

*Regional Cooperation for
Limited Area Modeling in Central Europe*



LAM-EPS activities in LACE

Clemens Wastl with contributions of LACE partners

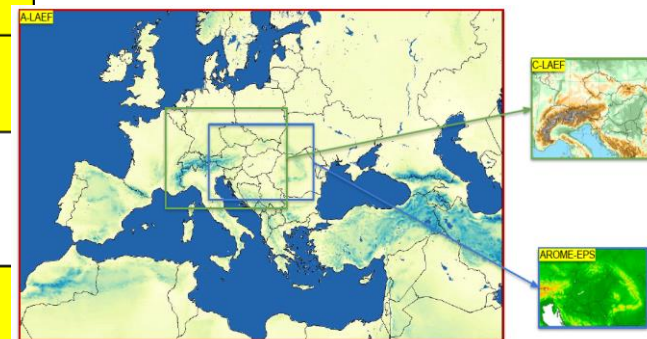


ARSO METEO
Slovenia

- **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)

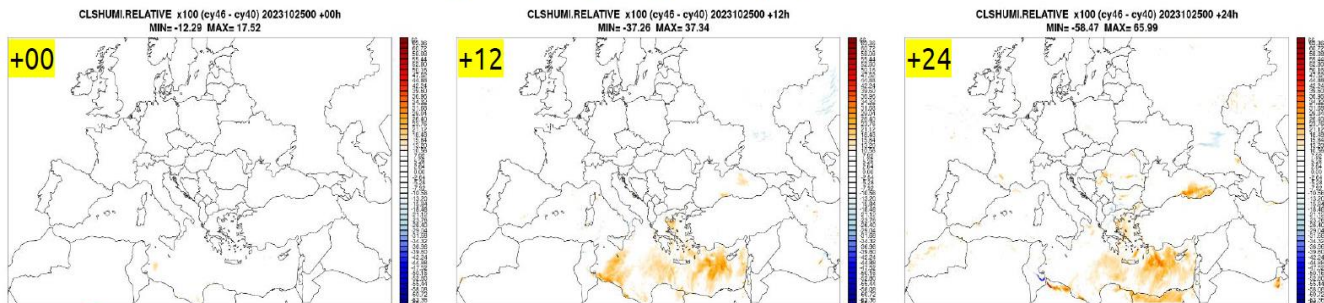


Upgrade of A-LAEF to cy46t1

- 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%

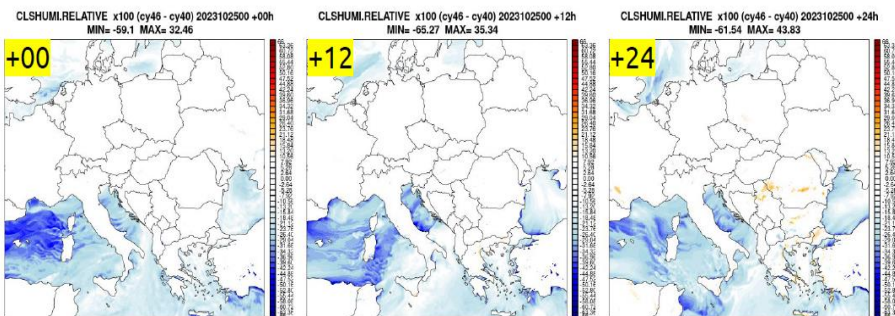
Upgrade of A-LAEF

cy46t1 (new) vs cy40t1 (oper) - e001

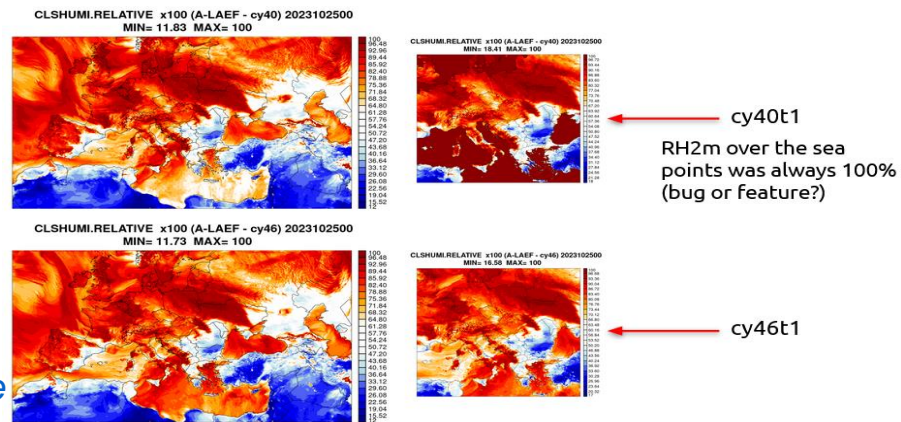


Differences of 2m relative humidity between cy46t1 Esuite and operational cy40t1 A-LAEF for 001 output (top) and fullpos output (bottom) for different lead times.

cy46t1 (new) vs cy40t1 (oper) - fullpos (LACE domain)



cy46t1 (new) vs cy40t1 (oper)

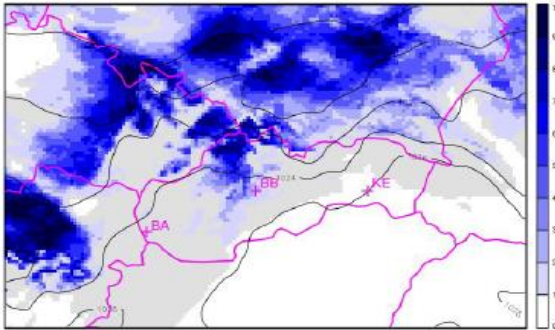


