

Working Area Data Assimilation

# Progress Report

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<b>Period:</b>	2025
<b>Date:</b>	27/02/2026

## Progress summary

The report summarizes the RC LACE DA activities in 2025, covering Q1–Q2 (**highlighted in blue**) and Q3–Q4 (**highlighted in black**). It focuses on the use of observational data—particularly radar, all-sky satellite assimilation, Mode-S, and GNSS ZTD—as well as on the implementation and refinement of hourly assimilation systems designed to support NWP-based nowcasting and surface data assimilation.

The research and development on radar data assimilation has a goal to enhance the realism of modeled precipitation patterns in the initial hours of the NWP forecast. Two scientific stays on radar data assimilation were executed. Several proposals to mitigate the observed drying effect in Bayesian inversion for reflectivity were implemented and validated. At the same time, considerable steps were made to reach and provide a robust solution to radar dealiasing, a prerequisite to be able to use radar Doppler winds from networks that only provide measurements on a low Nyquist interval.

Work on the assimilation of satellite observations continued, with the main focus on integrating the all-sky approach into a unified framework. Progress on the assimilation of visible channels was delayed due to technical issues in RTTOV v12, which are expected to be resolved with the transition to AROME Cy49T1. The all-sky assimilation of MTG FCI infrared radiances was successfully implemented and tested. Parallel work focused on advancing all-sky IASI assimilation in the C-LAEF 1k system using the Okamoto method, as preparatory work for the future MTG IRS sounder.

Work on high resolution TEMP data with focus on descending sounding is continuing. A bugfix in cy46t1\_bf07 enabled the assimilation of Mode-S EHS data in AROME/HU. Error inflation for Mode-S EHS was implemented independently from other aircraft data, along with the option to use temperature observations. Work is ongoing to determine the optimal thinning distance.

Research and development on ensemble variational (EnVar) assimilation continued. A bugfix and extension for 3DEnVar perturbation scaling were implemented, enabling the use of sub-ensembles with individual variance scaling. Initial tests in the C-LAEF1k system showed a small positive impact on departure statistics. Scale-dependent localization (SDL) was also tested, resulting in smoother increments and mixed impacts. The works focused mainly on technical issues, due to timestep length increase the IAU was incorporated to help with spin-up and avoid crashes (see section DA6).

Work on surface data assimilation progressed in several areas. A stay at GeoSphere Austria focused on CLAEF1k's surface DA using SURFEX multilayer physics and SEKF, addressing initialization challenges and preparing for future system upgrades. Separate efforts targeted snow assimilation, including improved snow depth analysis with advanced quality control and tuning in ALARO and AROME, as well as tests in Austria to reduce unrealistic snow accumulation via modified correlation functions and climatology relaxation. Soil moisture initialization tuning in Slovakia showed neutral effects from LISSEW smoothing but benefits from higher cycling frequency.

Last but not least, the first steps were taken to familiarize with the new C++ layer of the ACCORD/ALADIN code, which was earlier successfully ported and used to reproduce the current 3D-Var assimilation.

## Actions/Subjects/Deliverables

### Subject: *Operational implementation of DA systems [COM3]*

#### Description and deliverables:

An overview of the current operational DA systems in RC LACE countries are presented in the following two tables (yellow colors indicate the system upgrades and additions made):

Table E1: Operational DA for NWP systems run by RC LACE countries.

DA	AUSTRIA AROME	CROATIA ALARO	CZECH REP. ALARO	HUNGARY ALARO	HUNGARY AROME	SLOVAKIA ALARO	SLOVENIA ALARO
Resol	2.5L90, 600 x 432	4.0L73 480 x 432	2.3L87-NH 1069 x 853	8L49 349x309	2.5L60 490x310	4.5L87 625x576	4.4L87 432 x 432
Cycle	43t2bf11+loc.	43t2bf10	46t3mas_op1	cy40t1	cy46t1bf07	cy46t1bf07	43t2bf10
LBC	IFS 1h (lagged)	IFS 1h (lagged)	ARP 3h	IFS 3h (lagged)	IFS 1h (lagged)	ARP 3h	IFS 1h/3h (lagged)
Method	OI_main MESCAN + 3d-Var	OI + 3D-Var + Jk	OI + BlendVar	OI + 3D-Var	SEKF + 3D-Var	BlendVar + OI	OI + 3D-Var
Cycling	3h	3h	3h	6h	3h	6h	3h
B matrix	EDA on C-LAEF	EDA	EDA	EDA	EDA	Downscaled AEARP	Downscaled ECMWF ENS
Initialization	No (SCC)	No (SCC)	IDFI in production, SCC	DFI	No	No	No (SCC)
Obs.	Synop + AS, Amdar/MRAR /EHS-EU, AMV, Temp, ASCAT, Snow-grid/MODIS, snowmask, Ceilometer	Synop, Amdar/MRAR, AMV, Temp, Seviri, Radar RH (OPERA),	Synop + AS, Amdar/MRAR /EHS-EU, HRW, Profiler, Temp, ASCAT, Seviri, Radar Refl. (OPERA)	Synop + AS, Amdar, AMV, Temp, Seviri, AMSUA/MHS,	Synop + AS, GNSS ZTD, Amdar/MRAR, Temp, AMV+HRW,	Synop + AS TEMP HRW AMDAR + Mode-S ZTD	Synop + AS Amdar/MRAR/ EHS, AMV, Temp Seviri, AMSUA/MHS/ IASI, ASCAT/OSCAT, E-GVAP ZTD (passive)
Cut-off (prod / assim)	1:45h			3h	1:30h	2:35 / 7:45h	2:15 / 4:00h

Table E2: Operational DA for NWP-based nowcasting systems at hourly scale run by the RC LACE countries.

DA	AUSTRIA AROME RUC	CZECH REP. VarCanPack	SLOVENIA ALARO-RUC
Resol	1.2L90 900 x 576	2.3L87-NH 1069 x 853	1.3L87 589x589
Cycle	43t2bf11	46t3mas_op1	cy43t2bf10
LBC	AROME-Aut 2.5km 1h	-	ECMWF 1h
Method	OI_main MESCAN + 3d-Var + LHN + FDPA + IAU	3DVAR + OI	3D-Var + OI
Cycling	1h	-	1h
B matrix	Static EDA + differences of the day	EDA	static DSC ENS
Initialization	IAU		No (SCC)
Obs	Synop + AS, Amdar (q)/MRAR/EHS national, EHS-EU, AMV/HRW, bufrTemp, Seviri, AMSUA/MHS/HIRS/ATMS/IASI (+ Metop-C), ASCAT, GNSS ZTD (Austria + EGVAP 1h VarBC), GPSRO (ROMSAF/OPLACE), Radar RH/Dow, INCA + AS at hig.freq., MODIS snowmask, windfarms, celiometers, Profiler, towers, NOAA20 JPSS ATMS, NOAA21 ATMS, More snow from Swiss	Synop + AS, Amdar/MRAR/EHS-EU, HRW, Profiler, ASCAT, Seviri	SYNOPSIS + AWS, AMDAR/ MRAR/ EHS, AMV, TEMP, SEVIRI, AMSUA/MHS/IASI, ASCAT/OSCAT, radar reflectivity
Cutoff	0:27		0:35/1:10

*Table E3: Operational ensemble systems in RC LACE countries that include the DA component.*

DA	AUSTRIA C-LAEF	HUNGARY AROME-EPS	LACE A-LAEF
Resol.	2.5L90, 600 x 432	2.5L60, 490 x 310	4.8L60, 1250 x 750
Cycle	43t2bf11	cy46t1bf07	40t1 + loc.changes
members	16+1	10+1	16+1
LBC	IFS-EPS	IFS ENS 1h (lagged)	IFS 6h (lagged)
Method	OI_main MESCAN + 3d-Var, pert. obs. + Jk	3D-Var + SEKF	DF blending + ESDA
Cycling	3h	3h	12h
B matrix	EDA on C-LAEF	Static EDA	-
Additional Initialization	No	No	No
Obs.	Synop + AS, Amdar, Geowind, Temp, ASCAT, Snowgrid/MODIS	SYNOP + AWS, GNSS ZTD, AMDAR/MRAR, TEMP, AMV+HRW	Synop + AS
Obs. cutoff		1:30	1:00

In **Austria**, a 1 km version of C-LAEF (CLAEF Alpe Adria) is continuously developed on ECMWF HPC. The system consists from 16 EDA members, 1 control member +1 EnVar member. CLAEF is completely based on cy46t1 while the EnVar member is on cy48t3. Observations and other settings are mostly as in C-LAEF, GNSS-ZTDs data with revised whitelist and RADAR reflectivity data with Slovenian setting are used. For configuration e001 MF settings are used. Domain was extended southward and truncation changed to quadratic. Therefore new B- and V-Matrix was calculated. Main focus of works is tuning the EnVar member and AllSky assimilation.

In the **Czech Republic**, 3-h cycling is made operational from February 2024 after tuning of CANARI. Soil moisture increments depend on sun declination and they are averaged in time (LISSEW), relaxation to climatology is half of 6-h cycle, no relaxation of snow to climatology. OPERA radar reflectivity assimilation is operational since May 2025.

In **Croatia**, radar reflectivities from OPERA are successfully implemented to the operational chain. The CANARI was tuned to avoid oscillation in T2m forecasts from different network times (summer), smoothing of soil moisture in time is applied by running average of last 3 analyses and to fix unrealistic soil moisture evolution during year. Croatia joined the CLAEF Alpe Adria project and is continuing works on AllSky assimilation of IASI.

In **Hungary**, OPLACE national Synops were added to AROME, new whitelist for GNSS ZTD improves results. An AROME RUC e-suite is running with hourly cycling at 1.3 km horizontal resolution and 90 vertical levels since December 2023. Migration of AROME to cy46t1bf7 is finished and is operational.

In **Slovakia**, two ALARO-1 models are pre-operational, both with 1km resolution and L87 on cy46t1bf07. RUC1 runs hourly with lagged boundary conditions and 3D-Var assimilation. ALA1 has been in test mode since March 2025, running every 6 hours and featuring 3D-Var assimilation with radar reflectivity data from OPERA. A bug in quality control of relative humidity/soil wetness was corrected in CANARI (canami.F90).

In **Slovenia**, HOOF preprocessing rewritten to C++ lead to significant speed improvement, the new C++ version runs 6-8 times faster.

In **Romania**, there are ongoing efforts to set up data assimilation cycling with CANARI with promising results.

In **Poland**, the activities towards the first assimilation suite are ongoing.

**Contributors:** All (approx. 1 PM per country, more in some institutes)

**Subject:** *In-situ observations [DA1]*

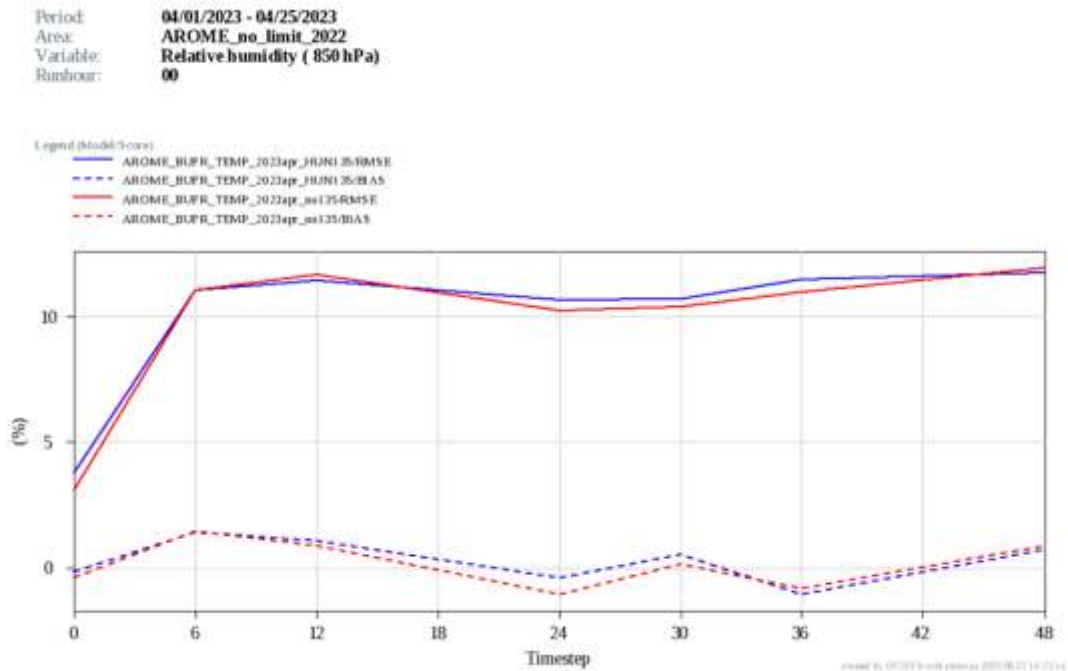
**Description and objectives:**

**Implementation of high-resolution ascent and decent radiosondes and wind profilers: optimize local pre-processing, extend observation operator, assess the quality and perform impact study. (DA1.1)**

In previous experiments with BURF TEMP in AROME/HU, a bug identified and corrected. The experiments were rerun, resulting in only minor differences that did not affect the previous conclusions. The figures were updated accordingly in the report from the LACE stay in Bratislava (November 2024).

**Dávid Lancz (HU)** made new experiments to examine the impact of assimilating data from descending radiosondes equipped with parachutes. At the Budapest meteorological station (12843), radiosondes with parachutes were launched during two measurement campaigns in April and August 2023. Three periods were selected for experiments: 1–25 April, 2–24 August and 1–24 June as reference. Two experiments were achieved for every period: with and without data of the descending radiosondes from this station. (There were no other radiosonde stations with descending data within the model domain.) The evaluation is ongoing; initial results do not indicate a positive impact from the descending data with parachutes (Figure 1.1.1).

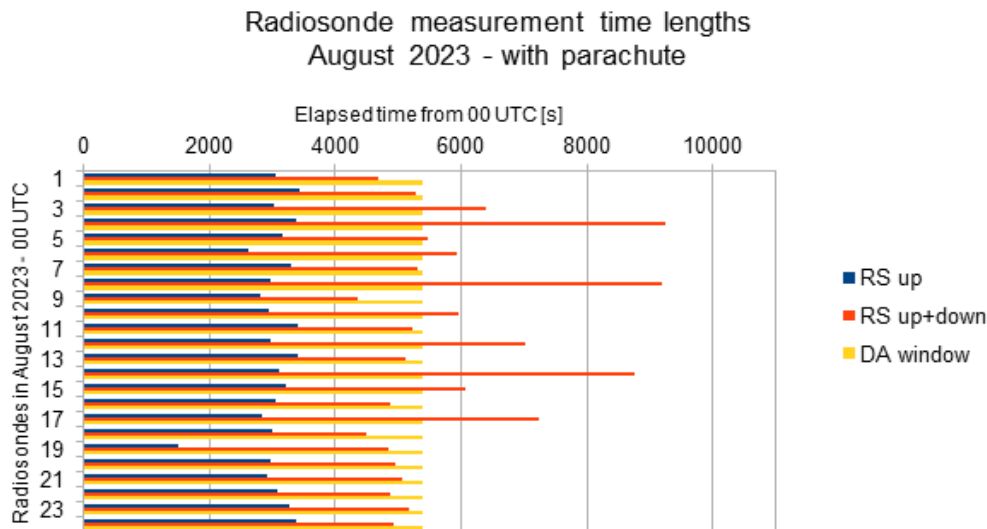
We plan to examine the timeliness of the radiosonde measurements to ensure that all data—particularly from the descending path—fall within the  $\pm 90$ -minute assimilation window. Additionally, we intend to carry out an experiment using BUFR TEMP and descending radiosonde data from a more recent period, and to verify the results against BUFR TEMP data instead of the currently used TAC TEMP.



