# Application and verification of ECMWF products 2014

*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 2009. Ensemble vertical profile based on standard pressure levels and all ensemble model levels have been operationally made for temperature, dew point, wind speed and wind rose since 2011. A new ensemble plume diagram was developed, containing four variables: 500 hPa temperature, isentropic potential vorticity at 320 K, potential temperature at 2 PVU and 300 hPa wind speed.

## 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 high resolution model (HRES) as lateral boundary conditions (LBC) for driving the limited area models ALADIN and AROME. The ALADIN and AROME models coupled with ECMWF lateral boundary conditions operationally provides short-range forecasts four times a day for forecasters. For the ALADIN model at 00 UTC +54h, at 06 and 12 UTC +48h and at 18 UTC +39h forecasts are made. For the AROME model, at 00 and 12 UTC +48h, and at 06 and 18 UTC +39h forecasts are made.

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

#### *2.1.3 Derived fields*

Local 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. 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 ensemble 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 ENS meteograms, ENS plumes, cluster products are available on the intranet for the whole community of the meteorological service. ENS meteograms are available for medium, monthly and seasonal forecast ranges. ENS calibration using VarEPS reforecast dataset was developed in 2008. Ensemble vertical profile based on standard pressure levels and all ensemble model levels have been operationally made for temperature, dew point, wind speed and wind rose since 2011 (*Ihász and Tajti*, 2011).
In 2013 a new ensemble plume diagram was developed, containing four variables: 500 hPa temperature, isentropic potential vorticity at 320 K, potential temperature at 2 PVU and 300 hPa wind speed (*Gaál and Ihász,* 2014).

# 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 HRES model were verified against all the Hungarian SYNOP observations for the whole 2013 year. The input forecast values for ECMWF HRES 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 HRES) are computed. The computed scores are presented on Time-TS diagrams (with the forecast range on the x-axis) (Fig 1-6).

**<u>2m temperature and 2m relative humidity:</u>**

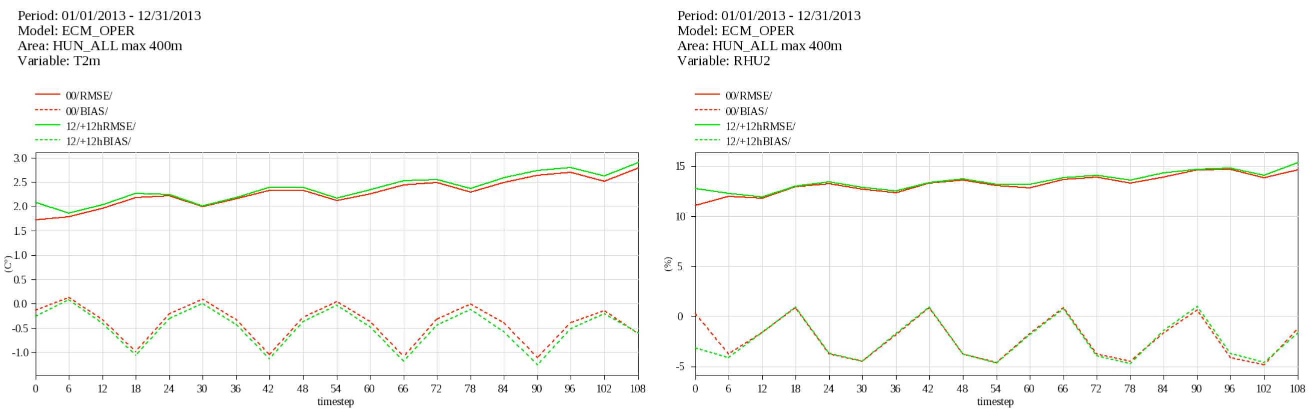


Fig. 1 RMSE and BIAS values for ECMWF 2m temperature and 2m relative humidity forecasts for Hungary

