Application and verification of ECMWF products 2013

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. 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.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

2.1.2 Physical adaptation

In December 2012 based on the positive experimental results it was considered to use the ECMWF IFS lateral boundary conditions (LBC) for driving the limited area model AROME. The AROME 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 (OMSZ) 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 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).

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 'V*erification 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 2012 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 1-8).

2m temperature:

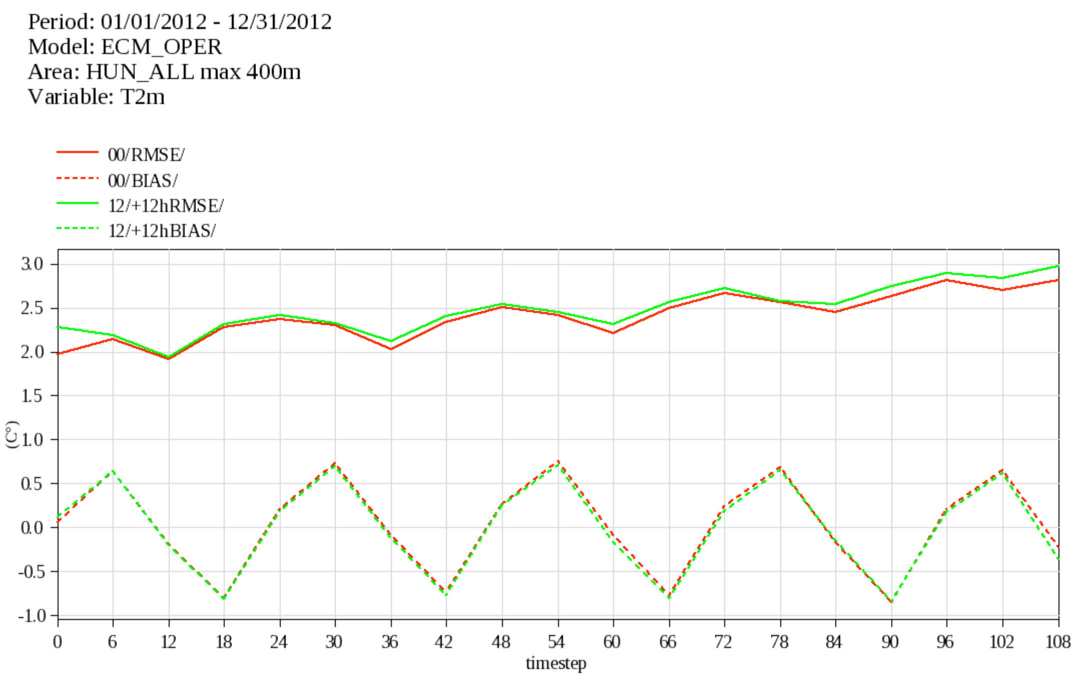

Fig. 1 RMSE and BIAS values for ECMWF 2m temperature forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates around zero with a strong diurnal cycle.

2m relative humidity:

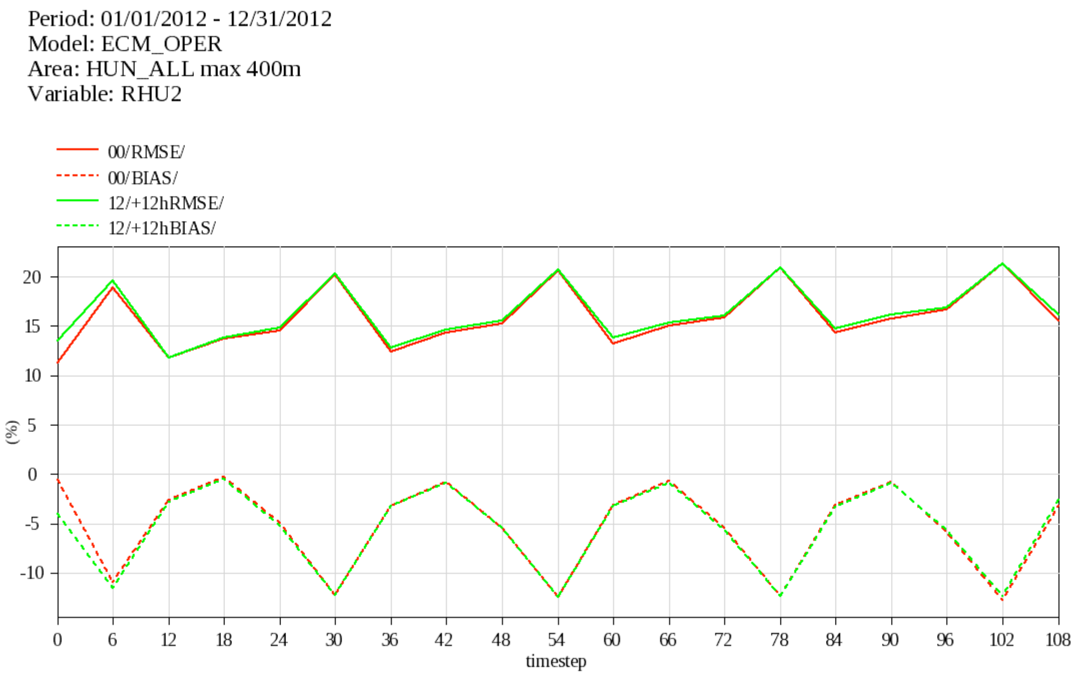

Fig. 2 RMSE and BIAS values for ECMWF 2m relative humidity forecasts for Hungary. The RMSE values are slightly increasing with the forecast range and the BIAS fluctuates with a strong diurnal cycle.

