# Application and verification of ECMWF products 2018

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.

## 2. Use and application of products

### 2.1 Post-processing of ECMWF model output

#### *2.1.1 Statistical adaptation*

None

#### *2.1.2 Physical adaptation*

The Hungarian limited are modelling activity consists three major systems and both of them uses LBCs interpolated from ECMWF forecasts in framework of Optional BC Programme.

The hydrostatic ALADIN model with 8 km resolution is coupled with three-hourly frequency and with 6 hourly time-lagged mode. It runs four-times per day: at 00 UTC +54h, at 06 and 12 UTC +48h and at 18 UTC +39h forecasts are made. LBCs are used from ECMWF's HRES since 2008 (*Bölöni et al.*, 2009).

The non-hydrostatic AROME model has 2.5 km horizontal resolution and it is coupled with one-hourly frequency and with 6-9 hourly time-lagged mode. It runs eight-times per day: at 00, 06, 12, 18UTC +48h and at 03, 09, 15, 21UTC +36h forecasts are realized. LBCs are used from ECMWF's HRES since 2012.

The LAMEPS is based on ALADIN model and it is coupled with three-hourly frequency. It runs one time per day at 18 UTC for +60 hours. Its 11 members are the downscaling of the first 11 members of ECMWF's ENS 18UTC run. This coupling method is operational since 2016 (*Szűcs et al.*, 2016).

#### *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. Altogether more than 100 ensemble fields are derived.

### 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. 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 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) 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, 2017*' 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 2017. BIAS and RMSE values are calculated 84 hours ahead with *1-hour* (60 hours ahead) and *3-hour* (after 60 hours) timestep for surface parameters and with *12-hour* timestep for upper air parameters. The verification is performed for the following variables: *2 m temperature*, *dew point*, *total cloudiness*, *2 m* / *925 hPa* / *700 hPa relative humidity*, *10 m wind speed* and *wind gust* (Fig. 1-4).

**2 m temperature and dew point**

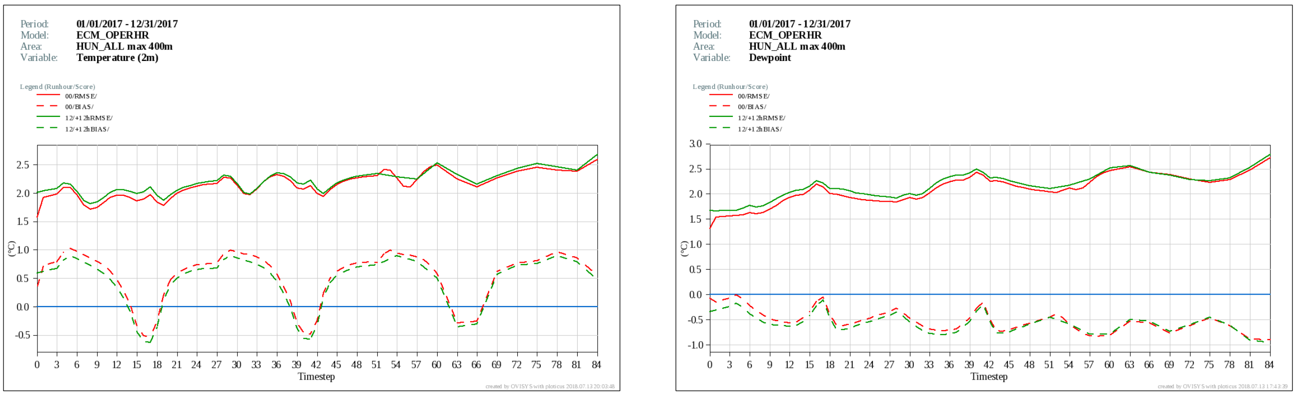



Fig. 1a-b RMSE (solid) and BIAS (dashed) values of a) 2 m temperature and b) dew point forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

**Total cloudiness and 2 m relative humidity**

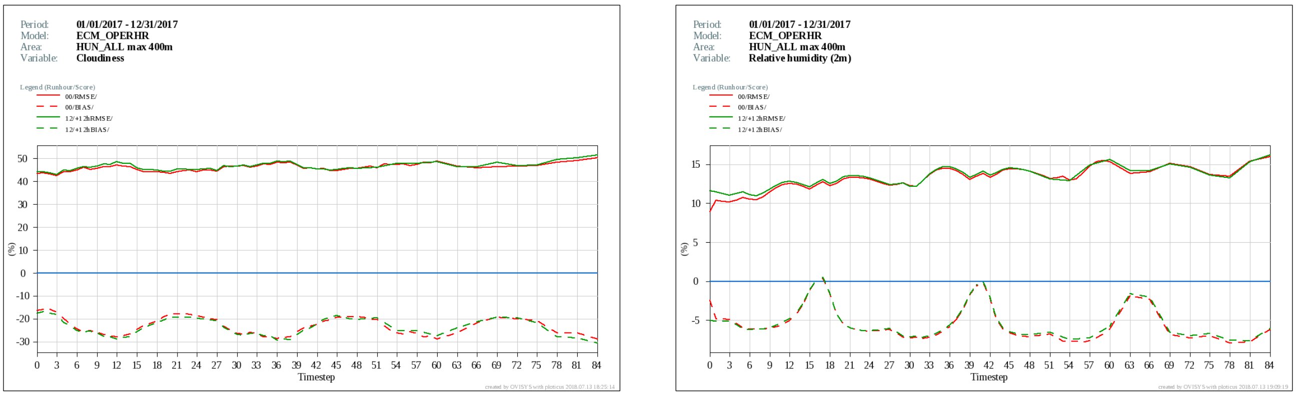
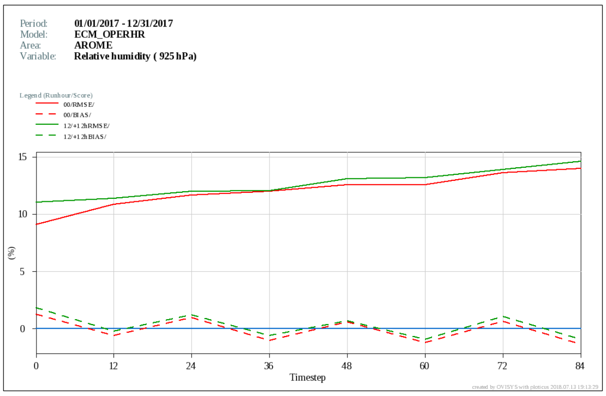



