Working Area Predictability

Progress Report

Prepared by:	Area Leader Martin Belluš
Period:	2020 (January-August)
Date:	September 2020

Progress summary

Despite several unfavorable circumstances which are happening since the beginning of the year, the commencing of the operational utilization of three ensemble systems operating within the RC LACE consortium (A-LAEF, C-LAEF and AROME-EPS) can be considered as progressing very well.

Unfortunately, due to the first and second waves of COVID-19 disease, there were no research stays organized this year (at least till August). The RC LACE stay of Réka in Bratislava was planned for April/May, then postponed to June/July, to be finally shifted to November. Although, with respect to the current situation and closed borders it is very uncertain what will eventually happen. My personal health issues preventing me from travelling either. Last 6 months we have been working mostly from the home offices. Therefore, we haven't been even thinking about the realization of other planned stays in such situation, not to mention the postponed stays from the previous year. Nevertheless, this doesn't necessarily mean a stagnation. There has been done a lot of work, locally with the remote access.

Scientific and technical main activities and achievements, major events

S1 Action/Subject/Deliverable: Optimization of A-LAEF

Description and objectives: This subject summarizes ongoing and completed tasks of the A-LAEF research and development. Achieved results, new tested implementations and gained expertise are going to be used for the further improvement of our common regional ensemble forecasting system.

- ❑ **Topic 1: A-LAEF operational runs (case studies)**

In the first half of 2020 a lot of work was done on A-LAEF suite in order to achieve the status of time critical application (see more details in S2). Since May 12 the full 3-day forecasts from A-LAEF suite were disseminated to the two RC LACE members (Slovakia and Slovenia) via operational ECPDS streams. This was indeed very good occasion to look at the forecasts very closely. What's more, the spring and summer seasons were rich in terms of extreme weather events.

- **Central Europe - Windstorm of February 10, 2020**

Just one week after the intensive windstorm called Petra (February 4th) with the wind gusts 25 to 30 m/s at the AT-SK-HU borders, there was a strong wind situation again - during the cold front passage on February 10, 2020 (see figure 1).

This time wind gusts were over-predicted by the deterministic model (see figure 3). That might have been a reason, why the highest warning level (3rd) for strong wind was issued again, even though the reality was not that bad. This was subsequently confirmed by the A-LAEF ensemble, where the threshold for level 3 wasn't reached (or better saying it was with very small probability only, see figure 2). Unfortunately, that time A-LAEF forecasts were not yet available to the forecasters in real time.

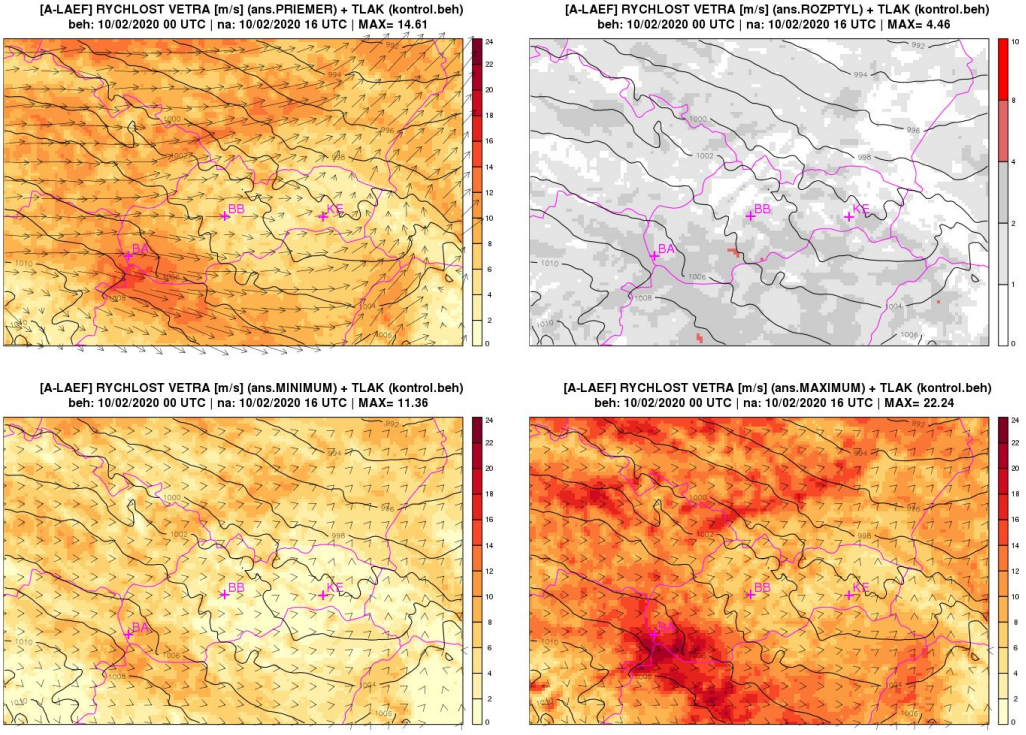

Figure 1: A-LAEF forecast of average wind speed and direction (ensemble mean top left, ensemble spread top right, minimum of ensemble bottom left, maximum of ensemble bottom right), in the background with MSLP from a control run. Valid at 16 UTC, February 10, 2020.

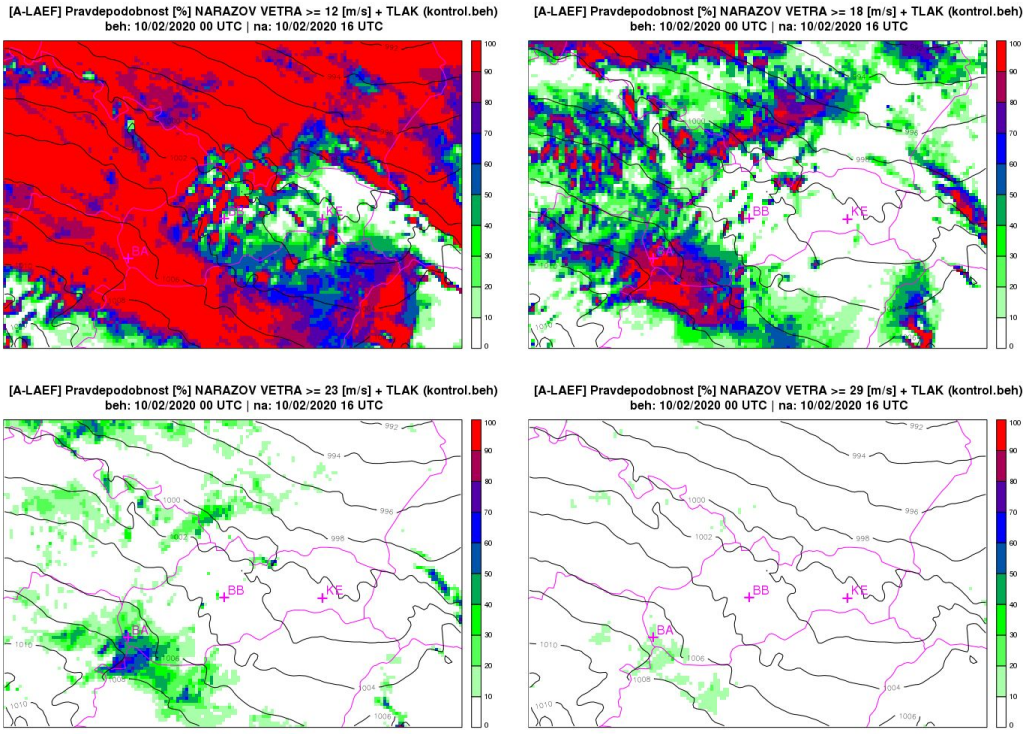

Figure 2: Probability of wind gusts for thresholds 12, 18, 23 and 29 m/s according to the A-LAEF ensemble forecast from February 10, 2020, 00 UTC valid at 16 UTC, in the background with MSLP from a control run.

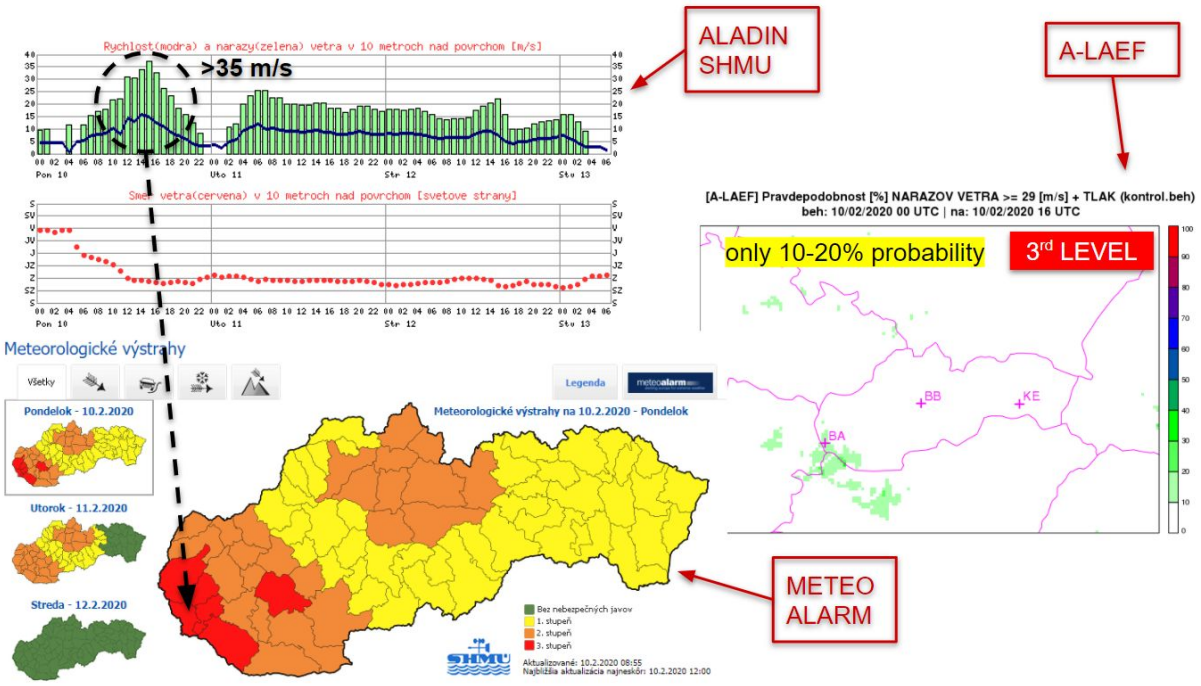

Figure 3: The operational deterministic forecast of wind gust in form of meteogram for Bratislava, A-LAEF wind gusts probability for threshold >= 29 m/s and issued meteorological warnings, for February 10, 2020.

- **Hungary - Extensive floods of July 24-25, 2020**

There were extremely high precipitation totals in just 24 hours (from July 24, 06 UTC till July 25, 06 UTC) in south-western part of Hungary.

According to the precipitation analysis by OMSZ (see figure 4, bottom left), up to 178 mm of precipitation fell, which caused extensive floods. The situation was captured by deterministic models, but the localization of maxima wasn't good enough to refine the warnings, as the precipitation amounts above 100 mm in 24 hours were predicted over relatively large territory.

The A-LAEF ensemble mean (or maximum of the ensemble) better corresponds to the real distribution of the precipitation field (see figure 4). The situation is also well illustrated by the probabilities of 24-hourly precipitation totals for the threshold values of 10, 20, 50 and 100 mm on figure 5.

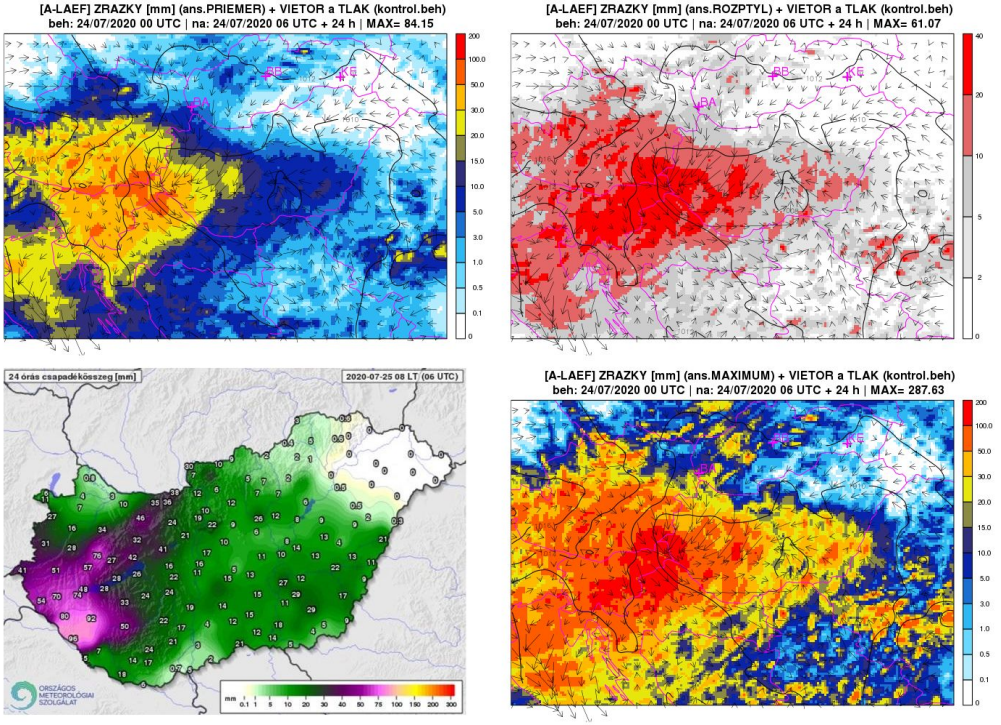

Figure 4: Total precipitation forecast for the period from July 24, 06 UTC to July 25, 06 UTC (A-LAEF ensemble mean top left, ensemble spread top right, maximum of ensemble bottom right), in the background with MSLP and wind barbs from a control run, and the analysis of 24-hourly precipitation totals for the same period in Hungary (bottom left, source: OMSZ). Note: maps are not in the same scale.

