Regional Cooperation for
Limited Area Modeling in Central Europe

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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

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- **Operational status**
- **A-LAEF: Upgrade to cy46t1, multiphysics, case studies**
- **ALARO based convection permitting EPS**
- **C-LAEF 1k; Envar, lagged ensemble**
- **SPP & flow dependent SPP**
- **Statistical EPS/machine learning**
- **Outlook and plans**

Operational status

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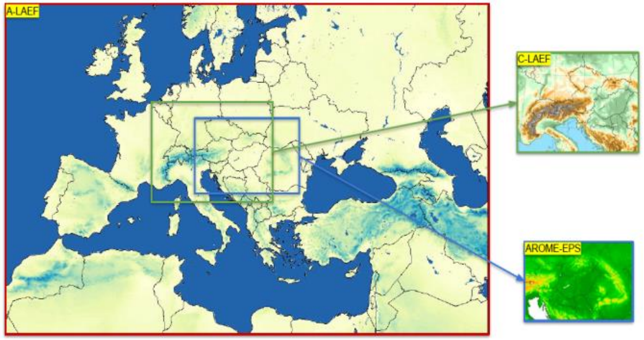
	A-LAEF	C-LAEF	AROME-EPS
CMC	ALARO	AROME	AROME
Code version	cy40t1	cy43t2	cy43t2
Horizontal resolution	4.8 km	2.5 km	2.5 km
Vertical levels	60	90	60
Runs per day	2	8	8
Forecast length	+72h (00/12 UTC)	+60h (00/12 UTC)	+48h (00/12 UTC)
Members	16+1	16+1	10+1
Assimilation cycle	yes (12h)	yes (3h)	yes (3h)
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

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Upgrade of A-LAEF to cy46t1

- Operational A-LAEF is still running on cy40t1
- Setting up a cy46t1 Esuite of A-LAEF on the ECMWF HPC in 2024
- New ALARO-1 multiphysics scheme
- Four different physics clusters based on latest ALARO-1 development
- Combination with SPPT for ISBA surface prognostic fields tested
- EL1 mixing length computation (revised Bougeault-Lacarrère with the inclusion of a shear member) with the PBL height computation based on vertical profile of TKE
- New features (e.g. precipitation type, helicity, etc.)
- New A-LAEF version successfully tested for case studies (downscaling)
- Problems in surface data assimilation, Optimal Interpolation not yet working
- long time verification period outstanding before final operationalization

Upgrade of A-LAEF

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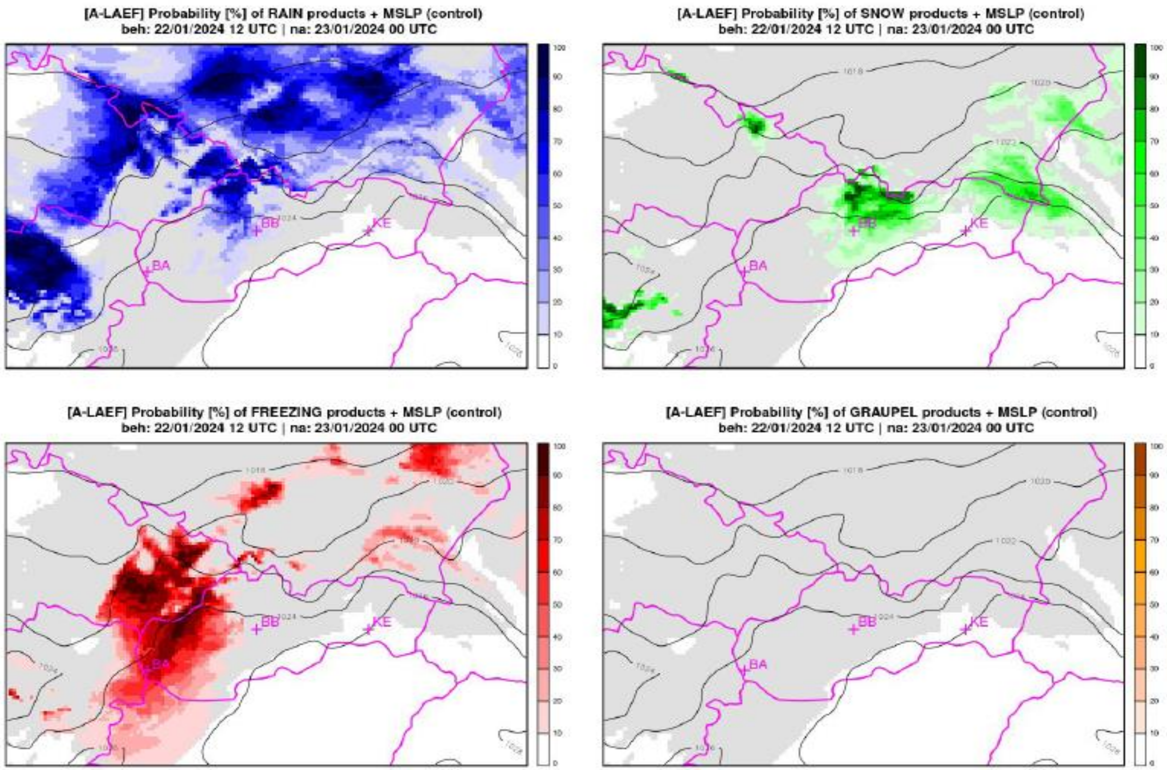
	cluster / member	phys01	phys02	phys03	phys04
		00,01,05,09,13	02,06,10,14	03,07,11,15	04,08,12,16
	namelist parameter	oper	double	oper	double
		EL0		EL1	
limits for hail/graupel classification in precip.type	RDHAIL1	2.8	2.4	2.8	2.4
	RDHAIL2	7.5	6.5	7.5	6.5
mixing length	CGMIXLEN	EL0	EL0	EL1	EL1
BL height based on TKE profile	LPBLH_TKE	F	F		
PBL height limit	XMAXLM	0.	0.	5	
TOUCANS (EL1 tunings)	ETKE_C0SHEAR	0.5	0.5		
	ETKE_DTHETA_S1	-5.0	-5.0		
	ETKE_DTHETA_S2	2.0	2.0		
	ETKE_R2SIM	0.2	0.2		
Lopez evaporation	LEVAPLOP	F	T		
roughness impact of snow via snow height	LZ0SNOWH	F	T		

