Working Area Data Assimilation

Progress Report

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Period:	2021 January-December
Date:	8/03/2022

Progress summary

The report summarizes the RC LACE DA activities in 2021. The focuses of the group were the use of additional observations, mainly the radar data, and implementation/refinement of hourly assimilation systems suitable for NWP-based nowcasting.

The research and development on radar data assimilation has a goal to enhance the realism of modelled precipitation patterns in the initial hours of the NWP forecast. Only one (radar related) stay was possible due to the COVID-19 travel restrictions. Nevertheless, LACE is on a good track to reach satisfactory results with radar reflectivity. 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. A stand-alone preprocessing software is meant for easier handling and consolidation of those developments to be shared within members.

Apart from the radar observations, enhanced use of AMV and some other observations was also considered. The amounts of aircraft increased in 2021 and this has increased attention for data assimilation studies again.

Significant efforts were given to further validation of SEKF and related use of surface observations, mainly in Hungary where several remaining issues were studied and partially resolved (e.g. tuning of background, observation errors and perturbation magnitude). Work on use of up-to-date leaf area index has continued at was shown to have potential to address the problems the NWP system is experiencing in stable atmospheric conditions.

The migration towards cy43 can now be considered almost finalized in terms of DA configurations and accompanying modernization of DA suites. Substantial efforts were 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 algorithm.

Action/Subject/Deliverable: ***Operational implementation of DA suites [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 2021):

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	38t1_bf8	43t2ag	cy43t2bf11	cy43t2bf11	cy43t2bf11	43t2_bf10
LBC	IFS 1h (lagged)	IFS 3h (lagged)	ARP 3h	IFS 3h (lagged)	IFS 1h (lagged)	ARP 3h	IFS 1h/3h (lagged)
Method	OI_main MES-CAN + 3d-Var	OI + 3D-Var	OI + BlendVar	OI + 3D-Var	OI_main + 3D-Var	OI + DF Blend-ing	OI + 3D-Var
Cycling	3h	3h	6h	6h	3h	6h	3h
B matrix	EDA on C-LAEF	NMC method	EDA	EDA	EDA	-	Downscaled ECMWF ENS
Initiali-zation	No (SCC)	No (SCC)	IDFI in pro-duction, SCC	DFI	No	No	No (SCC)
Obs.	Synop + AS Amdar/ Mode-S EHS EU Geowind Temp ASCAT, Snow-grid/MODIS snowmask.	Synop Amdar/MRAR Geowind Temp Seviri	Synop + AS (soil) Amdar/MRAR /EHS-EU) AMV/HR, Pro-filer, ASCAT, Temp Seviri,	Synop + AS Amdar Geowind Temp, Seviri AMSUA/MHS	Synop + AS GNSS ZTD Amdar/Mode -S MRAR Temp	Synop + AS	Synop + AS Amdar/MRAR/ EHS Geowind Temp Seviri AMSUA/MHS/IA SI 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
Resol	1.2 L90 900 x 576	2.3L87-NH 1069 x 853
Cycle	43t2bf11	43t2pt_op1
LBC	AROME 1h	-
Method	OI_main MESCAN + 3d-Var + LHN + FDDA	3DVAR + OI
Cycling	1h	-
B matrix	Static EDA + differences of the day	EDA
Initialization	IAU	-
Obs.	Synop + AS, Amdar/MRAR/EHS national, EHS EMADDC, Geowind, Temp, bufrTEMP, Seviri, AMSUA/MHS/HIRS/ATMS/IASI (+ Metop-C), ASCAT, GNSS ZTD (Austria + EGVAP, 1h VARBC), GPSRO (OPLACE), Radar RH/Dow (+HU), INCA + AS at hig.freq., MODIS snowmask	Synop + AS, Amdar/MRAR/EHS, Geowind/HRWIND,Pro-filer, ASCAT, Seviri

Table E3: Operational ensemble systems in RC LACE countries which 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**, the extensive parallel experiments were shown to be satisfying regarding verification scores and a switch to cy43t2 was made. There are slight changes in the operational setup: domains for C-LAEF and AROME_AUT are now fully harmonized; windfarm parametrization in AROME-RUC is extended and VARBC for GNSS is implemented on the hourly scale. A bugfix for OI-MAIN related to missing initialization of ZSCAL was introduced in all the 3 DA systems (otherwise the SST is kept constant in cycling where there is a misfit between the LSM and nature tiles). Model version cy46t1 export was compiled successfully. The scientific projects were partly delayed due to delayed observation delivery by the project partners.

In **Croatia**, a new procedure for creating national OBSOUL files was developed in the first half of 2021. The main changes are that the new procedure creates OBSOUL files directly from database for automatic stations and database for the Synop stations without the former intermediate step. Several new stations were added. Hourly coupling to IFS instead of current 3-hourly was tested inside DA e-suite cy43. 72h forecasts initialized from the 3- or 1-hourly DA cycle were calculated for period of two weeks. Validation is still ongoing, but first results are rather neutral. DHMZ is currently porting cy43 e-suite (ALARO CSC) to a new HPC; it is planned to be operational by the end of the year.

In the **Czech Republic**, DA staff was heavily occupied with porting activities to the new HPC. Preparational work for radar DA assimilation stay of S. Panežić was carried out by collecting the latest modifications from Meteo France.

In **Hungary**, the effort to apply 90 vertical levels to the 2.5 km AROME suite was continued with evaluation and tuning of the EDA-based B-matrix using the Desroziers' method. Tuning evaluation was repeated for summer and winter periods, by inter-comparing the older and new tuning experiments (Table C1).

Table C1: Settings in the data assimilation experiments (previous experiments in grey).

	CANOPY	NLEVBAL0/ NLEVBAL1	SIGMAO_COEF	REDNMC	REDNMC_Q
REF 60 lev	yes	11/17	0.9	1.2	-
EXP1 90 lev	no	0/0	0.71	1.26	-
EXP2 90 lev	no	0/0	0.9	1.2	1.67
EXP3 90 lev	yes	0/0	0.9	1.2	1.67
EXP4 90 lev	no	0/0	0.65	1.54	2.28
EXP5 90 lev	no	0/0	0.65	1.69	1.8
EXP6 90 lev	no	22/30	0.9	1.2	1.67
EXP7 90 lev	no	22/30	0.9	1.6	-

A couple of additional corrections with respect to the previous experiments were applied: correction to SIGMAO_COEFF to be applied to all obs. types, and values of parameters NLEVBAL0 and NLEVBAL1 were initialized more appropriately (by default, it is just defined for a selected number of vertical geometries). This last modification proved to have a positive impact on the 3h precipitation bias (Fig. C1).

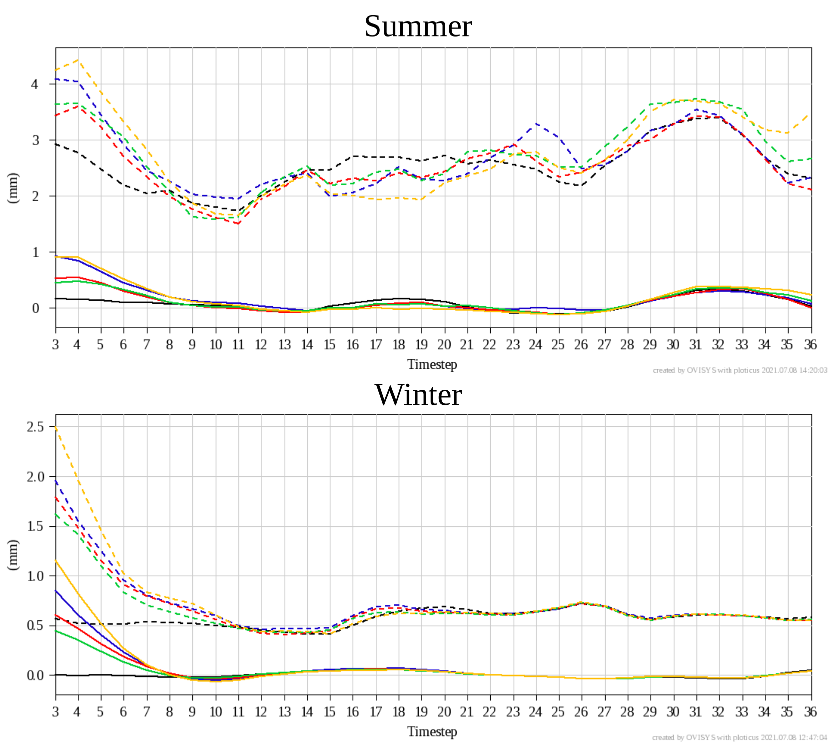

Fig. C1: Bias (solid line) and RMSE (dashed line) of 3-hour precipitation in the 0 UTC runs from 9 to 31 July 2020 (top) and from 25 November to 17 December 2019 (bottom) as a function of lead time. Black *line: AROME/HU at 60 levels; blue, red, green and yellow lines: assimilation runs at 90 levels with different tuning settings (EXP1, EXP2, EXP6 with corrected NLEVBAL parameters with a separate SIGMAO_Q tuning and EXP7 without the separate humidity treatment, see Table C1).*

A winter case study confirmed improved results of tuned experiment on the initial precipitation. Figure C2 shows that in experiment with adjusted NLEVBAL there is much smaller precipitation in the first 3 hours compared to previously tuned reference EXP2. Unfortunately on that day there was no precipitation at all which was well captured in the operational 60-level run but not in the 90 levels experiments. As the precipitation bias was considered too high, it was decided to **keep the current vertical resolution** with 2.5 km horizontal grid distance.

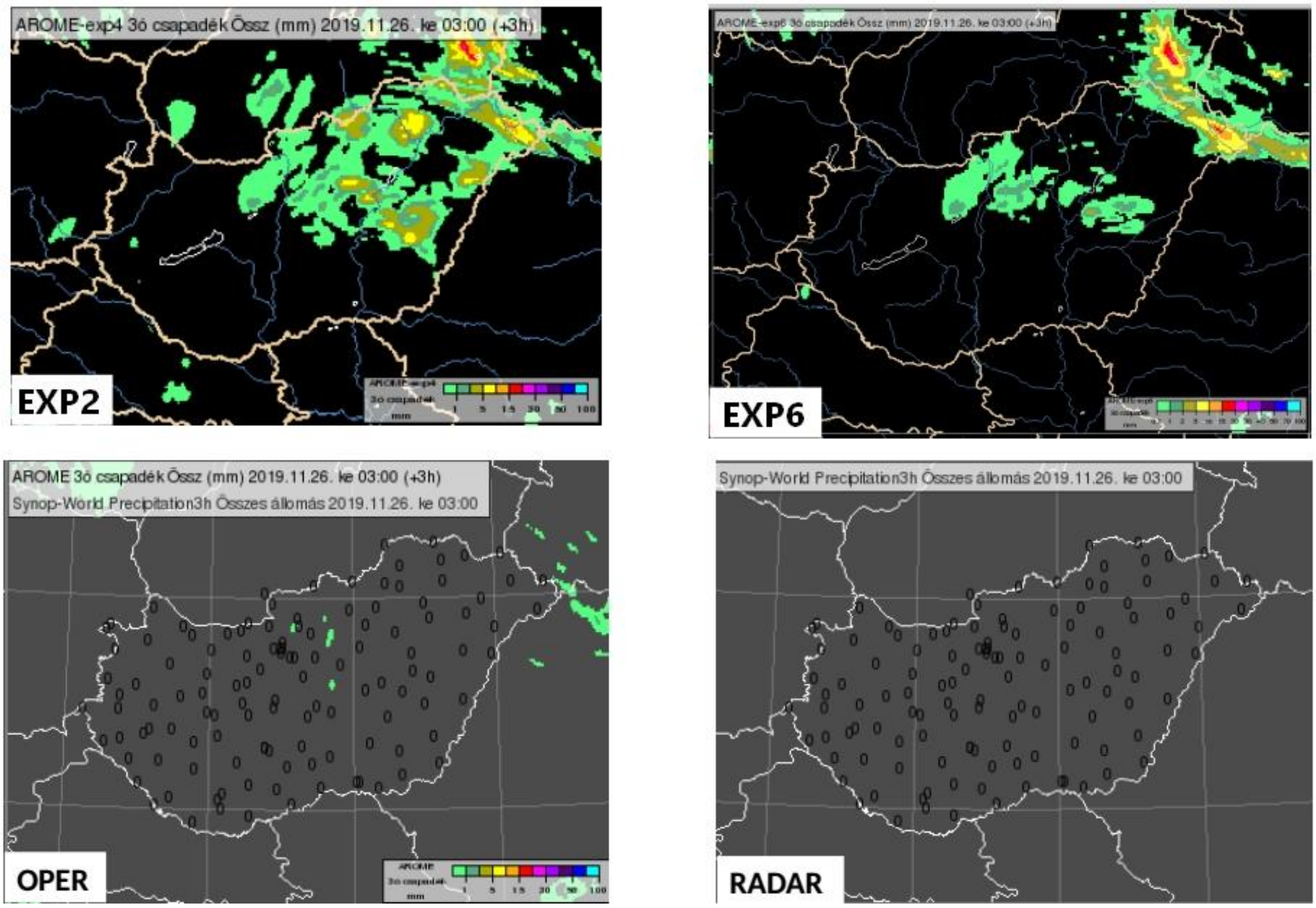

Fig. C2: 3-hour precipitation sum at 3 UTC on 26 November 2019 based on 3-hour forecasts from the 90-level experimental runs with EXP2 settings (top left) and EXP6 settings (top right), the 60-level operational run (bottom left) and radar data (bottom right).

Like in Austria, the SST update problem was investigated and the ZSCAL-related fix was introduced. Figure C3 shows the result of 1-month experiment for August 2021 with the modification. The 2-meter temperature forecast has improved significantly in Rijeka (Croatian coast, Fig. C3), but also the precipitation and cloudiness were affected. The implementation in the operational release was done on 5 January 2022.

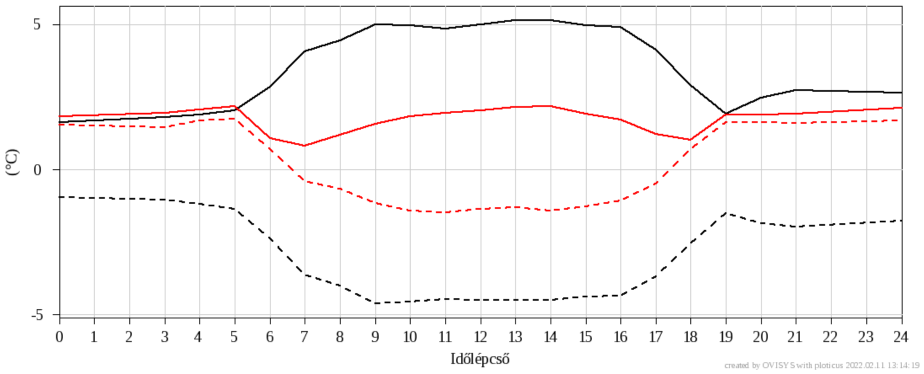

Figure C3: Bias (dashed line) and RMSE (solid line) of 2-meter temperature forecasts in Rijeka in the 0 UTC runs from 1 to 30 August 2021. Black and red lines: operational AROME/HU, modified AROME/HU, respectively.

In Slovakia, efforts were invested in validation of BlandVar and 3D-Var. The SHMI group supervised a bachelor thesis work on testing the hourly DA (comparing 6h with 3h assimilation cycle) and utilization of additional high-resolution observations. The technical modifications of the scripts/namelists were performed and several case studies were run. The work shall continue. A test with whitelisting of MUAC-EHS data showed positive results but this dataset was replaced by EHS-EU. Investigation of problematic analysis scores of Td at 300 hPa is ongoing. CANARI analysis was implemented and validated within the local conv. permitting ALARO suite (a short note will appear in the ACCORD newsletter).

In **Slovenia**, most local work was devoted to design and evaluate the nowcasting NWP setup with 1.3 km horizontal resolution and hourly cycling. The system was validated over 1 month in the summer and winter periods as described below and runs in real time mode with 35 min cutoff time. Improvements were achieved in utilization of diagnostic (operational obsmon) and verification packages (Harmonie monitor and harp) were achieved by adding the automatic stations from Italy, Austria and Slovenia to the surface verification datasets. Data assimilation scripts were upgraded and reordered so that surface analysis is performed before the upper-air assimilation (was in parallel before). Model version cy46t1 export was compiled successfully.

In **Romania**, the assimilation activities have been on hold in 2021. Apart from the 6.5 km suite, two additional model setups at 4 km and 2.5 km are under evaluation, and addition of DA component is planned for both setups.

In **Poland,** the activities towards the first assimilation suite are ongoing, the model cycle 43t2_bf10 will is used. The DA developments are coordinated within the DAsKIT.

Contributors: All (approx. 1 PM per country, more in some institutes - Hungary 4)

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

Description and objectives:

Upgrade of BlendVar data assimilation cycle frequency from 6 h to 3 h, explore surface analysis setting/coupling within SURFEX. [DA 1.5]

In **Slovakia**, the test BlendVAR suite was extensively validated together with utilization of additional observation types. Case studies were run as input for a scientific paper. Several tests included:

- For surface DA, MESCAN scheme was tested in CANARI with no spectacular improvement seen on the standard verification scores. This will not be switched to the operational suite for the time being.
- Use of all national AWS: no spectacular improvement seen on the standard verification scores, but positive impact demonstrated on several case studies of incorrect operational forecasts within a bachelor thesis. AWSs are ready to be included in the BLENDVAR e-suite soon.
- tests with GNSS ZTD data processed at the Slovak University of Technology (~50-60 stations), with static whitelisting. The results are mixed, improvements are seen in some case studies. The performance of VarBC for this data needs to be examined.

An important case study of the 07 June 2020 with convective precipitation over Slovakia was carried out. Operational forecast was rather poor and largely missed the precipitation patterns and amounts. Several experiments with the BlendVar suite using additional data were performed (3 days of DA cycling plus the forecast). 3-hourly accumulated precipitation forecasts are shown for +9 h forecast based on 07-06-2020_12 UTC (Fig. 1), using several setups as defined in Table 1.1. For this case an improvement of the precipitation pattern/maxima over SW Slovakia was brought namely by utilization of GNSS ZTD and Mode-S data. The progress with radial wind DA in CHMI setup as obtained during a RC LACE stay of K. Čatlošova is quite remarkable.

Table 1.1: Experiments conducted with BlendVAR setup at SHMU.

