

# Applications and Verification **Report**

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<b>Period:</b>	2024	
<b>Date:</b>	March 2025	

## Summary

The primary goal is to develop and adapt/use different specific applications into user-friendly mode. Many tools and software products were developed along the years for meteorological parameters. These days, it is imperative to have easy to use applications, maybe to find and to identify the operational activities, to make a common way for saving time and manpower resources. Nowadays, it is important to make the applications easy to implement without too much cost and to make a common way for saving time, computer costs and manpower. It is a big challenge to identify and to merge all the beneficial technical approaches and applications for all countries.

The report summarizes the Applications and Verification activities of the first 6 months of the year 2024:

- The work of Polly Schmederer at DMI (in an ACCORD stay) is related to the generalising spatial verification based on panelification harp panel tool.
- The results obtained by Martin Petráš, during his stay in Prague, in collaboration and supervised by Alena Trojáková, on extending harpIO to enhance its functionality for upper air verification within the OBSOUL framework.
- In Croatia, the work of Iris Odak Plenkovic in the development of a simple way to present wind scores, taking into account wind direction.
- The continuous work, in Austria, on the development of panelification and an important upgrade for hail and lightning verification and migrated to the newest version.
- The report provided by Hungary is based on 3 important aspects: the verification tool HARP was upgraded to version 2.0 and it was completed the operational scripts for monthly verification of AROME-EPS; were provided internal HARP training courses for HungaroMet colleagues and also a mentoring for a BSc student was mentored in order to perform the surface point verification of the 11-member AROME-EPS compared to the 51-member ECMWF ENS using HARP, for an early summer one-month-long period in 2024 when several convective events happened.
- Also in Hungary, the input data for the EMOS post processing for radiation runs daily are used the 11-member forecasts of AROME-EPS as well as measurements at 7 stations.
- For a more flexible mode for the evaluation of the operational model, the standard verification was extended in Croatia, in this way the scripts based on the verif module were written/modified in order to make them compatible when trying to calculate a vertical profile of some basic verification scores. Also, it was added the possibility to calculate scores in Python for EPS.
- Another topic in Croatia is the usage of an analog post-processing method for wind for the general public.
- In Czech Republic, it was prepared the code in order to have new outputs for aeronautical forecasts to the ALARO CMC.

- In Poland, it was performed the following validation for different experiments: ALARO cy43t2 with assimilation, ALARO cy46 – with modifications from colleagues from Prague, new LBC with 1h frequency and snow scheme in SURFEX – only for winter period.
- Another approach in Poland is the d-dimensional copula is a multivariate distribution function with uniformly distributed marginals. Sklar's Theorem. The goal is the error mitigation of the temperature forecast given by the ALARO model.
- In Romania, the HARP tool was used in order to perform verification for the 10 m wind gust, for experiments done in order to tune the parameter FACRAF. Another verification was performed for comparison between model versions cy43bf10 and cy43bf11, in order to be able to use cy43bf11 for the operational configuration.

## Action/Subject/Deliverable: Development of HARP [MQA1]

### Description and objectives:

Two important stays were done: the stay of Polly Schmederer at DMI in the frame of ACCORD and one of Martin Petráš at CHMI in collaboration with Alena Trojáková.

The report of Polly Schmederer is related to the generalising spatial verification based on panelification harp panel tool. The used observations were DMI's radar precipitation product: Surface Quantitative Precipitation Estimation (SQPE) using both rain gauge and radar data EUMETSAT SEVIRI data. The model outputs are the grib files generated in the DEODE workflow running HARMONIE cy46h1 (total precipitation and FULL POS simulated radiances channels WV\_062 & IR\_108). The work was done on ATOS.

The report of Martin Petráš, during his stay in Prague, in collaboration and supervised by Alena Trojáková, shows the work on extending harpIO to enhance its functionality for upper air verification within the OBSOUL framework. Their main purpose was to improve the accuracy and efficiency of processing and analyzing upper air observation data.

### Generalising spatial verification (Austria)

*The developments done during Polly Schmederer's ACCORD VS at DMI.*

#### Topics of VS

##### 1) Generalising spatial verification:

- use of reticulate package to interface R with Python
- generalise/ apply harp panel tool ("panelification")
- this is a harp and R based version of the originally python based panelification
- provide R scripting examples for reading, verification, harp panel tool usage

##### 2) Data used for spatial verification

- Observations:
  - DMI's radar precipitation product: Surface Quantitative Precipitation Estimation (SQPE) using both rain gauge and radar data
  - EUMETSAT SEVIRI data (<https://api.eumetsat.int/data/browse/collections>): High Rate SEVIRI Level 1.5 Image Data - MSG - 0 degree (native), e.g. MSG3-SEVI-MSG15-0100-NA-20240102235743.693000000Z-NA.nat
- NWP:
  - Grib files output of the DEODE workflow running HARMONIE cy46h1 (total precipitation and FULL POS simulated radiances channels WV\_062 & IR\_108)
  - As part of the WP6 of the CERISE (Copernicus Climate Change Service Evolution) project, DMI is contributing to the spatial verification of snow cover using the harp verification package.

The development was done on ATOS (shared using accord group). More details about the installation instructions of how to install the libraries are on github: [https://github.com/fbaordo/oper-harp-verif/blob/master/ACCORD\\_VS\\_202406/INSTALLATION.md](https://github.com/fbaordo/oper-harp-verif/blob/master/ACCORD_VS_202406/INSTALLATION.md).

### *Information displayed in the plot*

In the first panel the observation field is displayed, there is one panel for each of the verified models:

- observations: obs title - name + valid observation time
- models: model title - left: model name, initialisation time + lead time, (average FSS rank); right: average rank of basic scores (this is the average of all non-FSS scores that are passed in the definition file) and ranking of the models according to this average rank
- top box: ranks of FSS (using thresholds); ranks of FSS (using percentiles); basic scores - displaying the actual values (rank according to the value)

For more information on what you see on a panel plot, check the interpretation help.

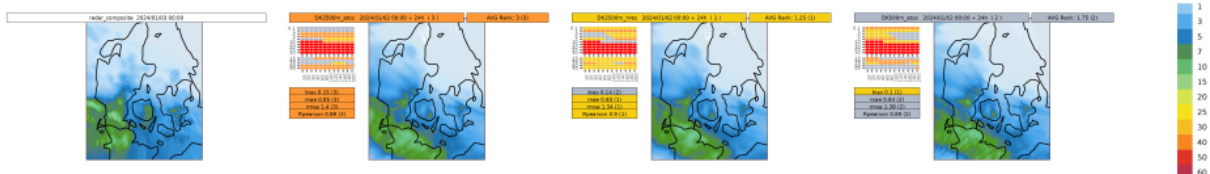
To add another model (panel) to panelification, a file with their definitions on how to read/verify must be added, which will then be added to the panelification.yml.

1. Know how to read the model that should be added. (An example on how the data may be read can be found in `example_read_DataUsingReticulate.R`).
2. Run `verify_spatial`, to see how the configurations must be passed to this function (see the examples `example_verify_tp_deode.R`, `example_verify_sat_deode.R` or `example_verify_snow_cover.R`).
3. Copy a `definitions_*` file (`definitions_<new>.R`) and change all parameters as needed to read/verify the data correctly.
4. Specify the new file in `panel_configs/panelification.yml` for model and parameter. (Define which config files to use > READING of the models/obs).

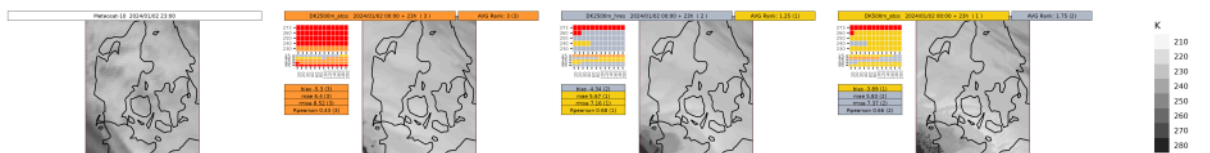
5. If a new parameter was added, also add a definition file for this parameter in panel\_configs/panelification.yml (Define which config files to use > PLOTTING of the fields).

*Some example plots*

### Panelification plot precipitation

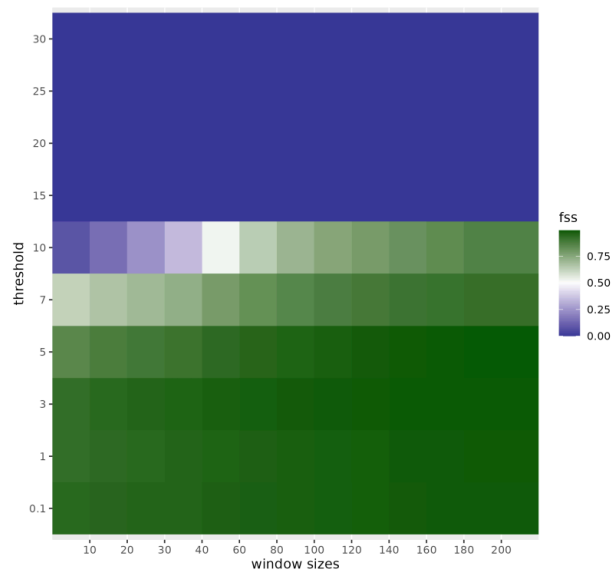


### Panelification plot IR 108



### FSS plot precipitation

Model: DK500m\_atos , Param: Accpcp3h  
Period: 2024010200 + 24



More details can be found on her report stay at DMI ([www.rlace.eu](http://www.rlace.eu)).

**Contributors, estimated efforts:** Polly Schmederer (1 pm)

## Extending harpIO to enhance its functionality for upper air verification within the OBSOUL framework (Slovakia and Czech Republic)

1) Martin Petras, during his stay in Prague, with Alena helping, worked on extending harpIO to enhance its functionality for upper air verification within the OBSOUL framework. This upgrade aims to improve the accuracy and efficiency of processing and analyzing upper air observation data. The improvements focus on optimizing data handling, processing, and analysis, ensuring more accurate and efficient verification processes for upper air observations. The next phase will focus on implementing these updates into the Harp development version. The report from this stay is in its final stages (more details on [www.rclace.eu](http://www.rclace.eu)).

Also, the plan is to integrate Harp into the LACE web - <https://www.rclace.eu/extra/monitor/> (Figure 1), allowing us to generate two distinct outputs: one from Monitor and another from Harp. Harp's verification will utilize observations from OBSOUL, while Monitor will rely on observations from vobs. In Slovakia, are archived GRIB files for all LACE countries, allowing to run Harp interfaces and verification on our HPC. However, this is still a future plan. Our immediate focus is on resolving several key issues, including:

- Establishing web data interfaces (for sending verified data and visualizing verification scores)
- Ensuring data production for OPLACE upper air (confirming if we have this capability)
- Addressing issues with station SID (ID) names.

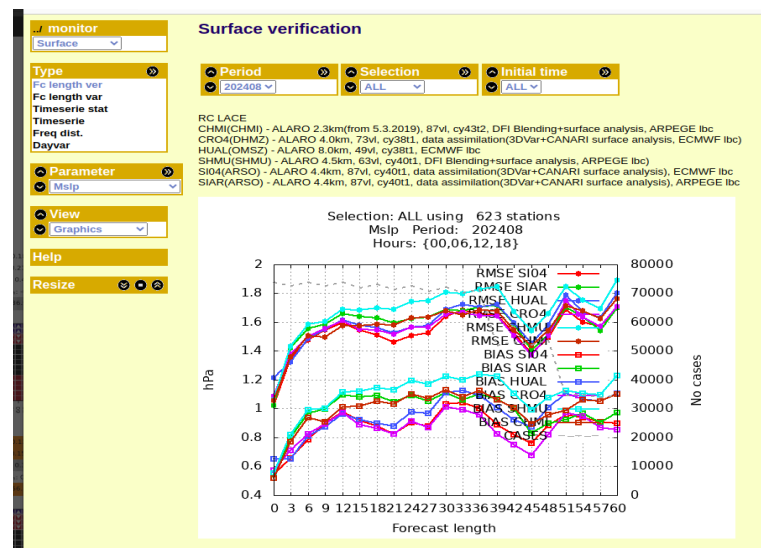


Figure 1. Example of verification on RC-LACE web page.

OBSOUL files, generated in ASCII format by the OULAN programme, are used as input to the NWP assimilation system. These files can contain data from a variety of sources, currently surface synoptic observation (SYNOP), radiosonde (TEMP) and aircraft data are provided by OPLACE. By incorporating TEMP data from

OBSOUL, we aim to improve the completeness of the verification datasets. TEMP data provides valuable insight into atmospheric conditions at different pressure levels, improving the overall quality of verification processes. Different observation types are represented by a corresponding number in the OBSOUL files, see the first column of Figure 2. Each of these types can contain different observation parameters represented by parameter numbers (Figure 3).

Observation type (obstype@hdr)	Data description
1	Land SYNOP and SHIP reports
2	Aircraft based measurements (AMDAR, EHS)
5	Radiosonde (TEMP) reports

Figure 2: Observation types are specified by the [obstype@hdr](#) column.

Observation parameter (varno@body)	Parameters description
1	geopotential [J/kg]
2	upper air temperature [K]
3	upper air u wind component [m/s]
4	upper air v wind component [m/s]
7	specific humidity (upper air and 2m)
29	upper air relative humidity [0-1]
39	2m temperature [K]
41	10m u wind component [m/s]
42	10m v wind component [m/s]
58	2m relative humidity [0-1]

Figure 3: Observed parameters specified by the number in the first column.

The parameter quality flag for TEMP can have four values depending on the pressure levels. It is set to **3680** in the case of the surface parameters, to **2560** for upper air parameters at standard levels and to **10304** or **10272** for significant and non-significant upper air levels depending on observed parameter.

