LACE Working Group for Data Assimilation: Report 2005

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Contents

1 Introduction

This paper is a summary of the work realized in 2005 within the LACE working group for data assimilation. The previously planned research topics are listed and the related work is evaluated following the same structure as it is in the research plan proposal for 2005.

2 Progress in research topics

2.1 Data Assimilation

2.1.1 Methods: algorithmic aspects

- **Tuning of the multivariate humidity formulation of the B matrix**
  Description: In some cases the multivariate humidity formulation can have a negative impact on the humidity analysis itself, in spite of the fact that it improves the mass analysis. Last year a proposal was worked out for the tuning of the humidity observation and background error variances in order to correct this fact.
  Realization: The tuning of the humidity error variances was worked out for stratospheric and tropospheric levels separately. The stratospheric tuning was based on previous experiences of the ECMWF and the tropospheric tuning was done using variances obtained by the Lönnberg-Hollingsworth method. The impact of the tuning was verified first in single observation experiments, which resulted in encouraging results in the expected way. As a second step full observation assimilation cycle experiments were run with small resulting impacts.
  Efforts: 1.5 p x m non LACE stay + 1.5 p x m local work
  Contributors: Kristian Horvath (CRO), Gergely Bölöni (HU)
  Documentation: RC LACE report available from Kristian Horvath

- **Computation of an ensemble B matrix for the ALADIN/HU domain**
  Description: The computation of a B matrix based on the ensemble technique has been done for ALADIN/HU. The motivation was that ithis technique simulates better background errors than the NMC method according to results at ECMWF and Meteo-France.
  Realization: An ARPEGE ensemble was created through perturbing the observations in parallel assimilation cycles at Meteo-France. This global

ensemble (4 members) was downscaled with ALADIN/HU and the 6-hour forecast differences between these members composed the sample for the B matrix computation. Diagnostic comparison of the statistics with the NMC statistics has been done and the impact of the ensemble B matrix in assimilation experiments has been examined.
Efforts: 2 p x m LACE stay + 1 p x m local work
Contributors: Kristian Horvath (CRO), Gergely Bölöni (HU)
Documentation: A preliminary report is available from the contributors.

- **Experiments with 3D-FGAT**
Description: The more accurate computation of the Jo innovations enabled by 3D-FGAT makes possible to use more observations than in the present 3DVAR system, where we ofthen use only a +/- 1 hour data cut-off. The aim of this work was to test the impact of the additional observations throug a comparison with 3DVAR.
Realization: As a first step, the FGAT code has been validated (4D screening + minimization). In a single observation experiment the 3DVAR result has been reproduced with FGAT, which is a good sign of the proper working. As a second step an FGAT assimilation cycle has been run and the results have been compared to those of a reference 3DVAR cycle. First results does not show signifcan improvement in terms of scores. Further scientific and technical developments are needed relating FGAT. Future plans aim to develop a technical background that makes possible to add the analysis increment to the background at the middle of the assimilation window (presently it is added at the beginning, which has to be so in 4DVAR but it might not be optimal in FGAT).
Efforts: 1.5 p x m local work + 2 p x m stay in Bp
Contributors: Steluta Vasiliu (RO), Sándor Kertész (HU)
Documentation: RC LACE report under preparation by Steluta Vasiliu

2.1.2 Observations

- **Assimilation of MSG/AMV data**
Description:AMV (Atmospheric Motion Velocity) observations from MSG were planned to implement into the assimilation system of HMS. Assimilation experiments including 15 days assimilation cycles were also planned in order to evaluate the impact of the data.
Realization: The technical implementation of the AMV data into the

assimilation system is done. As a second step, the data quality has been estimated computing obs - model and obs - analysis departures. Finally, assimilation experiments have been done with different settings (data quality, data thinning, use or not over land). The results indicate that: (a) a strict selection using only good quality data seems to be beneficial, (b) there are problems with the assimilation of these data over land. The experimentation on the best thinning distance will continue.
Efforts: 3 p x m
Contributors: Roger Randriamampianina (HU)
Documentation: not available yet

- **Assimilation of radar data**
  Description: The long term plan to work out a system that assimilates derived profiles from radar reflectivity was continuing.
  Realization: Work on the data screening has been done. Namely the radar simulator was implemented which creates simulated radar reflectivities from the model fields. The storage and usage of needed physical fields for the simulator was under investigation.
  Efforts: 2 months stay in Toulouse + coordination
  Contributor: Marian Jurasek (SK)
  Documentation: Not available yet.

- **Assimilation of AMDAR data**
  Description: A filter procedure (based on the lamflag program) was developed in 2004 in order to get rid of redundant aircraft data measured in very different times inside the cut-off window but close to each other in space. Its impact on the analysis and forecast was planned to be evaluated.
  Realization: The impact of the filter procedure was tested via assimilation cycling experiments. The filter has a small but systematically positive impact on the model forecast. Building on these experiments, the AMDAR data were included into the operative 3dvar suite of HMS using the filter procedure. The filter was developed as an external tool first. It is a rather complicated chain of procedures (ODB programs) that makes scripts quite heavy to read, so the procedure was also implemented into the screening code itself as a second step. This work has been finished and assimilation experiments have been run to check the impact again. The

evaluation of these results is on the way.
Efforts: 3 p x m
Contributors: Roger Randriamampianina (HU), Miklós Balgogh (HU), Sándor Kertész (HU)
Documentation: not available yet

- **Assimilation of wind profiler data**
  Description: The data were included into the ODB and into the monitoring system enabling the estimation of the quality of these data. The impact of the wind profilers will be studied during the rest of the year (see the point about EUCOS experiments).
  Realization: The data were included into the ODB and into the monitoring system enabling the estimation of the quality of these data. The impact of the wind profilers was studied in the frame of EUCOS experiments on observation impact studies (see the corresponding point later).
  Efforts: 3 p x m
  Contributors: Roger Randriamampianina (HU), Gergely Bölöni (HU)
  Documentation: A draft report on the EUCOS impact studies is available from the contributors.

- **Assimilation AMSU-B data**
  Description: This work was not planned formally in the 2005 plans, however the encouraging experiences in ARPEGE with the AMSU-B data initiated this work finally.
  Realization: This data type can be included into the assimilation system of HMS now. Also the impact of the data was investigated through assimilation experiments and they turned out to be useful. So, since mid August, a parallel assimilation suite is run and is under subjective evaluation at the moment.
  Efforts: 3 p x m
  Contributors: Roger Randriamampianina (HU)
  Documentation: not available yet

- **General observation impact studies (EUCOS project)**
  Description:HMS joined the EUCOS (EUMETNET Composite Observing System) project, which aims to explore the importance of the different elements of the European (ground and space based) observing system.

The goal of the project is to get feedbacks and proposals for the future developments of the observing system. Altogether 8 assimilation experiments were defined by EUCOS to be run for one winter and one summer period. Both periods last for one month (+ 10 days warm up cycling) and include interesting weather events.
Realization: The processing of the winter period has been started. As the LAM experiments are expected to be run with ECMWF LBC data, the first step was to download and convert the data into the Arpege/Aladin FA format. As a second step the assimilation experiments have been run and a strategy for the evaluation was set up.
Efforts: 6 p x m
Contributors: Roger Randriamampianina (HU), Gergely Bölöni (HU)
Documentation: A draft report is available from the contributors

2.2 LAMEPS

- **ALADIN EPS based on ARPEGE SV perturbations**
  Description: This work consisted mainly of two parts. On one hand (1) the new operative ARPEGE EPS (PEACE) system was planned to be downscaled (increased resolution and new optimization target domain since last year) and on the other hand (2) optimized SV perturbations were planned to compute for Central Europe (CE) on the same resolution as the present PEACE system.
  Realization:(1) The ALADIN EPS runs using the operational PEACE perturbations are finished. The results have been evaluated also. (2) The same run as in (1) were repeated using optimized singular vectors for CE generated still in ARPEGE on the operational PEACE resolution. Both downscalings were done on the formal LACE domain. As a very rough conclusion, it can be stated that with the optimization of the perturbations for the needed area, the LAMEPS runs can be improved. Also, a stay of Richard Mladek was organised in Budapest to get insight into the LAMEPS runs. He performed 2 interesting case studies with the downscaling of the PEACE system.
  Efforts: 10 p x m
  Contributors: Edit Hágel (HU), Richard Mladek (CZ)
  Documentation: available in the 27th ALADIN Newsletter, the RC LACE report of Richard Mladek is available from himself or from Gergely Bölöni

- **<u>Generation of perturbations with the Breeding method</u>**

  Description: The idea is to try to generate LAM initial perturbations with the breeding method.

  Realization: Breeding has been implemented at ZAMG. It has been also tested on a case study. The breeding code used at ZAMG was given to the Hungarian team. At HMS, apart from reading the literature nothing has been done so far. This work is shifted to the end of 2005 and to 2006 at HMS.

  Efforts: 5 p x m at ZAMG

  Contributors: Yong Wang (AU)

  Documentation: so far the presentation of Yong Wang at the 15th ALADIN workshop in Bratislava

- **<u>Ensemble Transformed Kalman Filter (ETKF)</u>**

  Description: The aim is to use ETKF on breeding vectors for generating new LAM initial perturbations.

  Realization: The ETKF code has been implemented at ZAMG. First tests have been performed which show some problems. These will be investigated in the future.

  Efforts: 5 p x m

  Contributors: Yong Wang (AU)

  Documentation: not available yet

- **<u>ALADIN EPS based on the ECMWF EPS system</u>**

  Description: Here the aim is to use the ECMWF EPS system as initial and lateral boundary information for the ALADIN model. The work was planned to be done in Zagreb, Budapest and Vienna independently and also in different ways concerning the choice of the initial perturbations. However, a strong cooperation was planned in order to work out together the technical steps for using ECMWF lateral boundary conditions for ALADIN runs.

  Realization: In the frame of a 3-day meeting (CRO and HU) the technical background was clarified and worked out to use ECMWF EPS data as LBC in ALADIN. Concerning the scientific work, in CRO 4 case studies are under examination. The downscaling is done for all the 50+1 members and also several clusterings are done for the time step +48h based on

different variables. There are technical dificulties at the moment related to the clustering (Metview). Also several tools were developed in CRO for probabilistic evaluation of the forecasts. In HU 3 case studies were run and evaluated. The representative members (10) of the ECMWF EPS system, were chosen by clustering (different clusterings were tested). The chosen members were used as initial and boundary conditions for the ALADIN forecasts. As a general conclusion one can state that the ALADIN forecasts are adding new small scale features to the ECMWF forecasts, and that the divergence of the global members is still kept after the ALADIN forecasts. Some of the cases were also compared and others are planned to be compared with the corresponding downscaling of the PEACE system. In AU, this topic is not yet under investigation.
Efforts: 6.5 p x m
Contributors: Stjepan Ivatek-Sahdan (CRO), Cedo Brankovic (CRO), Blazenka Matjacici (CRO), Balázs Szintai (HU), István Ihász (HU), Gergely Bölöni (HU)
Documentation: a technical doc on the processing of the ECMWF LBC files is available at the LACE web page, about the scientific work n HU an article has been submitted to Időjárás, and a preliminary report is available about the work done in CRO.

- **EPS post processing**
  Description: The goal is to apply correction methods on the LAMEPS forecasts in order to decrease systematic errors and to set up tools for easy representation and verification of the probabilistic forecasts.
  Realization: postponed
  Efforts:
  Contributors: Alexander Kann (AU)
  Documentation: Not available yet

2.3 Other

- **Downscaling of ARPEGE and ECMWF MAP reanalyses**
  Description: The ALADIN downscaling of MAP reanalyses of the 2 different global models can be interesting in order to study the possibility of coupling ALADIN with ECMWF compared to the usual coupling with ARPEGE.

Realization: Two MAP cases (IOP5 and IOP15) are studied via downscaling of the ARPEGE and ECMWF MAP reanalyses and of their mixture (ARPEGE surface + ECMWF upper air). As a conclusion it can be said that the downscaling of ARPEGE produced satisfactory high resloution forecasts. Using the ECMWF MAP reanalysis for the downscaling even improved the forecast especially for precipitation. The downscaling of the mixture of ARPEGE surface and ECMWF MAP reanalysis upper air fields produced similar forecast to the downscaling of ARPEGE.
Efforts: 2 p x m
Contributors: Stjepan Ivatek-Sahdan (CRO), Branka Ivancan-Picek (CRO)
Documentation: An article has been accepted in Met. Zeit. for special MAP issues

3 Means and status of the work in 2005

The following table gives an overview of the status of the developments planned for 2005. The data on manpower and the LACE support are the same so far as it was estimated in the plans.

Topic	**Efforts**	**LACE support**	**Status**
Tuning of the multivariate humidity formulation of the B matrix	3 p x m	none	finished
Computation of an ensemble B matrix for the ALADIN/HU domain	3 p x m	2 p x m	finished
Experiments with 3D-FGAT	3 p x m	2 p x m	finished
Assimilation of MSG/AMV data	3 p x m	none	on the way
Assimilation of radar data	3 p x m	none	finished
Assimilation of AMDAR data	2 p x m	none	on the way
Assimilation of Wind profiler data	2 p x m	none	finished
Assimilation of AMSUB data	3 p x m	none	finished
General observation impact studies (EUCOS project)	6 p x m	none	on the way
Total	**28 p x m**	**4 p x m**	
ALADIN EPS based on ARPEGE SV perturbations	10 p x m	1 p x m	finished
Breeding AU HU	 5 p x m 3 p x m	 none none	 on the way to be done
ETKF	5 p x m	none	on the way
ALADIN EPS based on the ECMWF EPS system AU CRO HU	 0 p x m 3.5 p x m 3 p x m	 none none 3 days	 postponed on the way finished
EPS postprocessing	0 p x m	none	postponed
Downscaling of ARPEGE and ECMWF MAP reanalyses	2 p x m	none	finished
Total	**31.5 p x m**	**1 p x m**	

Table 1: Summary of means in 2005

Workshop	**LACE support**
DA Symposium	2 p x w
HIRLAM - ALADIN DA workshop	2 p x w
LAMEPS workshop (Bologna)	1 p x w
Total	**5 p x w**

Table 2: Workshops in 2005

4 Presentation of the results

This section gives a bit more detailed explanation of the results obtained in the different topics. Possibly we give also a graphical presentation of the conclusions. The figures can be found at the end of the document.

- **Tuning of the multivariate humidity formulation of the B matrix**
  The following three different tunings were tried:
  - EX1Q: Reduce high level unbalanced humidity background error variance + adjust mid-level unbalanced humidity background error variances to the LH values
  - EX2Q: Reduce high level unbalanced humidity background error variance + adjust mid-level unbalanced humidity background error variances to the LH values + reduce observation error variances in the same extent
  - EX3Q: Adjust mid-level unbalanced humidity background error variances to the LH values + reduce observation error variances in the same extent

  In a single observation framework, the tunings modified the analysis in the wanted way, however the real assimilation experiments resulted in week impacts generally. The biggest impact was reached with the "EX3Q" tuning of which the results are shown on figures 1 - 3. The impact is mixed, i.e. in termes of RMSE, the humidity scores are worsened at the initial time and the very beginning of the forecast while on many levels there is an improvement for the longer forecast ranges. The humidity BIAS is improved on 700 and 500hPa while a little bit worsened on 850hPa. There is a positive impact on temperature which is very small and limited on the very beginning of the forecast.

- **Computation of an ensemble B matrix for the ALADIN/HU domain**
  Diagnostic comparison: Ensemble error variances are smaller than those of the standard NMC method except for divergence where they are similar. Correlation length scales are smaller for temperature and vorticity, bigger for humidity and similar for divergence. Vertical cross correlations are significantly sharper for ensemble statistics, mostly for large scale couplings (T-Pb, q-Pb). Vertical auto correlations are also somewhat sharper in case of the ensemble method. In comparison with the lagged-NMC

statistics the standard deviations gotten with ensemble method are larger except for humidity, length scales are smaller for vorticity, bigger for temperature and humidity and similar for divergence (picures available in the report of Kristian Horvath).
Three assimilation cycles have been run for the comparison of the impacts of B matrices:

- SNMC: Standard NMC B matrix is used
- ENSB: Ensemble B matrix is used
- ENS1: Ensemble B matrix is used + tuning (REDNMC=1.5)

SNMC turned out to be better than ENSB except for humidity which is significantly better in case of ENSB satistics. For experiment ENS1 the tuning (REDNMC=1.5) was chosen based on the French colleague's experience. ENS1 proved to provide similar quality forecasts as SNMC for geopotential, wind and temperature (fig. 5 - 8), better forecasts for humidity (fig. 7). It has to be mentioned that in spite of similar RMSE scores there is a strong temperature BIAS of the ENS1 forecast on 700 and 500 hPa. The tuning must be done in a more serious way (a posteriori validation or similar methods) in the future.

- **Experiments with 3D-FGAT**
  No graphical presentation of the results is included yet!

- **Assimilation of AMV data**
  Conserning the impact of the AMV data 2 experiments are shown. The reference is NAMV using SYNOP, TEMP, AMDAR, AMSU-Adata and the experiment referred as W025 which uses the same obs as NAMV + AMV. Our most important conclusions are as follows. The scores reflect a moderate improvement in humidity RMSE and BIAS (fig.9 and fig. 10). The impact on temperature is very small in terms of RMSE (fig. 11), for BIAS it is bigger, mixed on the lower levels and positive in the altitude (fig. 12). The results are mixed for wind (fig. 13 and fig. 14) and there is a degradation of the geopotential BIAS on midlle and low levels (fig. 15 and fig. 16).

- **Assimilation of radar data**
  Data flow is ready for screening radar observations (feeding ODB, quality flags, storage of physical fields) and the model radar simulator is working (fig. 17 and fig. 18). There are several problems with screening which will

be solved in the future. Namely there is an instability if there are more than 2 radar elevations used, and too many of the radar observations are rejected. The assimilation of radar data is planned in form of q and T profiles which will be prepared with a 1DVAR.

- **Assimilation of AMDAR data**
  The impact of AMDAR data is shown on the figures 19 - 26. The experiment AUHU is the one without AMDAR data (it uses SYNOP, TEMP and AMSU-A data). In the experiment AMFL all the obs were used as in AUHU + AMDAR data preprocessed with the filter developed at HMS. On humidity, the impact is generally positive in RMSE and also in BIAS on most of the levels. A generally positive impact can be seen for temperature as well. For wind, the impact is mixed depending on level and forecast range. The impact on geopotential is slightly positive generally in terms of RMSE and more mixed in terms of BIAS. The impact of the new pre-processing procedure of the AMDAR data is illustrated on fig. 27. The experiment AM25 is without and B25E is with the new filter. Generally we observed a slight improvement for all the variables.

- **Assimilation of wind profiler data**
  The impact of wind profilers proved to be slightly positive during the EUCOS observing system experiments (see pictures in explanation of EUCOS results). It's important to note that so far the ARPEGE backlist was used in this experiment.

- **Assimilation of AMSUB data**
  Figures 28 - 35 show the impact of AMSU-B data. The experiment HUN2 corresponds to the actual operative scores (SYNOP, TEMP, AMSU-A, AMDAR + filter are used) and TES2 means HUN2 + AMSU-B data. Humidity is improved around 700hPa, on other levels the impact is mixed depending on forecast range. There is a strong degradation on 250hPa at the beginning of the forecast (even the analysis is spoiled). However the 250hPa scores look dramatic, we do not consider this degradation fatal considering that humidity on high levels is not so important. Temperature scores are improved in the lower part of the atmosphere, while there is a small degradation for long ranges in the altitude in the RMSE (250hPa). The BIAS is improved in the altitude as well. The impact on wind is mixed. The impact on geopotential is very small in terms of RMSE, the BIAS shows a mixed impact depending on forecast range.

- **General (EUCOS) impact studies**

  The 8 experiments are explained in the following table: Results show a

exp/obs	SAT	TEMP (wind)	TEMP (T)	TEMP (RH)	AMDAR	Wind prof
EU01	x					
EU02	x				x	
EU03	x	x				
EU04	x	x	x			
EU05	x					x
EU06	x	x	x		x	
EU07	x	x	x	x		
EU08	x	x	x	x	x	x

Table 3: The observing system experiments

  high importance of the ground based observing system (different components of TEMP, AMDAR, Wind profiler were tested) (fig 36, 37 and 38). It can be further concluded that the most important elements of the ground based observing system are the TEMP observations (all components). Aircrafts (AMDAR) have a clear positive impact as well and wind profilers have very small contribution to the overall impact but clearly in a positive direction. Significance tests of the impacts are under investigation and case studies are to be run in the near future.

- **ALADIN EPS based on ARPEGE SV perturbations**

  On figures 39 - 42 one can see a comparison between the ALADIN downscaling of the operational PEACE and the ALADIN downscaling of the retargeted ARPEGE EPS runs for Central Europe. On the legend, "peacoper" stands for the previous and "exp1" for the latter. The runs are verified against the ARPEGE anlysis. What one can see on the Talagrand outliers (figures 39 and 40), is that "exp1" is closer to the expected value, which means a bigger and more representative spread of the retargeted EPS system downscaled by ALADIN. (If the percentage of Talagrand outliers is higher then the expected value, the spread is too small, the real event is often not described by any of the EPS members.) This result is generally true for other variables as well. The ROC area figures (fig. 41 and 42) show also some improvement due to the retargeting of the singular vector computations, namely the ROC area is higher for all forecast ranges for "exp1" than for "peaceoper". (The ROC area is the area on the ROC diagram which is under the ROC curve. A big ROC area corresponds to better FAR and POD scores, a small ROC area to worse FAR and POD scores.)

- **Generation of perturbations with the breeding method**
  No graphical presentation of the results is available yet.

- **ETKF**
  No graphical presentation of the results is available yet.