**<u>10m wind speed and Total cloudiness:</u>**

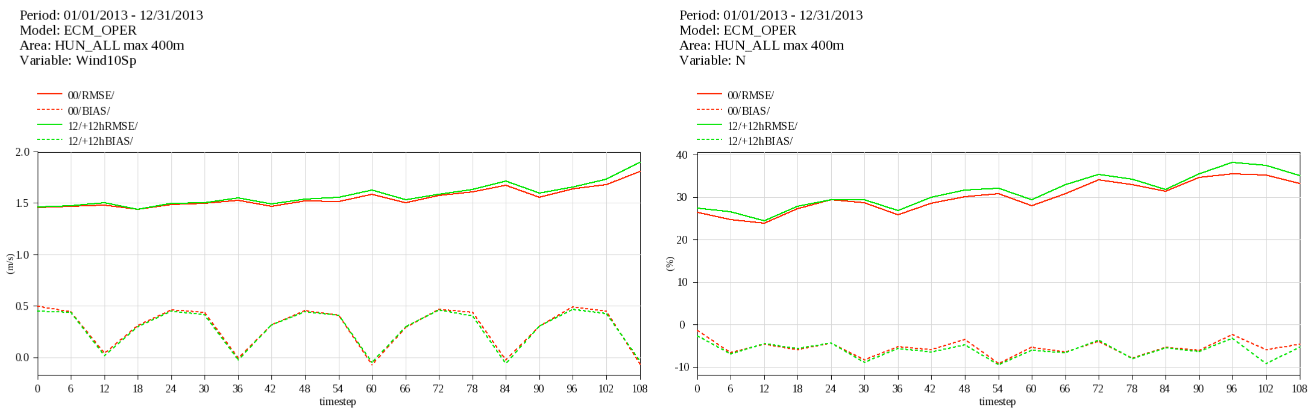


Fig. 2 RMSE and BIAS values for ECMWF 10m wind speed and total cloudiness forecasts for Hungary

### *3.1.2 ECMWF model output compared to other NWP models used by the OMSZ*

Hereafter the ECMWF HRES, ALADIN/HU and AROME models can be compared in the first 48 forecast ranges with the help of OVISYS. The forecast values from ECMWF HRES 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. 3-6). We can compare the results *for ECMWF HRES, ALADIN/HU and AROME models from 'Application and verification of ECMWF products, 2013'.*

**2m temperature:**

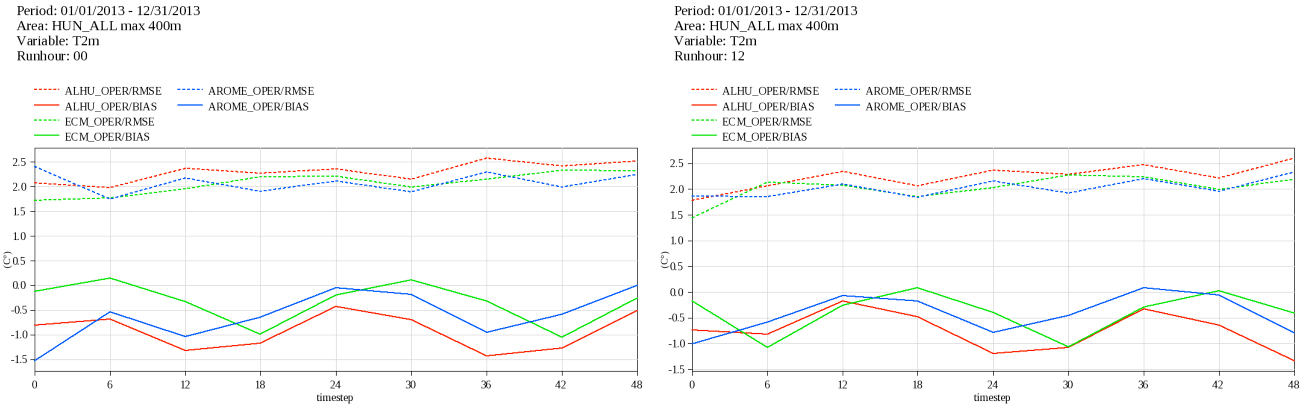


Fig. 3 Comparison of BIAS and RMSE values for ECMWF HRES (green), ALADIN/HU (red) and AROME (blue) 2m temperature forecasts over Hungary

