Application and Verification of ECMWF Products 2021

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1. Summary of major highlights

ECMWF products have been widely used by the Central and Regional Forecasting Offices in Czech Hydrometeorological Institute (CHMI) for short-range and medium-range weather forecasts. The clusters, plumes, EPS-grams and probability outputs are considered to evaluate the credibility of the main deterministic forecast as well as to prompt for possible scenarios in situations of low determinism. The Extreme Forecast Index and other probabilistic products are used especially in severe weather forecasting.

A great number of products of deterministic model and some probabilistic products are visualised at weather station Visual Weather (IBL soft.) both at the Central Forecasting Office and at the Regional Forecasting Offices. Using this weather station, also products of other models, including Aladin model (operated in CHMI), GFS and ICON are displayed and compared to ECMWF products.

The goal of the internal project at CHMI aimed at agrometeorology is to focus on several ECMWF parameters forecast analysis. Its results could be used for better evaluation of short-range and medium-range forecast of soil drought in the Czech Republic. Detailed information and important results of this project was given at this report two years ago.

2. Use and application of products

2.1 Direct Use of ECMWF products

ECMWF products have become the main products to issue short-range and medium-range weather forecasts including severe weather for both the whole territory of the Czech Republic and particular regions of the Czech Republic. It consists both general weather forecasts for media and the public and special forecasts for aviation, winter maintenance of roads and motorways, energetics, gasworks etc.

The final medium-range forecasts produced by forecasters of CHMI are used in the general weather forecasting for the public and state authorities and in the national Warning and Alert Service. Warning system has become the most important component of our service. Both probabilistic products and the Extreme Forecast Index are used to issue warnings. Ensemble products are considered in order to evaluate the credibility of the main deterministic forecast and to issue weather forecasts more than approximately 5 days in advance.

ECMWF deterministic temperature and precipitation forecasts serve also as optional input to hydrological model in cases when prolonged lead time is demanded (especially for the purpose of reservoir management).

Some of meteorological parameters (pressure, temperature, wind) predicted by ECMWF are used as an automatic input to some our products that are controlled and modified by forecasters.

Only some products from ecCharts are used – e.g. precipitation state, precipitation probability.

Most of products of ECMWF are also used by the Weather Service of Army of the Czech Republic.

2.2 Other uses of ECMWF output

The seasonal and monthly forecasts are consulted in the long-range forecast process. Currently the results of both deterministic and ensemble forecasts up to 15 days in advance and monthly forecasts are used for identification of the weather type in the analogue-based forecasting method for monthly forecasting.

2.2.1 Post processing

Objective statistical adaptation is used for 2 metre temperature prediction.

2.2.2 Derived fields

Derived fields are calculated to improve detection and prediction of severe weather, mainly severe thunderstorms with heavy rain, hail and severe wind gusts. They are calculated by weather station Visual Weather and they are depicted to tables, maps and diagrams by this weather station.

It is calculated instability of the atmosphere (CAPE, Lifted index, Showalter index, convective inhibition CIN, temperature gradient between 500 and 850 hPa), wind shear between different levels, SWEAT index, jet stream, low-level jet stream, mixing ratio and precipitable water. These parameters are used to improve prediction of thunderstorms and their dangerous events.

Other derived filds like type of precipitation, low level clouds and fogs, rime, snow drifts, ventilation index are used for prediction of other events.

Temperature, humidity, precipitation and wind speed predictions are also used for calculation of natural fire danger.

Three-dimensional wind forecasts over the Northern Hemisphere up to +120 hrs are used as the input to the trajectory model used for assessing of risk of distant nuclear or other major accidents.

2.2.3 Modelling

3. Verification of ECMWF products

3.1 Objective verification

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

CHMI carries out automatic evaluation of the main weather parameters (averages of minimum and maximum temperature, sunshine duration, precipitation total, percentage of region with precipitation, thunderstorms and fogs) of four numerical weather prediction models (Aladin, ECMWF, ICON, GFS) for both the whole Czech Republic and individual regions for five days ahead. The same method is used for evaluation of general forecasts issued by forecasters. Method is based on adapted Brádka's method of evaluation used by forecasters since the year 1958 and now uses new database system and computing capabilities.