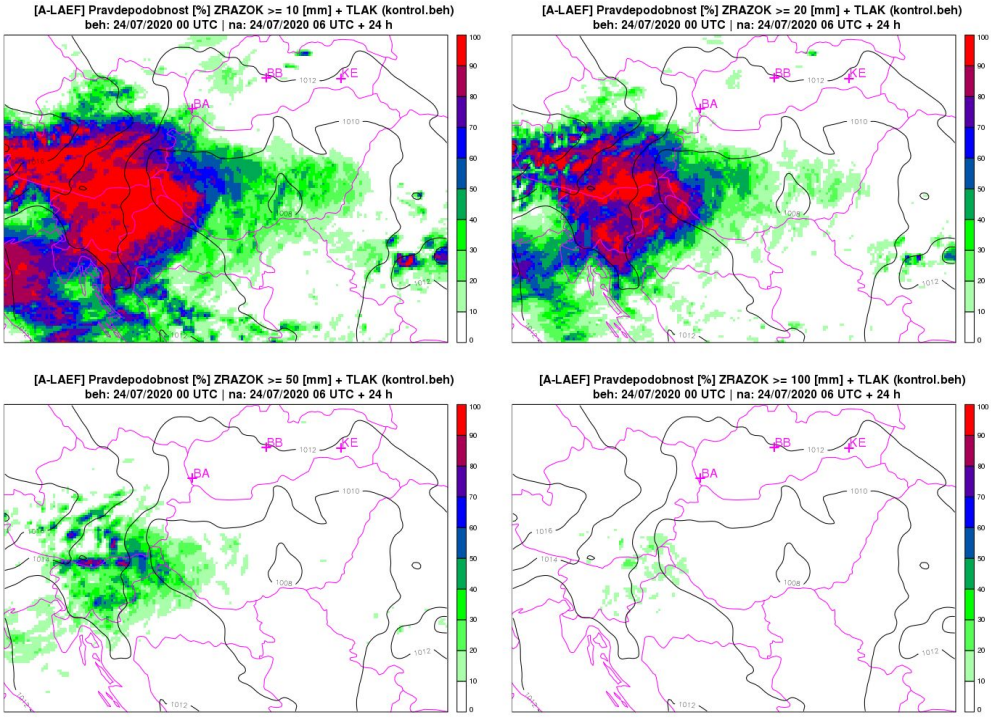

Figure 5: Probability of total precipitation for the threshold values of 10, 20, 50 and 100 mm in 24 hours, predicted by A-LAEF ensemble for the extreme precipitation event of July 24-25, 2020, in the background with MSLP from a control run.

- **Slovakia - Night storm case of 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 (see figure 6, bottom left).

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.

The A-LAEF ensemble system predicted the situation very well, i.e. the intense precipitation formed into a line of instability propagating from west to east (see figures 6 and 7) and the associated strong wind and wind gusts (see figures 8 and 9).

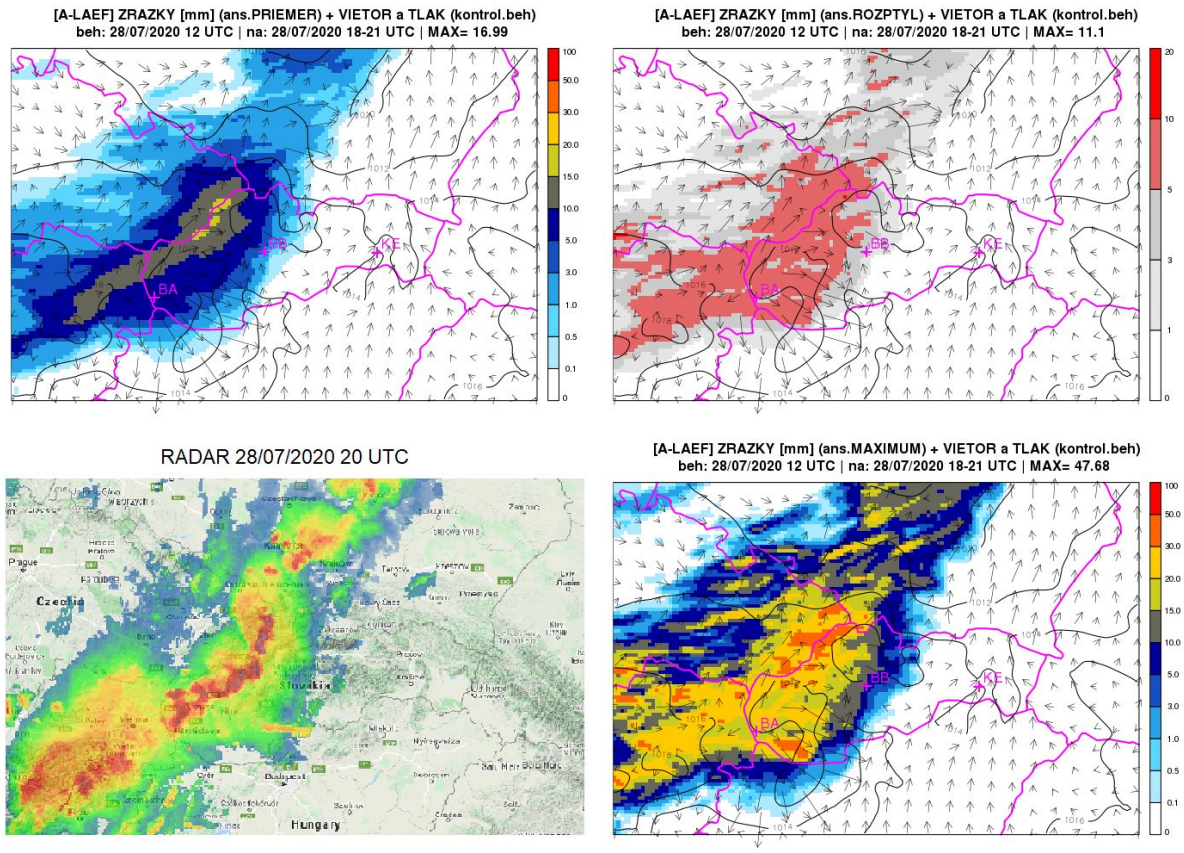

Figure 6: A-LAEF cumulative precipitation forecast of July 28, 2020, 12 UTC valid for 18 to 21 UTC (ensemble mean top left, ensemble spread top right, maximum of ensemble bottom right), in the background with MSLP and wind barbs from a control run, and combined radar information of July 28, 2020, at 20 UTC (bottom left).

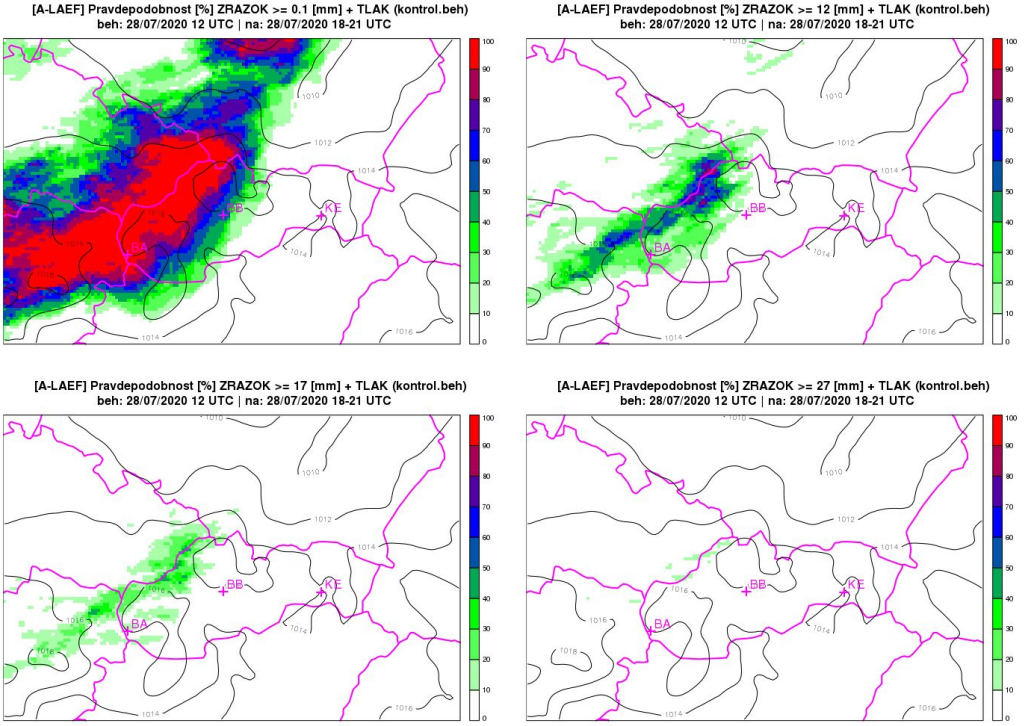

Figure 7: Probability of precipitation on July 28, 2020, valid for 18 to 21 UTC for the threshold values of 0.1, 12, 17 and 27 mm in 3 hours according to the A-LAEF ensemble forecast, in the background with MSLP from a control run.

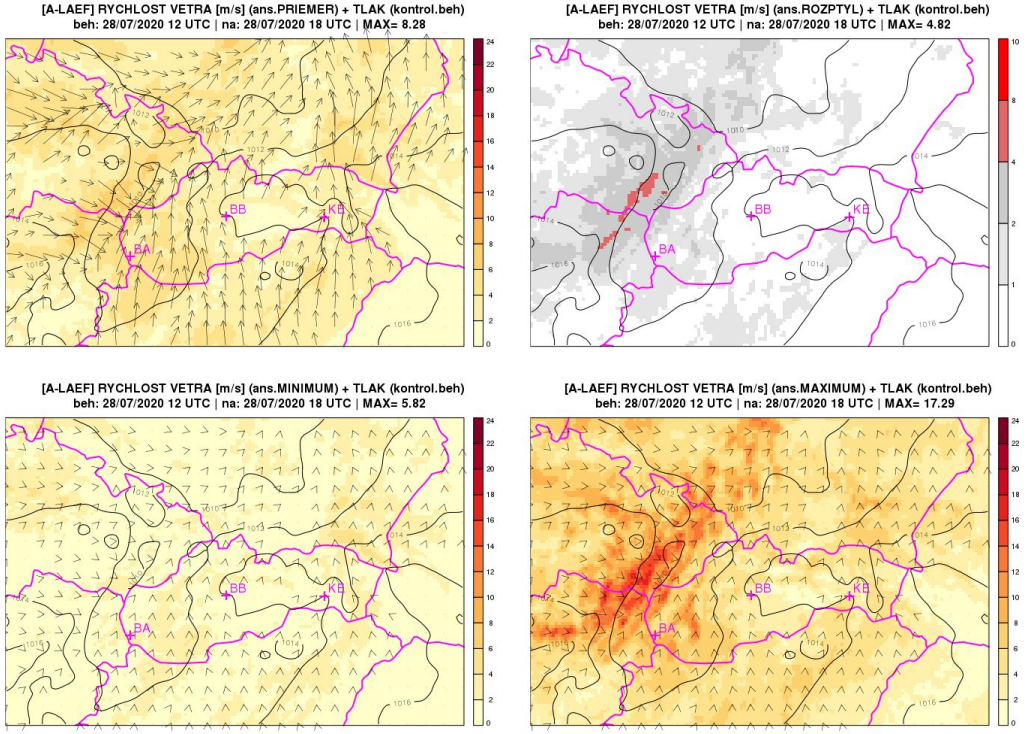

Figure 8: A-LAEF forecast of average wind speed and direction (ensemble mean top left, ensemble spread top right, minimum of ensemble bottom left, maximum of ensemble bottom right), in the background with MSLP from a control run. Valid at 18 UTC, July 28, 2020.

