Regional Cooperation for
Limited Area Modeling in Central Europe

LACE
nwp central europe

LAM-EPS activities in RC LACE

Martina Tudor and Martin Belluš with contributions of RC LACE partners

DHMZ ŠHMÚ ARSO METEO Slovenia OMSZ IMGW ZAMG ROMANIA ANM

Operational ensembles of RC LACE

Three independent systems:

- **A-LAEF**
  Common RC LACE EPS
  4.8 km / 60 L, based on ALARO-1 physics, 16+1 members
- **C-LAEF**
  Austrian convection-permitting EPS
  2.5 km / 90 L, based on AROME model, 16+1 members

TC2 @ ECMWF's HPCF

- **AROME-EPS**
  Hungarian convection-permitting EPS
  2.5 km / 60 L, based on AROME model, 10+1 members

local HPC

Operational ensembles of RC LACE

Operational domains (in proper scale):

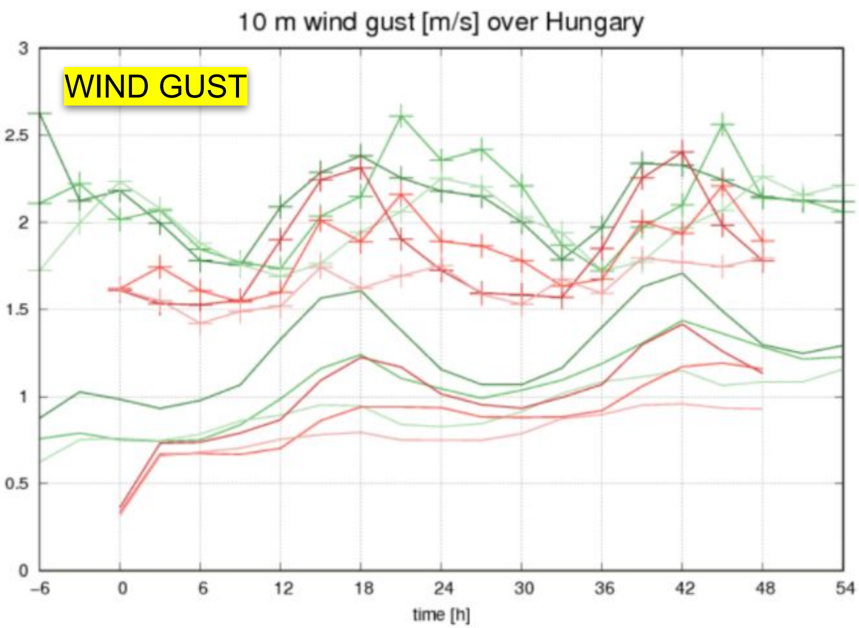
Operational ensembles of RC LACE

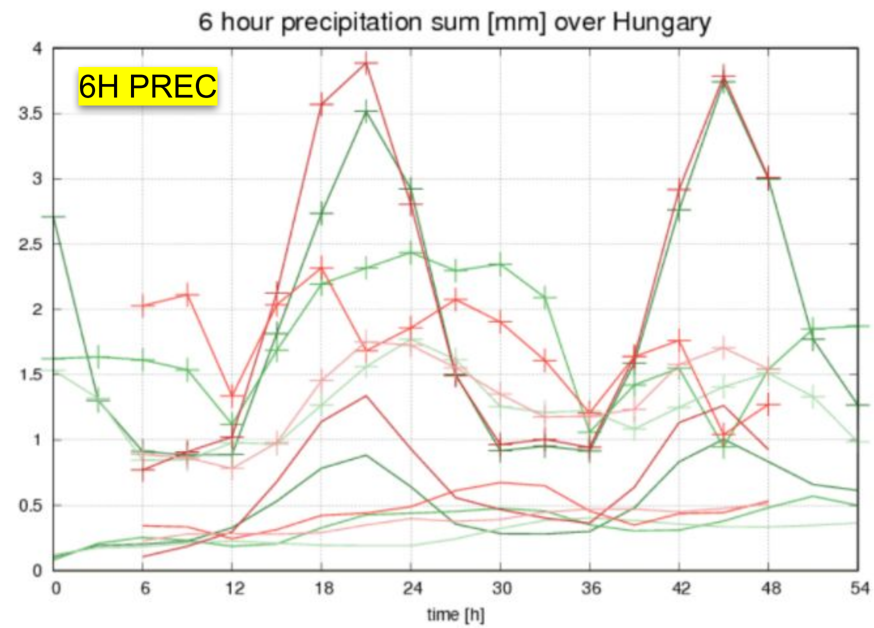
	A-LAEF	C-LAEF	AROME-EPS
CMC	ALARO	AROME	AROME
Code version	cy40	cy40	cy40
Horizontal resolution	4.8 km	2.5 km	2.5 km
Vertical levels	60	90	60
Runs per day	2	4	1
Forecast length	+72h (00/12 UTC)	+60h (00 UTC), +48h (12 UTC), +6h (06/18 UTC)	+48h (00 UTC)
Members	16+1	16+1	10+1
Assimilation cycle	yes (12h)	yes (6h)	-
IC perturbation	ESDA [surface], spectral blending by DFI [upper-air]	ESDA [surface], EDA, Ensemble-JK [upper-air]	downscaling (AROME-EDA is being tested)
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 (c903@cy46)	ECMWF ENS (c901+e927)	ECMWF ENS (c903@cy47)

AROME-EPS (Hungary)

AROME-EPS (Hungary)

AROME-EPS runs operationally at OMSZ since February 4, 2020. To see the strengths and weaknesses as well as the seasonal variation of AROME-EPS quality, a comparison of ALARO-EPS and AROME-EPS have been made for a longer period (from June 2019 till January 2020), covering three seasons of parallel run.

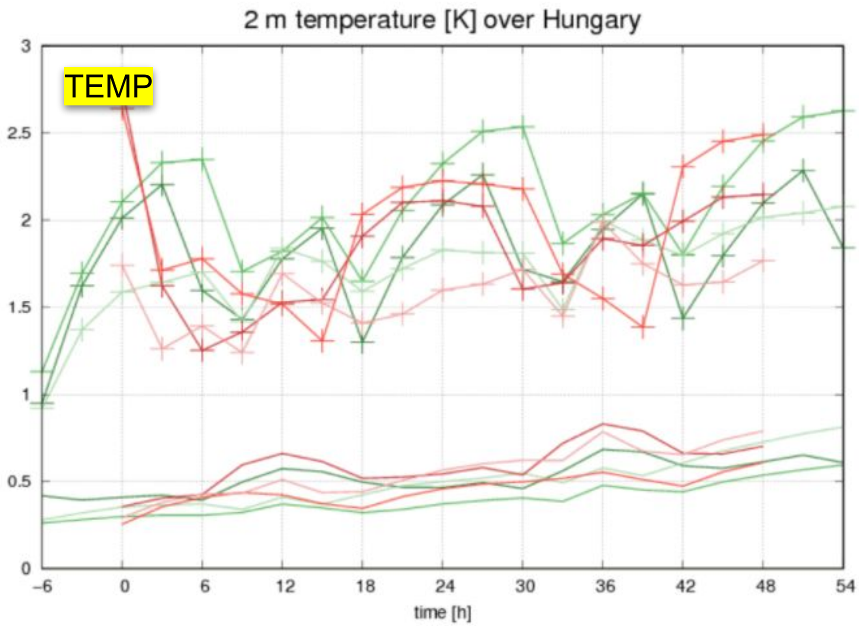


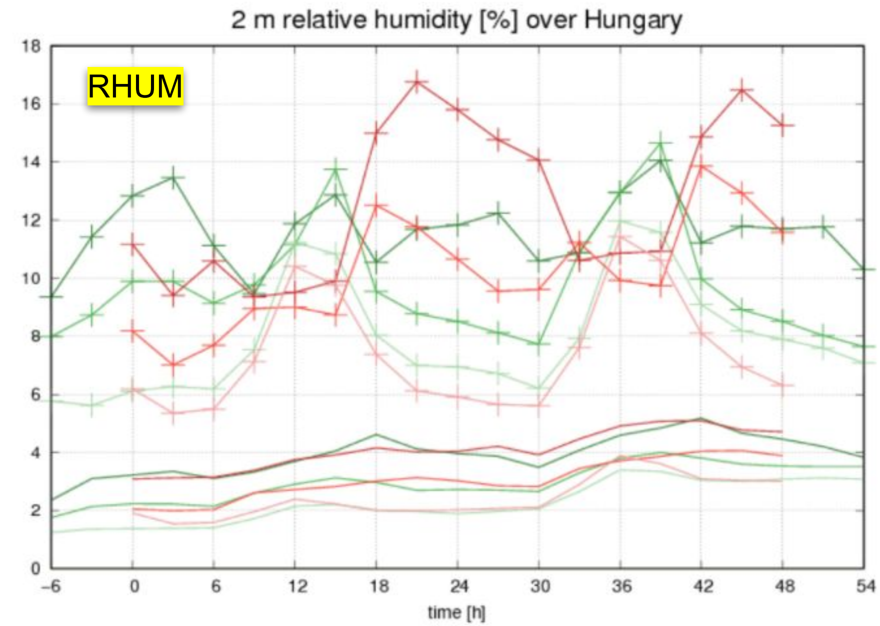


*RMSE of ensemble mean (symbols) and EPS SPREAD (solid) of ALARO-EPS (green), AROME-EPS (red) for wind gust (left), 6-hourly precipitation sum (right), for three months in the **convective season**: July, August and September 2019 in dark/base/light colors, respectively.*

AROME-EPS (Hungary)

AROME-EPS runs operationally at OMSZ since February 4, 2020. To see the strengths and weaknesses as well as the seasonal variation of AROME-EPS quality, a comparison of ALARO-EPS and AROME-EPS have been made for a longer period (from June 2019 till January 2020), covering three seasons of parallel run.