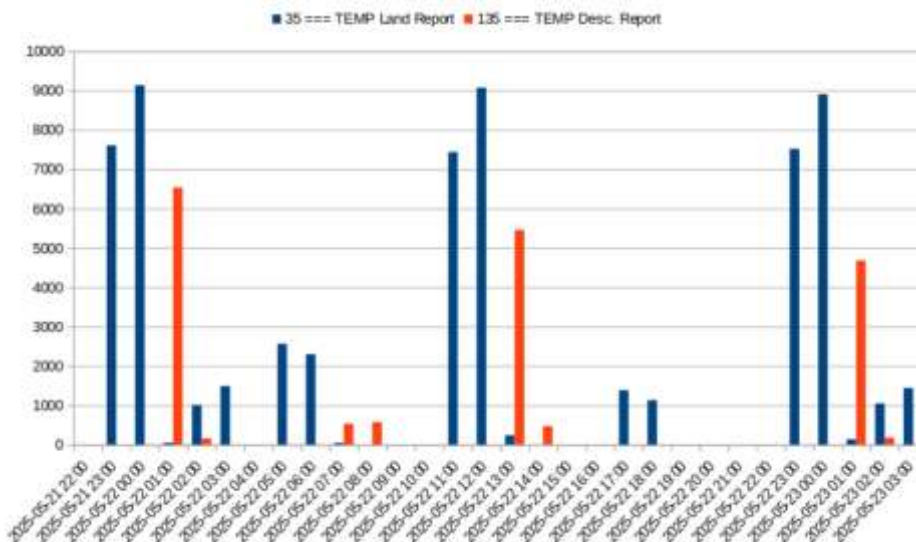
**Figure 1.1.1:** Bias (dashed line) and RMSE (solid line) of relative humidity forecasts at 850 hPa as a function of lead time for AROME experiments using BUFR TEMP data **with** (blue) and **without** (red) the assimilation of descending radiosondes data with parachutes from the Budapest station, all forecasts are initialized at 0 UTC for the period 1–25 April 2023.

**Dávid Lancz (HU)** examined the differences between the usage of OBSOUL TEMP and BUFR TEMP in assimilation. He also inspected the effect added by the data from descending paths and by using radiosondes with parachutes. He found that the increased number of measurements due the switch from OBSOUL to BUFR TEMP did not result in significant improvement of the forecast.

The additional data from the descending radiosondes has only minor impact, often in the wrong direction. A possible reason could be the drift of the radiosonde, because the trajectory is not followed (TEMPSONDORTRAJ=.T. is used in BATOR namelist) due to some memory issues. We did not gain systematic positive effect from parachutes in the quality of the forecast, the impact was rather weak and random. The duration of measurements along the descending paths (Fig. 1.1.2) often exceeds the length of the assimilation window. With hourly assimilation cycle (Fig. 1.1.3) the data from the descending paths are sometimes used in the assimilation 1-2 hours later than the nominal measurement time (e.g. 0 UTC TEMP descending reports are used at 1 UTC and 2 UTC assimilations). In our operational configurations we plan to switch from OBSOUL to BUFR TEMP but without the usage of descending data.



**Figure 1.1.2:** The duration of 0 UTC radiosonde measurements from Budapest (12843) station in August 2023. (The usual start of the 0 UTC sounding is at 23:19 UTC.) The blue bars represent the ascending path, the red bars also contain the descending path. The yellow bars span until the end of the assimilation window (1:30 UTC).



**Figure 1.1.3:** Number of TEMP reports from ascending (blue) and descending (red) paths of radiosondes used in the 0 UTC AROME-RUC experiment with hourly assimilation cycle.

**Surface observations (Ps, T2m, Hu2m, V10m): Perform impact assessment of high-quality and high-resolution SYNOP DA (DA1.2)**

**Testing corrected SYNOP wind data in AROME/HU 3D-Var**

The instruments of wind measurements are not installed at 10 meters everywhere in Hungary. The

height difference is significant in some SYNOP sites. The Unit of Climate Research at HungaroMet recomputed the wind speed and gust values to 10 meters using the raw data and the logarithmic profile:

$$v_t = \exp \left[ \gamma * \ln \left( \frac{\ln \left( \frac{h_t}{r} \right) * \ln \left( \frac{h_0}{0.1} \right)}{\ln \left( \frac{h_t}{0.1} \right) * \ln \left( \frac{h_0}{r} \right)} \right) \right] \exp \left[ \alpha * \ln \left( \frac{h_t}{h_0} \right) \right] * v_0$$

$h_0$  : original observation height,

$h_t$ : target height, e.g. 10 m,

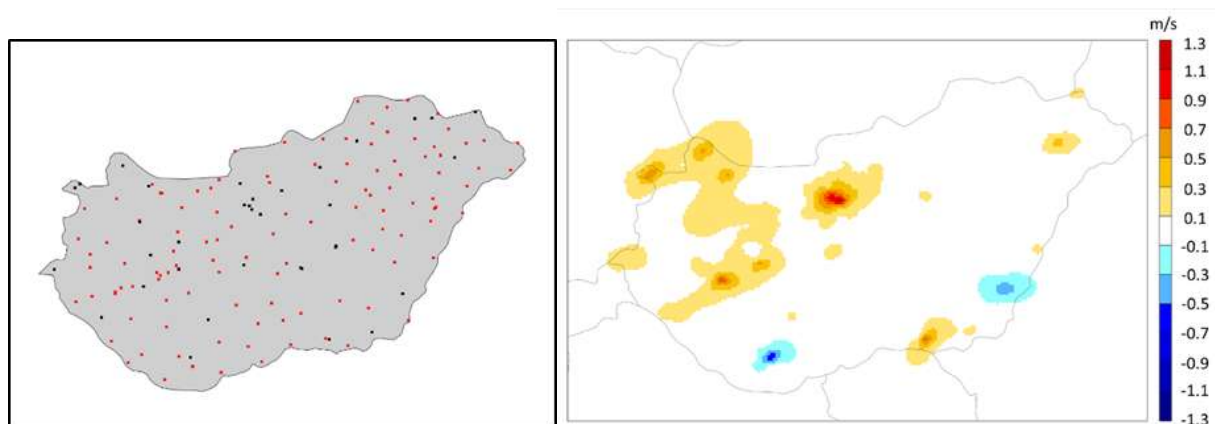
$r$ : roughness length of observation site,

$v_0$ : wind speed in the height  $h_0$ ,

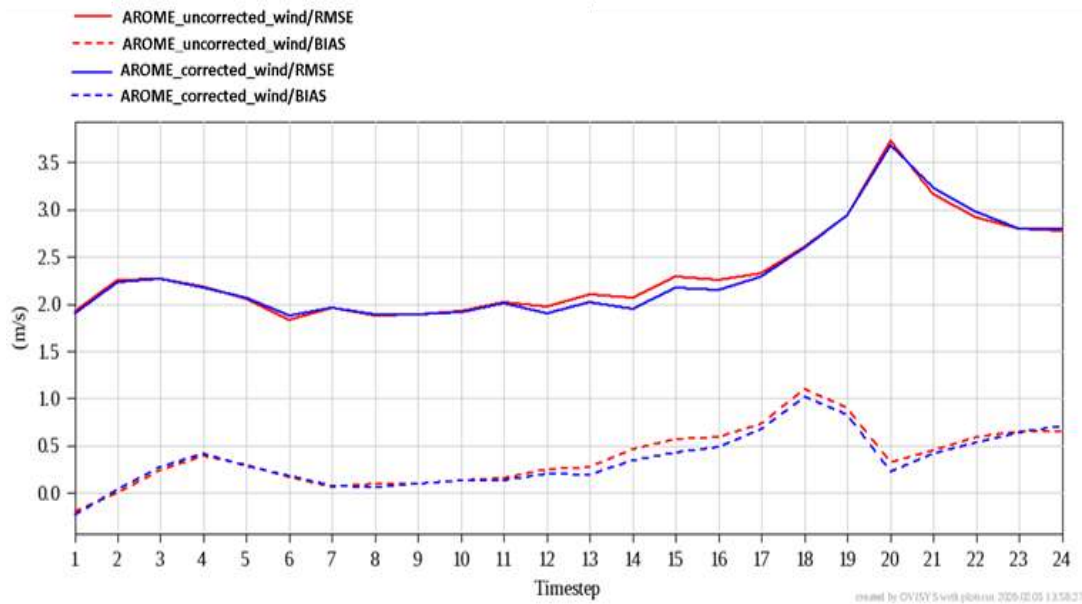
$v_t$ : wind speed calculated for the height  $h_t$ ,

$\alpha, \gamma$ : parameters depending on season and variable

In addition to the original data, the corrected ones are available routinely since July 2025: they are shared in OPLACE (as well as via GTS) as additional variables (windSpeed10, windGust10) in the netcdf files. Between 29 July and 4 August 2025, **Anikó Kardos-Várkonyi (HU)** evaluated the forecast impact of assimilating corrected 10-meter wind speed data using a 3-hourly AROME 3D-Var cycle. The same observation types were used as in the operational AROME/HU, with the only difference in wind speed values. The analysis changed according to our expectations: mostly in the locations where wind data was corrected (Figure 1.2.1). Correction of wind data showed no significant impact on the forecast for most parameters. The most visible difference in the results was found in the case of 10-meter wind gust, where a slight positive impact can be observed between the 12th and 16th hours of forecast range (Figure 1.2.2). Nevertheless, we do not plan to use the corrected data in AROME/HU assimilation, because they are available for Hungary only, and we would need to perform several modifications on our assimilation system in order to merge them with wind information for the entire AROME domain.



**Figure 1.2.1:** Left: location of untouched (red) and corrected (black) SYNOP wind measurements. Right: difference in the analysis of 10-meter wind speed between the experiments using original and corrected SYNOP data at 0 UTC on 29 July 2025.



**Figure 1.2.2:** Bias (dashed) and RMSE (solid) of 10-meter wind gust forecast in function of lead time [h] for AROME experiments using original (red) and corrected (blue) SYNOP data, all initialized at 0 UTC from 29 July to 4 August 2025. The verification was done against the original SYNOP data.

Modified observation error for SYNOP 2m values implemented in AROME-RUC

**Florian Meier (AT)** found a lack of low clouds in inner Alpine valleys in AROME-RUC and C-LAEF AA configuration. So far assimilation of 2m values in 3D-Var showed negative impact at night (see old national posters from AT and findings from CHMU on high spreading increments from surface in 3DVar). Therefore the LSOE switch is activated to not use 2m observations at night in Screening in all AROME configurations in Austria including even EnVar. But this leads to a lack of low level humidity information. Therefore, the idea is to apply an adapted observation error for 2m values to maybe get at least some beneficial moisture information into the model. Additional measures could be, to relax the rejection of SYNOP RH2m in case of orography differences between model and real orography (screening blacklist mf\_blacklist.mb) and instead apply an orography difference adapted observation error (proposed by Kaushambi Jyoti, University of Vienna after personal communication with Meteo Swiss). If EnVar is used, also an adapted vertical localization could help to prevent high spreading increments from surface under stable conditions. So far an adapted observation error (day/night + orographic difference) was coded for T2m/RH2m in addoer.F90. However, further tuning and testing is needed to get it into a shape for operationalization.

**High-resolution crowd-sourced surface observations (surface pressure, T2m, Q2m, V10m): further explore the potential of volunteered observations from crowd-sourced/private weather stations, cars, and smartphones (DA1.3).**

No work reported.

**Aircraft-based observations: assist implementation of Mode-S wind and temperature (EHS and MRAR); assess performance of fast observations from EMADDC. (DA1.4)**

Experiments with EMADDC Mode-S EHS data in AROME/HU data assimilation were conducted using cy46t1\_bf07. However, the assimilation of Mode-S EHS data initially did not work with this cycle. **Péter Elek (HU)** and Florian Meier (AT) did a bugfix which was uploaded to the common github repository during the working week in Krakow. The Hungarian AROME version was extended with further local modifications which makes it possible that

- Mode-S EHS observation error can be inflated independently from other aircraft datatypes (e.g. from AMDAR data) and
- Mode-S EHS temperature data can be included (or turned off with namelist LISTE\_LOC).

After that they continued with an experiment with 1.3 km resolution for the period of 1–10 April 2025 and 2.5km resolution for 2025 May. These experiments are done with Siebren's box thinning but because the Mode-S data is dense it still provides enough information to calculate the error correlations with the Desroziers method. They are working on specifying the optimal thinning distance. The evaluation of the results is in progress.

**Total efforts:** 13.25 months

**Contributors:** P. Elek (HU) 5, D. Lancz (HU) 4.75, M. Derkova (CZ) .25, A. Varkonyi (HU) 2.25, M. Nestiak (SK) 1

**Documentation:** /

**Status:** ONGOING

**Subject: *Use of ground-based remote sensing [DA 2]***

**Description of tasks:**

**Implementation of reflectivity data assimilation (OPERA data) based on common preprocessing HOOF and benefiting from recent recommendations on tuning of Bayesian inversion (DA 2.1)**

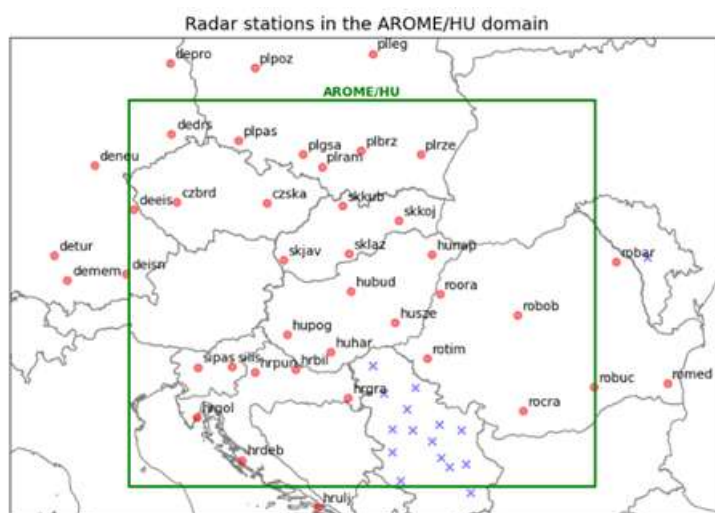
Setting up radar reflectivity experiment in **AROME/HU data assimilation**

As cy46t1\_bf07 was introduced into the operational AROME/HU system in February 2025, **Laura Magyar (HU)** transferred her radar reflectivity experiment to cycle 46, incorporating radar-related modifications from the cy46t1mp\_op3 modset provided by CHMI. All previously detected issues have either been resolved or are still under investigation:

- We tested HOOF2 on files from Hungarian, Czech, Slovak, Slovenian, Croatian, Romanian, Polish and German radars (Figure 2.1.1). Initially, the HOOF2 script required country-specific namelist changes, mainly modifying the 'Required DBZ moment quality groups' and commenting out '/dataset/how/NI = None' due to radar file differences. In the end, we created a single unified namelist that works for all countries.
- BATOR runs smoothly on all radar files except for the Polish ones. Currently, the Polish 15-minute radar products from NIMBUS are not suitable for assimilation purposes, as the files contain reflectivity factors at different resolutions (DBZH and TH), and only the TOTAL quality indicator is included in the metadata (Table 2.1.1). Nevertheless, the TOTAL quality field is not a unique quality indicator. It is defined by the minimum of three other quality indicators (ROPO, BLOCK and SAT), as described by Saltikoff et al. (2019). If none of the listed QC flags is present, the TOTAL quality field remains empty. Although we can select which quality task to be considered in BATOR (HODIM%ChosenTask), the idea behind the TOTAL field is to gather all the available quality information and choose only one task in the namelist for the filtering. The Polish team works on these issues.
- Due to the spatial accuracy of the Hungarian radar measurements, overlapping elevation angles are included in the assimilation. To address this problem, we modified the condition for selecting elevation angles in bator\_decodhdf5\_mod.F90.

We have started testing the radar-specific namelist settings of BATOR and screening. We are comparing the results with those of the modset's default settings, as well as with the export version, to ensure that everything works as expected. We have encountered difficulties when trying to implement the HIRLAM Obsmonitor, as the backend part is unable to convert the ODBs created by cycle 46. For this reason, we decided to use the ALADIN Obsmonitor. However, examining the results of the first experiment in ALADIN Obsmonitor raised further questions about the vertical coordinates of the radar observations. There are two types of vertical coordinate in the ODB: vertco\_reference\_1, which corresponds to the pressure level (in pascals), and vertco\_reference\_2, which corresponds to the altitude (in metres) of the observations. After the filtering process in BATOR, the variable vertco\_reference\_2 contains the altitude of the reflectivity observations, while vertco\_reference\_1

contains the altitude of the relative humidity observations. During screening, the surface pressure is calculated for each reflectivity profile and stored in `vertco_reference_1`. In ALADIN Obsmonitor, observations are mapped according to pressure levels, using the `vertco_reference_1` coordinates. Consequently, reflectivity reports are now incorrectly displayed at nearly the same low pressure level. In case of relative humidity, `vertco_reference_1` contains a mix of values in meters and pascals, depending on whether the observation is marked as 'active' or 'rejected'. This is because the variable is modified in `inv_refl1dstat.F90` based on the observation status, which makes use of RH in Obsmonitor more complicated. The work will continue with the verification of the experiment's results, as well as testing the radar-specific namelist settings, in order to mitigate the drying effect of “undetected” reflectivity measurements.



