Working Area Data Assimilation

Progress Report

Prepared by:	Area Leader Benedikt Strajnar
Period:	2021 January-August
Date:	13/09/2021

Progress summary

The report summarizes the RC LACE DA activities in the first half of 2021.

The research and development work was mainly focused on application of radar data assimilation in order to enhance the realism of modelled precipitation patterns in the initial hours of the NWP forecast. Only one (radar related) stay was possible by September due in the COVID-19 travel restrictions. Nevertheless, LACE is now 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, enhanced use of AMV and some other observations was also considered. The Covid-19 epidemic caused a drop in AMDAR observations, however signs of recovery were visible in the first part of 2021.

Increased attention was given to validation of SEKF and related surface observations, mainly in Hungary where several remaining issues were studied and partially resolved (e.g. tuning of background, observation errors and perturbation magnitude).

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 minimization.

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):

DA	AUSTRIA AROME	AUSTRIA C-LAEF	CROATIA AL-ARO	CZECH REP. ALARO	HUNGARY ALARO	HUNGARY AROME	SLOVAKIA AL-ARO	SLOVENIA AL-ARO
Resol	2.5L90, 600 x 432	2.5L90, 600 x 432	4.0L73 480 x 432	2.3L87-NH 1069 x 853	8L49	2.5L60	4.5L63	4.4L87 432 x 432
Cycle	40t1	40t1	38t1_bf8	43t2ag	cy43t2bf11	cy43t2bf11	cy43t2bf11	43t2_bf10
LBC	IFS 1h (lagged)	IFS-EPS	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_main MES-CAN + 3d-Var, pert. obs. + Jk	OI + 3D-Var	OI + BlendVar	OI + 3D-Var	OI_main + 3D-Var	OI + DF Blend-ing	OI + 3D-Var
Cycling	3h	6h	3h	6h	6h	3h	6h	3h
B matrix	Downscaled LAEF 11 km	static C-LAEF EDA	NMC method	EDA	EDA	EDA	-	Downscaled ECMWF ENS
Initiali-zation	No (SCC)	No (SCC)	No (SCC)	IDFI in pro-duction, SCC	DFI	No	No	No (SCC)
Obs.	Synop + AS Amdar Geowind Temp ASCAT, Snow-grid/MODIS snowmask., Mode-S EHS	Synop + AS Amdar Geowind Temp, ASCAT, Snow-grid/MODIS	Synop Amdar/MRAR Geowind Temp Seviri	Synop + AS (soil) Amdar/MRAR /EHS 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 /IASI ASCAT/OSCAT E-GVAP ZTD (passive)

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

DA	AUSTRIA AROME-RUC	CZECH REP. VarCanPack
Resol	1.2 L90 900 x 576	2.3L87-NH 1069 x 853
Cycle	40t1	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, Seviri, AMSUA/MHS/HIRS/ATMS/IASI (+ Metop-C), ASCAT, GNSS ZTD (Austria, 1h VARBC), GPSRO (OPLACE), Radar RH/Dow, INCA + AS at hig.freq., MODIS snowmask	Synop + AS, Amdar/MRAR/EHS, Geowind/HRWIND,Pro-filer, ASCAT, Seviri

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

In **Austria**, due to problems and optimization of 2m diagnostics, the work on DA was limited this year. The scientific projects are partly delayed due to delayed observation delivery by the project partners. The parallel experiments are satisfying now regarding verification scores and it is expected to be able to switch the operational configurations to cy43t2 rather soon. There are slight changes in the operational setup: extension of windfarm parametrization in AROME-RUC and VARBC of GNSS hourly instead of 24h in AROME-RUC.

In **Croatia**, a new procedure for creating national OBSOUL files was developed. 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. Some bugs were corrected and several new stations were added (14238, 14426, 14440, 14461, 14473). Hourly coupling to IFS instead of current 3-hourly was tested inside DA e-suite cy43. 72h forecasts initialized from 3 or 1 hourly DA cycle were calculated for period of two weeks. Validation is still ongoing, but first results are rather neutral.

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. Similarly, a code for VarBC of aircraft observations were made available for a planned stay on this topic.

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).

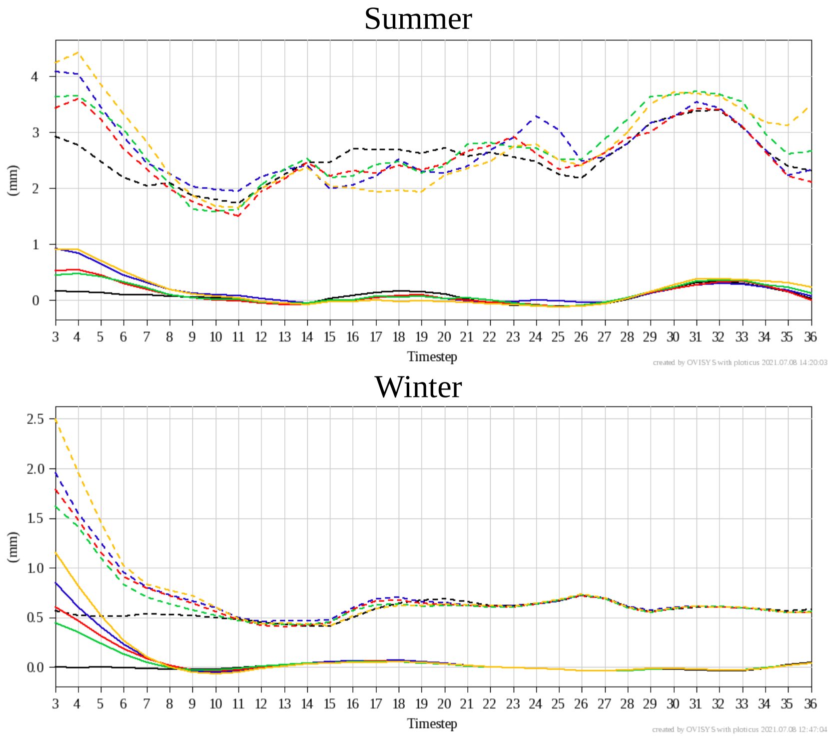

Fig. C1: Bias (solid line) and RMSE (dashed line) of 3-hour precipitation in the 0 UTC runs from 9 to 31 July 2020 (top) and from 25 November to 17 December 2019 (bottom) as a function of lead time. Black line: AROME/HU at 60 levels; blue, red, green and yellow lines: assimilation runs at 90 levels with 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.

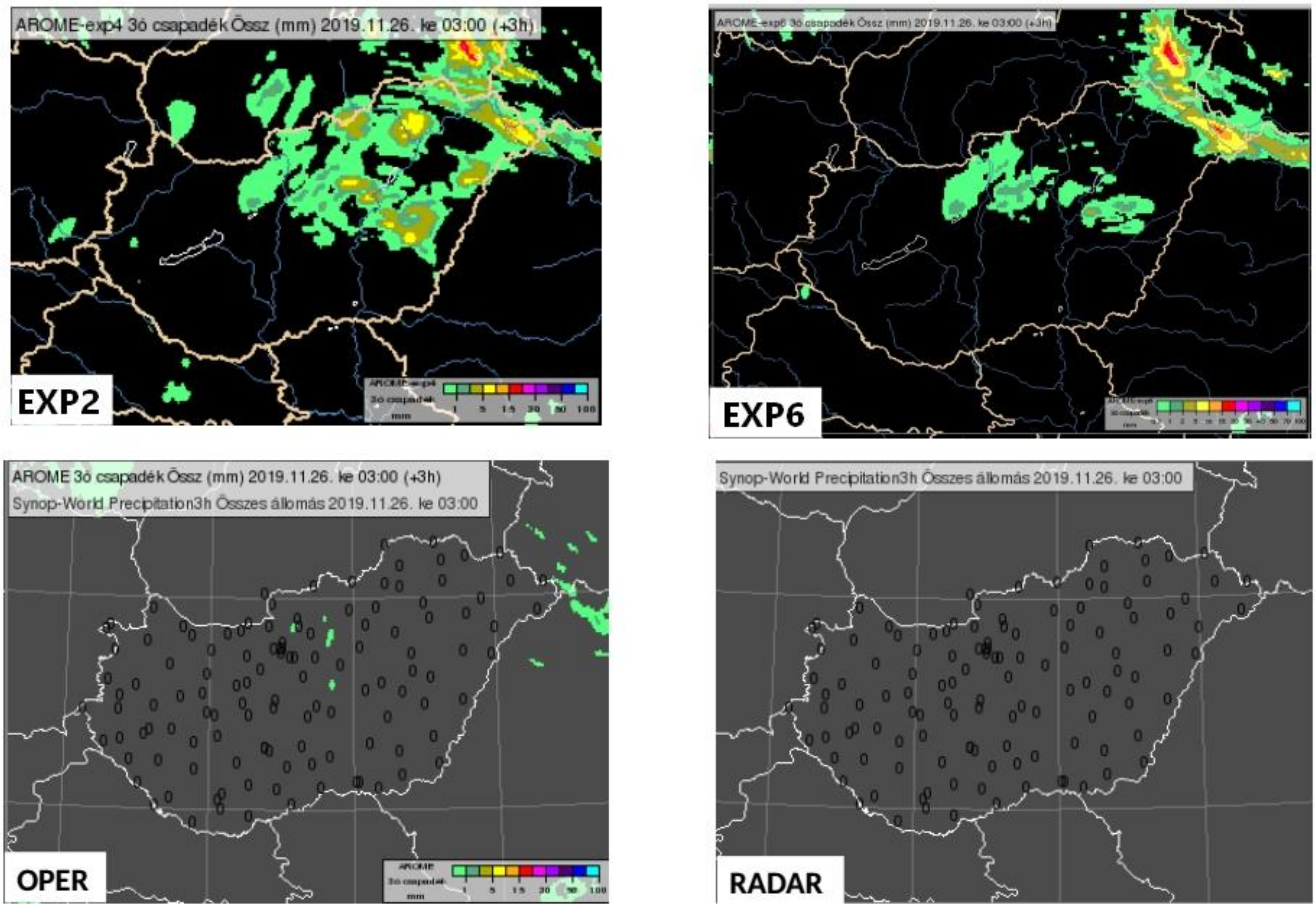

Fig. C2: 3-hour precipitation sum at 3 UTC on 26 November 2019 based on 3-hour forecasts from the 90-level experimental runs with EXP2 settings (top left) and EXP6 settings (top right), the 60-level operational run (bottom left) and radar data (bottom right).

In **Slovakia**, efforts were invested in validation of BlandVar and 3D-Var. The SHMI group supervised a bachelor thesis work (M. Petrovic) on testing the Rapid Update Cycle data assimilation (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.

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).

In **Romania**, the assimilation activities have been on hold in 2021. Two model setups at 4 km and 2.5 km are under evaluation, and addition of DA component is planned for the 4 km model setup.

