Application and verification of ECMWF products 2011

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. Ensemble histograms for predefined categories for precipitation amount, wind speed, minimum and maximum temperature have been operationally made since January 2011. Ensemble vertical profile based on standard pressure levels and 62 ensemble model levels have been operationally made for temperature, dew point, wind speed and wind rose since May 2011. Special ensemble meteogram containing convective available energy, wind shear between 10 meter and 500 hPa and average relative humidity between 850 and 500 hPa have been made since June 2011.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

2.1.2 Physical adaptation

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 non-hydrostatic LAM models. Nowadays AROME and WRF models are used. Both models are set with 2.5 km horizontal resolution and non-parameterized convection. AROME uses ALADIN/HU lateral boundary conditions, WRF uses ECMWF lateral boundary conditions, there are 4 daily model runs (00 06 12 18 UTC).

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

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 [V1]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 is 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). Ensemble vertical profile based on standard pressure levels and 62 ensemble model levels have been operationally made for temperature, dew point, wind speed and wind rose since May 2011 (*Ihász and Tajti*, 2011) (Fig 1 and 2).

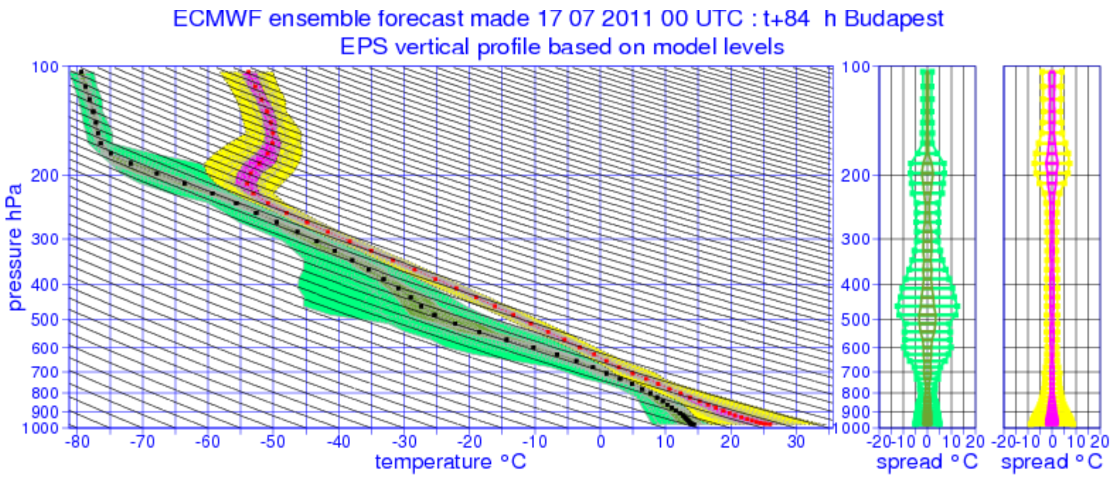

Figure 1 +84 hour forecasted ensemble temperature and dew point based on model levels. Forecast was issued 00 UTC 17 July 2011. Green part shows 0-25 and 75-100%, avocado shows 25-75% probability of dew point. Yellow part shows 0-25 and 75-100%, magenta shows 25-75% probability of temperature.

