Report on stay at ZAMG

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Surface perturbation in LAEF

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Contents

1 Introduction

Surface perturbations are introduced into LAEF by the so called Non-Cycling Surface Breeding (NCSB) method [1]. A LAM forecast is started at time t-12h, with initial conditions and LBC's from ECMWF-EPS, and integrated 12 hours, to generate the surface perturbations for LAEF initialized at time t. Because running the ALADIN LAM with the ECMW surface analysis leads to inconsistencies, the ECMWF surface is first replaced with the ARPEGE surface at time t-12h. The 12h integration is then done, using a multiphysics approach to account for model errors [2], leading to the perturbed 12h forecasts P_n. Finally, the initial conditions for the surface variables A_n (at time t) are calculated according to the following formula:

$$A_n = C + s\Delta P_n \,, \tag{1.1}$$

$$\Delta P_n = P_n - C \,, \tag{1.2}$$

where n denotes the n^{th} ensemble member, C is the control run, i.e., the Arpege surface analysis, and s is the scaling factor. In the current implementation of NCSB in LAEF, a scaling factor $s = 1$ is used, i.e., $A_n = P_n$. The aim of our stay was to investigate whether taking $s > 1$ and/or using

$$\Delta P_n = (-1)^{n+1}(P_n^+ - P_n^-) \,, \tag{1.3}$$

instead of (1.2), leads to improvements in LAEF performance. The P_n^+ and P_n^- in (1.3) are the positive and negative forecast respectively. Currently in LAEF there are 16 members, divided into 8 breeding pairs, with the odd members called 'positive' and the even members called 'negative'. The first pair consists of members 1 and 2, the second pair of members 3 and 4, etc., so we have $P_1^+ = P_1$ and $P_1^- = P_2$, $P_2^+ = P_1$ and $P_2^- = P_2$, $P_3^+ = P_3$ and $P_3^- = P_4$, etc.

2 Implementation of newNCSB

From here on we will refer to the operational NCSB with scaling factor 1, i.e., $A_n = P_n$, as NCSB and refer to all other NCSB versions as newNCSB.

To implement newNCSB into LAEF, a perl script surfbreed.pl was made (adaptation of M. Bellus's breed.pl), together with a Fortran program ptbSURFini (adaptation of Y. Wang's ptbPSini), which is used in surfbreed.pl. There are actually 6 basic versions

- surfbreed.pl (with ptbSURFini)
- surfbreedC.pl (with PptbSURFini and NptbSURFini)
- surfbreedX.pl (with ptbSURFini_X)
- surfbreedCX.pl (with PptbSURFini_X and NptbSURFini_X)
- surfbreed*.pl (with ptbSURFini_*)
- surfbreedC*.pl (with PptbSURFini_* and NptbSURFini_*)

where * can be a letter like 'A', 'B', 'U', ..., or X+ (see the directory *zaanfe:/home/mproj/smet*, the .f90 files are well documented, and should be compiled using makebred_0.0). In the above list, 'C' stands for 'centered', i.e versions of surfbreed with 'C' in the name, implement equation (1.3), while those without 'C' use equation (1.2). Not all surface variables are rescaled with formula (1.1). The FORTRAN programs (P/N)ptbSURFini without '*' only rescale the fields 'SURFTEMPERATURE', 'SURFRESERV.EAU' and 'SURFALBEDO' (with the same scale s, which is read from a file called 'surfscaling'). More and/or other fields are rescaled in the programs with '*', for instance, 'SURFTEMPERATURE', 'SURFRESERV.EAU', 'SURFALBEDO', 'PROFRESERV.EAU', 'SURFRESERV.INTER', 'PROFTEMPERATURE', 'SURFEMISSIVITE', 'SURFRESERV.GLACE', 'PROFRESERV.GLACE', 'SURFRESERV.NEIGE' (all with the same scale s) in the programs (P/N)ptbSURFini_X+, 'SURFALBEDO', 'PROFTEMPERATURE', 'PROFRESERV.EAU' in (P/N)ptbSURFini_P, etc. Finally, the difference between (P/N)ptbSURFini and all other verions is the following. The fields that are not rescaled in (P/N)ptbSURFini are rescaled with scale 0, i.e. we take the values from the Arpege analysis for them. On the other hand, in versions with an 'X' or '*', the fields that are not rescaled in (P/N)ptbSURFini_(X/*) (with scale s) are rescaled with scale 1 [using eqns. (1.1)-(1.2)], i.e. we take the values from the 12h surface forecast P_n.

WORD OF CAUTION!: The versions with '*' were sofar only run with scale s=5 and some of these experiments lead to crashes of certain ALADIN exe's on certain days, e.g. CX+ experiment on 2007062600 or CU experiment on 2007070600. We haven't had time yet to figure out what's causing this.

3 Experiments

The experiments were done over the LAEF domain with 18 km resolution (225x324 grid points) and 37 levels, with 110x196 grid points used for the post-processing domain. A multiphysics approach was taken for all experiments, see [2] for a description of the different ALADIN executables used. To get a clear idea of the effect of the surface perturbation, we used downscaled ECMWF for the upper air fields in all of the experiments, i.e. without employing breeding/blending. The scripts are stored in *zaanfe:/home/mproj/smet* (the directory *zaanfe:/home/mproj/surf* contains older unfinished experiments that used breeding/blending for the upperair fields). The output was written to *zaanfe:/data/laef/RESULT/surf* and then transfered to *zasmlpc1:/daten3/weid/mproj* to do the verification. Verification results and scripts can be found in *zasmlpc1:/home/mproj/smet/verif*. Finally, for future use, the fullpos files were stored in *zasmlpc1:/laka/geert*. We have done the following reference experiments:

- **surfSECM**: This is just downscaling of ECMWF eps, i.e. ECMWF surface is used.
- **surfSARP**: The ECMWF surface is replaced with ARPEGE surface.
- **surfNCSB**: The 12h surface forecasts P_n are used instead of ARPEGE surface, i.e NCSB.

The following newNCSB experiments were run and verified for a 1-month period (from 20-06-2007 until 20-07-2007):

- **surfCX50**: Uses surfbreedCX.pl with scale $s = 5.0$, i.e for the fields 'SURFTEMPERATURE', 'SURFRESERV.EAU' and 'SURFALBEDO' we used equations (1.1) and (1.3) with $s = 5.0$, and for the other fields we used P_n, as we already explained in the previous section.
- **surfCX20**: Uses surfbreedCX.pl with scale $s = 2.0$.
- **surfCT50**: Uses surfbreedCT.pl, with $s = 5.0$, i.e for the fields 'SURFTEMPERATURE' and 'PROFTEMPERATURE' we used equations (1.1) and (1.3) with $s = 5.0$, and for the other fields we used P_n.
- **surfCP50**: Uses surfbreedCP.pl, with $s = 5.0$, i.e for the fields 'PROFTEMPERATURE', 'PROFRESERV.EAU' and 'SURFALBEDO' we used equations (1.1) and (1.3) with $s = 5.0$, and for the other fields we used P_n.
- **surfCC50**: Uses surfbreedCC.pl, with $s = 5.0$, i.e for the fields 'SURFTEMPERATURE', 'SURFRESERV.EAU', 'PROFTEMPERATURE', 'PROFRESERV.EAU' and 'SURFALBEDO' we used equations (1.1) and (1.3) with $s = 5.0$, and for the other fields we used P_n.

4 Verification results

The experiments were done for a one month period from 20-06-2007 until 20-07-2007, and only for the 00 UTC run. It was found that at 0h runtime, the 3rd member (configuration HARMONIE [2]) has unrealistic values for the field 'CLSTEMPERATURE', but other fields like 'SURFTEMPERATURE' and 'SO37TEMPERATURE' seem alright. This leads to large errors in the verification at 0h runtime, but does not have any impact at later runtime. Hence, verification was done for a runtime from 6h to 54h.
Verification plots are shown in figures 1-37 in appendix A. The results can be summarized as follows:

- As is already well known, replacing the ECMWF surface by the ARPEGE surface, leads to big improvements for the surface weather variables, see figures 1-7.

- Using the NCSB scheme leads to an additional improvement, albeit a small one, when compared with experiment SARP. The improvement is most visible in the outliers plot and the Talagrand diagrams for 2m temperature anomaly (figure 2 and figures 4-7).

- All the newNCSB experiments lead to better results than the (old) NCSB scheme, for all the verification scores. The improvements is largest for the 2m temperature variable. Spread is increased, especially for the first 12 hours of the integration. See figures 1-14.

- Best results were obtained with experiment CC50, see figures 8-14. Unlike the other experiments, increased spread seems to persist over the whole 54h runtime, see figure 15. While the improvement is largest for the 2m temperature variable, there are also small improvements for other surface weather variables (MSL-pressure, total 12h precipitation, 10m wind speed), see figures 15-28.

- A scale $s = 5.0$ seems to give better results than a scale $s = 2.0$ (or lower), see figures 29-37. Plots of scale lower than 2.0 are not shown, but give worse results, i.e. closer to the (old) NCSB experiment. While sofar we have only run experiment CX with scale lower than 5.0, we expect the results to be true for the other experiments, e.g. CC, as well. This will be tested in the future.

Remarks:

- We have run the experiments with a rather large scale $s = 5.0$ to get a more pronounced effect. Although this seems unphysically large, the model apparently adapts well too it. While the perturbed surface fields, e.g. 'SURFTEMPERATURE', etc., initially have unrealistic values, the 6h values already look completely normal. See figures 38-39.

- It should also be noted that using formula (1.1) on the fields 'SURFRESERV.EAU' and 'PROFRESERV.EAU' can lead to unphysical (negative) values, since these fields should be positive or zero. Again however, the model seems to adapt well. Even if initially these fields have unphysical values, the 6h values are already much more reasonable and the fields still have similar structure as the initial fields. See figures 40-41. Nevertheless, perhaps some more sophisticated method for perturbing these fields should be looked for, to avoid these unphysical initial values.

- We have also done an experiment X50, to test formula (1.2) and compare with CX50, which uses formula (1.3). This experiment (X50) lead to a crash of the ALADIN executable of the first member for day 29-06-2007. We suspect that the perturbation of certain surface fields became too large for this member, as decreasing the scale to $s = 2.0$ solved the problem. For each pair of members, one of the members (positive or negative) is usually close to the analysis C, while the other one is quite far. Taking a large scale $s = 5.0$ then probably becomes problematic for the members far from the analysis. On the other hand, if we take a smaller scale, e.g. $s = 2.0$, then the members closest to the analysis will not be perturbed enough. This makes adding perturbations using the 'centered' method superior.

- The most succesful experiments were run for a one month period and only for 00 UTC, so that we could do more experiments. It might be worthwhile to do some tests on longer and/or different time periods.

5 Conclusions

We have shown that introducing surface perturbations using the NCSB method as its currently implemented into LAEF leads to a small performance improvement (for the surface weather variables), compared with just taking the Arpege surface analysis for each member. This improvement can be made bigger by implementing new versions of NCSB, which use eq. (1.3) instead of eq. (1.2) and a scale $s > 1$. Best results were obtained with experiment CC50, which perturbs the fields 'SURFTEMPERATURE', 'SURFRESERV.EAU', 'PROFTEMPERATURE', 'PROFRESERV.EAU' and 'SURFALBEDO' using newNCSB with scale $s = 5.0$. More research should be done to determine which scale s is most appropriate.

