Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

LAM-EPS activities in LACE

Clemens Wastl with contributions of LACE partners

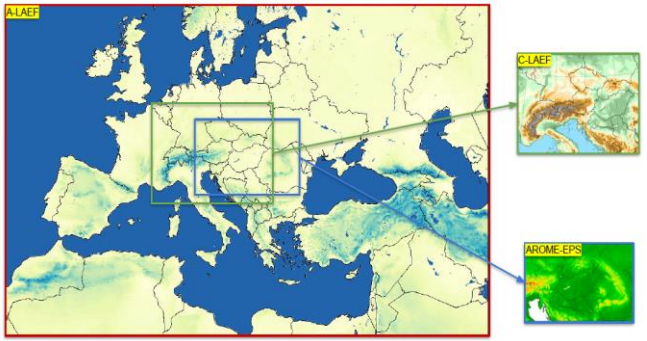
GeoSphere Austria · DHMZ · Czech Hydrometeorological Institute · HungaroMet Hungarian Meteorological Service · IMGW · METEO ROMANIA · SHMU · ARSO METEO Slovenia

Overview

- **Operational status**
- **A-LAEF: Upgrade to cy46t1, multiphysics**
- **ALARO based convection permitting EPS**
- **C-LAEF AlpeAdria; Envar, lagged ensemble**
- **SPP & flow dependent SPP**
- **Statistical EPS/machine learning**
- **Outlook and plans**

Operational status

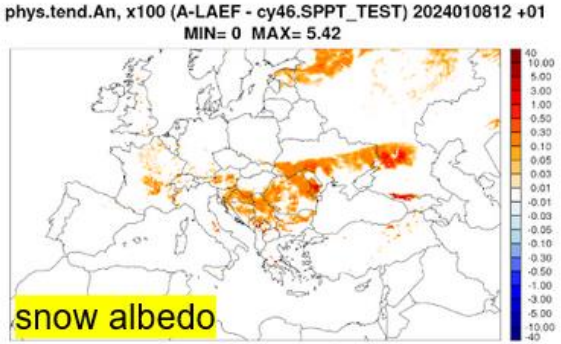
	A-LAEF	C-LAEF	AROME-EPS
CMC	ALARO	AROME	AROME
Code version	cy40t1	cy43t2	cy46t1
Horizontal resolution	4.8 km	2.5 km	2.5 km
Vertical levels	60	90	60
Runs per day	2	8	8
Forecast length	+72h (00/12 UTC)	+60h (00/12 UTC)	+48h (00/12 UTC)
Members	16+1	16+1	10+1
Assimilation cycle	yes (12h)	yes (3h)	yes (3h)
Coupling	ECMWF ENS (6h)	ECMWF ENS (1h)	ECMWF ENS (1h)
IC perturbation	ESDA [surface], spectral blending/DFI [upper-air]	ESDA [surface], EDA, Ensemble-JK [upper-air]	EDA
Model perturbation	ALARO-1 multi-physics + surface stochastic physics (SPPT)	Parameter perturbations (SPP)	-
LBC perturbation	ECMWF ENS (c903)	ECMWF ENS (c903)	ECMWF ENS (c903)

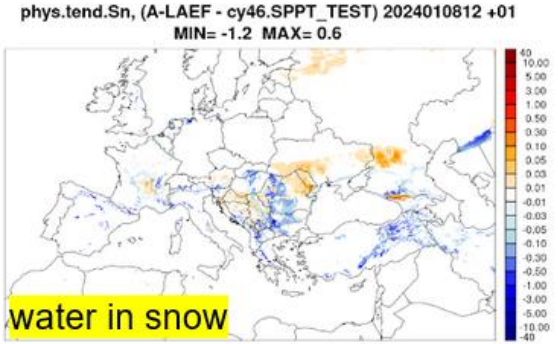


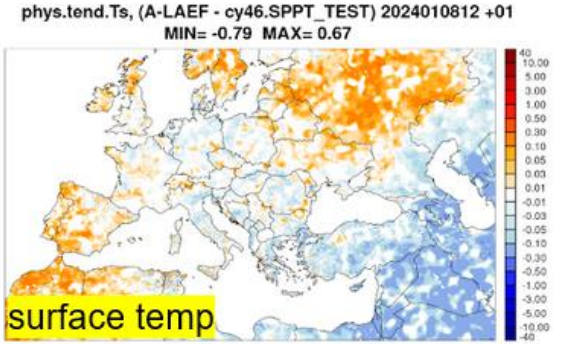
Upgrade of A-LAEF

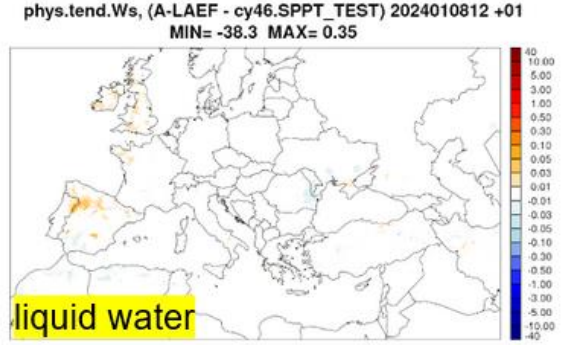
- Operational A-LAEF is still running on cy40t1
- Upgrade delayed due to leave of main contributor
- Plan to go operational end of 2025
- Cy46t1 Esuite of A-LAEF running on the ECMWF HPC since summer 2025
- New ALARO-1 multiphysics scheme
- Four different physics clusters based on latest ALARO-1 developments
- Combination with SPPT for ISBA surface prognostic fields
- New clim files based on ECOCLIMAP v2.6
- Grb2 output, new parameters (precipitation type, helicity, etc.)
- Performance analysed for several case studies

