Working Area Data Assimilation

Progress Report

Prepared by:	Area Leader Benedikt Strajnar
Period:	2020
Date:	16/03/2020

Progress summary

The report summarizes the RC LACE DA activities in 2020.

The research and development work focused on application of radar assimilation in order to enhance the knowledge of the underlying humidity pseudo-observation algorithm and to investigate suitability of observation operator to be used with ALARO physics. Out of 3 planned stays on radar DA, two were executed (partly influenced by Covid-19), and an additional stay was focused on radar winds instead of the planned aircraft observations. Consequently, LACE is now on a good track to reach satisfactory results with radar reflectivity. At the same time, we would like to reach and provide a robust solution to radar dealiasing, to be able to use at least part of radar Doppler winds. The stand-alone preprocessing software is meant for easier handling and consolidation of those developments to be shared within members.

The Covid-19 epidemic caused a drop in AMDAR observations, the data type with very high impact in DA systems run by LACE countries. To mitigate the drop in quality of forecasts, EMADDC of KNMI made an expedited progress in collection in distributing additional Mode-S observations. Their service now provides data from the MUAC area and additionally Denmark, Austria, Slovenia and Romania, and is on the way to ingest more data over the LACE area. The data was immediately shared/implemented with OPLACE, and some countries started to benefit from this very large additional data counts. Progress is visible also on use of local Mode-S data sources, although the situation with decreased data counts is not ideal for evaluation of these data sets.

Increased attention was given to validation of SEKF and related surface observations, apart from continuation of works in Austria the impact of SEKF was also substantially studied in Hungary, on several periods and interesting weather cases. The results indicate visible improvement in the description of the daily 2 m temperature cycle. Assimilation of surface data in the currently operational OI was tuned in some member countries.

There was a number of validation and impact studies for a variety of observations, many of which resulted in operational observation upgrades, as indicated in the summary tables.

Even more than usual, considerable part of the DA efforts were devoted to maintenance and upgrades in the local DA systems. In a large part, those efforts were invested into migration towards cy43 and accompanying modernization of DA suites. Members registered more than 15 person/months (out of planned 10 for the whole year) to accomplish this mostly technical work. These mainly local DA efforts are summarized in the first section of this report.

Action/Subject/Deliverable: *Maintenance and evolution of state-of-the-art DA systems [COM 3, DA 1.6]*

Description and objectives:

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 2020 and first months of 2021 for cycle upgrades):

DA	AUSTRIA AROME	AUSTRIA C-LAEF	CROATIA ALARO	CZECH REP. ALARO	HUNGARY ALARO	HUNGARY AROME	SLOVAKIA ALARO	SLOVENIA ALARO
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	43t2pt_op1	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 MESCAN + 3d-Var	OI_main MESCAN + 3d-Var, pert. obs. + Jk	OI + 3D-Var	OI + BlendVar	OI + 3D-Var	OI_main + 3D-Var	OI + DF Blending	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
Initialization	No (SCC)	No (SCC)	No (SCC)	IDFI in production, SCC	DFI	No	No	No (SCC)
Obs.	Synop + AS Amdar Geowind Temp ASCAT, Snowgrid/MODIS snowmask.,Mode-S EHS EMADDC	Synop + AS Amdar Geowind Temp, ASCAT, Snowgrid/MODIS	Synop Amdar/MRAR Geowind Temp Seviri	Synop + AS (soil) Amdar/MRAR /EHS Geowind/HRWIND,Profiler, ASCAT, Temp Seviri,	Synop + AS Amdar Geowind Temp Seviri AMSUA/MHS ASCAT	Synop + AS GNSS ZTD Amdar/MRAR Temp, Mode-S MRAR (SI, CZ),	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), GPSRO (OPLACE), Radar RH/Dow, INCA + AS at hig.freq., MODIS snowmask	Synop + AS, Amdar/MRAR/EHS, Geowind/HRWIND,Profiler, ASCAT, Seviri

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

In **Austria**, cy43t2 export was compiled and all local adaptations from ZAMG added (Jk, Nudging radar saturation, etc.). All steps were successfully technically tested and it was checked that local modifications do not interfere with other development. Parallel runs of AROME-Aut, AROME-RUC and CLAEF based completely on cy43t2 are currently running at ZAMG/ECMWF and are expected to become operational within this year. The domains are unchanged compared to oper versions except that AROME-AUT uses now exactly the same domain as CLAEF. The orography switched from GTOPO to GMTED with one filtering in PGD step. For AROME-RUC orography is unchanged (SRTM). Also the 2m diagnostics changed: In CLAEF/AROME-AUT CANOPY-scheme is still active but modified, in AROME-RUC Dian 2016 diagnostics (without CANOPY) is applied. Regarding DA, REDNMC switch is reduced drastically in AROME-Aut-parallel from 1.2 to 0.5 (as it was found to cause too dry near ground conditions in the mountains). As the number of AMDAR reports dropped drastically during the Covid-19 crisis. Additional EMADDC MODE-S data (including MUAC, DK, AT) was added to all three AROME systems in spring 2020.

In **Croatia**, the operational suite did not change. The plans for this year were heavily affected by earthquake in Zagreb, so the priority was to set up backup of operations at ECMWF HPC, so many efforts were devoted to that, together with increased operational maintenance on local side. DA system with cy43 was set up in the e-suite which is planned for operations after migration to the new HPC (to be available in the first half of 2021).

In the **Czech Republic**, local efforts were dedicated to impact studies for several observation types: as outcome, high resolution wind atmospheric motion vectors (HRWIND), wind profilers, SCAT are now assimilated by BlendVar and national SYNOP stations are used for soil analysis (after sensitivity study with correlation functions in CANARI). Based on research in 2019 (visit), a full EDA B-matrix was operationally implemented. An hourly (non-cycled) diagnostic analysis system VarCanPack is now operational (3D-VAR with short cut-off and OI for screen level parameters). Czech DA team was very involved in radar assimilation validation (2 stays and local work) as described later in the report.

In **Hungary**, the use of Mode-S observations (from Czech Republic and Hungary) and wind profiler data were investigated. For soil assimilation, the SEKF was tested within AROME-SURFEX for several periods and important cases when the quality of operational forecast was insufficient. The new 90 level EDA-based B-matrix was evaluated and Desrozier’s method was applied to search for an optimal tuning of observations and background errors. Use of Mode-

S and AMV observations was investigated. A switch to cycle cy43t2_bf11 was made in March 2021.

In **Slovakia**, efforts were put into porting and validation of data assimilation configurations in CY43t2 (CANARI, DFI blending, 3D-Var configurations) and the introduction of BlendVar. Both single observation experiments and full observations experiments have been evaluated. Some of the fixes have been promoted for CY43t2bf11. The switch to operations (for blending) was done in January 2021. The scripting system for DA assimilation (Perl scripts) was redefined in terms of modules, VARBC for GNSS was also implemented. Considerable efforts were spent on various tuition on DA topics. A nowcasting system prototype at 2 km was designed and first tests with surface assimilation were performed. A QC system for surface stations based on LAEF-A is under design. An examination of TEMP data in BUFR format was performed.

In **Slovenia**, most local work was devoted into design of a new nowcasting NWP setup (called NWCRUC) with 1.3 km horizontal resolution and hourly cycling. The system was run regularly over most of 2020 and was discontinued later in autumn to enable more validation runs as described below. An impact study of OSCAT was carried out and this led to operational implementation. By the end of the year, a change in the DA assimilation sequence (such that Blendsur step was moved the between surface and upper-air analysis step) was developed and was put to operations in early 2021. At the same time, the ODB_IO_METHOD=4 was introduced in order to reduce the number of pool subdirectories in the ODB. Considerable improvements in verification packages (Harmonie monitor and harp) were achieved by adding the automatic stations from Italy, Austria and Slovenia to the surface verification datasets. First steps towards installing the Obsmon DA validation package were made.

In **Romania**, the assimilation activities have been frozen in 2020.

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

Action/Subject/Deliverable: ***Basic data assimilation setup (DAsKIT) [SPDA 1]***

Description and objectives:

DAsKIT currently defines a basic set of DA infrastructure to ease developments of the DA from consortium members with no prior experience. Polish DA development is so far coordinated within the DAsKIT. Work included migration of existing 6 h DA cycle with CANARI from cy40t1 to cy43t2.

Efforts: 3 months

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Documentation: /

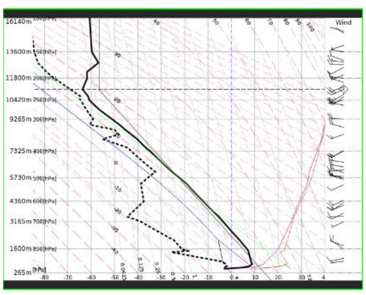
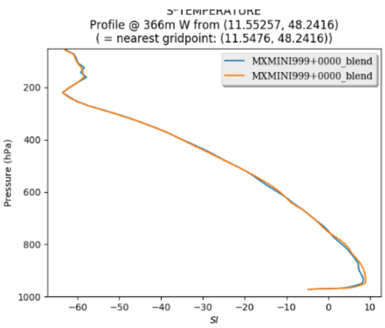
Status: ONGOING

Action/Subject/Deliverable: ***Development of assimilation systems suited for nowcasting (RUC, RAP, cycled and non-cycled hourly DA systems) [DA 5.2, DA 5.5, DA 7.2]***

Description and objectives:

Several implementations of rapid-update cycle are under development or evaluation, and two of the system reached operational status.

The AROME-RUC of **Austria** was put to operations by the end of 2019 but is under constant evaluation and improving since then. The order of CANARI and 3D-Var step was changed from parallel to usage of CANARI output in 3D-Var. For the latter, the 2m analyzed values are copied to 3D-Var first guess. Also the snow and surface temperature fields are replaced with CANARI output. A new Blendsur-like routine was written collecting surface temperature information from land, sea, inland water and combine it to SURFTEMPERATURE according to the parts in the grid box. As T2m and RH2m is used in both CANARI and 3D-Var an inconsistency of soil and atmosphere (double use of increment) is avoided by the modification. The 2 m diagnostics in AROME-RUC changed modified, in AROME-RUC the Dian (2016) diagnostics without CANOPY is applied. Much effort was put on this as the 2 m values with the previous setting were not satisfying at all with strong warm bias especially in stable conditions. In AROME-RUC-parallel BATOR for RADAR switched from Harmonie to MF version causing more Doppler winds and less reflectivity data entering the system as in cy40t1 (Harmonie version) and allows Hungarian radars to enter the system. In the AROME-RUC parallel, bufrtemp data (profiles, but no trajectories) is produced from a local database with an ASCII to bufr routine. This means a much better vertical resolution of the observations (see impact on Fig. N1). The VARBC cycling frequency combination script from HIRLAM was slightly adapted to VARBC format changes in cy43t2. To start VARBC, coldstart with option 2 (set bias to first guess departures) was chosen.

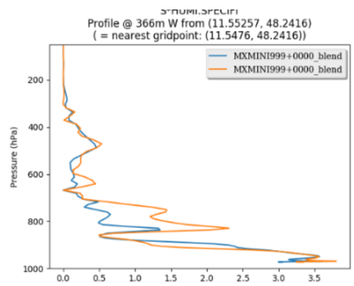


Figure N1: Radiosounding Munich 10868 3rd March 2021 06 UTC (left) and pseudosoundings from AROME-RUC-parallel analysis with Bufrtemp (blue) and obsoul temp (orange) T/°C (middle), Q/g/kg right.

In the Czech Republic, the VarCanPack nowcasting analysis framework was upgraded. The system runs from 2016 but was revised this year. It is based on adaptation of the operational NWP system ALADIN/CHMI. Only hourly analyses (0 hour forecast) are considered as starting point, but the system is planned to be further extended by +6h forecast. The 3DVAR and OI algorithm are employed and the operational forecast with different lead times are used as the first guess, see Figure H1. The 3DVAR analysis is done first, the hydrometeors are not analyzed but copied from the first guess. After 3D-Var the OI method is used to analyze screen-level parameters (not soil as done elsewhere). The observation cut-off time is reduced to 20 min to provide the hourly results as soon as possible - approx. 30 min after validity time. TH system uses all observations assimilated by ALARO BlendVar, except TEMPs which are not available in this very short cut-off time. Around 2500 observations are assimilated in the upper-air analysis in the day-time, with one half of it coming from aircraft observations. When Mode-S MRAR observations are added on top of AMDAR, the observations counts increase by further 50%.

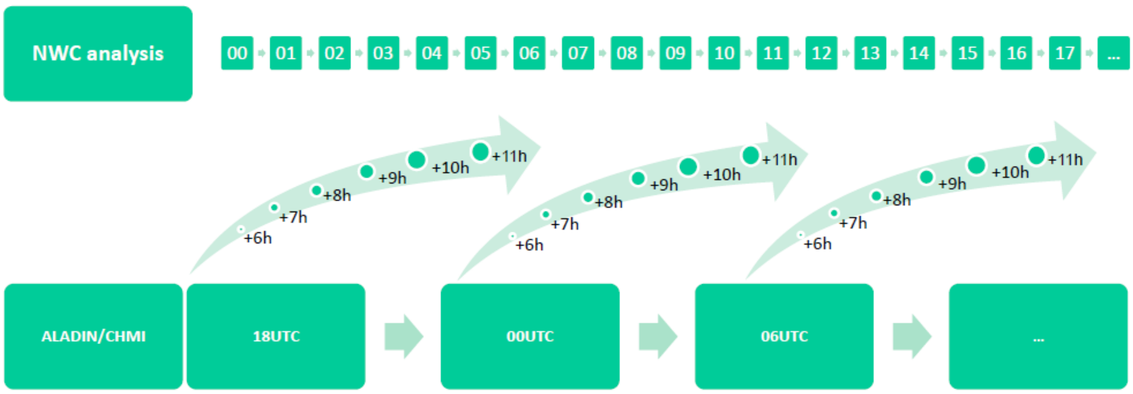


Figure H1: Design of VarCanPack analysis system at CHMI. First guesses for non-cycled assimilation are from operational BlendVar.

In Slovenia, a 3D-Var based nowcasting system at 1.3 km horizontal resolution has been set up and run regularly from June till November 2020 for evaluation purposes. 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 is followed by a production forecasts up to 36 h, which provide a selection of meteorological variables every 5 min (e.g. simulated radar reflectivity, Fig. H2) on top of the hourly model output. This forecast was run every 3h and it is planned to increase this to every hour in the preoperational phase. 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).

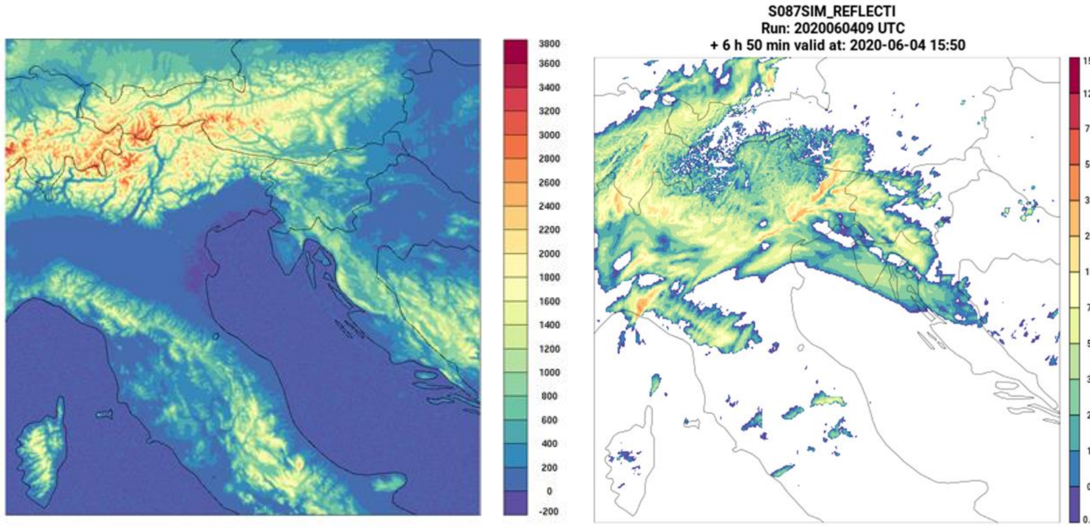


Figure H2: (left) NWCRUC model domain with orography and (right) simulated radar reflectivity for one precipitation case.