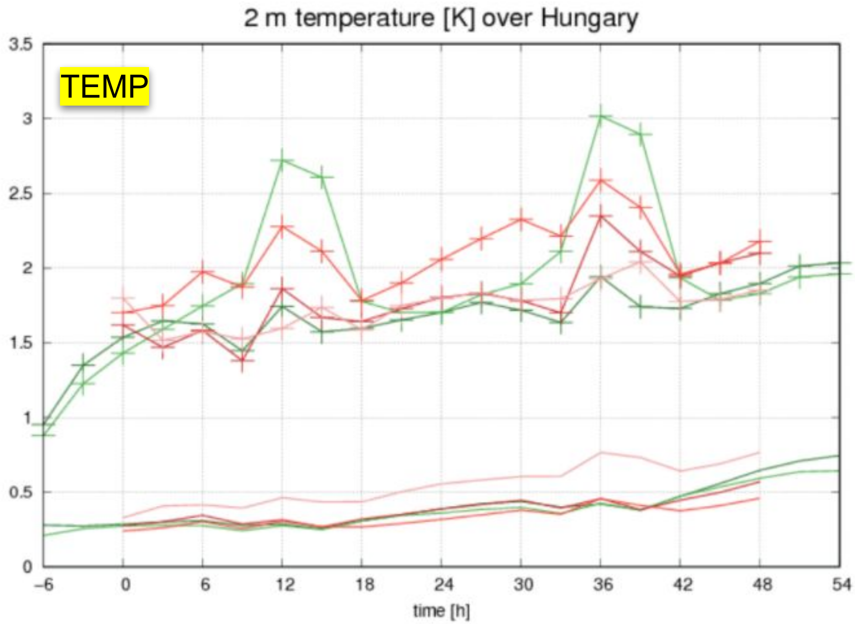


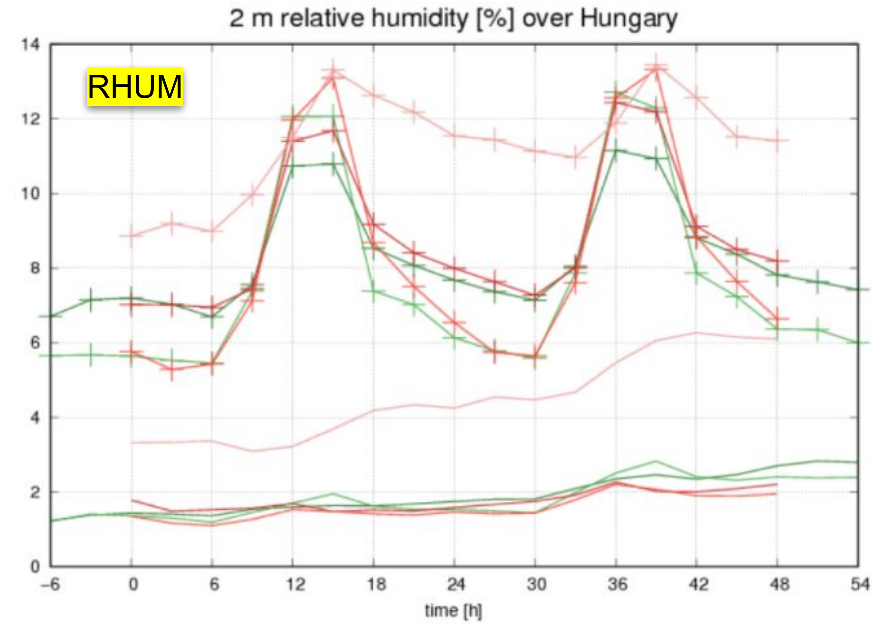


*RMSE of ensemble mean (symbols) and EPS SPREAD (solid) of ALARO-EPS (green), AROME-EPS (red) for 2m temperature (left) and relative humidity (right), for **autumn** 2019: September, October, November in dark/base/light colors, respectively.*

AROME-EPS (Hungary)

AROME-EPS runs operationally at OMSZ since February 4, 2020. To see the strengths and weaknesses as well as the seasonal variation of AROME-EPS quality, a comparison of ALARO-EPS and AROME-EPS have been made for a longer period (from June 2019 till January 2020), covering three seasons of parallel run.

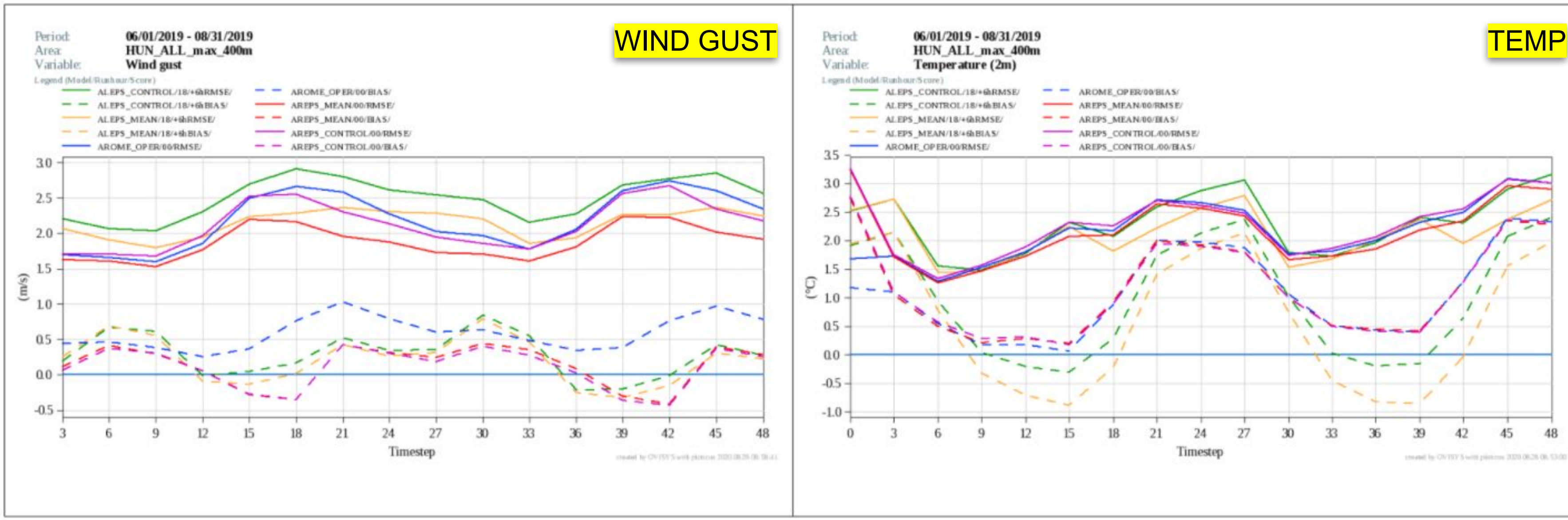




*RMSE of ensemble mean (symbols) and EPS SPREAD (solid) of ALARO-EPS (green), AROME-EPS (red) for 2m temperature (left) and relative humidity (right), for **winter** 2019-2020: December 2019, January and February 2020 in dark/base/light colors, respectively.*

AROME-EPS (Hungary)

Verification of control member and EPS mean for July and for summer 2019 showed similar results. Additionally, for most parameters RMSE of EPS mean is lower than that of deterministic run (AROME 00 UTC). In the seasonal average, this is the case for 10-meter wind speed, wind gust, cloudiness, 2-meter temperature and precipitation, which underlines the superiority of EPS over a deterministic forecast.



RMSE (solid) and BIAS (dashed) of AROME-EPS mean (red), control (purple), ALARO-EPS mean (yellow), control (green), compared to AROME deterministic run (blue) for wind gust (left) and 2m temperature (right), for the summer 2019 (June, July, August).

C-LAEF
(Austria)

C-LAEF (Austria)

C-LAEF runs operationally at ECMWF HPCF with 4 runs per day (00, 06, 12 and 18 UTC). The lead times vary between +60h (00 UTC), +48h (12 UTC) and +6h (06 and 18 UTC).

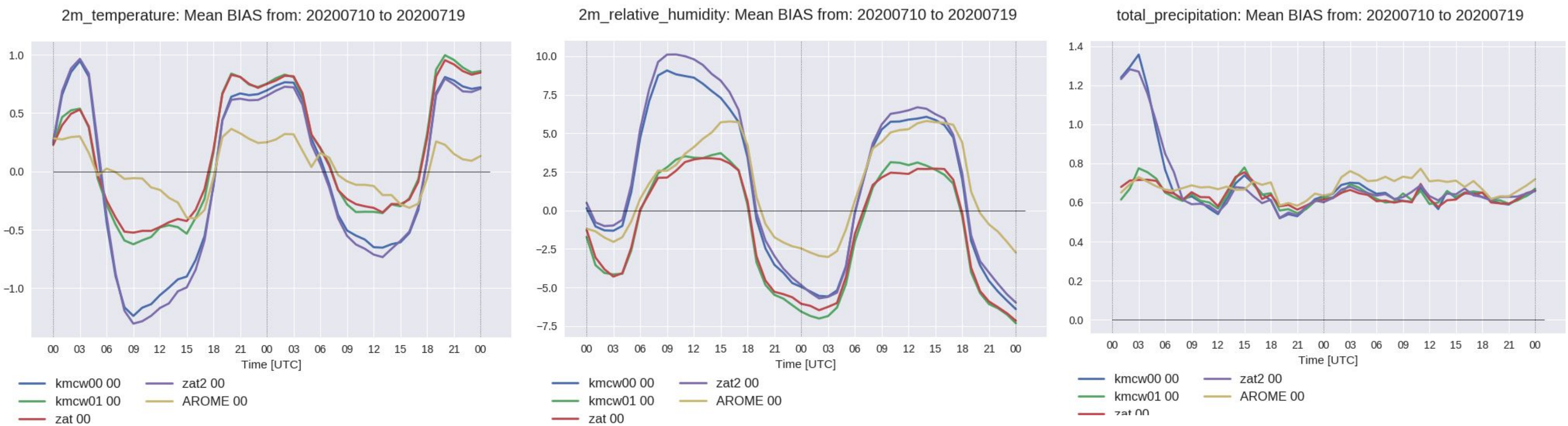
New development:

- Implementation of cy43t2 at the ECMWF HPC
- Local phasing of C-LAEF related code into cy43t2 (perturbation scheme)
- Re-coding of Endi's EnJK code for cy43t2 to get rid of external process step (epygram) to switch between grid point / spectral representation for humidity in EnJk
- Set-up of a complete C-LAEF e-suite with cy43t2
- New observations (GNSS, Mode-S, …) were tested in C-LAEF EDA
- C-LAEF SPP scheme was extended by the additional perturbation in microphysics for 2 processes connected to sublimation of snow/graupel
- Time lagged EPS out of AROME-RUC was created using neighborhood methods

C-LAEF (Austria)

Verification of new OBS in EDA:

- First results show a problem with **T2m** and **RH2m** during the day
- Too much soil moisture, caused by a positive precipitation bias in the first forecast hours
- The problem was identified to come from the VarBC for GNSS data (too long adaptation time)

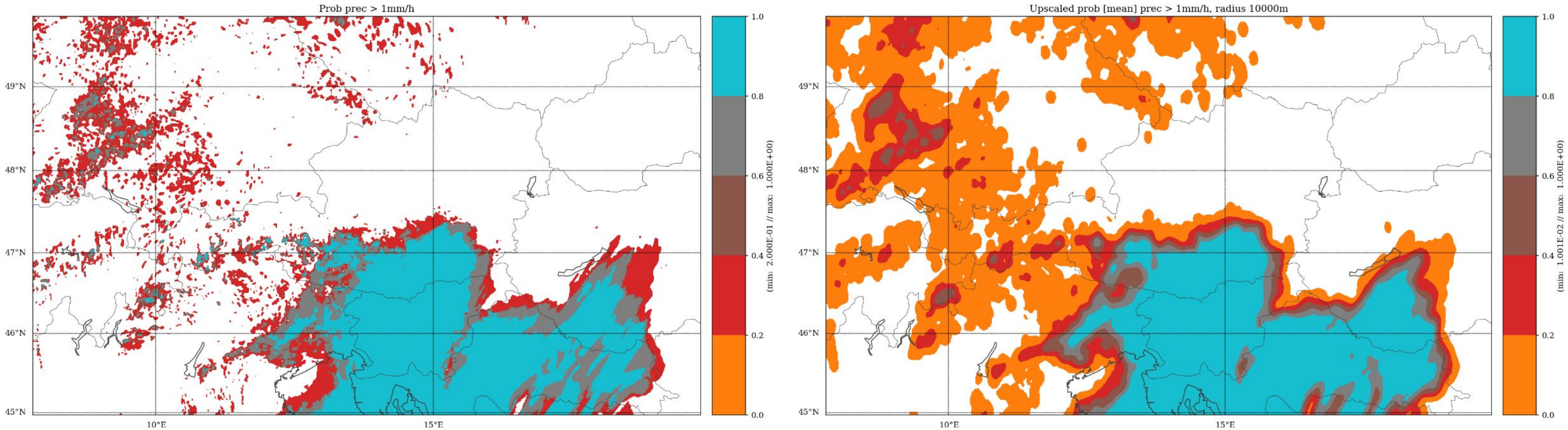


Verification of different sets of "new observations" for 1 week (July 10 – July 19, 2020). BIAS of 2-meter temperature (left), 2-meter relative humidity (middle) and precipitation (right).

C-LAEF (Austria)

Time lagged AROME-RUC-PEPS:

It was technically implemented for the precipitation. It runs regularly for selected INIT times of the AROME-RUC, generating a lagged ensemble with 5 members (lag=0h, -1h, …, -4h), with forecast range up to +8h and output frequency of 15 minutes, using neighborhood methods. AROME-RUC-PEPS visualization was implemented in Visual Weather.



AROME-RUC-PEPS grid-point wise probability (left) and upscaled probability using mean of all grid-points within 10 km radius (right).

A-LAEF
(RC LACE)

A-LAEF (RC LACE)

A-LAEF suite changelog:

- Addition of unperturbed control run (member=00)
- Implementation of ECPDS dissemination of grib files to the given user's destination (SK, SI)
- Grib files modification in order to be readable in Visual Weather software
- MSLP smoothing by spectral Gaussian filter within in-line fullpos (for all 16+1 members)
- Prolongation of forecast to 72 hours (since May 12, 2020)

Technical upgrades to meet the ECMWF's requirements for TC2 suite:

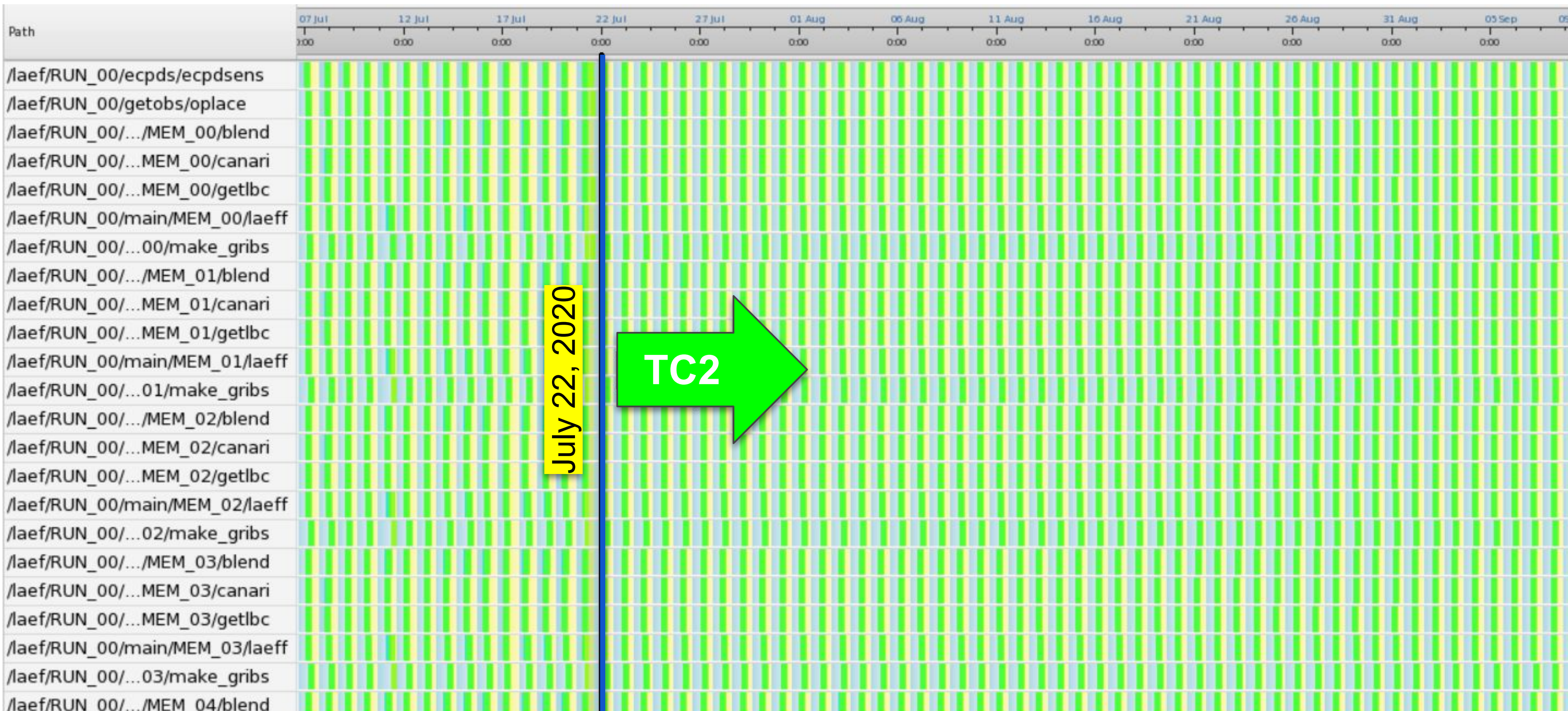
- Migration to new ecflow client/server 5.4.0 and schedule 1.7
- Optimization of disk space usage
- Implementation of white list
- Implementation of ECF_KILL and ECF_STATUS commands
- Implementation of live output from running jobs
- Separate dissemination family to send the products to different destinations

The formal request to run A-LAEF of RC LACE consortium under the Member State time-critical option 2 was officially approved by ECMWF on July 22, 2020. Since then, timing of the operational A-LAEF tasks is very stable and the output grib files are available at about 03:30 UTC and 15:30 UTC for 00 and 12 UTC runs, respectively.

