Working Area Data Assimilation

Progress Report

Prepared by:	Area Leader Antonín Bučánek
Period:	2023
Date:	23/02/2024

Progress summary

The report summarizes the RC LACE DA activities in 2023, with highlights on use of observations, mainly the radar data, implementation/refinement of hourly assimilation systems suitable for NWP-supported 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 assimilation of satellite radiances received more attention after a long time, with activities linked to validation of all-sky approach for certain SEVIRI channels and by studying properties of data to be provided by the future MTG IRS sounder.

After successfully implementing SEKF to their deterministic AROME suite, OMSZ implemented this advanced technique, together with 3D-Var atmospheric assimilation, to the AROME-EPS system. Numerous activities were aimed at improving the surface assimilation, either through tuning of optimal interpolation or adding new observations through the SEKF (moisture, LAI).

Several members approached the implementation of hourly DA systems (RUC) and several aspects of frequent cycling were studied, from observation availability to spin-up and interaction with surface data assimilation.

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. The first technical runs with ensemble variational (EnVar) assimilation are available, but this activity will require considerably larger person power input in the future.

Action/Subject/Deliverable: ***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 in 2023):

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	4.5L63 625x576	4.4L87 432 x 432
Cycle	43t2bf11+loc.	43t2bf10	46t1mp_op2	cy40t1	cy43t2bf11	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
Initiali-zation	No (SCC)	No (SCC)	IDFI in pro-duction, 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	Synop + AS, Amdar, AMV, Temp, Seviri, AMSUA/MHS,	Synop + AS, GNSS ZTD, Amdar/MRAR, Temp, AMV+HRW,	Synop + AS TEMP HRW AMDAR + Mode-S	Synop + AS Amdar/MRAR/ EHS, AMV, Temp Seviri, AMSUA/MHS/ IASI, ASCAT/OSCAT, E-GVAP ZTD (passive)
Cut-off (prod / assim)						2:35 / 7:45 (min.)	2:15 / 4:00

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	46t1mp_op2	cy43t2bf10
LBC	AROME 1h	-	ECMWF 1h
Method	OI_main MESCAN + 3d-Var + LHN + FDDA +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 (OPLACE), Radar RH/Dow, INCA + AS at hig.freq., MODIS snowmask, windfarms, celiometers, Profiler, towers	Synop + AS, Amdar/MRAR/EHS-EU, HRW, Profiler, ASCAT, Seviri	SYNOP + AWS, AMDAR/ MRAR/ EHS, AMV, TEMP, SEVIRI, AMSU-A/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	4.8L73, 1250 x 750
Cycle	43t2bf11	cy43t2bf11	40t1
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-1k) has been setup on ECMWF HPC. The EPS consists from 16 C-LAEF1k EDA members, 16 lagged C-LAEF1k EDA members and 16 downscaled IFS-EPS-coupling files +1 EnVar member. A first B-Matrix was calculated based on NMC method (+12+/36h forecast), a second one was meanwhile calculated based on CLAEF-1k EPS differences. CLAEF-1k is completely based on cy46t1. Observations and other settings are mostly as in C-LAEF. For configuration e001 MF settings are used. A parallel run of C-LAEF control using all satellite observations from RUC (MSG WV, IASI, MW) and GNSS-ZTDs in active mode was run in summer 2023. Specifically for AROME-RUC, the LHN weight was reduced due to too much drying for longer lead times and dynamics settings were adapted as in MF oper (COMAD for hydrometeors on). This results in longer living convective cells. Instead of 3D-Var+IAU, 3D-Var + Variational Constraints was tested. Data from two towers in Vienna were passively assimilated showing quite some bias in RH and T in both cases while wind was satisfactory.

In the **Czech Republic**, the porting to model cycle 46t1 was completed successfully. Data assimilation of SEVIRI was temporarily suspended due to VARBC performance issues after the Meteosat-10/Meteosat-11 mission swap in March 2023. 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.

In **Croatia**, the operational suite was successfully ported to a new HPC at the beginning of February 2023. Radar reflectivities from OPERA are successfully implemented to the operational chain from the end of 2023.

In **Hungary**, the AMV and HRWIND data are assimilated operationally since March 2023. GNSS ZTD data from SGO1 network was inactivated in spring due to quality problem, GNSS ZTD data from BMEG network have been used instead from June 2023. The DA component of AROME-EPS (3D-Var + SEKF) was put to operations in March 2023. An AROME e-suite is running with hourly cycling at 1.3 km horizontal resolution and 90 vertical levels since December 2023.

In **Slovakia**, operational implementation of BlendVar took place on 25 April 2023 (cy43t2bf11). The cy46t1 version was implemented at the end of year 2023. 1 km hourly RUC with 3D-Var is under construction and evaluation. 1-h and 6-h accumulations of precipitation along with 10-minute average intensity added to national data for OPLACE.

In **Slovenia**, no significant changes were made in data assimilation configurations.

In **Romania**, DA activities were reinitialized by performing a stay at CHMI where a static B-matrix was computed and diagnosed for Romanian domain. 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 based on model cycle 43t2_bf10.

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

Action/Subject/Deliverable: *Further development of 3D-Var [DA 1]*

Description and objectives:

Assimilation cycling strategy for RUC [DA 1.2]

In order to determine an optimal cycling strategy for RUC, Anikó Kardos-Várkonyi (HU) chose two periods with 1 week spin-up: (1) between 8 July and 7 August 2021, (2) between 14 December 2022 and 13 January 2023. The 3-hourly EDA B-matrix was used for experiments at 1.3 km horizontal resolution and 90 levels in AROME/HU. Three experiments were conducted and inter compared:

- 2.5km60L: operational AROME/HU at 2.5 km horizontal resolution with 60 vertical levels, 3-hourly assimilation,
- 1.3km90L: 1.3 km horizontal resolution with 90 vertical levels, 3-hourly assimilation cycle (-/+ 90 minutes cut-off time),
- 1.3km90L-RUC: 1.3 km horizontal resolution with 90 vertical levels, 1-hourly assimilation cycle (-/+ 30 minutes cut-off time).

The results show that the RMSE decreases with the increasing resolution in case of summer precipitation forecast (Fig. 1.1). With the 1-hourly assimilation cycle, further improvement is obtained compared to the 3-hourly assimilation cycle. In the case of winter, both RMSE and bias values for 2 m temperature (Fig. 1.2) and relative humidity show an improvement for 1-hourly RUC compared to 3-hourly cycles. The wind gust is overestimated at 1.3 km resolution which needs further investigation and tuning.

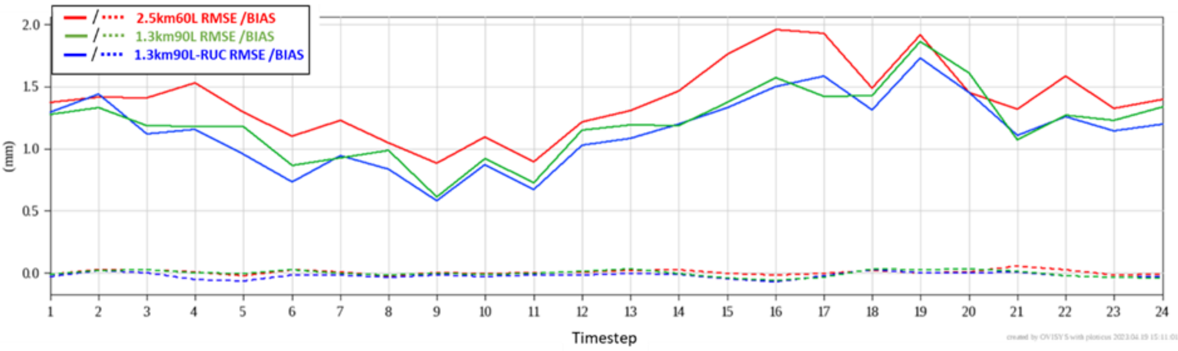

Figure 1.1: Bias (dashed) and RMSE (solid) of 1-hour precipitation forecasts in the function of lead time for AROME 2.5km60L (red), 1.3km90L (green) and 1.3km90L-RUC (blue) experiments (all initial-ised at 0 UTC) in the summer period.

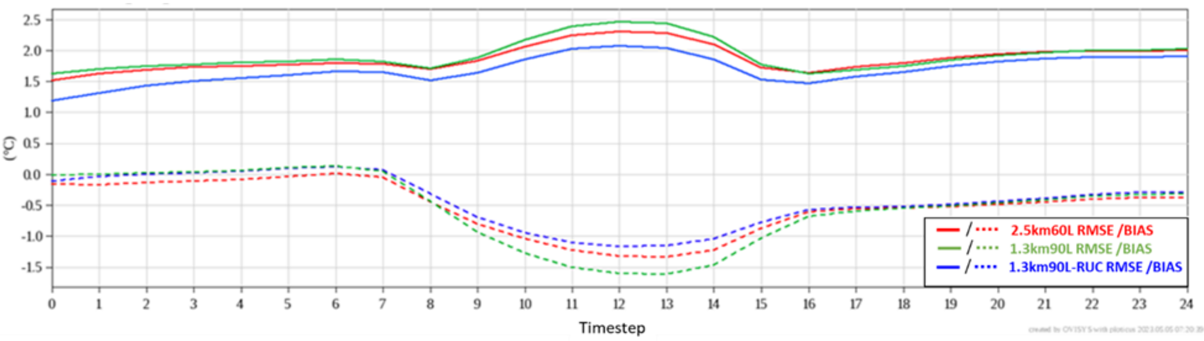

Figure 1.2: Bias (dashed) and RMSE (solid) of 2 m temperature forecasts in the function of lead time for AROME 2.5km60L (red), 1.3km90L (green) and 1.3km90L-RUC (blue) experiments (all initialised at 0 UTC) in the winter period.

The 1-hourly RUC system was also tested with less frequent surface assimilation, i.e. with 3-hourly surface assimilation in addition to the hourly 3D-Var. The motivation was that the previous experiment using optimal interpolation has clearly shown some benefit of the lower surface assimilation frequency, and considering that surface processes are slower than atmospheric ones, hourly surface assimilation is not necessary. The test periods were the same as above. Anikó Kardos-Várkonyi (HU) conducted two experiments at 1.3 km horizontal resolution with 90 levels and using simplified extended Kalman filter in the surface assimilation:

- 1.3km_90L-RUC with 1-hourly assimilation cycle (-/+ 30 minutes cut-off time) both in atmosphere and surface,
- 1.3km90L-RUC_sekf3h with 1-hourly assimilation cycle for atmosphere (-/+ 30 minutes cut-off time), 3-hourly assimilation cycle for surface (-/+ 90 minutes cut-off time).

The less frequent surface assimilation cycle had a more significant effect in summer than in winter. In winter, a small improvement is also observed for 1.3km-RUC_sekf3h at 2m temperature (Fig. 1.3) and relative humidity. Meanwhile in the summer period, quite strong negative bias is observed during daytime at 2m temperature for the 1.3km90L-RUC_sekf3h experiment (Fig. 1.3). At the same time, however, for 2m relative humidity, the RMSE and BIAS of 1.3km90L-RUC_sekf3h are better than in 1.3km90L-RUC for the first half of the forecast time. Since the results show a rather mixed picture with no clear detectable improvement by reducing the frequency of the surface assimilation cycle, we decided to use a homogenous RUC system with 1-hourly cycling both in surface and atmospheric assimilation. (0.5 PM)

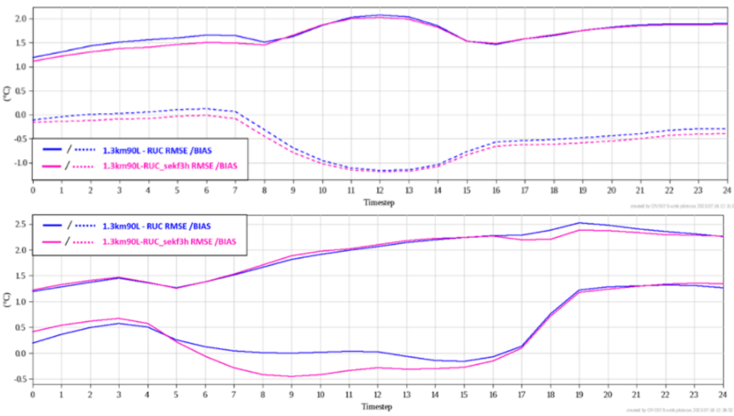

Figure 1.3: Bias (dashed) and RMSE (solid) of 2m temperature forecasts in the function of lead time for AROME 1.3km90L-RUC (blue) and 1.3km90L-RUC_sekf3h (pink) experiments (all initialized at 0 UTC) in the winter (top) and summer (bottom) periods.

Dávid Lancz and Anikó Kardos-Várkonyi (HU) prepared two real-time parallel-suites beside the operational AROME/HU runs, both using 1-hour (-/+ 30 min) data assimilation window. The goal was to study the number of incoming measurements as function of the assimilation cut-off time. Three configurations tested in which the time shift between the end of the assimilation window and the start of the assimilation process was +0 minutes (denoted RUC1), +30 minutes (RUC2) and +60 minutes (RUC3). The control experiments were conducted several hours after the nominal assimilation windows (mimicking a long cycle). The evaluation showed that SYNOP and AMV data arrive on time already for the RUC1 experiment, while GNSS ZTD data can be used only after 1 hour waiting time (RUC2, RUC3; Fig. 1.4). TEMP measurements are the latest to be available for assimilation, not entirely even for the RUC3 experiment. It was a surprise that the majority of the aircraft data arrive quite late, 90 minutes after the nominal starting time (RUC3) and only a few of them are used in the assimilation scheduled earlier. Since they provide important information about the upper atmosphere especially in the times when TEMP data are not available, a new test is ongoing for August to check if the low number of aircraft data is the effect of the “seasonal cycle” of the air traffic. An e-suite for forecasters will be designed, based on the final conclusions.

