Application and verification of ECMWF products 2010

Hungarian Meteorological Service

1. Summary of major highlights

The objective verification of ECMWF forecasts have been continued on all the time ranges from medium range forecast to seasonal forecast as in the previous years. The ALADIN/HU model has been operationally driven by ECMWF lateral boundary conditions since October 2008. Station based and GRID based ensemble calibration using ECMWF reforecast dataset have been operationally made since October 2009.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

2.1.2 Physical adaptation

Dispersion and forward/backward trajectory models based on ECMWF and ALADIN models have been operationally used for more than ten years.

In the middle of 2008 based on the positive experimental results it was considered to use the ECMWF IFS lateral boundary conditions (LBC) for driving the limited area model ALADIN. After having successful real-time double test-suite of the use of IFS boundaries with respect to ARPEGE (French global model) boundary conditions it was operationally introduced in October 2008 (*Bölöni*, 2009). The ALADIN/HU model coupled with ECMWF lateral boundary conditions operationally provides short range forecasts four times a day for forecasters. At 00 UTC +54h, at 06 and 12 UTC +48h and at 18 UTC +36 forecasts are made.

The nowcasting system of the Hungarian Meteorological Service uses ECMWF deterministic forecasts as basic background information. The first step of the nowcasting system is making numerical prediction using high resolution LAM models. Nowadays MM5 and WRF models are used. Both models are set with 2.5 km horizontal resolution 32 vertical levels and non-parameterized convection. Using ECMWF data there are 4 daily model runs (00 06 12 18 UTC). Observations are also assimilated (sounding and surface information) using nudging technique in MM5 and 3DVAR technique in WRF. The nowcasting system (MEANDER) uses real time remote sensing and observation and the above LAM information to make 3 hour forecast in every hour.

2.1.3 Derived fields

Clustering for Central European area has been operationally made since 2003. Cluster mean and representative members of the clusters are derived, a wide selection of the meteorological fields is available to the forecasters for both short and medium time range (*Ihász*., 2003). Several derived parameters from the deterministic and ensemble models are operationally available too. More details are available in '*Application and verification of ECMWF products, 2004*'. Altogether more than 100 EPS fields are derived.

2.2 Use of products

A wide range of the products are operationally available within the Hungarian Advanced Workstation (HAWK-3) for forecasters. Beside this tool quite a lot of special products, like EPS meteograms, EPS plumes, cluster products are available on the intranet for the whole community of the meteorological service. EPS meteograms are available for medium, monthly and seasonal forecast ranges. EPS calibration using VarEPS reforecast dataset was developed in 2008, products (EPS plumes are among them) have been operationally available for forecasters (*Ihász et al*., 2010, *Németh*, 2010).

3. Verification of Products

3.1 Objective verification

3.1.1 Direct ECMWF model output

(i) in the free atmosphere

(ii) local weather parameters for locations

The objective verification has been performed via the Objective Verification System (OVISYS) produced by the Hungarian Meteorological Service. More details are available in '*Verification of ECMWF products, 2006*'.

In the recent study the 00 and 12 hours runs of ECMWF model were verified against all the Hungarian SYNOP observations for the whole 2009 year. The input forecast values for ECMWF were taken from a 0.5°x0.5° post-processing grid. The verification was performed for the following variables:

- 2m temperature
- 2m relative humidity
- 10m wind speed
- Total cloudiness
- Daily accumulated amount of precipitation

BIAS and RMSE scores until 168 hours (only for ECMWF) are computed. The computed scores are presented on Time-TS diagrams (with the forecast range on the x-axis) (Fig 1 –5).

2m temperature:

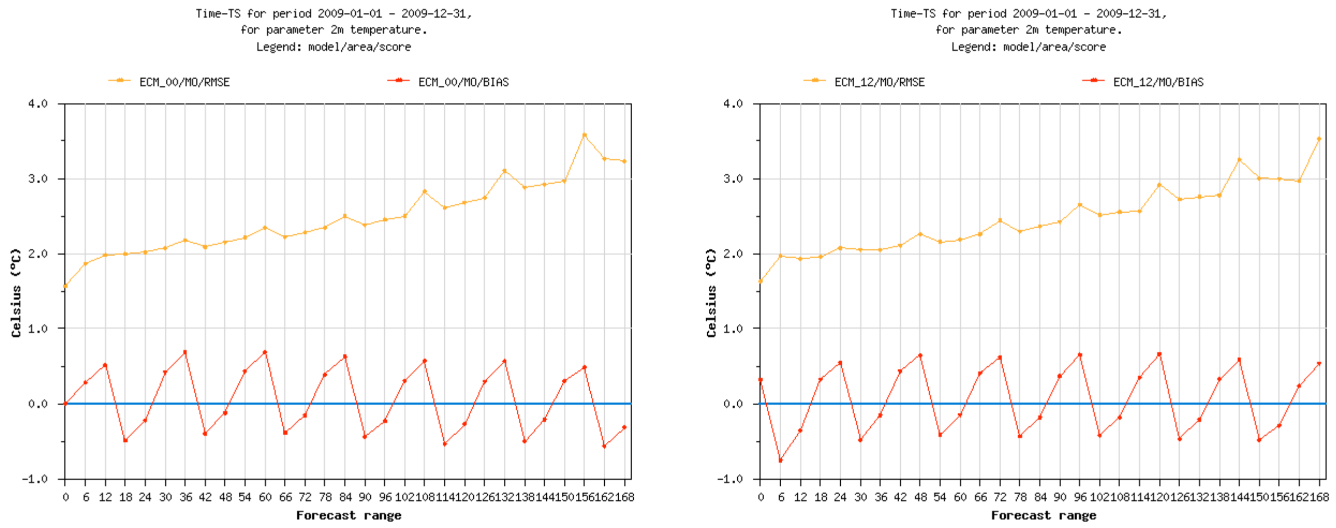

Fig. 1 RMSE and BIAS values for ECMWF 2m temperature forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates around zero with a strong diurnal cycle.

