Working Area Data Assimilation

Work Plan

Prepared by:	Area Leaders Benedikt Strajnar & Antonín Bučánek
Period:	2024
Date:	23/02/2024

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 person-power is typically 1-1.5 FTE per Member but a relatively large share of it 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 HPC computations.

At the time, six RC LACE countries run 7 operational DA systems to initialize their short-range deterministic weather forecasts plus 3 NWP-based nowcasting suites and 3 ensemble systems that also apply data assimilation. Poland and Romania have not yet reached operational level in data assimilation but have ambitions to do so.

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

The reporting and planning of work in the common ACCORD consortium is now managed also through the Rolling Work Plan (RWP), and the current plan is therefore highly aligned with RWP2024 (in its current draft form), where the packages were considerably restructured to simplify collaboration in smaller topical teams on data assimilation in ACCORD. The person power figures are currently provisional but they are expected to be finalized in October 2023.

Goal

The RC LACE focuses on optimizing 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 more frequently (1 hour) updated systems which are currently under design or validation (Hungary, Slovakia, Croatia) and further refinement of existing systems (Austria, Slovenia,

Czech Republic) and progressive migration to flow-dependent algorithms such as **ensemble-variational (EnVar)** assimilation enabled by the OOPS assimilation codes. First prototypes of such systems are available (Geosphere Austria) and under evaluation, and initial experience was shared in the consortium. An important prerequisite for EnVar is availability of a driving ensemble to enable a flow-dependent background error covariance estimation. For the two countries running operational LAM ensemble an obvious choice is to use this information, although this may turn out challenging with respect to number of ensemble members, schedules and overall tuning of these ensembles. For others a generic solution with external ensemble (i.e. with different resolution and model setup) may be considered, such as A-LAEF or global ensemble output from IFS/ECMWF.

Another direction of algorithmic development will be towards utilization of an alternative soil analysis scheme to operationally replace the currently used OI. Two approaches appear attractive: 1) the Simplified Extended Kalman Filter (SEKF) within the SURFEX land model is operational in Hungary and will be further validated 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 leaf area index (LAI), soil wetness index (SWI) and the land surface temperature (LST). 2) Moving towards incorporating real-time upper-air ensemble information, the 2D-EnVar for surface analysis was developed and validated at Meteo France within the OOPS system. Again, a precondition to develop such a system is availability of a suitable driving ensemble system.

Effective use of numerous observations remains the top priority of the LACE DA group. Most of the efforts in upper-air data assimilation is currently invested in implementation of the radar data assimilation and this is expected to continue in 2024. One of the outstanding goals in 2024 is to **widespread use of radar reflectivity** provided by OPERA. A stopping point for this is partly a marginally successful performance of Bayesion inversion which has been validated and tuned a lot with certain success, however is still does not perform satisfactory in all situations and thus often fails to meet rather high user expectations for convective scale NWP. New algorithms such as EnVar open way for a more direct approach to reflectivity assimilation by including hydrometeor fields in the control vector for assimilation. Furthermore, as a solution for dealiasing is now available, validation and impact studies with radar winds need to become a priority. GNSS-derived data are another example of important observations with already considerable past investment but relatively few operational applications, also because of issues with the data policity, isolated providers and quality issues. A couple of other observation types have certain potential for improvement (atmospheric motion vectors, and new types such as GNSS slant delays and microwave link delays), but also severe potential limitation as these efforts typically relies on external funding and limited data provision.

Action/Subject/Deliverable: ***Operational maintenance of DA suites [COM3.1]***

Description and objectives:

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

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

Action/Subject/Deliverable: ***In-situ observations [DA1]***

Description and objectives:

This LAM data assimilation relies to a large extent on existing traditional conventional in-situ observations. One of the basic goals of this package is to ensure their optimal use and evolution in terms of extended data provision (such as high-resolution and descent radiosonde data, high-resolution national automatic meteorological station networks, humidity from aircraft, growth of Mode-S derived aircraft observations). Furthermore, significant opportunities are offered by crowd-sourced in-situ observations from private weather stations, smartphones and other IoT devices with weather-related sensors.