New A-LAEF physics clusters setup.

	cluster / member	phys01	phys02	phys03	phys04
		00,01,05,09,13	02,06,10,14	03,07,11,15	04,08,12,16
critical RH profile tuning for radiation cloudiness	HUCREDRA	0.42	0.46	0.42	0.46
autoconversion to rain	RAUTEFR	0.5E-03	0.8E-03	0.5E-03	0.8E-03
autoconversion to snow	RAUTEFS	2.E-03	1.E-03	2.E-03	1.E-03
flash diagnostics	RCFLASH1	16.76	22.29	16.76	22.29
variation of exp-random cloud overlap in radiation	RDECRD1	10000.	8000.	10000.	8000.
	RDECRD2	20000.	215000.	20000.	215000.
liquid/ice partition for cloud condensate	RDTFAC	1.00	0.75	1.00	0.75
max. evaporation rate for rain	REVASXR	0.	7.E-07	0.	7.E-07
critical liquid w.c. for liquid cloud w. autoconv.	RQLCR	3.E-04	4.E-04	3.E-04	4.E-04
snow fraction	WCRIN	4.0	10.0	4.0	10.0
ratio of mechanical roughness length to obstacle height	RZ0_TO_HEIGHT	0.13	0.1	0.13	0.1
	FACRAF	10.0	3.6	10.0	3.6
wind diagnostics (TKE vs friction velocity)	LRAFTKE	F	T	F	T
	LRAFTUR	T	F	T	F

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.

ALARO based convection permitting EPS

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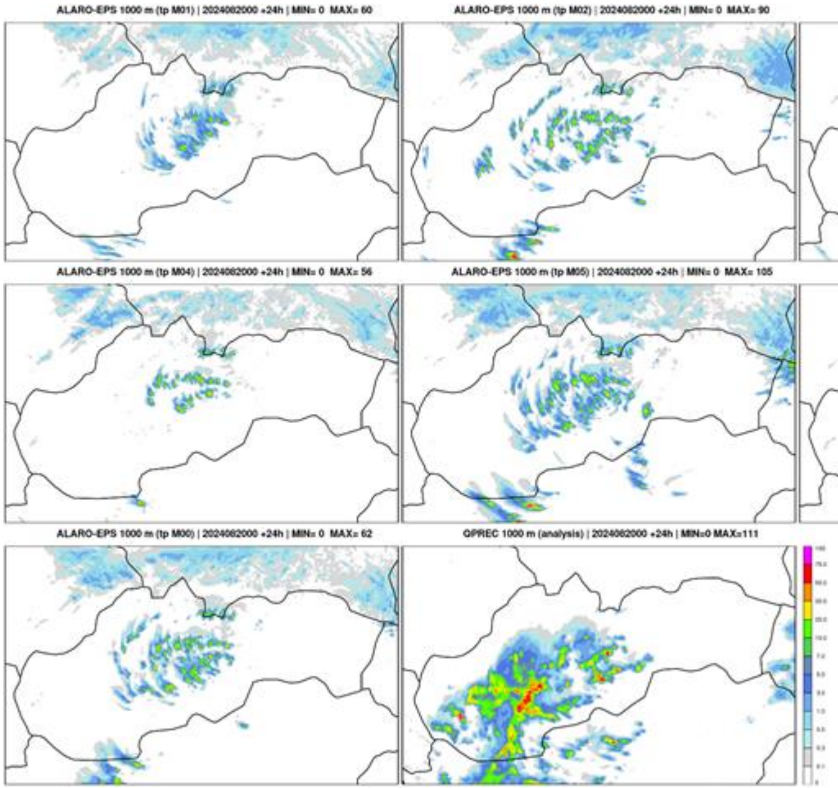
Convective event, August 2024



- ALARO-EPS with 1km spatial resolution, 87 vertical levels on Atos
- Domain covering Slovakia and the surrounding regions
- Coupled in A-LAEF, ALARO multi-physics combined with stochastic physics
- Suite tested for several case studies
- E.g. severe weather situation in August 2024 with intense thunderstorms formed and moved across Slovakia

24h accumulated precipitation for six perturbed ALARO-EPS members, along with one control run, and corresponding QPREC analysis based on Slovak RADAR and WS networks on August 20, 2024.