2m relative humidity:

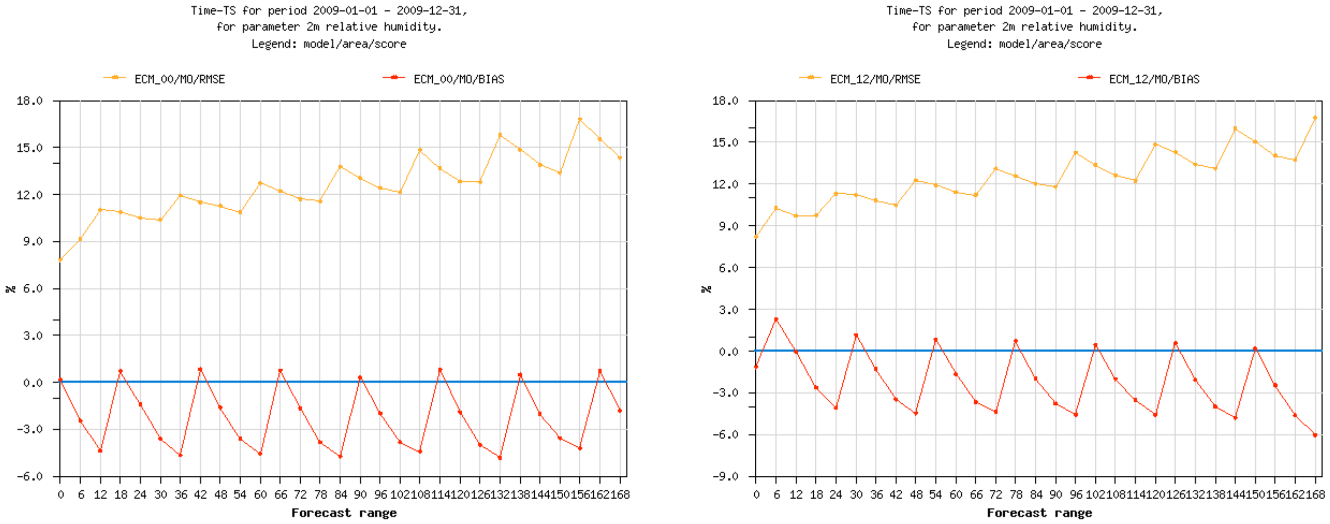

Fig. 2 RMSE and BIAS values for ECMWF 2m relative humidity forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates between –3 and 3% with a strong diurnal cycle.

10m wind speed:

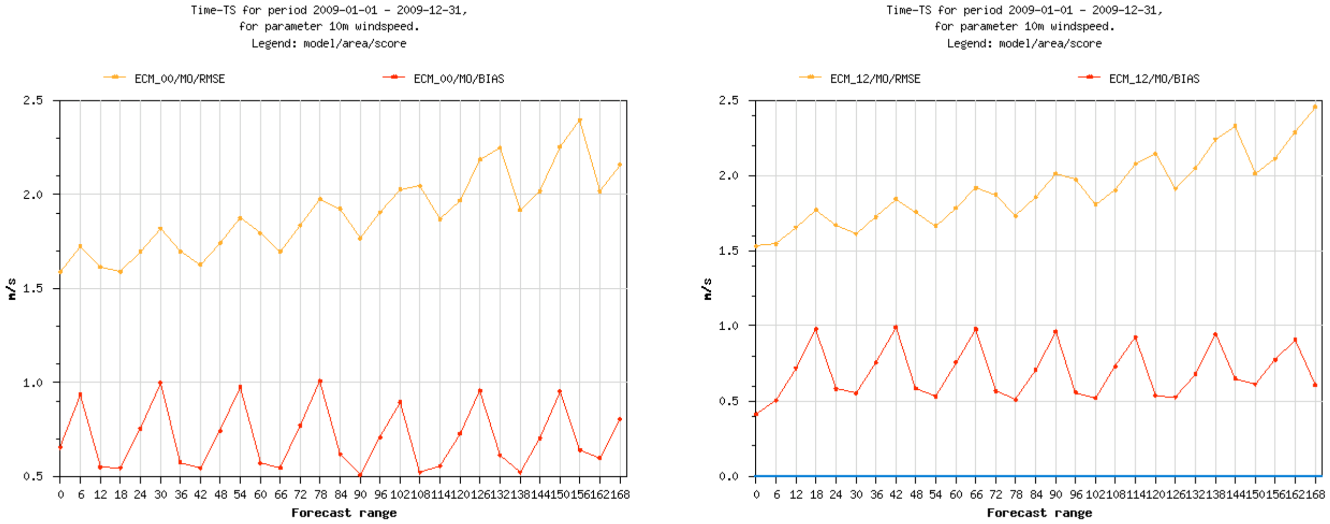

Fig. 3 RMSE and BIAS values for ECMWF 10m wind speed forecasts for Hungary. The RMSE values are rather constant in the first couple days, then there is a slight increase afterwards. The BIAS fluctuates in a diurnal cycle at a range of about 0.3 m/s (first 3 days) and about 0.5m/s (later).

Total cloudiness:

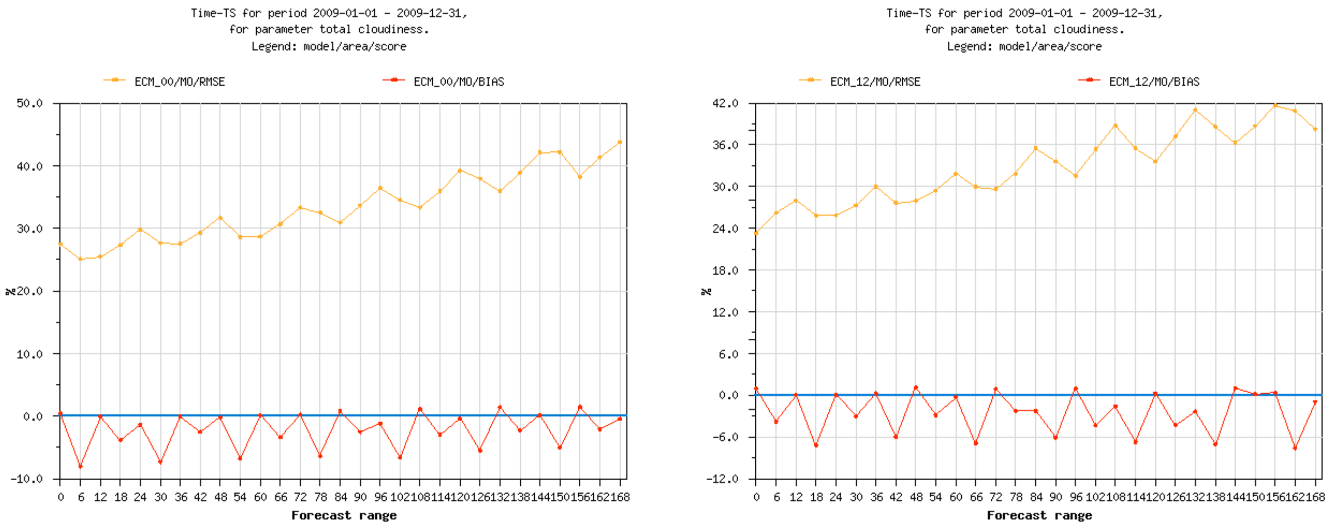

Fig. 4 RMSE and BIAS values for ECMWF total cloudiness forecasts for Hungary. There is a cloudiness underestimation at all ranges (around –5 and –10 percent). The RMSE values are strongly increasing along the forecast ranges.

