Application and Verification of ECMWF Products 2019

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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. Due ECMWF's invitation Hungarian Meteorological Service (OMSZ) intensively take parts in validation of ecPoint rainfall products for territory of Hungary. ECMWF's Forecast User Guide published in 2018 quite popular among forecasters and local users. Short summary of the benefits of the 25 years cooperation between OMSZ and ECMWF is just presented (*Ihász, Modigliani*, 2019).

2. Use and application of products

2.1 Direct Use of ECMWF Products

Wide range of ECMWF model forecasts has been used from short range to seasonal forecasts via extended range forecasts, too. We are pleased to see that ensemble vertical profile, which prototype has been developed in OMSZ (*Ihász, Tajti*, 2011), has been available in ecCharts since June 2019. Ensemble monthly forecasts with weekly resolution is quite popular among our external users, too.

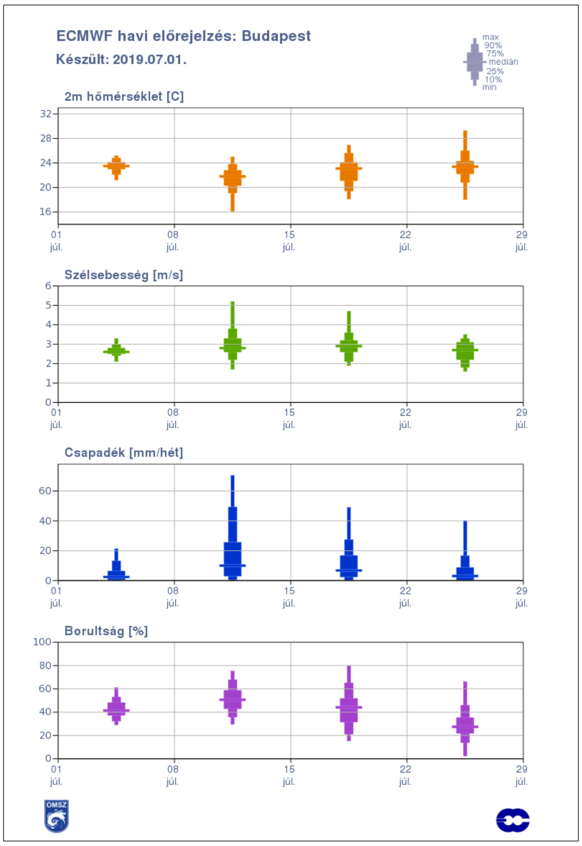


Fig.1 Weekly resolution monthly ensemble meteogram for 2 m temperature, 10 m wind speed, precipitation and cloudiness.

2.2 Other uses of ECMWF output

2.2.1 *Post-processing*

None.

2.2.2 *Derived fields*

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.

2.2.3 Modelling

The Hungarian limited area modelling activity consists three major systems and each 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).

3. Verification of ECMWF 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 results might be compared with the ones shown in "*Application and verification of ECMWF products, 2018*" for the verified models.

3.1.1 Direct ECMWF model output (only HRES), and other NWP models

First in this chapter the 00 UTC runs of ECMWF-HRES, ALADIN/HU and AROME/HU models are compared for the first 48 hours with 1-hour (in case of surface parameters) and 12-hour (in case of upper air parameters) timesteps 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 RMSE (Root Mean Square Error) and BIAS scores are computed using the observations and measurements of the 267 Hungarian SYNOP stations ***under*** 400 m above sea level for 2018, and are presented on Time-TS diagrams as a function of lead time (with the forecast range on the x-axis). The verification is performed for the following variables: ***2 m temperature***, ***dewpoint***, ***total cloudiness***, ***2 m / 925 hPa / 700 hPa relative humidity***, ***10 m wind speed***, and ***wind gust*** (Fig.2a-h).