diffs come from a bug in cy40t1 fullpos

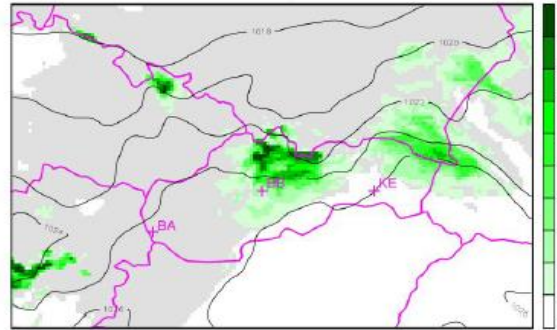
2m relative humidity of A-LAEF oper (cy40t1, top) and A-LAEF Esuite (cy46t1, bottom) for a test case in October 2023.

Freezing rain event, January 2024

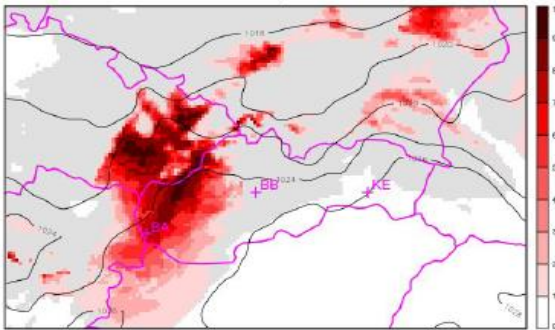
[A-LAEF] Probability [%] of RAIN products + MSLP (control)
beh: 22/01/2024 12 UTC | na: 23/01/2024 00 UTC



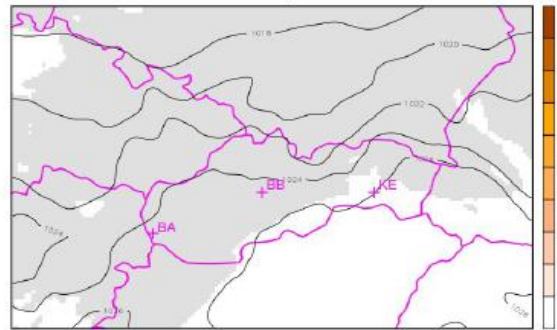
[A-LAEF] Probability [%] of SNOW products + MSLP (control)
beh: 22/01/2024 12 UTC | na: 23/01/2024 00 UTC



[A-LAEF] Probability [%] of FREEZING products + MSLP (control)
beh: 22/01/2024 12 UTC | na: 23/01/2024 00 UTC



[A-LAEF] Probability [%] of GRAUPEL products + MSLP (control)
beh: 22/01/2024 12 UTC | na: 23/01/2024 00 UTC



- 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.