Acknowledgement

I would like to thank all colleagues at ZAMG for their hospitality and especially Yong Wang, Christoph Wittmann, Florian Weidle, Martin Bellus and Stefan Schneider for their help during my stay.

A Figures

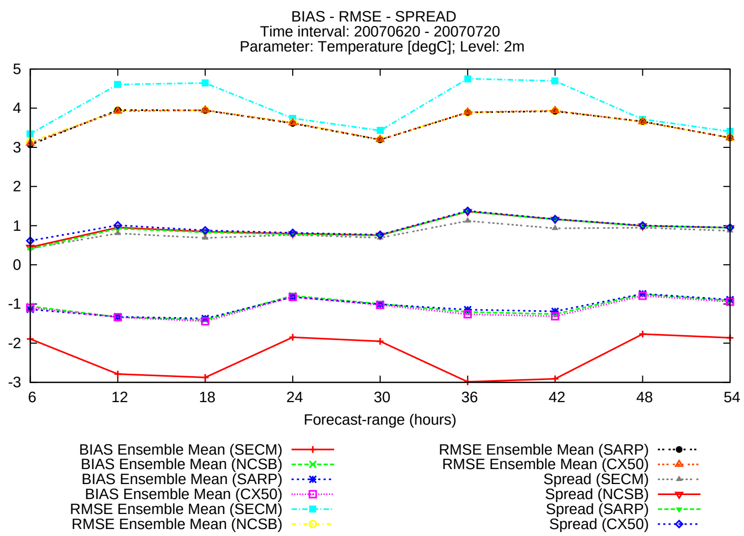

Figure 1: BIAS, RMSE and SPREAD for temperature anomaly at 2m

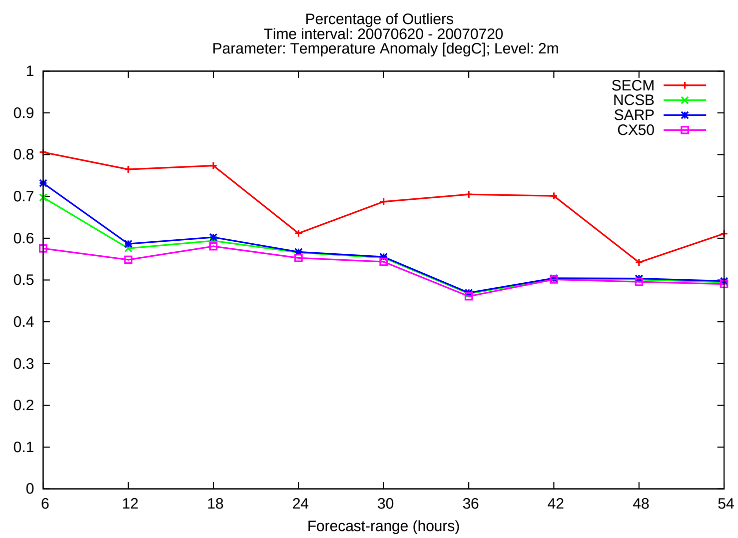

Figure 2: Percentage of outliers for temperature anomaly at 2m

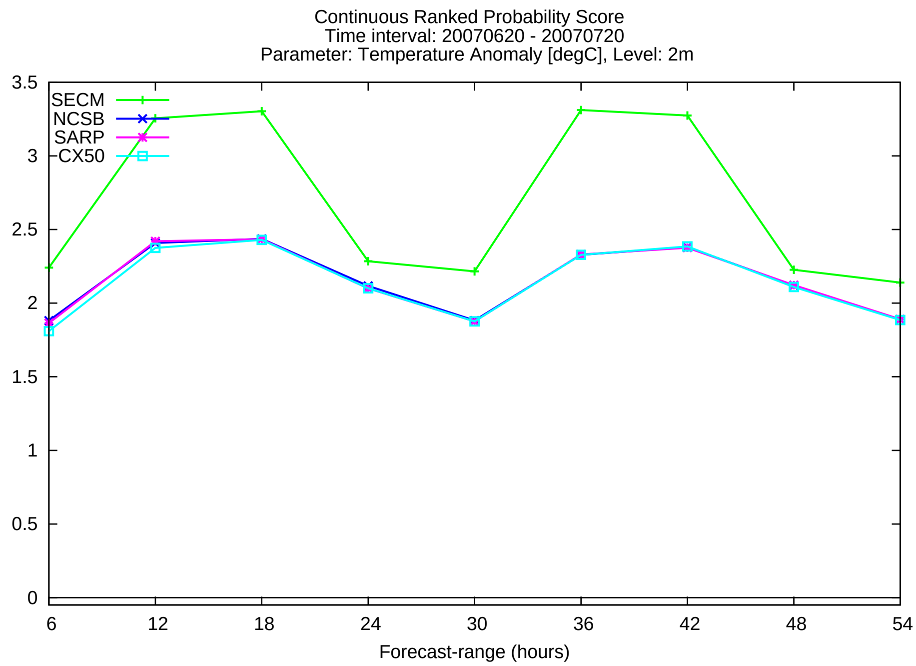

Figure 3: CRP score for temperature anomaly at 2m

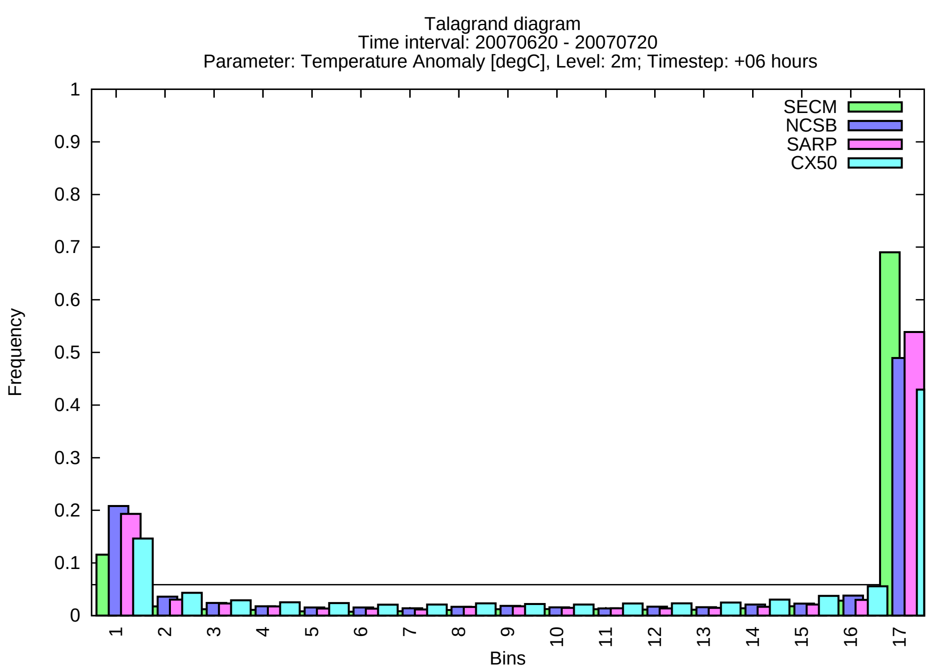

Figure 4: Talagrand diagram for temperature anomaly at 2m (+6h)

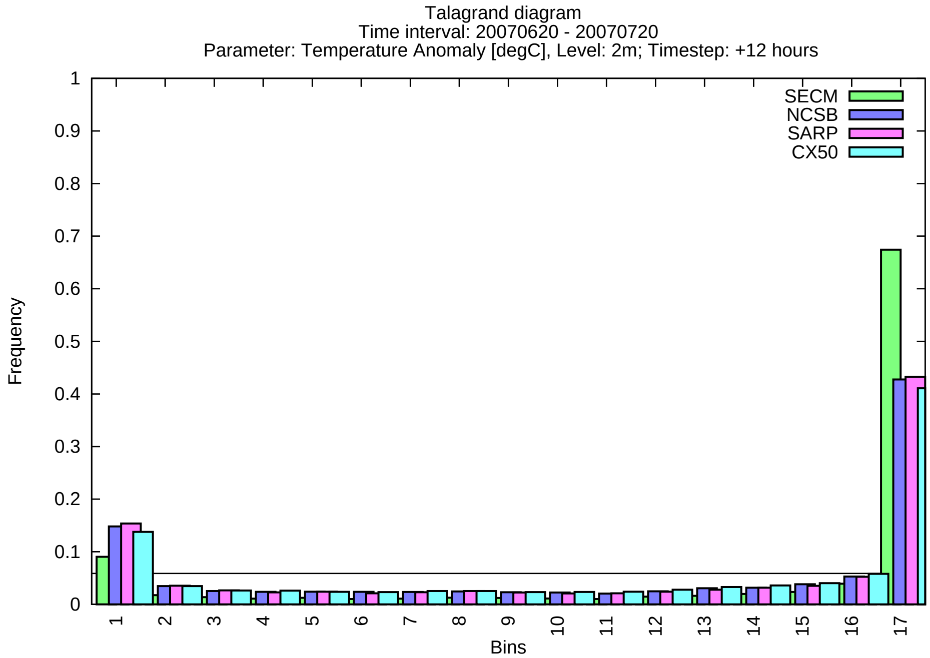

Figure 5: Talagrand diagram for temperature anomaly at 2m (+12h)

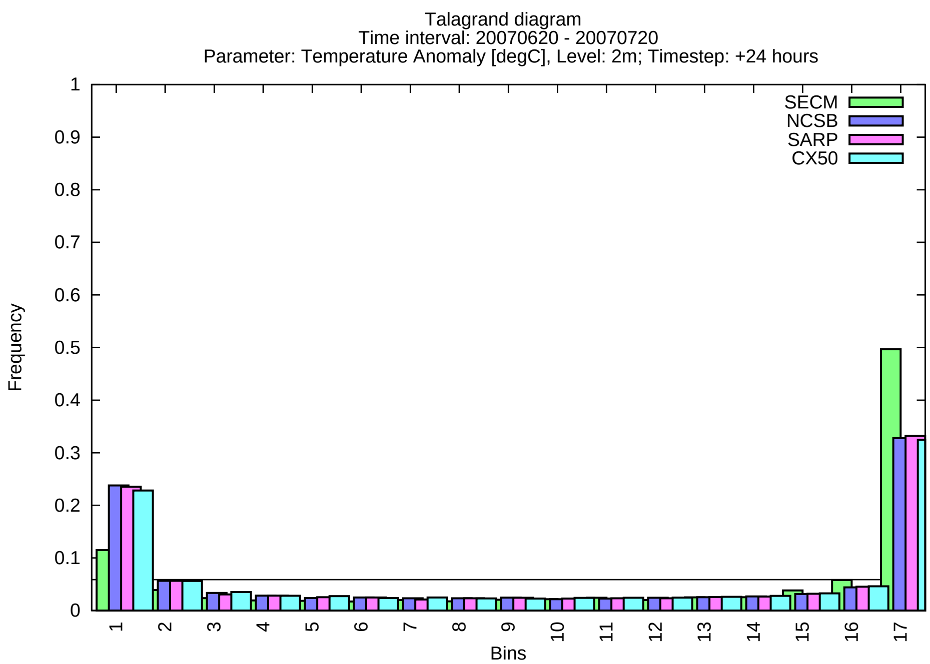

Figure 6: Talagrand diagram for temperature anomaly at 2m (+24h)