Experiment	Content	Description
TSTI	synop, temp, amdar	reference BLENDVAR setup
HRWN	as TSTI + hrwind	with code correction for HRWIND
ZTDS	as HRWN + GNSS ZTD	as HRWN + ZTD obsoul from SUT data, static whitelist
AWS1	as HRWN + AWS	as HRWN + all local AWS from OPLACE

MODE	as HRWN + Mode-S data	as HRWN + Mode-S data from OPLACE
MODS	as MODE	as MODE, but whitelist used for EHS
BFTT	as HRWN, TEMP BUFR - TT setup	BUFR TEMP, traj/time split off
BFFF	as HRWN, TEMP BUFR - FF setup	BUFR TEMP, traj/time split on => RS drift activated
ALLD	HRW+ZTDS+AWS+MODE+BFFF	all data
ALLS	HRW+ZTDS+AWS+MODS+BFFF	all data but EHS MODE-S whitelisted as in MODS
Ref	CHMI setup	run with ALADIN/CHMI
Rad	as CHMI + OPERA radial winds	outcome of stay at CHMI

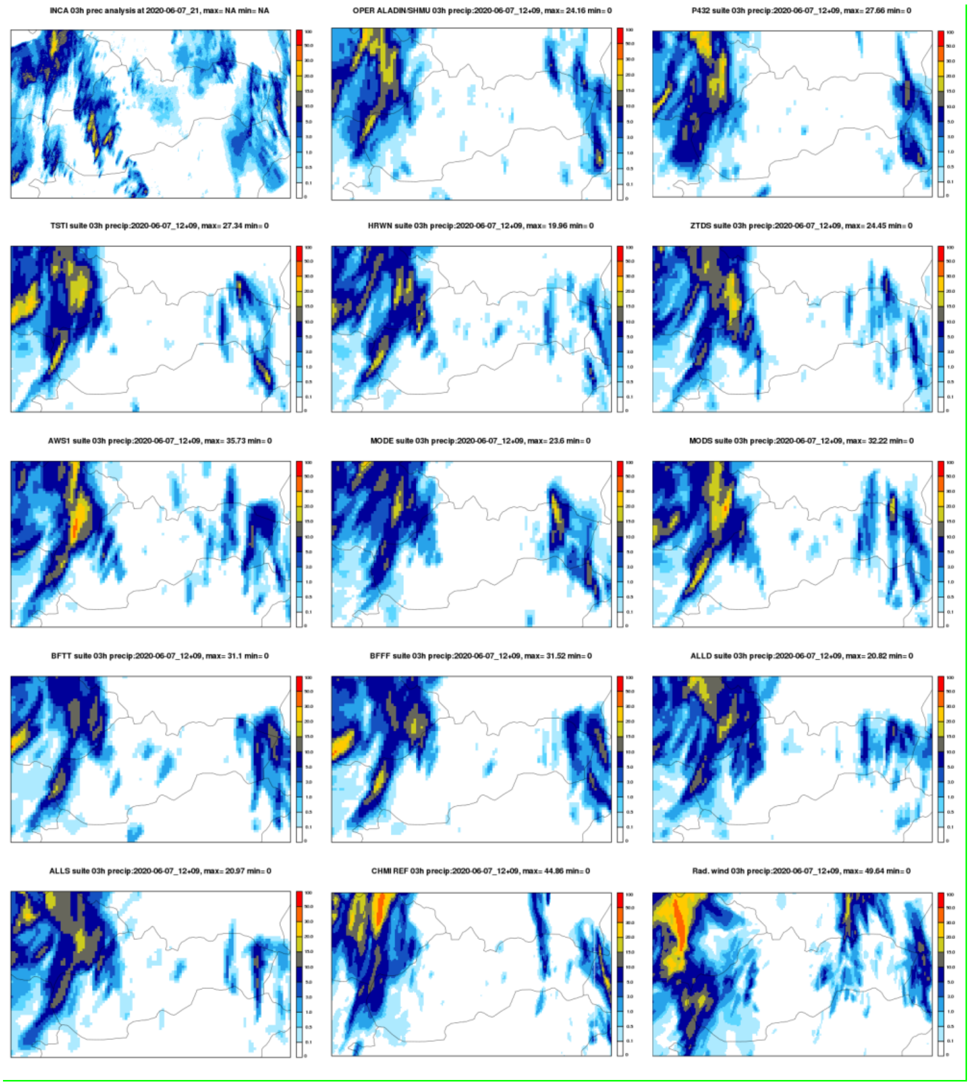

Figure 1.1: 3-hourly accumulated precipitation forecast from 07-06-2020_12 UTC for +9h. Top line from left to right: INCA analysis, operational forecast (DF BLENDING+CANARI), the same but with CY43t2 (as operational today). Other lines: various setups of BlendVAR as defined in the Table 1.1.

Recalculation of climatological B-matrix based on local ensemble data assimilation (EDA) and comparisons with static B. [DA 1.2]

Antonio Stanešić (CR) started the work on B-matrix computation for the ALARO CSC 4 km resolution model configuration using ensemble approach. The first step of the B-matrix calculation plan was to compute the spinup/downscaled B matrix. For downscaling, 16 members of ECMWF IFS ENS were interpolated to a 4 km model domain by Endi Keresturi (CR), using e903 configuration (two-week period in winter and summer). The problem is that the surface of the IFS model does not correspond well to the surface in the ALARO CSC. In order to explore the appropriate solution of the problem, several two-week (winter period) data assimilation cycles were set up, where some were initialised from the IFS ENS and the other from the ALARO CSC (e-suite) surface analysis. For these experiments, local data assimilation cycle was set up with CANARI for surface analysis and for upper-air fields no analysis is performed (upper air fields are simply interpolated from global models to a local model domain). By looking at the first guess departures and soil wetness index differences, it was concluded that the best way to initialise computations was by using the same ALARO CSC surface for all EDA members and to leave out the first 6 days for B-matrix computation.
Several sampling strategies were tested: all forecasts from 3-hourly data assimilation cycle were used (Bspinup); only forecasts valid at 00 UTC (winter) and 12 UTC (summer) were used (Bspinup00z12lj); only forecasts valid at 00 UTC, 06 UTC (winter) and 12 UTC, 18 UTC (summer) were used (Bspinup0006z1218lj), Fig. 1.2. When looking at spectral densities, Bspinup00z12lj proved to be too noisy, while Bspinup was too smoothed-out, so Bspinup0006z1218lj was chosen for the further evaluation. Next steps include the tuning of the spinup B-matrix and setting up of EDA with it in order to compute the ensemble B-matrix.

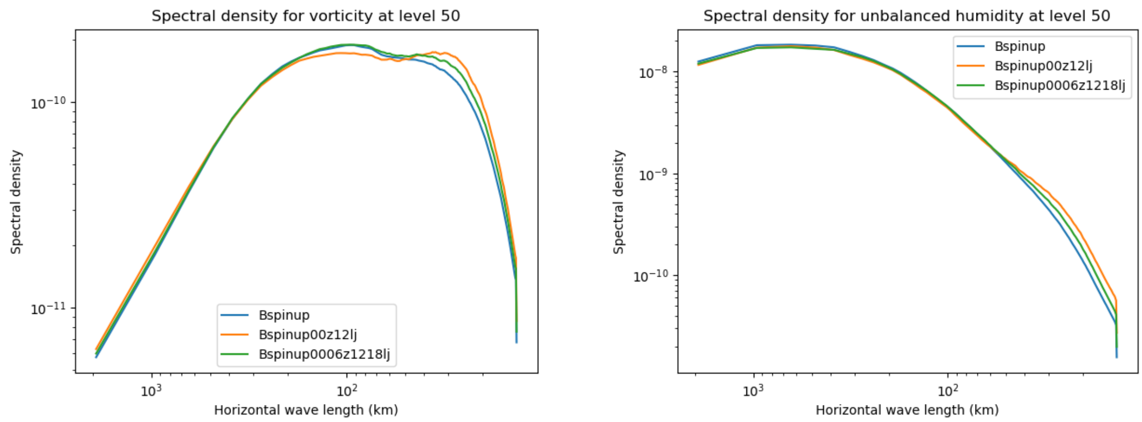

Figure 1.2: Horizontal spectral covariance densities for vorticity and unbalanced humidity at level 50.

Investigation of the effect of cycling of GFL fields in the DA cycle [DA 1.5]

In **Croatia**, cycling of 12 GFL fields was implemented in DA e-suite in cy43. Impact of cycling of GFL fields on 72 h forecast was investigated for the period from November 23 to December 10

2020. During that period, cases of severe fog, freezing rain and intensive cyclonic precipitation occurred. Verification scores were better for the new setup for 2 m relative humidity, cloud cover, and most of the upper-air fields, mainly during the first 20 hours of the forecast (Fig. 1.3).

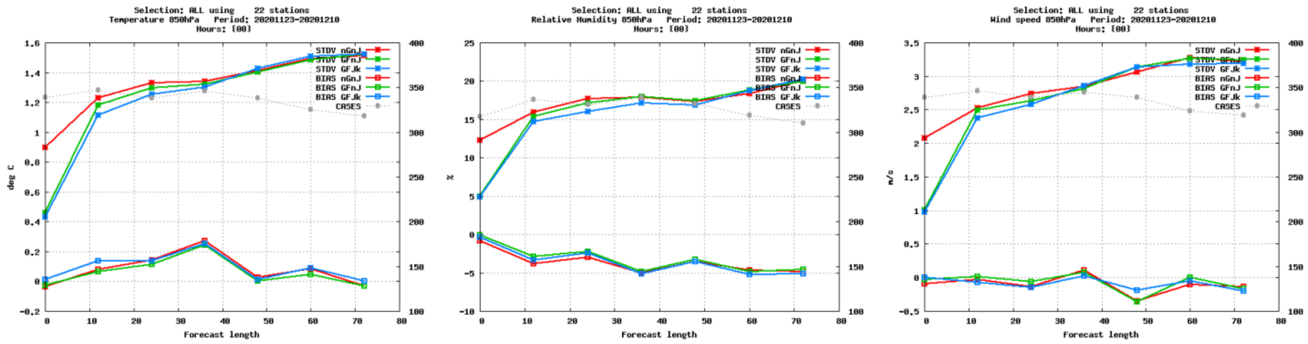

Figure 1.3: BIAS and STDEV for 850 hPa temperature (left), relative humidity (middle) and wind speed (right). Red line represents reference, green line GFL experiment and blue line GFL and Jk experiment.

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

Additionally, for the period described above, Jk method was also tested (blue line in Fig. 1.3). Verification results indicate a positive effect on the forecast for upper-air fields. Mean pressure tendencies were calculated over whole ALADIN-HR4 domain and over several DA cycles (Fig. 1.4). Results indicate that adding of GFL fields does not have impact on spinup, while using Jk has positive effect (smaller initial pressure tendencies).

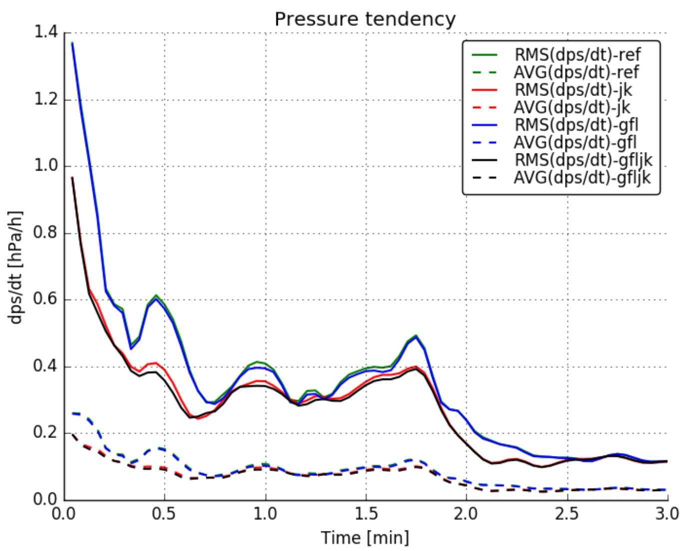

Figure 1.4: Mean (dashed) and root means square (full line) pressure tendencies for first three forecast hours inside DA cycle calculated over domain and several (6) DA cycles. Pressure tendencies were calculated for reference (green), reference with Jk (red), reference with GFL cycling (blue) and reference with Jk and GFL cycling (black).

Endi Keresturi (CR) explored the use of dynamically varying cut-off wavenumber (N) in the Jk method. The goal is to move away from constant value of N and to make it flow-dependent. This is still in the research phase so no experiments within the data assimilation itself were done, but they are planned for 2022.

Antonio Stanešić (CR) tested 1-hourly versus 3-hourly coupling inside ALARO CSC. Both data assimilation cycles were set up for a period of 21 days. After one week of warm-up period, 72h forecasts were calculated for 00 UTC run for the remainder of the period. Verification scores showed no significant differences.

Efforts: 8.25 month

Contributors: A. Stanešić (CR) 1.5, A. Šljivić (CR) 0.5, I. Dominović (CR) 0.25, M. Derkova (SK) 4, M. Dian (SK) 0.5, E. Keresturi (CR) 0.75, M. Nestiak (SK) 0.75

Documentation: /

Status: ONGOING

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

Description of tasks:

Validation of solutions for wind dealiasing and quality control

Peter Smerkol (SI) provided an upgrade of the homogenization tool for radar data files from OPERA (HOOF2). In HOOF, the radial wind dealiasing was implemented using the torus method, described in Haase and Landelius (2004). In this method, we assume a linear model for the radial wind as a function of azimuth. On aliased data, the model has discontinuities whenever it passes a multiple of Nyquist velocity. The model curve can be made continuous by mapping it onto a torus. With the mapped function now being differentiable, we can express the coefficients in the model with derivatives that can be calculated with data, and then fitted to solve for the radial wind components (Fig. 3.1). From these, the Nyquist multiplication factor needed to dealias the data can be determined. This procedure is done separately for different height intervals of 100 m, to be as close as possible to the assumption of linear wind (Fig. 3.2). The dealiasing procedure shows promising results, but a way of rejecting data that has been wrongly dealiased has to be devised.

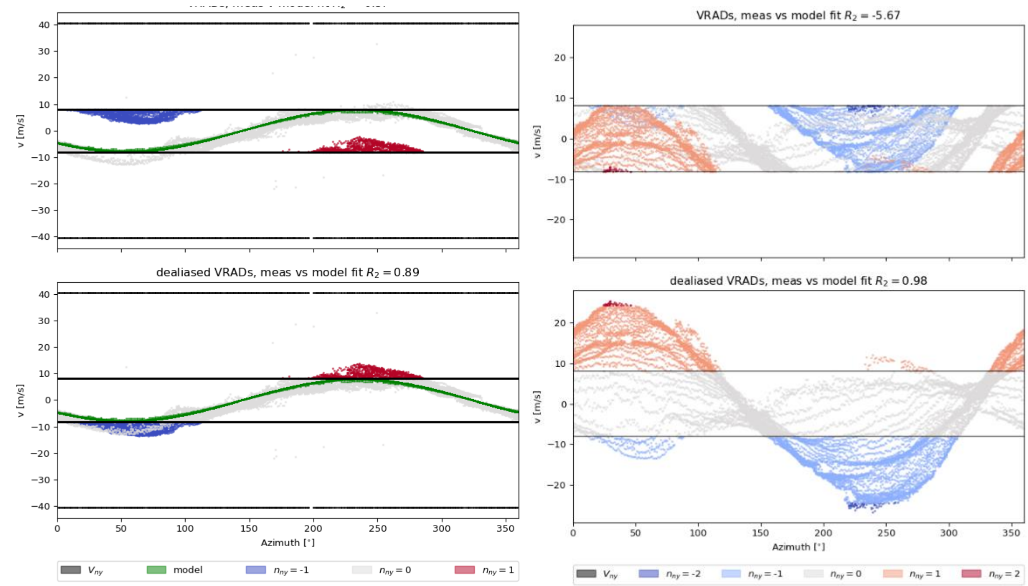

Figure 3.1: Dealiasing procedure for data from a single height sector (left) and for combined data from all height sectors in one radar elevation (scan). Aliased data is on the top and dealiased data on the bottom. Plots show dependence of radial wind on azimuth.

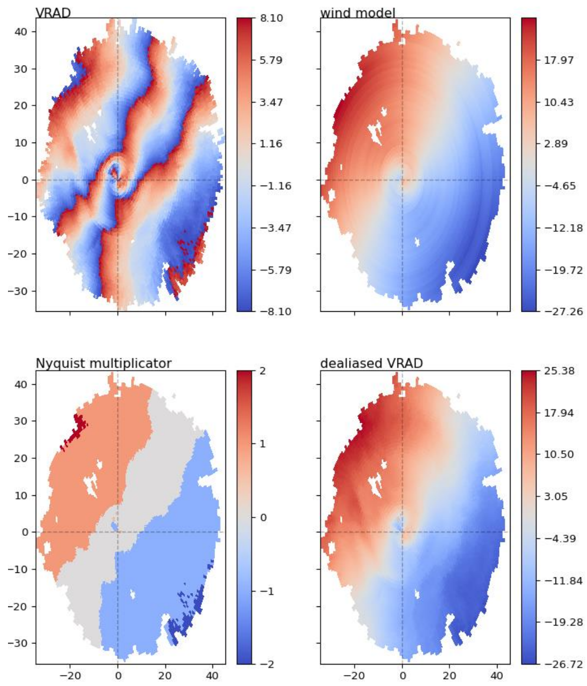

Figure 3.2: Dealiasing procedure combined for data from all height sectors in one radar elevation (scan). Plots are geographical plots in kilometers. Top left: Aliased radial wind. Top right: Radial velocity calculated from the wind model. Bottom left: Calculated multiplicator for dealiasing. Bottom right: De-aliased radial wind.

Impact studies with OPERA reflectivity observations

In **Austria**, an alternative initialization of hydrometeors is developed based on reflectivity and precipitation type derived from RADAR data (ZAMG radar department HDF5 product) using an inversion of the reflectivity operator in an offline (epygram +Fortran based) tool (Fig 3.3). The activity is ongoing and should be finished by the end of the year. In the AROME-RUC parallel run, the radars from Hungary are successfully integrated (they caused crashes in cy40t1 with HARMONIE Bator, but are OK within cy43t2 MF Bator). This required small modifications of the “prepopera.py” radar preprocessing script.

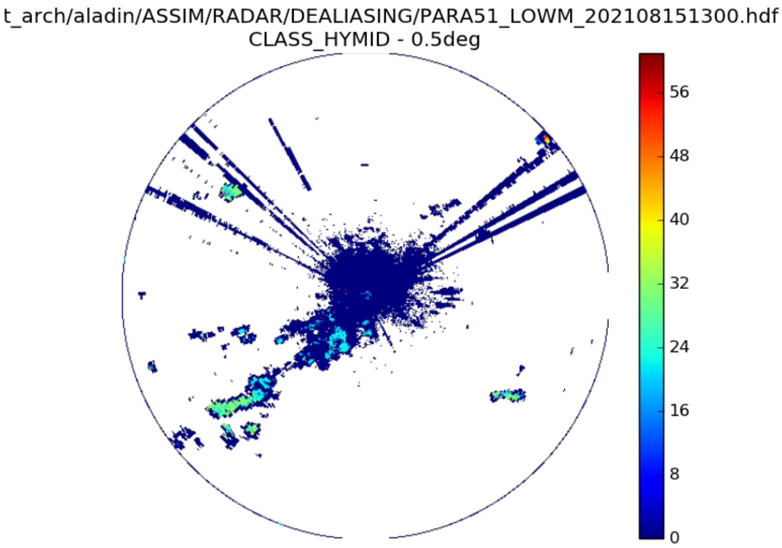

Figure 3.3: 3D hydrometeor classification based on RADAR (Vienna-Airport 20210815 13UTC) The classes are: 0 non meteorological, 11 crystals, 12 ice, 13 aggregates, 21 light rain, 22 moderate rain, 31 wet snow, 41 rimed ice 51 graupel, 61 hail.

In **Slovenia**, a radar reflectivity impact study was carried out by Benedikt Strajnar, in combination with evaluation of the hourly NWCRUC system (see the Nowcasting application section). The experiment using reflectivity was compared with the reference run at both 4.4 and 1.2 km resolutions. Radar sites from LACE countries (except Austria), Switzerland, Germany and France were used, depending on the domain extent, with 3 h and 1 h cycle length and thinning distances of 25 and 10 km at 4.4 and 1.3 km resolution, respectively. From subjective validation it was concluded that the radar DA was especially capable of removing spurious precipitation in the first guess. Additional moisture was added correctly to larger precipitation systems. For smaller and isolated convection, the system often suffered from removing the rainy pixels by the thinning procedure. The OMG analysis over both periods indicate net drying of the atmosphere by the reflectivity data assimilation. This was confirmed by the hourly precipitation verification using Synop and automatic rainfall measurements from Slovenia, northeastern Italy and Austria. Reduced frequency bias is apparent at both resolutions for up to 6h into the forecast. In winter this also contributes to the increased ETS while in summer the ETS impact rather is neutral. The impact is more mixed in summer and at 4.4 km resolution in general slightly negative in terms of bias (dry and cold bias) for upper air fields (Fig. 3.4). Standard deviation shows no significant changes. Adding additional weight to radar DA (SIGMAO_COEFF tuning) resulted in score degradations, which suggest that optimization was needed in the reflectivity assimilation procedure. Several modifications to the screening procedure were tested on a limited number of interesting events, mainly with a goal to select moist pixels for assimilation (Fig. 3.5). For example the preference to assimilate dry profiles in case both model and observations were dry was suppressed, which resulted in using less pixels while adding more moisture from the convective systems as shown in Fig. 3.6. Based on the radar measurement with maximum radar reflectivity shown in the middle, the default setup chose mostly dry pixels (upper-left), which resulted in no precipitation in the subsequent 1 h forecast (bottom left). The modified setup (dry pixels suppressed) in the right resulted in wet increment and the convective cell was included in the forecast.