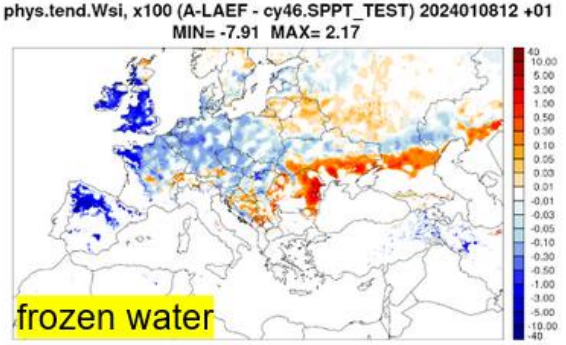
A-LAEF: Surface SPPT

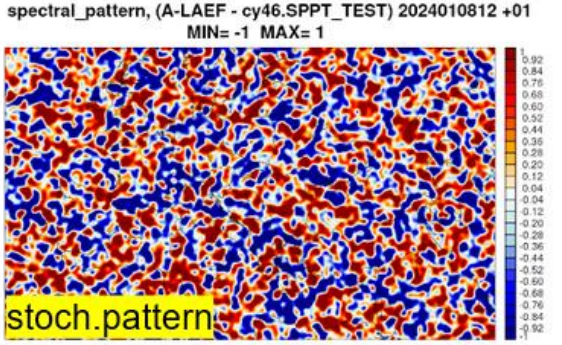












Surface SPPT of A-LAEF surface prognostic fields in ISBA.

A-LAEF: Case studies

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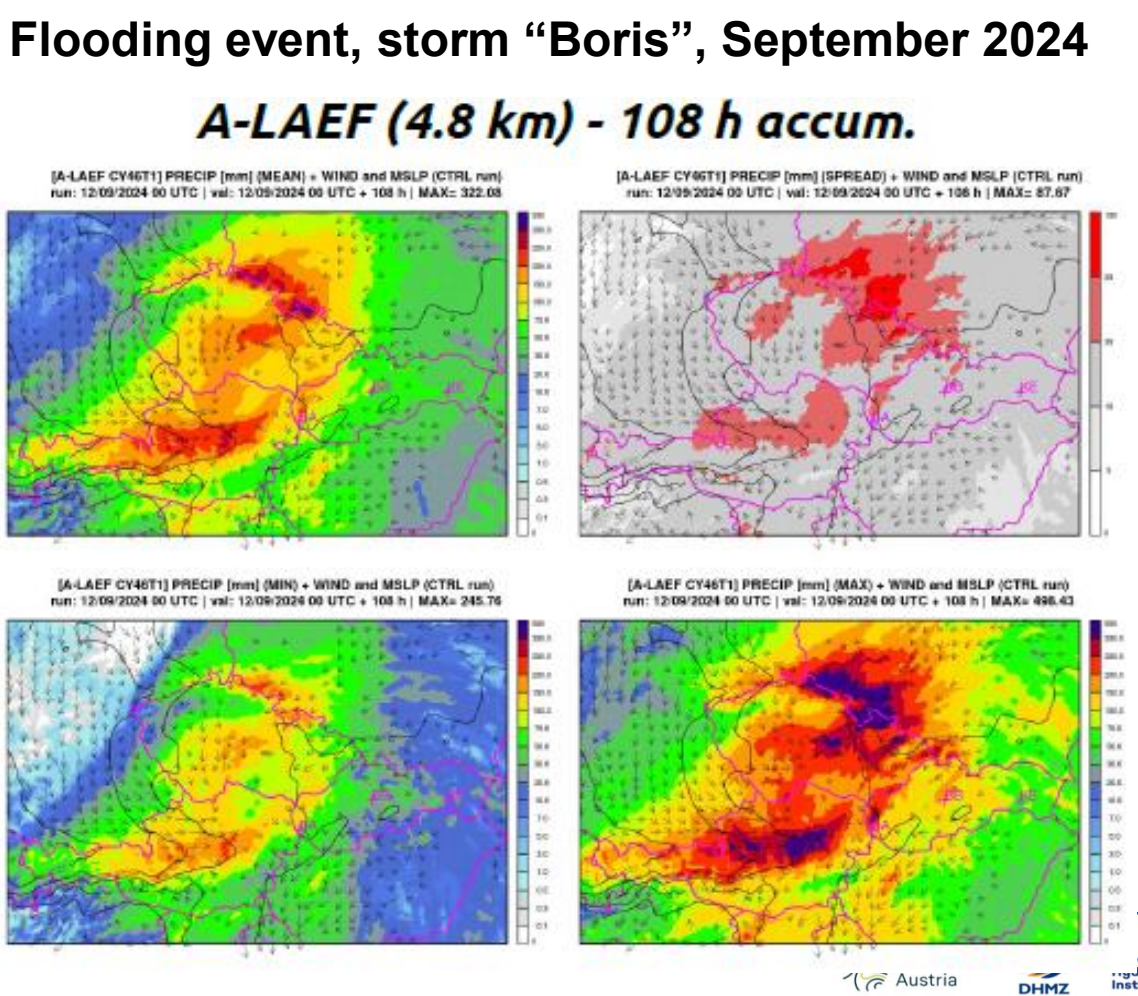
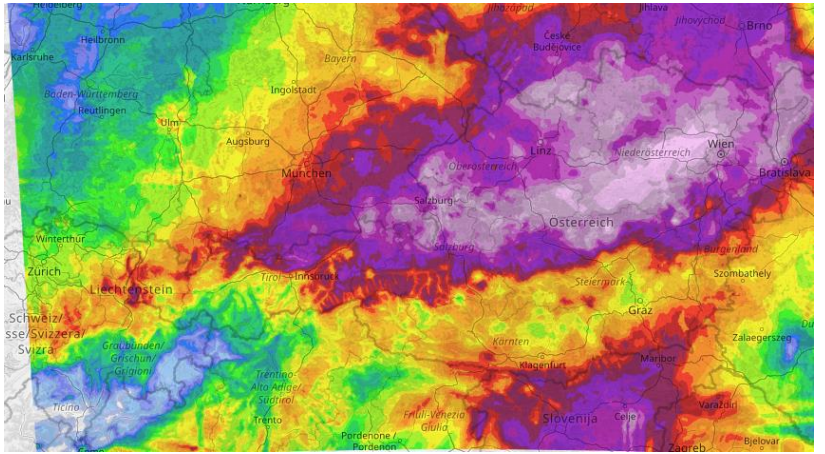
Flooding event, storm “Boris”, September 2024



INCA precipitation analysis.



