Working Area Predictability

Progress Report

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Period:	2021
Date:	March 2022

Progress summary

A lot of EPS related work has been done in 2021 within RC-LACE despite the unfavorable circumstances connected to the COVID-19 crisis. Most planned stays have been postponed or cancelled for this year. Only the stay of Iris Odak Plenkovic at ZAMG for 4 weeks in November/December took place, but it has been assigned as ACCORD stay. In December 2021 a first RC-LACE EPS meeting has been organized where the future of EPS in RC-LACE has been discussed. Most colleagues prefer to work on a common 1km EPS for RC-LACE in the future.

All three current ensemble systems within RC-LACE (A-LAEF, C-LAEF, AROME-EPS) are running in full operational mode. They are running very stable and smoothly and the usage of EPS at the meteorological centers is constantly increasing. AROME-EPS in Hungary and C-LAEF have been upgraded this year to cy43t2, a further upgrade of the common A-LAEF system is planned on the new ECMWF HPC. Some planned activities could not be fulfilled because of the delay of the new ECMWF HPCF in Bologna – the new plan is Q2/2022 to have full access to this supercomputer. First preparatory work for using C-LAEF in Turkey has been made, a new Mediterranean Sea domain for ocean models coupling has been set-up for A-LAEF and also an OBS backup using GTS data which is uploaded to OPLACE has been installed. The upgrade of the ECMWF-ENS to cy47r2 and the increase of the number of vertical levels from 91 to 137 in May 2021 has not caused any technical problems for the LAM-EPS within RC-LACE. Together with this upgrade also the coupling file production for the convection-permitting systems AROME-EPS and C-LAEF has been merged and is now done by a time-critical option 3 at ECMWF with 903.

Also the scientific work is progressing well, new developments like the surface perturbation scheme and new parameter perturbations for C-LAEF or the precipitation phase calculation and an incremental DFI step in spectral blending procedure for A-LAEF have been made and are tested and verified continuously in parallel EPS e-suites. In Hungary the work on EDA is ongoing and it is planned to have more operational AROME-EPS per day soon. New EPS applications (visualizations, maps, EPSgrams) have been developed and the templates for such visualizations (e.g. in Visual Weather) have been exchanged within the RC-LACE countries to provide some new products on the RC-LACE webpage.
In the verification subject it seems that more and more countries (Slovakia, Poland, Hungary, Austria) are using the R-based HARP package for verifying EPS.
Some papers have been published and the EPS related work has been presented at international workshops and conferences.

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.

The originally planned topics in 2021 (based on the EPS workplan generated in September 2020) were:

- ❑ Implementation and testing of new random number generator (SPG) suitable for LAM EPS environment in A-LAEF.
- ❑ Stochastic perturbation of fluxes instead of tendencies in order to preserve the energy balance in perturbed model.
- ❑ Utilization of A-LAEF operational forecasts for flow-dependent B-matrix computation to be used in local assimilation cycles of RC-LACE members.
- ❑ Continuation work on methods for analog-based post-processing of probabilistic fields on a regular grid

Most of them have been postponed because these topics should have been investigated in course of RC-LACE stays which have mostly been cancelled due to the COVID situation. Only 1 stay took place - Iris Odak Plenkovic worked on analog-based post-processing for 4 weeks at ZAMG. The work spent on S1 topic in 2021 comprises mostly following topics: Long-term and case study verification (Topic 1 + separate case studies report on RC-LACE webpage), creation of EPSgrams and costumer products (Topic 2), the calculation of precipitation phase based on EPS output (Topic 3), provision of A-LAEF export version with training course for RC-LACE partners (Topic 4) and application of analog-based method to gridded data post-processing (Topic 5 + stay report).

- ❑ **Topic 1: A-LAEF operational runs - Case studies and verification**

In 2021 a lot of work has been spent on the verification of the operational A-LAEF suite. Especially during the very wet summer 2021 several catastrophic flood events occurred in Central Europe which have been investigated and reported. These situations, but also a record breaking precipitation event in Northern Italy in October have shown the good quality of the A-LAEF system and in general the benefit of using a probabilistic forecasting system.

Due to the extensive number of case studies in 2021 the content of this topic has been prepared in a separate “case studies report” which is provided on the RC-LACE webpage.

For the first 11 months in 2021 (Jan-Nov) a long-term deterministic verification of A-LAEF (ensemble mean, 16+1 members), the operational ALADIN/SHMU model and the dynamical downscaling of ARPEGE model with ALARO (ALARO NH) has been made for the surface parameters temperature, relative humidity and wind speed.

Figure 1 shows the verification results (RMSE, standard deviation) over all Slovak stations. Ensemble mean of A-LAEF shows the best verification results for all investigated parameters. The advantage of using the output of a probabilistic system can also be seen in the HARP score card in Figure 2.

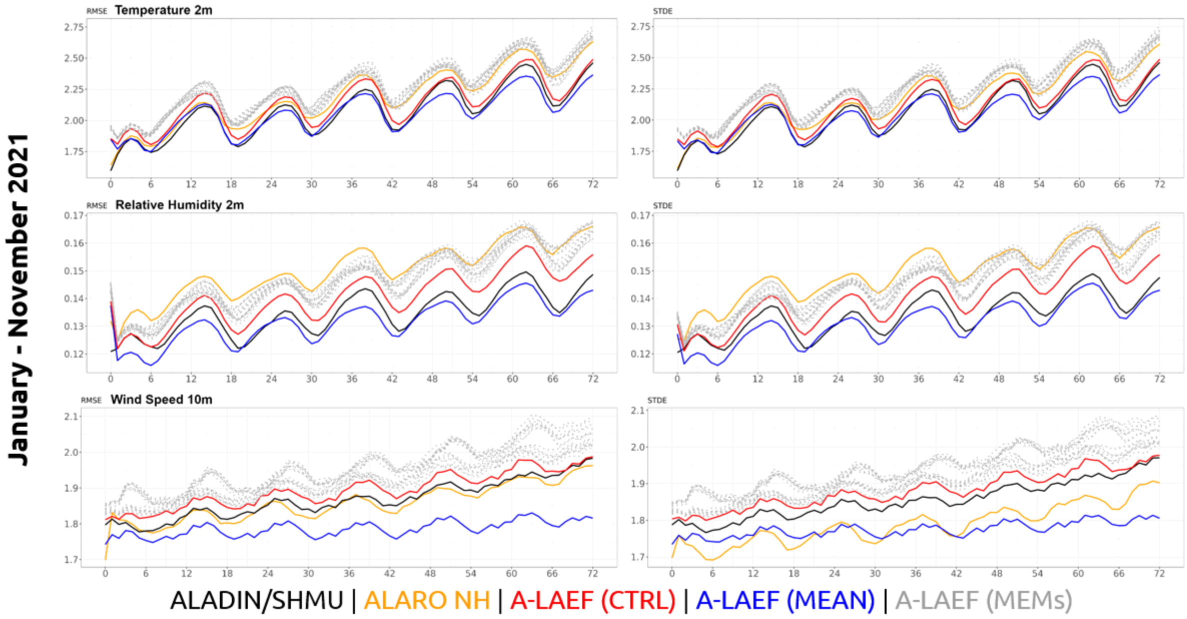


Figure 1: RMSE (upper row) and standard deviation (lower row) for T2m (left), relative humidity at 2m (center) and 10m wind speed (right) for the period Jan-Nov 2021.

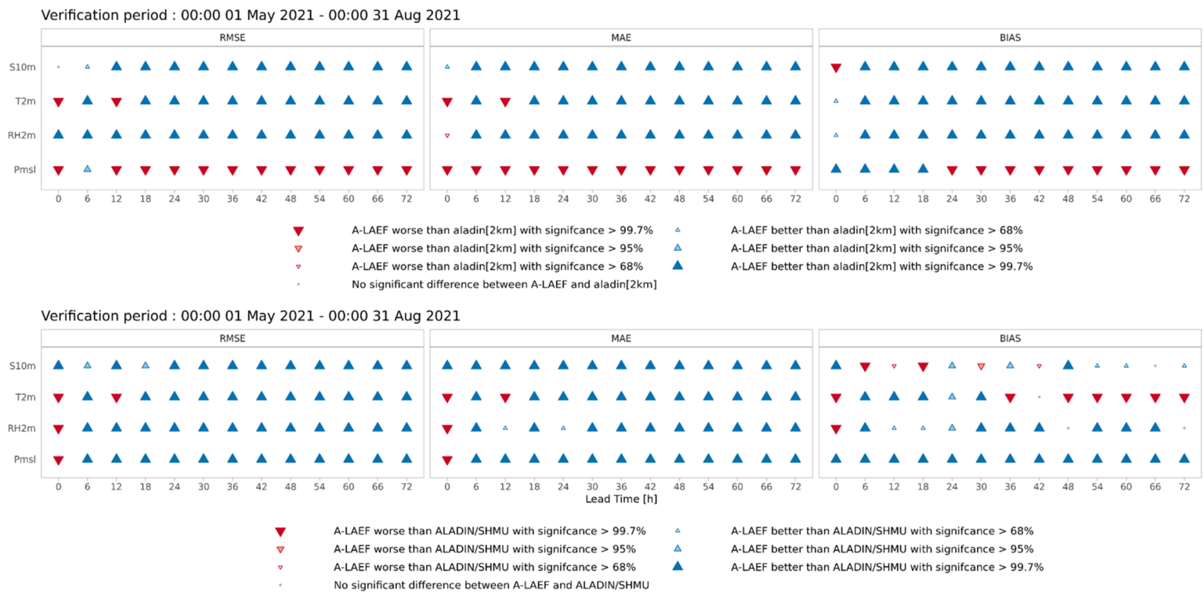


Figure 2: HARP score card of A-LAEF (4.8 km) vs. det. ALADIN/SHMU oper (4.5 km) and ALARO NH (2 km) - May-August 2021 for 96 SK stations.

❑ Topic 2: A-LAEF operational maps: EPSgrams

The existing set of probabilistic A-LAEF maps on the RC-LACE webpage prepared at SHMU has been complemented by EPSgrams for the capital cities within RC-LACE. Figure 3 shows an example of such an EPSgram for Bratislava on 29 August 2021.

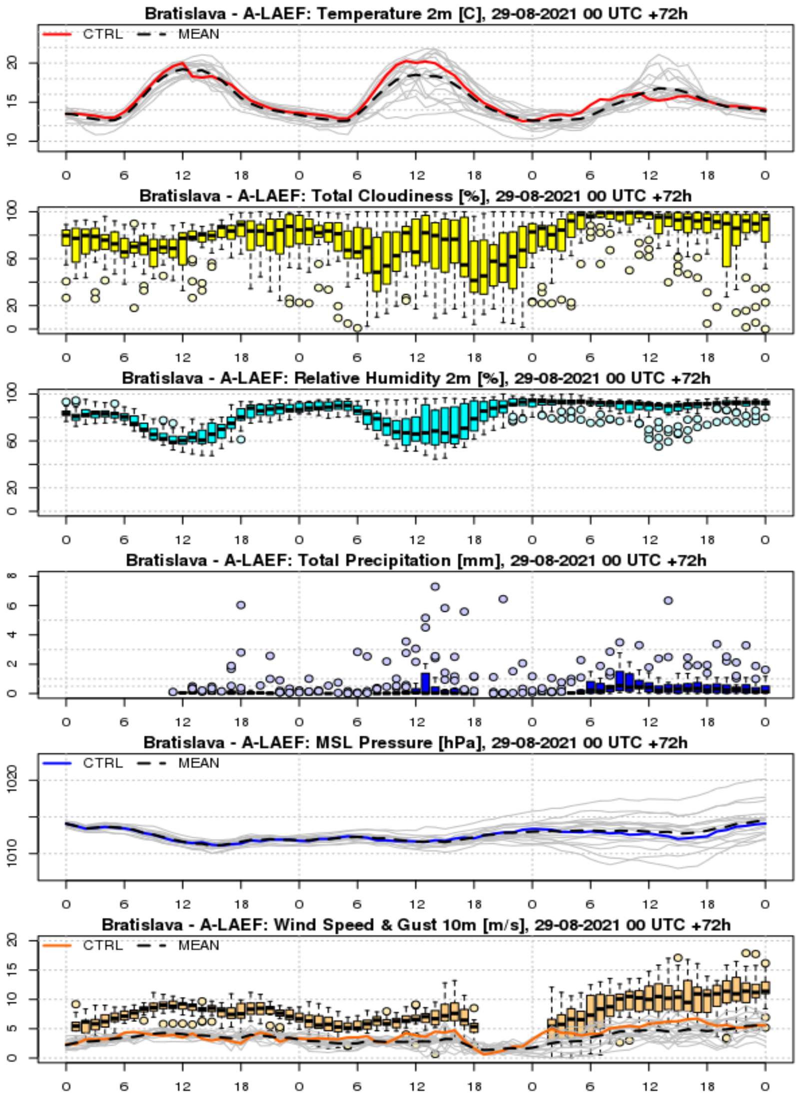


Figure 3: A-LAEF EPSgram for Bratislava based on 29 August 2021 00 UTC run.

In autumn 2021 information on min, max, sum and quantiles has been added to the A-LAEF EPSgrams (Figure 4).

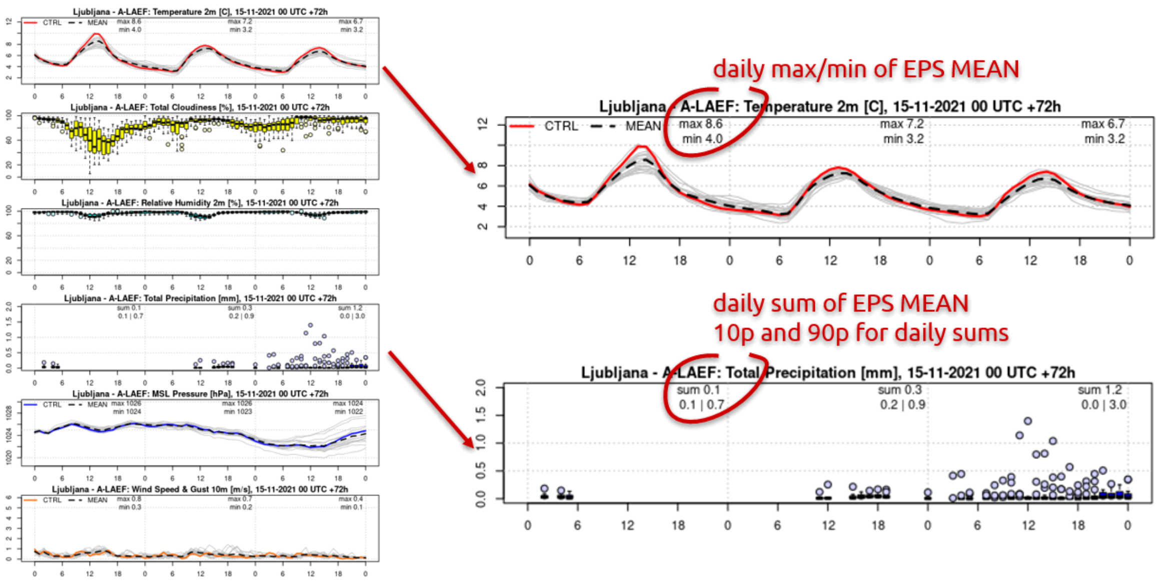
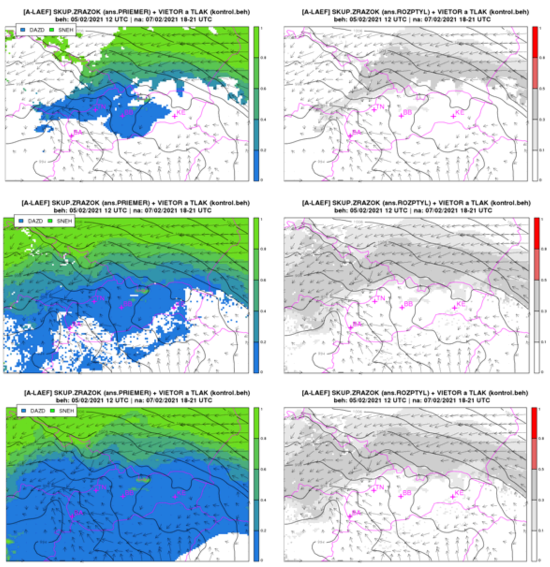


Figure 4: Upgrade of A-LAEF EPSgram with information on max, min, sum and quantiles.

❑ Topic 3: Precipitation phase calculation from EPS data

Different approaches of calculating precipitation phase from EPS data have been tested in A-LAEF. Figure 5 shows three different ways of such a precipitation phase calculation applied to an A-LAEF test case on 07 February 2021. For method a) the ensemble mean of precipitation phase is only defined in areas where the total precipitation of the ensemble minimum is > 0.1mm (07/02/2021 18-21 UTC), otherwise M and S are 0. In approach c) the ensemble mean of precipitation phase is defined in areas where the ensemble mean of precipitation is > 0.1mm (07/02/2021 18-21 UTC).

a)
b)
c)



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.