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C-LAEF 1k

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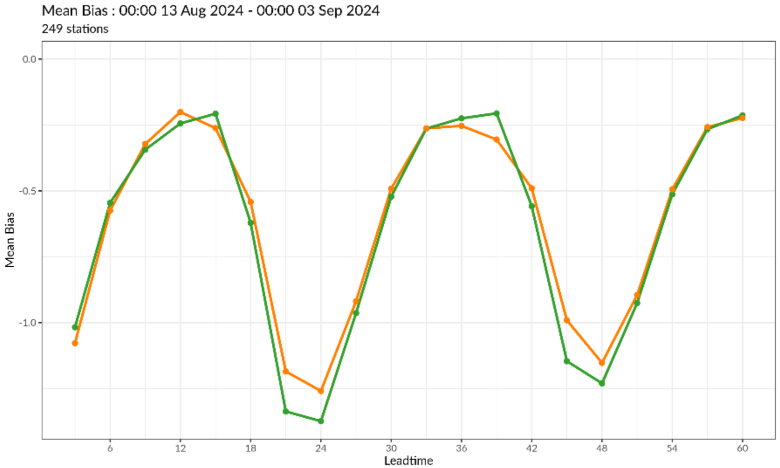
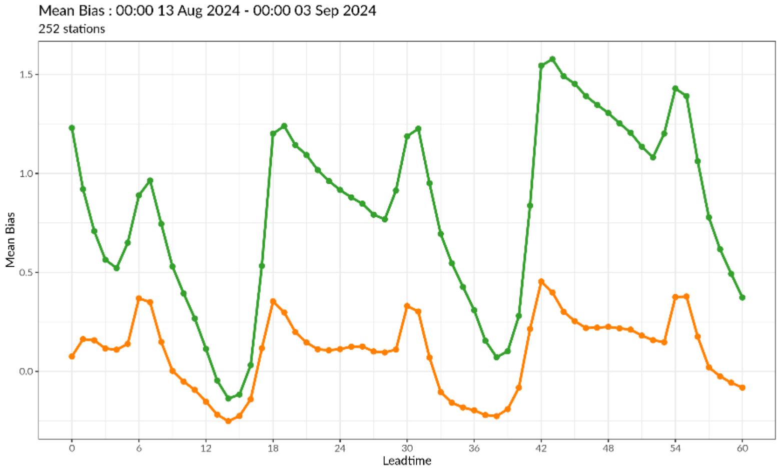
Upgrade of C-LAEF to 1km

- Co-operation between Austria, Croatia & Slovenia to develop a common EPS on 1km
- Full C-LAEF 1k suite running for a winter (Dec-Feb 2024) and summer (June-August 2024) period
- Cy46t1, I/O server, long 00 UTC run (+60), 4 long ctrl runs, 3h assimilation cycle, single precision
- New observations (GNSS, ceilometer, radar data, etc.)
- SPP perturbations, switch off canopy scheme, adaptation of dynamics setup (SLHD, COMAD)
- Additional control member using EnVar, all members switched from spectral to grid point
- New EnVar setup (cy48t3) uses in total 32 member as input, 16 members from the previous forecast and 16 members from the run before
- A lot of testing/tuning in 2024
- Provision of data and products to forecasters, grb files for Croatia and Slovenia

