*Regional Cooperation for*
*Limited Area Modeling in Central Europe*

LACE
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# LAM-EPS activities in LACE

Clemens Wastl with contributions of LACE partners

GeoSphere Austria | DHMZ | Czech Hydrometeorological Institute | OMSZ | IMGW | METEO ROMANIA | SHMU | ARSO METEO Slovenia

# Overview

- **Operational upgrades**
- **Migration of operational suites of A-LAEF and C-LAEF to Atos HPC in Bologna**
- **EDA in AROME-EPS**
- **SPP in C-LAEF**
- **Flow dependent parameter perturbations in C-LAEF**
- **Statistical EPS**
- **Outlook and plans**

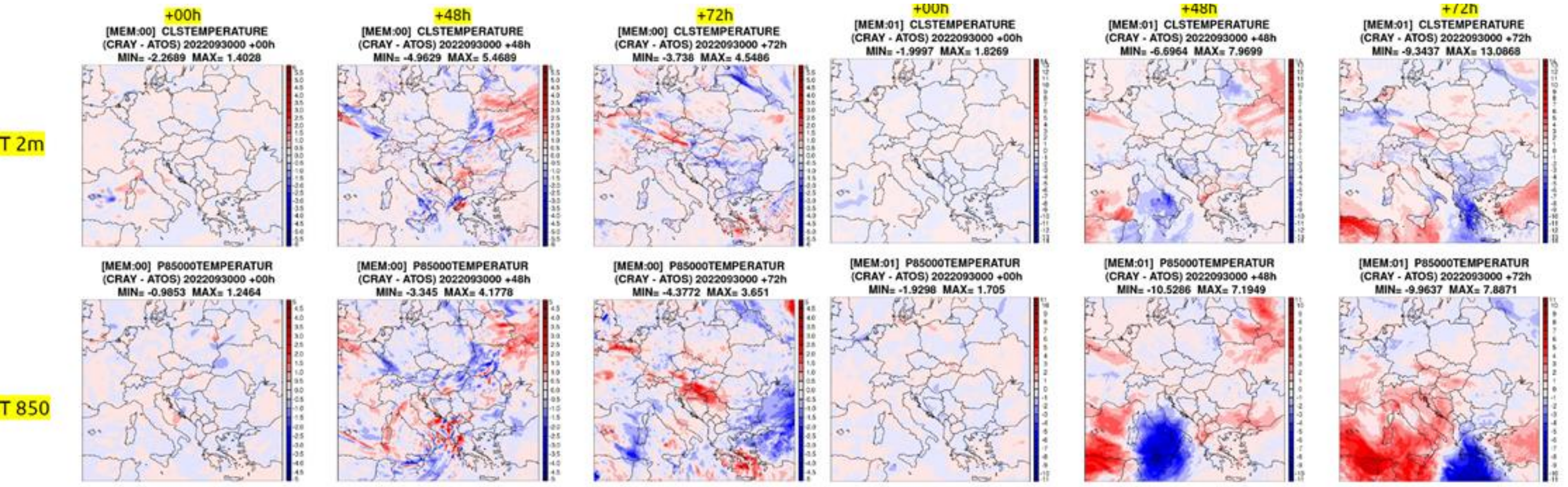
# Operational ensembles

| | 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 | 2 |
| 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) | - |
| 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] | - |
| Model perturbation | ALARO-1 multi-physics + surface stochastic physics (SPPT) | hybrid stochastic scheme comb. of parameter and tendency perturbations | - |
| LBC perturbation | ECMWF ENS (c903) | ECMWF ENS (c903) | ECMWF ENS (c903) |