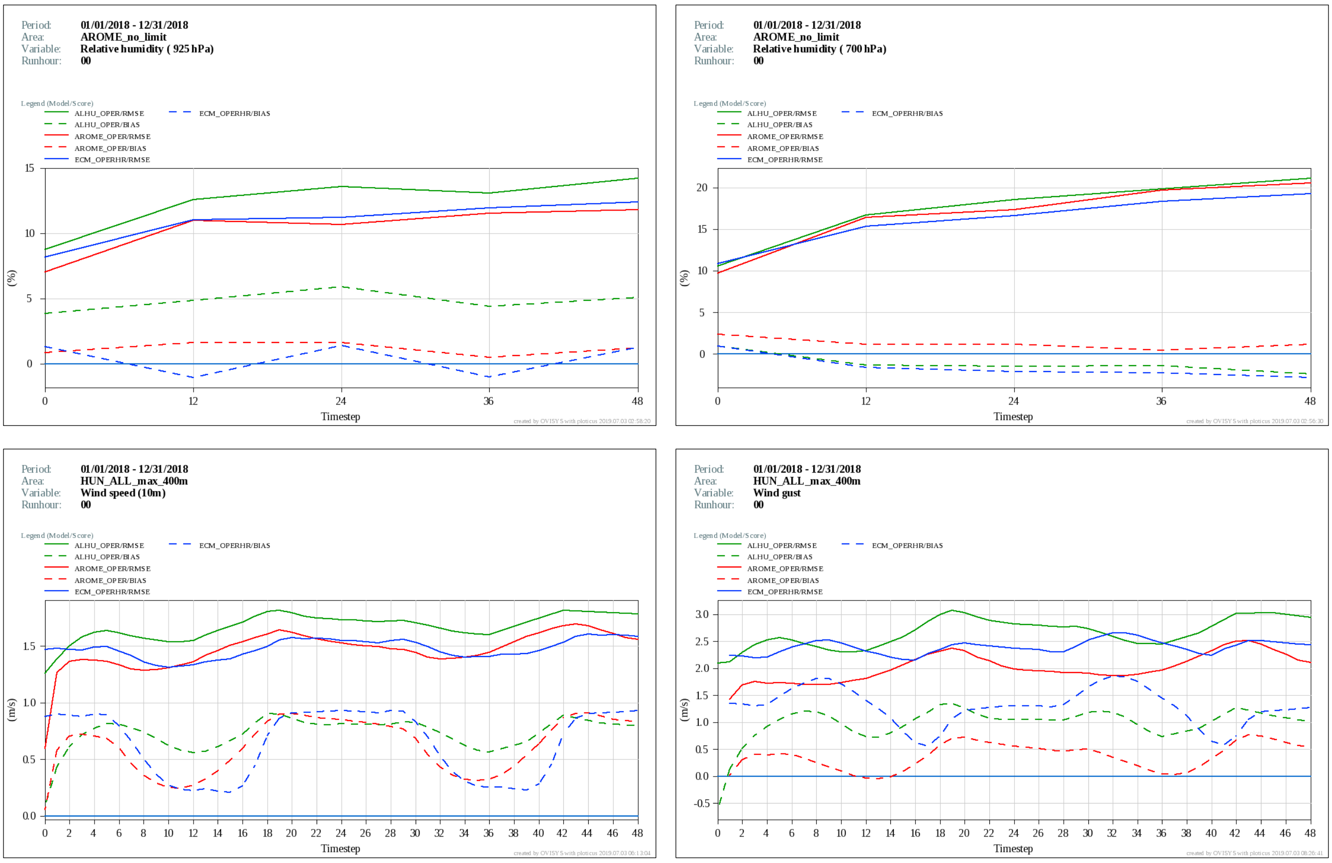


Fig.2a-h Comparison of RMSE (solid) and BIAS (dashed) values of a) 2 m temperature, b) dewpoint, c) total cloudiness, d) 2 m / e) 925 hPa / f) 700 hPa relative humidity, g) 10 m wind speed and h) wind gust forecasts of the 00 UTC runs of ECMWF-HRES (ECM_OPERHR – blue), ALADIN/HU (ALHU_OPER – green) and AROME/HU (AROME_OPER – red) models over Hungary for 2018 using the observations of the SYNOP stations under 400 m above sea level.

Since the ECMWF would particularly welcome conditional verification results demonstrating orographic effects, ***10 m wind speed*** (Fig.3a) and ***wind gust*** (Fig.3b) variables are performed in the same manner as above, but using the observations of the Hungarian SYNOP stations ***over 400 m above sea level*** as well. The results might be compared with Fig.2g-h, respectively.

Note that while 267 stations were considered under 400 m, then only 7 over 400 m (Hungary's highest point – the Kékestető – is only 1014 m above sea level).