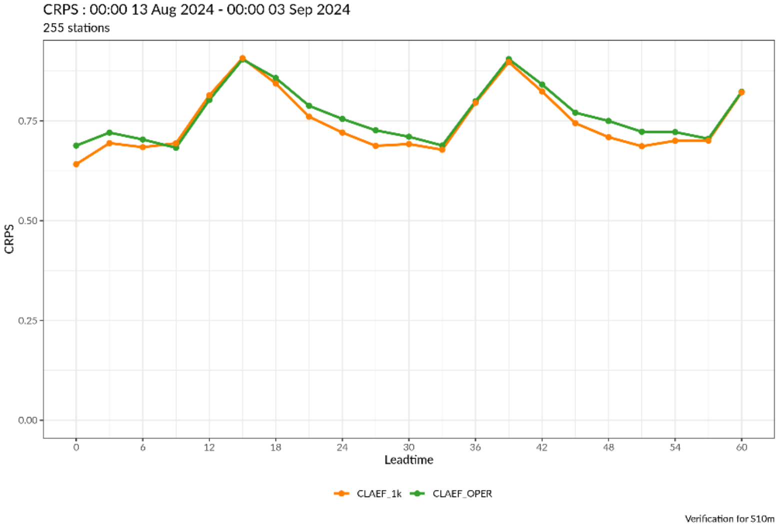
C-LAEF 1k

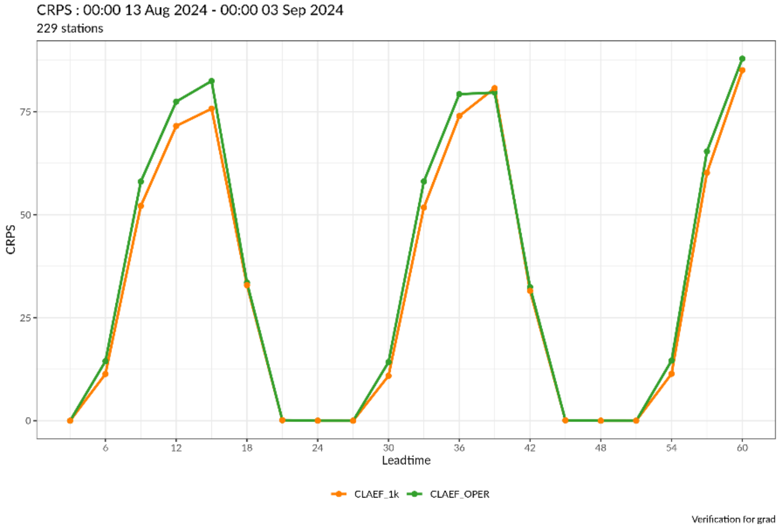
Mean Bias of 3h accumulated precipitation (left) and 2m temperature (right) for C-LAEF 1k (orange) and C-LAEF oper (green) for a test period in summer 2024.





CRPS of 10m wind speed (left) and global radiation (right)





C-LAEF 1k

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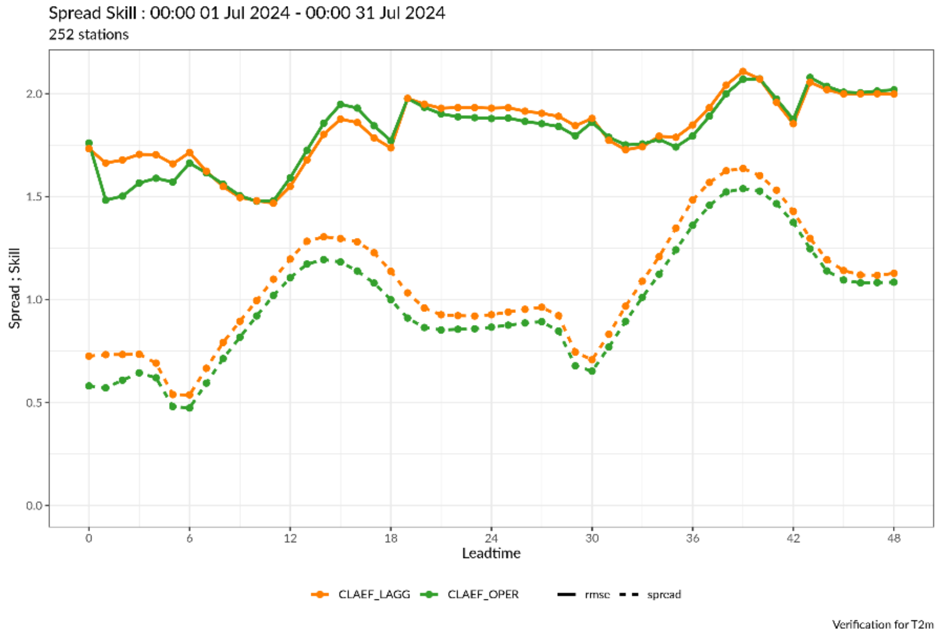
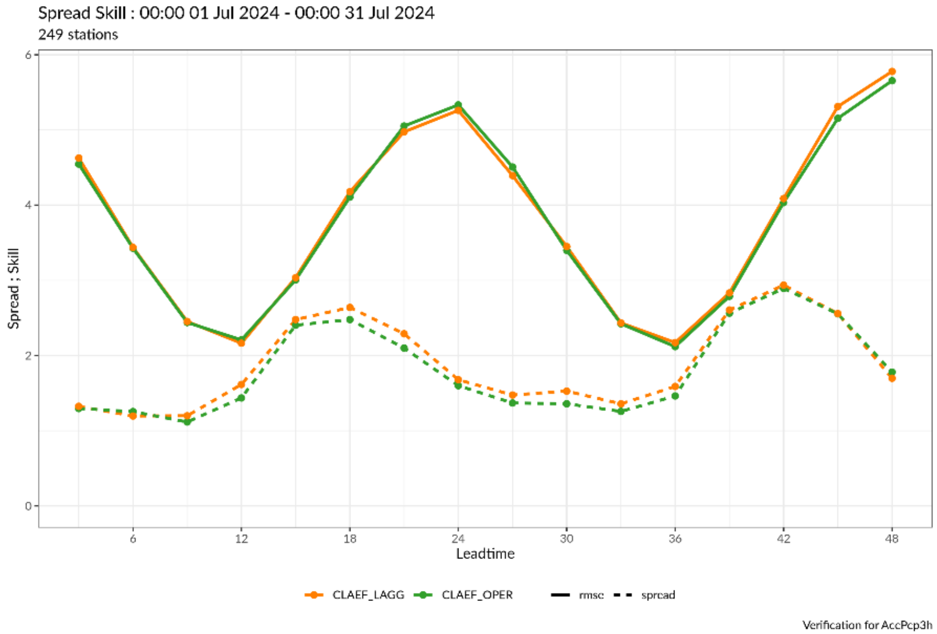
Continuous lagged ensemble