10m wind speed:

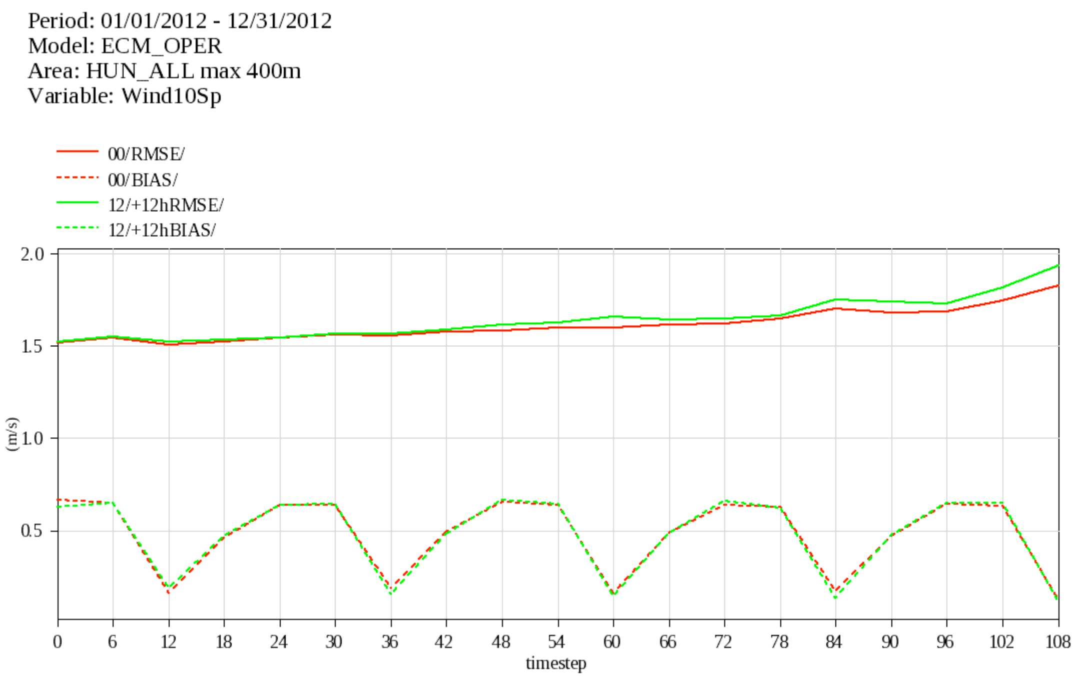

Fig. 3 RMSE and BIAS values for ECMWF 10m wind speed forecasts for Hungary. The RMSE values are rather constant in the first couple days, and then there is a slight increase afterwards. The BIAS fluctuates in a diurnal cycle at a range of about 0.3 m/s (first 3 days) and about 0.5m/s (later).

Total cloudiness:

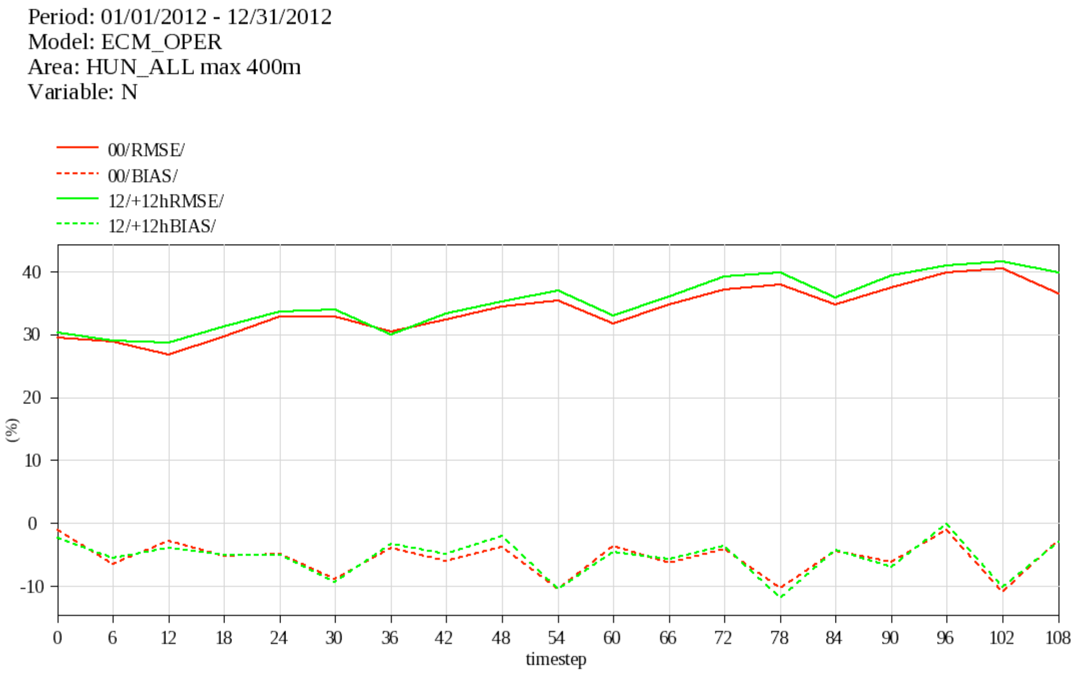

Fig. 4 RMSE and BIAS values for ECMWF total cloudiness forecasts for Hungary. There is a cloudiness underestimation at all ranges (around –5 and –10 percent).

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

Hereafter the ECMWF, ALADIN/HU and AROME models can 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°, from the ALADIN model are taken from a 0.1°x0.1° post-processing grid and from AROME model are taken from 0.025°x0.025° a (the original mesh size of the ALADIN model is 8km and original mesh size of the AROME model is 2.5 km on Lambert projection). The scores are computed against SYNOP observation for the Hungarian territory for the year of 2012 (Fig. 5-8). We can compare the results *for ECMWF and ALADIN/HU models from 'Application and verification of ECMWF products, 2009-2012'* verification for AROME model was not presented in the former years.

2m temperature:

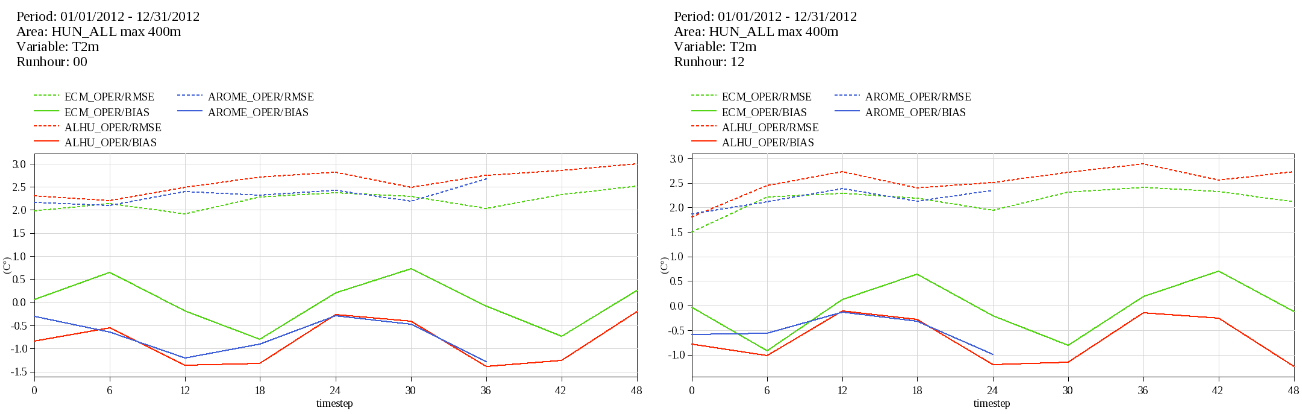

Fig. 5 Comparison of BIAS and RMSE values for ECMWF (green), ALADIN (red) and AROME (blue) 2m temperature forecasts over Hungary.

2m relative humidity:

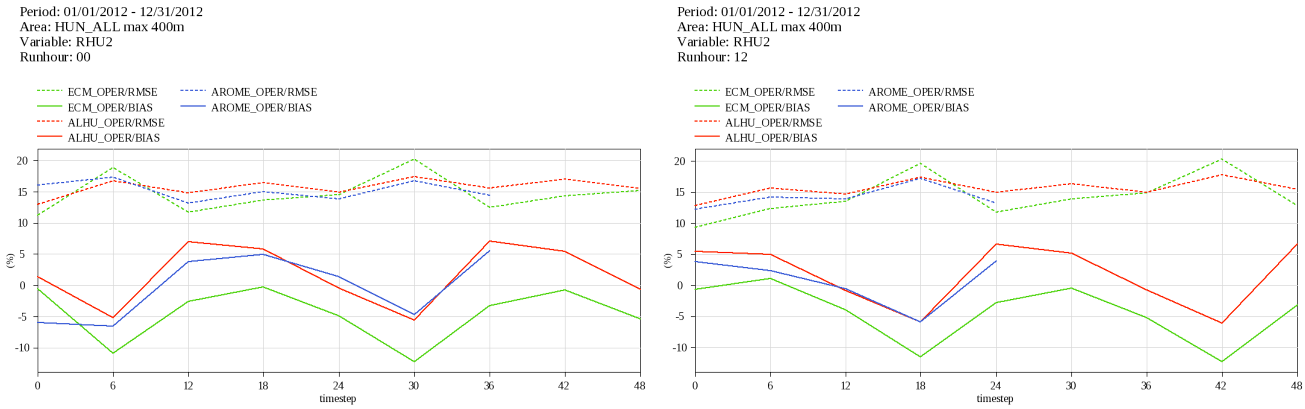

Fig. 6 Comparison of BIAS and RMSE values for ECMWF (green), ALADIN (red) and AROME (blue) 2m relative humidity forecasts over Hungary.