Daily accumulated amount of precipitation:

Verification software was migrated to another platform, so this kind of information has not yet been available for 2009

3.1.2 ECMWF model output compared to other NWP models used by the HMS

Hereafter the ECMWF and ALADIN/HU models will be compared in the first 48 forecast ranges with the help of OVISYS. The forecast values from ECMWF are taken from a 0.5°x0.5°, while for the ALADIN model from a 0.1° x 0.1° post-processing grid (the original mesh size of the ALADIN model is 8km on Lambert projection). The scores are computed against SYNOP observation for the Hungarian territory for the year of 2009 (Fig. 6–9). ALADIN/HU model showed better verification scores for 2m temperature and 2m relative humidity in 2009 than in 2008 it can be partly connected to use ECMWF boundary conditions (Fig. 6–7). We can compare the results from '*Application and verification of ECMWF products, 2009*'.

2m temperature:

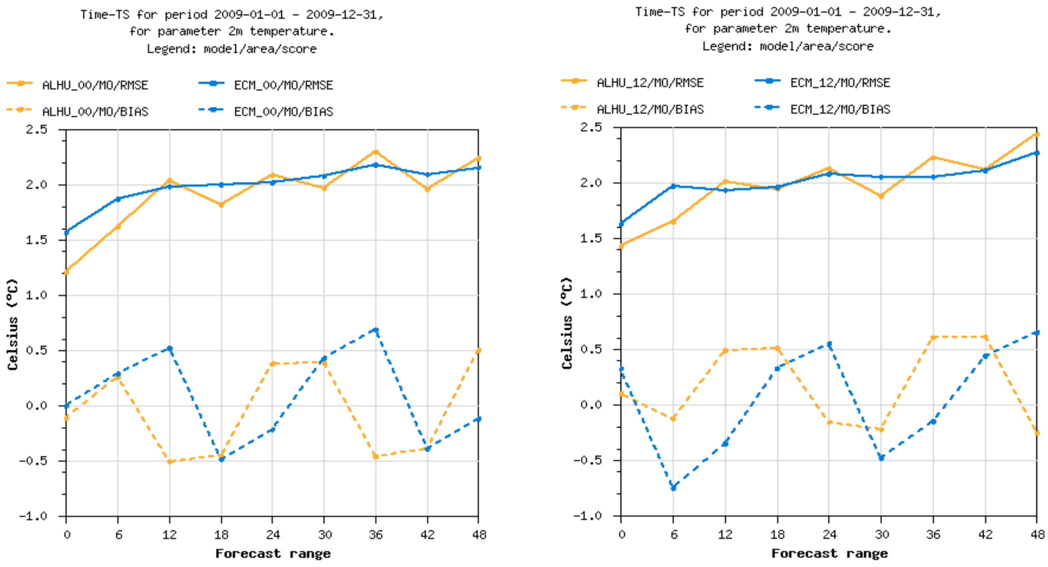

Fig. 5 Comparison of BIAS and RMSE values for ECMWF (blue) and ALADIN (orange) 2m temperature forecasts over Hungary.

2m relative humidity:

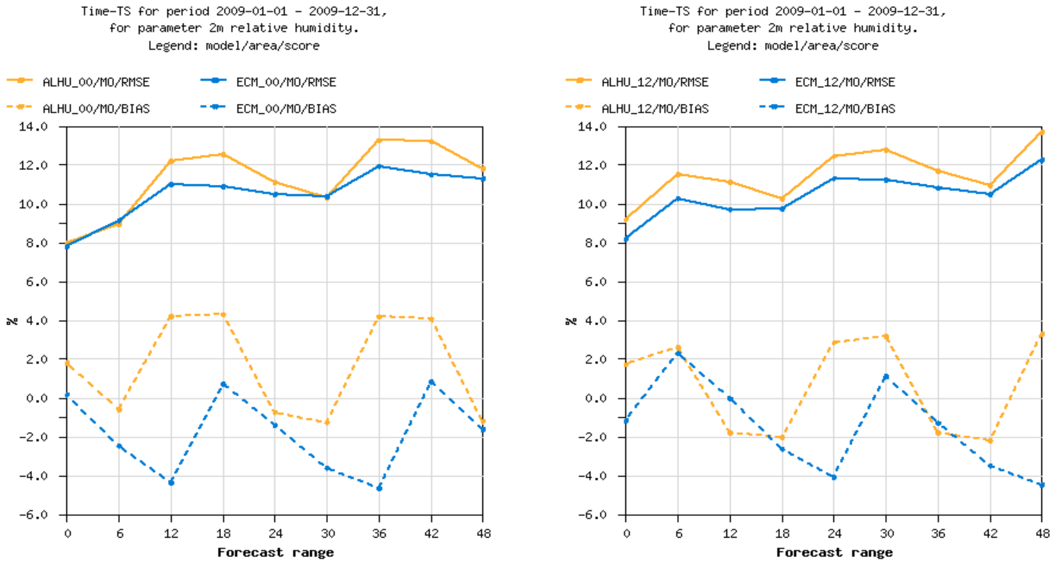

Fig. 6 Comparison of BIAS and RMSE values for ECMWF (blue) and ALADIN (orange) 2m relative humidity forecasts over Hungary.

