

Working Area Predictability

Progress Report

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Period:	Jan – Jun 2026
Date:	Sep 2026

Progress summary

The first half of 2026 was marked by significant progress in the development and operational maintenance of regional ensemble prediction systems (EPS) within RC LACE. The main achievements include the successful upgrade of the operational A-LAEF system to cycle 46t1 and the operational implementation of the new joint C-LAEF AlpeAdria system for Austria, Slovenia, and Croatia. Despite some delays caused by limited personnel resources, most key activities continued according to plan and several important research and development milestones were reached.

Research on model perturbations (SPP) remained an important activity. In C-LAEF AlpeAdria, SPP has been successfully integrated operationally and further tuning continues for high-resolution applications. At HungaroMet, extensive testing of SPP within AROME-EPS showed only a limited impact on forecast skill. Current investigations suggest that perturbations originating from lateral boundary conditions may dominate over internal model perturbations, providing valuable guidance for future ensemble design.

Significant progress was also achieved in the area of initial condition perturbations. Continuous testing of EnVar-based data assimilation in C-LAEF AlpeAdria has produced encouraging results, with verification indicating generally better performance than the traditional 3D-Var approach. The long-term goal is the gradual transition of all ensemble members of C-LAEF AlpeAdria towards EnVar-based assimilation.

In the field of surface perturbations, initial implementation work on SPP within SURFEX was completed during a collaborative stay at GeoSphere Austria. Several key land-surface parameters were successfully perturbed within CY50t2, providing the basis for future operational development. However, further testing and tuning remain necessary.

Strong progress was made in statistical post-processing and AI-based forecasting applications. Hungary finalized an improved similarity-based EMOS approach for solar radiation forecasts, which demonstrated added value compared to operational post-processing methods. Croatia and Austria advanced machine-learning applications for precipitation and solar-radiation forecasting and continued development of probabilistic renewable-energy forecast systems and AI-assisted ensemble generation methods. Although ensemble emulation using diffusion models remains experimental, valuable experience was gained regarding future AI integration into operational forecasting systems.

Poland worked on a publication of the innovative Cascading Ensemble Method (CEM), an ensemble approach in which additional members are introduced progressively during forecast integration and also on a comparison of different AI-based EPSs.

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 AlpeAdria running on ECMWF's HPC and the AROME-EPS running at the HPC at HungaroMet. Migration and implementation to new HPCs, operational upgrades, new cycles, optimizations and tunings.

The originally planned topics for 2026 were:

- ☐ Maintenance/monitoring of operational EPSs (A-LAEF, C-LAEF AlpeAdria) on ECMWF's HPC in Bologna
- ☐ Development of an ALARO-based convection-permitting EPS coupled to ECMWF ENS and A-LAEF
- ☐ First tests with SURFEX in ALARO-EPS
- ☐ Implementation of ENS BlendVar assimilation method in the A-LAEF system to improve the simulation of upper-air ICs uncertainty
- ☐ C-LAEF AlpeAdria for Austria, Slovenia and Croatia, operationalization; implementation of EnVar based EPS assimilation system
- ☐ Extension of C-LAEF based Ensemble Reanalysis dataset (ARA) from 2021 to 2025
- ☐ Introduction of model perturbations (SPP) in operational AROME-EPS

Finally, some major updates of both systems running on the ECMWF-HPC were successfully implemented in the first half of 2026. A-LAEF has been updated to cy46t1 in May 2026 and the joint system of Austria, Slovenia and Croatia C-LAEF AlpeAdria has been put into operations on June 18th 2026.

Some of the A-LAEF topics are still delayed because of missing resources (e.g. ALARO-based convection-permitting EPS, SURFEX in ALARO-EPS).

The C-LAEF reanalysis (2.5 km version) for the period 2012–2021 was completed in summer 2025, and the dataset is now being extended to cover up to the year 2025.

In Hungary, no changes in the operational AROME-EPS have been made so far in 2026.

☐ Topic 1: Upgrade of A-LAEF on ECMWF's HPC

After some years with developments and testing the upgrade of the A-LAEF system to cy46t1 was completed in May 2026.

Some highlights of this upgrade are summarized below:

- new clim files – slightly different terrain height
- new configuration of 903 which uses the oper forecast stream for the control member
- Canari upgrade to CY46t1 and increased number of surface measurements available in OPLACE
- blending upgrade to CY46t1
- multi-physics scheme updated to CY46t1. it still produces the usual ICMSH and fullpos files (CY46t1 can write out grib2 fields directly, but right now no tool can translate grib2 to grib1 on a Lambert projection)
- the fullpos to lat-lon domains still uses CY40t1, it is possible to use CY46t1 there, it works and can produce additional output fields that could be very interesting for the users
- grib1 on a Lambert projection are made from the output fullpos file and are in grib1
- grib1 on a lat/lon projection are made from the output fullpos files and are currently grib1

The upgrade of fullpos to cy46t1 and the production of grb2 files is still missing and will follow with the next upgrade of the suite.

Due to the upgrade of the ECMWF ENS system on May 12 2026, some of the jobs (e.g. Ecpdsens, getlbc) have been adapted.

The monitoring of the suite has been split between the teams from Poland, Czech Slovakia, Slovenia, and Croatia.

The A-LAEF system has shown good performance during a severe windstorm in August 2026 in Slovakia – this is also a showcase of the importance of running an ensemble prediction system.

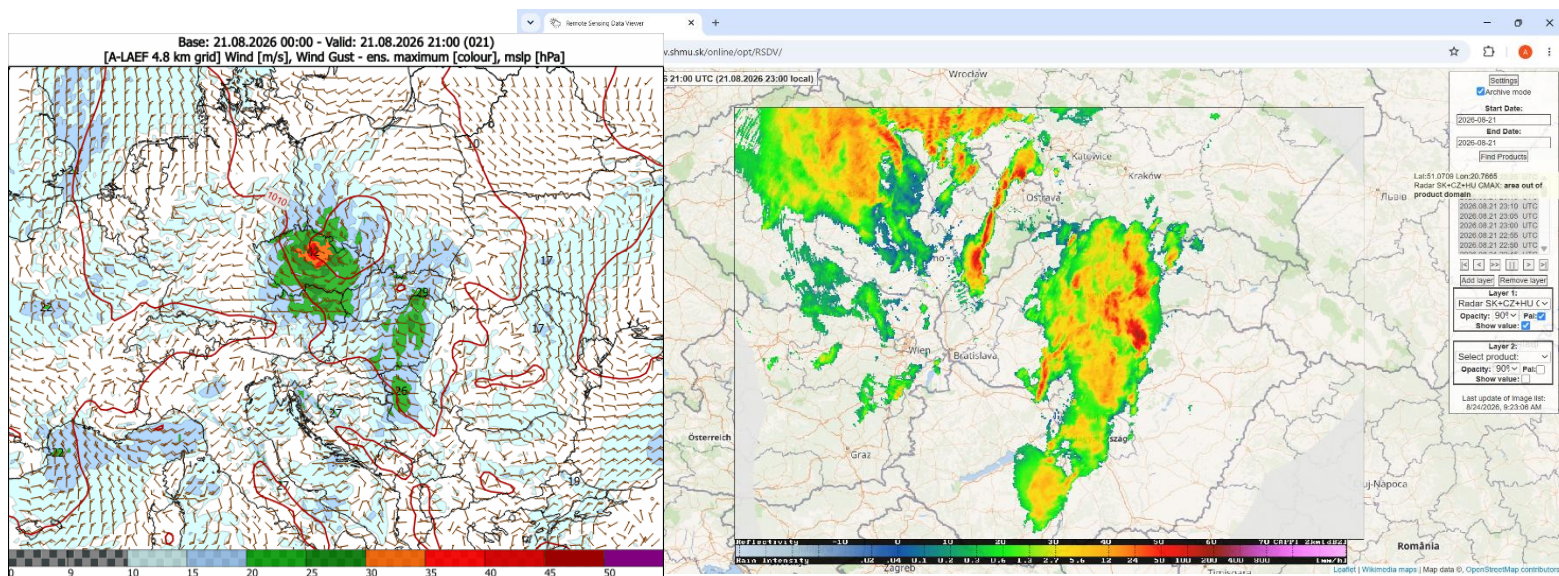


Figure 1: A-LAEF wind gust EPS maximum (left) and column maximum reflectivity (right) for 21 August 2026 21 UTC.

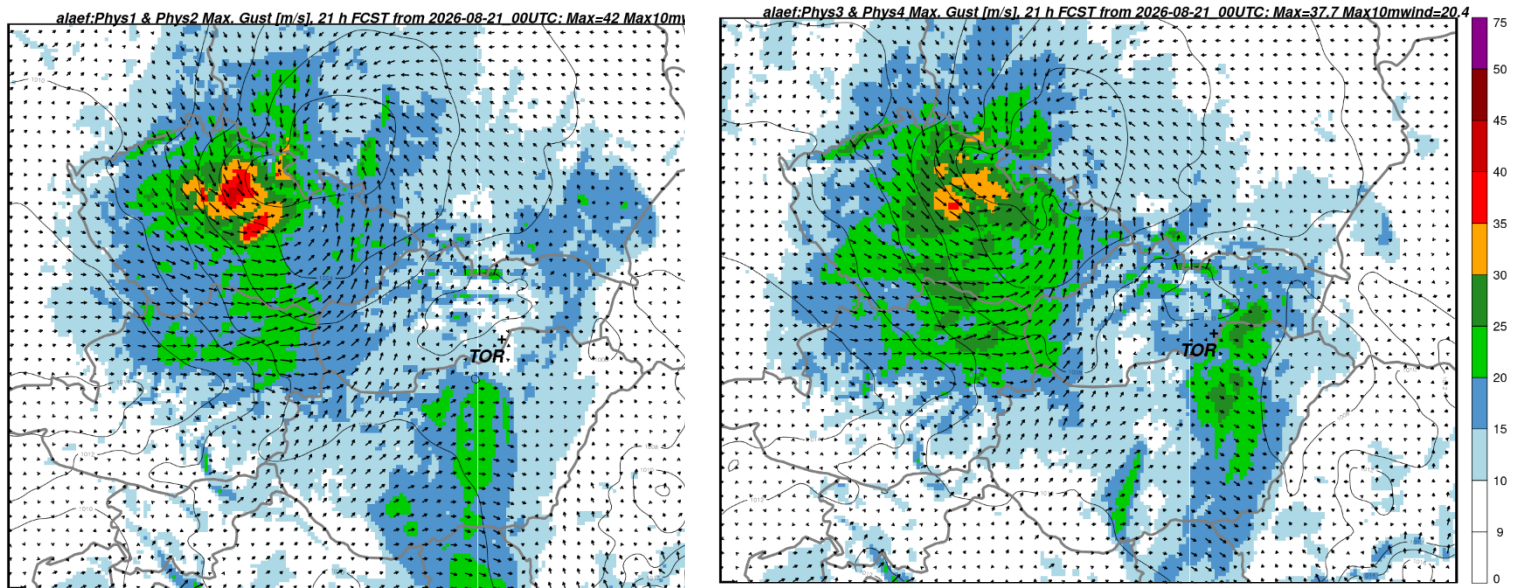


Figure 2: A-LAEF wind gust EPS maximum for 21 August 2026 21 UTC calculated from phys1 and phys2 cluster (left, EL0 Gelym-Cedilnik mixing length) and phys3 and phys4 cluster (right, EL1, Bougeault-Lacarrere + shear).