**2m relative humidity:**

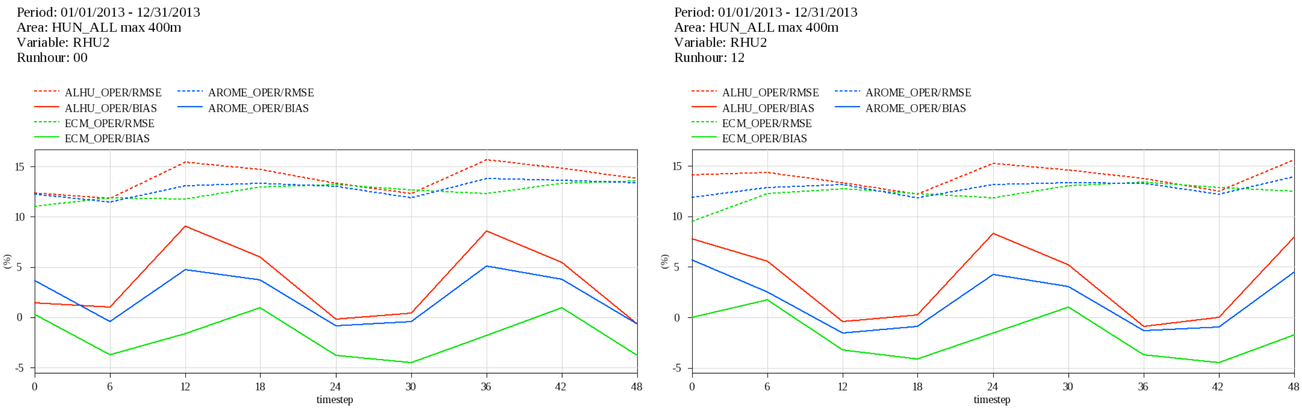


Fig.4 Comparison of BIAS and RMSE values for ECMWF HRES (green), ALADIN/HU (red) and AROME (blue) 2m relative humidity forecasts over Hungary

**10m wind speed:**

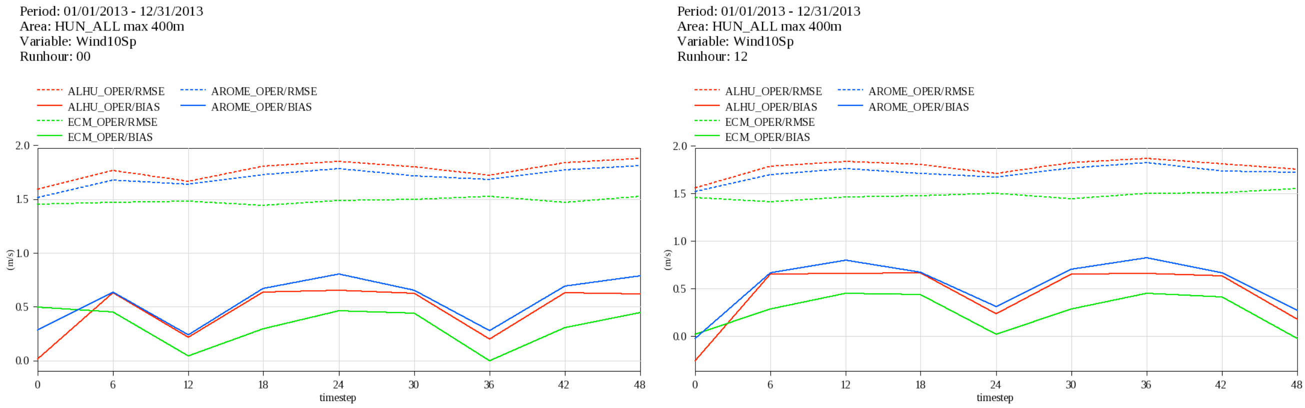


Fig. 5 Comparison of BIAS and RMSE values for ECMWF HRES (green) and ALADIN/HU (red) and AROME (blue) wind speed forecasts over Hungary

