Working Area Predictability

Progress Report

Prepared by:	Area Leader: Clemens Wastl
Period:	2022 (Jan-Jun)
Date:	September 2022

Progress summary

A lot of EPS related work has been done in the first half of 2022 within RC-LACE. Some of the planned actions are a bit delayed because of postponed stays (COVID, personal reasons), but most of them should be carried out in autumn 2022.
Furthermore, also the operational topics in S1 are delayed because of a strong delay in the availability of the new ECMWF HPC (Atos) in Bologna. It was originally planned to be available end of 2020, but first access was enabled not until March 2022. Therefore all the migration topics of the two operational suites running at the ECMWF HPC (A-LAEF and C-LAEF) which were originally planned in 2021, were postponed and could not start before spring/summer 2022. Now (end of September) Esuites of A-LAEF and C-LAEF are running in a pre-operational mode at the new ECMWF HPC and first verification results are promising. The final migration is planned to be finished until the end of October. With substantially more SBUs available on the new machine (about double), we are planning to expand the operational ensemble systems (e.g. higher resolution, longer lead time, etc.) in the near future.

In April the first ACCORD EPS working week was held in Innsbruck/Austria. Some of the EPS people of RC-LACE participated and it was a very good and intensive collaboration with the EPS experts from the other consortia (especially from HIRLAM). A lot of code (e.g. surface perturbations, SPP, etc.) and experiences were exchanged within the participants and it was decided to organize such EPS working weeks at least once a year (next one is planned in April 2023 in Helsinki).

Also the scientific work is progressing well in the EPS area of RC-LACE. New developments like the parameter perturbation scheme in C-LAEF or the EDA in the Hungarian AROME-EPS are far advanced and should be ready for operationalization soon. Some preliminary work has been made in the topic of flow-dependent model perturbations and also in the area of statistical post-processing some progress is visible.
Furthermore, some new EPS products and EPSgrams have been developed for the A-LAEF webpage, some articles have been published and the EPS related work has been presented at international workshops and conferences.

Scientific and technical main activities and achievements, major events

S1 Subject: Preparation, evolution and migration

Description and objectives: Maintain and monitor the operational suites of A-LAEF and C-LAEF running on ECMWF's HPC and the AROME-EPS running at the HPC at OMSZ. Migration and implementations to new HPCs, operational upgrades, new cycles, optimizations and tunings.

The originally planned topics for 2022 are:

- ❏ A-LAEF and C-LAEF: Migration to the new ECMWF's computer in Bologna and upgrades to cy43.
- ❏ A-LAEF: Upgrade of the upper-air IC uncertainty simulation by ENS BlendVar
- ❏ C-LAEF: Possible expansion of C-LAEF (higher resolution, more members, larger domain) with the expectation of more SBUs at the new HPC at the ECMWF
- ❏ C-LAEF: Adaptation to other domains (e.g. Turkey)
- ❏ AROME-EPS: Optimization and tuning of convection-permitting ensemble system on HPC at OMSZ;
- ❏ AROME-EPS: add new operational runs (00 UTC, 06 UTC)
- ❏ AROME-EPS: Introduction of EDA in AROME-EPS

Some of these topics have been postponed because of a significant delay in the availability of the new HPC of ECMWF in Bologna. It was originally planned to be fully available at the end of 2020, but first access to the system was possible not before Q2 2022. Now, end of summer 2022, still not everything is available (e.g. transfer, dissemination, archiving, etc.) and therefore a final pre-operational status of the A-LAEF and C-LAEF systems is not yet possible. The final migration work is now planned for September/October 2022. It has to be finished end of October, since the old HPC (Cray in Reading) should be switched off at this time (if not postponed).

For the operational A-LAEF suite on Cray (old ECMWF HPC) several interventions were needed due to OPLACE issues (related to OMSZ server upgrade). The SBU accounting was topped up in June (+30 M by Slovenia) and in August (+65 M by Turkey). Until end of August about 100 M SBUs were consumed by A-LAEF (as prospected).

The introduction of EDA in AROME-EPS is also delayed - some intensive testing is currently ongoing with cy43t2. This work has been devoted now to S3 – initial condition perturbations, since it is still research work and not yet ready for operations. The operational AROME-EPS has been updated by including an additional long term run and is now providing 2 long runs (00 and 12 UTC) a day.

The work spent on S1 topic in the first half of 2022 comprises mostly following topics: Migration of operational suites of A-LAEF and C-LAEF to new ECMWF HPC (first

steps), upgrades in the operational A-LAEF suite, possible expansion of C-LAEF and the adaptation of C-LAEF to other domains.

- **Topic 1: Migration to the new ECMWF's computer in Bologna and upgrades to cy43**

A lot of work in the first half of 2022 has been spent on getting used to the new HPC environment at the new centre in Bologna. First access to the new HPC was enabled end of March 2022. The official training course (High performance computing – Atos) has been attended by the relevant persons in RC-LACE (Florian Weidle, Clemens Wastl, Martin Bellus, Endi Keresturi, etc.) in March.

A-LAEF:

In summer 2022 the migration work of A-LAEF TC2 suite to the Atos HPC in Bologna started. The progress now end of September is satisfactory.

Figure 1: Cluster status of AC1 (a part of many complexes AA, AB, AC, AD; left) and the whole AC complex (right).

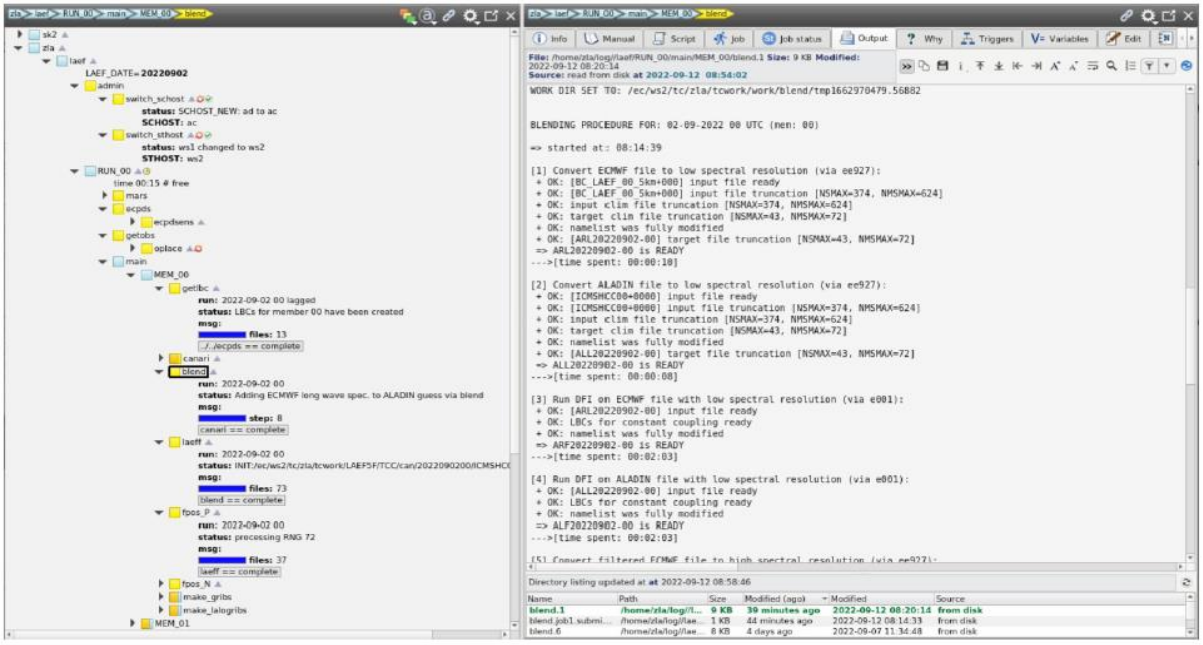

Figure 2: ecFlow suite of A-LAEF (TC2) in the development on HPCF Atos in Bologna.

