Working Area Data Assimilation

Work Plan

Prepared by:	Area Leader Benedikt Strajnar
Period:	2022
Date:	13/09/2021

Introduction and background

Within a broader collaboration in the framework of the ACCORD consortium, the RC LACE data assimilation activities are focused on implementation and operationalization of data assimilation systems at the LACE centers, which provide users with short-range NWP and NWP-based nowcasting. The DA manpower is typically 1-2 FTE per Member but a relatively large share of this manpower is usually spent on technically demanding continuous upgrades, specific to each institution in terms of code compilation and maintenance, data flow and archiving, and extensive computations.

Currently, 6 RC LACE countries are now operationally running 8 DA system plus 2 NWP-based nowcasting suites. Poland and Romania have not yet reach operational DA but plan to implement it in the future, partly through support and in collaboration with the DA starters kit (DAsKIT) organized within the ACCORD consortium.

The RC LACE members have continuously enhanced the use of commonly available and national observations over the last years and now use a large variety of conventional and remote-sensed observations, including higher resolution datasets than those provided by GTS where available. The LACE DA work plan is trying to support and consolidate this efforts by encouraging exchange of information within the group as well as with other ACCORD partners.

The planning of work common ACCORD consortium has become more unified and is now managed through the Rolling Work Plan (RWP) 2022. The structure of the current RC LACE DA plan for 2022 is therefore highly aligned with the RWP items.

Goal

The contribution of RC LACE focuses on optimization the current DA systems by enhancing observation use and design of suitable systems for nowcasting/convective scale NWP and observations suited for these systems. The members will be focused on implementation of new hourly updated systems that are currently under design or validation (Slovenia, Hungary, Slovakia) and further refinement or existing systems (Austria, Czech Republic) and progressive migration to flow-dependent algorithms such as ensemble-variational (EnVar) algorithms.

Another direction of algorithmic development will be towards utilization of an alternative soil analysis scheme to replace the currently used OI: the Simplified Extended Kalman Filter (SEKF) within the SURFEX land model will be further validated with AROME model and progressively explored also in combination with ALARO model physics (provided that validation of coupling with SURFEX will be completed). This also includes sensitivity studies with additional observations for surface and soil, such as land surface temperature (LST), soil wetness index (SWI) and leaf area index (LAI).

Effective use of observations stays the top priority of LACE DA group. Most of the efforts in upper-air data assimilation would be invested to implementation of the radar data assimilation. One of the outstanding goals in 2022 is to **consolidate current and previous work on radar reflectivity and radial**

winds, in order to increase the number of operational applications with enhanced success on the convective scale. Other important observations with already much investment but rare operational applications are GNSS-derived data. Use of other data such as wind profilers, atmospheric motion vectors, as well as new data types such as GNSS slant delays and microwave link delays will also be enhanced and developed.

Additionally, the familiarization with the OOPS code infrastructure is foreseen, not only to replace the current 3D-Var with its OOPS equivalent in the relatively near future, but also to be able to tackle advanced algorithms such as EnVar. The familiarization process has started in cooperation with MF, and the forthcoming DA code training which is to be organized in Toulouse is expected to bring initial knowledge about OOPS to the LACE groups.

Action/Subject/Deliverable: ***Operational implementation of DA suites [COM3]***

Description and objectives:

The action includes installation, technical and meteorological validation, specific validation based on user needs and operationalization of newer common model cycles. Operationalization of cy43 is still needed in Croatia. This item also covers design and implementation of operational suites, operational implementation of new observations (once tested and ready for operations), re-computation of background error covariances, coordination and reporting within the consortium.

The main goal for 2022 is operationalization of certain validated observation datasets.

Proposed contributors, estimated efforts: approx. 1 pm per Member, **8 PM**

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

Description and objectives:

This work package is devoted to additional scientific validation, tuning and optimization of the current 3D-Var based systems. This includes in particular the tuning of the background errors and their correlation length scales, where more and more members are expected to apply the EDA rather than downscaled covariances. On observation side, possible improvements are expected from optimization of observation thinning and possible supeobbing. Initialization techniques are also to be investigated here to achieve optimal control of small-scale noise.