A closer examination of the 21 August 2026 00 UTC run results showed that the members 3, 5, 7, 11, 12, 15, 16 were more successful in forecasting strong wind in the windstorm region. Except the member 5, all belong to clusters 3 or 4, using the EL1 formulation of the mixing length (revised Bougeault-Lacarrère with the inclusion of a shear term). This formulation made also the very high gusts over the Czech Republic somewhat weaker (though severe thunderstorms occurred there as well).

❑ Topic 2: C-LAEF AlpeAdria for Austria, Slovenia and Croatia, operationalization; implementation of EnVar based EPS assimilation system

In recent years, significant efforts have been put in Austria into the upgrade of the C-LAEF system to a 1 km grid and cy46t1. Starting in early 2025, Slovenia and Croatia joined this initiative by contributing both computational resources (SBUs) and personnel. Slovenia's contributions mainly focus on data assimilation and post-processing, while Croatia provides support in model perturbations and dynamics. This collaborative effort has resulted in the creation of the C-LAEF AlpeAdria (C-LAEF AlpeAdria) system which has been put into operations on 18 June 2026.

The C-LAEF AlpeAdria ensemble consists of 16+1 members which are coupled to the first 16 members of the ECMWF ENS. The system is designed as a continuous lagged ensemble with 4 members calculated every 3 hours with an extended forecast range. In the post-processing the members of 4 different initialization times are put together to provide a full 16+1 member ensemble with 60 hours lead time every 3 hours. A 3-hourly assimilation cycle is implemented, incorporating new types of observations such as radar, GNSS, and ceilometers. The system operates in single precision (configuration 001), utilizing an I/O server and a 45-second time step. The perturbation methods used include the SPP scheme for model perturbations, Ensemble-JK, EDA, and surface EDA for initial condition perturbations, as well as an external surface

perturbation scheme (pertsurf). The output format of C-LAEF AlpeAdria is GRIB2. Thanks to the collaboration with Slovenia and Croatia, the domain has been expanded to the south compared to the original C-LAEF system, with each country managing its own post-processing domain. A shared username (zacs) and SBU account (claeopf) have been created to facilitate the joint development and monitoring of the system.

Verification of C-LAEF AlpeAdria:



Figure 3: BIAS of 3h accumulated precipitation (top left), 2m temperature (top right), wind gusts (lower left) and 2m relative humidity (lower right) for C-LAEF AlpeAdria Ctrl (purple), C-LAEF median (blue), ECMWF (green) and ICON-D2 (orange) for July 2026.

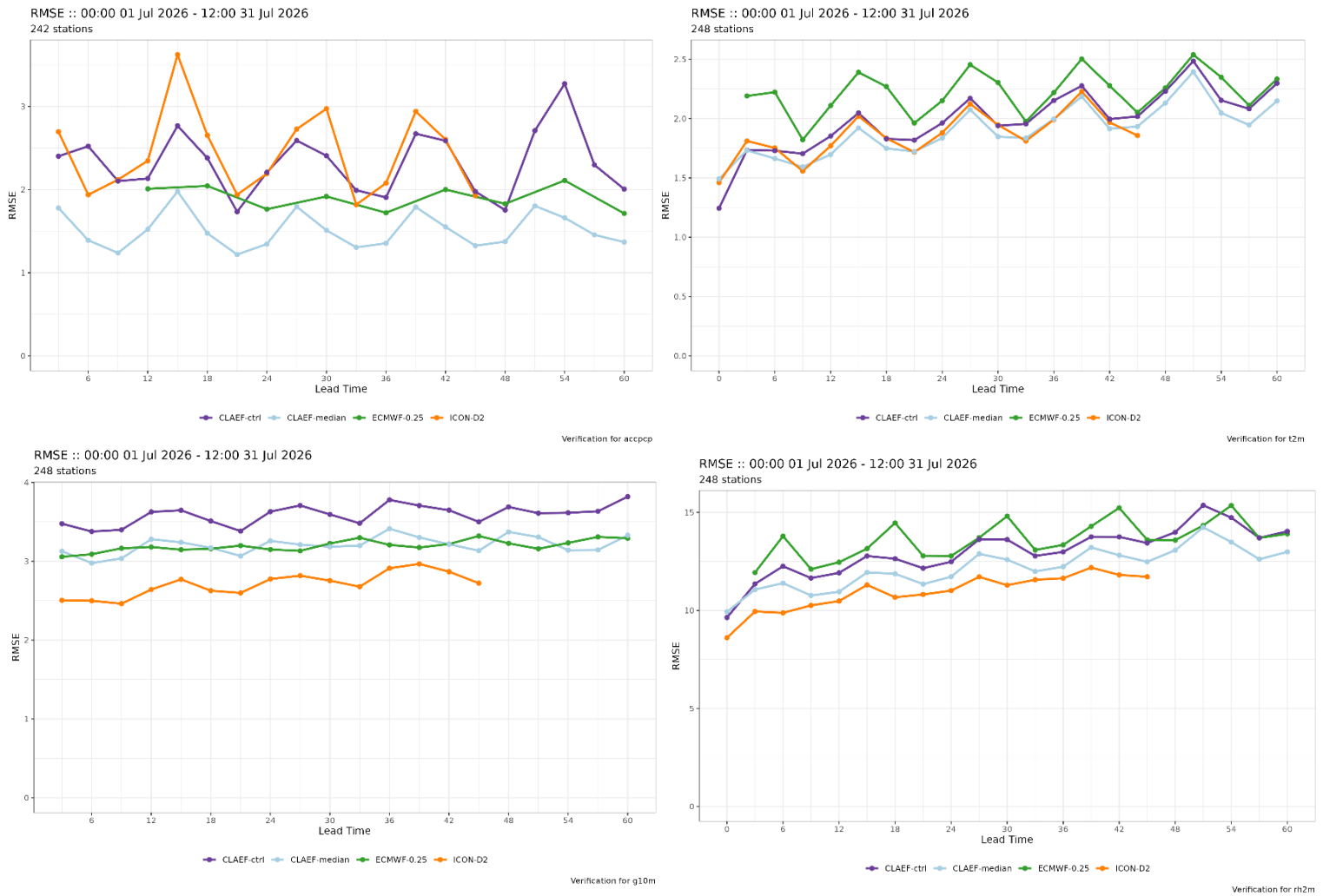


Figure 4: RMSE of 3h accumulated precipitation (top left), 2m temperature (top right), wind gusts (lower left) and 2m relative humidity (lower right) for C-LAEF AlpeAdria Ctrl (purple), C-LAEF median (blue), ECMWF (green) and ICON-D2 (orange) for July 2026.

The performance of the C-LAEF AlpeAdria system is continuously monitored using HARP verification. The verification results for July 2026 in the Figures 3 and 4 show a comparable performance for most of the parameter (except wind gusts) to the German ICON-D2 model and significantly better results than the global model ECMWF. For some convective events the precipitation amounts and the wind gusts in C-LAEF AlpeAdria were significantly overestimated, especially in the Alps. We are currently working to fix this by using a different dynamics setup (see next part of this report).

Dynamics optimizations:

The constant monitoring and verification of the C-LAEF AlpeAdria suite has revealed that there is a tendency to overestimate precipitation in the Alpine region (Figures 5 and 6). Intensive testing for some selected cases has shown that the dynamics settings are not very well tuned for the 1 km resolution.