**Figure 2.1.1:** Radar stations selected for the AROME/HU experiment. The stations are indicated by red dots and their ODIM code, and the approximate AROME/HU domain is marked by the green rectangle. Blue crosses indicate radar stations that are listed in the OPERA database but do not provide data.

**Table 2.1.1:** Quality flags per country corresponding to the radar stations in Figure. Green and red shadings indicate if the QC flag does or does not present in the HDF5 files, respectively.

Quality indicators per country					
	ROPO	BLOCK	SAT	TOTAL	HAC
Czechia	No	Yes	No	Yes	No
Croatia	Yes	Yes	Yes	Yes	Yes
Hungary	No	Yes	No	Yes	Yes
Poland	No	No	No	Yes	No
Romania	Yes	Yes	Yes	Yes	Yes
Slovenia	Yes	Yes	Yes	Yes	No
Slovakia	No	Yes	No	Yes	Yes
Germany	No	Yes	No	Yes	Yes

Reference:

Saltikoff, E., Haase, G., Delobbe, L., Gaussiat, N., Martet, M., Idziorek, D., Leijnse, H., Novák, P., Lukach,

M., & Stephan, K. (2019). OPERA the Radar Project. *Atmosphere*, 10(6), 320. <https://doi.org/10.3390/atmos10060320>

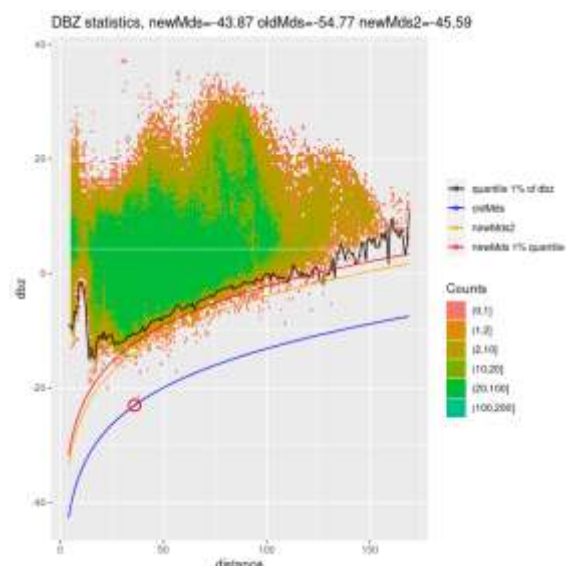
### AROME-RUC RADAR assimilation in Austria (Florian Meier, AT)

Due to changes in OPERA and other RADAR datasets some adaptations in Austrian RADAR pre-processing were made: RADAR Hochficht from Meteopress was included in AROME-RUC and three RADARS from Southern Poland and three from Germany (deneu, denhb, dedrs). The Polish radars are added as a temporal replacement of the Czech radars which currently change settings and are unavailable. Also the pre-processing of Croatian RADAR near Zagreb which was not entering due to name change was reset and the new radar at Bolzano (bilateral exchange) was pre-processed and successfully assimilated as well as Radars on Corse (France). RADAR Reflectivity will be also assimilated in the next operational version of C-LAEF.

**Antonín Bučánek (CZ)** continued efforts toward the operational implementation of radar reflectivity assimilation using a Bayesian inversion method at CHMI. Since undetected data are used as artificial observations with values equal to the radar's minimum detection threshold, it is essential to work with noiseless radar data.

As some radars show significant noise in DBZ, the method for computing the Minimum Detectable Reflectivity Factor (MDRF) was revised. The new approach removes the lowest 1st percentile of DBZ values at each distance step for a given elevation scan—i.e., the first percentile is removed from each column of the DBZ histogram (see Figure 2.1.2 below).

This modification has shown a neutral to slightly positive impact.



**Figure 2.1.2:** Histogram of observed DBZ from the DEDRS radar at 0.5° elevation on 7 December 2024 at 00 UTC. The blue line represents the old method of computing the detection threshold, while the red line shows the new algorithm.

Since **May 2025**, reflectivity data have been **used operationally at CHMI**. The current setup inflates

errors for undetected data and assimilates reflectivity only when the observed or modeled value exceeds 0 dBZ. It also incorporates the new algorithm for computing the Minimum Detectable Reflectivity Factor (MDRF).

### Radar data assimilation in rapid update cycle (RUC1) at SHMU

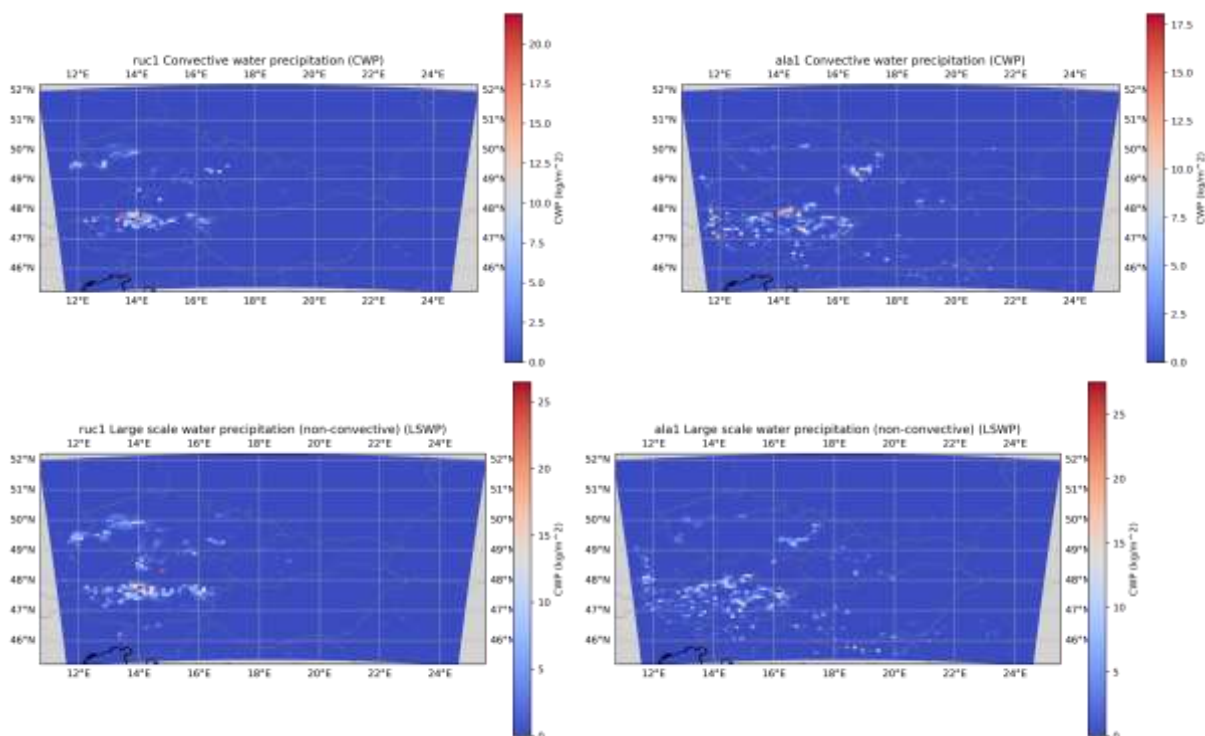
RUC1 development continued at SHMÚ by **Michal Nestiak**, **Andre Simon**, **Martin Imrišek**, a high-resolution (1 km, 87 vertical levels) configuration of ALARO-1 (cy46t1bf11) with 1h cycling. Michal Nestiak (SK) made a new test suite ALA1 including radar reflectivity assimilation. This advancement was enabled by insights gained during his research stay at CHMI (November 2024).

The ALA1 suite has been undergoing operational testing since March 2025. To manage computational resources and optimize performance during the initial tuning period, model runs are performed on a six-hour cycle, generating a six-hour (+06h) forecast. These runs assimilate radar data from the OPERA network, primarily utilizing measurements from Slovakia (SK) and the Czech Republic (CZ), supplemented by data from Hungary (HU) and Slovenia (SI) in specific cases.

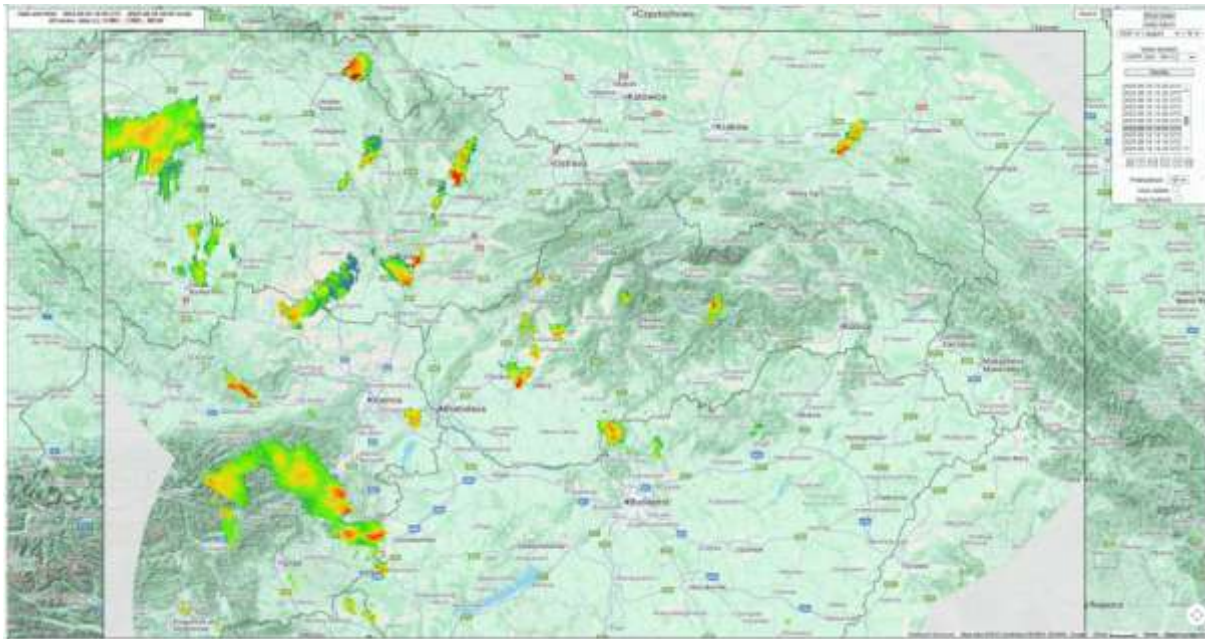
### Case study 2025-08-16 12UTC RUC1 vs ALA1

The areas with the greatest difference in Convective water precipitation (CWP) prediction between the model without data assimilation (RUC1) and the model with assimilation (ALA1) spatially coincide with the locations of real precipitation cells measured by radar.

### Forecast F+002 (14:00 UTC):



**Figure 2.1.3:** Comparison of 2025-08-16 12UTC F+02 CWP and LSWP in left column RUC1 vs right column ALA1 (with the assimilation of radar data).



**Figure 2.1.4:** Radar observations (CAPPI 2km) on 2025-08-16 12UTC.

The preparation of reflectivity assimilation in **AROME/HU** continued. During the execution of the first experiments using all radars within our domain, a memory issue was encountered. With the commonly used setting `NOBSPROFS(13)=225` (the number of model profiles required for the Bayesian inversion), the AROME/HU radar experiment could so far be completed only with a maximum of 3 Hungarian radars simultaneously. Running the screening and the minimization on 2 nodes using 24 CPUs improved the performance, but the reduction of the mailbox size (`MBX_SIZE`) did not help. During a 4-week ACCORD/LACE stay in November, **Laura Magyar (HU)** worked in collaboration with the Czech Hydrometeorological Institute (Antonín Bučánek), focusing on understanding and optimising the thinning method applied to radar reflectivity observations in ALARO/CZ (46t1as\_op1). The optimal thinning distance was selected based on the 0.2 threshold for error correlation between neighbouring observations. Following this, a 10-day sensitivity study was conducted using three different configurations to assess the impact of various thinning choices on verification scores. The results of this work were presented in more detail in the ACCORD NL8 newsletter. Building on the experience gained at CHMI, we plan to investigate the optimisation of thinning parameters for AROME/HU. It may also be of interest to compare the “traditional” thinning approach with the superobbing method, which combines closely spaced observations into a single superobservation whose value best represents the aggregated points. Testing of the radar-specific namelist settings will also continue, as we are now able to run AROME with all five Hungarian radars. In the future, we also plan to extend the list of assimilated radars with those from neighbouring countries.

During the stay, we also briefly addressed the issue of running the HIRLAM Obsmonitor. Its backend, compiled with cycle 46 by GeoSphere Austria, was copied from ECMWF Atos to our local HPC. During the test run, however, we encountered the same error as before, and therefore no solution has been found yet.

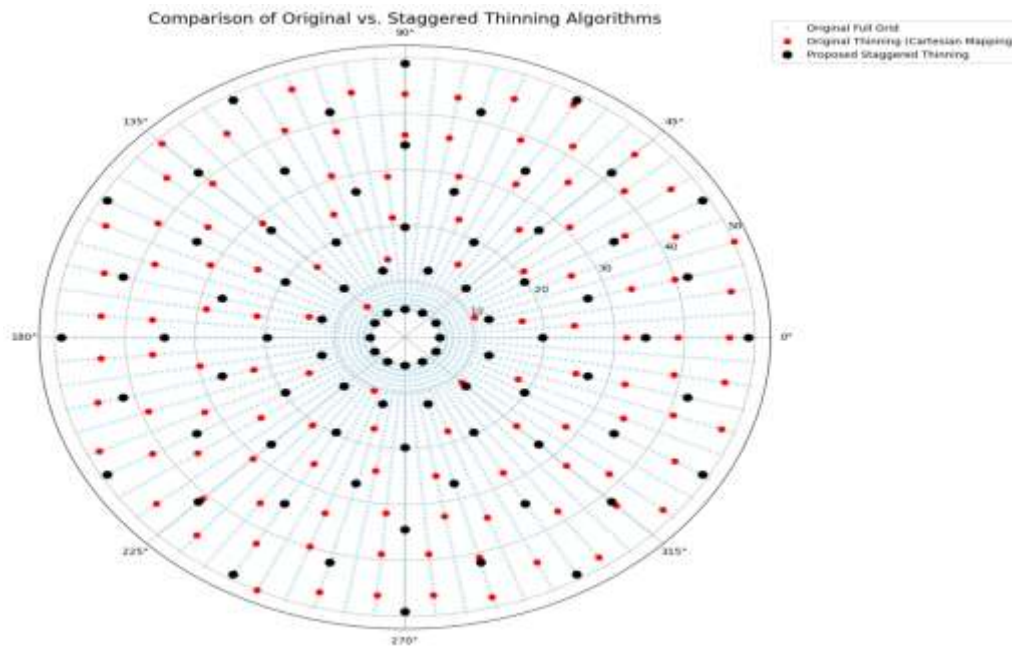
We would also like to note that the **issue concerning Polish radar data**, reported during the ACCORD working week in Krakow, still **remains unresolved**. The Polish files currently available in the OPERA database still do not contain quality indices, and the corresponding DBZH and TH data are provided at

different resolutions.

