*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

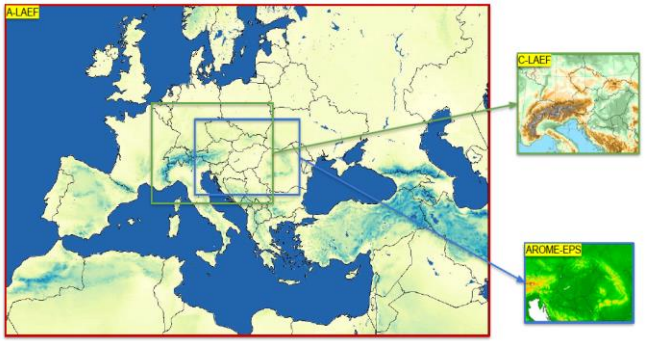
GeoSphere Austria · DHMZ · Czech Hydrometeorological Institute · HungaroMet Hungarian Meteorological Service · IMGW · METEO ROMANIA · SHMU · ARSO METEO Slovenia

# Overview

- **Operational status**
- **A-LAEF: Upgrade to cy46t1**
- **A-LAEF: Case studies of severe weather events**
- **C-LAEF 1k/EnVar**
- **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 | cy43t2 |
| 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) |

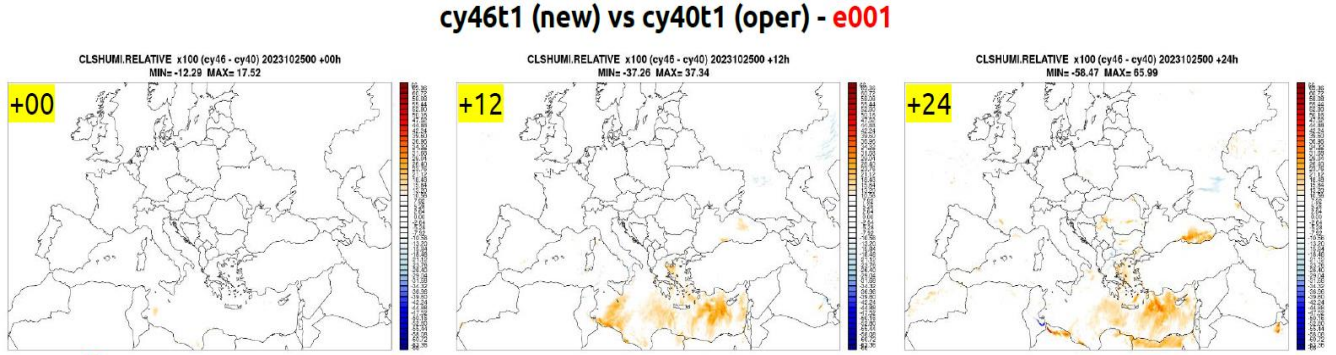


# Upgrade of A-LAEF

## Upgrade of A-LAEF to cy46t1

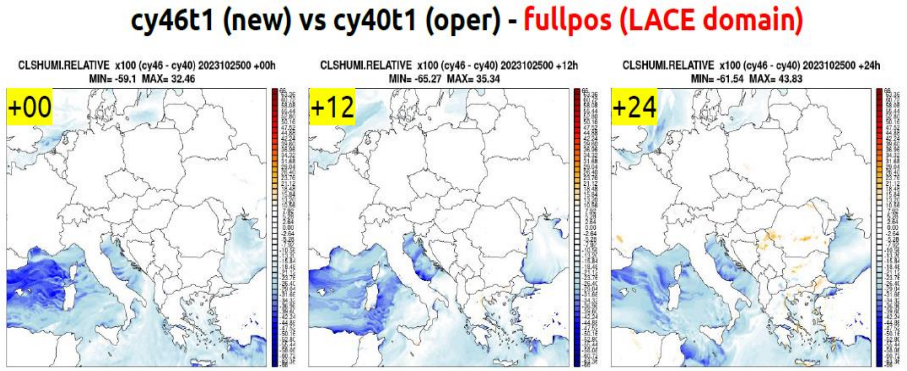
- operational A-LAEF is still running on cy40t1
- planned upgrade of operational A-LAEF in 2024
- setting up a cy46t1 Esuite of A-LAEF on the ECMWF HPC in 2023
- inline grib production (grib 2) which replaces the previously used external GL tool
- Upgrade of upper-air spectral blending by digital filter (DFI) to cy46t1
- DFI within the blending procedure was tuned and validated
- small discrepancy between cy40t1 (oper) and cy46t1 (new) below level 30
- differences getting smaller near the lowest model level
- verifying the cy46t1 Esuite showed an issue with 2m rel. humidity over the sea in cy40t1 - fullpos bug in the operational cy40t1 suite, 2m relative humidity over sea was always 100%