Several technical upgrades of the A-LAEF tasks have been made. The LBC preparation (c903) was upgraded to cy48t2 (multi-domain processing possible) and some child processes have been added to the A-LAEF integration (e001) for live monitoring of tasks' progress (Figure 2). Quite some time was spent on ENV issues and also on the jobs tuning on the Atos system. The results are very promising - keeping the consumption of SBUs on a current level, some jobs run substantially faster. The ECTRANS connection to OPLACE has already been established to fetch the OBS files for assimilation cycle. Currently, just the conversion of FA files (both for the LACE's Lambert domain, and the users' latlon domains) still needs to be done, and there is also a small issue with shuffle within the assimilation cycle which needs to be solved.

C-LAEF:

After migrating the C-LAEF scripts/environment to Atos and compiling of AROME code, the first test runs of C-LAEF on the new machine (on personal users) have been done in May/June. At the beginning a lot of stability problems (jobs suddenly crashed, etc.) appeared, which could be solved together with the ECMWF staff. A first, stable version of C-LAEF E-suite on Atos could be launched at the beginning of July. Verification of the summer months (July, August - Figure 3) shows comparable results for all the relevant parameters. Some time has also been spent on the optimization of the task arrangement on the new facilities (number of cores, CPUs, etc.).

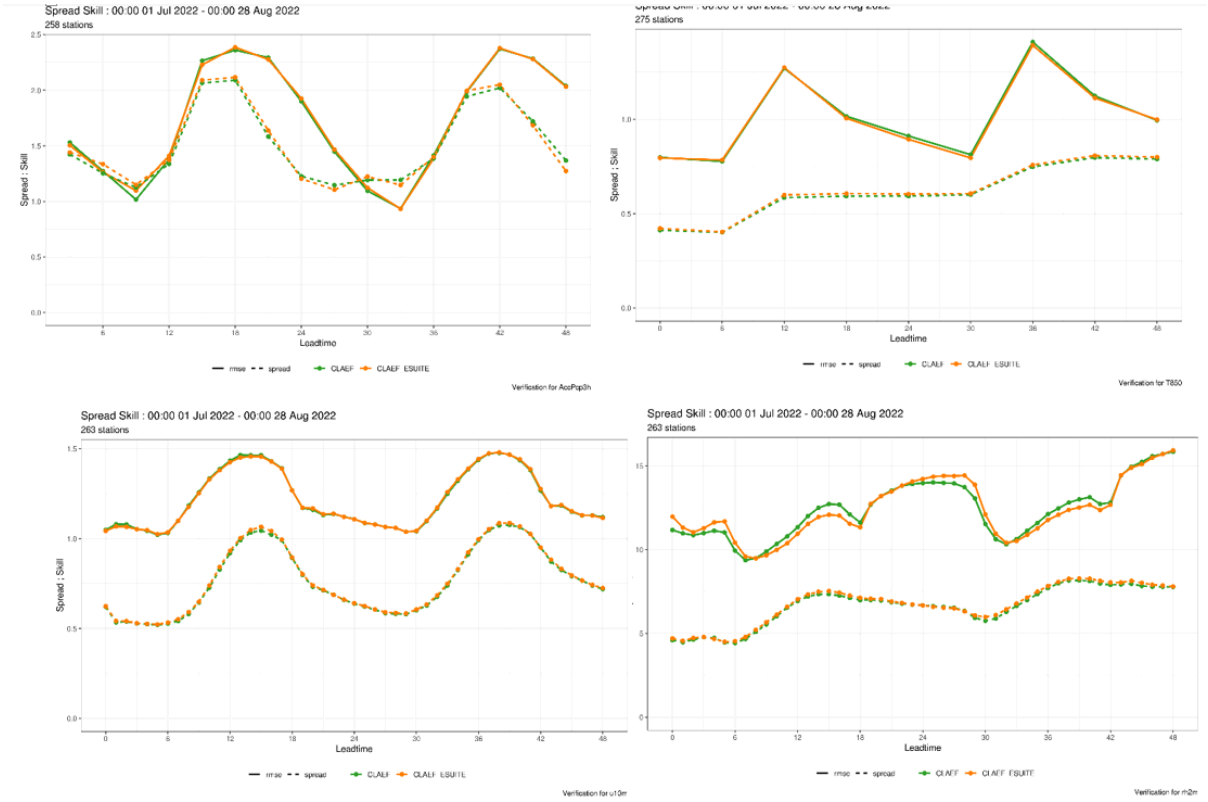

Figure 3: Comparison of operational C-LAEF (on Cray, green) and C-LAEF E-suite (on Atos, orange) for 3h accumulated precipitation (upper left), 850hPa temperature (upper right), u-component of 10m wind (bottom left) and 2m relative humidity (bottom right) for the period July-August 2022. Dashed lines show ensemble spread and solid lines RMSE.

In August we started to work on the C-LAEF suite for the operational TC2 users for C-LAEF (zat, zat2). Until now (end of September) still not everything is available on Atos: 1 filesystem (ws1) is still missing, the transfer from ECMWF to ZAMG with ectrans is not yet possible, couplingfiles from the ECMWF-ENS E-suite on Atos are not yet available, ecaccess (e.g. for automatic job triggering) is not yet available, etc.

- ❑ **Topic 2: C-LAEF: Possible expansion of C-LAEF**

With the expectation of much more SBUs on the new ECMWF HPC (about double the amount compared to the old Cray HPC) we have some freedom in expanding the operational C-LAEF suite. There are several possibilities to spend the additional SBUs – e.g. more members (currently 16+1), more long runs (currently 2), longer lead time (currently 60h), higher resolution (currently 2.5km), larger domain. We have made some tests to assess the additional SBUs needed for longer leadtimes (expansion to +72h), more long runs (00, 06, 12 UTC) and higher resolution (1km). We finally decided that the main priority will be set to the higher resolution. First long test runs with a C-LAEF 1km suite (pure downscaling without data assimilation) have been started in summer 2022. Despite the increased amount of SBUs on the new ECMWF HPC, we will not be able to completely cover the necessary resources (at least six times more than the current 2.5km operational suite) without optimizations. The first step in this direction has already been made by setting up a C-LAEF 1km suite on the new ECMWF HPC based on the single precision code. This code saves up to 30-40% of resources. Another important step towards a C-LAEF 1km system is the new ZAMG HPC, which is expected at the end of 2023. The idea is to use the power of both HPCs (ECMWF and ZAMG) and set-up a kind of shared C-LAEF system (e.g. split of members, common scripting system, common assimilation, etc.).

- ❑ **Topic 3: Adaptation of C-LAEF to other domains**

To increase the usage of C-LAEF it is planned to provide the C-LAEF system (scripts, source code, namelists, etc.) to other meteorological services. Turkey has already announced their interest in a high resolution EPS a few years ago. Due to COVID and other unfavorable circumstances the planned stay of a Turkish colleague at ZAMG to set-up C-LAEF for a Turkish domain has been postponed several times. Now it is finally fixed to take place in October 2022. A lot of preparatory work has already been made in spring/summer 2022. Scripts, source code and namelists have been provided to the Turkish colleagues, a first test suite on ECMWF-HPC Cray has been set-up and the B-Matrix for the assimilation has already been calculated. Most of this work has been done by Turskish colleagues, so it is not directly part of the RC-LACE report.

