Regional Cooperation for
Limited Area Modelling in Central Europe

LACE
nwp central europe

LAM-EPS activities in RC LACE

Clemens Wastl with contributions of RC LACE partners

DHMZ SHMU ARSO METEO Slovenia OMSZ IMGW ZAMG ROMANIA ANM

Operational EPSs

3 independent LAM EPSs operationally running within RC-LACE

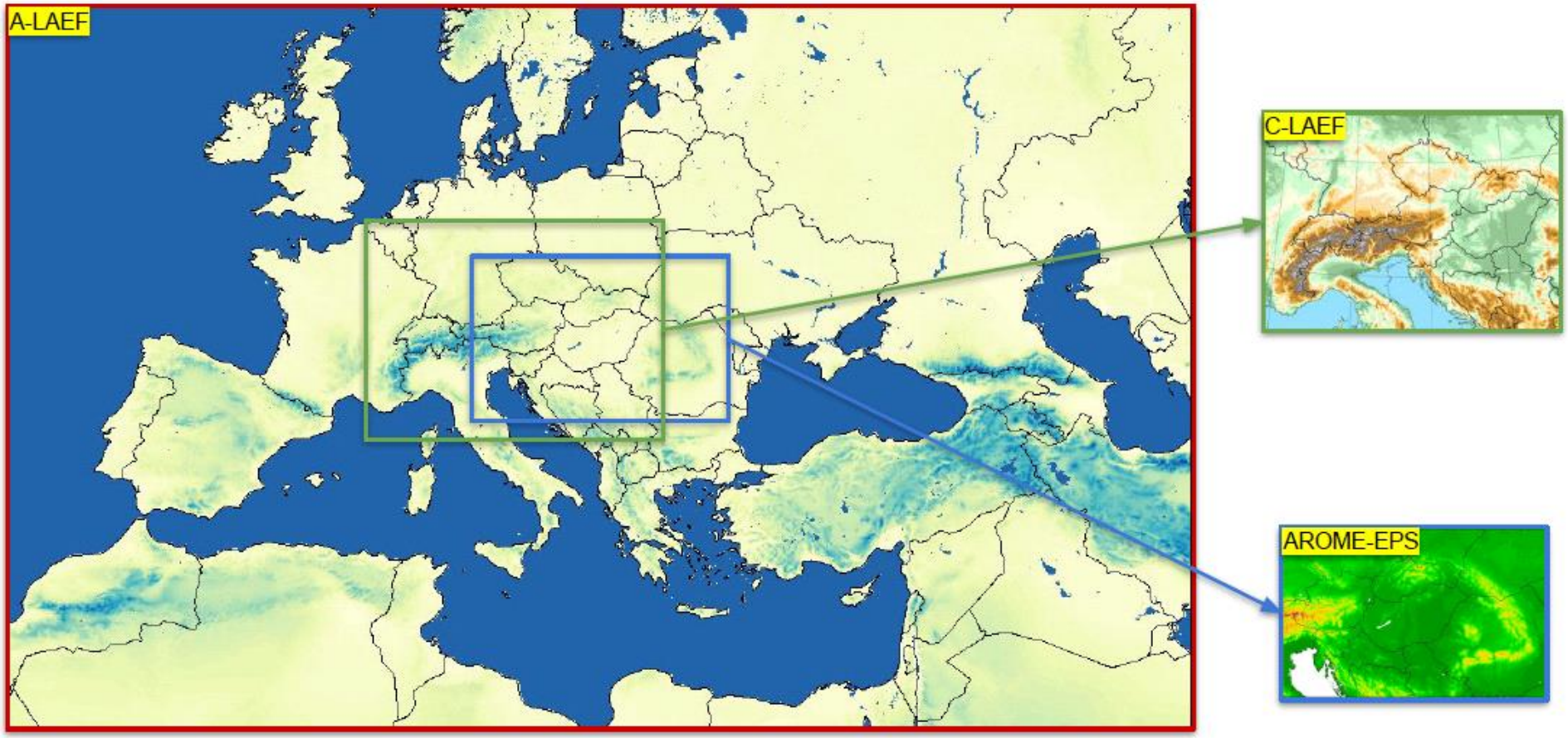
- **A-LAEF**
  Common RC-LACE EPS with 4.8 km horizontal resolution based on ALARO-1 physics.
- **C-LAEF**
  Convection-permitting EPS of Austria with 2.5 km horizontal resolution based on AROME physics.

ECMWF HPC

- **AROME-EPS**
  Convection-permitting EPS of Hungary with 2.5 km horiziontal resolution based on AROME physics.

Local HPC

Operational ensembles



Operational ensembles

	A-LAEF	C-LAEF	AROME-EPS
CMC	ALARO	AROME	AROME
Code version	cy40t1	cy40t1	cy43t2
Horizontal resolution	4.8 km	2.5 km	2.5 km
Vertical levels	60	90	60
Runs per day	2	4	1
Forecast length	+72h (00/12 UTC)	+60h (00 UTC), +48h (12 UTC), +6h (06/18 UTC)	+48h (00 UTC)
Members	16+1	16+1	10+1
Assimilation cycle	yes (12h)	yes (6h)	-
Coupling	ECMWF ENS (6h; c903)	ECMWF ENS (3h; c903)	ECMWF ENS (1h; c903)
IC perturbation	ESDA [surface], spectral blending by DFI [upper-air]	ESDA [surface], EDA, Ensemble-JK [upper-air]	downscaling
Model perturbation	ALARO-1 multi-physics + surface stochastic physics (SPPT)	hybrid stochastic scheme with a combination of parameter and tendency perturbations	-
LBC perturbation	ECMWF ENS	ECMWF ENS	ECMWF ENS

A-LAEF (LACE)

A-LAEF work in 2021:

- **Operational activities**
  - added Mediterranean Sea domain (MSEA) for ocean models coupling - NEMO, SHYFEM
  - Upgrade of ECMWF-ENS coupling files to cy47r2 (L91 => L137 for ENS) in May 2021
  - OBS backup implemented (using GTS data generated at SHMU and uploaded to OPLACE)
  - A-LAEF GRIBs dissemination optimization, scripts for archiving to ECFS, CZ/TR fullpos optimization