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

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

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

Figure 5: Calculation of precipitation phase (snow, rain) for a test case on 07 February 2021. The left column shows the ensemble mean precipitation phase (0=rain, 1=snow) based on the respective calculation method (a, b, c), the right column the ensemble spread.

Such precipitation phase definitions work for many cases quite well as the comparison with observations shows in Figure 6.

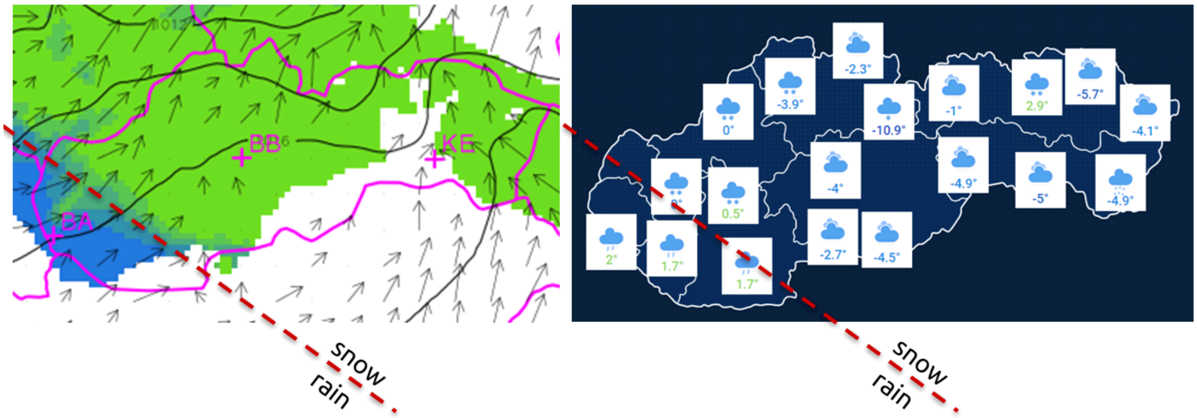


Figure 6: Precipitation phase forecast (left) and observations (right) for a test case on 19 January 2021 (18-21 UTC) in Slovakia.

❑ Topic 4: A-LAEF export version and training for RC-LACE partners

An export version of the A-LAEF scripting system has been developed by SHMU for an easy installation under standard users at ECMWF (Figure 7).

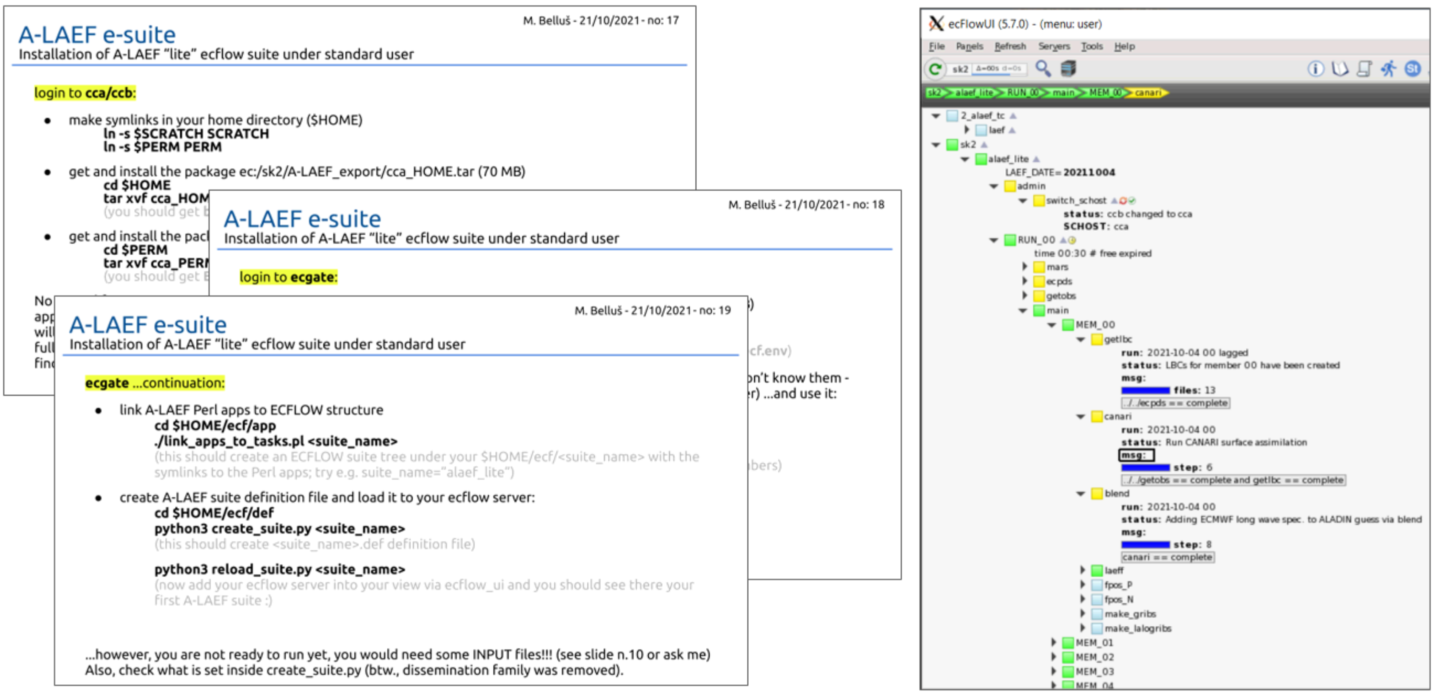


Figure 7: Some slides to describe the A-LAEF export version.

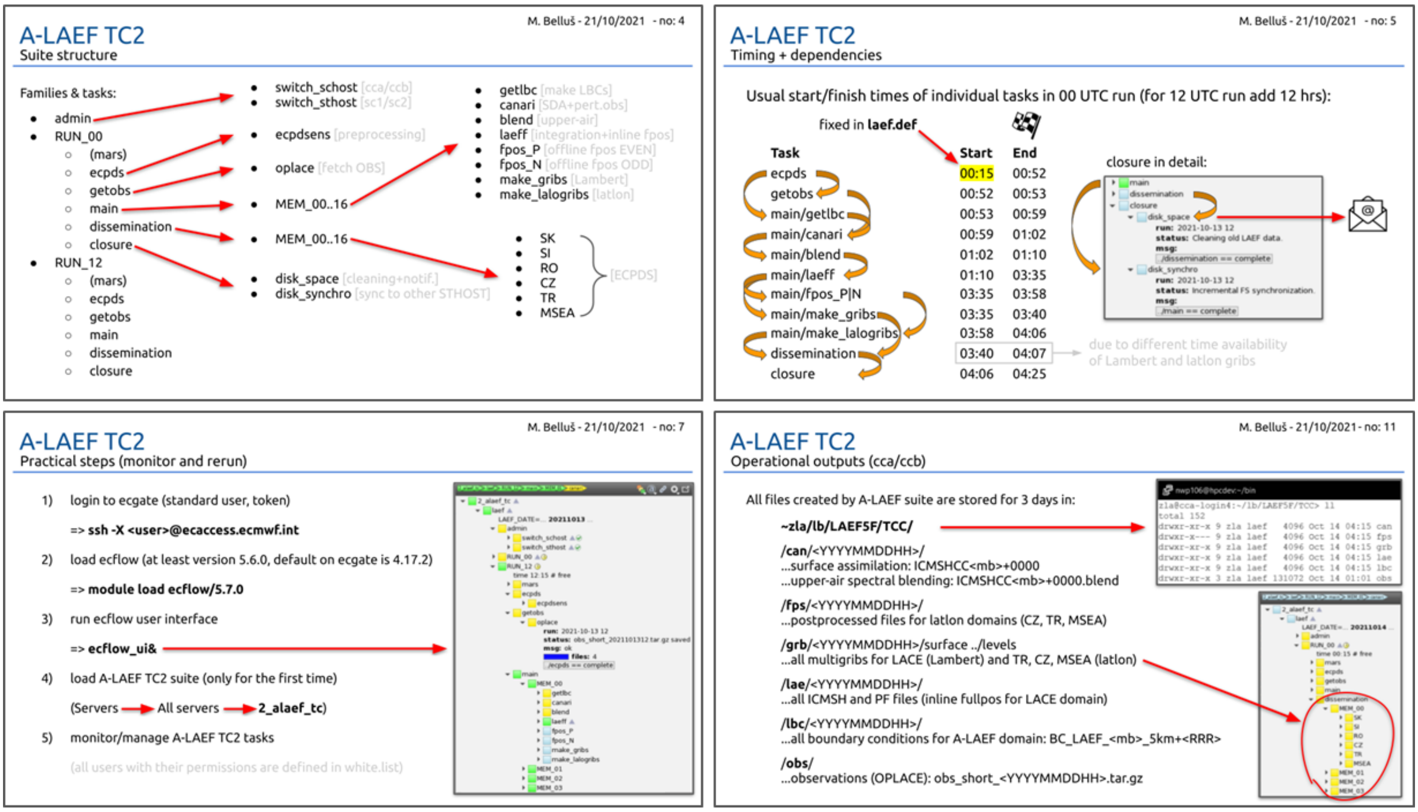


Figure 8: Some slides of the A-LAEF training session for RC-LACE partners.

In October 2021 an online training session to use the A-LAEF TC2 suite (ecflow) has been organized for RC-LACE partners by SHMU in order to help Martin Bellus with emergency duties.

- ❑ **Topic 5: The analog-based method application to gridded data post-processing**

Iris Odak Plenkovic made a 4 weeks stay at ZAMG in November/December 2021 where she was working on the analog-based post-processing method applied to an NWP model output for gridded forecasts. "This is the continuation of previous work carried out during several previous stays. Analogies between, for example, similar past forecasts, measurements, or analyses are a potentially useful tool when the training dataset is long enough, thus enabling an adequate identification of true analogs. Thus, reducing the number of degrees of freedom in the matching procedure makes this method an excellent candidate for point-based post-processing, where NWP input can be deterministic or ensemble forecast. Previously, the point-based analog approach was thoroughly tested as a deterministic approach (Odak Plenkovic et al., 2018) and applied to calibrate the A-LAEF ensemble (Odak Plenkovic et al, 2020). However, accurate forecasts at remote locations are used to drive many user-specific applications (e.g., road temperature forecasts along an entire roadway, soil temperature forecasts for agriculture, wind speed for windfarms). For that reason, besides the point-based post-processing for the measuring sites, there is also an increasing demand for gridded products. The latter is a direct motivation for the development of tools needed for using an analog-based method to produce gridded output based on an analysis. During this stay, the algorithms for two analog-based experiments that produce gridded products were developed and tested." Cited from her stay report, to be found on the RC-LACE webpage. This work has also been presented at the ACCORD-EPS online meeting on ensemble calibration and user-oriented approaches on October 7th, 2021.

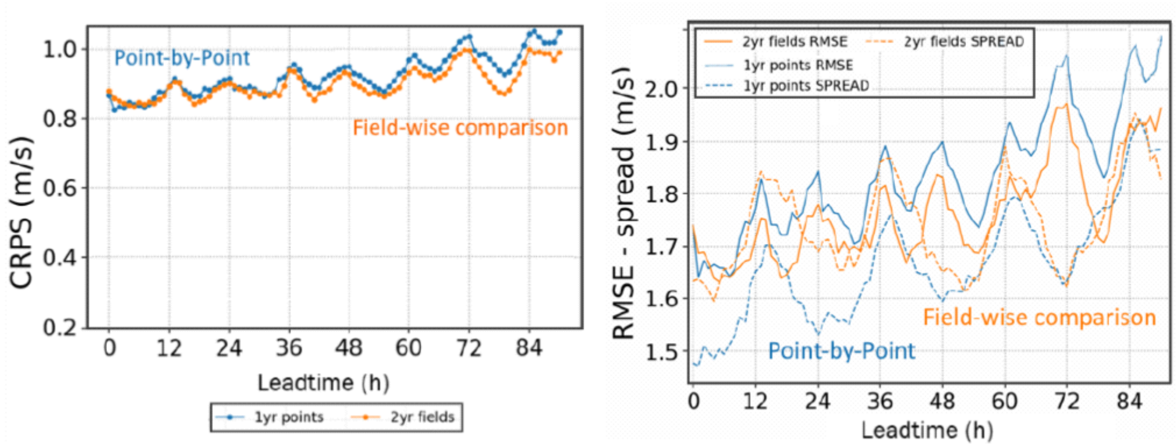


Figure 9: The CRPS (left) and RMSE-spread (right) for the Point-by-Point analog-based approach (using a 1-year-long training dataset) is compared to the Field-wise approach (using a 2-years-long training dataset) during January 2019. All forecasts are verified using INCA analysis wind speed values on the entire domain.

Furthermore, the integration of a full A-LAEF domain on the new NEC HPC@SHMU has been tested for a 72h control forecast which only took about 3.5 min on 200 nodes (Figure 10).

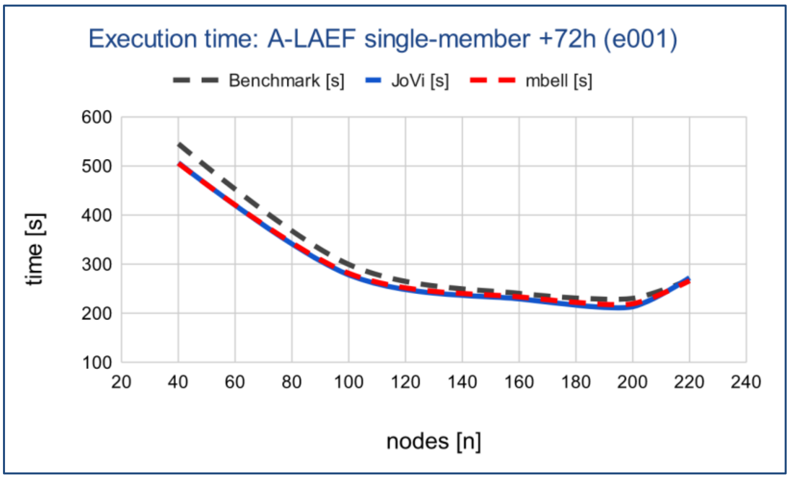


Figure 10: Scalability test for a +72h forecast of A-LAEF (control member) with 3 different masters on 40~220 nodes on the new NEC HPC at SHMU.

Efforts: 8.5 PM

Contributors: Martin Belluš, Mária Derková (SHMU), Endi Keresturi, Iris Odak Plenkovic (DHMZ)

Documentation: Reports on stays and case studies (on webpage); papers submitted to scientific journals; improvement of current regional ensemble system through the results and outcomes of R&D

Status: Ongoing; a lot of delays and shifts in topics due to postponed stays (COVID)

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 RC-LACE partners is ensured.

The originally planned topics in 2021 (based on the EPS workplan generated in September 2020) were:

- Migration of A-LAEF system to the new ECMWF's computer in Bologna and its upgrade to cy43 or cy46 (if available).
- Upgrade of the upper-air IC uncertainty simulation by ENS BlendVar (if feasible with respect to the available resources).
- Unification of A-LAEF grib coding and inclusion of new fullpos fields according to users' requirements.
- Technical support for Turkey with the utilization of A-LAEF operational data.
- A-LAEF coupling for the local convection-permitting EPS applications

Some of these topics (e.g. migration) have been postponed due to the delay in the availability of the new ECMWF supercomputer in Bologna which is planned now for Q2 2022. Hence, the work spent on S2 topic in 2021 comprises following topics: The preparation of new Mediterranean Sea domain (Topic 1), ECMWF ENS upgrade to cy47r2 and cy47r3 (Topic 2) and OBS backup based on GTS data (Topic 3). Furthermore, the A-LAEF GRIB dissemination, the scripts for archiving to ECFS and the fullpos for Turkey and Czech Republic have been optimized. Last but not least also the technical documentation of A-LAEF TC2 suite on the RC-LACE webpage has been updated.

- **Topic 1: Preparation of Mediterranean Sea domain (MSEA) for the ocean models coupling**

Since 28 April 2021 several fields (see list below) for all 16+1 A-LAEF members are processed for a new Mediterranean Sea fullpos domain (MSEA, Figure 11). These output is operationally produced (00 and 12 UTC run) and can be used for the ocean models coupling (e.g. NEMO, SHYFEM).

