Working Area Predictability

Progress Report

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Period:	2022
Date:	March 2023

Progress summary

A lot of EPS related work has been done in 2022 within RC-LACE. Some of the planned actions were a bit delayed because of postponed stays (COVID, personal reasons), but most of them could be finally arranged in autumn 2022.
Furthermore, also the operational topics in S1 were 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. The final migration of the operational A-LAEF and C-LAEF suites to the new Atos HPC started at the beginning of October and could technically be finished within a few days. When verifying the Esuites on the Atos HPC we found out that the results of the Cray HPC could not be reproduced on Atos. Further investigations showed that this problem originated in the ECMWF-ENS coupling files which already showed some significant differences between the production line on Cray and Atos (new cycle). However, we had to cope with these discrepancies and finally operationalized the TC2 suites of A-LAEF on October 19th and C-LAEF on October 18th. After some stability problems at the beginning based on hardware and software issues on ECMWF site, the systems now run very stable and reliably. 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 an EPS working week every year (next one is planned in April 2023 in Oslo).

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 operationalized soon. Some preliminary work has been made in the topic of flow-dependent model perturbations (research stay of Endi) and also in the area of statistical post-processing (research stay of Iris) 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 were:

- ❑ A-LAEF and C-LAEF: Migration to the new ECMWF HPC 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 ECMWF HPC
- ❑ 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 ECMWF HPC in Bologna. It was originally planned to be fully available at the end of 2020, but first access to the system was not possible before Q2 2022. The final migration of the operational suites of A-LAEF and C-LAEF started in October, when the Atos HPC was finally released. It was really a tight schedule from ECMWF since the old HPC (Cray in Reading) had to be definitely switched off on November 1st 2022. However, we finally managed to complete our work on time – A-LAEF went operational on Atos on October 19th and C-LAEF on October 18th.

For the operational A-LAEF suite on Cray (old ECMWF HPC) several interventions were needed due to OPLACE issues (related to OMSZ server upgrade) in the first half of the year. Also on Atos some stability problems (related to ECMWF hardware and software issues) occurred in the first weeks, but these problems could be solved and the suite is now running very stable. The SBU accounting was topped up in June (+30 M by Slovenia) and in August (+65 M by Turkey) and with this amount it was possible to run A-LAEF for the complete year 2022 as prospected. The upgrade of A-LAEF to cy43t2 and the upgrade of the upper-air IC uncertainty simulation by ENS BlendVar have been postponed to 2023.

For C-LAEF, the forecasting range of the 12 UTC run was extended from 48h to 60h - both long runs (00 and 12 UTC) do now have the same forecasting range (60h). The adaptation of C-LAEF for the Turkish domain had to be postponed to 2023 (May is planned) because of some personal reasons of the stay candidate.

The introduction of EDA in AROME-EPS is also delayed - some intensive testing is currently ongoing with cy43t2 and a pre-operational E-suite is running since August 2022. The EDA related 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.

To summarize, the work spent on S1 topic in 2022 comprises mostly following topics: Migration of operational suites of A-LAEF and C-LAEF to new ECMWF HPC, upgrades in the A-LAEF suite and expansion of C-LAEF and AROME-EPS.

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

A lot of work has been spent in 2022 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 started.

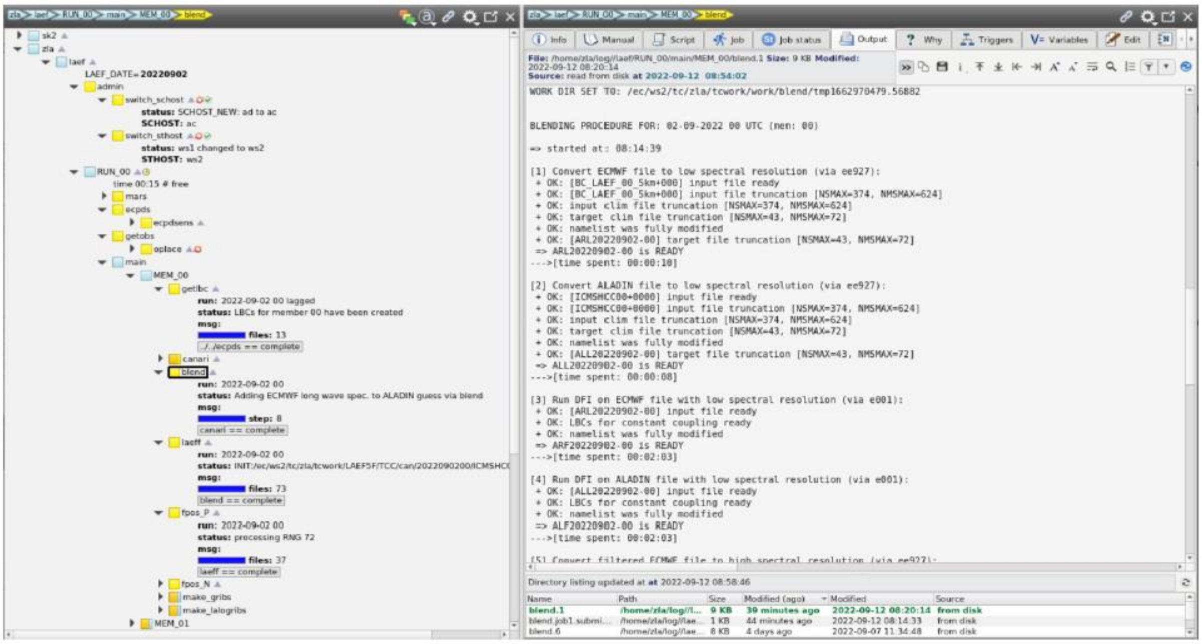

Figure 1: ecFlow suite of A-LAEF (TC2) on HPCF Atos in Bologna.

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 1). Quite some time was spent on ENV issues and also on the jobs tuning on the Atos system with successful results - keeping the consumption of SBUs on a current level, some jobs ran substantially faster compared to Cray. The ECTRANS connection to OPLACE has also been established to fetch the OBS files for assimilation cycle in September. Some random problems on Atos at the beginning - unreproducible freezing of e001 jobs related to the MPI modules usage and random freezing of assimilation jobs - could be solved soon. Furthermore, the conversion of FA files to Lambert and latlon GRIBs has been upgraded and the order of packing in PROGRID for latlon GRIBs has been changed. In October the final migration of the operational A-LAEF to Atos HPC could be started. It was technically finished within some days and a parallel suite on Atos could be launched on October 6th. With the verification of this test suite of A-LAEF on Atos an issue with significant differences originating in the LBCs came up.

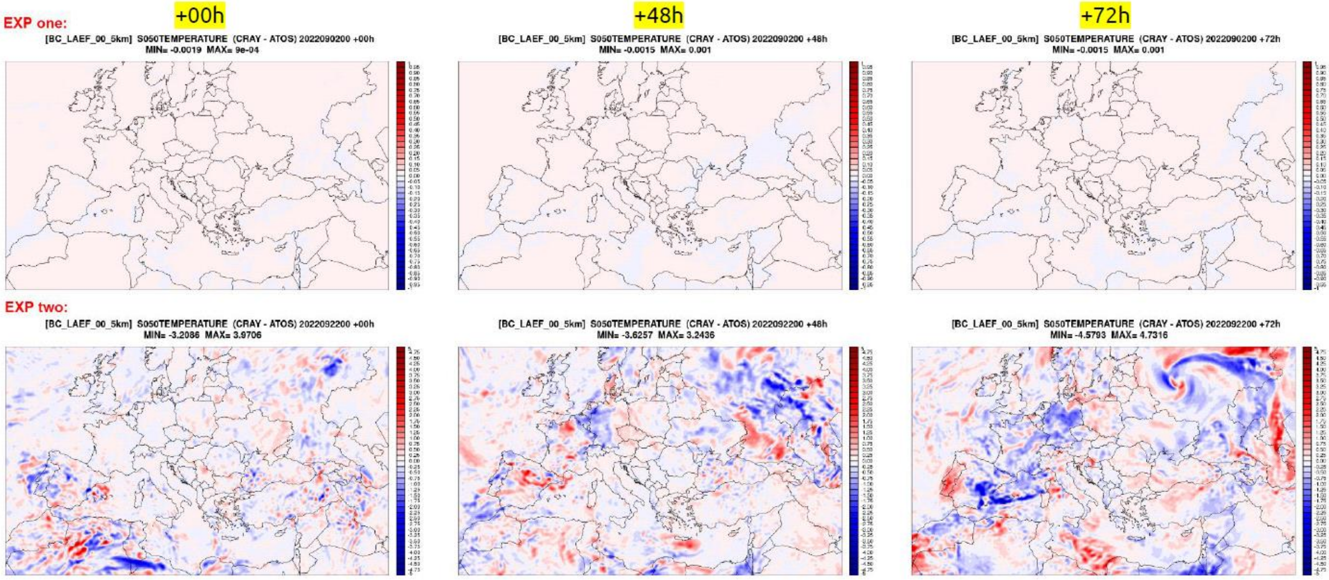

Figure 2: Differences in temperature at level S050 between LBCs created on Cray and on Atos for two experiments and different lead times (columns). Experiment 1 is based on ECMWF cy47r3 input in Reading and experiment 2 on ECMWF cy47r3 input in Bologna (release candidate at that time).

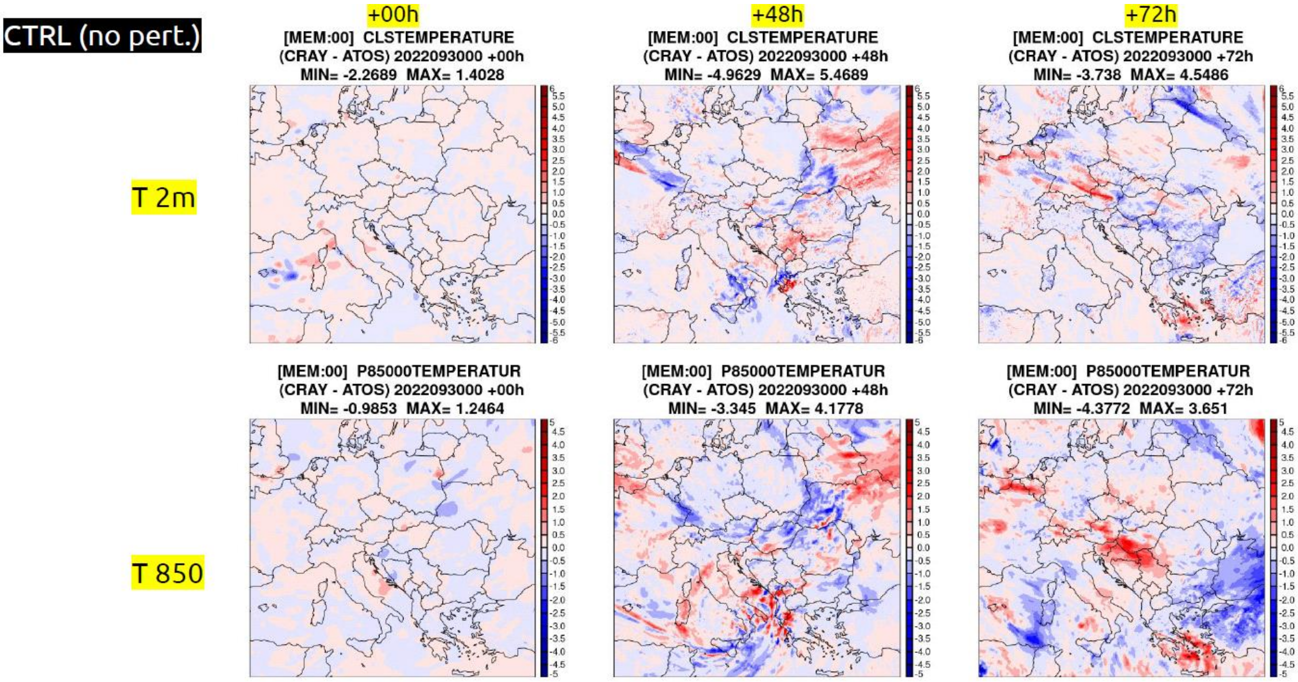

Figure 3: Differences of temperature at 2m (upper panel) and 850 hPa (lower panel) for 3 lead times (columns) between A-LAEF control member at Cray and Atos HPC.

Figure 2 shows that the production of LBCs (based on ECMWF-ENS) with 903 is reproducible on Atos (first row), but when using ECMWF cy47r3 input of Atos in Bologna instead, significant differences for e.g. temperature (S050 level) are evident. This also has a significant impact on A-LAEF forecasts when comparing the two suites on Cray and Atos HPC (Figures 3 and 4).