Efforts: 7.25 PM (planned 21 PM total in 2022)

Contributors: Martin Belluš (SHMU), Clemens Wastl, Florian Weidle and Christoph Wittmann (ZAMG), Katalin Jávorné-Radnóczi and David Lancz (OMSZ)

Documentation: Reports on stays and case studies (on webpage); papers submitted to scientific journals; improvement of current regional ensemble system through the results and outcomes of R&D

Planned stays:

1. Martin Bellus (4 weeks at ZAMG) – A-LAEF migration and upgrade – postponed
2. Mustafa Başaran (1 week at ZAMG) - ACCORD stay - set-up of C-LAEF for Turkish domain – planned for October 2022

Status: Ongoing; a lot of delays and shifts in this topic due to postponed stays (COVID) and the delay of the new EMCWF-HPC.

S2 Action/Subject/Deliverable: Model perturbations

Description and objectives: Research and development concerning model perturbations in the three EPSs within RC-LACE. Study ways to represent uncertainty in the atmospheric models itself and how to best incorporate this into the models.

The originally planned topics for 2022 are:

- ❏ A-LAEF: Stochastic perturbation of fluxes instead of tendencies in order to preserve the energy balance in perturbed model.
- ❏ C-LAEF: Improvement of stochastic parameter perturbations (SPP) with special focus on convective hazards (e.g. processes in microphysics)
- ❏ C-LAEF: Development of flow-dependent model perturbations

Some of these topics (e.g. stochastic perturbation of fluxes, development of flow-dependent model perturbations) are delayed because the respective stays have been postponed due to COVID or personal reasons. Main work in this action so far in 2022 has been spent on the stochastic parameter perturbation scheme in C-LAEF and on the flow-dependent model perturbations.

- ❏ **Topic 1: C-LAEF - Improvement of stochastic parameter perturbations (SPP) with special focus on convective hazards (e.g. processes in microphysics)**

C-LAEF is based on the non-hydrostatic AROME model with a horizontal resolution of 2.5 km and 90 vertical levels. It has 16 perturbed members (and 1 unperturbed control run) coupled to the first 16 members of ECMWF-EPS. Model error is represented by a hybrid stochastic perturbation scheme, where perturbations of tendencies in shallow convection, radiation and microphysics are combined with parameter perturbations in the turbulence scheme.

The idea is to replace this hybrid system with a pure parameter perturbation scheme (SPP - stochastically perturbed parametrizations; Ollinaho et al., 2017), because of the increased physical consistency of this scheme. In SPP uncertain parameters are directly perturbed in the physics parametrizations with some random noise generated by a pattern generator (SPG, Tsyrulnikov and Gayfulin, 2017). A first version of the SPP scheme has already been implemented in a C-LAEF E-suite in 2021 (see report of last year). This first version includes a set of 13 stochastically perturbed parameters - 11 of those parameters are listed in the following Table 3. Additionally, 2 microphysics parameters are perturbed which are controlling the sublimation of graupel and snow hydrometeors (ZRDEPGRED, ZRDEPSRED). They have been added because of too strong orographic precipitation influence on the precipitation field in the operational C-LAEF (too much precipitation on the mountains and in the luv, too less in the valleys and in the lee). By stochastically perturbing these parameters, the precipitation field in the Alps could be improved significantly.

Table 1: Parameters which are perturbed stochastically in the SPP scheme currently implemented in a C-LAEF E-suite (in yellow boxes).

Scheme	Parameter	Physical meaning	Default	Range
Radiation	RSWINHF	Shortwave inhomogeneity factor	1	0.6 - 1
	RLWINHF	Longwave inhomogeneity factor	1	0.6 - 1
Microphysic	RCRIAUTI	Snow Autoconversion threshold	0.2e-3	0.2e-4 - 0.25e-3
	RCRIAUTC	Rain Autoconversion threshold	1e-3	0.4e-3 - 1e-3
	VSIGQSAT	Constant for subgrid condensation	0.02	0 - 0.1
Turbulence	XLINI	Minimum mixing length	0	0 - 0.2
	XCTD	Constant for dissipation	1.2	0.98 - 1.2
	XCTP	Constant for T-P correlations	4.65	1.035 - 22.22
	XCEP	Constant for V-P correlations	2.11	0.225 - 4.0
	XCED	Constant for dissipation of TKE	0.85	0.4 - 2
Diffusion	XPHI_LIM	Threshold value for Sc^{-1} and Pr^{-1}	3	1 - 4.5
	XCET	Constant for transport of TKE	0.4	0.072 - 1.512
	SLHDEPSH	Strength of SLHD	0.060	0.01 - 0.09
	SLHDKMIN	Diffusion function minimum	0	-1 - 1
	SLHDKMAX	Diffusion function maximum	6	4 - 12
Surface	XRIMAX	Critical Richardson Number	0.2	0 - 0.2
	XFRACZ0	Coefficient of orographic drag	5	2 - 10
Convection	XCMF	Closure coefficient at bottom level	0.065	0 - 0.1
	XABUO	Coefficient of the buoyancy	1	0.7 - 1.5
	XBDETR	Coefficient of the detrainment	1e-6	0 - 1
	XENTR_DRY	Coefficient for dry entrainment	0.55	0.1 - 0.699

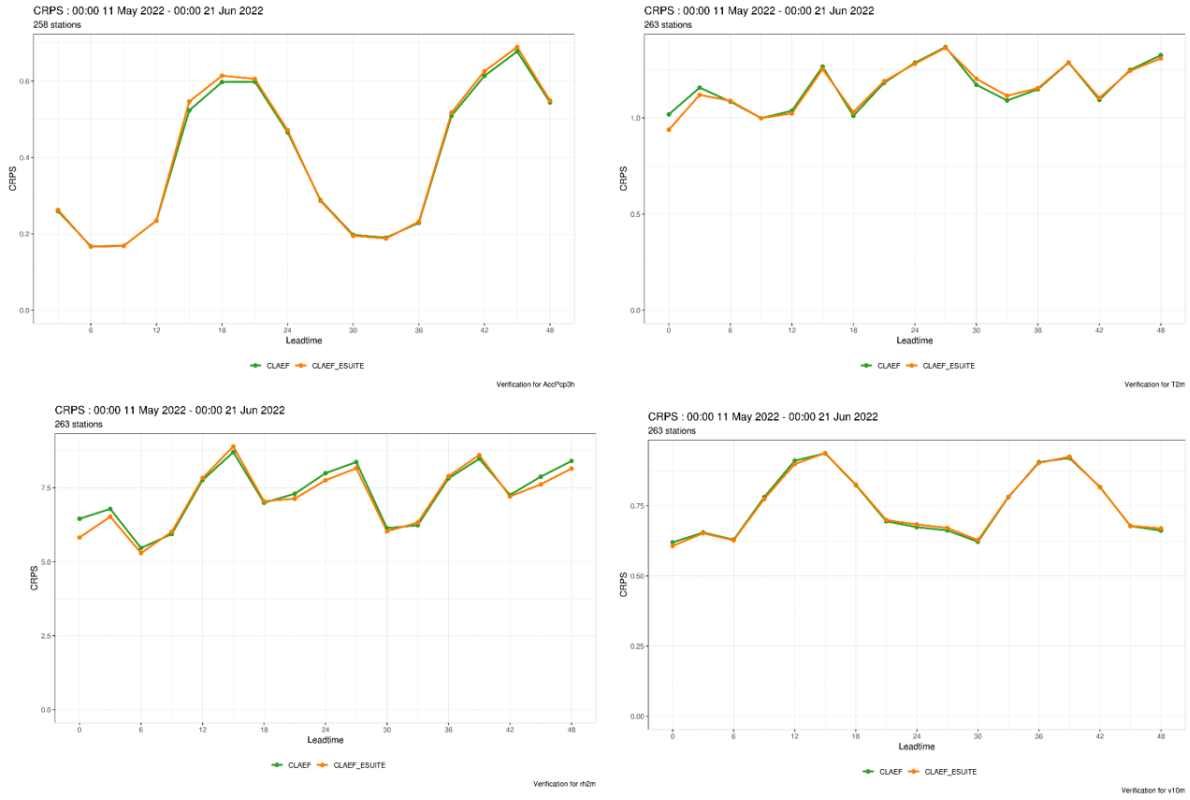

Figure 4: CRPS of operational C-LAEF with hybrid stochastic perturbation scheme (green) and C-LAEF E-suite with new SPP scheme (orange) for 3h accumulated precipitation (upper left), 2m temperature (upper right), 2m relative humidity (bottom left) and v-component of 10m wind (bottom right) for the period 11 May – 21 June 2022.

