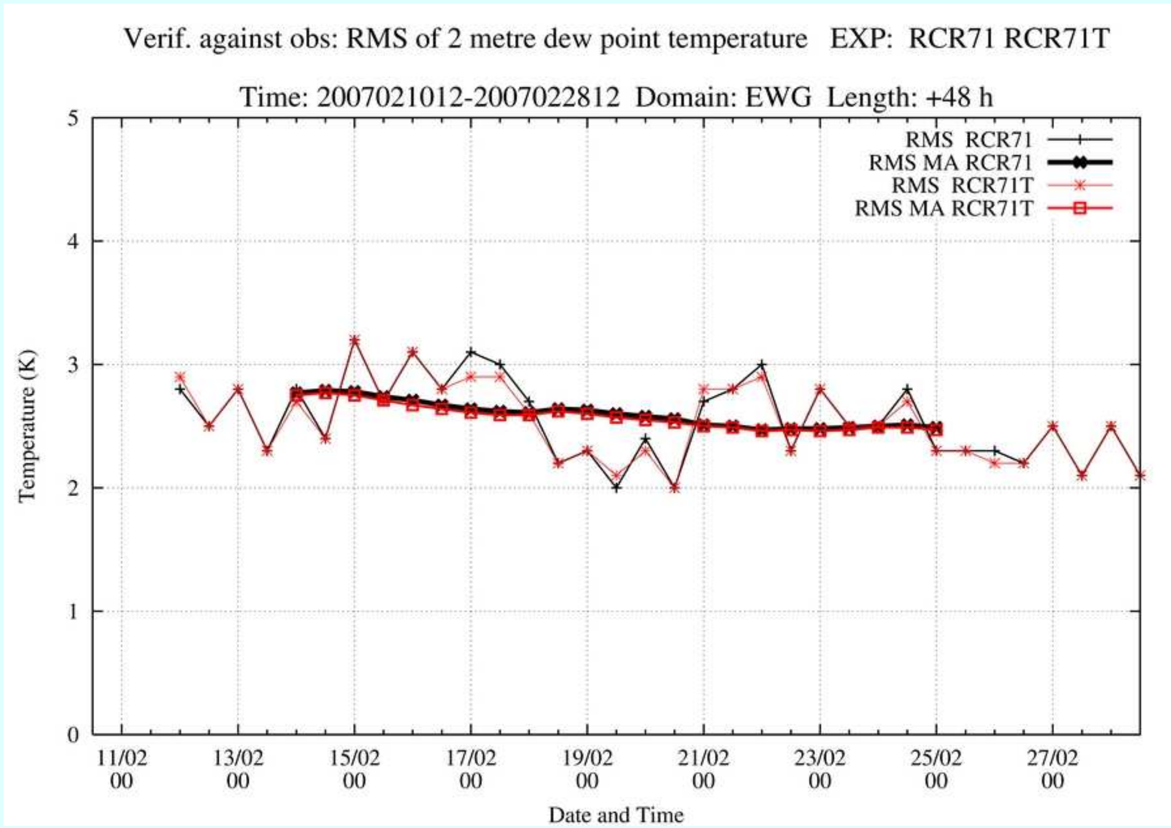
As the figures above show the impact of the refined determination of soili on surface parameters is very small. The new definitions have slight tendency to higher 2m humidity, and in accordance to this, a slight tendency to lower 2m temerature. When considering the model bias for T2m and RH2m, these tendencies seem to be rather counter-productive, however. There is no visible impact on 10m wind speed. For mean sea level pressure, a very small improvement of the negative bias in the April period is visible (upper left figure of the left panel on this sheet).