Fig. 2a-b RMSE (solid) and BIAS (dashed) values of a) total cloudiness and b) 2 m relative humidity forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

**925 and 700 hPa relative humidity**



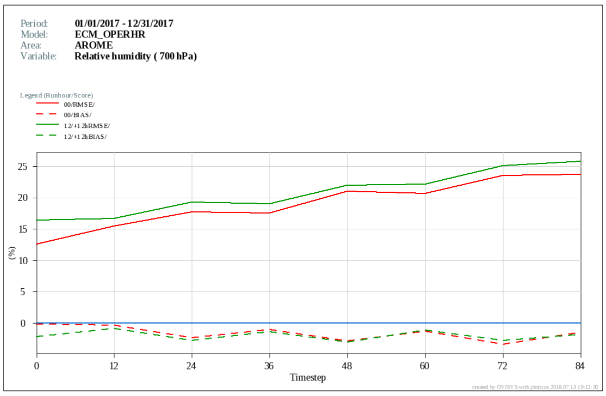
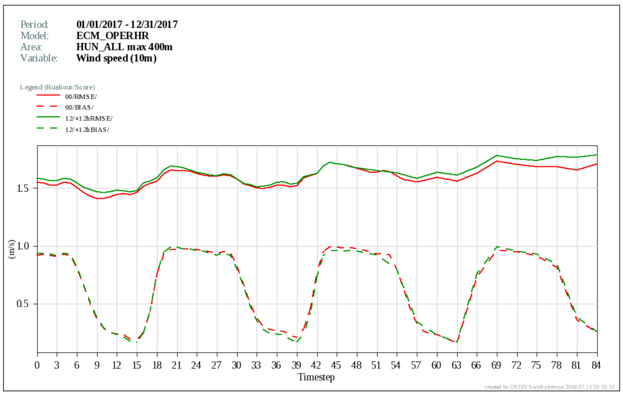




Fig. 3a-b RMSE (solid) and BIAS (dashed) values of a) 925 and b) 700 hPa relative humidity forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

**10 m wind speed and wind gust**



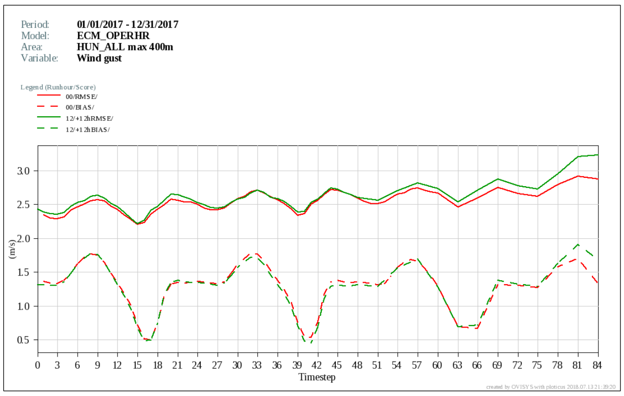
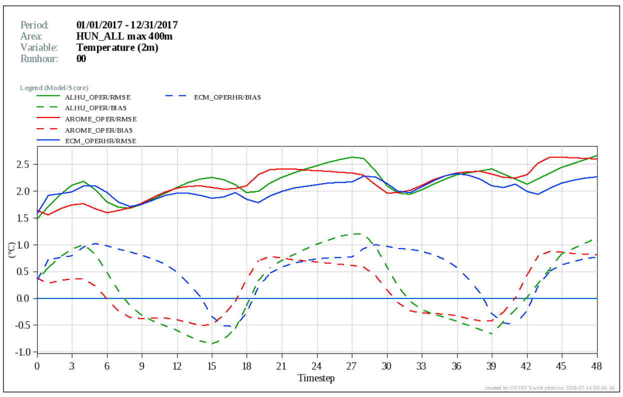




Fig. 4a-b RMSE (solid) and BIAS (dashed) values of a) 10 m wind speed and b) wind gust forecasts of the 00 (red) and 12 (green) UTC runs of ECMWF HRES model for Hungary.

### *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 are 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 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 8 km, 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 2017. The verification is performed for the following variables: *2 m temperature*, *dew point*, *total cloudiness*, *2 m* / *925 hPa* / *700 hPa relative humidity*, *10 m wind speed*, *wind gust* and – only for 00 UTC runs – *daily accumulated precipitation* (Fig. 5-13).