In 2022 a lot of tuning considering the perturbation scale and range has been made based on verification results from previous test periods and some case studies of severe weather events. In spring 2022 a full C-LAEF E-suite with SPP has been set up on the old ECMWF HPC Cray and it was running in May and June. Verification results of this test period can be found in Figure 4. The performance of the new SPP scheme is for most variables comparable to the previous hybrid scheme. For some parameters (e.g. relative humidity and temperature at 2m) the scores are even slightly better. However, the new scheme is more physically consistent and it is a bit cheaper (around 5%).
In summer 2022 this SPP scheme has been migrated to the C-LAEF suite on the new Atos HPC in Bologna. Furthermore the way how the perturbations are applied has been adapted according to the new perturbation code of the colleagues from HIRLAM (Ulf Andrea). A full C-LAEF E-suite on the Atos HPC is planned for autumn 2022. If the verification results are good, it is planned to operationalize this scheme in the beginning of 2023.

- **Topic 2: C-LAEF - Development of flow-dependent model perturbations**

SPP scheme is a widely used perturbation scheme to represent model uncertainties but it is purely stochastic - the perturbations are applied completely randomly without any consideration of the weather/flow situation. The idea in this subject is to develop a kind of intelligent perturbation scheme which applies perturbations especially in area where most impact can be expected. First preparatory work (literature research, code study, etc.) in this area has started in summer 2022, but main work is a bit delayed because of the postponed stay of Endy Keresturi at ZAMG. This stay is now planned for October 2022.

Efforts: 2 PM (planned 6.25 PM in total in 2022)

Contributors: Clemens Wastl (ZAMG

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (SHMU, ZAMG, OMSZ); EPS documentation

Planned stays:

Endi Keresturi (4 weeks at ZAMG) – stochastic perturbations in C-LAEF – planned for October 2022

Status: Ongoing; mostly in time, some delays due to postponed stay of Endi Keresturi

3 Action/Subject: Initial condition perturbations

Description and objectives: Research and development concerning initial condition perturbations in the three EPSs within RC-LACE.

The originally planned topics for 2022 are:

- ❑ A-LAEF: Utilization of A-LAEF operational forecasts for flow-dependent B-matrix computation to be used in local assimilation cycles of RC-LACE members.

This topic is delayed because the planned stay of Martin Bellus at ZAMG could not take place so far (COVID, personal reasons). Therefore also the main work in this action has to be postponed to 2023.

However, all the preparatory work on the introduction of EDA in AROME-EPS in Hungary (topic S1) has been devoted to this task, because it is still in research status and not yet operational.

- ❑ **Topic 1: AROME-EPS EDA experiments**

Operational AROME-EPS is dynamical downscaling of the first 11 members of ECMWF-ENS at 2.5 km horizontal resolution and 60 vertical levels. Experiments to introduce local perturbations were started with CY40T1 using ensemble of data assimilations (EDA) technique. During the recent work, a 1-month experiment was running using CY43T2. The selected time period covered 1-31 July 2021, and case study related to a cold front was selected on 1 July for deeper investigation.

The setup of the EDA experiment is the following:

• Forecast at 00 UTC with 11 members, lead time: 24 hours

• Hourly coupling to ECMWF ENS;

• 3 hourly assimilation cycle, using OI-main for surface and 3D-Var for upper air analysis;

• The same conventional and GNSS ZTD measurements were used as in AROME/HU assimilation;

• Operational AROME/HU domain (over the Carpathian Basin);

• Resolution of 2.5 km, 60 vertical levels;

• Model cycle: 43T2_bf11.

After a cold start, the experiment was started with a 10-day spinup period between 20 and 30 June 2021. The observations were perturbed offline before the surface assimilation and after screening. The results were compared to the 00 UTC operational AROME-EPS run.

Applying EDA in the AROME-EPS caused noticeable improvement in the surface parameters in general. For the 10m wind speed, 10m wind gust, 2m temperature and 2m relative humidity, the forecast is usually better during day time: the CRPS values

and bias of the ensemble mean and control member (Figure 5) are higher during the night. EDA rather decreases the error in the first 6 hours and during day time, and it has slight impact during the evening hours. The spread of these parameters increased for the whole forecast time.