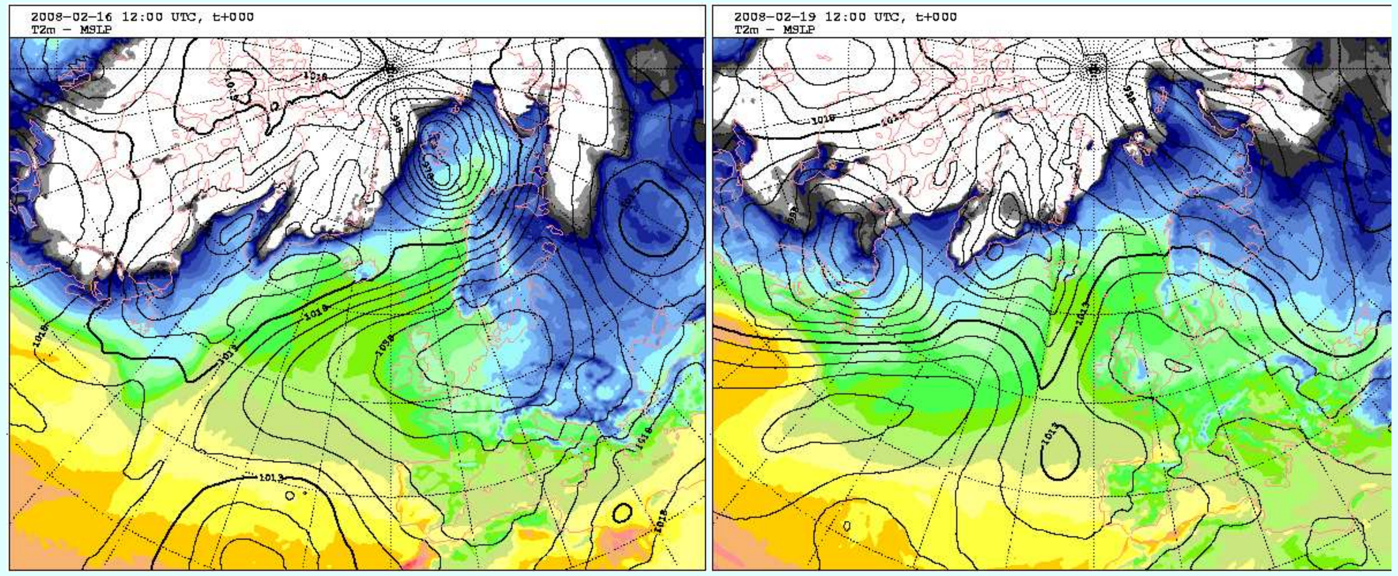
Impact on surface parameters

Time series

A look at the time evolvement of the verification scores confirms the slight impact almost at all times. Respective figures are shown for the 2m dew point to the right and further below (bias and rms).
The dew point parameter experiences the biggest influence, but still it is a very small one.
An exception is a short period around the 17th and 18th of February 2007, where the refined soili settings have a visible postitive impact on the RMS of the dew point (see lower figure to the right. The period between 16th and 19th of February was characterized by a warming over the European continent, especially the eastern and some of the northern parts. The following two maps of 2 metre temperature illustrate this:

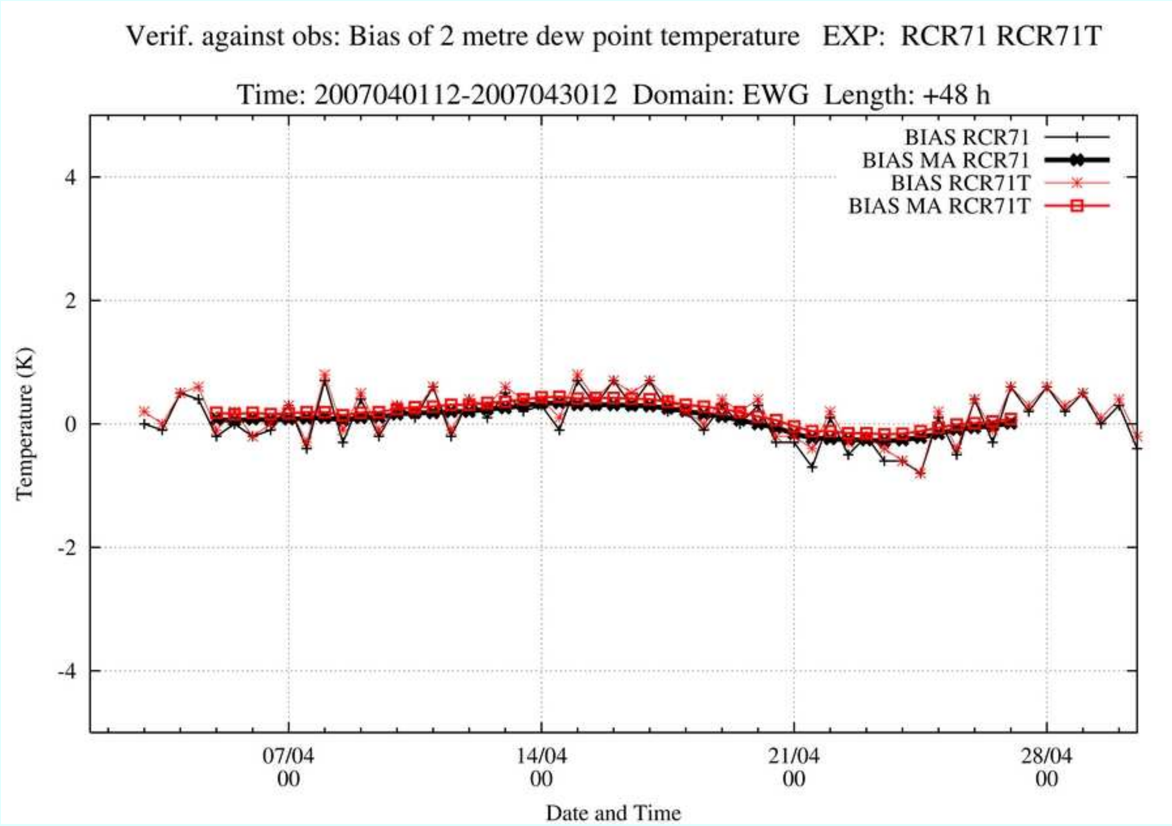


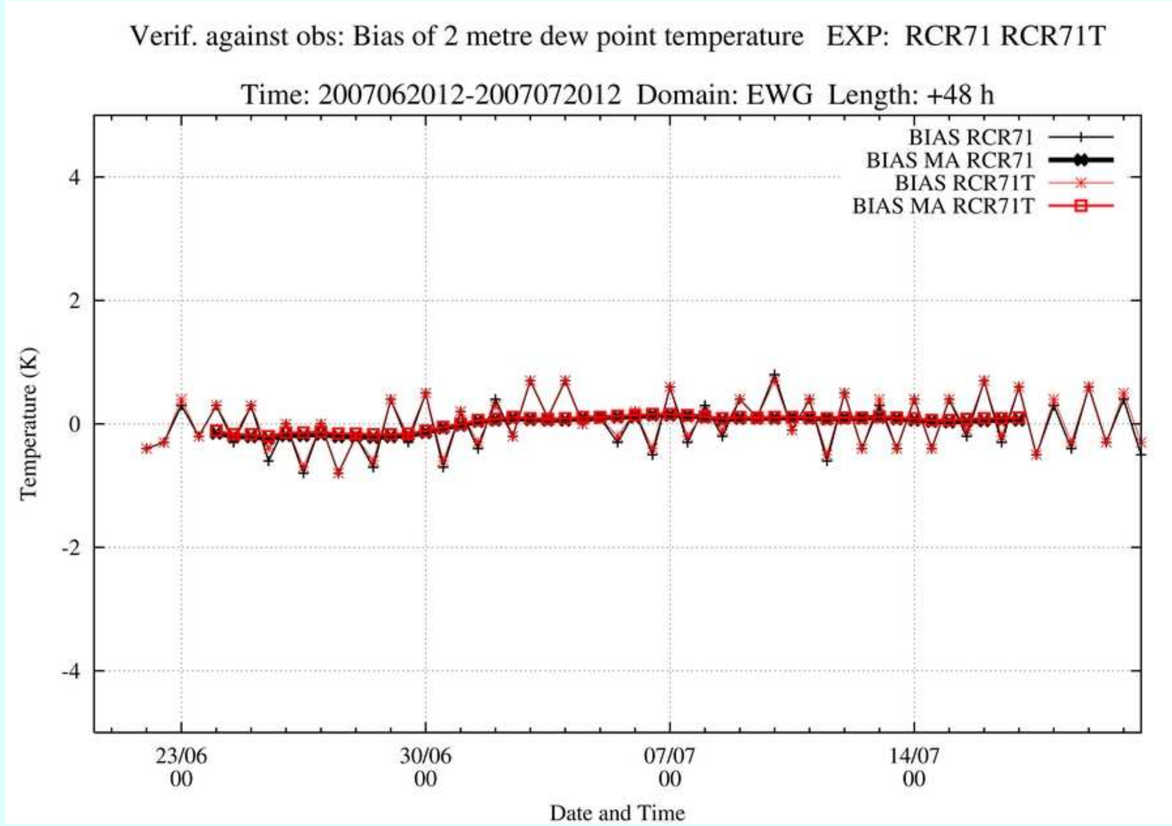


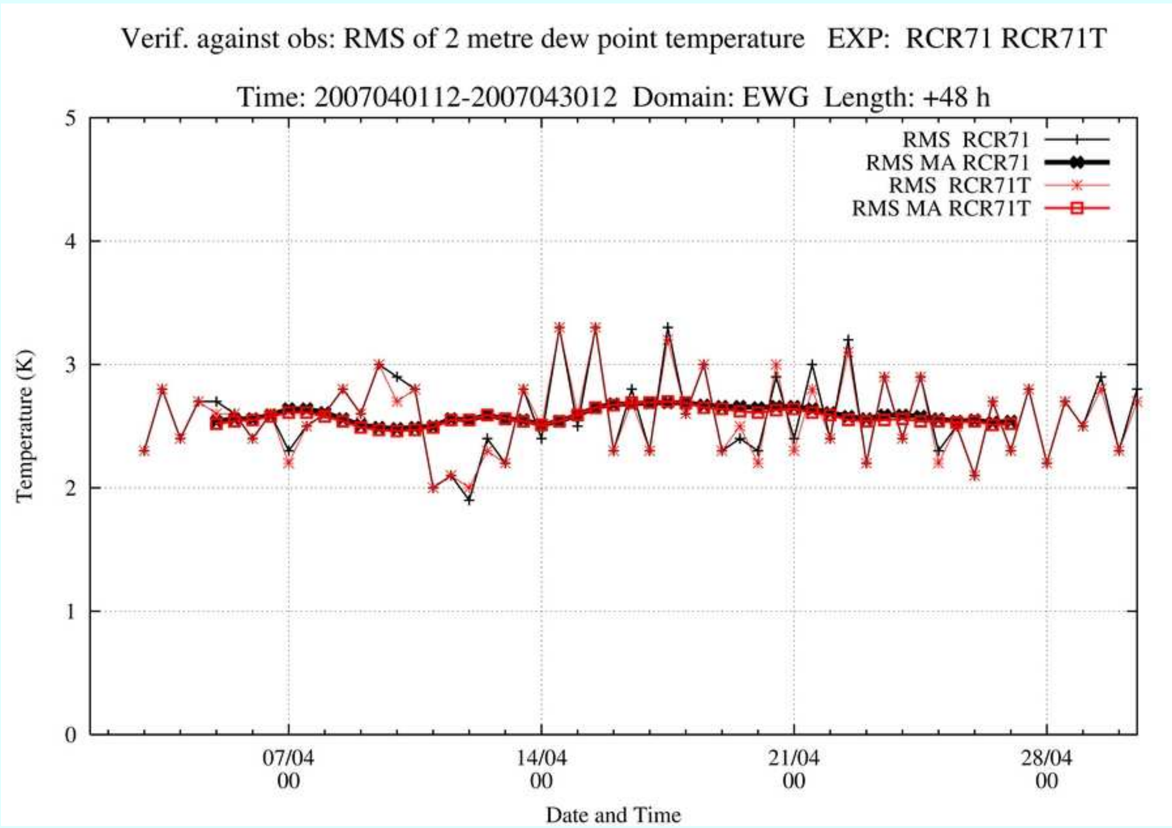


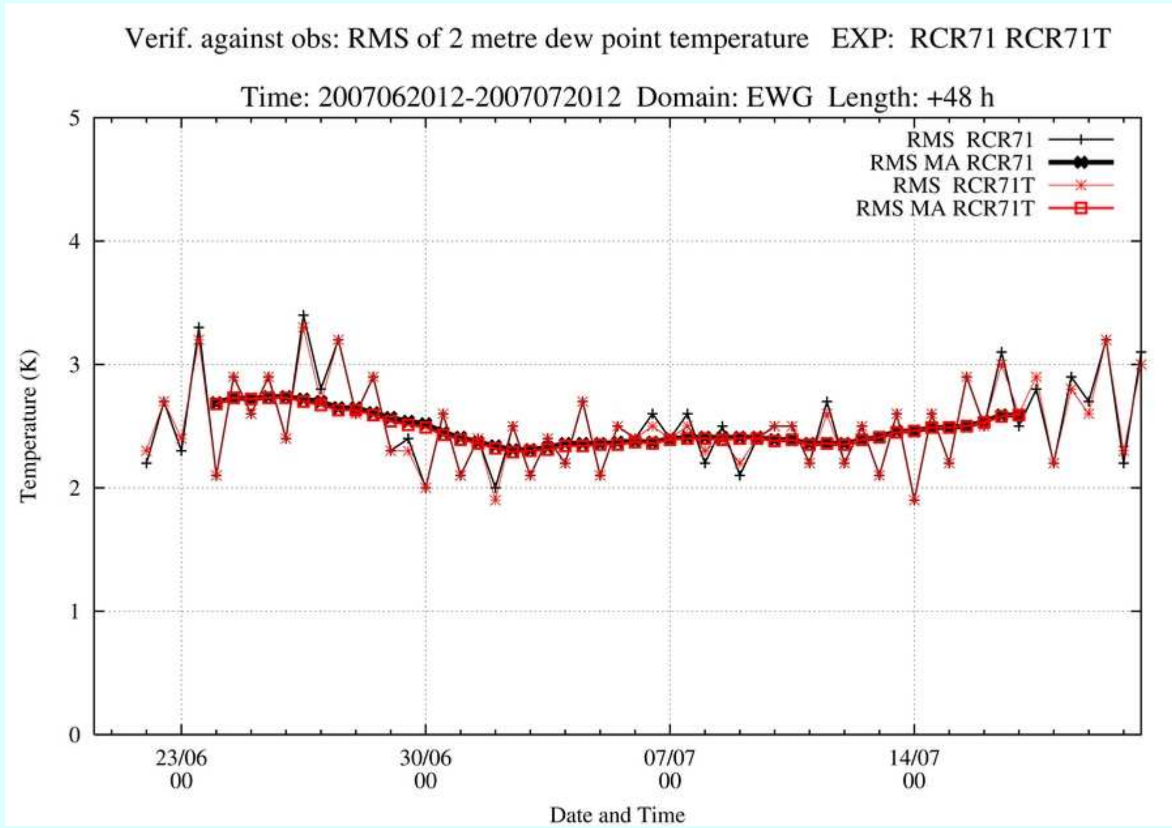
2m temperature and mean sea level pressure at 16th and 19th February 2007

Impact on surface parameters









Impact on surface parameters

Spatial distribution