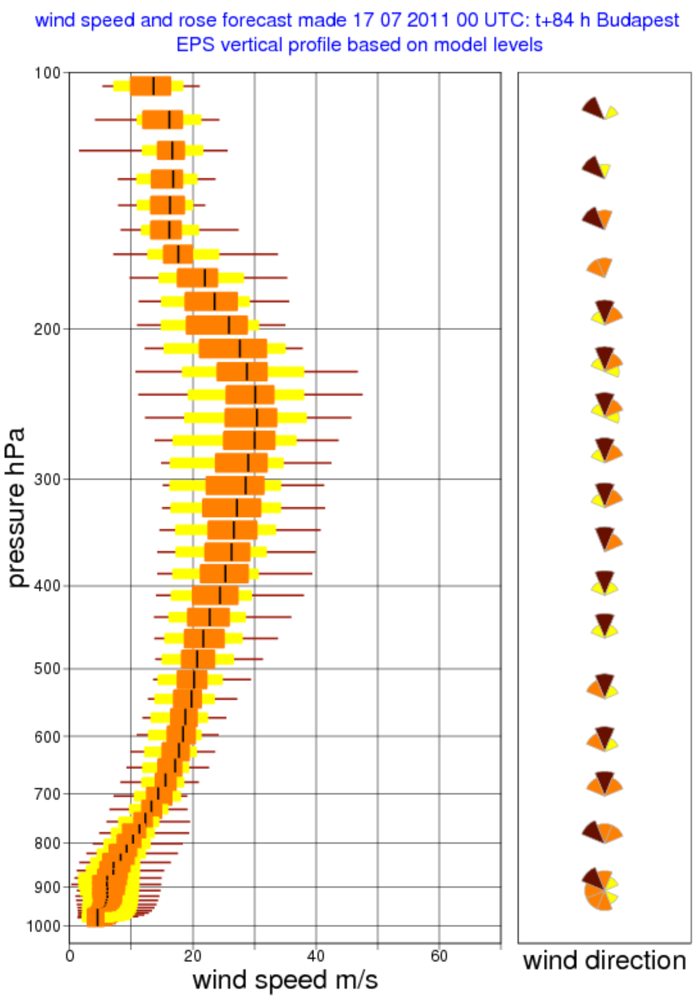

Figure 2 +84 hour forecasted ensemble wind speed and rose based on model levels. Forecast was issued 00 UTC 17 July 2011. On left panel yellow shows 10-25 and 75-90%, orange shows 25-75% probability of wind speed. On right panel yellow shows less than 5 %, orange shows between 5 and 25%, brown shows larger than 25% probability of wind direction in the given section.

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 2010 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 3-7).

2m temperature:

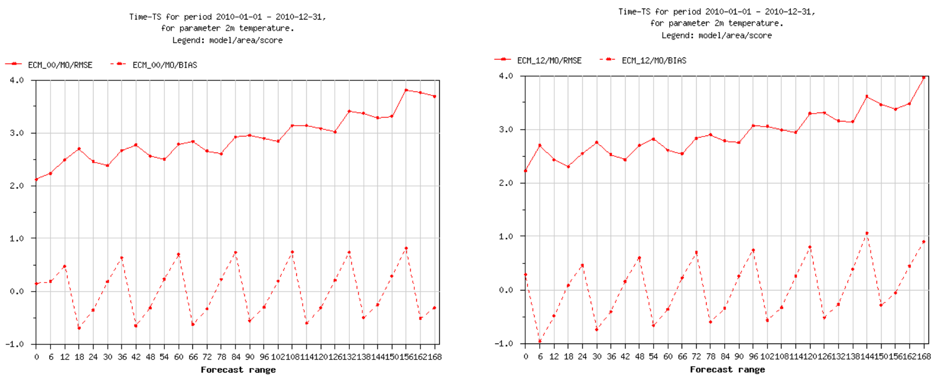

Figure 3 RMSE and BIAS values for ECMWF 2m temperature forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates around zero with a strong diurnal cycle.

2m relative humidity:

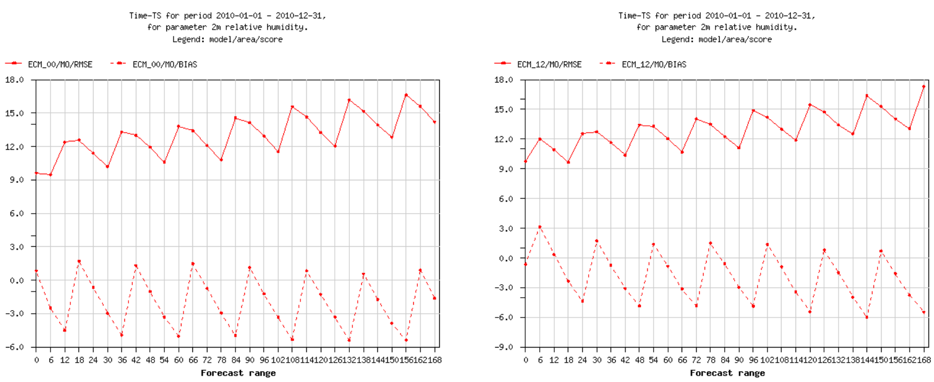

Figure 4 RMSE and BIAS values for ECMWF 2m relative humidity forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates between –3 and 3% with a strong diurnal cycle.