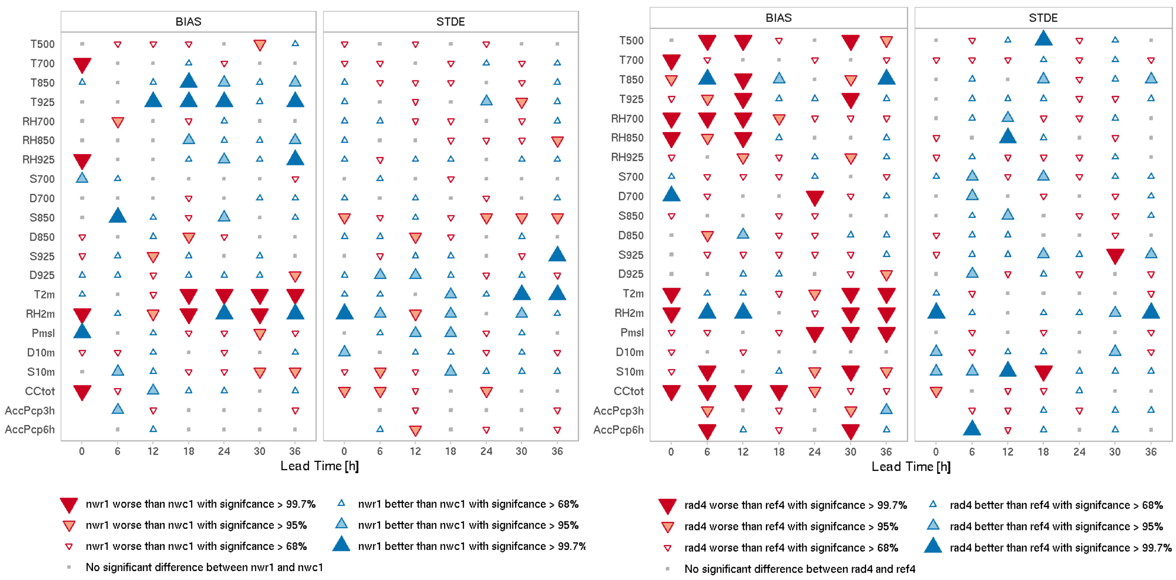

Figure 3.4: Scorecard of radar reflectivity experiments with respect to references for 1.3 km (left) and 4.4 km (right) resolutions. Blue color means improvement of runs using radar DA.

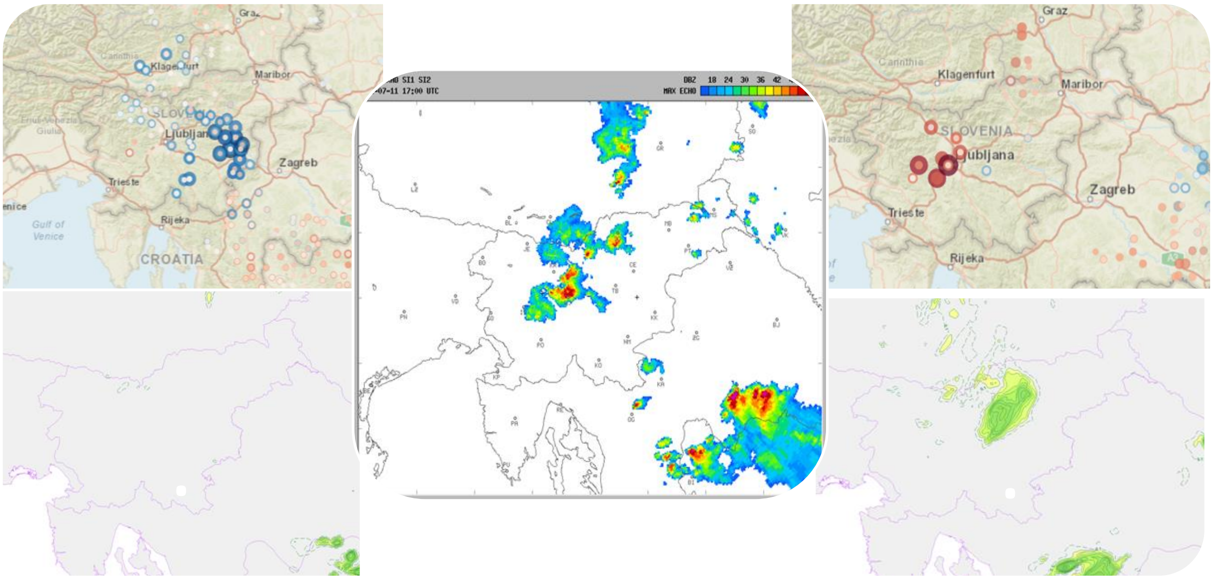

Figure 3.5: Modifications of the screening selection procedure for radar reflectivity for 11 July 17 UTC. Left: analysis increment at selected pixels (blue is dry, red is wet) and the resulting 1h precipitation forecast field of a default setup. Right: analysis increment at selected pixels and the resulting 1h precipitation forecast field of a modified setup with less preference for dry pixels. Middle: maximum radar reflectivity map of the input radar datasets (composite of 2 Slovenian radars).

Further effort was focused on use of dry observations and their effect on humidity fields. A major concern is proper use of “undetect” observations, to which a detection threshold, deduced from observed data, is assigned and used to compute Bayesian weights. Two alternative scenarios were evaluated in separate experiments: the first only allows wet-to-wet or wet-to-dry comparisons so comparison only takes place if either the model background or observation value is above a given rain threshold (e.g.13 dBZ); the second one uses alternative averaging of humidity profiles in the neighbourhood in case drying is needed. Instead of only averaging the fully dry ones, all the profiles below the rain threshold are used in the Bayesian inversion. As a separate experiment, recent operational modifications by Meteo France (on top of the export version cy43t2, Maud Martet) were evaluated. The impact was studied over August 2020 and for two resolutions used at ARSO (4.4 and 1.3 km).

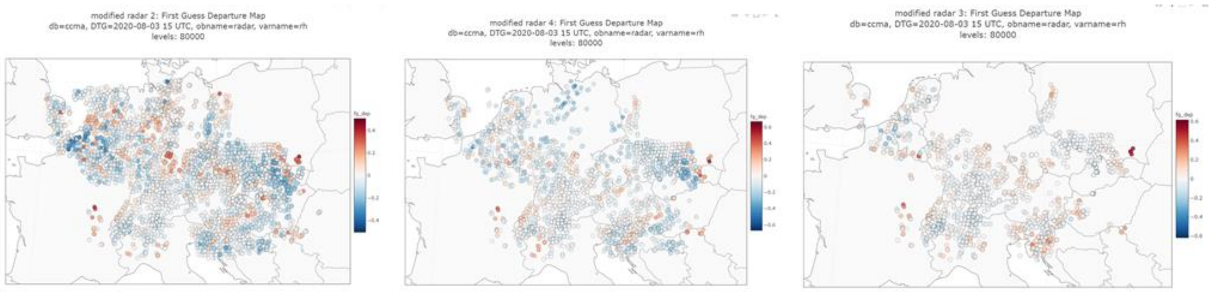

Figure 3.6: Observation-minus-background departures of relative humidity for assimilated reflectivity points at 800 hPa. Default 4.4 km ALARO setup (left), only wet pixels (middle) and modified averaging during the drying cases (right).

The different setups largely influence (reduce) the number of assimilated observations (Fig. 3.6). While the reduction from "wet-only" run is quite logical, a further reduction in the "modified drying" experiment is a result of more rejections from the QC, where the same sign of increment in reflectivity and humidity is required. Objective verification was focused on precipitation.

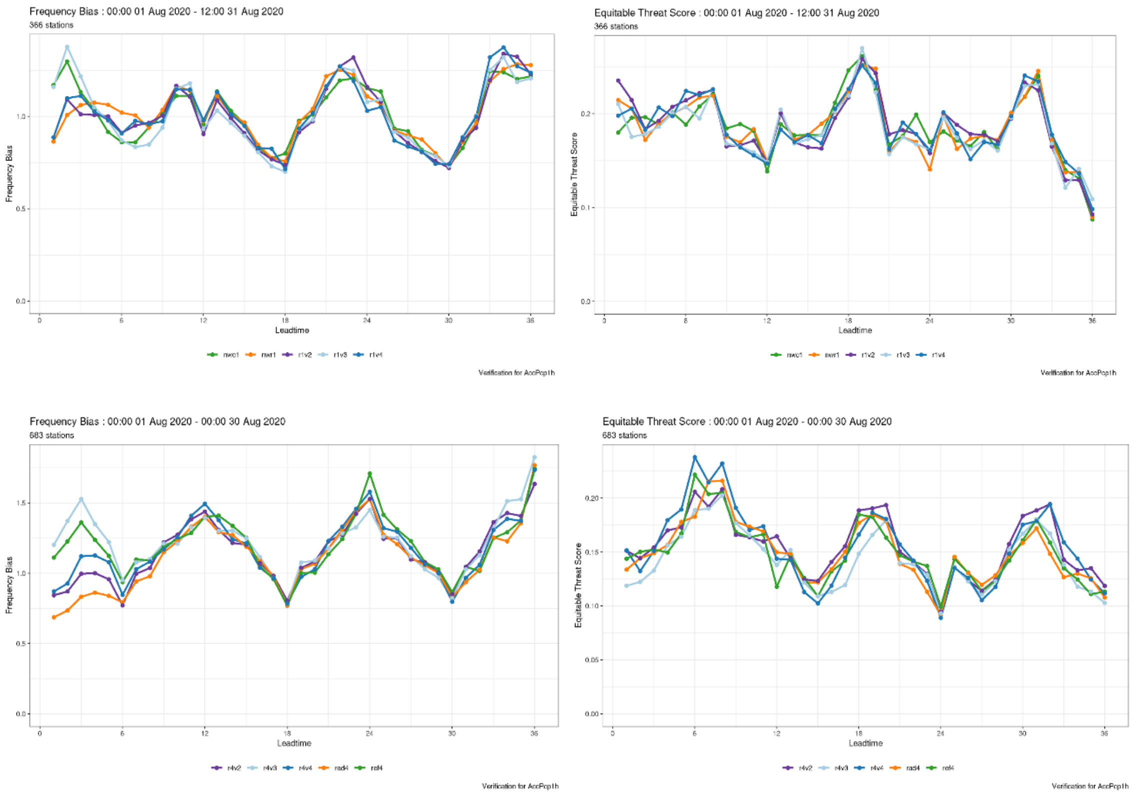

Figure 3.7: Frequency bias (left) and ETS score (right) for 2 mm threshold of hourly precipitation amount in 1.3 km (top row) and 4.4 km model suite (bottom). The reference without reflectivity DA is in green

and default DA setup in orange. The dark blue is the “wet-only” experiment and the light blue is the “modified drying” experiment. The purple line represents operational setup at MF.

Looking at several precipitation thresholds and accumulation times (such as in Fig. 3.7) and other variables such as cloudiness it is concluded that the “modified MF setting” experiment outperforms the default one and that the “wet only“ experiment is improving that one mainly in terms of bias and is expected to be used in the first operational setup. The “modified drying” experiment is the only one that leads to additional moistening with respect to the reference run.

At **CHMI**, Suzana Panežić (CR), Alena Trojáková and Antonín Bučánek (CZ) performed a number of radar reflectivity data assimilation sensitivity tests in ALARO CSC using OIFS OPERA data. The tests include sensitivity to the number of model simulated profiles, the selection box size of the model simulated profiles and on the reflectivity observation error. Results show that there is a small sensitivity to the selection box size, with smaller box size being a better choice. The smaller observation error shows a better fit of pseudo-observed reflectivity to the observations, but a larger bias of pseudo observed relative humidity. Case studies suggested that reflectivity data assimilation with the current setup is effectively drying the atmosphere, in particular in the lower troposphere and consequently removing precipitation from the model forecast, which is not a desirable behaviour. Drying effect persists even in the no precipitating conditions which suggests the problem lies within the dry observation data assimilation, see also bottom row in Fig. 3.8. A large number of dry pseudo observations was found above 200hPa. It’s questionable if this is realistic and further understanding is needed.

By reducing the number of dry observations, the problem is partially mitigated but in turn the added moisture in the atmosphere creates strong and spurious convection with excessive amounts of rain. No firm solution to the drying problem was offered. For the next steps it is proposed to revisit the calculation of radar detection threshold in BATOR, to consider modification of weights in the inversion process and/or deeper investigation of the reflectivity observation operator. For more details see the RC LACE report.

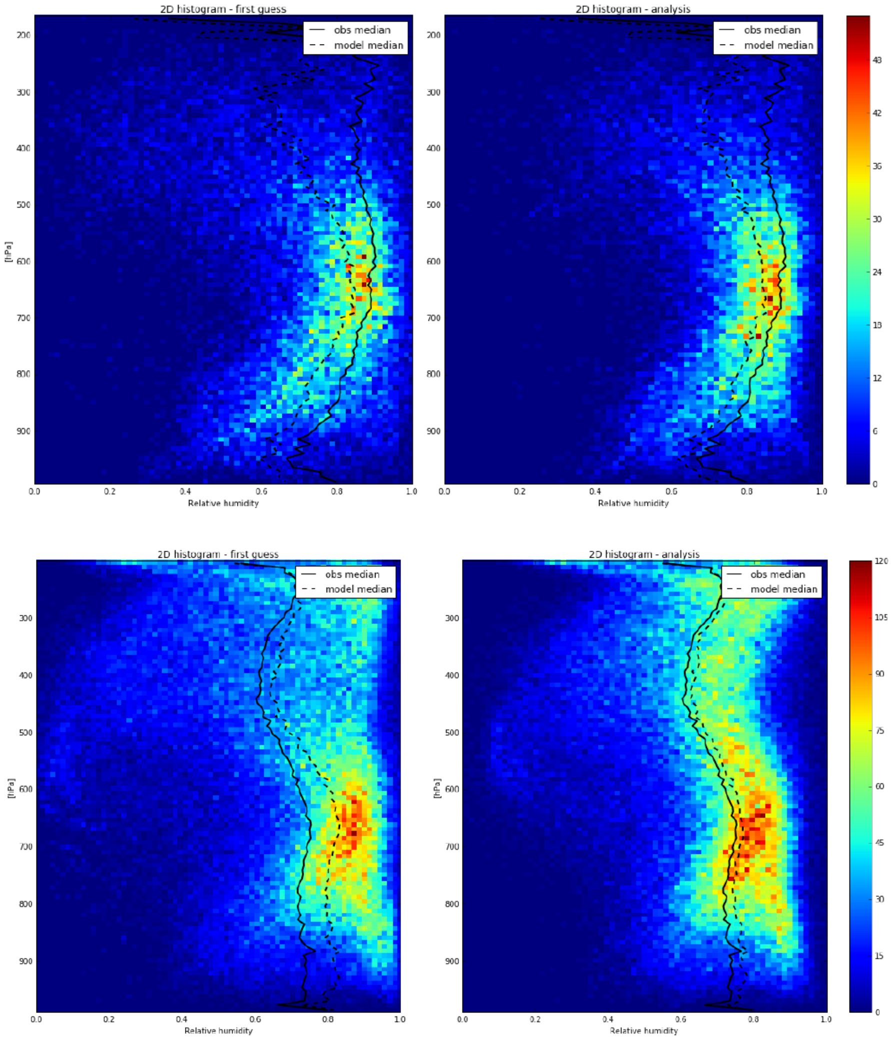

Figure 3.8: Histogram of first guess (left column) and analysis departures of RH for wet (top row) and dry (bottom) radar pixels. Median profiles are added as black lines for observations (full) and the model (dashed).

In **Slovakia**, a case study of heavy precipitation event with a poor operational forecast was studied (see also section “Further development of 3D-Var”) and the results are summarized in a submitted paper. The addition of radial winds into ALARO/CHMI resulted in a substantial improvement of precipitation forecast as indicated in Fig. 3.9.

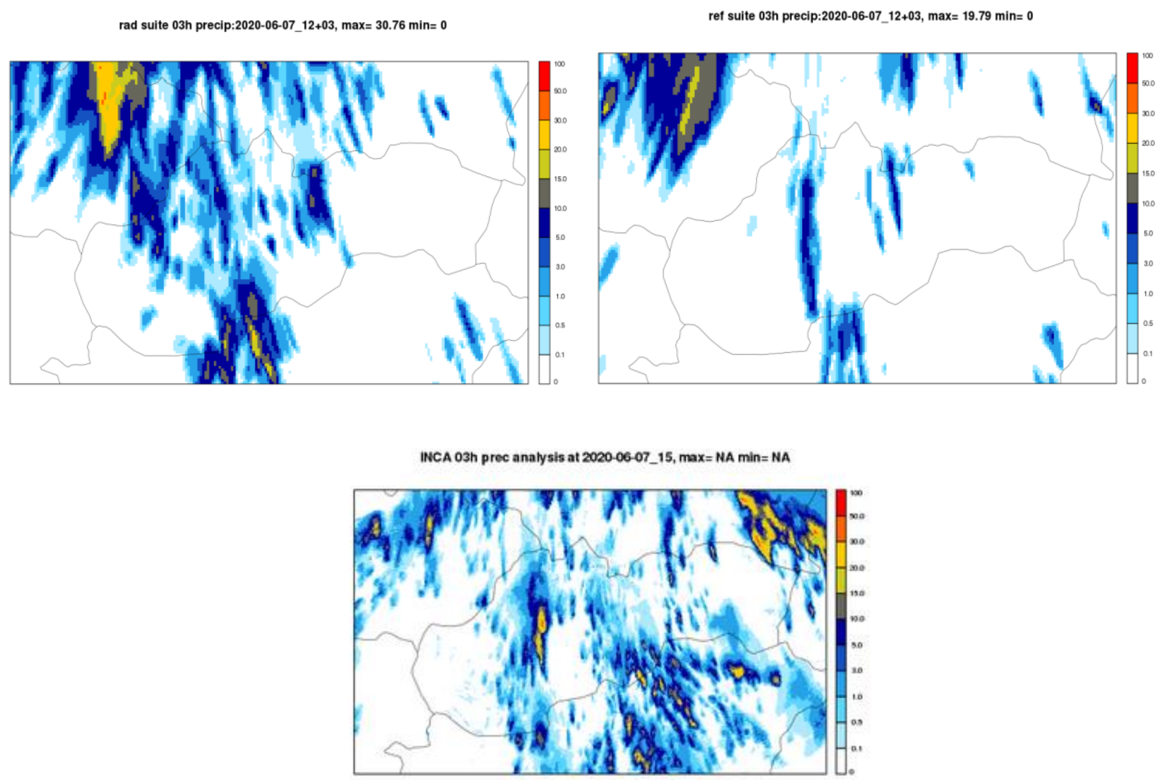

Figure 3.9: *3-hourly accumulated precipitation forecast in ALARO/CHMI from 07-06-2020_12 UTC +3h. The experiment rad used radar radial winds (top left) on top of other observations used in the ref experiment (top right) and 3h INCA analysis as a reference (bottom).*

In **Croatia**, work on radar DA has been restarted by learning, reading reports and scientific articles as preparation for a RC LACE stay at CHMI and performing technical tests of radar DA in the cy43 e-suite (sequence of HOOF, bator, screening, minimizaton).

