Application and verification of ECMWF products 2017

Hungarian Meteorological Service, István Ihász, Antal Fischer, Balázs Fehér and Mihály Szűcs

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). A detailed verification of humidity parameters was made for the extended winter period of 2016/2017, due to the frequent underestimation of persistent low level cloudiness and fog in the Carpathian Basin (*Kolláth and Fischer*, 2017).

2. Use and application of products

2.1 Post-processing of ECMWF model output

Describe the different ways in which you post-process ECMWF forecasts, in the following categories:

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

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 (Hewson, 2017). Similar type graphical product was developed for visibility before winter season in October 2016 (Fig. 1). This product got wide attention and quite positive feedback from forecasters and internal users.

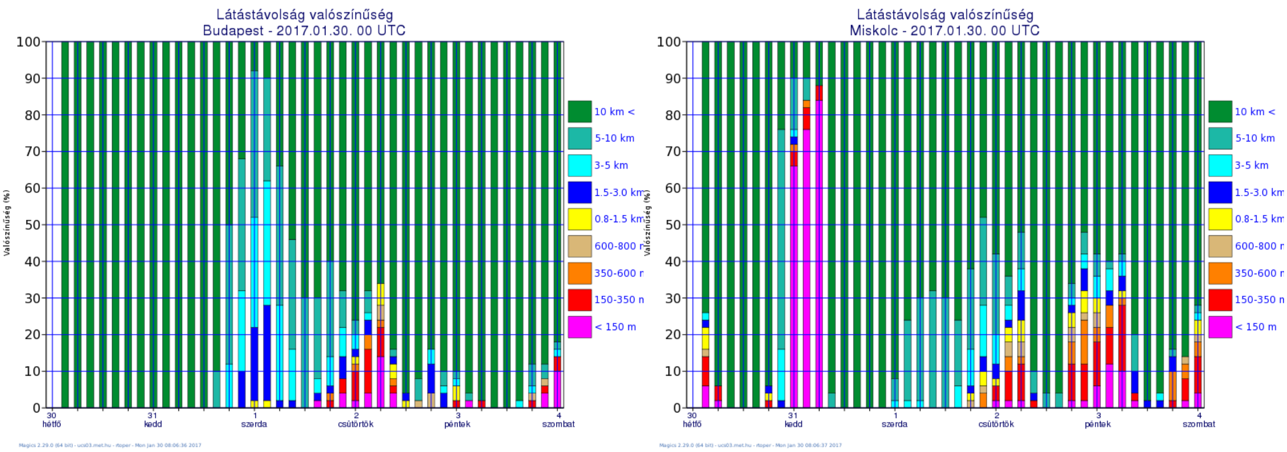


Fig. 1 Visibility probability diagram for two different locations (Budapest and Miskolc) in Hungary at the same day (forecast base time: 00UTC 30 January 2017).

2.2 ECMWF products

2.2.1 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 2011 a special ensemble meteogram was developed containg CAPE index, wind shear between 500hpA and 10m and average relative humidity of the layer of 850-700 hPa (*Lázár and Ihász*, 2016).

In 2013 an 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, *Gaál and Ihász*, 2015). In 2014 and 2015 predictability of extreme precipitation for river catchments was studied for 120 selected cases, including extreme flood occurred in river Danube between May and June 2013. Uncalibrated and calibrated precipitation ensemble forecasts were compared, as a result of objective verification based on 120 extreme situations ensemble calibration can slightly improve the forecasts in extreme cases too (*Mátrai and Ihász, 2017*).

2.2.2 Product requests

None

3. Verification of products

3.1 Objective verification

The objective verification is performed via the Objective Verification System (OVISYS) developed in the Hungarian Meteorological Service. More details on OVISYS are available in '*Verification of ECMWF products, 2006*'. The computed scores are presented on Time-TS diagrams as a function of lead time (with the forecast range on the x-axis) (Fig. 2-10). All the results presented here use the measurements of Hungarian SYNOP stations under 400 m above sea level for verification.

The results might be compared with the ones shown in '*Application and verification of ECMWF products, 2016*' for the verified models.

3.1.1 Direct ECMWF model output (only HRES)

In this chapter the 00 and 12 UTC runs of ECMWF HRES (ECM_OPERHR) model were verified against the Hungarian SYNOP observations for 2016. BIAS and RMSE values are calculated *84* hours ahead with *3-hour* timestep. The verification is performed for the following variables: *2m temperature*, *2m relative humidity*, *10m wind speed*, and *total cloudiness* (Fig. 2-3).