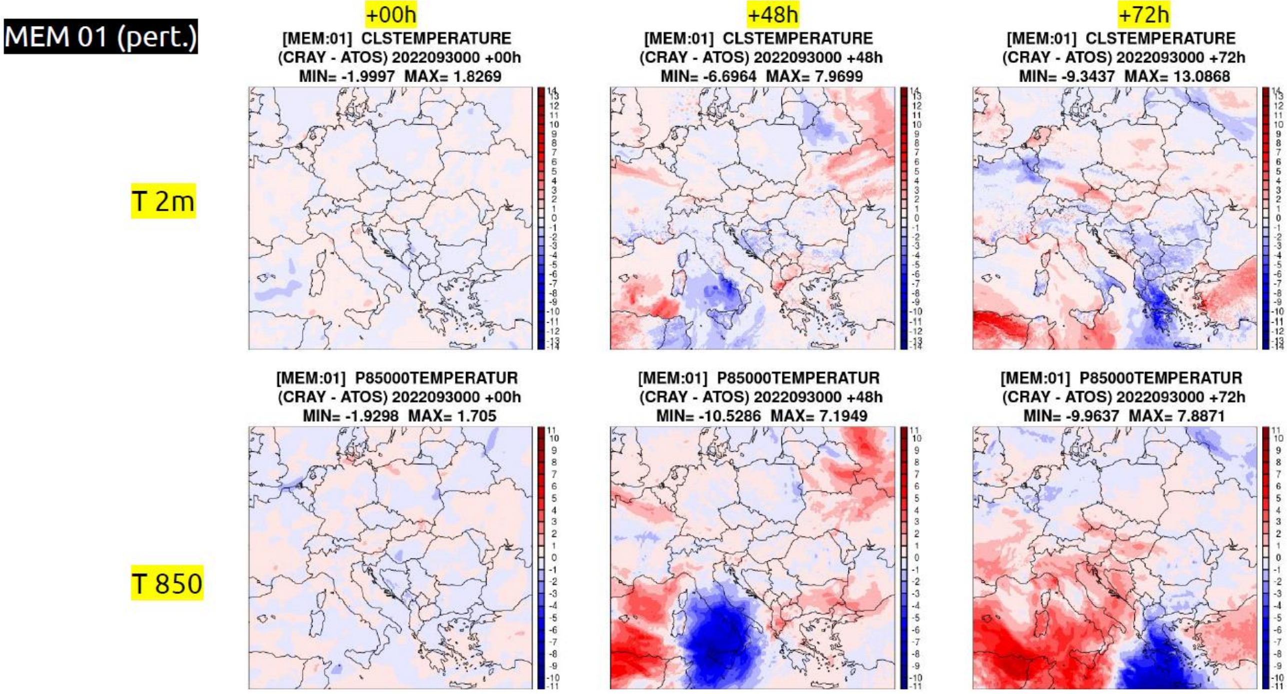

Figure 4: Differences of temperature at 2m (upper panel) and 850 hPa (lower panel) for 3 lead times (columns) between A-LAEF member 1 at Cray and Atos HPC.

For the unperturbed control run (Figure 3) the forecast differences are rather small but they increase with lead time. This corresponds to the observed discrepancy in the LBCs generated out of ECMWF's operational vs. release candidate outputs (both cy47r3, but running on different platforms, Figure 2).
For the perturbed ensemble members (Figure 4), the differences are about twice as big, and they tend to increase faster with lead time. In addition to the forcing by coupling, the stochastic physics has a significant impact on the errors' growth too. Due to the stochastic nature of perturbation patterns, the same ensemble members are mutually incomparable between two platforms (Reading vs. Bologna), even though the physics setting is constant for a given A-LAEF member. An impact on the operational A-LAEF products is shown in Figures 5 and 6. However, we had to accept these discrepancies - the old suite on the Cray HPC has been finally switched off and the TC2 suite on the Atos became fully operational on October 19th. Also the dissemination of A-LAEF products via ECPDS switched to Bologna for all involved LACE partners and Turkey at that time. The ECMWF operators started to officially monitor the A-LAEF suite on October 27th.
After that also some minor upgrades/changes in A-LAEF could be arranged:

- upgrade of getlbc task (an automatic switch to MARS inputs if ECPDS local stream is unavailable)
- changes made in suite tasks to reflect the SLURM upgrade to v22.05
- found and reported a bug in grib_ls tool for eccodes v2.23, v2.26, v2.27

(decoding of latlon GRIBs with a second order constant width grid)
- increased spatial coverage of OBS data in OPLACE backup files uploaded by Slovakia (used in A-LAEF TC2, Figure 7)

In the first weeks on Atos several emergency interventions were needed for A-LAEF due to hardware/software issues. Since December, the suite is running very stable.

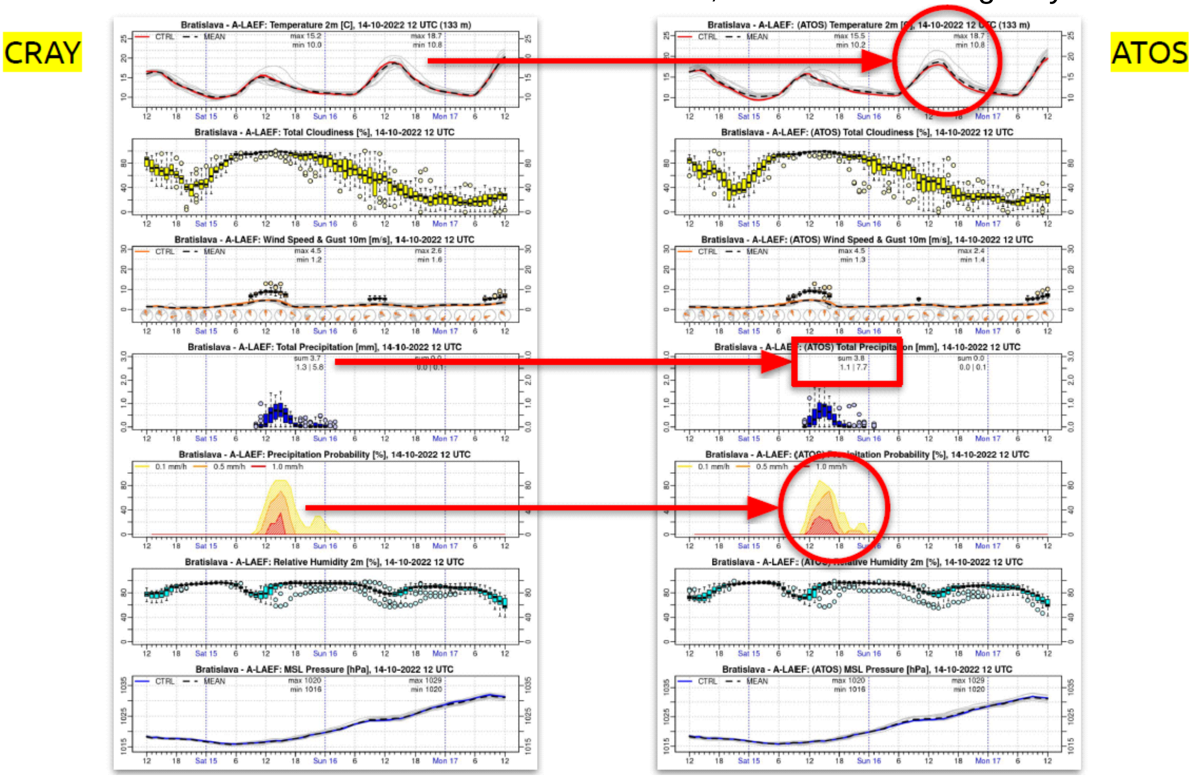

Figure 5: Meteograms for Bratislava for a case in October 2022 based on A-LAEF forecast on Cray (left) and Atos (right) HPC.

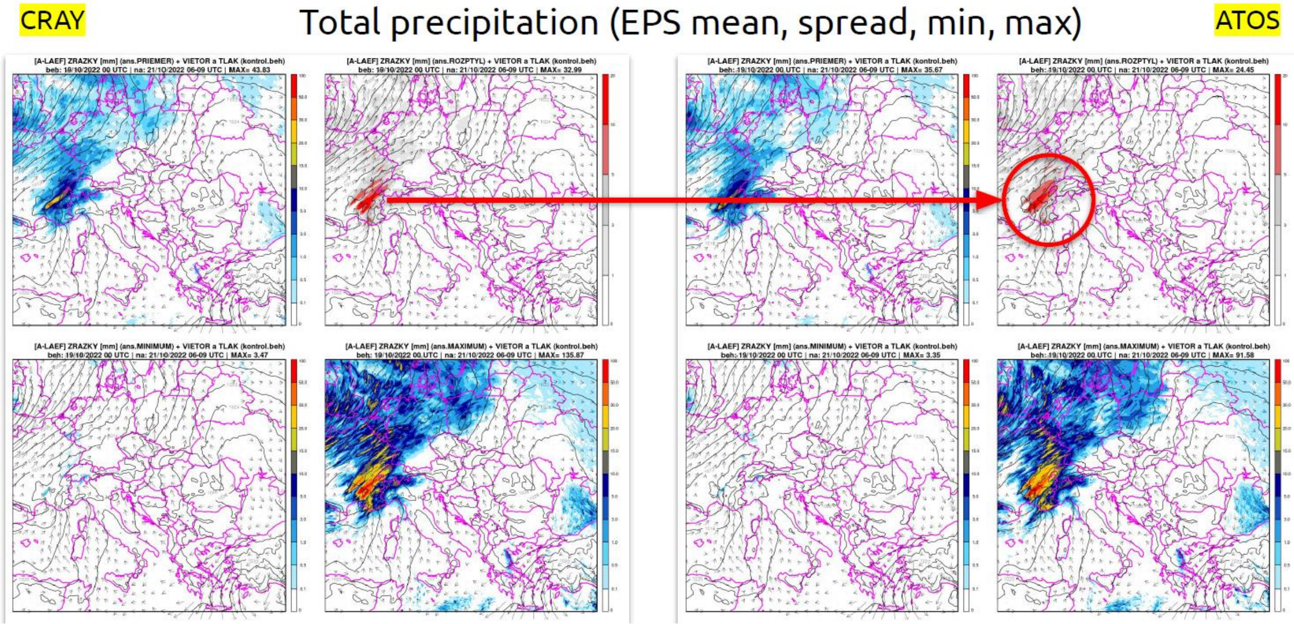

Figure 6: 3-hourly precipitation (EPS mean, spread, min, max) for October 21st (06-09 UTC) based on A-LAEF (00UTC at October 19th) on Cray (left) and Atos (right).

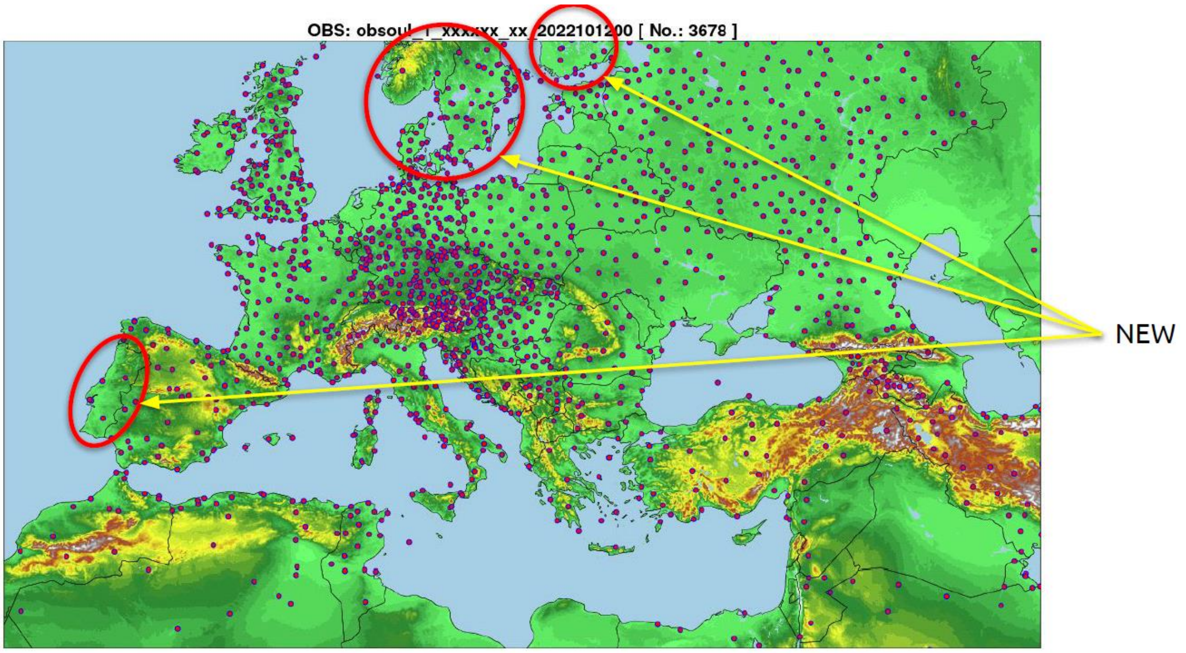

Figure 7: New observation sites in OP-LACE backup files uploaded by SHMU.