### Reducing the computational cost and optimisation of radar observation pre-thinning in BATOR (SK).

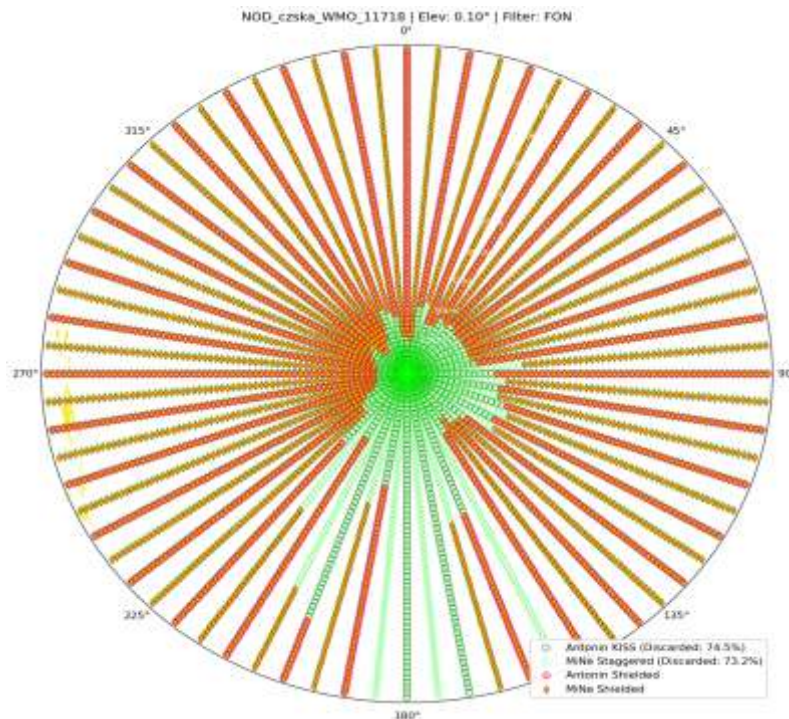
The main driver for this work was the search for "hidden reserves" in the computational efficiency and optimisation of used data in the RUC1 (ALARO-1 with radar data assimilation) at SHMÚ. As radar data volume increases, the pre-processing stage in BATOR becomes potentially delaying the delivery of high-resolution forecasts. Analysis of the `bator_decodhdf5_mod.F90` module revealed a significant inefficiency in how the data grid is traversed. The original code used a "brute-force" approach. The program iterated through every single point of the high-resolution radar scan. A modulo condition (MOD) combined with a CYCLE command was used to skip unnecessary points. Even if we wanted to keep only 1% of the data, the CPU still had to visit 100% of the points, evaluate the MOD logic, and perform redundant calculations (such as `atan2`), which are computationally expensive.

**M. Nestiak (SK)** proposed Staggered Polar Pre-thinning which was presented at the regular RC LACE DA meeting. This approach uses a staggered polar grid to achieve better spatial coverage.



**Figure 2.1.5:** Comparison of Staggered grid vs. original "Cartesian grid" pre-thinning.

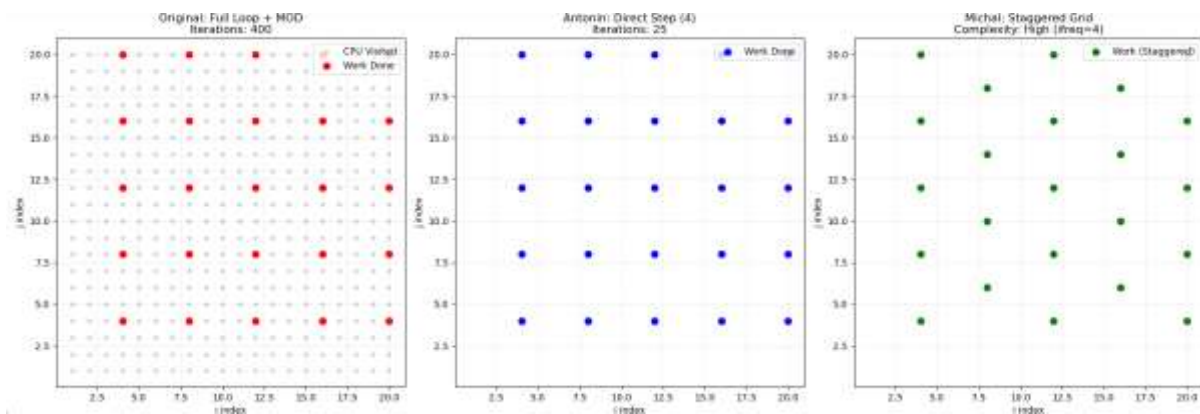
Another optimization and added value of M. Nestiak staggered grid solution is usage of `'se.smhi.detector.beamblockage'` to filter bins on a ray that are located behind a bin already identified as shielded. We were not using bins on the beam that were already shielded from the radar on the way from the radar.



**Figure 2.1.6:** Example of shielded data point.

While statistically beneficial, it requires more complex indexing and additional logic in the code, which partially negates the effort for maximum speed-up compared to the direct step approach.

In response to Michal's proposal offered **A. Bučánek (CZ)** the simple solution. A. Bučánek proposed simple Direct Step modification which consists of changing the definition of the loop itself so that the processor visits only the points designated for processing.



**Figure 2.1.7:** Comparison of selection point with two different optimization proposals.

The Antonin's Direct Step approach has been selected as the optimal solution for the current implementation of SHMU's RUC1 system. M. Nestiak continues on testing and developing Staggered grid with beamblockage to have statistical results for this method. Efforts are currently focused also on implementing an integrated attenuation filter, capped at a 20 dB limit, to systematically exclude radar data shielded by high-reflectivity.

**RADAR assimilation in C-LAEF Alpe Adria AROME-OOPS (Florian Meier AT)**

Direct assimilation of reflectivity (approach of Maud Martet) was tested in a case in C-LAEF Alpe Adria configuration in EnVar based on a user pack including the necessary code changes BATOR+OOVAR. Reasonable hydrometeor and moisture increments were derived. Maud mentioned in OPERA user meeting that radar obs perturbation could create RH observations above 100% or negative. Florian Meier coded a modification into arpis/obs\_preproc/pertobs\_uncorr.F90 where the obs\_error used to perturb observations decreases linearly to 0 above 90% and below 10% of relative humidity such that this problem should be avoided.

**Impact studies with original and de-aliased OPERA Doppler wind data. (DA 2.1)**

**Peter Smerkol, Vito Švagelj and Benedikt Strajnar (SI)** refined the torus mapping algorithm in the HOOF software and the work resulted in a published scientific paper ([10.1127/metz/1256](https://doi.org/10.1127/metz/1256)). Peter Smerkol rewrote the HOOF in C++, making it considerably faster (about 6-8 times faster than the Python version). The code is available from him and will be shared with the community via the AccordPreprocTools repository.

**Martin Petrovič (SK) and Alena Trojáková (CZ)** studied the radar data pre-processing HOOF2, which incorporates the most recent version of the radial wind dealiasing algorithm. During the two-week period of Martin's visit, the passive data assimilation experimental framework over the LACE domain was prepared to investigate data quality, as well as optimal settings for quality control, thinning, and super-obbing. This work is scheduled to continue in Q4 2025.

**Test of super observation functionality in HOOF for radar reflectivity (or alternatively radial wind). (DA 2.1)**

Only preparatory work was done by Martin Petrovič (SK), see above.

**Further elaborate the assimilation of GNSS ZTD observations and conduct impact studies, focusing on data from regional providers, assist quality improvement of solutions from these centers (DA 2.2)**

**Martin Imrišek (SK)** operationally implemented the GNSS ZTD observations at SHMÚ.



**Figure 2.2.1:** Changes of the scores in ALADIN/SHMU, between reference (63L) and esuite (87L) for MSLP.

### GNSS slant delay impact studies with 3D-Var (DA 2.2)

No work reported.

**Total efforts:** 25 months

**Contributors:** F. Meier (AT) 4.5, M. Nestiak (SK) 3.5, A. Bučánek (CZ) 2.75, A. Trojakova (CZ) 1, M. Petrovič (SK) 0.5, P. Smerkol (SI) 0.5, M. Imrišek (SK) 2, L. Magyar (HU) 8, B. Strajnar 1, P. Smerkol 0.5

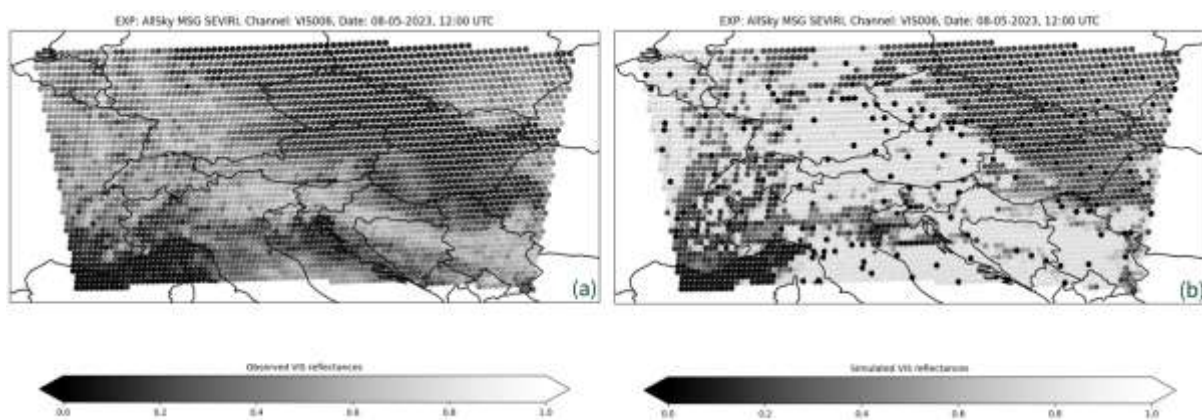
**Documentation:** /

**Status:** ONGOING

**Subject: *Satellite-based remote sensing observations [DA 3]***

**First steps towards using visible information from MSG with RTTOV visible operator and implementation of assimilation interface. Provide good description of albedo to screening and minimization. (DA 3.2)**

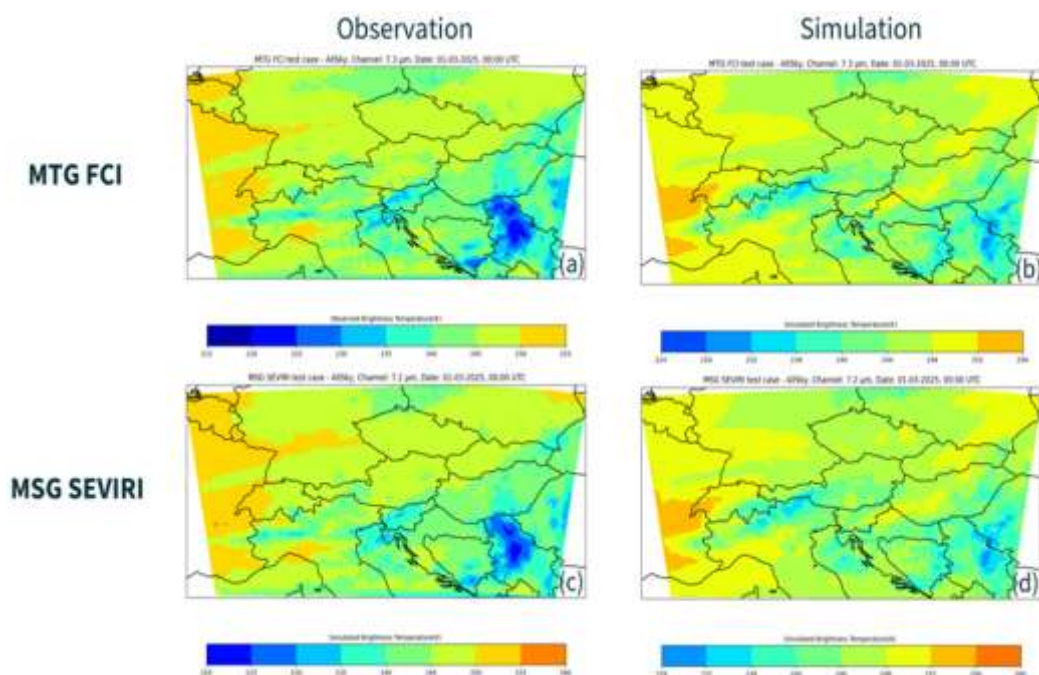
**Florian Meier(AT) and Adhithiyan Neduncheran(AT)** continued their research on the assimilation of visible channels. However, progress has been delayed due to technical challenges in the RTTOV v12 code version. These issues will be mitigated by switching to AROME Cy49T1 at a later stage. The objective is to integrate both VIS and IR channels in a unified assimilation framework once the necessary technical advancements and testing are completed.



**Figure 3.2.1:** Visible channel 0.6 $\mu$ m, Observation(left) and Simulation(right) from MSG SEVIRI.

**Florian Meier(AT) and Adhithiyan Neduncheran(AT):** The all-sky assimilation of MTG FCI infrared radiances was successfully implemented and tested within the AROME-Austria 2.5 km configuration using a 3D-Var framework. The system setup builds on the established all-sky methodology previously developed for MSG SEVIRI, ensuring technical consistency and minimizing integration risks. As a next step, a dedicated month-long experiment is planned for the summer season within the CLAEF AlpeAdria, ensemble prediction system jointly being developed by Austria, Croatia and Slovenia. This will allow assessment of the impact of FCI assimilation under convectively active conditions and in a probabilistic forecasting context.

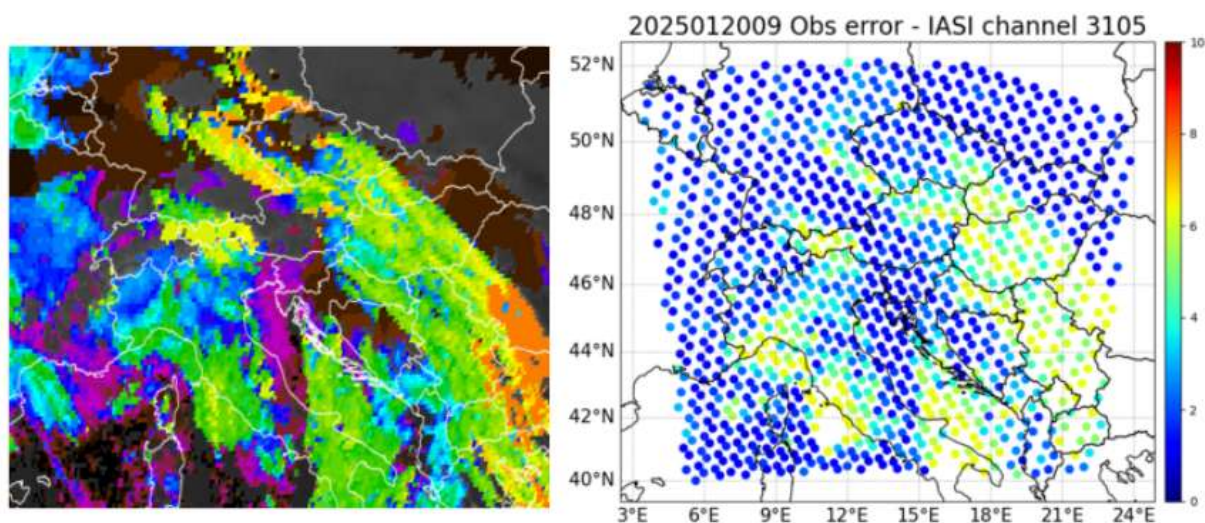
In parallel, the capability to assimilate SEVIRI visible (VIS) channels has now been established, marking an important extension of the all-sky assimilation. Further developments in CY50T1 will focus on the combined assimilation of FCI VIS and IR channels, with the objective of exploiting complementary cloud and moisture information.



**Figure 3.2.2:** WV7.3  $\mu\text{m}$  channel from MTG FCI(top) and MSG SEVIRI (bottom), (a & c) Observed brightness temperature, (b & d) AllSky simulated brightness temperature.

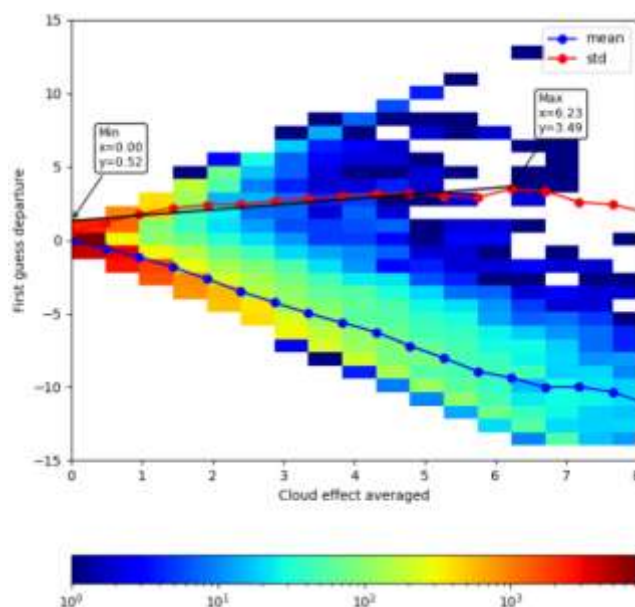
**Implement new or revised all sky assimilation strategy for IASI as preparation to use similar data from MTG IRS. (DA 3.2)**

**Suzana Panežić (HR)** and **Benedikt Strajnar (SI)** continued their work on the Okamoto method implementation for all-sky assimilation of IASI data within the EnVar member of the C-LAEF 1k system. A new external namelist to store statistical values for modeling observation errors (cloud-dependent error bounds), was introduced. The CY48T3 code was modified to dynamically assign observation errors based on the averaged cloud effect, which is derived from simulated cloudy, simulated clear, and observed cloudy brightness temperatures. Assigned observation errors increase linearly with the cloud effect up to a predefined maximum (plateau, Figure 3.2.1). Modset from **Adhithyan Neduncheran (AT)** for the all-sky data assimilation of SEVIRI data was used as the basis.