- **ALADIN EPS based on the ECMWF EPS system**
  Few results of the work done in Hungary are shown on figures 43 - 46. In lack of longer statistics (ROC or Talagrand diagrams) preliminary conclusions were drawn based upon visual comparison of stamp and probability maps and the observations. What one can conclude from the stamp maps is that the ALADIN forecasts describe more small scale structures compared to the ECMWF runs and that the spread is clearly kept after the downscaling (figures 43 and 44). If one makes comparison with the observations, it turns out that ECMWF members underestimate the precipitation in general, while there exist ALADIN members that predicts similar structure and quantity to the observed values. On figures 45 and 46 we show the probability of the precipitation (>10mm) based on the ALADIN EPS members and the observed precipitation (>10mm). The bands of high probabilities are comparing quite well with the bands of observed precipitations. For more accurate comparison with the observations, new diagnostics will be worked out in the future. Conclusions about the efficiency of different clusterings (3 different clusterings were tried using different target domains and different sizes of ensembles) are not straightforward according to the results available so far, i.e. the behaviours are different case by case and the visual comparison is not easy as the differences are quite small.

- **Downscaling of ARPEGE and ECMWF MAP reanalyses**
  No graphical presentation of the results is available yet.

5 Figures

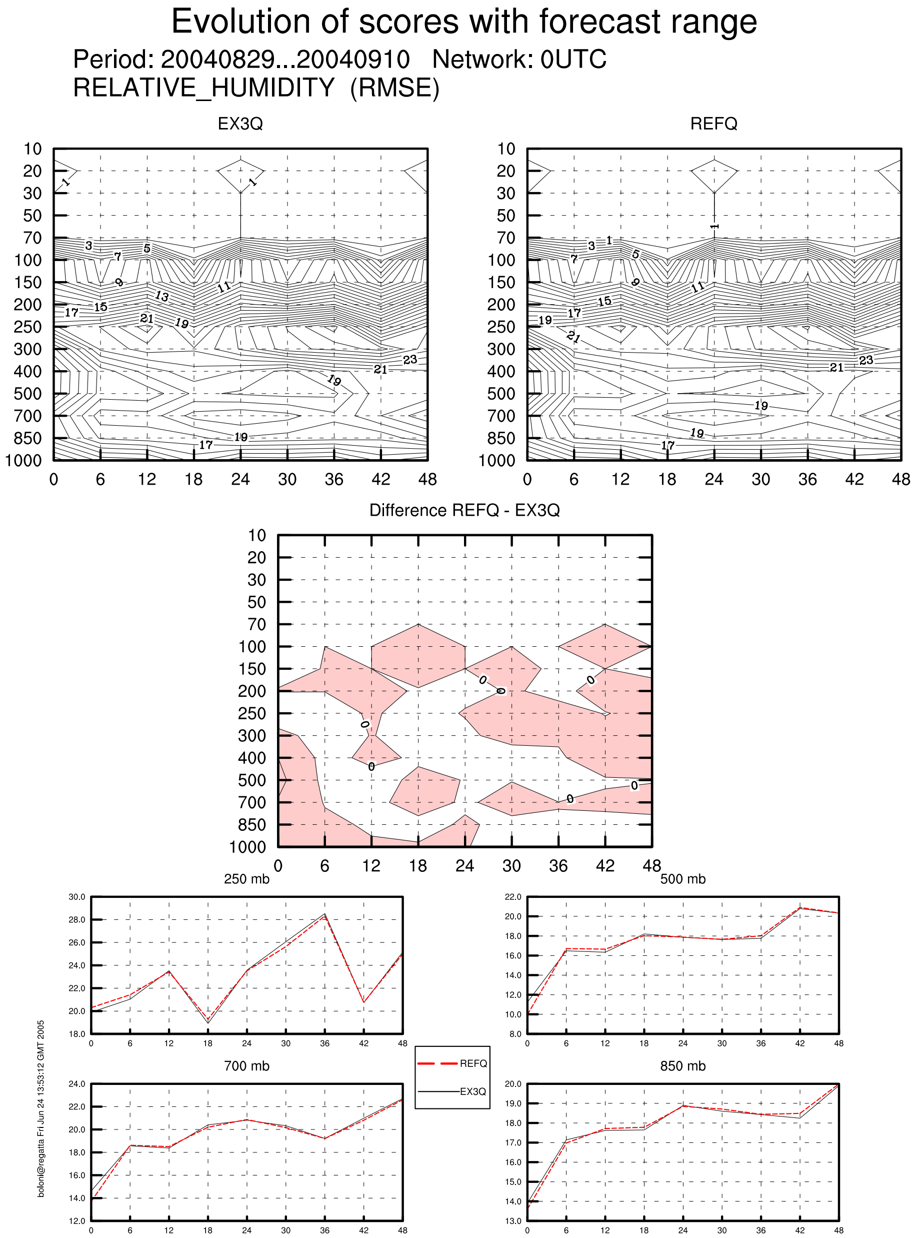

Figure 1: Impact of the tuning "EX3Q"

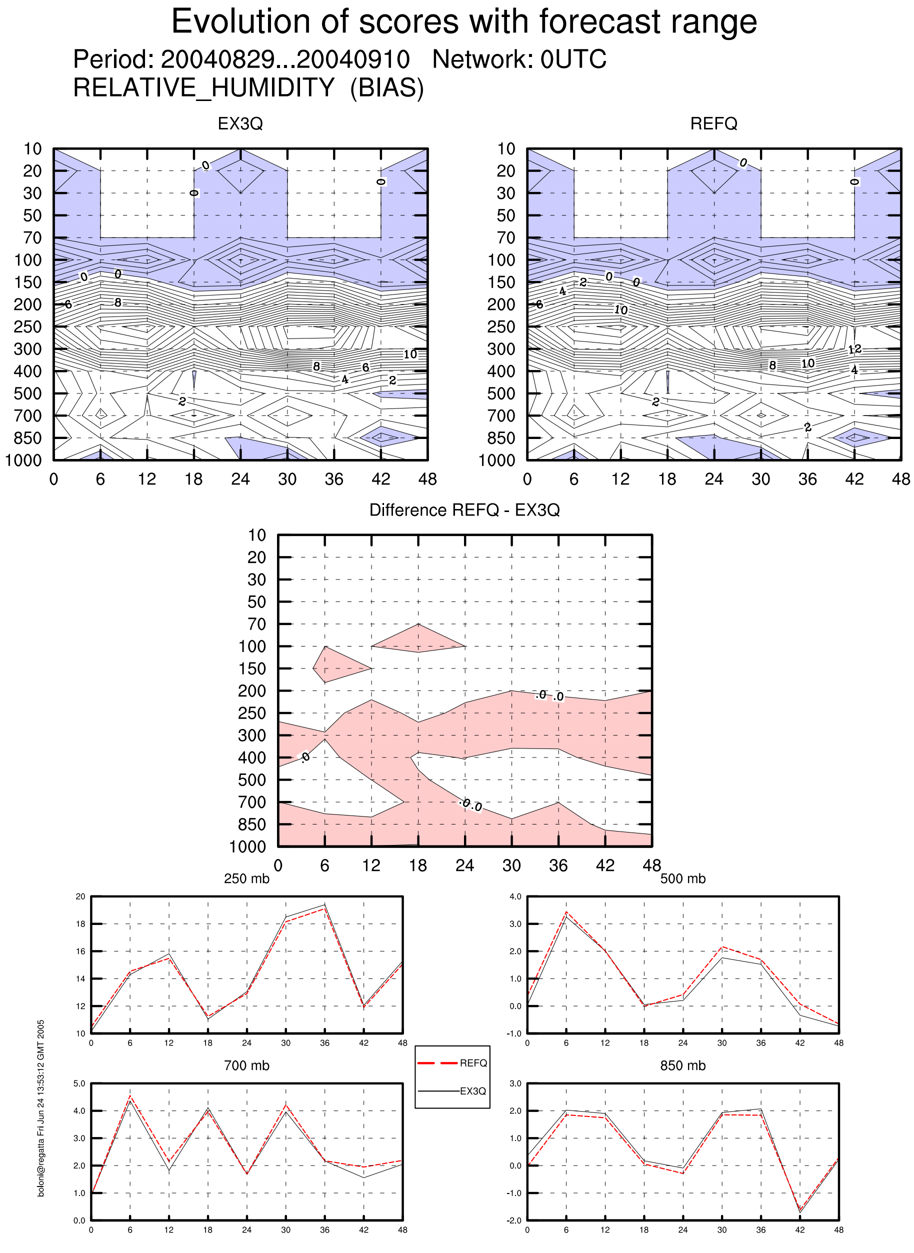

Figure 2: Impact of the tuning "EX3Q"

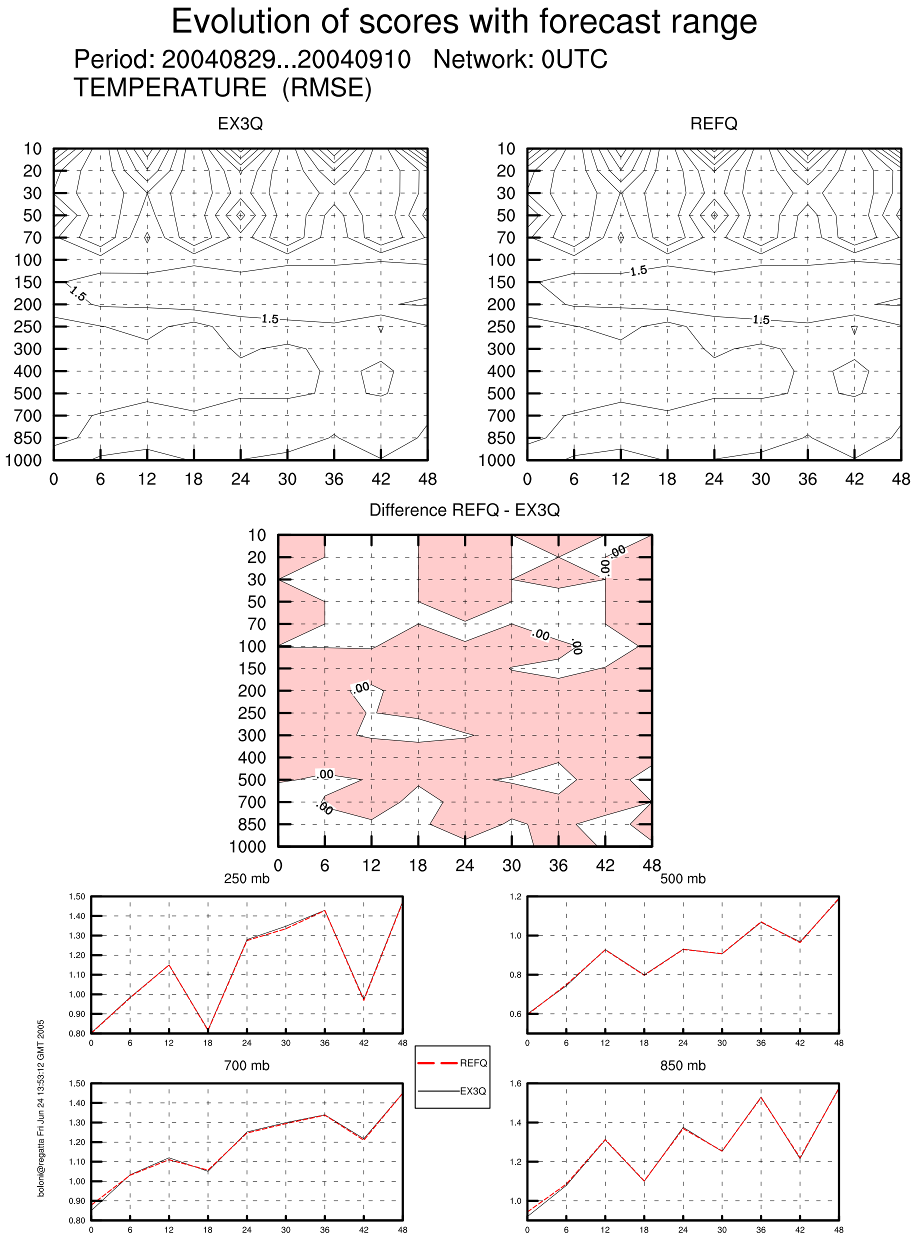

Figure 3: Impact of the tuning "EX3Q"

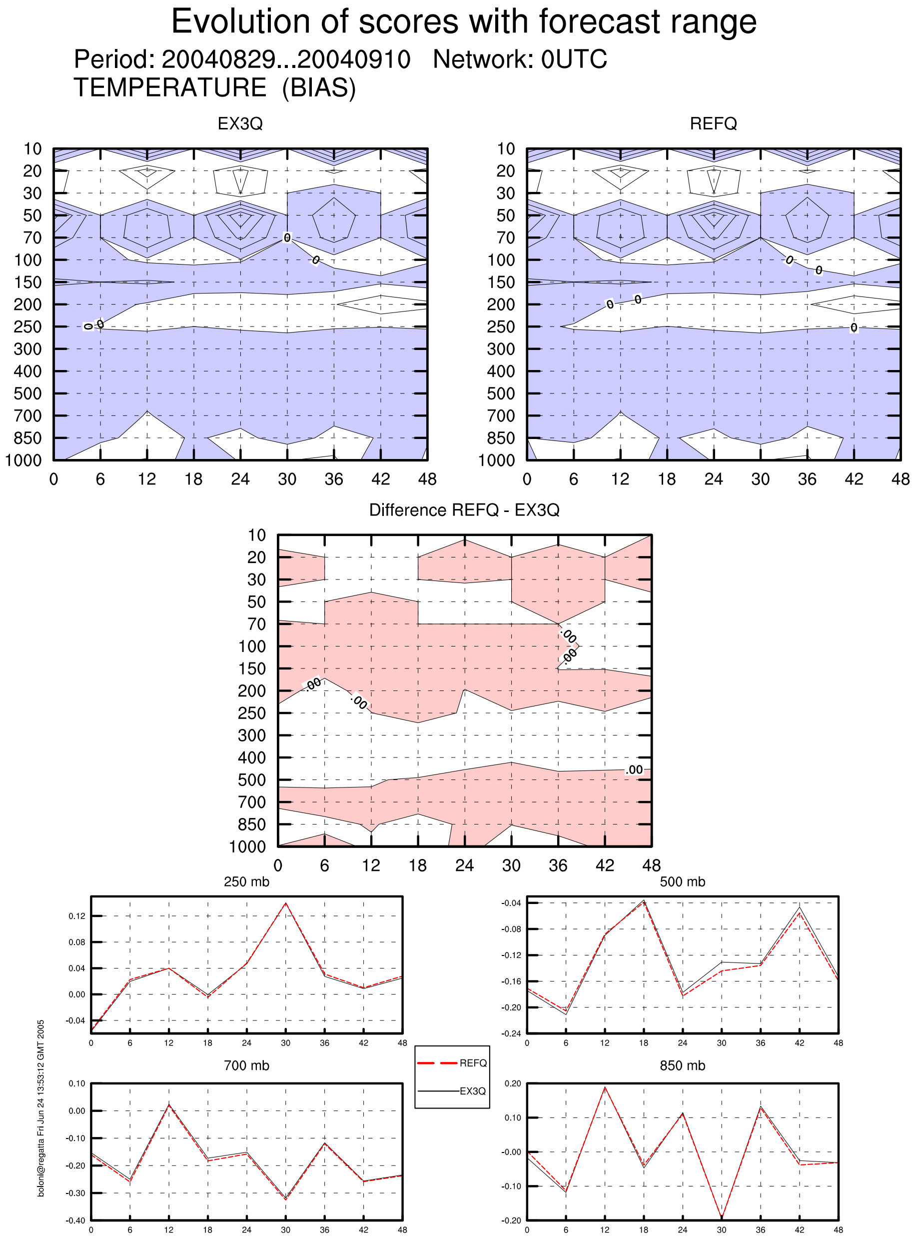

Figure 4: Impact of the tuning "EX3Q"