- To expand the C-LAEF 1k system in the future (more runs, longer leadtimes, more members) a lagged ensemble approach has been tested
- In this mode 4 members (alternating) + 1 control run of C-LAEF1k are running every 3h with an extended forecasting range of +69h, the rest of the members is kept short with +3h lead time
- Combining the members of the 4 most recent runs (the oldest members are 9h old), a lagged ensemble with 16 +1 members can be created every 3h
- Lagged ensemble (based on cy43t2 and 2.5km) has been running for a winter (February 2024) and summer (July 2024) period and verified with HARP
- For almost all parameters the scores of the lagged ensemble are equal or even better than for the classical ensemble (increase of spread), only for T2m at the beginning worse, no clustering

C-LAEF 1k

Continuous lagged ensemble





Ensemble spread (dashed) and RMSE (full) of 2m temperature (left) and 3h accumulated precipitation (right) for C-LAEF lagged (orange) and C-LAEF operational (green) for a test period in July 2024.

CLAEF 1k: Flow dependent SPP

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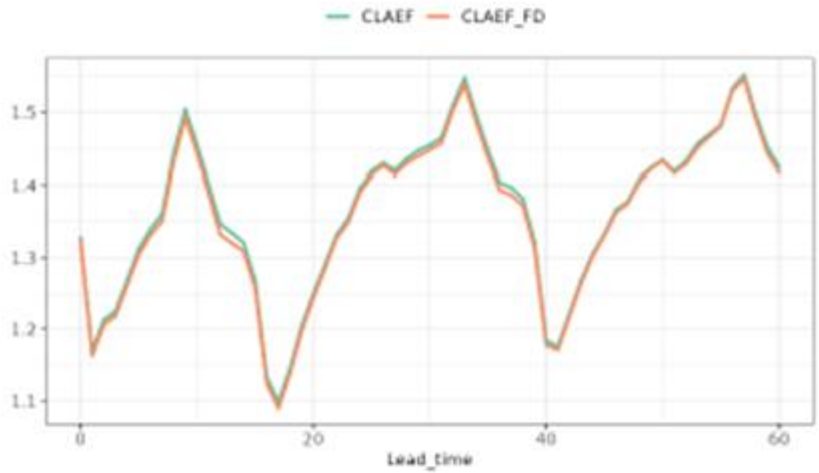
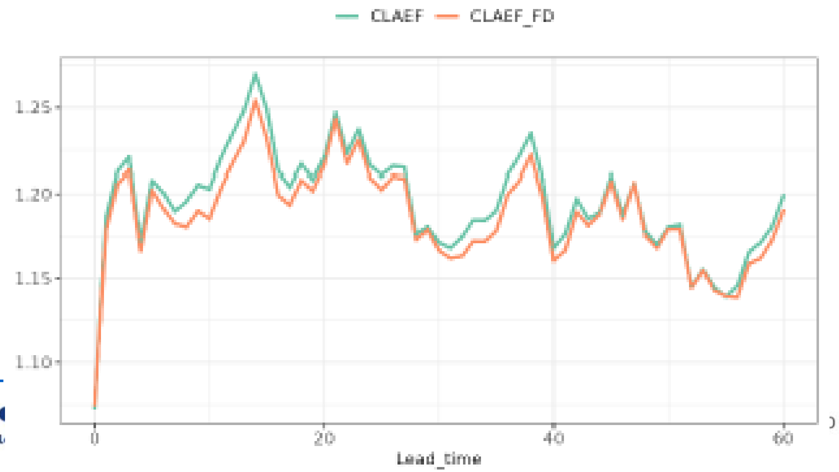
Development of flow-dependent parameter perturbations in C-LAEF

- 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 amplifies perturbations in areas where most impact can be expected
- Pattern generator is not changed, but the existing pattern is modified by some weights
- Identification of interesting areas - for each parameter a particular model variable is used: cloud fraction for microphysics and radiation; TKE for turbulence and shallow convection; 10m wind speed for SURFEX
- Stays of Endi Keresturi (2022, 2023, 2024)
- Flow dependent SPP for all 12 parameters perturbed (6 parametrization schemes) in C-LAEF 1k
- Tested for case studies, long term verification for winter (February 2024) and summer (June 2024)