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. 0.5 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

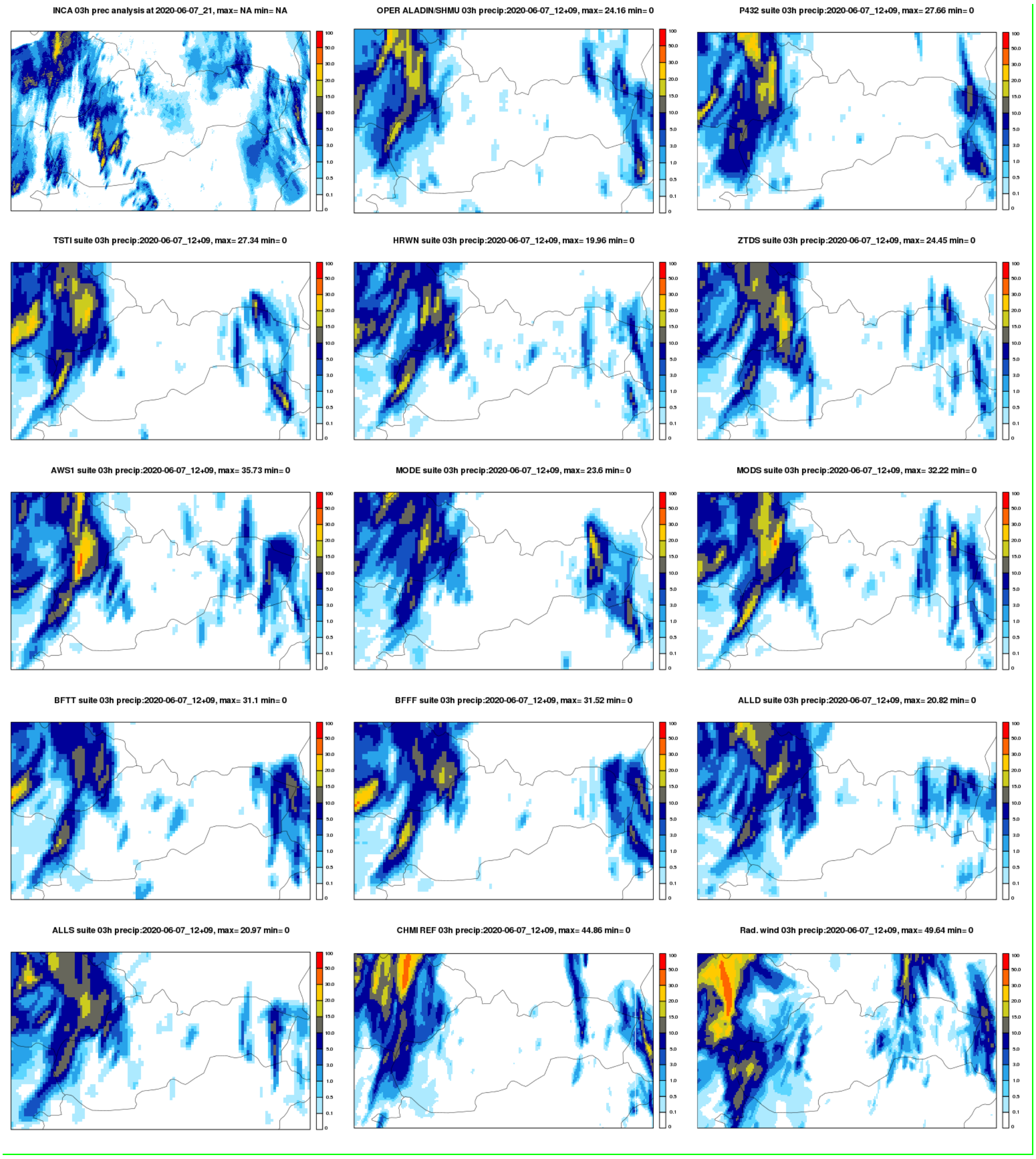

Figure 1.1: 3-hourly accumulated precipitation forecast from 07-06-2020_12 UTC for +9h. Top line from left to right: INCA analysis, operational forecast (DF BLENDING+CANARI), the same but with CY43t2 (as operational today). Other lines: various setups of BlendVAR as defined in the Table 1.1.

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

No progress.

Investigation of the effect of cycling of GFL fields in the DA cycle [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. 1.2).

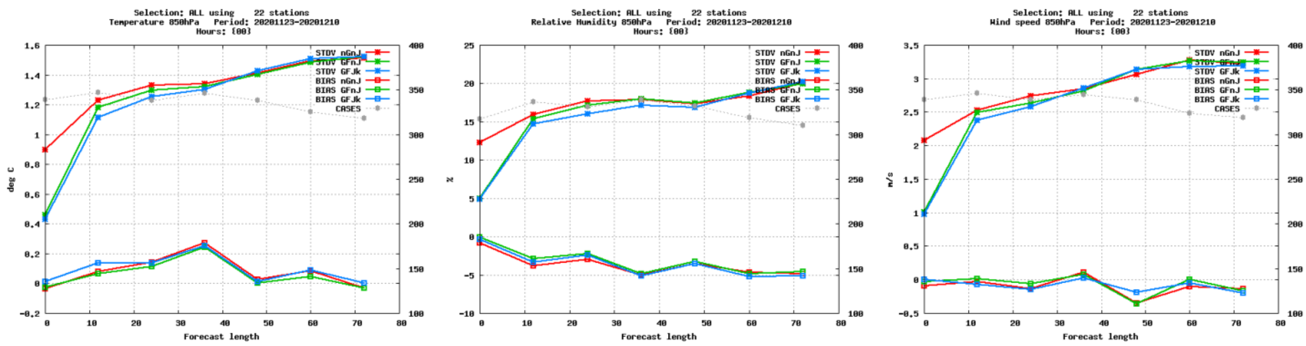

Figure 1.2: BIAS and STDEV for 850 hPa temperature (left), relative humidity (middle) and wind speed (right). Red line represents reference, green line GFL experiment and blue line GFL and Jk experiment.

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

Additionally, for the period described above, Jk method was also tested (blue line in Fig. 1.2). 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. 1.3). Results indicate that adding of GFL fields does not have impact on spinup, while using Jk has positive effect (smaller initial pressure tendencies).

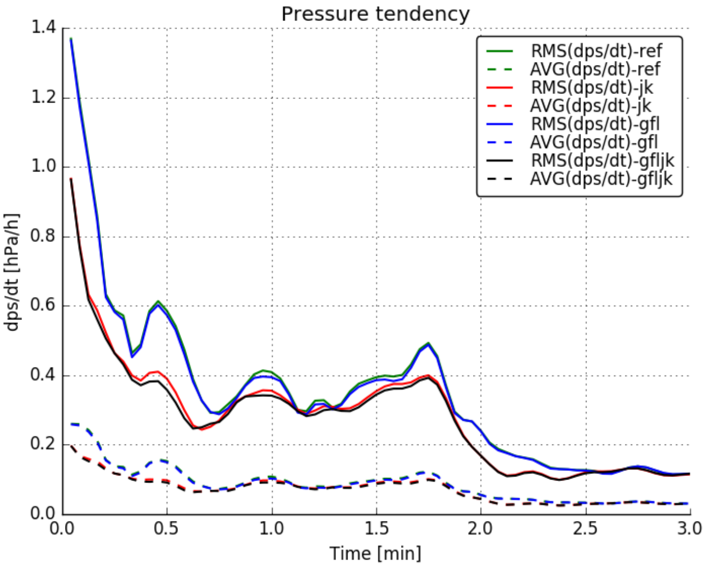

Figure 1.3: Mean (dashed) and root means square (full line) pressure tendencies for first three forecast hours inside DA cycle calculated over domain and several (6) DA cycles. Pressure tendencies were calculated for reference (green), reference with Jk (red), reference with GFL cycling (blue) and reference with Jk and GFL cycling (black).

Efforts: 4.25 month

Contributors: A. Stanešić (Cr) 0.5, A. Šljivić (Cr) 0.5, I. Dominović (Cr) 0.25, M. Derkova (Sk) 3

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

The torus mapping method (based on Haase and Landelius, 2004) was implemented in a Python (to become part of the HOOF preprocessing software). The method uses a linear wind model which is fitted against radial wind measurements mapped on to a torus (Fig. 3.1). Individual measurements are then dealiased by a multiplier of the Nyquist velocity according to the best fit to the model. Instead of using the method on the whole radar scan or on only one radar scan, the measurements from entire radar volume are divided into height sectors, and the method is applied to each sector individually, disregarding the scan from which each measurement came from (Fig. 3.1). While the wind model is fixed for a given height sector, a complete elevation is dealiased by a number of different wind models (Fig. 3.2).

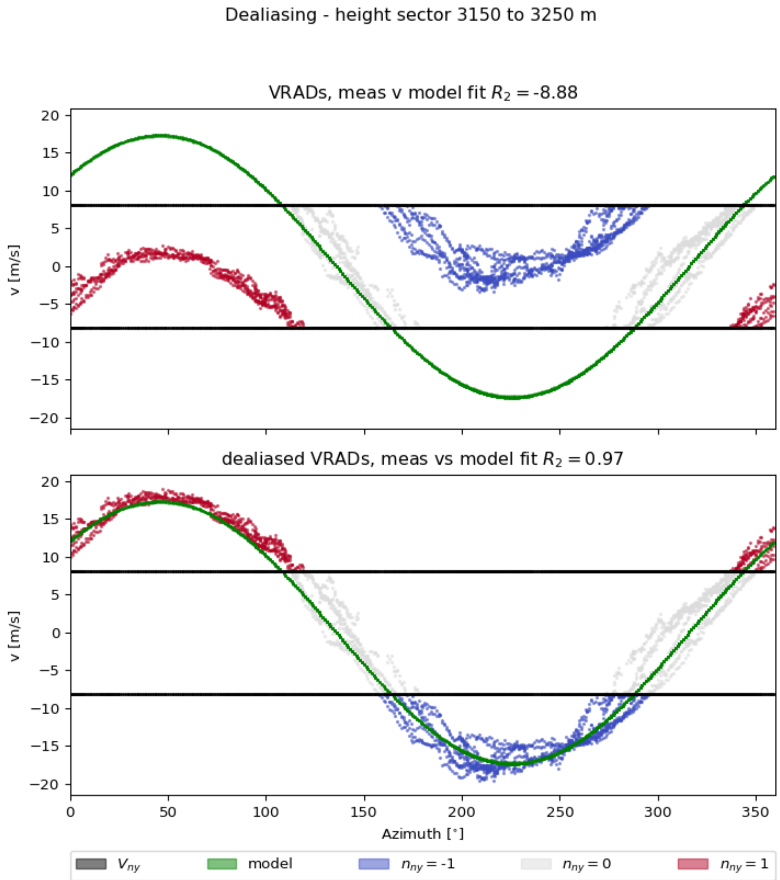

Figure 3.1: Raw (top) and dealiased (bottom) winds by azimuth in a given height sector of a single radar scan (Slovenian radar Pasja ravan - sipas). Shown are the assumed wind model (green line) and individual radial winds colored according to the chosen Nyquist multiplier. Black lines represent the Nyquist velocity.

