Application and verification of ECMWF products 2017

Czech Hydrometeorological Institute (CHMI)

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, tubes, plumes and EPS-grams are considered in order 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 have been used especially in severe weather forecasting. ECMWF graphical products are also used by the Weather Service of Army of the Czech Republic.

At the beginning of 2007 CHMI implemented weather station Visual Weather of IBL soft. Increasing number of products of deterministic model and some probabilistic products are visualised on this weather station both at the Central Forecasting Office and at the Regional Forecasting Offices. Using this weather station, products of other models including Aladin model (operated in CHMI), GFS and ICON model can be easily displayed and compared to ECMWF model.

ECMWF products have become the main products to issue short-range and medium-range weather forecasts for both the whole territory of the Czech Republic and particular regions of the Czech Republic. The goal of one of the internal projects at CHMI 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.

2 Use and application of products

2.1. Post-processing of model output

2.1.1. Statistical adaptation

Objective statistical adaptation is used for 2metre temperature prediction.

2.1.2. Physical adaptation

No limited area modeling using the ECMWF products is carried out operationally, but ECMWF lateral boundary conditions can be used as a back-up for the ALADIN model.

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.

ECMWF deterministic temperature and precipitation forecast serves as optional input to hydrological model in cases that prolonged lead time is demanded (especially for the purpose of reservoir management), however it is quite rare practice in Czech Republic.

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.

2.1.3. 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 (VW) of IBL soft and depicted to tables, maps and diagrams by means of the same 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.

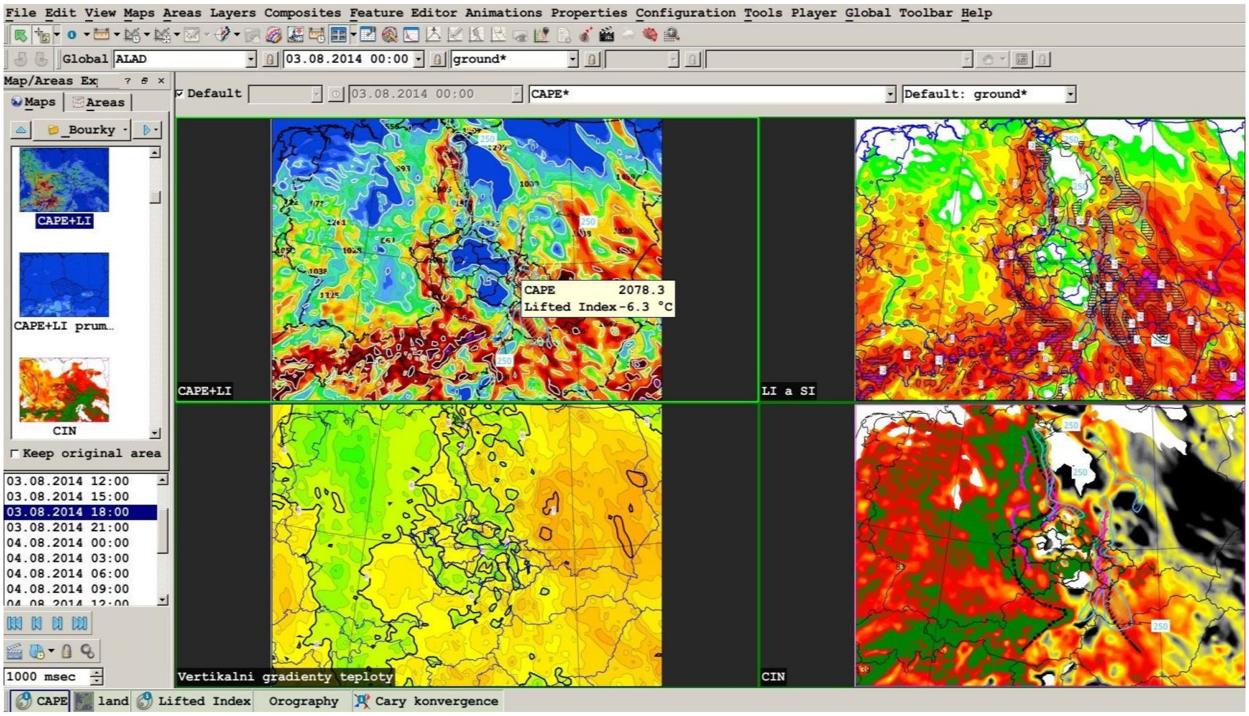

Fig. 1: Example of derived fields that are used for thunderstorm event prediction. In summer time forecasters plots convergence and instability lines and instability areas to these maps.

