<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2024–2025

MEMBER STATE: Croatia

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Project Title: A-LAEF upgrade and development

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP**cralae	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for the years: (To make changes to an existing project please submit an amended version of the original form.)		**2024**	**2025**	**2026**
High Performance Computing Facility	(SBU)	15M	15M	15M
Accumulated data storage (total archive volume)[2]	(GB)	20000	40000	60000

Continue overleaf

[1] The Principal Investigator will act as contact person for this Special Project and, in particular, will be asked to register the project, provide annual progress reports of the project's activities, etc.

[2] These figures refer to data archived in ECFS and MARS. If e.g. you archive x GB in year one and y GB in year two and don't delete anything you need to request x + y GB for the second project year etc.

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Extended abstract

Introduction

A meso-scale ensemble system ALARO - Limited Area Ensemble Forecasting (A-LAEF) is running operationally as Time Critical level 2 application on ECMWF HPCF (Belluš et al., 2022) supported by the SBU quotas of several ECMWF Members (currently: Croatia, Slovenia and Türkiye). The present request for the special project resources should cover mostly only the needs of Cooperating Member users who participate in maintenance, upgrades and development of the operational A-LAEF system.

The current A-LAEF operational run costs amount to about 160 M SBU/year. For testing and development purposes in the framework of this special project, we ask for 15 M SBU per year (as this is a late SP proposal and we are not aware if there are additional limitations).

The A-LAEF system is developed and maintained in the frame of Regional Cooperation for Limited Area modelling in Central Europe (RC LACE) consortium, focusing on short range (currently up to 72 hours) probabilistic forecasts. Its main purpose is to provide probabilistic forecast on daily basis for the national weather services of RC LACE partners and Türkiye who provides SBUs for the operational runs. It also serves as a reliable source of probabilistic information applied to downstream applications in the RC LACE member states as well as Türkiye.