The verification scores of the surface parameters MSLP, T2m, RH2m and W10m compare very similarly between the two experiments, when regarding the stationwise scores from the two HIRLAM experiments. The following figures show the distributions of bias (panels to the left) and rms scores (panels to the right) valid for 48h forecast length. The experiments shown are:

RCR71.
: used the curent soili settings in HIRLAM
shown on the left hand side of each panel respectively

RCR71T.
: used the refined soili settings
shown on the right hand side of each panel respectively

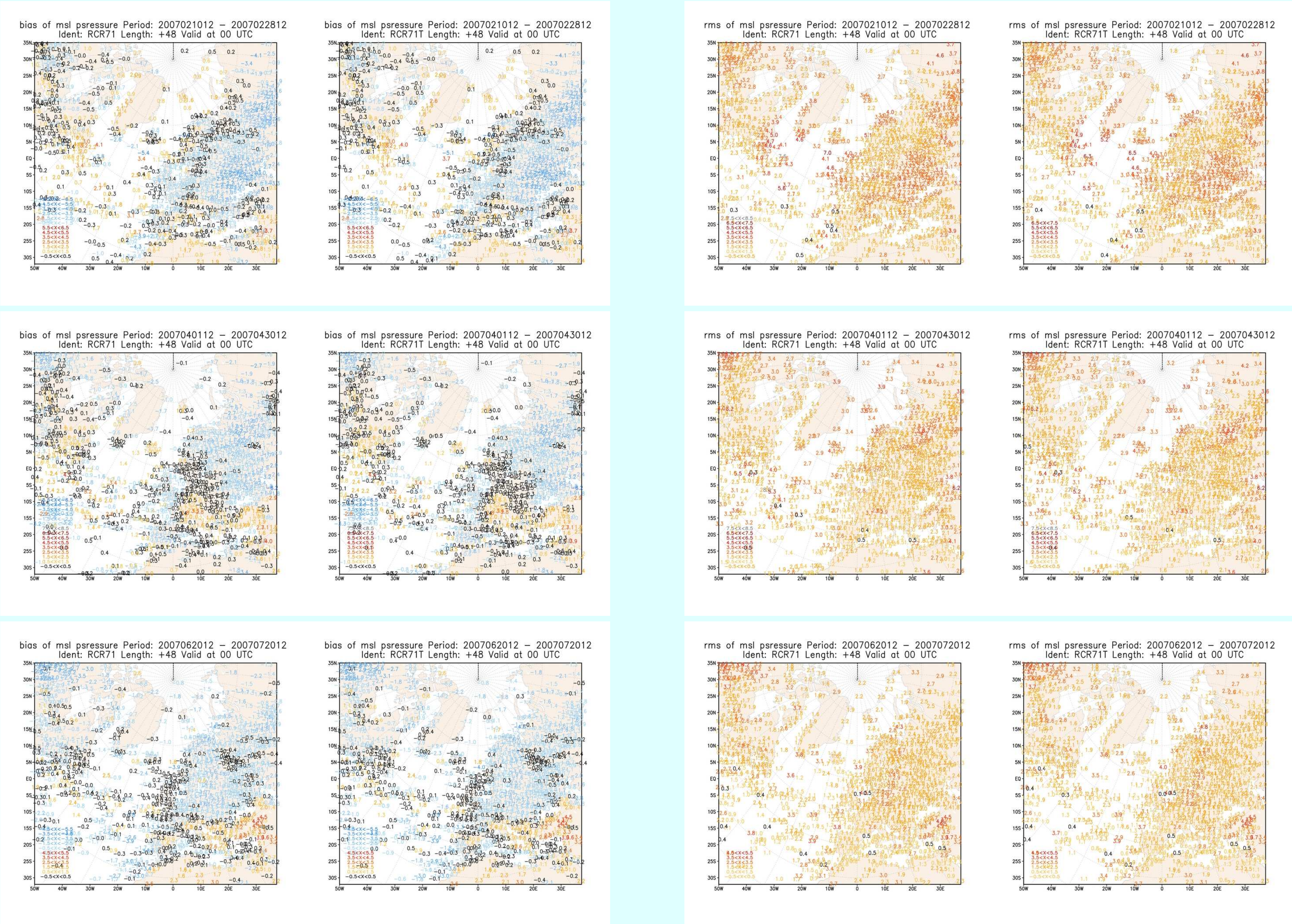
Each row in a panel refers to one of the three periods.