CLAEF 1k: Flow dependent SPP

- Results in winter are generally positive - ensemble spread is slightly increased for all variables/lead times, impact on RMSE is slightly positive, CRPS improved
- Results for June are unexpectedly more neutral, almost no increase in spread, RMSE is decreased for wind and is neutral for other variables
- SPP not properly tuned for convective season (small impact of SPP in summer compared to winter)





CRPS for CLAEF_oper (green) and CLAEF_FD (orange) for February 2024 averaged over Austrian stations for 2m temperature (upper) and 10m wind speed (lower).

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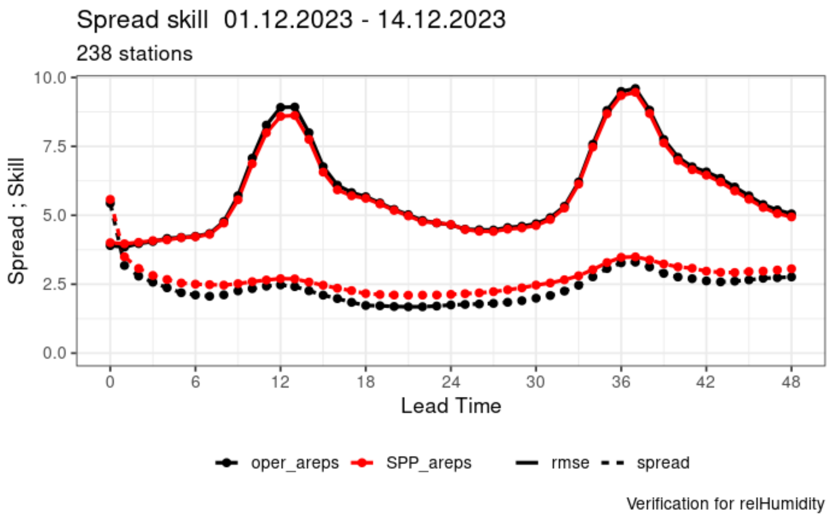
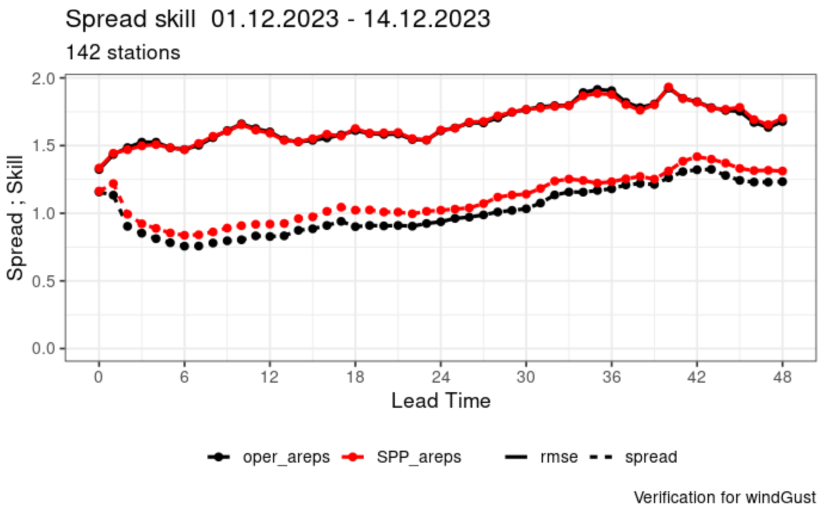
AROME-EPS

SPP in AROME-EPS

- HungaroMet started in 2023 to work on SPP
- First version implemented end of 2023
- A lot of tuning in 2024 (temporal length scale, SPP in EDA)
- test periods: 2 weeks in July and December 2023
- Increase of spread, small impact on RMSE
- Case study showed better localization and better estimation of intensities in AROME-EPS with SPP compared to oper setup
- Next step is to phase it to cy46t1
- Operationalization in 2025