10m wind speed:

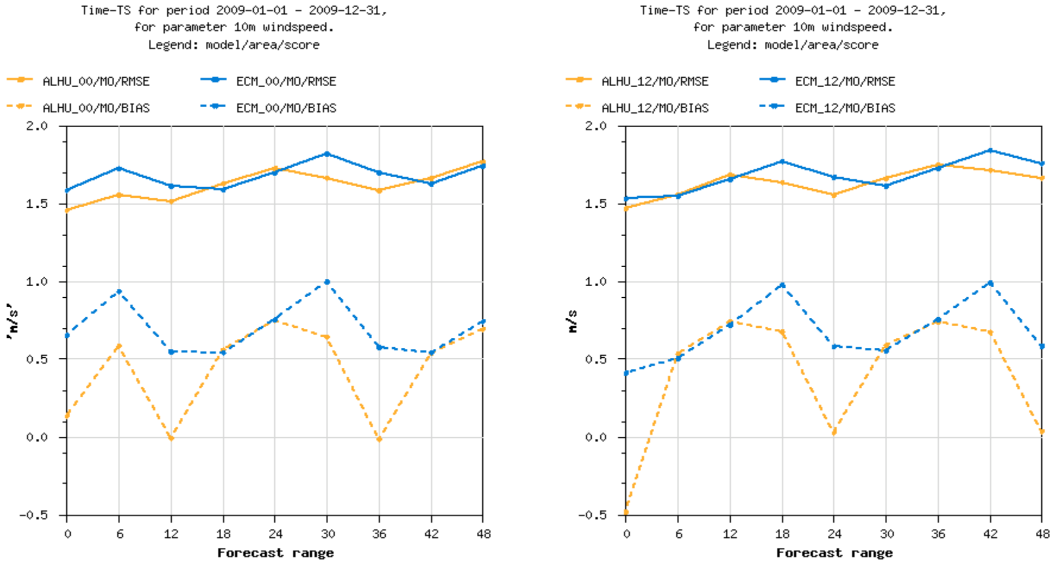

Fig. 7 Comparison of BIAS and RMSE values for ECMWF (blue) and ALADIN (orange) wind speed forecasts over Hungary. In RMSE there is no significant difference between the two model forecasts, in BIAS ALADIN is better than ECMWF.

Total cloudiness:

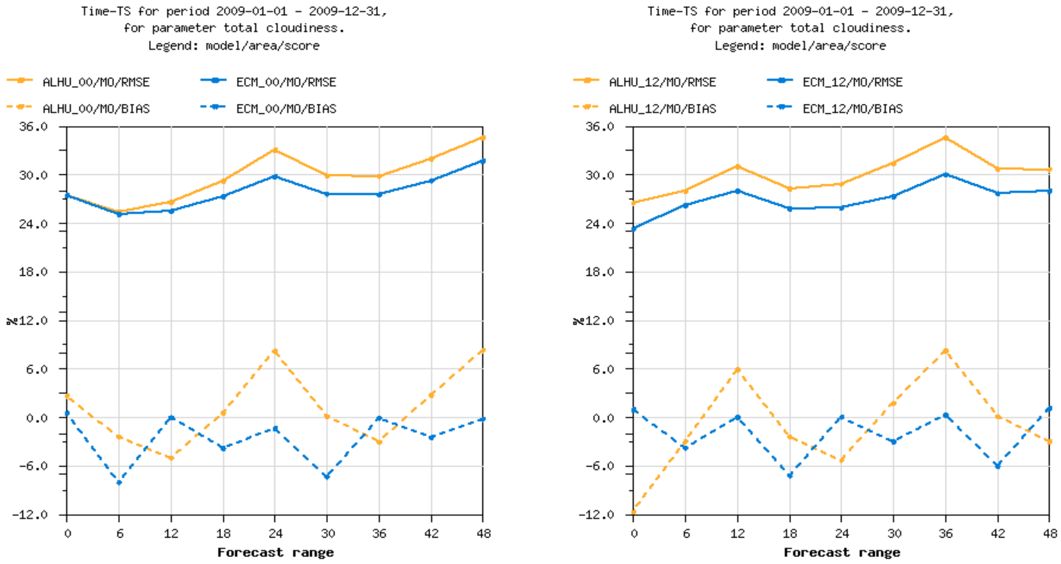

Fig. 8 Comparison of BIAS and RMSE values for ECMWF (blue) and ALADIN (orange) total cloudiness forecasts over Hungary. RMSE values of the ECMWF forecasts are smaller than that of the ALADIN ones during all time ranges. There is a systematic underestimation in the ECMWF forecasts.

3.1.3 Post processed products

Post processed products are regularly verified in OVISYS. Verification software was migrated to another platform, so regular verification scores and figures have not yet been available for 2009.

After having encouraging verification results concerning the ensemble calibration at the selected synoptical stations it was considered to extend calibration for 0.5 by 0.5 degrees grid belonging to EPS model resolution valid in 2009. Synoptical stations and the grid covering the territory of Hungary can be seen on *Fig. 9*. The area of the country is 93 030 km^2 , it is covered by approximately 70 grid points, so 70 stations were selected for providing 'observed' climate distributions for all grid points.

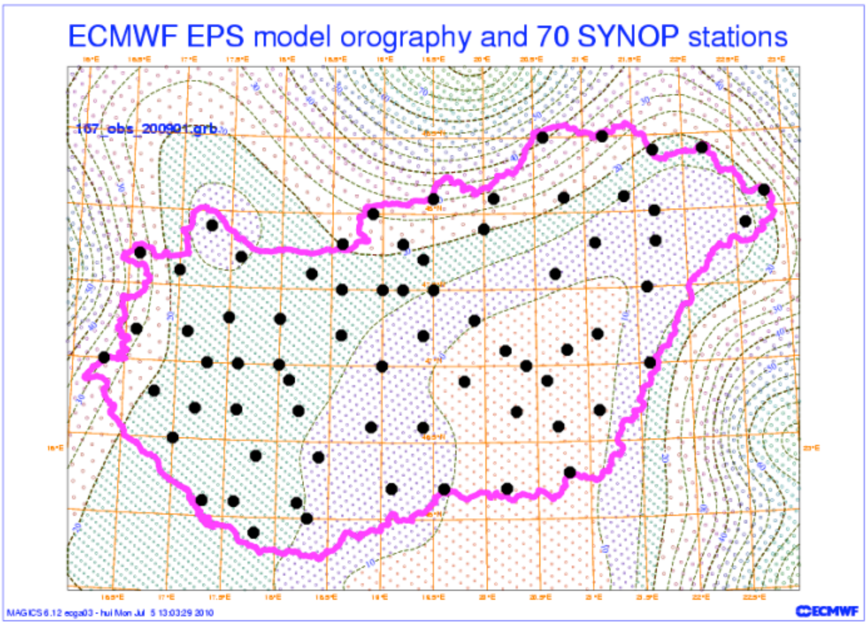

Fig. 9 Ensemble grid and Hungarian synoptical stations user for calibration

For the largest part of the country is flat and in the mountainous regions the density of the observation is not completely enough for providing perfect interpolation for ensemble grid so ‘observed climate’ distribution of each gridpoints is represented by the distribution of the closest observation. The method of the calibration was exactly the same as in case of station based calibration. An important advantage of the grid based calibration is that uncalibrated and calibrated meteorological fields are can easily be visualised and local forecast can be easily derived for end users.