10m wind speed:

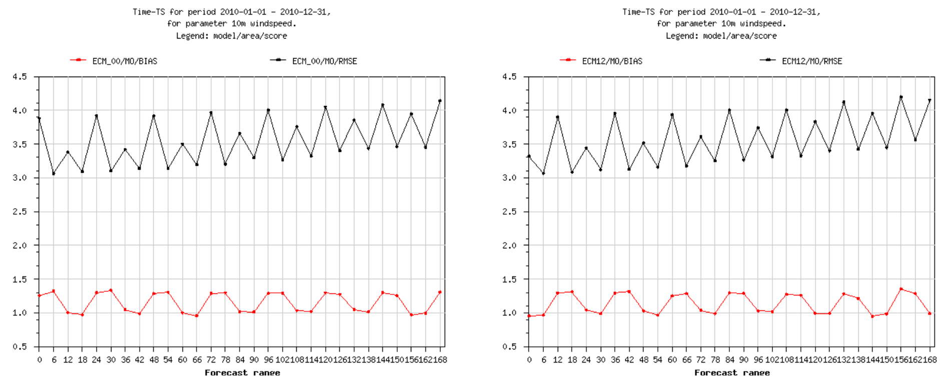

Figure 5 RMSE and BIAS values for ECMWF 10m wind speed forecasts for Hungary. The RMSE values are rather constant in the first couple days, then there is a slight increase afterwards. The BIAS fluctuates in a diurnal cycle at a range of about 0.3 m/s (first 3 days) and about 0.5m/s (later).

Total cloudiness:

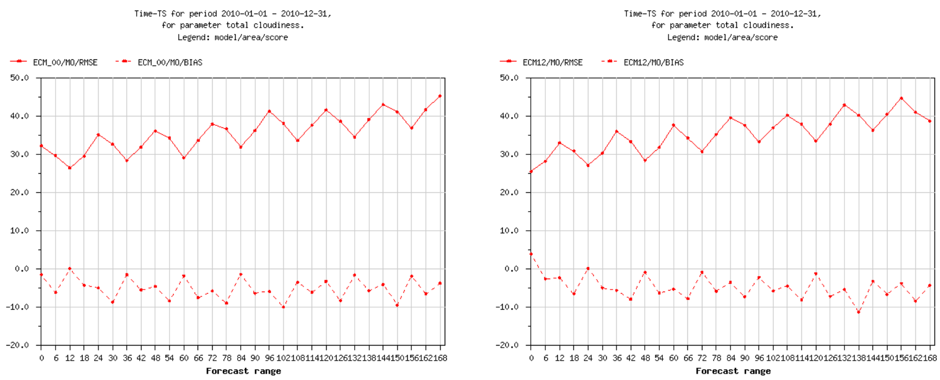

Figure 6 RMSE and BIAS values for ECMWF total cloudiness forecasts for Hungary. There is a cloudiness underestimation at all ranges (around –5 and –10%). The RMSE values are strongly increasing along the forecast ranges.

Daily accumulated amount of precipitation:

Verification software was migrated to another platform, so this kind of information has not yet been available for 2010

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°x0.1° 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 2010 (Fig. 7–10). We can compare the results from '*Application and verification of ECMWF products, 2009 and 2010*'.

2m temperature:

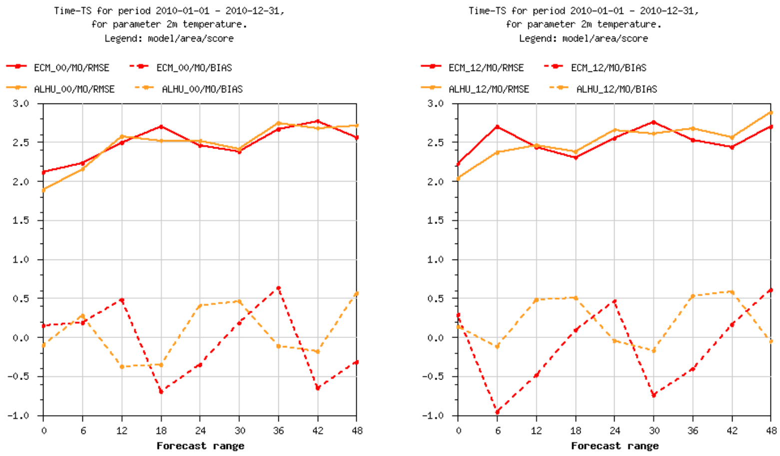

Figure 7 Comparison of BIAS and RMSE values for ECMWF (red) and ALADIN (orange) 2m temperature forecasts over Hungary.