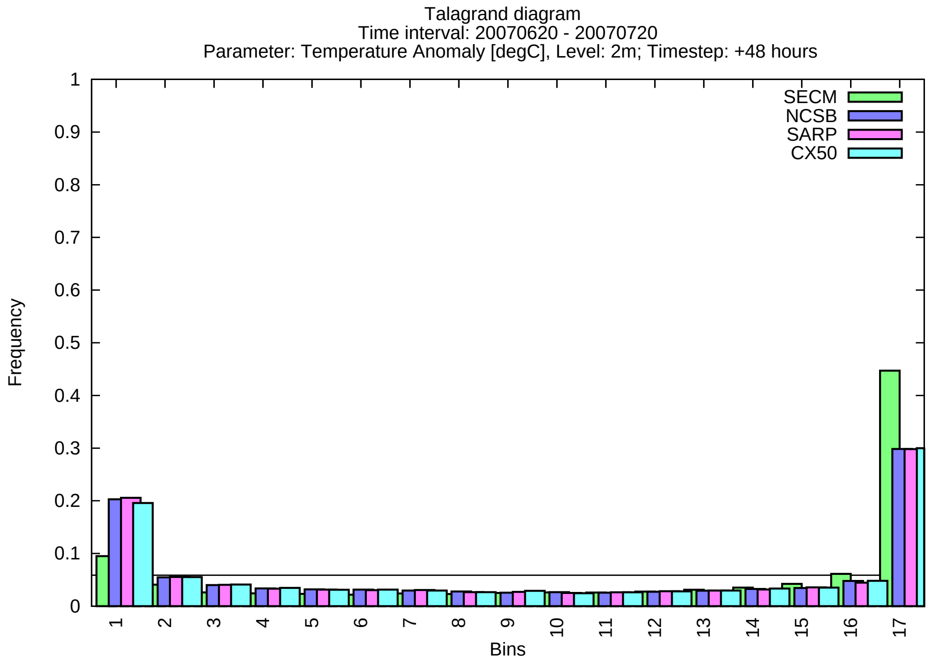

Figure 7: Talagrand diagram for temperature anomaly at 2m (+48h)

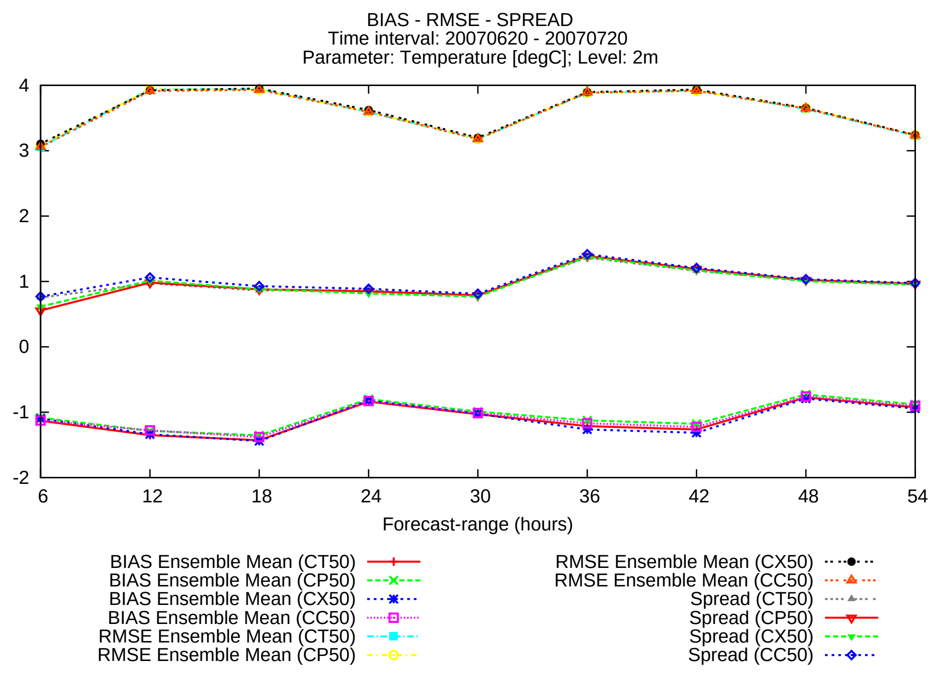

Figure 8: BIAS, RMSE and SPREAD for temperature anomaly at 2m

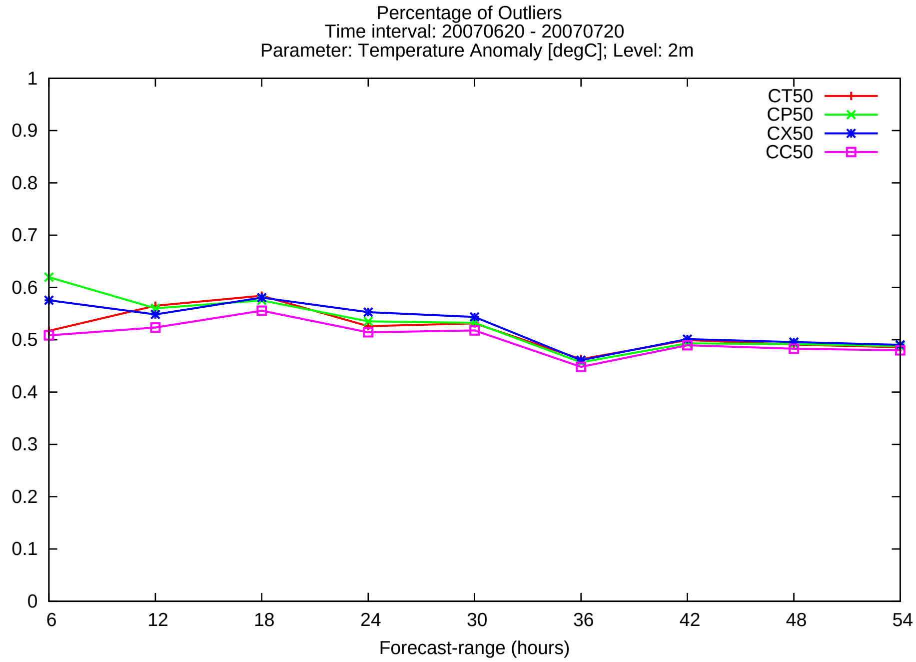

Figure 9: Percentage of outliers for temperature anomaly at 2m

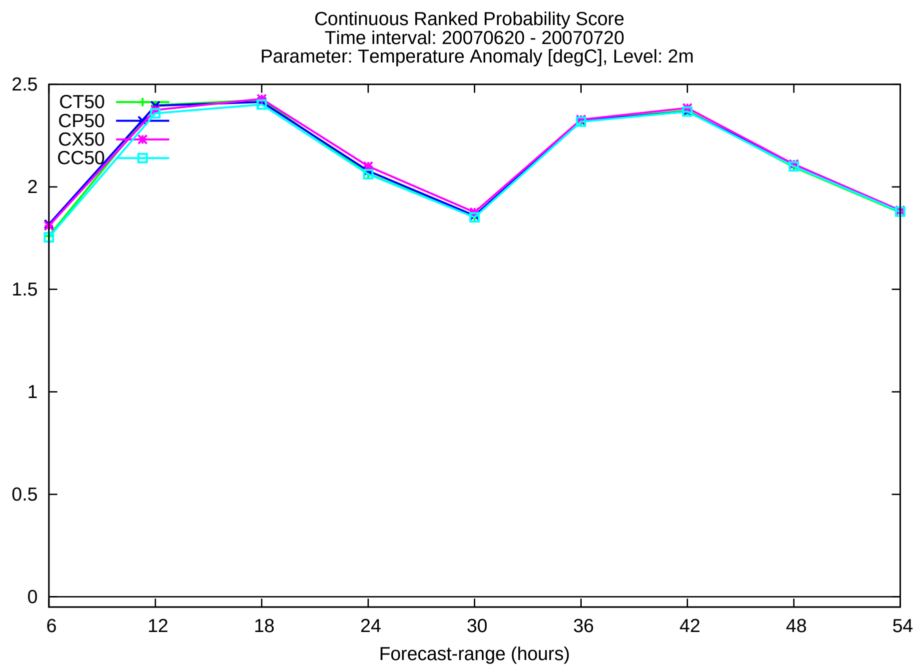

Figure 10: CRP score for temperature anomaly at 2m

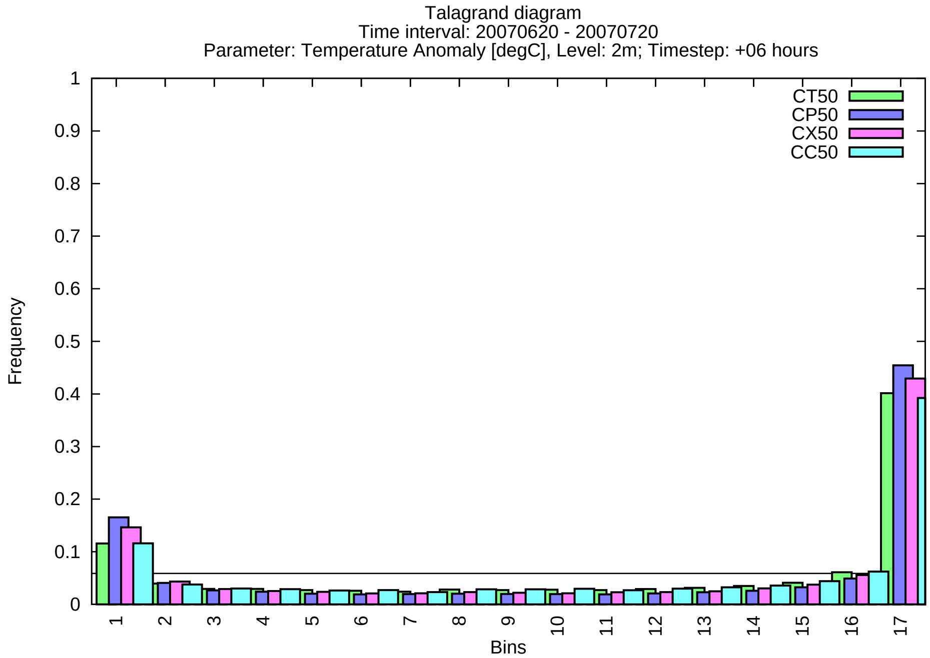

Figure 11: Talagrand diagram for temperature anomaly at 2m (+6h)