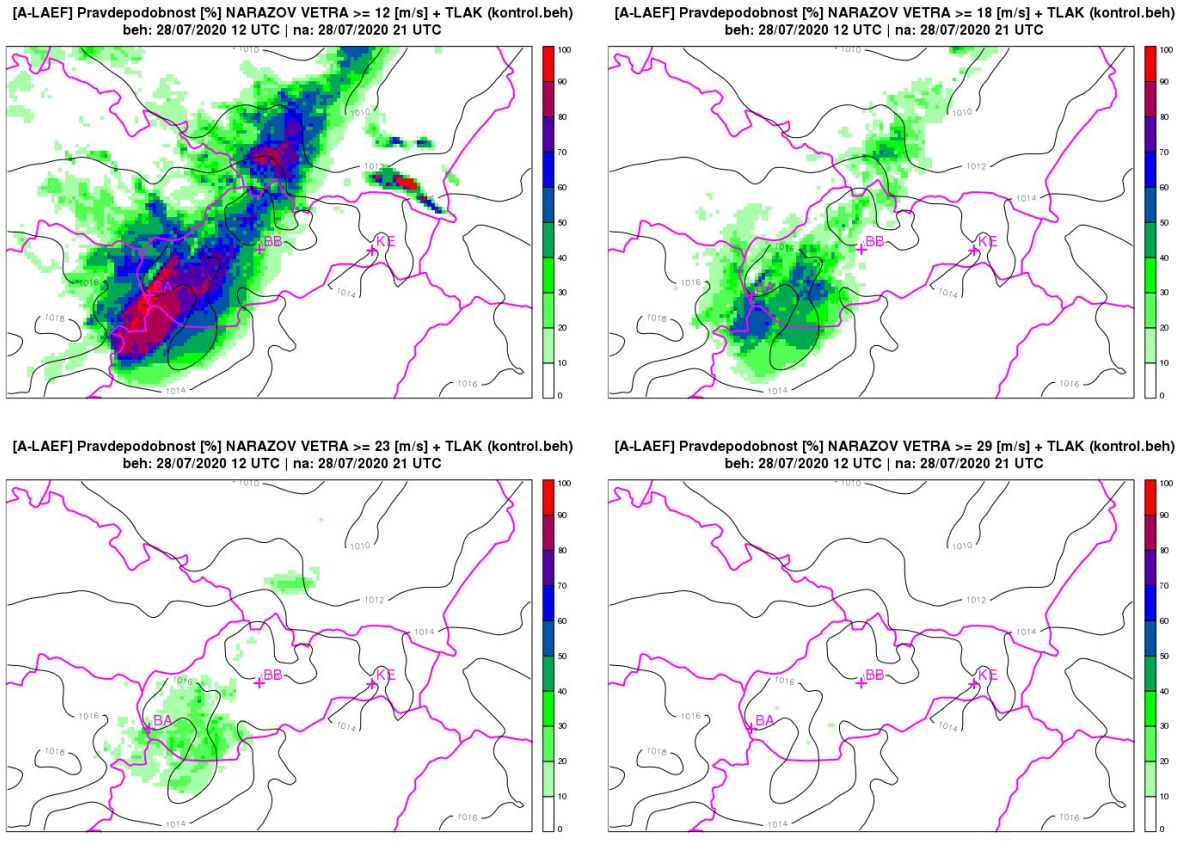

Figure 9: Probability of wind gusts for thresholds 12, 18, 23 and 29 m/s according to the A-LAEF ensemble forecast from July 28, 2020, 12 UTC valid at 21 UTC, in the background with MSLP from a control run.

- **Slovenia - Precipitation case of August 29, 2020**

In Slovenian institute (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.

In the figures 10 and 11 there is just one example of +62h precipitation forecast for the Slovenian domain. Furthermore, in figure 12 one can see 6-hourly precipitation analysis based on 2 Slovenian radars and the observation network, valid for the same time period as the above ensemble forecasts.

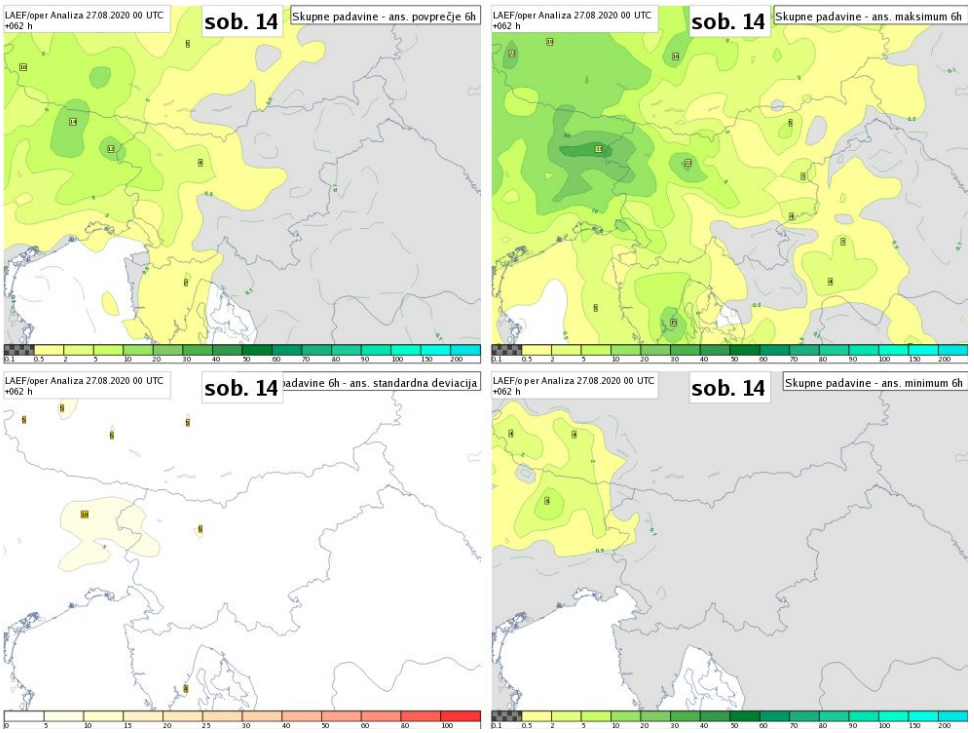

Figure 10: ALADIN-LAEF (old system) precipitation forecast of August 27, 2020, 00 UTC valid for August 29, 8 to 14 UTC (ensemble mean top left, maximum of ensemble top right, standard deviation bottom left, minimum of ensemble bottom right).

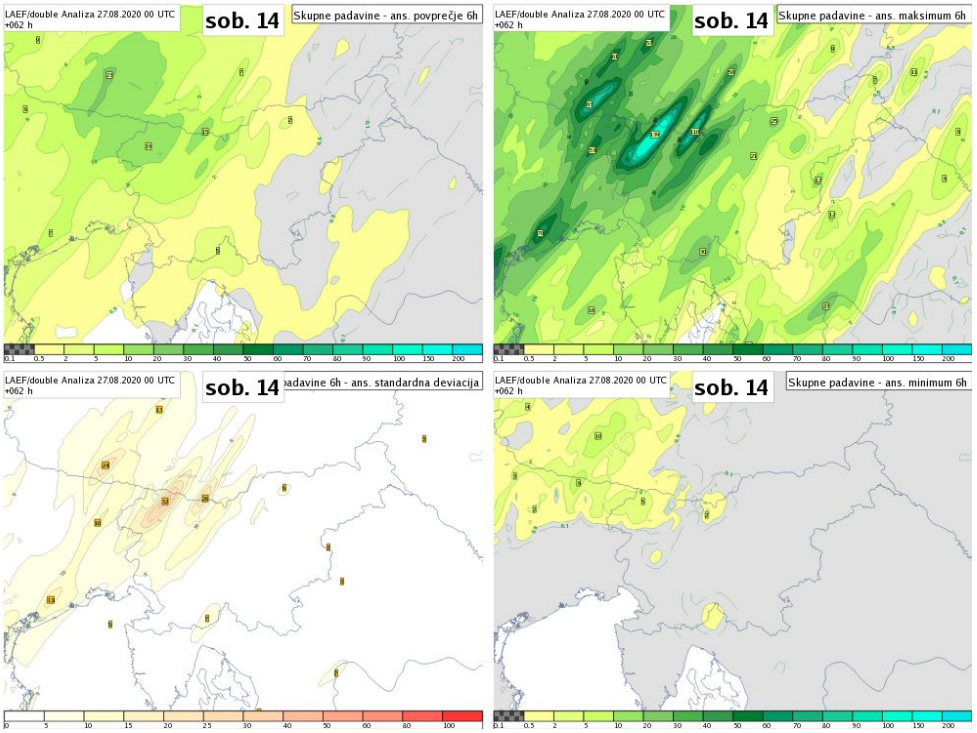

Figure 11: A-LAEF (new system) precipitation forecast of August 27, 2020, 00 UTC valid for August 29, 8 to 14 UTC (ensemble mean top left, maximum of ensemble top right, standard deviation bottom left, minimum of ensemble bottom right).

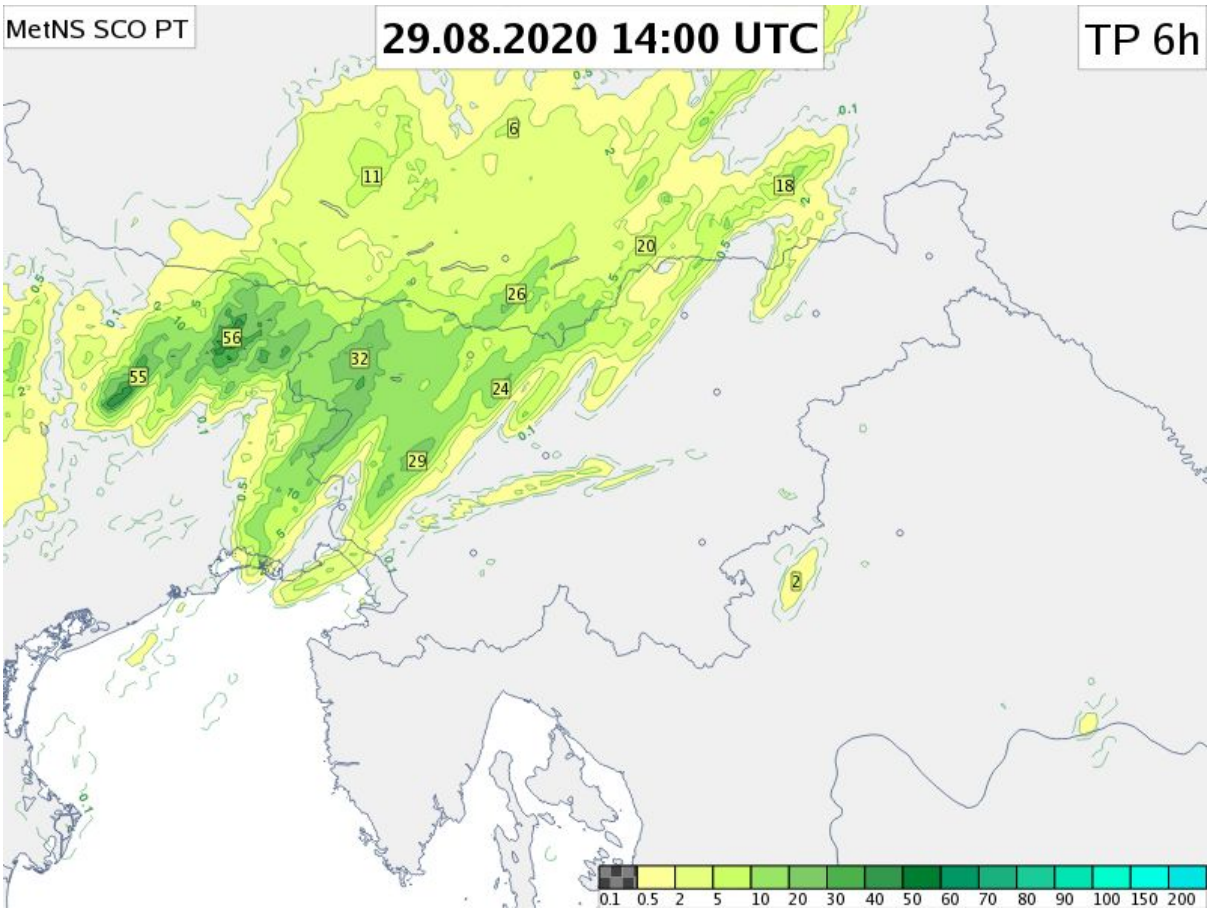

Figure 12: 6-hourly precipitation analysis based on 2 Slovenian radars and the observation network, valid for August 29, 2020, 8 to 14 UTC.

❑ Topic 2: A-LAEF operational maps

A set of probabilistic A-LAEF maps was prepared at SHMU and put to operations using combination of Perl and R-script coding, exploiting parallel processing on the HPC (hence the production of about 500 maps can be processed very quickly). The user interfaces for public website and SHMU intranet were created to enable easy browsing through the A-LAEF probabilistic map products (see figures 13 and 14).

The public website can be reached at http://www.shmu.sk/produkty/nwp/alaef/, but the whole presented information must be restricted to Slovakia (and close neighborhood). Therefore, also an intranet map browser exists to provide both zoomed (SK) and full size domain (LACE) maps, together with even wider selection of products which are not available for the public. Both interfaces are also optimized for running on smartphone devices with small screens and touch control.

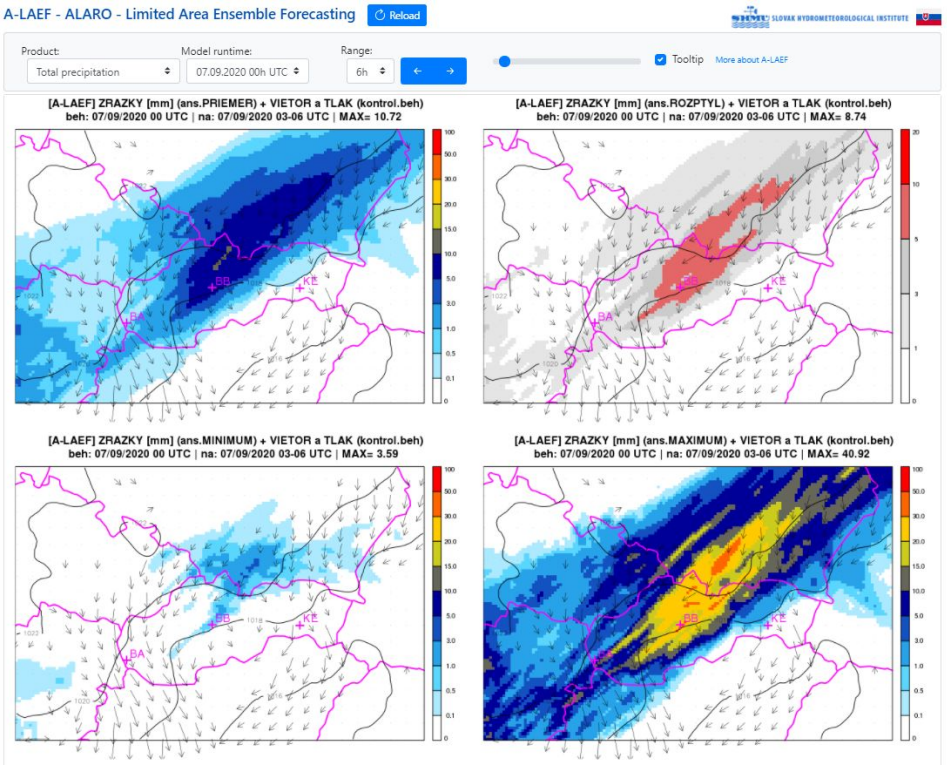

Figure 13: Public website with the operational A-LAEF maps.