2.2. Use of ECMWF products

2.2.1 Use of Products

The final medium-range forecasts produced by forecasters of CHMI are currently used in the general weather forecasting for 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.

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.

2.2.2 Product requests

3 Verification of products

There is currently no objective or systematic subjective verification of ECMWF medium range forecast products carried out. The general scores calculated and published by ECMWF are considered informative. For now we also use verification of ECMWF products from the Green Book. Considering the character of medium-range weather forecasts, the verification scores from neighboring countries are well applicable also for our service.

3.1 Objective verification

3.1.1 Direct ECMWF model output (both HRES and ENS)

At CHMI the agrometeorological parameters are modelled by the AVISO model for the Czech Republic as a whole on a regular basis based on meteorological measurements. We have decided to predict these inputs using ECMWF data. We have used deterministic forecasts of air temperature, relative humidity, wind speed, total precipitation and global radiation for almost 200 measurement points for the most of the year 2014 and 2015 and we have compared them with actual real data. For this purpose daily averages or daily sums of the mentioned parameters were needed. The aim of this part of the project was to analyse forecasted parameters subsequently used by the AVISO model in forecast mode up to 8 days. By this analysis some errors, deviations and dependencies were identified and then used to modify input data to the AVISO model. Below are some of the most important results and findings.

The mean deviations during the whole period and for all stations are very close to zero in case of all the parameters. However, in case of the individual stations, we can clearly see that the **mean deviations are dependent on station elevation** and the **range between extreme values increases with increased forecast time span**. Systematic error is due to low resolution of orography in the numerical model, especially at higher elevations in the Czech Republic.