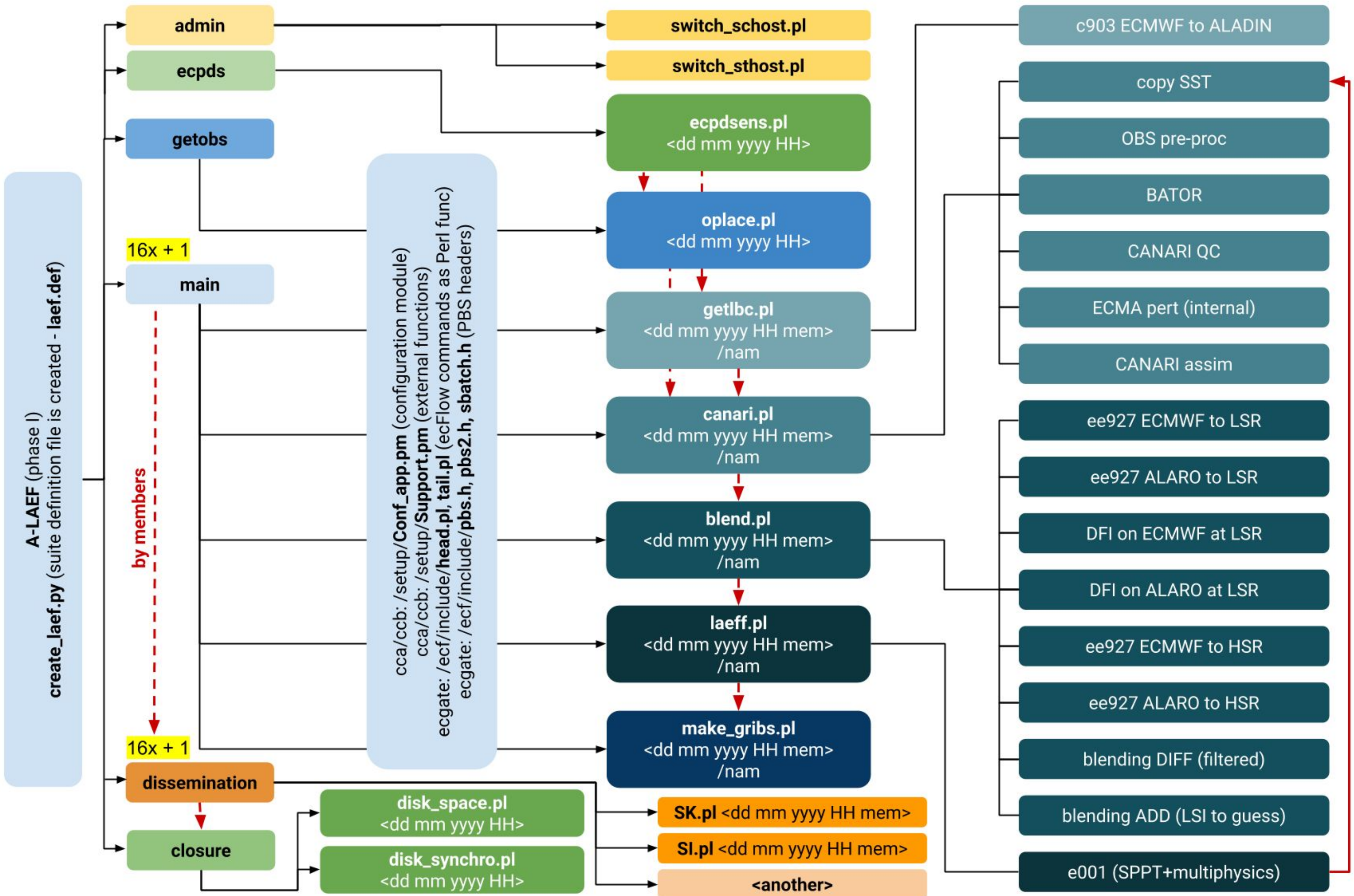
A-LAEF (RC LACE)

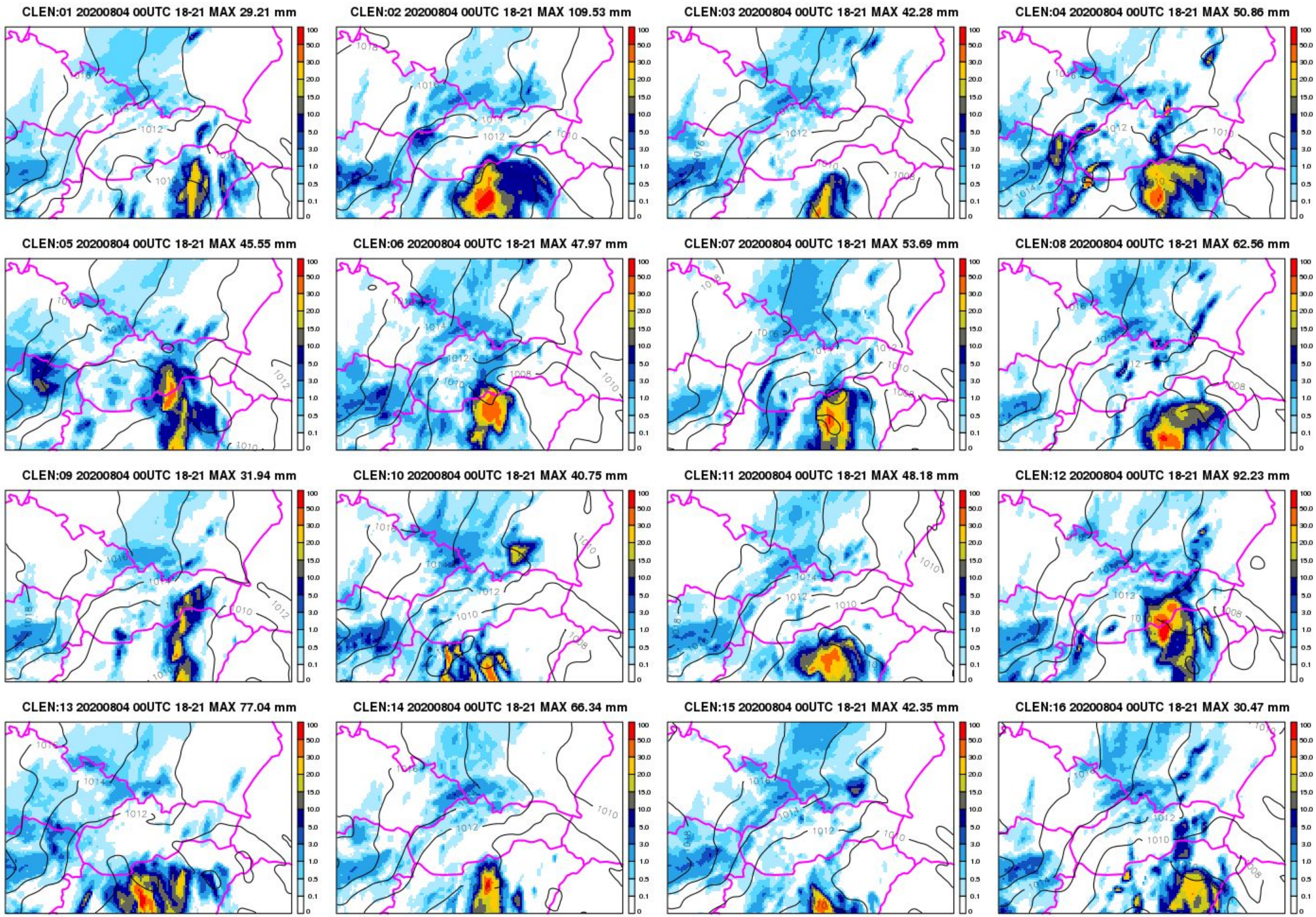
00:30|12:30 UTC → → → 03:30|15:30 UTC → 03:50|15:50 UTC

ECMWF — SHMU



A-LAEF (RC LACE)




CLEN:01 20200804 00UTC 18-21 MAX 29.21 mm
CLEN:02 20200804 00UTC 18-21 MAX 109.53 mm
CLEN:03 20200804 00UTC 18-21 MAX 42.28 mm
CLEN:04 20200804 00UTC 18-21 MAX 50.86 mm
CLEN:05 20200804 00UTC 18-21 MAX 45.55 mm
CLEN:06 20200804 00UTC 18-21 MAX 47.97 mm
CLEN:07 20200804 00UTC 18-21 MAX 53.69 mm
CLEN:08 20200804 00UTC 18-21 MAX 62.56 mm
CLEN:09 20200804 00UTC 18-21 MAX 31.94 mm
CLEN:10 20200804 00UTC 18-21 MAX 40.75 mm
CLEN:11 20200804 00UTC 18-21 MAX 48.18 mm
CLEN:12 20200804 00UTC 18-21 MAX 92.23 mm
CLEN:13 20200804 00UTC 18-21 MAX 77.04 mm
CLEN:14 20200804 00UTC 18-21 MAX 66.34 mm
CLEN:15 20200804 00UTC 18-21 MAX 42.35 mm
CLEN:16 20200804 00UTC 18-21 MAX 30.47 mm
100
50.0
30.0
20.0
15.0
10.0
5.0
3.0
1.0
0.5
0.1
0

A-LAEF extreme weather case studies (1/5)

Strong wind events:

- Central Europe - **Storm Petra (February 4, 2020)**

The center of deep cyclone was located over the central part of Slovakia, which led to extremely strong and gusty wind especially at south-west. In Bratislava and Nitra maximum wind gusts about 28-29 m/s were recorded. At the small Carpathian ridge it was 33 m/s, elsewhere mostly in the interval 25-30 m/s. It is not very often when the highest warning level (3rd) is issued for capital city Bratislava. Similar situation was in eastern part of Austria and north-western part of Hungary.