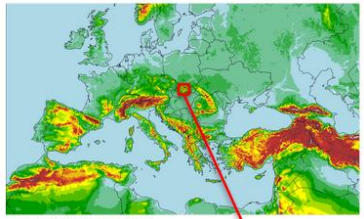
108h accumulated precipitation of the A-LAEF cy46t1 Esuite for storm Boris initialized on September 13 2024 00 UTC. Ensemble mean, ensemble spread, ensemble minimum and maximum.

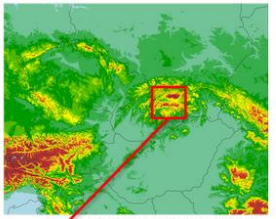
Austria DHMZ HungaroMet Hungarian Meteorological Service IMGW METEO ROMANIA SHMÚ ARSO METEO Slovenia

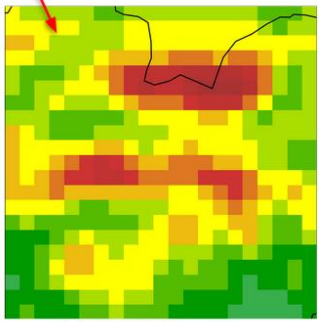
ALARO based convection permitting EPS

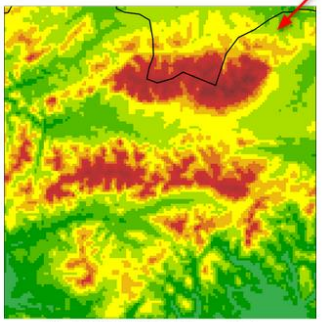
- Setup of mini (6+1 members) ALARO-EPS in course of DEODE project
- 750m horizontal resolution and 87 vertical levels, coupled with ECMWF-ENS
- Domain covering Slovakia and the surrounding regions
- ALARO-1 multi-physics scheme and surface stochastic physics (SPPT)
- Scripting system based on A-LAEF suite in ecflow
- Suite tested for several case studies: severe weather situation with floodings in Central Europe in September 2024 (storm Boris); lee wave event on Christmas 2024; freezing rain event in January 2025
- Gain experience with convection-permitting ensembles on kilometric scales and contribute to the development of a ALARO-EPS coupled in A-LAEF at SHMU