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. Some time has also been spent on the optimization of the task arrangement on the new facilities (number of cores, CPUs, etc.). Verification of the C-LAEF E-suite during the summer months (July, August) showed comparable results for all the relevant parameters (Figure 8).

In August we started to work on the C-LAEF suite for the operational TC2 users for C-LAEF (zat, zat2). In September ECMWF provided new coupling files (produced by 903) based on the new cy47r3 release candidate on Atos. When comparing the coupling files from the ECMWF suites on Cray and Atos we recognized some significant differences (details in the A-LAEF part of this section). However, we had to cope with these discrepancies. With the final release of the Atos HPC for operational users in October we ultimately migrated the C-LAEF TC2 suite to Bologna on October 18th. After some stability problems in the first weeks, the C-LAEF suite is now running very stable.

Some small upgrades in C-LAEF have also been made with the migration to Atos:

- compilation of code with ompi to improve numerical stability on Atos and to increase the efficiency
- upgrade in minimization: in the new version the hydrometeor blending at the end of minimization is no more necessary
- usage of ceilometer observation data: ceilometer observations have been added to some random members of the C-LAEF assimilation to improve the forecast of low stratus and to increase the spread of some surface variables

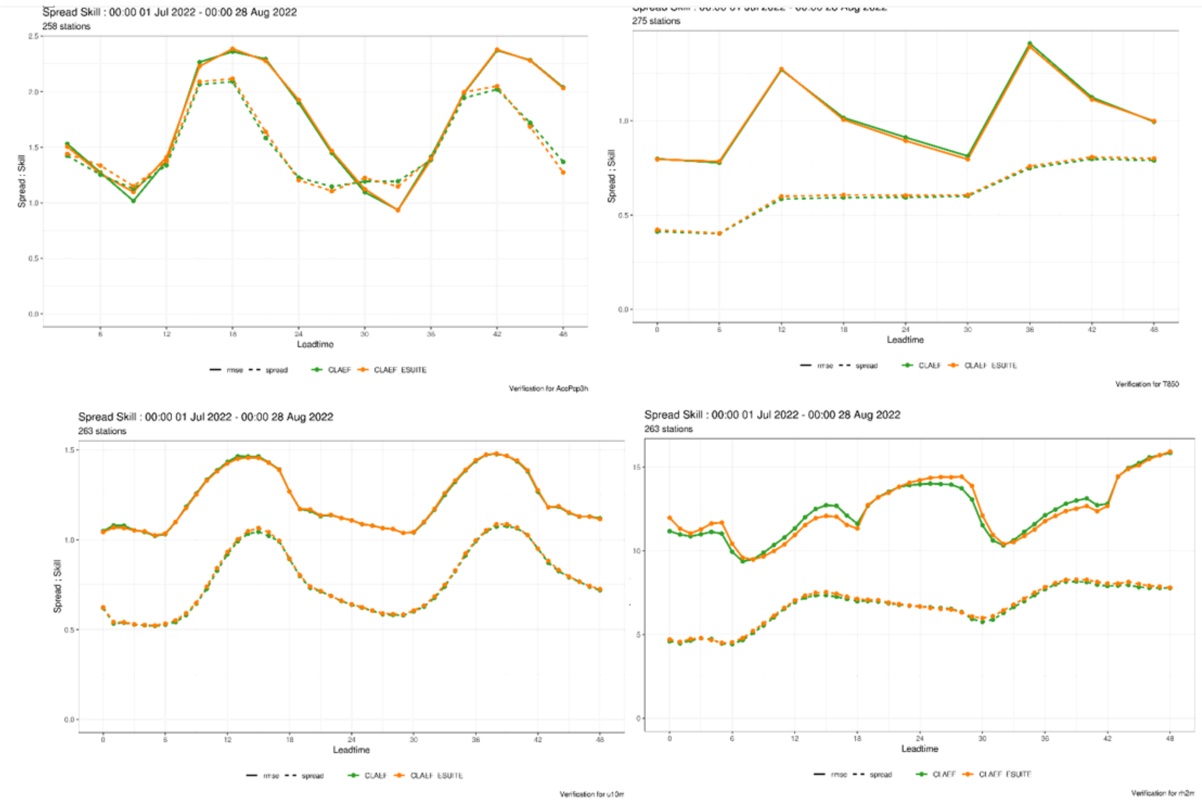

Figure 8: Comparison of operational C-LAEF (on Cray, green) and C-LAEF E-suite (on Atos, orange) for 3h accumulated precipitation (upper left), 850hPa temperature (upper right), u-component of 10m wind (bottom left) and 2m relative humidity (bottom right) for the period July-August 2022. Dashed lines show ensemble spread and solid lines RMSE.

- **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 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). Based on this, we increased in a first step the lead time of the 12 UTC run of C-LAEF from 48h to 60h in summer 2022. Now both C-LAEF runs have 60h lead time. For the future we decided to put the main priority to increase the horizontal resolution. First long test runs with a C-LAEF 1km suite (pure downscaling without data assimilation) 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 E-suite on the new ECMWF HPC based on the single precision code. This code saves up to 30-40% of resources and the results are comparable to the double precision version (Figure 9). Another important step towards a C-LAEF 1km system is the new ZAMG HPC, which can be 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.).

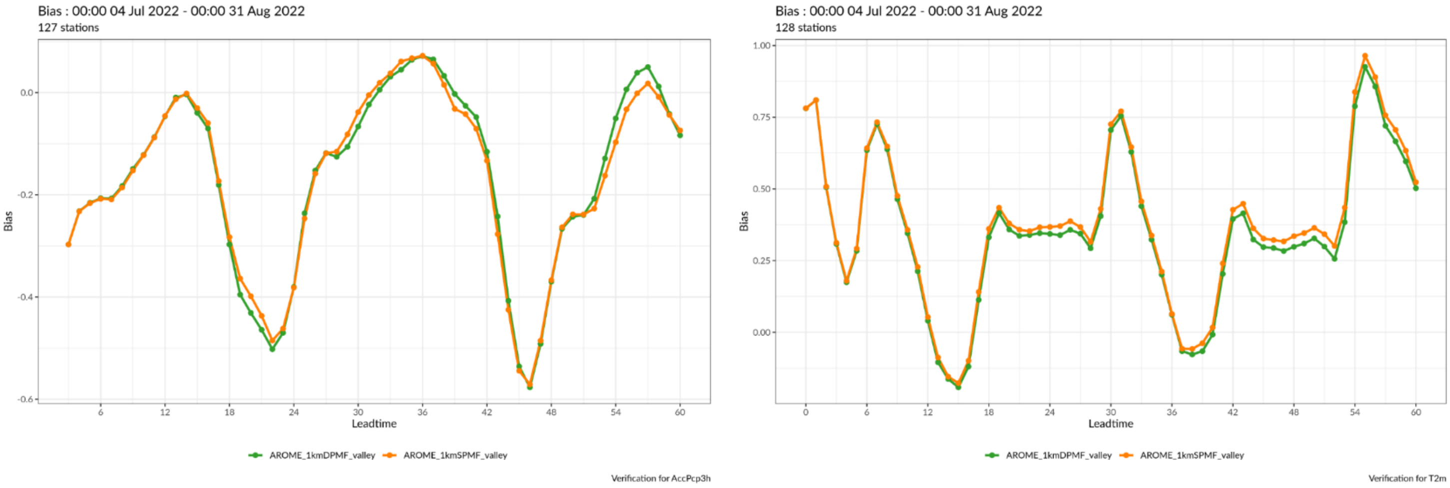

Figure 9: Bias of 3h accumulated precipitation (left) and 2m temperature (right) for the period from 4 July to 31 August 2022 for Austrian stations located in valleys. Single precision experiment in orange, double precision in green.

❑ 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 its 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. It is now planned to take place in May 2023. 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 Turkish colleagues, so it is not directly part of the RC-LACE report.

Efforts: 14.5 PM (planned 21 PM total in 2022)

Contributors: Martin Belluš (SHMU), Clemens Wastl, Florian Weidle and Christoph Wittmann (ZAMG)

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 – cancelled
2. Mustafa Başaran (1 week at ZAMG) - ACCORD stay - set-up of C-LAEF for Turkish domain – postponed to May 2023

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 were:

- ❑ A-LAEF: Stochastic perturbation of fluxes instead of tendencies in order to preserve the energy balance in a 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

The A-LAEF topic (stochastic perturbation of fluxes instead of tendencies) is delayed because Martin Bellus could not make his stay in Vienna due to personal reasons. Main work in this action in 2022 has therefore been spent on the C-LAEF topics stochastic parameter perturbation scheme and 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
	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
Diffusion	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
	XCMF	Closure coefficient at bottom level	0.065	0 - 0.1
Convection	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

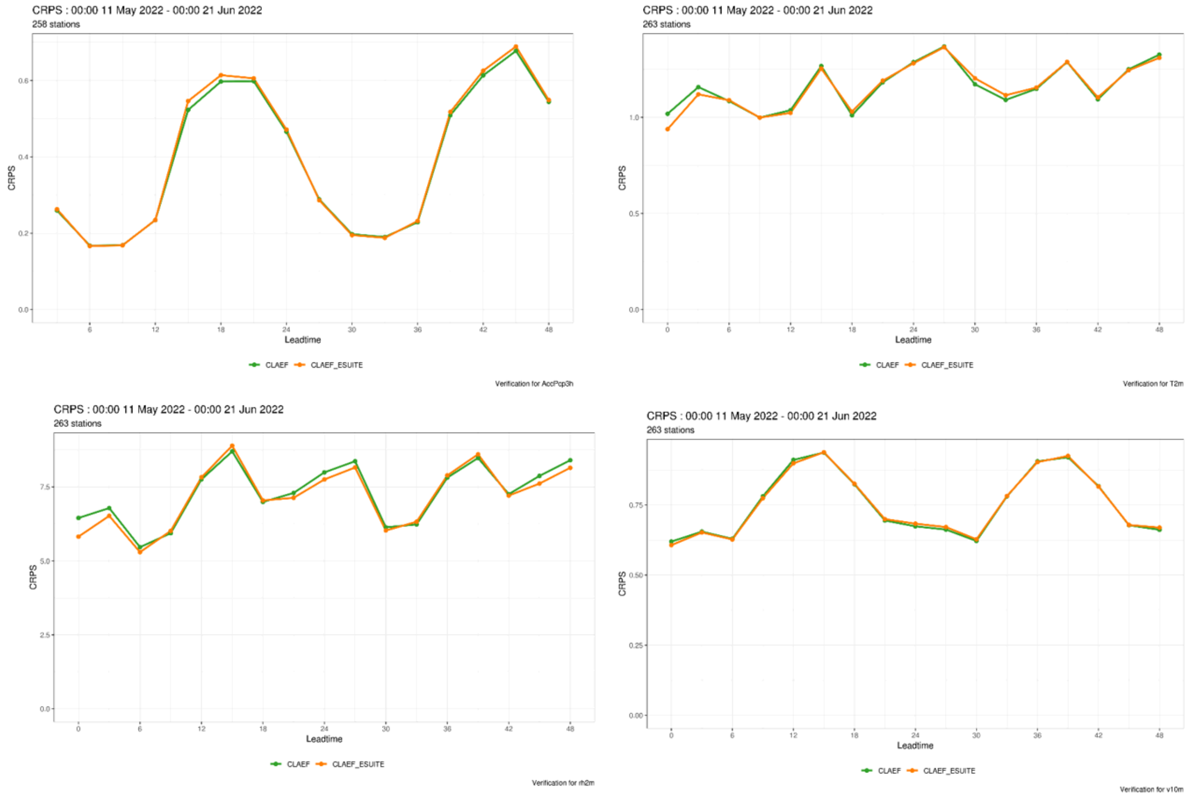

Figure 10: CRPS of operational C-LAEF with hybrid stochastic perturbation scheme (green) and C-LAEF E-suite with new SPP scheme (orange) for 3h accumulated precipitation (upper left), 2m temperature (upper right), 2m relative humidity (bottom left) and v-component of 10m wind (bottom right) for the period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

In 2022 a lot of tuning considering the perturbation scales and ranges 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 10. 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 a new perturbation code of the colleagues from HIRLAM (Ulf Andrea). A full C-LAEF E-suite on the Atos HPC has been set-up at the beginning of November 2022 and was running until end of December. The verification results are very similar to the summer period on the Cray HPC (Figure 11). RMSE could be reduced for most parameters together with a slight decrease in ensemble spread. With these (more or less neutral) verification results it is planned to operationalize the new SPP scheme with the next upgrade of C-LAEF in spring 2023.

