Working Area Data Assimilation

Progress Report

Prepared by:	Area Leader Benedikt Strajnar
Period:	2022
Date:	1/3/2023

Progress summary

The report summarizes the RC LACE DA activities in 2022, with highlights on use of additional observations, mainly the radar data, and implementation/refinement of hourly assimilation systems suitable for NWP supported nowcasting.

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 radar stays were executed (one remotely). RC-LACE is now on a good track to reach satisfactory results with radar reflectivity, although the overall drying effect when using all radar observations still has to be fully resolved and eliminated. At the same time, considerable steps were made to reach and provide a robust solution to radar dealiasing, to be able to use at least part of radar Doppler winds in some countries (Slovenia, Croatia). A stand-alone preprocessing software is meant for easier handling and consolidation of those developments to be shared within members.

The potential value of other observation types has been continuously investigated, among others the microlinks (rain information), InSAR and ZTD delays (humidity profile).

Significant efforts in Hungary to validate of SEKF and related use of surface observations resulted in the first operational implementation of SEKF.

Substantial efforts were still invested into tuning of assimilation in the new models setups (e.g. extensions to 90 levels in AROME Hungary) and validation of BlendVAR as future operational algorithm in Slovakia.

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

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 2022):

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

DA	AUSTRIA AROME	CROATIA AL-ARO	CZECH REP. ALARO	HUNGARY ALARO	HUNGARY AROME	SLOVAKIA AL-ARO	SLOVENIA AL-ARO
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	43t2bf10	43t2ag_op2	cy43t2bf11	cy43t2bf11	cy43t2bf11	43t2_bf10

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	OI + DF Blending	OI + 3D-Var
Cycling	3h	3h	6h	6h	3h	6h	3h
B matrix	EDA on C-LAEF	EDA	EDA	EDA	EDA	-	Downscaled ECMWF ENS
Initialization	No (SCC)	No (SCC)	IDFI in production, SCC	DFI	No	No	No (SCC)
Obs.	Synop + AS Amdar/ Mode-S EHS EU Geowind Temp ASCAT, Snowgrid/MODIS snowmask.	Synop Amdar/MRAR Geowind Temp Seviri	Synop + AS (soil) Amdar/MRAR /EHS-EU) AMV/HR, Profiler, ASCAT, Temp Seviri,	Synop + AS Amdar Geowind Temp, Seviri AMSUA/MHS	Synop + AS GNSS ZTD Amdar/Mode -S MRAR Temp AMV+HRW	Synop + AS	Synop + AS Amdar/MRAR/ EHS Geowind Temp Seviri AMSUA/MHS/IASI ASCAT/OSCAT E-GVAP ZTD (passive)

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

DA	AUSTRIA AROME-RUC	CZECH REP. VarCanPack	SLOVENIA ALARO-RUC
Resol	1.2 L90 900 x 576	2.3L87-NH 1069 x 853	1.3L87 589x589
Cycle	43t2bf11	43t2ag_op1	cy43t2bf10
LBC	AROME 1h	-	ECMWF 1h
Method	OI_main MESCAN + 3d-Var + LHN + FDDA	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/MRAR/EHS national, EHS EMADDC, Geowind, Temp/BUFR Temp, 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, ceilometer	Synop + AS, Amdar/MRAR/EHS, Geowind/HRWIND,Profiler, ASCAT, Seviri	SYNOP + AWS, AMDAR/MODE-S MRAR/EHS, AMV, TEMP, SEVIRI, AMSU-A/MHS/IASI, ASCAT/OSCAT, OIFS radar reflectivity

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

DA	AUSTRIA C-LAEF	LACE A-LAEF
Resol.	2.5 L90, 600 x 432	4.8 L73, 1250 x 750
Cycle	43t2bf11	40t1
members	16+1	16+1
LBC	IFS-EPS	IFS 6h (lagged)
Method	OI_main MESCAN + 3d-Var, pert. obs. + Jk	DF blending + ESDA
Cycling	3h	12h
B matrix	EDA on C-LAEF	-
Initialization	No	No
Obs.	Synop + AS, Amdar, Geowind, Temp, ASCAT, Snowgrid/MODIS	Synop + AS

In **Austria**, a modification to 2m diagnostics (CANOPY) was applied to reduce bias in summer 2022. Model version cy46t1 export was successfully compiled (Masterodb, Bator, Blend, Blendsur, Oovar), and also other components (927/001) and OOPS versions (EnVar and Hybrid EnVar) are technically working at ZAMG and new ECMWF. The ceilometer observations from

53 stations are converted to pseudo relative humidity point observations taking into account cloud height and cover observation and model critical humidity profile and quality checks against model/satellite and then assimilated as obstype 6 RH. This can be used in the case of missed low stratus clouds (see also 2022 ACCORD workshop poster). A parallel run of AROME-Aut using all satellite observations from RUC (MSG WV, IASI, MW) and GNSS-ZTDs in passive mode was set up. Further it includes the assimilation of ceilometers as pseudo RH (obstype 6) in active mode. The results, especially cloudiness are promising, but further evaluation is needed to put it to operations. A first B-Matrix for a future 1km C-LAEF/AROME was calculated using NMC method and new festat from cy46t1 without FEMARS. In the RUC system, lake initialisation was again slightly modified to avoid too warm lakes in summer. Input for windfarm parameterization was extended and updated using additional datasets (Open street map, various German open data).

In the **Czech Republic**, the fully prognostic graupel was implemented in May 2022. The screening for aircraft data was optimised (speeded up 3 times on vector-HPC minor change on scalar-HPC platforms). The format change of SEVIRI data from GRIB to netCDF was tested offline with neutral scores (to become operational in early 2023). Porting of the export cy46t1 is ongoing.

In **Croatia**, migrations to the new HPC was completed at the beginning of February 2023. Model version 43t2bf10 is now used operationally which concludes this upgrade in RC LACE. DHMZ is also the first member to apply large-scale constraint Jk to operational data assimilation.

In **Hungary**, a lot of development work, registered mainly under COM3.1, was invested into validation of the components of the future hourly assimilation cycle with AROME on 1.3 km resolution and 90 vertical levels. ECHKEVO diagnostics were run to investigate the spin-up time of AROME on 1.3 km resolution but the results were not valid for all variables. It was concluded that the points in mountainous areas have longer spin-up time with higher amplitude compared to points over flat area. The ensemble data assimilation (EDA) technique was used to compute the background error statistics. Forecast experiments were run to check the impact of using different B-matrices on the forecast quality. Testing the new B-matrix will continue for several periods. After investigations, use of AMV was switched on in operational AROME.

In **Slovakia**, tuning of the 3D-Var SIGMA_COEF and REDNMC by Tune BR package for the operational SHMU/SK domain. The long term experiments and case studies were performed. Validation of cy46t1 DA components were performed, most work was spent on CANARI debugging. BlendVar (DF blending + 3D-Var using SYNOP+AWS, TEMPs, HRW, AMDAR+Mode-S) is in the e-suite with promising results, with a target for operations in Q1/2023. 1-km hourly RUC with 3D-Var is under construction.

In **Slovenia**, the 1.3 km 1h AROME_RUC was implemented in the operations. Products for forecasters were prepared, and prototypes of more advanced validations such as joined “stamp” plots of different runs compared to radar images and contours of strong echo cores from multiple runs. The system uses radar reflectivity DA with local adaptations of the algorithm and several radar stations, the new Croatian radars on the Adriatic coast were also progresivelly included. It was decided to skip the upgrade to CY46t1_export, apart from validation the OOPS components.

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

In **Poland,** the activities towards the first assimilation suite are ongoing, the model cycle 43t2_bf10 will be used.

Contributors: All (approx. 1 PM per country, more in some institutes – OMSZ 3.5)

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

Description and objectives:

Validation of BlendVar algorithm, increasing the assimilation cycle from 6h to 3h [DA 1.5]

At **SHMU**, the tuning and evaluation of the BlendVar e-suite of ALADIN/SHMU (ALARO, 4.5km/L87) continued. Although the BlendVar scores with respect to the OPER (DF Blending) are in general better, two problems were identified: i) worsening of screen level parameters BlendVar scores in winter (see Fig. 1.1, top), ii) worse BlendVar scores of dew point temperature ~300 hPa (Fig. 1.1, bottom). Impact of individual observation types is being evaluated to identify possible sources of the problem.

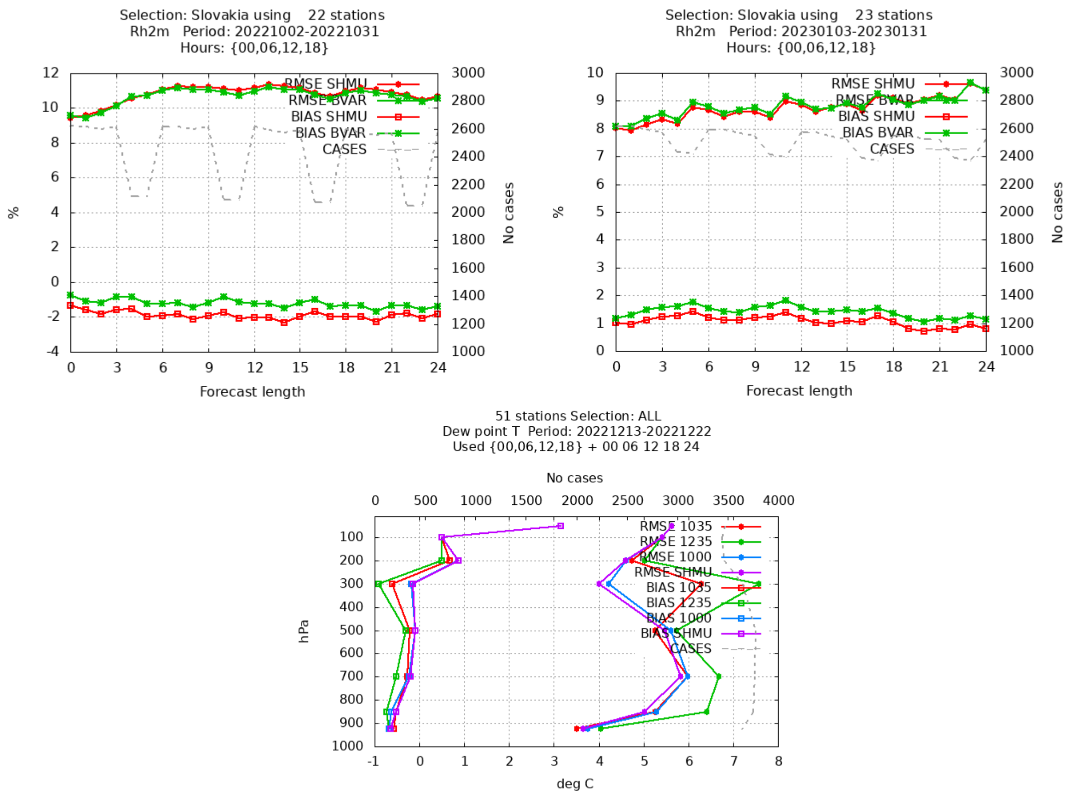


Figure 1.1: RH2m scores over Slovakia in October 2022 - BVAR better than SHMU OPER (upper–left) and December 2022 - OPER outperforms BVAR (upper right). Bottom: vert. profile of Td scores when different obs. types were used in BVAR, with respect to SHMU OPER DF Bending.

In a separate experimentation, the large-scale contribution from DF blending vs. 3D-Var in the experimental setup of ALADIN/SHMU (ALARO, 4.5km/L63) was evaluated. Two experiments were performed where the order of Blending and 3D-Var steps was swapped (BlendVar vs. VarBlend). E-suite and case studies have been run and several diagnostics (ECHKEVO, ECTOPLASM) were checked. No difference between BVAR and VARB has been identified in the spectra inter comparison. The level of noise checked by ECHKEVO was similar, see Fig. 1.2. No relevant conclusion on VARB outperforming BVAR could be made based on case studies. The e-suite scores were slightly better for BVAR wrt VARB (Fig. 1.3).

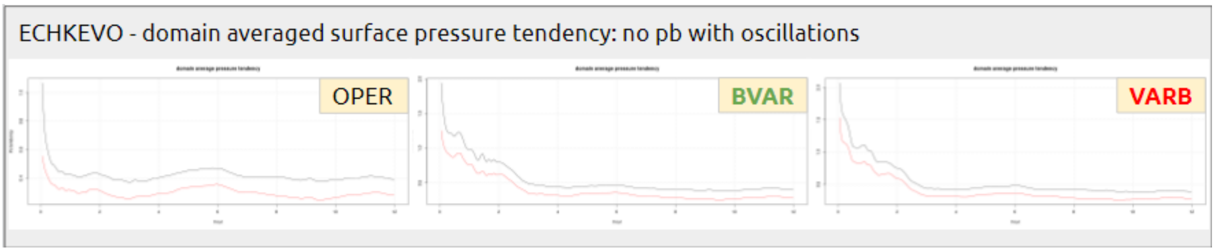


Figure 1.2: Noise in the initial state estimated by Ps tendency of SHMU OPER, BVAR and VARB.

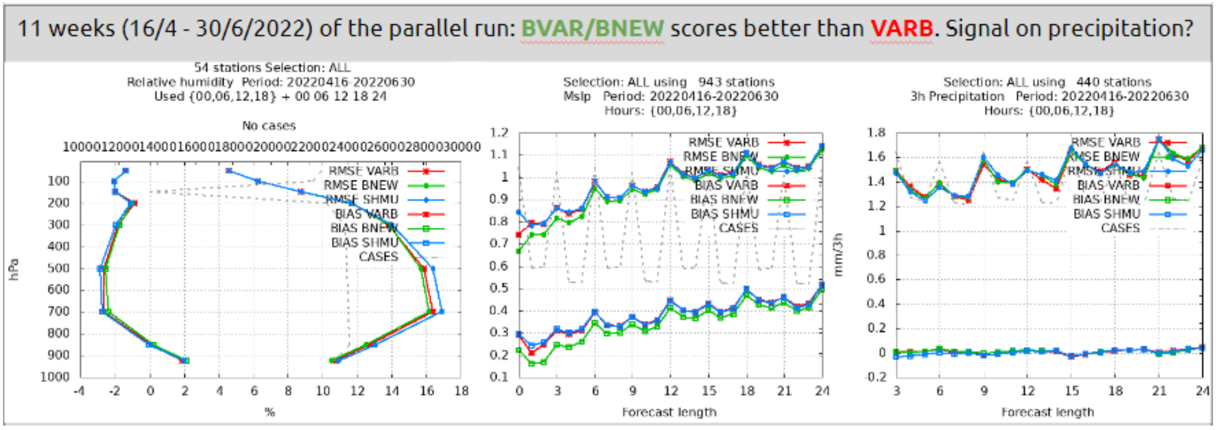


Figure 1.3: Selection of scores of BVAR (here denoted NEWB) vs VARB vs SHMU OPER experiments for RH profile (left), MSLP (middle) and 3h precipitation (right)

Refinements of B-matrix representation (EDA) [DA 1.2]

On top of earlier experiments with spin up B-matrix computation, Antonio Stanešić (CR) and Endi Keresturi (CR) calculated EDA B matrix with the same LBCs - 16 members of IFS ensemble for two-week period in winter (20210209-20210223) and two-week period for summer (20210621-20210704). Ensemble data assimilation with perturbed observations and different LBCs from the global IFS ensemble. Statistics were computed separately for winter and summer. Same sampling strategies were tested as for Bspinup: differences every 3 hours (Bens), differences valid at 00 during winter and 12 during summer (Bens00z12lj) and differences valid at 00/06 winter and 12/18 summer (Bens0006z1218lj). Comparison of Bspinup and Bens shows that for Bens more energy is present at smaller scales. This is the expected result as by adding observation perturbations we expect to generate more energy at smaller scales. Background error standard deviations are generally larger for ensemble B then Bens with rather similar shape. Overall obtained results are expected for methods used to generate forecast differences. As for the sampling strategy the best results are obtained by using 00/06 and 12/18 differences which gives less smoothed diagnostics. Tuning was done using the method proposed in Desroziers et. al (2005), using the TuneBR package. Scripts were adapted to our local environment and MANDALAY was replaced by a call to odb_legacy (odbsql.x). At first data assimilation cycle (3h) using Bens and synop, amdar, mode-s mrar si/ch, geowind, temp and Seviri data was set up with Bens, REDNMC=0.7 and SIGMAO_COEF=1 for all obstypes. Cycling was performed for the period 01.05.2021 – 15.06.2021 and the period from 15.05 - 15.06.2021 was used for diagnosing observation error standard deviations (so) and background error standard deviations (sb). Final output of calculations in this package are ratios of diagnosed and predefined values for background (rb) and observations error (ro). These ratios are presented for several variables averaged over height and as averages over all variables weighted by the number of data. From these ratios new REDNMC can be obtained as REDNMCnew = rb * REDNMC. For observation error, tool returns diagnosed values per variable and averaged over all obstypes. On the other hand tuning is possible via SIGMAO_COEFF (Bator, Screening, Minimization namelists) where one can modify values of observation errors per obstype (one SIGMAO_COEF value for obstype multiplies values for all variables in given obstype). Thus, results obtained via this tool does not give us possibility to make obstype dependant tuning rather one value could be used for all obstypes. Several iteration were performed, but instead of getting convergence REDNMC was increasing while SIGMAO_COEF was decreasing with every iteration. The starting values were kept finally.