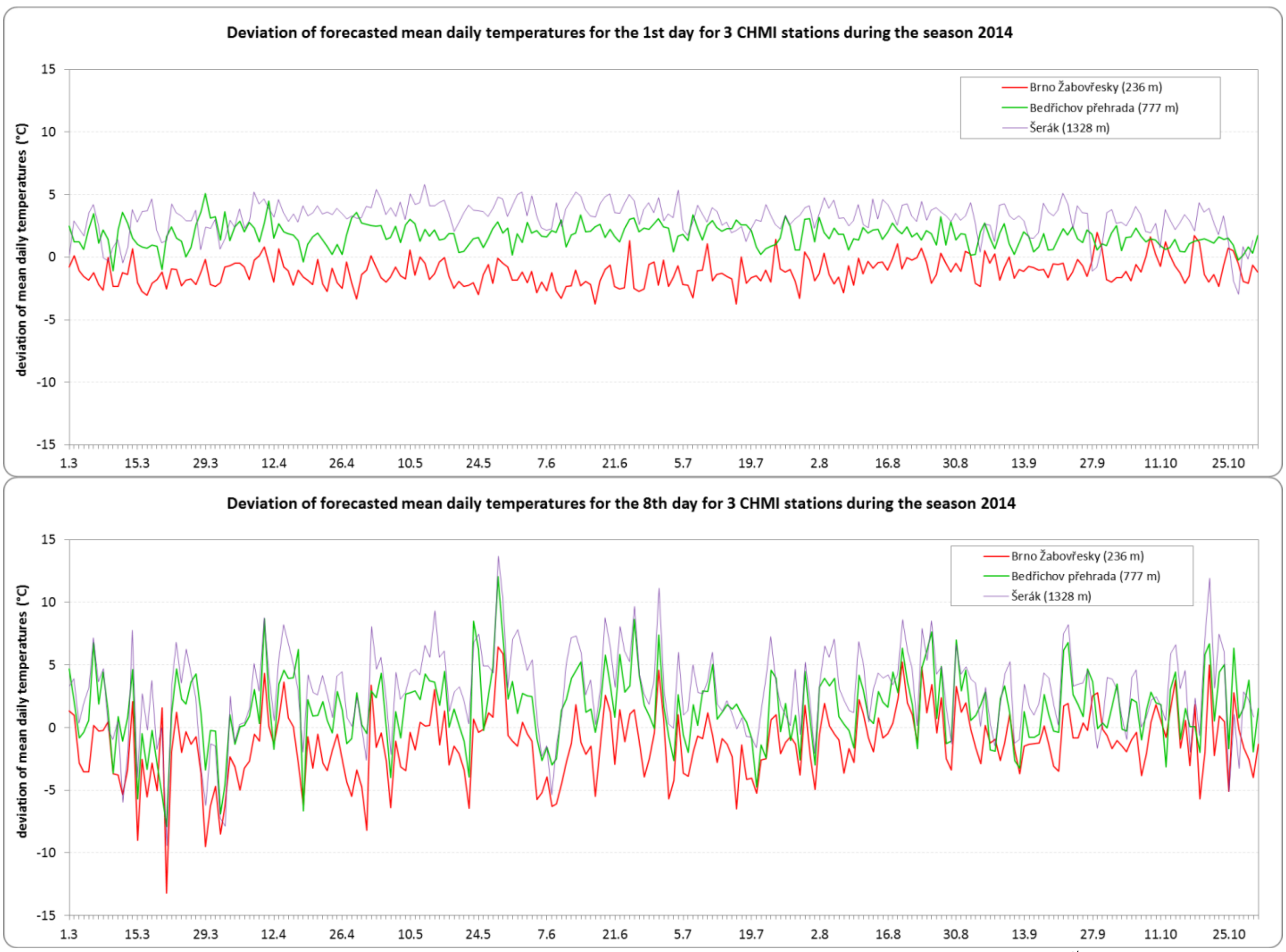

Fig. 2: Deviation of forecasted mean daily temperatures for each day in season 2014 for 1st day (top) and 8th day (bottom) for 3 stations at different elevations: red = Brno 236 m; green = Bedřichov 777 m; purple = Šerák 1328 m.

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The greatest overestimation of mean daily temperature was found at the Sněžka station (1602 meters above sea level, both years over 5 °C). The majority of the stations are at elevations between 150 m and 600 m where the average deviation of mean daily temperatures are in most cases only between -1 to +1 °C. However, the term temperature deviation can in extreme cases range between -20 and +20 °C regardless of the station elevation. Nevertheless, these extremes are rare and only detected in forecasts for days 6, 7 and 8 especially at 12 UTC.

Relative humidity is a very variable parameter and it is very sensitive to local conditions and so the errors in forecasts can be quite substantial (average of mean daily deviation ranges from -40 to +40 %, individual extreme term deviations from -60 to +80 %). The relationship between mean daily relative humidity deviation and elevation is not so clear. The higher the elevation, the more frequently the relative humidity is underestimated, which could also be explained by the fact that the model uses points at lower elevations. In contrast, large overestimation of values is related to very dry air above the inversion layer, which is in reality at higher level than what the numerical model assumes.

In general, the wind speed forecast of the ECMWF model does not change much with increasing forecast time span. Forecasts for the 8th day are not so different from the ones for the 1st day. However, there is a strong relationship with elevation. Very high errors in wind speed are observed especially in case of mountain stations in open space (rarely over 30 m/s in term forecast). Average of mean daily deviation ranges from -4 to +6 m/s, individual extreme term deviations range from -33 to +9 m/s.

Global radiation is a very special parameter that is measured only at 19 stations in the Czech Republic. It is difficult to evaluate the daily course of cloudiness from daily sums of global radiation. There is a large range in measured daily sums of global radiation values during the season, and also during overcast days. It is interesting to analyse days with clear sky or maximum measured sunshine duration. It can be said that in the summer there is a significant underestimation of daily sums of global radiation (max. 12 %) during sunny days.