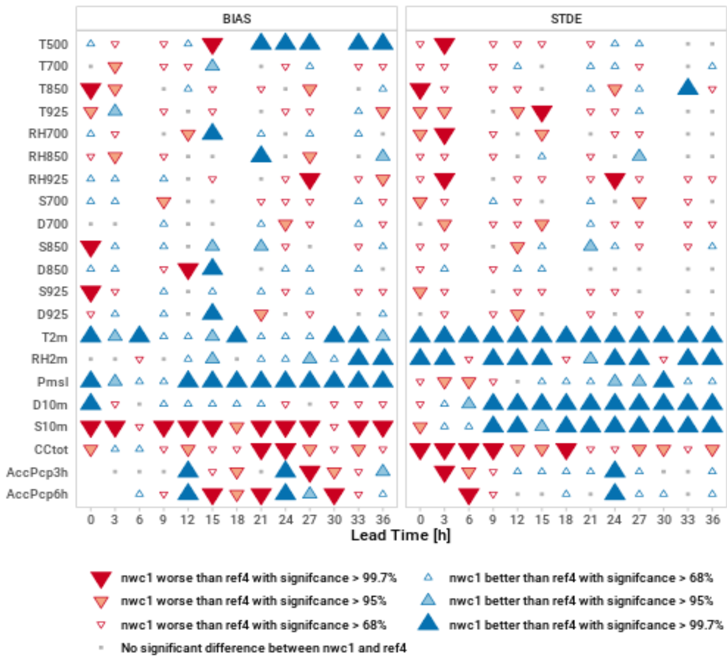


Figure H3: Verification scorecard, comparing NWCRUC and ALADIN 4.4 km over the summer period.

The 36h 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. H3 as a scorecard. The 1.3 km suite significantly improves the near surface variables. A concern remains with cloudiness which is degraded over the first 12 h. The impact on precipitation forecasts was further assessed using the categorical verification. Fig. XXX4 of the radar section shows the frequency bias of 1 h precipitation sums over the winter period, for various thresholds. It is evident that all models tend to overestimate the precipitation amounts for precipitation intensities below 5 mm/h. The 1.3 km runs however decrease this bias for about one half in comparison to 4.4 km model. Spatial verification is also planned.

Efforts: 6.5 months

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Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Studies of background error statistics in 3D-Var [DA 1.2 – 1.4, 2.5]***

Description and objectives:

In **Slovenia**, an experimental EDA system with 20 ensemble members was developed at a current horizontal resolution of 4.4 km in 2019. The ensemble is used to compute background error covariances on daily basis (with the sample size of 160 differences over the last 8 analysis times. Analysis of daily covariances show that in all cases the variances were higher and more centered towards small scales in the EDA experiment, compared to operational downscaled (spin-up) B-matrix. Sensitivity experiment was carried out over 1-month period, using the operational, mean EDA and flow-dependent EDA. The results indicated slightly detrimental impact of the EDA B-matrices on most of parameters except short-range precipitation. Differences between mean and daily variances were relatively smaller. It is expected that the tuning of the REDNMC parameter would be needed in further evaluations. This work on EDA may be latter combined with development of an EnVar under OOPS.

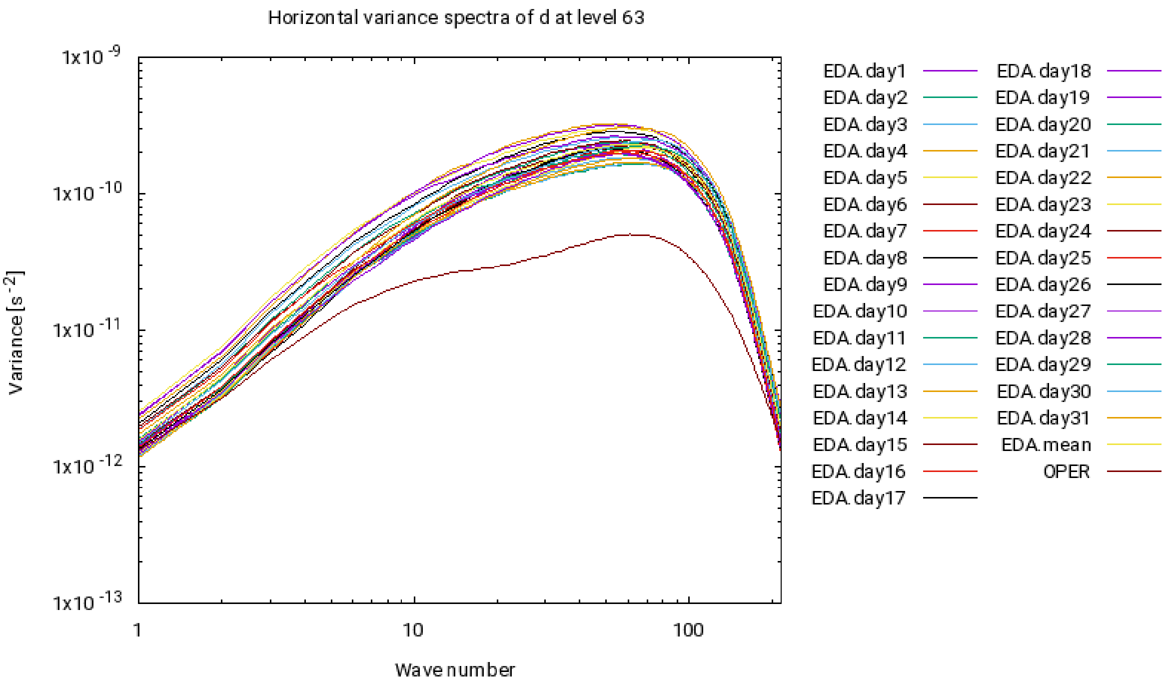

Figure B1: Daily evolution of divergence spectra in EDA at model level 63/87 over one month period, and comparison with the downscaled B (OPER ALADIN/SI at 4.4 km).

In **Hungary**, efforts to recalculate B-matrix continued by running a full EDA experiment based on the previously calculated B-matrix (from the downscaled EDA) and computing a new B-matrix for 90 level model setup. An experiment over a longer period was prepared with the new B-matrix with mixed results, so a retuning of DA was considered. The following tuning parameters based on the Desroziers method were calculated for the system: REDNMC=1.26 and SIGMAO_COEF=0.71. The experiments showed degraded forecast scores with these tuning values, so in the next step the following ideas were tested: no GNSS assimilation (the different model top may cause lower model-equivalent), switching off the CANOPY scheme (similar to Météo-France), choosing a different time period (the first tests were made in a very rainy spring period). The studied time period was from 9 to 31 July 2020 with mainly anticyclone in the beginning and upper-level cyclone afterwards which caused lots of showers and thunderstorms in the second part of the period. Beside the reference run with 60 vertical levels, a dynamical adaptation run at 90 levels was carried out. Figure B2 shows impact of the tuning on 2 m temperature forecast. The EXP1, EXP2 and EXP3 are different tunings of the 90-level B-matrix and the use of Canopy scheme, according to the table BT1. A positive impact on bias and RMSE was shown with tunings EXP1 and EXP2.

Table BT1: Settings in the Hungarian 90 level B-matrix experiments.

Experiment	Number of vertical levels	CANOPY	REDNMC	SIGMAO_COEF	REDNMC_Q
REF	60	on	1.2	0.9	-
EXP1	90	off	1.26	0.71	-
EXP2	90	off	1.2	0.9	1.67
EXP3	90	on	1.2	0.9	1.67

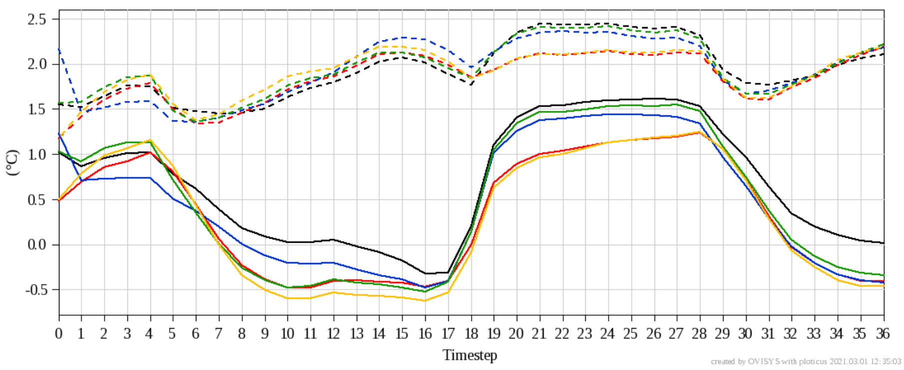

Figure B2: Bias (solid line) and RMSE (dashed line) of 2 m temperature forecasts in the 0 UTC runs from 9 to 31 July 2020. Black: AROME/HU at 60 levels; blue: dynamical adaption run at 90 levels; yellow, red and green: assimilation runs at 90 levels with EXP1, EXP2 and EXP3 settings, respectively.

Figure B3 illustrates also the impact of the REDNMC_Q settings. With the higher value of REDNMC_Q the large bias and RMSE of the 3-hour precipitation decreased in the beginning of the lead time. However, a separate case study showed improvements in the longer rain accumulation with the new 90-level setting. Overall, the finer vertical resolution also shows mostly positive impact on the surface parameters and more or less neutral impact in the upper-air.

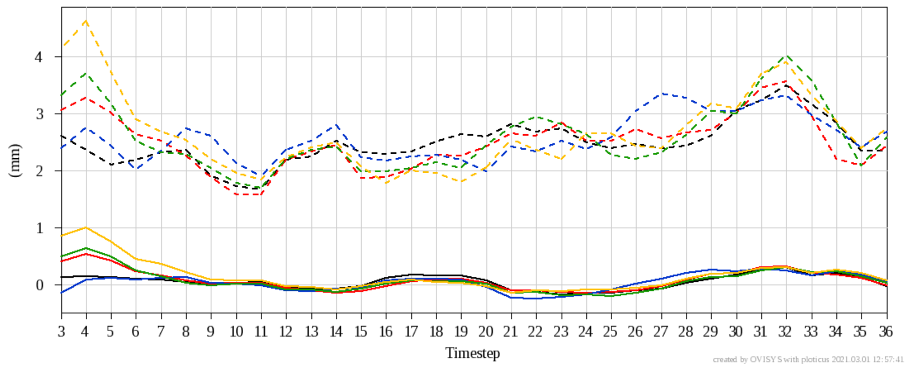

Figure B3: Bias (solid line) and RMSE (dashed line) of precipitation forecasts in the 0 UTC runs from 9 to 31 July 2020. Black: AROME/HU at 60 levels; blue: dynamical adaption run at 90 levels; yellow, red and green: assimilation runs at 90 levels with EXP1, EXP2 and EXP3 settings, respectively.

In **Croatia**, the Jk method for including large scale information from global model in the process of minimization was tested. The related V-matrix was computed from 16-member ECMWF ensemble interpolated to ALADIN-HR4 domain. Differences were calculated over one month period and using 6-h forecast for 00 and 12 UTC (N =480). The Jk term needs to be truncated such that only large scales are kept from the host model. To determine the exact scale of truncation, the procedure from Guidard and Ficher (2008) was adopted. It can be observed that beyond k* ~ 25 (Fig. B4), two spectra begin to diverge (this number is slightly different for other levels), and little energy is contained in mesoscale spectra of the host model. We thus do not expect to derive any useful information from the host model at these scales. With the aim to keep only the largest scales from host model, the truncation was set at k* = 15 (115 km). This value of the truncation was kept constant on all model levels for all variables and all assimilation cycles.

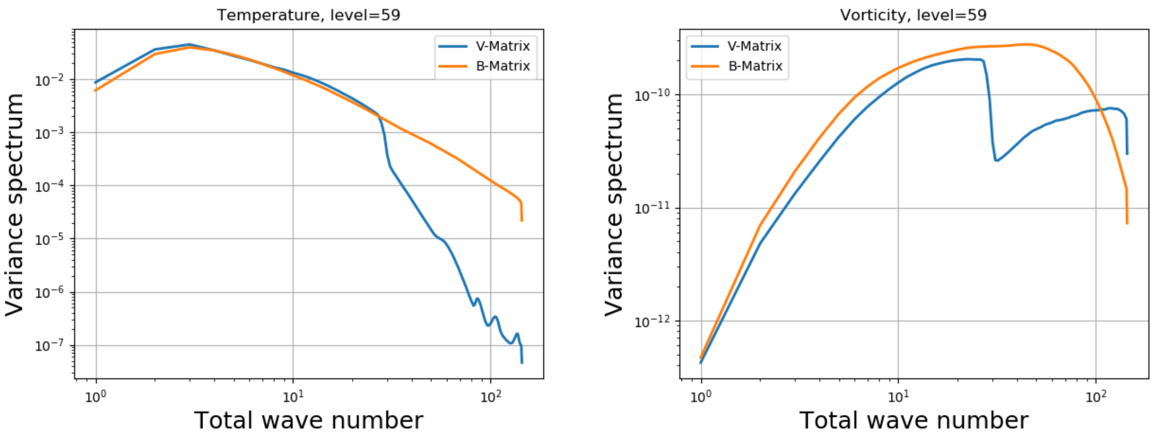

Figure B4: Variance spectrum for temperature (left) and vorticity (right) at level 59 of the ALADIN-HR4 setup.

Rather short period of 6 days was used to get first verification. Results indicate that Jk has improved forecast for first ~12 hours, mainly for humidity. Still, a more relevant result will be obtained by extending the verification period. One case where using Jk improved precipitation forecast is shown in Fig. B5. Reference run simulated too narrow precipitation field on 6 October 2020, while Jk run predicted a bit broader precipitation area which was more in accordance with radar measurements.

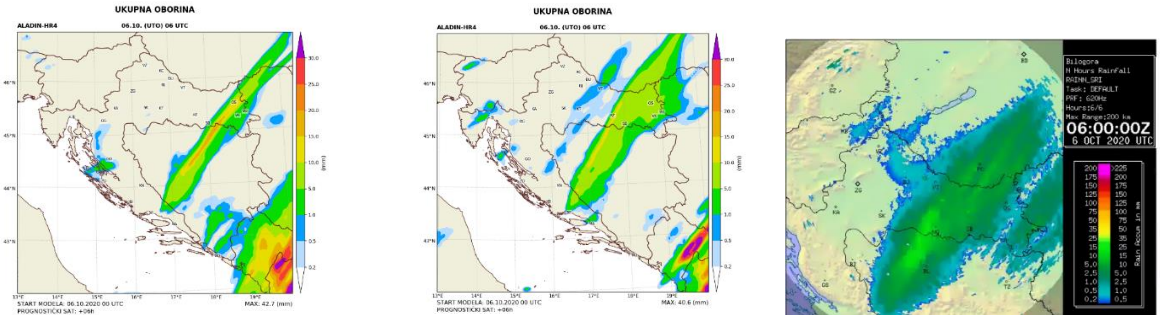

Figure B5: 6-hour accumulated precipitation from reference (left), run with Jk (middle) and radar measurement (right).

Efforts: 3.5 months

Contributors: B. Strajnar (Si) 0.5, V. Homonnai (Hu) 2, A. Stanešić (Cr) 0.75, E. Keresturi (Cr) 0.25

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Surface Data Assimilation using Extended Kalman Filter [SU2, SU 3.4]***

Description and objectives:

Validation of EKF has (re)started in **Hungary** by validation over the Hungarian domain with AROME cy40t1 and SURFEX 7.3. Two cases were first studied in detail by conducting impact studies with respect to AROME/HU OI-MAIN operational model. 3-hourly data assimilation cycle was started two weeks before the events. Forcing required to offline SURFEX run were coming from AROME inline forecasts at 9 m (radiation, precipitation, wind, humidity, pressure). In the winter case, too much low clouds and corresponding under- forecast of daytime surface temperature were observed. For this case, the analysis of 2 m temperature and low-level cloudiness using SEKF did not really differ from the result of the operational run: similarly false low-level cloud and overestimated temperature analysis were obtained. The analysis increments and Jacobians of the observation operator were investigated. Figure S1 shows a boxplot representations of the Jacobian elements for the case of January 8, 2020. The values have the lowest variation during daylight hours, especially at 12 and 15 UTC, and are closest to 0, i.e., the effect of assimilation is the smallest at these times.

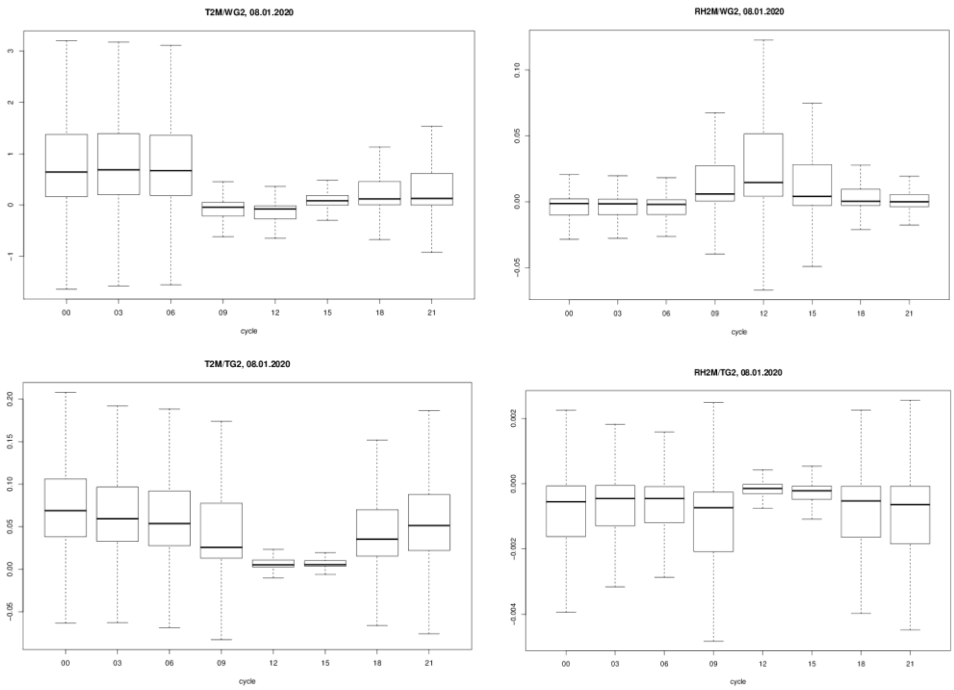

Figure S1: Boxplots for Jacobi matrix elements at different times of day (8 January 2020): dT2M/dWG2 (top left), dRH2M/dWG2 (top right), dT2M/dTG2 (bottom left), dRH2M/dTG2 (bottom right).