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

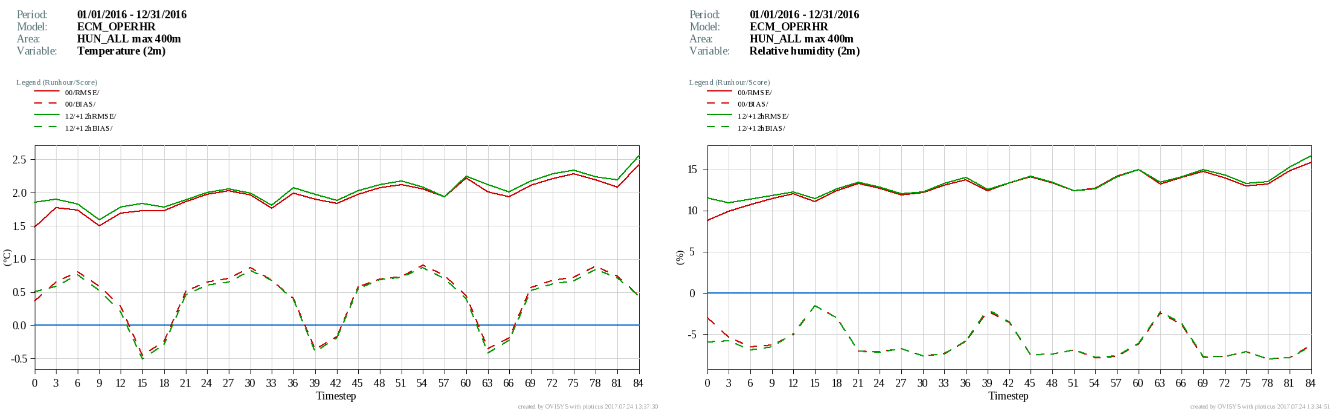
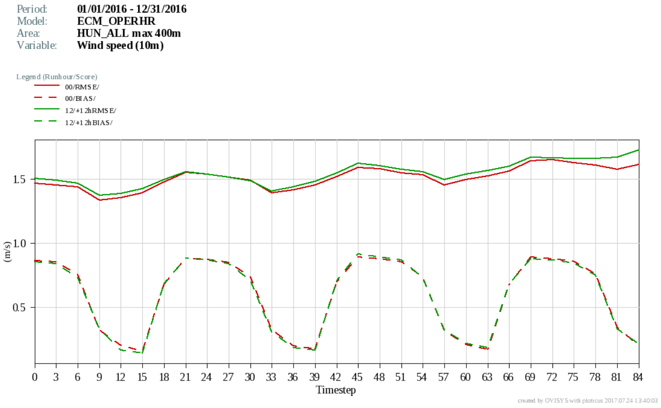


Fig. 2a-b RMSE (solid) and BIAS (dashed) values of a) 2m temperature and b) 2m relative humidity forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

10m wind speed and total cloudiness:



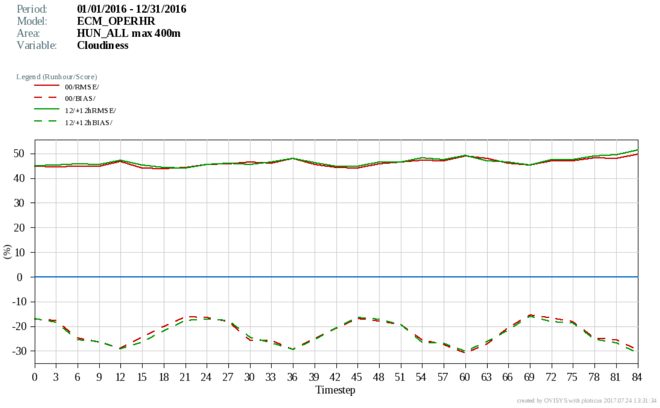
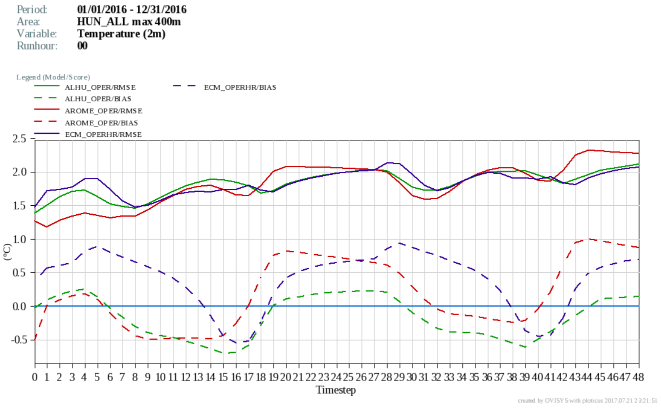


Fig. 3a-b RMSE (solid) and BIAS (dashed) values of a) 10m wind speed and b) total cloudiness forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

3.1.2 ECMWF model output compared to other NWP models

Hereafter the performance of the 00 and 12 UTC runs of ECMWF HRES (ECM_OPERHR), ALADIN/HU (ALHU_OPER) and AROME/HU (AROME_OPER) models is compared in the first *48* forecast hours with *1-hour* timestep via OVISYS. The forecast values are taken from the (highest resolution) grid box from the ECMWF HRES, a 0.1°x0.1° post-processing grid from the ALADIN/HU, and from a 0.025°x0.025° grid from the AROME/HU model (the original mesh size of the ALADIN/HU model is 8km, while for the AROME/HU model it is 2.5 km, both are on Lambert projection). The scores are computed using the Hungarian SYNOP observations for 2016. The verification is performed for the following variables: *2m temperature*, *2m relative humidity*, *10m wind speed*, *total cloudiness* and – only for 00 UTC runs – *daily accumulated precipitation* (Fig. 4-8).

2m temperature:



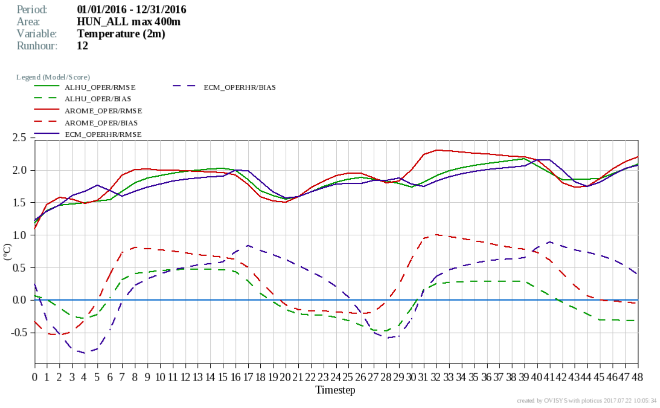
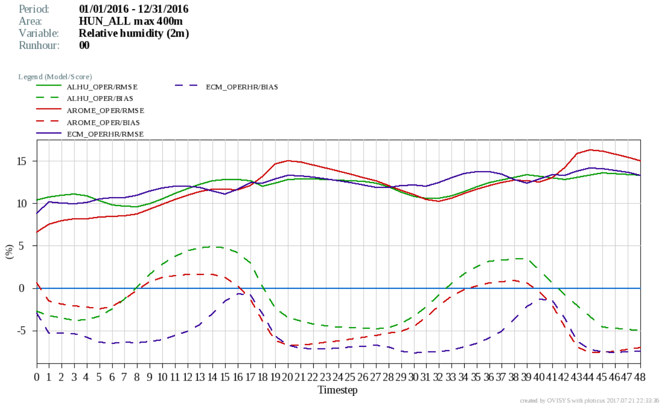