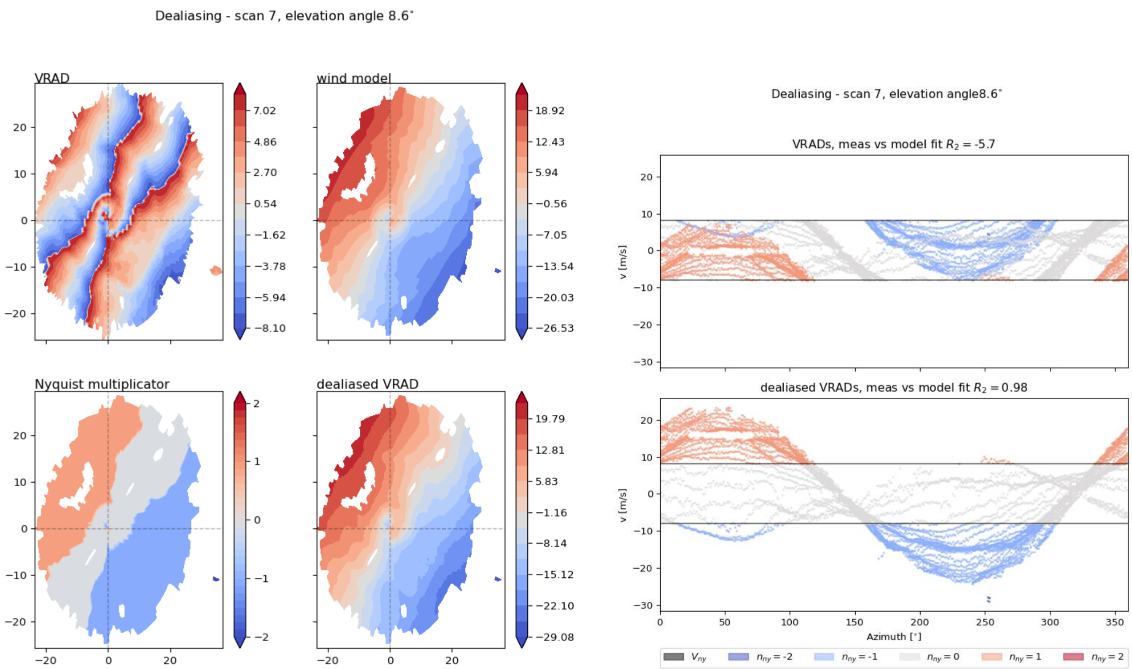

Figure 3.2: Left panel: Raw radial wind measurement (top left), the assumed wind model (top right), the chosen Nyquist multiplicator (bottom left) and dealiased solution (bottom right) for a single elevation scan (Slovenian radar Pasja ravan - sipas). Right panel: Same as Fig. 3.1 but now including several height sectors and thus several different wind models as applied to the given elevation.

Further work ideas include determination of falsely dealiased points by using a smart statistic and test of an alternative numerical scheme for calculation of derivatives in the azimuth direction.

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.

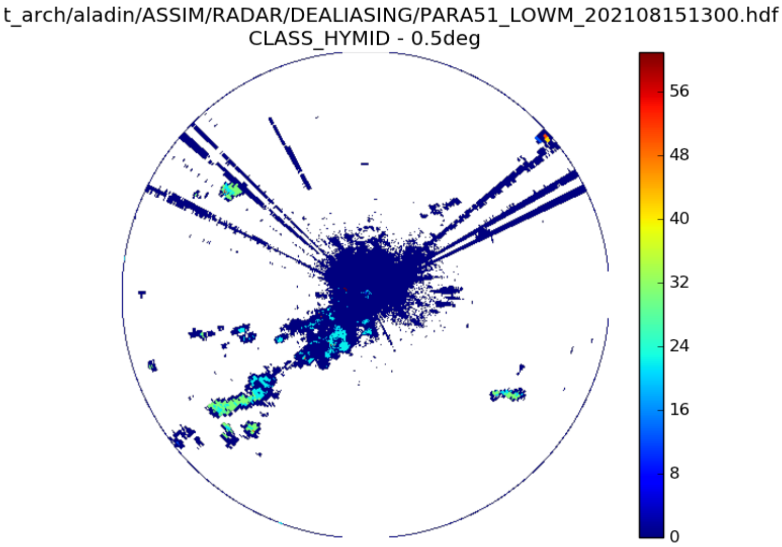

Figure 3.3: 3D hydrometeor classification based on RADAR (Vienna-Airport 20210815 13UTC) The classes are: 0 non meteorological, 11 crystals, 12 ice, 13 aggregates, 21 light rain, 22 moderate rain, 31 wet snow, 41 rimed ice 51 graupel, 61 hail.

In **Slovenia**, a radar reflectivity impact study was carried out, 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 is confirmed by the hourly precipitation verification (Fig. 3.4), 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 (Fig. 3.5) and at 4.4 km resolution in general slightly negative in terms of bias (dry and cold bias) for upper air fields. 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 more moist pixels for assimilation. 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. Also, the NOBSPROFS variable was increased to search for more similar profiles in the Bayesian retrieval and finally, the modifications proposed by Maud Martet (2021) for cy46 were compiled but not yet tested.

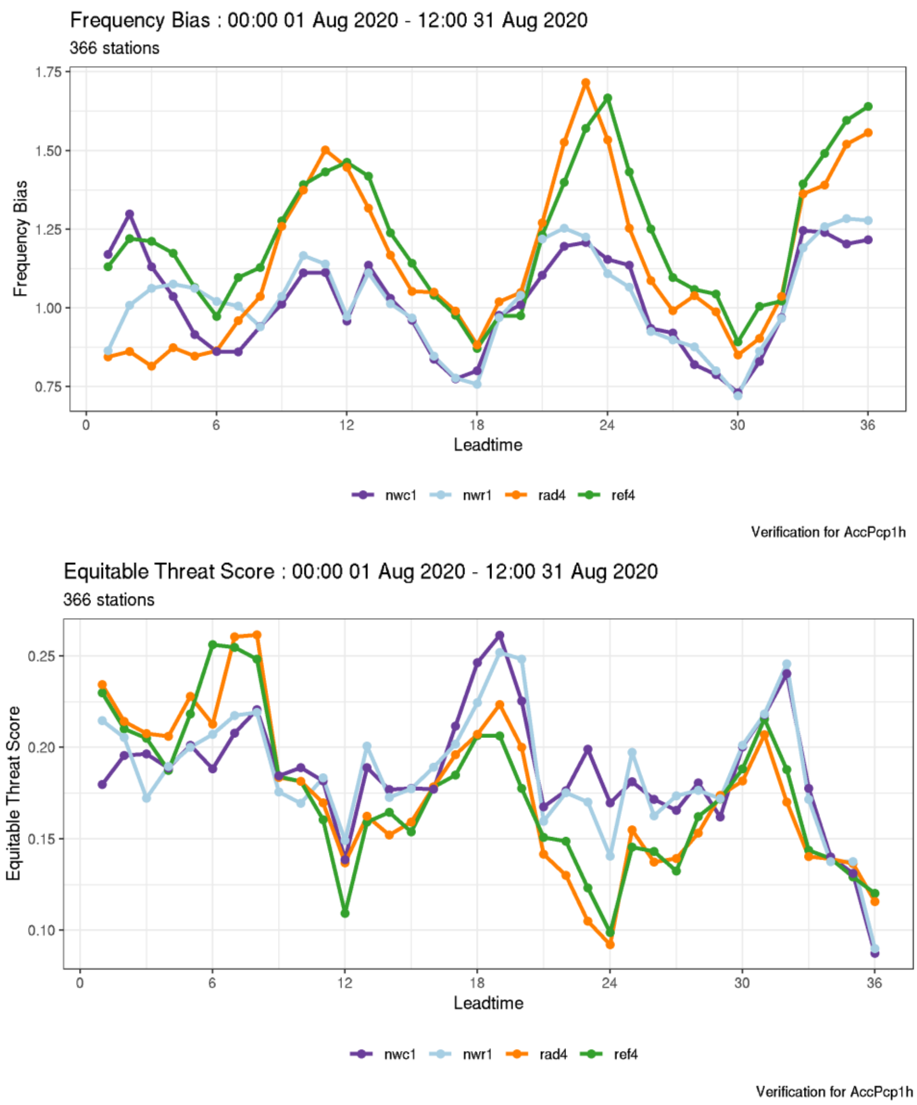

Figure 3.4: Verification of NWCRUC (nwc1 – without radar reflectivity, nwr1 – with reflectivity) in comparison to operational ALADIN 4.4 km (ref4 – without refl., rad4 – with reflectivity) over August 2020. Shown are frequency bias (top) and ETS (bottom) for 2 mm precipitation threshold.

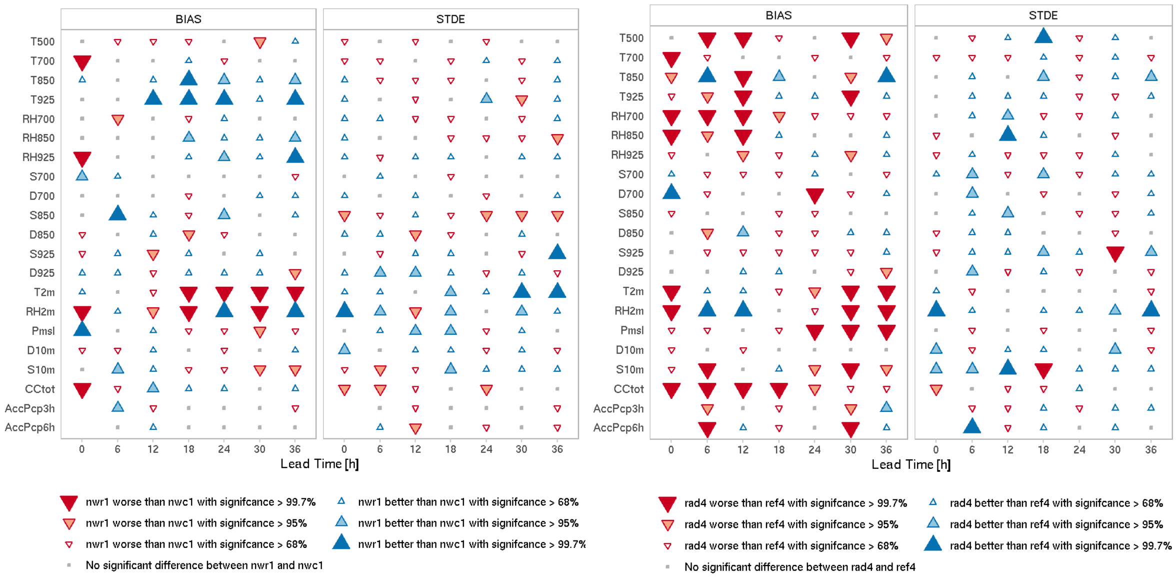

Figure 3.5: Scorecard of radar reflectivity experiments with respect to references for 1.3 km (left) and 4.4 km (right) resolutions in the experiment names are as in Fig R1.