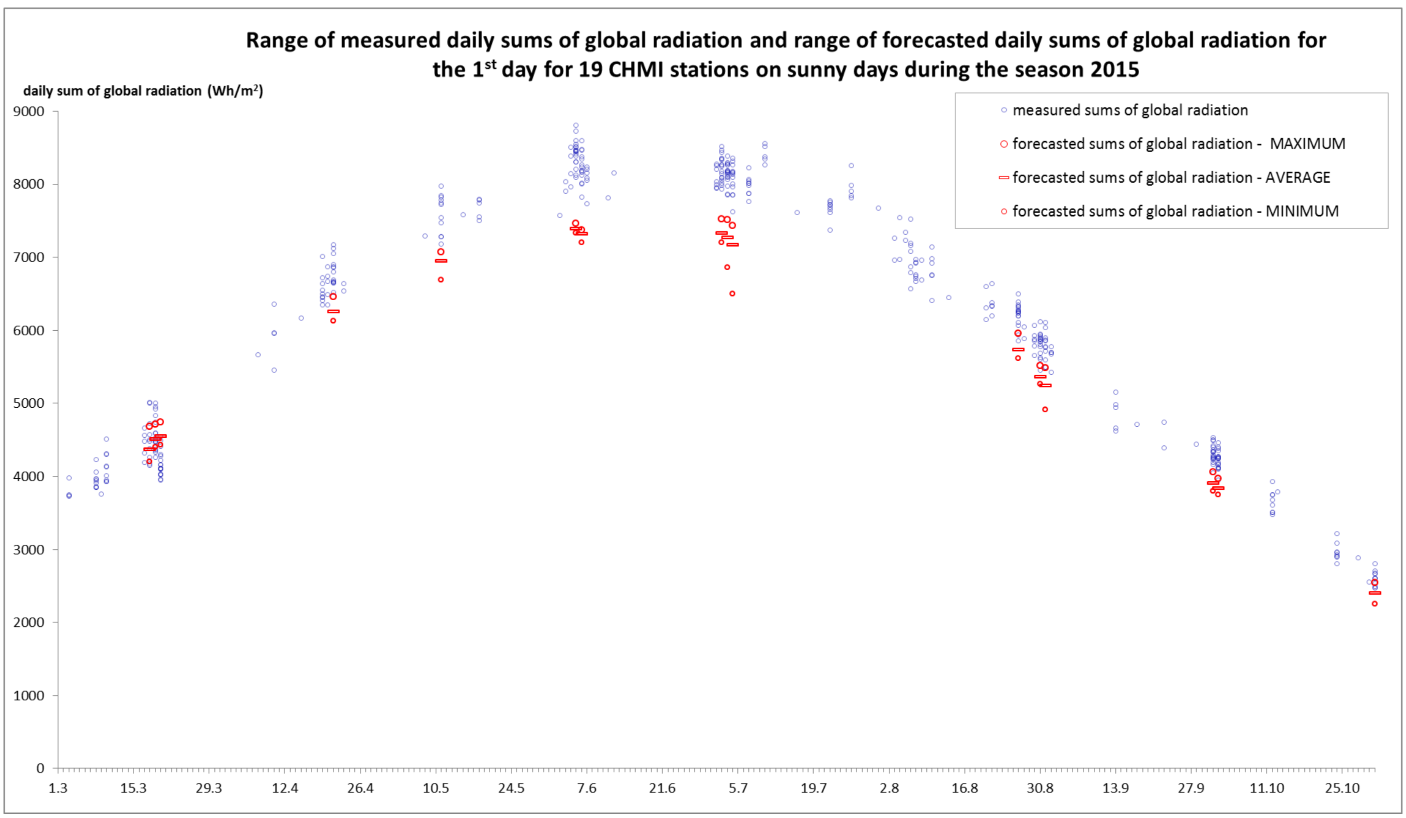

Fig. 3: Range of measured daily sums of global radiation (blue) and range of forecasted daily sums of global radiation (red – MIN, AVG, MAX) for the 1st day for 19 CHMI stations on sunny days during the season 2015.

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In season 2015 there were three periods with nearly unchanging weather conditions where we can see typical progress of cumulative deviation of forecasted daily sums of global radiation (fig. 4). At the beginning of July there were several clear days and one can see that the cumulative deviation rapidly decreases because of underestimation of the forecasted global radiation. The same situation was observed at the beginning of August. In the middle of October cumulative deviation slowly increased because of low clouds and very low daily sums of global radiation that were overestimated by the model on some days.