# Migration to Atos HPC

- **Migration of operational suites of A-LAEF and C-LAEF to new Atos HPC in Bologna**
  - Stability problems at the beginning - a lot of time spent for ENV issues and optimizations
  - Parallel E-Suites of A-LAEF (August 2022) and C-LAEF (summer 2022) – very similar results
  - New ECMWF-ENS coupling files in September (from release candidate cy47r3) – big differences
  - Turned out that the differences already exist in the coupling files
  - Produced with 903: for A-LAEF they are produced by SHMU based on ECMWF-ENS in ECPDS; for C-LAEF and AROME-EPS they are produced directly by ECMWF
  - For the unperturbed control the differences are rather small (comparable to LBCs)
  - For the perturbed members the differences are much bigger and they grow very fast with lead-time – due to stochastic physics
  - We had to cope with these differences - operationalization of A-LAEF and C-LAEF on 19 October

# Migration to Atos HPC




*Differences of temperature at 2m (upper panel) and 850 hPa (lower panel) for 3 lead times (columns) between A-LAEF at Cray and Atos HPC. Control member (left 6 panels) and member 01 (right).*

# Expansion of C-LAEF

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- **Possible expansions of C-LAEF with additional SBUs at Atos**
  - About double the amount of SBUs on the new ECMWF HPC
  - Several possibilities: more members (currently 16+1), more long runs (currently 2), longer lead times (currently 60h), higher resolution (currently 2.5km), larger domain
  - Tests to assess the additional SBUs needed for some of these expansions
  - Lead time of operational C-LAEF 12 UTC run was expanded to +60h in May (from +48h)
  - Now focus on C-LAEF 1km (needs much more SBUs)
  - First test suites on ECMWF HPC based on the single precision code (saves about 30-40%)
  - New GeoSphere Austria HPC is expected at the end of 2023 - set-up a kind of shared C-LAEF system (e.g. split of members, common scripting system, common assimilation, etc.)
  - Possibility of expansion of C-LAEF domain for other LACE countries