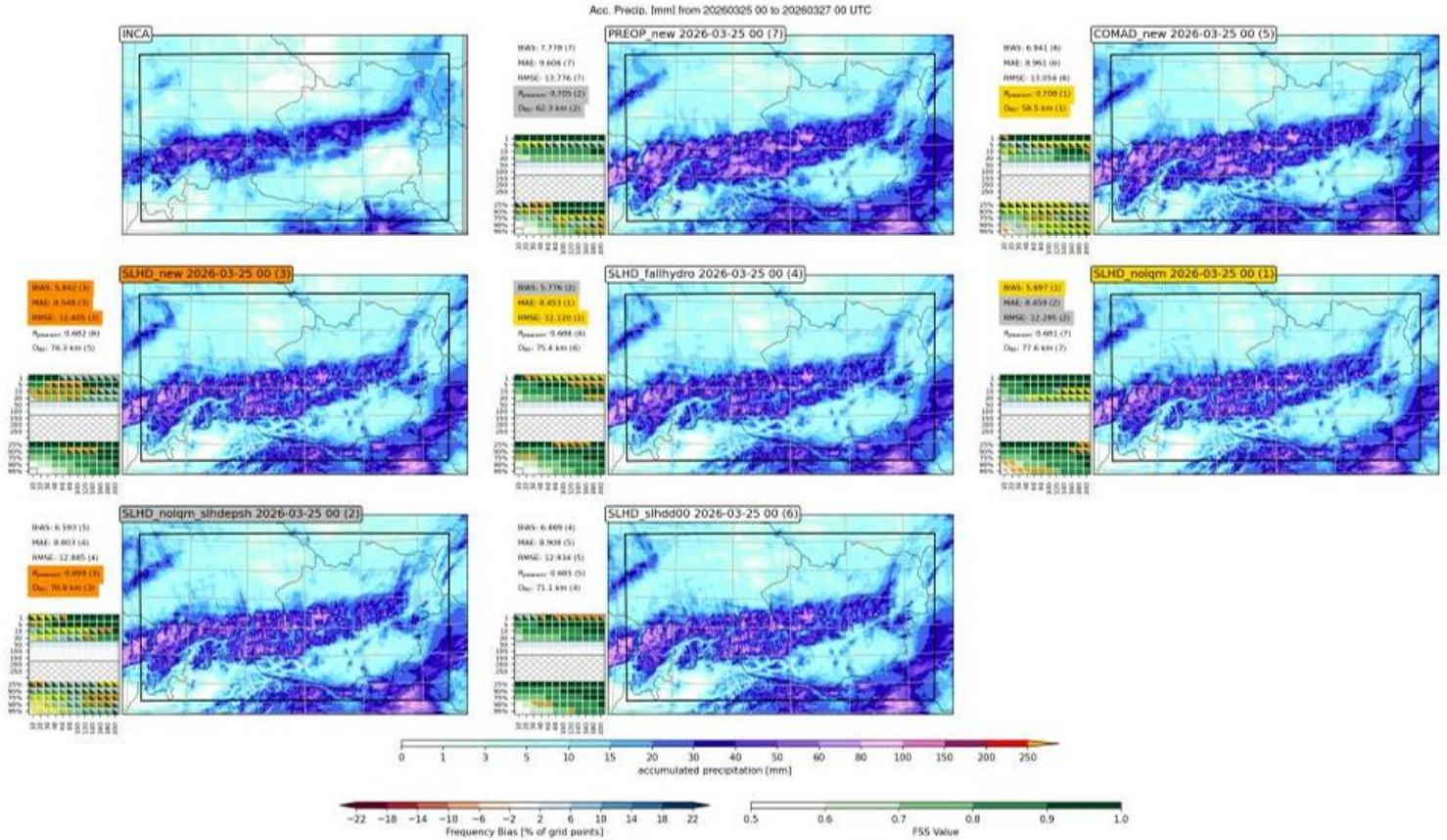


Figure 5: Precipitation verification for a test case in March 2026. Top left is INCA analysis, then we have the operational setup and COMAD, in the second row different setups with SLHD.

The most effective way to reduce the positive precipitation BIAS in C-LAEF AlpeAdria in the Alps is when turning on SLHD on YQ (humidity). But this leads to an underestimation of convective precipitation in summer in this region. Hence a lot of testing and tuning is ongoing to provide an appropriate setup for all seasons. At the moment we are working on using a vertical profile of Kappa which steers the strength of diffusion (less in higher levels). Further details will be provided in the next report.

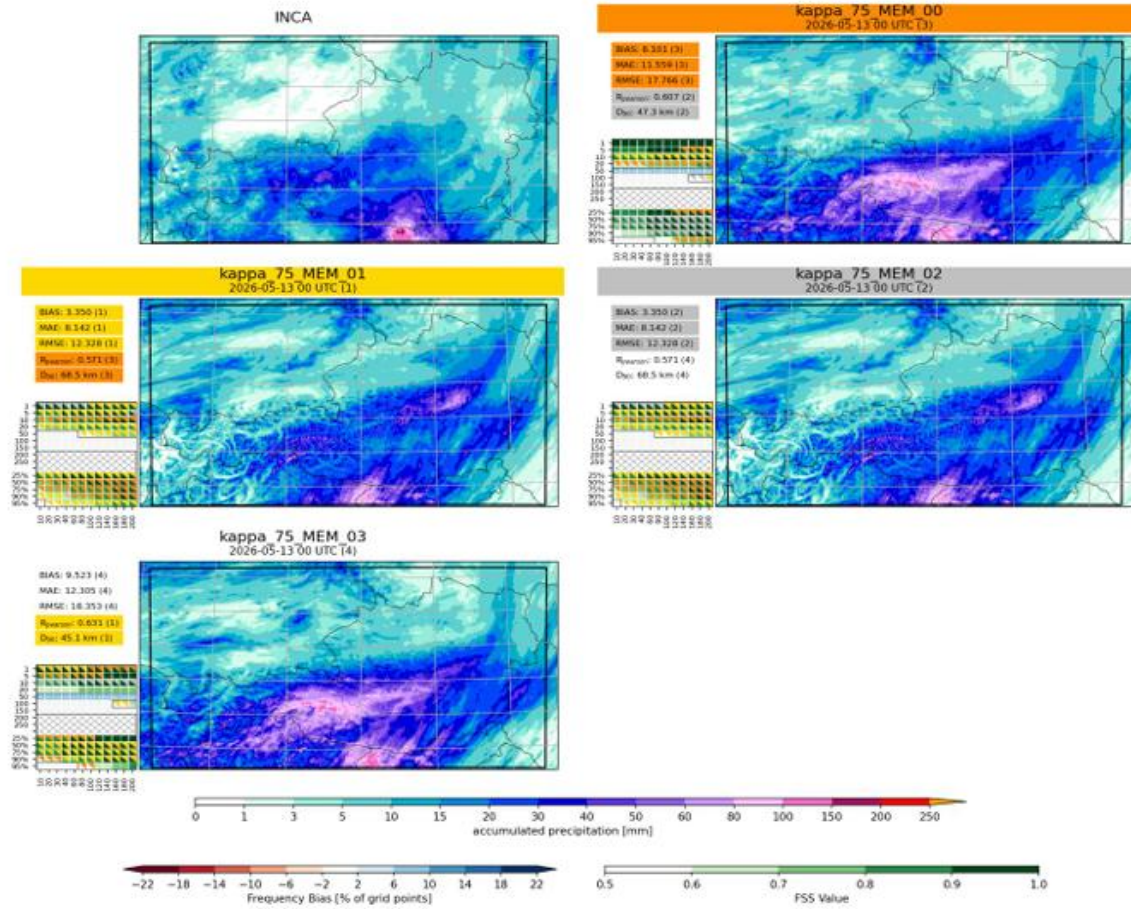


Figure 6: Precipitation verification for a large-scale event in May 2026. Top left is INCA analysis, the other plots show different setups of the Kappa profile.

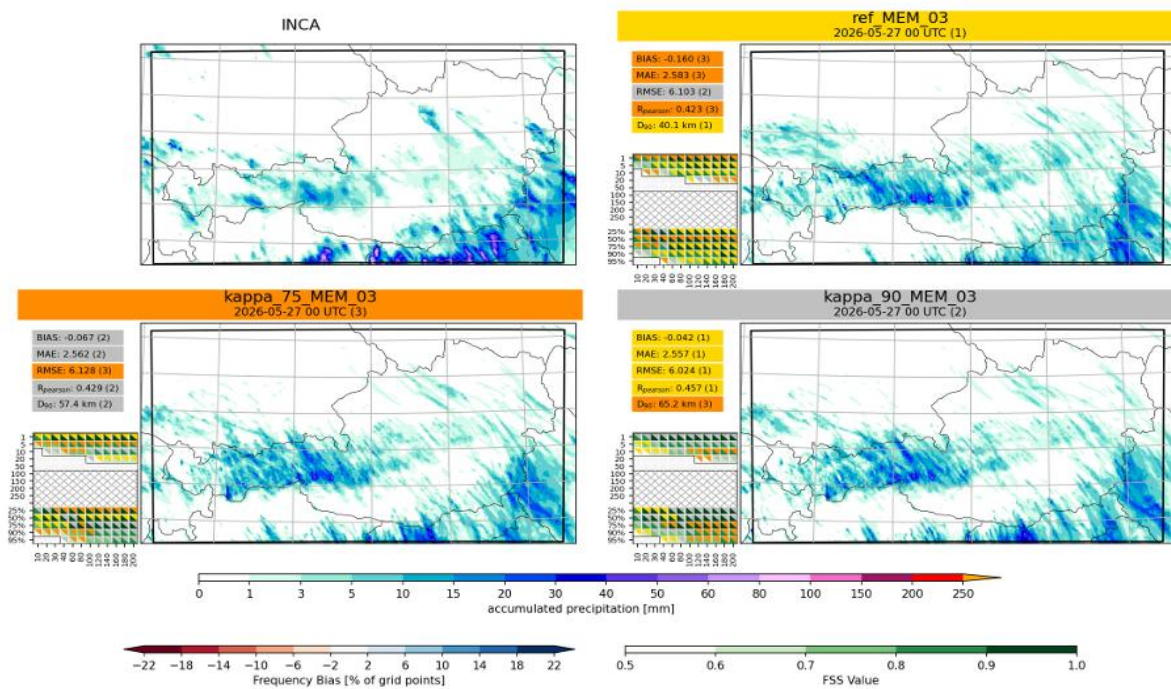


Figure 7: Precipitation verification for a convective case in May 2026. Top left is INCA analysis, the other plots show different setups of the Kappa profile.

EnVar:

In the current operational version of C-LAEF AlpeAdria the atmospheric assimilation is based on the classical 3DVar approach for all members, except for member 1 where EnVar is used. The plan with C-LAEF AlpeAdria is to use EnVar in all members in the future, but some more testing and optimization is necessary. The scores for summer 2026 show a generally good performance of the EnVar member compared to the 3DVar ctrl member of C-LAEF AlpeAdria. More details can be found in Subject S3 of this report and in the area leader report for data assimilation.

❑ Topic 3: Reanalysis of C-LAEF for 2012 – 2021 period

As part of the ARA (High resolution Austrian Re-analysis ensemble with AROME) project at GeoSphere Austria a first of its kind high resolution (2.5 km) reanalysis ensemble dataset for Austria has been created. It provides a detailed (2D and 3D) information on the state of atmosphere in Austria from 2010 – 2021 – see EPS report of September 2025. This ARA dataset is now being extended to cover up to the year 2025.