Specific tasks for 2022:

- Upgrade of BlendVar data assimilation cycle frequency from 6 h to 3 h, explore surface analysis setting/coupling within SURFEX. [DA 1.5]
- Evaluation of error statistics for the methods allowing to preserve results of host model analysis in a LAM domain Jk. Adapted V matrix and optimizations. [1.3]

Proposed contributors, estimated efforts: A. Trojáková (Cz) 3, A. Bučánek (Cz) 2, M. Derkova (Sk) 2.5, A. Stanešić (Cr) 1, E. Keresturi (Cr) 0.75, **9.25 PM**

Planned time frame: whole year

Planned deliverables: reports on LACE DA working days, ACCORD newsletter

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

Description and objectives: A major strategical goal will be to migrate to flow-dependent DA algorithms (mainly in OOPS-based Var and EnVar) and bring them to experimental/pre-operational stage for a few early members. This also involves scientific improvements of the ensemble data assimilation (EDA) system, e.g. related to ensemble size and model perturbations. Task for 2022:

- Make first steps towards 3D EnVar by getting familiar with the relevant OOPS code (also cooperation with university in Vienna)

Proposed contributors, estimated efforts: F. Meier (At) 1.5, **1.5 PM**

Planned time frame: whole year

Planned deliverables: reports on LACE DA working days, ACCORD newsletter

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

Radar reflectivity and radial wind observations remain among the top-priority observations in RC LACE. The area is quite well covered by radar sites and most of them are available through OPERA/OIFS data. This data set is complemented by national data or data from bilateral exchange. The radar data assimilation is operationally used in Austria (both wind and reflectivity) in their AROME-based system and in e-suite in the ALARO-RUC in Slovenia (only reflectivity).
The reflectivity DA (Bayesian inversion technique) is dependent on the radar site characteristics while the radar obs. operator depends on the use microphysical parametrization and used quantities. The reflectivity assimilation in ALARO is thus related also with implementation of prognostic graupel. To be able use Doppler wind from all radar stations, the dealiasing algorithm problem needs to be sufficiently solved first. A facility in the radar pre-processing software HOOF is foreseen to accomplish this, based on comparison and implementation of existing methods.
Further validation and especially sensitivity and impact studies are foreseen, and this is hoped to lead to more operational implementations.

Concrete tasks on the radar action to be addressed:

- Finalization and possible extensions on solution for wind dealiasing (torus mapping). [DA 3.1]
- Impact studies with original and de-aliased OPERA Doppler wind data [DA 3.1]
- Impact studies with OPERA reflectivity observations using Bayesian inversion, fine tuning of data/profile selection, thinning and application of superobbing. Investigation of the drying effect. [DA 3.1]

- Updates of the HOOF preprocessing tool. [DA 3.1]

Proposed contributors, estimated efforts: A. Bučánek (Cz) 4, A.Trojáková (Cz) 2, B. Strajnar (Si) 2, P. Smerkol (Si) 0.5, Kristóf Szanyi (Hu) 5, A. Stanešić (Cr) 1, S. Panežić (Cr) 3, M. Nestiak (Sk) 1, **18.5 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page, non t-code software

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

This action includes validation and progressive operational implementation of several observation types that have become available over the last years and are (most of them) distributed to Members via the OPLACE preprocessing system. For LACE this includes radar observations as top priority (see above) and other observations such as various surface observations, aircraft-derived data (ADD) including Mode-S EHS/MRAR, GNSS ZTD, various atmospheric motion vectors (AMV) and radiances from polar-orbiting satellites. Tasks to be accomplished in 2022:

- Refining the application of Mode-S observations in DA systems with increased assimilation cycle frequency, including application of variational bias correction (Var-BC) procedures. [DA 3.2]
- Evaluation and impact assessment of E-GVAP ZTD (possibly during a RC LACE stay). [DA 3.3]
- Use of mobile GNSS sensors on Austrian trains in cooperation with Technical university of Vienna. [DA 3.3]
- Further impact study with (extended) AMV observations in Hungary. [DA 3.5]
- Make initial proposal on the use of cloudy radiances for assimilation. [3.7]
- Implementation and test of high-resolution radiosondes (from OPLACE) in BUFR. [DA 3.8]
- Assimilation of Sodar/RASS observations - assessment of quality, finding or developing a suitable obs. Operator for wind/temperature information. [DA 3.10]

Proposed contributors, estimated efforts:

B. Strajnar (Si) 0.5, J. Cedilnik (Si) 2, A. Trojáková (Cz) 1, A. Bučánek (Cz) 1, G. Tóth (Hu) 2, H. Tóth (Hu) 0.5, Z. Kocsis (Hu) 1, M.Derkova (Sk) 1, A. Stanešić (Cr) 0.5, S. Panežić (Cr) 1, F. Weidle 3, F. Meier (At 0.5, M. Imrišek (Sk) 2, **16 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page, non t-code software

