Application and Verification of ECMWF Products 2019

Croatian Meteorological and Hydrological Service, DHMZ

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1. Summary of major highlights

At Croatian Meteorological and Hydrological Service, ECMWF products are considered as the main source in the operational forecast, particularly for the medium- and long-range. For short-range forecast other models are included also, especially ALADIN. ECMWF model is also widely used as input for running other hydro/meteorological forecasts, such as ALADIN, WRF, RegCM4 and MIKE as well as air quality models.

Regular verification for short- and medium-range is done by the point-to-grid method, with SYNOP data verified against nearest grid point of the model. The emphasis of the verification is on 2m-temperature and precipitation. Parallel to that, since the beginning of this year a more comprehensive real-time verification has been performed by the grid-to-point method, where gridded values are interpolated to SYNOP data points and verified. Some results and scores of the verification of 2m-temperature will be shown. Long-range forecasts are also comprehensively monitored and verified.

For subjective verification, results of the updated forecasters' survey are presented, raising several comments/issues of the model, particularly its 45r1 cycle available since June 2018. For example, strictly for Croatian area the survey points out improvements in inversion situations and visibility/low cloud prediction. On the other hand there is no improvement in precipitation (QPF) forecast observed, although almost all forecasters agree about usefulness of Precipitation Type product. Some other results regarding model performance as well as evaluation of different tools and products will be presented later in this document.

2. Use and application of products

A variety of ECMWF products is used, and ensemble approach is constantly increasing with time. As already mentioned, ECMWF products are considered as the main source in the operational forecast, particularly for the medium- and long-range.

2.1 Direct Use of ECMWF Products

Direct use of ECMWF Products include GRIB fields from MARS database disseminated via RMDCN and visualized in house using Metview and the new operational workstation system. The ecCharts are also extensively used, particularly for ENS meteograms with climatology, EFI products and other specific prognostic tools developed at ECMWF. Although some long-range forecasts are visualized at the Service, other are monitored via ECMWF web page. Since recently we are also using permalink option for visualized EFI products and ENS meteograms.

Except regular usage of common products, we use ECMWF's products for specific weather situations and we have developed our own products. Some of them are described in Section 2.2.2. For example, for severe weather forecasting different ecCharts products are frequently used: all kind of EFI products, probabilities of exceeding a threshold, lightning probability/density and also vertical profiles tools.

Vertical profiles tools have almost equal positive and negative feedback from forecasters but there are also forecasters who don't use ecCharts and tools available there. Some forecasters state that in several cases vertical profiles tools helped in forecasting fog and low level stratus clouds even at sea shore. Surprisingly, there is a case of successful elevated convection forecast using vertical profiles tools. However, there is a criticism against ECMWF CIN calculation, not only in vertical profiles. Also, instead of the dewpoint depression spread shown together with wind barbs, a wind speed spread would be more welcome. Forecasters would be more satisfied with better temporal resolution which is obviously not possible at the moment.

Extended range test products available at ECMWF confluence were rarely monitored but there is a positive feedback on "Early warning for cold spells over Europe" reported by some forecasters. Similar situation is with the "Stratospheric Sudden Warming" test product. The "Weather regimes extended range forecasts" were not monitored so there is no feedback on usefulness, although forecasters welcome the idea.

2.2 Other uses of ECMWF output

2.2.1 Post-processing

No systematic nor operational post-processing of ECMWF model data is performed at our Service.

2.2.2 Derived fields

The new Integrated operational environment for weather analysis and forecast at DHMZ allows easy combination of different meteorological parameters and calculation of derived fields.

Some of the derived fields worth mentioning include probability of road icing (as a combination of temperature, humidity, precipitation and wind), frost alert (temperature and wind), guidance for fog occurrence (vertical temperature gradient, humidity, surface wind), guidance for deep moist convection (CAPE, CIN, vertical wind shear, sources of lift etc.), heat wave indicator (geopotential heights and temperature), wind chill and heat index (temperature, wind, humidity), Haines index as indicator of dangerous fire weather (temperature and dewpoint temperature at pressure levels).