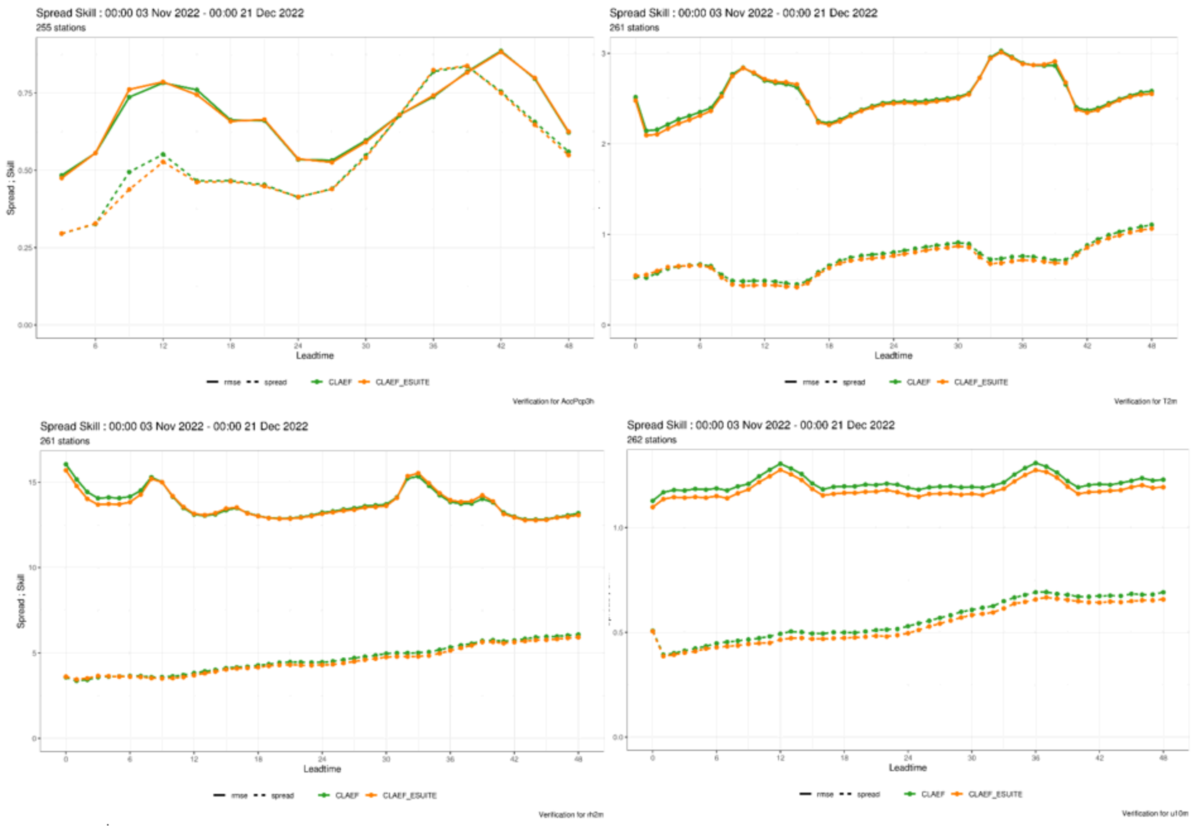

Figure 11: Spread (dashed) and RMSE (full) of operational C-LAEF with hybrid stochastic perturbation scheme (green) and C-LAEF E-suite with new SPP scheme (orange) for 3h accumulated precipitation (upper left), 2m temperature (upper right), 2m relative humidity (bottom left) and v-component of 10m wind (bottom right) for the period 03 November – 21 December 2022.

❑ 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 areas where most impact can be expected (frontal zones, convective areas, etc.). First preparatory work (literature research, code study, etc.) in this area has been made in summer 2022, but main work started with the stay of Endy Keresturi at ZAMG in Vienna in October (17-28). Due to several reasons (HPC migration, other urgent work) the stay had unfortunately to be reduced to two weeks, but a continuation for this work is planned for 2023 in combination with another stay in Vienna.

In the first version of this flow dependent perturbation scheme, the focus was set on the microphysics parametrization (parameters ZRDEPSRED, ZRDEPGRED, RCRIAUTI and RCRIAUTC, see Table 1). The pattern generator and the perturbation strategy of SPP has not been modified, instead the approach is based on modifying the existing pattern by some weights. The idea is to diagnose which areas in the model are the most unstable for each parameter and then to modify the pattern so that it perturbs more in those areas. The question is how to find which areas of the domain to target, i.e., how to determine the magnitude and the spatial distribution of weights. For microphysics, several model fields have been tested (precipitation, vertical moisture profile, cloudiness). The problem is how to convert these fields to weights (for example, to between 0 and 1) because they cannot be normalized easily as we do not have the access to the whole fields (parallelization). For this reason, cloud fraction has been chosen because it is already in fractions – between 0 and 1 so it is almost ready to be used as weight. First, as this field is given for all model levels separately, it needs to be summed up over all model levels. The normalized cloud fraction (Equ. 1) can now be applied to the SPP scheme (Equ. 2). w is the weighting factor, w' the vertically integrated cloud fraction, N_l the number of vertical levels, N an arbitrary factor to weight the influence, P the unperturbed parameter value, c a constant, φ the stochastic pattern and P^ the final flow dependent perturbation field.

(1) $$w = \left(\frac{w\prime}{N_l} \times N\right) + 1$$ (2) $$\hat{P} = P\, e^{c+w\varphi}$$

Figure 12 shows the impact of the cloudiness on the stochastic pattern for a selected microphysics parameter. The new flow dependent parameter perturbation scheme has been tested for a case study on 3 November 2022 (cold front passage). Figure 13 shows the impact on the ensemble spread in comparison to SPP without flow dependency. The impact is rather small, but it is nice to see that the method is principally working, since a difference is not visible before the cold front enters the domain (e.g. lead time +20h). More details can be found in Endy's stay report on the LACE webpage.

This is just a first step into the direction of an operational flow dependency in the model error representation of C-LAEF. In a next step (research stay in 2023) it is planned to expand this methodology to other parametrizations (turbulence, shallow convection, radiation), to optimize it and test it over a longer period.

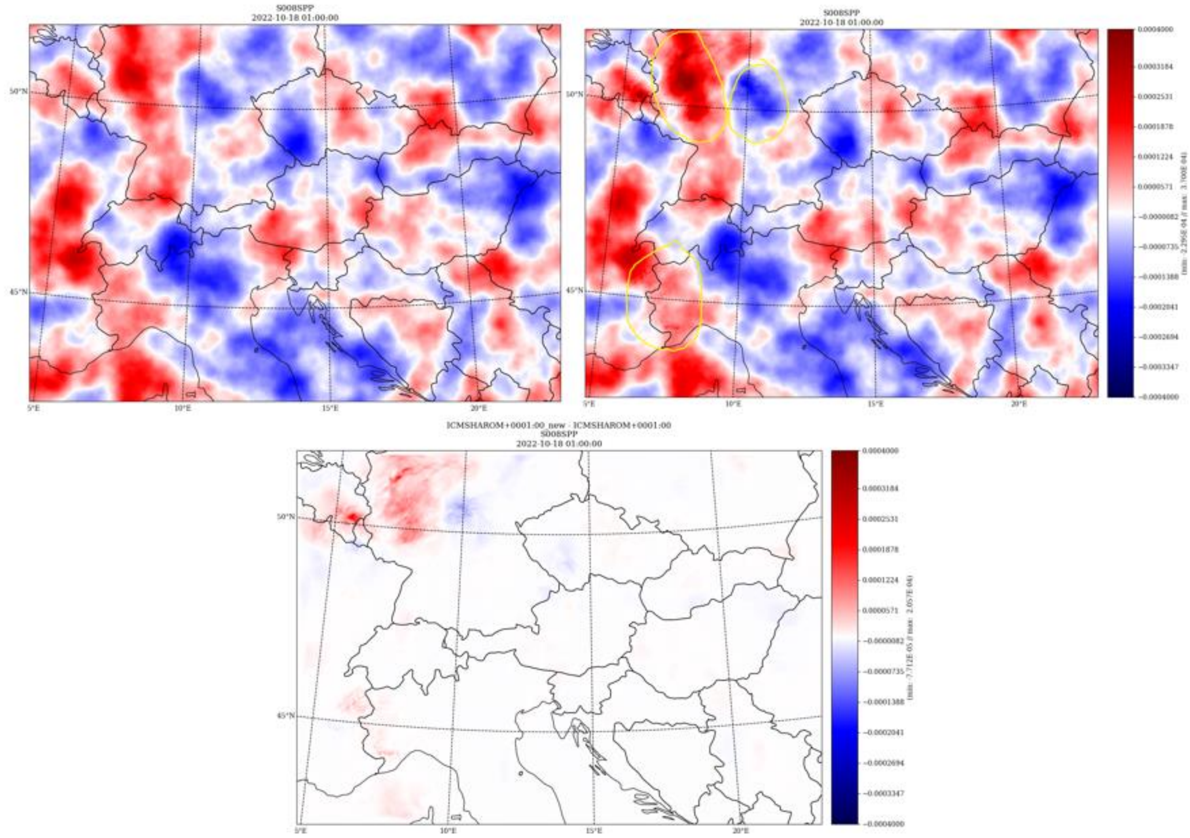

Figure 12: Impact of the cloudiness to the stochastic perturbation field of a microphysics parameter in SPP. Upper left: SPP without flow dependency, upper right: SPP with flow dependency, lower panel: difference.

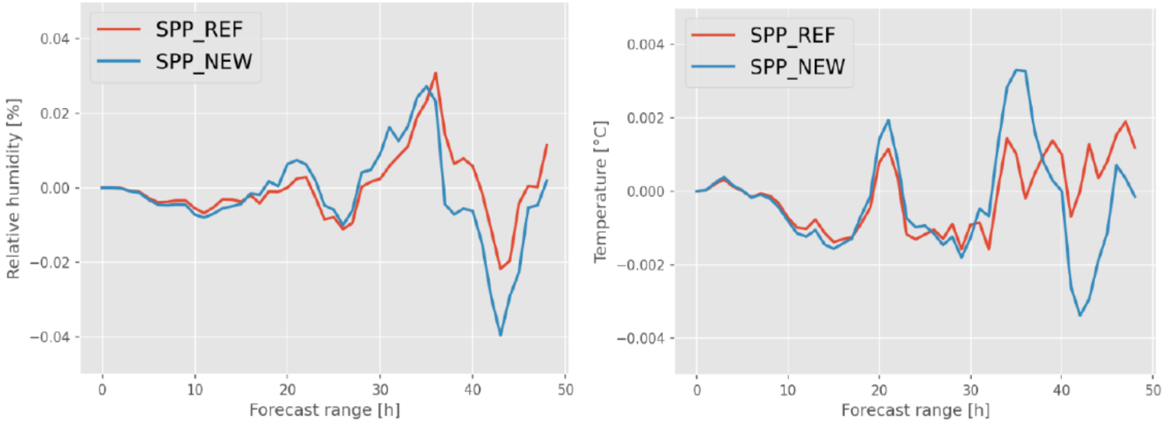

Figure 13: Domain average of relative ensemble spread of two SPP experiments for a test case on November 3rd 2022. SPP_REF is standard SPP, SPP_NEW is flow dependent SPP. Spread is relative to an experiment without any model error representation.

Another approach in the research topic of flow dependency is currently under development at ZAMG. In this approach the large scale weather type (classification from ZAMG) is used to perturb selected parameters in the physics. A first version has already been implemented and technically tested. It is based on an external python script which reads the weather type class and modifies the AROME 3D moisture field in case of high pressure situations with low stratus. The big advantage of this methodology is that it can be specifically applied to well-known model weaknesses (e.g. temperature BIAS in Alpine valleys, low stratus, etc.). It is therefore able to significantly reduce model BIASs. Some further investigations in this directions are planned in 2023.

Efforts: 4.75 PM (planned 6.25 PM in total in 2022)

Contributors: Clemens Wastl (ZAMG), Endi Keresturi (DHMZ)

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: reduced to 2 weeks (17 – 28 October 2022)

Status: Ongoing; mostly in time

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 be arranged 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 initial perturbations originally started with CY40T1 using ensemble of data assimilations (EDA) technique. After an upgrade to CY43T2 EDA has been running for a 1-month test period in summer (July 2021) and winter (January 2022).