Bratislava/Slovakia 4/2/2020

OGIMET synop based Daily summary by state

Day before:
(2020/02/03) 12:00 UTC

02/04/2020 12:00 UTC

SLOVAKIA

Station	Temperature (C) Max	Min	Med	Td. Med (C)	Hr. Med (%)	Wind (km/h) Dir.	Int.	Gust	Pres. s.lev (Hp)	Prec. (mm)	TotCl Oct	Low Cl Oct	Sun D-1 (h)	Vis Km	Snow Dep. (cm)	Daily weather summary
Malacky	9.6	5.2	7.4	3.5	76.9	WSW	23.1	100.9	1008.3	4.0	7.7	5.9	---	17.7	----	
Maly Javornik	5.2	1.6	4.2	2.5	89.2	W	39.5	----	----	7.0	---	---	0.0	16.1	----	
Bratislava-koliba	8.2	4.8	6.7	3.2	79.4	W	18.0	93.7	1007.3	4.0	7.8	6.3	0.0	41.7	----	
Bratislava Ivanka	9.7	5.9	7.8	3.7	76.0	W	26.3	100.9	1007.4	6.0	7.2	4.6	0.0	39.5	----	
Jaslovske Bohunice	9.1	5.3	6.9	3.9	81.9	WSW	26.7	79.3	1006.7	13.0	---	---	2.3	----	----	
Piestany	9.2	5.5	7.1	3.8	80.6	WSW	18.9	86.5	1006.8	15.0	7.0	5.1	0.1	32.7	----	
Zilina / Hricov	7.2	3.3	5.4	3.4	87.6	WSW	13.1	36.0	1005.6	26.0	7.7	7.1	0.0	17.4	----	
Nitra	9.8	5.8	7.4	4.1	80.7	WNW	22.2	104.5	1006.6	14.0	7.1	5.4	0.0	16.3	----	
Mochovce	8.4	4.6	6.3	4.0	86.5	WNW	14.7	75.6	1007.0	17.0	---	---	0.0	----	----	
Hurbanovo	10.3	6.3	8.1	4.1	76.8	W	16.8	79.3	1007.9	4.0	7.8	6.3	0.0	44.2	----	
Prievidza	8.5	5.0	6.1	5.1	93.8	SW	14.3	43.2	1006.2	24.0	7.3	6.1	0.0	10.5	----	
Dudince	8.9	4.6	6.7	4.8	88.6	W	10.7	75.6	1007.2	17.0	7.5	7.3	---	18.3	----	
Ziar Nad Hronom	9.1	4.1	6.1	4.1	87.4	W	9.0	----	1006.5	20.0	---	---	0.7	13.8	----	
Sliac	7.7	1.0	4.8	2.9	88.5	NW	8.4	----	1006.4	24.0	7.5	7.4	0.0	10.1	----	
Chopok	-3.2	-5.8	-4.7	-5.3	95.4	WNW	51.9	100.9	784.1	12.0	---	---	---	0.0	107	
Liesek	5.1	0.4	2.9	1.6	91.7	WSW	15.6	----	----	11.0	7.4	6.9	---	19.7	----	
Lucenec	9.4	4.1	5.7	4.0	89.9	WSW	9.5	----	1006.0	15.0	6.3	6.3	0.2	21.7	----	
Lomnicky Stit	-5.3	-9.5	-8.0	-8.7	94.4	WNW	27.8	111.7	722.1	34.0	---	---	0.0	0.0	132	
Strbske Pleso	0.4	-1.2	-0.8	-0.8	99.6	NNW	7.8	28.8	853.7	35.0	---	8.0	0.0	0.3	40	
Poprad / Tatry	6.7	0.4	2.8	1.0	89.4	WSW	23.6	57.6	----	5.2	6.1	5.3	3.1	27.6	----	
Telgart	4.5	-0.3	1.3	0.0	92.1	WSW	26.0	57.6	899.4	13.0	4.9	4.5	---	9.9	0	
Poprad-Ganovce	6.5	0.2	2.5	0.3	86.8	WNW	17.4	----	----	3.0	---	---	---	----	----	
Presov	10.4	0.9	4.7	1.7	83.9	SW	11.1	----	1005.3	6.3	6.6	6.5	---	17.8	----	
Kojsovska Hola	3.4	-2.5	-0.6	-1.8	92.7	W	13.5	----	861.9	5.0	---	---	2.4	11.8	----	
Kosice	11.2	-1.2	4.0	2.1	89.2	SSW	11.4	----	1005.9	10.2	4.8	4.5	2.9	17.5	----	
Stropkov, Tisinec	9.1	2.7	4.3	3.4	95.3	NNE	5.4	----	1005.5	15.9	7.5	7.1	---	21.0	----	
Milhostov	11.4	0.8	4.8	3.2	91.5	E	7.7	----	1005.9	8.3	6.3	6.2	1.4	17.9	----	
Kamenica Nad Ciro...	9.8	3.7	5.5	3.2	86.7	SSE	8.0	----	1005.7	8.9	7.3	7.3	3.3	16.0	----	
Summary	7.2	2.0	4.1	2.0	87.6	W	15.1	77.0	1006.5	13.5	6.9	6.2	0.8	18.4	70	

A-LAEF extreme weather case studies (1/5)

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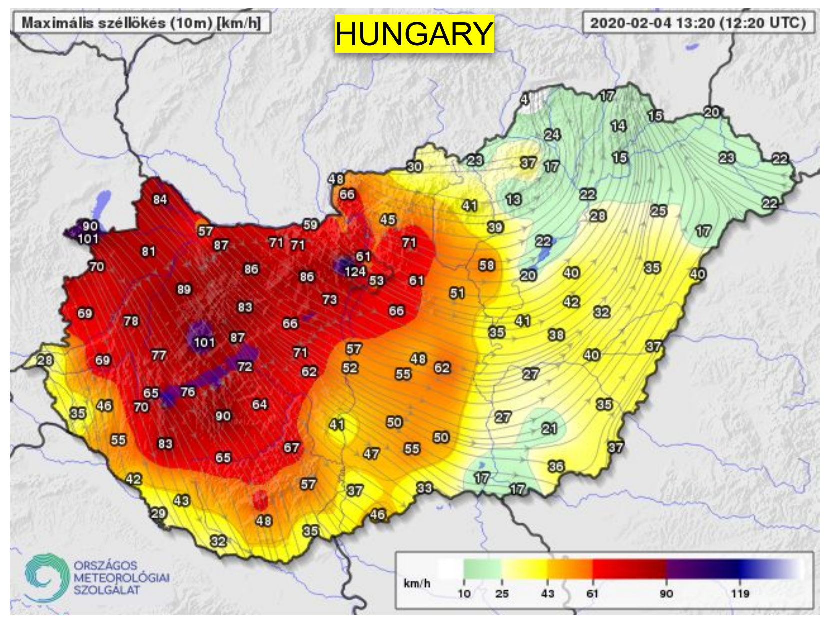
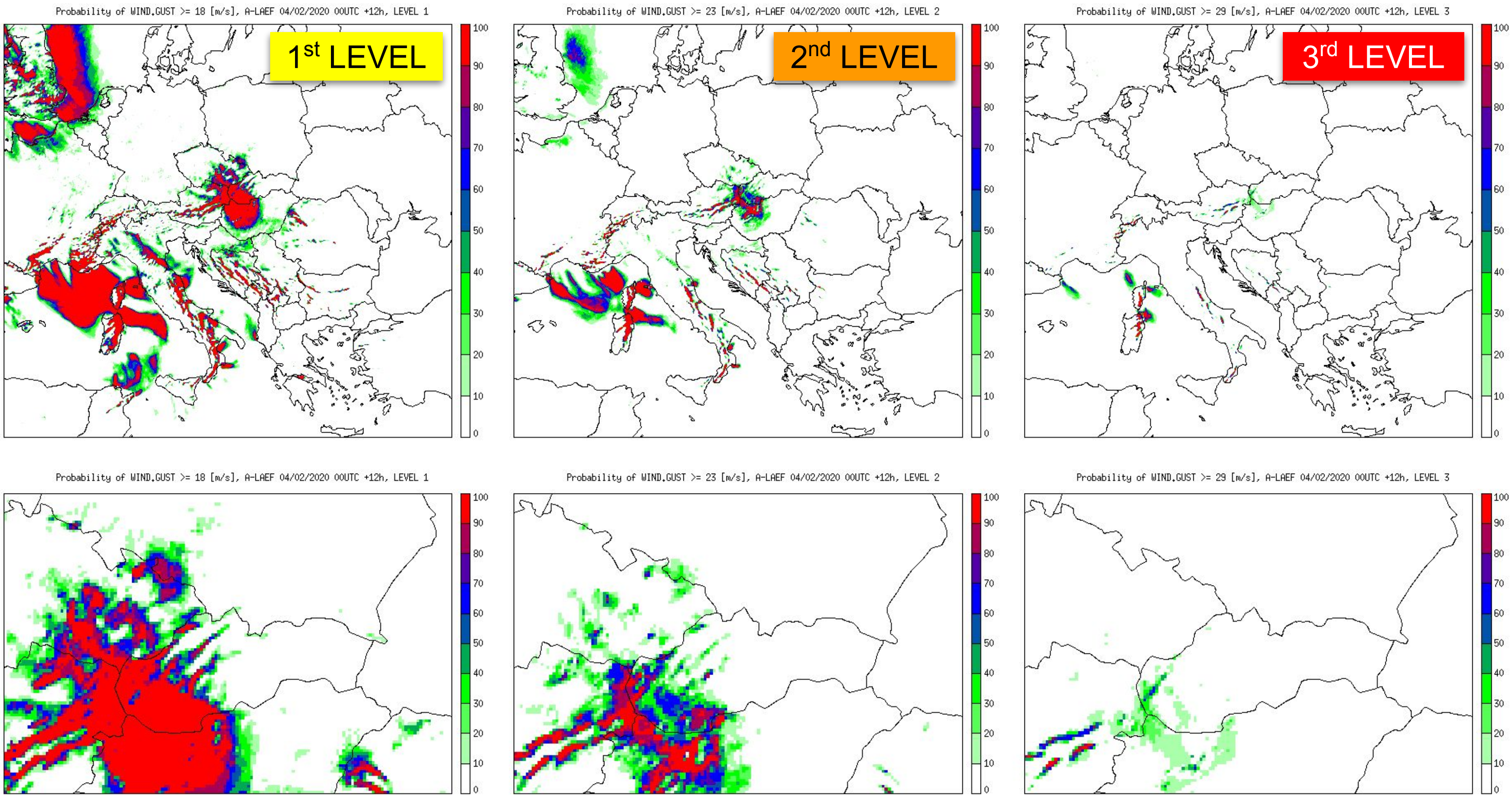
Bratislava/Slovakia 4/2/2020



A-LAEF extreme weather case studies (1/5)

wind gusts >= 18 m/s | wind gusts >= 23 m/s | wind gusts >= 29 m/s



A-LAEF probability maps for wind gusts with different thresholds.