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 eflow-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

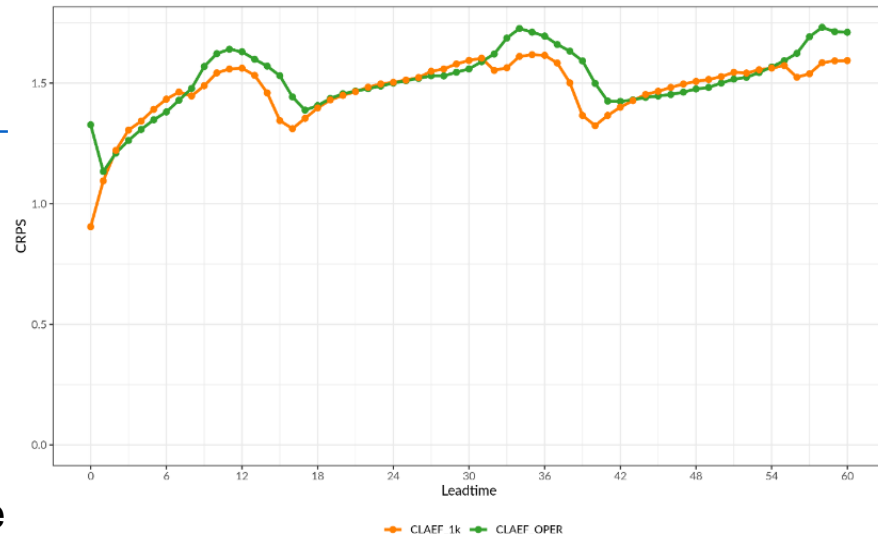
C-LAEF 1k

Upgrade of C-LAEF to 1km

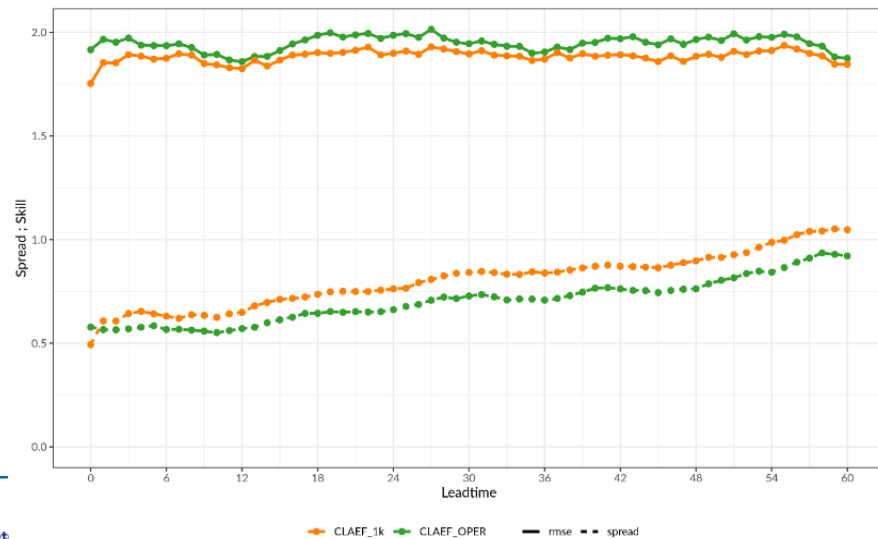
- the performance of C-LAEF 1k is monitored objectively calculating verification scores at 250 stations over various periods and for case studies
- for most parameters and most leadtimes the scores for the 1km version are comparable or even better than for the current operational C-LAEF suite
- still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