10m wind speed:

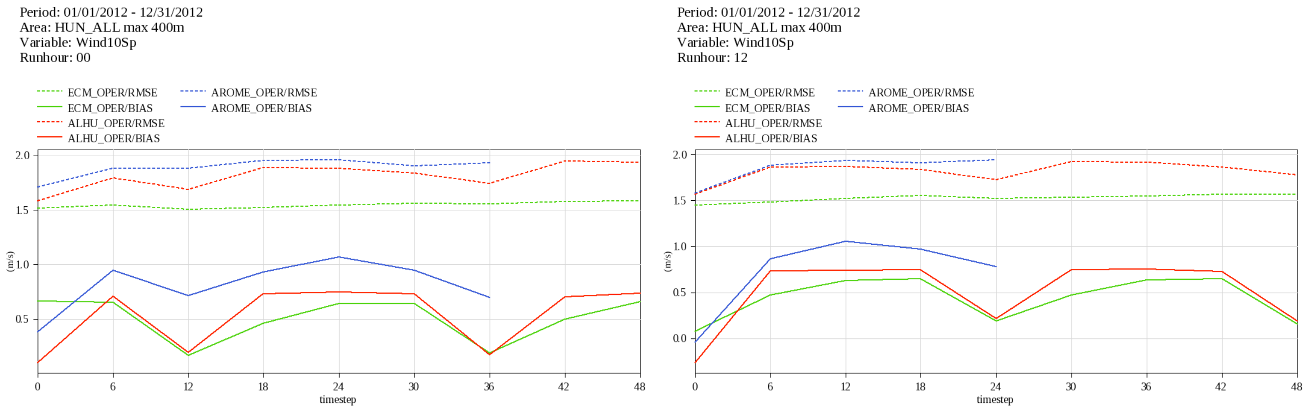

Fig. 7 Comparison of BIAS and RMSE values for ECMWF (green) and ALADIN (red) wind speed forecasts over Hungary. In BIAS there is no significant difference between ALADIN and ECMWF model forecasts, AROME model is the worst in BIAS and RMSE too.

Total cloudiness:

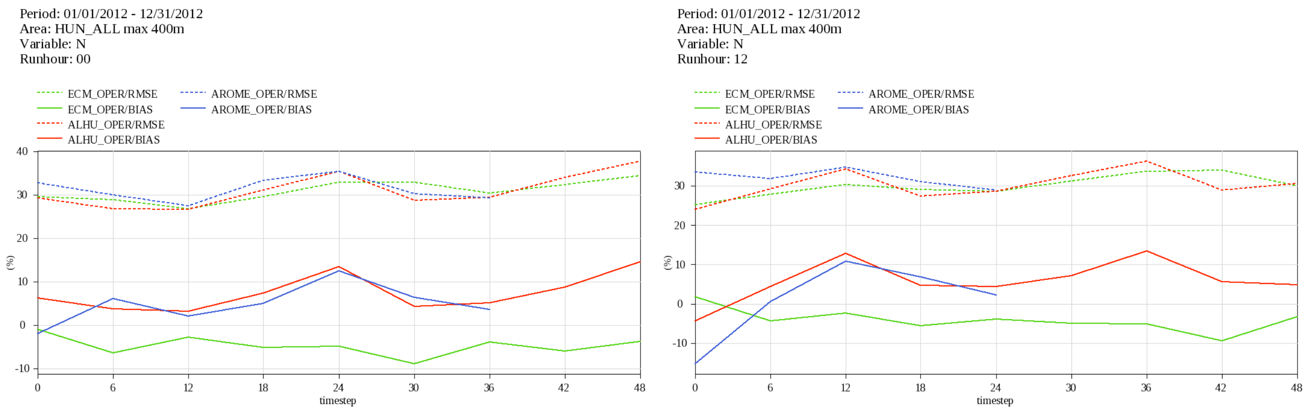

Fig. 8 Comparison of BIAS and RMSE values for ECMWF (green) and ALADIN (red) total cloudiness forecasts over Hungary. There is a systematic overestimation in the ALADIN and AROME forecasts from +6 hours forecast on all time ranges.

Precipitation:

The frequency bias and the SEDI (Symmetric Extremal Dependence Index) have been verified against the precipitation threshold. These verification measures are independent from each other and – among the verification measures of binary events - SEDI has the most desirable properties, as far as the book of I.T. Jolliffe and D.B. Stephenson: Forecast Verification is concerned (Table 3.4). As it is well known, the perfect score of the frequency bias and SEDI is +1. The range of frequency bias is between zero and infinite, and of SEDI is -1 and +1.