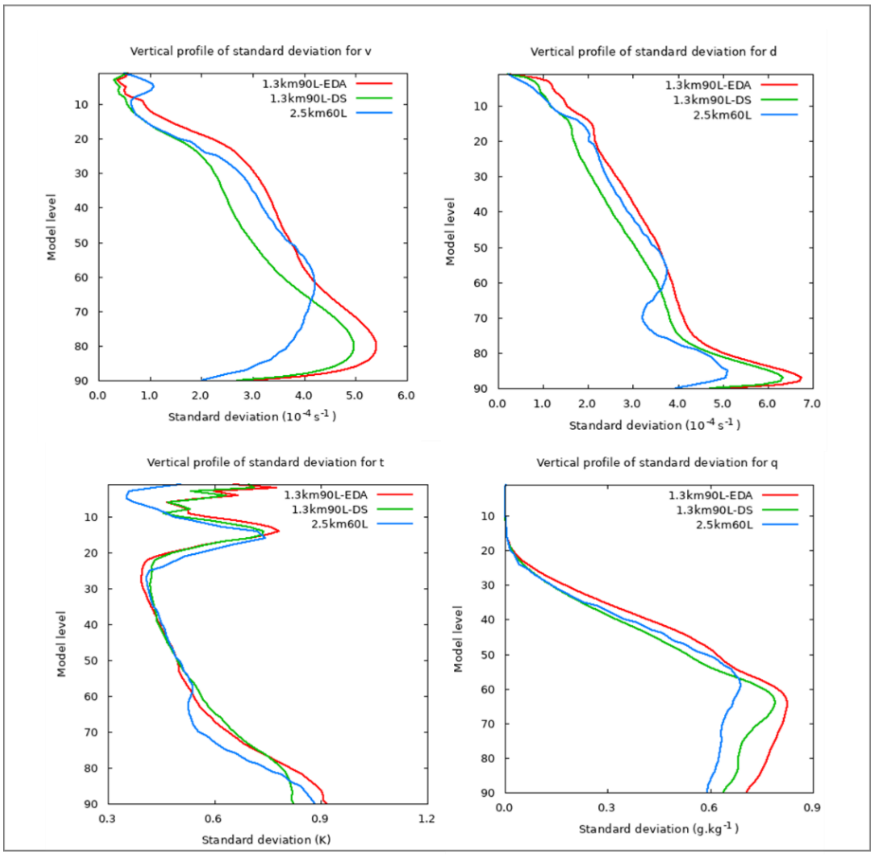


Figure 1.4: Vertical profiles of standard deviation for vorticity (top left), divergence (top right), temperature (bottom left) and humidity (bottom right) in the EDA B-matrix at 1.3 km and 90 levels resolution (red), the downscaled B-matrix at 1.3 km and 90 levels resolution (green), the previously computed (EDA) B-matrix at 2.5 km and 60 levels resolution (blue).

The ensemble data assimilation (EDA) technique is applied at **OMSZ** to compute the background error statistics. Current work is devoted to preparing a B-matrix for 90 levels, suitable for high-resolution data assimilation, including RUC. After having computed the downscaled B-matrix version, a 6-member AROME EDA with perturbed observations was prepared and run over two 15-day periods for summer and winter. Figure 1.4 presents comparison to the 60 level version (with levels adjusted by a factor of 1.5 in order to match similar heights). Overall, the 90-level variances are larger, both for the downscaled and EDA case, especially for levels in the PBL. Impact on scores was also evaluated over 14 days in summer 2021 and showed that use of EDA-based covariance often results in improved results (Fig. 1.5).

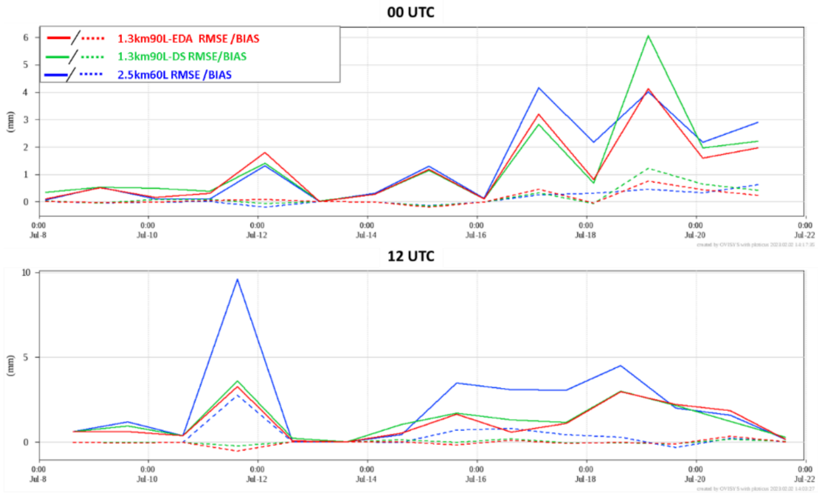


Fig. 1.5: 1-hourly precipitation RMSE (solid lines) and bias (dashed lines) for the third hour of the forecast for 00 UTC runs (top) and 12 UTC runs (bottom).

Evaluation of error statistics for the methods allowing to preserve results of host model analysis in a LAM domain Jk. [DA 1.3]

The impact of Jk and its different configurations were assessed by Endi Keresturi (CR) in the ALADIN-HR4 (4 km, ALARO, cy43 based configuration) assimilation cycle. ECMWF-EPS files (all 4 runs and 0-6 forecast ranges) were interpolated to this domain by doing c903 for two different periods: 9. 2. - 23. 2. 2021 (winter) and 21. 6. - 4. 7. 2021 (summer). Three alternatives of the V-matrix were calculated:

- using +000 (analysis) files from ECMWF-EPS. Differences were calculated using the first 10 members (1-2, 3-4, etc.). 00 and 06 (12 and 18) UTC runs were used from the winter (summer) period. This gives a total number of 290 differences.

- using +003 files. Everything is the same as above.
- using +006 files. Everything is the same as above except that 18 and 0 (6 and 12) UTC runs were used from the winter (summer) period.

Each of these three matrices is used with the appropriate global model analysis/forecast in data assimilation cycle. Three different experiments (to find the optimal configuration for Jk) during the period of one month (15. 5. - 15. 6. 2021; 0 runs have been verified) were done:

- Different values of ALPHAK* coefficients were tested. They control the large-scale impact of each control variable independently. Results indicate that it is better to add more weight to the large-scale variables (vorticity and temperature) and less weight to humidity and divergence. Adding too much weight to the humidity had the effect of drying the model.
- Impact of PRESINFJK and PRESUPJK coefficients were tested. They control the height from which the Jk will start to make an impact. Results indicate that the impact of Jk for surface variables is stronger if it is active closer to the ground.
- Different values of the large-scale cut-off wavenumber (N). Here, a new method of dynamically varying (i.e. flow-dependent) wavenumber was tested (Feng et al., 2020). Results indicate that experiments are not that sensitive to the value of N, and experiment using flow-dependent N is not significantly different from the one using static N. However, the 12 UTC runs and individual cases haven't been investigated yet.

Finally, the impact of Jk itself was assessed over the same verification period. Overall, using Jk has a positive impact on the model forecast (Figure 1.6), mainly visible for upper-air variables; the Jk will be used in operation at DHMZ.

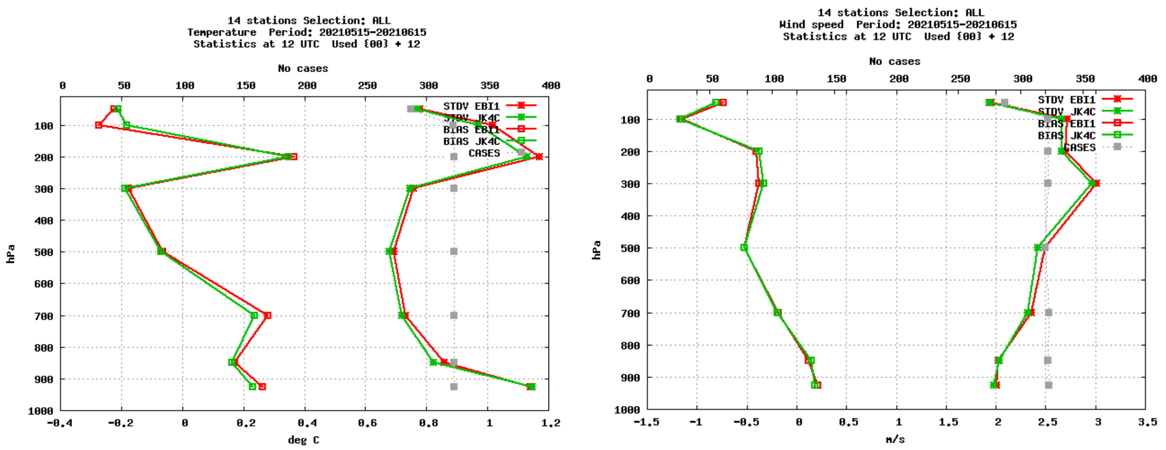


Figure 1.6: Comparison of reference (no Jk; red) and Jk (with Jk; green) experiments for temperature (left) and wind speed (right) for +12 forecast range.

Efforts: 6.75 month

Contributors: A. Stanešić (CR) 1, E. Keresturi (CR) 0.25, S. Panežić (CR) 1, M. Derkova (SK) 1.75, K. Javorne-Radnoczi (Hu) 0.25, D. Lancz (Hu) 0.25, A. Kardos- Varkonyi (Hu) 0.75, B. Strajnar (SI, coord.) 1.5

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Development of flow-dependent algorithms [DA 2]***

Description of tasks:

Make first steps towards 3D EnVar by getting familiar with the relevant OOPS code

Work reported under DA6.

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 (SI), Peter Smerkol (SI) and Benedikt Strajnar (SI) evaluated dealiasing method implemented in HOOF by studying and inter comparing first guess departures of radar radial winds, aircraft winds and radiosonde winds for all analysis times (3-hourly cycle) over year 2021. The goal is to estimate the quality of dealiased winds by multiple collocations 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 dealiasing significantly reduces standard deviation of differences with respect to raw observations, by shifting data from side (aliased) peaks in the difference distribution to the main peak. The spread of distribution becomes comparable to the spread of aircraft-radiosonde distributions. Figure 3.1 shows the inter-comparison for radar sites with NI > 30 m/s, those with NI < 30 m/s and separately for Slovenian radars with NI = 8 m/s. It can be concluded that the dealiased data sets are in general of lower quality, but for the radar that are noise-free, a good quality can be reached. Similar conclusion can be drawn from the first guess departure analysis. Surprisingly, the gain of dealiasing is also visible for radars with higher Nyquist velocity (> 30 m/s) such as in the German radar network (Fig. 3.2). A scientific paper on these results is to be submitted soon, followed by impact experiments.

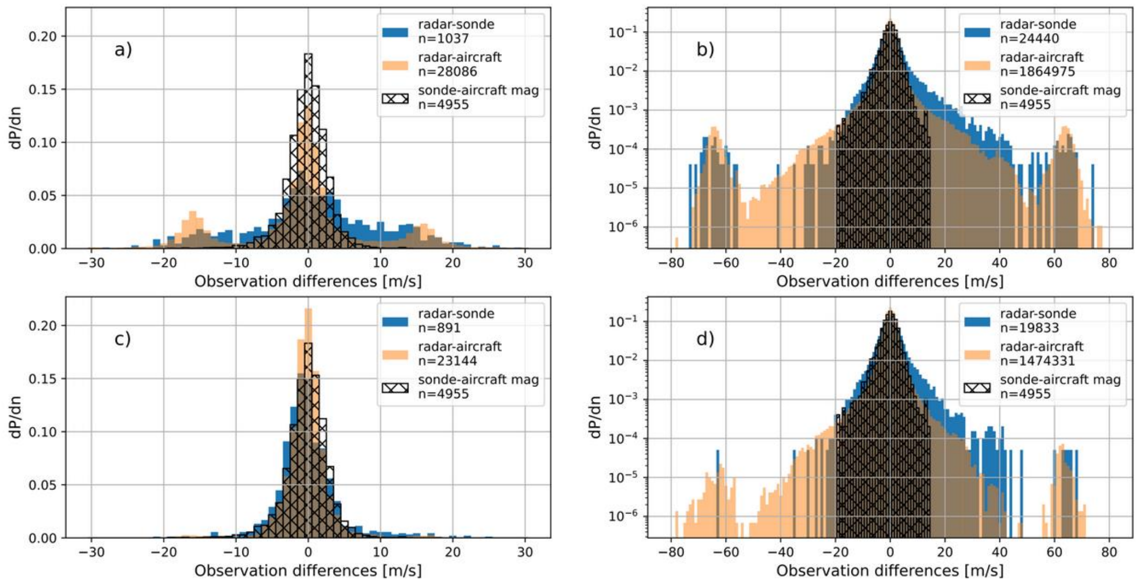


Figure 3.1.: Differences between collocated pairs of observations (ASD, RAD, RSD) for (a) aliased Dataset from Slovenia, (b) aliased Dataset for high NI radars, (c) dealiased Dataset from Slovenia and (d) dealiased Dataset for high NI radars. Note the linear and logarithmic scale on y axis.

