Application and verification of ECMWF products 2016

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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 all ensemble model levels have been operationally made for temperature, dew point, wind speed and wind rose since 2011. Since the middle of July 2015 two additional ensemble model runs are available by ECMWF up to +144 hours at 06 and 18 UTC. Locally produced ensemble plumes derived from all ensemble model runs have been available for our forecasters and these new ensemble forecasts are considered to be used as a lateral boundary condition for our limited area model (*Szűcs et al.,* 2016).

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 provide short-range forecasts four and eight 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 eight forecasts per day are made since March 2016, at 00 and 12 UTC +48h, at 06 and 18 UTC +39h and at 03, 09, 15 and 21 UTC +36h forecasts are made.

Dispersion and forward/backward trajectory models based on ECMWF HRES and ALADIN/HU models have been operationally used for more than fifteen 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 (*Ihász*, 2003). Several derived parameters from the deterministic and ensemble models are operationally available too. Altogether more than 100 ensemble fields are derived. Operational model version CY41R1 introduced 12 May 2015 contains information on type of the precipitation. At OMSZ new operational graphical product had been developed before winter season 2015/16, this product got large attention and very positive feedback from forecasters and internal users (Fig. 1).

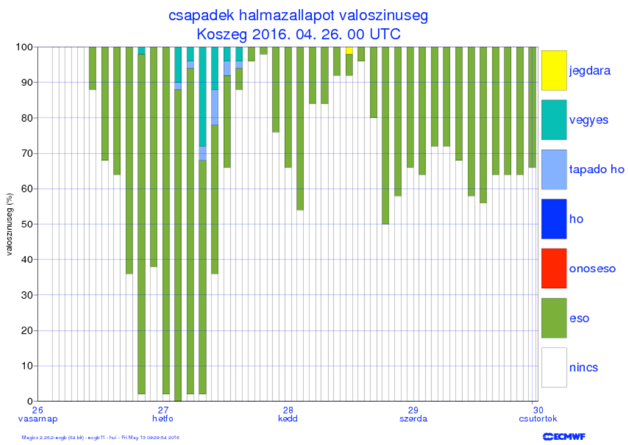


Fig. 1 Precipitation type probability diagram (rain, snow, wet snow, freezing rain and mixed type)

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 (*Ihász et al., 2010*). 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). In 2014 and 2015 predictability of extreme precipitation for river catchments was studied for 100 selected cases, including extreme flood occurred in river Danube between May and June 2013. Uncalibrated and calibrated precipitation ensemble forecasts were compared (*Mátrai and Ihász, 2015*).

3. Verification of Products

3.1 Objective verification

3.1.1 Direct ECMWF model output

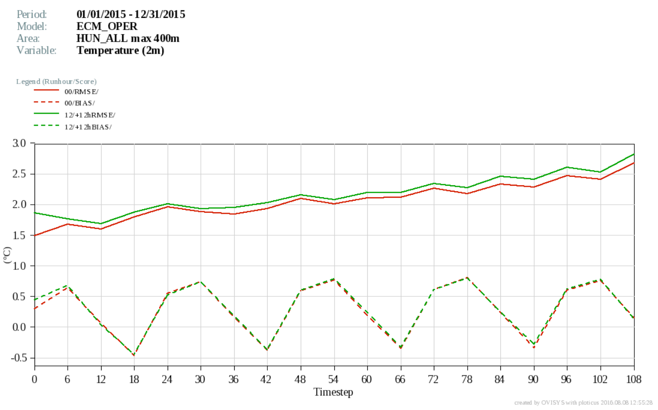
(i) in the free atmosphere

(ii) local weather parameters for locations

The objective verification is performed via the Objective Verification System (OVISYS) developed at the Hungarian Meteorological Service. More details on OVISYS are available in '*Verification of ECMWF products, 2006*'. In this study the 00 and 12 UTC runs of ECMWF HRES model were verified against the Hungarian SYNOP observations for 2015. The verification is performed for the following variables: 2m temperature, 2m relative humidity, 10m wind speed, total cloudiness and daily accumulated precipitation.

BIAS and RMSE values of the ECMWF HRES model are calculated 108 hours ahead. The computed scores are presented on Time-TS diagrams as a function of lead time (with the forecast range on the x-axis) (Fig. 2-7.). All the results presented here use the measurements of Hungarian SYNOP stations under 400 m above sea level for verification.

2m temperature and 2m relative humidity:



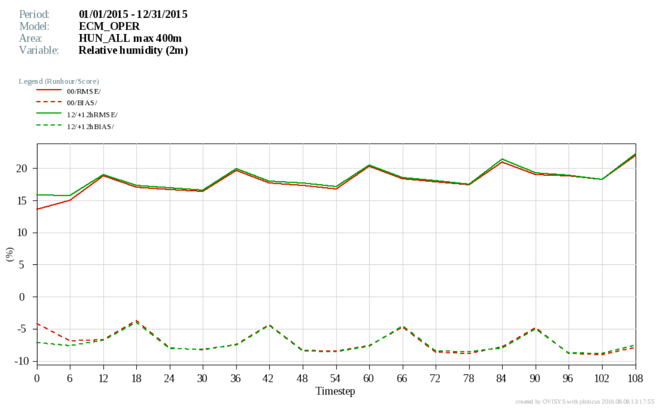


Fig. 2 RMSE (solid) and BIAS (dashed) values of 2m temperature and 2m relative humidity forecasts of the ECMWF HRES for Hungary.