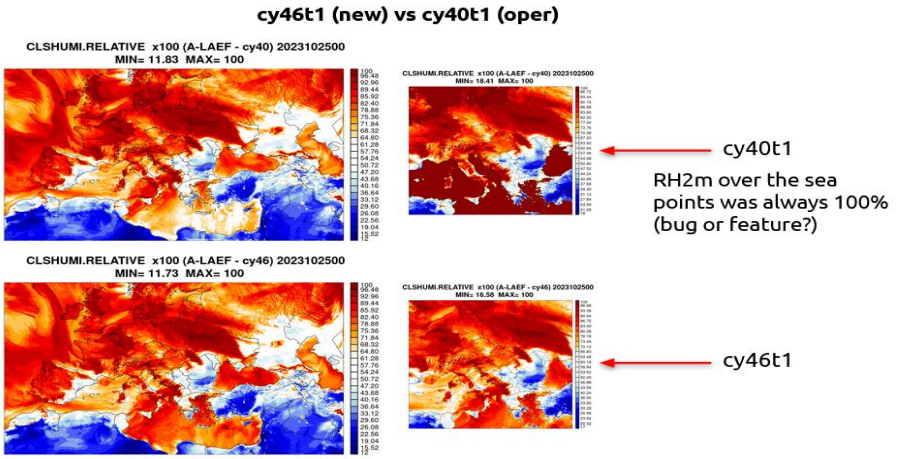
# Upgrade of A-LAEF




*Differences of 2m relative humidity between cy46t1 Esuite and operational cy40t1 A-LAEF for 001 output (top) and fullpos output (bottom) for different lead times.*

diffs come from a bug in cy40t1 fullpos

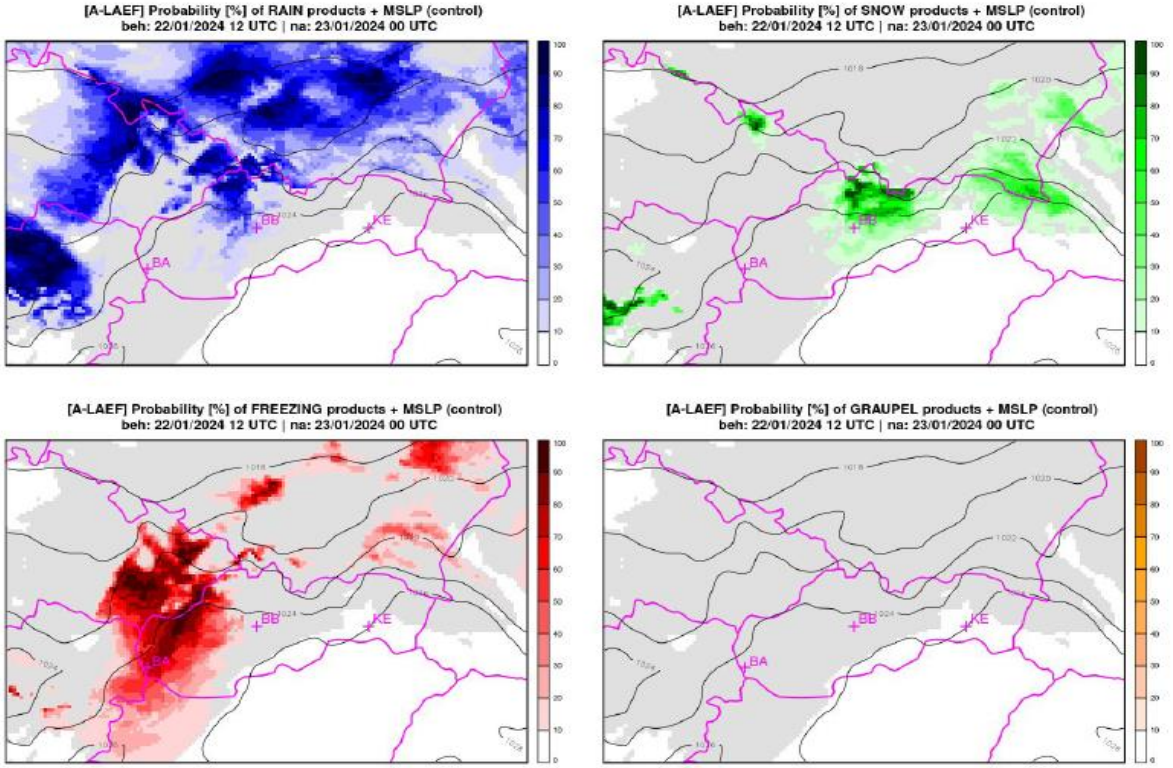



*2m relative humidity of A-LAEF oper (cy40t1, top) and A-LAEF Esuite (cy46t1, bottom) for a test case in October 2023.*

# A-LAEF: Case studies

## Freezing rain event, January 2024




- new cy46t1 code used in A-LAEF Esuite includes prognostic graupels, diagnostics of 16 distinct precipitation types, flashes, wet snow and its accretion on high voltage wires (by André Simon)
- probabilistic products - new maps for precipitation types
- tested during a freezing rain event in Slovakia in January 2024