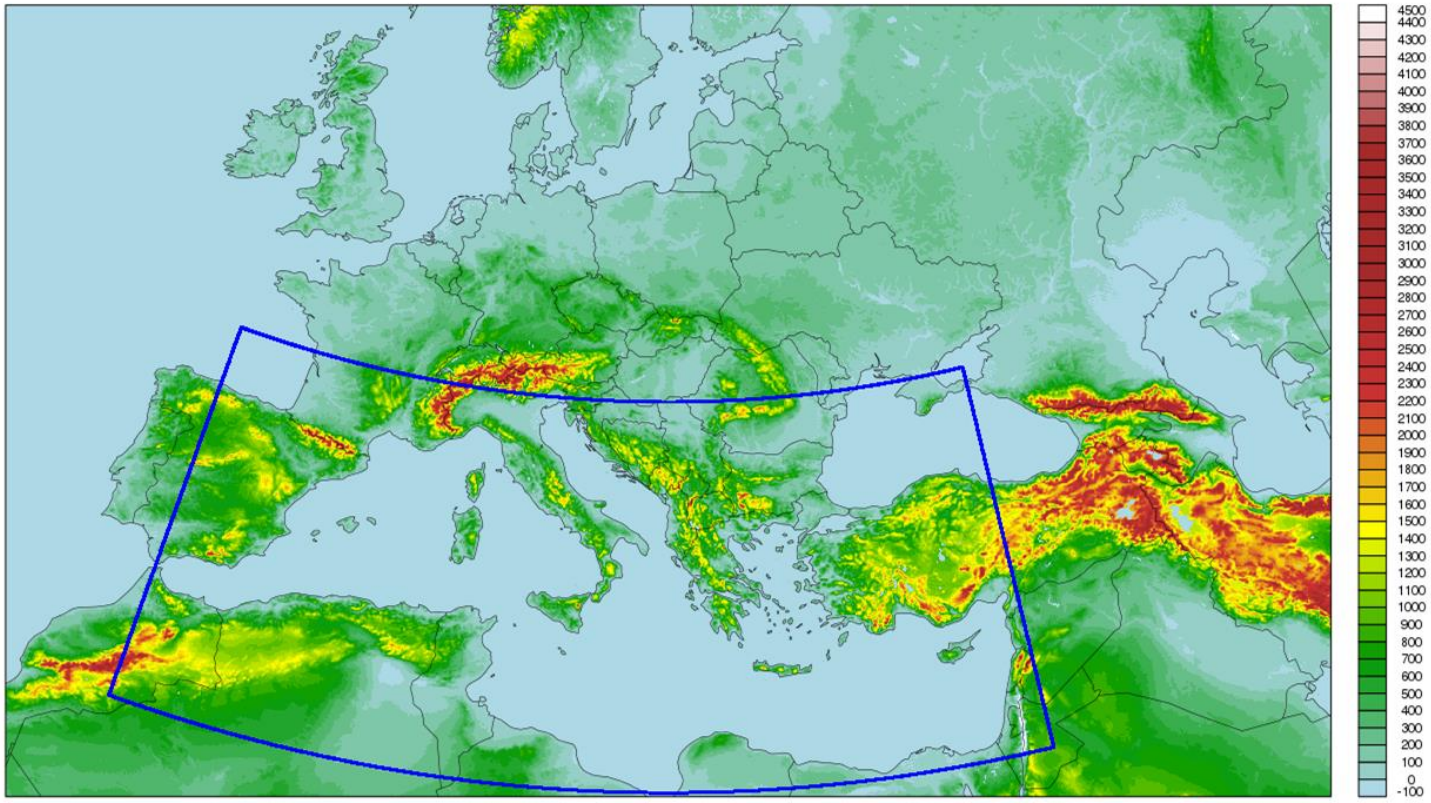
- **Research & Development**
  - precipitation phase calculation from EPS data
  - implementation and testing of incremental DFI step in spectral blending procedure
  - update of technical documentation of A-LAEF TC2 suite
  - upgrade of obsoul_merge tool (v07) - added whitelisting, zipped files support, strict formatting mandatory since cy46
  - development of A-LAEF EPSgrams for RC LACE webpage using Perl/R
  - good performance of A-LAEF for severe weather situations (floodings in Germany and Austria)

A-LAEF (LACE)

New MSEA domain for ocean models coupling (oper. since 18/04/2021):

available fields (for all 17 members):

SURFTEMPERATURE
SURFPREC.EAU.CON
SURFPREC.NEI.CON
SURFPREC.EAU.GEC
SURFPREC.NEI.GEC
SURFFLU.RAY.SOLA
SURFFLU.RAY.THER
SURFRAYT THER DE
SURFRAYT SOLA DE
SURFFLU.LAT.MSUB
SURFFLU.CHA.SENS
SURFFLU.MSUBL.NE
CLSTEMPERATURE
SURFNEBUL.TOTALE
CLSVENT.ZONAL
CLSVENT.MERIDIEN
CLSU.RAF.MOD.XFU
CLSV.RAF.MOD.XFU
CLSHUMI.SPECIFIQ
MSLPRESSURE

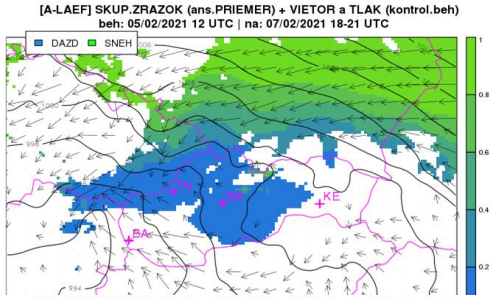


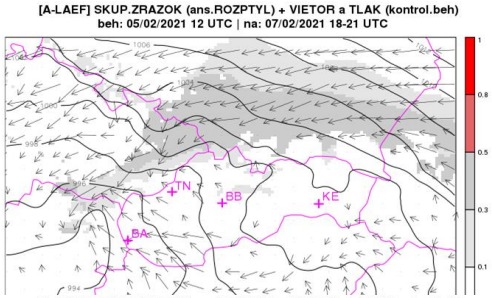
MSEA fullpos domain within A-LAEF integration domain.

A-LAEF (LACE)

Precipitation phase calculation:

a)





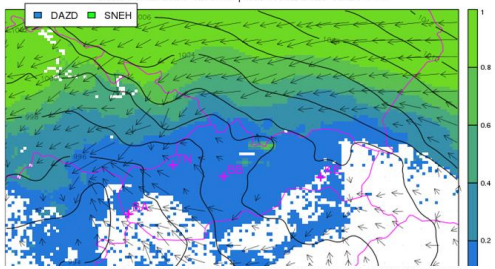
mean snow spread

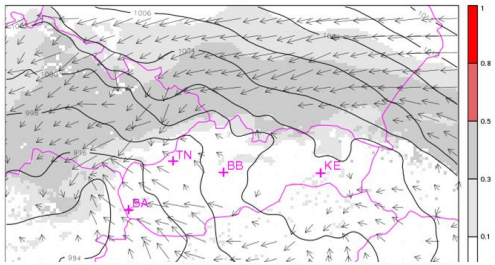
$$M = \frac{1}{n}\sum_{i=1}^{n}\frac{SN_i}{TP_i} \qquad S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{SN_i}{TP_i} - \frac{1}{n}\sum_{i=1}^{n}\frac{SN_i}{TP_i}\right)^2}$$

$$TP_i < 0.1 \rightarrow M = 0, S = 0$$

total prec.