10m wind speed and Total cloudiness:

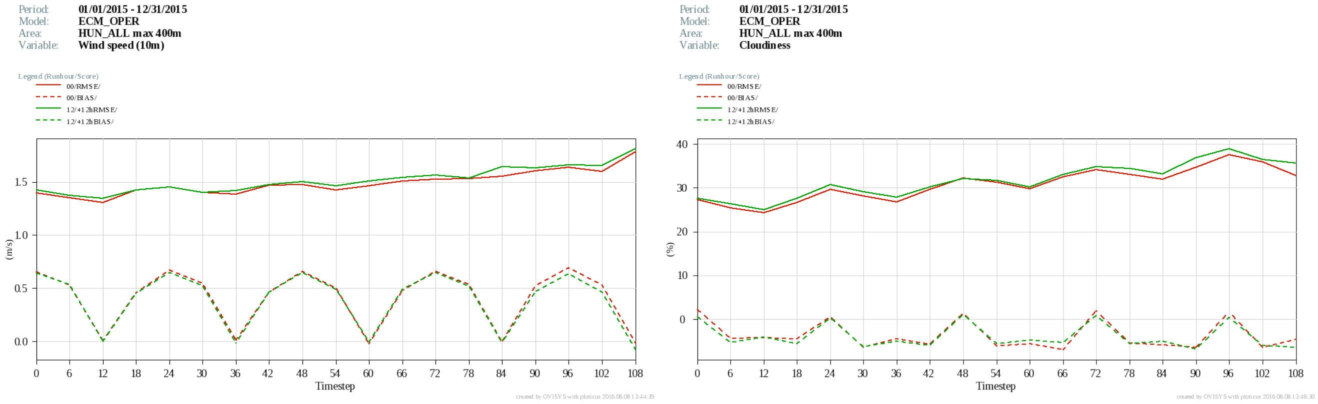


Fig. 3 RMSE (solid) and BIAS (dashed) values of 10m wind speed and total cloudiness forecasts of the ECMWF HRES for Hungary.

Hereafter the performance of the ECMWF HRES, ALADIN/HU and AROME models is compared in the first 48 forecast hours with OVISYS. The forecast values are taken from a 0.125°x0.125° grid box from the ECMWF HRES, a 0.1°x0.1° post-processing grid from the ALADIN, and from a 0.025°x0.025° grid from the AROME model (the original mesh size of the ALADIN model is 8 km, while for the AROME model it is 2.5 km, both are on Lambert projection). The scores are computed using the Hungarian SYNOP observations for 2015 (Fig. 4-7). The results might be compared with the ones shown in '*Application and verification of ECMWF products, 2015*' for the ECMWF HRES (ECM_OPER), ALADIN/HU (ALHU_OPER) and AROME (AROME_OPER) models.

2m temperature:

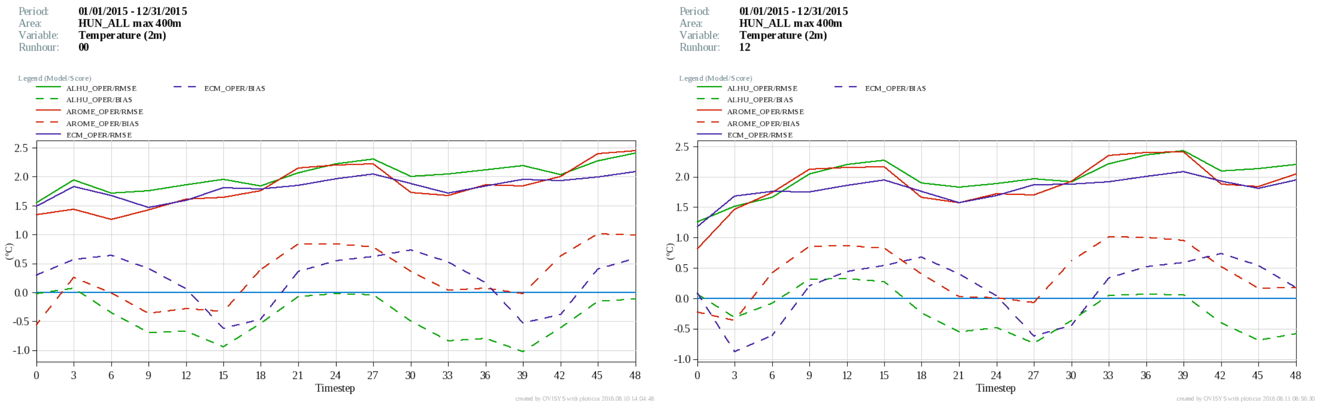


Fig. 4 Comparison of RMSE (solid) and BIAS (dashed) values of 2m temperature forecasts of the ECMWF HRES (blue), ALADIN/HU (green) and AROME (red) models over Hungary.