According to the results it is conspicuous that while for the lower stations all three models are overestimated, then for the mountain stations the BIAS clearly become negative – except wind gust scores for ECMWF-HRES in daytime (Fig 3b). It is also clear that the AROME/HU with better horizontal resolution is better taken into account the orography therefore it is less underestimate the 10 m wind speed in the mountains than ECMWF-HRES and ALADIN/HU (Fig. 3a).

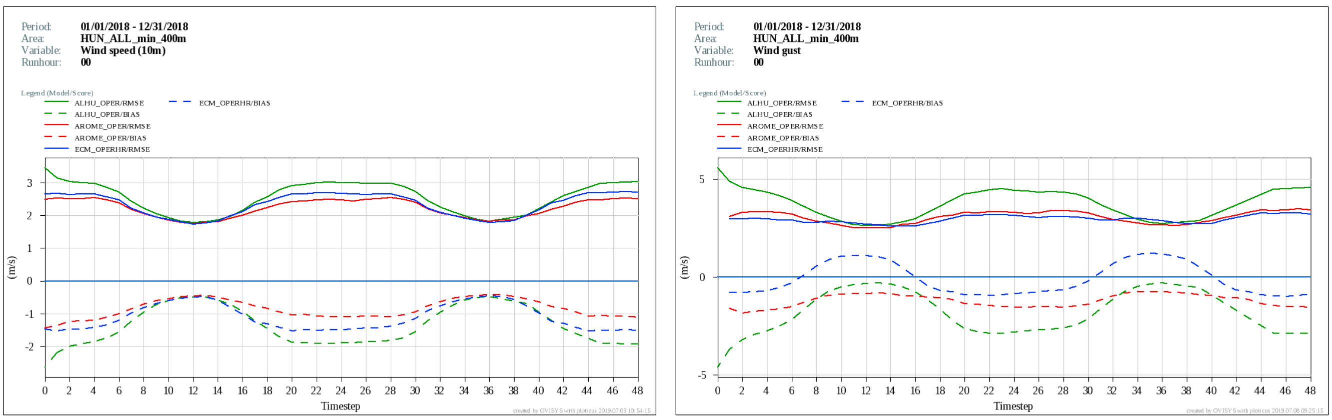
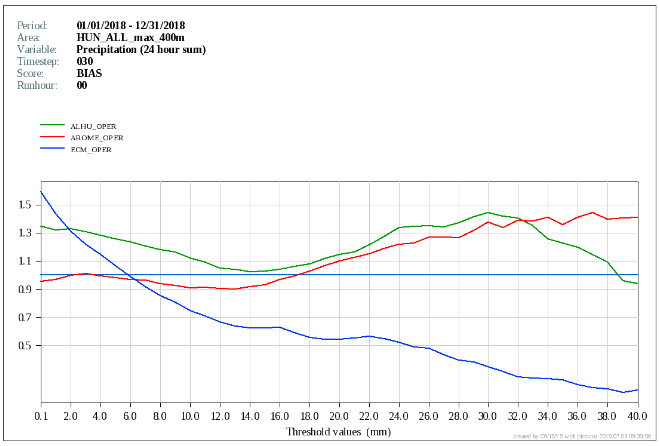


Fig.3a-b Comparison of RMSE (solid) and BIAS (dashed) values of a) 10 m wind speed and b) wind gust forecasts of the 00 UTC runs of (ECM_OPERHR – blue), ALADIN/HU (ALHU_OPER – green) and AROME/HU (AROME_OPER – red) models over Hungary for 2018 using the observations of the SYNOP stations over 400 m above sea level.

In the following the frequency BIAS and the SEDI (Symmetric Extremal Dependence Index) verification scores of ***daily accumulated*** (24h) ***precipitation*** of the same three models can be seen in the 30th hour of the 00 UTC forecasts as a function of certain precipitation thresholds (Fig.4a-b). 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 here instead of the HRES.

For an example of detailed interpretation of the figures, please see "Application and verification of ECMWF products, 2018".