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

This action contains research and development activities related to exploitation of new, not yet routinely available observation data sources. Given the current observation structure in high resolution LAMs run by RC LACE members, the priority is on moisture and wind observations. Examples of this are GNSS-derived products apart from ZTD, aircraft humidity observations and delays in telecommunication links due to rain and use of advances satellite techniques. Research on these items include data provision, preprocessing and quality control in order to ensure reliable data sets of sufficient quality. In RC LACE, the following items are planned for 2022:

- Finalization of the implementation of slant tropospheric delays (STD) in the common model cycles (in cooperation with HIRLAM). [DA 4.2]
- 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]
- Refinement of the preprocessing to efficiently separate dry and wet attenuation, which should lead to a reliable relationship between attenuation and rain rate. Assimilation of rain rates using the obs. operator from P. Lopez. [DA 4.10]
- Test of assimilation of mobile phone links (from Austrian mobile phone provider) via the INCA-LHN in AROME-RUC. [DA 4.10]
- Test/feasibility study of assimilation of Sentinel 1 radar delays as ZTDs.

Proposed contributors, estimated efforts: B. Strajnar (Si) 1, P. Smerkol (Si) 2, P. Scheffknecht (At) 4, F. Meier 2.5, M. Imrišek (Sk) 2, M. Nestiak (Sk) 1, **12.5 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page, t-code contributions

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

Frequently updated assimilation approach ensures to employ more observations with reduced representativeness error in time. Hourly analyses can be carried out by fully cycled (RUC) and non-cycled data assimilation systems or combination of both. The observational datasets are constrained by fast delivery. In 2022, the following experimental (pre)operational RUC setups are planned:

- Validation and application of observations (those from DA 3) in RUC/nowcasting system and preparation of high resolution observational dataset suitable for nowcasting: the focus is on data with fast delivery, humidity observations (radar, ZTD) and locally available data which can enhance the widely available datasets. [DA 5.1]
- Design/improvement of existing and new hourly or sub-hourly RUC prototypes based on 3D-Var (Austria, Hungary, Slovenia, Slovakia). [DA 5.2]
- Explore possibility to initialize/modify the hydrometeors values in AROME-RUC by radar-derived rain type in AROME-RUC. [DA 5.3]

Proposed contributors, estimated efforts: A. Trojáková (Cz) 0.5, A. Bučánek (Cz) 0.5, B. Strajnar (Si) 1, K. Szanyi (Hu) 5, H. Tóth (Hu) 2, F. Weidle (At) 0.5, **9.5 PM**

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

The general goal of this action in (as defined in the RWP2022) is to enable the object-oriented C++ layer for control of the LAM data assimilation (and forecast model) applications. The computational code remains in FORTRAN, based on the IFS/Arpège/LAM shared codes, but has to be adapted (re-factored) towards an OO coding. LACE has been partly involved in 2021 by porting and comparing the existing MASTERODB version of 3D-Var minimization with the OOPS-based one (available from cycle 46t1). The ultimate target is be to be ready to switch any NWP system to OOPS binaries after ECMWF and MF have done so (presumably 2023). The following concrete task is planned:

- Prepare a prototype of full-scale OOPS-based DA system (initially 3D-Var, with possible extension to 3D/4D EnVar).

Proposed contributors, estimated efforts: B. Strajnar (Si) 1.5, P. Smerkol (Si) 2, **3.5 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

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

The work package includes mainly the maintenance and evolution of the OPLACE preprocessing service which provides majority of observations for RC LACE DA systems (see also LACE DM plan). Additional this work package includes implementation and extension of diagnostics tools such as ObsTool (determination of observation error and thinning distance), DFS (weight of observations in the analyses), ObsMon (observation monitoring), moist total energy norm (weight of relative observation impact on forecast) and adjoint forecast sensitivity to observation (FSOI). All of them except FSOI are used within RC LACE but some of the tools would need an update (scripts, executables and support for new obs. types).