2m relative humidity:

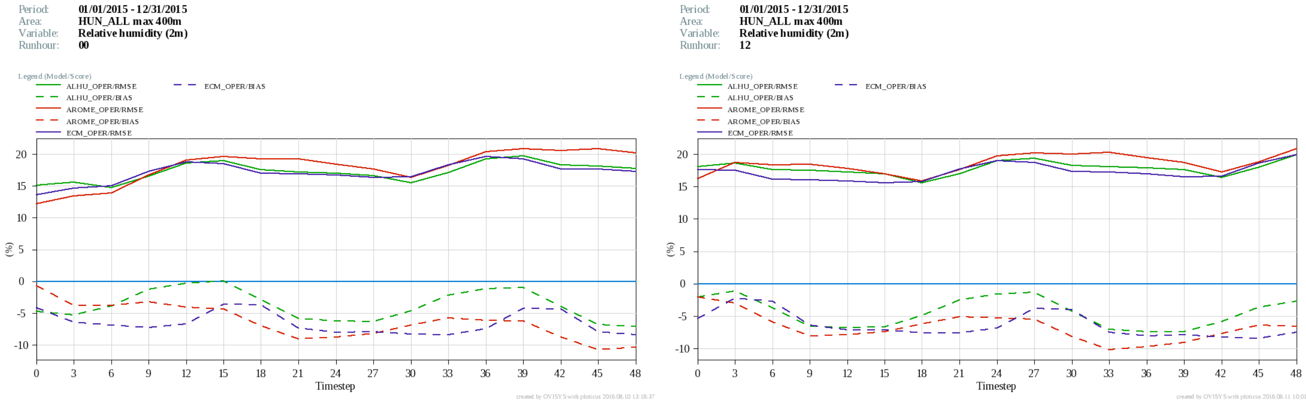


Fig.5 Comparison of RMSE (solid) and BIAS (dashed) values of 2m relative humidity forecasts of the ECMWF HRES (blue), ALADIN/HU (green) and AROME (red) models over Hungary.

10m wind speed:

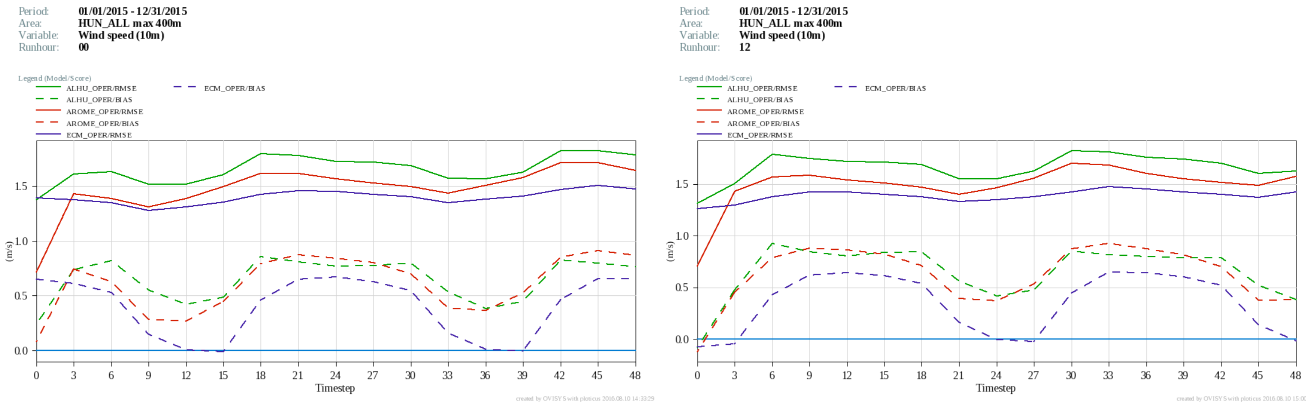


Fig. 6 Comparison of RMSE (solid) and BIAS (dashed) values of 10m wind speed forecasts of the ECMWF HRES (blue), ALADIN/HU (green) and AROME (red) models over Hungary.

Total cloudiness:

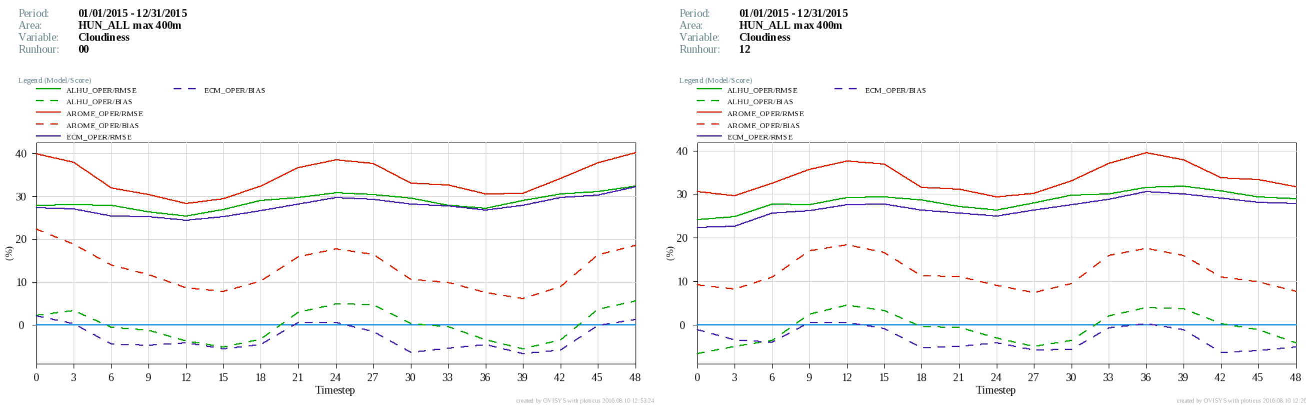


Fig. 7 Comparison of RMSE (solid) and BIAS (dashed) values of total cloudiness forecasts of the ECMWF HRES (blue), IN/HU (green) and AROME (red) models over Hungary.