CRPS : 00:00 15 Nov 2023 - 00:00 15 Dec 2023
252 stations

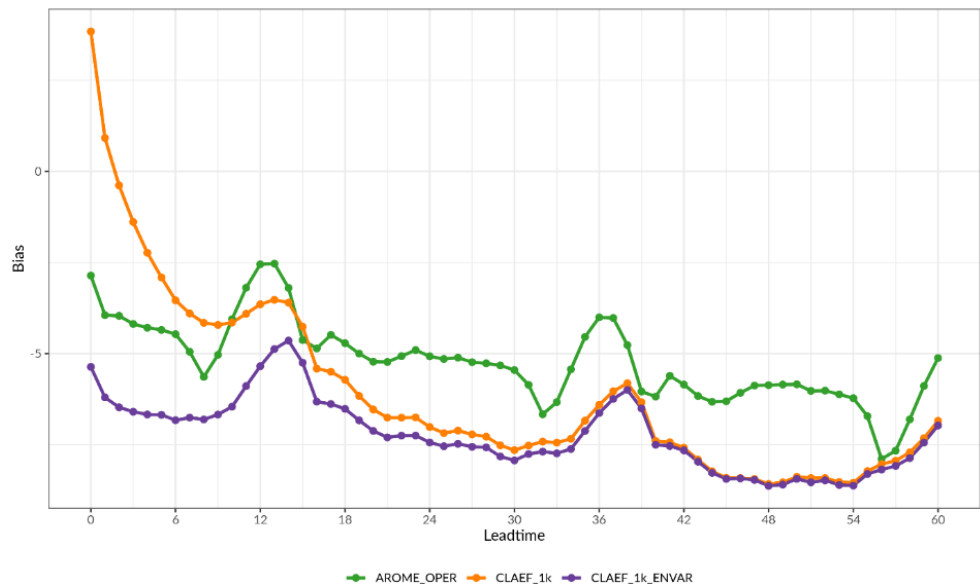


Spread Skill : 00:00 15 Nov 2023 - 00:00 15 Dec 2023
254 stations



Bias : 00:00 15 Nov 2023 - 00:00 15 Dec 2023

253 stations



Verification for RH2m

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.

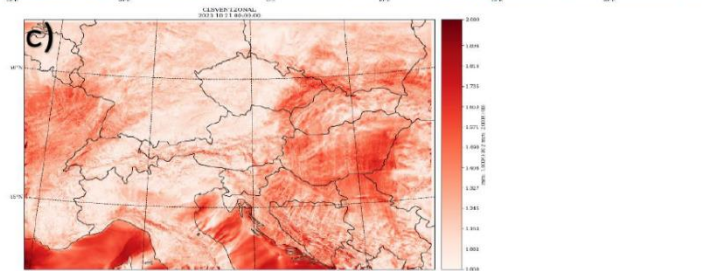
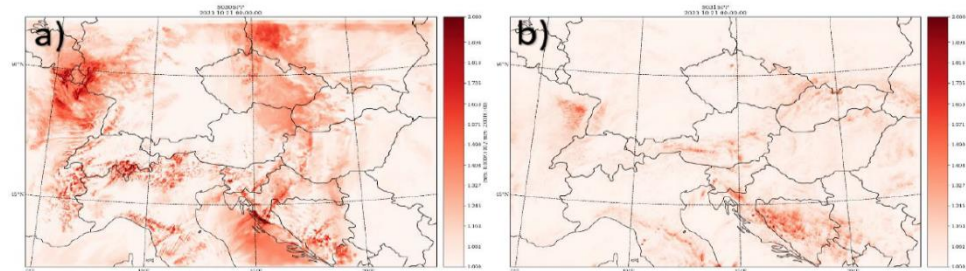
- additional EnVar control member; uses 48 member as input, 16 member from previous forecast, 16 member from last 00 UTC run and 16 member from ECMWF
- overall performance of EnVar member was comparable to other C-LAEF 1k members
- significant differences were observed in humidity and precipitation where 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)