Tasks:

- Maintenance and development of observation preprocessing system OPLACE (details with manpower in Data Manager plan) [DA 7.5]
- Optimization and customization of the Obsmon observation monitoring package. Application of DFS and MTEN. [DA 7.2]

Proposed contributors, estimated efforts: S. Panežić (Cr) 1, A. Stanešić (Cr) 1, **2 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

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

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. Poland and Romania, which are for the time being also part of the DAsKIT, plans to consider the following tasks:

- 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 system. [DA 8.1]

Proposed contributors, estimated efforts: M. Szczech-Gajewska (Pl) 4, A. Dumitru (3), **7 PM**

Planned time frame: whole year

Planned deliverables: reports on DAsKIT working days, ALADIN/HIRLAM newsletters

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

Description and objectives:

The Simplified Extended Kalman Filter (SEKF) framework in SURFEX land model allows for assimilation of conventional and non-conventional observations to generate surface analysis in a more flow-dependent way. In this LACE action both AROME and ALARO models are considered to be utilized within SEKF. In 2022 the following actions are foreseen:

- Experiments, design of parallel suites and operationalization with SEKF and SYNOP observations in AROME cy43t2, application to high resolution (Hungary) [SU 1.1]

Proposed contributors, estimated efforts: H. Tóth (Hu) 3, **3 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

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

Description and objectives:

One of the main advantages offered by the Extended Kalman Filter (EKF) approach to surface and soil data assimilation is to be able to successfully assimilate non-conventional observations, such as land surface temperature (LST), leaf-area index (LAI), different surface/soil properties such as albedo and snow water equivalent. This action is devoted to make benefit from rapidly evolving satellite soil observation methods. The following tasks are planned for 2022:

- Assimilation of Sentinel-2 based LAI within SEKF in AROME/SURFEX, impact experiments [SU 2.8.2]

- Application of daily-updated LAI in AROME/HU using SURFEX-ISBA-Ags [SU 2.8.2]
- Evaluation of LSA LST in SEKF [SU 2.9.1]

Proposed contributors, estimated efforts: H. Tóth (Hu) 1, B. Szintai (Hu) 4, S. Oswald (At) 1.5, S. Schneider (At) 0.5, **7 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

Summary of resources

Subject	Estimated manpower (PM)	From LACE	Other (HIRLAM, ALADIN)
Operational implementation of DA suites [COM3]	8	8	-
Further development of 3D-Var [DA 1]	9.25	9.25	
Development of flow-dependent algorithms [DA 2]	1.5	1.5	-
Use of existing observations [DA 3.1] – radar	18.5	18.5	-
Use of existing observations [DA 3] – other data types	16	16	
Use of new observations types [DA 4]	12.5	12.5	-
Development of assimilation setups suited for nowcasting [DA 5]	9.5	9.5	-
Participation in OOPS development [DA 6]	3.5	3.5	
Observation pre-processing and diagnostic tools [DA 7]	2	2	-
Basic data assimilation setup (DAsKIT) [DA 8]	7	7	-
Algorithms for surface assimilation [SU 1]	3	3	-
Use of observations in surface assimilation [SU 2]	7	7	-
Total	**97.75**	**97.75**	**-**

Meetings, events and list of RC LACE stays

AL travels:

1) 3rd ACCORD ASW 2022, Ljubljana.
2) 44th EWGLAM meeting and 29th SRNWP workshop 2022.
3) Spring and autumn LSC meetings and RC LACE management meeting.
4) 8 participants at DA Working Days/ DAsKIT meeting or other equivalent ACCORD DA meeting 2022.
5) Attendance to SURFEX working days.
6) Participation of AL to other ACCORD DA working weeks (if organized as physical meeting), online participations to other ACCORD DA events.

LACE stays:

1) S. Panezić (Further sensitivity studies with radar reflectivity DA) – CHMI Prague (3-5w)
2) P. Scheffknecht (assimilation of microwave links) – ARSO Ljubljana (3-4 w, postponed from 2021)
3) A. Dumitru (Computation of background-error covariances) - CHMI Prague
4) K. Szanyi (Reflectivity data assimilation incl. test of superobservations)
5) M. Ličar (Remote-sensed observations in SEKF) – ZAMG Austria or OMZS Hungary

Additional open proposals (please propose candidates):

- Hosts: CHMI (GNSS ZTD assimilation)

Execution will highly depend on Covid-19 conditions and restrictions.

Problems and opportunities

- Part of the planned activities (stays, DA code training) might be finally cancelled or delayed due to Covid-19 conditions.
- Considerable manpower spent on maintenance & evolution of systems (on the longer term, implementation of DA in OOPS is expected to ease maintenance).
- Too little focus on algorithms compared to observation developments: progressively, more manpower should to be directed to DA algorithms (such as EnVar in OOPS for instance or algorithms suited for NWP-based nowcasting).

- Changes of staff in some countries.
- Opportunity: wider coordination and exchange within the new ACCORD DA area