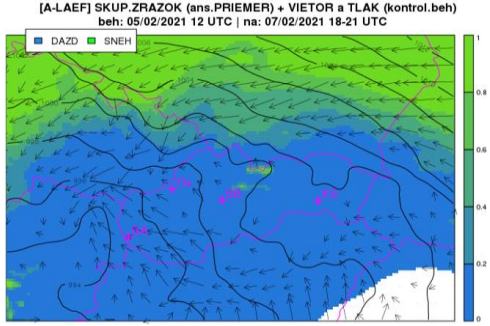
b)

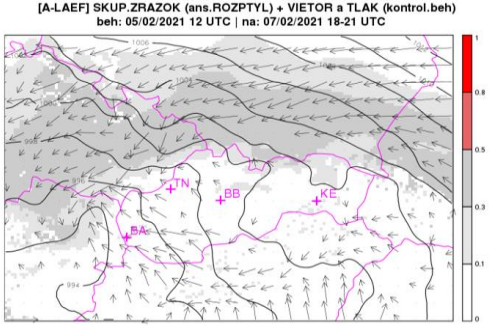




$$M = \frac{1}{n}\sum_{i=1}^{n}\frac{SN_i}{TP_i} \qquad S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{SN_i}{TP_i} - \frac{1}{n}\sum_{i=1}^{n}\frac{SN_i}{TP_i}\right)^2}$$

c)





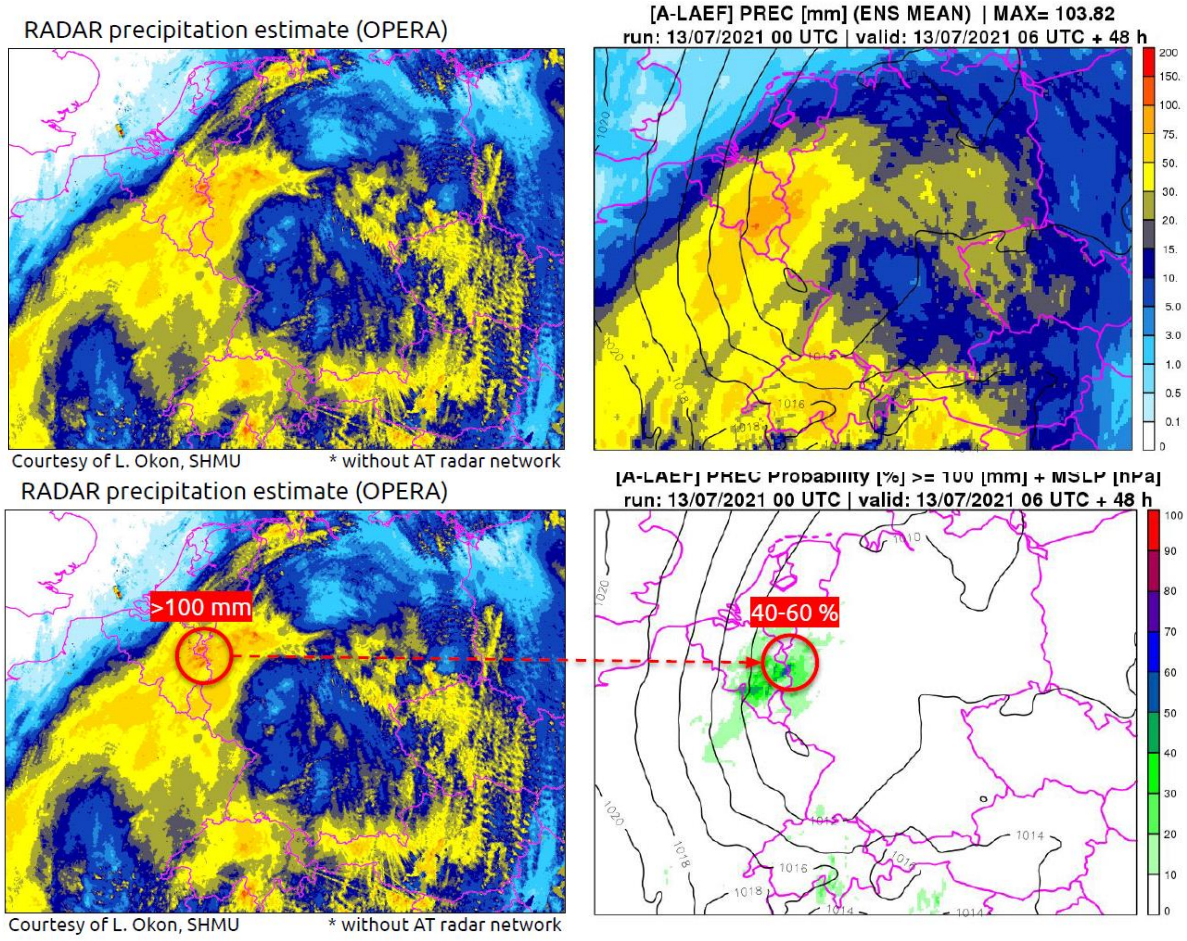
$$M = \frac{\frac{1}{n}\sum_{i=1}^{n} SN_i}{\frac{1}{n}\sum_{i=1}^{n} TP_i} \qquad S = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{SN_i}{TP_i} - \frac{1}{n}\sum_{i=1}^{n}\frac{SN_i}{TP_i}\right)^2}$$

$$\frac{1}{n}\sum_{i=1}^{n} TP_i < 0.1 \rightarrow M = 0$$

A-LAEF (LACE)

A-LAEF performance at severe weather events:

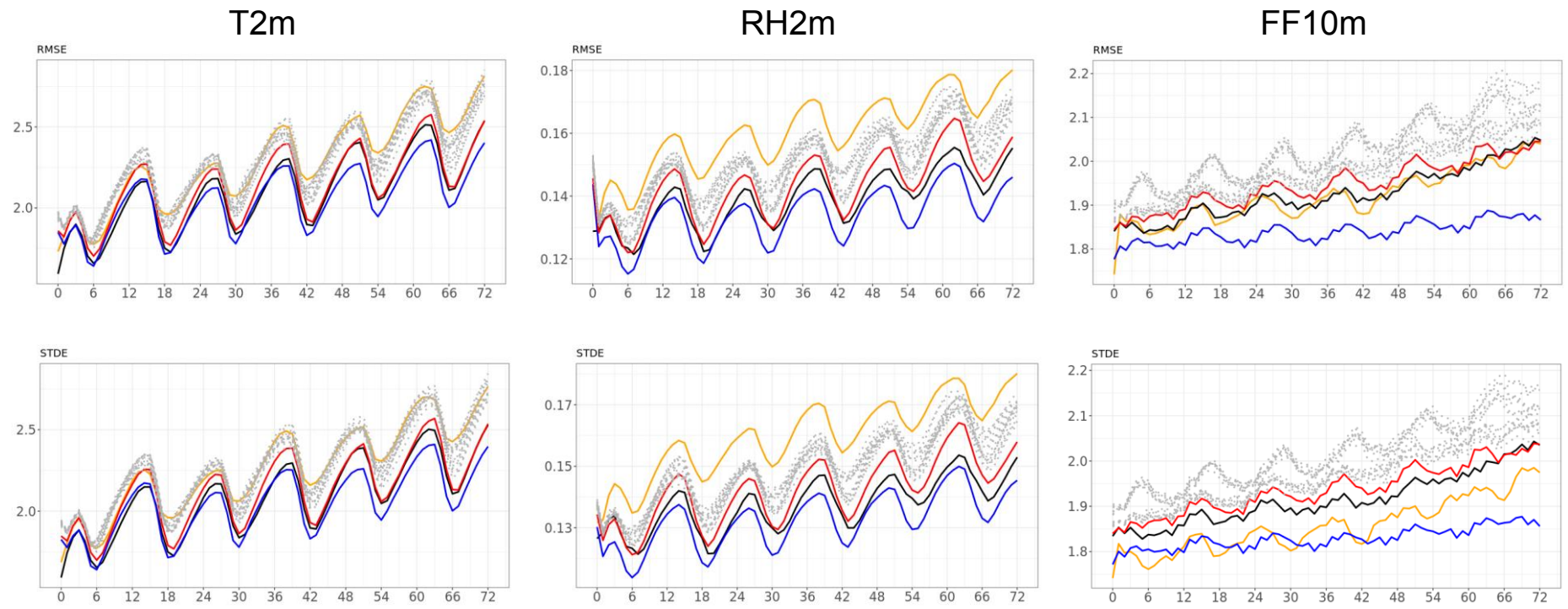
- Extreme flooding event in Germany in July 2021 (13-15)
- More than 160 people lost their lives
- A-LAEF ensemble successfully captured the precipitation event
- well localized patterns (even with unusually high probabilities of extreme precipitation amounts) –