Fig. 4a-b Comparison of RMSE (solid) and BIAS (dashed) values of 2m temperature forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

2m relative humidity:



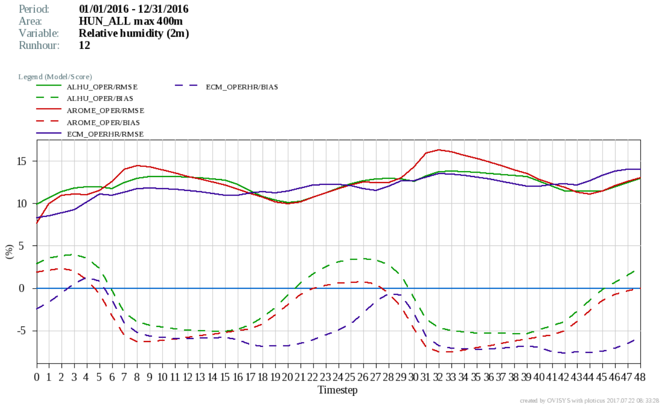
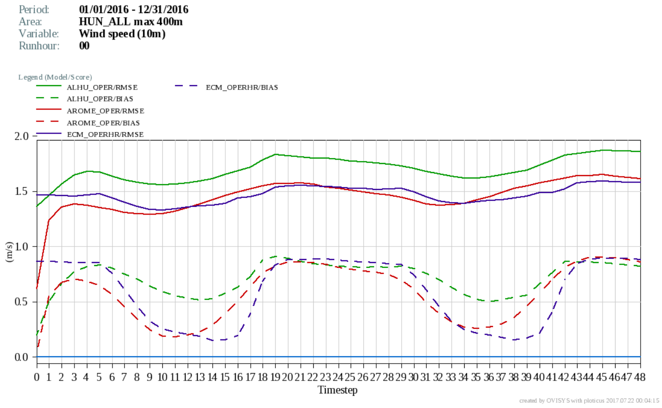


Fig. 5a-b Comparison of RMSE (solid) and BIAS (dashed) values of 2m relative humidity forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

10m wind speed:



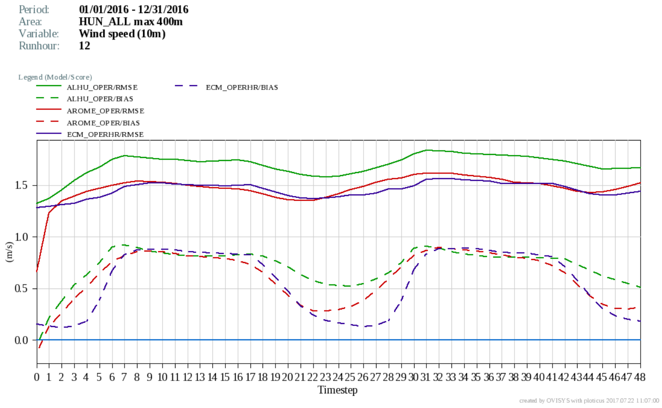
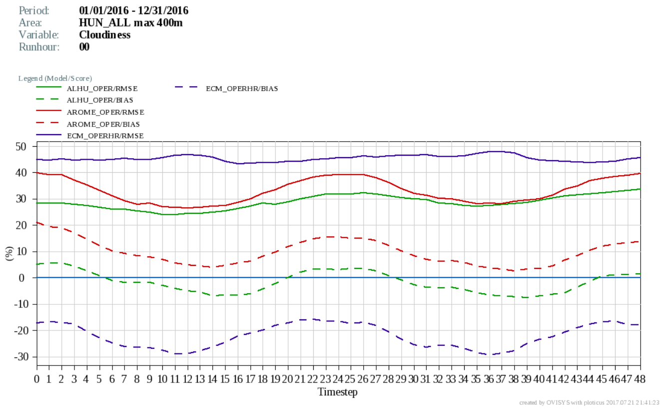


Fig. 6 a-b Comparison of RMSE (solid) and BIAS (dashed) values of 10m wind speed forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

Total cloudiness:



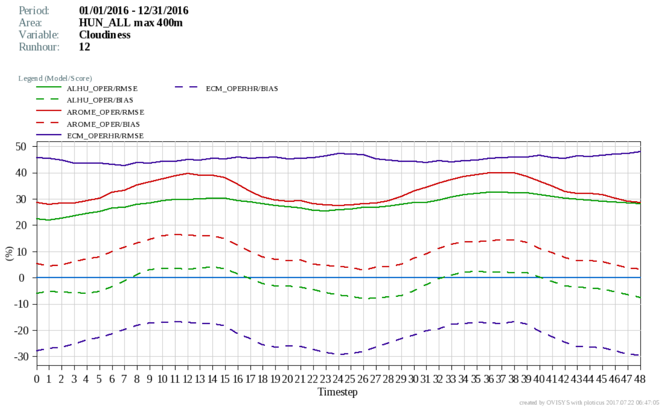


Fig. 7a-b Comparison of RMSE (solid) and BIAS (dashed) values of total cloudiness forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