The setup of the EDA experiments 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 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 spin-up period. The observations were perturbed offline before the surface assimilation and after screening. The results were compared to the 00 UTC operational AROME-EPS run.

During the summer period, applying EDA in the AROME-EPS caused noticeable improvements 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 14) 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.

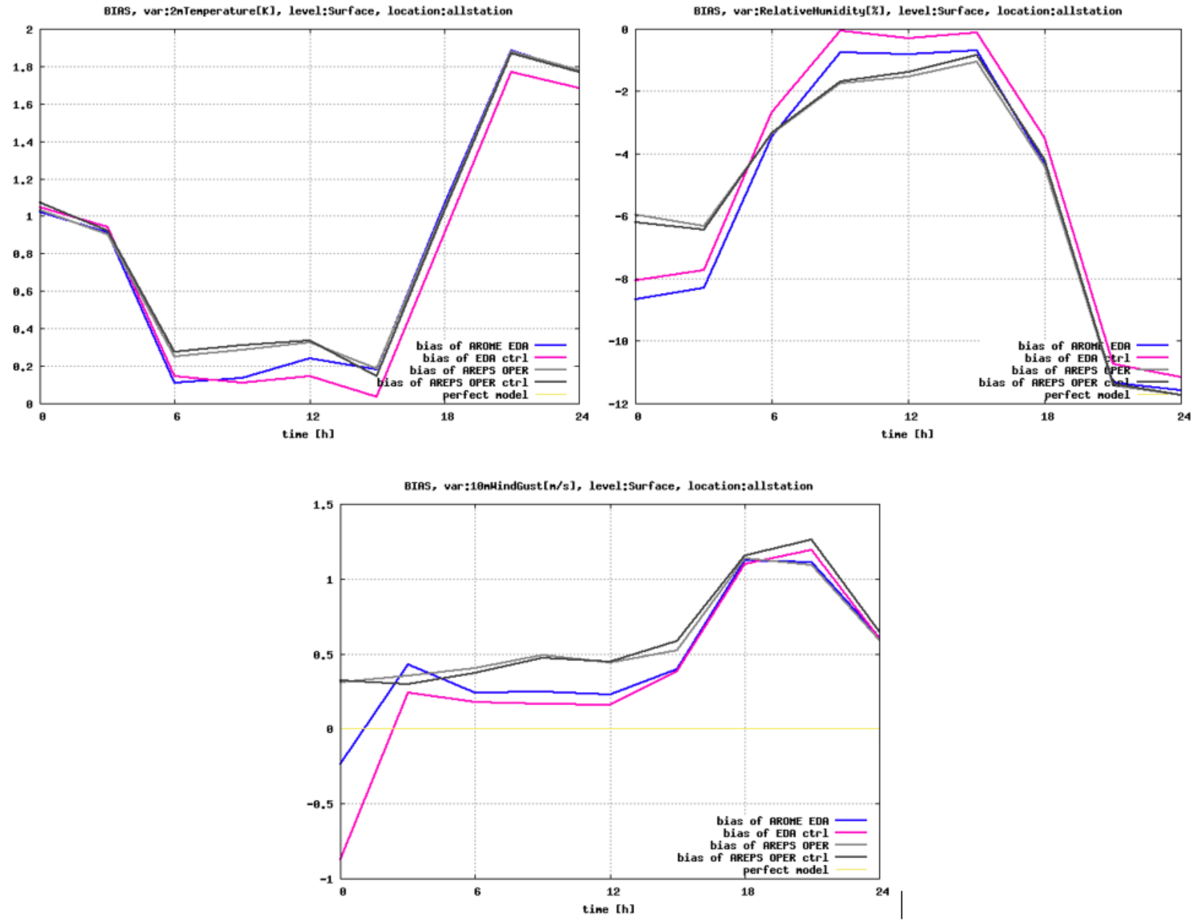

Figure 14: Bias of 2m temperature and relative humidity and 10m wind gust based on operational AROME-EPS mean (grey), AROME-EPS-EDA mean (blue), control member of operational AROME-EPS (black) and control member of AROME-EPS-EDA (pink) averaged for 30 Hungarian stations and the summer period July 2021.

Precipitation results for the summer period are variable: both RMSE and spread is increasing during the first few hours, while the impact of the EDA is almost neutral later (Figure 15). 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 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.

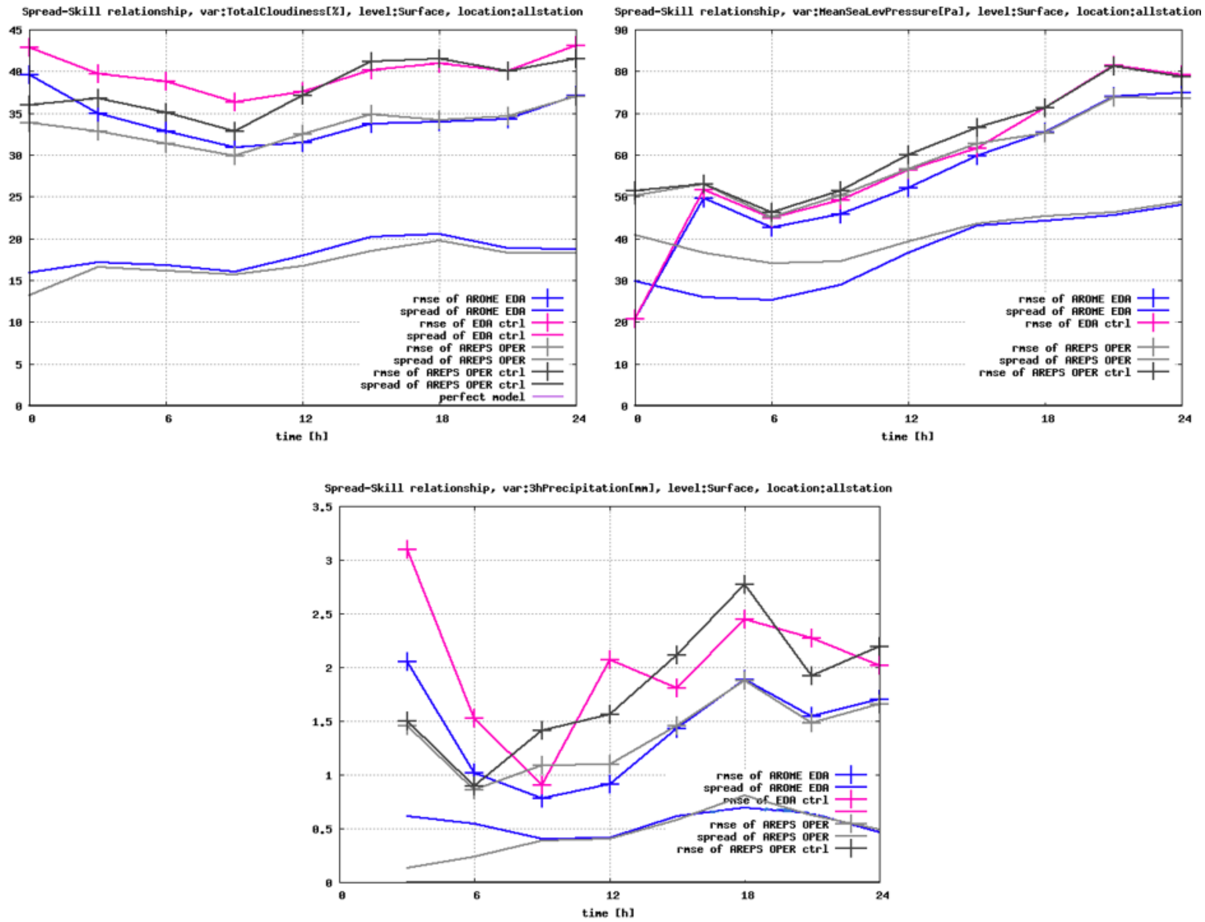

Figure 15: Spread (–) and RMSE (+) of total cloud cover, mean sea level pressure and precipitation based on operational AROME-EPS mean (grey), AROME-EPS-EDA mean (blue), control member of operational AROME-EPS (black) and control member of AROME-EPS-EDA (pink) averaged for 30 Hungarian stations.

The best results in the summer period are obtained on the near-surface pressure levels. 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.

Compared to the results of the summer experiment, EDA caused less improvements in winter, especially in the first few hours of the forecast time. In most cases, the impact was rather neutral. The best results were obtained for the 10m wind speed and wind gusts. Both RMSE of the ensemble mean and the CRPS decreased during the first 9 hours. For the 2m temperature, slight increase is seen in both scores, except the initial time. For relative humidity, the error increased during daytime and the impact of the EDA was mostly neutral, except the early morning hours (Figure 16). The ensemble spread increased in the first 9-18 hours, however, the ensemble is still underdispersive.

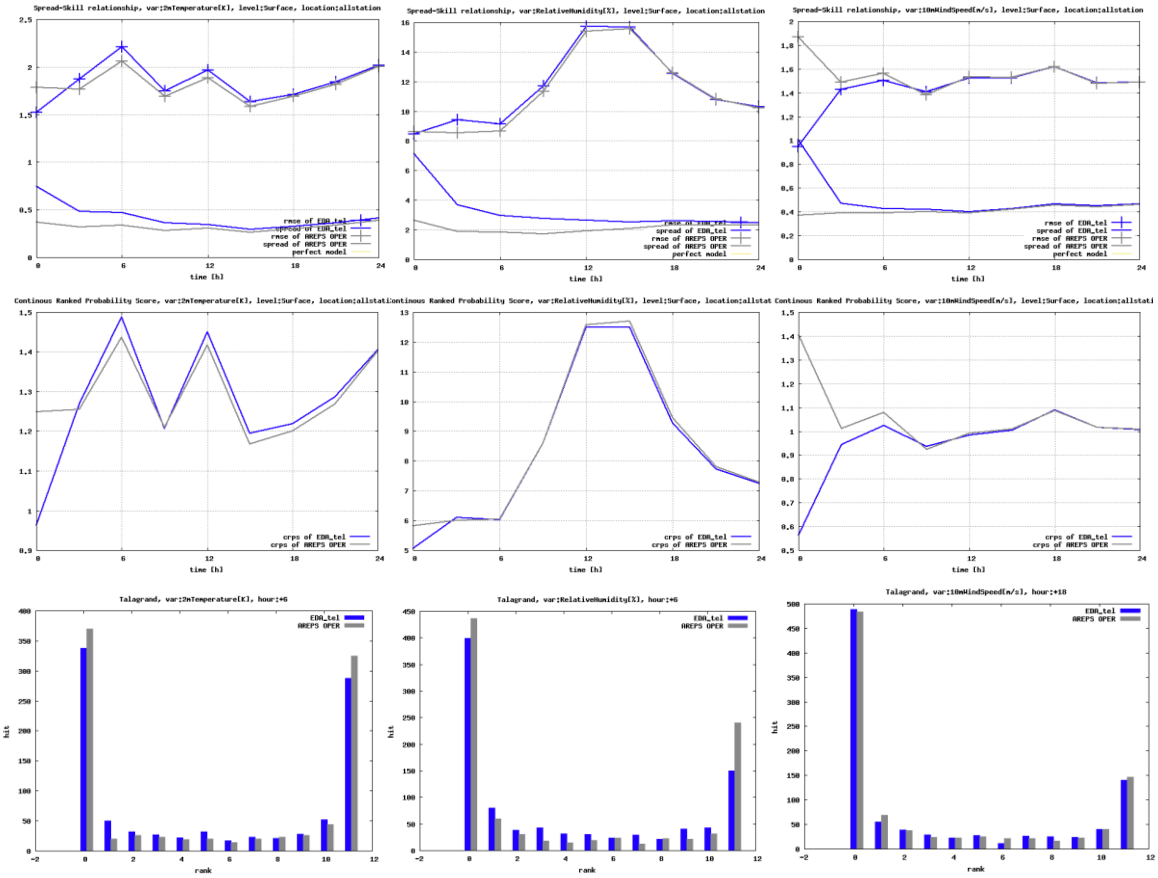

Figure 16: Spread and RMSE (first row), CRPS (second row) and Talagrand-diagram (third row) of 2m temperature (left), 2m relative humidity (middle) and 10m wind speed (right) based on the operational AROME-EPS (grey) and AROME-EPS-EDA (blue) forecasts, verified against data of 30 Hungarian meteorological stations

In case of precipitation, the error of the operational AROME-EPS is higher in the late afternoon and at the evening, and EDA was able to slightly decrease the underestimation. However, it increased the error at the initial time (Figure 17).