ALARO based convection permitting EPS


A-LAEF@4.8km

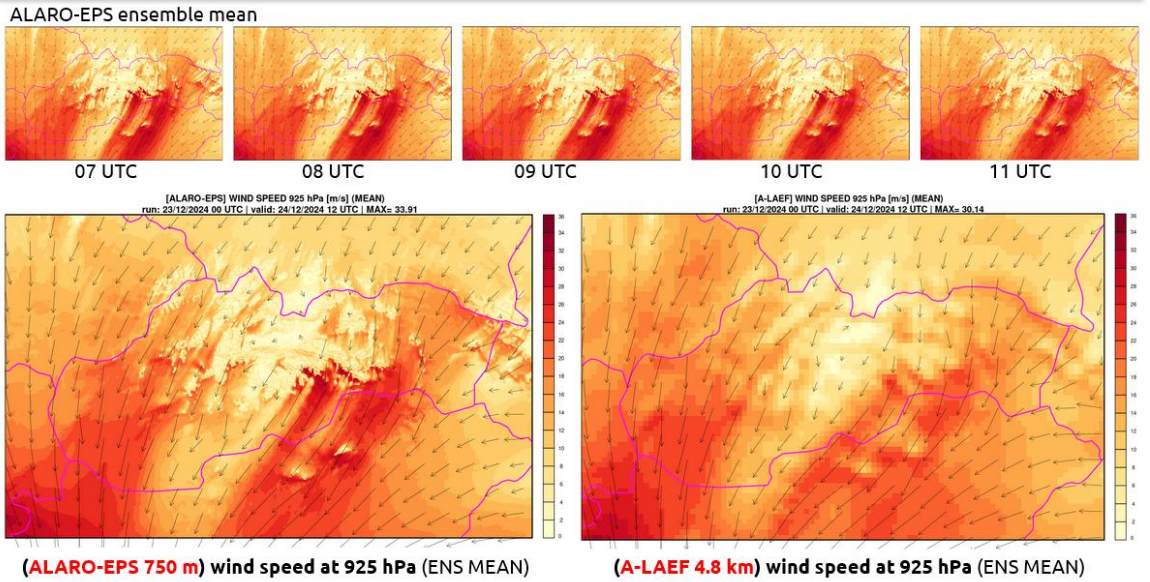

ALARO-EPS@750m


A-LAEF@4.8km - Tatras

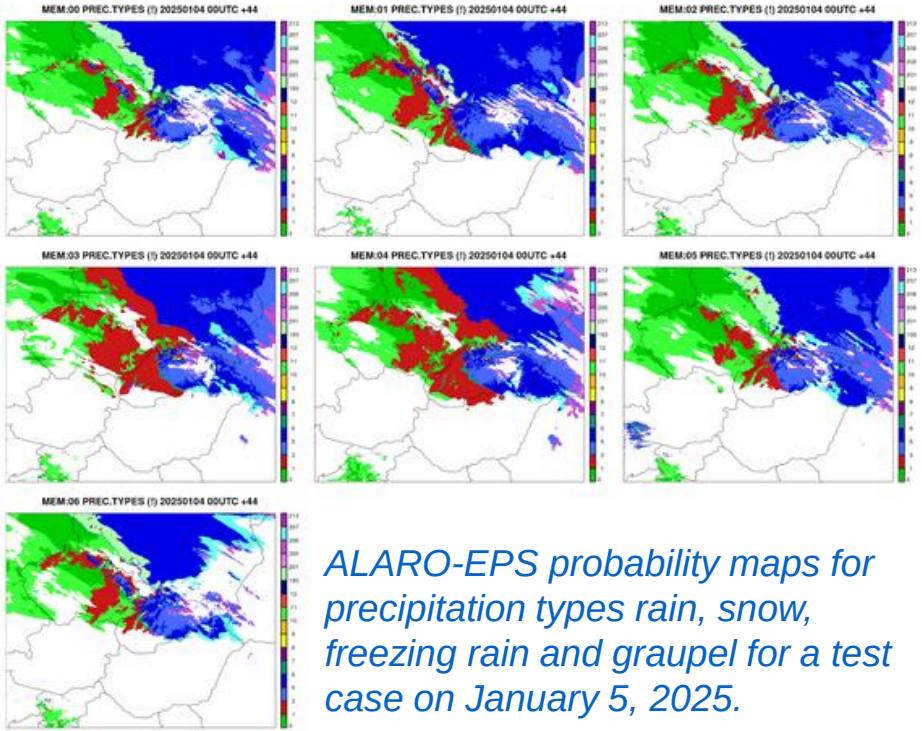

ALARO-EPS@750m - Tatras

Comparison of the A-LAEF domain (left) and the ALARO-EPS domain (right).

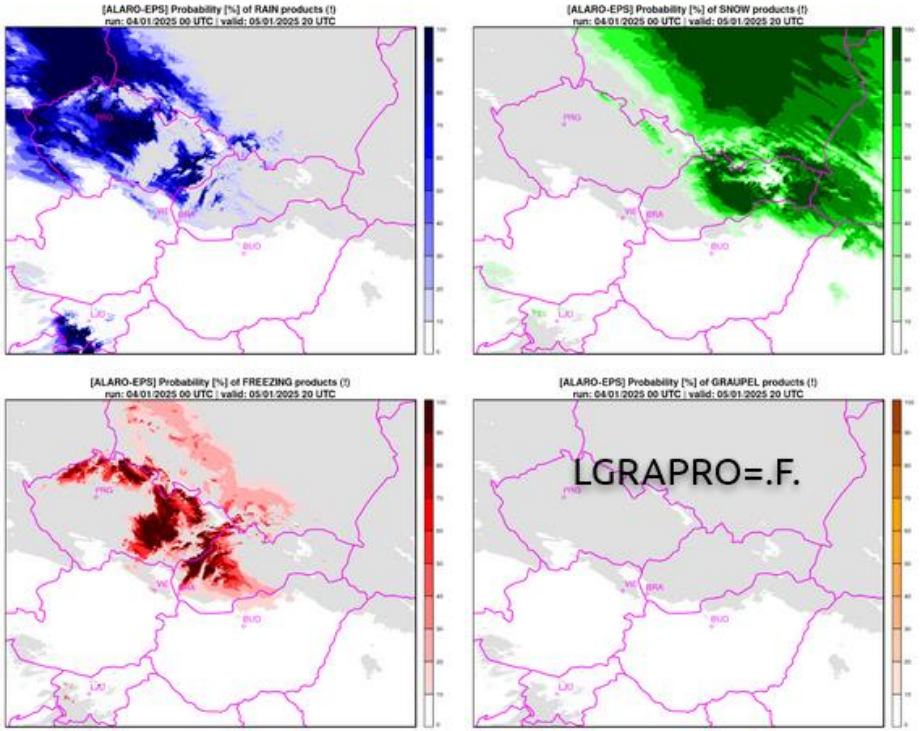
Wind speed at 925 hPa in ALARO-EPS (left) and A-LAEF (right) for a lee wave event on December 24, 2024.



ALARO based convection permitting EPS

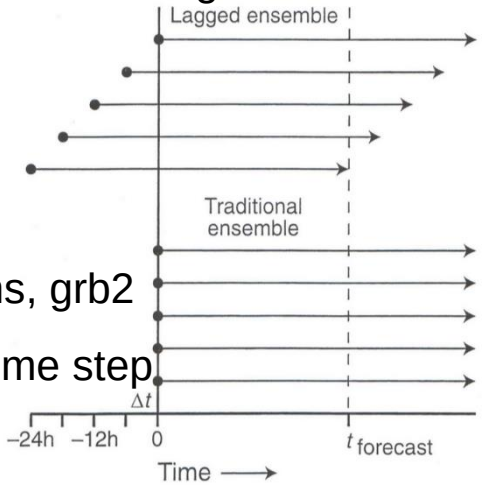


ALARO-EPS probability maps for precipitation types rain, snow, freezing rain and graupel for a test case on January 5, 2025.