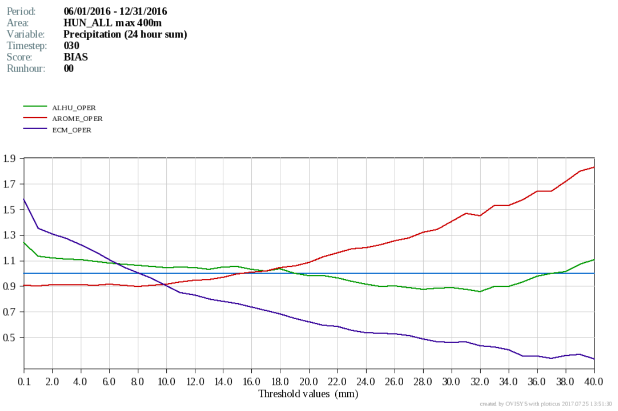
Precipitation:

In the following the frequency BIAS and the SEDI (Symmetric Extremal Dependence Index) verification scores of 24 h precipitation of the three models (ECMWF, ALADIN/HU and AROME/HU) can be seen in the 30th hour of the forecast for 2016 as a function of certain precipitation thresholds. These verification measures are independent of 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.

Note that – due to SEDI is independent of the BIAS – the models would show the same results concerning SEDI after a bias correction, and – due to a data collection error – the verified period is 06/01/2016 - 12/31/2016 and the ECMWF model has only 0.5°x0.5° resolution instead of the full year and ECMWF HRES.

Concerning the values of frequency BIAS (Fig. 8a), until the 7 mm/day and between the 10 and 19 mm/day threshold the ALADIN/HU and the AROME/HU show the best result – both are running close to the perfect +1 value (especially between 15 and 18 mm/day). Over the 19 mm/day threshold the ALADIN/HU is the best model. The ECMWF has similar or slightly better results only between 7 and 9 mm/day, but under 7 and over 9 mm/day, it has obviously the biggest frequency BIAS, therefore it is the worst (Fig. 8a).

Regarding the SEDI score (Fig. 8b), under the 10 mm/day threshold the ECMWF gives the highest (i.e. the best) results. Between 10 and 18 mm/day all three models show similar scores. Between 18 and 33 mm/day the AROME/HU is slightly better than the ECMWF and much better than ALADIN/HU model. The ALADIN/HU has the best results only over 36 mm/day. Over 33 mm/day the ECMWF is much worse than the two regional models.



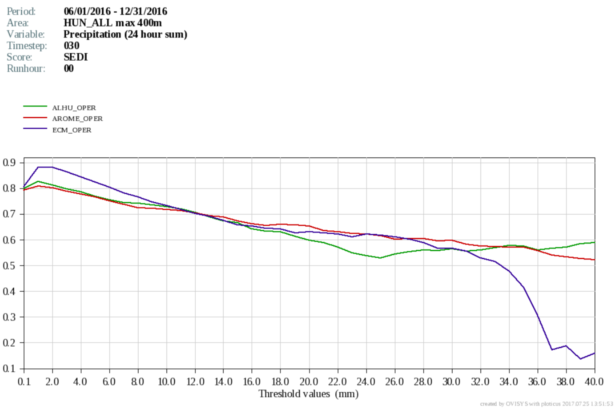


Fig. 8a-b The a) frequency BIAS and b) SEDI values of 24 h precipitation forecasts (in the 30th hour of the forecast) of the ECMWF (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary against precipitation thresholds. *Note that – due to a data collection error – the verified period is 06/01/2016 - 12/31/2016 and the ECMWF model has only 0.5°x0.5° resolution instead of the full year and ECMWF HRES.*

Finally, some more interesting examples will be presented from the seasonal and periodic verification results that regularly made with OVISYS as well. During this the performance of the 00 UTC runs of ECMWF HRES (ECM_OPERHR), ALADIN/HU (ALHU_OPER), AROME/HU (AROME_OPER), FOCUS (FOCUS_OPER) and WRF (WRF_OPER) models is compared in the first *48* forecast hours with *1-hour* (in case of surface parameters) and *12-hour* (in case of upper air parameters) timestep. The forecast values of the ECMWF HRES, ALADIN/HU and AROME/HU 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 2016 (Fig. 9-10).

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.

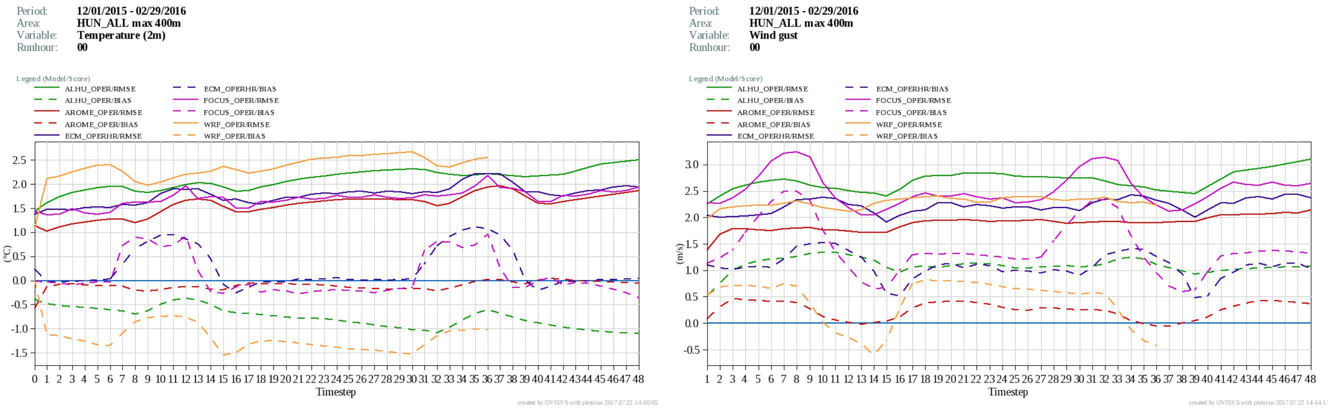


Fig. 9a-b Comparison of RMSE (solid) and BIAS (dashed) values of the 00 UTC runs of ECMWF HRES (blue), ALADIN/HU (green), AROME (red), FOCUS (purple) and WRF (yellow) models over Hungary in terms of a) *2m temperature* in the winter of 2015/2016 and b) *wind gust* in the summer of 2016.