The following example of a TEMP record is the same as for SYNOP, but other observations may have different structures:

```
23 5 10003035 70.93957 -8.66930 '01001' 20240401 90000 1.00000E+01 135 11111 0 1 1.02950E+05
1.70000E+38 9.80600E+01 3680 39 1.02950E+05 1.70000E+38 2. 67970E+02 3680
```

It contains two bodies, the first body has following elements:

- 1: observation parameter number of geopotential
- 1.02950E+05: vertical coordinate
- 1.70000E+38: fill value
- 9.80600E+01: observed value
- 3680: flag



and the second body following ones:

- 39: observation parameter number of 2m temperature
- 1.02950E+05: vertical coordinate
- 1.70000E+38: fill value
- 2.67970E+02: observed value
- 3680: flag

The header part contains:

- 23: number of items (n + header + bodies) for this record
- 5: type of observation
- 10003035: observation code (it is assigned by program OULAN)
- 70.93957: latitude
- -8.66930: longitude
- '01001': identification of the station/flight
- date
- time
- altitude
- number of bodies following the header
- observation quality flags (assigned by program OULAN)
- site dependant information (assigned by program OULAN)

This update to Harp version 0.2.2 expands its capabilities to read both SYNOP and TEMP data from OBSOUL files. While the SYNOP and TEMP OBSOUL formats have some structural similarities, the main difference is in the number of data columns. The TEMP data have additional vertical levels than the SYNOP data, with each level data stored in a separate column in the OBSOUL file. In some cases, the number of columns exceeds 2,000. To account for this difference, modifications were made to the `read_obsoul` function.

As is mentioned before a TEMP file can be populated with columns of any length. It was therefore necessary to make some changes in order to read such a long columned file. The reading of files in R can be accomplished using a variety of functions. In our case, `read.table1` is used to read a file in R. In some cases, we faced that this function does not work properly. Some columns were not properly sorted, which caused the problem. There should be a single row for every record



from the TEMP. It happened in some cases that one record was split into two rows, which wasn't supposed to happen.

The `read_obsoul` function plays a crucial role in Harp. It transforms raw data from OBSOUL files into a well-organized format, making it easier to analyze and visualize. This update focuses on significant changes made to this function to effectively handle TEMP data, which has a 1Reads a file in table format and creates a data frame from it, with cases corresponding to lines and variables to fields in the file 4 Regional Cooperation for Limited Area Modeling in Central Europe different structure compared to SYNOP data. SYNOP data only contains records for surface observations.

A series of comparative tests were conducted in order to verify the new interface for OBSOUL TEMP with respect to the VOBS data. These tests involved separately reading observations from each source. The forecast data used for comparison originated from CHMU's operational model, ALADIN CY46 (2.3km resolution). We will present the results of these tests, focusing on comparisons of data time distributions and verification scores.

A comparison of data count distributions for parameter T between Praha-Libus (Czech Republic) and Ganovce (Slovakia) is shown in Figure 4 and 5. It can be seen that the data distributions are different between the VOBS and OBSOUL files. Data from OBSOUL are available in term 00:00, while data from VOBS are available in term 23:00 and 01:00. The same thing happens in 12:00, only in term 06:00 we have data from both.

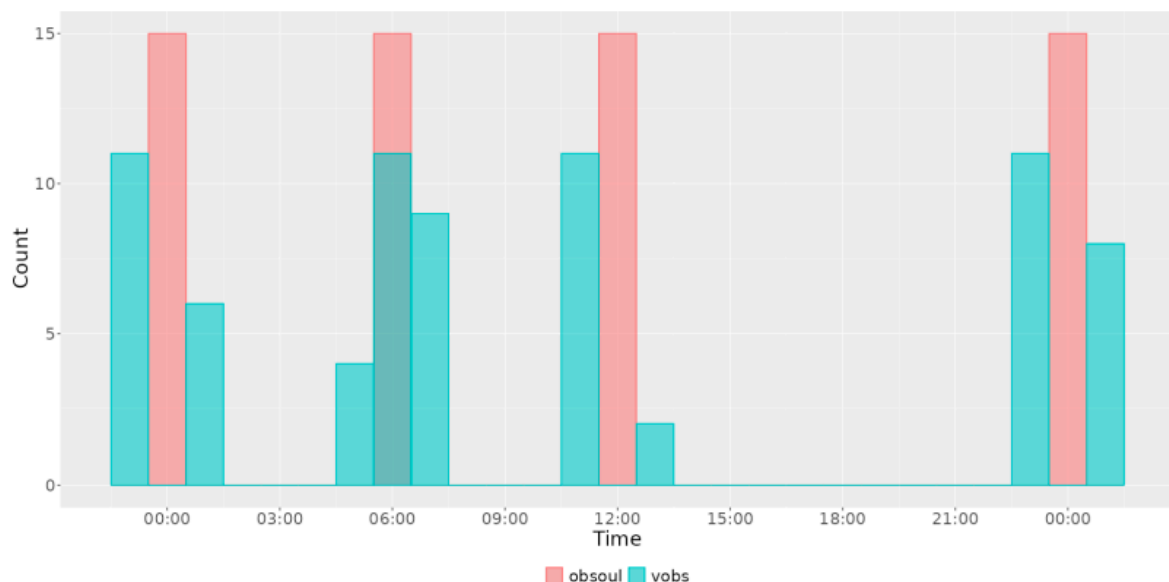


Figure 4: Parameter T time distribution station Praha-Libus [11520].

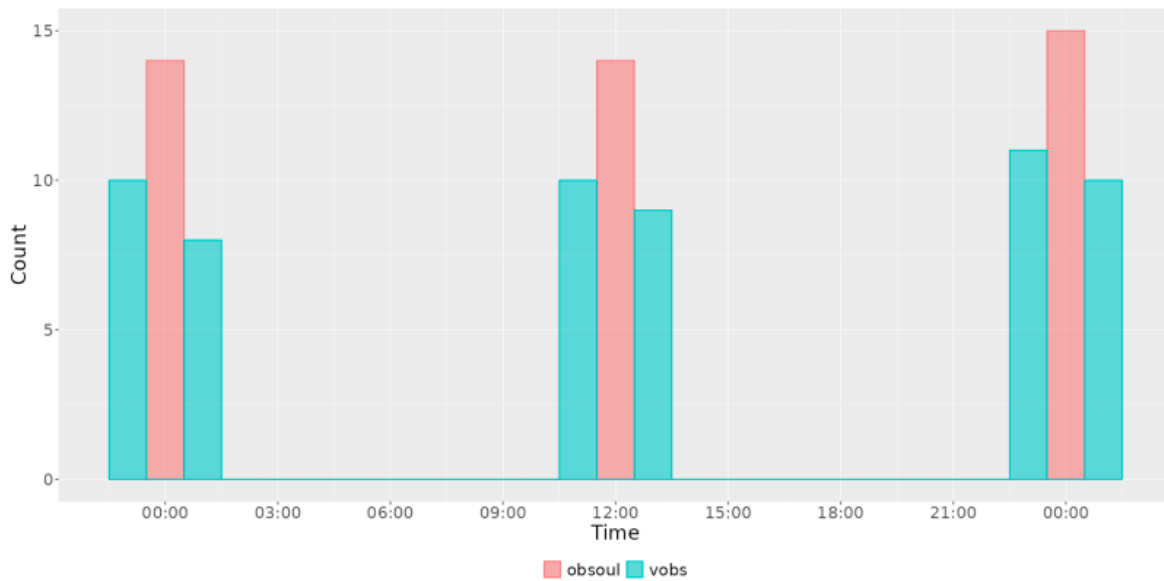


Figure 5: Parameter T time distribution, station Ganovce [11952].

The verification scores are shown for temperature (T), relative humidity (RH) and geopotential (Z). The scores compare observations from two sources: OBSOUL and VOBS. The verification period covers two days, from April 1, 2024, at 00:00 UTC to April 3, 2024, at 00:00 UTC.

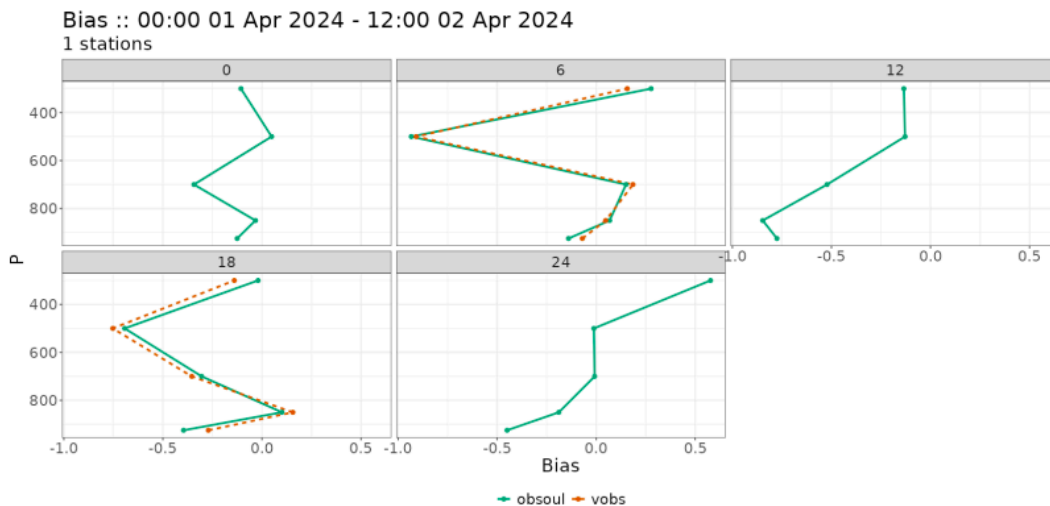
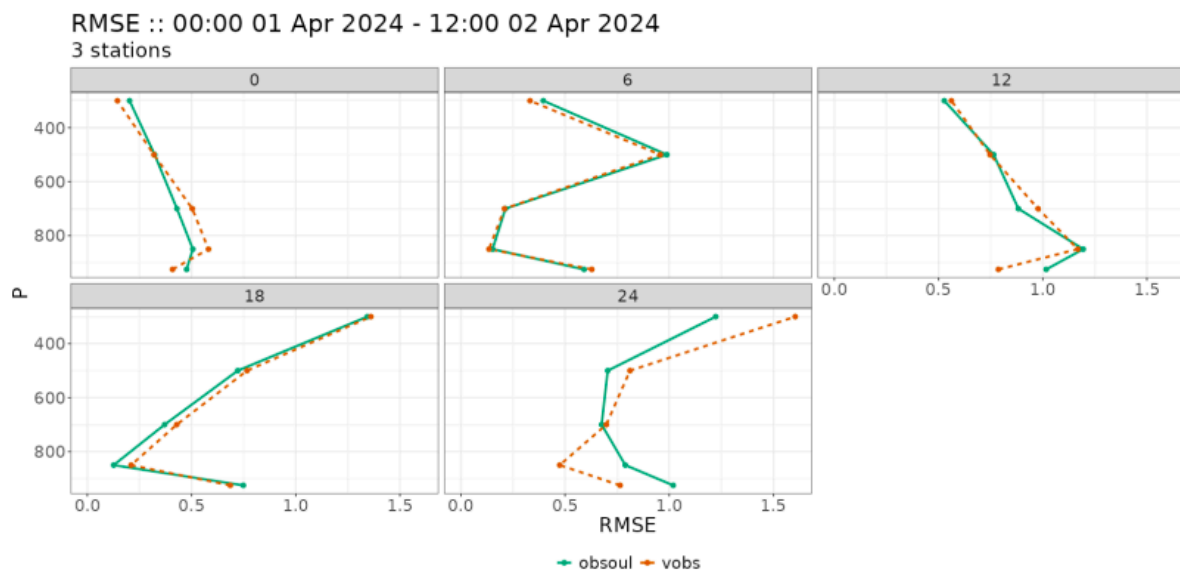
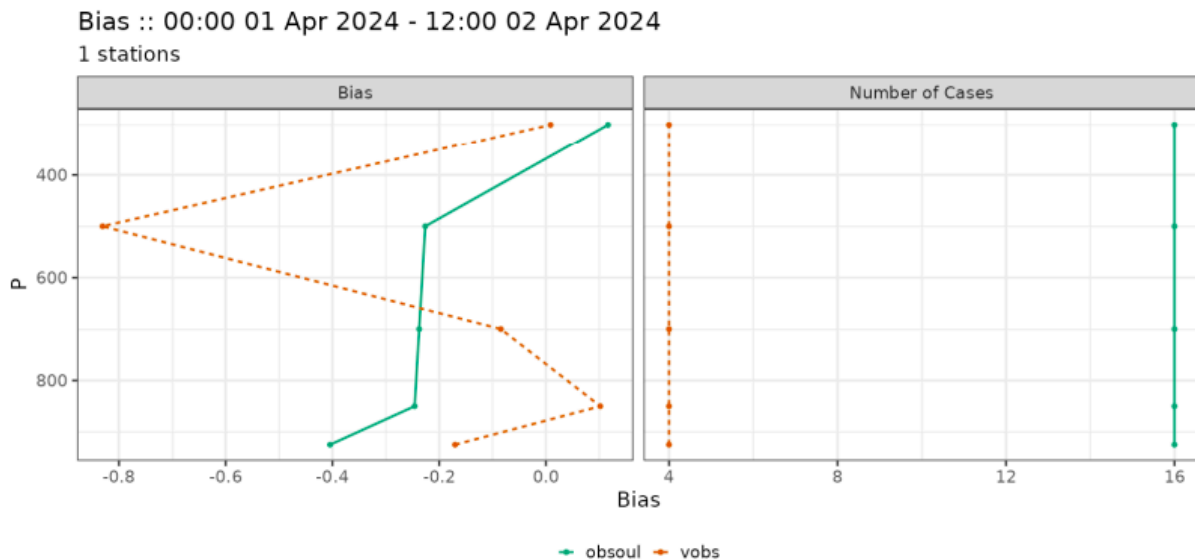


Figure 6: bias for station Praha-Libus [11520].

The findings confirm that some VOBS data is unavailable for lead times 00, 12, and 24, resulting in missing scores for these periods. BIAS scores are only comparable for lead times 06 and 18, and even then, the observed differences are minimal, likely attributable to rounding errors (Figure 6). This is further evident in

Figure 7. Notably, VOBS offers only 4 observations per pressure level, whereas OBSOUL provides 16. This disparity in data density can significantly impact verification scores, particularly when using an "all-in-one" verification approach that considers both forecast cycle and lead time. Figure 8 demonstrates that including data from other stations populates all time intervals. This confirms our expectation that the lack of data for certain time periods is specific to some stations, not a widespread issue.