C-LAEF AlpeAdria

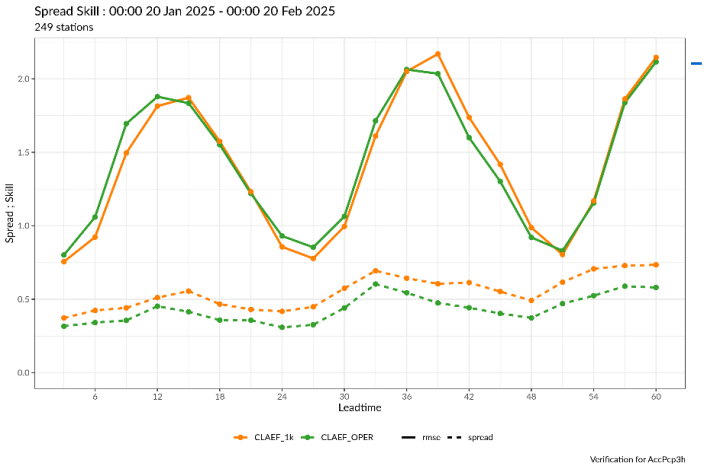
- Co-operation of Austria, Croatia and Slovenia to develop a common EPS on 1km
- Full C-LAEF AlpeAdria suite running for a winter (Jan-Feb 2025) and summer (June-August 2025) period
- Cy46t1, I/O server, 3h assimilation cycle, single precision, 8 long (+60h) runs per day, 16 + 1 members
- Continuous lagged ensemble mode, 4 members + 1 control run of C-LAEF AA are running with an extended forecasting range of +69h, the rest of the members is kept short
- Combining the members of the 4 most recent runs (the oldest members are 9h old), a lagged ensemble with 16 +1 members is created every 3h
- New observations (GNSS, ceilometer, radar data), ICE3_new, 3 FPOS domains, grb2
- SPP perturbations, new dynamics setup (SLHD), quadratic truncation, 60sec time step
- Additional control member using EnVar (cy48t3), 32 members as input (from the latest 2 runs)
- Pre-operational status – operationalization planned beginning of 2026

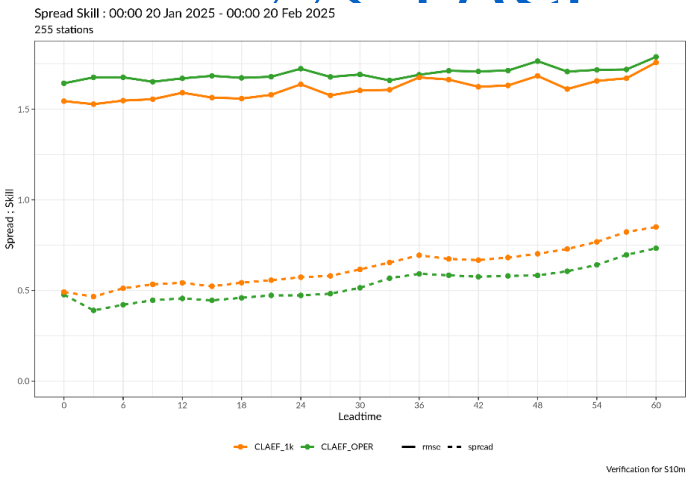


Warner et al., 2011

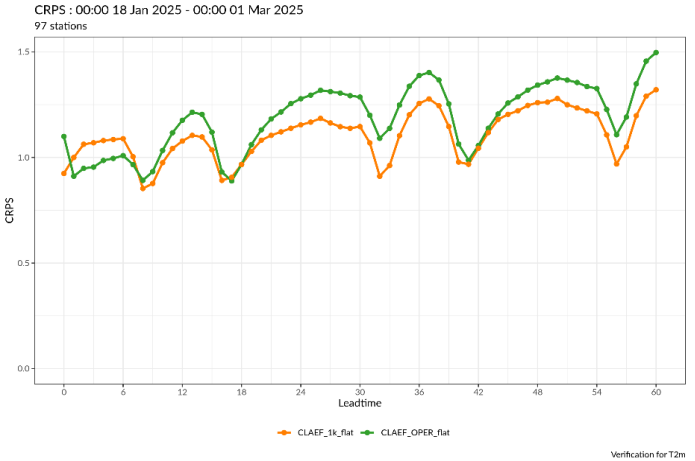
C-LAEF AlpeAdria

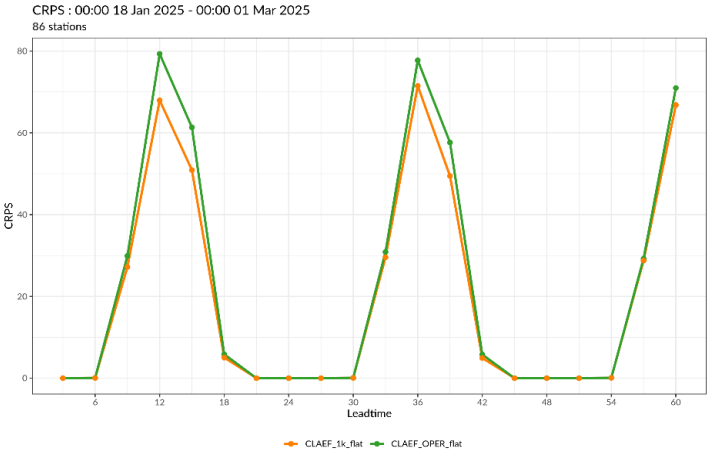
Spread/skill of 3h accumulated precipitation (left) and 10m wind speed (right) for C-LAEF (green) And C-LAEF AlpeAdria (orange) in the winter test period.





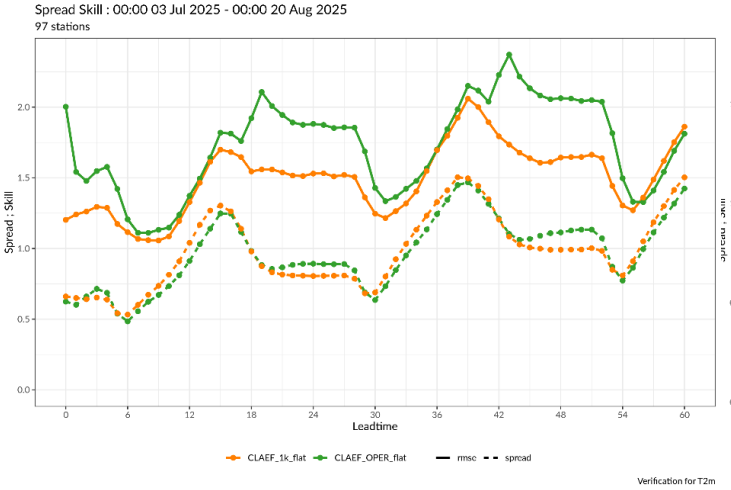
CRPS of 2m temperature (left) and global radiation (right).