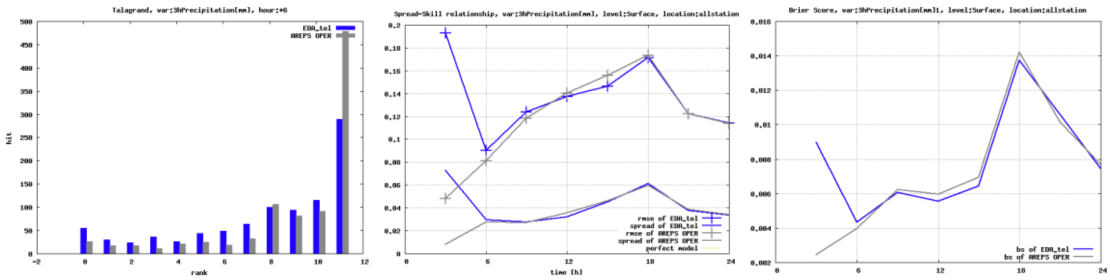

Figure 17: Talagrand-diagram (left, lead time=18h), spread and RMSE (middle) and Brier-score (right, for threshold of 1mm) for 3 hourly sum of precipitation, based on the operational AROME-EPS (grey) and AROME-EPS EDA (blue) forecasts.

A quasi-operative AROME-EPS-EDA E-suite has been started in August 2022, and it was intensively tested in comparison with the operational AROME-EPS by forecasters and model developers from 15 November 2022 to 15 December 2022. Compared to the EDA experiments before, this E-suite contains two runs a day (00 and 12 UTC) and uses a Simplified Ensemble Kalman Filter (SEKF) in surface assimilation (identical to operational AROME-HU deterministic model). To evaluate the results of the parallel AROME-EDA E-suite, HARP-3 was used. The HARP-based system verifies against measurements of all stations over the AROME-HU domain, while the method applied previously used only data of 30 stations. Nevertheless, the conclusions based on both systems are similar.

Similar to the winter experiment for January 2022, the most positive effects of EDA are seen for the wind speed and wind gust (Figure 18). For relative humidity, the impact was rather neutral, except the initial time. At the same time, EDA slightly increased the error of the 2m temperature forecast. It generally predicted lower temperature than the operational AROME-EPS during the test period, which was advantageous in many cases. However, the EDA run predicted a typically more stable air stratification during anticyclonic weather and overestimated the amount of stratus and low level clouds. In addition to the temperature, the dewpoint forecast was also underestimated. The period around sunrise and sunset was typically predicted with a higher error for these two parameters.

The effect of EDA was rather small on the precipitation forecast, and was very similar to the experiment for January 2022 (Figure 19). The error was the highest at night and lower during the day, when EDA improved the forecast even more. Although it increased the error in the first hours. In forecasting of snow and freezing precipitation, EDA sometimes gave lower probabilities, but over a larger area, than the operational AROME-EPS.

As final conclusion, applying ensemble data assimilation in the Hungarian AROME-EPS had less positive effect in winter than in summer. The highest impact was seen at the beginning of the forecast time, both in growing spread and reduced error. The best results were obtained for the 10m wind gust and wind speed. Considering the results of all experiments, EDA is planned to become operational in the Hungarian AROME-EPS in the second half of March.

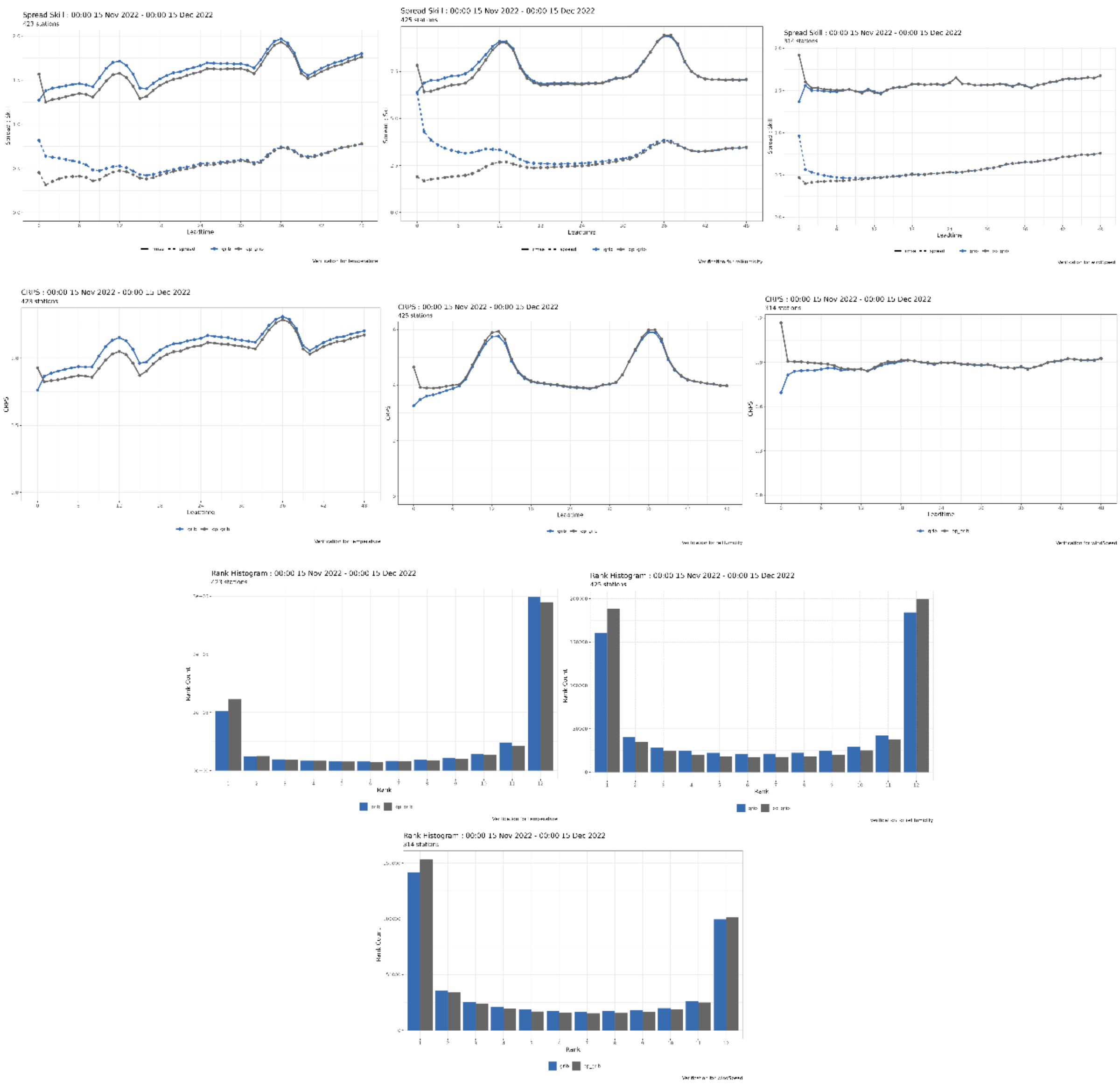

Figure 18: Spread and RMSE (first row), CRPS (second row) and Talagrand-diagram (third row) of 2m temperature (left), 2m relative humidity (middle) and 10m wind speed (right) based on the operational AROME-EPS (grey) and AROME-EPS-EDA (blue) forecasts, verified against data of meteorological stations over the AROME-HU domain.

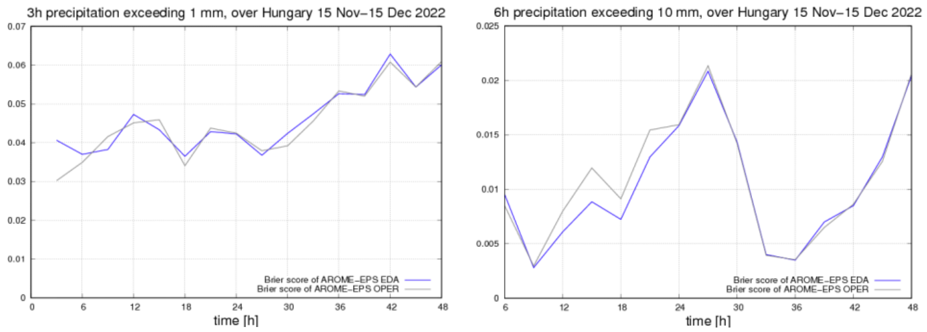

Figure 19: Brier-score for 3 hourly sum of precipitation exceeding 1mm (left) and 6 hourly sum of precipitation exceeding 10mm (right), based on the operational AROME-EPS (grey) and AROME-EPS EDA (blue) forecasts

Efforts: 5.25 PM (planned 1 PM in total in 2022)

Contributors: Katalin Jávorné-Radnóczi, David Lancz, David Tajti and Gabriella Tóth (all 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 and therefore it has been put into operations 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. New surface perturbation scheme put into operations 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).

In 2022 the configuration 903 has been upgraded to cy48t2 and 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.

Additionally, an A-LAEF test suite has been set-up to prepare LBCs on a Slovakian domain to couple the local convection-permitting EPS.

Efforts: 0.5 PM (planned 1 PM in total in 2022)

Contributors: Martin Bellus (SHMU)

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, AROME-EPS: 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 could be spent in 2022. Some progress has been achieved in the EPS products on the RC-LACE webpage and in the analog-based processing of probabilistic fields on a regular grid (stay of Iris). At ZAMG the statistical post-processing of EPS data (SAMOS) have been put into operations and at OMSZ some colleagues started to work in the area of machine learning post-processing.

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

In the area of analog-based post-processing of probabilistic fields on a regular grid some work has been spent on training dataset quality control, sensitivity tests, updated predictor weights and on the 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.

During her stay at ZAMG in Vienna in winter 2022 (21 November – 16 December) Iris Odak Plenković mainly worked on code-related topics. The algorithm to calculate point-by-point analog forecasts on the grid better has been improved significantly. Now it can run in a reasonable amount of time. The predictor normalization by standard deviation has been made independent on location and leadtime, or at least one of those independencies. However, it still needs to be tested whether this adaptation has a positive impact on the results. Furthermore, temperature has been added as an additional predictor variable to wind speed and direction. Of course, it would make sense to optimize the predictor weighting, but this needs a lot of time and could not yet been realized during this stay. Therefore values that were found appropriate based on previous experience have been chosen. More details can be found in Iris' stay report which should be published on the LACE webpage soon.

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

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. It has been put into operations in 2022. 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 (Figures 20 and 21) 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.

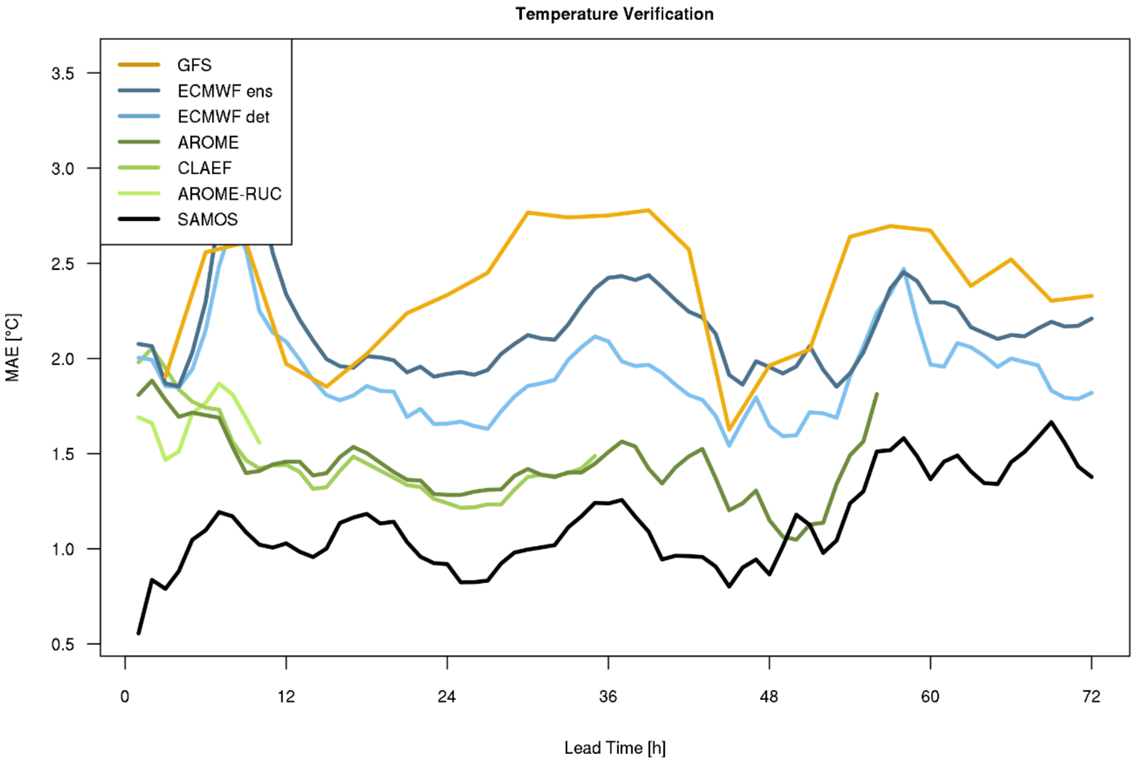

Figure 20: MAE of 2m temperature for different models and SAMOS for a case study in Austria.