In Fig. 9a the frequency bias and in the Fig. 9b the SEDI of four models (ECMWF, WRF, AROME, ALADIN/HU) can be seen for the whole 2012 and for 24h precipitation in the 30th time step and for the Hungarian synop stations under 400m. As far as the bias is concerned, the WRF and the ALADIN/HU show the best result and the AROME has the biggest frequency bias - worst (Fig. 9a). On the other hand, over 6-7 mm/day thresholds, the AROME model gives the best results regarding the SEDI scores. Under 6 mm/day thresholds, - which is the most frequent case - the ECMWF give the biggest (best) SEDI scores. Note, that – because of the independence - the models would show the same results in SEDI after a bias correction.

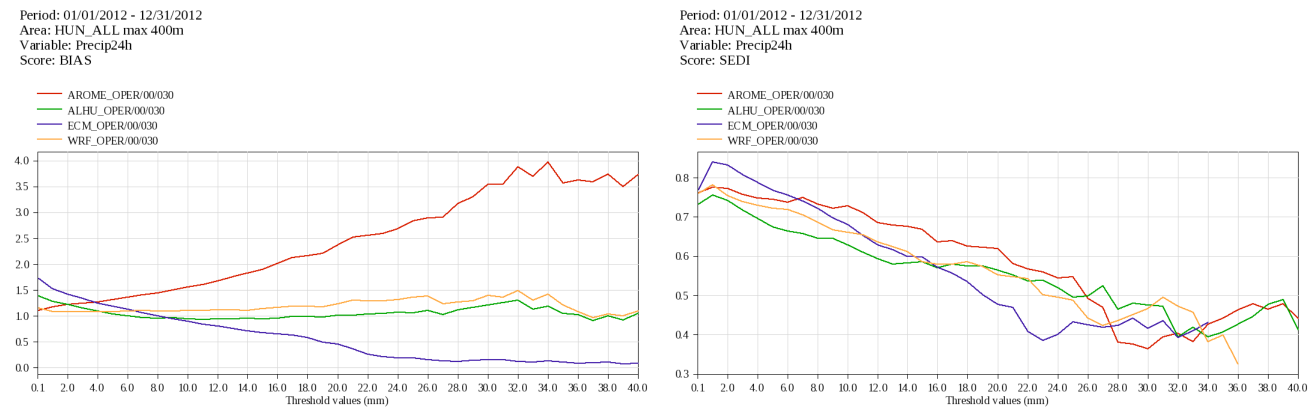

Fig. 9. a) The frequency bias of ECMWF, WRF, AROME, ALADIN/HU for the whole 2012 and for 24h precipitation in the 30th time step, for the Hungarian synop stations under 400m, against the precipitation threshold b) he SEDI (Symmetric Extremal Dependence Index) of ECMWF, WRF, AROME, ALADIN/HU for the whole 2012 and for 24h precipitation in the 30th time step, for the Hungarian synop stations under 400m, against the precipitation threshold

3.1.3 Post processed products

Post-processed products are regularly verified in OVISYS.

After having encouraging verification results concerning the ensemble calibration at the selected synop 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 km^2, 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 the 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, the EPS mean and ALADIN running at 00 UTC. ECMWF EPS mean is available only after 10 local time, so medium-range forecaster is able to use it when predicting day 5, day 6 and day7. Studying the diagrams on Fig 10 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 wind gust and precipitation existence. 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 and minimum temperature where human practice can improve on all the models. ALADIN model developed for short-range is best in forecasting mean wind speed and precipitation.

A complex score is also derived using the scores of each variable. To calculate a difference between the result of the forecaster and of the model we obtain a diagram in Fig 11. 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 %. The improvement on ALADIN is approximately 5-10% and it is a very rarely situation when forecaster cannot improve on this model in complex score.