❑ Topic 4: AROME-EPS: Optimization and tuning of convection-permitting ensemble system on HPC at HungaroMet

The latest upgrade of the Hungarian AROME-EPS has been made in February 2025. In the current version of AROME-EPS no representation of the model error is done. The plan is to include the stochastically perturbed parameterization scheme (SPP) in a next step. In the first half of 2026 the SPP scheme has been successfully implemented and intensively tested in AROME-EPS. The verification showed that the impact of SPP is very small and therefore a lot of tuning and optimization is ongoing at the moment (see subject S2 for more details). The goal is to put SPP into operations end of 2026.

Efforts: 4 PM (planned 15.0 PM in 2026)

Contributors: Katalin Jávorné-Radnóczy and Zsófia Szalkai (HungaroMet), Clemens Wastl, Florian Weidle, Brigitta Goger (GeoSphere Austria), Jadwiga Róg (IMGW), Martina Tudor (DHMZ)

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: Jadwiga Róg (April 27 - May 15 2026, in Zagreb) – A-LAEF upgrade; probably one more stay in autumn 2026

Status: Ongoing, some delays.

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 2026 were:

- ☐ Stochastic perturbation of fluxes instead of tendencies in order to preserve the energy balance in the perturbed model.
- ☐ Introduction of new SPP parameters to C-LAEF AlpeAdria – dynamics parameters, etc.
- ☐ Development of flow-dependent model perturbations in C-LAEF AlpeAdria; Investigate the possibility of using AI
- ☐ Add more parameters to the SPP scheme in AROME-EPS at HungaroMet, tests, verification, optimization

The topic of "stochastic perturbation of fluxes instead of tendencies" has been postponed, and it is currently uncertain whether it will continue due to limited resources.

SPP has been integrated into the operational version of the C-LAEF AlpeAdria ensemble using cy46t1. A lot of tuning of SPP parameters on 1km and hectometric (DEODE) scales has been done. Future plans include applying the SPP perturbations to the model's dynamics component, with the first parameter (SLWIND) successfully tested. Unfortunately, this is a bit delayed because of resource constraints.

As part of the DEODE project, the SPP code for AROME has been phased to cy50t2.

The flow-dependent SPP code has been phased to cy50t2 and has been prepared for entering the common ACCORD IAL repository. Further testing over longer periods is necessary before putting it into operations.

Considerable effort has been devoted to the implementation and optimization of SPP within the Hungarian AROME-EPS. It is expected to become operational end of 2026 after further fine-tuning of the perturbation scales.

☐ **Topic 1: Implementation of model perturbations (SPP) in AROME-EPS**

HungaroMet began testing the Stochastically Perturbed Parametrizations (SPP) scheme experimentally in 2023, focusing on selected parameters from different physical parametrization schemes. Previous studies (e.g., Lang et al., 2021; Wastl et al., 2019; Wimmer et al., 2021) did not provide clear guidance regarding the optimal number or selection of parameters to perturb. Ideally, parameters with high uncertainty, as well as those affecting different atmospheric levels or geographical regions, should be perturbed simultaneously.

In our most recent experiment, we hypothesized that the neutral forecast impact of the SPP scheme in AROME-EPS was caused by interactions among the ten perturbed parameters. To investigate this further, we conducted two AROME-EPS experiments during 1-14 July 2025 and 17-30 November 2025, perturbing only one parameter from each parametrization scheme, resulting in a total of five perturbed parameters (Table 1). AROME-EPS was run with six perturbed members and one control member.

Table 1: The parameters perturbed in AROME-EPS in Hungary.

Name of the parameter	Parametrisation scheme	Unperturbed value
VSIGQSAT	Microphysics	0.02
RSWINHF	Radiation	1
XCED	Turbulence	0.85
XCMF	Convection	0.065
XFRACZ0	Surface	10

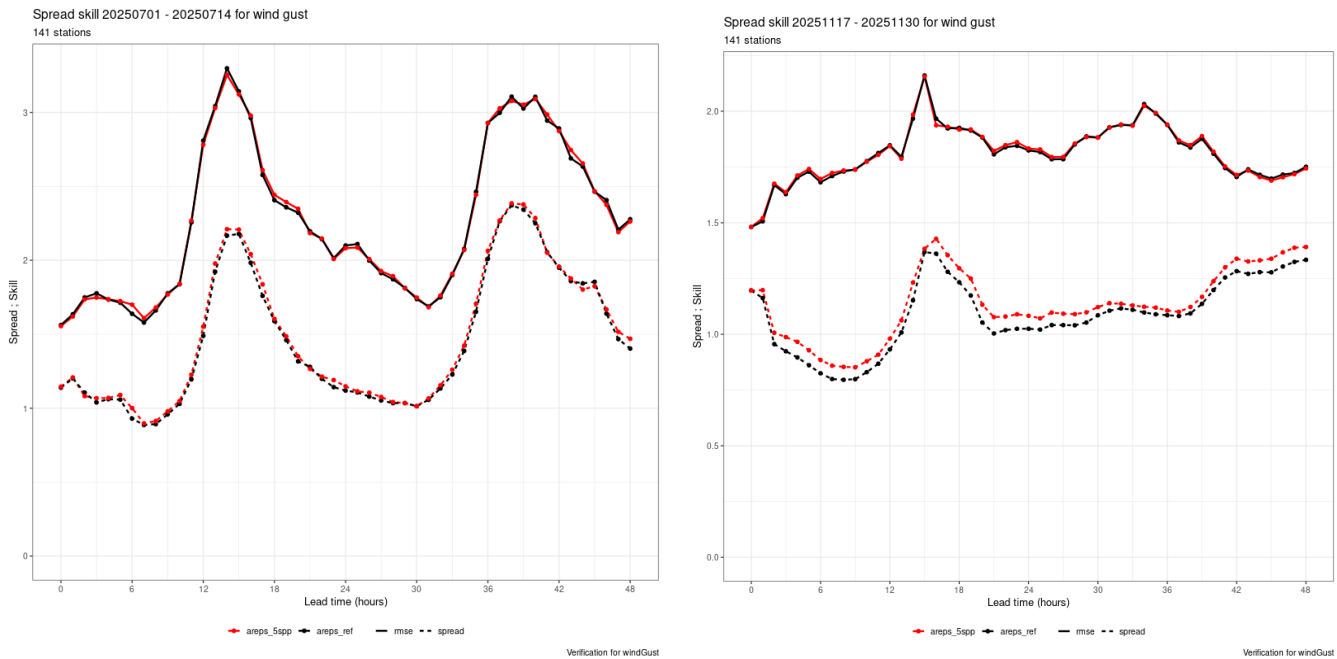


Figure 8: Spread–skill diagram for 10m wind gust (ms^{-1}) as function of lead time (h), based on AROME-EPS; with 5 perturbed parameters (red) and without SPP (black); 1–14 July (left), 17–30 November (right), 2025, 00 UTC, Hungary.

Compared to the reference run without stochastic parameter perturbations, the overall impact remained largely neutral. A slight improvement was observed only in the winter experiment. For example, the ensemble spread increased and the RMSE decreased slightly for 10 m wind gusts, as shown in Figure 8.

Given this unexpectedly neutral impact, we designed a new set of experiments in which only VSIGQSAT was perturbed, as this parameter had shown a strong impact in one of our earliest single-parameter perturbation experiments. Additional parameters were then introduced one by one to investigate possible interactions among them. However, even the first experiment produced a largely neutral impact compared to the reference run without stochastic parameter perturbations. An example is shown in Figure 9.

We therefore hypothesized that perturbations of the initial conditions or lateral boundary conditions (LBCs) might be masking the effect of the SPP scheme. Consequently, we initiated a systematic evaluation to better understand the underlying mechanisms.

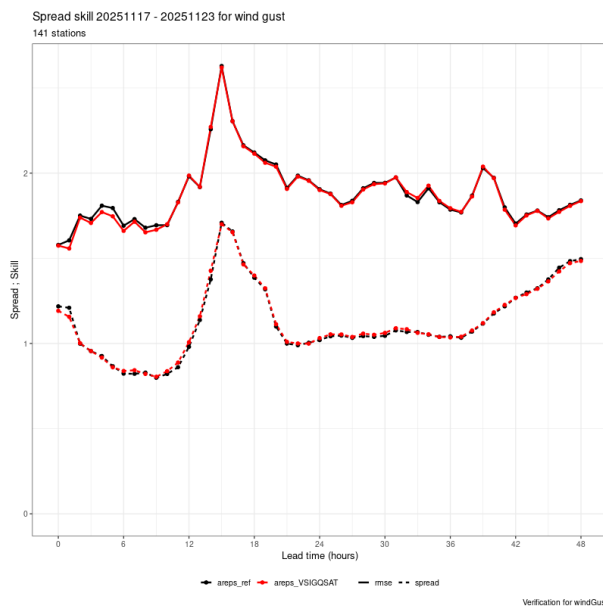


Figure 9: Spread–skill diagram for 10m wind gust (ms^{-1}) as function of lead time (h), based on AROME-EPS; with perturbation only of VSIGQSAT (red) and without SPP (black); 17–30 November, 2025, 00 UTC, Hungary

To further investigate this hypothesis, we conducted two additional AROME-EPS experiments perturbing only VSIGQSAT: one without EDA perturbations and one without LBC perturbations. In the experiment with EDA switched off, the ensemble spread generally decreased during the first forecast hours, while the RMSE also decreased slightly. Otherwise, only minor differences were found between the reference experiment (without SPP, with EDA and LBC perturbations activated) and the SPP experiment. An example is shown in Figure 10.

In the second experiment, all ensemble members used identical LBCs while VSIGQSAT perturbations were retained. In general, the RMSE, spread, and CRPS all deteriorated in the SPP experiment: RMSE and CRPS increased, while the spread decreased. Moreover, the differences from the reference experiment (without SPP, with EDA and LBC perturbations) became larger with increasing lead time. An example is shown in Figure 11. These results suggest that once LBC perturbations are introduced, they dominate the forecast uncertainty and largely overshadow the impact of the SPP perturbations.