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

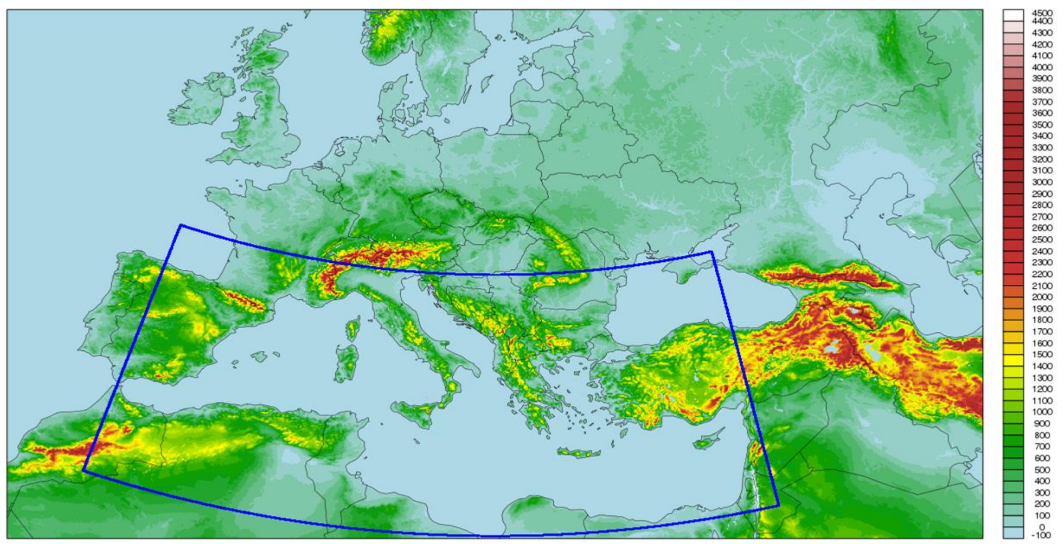


Figure 11: New Mediterranean Sea (MSEA) fullpos domain for ocean models coupling in blue.

- **Topic 2: Impact of ECMWF ENS upgrade to cy47r2 in May 2021**

The ECMWF-ENS model has been upgraded to cy47r2 on 11 May 2021 which also includes an increase of the number of vertical levels from 91 to 137. This of course has also an impact on all the coupled models like A-LAEF. The new coupling files have been provided by ECMWF in advance to test the upgrade technically. The upgrade was very smooth without any technical problems for A-LAEF. For a selected case the impact of the higher number of vertical levels in the new coupling files has been tested in A-LAEF for some parameters at the surface and in the upper air (Figure 12).

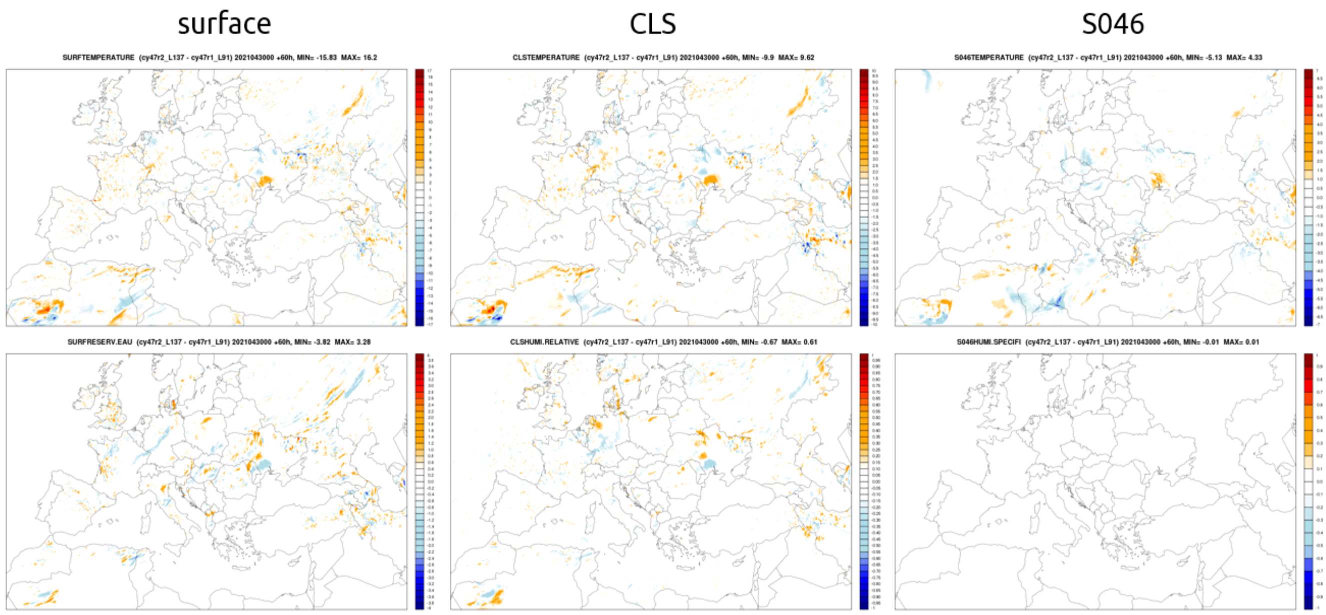


Figure 12: Impact of the higher number of vertical levels (137 vs. 91) in the new ECMWF-ENS coupling files on the A-LAEF forecast of temperature (first row) and moisture (second row). All plots show differences of a +60h A-LAEF forecast version with 137 levels – version with 91 levels.

In autumn an upgrade of ECMWF-ENS coupling files from cy47r2 to cy47r3 has been realized. Before the operational upgrade, it has been thoroughly tested (Figures 13-15).

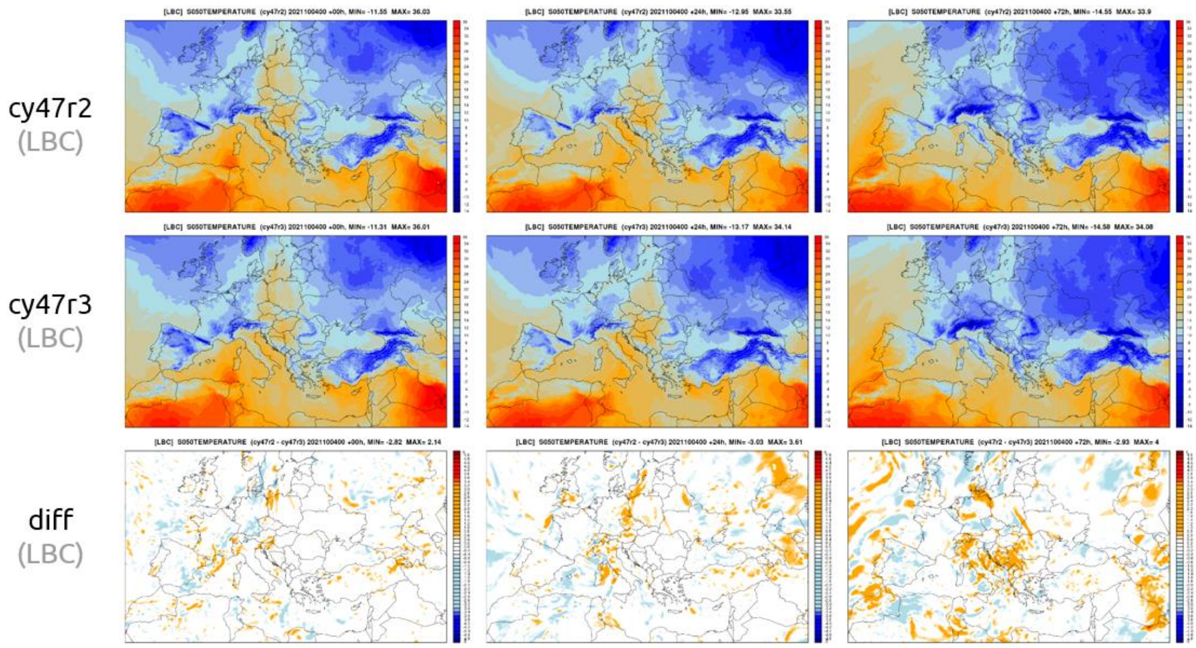


Figure 13: ECMWF-ENS LBC temperature at level 50 for +00h (left), +24h (center) and +72h (right) with cy47r2 (first row), cy47r3 (second row) input and the difference between these two experiments (last row).

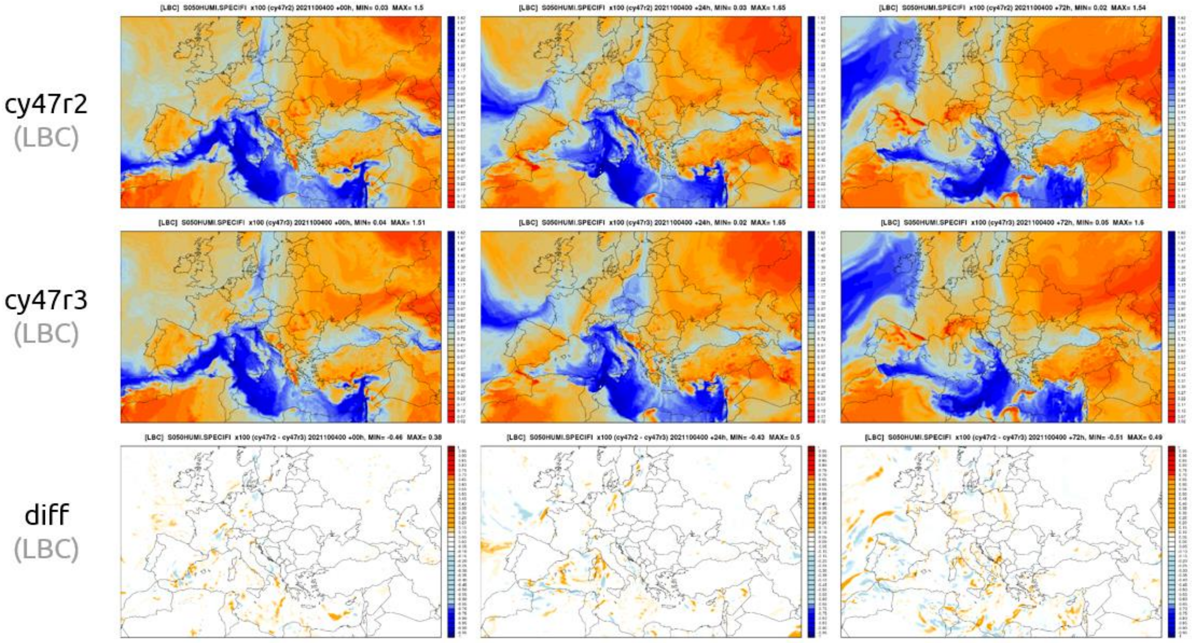


Figure 14: ECMWF-ENS LBC specific humidity at level 50 for +00h (left), +24h (center) and +72h (right) with cy47r2 (first row), cy47r3 (second row) input and the difference between these two experiments (last row).

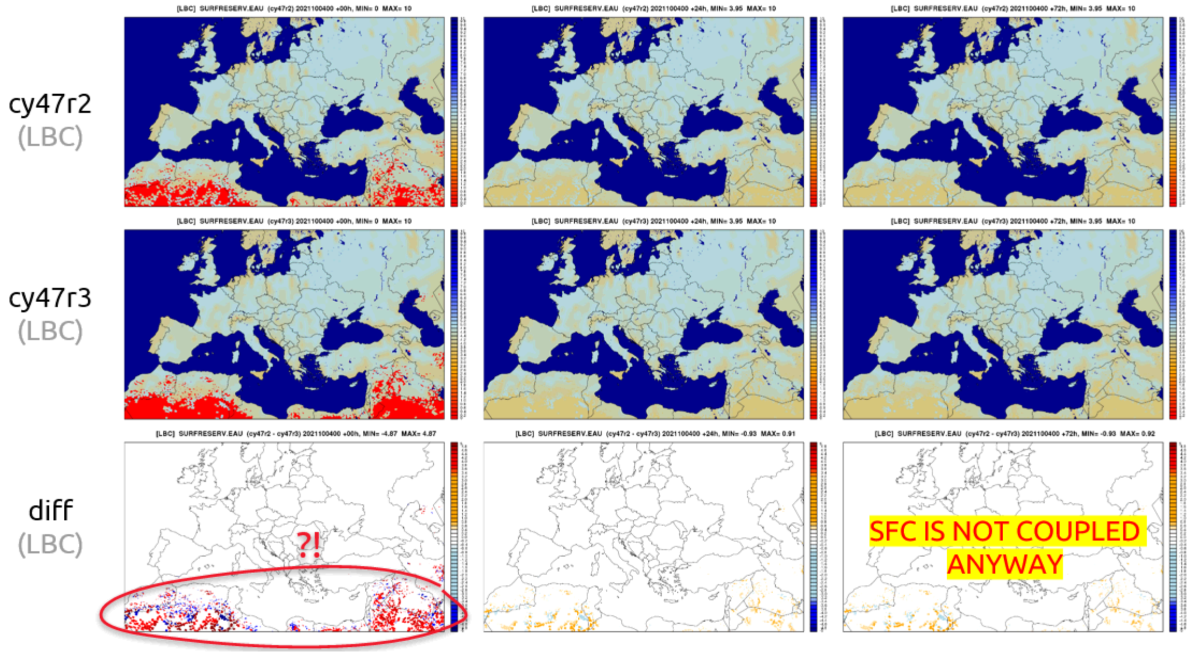


Figure 15: ECMWF-ENS LBC surface water reservoir at level 50 for +00h (left), +24h (center) and +72h (right) with cy47r2 (first row), cy47r3 (second row) input and the difference between these two experiments (last row).

❑ Topic 3: OBS backup for A-LAEF TC2

For the operational A-LAEF TC2 suite an OBS backup using GTS data has been implemented (Figure 16). The GTS data are generated at SHMU and uploaded to OPLACE (gtsbck_sk files).

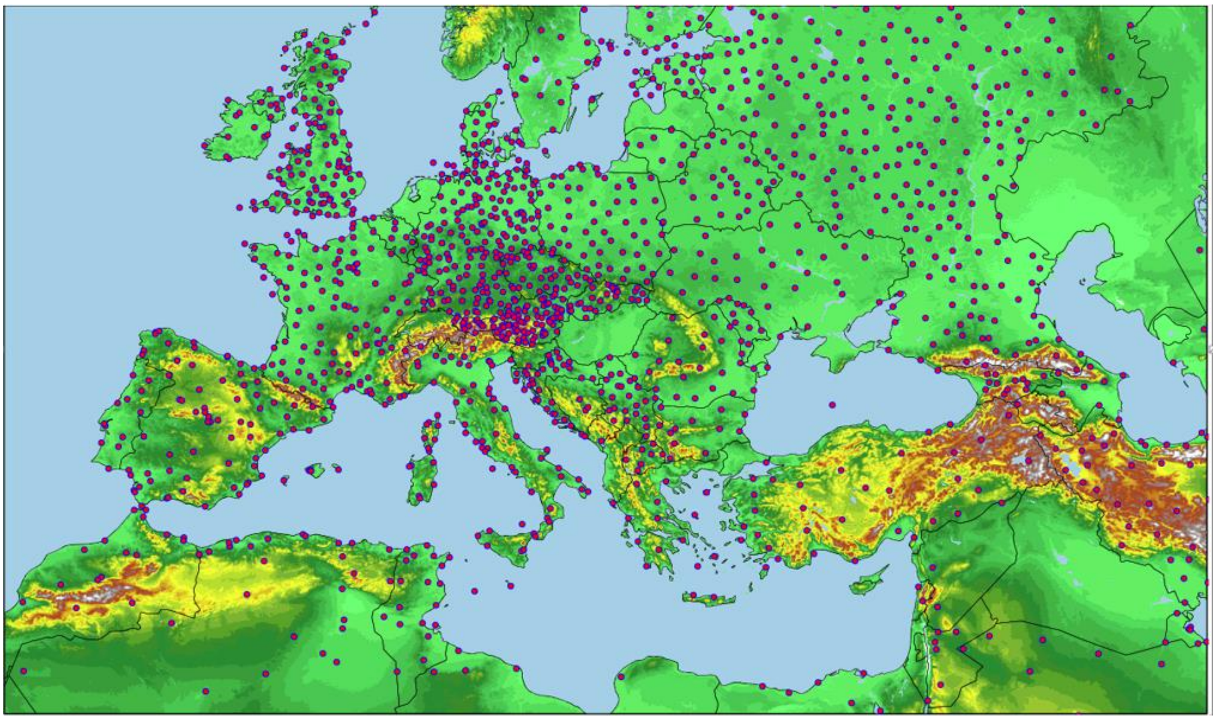


Figure 16: Stations with OBS backup using GTS data uploaded to OPLACE.

Efforts: 3 PM

Contributors: Martin Belluš (SHMU)

Documentation: **:** A-LAEF operational suite running at ECMWF HPCF; probabilistic forecast products delivered to the RC-LACE partners and available on RC-LACE webpage; Flow charts; presentations; reports; technical documentation of A-LAEF TC2 suite running at ECMWF

Status: Ongoing; some delays and shifts in topics due to delay of new ECMWF HPC and due to postponed stays (COVID)

S3 Action/Subject/Deliverable: AROME-EPS

Description and objectives: This task covers research and development of the regional convection-permitting ensembles. Such high-resolution ensembles utilizing non-hydrostatic model AROME are in operation currently in Hungary at OMSZ and in Austria at ZAMG.