The verification result for the extended winter period of 2016/2017 (11/01/2016 – 03/31/2017) – performed for the following variables: *2m relative humidity*, *925 hPa relative humidity* (except FOCUS), *dewpoint* (except FOCUS) and *total cloudiness* – (Fig. 10a-d) are made for two reasons:

i) At this point of time (2017) ECMWF would particularly welcome any verification related to surface humidity measures (e.g. dewpoint, relative humidity, specific humidity) (as you wrote in the report template).

ii) Forecasting of low-level planetary boundary layer clouds is still a big challenge for the ECMWF and also for our local models running with ECMWF lateral boundary conditions.

In the winter of 2016/2017, which were dominated by cold anticyclonic weather regimes that is, persistent low-level stratiform clouds was frequent in the Carpathian Basin, ECMWF (both HRES and ENS) underrepresented fog and low clouds in many cases. Therefore conditional occurrences of large forecast errors were investigated according to air mass characteristics, flow regimes to find reasons for particularly high number of days with serious underestimation of low level cloudiness in 2016/2017 winter. More information and results are available in this poster (*Kolláth and Fischer*, 2017): https://www.ecmwf.int/sites/default/files/elibrary/2017/17290-stratus-clouds-wintertime-anticyclones-hungary.pdf

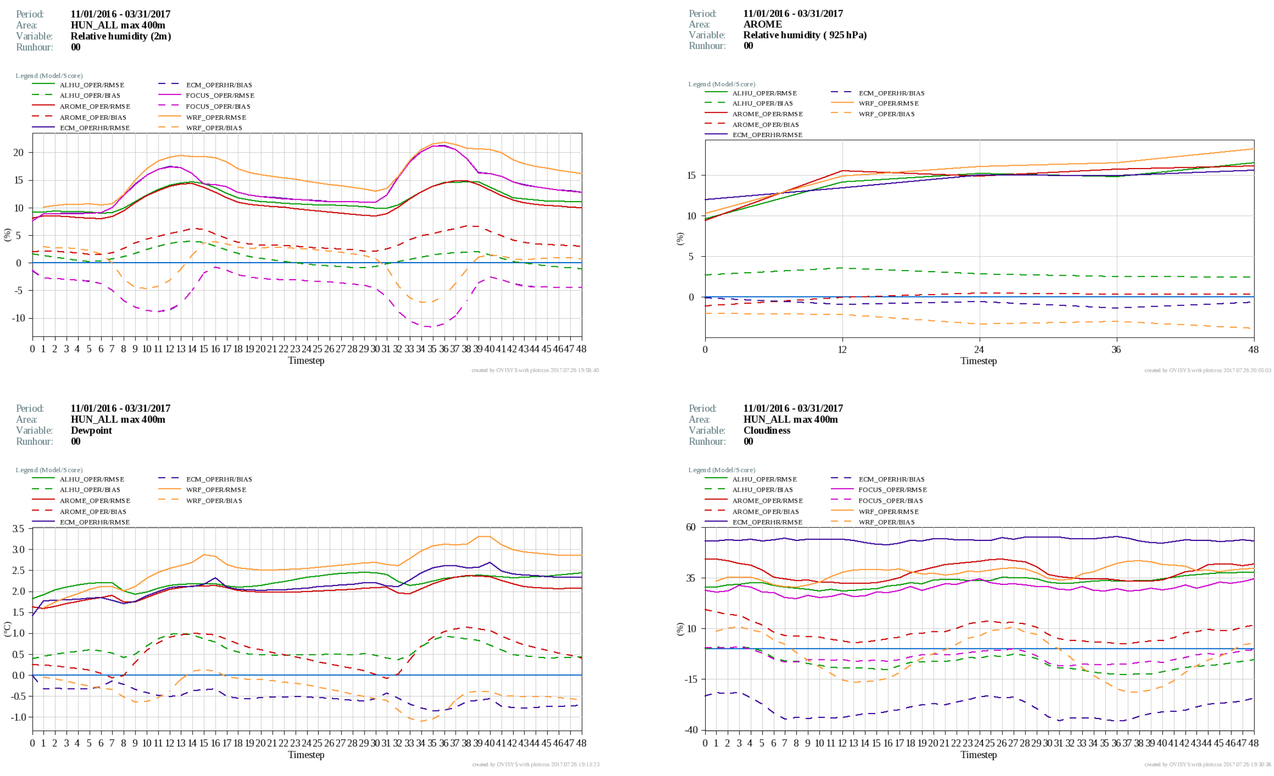


Fig. 10a-d Comparison of RMSE (solid) and BIAS (dashed) values of the 00 UTC runs of ECMWF HRES (blue), ALADIN/HU (green), AROME (red), FOCUS (purple) and WRF (yellow) models over Hungary in terms of a) *2m relative humidity*, b) *925 hPa relative humidity*, c) *dewpoint* and d) *total cloudiness* for the period of 11/01/2016 – 03/31/2017.