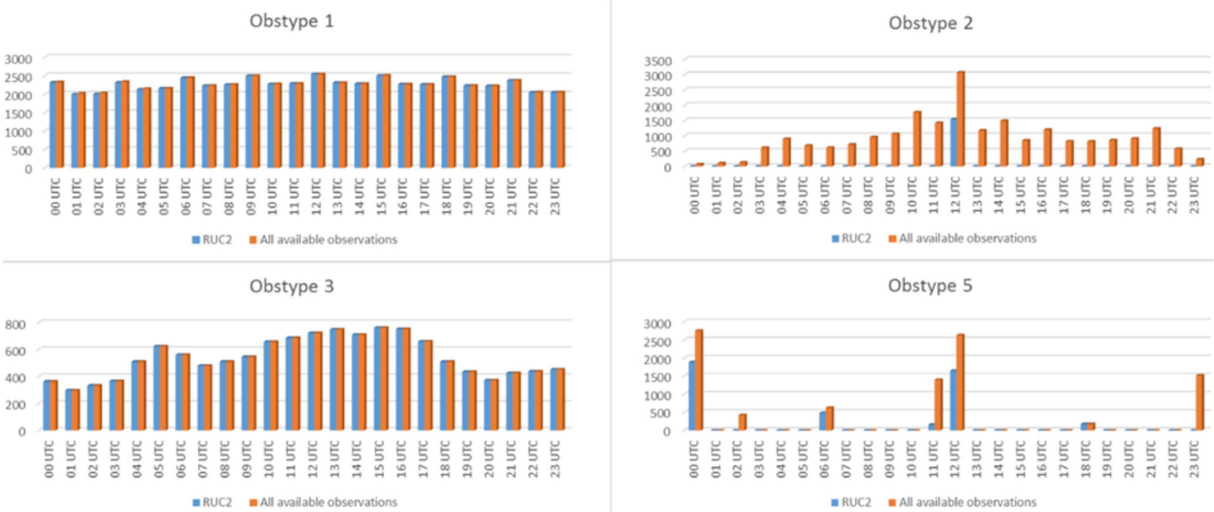

Figure 1.4: Number of assimilated observations in the RUC2 (blues) and the control (red) experiments on 29 May 2023. Obstype 1: SYNOP, GNSS ZTD, obstype 2: AMDAR, Mode-S MRAR, obstype 3: AMV, obstype 5: TEMP.

In October 2023 Dávid Lancz (HU) launched the first test-suite of AROME Rapid Update Cycle (RUC) with 1-hour data assimilation (DA) frequency using 3D-Var and Simplified Extended Kalman Filter at 1.3 km horizontal resolution and 90 levels. The schedule is sketched in Figure 1.5. The 1-hour assimilation window is centered around the initial time (-/+ 30 min). 30 minutes after the nominal initial time we immediately start the assimilation and then the forecast procedures for the early delivery of the products. (The whole chain lasts slightly less than 50 minutes.) The forecasts initialized from these short-cutoff analyses are 12 hours long and run at 0, 3, 6, 9, 12, 15 and 18 UTC. A long-cutoff assimilation cycle is also maintained. It is scheduled 2 hours after its nominal initial time, so with 90-minute shift (example: 0 UTC long-cutoff run starts at 2 UTC). The 2-hour forecast prepared from the long-cutoff analysis serves as a background field for the short-cutoff analysis in every 3 hours (example: forecast from the 1 UTC long-cutoff run provides the first guess for the short-cutoff DA at 3 UTC). The forecast outputs are regularly monitored by the developers and automatically processed for verification. (1 PM)

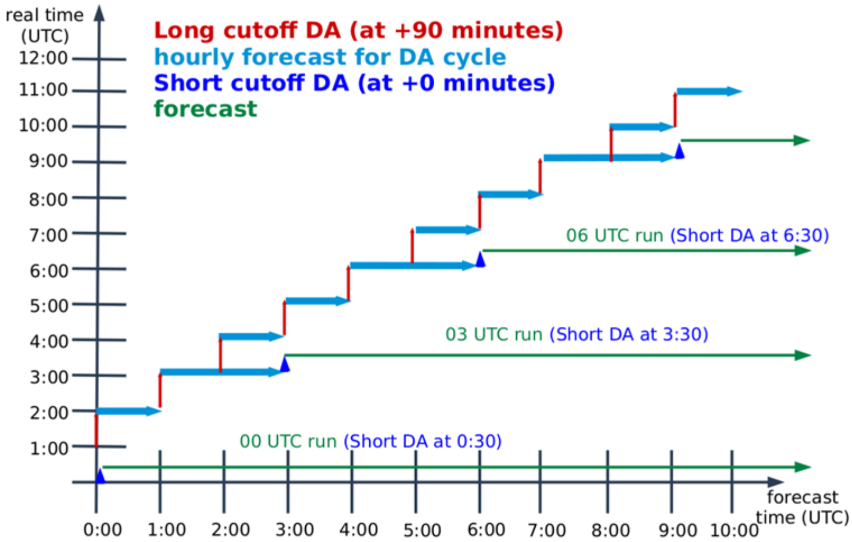

Figure 1.5: Schedule of AROME RUC.

In 2023, the Slovak Hydrometeorological Institute (SHMU) operates an hourly 1km Rapid Update Cycle (RUC) utilizing the ALARO-1 cy43 L63 model with 3DVAR on HPC3. Cut off for input data is 30 minutes after full hour.

In the autumn of 2023 Martin Imrisek(SK), Andre Simon(SK), Michal Nestiak(SK), Maria Derkova(SK) prepared upgrade to cy46 and number of levels was also increased L87. Digital filter is applied in the new version. Not negligible change in the new RUC is also inline fullpos and multigribs. Upgraded RUC will be applied to operational chain in spring 2024.

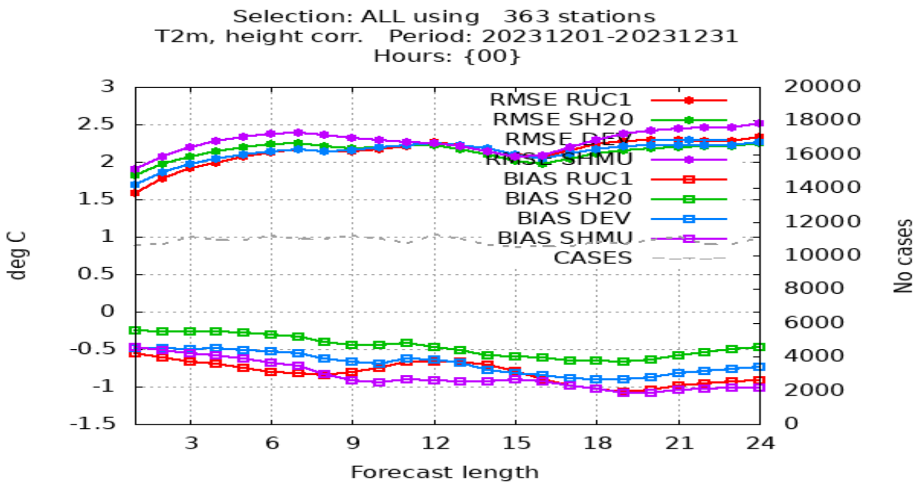

Figure 1.6: T2m verification scores for RUC.

During the preparation phase several setups were tested, e.g. 1-hour, 3-hour, and 6-hour forecasts as initial guesses. Not only standard verification tools were used for comparison but also evolution charts of specific fields (see Figure 1.7 and 1.8). Presently, the latest finished run from the preceding six hours serves as the guess in the current version of RUC.

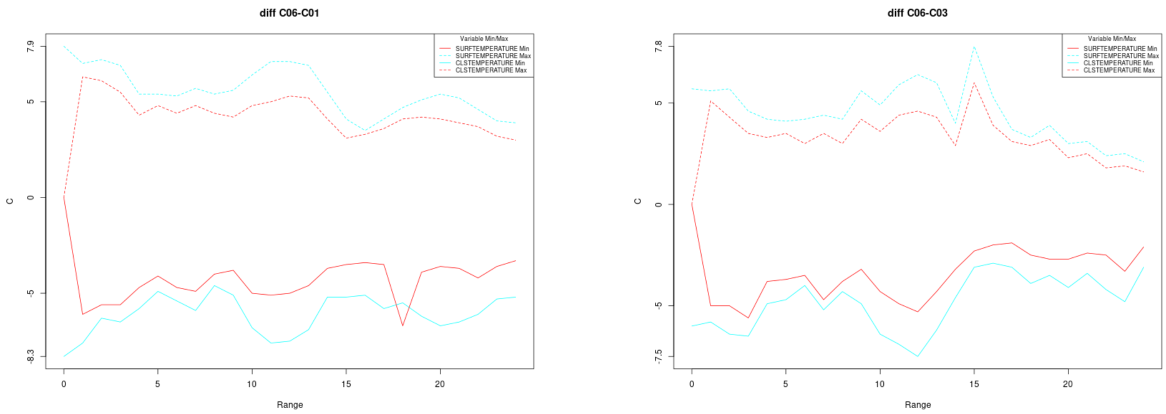

Figure 1.7: Difference in SURF and CLS temperatures for different guess strategy. In left guess F+06h minus F+01h and in right guess F+06h minus F+03h.

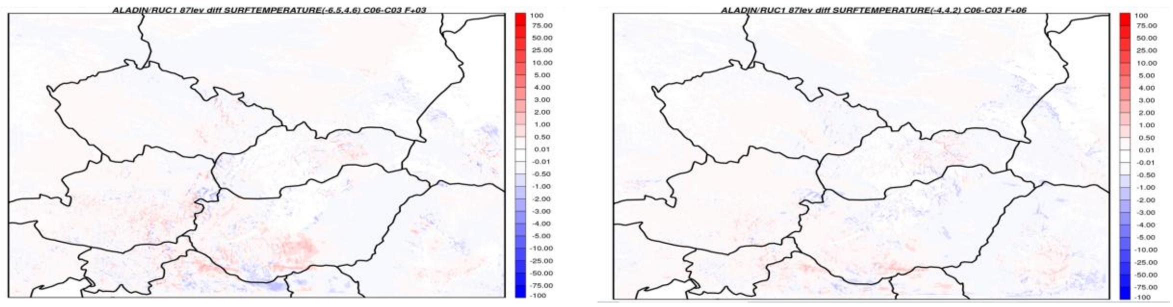

Figure 1.8: SURFTEMPERATURE difference between C06 and C03 guess strategy at +3h and +6h forecasts lead times.

Refinements of B-matrix representation [DA 1.3]

A new B-matrix was computed for the 1.3 km horizontal resolution and 90-level version of AROME/HU and Anikó Kardos-Várkonyi (HU) calculated some statistics using the TuneBR program to diagnose observation error standard deviations (so) and background error standard deviations (sb). Two 1-month periods were used: (1) between 8 July and 7 August 2021, (2) between 14 December 2022 and 13 January 2023. The following observation types were assimilated: SYNOP, TEMP, AMDAR and (Slovenian and Czech) Mode-S MRAR (note: no GNSS ZTD). For calculation of the EDA B-matrix and further experiments the default values were used for REDNMC (0.7) and SIGMAO_COEF (0.9) for all observation types. The final outputs of the calculations in this package are the ratios of diagnosed and predefined values for background error (rb) and observations error (ro). In the case of ro, all variables have similar values. The largest difference between the predefined and diagnosed background error standard deviation is observed for kinetic energy. In comparison of seasonal statistics we detected the largest difference in the ratio between winter and summer for specific humidity (Table 1.1). In conclusion, we apply the default values in the experiments at 1.3 km horizontal resolution and 90 vertical levels actually since they provide satisfactory results so far.

Table 1.1: Seasonal predefined and diagnosed observation and background error standard deviations and the ratio values for specific humidity, temperature, kinetic energy and their average.

Variable	Cases	Predefined s_b	Diagnosed s_b summer	Ratios r_b summer	Diagnosed s_b winter	Ratios r_b winter
q	52868	$4.44*10^{-4}$	$6.47*10^{-4}$	1.46	$3.68*10^{-4}$	0.83
T	315921	0.58	0.74	1.28	0.82	1.4
ke	350750	3.93	2.06	0.52	2.15	0.54
	Sum: 719539			**Average: 0.99**		**Average: 1.04**

Initialization and spinup [DA 1.5]

Maria Derkova (SK) has supervised a diploma thesis of Martin Petrovic (Comenius University, SK) checking the spin up properties in the experimental hourly RUC setup @1 km of ALARO CSC. Digital filter initialisation (DFI), incremental digital filter initialisation (IDFI) and uncentered incremental analysis update (IAU) techniques have been tested with different tuning for selected case studies. The level of noise based on the ECHKEVO diagnostics and the reduction/preservation of important meteorological signals after the initialisation have been studied. The DFI smoothed local meteorological structure in some situations too strongly. The IDFI filtering was mostly insufficient (perhaps due to wrong tuning). The uncentered IAU has been evaluated as the best technique, to be further used in the nowcasting suite which is under preparation at SHMU.

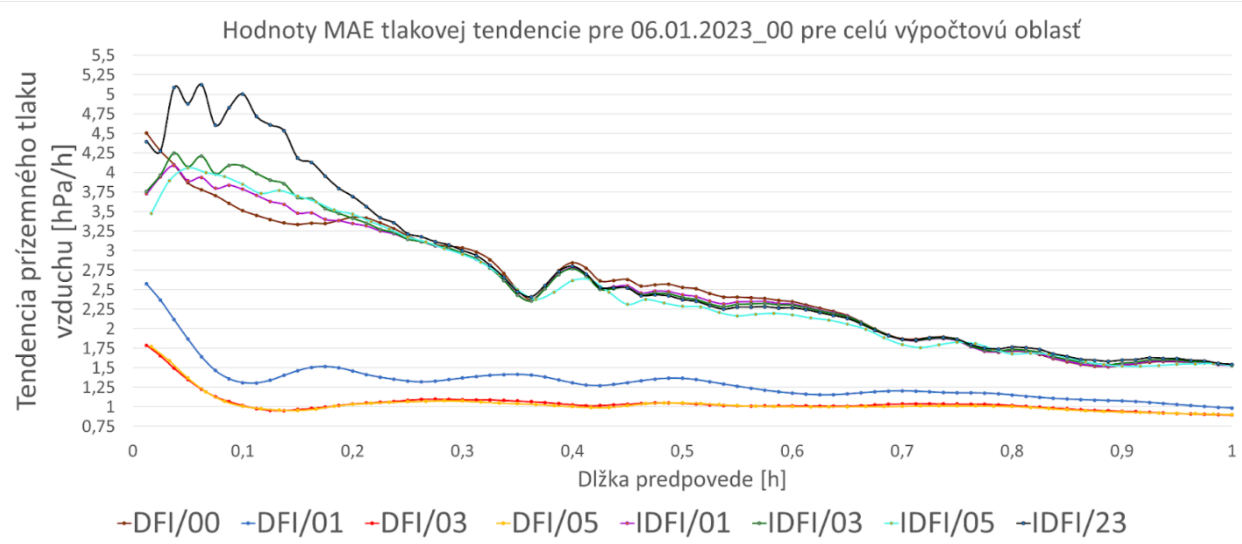

Figure 1.2: MAE of surface pressure tendency: No initialisation (reference - brown), various DFI tuning (red, yellow, blue), various IDFI tunings (green, cyan, black, violet).