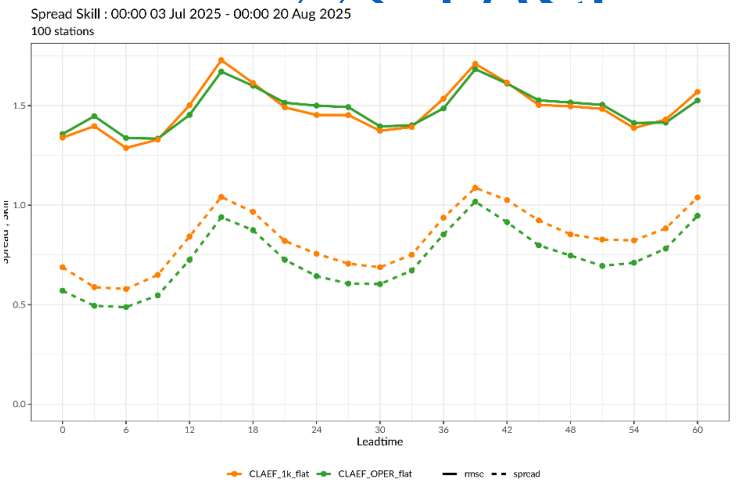




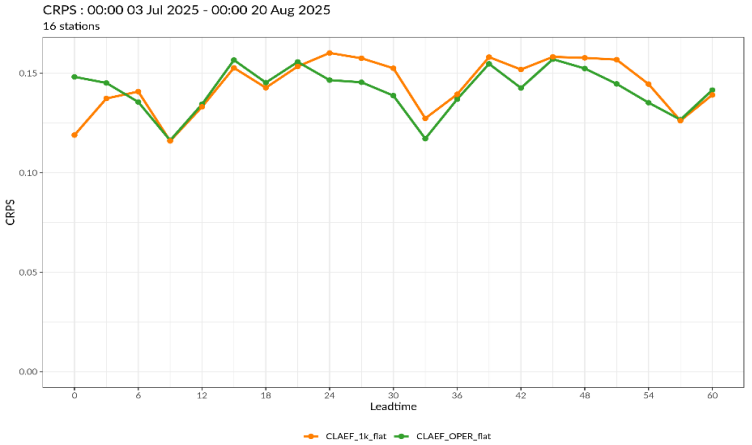
C-LAEF AlpeAdria

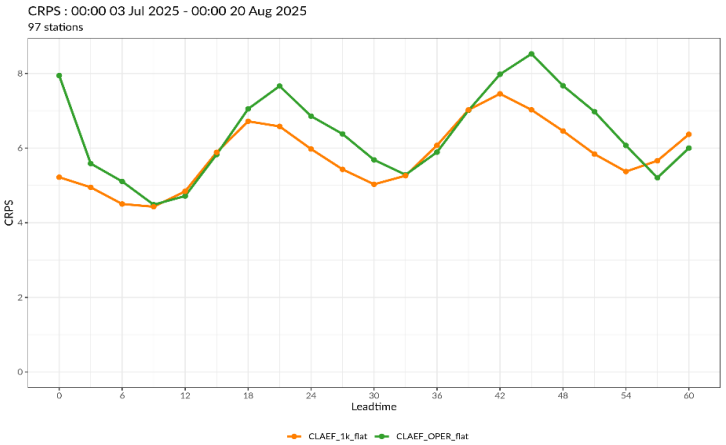
Spread/skill of 2m temperature (left) and 10m wind speed (right) for C-LAEF (green) and C-LAEF AlpeAdria (orange) in the summer test period.





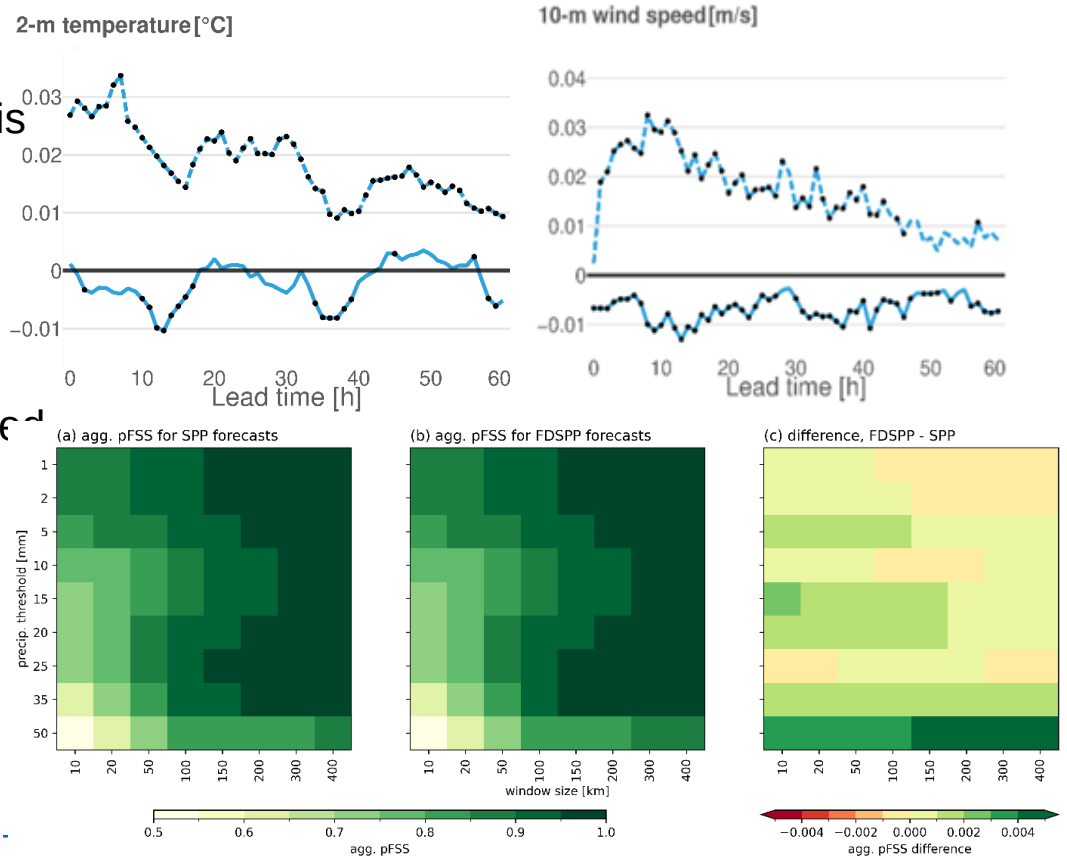
CRPS of total cloudiness (left) and 2m relative humidity (right)