On the second case, 8 April, 2020, the daily temperature cycle was studied (Fig. S2). 3-hourly data assimilation cycle was started two weeks before to get appropriate first guess for the experiment, similar as in the winter-case study. This period was slightly warmer than usual and unusually dry with almost no precipitation over the whole country. It is a typical problem in AROME/HU that the minimum temperature is usually overestimated and maximum temperature is underestimated in these long-live anticyclonic cases. The 2-metre temperature analysis was inaccurate in AROME/HU OI-MAIN (Fig. S2 a). More accurate analysis and forecast was provided by the SEKF experiment, as shown in comparison with SYNOP station Baja.

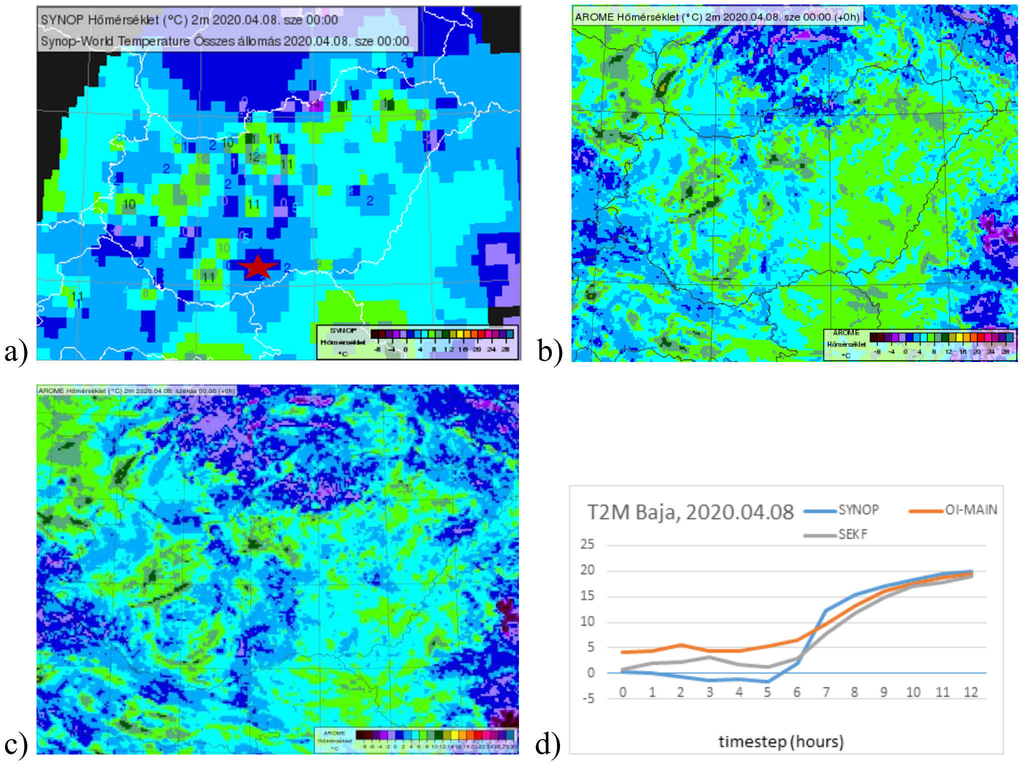

Figure S2: Summer case SEKF vs. OI comparison: a) SYNOP observation, b) and c) analysis of AROME/HU OI-MAIN and SEKF, respectively, at 0 UTC on 8 April 2020, d) analysis, forecasts and observations of T 2m at Baja meteorological station.

Further experimentation was carried on in the second half of 2020 after the implementation of the AROME cy43t2_bf11 with SURFEX 8.0+ version. In addition to the standard binaries (001, 927 etc.) the SURFEX OFFLINE and SODA binaries were also tested. Then two test runs were performed and validated. The summer experiment lasted from 9 to 31 July 2020 (2-week spin up from 25 June), the winter experiment lasted from 25 November to 17 December 2019 (spin up from 11 November). The 2 m temperature shows large improvement for the nighttime hours and the large warm bias in the nights was reduced by SEKF with respect to the operational OI-MAIN (Fig. S3). SEKF was able to improve the 2 m temperature analysis throughout the whole period (Fig. S4, left), however, its daytime forecasts over Hungary do not differ spectacularly from the OI-MAIN ones (Fig. S4, right).

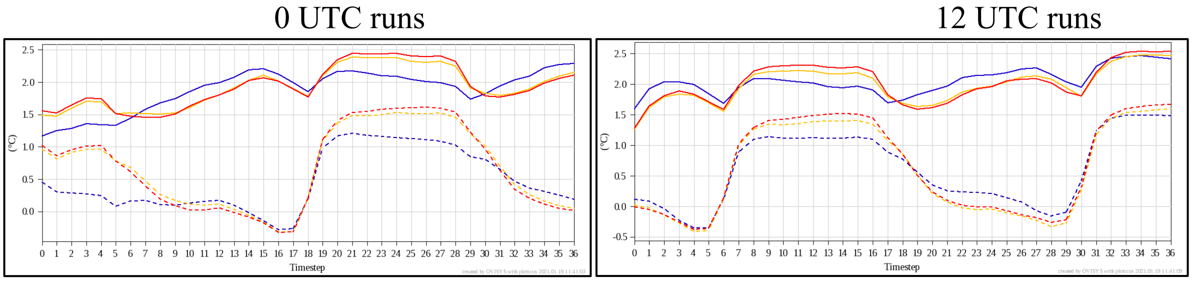

Figure S4: Bias (dashed line) and RMSE (solid line) of 2 m temperature forecasts in the 0 and 12 UTC

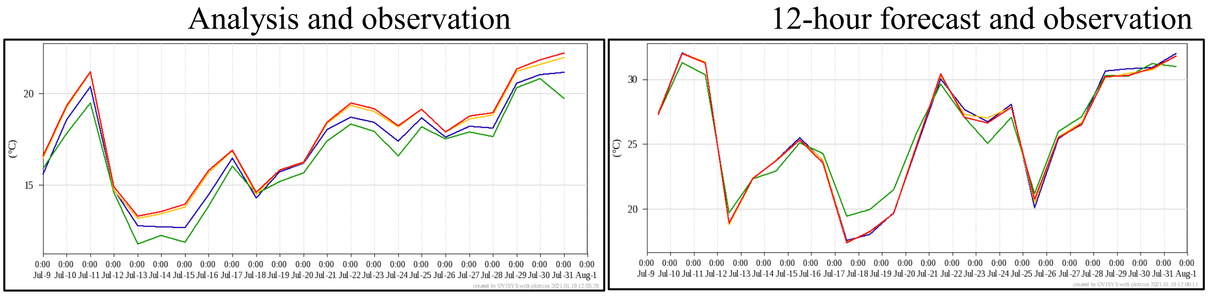

Figure S5: Evolution of 2 m temperature analysis and 12h forecast in the 0 UTC runs and observations (green) from 9 July to 31 July 2020. Blue: cy43 with EKF, orange: cy43 with OI-MAIN, red: cy40 with OI-MAIN.

Further investigation was devoted into the soil water content – 2 m temperature relation. Dew point forecast of SEKF suffered from cold bias most likely caused by the too dry soil. The 2 m relative humidity verification shows very similar behavior as the 2 m temperature one: improvement at night and deterioration during the day. The case study for 15 July 2020 indicated that the 2-metre temperature analysis was inaccurate using OI-MAIN (Fig. S6, left). More accurate analysis was provided by SEKF, especially in the central part of the country (Fig. S6, middle). At the same time the 12-hour forecast of SEKF resulted in an unrealistic warm pattern over the south part of the domain (Fig. S7, middle). Soil moisture was drastically decreased when applying SEKF as shown by checking water content in a specific point in this area when the prevailing soil texture was sand.

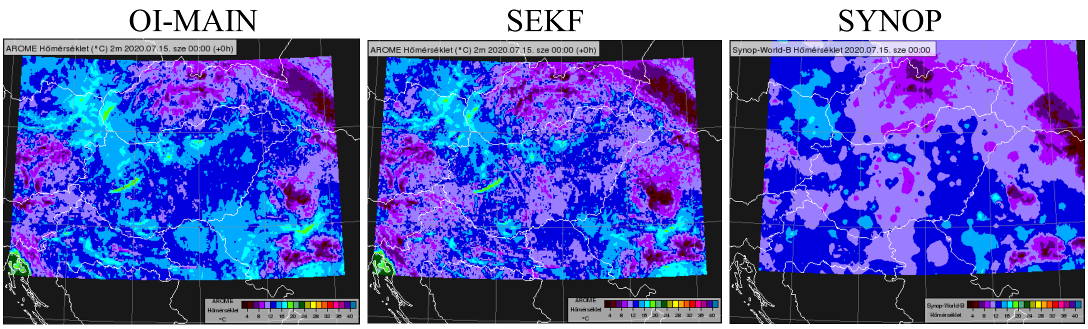

Figure S6: 2 m temperature analysis in AROME cy43 with OI-MAIN and SEKF, observations at 0 UTC on 15 July 2020.

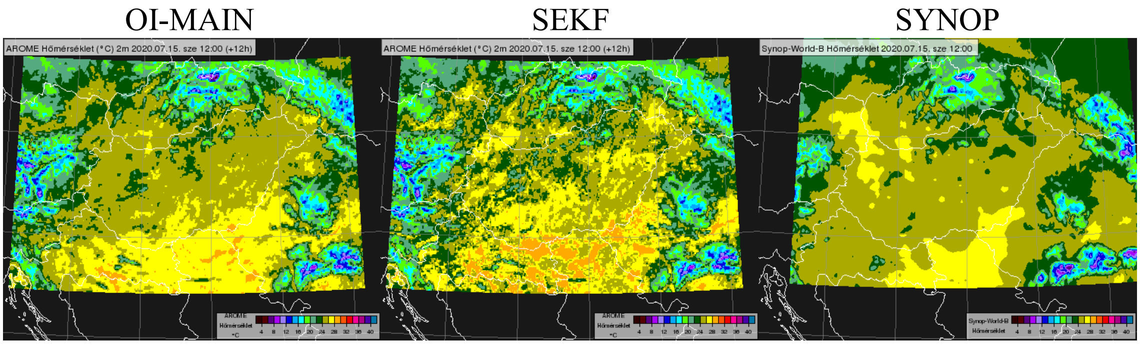

Figure S7: 12-hour forecast of 2 m temperature in AROME cy43 with OI-MAIN and SEKF, observations at 12 UTC on 15 July 2020.

The analysis increments for soil temperature and soil moisture in different analysis times, summed for the whole period and for all grid points over the domain, is shown in Fig. S8. The TG2 increment is bigger for the nighttime and smaller for the daytime periods in case of SEKF. For OI-MAIN the TG2 increments are small and consistent. In contrast, the WG2 increments are large for daytime and smaller for nighttime for both methods and are also higher in the SKF.

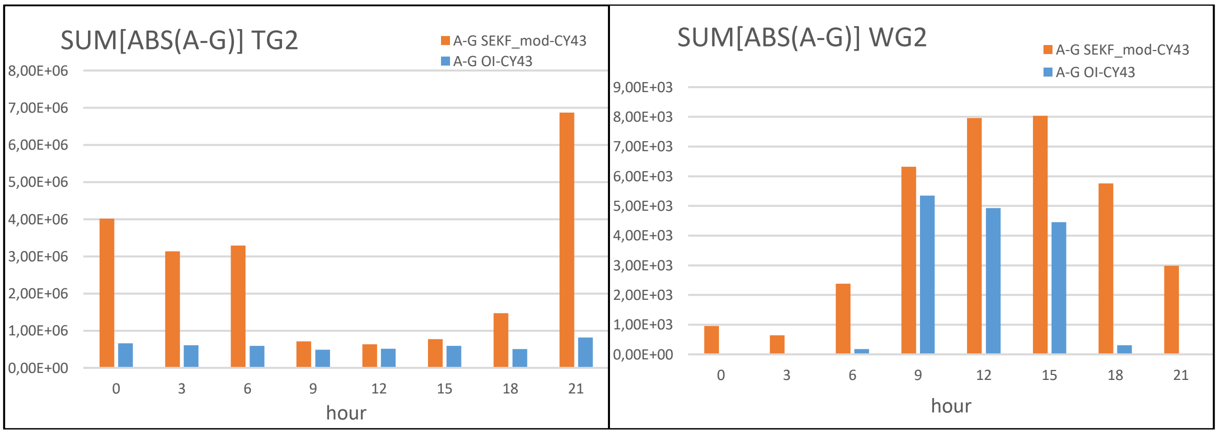

Figure S8: Summed soil temperature (TG2) and soil moisture (WG2) increments for all of the grid points over the domain from 9 July to 31 July 2020 for SEKF (blue) and OI-MAIN (orange).

Verification of 2 m temperature shows small but significant overall improvement in the winter period. The cold bias detected with OI-MAIN was slightly reduced by SEKF. Neutral impact was obtained for dew point and small positive effect can be seen for 2 m relative humidity. In spring a parallel suite is going to start with SEKF and after several test periods it is planned to be turned operational in 2021.

In **Austria,** SEKF experiment at ZAMG have been a combination of AROME CY40T1 with code extensions of HIRLAM to activate the ISBA diffusion scheme for forecasts and a standalone version of SURFEX 8.1 for the soil assimilation. This solution is facing the problem that the input/output files of SURFEX7.3 (in AROME) and 8.1 are not compatible. Thus it is planned to update AROME to CY43T2 and switch from the ISBA force-restore (3-L) to the ISBA diffusion (DIF) soil scheme. As a first step in this direction, a comparison of the two soil schemes is taking place. For this purpose, AROME was computed from 07/2018 to 06/2020 with ISBA 3-L and D95 snow scheme on the one hand and ISBA DIF and 3-L snow scheme on the other hand. AROME is run with the operational Austrian namelist setting on a 2.5 km grid, is coupled to IFS and no data assimilation is computed in this test run. The soil fields have been initialized as similar as possible for the two test runs and soil fields are cycled, which means that the +24hour forecast is used as initial file for the next forecast run. Forecasts of T2M have been validated against SYNOP stations in Austria. With respect to the complex topography in the model domain, stations have been grouped into flat land stations, stations in alpine valleys and mountain top stations. Furthermore, seasonal impacts have been investigated. Overall it can be stated that the diffusion scheme is resulting in warmer and drier conditions (T2M and RH2M) on average, thus performing slightly better (RMSE closer to zero) for the domain investigated (Fig. S9).

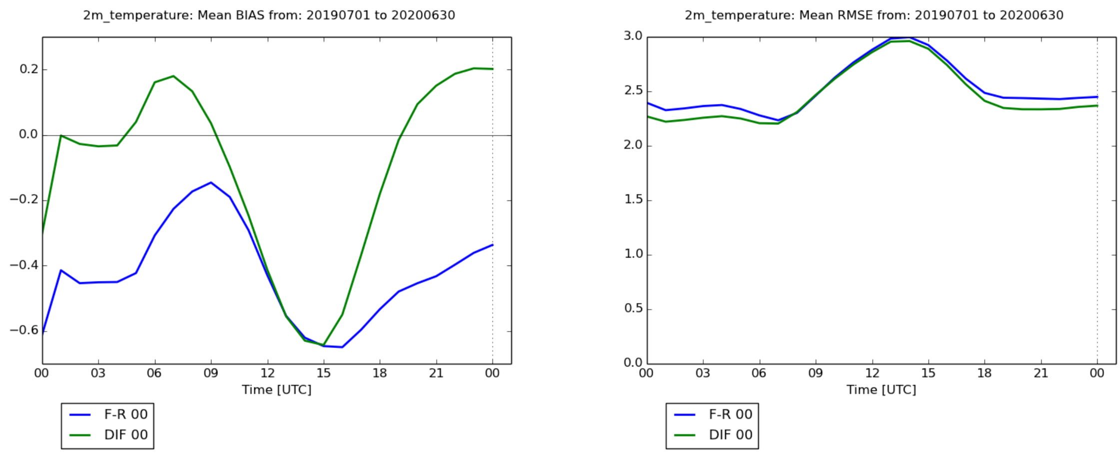

Figure 5: Bias (left) and RMSE (right) for force-restore (blue) and diffusion (green) soil scheme averaged for one year (20190701-20200630) and all SYNOP stations in Austria. Forecast runs are starting at 00UTC and have a forecast range of 24 hours.