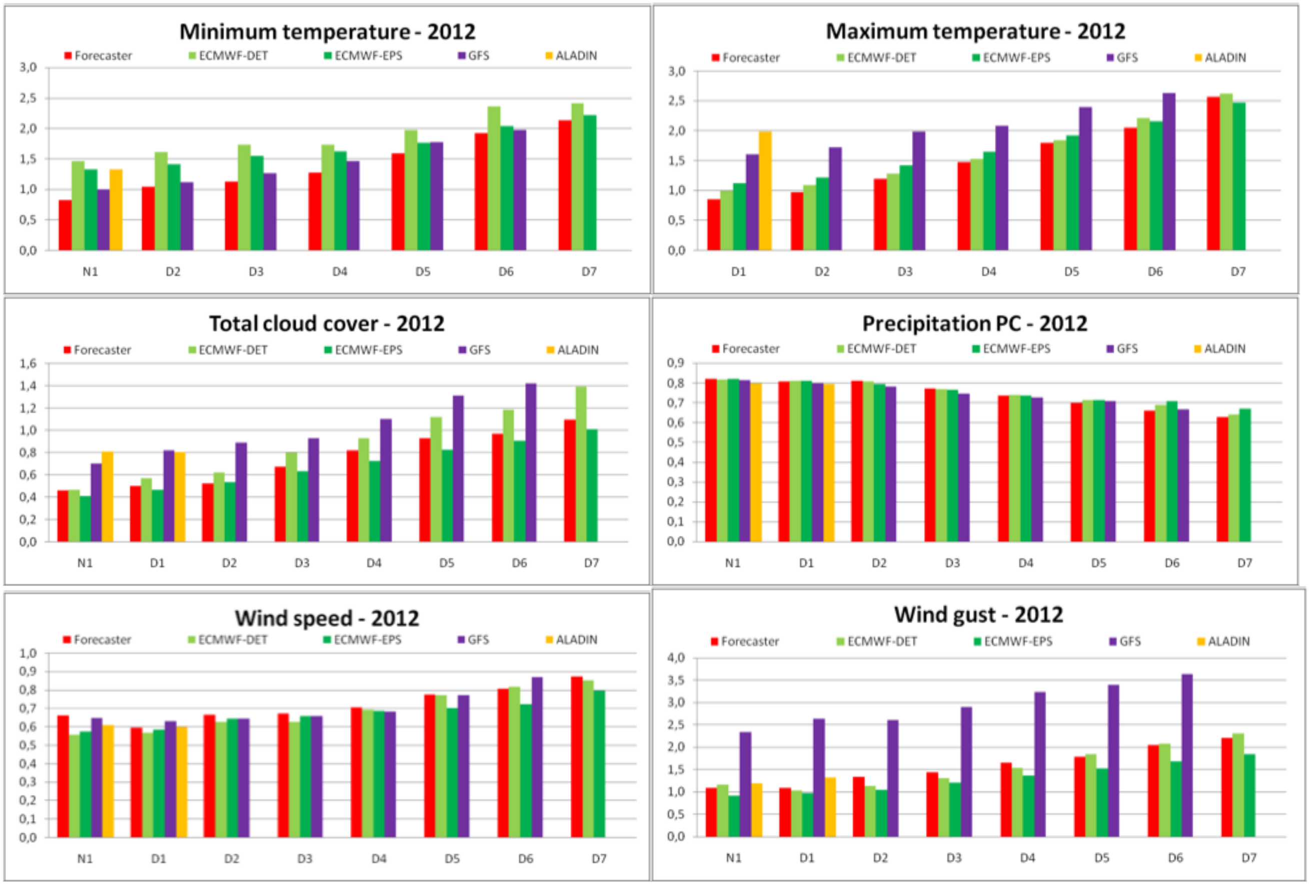

Fig. 10 Mean Absolute Error (MAE) of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation occurrence forecasts for different forecast ranges in case of ALADIN, ECMWF Deterministic, ECMWF EPS mean, GFS and the Operational Forecaster for 2012. N1 represent the first night, D1, D2, … etc the days after the issue of the forecast.

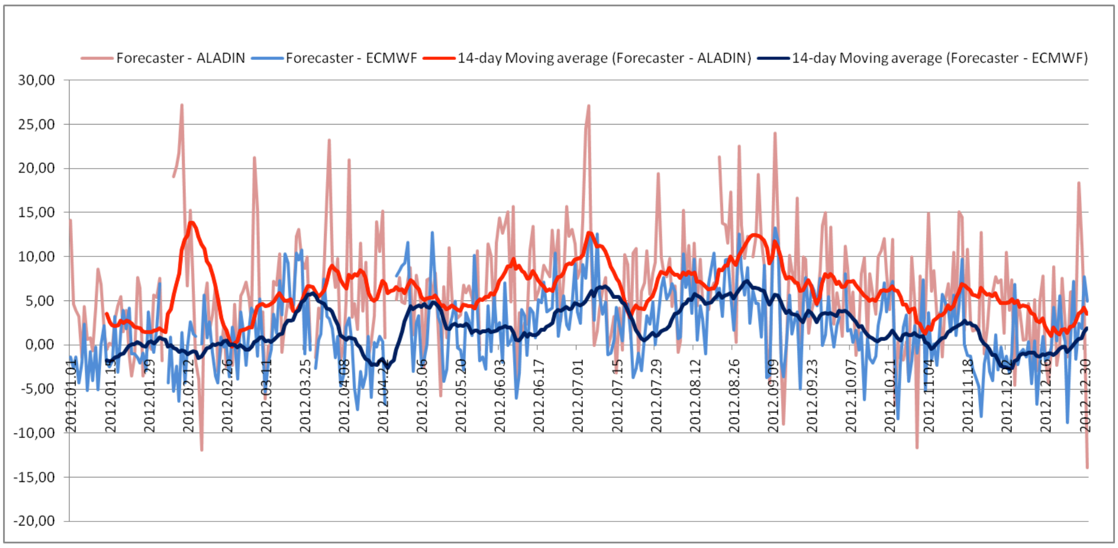

Fig. 11 Difference of the daily Complex Score for *the first day* calculated for the Forecaster and the models in 2012; 14-day moving averages are also shown.