**2 m temperature**



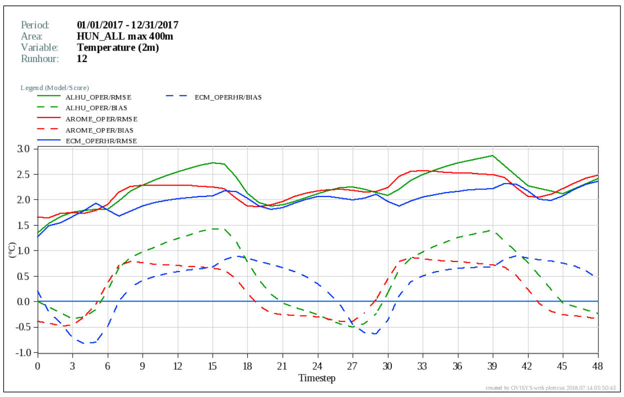
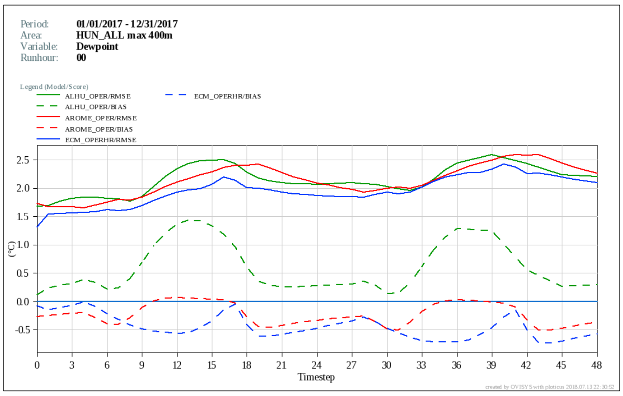




Fig. 5a-b Comparison of RMSE (solid) and BIAS (dashed) values of 2 m temperature forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## Dew point



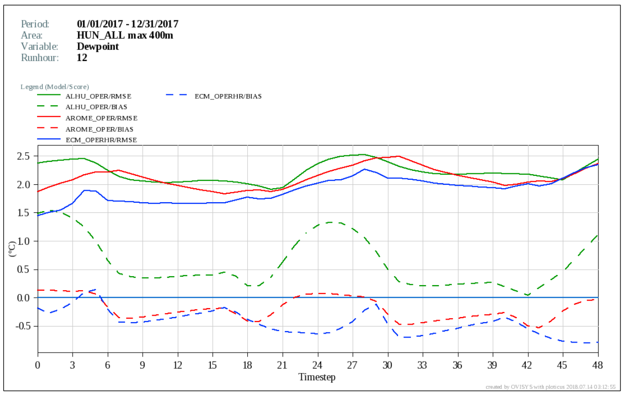
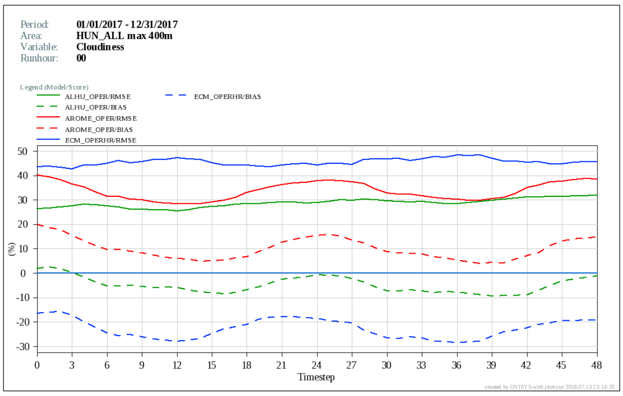




Fig. 6a-b Comparison of RMSE (solid) and BIAS (dashed) values of dew point forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## Total cloudiness



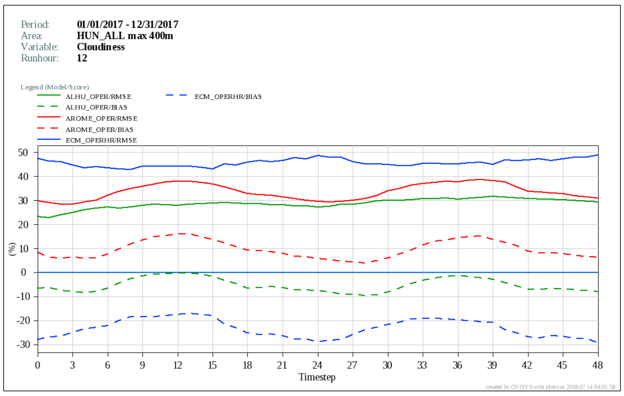
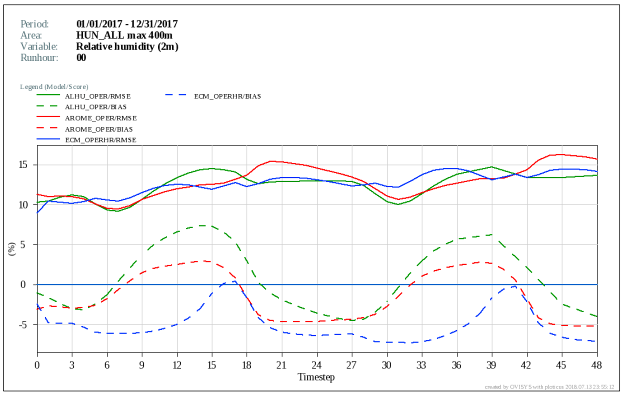




Fig. 7a-b Comparison of RMSE (solid) and BIAS (dashed) values of total cloudiness forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## 2 m relative humidity



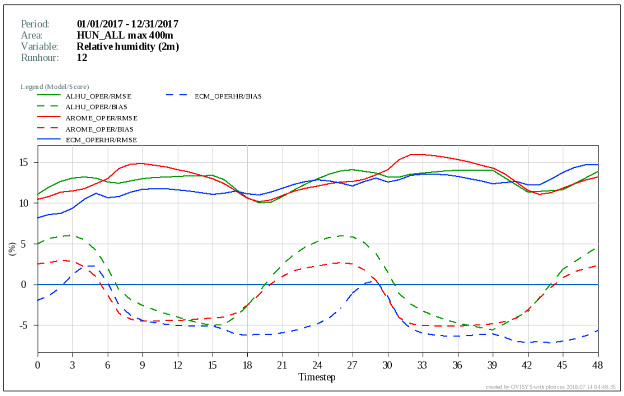




Fig. 8a-b Comparison of RMSE (solid) and BIAS (dashed) values of 2 m relative humidity forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## 925 hPa relative humidity