*New A-LAEF probability maps for precipitation types rain, snow, freezing rain and graupel for a test case on January 23, 2024.*

# C-LAEF 1k

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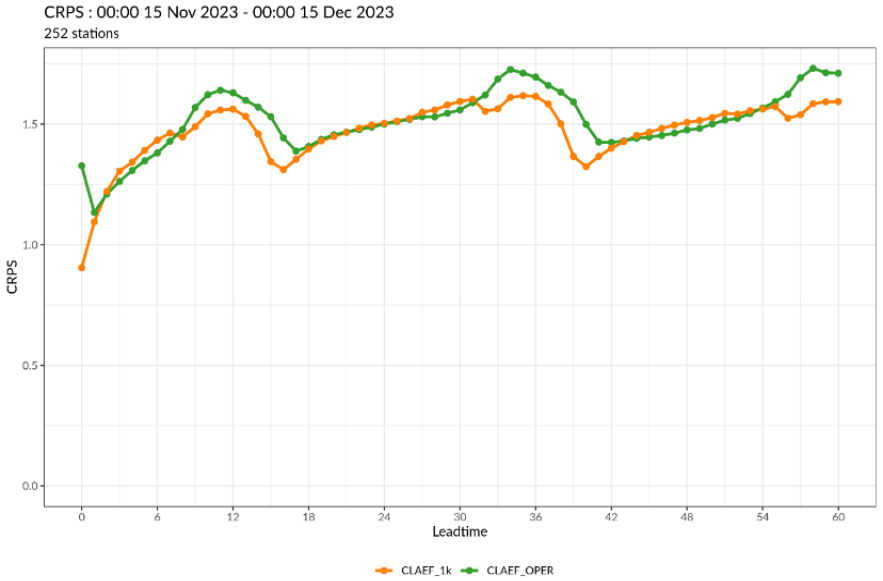
## Upgrade of C-LAEF to 1km

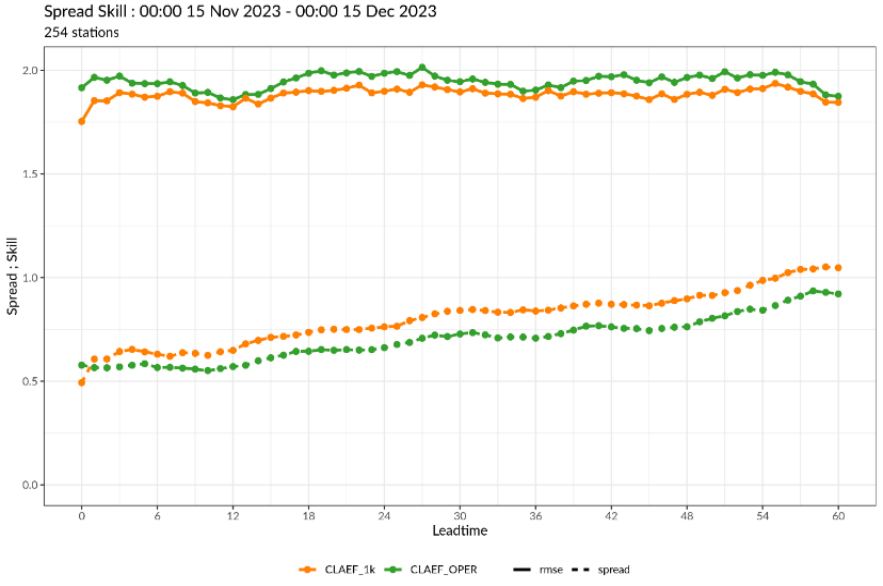
- Strong effort in Austria on upgrading C-LAEF to 1km (plan: operationalization in 2025)
- set up of full C-LAEF 1k suite in May 2023 – running continuously till January 2024
- afterwards only the control and some selected members are kept (save SBUs)
- full C-LAEF 1k planned for convective season in May 2024
- cy46t1, I/O server, long 00 UTC run (+60), 3h assimilation cycle, SPP perturbations
- additional control member using EnVar, all members switched from spectral to grid point
- addition of ceilometer observations in 3D-Var (Austrian stations only); radar data, latent heat nudging
- switch off CANOPY scheme
- complete new ecflow-suite – more user friendly to be shared with partners on github
- computing resources on ATOS for the 1km Esuite of about 1.4 Mio SBUs per day
- cooperation with Slovenia and Croatia – common development and maintenance of C-LAEF1k