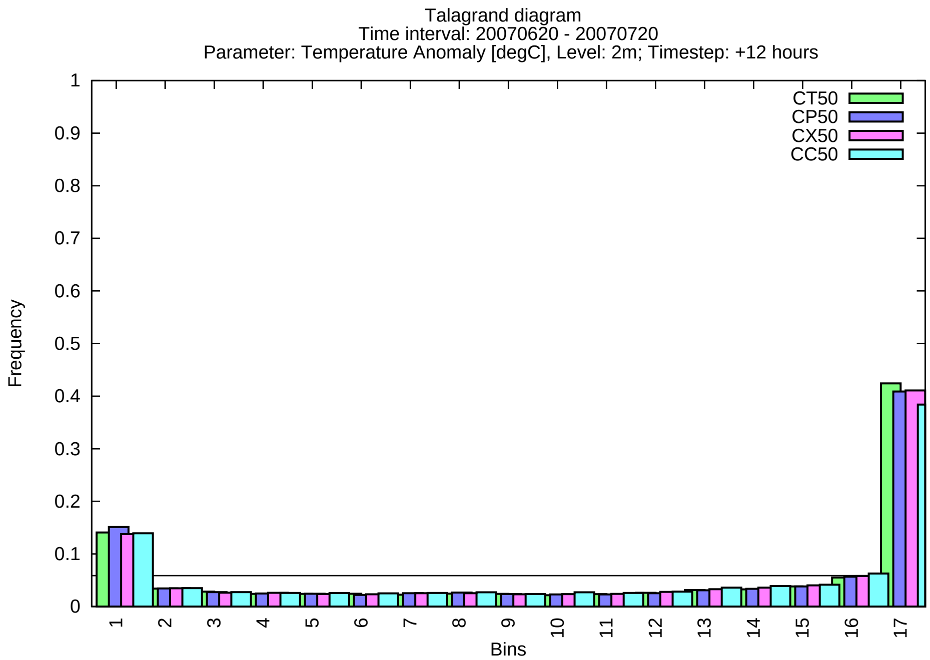

Figure 12: Talagrand diagram for temperature anomaly at 2m (+12h)

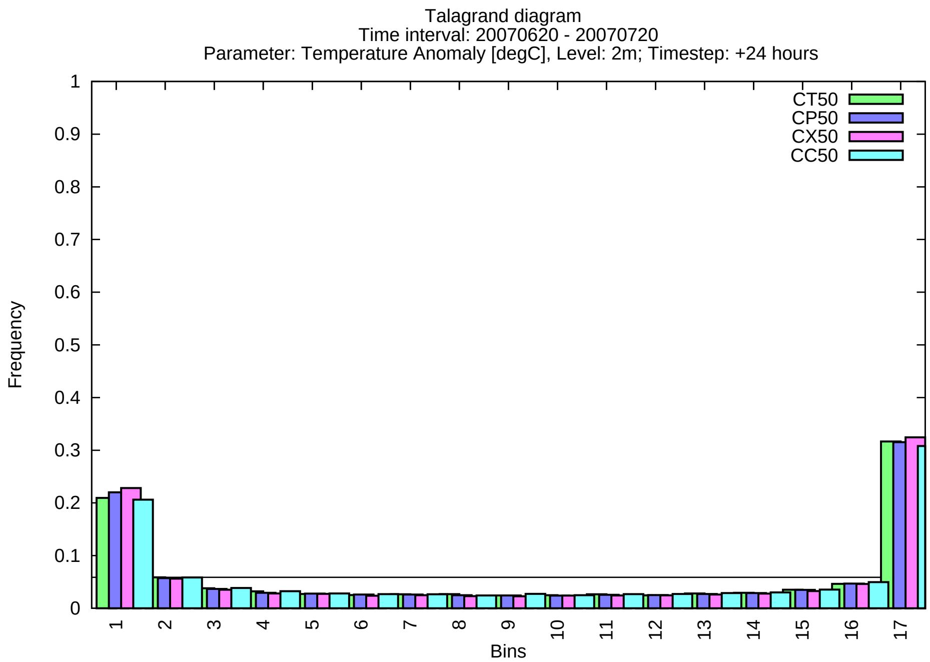

Figure 13: Talagrand diagram for temperature anomaly at 2m (+24h)

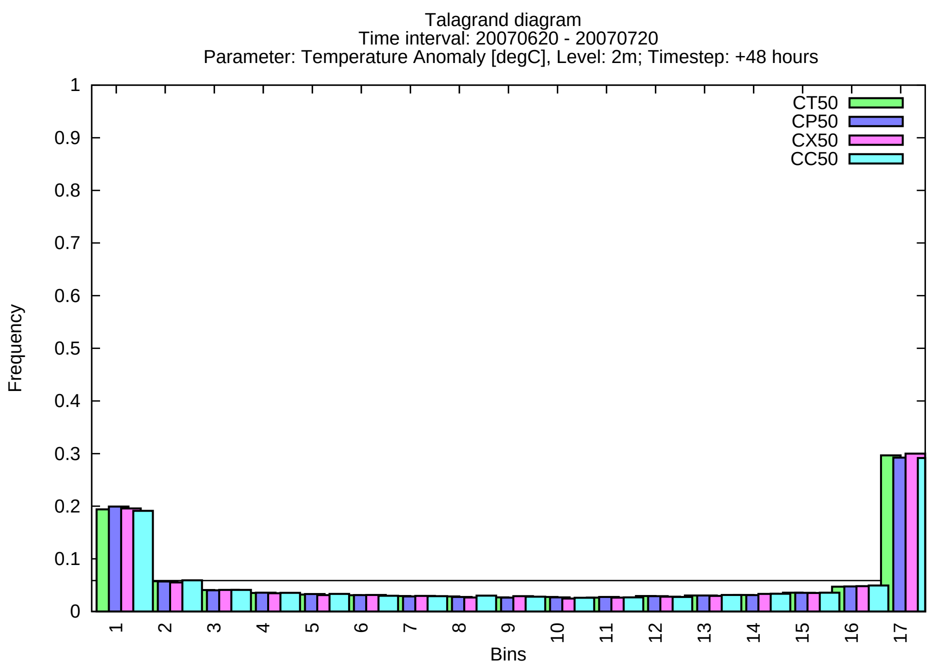

Figure 14: Talagrand diagram for temperature anomaly at 2m (+48h)