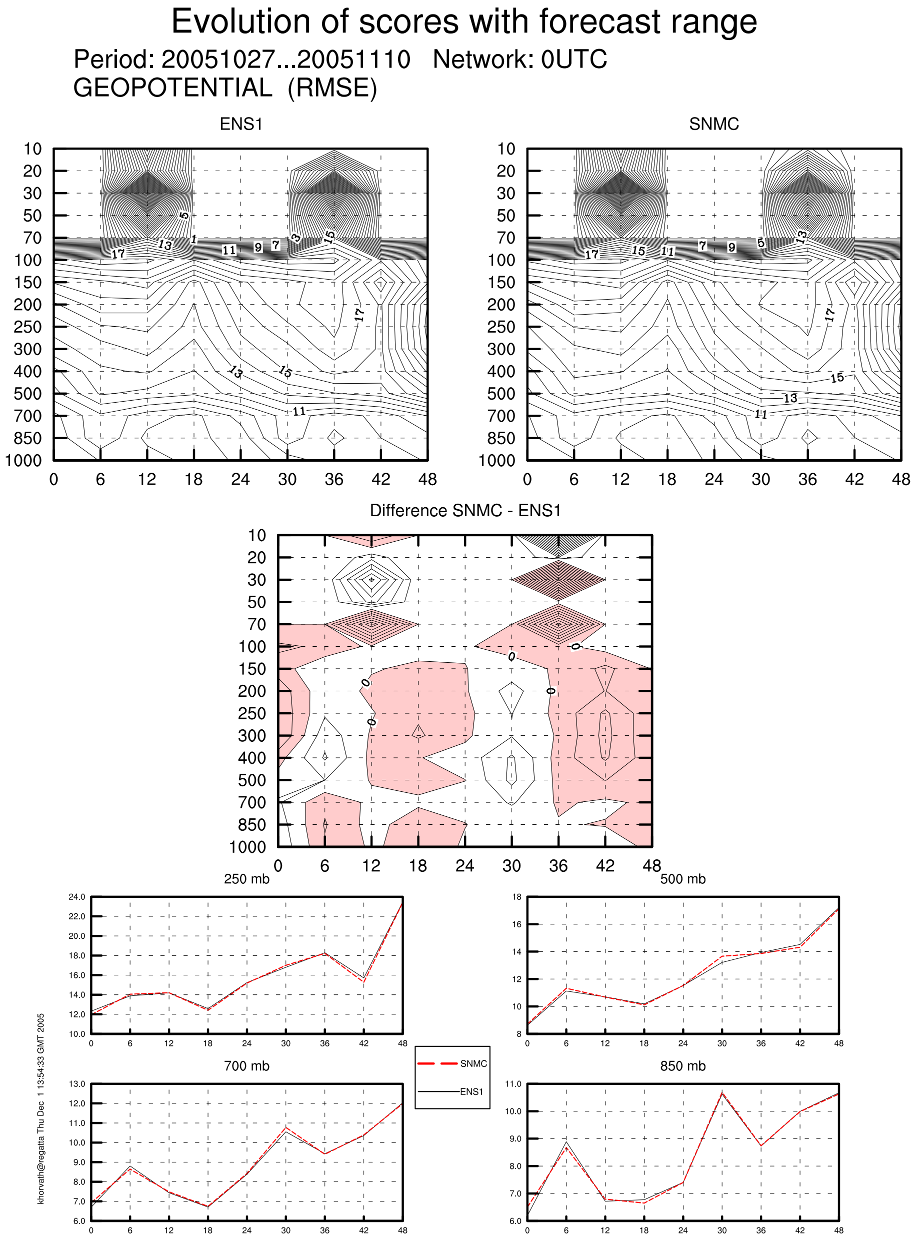

Figure 5: Ensemble - NMC comparison

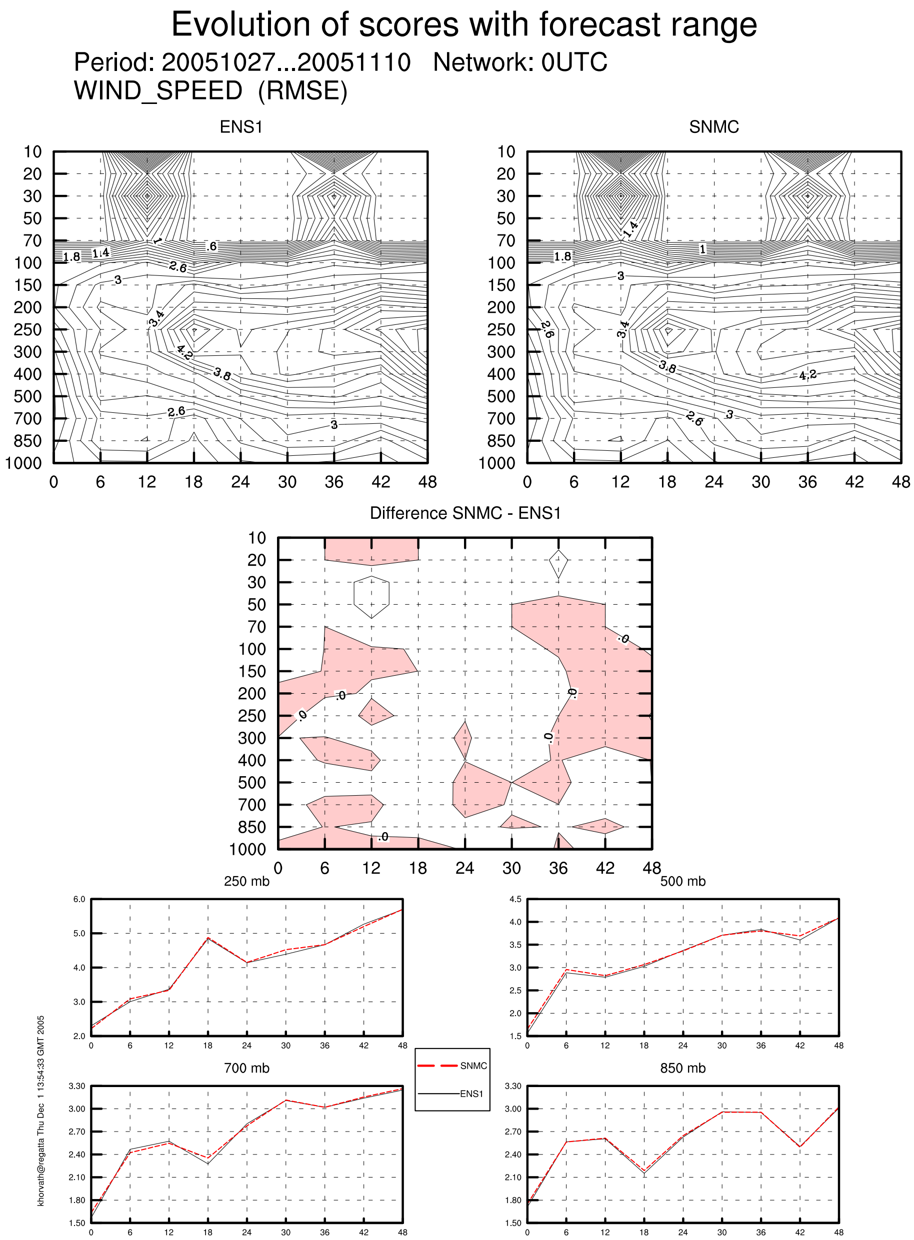

Figure 6: Ensemble - NMC comparison

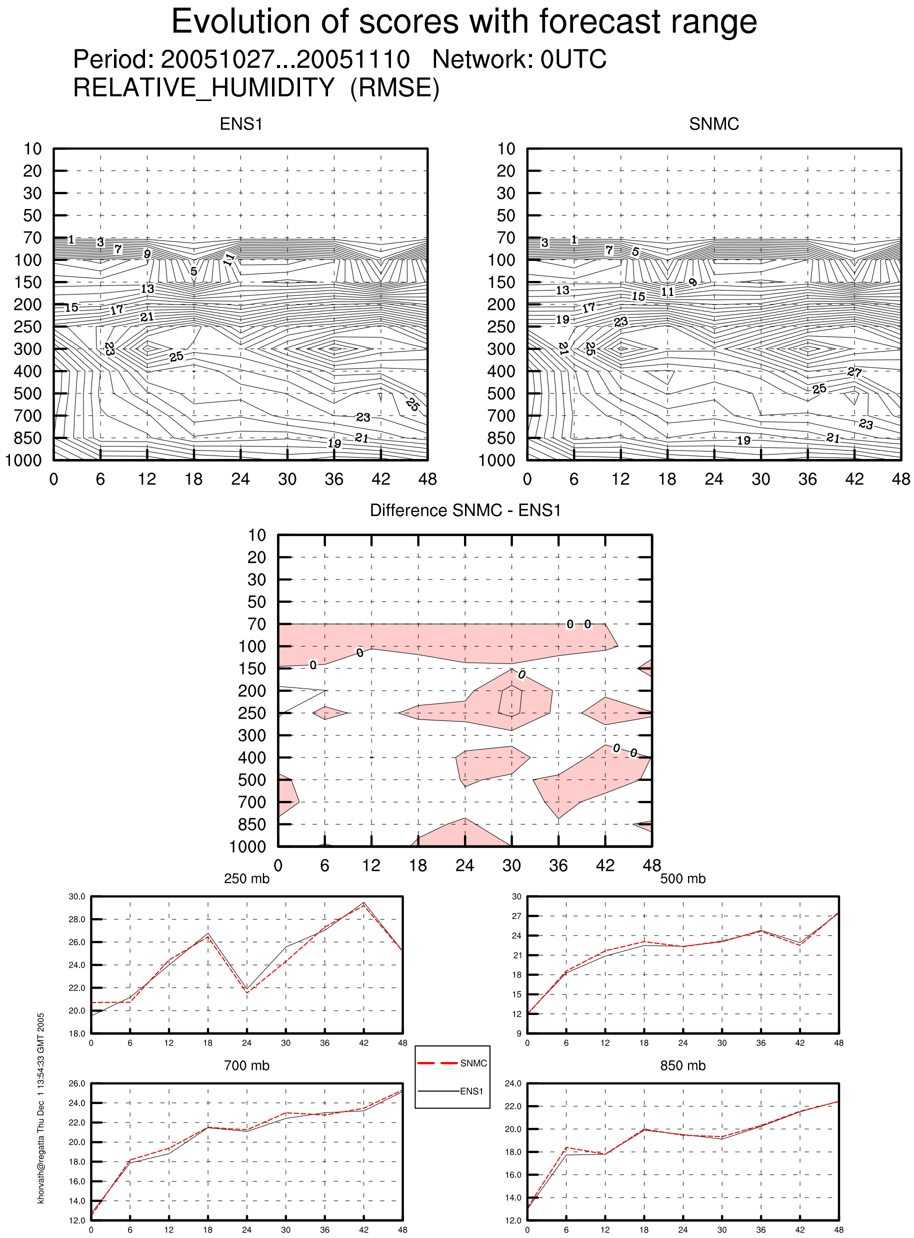

Figure 7: Ensemble - NMC comparison

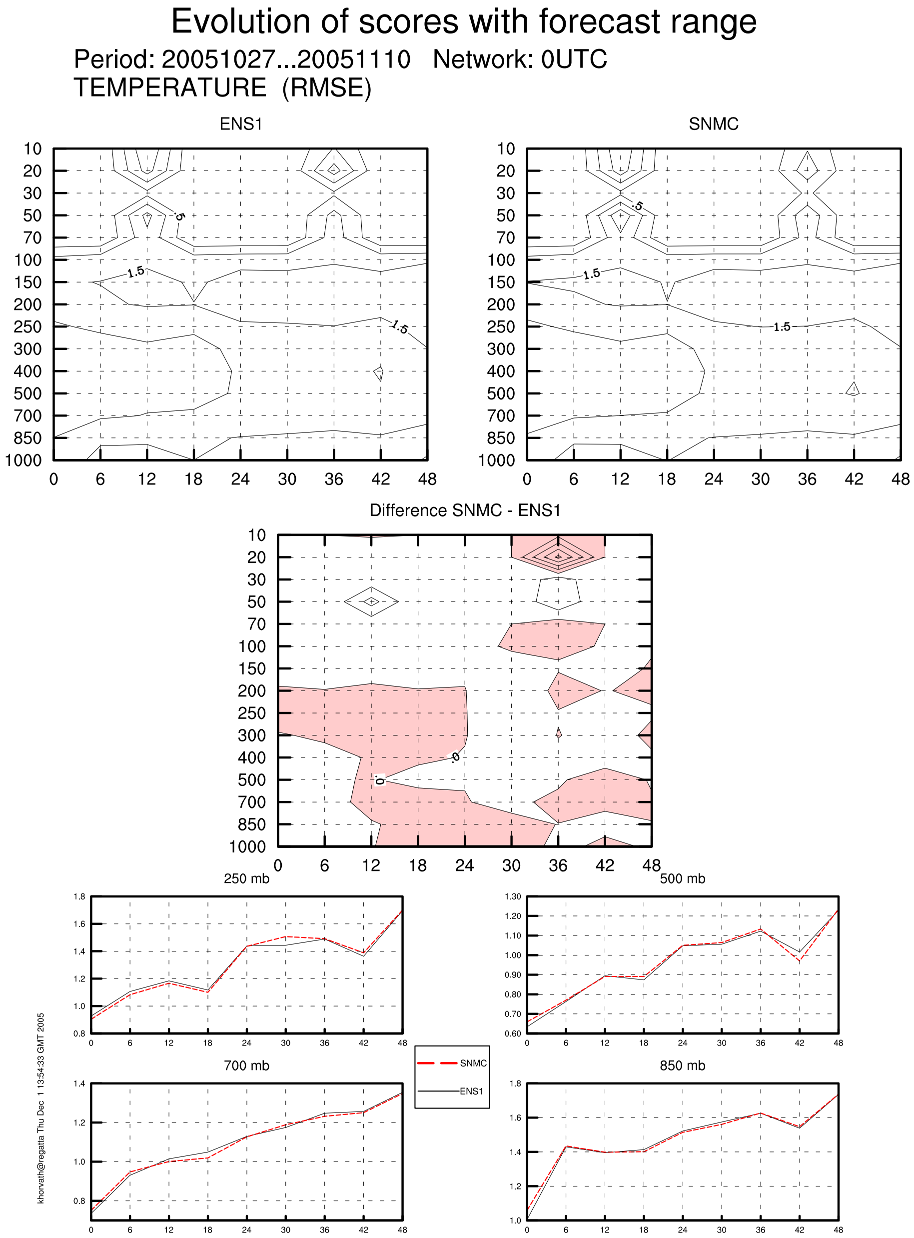

Figure 8: Ensemble - NMC comparison

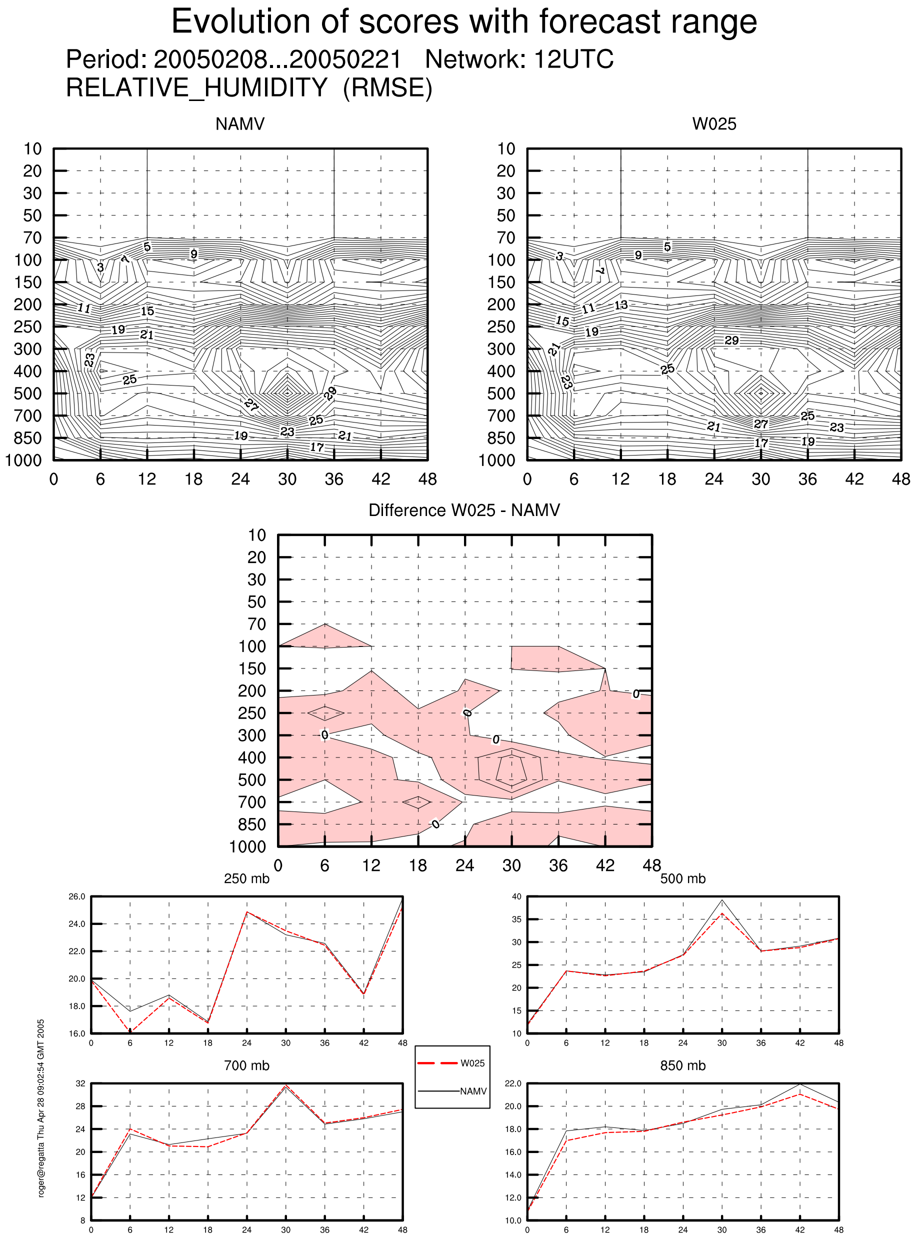

Figure 9: The impact of AMV data

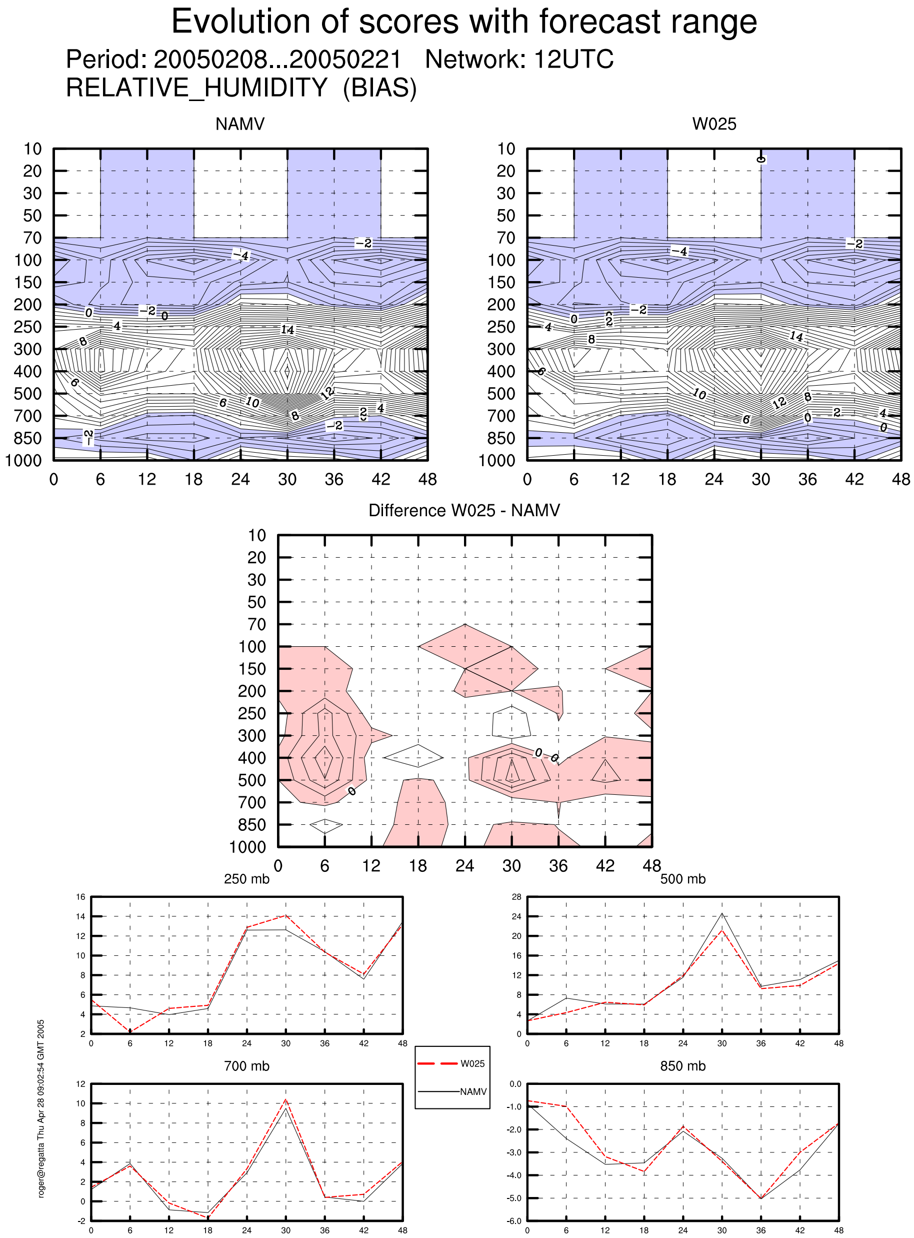

Figure 10: The impact of AMV data

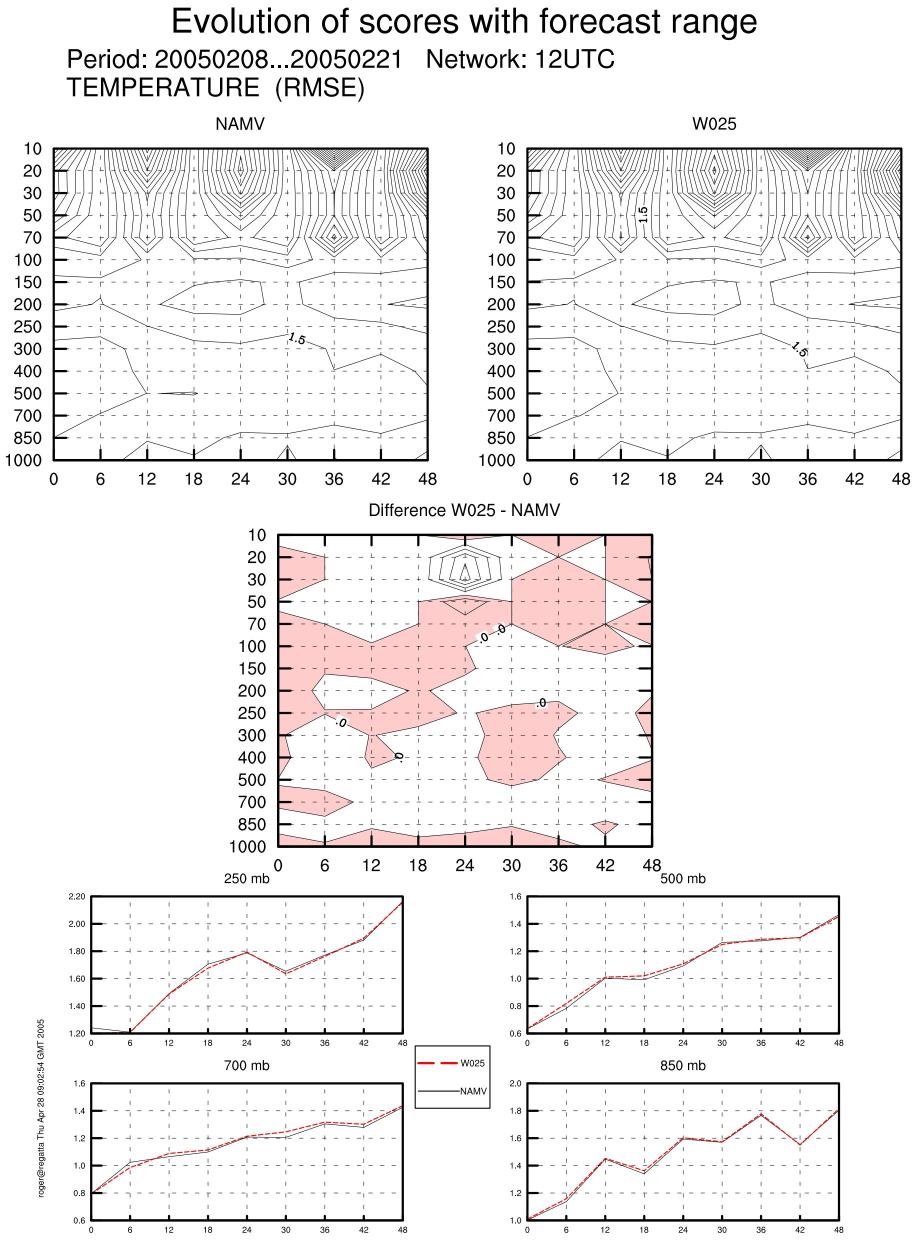

Figure 11: The impact of AMV data

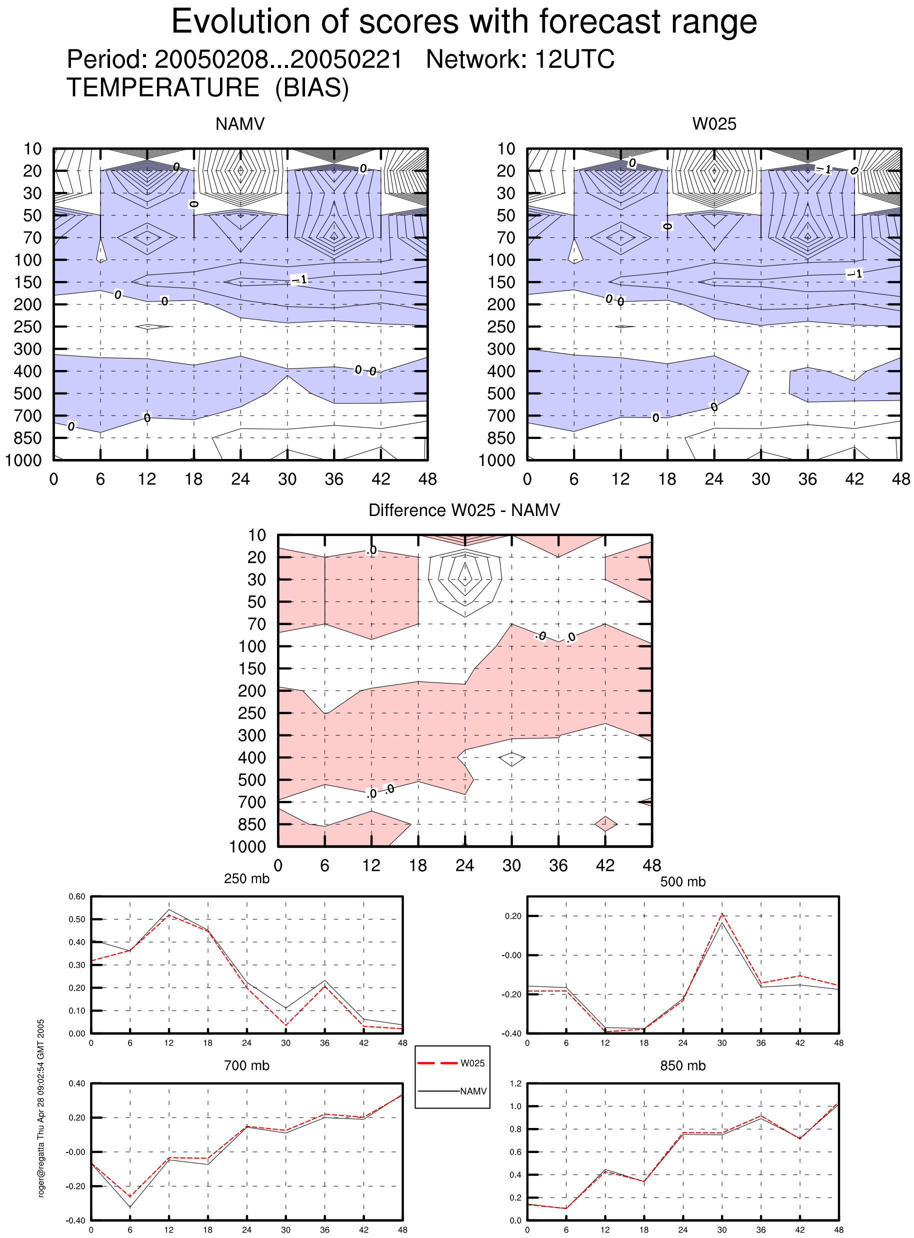