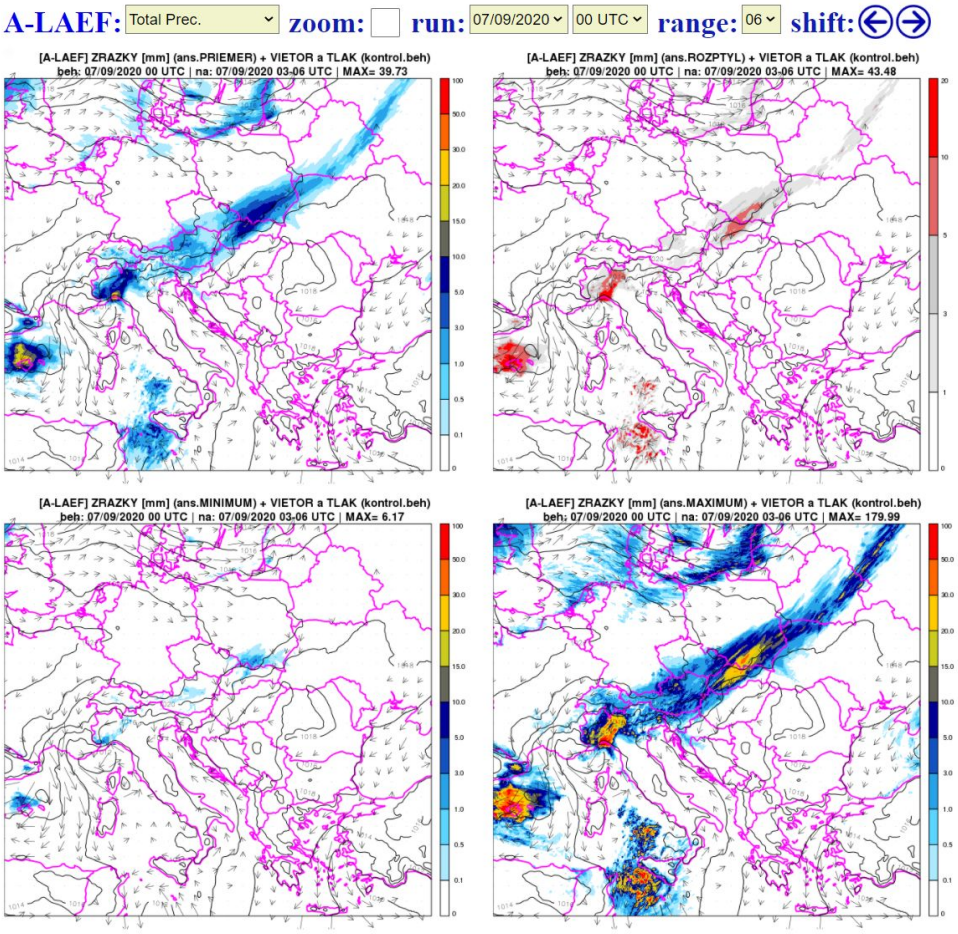

Figure 14: Local intranet site with the operational A-LAEF maps.

❑ Topic 3: QC based on A-LAEF spread

The experiences gained through INCA nowcasting and high resolution ALARO-1 reanalyses on 1-2 km grids lead to a necessity of automatic quality control (QC). Without a proper QC, the automatic weather station (AWS) measurements often brought a spurious signal into the analysis. A physically consistent spread of the meteorological fields provided by the A-LAEF ensemble was the main motivation for its use in an automatic QC procedure (in a new software layer above MySQL database). It is something, the deterministic model cannot provide. As a first attempt the QC of 2m temperature was tested at SHMU. The suspicious AWS measurements with values out of the A-LAEF spread were identified (see figure 15).

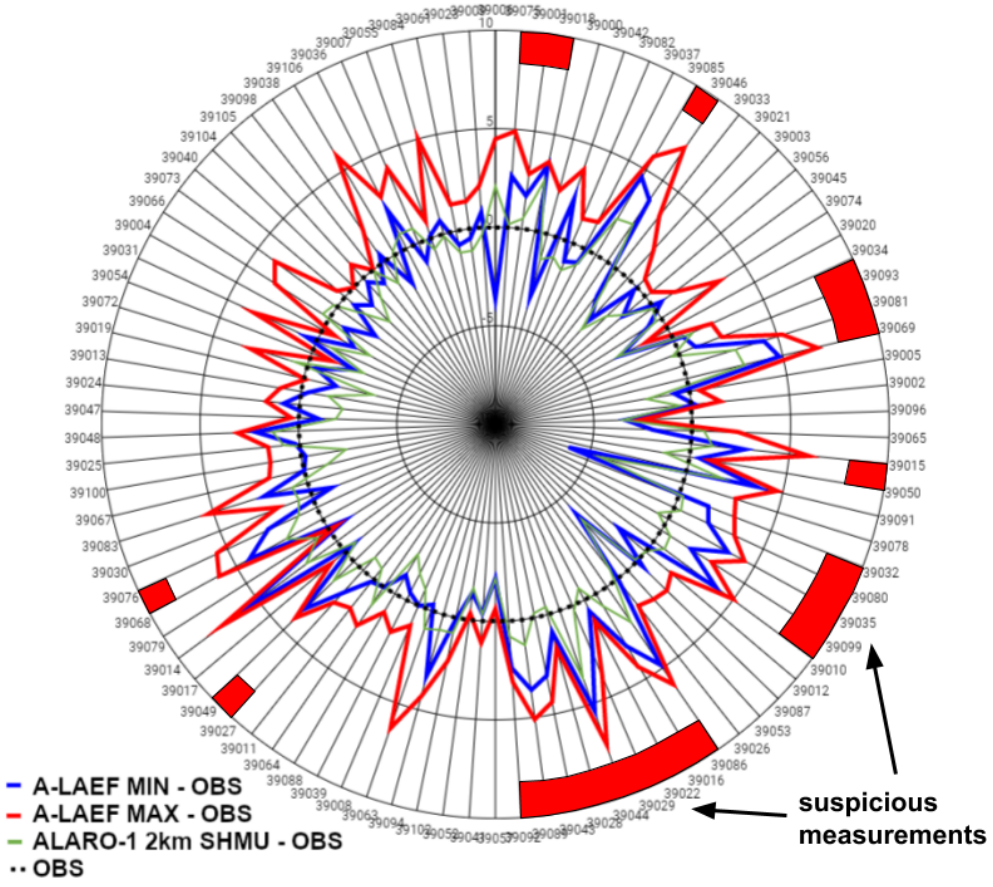

Figure 15: Quality control for the AWS measurements based on A-LAEF ensemble spread.

Efforts: 3.5 PM

Contributors: Martin Belluš (SHMU), Neva Pristov (ARSO), Michal Neštiak (SHMU)

Documentation: Reports on stays; presentations; papers for publication in scientific journals

Status: Ongoing

S2 Action/Subject/Deliverable: A-LAEF maintenance

Description and objectives: The main objective of this task is to maintain and monitor the operational suite of A-LAEF running at ECMWF HPC facility. As a result a stable operational suite of A-LAEF is guaranteed and the delivery of probabilistic forecast products (GRIB files) for the LACE partners is ensured.

❑ Topic 1: A-LAEF TC2 operational suite under ecFlow

Development of A-LAEF system continued in the first half of 2020 very intensively, which eventually led to a formal acceptance of the suite as Time Critical 2 application. The work was executed under the LACE's TC user at ECMWF HPCF remotely from SHMU (in particular from Home Office).

Huge effort was put into the final tuning and to several technical upgrades of the A-LAEF suite to meet the ECMWF's requirements for TC2 application. The suite was migrated to ecflow client/server 5.4.0 with schedule 1.7 allowing for proper implementation of ECF_KILL_CMD and ECF_STATUS_CMD (tools used mainly by the operators). The usage of disk space was optimized, reducing the temporal storage of big global input data delivered via local ECPDS distribution. Furthermore, a white list was implemented to ensure the access to the ecflow tasks only for the authorized users. For more advanced monitoring, the possibility to see live output from running jobs was included as well. Last but not least, the structure of the suite was reorganized in order to have a separate dissemination family to send the products to different destinations (see figure 16). The benefits of such solution are being a) optimal load on the network lines, b) possibility to restart or suspend the entire distribution at once (if necessary) and c) distribution of products clearly separated from the rest of the suite (easy for the operators).

Except for the above technical upgrades of the suite, finally also the unperturbed control run was added into the A-LAEF ensemble. This was instantly utilized by the Croatian meteorological service who backed up its production at ECMWF after the earthquake (DHMZ building hosting also their computer was damaged in March 2020). To set up their data assimilation at ECMWF HPCF in such a short time was not possible. Instead, they have used the initial conditions obtained from the unperturbed member of A-LAEF ensemble (A-LAEF system involves the surface assimilation and the upper-air spectral blending by DFI).

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. The suite is running well (see figure 17), and no single crash was present at least within the last 10 months (except the occasional delays due to queuing at HPCF when it wasn't yet running in the priority queues prior to July 2020).

During July also the available billing units (SBUs) used for running A-LAEF suite were almost depleted. Thanks to a prompt reaction of Slovenian partner the allocation of our operational account (allaefop) was increased by 20 mio SBUs. Current allocation for this year reads 70 mio SBUs (HR 30 + SI 40) with already 60

mio used for the operations up to now. Therefore, another refill of billing units will be needed very soon (within one month).

For more details about the current status of A-LAEF suite at ECMWF, please see the updated technical documentation from June 2020, attached at the end of this report.

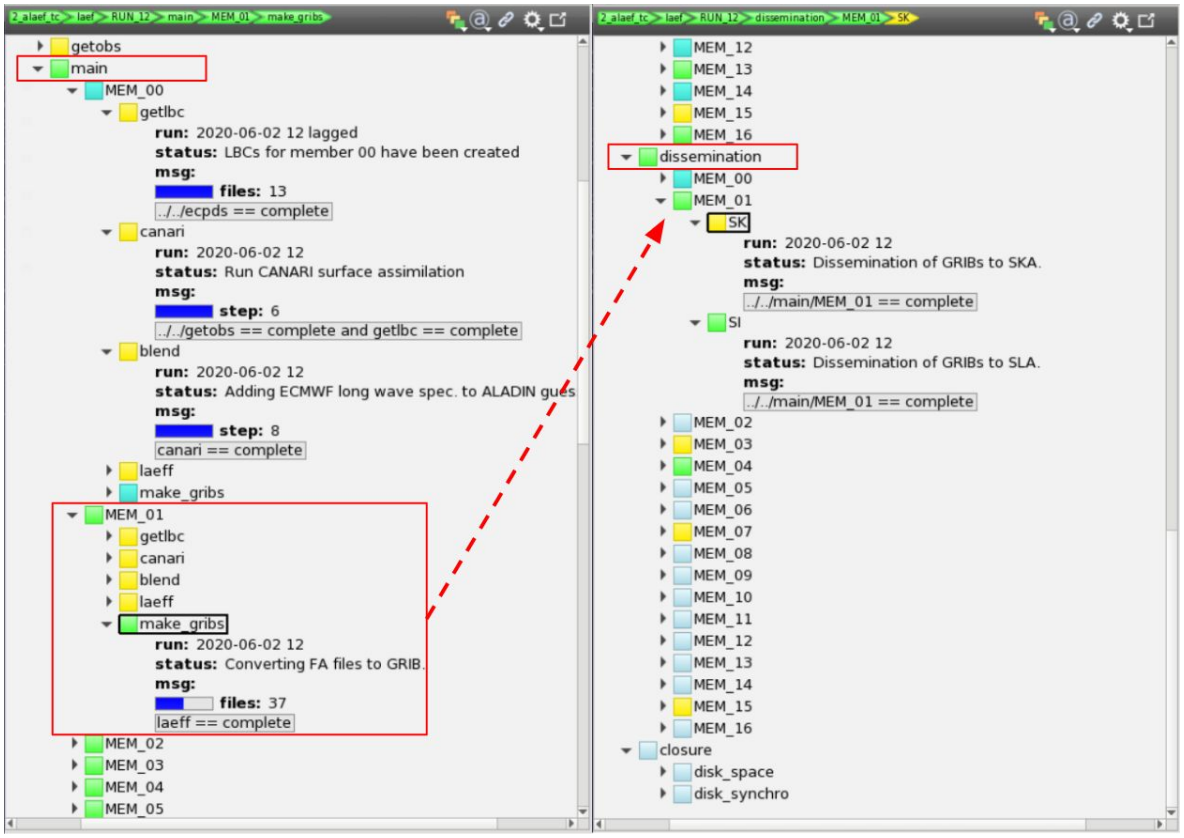

Figure 16: User interface (ecFlow) for A-LAEF suite with new dissemination family.