2m relative humidity:

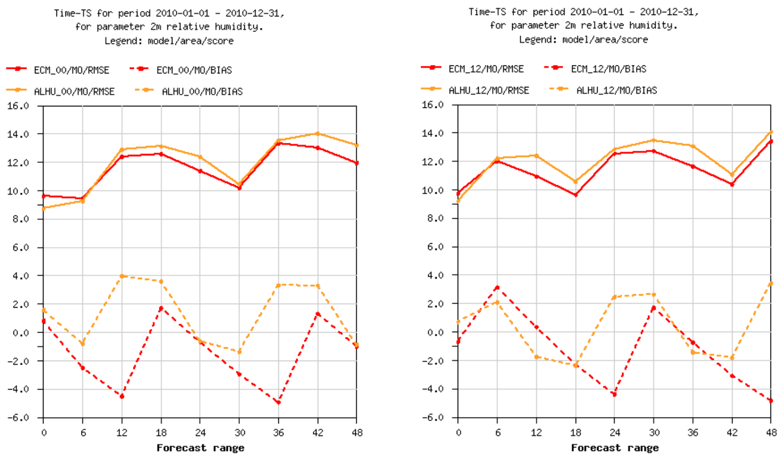

Figure 8 Comparison of BIAS and RMSE values for ECMWF (red) and ALADIN (orange) 2m relative humidity forecasts over Hungary.

10m wind speed:

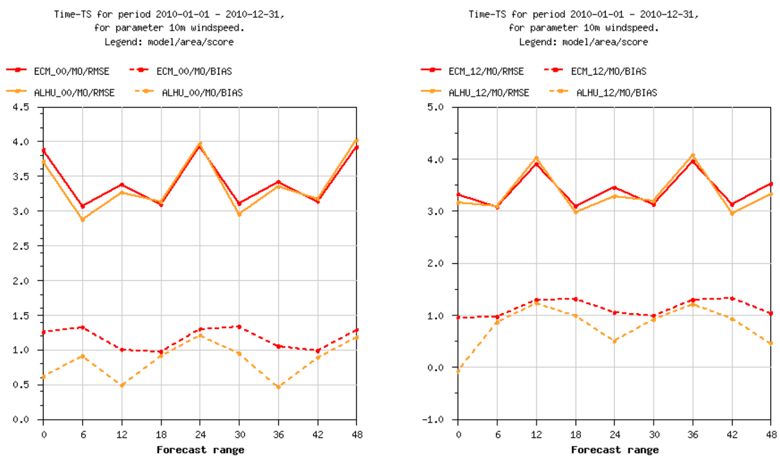

Figure 9 Comparison of BIAS and RMSE values for ECMWF (red) and ALADIN (orange) wind speed forecasts over Hungary. In RMSE there is no significant difference between the two model forecasts, in BIAS ALADIN is better than ECMWF.

Total cloudiness:

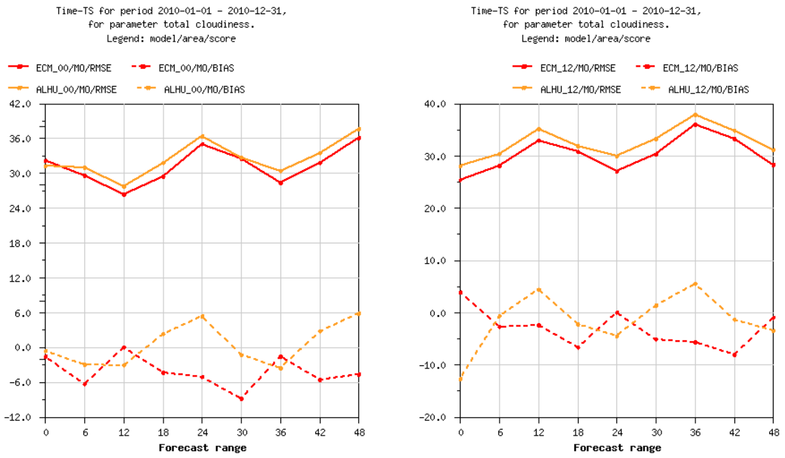

Figure 10 Comparison of BIAS and RMSE values for ECMWF (red) and ALADIN (orange) total cloudiness forecasts over Hungary. RMSE values of the ECMWF forecasts are smaller than that of the ALADIN ones during all time ranges. There is a systematic underestimation in the ECMWF forecasts.

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 20109.

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. The area of the country is 93 030 km2, it is covered by approximately 70 grid points, so 70 stations were selected for providing 'observed' climate distributions for all grid points.

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 easily visualised and local forecasts are easily derived for end users (*Ihász et al.*, 2010).