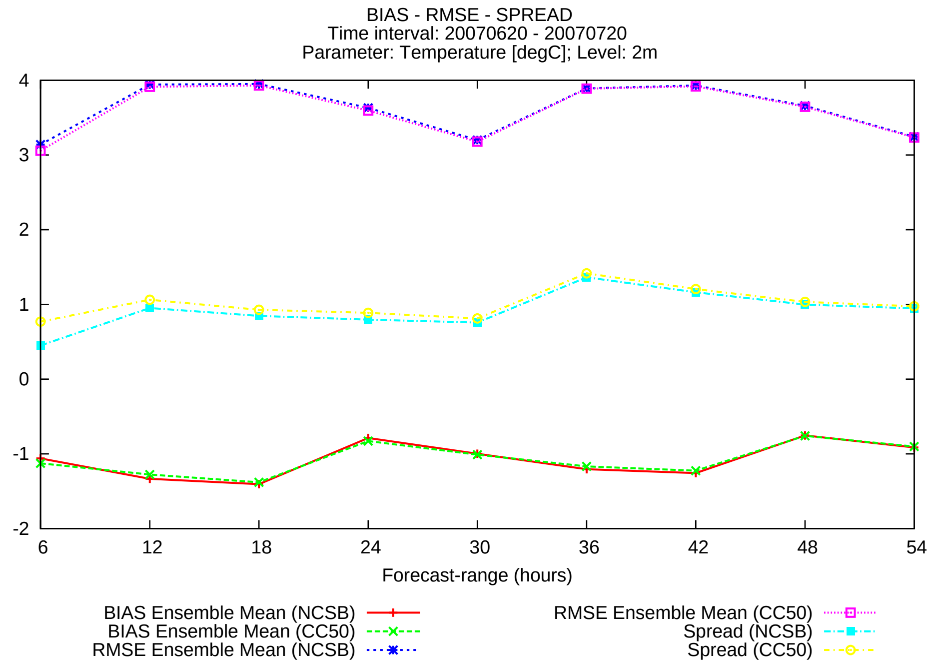

Figure 15: BIAS, RMSE and SPREAD for temperature anomaly at 2m

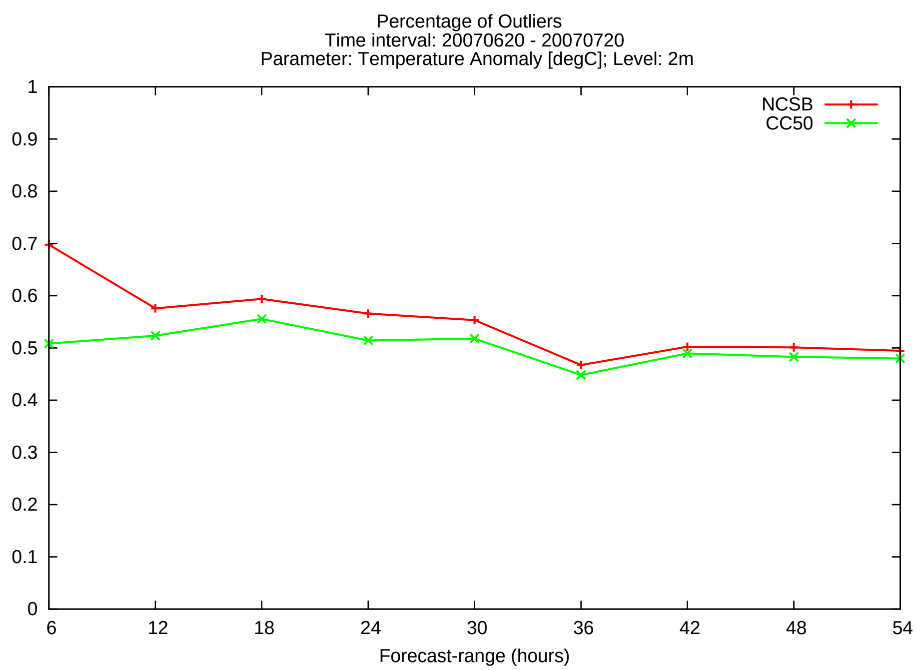

Figure 16: Percentage of outliers for temperature anomaly at 2m

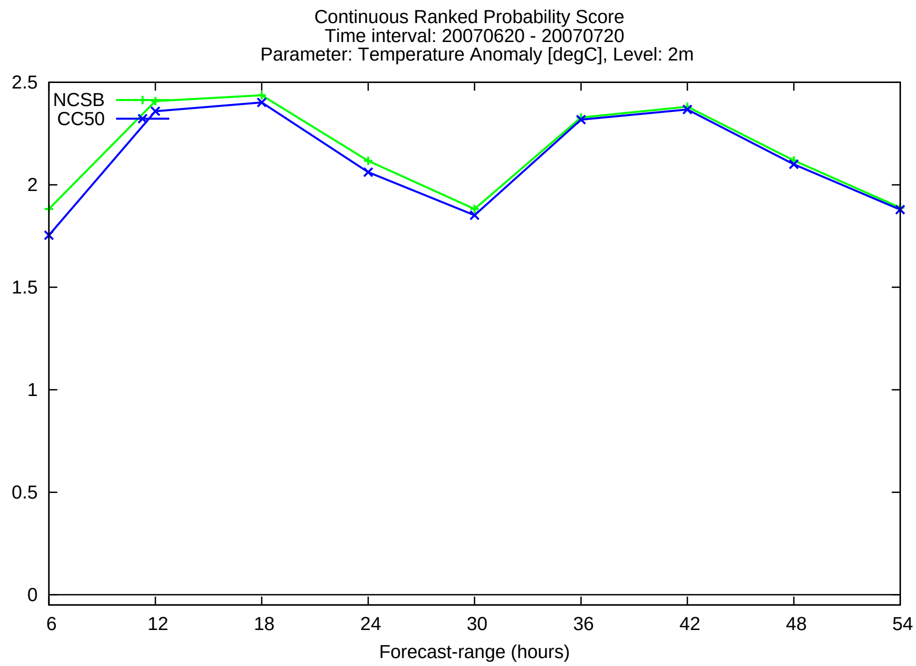

Figure 17: CRP score for temperature anomaly at 2m

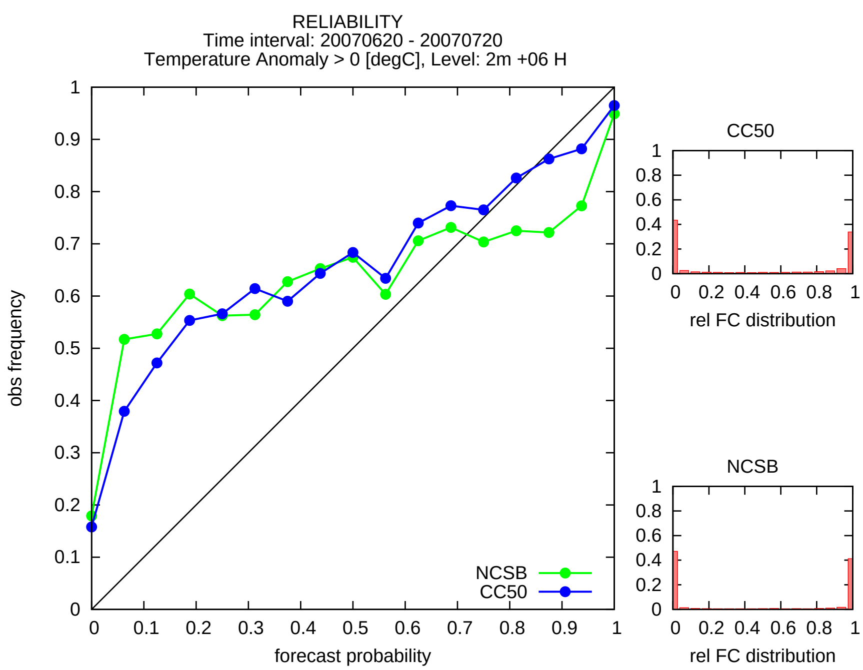

Figure 18: Reliability for temperature anomaly > 0 deg. at 2m (6h)

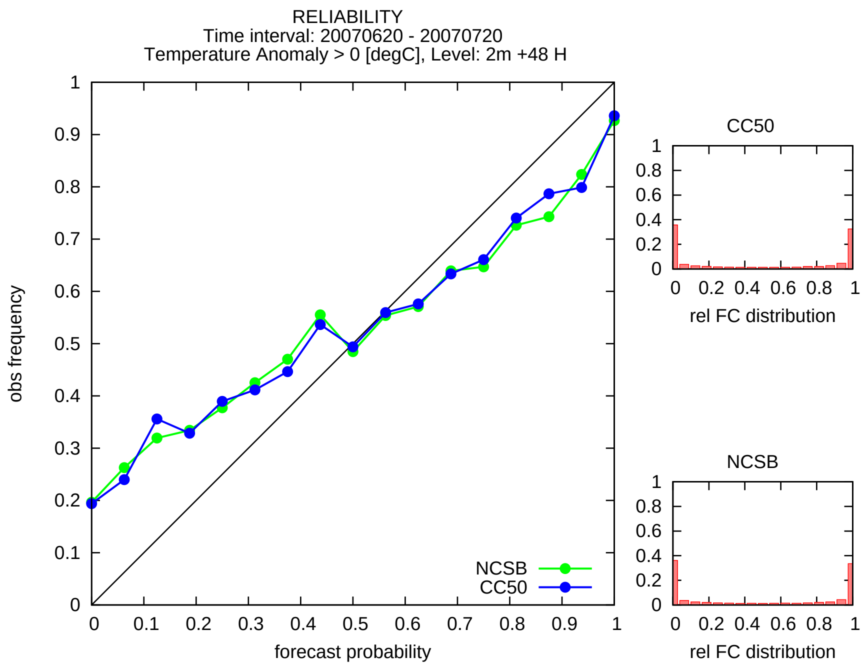

Figure 19: Reliability for temperature anomaly > 0 deg. at 2m (48h)