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

Development of flow-dependent parameter perturbations in C-LAEF

- modify perturbed parameter (P^\wedge) 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 $[1, Wmax]$
$$w = MIN[(w'NlxN)+1, Wmax]$$
- 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

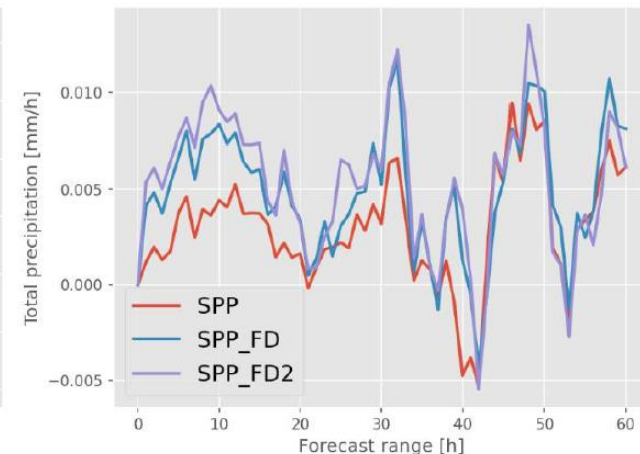
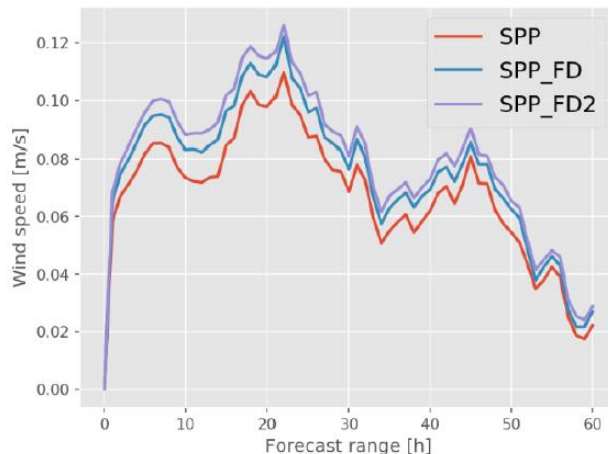
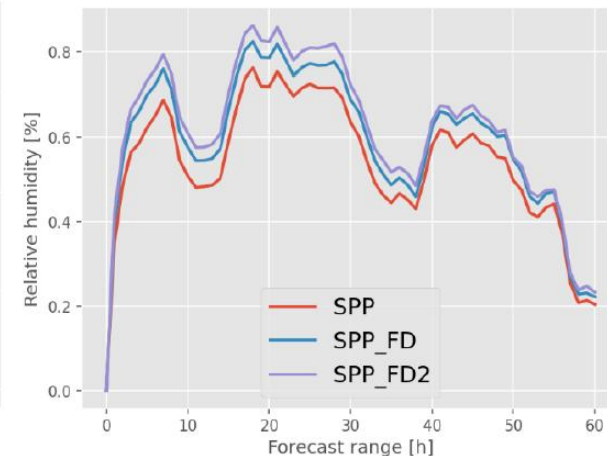
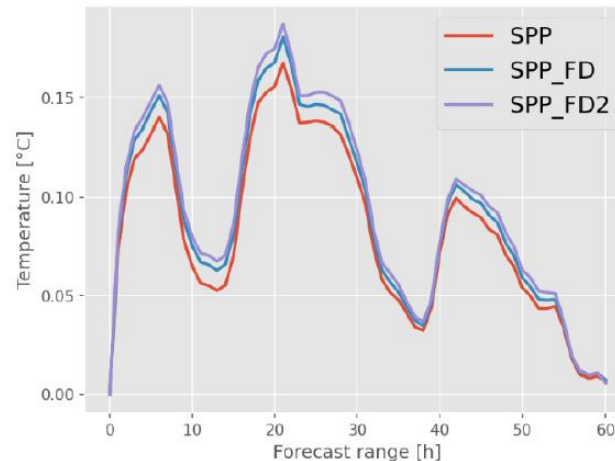


Example of flow-dependent weights obtained from a) cloud fraction, b) TKE and c) 10 m wind speed for ensemble member 2 valid at 21. 10. 2023 at 00 UTC.