3.1.2 Post-processed products and end products delivered to users

3.1.3 Monthly and Seasonal forecasts

Evaluation of monthly forecasts of temperature and precipitation of ECMWF

1. Evaluation of predictions of average weekly temperature deviations

ECMWF issues monthly forecasts twice a week, starting from Monday 00 UTC and Thursday 00 UTC. The evaluated period was the year 2019, so 2x 52 issued monthly forecasts were evaluated, ie. a total of 104 monthly forecasts. Their outputs are mainly forecasts for 4 week periods, always from Monday to Sunday. Thus a total of 416 weekly forecast periods were evaluated. For each of them, predicted deviations of the average weekly air temperature at a height of 2 m and predicted deviations of weekly total precipitation for the next four weeks in the Czech Republic were taken. These predicted values of both meteorological elements were compared with those calculated on the basis of values measured at meteorological stations (fact).

ECMWF forecast errors from the actual (measured) deviation of the air temperature at a height of 2 m are shown for individual weekly forecast periods at the Table 1. Since the weekly periods are always from Monday to Sunday, in the case of the monthly forecast from the initial date of Thursday 00 UTC, these are forecasts for 5-11. days, 12.-18. days, 19.-25. days and 26.-32 days. From the initial date Monday 00 UTC on the forecasts for 1.-7. days, 8.-14. days, 15.-21. days and 22.-28. days. The individual weekly periods are sorted in the table according to the advance of the forecast, so in individual rows from left to right we can observe the change of the forecast error for a specific week with the shortening of the forecast advance.

The far right column shows the actual (measured) deviations of the air temperature at 2 m above the ground for the individual calendar weeks. The weeks are sorted in ascending order of the magnitude of the temperature deviation. Weeks with temperature below normal are highlighted in blue, temperature above normal red, temperature average weeks are not highlighted (white). It is evident that for both below-average and above-average weeks, the forecasts have large errors about 14 days or more in advance (unsuccessful forecasts highlighted in brown, partially successful in light pink, successful without highlighting). Forecasts with more than 14 days lead time often show values close to climatological.

This is also shown in the Table 2. We can see here the number of successful predictions (deviation up to 1.7 ° C), forecasts differing by 1 category (deviation above 1.7 ° C - partially successful) and differing by 2 categories (deviation above 3.4 ° C - unsuccessful) in comparison to reality.

The table shows that the success of forecasts decreases rapidly with increasing advance of the forecast. Predictions with an advance of 3 and especially 4 weeks are close to the climatological average, the predicted deviations are at most up to + - 2 ° C. The increase in success begins approximately in advance of the forecasts on the 15th - 21st day (3 weeks in advance). It means that only predictions with an advance of 1 and 2 weeks are well usable, with an advance 3 weeks are only partly usable.

There were also cases where successive runs of the model consistently showed that the third or fourth week of the forecast would be above average, as the week approached, the model showed a cold air inflow – temperature below average, which turned out to be true (in the table especially 19 and 28 week).