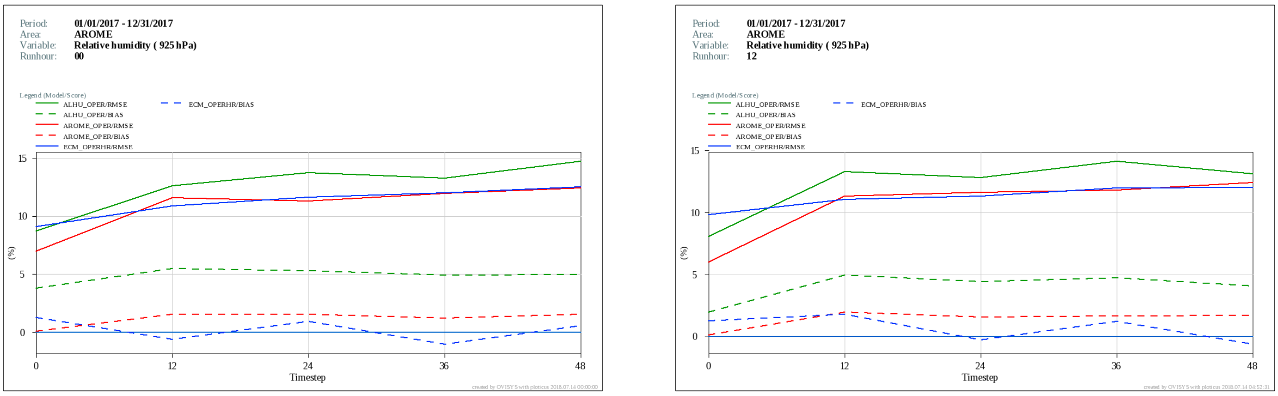



Fig. 9a-b Comparison of RMSE (solid) and BIAS (dashed) values of 925 hPa relative humidity forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## 700 hPa relative humidity

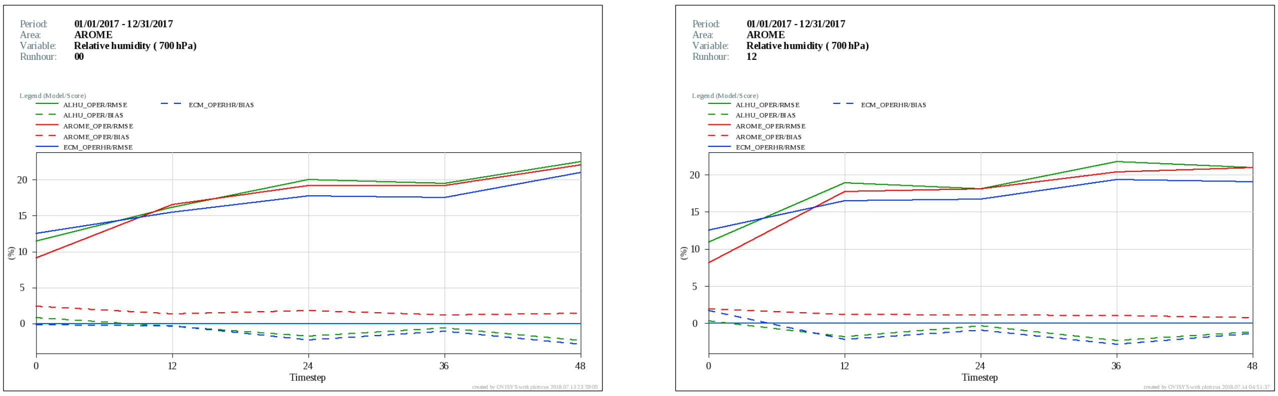



Fig. 10a-b Comparison of RMSE (solid) and BIAS (dashed) values of 700 hPa relative humidity forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## 10 m wind speed

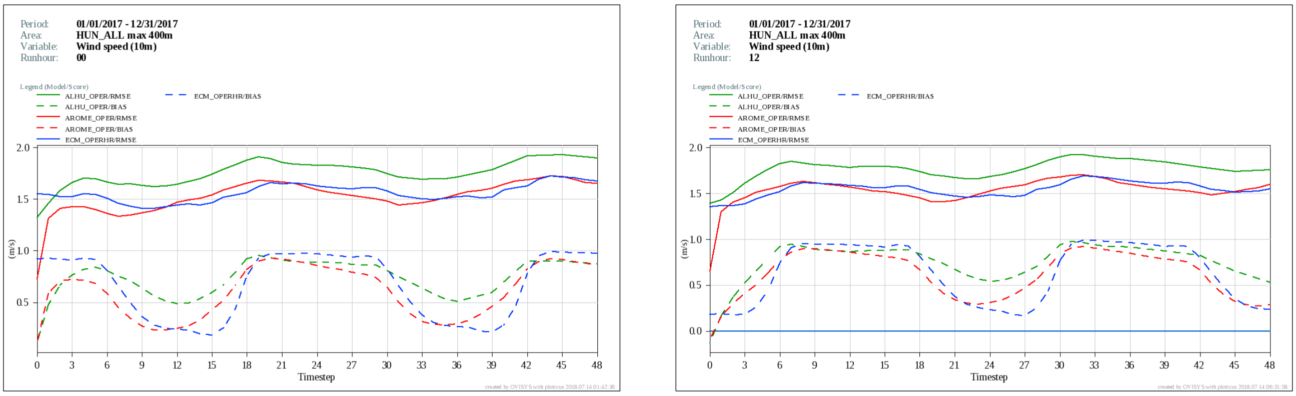



Fig. 11a-b Comparison of RMSE (solid) and BIAS (dashed) values of 10 m wind speed forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## Wind gust