Figure 12: The impact of AMV data

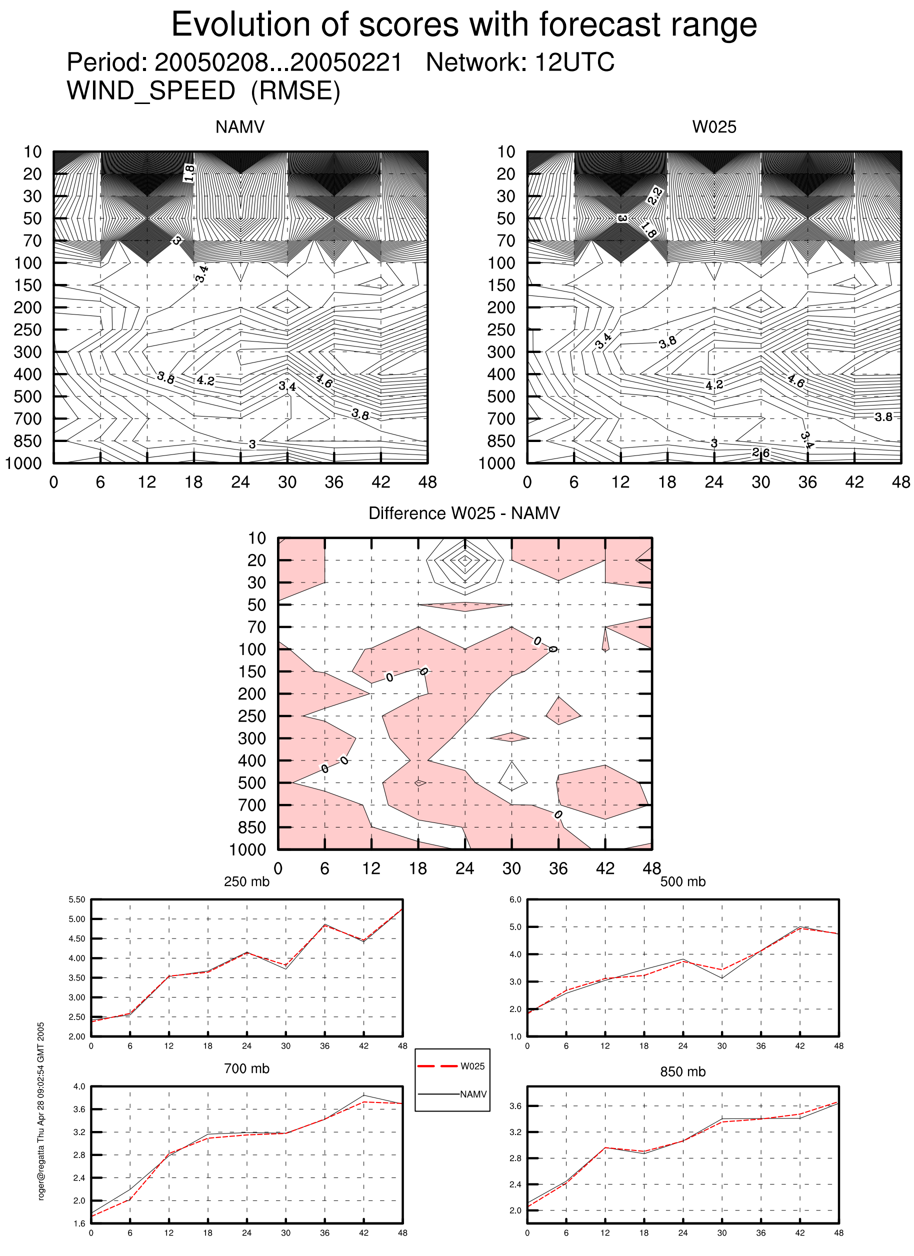

Figure 13: The impact of AMV data

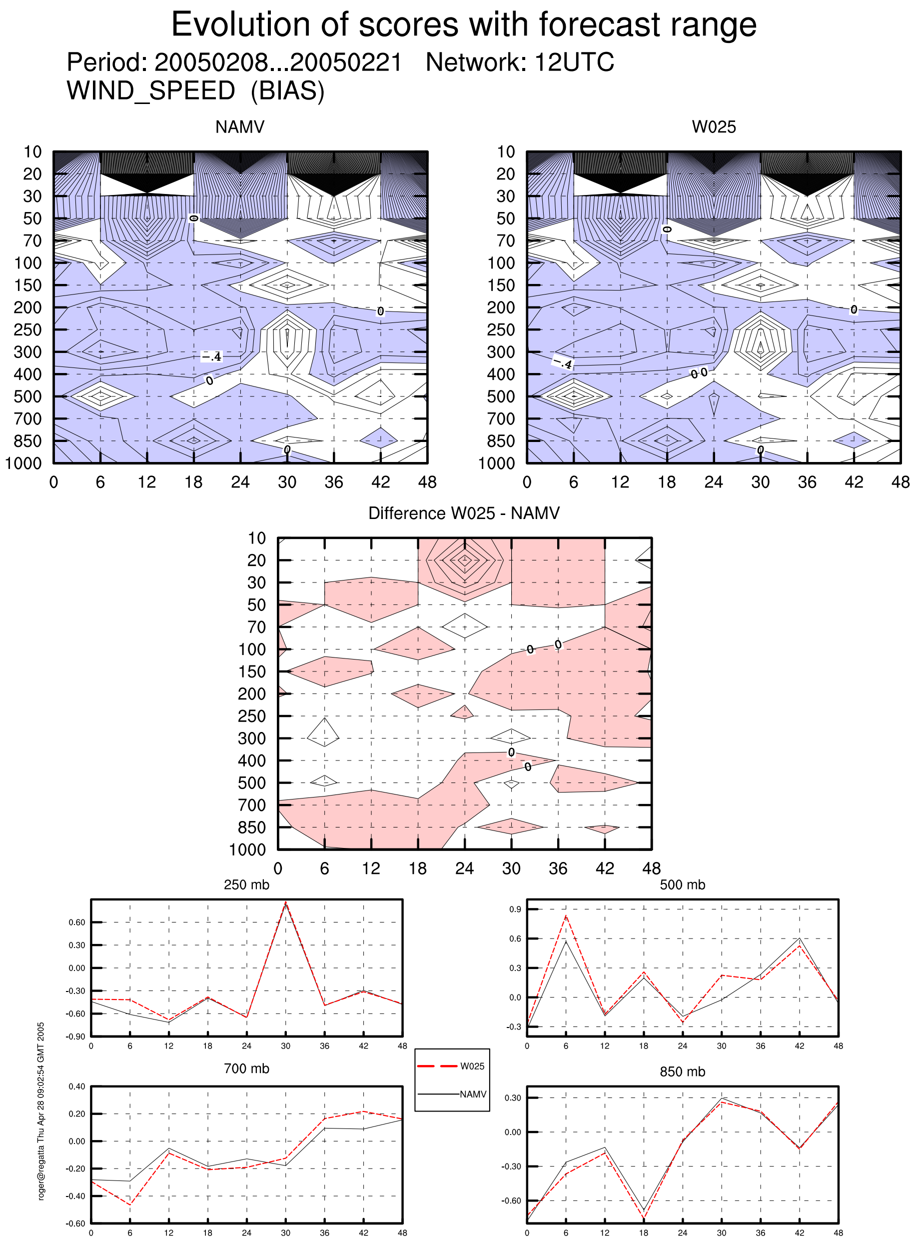

Figure 14: The impact of AMV data

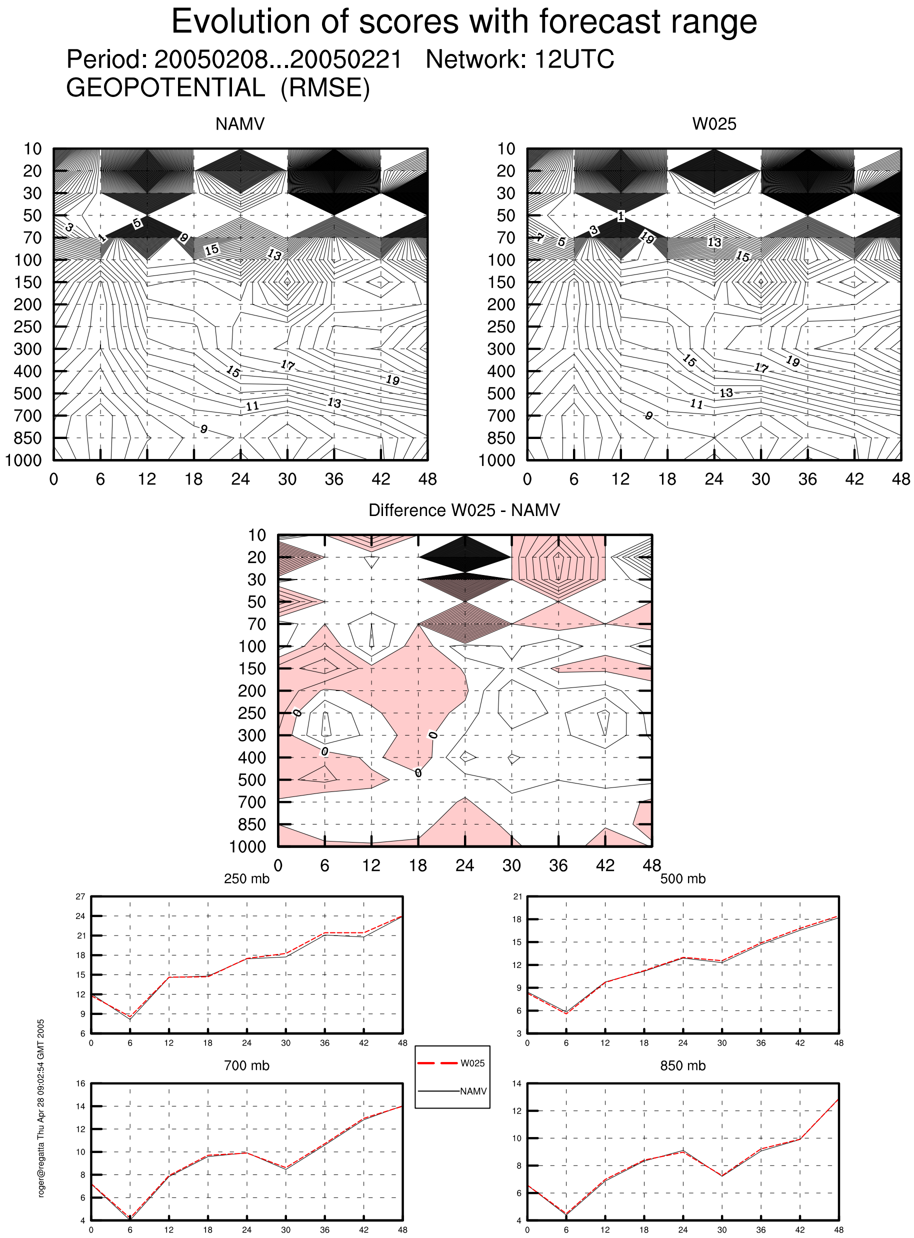

Figure 15: The impact of AMV data

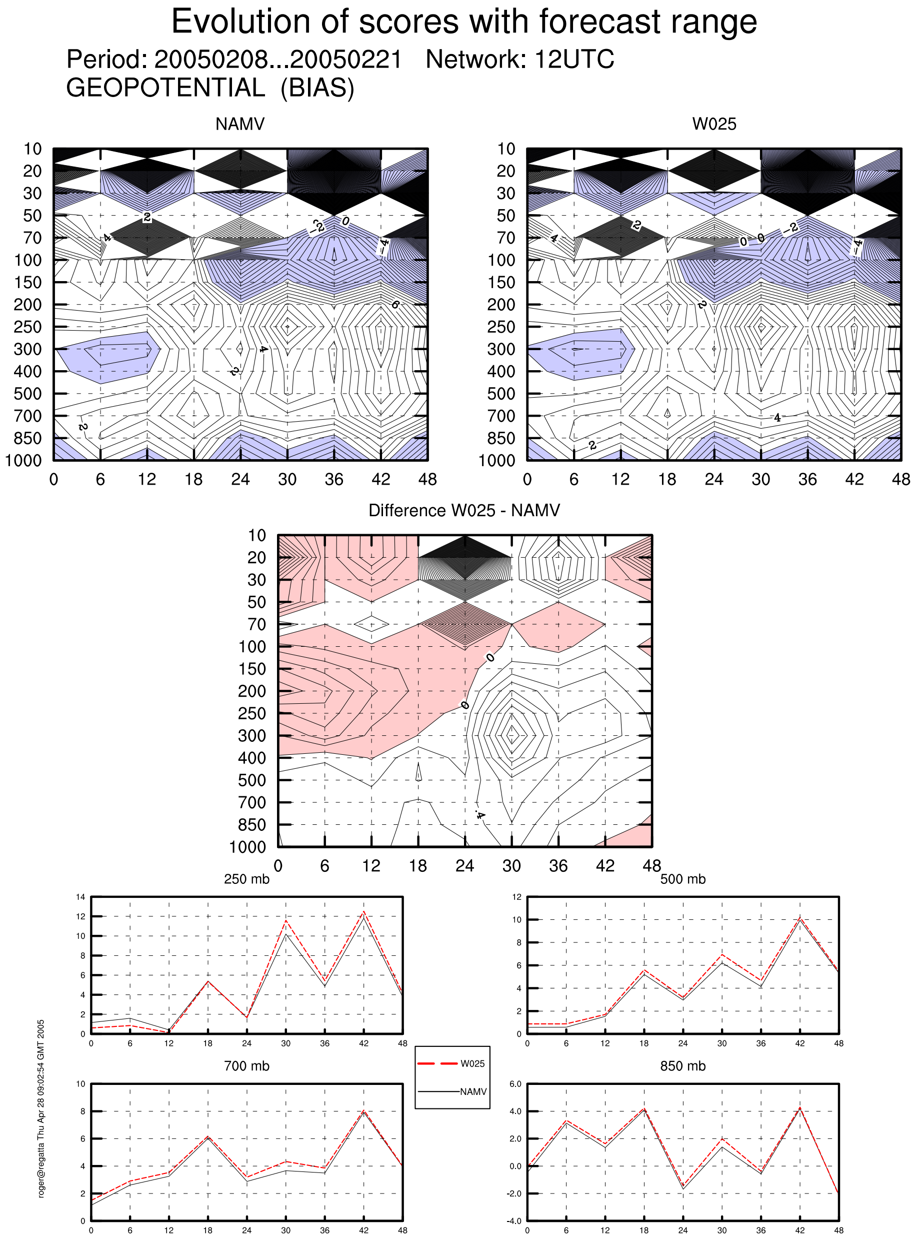

Figure 16: The impact of AMV data

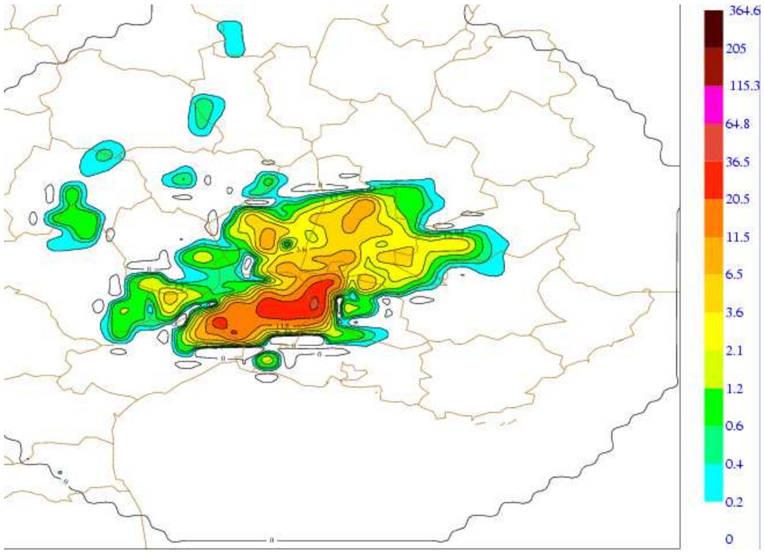

Figure 17: Example of observed radar reflectivities

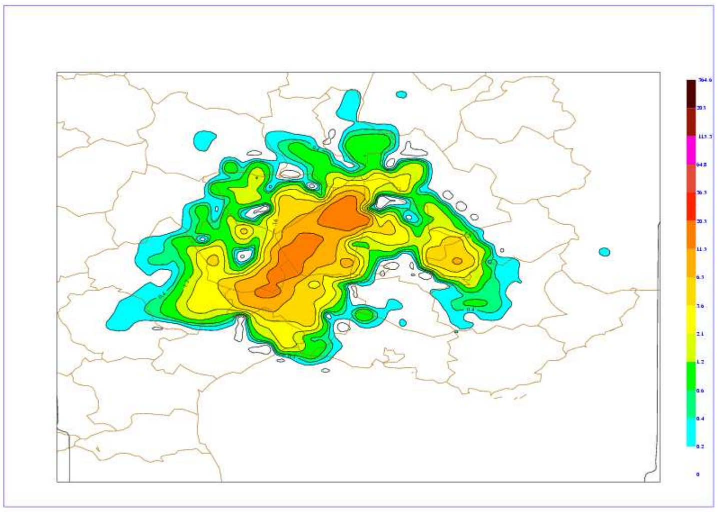

Figure 18: Example of simulated radar reflectivities

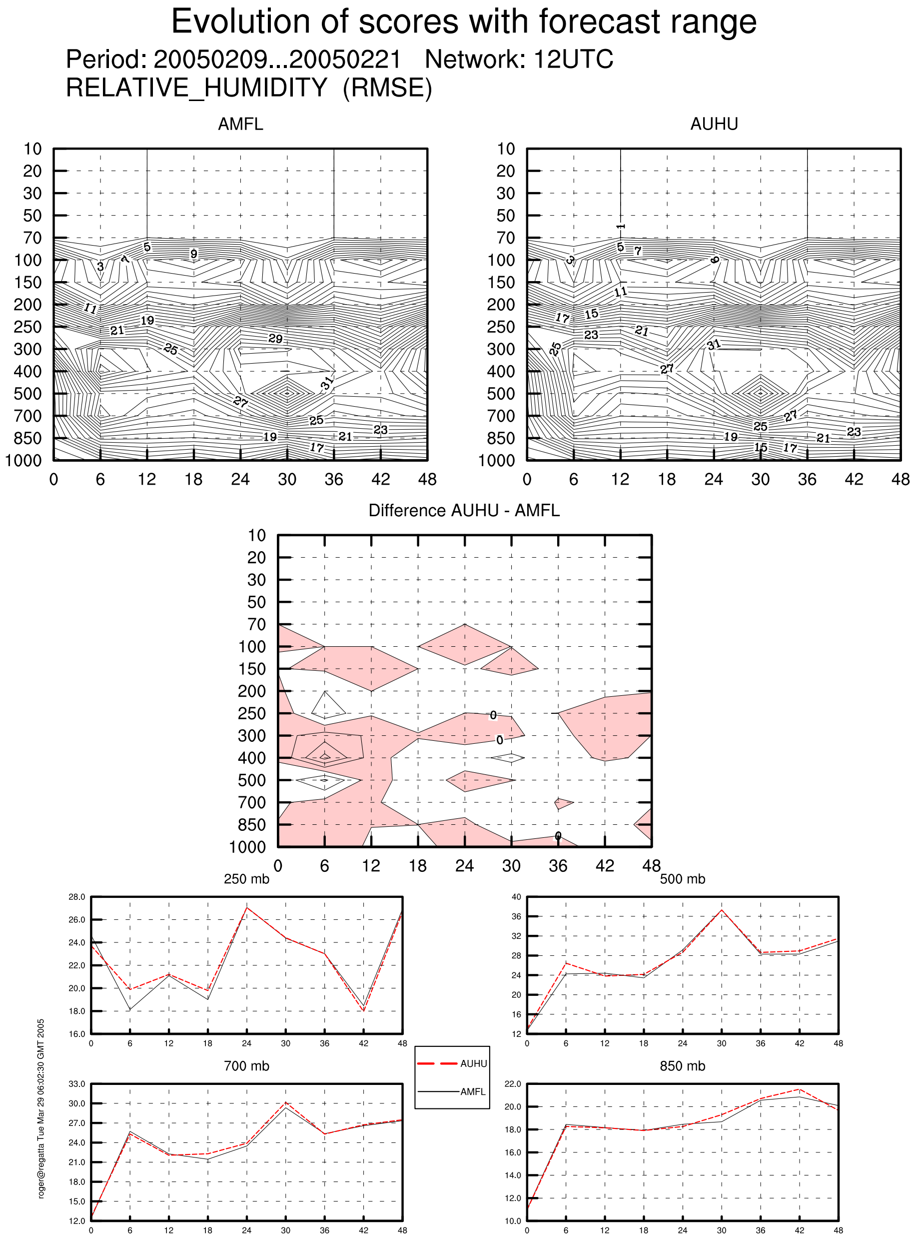