Florian Meier (AT) coded the changes in radar thinning and inversion by Maud Martet into the local cy43t2 code version. Unlike in the ALARO systems described above, the check of first guess departures show no drying effect within Austrian AROME-RUC, but it might be hidden by other initialisation settings like national GNSS and/or latent heat nudging, IAU and profile saturation.

Updates of the HOOF preprocessing tool, addition of functionality to create super-observations based on proposal from HIRLAM.

The HOOF's purpose is to prepare all files from OPERA for input into BATOR by homogenizing it's HDF5 structure (groups, datasets and metadata). In the upgraded version, the code was rewritten in Python 3.6 and dealiasing of radial wind measurements and superobing of data was added.

In the homogenization part, the code was restructured because of new developments and the move to Python3, some minor bugs were found and corrected, and the splitting of the original OPERA to single measurements was abandoned, because it could not be consistently done for all radars. Besides the abandoned splitting, the results of the homogenization remain the same as in HOOF1.

In addition, a graphical user interface was developed for HOOF2, which can be used to preprocess one file at a time, and revise the results immediately. HOOF2 is controlled via a namelist file, which was also rewritten to be more readable. Writing of official documentation is in progress and will be done as soon as possible, but the current (working) version of HOOF is already posted on the ACCORD wiki.

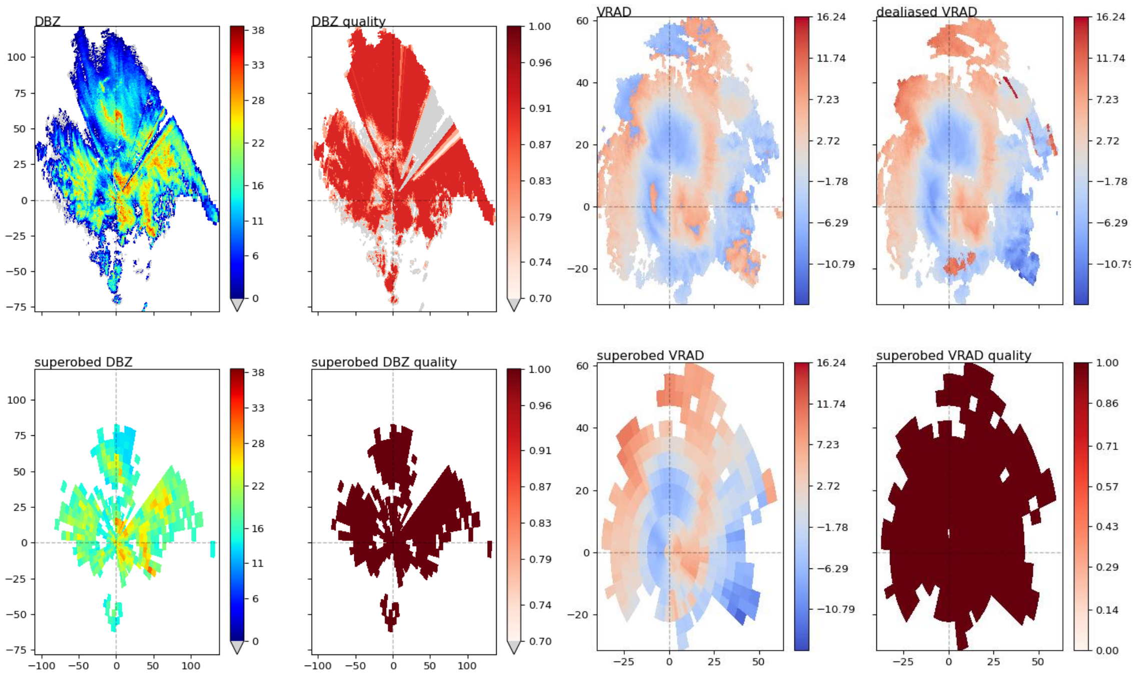

Figure 3.10: Superobing procedure for reflectivity data (left four plots) and radial wind data (right four plots) in geographical plots. For reflectivity, top left plot shows original data, top right original quality of data, bottom left the superobed data and the bottom right the new superobed quality. For radial wind data, top left plot shows original aliased data, top right dealiased data, bottom left superobed dealiased data and bottom right the new superobed quality.

Efforts: 19.75 month

Contributors: B. Strajnar (SI) 2.75, P. Smerkol (SI) 4.75, A. Bučánek (CZ) 4.25, A. Trojáková (CZ) 2, K. Čatlošová (SK) 1.5, A. Stanešić (CR) 0.5, S. Panežić (CR) 3, F. Meier (AT) 1

Documentation: HOOF user guide, updated; RC lace stay report.

Status: ONGOING

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

Validation and impact assessment of newly available Mode-S EHS (EMADDC, local data sets) and MRAR observations. [DA 3.2]

Members followed production switch of EMADDC/KNMI regarding the MODE-S dissemination and were involved in related coordination. Antonio Stanešić (CR) started the tests with the assimilation of MODE-S MRAR CZ (modes_mrar_cz) and MODE-S EHS (modes_ehs) data on top of the current AMDAR and MODES-MRAR SI observations (ref). For wind components, first guess and analysis departure statistics were similar, while for MODE-S EHS temperatures, higher values were observed (Fig. 3.11).

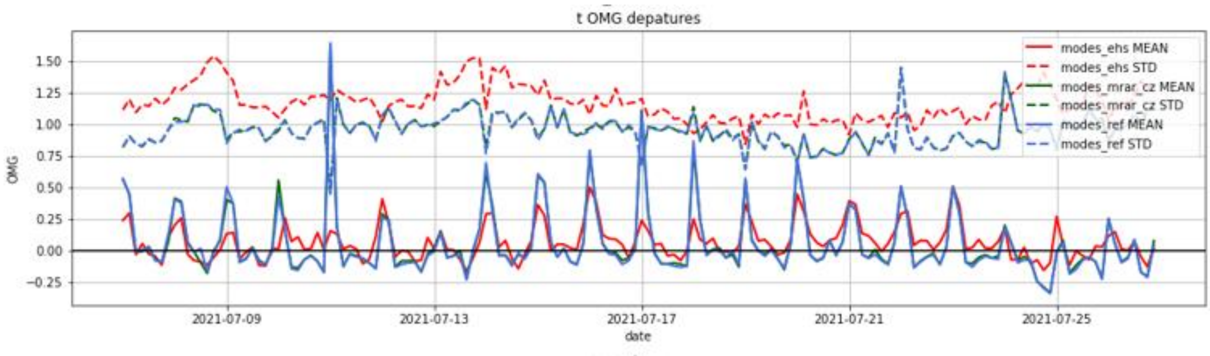

Figure 3.11: First guess departures for several DA experiments where on top of operational settings (blue) assimilation of MODE-S MRAR CZ (green), and MODE-S MRAR CZ + MODE-S EHS (red) was added.

72-h forecast verification scores were calculated for a 20-day period. Results showed negligible differences between ref and modes_mrar_cz experiments and a small impact (mixed) when comparing modes_ehs to ref. Further evaluation on different and longer periods is planned.

Refining the application of Mode-S observations in DA systems with increased assimilation cycle frequency, including application of variational bias correction (Var-BC) procedures (subject of a RC LACE stay). [DA 3.2]

No progress, stay canceled.

Evaluation and impact assessment of E-GVAP ZTD (possibly during a RC LACE stay). [DA 3.3]

In **Slovenia**, the E-GVAP data stay in passive data assimilation mode, this datatype was implemented and tested in the Obsmon validation software. Long term statistics reveal certain day-to-day jumpiness in the bias estimates, especially over the summer period (Fig. 3.12). In order to try to stabilize this, the observation error was decreased (from 100- to 10-times the default value of 0.01 m). An impact study is planned after the eventual stabilization of the bias estimates. The arrangements to use local data via the computation of ZTD by foreign partners are ongoing.

Benedikt Strajnar (SI) also worked on including the Slovenian national data to E-GVAP processing at SGO (Hungary) and coordinated its transfer via the E-GVAP and OPLACE. Data quality decrease for Hungarian SGO1 network was detected. SGO will try to improve the quality of ZTD data processing in an attempt to be moved from “test” to “oper” stream at E-GVAP after a successful month. Note that test ZTD data from E-GVAP are already used operationally at some institutes.

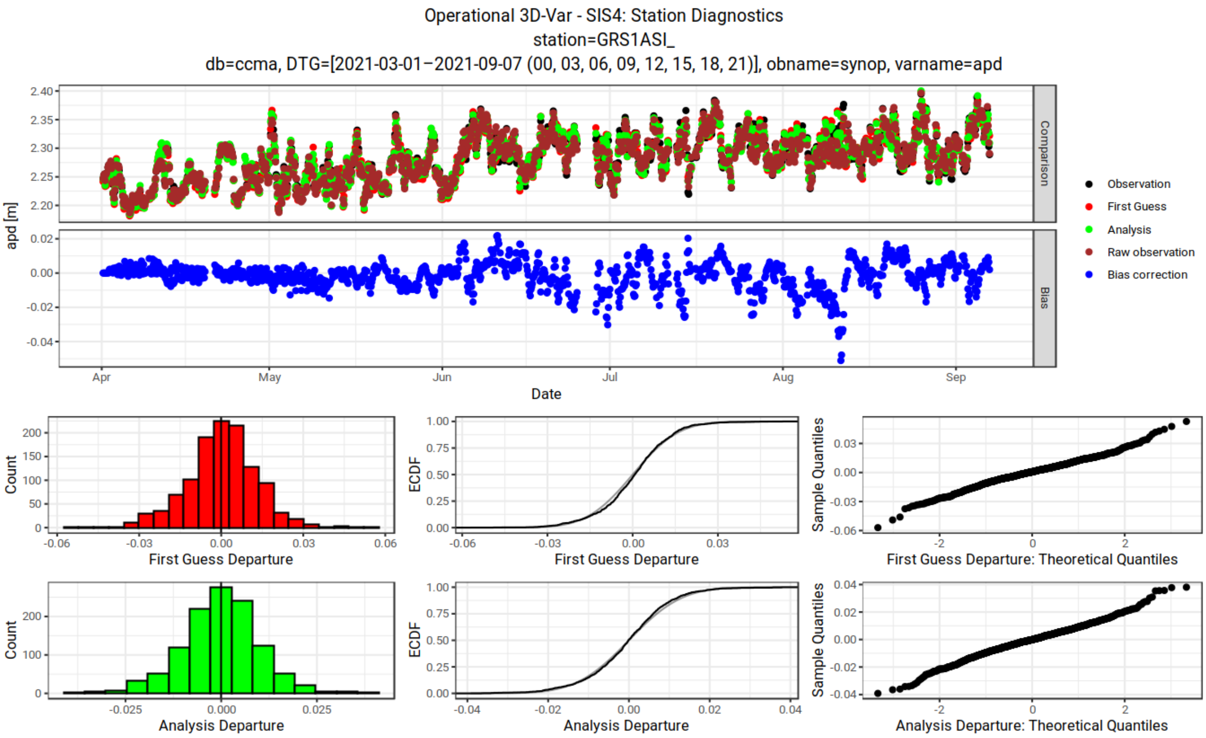

Figure 3.12: Evolution of observations, first guess and analysis (upper panel) and bias estimates (blue), and overall departure statistics in passive assimilation in the period March-August 2021 for Ljubljana GNSS station.

In **Croatia**, a technical test with GNSS data in cy43 was performed with the MF whitelist (increments in Fig. 3.13). For further testing a more suitable whitelist will be set up and data will be evaluated.

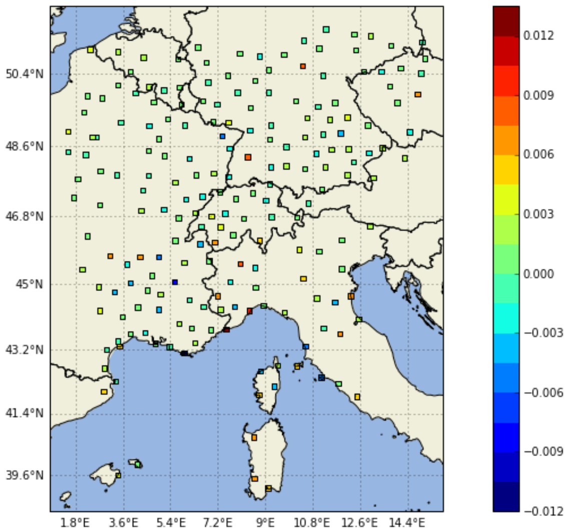

Figure 3.13: Analysis departure of GNSS data in a technical test at DHMZ.

Florian Meier (AT) extended the whitelist from national GNSS-ZTD to EGVAP data by averaging first guess departures of several-days passive assimilation. Afterwards the assimilation was activated first in E-Suite of AROME-RUC which became finally operational in December 2021. The observation error and Jo/n is comparable to national data. The average number of GNSS observations per hour increased from 47 to about 200.

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

In the project "Train" with Technical University in Vienna, the ZTD on board Austrian railways ÖBB engines should be assimilated into AROME-RUC as presented in 1st ACCORD workshop. As only data from two trains have been made available so far, the progress of the project is delayed. In this project also first steps to test sub-hourly cycling should be undertaken, but this activity did not start yet. Challenges are the bias correction and thinning of the train data. For the later a simple pre-selection routine was written. Florian Weidle (AT) performed tests for the few cases ZTD data from moving trains were already available. Data for a one-month period in autumn 2021 were delivered and are currently processed by project partners. Observations from 10 to 15 trains per day will be available for the test period (sections shown in Fig. 3.14).

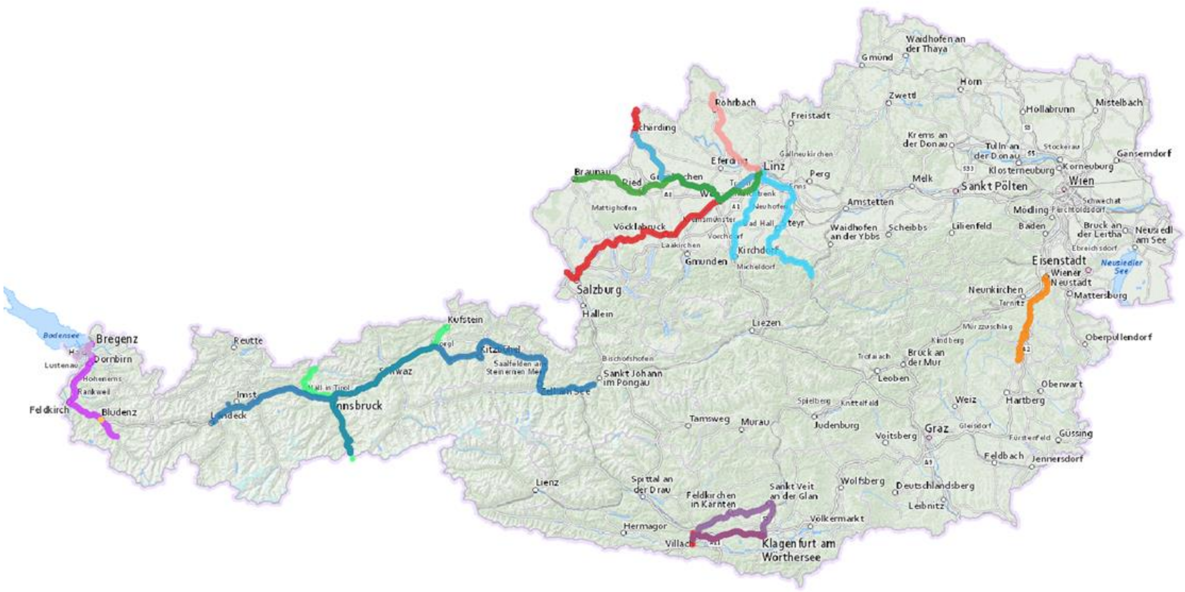

Figure 3.14: Example of train positions for one day in the test period. Colors denote different trains.

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 (extended) AMV data was carried out at OMSZ Hungary over several time periods. During spring and summer, a small negative impact was observed for the 2-meter temperature and a small positive impact for the surface pressure and 2-meter dew point (Figs. 3.15 and 3.16), using the default blacklisting which implies lack of mid-atmosphere observations.

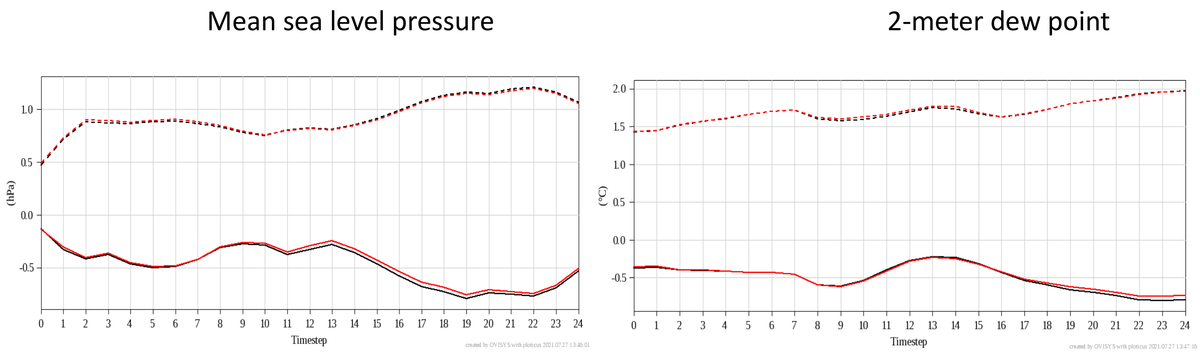

Fig. 3.15: Bias (solid line) and RMSE (dashed line) of mean sea level pressure (left) and 2-meter dew point (right) forecasts in the 0 UTC runs from 1 to 18 December 2019 as a function of lead time. Red and black lines: AROME/HU with and without AMVs, respectively.

As previously shown based on the long term OMG statistics, the data between 350 and 800 hPa (700 hPa over land) can be safely included. Using more data over the winter period showed very small, almost no impact for surface parameters compared to the initially used AMV data. The impact was rather neutral for upper-air fields as well, although for some of the variables positive changes can be observed. In Figure 3.16, we can see how these extra wind measurements help to decrease (or retain) the bias and RMSE for the wind speed at 500 hPa at the early forecast hours.

0 UTC runs 12 UTC runs

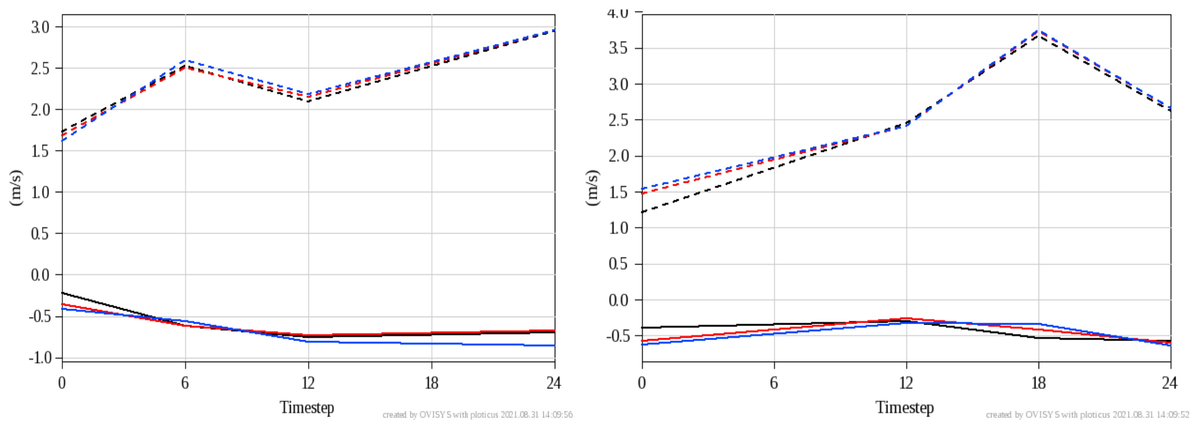

Fig. 3.16: Bias (solid line) and RMSE (dashed line) of wind speed forecasts at 500 hPa in the 0 UTC (left) and 12 UTC (right) runs from 1 to 18 December 2019 as a function of lead time. Blue, red and black lines: AROME/HU without AMVs, with AMVs with the original blacklisting settings and with additional active AMVs between 800 (700 over land) and 350 hPa, respectively.