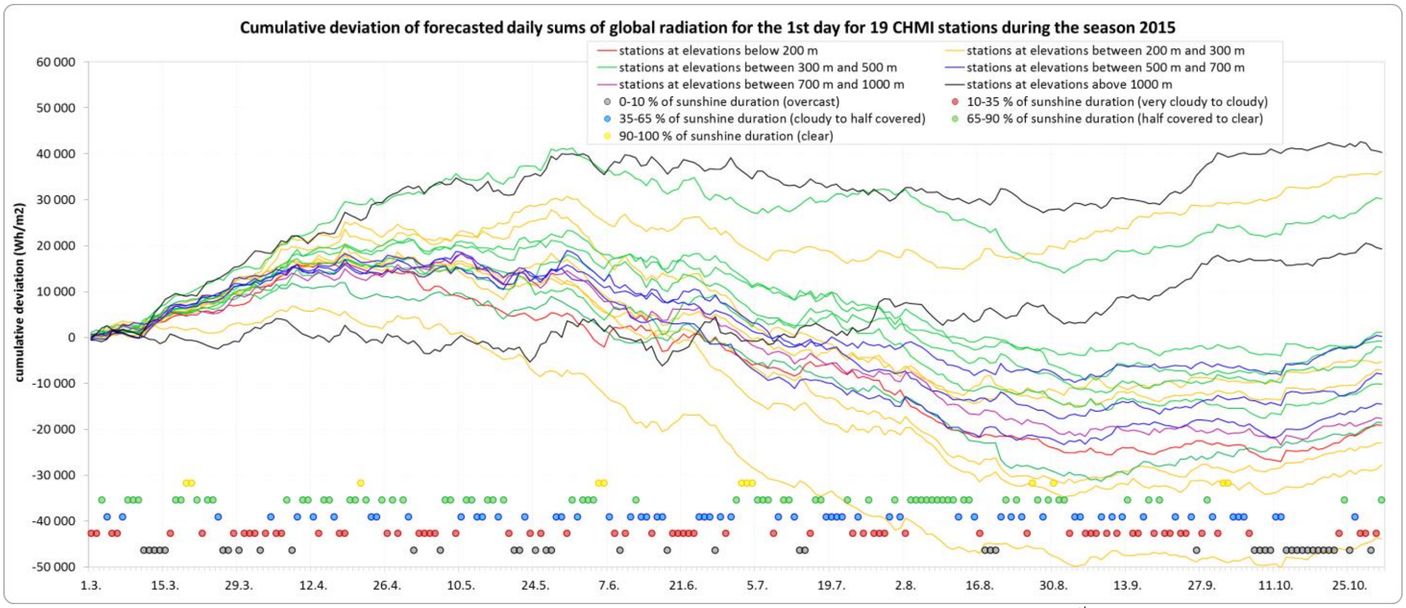

Fig. 4: Cumulative deviation of forecasted daily sums of global radiation for the 1st day for 19 CHMI stations during the season 2015. Points at the bottom of the graph show mean relative sunshine duration for these stations (black = overcast, red = very cloudy to cloudy, blue = cloudy to half covered, green = half covered to clear, yellow = clear).

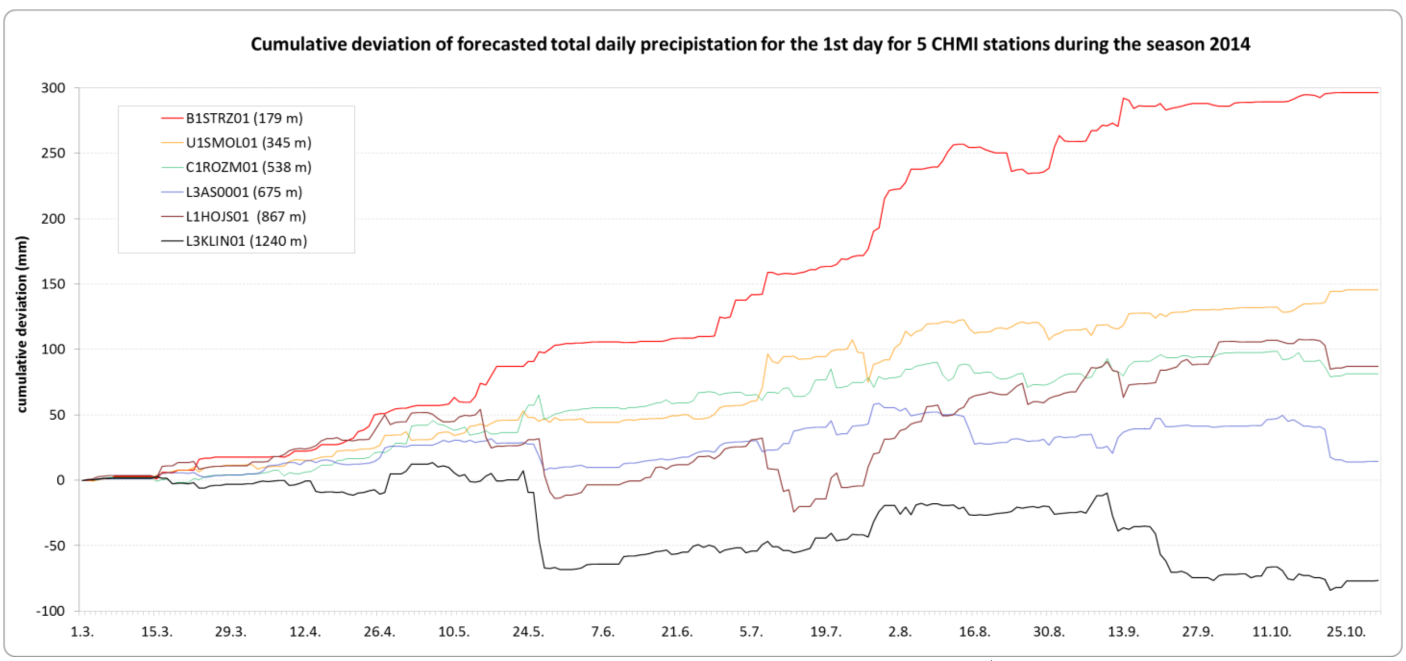

Fig. 5: Cumulative deviation of forecasted total daily precipitation for the 1st day for 5 CHMI stations at different elevations during the season 2014.