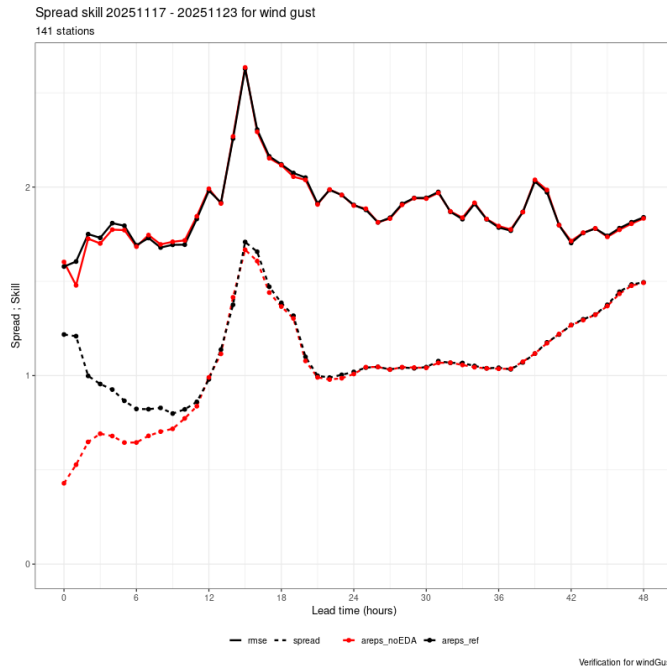
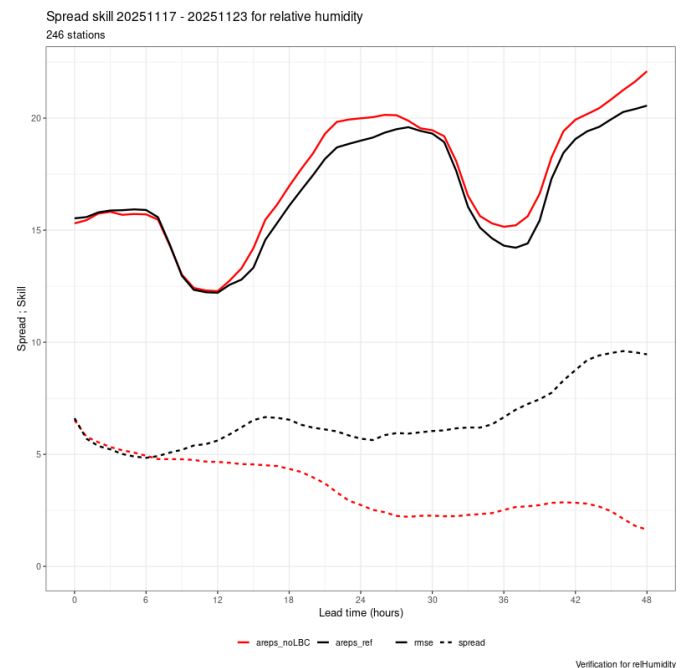


Figure 10: Spread-skill diagram for 10m wind gust (ms^{-1}) as function of lead time (h), based on AROME-EPS; with perturbation only of VSIGQSAT and with EDA perturbations switched off (red) and without SPP but with EDA perturbations (black); 17–30 November, 2025, 00 UTC, Hungary.

Figure 11: Spread-skill diagram for 10m wind gust (ms^{-1}) as function of lead time (h), based on AROME-EPS; with perturbation only of VSIGQSAT and with LBC perturbations switched off (red) and without SPP but with LBC perturbations (black); 17–30 November, 2025, 00 UTC, Hungary.



A further experiment is currently underway in which only VSIGQSAT is perturbed, while all other sources of perturbation are switched off. This setup reproduces our earliest single-parameter perturbation experiment, which yielded particularly promising results. The objective is to compare all five experimental configurations over the same time period and draw a final conclusion regarding the relative contribution of each perturbation source.

Efforts: 2 PM (planned 8.0 PM in total in 2026)

Contributors: Clemens Wastl (GeoSphere Austria), Endi Keresturi (DHMZ), Katalin Jávorné Radnóczy, Zsófia Szalkai (HungaroMet)

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

Planned stays:

Endi Keresturi (4 weeks at GeoSphere Austria) – flow dependent SPP perturbations/C-LAEF AlpeAdria – postponed

Status: Ongoing; some delays

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 2026 were:

- ☐ Preparation of flow-dependent B-matrix for local 3DVar assimilation systems based on ALARO CMC using A-LAEF operational outputs
- ☐ EnVar and Hybrid EnVar in C-LAEF AlpeAdria to create initial conditions for ensemble members. Test what perturbations are suitable and perform the best. Preparation for operationalization
- ☐ Perturbation of initial conditions in global AI models to be used in regional NWP models

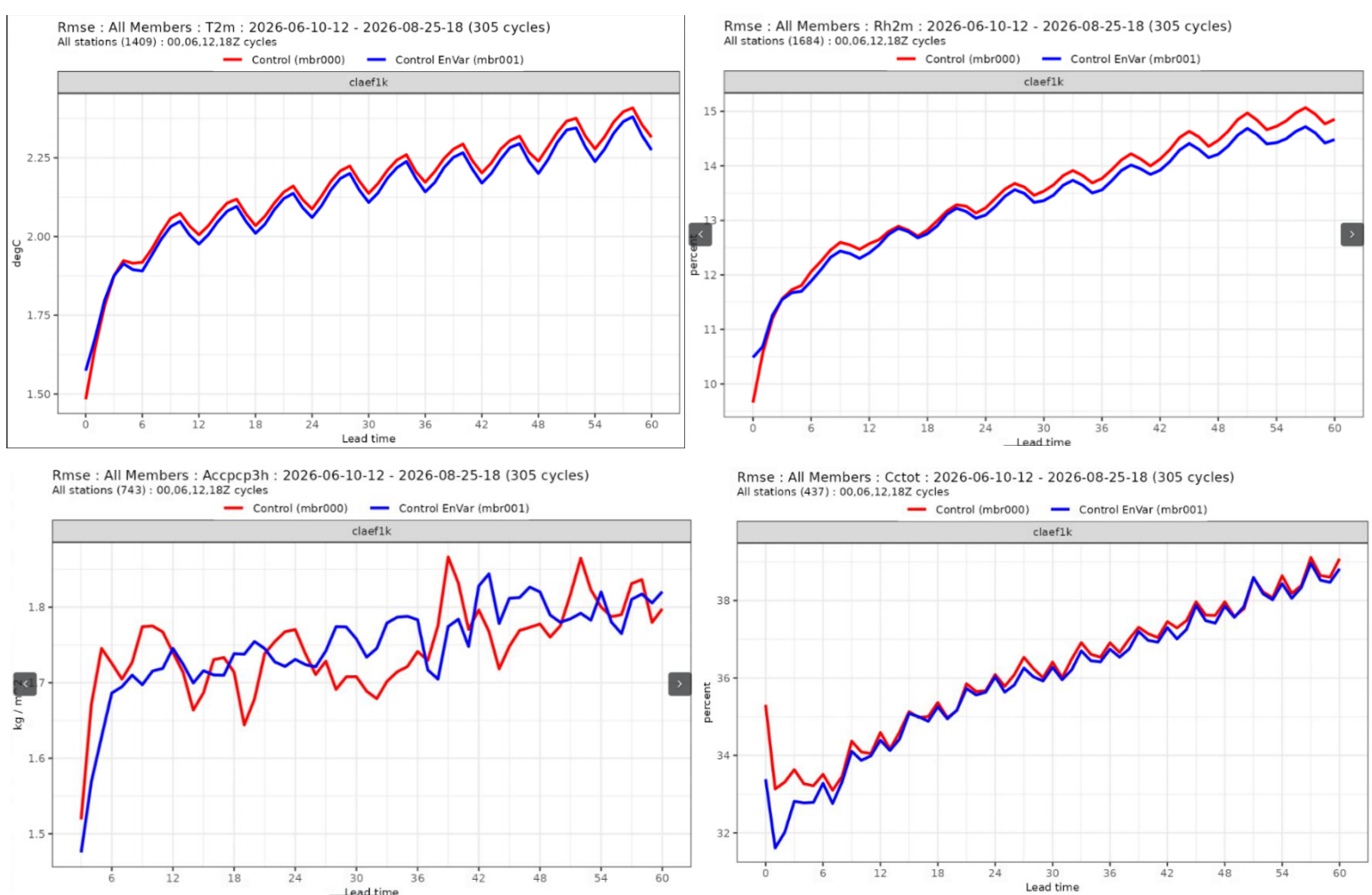


Figure 12: RMSE of 2m temperature, 2m relative humidity, 3h accumulated precipitation and 10m wind speed for the 3DVar (red) and EnVar (blue) member of C-LAEF AlpeAdria for summer 2026.

The A-LAEF topic is delayed because of the lack of manpower– it is unclear at the moment when this could be arranged.

Work on the EnVar system for C-LAEF AlpeAdria is currently ongoing. The operational system consists of 16 members using 3DVar atmospheric data assimilation and one member based on EnVar. This member has been running continuously for more than one year and is being evaluated using HARP verification. The verification scores are encouraging (Figure 12), and the long-term objective is to replace the classical 3DVar members with EnVar in C-LAEF AlpeAdria. The EnVar development for C-LAEF AlpeAdria is a joint effort between Austria and Slovenia; additional details are provided in the data assimilation report.

Efforts: 0.0 PM (planned 1.0 PM in total in 2026)

Contributors: Florian Meier (GeoSphere Austria), Benedikt Strajnar (ARSO)

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

Planned stays:

Status: Ongoing.