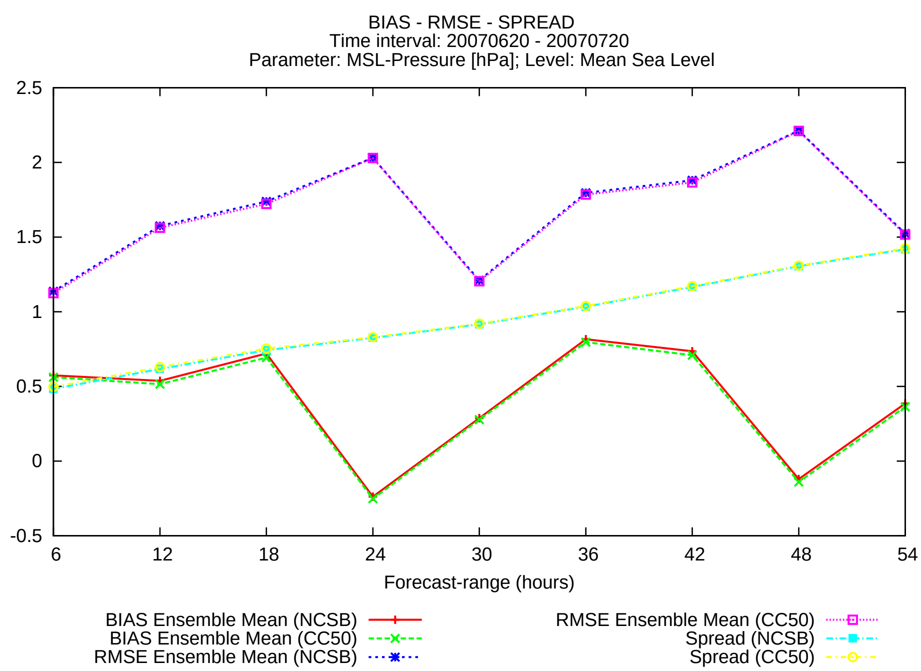

Figure 20: BIAS, RMSE and SPREAD for mean sea level pressure

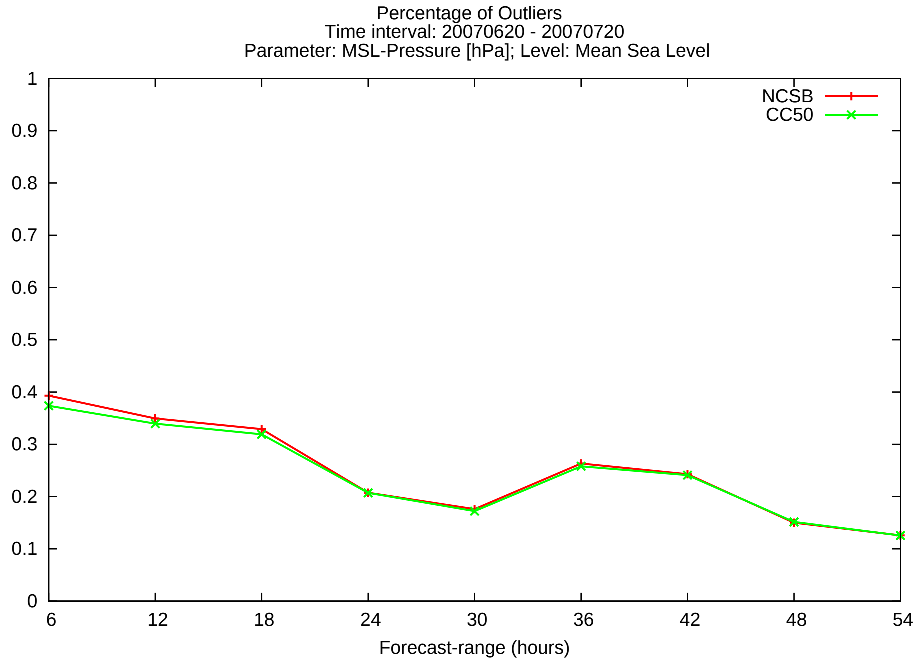

Figure 21: Percentage of outliers for mean sea level pressure

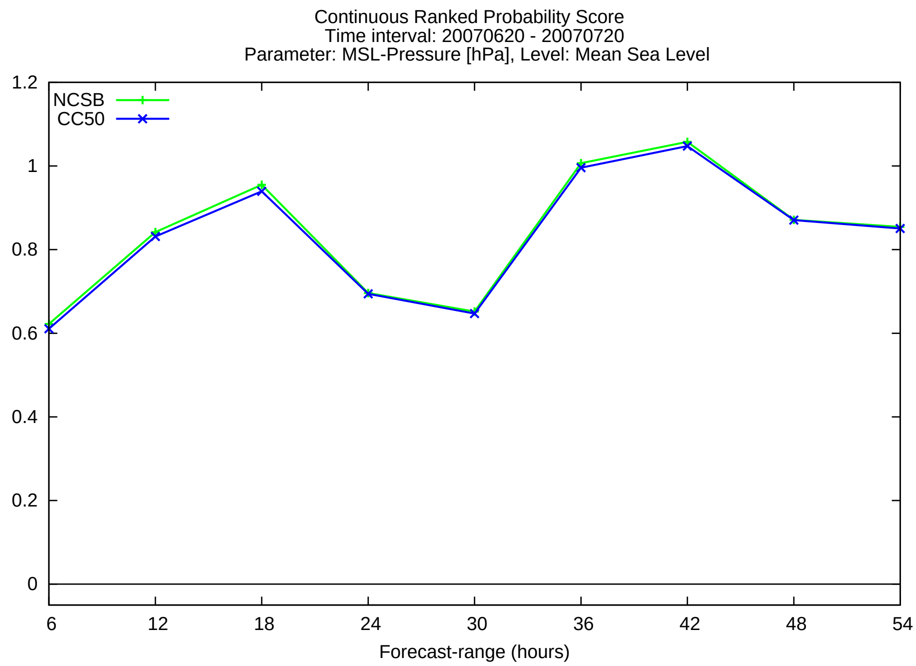

Figure 22: CRP score for mean sea level pressure

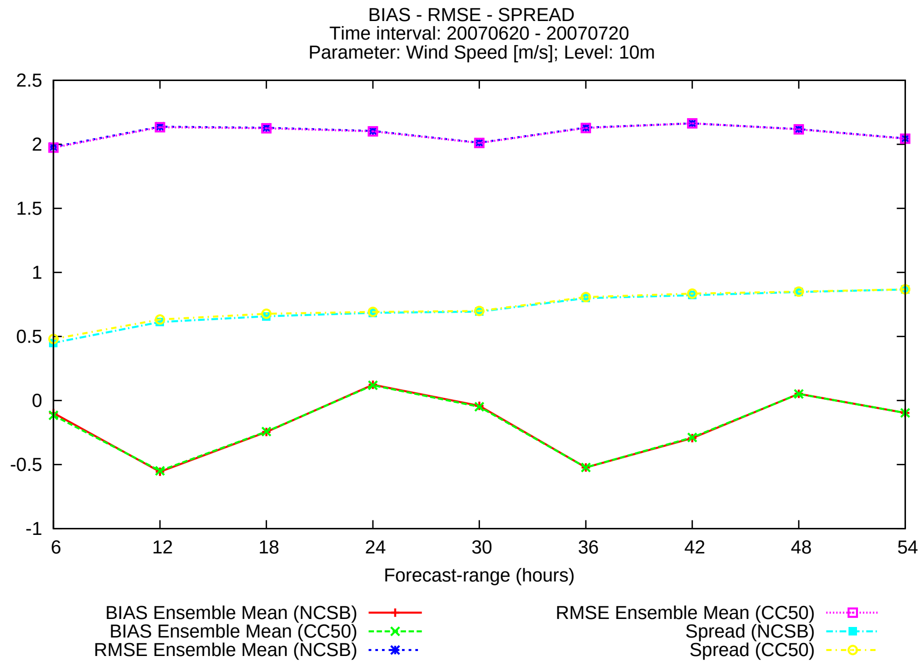

Figure 23: BIAS, RMSE and SPREAD for wind speed at 10m

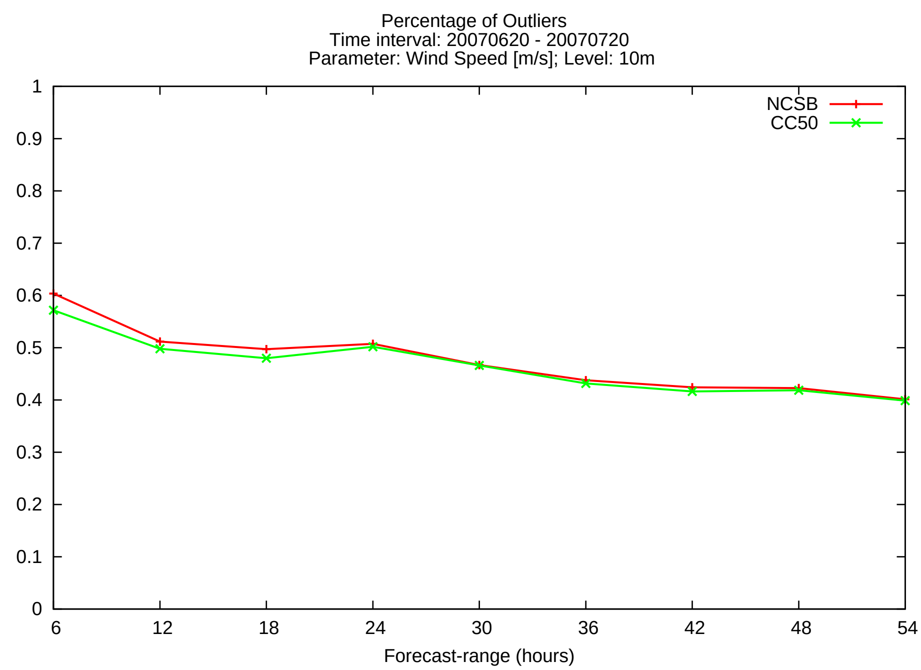

Figure 24: Percentage of outliers for wind speed at 10m

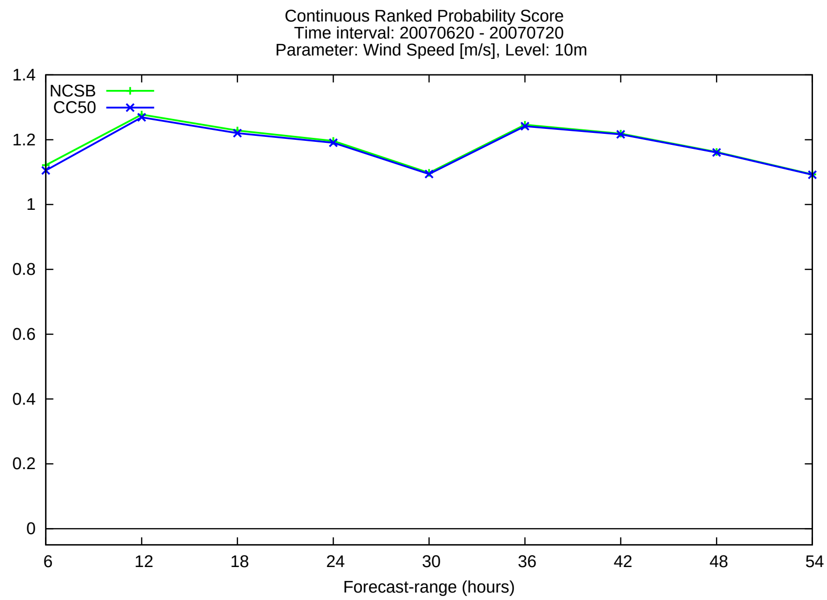

Figure 25: CRP score for wind speed at 10m

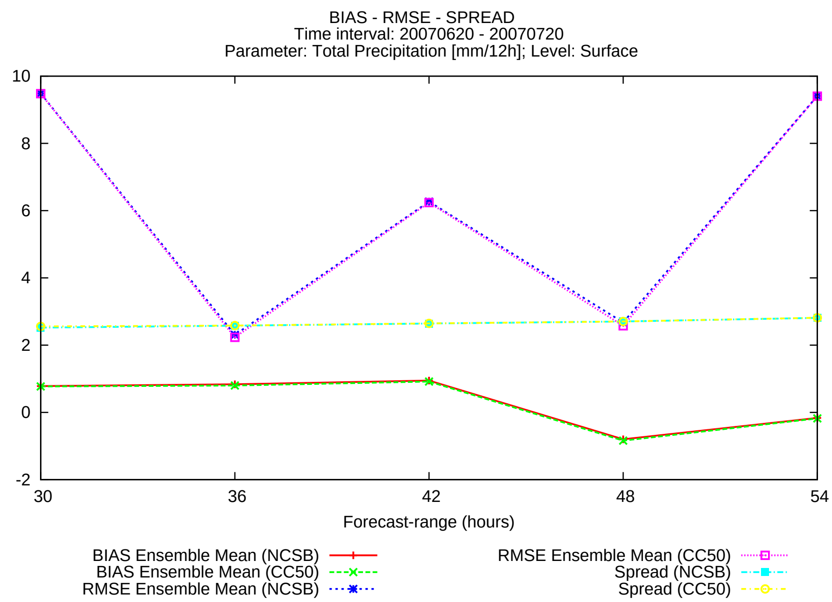

Figure 26: BIAS, RMSE and SPREAD for total precipitation (mm/12h) at the surface

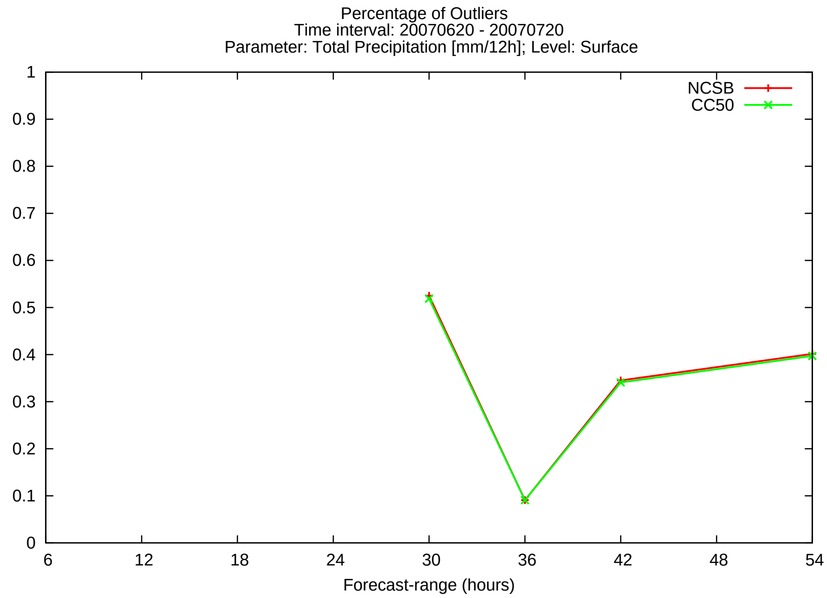

Figure 27: Percentage of outliers for total precipitation (mm/12h) at the surface