**Contributors, estimated efforts:** Martin Petras (5 pm), Alena Trojáková (0.75 pm)

**Course participation** at HARP Working week, 4-8 Mar 2024 in Dublin

- Piotr Sekula - ACCORD/RC-LACE funds
- Polly Schmederer, Phillip Scheffknecht and Martin Petras - RC-LACE funds

**Contributors, estimated efforts:** Piotr Sekula (0.25 pm), Polly Schmederer (0.25 pm), Phillip Scheffknecht (0.25 pm) and Martin Petras (0.25 pm)

**MQA1 contributors, estimated efforts:** Polly Schmederer (1 pm), Martin Petras (5 pm), Alena Trojáková (0.75 pm), Piotr Sekula (0.25 pm), Polly Schmederer (0.25 pm), Phillip Scheffknecht (0.25 pm) and Martin Petras (0.25 pm)

**MQA1 total: 7.75 pm**

**Action/Subject/Deliverable: Development of new verification methods [MQA2]****Description and objectives:**

In Croatia, one important topic was the starting work of Iris Odak Plenkovic in the development of a simple way to present wind scores, taking into account wind direction.

***Development of a simple way to present wind scores (Croatia)***

The development of a simple way to present wind scores was started in Croatia, taking into account wind direction. At this point, RMSE or other scores are presented in a polar system that is ordered as a wind rose. Also, some investigation is done for a simplified version of M. Tesini's work, who used categorical verification using the wind rose fields. However, when this approach is tested and the users are asked, the answer is that they are overwhelmed since there are so many details. Thus, there is a need to verify both speed and direction but find the middle ground.

**Contributors, estimated efforts:** Iris Odak Plenkovic (0.5 pm)

**MQA2 total: 0.5 pm**

**Action/Subject/Deliverable: Verification, evaluation and error attribution [MQA3]**

## Description and objectives:

The continuous work, in Austria, on the development of Panelification and an important upgrade for hail and lightning verification and migrated to the newest version. The report provided by Hungary is based on 3 important aspects: the verification tool HARP was upgraded to version 2.0 and it was completed the operational scripts for monthly verification of AROME-EPS; were provided internal HARP training courses for HungaroMet colleagues and also a mentoring for a BSc student was mentored in order to perform the surface point verification of the 11-member AROME-EPS compared to the 51-member ECMWF ENS using HARP, for an early summer one-month-long period in 2024 when several convective events happened. Also in Hungary, the input data for the EMOS post-processing for radiation runs daily are used the 11-member forecasts of AROME-EPS as well as measurements at 7 stations. For a more flexible mode for the evaluation of the operational model, the standard verification was extended in Croatia, in this way the scripts based on the verif module were written/modified in order to make them compatible when trying to calculate a vertical profile of some basic verification scores. The possibility to calculate scores in Python for EPS was also added. Another topic in Croatia is the usage of an analog post-processing method for wind for the general public. In Czech Republic, the code was prepared in order to have new outputs for aeronautical forecast to the ALARO CMC. In Poland, were performed the following validation for different experiments: ALARO cy43t2 with assimilation, ALARO cy46 – with modifications from colleagues from Prague, new LBC with 1h frequency and snow scheme in SURFEX – only for winter period. Another approach is the d-dimensional copula is a multivariate distribution function with uniformly distributed marginals. Sklar's Theorem. The goal is the error mitigation of the temperature forecast given by the ALARO model. In Romania, the HARP tool was used in order to perform verification for the 10 m wind gust, for experiments done in order to tune the parameter FACRAF. Another verification was performed for comparison between model versions cy43bf10 and cy43bf11, in order to be able to use cy43bf11 for the operational configuration.

In Croatia the progress regarding verification topics was continued. Their work is quite active locally and have prepared (internally and in Croatian) the report on the operational models, using the 2023 dataset (2 model configurations - HR20 at 2km and HR40 at 4 km, both deterministic) for temperature and wind speed. It took quite some time to do quality control before using the dataset. In addition to the verification methodology, they wrote and implemented the algorithms that calculate deterministic scores on different vertical levels, consistent with the desired outputs. The verification was performed for all measuring stations within the HR20 domain, and then the (only) 2 stations we have in Croatia.

In the work package 9.3 in DEODE, it was added the station list for HARP from OPLACE and also some bugfix of OPLACE data conversion to sqlite.

In Hungary, were performing tests of the impact of IFS cy49r1 on AROME/HU and AROME-EPS, comparative verification of AROME, IFS HRES and AIFS forecasts.

### Paneification (Austria)

The work of Phillip on the development of Panelification:

- Fixed a long standing contouring bug which sometimes caused observations to be display wrongly. Higher contour level will no longer obscure all lower values.
- Upgraded hail and lightning verification and migrated to the newest version (Figure 9).

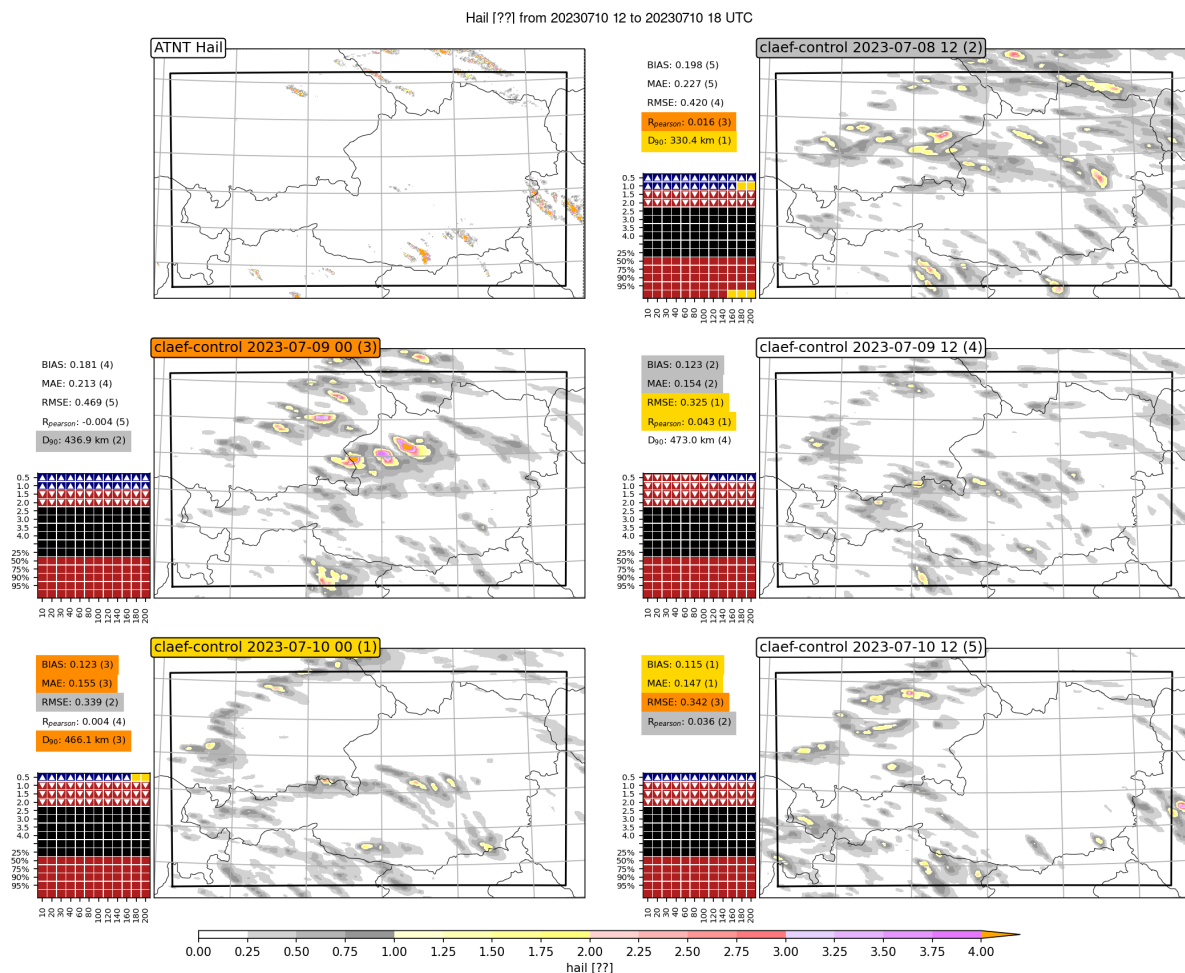


Figure 9. One example of hail from 10.07.2023, 12 UTC to 10.07.2023, 18 UTC.

**Contributors, estimated efforts:** Phillip Scheffknecht (0.5 pm)

**Verification of the DE-330 (Czech Republic)**

In the work package 9.3 in DEODE, it was added the station list for HARP from OPLACE and also some bugfix of OPLACE data conversion to sqlite.

**Contributors, estimated efforts:** Alena Trojáková (0.25 pm).

**Evaluation of the operational forecasts: HR20 and HR40 models for 2023 (Croatia)**

In Croatia the progress regarding verification topics was continued. Their work is quite active locally and have prepared (internally and in Croatian) the report on the operational models, using the 2023 dataset from two 2 model configurations at different horizontal resolutions - HR20 at 2km and HR40 at 4 km, both deterministic, for temperature and wind speed. It took quite some time to do quality control before using the dataset. In addition to the verification methodology, they wrote and implemented the algorithms that calculate deterministic scores on different vertical levels, consistent with the desired outputs. The verification was performed for all measuring stations within the HR20 domain, and then the (only) 2 stations we have in Croatia. For these forecasts, verification was performed for the following variables:

- temperature at 2 m altitude T (°C),
- average wind speed in 10-min. period at 10 m — wind speed V (m/s) and
- maximum wind speed in 10-min. period at 10 m - wind gust VMAX (m/s).

It should be noted that quality control was carried out on the measured data, and the irregular data were removed. The control of the data is done by the modified TITAN data control system, and visual control of time series. Data from the following number of stations were used for the verification: 41 stations throughout the Republic of Croatia for the variable T, and 53 stations for the variables V and VMAX.

The forecasts of the operational ALADIN-HR40 model for different vertical levels using one-year period were also verified for the following variables:

- temperature T (°C),
- average wind speed in 10-min. period – wind speed V (m/s).

Data from 19 stations for variables T and V were used in the verification of a vertical profile, where all locations for which the share of missing data exceeds 35% were automatically excluded. It should also be noted that the data for each station refer to all 6 altitudes (950 hP, 925 hP, 850 hP, 70 hP, 50 hP and 30 hP). The most of the missing data for both variables and for all stations refers to data from a height of 950 hP. The verification was performed for different scores and for different thresholds. The verification was made by using different evaluation approaches such as: total error measured by RMSE, analysis by location, annual cycle, large errors, vertical and categorical verification scores.



Temperature measurements show a daily cycle with a maximum average value in 13 UTC, amounting to 18.7 °C, while the temperature takes on an average minimum value in 4 UTC, and it is 12.1 °C (Figure 10). The HR40 forecast reproduces the daily temperature fluctuation in a timely manner, but it is of a reduced amplitude. In other words, due to the underestimation of higher values of the mean during the day, and the overestimation of lower temperature values in the night hours, the diurnal bias changes the sign throughout the day. The HR20 forecast overestimates the average temperature values for almost all forecast hours, so the mean bias is most often positive. The HR20 forecast also shows a diurnal bias because the overestimation is most pronounced during daylight hours (maximum at 11 UTC), while it is less pronounced during the afternoon, evening and night hours. Although the biases of these models are often in the counterphase, the HR20 forecast takes on higher absolute bias values.

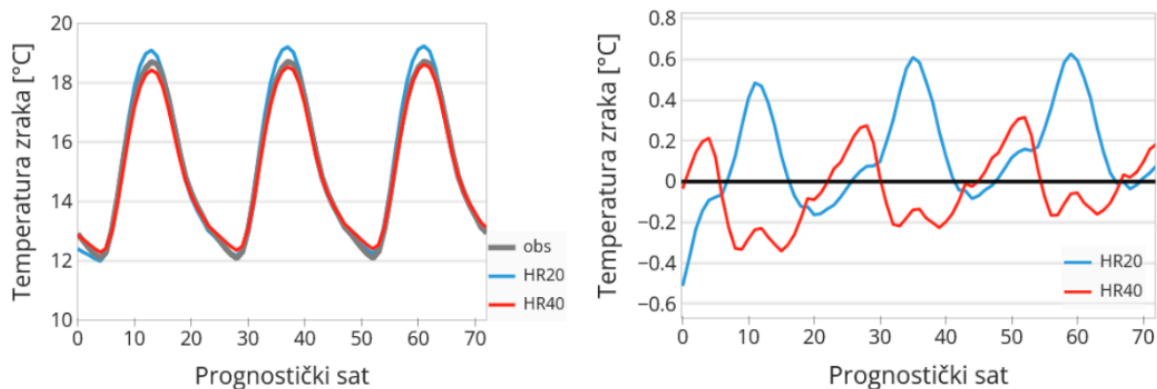


Figure 10. Forecasted and measured temperature values  $T$ , averaged over the forecast hour (left). The difference between these values is called bias (right). The data refer to HR40 and HR20 forecasts initialized at 0 UTC during 2023, while measurements were collected at 41 locations in Croatia.

Measurements of mean wind speed show a pronounced daily cycle with a maximum average value at 13 UTC, which is 3.41 m/s, while the wind speed is weaker at the end of the day and at night, with a minimum value at 19 UTC of 2.79 m/s (Figure 11). It can be seen that both forecasts take on positive values of the mean bias for almost all forecast hours. At the same time, the HR20 forecast overestimates the average values in the evening and night hours more than the HR40 forecast, and overestimates the average values during the day less than the HR40 forecast. The HR40 forecast is almost unbiased at night. Both forecasts reproduce the daily cycle in a timely manner. It can be noticed, which will often be the case, the pronounced HR20 forecast underperformance in the initial forecast hour.