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 2026 were:

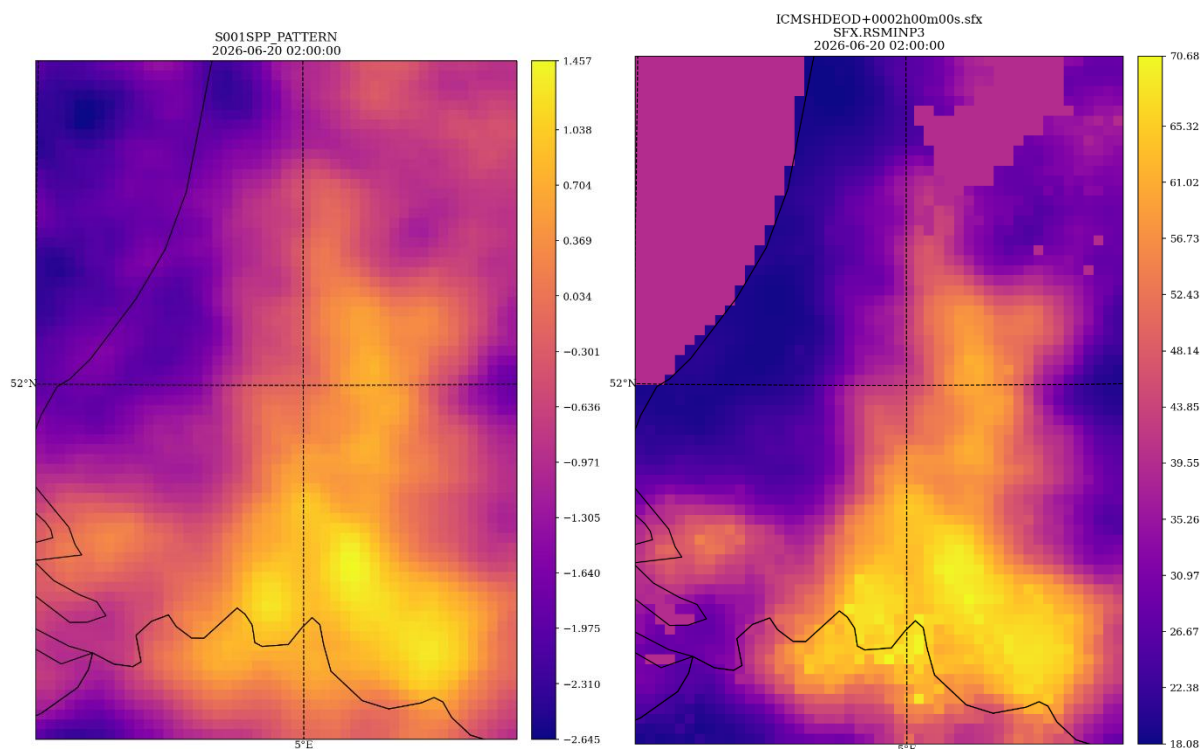
- ☐ Implementation of surface perturbations in AROME-EPS
- ☐ SPP in SURFEX, implementation and testing

An externalized surface perturbation scheme (pertsurf) is currently used operationally in C-LAEF AlpeAdria. However, this scheme is relatively old, and the long-term objective within ACCORD is to extend the SPP approach to SURFEX.

Work on a SURFEX-based SPP implementation was initiated by Zsófia Szalkai during her stay in Vienna in June 2026. The visit was primarily dedicated to technical preparations and code development. During this period, she successfully implemented four SURFEX parameters in CY50t2: CV, RSMIN, CH_COEFF_1, and CD_COEFF_11. The implementation is technically functional; however, further testing, validation, and tuning are still required before the impact of these perturbations can be properly assessed.

Preliminary results are presented in Figure 13, although a more detailed evaluation will be provided in Zsófia's forthcoming stay report.

This work is planned to continue during another stay by Zsófia in Vienna in 2027.



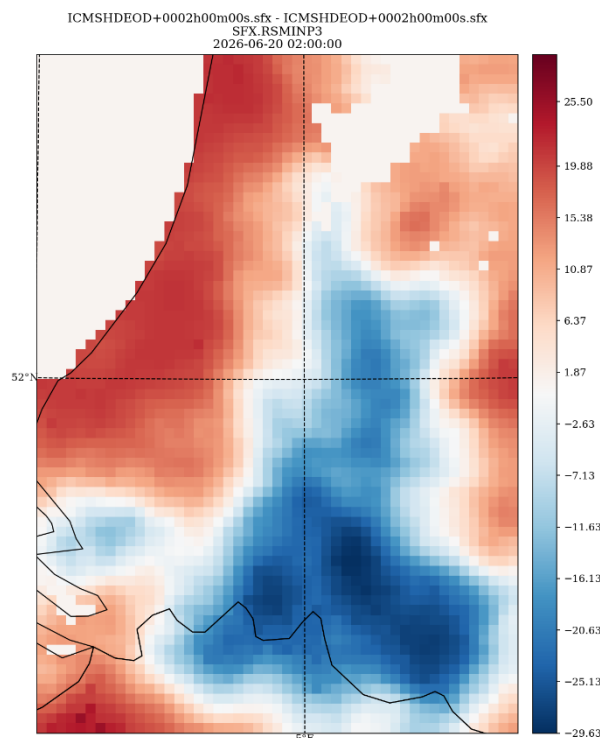


Figure 13: The original, unscaled, uniformly distributed perturbation pattern for RSMIN (top left), the perturbed field of RSMIN (top right) and the difference between the unperturbed and perturbed fields of RSMIN (lower).

The inclusion of surface perturbations in ensemble prediction systems is also one of the objectives of DEODE Phase 3, which started in spring 2026. Within DEODE, the aim is to integrate the existing pertsurf surface perturbation scheme into the operational workflow. Initial development work has already begun, and further implementation and evaluation activities are planned during the course of the project.

Efforts: 1.0 PM (planned 1.0 PM in total in 2026)

Contributors: Clemens Wastl, Daniel Deacu (GeoSphere Austria), Zsolia Szalkai (HungaroMet)

Documentation:

Planned stays: Zsolia Szalkai (June 1 – June 26 2026, in Vienna) – SPP in Surfex

Status: Delayed

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 2026 were:

- ☐ No topics planned.

Efforts: 0.0 PM (planned 0.0 PM in total in 2026)

Contributors:

Documentation:

Planned stays:

Status:

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 2026 were:

- ☐ Work on statistical post-processing of EPS data (e.g. more flexible calibration methods, etc.)
- ☐ Work on EPS post-processing by different machine learning (ML) methods: focus on solar radiation and wind
- ☐ Generation of ensemble members by deep learning algorithms
- ☐ Work on the new ensemble technique CEM (Cascading Ensemble Method)
- ☐ Development of new probabilistic products to meet users' requirements

Several LACE countries are currently active in this field, and interest in AI-based forecasting products is growing rapidly. Croatia, for example, has shifted its focus from analogue-based wind speed post-processing to AI-driven irradiance nowcasting using the SHADEcast model.

Solar radiation forecasting is also being pursued in Austria using the Multivariate Spatio-Temporal Neighbourhood Ensemble Method, and in Hungary, where AROME-EPS and EMOS are applied for this purpose. In addition, GeoSphere Austria is developing approaches to generate ensemble members using deep-learning techniques. Progress in this area has been relatively slow due to limited available resources. Météo-France has already implemented an extension of its ensemble prediction system in which AI-generated members are incorporated into the ensemble. However, the initial results have so far been rather inconclusive and have not demonstrated a clear improvement in forecast skill.

Poland has continued its work on the Cascading Ensemble Method (CEM), combining the global AI model FourCastNet with an ALARO-based EPS. CEM is an ensemble forecasting technique in which the number of ensemble members increases progressively through a cascading approach. Furthermore, Romania has recently initiated activities in the field of AI-based weather prediction, highlighting the growing interest in machine-learning applications across the LACE community.

☐ Topic 1: Work on statistical post-processing of EPS data

Hungary has been working on EMOS-based post-processing of AROME-EPS radiation forecasts over the past year. The main objective was to improve ensemble point post-processing by using groups of similar stations. Details of this approach can be found in the Verification Area Report of February 2026. Station similarity was

quantified based on model error characteristics, namely bias and CRPS, following the methodology of Lerch et al. (2017).

A new semi-local EMOS approach (Sim) was developed, in which a separate group of the most similar stations is defined for each target station. This method was compared with the operational EMOS configuration (Oper), which uses data from seven randomly selected Hungarian stations (Schulz et al., 2021), as well as with an alternative configuration (Diff) based on seven stations that differ substantially in geographical location and error characteristics and include all target stations.

Several modifications were made compared to the original one-year study. These included extending the operational post-processing framework to arbitrary stations and correcting results affected by erroneous observations from the Eger station that had been used previously (Table 2).

Table2: Summarized results for the EMOS runs with similar stations.

Target station	Szeged	Pogány	Sármellék	Budapest	Pér	Debrecen
Lowest average CRPS [W/m ²] reached in the tests	41.1	40.9	39.0	41.2	41.3	40.6
Improvement in CRPS [%] upon raw EPS (wrt. Oper, wrt. Diff)	10.5 (+1.9; +1.6)	19.3 (+2.1, +2.5)	13.6 (+2.9, +0.6)	13.6 (+1.4, +0.6)	11.9 (+0.8, -0.1)	9.9 (+1.9, +2.6)

Additional case studies demonstrated that the similarity-based semi-local EMOS approach provides added value in approximately 50-60% of cases. The improvement mainly results from a more accurate prediction of the expected value, rather than merely increasing the spread of the post-processed radiation forecasts, thereby yielding a further reduction in CRPS compared to the operational EMOS configuration. However, this benefit was primarily observed on days when the raw EPS forecasts exhibited moderate errors. In contrast, when the raw EPS forecasts had larger CRPS values, the new method generally provided little or no additional benefit.

Both types of behaviour are illustrated by a case study of a slowly moving frontal system affecting Szeged on 19 November 2024, when the city was located in the warm sector ahead of a wave front. None of the experimental EMOS configurations were able to fully correct the substantial radiation forecast errors before 11 UTC. Nevertheless, EMOS-Sim provided a more appropriate station-specific correction during the afternoon period (Figure 14).