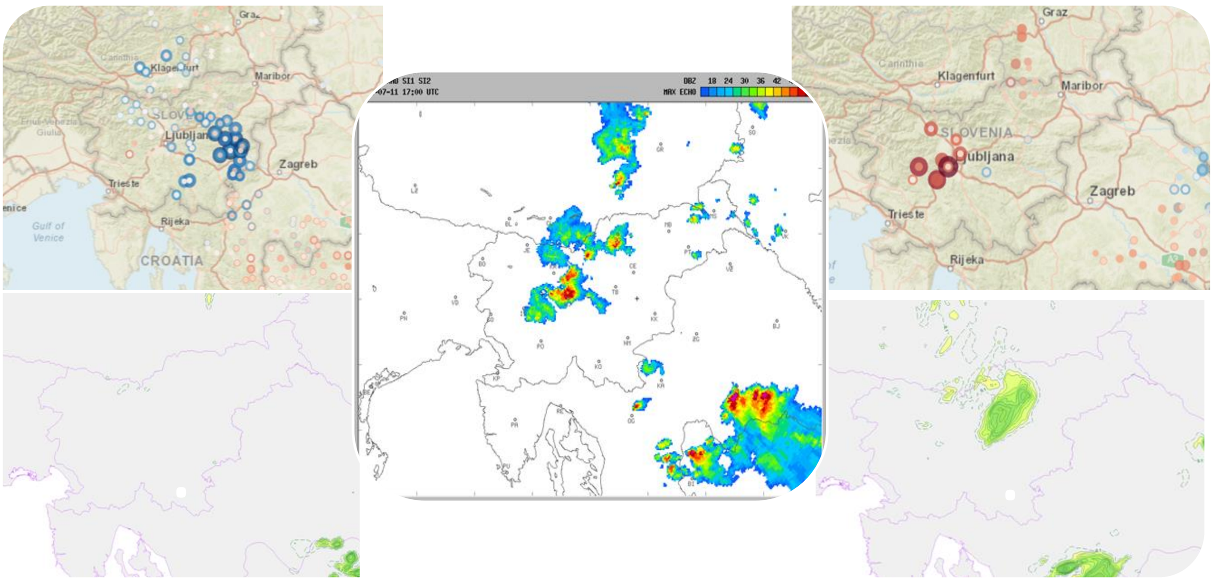

Figure 3.6: Modifications of the screening selection procedure for radar reflectivity for 11 July 17 UTC. Left: analysis increment at selected pixels (blue is dry, red is wet) and the resulting 1h precipitation forecast field of a default setup. Right: analysis increment at selected pixels and the resulting 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).

In the **Czech Republic**, the reflectivity observation operator has been studied and the latest modifications from Meteo France (the corrections of the air density calculation and adding cloud ice in the observation operator) are tested but there are no conclusions yet. The LACE stay of Suzana Panežić on assimilation of reflectivity data is ongoing. The aim of this stay is to investigate sensitivity of the Bayesian inversion on number of reflectivity profiles, the box-size, and the sigma value.

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. 3.7.

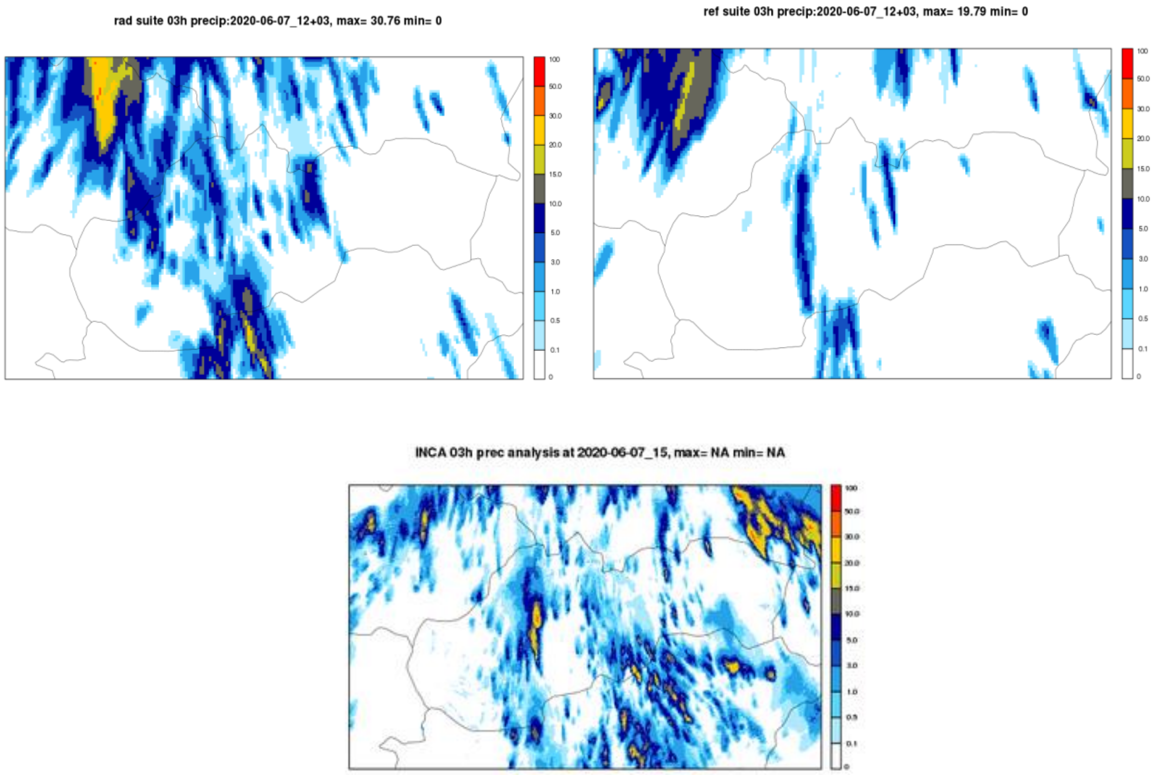

Figure 3.7*: 3-hourly accumulated precipitation forecast in ALARO/CHMI from 07-06-2020_12 UTC +3h. The experiment rad used radar radial winds (top left) on top of other observations used in the ref experiment (top right) and 3h INCA analysis as a reference (bottom).*

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).

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

A first working version of superobbing functionality in HOOF is available (Fig. 3.8) and ready to be tested for reading in Bator. Further modifications are possible – for example the variable quality flag according to the partial flags of the selected radar pixels.

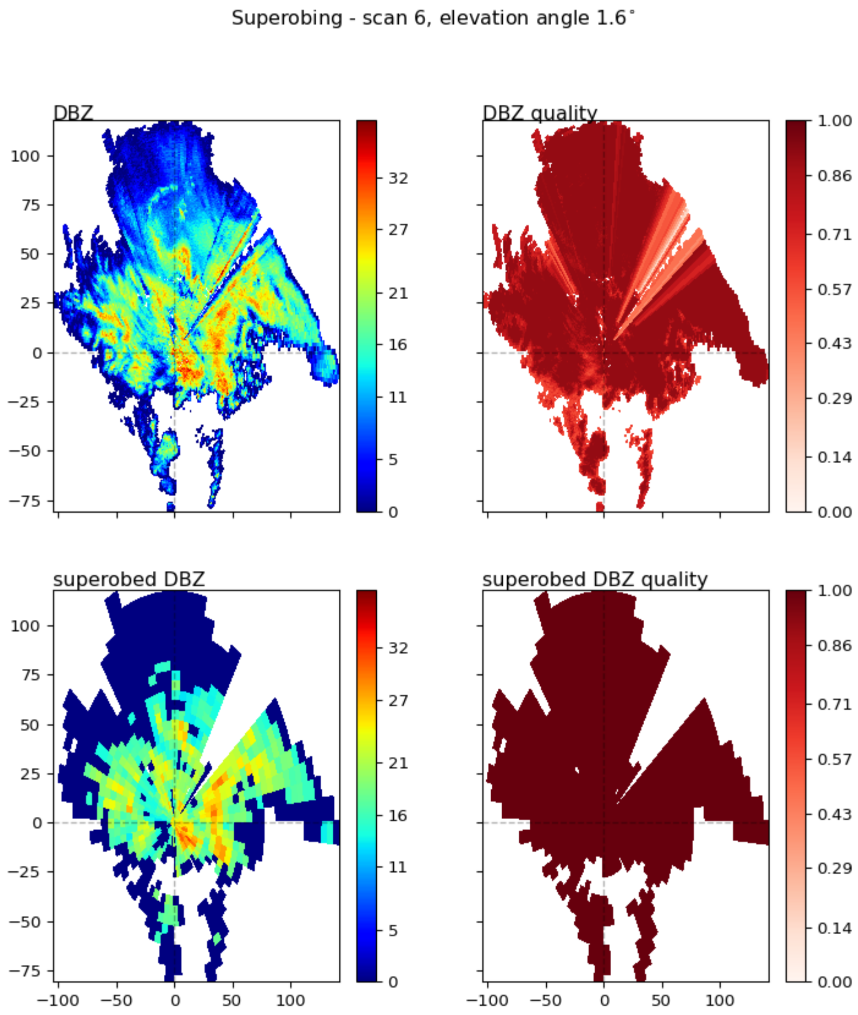

Figure 3.8: Original (top left) radar reflectivity for one elevation (Slovenian radar "silis") and related input quality flag (top right) and superobbed elevation (bottom left, large average size for illustration) plus the assigned quality flag, equal to 1.

Efforts: 9.5 month

Contributors: B. Strajnar (Si) 1.5, P. Smerkol (Si) 4, A. Bučánek (Cz) 0.5, A.Trojáková (Cz) 1, K. Čatlošová (Sk) 1.5, A. Stanešić (Cr) 0.25, S. Panežić (Cr) 0.75, F. Meier (At) 1

Documentation: HOOF user guide, updated.

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 (Sk, Si, Hu, Cz). [DA 3.2]

Little work was invested, Members followed production switch of EMADDC/KNMI regarding the MODE-S dissemination and were involved in related coordination.

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. 3.9). 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.

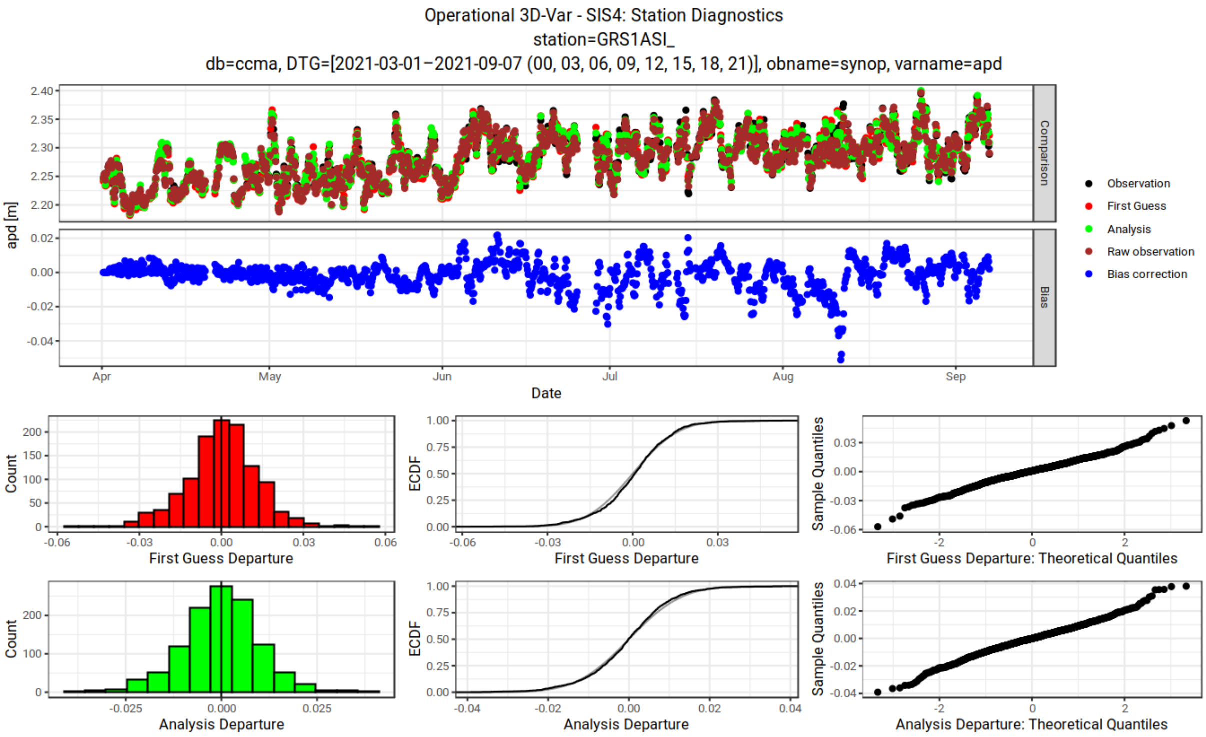

Figure 3.9: Evolution of observations, first guess and analysis (upper panel) and bias estimates (blue), and overall departure statistics in passive assimilation in the period March-August 2021 for Ljubljana GNSS station.