- ❑ **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 own HPCF. The operational system runs once per day coupled to the 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 17). 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 a 3-hourly assimilation cycle. The upper-air fields are downscaled from the boundary conditions. In April 2021 the operational AROME-EPS has been upgraded to cy43t2 (ACCORD Newsletter contribution) and in May a 1-h coupling has been implemented.

AROME-EPS runs operationally at OMSZ with the following current configuration:

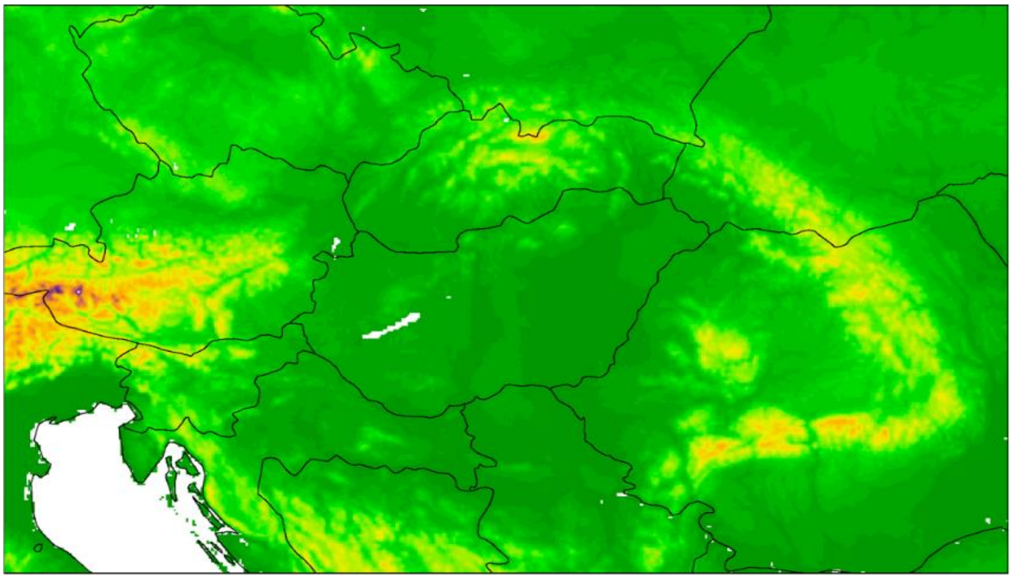


Figure 17: Integration domain of the operational AROME-EPS.

- Model cycle: cy43t2
- Domain: Carpathian Basin, 2.5 km resolution
- Vertical levels: 60 vertical levels
- Assimilation: none (surface from AROME)
- LBC coupling: ECMWF-ENS LBC coupling at every hour (10 perturbed members + control member)
- Number of ensemble members: 10+1 members
- Forecast runs: 00 UTC

- Forecast range: 48 h
- initial condition perturbation: none
- model perturbation: none

- **Testing of the higher vertical and temporal resolution of LBCs:**

Lateral boundary conditions as well as atmospheric initial condition for the Hungarian AROME-EPS are provided by ECMWF ENS. The coupling frequency was 3 hours until May 2021. ECMWF upgraded the IFS model cycle from 47r1 to 47r2 in May which brought two changes in the Hungarian LAMEPS system:

- The number of the vertical levels in the raw boundary conditions increased from 91 to 137.
- A higher, 1-hour coupling frequency was applied in AROME-EPS.

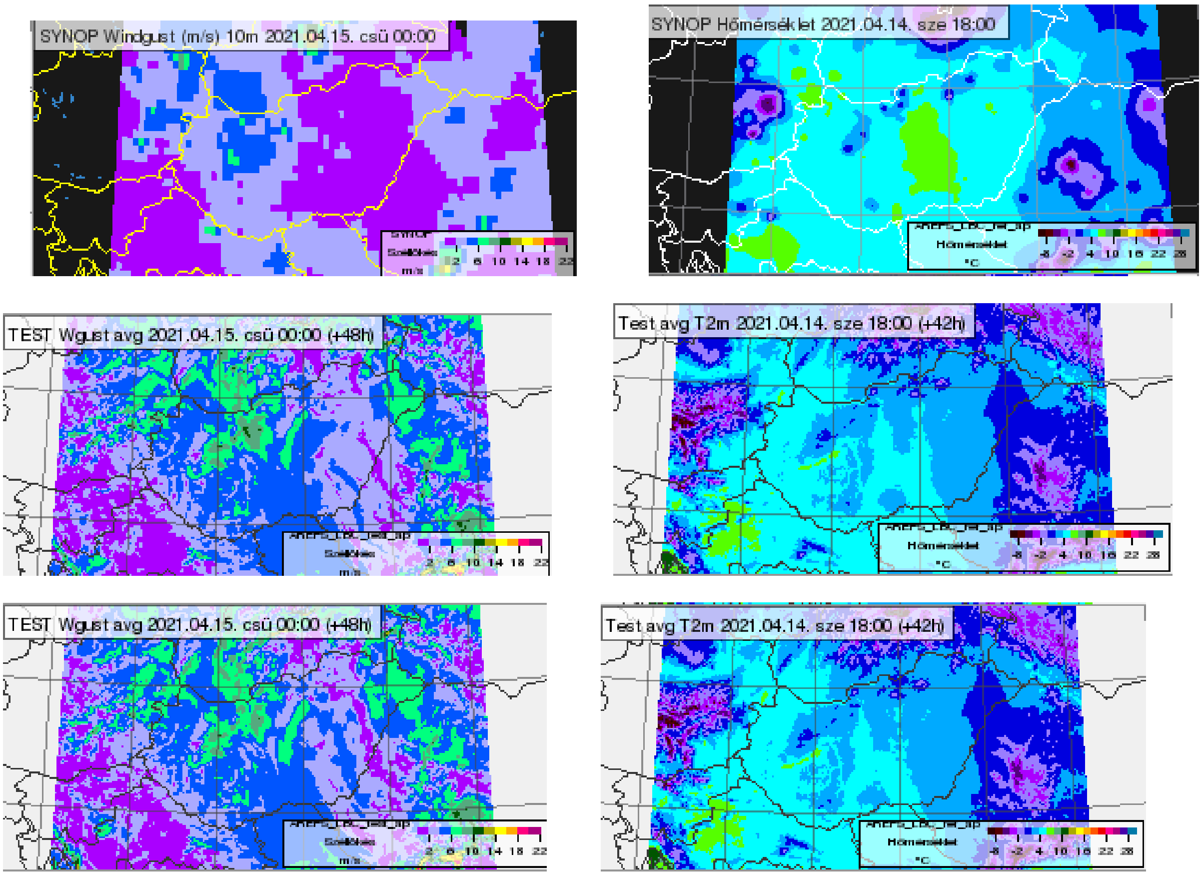


Figure 18: Wind gust at 0 UTC on 15 April 2021 (left) and 2-meter temperature at 18 UTC on 14 April 2021 (right) based on SYNOP measurements (top), ensemble mean of AROME EPS forecasts started at 0 UTC on 13 April 2021 with hourly (middle) and 3 hourly (bottom) coupled LBCs.

ECMWF provided test data before operational introduction of the new cycle and update of the LBC production (i.e. in the period of March–May). We conducted some case studies to check (1) the impact of more vertical levels and (2) the joint impact of more levels and higher coupling frequency.

Three test days were selected to compare the forecasts with the operational LBCs and the higher resolution test versions: 30 March 2021 was an uneventful, anticyclonal day, while on 13-14 April 2021 a complex front system crossed the territory of Hungary. Two experiments were conducted:

First, experiments with 3-hourly LBC coupling were run for all the three test days, using the operational settings.

The 1 hourly coupling was tested on 13 April 2021, as it was the most interesting day in terms of weather conditions.

However, significant difference was not noticed between the results of the two coupling settings, the 1-hour coupling shows a slight improvement (Figure 18).

The positive impact of the higher vertical resolution of LBCs is visible only in the forecasts longer than 24 hours (Figures 19 and 20).

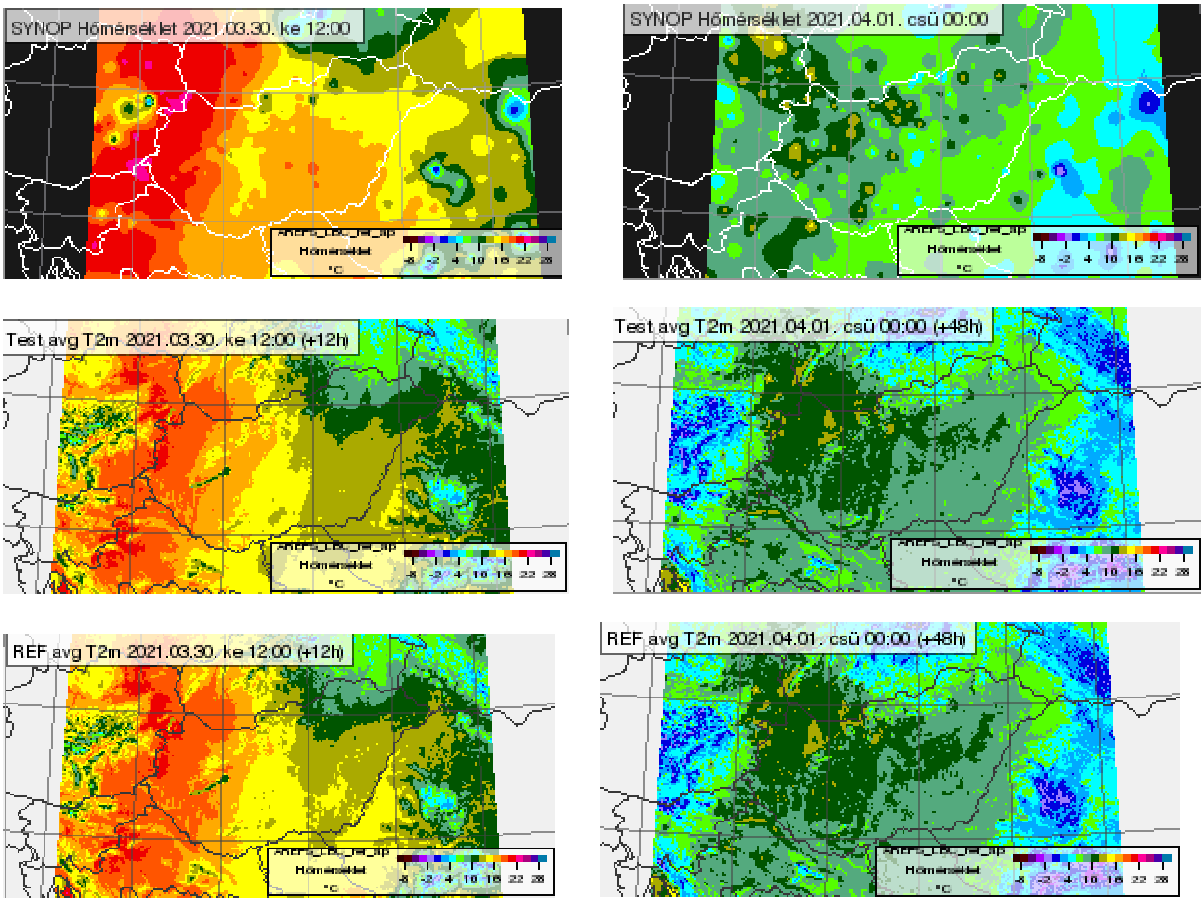


Figure 19: 2-meter temperature at 12 UTC on 30 March 2021 (left) and at 0 UTC on 1 April 2021 (right) based on SYNOP measurements (top), ensemble mean of 3-hourly coupled test (middle) and operational (bottom) AROME EPS forecasts started at 0 UTC on 30 March 2021.

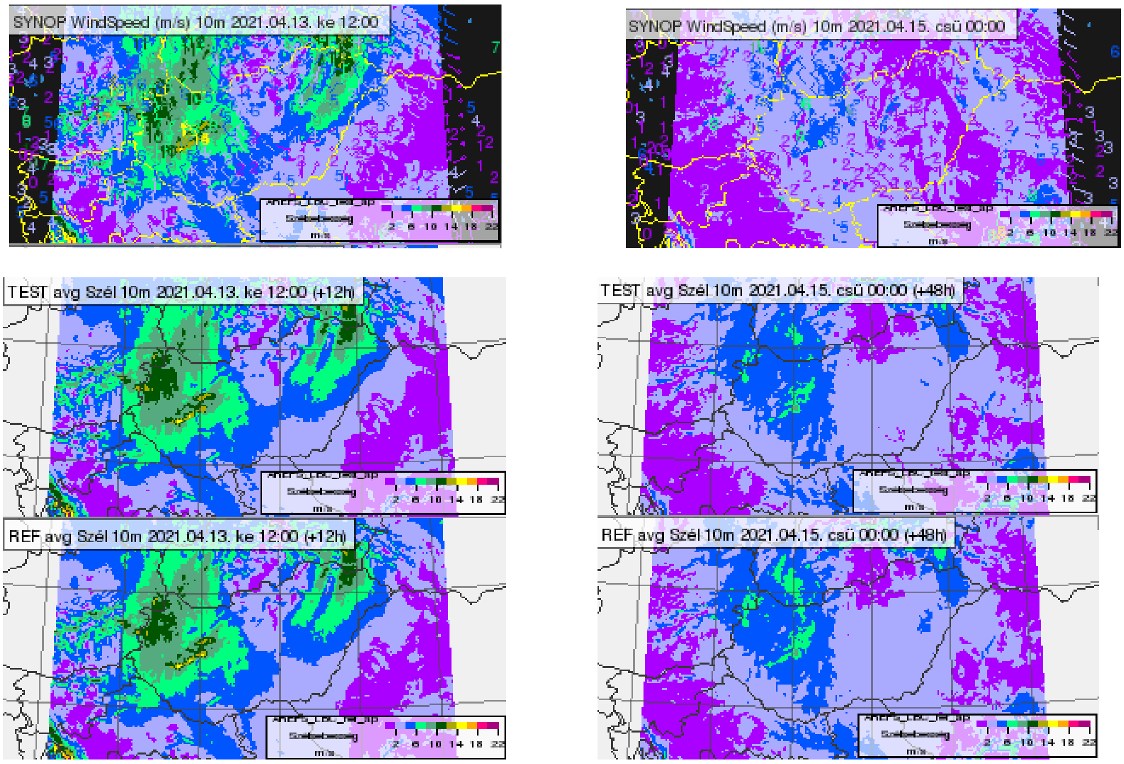


Figure 20: 10-meter wind speed at 12 UTC on 13 April 2021 (left) and at 0 UTC on 15 April 2021 based on SYNOP measurements (top), ensemble mean of the 3-hourly coupled test (middle) and operational (bottom) AROME EPS forecasts started at 0 UTC on 13 April 2021.

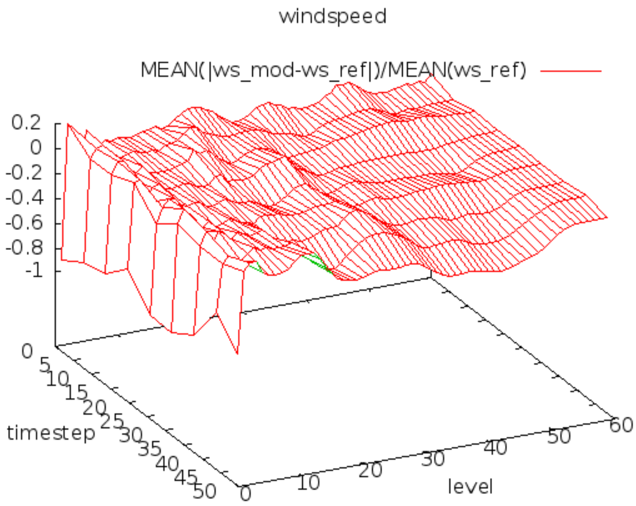


Figure 21: Mean relative difference between the wind speed forecasts of the AROME-EPS using 137-level LBCs and the operational AROME-EPS started at 0 UTC on 13 April 2021, for the control member, as function of time step and model level.

The case on 13 April 2021 was interesting as the operational AROME-EPS forecast aborted in the 4th member because of too strong wind speeds in the top model levels at the beginning of the forecast. As the problem did not appear in the experiment using the high vertical resolution LBCs over the same time period, the LBCs were comparatively investigated after being interpolated for the same AROME grid (with 60 vertical levels). Significant difference can be seen between the wind forecasts of the two experiments in the top of the model, which gradually disappears from the 3rd model level towards the surface (Figures 22-29). The experiment using the operational LBCs produced remarkably higher wind speeds in every ensemble member on the highest model levels at the beginning of the forecast period (see Figure 21 for the control member).