Firstly 2m temperature was chosen and testing the new grid based calibration, because 2m temperature is quite sensitive to the influence of orography (*Németh*, 2010). Verification of calibration was made for all 2009. Calculation of the monthly mean of raw and calibrated ensemble forecasts in addition to observed values was made for each months of 2009. Maps belonging to each months showed that calibration forecasts are definitely closer to the reality, especially in the mountainous regions (*Fig. 10*).

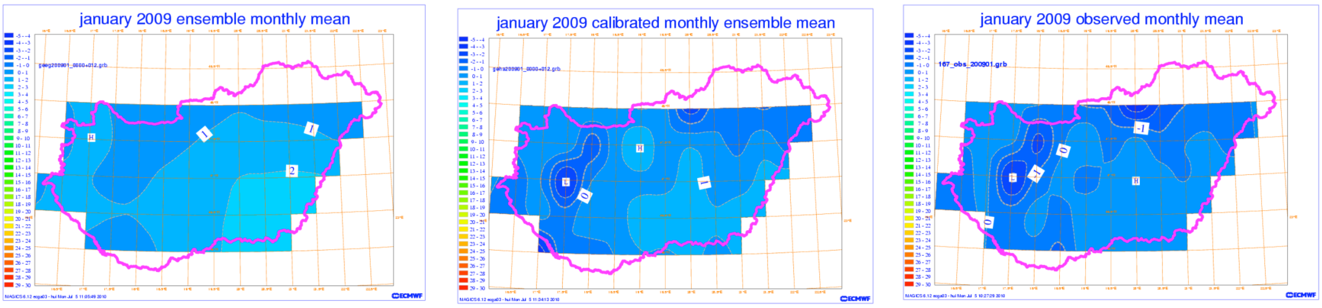

Fig. 10 Monthly mean chart of raw, calibrated and observed values in January 2009.

Mean error and root mean square error maps were also made between raw and observed values beside calibrated and observed values. Finally outlier maps as a not so widely used verification technique were used. It clearly showed the regions where under or overestimation appeared (*Fig. 11*).

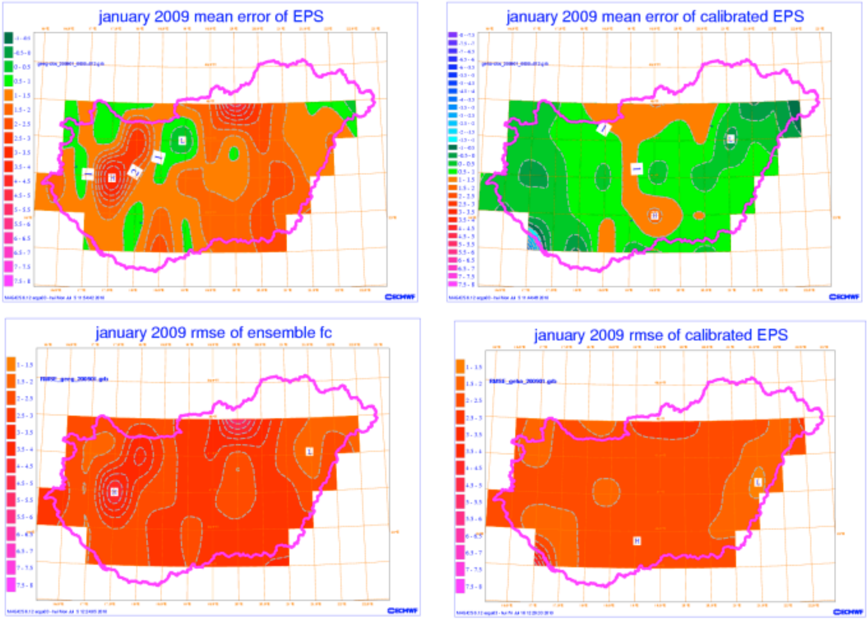

Fig. 11 Mean error /upper raw/ and root mean square error /lower raw/ of raw /left column/ and calibrated /right column/ forecast in January 2009.

It was found the ensemble spread was not enough at lower time steps but after about 3 day lead time was good but on at all time steps examined between +12 and +180 hours critical mountainous regions show systematic overestimation of the raw forecast and overestimation could be eliminated well by calibration (*Fig. 12*). As it was found ensemble calibration could especially improve the forecast in mountainous region, so a grid point was chosen in the area in Bakony hill in the Transdanubian region. It can clearly be seen that calibration successfully eliminates the systematic error (*Fig. 13*) Grid based calibration has been operationally running since October 2009.

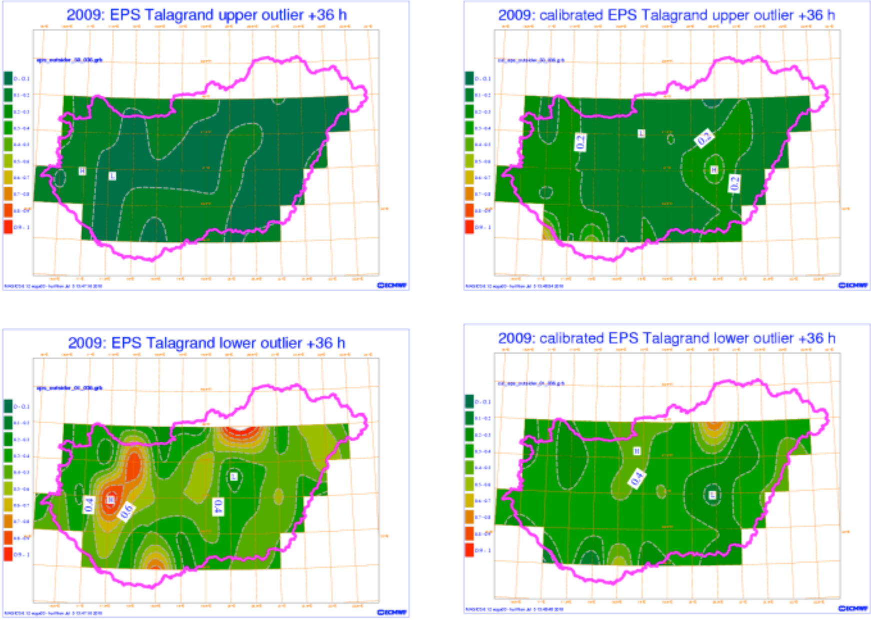

Fig. 12 Talagrand outlier maps at timestep +36 h for all 2009. Upper raw shows the upper outliers and lower raw belongs to lower outlier