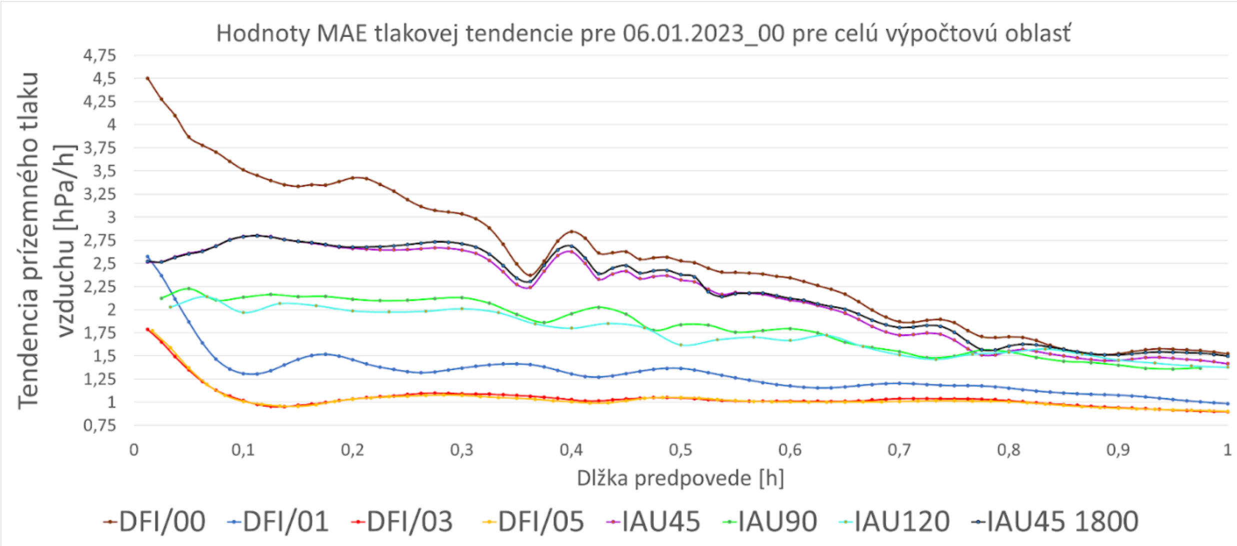

*Figure 1.3: MAE of surface pressure tendency: No initialisation (reference - brown), various DFI tuning (red, yellow, blue), various **IAU** tunings (green, cyan, black, violet).*

Validation of BlendVar algorithm, increasing the assimilation cycle from 6h to 3h [DA 1.7]

At **SHMU**, a new B matrix (static downscaled ENS) for SHMU BlendVar setup was prepared. The LBC data were derived from the Arpege ensemble DA cycle using the first six members, for two weeks period - July 2022, January 2023. The new B matrix benefit from the Arpege upgrade to CY46t1 compared to the older error statistics from 2016. Checking the properties of the new B-matrix: the main difference was observed in the decrease of the specific humidity length scales (Fig. 1.1 left), leading to improvement of the humidity-related parameters (right panel). New B matrix has been used in the operational implementation of Blendvar at SHMU since April 2023.

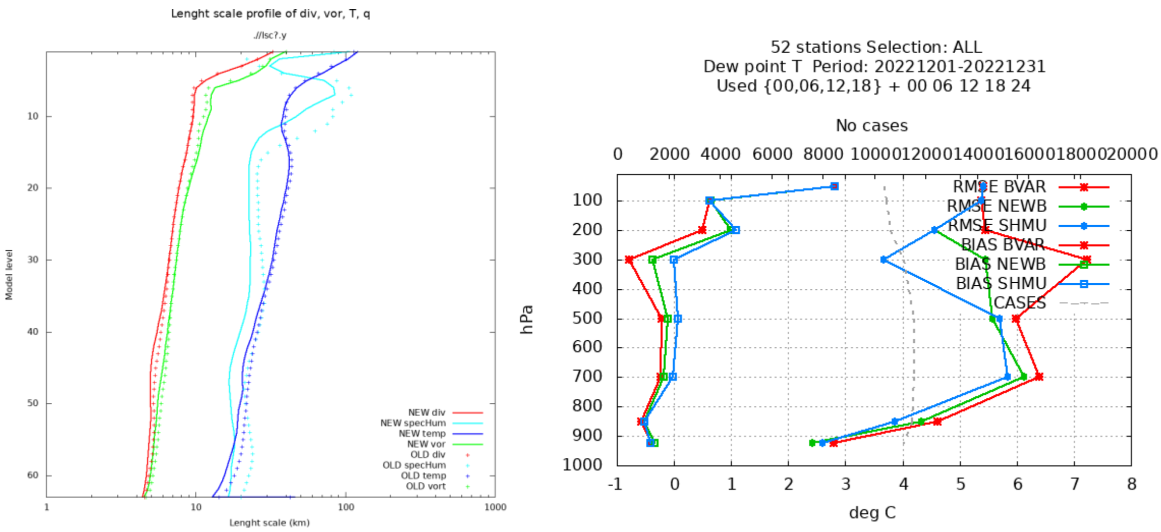

Figure 1.1: Left side: vertical profiles of the T, q, div, vor length scales for old (full line) and new (crosses) B-matrix. Right: verification scores for Td SHMU Blending (blue), BlendVar (red) and BlendVar with new B matrix (green).

Total efforts: 10.5 months

Contributors: D. Lancz 2, A. Kardos- Varkonyi (Hu) 3.25, A. Simon (SK) 0.25 (registered in HR), M. Neštiak (SK) 2.25, M. Derkova (SK) 2, S. B. Szintai (HU) 0.75

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Use of existing observations – radar [DA 3.1]***

Description of tasks:

Validation of the solution for wind dealiasing (torus mapping)

Vito Švagelj, Peter Smerkol and Benedikt Strajnar (SI) prepared a scientific publication on the application of torus mapping method as implemented in HOOF for Copernicus AMT (preprint and discussion online at egusphere.copernicus.org). It compares observed data and first guess departures of radar radial winds, aircraft winds and radiosonde winds for all analysis times (3-hourly cycle) in the year 2021. The goal is to estimate the error of dealiased winds by (triple) collocation between observations and in comparison with the first guess, and to study the performance of QC for radial winds. From the inter comparison between collocated observations it is evident that the standard deviation of differences between observations are higher when radar wind is involved. The overall first guess departure standard deviation of radial winds after the dealiasing is also higher than those for radiosondes or aircraft (4.6 vs. 2.8 m/s) but a fairly similar value of 2.9 m/s can be reached when the rejection limit in the background check is set to 15 m/s. From comparison with the first-guess departures it is evident that dealiasing improves the distributions for highly aliased datasets (e.g. Slovenian, NI = 8 m/s) but also reduces tails radar wind datasets that are less frequently aliased (e.g. German dataset with NI = 30 m/s) and is thus useful to increase the number of active radar wind observations.

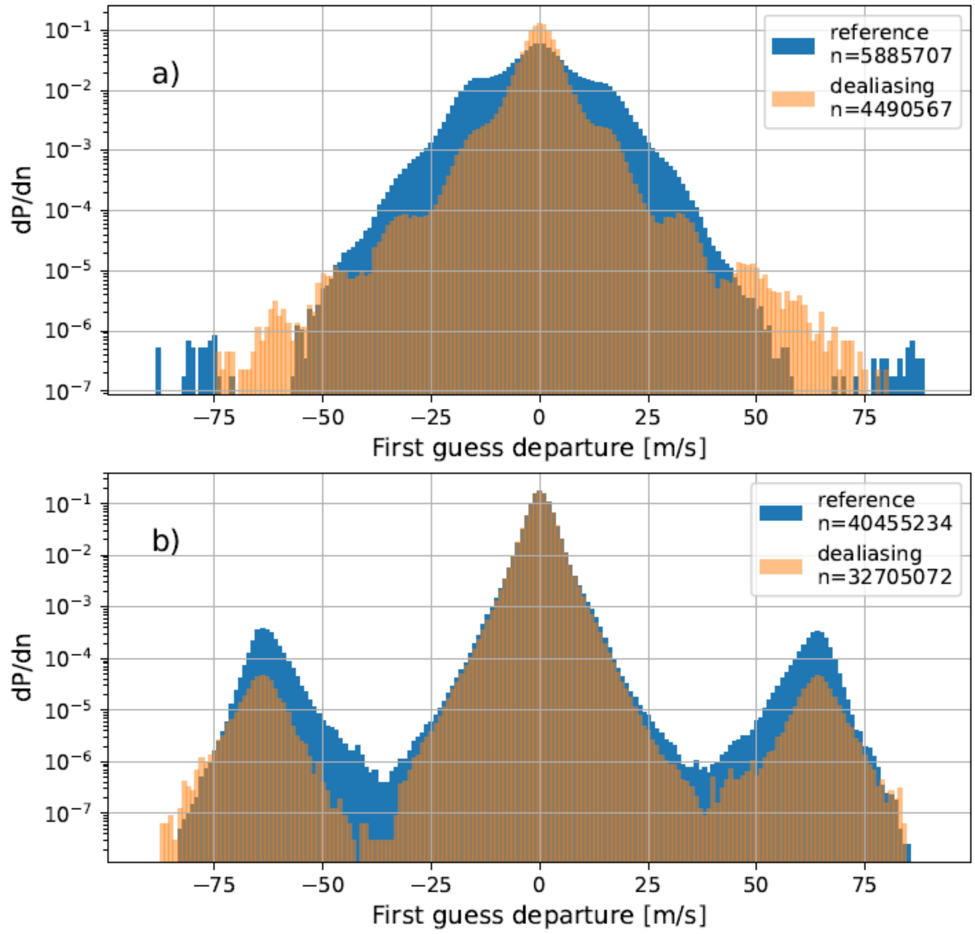

Figure 3.1: First guess departure distributions before (blue) and after the dealiasing (orange) for all radar Doppler wind observations in 2021 for (a) Slovenian dataset and (b) German dataset.

After a rejection of the paper manuscript by one of the referees, Vito Švagelj, Peter Smerkol and Benedikt Strajnar (SI) worked on its revision to submit it to another journal. The main challenge is the justification of the chosen method (torus mapping is a simple and fast one, but with difficulties in the horizontally sheared environments or when the measurements are noisy). Figure 3.2 shows first guess departures of collocated aircraft and raw aliased wind datasets, where aliasing shows up as side peaks in the distribution. To focus on aliasing alone, Slovenian and German datasets are chosen for validation: other networks either have less aliasing problems due to measurement technique or additional preprocessing, or the wind is too noisy (wide non-gaussian distributions) for the dealiasing algorithm.

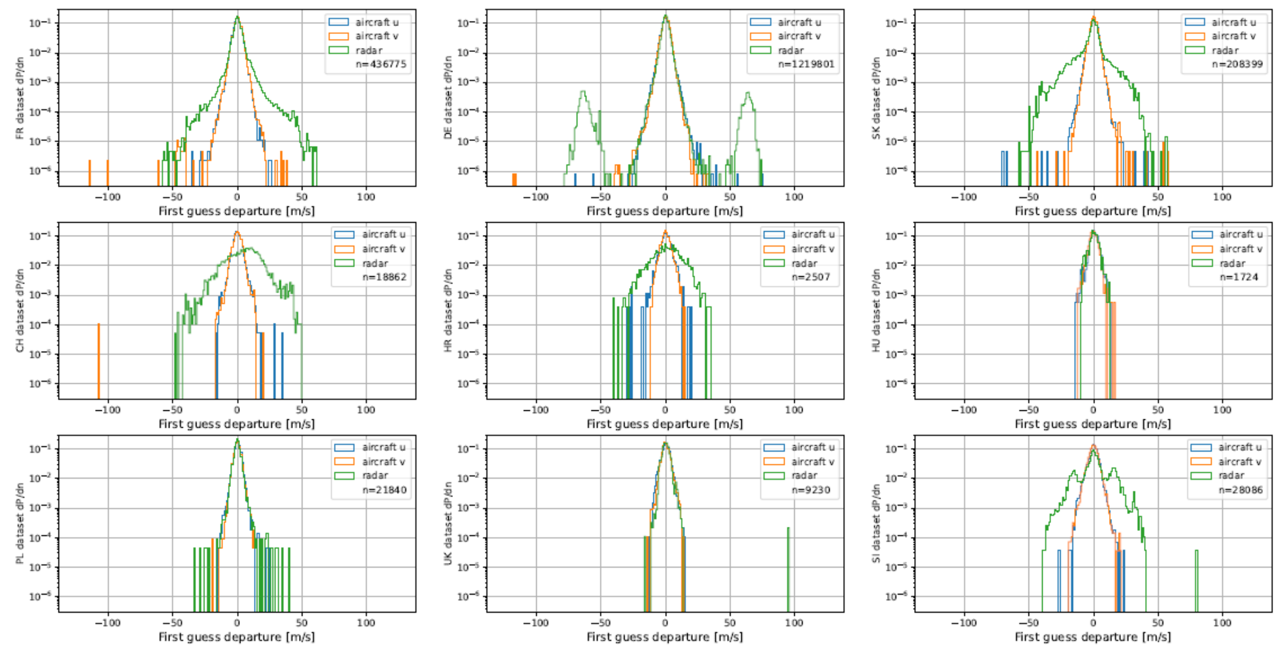

Figure 3.2: First guess departures of aliased data of radar and collocated aircraft measurements per national provider for all available OPERA radar datasets.

Impact studies with original and de-aliased OPERA Doppler wind data

No work reported.

Impact studies with OPERA reflectivity observations

Sensitivity studies of the radar reflectivity DA in ALARO CMC by Suzana Panežić (CR), Alena Trojáková (CZ) and Antonín Bučánek(CZ) continued. Main focus of the studies was to further explore the drying effect and possible solutions in reducing it. Usage of a fixed table of OPERA prescribed MDRF values was investigated, as well as possible location of the drying considering the distance from the radar. A new proposal of increasing the relative humidity observation error for the dry pseudo-observations was also explored. Additionally, modification to remove dry observations with flipped signs to combat the drying effect was tested. Results showed that keeping a fixed table of OPERA prescribed MDRF values for operational purposes would be very challenging as these values change after each radar's maintenance. The idea that the drying effect is directly linked to the low dry observation values near the radar site was rejected as no drying near the radar site was observed during the evaluation.

It was also shown that the inflation of the relative humidity observation error decreased the drying effect. Best scores were observed with the 0.35 value increase, after which the results showed degradation towards too large precipitating convective systems. Results showed that this modification performed well in the wet winter period as well. Removal of dry observation with flipped signs also showed a significant decrease of the drying effect, but it also showed an increase in the severe convection appearance (threshold above 60 mm). Further tests are needed to evaluate the impact of this modification. Further details on this work can be found in the stay report.

Capitalizing from these findings, a systematic study of validation of all these proposals (the above contributors and Benedikt Strajnar (SI)) is made. Four experiments were set up using the ALARO-CZ DA system with 3h cycling: reference run, MF setup, obs. error inflation with 0.35 offset and threshold method with 12 dBZ threshold. Results from summer and winter period in 2023 are available and the verification with respect to a large European observation dataset is ongoing. Observation dataset was prepared by Alena Trojakova (CZ) and Benedikt Strajnar (SI) and it combines

Synop surface stations, national automatic stations from LACE, Germany and parts of Italy. The main goal is to validate precipitation at hourly scale. The work is ongoing in 2024 [Contributors: Suzana Panežić (CR), Alena Trojáková (CZ), Antonín Bučánek(CZ) and Benedikt Strajnar (SI)].