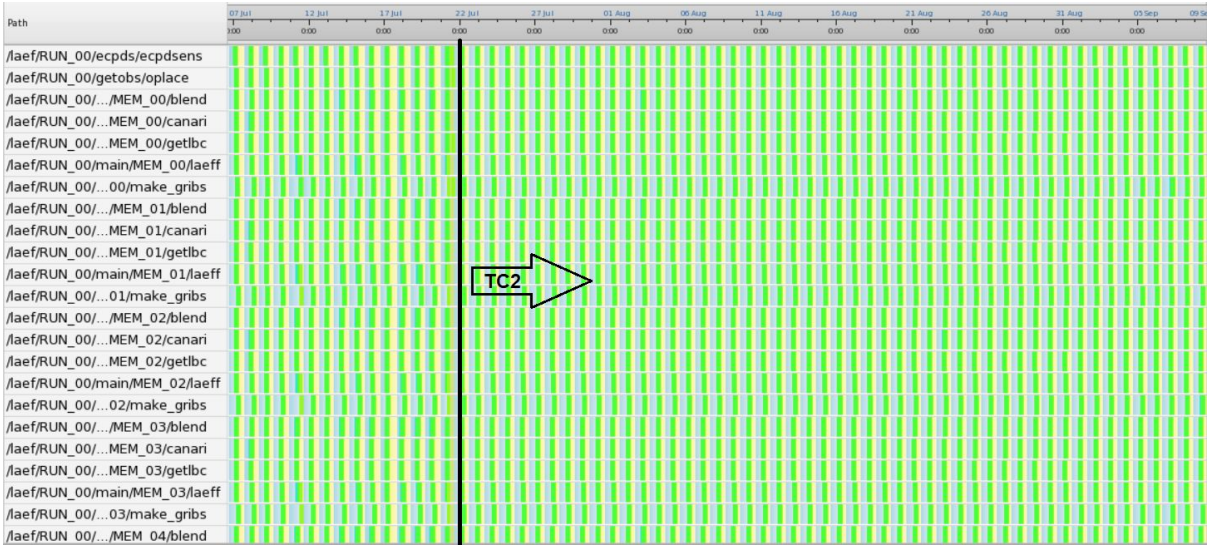

Figure 17: Timetable of some A-LAEF tasks from July 7 till September 9, 2020.

Table 1: Time duration of main A-LAEF tasks for +72h forecast length and their

usual finishing wall clock time for 00 and 12 UTC runs.

Task	CPUs	+72h forecast (duration)	00 UTC (wall clock)	12 UTC (wall clock)
ecpdsens	1	00:22:00	00:52-00:54	12:52-12:56
oplace	1	00:00:30	00:53-00:55	12:54-12:56
getlbc	36	00:06:00	00:57-00:59	12:57-12:59
canari	288	00:02:45	01:00-01:02	13:00-13:05
blend	288	00:08:00	01:08-01:11	13:08-13:14
laeff	288	02:02:00	03:08-03:15	15:06-15:16
make_gribs	18	00:01:30	03:11-03:17	15:09-15:20

Efforts: 5 PM

Contributors: Martin Belluš (SHMU), Martina Tudor (DHMZ), Neva Pristov (ARSO)

Documentation: Flow charts; presentations; reports; technical documentation of A-LAEF TC2 suite running at ECMWF

Status: Development and upgrade of ecFlow scripts; A-LAEF suite implementation under the time critical environment at ECMWF HPCF; maintenance tasks

S3 Action/Subject/Deliverable: AROME-EPS

Description and objectives: This task covers research and development of the convection-permitting ensembles. Such high-resolution ensembles utilizing non-hydrostatic model AROME are developed concurrently at OMSZ and ZAMG institutes.

- **Topic 1: EPS related development at OMSZ**

At OMSZ, a non-hydrostatic convection-permitting system AROME-EPS is being developed and operationally used, running on their new HPC. New system runs once per day coupled to 18 UTC run of ECMWF ENS. In the lagged mode the forecast from 00 UTC is produced for the next +48h. The ensemble comprises 10 members + 1 control forecast, and covers a Carpathian Basin domain with the horizontal grid spacing of 2.5 km (see figure 18). For the time being there is no assimilation cycle involved and the initialization uses first guess (hydrometeors) and surface analysis of deterministic AROME, which runs with 3-hourly assimilation cycle. The upper-air fields are downscaled from the boundary conditions.

AROME-EPS runs operationally at OMSZ since February 4, 2020, with the following configuration:

- Forecast range: +48h (00 UTC)
- LBCs: ECMWF ENS at 18 UTC (6-hourly lagged)
- Coupling frequency: 3h
- Resolution: 2.5 km with 60 vertical levels
- Domain: AROME/HU
- Number of ensemble members: 10 + 1 control forecast
- Data assimilation: not yet available
- Model: AROME cy40

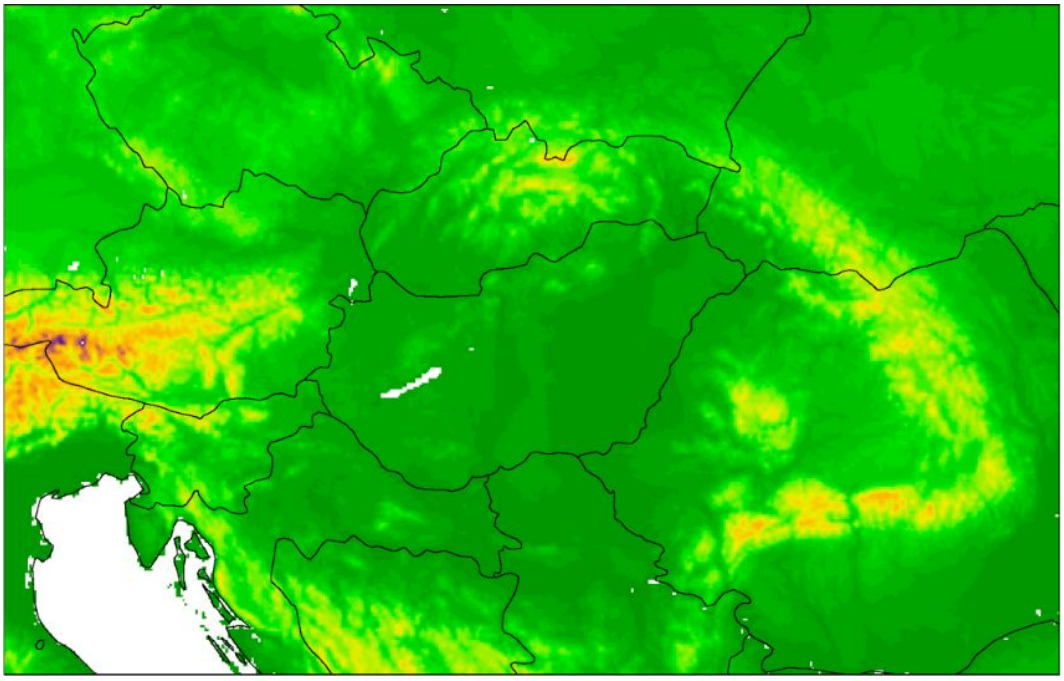

Figure 18: Integration domain of the operational AROME-EPS.

To see the strengths and weaknesses as well as the seasonal variation of AROME-EPS quality, a comparison of ALARO-EPS (ALEPS) and AROME-EPS (AREPS) have been made for a longer period (from June 2019 till January 2020), covering three seasons of parallel run. For the main surface parameters, the following conclusions can be drawn:

- Wind gust is getting better for the ensemble mean of the convection-permitting EPS in all seasons (on average with ca. 0.5 m/s; see figure 19, left). For the average wind, this is also true, except for the convective season (June – September) in the afternoon hours.

- For 2-meter temperature, relative humidity (see figures 20 and 21), total cloudiness, and in the convective season, also mean sea level pressure (MSLP) have a lower RMSE of EPS mean for AROME-EPS in the daytime

hours, but get worse during the night. Except convective months, AROME-EPS has a better quality in these parameters, than ALARO-EPS. This can be an important aspect for users (e.g. for renewable energy sector).

- For precipitation, one can see lower RMSE values in winter and autumn, and higher values in summer for the AROME-EPS forecast, especially in the afternoon hours, when thunderstorm activity and heavy precipitation events occur most frequently (see figure 19, right).

It must be stressed, that a point-wise verification method was applied, therefore the other methods are being initialized, e.g. investigating the interesting events through case studies.

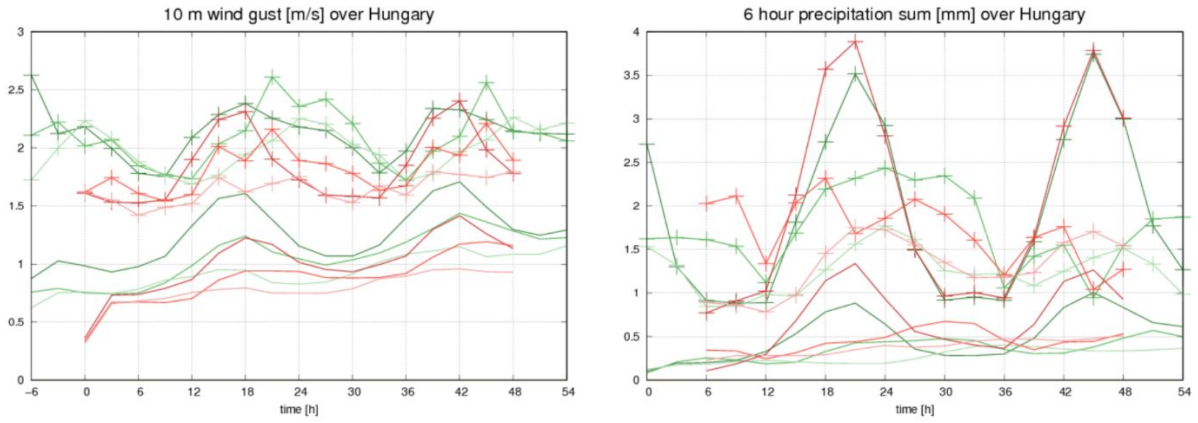

Figure 19: RMSE of ensemble mean (symbols) and EPS spread (solid) of ALARO-EPS (green), AROME-EPS (red) for wind gust (left), 6-hourly precipitation sum (right), for three months in the convective season: July, August and September 2019 in dark/base/light colors, respectively.

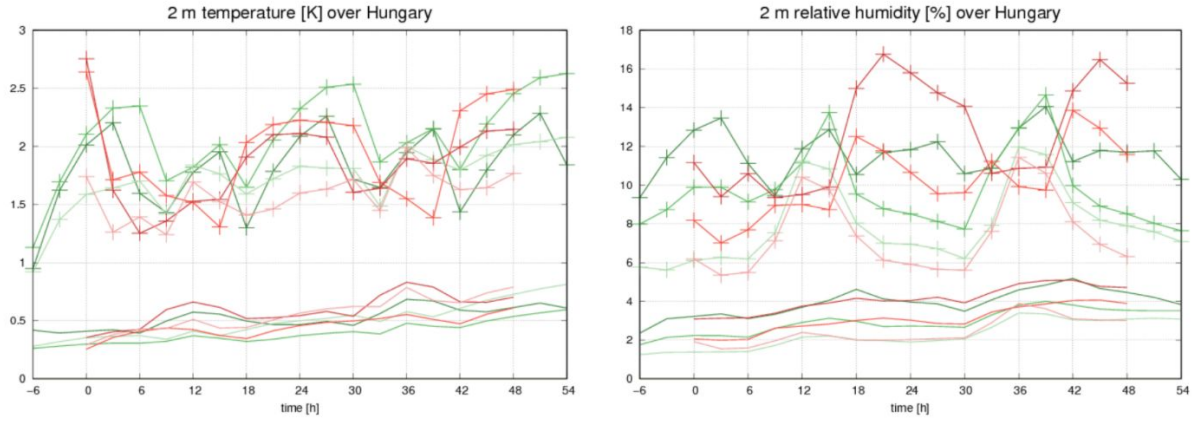

Figure 20: RMSE of ensemble mean (symbols) and EPS spread (solid) of ALARO-EPS (green), AROME-EPS (red) for 2m temperature (left) and relative humidity (right), for autumn 2019: September, October, November in dark/base/light colors, respectively.

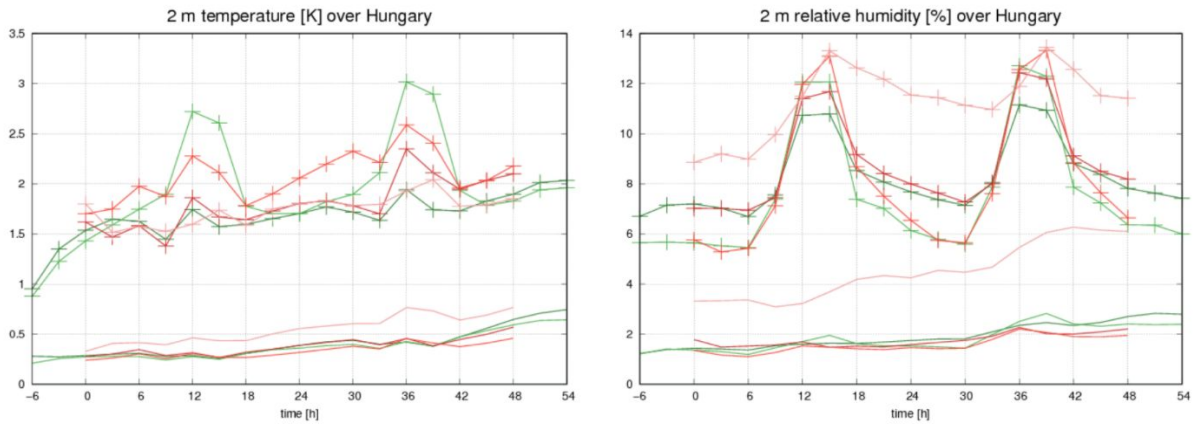

Figure 21: RMSE of ensemble mean (symbols) and EPS spread (solid) of ALARO-EPS (green), AROME-EPS (red) for 2m temperature (left) and relative humidity (right), for winter 2019-2020: December 2019, January and February 2020 in dark/base/light colors, respectively.