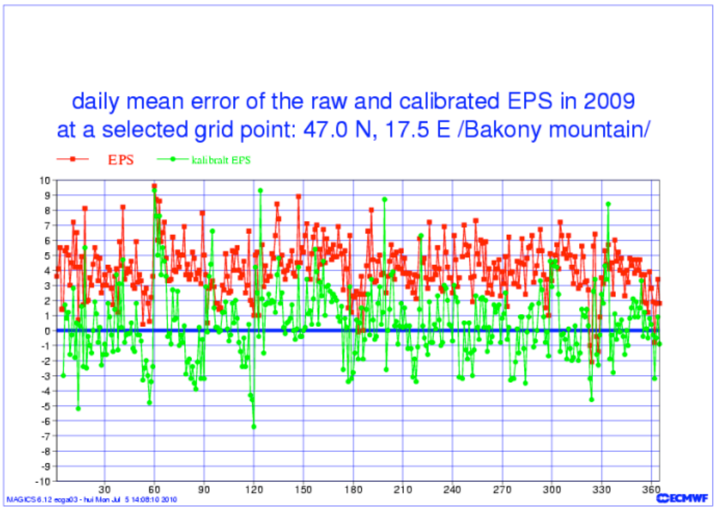

Fig. 13 Time series of forecasted 12 UTC temperature based on raw (red) and calibrated (green) temperature at a selected mountainous grid point (N47.0, E17.5)

3.1.4 End products delivered to users

In case of minimum and maximum temperature, total cloud cover as well as wind gust, the forecaster was able to improve on the model forecasts on average for all forecast ranges. For precipitation occurrence, there is no significant difference in skill between automated forecast products and those prepared by the forecasters. In case of the average wind speed, forecasts generated automatically from ALADIN proved to be the best on average for short-range, while operational forecasters were able to improve on ECMWF forecasts in each period, except on day 1 (*Fig 14*).

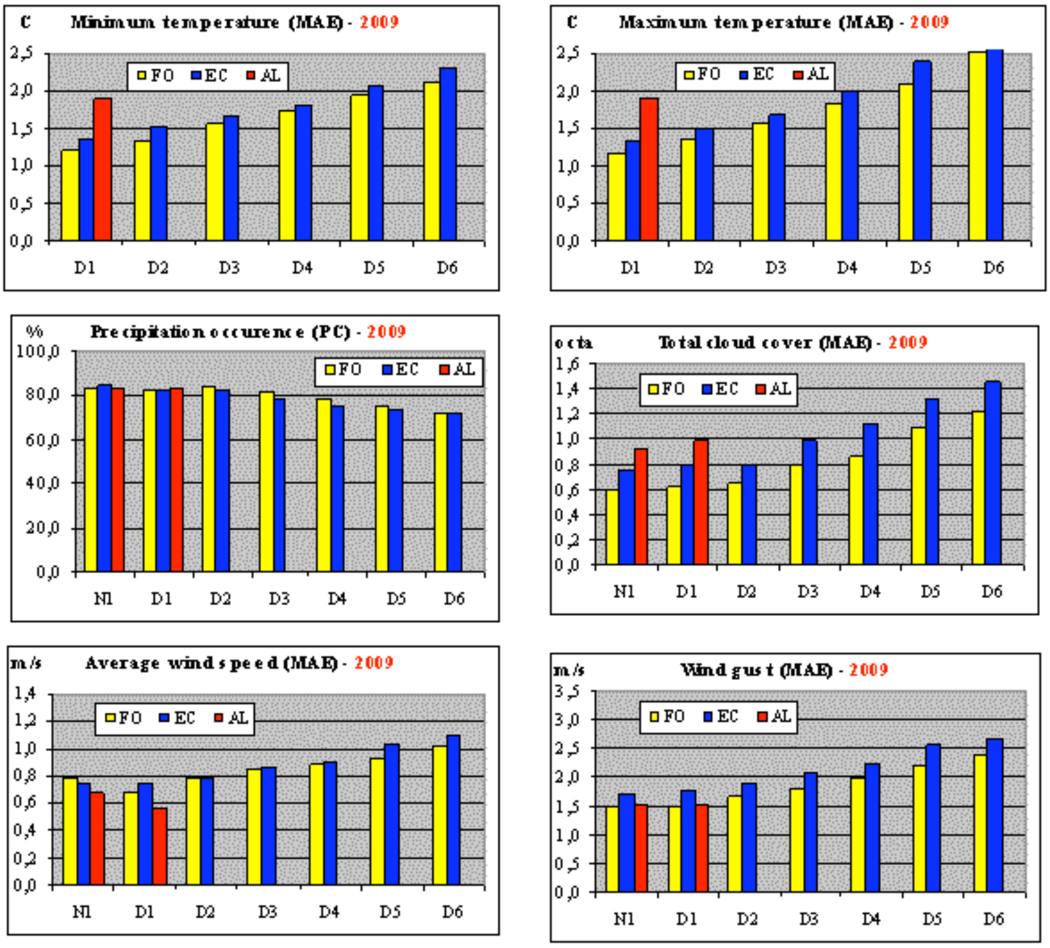

Fig. 14 Mean Absolute Error (MAE) of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation occurrence forecasts for different forecast ranges (D0 stands for the first night where relevant) in case of ALADIN (AL) [red], ECMWF (EC) [blue] and the Operational Forecaster (Fo) [yellow] for 2009.

Positive values indicate higher overall skill for the Forecaster. The daily improvement of the Forecaster on ECMWF has usually remained under 5 – 10% except for early January, when a strong winter inversion situation developed in Central-Europe with overcast sky due to low clouds. The models usually have problems to handle these situations. In 2009 this inversion situation occurred in January and lasted for a few days. Forecasters were able to improve on the ECMWF model by up to 10 % as it is shown in *Fig. 15*.