48h accumulated precipitation (13/07 – 15/07/2021 06 UTC) from RADAR composite (left) and A-LAEF ensemble mean forecast (upper right) and probability of exceeding 100mm (lower right).

A-LAEF (LACE)

Long term verification with HARP:



ALADIN/SHMU | ALARO NH | A-LAEF (CTRL) | A-LAEF (MEAN) | A-LAEF (MEMs)

Verification period 01/01/2021 - 31/07/2021 (00 and 12 UTC runs included) - SK stations. ALARO NH is dynamical downscaling (2 km) of ARPEGE.

AROME-EPS (Hungary)

Overview on AROME-EPS activities in 2021:

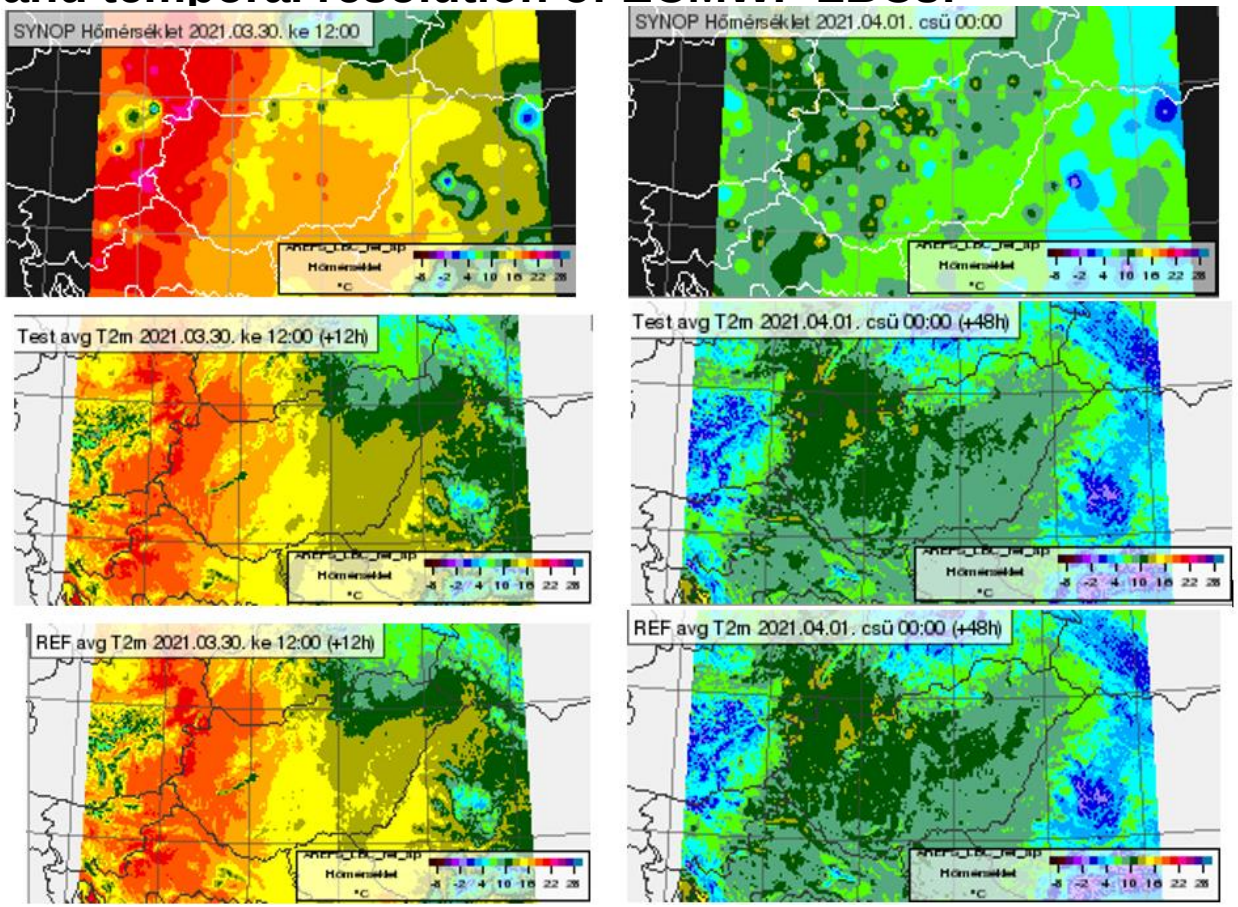
- **Operational activities**
  - Upgrade of operational AROME-EPS to cy43t2 in April 2021
  - Upgrade of ECMWF-ENS coupling files to cy47r2 (L91 => L137 for ENS) in May 2021
  - Upgrade of coupling frequency in AROME-EPS from 3h to 1h in May 2021

- **Research & Development**
  - Testing of impact of higher coupling frequency (1h vs. 3h) for 3 selected case studies
  - Testing of impact of new EMCWF-ENS coupling files for 3 selected case studies
  - Comparison of AROME-EPS and ECMWF-ENS for a convective test case

AROME-EPS (Hungary)

Testing of higher vertical and temporal resolution of ECMWF LBCs:

- upgrade of ECMWF-ENS coupling files to cy47r2 (L91 => L137) in May 2021
- ECMWF provided test data for the period March-May 2021
- testing of impact of this upgrade on the AROME-EPS performance for 3 selected case studies
- significant differences in the wind forecasts for one test case at the top of the model
- differences gradually disappear from the 3rd model level downwards
- general slight positive impact of the higher vertical resolution of LBCs is visible only in the forecasts longer than 24h