The local development of the RC LACE radar assimilation has reached a stage where we have decided to contribute to the common cycle CY49T0. Beside the minor fixes, there were several suggestions to minimize the drying effect of radar reflectivity assimilation. The most promising ones are included in the contribution, such as the relative humidity observation error inflation and the threshold method. Antonín Bučánek (CZ) carried out the phasing into the cycle CY49T0 mainly during a stay in Zagreb.

Work on local implementation of radar reflectivity DA at DHMZ was started by Suzana Panežić (CR) and Anamarija Zajec (CR). Modifications to CY43 code regarding inflation of relative humidity observation error and threshold method (latest modification proposed by Benedikt Strajnar and Maud Martet during the working week at KNMI in February 2023) were made and tested for the winter period of 2023. Initial results showed that both methods (rad2 and rad3) reduced the drying effect in the Croatian operational system (diff) when compared to default MF settings (rad1). Combining both methods together showed the least amount of degradation (rad2_3).

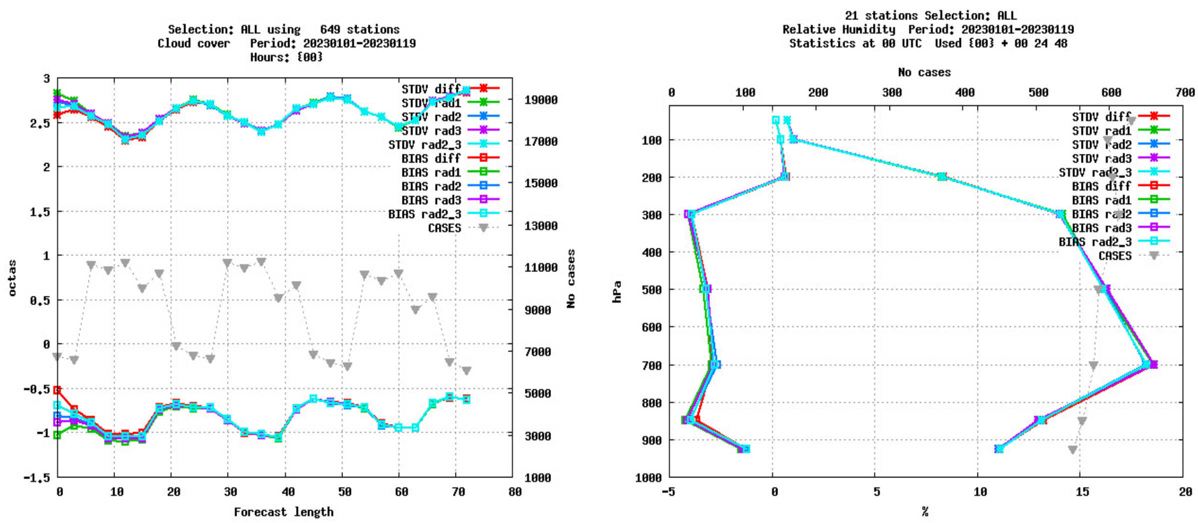

Figure 3.3: Bias and STDV for cloud cover (left) and RH profile (right) - no radar DA (diff), radar DA reference (rad1), inflation of RH error for dry obs (rad2), threshold method (rad3), combined inflation and threshold methods (rad2_3).

Suzana Panežić and Anamarija Zajec (CR) continued work on the local implementation of radar reflectivity DA**.** Inflation of relative humidity observation error (rad2), threshold method (rad3) and their combination (rad2_3) were tested for the summer period of 2023. Results showed that the combined method (rad2_3) with the error inflation offset of 0.35 and the threshold of 0.0 performed the best, giving neutral scores when compared with the operational system (HR40) and improved 1h rain rates at the location of Croatian automatic stations. Additionally, tests with profile saturation were performed but showed the negative impact. The operational system was enhanced with rad2_3 settings to incorporate OPERA radar reflectivities during DA. The parallel cycle was set up to test the NIMBUS production line of OPERA radar data.

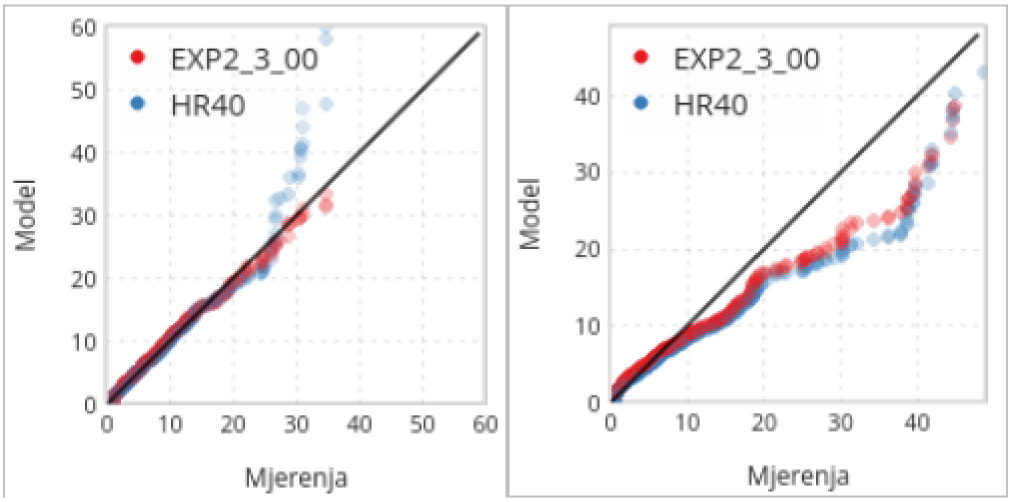

Figure: Comparison of 1h rain rates from the model and observations at the location of Croatian automatic stations; period 1.7.2023.-15.08.2023.; continental stations (left) and coastal stations (right); operational system (HR40) and radar DA (EXP2_3_00)

Regular upgrades of the HOOF preprocessing tool. [DA 3.1]
No work reported.

Efforts: 19 months

Contributors: S. Panežić (CR) 4.25, B. Strajnar (SI) 2.5, A. Trojáková (CZ) 2.25, A. Bučánek (CZ) 3.75, F. Meier (AT) 0.25, Vito Švagelj (SI) 2, Peter Smerkol (SI) 4

Documentation: HOOF user guide, updated; RC lace stay reports

Status: ONGOING

Action/Subject/Deliverable: ***Use of existing observations - other observations [DA 3]***

Refining the application of Mode-S observations in DA systems with increased assimilation cycle frequency, change of data source, whitelisting. [DA 3.2]
No work reported.

Evaluation and impact assessment of E-GVAP ZTD. [DA 3.3]
The quality of the SGO1 GNSS ZTD data deteriorated significantly from the beginning of 2023, which also negatively affected the AROME/HU forecasts. For this reason, Helga Kolláthné Tóth (HU) removed these data from the assimilation cycle on 18 April 2023, however, assimilation of ZTD continued with data from WUEL, GF1R, and ASI networks. At the same time, Budapest University of Technology and Economics started to provide GNSS ZTD data under the BMEG network for E-GVAP from February 2023. The data show similar territorial coverage to SGO1. A new whitelist was prepared with BMEG, WUEL, GF1R, and ASI data for March 2023. 115 stations were selected: 30 from BMEG, 34 from WUEL, 40 from GF1R, and 11 from ASI. Forecast was made with the new whitelist from 1 April to 6 May 2023 with 6-day spin-up, and new VARBC predictor entries were created. The evaluation was carried out in 2 steps, because the removal of SGO1 data from the operational assimilation: (1) impact of SGO1 and BMEG data on the analysis and the forecast for 7–18 April 2023 was compared (2) the added value of

BMEG data from 19 April to 6 May 2023 was examined. The verification scores show an improvement of T2m for the whole forecast range, if BMEG data was assimilated instead of SGO1 in period 1 and a neutral impact was seen in period 2 (Fig. 3.4). Assimilation of BMEG data with the new whitelist is operational in AROME/HU since June 2023.

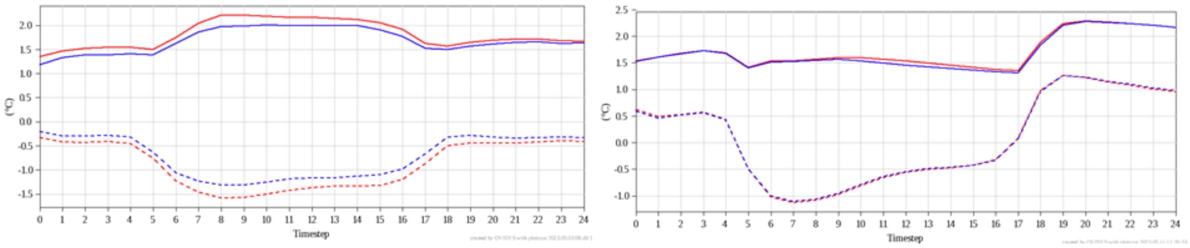

Figure 3.4: RMSE (solid) and bias (dashed) of 2 metre temperature forecasts for period 1 (left) and period 2 (right). Red: AROME/HU operational run (with SGO1 in period 1, without SGO1 in period 2); blue: AROME/HU run using BMEG data.

Use of mobile GNSS sensors on Austrian trains in cooperation with Technical university of Vienna [DA 3.3]

Florian Weidle (AT) conducted a number of case studies with ZTD observations retrieved from moving trains. The first guess departures from reference AROME-RUC runs with passively assimilated ZTD from trains over a 10-day period were analysed. It was shown that applying a static bias correction based on train IDs is a valid approach since the first guess departures are close to the Gaussian distribution, even for trains that travel through highly orographic terrain. In case studies it was shown that adding ZTD observations from trains can improve the forecast quality of AROME-RUC forecasts. To mimic the usage of train data in a possible operational workflow case studies have been done using train data with one hour time delay as well as using only observations of the last hour if a train passes a larger train stations. The reasoning for the latter experiment is that one approach for an operational workflow would be the data transfer of observed values in larger stations with good internet connectivity. In both experiments the impact of the train data was degraded but still visible.

Test feasibility and impact of InSAR slant delay assimilation from Sentinel-1. [DA 3.3]

Florian Meier (AT) continued testing of InSAR Sentinel-1 delay assimilation with STD slant delay operator (de Haan and Imrisek) in cy43t2 3D-Var. Meanwhile a full summer season (April-November 2022) dataset is available. The absolute first guess values derived from Screening ODB at first overpass are added to the differential delays to get absolute slant delays at each following observation time slot. Tests of assimilating these data show large scale bias. Therefore, work on a bias correction is ongoing based on FG departure statistics. Also reasonable data thinning has to be considered.

Two summer season data 2022/2023 is now available work will continue in spring 2024 till end of 2024.

Sensitivity studies with individual polar-orbiting sensors, with emphasis on new sensors such as ATMS and IASI, which will be included on board the next generation geostationary satellites (MTG). Eventually feasibility study with GNSS-RO. [DA 3.6]

Suzana Panežić (CR) started the work on preparation for MTG-IRS data. Provided spectral radiances were reconstructed from the principal component scores. It was shown that reconstructed data match well the provided data. RTTOV v13.2 GUI was used to simulate spectral radiances from the provided IRS coefficients and profiles.

Preparation for MTG and related plans IR all-sky assimilation were discussed during the DAWW2 hosted by IPMA.

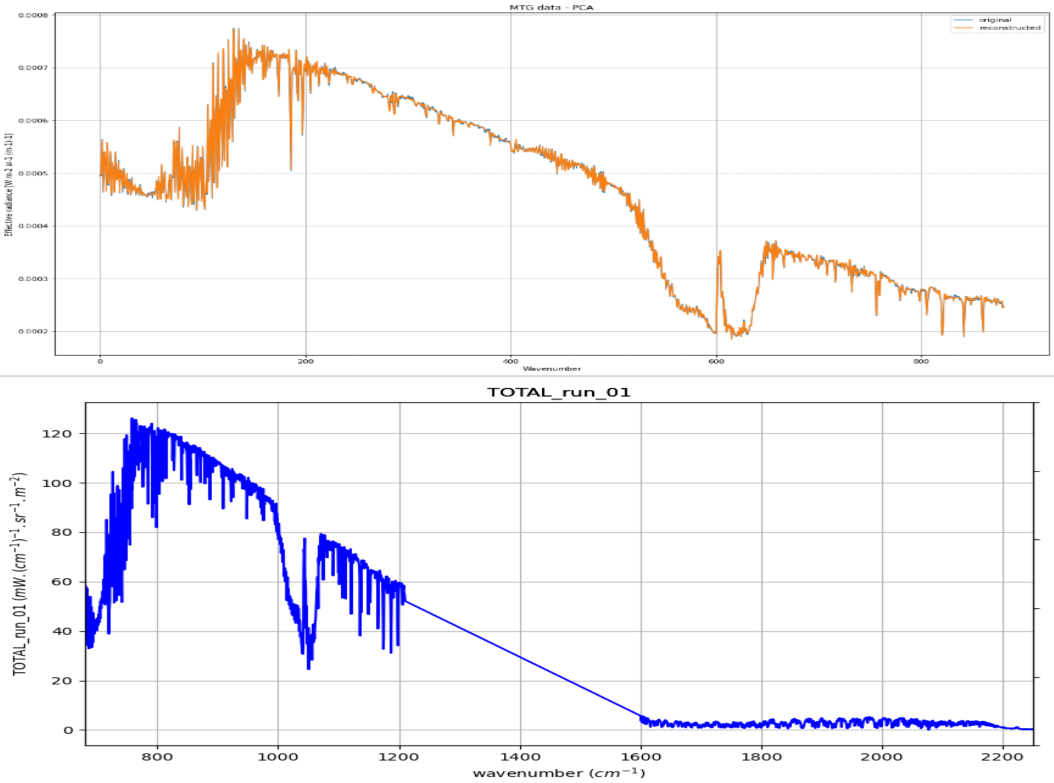

Figure 3.5: Original (blue) and reconstructed (orange) spectral radiances from MTG-IRS test data (top picture), simulated spectral radiance using the RTTOV v13.2 GUI tool (bottom picture).

Implementation and test of high-resolution radiosondes in BUFR. Sensitivity of extra radiosonde data. [DA 3.8]

No work reported.

Enhanced QC for dense surface observations base on A-LAEF. [DA 3.9]

No work reported.

Assimilation of Sodar/RASS observations [DA 3.10]

No work reported.

Efforts: 9 months

Contributors: F. Weidle (AT) 3.25, F. Meier (AT) 2, H. Toth (HU) 1, S. Panežić (CR) 0.5, A. Stanesic (CR) 0.5, B. Strajnar (SI) 1.5, Z. Kocsis (HU) 0.25,

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Use of new observations types [DA 4]***

Finalization of the implementation of slant tropospheric delays (STD) in the common model cycles (in cooperation with HIRLAM). [DA 4.2]

Martin Imrišek (SK) continued his work on phasing slant total delays from CY48T1 to CY48T3 as a branch on the ACCORD IAL GitHub.