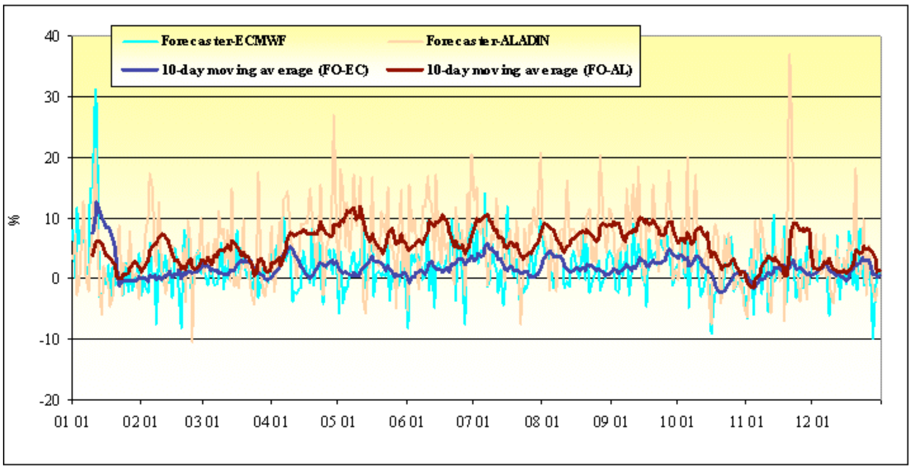

Fig. 15 Difference of the daily Complex Score for the first day calculated for the Forecaster and the models in 2009 (difference between the Forecaster and ALADIN [red] as well as the Forecaster and ECMWF [blue]). 10-day moving averages are also shown.

3.1.5 Seasonal forecasts

At the HMS a statistical technique for long-range forecasting was developed and forecasts based on this method had been issued for more than 20 years. Beside the operational statistical method, in 1998 investigation of the applicability of ECMWF's long-range forecasting system System1 for Hungary was started. In March 2003 the seasonal forecasts based on the ECMWF's System2 became operational in the HMS. Since May 2007 the operational forecasts are based on System3. Forecasts for the 2 metre, maximum and minimum temperature and the amount of precipitation, for six regions of Hungary are issued in every month.

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On Fig 16 the mean absolute error skill score of the country wide average of the above mentioned parameters is shown for the six forecasted months of the seasonal forecasts. The 12 forecasts issued in 2009 were divided into single months, the one's with the same lead time were accumulated and the verification was performed on these datasets to see how the forecasts develop in time. It can be seen that the System3 forecasts were outperformed by the climate of the 1971-2000 period which was used as reference forecast while computing the mean absolute error skill score. More detailed analysis of the results shows that the reason of this performance were mainly the autumn and winter months when the forecasts predicted higher than average monthly mean temperatures while the observations were either around the climate values or lower than those with the exception of November when the forecasted higher monthly mean temperature was observed. On the other hand the exceptionally warm temperature of April was not predicted appropriately while the forecast for June suggested significantly higher temperature than the climate but the observation showed a bit lower monthly mean temperature than the climate.

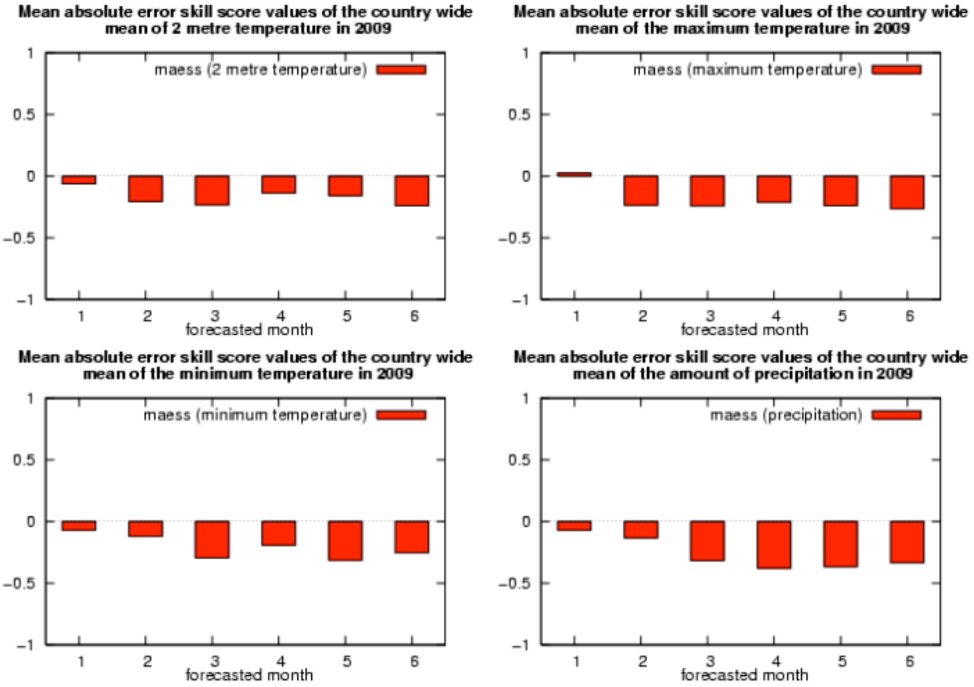

Fig. 16 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2009. Reference forecast was the 30-year climatological mean.

This year we introduced a new type, real time verification of the monthly mean temperature to give more feedback for the forecasters about the behaviour of the System 3 forecasts in the previous months. Fig. 17a shows the predicted ensemble mean for the country wide monthly average temperature (blue line) the observed values (red line) and the climate of the 1971-2000 period (black line) as well starting from the previous for months while Fig. 17b shows the same parameters starting from five, six and seven months before the actual month. Used this way forecasters can see how the prediction of System 3 changed depending of the starting date and how it performed in the previous months.

3.1.6 Monthly forecasts

Monthly forecasts have been operationally used at the HMS since the beginning of its experimental run, March 2002. Once a week ensemble means for weekly mean, minimum and maximum 2m temperature and accumulated precipitation amounts are calculated. The verification has been realized for 6 regions of Hungary and also for the entire country. The calculated statistics are the daily mean error (ME), mean absolute error (MAE) and root mean square error (RMSE) (*Fig. 18*). Weekly Skill Scores based on the mean absolute error are also calculated. In that case the reference dataset was the climate mean, which was expressed by the measured values averaged between 1961and 1990 (*Fig. 19*).