CLAEF 1k: Flow dependent SPP

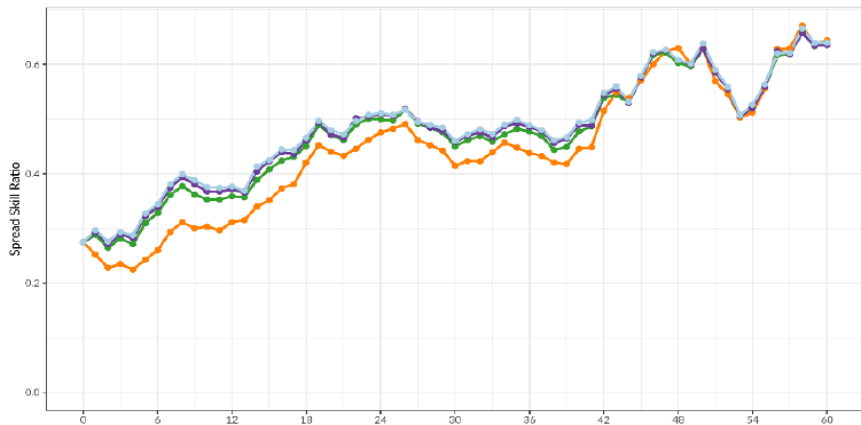
- SPP FD has been tested for 2 case studies (08/10 2023)
- full C-LAEF 1k ensemble, +60h
- SPP FD behaves expectedly - in target regions perturbations are amplified and differences “move” with the weather
- spread is increased for all variables and for almost all lead times
- RMSE/spread ratio is improved

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.

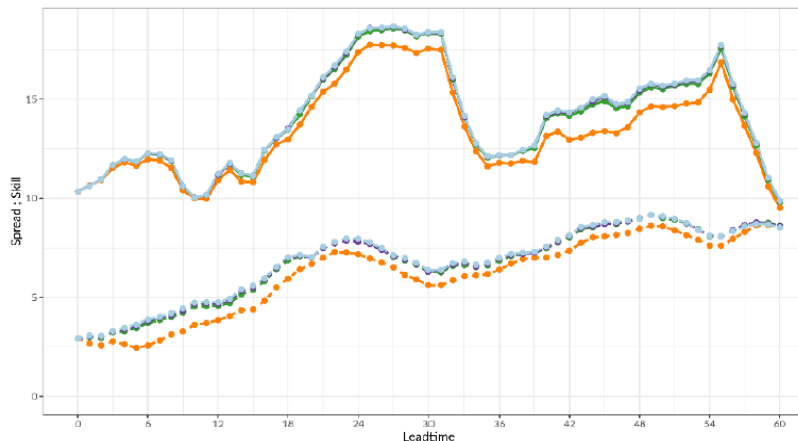


CLAEF 1k: Flow dependent SPP

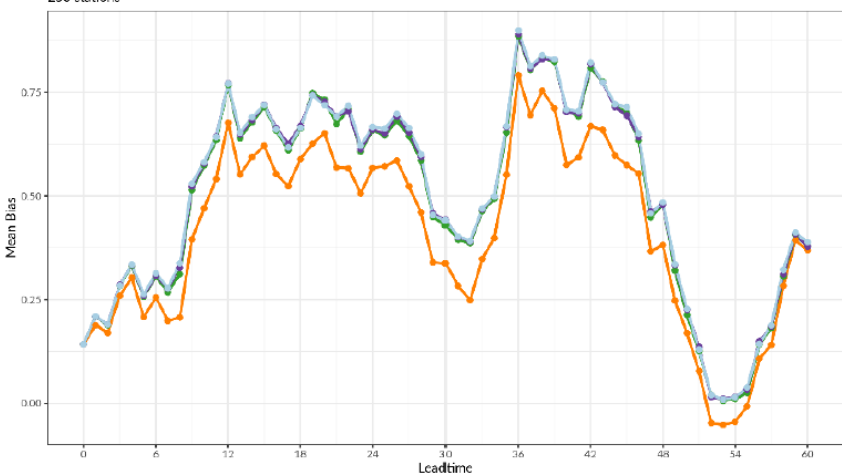
Spread Skill Ratio : 00:00 19 Oct 2023 - 00:00 20 Oct 2023
253 stations