**Figure 3.2.1:** Case 20.01.2025.: EumetView Cloud top height product (left), modeled observation error values for IASI channel 3105 (right) – maximum observation error dummy value used as a plateau for testing purposes was 6.34

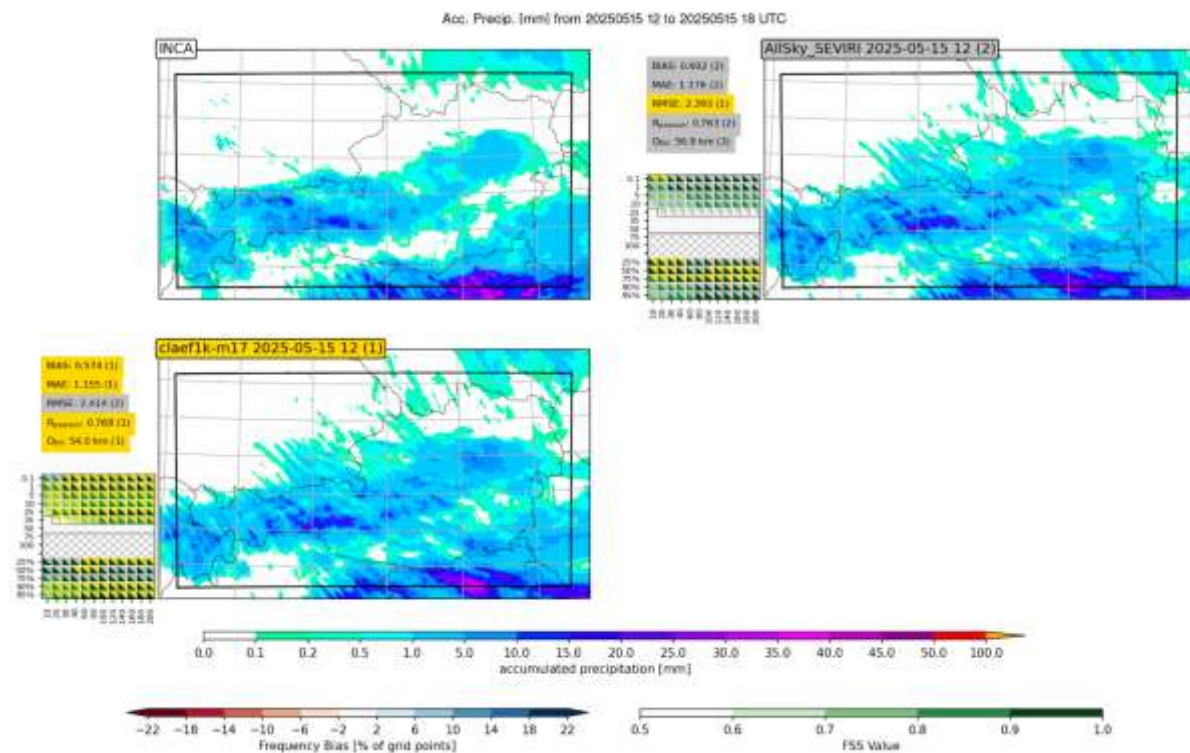
To calibrate the observation error model, an assimilation cycle was run from the cold start (15.01.–15.02.2025.) using **IASI data** in passive mode. First-guess departure statistics were analyzed to define observation error bounds for four IASI channels, applying the linear fit to the standard deviation values (Figure 3.2.2). Preliminary results showed that the bias is growing (in absolute value) with the average cloud effect. To address this, a new cloud-based predictor was coded to the VARBC procedure using the averaged cloud effect. Its impact is still under evaluation. (**Suzana Panežić (HR)**, **Benedikt Strajnar (SI)**, **Florian Meier (AT)**).



**Figure 3.2.2:** IASI channel 3105: 2D histogram with the mean and standard deviation of first guess departures as a function of cloud effect for brightness temperatures (blue and red line respectively); Linear fit to standard deviation values (black line) with assessed minimum and maximum values for observation error modeling.

During the Data Assimilation Working Week in Oslo, the proposed implementation was successfully tested using multiple sensors at the same time (**IASI and SEVIRI**) together within the EnVar member of the C-LAEF 1k system. While IASI integration worked well, SEVIRI required additional adjustments due to CY48T3-related issues with radar interactions and channel blacklisting. (**Suzana Panežić (HR), Adhithiyar Neduncheran (AT)**).

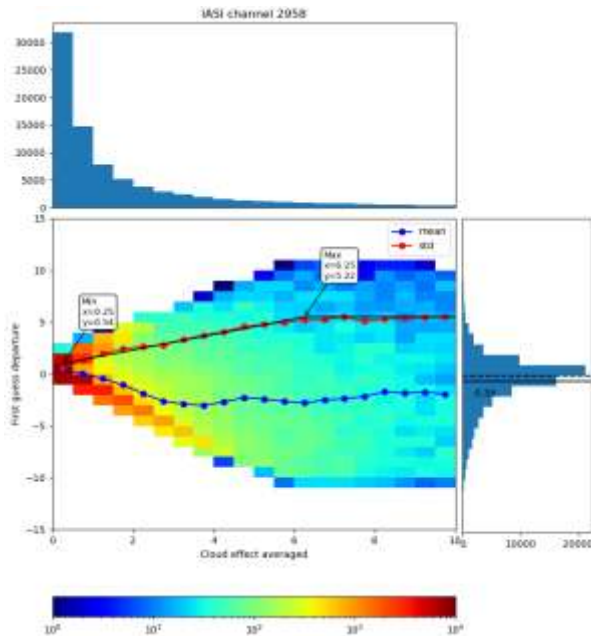
**Florian Meier(AT)** and **Adhithiyar Neduncheran(AT)** completed a month long AllSky assimilation of MSG **SEVIRI water vapor channels** in the CLAEF-AlpeAdria 3D-EnVar system using AROME Cy48T3, while adding the ice particles in the control vector to assess the impact of the AllSky assimilation.



**Figure 3.2.3:** Comparison of INCA with the EnVar member from the CLAEF-AlpeAdria system and the AllSky SEVIRI experiment.

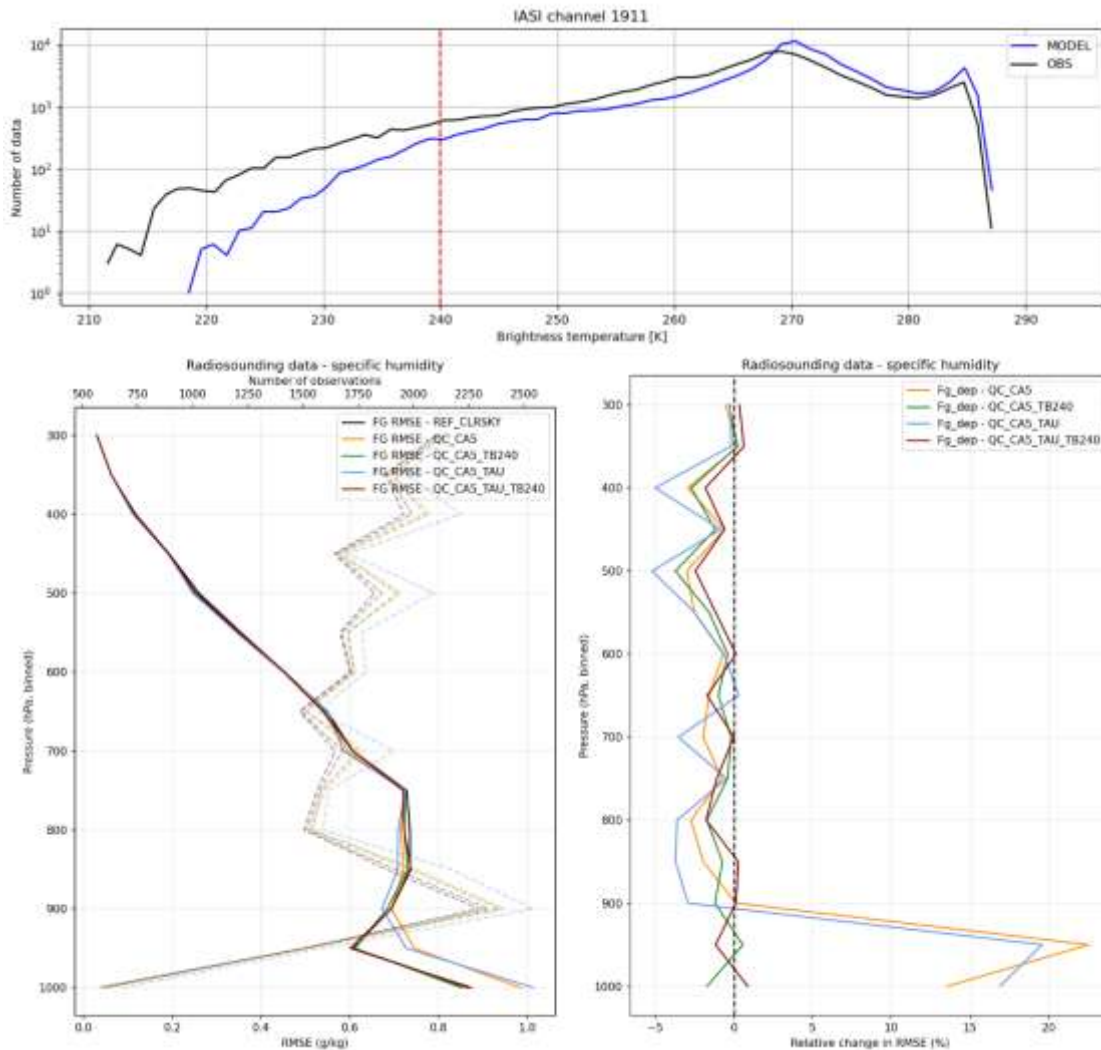
Preliminary results from the AllSky experiment are similar to those of the EnVar member, and further analysis is still ongoing. The newly tuned observation error model will be used in future experiments, hopefully improving the analysis. Further research is planned, after Suzana Panežić (HR) evaluate the cloud amount predictor introduced in the VARBC, which is presumably expected to give better results according to some on-going research in our community.

**Suzana Panežić (CR) and Benedikt Strajnar (SI)** continued their work on the Okamoto method implementation for all-sky assimilation of IASI data within the EnVar member of the C-LAEF 1k system (now called C-LAEF AlpeAdria). Observation error model was recalibrated by applying the linear fit to the standard deviation values, after running an assimilation cycle using IASI data in active mode.



**Figure 3.2.4.**

Observations were compared to their model-equivalent values (from RTTOV) in order to identify observations that are poorly simulated by the model. Diagnostics was done using a window channel 1911 which is characterized by negligible gas absorption and a strong sensitivity to clouds. It was shown that the model exhibits a general lack of clouds and struggles to represent very cold cloud tops, typically associated with high ice clouds. Therefore, observations with brightness temperatures below 240 K should be rejected.

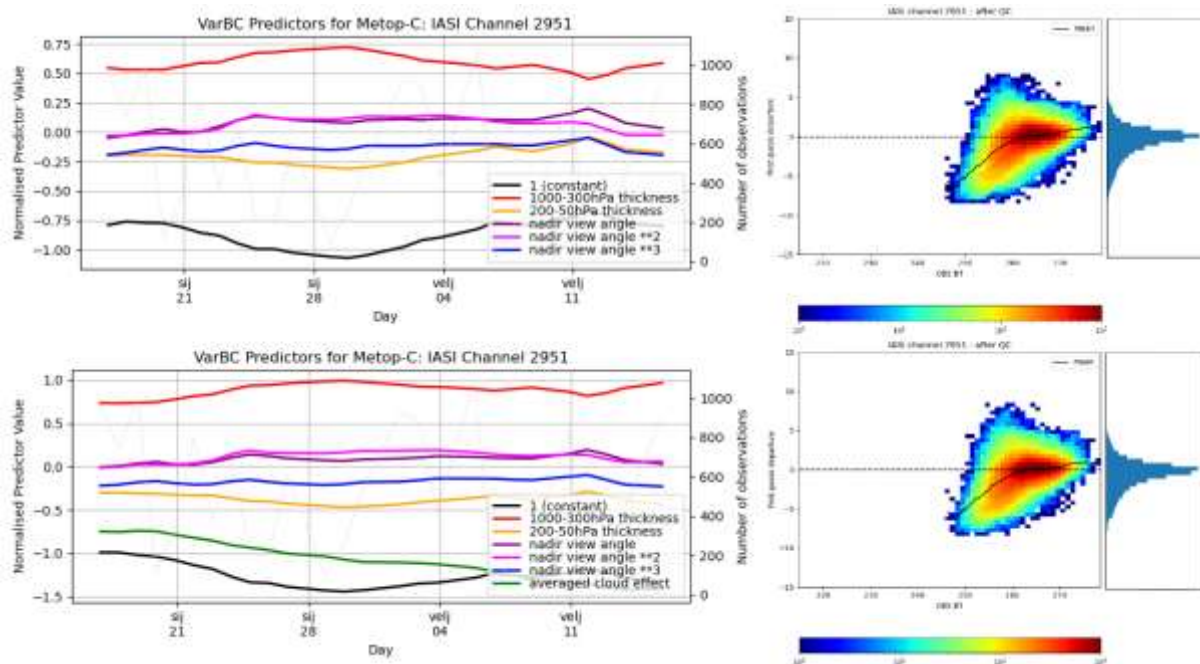


**Figure 3.2.5:** Channel 1911 diagnostics - number of observed and model-equivalent data per brightness temperature; Impact on radiosounding data - RMSE of specific humidity and its relative change depending on a clear-sky reference (CA5 - rejection of data with averaged cloud effect > 5; TAU - rejection of data with transmittance > 0.01; TB240 - rejection of data with brightness temperature < 240 K)

Additional tests were performed by rejecting strongly-affected data (averaged cloud effect > 5.0 K) and opaque clouds (transmittance ( $\tau$ ) > 0.01). In order to evaluate the impact of different all-sky components in the assimilation of IASI data, ODB content was explored. In particular, their influence on other types of assimilated observations, such as radiosounding and AIREP data, was assessed. These observations provide valuable information across the full vertical profile of the atmosphere and are therefore well suited for quantifying the impact of all-sky IASI assimilation on the model background state. It was shown that appropriate quality control keeps a larger number of radiosounding and AIREP data with improved or neutral impact for all variables. However, if observations with brightness temperatures < 240K are not rejected, the negative increments meant for the upper atmosphere can be incorrectly projected to lower levels, which can degrade near-surface temperature and humidity. Additional tests are needed to find the exact mechanism for near-

surface degradation.

A test with an additional cloud-aware VARBC predictor is still ongoing due to its long warm up period. Even if the predictor still hasn't reached its final value after two months of cycling it can be seen that its usage stabilizes other VARBC predictors within the system. It also reduces the bias of clear-sky and near clear-sky observations.



**Figure 3.2.6:** Channel 2951 - METOP-C 21UTC VARBC predictor values and 2D histogram of first-guess departure depending on observed brightness temperature values; no cloud-aware predictor (upper figures) and with cloud-aware predictor (lower figures)

### Atmospheric Motion Vectors (AMV). (DA 3.6)

**Florian Meier (AT)** downloaded MTG FCI AMV level 2 product from EUMETSAT (bufr) and tested it in AROME-RUC/C-LAEF Alpe Adria environment. It went through with minor adaptations (bator namelist, blacklist in screening). Resolution seems to be similar to the MSG-HR product. There is also a HR MTG FCI product from NWC-SAF. The latter was not tested yet and has according to NWC-SAF an about factor 2.5 higher resolution.