**Total cloudiness:**

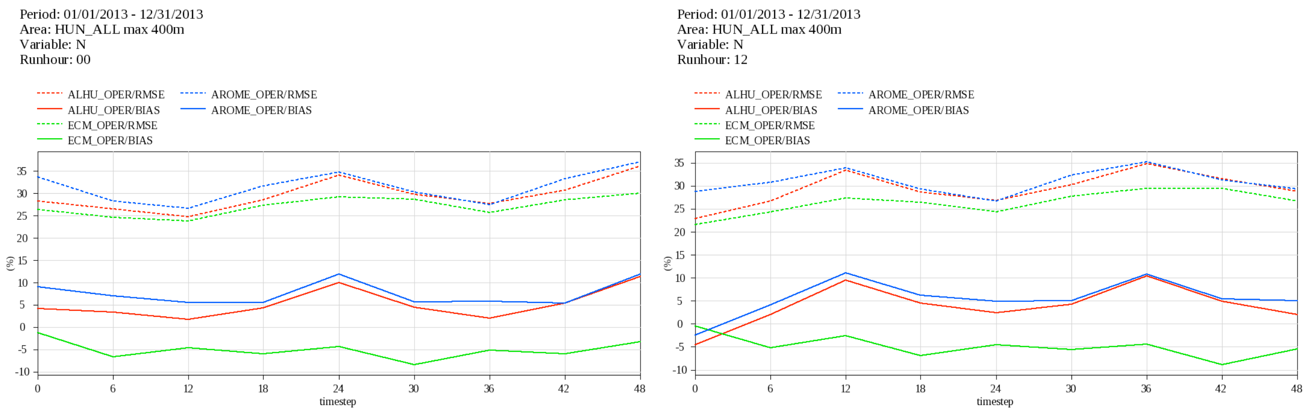


Fig. 6 Comparison of BIAS and RMSE values for ECMWF HRES (green), ALADIN/HU (red) and AROME (blue) total cloudiness forecasts over Hungary

**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. 7a the frequency bias and in the Fig. 7b the SEDI of four models (ECMWF HRES, AROME, ALADIN/HU) can be seen for the whole 2013 and for 24 h precipitation in the 30th time step and for the Hungarian synop stations under 400 m. As far as the bias is concerned, the ALADIN/HU shows the best result and the AROME has the biggest frequency bias - worst (Fig. 7a). 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 HRES gives the biggest (best) SEDI scores. Note, that – because of the independence - the models would show the same results in SEDI after a bias correction.