Efforts: 6.75 months

Contributors: H. Tóth 3.75, S. Schneider (At) 3, V. Tarjáni (Sk)

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Observations suitable for soil schemes [SU 2.2.3, SU 2.5.2]***

Description and objectives:

In **Austria**, experiments to investigate the impact of a local observation error for SCATSAR-SWI on the forecast of screen level parameters have been finalized. While the assimilation algorithm is working properly, the improvement on the forecast quality compared to the global observation error is small and not significantly positive (Fig. SU1). Given a the large additional effort necessary to define the local observation error (2 independent satellite data sets and one model run, all of the available for at least one year, are necessary as input data) is not arguable compared to the increase in forecast performance for an operational implementation.

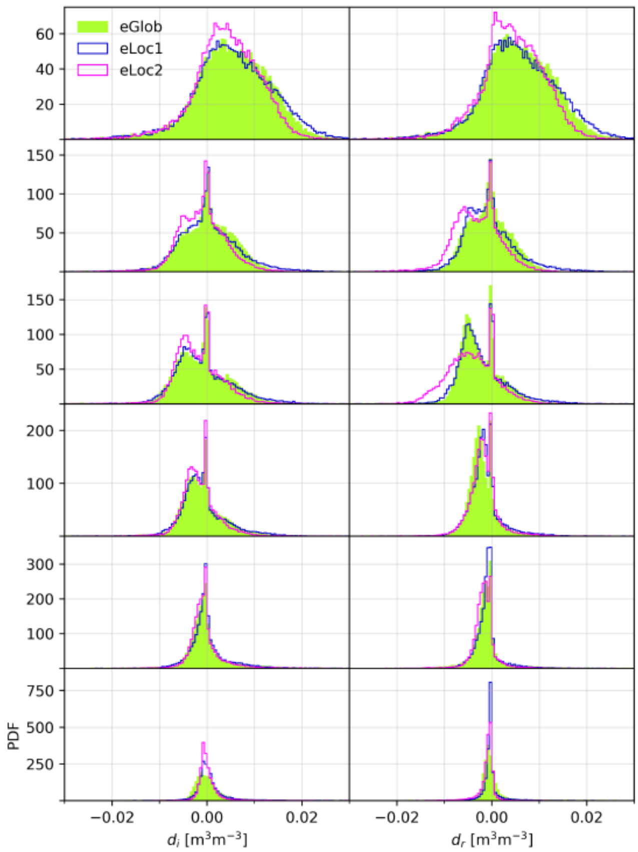

Figure SU1: Probability density functions of innovations d_i (left) and residuals d_r (right) for all experiments. Within each column, each quantity is shown for the soil layers WG1 to WG6 from top to bottom. Zero values were omitted for the computations. eGlob is the experiment with a global observation error, eLoc1 and eLoc2 are experiment with different local observation errors.

The approach to assimilate LST data with SEKF in AROME is working, but the impact is rather small and not continuously positive. As the surface temperature is a rapidly changing parameter both in space and time due to the missing storing capacity of the surface, it is difficult to achieve long-lasting changes in the model soil due to the assimilation. Based on the combined MSG-Sentinel3-LST data set that has been developed at ZAMG, measurements are available with a spatial spacing of 1 km and a temporal spacing of 15 minutes (in case of cloud free conditions). Comparing different settings lead to the conclusion that a short OFFLINE perturbation window (1 hour) and a rapid update (hourly LST assimilation) leads to the best results. AROME forecasts have been computed once per day for up to +24 hours. Furthermore it is beneficial to use the soil temperature of the uppermost six layers (0 to 60 cm) as control variables in the SEKF (given short memory of near surface fields). The forecast performance currently limits operational implementation.

Efforts: 8.5 months

Contributors: S. Schneider (At) 4.5, J. Vural (At) 4

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of radiance observations in DA systems [DA 3.6]***

Description and objectives:

Efforts: 0 months

Contributors:

Documentation: /

Status: ON HOLD (no manpower)

Action/Subject/Deliverable: ***Implementation of RADAR reflectivity and radial wind [DA 3.1]***

Description and objectives:

RADAR reflectivity and radial wind observations are essential components of a mesoscale DA system especially with increased analysis cycle frequency. It received more attention in 2019 and 2020 by several stays and regular DA group videoconferences. Three stays were devoted to radar assimilation, first two into assimilation reflectivity and the last one to the Doppler winds.

During a stay in Ljubljana, A. Trojáková investigated the use of the radar reflectivity observation operator within ALARO model configuration, studying the effect of graupel in the ALARO microphysics scheme on simulated radar reflectivity. A short tests have been performed. The ALARO version with prognostic graupel provides very similar precipitation structures with slightly smaller intensities compared to the version without prognostic graupel. This conclusion was based on a single case study. The prognostic graupel in ALARO are still considered as a very fresh development which needs detailed evaluations in NWP context. The graupel initialization to zero is necessary for the reflectivity observation operator even in case of ALARO without prognostic graupel to avoid extremely high simulated reflectivity in radar assimilation. The initialization of graupel in both cases should be better understood and eventually fixed. It was found that prognostic graupel in ALARO microphysics has positive effect on simulated reflectivity, namely by a small reduction of random error (STD) of reflectivity innovations, see Fig R1. To make a reference to existing operational radar assimilation, ALARO and AROME-FR reflectivity innovations were compared over Germany. Both setups provide qualitatively similar statistics which give us more confidence for further testing of radar reflectivity data assimilation within ALARO configuration.

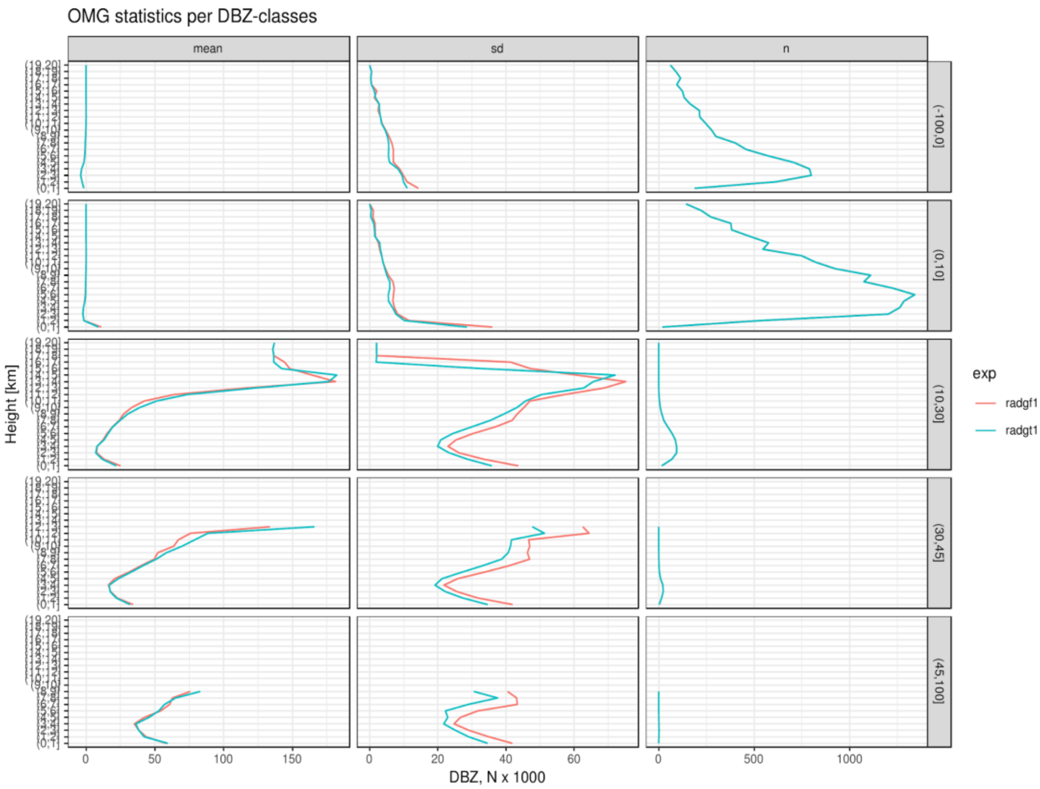

Figure R1: Vertical profile of reflectivity innovations separated by DBZ-classes. Bias (left), standard deviation (middle) and number of innovations for ALARO without graupel (red) and with graupel (green).

The second stay in Vienna (Antonín Bučánek) was dedicated to familiarization with screening procedure for radar reflectivity in AROME/ALARO, the construction of pseudo observed relative humidity columns, and thinning. The work continued at CHMI after the stay has been shortened. Three minor bugs were spotted during investigation and discussed with MF. A reproducibility problem was identified in thinning if 2 or more input hdf5 files from one station were ingested. A few open questions related to the current data selection setup are still opened. One is the modification in BATOR (in cy43t2_op4.03) for no-rainy observations as only observations with minimum detectable signal <= 0 are now allowed for assimilation. For French radars, this means observations at distance up to about 100 km, and the setting may be questionable for LACE area. Another yet unresolved issue is assimilation of dry reflectivity observations with zero first guess departure, which can only happen when model is dryer than radar (i.e. below detection threshold) at given observation location and elevation. It would be preferable to discard those observation from assimilation, but by default they keep being assimilated and produce pseudo-humidity columns with resulting positive or negative increments which may be unrealistic.

The third stay of Katarina Čatlošová in Prague was dedicated to radar radial wind DA. At first, an overview of the available OPERA data was done with focus on radar scanning strategies and selection of radars providing radial wind observations with Nyquist velocity larger than 30 m/s. The format conversion (HDF5 -> ODB) within BATOR was briefly checked. Finally, passive data assimilation experiments were prepared, observation-minus-background (OMG) statistics were evaluated and first case studies were performed. The work continued by studying a few significant cases. Fig. R2 shows a simulation of frontal precipitation band on 2020-05-23 with and without assimilated Doppler wind (DOW). The differences are generally small.

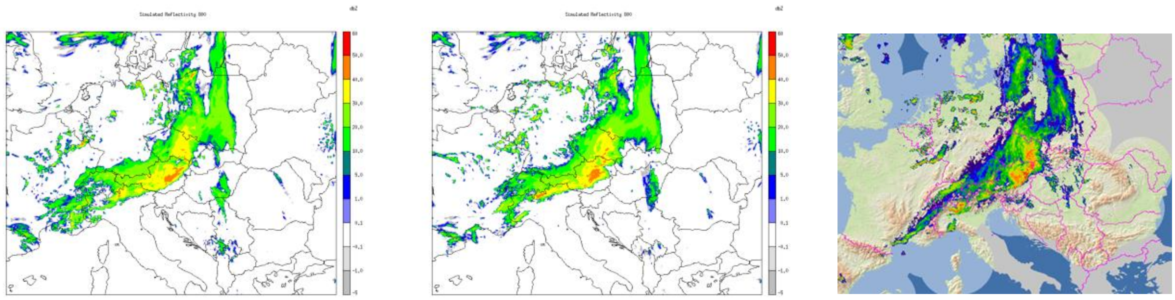

Figure R2: Comparison of simulation using Doppler wind from all sites (left) and the reference without DOW (middle), compared to the verifying OPERA composite.

Another experiment was to verify the impact of biased Danish dataset with the OPERA data. Verification scores (6 h forecast) for all LACE OPERA radars (black) and all LACE OPERA radar without DK and UK indicated improvement when omitting the two datasets.

In **Austria**, adaptations for cy43t2 were made in the prepopera preprocessing software (addition of Nyquist velocity). The number of reflectivity assimilated is significantly lower within cy43t2 and for DOW slightly higher compared to cy40t1 probably because of presence of check of QC flag > 0.7. The pre-processing was adapted that for stations where only 1 hour old data were available in time now 15 min old data can be used – this is now the maximum age for the AROME-RUC system. The problem of suspicious Doppler wind DFS values (orders higher than other obs) was solved by re-definition of (hard coded) rejection limits (bugfix 11 cy43t2) and application of VARQC.

In **Slovenia**, three methods (the method used in Austria, CINDA method, torus mapping) for wind dealiasing were implemented and tested on a set of precipitation cases over two years, via check versus other observations (little overlapping observations) and more successfully ALADIN/SI first guess. Figure R3 shows results of this OMG validation. The methods were shown to give comparable results, the torus method being slightly better than others. The torus mapping method has been chosen to be implemented in the HOOF preprocessing system. Work on the reorganization of the package is ongoing.

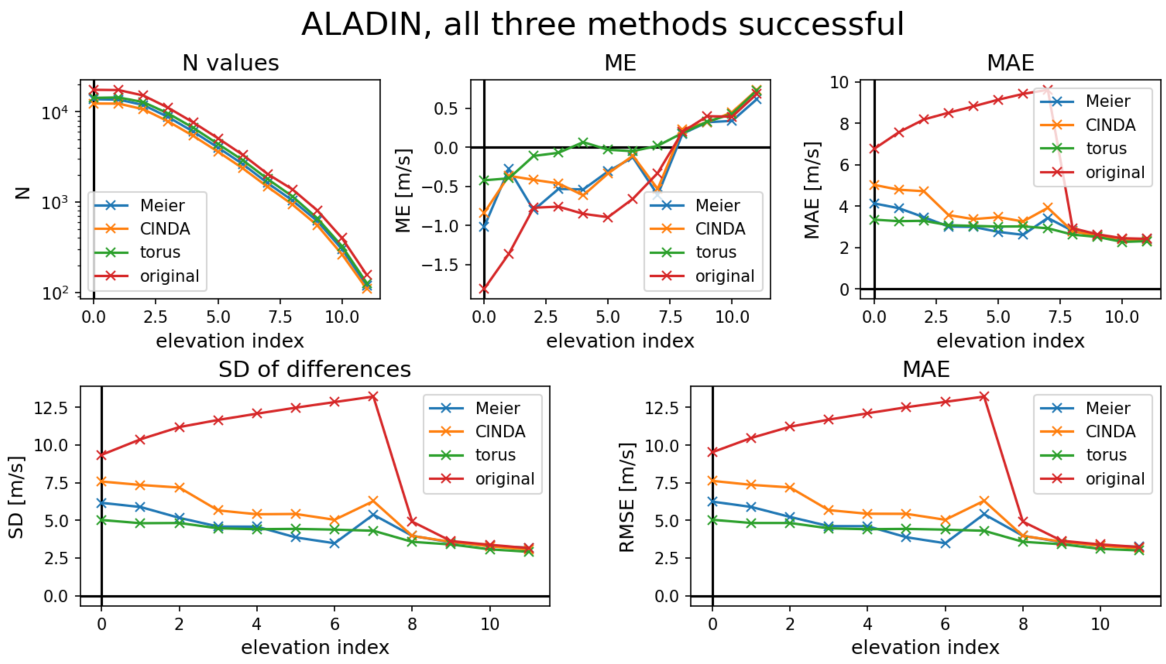

Figure R3: OMG statistics for radar radial velocity after dealiasing. Elevations from 0 to 7 are subject to de-aliasing, while upper 4 elevations (8-11). Reference (no de-aliasing) is shown in red.

In the second part of 2020, 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. Especially at kilometer resolution and hourly cycle, the DA system was mostly able to follow the convection onset by correcting the hourly guess in the right direction, as demonstrated in Fig. R4.

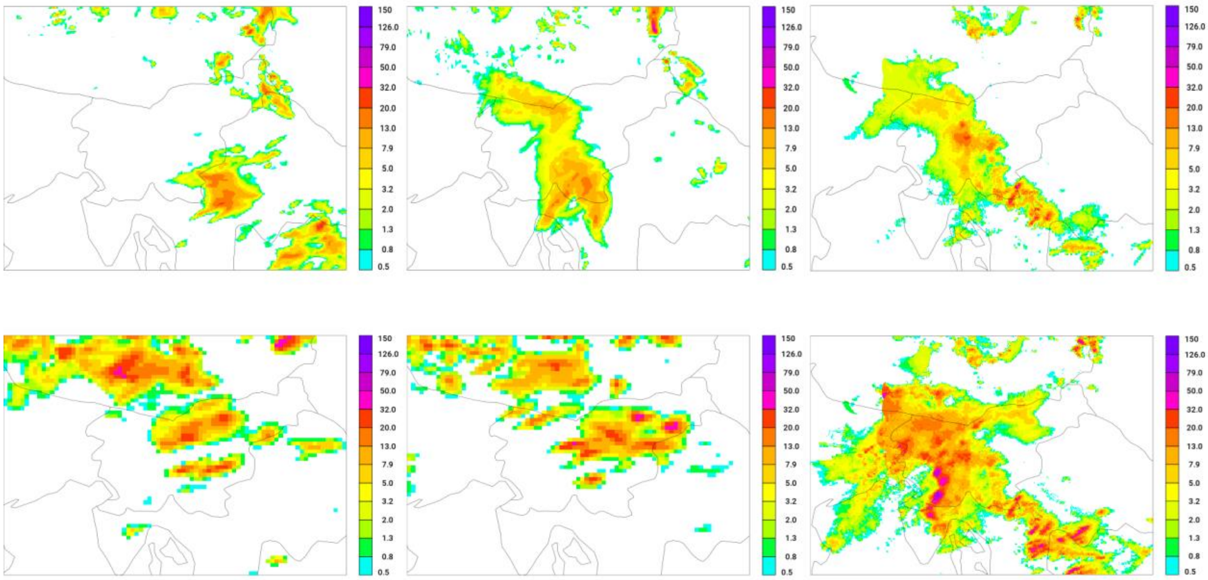

Figure R4: Simulated rainfall in one assimilation cycle (same end time) for the reference forecast (left column), the run using radar reflectivity (middle) and the verifying INCA analysis (right). Top row: the hourly NWCRUC system at 1.3 h, bottom row: the 3h ALADIN 4.4 km.