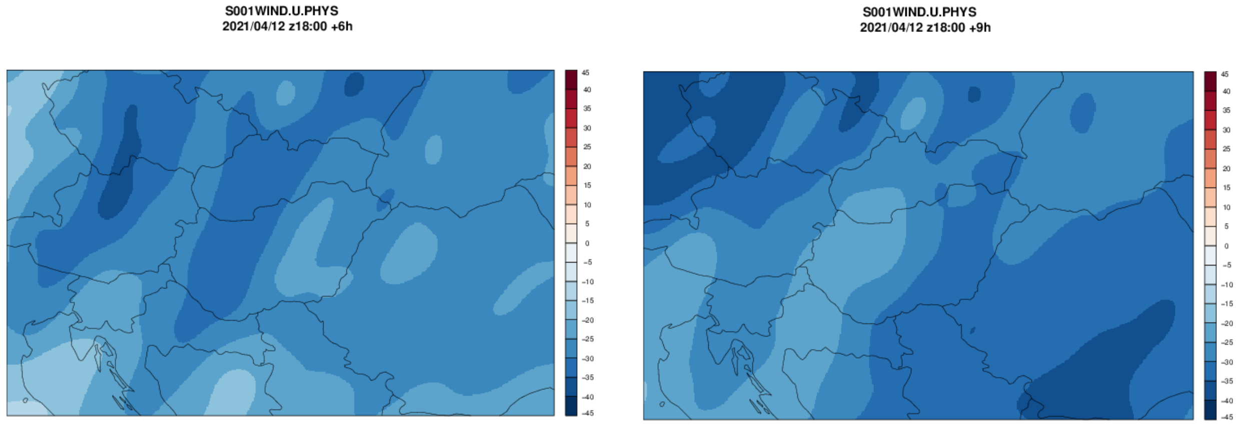


Figure 22: Differences between the LBCs interpolated from the 137- and 91-level raw LBCs to the 60-level AROME grid for U component of wind on the 1st AROME model level at 0 UTC (left) and at 3 UTC (right) for the 4th member.

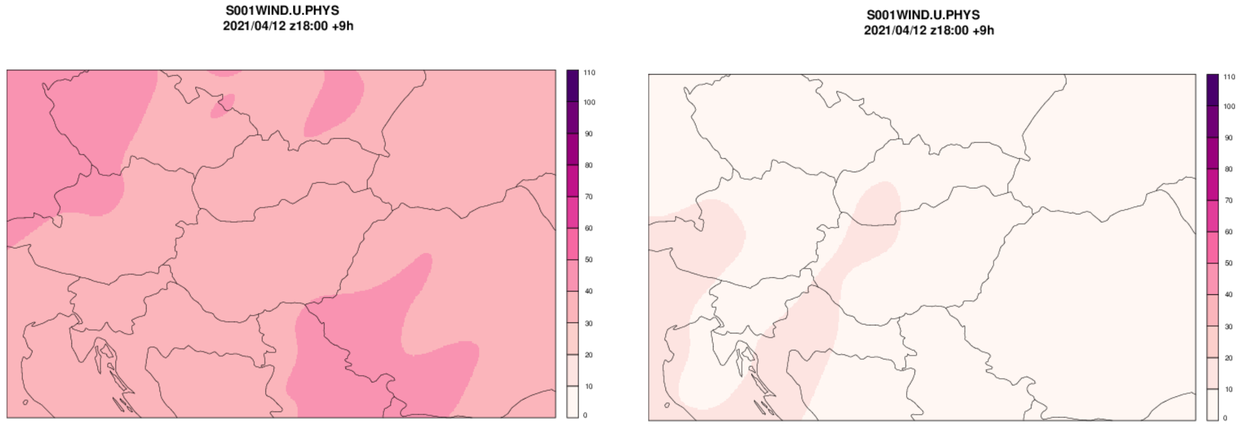


Figure 23: LBCs interpolated from the 91- (left) and 137-level (right) raw LBCs to the 60-level AROME grid for U component of wind on the 1st AROME model level at 3 UTC, for the 4th member.

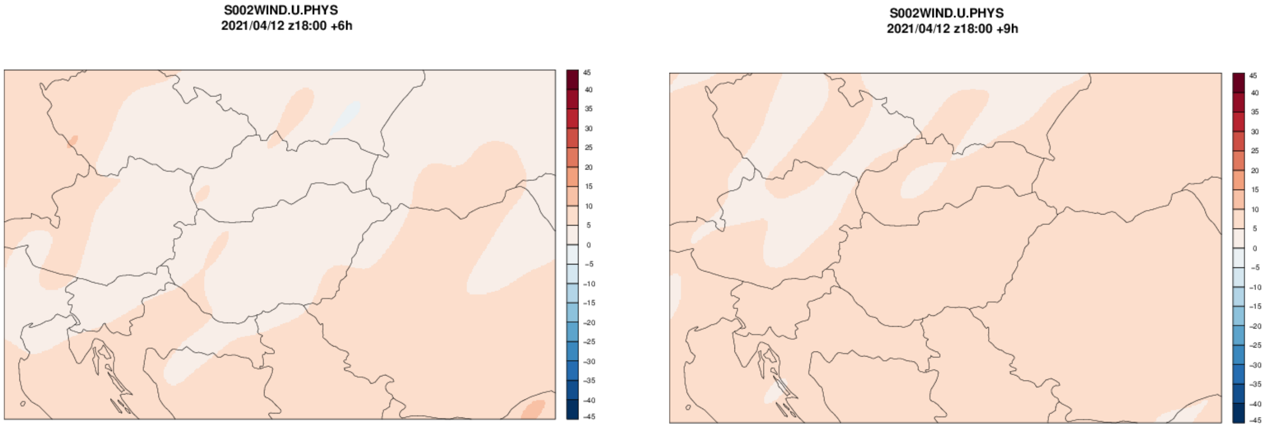


Figure 24: Differences between the LBCs interpolated from the 91- and 137-level raw LBCs to the 60-level AROME grid for U component of wind on the 2nd AROME model level at 0 UTC (left) and at 3 UTC (right) for the 4th member.

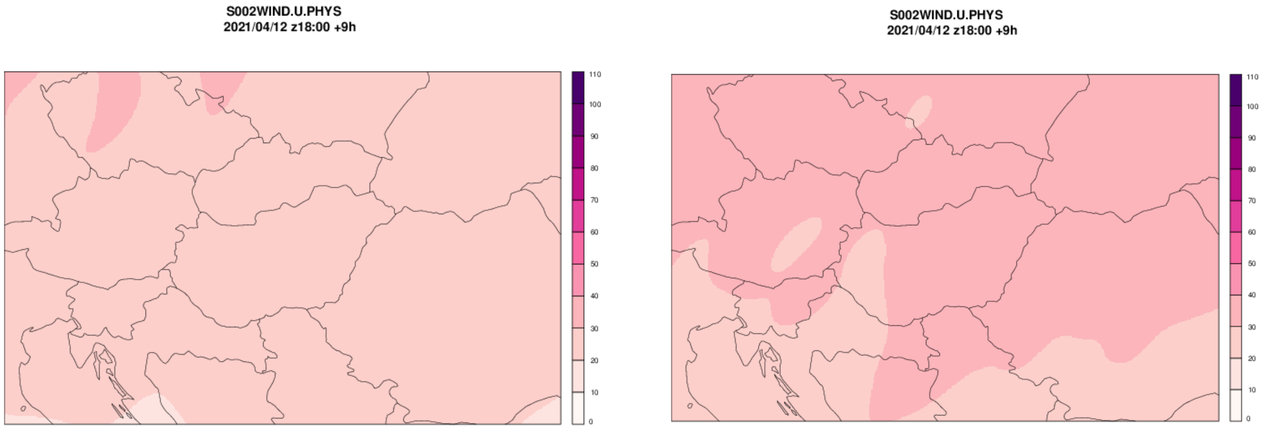


Figure 25: Same as Figure 23, but for the 2nd AROME model level.

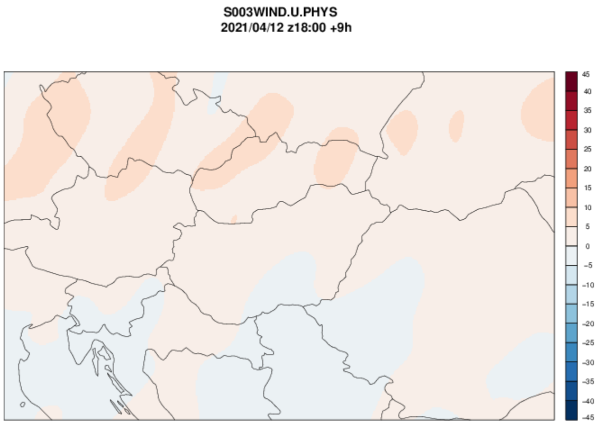


Figure 26: Same as the right panel of Figure 25, but for the 3rd AROME model level.

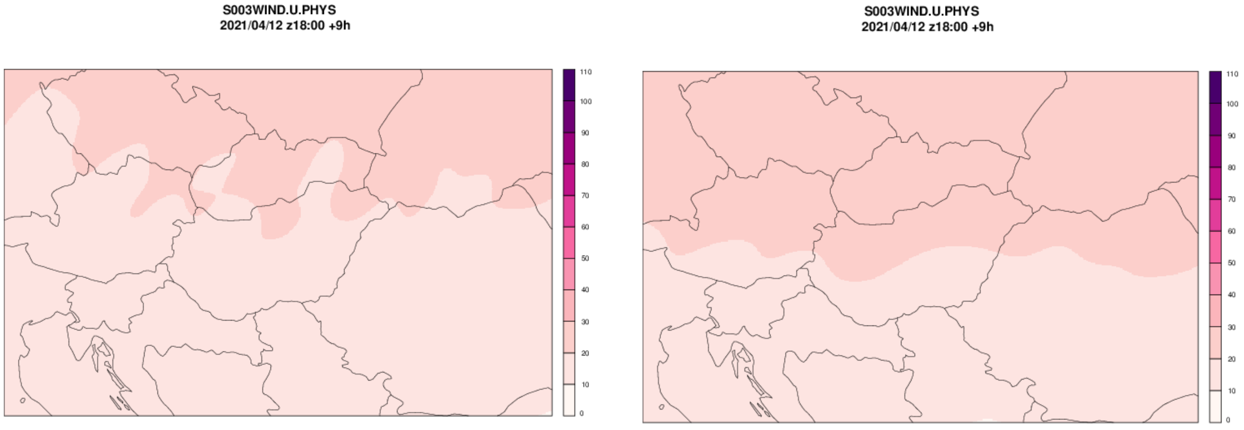


Figure 27: Same as Figure 23, but for the 3rd AROME model level.

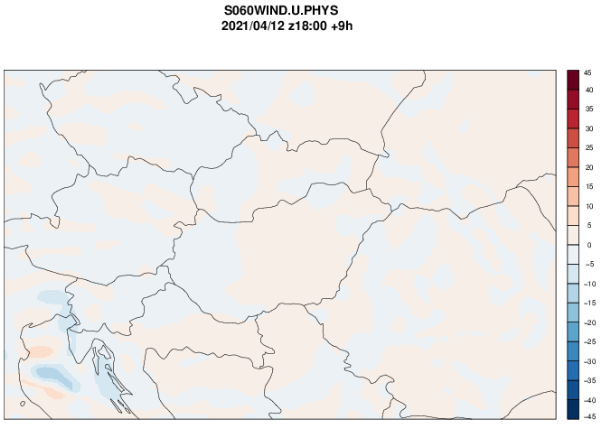
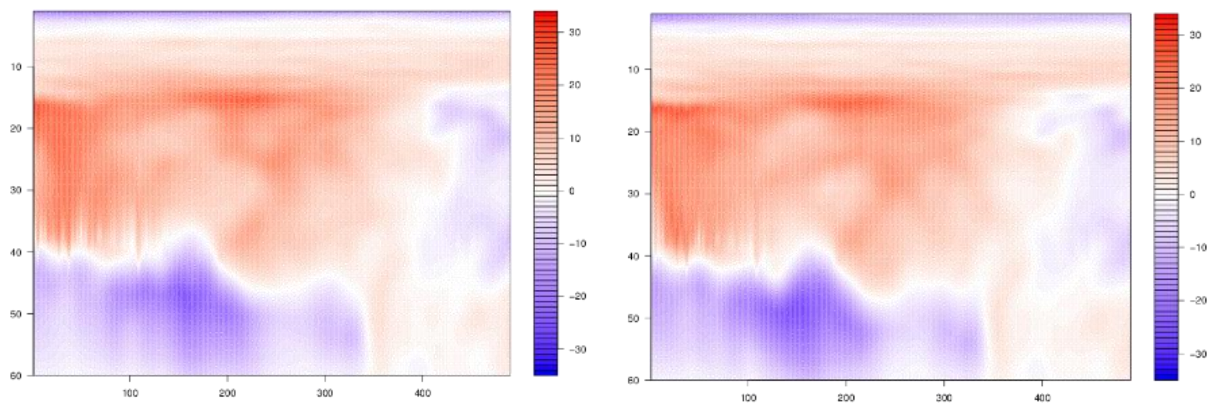


Figure 28: Same as the right panel of Figure 24, but for the 60th (lowest) AROME model level.



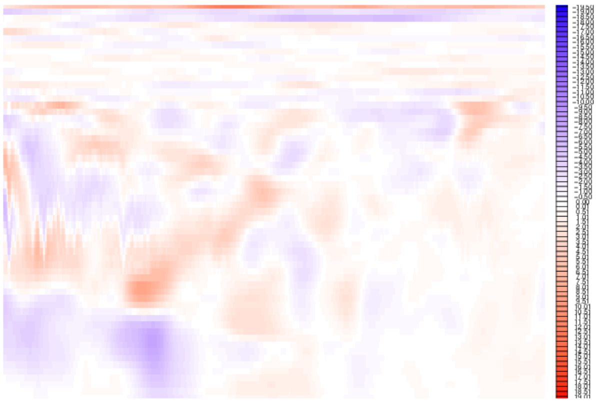


Figure 29: Vertical cross section of the V component analyses of the operational AROME-EPS (top left) and the AROME-EPS using 137-level LBCs (top right) at 0 UTC on 13 April 2021, for the 7th member and the difference between them (bottom). The section was made in x-direction in the middle of the domain.

As consequence of the high wind speed in the LBCs, the operational forecast produced much higher wind speed at the top model levels in the first few time steps of the forecast on 13 April 2021, but the difference has been balanced during the further time steps.

After the testing procedure, the higher vertical resolution LBCs were introduced into the operational AROME EPS/HU model at 0 UTC on 12 May 2021, on the first day with 3-hourly coupling. One day later, on 13 May 2021, the AROME-EPS run with 1-hourly coupling.

- **Comparison of AROME-EPS and ECMWF-ENS:**

A convective situation was chosen to compare AROME-EPS to ECMWF ENS. A high-pressure system dominated over western and central part of Europe on 30 May 2021, while a cold air drop induced some instability over the Carpathian Basin. Some showers and thunderstorms are generated during the day over North Hungary and moved to Southeast during the night. Three sets of ensembles are evaluated: (1) 11-member AROME-EPS running at 0 UTC on 30 May; (2) 51-member ECMWF ENS running at 0 UTC on 30 May; (3) 11 members of ECMWF ENS running at 18 UTC on 29 May. Comparing set 1 and set 3, we assess the added value of AROME-EPS with respect to its LBCs, while investigating set 1 and set 2, we can compare the ensemble predictions available for forecasters at the same time.

The spatial structure and the amount of small-scale precipitation are well captured by the convection-permitting AROME-EPS. The coarser resolution ECMWF ENS spread the rain over the country on the first forecast day. Its first 10 members overestimated the precipitation amount which was improved by downscaling with AROME-EPS (Figure 30). The shift of precipitation towards Southeast was predicted by all forecasts on the second day, but the chance of higher quantity was shown only by AROME-EPS (not shown). The corresponding wind gust and temperature forecasts were closer to the reality in AROME-EPS, whereas most members of ECMWF ENS overestimated the wind gust and underestimated the temperature (Figure 31) over West.