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 00 UTC AROME run. In the seasonal average, this is the case for 10-meter wind speed, wind gust, cloudiness, 2-meter temperature and precipitation, which underlines the advantages of EPS in contrast to a deterministic forecast (see figure 22).

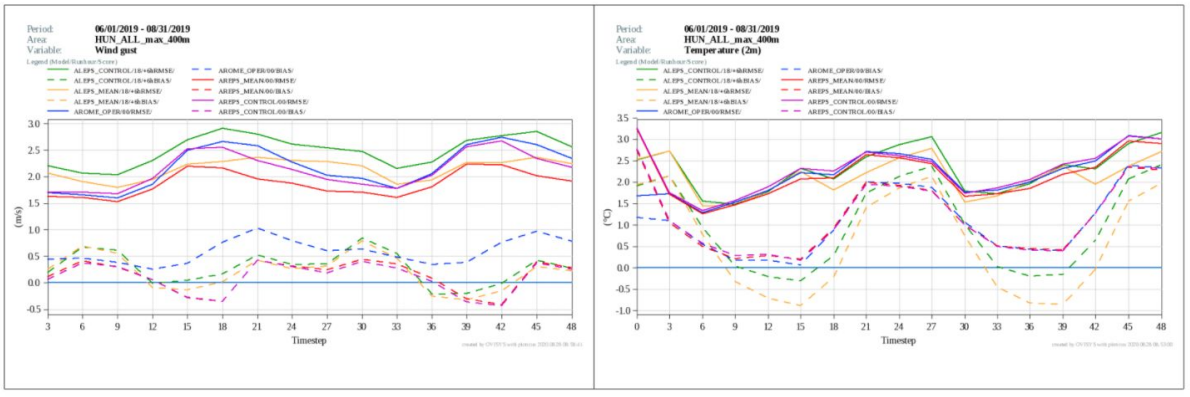

Figure 22: RMSE (solid) and bias (dashed) of AROME-EPS mean (red), control (purple), ALARO-EPS mean (yellow), control (green), compared to AROME deterministic run (blue) for wind gust (left) and 2m temperature (right), for the summer 2019 (June, July, August).

Because the forecasters are satisfied with the new AROME-EPS outputs, the parallel run of ALARO-EPS was finally terminated as of July 22, 2020.

❑ Topic 2: EPS related development at ZAMG

Convection-permitting - Limited Area Ensemble Forecasting system (C-LAEF) is being developed at ZAMG, running operationally at ECMWF HPCF as a time critical 2 application.

C-LAEF is based on non-hydrostatic AROME model with a horizontal resolution 2.5 km and 90 vertical levels. It has 16 perturbed members (and 1 unperturbed control run) coupled to the first 16 members of ECMWF-EPS. The initial condition uncertainties are represented by 3D-Var EDA with ensemble Jk method and by screen-level observation perturbations in CANARI. The assimilation cycles are performed every 6h. Model error is represented by a hybrid stochastic perturbation scheme, where perturbation of tendencies in shallow convection, radiation and microphysics are combined with parameter perturbations in the turbulence scheme.

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).

In the first half of 2020, the following activities were realized:

- Implementation of new cy43t2 at the ECMWF HPC
- Local phasing of C-LAEF related code in cy43t2 (perturbation scheme, etc.)
- Preparation of bugfixes for cy43t2_bf11 phasing (orographic shadowing, sunshine duration, etc.)
- Re-coding Endi's EnsembleJK code for cy43 to get rid of external process step (using epygram) to switch between grid point / spectral representation for humidity in EnJk
- Set-up of a complete C-LAEF e-suite with cy43t2 including adaption of script system
- New observations (GNSS, Mode-S, …) were tested in C-LAEF EDA; several short e-suites with different sets of new observations were prepared and verified (see figure 23)
- C-LAEF SPP scheme was extended by the additional perturbation in microphysics for 2 processes connected to sublimation of snow/graupel (see figure 24)
- Different orographies (GMTED, GTOPO, filtered vs. non-filtered) were tested and their impact on temperature in Alpine valleys / mountain tops was checked
- Time lagged EPS out of AROME-RUC was created using neighborhood methods (see figures 25 to 27)

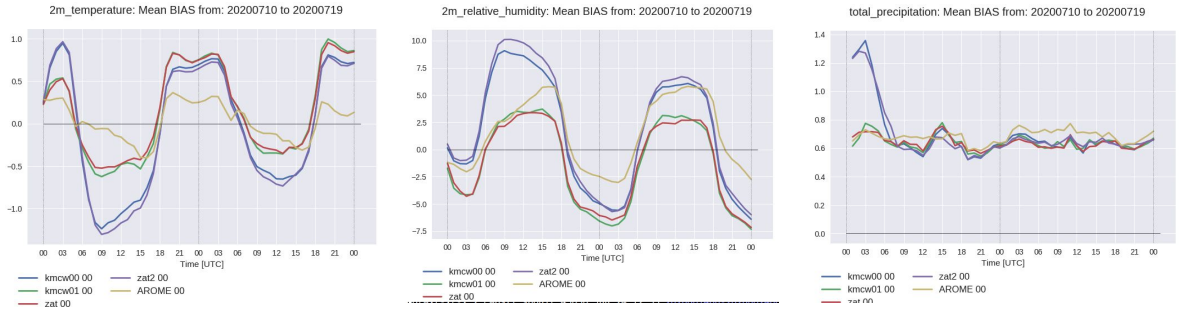

Figure 23: Verification of different sets of "new observations" for 1 week (July 10 – July 19, 2020).

First verification results (see figure 23) show a problem with 2m temperature and humidity during the day. There is also too much soil moisture, caused by a positive precipitation bias in the first forecast hours. The problem was identified to come from the variational bias correction for GNSS data. Adaptation time was set too long by default, which was already changed. Although, further tests are not yet evaluated due to the paternity leave of Clemens.

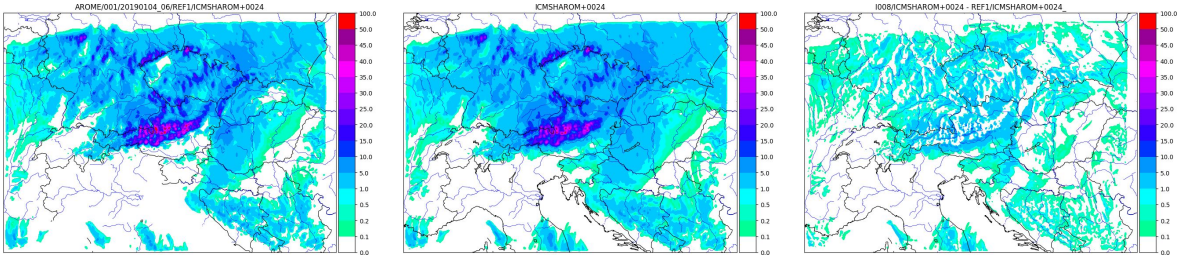

Figure 24: Sensitivity tests on sublimation of snow/graupel in wintertime in modified C-LAEF perturbation scheme (reference left, experiment with reduced sublimation middle, difference between EXP and REF right).

Furthermore, the AROME-RUC-PEPS system 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. AROME-RUC-PEPS visualization was implemented in Visual Weather (see figures 25 to 27).

Post-processing of precipitation probabilities within AROME-RUC-PEPS:

- The calculation of upscaled probability fields was implemented
- Outputs being in grib (version 1) files that contain the calculated probability fields
- Probabilities for different thresholds and upscaled probabilities can be calculated for different search radius using different methods (maximum probability, mean probability, and further methods are subject of current work)
- The visualization of probability grib files has some technical issues in Visual Weather software

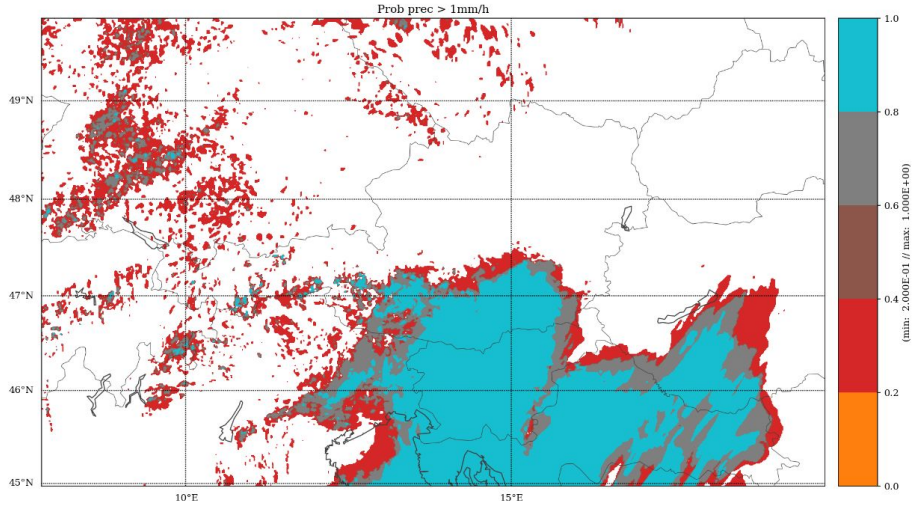

Figure 25: AROME-RUC-PEPS - the probability (grid-point wise).

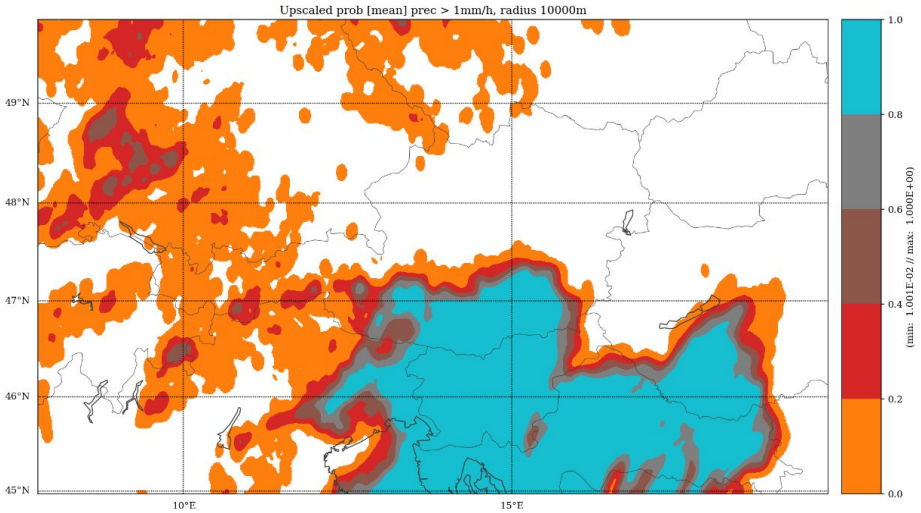

Figure 26: AROME-RUC-PEPS - upscaled probability (mean of all grid-points within 10 km radius).

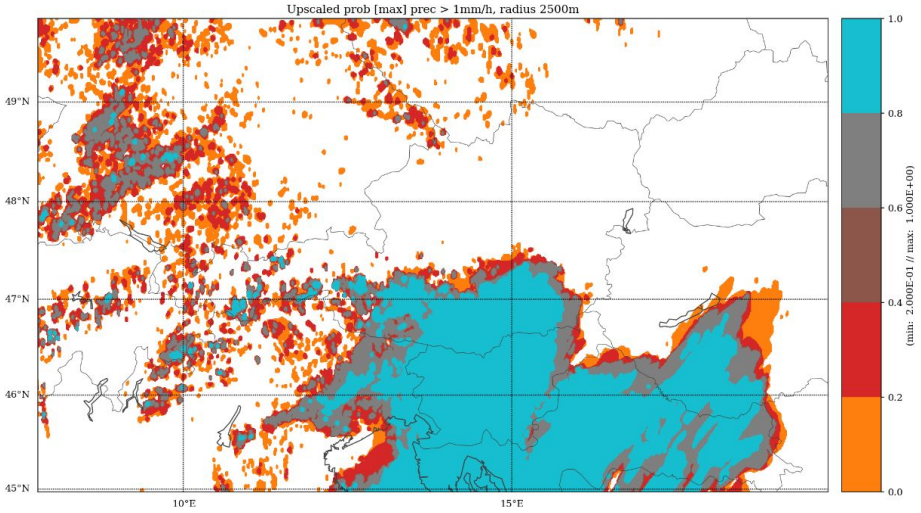

Figure 27: AROME-RUC-PEPS - upscaled probability (max of all grid-points within 2.5 km radius).

Efforts: 12 PM

Contributors: Réka Suga, Viktória Homonnai, Katalin Jávorné-Radnóczi (all OMSZ), Christoph Wittmann, Clemens Wastl, Florian Weidle (all ZAMG)

Documentation: Reports on stays; papers for publication in scientific journals

Status: C-LAEF suite implementation under the time critical environment at ECMWF HPCF; AROME-EPS development and operational runs at OMSZ

S4 Action/Subject/Deliverable: EPS - Verification

Description and objectives: A robust and reliable verification tool is needed in order to establish the quality and weaknesses of our probabilistic forecasting systems. The huge amount of data must be processed, which requires an appropriate, optimized and flexible verification software.

The LAEF verification tool has being developed, maintained and used already for several years. Since then, distinct versions of the source code have been created under the different users. These versions may diverge from each other and involve various levels of modifications and bug fixes. If we intend to use this verification tool further, it is necessary to merge the latest development under one common library and treat the known bugs equally. Unfortunately, such actions are frozen since 2018.