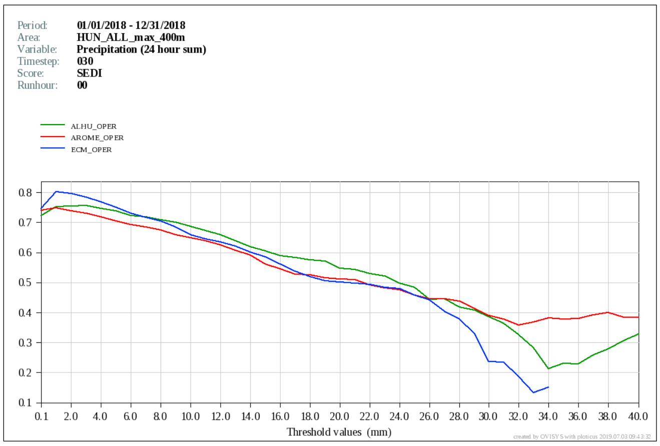
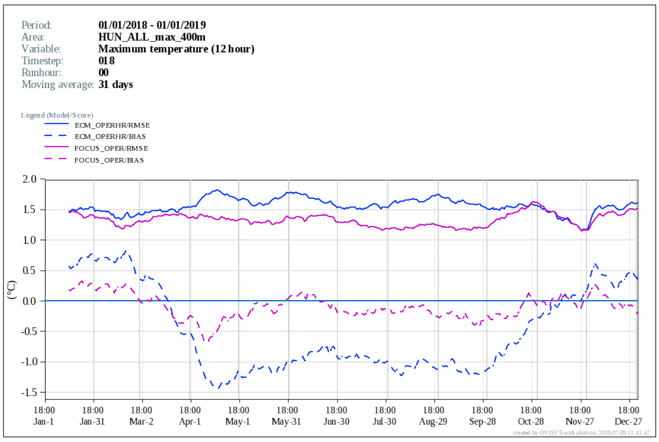


Fig.4a-b The a) frequency BIAS and b) SEDI values of 24h precipitation forecasts (in the 30th hour of the forecast) of the 00 UTC runs of ECMWF (ECM_OPER – blue), ALADIN/HU (ALHU_OPER – green) and AROME/HU (AROME_OPER – red) models against precipitation thresholds over Hungary for 2018 using the observations of the SYNOP stations under 400 m above sea level.

Finally, the temperature forecasts of ECMWF-HRES and ***FOCUS*** (Unified Gridded Forecast Database, for the description, please see "*Application and verification of ECMWF products, 2017*") database are compared as a more interesting example that made with OVISYS as well. The verification is performed in the 18th – in the case of ***12 hour maximum temperature*** (Fig.5a) – and in the 30th – in the case of ***12 hour minimum temperature*** (Fig.5b) – hour of the 00 UTC forecasts. The computed RMSE and BIAS results are presented on Time-T diagrams as a function of time (with the days of the year on the x-axis) with 31-day moving average.

Based on the results it is clearly visible that from April to October the forecasters can significantly improve the model performance, ie reduce the underestimation of the daily maximum (Fig.5a) and the overestimation of the daily minimum (Fig.5b) temperature.



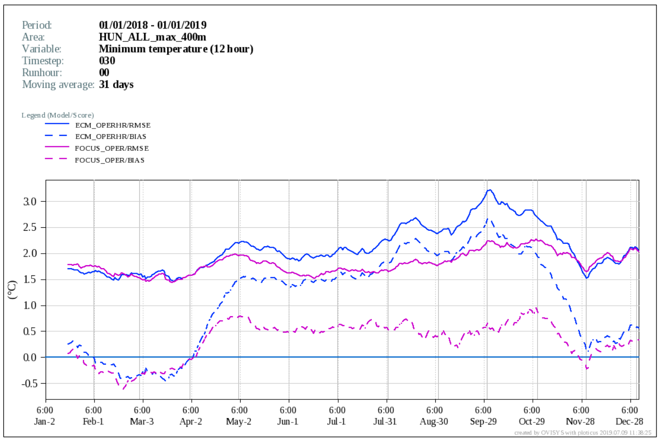


Fig.5a-b Comparison of RMSE (solid) and BIAS (dashed) values of a) 12 hour maximum temperature and b) 12 hour minimum temperature forecasts of the 00 UTC runs of (ECM_OPERHR – blue) and FOCUS (FOCUS_OPER) during the days of 2018 over Hungary using the observations of the SYNOP stations under 400 m above sea level.

