SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2022
Project Title:	ALARO Limited Area Ensemble Forecast (A-LAEF)
Computer Project Account:	spcralae
Principal Investigator(s):	Martina Tudor and Martin Belluš
Affiliation:	Croatian Meteorological and Hydrological Service and Slovak Hydrometeorological Service
Name of ECMWF scientist(s) collaborating to the project (if applicable)	Neva Pristov (Slovenia), Maria Derkova (Slovakia), Simona Tasku (Romania), Endi Keresturi (Croatia), Bogdan Bockenek (Poland)
Start date of the project:	1.4.2020
Expected end date:	31.12.2023

Computer resources allocated/used for the current year and the previous one
(if applicable)
Please answer for all project resources

		Previous year		Current year	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	12.000.000		12.000.000	
Data storage capacity	(Gbytes)				

October 2021

Summary of project objectives (10 lines max)

A mesoscale ensemble forecasting system A-LAEF is running operationally on ECMWF HPC as TC2 supported by national SBU quotas of Turkey, Slovenia and Croatia. The system is running using multi-scale ALARO physics in 4.8 km horizontal resolution with linear grid on 60 levels. There is one unperturbed control and 16 perturbed members. The project resources are intended for tests using new version of the forecast model and further development of perturbation methods (also in the assimilation system), focus on studying the cases of forecast failure and improvements needed, new SPG for stochastic physics, perturbation of fluxes instead of tendencies, and flow-dependent B-matrix for local 3DVar ALARO systems.

Summary of problems encountered (10 lines max)

During 2021, most of the research work within RC LACE done during the research stays was practically suspended during the Covid19 crisis. The work continued, like adapting the suite to changes in the operational IFS (running tests using input data from a parallel suite). Several researchers were added to the group of people working on A-LAEF and training on the way scripting system works is ongoing. Adapting the time critical scripts of the TC2 suite for testing was very time consuming and it was easier to do the tests using national resources. However, the scripts were adapted for research purposes and use the special project SBUs.

Summary of plans for the continuation of the project (10 lines max)

Move of the scripts and adaptation to the new ATOS system will require a lot of work, however it will probably use little to no billing units from the special projecd due to the decision not to charge for jobs during the transition. There are issues in adapting the system, especially those that cause substantial increase in SBU consumption whem the job is used on the new system, but there are also fixes for such issues. Therefore, for tests of some solutions, SBUs might still be used for that. With the planned upgrade of the operational forecast system to the latest export version of the LAM code, d the multi-physics choices used in the EPS system are going to be adjusted due to changes introduced with several options used, testing the new SPG for stochastic perturbations of physics tendencies. Combination of an ensemble of upper-air spectral blending with the 3D-variational data assimilation has started and is going to continue.

List of publications/reports from the project with complete references

- Belluš, M., Tudor, M., Abellan, X. 2022: The mesoscale ensemble prediction system A-LAEF. ECMWF Newsletter 172.

Summary of results

If submitted **during the first project year**, please summarise the results achieved during the period from the project start to June of the current year. A few paragraphs might be sufficient. If submitted **during the second project year**, this summary should be more detailed and cover the period from the project start. The length, at most 8 pages, should reflect the complexity of the project. Alternatively, it could be replaced by a short summary plus an existing scientific report on the project attached to this document. If submitted **during the third project year**, please summarise the results achieved during the period from July of the previous year to June of the current year. A few paragraphs might be sufficient.

Few topics were tackled in depth. The most recent export version of the LAM code, CY46T1, implies the rules of strict output formatting whichs necessitates an upgrade in the tool for the observation preprocessing used in the data assimilation Various case studies have been investigated using the A-LAEF ensemble system.

The best overview of the A-LAEF system and associated work is given in the ECMWF Newsletter overview in the reference given above. Here only the most interesting parts will be repeated.