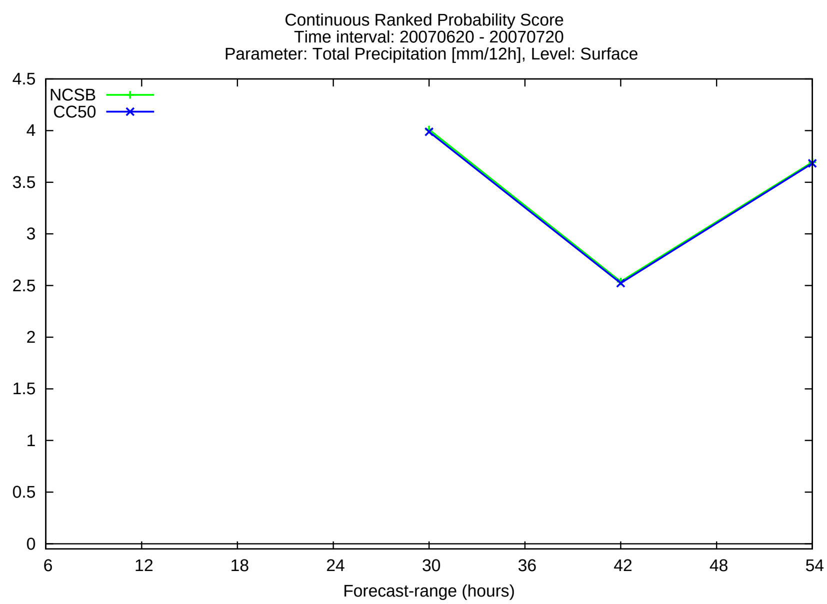

Figure 28: CRP score for total precipitation (mm/12h) at the surface

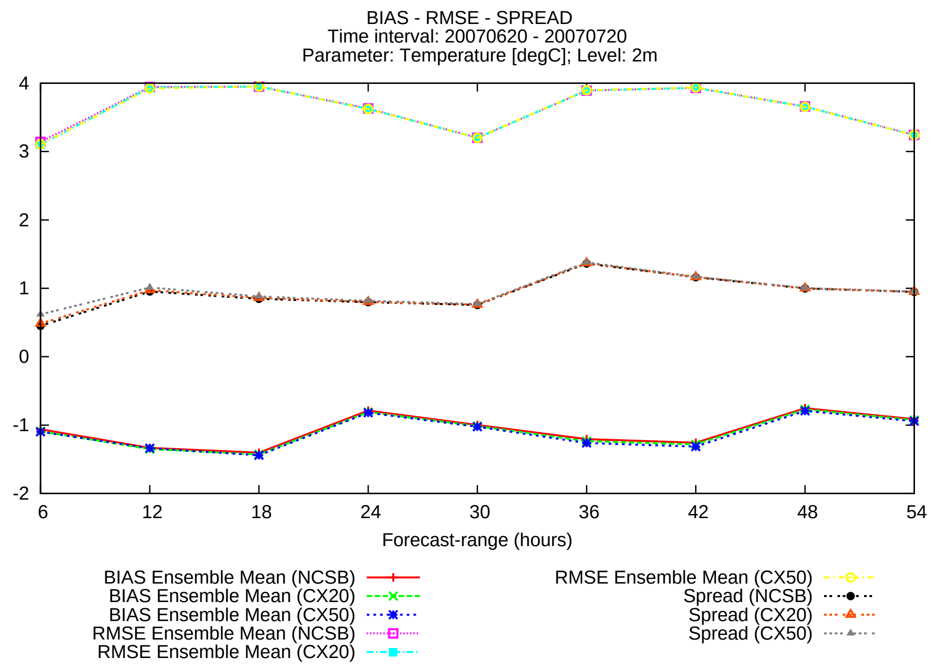

Figure 29: BIAS, RMSE and SPREAD for temperature anomaly at 2m

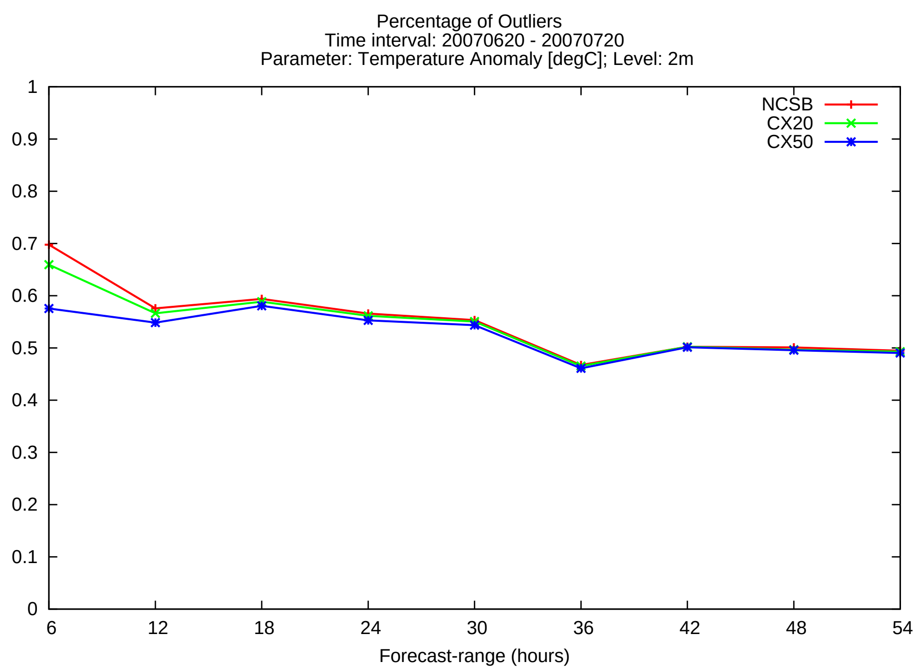

Figure 30: Percentage of outliers for temperature anomaly at 2m

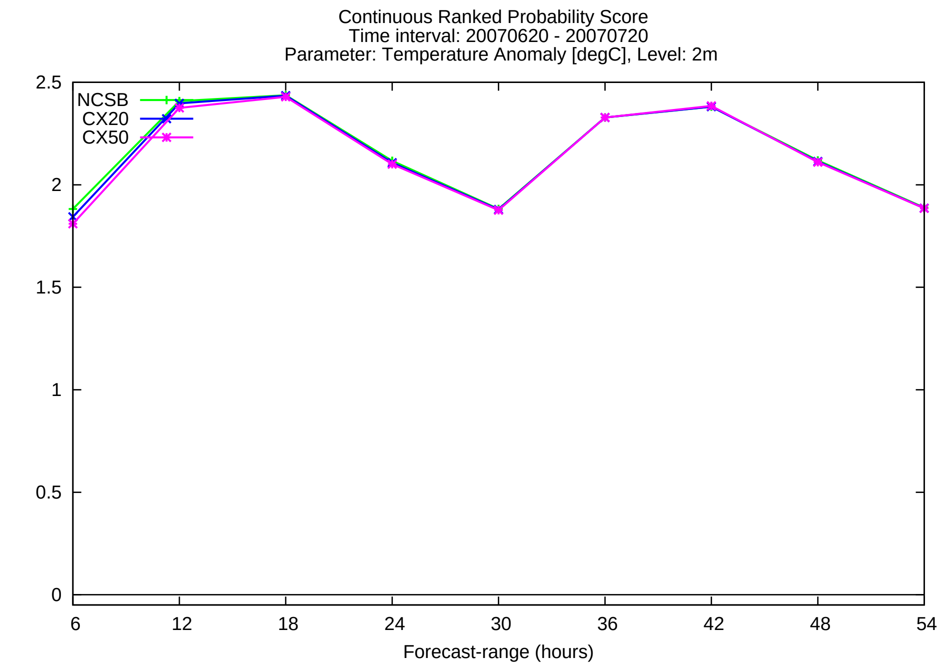

Figure 31: CRP score for temperature anomaly at 2m

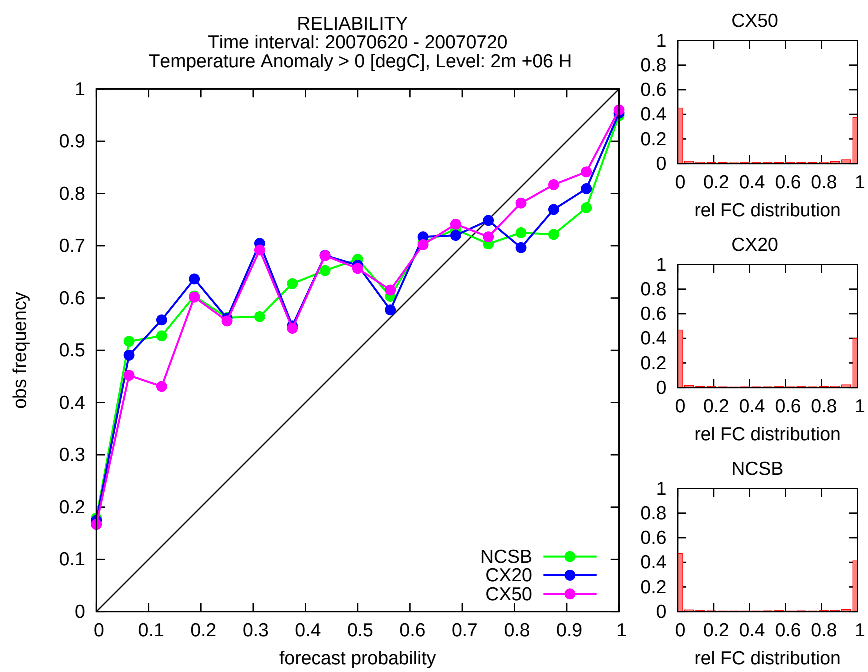

Figure 32: Reliability for temperature anomaly > 0 deg. at 2m (6h)

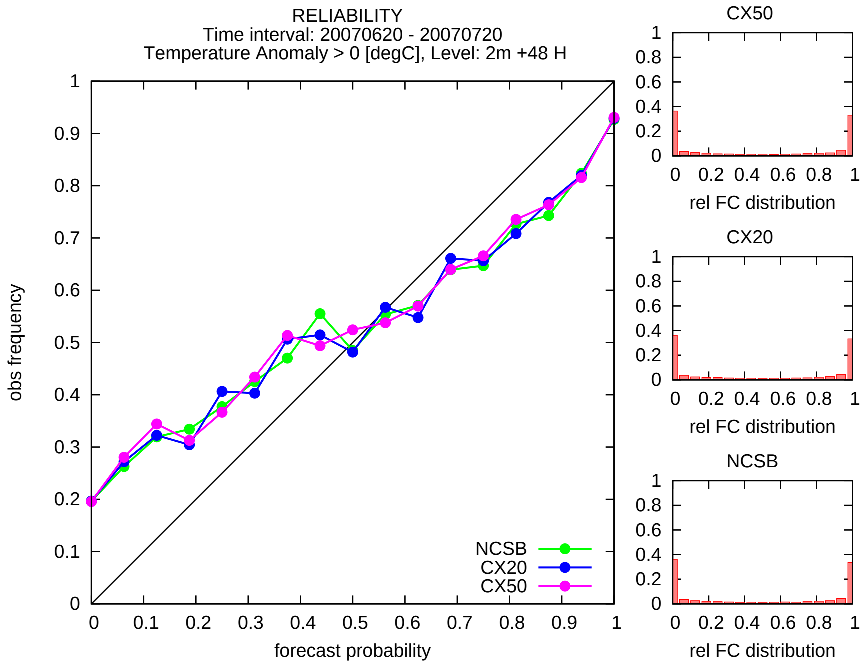

Figure 33: Reliability for temperature anomaly > 0 deg. at 2m (48h)

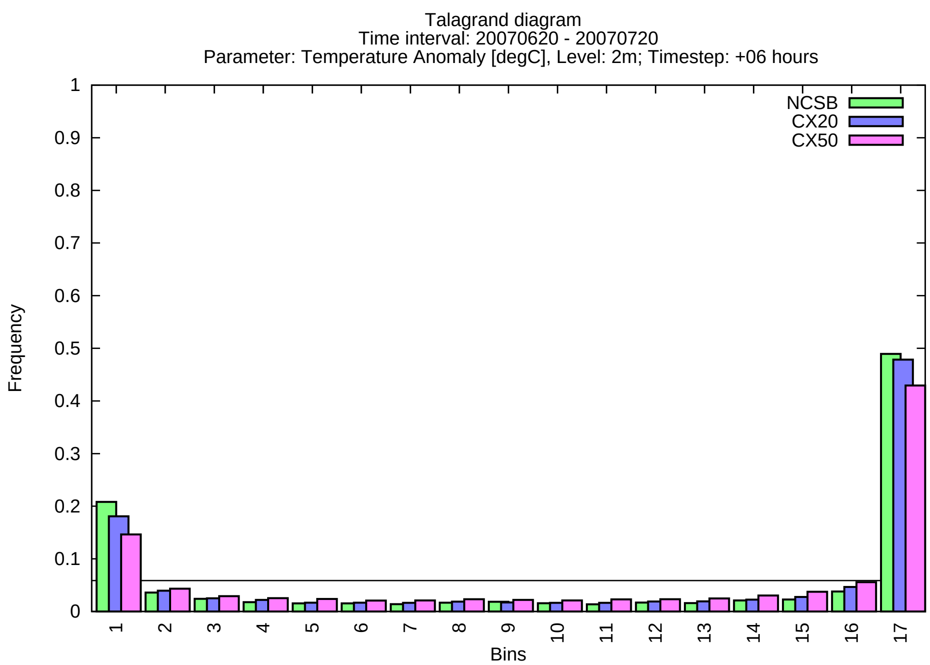

Figure 34: Talagrand diagram for temperature anomaly at 2m (+6h)