In **Croatia**, a technical test with GNSS data in cy43 was performed with the MF whitelist (increments in Fig. 3.10). For further testing a more suitable whitelist will be set up and data will be evaluated.

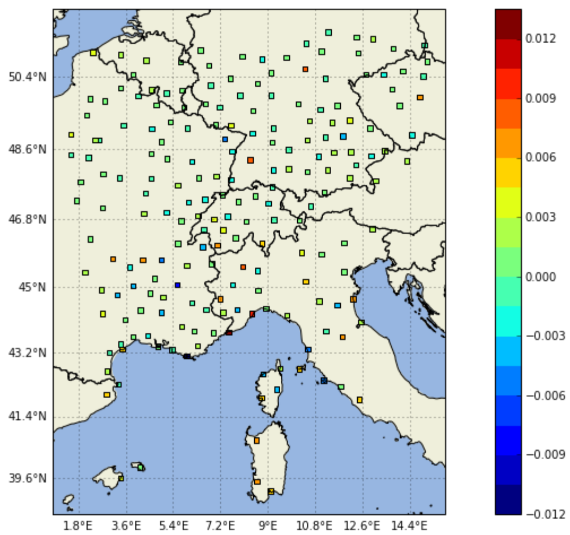

Figure 3.10: Analysis departure of GNSS data in a technical test at DHMZ.

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.

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. 3.11 and 3.12), using the default blacklisting which implies lack of mid-atmosphere observations.

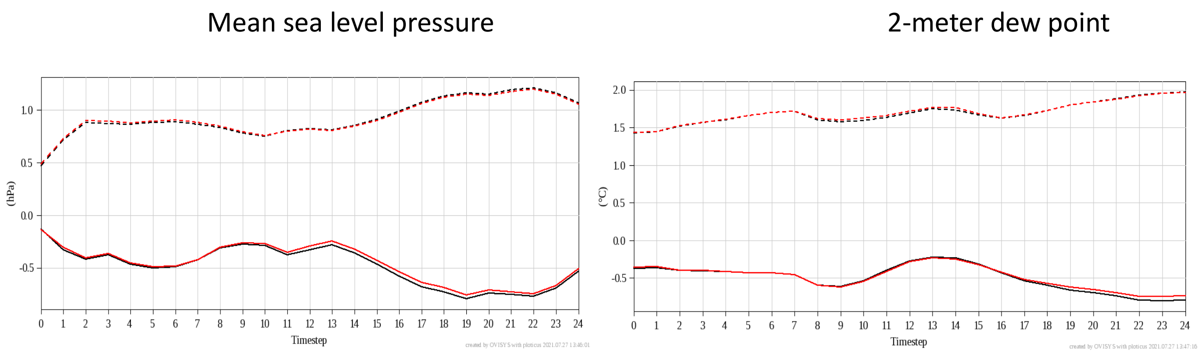

Fig. 3.11: Bias (solid line) and RMSE (dashed line) of mean sea level pressure (left) and 2-meter dew point (right) forecasts in the 0 UTC runs from 1 to 18 December 2019 as a function of lead time. Red and black lines: AROME/HU with and without AMVs, respectively.

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. Figure 3.12 shows the improvement of the temperature and relative humidity forecasts at 850 hPa. In Figure 3.13, 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. It is planned to test the impact of the new blacklisting setting during a convective period as well.

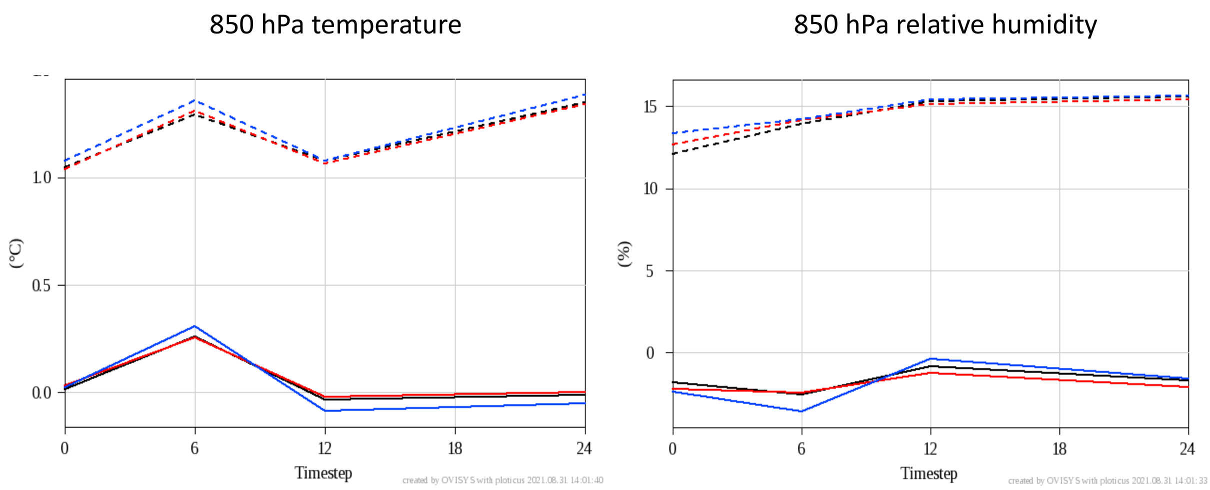

Fig. 2.11: Bias (solid line) and RMSE (dashed line) of temperature (left) and relative humidity forecasts (right) at 850 hPa in the 0 UTC runs from 1 to 18 December 2019 as a function of lead time. Blue, red and black lines: AROME/HU without AMVs, with AMVs with the original blacklisting settings and with additional active AMVs between 800 (700 over land) and 350 hPa, respectively (the value at 18 hour range is interpolated).

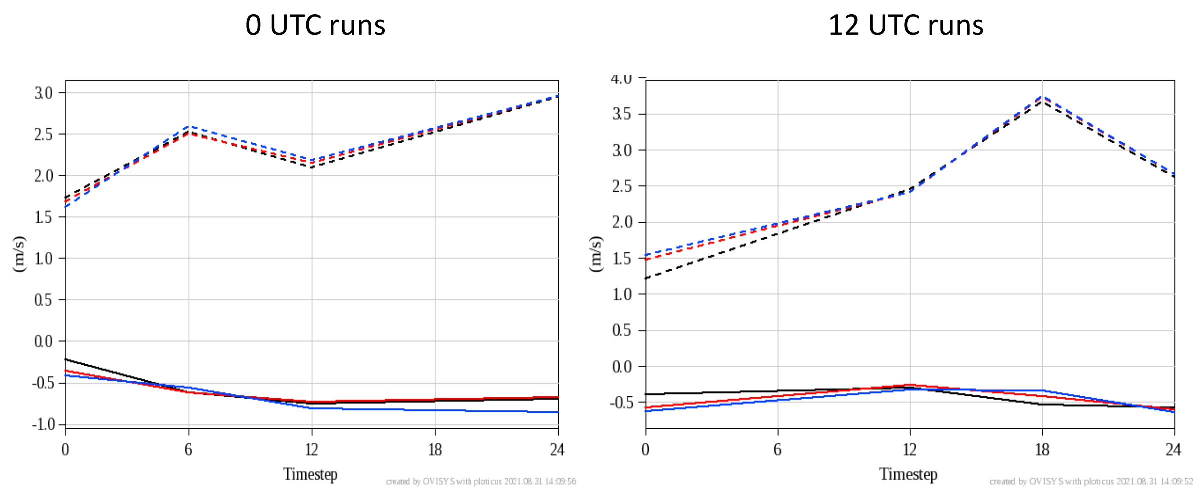

Fig. 3.13: Bias (solid line) and RMSE (dashed line) of wind speed forecasts at 500 hPa in the 0 UTC (left) and 12 UTC (right) runs from 1 to 18 December 2019 as a function of lead time. Blue, red and black lines: AROME/HU without AMVs, with AMVs with the original blacklisting settings and with additional active AMVs between 800 (700 over land) and 350 hPa, respectively.

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

No progress.

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. 3.14 and 3.15) 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.

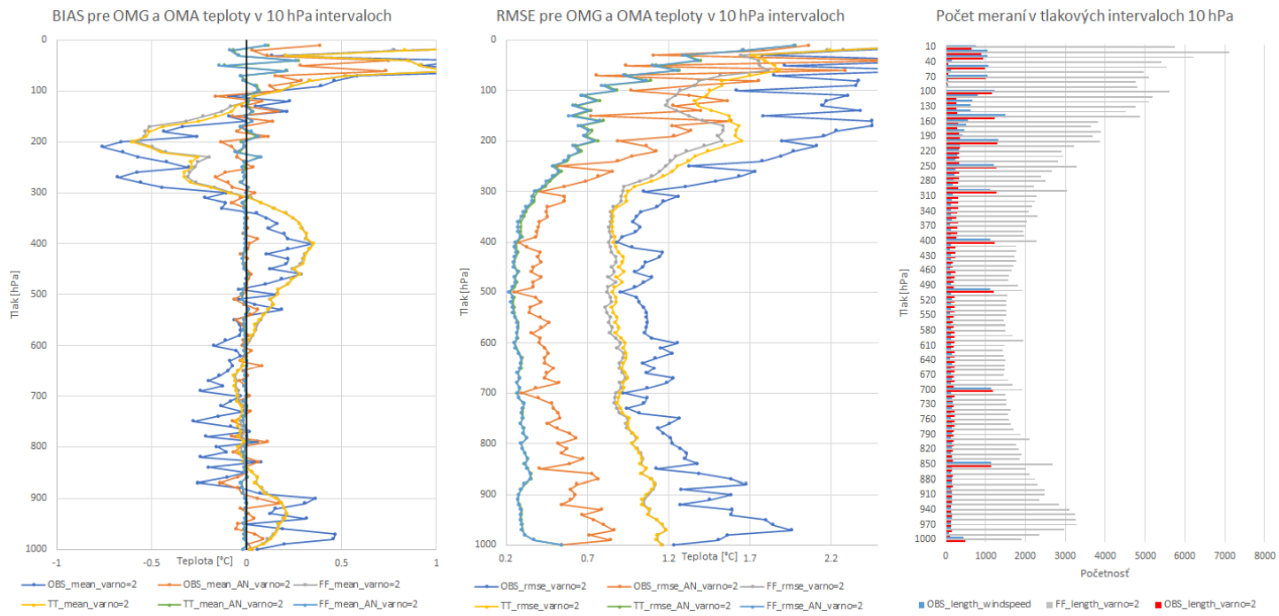

Figure 3.14: Vertical profiles of OMA and OMG for temperature - BIAS (left) and RMSE (middle), grouped by 10 hPa. Reference exp. with OBSOUL TEMP: OBS_OMA (orange), OBS_OMG (blue). TT exp.: TT_OMA (green), TT_OMG (light yellow). FF exp. (drift): FF_OMA (light blue), FF_OMG (grey). Right panel - number 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)