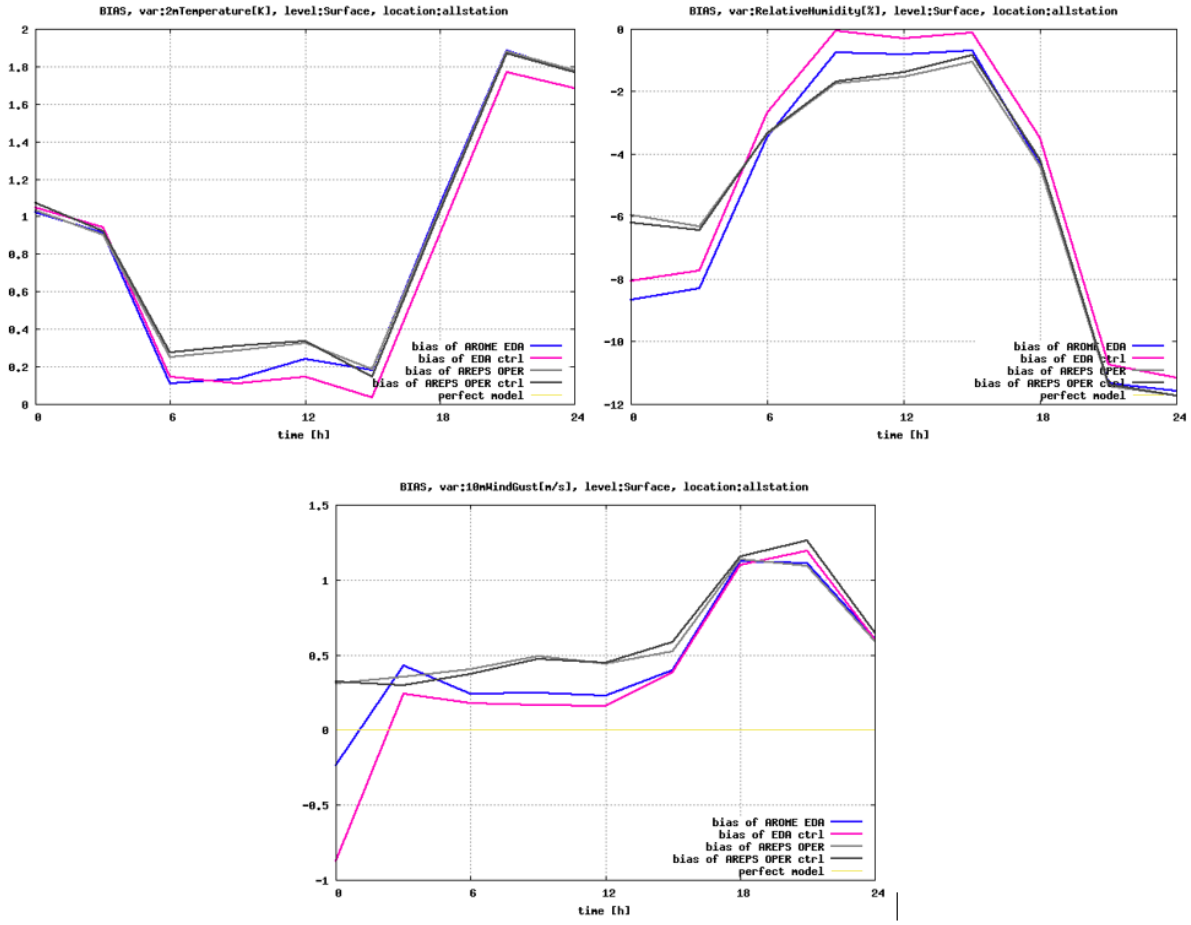

Figure 5: Bias of 2m temperature and relative humidity and 10m wind gust based on operational AROME-EPS mean (grey), AROME-EPS-EDA mean (blue), control member of operational AROME-EPS (black) and control member of AROME-EPS-EDA (pink) averaged for 30 Hungarian stations.

Precipitation results are variable: both RMSE and spread is increasing during the first few hours, while the impact of the EDA is almost neutral later (Figure 6). Similar conclusions can be drawn for mean sea level pressure and cloudiness: EDA has the same impact in the first 6 and 10 hours, respectively, while after 15-18 hours no significant impact is seen. Over the selected experimental period, EDA made flat the originally U-shape of the Talagrand diagram and increased the spread in case of 2m temperature, 2m relative humidity, 10m wind gust and 10m wind speed. On the other hand, the underestimation of the precipitation and the low spread for MSLP and total cloudiness did not improve compared to the operational AROME-EPS.

Two comparisons were made during the verification of the upper air results: one against TEMP measurements and one against the ECMWF analysis. The verification against the TEMP measurements is based on data of 2-3 stations per forecast, while

the comparison with the ECMWF analysis was made on the AROME grid. The improvement in the analysis time and the first 12 hours is more apparent in the comparison with TEMP which reflects, that although EDA works quite well close to the stations TEMP measurements are made, has less impact on the upper air grid points overall. It follows, that more upper air measurements are needed.

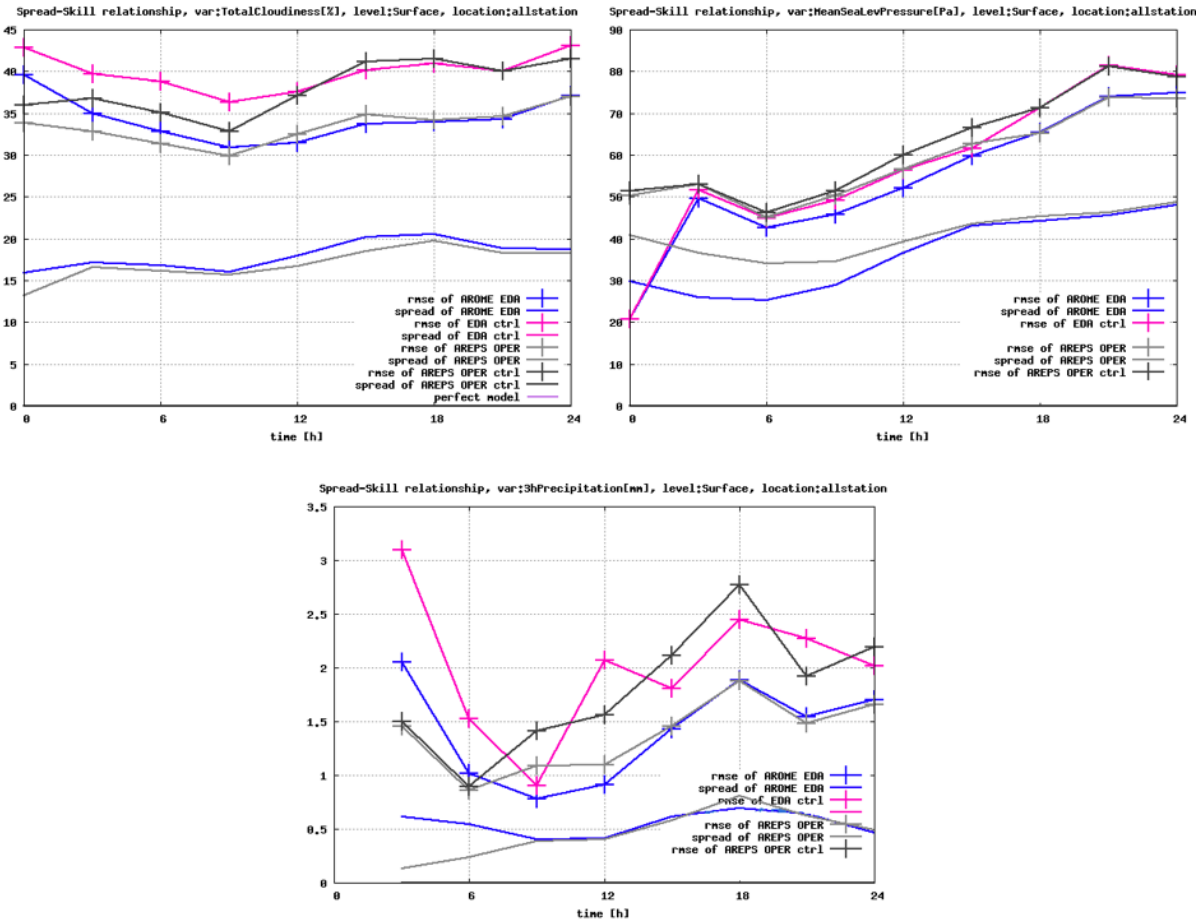

Figure 6: Spread (–) and RMSE (+) of total cloud cover, mean sea level pressure and precipitation based on operational AROME-EPS mean (grey), AROME-EPS-EDA mean (blue), control member of operational AROME-EPS (black) and control member of AROME-EPS-EDA (pink) averaged for 30 Hungarian stations.

The best results are obtained on the near-surface pressure levels (Figure 7). Wind speed forecasts performs the best with EDA on most of the pressure levels in comparison with the operational AROME-EPS. There is also noticeable improvement by temperature and relative humidity on different heights.

From the experimental period, a case study was selected on 01.07.2021, when a cold front crossed the territory of Hungary. The results show that the EDA forecasts had less overestimation for temperature over East Hungary. EDA also increased the spread compared to the operational EPS. As a summary, data assimilation in AROME-EPS leads to improvement in the forecast quality in summer primarily in the near-surface parameters, especially temperature, relative humidity, wind speed and wind gust. For these parameters, EDA decreases the forecast error and increases the spread. For precipitation, cloudiness and mean sea level pressure, the quality of the

forecast is decreasing in the first 6 hours. We will continue the investigation with some case studies for precipitation.