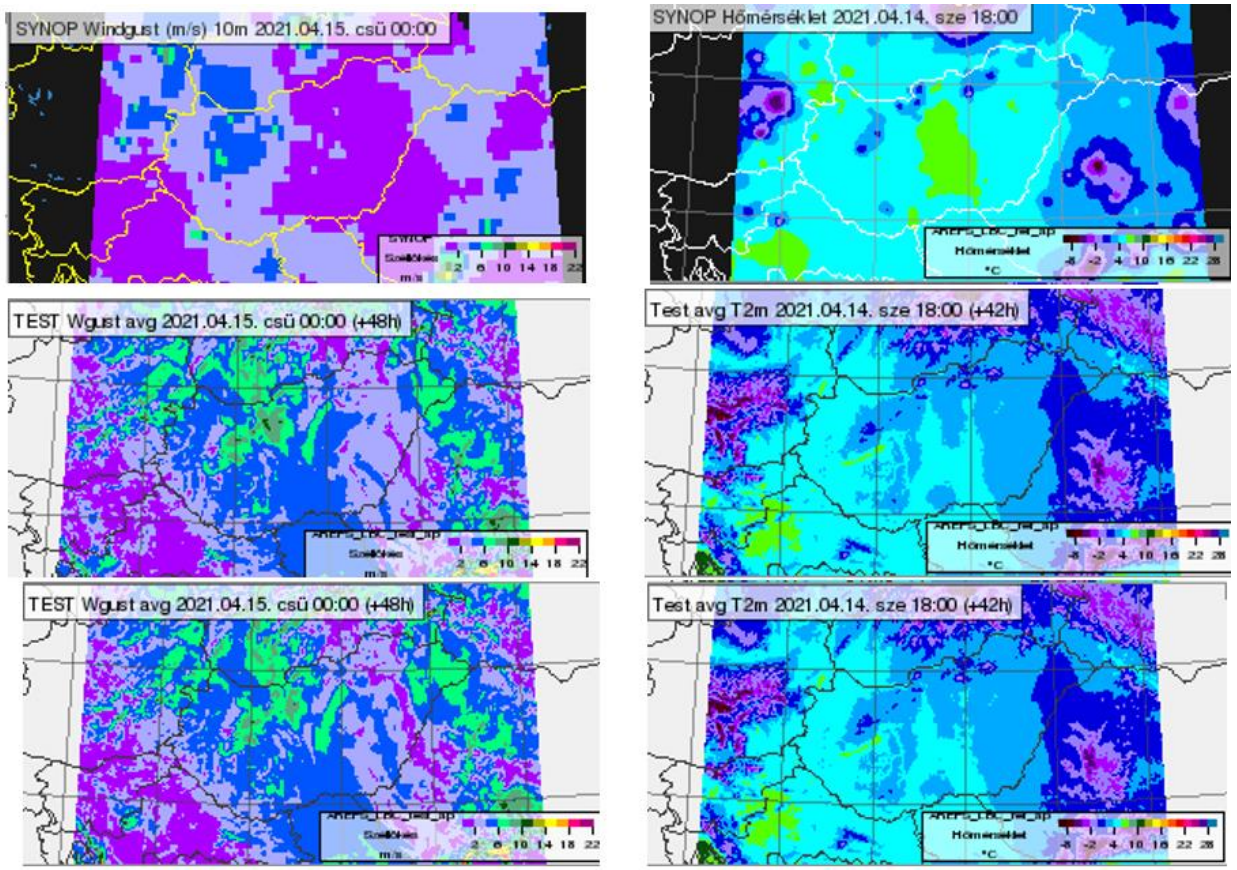


T2m at 12 UTC on 30 March 2021 (left) and at 00 UTC on 1 April 2021 (right) based on SYNOP measurements (top), ensemble mean of 3h coupled (L137, middle) and operational (L90, bottom) AROME EPS forecasts started at 00 UTC on 30 March 2021.

AROME-EPS (Hungary)

Testing of higher vertical and temporal resolution of ECMWF LBCs:

- upgrade of coupling frequency of operational AROME-EPS suite from 3h to 1h in May 2021
- significant differences were not noticed
- 1h coupling shows a slight improvement

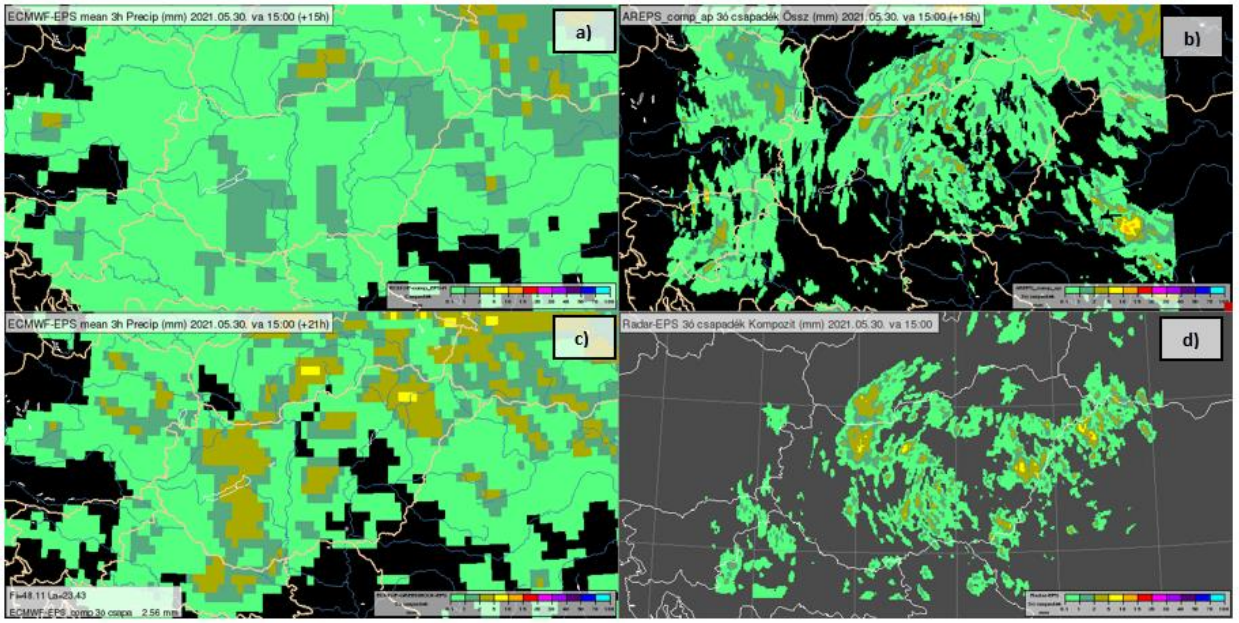


Wind gusts at 00 UTC on 15 April 2021 (left) and T2m at 18 UTC on 14 April 2021 (right) based on SYNOP measurements (top), ensemble mean of AROME EPS forecasts started at 00 UTC on 13 April 2021 with 1h (middle) and 3h (bottom) coupled LBCs.