However, it should be noted that this forecast hour has no practical value because th

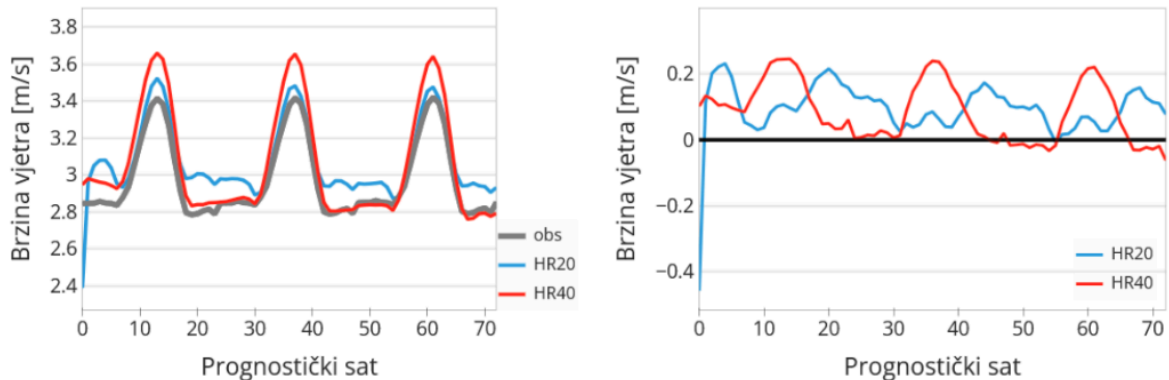


Figure 11. Forecasted and measured values of mean wind speed  $V$ , averaged per forecast hour (left). The difference between these values is called bias (right). The data refer to HR40 and HR20 forecasts initialized at 0 UTC during 2023, while measurements were collected at 53 locations in Croatia.

In the figure 12, it is shown the average temperature during 2023 with values between 9.72 °C and 18.70 °C and also the average measured mean wind speed and maximum wind gust values.

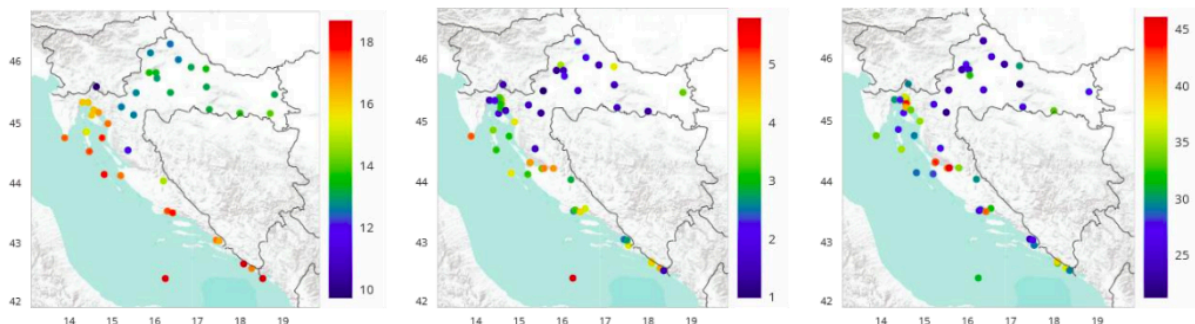


Figure 12. Mean air temperature (°C) (left), average measured mean wind speed (m/s) (middle) and maximum wind gust values (m/s) (right) during 2023.

**Contributors, estimated efforts:** Iris Odak (1 pm), Ivan Vujec (2 pm)

### **Operational verification of AROME\_EPS using HARP (Hungary)**

The report provided by Hungary is based on 3 important aspects:

- a) The verification tool HARP was upgraded to version 2.0 and it was completed the operational scripts for monthly verification of AROME-EPS by using this tool. More details about the description of the work can be found in the report from February 2024. Pointwise verification is regularly done monthly for the last 1 and 3 months. For each case, two documents are produced: one for surface verification

against SYNOP data, and another one for upper air verification against radiosonde data.

- b) Internal HARP training courses were provided for HungaroMet colleagues.
- c) A BSc student was mentored in order to perform the surface point verification of the 11-member AROME-EPS compared to the 51-member ECMWF ENS using HARP, for an early summer one-month-long period in 2024 when several convective events happened. Her practice lasted 6 weeks.

**Contributors, estimated efforts:** Katalin Jávorné Radnóczy (a - 1.25 pm), Dávid Tajti (a - 0.25 pm), Katalin Jávorné Radnóczy (c - 2 pm), Dávid Tajti (c - 1.5 pm), Boglárka Tóth (c - 1.5 pm)

### *Testing improvement possibilities of AROME-EPS EMOS post processing for radiation (Hungary)*

Operational EMOS post processing for radiation runs daily, as described in the February 2023 verification report. As input data are used the 11-member forecasts of AROME-EPS as well as measurements at 7 stations (Figure 10) from a running training period of 31 days. It is applied regional method, i.e. data from all stations are handled together to give an estimation for a few selected points. CRPS of the probabilistic forecasts was reduced by 15-17% with respect to the raw EPS for the first half of 2024, however, trying to improve the performance even further.

The main development idea comes from station-wise verification results: the scores of raw EPS (especially bias of ensemble mean), and consequently the performance of EMOS are much different at some stations, depending on their geographical conditions. Therefore, the stations were classified based on their characteristics to choose their optimal combination providing the highest improvement for the target station. For classification, the method of Lerch and Baran (2017) was adapted. The test period was chosen from 2 May to 31 August 2023 partly because there are a large number of radiation measurements from a private company for this period (though they were not used in this study).

It was evaluated the model error characteristics, the observation climatologies and the geographical distances among 34 HungaroMet stations. Then the EMOS postprocessing was ran for some new groups of stations. Experimental station-groups were determined by taking into account the lead-time dependent characteristics of each station, i.e. bias, median absolute error, CRPS and observation climatology in the test period. As the performance got worse with 31-day training period for most cases, some experiments were performed by increasing or decreasing length of training (in 4 days steps) inspired by e.g. Gneiting et al. (2005). The number of stations used in a group was tested.

In the best test run for Debrecen station, CRPS could be further improved only by 1.5% wrt. the raw EPS, however, for Pécs it was reached additional 9.5% when it

was used data from stations from the same class (station groups are shown in Figure 13). This difference in improvement is caused by different characteristics of the two stations. Biases comparing operational and test setup with raw EPS scores for both stations are shown in Figure 14. The work is ongoing, tests involving more stations and for longer period are planned.

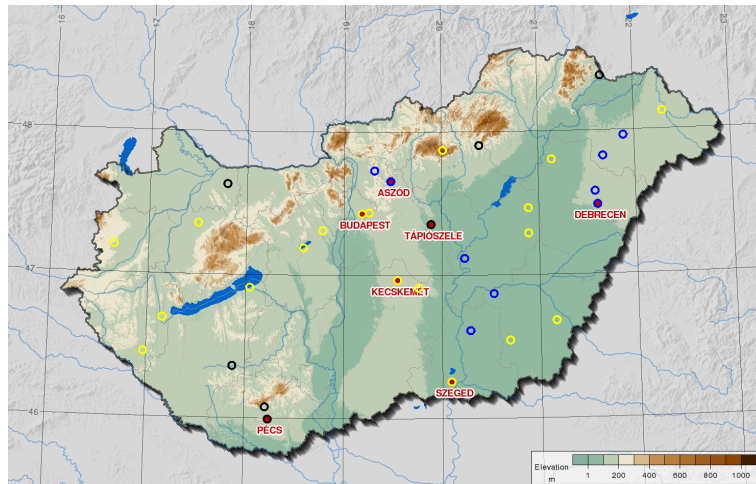


Figure 13: Stations used for operational AROME-EPS radiation postprocessing (red points and text), test runs for Debrecen (blue) and Pécs (black), unused stations in test runs (yellow)

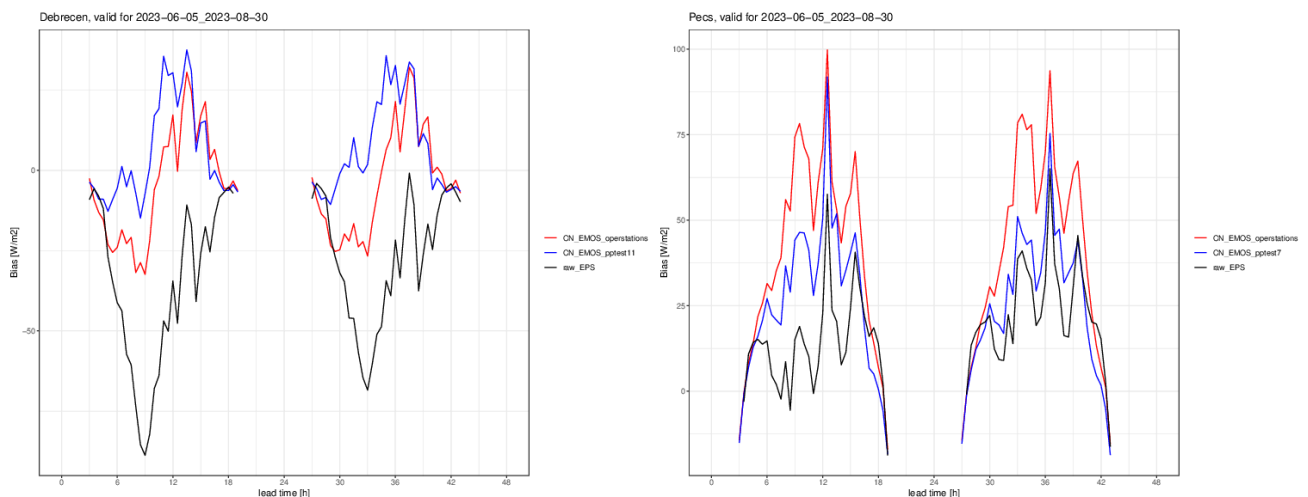


Figure 14: Radiation bias ( $\text{W/m}^2$ ) for the operational selection of stations (red) and the best test selection of stations (blue) for the target of Debrecen (left) and Pécs (right) from 5 June to 30 August 2023, as a function of forecast lead time (h). Raw EPS scores are also shown in black.

**Contributors, estimated efforts:** Katalin Jávorné Radnóczy (2 pm)

## Testing the impact of IFS cy49r1 on AROME/HU and AROME-EPS EPS (Hungary)

A comparison was performed for 6 UTC runs of HRES and ENS forecasts of IFS cy49r1 and cy48r1 as well as for 12 UTC AROME/HU and AROME-EPS forecasts using IFS forecasts as lateral boundary conditions (LBCs) on 13 and 14 September 2024, when cyclonic weather (Boris) caused high precipitation and strong wind gusts in Hungary. Generally, IFS and AROME forecasts performed well over Hungary in this case.

We received test (cy49r1) and operational (48r1) LBC files in format of FA files at 105 vertical levels. We carried out average and field-wise comparisons for specific humidity, temperature and horizontal wind speed for some vertical levels, for ENS CTRL and some perturbed members. We found only little differences, which seem reasonable: maximum 4% relative difference in specific humidity (at middle levels); average differences smaller than 1K in temperature and 0.5 m/s in wind speed (for the control member).

AROME/HU and AROME-EPS test runs were performed using both LBCs. Overall, there was little difference in surface parameters between the runs with 49r1 and cy48r1 LBCs. A little reduction of both the slight overestimation of wind and the slight underestimation of temperature was seen in the cy49r1-driven AROME. In AROME-EPS, the standard deviation is reduced for most surface parameters, but still covers the measurements well (Figure 15) and there was less overestimation of precipitation intensity in each member. It has to be emphasized that a single case study serves only for a quick technical and meteorological test, but it cannot show any systematic departure due to the cycle change.

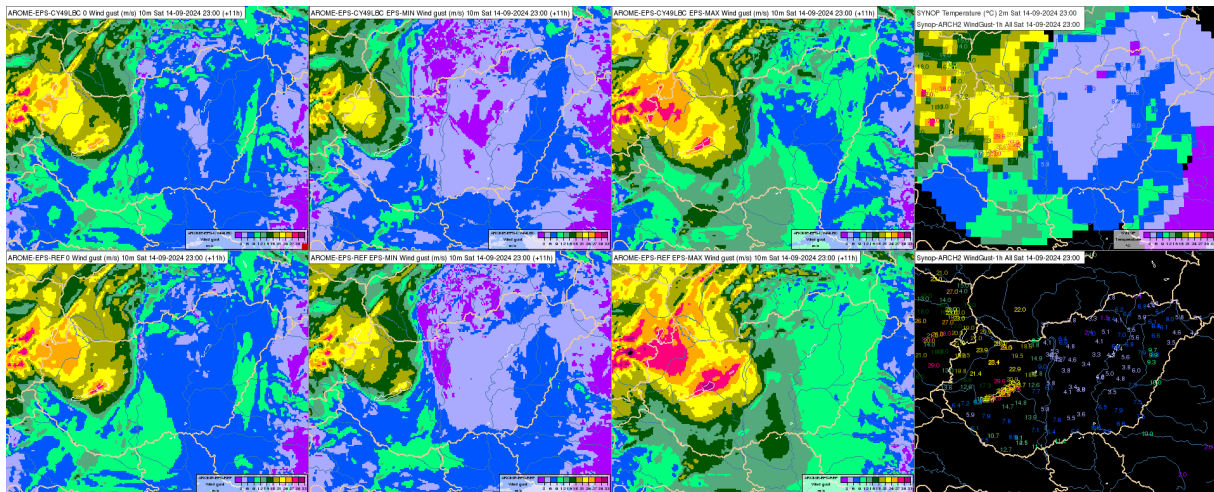


Figure 15: Wind gust (m/s) forecasts from the two versions of AROME-EPS (columns 1-3, with CY49 LBC above, CY48 below): AROME-EPS control member (left column), EPS minimum (column 2) and maximum (column 3) compared to surface measurements (top right) in the +11hours time step of the 12UTC run 14/09/2024.