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. R5), using Synop and automatic rainfall measurements from Slovenia, northeastern Italy and Austria. Reduced frequency bias is apparent at both resolutions and this results in the increased ETS for up to 6h into the forecast. The impact on other variables is more mixed (Fig. R5) 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. To still increase the impact of radar observations, tuning of observation and background error is foreseen.

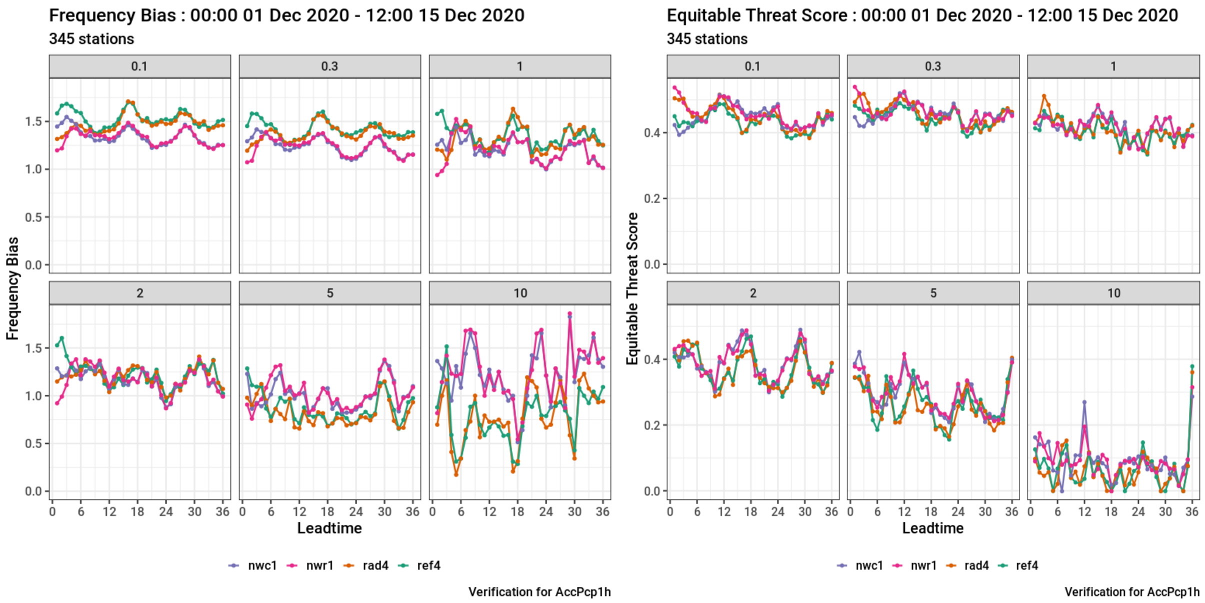

Figure R5: Frequency bias (left) and ETS score (right) of hourly precipitation forecast. Runs are reference NWCRUC (denoted nwc1), NWCRUC + radar reflectivity (nwr1), reference ALADIN 4.4 km (ref4) and reference ALADIN 4.4 km + radar reflectivity (rad4). Period is 1-15 December 2020.

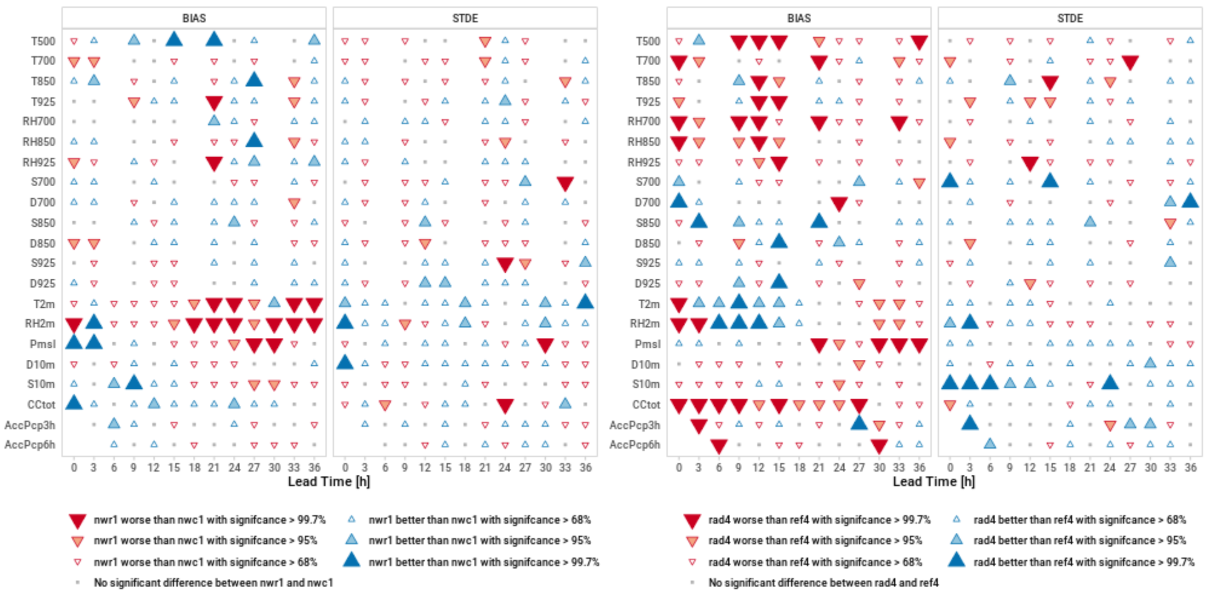

Figure R6: Scorecard of radar reflectivity experiments with respect to references for 1.3 km (left) and 4.4 km (right) resolutions in the experiment names are as in Fig R4.

In the **Czech Republic**, the first impact studies of reflectivity data assimilation was performed but the main efforts were dedicated to spatial verification of precipitation. The idea is to compute Fraction Skill Score (FSS) of model rainfall forecast against radar rainfall estimates + rain gauges product (called Merge2) over the Czech Republic. The verification is realized in R, the FSS algorithm from verification package was optimized for better performance. The optimized package is called fsspkg. When both model and observations are on the same grid the FSS is computed for several box sizes and several precipitation thresholds.

Last but not least, the HOOF tool for homogenization of OPERA/OIFS radar measurements was improved with a number of small corrections based on user feedback (discovered especially during radar stays). Further work is needed for data splitting, which is not satisfactory for the radar sites with irregular/random scanning order.

Efforts: 19 months

Contributors: A. Trojáková (Cz) 3.5, A. Bučánek (Cz) 6, V. Švagelj (Si) 2.5, B. Strajnar (Si) 2.5, F. Meier(At) 0.5, K. Čatlošová (Sk) 3.5, M. Nestiak(Sk) 0.5

Documentation: Software and documentation/reports

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of GNSS path delays (ZTD, STD, GNSS-RO, refractivity index, gradients) [DA 3.3, DA 4.2, DA 5.1]***

Description and objectives:

The usage of GNSS-derived observations is planned in most of the RC LACE member countries and is currently operational in Hungary and Austria (in AROME-RUC).

In **Slovakia**, a comparison between TPW (total precipitable water) from NWC SAF and PWV (precipitable water vapour) from GNSS was performed. The PWV were computed from ZTD estimated at near real time and atmospheric parameters from operational configuration ALADIN/SK. Positive correlations were noticed between TPW and PWV at multiple GNSS stations (Fig. G1). The assimilation tests of available STDs from GNSS station BASV were performed, the positive increments (more specific humidity in analysis) are located mainly eastwards of the station. Actually, some negative increments were noticed west of the station. Asymmetrical increments at GNSS station are an expected feature of assimilation of all available slant total delays at GNSS station. The STD code was compiled into cy46t1 on beaufix (MF). The aim is to implement all the developments first to this release and later to cy48.

In **Croatia**, the ROM SAF GBGP (Ground-Based GNSS package) has been adapted and installed on the local HPC to test the conversion from "COST" ASCII to BUFR format. For successful installation, the default ifort compiler has to be replaced by gcc (8.2). Data conversion was tested on an hourly operational data from E-GVAP by a GBGP "cost2bufr" function. A relevant entry for the param.cfg namelist of BATOR was prepared. Data conversion was tested on the hourly operational data from E-GVAP by a GBGP "cost2bufr" function.

In **Slovenia**, it was agreed with data provider (GIS institute) to verify their observations by comparison to other E-GVAP data, so it adapted the local solution, called SIGNAL. Initial updated datasets were provided by the end of 2019 and now much more correspond to other E-GVAP solution, compared on common reference GNSS sites. An evaluation of those observations were performed in ALADIN, suing 3 VarBC predictors. In the first place, comparison of observation and the model reveals systematic biases between SIGNAL2 and ALADIN. These can originate both from the model deficiencies or observations, and a common source of such bias is a mismatch between station height and the model terrain height. This is clearly visible for stations located in narrow valleys like BOVC (Bovec, northwest Slovenia) which also gets one of the highest bias correction in the described experiments. A one-month data set was shown to be too short for VarBC warm-up, so the experiment was recycled for another month using the VarBC parameters from previous run. Verification scores were computed for the experiments with 1 and 2 months of warm-up cycling, against the operational setting for reference. The verification suggests rather high impact of ZTD but increase of bias for 2 m temperature and humidity (reduced in the experiment with longer warm-up period) while the cloudiness as well as some layers in the free atmosphere are improved. Even though the results with ZTD assimilation are not yet satisfactory, the new SIGNAL dataset performed clearly better than the previously used dataset. The bias correction investigation suggests that a longer data set will be needed to reach optimal observation values for ALADIN/SI (3-6 months). The final agreement foresees provision of raw GNSS data to ARSO and the ZTD computation is to be done with an external partner.

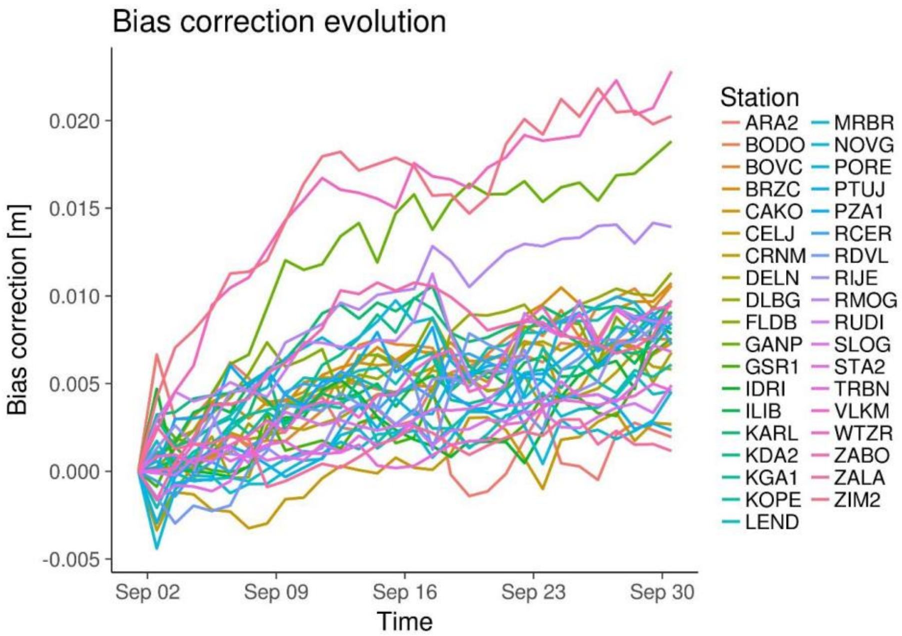

Figure G: Evolution of bias estimates for Slovenian SIGNAL observations at 12 over the warm-up period.

By the end of 2020, E-GVAP observations were implemented into the OPLACE preprocessing system. A whitelist of E-GVAP GNSS sites was computed over 30 days for Slovenian 4 .4 km domain, and that included 930 stations (Fig. G2). Further work included modification of the screening code (cy43t2) in order to use passive assimilation to enable a long-enough spin-up time. Modifications also included a tool (based on HIRLAM solution and adapted by Florian Meier) to merge hourly VARBC files for ZTD and daily files for satellite radiances. All this developments were tested and prepared to enter the operations in 2021.

Figure G2: Whitelisted (red) E-GVAP stations for the ALADIN/SI 4.4 km model domain.

Efforts: 3.75 months

Contributors: M. Imrišek (Sk), 2.5, B. Strajnar (Si) 1, S. Panežić (Cr) 0.25

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of Mode-S (EHS and MRAR) observations [DA 3.2, DA 5.1]***

Description and objectives:

The use of Mode-S high-resolution aircraft observations (both MRAR and EHS sub types) are fast growing observations network with increasing importance in mesoscale DA systems.

During the Covid-19 outbreak in 2020, the EMADDC service of KNMI started to provide new Mode-S data sets, containing EHS data from MUAC and Denmark, and later also Austria and Romania (the so-called “test” and “test 2” data from secondary processing servers - not to be interchanged by the previous MUAC data). In OPLACE, two data streams are now available as “ehs_nl” (standard operational MUAC) and “ehs_eu” (EMADDC test 2, including data from Denmark, Austria, Romania). A short obs-minus-guess study was conducted immediately after the release of new EMADDC data set. From this first evaluation of a degradation of wind from the Austrian and Romanian airspace compared to the Netherlands and Germany was observed. In autumn during the DA working days Siebren de Haan presented upgrades in

EMADDC processing of Mode-S data. Therefore OMG statistics of the European Mode-S EHS data (EHS_EU) have been re-checked for the two periods: 2-12 October and 13-28 October 2020. The OMG statistics (MEAN, STD) separated by type and areas are illustrated in Fig. M1. The overall EHS_EU wind statistics are now comparable with AMDARs. The separation by areas shows somewhat larger temperature STD for Romanian airspace which was reported back to EMADDC. An impact study using European Mode-S data has been also performed in the Czech Republic but evaluations are still ongoing.

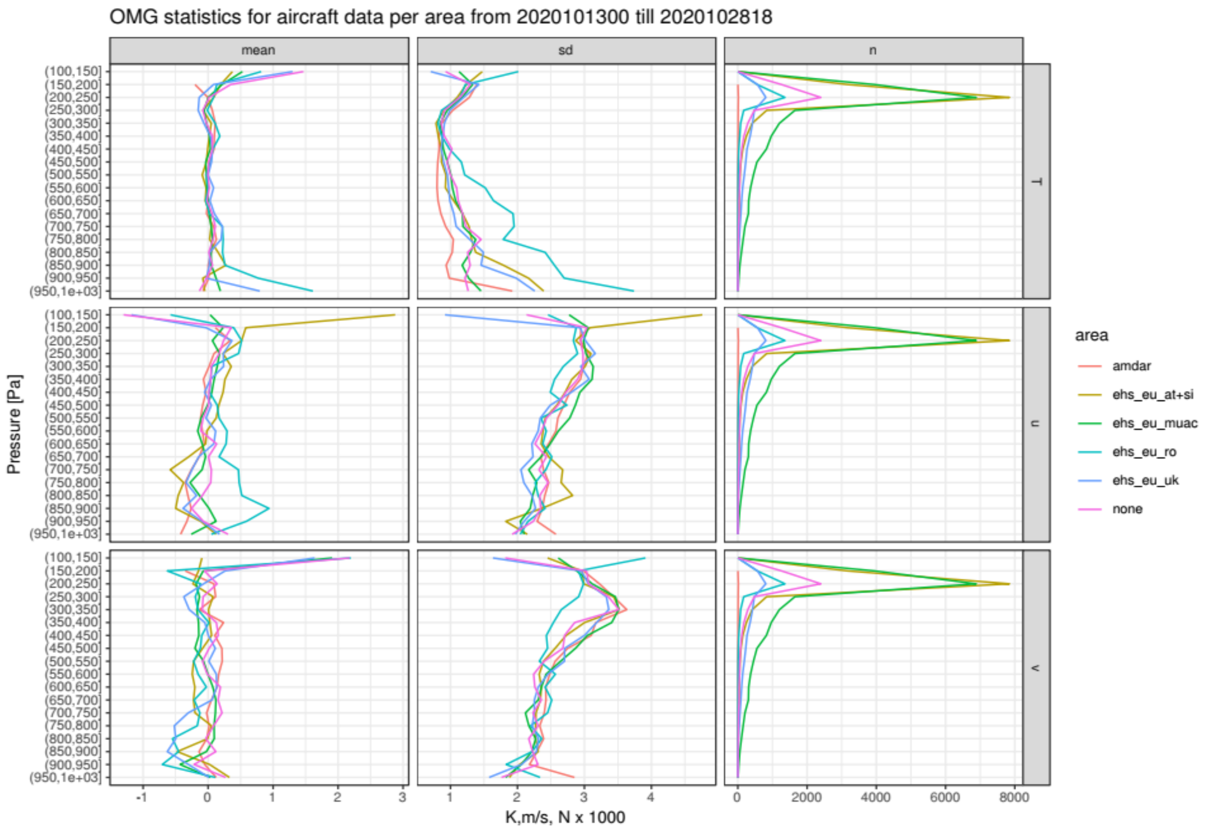

Fig M1: Vertical profile of aircraft innovations separated by geographical areas. BIAS (left), STD (middle) and number of innovations for all AMDAR data (red), MUAC area (green), UK area (blue), Romanian area (light blue), Austrian and Slovenian area (brown) for period of 13-28 October 2020.