Case study of 13-15 July 2021, flooding in Germany, Belgium

After several episodes of heavy rain, a cyclonic weather system (Bernd) caused persistent or recurring heavy rainfall between the 13 and 15 of July 2021 in Germany. The west of Rhineland-Palatinate and the southern half of North Rhine-Westphalia were largely affected. As a result, small rivers swollen up locally and formed flash floods. In addition to immense property damage, over 160 people lost their lives.
The A-LAEF ensemble successfully captured the precipitation event, with well-localised patterns and unusually high probabilities of extreme precipitation amounts.
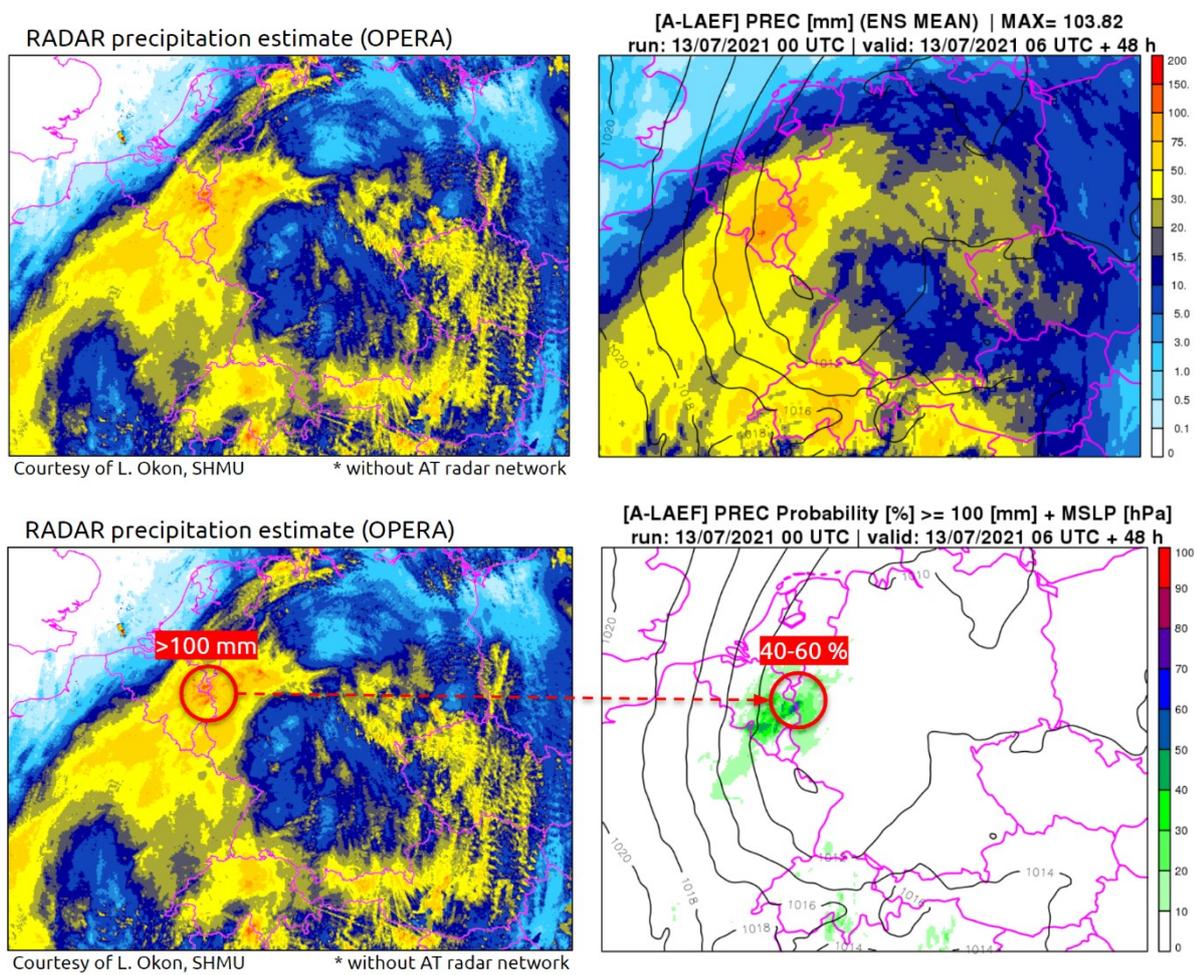
Figure 1. The charts show at top left the precipitation estimate by the OPERA radar network, at the top right the A-LAEF ensemble mean forecast starting at 00 UTC on 13 July 2021, the radar precipitation estimate from OPER at the bottom left and at the bottom right the A-LAEF forecast starting at the same time of the probability for a precipitation threshold of at least 100 mm, valid for the 48-hour accumulation period from 13 July 2021 until 15 July 2021 (06 to 06 UTC).