# EDA in AROME-EPS

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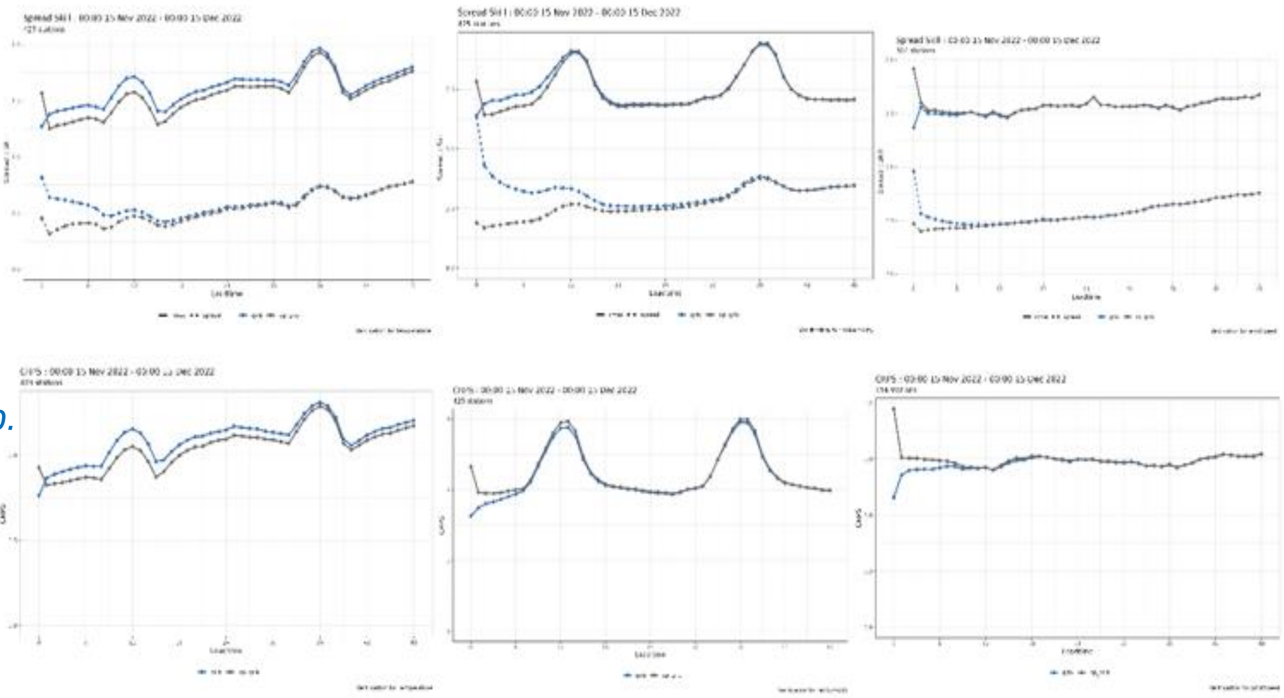
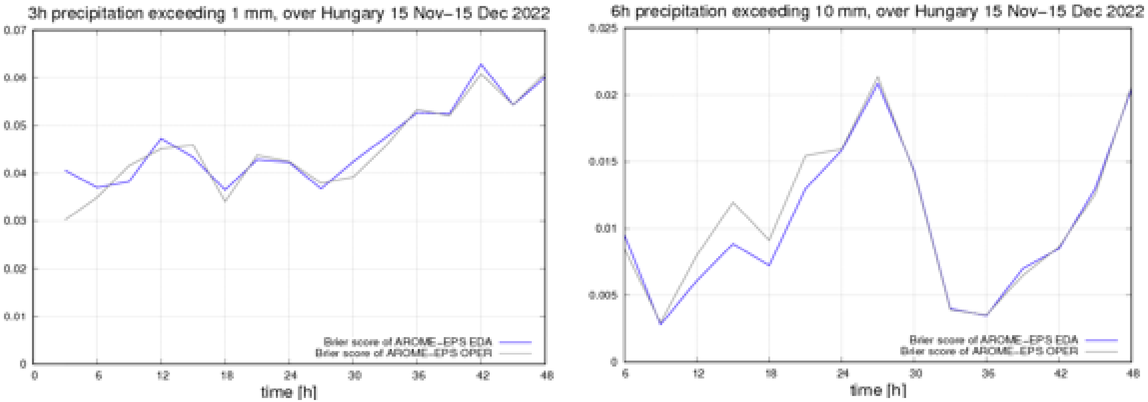
- **Introduction of EDA in AROME EPS (Hungary)**
  - Operational AROME-EPS is dynamical downscaling of the first 11 members of ECMWF-ENS
  - Experiments to introduce local perturbations using EDA - CY43T2
  - Pre-operational AROME-EPS E-suite with EDA in August 22
  - Intensively tested and verified (with HARP, in comparison to AROME-EPS)



*Spread and RMSE (first), CRPS (second ) of 2m temp. (left), 2m rel. hum. (middle) and 10m wind speed (right) based on the operational AROME-EPS (grey) and AROME-EPS-EDA (blue).*

# EDA in AROME-EPS

- **Introduction of EDA in AROME EPS (Hungary)**
  - EDA in AROME-EPS has strong impact in first forecast hours
  - Stronger impact in summer than in winter
  - Most positive effect on wind speed and gusts, neutral for rel. humidity, slight improvements for temperture and precipitation
  - Operationalization in March 2023




*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.*

# SPP in C-LAEF

- **Parameter perturbations in C-LAEF**
  - Operational C-LAEF comprises model error repr. by perturbation of tendencies (shallow convection, microphysics, radiation) and parameters (turbulence)
  - Implementation of full SPP parameter perturbations to increase physical consistency
  - Implementation of SPG pattern generator
  - Set-up of E-suite with 13 perturbed parameters
  - A lot of tuning necessary
  - SPP is cheaper (5%) than hybrid system
  - Verification of E-suite in summer and winter (6 weeks)
  - Operationalization planned in April 2023

| 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 |
| Convection | XCMF | Closure coefficient at bottom level | 0.065 | 0 - 0.1 |
| | XABUO | Coefficient of the buoyancy | 1 | 0.7 - 1.5 |
| | XBDETR | Coefficient of the detrainment | 1e-6 | 0 - 1 |
| | XENTR_DRY | Coefficient for dry entrainment | 0.55 | 0.1 - 0.699 |