The figures show that small local differences occur, usually with improvements in one region and deterioration at another location at the same time.

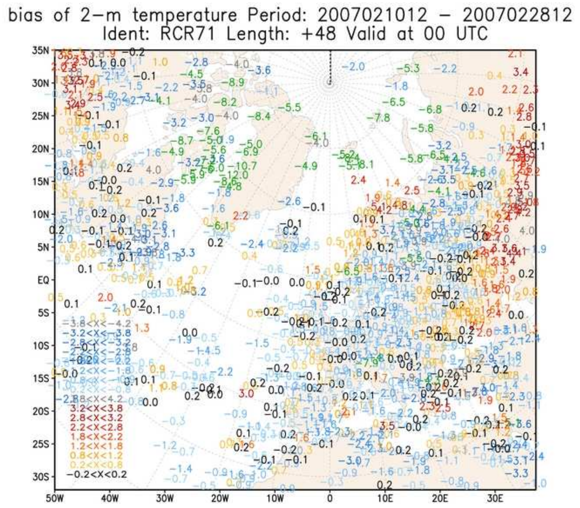
It is interesting to notice, still, that differences also occur over the open sea. This may indicate that the differences of surface parameter scores induced by the change in soili fields over land tiles have propagated through the model domain within the time period of the forecast range.

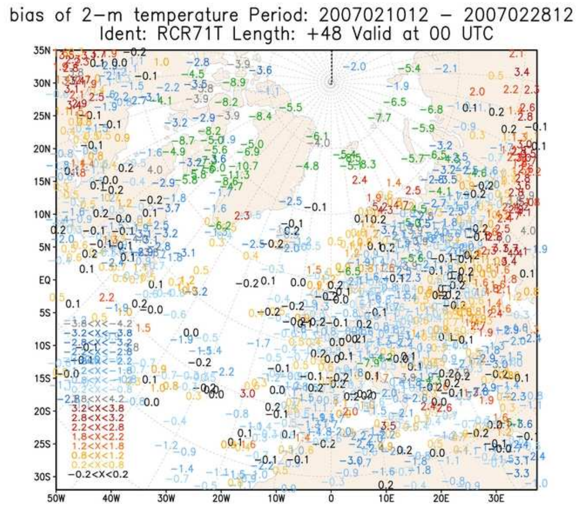
So the effect of changing soili does not remain a local one, but it spreads over the model domain within the usual forecast range. It can also be expected that the effect has (small) impact on the daily cycle in an operational setup of HIRLAM.

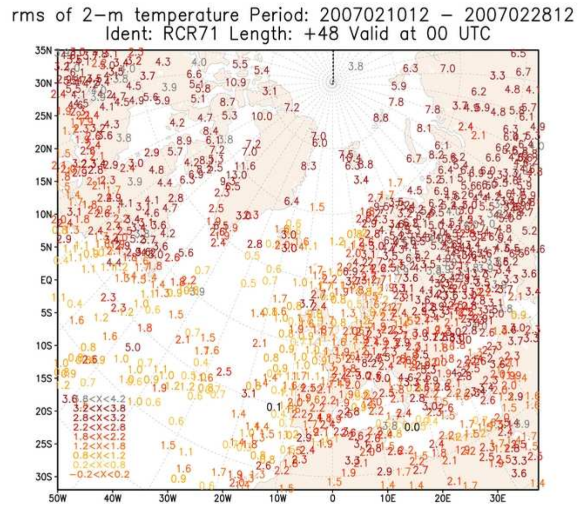
Impact on surface parameters (mean sea level pressure)

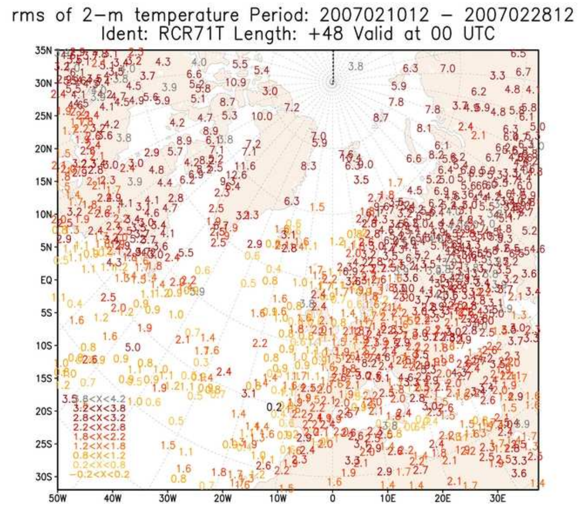


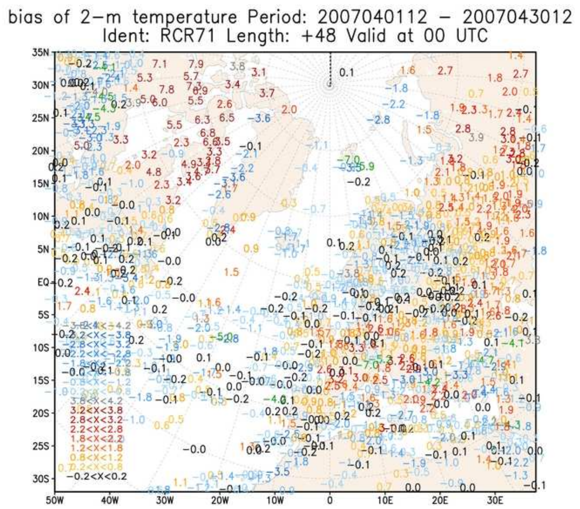
Impact on surface parameters (2m temperature)