In all **Austrian** AROME suites, the Mode-S EHS from MUAC and Denmark (available as "test" data) are assimilated from May 2020 on top of national EHS observations. In AROME-RUC, the "test 2" EMADDC data are also used operationally. However, they come too late for the hourly analysis and therefore MUAC oper data are used on top for this time, while "test 2" data are used for the hour before (-90min-+30min window). The impact was not evaluated so far, but number of observations in AROME-Aut with new data is higher than before COVID AMDAR only data - except very low levels (Fig. M2).

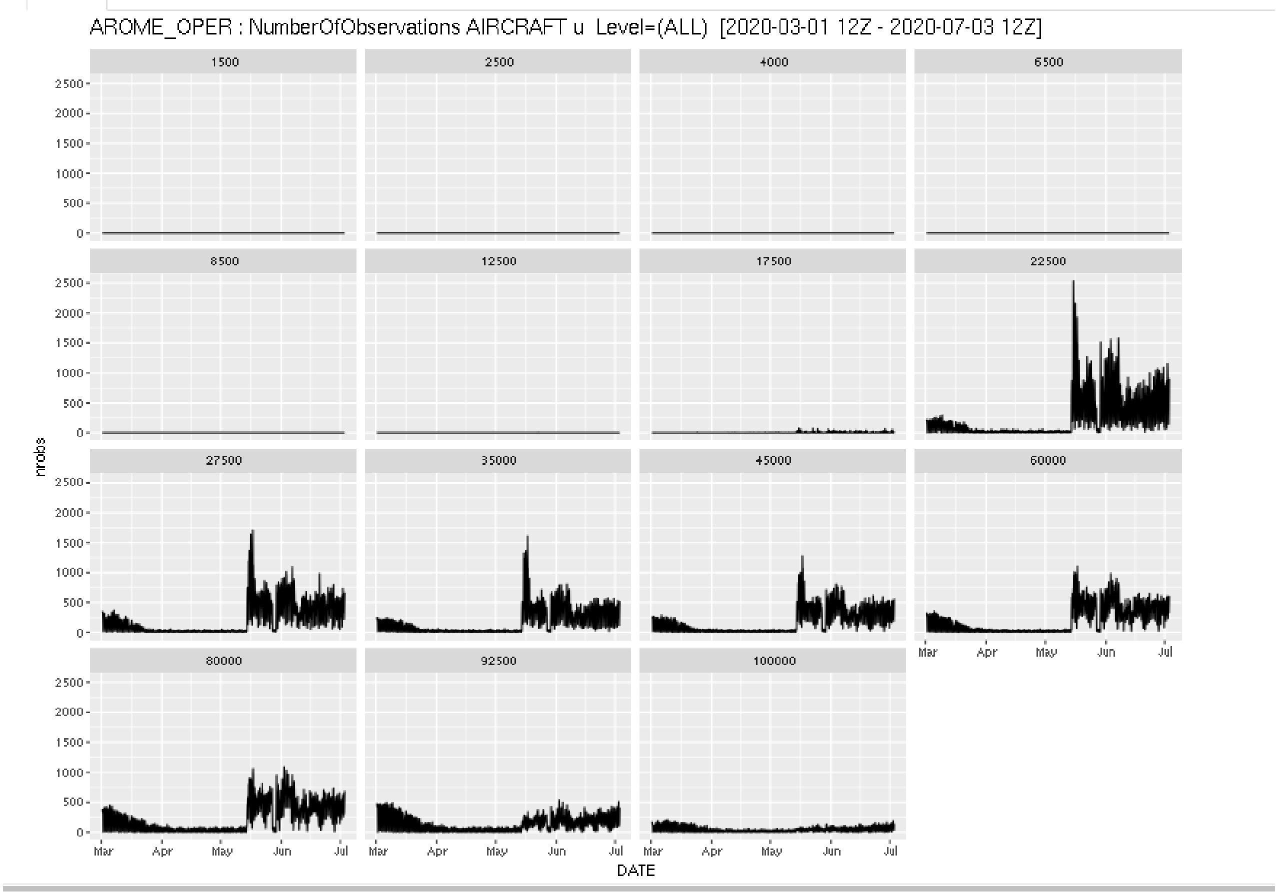

Figure M2: Increase of aircraft number assimilated in AROME-Aut 2.5 km during COVID 19 crisis on various pressure levels. In mid-May, MODE-S EHS from KNMI-test (OPLACE) was activated. The loss of AMDAR can be rather well compensated by MODE-S, but still little less observations are available around 925 hPa.

In **Hungary**, a series of experiments were carried out in order to investigate the impact of Czech Mode-S MRAR data on the quality of the forecast. They covered a winter (December 2019) and a summer period (June 2020) and were based on the operational AROME/HU. Pointwise verification was achieved for both periods using SYNOP and TEMP observations. The verification results show little improvement for the winter period: scores are usually very close to the operational ones, although a slight improvement can be detected in most cases. A remarkable, albeit small positive impact can be seen regarding precipitation (Fig. M2), although it has to be noted that there were only a few days with considerable amount of precipitation in this specific period. Results on the summer period were impacted by Covid-19 traffic reduction. It can be concluded that the assimilation of Czech Mode-S data yields only slightly different results in the forecast. The impact of the Mode-S dataset was quite substantial for specific days, at least for the summer period, but the difference is usually much smaller. The beneficial impact on precipitation is also reflected in increase of ETS (Figs. M3, M4). Other surface variables, however, show little to no improvement, and this is quite similar to the impact seen in the winter experiment. The assimilation of the Czech Mode-S MRAR data turns to operational in AROME/HU from March 2021 (already in cycle 43t2).

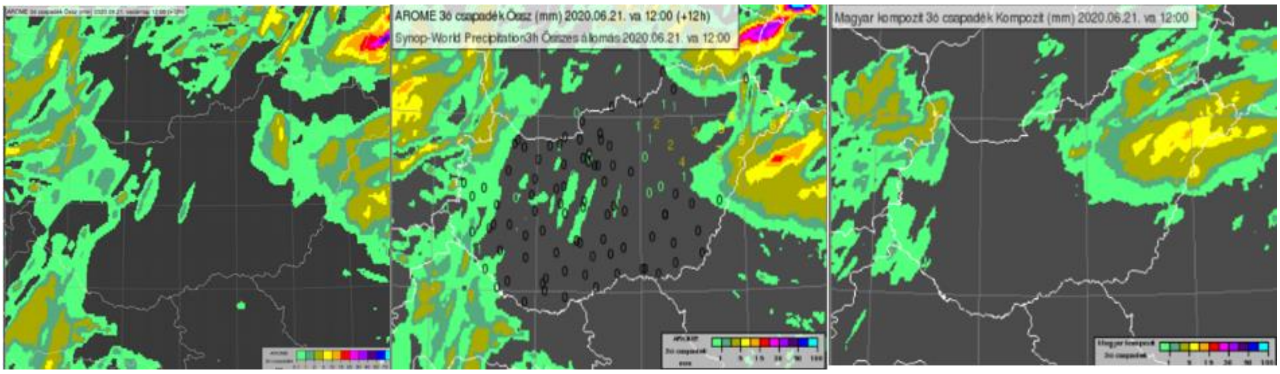

Figure M2: 12-hour forecast of 3-hour precipitation sum in the experiment using Mode-S data (left), reference run (middle), and the radar data (right) at 12 UTC on 21 June 2020.

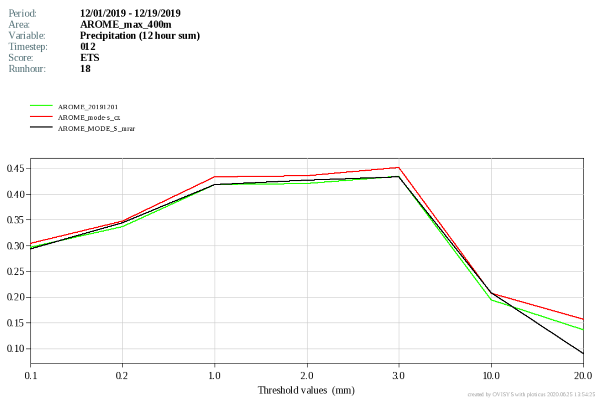

Figure M3: ETS score of 12-hourly precipitation in the 18 UTC runs from 1 to 19 December 2019. Red line: experiment with Czech Mode-S data, black line: experiment with Hungarian Mode-S data, green line: reference experiment without any Mode-S data.

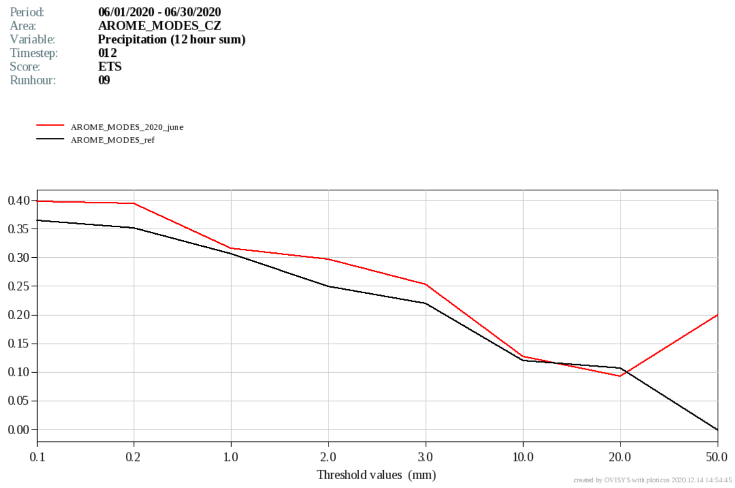

Figure M4: ETS score of 12-hourly precipitation in the 9 UTC runs from 1 to 30 June 2020. Red line: experiment with Czech Mode-S data, black line: reference run.

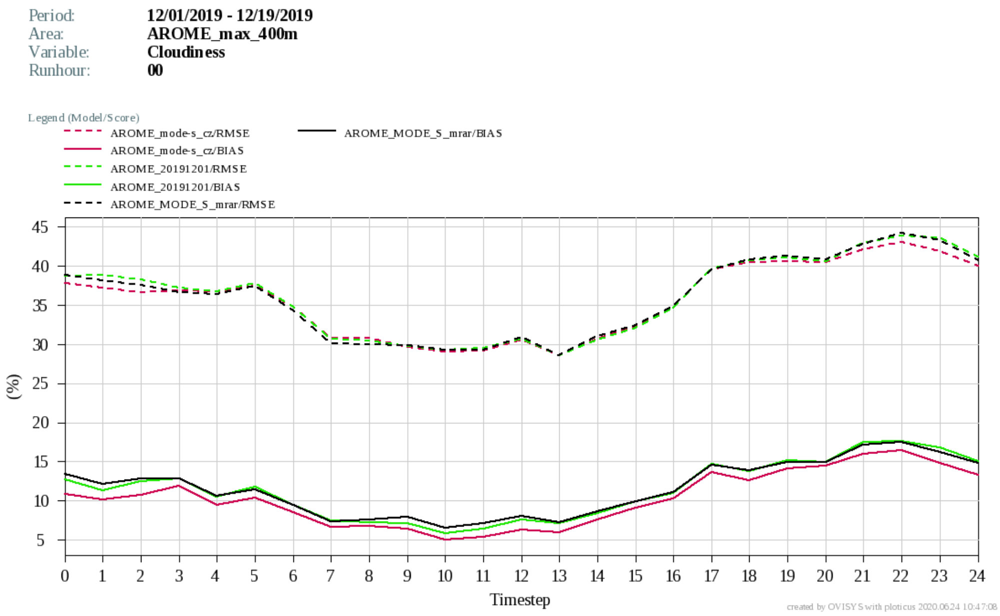

Figure M5: Bias (solid line) and RMSE (dashed line) of cloud forecasts in the 0 UTC runs. Red: experiment with assimilation of Czech Mode-S data, green: experiment with assimilation of Hungarian Mode-S data, black: operational AROME/HU without any Mode-S data.

Apart from using Czech MRAR data, first test with 4 weeks of Hungarian data, provided by Hungarian ATC (HungaroControl) were conducted. The first verification results showed that the accuracy of the AROME/HU forecasts were not affected remarkable by the raw MRAR dataset (see Figs. M3 and M5, comparison between green and black line). At nighttime, differences are slightly bigger with respect to the ones at daytime but their magnitudes are not considerable. The results were compared also to the results of the experiment with Czech Mode-S data. After the first test phase, HungaroControl expanded the dataset to cover around 4 moths. As next step, a whitelisting procedure was carried out with similar thresholds as those applied in the other LACE Members which resulted in retaining 72 % temperature and 64 % wind observations of the dataset. The follow-up impact study show slight difference in comparison with the reference forecasts, which are more apparent in the 12 UTC runs when there are more flights (Fig. M6). The Hungarian Mode-S MRAR data positively affect the 2 m temperature and relative humidity analysis leading to tiny improvements in precipitation, relative humidity, total cloud cover and wind gust forecasts, while in case of the other variables the impact is rather neutral. This investigation will continue after the Covid-19 pandemic.

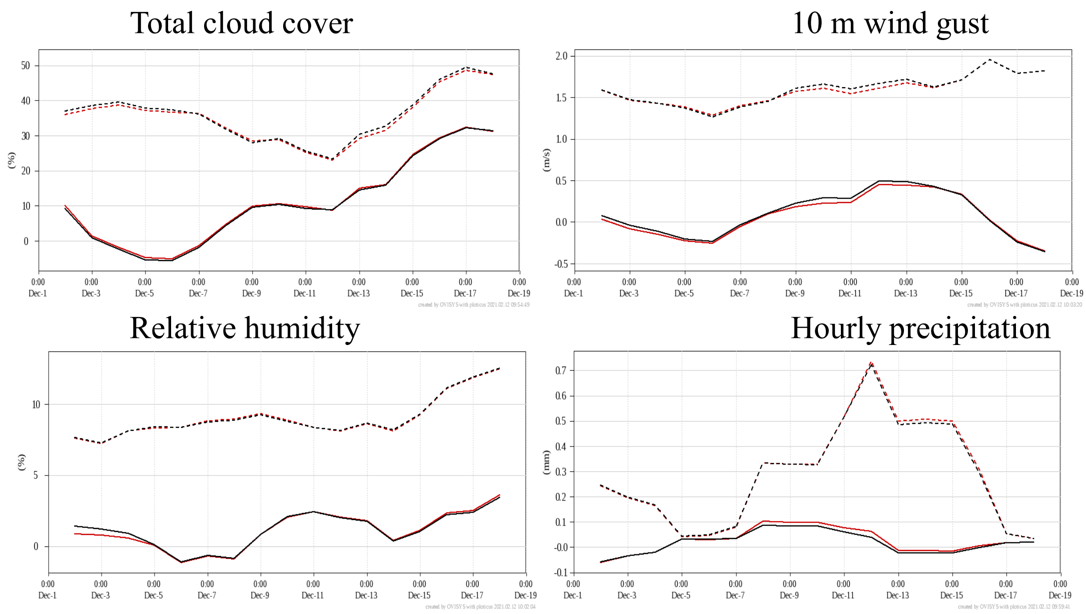

Figure M6: Bias (solid line) and RMSE (dashed line) of 12-hour forecasts for total cloud cover, 10 m wind gust, 2 m relative humidity and precipitation in the 12 UTC runs from 1 to 18 December 2019. Red line: experiment with Hungarian Mode-S data, black line: reference run.

In **Slovakia**, a comparison of Mode-S EHS and Mode-S MRAR data originating from the same aircrafts was performed. The dataset was retrieved from Buchtuv kopec (Czech Republic) where both data types were available over the period of Jan-Feb 2018. Significant differences in temperature measurements were observed. An illustration of OMG departures for active EHS and MRAR data is depicted in Fig. M7. Further experiments included work on tuning the thinning of Mode-S data (Fig. M8). Results are rather mixed and the added value of Mode-S cannot be clearly demonstrated (the impact is slightly negative for temperature). Longer verification periods are ongoing.