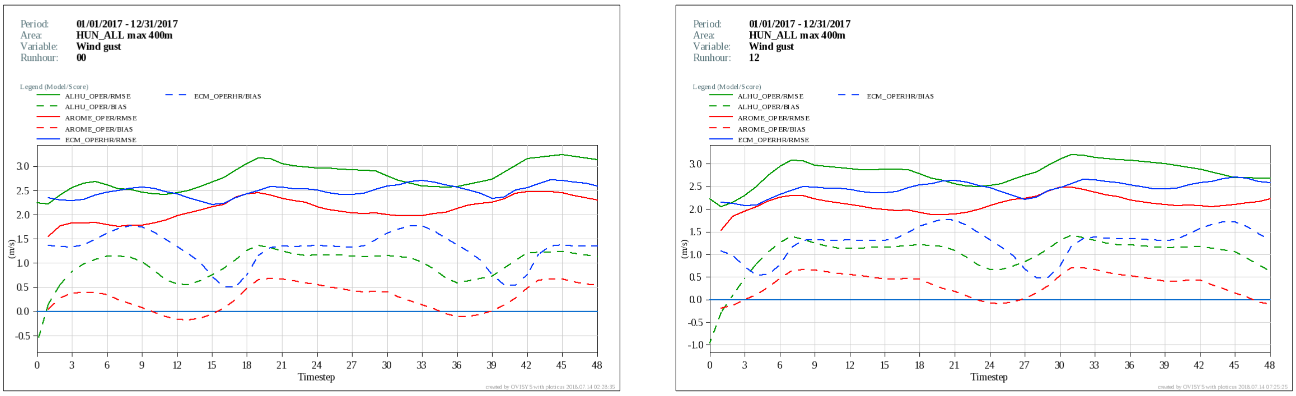



Fig. 12a-b Comparison of RMSE (solid) and BIAS (dashed) values of wind gust forecasts of the a) 00 and b) 12 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary.

## 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 2017 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 ECMWF model has only 0.5°x0.5° resolution instead of the ECMWF HRES.*

Concerning the values of frequency BIAS (Fig. 13a), the AROME/HU shows the best result at every threshold since it runs closest to the perfect +1 value (especially until 22 mm/day) and we can state that it is obviously overforecasted over 22 mm/day. The ECMWF has similar results only between 5 and 7 mm/day and has slightly better results only at 6 mm/day, but under 2 and over 12 mm/day, it has obviously the biggest frequency BIAS, therefore it is the worst. The ECMWF is overforecasted under 6 mm/day and underforecasted over 6 mm/day. The ALADIN/HU is better than ECMWF only under 2 mm/day and over 12 mm/day, but never has the best result and at every threshold it is overforecasted.

Regarding the SEDI score (Fig. 13b), under the 8 mm/day threshold the ECMWF gives the highest (i.e. the best) results. Between 8 and 13 mm/day all three models show similar scores. Between 13 and 21 mm/day the ALADIN/HU and the AROME/HU have similar scores but the ECMWF is already much worse and it remains the worst model until 37 mm/day. Between 21 and 28 and over 37 mm/day the ALADIN/HU, while between 28 and 36 mm/day the AROME/HU is slightly the best model.

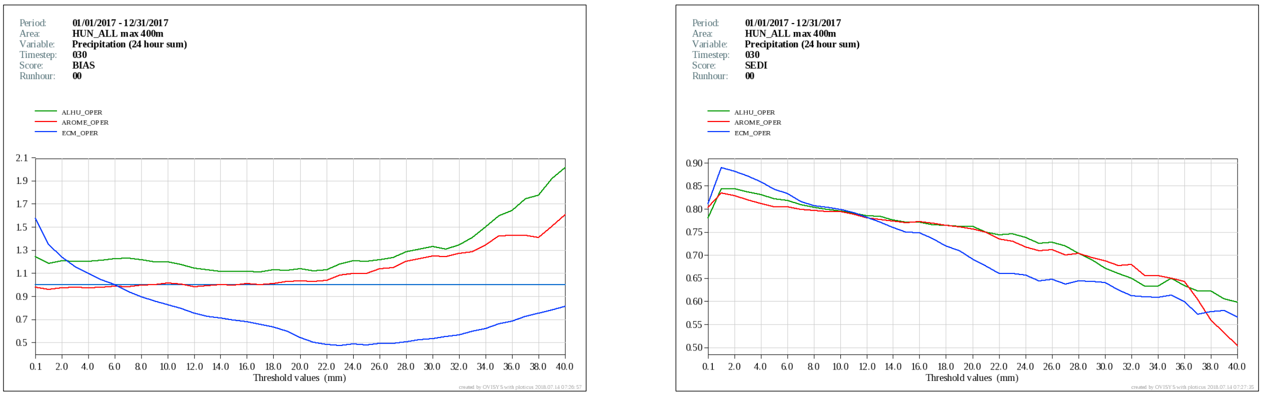
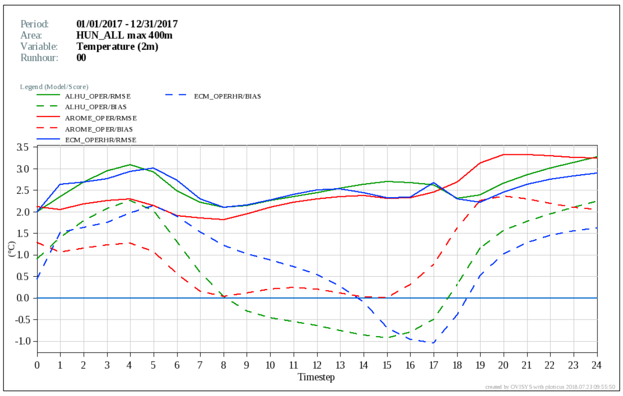