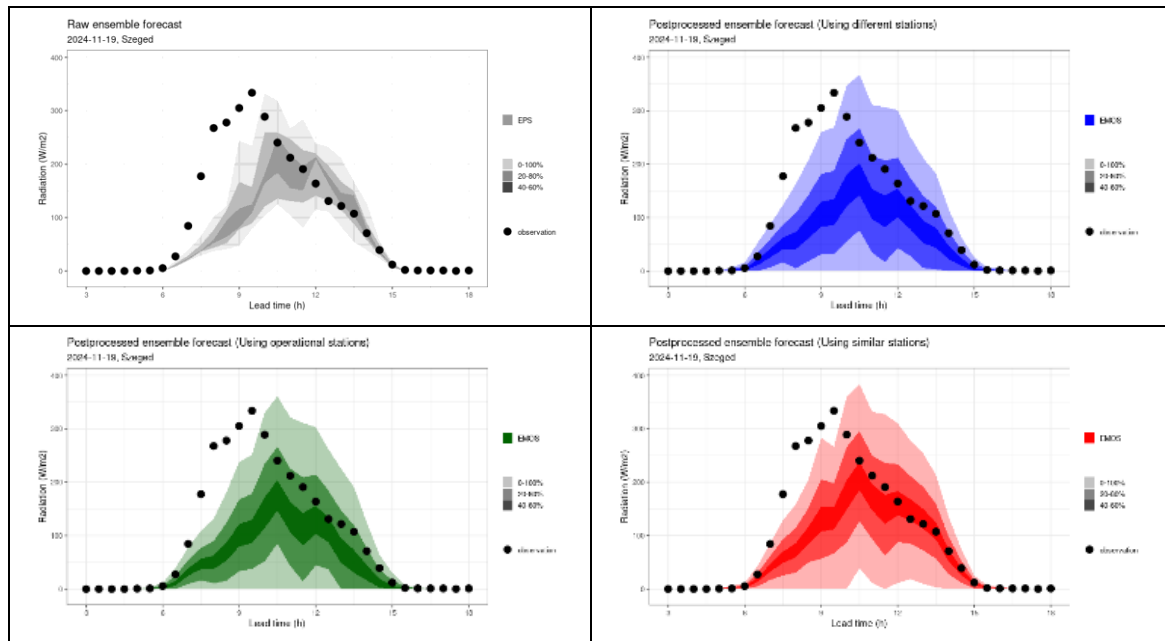


Figure 14: Global radiation forecasts (W/m²) of raw AROME-EPS (grey), EMOS-Diff (blue), EMOS-Oper (green) and EMOS-Sim (red) on 19 November 2024 as function of lead time (h) and the corresponding SYNOP observation (black dots) for Szeged, a city in the Southern Great Plain region of Hungary.

The results were presented in a conference poster (Jávorné Radnóczy, 2026), and a journal article in Hungarian is currently under preparation. The new method is considered mature enough for operational implementation and is expected to support solar energy forecasting applications.

❑ Topic 2: Work on EPS post-processing by different machine learning (ML) methods

Iris Odak visited GeoSphere Austria in summer 2026 (August 4 – 28 2026) with the objective of exploring the use of the state-of-the-art SHADECast model and satellite observations to improve solar radiation forecasts.

SHADECast is a modular deep generative nowcasting framework designed for satellite-based short-term forecasting of solar radiation, specifically Clear-Sky Index (CSI) fields. The framework is implemented in Python, based on PyTorch, and is freely available through Git repositories. SHADECast consists of several interconnected modules that form a complete training and inference pipeline. Its main components are:

- Variational Autoencoder (VAE): Compresses CSI input fields into a lower-dimensional latent space.
- AFNO Nowcaster: A deterministic forecasting module operating in latent space.
- Latent Diffusion Model: A stochastic generator that produces ensemble forecasts in latent space.

- Decoder: Reconstructs full-resolution CSI fields from the latent-space forecasts.

The research visit was highly successful. Iris managed to train both the VAE and the Nowcaster components and obtained reasonably realistic forecast results. Work on the cloud advection capabilities of the Nowcaster is still ongoing, as some technical issues remain unresolved. However, the cloud dissipation component is already functioning properly and has shown promising results. More details can be found in the upcoming stay report of Iris.

These developments represent an important step towards the implementation of advanced machine learning techniques for solar radiation forecasting and provide a solid basis for further development of the SHADECast framework within operational forecasting applications.

Another stay in that area was made by Ivan Vujec (DHMZ) in October (6 – 31) 2025 at GeoSphere Austria dealing with rain NWP postprocessing using neural networks. The stay report has just been published, therefore I have added some information to this report. The topic was to investigate the use of neural network-based machine learning methods to improve probabilistic precipitation forecasts generated from numerical weather prediction models. The work focused on post-processing forecasts from the deterministic ALADIN and IFS weather models and comparing their performance with the operational IFS ensemble forecasting system. The study used one year of forecast and observational data from meteorological stations in Croatia and Austria. Neural networks were trained to predict the probability of precipitation occurrence and tested for their ability to generalize across different geographical regions and forecasting systems. A key objective was to evaluate model transferability. Results demonstrated that neural networks trained in one geographical domain can be successfully applied to another domain, provided that the original preprocessing and feature-scaling procedures are preserved. Furthermore, models trained using one NWP system (IFS) achieved comparable performance when applied to forecasts from a different model (ALADIN). These findings indicate that machine learning post-processing models can be reused across regions and forecasting systems, reducing the need for extensive retraining and lowering computational costs.

The second major focus was the blending of deterministic ALADIN and IFS forecasts within a neural network framework. Several blending configurations were tested and compared to the operational IFS ensemble forecast. The results showed that all neural network-based blending approaches produced lower forecast errors and better reliability than the operational ensemble for most forecast lead times. While the ensemble forecasts were generally sharper, they also tended to be overconfident. Overall, the neural network solutions delivered more accurate and reliable probabilistic precipitation forecasts.

In conclusion, the project demonstrates the strong potential of machine learning for weather forecast post-processing. The successful transferability of neural network models across domains and forecasting systems, combined with the superior performance of blended deterministic forecasts, highlights opportunities for meteorological services to improve forecast quality while making more efficient use of computational resources

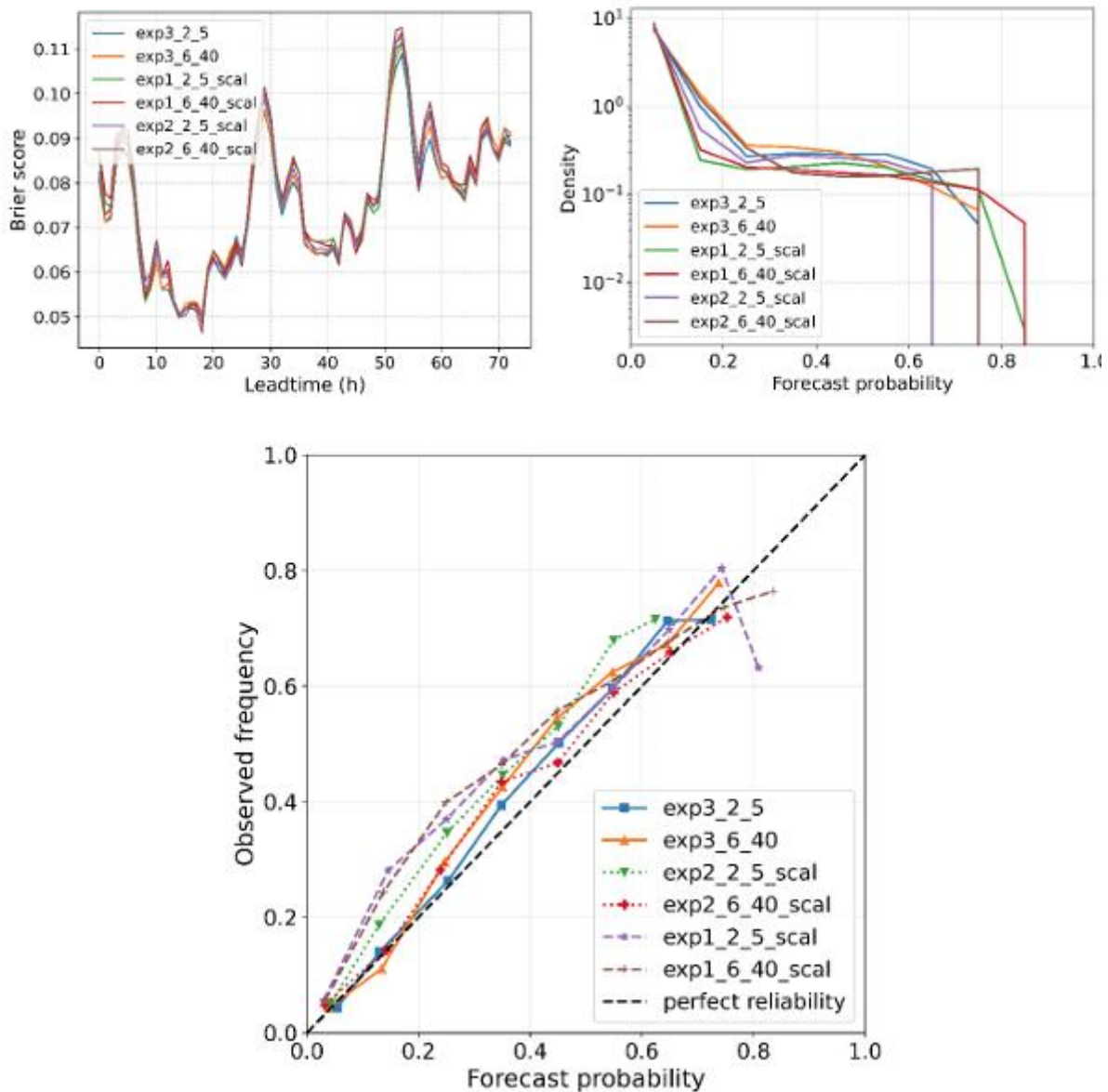


Figure 15: Brier score (upper left), frequency diagram (upper right), and reliability diagram (bottom) for probabilistic precipitation forecasts generated by different neural network architectures during the September 2024 test period using observations from the Croatian station network and ALADIN as NN input. The models labelled „exp1“ were trained using IFS forecasts and observations from the Austrian station network, the models labelled „exp2“ were trained using IFS forecasts and observations from the Croatian station network, whereas all other models were trained using ALADIN forecasts and observations from the Croatian station network. The forecasts labelled scal use the scaler derived from the corresponding original training datasets, while the remaining forecasts use scalers fitted to training datasets based on ALADIN forecasts and Croatian observations.