In the second half of 2021, these experiments were extended for the convective season as well using AMVs between 800 and 350 hPa. Using more data showed very small, almost no impact for surface parameters compared to the initially used AMV data, apart from the 10-metre wind gust. Using AMVs with the initial settings performs better at the first forecast time steps in the 0 UTC runs while gives slightly higher bias and RMSE towards the end of the forecast period (Figure 3.17). In the 12 UTC runs, RMSE scores are better when using AMVs also between 800 and 350 hPa layers. Looking at some cases where the wind gust showed differences in the experiments, it cannot really be determined which settings are more preferable. Activating the AMVs between 800 and 300 hPa mostly has neutral impact in the upper levels as well, although for some variables positive changes can be observed in the verification scores compared to the initial settings. As all the presented experiments were conducted with AROME cy40t1, final tests will be done using cy43t2_bf11 before operational switch. In the operational version we plan to use the new blacklist settings, i.e. with additional AMV data between 800 (700 over land) and 350 hPa.

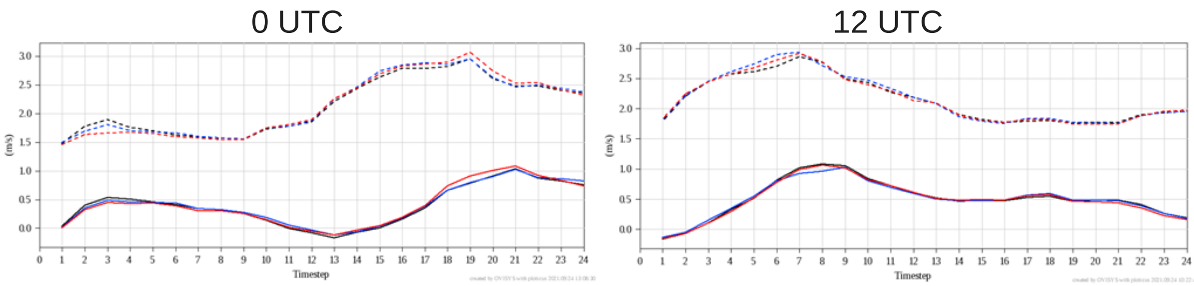

Figure 3.17: Bias (solid line) and RMSE (dashed line) of 10-meter wind gust forecasts in the 0 UTC (left) and 12 UTC (right) runs from 5 July to 7 August 2019 as a function of lead time. Blue, red and black lines: AROME/HU without AMVs, with AMVs and with active AMVs also between 800 (700 over land) and 350 hPa, respectively.

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]

The assimilation of radiances was mostly on hold. As the only related activity, Florian Meier (AT) built a tool to provide the CANARI surface temperature update also to upper-air files, a solution based on blendsur.F90 in cy40t1 and cy43t2. SURFTEMPERATURE field is replaced by the tile temperatures weighted by the part of tile in the gridbox and then provided together with the 2 m values and SURFRESERV.NEIGE from CANARI to the 3D-VAR in AROME-RUC.

Implementation and test of high-resolution radiosondes in BUFR. [DA 3.8]

In Slovakia, a diploma thesis work of P. Strban was devoted to 3D-Var data assimilation using high-resolution radiosonde data in the BUFR format. The assimilation of BUFR data was tested on one sounding measurement, followed on assimilation of data from the entire computational domain, on which the increasing influence of the radiosonde drift with height and its dependence on the weather situation was observed. In the next step, case studies were investigated and observation minus first guess (OMG) and observation minus analysis (OMA) were statistically processed for a series of prepared forecasts. The work covers the period from 22.2. - 5.3.2020. The influence of a large number of assimilated measurements from BUFR data on the preparation of the initial conditions and the forecast was observable throughout whole thickness of the atmosphere, while the influence of the radiosonde drift increased with height. There was no particular improvement of 3DVAR with BUFR RS in two realized case studies (the selection of cases might not be optimal for testing BUFR RS). Similarly, there was no improvement seen when using “standard” HARMONIE verification package - probably due to the method itself that is penalizing finer analysis verified against rather sparse standard verification levels. When the statistical scores for all available observations at all levels are done, improvement is seen for analysis and the first forecast hours. Generally, a bigger impact is seen when an update from OBSOUL (denoted OBS in Figs. 3.18 and 3.19) to high-res data (denoted TT) is applied compared to activation of RS drift (denoted FF) on top of TT setting. For full drift experiment FF, the improvement is seen above 700 hPa for the 6h forecast (Fig. 3.14). Experimental setup is specified in Table 3.1.

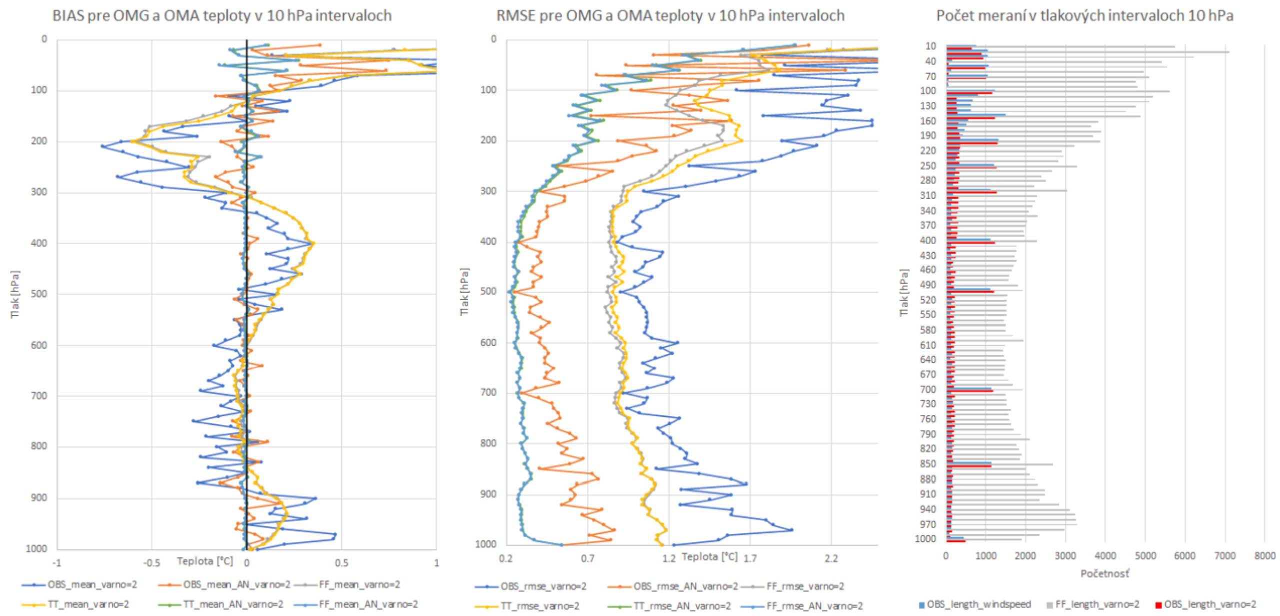

Figure 3.18: Vertical profiles of OMA and OMG for temperature - BIAS (left) and RMSE (middle), grouped by 10 hPa. Reference exp. with OBSOUL TEMP: OBS_OMA (orange), OBS_OMG (blue). TT exp.: TT_OMA (green), TT_OMG (light yellow). FF exp. (drift): FF_OMA (light blue), FF_OMG (grey). Right panel - number of temperature and wind observations for TEMP OBSOUL (red and blue respectively), and number of temperature measurements for FF experiment (grey). Verification period 22.2.-5.3.2020, 6-hourly cycling.

Vertical profile of RMSE for temperature for analyses, 6h and 24h forecasts shown on Fig. 3.15: for analyses, 3D-Var either with OBSOUL or BUFR (TT or FF exp.) is better than the operational Blending. Full drift (FF) is better than high-res RS above 700 hPa. For the 6h forecast operational blending is better (note, that experiments with TEMP used only 3D-Var, not BlendVAR). For +24h scores are similar, although 3D-Var outperforms the Blending around 700-800 hPa.

Table 3.1: Description of experimental settings for BUFR-RS tests

parameters	data format	explanation	label
TEMPSONSPLIT=T TemPSondOrTraj=T	BUFR	high-res profile with individual time intervals	TT
TEMPSONSPLIT=F TemPSondOrTraj=F	BUFR	RS drift: hig-hres profile with individual time intervals and position coordinates	FF
-	OBSOUL	3D-Var reference	OBS

-	-	Blending by DF, no 3D-Var	SHM(U)

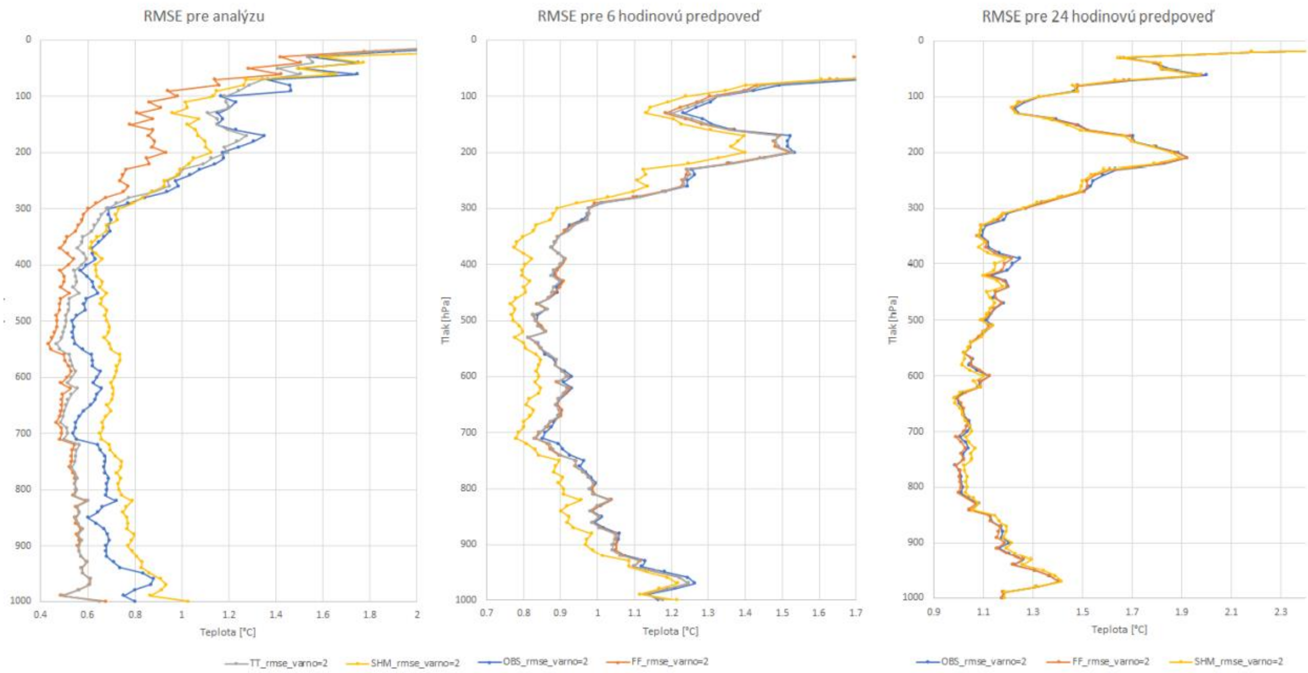

Figure 3.19: Vertical profiles of RMSE for temperature for 00 UTC: analysis (left), +6h forecast (middle) and +24h forecast (right), grouped by 10 hPa. Reference OBS exp. with OBSOUL TEMP (blue), TT exp (grey), FF exp. (orange), SHMU operational (light yellow). Verification period 23.2.-4.3.2020, 6-hourly cycling.

In **Austria**, Florian Meier creates radiosonde observation files in BUFR format from local GTS based database (Fortran program and short description is on the LACE forum). The highly resolved radiosonde data were tested over several days in the hourly cycling of AROME nowcasting configuration against a reference experiment with data OPLACE. No trajectories of the radio soundings, but just vertical profiles were considered so far. Largest impact was found for 2 m relative humidity with an improvement by the new bufrtemp data, while for other parameters impact was mostly neutral (Fig. 3.20).

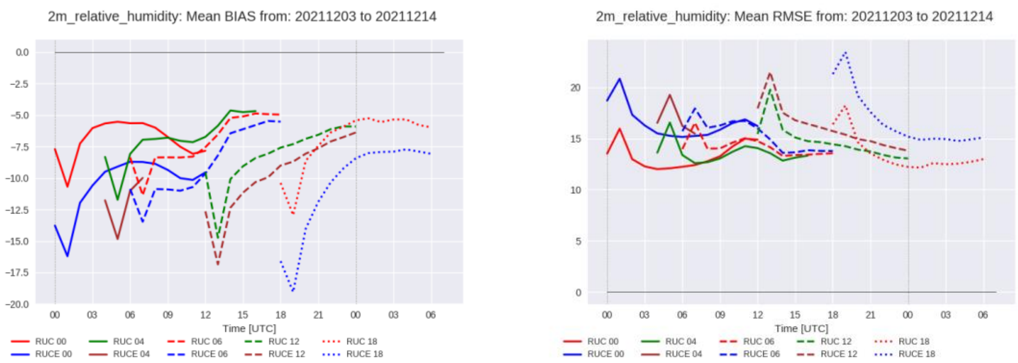

Figure 3.20: 2m relative humidity bias (left) and RMSE (right) against Austrian surface stations for a December 2021 period and several AROME Nowcasting runs with obsoul temp (RUCE, blue and brown) vs HR BUFR temp (RUC, red and green).

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

No progress.

Assimilation of Sodar observations [DA 3.10]

Limited activity on this subject in Slovenia included evaluation of 1-month OMG statistics for one Sodar site in Slovenia. A solution for temperature (virtual temperature is actually measured) is being explored. SODAR RASS measurements at the location of Krško (SE Slovenia) were passively assimilated over a one month period in the operational set-up environment at 4.4 km resolution. Another such instrument has been acquired at a location close to Ljubljana and the general goal is to assimilate both. The SODAR RASS performs measurements of the vertical profile of wind and virtual temperature up to a few hundred metres above ground. As an initial step, the SODAR RASS measurements were coded individually as point aircraft observations and fed into the model. The temperature time series plots of measurements and model and the first results for OMG statistics are presented in Fig. 3.21. Notice that the comparison is slightly flawed due to the reason that the instrument actually measures virtual temperature, hence the bias in the OMG statistics on the order of 1-2 K - this would lead to an estimation of mixing ratio being around 10 g/kg which seems completely sound. Other than that, the statistics seem promising for active assimilation. No significant deterioration or systematic bias was observed related to different heights of observation.

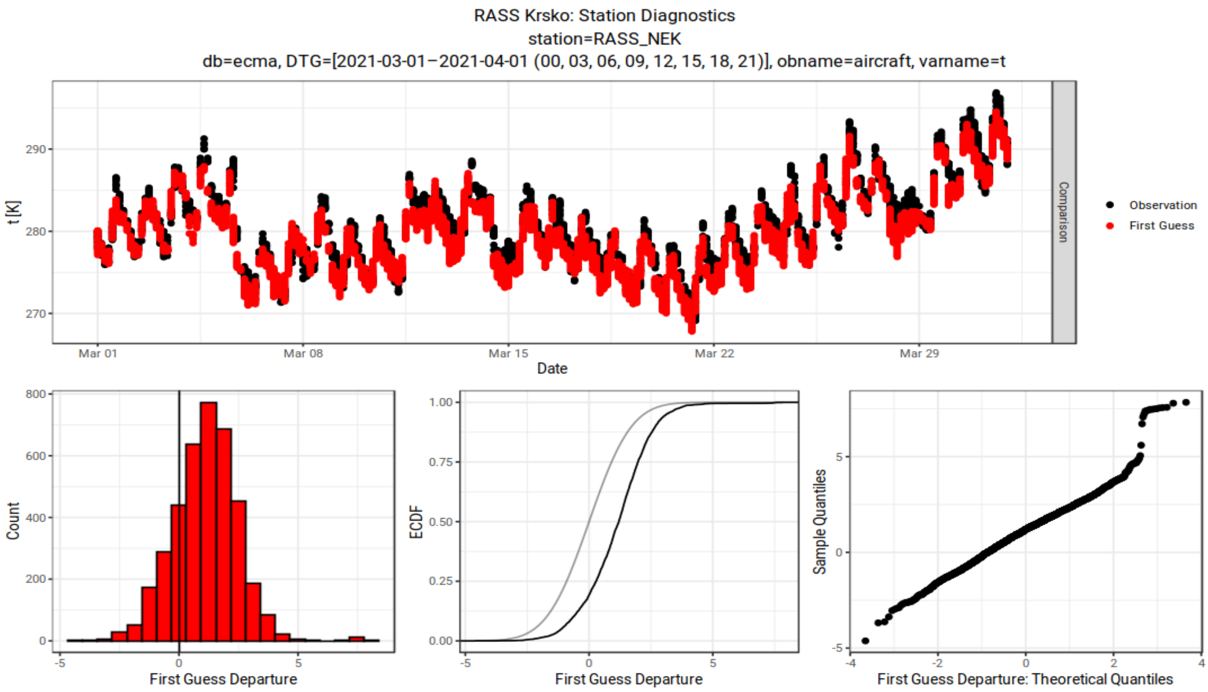

Figure 3.21: Time-series of temperature for observation [black] and model [red] for all available heights (up to a few hundred metres) for the SODAR RASS measurements for the location of Krško (SE Slovenia). Notice the systematic bias coming from comparison of observed virtual temperature and "ordinary" temperature from the model.

Efforts: 8.25 month

Contributors: Z. Kocsis (HU) 2.25, B. Strajnar (Si) 0.75, M. Derkova (SK) 1, F. Meier (AT) 1.25, F. Weidle (AT) 1.75, J. Cedilnik (Si) 0.25, S. Panežić (CR) 0.25, A. Stanešić (CR) 0.25, A. Trojáková (CZ) 0.5

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]

The phasing of the GNSS Slant Total Delay observation operator from CY43 to CY46 was completed. To test it, the upgrade of assimilation scripts (from cycle 43 to cycle 46) was necessary. A minor bug fix (related to ASCAT data, interference with STD) was provided by Siebren de Haan. The work is still ongoing (examination of AD observation operator), however first steps were already taken towards the phasing to current CY48.

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 progress.