2.2.3 Modelling

ECMWF lateral boundary conditions (LBC) are used for running a 72hr forecast with ALADIN-HR8 (8km grid spacing) and ALADIN-HR4 (4km grid spacing) operational runs. Due to time constraints for availability of ALADIN 72hr forecast ECMWF LBCs in production are used in so-called lagged mode (ECMWF forecast initialized 6h earlier than ALADIN initial time is used as LBC). As no SST data assimilation is performed locally, the initial SST is taken by combining data from OSTIA analysis. Since 6th Feb 2018, hourly LBCs are provided by ECMWF. The operational LBCs are currently provided in lower spatial resolution than the HRES model. The alternative setup is being developed and tested. Current operational procedure involves many interpolation steps. A new model configuration 903 for interpolation straight from the IFS octahedral cubic grid to a Lambert conformal (or any other) grid is tested in ECMWF facilities.

ECMFW initial and boundary conditions derived from operational analysis are used for running WRF (Weather Research and Forecasting) microscale simulations (hectoscale and large eddy) of wind events in Croatia. It was noted that better results are achieved with the use of operational analysis than ERA-Interim reanalysis. Accurate wind forecasts are especially important for wind energy utilization as wind power plant production heavily depends on wind speed. In Croatia almost all wind power plants are located in the mountainous area near Adriatic coast which is well known for its strong downslope wind – bora. As global models still do not resolve many of these local weather patterns, high resolution limited area models such as WRF and ALADIN provide an added value. Analysis of wind power plant production and wind speed forecast is done for the specific wind power plant located in mountainous area near Senj in Croatia. This power plant is exposed to strong bora events and thus frequently switched off. Wind turbine shuts down when wind speed reaches a cut-out speed of 25 m/s and, typically, errors are largest around this cut-out wind speed meaning that wind forecast improvement is needed, especially for higher speeds. An example of strong bora event happened on 14 November 2017. Only ALADIN-HRDA (2 km dynamical adaptation of 8 km ALADIN) forecasted 80 m winds over 25 m/s of the four tested models (ALADIN, ECMWF, GFS and UKMET). Additionally, verification over three month period showed that only ALADIN-HRDA is able to forecast wind speeds over 25 m/s for this location.

In the previous period, focus was still given to ERA-Interim dynamical downscaling using RegCM4 regional climate model at the 12.5 km horizontal resolution (nested in ERA-Interim) and 4 km horizontal resolution (nested into 12.5 km RegCM4). Besides the grid spacing (and the time step), two RegCM4 simulations differ in the number of vertical levels (23 levels in 12.5 km run vs. 41 levels in 4 km run) and the use of hydrostatic (12.5 km run) versus non-hydrostatic dynamical core (4km run). Also, the 4 km RegCM4 simulation has the convective scheme disabled (assuming the *convection permitting* approach), while all other physics schemes are identical in 4 km and 12.5 km run. During 2019 we plan to finalize the downscaling of the ERA-Interim for the period 1999-2018, and begin RegCM4 simulations using one of the CMIP5 global climate models (GCM). Both ERA5 reanalysis and CMIP6 GCM will be considered during the next year (i.e., 2020). As before, all activities are performed for the research purposes.

The Operational hydrological forecasting system with MIKE11 is based on real-time data received from available online stations in Croatia and Bosnia and Herzegovina, relevant online data received from Slovenia and temperature and precipitation forecast from the meteorological models ALADIN (8 km resolution, lead time 0-71 h, 4 runs per day - 00, 06, 12 and 18 UTC) and ECMWF (16 km resolution at the moment, lead time 72-120 h, 2 runs per day - 00, 12 UTC). The hydrological forecasting model is mainly driven by precipitation input. The model has to deal with uncertainty in rainfall, which is usually the largest source of uncertainty in hydrological modelling. There is an operational plan to use ECMWF 10 km and ALADIN 4 km resolution in the next few months.