Precipitation:

In the following the frequency bias and the SEDI (Symmetric Extremal Dependence Index) verification scores are shown as a function of certain precipitation thresholds. These verification measures are independent from each other. 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 (see Table 3.4) is concerned. As it is well known, the score of a perfect forecast for the frequency bias and SEDI is +1. The range of frequency bias is between zero and infinity, and it is between -1 and +1 for SEDI.

The frequency bias (fig. 8a) and the SEDI score (fig. 8b) of 24 h precipitation of the three models (ECMWF HRES, ALADIN/HU and AROME) can be seen in the 30th hour of the forecast for 2015. Concerning the values of bias, until the 16 and over the 24 mm/day threshold the AROME show the best results. Between 16 and 24 mm/day both the ALADIN/HU and the AROME running close to the perfect +1 value. Under 8 mm/day, the ECMWF HRES has similar results compared to the other two models, but over 8 mm/day, the ECMWF HRES has obviously the biggest frequency bias, therefore it is the worst (Fig. 8a).

Regarding the SEDI score, from 1 mm/day threshold the ALADIN/HU model gives the best and the ECMWF HRES gives the worst results. Note that – due to SEDI is independent of the bias - the models would show the same results concerning SEDI after a bias correction.

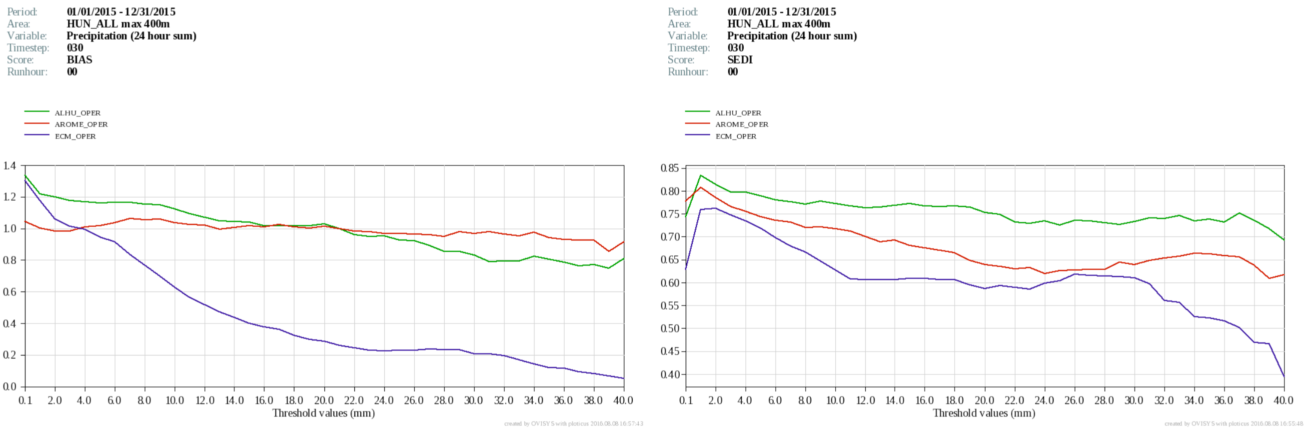


Fig. 8. a) The frequency bias values of 24 h precipitation forecasts (in the 30th hour of the forecast) of the ECMWF HRES (blue), ALADIN/HU (green) and AROME (red) models for 2015, for the Hungarian synop stations under 400m, against precipitation thresholds b) The SEDI values of 24 h precipitation forecasts (in the 30th hour of the forecast) of the ECMWF HRES (blue), ALADIN/HU (green) and AROME (red) models for 2015, for the Hungarian synop stations under 400m, as a function of precipitation thresholds.

Finally, some examples will be presented from the seasonal verification results that made with OVISYS as well. During this the performance of the ECMWF HRES, ALADIN/HU, AROME, FOCUS and WRF models is compared in the first 48 forecast hours. The forecast values of the ECMWF HRES, ALADIN/HU and AROME models are taken similarly as above and from a 10x10 km grid box from FOCUS and from a 0.036°x0.024° grid from the WRF model (the original mesh size of the WRF model is 2.6 km). The scores are computed using the Hungarian SYNOP observations for 2015 (Fig. 9a-d).

FOCUS (Unified Gridded Forecast Database) is a multi-model solution developed in the Hungarian Meteorological Service. It is a gridded NetCDF database with 10 km horizontal resolution over a large Hungarian region with1-hour temporal resolution up to D+15. The initialisation of FOCUS is done with deterministic ECMWF with an option to use ALADIN for short range. It includes all main categorical weather parameters with some probabilities and the data is extracted directly from the grid without further corrections for hundreds of products. A Grid Editor (Graphical Forecast Editor – US National Weather Service) is used by the forecasters to modify FOCUS fields (only temperature parameters – min, max – and time steps are modified). More details on FOCUS are available in this presentation: http://www.ecmwf.int/sites/default/files/elibrary/2011/14922-developments-towards-multi-model-based-forecast-product-generation.pdf

The operational **WRF** model used by Hungarian Meteorological Service is running with high resolution (2.6 km) non-hydrostatic configuration on the supercomputer service four times a day. The model provides basic data for the ultra-short-term forecasting system of the OMSZ and for the country and the lake storm warnings as well.