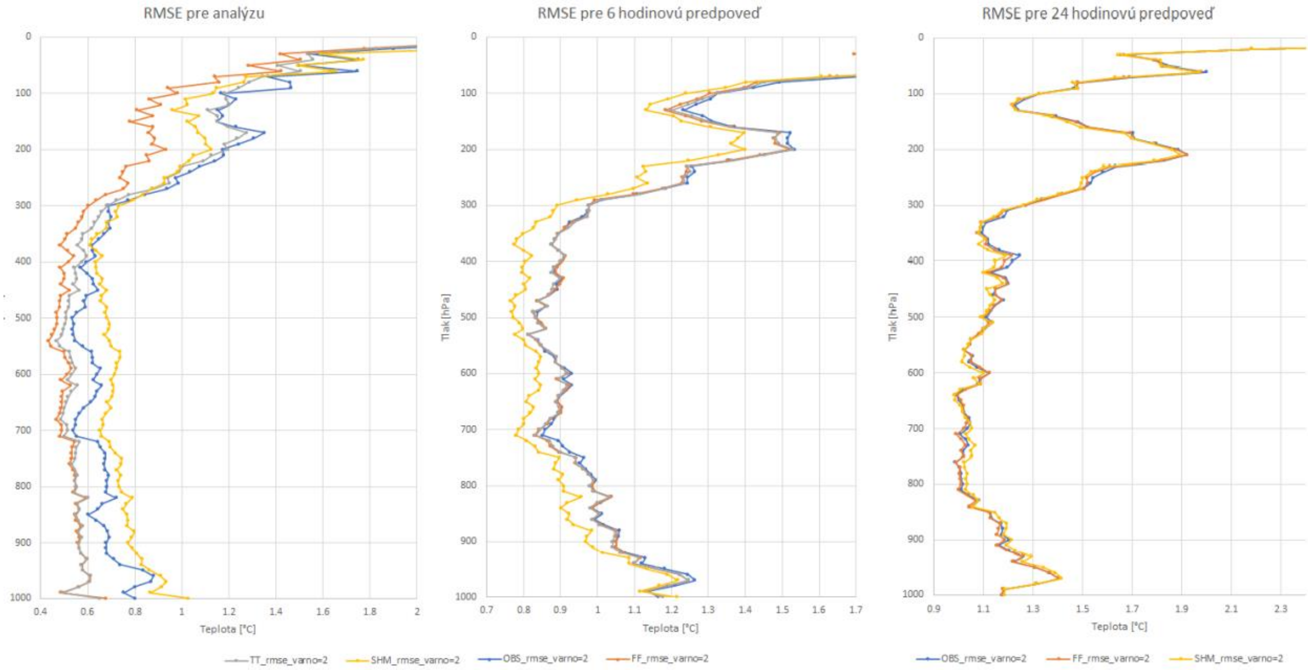

Figure 3.15: Vertical profiles of RMSE for temperature for 00 UTC: analysis (left), +6h forecast (middle) and +24h forecast (right), grouped by 10 hPa. Reference OBS exp. with OBSOUL TEMP (blue), TT exp (grey), FF exp. (orange), SHMU operational (light yellow). Verification period 23.2.-4.3.2020, 6-hourly cycling.

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.

Efforts: 3.75 month

Contributors: Z. Kocsis (Hu) 0.75, B. Strajnar (Si) 0.5, M. Derkova (Sk) 1, F. Meier (At) 0.25, F. Weidle (At) 1, J. Cedilnik (Si) 0.25

Documentation: /

Status: ONGOING

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

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

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]

In Austria, **ZAMG** got data from Austrian telecommunication provider Drei Hutchison. The data were pre-processed with KNMI software rainlink (Overeem et al.) to derive rain rates (Fig. 4.1) and further quality control is under development based on ML techniques in cooperation with research school Sankt Pölten (as presented in 1st ACCORD workshop). 1D-3D rain-rate assimilation software from P. Lopez, which is planned beside Latent Heat Nudging to be tested for assimilation of the rain rates into AROME.

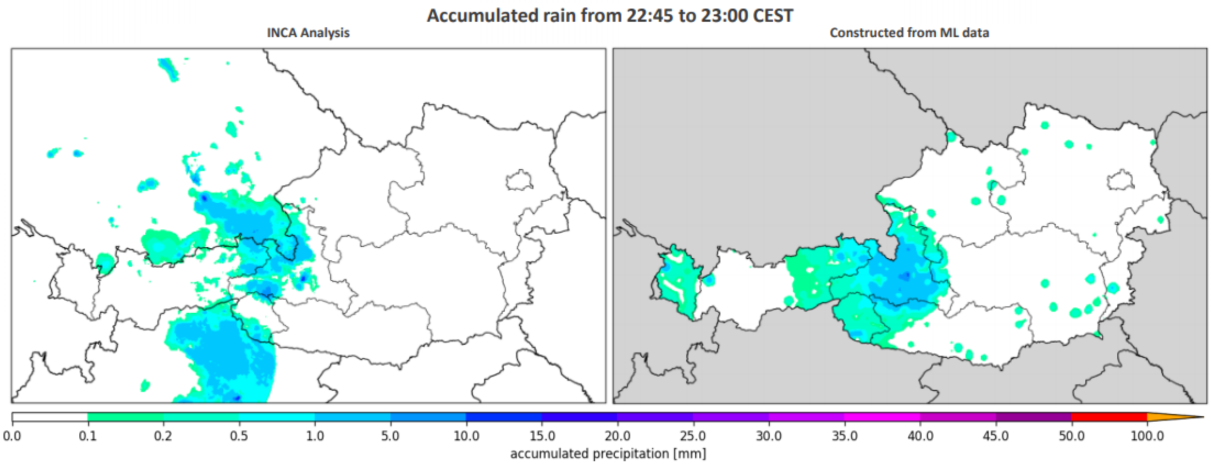

Figure. 4.1: INCA analysis of 2D rain (left) as reference and microwave derived rain (right, no data outside Austria).

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: 6.5 month

Contributors: M. Imrišek (Sk) 4.5, P. Scheffknecht (At) 1.75, 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: the focus is on data with fast delivery and locally available data which can enhance the widely available datasets. [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.

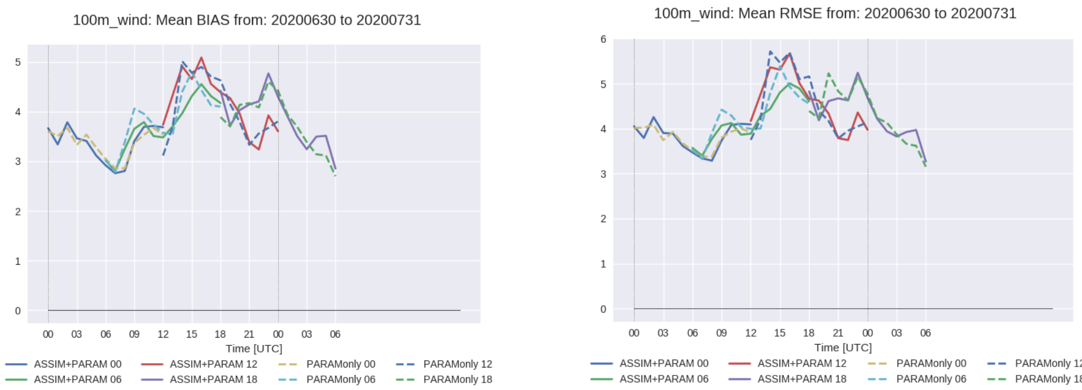

Figure 5.1: Assimilation of SCADA data July 2020 in AROME RUC 00/06/12/18 UTC runs. Bias (left) and RMSE (right) of 100m wind. Reference without assimilation is dashed, experiment with assimilation solid. Positive impact especially in 06 UTC runs (green solid vs. light blue dashed).

In AROME-RUC parallel run vertically higher resolved BUFR-temp data are used instead of obsoul. The data are derived from local database and coded into temp BUFR via a Python script. The amount of data assimilated increases significantly. EGVAP ZTD data from OPLACE are currently assimilated passively in AROME-RUC parallel. When observation error from ODB statistics is derived, the data can be tested in active mode. The number of stations is significantly larger (several hundred) than that of the national network (46 stations, Fig. 5.2).

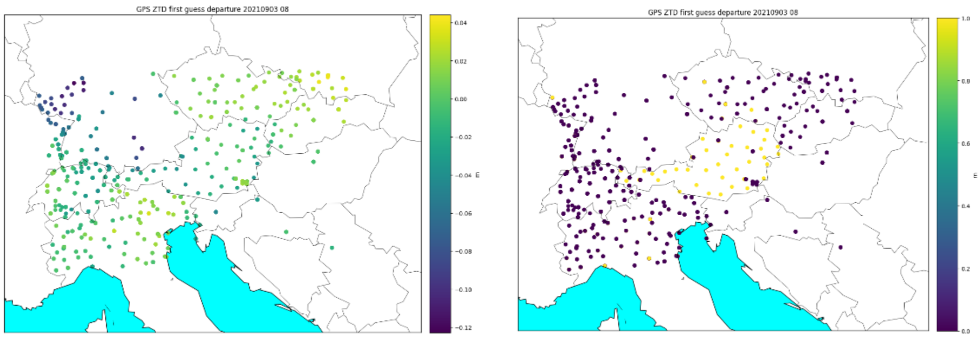

Fig. 5.2: First Guess departures of ZTD stations within AROME-RUC domain (left). The yellow stations on the right are actively assimilated within AROME-RUC parallel run.

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).

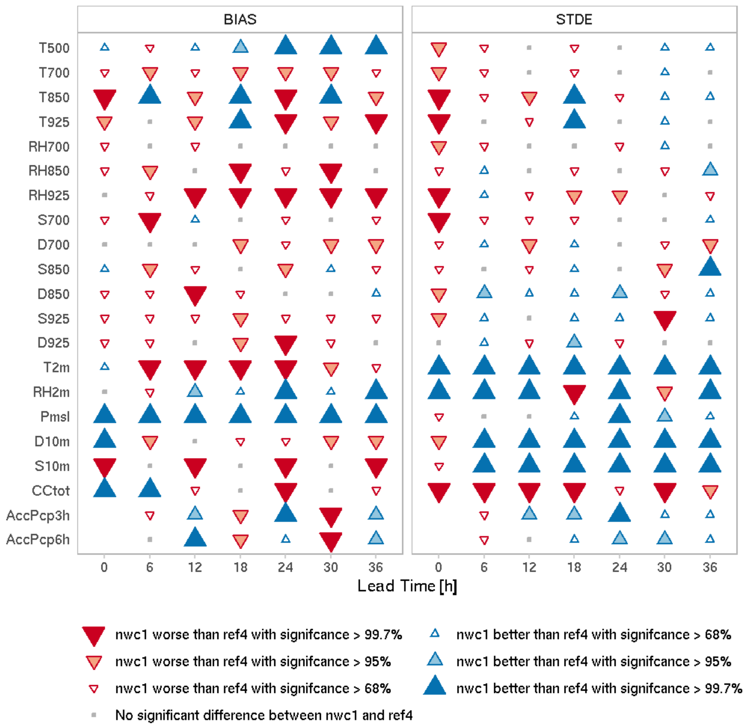

Figure 5.3: Verification scorecard, comparing NWCRUC and ALADIN 4.4 km over the 1 month summer period.