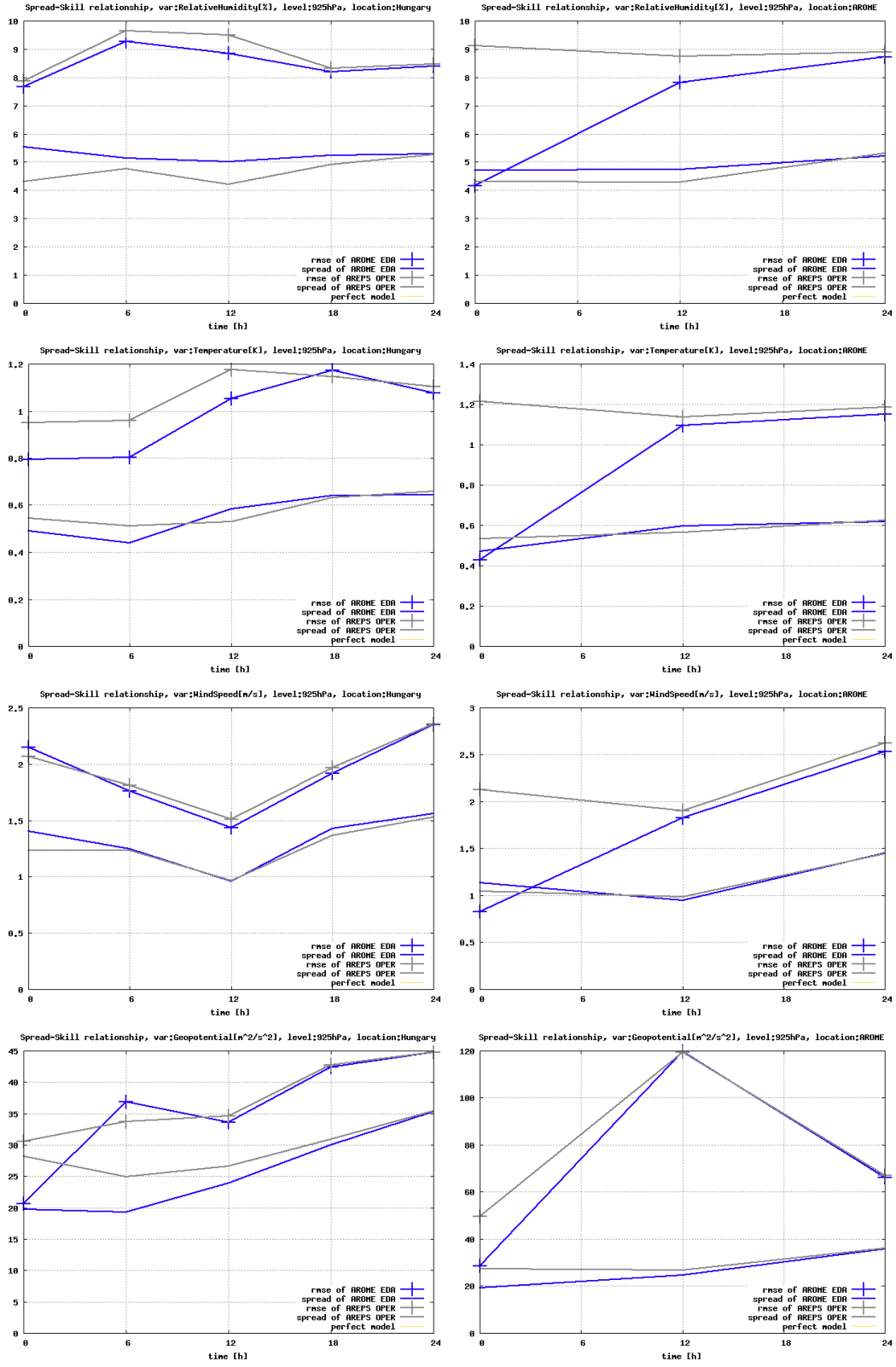

Figure 7: Ensemble spread (solid line) and RMSE of the ensemble mean for temperature, relative humidity, wind speed and geopotential at 925 hPa based on operational AROME-EPS mean (grey) and AROME-EPS-EDA mean (blue) verified against the ECMWF analysis (left) and TEMP measurements (right).

Efforts: 2.75 PM (planned 1 PM in total in 2022)

Contributors: Katalin Jávorné-Radnóczi and Gabriella Tóth (both OMSZ)

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (SHMU, ZAMG, OMSZ); EPS documentation

Planned stays:

1. Martin Bellus (4 weeks at ZAMG) – flow-dependent B-Matrix – postponed to 2023

Status: Ongoing. Delay because of postponed stay of Martin Bellus at ZAMG

4 Action/Subject: Surface perturbations

Description and objectives: Research and development concerning surface perturbations in the three EPSs within RC-LACE.

The originally planned topics for 2022 are:

- ❑ C-LAEF: Improve uncertainty representation of surface processes

The perturbation scheme in the operational C-LAEF version comprises perturbations of initial conditions (observation perturbations near the surface and in the upper air; ensemble JK), lateral boundary conditions (coupling with different ECMWF-ENS members) and a combination of tendency and parameter perturbations for the representation of model error (Wastl et al., 2021). A surface perturbation scheme based on Météo France (Bouttier et al., 2016) has been implemented to C-LAEF with the operational upgrade in December 2021. In this scheme (activation by switch LPERTSURF) several surface parameters (e.g. LAI, roughness length, soil temperature and moisture, snow depth, etc. are perturbed stochastically at the beginning of each model integration. This means that the output file of the surface assimilation (CANARI in our case) is perturbed by the external routine pertsurf.F90. By doing so the spread of surface parameters like T2m or RH2m has significantly increased.

In 2022 some work has been spent on recoding this surface perturbation scheme based on the code developed in HIRLAM (Andrea Ulf). The new code is cleaner and faster and the perturbations can be steered by namelist switches. The new surface perturbation code has been tested in the C-LAEF E-suite running on the new Atos HPC in Bologna for the summer period 2022. Results are comparable to the previous scheme - so it is planned to operationalize it with the final migration of the TC2 C-LAEF suite to the Atos HPC in October.

Efforts: 0.25 PM (planned 0.25 PM in total in 2022)

Contributors: Clemens Wastl (ZAMG)

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (SHMU, ZAMG, OMSZ); EPS documentation

Planned stays:

Status: On time. Final operationalization of new surface perturbation scheme planned in October 2022.

5 Action/Subject: Lateral boundary condition perturbations

Description and objectives: Research and development concerning lateral boundary condition perturbations in the three EPSs within RC-LACE.

The originally planned topics for 2022 are:

- ❑ A-LAEF: Coupling for the local convection-permitting EPS applications

This topic is delayed because of missing resources of Martin Bellus (focus on new HPC at SHMU and migration of A-LAEF suite to Atos HPC). The only work done in 2022 so far was dedicated to the upgrade of configuration 903 to cy48t2, which is now capable to create LBCs for several domains at once. That will be most probably used for the initial technical testing, until the files are not created from A-LAEF ICMSHs. Furthermore, the internet connection at SHMU has been upgraded to have a chance to fetch those files from ECMWF.

Efforts: 0 PM (planned 1 PM in total in 2022)

Contributors:

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (SHMU, ZAMG, OMSZ); EPS documentation

Planned stays:

Status: Delayed

6 Action/Subject: Statistical EPS and user-oriented approaches

Description and objectives: Research and development concerning statistical calibration of EPS data to reduce systematic errors; research and development of new products; user-oriented approaches to increase the reputation of EPS

The originally planned topics for 2022 are:

- ❏ A-LAEF: Continuation work on methods for analog-based post-processing of probabilistic fields on a regular grid
- ❏ C-LAEF: Work on statistical post-processing of EPS data
- ❏ C-LAEF: Early warnings of severe rainfall and severe wind (EFI, SOT)
- ❏ C-LAEF: Detection of precipitation objects in ensembles, neighbouring
- ❏ ALL: Development of new probabilistic products
- ❏ ALL: Development of decision-making criteria based on EPS for various users (e.g. hydrology, renewable energy, road safety)
- ❏ ALL: New EPS products on the RC-LACE webpage

A lot of work has been originally planned for this subject, but not all of the planned PMs have yet been spent in the first half of 2022. Some progress has been achieved in the EPS products on the RC-LACE webpage, in the analog-based processing of probabilistic fields on a regular grid and some work has started on the statistical post-processing of EPS data at ZAMG. A colleague of OMSZ (David Tajti) participated the EMCWF Machine Learning Training course.