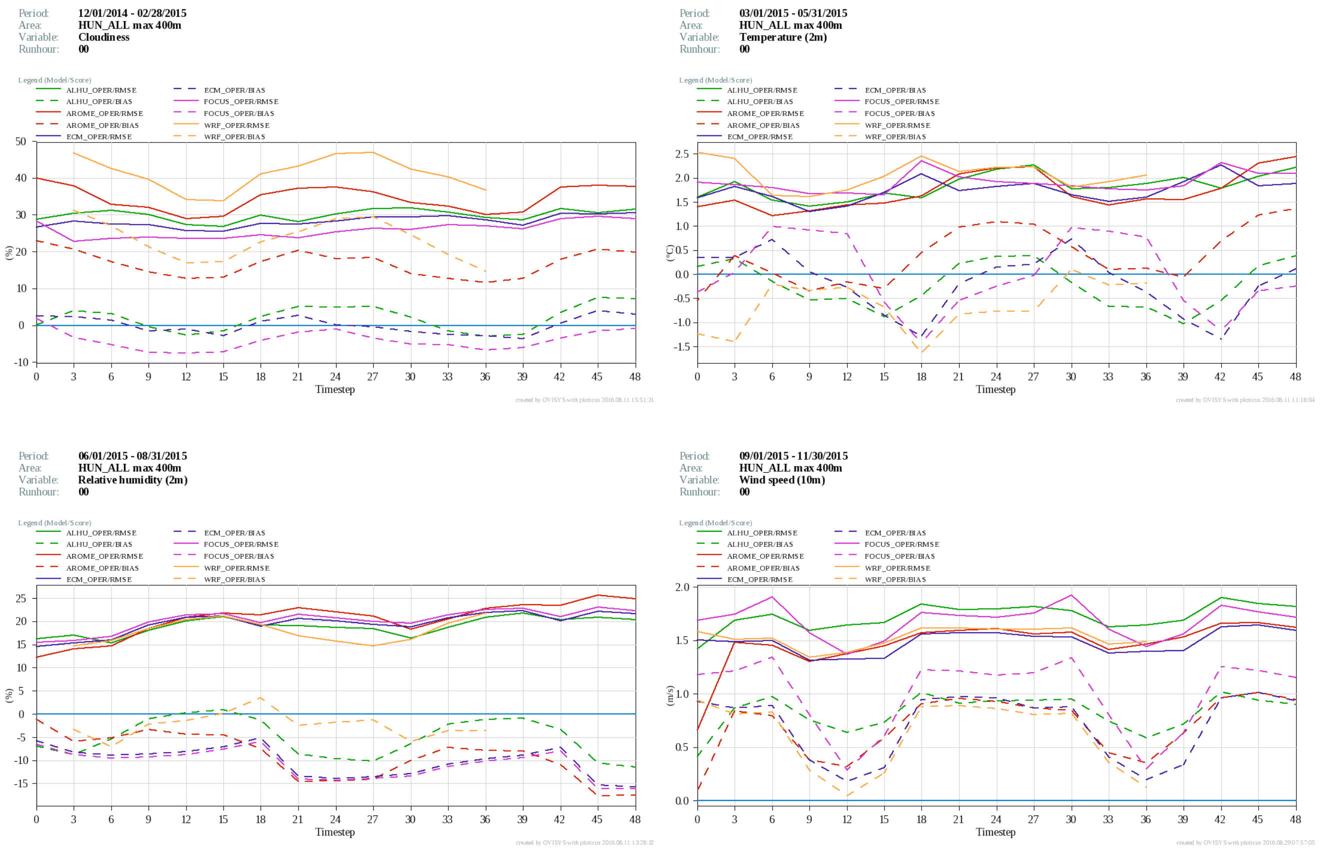


Fig. 9. Comparison of RMSE (solid) and BIAS (dashed) values of the ECMWF HRES (blue), ALADIN/HU (green), AROME (red), FOCUS (purple) and WRF (yellow) models over Hungary in terms of a) total cloudiness in the winter of 2014-2015 b) 2m temperature in the spring of 2015 c) 2m relative humidity in the summer of 2015 d) 10m wind speed in the autumn of 2015.

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 0.25 by 0.25 degrees grid belonging to ENS model resolution valid in 2015.

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 gridpoint 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 (HRES) model, the ENS mean, the ALADIN/HU and non-hydrostatic model AROME 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. 10 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/HU and AROME models are 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. 11. Positive values indicate higher overall skill for the forecaster. The 14-day moving average of the improvement of the forecaster on ECMWF' HRES has usually remained under 10 %.