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

# SPP in C-LAEF

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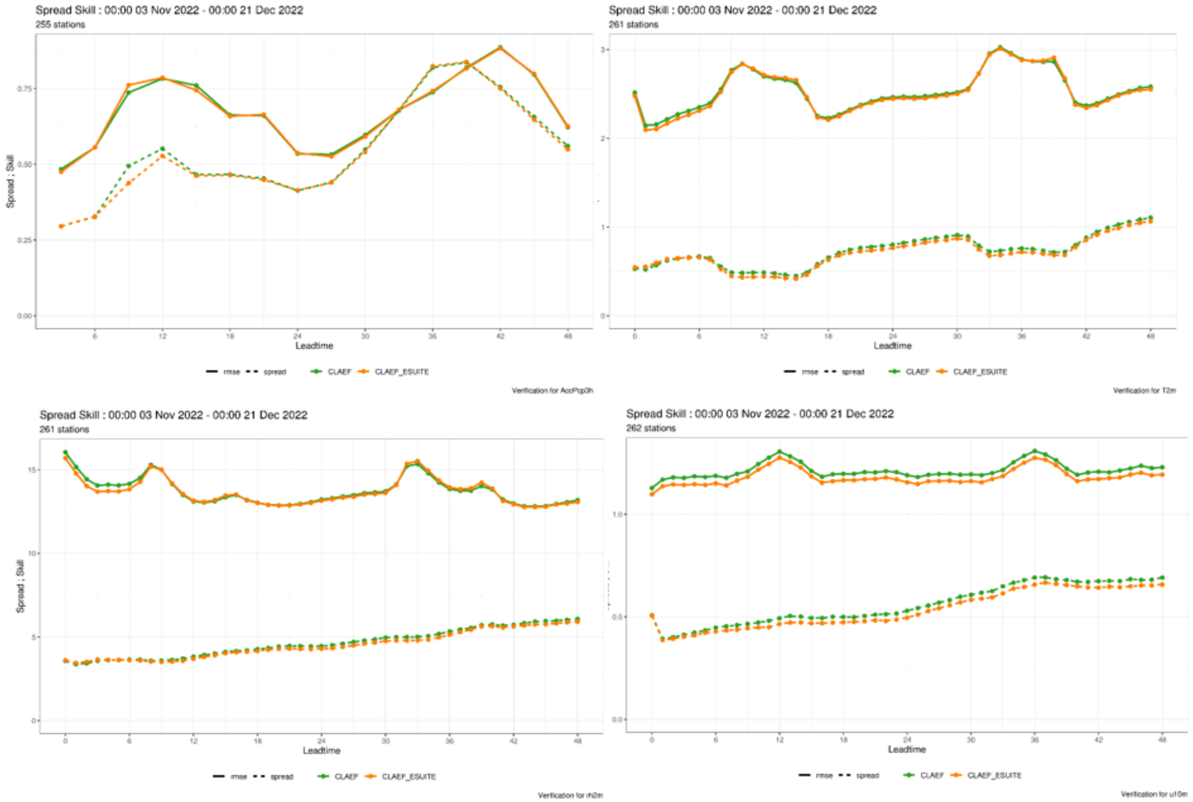


*Spread (dashed) and RMSE (full) of operational C-LAEF with hybrid stochastic perturbation scheme (green) and C-LAEF E-suite with new SPP scheme (orange) for 3h accumulated precipitation (upper left), 2m temperature (upper right), 2m relative humidity (bottom left) and v-component of 10m wind (bottom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