týden	týden	26.-32.	22.-28.	19.-25.	15.-21.	12.-18.	8.-14.	5.-11.	1.-7.	skutečost
20	13.5.-19.5.	-4,8	-3,8	-3,8	-3,8	-3,8	-1,8	-0,8	-1,8	-3,8
19	6.5.-12.5.	-5,6	-5,6	-5,6	-3,6	-2,6	-1,6	-1,6	-0,6	-3,6
18	29.4.-5.5.	-3,2	-5,2	-4,2	-5,2	-4,2	-5,2	-1,2	-0,2	-3,2
28	8.7.-14.7.	-3,8	-3,8	-4,8	-4,8	-1,8	-2,8	-0,8	0,2	-2,8
4	21.1.-27.1.	-3,6	-2,6	-2,6	-1,6	-0,6	-0,6	1,4	-0,6	-2,6
38	16.9.-22.9.	-2,1	-2,1	-2,1	-2,1	-1,1	-0,1	-1,1	-0,1	-2,1
40	30.9.-6.10.	-1,4	-1,4	-0,4	-3,4	-1,4	-2,4	-0,4	-0,4	-1,4
44	28.10.-3.11.	-1,3	-1,3	-3,3	-1,3	-2,3	0,7	0,7	0,7	-1,3
15	8.4.-14.4.	-0,8	-1,8	-1,8	-1,8	-1,8	-1,8	-0,8	1,2	-0,8
33	12.8.-18.8.	-1,7	-1,7	-0,7	-0,7	0,3	0,3	0,3	0,3	-0,7
21	20.5.-26.5.	-1,5	-1,5	-1,5	-0,5	-1,5	-0,5	-0,5	0,5	-0,5
6	4.2.-10.2.	0,9	1,9	1,9	-0,1	0,9	-0,1	0,9	-0,1	-0,1
29	15.7.-21.7.	-0,8	-0,8	-0,8	-0,8	-0,8	1,2	1,2	0,2	0,2
36	2.9.-8.9.	0,2	-1,8	-0,8	-1,8	-0,8	-0,8	1,2	1,2	0,2
41	7.10.-13.10.	0,2	0,2	0,2	0,2	0,2	0,2	1,2	0,2	0,2
37	9.9.-15.9.	0,4	-0,6	-0,6	0,4	0,4	2,4	1,4	0,4	0,4
31	29.7.-4.8.	-0,5	0,5	-0,5	-1,5	-1,5	-3,5	-0,5	-0,5	0,5
22	27.5.-2.6.	-0,4	0,6	-0,4	0,6	1,6	1,6	2,6	1,6	0,6
13	25.3.-31.3.	0,6	0,6	-0,4	-1,4	-0,4	-1,4	1,6	0,6	0,6
49	2.12.-8.12.	-0,3	-0,3	-1,3	-1,3	-1,3	2,7	0,7	0,7	0,7
3	14.1.-20.1.	-0,2	-0,2	-0,2	0,8	0,8	-1,2	-0,2	-0,2	0,8
5	28.1.-3.2.	2,1	3,1	3,1	2,1	5,1	1,1	2,1	-0,9	1,1
27	1.7.-7.7.	-0,7	0,3	1,3	1,3	1,3	0,3	-0,7	0,3	1,3
34	19.8.-25.8.	1,3	1,3	1,3	2,3	1,3	2,3	2,3	0,3	1,3
53	30.12.-5.1.	-0,5	0,5	0,5	1,5	1,5	-0,5	1,5	-0,5	1,5
12	18.3.-24.3.	-0,3	0,7	-0,3	-0,3	1,7	-2,3	0,7	-0,3	1,7
32	5.8.-11.8.	0,7	0,7	0,7	-0,3	1,7	0,7	0,7	-0,3	1,7
11	11.3.-17.3.	-0,1	-0,1	-0,1	-0,1	0,9	-0,1	1,9	-0,1	1,9
16	15.4.-21.4.	0,9	1,9	0,9	1,9	1,9	1,9	0,9	0,9	1,9
8	18.2.-24.2.	1,9	1,9	1,9	0,9	1,9	-3,1	-1,1	-1,1	1,9
17	22.4.-28.4.	2	0	2	1	0	-1	-2	-1	2
39	23.9.-29.9.	2,1	2,1	2,1	0,1	1,1	-0,9	1,1	0,1	2,1
50	9.12.-15.12.	0,2	0,2	0,2	2,2	0,2	0,2	0,2	1,2	2,2
2	7.1.-13.1.	2,2	1,2	1,2	1,2	1,2	3,2	3,2	2,2	2,2
45	4.11.-10.11.	2,2	2,2	2,2	4,2	3,2	-0,8	0,2	1,2	2,2
48	25.11.-1.12.	2,7	1,7	0,7	0,7	-0,3	-1,3	-1,3	0,7	2,7
46	11.11.-17.11.	2,7	2,7	2,7	1,7	1,7	0,7	1,7	1,7	2,7
14	1.4.-7.4.	2,1	3,1	2,1	1,1	3,1	3,1	3,1	1,1	3,1
52	23.12.-29.12.	3,4	1,4	1,4	1,4	0,4	-0,6	1,4	0,4	3,4
23	3.6.-9.6.	2,5	2,5	3,5	3,5	3,5	1,5	-0,5	0,5	3,5
25	17.6.-23.6.	3,7	3,7	1,7	1,7	2,7	-0,3	-0,3	0,7	3,7
7	11.2.-17.2.	4,7	4,7	4,7	3,7	3,7	1,7	4,7	-0,3	3,7
30	22.7.-28.7.	4,1	3,1	3,1	2,1	3,1	1,1	1,1	1,1	4,1
42	14.10.-20.10.	4,6	4,6	4,6	4,6	4,6	0,6	0,6	-0,4	4,6
9	25.2.-3.3.	4,7	3,7	4,7	2,7	0,7	1,7	-0,3	0,7	4,7
10	4.3.-10.3.	5,1	3,1	3,1	3,1	1,1	2,1	1,1	1,1	5,1
47	18.11.-24.11.	5,1	6,1	4,1	4,1	3,1	3,1	2,1	2,1	5,1
43	21.10.-27.10.	5,3	5,3	5,3	3,3	3,3	2,3	1,3	0,3	5,3
26	24.6.-30.6.	4,4	3,4	3,4	1,4	3,4	2,4	0,4	1,4	5,4
51	16.12.-22.12.	4	5	4	1	2	1	0	-1	6
35	26.8.-1.9.	6,5	6,5	4,5	5,5	6,5	4,5	2,5	2,5	6,5
24	10.6.-16.6.	6,7	6,7	6,7	4,7	4,7	3,7	4,7	0,7	6,7