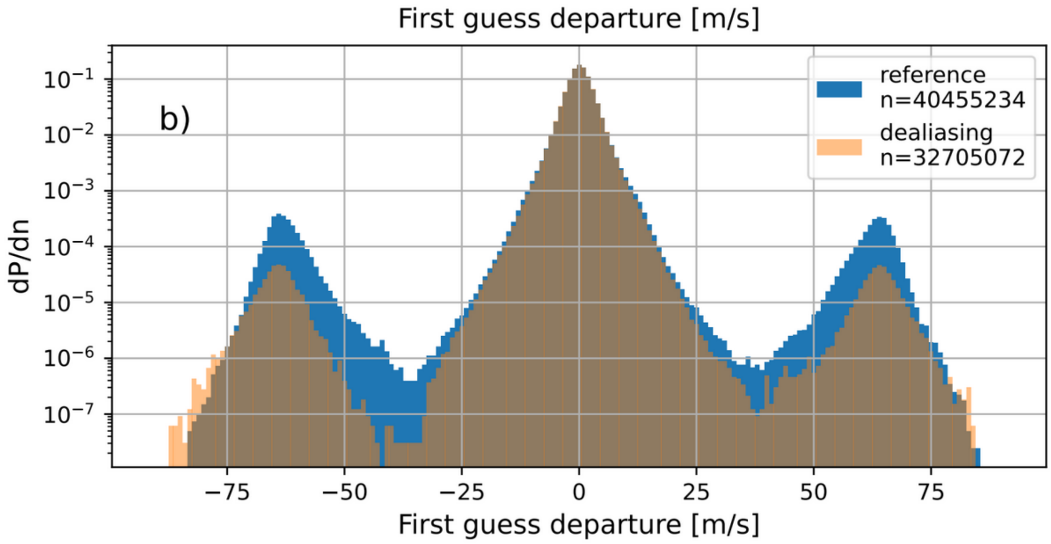


Figure 3.2: Radar first guess departure distribution for all observations for aliased and dealiased German dataset.

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

No work reported.

Impact studies with OPERA reflectivity observations

Benedikt Strajnar (**ARSO**) continued impact studies with radar reflectivity observations from

OPERA in the ALARO model over central Europe, with focus on the use of dry reflectivity observations. Apart from two alternative approaches to the use of “undetect” observations (use of wet pixels in obs/fg. only, modified drying using the non-rainy model environment, Fig. 3.3), a modification of estimation of minimum detectable signal, as proposed by Antonin Bučanek (CZ), is also considered for comparison. A bugfix which prevented using French radars (OPERA product) was also applied in BATOR. The experiments, migrated to VEGA EURO-HPC centre, showed a difference with respect to earlier conclusions which needs to be better understood in terms of performance of MF proposal when French radars are also used (the total bias is less than seen earlier). However, the local solution to use less reflectivity data was shown to work relatively well.

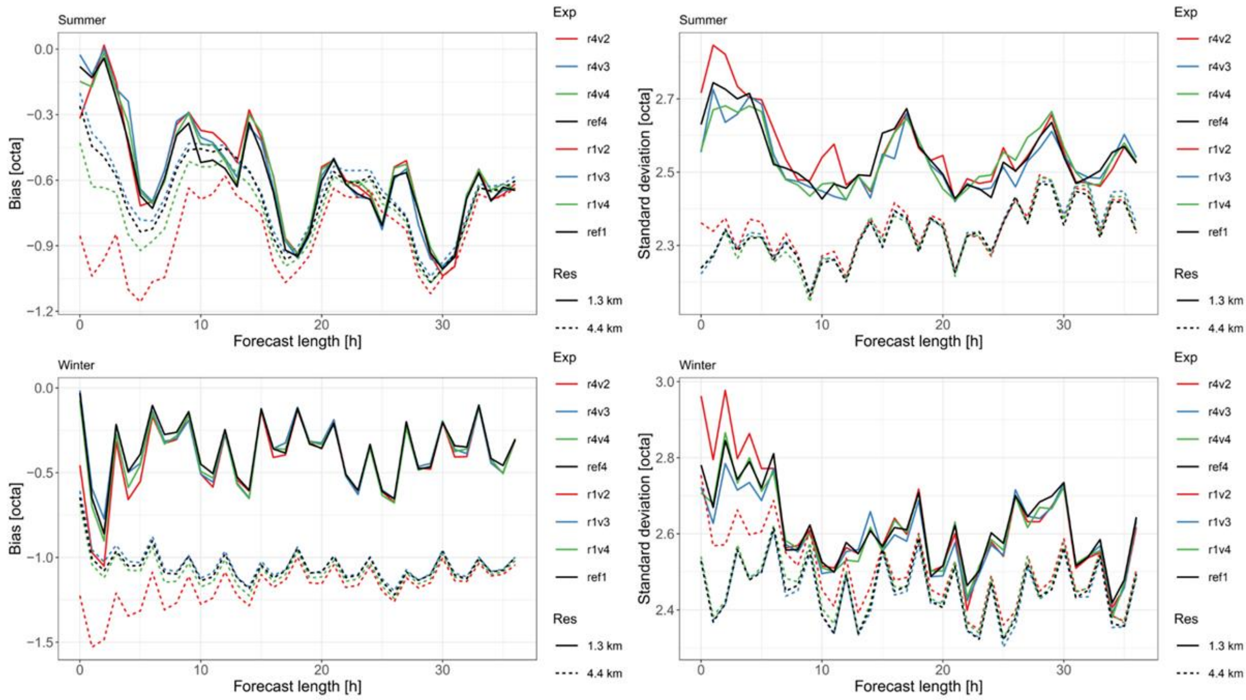


Figure 3.3: Bias (left) and standard deviation (right) of cloudiness for summer and winter period in AL-ARO suites at 1.3 (full line) and 4.4 km (dashed line). Reference experiment (black), default radar DA in red, wet-pixels only experiment (green) and modified drying using the non-rainy environment (blue). The default radar reflectivity DA setup clearly degrades the cloudiness while the alternative approaches perform clearly better.

At **CHMI**, Alena Trojáková, Antonín Bučánek, and Suzana Panežič continued sensitivity studies of the radar reflectivity DA in ALARO CMC by. The main focus of the studies was to evaluate two proposed solutions for the suppression of the drying effect observed during the DA process. Benedikt Strajnar(SI) proposed to assimilate only observation places where considerable precipitation is either forecasted or observed and Antonín Bučánek(CZ) suggested to introduce a fixed table of minimum detectable reflectivity factor (MDRF) at 1 km from radar and to suppress moistening by dry observations. Sensitivity to MDRF was also explored. Results showed that Strajnar's approach eliminates a lot of observations. However, even with a very small amount of data, it provides good results. The Bučánek approach showed pronounced drying in the higher atmosphere due to the existence of only dry observations at such altitudes. The additional removal of very high dry observations showed that different non-optimal profiles might be selected during the screening process, which might degrade the forecast. Additional results showed large sensitivity to MDRF which define values applied to dry observations. Adding a positive offset to the MDRF reduced the drying effect and improved the forecast of precipitation and relative humidity. Testing different MDRF values depending on elevation showed very small impact. More details are available in the stay report by S. Panežić.

Kristóf Szanyi (HU) worked in a remotely organized LACE stay in Hungary on the topic of assimilating OPERA radar reflectivity data in the AROME/HU system under the supervision of Benedikt Strajnar (SI). The main goal was to introduce radar reflectivity data assimilation in a test experiment based on the operational model and evaluate the impact on the forecast quality. Two experiments were set up: (1) a reference run based on the operational AROME setup which does not include any radar measurements and (2) an experimental setup including the assimilation of radar reflectivity data. Both experiments were run between 27 June and 31 July 2021 with 36-hour forecasts each day at 0, 6, 12 and 18 UTC. During the screening and minimization processes a number of memory-related issues have arisen due to the size of the radar data. These issues were solved by reducing the number of assimilated radars to only six (four Hungarian and two Slovenian) radars. The largest positive impact was found in precipitation, relative humidity and cloud cover forecasts. The improvement in the cloudiness forecasts (Figure 3.4) is most likely linked to the drying effect caused by the assimilation of radar reflectivity that was experienced by others in similar experiments. The verification shows neutral to small negative impact in case of surface and upper-air parameters.

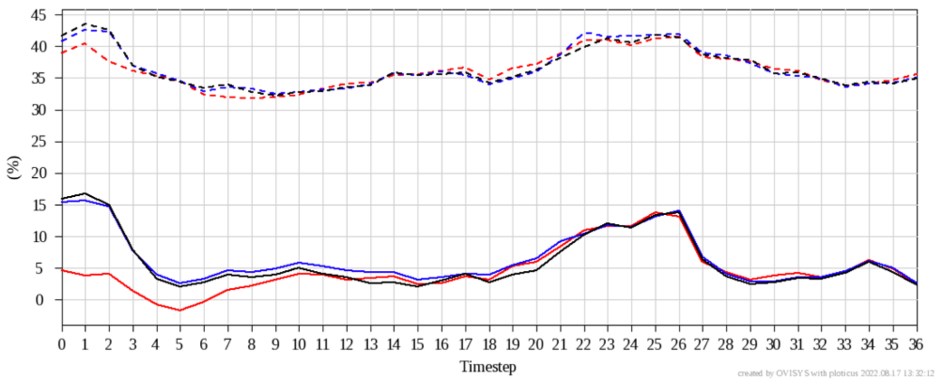


Figure 3.4: Bias (solid line) and RMSE (dashed line) of total cloudiness in function of the lead time for the 0 UTC runs of the test experiment (red), the reference run (blue) and the operational AROME (black).

Following further investigation of these technical issues, a new experiment to assimilate all reflectivity data, which means about 2-3 times more data on the AROME-HU domain, has been set up. No other changes have been made in the test experiment, i.e. both experiments were run on the period between 1 and 31 July 2021 with 36-hour forecasts four times each day at 0, 6, 12 and 18 UTC. The reference run also remained unchanged. Verification results show that there were only negligible differences between both experiments and the reference run for most surface and upper-air variables. A much bigger impact can be observed in the case of precipitation, and the two experiments behave somewhat differently. While the experiment using less radar data shows a little improvement or at least gives neutral results, the experiment with more data produces some considerable errors (Fig. 3.5). This behaviour in the precipitation forecast was further investigated using SAL verification and specific case studies, both of which support the fact that the use of more radars did not lead to an improved forecast. In SAL verification results, there is a clear indication of overestimating the amount and intensity of precipitation, especially at the first few hours. This is confirmed also by case studies for specific days with high-precipitation (Fig. 3.6).

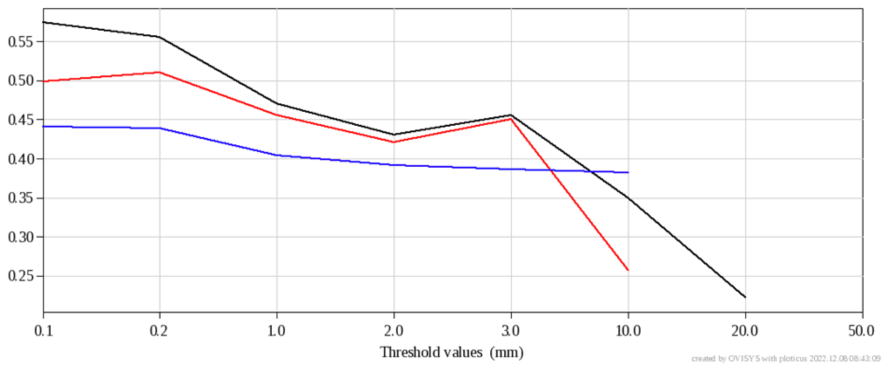


Figure 3.5: SEDI scores for 12-hour forecast of 3-hour sum of precipitation for the 06 UTC runs of the experiment with data of 6 radars (red), with more radar data (blue) and the reference run (black). A SEDI score of 1 indicates a perfect forecast.

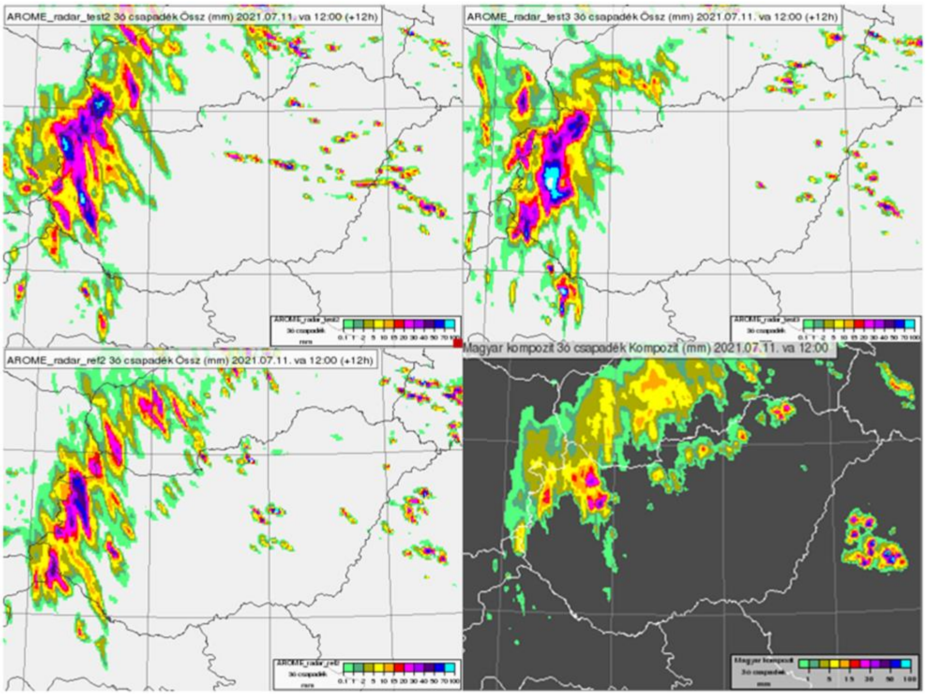


Figure 3.6: 12-hour forecast of the 3-hour sum of precipitation for the 0 UTC run on 11 July 2021 in the experiment with data of 6 radars (upper left), with more radar data (upper right) and the reference run (bottom left) with the actual radar measurement shown in the bottom right.

Updates of the HOOF preprocessing tool

Peter Smerkol (SI) developed an upgrade of the homogenization, dealiasing and superobbing tool for radar data files from OPERA (HOOF2). The dealiasing procedure has been slightly modified, in order to improve the rejection of wrongly dealiased data. Before, the 100 m height intervals, which did not contain enough points, were increased by steps of 100 m until they contained enough points, but this led to many height intervals for which the linear wind assumption was no longer correct. Now, intervals with a small number of points are simply rejected. The second change is that a maximum allowed dealiased velocity in the fit is introduced as a settable parameter (with a default value of 60 m/s). This change rejects non converged fits which would set the dealiased velocity to a very large number and as a side effect, also prevents the dealiasing of radars with a large Nyquist velocity that do not need to be dealiased. The HOOF now also includes superobing, based on the prepopera.py script, with some minor changes - the elevations are not reduced if they overlap, and the procedure for superobing was changed to allow for bins of (almost) arbitrary size in the ray direction.

Efforts: 24

Contributors: A. Bučánek (CZ) 6.25, A. Trojáková (CZ) 0.75, B. Strajnar (SI) 3.75, P. Smerkol (SI) 3.5, V. Švagelj (SI) 2.75, K. Szanyi (HU) 3, S. Panežić (Cr) 2

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]

Since the beginning of February 2022, GOP1 (Czech) network has been missing from the E-GVAP ZTD database. Partly for this reason and partly because the whitelist was updated a long time ago, a new whitelist for AROME-HU was created by Helga Tóth (HU). In addition to SGO1 (Hungarian) and WUEL (Polish) GNSS ZDT data, the goal is to assimilate as many observations as possible, i.e. from two other centers, GF1R (German) and ASI (Italian). Passive assimilation was run for 1 month (September 2022) to collect OMG departures (fg_departure) for the entire period for all points. A bias correction (Poli et al., 2007) was then applied to calculate the bias and standard deviation of OMGs and to obtain the whitelist of the stations. The program chose 129 stations: 43 from SGO1, 35 from WUEL, 34 from GF1R, and 17 from ASI (Fig. 3.7). An experiment was run with the new whitelist for 1-31 October 2022 to warm-up additional VARBC entries. Compared to the operational model, much more data were assimilated, and the rate of rejected data also improved (Fig. 3.8). 36-hour forecasts starting from 00 UTC between 10 and 31 October 2022 were evaluated. The period was very dry, and there was hardly any precipitation, however, at the end of the month some cold pad situations appeared. Basically, a neutral result was detected, a small positive effect was found in the 2 metre temperature forecast in the first 5 hours. There was also some improvement in the dewpoint forecast, because the assimilation of GNSS ZTD data added some moisture to the near-surface layers. After its careful evaluation, an updated whitelist was introduced in the operational AROME suite in January 2023. At the same time, serious quality issues regarding the SGO1 data were frequently detected, so another modification to handle the GNSS ZTD is planned.