Fig. 13a-b The a) frequency BIAS and b) SEDI values of 24 h precipitation forecasts (in the 30th hour of the forecast) of the ECMWF (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary against precipitation thresholds. *Note that – due to a data collection error – the ECMWF model has only 0.5°x0.5° resolution instead of the ECMWF HRES.*

Finally, some more interesting examples will be presented that made with OVISYS as well. The participating models are the same as above (*see the first paragraph in this chapter*), but only the performance of the 00 UTC runs and only in the first 24 forecast hours with *1-hour* timestep was examined. Since the ECMWF would particularly welcome '*some conditional verification results (e.g. 2 m temperature bias stratified by cloud cover)*' (as you wrote in the report template) at this point of time (2018), the verification results in this case are performed for 2 m temperature (Fig. 14a-b) and total cloudiness (Fig. 15a-b) in those days when the sky was *clear* (for a total of 33 days in 2017) and when it was *covered by low-level clouds* (stratus) (for a total of 56 days in 2017) in most parts of Hungary (based on the forecasters' reports).



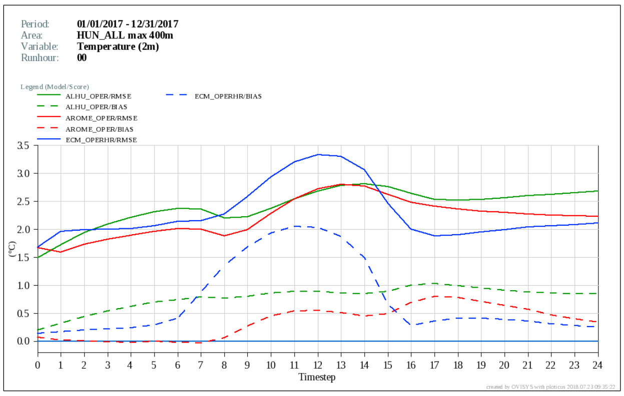
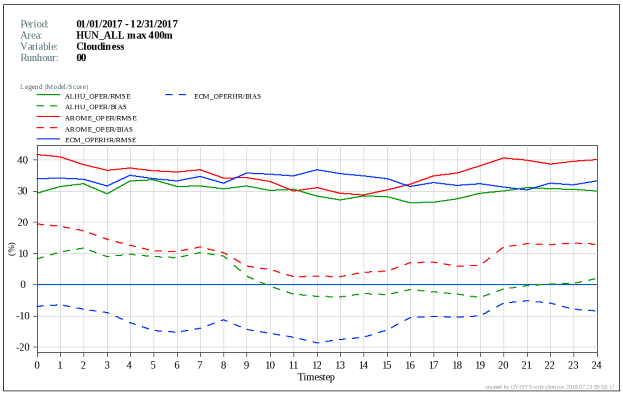




Fig. 14a-b Comparison of RMSE (solid) and BIAS (dashed) values of 2 m temperature forecasts of the 00 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary when the sky was a) clear and b) covered by low-level clouds in the most parts of the country.



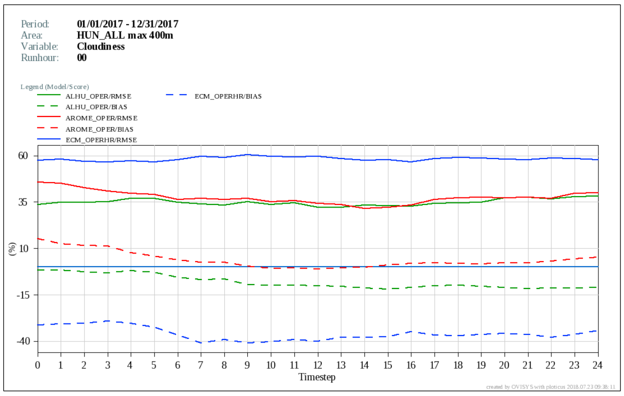




Fig. 15a-b Comparison of RMSE (solid) and BIAS (dashed) values of total cloudiness forecasts of the 00 UTC runs of ECMWF HRES (blue), ALADIN/HU (green) and AROME/HU (red) models over Hungary when the sky was a) clear and b) covered by low-level clouds in the most parts of the country.

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. 16 and 17. Details of calculating Complex Score is available in '*Application and verification of ECMWF products, 2017*'.

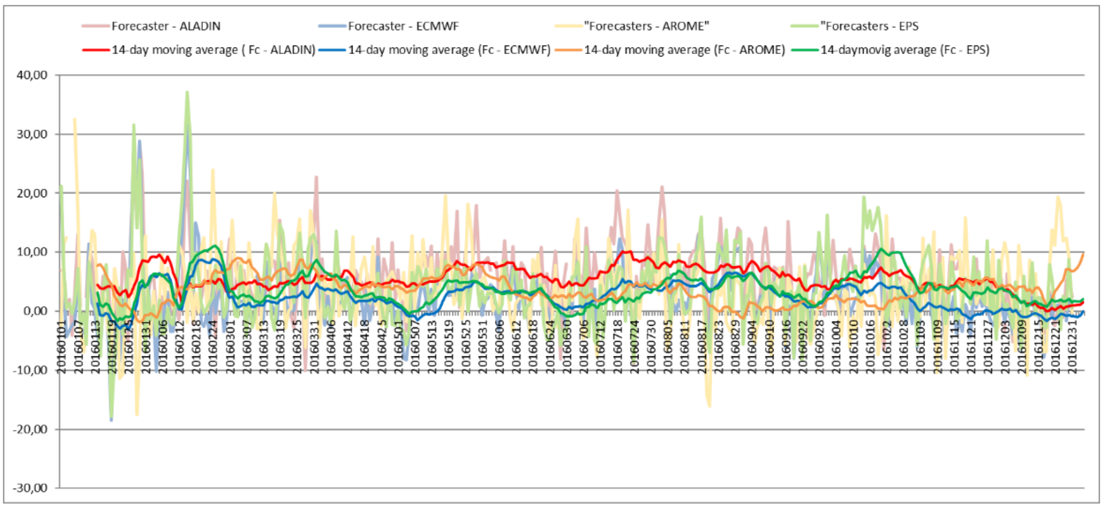



Fig. 16 Difference of the daily Complex Score for *the first day* calculated for the forecaster and the models in 2017; 14-day moving averages are also shown.