AROME-EPS (Hungary)

Comparison of AROME-EPS and ECMWF-ENS:

- investigation of differences between AROME-EPS and ECMWF-ENS for a convective test day in May 2021
- 3 sets of ensembles are evaluated:
  a) 51 member ECMWF-ENS
  b) 11 member AROME EPS
  c) 11 member ECMWF-ENS
- spatial structure and the amount of small-scale precipitation are well captured by AROME-EPS
- in ECMWF-ENS the rain is more spread over the country
- the 11 member ECMWF-ENS overestimates precipitation amount
- also for 2m temperature and 10m wind speed AROME-EPS shows better structures



Ensemble mean of 3h precipitation forecasts on a) 30/05/2021 00 UTC + 15h by 51 member ECMWF ENS, b) 30/05/2021 00 UTC + 15h by 11 member AROME-EPS, c) 29/05/2021 18 UTC + 21h by 11 member ECMWF ENS, and d) Hungarian radar data.

C-LAEF (Austria)

Overview on C-LAEF activities in 2021:

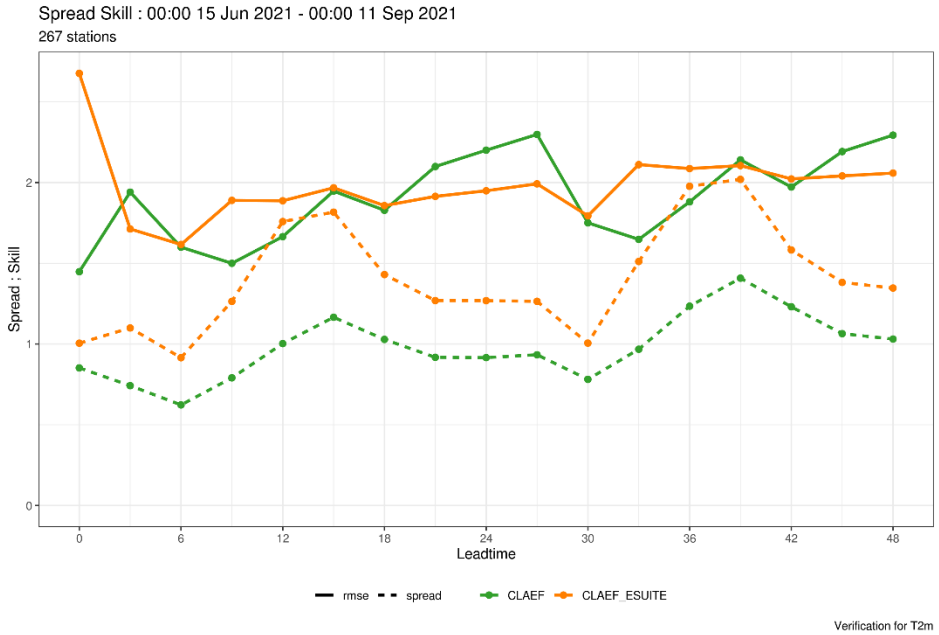
- **Operational activities**
  - Coupling file production by ECMWF with 903 configuration for a common domain (Hungary + Austria)
  - Upscaled probabilities production with C-LAEF
  - Operational production of EPS maps and EPSgrams (new summer version) with Visual Weather
  - Operational provision of C-LAEF data for ESSL (European Severe Storm Laboratory) for summer period 2021 (May – September)

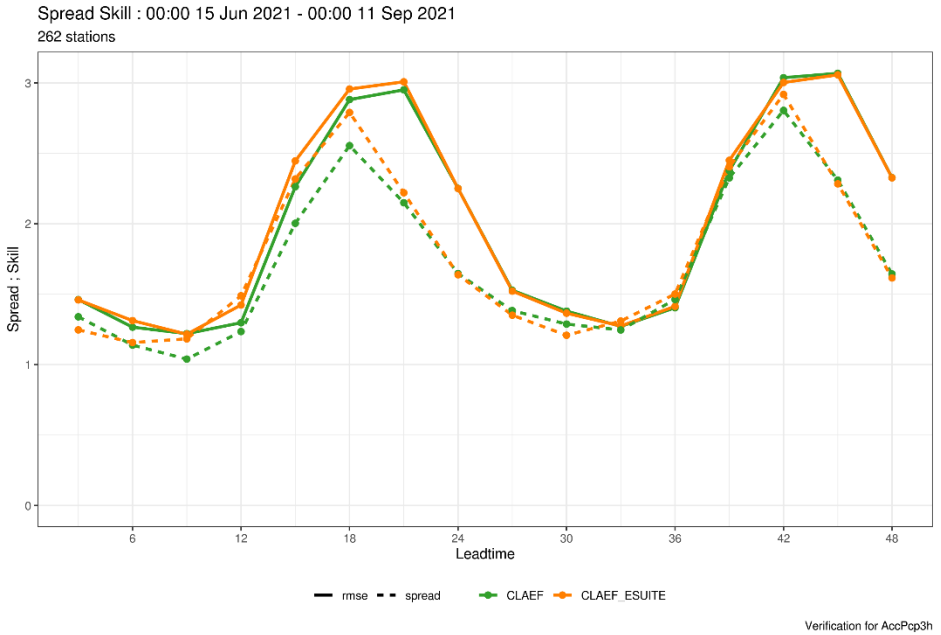
- **Research & Development**
  - full cy43t2 e-suite of C-LAEF during summer period (Jun-Sep) at the ECMWF HPCF including continuous HARP verification
  - investigation and verification of C-LAEF performance for severe weather events
  - implementation of new surface perturbation scheme in C-LAEF e-suite
  - extension of C-LAEF SPP scheme by additional perturbations in physics parametrizations; implementation of SPG pattern generator
  - preparation and provision of C-LAEF data for the SRNWP EPS project (summer 2020 period)
  - Set-up of C-LAEF for Turkish domain – support, scripts, input files, etc.

C-LAEF (Austria)

Verification of C-LAEF cy43t2 e-suite:

- full cy43t2 e-suite of C-LAEF during summer period (Jun-Sep) at the ECMWF HPCF
- 16 + 1 members, 4 runs per day (1 long), 6h assimilation cycle, same resolution, same perturbation scheme as in C-LAEF oper
- cy43t2 additionally contains a surface perturbation scheme
- implementation of continuous HARP verification for C-LAEF and C-LAEF e-suite