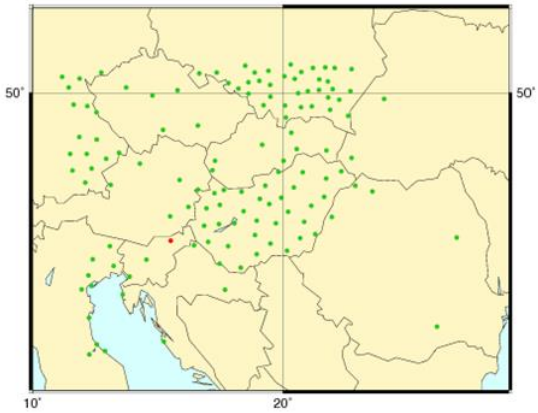


Figure 3.7: Preselected GNSS stations from SGO1, WUEL, GF1R and ASI networks.

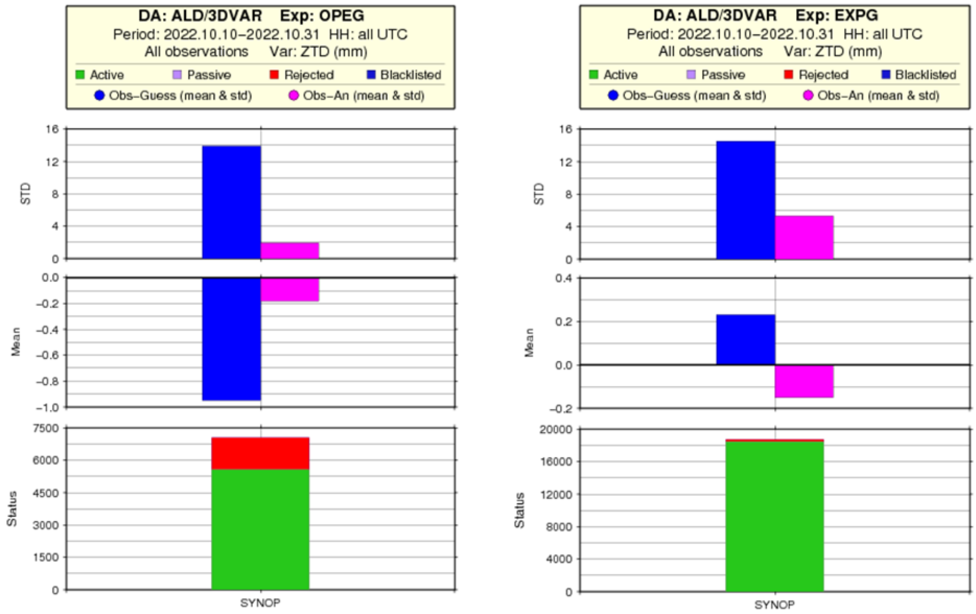


Figure 3.8: Observation monitor statistics for 10-31 October 2022 with the operational whitelist (left) and with the new whitelist (right).

Test feasibility and impact of InSAR delay assimilation from Sentinel-1. [DA 3.5]

Florian Meier (AT) built a Python interface to convert Sentinel-1 InSAR data into slant delay obsoul format and thin the data. This also includes a conversion from relative change to absolute delays by adding FG values from ODB. First assimilation test shows that the data are strongly biased and therefore appropriate bias correction development will be the next step. He also started to implement VARBC for slant delays.

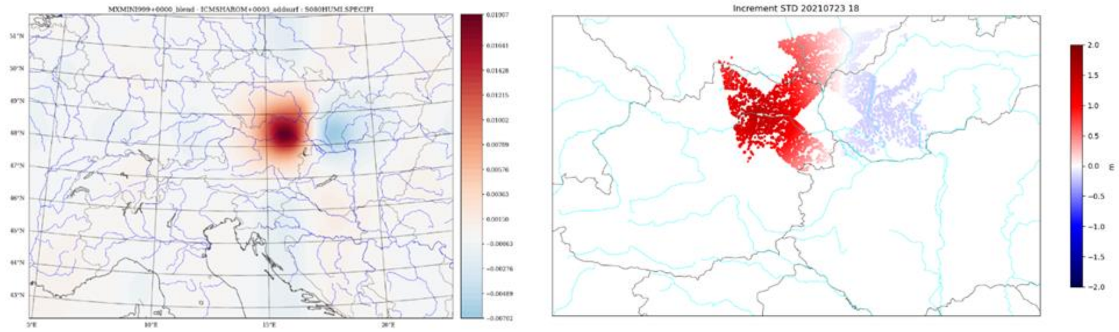


Figure 3.9: Increment in specific humidity level 80 (about 200 m above ground) (left) and increment of STD at observation points (~24300) 23rd July 2021 18UTC (right).

To switch from relative to absolute delay values it is planned to provide simulated model data for the first time slot and then continuously add the differential delays. The processing of a longer data period is still ongoing. A Jupyter notebook routine from Gitlab was installed at Geosphere's HPC to get for a given footpoint latitude and longitude the orography altitude from the HR euro digital elevation model.

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

Florian Weidle (AT) evaluated the data set of ZTD observations from moving retrieved for the period from 9.9.2021 to 15.10.2021. For this period data from approximately 10 trains per day are now available and will be used in AROME-RUC. The trains are located in roughly 5 areas for most of the days. A reference run with AROME-RUC has been set up where the train data are assimilated passively to analyze the FG-departures and to develop a reasonable bias correction (Fig. 3.10).

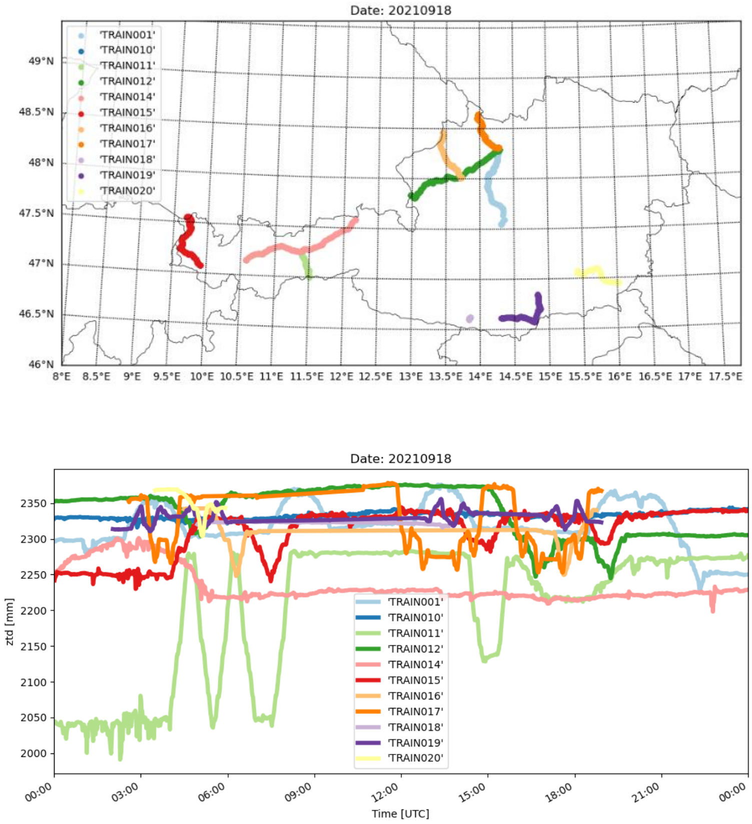


Figure 3.10: Example of train tracks available for one day. Train tracks are shown in the upper panel and the observed ZTD as a function of time in the lower panel. Some trains (e.g. TRAIN011) are circulating several times between two cities.

The reference run was completed and the first guess departures for the ZTD observations from trains were evaluated. The first 10 days of the period under investigation serve as a training/warm-up period and will not be used in the verification of the later experiments. The first guess departures from trains are compared to the first guess departures from static stations. The scatter plot of first guess departures against observed values from GNSS receivers mounted on trains and from static stations are in good accordance (Fig. 3.11). The histograms of the first guess departures separated by the Train ID show for the most of the trains a Gaussian-like distribution with positive bias on average (Fig. 3.12). It was also investigated if a bias correction based on the location of the trains is beneficial, by defining a grid of different mesh sizes over the Austrian Domain. However, it turned out that the fg. departures are either less Gaussian distributed for larger mesh sizes (approximately 100 km) or for smaller mesh sizes most of the grid boxes are rarely populated. Based on the evaluation of the first guess departures the average bias for every train is used to apply a static bias correction for further case studies.

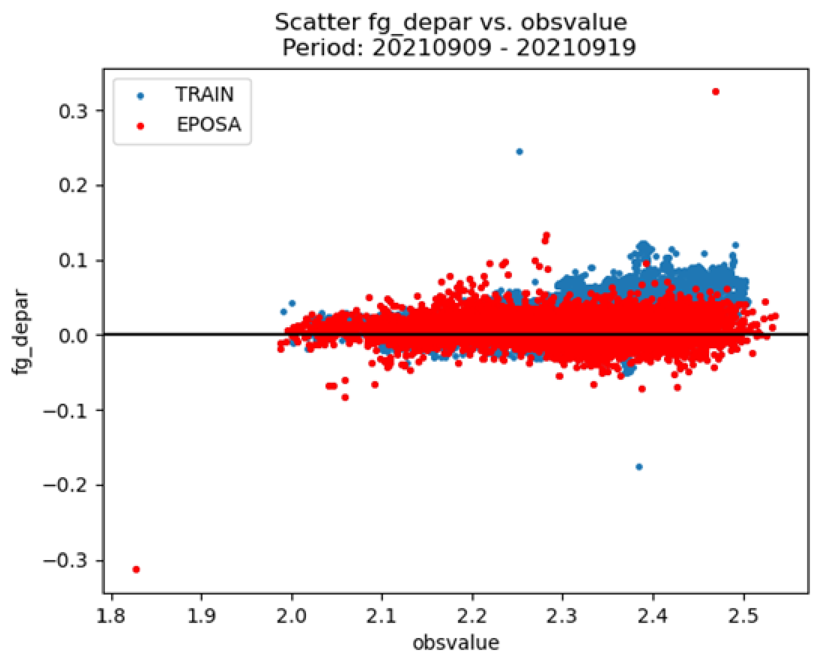


Figure 3.11: Scatter plot of first guess departures vs. observed ZTD values for GNSS receivers mounted on trains and from fixed stations. Only values of the first ten days of the period under study are shown.

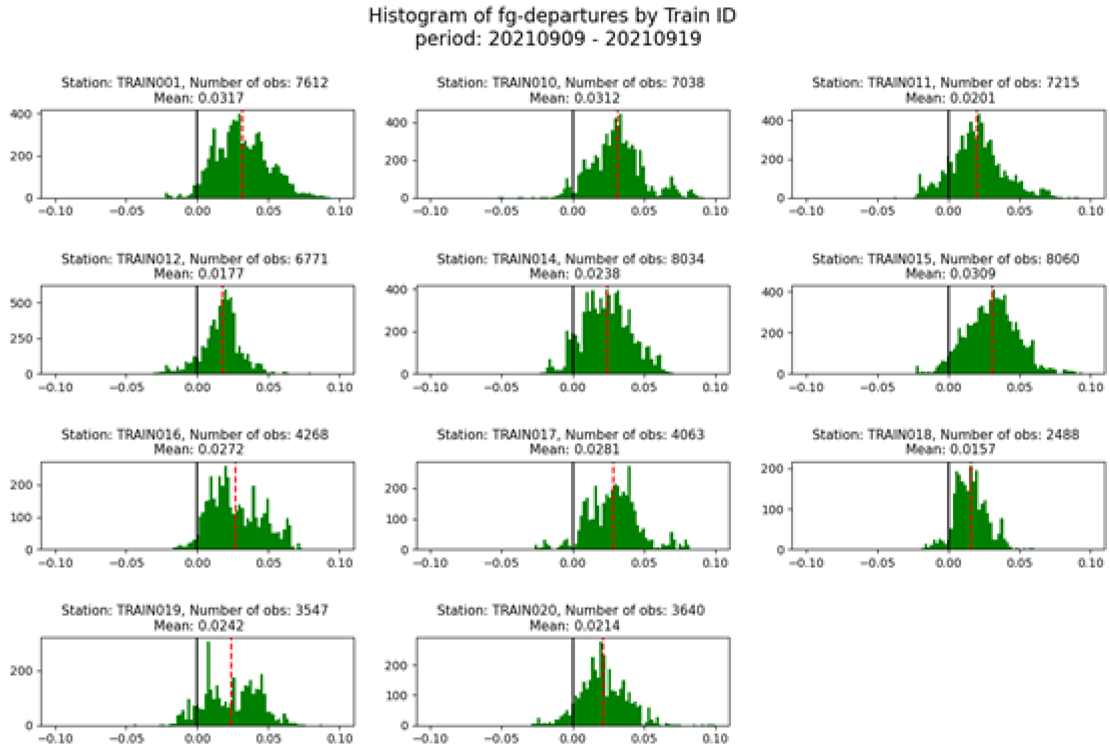


Figure 3.12: Histogram of first guess departures for GNSS receivers mounted on trains. Every panel represents fg-departures from one train for the training period of 10 days.

Optimization of the use of existing AMV observations, including high resolution winds (NWC/GEO-HRW), optimization of blacklisting and performing impact studies. [DA 3.5]

Experimental assimilation of AMV data had been made by Zsófia Kocsis (HU) for several periods in the past with different blacklisting settings for CY40 with neutral impact. The same experiments were repeated with CY43 over a 1-month period in summer. In CY43, AMVs had the same impact as in CY40, which was described in previous reports. Activating the AMVs between 800 and 350 hPa mostly had a neutral impact, although for some of the variables in the upper levels positive changes could be observed in the verification scores compared to the initial settings (LACE report, 2022). Beside the usual verification procedure, HARP was also used to determine the significance of the verification scores and to help to see the differences between the AMV blacklisting settings. Score cards were generated for both experiments (using the stricter ALADIN/HU blacklist and using AMVs also between 350 and 800 hPa) with bootstrap method (Fig. 3.13). The scorecards also support the neutral impact seen in the previous verification. Significant but very small bias for the 2 metre temperature and dewpoint can be observed. Based on the results, the EUMETSAT AMV and the NWCSAF HRW data (also using AMVs between 350 and 800 hPa) were included in the operational assimilation flow in February 2023.