- ❏ **Topic 1: Analog-based post-processing of probabilistic fields on a regular grid**

For the continuation work on the analog-based post-processing of probabilistic fields on a regular grid a stay of Iris Odak Plenković at ZAMG was planned, but it has to be postponed to autumn 2022 (November). However, some work already spent in this area was related to training dataset quality control, sensitivity test and updated predictor weights, statistical correction for extremes for the operational system. It works well, even though no systematic assessments are made at the moment. It is also part of the ACCORD verification package, the idea is to test the "standardized" verification measures and the end result will be assessment for operational analogs forecast for 2021 in the comparison to the model.
Another issue was the data quality from Croatian automated measuring stations as a preparatory step. The idea is to consider a Kalman filter based algorithm as well, on top of the analogs for wind speed post-processing. That one needs (good) recent measurements. The idea is to implement it probably next year.

❑ Topic 2: Work on statistical post-processing of EPS data

There is some ongoing work at ZAMG in the area of statistical post-processing of EPS data. SAMOS (standardized anomaly model output statistics) has been developed and implemented at ZAMG to improve direct model output from ensembles (EMCW-ENS, C-LAEF) especially for costumers. At the moment it has been implemented for 2m temperature and relative humidity, precipitation and 10m wind speed. Verification shows that SAMOS is able to improve the BIAS of the EPSs significantly (Figure 8) and is also able to correct the under-dispersion. SAMOS is providing spatial forecasts and offers a seamless forecast from analysis over short-range to middle-range forecasts.

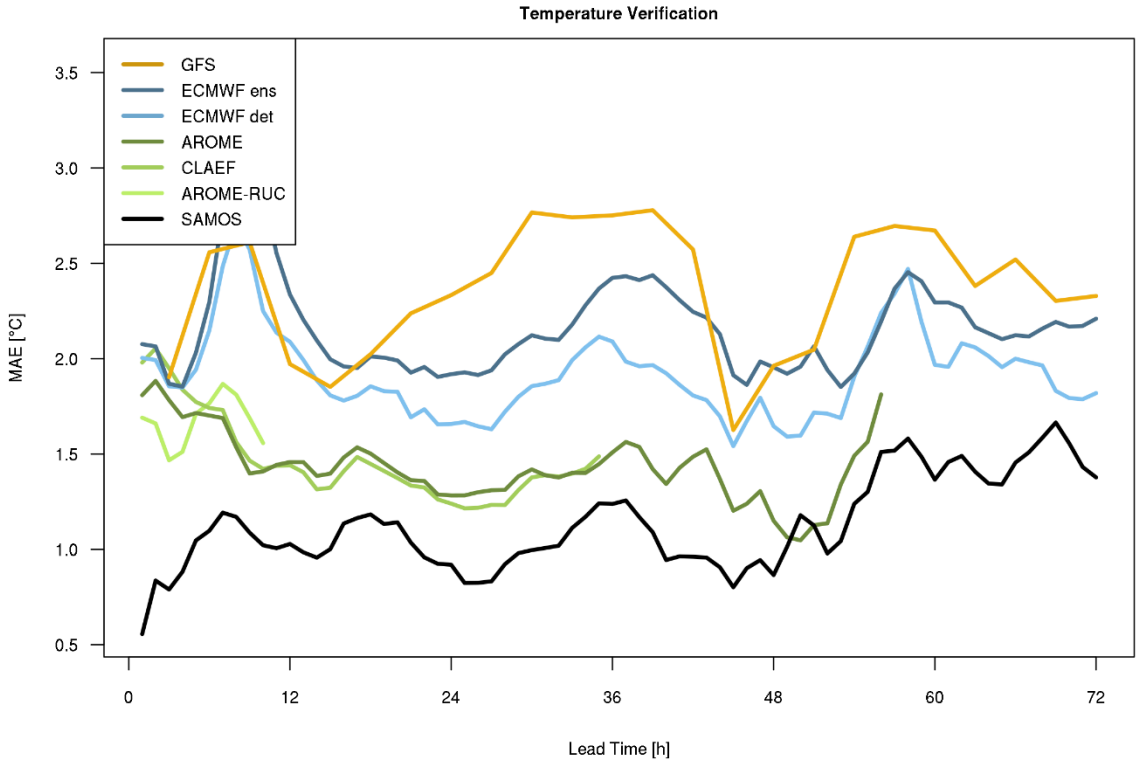

Figure 8: MAE of 2m temperature for different models and SAMOS for a case study in Austria.

Furthermore, some work is ongoing in the field of road temperature forecasts. For a selected case study on road temperature forecast a first implementation of a quantile regression forest and a Bayesian based ensembling started. So far, no verification results are finished.

❑ Topic 3: New EPS products on the RC-LACE webpage

The A-LAEF Epsgrams (PRO & Public versions) have been upgraded by including precipitation probabilities and information on the wind direction (Figure 9). Furthermore, the Epsgrams have also been verified by using data of automatic weather stations (Figure 10).

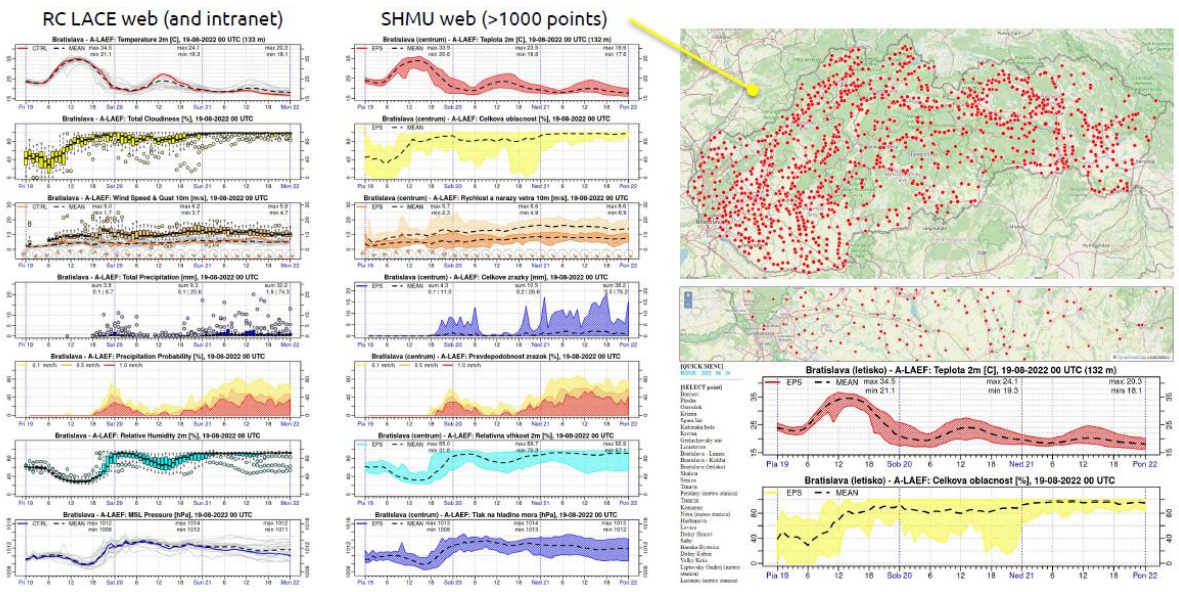

Figure 9: Redesigned/upgraded Epsgrams and simplified version for the public SHMU webpage.