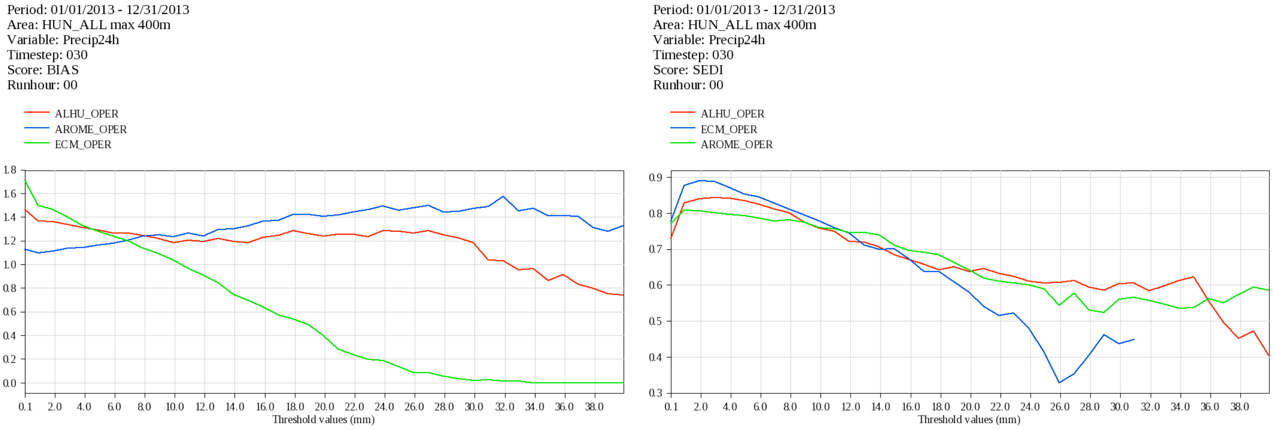


Fig. 7. a) The frequency bias of ECMWF HRES, AROME, ALADIN/HU for the whole 2013 and for 24h precipitation in the 30th time step, for the Hungarian synop stations under 400m, against the precipitation threshold b) he SEDI (Symmetric Extremal Dependence Index) of ECMWF HRES, AROME and ALADIN/HU for the whole 2013 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 also 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 ENS model resolution valid in 2013. 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.

### *3.1.4 End products delivered to users*

The product of the forecasters issued in the forenoon is compared with the ECMWF high resolution model, the ENS mean and ALADIN running at 00 UTC. ECMWF ENS mean is available only after 10 LT (in winter time after 9 LT), so medium-range forecaster is able to use it when predicting day 5, day 6 and day 7. Studying the diagrams on Fig. 8 it can be established that the scores of the forecasters are usually better than the results of the different models. On the other hand, ENS mean gives better result in some variables like wind speed and wind gust. After day 4 the reliability of ENS mean exceeds the high resolution 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 is developed for short-range is best in forecasting wind speed and wind gust.

A complex score is also derived using the scores of each variable. To show the difference between the result of the forecaster and of the models we present a diagram in Fig. 9. 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 massive positive values between ECMWF and forecaster in summertime are because of the permanent underestimation of the maximum temperature. 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.