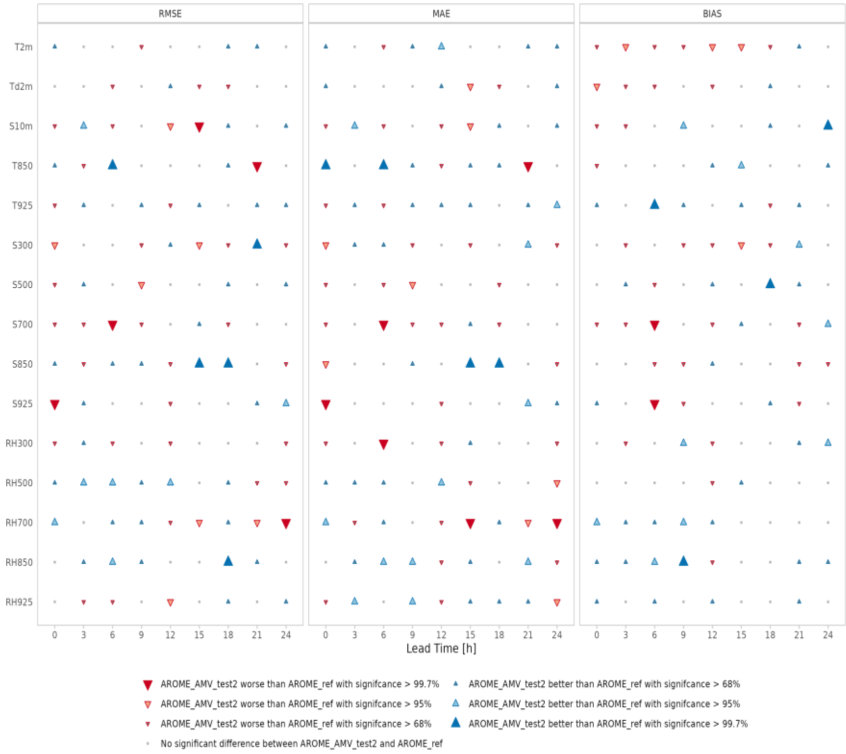


Figure 3.13: Scorecards indicating bias, RMSE and MAE for different parameters, AROME/HU with active AMVs also between 800 (700 over land) and 350 hPa to AROME/HU without AMVs.

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]

No work reported.

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

Four days in December 2021, extra radiosonde measurements were added to the AROME assimilation system at 6 UTC in Szeged and/or Budapest in addition to the regular radiosondes at 0 UTC and 12 UTC. The impact of the extraordinary radiosondes was investigated in case studies by Anikó Várkonyi (HU). Two experiments were run: AROME_TEMP6 represents the operational AROME/HU which includes all available observations, while AROME_noTEMP6 represents the run without the extraordinary 6 UTC sounding data. The analysis increments are much larger in AROME_TEMP6 both at higher and lower model levels (Figure 3.14). In these winter precipitation conditions, a positive effect of the extra radiosonde measurement was observed in the first hours of the forecast. Greater improvements were seen in the high atmosphere parameters than in the surface parameters, but in several cases significant improvements were also seen at the surface.

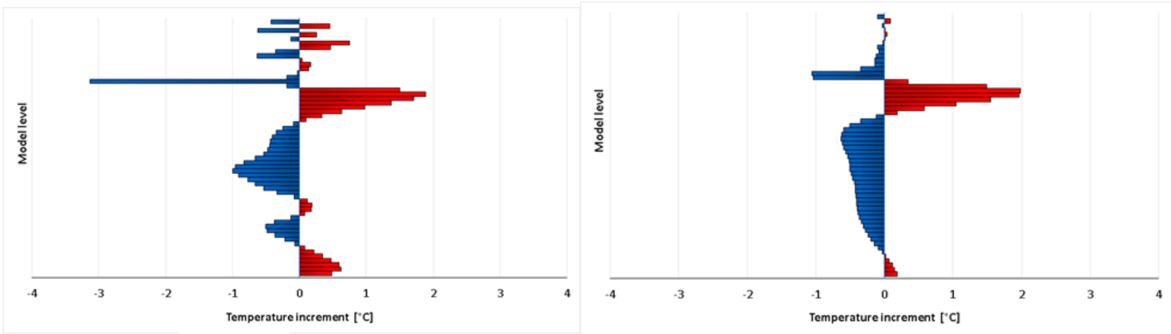


Figure 3.14: Analysis increments with radiosonde data at 6 UTC on 12 December 2021 (left) and without it (right) as a function of model levels.

Additional radiosonde measurements were also carried out on 20 August, a national holiday with fireworks in Hungary, due to a highly uncertain weather situation. Apart from regular soundings available at 00 UTC and 12 UTC in Budapest (12843) and Szeged (12982), extra soundings were taken at 06 and 18 UTC on 19 August and 06 and 14 UTC on 20 August at both locations. The impact of the extra soundings on the forecast is evaluated through the AROME 06 UTC forecast of 20 August, which was the last AROME run before the decision to hold the fireworks was taken. Two experiments were run: AROME_OPER represents the operational AROME/HU which includes all available observations, while AROME_noTEMP represents the run without the extraordinary sounding data (i.e. only with the regular TEMP data). Considering the vertical distribution of the specific humidity increments (Fig. 3.15), it can be concluded that near the surface and at model levels near 700 and 500 hPa there are much larger positive increments in AROME_OPER than in AROME_noTEMP. Differences are visible also at higher model levels, as AROME_OPER has negative increments at model levels 34, 35 and between the model levels 40 and 45, while positive increments are observed in AROME_noTEMP. So it can be concluded that overall more moisture was added to the analysis due to the extra soundings. The larger increments had a positive effect in the first few hours of the forecast: for example, in the 4-hour forecast, the precipitation in the southern part of the country is lighter in AROME_OPER and therefore closer to reality than in AROME_noTEMP. In the following hours, however, no significant improvement is observed, only a small difference in the structure and location of the precipitation field (Fig. 3.16).

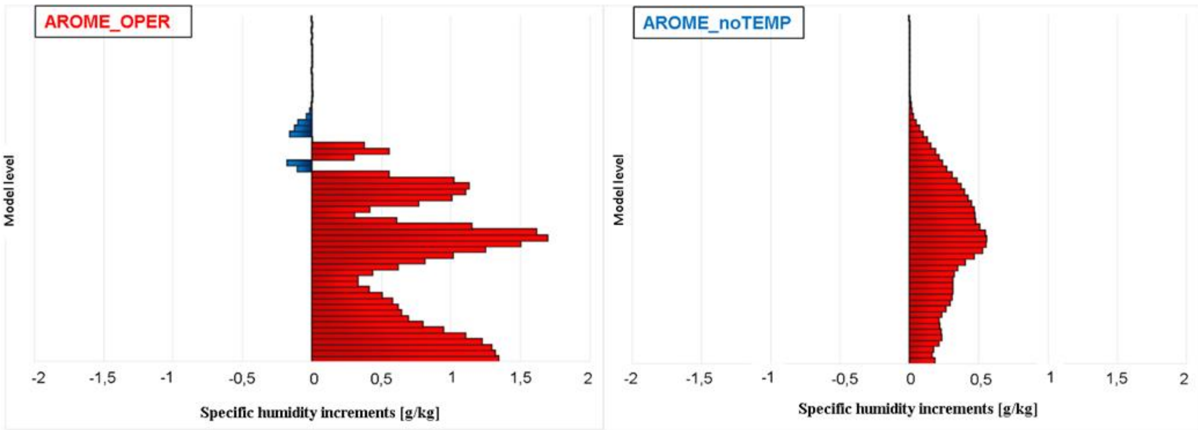


Figure 3.15: Analysis increments over Budapest with radiosonde data at 6 UTC on 20 August 2022 (left) and without it (right) as a function of model level.

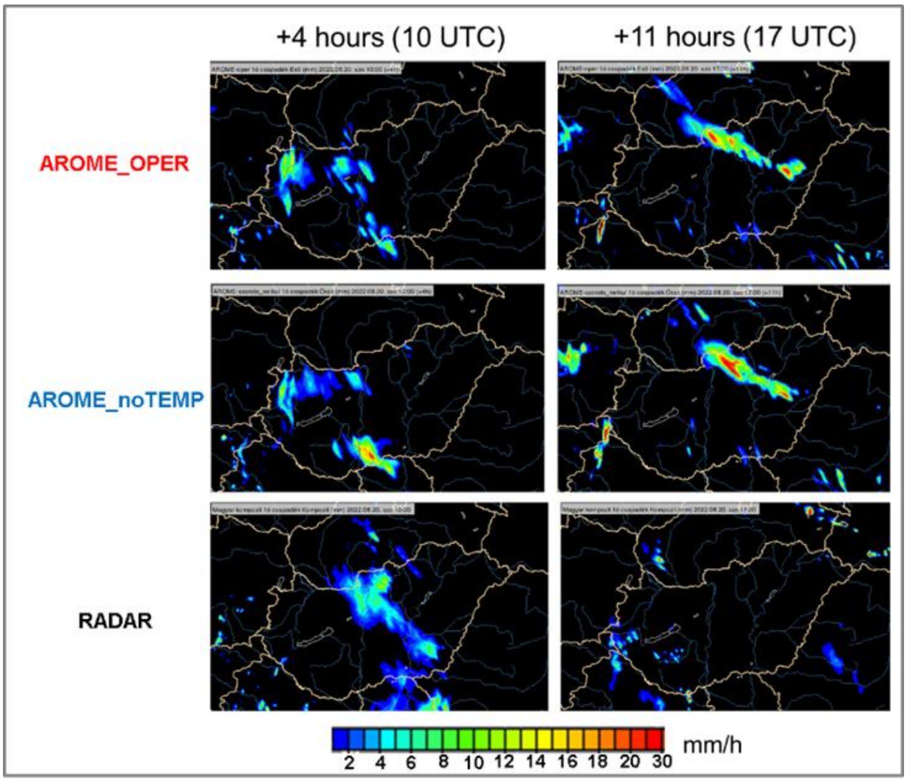


Figure 3.16: 1-hour precipitation amount at 10 and 17 UTC on 20 August 2022: 4- and 11-hour forecasts of AROME_OPER and AROME_noTEMP and the corrected radar fields.

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

No work reported.

Assimilation of Sodar observations [DA 3.10]

No work reported.

Efforts: 11.25 months

Contributors: F. Weidle (AT) 2.75, A. Kardos-Varkonyi (HU) 2, F. Meier (AT) 3.25, H. Toth (HU) 2.25, S. Panežič (HU) 0.25, Z. Kocsis (HU) 0.75

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 continued his work on phasing slant total delays from CY48T1 to CY48T3 as a branch on the ACCORD GitHub.

Explore the potential of volunteered observations from crowdsourced, private weather stations. Use these measurements for NWP case studies to show their potential. [DA 4.4]

No work reported.

Refinement of the preprocessing to efficiently separate dry and wet attenuation, which should lead to a reliable relationship between attenuation and rain rate. [DA 4.10]

Peter Smerkol (SI) studied methods to obtain rain rate observations from attenuation of microwave signals, using 3 months of data obtained from the mobile link network of one of commercial mobile providers. Rain rate is obtained from attenuation of microwave links with a general formula Delta P = A_R + A_B, where Delta P is the difference between the power from the transmitting antenna and power on the receiving antenna, A_R is the attenuation of signal from rain and A_B is the baseline attenuation, which contains power losses from all other sources (free space loss, wet antenna attenuation, losses in the receiving and transmitting antennas, air humidity, vegetation, etc.). Rain rate attenuation can be expressed by using Mie scattering calculations (Hergert et al.) and an approximation for path-averaged quantities along the link (Olsen et al., Leijnse et al.). The final expression is A_R = La<R>^b, where L is the microwave link length, <R> is the path-averaged rain rate, and a and b are coefficients dependent on signal frequency, drop size distribution, temperature, etc., but not on the rain rate. For a and b, a table of coefficients for different frequencies is used, taken from the RAINLINK R package (Overeem et al.). The problem is then translated to determining the baseline attenuation A_B, which is not dependent on the rain rate, but is dependent on a large number of other quantities. Accurately determining the baseline is connected to determining the wet and dry period in the data. This can be difficult, because the baseline fluctuates due to its many dependencies, and at least for the start of the rainy period, the rain rate attenuation is comparable to the baseline fluctuations. There are many propositions for automated algorithms that determine the baseline and after trying some of them, we opted to use the factor graph algorithm (Loeliger et al., Reller et al.), which uses the factor graph approach to process the time series of attenuation data. It simultaneously determines the wet and dry periods and the baseline itself by treating the attenuation data as noisy observations of a time series, with dry periods having much smaller noise than the wet periods. A program which implements the Loeliger algorithm was written in Python and C++. It was tested on a dataset provided by one of the commercial mobile providers. The dataset has about 3 months of attenuation data from 1700 mobile links, measured in 15-minute intervals and contains dry and rainy periods. The algorithm seems to work reasonably well (see examples below), but tuning of free parameters and verification is yet to be done.

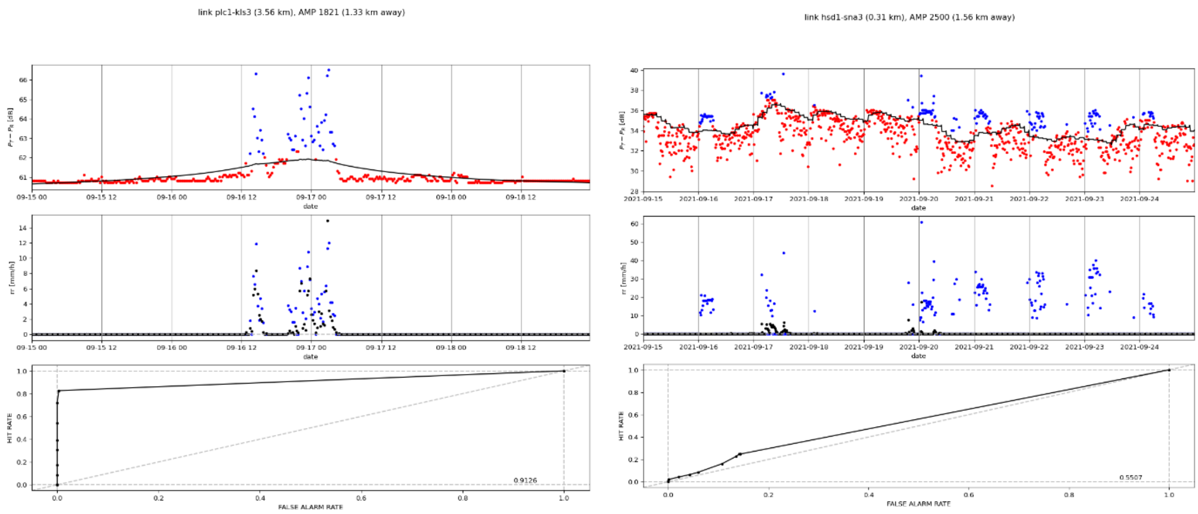


Figure 4.1: Examples of good (left) and bad (right) baseline determination with the factor graph algorithm. Upper plots show the determined wet (blue) and dry (red) points and the calculated baseline (black line). Middle plots show the calculated rain rate (blue points) in comparison to measurement from a nearby measuring station (black points). Bottom plots show the ROC curve.

Phillip Scheffknecht(AT) prepared an AROME installation to assimilate the detected rain events as 100% relative humidity at the centre point of the microwave links and wrote a Python program to convert the data to pseudo-radiosondes, i.e. a sounding with a single observation point at a given height. This allows the point observation to be placed at the exact location and altitude. The 100% RH observations were tested with the 3D-VAR of AROME. The idea is to moisten the atmosphere in locations where rain is observed to support the formation of convection within the model in locations where it might have been missed. The binario observations (rain vs. no rain) were converted into single 100% relative humidity points and then into OBSOUL as PILOT observations, as these conveniently allow to set longitude, latitude, and altitude of the observation without having to convert metres above sea level to pressure.