Spread Skill : 00:00 19 Oct 2023 - 00:00 20 Oct 2023
252 stations



Mean Bias : 00:00 19 Oct 2023 - 00:00 20 Oct 2023
253 stations



- 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

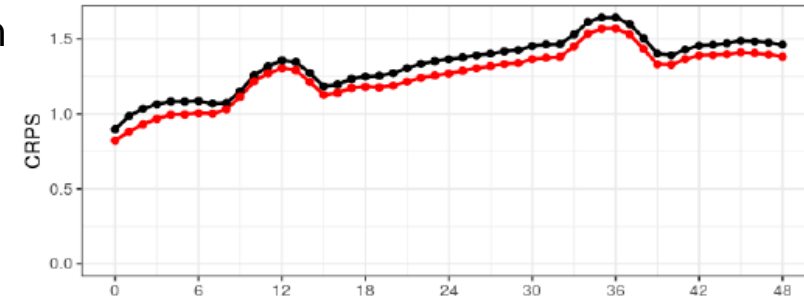
SPP in AROME-EPS

- 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

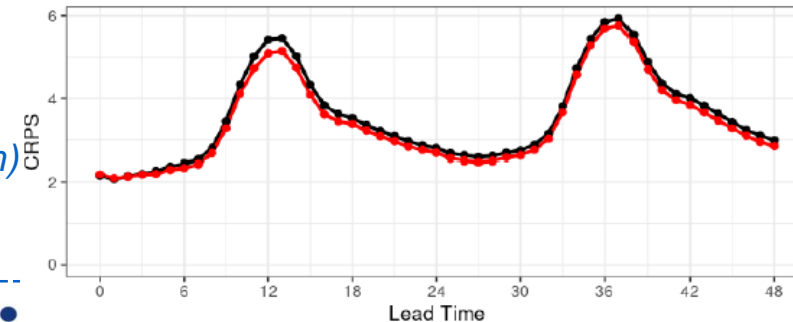
CRPS of 2m temperature (upper) and 2m relative humidity (bottom) for AROME-EPS oper (black) and AROME-EPS SPP (red) for a 2 weeks period in December 2023.

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	[$0.1 \cdot 10^{-3}$, $1.1 \cdot 10^{-3}$]
RCRIAUTC: rain auto conversion threshold	0.02	[$0.4 \cdot 10^{-3}$, $1 \cdot 10^{-3}$]