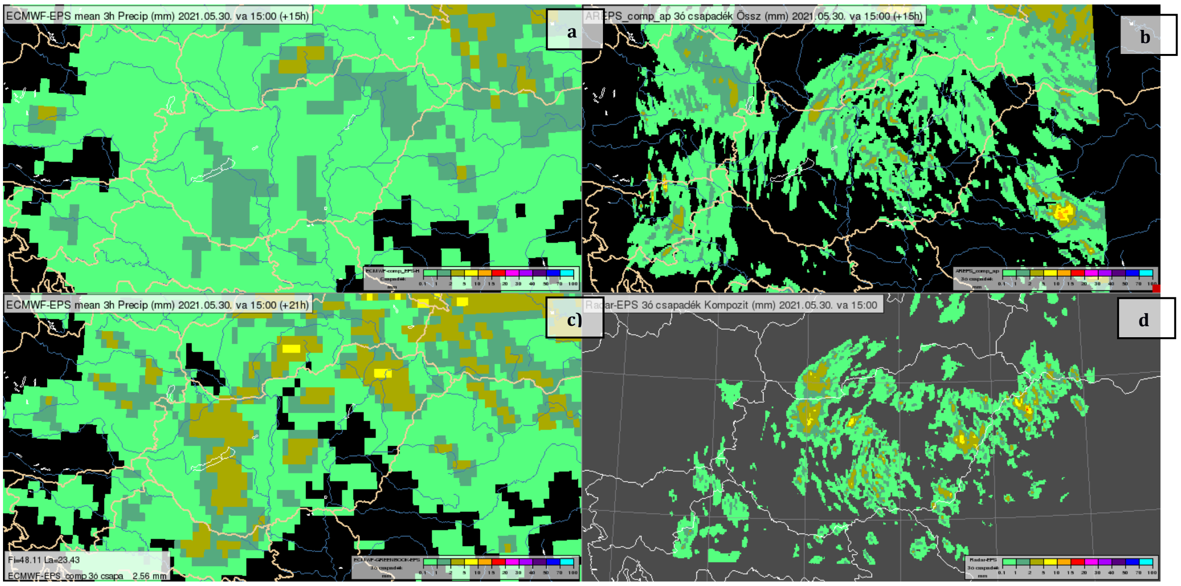


Figure 30: Ensemble mean of 3-hour precipitation forecasts on a) 30/05/2021 0 UTC + 15h by 51-member ECMWF ENS, b) 30/05/2021 0 UTC + 15h by 11-member AROME-EPS, c) 29/05/2021 18 UTC + 21h by 11-member ECMWF ENS, and d) Hungarian radar data.

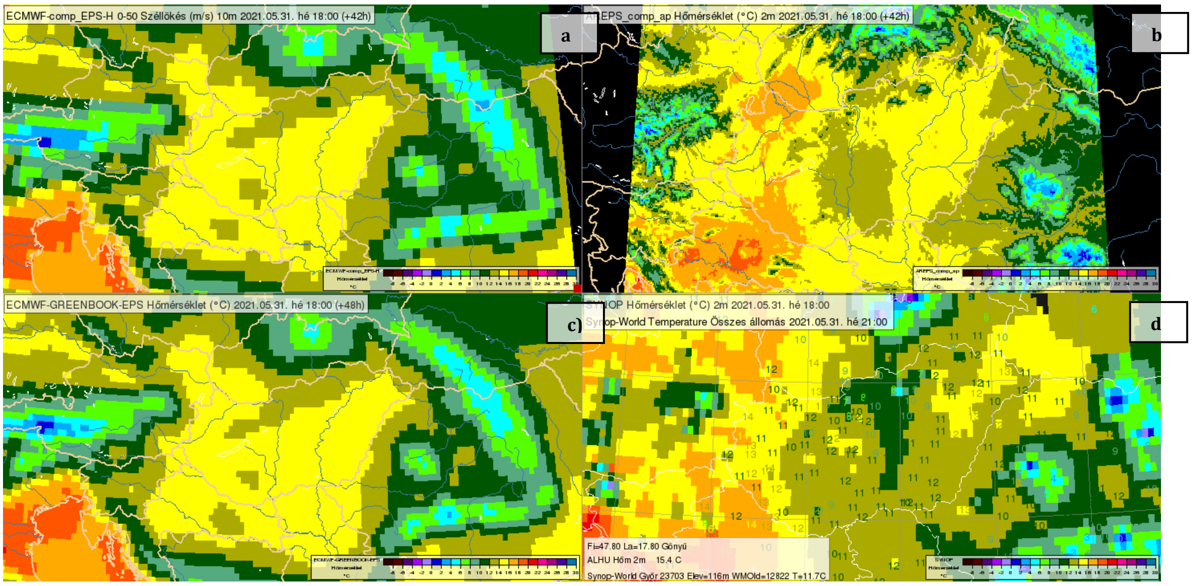


Figure 31: Ensemble mean of 2-meter temperature forecasts on a) 30/05/2021 0 UTC + 42h by 51-member ECMWF ENS, b) 30/05/2021 0 UTC + 42h by 11-member AROME-EPS, c) 29/05/2021 18 UTC + 48h by 11-member ECMWF ENS, and d) S

- **Testing of AROME-EPS 12 UTC run:**

The operational AROME-EPS provides ensemble data daily at 00 UTC. With increased computing capacity OMSZ introduced in 2021 an additional AROME-EPS forecast initialized at 12 UTC, as a parallel suite. All properties of operational AROME-EPS are kept, i. e. 2.5 km resolution, non-hydrostatic ensemble runs as a downscaling of the first 11 members of the ECMWF ENS global EPS with 6 hours time-lag and hourly coupling; analysis taken from AROME deterministic run is used as surface initial state in all EPS members; lead time of 48 hours. AROME model version is CY43. The product has become available for forecasters in February 2022. The advantage of the new run comes from the more current global run, which could be observed in some cases in the near-ground parameters, an example is shown in Figure 32, when an afternoon precipitation event associated with a low pressure system was better captured by the latest AROME-EPS run. This can be seen for precipitation, 2 meter temperature and 10 meter wind gust. However, systematic verification, as well as some feedback from the forecasters are needed to evaluate the added value of this second EPS run which can be even higher in summer convective cases. The AROME-EPS 12 UTC run is planned to become operational in April 2022 latest. In between OMSZ is testing a third run at 06 UTC. This requires some reorganization of the current operational suites, because at the same time we intend to make the forecasts product generation faster.

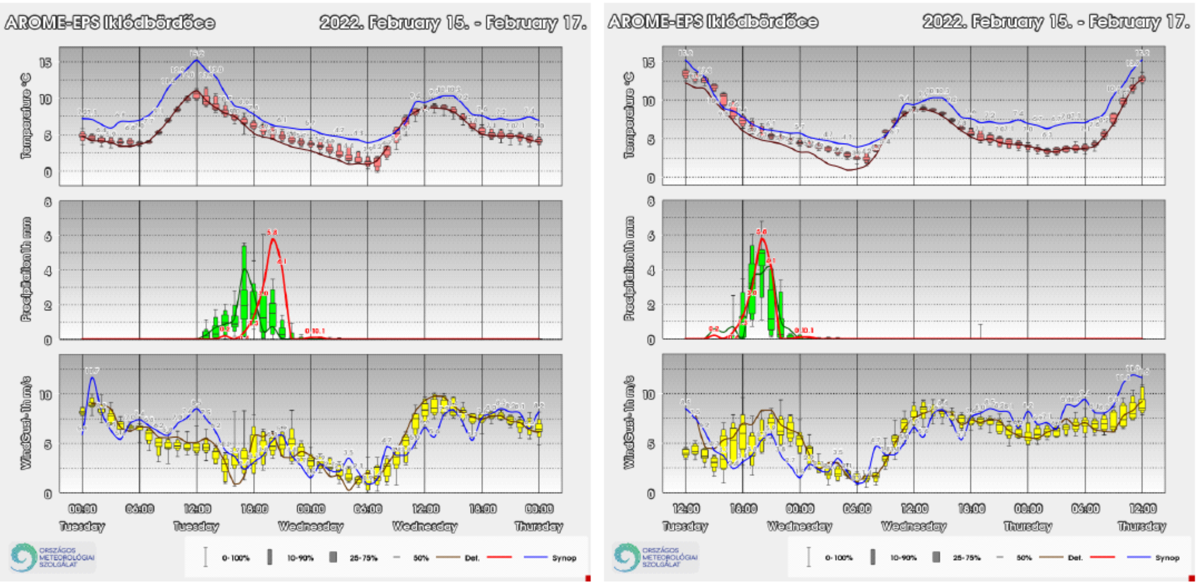


Figure 32: EPSgram for near-surface parameters for AROME-EPS run at 00 (left) and 12 UTC (right) on 15th February 2022 at Iklódbördőce, in the Southwest of Hungary. 2 meter temperature (top panel), hourly precipitation (middle panel) and 10 meter wind gust (bottom panel) forecasts (bars: AROME-EPS, line: AROME deterministic) and measurements (blue and red lines with numbers) are shown.

❑ Topic 2: EPS related development at ZAMG

Convection-permitting - Limited Area Ensemble Forecasting system (C-LAEF) has been developed at ZAMG and is running operationally at ECMWF HPCF as a time critical 2 application since November 2019.

C-LAEF is based on the non-hydrostatic AROME model with a horizontal resolution of 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 cycle has been 6h until the major upgrade in December 2021 and is now 3h. Model error is represented by a hybrid stochastic perturbation scheme, where perturbations 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 8 runs per day (00, 03, 06, 09, 12, 15, 18 and 21 UTC). The lead times vary between +60h (00 UTC), +48h (12 UTC) and +3h (all intermediate runs).

In 2021, the following activities were realized:

- Full cy43t2 e-suite of C-LAEF during summer and autumn period 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
- Common RC-LACE-EF coupling file production at ECMWF (903); implementation and testing of new coupling files from ECMWF-ENS for C-LAEF
- Upscaled probabilities for C-LAEF
- Extension of C-LAEF SPP scheme by additional perturbations in physics parametrizations; implementation of SPG pattern generator
- Major upgrade of operational C-LAEF on December 6th 2021 (cy43t2, 3h assimilation cycle, surface perturbations, new parameters, advanced 2m diagnostics, etc.)
- Organization of RC-LACE EPS meeting (Dec 9th 2021) with discussion on the future of EPS in RC-LACE
- Development and operational production of EPS maps and EPSgrams (new summer version) with Visual weather for forecasters and customers
- Preparation and provision of C-LAEF data for the SRNWP EPS project (summer 2020 period)
- Provision of C-LAEF data for the ESSL (European Severe Storm Laboratory) testbed for the period May to September 2021; deep investigation of C-LAEF performance for severe convective situations
- Set-up of C-LAEF for Turkish domain – support, scripts, input files, etc.

- **Cy43t2 e-suite of C-LAEF at ECMWF HPCF**

In autumn 2020 the cy43t2 code was compiled and implemented under the Austrian operational user at the ECMWF HPCF. It was tested (mainly technically) and was run for some selected case studies. In spring 2021 this cy43t2 e-suite was set-up to run in full parallel mode with the full ensemble size (16+1), 4 runs per day (only 1 long-term run), full assimilation cycle (6h), same resolution (2.5km) and the same perturbation schemes as in the operational C-LAEF suite. Additionally, the cy43t2 e-suite contains a new surface perturbation scheme (described later in this report). Due to the very high computational costs (about 5 Mio SBUs per month) it was decided to run the C-LAEF cy43t2 e-suite only for selected months (summer season, November/December). To have a continuous verification and to have a good overview on the daily performance of the cy43t2 e-suite especially in comparison to the operational C-LAEF suite, the HARP verification package with monitor was installed and set up at the ECMWF machines.

From the technical point of view, the e-suite was running very stable with only some small interruptions due to system sessions at the ECMWF-HPCF. The HARP verification (Figures 33-39) shows a general quite good performance for most investigated parameters, but also some weaknesses especially for T2m, global radiation and cloudiness, which are related to some general problems in C-LAEF and are also present in the operational cy40t1 version (see physics report).

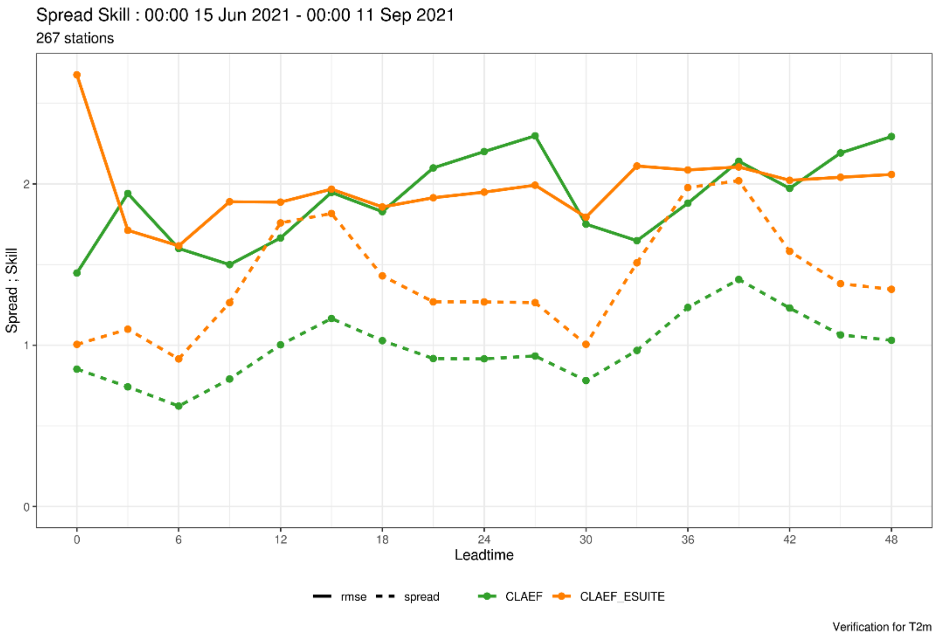


Figure 33: Spread and RMSE of T2m of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

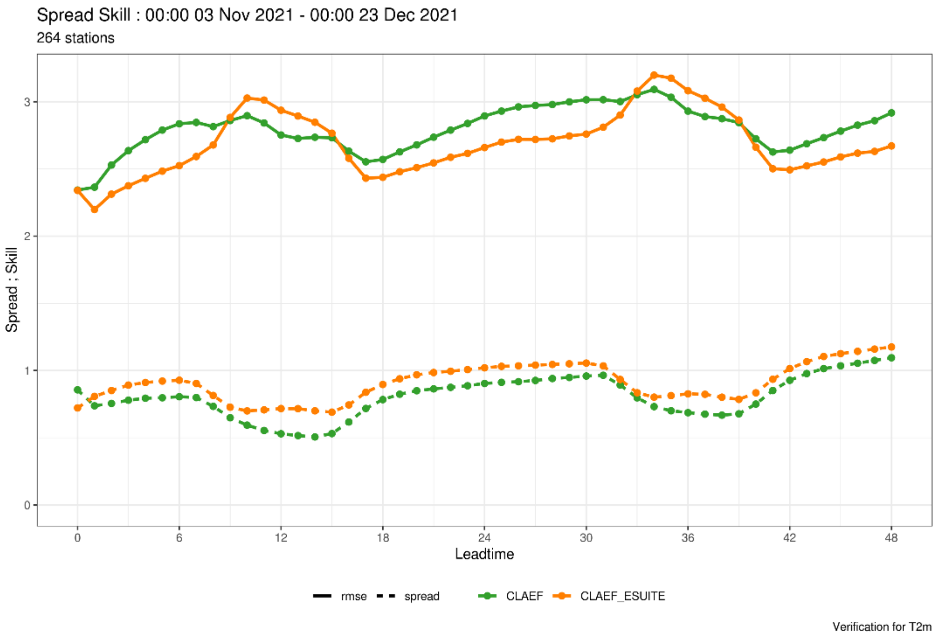


Figure 34: Spread and RMSE of T2m of C-LAEF and C-LAEF cy43t2 e-suite for November/December 2021.