At GeoSphere Austria, considerable effort has been devoted to improving AI-based nowcasts for the photovoltaic (PV) sector. As part of this work, Ksvre has been developed, an operational Python library for ensemble post-processing and renewable energy and power grid applications. The system uses the C-LAEF

AlpeAdria ensemble (16 perturbed members plus one control member) as its primary input, supplemented by the ECMWF ENS (51 members). In addition, a time-lagged ensemble configuration has been implemented. An analog ensemble (AnEn) approach is currently under development.

The post-processing framework includes marginal calibration using EMOS/NGR, with parameters estimated in a leave-one-month-out cross-validation framework. Multivariate dependence structures are represented through Ensemble Copula Coupling (ECC) and the Schaake shuffle. Additional components include ensemble member re-centering, flow-dependent spread calibration, and a C-LAEF-to-INCA radiation (SSRD) bias correction specifically designed for photovoltaic applications.

Furthermore, Gaussian-copula COBASE and non-Gaussian marginal distributions based on a generalized logit transformation have been implemented and are currently being evaluated. This work required the creation of a dedicated local archive containing the parameters needed for the various renewable energy applications.

In its operational configuration, the system provides a 15-minute seamless probabilistic PV forecast, combining the C-LAEF ensemble with a blended SATNOW/INCA nowcast (Figure 16). Additional operational products include a probabilistic wind-power forecasting baseline and a 17-member probabilistic Dynamic Line Rating (DLR) forecast. The resulting services support applications such as dynamic line rating, small hydropower production, and photovoltaic power generation at multiple sites.

The Dynamic Line Rating workflow, including ampacity forecasts (P10, P50, and P90) and a six-class compound-event detector, was developed within the DEODE project.

The performance of the post-processing and forecasting systems has been evaluated using a comprehensive verification framework, including CRPS, spread-skill relationships, PIT and rank histograms, reliability diagrams, and the multi-site energy score.

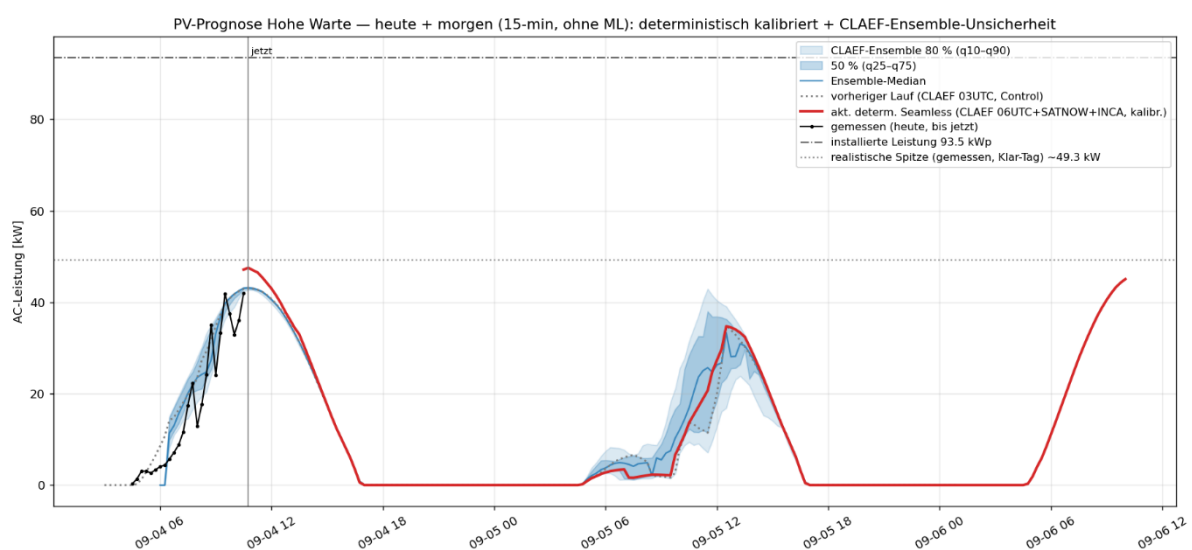


Figure 16: PV forecast for the station Vienna Hohe Warte, deterministic calibrated and uncertainty from the C-LAEF AlpeAdria ensemble.

❑ **Topic 3: Generation of ensemble members by deep learning algorithms**

GeoSphere Austria is currently investigating the generation of ensemble members using deep learning techniques. The technical installation and implementation of a diffusion-based model for ensemble emulation (CorrDiff) has been successfully completed on the Leonardo HPC system. Initial tests of both model training and inference have been carried out using a small ensemble dataset. The CorrDiff framework is trained in a two-step process. First, a pre-training phase is performed by downscaling ERA5 data to the C-LAEF reanalysis. In the second step, the model is fine-tuned using the downscaling of IFS-ENS ensemble members to the C-LAEF domain. Owing to limited computational and personnel resources, the method has so far been evaluated only for a small number of selected case studies. Before the approach can be considered for operational implementation, a substantially larger training dataset and more extensive validation are required. At present, further development of this activity has been postponed because of resource constraints.

Météo-France has already advanced this line of research further and has tested a similar approach over a considerably longer evaluation period. However, the results obtained so far have not been particularly encouraging. Consequently, it remains uncertain whether diffusion-based ensemble emulation will become a viable operational solution in the future or whether further effort will be invested in this approach.

❑ **Topic 4: Cascading Ensemble Method (CEM)**

The Cascading Ensemble Method (CEM), developed by IMGW (Poland), is an ensemble forecasting approach in which additional ensemble members are introduced progressively during model integration as forecast uncertainty increases. The aim is to achieve forecast skill comparable to, or better than, conventional ensemble prediction systems (EPS) while reducing computational and storage requirements.

CEM was first evaluated using FourCastNet, Nvidia's AI-based global weather forecasting model trained on ERA5 reanalysis data for the period 1979-2015. In the CEM framework, the ensemble size increases during the forecast, reaching $2n^{2^n}$ members after n timesteps. The method was tested using one month of forecasts (January 2023) with 00 UTC initializations and a forecast range of 120 hours (20 timesteps). The ensemble size grew from a single member to 256 members, doubling at each timestep up to timestep 8. Verification against observations from global WMO synoptic stations focused on 2-metre temperature and mean sea-level pressure, using BIAS, RMSE, and CRPS as evaluation metrics.

The results show that CEM produces a steadily increasing ensemble spread throughout the forecast period, ultimately exceeding that of the conventional ensemble. BIAS and RMSE were generally similar for both approaches, although the traditional ensemble displayed a stronger diurnal cycle. The largest differences were found for CRPS. While the conventional ensemble exhibited a rapid increase during the first few forecast steps, CEM showed a smoother and more gradual evolution, resulting in consistently lower overall CRPS values. These findings suggest that CEM can provide improved probabilistic forecast performance while maintaining a lower

computational cost than traditional ensemble approaches. A scientific manuscript has been submitted; however, the reviewers requested substantial revisions.

Another publication prepared at IMGW focuses on a probabilistic comparison of three state-of-the-art AI forecasting systems, AIFS-ENS, FourCastNet3, and GenCast, for lead times of up to 15 days. The study demonstrates that GenCast is markedly under-dispersive at short lead times, particularly for mean sea level pressure and at the station scale, whereas AIFS-ENS and FourCastNet3 exhibit better-calibrated ensemble spread. Furthermore, the results show that multi-model ensembles consistently outperform each individual forecasting system, highlighting the benefits of combining complementary sources of forecast uncertainty. These findings suggest that multi-model approaches can provide improved forecast reliability and skill compared to standalone AI-based forecasting systems.

Efforts: 6.25 PM (planned 14.0 PM in total in 2026)

Contributors: Iris Odak, Ivan Vujec (DHMZ), Alexander Kann, Irene Schicker (GeoSphere Austria), Katalin Jávorné-Radnóczy (HungaroMet), Bogdan Bochenek, Jadwiga RÓG (IMGW)

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

Planned stays: Iris Odak (August 4 - 28 2026, in Vienna) – ML based post-processing methods

Status: Ongoing, on time.

Activities of management, coordination and communication

- ❑ 46th LSC Meeting, March 3-4 2026, Zagreb
- ❑ 6th ACCORD All Staff Workshop, April 13 – 17 2026 (Marrakech)
- ❑ ACCORD System and Tactus Working Week, May 26 – 29 2026 (Brussels)

Publications

Bochenek et al., 2026: Combining AI weather prediction systems improves the calibration of medium-range ensemble forecasts, submitted to Weather and Forecasting.

RC LACE supported stays – 2.75 PM in 2026 (till end of August)

Two full stays with 4 weeks and one 3-week long stay were successfully completed in the EPS area of RC LACE so far in 2026: The stay of Iris Odak (4 weeks at GeoSphere Austria, August 4 – 28 2026) on ML based post-processing methods, the stay of Zsolia Szalkai (4 weeks at GeoSphere Austria, June 1 – 26 2026) on the implementation of SPP in Surfex and the stay of Jadwiga Rog (3 weeks at DHMZ, April 27 – May 15 2026) on the A-LAEF upgrade.

The stay of Endi Keresturi in Vienna (flow dependent SPP) could not have been realized due to resource constraints.

Summary of resources [PM] – 2026 (Jan – Jun 2026)

Subject	Manpower		RC LACE		ACCORD	
	plan	realized	plan	realized	plan	realized
S1: Preparation, evolution and migration	15	4	1	0.75	0	0
S2: Model perturbations	8	2	1	0	0	0
S3: IC perturbations	1	0	0	0	0	0
S4: Surface perturbations	2	1	0	0	1	1
S5: LBC perturbations	0	0	0	0	0	0
S6: Statistical EPS and user-oriented approaches	14	6.25	2	1	0	0
Total:	40	13.25	4	1.75	1	1

References

Jávorné Radnóczy, K., 2026: Semi-local EMOS postprocessing based on AROME-EPS, Poster, European Nowcasting and Weather Forecasting Conference 2026.

Lerch, S. and Baran, S., 2017: Similarity-based semilocal estimation of postprocessing models. Appl. Statist. 66, Part 1, 29–51.

Schulz, B., El Ayari, M., Lerch, S., and Baran, S., 2021: Post-processing numerical weather prediction ensembles for probabilistic solar irradiance forecasting. Sol. Energy 220, 1016–1031.