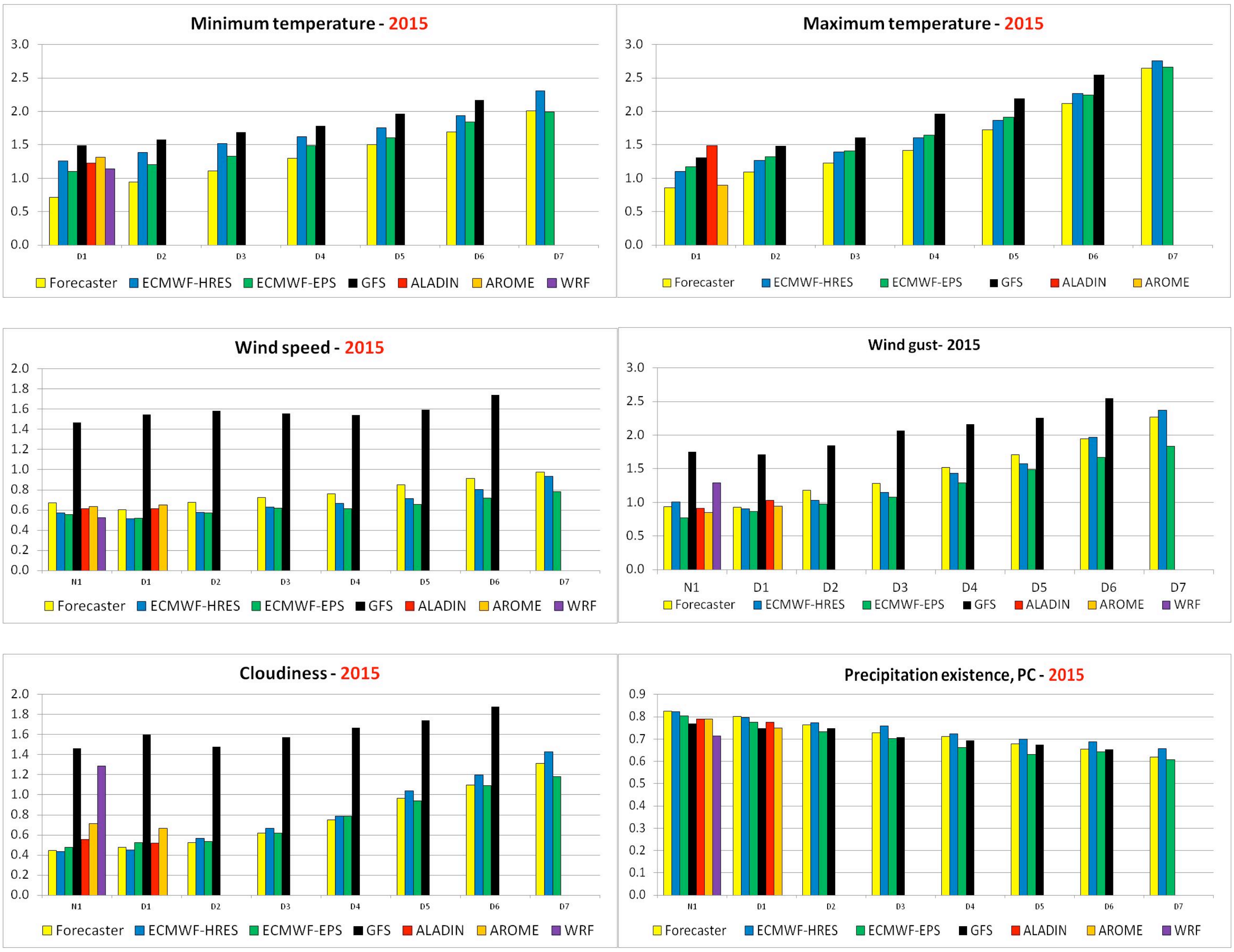


Fig.10 Mean Absolute Error (MAE) of temperature, total cloud cover, average wind speed and wind gust forecasts and Percent Correct (PC) of precipitation occurrence forecasts for different forecast ranges in case of ALADIN, AROME, ECMWF HRES, ECMWF ENS mean, GFS and the Human Forecaster for 2015. N1 represent the first night, D1, D2, … etc the days after the issue of the forecast.

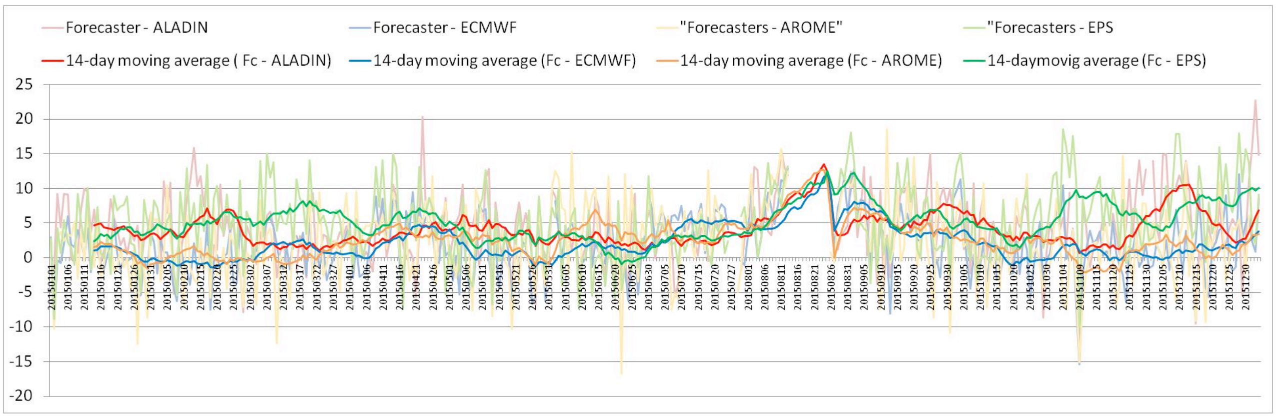


Fig.11 Difference of the daily Complex Score for *the first day* calculated for the forecaster and the models in 2015; 14-day moving averages are also shown.