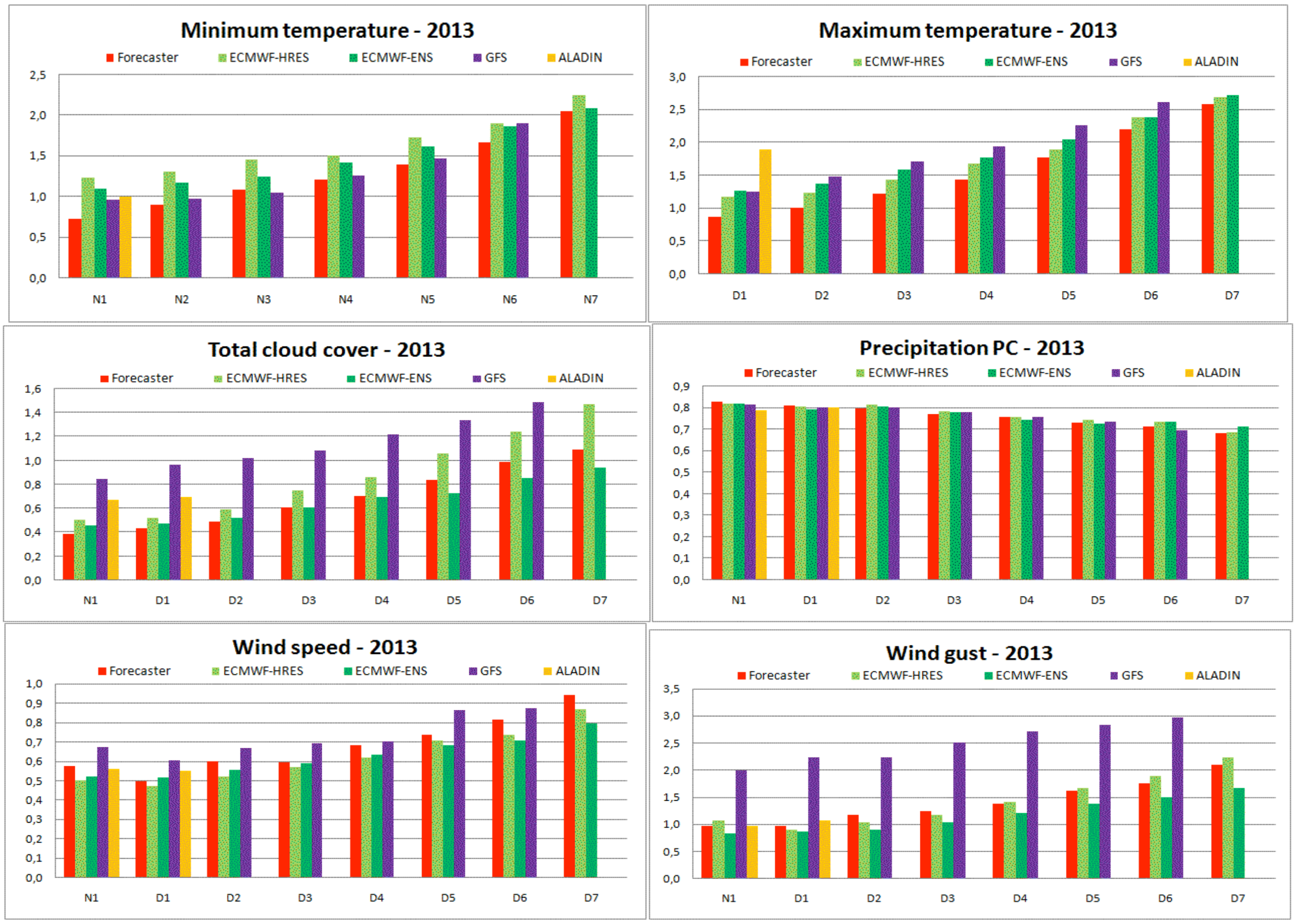


Fig. 8 Mean Absolute Error (MAE) of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation occurrence forecasts for different forecast ranges in case of ALADIN, ECMWF HRES, ECMWF ENS mean, GFS and the Human Forecaster for 2013. N1 represent the first night, D1, D2, … etc the days after the issue of the forecast.