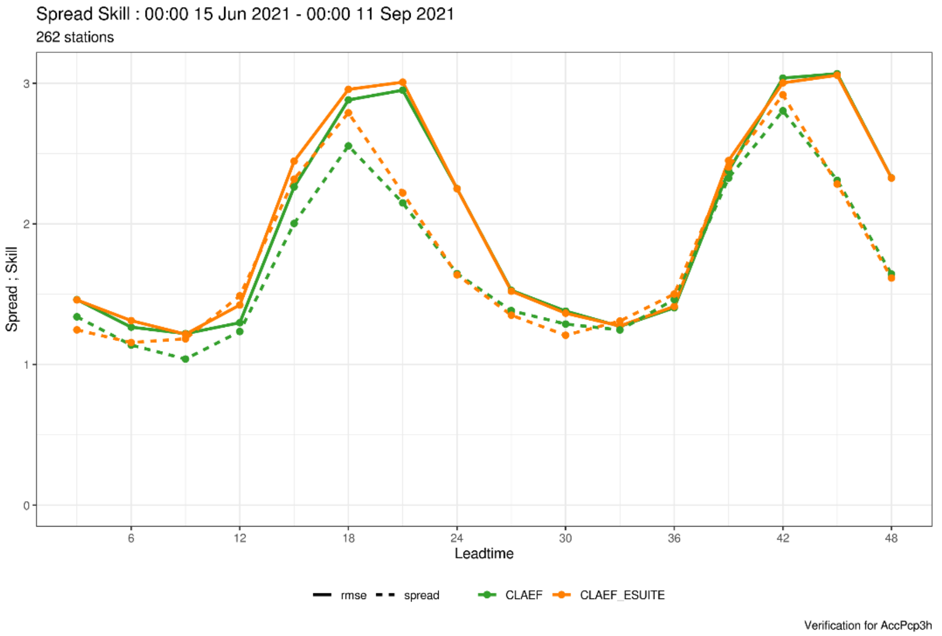


Figure 35: Spread and RMSE of 3-h accumulated precipitation of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

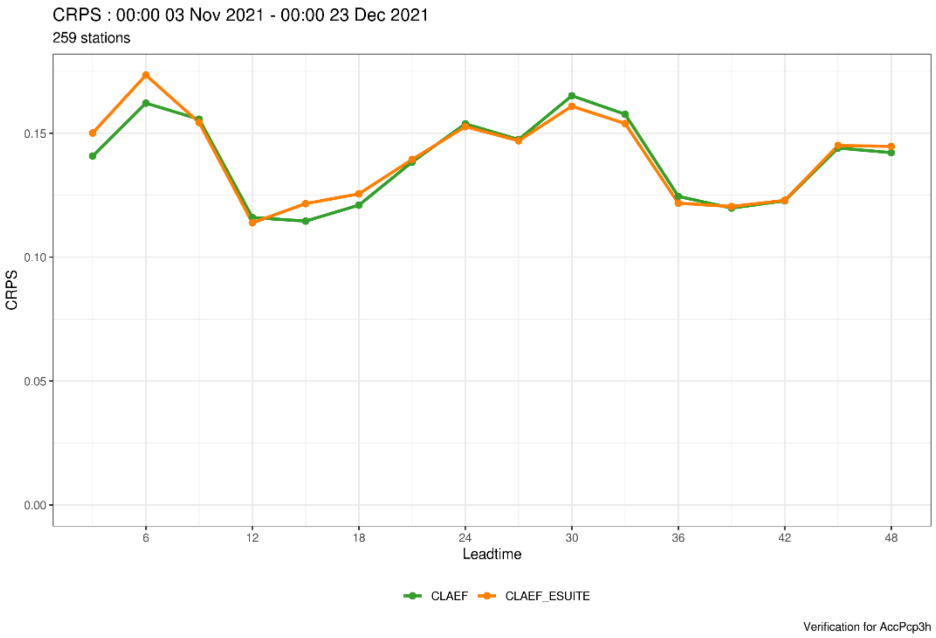


Figure 36: CRPS of 3-h accumulated precipitation of C-LAEF and C-LAEF cy43t2 e-suite for November/December 2021.

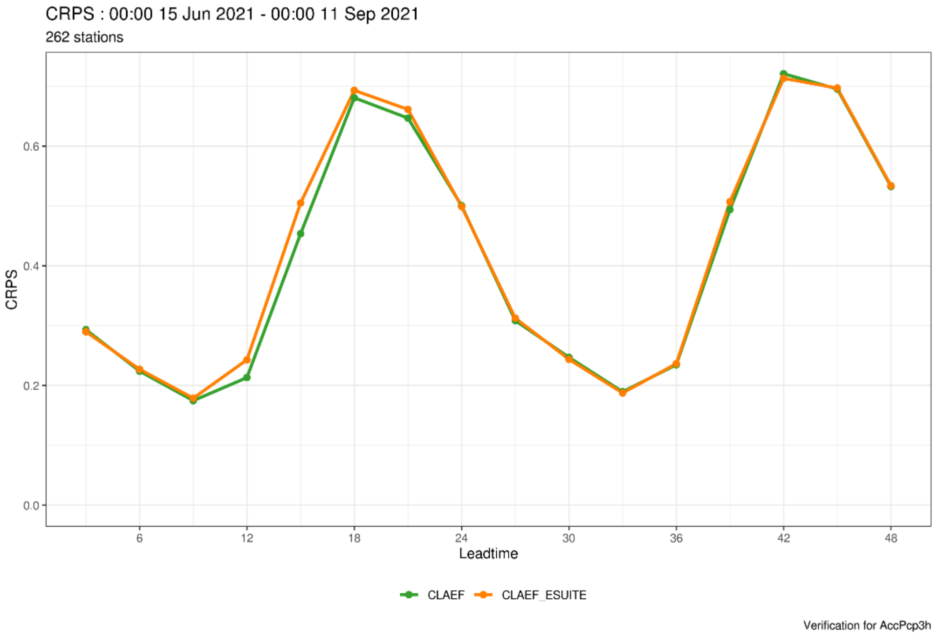


Figure 37: CRPS of 2m relative humidity of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

Figure 38: CRPS of 700 hPa u-component of wind of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

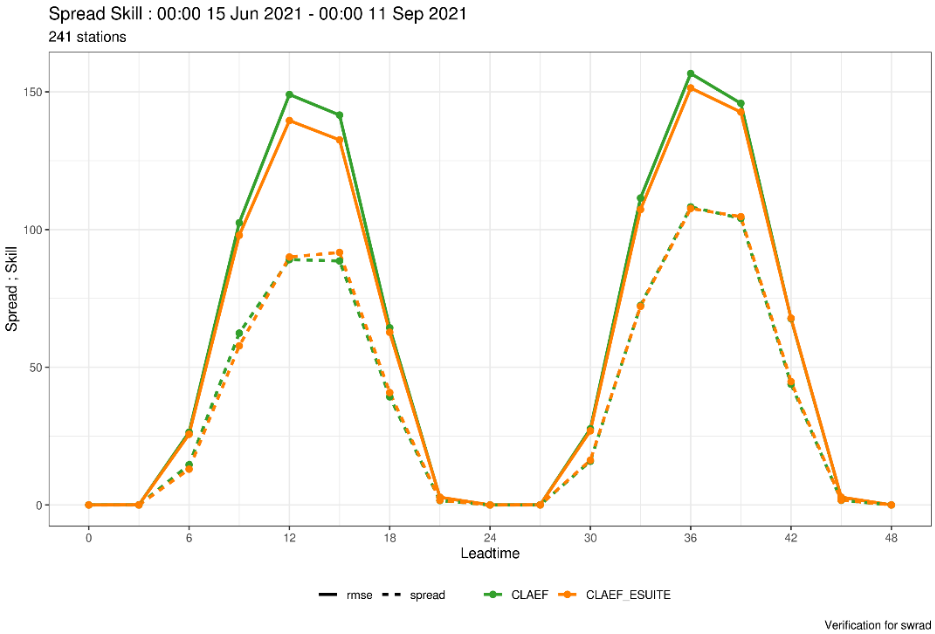


Figure 39: Spread and RMSE of global radiation of C-LAEF and C-LAEF cy43t2 e-suite for summer 2021.

With the present verification results it has been decided to switch to a new cy43t2 C-LAEF version in operational mode on December 6th 2021.

- **C-LAEF performance for severe weather events**

In 2021 several severe weather situations occurred in Austria where the operational C-LAEF system has shown its important role in the ZAMG forecasting and warning procedures. The results of two summertime case studies - one severe thunderstorm event and one large-scale precipitation event, have been collected in the “case study report 2021” which can be found on the RC-LACE webpage.

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

The perturbation scheme in the operational C-LAEF version comprises perturbations of initial conditions (observation perturbations near the surface and in the upper air; ensemble JK), lateral boundary conditions (coupling with different ECMWF-ENS members) and a combination of tendency and parameter perturbations for the representation of model error (Wastl et al., 2021). So far, no perturbation of soil/surface parameters (e.g. LAI, snow cover, vegetation, etc.) is considered in the operational version. To close this gap the surface perturbation scheme of Météo France (Bouttier et al., 2016) has been implemented and tested in the C-LAEF e-suite. In this scheme (activation by switch LPERTSURF) the parameters in Table 1 are perturbed stochastically at the beginning of each model integration. This means that the output file of the surface assimilation (CANARI in our case) is perturbed by the external routine pertsurf.F90. In case of Météo France the surface analysis of the unperturbed control (member 00) is used in all members and this analysis is then perturbed by LPERSTURF with different seeds in each member. When we verified first runs with this scheme and compared it with the operational C-LAEF (without surface perturbation) we found a significant reduction of spread in the parameters near the surface. It turned out that this comes from using the same surface analysis in all members of the e-suite. In the operational C-LAEF version the surface analysis is made separately for each member with own observation perturbation of T2m and RH2m. To overcome this problem we have modified the Météo France LPERTSURF scheme accordingly:

- 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 then perturbed with different seeds in each member (same as Météo France does)
- 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 parameters are cycled in each member

By doing so we can increase the spread of surface parameters like T2m or RH2m significantly compared to the Météo France method. Figure 40 shows the impact of the new surface perturbation scheme on the T2m temperature for a two weeks test period in November 2021. Spread is significantly increased over the whole forecasting range, while RMSE is not negatively influenced. This results in a much better spread/skill ratio.

Besides the good verification scores over the summer and winter test period, the new surface perturbation scheme also shows some improvements for selected case studies - for example in the prediction of low stratus/fog. The surface perturbation scheme increases the spread in the C-LAEF ensemble, which has a positive impact on the horizontal distribution of low stratus/fog in the model. Some more tuning is necessary and planned for the future.

Table 1: 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

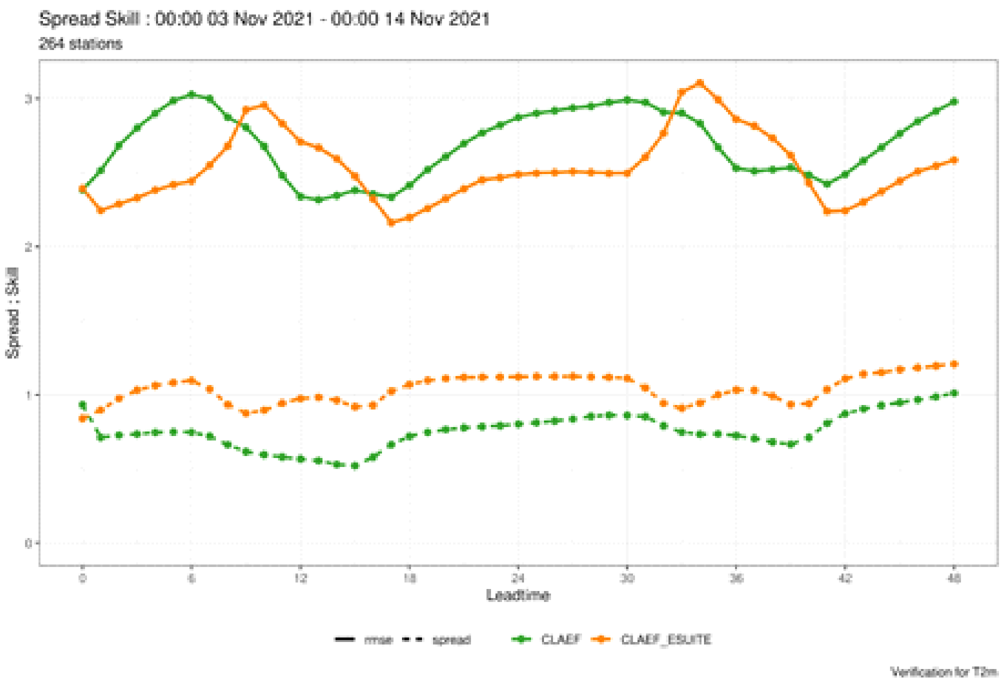


Figure 40: Spread and RMSE of T2m of C-LAEF and C-LAEF cy43t2 e-suite (with surface perturbation scheme) for a 2 weeks test period in November 2021.

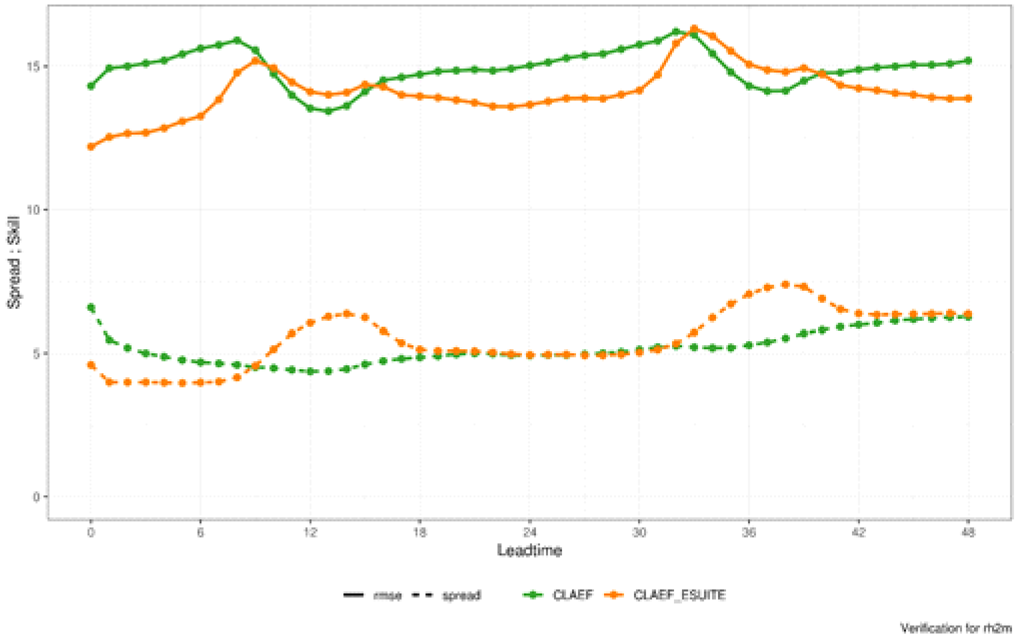


Figure 41: Spread and RMSE of RH2m of C-LAEF and C-LAEF cy43t2 e-suite (with surface perturbation scheme) for a 2 weeks test period in November 2021.

- **Common RC-LACE-EF coupling file production at ECMWF**

Coupling files from ECMWF-ENS runs are produced under Time-critical option 3 at ECMWF and were used by Hungarian AROME-EPS as coupling files in the past. Whereas the other operational EPS systems in the RC-LACE community produced their LBCs running configuration 903 (A-LAEF) and 901/927 (C-LAEF) on their own. Since the requirements for LBCs of AROME-EPS and C-LAEF are rather similar it was planned to find a common setup to reduce duplicated work.

Table 2: Reorganization of ECMWF ENS coupling file production for RC-LACE.

LACE_EF	47R1	Next Config - 47R2	Comments
00/12	11 Members - 3-hourly to STEP=12 47 levels	**17 Mem. - hourly to STEP=18 60 levels**	New config ~6 times more expensive than existing one.
06/18	11 Members - 3-hourly to STEP=60 47 levels	**17 Mem. - hourly to STEP=72 60 levels**	But cost compensated by new job organisation.

The current, and as far as possible future requirements of C-LAEF and AROME-EPS were identified and communicated to ECMWF. The additional costs of the new requirements (~ 6x more expensive) were compensated by a reorganization of the 903 setup running in TC-3 at ECMWF. The switch to the new setup was implemented with ECMWF upgrade to cycle 47R2 on 11/05/2021.

- **Upscaled probabilities for C-LAEF**

A post-processing tool was technically implemented to calculate upscaled fields of e.g. precipitation for C-LAEF. The tool reads the final C-LAEF grib files and adds the upscaled fields as new fields to the grib. It allows to calculate the mean value of a given field in a predefined radius for every grid point and/or assigns the maximum value in the given radius. The evaluation of these fields is still in progress.

- **Extension of C-LAEF SPP scheme**

Some work in 2021 has also been dedicated to the model error representation in C-LAEF. Model error in the operational C-LAEF version is currently represented by a hybrid stochastic perturbation scheme, where perturbations of tendencies in shallow convection, radiation and microphysics are combined with parameter perturbations in the turbulence scheme. To increase the physical consistency in the perturbation scheme, the SPP (stochastically perturbed parametrizations; Ollinaho et al., 2017) approach has been applied to the radiation, microphysics and shallow convection scheme in C-LAEF as well. The perturbations are produced by the newly implemented SPG pattern generator (Tsyrulnikov and Gayfulin, 2017).
A C-LAEF e-suite has been set up including a SPP scheme with 13 stochastically perturbed parameters. 11 of those parameters are listed in the following Table 3. Additionally, 2 microphysics parameters are perturbed which are controlling the sublimation of graupel and snow hydrometeors (ZRDEPGRED, ZRDEPSRED). They have been added because of too strong orographic precipitation influence on the precipitation field in the operational C-LAEF (too much precipitation on the mountains and in the luv, too less in the valleys and in the lee). By stochastically perturbing these parameters, the precipitation field in the Alps could be improved significantly.