# C-LAEF 1k

## Upgrade of C-LAEF to 1km

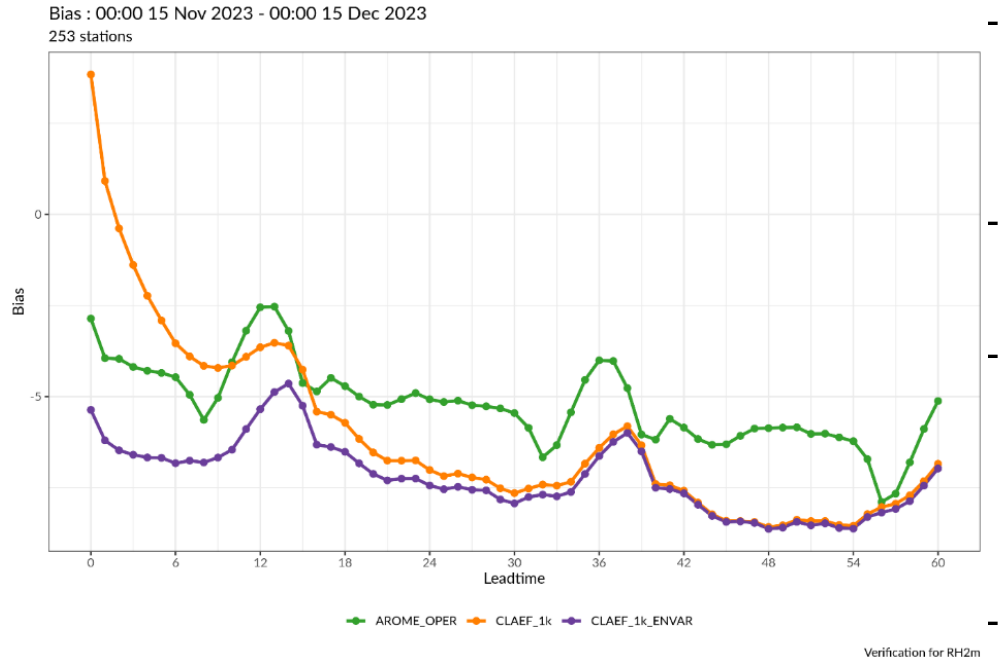
- the performance of C-LAEF 1k is monitored objectively calculating verification scores at 250 stations over various periods and for case studies
- for most parameters and most leadtimes the scores for the 1km version are comparable or even better than for the current operational C-LAEF suite
- still some optimizations necessary




*CRPS of 2m temperature (upper) and spread skill of 10m wind speed (bottom) of C-LAEF 1k (orange) and C-LAEF oper (green) for a verification period in November/December 2023.*

# C-LAEF 1k




*BIAS of 2m relative humidity of AROME operational (green), C-LAEF 1k control member (orange) and C-LAEF 1k EnVar member (purple) for November/December 2023.*

- additional EnVar control member; uses 48 member as input, 16 member from previous forecast, 16 member from last 00 UTC run and 16 member from ECMWF
- overall performance of EnVar member was comparable to other C-LAEF 1k members
- significant differences were observed in humidity and precipitation where the EnVar Member lacks the overestimation of precipitation in the first forecast hours
- EnVar setting appears to be too dry compared to observations
- further testing/optimization needed (together with Slovenia)

# CLAEF 1k: Flow dependent SPP

## Development of flow-dependent parameter perturbations in C-LAEF

- SPP scheme is purely stochastic: the perturbations are applied completely randomly without any consideration of the weather/flow situation (in contrast to SPPT)
- idea to develop a kind of intelligent perturbation scheme which applies perturbations especially in areas where most impact can be expected
- first stay of Endi Keresturi (October 2022) – simple version (some parameters, simplified weights); second stay in October 2023 – flow dependent SPP for all 12 parameters perturbed (6 parametrization schemes) in C-LAEF 1k
- tested for 2 case studies
- C-LAEF Esuite with SPP FD running on Atos for February 2024, summer month planned (June 2024); one more stay (June 2024) & publication