CRPS 01.12.2023 - 14.12.2023
237 stations



CRPS 01.12.2023 - 14.12.2023
238 stations

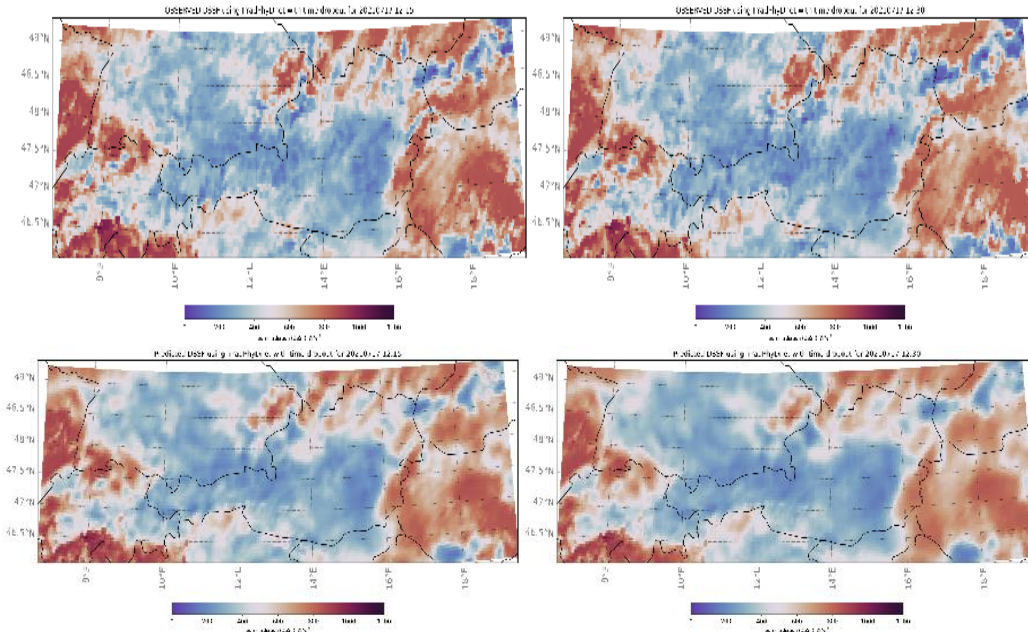


oper_areps SPP_areps

Application of Machine Learning approaches

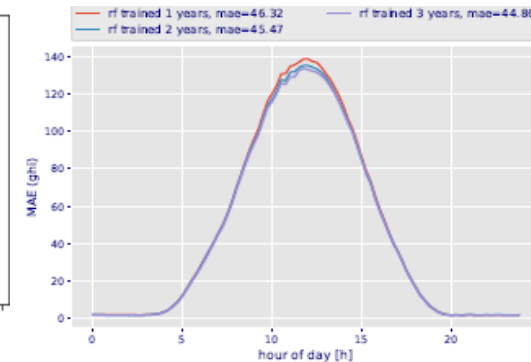
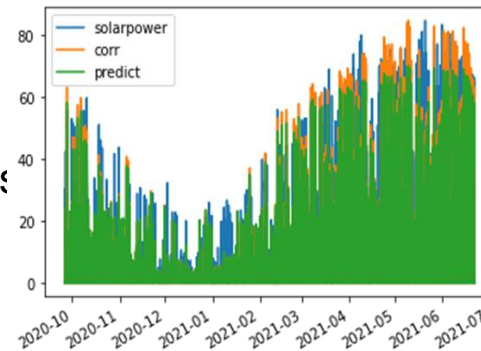
- new spatial data-driven nowcasting approaches developed at GeoSphere Austria based on various machine learning methods (NN, deep FFNN) for solar radiation, wind speed and precipitation
- 4-years training data set for the nowcasting
- the algorithm provides 3 hours forecast based on the past 3 hours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



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.

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

- **Presentations**

- Presentation of LACE EPS activities at ACCORD ASW in Tallinn in April 2023 and EWGLAM in Reykjavik in September 2023
- Presentation of flow dependent SPP at EPS working week in February 2024 in Budapest

- **Publications**

- Bellus, M., A. Simon, 2023: A-LAEF migration to Bologna and extrem weather forecasts, poster at 3rd ACCORD all staff workshop, 27-31 March 2023, https://www.umr-cnrm.fr/accord/IMG/pdf/a-laef_accord_asw_2023.pdf
- Szépszó G., Á. Baran, S. Baran , K. Jávorné Radnóczy , M. Korniyik, D. Tajti , 2023: Operational statistical post-processing of short-range global radiation and low-level wind forecasts (in Hungarian). Légekör 68, 3, 118–125. [DOI: 10.56474/legkor.2023.3.1](https://doi.org/10.56474/legkor.2023.3.1)
- Wastl C., M. Belluš and G. Szépszó, 2023: EPS research and development in RC LACE in 2022, 4th ACCORD Newsletter, <https://www.umr-cnrm.fr/accord/IMG/pdf/accord-nl4.pdf>

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Thank you for your attention.