Martin Imrišek (SK) has successfully ported the development of GNSS STD to repository IAL tag CY49T1 in second half of the year 2023. The development is originally based on code of Siebren de Haan (NL), furthermore information are available in report GNSS STD in the ALADIN NWP system. The development was consulted and guided also by Peter Lean (ECMWF).

Assimilation of microlink rain rates using direct RH estimate or obs. operator from P. Lopez or latent heat nudging. [DA 4.8]

Description to be provided.

Test of MSG visible and WV assimilation operator (cy48) with RTTOV and implementation of assimilation interface.

Adhithiyan Neduncheran (AT) and Florian Meier (AT) are working on all-sky assimilation (obstype 16) of two water vapor channels (6.2 µm and 7.3 µm) of SEVIRI on board MSG-3 and testing it over the AROME-Austria/C-LAEF operational domain using CY48T1OP1. First look results are quite similar to clear sky (ClrSky) assimilation of satellite radiances under SATEM (obstype 7). Figure 4.1 shows increments in specific humidity and temperature at 500hPa where the 7.3 µm WV channel is sensitive. The work is still ongoing, especially the error tuning with respect to specific channels over land and ocean remains to be tested under AllSky. Later, the test of VIS channel assimilation is envisaged. In this context, offline RTTOV tests are conducted by a PHD student Sandy Chkeir at university of Vienna (IMGW) to investigate the operator functionalities.

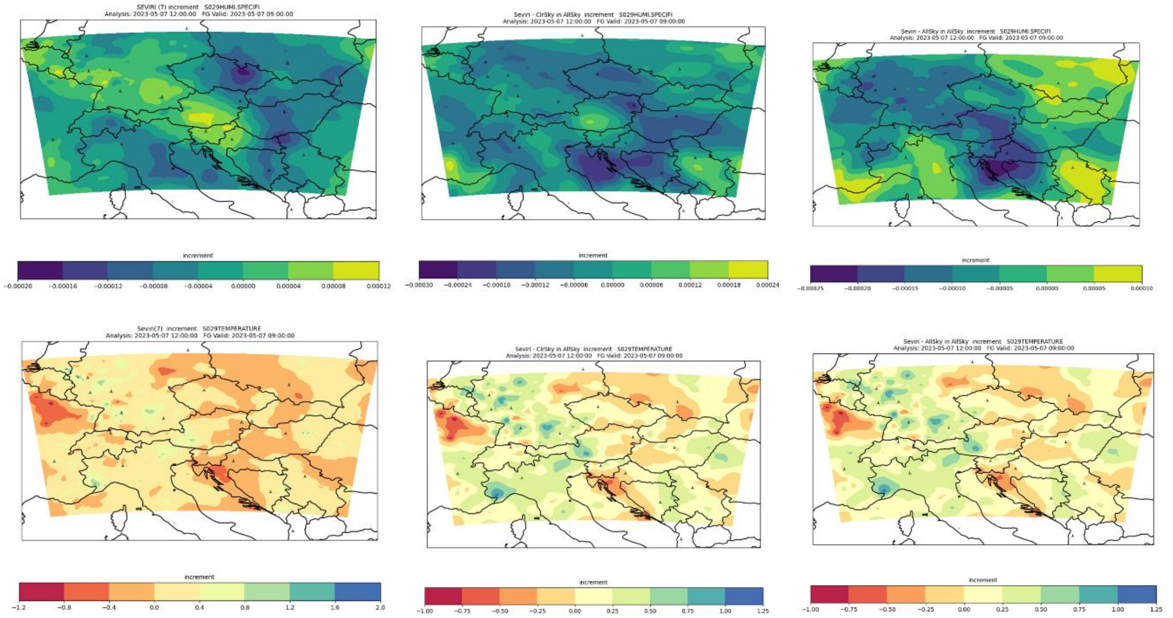

Figure 4.1: Increments of 3D-Var OOPS assimilation of SEVIRI WV channels specific humidity (top) and temperature (bottom) on model level 29 (~500 hPa). As obstype 7 (left), obstype 16 all_sky but clouds neglected (middle) and obstype 16 all_sky (right).

Adhithiyan Neduncheran (AT) continued the work on assimilation of SEVIRI MSG WV channels in all-sky mode in second half of year 2023. Instead of further usage of obstype 16 he switched back to obstype 7 with just activating addclouds option in RTTOV to run all_sky mode. For observation error the default setting and an inflated constant value was tried. Recently this setting was tested for 7th May 2023 12 UTC case also with EnVar using 50 EPS members from C-LAEF 2.5km.

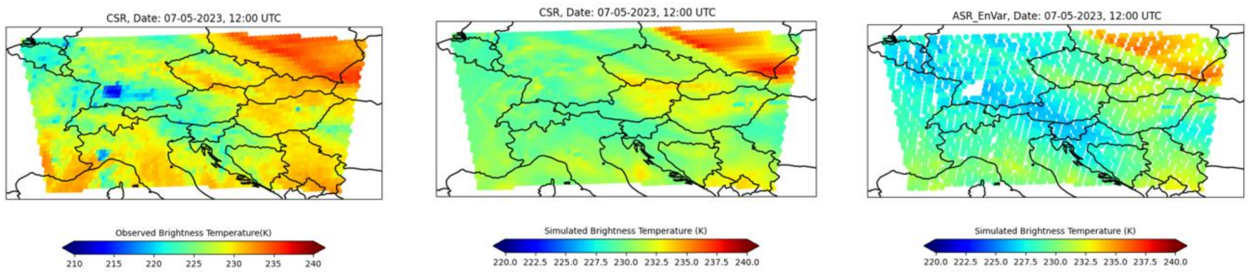

Figure 4.2: observed (left) and simulated (FG, middle) brightness temperature of 6.2 µm channel on 7th May 2023 12 UTC and simulated values after 50 member EnVar was run (right) in all_sky mode. Very low temperatures are blacklisted.

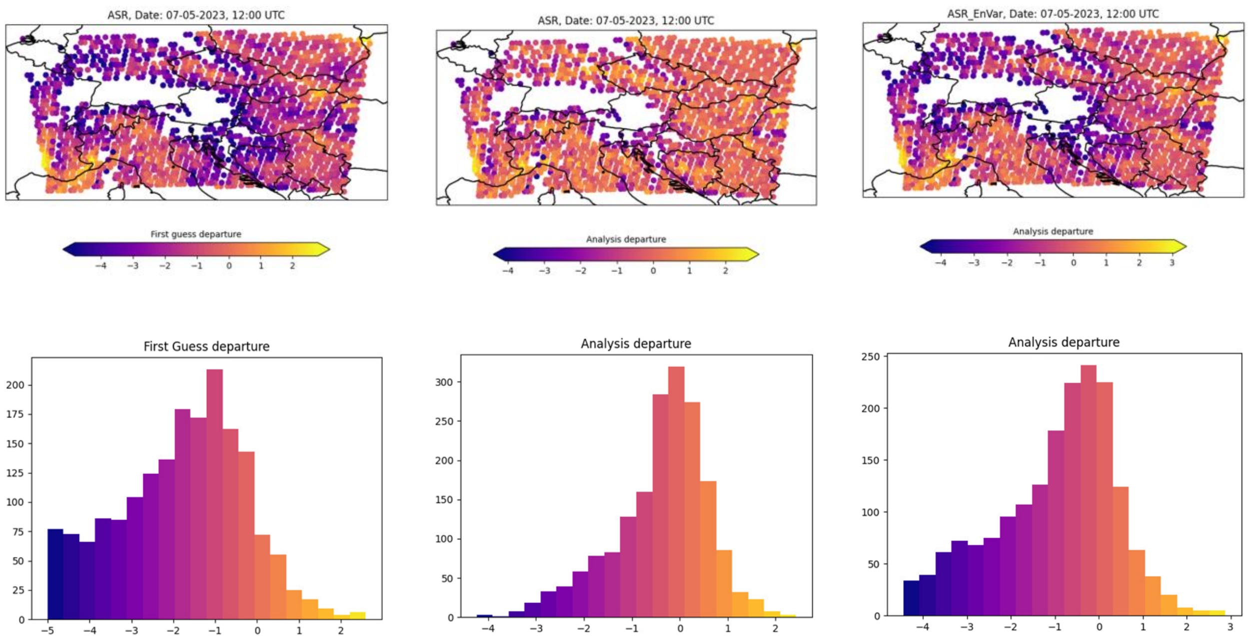

Figure 4.3: First guess departure (left) and analysis departure (3D-Var middle, and 3D-EnVar right) for the same case as Figure 4.2.

In the next steps we plan to implement 0.6 µm VIS channel and try to extended control variable in EnVar.

Efforts: 16 month

Contributors: F. Meier (AT) 0.5, A. Neduncheran (AT) 6.5, M. Imrišek (SK) 5, P. Scheffknecht (AT) 2.5, S. Panežić (CR) 1, B. Strajnar 0.5,

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Participation in OOPS development [DA 6]***

Contribute to preparation of a prototype of full-scale OOPS-based 3D-Var and EnVar systems. [DA 6.4]

Florian Meier and Florian Weidle (AT) started to run a parallel test with EnVar-OOPS in cy46t1 C-LAEF 1km configuration (16 member 1km L90 AROME-EPS 3d-Var EDA). While analysis generation was successful, forecast crashed. Next step will be to extend ensemble size by including downscaled global and lagged members and reconsider localization and inner loop settings. It was also successfully tested on a single case to initialise the higher resolved AROME-RUC 1.2km with the 2.5km EPS. OOPS cy48t1 was compiled and installed at ECMWF and assimilation is technically working.

Florian Meier and Florian Weidle (AT) continued with testing EnVar option in cy46t1 in CLAEF-1km domain. The EPS consisted 16 C-LAEF1k EDA members, 16 lagged C-LAEF1k EDA members and 16 downscaled IFS-EPS-coupling files. The scheme was integrated in CLAEF1k ecflow and a near real time test period with one EnVAR-member was run since autumn 2023. First results showed rather good scores regarding T2m values compared to 3D-Var, but humidity and clouds were less convincing. It is planned to reconsider and test different EPS settings to improve the scheme and restart a parallel test in the convective period in 2024. Also a change to newer cycle (48t3/49t1) is envisaged.

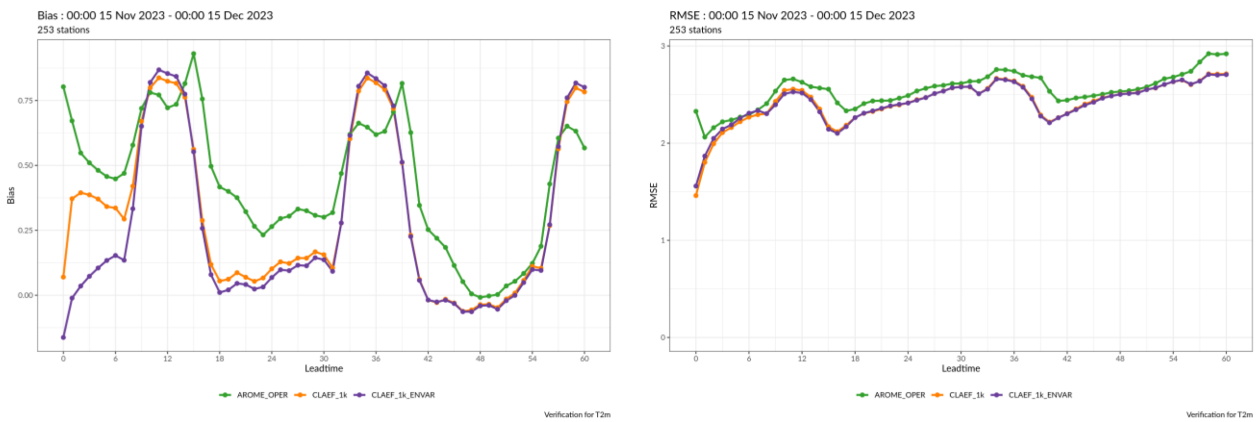

Figure 6.1: One month comparison of C-LAEF1km 3D-Var and 3D-EnVar and 2.5km 3D-Var (oper). T2m bias left, RMSE right.

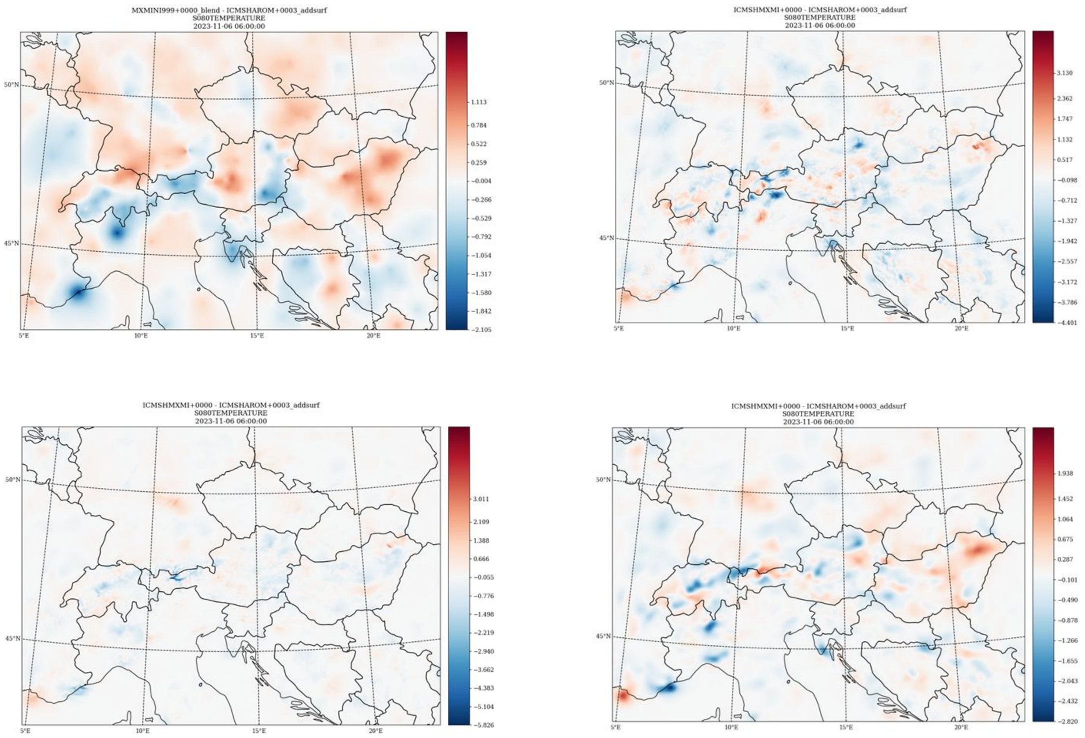

Figure 6.2: A comparison of AROME 2.5km increments on 6th November 2023 06UTC at level 80 (about 150m above ground): OOPS 3D-Var (top left), 3D-EnVar with mixture of C-LAEF lagged EPS 34 member + IFS-downscaled EPS 16 member (top right), 3D-Var based on pure C-LAEF lagged EPS 34 member (bottom left) and 3D-EnVar based on pure downscaled IFS-EPS 34 member.