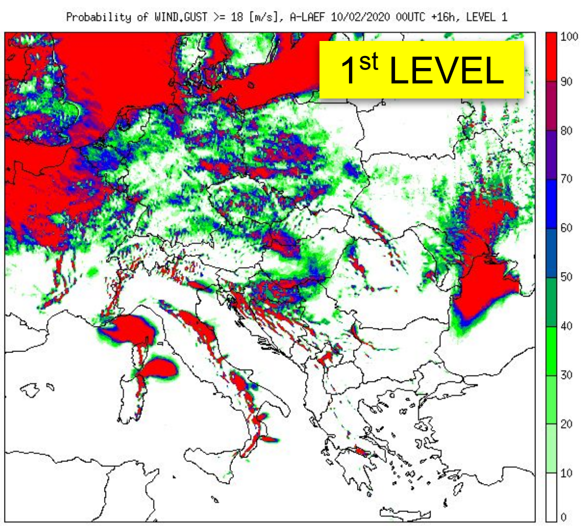
A-LAEF extreme weather case studies (2/5)

Strong wind events:

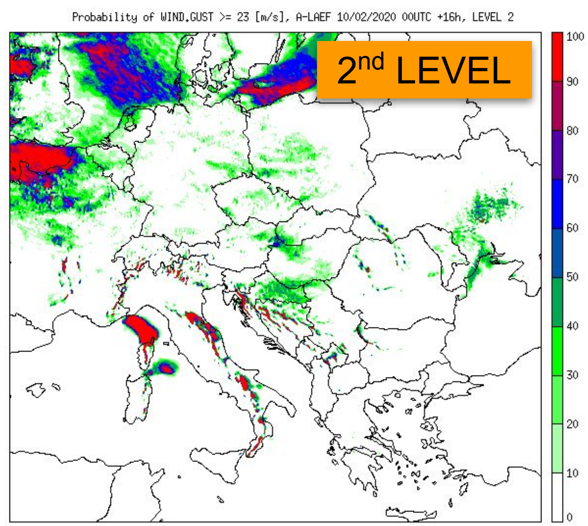
- Central Europe - **Windstorm (February 10, 2020)**

Another strong wind situation during cold front passage just one week later. This time wind gusts were over-predicted by deterministic model. The highest warning level for strong wind was issued again, even though the reality was not that bad. This was subsequently confirmed by A-LAEF ensemble, were the threshold for level 3 was not reached (unfortunately, A-LAEF forecast was not available to the forecasters yet).

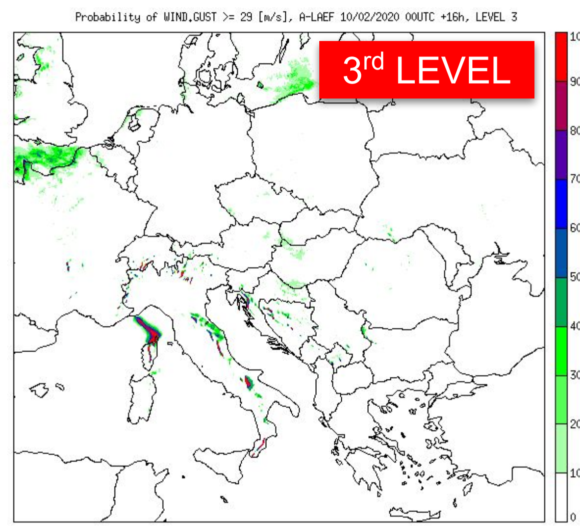
wind gusts >= 18 m/s



wind gusts >= 23 m/s



wind gusts >= 29 m/s



A-LAEF probability maps for wind gusts with different thresholds.

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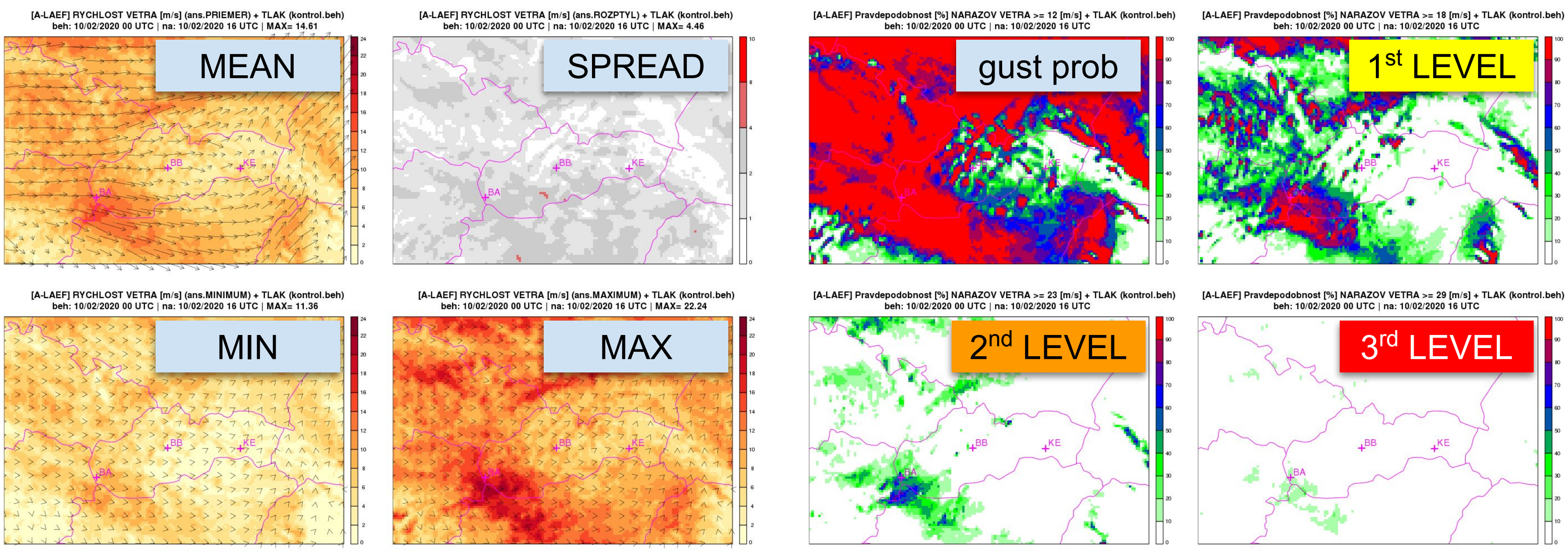
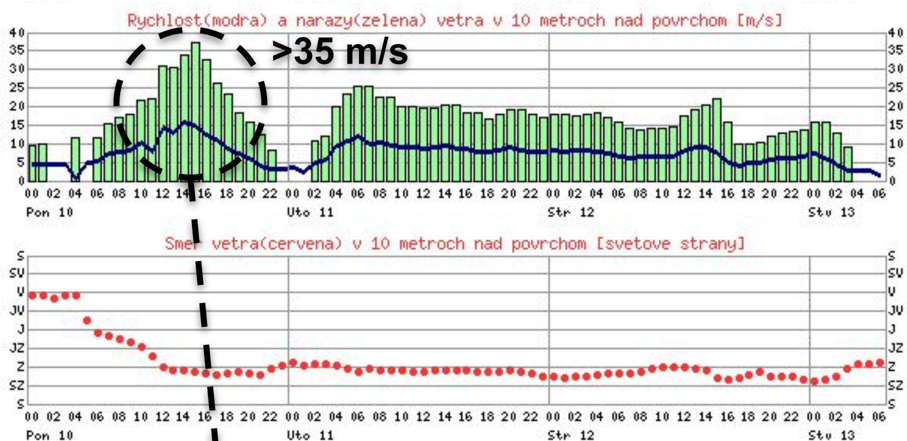


A-LAEF wind field forecast (left) and probability maps for wind gusts with different thresholds (right).