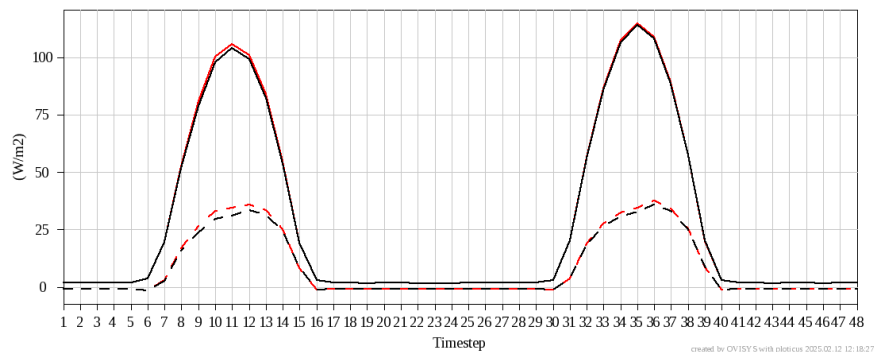
**Contributors, estimated efforts: Dávid Lancz (0.25 pm)**



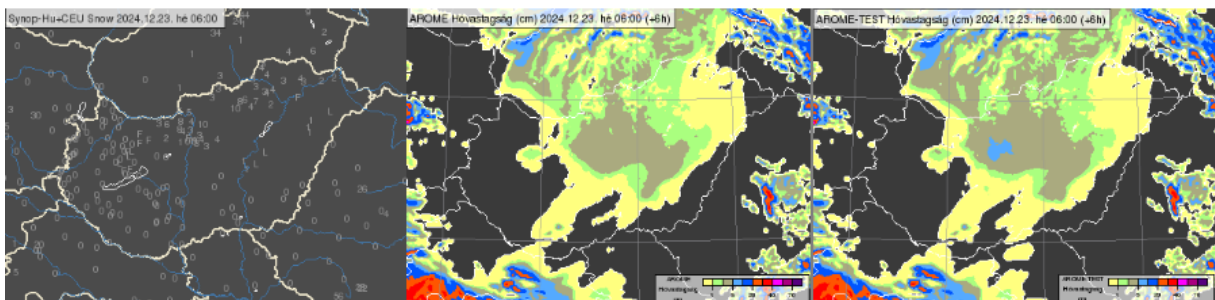
### Comparing AROME cy43t2 and cy46t1 model versions (Hungary)

The forecasts made with the two AROME cycles were compared for June 2024 and January and February 2024. These tests showed no significant differences during the winter period and only minor changes in summer. The summer period was also examined with the AROME-RUC settings (with 1.3 km horizontal resolution, 1 hour data assimilation cycle) and we found a mild improvement in the favour of the AROME cy46t1 with respect to cy43t2.

For a more comprehensive evaluation the AROME-TEST with cy46t1 was running in parallel to the operational AROME/HU (cy43t2) forecasts at 0 and 6 UTC since the beginning of November 2024 until the end of December. As usual, some objective and subjective evaluations were carried out and the forecasters were involved as well in the verification process. In this experimental period it was challenging to forecast fog and low level cloud in an anticyclonic situation, as well as mixed precipitation and snow depth. There was almost no difference between the two forecasts in case of many parameters, and even if there was, it was within the first few hours of the run (2 m temperature, dewpoint). A small positive effect was seen in the reducing overestimation of the incoming solar radiation (*Figure 16*), while the most significant difference was in snow depth, where the AROME-TEST overestimated the snow depth in most cases. It is important to highlight that the differences were minimal, as confirmed by the case studies, where in some cases only a few pixels showed difference between the two model versions (*Figure 17*).



*Figure 16: RMSE (solid lines) and bias (dashed lines) of 1-hour global radiation (in  $W/m^2$ ) AROME (red) and AROME-TEST (black) forecasts as function of lead time.*



*Figure 17: Snowdepth (in cm) based on 00 UTC + 6h forecasts of AROME (middle) and AROME-TEST (right), and SYNOP observations marked with numbers (left) on 23 December 2024.*

A case study with AROME-EPS was also performed, without any notable results. Before the operational implementation (planned by end of February) the two cycles will be tested in further experiments with a new PGD file (more description in the physics report).

**Contributors, efforts:** Katalin Jávorné Radnóczy (0.25 pm), Dávid Lancz (2.5 pm), Boglárka Tóth (0.25 pm)

### Comparative verification AROME, IFS HRES and AIFS forecasts (Hungary)

During the last semester we mentored an MSc student who performed some verification of ECMWF AIFS (Artificial Intelligence/Integrated Forecasting System) compared to AROME/HU and IFS HRES using HARP. The verification was concentrating on surface parameters over the Carpathian Basin for September in 2024. The temperature and precipitation in September were both higher than the climatological means between 1991 and 2020, although the rainfall was concentrated just on a few days in connection to Storm Boris. The horizontal resolution of AIFS, IFS HRES and AROME is 25, 8 and 2.5 km, respectively.

As AIFS was trained to minimise RMSE, it gives the best RMSE values. Nevertheless, AROME/HU (and IFS HRES) performed better in bias for the 6-hour accumulated precipitation (Figure 18). However, the precipitation should be examined further in case studies.

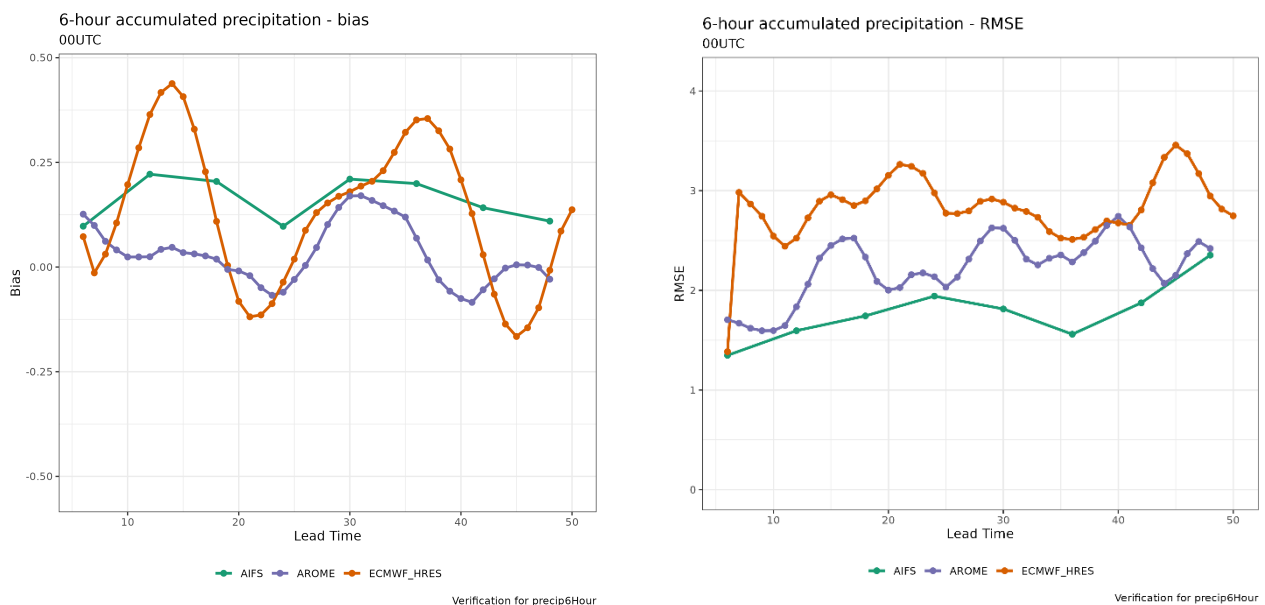


Figure 18: Bias (left) and RMSE (right) of AIFS (green), IFS-HRES (red) and AROME/HU (blue) forecasts for 6-hour accumulated precipitation (mm) in September 2024.

**Contributors, efforts:** Dávid Lancz (0.25 pm)

## References



Gneiting, T., Raftery, A. E., Westveld, A. H. and Goldman, T. (2005): Calibrated probabilistic forecasting using ensemble model output statistics and minimum CRPS estimation. Monthly Weath. Rev. 133, 1098–1118.

Lerch, S. and Baran, S. (2017): Similarity-based semilocal estimation of postprocessing models. Appl. Statist. 66, Part 1, 29–51.

### Verification in Python (Croatia)

In order to expand the standard verification procedure when evaluating the operational model, the scripts based on the `verif` module were written/modified in order to make them compatible when trying to calculate a vertical profile of some basic verification scores. Also, it was added the possibility to calculate scores in Python for EPS. The operational model was used in order to evaluate this tool.

**Contributors, estimated efforts:** Endi Keresturi and the other colleagues (1.5 pm)

### The usage of an analog post-processing method for wind for general public (Croatia)

This year a work was started related to the usage of an analog post-processing method for wind presented on meteograms for the general public ([https://meteo.hr/prognoze\\_e.php?section=prognoze\\_model&param=3d](https://meteo.hr/prognoze_e.php?section=prognoze_model&param=3d)). One example of how this meteograms show, it can be observed in the following figure 19.

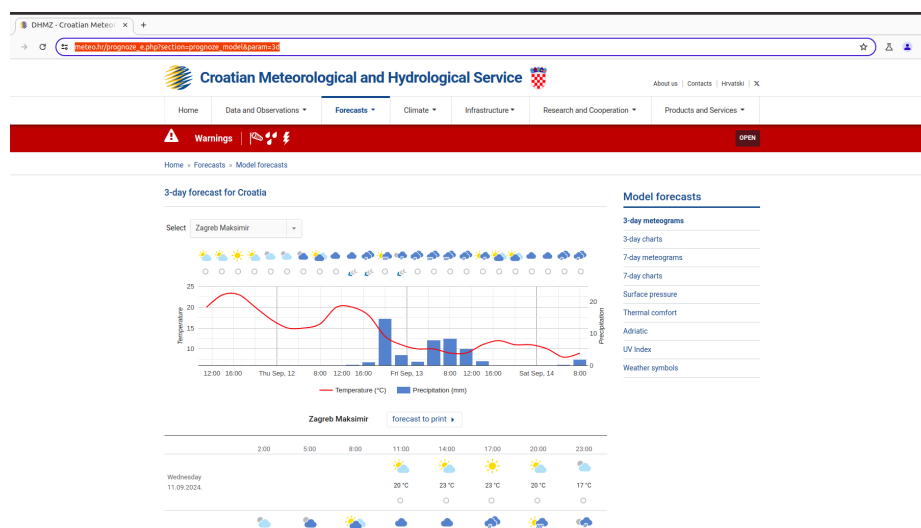


Figure 19: One example of how this meteograms.

**Contributors, estimated efforts:** Iris Odak Plenkovic and Ivan Vujec (0.5 pm)

***New outputs for aeronautical forecast to the ALARO CMC (Czech Republic)***

- Determination of cloud base height either in meters or pressure;
- Calculation of Eddy Dissipation Rate (EDR), which depends on turbulence length-scale: with the help of Mario to see which length scale should be taken in case of TOUCANS scheme;
- Calculation of inflight icing index (backphasing from CY48T1 cycle).

The preparation of the code to get these outputs was done and for the moment it was not done any validation.

**Contributors, estimated efforts:** Radmila Brožková (0.5 pm)

***Verification activities in Poland (Poland)***

1. Regarding the operational/pseudo-operational verification, in Poland were performed the following validation:

- ALARO cy43t2 with assimilation
- ALARO cy46 – with modifications from colleagues from Prague
- New LBC with 1h frequency
- Snow scheme in SURFEX – only winter period

The operational models at IMGW-PIB:

- ICON (res. 2.8km)
- COSMO (res. 2.5km, 7km)
- WRF (res. 2km)
- ALARO (res. 4km)
- AROME (res. 2km)

The validation was done for the ALARO cycle 43t2 with assimilation compared with the operational version of ALARO for different meteorological parameters as follows: T2m, RH2m, wind speed, wind direction and atmospheric pressure. The verification period is 15.06.2024 – 15.07.2024. In Table 1, are specified the summarized results for all parameters. In figure 20 are shown the values of mean BIAS and RMSE for T2m – mean BIAS for the interval 15.06.2024 – 15.07.2024, in figure 21 the same scores for RH2m and in figure 22 the ones for PMSL.

Parameter	BIAS	RMSE
T2m	Lower BIAS, higher amplitude	Lower RSME
RH2m	Positive BIAS	Reduction of RMSE at afternoon/night hours
Wind Speed	NO significant impact	NO significant impact
Wind Direction	NO significant impact	NO significant impact
Atm. Press.	Positive BIAS	NO significant impact

Table 1: The results of verification for the ALARO cycle 43t2 with assimilation compared with the operational version of ALARO for different meteorological parameters.