CLAEF AlpeAdria: Flow dependent SPP

- SPP_FD: intelligent perturbation scheme which amplifies SPP perturbations in active areas
- Pattern generator is not changed, existing pattern is modified by some weights
- Identification of interesting areas - for each parameter a particular model variable is used
- Flow dependent SPP for all 12 parameters perturbed (6 parametrization schemes) in C-LAEF AlpeAdria
- Tested for case studies, long term verification for winter (February 2024) and summer (June 2024)

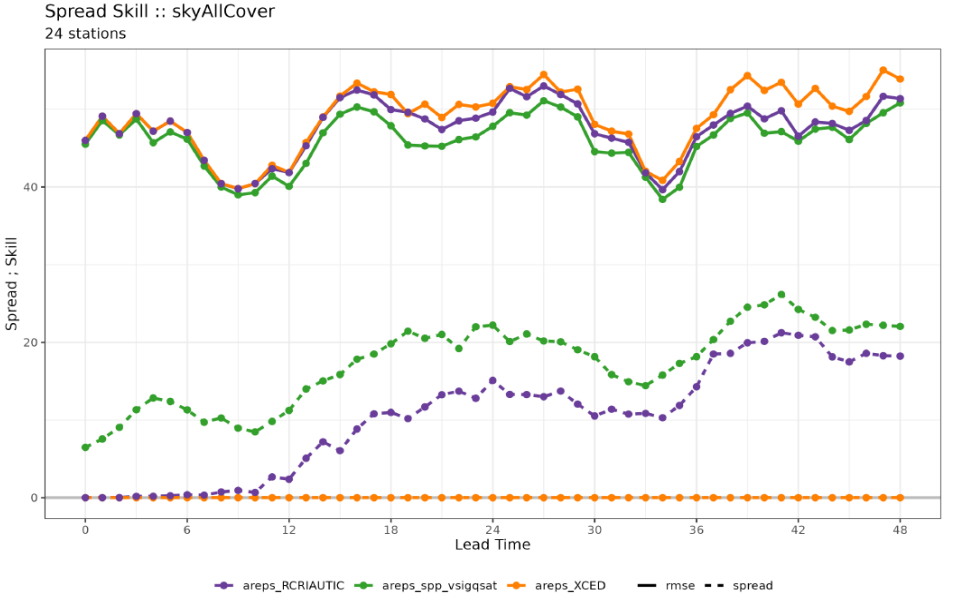


Relative spread/skill (SPP_FD – SPP, upper) and FractionSkill score (lower) for winter period 2024.

SPP in AROME-EPS

- HungaroMet started to work on SPP in AROME-EPS
- Tuning in 2024, test periods, phasing of SPP to cy46t1
- co-operation with applied mathematician students of University of Budapest to assess the impact of the individ perturbations of SPP parameters using AROME-EPS
- Two weeks test period in May/June 2024
- Focus on 3 most effective SPP parameters

Parameter	Description	Effects on met. variables
VSIGQSAT	constant for subgrid condensation	precipitation, cloudiness, global radiation
XCED	constant for dissipation of turbulent kinetic energy	wind, precipitation, humidity, temperature
RCRIAUTC	rain autoconversion threshold	precipitation



CRPS for 3h accumulated precipitation (upper) and spread/skill of cloudiness (lower) for 3 different SPP experiments.

GeoSphere Austria DHMZ

Statistical EPS & AI

Application of Machine Learning for EPS nowcasting

- A lot of work is ongoing in LACE in the area of machine learning
- Strong request for accurate global radiation (PV) and precipitation (hydro power plants) nowcasts
- Uncertainty of the forecasts needs to be accounted for - using EPSs as input
- For PV prediction use a state-of-the-art SHADEcast model together with satellite data, python based, free