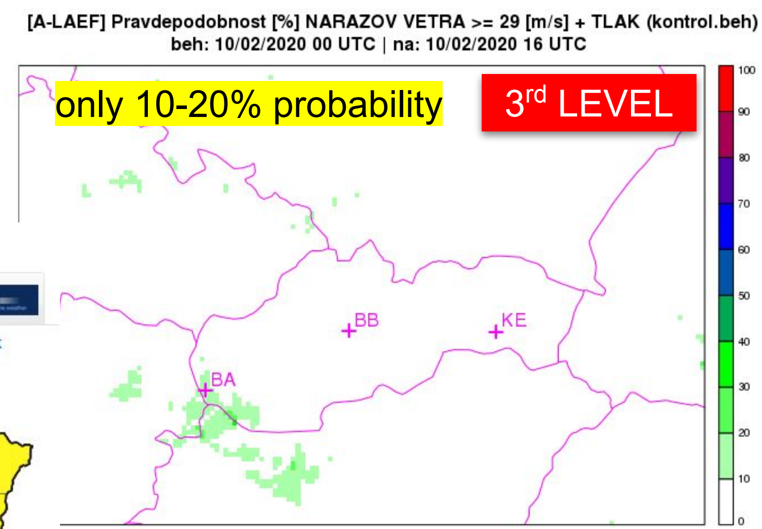
A-LAEF extreme weather case studies (2/5)

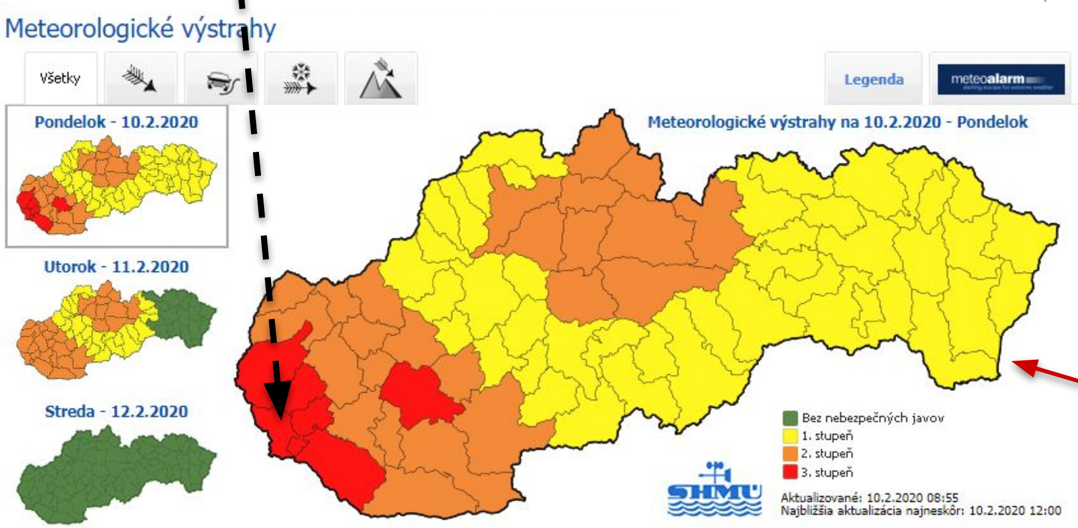
One deterministic forecast is not enough!



ALADIN SHMU

A-LAEF





METEO ALARM

A-LAEF extreme weather case studies (3/5)

Extreme precipitation events:

- Hungary - **Extensive floods (July 24-25, 2020)**

There were extremely high precipitation totals in just 24 hours in south-western Hungary. Up to 178 mm of precipitation fell, which caused extensive floods. The situation was captured by deterministic models, but the localisation wasn't good to refine the warnings, as the amounts above 100 mm in 24 hours were predicted over relatively large area.

Severe Weather Europe

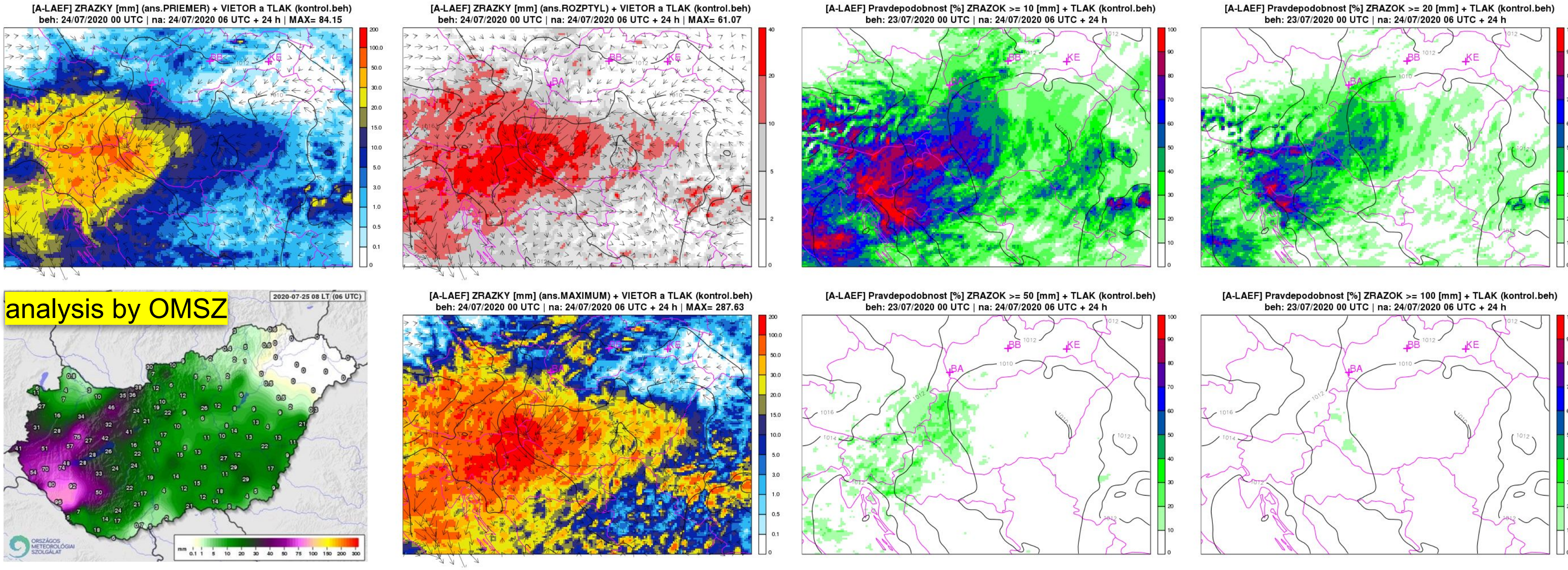
Severe Weather Europe

A-LAEF extreme weather case studies (3/5)

Extreme precipitation events:

- Hungary - **Extensive floods (July 24-25, 2020)**

A-LAEF ensemble mean (or maximum of the ensemble) better corresponded to the real distribution of precipitation field. The situation is also well illustrated by the probabilities of 24-hour precipitation totals for the threshold values of 10, 20, 50 and 100 mm.



A-LAEF 24-hour precipitation totals (mean, spread, max) compared to the analysis (left panel) and probabilities for threshold values 10, 20, 50 and 100 mm/24h (right panel).

A-LAEF extreme weather case studies (4/5)

Extreme precipitation events:

- Slovakia - **Night storm (July 28, 2020)**

During the night hours a strong line of deep convection accompanied by shelf cloud was propagating in the low-pressure trough from west to east part of Slovakia. According to the Slovakian Presidium of the Fire and Rescue Service, the storm activity associated with a strong wind gusts required 83 firefighters' interventions. In most cases, they helped remove fallen trees from roads, houses, buildings and parked vehicles. In 13 cases, their help was needed to drain water from flooded cellars, garages and streets.

courtesy of Tibor Csorgei

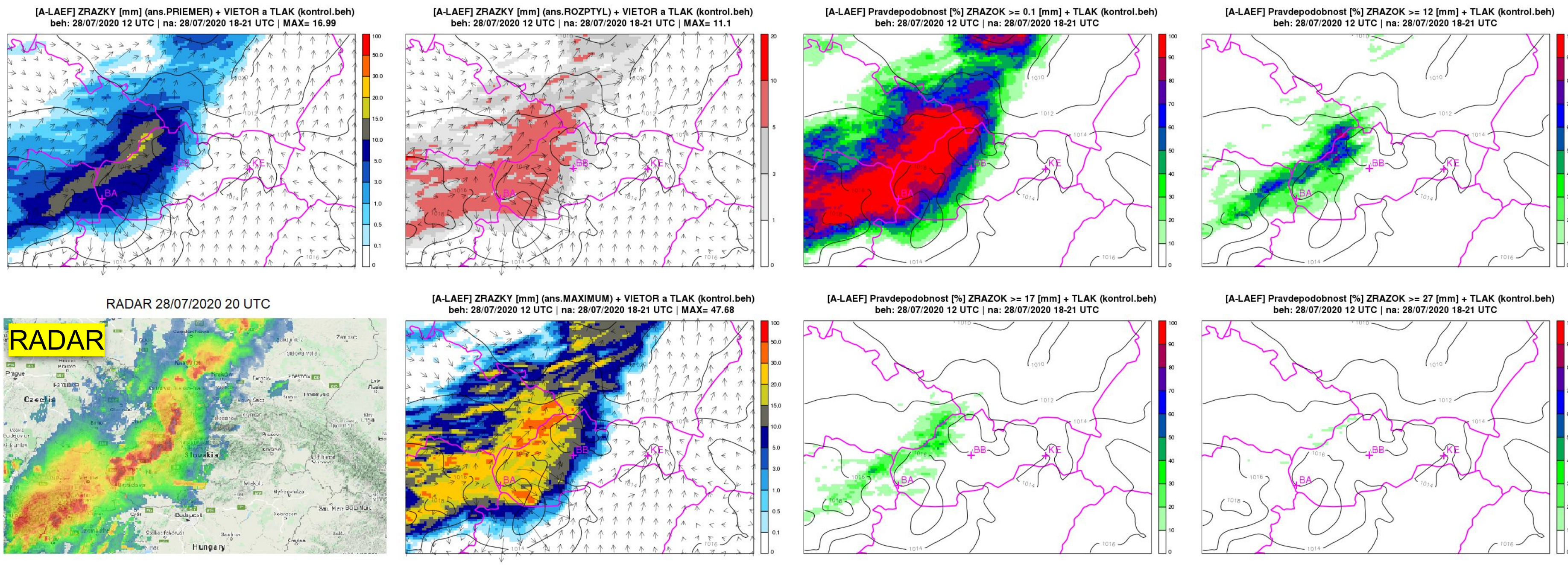
courtesy of Tibor Csorgei

A-LAEF extreme weather case studies (4/5)

Extreme precipitation events:

- Slovakia - **Night storm (July 28, 2020)**

A-LAEF predicted the situation very well, i.e. the intense precipitation formed into a line of instability propagating from west to east and the associated strong wind and wind gusts.