Fig. 17a-f Mean Absolute Error (MAE) of a) minimum and b) maximum temperature, c) average wind speed and d) wind gust, e) total cloudiness forecast and f) Complex score for different ranges in case of ALADIN, AROME, ECMWF HRES, ECMWF ENS mean, GFS and the Human Forecaster (IEO) for 2017. N1 represent the first night, D1, D2, … etc. the days after the issue of the forecast.

### *Seasonal forecast*

As soon as it was possible in 1998 investigation of the applicability of ECMWF's seasonal forecasting system was done. Forecasts for the 2 meter, maximum and minimum temperature and the amount of precipitation, for six regions of Hungary are issued in every month.

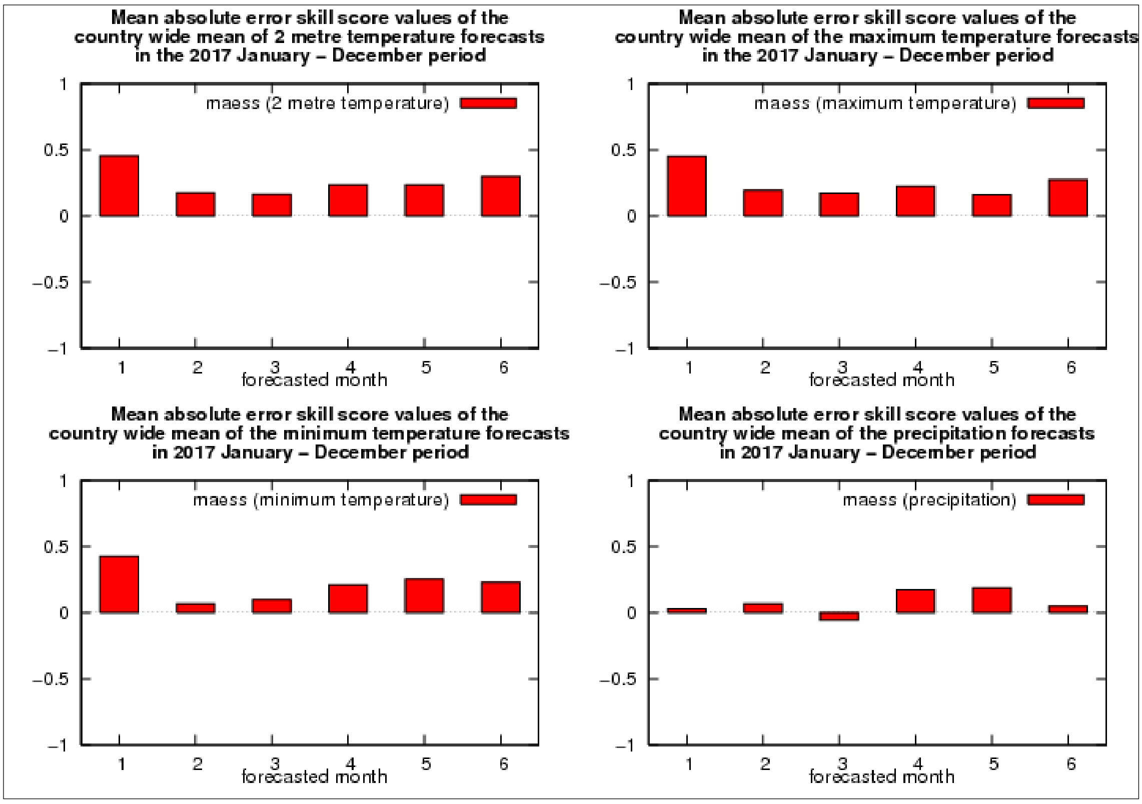



Fig. 18 Mean Absolute Error Skill Score of ensemble means of 2 meter, maximum, minimum temperature and precipitation for the 6 forecasted months in a forecast for 2017. Reference forecast was the 30-year climatological mean.

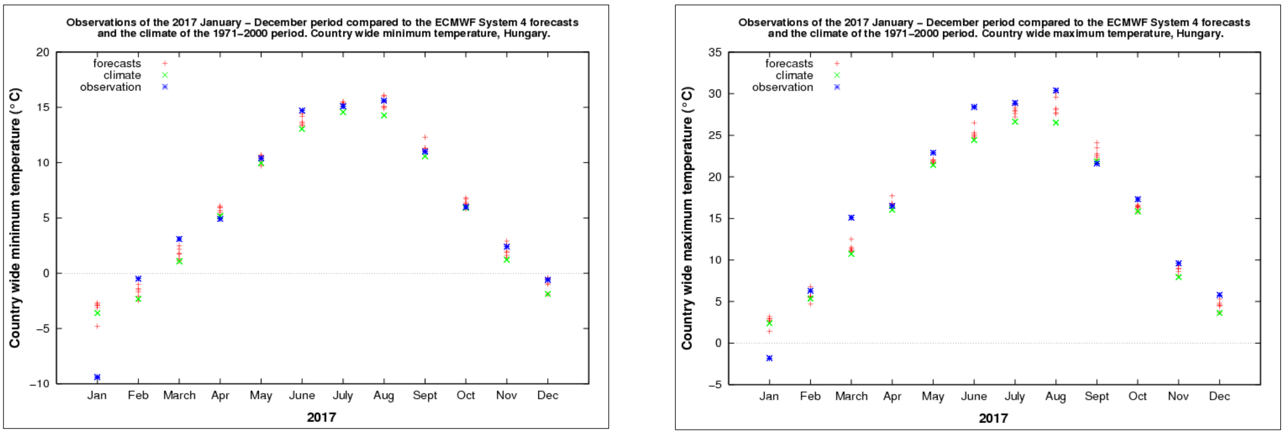



Fig. 19a-b Comparison of the forecasts issued for the 2017 January-December period with the observations and the climate for a) minimum and b) maximum temperature.