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]

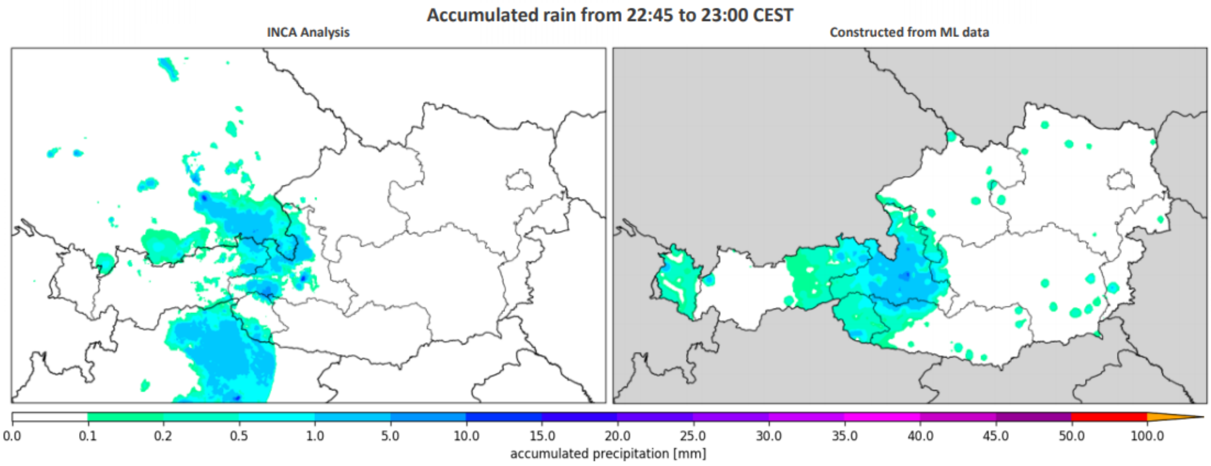

Figure. 4.1: INCA analysis of 2D rain (left) as reference and microwave derived rain (right, no data outside Austria).

In **Austria**, Drei Hutchison has been providing monthly data sets of their microwave link signal loss for all of their links in Austria since August 2021 to provide a large set of link data. Initially, RAINLINK (https://github.com/overeem11/RAINLINK) was used to convert the link data into rain rates (Fig. 4.1). However, this approach did not lead to satisfactory results due to the strong underestimation of precipitation rates. The reasons for this are not fully known, but one key difference is that the Python package was initially developed using links of only one type, i.e. one frequency and the same type of emitter and antenna. The Austrian dataset consists of different types of links at multiple frequencies and with varying equipment. In addition, the geographic setting is different and the terrain is mountainous rather than flat, like over the original area in the Netherlands.

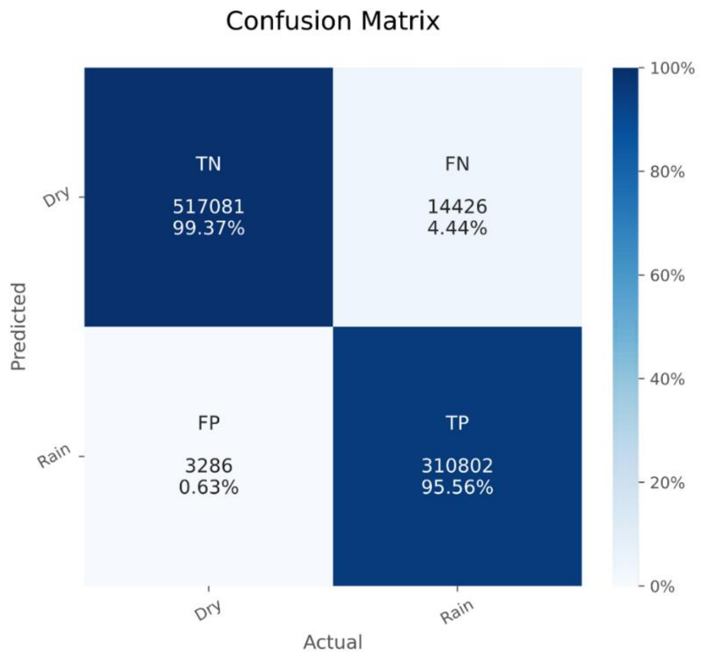

Figure 4.2: Confusion matrix for the rain vs no rain classification by FH St. Pölten using the entire 3-minute dataset of microwave links.

The project partner FH St. Pölten has then taken over the conversion from link data into rain data and is using machine learning to distinguish between rain and non-rain data points as a first step. The results are promising, as they are able to reliably detect days with rain. Their ground truth is the Austrian INCA precipitation analysis and the model is trained using this data. Figure 4.2 shows their results with only 0.63% false positives and 4.44% false negatives.

Phillip Scheffknecht (AT) prepared an AROME installation to assimilate the detected rain events as 100% relative humidity at the center 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. As soon as data is available, the experiments will start.

In **Slovenia**, a new, larger dataset became available, but the evaluation has not started yet.

Test of assimilation of mobile phone links (from Austrian mobile phone provider) via the INCA-LHN in AROME-RUC. [DA 4.10]

No progress.

Efforts: 8.75 month

Contributors: M. Imrišek (SK) 5.25, P. Scheffknecht (AT) 3.25, J. Cedilnik (SI) 0.25

Documentation: /

Status: ONGOING

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

Validation of existing observations (those from DA 3) in RUC and preparation of high resolution observational dataset suitable for nowcasting [DA 5.1].

Within the project WINDSOR, **ZAMG** got access to SCADA data from Austrian windfarms in the Austrian-Hungarian border region. They are assimilated hourly into AROME-RUC using the wind profiler operator with slightly adapted observation error and interpolation height to pressure based on first guess temperature profile (switch LPILOTLEVCALC=.True., in common code cy48t1). Within 2021 a one month period was run (July 2020) using SCADA assimilation (wind speed and direction, temperature) and a reference run without assimilation of these data. The effect of the wind turbines on the flow is parameterized in AROME-RUC by the Fitch et al. (2012) parametrization running operationally since 2019. Also a reference without parameterization and assimilation was added for the test period. Results show an improvement of 100 m wind forecast (Fig. 5.1, verified against SCADA), but also slight improvement of 10 m wind. The impact on other parameters is rather neutral.

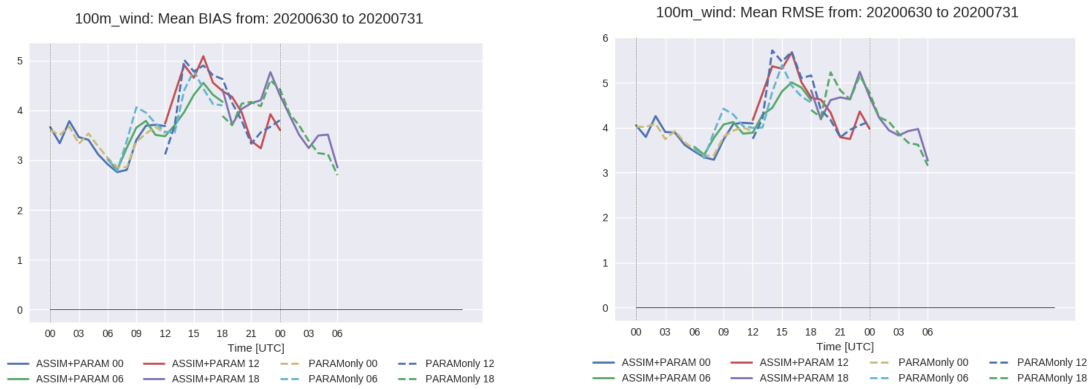

Figure 5.1: Assimilation of SCADA data July 2020 in AROME RUC 00/06/12/18 UTC runs. Bias (left) and RMSE (right) of 100m wind. Reference without assimilation is dashed, experiment with assimilation solid. Positive impact especially in 06 UTC runs (green solid vs. light blue dashed).

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

a) Slovenia

In Slovenia, a 3D-Var based nowcasting system at 1.3 km horizontal resolution has been further validated. The hourly analysis using 3D-Var and OI for soil is carried out with a cut off time of 35 minutes after the nominal analysis time (this was extended to 45 mins due to delays in OPERA files provision, and reduced after OPERA/OIFS server fixes in July 2021). This is followed by hourly production forecasts up to 36 h, which provide a selection of meteorological variables every 5 min (e.g. simulated radar reflectivity) on top of the hourly model output. The analysis step is repeated 35 min later (70 min after the nominal analysis time), and this second analysis is used to compute the first guess for the next production run. The observation data set includes all types of the ALADIN 4.4 km plus the radar reflectivity. Observations, such as Mode-S datasets, are used with a higher spatial resolution. Apart from daily runs which were assessed subjectively by the NWP department, an objective verification period was carried out for a summer and winter period. For these two periods, four experiments were prepared: both reference operational ALADIN 4.4 km setup (3h DA cycling) and the new hourly NWCRUC (1h cycling) were rerun twice, with and without radar reflectivity data assimilation (see also the radar section of this report).

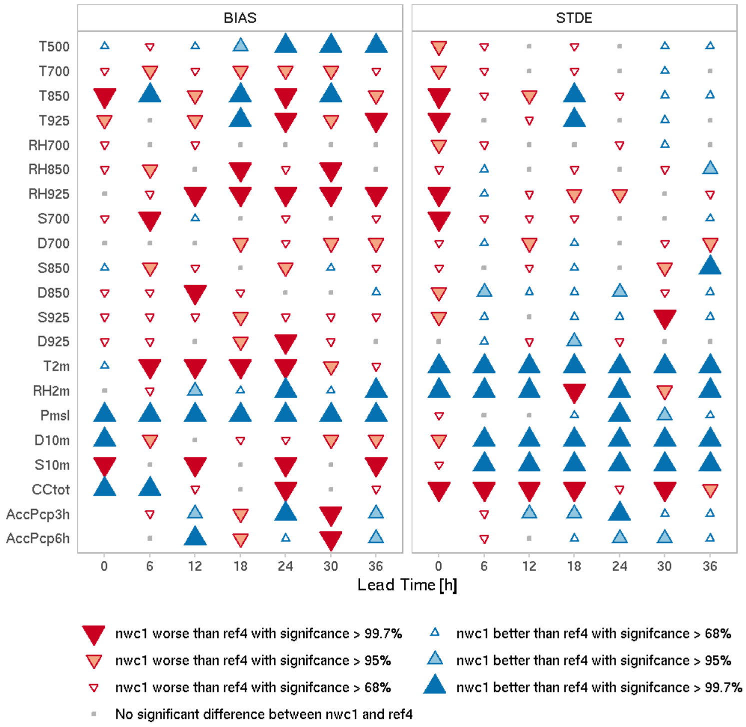

Figure 5.2: Verification scorecard, comparing NWCRUC and ALADIN 4.4 km over the 1 month summer period.

The 36 h forecasts were verified against Synop stations over the whole domain plus automatic surface stations in Slovenia, Austria and Italy, and radiosondes. A comparison between reference operational ALADIN 4.4 km and NWCRUC (both without radar data assimilation) for the summer period is shown in Fig. 5.2 as a scorecard. The 1.3 km suite significantly improves the near surface variables in terms of standard deviation while the impact on bias is mixed. In upper-air scores, there is a degradation in bias and mostly neutral score in terms of standard deviation. The impact on precipitation forecasts was further assessed using the categorical verification. It was found from categorical verification that the operational 4.4 km model overestimates the precipitation which is corrected for the 1 km model. In terms of the ETS, the 1.3 km model performs better except for the first 6-7 hours of the forecast (possible reason is spin up in the 1.3 km model). For this precipitation threshold the radar reflectivity assimilation does not significantly impact the scores; for light precipitation, however, the frequency bias is much smaller in radar assimilation is applied.

The analysis of precipitation scores for the validation period brings us to the following conclusions on 1.3 km runs (NWCRUC):

- The 1.3 results are satisfactory for winter runs for small and large thresholds (1,20,25 mm per 6h),
- In summer period there is a degradation for small thresholds (0.1, 0.2, 0.5) on ETS scores, coming from decreased hit rate. This is connected to excessive drying from reflectivity assimilation and triggered research on modification of reflectivity inversion (see the radar section).
- There are large areas with light precipitation over the orography, suggesting a too active sub grid convection (not related to DA).

In the summer period, a degradation for small thresholds (0.1, 0.2, 0.5) on ETS scores was corrected by modifications applied to radar reflectivity DA.

b) Hungary

Following the earlier experiments which combined upper-air and surface assimilation at different frequency, the impact of using 1 hourly surface assimilation instead of the standard 3 hourly assimilation with the AROME-RUC system was investigated by using two experimental setups, applying symmetric 1-hour and 3-hour assimilation windows on the surface OI-main. Both experiments used an hourly assimilation cycle for the upper atmospheric 3D-Var, and all other settings remained the same as in the current operational AROME/HU setup. The experiments covered a 3-week period between 1 and 22 July 2020 after a two weeks long spin-up period. The chosen period was well-suited for verification purposes, as some severe weather events with high precipitation took place. Figures 5.3 and 5.4 show two cases in which the experiment with hourly surface assimilation frequency produced somewhat better forecasts than the one with 3-hourly surface assimilation frequency. Generally, it can be concluded from several case studies that the hourly update of the surface initial condition mostly produces more moderate forecasts in terms of precipitation and wind gust. The case study shown in Fig. 5.5 demonstrates that hourly surface update can alleviate the overestimations produced by 3 hourly surface update. In other cases, however, this effect can also lead to less accurate forecasts (not shown).

1 hourly surface DA 3 hourly surface DA SYNOP

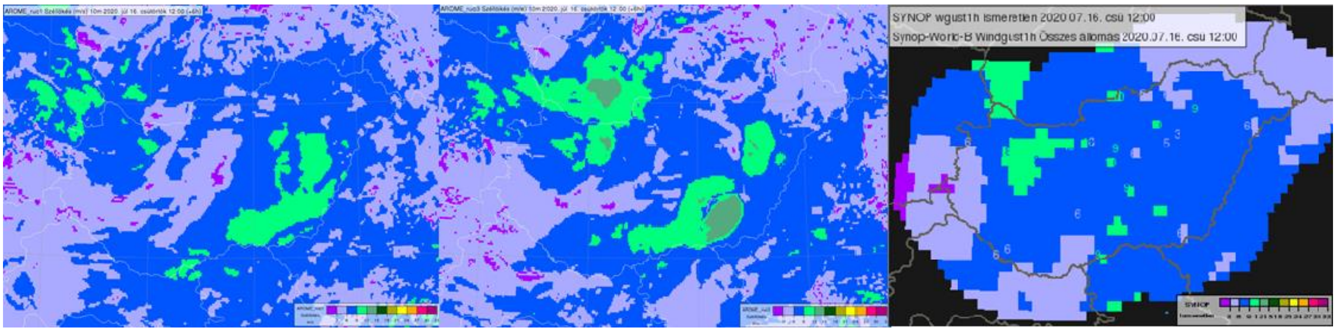

Fig. 5.3: 10-meter wind gust at 12 UTC on 16 July 2020 based on the 6-hour forecast of the RUC experiments using 1 and 3 hourly surface assimilation frequency (left and middle, respectively) and the SYNOP observations (right).

1 hourly surface DA 3 hourly surface DA radar

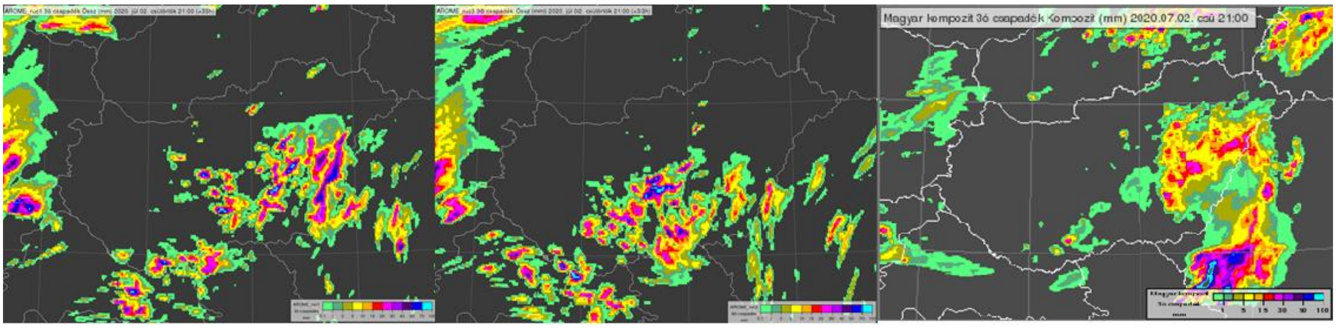

Fig. 5.4: 3-hour precipitation sum at 21 UTC on 2 July 2020 based on the 33-hour forecast of the RUC experiments using 1 and 3 hourly surface assimilation frequency (left and middle, respectively) and the radar data (right).

Pointwise verification confirmed the improvement gained with the hourly surface initialization, with respect to its 3 hourly counterpart (Fig. 5.5), and it sometimes also produces slightly better results than by the operational AROME setup. The differences are somewhat greater for 2-meter temperature and 10-meter wind gust, while other surface variables, such as 2-meter relative humidity and cloudiness, show very little improvement. Precipitation results are mixed (Fig. 5.6): in case of low precipitation amounts the full hourly RUC experiment does not outperform the one with 3 hourly surface assimilation, the events are under-forecast with both settings; on the contrary, the precipitation events exceeding 10 mm/day are over-forecast in the experiment with 3 hourly surface update, whereas the frequency bias of full hourly RUC close to the ideal value of 1.

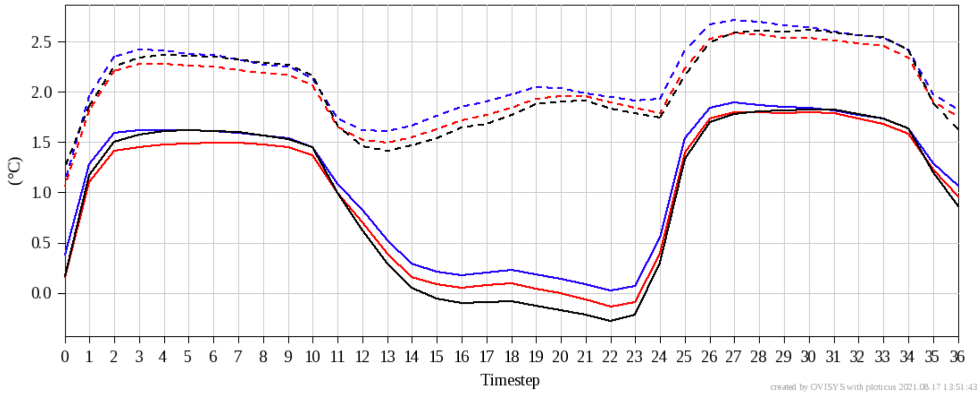

Fig. 5.5: Bias (solid line) and RMSE (dashed line) for 2-meter temperature forecasts in the 18 UTC runs from 1 to 22 July 2020 as a function of lead time. Red, blue and black lines: RUC experiments with hourly and 3 hourly surface initialization and operational AROME/HU, respectively.

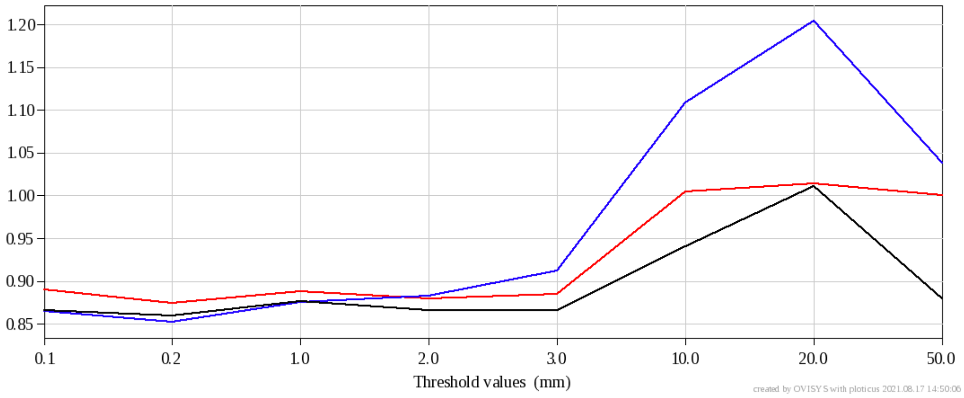

Fig. 5.6: Frequency bias for 24-hour precipitation sum in the 18 UTC runs from 1 to 22 July 2020 as a function of precipitation amount. Red, blue and black lines: RUC experiments with hourly and 3 hourly surface initialization operational AROME/HU, respectively.