For Air Quality Modelling IFS meteorological fields and variables are used as follows:

Operational archive (class: od)
Atmospheric model (stream: oper)
Forecast (type: fc)
Surface: (sfc)
1h-F1280
param:
- 'blh' -> boundary layer height
- '2t' -> 2 meter temperature
- '2d' -> 2 meter dewpoint temperature
- '10u' -> 10 meter U wind component
- '10v' -> 10 meter V wind component

Model levels: (ml)
3h-F1280
param:
- 'lnsp' -> logarithm of surface pressure
- 't' -> temperature
- 'q' -> specific humidity
- 'u' -> U component of wind
- 'v' -> V component of wind
- 'cc' -> fraction of cloud cover
- 'clwc' -> specific cloud liquid water content

'sstk' -> sea surface temperature
'ci' -> sea ice area fraction
'swvl1' -> volumetric soil water layer 1
'swvl2' -> volumetric soil water layer 2
'swvl3' -> volumetric soil water layer 3
'swvl4' -> volumetric soil water layer 4
'sd' -> snow depth
'ssr' -> surface net solar radiation
'ssrd' -> surface solar radiation downwards
'lsp' -> large scale precipitation
'cp' -> convective precipitation
'sf' -> snowfall
tcc' -> total cloud cover

Fire emissions
stream=gfas
type=gsd

In addition, IFS is used for WRF meteorological model on fine scale resolution. Furthermore, emission data from CAMS are used for all numerical air quality models (LOTOS-EUROS, EMEP). ERA 5 reanalysis data are used for development of statistical models and 'training' of air quality models based on neural networks. So far, ECMWF meteorological data are validated implicitly.

3. Verification of ECMWF products

3.1 Objective verification

As already introduced in the Summary a new verification system has been introduced since the beginning of this year. The main goal of this more comprehensive verification is to evaluate particularly forecasters' performance but also to compare it to available NWP models.

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

For now the emphasis of the verification is put to the forecast of 2m temperature for the next day what is one as the everyday tasks of our forecasters. The minimum and maximum values for dozens of places (synoptic stations) are forecast one day in advance (tomorrow). The future plan is to verify also 24h precipitation amounts for next day, at least for several places.

The method used is grid-to-point, where gridded values of direct model outputs are interpolated to SYNOP observation points and verified. Our new operational workstation system allows interpolation of model data so this method was natural and easy choice.

Models included in the verification are ALADIN 4 km and 8 km (00 UTC run), DWD Icon Europe 6.5 km (00 UTC run) and latest available cycle of ECMWF HRES, 00 UTC run and 12 UTC run from a day before, referred as Ala4, Ala8, DWD, EC00 and EC12, respectively. DHMZ's forecasters are referred as D1. The simple verification scores for the spring of 2019 (MAM) were calculated for each synoptic station but also aggregated for all stations including three mountainous ones. Scores for 2m minimum and maximum temperature include Bias, MAE and RMSE.

In the spring of 2019 aggregated scores for the maximum and minimum temperature forecast from yesterday (Tmax and Tmin) are shown in Figure 1.