**Total efforts:** 18.75 months

**Contributors:** F. Meier (AT) 0.75, A. Neduncheran (AT) 9.5, S. Panežić (HR) 4.75, B. Strajnar (SI) 3, J. Ševčík (CZ) .75

**Documentation:** /

**Status:** ONGOING

**Subject:** *Observation pre-processing, quality control, bias correction and representation error [DA4]*

**Benedikt Strajnar (SI)** worked on the implementation of Slovenian GNSS observations into the OPLACE system.

#### **Maintenance and development of ODB software and tools (DA 4.1)**

The comparison of BATOR and OBSCONVERT continued, primarily during the ACCORD DA WW3. Before the WW, a sample of BUFR files was collected, including the param.cfg and BATOR namelist for 1 September 2025. Simple scripts on cy48t1 for testing of OBSCONVERT and BATOR functionality have been updated on the Belenos HPC system (**Alena Trojáčková, CZ**) and Atos ECMWF (**Benedikt Strajnar, SI**). A variety of observations used by local DA systems were tested during the DAWW3. An IAL PR (<https://github.com/ACCORD-NWP/IAL/pull/511>) was prepared by **Eoin Whelan (IE)** to collect modifications needed to ingest BUFRs produced by SAPP.

Testing of the OBSCONVERT showed that there was an issue with processing the AMV special template (310077, from the NWC SAF), and that the 'europrofil' routine only decoded a limited number of observations. The investigation is ongoing. (**Alena Trojáčková, CZ**)

The progress with testing observations is tracked in a table form here: [Obsconvert\\_validation](#)

#### **Regular upgrades of the HOOF preprocessing tool. (DA 4.2)**

See DA2.1.

#### **Tuning of observations and background and representation error, revise thinning, QC and VarBC settings. (DA 4.5)**

No work reported.

Information on OPLACE maintenance work and developments is provided in the DM's report.

**Total efforts:** 4.5 months

**Contributors:** B. Strajnar (SI) 1, P. Smerkol (SI) 1, A. Trojáčková (CZ) 1.75, F. Meier (AT) 0.5, Z. Kocsis 0.25,

**Documentation:** /

**Status:** ONGOING

**Subject: *Variational assimilation systems [DA5]***

**Develop, validate and consolidate full assimilation cycles using OOPS binaries (DA 5.1)**

**Benedikt Strajnar (SI)** prepared a sample environment at Atos ECMWF (/hpcperm/sis/sample\_oops) to demonstrate implementation and execution of screening and 3D-Var (or 3D-EnVar) minimization and was used by the ACCORD teams during DAWW3 in October 2025, for familiarisation and identification of remaining differences in observation use wrt. MASTERODB.

**Florian Meier (Geosphere AT)** tested hybrid 3DVar in cy48t3. The only change on top of 3D-Var/EnVar configuration is a modified Json file. Different to cy46t1 the waiting between static and ensemble B is simplified to just one factor in cy48t3 json namelist. The hybrid will be further investigated by University of Vienna (IMGW) PHD student.

**Maintenance, setting up and evolution of current DA suites (3D-Var, BlendVar), exchange of scientific achievements between ACCORD partners. (DA 5.6)**

Poland is continuing preparatory works for 3D-Var assimilation setup, due to migration to new HPC works are delayed.

**Total efforts:** 4.5 months

**Contributors:** M. Szczech (PL) 3.5, M. Derkova (CZ) 1

**Documentation:** /

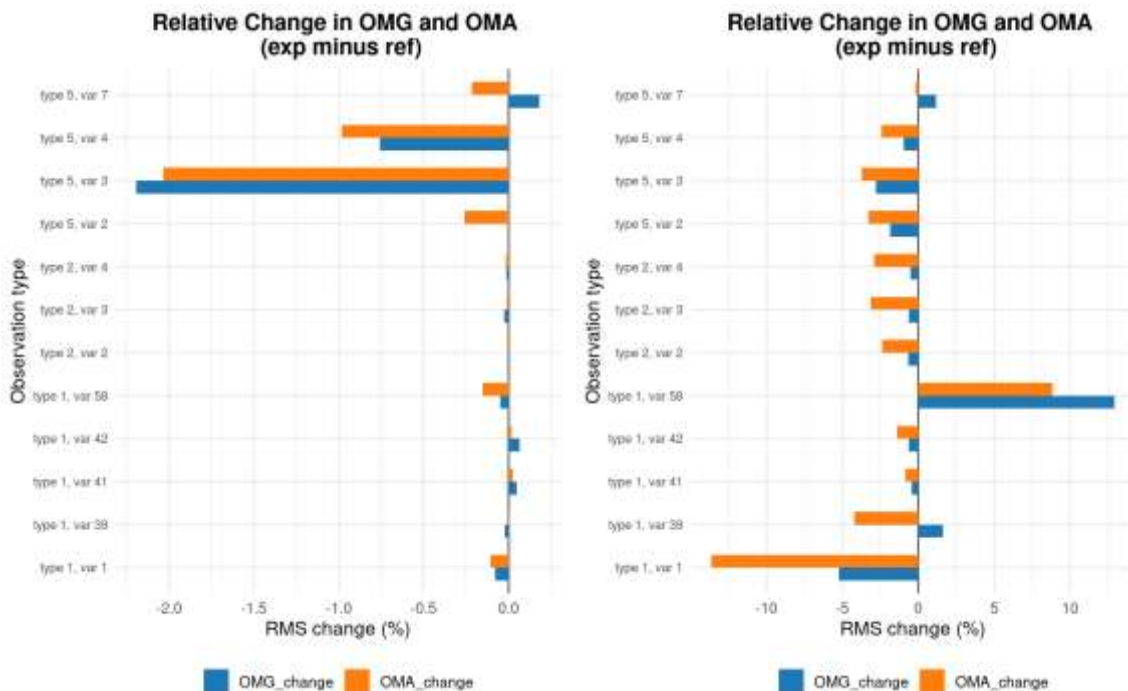
**Status:** ONGOING

**Subject: *EnVar, EDA and variants [DA6]***

**Prepare a prototype of full-scale OOPS-based 3D/4D EnVar system (DA 6.1, DA 6.2)**

The normalization and scaling of perturbations for 3DEnVar have been modified during the DAWW1 (**Benedikt Strajnar (SI)** with help from **Benjamin Menetrier (NO)**) to allow ensemble members to be grouped into sub-ensembles of varying sizes (e.g., current members, older lagged members, LBC data). This is implemented by adding “i\_subens” parameter for each perturbation to define a sub-ensemble (default 0); ensemble mean is then subtracted per group so that different scaling to variances is applied. Code is available cy48t3 (on Atos) but still has to be submitted to upstream IAL. <https://opensource.umr-cnrm.fr/attachments/download/6263/SubEnsembles3DEnVar.pptx.pdf>. The impact was tested in an assimilation cycle in Cleaf1k system over one month, taking 3 h forecasts as the first and 6 h forecasts as the second ensemble, both 16 members. A small positive impact on observation-minus-guess statistics (mainly radiosonde wind) can be demonstrated (see left side of Figure 6.1.1 below).

**Benedikt Strajnar (SI)** also tested scale-dependent localization (SDL) in EnVar. The first setup used the following horizontal localization lengths for three spectral bands: 150, 75 and 15 km for wavenumbers 2, 8, 25. The SDL produced smoother increments compared to vertically-dependent horizontal localization. The demonstrated impact (right side of the below Figure) has been overall positive for upper-air observations mixed, but there is a large negative impact on observation fit from surface humidity, and to some extent surface temperature. Further SDL localization settings will be considered.



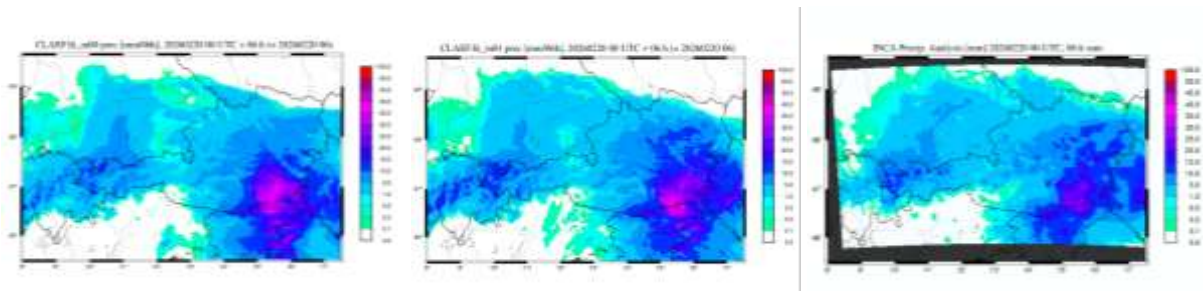
**Figure 6.1.1:** (left) Impact of 3DnEnVar perturbations as two sub-ensembles in ClaeF1k on departure statistics, (right) Impact of scale-dependent localization (SDL). Negative values indicate improvement with respect to the reference. Validation period is 1 month in winter 2025.

**Florian Weidle (AT)** validated EnVar vs 3DVar in CLAEF Alpe Adria (1km) this summer. Scores for Temperature and wind are rather neutral to slightly positive. Verification of precipitation is still ongoing.

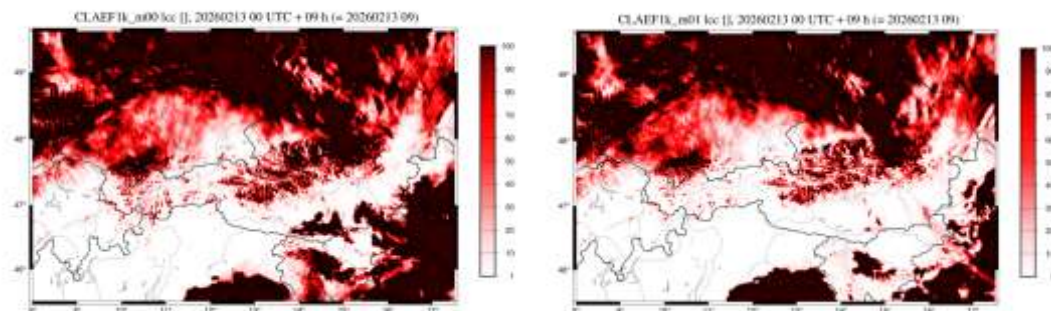
**Florian Meier (AT)** rescaled inflation factor in C-LAEF Alpe Adria EnVar run from 1.0 to 0.7 to avoid crashes in 001 which occurred previously on a weekly basis in EnVar due to too big increments especially in PBL. This can be also justified by the fact that we use a 16+16 3h/6h EnVar mix as input for the deterministic 3h EnVar cycle meaning background error would be overestimated with default inflation 1.0.

Finally observation perturbation and running EnVar with gridpoint field output was successfully tested in cy48t3. For the latter spectral orography from the climate file has to be added to the First Guess to success (running addsurf binary). This means that there are no technical obstacles to make full EPS EnVar based now, which is the longer term plan for C-LAEF Alpe Adria.

Recent work on DA in C-LAEF Alpe Adria (**Florian Meier, AT & Benedikt Strajnar, SI**) was mostly focused on monitoring and solving technical issues. The system is stable, and EnVar member overall performs similar to 3D-Var. This winter inner Alpine stratus in valleys was often even more underestimated in EnVar compared to 3D-Var. We assume that this might be related to rather short localization lengths. Otherwise the system performs overall similar to 3D-var with sometimes slightly better precipitation structures. Differences can be found up to 24h rarely beyond.

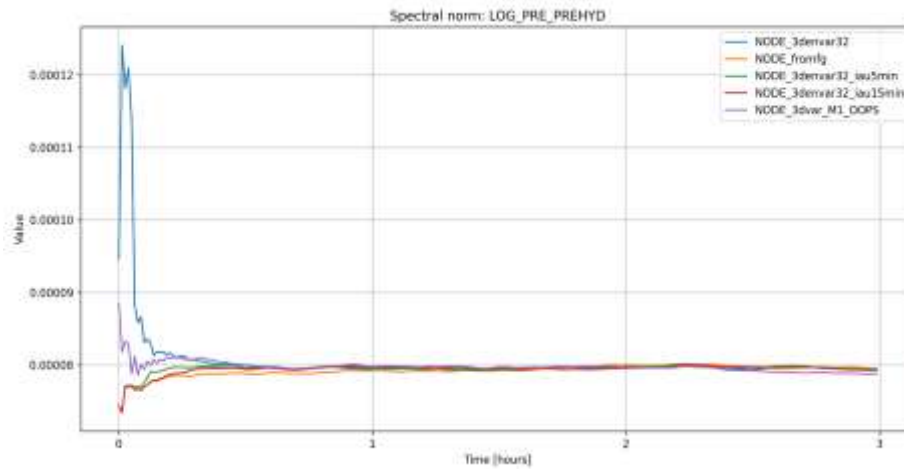


**Figure 6.1.2:** 6h total precipitation on 20th February 2026 00UTC+6h (C-LAEF AA 3D-Var left, EnVar middle and INCA as reference right). EnVar is not better everywhere, but the SW-NE tilt over Styria and the structure in Bavaria fits better. On the other hand we see more overestimation in Switzerland and elsewhere.



**Figure 6.1.3:** Low cloud forecast 13th February 2026 00UTC+9h (C-LAEF Alpe Adria 3D-Var left, EnVar right) where EnVar shows significant less low clouds in Klagenfurt Bassin and Graz region (better in this case, but sometimes worse). In narrow valleys, both system often fail to initilise stratus (Inn, Enns, Salzach, Mürz valleys).

In certain occasions, especially after increasing the model timestep to 60 s in autumn 2025, the forecast after the 3D-EnVar analysis crashed due to pronounced spin-up, as diagnosed by the temporal evolution of norms and comparisons with members using 3D-Var. To overcome such issues, **Benedikt Strajnar (SI)** applied an IAU (15 min interval was chosen) procedure for a smoother start of the forecast. The setting is kept for safety even after the recent decrease of timestep back to 45 s.



**Figure 6.1.4:** Norms of variable LOG\_PRE\_PREHYD during a 3-hour forecast. 3DEnVar run (blue) without IAU shows much larger initial imbalances and pronounced spinup compared to 3DVar (purple), 3DEnVar runs with different IAU windows (green, red) or when forecast is initiated from first guess (orange).

**Total efforts:** 7.75 months

**Contributors:** F. Meier (AT) 4, B. Strajnar (SI) 2.25, F. Weidle (AT) 1.5

**Documentation:** /

**Status:** ONGOING

**Subject:** *Initialization methods and nowcasting [DA7]*

No work reported.

**Subject:** *Diagnostic methods, optimization of assimilation cycling [DA8]*

No work reported.

**Subject:** *AI/ML methods for data assimilation [DA9]*

**Using AROME/HU data as input to ML-based solar nowcasting model (including 2-week SRNWP-funded visit in Austria)**

A machine learning based solar nowcasting system is being developed by **Soma Oláh (HU)** at HungaroMet to support weather-dependent renewable energy production. The system provides solar irradiance forecasts with a lead time of 3 hours, a 15-minute temporal resolution, and a 0.05° spatial grid using convolutional neural network architecture. The primary dynamic input is the MDSSFTD satellite product of EUMETSAT Land Surface Analysis SAF which is disseminated in near-real-time, ensuring the immediate use of data from the latest measurements. These satellite data are complemented by static metadata such as latitude, longitude, elevation, and temporal features to facilitate the learning of spatial patterns as well as diurnal and seasonal characteristics. Ongoing

research focuses on integrating AROME/HU regional numerical weather prediction fields as auxiliary predictors. This new approach is being developed in collaboration with experts from GeoSphere Austria within the framework of a EUMETNET Short-Term Scientific Mission. It is motivated by the expected benefit of further supporting features, enabling a more accurate estimation of future atmospheric conditions that influence solar irradiance at the ground level. Therefore, modifications to the network architecture, data curation strategy, and training procedure have been introduced. Future work will focus on the quantitative verification of these different model configurations to determine the impact of added NWP data.