Overall, the current results suggest that the full hourly RUC experimental setup (hourly 3D-Var and OI-main) can yield more accurate forecasts than if we reduce the frequency of the surface assimilation to 3 hours. Additional examinations are needed to assess the value of the hourly setup. Further experiments are planned to evaluate the number of the observations assimilated in full hourly RUC using real-time observations instead of archive data.

Kristóf Szanyi also investigated the impact of symmetry of the assimilation window in hourly AROME Rapid Update Cycle (RUC). Two experimental setups were created: the first experiment used a symmetrical assimilation window from -30 to +30 minutes around the analysis time, while the second experiment used an asymmetrical one from -45 to +15 minutes around the analysis time. The goal of these experiments was to determine whether an asymmetrical setup would be beneficial over the symmetrical setup, especially considering the planned operational implementation. Both experiments covered a 1-month 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. The experiments simulated the situation when the observations are assimilated in real time (and not from the archive). Pointwise verification using SYNOP and TEMP observations shows little to no difference between the two experimental setups. In the few cases of more meaningful differences, however, the experiment with the symmetrical assimilation window usually yields better verification scores compared to the other experiment. In the case of upper-air variables (Fig. 5.7), however, both RUC experiments show some serious problems in upper-air wind (Figure), and to a lesser extent, upper-air temperature with respect to the operational AROME/HU forecasts (cycled 3-hourly). Verification result indicate that the RUC experiments' analyses had large errors on some days of the experimental period. The exact cause of this problem is not known yet; further investigation is needed to determine why this error occurs in the forecast and the analysis as well.

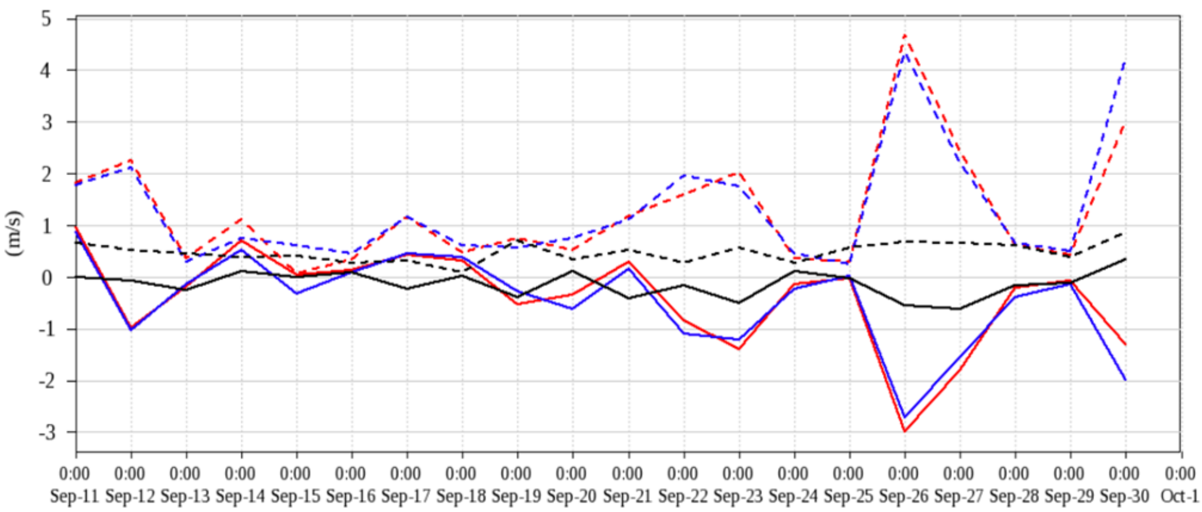

Figure 5.7: Bias (solid line) and RMSE (dashed line) of wind speed analyses at 925 hPa at 0 UTC from 11 to 30 September 2021. Black, red and blue lines: operational AROME/HU with 3-hourly cycling, hourly RUC with symmetrical and asymmetrical setups, respectively.

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

Report of this work in section "Use of existing observations – radar data".

Total efforts: 7.5 months

Contributors: Kristóf Szanyi (HU) 5, B. Strajnar (SI) 1.75, F. Meier (AT) 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.

The OOPS familiarization exercise started by running the provided executables (provided by E. Arbogast and bug fixes from P. Brousseau/V. Vogt) on belenos HPC from shell environment. To do this, a scripting environment for cy46t1 provided by Alena Trojáková (bator, screening, minimization) was used and minimization part was adapted to run the OOVAR executable instead of MASTERODB. This includes provision of a central driving namelist called oops.json and splitting of fort.4 namelist to several parts for different model components. For a number of observation types, it was shown that 3D-Var with the Congrad minimizer can be reproduced at high accuracy with the OOVAR.

In the continuation, the OOVAR binary was ported to the local HPC at ARSO (gmkpack and intel_fc/16.2). To compile C++ binaries, an installation of the supporting software from ECMWF is needed (eckit (1.16.1), fckit (0.9.2). Minimal adaptation was needed for successful compilation (e.g. in error_covariance_3D-mod.F90 - inconsistent use of pointer/target declarations, probably depending on compiler version). A comparison with MASTERODB cy46t1 was done for most obstypes: synop, aircraft, temp, radiances (except Seviri) without VarBC, scatterometers and radar reflectivity. While differences for other observation types are negligible, a difference of the order of 0.01 K was still observed in the case of assimilated radar reflectivity, T2M and RH2m (Fig 6.1). This was investigated with help of MF colleagues (by applying their bugfixes related to radar DA) but not yet fully resolved for screen-level parameters. A sample DA scripting sequence (Bator, screening, minimization) using OOPS was prepared at Belenos (MF) and will be used as a hands-on exercise at DA Code training in May 2022.

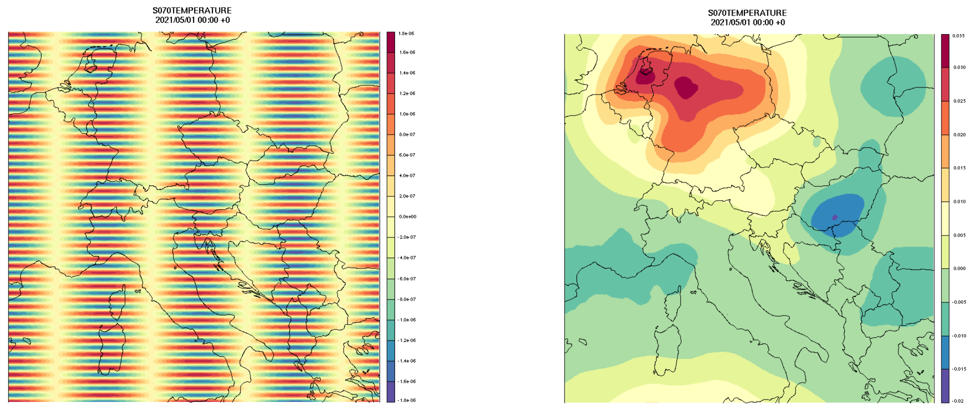

Figure 6.1: Difference between analysis of 700 hPa temperature with OOVAR and MASTERODB executables for conventional and satellite observations (left) and additionally the radar reflectivity (right). The order of difference is 10^{-8} K on the left and 10^{-2} on the right.

Total efforts: 1 month

Contributors: B. Strajnar (SI) 1

Documentation: /

Status: ONGOING

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

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

No progress.

Maintenance and development of observation preprocessing system [DA 7.5]

Provided in the DM's report.

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

The obsmon package was installed in **Slovenia** and runs operationally for the ALADIN 4.4 km and experimental 1.3 km RUC. The backend (which needed adaptations for parallel execution and using all obstypes) is triggered once per day to prepare statistics for all network times of the past day. Containerization of the shiny application is planned.

In **Croatia,** the Obsmon tool for observation monitoring was installed. Backend installed at a local HPC. Some problems related with extraction of data for observations with more parameters and levels was experienced, but finally a bug was found (misplaced counter in a loop in module_obstypes.f90) and corrected. The frontend/shiny was installed on a local server and several multi-plots were configured. Daily operational monitoring was set up for DA e-suite cy43.

Total efforts: 1 month

Contributors: B. Strajnar (SI) 0.25, S. Panežić (CR) 0.25, A. Stanešić (CR) 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, the migration of existing 6h DA cycle with OI (CANARI) from cy40t1 to cy43t2 is finnished and runs in a test mode and verification is ongoing. Surface stations from OPLACE are used. There was no considerable progress with upper-air assimilation.

Total efforts: 4.75 months

Contributors: M. Szczech-Gajewska (PL) 4.5, A. Trojáková (CZ) 0.25

Documentation: /

Status: ONGOING

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

Experiments with SEKF and SYNOP observations in AROME cy43t2 using ISBA force-restore and ISBA-DIF surface scheme (Austria, Hungary) [SU 1.1]

In **Hungary**, further experiments were carried out with the simplified extended Kalman filter (SEKF) implementation in AROME cy43t2. The system uses a 3-layer ISBA force-restore scheme with one patch, TG1, TG2, WG1, and WG2 as control variables and assimilates SYNOP temperature and relative humidity observations. A *winter* experiment was carried out achieved from 25 November to 17 December 2019 (with spin up from 11 November). As spurious TG1 and TG2 values were noticed over the Alps at the end of the experimental time (lower than 200 K), initial efforts were invested into finding the root cause for this behavior. A linearity check of Jacobians (LCJ) was switched on to keep the large but valid Jacobians. Positive and negative perturbation runs for all control variables were carried out, then a check of the Jacobians (H) was provided: if $|H^{+}+H^{-}| > 0.2*(|H^{+}|+|H^{-}|)/2.0$ the system is nonlinear, and H is set to zero. This check corrected slightly the TG2 analysis, but the values became false in the target point later (Fig. 9.1).

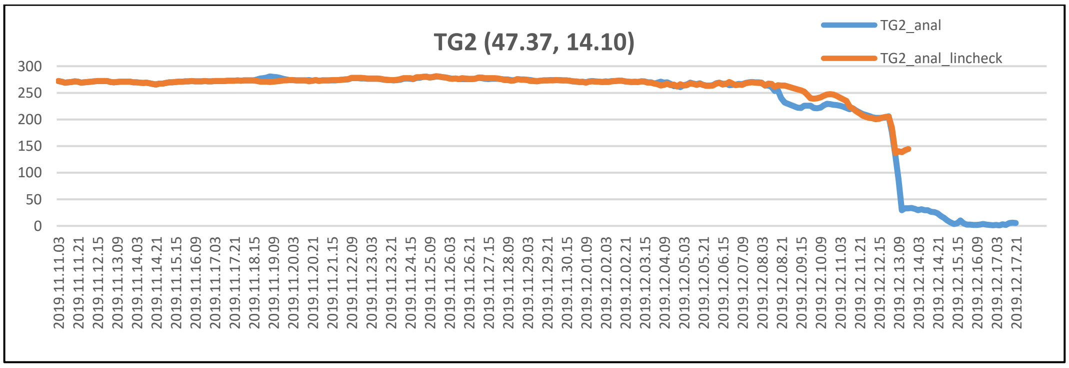

Figure 9.1: Evolution of TG2 at the target point between 11 November and 17 December 2019 (blue: SEKF, orange: SEKF+LCJ).

Further investigation continued by blacklisting of the neighboring SYNOP stations and applying some limitations in the SEKF equations (on the Jacobians, innovations, increments) without particular success. After personal consultations with the SURFEX community it turned out that the error was closely related to the choice of basic assimilation settings: observation errors (XERROBS), background errors (XSIGMA) and perturbation sizes (XTPRT). In addition, there was also a bug in the code as the innovation (obs-guess) was calculated from the offline reference run instead of the inline guess which was incorrect. The list of modified routines includes soda.F90, modd_assim.F90, assim_nature_isba_ekf.F90, read_isban.F90. This code modification resulted in a non-negligible difference in the soil parameters (Fig. 9.2): the unrealistic low soil moisture patterns in the center part of the domain disappeared in the modified experiment.

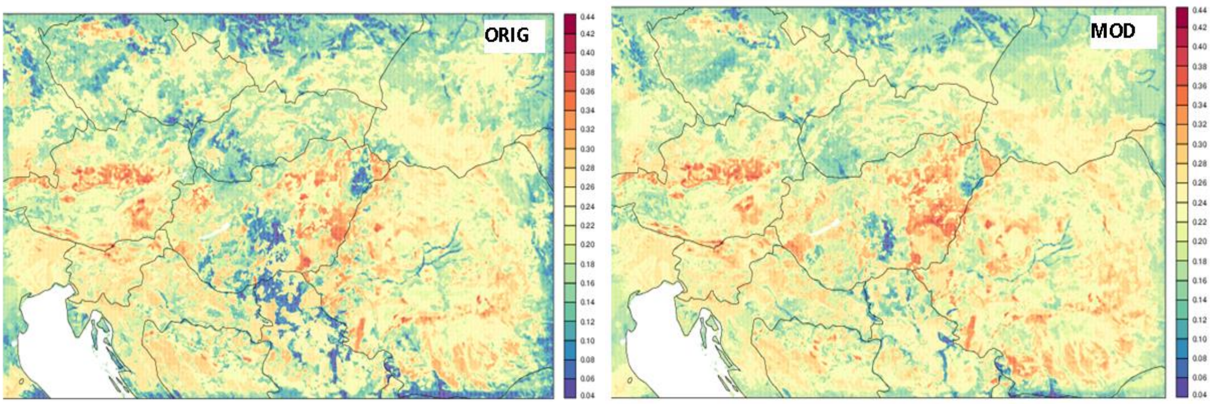

Figure 9.2: WG2 analysis at 12 UTC on 31 July 2020 for original and modified runs.

The experimental setups to test different assimilation settings are summarized in Table S1. In a study by ECMWF (Fairbairn, 2019), it was demonstrated that the tuning of the observation errors was important to design the operational surface assimilation. The difference between EXP1 and EXP3 was the XERROBS values resulting in a very different quality of TG2. A lower observation error for both T2M and HU2M (increasing the influence of the observations in the analysis) produced unbalanced assimilation of the control variables in EXP1. The perturbation sizes (XTPRT) were different in EXP2, while the rest of the settings were the same as EXP1.

However, TG2 still became unacceptable, and therefore XERROBS seemed to be a more important factor in SEKF than XTPRT. DEF experiment was run with the default values (*default_assim.F90)*, and with these options, acceptable soil moisture and temperature analysis and forecast was obtained which could be a promising and reliable solution for the future work. In EXP4 the HU2M XERROBS was tuned similarly as in the DEF experiment. ECM represents the run with XERROBS applied in ECMWF, while in ECM_B XSIGMA is modified with the setting used in ECMWF. Using XERROBS from ECMWF (ECM experiment) false TG2 values were provided at the end of the period, proving that both T2M and HU2M observation errors were equally important in SEKF and the too low values could cause an imbalance in the system. Using both observation and background errors applied in ECMWF (ECM_B experiment) this imbalance disappeared, and TG2 became acceptable.

Table 9.1: Data assimilation settings in the experiments and the main conclusion.

	EXP1	EXP2	EXP3	DEF	ECM	ECM_B	EXP4
XERROBS T2M HU2M	 **0.5** **0.2**	 **0.5** **0.2**	 **1.0** **0.4**	 **1.0** **0.1**	 **1.0** **0.04**	 **1.0** **0.04**	 **1.0** **0.07**
XSIGMA WG2 WG1 TG2 TG1	 **0.1** **0.1** **2** **2**	 **0.15** **0.1** **2** **2**	 **0.15** **0.1** **2** **2**	 **0.15** **0.1** **2** **2**	 **0.15** **0.1** **2** **2**	 **0.01** **0.01** **1** **1**	 **0.15** **0.1** **2** **2**
XTPRT WG2 WG1 TG2 TG1	 10^{-4} 10^{-4} 10^{-5} 10^{-5}	 10^{-3} 10^{-3} 10^{-4} 10^{-4}	 10^{-4} 10^{-4} 10^{-5} 10^{-5}	 10^{-4} 10^{-4} 10^{-5} 10^{-5}	 10^{-4} 10^{-4} 10^{-5} 10^{-5}	 10^{-4} 10^{-4} 10^{-5} 10^{-5}	 10^{-4} 10^{-4} 10^{-5} 10^{-5}
Acceptable TG2?	**no**	**no**	**yes**	**yes**	**no**	**yes**	**yes**

Summarizing the results, acceptable TG2 values were provided by EXP3, DEF, ECM_B and EXP4 experiments. The *summer* experiments included all the successful setups from the winter period (apart from EXP3 which is missing due to a technical issue) and EXP1 and OI-main in addition. The summer experiments lasted from 9 to 31 July 2020 (with 2-week spin up from 25 June). Figure 9.3 shows the pointwise verification of 2-meter temperature and dew point forecasts. The best T2M scores were experienced with EXP4 with an improvement in the nighttime hours compared to OI-main. The cold dew point bias improved with ECM_B settings, but the RMSE changes from time to time. Scores of 10-meter wind speed and gust, cloudiness and mean sea level pressure were rather neutral.

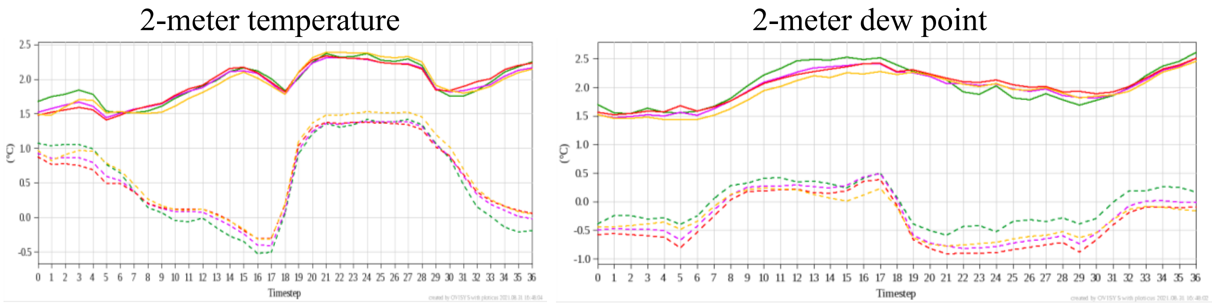

Figure 9.3*: Bias (dashed line) and RMSE (solid line) of 2-meter temperature (left) and 2-meter dew point (right) forecasts for the 0 UTC runs from 9 July to 31 July 2020. Curves represent: OI-main, EXP4, DEF, ECM_B.*

Evolution of the T2M analysis is illustrated in the left panel of Fig. 9.4. Small differences can be found between EXP4, DEF and OI-main, larger errors were obtained by ECM_B in some dates. RMSE of the dew point analysis was higher for ECM_B and rather neutral for the others in the first part of the period (Fig. 9.4, right). These findings were confirmed also by plotting the T2m maps in comparison with SYNOP analysis (not shown).

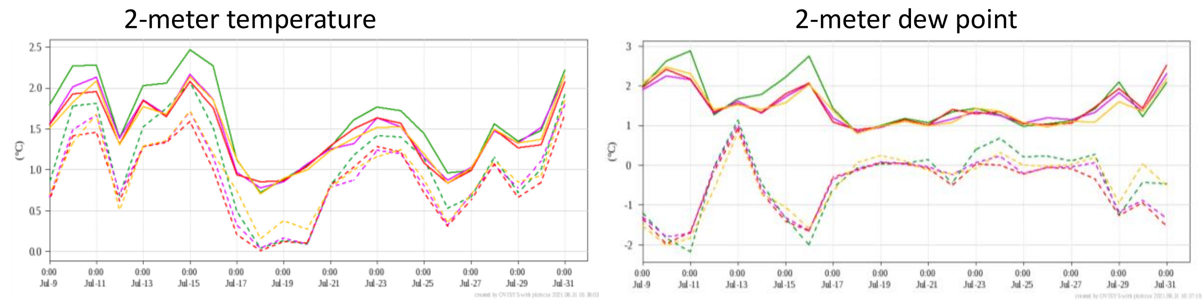

Figure 9.4: Evolution of bias (dashed line) and RMSE (solid line) of 2-meter temperature (left) and 2-meter dew point (right) analyses at 0 UTC from 9 July to 31 July 2020. Curves represent: OI-main, EXP4, DEF, ECM_B.