Generation of ensemble members in C-LAEF by deep learning algorithms

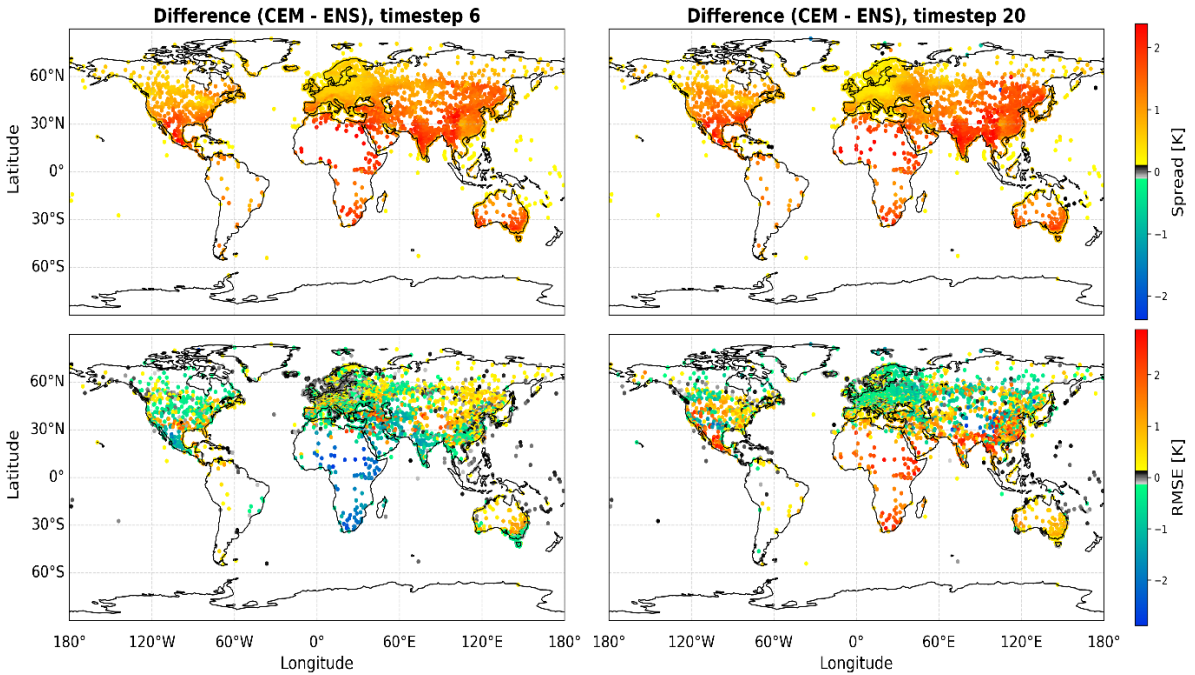
- Technical installation and implementation of a diffusion-based model for emulating ensemble members (CorrDiff model) has been successful on the Leonardo HPC
- The training and the interference has been tested based on a mini ensemble
- The model itself is trained as a two-step process:
- Pre-training with ERA5 downscaling on C-LAEF reanalysis
- In a second step the finetuning with downscaling of IFS-ENS members on C-LAEF is done

Statistical EPS & AI

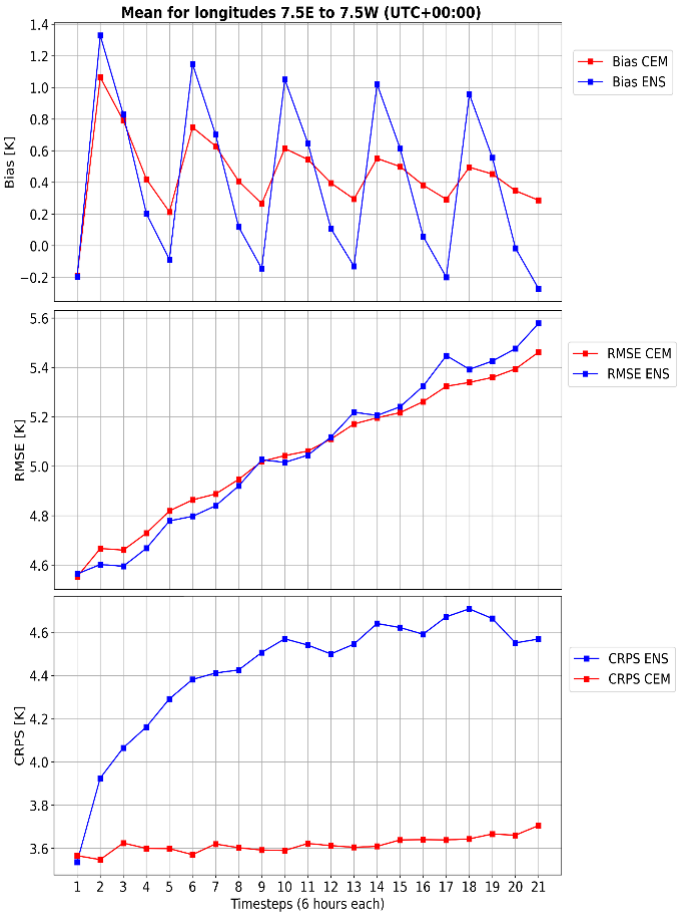
Cascading Ensemble Method (CEM)

- IMGW in Poland has developed a new ensemble technology CEM (Cascading Ensemble Method)
- CEM is adding new members to EPS during the forecast when uncertainties increase
- Number of ensemble members rises with the number of timesteps, for n timesteps, the final ensemble count is 2 to the n-th power
- Aim is to achieve similar or better results compared to the traditional methods, but at a lesser computational cost and less storage usage
- CEM was tested first with the data-driven global weather forecasting model FourCastNet from Nvidia (trained on ERA5)
- 20 atmospheric variables (5 on the surface), timestep of 6 hours, 0.25° spatial resolution
- CEM should be tested with ALARO in Poland in the near future

Statistical EPS



Difference maps of both methods for spread and RMSE.



Mean bias, RMSE and CRPS progression through timesteps for a 15 deg wide area.

Outlook & Plans

Operational plans

A-LAEF: - Upgrade to cy46t1 end of 2025

- Local convection-permitting ALARO-EPS in SK

C-LAEF: - New C-LAEF AlpeAdria operational in 2026

- Flow dependency (EnVar, perturbations)

AROME-EPS: - operationalization of SPP in 2026

- SPP in SURFEX

Research & development

- EnVar and Hybrid EnVar in EPS
- Research on flow-dependent model perturbations (include AI)
- Improved surface perturbations (SPP in SURFEX)
- EPS on hectometric scale
- Generation of ensemble members by ML
- Work on statistical post-processing of probabilistic fields
- Extension of data-driven ML ensemble methods