Analysing the forecast for the total daily precipitation in the whole area is the most difficult task. Most of precipitation is of very local nature because of intensive showers and thunderstorms making the errors in point forecast potentially quite large. The overall success rate of total daily precipitation forecast depends on how many days without precipitation there were. Over 95 % of accurate forecasts (i.e. absolute deviation of less than 0.05 mm) are observed on days with no precipitation and only 1 % or 0.6 % of accurate forecasts are cases with total daily precipitation of 2 mm or more in 2014 or 2015 respectively. Over 75 % of all forecasts (over 80 % in 2015) have absolute deviation of 2 mm or less for the 1st day of forecast, which seems quite accurate; however, these are mostly cases with very low total daily precipitation (0 to 2 mm).

Weak relationship between total daily precipitation and elevation is apparent only when looking at the cumulative deviations for the whole season. This relationship, however, is outweighed by larger forecast errors in individual cases. In case of the whole season most of the stations at lower elevations have positive cumulative deviation (mean for stations at elevations below 600 m is +100 mm, max. +350 mm). At higher elevations approximately half of the stations have a negative cumulative deviation (mean for stations with elevations above 600 m is +50 mm, max. -240 mm). Figure 5 shows that forecasted total daily precipitation at lower elevations is constantly overestimated by small rainfall amounts. There are only a few cases of more intense rains, which decrease the cumulative deviation. In mountain areas, the total precipitation is on average higher, therefore the weak or moderate precipitation is forecasted relatively accurately, but intense showers and thunderstorms are at higher elevations substantially underestimated because of the model resolution and also lower elevation used by the model.

Another possible analysis of the precipitation forecast accuracy was to look at the weather conditions on the days with largest forecast error (deviation equal to or greater than 10 mm). Days were categorized based on the number of stations with absolute deviation of total daily precipitation of 10 mm or more. Two categories are of high-pressure type weather with no precipitation or with insignificant number of cases with any deviation in total daily precipitation. Three categories are of low-pressure type and usually correspond to cases with high number of inaccurate forecasts or large absolute deviation in total daily precipitation.

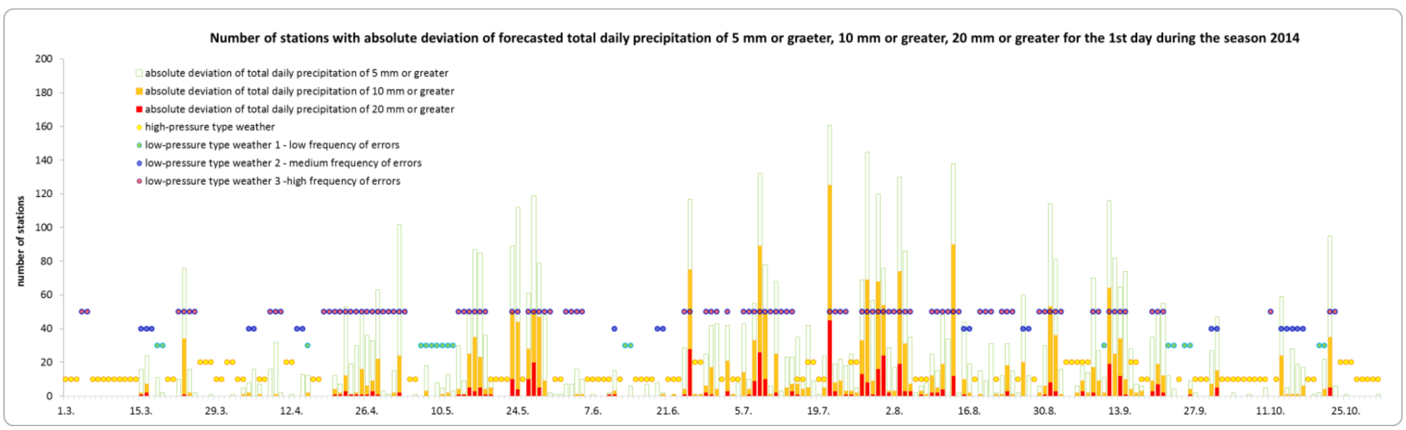

Fig. 6: Number of stations with absolute deviation of forecasted total daily precipitation of 5 mm or greater (green column), 10 mm or greater (orange column), or 20 mm or greater (red column) for the 1st day during the season 2014. Yellow dots - days of high-pressure type weather, remaining dots – days of low-pressure type weather categorized based on frequency of number of stations with absolute deviation in total daily precipitation of 10 mm or more.