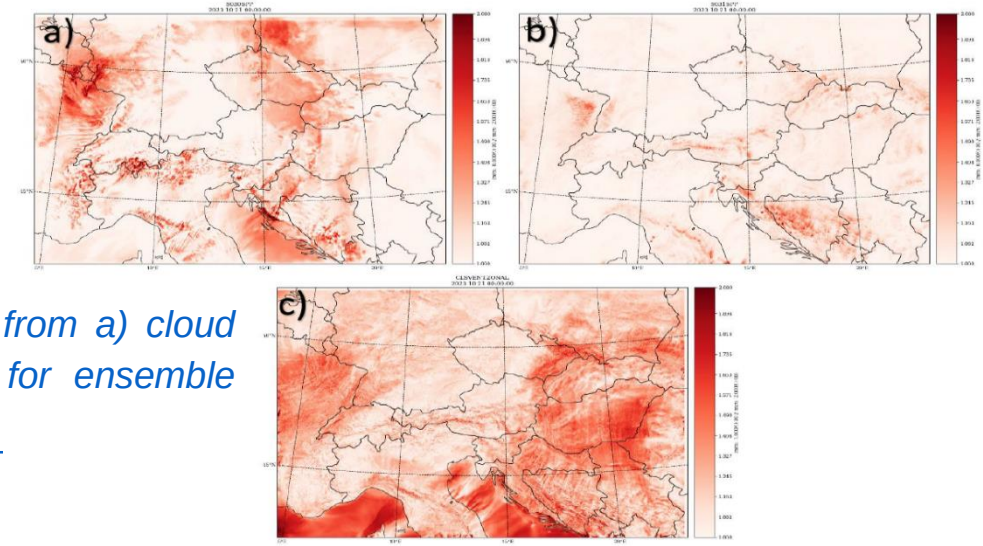
# CLAEF 1k: Flow dependent SPP

**Development of flow-dependent parameter perturbations in C-LAEF**

- modify perturbed parameter (P^) by adapting w $\hat{P} = P\, e^{c+w\varphi}$
- pattern generator is not changed, but the existing pattern is modified by some weights
- weights are transformed to [1, Wmax] $w=MIN[(w'Nl\times N)+1, Wmax]$
- diagnose which areas in the model are the most unstable for each parameter
- pragmatic approach – for each of the 12 parameters a particular model variable is used
- cloud fraction for microphysics and radiation;

  TKE for turbulence and shallow convection;

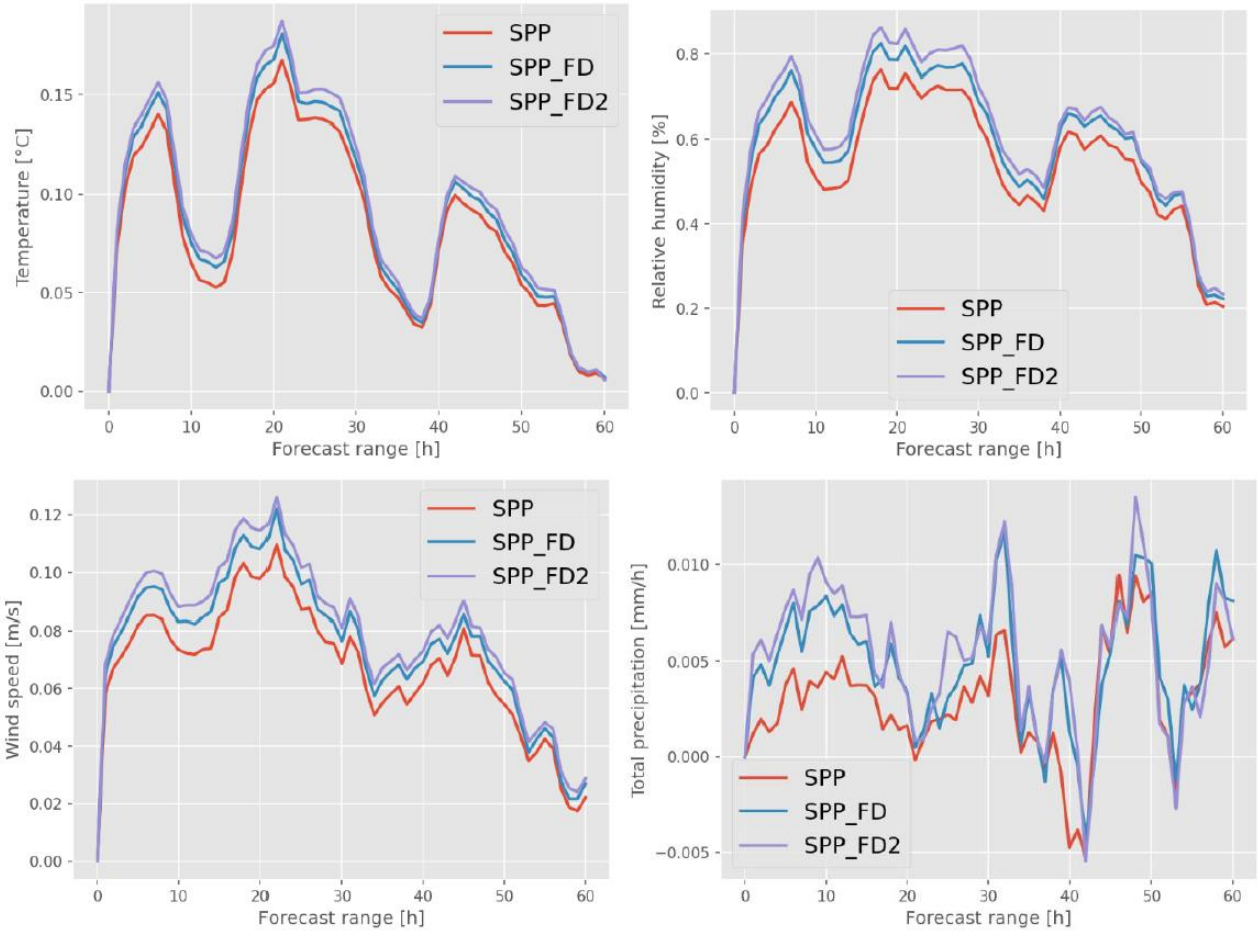
  10m wind speed for SURFEX




*Example of flow-dependent weights obtained from a) cloud fraction, b) TKE and c) 10 m wind speed for ensemble member 2 valid at 21. 10. 2023 at 00 UTC.*