Table 3: Parameters which are perturbed stochastically in the SPP scheme currently implemented in a C-LAEF e-suite (in yellow boxes).

Scheme	Parameter	Physical meaning	Default	Range
Radiation	RSWINHF	Shortwave inhomogeneity factor	1	0.6 - 1
	RLWINHF	Longwave inhomogeneity factor	1	0.6 - 1
	RCRIAUTI	Snow Autoconversion threshold	0.2e-3	0.2e-4 - 0.25e-3
Microphysic	RCRIAUTC	Rain Autoconversion threshold	1e-3	0.4e-3 - 1e-3
	VSIGQSAT	Constant for subgrid condensation	0.02	0 - 0.1
	XLINI	Minimum mixing length	0	0 - 0.2
	XCTD	Constant for dissipation	1.2	0.98 - 1.2
	XCTP	Constant for T-P correlations	4.65	1.035 - 22.22
Turbulence	XCEP	Constant for V-P correlations	2.11	0.225 - 4.0
	XCED	Constant for dissipation of TKE	0.85	0.4 - 2
	XPHI_LIM	Threshold value for Sc^{-1} and Pr^{-1}	3	1 - 4.5
	XCET	Constant for transport of TKE	0.4	0.072 - 1.512
	SLHDEPSH	Strength of SLHD	0.060	0.01 - 0.09
Diffusion	SLHDKMIN	Diffusion function minimum	0	-1 - 1
	SLHDKMAX	Diffusion function maximum	6	4 - 12
	XRIMAX	Critical Richardson Number	0.2	0 - 0.2
Surface	XFRACZ0	Coefficient of orographic drag	5	2 - 10
	XCMF	Closure coefficient at bottom level	0.065	0 - 0.1
	XABUO	Coefficient of the buoyancy	1	0.7 - 1.5
Convection	XBDETR	Coefficient of the detrainment	1e-6	0 - 1
	XENTR_DRY	Coefficient for dry entrainment	0.55	0.1 - 0.699

However, a lot of tuning considering the perturbation scale and range has to be made before a final operationalization. For the future it is planned to add some more parameters to the perturbation list above, especially in the microphysics scheme were we would expect some more improvements during summertime convective situations. Due to the postponed stay of Endi Keresturi at ZAMG this topic is delayed a bit at the moment.

- **Upgrade of operational C-LAEF suite**

After intensive testing and several month of parallel cy43t2 CLAEF e-suite we have finally upgraded the operational TC2 C-LAEF suite at the ECMWF HPC on December 6th 2021. This upgrade comprises following topics:

- Upgrade of AROME code cycle from cy40t1 to cy43t2
- Upgrade of assimilation cycle from 6h to 3h, which means that we now have 8 C-LAEF runs per day (only 2 long runs)
- Implementation of surface perturbation scheme
- New parameters (precipitation type, WWcode, weather symbols, storm relative helicity, updraft helicity)
- Improved 2m diagnostics (T2m, RH2m) with distinction between mountain, valley and flatland areas

- **EPS meeting**

On December 9th an EPS online meeting has been organized for all the EPS related persons within RC-LACE. The main topic of this meeting was the "Future of EPS in RC-LACE". We discussed the common direction we want to go for within RC-LACE, mainly whether we should go towards a common 1km EPS (A-LAEF) or if we should continue with 3 different EPS and develop these 3 systems independently. Most of the participating colleagues prefer a common 1km system – details about physics/surface configuration, computing resources or manpower have to be clarified in the near future. The minutes and presentations of this meeting can be found on the RC-LACE webpage.

- **Development and operational production of EPS maps and EPSgrams**

Strong focus on EPS related work at ZAMG in 2021 was put on the development and production of EPS maps and EPSgrams for forecasters and customers. In a close co-operation between model developers and forecasters needs and ideas were evaluated and specific probabilistic products and maps were developed. These products comprise classical probability maps such as probability of exceeding certain thresholds, extreme members, median, etc. but also EPSgrams for more than 250 points in the Alps. All these maps and EPSgrams are produced with the software Visual Weather. With the operational implementation of these EPS products, the acceptance and usage of C-LAEF within the routine work of the forecasters has significantly increased. A new summer version (May – September) of the C-LAEF EPSgrams has been developed with strong focus on convective indices (Figure 42). After consultation with the product developers at ZAMG it has been decided to share the Visual Weather template for the C-LAEF EPSgrams within RC-LACE partners and to publish such EPSgrams for selected points on the RC-LACE webpage.

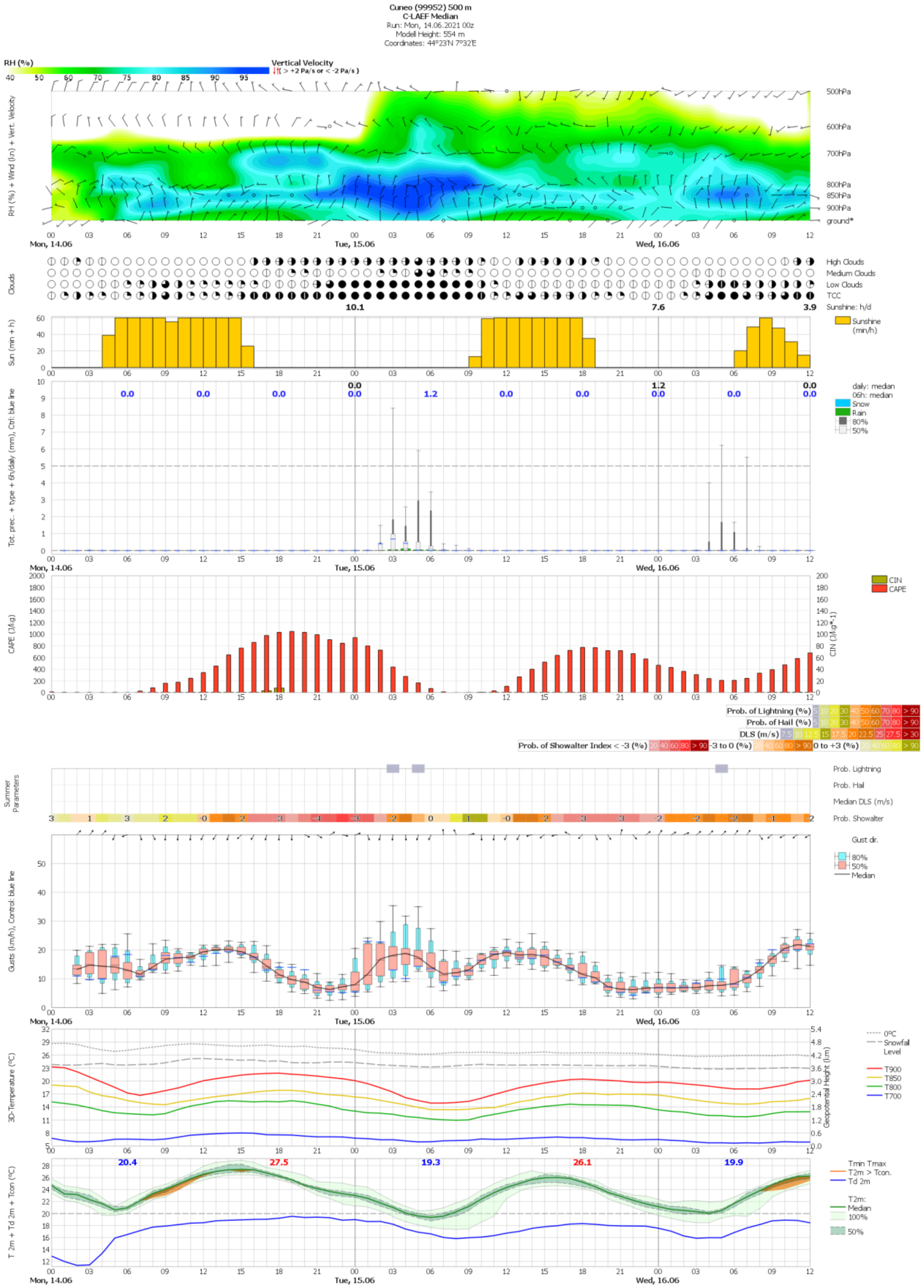


Figure 42: C-LAEF Epsgram for a point in northern Italy on June 14 2021 produced with Visual Weather.

Bouttier, F., Raynaud, L., Nuissier, O. and Ménétrier, B. (2016) Sensitivity of the AROME ensemble to initial and surface perturbations during HyMeX. Quart. J. Roy. Meteor. Soc. 142, 390-403, https://doi.org/10.1002/qj.2622

Ollinaho, P., Lock, S. J., Leutbecher, M., Bechtold, P., Beljaars, A., Bozza, A., Forbes, R. M., Haiden, T., Hogan, R. J. and Sandu, I. (2017). Towards process-level representation of model uncertainties: Stochastically perturbed parametrisations in the ECMWF ensemble. Quart. J. Roy. Meteor. Soc. 143, 408–422, https://doi.org/10.1002/qj.2931

Tsyrulnikov, M. and D. Gayfulin, 2017: A limited-area spatio-temporal stochastic pattern generator for simulation of uncertainties in ensemble applications, Meteorologische Zeitschrift 26(N 5), 549-566, DOI: 10.1127/metz/2017/0815.

Wastl, C., 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

Efforts: 11.5 PM

Contributors: David Lancz, Katalin Jávorné-Radnóczi, Gabriella Szépsó (all OMSZ), Christoph Wittmann, Clemens Wastl, Florian Weidle (all ZAMG)

Documentation: papers published in scientific journals; convection-permitting ensemble systems for operational use (ZAMG, OMSZ); EPS documentation at ECMWF confluence site; minutes on RC-LACE webpage; EPS products and visualizations

Status: Upgraded C-LAEF suite running in full operational mode under the time critical environment at ECMWF HPCF; C-LAEF e-suite running at ECMWF HPCF; AROME-EPS operationally running at OMSZ; some delays due to postponed stays (COVID)

S4 Action/Subject/Deliverable: EPS - Verification

Description and objectives:

This topic has been mainly shifted to the new area Applications and Verification

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 been 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 have been frozen since 2018. With the new area “Applications and Verification” this topic has been restarted in 2021. Simona Tascu verified A-LAEF forecasts in the period 01/01/2021 to

31/03/2021 for 157 synop stations in Romania with the LAEF verification package (BIAS, RMSE, spread, brier score, CRPS for T2M, MSLP and 10m wind speed). Results can be found on the RC-LACE webpage.

The HARP verification package, providing suitable tools for probabilistic and mesoscale forecast verification, with focus on spatial aspects as well, is more and more used within the RC-LACE consortium. It is extensively used in Austria at ZAMG where continuous verification of operational C-LAEF and C-LAEF e-suite is done with HARP. Visualization of verification results (HARP monitor) is based on the interactive application originating from HARPVis functionalities, as well as with standard R graphics functions.
Also at SHMU in Slovakia and at OMSZ in Hungary it is used regularly and also Poland is at the moment starting to work with the HARP verification package. Several LACE countries participated at a HARP online training course in February 2022.

Efforts: shifted to new area Applications and Verification

Contributors: Martin Petráš (SHMU), Dávid Tajti, Katalin Jávorné-Radnóczi (OMSZ), Clemens Wastl, Florian Weidle, Christoph Zingerle (all ZAMG), Simona Tascu (METRO)

Documentation: Local installations (SHMU, ZAMG, OMSZ, IMGW) and documentation of case studies with the HARP verification package

Status: Shifted to new area Applications and Verification

S5 Action/Subject/Deliverable: Collaborations

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

The new ACCORD area leader for EPS (Henrik Fedderson) has initiated stronger cooperation between the area leaders of the different consortia (Inger-Lise Frogner, Laure Raynaud, Clemens Wastl), resulting in several online meetings about RWP and common EPS topics in 2021. As a result of this stronger cooperation the ACCORD RWP has been completely reorganized from consortia based actions to thematic actions. Due to this fact also the RC-LACE workplan for 2022 has been reorganized accordingly. The first ACCORD EPS working week will take place from 25-29/04/2022 in Innsbruck where also some RC-LACE colleagues will participate.

Exchange of EPS data within the EUMETNET SRNWP-EPS project has also been intensified. C-LAEF has already been provided for the SRNPW-EPS database for the summer 2020 period and is also planned to provide A-LAEF data for this purpose.

Efforts: 1.5 PM

Contributors: Martina Tudor (DHMZ), Clemens Wastl (ZAMG)

Documentation: Exchange of the expertise between the other consortia and the new ACCORD consortium; contact with experts within the relevant projects

Status: Ongoing

S6 Action/Subject/Deliverable: **Publications**

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

1 paper was published in QJRM, 1 paper in HPC Focus and 2 papers in Időjárás.

K. Jávorné-Radnóczi and B. Tóth, 2021: Short range probabilistic forecasts at Hungarian Meteorological Service: evaluation of AROME-EPS and impact of EDA, Időjárás, in revision.

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", Időjárás, Vol. 125, No. 4, DOI:10.28974/idojaras.2021.4.3 (pp. 571-607).

J. Vivoda, M. Belluš, M. Derková, 2021: "High performance computing and weather forecasting at SHMU" (ENG version), HPC Focus, p44-53, ISSN 2729-9090, https://vs.sav.sk/magazine/issues/magazine_2021010_print.pdf

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

Efforts: 2.75 PM

Contributors: Yong Wang, Florian Weidle, Christoph Wittmann, Clemens Wastl, Christoph Zingerle (all ZAMG), Endi Keresturi (DHMZ), Martin Belluš, Jozef Vivoda, Maria Derková (SHMU), B. Tóth, Katalin Jávorné-Radnóczi (OMSZ)

Documentation: Reviewed papers

Status: In progress

List of actions, deliverables including status

S1 Subject: Optimization of A-LAEF

Deliverables: A-LAEF e-suite; Verification results; papers submitted to scientific journals; stay reports; improvement of current regional ensemble system through the results and outcomes of R&D

Status: Ongoing; a lot of delays and shifts in topics due to postponed stays (COVID)

S2 Subject: A-LAEF maintenance

Deliverables: A-LAEF operational suite running at ECMWF HPCF; probabilistic forecast products delivered to the RC-LACE partners; Flow charts; presentations; reports; technical documentation of A-LAEF TC2 suite running at ECMWF

Status: Ongoing; some delays and shifts in topics due to delay of new ECMWF HPC and due to postponed stays (COVID)

S3 Subject: AROME-EPS

Deliverables: operational convection-permitting ensemble systems (ZAMG, OMSZ); papers published in scientific journals; running e-suites – verification results; C-LAEF documentation on ECMWF confluence site; EPS products and visualizations

Status: Ongoing; Upgraded C-LAEF suite running in full operational mode under the time critical environment at ECMWF HPCF; C-LAEF e-suite running at ECMWF HPCF; AROME-EPS operationally running at OMSZ; some delays due to postponed stays (COVID)

S4 Subject: EPS - Verification

Deliverables: Local installations (SHMU, ZAMG, OMSZ, IMGW) and documentation of case studies with the HARP verification package

Status: Shifted to new area Applications and Verification

S5 Subject: Collaborations

Deliverables: Exchange of the expertise between the other consortia and the new ACCORD consortium; contact with experts within the relevant projects

Status: Ongoing

S6 Subject: Publications

Deliverables: 1 paper was published in QJRM, 1 paper in HPC Focus and 2 papers in Időjárás.

Status: In progress

Activities of management, coordination and communication

- 36th LSC Meeting, 23-24 March 2021 (*online*)
- 1st ACCORD All Staff Workshop 2021, 12 - 16 April 2021 (*online*), RC-LACE EPS activities presented by Clemens Wastl
- 37th LSC Meeting, 20-21 September 2021 (*online*)
- 43rd EWGLAM & 28th SRNWP Meeting 2021, 27 September - 1 October 2021 (*online*), RC-LACE EPS activities presented by Clemens Wastl
- RC-LACE EPS Meeting, 09 December 2021
- Several online meetings within the EPS area leaders in ACCORD

RC-LACE supported stays – 0 PM in 2021

Unfortunately, due to COVID-19 pandemic, there were no research stays organized this year so far. The only stay that took place in 2021 in the EPS area was the one of Iris in Vienna (November/December) but it has been assigned as an ACCORD stay.

Summary of resources [PM] – 2021

Subject	Manpower		RC-LACE		ACCORD	
	plan	realized	plan	realized	plan	realized
S1: Optimization of A-LAEF	**10**	**8.5**	**2**	**0**	**1**	**1**
S2: A-LAEF maintenance	**5**	**3**	**1**	**0**		
S3: AROME-EPS	**20**	**11.5**	**1**	**0**	**1**	**0**
S4: EPS – Verification	**0**	**0**				
S5: Collaborations	**2**	**1.5**				
S6: Publications	**6**	**2.75**				
Total:	**47**	**27.25**	**4**	**0**	**2**	**1**