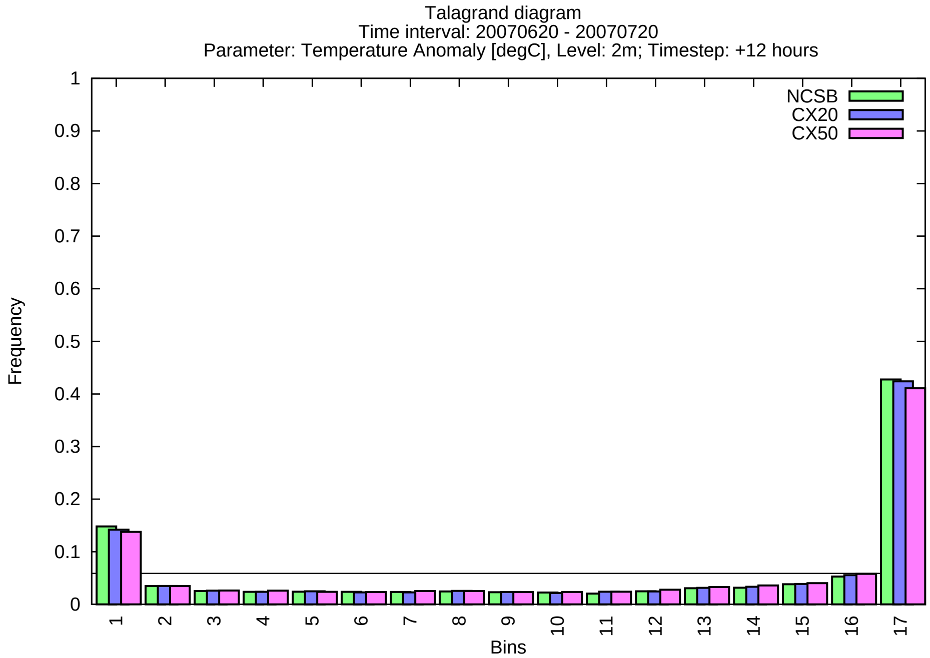

Figure 35: Talagrand diagram for temperature anomaly at 2m (+12h)

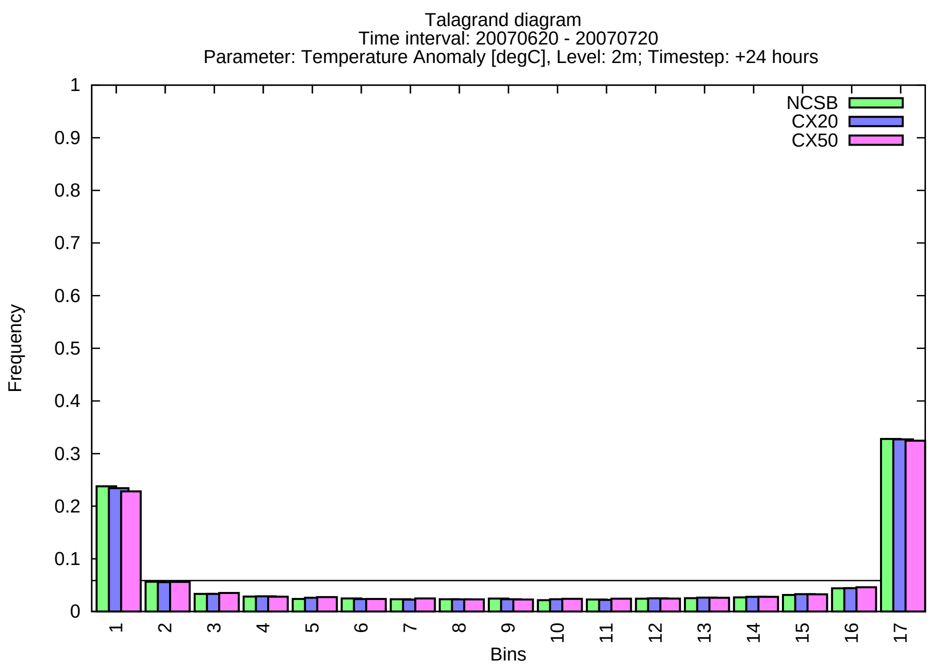

Figure 36: Talagrand diagram for temperature anomaly at 2m (+24h)

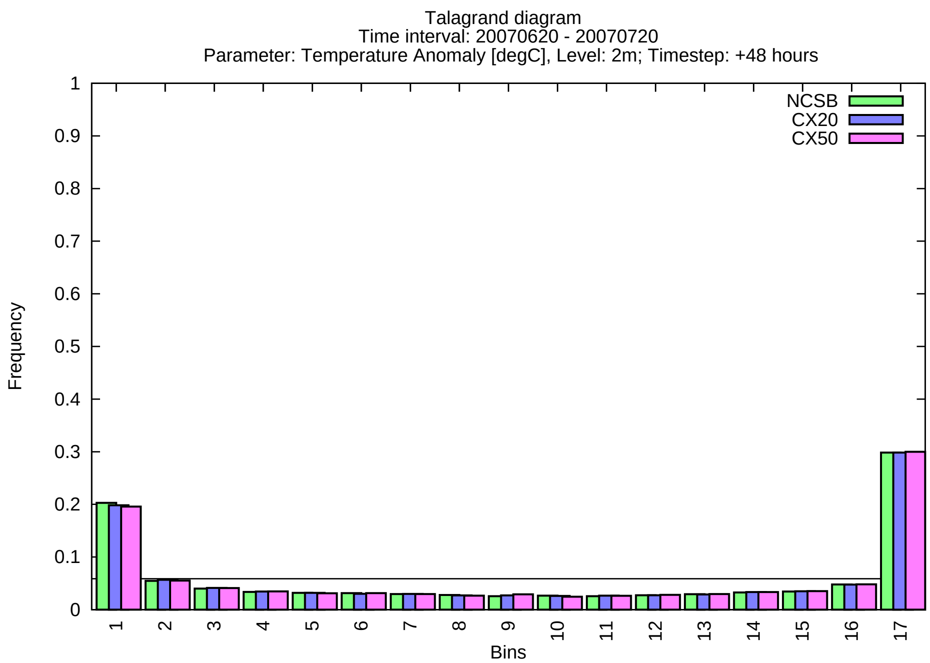

Figure 37: Talagrand diagram for temperature anomaly at 2m (+48h)

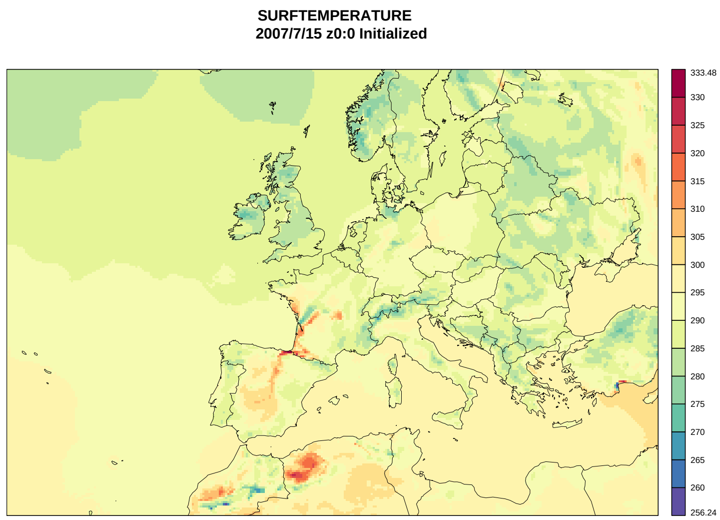

Figure 38: Initial values of field 'SURFTEMPERATURE' (in experiment CX50).

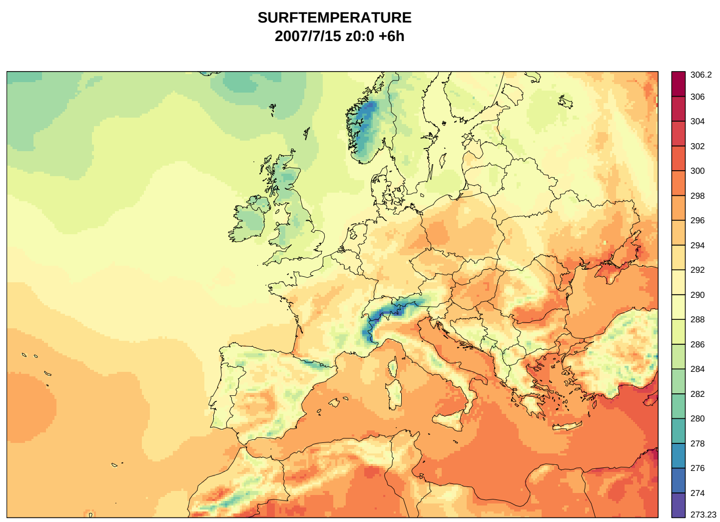

Figure 39: Values of field 'SURFTEMPERATURE' after 6h integration (in experiment CX50).

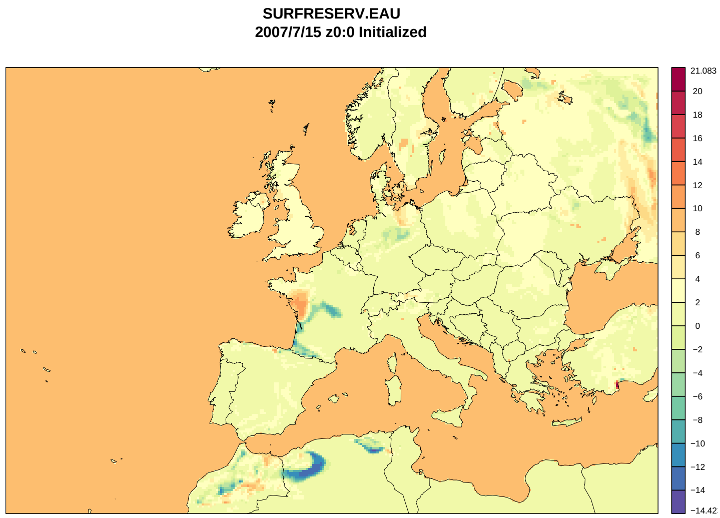

Figure 40: Initial values of field ‘SURFRESERV.EAU’ (in experiment CX50).

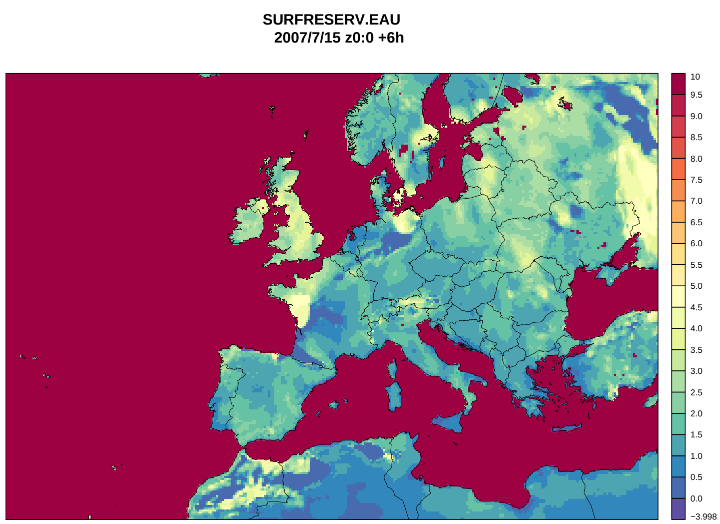

Figure 41: Values of field ‘SURFRESERV.EAU’ after 6h integration (in experiment CX50).

References

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