All these results can help to evaluate weather forecasting for agrometeorological purposes. Some of the found deviations could be corrected systematically. Being aware of the uncertainties in the total daily precipitation forecast in case of some of the low-pressure type days could be beneficial in preparing for such situations and in decision making. Follow-up analysis could compare data from improved numerical model, which uses a higher resolution and is being used since 2016.

3.1.2 ECMWF model output compared to other NWP models

For now, the maps which compare forecasted and real estimated precipitation are only used for information purposes and not for any further analysis. The real total precipitation is estimated using a combination of meteorological radar data and rain gauge measurements (MERGE). Differences between model and MERGE give quantitative information about deviation in total precipitation over the whole area. For basic comparison, maps for the 1st day of yesterday's forecast from Aladin (CZE), ICON-EU (GER), ECMWF (GBR) and GFS (USA) model are being generated.

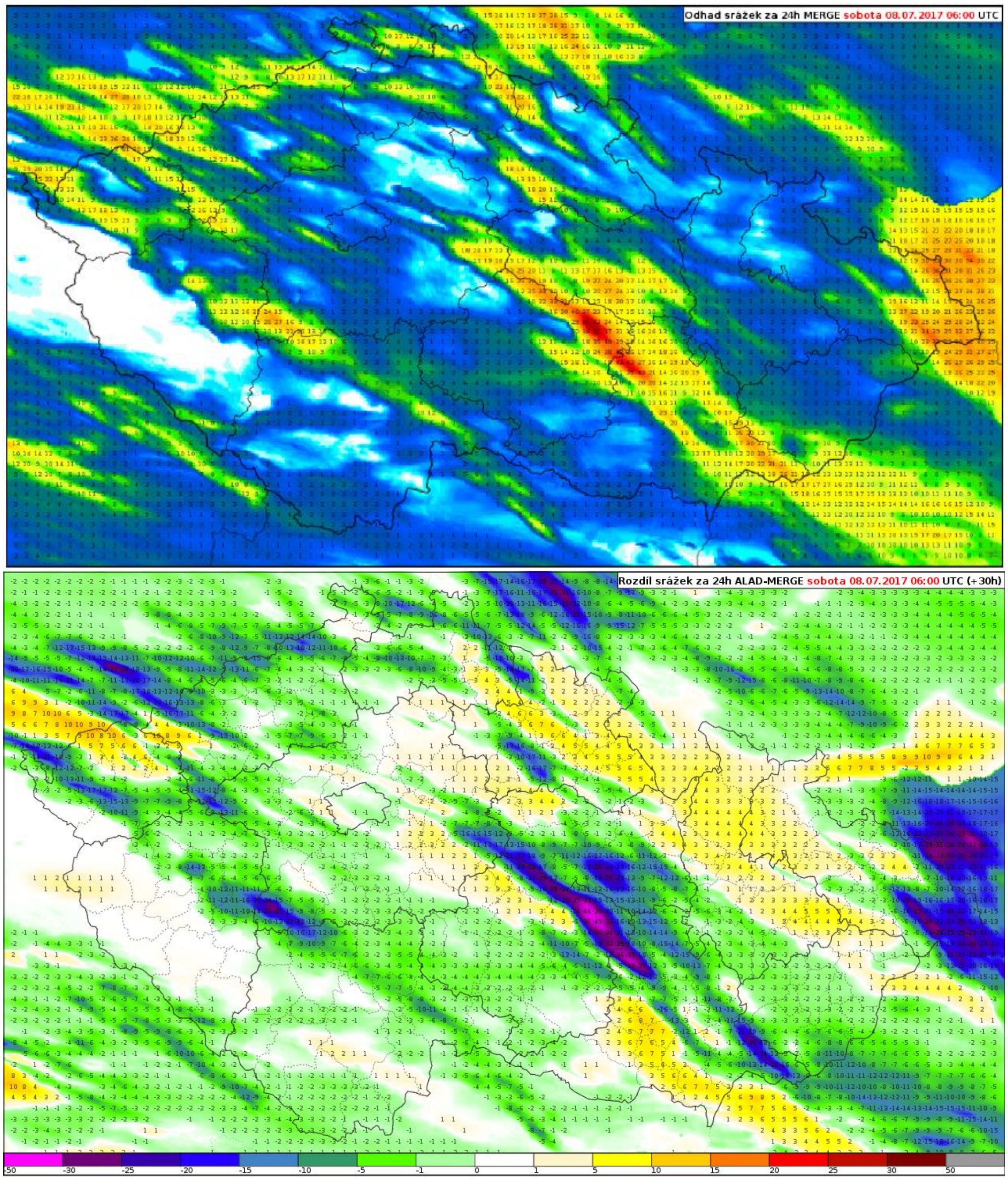

Fig. 7: Estimated total precipitation in the Czech Republic – MERGE (top) and difference in total precipitation between ALADIN and MERGE (bottom) in mm for the 8th July 2017.