Figure 19: The impact of AMDAR data

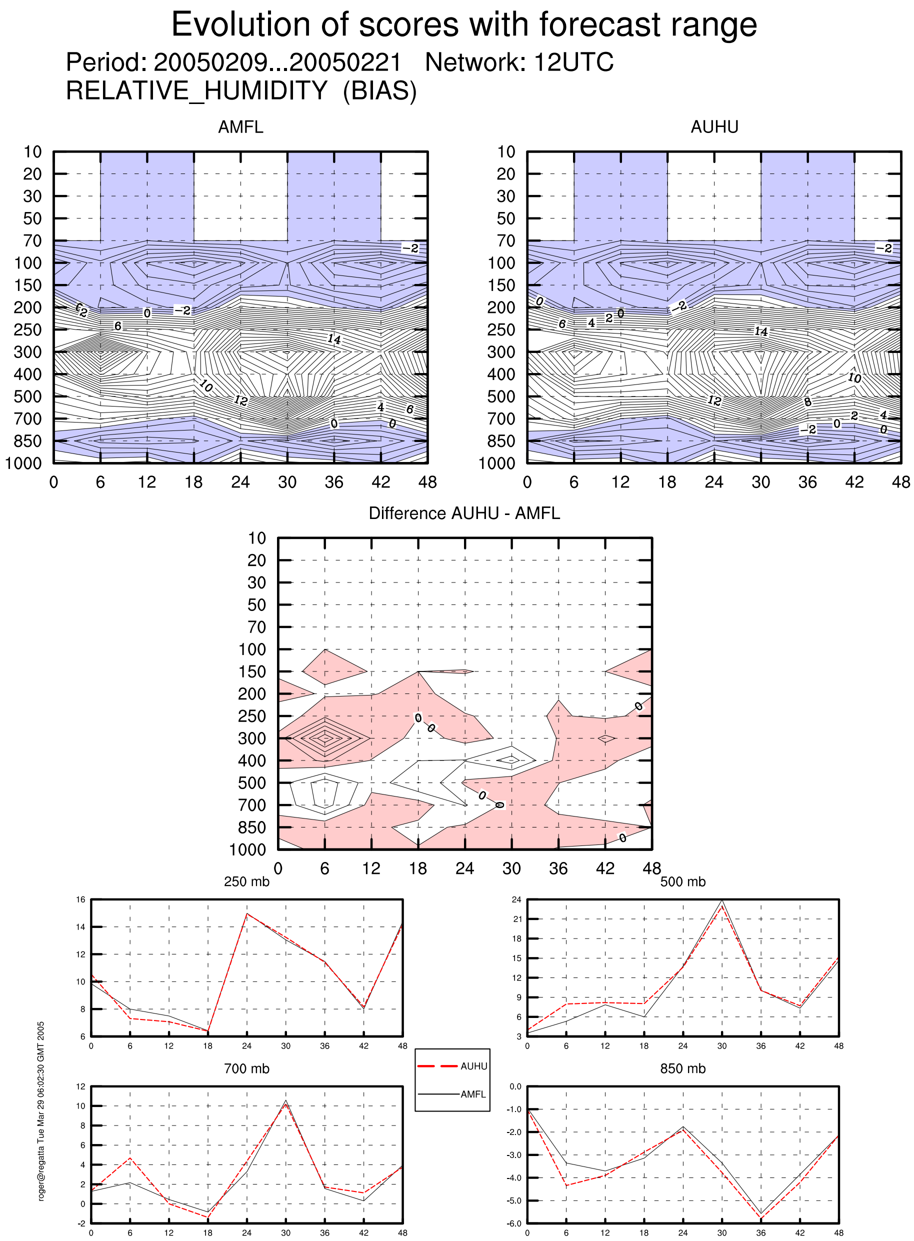

Figure 20: The impact of AMDAR data

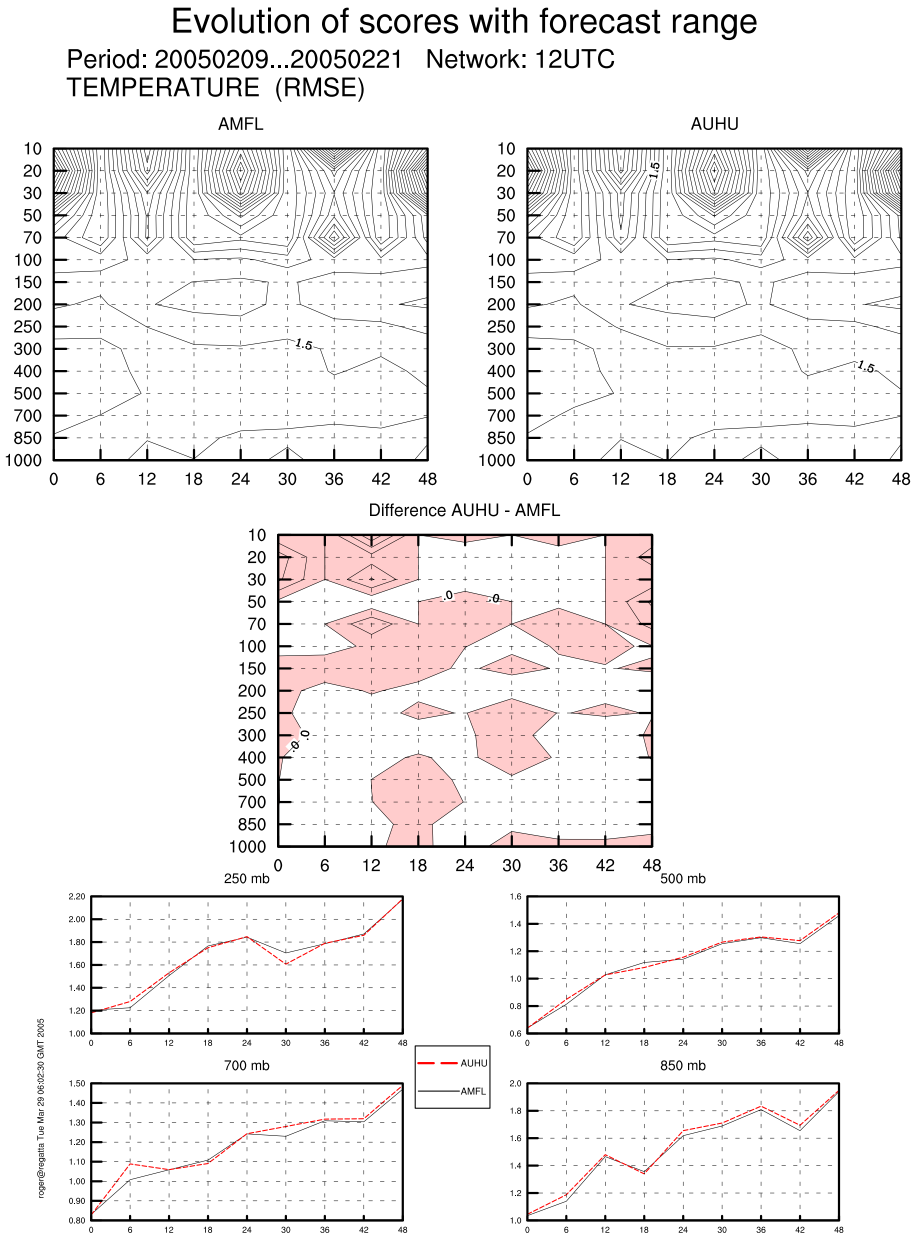

Figure 21: The impact of AMDAR data

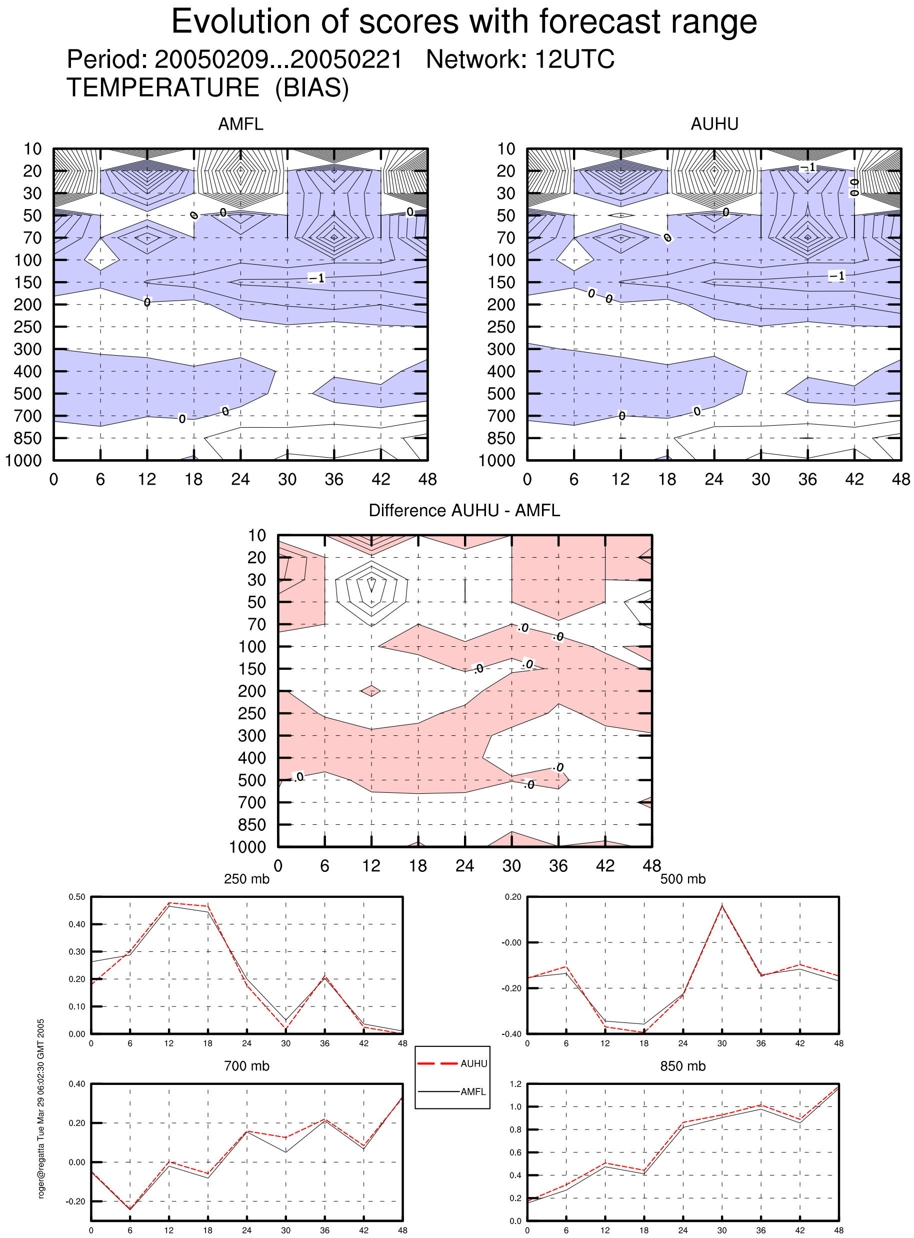

Figure 22: The impact of AMDAR data

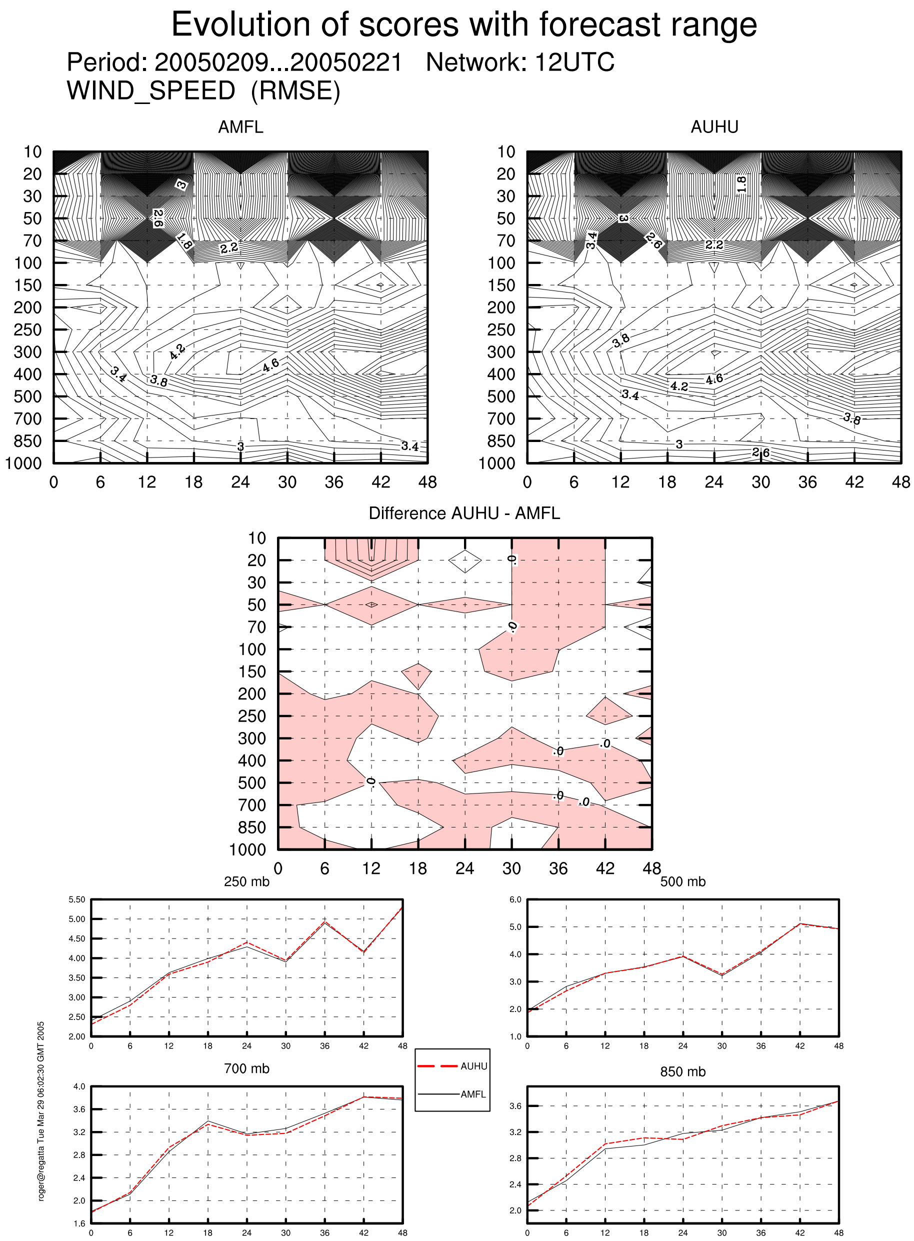

Figure 23: The impact of AMDAR data

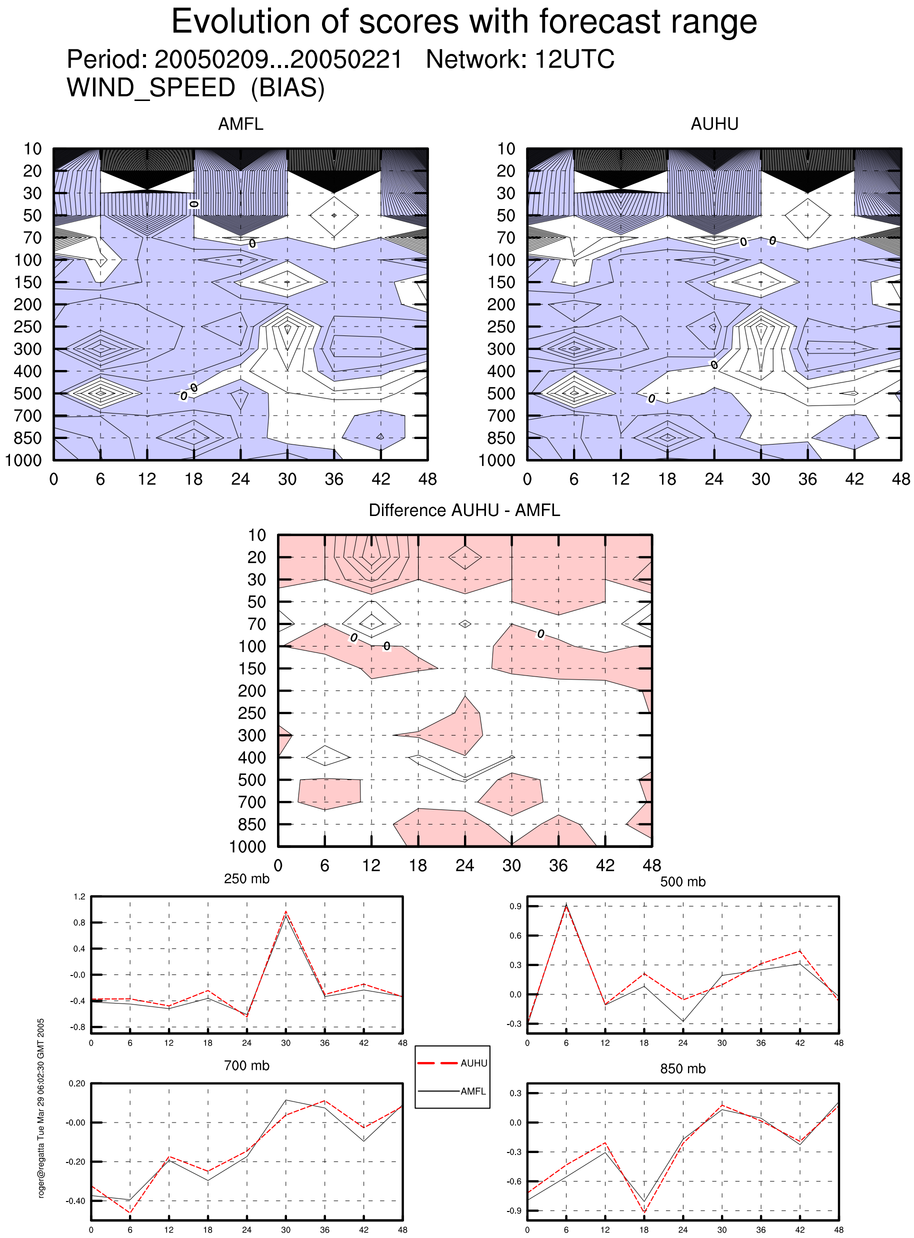

Figure 24: The impact of AMDAR data

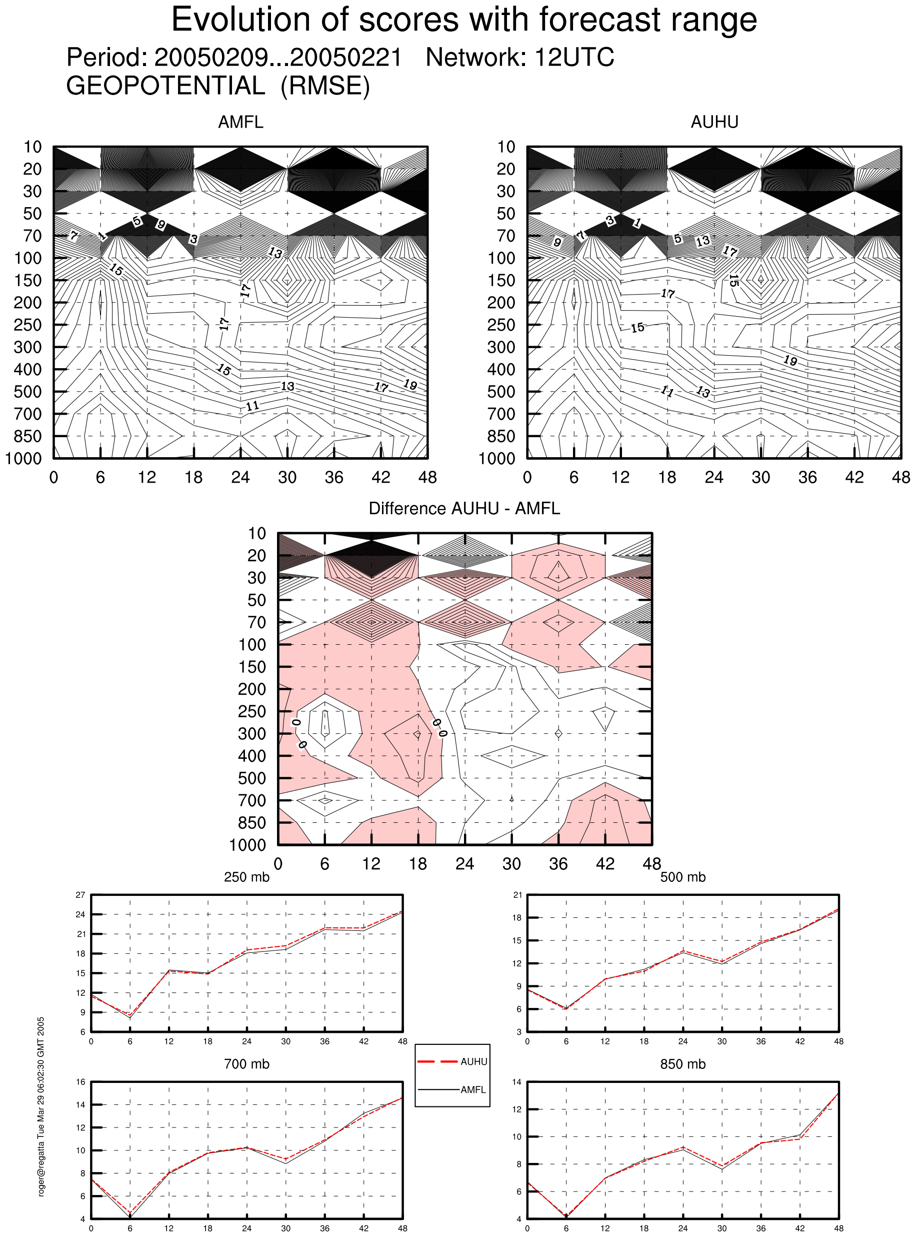

Figure 25: The impact of AMDAR data

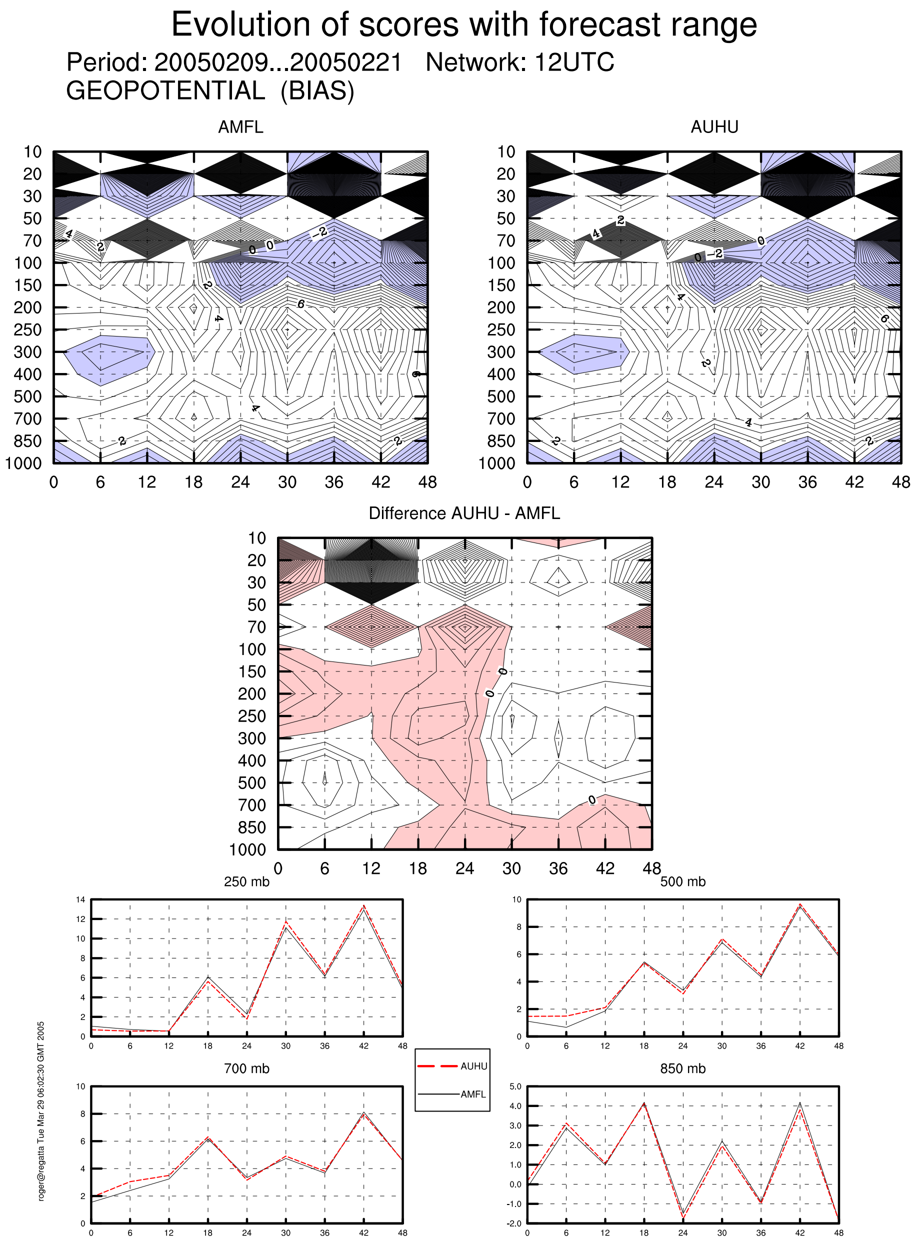

Figure 26: The impact of AMDAR data