List of tasks in this package:

- Implementation of high-resolution ascent and decent radiosondes and wind profilers: optimize local pre-processing, extend observation operator, assess the quality and perform impact study. (DA1.2)
- High-resolution crowd-sourced surface observations (surface pressure, T2m, Q2m, V10m): further explore the potential of volunteered observations from crowdsourced, private weather stations, cars, and smartphones (DA1.3).
- Aircraft-based observations: assist implementation of Mode-S wind and temperature (EHS and MRAR); assess performance of fast observations from EMADDC. (DA1.4)

Proposed contributors, estimated efforts: H. Tóth (HU) 2, V. Homonnai (HU) 1, D. Lancz (HU) 2, A. Dumitru (RO) 2, A. Stanešić (CR) 2, B. Strajnar (SI) 1, M. Nestiak (SK) 1, M. Derkova (SK) 1, **12 PM**

Action/Subject/Deliverable: ***Use of ground-based remote sensing [DA 2]***

Description and objectives:

The general goal is to optimize the use of ground-based remote sensing observations from currently used sources and networks. A major data source in this group are meteorological radar and close collaboration with OPERA is foreseen important to ensure optimal use of their products. Apart from the ongoing activities with reflectivity, more investigation needs to be devoted to use of radar wind information and the dealiasing methods, and possibly also derived cloud and hydrometeor information. Other important techniques include GNSS (through E-GVAP) and wind profilers. In addition, we aim to explore new products from existing and new networks. Examples of such new products are GNSS slant delays (SD) and horizontal gradients (HG), microwave links.

List of tasks:

- Implementation of reflectivity data assimilation (OPERA data) based on common preprocessing HOOF and benefiting from recent recommendations on tuning of Bayesian inversion (DA 2.1)
- Impact studies with original and de-aliased OPERA Doppler wind data. Finalization of a scientific paper on implementation of dealiasing. (DA 2.1)
- Test of super observation functionality in HOOF for radar reflectivity (or alternatively radial wind). (DA 2.1)
- Further elaborate the assimilation of GNSS ZTD observations and conduct impact studies, focusing on data from regional providers, assist quality improvement of solutions from these centres (DA 2.2)
- GNSS slant delay impact studies with 3D-Var (DA 2.2)
- Attenuation in telecom. microwave links due to rain/cloud: refine the processing to efficiently separate dry and wet attenuation. Study suitable observation operators to assimilate retrieved rain rates (cloud ingestion, standalone physics package from P. Lopez, etc.) (DA 2.3)

Proposed contributors, estimated efforts: A. Trojáková (CZ) 3, A. Bučánek (CZ) 5, S. Panežić (HR), A. Zajec (HR), M. Nestiak (SK) 2, M. Imrišek (SK), M. Petrovic (SK) 2, H. Toth (HU), newcomer (HU) 3, P. Smerkol (SI), B. Strajnar (SI), P. Schefknecht (AT), F. Meier (AT), F. Weidle(AT), **20 PM**

Planned time frame: whole year

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

Action/Subject/Deliverable: ***Satellite-based remote sensing observations [DA 3]***

Various type of satellite observations are presently being used in the LACE DA systems. A particular challenge in central Europe is that only a small fraction of model domain is covered by sea, and implementation of radiance assimilation over land is more difficult du to ground contamination. Currently the radiances are used in clear-sky mode only but there is interest in using cloudy information to support analysis during convective activity. For observation types already available in the assimilation system, ways are being investigated to optimize their use with regard to quality control, thinning/superobbing, cloud detection and bias correction. An international collaboration in necessary to ease implementation of new sensors and to be able to refine the use of existing data from traditional instruments and react to abrupt changes in delivery or quality. Preparation activity for new sounders such as MTG-IRS should also be prioritized due to its expected significant information content.

Tasks:

- First steps towards using visible information from MSG with RTTOV visible operator and implementation of assimilation interface. Provide good description of albedo to screening and minimization. (DA 3.2)
- Implement new or revised all sky assimilation strategy for IASI as preparation to use similar data from MTG IRS. (DA 3.2)

Proposed contributors, estimated efforts: A. Neduncheran (AT) 4, F. Meier (AT) 2, S. Panežić (CR) 4, B. Strajnar (SI) 1, **11 PM**

Planned time frame: whole year

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

Action/Subject/Deliverable: ***Observation pre-processing, quality control, bias correction and representation error [DA4]***

List of tasks:

- Maintain and develop a near-real time observation monitoring of surface, aircraft and radar observations over a large European domain, using IFS/ECMWF background (DE_330). (DA 4.2)

- Maintenance and development of observation preprocessing system OPLACE (details with person power in Data Manager plan). (DA 4.3)
- Tuning of observations and background and representation error, revise thinning, QC and VarBC settings. (DA 4.6)

Proposed contributors, estimated efforts: D. Lancz (HU), H.Toth (HU) 1, B. Strajnar (SI), N. Kastelec (SI) 1, **3 PM**

Planned time frame: whole year

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

Action/Subject/Deliverable: ***Variational assimilation systems [DA5]***

The general goal is to refine and optimize the existing variational systems, including the use of large scale information in the LAM analysis.

This currently applies to both the MASTERODB and the OOPS environments, although the long term goal is to have all applications and facilities functional within OOPS. The testing and development of OOPS components will benefit from the DAVAI framework, now ported to ECMWF computing framework.