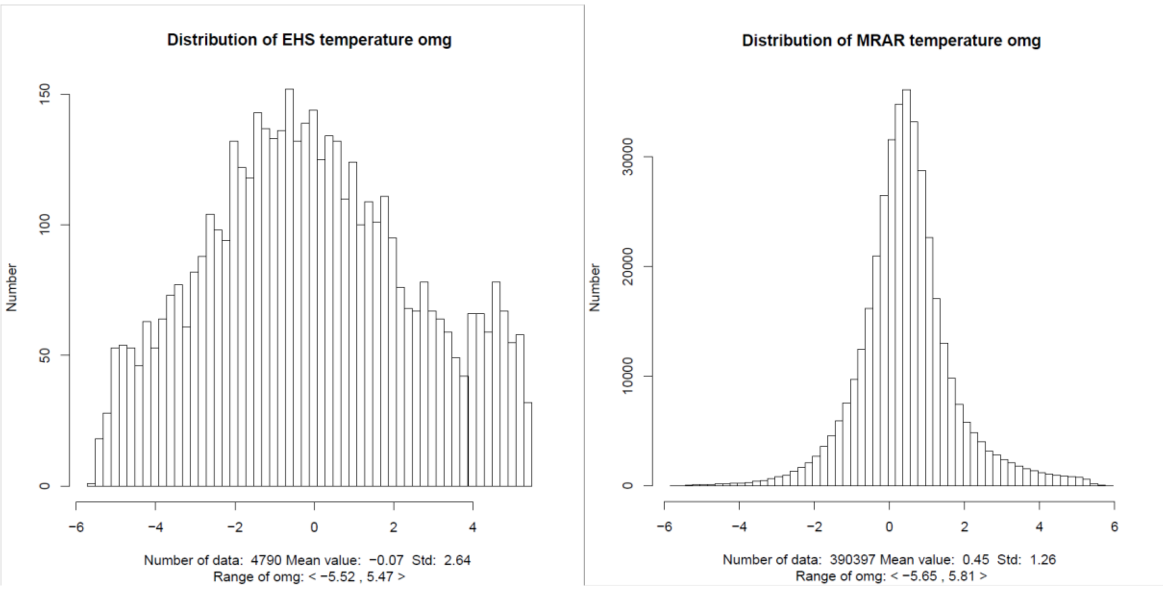

Figure M7: EHS (left) and MRAR (right) OMG departures computed for a particular flight.

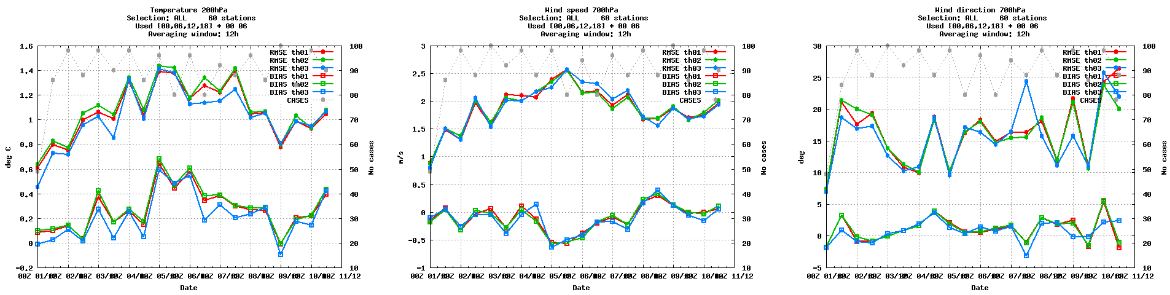

Figure M8: Verification of Mode-S thinning experiments: 25 km & 15 hPa (red), 5 km & 5 hPa (green) and no Mode-S data (blue) for temperature wind speed and wind direction.

Efforts: 13.25 months

Contributors: F. Meier (At) 0.5, Gabriella Tóth (Hu) 2.75, Anikó Várkonyi (Hu) 0.75, B. Strajnar (Si) 0.25, K. Čatlošová (Sk) 6.5, Kristóf Szanyi 2, A. Trojákova (Cz) 0.5

Action/Subject/Deliverable: ***The use of AMV products (Geowind, HRW and Multi-Metop) [DA 3.5]***

Description and objectives:

An impact study was carried out in Hungary in order to evaluate AMV (GEOWIND and HRWIND) in AROME/HU over two periods with frequent weather fronts and convection. In the assimilation, AMVs were used in both long and short forecasts as the timelines of the data allows it. The AMVs were generated form IR, VIS and WV channels. For the thinning and blacklisting, the same settings as used in ALADIN/HU was adopted. In both periods, only a small fraction of the data was active in the assimilation, with lots of blacklisted data (above QI 85%). According to this, most of the active wind vectors were located between 300 and 250 hPa and a few measurements were used between 1000 and 850 hPa.

Experiments showed very small, mostly neutral impact of the AMV data in both periods for the surface parameters (temperature, humidity, wind, pressure). In the convective period a small, rather positive effect can be seen for the surface wind gusts. In the precipitation larger differences could be observed between the experiment results obtained with and without AMVs (Fig. G1). This is an example where cells with small precipitation were better initiated when AMVs were assimilated. The impact was also supported by differences in the SEDI parameter of 24-hour precipitation amounts. For days with very small and large precipitation amount a positive impact can be seen while for moderate precipitation amount the reference model run performed better. A study and possible revision of the blacklisting setup is planned in order to get more impact.

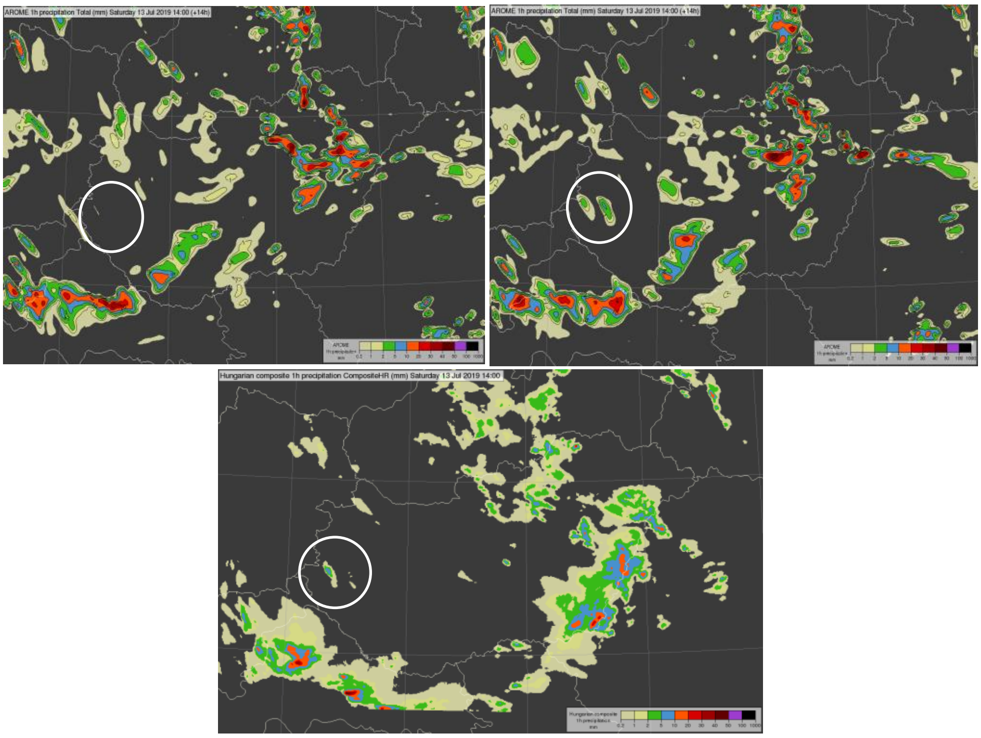

Figure G1: 14-hour forecast of hourly precipitation without (upper left) and with (upper right) AMVs at 14 UTC on 13 July 2019. Hourly precipitation sum based on radar data at 14 UTC on 13 July 2019 (bottom).

Further experimentation included different blacklisting to increase the number of active AMVs and check their distribution and characteristics. Observation minus background (O-B) statistics were calculated for two different blacklisting settings (Fig. G2). In the experiment denoted

AMVA, all AMVs were used where the quality index reached or exceeded 85%. Comparing with initial experiment (TARR), a relatively large increase in the number of active observations can be observed. In the second experiment AMV8, only observations between 800 and 350 hPa were added compared to default setup so that AMVs below 700 hPa pressure level are not used over land. O-B statistics between 800 and 350 hPa do not show suspicious features so it can be assumed they would be useful in assimilation. Further tests to show that are planned.

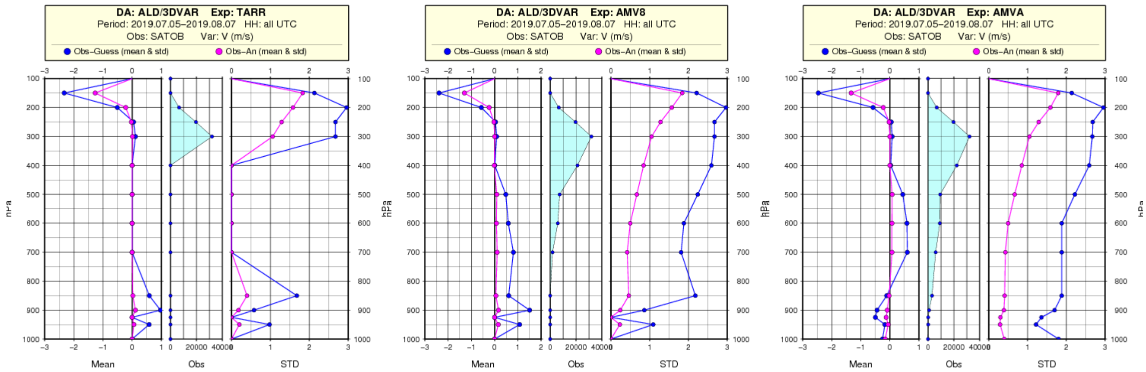

Figure G2: The vertical distribution of the active observations for our initial experiment (left), for experiment AMV8 (middle) and for experiment AMVA (right) over the AROME/HU domain from 5 July to 7 August 2019.

In the Czech republic, HRWIND data were investigated in an impact study (together with wind profiler and scatterometer data) in order to extend the use of existing observations in the operational version of ALADIN/CHMI. The comparison with respect to the NWP model was used to assess the quality of the additional observations. Sensitivity studies were performed to evaluate impact on forecast. Statistical analysis of observation-minus-background (OMG) showed a larger number and a better quality of HR-AMV compared to standard AMV. Therefore AMV data were replaced by HR-AMV. The impact study showed neutral forecast scores.

Efforts: 2.75 month

Contributors: Zsófia Kocsis (Hu) 2.5, A. Trojáková (Cz) 0.25

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of wind profilers and wind turbine data [DA 3]***

Description and objectives:

In Austria, the assimilation and parametrization of windfarms was ported and tested in cy43t2. A major issue found was that height pressure attribution in BATOR for wind profiler (and wind turbines) was made so far based on constant standard atmosphere assumption, which is especially dangerous for low levels (possibility of inversions and resulting vertical errors in height of 20 m and more). An optional modification was coded within hretr routine (cy40t1) / hretr_conv (cy43t2) to use first guess temperature/pressure profile for the height attribution. To fill the data gap caused by COVID 19 airline grounding, the usage of two Austrian sodar profiles (Linz and Vienna Airport) as "wind profiler" was enabled within AROME-RUC. Although the data are noisier than regular wind profilers, they can be used if rejection limits are properly set. The wind profiler at Vienna Airport was replaced by Austrocontrol in spring. Most meteorological services blacklisted the old one due to bad quality.

In the Czech Republic, an ad-hoc thresholds of OMG, bias, and standard deviation were applied to wind profiler data to keep only "good" stations. This approach is was considered as the first step for wind profiler data assimilation. The impact study showed neutral scores which was expected considering a small number of new stations and rather sparse observation reference (verification scores are computed with respect to radiosonde observations).

Efforts: 0.75 month

Contributors: F. Meier 0.5, A. Trojáková (Cz) 0.25

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of attenuation in telecommunication microwave links [DA 4.11]***

Description and objectives:

The attenuation of telecommunication inter-antenna links in cellular networks due to rain is an attractive new observation data source. In **Slovenia**, work on efficient separation of dry and wet delays continued in the beginning of 2020. Improvements to a second-order linear state-space model for baseline was applied in order to make the algorithm more robust. Effect of wet antenna on rain estimates needs to be studied because it can influence the wet/dry period separation. The assumed power law relation between attenuation and rain rate also needs to be studied in more detail. Unfortunately, the current sample data volumes prevented from further verification as not enough rainy cases were provided. This work is expected to continue when more data get available.

Within the project called LINK in **Austria**, microwave links from Austrian mobile phone network will be assimilated into the AROME-RUC. Currently, the pre-processing from signal to equivalent rain is ongoing. First test data were received and the software Rainlink (developed in the Netherlands) for pre-processing is installed. A standalone 1D-Var software from Phillippe Lopez (ECMWF) to transform rain rates and first guess to humidity profiles, which can be used in 3D-Var later (used also in Morocco to assimilate 2D radar rain fields) was obtained. Another option tested to assimilate the data will be the latent heat nudging.

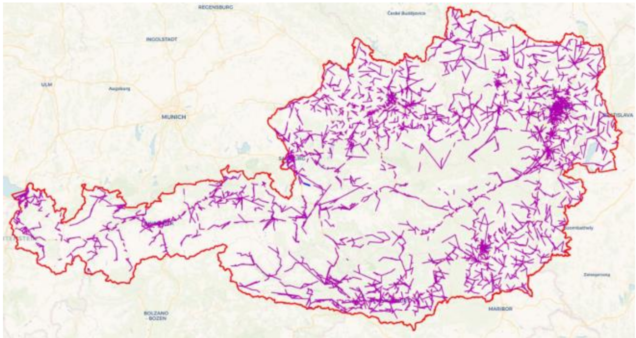

Figure L1: microwave links over Austria.

Efforts: 1.5 month

Contributors: P. Smerkol (Si) 1.5, P. Scheffknecht (At)

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of scatterometer data (ASCAT, OSCAT, HSCAT) [DA 3.4]***

Description and objectives:

In Slovenia, the impact of OSCAT wind observations (onboard Indian Scat) in ALADIN/SI NWP model was investigated over a period of one month. OSCAT is a scatterometer instrument on board ScatSat-1 satellite and provides near surface wind vector observations over ocean. The data are available over ocean surfaces with the horizontal resolution of approx. 25 km. The satellites carrying ASCAT (Metop B and C) and OSCAT (ScatSat-1) scatterometers overpass Europe twice daily in a time interval of less than one hour. The satellite retrieval process results in 2-4 possible solutions for near surface wind vectors. All available solutions are read and one solution is chosen during the assimilation process. The majority of the data was available for assimilation at 09 and 21 UTC and therefore had little impact on forecasts at typical synoptic times. OMG/OMA investigation showed an impact of OSCAT data on the analysis (Fig. A1), however, the impact on the forecast at some distance from the observations was largely neutral. OSCAT data represent a complementary dataset to the more widely used ASCAT data. As both cover data sparse regions over the seas and oceans they represent a valuable source of information for NWP. When both are assimilated OSCAT reduces the impact of ASCAT data and causes the problem of redundancy. Still, this does not cause any negative impact on the forecast. As we expect OSCAT to be able to fill the gap in case of ASCAT failure or other problems, it should be beneficial to include OSCAT data into the operational analysis.

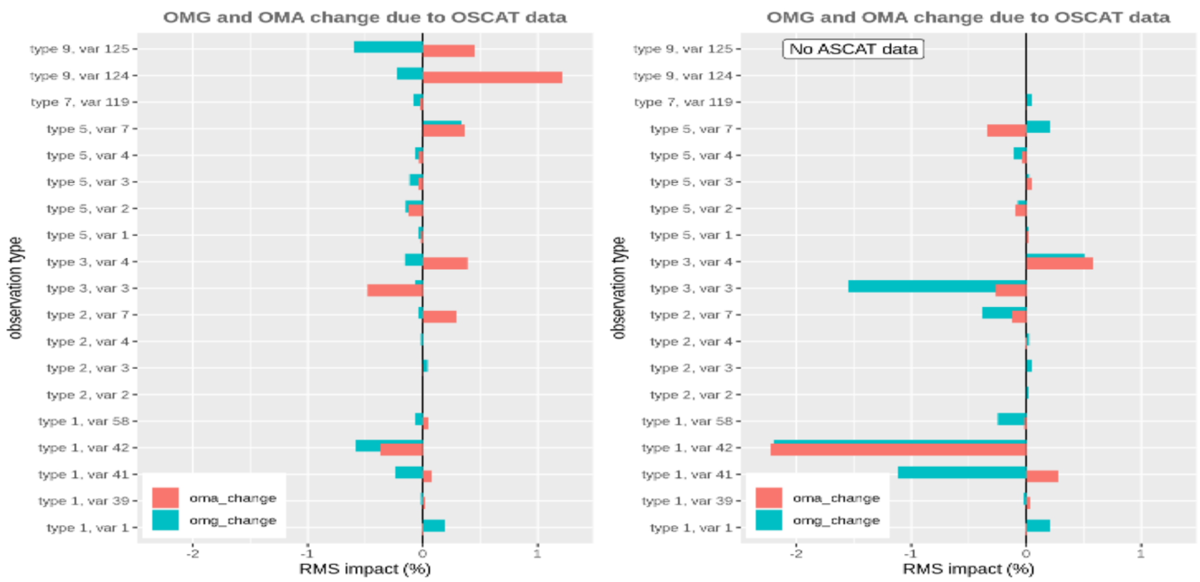

Figure A1: OMG relative change due to assimilated OSCAT observations when ASCAT is also (left) or not assimilated (right).