3.1.4 End products delivered to users

The product of the forecasters issued in the morning is compared with the ECMWF deterministic model and ALADIN running at 00 UTC and the ECMWF EPS mean running on the previous day at 12 UTC. Studying the diagrams on Fig 11 it can be established that the scores of the forecasters are usually better then the results of the deterministic model. On the other hand, EPS mean gives better result in some variables like cloudiness, wind gust. After DAY 4 the reliability of EPS mean exceeds the deterministic model and in some cases it is better then the forecaster. Except at maximum temperature where human practice can improve on the models. ALADIN model developed for short-range is best in forecasting wind gust and mean wind speed.

A complex score is also derived using the scores of each variables. To calculate a difference between the result of the forecaster and of the model we obtain a diagram in Fig 12. Positive values indicate higher overall skill for the forecaster. The 14-day moving average of the improvement of the forecaster on ECMWF has usually remained under 5% except in case of strong winter inversion situation like it was at the end of the year. The models usually have problems to handle these situations. The improvement on ALADIN is approximately 3% higher.

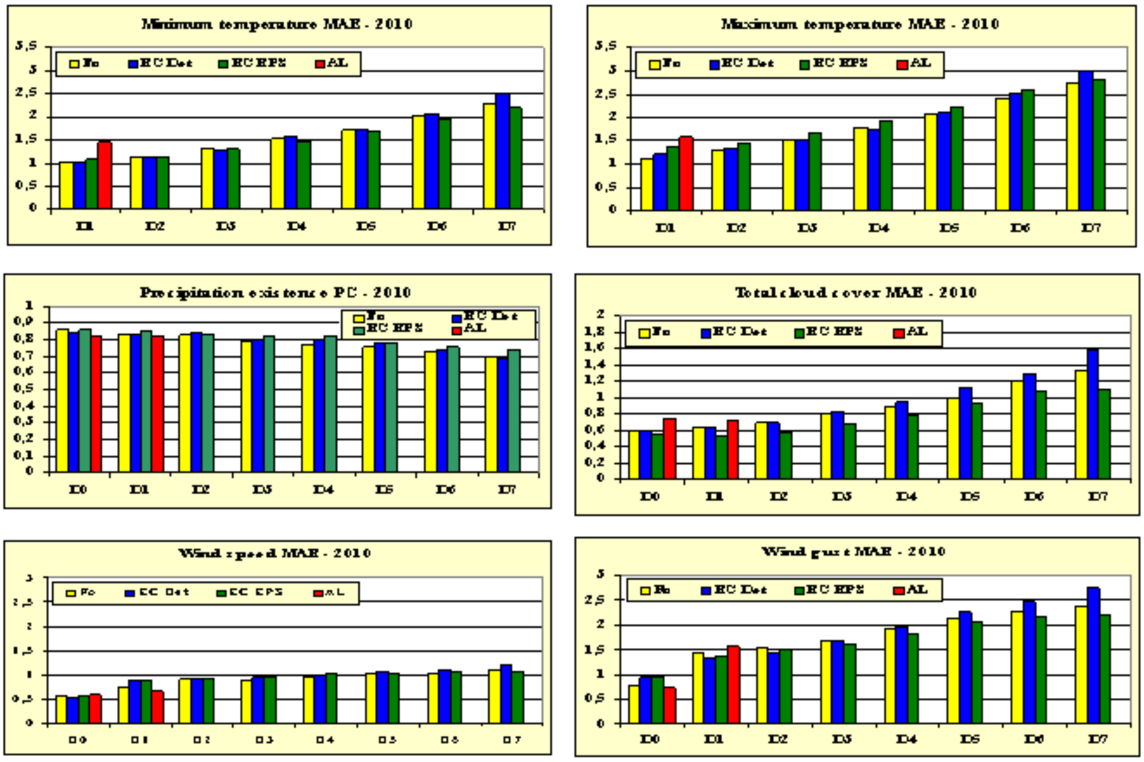

Figure 11 Mean Absolute Error (MAE) of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation occurrence forecasts for different forecast ranges (D0 stands for the first night where relevant) in case of ALADIN (AL), ECMWF Deterministic (EC Det), ECMWF EPS mean (EC EPS) and the Operational Forecaster (Fo) for 2010 D0 represent the first night, D1, D2, … etc the days after the issue of the forecast.