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 in case of minimum and maximum temperature. The 14-day moving average of the improvement of the forecaster on ECMWF HRES has usually remained under 10 % (Fig 12).

In the calculation of Complex Scores both temperature and cloudiness are playing significant role. That is the explanation of the low values in December (the higher the score the better the forecast) when many low-stratus event occurred which cloudiness was underestimated by the models. That caused usually overestimation in maximum temperature and underestimation in minimum temperature which is mainly corrected by the forecasters, because it was relatively easy to know the behaviour of the model day by day.

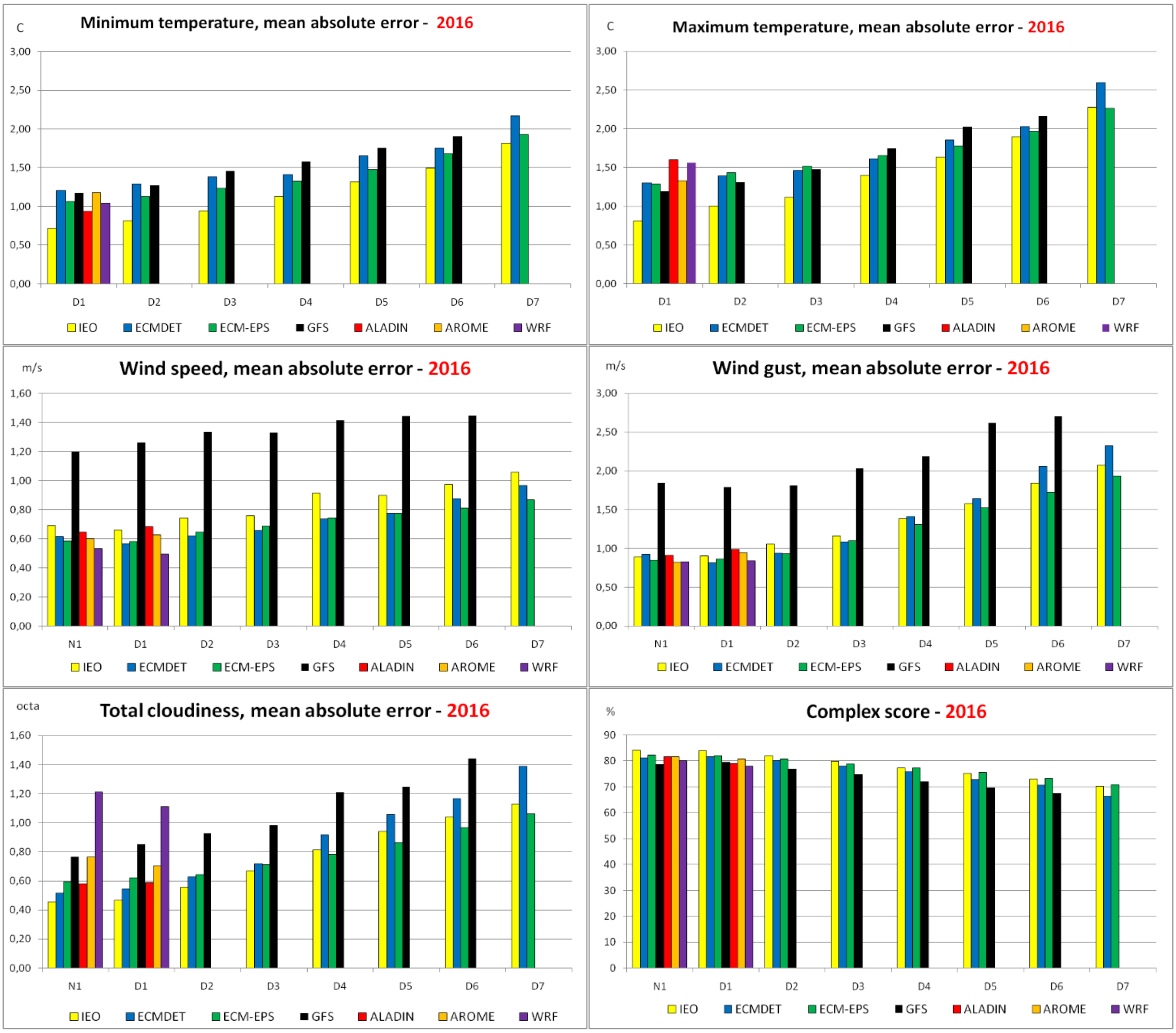


Fig. 11 Mean Absolute Error (MAE) of minimum and maximum temperature, average wind speed and wind gust, total cloudiness forecast and Complex score for different ranges in case of ALADIN, AROME, ECMWF HRES, ECMWF ENS mean, GFS and the Human Forecaster for 2016. N1 represent the first night, D1, D2, … etc the days after the issue of the forecast.