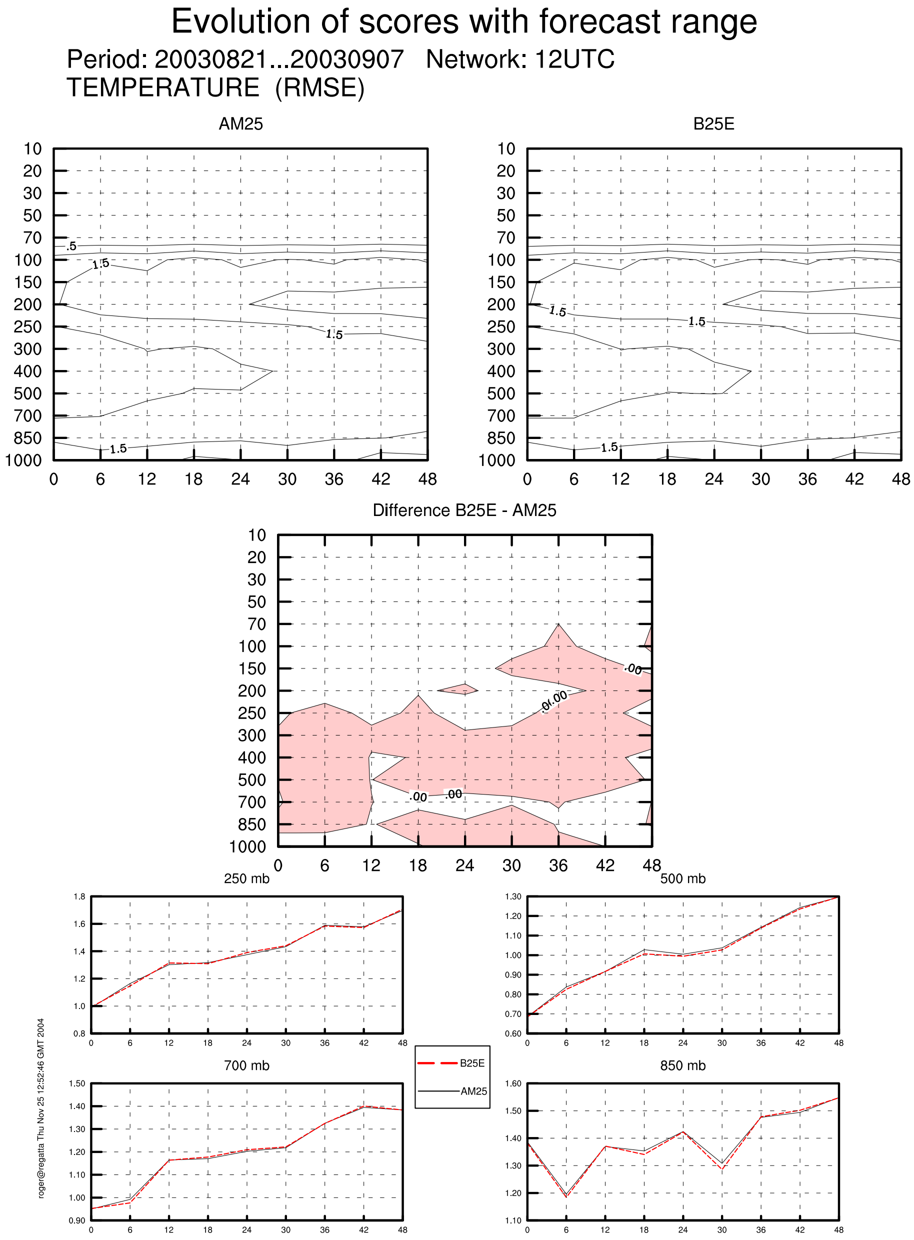

Figure 27: The impact of the new pre-processing of AMDAR data

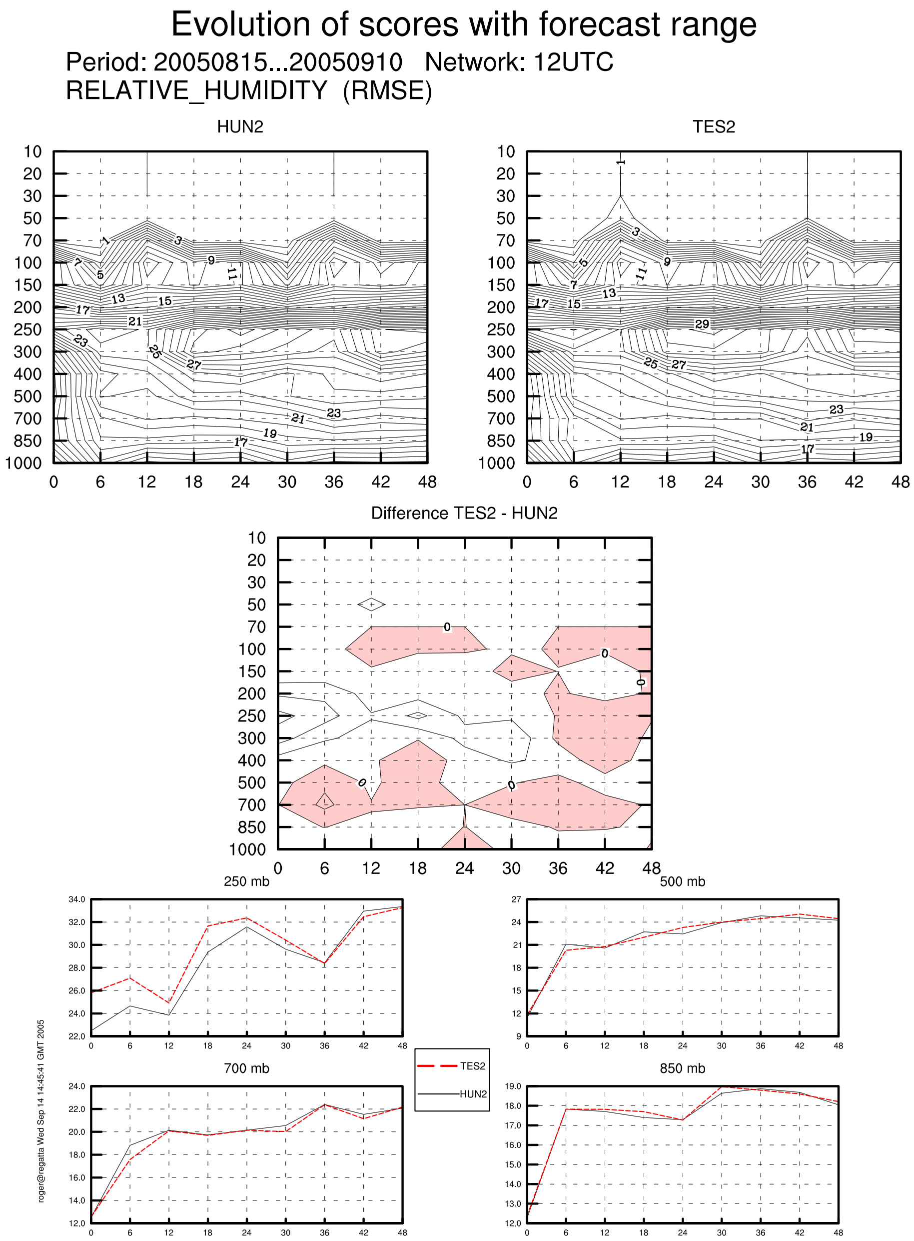

Figure 28: The impact of AMSUB data

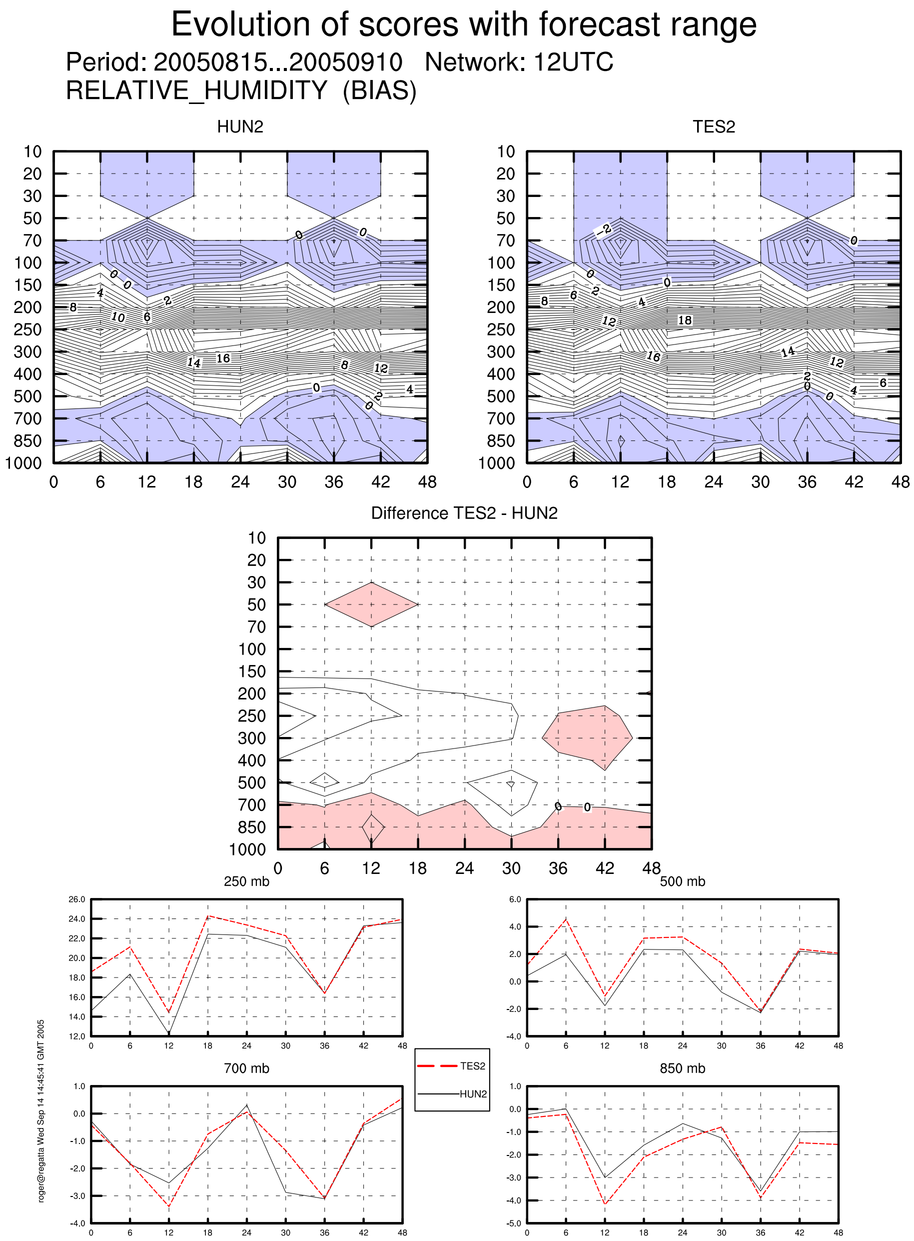

Figure 29: The impact of AMSUB data

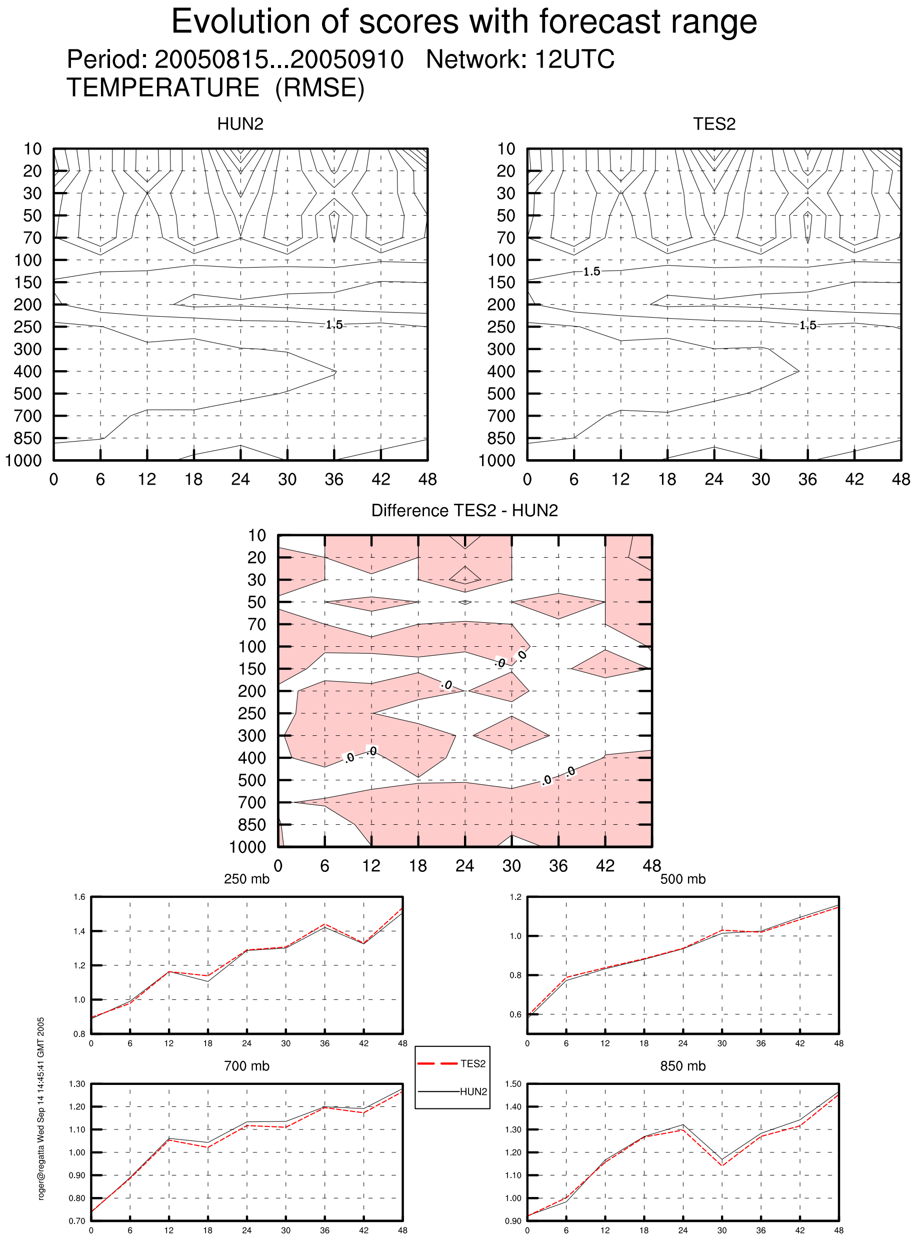

Figure 30: The impact of AMSUB data

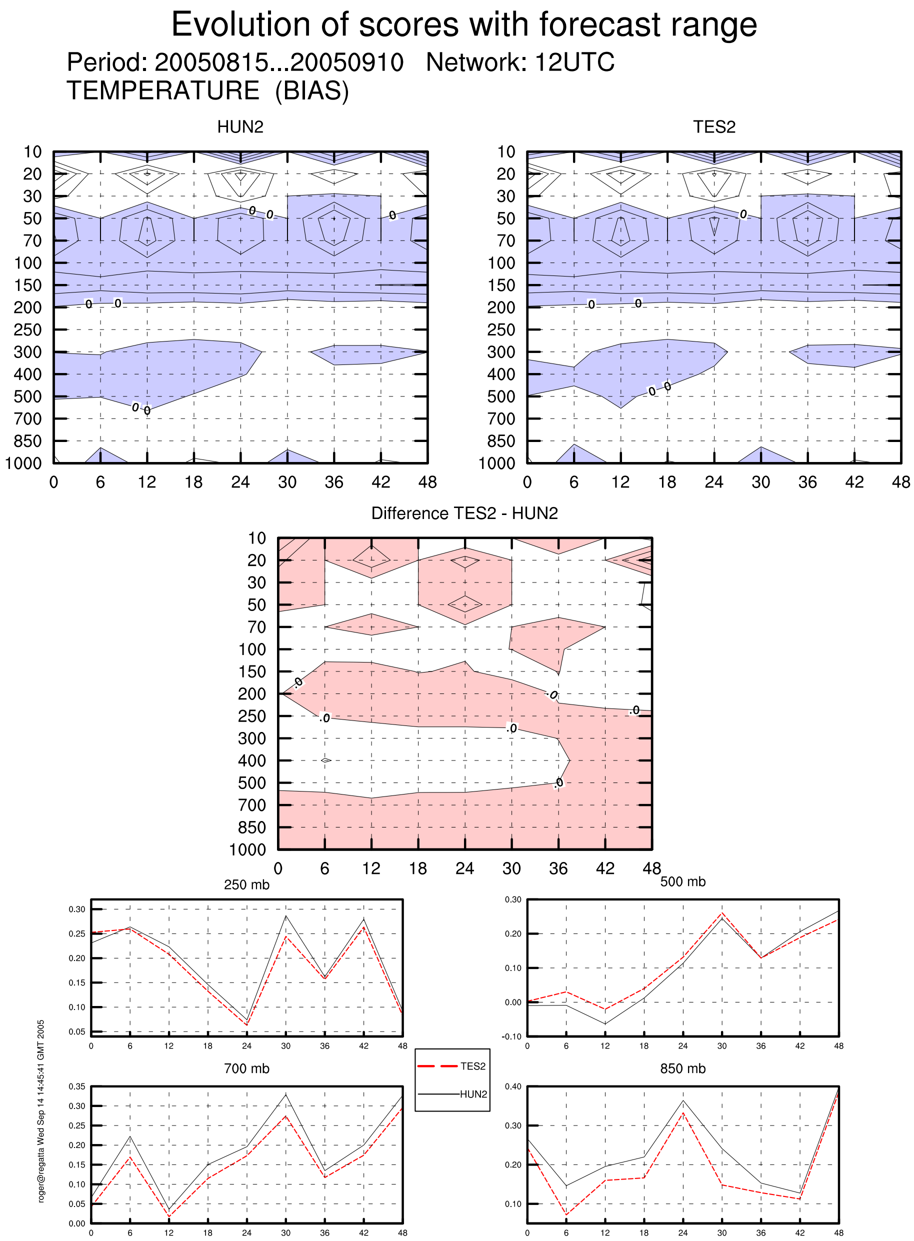

Figure 31: The impact of AMSUB data

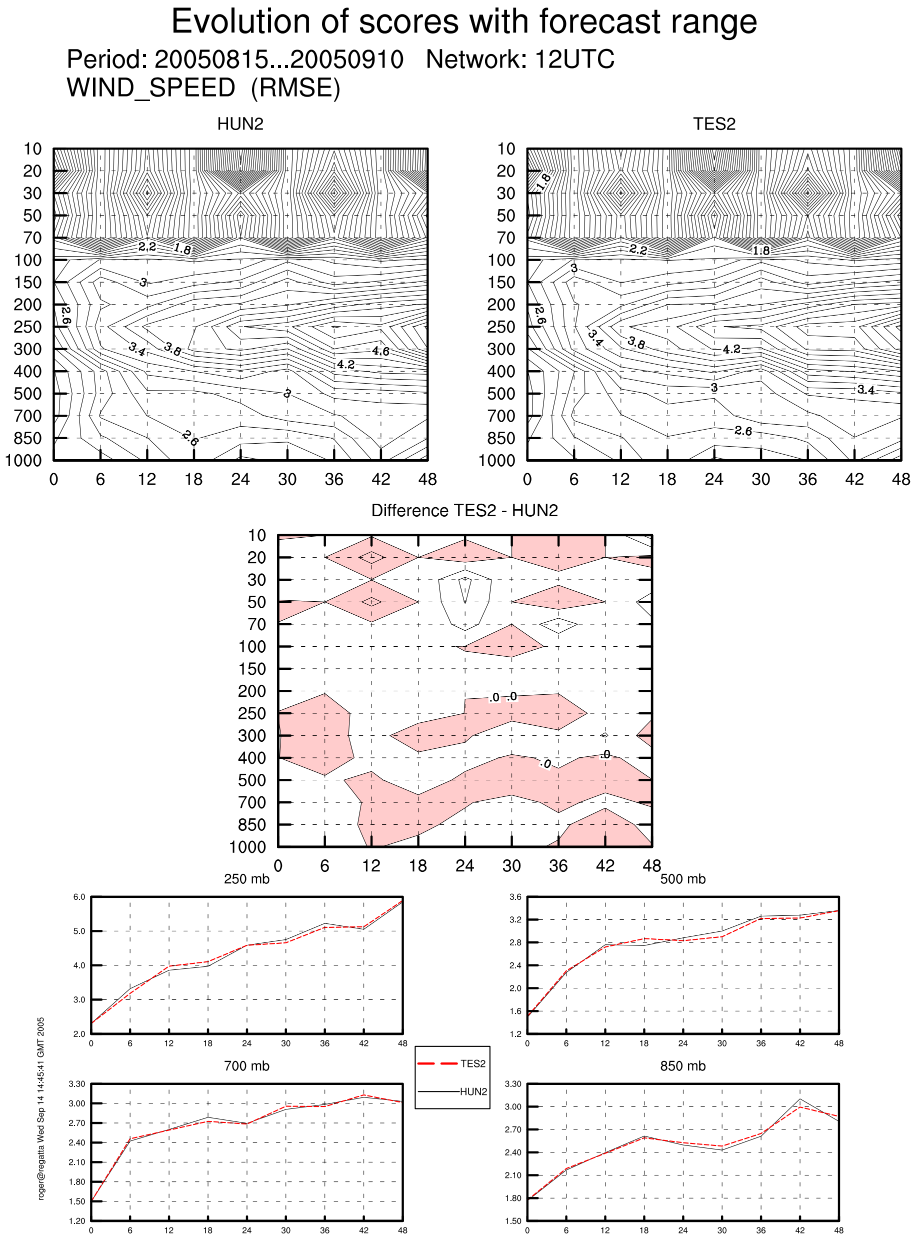

Figure 32: The impact of AMSUB data

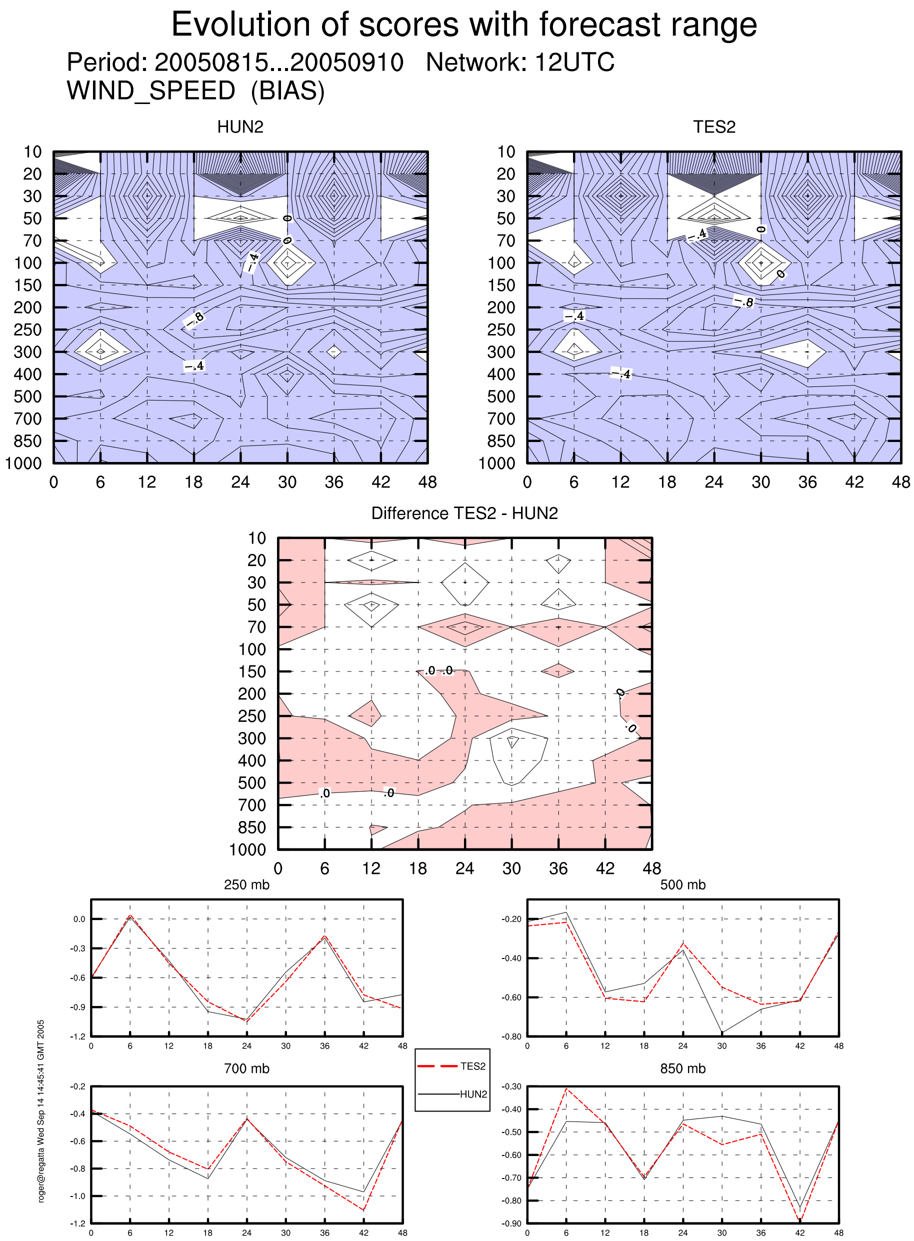

Figure 33: The impact of AMSUB data