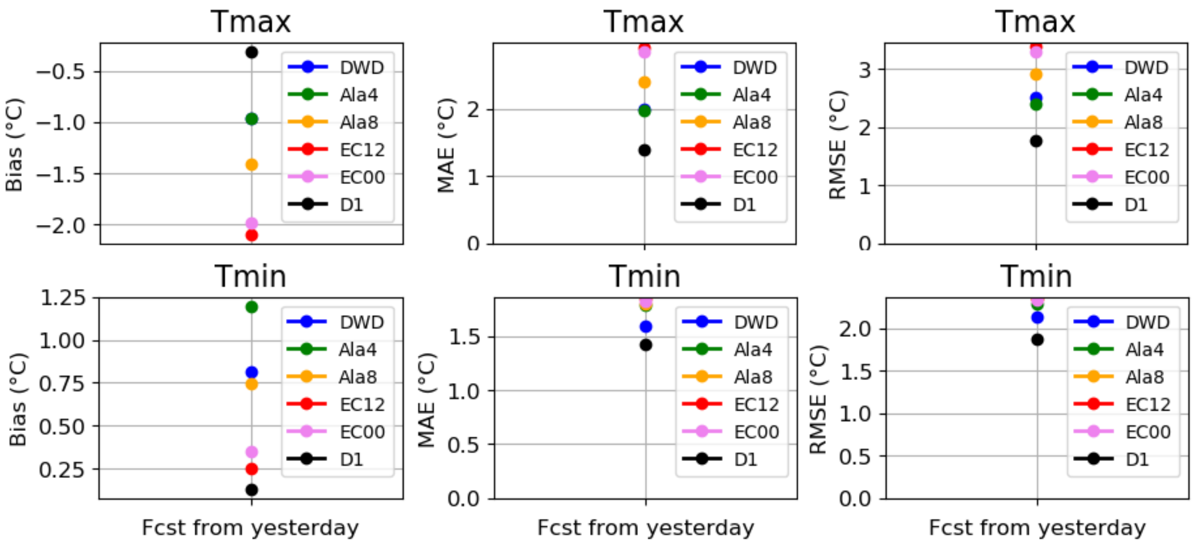

Fig.1 Bias, MAE and RMSE for maximum and minimum temperature forecast one day in advance for all synoptic stations during spring 2019.

For Tmax Bias was negative for all forecasts but smallest for D1 and biggest for EC (both 00 and 12). Generally speaking, EC delivers 2 °C lower maximum temperature forecast for Croatia and the biggest contribution to this cold bias came from the stations at the Adriatic Sea. Similarly MAE was biggest for EC, also RMSE (both around 3 °C)

For Tmin Bias of the EC forecast was slightly positive, comparable to D1 and smaller than the other models. However, mean absolute error was similar for all forecasts, 1.5 °C or more. Also was RMSE but around 2 °C.

As already mentioned, Tmax forecast MAE of the EC (both 00 and 12) was biggest in comparison to D1 and other models. The error was larger for stations at Adriatic Sea or near it as well as for stations in mountainous area than for those in the continental part (Figure 2). Some stations at the sea shore with steep mountains behind had mean absolute errors as big as 4 °C during spring. It was also the case for the stations located on small islands not distinguished by the model (i.e. model point is located in the sea), particularly in the northern Adriatic. However, these large MAE is mainly a result of the strong cold bias due to cooling influence of the sea that seems to be the largest during spring time (not shown). So, a simple post-processing method like the bias removal (using observed Tmin/Tmax values and model temperature tendencies) makes these EC temperature forecasts usable.