3.1.5 Seasonal forecasts

At the Hungarian Meteorological Service a statistical technique for long-range forecasting was developed and forecasts based on this method had been issued for more than 30 years. Beside the operational statistical method, in 1998 investigation of the applicability of ECMWF's long-range forecasting system. The newest version (System4) became operational in 2011 in the HMS. 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 12 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 predicted variables and the climate is compared. If the score is below zero, the clime would have been a better prediction than the model. This case used to appear quite frequently in previous years, but this time it can be noticed only in case of January precipitation.

On Fig 13 and Fig 14 we can compare the climate, the forecasts and observation. February was much colder than the climatic average, but it was not appear in the model. In other months the model usually predicted warmer than the climate, which was fine according to the scores. The year 2012 was very dry in Hungary, which was predicted well, although the precipitation was still overestimated. This dry prediction of the model has been noticed for years, so it cannot be decided if the better scores came because of the dry year or the improvement of System-4.

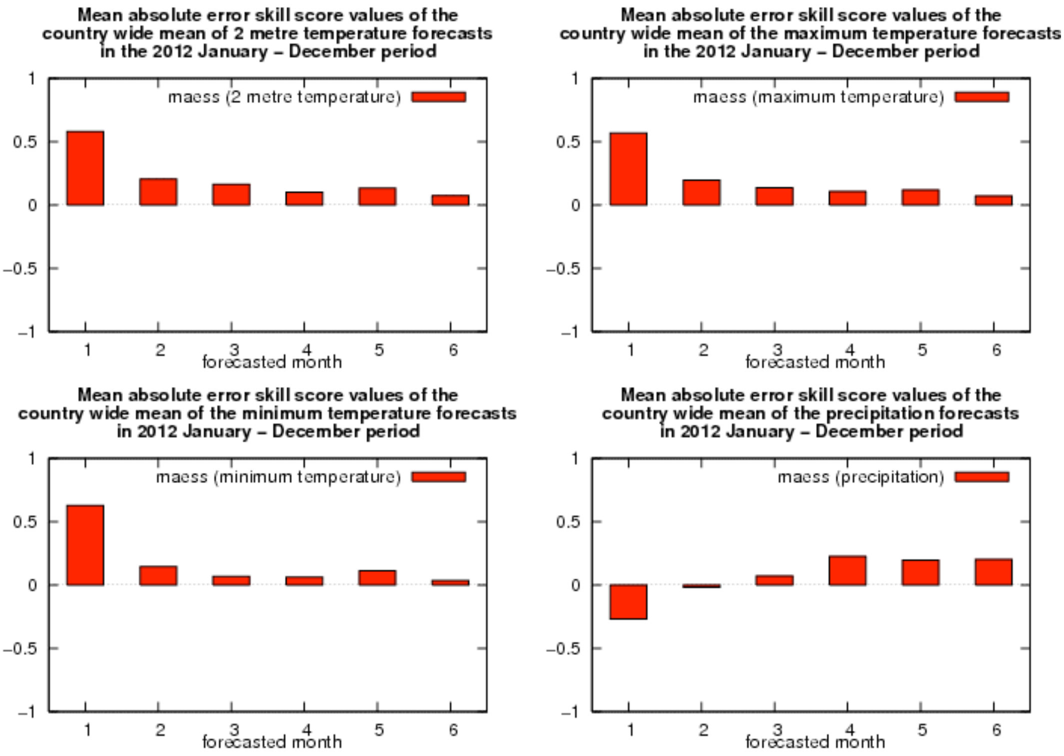

Fig. 12 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2012. Reference forecast was the 30-year climatological mean.

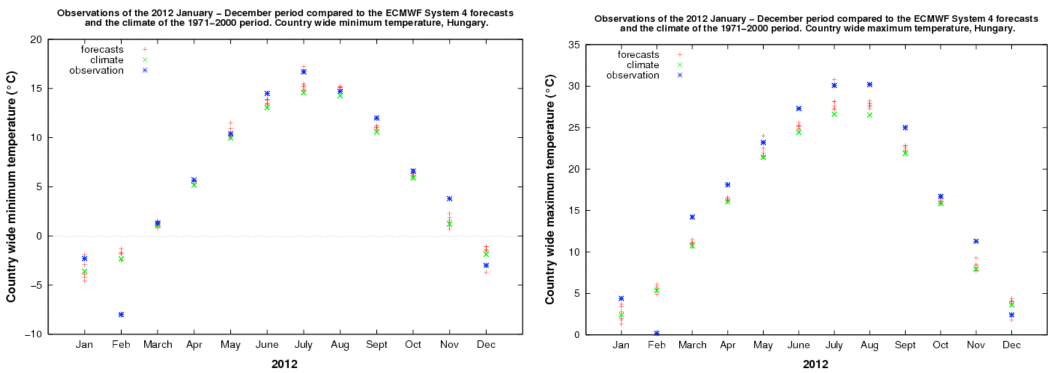

Fig. 13 Comparison of the forecasts issued for the 2012 January-December period with the observations and the climate for minimum and maximum temperature.