There is a close relation of this package with cycling strategies (DA8), as well as observation usage, quality control and monitoring (DA1-DA4, DA7).

List of tasks:

- Develop, validate and consolidate full assimilation cycles using OOPS binaries (DA 5.1)
- Maintenance and evolution of current DA suites (3D-Var, BlendVar), exchange of scientific achievements between ACCORD partners. (DA 5.6)

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

Planned time frame: whole year

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

Action/Subject/Deliverable: ***EnVar, EDA and variants [DA 6]***

The work package is devoted to use of ensemble approaches in data assimilation, with two main R&D axes: 1) use and development of ensemble data assimilation (EDA) technique, where error contributions are simulated (through corresponding perturbations) and propagated during the assimilation cycling, to provide a sample of background perturbations. b) development of ensemble-variational (EnVar or hybrid-EnVar, 3D and 4D versions) assimilation algorithms that use this sample to specify the B-matrix (with specific filtering methods) during the minimisation step. Background error perturbations are usually used to model the B-matrix within deterministic/variational algorithms (DA5) most often provided by an ensemble approach with several possible computation methods which are to be investigated and refined. For EnVar, several implementation options can be explored (i.e. using ensemble members at coarser resolution, different LAM ensemble system or global model). Furthermore, the EnVar relaxes the specification of control vector for minimization so adding additional fields (e.g. hydrometeors and NH variables, surface fields) can be considered and is a mid-term goal.

List of tasks:

- Prepare a prototype of full-scale OOPS-based 3D/4D EnVar system. (DA 6.1, DA 6.2)
- Explore the use of global ensemble in LAM 3D/4D EnVar (DA 6.9)

Proposed contributors, estimated efforts: B. Strajnar (SI) 3, F. Meier (AT) 3, **6 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

Action/Subject/Deliverable: ***Initialization methods and nowcasting [DA 7]***

Weather forecasting in the nowcasting mode is very challenging for forecasters and sufficiently accurate near real time automatic nowcast products are among most anticipated deliverables by the LAM community. The goal of this work package is to improve the existing NWP-based nowcasting suites, based on DA methodologies dealt with in DA 5-6, by focusing on methodologies and approaches that can contribute to faster, more accurate and/or more balanced initialization. Objectives are:

Tasks:

- Explore enhancements of radar DA with nudging techniques. (DA 7.3)
- Inter compare and tune initialization options suitable for 1h DA cycling in RUC. (DA 7.4)

Proposed contributors, estimated efforts: M. Derkova (SK), M. Petrovič (SK), **1 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

Action/Subject/Deliverable: ***Diagnostic methods, optimization of assimilation cycling [DA8]***

The objective this work package is to maintain, develop and apply various diagnostics tools to assess and improve the quality of the assimilation cycle, through learning about the relative impact of observations and tuning of components of the DA system. The central approach taken in ACCORD is application of a-posteriori diagnostics and tuning based on covariance of residuals (Desrozier's method). This methodology allows for individual tuning of observation and background errors and diagnostics of relative impact of observations (e.g. degree of freedom for signal), and the relative impact of a given observations on the short-range forecasts of the assimilation cycle. Further optimization can be gained by adjusting the length and position of data assimilation window with respect to nominal analysis time and by relaxing the definition of assimilation window (e.g. moving or overlapping windows, continuous data assimilation).

List of tasks:

- Consolidate the existing DA diagnostic tools developed in LACE (e.g. Obstool, TuneBR) and make them available as stand-alone applications in ACCORD-NWP git repository. (DA 8.1)
- Optimize assimilation cycling strategy (window length, cutoff) for RUC to benefit from enough recent observations. Explore several options with respect to frequency of surface assimilation in RUC. (DA 8.3)

Proposed contributors, estimated efforts: A. Bučanek (CZ) 1, B. Strajnar (SI) 1, A. Stanešić (CR) 1, **3 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page, contributions to ACCORD/NWP git

Action/Subject/Deliverable: ***AI/ML methods for data assimilation [DA9]***

Description and objectives:

The Objective of WP9 is to explore abilities of non-linear statistical methods to achieve a more efficient use of observations to improve quality of short range numerical weather prediction forecast and nowcasts. The focus of the WP9 is on the tasks where the traditional

NWP experiences challenges at present and where an added value of high-resolution NWP is expected, such as modeling of relationships between the model state and the observed quantities, extraction of relevant information from observations, emulation of expensive processes, sampling of uncertainty, initialisation issues, improved quality of the short range forecasts.

No concrete planned tasks are current identified. Realization of AI activities depend on success of several external project proposals.