TTable 1 Forecast errors of the deviation of the average weekly air temperature at 2 m above the

ground in comparison with the actual deviation calculated from the measured values depending on the advance of the forecast. Explanation in the text.

Initial day	Thursday	Monday	Thursday	Monday	Thursday	Monday	Thursday	Monday
Lead time	26.-32.	22.-28.	19.-25.	15.-21.	12.-18.	8.-14.	5.-11.	1.-7.
successful	22	21	23	27	27	30	40	47
partly successful	13	17	15	13	16	18	10	5
unsuccessful	17	14	14	12	9	4	2	0

Table 2 Number of successful, partially successful and unsuccessful forecasts of the average weekly air temperature at 2 m above the ground depending on the advance of the forecast (days).

2. Evaluation of forecasts of deviations of weekly precipitation totals

Table 3 shows predicted deviations of the weekly precipitation totals from the long-term average (normal), starting in advance of the forecast on the 26th - 32nd day and ending on the 1st - 7th day. The column on the far right shows the real (from measured values) deviations of precipitation from the long-term average for individual calendar weeks. Also in this table, these weeks are sorted in ascending order according to the real precipitation deviations. Predicted and measured deviations are highlighted in color according to their size, the larger deviation (in absolute value), the darker color. It is obvious that forecasts with an advance of 15-21 days and more usually do not give any signal, even in the case of weeks that are strongly below normal or above normal. A certain signal usually starts to appear in forecasts ahead of the 8th - 14th day, but it is only weak. Even in advance of the 1st - 7th day, the predicted precipitation deviations are often significantly underestimated in the case of precipitation (strongly) below-average and above-average weeks.

The success rate of precipitation forecasts is generally lower than success rate of temperature forecasts. Not surprisingly, significant precipitation during the week often occurs in an episode lasting one or a few days, when a cold front waves in the central Europe. If this front wave shifts, it will affect on precipitation localization. This is often the reason why prediction of the amount of precipitation for a longer period is often burdened with large errors. The usability of precipitation forecasts of monthly forecast is thus only limited, basically only for the 1st and 2nd

week of the forecast.