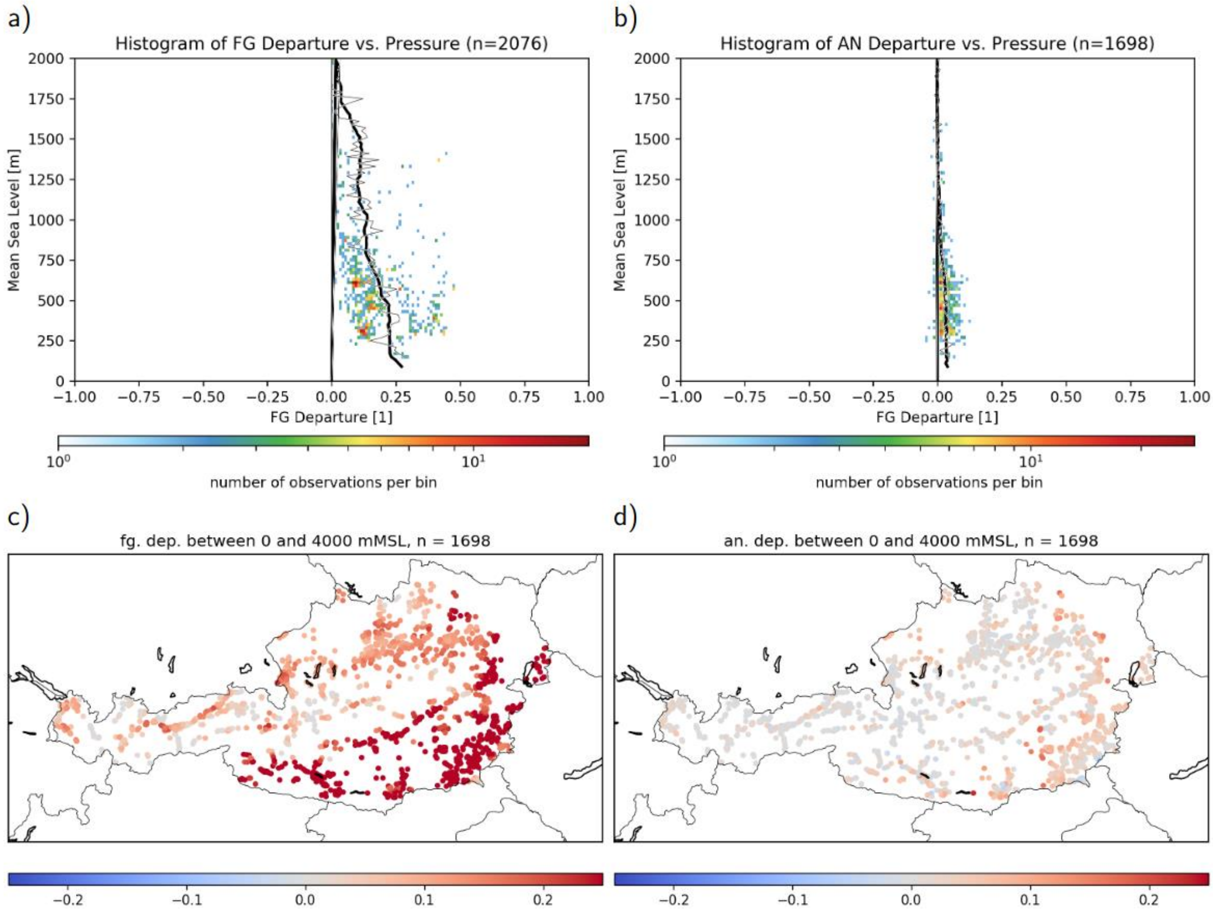


Figure 4.2: 2D height-departure histogram of the link measurements assimilated during the init01 experiment. The colour indicates the amount of observations for the given altitude and with the given first guess departure. The total number of observations is 1690 (out of 2084 screened observations). The thin black line shows the average departure for each altitude level, the thick black line shows five point running mean over multiple levels.

The model corrects heavily toward the new humidity observations, no thinning happens because it is generally assumed that PILOT observations are relatively scarce. In addition, most other humidity observations are surface stations whereas the links provide points above the ground. Figure ML2 shows a height-departure histogram for the first guess (a) and analysis (b) departures. The heavy correction is visible as concentration of the points close to the zero-line. Geographically, the first guess (c) and analysis (d) departures show the most extreme values over the south of Austria, where relative humidity has increased by about 20%. To account for the increase in instability, the model decreases temperature by around 0.5 - 1.5 °C. Despite this, the resulting forecast overestimates rain significantly (verification not included here). This result shows that such binary observations could potentially be used to insert humidity into cases where the model is too dry, but a substantial amount of tuning would be necessary, like adjusting the observation error accordingly and thinning the observations. However, the higher priority goal in the near future is to make use of quantitative observations from 80 GHz links, which were completed during the summer. Ongoing work will focus on those observations.

Efforts: 4.5 month

Contributors: P. Scheffknecht (AT) 2.5, P. Smerkol (SI) 1.5, M. Imrišek (SK) 0.5

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Development of assimilation setups suited for nowcasting [DA 5]***

Validation and application of observations (those from DA 3) in RUC

No work reported.

Design/improvement of existing and new RUC prototypes based on 3D-Var (Austria, Hungary, Slovenia, Slovakia). [DA 5.2]

André Simon, Michal Neštiak, Martin Dian, Mária Derková, Martin Imrišek (all SK) worked on a RUC prototype with hourly cycling aimed as a future nowcasting and very-short-range forecasting system at SHMÚ. It provides 0-12h forecasts with 1 km horizontal resolution and 63 vertical levels, using non-hydrostatic dynamics, CANARI and 3DVAR assimilation. Currently, basic setup of the RUC is still developed and tested, the system runs regularly but it is not operational yet. Stability tests, comparisons with INCA-SK nowcasts and case studies were performed. Situations with frontal passage and deep convection focusing on the Lake Balaton region (Hungary) were investigated with more details and consulted with colleagues from OMSZ. Deficiencies of the RUC forecasts in nowcasting range (0-6h) were identified, namely lack of upper-air data in short cut-off time (35 min.) archive followed by inconsistency of the upper air temperature with the conditions in 2m. Consequent suppression of deep convection caused a substantial (~2 h) delay in the forecast of the frontal passage over the Lake. Experiments indicated that use of additional observations (e.g. in the long cut-off archive, not available at the time of the original run) can substantially improve the results (see the Figure below). Although less perspective from nowcasting point of view (due to up to 6h delay), further sensitivity tests may reveal the impact of respective assimilated surface and upper-air data on the dynamics of front passages and density currents associated with deep convection. Results should help to find optimal strategy for the RUC suite (cycling, right timing of the run, when key data are available, etc.) and its use in nowcasting and very-short-range forecasting.

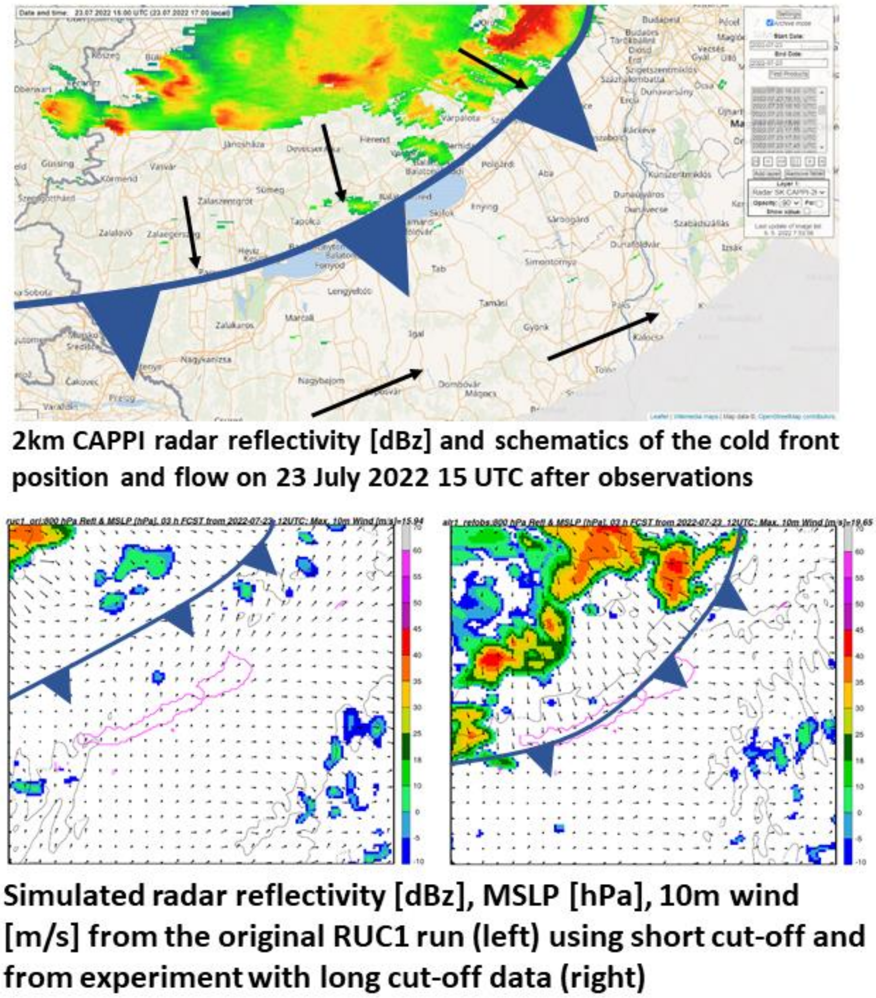


Figure 5.1: Comparison of short (NWC) and long cut-off high-resolution (1 km) runs.

Benedikt Strajnar (SI) performed final validations of the ALARO-RUC prototype which turned operational in May 2022, including the implementation of Obsmon for assimilation and production cycle. Radar dataset was expanded with new sites from Croatia. Special products to visualize different model runs at the same time were also designed.

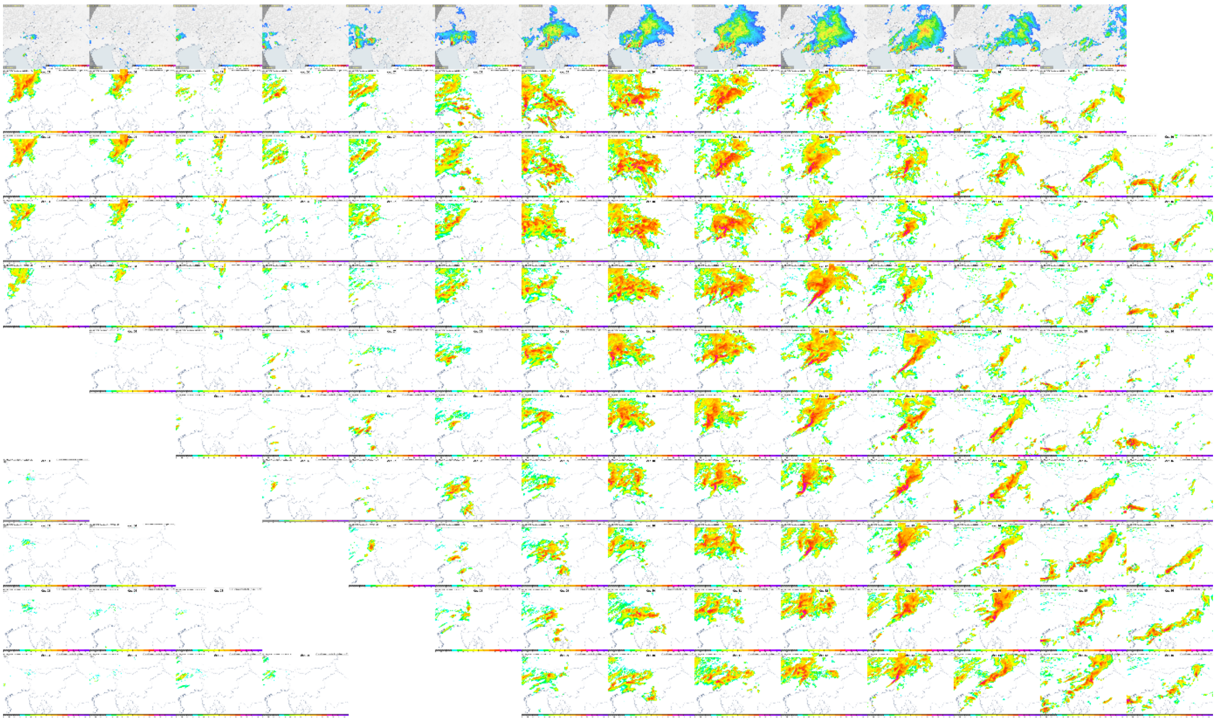


Figure 5.2: Comparison of hourly radar images (top row) with corresponding ALARO-RUC forecasts of different age. White frames indicate missing runs.

David Lancz (HU) set up two experimental AROME Rapid Update Cycle (RUC) suites for the period between 28 August and 30 September 2021, with forecasts from 11 September. The analysis was updated hourly both in 3D-Var and OI-main using an assimilation window from -30 to +30 minutes around the analysis time. The first experiment simulated the situation when the observations are assimilated in real time, while the second experiment assimilated the archived observations. 12-hour long forecasts were made at 00, 06, 12 and 18 UTC. It was concluded in LACE report 2022, that the experiment assimilating “real time” observations suffers from serious RMSE and bias in upper-air wind analysis during some days. This discrepancy was not seen in the experiment using archived observations. Studying wind fields it was identified that the error originates from Northern Croatia and this was confirmed with a verification made without observations from the Zagreb TEMP (14240) station (Fig. 5.3). A concluded from observation monitor statistics, the data of this station was consequently missing from the short cut-off assimilation in the “real-time” experiments, while it was assimilated in the experiments with archived observations leading to around 8 K difference in OMG departures between the two cases over Zagreb. This shows the importance of data from sparsely observed areas in the assimilation. As the next step a parallel-suite to the operational runs with 1-hour RUC assimilation is planned to judge the number of the assimilated measurements in a real “real time experiment”.

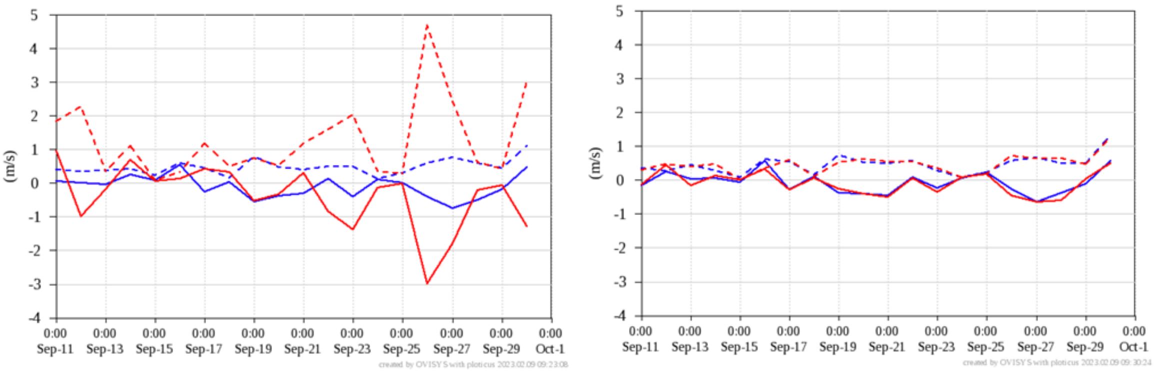


Fig. 5.3: Bias (solid lines) and RMSE (dashed lines) of wind speed analyses at 925 hPa 00 UTC from 11 to 30 September 2021 as a function of time. Red and blue lines represent the experiments assimilating "real time" and archived observations, respectively. The verification on the left used every possible TEMP measurement over AROME/HU domain, on the right the Zagreb station (14240) was left out.

Explore a possibility to initialize/modify the hydrometeors values in AROME-RUC by radar-derived rain type in AROME-RUC. [DA 5.3]

No work reported.