Another option is HARP verification package, providing suitable tools for probabilistic and mesoscale forecast verification, with focus on spatial aspects as well. It was implemented at SHMU's HPC and tested on the operational A-LAEF grib files. The manipulation with big A-LAEF multi-gribs is very challenging and verification of longer time period would require a lot of disk space and processing time. For the time being, just the very first results (more like a proof of concept) are available. One can see 10-days verification of 2m temperature against the Slovak OBS network in figures 28 and 29.

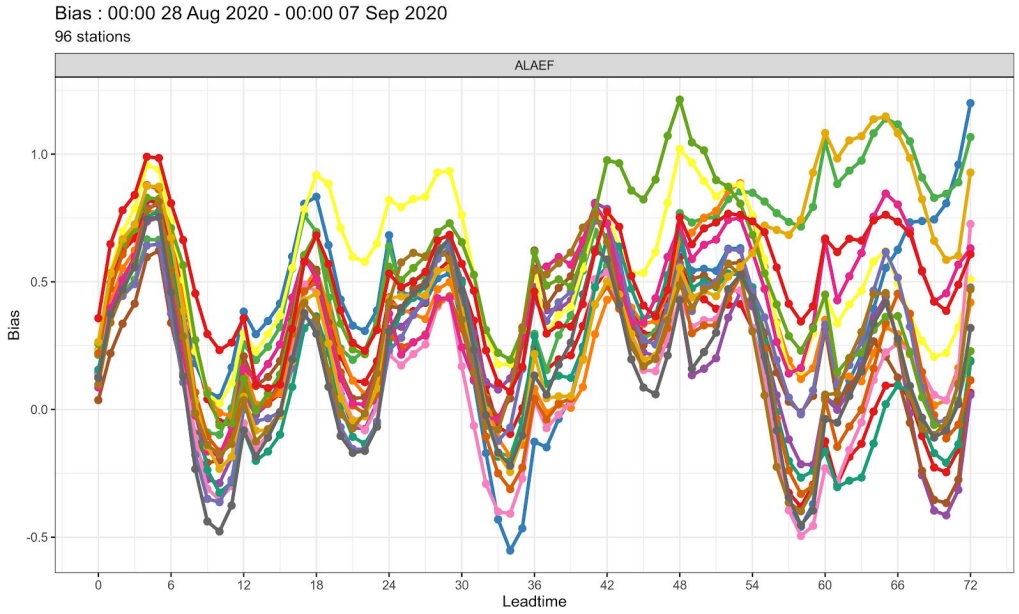

Figure 28: T2m BIAS of individual A-LAEF members for the verification period August 28 - September 7, 2020.

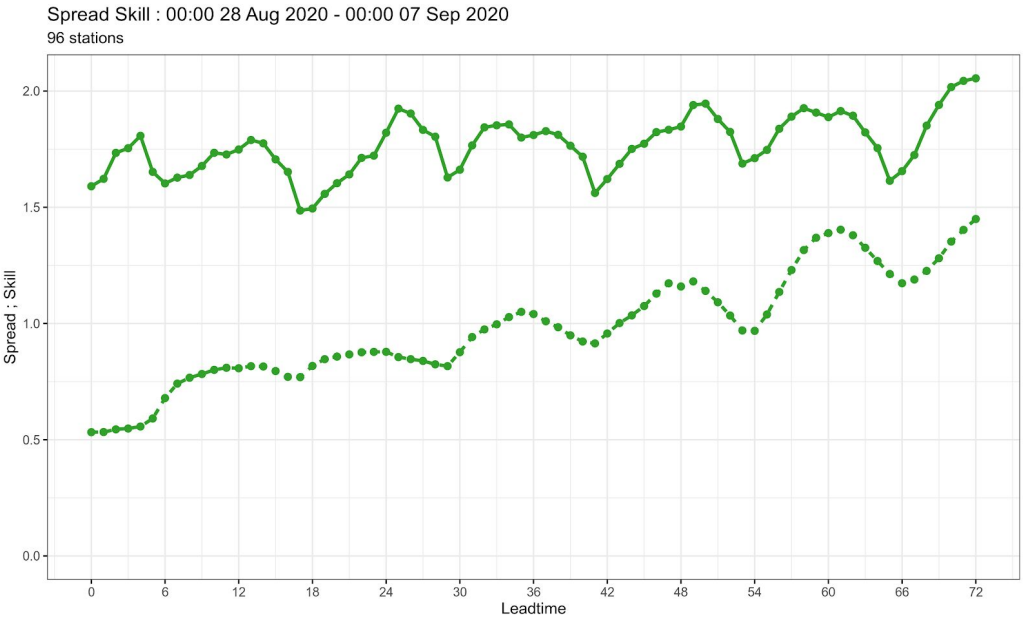

Figure 29: RMSE (solid line) and SPREAD (dashed line) of T2m A-LAEF ensemble mean for the verification period August 28 - September 7, 2020.

Efforts: 2 PM

Contributors: Martin Petráš (SHMU)

Documentation: -

Status: Restored

S5 Action/Subject/Deliverable: Collaborations

Description and objectives: Activities merging different areas, collaboration with other consortia, applications, projects.

Except the standard cooperation between the ALADIN and HIRLAM communities and inter-area collaboration within RC LACE, there is almost nothing to report. An initiative regarding the special project at ECMWF with the aim of Limited Area Ensemble Forecasting has been started by DHMZ partner, involving researchers from SHMU, OMSZ and Meteo Romania. The request was approved by ECMWF (in January 2020), which gives us at least 5 mio SBUs to be spent in 2020 on R&D of new A-LAEF system. Although, depending on the resource situation later in the year we might get additional 5 mio SBUs.

Efforts: 1 PM

Contributors: Martina Tudor (DHMZ), Martin Belluš (SHMU)

Documentation: Request for a special project 2020-2022

Status: Ongoing

S6 Action/Subject/Deliverable: Publications

Description and objectives: The scientific achievements of the LACE EPS R&D activities are being presented at the international workshops and published in the scientific journals.

The full list of recently submitted and published papers can be found in the Documents and publications chapter.

Efforts: 2 PM

Contributors: Yong Wang, Florian Weidle, Christoph Wittmann, Florian Meier, Clemens Wastl, (all ZAMG), Endi Keresturi, Iris Odak Plenković, Martina Tudor (all DHMZ), Martin Belluš (SHMU)

Documentation: Reviewed papers

Status: In progress

List of actions, deliverables including status

S1 Subject: Optimization of A-LAEF

Deliverables: Reports on LACE stays; papers submitted to scientific journals; improvement of current regional ensemble system through the results and outcomes of R&D

Status: Ongoing

S2 Subject: A-LAEF maintenance

Deliverables: A-LAEF operational suite running at ECMWF HPCF; probabilistic forecast products delivered to the LACE partners

Status: Development and upgrade of ecFlow scripts; A-LAEF suite implementation under the time critical environment at ECMWF HPCF; maintenance tasks

S3 Subject: AROME-EPS

Deliverables: Reports on LACE stays; papers submitted to scientific journals; convection-permitting ensemble systems for operational use (ZAMG, OMSZ)

Status: C-LAEF suite implementation under the time critical environment at ECMWF HPCF; AROME-EPS development and operational runs at OMSZ

S4 Subject: EPS - Verification

Deliverables: Local installation (SHMU) and testing of HARP verification package

Status: Restored

S5 Subject: Collaborations

Deliverables: Exchange of the expertise between the other consortia or within the relevant projects

Status: Ongoing

S6 Subject: Publications

Deliverables: 1 paper was published in QJRMS and 2 papers were submitted (QJRMS, MC); due to not realized R&D stays there are no new reports available online via RC LACE portal; 1 doctoral thesis was defended; for more details please see the list of publications down below

Status: In progress

Documents and publications

Published papers:

- 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", Quarterly Journal of the Royal Meteorological Society, 146: 1842– 1860, https://doi.org/10.1002/qj.3769

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", submitted to Meteorologický časopis, SHMÚ

Iris Odak Plenković also 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.

Activities of management, coordination and communication

- 34th LSC Meeting, 11-12 March 2020 (*online*)
- Joint 30th ALADIN Workshop & HIRLAM All Staff Meeting 2020, 30 March - 2 April 2020 (*online*), LACE EPS activities presented by Martin Belluš

LACE supported stays – 0 PM in 2020 (till August)

Unfortunately, due to the first and second waves of COVID-19 disease, there were no research stays organized this year (at least till August).

Summary of resources [PM] – January ~ August 2020

Subject	Manpower		LACE		ALADIN	
	plan	realized	plan	realized	plan	realized
S1: Optimization of A-LAEF	11	3.5	3			
S2: A-LAEF maintenance	4	5	1			
S3: AROME-EPS	20	12	1			
S4: EPS – Verification	1.5	2	1			
S5: Collaborations	2	1				
S6: Publications	6	2				
Total:	44.5	25.5	6	0	0	0

A-LAEF ecFlow TC2 Suite

(technical documentation)

Martin Belluš (SHMÚ)
martin.bellus@shmu.sk

October 2019, Bratislava
(updated in June 2020)

Introduction

A meso-scale ensemble system A-LAEF (ALARO - Limited Area Ensemble Forecasting) based on ALADIN canonical model configuration ALARO (Termonia et al., 2018) has been developed in the frame of RC LACE consortium (Regional Cooperation for Limited Area modelling in Central Europe). It is focused on short range probabilistic forecast and profits from the advanced multi-scale ALARO physics (which is adapted to perform on horizontal mesh-sizes of 2-10 km). Its main purpose is to provide probabilistic forecast for the national weather services of RC LACE partners (Wang et al., 2017) who could not achieve that with their own HPC resources. It also serves as a reliable source of probabilistic information applied further into the downstream models of hydrology, energy industry and even in the nowcasting.

New A-LAEF system is a sequel to the ALADIN-LAEF (Aire Limitée Adaptation dynamique Développement InterNational - Limited Area Ensemble Forecasting), which was operational on ECMWF HPCF as TC2 application since 2011 (Wang et al., 2011).

A-LAEF system

In A-LAEF system we use several strategies to simulate the uncertainty of the initial conditions and of the numerical model, while the perturbations at the boundaries are prescribed by the downscaled information from driving global EPS.

a) IC perturbations

The surface and soil prognostic fields uncertainty in the initial conditions of A-LAEF system is simulated by the ensemble of surface data assimilations - ESDA (Belluš et al., 2016). Each ensemble member has its own data assimilation cycle with randomly perturbed screen-level measurements.

The uncertainty of the upper-air part of the initial conditions used in A-LAEF system is currently simulated by the upper-air spectral blending (Derková and Belluš, 2007; Wang et al., 2014). It combines the large-scale perturbations provided by the driving global ensemble (ECMWF EPS) with the small-scale perturbations coming from A-LAEF first guess within the pseudo-assimilation cycle. It is going to be replaced by so-called ENS BlendVar (ensemble of blending + 3DVar) at the Phase II.

b) Model perturbations

The model uncertainty is simulated by the combination of ALARO multi-physics (four different setups of micro-physics, deep and shallow convection, radiation and turbulence schemes) and the stochastic perturbation of physics tendencies (Wang et al., 2019).

c) LBC perturbations

The A-LAEF system is coupled to the global ECMWF EPS. The perturbed lateral boundary conditions are retrieved from the first 16 ENS members with a coupling frequency of 6h to account for the uncertainties at the domain boundaries.

A-LAEF system specifications can be seen in Table 1, while the integration and postprocessing domains are shown in Figure 1.

Tab.1: *A-LAEF system specifications.*

Code version	cy40t1
Horizontal resolution	4.8 km
Vertical levels	60
Number of grid points	750x1250
Grid	linear
Time step	180s
Forecast length	72 h (00/12 UTC)
Members	16+1
IC perturbation	ESDA [surface], blending (Phase I) / ENS BlendVar (Phase II) [upper-air]
Model perturbation	ALARO-1 multi-physics + surface SPPT
LBC perturbation	ECMWF ENS

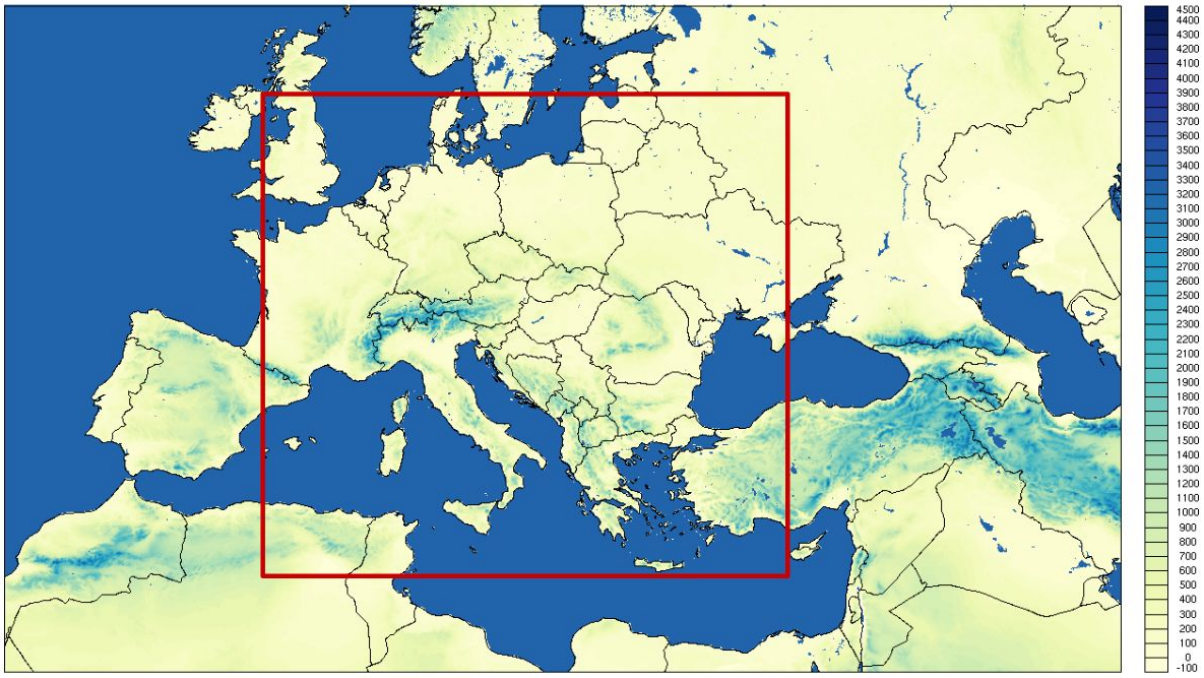

Fig.1: *A-LAEF integration and postprocessing domain (in red) with model orography.*

Technical specifications

Suite definition file is generated by Python script (create_laef.py). The ECF_MICRO character used for the code preprocessing was redefined to "^" (caret). The reason is to

have the least interaction with the original Perl code. The default setting for ECF_MICRO is "%" (percent), which is used for the hash associative arrays in Perl and thus is widely spread in the code. Even now, all the original caret signs (e.g. in some regular expressions) must have been exchanged by "^^" (caret caret) to avoid their substitution by ecFlow preprocessing.