In the Czech Republic, an impact study was carried out for ASCAT (together with other observations). A neutral impact was detected, presumably also due to lack of observation reference.

Efforts: 2 month

Contributors: B.Strajnar (SI) 0.25, A. Trojáková (Cz) 0.25, J. Čampa 1.5

Documentation: /

Status: ONGOING

Action/Subject/Deliverable: ***Assimilation of surface observations (SYNOP, national data, private observation networks) for upper-air and soil data assimilation [DA 3.8, SU 2]***

In the first part of 2020, significant efforts were put into optimization of surface data (Synop, national stations) for surface analysis.

In the **Czech Republic**, sensitivity of the CANARI analysis to the structure functions was investigated in order to increases impact of the national synoptic observations in soil analysis. To achieve this, an artificial environment with one forecast run as a truth and for generation of synthetic measurements. Those observations are assimilated in an older guess (12-h forecast). The test include a single CANARI step and different background-error correlation functions: old and new CANARI correlation functions, Mescan, Mescan with orographic drop of correlation and land sea mask and new CANARI correlation function, Mescan with tuned orographic correlation (ZCORRT2 parameter), Mescan with modified correlation function + tuned ZCORRT2. Those functions were used at different correlation lengths from 10 to 160 km. Figure T1 shows the shape those correlation functions for one member of different correlation types, without orographic drops. The old correlation function is at short distance dropping the correlation slowly but later on it drops correlation very quickly and for distance longer than 100 km there is almost no correlation, the function has “Gaussian shape”. The new correlation function is representing exponential decay (e-x) and Mescan correlation function is something in between old and new correlation function. The modified Mescan correlation function firstly drops correlation quickly but some level of correlation persist to very long distance. The ZCORRT2 tuning was according to documentation by Cornel Soci which states that the drop of correlation to 0.5 should appear when orography distance exceeds 500 m (not 250 m as coded in cy43t2).

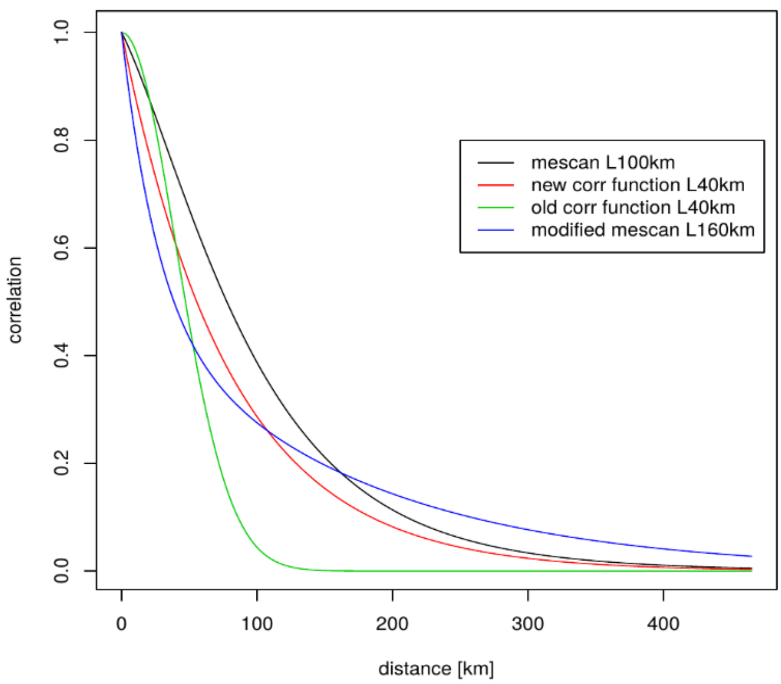

Fig T1: Correlation functions tested in CANARI.

The summary of results for 2m temperature is shown in in Fig. T2. RMSE is computed between analysis file and the truth file in gridpoint space for all mentioned correlation functions. The new correlation function has the lowest RMSE compared to the other correlation functions (similar results are also for RH2M). The best length scale is 40 km in this test. Based on this “controlled environment”, three new setups were selected for tests with full assimilation cycle over 1-month period; the new correlation function with 40 km length scale (N40), Mescan correlation function with 100 km length scale (M100) and Mescan corr. function with tuned orographic scale with 100 km length scale (4M100). The selected period is one month (September 2019). The national SYNOP stations are assimilated in all 3 setups while operational setup does not assimilate the extended set of SYNOPs. The assimilation cycle is 6 h with two productions at 0 and 12 UTC for up to 48 hours.

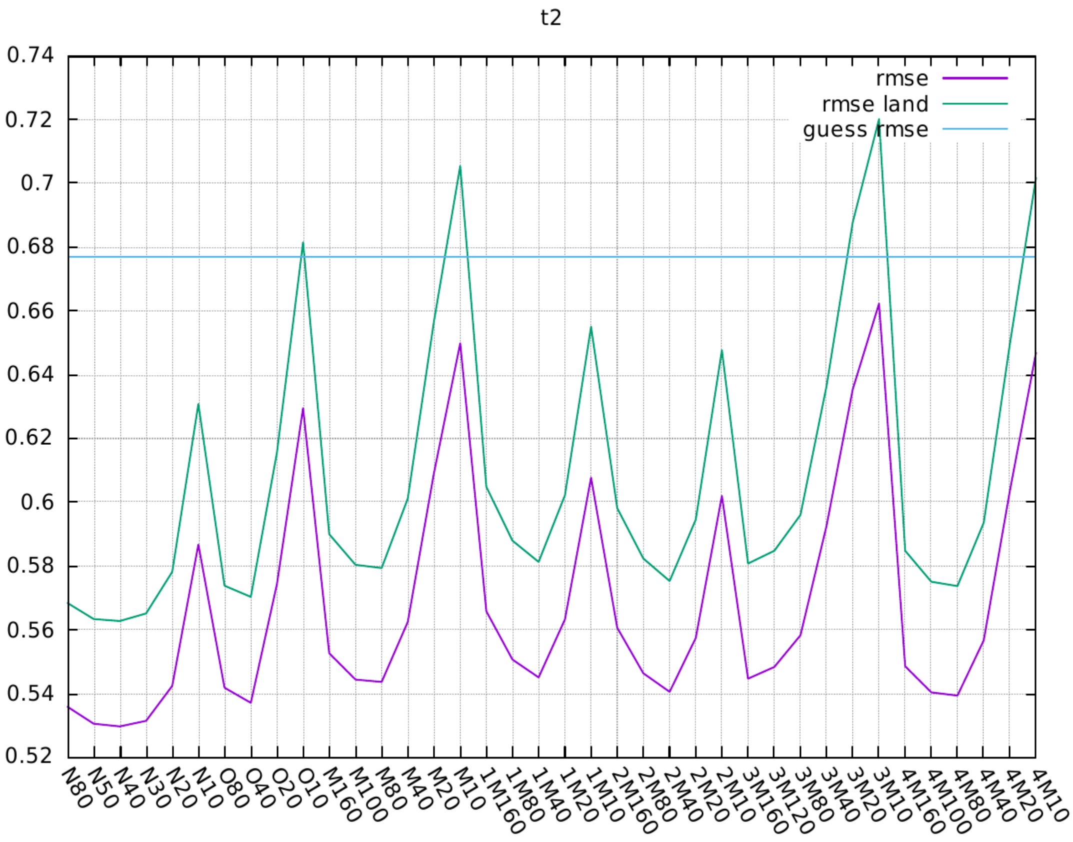

Fig T2: RMSE between truth (fc+6h) and analysis for 2m temperature when different correlation function and its length scale were used in CANARI over 14 days. N (new), O (old) and M (Mescan) correlation functions at different length scales and tuning are plotted.

The verification against GTS SYNOP observations shows positive impact of the N40 compared to Oper setup (N80) and M100, 4M100. Figure T3 shows visible improvement of RMSE of N40 at analysis time and up to 6/12h of forecast compared to the other setups. Statistical significance is denoted by blue circles.

Within the validation of cy43t2, the influence of using Mescan correlation functions compared to those used in CANARI was tested in Croatia, by conducting three experiments with surface DA: Mescan with default settings (length scale 55 km), CANARI with the same options, and Mescan with the increased radius of influence in order to get increments of same size (spatially) as for CANARI. For all instances, cy43 operational backup (on cca) 00 UTC forecast was calculated over a two-month frame in summer. Verification was performed over one month and a half, in comparison with the operational model. While all three cy43 instances showed a major improvement over currently operational cy38 model (CRO4), there were no significant differences between the three (Fig. T4).

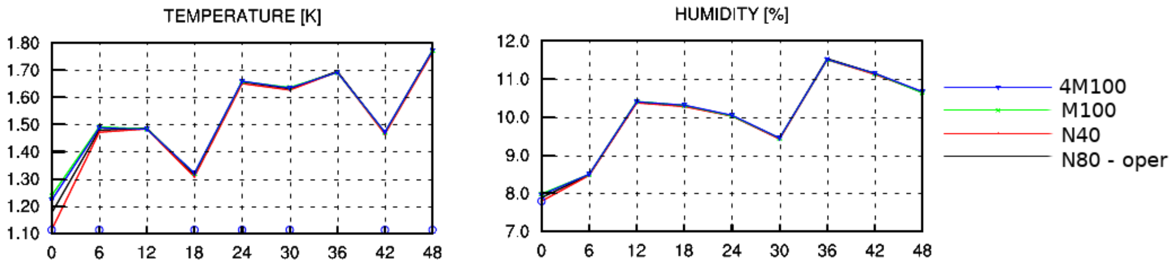

Fig T3: RMSE of T 2m, RH 2 m for forecast up to 48 h verified against GTS SYNOP observations. The period is one month September 2019.

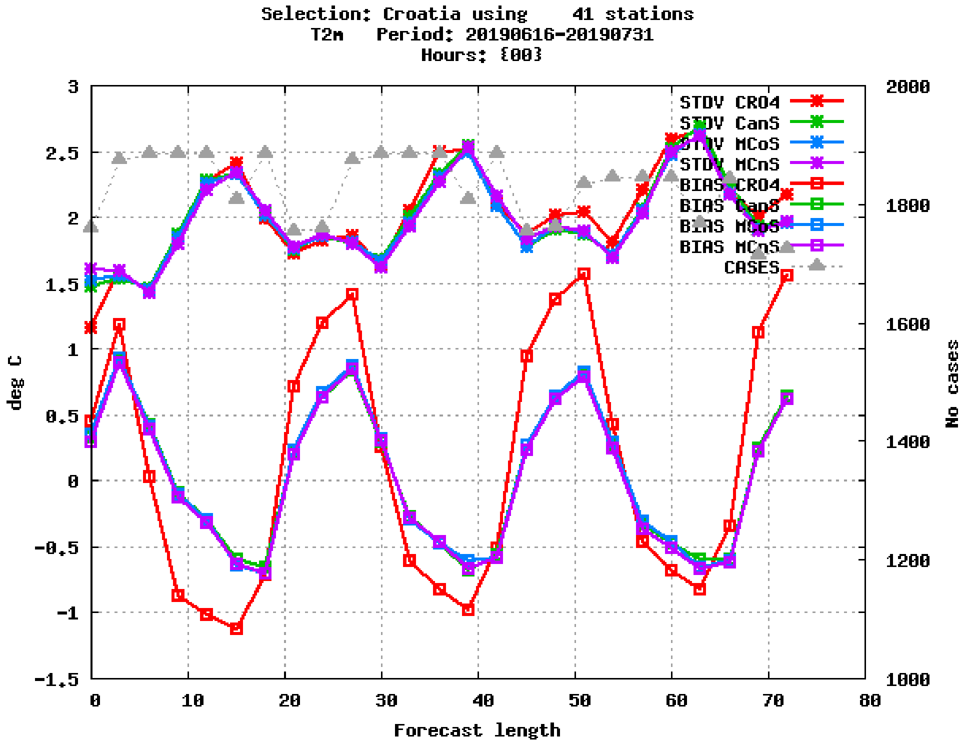

Figure T4: Standard deviation and bias in temperature fields for all experiments (CRO4 – operational model, CanS – CANARI, MCOs and MCns - Mescan).

In **Austria**, the titanlib quality check software (from MetNo) was installed and tested in combination with Austrian NETATMO data set from 2019 (about 8000 stations, much less for wind). It was found that Titanlib can successfully detect and eliminate outliers (about 50% of the stations). However, especially for MSLP an additional check is needed as the observations suffer from significant bias due to wrong/not precise sensor/station heights. The orography check described in the paper is not part of current titanlib version. Also T 2m might need some additional QC while wind and RH 2m was found to show similar first guess departures as for Synop after Titanlib was applied. Another use case of dense surface observaitons was made in the scope of special project on resilience in crisis situations. Under this the framework the nowcasting (INCA) group generated several analyses based on radar + private rain gauges from NETATMO (loss of synop network) and satellite based precipitation + synop (loss of RADAR network). These analyses were also nudged via LHN into AROME-RUC and compared with reference INCA (synop+radar). The satellite experiment was also repeated with switched off radar DA in 3D-Var. Several case studies have been conducted.

Efforts: 3.5 months

Contributors: F. Meier (At) 0.75, F. Weidle (At) 0.75, A. Bučánek (Cz) 1, Antonio Stanešić (Cr) 0.5 (pm), S. Panežić (Cr) 0.5 (pm)

Documentation: /

Status: ONGOING

Documents and publications

Scientific papers

- Vural, J., Schneider, S., Bauer-Marschallinger, B., & Haslinger, K. (2021). Assimilation of the SCATSAR-SWI with SURFEX: Impact of Local Observation Errors in Austria, *Monthly Weather Review*, *149*(3), 773-791. https://journals.ametsoc.org/view/journals/mwre/149/3/MWR-D-20-0160.1.xml
- Atencia, A., Kann, A., Wang, Y. and Meier, F. (2020): Localized variational blending for nowcasting purposes. Meteorologische Zeitschrift 29(3), 247-261, http://dx.doi.org/10.1127/metz/2020/1003
- Čatlošová , K.: Paper on Mode-S DA for Meteorological applications, in finalization.

List of stay reports:

- Alena Trojáková, 2020/03: ALARO test of radar observation operator
- Antonin Bučánek, 2020/03: Processing of radar reflectivities in screening
- Katarína Čatlošová, 2020/08: Assimilation of radial wind (DOW) from radars with high Nyquist velocity

Other technical reports:

- Benedikt Strajnar, 2020/05: Validation of Slovenian GPS observations
- Jana Čampa, 2020/08: Validation of OSCAT observations

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.

Posters:

- Phillip Scheffknecht: GSPRO Assimilation Experiments with AROME using Synthetic Data
- Katarína Čatlošová: Mode-S data assimilation at SHMU
- Martin Imrišek : GNSS slant total delays in the ALADIN NWP system: Phasing of the source code from cy40h1 to cy43t2

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 2020, 14 January, coordinated by AL
2) Task team leader (TTL) for ALH DA strategy, preparation of DA strategy document (including 2 web conferences) as input to ALH Strategy meeting in February 2020.
3) Attendance to HIRLAM videoconferences on radar DA, 17 March 2020
4) Joint 30th ALADIN Workshop & HIRLAM All Staff Meeting 2020, 30 March – 3 April 2020, videoconference.
5) Joint LACE Data Assimilation Working Days and ALADIN Data Assimilation basic kit Working Days, videoconference, 14-16 September 2020
6) 42th EWGLAM and 27th SRNWP 2020 meeting, 28 September - 1 October, online event.
7) Attendance to autumn HIRLAM DA working week, 26-30 October, online.
8) OPERA users group radar data assimilation meeting, 26 November, online.
9) LSC meetings

Summary of resources

Action (PM)	Resource		LACE stays (months)	
	Planned	Realized	Planned	Realized
Maintenance, evol. of oper. Systems	10	15	-	-
DAsKIT	5	3	-	-
Hourly RUC	13.75	6.5	-	-
B-matrix	5	3.5	-	-
SEKF	5	6.5	.	.
OBS for SEKF	8	8.5	-	-
Radiance obs.	1	-	-	-
RADAR obs.	17	19	2.25	2.5*
GNSS obs.	8	3.75	1	-
Mode-S obs.	12.75	13.25	1	-
AMV obs.	1	2.75	-	-
RAINLINK obs.	3.5	1.5	-	-
SCAT obs.	1.5	2	-	-
SYNOP obs. (incl. OI)	3	3.5	-	-
PROFILER obs.	2.5	0.75		
Total	**97**	**89.5**	**4.25**	**2.5**

* Impacted by Covid-19 situation, planned work continues locally.

Problems and opportunities

The main problems in 2020 were:

- Even more than usual, a lot of manpower is spent for local validation, maintenance and technical issues, there is partial duplication 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 3D-Var performance.

- 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 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:

- To increase the level of cooperation inside and outside RC LACE and support cooperation with other areas (e.g. DA & EPS common activities). 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.