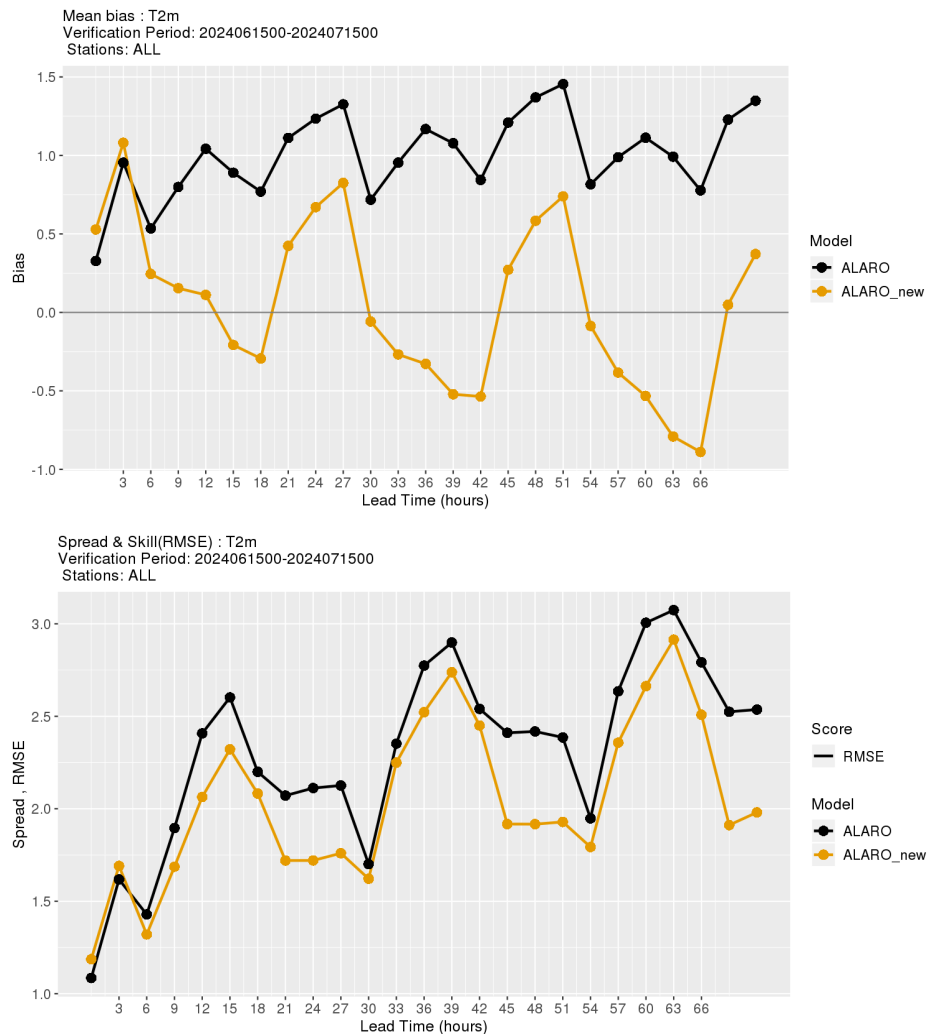


Figure 20: T2m – mean BIAS (top) and spread & skill (RMSE – bottom) for the interval 15.06.2024 – 15.07.2024 for ALARO with Assim – **ALARO\_new** and operational version of ALARO – **ALARO**.

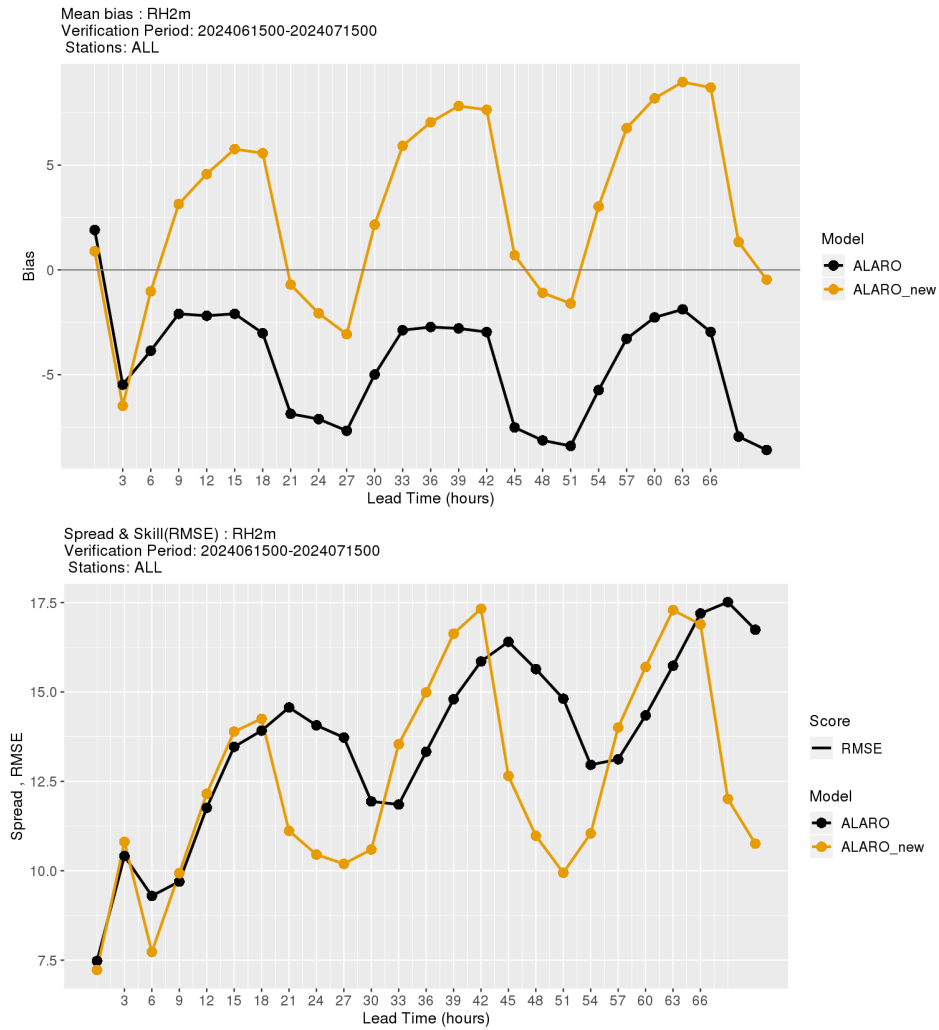


Figure 21: RH2m – mean BIAS (top) and spread & skill (RMSE – bottom) for the interval 15.06.2024 – 15.07.2024 for ALARO with Assim – **ALARO\_new** and operational version of ALARO – **ALARO**.

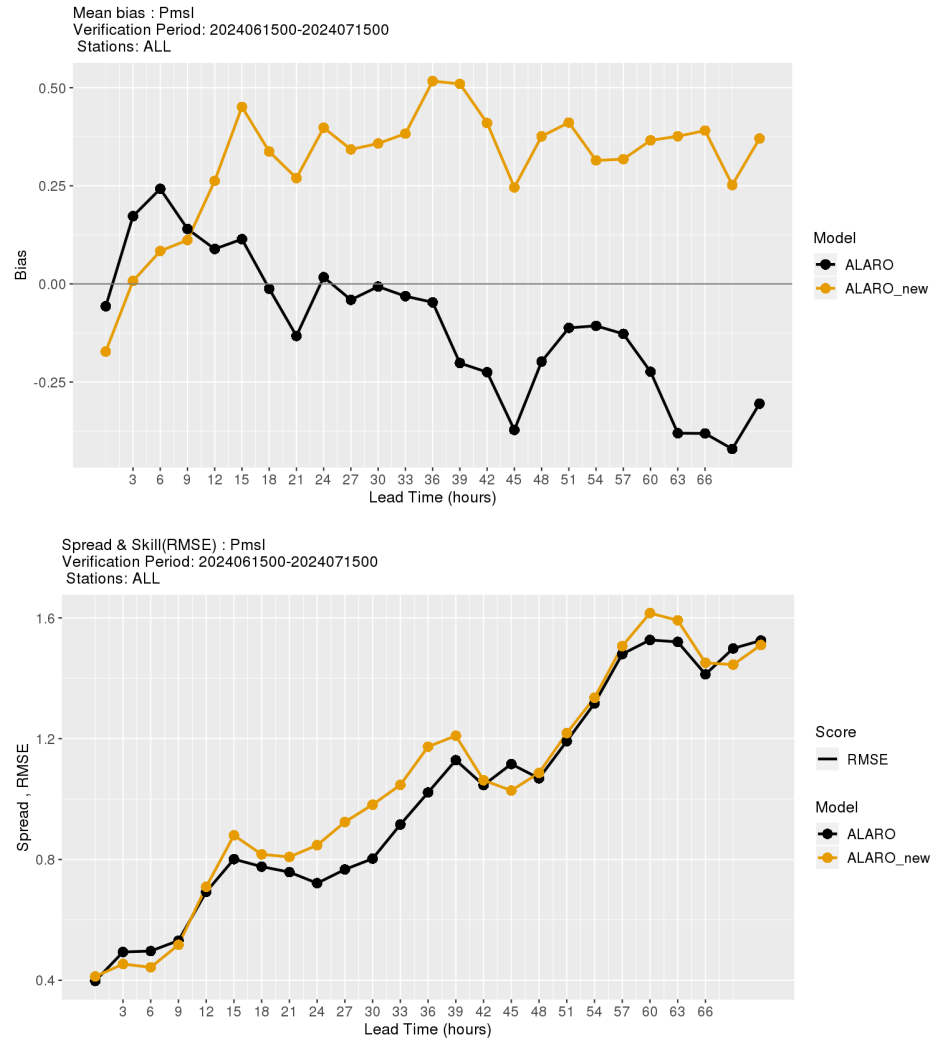


Figure 22: PMSL – mean BIAS (top) and spread & skill (RMSE – bottom) for the interval 15.06.2024 – 15.07.2024 for ALARO with Assim – **ALARO\_new** and operational version of ALARO – **ALARO**.

## 2. ALARO cy46t1 & New LBC with 1h freq

In figure 23 are shown the results of BIAS and RMSE for the T2m, for the interval 01.07.2024 – 31.07.2024 by taking into consideration the following experiments:

- ALARO cy 46 with new settings from Prague – **ALARO46**,
  - ALARO with 1 hour LBC – **ALARO\_new2**
  - operational version of ALARO with 3 hours LBC – **ALARO**
- By doing a comparison of LBC with one hour frequency with the operational settings at 3 hours frequency, there were no significant improvement for LBC with 1h.
- Better scores for ALARO cy46 with modifications from Prague and operational model (cy43t2).

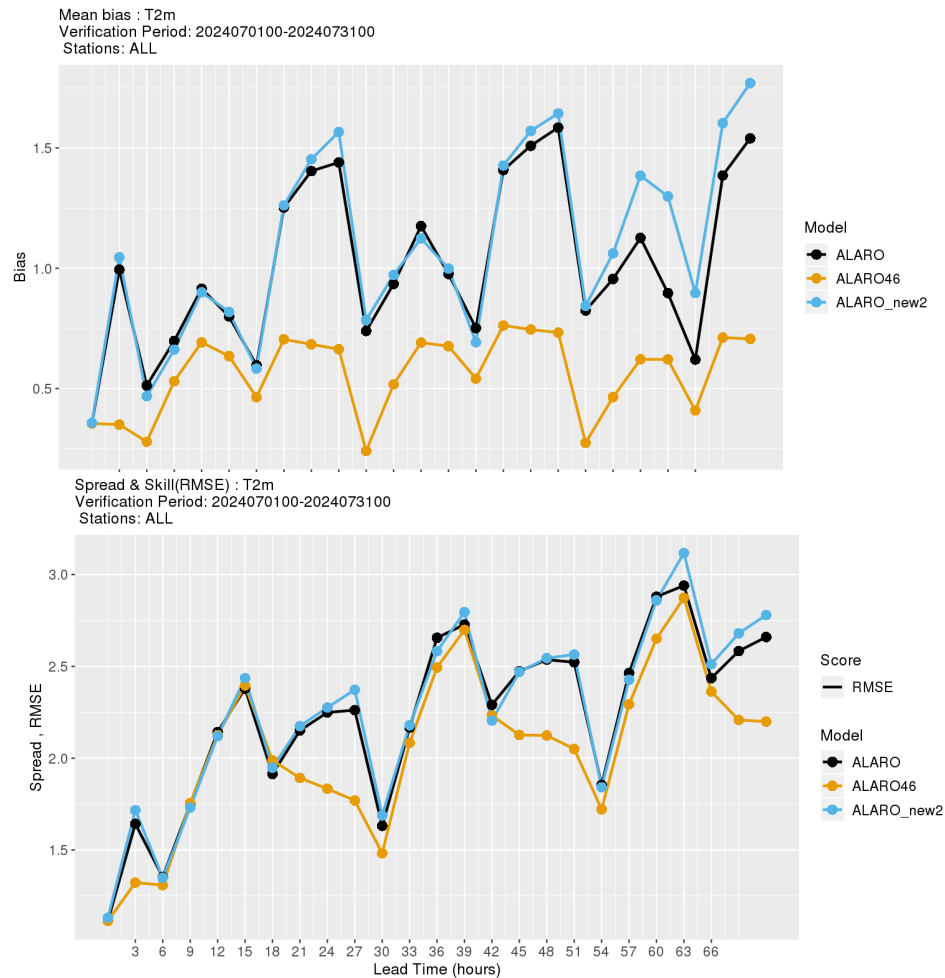


Figure 23: T2m – mean BIAS (top) and spread & skill (RMSE – bottom) for the interval 01.07.2024 – 31.07.2024 for ALARO cy 46 – **ALARO46**, ALARO with 1 h LBC – **ALARO\_new2** and operational version of ALARO – **ALARO**

### 3. Snow scheme verification

The verification was done for 2 m temperature, snow depth and snow water equivalent for season 2022/2023 for the high mountain station named Kasprowy Wierch 1991 m a.s.l (Figure 24). Model AROME at 2x2 km for 24h forecast was used. The verification of air temperature from AROME model for mountain stations during winter season 2022/2023 can be noticed in Table 2.

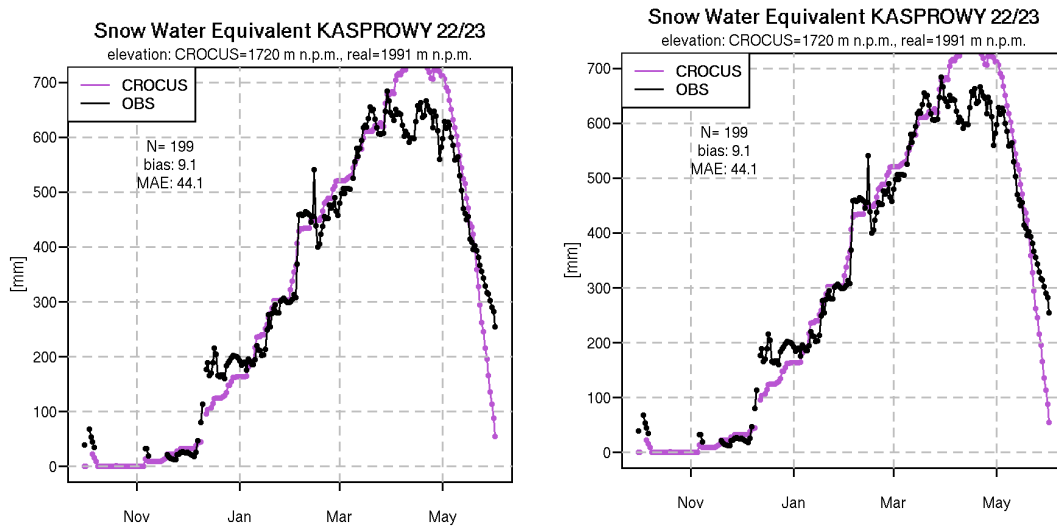


Figure 24. Snow depth (left) and snow water equivalent (right) for season 2022/2023 for the high mountain station named Kasprowy Wierch 1991 m a.s.l by using AROME at 2x2 km for 24h forecast.