The "laef" suite has three essential families: "admin" to make an easy switch between the computational clusters (SCHOSTs) and file systems (STHOSTs); "RUN_00" and "RUN_12" for 00 and 12 UTC cycles respectively. Each of the last two contains five other families for processing input data ("ecpds"); fetching observations ("getobs"); running ensemble ("main"); dissemination of products ("dissemination") and final cleaning/mirroring of the data ("closure"). The family "main" has subfamilies for each member ("MEM_<nn>") involving preparation of the coupling files (task "getlbc"), surface data assimilation (task "canari"), upper-air spectral blending by DFI (task "blend"), model integration (task "laeff") and GRIBs production (task "make_gribs").

All the ecFlow scripts (Perl application tasks, Python script to generate the "laef" suite definition file and include files) are stored on ecgate server. The "laef" suite is generated at virtual machine ecgb-vecf and also loaded into the ecFlow server running on that VM to avoid the load on the interactive node on ecgate.

ecgate: /home/ms/laef/zla/ecf

drwxr-x---. 3 zla laef 4096 Oct 22 11:09 **app**	ecFlow tasks
drwxr-x---. 3 zla laef 4096 Oct 21 16:16 **def**	suite definition
drwxr-x---. 2 zla laef 4096 Oct 21 13:10 **include**	head, tail, pbs
drwxr-x---. 4 zla laef 4096 Oct 9 07:12 **laef**	suite*

(*) auto-generated by Perl script app/link_apps_to_tasks.pl

On the other hand, the compiled binaries, namelists and input files must be located on HPCF cluster (cca/ccb), because this is where the jobs are executed under the queuing system (PBS).

cca/ccb: /$STHOST/tcwork/zla/lb/app_LAEF5F

drwxr-x--- 3 zla laef 4096 Apr 24 11:08 **blend**	blending namelists
drwxr-x--- 3 zla laef 4096 Apr 24 11:11 **canari**	surface namelists
drwxr-x--- 3 zla laef 4096 Apr 24 11:18 **getlbc**	namelist for c903
drwxr-x--- 3 zla laef 4096 Apr 24 11:18 **laeff**	e001 namelists
drwxr-x--- 2 zla laef 4096 Oct 22 11:42 **setup**	main laef config*

(*) Conf_app.pm and Support.pm Perl modules

cca/ccb: /$STHOST/tcwork/zla/lb

drwxr-xr-x 2 zla laef 4096 Oct 23 12:57 **BIN**	all executables*
drwxr-x--- 5 zla laef 4096 Apr 24 13:13 **CLIM**	clim files
drwxr-x--- 4 zla laef 4096 Oct 16 15:09 **LBC**	input from ECMWF
drwxr-xr-x 3 zla laef 4096 Jun 28 12:19 **LAEF5F**	A-LAEF output
drwxr-x--- 2 zla laef 4096 Oct 9 06:55 **bin**	Perl tools

(*) sources and compilation: /perm/ms/at/kmxy/packs/40t1_LAEF5_FULL

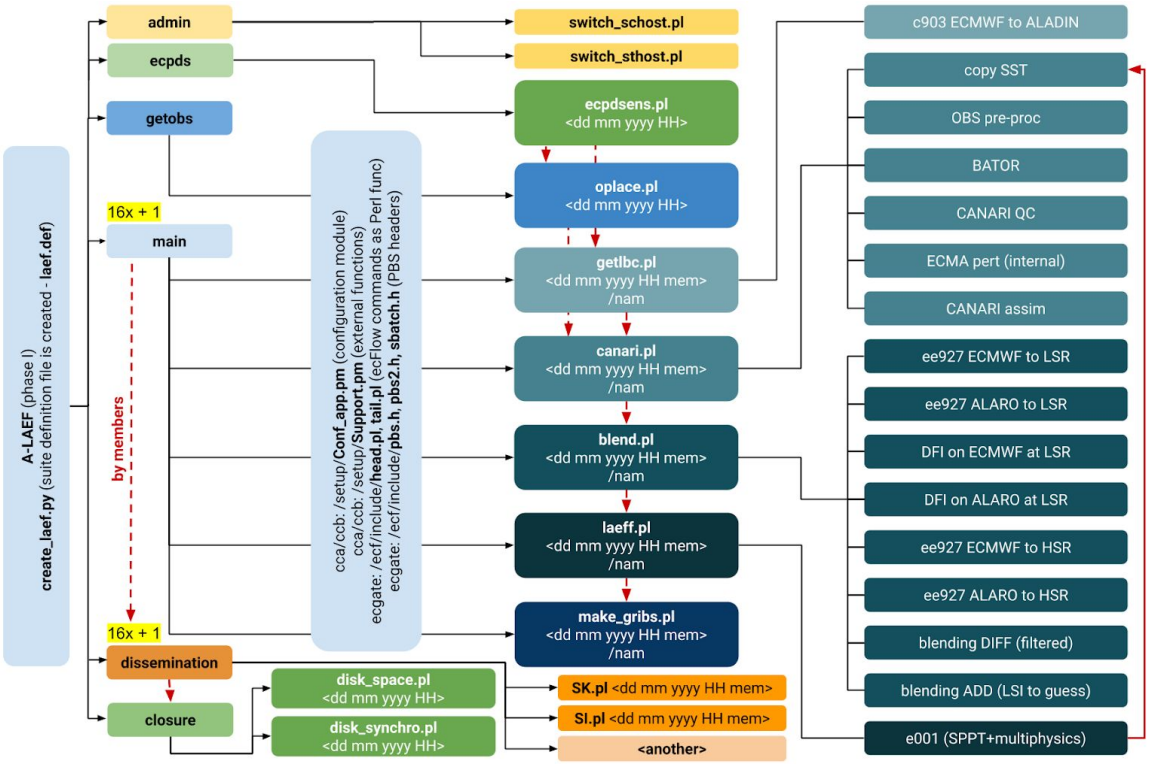

Fig.2: *New A-LAEF suite built under the ecFlow environment. Suite definition file is generated by Python code, while all tasks, include-files and configuration modules are written in Perl. Task dependencies are denoted by the red dashed arrows.*

Tab.2: *Overview of the "laef" suite requirements.*

1. Run time of suite	Start time	• 00:30 UTC (RUN 00) • 12:30 UTC (RUN 12)
	End time	• Preferably before 4:00 and 16:00 UTC.
	Availability requirements	• As soon as possible, but there is no deadline.
2. Input data	Dependence on ECMWF forecast products	• ENS 00/12 UTC 6-hourly output to STEP=84 for the first 16 members and control run (for 12h-lagged coupling).
	Dependence on other data	• OPLACE obsouls*
	How is this transferred to ECMWF?	• ectrans Gateway: ecaccess.ecmwf.int Host: ftp.met.hu
	Backup procedure?	• Not applicable.

3. HPC compute resources	Number of nodes/CPUs (maximum)	• 17x(8 nodes / 288 CPUs)
	Times at which peak number of CPUs are needed	• For ~2 hours (01:00~03:00 UTC; 13:00~15:00 UTC).
4. HPC storage resources	Input data volume	• 500 GB per cycle / 1 TB per day
	Output data volume	• 1 TB per cycle/ 2 TB per day
	Permanent storage requirements (for scripts, libraries and binaries)	• 10 GB on $TCWORK/lb
	Number of days of data to be stored	• 3 days of input data (3 TB) • 3 days of output data (6 TB)
5. Data handling storage requirements (archiving)	Data to be stored on MARS	• None
	Data to be stored in ECFS	• To be decided.
6. Volume of data to be transferred from ECMWF to local site(s)		• ~26 GB per cycle.
7. Software requirements	ECMWF software	• ecFlow, ECaccess, ecCodes.
	Other software	• Specific software and libraries for running ALARO CMC model chain.

(*) observations are retrieved from OPLACE archive (operational database of RC LACE)

Tab.3: *Contacts.*

Emergency contact	Martin Belluš	martin.bellus@gmail.com	+421 918 412 792	24x7

Tab.4: *Description of the "laef" suite.*

Family	Task	Sys	Description
admin	switch_schost	ecgb	Switching between clusters (cca/ccb).
	switch_sthost	ecgb	Switching between FSs (sc1/sc2).
RUN_00|12			00 and 12 UTC runs
ecpds	ecpdsens	cca/ ccb	Processing local ECPDS stream (ENS/DET input global fields).
getobs	oplace	cca/ ccb	Fetching OBS files from OPLACE. Trigger("../ecpds == complete")
main/MEM_00|01|..16	getlbc	cca/ ccb	Creating LBCs for A-LAEF domain from global ENS gribs by conf 903. Trigger("../../ecpds == complete")
	canari	cca/ ccb	Surface assimilation using perturbed OBS by conf 701. Trigger("../../getobs == complete and getlbc == complete")
	blend	cca/ ccb	Upper-air spectral blending by DFI. Trigger("canari == complete")
	laeff	cca/ ccb	Model integration by conf e001. Trigger("blend == complete")
	make_gribs	cca/ ccb	Converting FA files to GRIBs. Trigger("laeff == complete")
dissemination/MEM_ 00|01|..16	SK	cca/ ccb	Sending GRIBs via ECPDS to Slovakia. Trigger("../../main/MEM_xx == complete")
	SI	cca/ ccb	Sending GRIBs via ECPDS to Slovenia. Trigger("../../main/MEM_xx == complete")
	<another>	cca/ ccb	Sending GRIBs via ECPDS to <another> Trigger("../../main/MEM_xx == complete")
closure	disk_space	cca/ ccb	Old data cleaning (also mirrored files). Trigger("../dissemination == complete")
	disk_synchro	cca/ ccb	Incremental synchronization (mirroring). Trigger("../main == complete")

Tab.5: *Location of the "laef" suite scripts and data.*

Data	Host	Location
Suite scripts	ecgate	/home/ms/laef/zla/ecf/laef
A-LAEF executables	cca/ccb	/$STHOST/tcwork/zla/lb/BIN
A-LAEF namelists	cca/ccb	/$STHOST/tcwork/zla/lb/app_LAEF5F
A-LAEF configuration	cca/ccb	/$STHOST/tcwork/zla/lb/app_LAEF5F/setup
Model climatology files	cca/ccb	/$STHOST/tcwork/zla/lb/CLIM
Input ENS data	cca/ccb	/$STHOST/tcwork/zla/lb/LBC/ECPDS/YYYYMMDDHH
A-LAEF output data	cca/ccb	/$STHOST/tcwork/zla/lb/LAEF5F/TCC
Job output files	cca/ccb	/$STHOST/tcwork/zla/sb/ECF/laef

The time duration of individual A-LAEF tasks within the whole suite (+72h forecast) is shown in table 6. Processes like ensemble of surface data assimilation (ESDA) and upper-air spectral blending are not dependent on the forecast length and their duration is marginal. OBS retrieval from OPLACE archive is negligible and the preparation of coupling files - although for full forecast length (+72h) - is still fast when using 903 configuration in NFPSERVER mode (with the loop on files inside). The only time demanding task is the model integration itself. For the configuration involving 288 CPUs (8 nodes) the +24h forecast takes about 42 minutes and +72h forecast about 2 hours.

Tab.6: *Time duration of individual tasks for +72h forecast length and their usual finishing times for 00 and 12 UTC run.*

Task	CPUs	+72h forecast	00 UTC	12 UTC
ecpdsens	1	00:22:00	00:52-00:54	12:52-12:56
oplace	1	00:00:30	00:53-00:55	12:54-12:56
getlbc	36	00:06:00	00:57-00:59	12:57-12:59
canari	288	00:02:45	01:00-01:02	13:00-13:05
blend	288	00:08:00	01:08-01:11	13:08-13:14
laeff	288	02:02:00	03:08-03:15	15:06-15:16
make_gribs	18	00:01:30	03:11-03:17	15:09-15:20

Tab.7: *Technical characteristics of the main tasks running on HPCF (not including preprocessing and postprocessing).*

Task	CPUs	Wall (s)	Output	SBUs	Total SBUs
	values per member				16+1 mem (+72h, 2x/day)
canari	288	~166	518 MB	~215	~7310
blend	288	~480	518 MB	~610	~20740
laeff	288	~7300	15 GB	~9540	~324360
Total SBUs consumption per year (an approximation only)					~129 mio

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