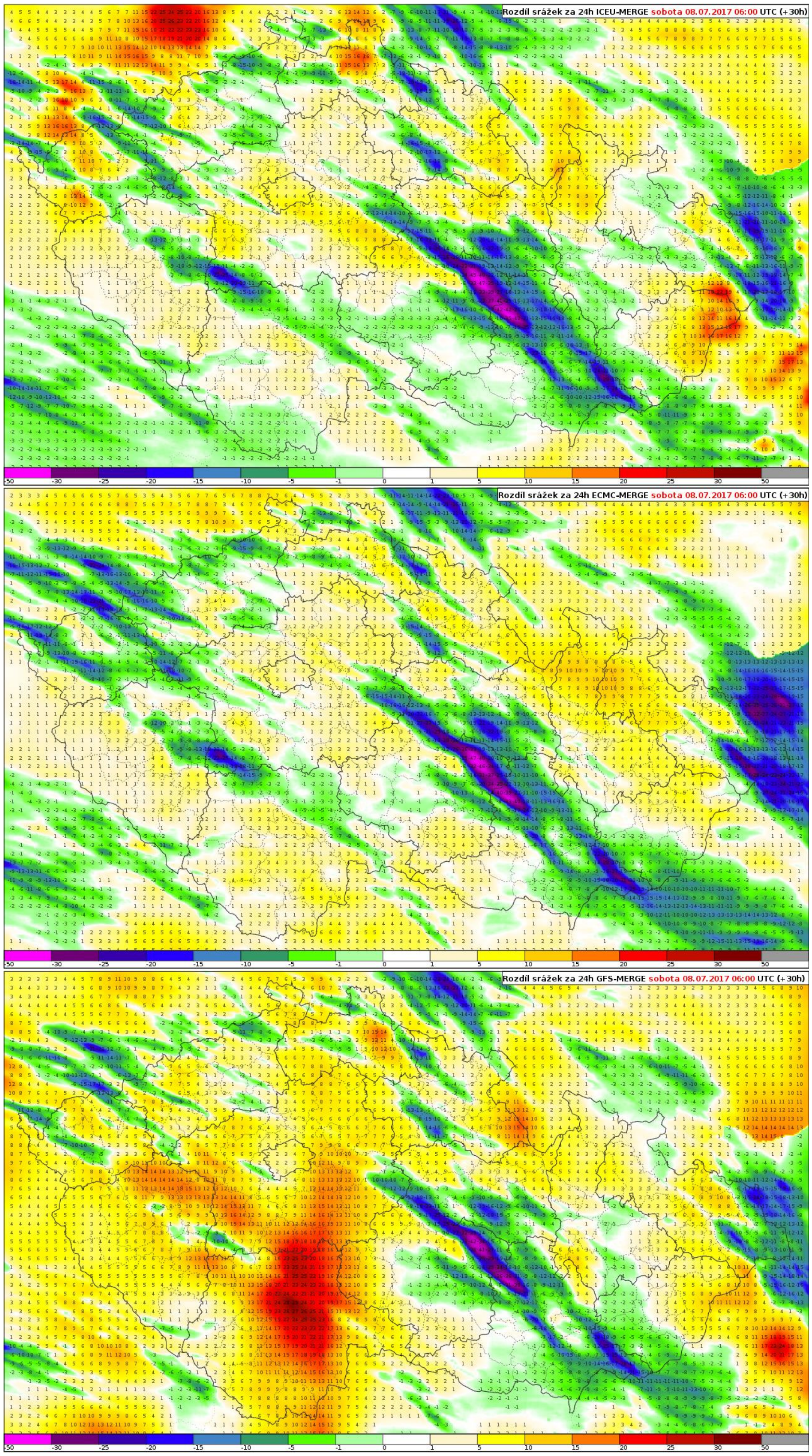

Fig. 8: Differences in total precipitation between ICON-EU and MERGE (top), ECMWF and MERGE (middle), GFS and MERGE (bottom) in mm for the 8th July 2017.

3.1.3 Post-processed products

3.1.4 End products delivered to users

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 Feedback on ECMWF "forecast user" initiatives

We use the page "Known IFS forecasting issues", it is useful to be aware of them. Of course some of described issues are common not only to ECMWF model, but also to other numerical weather prediction models. We are interested mainly in precipitation forecasts issues and danger weather issues in general.

Severe weather catalogue is not used often but in some cases it is very useful.

5. References to relevant publications