Objective verification of the regional (ALADIN, AROME) and global (ECMWF-HRES, ECMWF-ENS mean, GFS) models with including human forecasts (IEO) are available for weather parameters is available on Fig.6a-f.

Fig.6a-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 (ECMDET), ECMWF-ENS mean (ECM-EPS), GFS and the Human Forecaster (IEO) for 2018. N1 represents the first night, D1, D2, …, etc. the days after the issue of the forecast.

3.1.2 Post-processed products and end products delivered to users

None.

3.1.3 Monthly and Seasonal forecasts

As soon as it was possible in 1998 investigation of the applicability of ECMWF's seasonal forecasting system was done. Forecasts for the 2-metre maximum and minimum temperature and the amount of precipitation, for six regions of Hungary are issued in every month. Results of the verification can be seen on Fig.7.

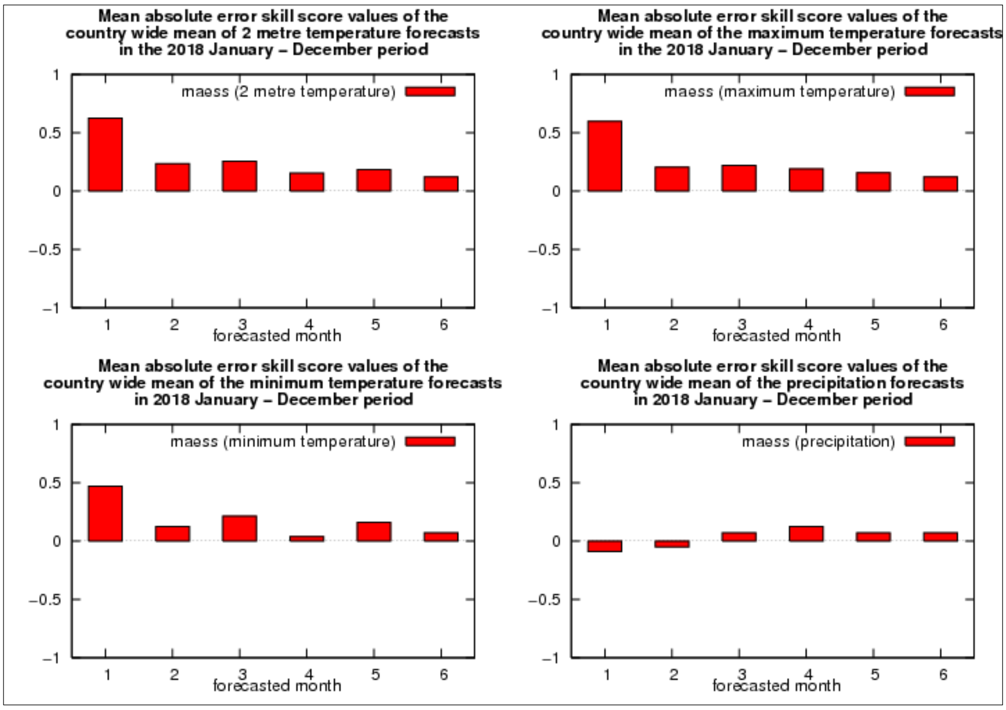


Fig.7 Mean Absolute Error Skill Score of ensemble means of 2 m, maximum and minimum temperature and precipitation for the 6 forecasted months in a forecast for 2018. Reference forecast was the 30-year climatological mean.

3.2 Subjective verification

3.2.1 Subjective scores

The subjective verification – which has been performed since April 2012 – has been continued also in 2019. It is occasionally made, when weaknesses and strongnesses of the forecast are quite crucial in case of severe or high impact weather, and more often during parallel model runs (e.g. before model cycle changes, etc.). In addition, 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 ("(very) interesting cases"). For more information, please see *"Application and verification of ECMWF products, 2013-2014*".

3.2.2 Case studies

None.

4. Requests for additional output

None.

5. Feedback on ECMWF "forecast user" initiatives

- ECMWF's "Forecast User Portal" is well organized and regularly visited by our forecasters.
- Complexity of information of the User Guide Web page is very good, this development is very much appreciated among forecasters and regional NWP model developers.

6. 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

Ihász, I. and Modgliani, U., 2019: 25 years of cooperation between the Hungarian Meteorological Service and ECMWF. *ECMWF Newsletter*, **160**, 9–10

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