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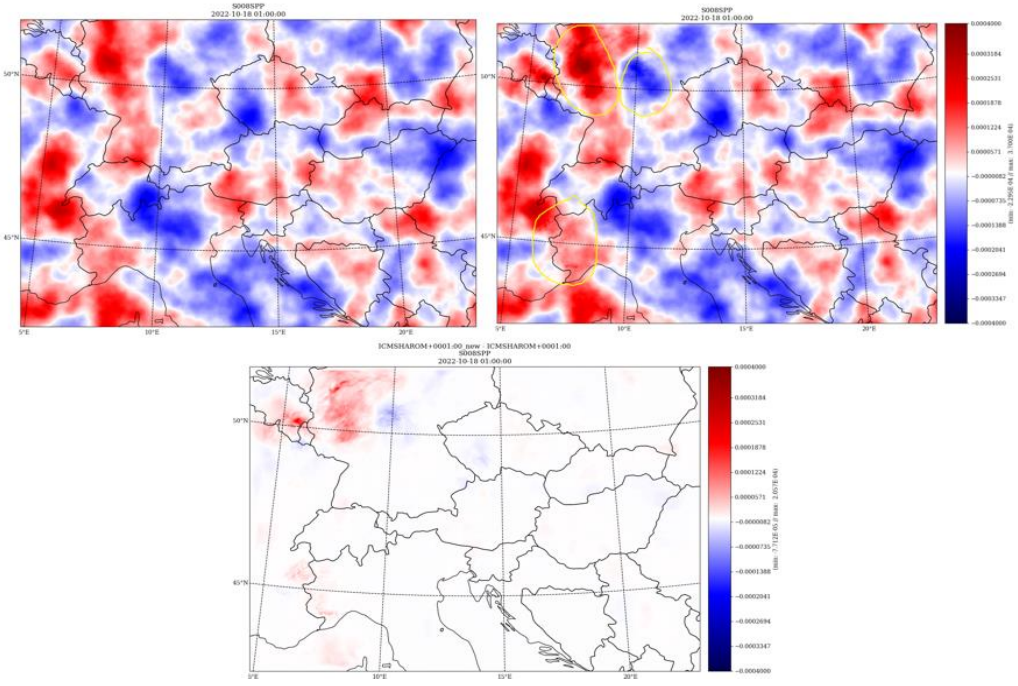
# Flow dependent perturbations

- **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 preparatory work in summer 2022 (literature research, code study, etc.)
  - Stay of Endi Keresturi in Vienna in October 2022
  - Focus on microphysics parameters in the first version (ZRDEP(S/G)RED, RCRIAUTI(C))
  - Pattern generator (SPG) and SPP not modified – adapt existing pattern with weights
  - How to find areas of interest? Investigation of severel model fields for microphysics (cloudiness, precipitation, moisture profile, etc.)

# Flow dependent perturbations

- **Development of flow-dependent parameter perturbations in C-LAEF**
  - Problem is conversion of these fields to weights (because of parallelization)
  - Cloud fraction used in a first step

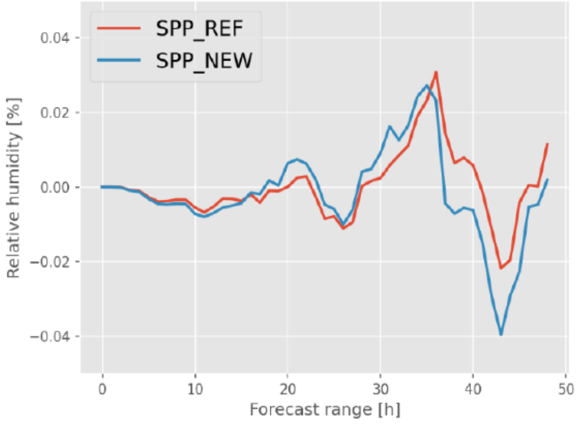
(1) $w = \left(\frac{w\prime}{N_l} \times N\right) + 1$ (2) $\hat{P} = P\, e^{c+w\varphi}$