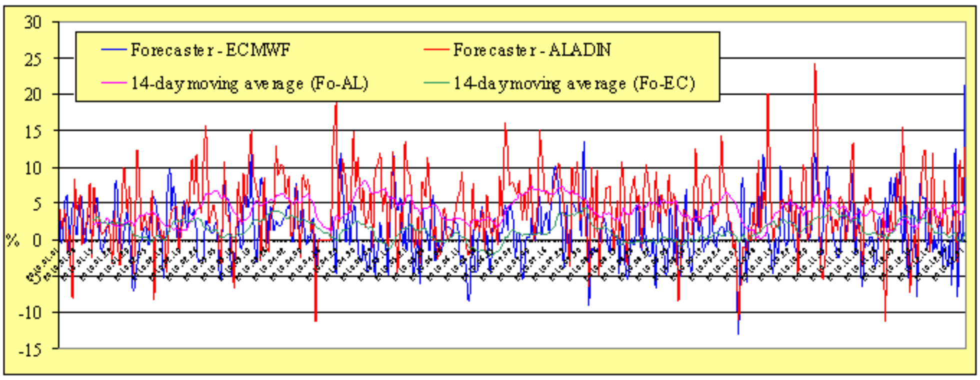

Figure 12 Difference of the daily Complex Score for the first day calculated for the Forecaster and the models in 2010 (difference between the Forecaster and ALADIN as well as the Forecaster and ECMWF). 14 day moving averages are also shown.

3.1.5 Seasonal forecasts

At the Hungarian Meteorological Service (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-meter, maximum and minimum temperature and the amount of precipitation, for six regions of Hungary are issued in every month.

On Fig 13 the mean absolute error skill score of the countrywide average of the above-mentioned parameters is shown for the six forecasted months of the seasonal forecasts. The 12 forecasts issued in 2010 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 generally outperformed by the climate of the 1971–2000 period – which was used as reference forecast while computing the mean absolute error skill score – except for the first month in the case of the maximum and the minimum temperature.

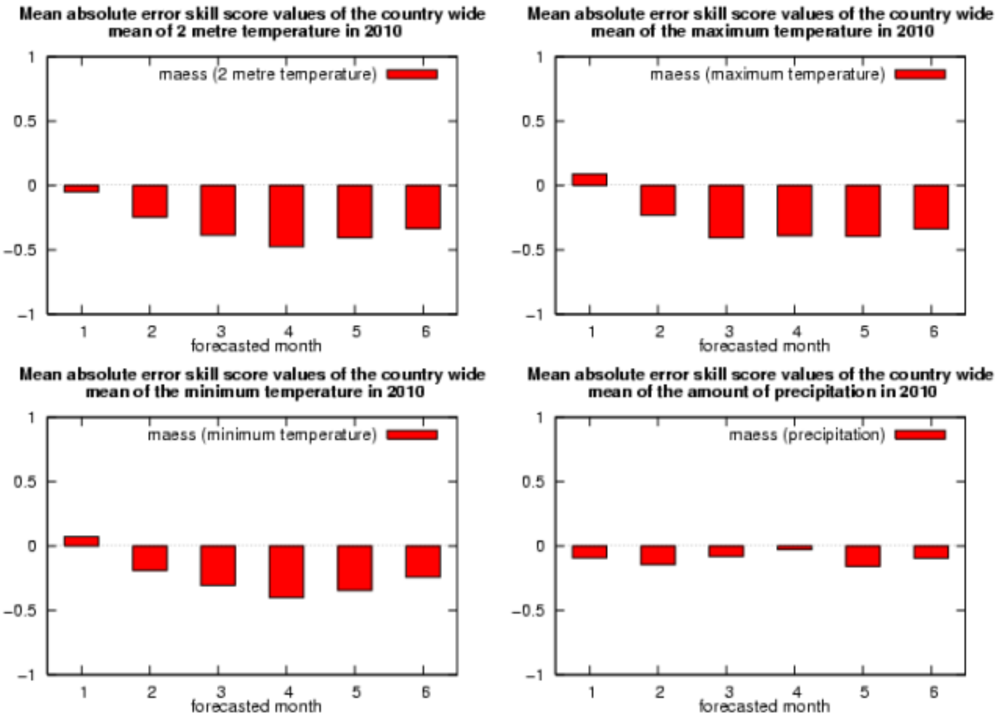

Figure 13 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2010. Reference forecast was the 30-year climatological mean.

The reason for this performance can be examined on Fig 14-15 where we show the comparison of the forecasts issued for the 2010 January-December period with the observations and the climate. In the cases of the temperature parameters January, February, September, October and December of 2010 was forecasted to be more or less warmer than the climate but the observations show lower temperatures than that while March and April was predicted to be cooler than the climate but in reality these months had higher than average temperature. In May and November the direction of the anomaly was correct – negative in May, positive in November – but the scale of these anomalies were overdrew. In the case of the mean and minimum temperature the forecasts for the summer months of 2010 predicted warmer than average temperatures which was successful while in the case of the maximum temperature lower than the climate values were forecasted which was correct in June and August but in July the monthly mean of the maximum temperatures were higher than the average (Fig 15).