Total efforts: 6 months

Contributors: K. Szanyi (HU) 2.5, B. Strajnar (SI) 0.5, A. Simon (SK) 0.75, M. Neštiak (SK) 0.5, M. Dian (SK) 1, M. Derková (SK), M. Imrišek (SK), partly reported under HR, H. Toth (HU, pm in DA3), D. Lancz (HU) 0.75

Documentation: /

Status: ONGOING

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

Run and compare 3D-Var minimization run using OOPS and non-OOPS binary with similar setting, initially at MF's computing platform. Port the relevant cy46t1 code and reproduce the experiment locally.

Florian Meier (AT) built scripts to run OOPS 3D-Var, 3D-EnVar and hybrid 3D-Var with cy46t1 export and a script based on ePyGram command-line applications to prepare C-LAEF files for EnVar (conversion to GP space output, removal of some fields) on ZAMG HPC and new ECMWF HPC. This information was also provided to the ACCORD team during DAWW. It was tried to run a whole 3D-EnVar cycle with GP space files, but OOPS EnVar failed to read GP first guess files so far. Also the change of resolution between EPS and analysis in EnVar was successfully tried. Increments look reasonable and the usage of a lagged ensemble in EnVar creates a very similar increment shape. Several horizontal localization lengths were tested.

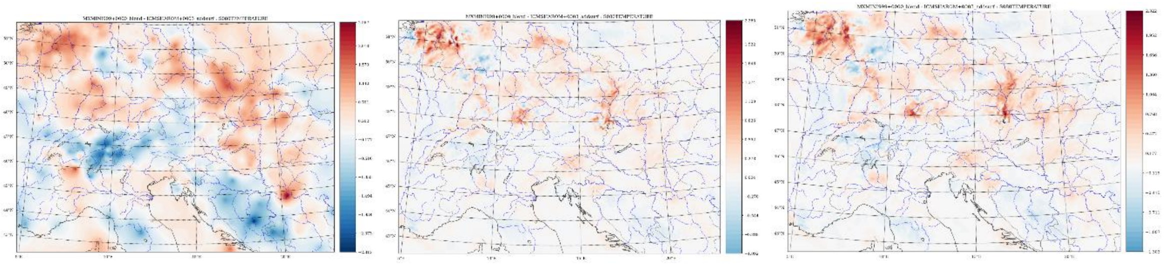
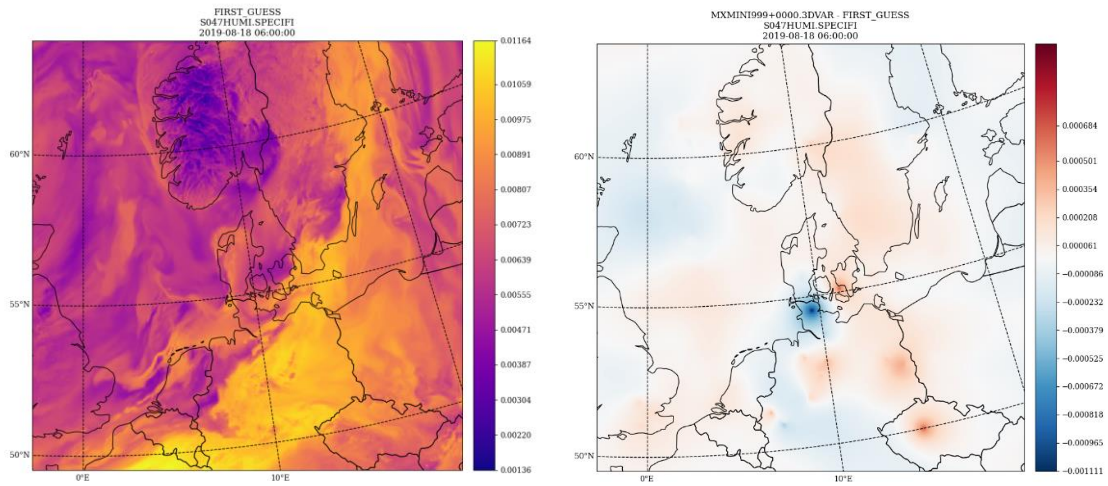


Figure 6.1: 3h AROME temperature increment on level 80 (200m above ground) 29th July 2022 06UTC: OOPS-3D-Var(left), EnVar with 16 member C-LAEF(middle) inflation 0.5, 34 member EnVar lagged C-LAEF+2 control(right) inflation 0.6. Localization type 1; 100km/0.2.

The extension of the control variable to hydrometeors via namelist had no effect so far on the results as hydrometeor observations are not used at the moment. Using the hybrid version showed that the weighting strongly depends not only on the weights used itself, but also on correct REDNMC setting. For a PHD student working on EnVar, a 50 member ensemble was created for a case study on 12th August 2022 00UTC based on 10 ERA 5 members (LBCs) and coupled C-LAEF perturbations on different components cycled from 11th August 12 UTC on and starting with operational AROME soil.



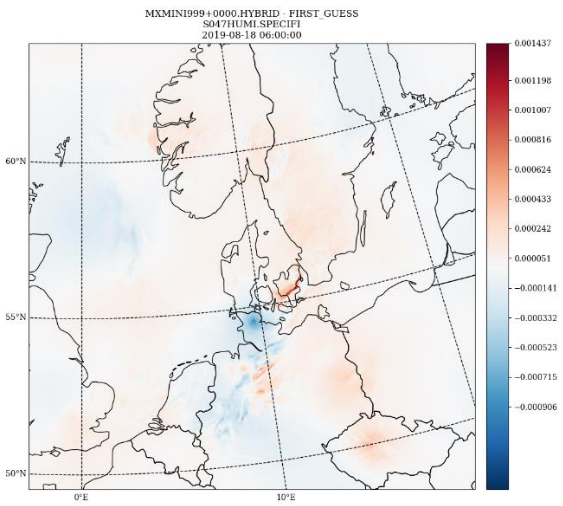


Figure 6.2: Specific humidity increment at level 47/60 in AROME-DK. Figst guess field (upper left), 3D-Var increment (upper-right), hybrid EnVar (bottom left), and pure EnVar (bottom right).

During the ACCORD DA workshop in Barcelona, advanced algorithms enabled by the OOPS system were technically tested by Benedikt Strajnar (SI) over a sample Dannish AROME domain and using the MetCOOP EPS system (Fig. 6.2). Results look realistic: EnVar increments are anisotrophic and aligned with the frontal zone which they don't cross. On the other hand, EnVar produces smaller and noisier analysis so a hybrid combination with 3D-Var may be preferable. During working days at DMI October, the OOPS version of screening was successfully tested, using new additions by Meteo France in cy48t3.

Total efforts: 4.25 months

Contributors: F. Meier (AT) 3, B. Strajnar (SI) 1.25

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]

Information on OPLACE maintenance and improvements are provided in the DM's report.

Within the Destination Earth On Demand Extremes (DE_330) project, one of the goals in the phase 1 is to prepare an observation monitoring system over a large European domain, in order to understand what observations would be available for possible data assimilation activities in the next phases of the project. Two hourly monitoring suites have been set up at ECMWF/Atos platform: one with 30 min latency to estimate near-real time availability, and one run with a delayed cut-off of 12 hours to monitor all available observations. The two main sources are ECMWF (through a dedicated SAPP extraction) and OPLACE. Both obsoul and test bufr streams of OPLACE for surface observations are used in inter-compared, also with the aim to help assist operational migration to BUFR in LACE DA systems. Figure 7.1 shows availability of surface data at 6 UTC for an arbitrary date.

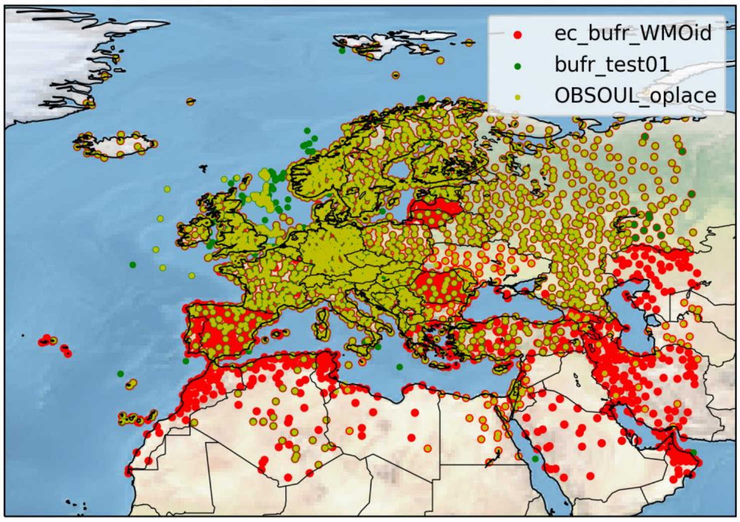


Figure 7.1: Synoptic observations at 6 UTC as available from ECMWF (red), from OPLACE in obsoul format (yellow) and from OPLACE in bufr format (green).

Installation and customization of the Obsmon observation monitoring package. [DA 7.2]

No work reported.

Total efforts: 0.5

Contributors: Benedikt Strajnar (SI) 0.5

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Basic data assimilation setup (DAsKIT) [DA 8]***

Follow the DAsKIT implementation plan which includes a gradual implementation of OI for the surface analysis and 3D-Var (with static B) for the upper-air analysis for the ALARO-based system. [DA 8.1]

In Poland, preparatory work in order to set up a 2 km AROME surface and upper-air data assimilation has been performed. Surface stations from OPLACE are used. A so called support-team working week was organized in Barcelona, with the main goal of familiarization and implementation of DA diagnostic tools.

In preparation for the Romanian DA system, Alina Dumitru (RO) computed the background-error statistics. This task was completed during a research stay at CHMI. The method chosen was the spin-up ensemble method. A period of 30 days in two different seasons: summer (20210611 - 20210625) and winter (20220108 - 20220122) was selected. For creation of the LBC from global assimilation ensemble were used the first 6 members of AEARP. The LAM operational configurations of EE927, DFI Initialisation and E001 was used for creation of 6 hours forecast of each member of AEARP and based on this results, the differences between members were computed for all days of selected period valid at 00, 06, 12 and 18 UTC. A total of 360 differences were computed and the outputs, stored in grib files, were used for computation of B matrix. The binaries festat and fediacov were compiled with gmkpack. The next step was to test and see the impact of assimilation of observation on the weather forecast. For this purpose the SYNOP, TEMP and AMDAR observations and default values for REDNMC (0.7) and SIGMAO_COEF (0.9) were used. Experiments which contain only CANARI or CANARI and 3DVAR (gradually introducing each type of observation) were performed and analyzed based on a posteriori diagnostics available on RC-LACE forum. More details about the methods and results obtained can be found in a report on the RC-LACE website.

Total efforts: 4.25 months

Contributors: M. Szczech-Gajewska (PL) 2, A. Dumitru (RO) 2.25

Documentation: /

Status: ONGOING

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

Validation of SEKF surface assimilation with SYNOP observations and operational upgrades

AROME-TEST has been running in parallel to the operational AROME/HU forecasts since November 2021 by Helga Tóth (HU). Simplified extended Kalman filter (SEKF) was applied in the test run for surface data assimilation, while in the operational AROME/HU model used the optimum interpolation (OI-main) method. A 1-month convective test period (2022. 05. 04 – 2022. 06. 01) was chosen to evaluate and compare the forecasts. The assimilation settings were as follows:

- XERROBS (T2M, HU2M) = 1.0, 0.07
- XSIGMA (WG2, WG1, TG2, TG1) = 0.15, 0.1, 2.0, 2.0
- XTPRT (WG2, WG1, TG2, TG1) = 10-4, 10-4, 10-5, 10-5

AROME-TEST was run in parallel to the operational forecasts 3 times a day (at 0, 6 and 12 UTC). During the test period, less than average precipitation fell, in the form of showers and thunderstorms. In some events intense hail also occurred in addition to stormy winds. Typically, however, local precipitation events dominated. At the first forecast hours, the two models performed similarly for 2 metre temperature, then the biggest difference usually appeared at night (Figure). In the case of forecasts beyond 24 hours, the difference between the two models decreased and AROME-TEST mostly performed better. The operational run had a smaller dew point error during the daytime hours, but the SEKF reduced the underestimation at night. Events with a precipitation amount of less than 6-7 mm were underpredicted by the models, and events exceeding this threshold were overpredicted. For high precipitation events (>10 mm), AROME-TEST performed better and the difference between the two models increased proportionally as the threshold increased. The occurrence of false alarms was lower in AROME-TEST than in the operational model for almost all thresholds, and overestimation of the intensity was reduced. After its careful evaluation, SEKF was introduced in the operational AROME deterministic suite on 29 June 2022.

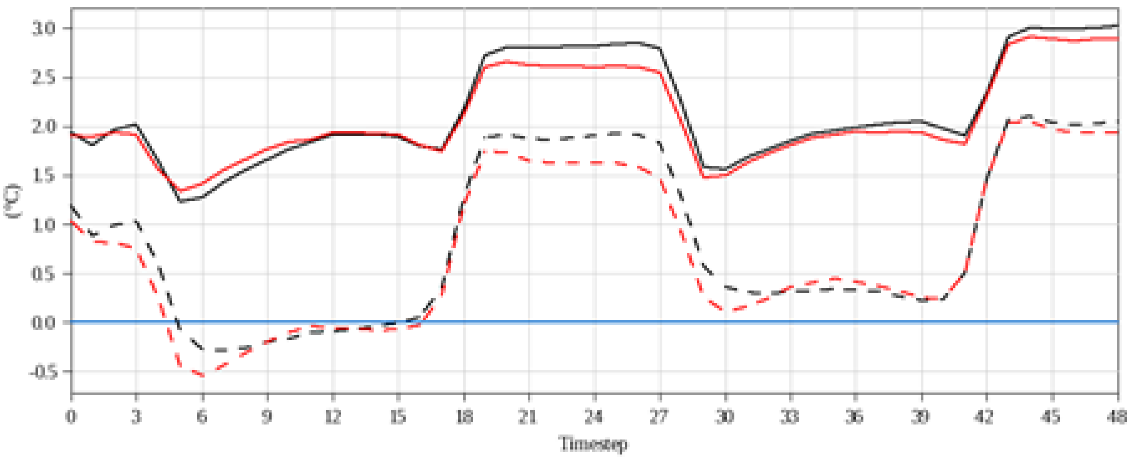


Figure S1.1: Bias (dashed line) and RMSE (solid line) of 2-metre temperature forecasts for the 0 UTC runs from 4 May to 1 June 2022. Curves represent: AROME-OPER (black), AROME-TEST(red).

Tuning of CANARI/MESCAN and OI soil assimilation

Radmila Brožková (CZ) has been testing the deep soil water reservoir analysis activity in CANARI. What is recommended and used now in ARPEGE and also AROME, is to make this activity dependent on the sun zenith angle μ0. When using this zenith angle dependency, then during the night or for small sun elevations, deep soil water increments are set to zero or are very small. This prevents the analysis from correcting the deep soil water reservoir at every analysis step, which is desirable. Otherwise, especially in spring and summer, with important diurnal amplitudes of T2M, RH2M, one gets oscillations of the soil water. This in turn modifies evaporation from soil and via the latent heat flux it influences T2M. In case we leave the analysis active, we get oscillations of soil water reservoir, together with T2M jumpiness from one model run to the next. Hence it is desirable not to touch the soil water that much. However, when activating the recommended sun zenith angle µ0 option by setting SMU0=7. in the namelist, one gets another problem. In winter the analysis is almost inactive at our latitudes, and the soil gets too wet, with cold T2M bias. In summer, the analysis is active during the day time, mainly 12 UTC, and so the effect is drying, bringing also warm T2M bias. A modified version of the TANH function argument was tested, however this helped only partially. Current experimentation involves testing another proposal based on the annual sun declination, where we need to suppress the analysis activity during spring and summer when diurnal amplitudes of screen level parameters are big. The current results are promising but a final version is not yet available.