3.1.5 Seasonal forecasts

The newest version (System-4) became operational in 2011 in the OMSZ. Forecasts for the 2-metre 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. On Fig. 13 and Fig. 14 we can compare the climate, the forecasts and observation.

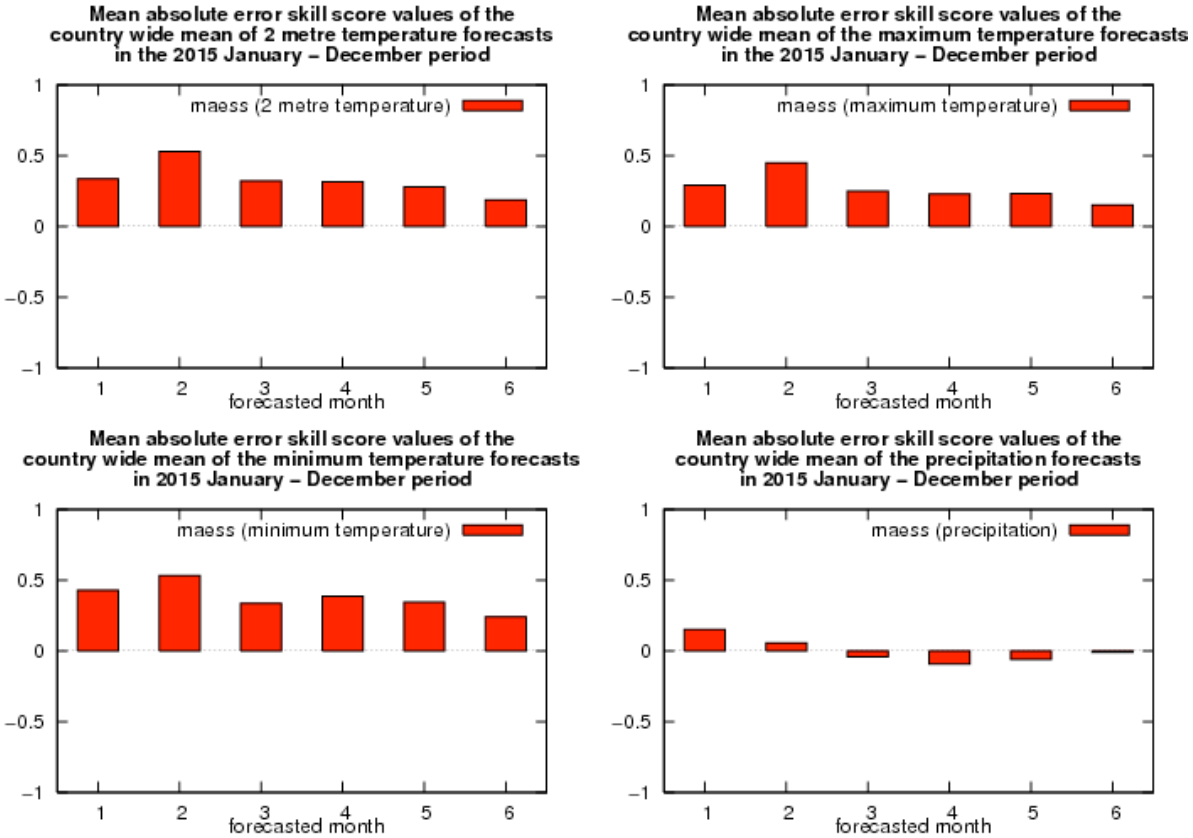


Fig. 12 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2015. Reference forecast was the 30-year climatological mean.

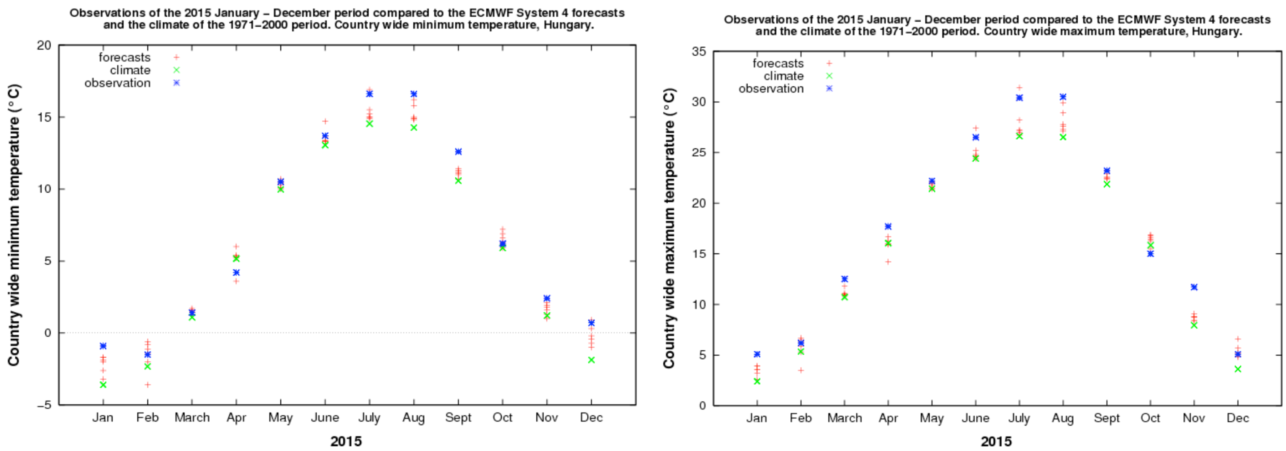


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Fig. 13 Comparison of the forecasts issued for the 2015 January-December period with the observations and the climate for minimum and maximum temperature.