During ACCORD WW some experiments with cy46t1 OOPS have been conducted based on different EPS-settings in 3D-EnVar. It shows that EnVar significantly changes increments especially in complex terrain near ground compared to 3D-Var, but coarse EPS partly blurs this effect and can even lead to different signs of increments. The mixture of global and local EPS lies in between.

Total efforts: 1.75 months

Contributors: F. Meier (AT) 1.75, F. Weidle (AT)

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: *Observation pre-processing and diagnostic tools [DA 7]*

Feasibility study to implement/use FSOI. [DA 7.2]

No work reported.

Maintenance and development of observation preprocessing system [DA 7.5]

Benedikt Strajnar (SI) has upgraded an observation monitoring system on European scale for the DE_330 project. The system focuses mainly on in-situ observations, including surface stations and marine platforms, radiosondes and aircraft observations (radar datasets not available yet but in preparation). The system performs the background check at hourly scale against the IFS/ECMWF background, interpolated on a 5.5 km domain (the one used for the CERRA reanalysis). To examine observation availability, two instances of the system are continuously run: the near-real time one uses observations available with a 30 min cutoff (rapid datasets), and the delayed one with 12h cutoff (all observations). The data is a combination of observations disseminated by ECMWF for member states and those provided by the OPLACE preprocessing system. The system has been continuously upgraded by adapting BUFR decoding (param.cfg and decoding routine) of this very heterogeneous dataset. Statistics and plot are available at Atos through the Obsmon tool.

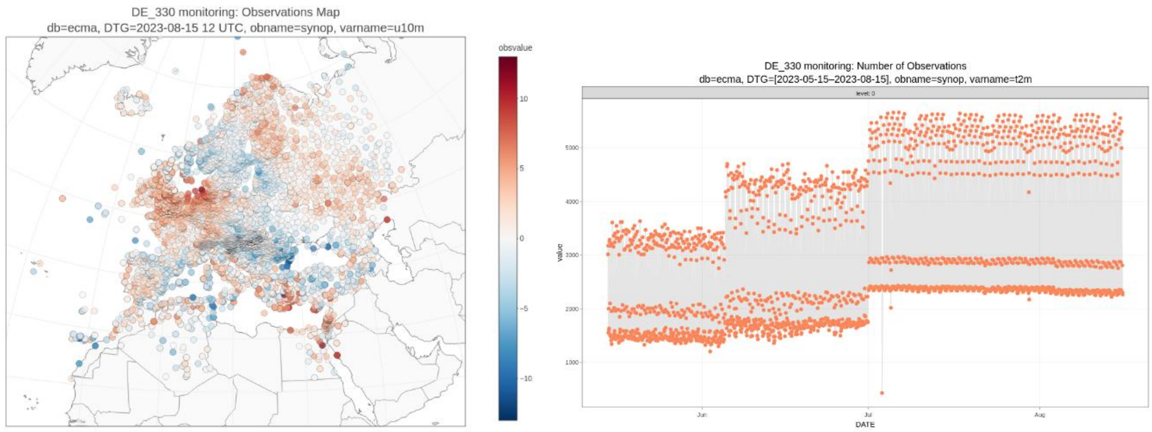

Figure: Growing number of T2m surface observations in DE_330 observation monitoring in the period 15 May - 15 Aug 2023 (left) and 10m wind observation coverage on 15th August 2023 12 UTC.

The analysis indicates that a substantial portion of data, almost all surface stations, around 75 % percent for aircraft observations, and roughly 30-50 % of radiosondes (depending on observation time) are available within 30 minutes from the nominal analysis hour. Presently, the dissemination speed cannot be augmented, given that the update times of the OPLACE and ECMWF extraction for member states align with the operational requirements of the existing LAM data assimilation suites of the ACCORD consortium. Final report on observation availability for DE_330 is under evaluation with ECMWF.

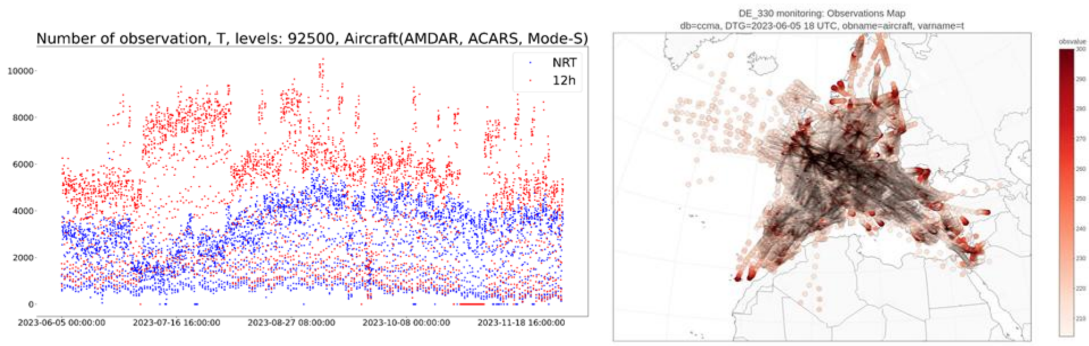

Figure: Evolution of the number of aircraft data (AMDAR, ACARS, Mode-S) at typical cruise levels (upper left), mid-tropospheric (upper right) and low-level data (bottom left) and typical afternoon horizontal coverage.

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

Customization of the Obsmon observation monitoring package. [DA 7.2]

No work reported.

Total efforts: 5.5

Contributors: Benedikt Strajnar (SI) 2.5, N. Kastelec (SI) 2.5, A. Stanesic (CR) 0.5,

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: *Algorithms for surface assimilation [SU 1]*

Validation of SEKF surface assimilation with SYNOP observations and operational upgrades

No work reported.

Tuning of CANARI/MESCAN and OI soil assimilation

Degradation of moist screen level parameters in experimental BlendVar suite in winter was investigated at SHMU. An approach to decouple CANARI and atmospheric parameters (decrease ANEBUL, increase SPRECIP and V10MX) was tested (experiment BCTC in Fig. S1.1). With such a tuning the 2m scores improved, however for the wrong reason: the deep soil water reservoir in this setup is diminishing as illustrated in Fig S1.2. Investigation is to be continued.

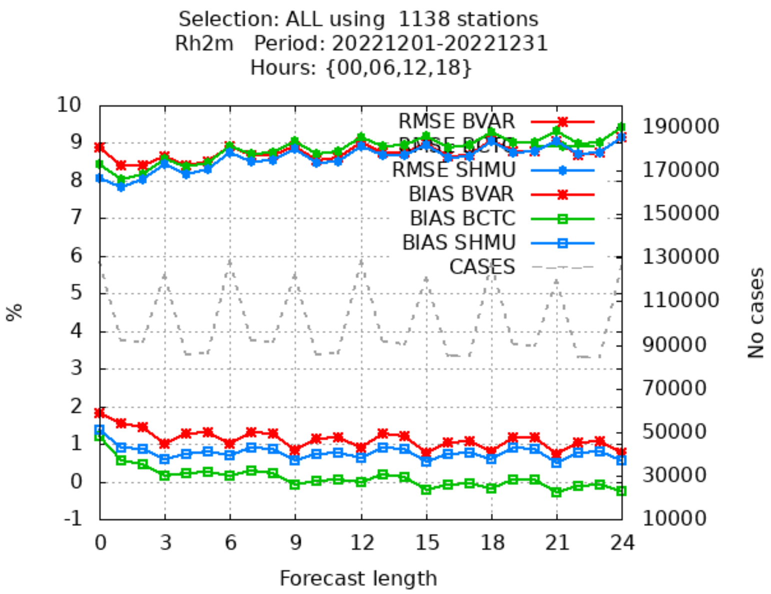

Figure S1.1: Scores of 2m RH for December 2022: operational suite SHMU (blue) at that time, Blend-Var (red) and BlendVar with experimental CANARI tuning BCTC (green).

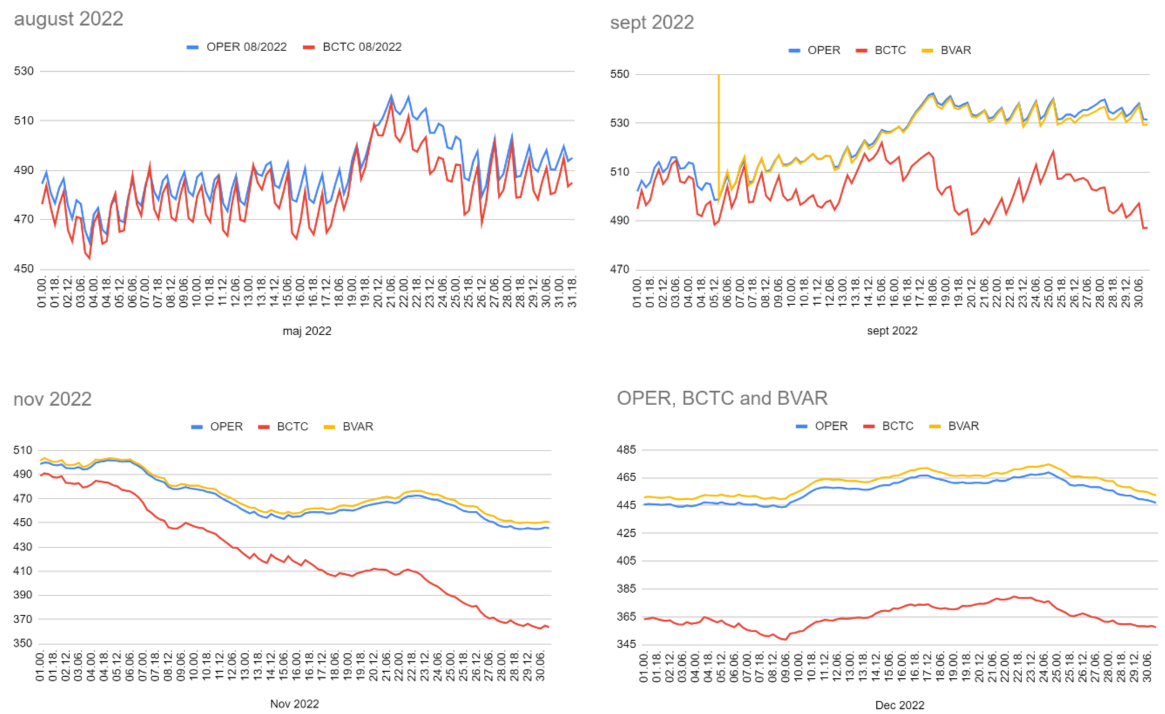

Figure S1.2: Evolution of the deep soil water content reservoir for operational configuration at that time (blue), BlendVar (yellow) and BlendVar with experimental CANARI tuning BCTC (red) for August, September, November and December 2022, respectively.

Antonín Bučánek (CZ) was tuning CANARI for a 3h data assimilation cycling with ALARO physics. The problem to cure is the jumpiness of the T2m forecast from one run to the next in the warm part of the year. It is caused by too large deep soil reservoir increments in CANARI in the warm part of the year. Radmila Brožková (CZ) proposed to modulate deep soil reservoir analysis increments by function depending on the annual cycle of sun declination. This modification itself was not sufficient for 3h cycling so we revived the possibility to average the increments of deep soil reservoirs (in time) in Canari over several runs of the model ("LISSEW"). The lissew key was extended to use up to 24 increments back, for the case of 1h cycling. Averaging of deep soil increments further helped with reducing the jumpiness of forecast. More details are available on the poster at ASW: http://www.accord-nwp.org/IMG/pdf/poster_cz_chmi_asw_2023.pdf

A relaxation towards climatology was switched off (as proposed by Antonio Stanešić) which has a positive effect on the amount of snow in winter and T2m temperature bias.

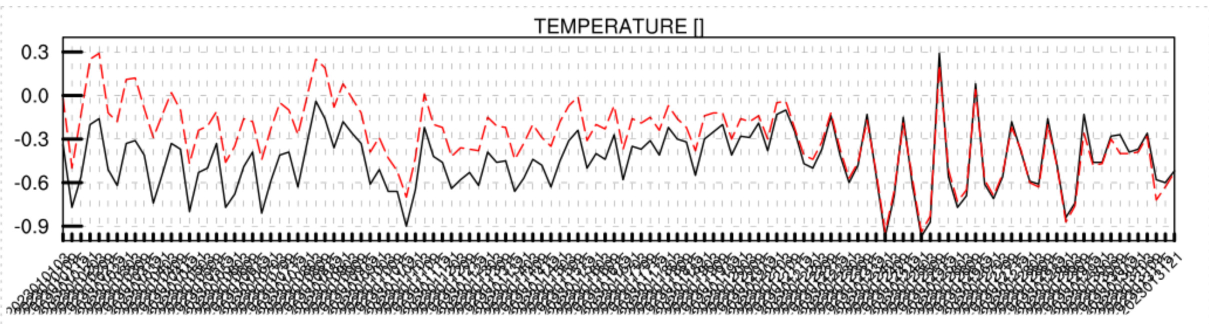

Figure S1.3: Daily evolution of T2m bias of guesses in 3h cycling, period of January 2023. Black line is

3h cycling with relaxation to climatology 0.045 while the red line is the same setting without relaxation.

When preparing a parallel suite with 3-h cycling, it was found that turning off relaxation to climatology has a detrimental effect on the 2m temperature bias during autumn. To overcome this bias, the relaxation to the climatology was turned on again, but with half the coefficients of the 6-h cycle. Relaxation into the snow remained off. The new 3-hour cycling strategy was launched to operations in February 2024. The work was done by Antonín Bučánek (CZ) and Radmila Brožková (CZ).

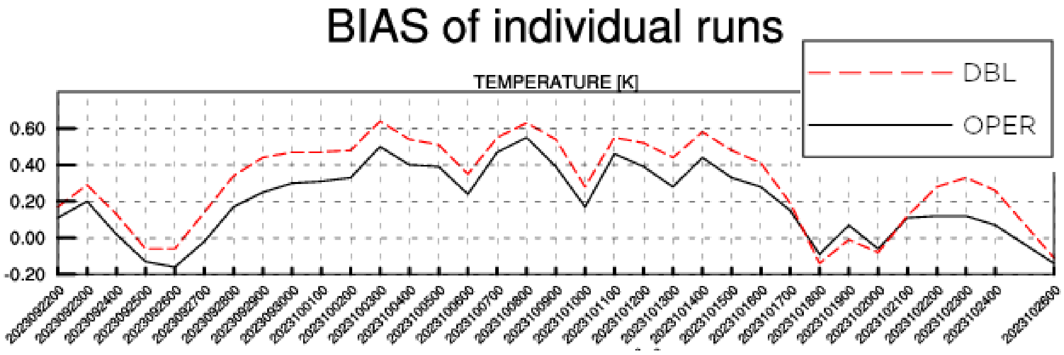

Figure S1.4: Daily evolution of T2m bias of forecasts +6h in 3-h cycling, period of October 2023. Black line was operational 6-h cycling with relaxation to climatology 0.045 while the red line is 3-h cycling without relaxation.