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. 5.3 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. Fig. 3.4 of the radar section shows the frequency bias and equitable threat score of 1 h precipitation sums over the summer period, for 2 mm/h precipitation threshold. It is evident that the operational 4.4 km model overestimates the precipitation which is corrected for the 1 km model. In terms of the EHS, the 1.3 km model performs better except for the first 6-7 hours of the forecast. 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 possibly connected to excessive drying from reflectivity assimilation,
- There are large areas with light precipitation over the orography, suggesting a too active sub grid convection (not related to DA).

Additionally (based on subjective analysis of convective cases), there is an imbalance on the number of selected dry versus moist pixels used for radar DA and thus reflectivity assimilation filters out some convective events. Several code adaptations were tried and evaluated but a satisfactory solution was not yet found. Further tunings will be needed before full operationalization.

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 5.4 and 5.5 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

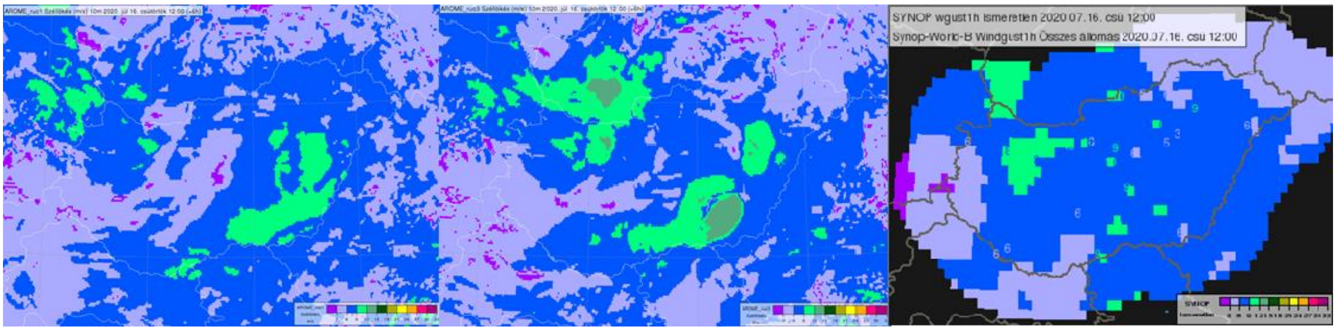

Fig. 5.4: 10-meter wind gust at 12 UTC on 16 July 2020 based on the 6-hour forecast of the RUC experiments using 1 and 3 hourly surface assimilation frequency (left and middle, respectively) and the SYNOP observations (right).

1 hourly surface DA | 3 hourly surface DA | radar

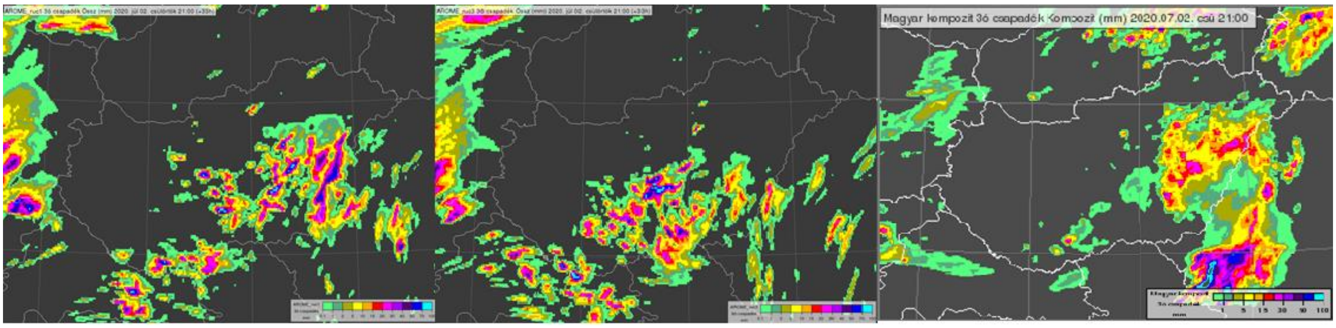

Fig. 5.5: 3-hour precipitation sum at 21 UTC on 2 July 2020 based on the 33-hour forecast of the RUC experiments using 1 and 3 hourly surface assimilation frequency (left and middle, respectively) and the radar data (right).

Pointwise verification confirmed the improvement gained with the hourly surface initialization, with respect to its 3 hourly counterpart (Fig. 5.6), 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. 5.7): 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.

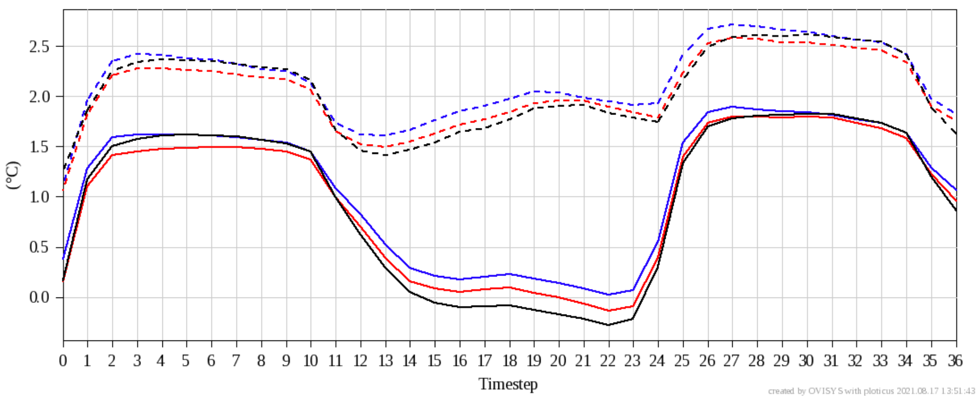

Fig. 5.6: Bias (solid line) and RMSE (dashed line) for 2-meter temperature forecasts in the 18 UTC runs from 1 to 22 July 2020 as a function of lead time. Red, blue and black lines: RUC experiments with hourly and 3 hourly surface initialization and operational AROME/HU, respectively.

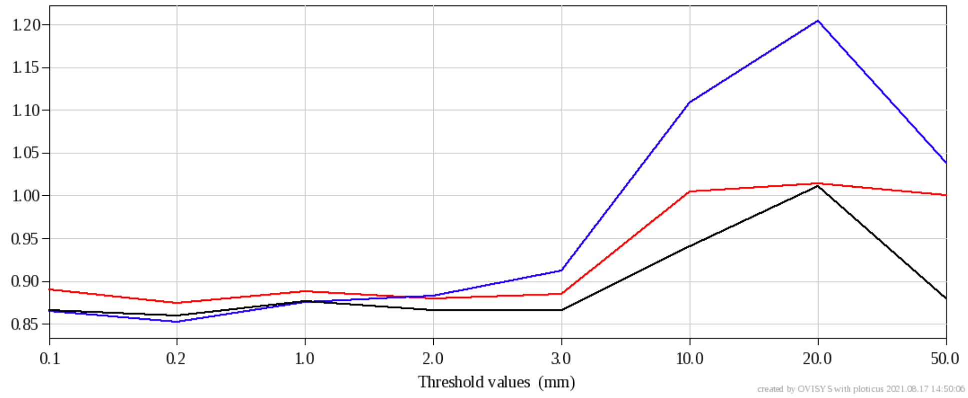

Fig. 5.7: Frequency bias for 24-hour precipitation sum in the 18 UTC runs from 1 to 22 July 2020 as a function of precipitation amount. Red, blue and black lines: RUC experiments with hourly and 3 hourly surface initialization operational AROME/HU, respectively.

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.

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: 5.25 months

Contributors: Kristóf Szanyi (Hu) 3, B. Strajnar (Si) 1.5, 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 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 Trojakova (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.

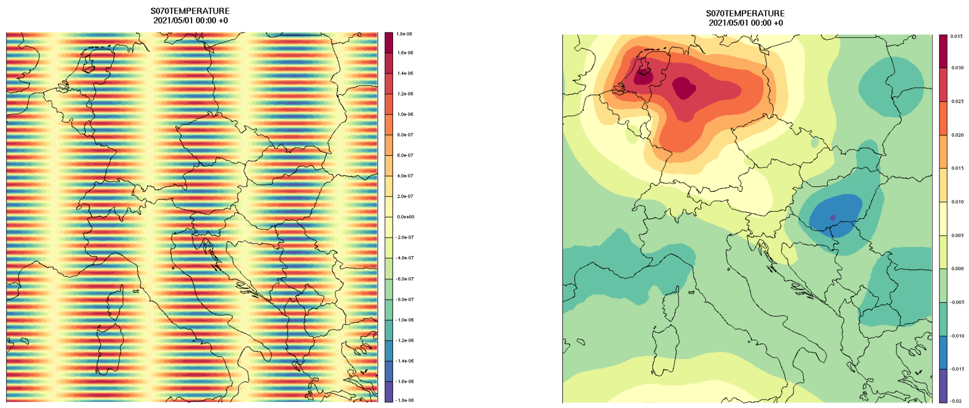

Figure 6.1: Difference between analysis of 700 hPa temperature with OOVAR and MASTERODB executables for conventional and satellite observations (left) and additionally the radar reflectivity (right). The order of difference is 10^{-8} K on the left and 10^{-2} on the right.

Total efforts: 1 months

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: 3 months

Contributors: M. Szczech-Gajewska (Pl) 3

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).

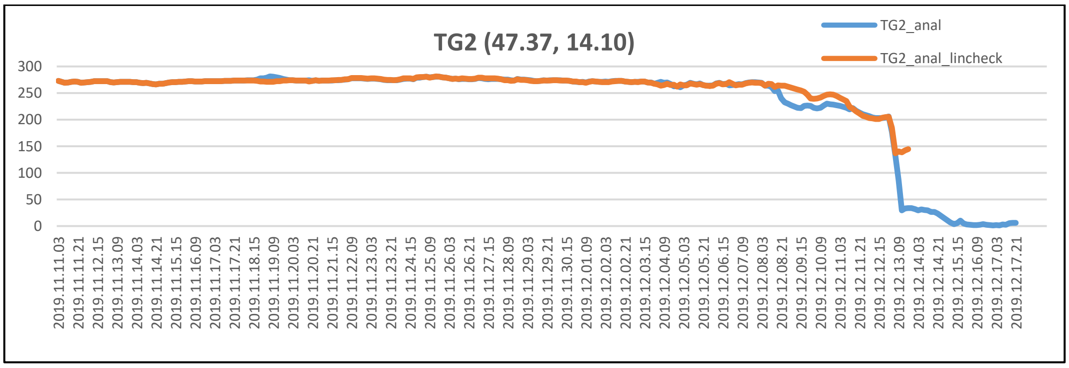

Figure 9.1: Evolution of TG2 at the target point between 11 November and 17 December 2019 (blue: SEKF, orange: SEKF+LCJ).