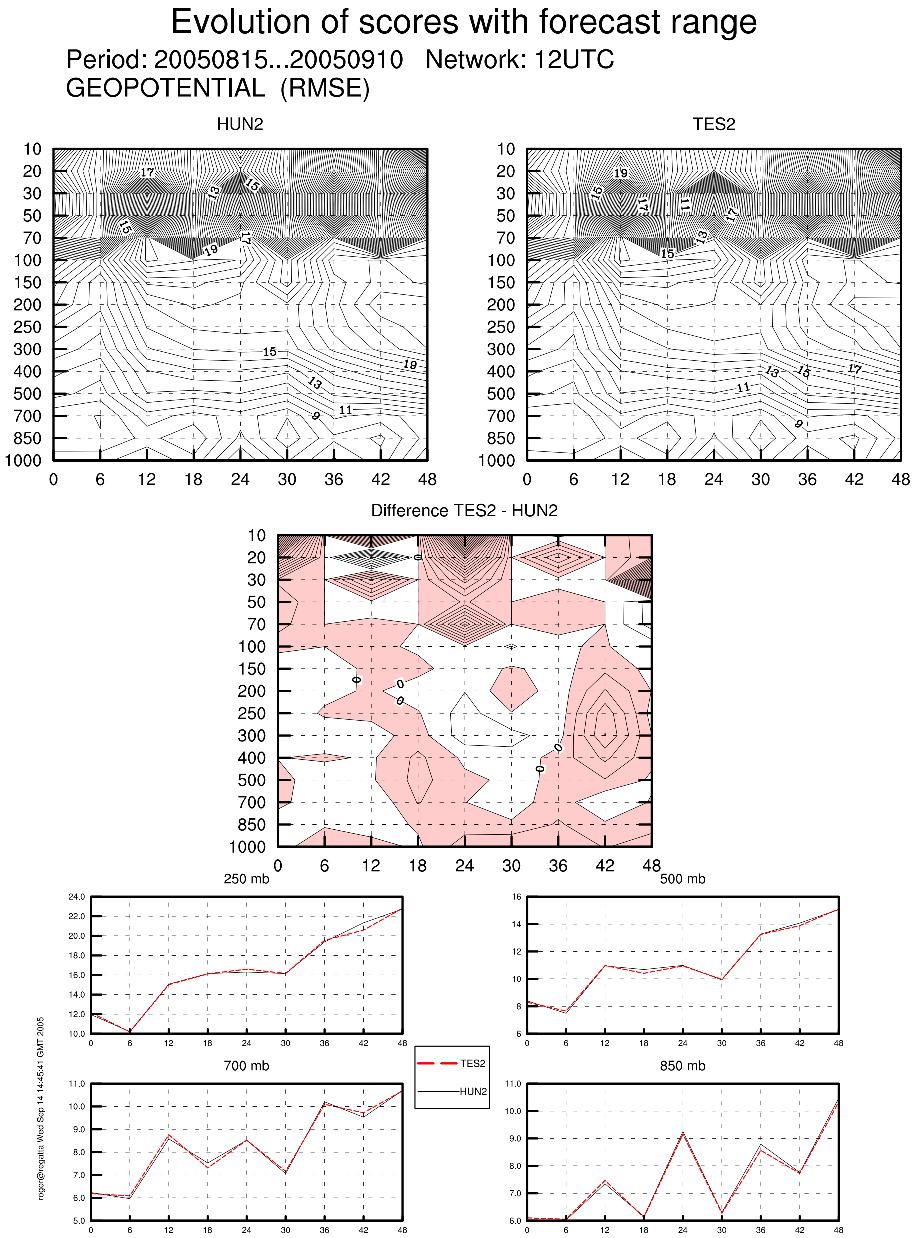

Figure 34: The impact of AMSUB data

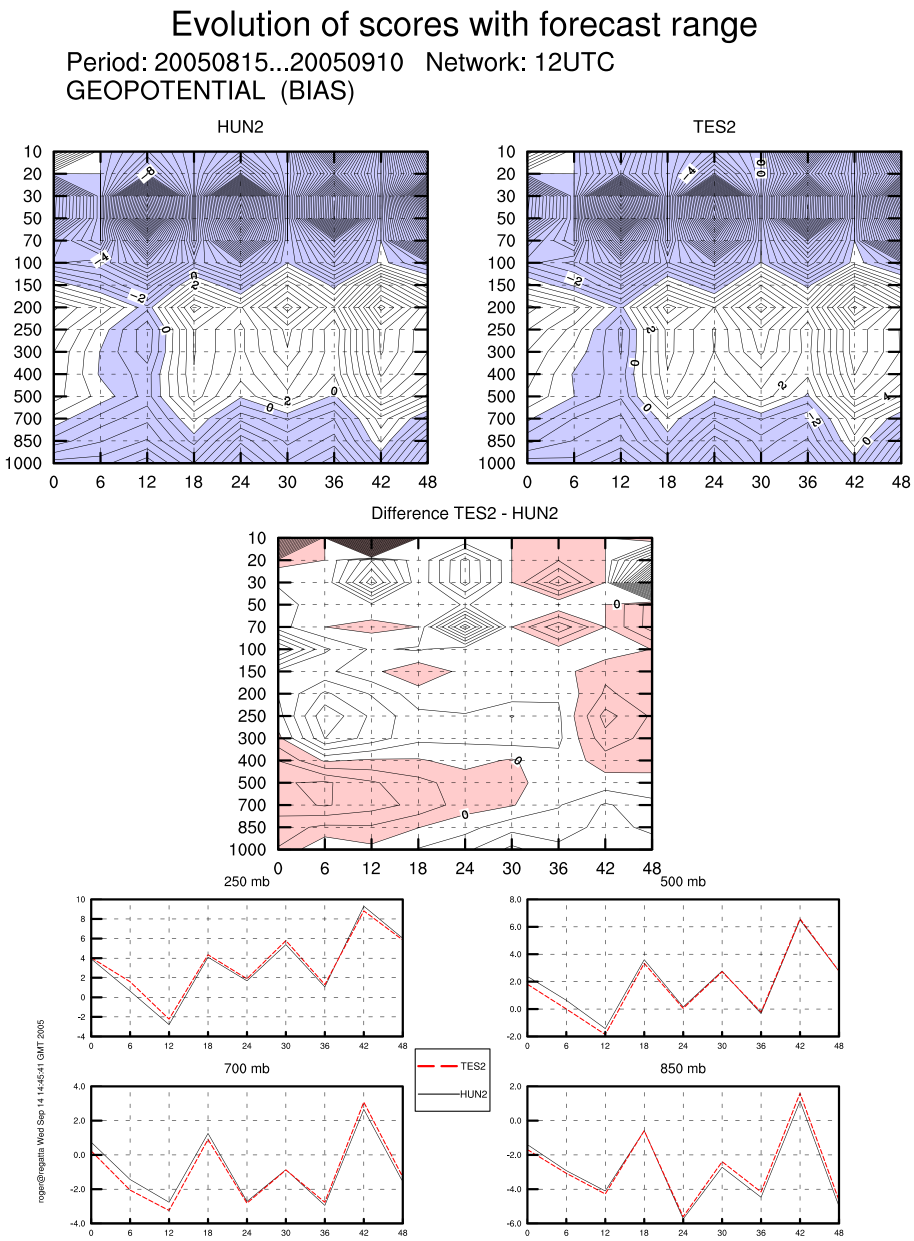

Figure 35: The impact of AMSUB data

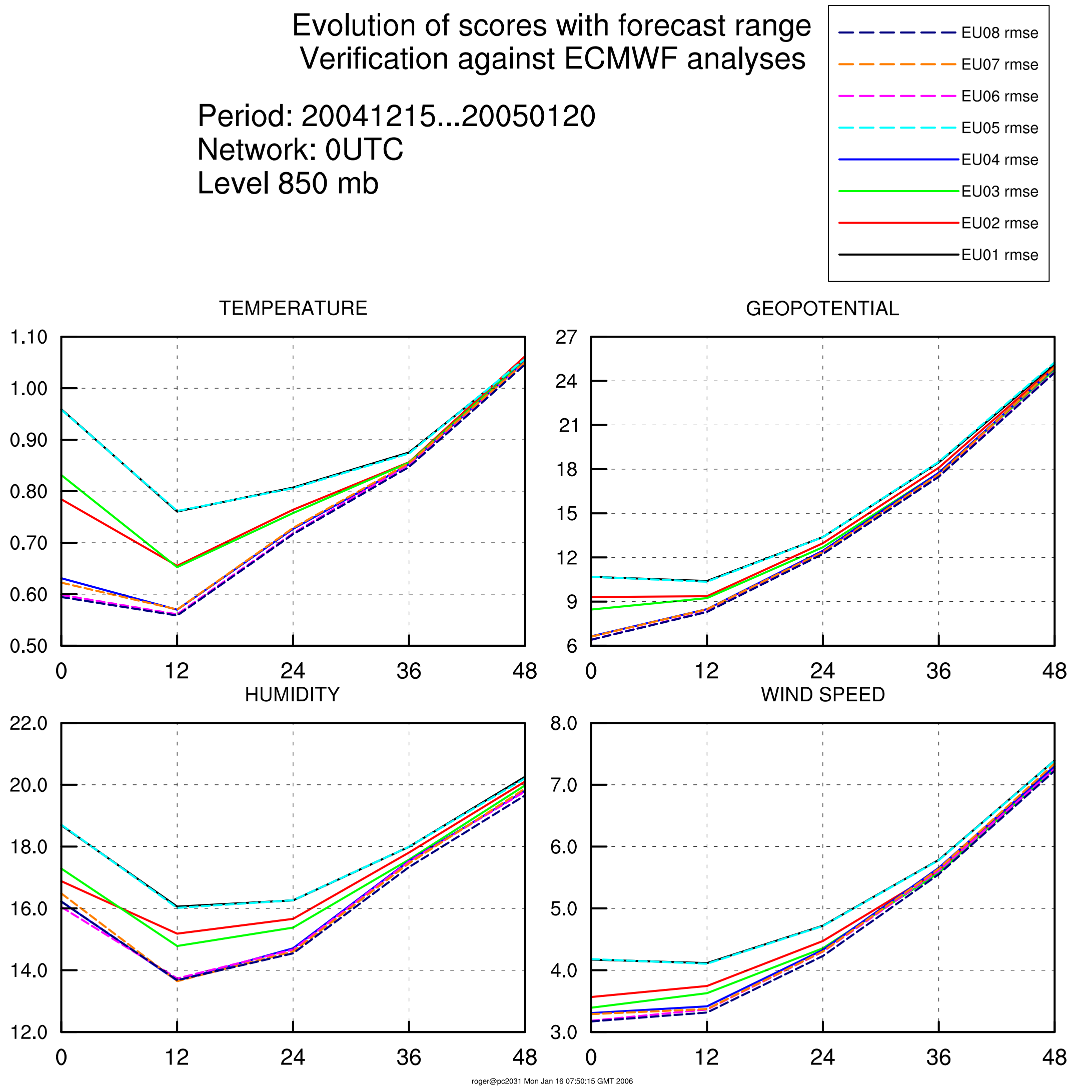

Figure 36: EUCOS OSE

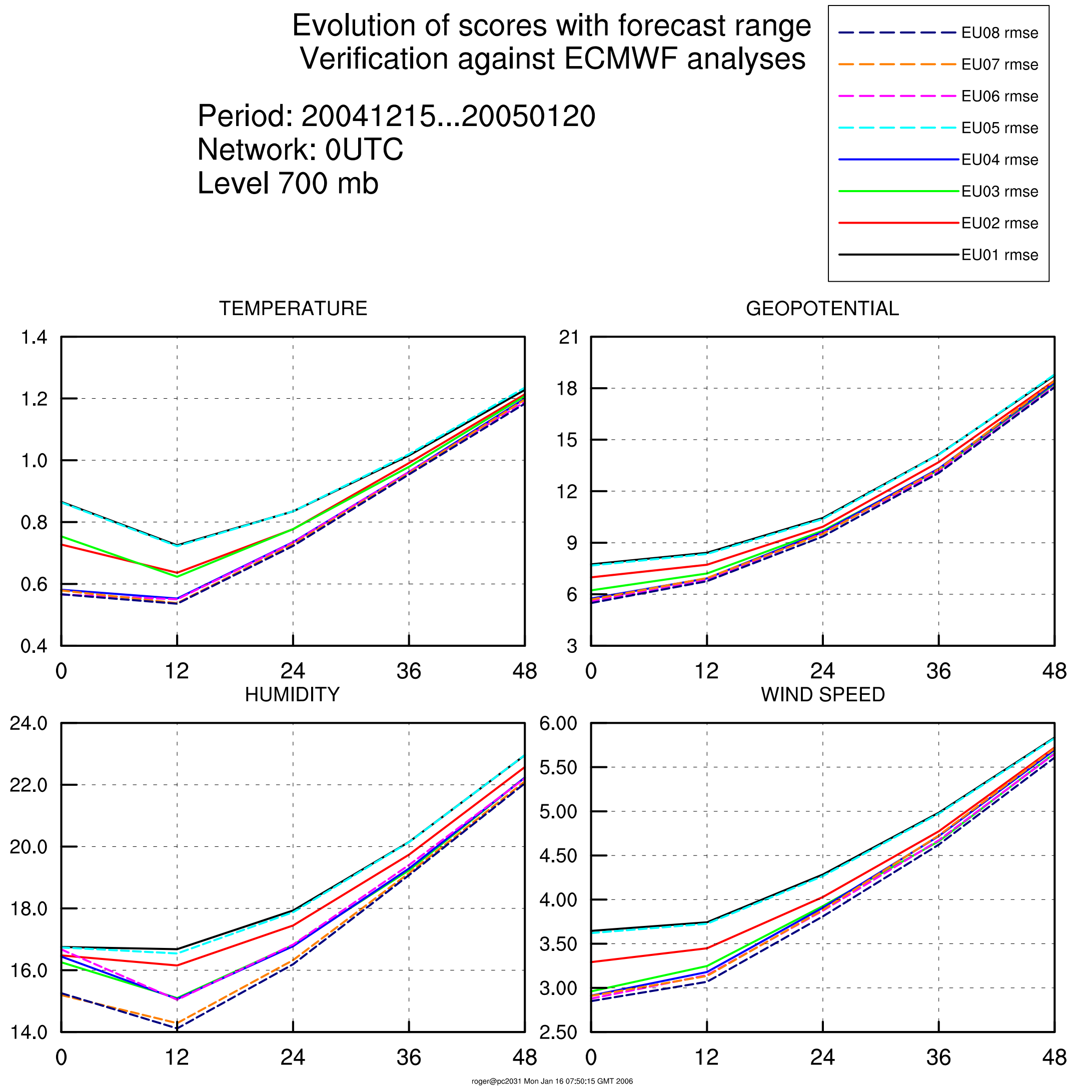

Figure 37: EUCOS OSE

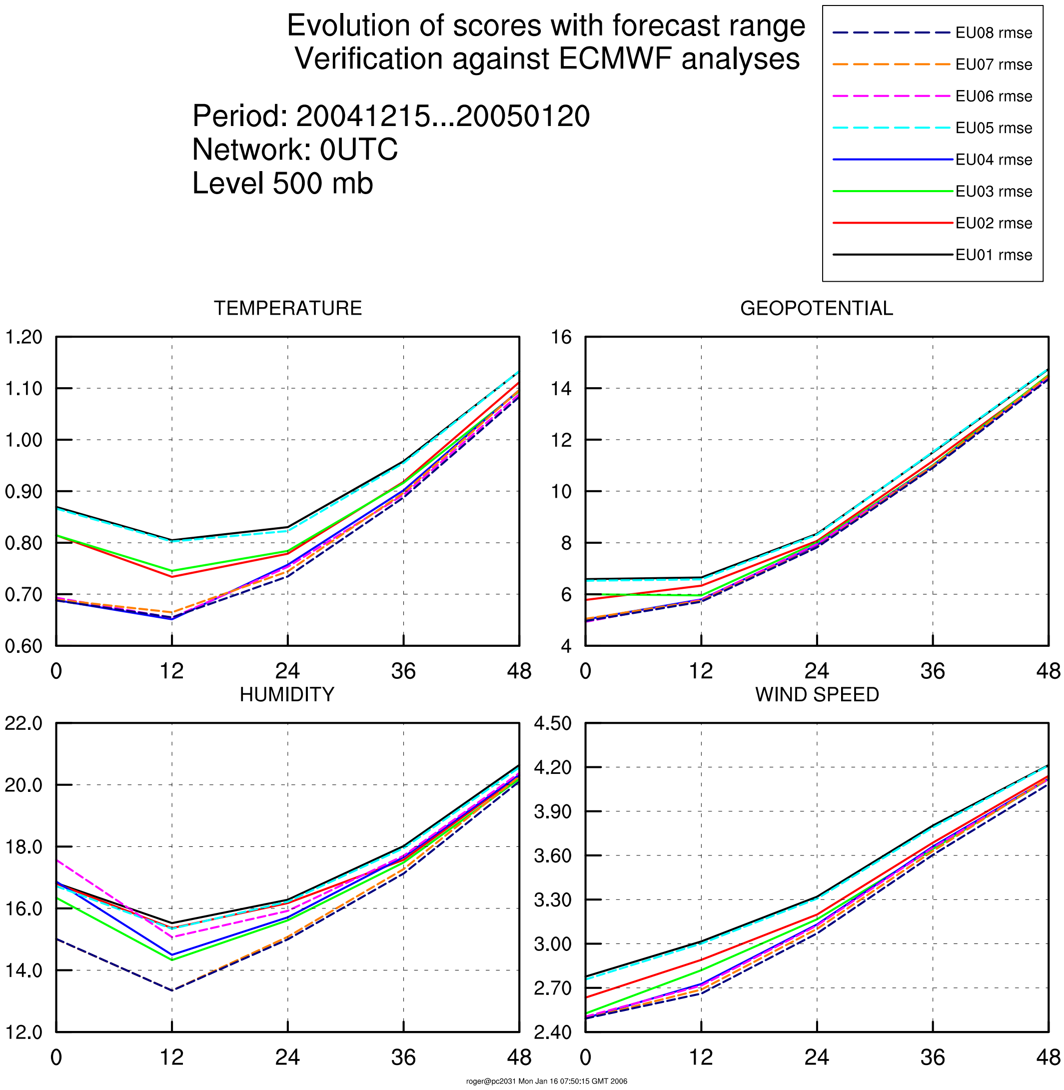

Figure 38: EUCOS OSE

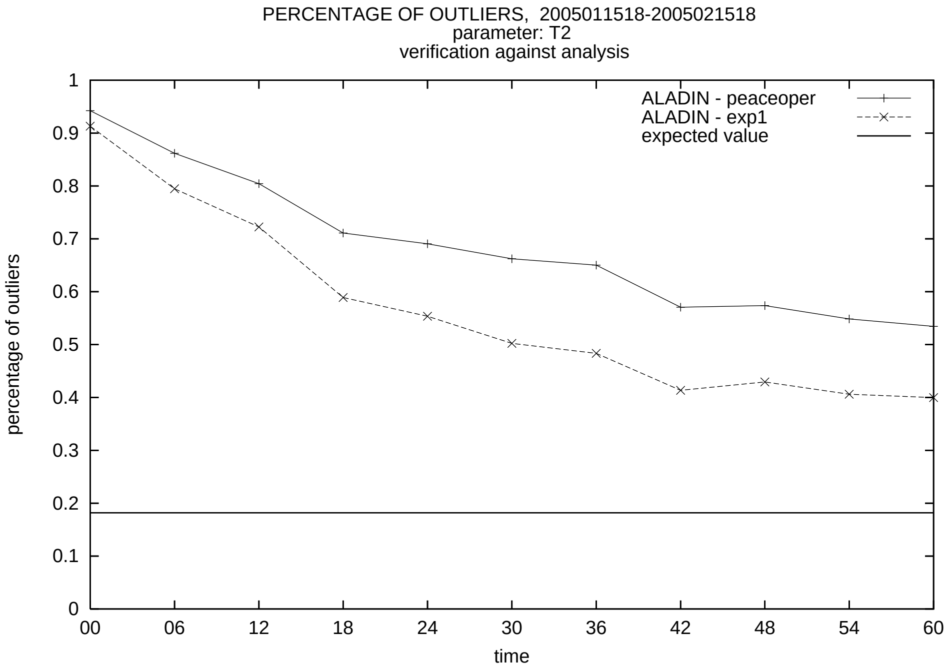

Figure 39: Talagrand outliers for 2m temperature

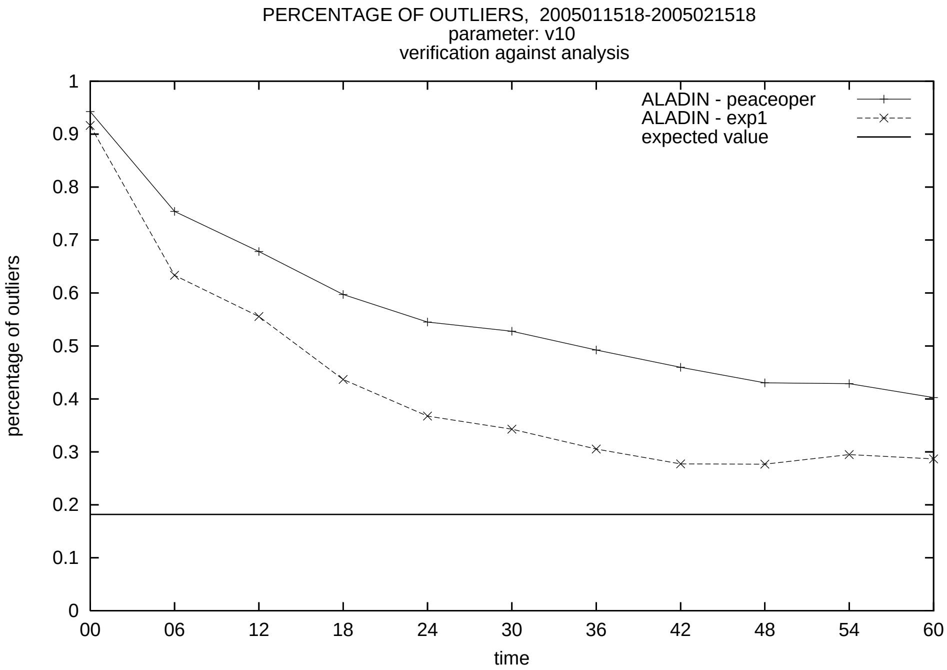

Figure 40: Talagrand outliers for 10m wind

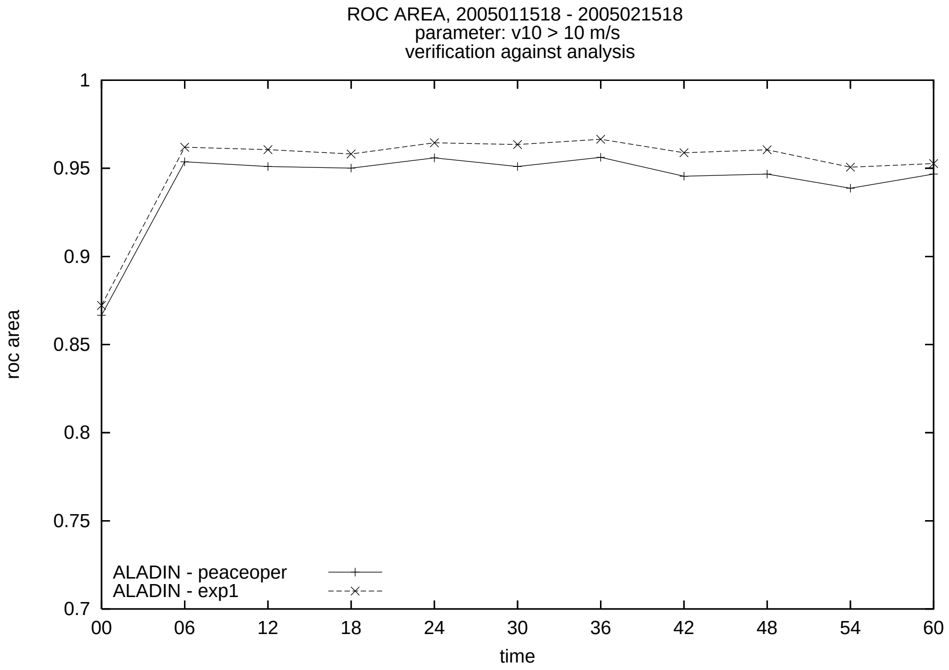