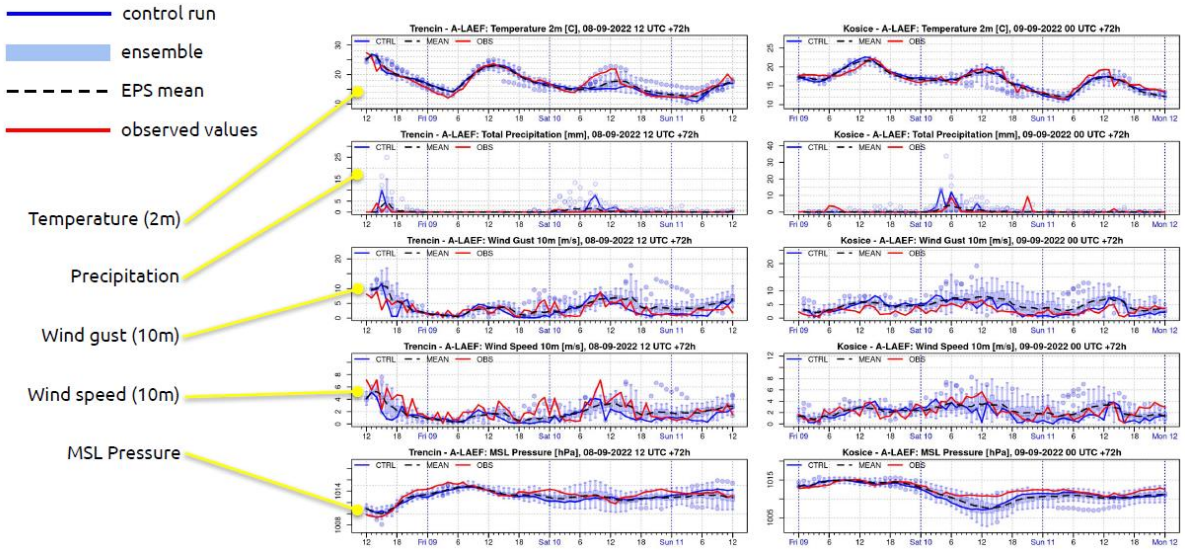

Figure 10: Verification of A-LAEF Epsgrams using automatic weather station data.

Efforts: 1.5 PM (planned 10.5 PM in total in 2022)

Contributors: Iris Odak Plenković (DHMZ), Martin Bellus (SHMU), David Tajti (OMSZ)

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (SHMU, ZAMG, OMSZ); EPS documentation

Planned stays:

1. Iris Odak Plenković (4 weeks at ZAMG) - analog-based post-processing methods – planned in November 2022

Status: Ongoing, some delays.

7 Action/Subject: Collaboration and Publication

Description and objectives: Activities merging different areas, collaboration with other consortia, applications, projects. Publication and presentation of relevant scientific output at international workshops and in scientific journals.

The originally planned topics for 2022 are:

- ❏ A-LAEF: Collaboration with DA group on ensemble assimilation methods (flow dependent B-matrix, etc.).
- ❏ ALL: Contributions to workshops and meetings.
- ❏ ALL: Collaboration with ACCORD predictability area
- ❏ ALL: Publications in scientific journals

Stronger cooperation between ACCORD and RC-LACE has been initiated in the past months. The first ACCORD EPS-working week took place from 25-29/04/2022 in Innsbruck where also some RC-LACE colleagues participated. As a result of the improved cooperation the exchange of code (e.g. SPP code of HIRLAM, surface perturbation code, etc.) between ACCORD and RC-LACE has been much more enforced.

Exchange of EPS data within the EUMETNET SRNWP-EPS project has also been intensified. C-LAEF has already been provided for the SRNPW-EPS database for the summer 2020 period and is also planned to provide A-LAEF data for this purpose.

The progress in EPS in RC-LACE has been summarized in an article in the 2nd ACCORD newsletter in February 2022. An article on the A-LAEF system has been published in the ECMWF newsletter in July 2022.

C. Wastl, M. Belluš and G. Szépsó, 2022: EPS research and development in RC-LACE in 2021, http://www.accord-nwp.org/meshtml/coordoper/ACCORD-NL2.pdf

M. Belluš, M. Tudor, X. Abellan, 2022: “The mesoscale ensemble prediction system A-LAEF”, ECMWF Newsletter, No. 172 - Summer 2022, p27-34, DOI: 10.21957/xa927ug5k0, https://www.ecmwf.int/node/20453

Efforts: 2.25 PM (planned 3 PM in total in 2022)

Contributors: Martin Belluš (SHMU), Clemens Wastl (ZAMG), Katalin Jávorné-Radnóczi and Gabriella Tóth (OMSZ)

Documentation: Participation in EPS workshops, EWGLAM, ACCORD workshop; presentation at international conferences; publication of papers in scientific journals;

Planned stays:

Status: Ongoing

Activities of management, coordination and communication

- ❏ 38th LSC Meeting, 8-9 March 2022 (*online*)
- ❏ 2nd ACCORD All Staff Workshop 2022, 4 - 8 April 2022 (Ljubljana), RC-LACE EPS activities presented by Clemens Wastl
- ❏ 1st ACCORD EPS working week, 25 – 29 April 2022 (Innsbruck)
- ❏ ESSL Testbed 4 – 8 July 2022 (Wiener Neustadt)

RC-LACE supported stays – 0 PM in first half of 2022

Unfortunately, due to several reasons (COVID, personal reasons), there were no research stays organized this year so far. However, some of the stays (Endi Keresturi, Iris Odak Plenković, Mustafa Başran) are foreseen for autumn 2022.

Summary of resources [PM] – 2022

Subject	Manpower		RC-LACE		ACCORD	
	plan	realized	plan	realized	plan	realized
S1: Preparation, evolution and migration	**21**	**7.25**	**1**	**0**	**1**	**0**
S2: Model perturbations	**6.25**	**2**	**1**	**0**		
S3: IC perturbations	**1**	**2.75**	**1**	**0**		
S4: Surface perturbations	**0.25**	**0.25**				
S5: LBC perturbations	**1**	**0**				
S6: Statistical EPS and user-oriented approaches	**10.5**	**1.5**	**1**	**0**		
S7: Collaboration and publication	**3**	**2.25**				
Total:	**43**	**16**	**4**	**0**	**1**	**0**

References

Bouttier, F., Raynaud, L., Nuissier, O. and Ménétrier, B. (2016) Sensitivity of the AROME ensemble to initial and surface perturbations during HyMeX. Quart. J. Roy. Meteor. Soc. 142, 390-403, https://doi.org/10.1002/qj.2622

Ollinaho, P., Lock, S. J., Leutbecher, M., Bechtold, P., Beljaars, A., Bozza, A., Forbes, R. M., Haiden, T., Hogan, R. J. and Sandu, I. (2017). Towards process-level representation of model uncertainties: Stochastically perturbed parametrisations in the ECMWF ensemble. Quart. J. Roy. Meteor. Soc. 143, 408–422, https://doi.org/10.1002/qj.2931

Tsyrulnikov, M. and D. Gayfulin, 2017: A limited-area spatio-temporal stochastic pattern generator for simulation of uncertainties in ensemble applications, Meteorologische Zeitschrift 26(N 5), 549-566, DOI: 10.1127/metz/2017/0815.