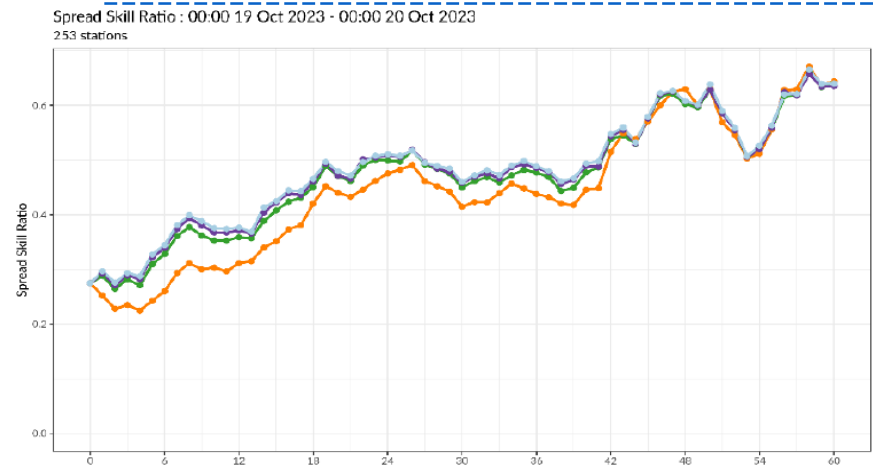
# CLAEF 1k: Flow dependent SPP

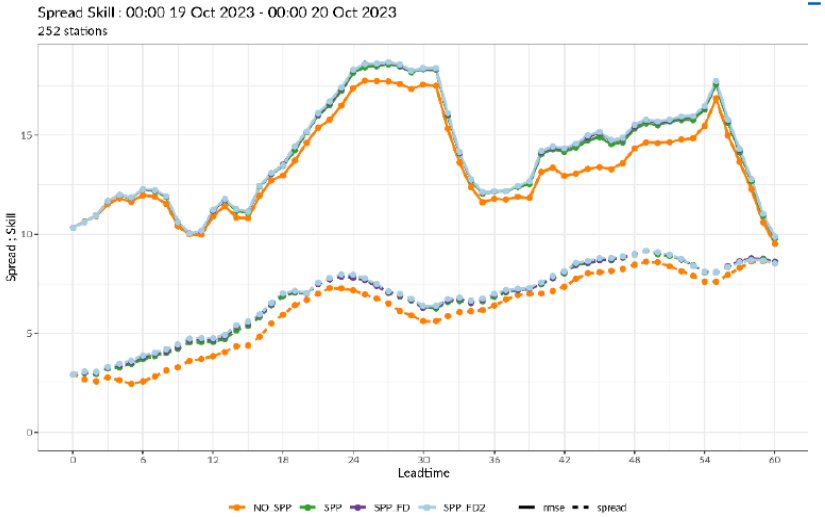
- SPP FD has been tested for 2 case studies (08/10 2023)
- full C-LAEF 1k ensemble, +60h
- SPP FD behaves expectedly - in target regions perturbations are amplified and differences “move” with the weather
- spread is increased for all variables and for almost all lead times
- RMSE/spread ratio is improved

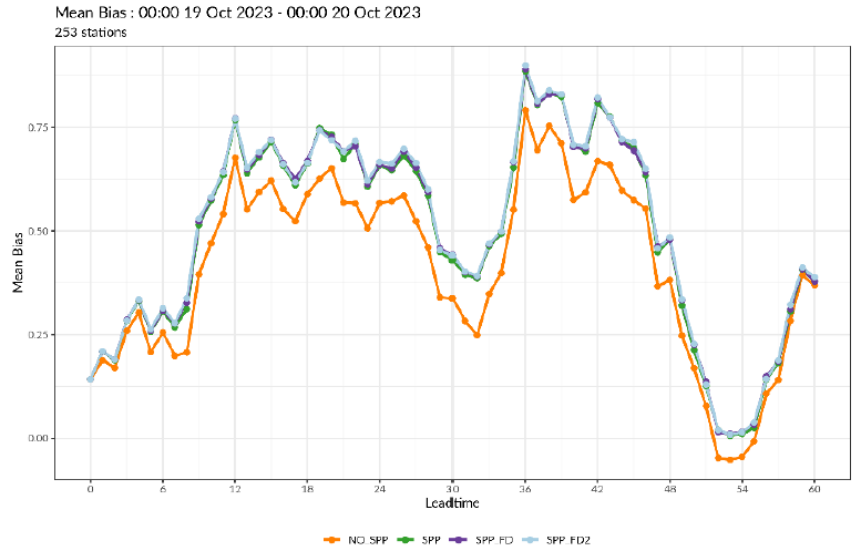



*Domain averaged spread (19/10/2023) for 3 SPP experiments with respect to NO_SPP for 2m temp., rel. hum., 10m wind and total precipitation.*