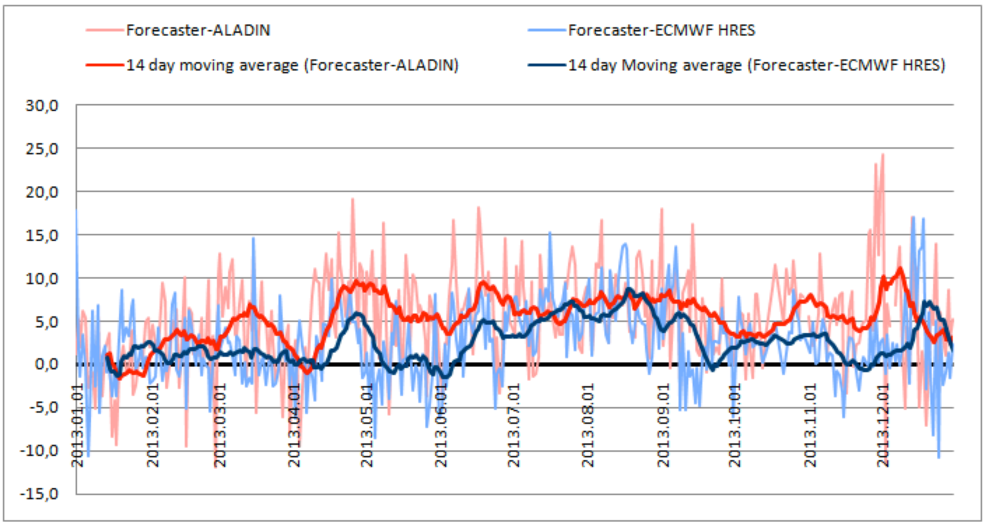


Fig. 9 Difference of the daily Complex Score for *the first day* calculated for the Forecaster and the models in 2013; 14-day moving averages are also shown.

### *3.1.5 Seasonal forecasts*

As soon as it was possible in 1998 investigation of the applicability of ECMWF's seasonal forecasting system was done. The newest version (System-4) became operational in 2011 in the OMSZ. 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. 11 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. On Fig. 12 we can compare the climate, the forecasts and observation. Under- and overestimation also appears in the different month. The errors are higher for precipitation forecast. In this case underestimations appear more generally, although the extremely dry December was quite overestimated.

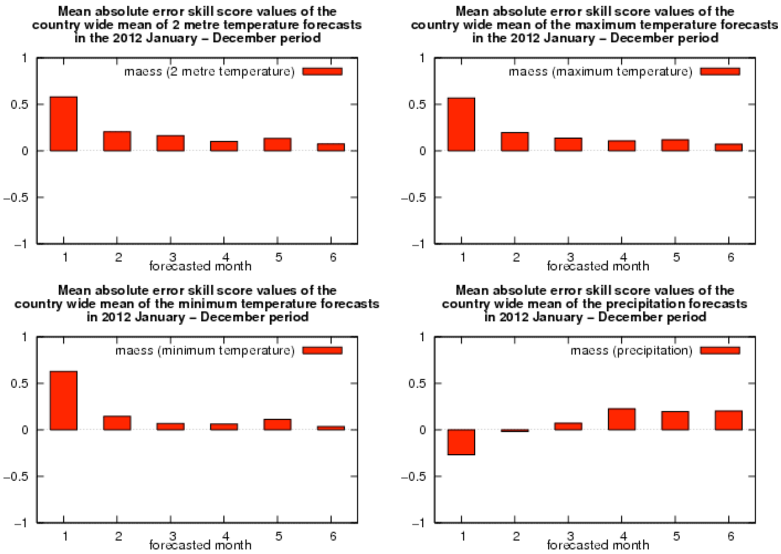


Fig. 10 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2013. Reference forecast was the 30-year climatological mean.

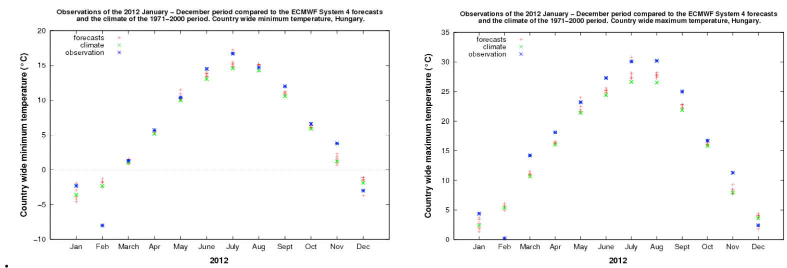


Fig. 11 Comparison of the forecasts issued for the 2013 January-December period with the observations and the climate for minimum and maximum temperature.