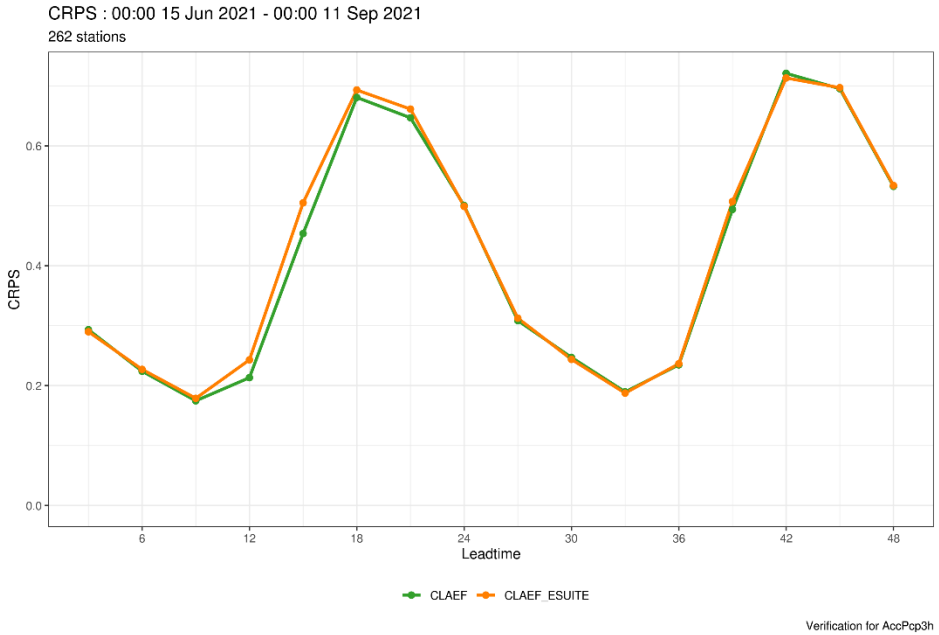


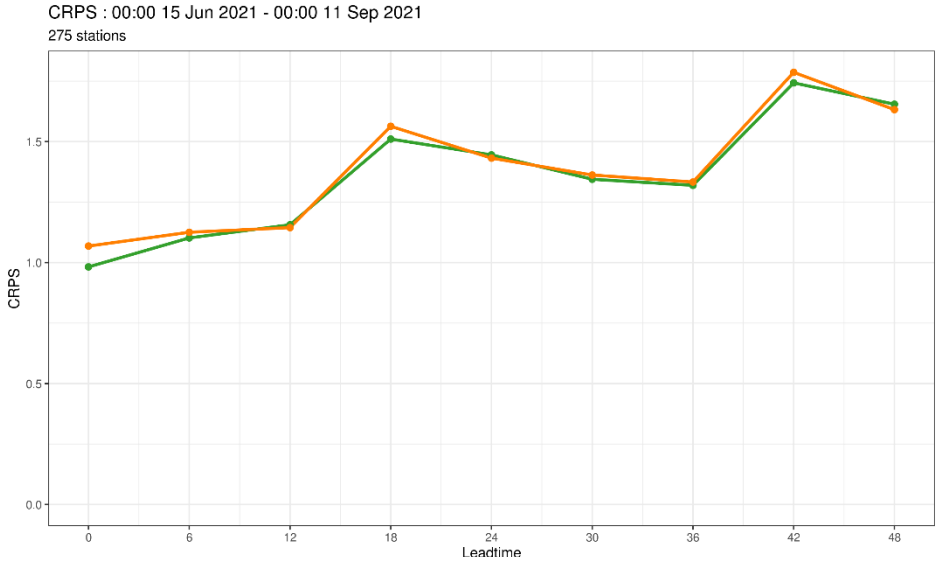
Spread and RMSE of T2m (left) and 3h accumulated precipitation (right) of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

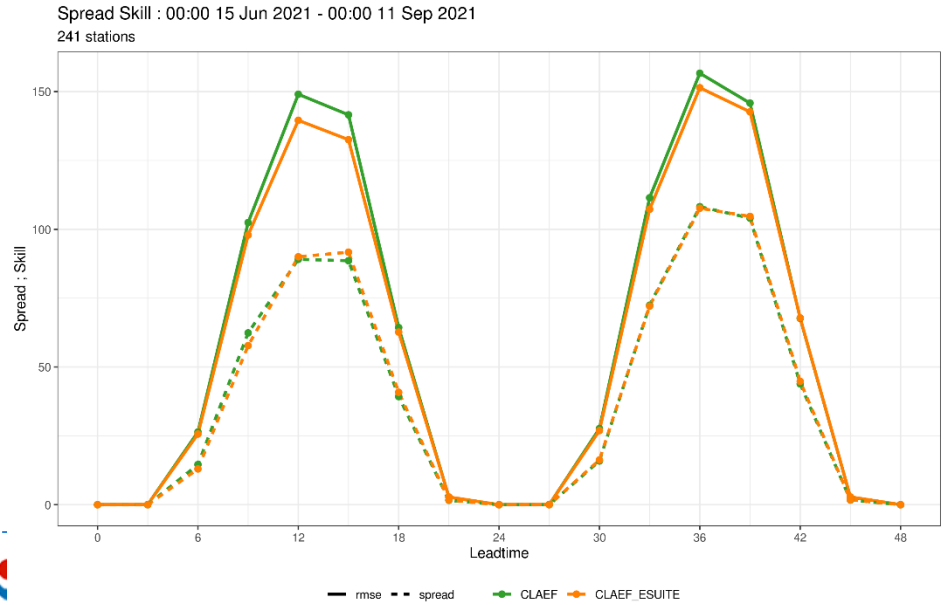
C-LAEF (Austria)

Verification of C-LAEF cy43t2 e-suite:

- quite good performance for most investigated parameters
- plan to switch operational C-LAEF to cy43t2 end of 2021





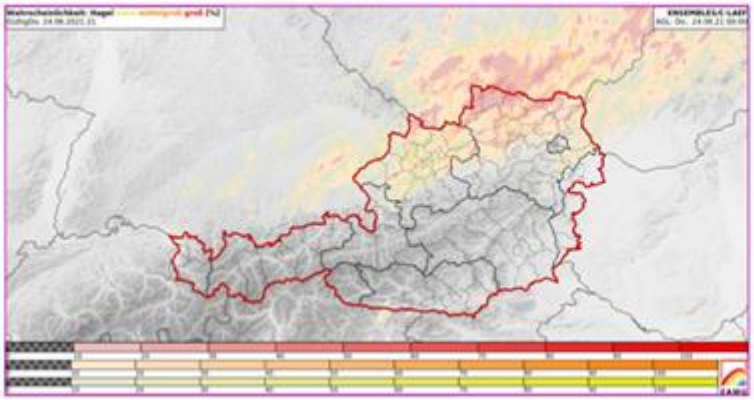


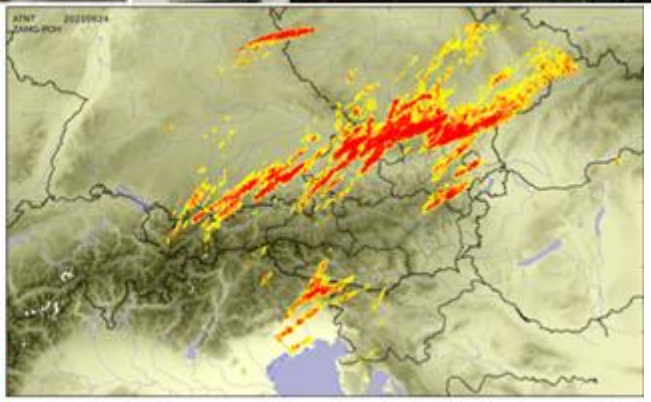
CRPS of 2m relative humidity (left), 700 hPa u-component of wind (upper right) and spread/RMSE of global radiation (lower right) of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

C-LAEF (Austria)

C-LAEF performance at severe weather events:

- Severe hailstorm and a devastating tornado occurred near the Austrian/Czech border with about 250 persons injured in the afternoon/evening of 24 June 2021
- situation was very well captured by C-LAEF predicting high probability of large hail, massive wind gusts (> 100km/h) and strong lightning





Massive hailstones near the Austrian/Czech border and devastating tornado (upper panel; www.hagel.at; www.stern.de).
C-LAEF probability of hail (left) and hail analysis (right) for 24/06 21 UTC (lower panel).