In the case of the precipitation we can see negative mass values for all forecasted months. The primary cause of this was the unusually wet period between May and September – especially the three summer months when the forecasts predicted less precipitation than the climate of the 1970–2000 period while observations show more than average precipitation – System 3 could not predict properly (Fig 14). On the other hand for March and October was forecasted to be more wet than the climate while these months were actually drier. In January, February, April, November and December the forecasts generally predicted successfully the higher than average precipitation.

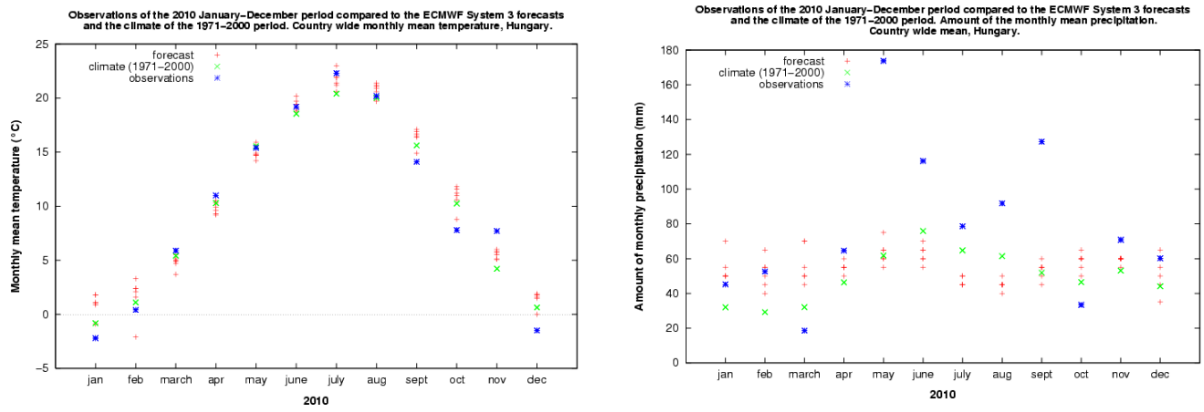

Figure 14 Comparison of the forecasts issued for the 2010 January-December period with the observations and the climate. Monthly mean temperature (left) and monthly amount of precipitation (right).

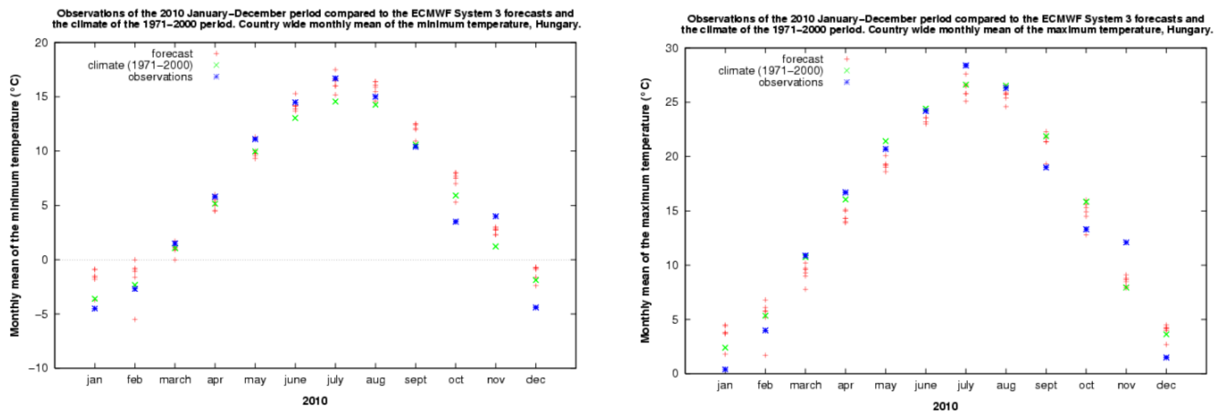

Figure 15 Comparison of the forecasts issued for the 2010 January-December period with the observations and the climate. Monthly mean of the minimum (left) and maximum (right) temperature.

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). 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 1961 and 1990.