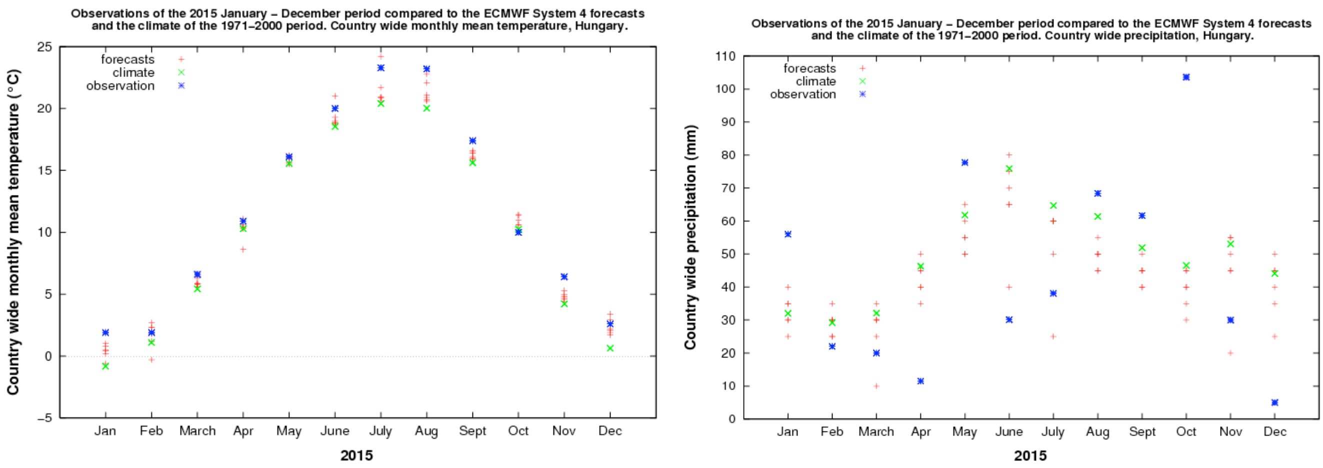

Fig. 14 Comparison of the forecasts issued for the 2015 January-December period with the observations and the climate for monthly mean temperature and monthly amount of precipitation.

3.1.6 Monthly forecasts

The verification of the monthly forecast started last year, so this is the first occasion we can produce diagram for the whole year. The prediction is issued each week, the time-resolution is 1 day. This product is based on the monthly forecast of the ECMWF, but the first 7 days is corrected by the forecaster. Fig. 15 shows the mean absolute error skill scores of the minimum-, maximum- and daily mean temperature.

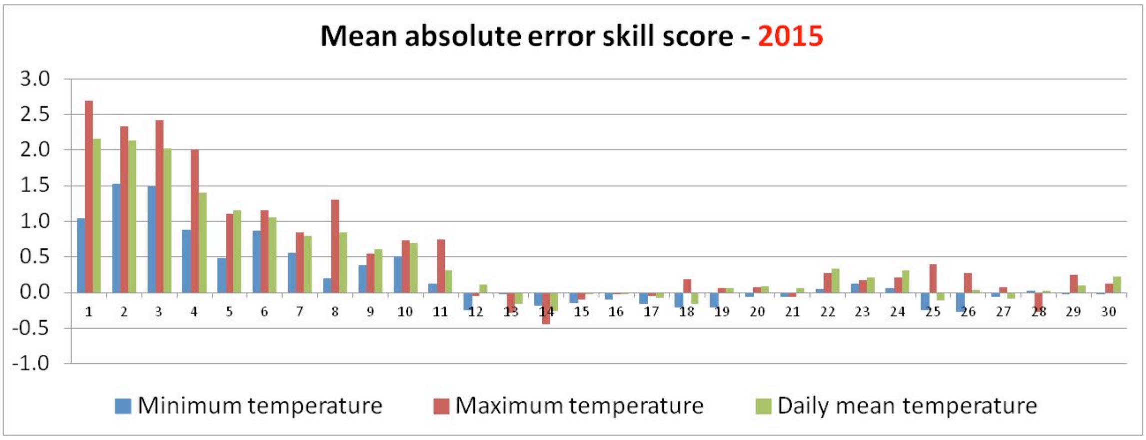

Fig. 15 Mean absolute error skill score of the monthly forecast for 2015.

3.2 Subjective verification

3.2.1 Subjective scores

The subjective verification is occasionally made, when weaknesses and strengths of the forecast are quite crucial in case of severe or high impact weather.

4. Feedback on ECMWF “forecast user” initiatives

The Known Forecasting Issues page is a very useful development, although it is not used in the OMSZ each day. It is good to know that the problems we report are handled and projected to maintain. The Severe Weather Catalogue is not used generally either. It could be useful if someone would like to get some information on a severe event quickly (no data retrieve and visualization required). We use our own visualization software and focus on the events in connection with the Carpathian Basin or Central Europe.

5. References

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