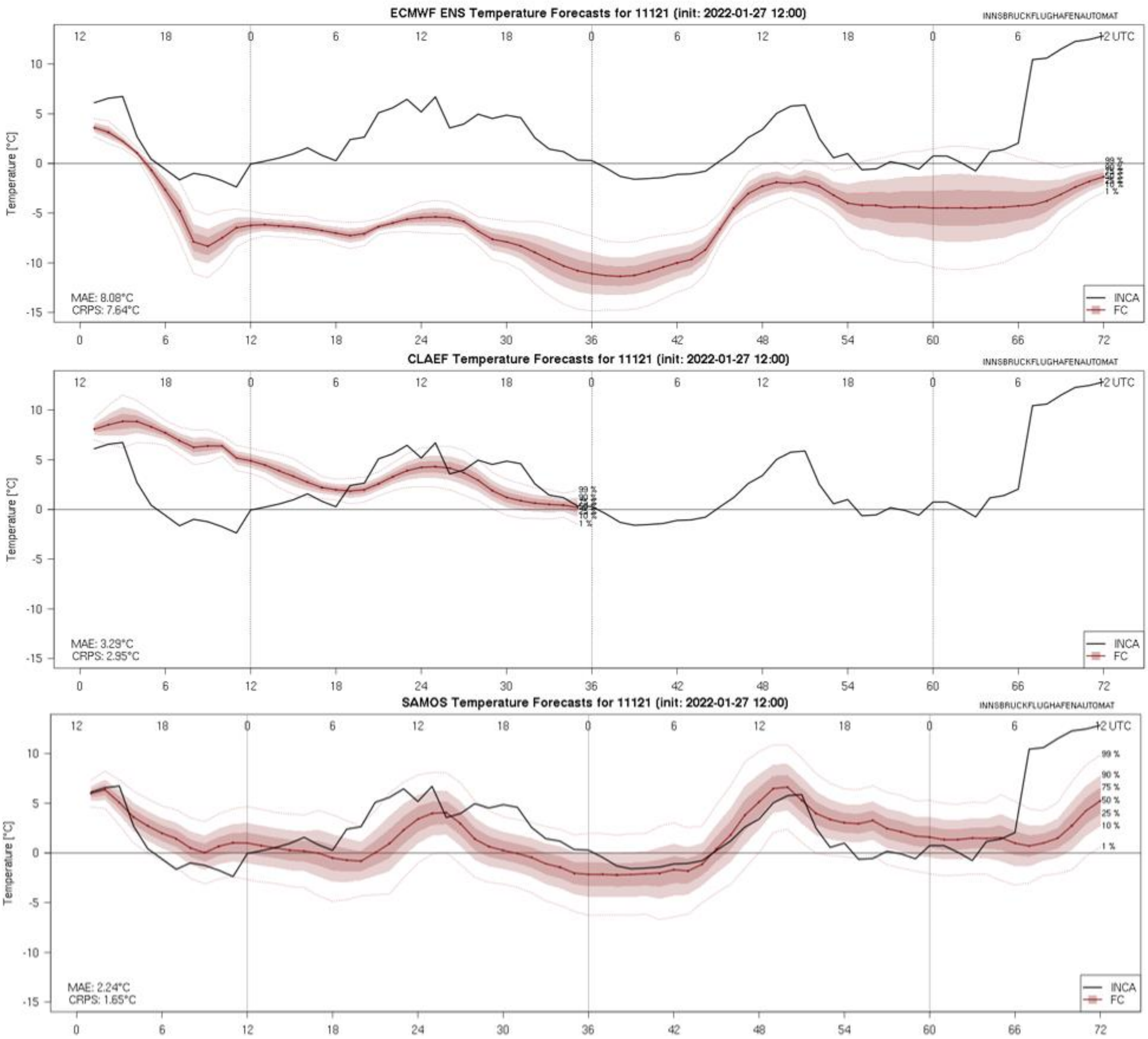

Figure 21: 2m temperature forecast for the station of Innsbruck on 27 January 2022 based on ECMWF-ENS (upper panel), C-LAEF (center) and SAMOS (lower).

SAMOS has already been implemented for the surface parameters 2m temperature and relative humidity, 10m wind speed and precipitation. Gusts should follow soon. The training of the data is done every three hours with a rolling 45 days period in the past.

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 ensemble started. So far, no verification results are finished.

❑ Topic 3: Adaptation of machine learning post-processing methods at OMSZ

OMSZ provides forecasts from numerical weather prediction models to support partners producing renewable energy. With statistical post-processing, errors of global radiation and near-surface wind forecasts can be reduced. As part of a project, mathematician colleagues developed machine learning and EMOS (ensemble model output statistics) methods applicable to AROME and AROME-EPS ensemble forecasts in 2021. OMSZ worked on applying these procedures in operational practice as well. In doing so, the needs of the partners have to be taken into account. Furthermore, the availability and quality of the data used have to be considered and one has to deal with possible data gaps, since the training is partly based on long data series.

To improve global radiation and 100 m wind forecasts, the mathematician colleagues developed different methods, taking into account the properties of these quantities. In both cases, a one-year data series was used by them for testing (see LACE report in March 2022). For radiation, the EMOS technique proved to be successful, in which the distribution of predictions was approximated with censored normal (CN) or censored logistic (CL) functions. Using a 31-day rolling training period, parameters of the distribution were estimated based on data of seven stations of OMSZ measuring network and 11 members of AROME-EPS (Jávorné et al., 2020) forecasts initialized at 00 UTC in the grid points to nearest the stations. As a result, the CRPS of the improved probabilistic forecast could be reduced by 16-18% with respect to the CRPS of the raw AROME-EPS (Schulz et al., 2021). CN-EMOS method proved to be numerically somewhat more stable.

For wind, EMOS based on truncated normal (TN), log-normal (LN) and truncated generalized extreme value (TGEV) distributions were applied, and also, multilayer perceptron (MLP) machine learning method based on TN or LN distributions. Observations of three wind farms in the northwestern part of Hungary and corresponding AROME-EPS forecasts at hub height (100m) and nearest grid points were used. A 51-day long training period was found to be optimal. MLP was the most successful, with CRPS improved by 10-15% of the raw EPS (Baran and Baran, 2021). In the received R and python3 codes, sampling and verification routines are also included.

OMSZ is working on integrating the received code into the operating system. The improved forecasts are produced daily: the output gives the value of the improved forecast per station and every 15 minutes by determining 11 equal quantiles from the given distribution function. (Each method handles each lead time independently.) The running procedure consists of 3 steps:

1. The collection of forecast data for the given day and observations for the preceding day is done by the (pre-)operational suite on the HPC.
2. The EMOS fitting and the MLP training run on a separate computer and produce the outputs.
3. At the end, verification is done for the forecasts for the preceding day, some statistics are calculated for the previous period of about one week, and also a few simple meteograms (Figure 22, left) and verification plots (Figure 22, right) are produced to compare the improved forecast and the raw AROME-EPS.

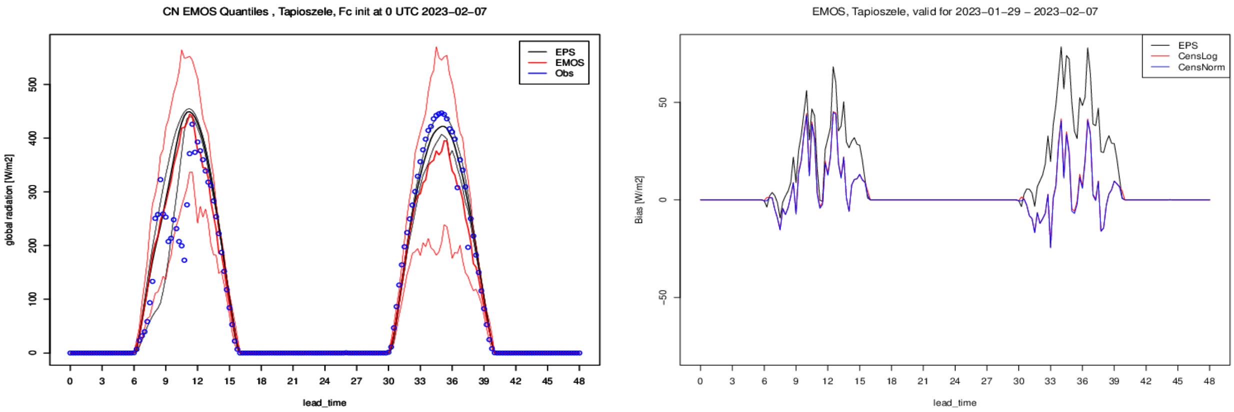

Figure 22: Left: Ensemble meteogram for radiation on 7 February 2023 based on raw AROME-EPS forecasts (ensemble mean in black, minimum and maximum in grey), on CN-EMOS (ensemble mean estimated from the corrected distribution function with thick red line, upper and lower quantiles with thin red lines) and observations with blue circles. Right: bias of ensemble mean for radiation as function of lead time between 29 January and 7 February 2023 based on raw AROME-EPS forecasts (black), CN-EMOS (blue) and CL-EMOS (red). Both plots are valid for station of Tápiószele.

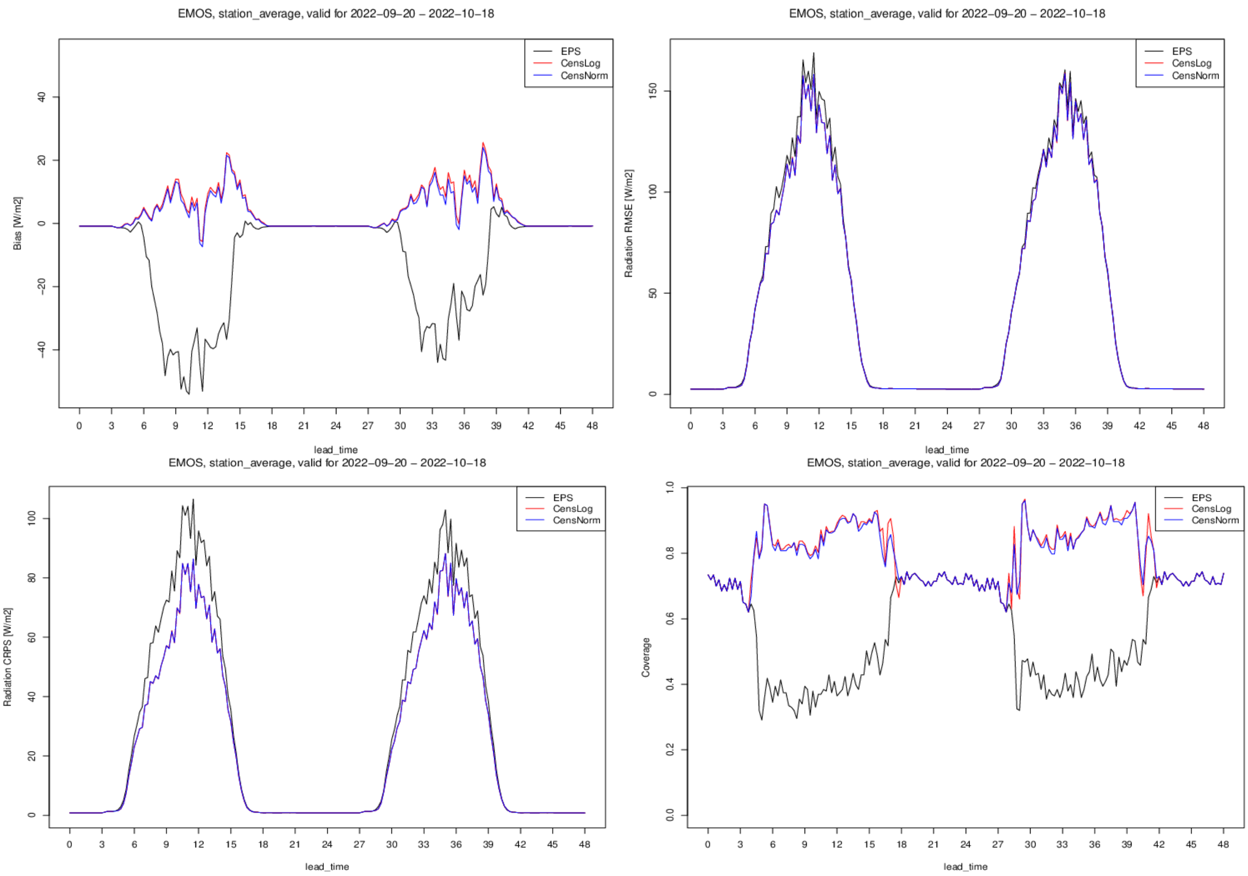

Figure 23: Verification scores for global radiation forecasts between 20 September and 18 October 2022 for 7 stations: CRPS (top left), coverage (top right), bias of ensemble mean (bottom left) and RMSE of ensemble mean (bottom right) based on raw AROME-EPS forecasts (black) and the predictive distribution functions provided by CN-EMOS (blue) and CL-EMOS (red).