Table 2. The verification of air temperature verification from AROME model for mountain stations during winter season 2022/2023.

Short name	elev_real [m n.p.m.]	elev_rome [m n.p.m.]	bias [°C]	RMSE [°C]
SBSL	1523	1643	-1,31	2,09
MOKO	1400	1698	-1,51	2,88
D5ST	1674	1681	-0,71	1,75
KASPROWY	1991	1522	2,34	3,33
DKOSC	1109	1391	-0,69	2,44
DCHOCH	1145	1345	-0,93	1,89
SNEZKA	1603	1156	2,92	3,6
PILSKO	1274	1193	0,84	1,79
MSZCZ	1180	1087	1,03	1,73
TURBACZ	1260	1098	1	1,97
PWETL	1230	902	0,91	1,99

#### 4. New HARP version

- work in progres – operational in 2025



- verification of new LBC with frequency 1 and 3 hours (Figure 25)
- study period: 01.03.2024 – 28.05.2024



(Figure 25). Example for the new HARP version, study period 01.03.2024 – 28.05.2024

## 5. Current task: Upgrade HARP verification system – not yet operational

**Contributors, estimated efforts:** Marcin Kolonko (3 pm), Piotr Sekula (3.5 pm), Bogdan Bochenek, Małgorzata Szczęch-Gajewska, Marcin Kolonko, Jadwiga Róg, Piotr Sekula, Gabriel Stachura, Natalia Szopa.

## Vine copula application to ensemble postprocessing (Poland)

### Mathematical background of the copula approach

A  $d$ -dimensional **copula** is a multivariate distribution function on with **uniformly distributed marginals**. **Sklar's Theorem:** For a  $d$ -dimensional cumulative distribution function, there exists a copula, such that ,where  $F$  is a joint cumulative distribution function and are marginals. This theorem allows to separate univariate margins from the dependence structure.

### Method

*The goal is the error mitigation of the temperature forecast given by the ALARO model. It was construct a copula that contains both the information about the correlations between variables affecting the forecast error and their individual probability distributions. From a copula-given conditional probability distribution we can obtain a sample of pseudo-observations. We aim to check whether the choice of different conditioning variables has a significant effect on the correct fit of the model to pre-existing real data. We then calculate the average of these generated forecast*

errors, which we then add to the ALARO model's temperature forecast and check how much the corrected forecast is better than the original forecast using RMSE.

### **Data and results**

- forecasts of air temperature values at 2m above ground level of NWP models at 12 UTC (forecast starting at 00 UTC) for 35 Polish synoptic stations
- training set: forecasts from 01.01.2019 – 31.12.2019
- test set: forecasts from 01.01.2020 – 31.12.2020
- results can be seen in figure 26

Indicators and the description of the conditioning variables:

- a - AROME model forecast for the current day
- b - COSMO model forecast for the current day
- c - Forecast error of the ALARO model on the previous day
- d - Value of observed temperature at 00 UTC
- e - Forecast error of the AROME model on the previous day
- f - Forecast error of the COSMO model on the previous day
- g - Forecast error of the AROME model on the current day
- h - Forecast error of the COSMO model on the current day
- i - Difference between the forecast on the previous day and the current day of the ALARO model
- j - Difference between the previous day's relative humidity forecast and the current day's ALARO model forecast

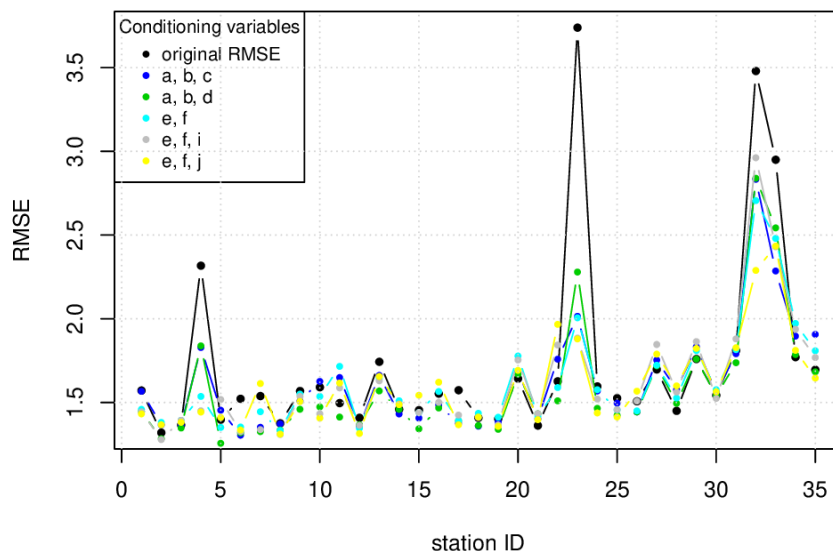


Figure 26. Root Mean Squared Error for various sets of conditioning variables for 35 meteorological stations.

## Results

- The results are verified by checking the percentage change in the root mean squared error (RMSE) of the ALARO model's temperature prediction.
- A slight correction in the temperature prediction of the ALARO model is noted (figure 27).

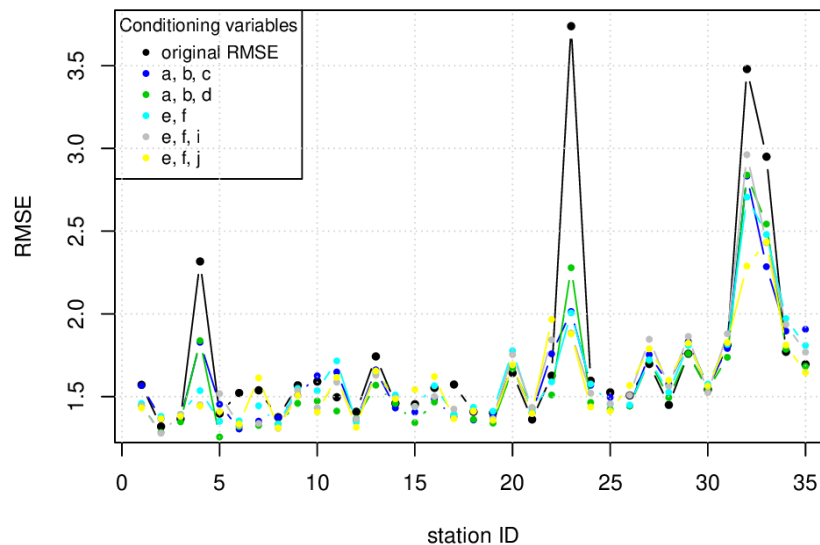


Figure 27. Root Mean Squared Error for various sets of conditioning variables for 35 meteorological stations.

## Conclusions

**The vine copula method allows reduction of systematic errors** and generation of synthetic multi-dimensional data obtained by models in the hindcast. We can generate a sample from copula probability distribution and thus save CPU which is critical to ensemble forecasting.

**Contributors, estimated efforts:** Natalia Szpoza (4 pm)

## Using HARP for different experiments (Romania)

In Romania, during last month, after installing the HARP package in the operational user on our working machine, a script structure was built in order to facilitate the obtaining of verification score plots. A series of scripts was created, first

to extract observation data from the local database, and then to process the output files in order to obtain the vobs files needed for the HARP package.

Also, a main script was created that allows the direct launch of the verification scripts without their previous editing. At this moment we are able to verify surface parameters like 2 m temperature, 2 m relative humidity, 10 m wind direction, 10 m wind speed, 10 m wind gust, precipitation cumulated in 1 h.

Using HARP, a verification was performed for the 10 m wind gust, for experiments done in order to tune the parameter FACRAF. They were obtained for the operational ALARO version at 4 km, bf11, for several values for FACRAF, using observation data from 151 stations, for July 2023. Several cases in July 2023 were selected when the operational ALARO led to significant overestimation of the wind gusts. Several values for FACRAF were tested: 3, 3.5, 4, 4.5, 5, 7, 7.5, 8. Value of FACRAF in the operational configuration is 10. The results are shown in the figures below from 28 to 33.

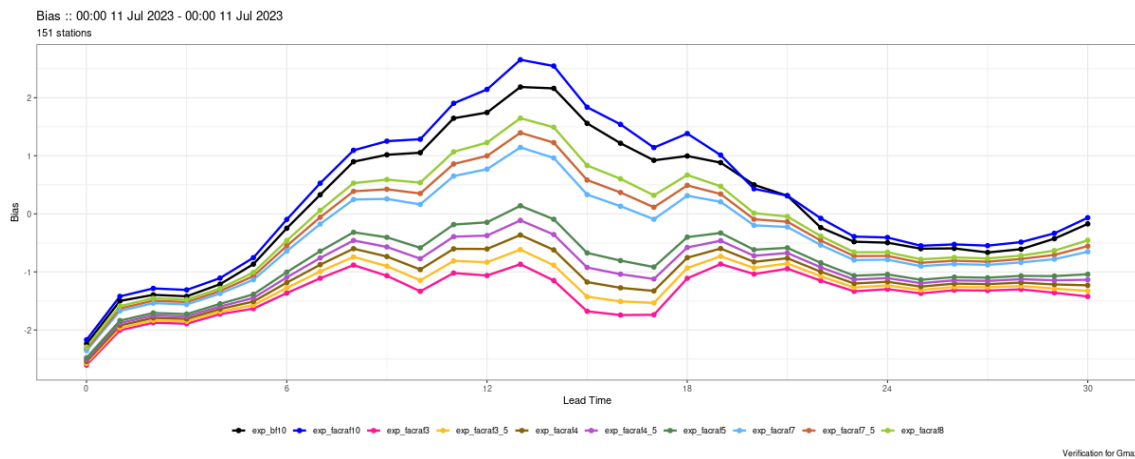


Figure 28. BIAS score for 11.07.2023, run 00, all tested values of FACRAF, for 30 h anticipation.

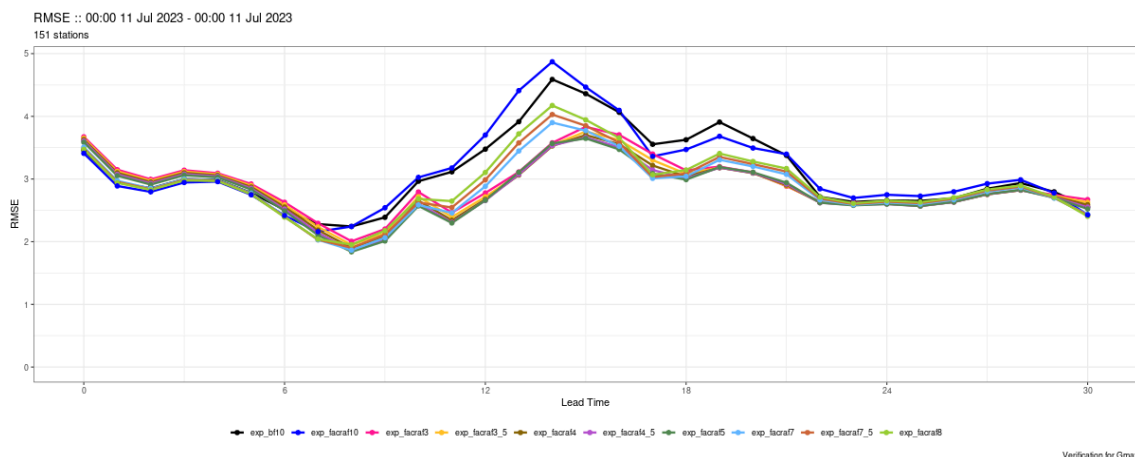


Figure 29. RMSE score for 11.07.2023, run 00, all tested values of FACRAF, for 30 h anticipation

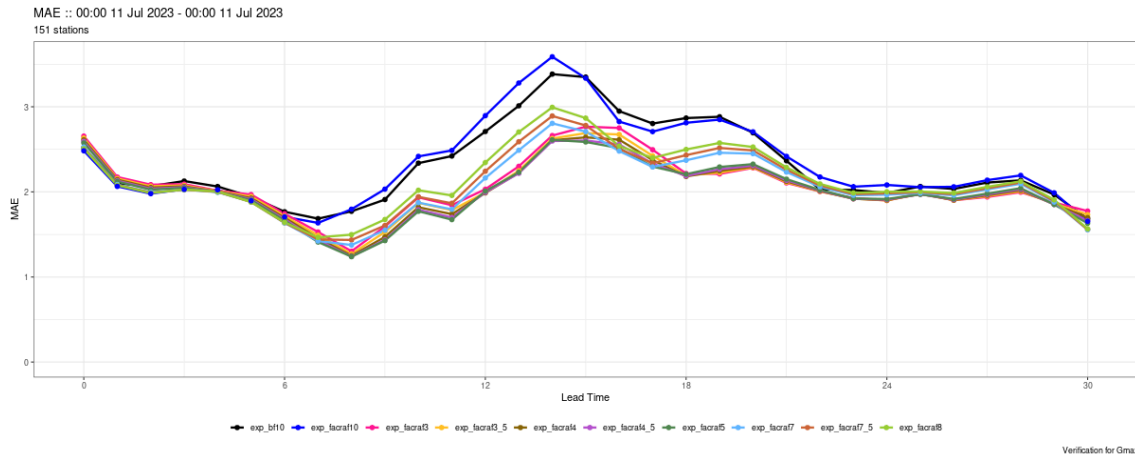


Figure 30. MAE score for 11.07.2023 period, run 00, all tested values of FACRAF , for 30 h anticipation

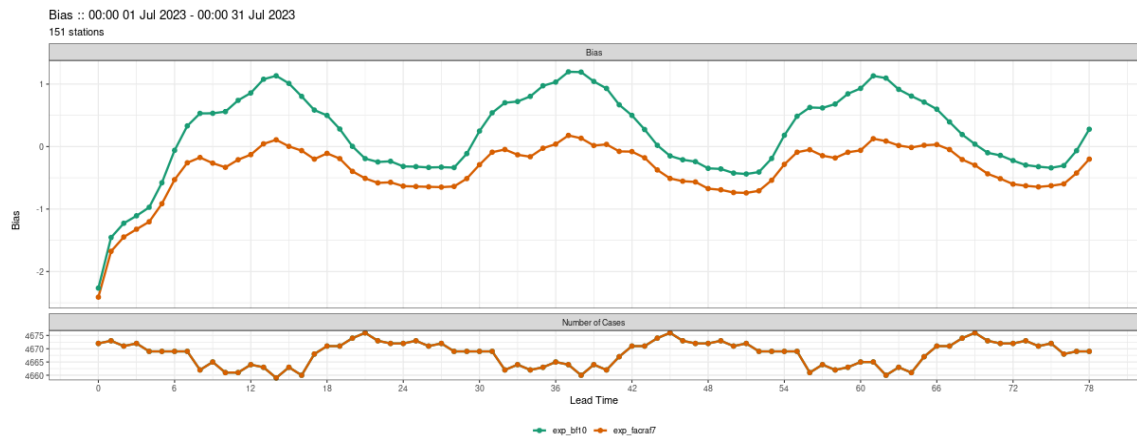


Figure 31. Monthly BIAS score for July 2023, run 00, for ALARO-oper version vs. ALARO\_facraf7 version.