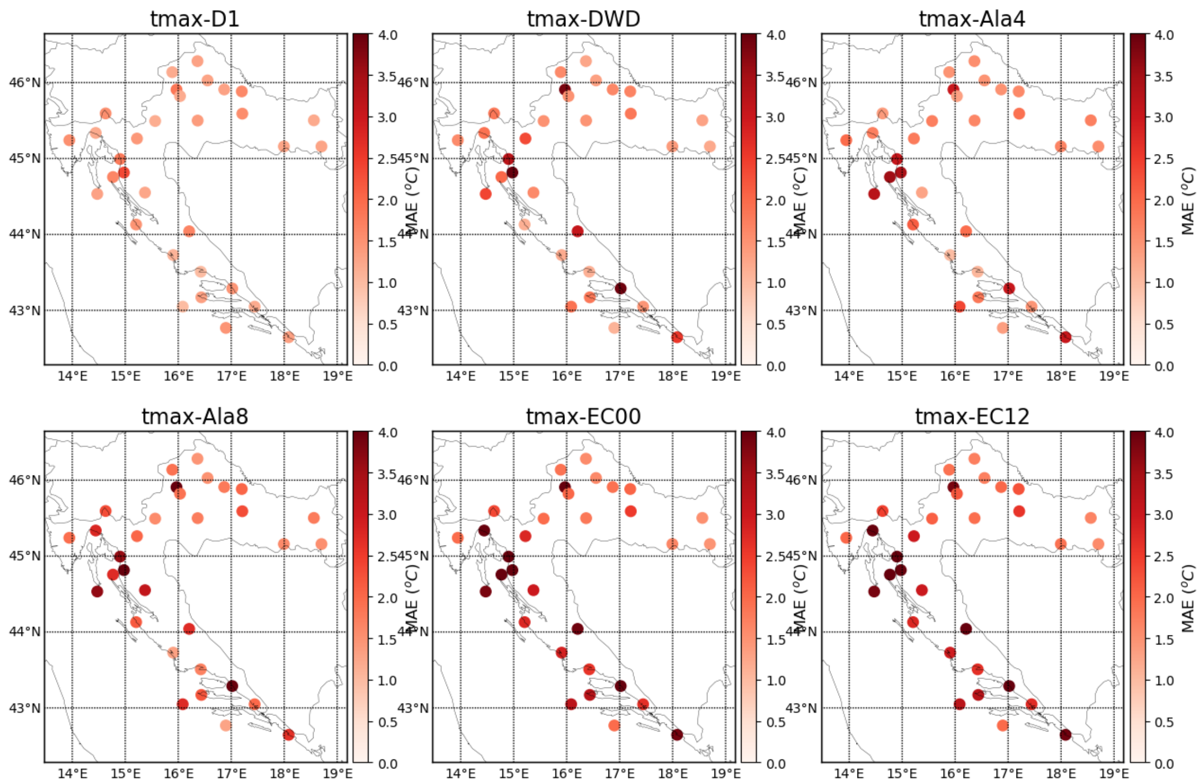

Fig.2 MAE of the maximum temperature forecast one day in advance during spring 2019.

From both Figures it is also seen that there was a very little difference between two successive EC runs in forecasting Tmin and Tmax for one day in advance. However, benefit from latest runs can be seen for longer lead times than tomorrow.

3.1.2 Post-processed products and end products delivered to users

No verification of post-processed ECMWF products nor end products is done at our Service.

3.1.3 Monthly and Seasonal forecasts

Verification of the monthly forecast for 4 weeks in advance leads to several conclusions:

- still the best for the first week, satisfactory for the second, but not good enough for third and fourth week
- skill score of the Monday run is better than those of Thursday for first two weeks
- extremes still not forecast well but results are acceptable if only positive/negative anomalies are verified (categorical forecast)
- as expected, forecast success of the temperature anomalies is higher than precipitation anomalies, but in 2018 there was an exception in first week forecast of Monday run in some area

- forecast success of the temperature anomalies as well as precipitation anomalies were lower in 2018 in comparison to 2017 but with the same exception for Monday run

From the verification of the seasonal forecast for 6 months in advance several conclusions can be drawn:

- skill score is relatively low, even for the temperature anomalies but if only positive/negative anomalies are verified results are more acceptable
- as expected temperature anomalies forecast is better than precipitation
- as expected forecast of the seasonal anomalies is better than forecast of the monthly anomalies
- extreme anomalies are rarely forecast well
- there is no obvious improvement in System 5 in comparison to System 4 for Croatian region; for now System 5 seems to show even worse results
- temperature anomalies forecast error increases for second month in advance, but decreases for 3rd, 4th and 5th month which are comparable to 1st month error in System 5
- precipitation anomalies forecast has expected decrease in skill score up to 3rd month in advance, but surprisingly higher skill scores are reported for 4th and 5th month; even the forecast error of 6th month is comparable to first and second month

3.2 Subjective verification

3.2.1 Subjective scores

For subjective evaluation purpose of ECMWF model fields and products in Croatia, a survey is being carried out in the Forecasting Department also this year. Some topics, also new one, are proposed to the forecasters to confirm/reject, but forecasts are invited to raise their own topics, and others can join the discussion/voting. Of particular interest were changes brought by IFS cycle 45r1 introduced in June 2018. Twenty-nine forecasters participated in the survey.

The evaluation of ECMWF model fields brings some interesting results:

- more than a half of forecasters disagree that HRES precipitation forecast has been improved since June last year, others are not sure; there is no single positive feedback on the improvements in precipitation; almost all agree that HRES model occasionally forecasts extreme precipitation by the end of forecasting period what actually rarely happens
- about improvements in HRES wind and temperature forecast almost all forecasters are neutral i.e. could not agree or disagree; just few of them reported better wind forecast; there are still forecasters thinking that minimum temperature is underestimated in case of clear nights with snow cover on the ground, i.e. model is too cold is such situations
- almost all agree that HRES is very good in forecasting cloudiness and also in differentiating between high, medium and low cloud cover; accordingly, model is now much better in forecasting low stratus cloud or fog during temperature inversion situations both on land and sea (also more reliable than some finer resolution models)
- half of the forecasters report “jumpiness” of HRES forecasts in longer lead times (that is even more than has been reported in survey of 2018) and obviously dislike it; some also report “jumpiness” in ENS forecasts
- there are still a lot of forecasters who think that CAPE is unrealistic (particularly over sea) but in this latest survey there are also those who find it OK; it has to be mentioned that half of forecasters is not sure about CAPE values and which method of CAPE calculation is best; accordingly, as already mentioned, there is a criticism against CIN calculation
- although not all of the forecasters are experts in monthly and seasonal forecasts, those who are can confirm that monthly forecast is “jumpy” (too much under the influence of actual anomaly) and that seasonal forecast still have large errors in monthly anomalies; one of them reported very critically: “Seasonal forecast was disaster in recent months, especially since the beginning of 2019 - the model does not see at all a negative anomaly of temperature. But the experts in ECMWF are aware of bad scores of seasonal forecast and therefore do not recommend using it for midlatitudes.”

Here are some results of the evaluation of ECMWF products:

- there is a big praise among forecasters about EFI forecasts and products (all agree EFI/CDF is good indicator of weather extremes, generally for precipitation, wind and temperature); there is some positive feedback on reliability of EFI CAPE/CAPESHEAR product but it seems that forecasters are still not familiar with it
- Visibility product is monitored frequently but with mixed feedbacks on fog forecast; it is reliable as indicator of potential fog development somewhere in the broader area (even for longer lead times), but for point forecast it is often misleading, e. g. useful in general or public forecast and not useful in airport or marine forecasts

- relatively new Lightning density product from HRES is also accepted well by some forecasters who state its reliability in potential for convection development but would like higher temporal resolution than 6 hours; some state it could be misleading in case of weak signal and has to be used together with other convection parameters; also there are statements like "Lightning density probability product from ENS is inferior to Lightning density from HRES"
- and the gold medal goes to product "Precipitation type" (particularly one from HRES but also ENS including ensgrams); although all forecasters like to use it and find it reliable as much as precipitation forecast allows itself, some still recommend precaution when using it; the similar situation is with "Freezing rain probability" product while on the other hand "Accumulated freezing rain" products tends to overestimate accumulation

3.2.2 Case studies

ECMWF is generally very good model for Croatian area so there were rarely severe weather situations it missed or in which it had big errors. Here are listed some of them as well as severe situation when model was quite good:

- 11 June 2019: very good forecast of severe evening convection (heavy rain/hail) initiated in Slovenia and propagated to Croatia (heavy precipitation, particularly in latest 00 run, was a major hint)
- 13-14 May 2019: very reliable forecast of severe wind episode (good guidance days in advance, particularly EFI); on 14th too strong signal for snow in mountainous areas (HRES)
- 22-23 February 2019: severe Bora (NE) wind case in Dalmatia well forecast (exceptionally good EFI/CDF guidance)
- 29 November and 28-29 October 2018: very good forecast of severe Jugo (SE) wind (EFI very useful)
- 26 October 2018: model was too wet; misleading to heavy precipitation in Rijeka area
- 24-25 September 2018: a cold front passage very well forecast in all parameters, particularly wind and MSLP
- 17 July 2018: model was too wet giving heavy precipitation that did not occur
- 9 June 2018: reports on missed convection processes in eastern Croatia
- 5 March 2018: model had too strong signal for freezing rain
- February 2018: "Sudden stratospheric warming" gave good signal for cold spell in Croatia (reported by one forecaster)

4. Requests for additional output

Derived products such as long-range drought forecast (e.g. SPI, SPEI indices) would be very welcome.

5. Feedback on ECMWF "forecast user" initiatives

No feedback has been collected about use of "Forecast User Portal" and "Forecast User Guide".

6. References to relevant publications

No publications have been cited in this report.

7. Structure of these Reports

Regarding our Service schedule for collecting input would be better after summer months, e.g. in September, or before summer. Report content and layout look all right.