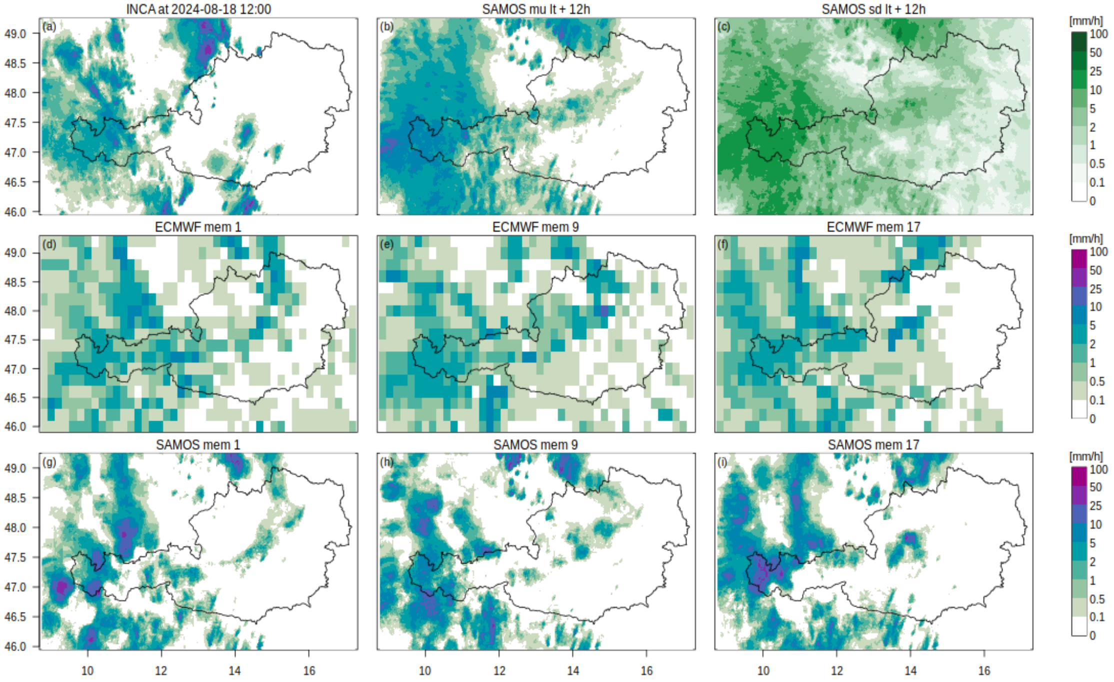


Ensemble spread and RMSE for 2m relative humidity (upper) and 10m wind gusts (lower); 01-14.12.2023 00UTC.

Statistical EPS

SAMOS - Standardized Anomaly Model Output Statistics

- SAMOS is running operationally at GeoSphere
- SAMOS is providing seamless spatial forecasts (mean and SDEV) from analysis to long-range
- Lacking the characteristic members (consistent in space and time) of an EPS
- Reconstructing of ensemble members from NWP in SAMOS (Ensemble Copula Coupling)
- 16 members of ECMWF-ENS are used
- SAMOS members are able to show individual cells of heavy precipitation

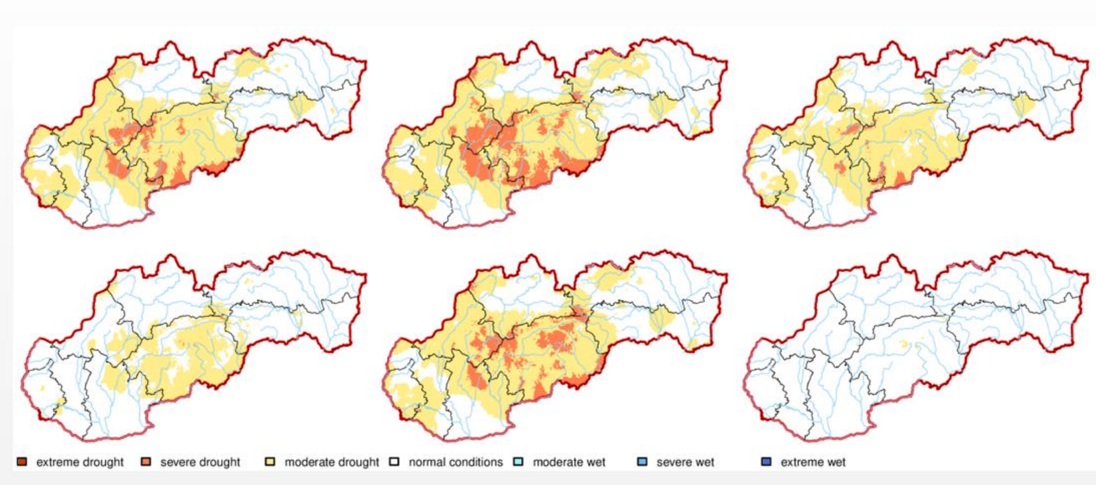


Observed global radiation (up) and radiation output of a pure machine learning model (bottom) for a test case in 2023

Statistical EPS

Probabilistic SPEI

- Drought research and monitoring has become an important topic in the recent years - frequent occurrence and strong intensity of droughts
- Standardized Precipitation and Evapotranspiration Index (SPEI) is used for evaluation of drought
- SPEI index is designed to account for both precipitation and potential evapotranspiration (PET)
- Floating window with accumulation period of 30 days
- Given the significant uncertainty inherent in precipitation forecasts, SPEI is calculated in a probabilistic manner



An example of SPEI forecast uncertainty (from left to right: mean, 10 and 90 percentiles) 3 days ahead based on A-LAEF EPS (top) and 7 days ahead based on ECMWF ENS (bottom). EPS inputs are from 2024-08-15 00 UTC.