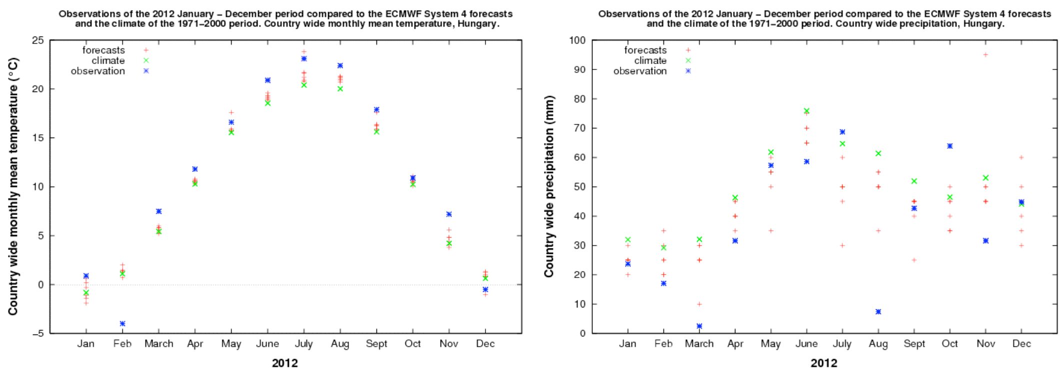

Fig. 14 Comparison of the forecasts issued for the 2012 January-December period with the observations and the climate for monthly mean temperature and monthly amount of precipitation.

3.1.6 Monthly forecasts

Monthly forecasts have been operationally used at the OMSZ 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.

3.2 Subjective verification

3.2.1 Subjective scores

Subjective verification

Daily-based subjective verification has been performed since April 2012. Duty system was developed to ensure the continuously evaluation. The subjective verification is made by applying of HAWK-3 visualization system. The aim of this activity is to get a view of the model behaviour and to collect some interesting case studies for further investigations.
The verified NWP products are hydrostatics models: ALADIN, ECMWF high resolution and ALADIN-EPS and nonhydrostatic ones: AROME and WRF. The analyzed meteorological parameters are 2 m temperature, cloudiness, precipitation and 10 m wind. Marks and textual analysis are given for each element. From the moving averages (calculated from April to December 2012) it can be established that the ECMWF high-resolution model (blue) produced the best cloudiness (left) forecast for the period and the wind prediction (right) is also very good (Fig. 15).

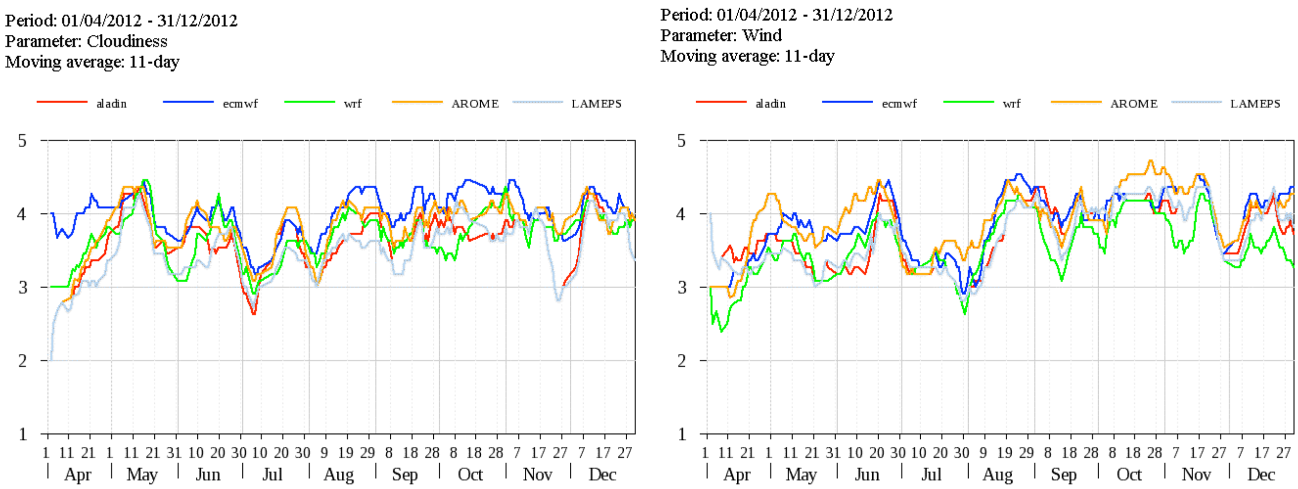

Fig. 15. Moving average for the marks of cloudiness and wind for April-December 2012

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
Ihász I., Z. Üveges, M. Mile and Cs. Németh, 2010: Ensemble calibration of ECMWF's medium range forecasts. *Időjárás* 114, 275-286.
Ihász, I. and D. Tajti, 2011: Use of ECMWF's ensemble vertical profiles at the Hungarian Meteorological Service. *ECMWF Newsletter* 129. 25-29.