**Total efforts:** 2 months

**Contributors:** Soma Oláh (HU) 2

**Subject: *Surface assimilation [SU1]***

**Implementation, experiments, design of parallel suites with OI and SYNOP observations in AROME or ALARO with SURFEX or ISBA. (SU1.1.11, SU1.2.1)**

A LACE stay on the topic of surface data assimilation in SURFEX in the context of the pre-operational CLAEF Alpe Adria ensemble system (CLAEF1k) was conducted in May 2025 at GeoSphere Austria by **Matjaž Ličar (SI)** and supervised by **Stefan Schneider (AT)**.

The CLAEF1k system consists of 16 deterministic AROME ensemble members + 1 control member, all with a 1 km resolution over a domain of 1500 × 1350 grid points. Currently, the system runs on cycle 46 with SURFEX v8.0, using the legacy ISBA force restore option with 1 patch. The surface assimilation scheme consists of the CANARI analysis of the 2m temperature and humidity, which is then used by OI\_MAIN to update the ISBA fields. Recent SURFEX developments include multilayer physics, ECOCLIMAP-SG physiography, and multi-patch support for NWP. Integrating these features, along with additional observation types, should be considered for future CLAEF1k versions.

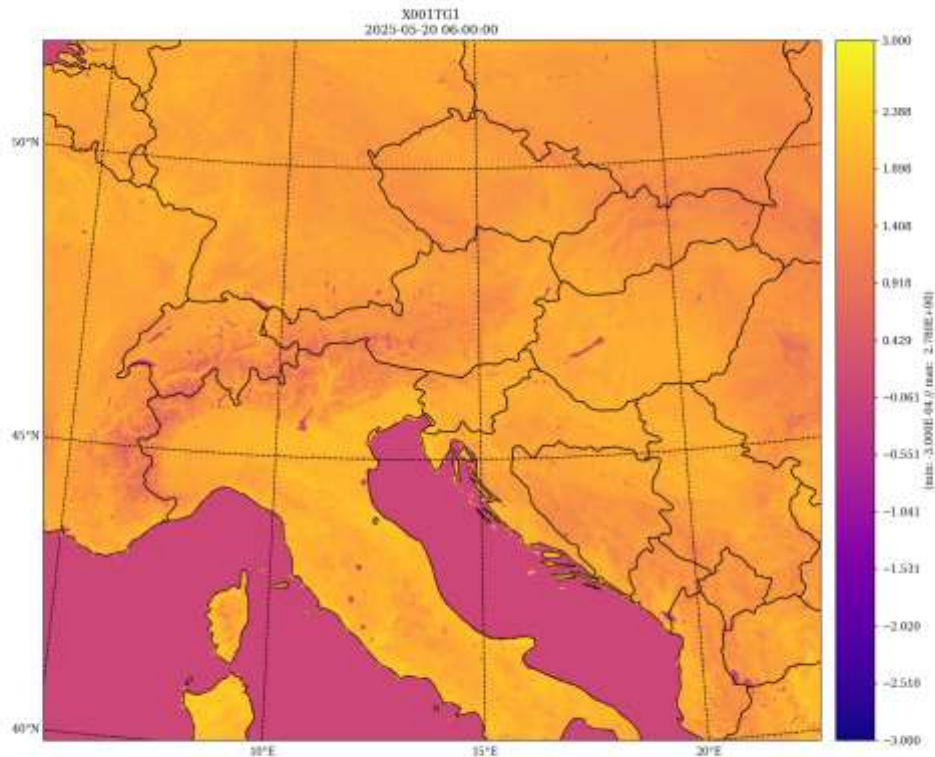
The objective of the stay was to perform a simple DA experiment of 2m quantities from CANARI with the SEKF method in SODA with the ISBA diffusion multilayer scheme. Although the EnKF method could in principle leverage the advantages of an ensemble system at a reduced computational cost, we decided not to use it at this stage due to a lack of experience with the technical details on our part and the lack of validation of the EnKF algorithm in SODA.

The experiment was run in offline mode using the standalone version of SURFEX v8.1, since SURFEX v8.0 does not support multi-layer physics. Moreover, the high resolution and large domain of the CLAEF1k system incurs a high computational cost when running the entire system. Given our focus on DA, an offline run should be sufficient for basic evaluation before the migration to a newer cycle of the CLAEF1k system

The most challenging task was initializing the multilayer ISBA-dif scheme from the ISBA force restore used in CLAEF1k. Although interpolation functionality exists in SURFEX v8.0 and v8.1, mismatches between SURFEX versions and the physiographic PGD or initial PREP files caused various errors. The initial PREP file was created through a somewhat convoluted process using EPyGram to transfer fields between files from different SURFEX versions.

There is a further issue regarding the initialization of the multilayer snow scheme from the D95 scheme, as this is not yet implemented in SURFEX. We used a naive approach to manually initialize the snowpack to layers of equal height and density according to the D95 fields. This leads to unrealistic snow compaction particularly in areas with a thick snow pack and is thus not suitable for operations.

In the end, we managed to produce an analysis for a single case. Several combinations of control variables were tested, which seem to produce realistic results (Figure su1.1). Unfortunately, the stay had concluded before any experiments for a longer period or a comparison with the operational system could be performed. A more detailed report will be available on the RC LACE website.



**Figure su1.1:** Increments of TG1 using SODA/SEKF and CANARI 2m analysis as observation for a single test case.

#### Development of SYNOP-based snow analysis in CANARI. (SU1.1.4)

Jáchym Ševčík and Alena Trojáková (CZ) continued the testing of snow analysis for ALARO CSC with the ISBA scheme. The main aim of the Master's study is to implement snow analysis and find the optimal settings for the ALARO CSC used at CHMI. A simplified framework was considered to eliminate possible feedbacks during model integration, for example those related to the influence of snow cover on surface albedo, radiative balance and consequently surface temperature. To avoid these complications and assess the influence of the snow depth analysis alone, the fully cycled experiment was omitted. Instead, only the backgrounds from the operational run are used and adjusted towards the observations through a dedicated snow depth analysis. The fields after the snow analysis are solely used for subsequent verification.

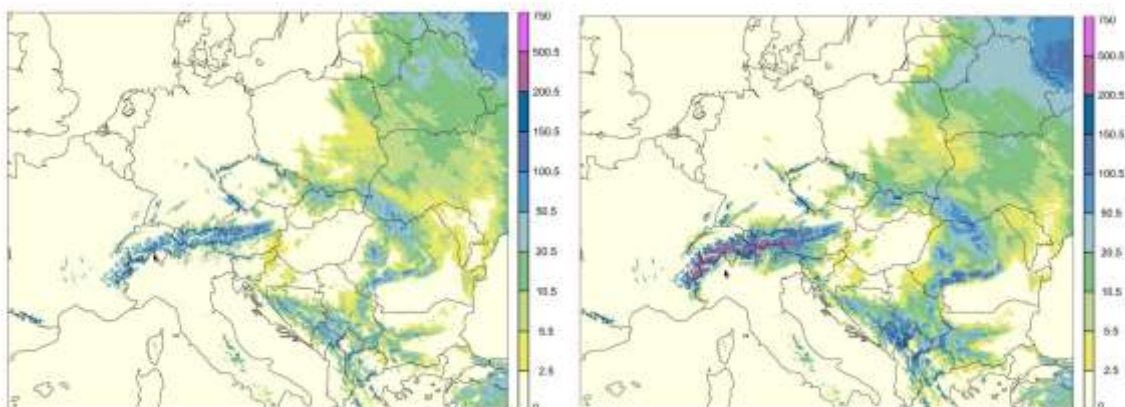
Additionally, only the 06:00 UTC analysis times are considered, as this is when the highest number of measurements is available. Snow depth observations from various sources (including SYNOP data, the Czech and Hungarian national snow-measuring networks, and local data from GeoSphere Austria and the Swiss WSL Institute for Snow and Avalanche Research) have been gathered and preprocessed for January 2022.

Another key part of the experimental design is verification. Independent observations are suitable for this, particularly in this setup where snow analysis results are not directly connected by model integration. However, relying on independent data for verification conflicts with NWP practice of using as many available observations as possible. To solve this, we chose a cross-validation approach. This is a method that divides observational data into training and validation subsets to test a model's performance on independent data. This strategy has subsequently been used in multiple experiments.

First, the reference run without snow analysis was validated, showing that ALADIN underestimates snow depth at all altitudes, with the underestimation increasing proportionally with altitude. Subsequently, experiments with different quality control settings were validated, resulting in the further use of a quality control version utilising both spatial and first-guess quality control and more benevolent QC towards higher-elevation measurements (a modification adopted from GeoSphere Austria).

The sensitivity of the analysis scheme with the chosen QC was then studied for various tuning parameters (ORODIF, quality control parameter  $q$ , the vertical and horizontal correlation scaling parameters, and the observation and model background error estimates). Above 1500 m a.s.l., the analysis favors active settings—permissive quality control, greater observational weight, and larger correlations—while lower altitudes prefer a more conservative approach. Complex feedbacks between observation density, quality control, and parameter tuning complicate optimization based solely on physical understanding.

To address this, the fine tuning of the parameters was formulated as a multidimensional minimisation problem using a specific cost function,  $RMSE^*$ , which is defined as a weighted sum of RMSE in four different altitude groups. Minimisation was performed using two methods: a basic form of the coordinate descent approach and the downhill simplex method. These minimisation approaches produced different parameter settings. The coordinate-descent solution results in a more active analysis and performs better at higher altitudes. The simplex solution is more conservative, leading to a balanced compromise between the different altitude groups, and has been chosen as the final setting. The snow reservoir field produced by analysis with this setting is more realistic than the reference, as it better captures both topography and continental gradients, see Figures su1.2 below. [The manuscript contains further information.](#)



**Figure su1.2:** The snow reservoir of first guess (on left) and analysis (on right) on 25th January 2022. The analysis is using the simplex settings.

### “Snow towers”

**Ján Mašek (CZ)** found through CHMI’s climate simulation (which does not analyse snow nor relax snow towards climatology) that snow is accumulated in reservoirs above the permanent snow line. The accumulation can be really big in certain areas, hence the name 'snow towers'. The Meteo France climate group uses a simple glacier parametrisation to maintain a reasonable amount of snow, but we do not use it in NWP.

In our operational NWP system, we stopped using relaxation of snow towards climatology in spring 2024, and we do not yet analyse snow directly. Since then, up to August 2025, a significant amount of snow has accumulated. The maximum snow reservoir reached approximately 8600 kg/m<sup>2</sup>, which corresponds to ~43 meters of snow (assuming a snow density of 200 kg/m<sup>3</sup>).

We plan to implement a "workaround" to remove unrealistic values of snow above the namelist-driven threshold in the CANARI (casnas.F90).

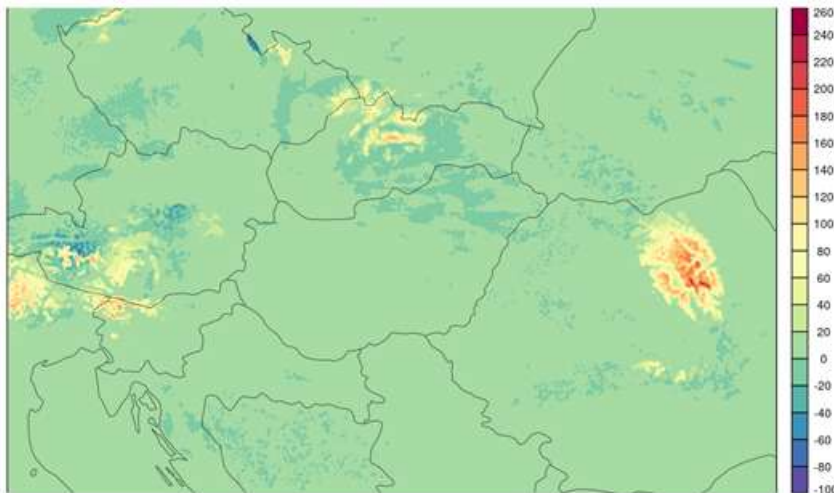
### SYNOP snow depth assimilation in AROME/HU

Assimilation of both (human) controlled and raw SYNOP in-situ snow depth observations has been continued in AROME cy46t1 by **Helga Kolláthné Tóth (HU; 1 PM)**. Based on evaluation of the measurements for a 3-month period, 82% of the Hungarian raw data were accepted by the data controllers within a day. So it was decided to allow all raw observations to enter the database immediately. They have also been added to OPLACE since 27 February 2025. A bugfix released by Alena Trojakova (CZ), Jachym Sevcik (CZ) and Florian Meier (AT) has been implemented in our system. It includes some corrections of the CANARI assimilation flags in datum\_anflag.final. In addition, the snow observations above 1500 m have been considered, and an altitude-dependent quality check for the departure from the guess has been built in the code (the higher a station, the higher the limit for the quality check). Furthermore, a new logical switch (LOBSNEG) has been introduced to filter out the negative snow depth measurements. Experiments were carried out for a snowfall case at 6 UTC on 2 February 2025 (with spin up from 31 January). The reference run used the original snow assimilation, while the experiment run applied the modified setup described above. Key CANARI namelist parameters are listed below (the bold values were used only in the experiment run):

- LAESNM = .T. (active snow assimilation)
- REF\_S\_SN = 5 kg/m<sup>2</sup> (background error standard deviation)
- REF\_A\_SN = 50.000 m (horizontal correlation length)
- REF\_AP\_SN = 0.05 m (vertical correlation length)
- ECTERO(1,1,92,1) = 4 kg/m<sup>2</sup> (observation error standard deviation)
- LAOROFLEXREJSN = .T. (altitude-dependent quality check)**
- OROFLEXREJS = 20.**
- LOBSNEG = .T.**
- ORODIF = 10.000 m (maximum altitude difference between the observation and the model grid point)
- OROLIM = 10.000 m (maximum altitude for surface observation)

- LAECHK = .F. (spatial quality check)

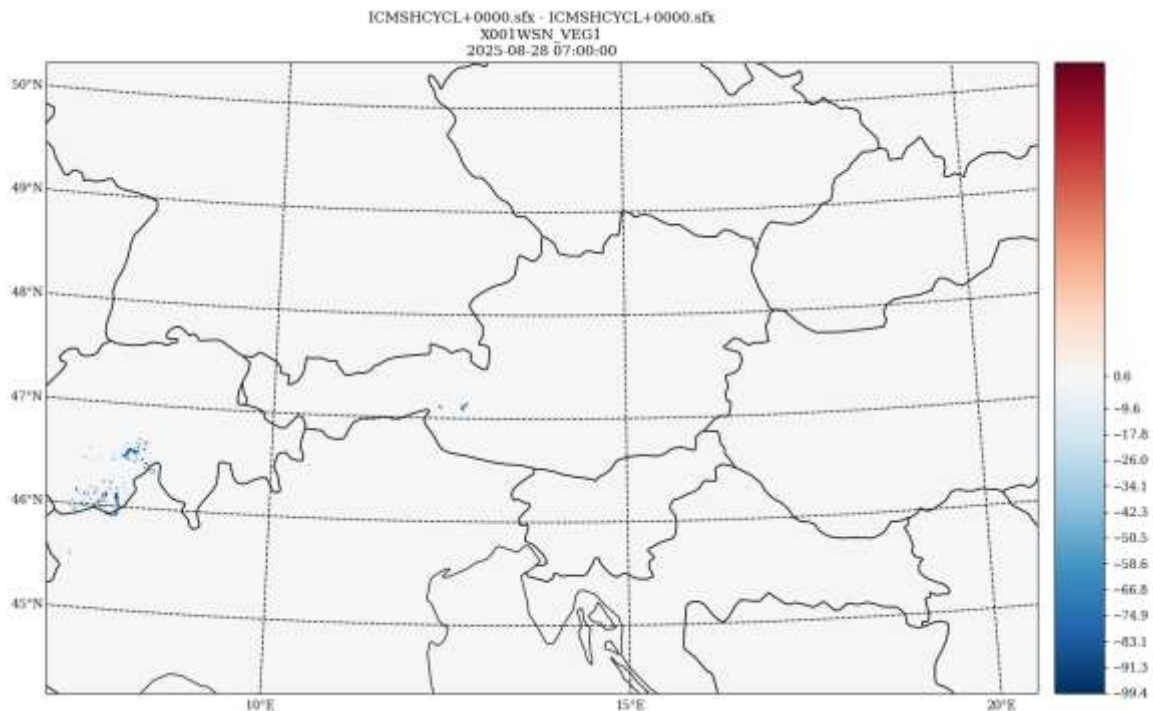
Figure su1.3 shows the difference in snow-water equivalent between the experiment and the reference run at 6 UTC on 2 February 2025. More high-altitude observations were included in the experiment than in the reference run: 373 with respect to 351 measurements. This additional data had a significant impact on the analysis. We are going to continue the evaluation by starting a long-term experiment with the new modset during the next winter (snow) season. The forecasters will also be involved into the evaluation.