In autumn 2022 the test was done on the current operational AROME-EPS which is downscaling of ECMWF-ENS and we experienced the expected improvement as a result of the post-processing (Figures 23 and 24). In general, the operational AROME-EPS is underdispersive and biased, both features seem to be improved after the post-processing. During the recent winter days the test is done on the pre-operational AROME-EPS EDA suite (see EPS report for details) and the improvement is not so clear. The reason may be both the different AROME-EPS basis and different weather situations. We note that an improvement in CRPS does not mean an improvement in RMSE of ensemble mean to the same extent, i.e. end users should consider the probability information and not only EPS mean.
Some smaller corrections and improvements have been done on verification and plotting scripts. After that, it is aimed to choose the best predictive distribution function and method, by running and verifying all of them over a longer period of time. In the future, it is planned to test these methods on additional stations and data and develop the data pre-processing procedure.

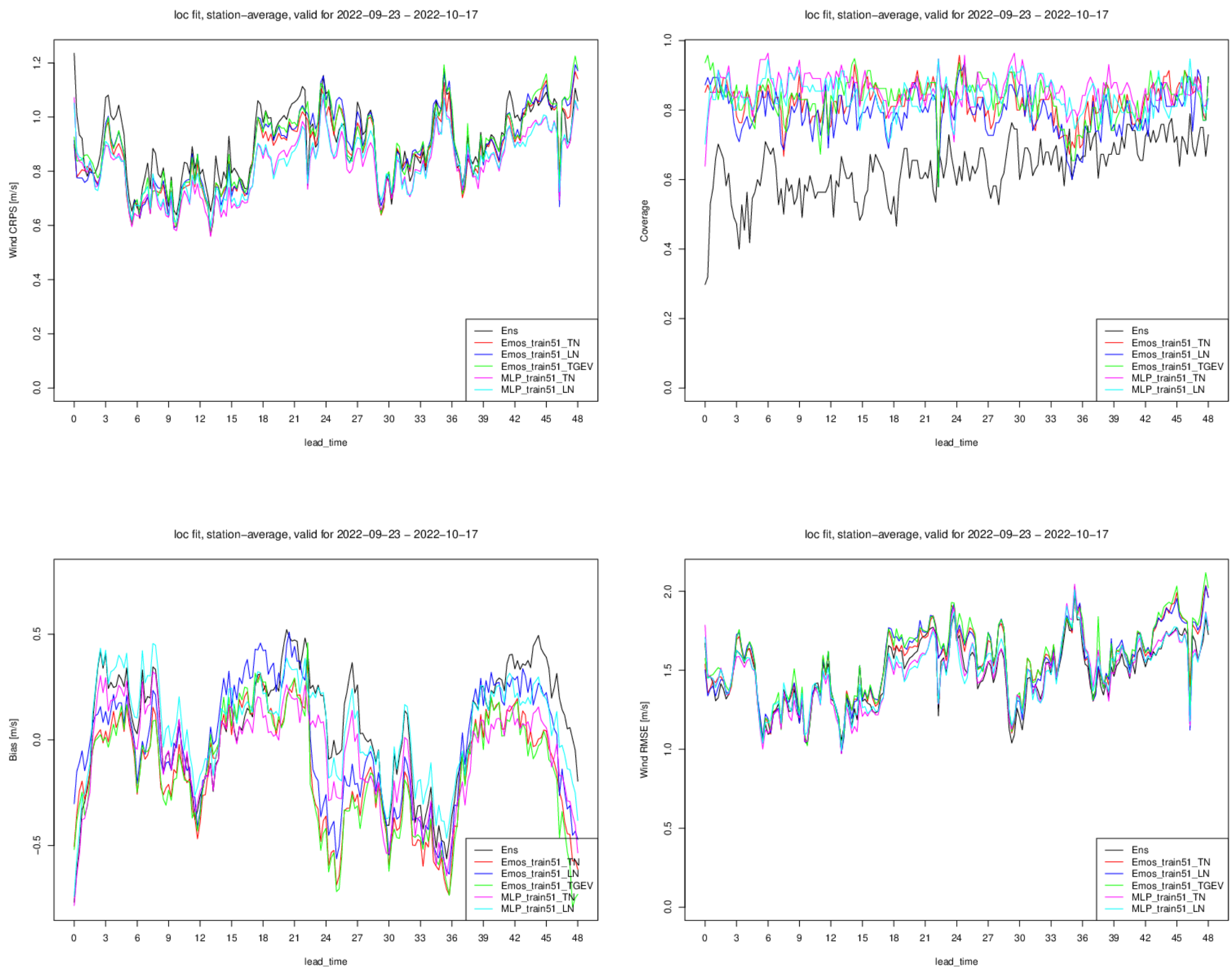

Figure 24: Verification scores for 100m wind forecasts between 23 September and 17 October 2022 for 3 stations: CRPS (top left), coverage (top right), bias of ensemble mean (bottom left) and RMSE of ensemble mean (bottom right) based on raw AROME-EPS forecasts (black) and the predictive distribution functions provided by TN-EMOS (red), LN-EMOS (blue), TGEV-EMOS (green), TN-MLP (magenta), LN-MLP (cyan).

❑ Topic 4: 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 25). Furthermore, the Epsgrams have also been verified by using station data (Figure 26).

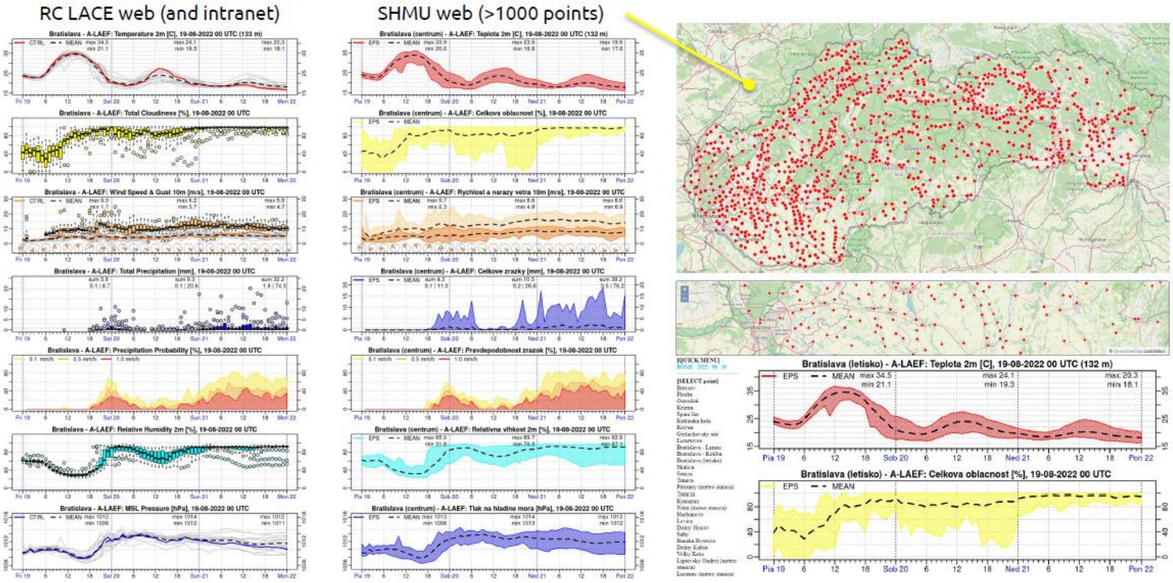

Figure 25: Redesigned Epsgrams + simplified version for the public SHMU webpage.

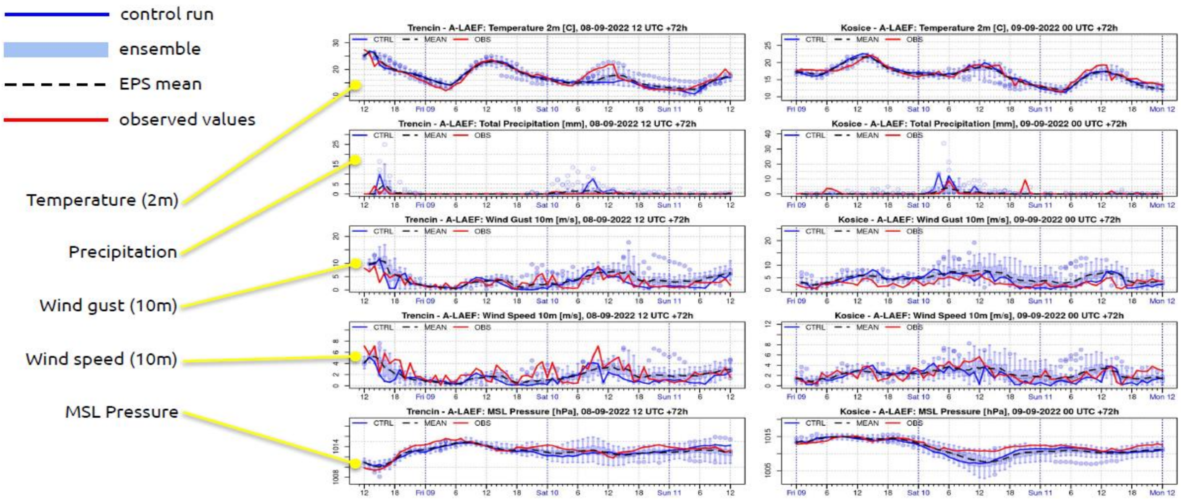

Figure 26: Verification of A-LAEF Epsgrams using automatic weather station data.

Efforts: 8.75 PM (planned 10.5 PM in total in 2022)

Contributors: Iris Odak Plenković (DHMZ), Martin Bellus and Viktor Tarjani (SHMU), Katalin Jávorné-Radnóczi and David Tajti (OMSZ)

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

Planned stays: Iris Odak Plenković (4 weeks at ZAMG) - analog-based post-processing methods – 21 November - 16 December 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. The first ACCORD EPS-working week took place from 25-29 April 2022 in Innsbruck where also some RC-LACE colleagues participated. As a result 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.

All of the work planned/done in this subject can be moved to the other subjects in EPS and therefore it is planned to remove this subject in the EPS plan for 2023.

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

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Efforts: 0 PM (planned 3 PM in total in 2022)

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

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)
- 39th LSC Meeting, 19-20 September 2022 (Bucharest)
- 44th EWGLAM and 29th SRNWP workshop, 26-29 September 2022 (Brussels)

RC-LACE supported stays – 1.5 PM in 2022

Unfortunately, due to several reasons (COVID, personal reasons), no research stays could be organized in the past two years. Finally, in autumn 2022 at least 2 long-planned stays could take place. From 17 -28 October Endy Keresturi stayed in Vienna to work on flow dependent model perturbations in C-LAEF and from 21 November to 16 December 2022 Iris stayed in Vienna to proceed her work on 2D analogs. The ACCORD stay of Mustafa Başran in Vienna to set-up C-LAEF for the Turkish domain has unfortunately been postponed to May 2023 because of personal reasons, as well as the planned stays of Martin Bellus in Vienna.

Summary of resources [PM] – 2022

Subject	Manpower		RC-LACE		ACCORD	
	plan	realized	plan	realized	plan	realized
S1: Preparation, evolution and migration	21	14.5	1	0	0.25	0
S2: Model perturbations	6.25	4.75	1	0.5		
S3: IC perturbations	1	5.25	1	0		
S4: Surface perturbations	0.25	0.25				
S5: LBC perturbations	1	0.5				
S6: Statistical EPS and user-oriented approaches	10.5	8.75	1	1		
S7: Collaboration and publication	3	0				
Total:	43	34	4	1.5	0.25	0

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