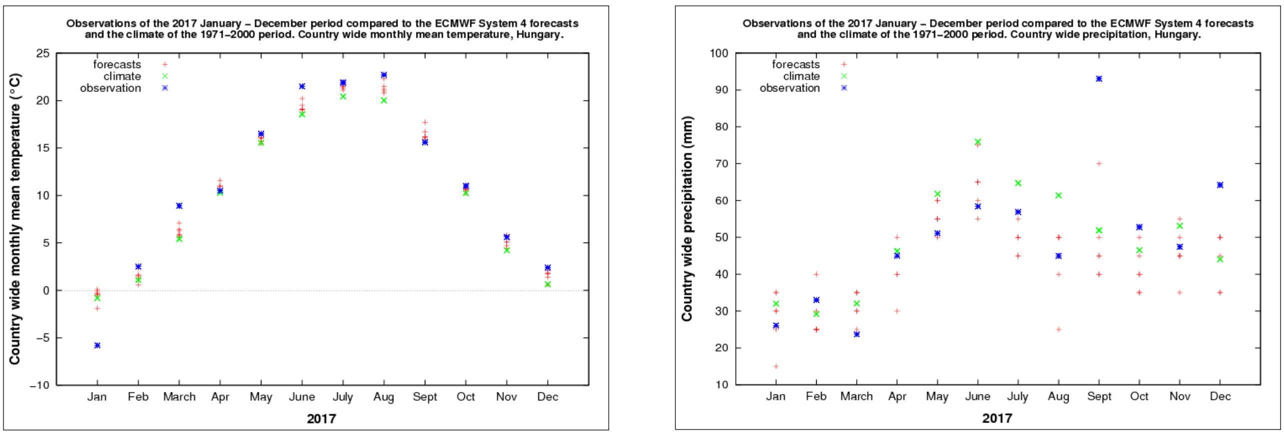



Fig. 20a-b Comparison of the forecasts issued for the 2017 January-December period with the observations and the climate for a) monthly mean temperature and b) monthly amount of precipitation.

***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.

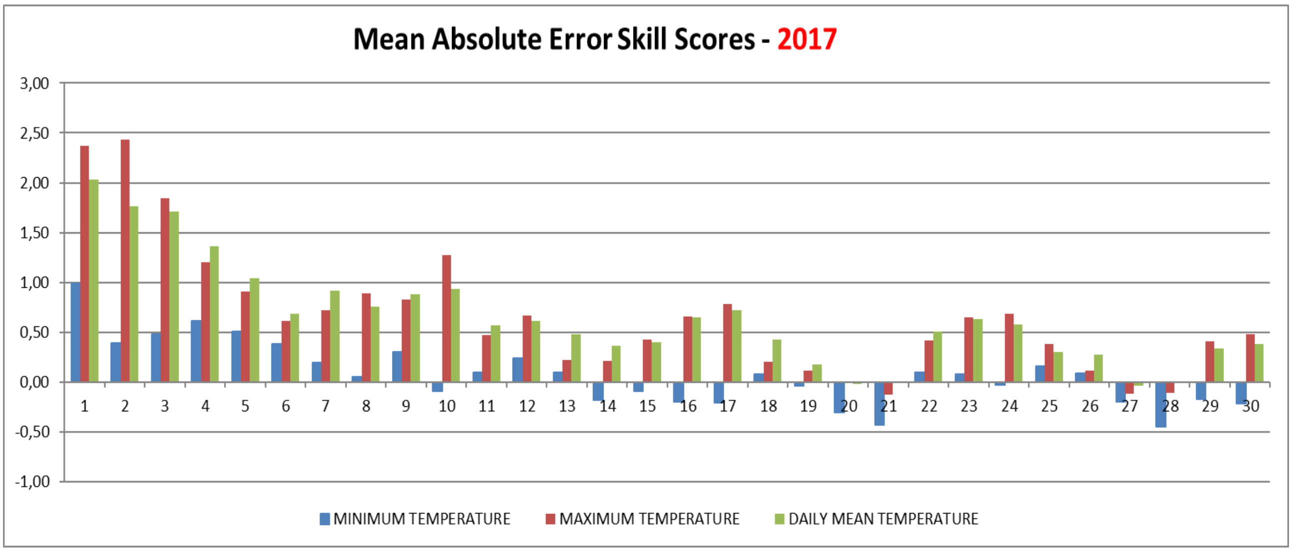



Fig. 21 Mean Absolute Error skill score of the monthly forecast for 2017.

### *3.1.3 Post-processed products*

None

### *3.1.4 End products delivered to users*

None

## 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.
- Complexity of information of the new User Guide Web page is very good, this new development is very much appreciated among forecasters and regional NWP model developers.

# 5. References to relevant publications

**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.** and **D. Tajti**, 2011: Use of ECMWF's ensemble vertical profiles at the Hungarian Meteorological Service. *ECMWF Newsletter*, **129**. 25-29.

**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.