In addition to above-mentioned usual verification of monthly forecast a new type of the verification was also developed (*Lázár*, 2011). Ensemble mean and spread calculated for each calendar week (between Monday and Sunday), i.e. day 5-11, 12-18, 19-25 and 26-32 of the monthly forecast was compared to weekly mean calculated from ERA Interim (Fig 16).

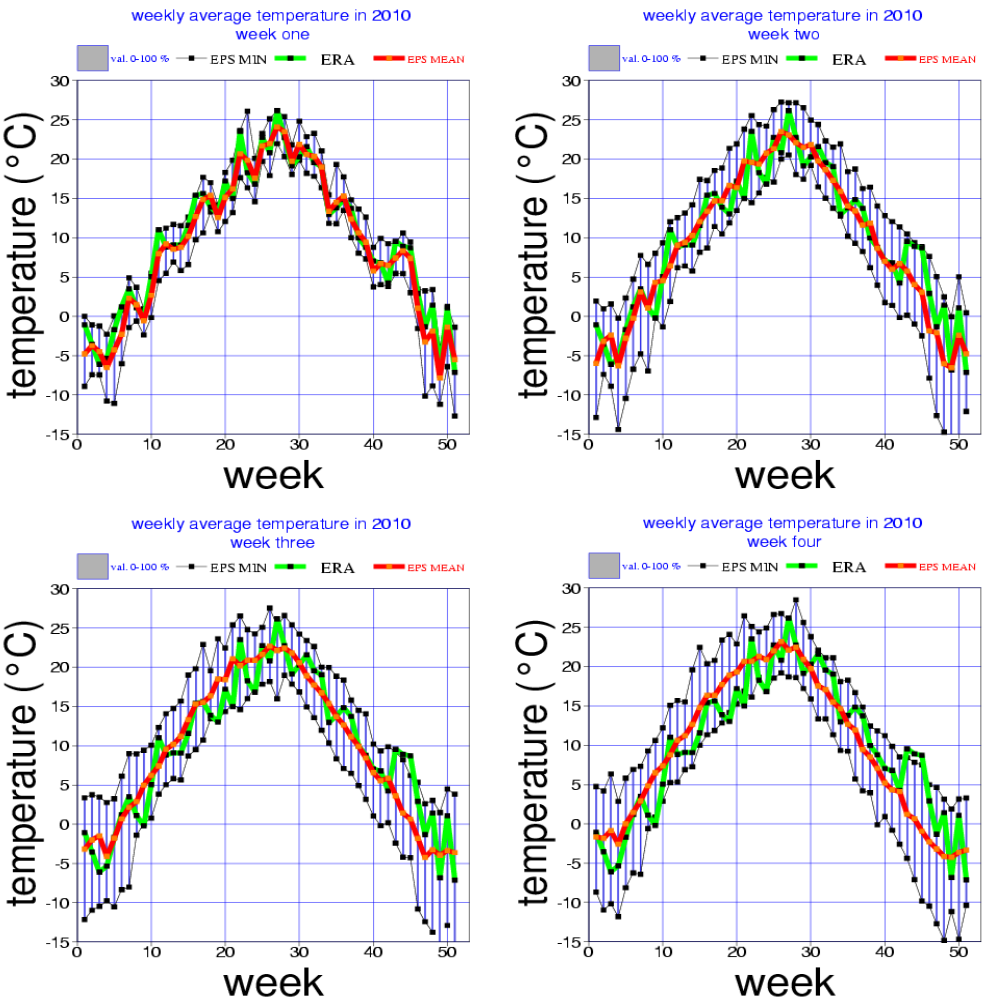

Figure 16 Comparison of the weekly mean of the ensemble forecast and weekly mean of ERA Interim for temperature in Hungary in 2010.

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

Bölöni, G., Kullmann, L. and **Horányi, A.** 2009: Use of ECMWF lateral boundary conditions and surface assimilation for the operational ALADIN model in Hungary. *ECMWF Newsletter,* **119**, 29–35.

Ihász I., Z. Üveges, M. Mile and **Cs. Németh**, 2010: Ensemble calibration of ECMWF's medium range forecasts. *Idöjárás* 114, 275–286.

Ihász, I. and **D. Tajti**, 2011: Use of ECMWF's ensemble vertical profiles at the Hungarian Meteorological Service. *ECMWF Newsletter*, **129**. (accepted for publication)

Lázár, D., 2011: Verification of ten day and monthly ensemble plumes. *BSc Thesis*, Eötvös Loránd University, Budapest, pp 52.

Tajti, D., 2011: Investigation of the ensemble vertical profiles. *Master Thesis*, Eötvös Loránd University, Budapest, pp 53.