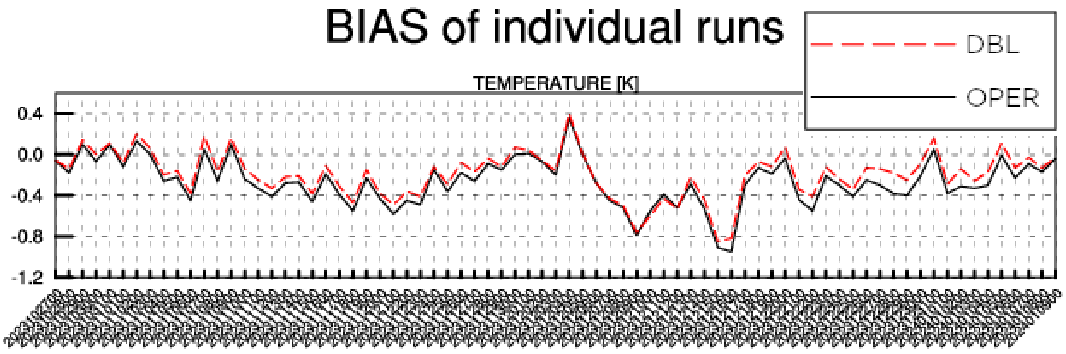

Figure S1.5: Daily evolution of T2m bias of forecasts +6h in 3-h cycling, period of November 2023-January 2024. Black line was operational 6-h cycling with relaxation to climatology 0.045 while the red line is 3-h cycling with relaxation 0.0225.

Alina Dumitru (RO) continued the work related to the implementation of surface data assimilation to the operational chain. A set of CANARI experiments were made after resolving errors related to GNU complier used in Romania. The experiments were set up as follows: cy43t2bf10, 4km horizontal resolution, 60 vertical levels with a 6-h cycling. In the first experiment (EXP1) CANARI was run for the May-August 2023 period where an improvement of surface parameters could be observed. To get a bigger impact in forecast another three experiments with different versions of ISBA polynomes were run for July 2023, see Table S1.1. The impact on the first 30 hours of forecast could be observed in the following two figures. Further work: new experiments are ongoing in order to find out the most optimal solution, and some case studies will be investigated

Table S1.1: Differences between ISBA polynomes files

Name of experiment	EXP1	EXP2	EXP3	EXP4
Version of analyse.isba file	Analyse.isba02	Analyse.isba03	Analyse.isba04	Analyse.isba05
Origin of the analyse.isba file	From Meteo-France	From Meteo-France	Create based on analyse.isba02 file where values from third column on were multiply by 2	Create based on analyse.isba03 file where values from third column on were divided by 2

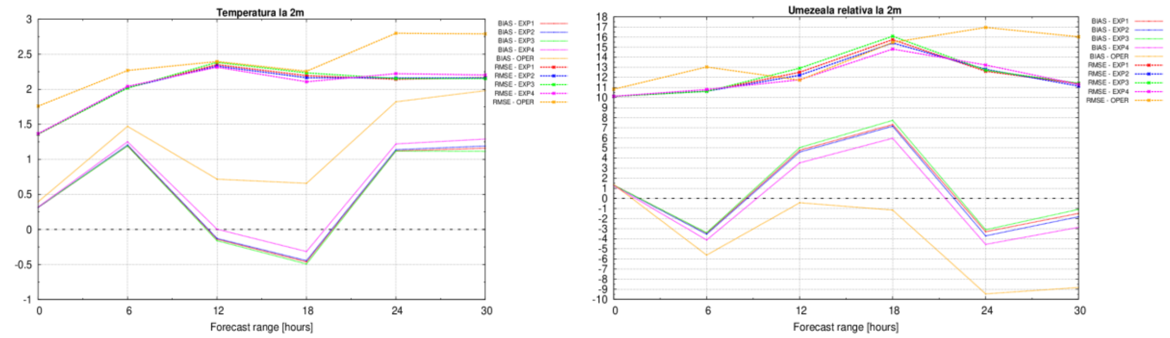

Figure S1.6: BIAS and RMSE for 2m temperature (left) and 2m relative humidity (right) for July 2023, 00 UTC where orange is the current operational configuration, EXP1 red, EXP2 blue, EXP3 green and EXP4 magenta.

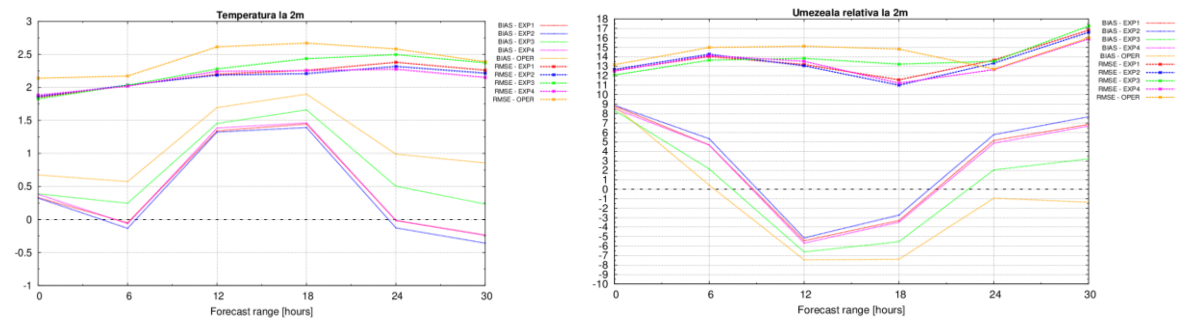

Figure S1.7: BIAS and RMSE for 2m temperature (left) and 2m relative humidity (right) for July 2023, 12 UTC where orange is operational configuration, EXP1 red, EXP2 blue, EXP3 green and EXP4 magenta.

Total efforts: 7.25 months

Contributors: M. Derkova (SK) 0.25, A. Bučánek (CZ) 2.5, R.Brožková (CZ) 1, A. Stanešić 0.5, V. Tarjani (SK) 2.75, A. Dumitru (RO) (reported in DA3 5pm), F. Meier 0.25, M. Szczech (PL) (reported in DA3 4pm),

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: *Use of observations in surface assimilation [SU 2]*

Assimilation of soil moisture products for use in surface data assimilation [SCATSAR-SWI] (combined Sentinel-1 + ASCAT product)

In Austria it is planned for soil moisture monitoring to run stand-alone SURFEX (GIT SURFEX-NWP v8.1) forced with atmospheric forecasts from AROME (cy43t1) on a daily basis. For this purpose, the newest version of SCATSAR-SWI shall be assimilated with SEKF. So far, the satellite data pre-processing, mainly the re-projection of data has been done (work of Stefan Schneider (AT)).

During a stay at OMSZ, Matjaž Ličar (SI) performed an inline data assimilation experiment of satellite based superficial soil moisture observations with SURFEX. The observations used are available in the form of the H08–SM-OBS-2 (H08) satellite product provided by EUMETSAT. This product is based on ASCAT measurements onboard Metop satellites. Downscaling and processing of raw data at 25 km resolution is performed at GeoSphere, which results in a superficial soil moisture product at 1km resolution. This product is available in near real time two times per day, when the satellite passes central Europe. The setup of the assimilation experiments was based on the operational AROME model at a 2.5km resolution used at OMSZ. The 3h assimilation cycle consists of 3Dvar assimilation for upper air, as well as surface assimilation using SODA with the SEKF algorithm. SODA updates the SURFEX soil fields by treating the CANARI analysis of T2m and RH2m as observations. Three experiments were performed for a period 31 days from 2023-05-01 to 2023-05-31, with a 7 day spin up period. The experiments were identical in all but the treatment of surface assimilation. The first experiment was identical to the operational AROME model. In the second surface assimilation was omitted. In the third experiment, data assimilation of satellite based SSM was performed using SODA/SEKF, with 4 control variables (TG1,TG2,WG1 and WG2), performed at 09h and 21h. Forecast with the range of 24h were performed at 00 and 12 for all experiments for validation purposes. We have shown that due to the near real time nature of the satellite observations, the use of such a product is feasible in an operational setting. The neutral or even deteriorated results of the experiments are however not yet satisfactory. More details in RC LACE stay report.

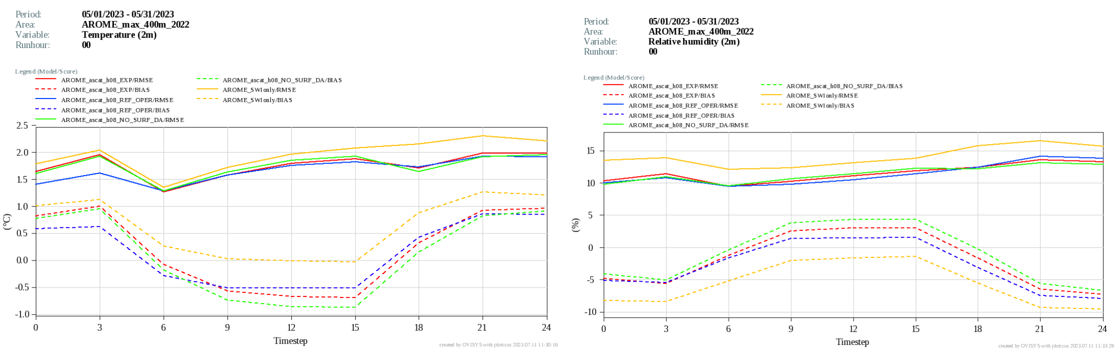

Figure S2.1: Bias (dashed) and RMSE (solid) of T2m (left) and RH2m (right) with respect to synop observations as a function of lead time for operational AROME reference (blue), case with no surface DA (green), experiment with satellite SSM DA (red for σ_{obs}=0.4, yellow for σ_{obs}=0.1).

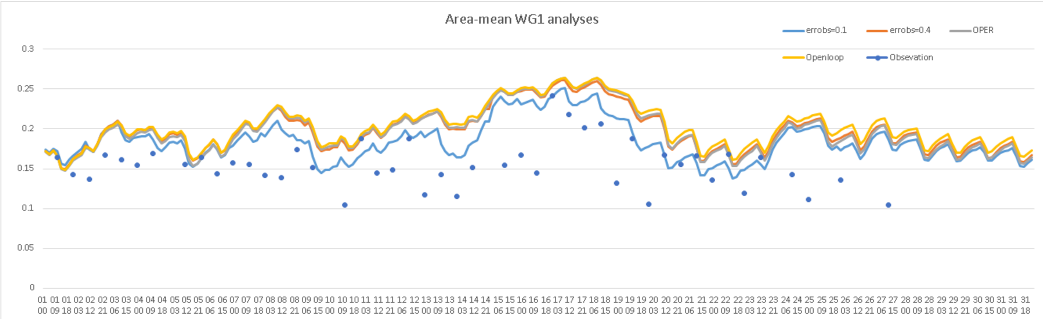

Figure S2.2: Analyses of surface soil moisture layer WG1 for SSM DA experiments (blue for σobs=0.1, red for σobs=0.4), experiment with no surface DA (yellow), operational reference experiment (grey) and satellite SSM observations (points). Averaged for 116 locations.

MetOp-B is a quasi-polar satellite, it orbits at an altitude of 800 km and has been making measurements since 2012 [1]. The satellite carries the Advance SCATterometer (ASCAT) instrument, which measures backscatter, at a frequency of 5.255 GHz. It passes over Europe twice a day, around 9 and 19 UTC. EUMETSAT produces near-real time soil moisture data based on it in the framework of the H-SAF collaboration [2]. In this study, Helga Kolláthné Tóth (HU) used the H08 superficial soil moisture products expressed in percentage, valid for the European region, at a horizontal resolution of 1 km. Several studies deal with the assimilation of ASCAT soil moisture values (Mahfouf, 2010; de Rosnay et al., 2013), demonstrating its positive impact on analyses and forecasts. To prepare the observations for assimilation, the first step is to interpolate the raw satellite data to the Lambert grid used by the AROME/HU, and convert the percentage values to volumetric water content data. In addition, the systematic error of the soil moisture measured by ASCAT and modeled by AROME are different, so the satellite observation data must be calibrated. For this purpose, we used a CDF matching technique (Scipal et al., 2008). The data assimilation runs were performed with AROME cy43t2, with 2.5 km horizontal resolution and 60 vertical levels. The test period lasted from 1 to 31 May 2023 with 1-week spin-up. We used 3-hourly assimilation in the upper air, while several settings were tested on the surface (Table 1). We tested different values for observation and modelling errors based on Mahfouf, (2010) and de Rosnay et al. (2013).

Table S2.1: Main characteristics of the experiments.

Experiments	**REF ("OPER")**	**ECM (de Rosnay, 2013)**	**JFM (Mahfouf, 2010)**	**HYB**
Observations	SYNOP T2M, HU2M	ASCAT SM	ASCAT SM	SYNOP T2M, HU2M ASCAT SM
Control variables	WG1, WG2, TG1, TG2	WG1, WG2	WG1, WG2	WG1, WG2, TG1, TG2, WG1, WG2
Observation errors	1K, 7%	0.05 m3/m3	0.06 m3/m3	1K, 7% 0.05 m3/m3
Model errors	0.1 m3/m3, 0.15 m3/m3, 2K, 2K	0.01 m3/m3 , 0.01 m3/m3	0.06 m3/m3, 0.03 m3/m3	0.1 m3/m3, 0.15 m3/m3, 2K, 2K 0.01 m3/m3

Analyses (UTC)	00, 03, 06, 09, 12, 15, 18, 21	09, 18, 21	09, 18, 21	SYNOP: 00, 03, 06, 12, 15 ASCAT: 09, 18, 21
Forecast	00 UTC + 24h	00 UTC + 24h	00 UTC + 24h	00 UTC + 24h

Figure S2.3 shows the root-zone soil moisture analysis by the end of May, for the whole domain. Large differences can be observed in the soil moisture values of the runs containing SYNOP data and those assimilating only ASCAT data at the end of the month. There is a larger dry patch in the middle of the domain, which is quite noticeable in the REF and HYB experiments, but much less dry in the ECM and JFM runs. At the same time, the REF and HYB experiments produced much higher soil moisture values in Eastern part of Hungary than the ECM and JFM runs using only ASCAT data. The research continues by testing joint assimilation of SYNOP and ASCAT data (when both are available) and by tuning the model errors.