# CLAEF 1k: Flow dependent SPP




- longer verification period necessary (02/06 2024)
- optimizations to improve impact

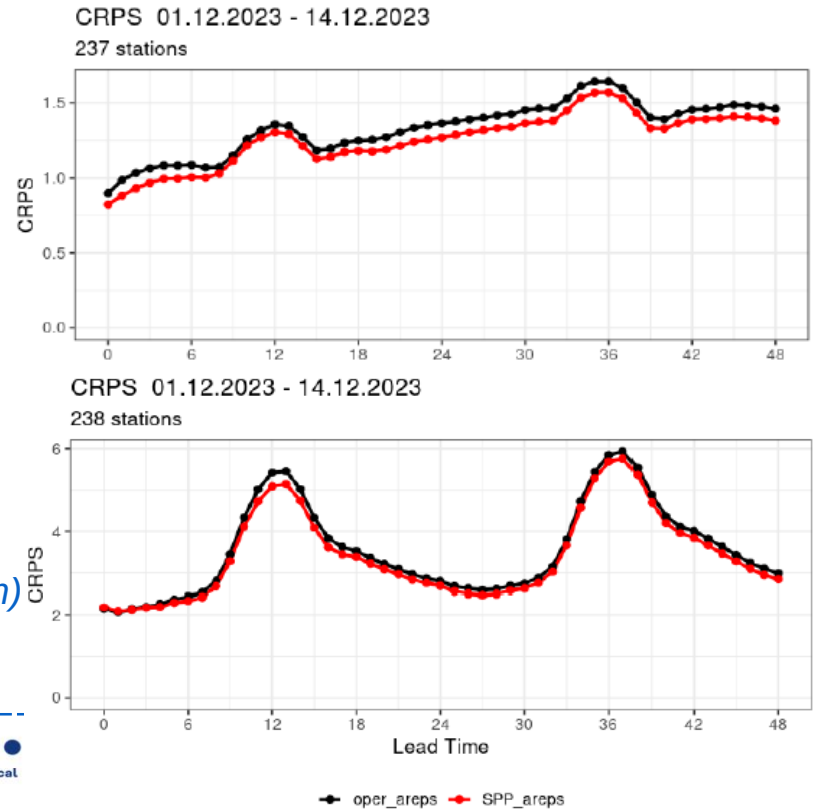
*BIAS (upper left), RMSE/spread (upper right) and spread/skill ratio (bottom) for 10m wind speed on 19 October 2023 for the four experiments.*

# AROME-EPS

## SPP in AROME-EPS

- LACE stay of Gabriella Toth: implementation of SPP
- 10 parameters are perturbed
- unperturbed values of the parameters followed the suggestion of Meteo France
- a lot of tuning and optimization to get optimal parameter distribution
- first SPP experiment between 01 and 14 December 2023
- initial conditions identical with operational AROME-EPS

| Parameter | CMPERT | Range |
|---|---|---|
| PSIGQSAT: constant for sub grid condensation | 0.4 | [0, 0.1] |
| RSWINHF: short-wave inhomogeneity factor | 0.05 | [0.6, 1] |
| RLWINHF: long-wave inhomogeneity factor | 0.04 | [0.6, 1] |
| XCTP: constant for temperature and vapour pressure correlations | 0.3 | [1.035, 22] |
| XCEP: constant for wind-pressure correlations | 0.2 | [0.225, 4] |
| XCED: constant for dissipation of TKE | 0.2 | [0.4, 2] |
| XCMF: closure coefficient at the bottom level | 0.1 | [0, 0.1] |
| XFRACZ0: coefficient for the orographic drag | 0.15 | [2, 10] |
| RCRIAUTI : snow auto conversion threshold | 0.2 | [0.1* $10^{-3}$, 1.1* $10^{-3}$] |
| RCRIAUTC: rain auto conversion threshold | 0.02 | [0.4* $10^{-3}$, 1*$10^{-3}$] |




*CRPS of 2m temperature (upper) and 2m relative humidity (bottom) for AROME-EPS oper (black) and AROME-EPS SPP (red) for a 2 weeks period in December 2023.*