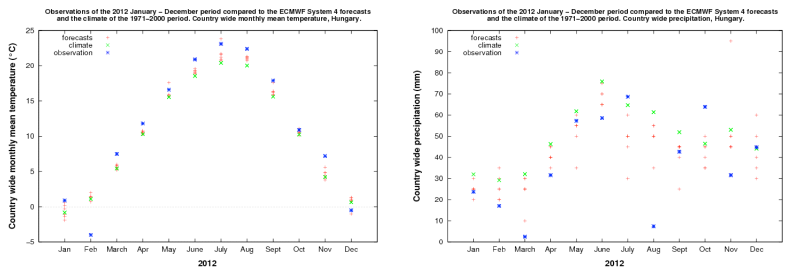


Fig. 12 Comparison of the forecasts issued for the 2013 January-December period with the observations and the climate for monthly mean temperature and monthly amount of precipitation.

#### *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*

The subjective verification – which has been performed since April 2012 – has been continued also in 2013. The evaluation was done on daily duty till May 2013, and then we moved to the success of forecast-dependent. Since the model predictions are followed on daily basis by the forecasters, they are the competent who are able to decide and indicate on the website that the situation (weather and/or forecasts) is suitable for the further evaluation. The forecaster can denote some comments on the website about his/her impressions of the model predictions. The website was expanded by some new statistics and searching functions in 2013.

The subjective verification is done by using of HAWK-3 visualization system or its saved figures. The verified NWP products are hydrostatics models: ALADIN, ECMWF HRES 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 January to December 2013) it can be established that the ECMWF high resolution model (blue) produced the best cloudiness (left) forecast for the period (similarly to 2012) and the temperature prediction (right) is also very good (Fig. 13).

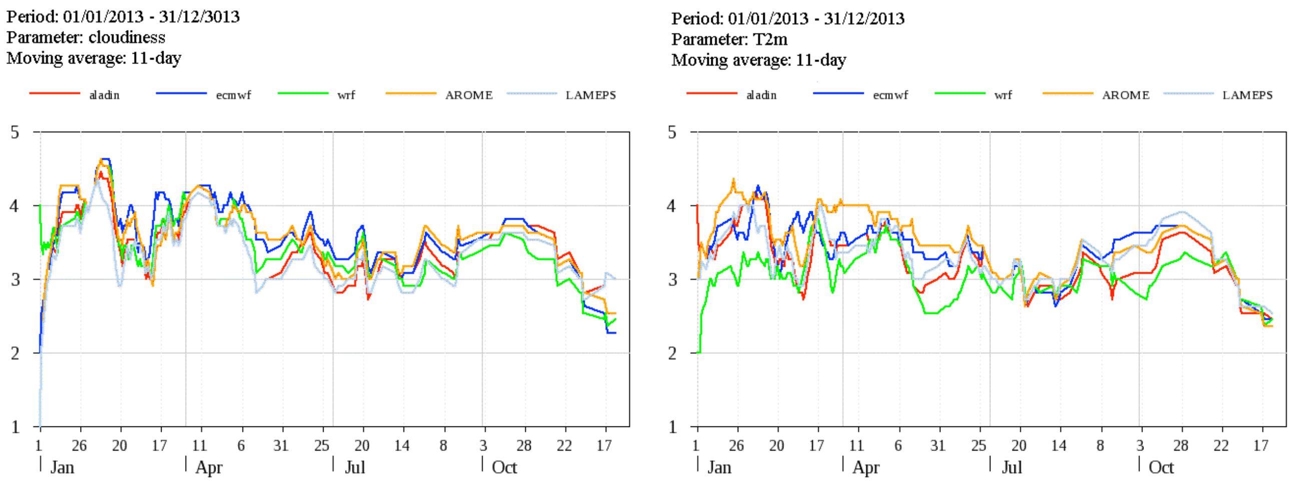


Fig. 13. Moving average for the marks of cloudiness and temperature for January December 2013

## 4. References

**Ihász, I. and D. Tajti**, 2011: Use of ECMWF's ensemble vertical profiles at the Hungarian Meteorological Service. *ECMWF Newsletter* **129**. 25-29.
**Gaál, N. and I. Ihász**, 2014: Predictability of the cold drops based on ECMWF's forecasts over Europe. *ECMWF Newsletter* **140**. 26-30.