**Figure su1.3:** The difference of the snow-water equivalent [ $\text{kg/m}^2$ ] between experiment with the modifications and the reference run at 6 UTC on 2 February 2025.

### Snow assimilation in Austria

In Austria we tested modification of the snow correlation function in CANARI-OIMAIN with MESCAN approach applied for snow as the default vertical correlation function is not very satisfying for higher peaks. This works well in the mountains in winter, but leads to increments spreading too far down into the valleys in summer over the Alps. Probably, a temperature dependent correlation length should be considered? Furthermore, relaxation against climatology was tested within the AROME-RUC system. This can help to avoid snow accumulation on the highest Alpine peaks (finding by CZ colleagues and also valid for us), which are not covered by observations, however code modifications in oi\_control.F90 are needed to let climatology values enter properly CANARI-OIMAIN in cy43t2/cy46t1. Finally, snow observations for OPLACE national (obsoul snow in [m]) were prepared and might enter OPLACE after validation by the partners.



**Figure su1.4:** Reduction of snow amount on highest peaks if XRCLIMCA=0.1 (relaxation to climatology) is applied in OIMAIN. Some code fixes are needed to make XRCLIMCA>0. running in older cycles (cy43t2/cy46t1) as some climatology related switches cannot be read by the namelist and some climatological fields are set to XUNDEF by default.

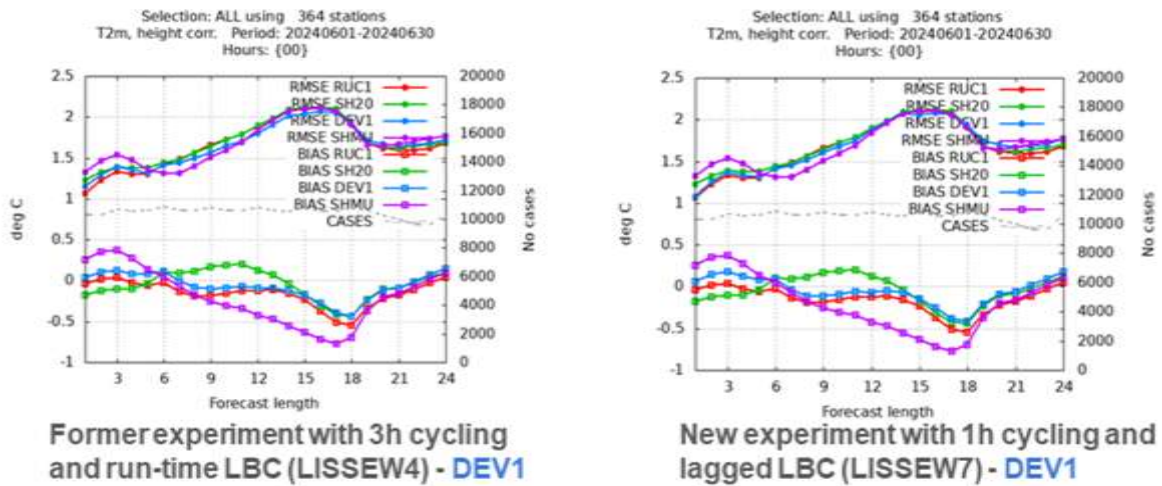
In the second half of 2025, testing of snow analysis for ALARO CSC with the ISBA scheme continued in a full NWP context, combining long cut-off assimilation cycle with short cut-off productions. Simplex tuning was addressed again for the MF default, Gaussian and MESCAN correlation functions proposed by Florian Meier, in order to consider the assimilation cycling and fix a bug in the relaxed QC (RCOEFK) implementation. Results of simplex tuning have been tested in longer experiments during winter season 2021/22 and are about to be summarized in an article. (**Jáchym Ševčík** and **Alena Trojáková, CZ**).

**Florian Meier (AT)** fetched additional snow observations from Meteo Swiss open data server hourly (~36) automatic and daily (~94) manual and converted it into obsoul format with a python script. The data were tested within AROME-RUC parallel run and cover also Swiss flat parts, not well covered by previously considered SLF data. It was checked if slope and solar zenith angle could be used to adapt correlation length in snow assimilation, but this is not straight forward as correlations are treated within CANARI by ODB entries rather than in model grid point space.

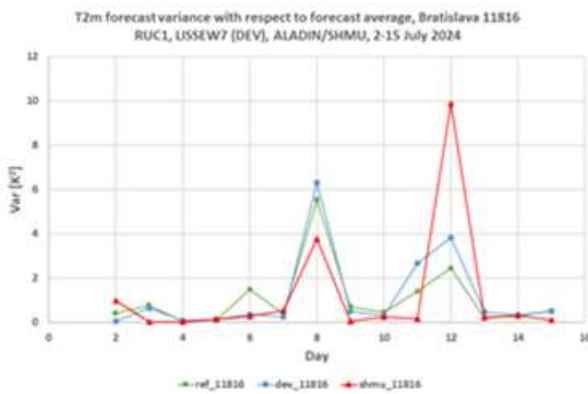
#### **Tuning of soil water content initialization in OI/CANARI. (SU1.1.11)**

**André Simon (SK)** tested the key LISSEW=.T. in RUC1 dev suite (dev). The setting of former experiments (3h cycling, LBC based on the actual run) was modified to 1h cycling frequency and for lagged LBC data (as in the regular RUC1). Scores were calculated and compared to RUC1 runs and also to former LISSEW experiments. It was found that smoothing of deep soil wetness had a neutral or

slightly negative impact on the scores of some surface parameters (T2m, Q2m). It was rather the 1h cycling frequency, which had a dominant and positive effect (with respect to 3h cycling frequency). Some positive effects could be seen in cases with severe thunderstorms (not shown). It is also questionable, whether the smoothing of deep soil wetness decreases the variance in the 2m temperature forecasts in RUC, since some examples from the tests with LISSEW do not support this theory (no systematic decrease of variance was observed with the smoothing).



**Figure su1.5:** Scores from the “dev” experiments with smoothing the deep soil wetness in 1km resolution rapid update cycle for the 1 month period of June 2024.



**Figure su1.6:** Comparison of the forecast variance of T2m forecasts from 00,06,12,18 UTC with respect to their average, in case of the reference RUC (ruc), experiment with smoothing the deep soil wetness (dev) and operational ALADIN/SHMU (shmu) for station Bratislava (11816).

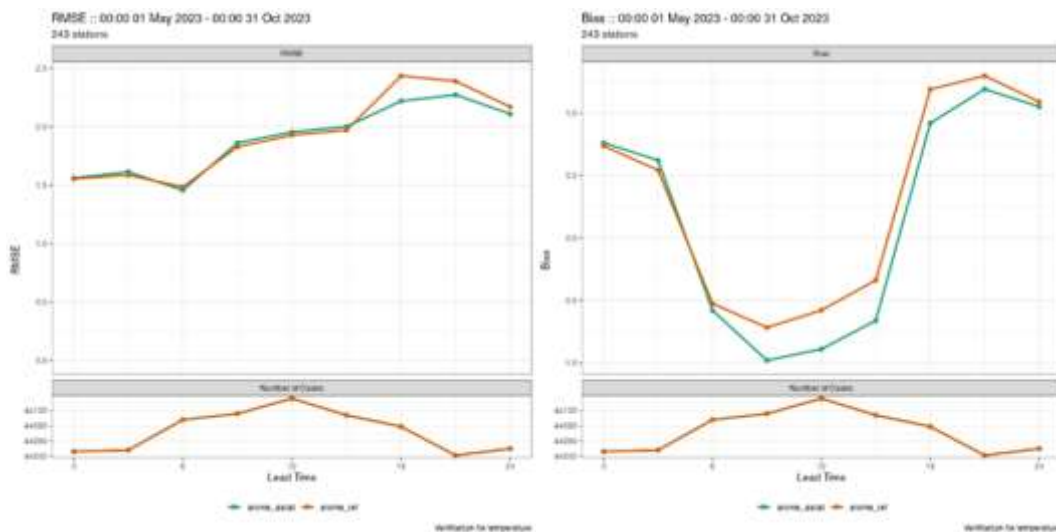
### Assimilation of satellite moisture information (SWI) within SEKF in AROME/SURFEX, impact experiments (SU1.3.4)

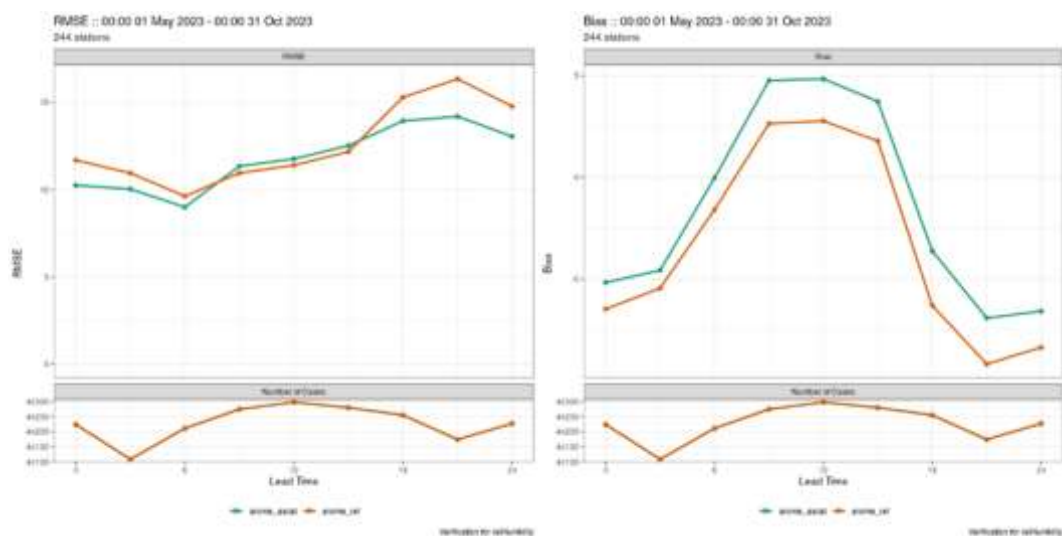
The assimilation of ASCAT H08 Level-2 soil moisture product was continued by **Helga Kolláthné Tóth (HU)**. The experiments were performed with AROME cy43t2, with 2.5 km horizontal resolution and

60 vertical levels. The test period lasted from May to October 2023 with a 1-week spin-up using 3-hourly assimilation cycle. The following settings were used in SEKF for observation and model errors:

- xerrobs: ASCAT wg1 = 0.1 (wfc-wwilt) m3/m3; T2M = 1 K; Rh2M= 7%,
- xsigma: wg1 = 0.1 (wfc-wwilt) m3/m3; wg2 = 0.1 (wfc-wwilt) m3/m3; tg1 = 2 K; tg2 = 2 K,

where wfc and wwilt are the water content at field capacity and at wilting point, respectively. The produced soil moisture and temperature were compared and validated against the in situ observations from drought monitoring system of the water management, while the 0 UTC forecasts were evaluated in the traditional way. With assimilation of ASCAT data, the root zone soil moisture became more realistic and less underestimated, especially in the central-southern part of Hungary and northern part of Serbia during the summer season. The RMSE values of 2-meter temperature and relative humidity improved at night, however, the daytime systematic errors increased (Figure su1.7). The assimilation of ASCAT soil moisture also helped to mitigate the overestimation of high summer temperatures. We tested analysis sensitivity to the choice of observation and model errors in the surface assimilation. The enhanced model and the observation errors resulted in high variability in the spatial distribution of soil moisture, with very wet and very dry areas occurring next to each other, leading to unrealistic small-scale spatial fluctuations. However, with reduced model and observation errors the analysis increments became very small, indicating that the system relied more on the background field and corrections from the observations are limited. In the following experiments the new H28 ASCAT products will be tested.





**Figure su1.7:** RMSE (left) and bias (right) for 2-meter temperature (K; top) and 2-meter relative humidity (%; bottom) in function of lead time [h] over Hungary for March–October 2023 based on 0 UTC runs of AROME assimilating (brown) and without (green) ASCAT data.

**Total efforts:** 19.75 months

**Contributors:** M. Szczech (PL) (reported in DA5 ?pm), M. Ličar (SI) 3, H. Tóth (HU) 6.5, A. Trojakova (CZ) 2.75, J. Sevcik (CZ) 5.75, , F. Meier (AT) 1, P. Schmederer (AT) 0.5, S. Schneider (AT) 0.25

**Documentation:** /

**Status:** ONGOING

## Documents and publications

### Publications:

- Smerkol, Peter & Švagelj, Vito & Zgonc, Anton & Strajnar, Benedikt. (2025). Validation of torus mapping dealiasing method on Doppler velocities for use in numerical weather prediction. Meteorologische Zeitschrift. 34. [10.1127/metz/1256](https://doi.org/10.1127/metz/1256).

### Stay reports:

- M. Ličar, 2025/05: [Testing SEKF with Multi-Layer ISBA on the CLAEF-1k Domain](#)
- P. Elek, 2025/09: [Back-phasing the Mode-S thinning and adaptive weighting from AROME cy49 to cy46](#)
- S. Panežić, 2025: [Data assimilation of all-sky radiance observations from MTG IRS II](#)

## DA contribution of RC LACE to the All Staff Workshop

5th All Staff Workshop, 31 March - 4 April 2025, Zalakaros & hybrid

### List of presentations:

- BUČÁNEK Antonín: [Data assimilation activities in RC LACE](#)
- NEDUNCHERAN Adhithyan: [AllSky VIS/IR assimilation activities at GeoSphere Austria](#)
- MEIER Florian: [Assimilation of Sentinel-1 delays into AROME](#)
- STRAJNAR Benedikt: [First Experience with 3DEnVar in Routine Runs of the Claef1k Ensemble](#)

**National posters:** Austria, Croatia, Czech Republic, Hungary, Slovakia, Romania, Slovenia

## Activities of management, coordination and communication

- 1) Online attendance to 5th All Staff Workshop, 31 March - 4 April 2025, Zalakaros & hybrid
- 2) Attendance to EUMETSAT Core NWP meeting, online.
- 3) Attendance to OPERA NWP user group meeting, online. 4.2.2025
- 4) Attendance to Accord DAWW preparation meetings, online.
- 5) Organization of informal LACE DA meetings (2<sup>nd</sup> Wednesday every two months), online.
- 6) ACCORD DA RD topical meetings, online.
- 7) LSC meetings.

## Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized	Planned	Realized
Operational implementation of DA suites [COM3]	8	4.00		
In-situ observations [DA1]	6.5	13.25	0.5	0.50
Use of ground-based remote sensing [DA2]	8	25.00	2.0	2.0
Satellite-based remote sensing observations [DA3]	11	18.75	1.5 +1acd	2.50
Observation pre-processing, quality control, bias correction and representation error [DA4]	0.5	4.50		
Variational assimilation systems [DA5]	12	4.50		
EnVar, EDA and variants [DA6]	4	7.75		
Initialization methods and nowcasting [DA7]	0.5	0.00		

Diagnostic methods, optimization of assimilation cycling [DA8]	4	0.00		
AI/ML methods for data assimilation [DA9]	?	2.00		
Surface assimilation [SU1]	17	19.75	1.0	1.0
<b>Total</b>	<b>71.5</b>	<b>99.50</b>	6.0	6.0

## Problems and opportunities

The main problems in 2025 are/remain:

- Distribute operational applications: local validation, maintenance and technical issues bring duplications of work that cannot be avoided.
- We are working on the different DA setups (cycle, method, resolution, physics) so individual results and setups are rarely directly applicable at other Members.

Opportunities for more effective future work are:

- Collaboration within the ACCORD consortium has generally improved due to numerous possibilities:
  - ACCORD Wiki – Working days mini subpages
  - RD on algorithms and observations related Slack communication exchange.
  - More coordination with MF accomplished (e.g. common topical reporting).
- On the other hand we keep LACE internal communication, mainly to discuss implementation results. The first feedback was positive.
- To try to unify the local developments, e.g. to try to achieve approximately the same level of development in majority of member countries.
- To actively participate in discussions and knowledge exchange regarding EUMETNET observations such as E-ABO, E-GVAP and OPERA.