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.

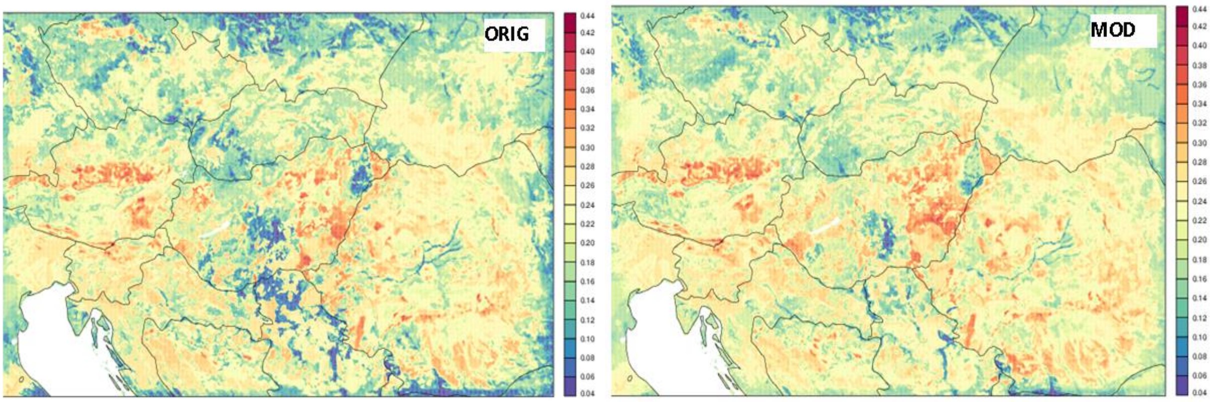

Figure 9.2: WG2 analysis at 12 UTC on 31 July 2020 for original and modified runs.

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.

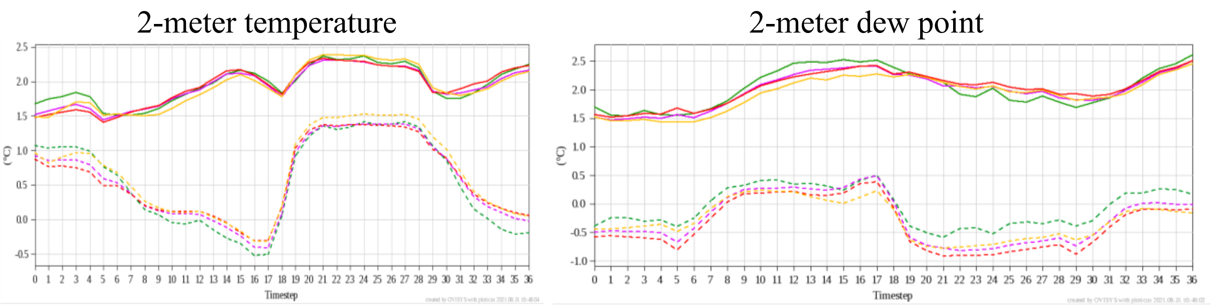

Figure 9.3: Bias (dashed line) and RMSE (solid line) of 2-meter temperature (left) and 2-meter dew point (right) forecasts for the 0 UTC runs from 9 July to 31 July 2020. Curves represent: OI-main, EXP4, DEF, ECM_B.

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).

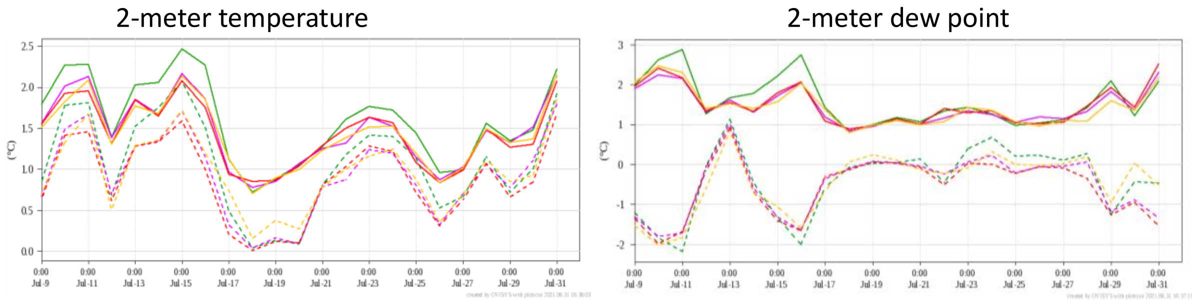

Figure 9.4: Evolution of bias (dashed line) and RMSE (solid line) of 2-meter temperature (left) and 2-meter dew point (right) analyses at 0 UTC from 9 July to 31 July 2020. Curves represent: OI-main, EXP4, DEF, ECM_B.

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).

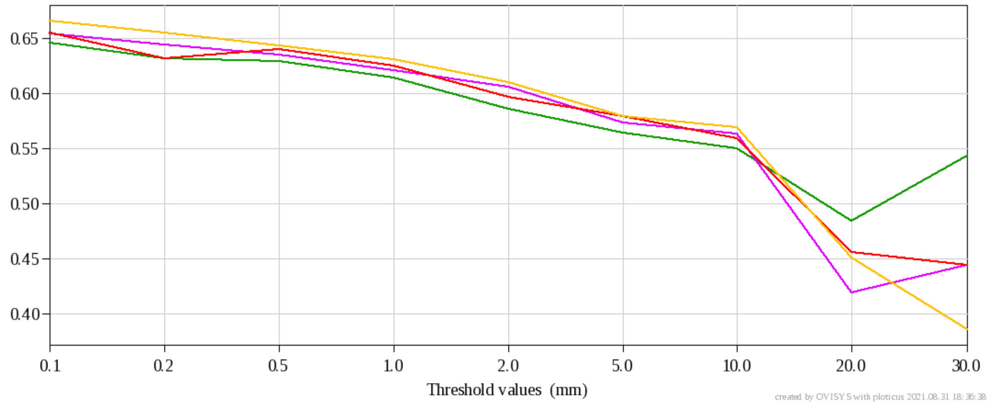

Figure 9.5: SEDI score of 30-hour forecasts of 24-hour precipitation sum for the 0 UTC runs from 9 to 31 July 2020 as a function of precipitation amount. Curves represent: OI-main, EXP4, DEF, ECM_B.

A parallel suite is planned with the EXP4 settings. Application of SEKF in AROME/HU with 1.3 km horizontal resolution and 90 vertical levels is also planned.

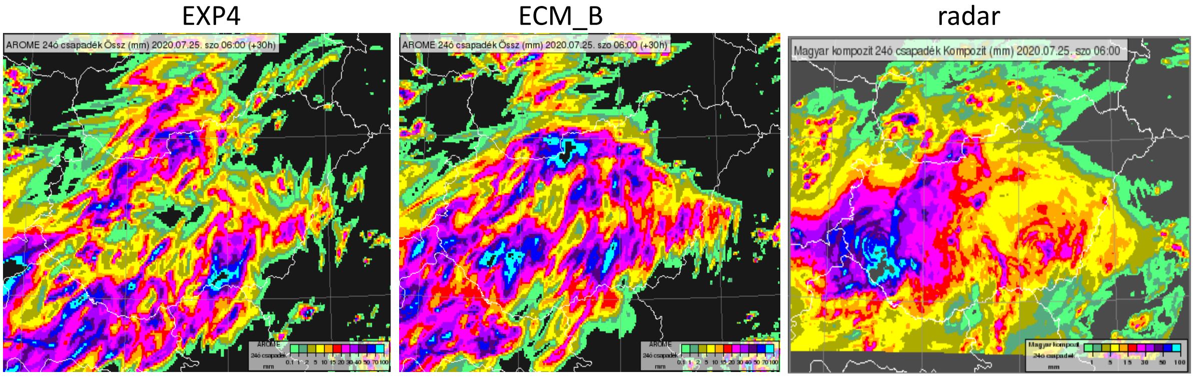

Figure 9.6: 24-hour precipitation sum at 6 UTC on 25 July 2020 in 30 h forecast of EXP4 (left) and ECM_B (middle) experiments and the radar estimate (right).

Total efforts: 4.25 months

Contributors: H. Tóth (Hu) 4, S. Schneider (At) 0.25

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 2.8.2]

Description to be available soon (contributors S. Oswald and S. Schneider).

Application of daily-updated LAI in AROME/HU [SU 2.8.2]

Evaluation of LSA LST in SEKF [SU 2.9.1]

Total efforts: 3.75 months

Contributors: S. Schneider (At) 2.5, S. Oswald (At) 1.25

Status: ONGOING

Documents and publications

Scientific papers:

Simon A. et al.: *Numerical simulations of 7 June 2020 convective precipitation over Slovakia using deterministic, probabilistic and convection-permitting approaches.* Submitted to *Idoja-ras*.

List of stay reports:

Other documentation:

- Peter Smerkol (updated): 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 interview, 19 March 2021.
3) Joint 1th ACCORD all staff workshop 2021, 12-16 April 2021, videoconference.
4) EUMETSAT Core NWP User Group Meeting #3, 22 June 2021, online.
5) Attendance to ACCORD DA working days, 29 May – 4 June 2021
6) LSC meetings

Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized	Planned	Realized
Operational implementation of DA suites [COM3]	8	~6		
Further development of 3D-Var [DA 1]	12	4.25		
Use of existing observations [DA 3.1] – radar	23	9.5	1.25	ongoing

Use of existing observations [DA 3] – other data types	21.75	3.75	1	canceled
Use of new observations types [DA 4]	12	6.5	1*	0
Development of assimilation setups suited for nowcasting [DA 5]	20	5.25	1.25*	0
Observation pre-processing and diagnostic tools [DA 7]	1	1		
Basic data assimilation setup (DAsKIT) [DA 8]	3	3		
Algorithms for surface assimilation [SU 1]	8	4.25		
Use of observations in surface assimilation [SU 2]	7	3.75		
Total	**115.75**	**47.25**	**4.5**	**0**

* Impacted by Covid-19 situation.

Problems and opportunities

The main problems in 2021 remain:

- *Distributed manpower. Local validation, maintenance and technical issues bring duplications of work which cannot be avoided. This work should be registered as COM3.1 when it is related to operationalization, cycle upgrades or verification and as DA 1 (currently DA 1.6) when it contributes to improved design, wider understanding and improvement of performance of 3D-Var based systems.*
- *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 (e.g. national Mode-S).*
- *We are working on the different DA setups (cycle, method, resolution, physics) so individual results and setups are rarely directly applicable at other Members.*

Opportunities for more effective future work are:

- *A much wider collaboration within the ACCORD consortium. The AL for DA already proposed dedicated research and support teams for different areas (algorithm and observations). Idea is to organize additional videoconference of LACE DA group at* *least once per year and regularly attend videoconferences organized by the ACCORD AL.*

- *To try to unify the local developments, e.g. to try to achieve approximately the same level of development in majority of member countries.*
- *Increase communication with DA colleagues at Météo France, AL should try to collect issues to be addressed to them.*
- *Actively participate in discussions and knowledge exchange regarding EUMETNET observations such as E-ABO and OPERA.*