The symmetric extremal dependence index (SEDI) score of the 24-hour precipitation forecasts is shown in Fig. 9.5. Basically, the performance of different experiments was rather similar, however, a larger difference was obtained between the models for the heavy rainfall situations (over 20 mm/day). Both EXP4 and ECM_B experiments overestimated the 24-hour precipitation sum in the central part of the domain, however, the heavy rainfall area was better captured by ECM_B in the western part of the country (Fig. 9.6).

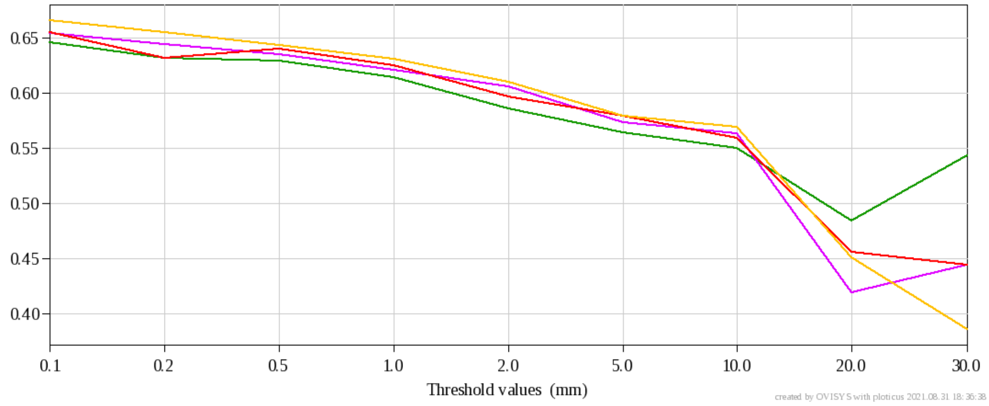

Figure 9.5: SEDI score of 30-hour forecasts of 24-hour precipitation sum for the 0 UTC runs from 9 to 31 July 2020 as a function of precipitation amount. Curves represent: OI-main, EXP4, DEF, ECM_B.

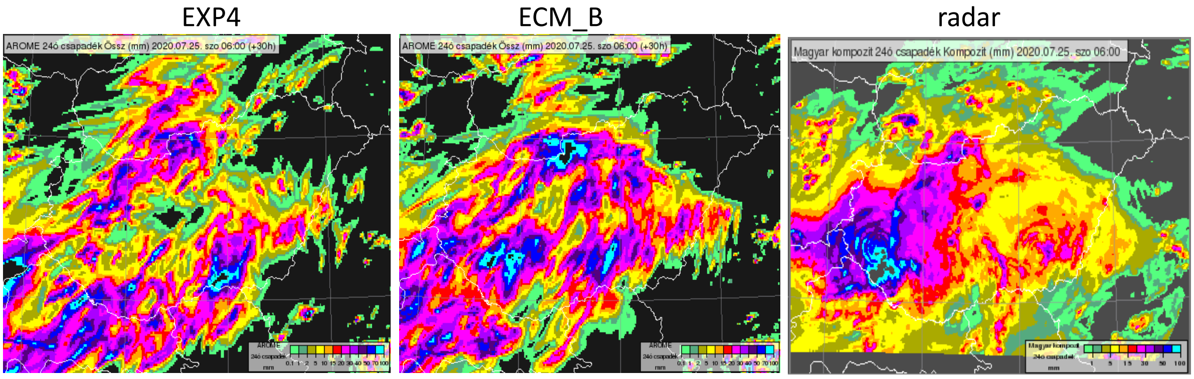

Figure 9.6: 24-hour precipitation sum at 6 UTC on 25 July 2020 in 30 h forecast of EXP4 (left) and ECM_B (middle) experiments and the radar estimate (right).

From 15 November 2021, an additional AROME-TEST SEKF parallel suite was launched for a period of one month. 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.

In addition to the usual objective verification, the forecasters were also involved in the evaluation focusing on differences between the operational and test forecasts at 0, 6 and 12 UTC. Their comments were recorded daily. At the same time, subjective verification was done by the model developers in interesting weather situations, ranking the 2-meter temperature, 10-meter wind and gust, precipitation and cloudiness forecasts from 1 to 5 (where 5 is the best). During the first weeks the models faced with the challenges of forecasting fog and low level cloud in an anticyclonic situation. In the rest of the period, several front systems passed Hungary often with mixed-phase precipitation. A systematic underestimation for both 2-meter temperature and dew point was experienced during the test period by both model versions. The temperature underestimation was especially large in the middle of the day, i.e. for the maximum values (Figure 9.7) which was even greater when using the Kalman filter. The reasons behind the temperature underestimation are manifold: it is related to overestimation of low-level cloud (fog) existence in some weather situations, while it is linked to some fake snow persistence in December. There was no significant difference between the two forecasts in case of precipitation, 10-meter wind and gust during the test period. The minor differences concluded near the surface reduced at higher levels for the upper-level parameters. Overall the results are promising but highly weather-dependent, so an additional verification campaign is planned in May.

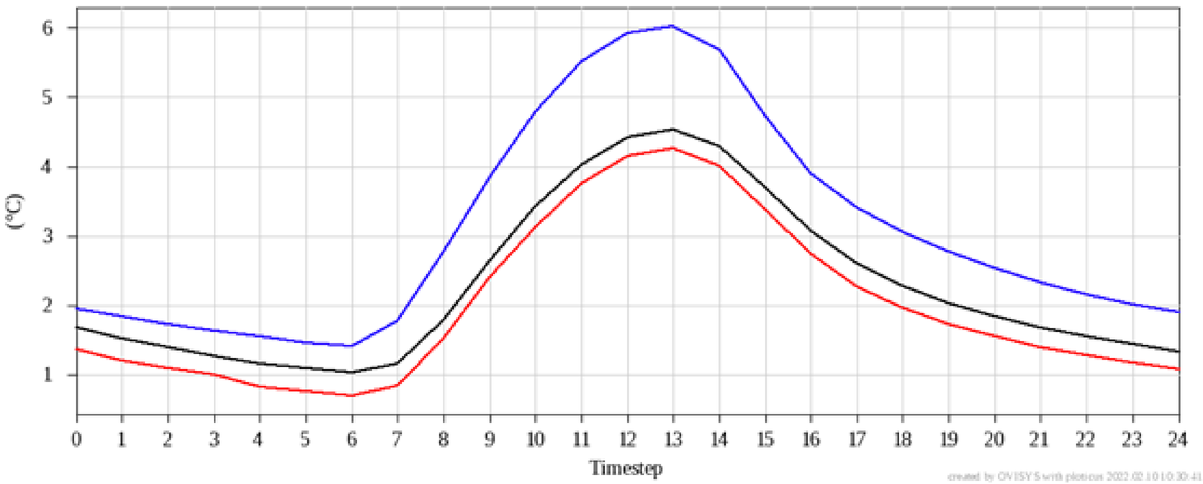

Figure 9.7: Mean diurnal cycle of 2-meter temperature from 15 November to 17 December 2021. Black, red and blue lines: operational AROME/HU with OI-main, AROME-TEST with SEKF, and SYNOP data, respectively.

In **Austria**, both OFFLINE and SODA executables have been integrated in the script environment of the operational AROME system at ZAMG. To benefit from recent developments in the simplified Extend Kalman Filter, the executables are based on SURFEX 8.1, while AROME is still on CY43/SURFEX 8.0. In the first step, SYNOP data for 2m temperature are assimilated with the SEKF, using TG1, TG2, WG1 and WG2 (ISBA force-restore soil scheme with 3 layers) as control variables 8 times per day. The resulting analysis are not used currently for any further application but shall be compared to the operational OIMAIN output.

Total efforts: 6.25 months

Contributors: H. Tóth (HU) 5.75, S. Schneider (AT) 0.25, B. Tóth (HU) 0.25

Documentation: /

Status: ONGOING

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

Assimilation of Sentinel-2 based LAI within SEKF in AROME/SURFEX, impact experiments [SU 2.8.1]

A daily updated leaf area index (LAI) is planned to be introduced in AROME/HU instead of the climatological LAI. For this purpose, SURFEX-offline with prognostic LAI (ISBA-Ags scheme) will be run separately applying a land data assimilation system (with extended Kalman filter) using satellite observed LAI data (as described in Tóth and Szintai, 2021). LAI values computed by this offline system will be put in AROME/HU on a daily basis. **Balázs Szintai (HU)** set up an offline system based on SURFEX 8.1 without data assimilation (openloop run) on the 2.5 km horizontal resolution AROME/HU grid. Atmospheric forcings are derived from the operational AROME/HU forecasts. A longer period was computed with SURFEX-offline using ISBA-Ags in openloop mode between summer 2020 and autumn 2021. Severe droughts occurred in the hot and dry summer of 2021, affecting crops (maize) in Southern Hungary and Northern Serbia. Figure 10.1 compares the daily updated LAI and the climatological values for a selected date. In the second step, satellite LAI data was pre-processed in order to be used for (i) validation of the SURFEX-offline run and (ii) to be assimilated in SURFEX-offline at a later stage. LAI observations are derived from Sentinel-3 satellite of the Copernicus Global Land Service and provide a global coverage at 300 m resolution. This global product was filtered according to the appropriate quality flags and then interpolated on the Lambert grid of AROME/HU. In the third step, the LAI field produced by SURFEX-offline was put in AROME/HU for a selected case study to investigate the impact of LAI difference on the weather forecast. After solving some technical problems, a 12-hour forecast was made with the new LAI and simulated meteorological fields were compared to the operational AROME/HU forecasts. The largest impact was found in 2-meter temperature (Fig. 10.2), as this was a day with nearly no clouds and weak synoptic forcing over the area of interest. In the next step it is planned to run SURFEX-offline with EKF assimilation of LAI and use these improved LAI fields in AROME/HU.

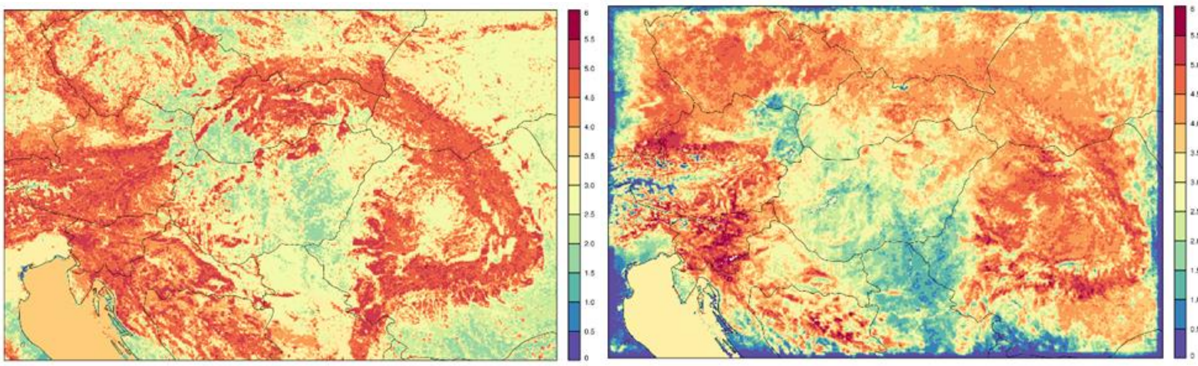

Fig. 10.1: LAI values from the operational AROME/HU (left) and from SURFEX-offline with ISBA-Ags (right) on 15 July 2021.

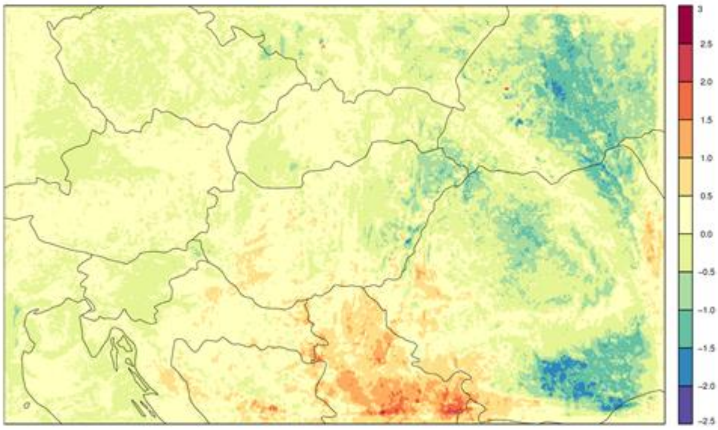

Fig. 10.2: Difference between 2-meter temperature forecasts of AROME using LAI computed by SURFEX-offline and operational AROME/HU (positive values mean lower temperatures in the operational AROME/HU). The forecasts are initialized at 00 UTC and valid at 12 UTC on 15 July 2021.

Measured LAI data, based on Sentinel-2 data and processed by BOKU (University of Natural Resources and Life Sciences, Vienna) for Austria on a 10 m grid are assimilated with SEKF (SODA in SURFEX 8.1) once per day. The analysis is used to initialize AROME. Work is based on the working hypothesis that a better representation of LAI should improve screen level parameters. To gain advantage of the high resolution of the LAI measurements, it is planned to run the soil model and the data assimilation in offline mode on a 1 km grid while AROME is running on 2.5 km, so the analysis is upscaled to fit to AROME. A requirement for LAI assimilation is the use of 12 patches and prognostic biomass (ISBA-Ags) in the soil model (CPHOTO=NIT). Furthermore, the ISBA diffusion soil scheme is used. Current validation against station measurements in Austria indicate that the assimilation is beneficial as e.g. the bias for 2 m air temperature forecasts reduced compared to the reference run (see Fig. 10.3). No atmospheric data assimilation is used in these experiments. Further tests are planned to investigate the impact of running the assimilation on higher resolution (e.g. 1000 m or 500 m grid) as the LAI data are available on a 50 m grid.

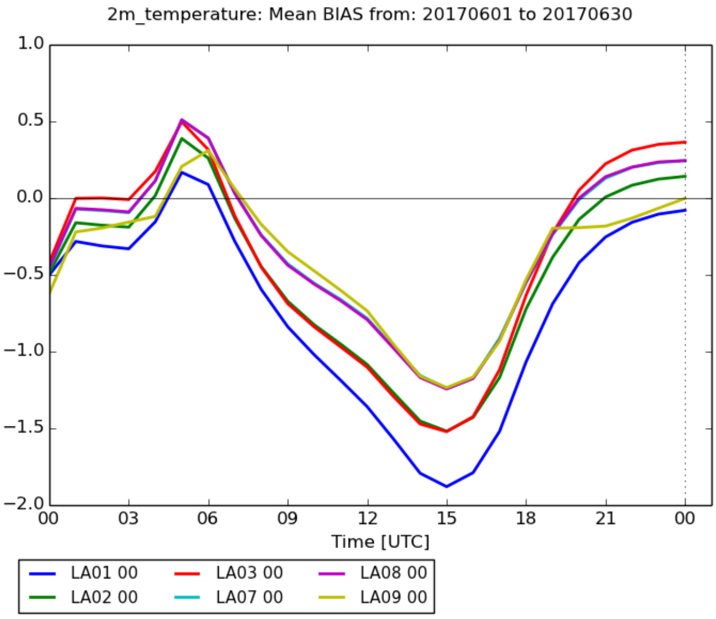

Fig. 10.3: 2 m temperature bias averaged for 30 forecasts in June 2017 and ~250 stations in Austria. LA01 is the reference run without data assimilation and climatological LAI with 1 patch. LA02 and LA03 are versions with 12 patches. LA07, LA08 and LA09 are versions with LAI data assimilation with different configurations.

Total efforts: 5.75 months

Contributors: S. Schneider (AT) 3.5, S. Oswald (AT) 1.25, B. Szintai (HU) 1

Documentation: Published paper.

Status: ONGOING

Documents and publications

Scientific papers:

Randriamampianina R. et al., 2021: Historical observation impact assessments for EUMET-NET using the ALADIN/HU limited area model. IDŐJÁRÁS, 125(4), DOI:10.28974/idoja-ras.2021.4.2 (pp. 555–570).

Simon A. et al., 2021: Numerical simulations of 7 June 2020 convective precipitation over Slo-vakia using deterministic, probabilistic and convection-permitting approaches, 2021. IDŐJÁRÁS, 125(4), DOI:10.28974/idojaras.2021.4.3 (pp. 571–607).

Tóth, H. et al., 2021: Recent developments in the data assimilation of AROME/HU numerical weather prediction model. IDŐJÁRÁS, 125(4), DOI:10.28974/idojaras.2021.4.1 (pp. 521–553).

Tóth, H., Szintai, B., 2021: Assimilation of Leaf Area Index and Soil Water Index from Satellite Observations in a Land Surface Model in Hungary. Atmosphere 12(8), 944.

Stay reports:

- Suzana Panežić: Impact studies with OPERA reflectivity observations, 9 August – 10 September 2021, Prague. https://www.rclace.eu/media/files/Data_Assimilation/2021/rapStay_SPanezic_reflAssim_CHMI_2021.pdf

Other documentation:

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

RC LACE DA at 30th ALADIN Workshop & HIRLAM All Staff Meeting 2020, 30 March – 3 April 2020, videoconference

List of presentations:

- Benedikt Strajnar: Overview of RC LACE data assimilation activities.
- SCHEFFKNECHT Phillip: Exploring New Observations for Austria's AROME RUC Nowcasting System

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

Activities of management, coordination and communication

1) Internal hangout meeting on RC LACE radar DA in 2021, January, coordinated by AL,
2) EUMETSAT NWP consortia preparation on MTG interview, 19 March 2021,
3) Joint 1th ACCORD all staff workshop 2021, 12-16 April 2021, videoconference,
4) Attendance to ACCORD DA working days, 29 May – 4 June 2021,
5) EUMETSAT Core NWP User Group Meetings, 22 June 2021, 1 December 2021, online,
6) RC-LACE Data assimilation working days, 22-24 September 2021,
7) EWGLAM (ACCORD observation use overview), 27 September – 1 October 2021,

8) OPERA users group meeting, 29 November 2021,

9) Informal LACE DA meetings (2nd Wednesday every two months),

10) ACCORD DA RT/ST topical meetings,

11) LSC meetings.

Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized	Planned	Realized
Operational implementation of DA suites [COM3]	8	10		
Further development of 3D-Var [DA 1]	12	8.25		
Use of existing observations [DA 3.1] – radar	23	19.75	1.25	1.25
Use of existing observations [DA 3] – other data types	21.75	8.25	1	canceled
Use of new observations types [DA 4]	12	8.75	1	postponed to 2022
Development of assimilation setups suited for nowcasting [DA 5]	20	7.5	1.25	-
Observation pre-processing and diagnostic tools [DA 7]	1	1		
Basic data assimilation setup (DAsKIT) [DA 8]	4.75	4.75		
Algorithms for surface assimilation [SU 1]	8	6.25		
Use of observations in surface assimilation [SU 2]	7	5.75		
Total	**115.75**	**80.25**	**4.5**	**1.25**

Problems and opportunities

The main problems in 2021 are/remain:

- *Distributed manpower. Local validation, maintenance and technical issues bring duplications of work which cannot be avoided. Some useful observation sources are limited to national use and thus needs to be studied and pre-processed separately in each country, even if the impact is relatively predictable.*
- *Lots of opened/ongoing subjects, especially in the DA3 package (other than radar).*
- *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 it is difficult to keep track of all activities.*

Opportunities for more effective future work are:

- *Wider collaboration within the ACCORD consortium, where possibilities are numerous: ACCORD Wiki, RTs/STs on algorithms and observations, Slack communication exchange.*
- *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.*