C-LAEF (Austria)

Implementation of new surface perturbation scheme in C-LAEF e-suite:

- operational C-LAEF comprises perturbation of initial conditions (EDA; SEDA; ensemble JK), lateral boundary conditions (coupling with different ECMWF-ENS members) and a combination of tendency and parameter perturbations for model error
- no surface perturbation scheme
- implementation of LPERTSURF scheme of Météo France (Bouttier et al., 2016) in cy43t2 e-suite
- stochastic perturbation of fields after surface assimilation (CANARI) and before integration
- surface assimilation file of unperturbed control is used in all members at Météo France
- perturbation is applied with different seed in each member
- this caused a reduction of spread for surface parameters (temperature, humidity, etc.)
- C-LAEF oper uses a cycling for surface assimilation with perturbation of surface observations (SEDA)
- Soil/surface can develop independently in the members

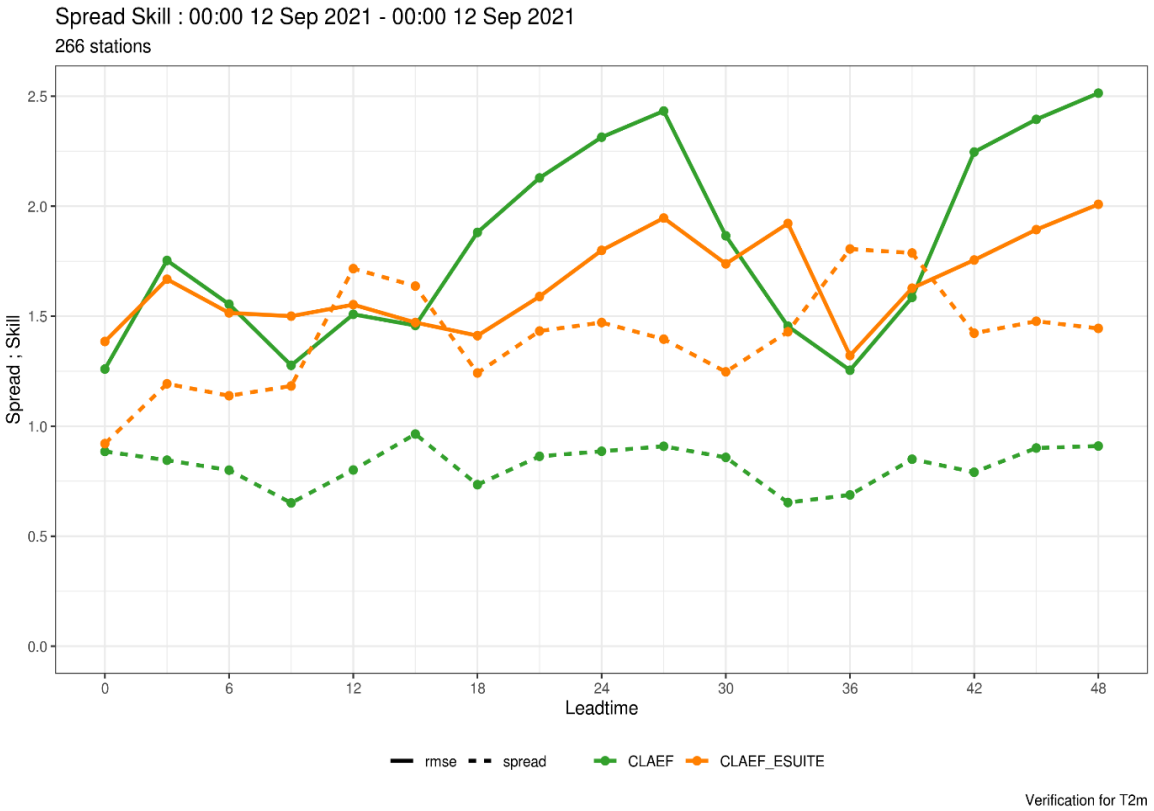
Parameters which are perturbed in the surface perturbation scheme in C-LAEF with standard deviation and perturbation type.

Parameter name	Std. dev.	Perturbation type
Vegetation index	0.1	Multiplicative
Vegetation heat coefficient	0.1	Multiplicative
Leaf area index	0.2	Multiplicative
Land albedo (all wavelengths)	0.1	Multiplicative
Land roughness length	0.2	Multiplicative
Soil/sea surface temperature (K)	1.5	Additive
Soil moisture	0.1	Multiplicative
Snow depth	0.5	Multiplicative
Sea surface fluxes	0.2	Multiplicative

C-LAEF (Austria)

Implementation of new surface perturbation scheme in C-LAEF e-suite:

- development of new (adapted) surface perturbation scheme
- seasonal or constant fields (vegetation index, vegetation heat coefficient, leaf area index, land albedo, land roughness length) are taken from the unperturbed control run and are perturbed with different seed in each member prognostic fields (soil moisture, soil temperature, snow depth, sea surface fluxes) are taken from the surface analysis (CANARI) and are then perturbed with different seed in each member
- this means that those prognostic fields are cycled in each member and can develop independently



Spread and RMSE of T2m of C-LAEF and C-LAEF cy43t2 e-suite (with surface perturbation scheme) for 12 September 2021.

Publications

Published papers:

- C. Wastl, Y. Wang, A. Atencia, F. Weidle, C. Wittmann, C. Zingerle, E. Keresturi, 2021: C-LAEF: Convection-permitting Limited-Area Ensemble Forecasting system. Quarterly Journal of the Royal Meteorological Society, 147, 1431– 1451. https://doi.org/10.1002/qj.3986.
- J. Vivoda, M. Belluš, M. Derková, 2021: "Vysokovýkonné počítanie a predpoveď počasia na SHMÚ", HPC Focus, p44-53, ISSN 2729-9090.

Submitted papers:

- A. Simon, M. Belluš, K. Čatlošová, M. Derková, M. Dian, M. Imrišek, J. Kaňák, L. Méri, M. Neštiak and J. Vivoda, 2021: "Numerical simulations of 7 June 2020 convective precipitation over Slovakia using deterministic, probabilistic and convection-permitting approaches", submitted to Idojaras on May 2021 (accepted for publication).
- K. Jávorné-Radnóczi and B. Tóth, 2021: Short range probabilistic forecasts at Hungarian Meteorological Service: evaluation of AROME-EPS and impact of EDA, submitted to Idojaras.

Contributions to the ALADIN and ACCORD newsletters

Participation at workshops (ACCORD, EWGLAM)