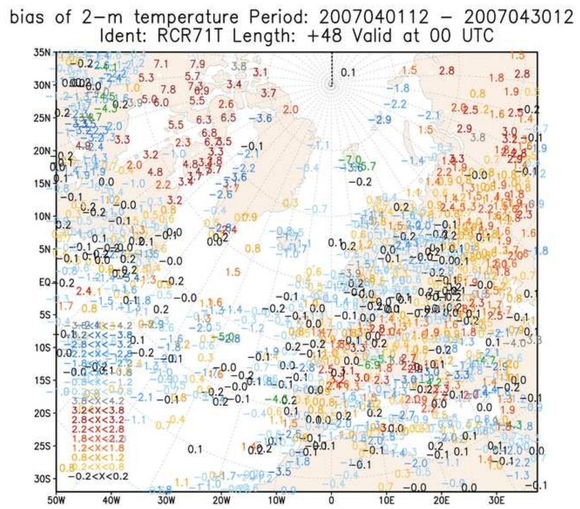


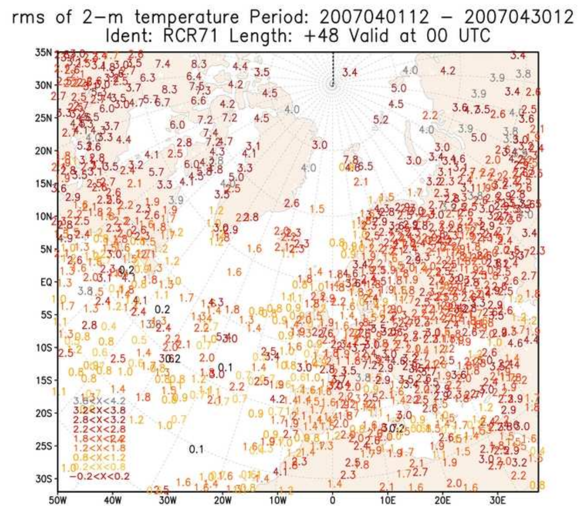


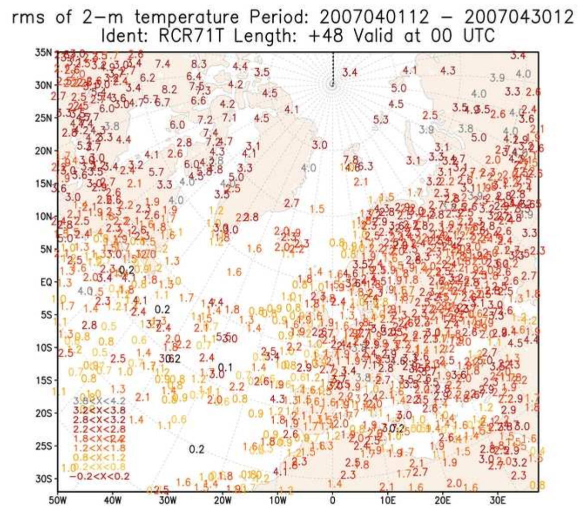


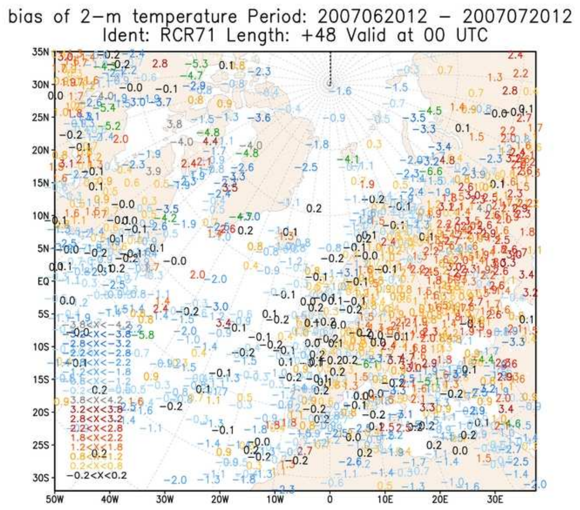


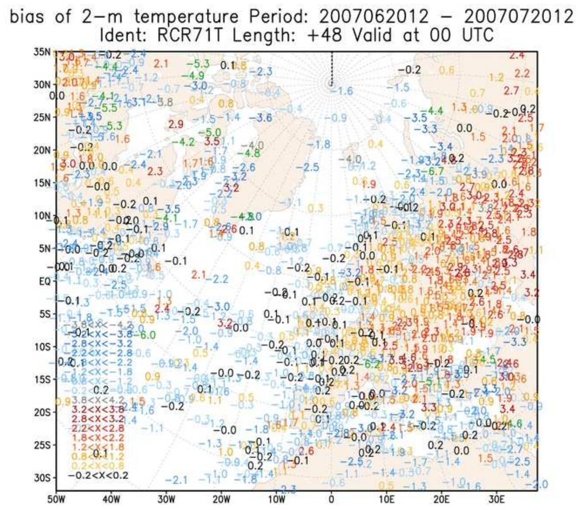


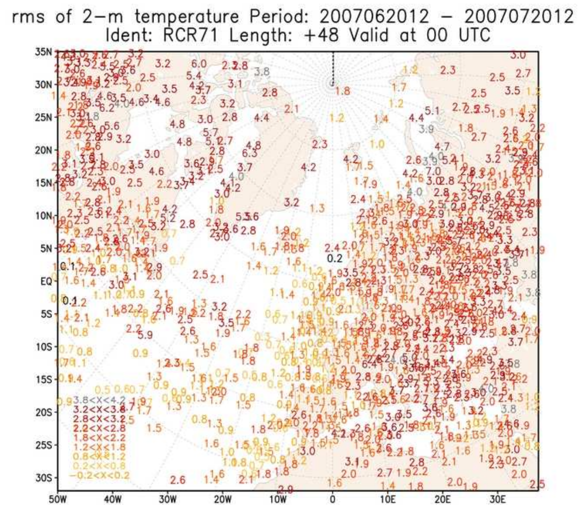


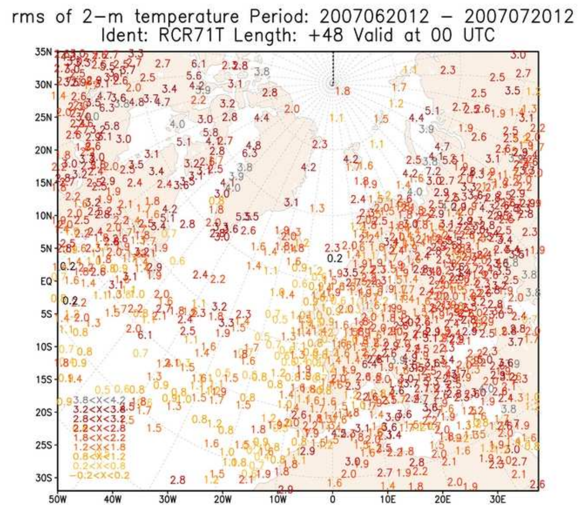




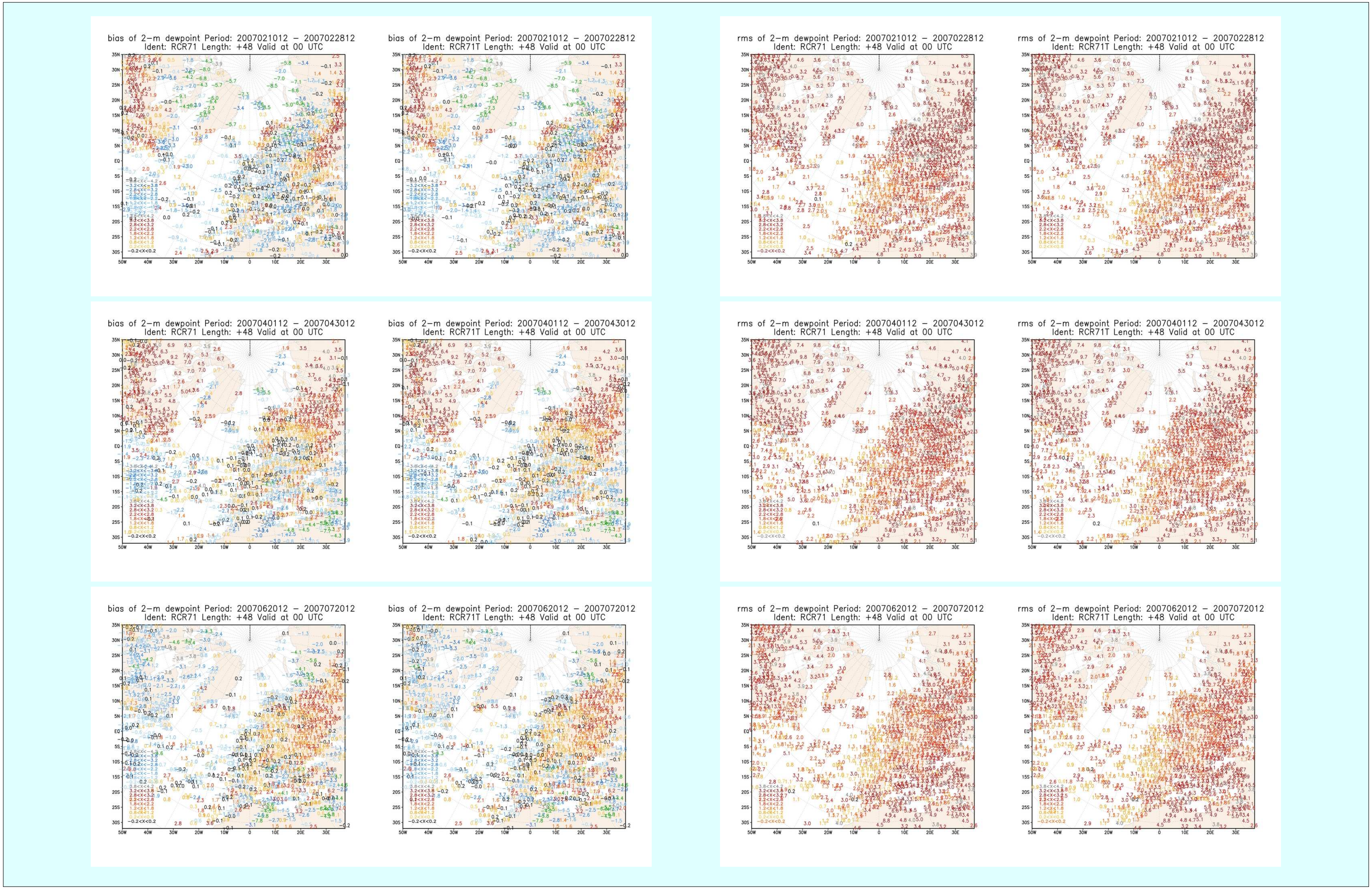




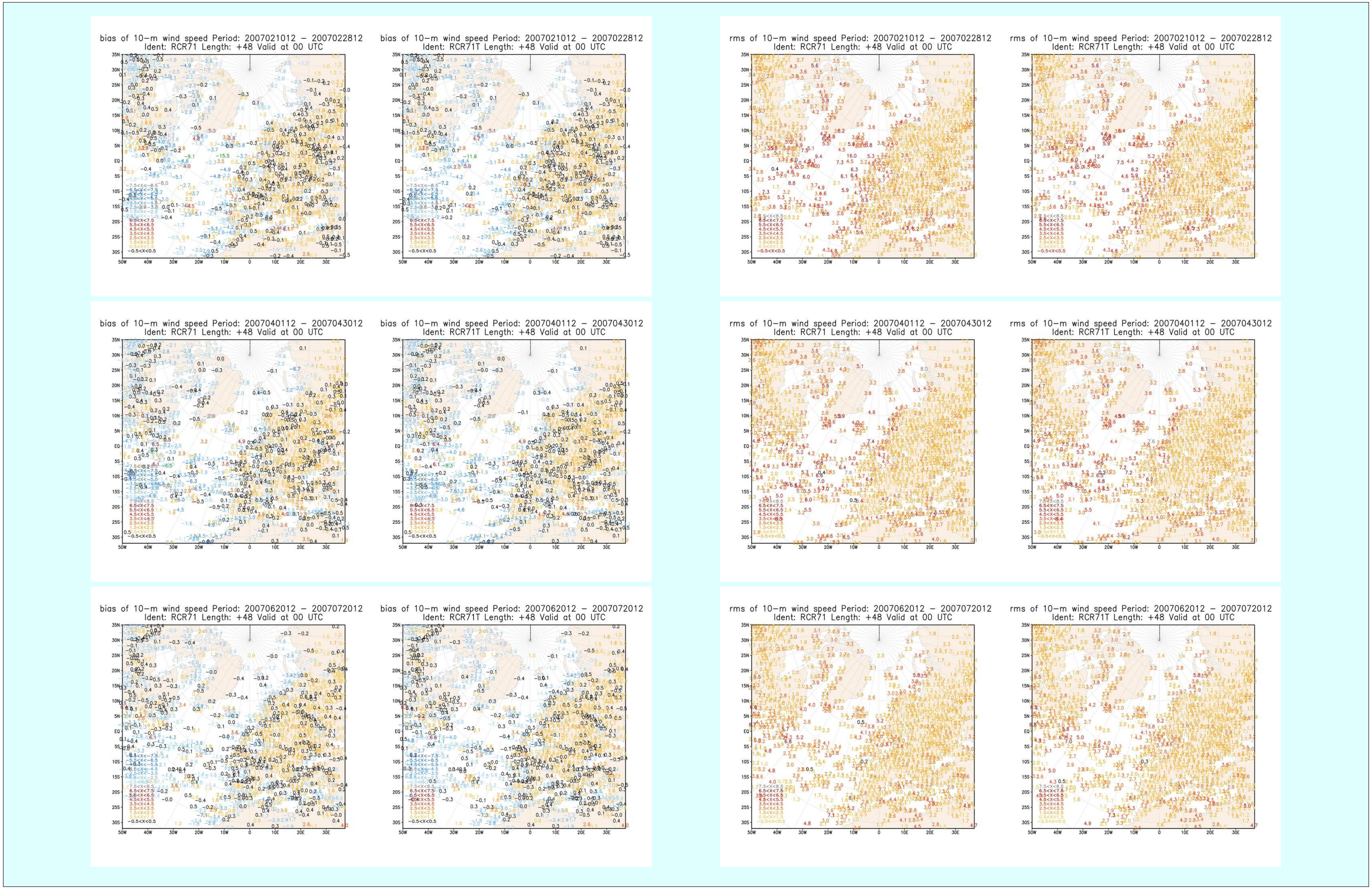




Impact on surface parameters (2m dew point temperature)



Impact on surface parameters (10m wind speed)



Summary and Conclusions

This work tries to investigate the effect of changing the ISBA soil type fields (soili) in HIRLAM on the verification scores of surface parameters mean sea level pressure, 2m temperature, 2m humidity and 10m wind speed.

The new soili fields are based on a refined determination of the soil type. This refinement takes both the FAO soil type as well as the sub-surface type vegi into account when defining one of the three ISBA soil types for a certain land tile of the HIRLAM grid. This methodology has been in use for the sub-grid surface tile 3 (no vegetation land) since the ISBA scheme was introduced into HIRLAM, but it was never applied for the sub-grid surface tiles 4 (low vegetation land) and 5 (forest).

The refined methodology was compared to the current procedure in HIRLAM by running HIRLAM experiments for three periods of several weeks duration each. The periods represent winter season, spring and summer conditions. The comparison comprises standard verification scores for the surface parameters mentioned above.

Results show that refining the soili determination in HIRLAM has a small effect on the vefification scores. This effect consists mainly in the tendency towards slightly increased humidity and slightly decreased temperature close to the surface.

In cases where the temperature bias of HIRLAM is negative, or where humidity bias is positive, the refinement of soili has a rather negative influence.

In the same way, in case of positive temperature bias, or negative humidity bias in HIRLAM, the soili refinement has a slight positive effect.

The spring case also indicates a slight improvement of mean sea level pressure bias.

Local differences in scores occur, as well as there are local differences in bias scores, so the effect of the soili refinement changes from region to region. An improvement of verification scores for surface parameters due to soili refinement can therefore hardly be stated in general.

A single case within the first comparison period indicates, however, an improved rms in dew point during some days of the winter period.

References

Bringfelt B., Gustafsson N., Vilmusenaho P., Järvenoja S. 1995: Updating the HIRLAM physiography and climate data base. *HIRLAM Tech. Rep.*, **19**.

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