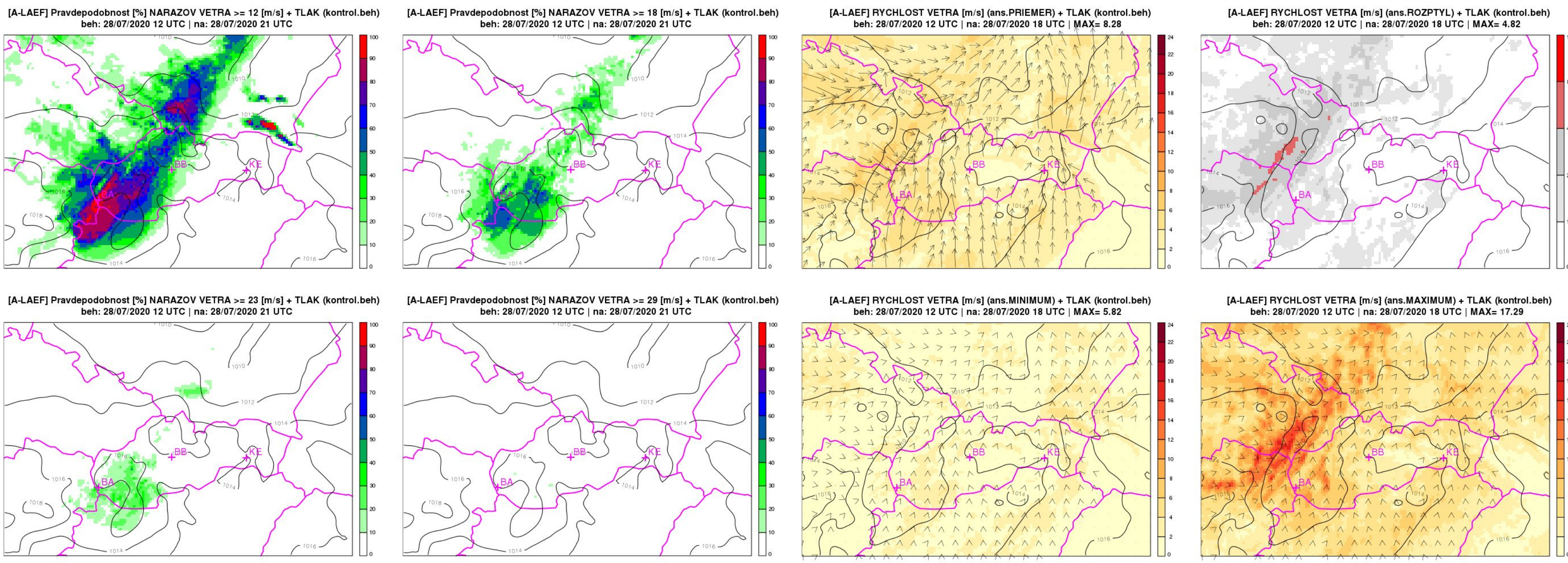
A-LAEF 3-hour precipitation totals (mean, spread, max) compared to the RADAR reflectivity (left panel) and probabilities for threshold values 0.1, 12, 17 and 27 mm/3h (right panel).

A-LAEF extreme weather case studies (4/5)

Extreme precipitation events:

- Slovakia - **Night storm (July 28, 2020)**

A-LAEF predicted the situation very well, i.e. the intense precipitation formed into a line of instability propagating from west to east and the associated strong wind and wind gusts.



Probability of wind gusts for thresholds 12, 18, 23 and 29 m/s (left panel), and A-LAEF forecast of average wind speed and direction (mean, spread, min, max - right panel).

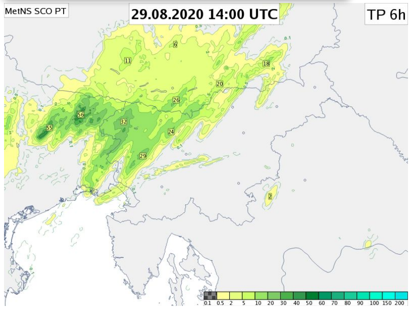
A-LAEF extreme weather case studies (5/5)

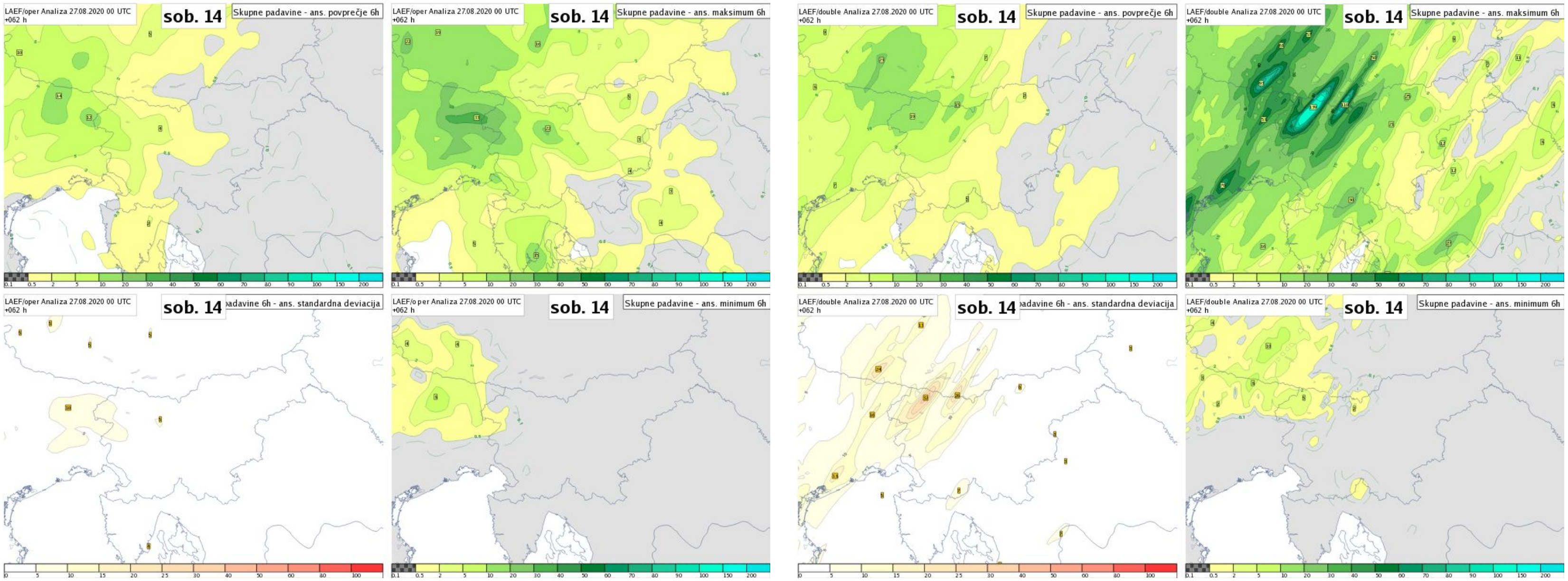
Extreme precipitation events:

- Slovenia - **Precipitation case (August 29, 2020)**

At ARSO, the A-LAEF operational grib files are now included in their Visual Weather environment and are available to the forecasters on daily basis. They can easily switch between the old and new ensemble systems. Therefore, that was a great opportunity for the validation of new A-LAEF forecasts against the former (still operational) system.

analysis (RADAR+OBS)





ALADIN-LAEF (left) and new A-LAEF (right), panels with EPS mean, max, stdev and min.

New publications

Published papers:

- Wastl C., Y. Wang, C. Wittmann, 2019: “A comparison of different stochastically perturbed parametrization tendencies schemes”, Meteorologische Zeitrschrift, DOI: 10.1127/metz/2019/0988
- Plenković, I. O., I. Schicker, M. Dabernig, K. Horvath, E. Keresturi, 2020: "Analog-based post-processing of the ALADIN-LAEF ensemble predictions in complex terrain", accepted for publication in Quarterly Journal of the Royal Meteorological Society

Submitted papers:

- Wastl et al., 2020: “C-LAEF - Convection permitting Limited Area Ensemble Forecasting System”, submitted to QJRMS
- Belluš, M., 2020: “Nový regionálny ansámblový systém s vysokým rozlíšením: A-LAEF”, Meteorologický časopis, SHMÚ

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Stay reports:

- Iris Odak Plenković, 2019: Work on analog-based post-processing method, Report on stay at ZAMG, 11/11~06/12, 2019, Vienna, Austria

Annual report (January-August):

- Martin Belluš, 2020: Working Area Predictability Progress Report 2020

Doctoral thesis:

Iris Odak Plenković successfully defended her doctoral thesis “Wind speed prediction using the analog method over complex topography” in July, at Faculty of Science, Department of Geophysics, University of Zagreb.

http://www.rclace.eu/?page=40

What's next?

Main topics:

- SPG
- Stochastic perturbation of fluxes instead of tendencies
- flow-dependent B-matrix
- analog-based post-processing
- migration to Bologna HPCF
- upgrade to cy43 or cy46 (if available)
- ENS BlendVar
- uncertainty representation of surface processes
- stochastic parameter perturbations (SPP)
- decision-making criteria based on EPS
- HARP verification

Thank you for your attention!