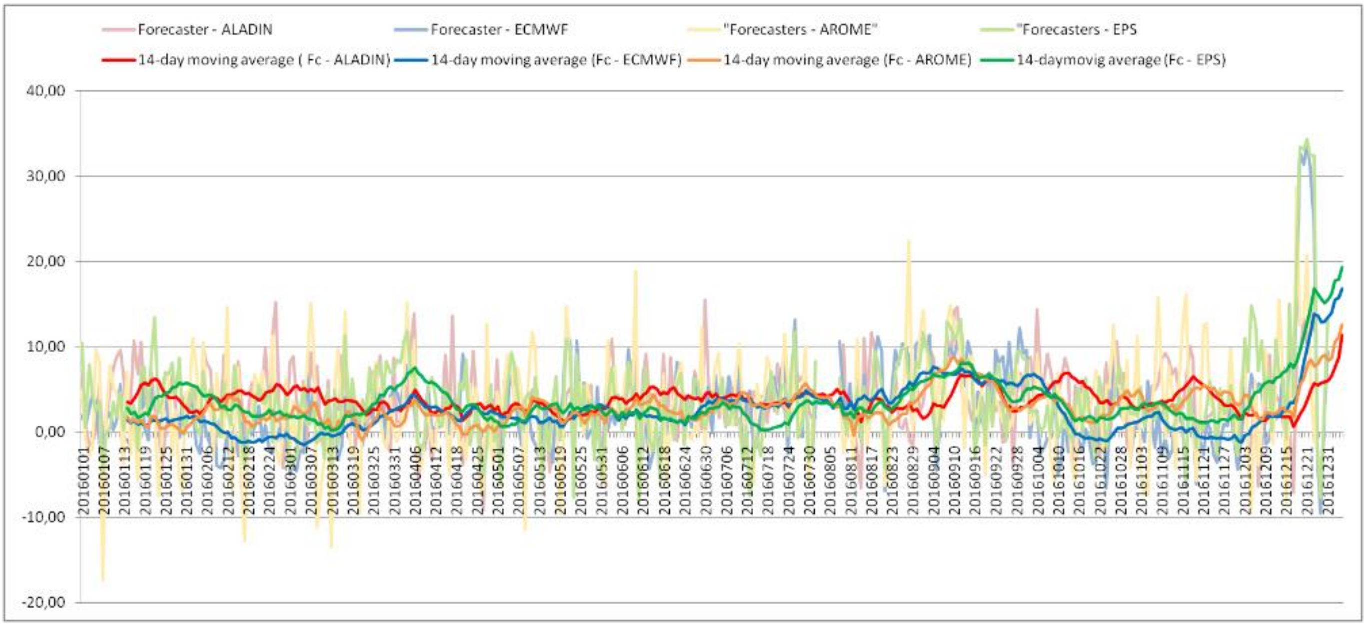


Fig. 12 Difference of the daily Complex Score for *the first day* calculated for the forecaster and the models in 2016; 14-day moving averages are also shown.

As soon as it was possible in 1998 investigation of the applicability of ECMWF's seasonal forecasting system was done. The use of 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. Verification results for 2016 are showed on Fig 13-15.

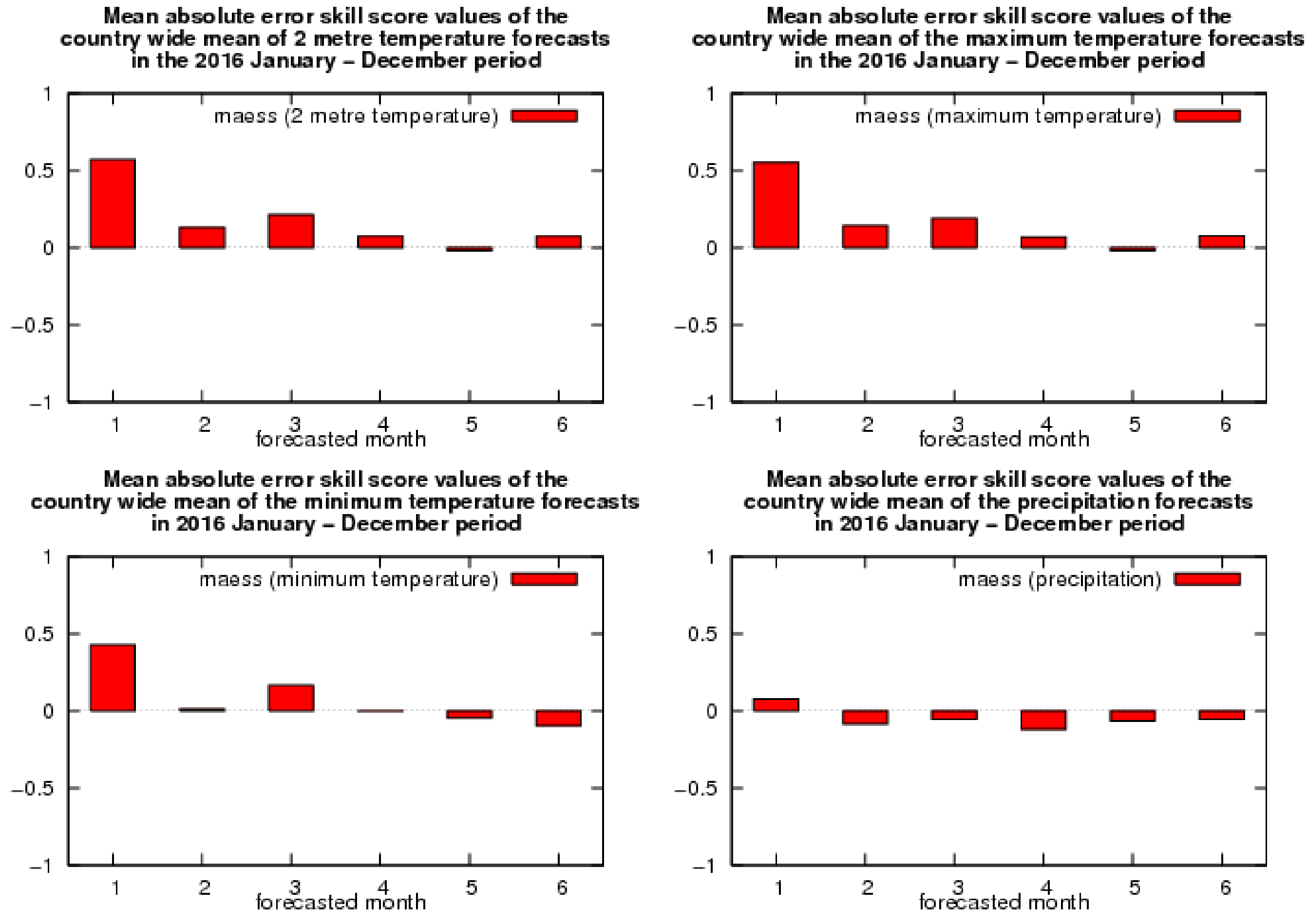


Fig. 13 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2016. Reference forecast was the 30-year climatological mean.