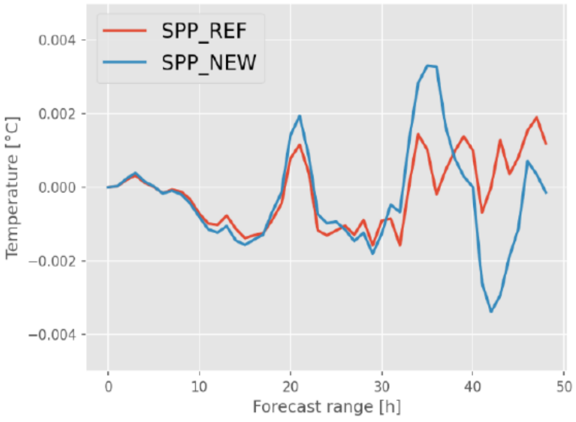



*Impact of the cloudiness to the stochastic perturbation field of microphysics parameters in SPP. Upper left: SPP without flow dependency, upper right: SPP with flow dependency, lower panel: difference.*

# Flow dependent perturbations

- **Development of flow-dependent parameter perturbations in C-LAEF**
  - Impact of flow dependent SPP tested for one case in November 2022 (cold front)
  - Rather small impact, but algorithm principally works
  - More work planned for stay 2023: optimization, expansion to other parametrizations