Figure 41: ROC area for 10m wind

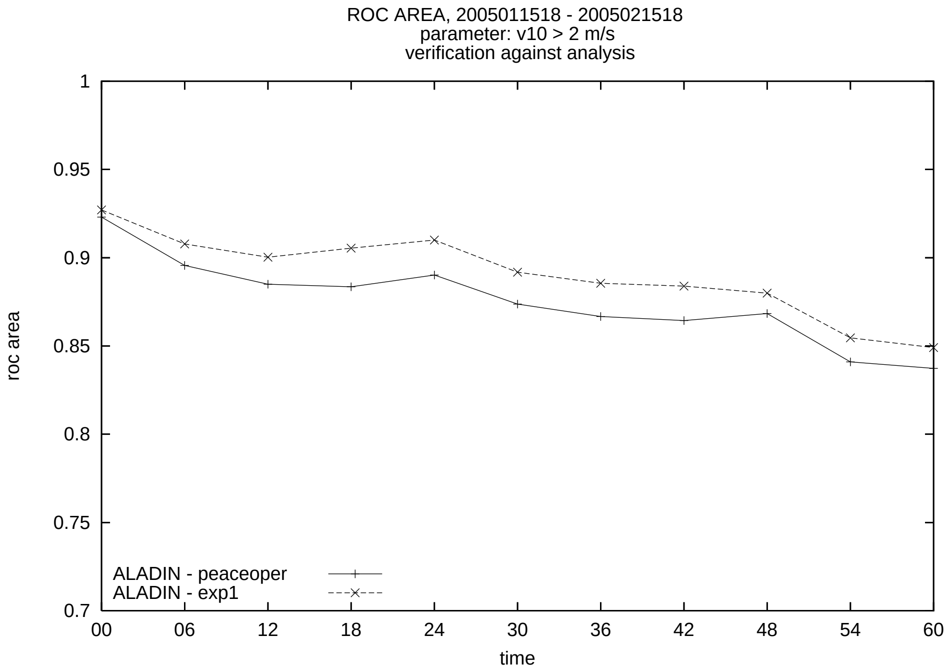

Figure 42: ROC area for 10m wind

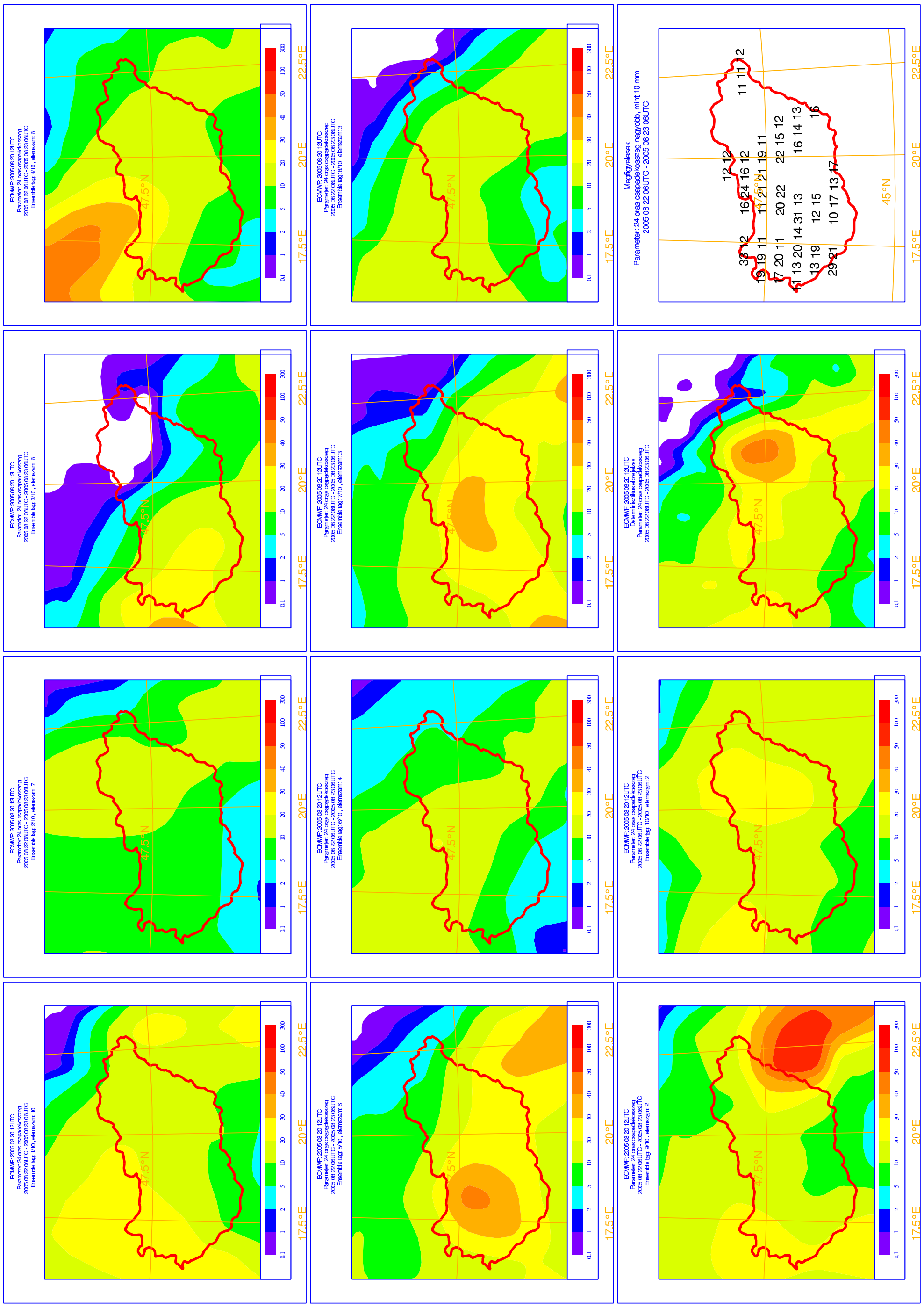

Figure 43: Stamp maps of the clustered ECMWF EPS precipitation forecasts

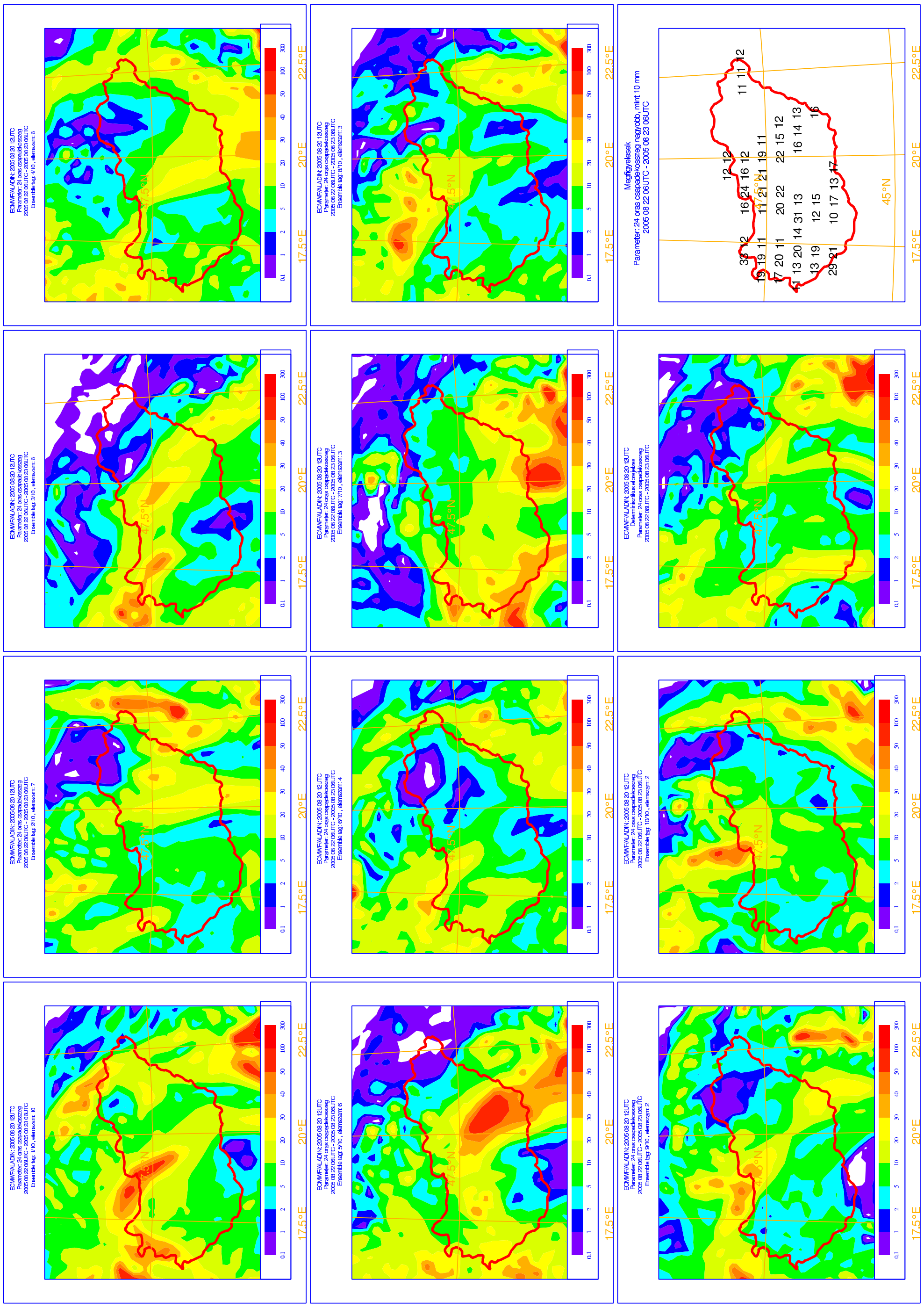

Figure 44: Stamp maps of the clustered ALADIN EPS precipitation forecasts

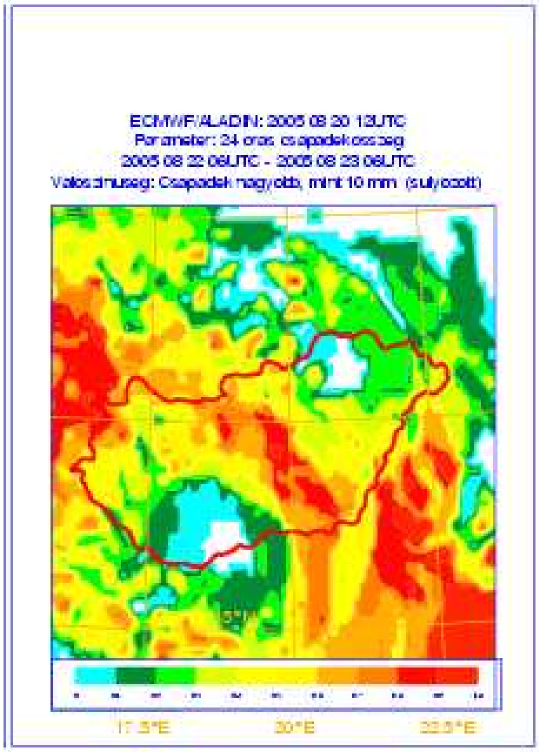

Figure 45: Probability map of the 24h precipitation forecast (probability of the precip > 10mm)

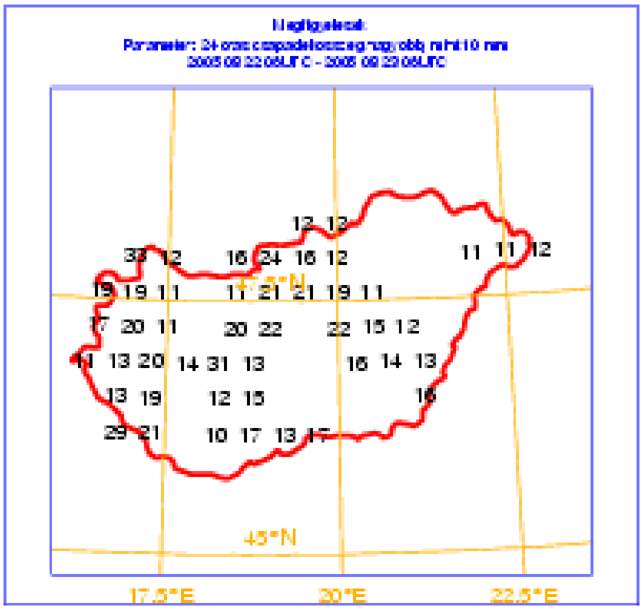

Figure 46: 24h precipitation observations (precip > 10mm)