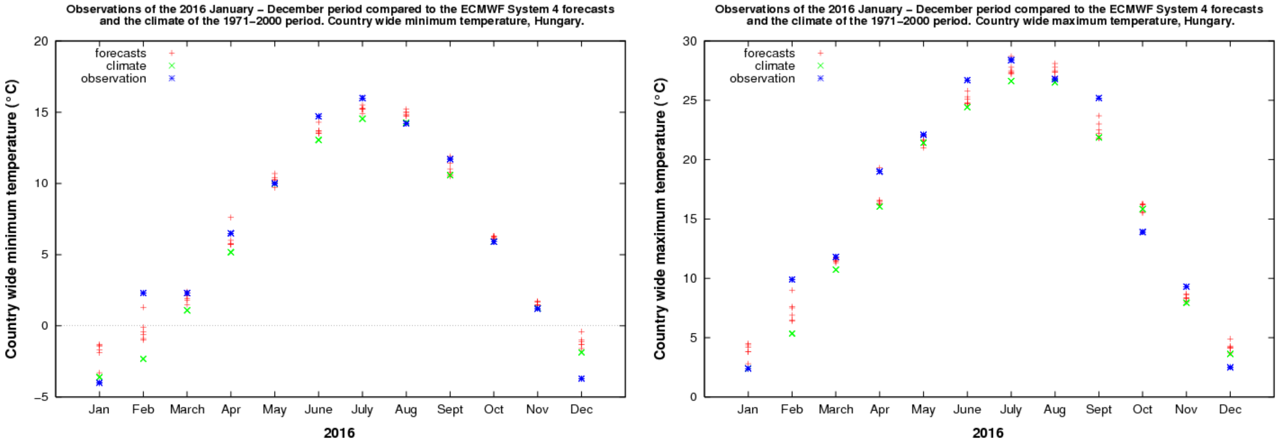


Fig. 14 Comparison of the forecasts issued for the 2016 January-December period with the observations and the climate for minimum and maximum temperature

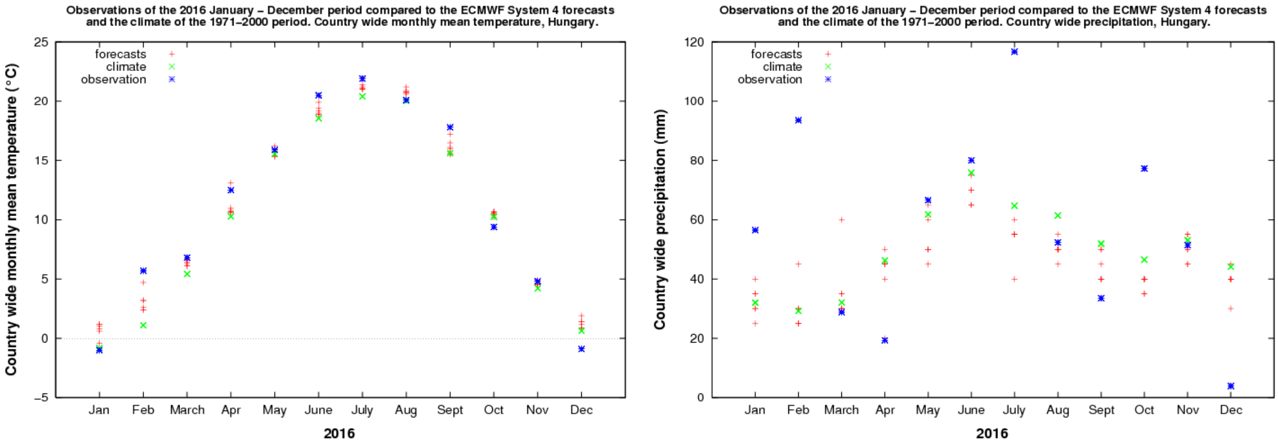


Fig. 15 Comparison of the forecasts issued for the 2016 January-December period with the observations and the climate for monthly mean temperature and monthly amount of precipitation.

3.1.3 Post-processed products

None

3.1.4 End products delivered to users

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

None

3.2.2 Case studies

None

4. Feedback on ECMWF “forecast user” initiatives

- The Known Forecasting Issues page is a very useful development, although it is not used each day in the OMSZ. 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 to relevant publications

Hewson, T, 2017: Use and Verification of ECMWF Products in Member and Co-operating States (2016), *ECMWF Technical Memoranda*, 797.

Gaál, N. and I. Ihász, 2014: Predictability of the cold drops based on ECMWF's forecasts over Europe. *ECMWF Newsletter* 140. 26-30.

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Lázár, D. and I. Ihász, 2016: Potential benefit of the ensemble forecasts in case of heavy convective weather situations. *Időjárás*, 120, 383-394.

Mátrai A. and I. Ihász, 2017: Calibrating forecasts of heavy precipitation in river catchments; *ECMWF Newsletter* 152, 34-40.

Szűcs, M., P. Sepsi and A. Simon, 2016: Hungary's use of ECMWF ensemble boundary conditions. *ECMWF Newsletter* 148. 24-30.