týden	týden	26.-32.	22.-28.	19.-25.	15.-21.	12.-18.	8.-14.	5.-11.	1.-7.	Skutečnost
16	15.4.-21.4.	-5	-10	-5	0	0	-10	-10	-20	-100
26	24.6.-30.6.	0	0	0	0	0	5	-20	-30	-98
12	18.3.-24.3.	0	-5	0	-5	-5	0	-10	-10	-97
14	1.4.-7.4.	-5	0	0	-5	0	-5	-5	-10	-92
7	11.2.-17.2.	0	0	0	0	0	-10	5	-10	-83
15	8.4.-14.4.	0	0	-5	-5	-5	-10	0	-10	-82
43	21.10.-27.10.	0	0	0	0	0	0	-5	-15	-82
38	16.9.-22.9.	0	0	0	0	-5	-10	-5	-15	-76
42	14.10.-20.10.	0	0	0	0	5	-5	-10	-5	-75
13	25.3.-31.3.	-5	0	0	0	-5	-10	-10	-10	-73
53	30.12.-5.1.	0	0	0	0	-5	0	-15	-15	-72
48	25.11.-1.12.	0	0	-10	-5	-10	-5	0	-10	-70
30	22.7.-28.7.	0	0	0	0	-5	-10	-20	-15	-69
27	1.7.-7.7.	0	0	0	0	0	-15	-20	-20	-64
9	25.2.-3.3.	0	0	0	-10	-5	-10	-15	-20	-63
49	2.12.-8.12.	0	0	-5	0	10	10	5	0	-62
29	15.7.-21.7.	0	0	0	0	0	-10	-10	-25	-60
6	4.2.-10.2.	0	0	0	-5	-10	-5	-10	-15	-55
37	9.9.-15.9.	0	0	0	0	5	5	5	-5	-54
3	14.1.-20.1.	0	0	0	0	0	10	15	5	-48
47	18.11.-24.11.	0	0	-5	-5	-5	-10	-10	-10	-47
45	4.11.-10.11.	0	0	0	-5	0	-5	10	0	-47
50	9.12.-15.12.	0	0	0	10	10	-5	5	-5	-38
4	21.1.-27.1.	0	0	5	0	0	-10	-10	-15	-34
8	18.2.-24.2.	0	0	0	0	-5	-10	-15	-15	-33
20	13.5.-19.5.	0	0	0	0	-10	-5	0	5	-32
44	28.10.-3.11.	0	-5	0	0	0	-5	-10	-10	-28
39	23.9.-29.9.	0	0	0	0	0	-5	15	10	-27
23	3.6.-9.6.	0	0	0	-5	0	0	-10	-20	-25
17	22.4.-28.4.	0	0	0	0	0	-5	-10	0	-16
25	17.6.-23.6.	0	0	0	0	0	-5	-5	5	-14
52	23.12.-29.12.	0	0	0	0	0	5	-10	0	-14
35	26.8.-1.9.	0	0	0	0	0	-5	5	-10	-7
51	16.12.-22.12.	0	0	0	0	-5	-10	-15	-10	-5
24	10.6.-16.6.	0	0	0	0	0	0	5	0	1
19	6.5.-12.5.	-5	0	0	0	-5	0	-10	-10	3
28	8.7.-14.7.	0	0	0	0	-5	-10	-15	-10	6
31	29.7.-4.8.	0	0	0	0	0	-10	15	10	13
33	12.8.-18.8.	0	0	5	5	5	10	10	5	15
32	5.8.-11.8.	0	0	0	0	5	10	5	0	19
22	27.5.-2.6.	-5	0	-5	0	5	0	5	10	37
18	29.4.-5.5.	0	0	0	-10	0	0	5	15	55
46	11.11.-17.11.	-5	0	0	0	0	0	20	20	60
34	19.8.-25.8.	0	0	0	0	0	15	25	0	74
11	11.3.-17.3.	0	-5	0	0	5	10	20	15	78
21	20.5.-26.5.	0	0	0	0	5	10	20	10	80
41	7.10.-13.10.	5	0	0	0	10	5	5	10	88
40	30.9.-6.10.	0	5	5	0	10	10	15	15	99
36	2.9.-8.9.	0	0	0	0	10	10	25	5	104
10	4.3.-10.3.	-5	0	0	-5	0	5	10	10	113
5	28.1.-3.2.	0	5	0	0	-10	-10	-10	-5	135
2	7.1.-13.1.	0	5	0	10	5	10	15	15	196

Table 3. Predicted deviations of weekly precipitation totals from the long-term average (normal) depending on the advance of the forecast and their comparison with the actual deviation from the measured values. Explanation in the text.

3. Conclusions

The outputs of monthly forecasts are partly used in the process of creation of the CHMI monthly forecasts for the public and other users. The evaluation of ECMWF monthly forecasts for 2019 showed that the forecasts of temperature are usable for the first and second weeks of the forecast, only to a very limited extent for the third week. In the third and fourth week of the forecast, the number of successful forecasts decreases rapidly.

The success rate of forecasting weekly precipitation totals is even lower than weekly temperature averages. The first week of the forecast is useful, the second one is useful only to a very limited extent. The prediction of precipitation totals is generally more complicated than temperatures. It is similar with the monthly CHMI forecasts, which are based on a statistically analog method, where the success of temperature forecasts is generally also higher than the success of precipitation forecasts.

3.2 Subjective verification

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

The seasonal and monthly forecast products ECMWF are considered as having some informative value.

3.2.2 Case studies

4. Requests for additional output

5. References to relevant publications