Statistical EPS

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Application of Machine Learning approaches

- A lot of work is ongoing in LACE in the area of machine learning
- Strong increase of very localized PV generation and hydropower plants; necessitate very localized and accurate predictions of expected generation to better schedule network and power production
- Uncertainty of the forecasts needs to be accounted for - using EPSs as input
- To generate very localized predictions with AI methods (random forest, LSTM) metadata + historical observations + historical forecasts (reanalysis) + historic production data are needed
- Since not enough historic production data are available, synthetic data is generated with ML method
- For PV prediction forecasts additional satellite nowcasts can improve the performance significantly
- Model provides 3 hours forecast based on the past 3 hours (6h forecasts tested)
- Running operationally and provides forcasts every 15 min

Statistical EPS

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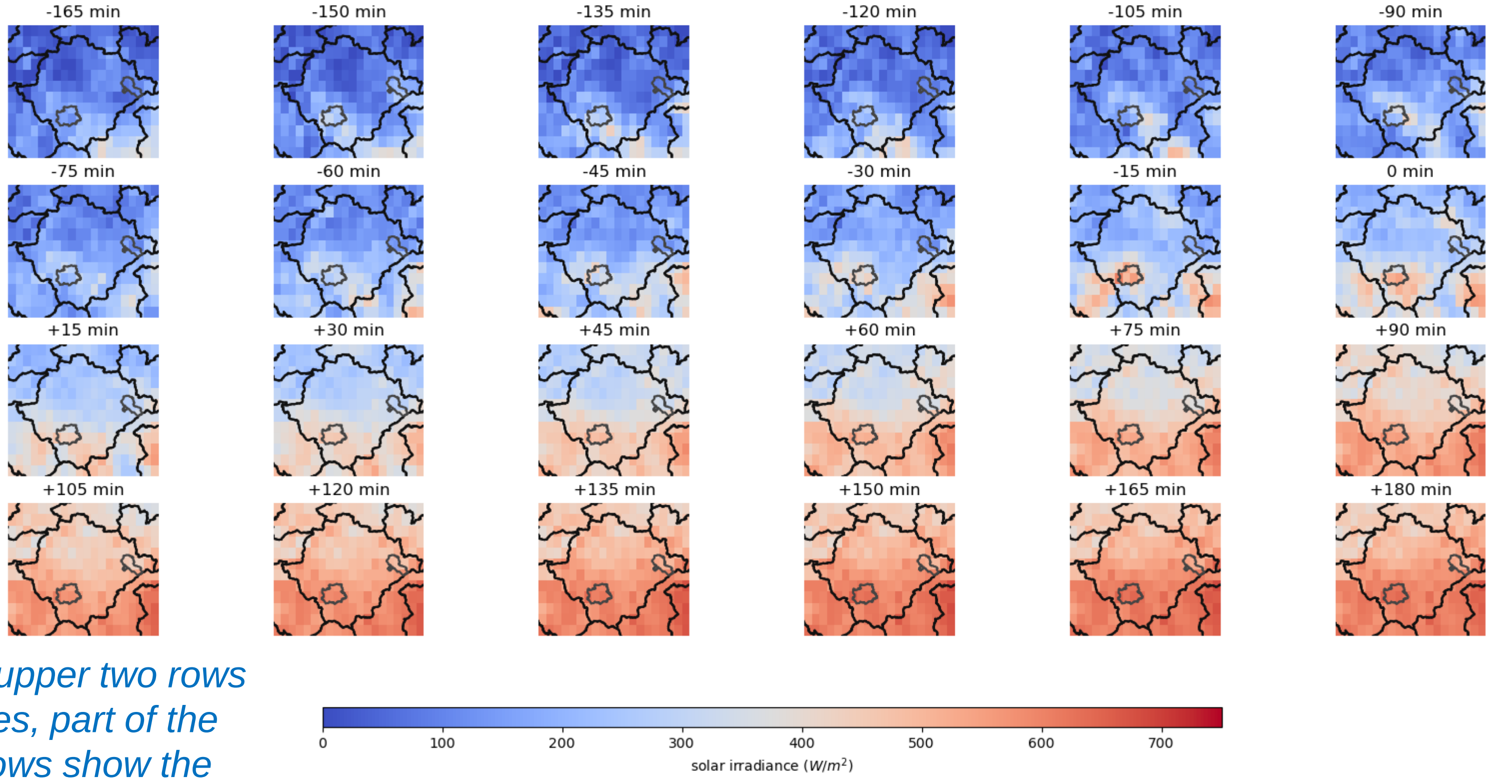

Forecast from 9:00 26.04.2023, upper two rows show ground truth satellite images, part of the input to the model, bottom two rows show the forecasted solar irradiance frames for the following three hours.

Outlook & Plans

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Operational plans

A-LAEF: - Upgrade to cy46t1 end of 2024

- 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: - Upgrade to cy46t1 (2025)

- operationalization of SPP in AROME EPS (2025)

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