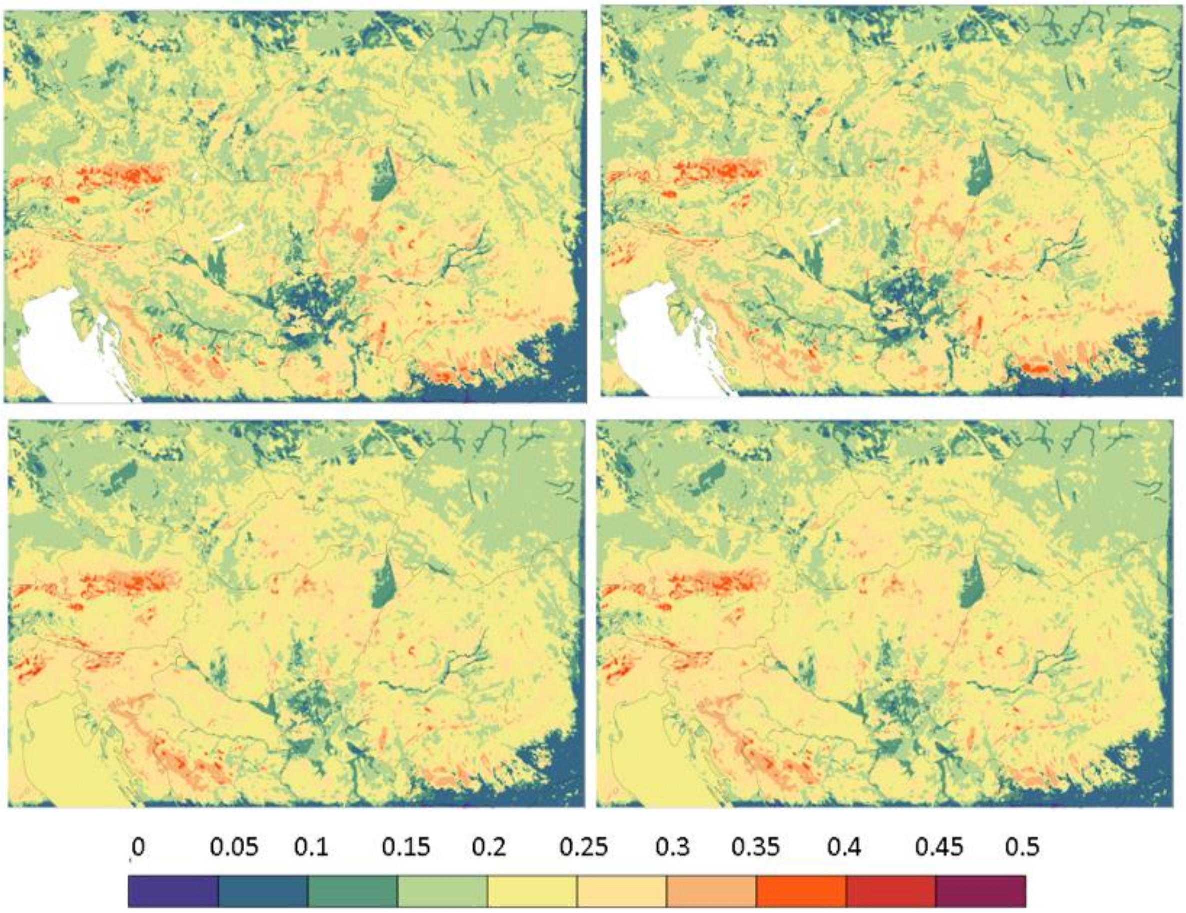

Figure S2.3: Soil moisture (WG1 and WG2) analyses at 00 UTC on 31 May 2023 (top left: REF, top right: HYB, bottom left: ECM, bottom right: JFM).

Assimilation of Synop snow observations (SU2.7)

Florian Meier (AT) found that FG check for Synop snow height in CANARI is independent of station height and therefore mountain peak station data often get rejected due to higher total snow amounts and therefore higher errors and higher station-model orography deviations. Therefore, a switch to make the rejection limit height dependent was implemented in local cy43t2, but is not yet in the common code. Swiss SRF opened access to daily snow height measurements (about 100 stations).

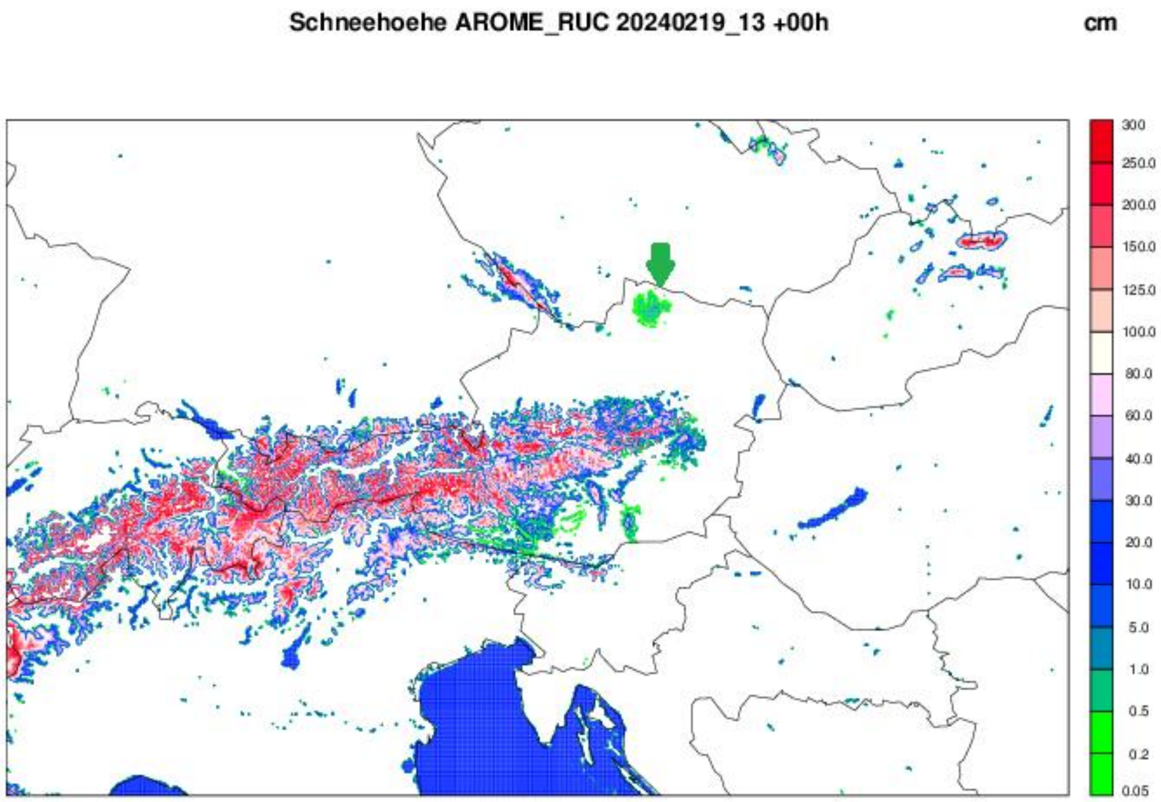

Figure.S2.4: Snow height in AROME-RUC. The snow in Northern Austria (green arrow) is caused by wrong station value (in reality no snow).

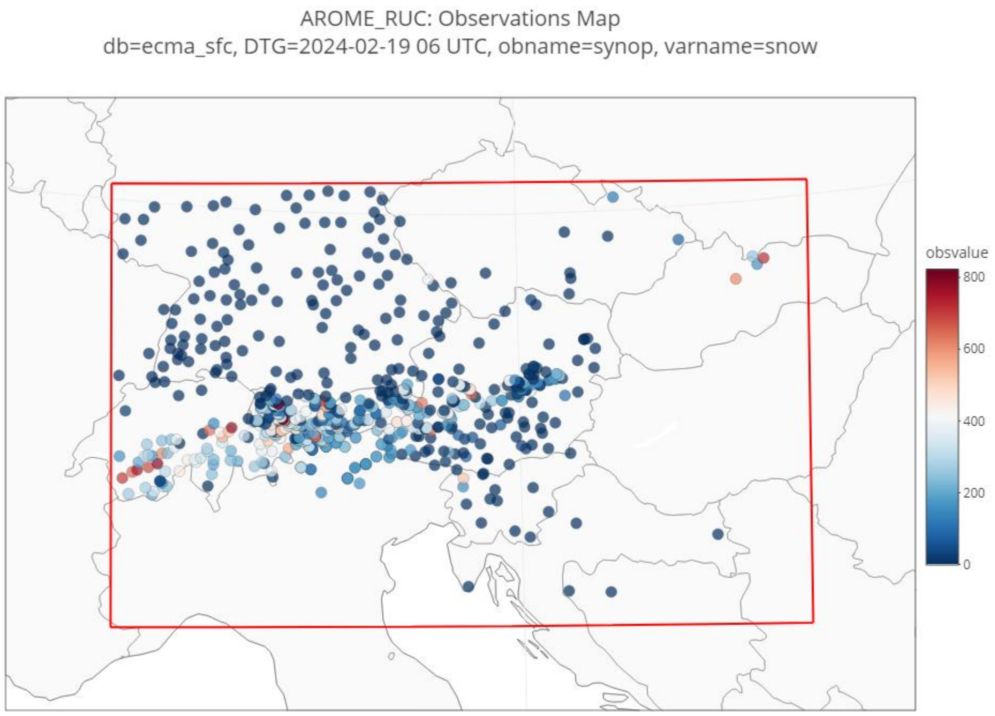

Figure S2.5: Snow observations in CANARI OIMAIN at 06 UTC.

It is planned to implement snow assimilation in AROME/HU. In the first step only in-situ observations will be assimilated and the CANARI assimilation routine LAESNM=T will be used. As a starting point, snow observations in Hungary were studied by Balázs Szintai (HU). There are around 100-200 snow observations locations per day in Hungary, however, these are mostly citizen observations and only 14 stations are maintained by HungaroMet personnel. According to the internal regulations of HungaroMet, all snow observations have to be checked by human data controllers before these can enter the database. This creates a considerable delay in availability of the observations. Snow observations are usually done at 05:45 UTC, but due to human check they enter the observation database between 08:00 and 10:00 UTC, this is too late for the 06:00 UTC assimilation cycle. The situation was discussed with the Hungarian observation team and soon there will be a new variable in the SYNOP BUFR (csbs) file containing the uncontrolled Hungarian snow observations (with no time delay). Another difficulty was the coding of Hungarian snow observations in the SYNOP BUFR (csbs) file. These are not coded as part of the standard SYNOP message but have a different attribute (source=8). Consequently, OPLACE was modified by Alena Trojáková (CZ) to ingest these data. With the modified version of OPLACE a one month period from February 2023 was rerun. The new OBSOUL files were tested in AROME/HU (cy43t2). However, it seems that snow assimilation is not working properly in this cycle. The plan is to continue the work with cy46 as soon as this is available in Hungary.

Assimilation of LAI within SEKF in AROME/SURFEX, impact experiments (SU 2.8.1)

In Austria AROME (cy43t1 with modifications in SURFEX 8.0 to run prognostic LAI) was tested with LAI assimilation to test the impact on forecast quality. There have been several model setups (AROME with 1 patch, 12 patches, 12 patches with prognostic LAI, high-resolution land cover data instead of ECOCLIMAP). LAI observations, based on Sentinel-2 data, have been interpolated to the model grid and were assimilated either for the average LAI or separated for broadleaf forests (P4), needle leaf forests (P5) and grassland (P10). For the latter, the SEKF code in SURFEX (mainly assim_nature_isba_ekf.F90) has been modified.

The impact of the assimilation was tested against AROME forecasts of 2m temperature and rainfall at Austrian weather stations. The experiments indicate that a good representation of vegetation is relevant to improve model forecast quality. While the impact for screen-level parameters (e.g. 2m temperature) is strong and positive, precipitation is only slightly affected. It can be concluded that vegetation influences convection, but it is just one parameter among many others (work of Stefan Schneider).

Figure S2.4: Validation of AROME forecasts with the reference run (green – 1 patch, no assimilation), prognostic LAI (purple) and LAI assimilation (blue).

Total efforts: 9.75 months

Contributors: S. Schneider (AT) 2, M. Ličar (SI) 1.75, H. Tóth (HU) 3, Balázs Szintai (HU) 2.5, A. Trojakova (CZ) 0.5

Documentation: /

Status: ONGOING

Documents and publications

Publications:

- Smerkol, P., Švagelj, V., Zgonc, A., and Strajnar, B.: Validation of torus mapping method for dealiasing Doppler weather radar velocities, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1182, 2023. Online discussion.
- Scheffknecht and Wittman, 2023: Assimilation of Microwave Link Signal Attenuation as Precipitation Rates using Machine Learning, 1D-VAR and 3D-VAR, ACCORD Newsletter 4, 25-32.

Stay reports:

- S. Panežić: Sensitivity studies of reflectivity assimilation impact in ALARO with focus on the drying effect, 30th January - 24th February 2023, Prague. https://www.rclace.eu/media/files/Data_Assimilation/2023/repStay_SPanezic_reflAssim_CHMI_2023.pdf

- M. Ličar: Inline data assimilation of ASCAT SSM using SODA/SEKF, 5th June - 30th June 2023, Budapest. https://www.rclace.eu/media/files/Data_Assimilation/2023/repStay_MLicar_SWIAssim_OMSZ_2023.pdf

RC LACE DA at 3rd ACCORD All Staff Workshop 2023, 27 March – 31 March 2023, Tallin

List of presentations:

- WEIDLE Florian: Assimilation of train-based ZTD observations in AROME-RUC
- SMERKOL Peter: Validation of torus mapping method for dealiasing Doppler weather radar velocities
- STRAJNAR Benedikt: Data assimilation activities in RC LACE

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

Activities of management, coordination and communication

1) Joint 3rd ACCORD all staff workshop 2023, 27-31 March 2023, Tallin,
2) Attendance to 1st ACCORD DA working days on DA diagnostics and OOPS, 20 – 23 June 2022, Barcelona, KNMI, De Bilt.
3) Attendance to 2nd ACCORD DA working days on satellite observations, diagnostics and implementation support, 20 – 23 June 2022, IPMA, Funchal.
4) Informal LACE DA meetings (2nd Wednesday every two months),
5) ACCORD DA RD topical meetings,
6) LSC meetings.

Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized	Planned	Realized
Operational implementation of DA suites [COM3]	8.0	16.00		
Further development of 3D-Var [DA 1]	18.5	10.50		
Use of existing observations [DA 3.1] – radar	16.5	19.00	2	2
Use of existing observations [DA 3] – other data types	9.5	9.00		
Use of new observations types [DA 4]	6.0	16.00		
Participation in OOPS development [DA 6]	5.0	1.75		
Observation pre-processing and diagnostic tools [DA 7]	3.0	5.50		
Algorithms for surface assimilation [SU 1]	9.0	7.25		
Use of observations in surface assimilation [SU 2]	17.5	9.75	1	1
Total	**93.0**	**94.75**	**3**	**3**

Problems and opportunities

The main problems in 2023 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.