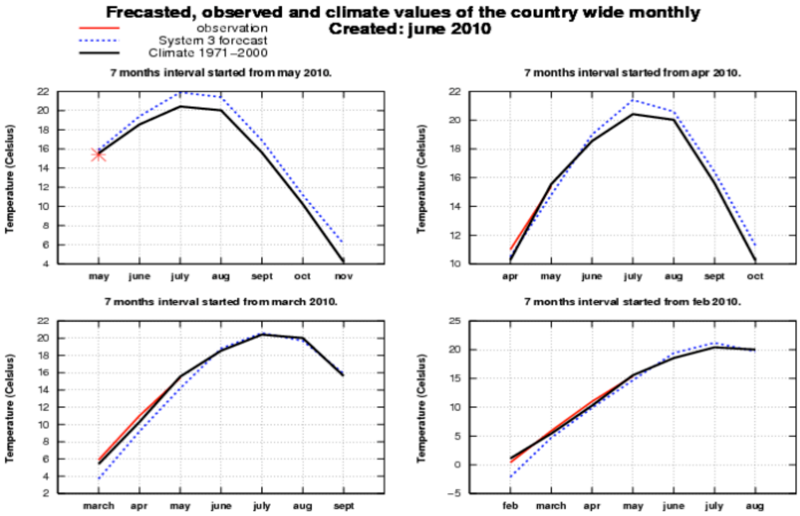

Fig. 17a Comparison of the System 3 forecast with observed and climate values starting from the previous four months. Monthly mean temperature

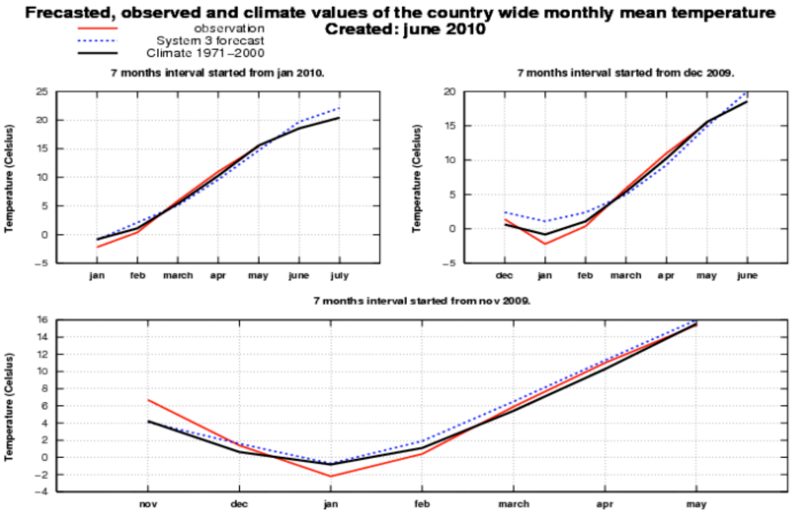

Fig. 17b Comparison of the System 3 forecast with observed and climate values starting from five, six and seven months earlier. Monthly mean temperature

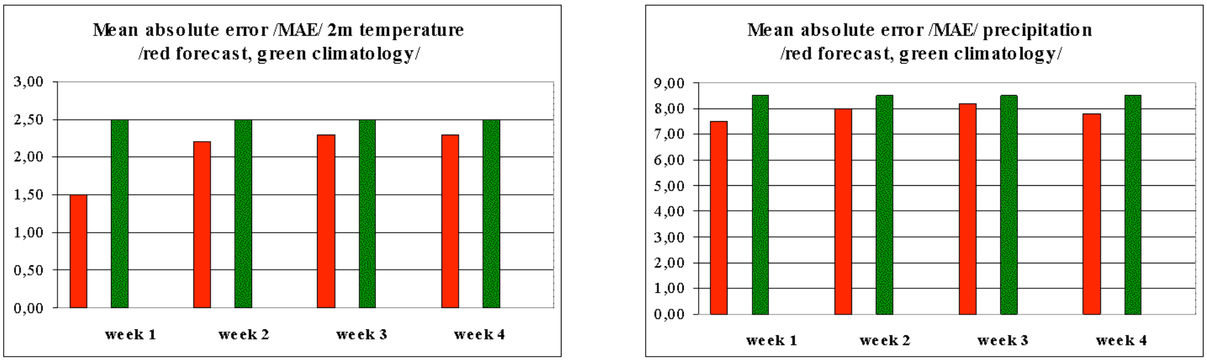

Fig. 18 Mean absolute error of weekly mean 2m temperature and precipitation /red is ECMWF forecast, green is climatology/.

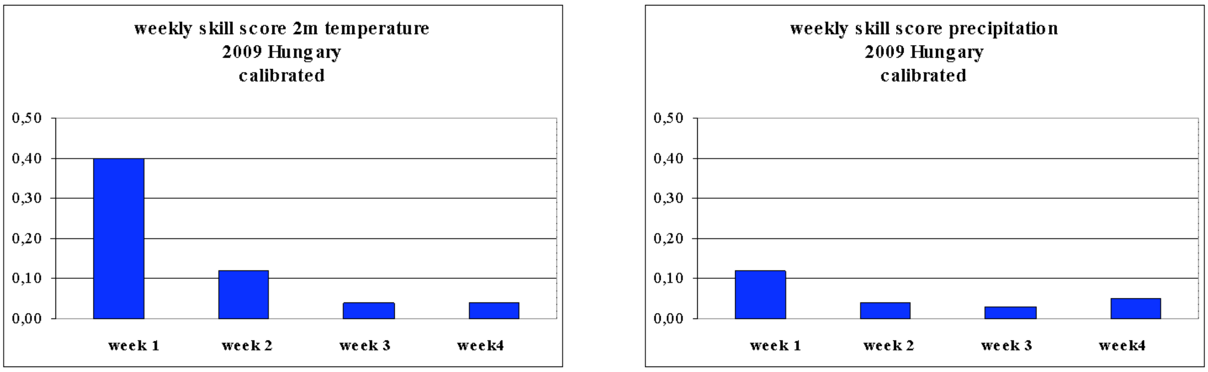

Fig. 19 Weekly Skill Scores based on the mean absolute error for 2m temperature /left/ and precipitation /right/.

3.2 Subjective verification

3.2.1 Subjective scores

none

3.2.2 Synoptic studies

none

4. References

Ihász, I., 2003: Experiments of clustering for central European area especially in extreme weather situations. *Proceedings of the Ninth ECMWF Workshop on Meteorological Operational Systems*, Reading UK, 10-14 November 2003, 112–116

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