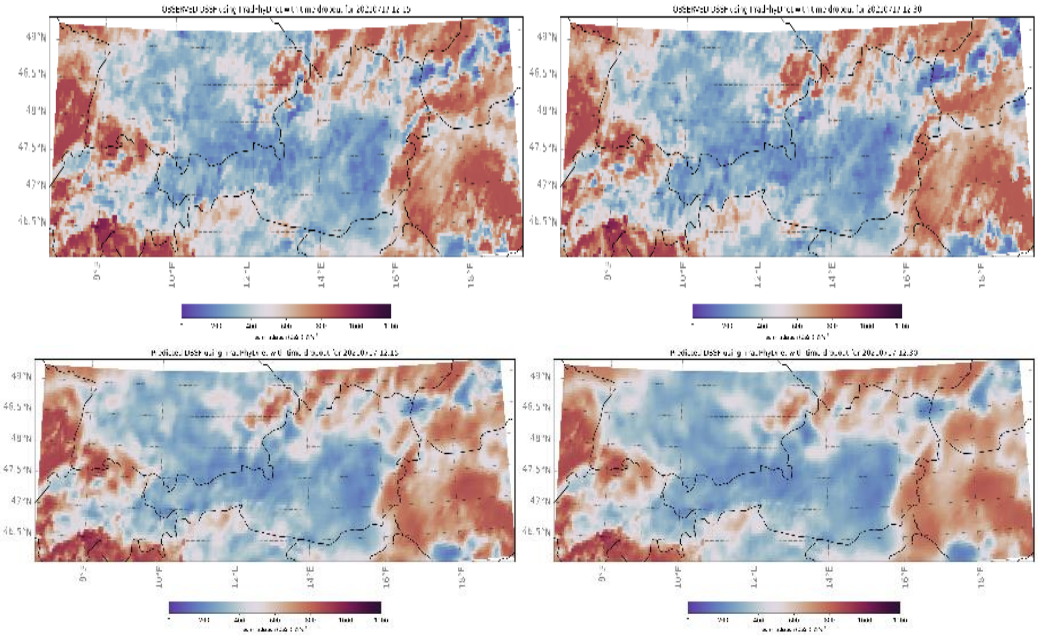


GeoSphere Austria DHMZ Czech Hydrometeorological Institute

# Statistical EPS

## Application of Machine Learning approaches

- new spatial data-driven nowcasting approaches developed at GeoSphere Austria based on various machine learning methods (NN, deep FFNN) for solar radiation, wind speed and precipitation
- 4-years training data set for the nowcasting
- the algorithm provides 3 hours forecast based on the past 3 hours
- it is running operationally and provides forcasts every 15 min
- 6h version in test

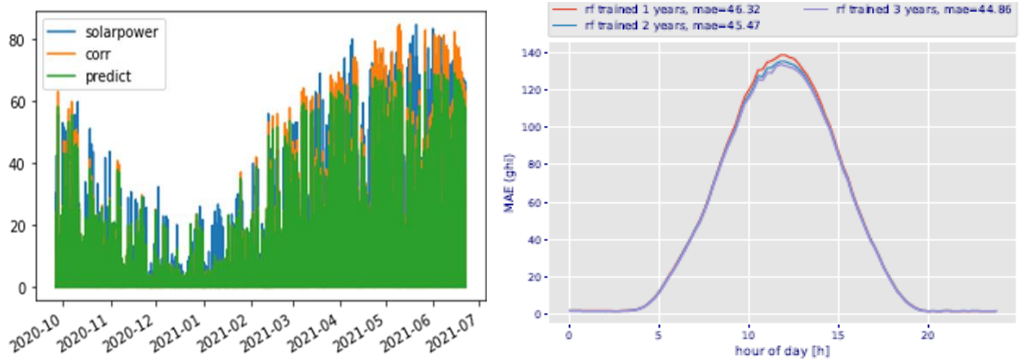


*Observed global radiation (up) and radiation output of a pure machine learning model (bottom) for a test case in 2023*

# Statistical EPS

## Application of Machine Learning approaches

- additionally to the spatial data-driven forecasting, also a point data-driven forecasting and post-processing ML technique has been developed at GeoSphere Austria
- main purpose of this model is the application in the energy sector, where point forecasts for PV and wind power production are provided
- for PV production this is done by a random forest method combining observations of different sources trained on short available time series
- for wind power production we combine different observation sources and power curves from known specifications and correct them with wind atlas data




*Left: PV power production forecast from ML algorithm (green is model output, orange is correction with wind atlas, blue is real production). Right: MAE of ML forecasts for global radiation at TAWES site based on different training periods.*

# Outlook & Plans

## Operational plans

**A-LAEF:** - Upgrade to cy46t1 in 2024

- Implementation of SURFEX in A-LAEF
- Local convection-permitting ALARO-EPS in SK

**C-LAEF:** - Upgrade to 1km with SLO/CRO (2025)

- New HPC at GeoSphere Austria
- Flow dependency (assimilation, perturbations)

**AROME-EPS:** - Operationalization of SPP in AROME EPS (2024)

## Research & development

- Flow-dependent B-matrix in assimilation
- EnVar and Hybrid EnVar in EPS
- Development of flow-dependent model perturbations
- Improved surface perturbations (SPP in SURFEX)
- Generation of ensemble members by ML
- Work on statistical post-processing of probabilistic fields
- Extension of data-driven ML ensemble methods
- Development of new/improved probabilistic products