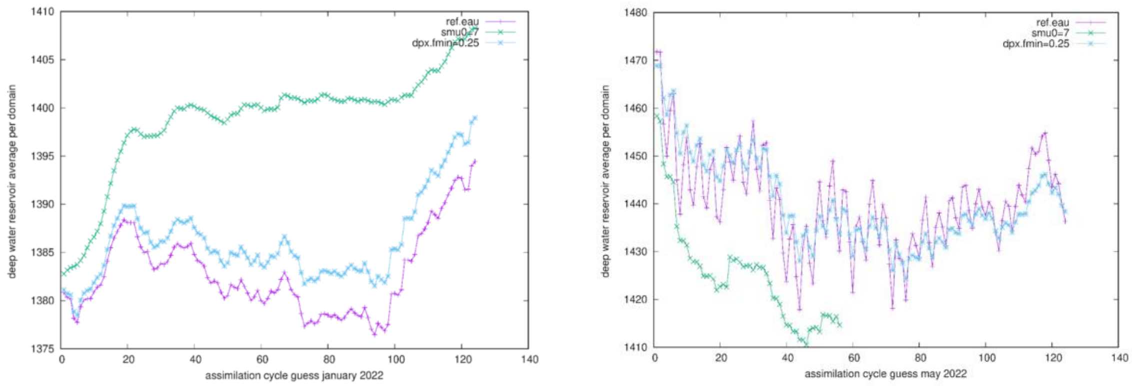


Figure S1.2: The evolution of the horizontal average of deep soil water reservoir during the assimilation cycle. The examples are from January and May 2022. In reference the deep soil water increment is not diminished, which in summer causes diurnal oscillations. When the modulation increments by solar zenith angle is applied setting SMU0=7., we remove diurnal oscillations but in winter the reservoir drifts to wet and in summer to dry values and this impacts T2m accordingly. The third experiment (blue colour) modulates increments following the season (sun declination), i.e. they are more dumped in summer and less in winter.

Dependence of deep soil water reservoir on sun declination was applied by Antonin Bučánek (CZ) in the implementation of 3h cycle which did not diminish the amplitude of daily cycle of deep soil water reservoir sufficiently in summer. To make the daily cycle of the reservoir even smaller the possibility to average the increments of deep soil reservoir in Canari was used (“LISSEW”). The code with LISSEW was commented out (CY43t2_bf11) so it was necessary to make it working again. Canari is then averaging the last 4 analysis increments, which makes the amplitude smaller but with a shifted phase. To overcome this issue the 8 analysis increments are used in averaging. Results are not available yet but we expect improvement.

Total efforts: 5.5 months

Contributors: H. Tóth (HU) 0.75, R. Brožková (CZ) 1.5 (CZ), A. Bučanek (CZ) 1.5, A. Trojakova (CZ) 0.25, V. Tarjani (SK) 1.5

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)

A 4-week stay at OMSZ Budapest was performed by Matjaž Ličar (SI) with Helga Tóth (HU) as the supervisor. The objective of the stay was to prepare an offline data assimilation experiment of satellite based soil moisture observations using a simplified extended Kalman filter algorithm with SODA. The Copernicus satellite product used as observations in the experiment is a fusion of Sentinel-1 C-band SAR and Metop ASCAT sensors. Satellite data is available daily on a lat/lon grid with a spatial resolution of 1km. Calibration of observations was performed with a CDF matching method and data from operational Hungarian AROME analyses. SURFEX was set up with 1 patch running the 3 layer ISBA force restore scheme on a domain identical to the AROME/HU domain. Several short experiments with forcing based on operational AROME/HU analyses were performed: an open loop run with no data assimilation, and several experiments with different control variable configurations and different prescribed observation errors. The results show that performing data assimilation in this manner is technically feasible, however additional work on tuning and validation is needed for applicable usage.

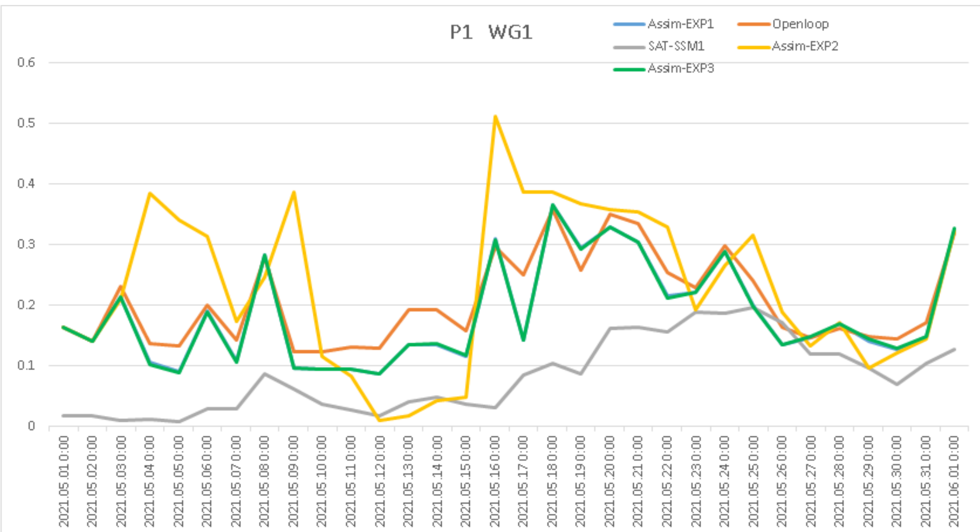


Figure S2.1: Satellite superficial soil moisture observations along with an open loop SURFEX run and various data assimilation experiments for a point near Budapest for a period of one month.

Assimilation of LAI within SEKF in AROME/SURFEX, impact experiments

A one month long period (2021-06-28 – 2021-07-28) was run by Balázs Szintai (HU) to investigate the impact of daily updated LAI in AROME/HU. This period was characterised by a severe drought over Southern Hungary and Northern Serbia which caused negative LAI anomalies in this region. The experimental run was the same as the reference, the only difference was that it was using LAI values computed by an offline SURFEX ISBA-Ags run applying the prognostic vegetation scheme. In the offline SURFEX run the LAI product from Copernicus Land Service (Sentinel-3) was assimilated with SEKF. Pointwise verification over the whole AROME/HU domain did not show impact on forecasted meteorological variables. The verification domain was reduced to an area of about 150 km x 150 km over Southern Hungary and Northern Serbia, affected by the drought. These scores show a slight improvement of 2 metre temperature during daytime (Figure). For 2 metre dewpoint a slight improvement is obtained in the first five forecast hours (until sunrise), then during daytime a slight deterioration can be observed. Verification scores for precipitation show mixed results: improvement is seen for low and high precipitation, but forecasts of moderate precipitation deteriorate.

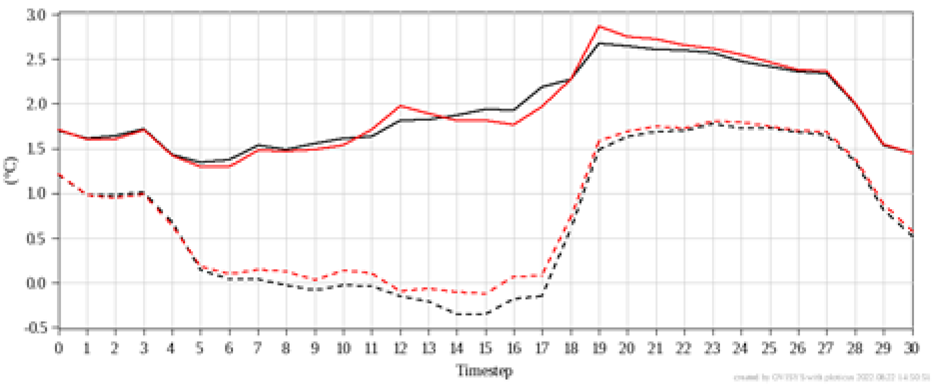


Figure S2.2: RMSE (solid line) and bias (dashed line) of 2 metre temperature forecasts for the time period 2021-06-28 – 2021-07-28 (only 0 UTC runs). Black: AROME reference simulation; red: AROME run using prognostic LAI.

Following the first experiments run for 2021, a second experiment was computed by Balázs Szintai (HU) for the summer of 2022 to investigate the impact of daily updated LAI in AROME/HU. This period was characterized by a very severe drought over Hungary which caused negative LAI anomalies in this region. Verification showed that the modification has an overall neutral impact, significant differences can only be detected if the verification is narrowed to a time interval with anticyclonic situations (15-28 July 2022) and spatially to the Eastern part of Hungary (which was mostly affected by the drought). In this verification, scores show a slight improvement of 2 m temperature during daytime and a deterioration during nighttime. For 2 m dewpoint (Figure S2.3) an improvement is shown for the whole forecast range. In the following months results will be further analyzed and it will be investigated if this development could enter the operational NWP chain of OMSZ.

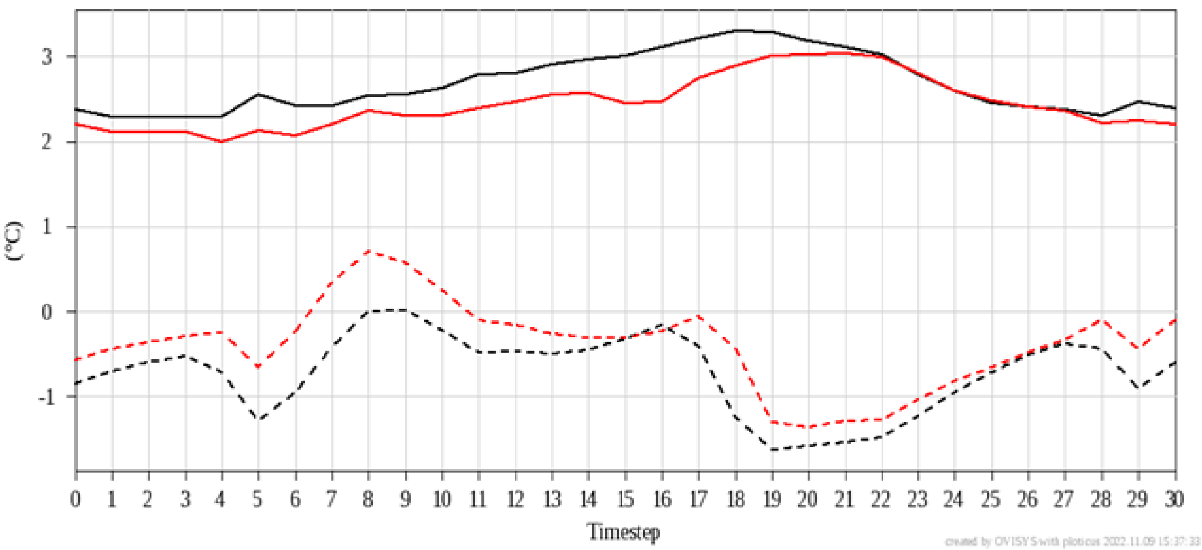


Figure S 2.3: RMSE (solid line) and bias (dashed line) of 2 m dew point forecasts for the time period 2022-07-15 – 2022-07-28 (only 0 UTC runs). Black: AROME reference simulation; red: AROME run using prognostic LAI.

Total efforts: 13.25 months

Contributors: H. Tóth (HU) 0.5, M. Ličar (SI) 1.25, B. Szintai (HU) 3, S. Schneider (AT) 1, S. Oswald (AT) 0.75, P. Schmederer (AT) 6.75

Documentation: /

Status: ONGOING

Documents and publications

Publications:

- Szintai, B., Szanyi, K., 2022: High resolution experiments with the AROME Numerical Weather Prediction model over Hungary. CMFF-2022 conference proceedings, Budapest.
- Dian et. al. 2022: Algorithmic amelioration of the deficiencies in the screen level parameters forecast based on a dynamical downscaling approach. 2nd ACCORD Newsletter, pp 91-95.
- Tóth, H., Tóth, B., 2022: Implementation of Simplified Extended Kalman Filter in the

operational AROME/HU. ACCORD Newsletter 3, 15-20.

Stay reports:

- M. Ličar: Assimilation of Satellite Based SWI Observations using a Simplified Extended Kalman Filter Algorithm in SURFEX, 30 May – 24 June 2022, Budapest. https://www.rclace.eu/media/files/Data_Assimilation/2022/repStay_MLicar_SWI-SEKF_OMSZ_2022.pdf

- S. Panežić: Further sensitivity studies with radar reflectivity data assimilation, 18 July – 19 August 2022, Prague. https://www.rclace.eu/media/files/Data_Assimilation/2022/repStay_SPanezic_radarRefl_Prague_2022.pdf

- K. Szanyi: Assimilating OPERA reflectivity observations in the AROME-HU system, remotely supervised stay, 16 May – 15 June 2022, https://www.rclace.eu/media/files/Data_Assimilation/2022/repStay_KSzanyi_reflDA_remote_2022.pdf

- A. Dumitru: Computation of the background-error covariances, 22 August - September 2022, Prague. https://www.rclace.eu/media/files/Data_Assimilation/2022/repStay_ADumitru_Bmatrix_Prague_2022.pdf

Other documentation:

- Peter Smerkol (updated on LACE forum and ACCORD wiki, 2022): Documentation for the Homogenization Of Opera files (HOOF) tool

RC LACE DA at 31th ALADIN Workshop & HIRLAM All Staff Meeting 2022, 30 March – 3 April 2022, Ljubljana.

List of presentations:

- Benedikt Strajnar: Overview of RC LACE data assimilation activities

- Antonin Bučanek: Progress on reflectivity DA at CHMI

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

Activities of management, coordination and communication

1) Joint 3rd ACCORD all staff workshop 2022, 27-31 March 2022, Ljubljana,
2) EUMETSAT MTG&EPS-SG User days, 31 May-2 June 2022, Darmstadt
3) Attendance to ACCORD DA working days on DA diagnostics and OOPS, 20 – 23 June 2022, Barcelona
4) Attendance to ACCORD DA working days on OOPS and flow-dependent DA, 7 – 11 November 2022, Copenhagen
5) Informal LACE DA meetings (2nd Wednesday every two months),
6) EWGLAM meeting, Brussels, remote participation
7) ACCORD DA RT/ST topical meetings,
8) Radar NWP-OPERA users group meeting,
9) LSC meetings.

Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized (Q1-Q2)	Planned	Realized
Operational implementation of DA suites [COM3]	8	10		
Further development of 3D-Var [DA 1]	13.25	6.75		
Development of flow-dependent algorithms [DA 2]	2	0		
Use of existing observations [DA 3.1] – radar	20.5	24	2.25	2.25 (1 remote)
Use of existing observations [DA 3] – other data types	18	11.25		
Use of new observations types [DA 4]	12	4.5	1	cancelled

Development of assimilation setups suited for nowcasting [DA 5]	14	6		-
Participation in OOPS development [DA 6]	3.5	4.25		
Observation pre-processing and diagnostic tools [DA 7]	2	0.5		
Basic data assimilation setup (DAsKIT) [DA 8]	7	4.25	0.75	1.5 (0.75 remote)
Algorithms for surface assimilation [SU 1]	6	5.5		
Use of observations in surface assimilation [SU 2]	8	13.25	1	1
Total	**120.75**	**90.25**	**5**	**4.75**

Problems and opportunities

The main problems in 2022 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.
- After merge into ACCORD there are numerous subgroup meetings on DA and working weeks, making it difficult to keep track of all activities.

Opportunities for more effective future work are:

- Collaboration within the ACCORD consortium has generally improved, possibilities are numerous: ACCORD Wiki, RTs/STs on algorithms and observations, Slack communication exchange. More coordination with MF desired (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.