European precipitation record(s) set in Liguria, Italy, 4th October 2021

In the second example shown, on 4 October 2021, a European precipitation intensity record was broken in Northern Italy (Liguria region), where more than 740 mm of rain fell within a 12-hour period, causing floods and landslides. During this event, 178 mm of rainfall was measured in just 1 hour in Urbe Vara Superiore, and over 900 mm in 24 hours in Rossiglione. The localisation of such extreme precipitation amounts was exceptionally precise in the A-LAEF forecast (Figure 6), even though the ensemble mean was much lower in magnitude than the measurements. It was, however, still remarkably high for a numerical precipitation forecast. Looking at individual ensemble members, we can see several scenarios much closer to reality, with an ensemble maximum of 501 mm in 24 hours (Figure 7). A comparison with the operational deterministic forecast of ALADIN/SHMU is shown in Figure 8. The deterministic forecast failed to correctly predict the location of extreme precipitation or the amount.

Furthermore, as part of ECMWF's special project SPCRALAE, an export version of A-LAEF was prepared in order to allow any standard ECMWF user to install and run it under their own environment. This version was also used to run a parallel experiment for the record precipitation event in Italy, where the operational A-LAEF forecast coupled to Cycle 47r2 of ECMWF's Integrated Forecasting System was compared to the new coupling to Cycle 47r3. Although the ensemble mean characteristics and the probabilities for given thresholds were not significantly changed, the unperturbed control run coupled to Cycle 47r3 was better at predicting the location of the main precipitation area (not shown).
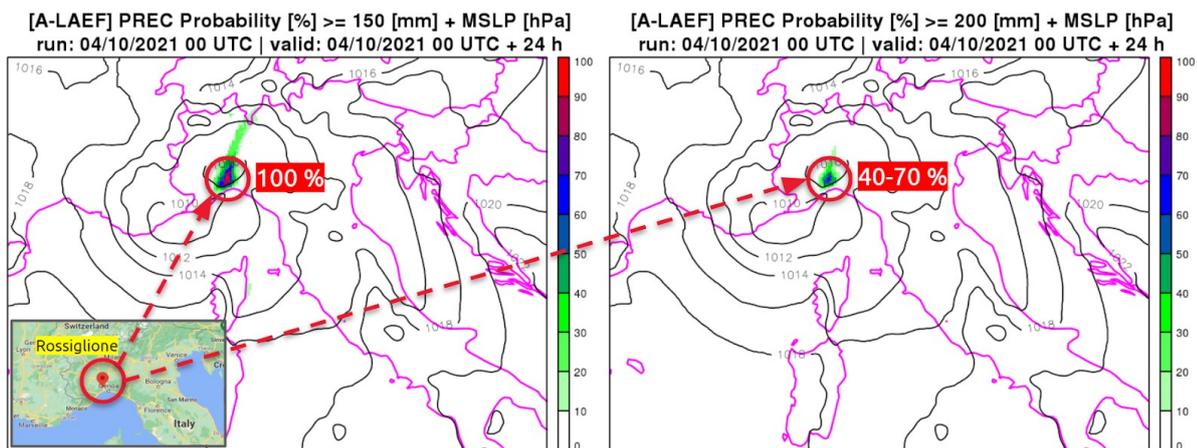
Figure 2. The A-LAEF forecast of probability for a precipitation threshold of (a) at least 150 mm, and (b) at least 200 mm, valid for the 24-hour accumulation period on 4 October 2021. The location in northwest Italy with observed record precipitation is marked by the red circle.
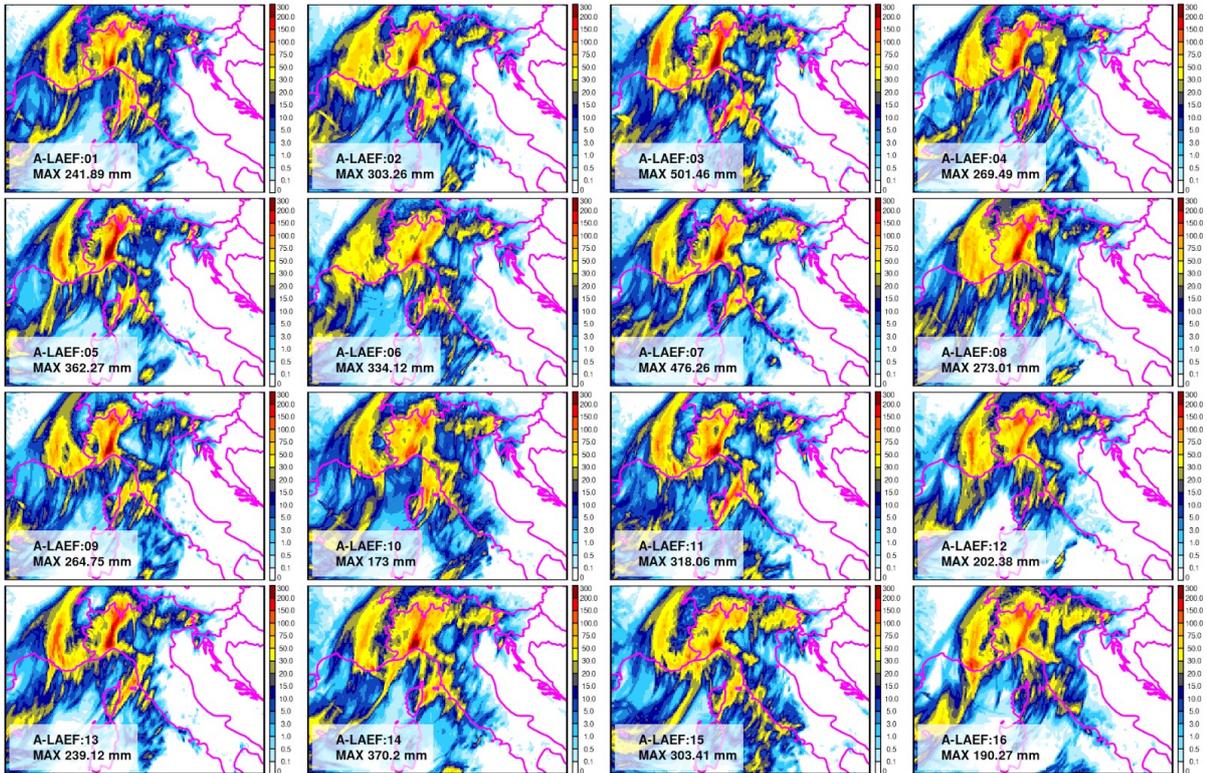
Figure 3. Different scenarios for 24-hour precipitation on 4 October 2021 in northern Italy by the perturbed A-LAEF ensemble members, in forecasts starting at 00 UTC on the same day. A maximum of 501 mm was predicted by member 03.
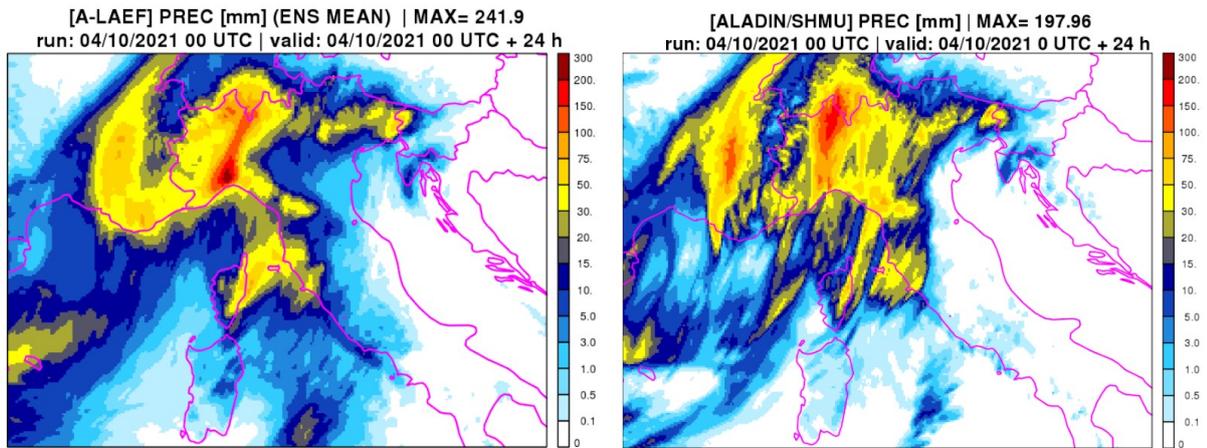
Figure 4. These plots show (a) the A-LAEF ensemble mean precipitation forecast, and (b) the ALADIN/SHMU deterministic precipitation forecast, starting at 00 UTC on 4 October 2021 and valid for the 24-hour accumulation period on the same day.