- A feasibility study to find optimal/representative model reflectivity profile for radar reflectivity DA in inversion routine

Proposed contributors, estimated efforts: (SI ?) **PM**

Planned time frame:

Planned deliverables:

Action/Subject/Deliverable: ***Surface assimilation [SU1, SU2]***

Description and objectives:

To initial soil fields for use in NWP, traditional SYNOP observations are combined or replaced with satellite based products/radiances representing e.g. surface temperature (land/sea-ice/lake), Leaf-Area Index (LAI), Vegetation Optical Depth (VOD), surface soil moisture, snow cover, snow water equivalent and snow albedo. Attempts are planned to assimilate both retrieval products (such as soil moisture and LAI) and radiances, using appropriate observation operators. The tasks include data pre-processing, as a preparation for 2D spatialisation. The dominating tool for 2D horizontal spatialisation in CANARI is Optimum Interpolation (OI) but development of 2D-Var and 2D-EnVar methods are also ongoing in ACCORD. Algorithms of the vertical assimilation part in SODA are based on Optimum Interpolation (OI), Simplified Extended Kalman Filter (SEKF) and Ensemble Kalman Filter (EnKF).

List of tasks:

- Implementation, experiments, design of parallel suites with OI and SEKF and SYNOP observations in AROME and ALARO, application to high resolution. [SU 1.3.1]
- Consider, develop and evaluate SEKF for explicit snow scheme as implemented in SURFEX/SODA. (SU 1.1.3)

- Develop an offline analysis environment based on full physics in SURFEX forced by a near-real-time to provide an initial state for SURFEX variables in a new cycle. (SU 1.7.1)
- Tuning of soil water content initialization in OI/CANARI. (SU 1.1.11)
- Assimilation of daily updated LAI (Sentinel-based) within SEKF in AROME/SURFEX, impact experiments (SU 1.3.5)
- Development of SYNOP-based snow analysis in CANARI. (SU 1.1.4)
- Assimilation of satellite moisture information (SWI) within SEKF in AROME/SURFEX, impact experiments (SU 1.3.4)

Proposed contributors, estimated efforts: B. Szintai (HU) 6, H. Toth (HU) 6, S. Oswald (AT), S. Schneider (AT) 4, M. Ličar (SI) 6, A. Bučanek (CZ) 2, A. Trojakova (CZ) 1, J. Ševčík (CZ), **25 PM**

Planned time frame: whole year

Planned deliverables: report on LACE web page

Summary of resources

Subject	Estimated manpower (PM)	DEODE (PM)	Other (HIRLAM, ALADIN)
Operational maintencance of DA suites [COM3]	8		-
In-situ observations [DA1]	12		
Use of ground-based remote sensing [DA2]	20		-
Use of satellite observations [DA3]	11		
Observation preprocessing, quality control, bias correction and representation error [DA4]	3		-
Variational algorithms [DA5]	8		
Ensemble methods (EDA, EnVar) [DA6]	6		-

Initialization methods and nowcasting [DA7]	1		-
Diagnostic methods, optimization of assimilation cycling [DA8]	3		
ML in data assimilation [DA9]	?		
Surface assimilation [SU1/SU2]	25		-
Total	**97**	0	**-**

Meetings, events and list of RC LACE stays

AL travels (or online attendance):

1) ACCORD ASW, March 2024.
2) Working weeks for ACCORD DA research and development teams (up to 3 meetings).
3) 46th EWGLAM meeting and 31th SRNWP workshop 2024 (Prague).
4) EUMETSAT Core NWP meetings, online.
5) OPERA NWP user group meeting, online.
6) WMO workshop, Impact of various observations
7) Spring and autumn LSC meetings and RC LACE management meetings.

Plan of LACE stays:

1) **David Lancz (HU)**: Data assimilation of high-resolution and descent data from radiosondes - SHMU Bratislava (4W)
2) **Michal Nestiak (SK)**: Testing of radar data from new OPERA NIMBUS production line - CHMI Prague (2W)
3) **Martin Petrovič (SK)**: Data assimilation and validation of radar radial winds observations - CHMI Prague (4W)
4) **Suzana Panežić (CR)**: Data assimilation of all-sky radiance observations from MTG IRS - ARSO Ljubljana (2W)
5) **Suzana Panežić (CR)**: Data assimilation of all-sky radiance observations from MTG IRS - Geosphere Vienna (2W)
6) **Anamarija Zajec (CR)**: ALARO/SURFEX surface data assimilation - ARSO Ljubljana (4W)
7) **Alina Dumitru (RO)**: ALARO/SURFEX surface data assimilation - CHMI Prague (4W)

Problems and opportunities

- Considerable manpower spent on maintenance & evolution of local systems (on the longer term, implementation of DA in OOPS is expected to someshat ease maintenance).
- Progressively, more manpower should to be invested to DA algorithms (such as EnVar in OOPS for instance or algorithms suited for NWP-based nowcasting).
- Interference with DEODE (skilled people are involved there even when newcomers are formally employed, opportunity to increase manpower).