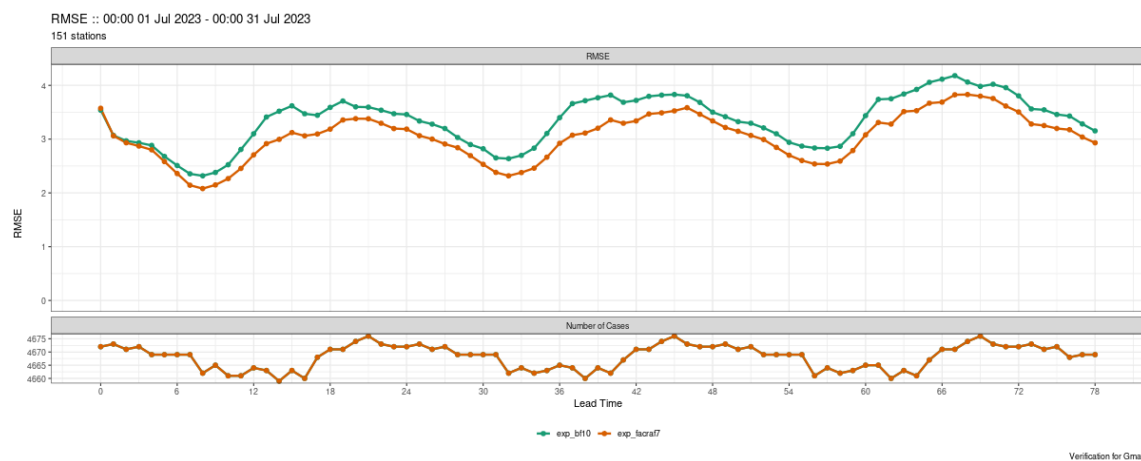
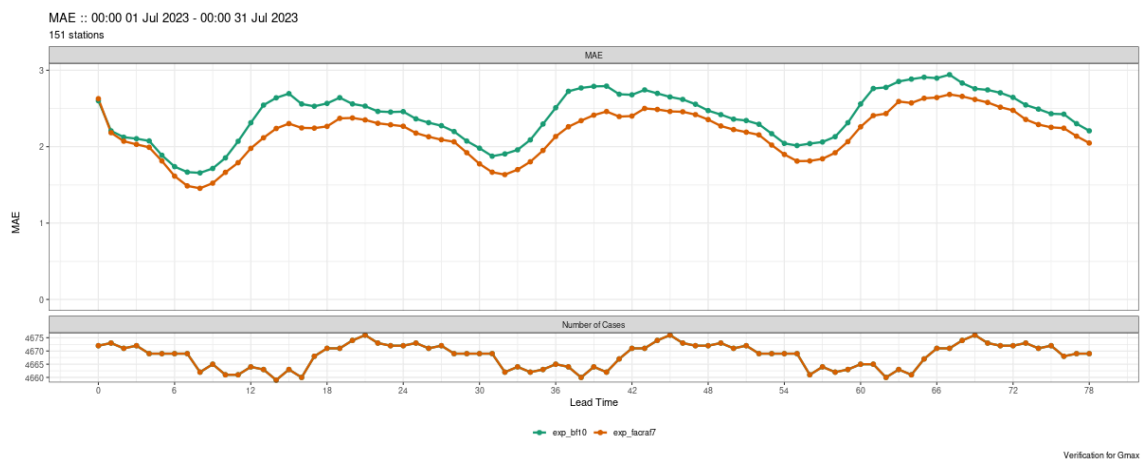


Figure 32. Monthly RMSE score for July 2023, run 00, for ALARO-oper version vs. ALARO\_facraf7 version

Figure 33. Monthly MAE score for July 2023, run 00, for ALARO-oper version vs. ALARO\_facraf7 version

Close values of FACRAF lead to similar results. It was observed that the overestimation of the wind gust is reduced, for some hours, the bias is almost 0. There is an improvement in the scores over daytime, that is bigger than the underestimation introduced over nighttime. Overall in the monthly scores, the MAE score shows that the error is slightly smaller in all hours for FACRAF=7. This value could be a good candidate for the new operational setting.



**Contributors, estimated efforts: Raluca Pomaga (2.75 pm)**

### Comparison between versions cy43bf10 and cy43bf11 (Romania)

Verification was performed for comparison between model versions cy43bf10 and cy43bf11, in order to be able to use cy43bf11 for the operational configuration. The scores are shown for the month of May 2024, for the following parameters: MSLP, 2 m temperature, 2 m relative humidity, 6 h Precipitations and 10 m wind speed (Figure 34). It was observed that the results are very similar.

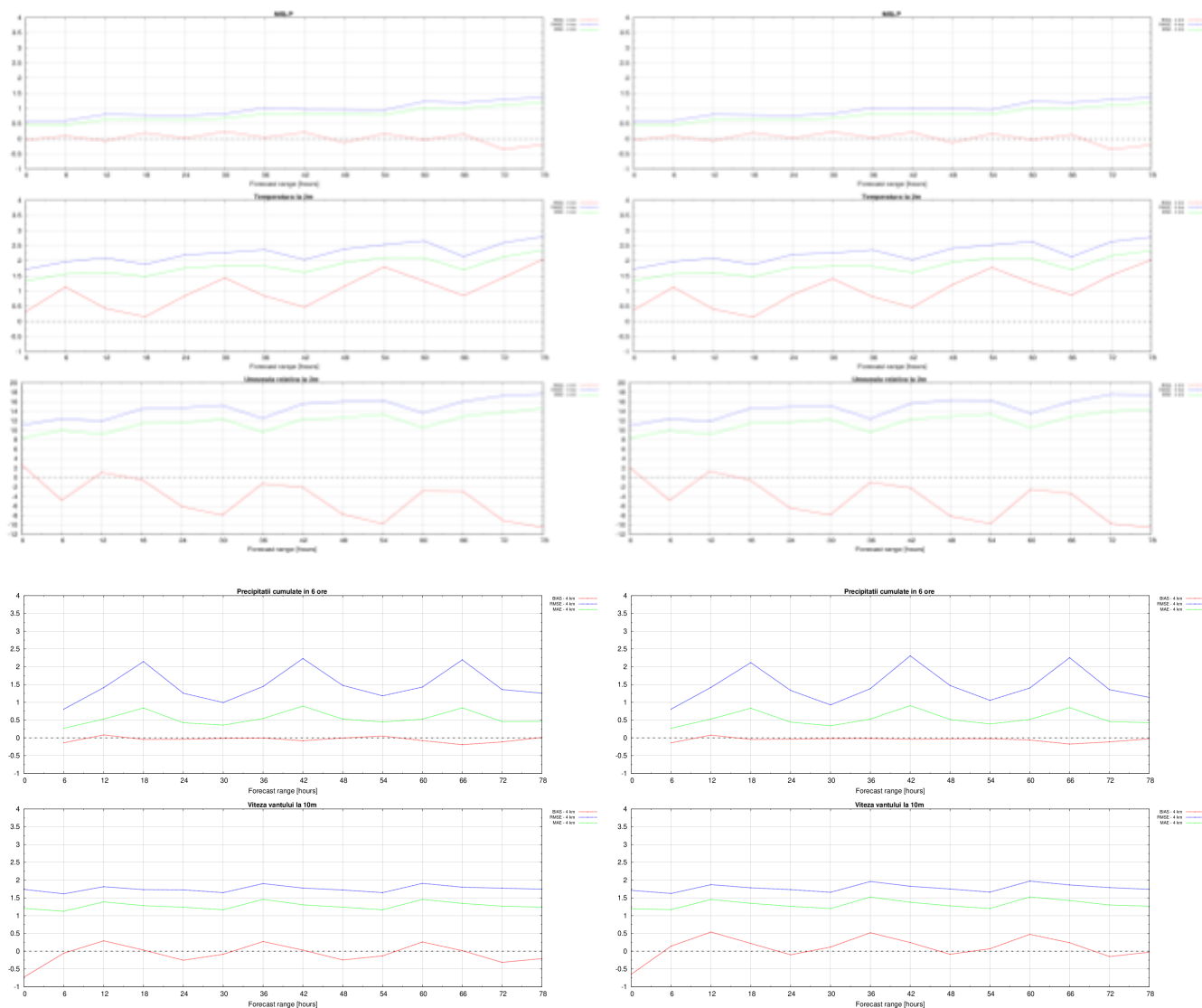


Figure 34. Monthly scores for cy43bf10 (left) and cy43bf11 (right) for MSLP, 2 m temperature, 2 m relative humidity, 6 h Precipitations and 10 m wind speed.

### Contributors, estimated efforts: Alexandra Crăciun (0.5 pm)

**MQA3 contributors, estimated efforts:** Alena Trojáková (0.25 pm), Iris Odak (1 pm), Ivan Vujec (2 pm), Dávid Lancz (0.25 pm), Katalin Jávorné Radnóczy (0.25 pm), Dávid Lancz (2.5 pm), Boglárka Tóth (0.25 pm) Phillip Scheffknecht (0.5 pm), Katalin Jávorné Radnóczy (a - 1.25 pm), Dávid Tajti (a - 0.25 pm), Katalin Jávorné Radnóczy (c - 2 pm), Dávid Tajti (c - 1.5 pm), Boglárka Tóth (c - 1.5 pm), *Katalin Jávorné Radnóczy (2 pm)*, Endi Keresturi and the other colleagues (1.5 pm), Iris Odak Plenkovic and Ivan Vujec (0.5 pm), Radmila Brožková (0.5 pm), Marcin Kolonko (3 pm), Piotr Sekula, Bogdan Bochenek, Małgorzata Szczęch-Gajewska, Marcin



Kolonko, Jadwiga Róg, Piotr Sekuła, Gabriel Stachura, Natalia Szopa (3.5 pm),  
Natalia Szpoza (4 pm), Raluca Pomaga (2.75 pm), Alexandra Crăciun (0.5 pm)  
**MQA3 total: 25.25 pm.**

**Action/Subject/Deliverable: Ensemble calibration by use of the machine learning and deep learning algorithms. [E6.3]**

***Tuition of MSc student's work on AROME-EPS radiation postprocessing (Hungary)***

Operational EMOS postprocessing for radiation runs daily, as described in the report of February 2023. As input data we use the 11-member forecasts of AROME-EPS as well as measurements at 7 stations from a running training period of 31 days. It was applied a regional method, i.e. data from all stations are handled together to give an estimation for a few selected points.

It was continued the work on improvement of this postprocessing (as described in the report of August 2024) with an MSc student. The method is based on the work of Lerch and Baran (2017), and compares verification statistics of the individual stations. Our aim is to find groups of similar stations, for which the performance of EMOS can be improved for some target stations. Beside the data of 34 HungaroMet stations, we use additional radiation observation data for 96 stations, provided by one of our partners. Some technical work on fusion of the different data sets was done. We classified stations, based on geographical distance. The work is ongoing.

**Contributors, estimated efforts: Katalin Jávorné Radnóczy (0.5 pm)**

**References**

Lerch, S. and Baran, S. (2017): Similarity-based semilocal estimation of postprocessing models. Appl. Statist. 66, Part 1, 29–51.

**Maintenance and Partners' implementations of the ACCORD system [COM3.1]**

***Verification using VERAL (Czech Republic)***

The main topic was the extension of the operational verification (using the VERAL package) from 6 hours to 3 hours. We are also working on implementing the snow depth verification in the VERAL.

**Contributors, estimated efforts:** Alena Trojáková (1 pm).

**Summary of resources [PM]**

Subject/Action	Resource (realized)	LACE stays
Development of HARP [MQA1]	7.75	1 pm
Development of new verification methods [MQA2]	0.5 pm	
Verification, evaluation and error attribution [MQA3]	29.5 pm	
<b>Total</b>	<b>37.75</b>	<b>1 pm</b>

**Activities of management, coordination and communication**

1. 42nd LACE Steering Committee meeting, 27-28 February 2024. Budapest, Hungary
2. 4th ACCORD All Staff Workshop 2024, 15 - 19 April 2024 (Norrköping), RC-LACE verification activities presented by Simona Tascu
3. 43rd LSC Meeting, 18-19 September 2024, Vienn