*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.*

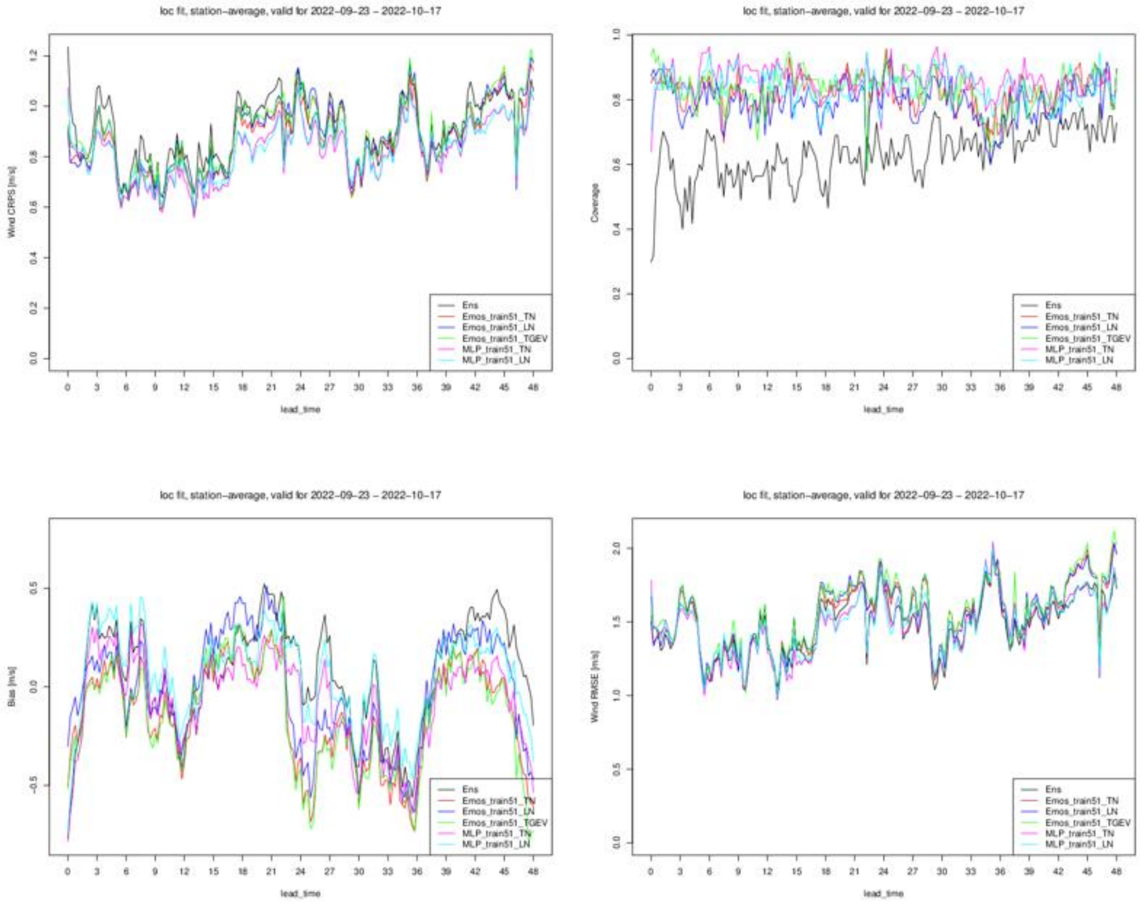
# Flow dependent perturbations

- **Development of flow-dependent parameter perturbations in C-LAEF**
  - Another approach is currently under development at GeoSphere Austria
  - Use the large scale weather type classification to perturb selected parameters in the physics parametrizations (random parameter approach)
  - First version: external python based perturbation tool which reads weather type class and modifies C-LAEF fields (e.g. moisture) or namelist settings (e.g. temperature)
  - Tested for 2m diagnostics - reduction of temperture BIAS
  - Tested for low stratus events – reduction of model BIAS
  - Further investigations planned in 2023

# Statistical EPS

- **Statistical post-processing at GeoSphere Austria**
  - SAMOS (standardized anomaly model output statistics) implemented to improve direct model output from ensembles (EMCW-ENS, C-LAEF) of 2m T and RH, precipitation and 10m wind (gusts soon)
  - SAMOS is providing spatial forecasts in a seamless forecast from analysis to middle-range forecasts
  - SAMOS is able to improve the BIAS significantly and is also able to correct the under-dispersion
- **Analog-based post-processing on a regular grid (Croatia)**
- **Application of machine learning post-processing at OMSZ**
  - OMSZ provides NWP forecasts to support partners in renewable energy sector
  - Post-processing helps to improve global radiation and near-surface wind forecasts
  - Application of EMOS (ensemble model output statistics with censored normal or censored logistic functions) and machine learning to improve AROME-EPS output
  - 16-18% CRPS improvement for radiation and 10-15% for wind speed
  - Improvements visible in BIAS and ensemble spread
  - Integration into the operating system planned

# Statistical EPS




*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).*

# Outlook & Plans

## Operational plans

**A-LAEF:** - Upgrade to cy43t or cy46t1 (to be decided)

- Upgrade of upper-air IC uncertainty representation by ENS BlendVar

**C-LAEF:** - Operationalization of SPP in C-LAEF (April)

- Upgrade to 1km until 2025
- Set-up of split system with ECMWF and GeoSphere Austria HPC

**AROME-EPS:** - Implementation of stochastic physics for model error representation

## Research & development

- Flow-dependent B-matrix in assimilation
- EnVar
- Development of flow-dependent model perturbations
- Generation of ensemble members by deep learning algorithms
- Work on statistical post-processing of probabilistic fields
- Development of new/improved probabilistic products
- Increase the reputation of EPS by user-oriented approaches

# Publications

- **Presentations**
  - Presentation of LACE EPS activities at ACCORD ASW in Ljubljana in April 2022 and EWGLAM in Brussels in September 2022
  - Presentation of C-LAEF at ESSL Testbeds in June/July 2022
- **Publications**
  – 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
  – N. E. Gáspár, 2022: Evaluation of AROME-EPS radiation forecasts. BSc Thesis, Eötvös Loránd University, Department of Meteorology, Budapest.
  – G. Szépszó, K. Csirmaz, A. Kardos-Várkonyi, D. Lancz, A. Simon, F. Prates, M. Belluš, M. Neštiak, 2022: “A 2022. augusztus 20-ai előrejelzések meteorológiai háttere”, LÉGKÖR, Vol. 67, No. 4, p181-188, DOI: 10.56474/legkor.2022.4.1