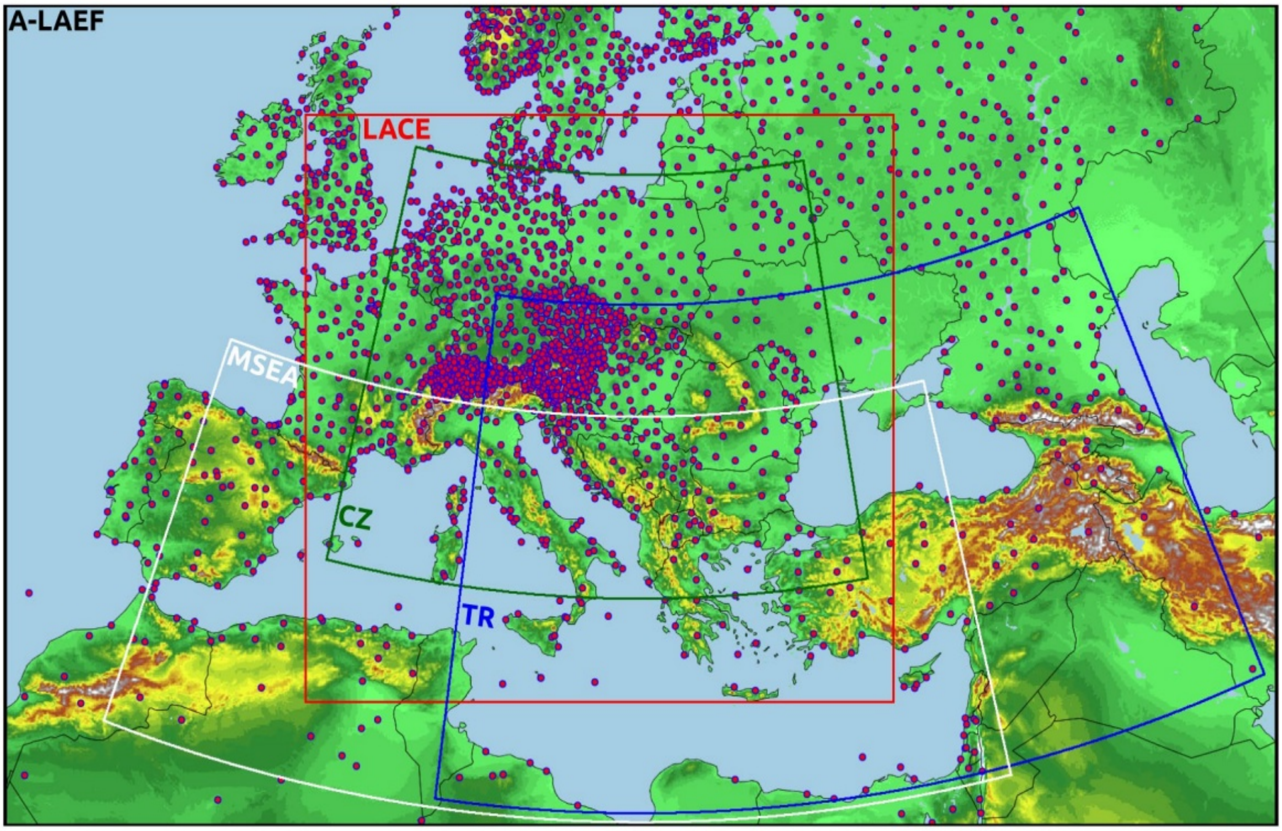

Figure 1. A-LAEF operational domains with the observation sites used in ESDA. The map shows the A-LAEF integration domain with model orography and all post-processed subdomains for LACE, Czech Republic (CZ), Türkiye (TR) and MSEA (to couple ocean models). The dots represent SYNOP observation sites used in ESDA fetched from the Observation Preprocessing System for RC LACE (OPLACE).

The A-LAEF system

A-LAEF is a successor of the former regional ALADIN-LAEF ensemble running at ECMWF as a common ensemble prediction system (EPS) project (Wang et al., 2011) of the RC LACE (Regional Cooperation for Limited-Area modelling in Central Europe) consortium (Austria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia) since 2011 (Wang et al., 2018).

The process of technical and scientific transformation from ALADIN-LAEF to A-LAEF is documented in Belluš at al. (2019) and Belluš (2019) and the resulting operational ensemble system is described in Belluš et al (2022). The spatial density of gridpoints increeased five times with respect to the version operational until 2020 and 14 times with respect to the original version.

The number of limited area model (LAM) ensemble prediction systems (EPSs) in Europe is increasing. RC LACE is running one since 2011. Initially, Aire Limitée Adaptation dynamiquevDéveloppement InterNational - Limited Area Ensemble Forecasting (ALADIN-LAEF) became operational in 2011, at that time having horizontal resolution of 18 km and 37 vertical levels (Wang et al., 2011). In 2013 the first substantial upgrade was made, incorporating the increase of horizontal and vertical resolutions to 11 km and 45 vertical levels, geographically bigger computational domain and a new ensemble of surface data assimilations involving perturbed screen-level observations (Belluš et al., 2016). There are currently two more EPS systems run by RC LACE Members, albeint on very small domains that do not cover the needs of all its members.

The new A-LAEF system aims for reliable probabilistic forecasts of meso-synoptic scales up to three days ahead. Belluš et all (2022) show that within that time range A-LAEF can outperform deterministic models that have a similar or even higher spatial resolution through statistical verification of A-LAEF against the operational deterministic model ALADIN/SHMU and the experimental non-hydrostatic ALARO model with 2 km horizontal resolution running in a dynamical adaptation. Belluš et all (2022) also show the benefit and quality of A-LAEF probabilistic forecasts on examples of high-impact weather situations.

Table 1. A-LAEF system specifications

Code version	cy40t1
Horizontal resolution	4.8 km
Grid	linear
Number of gridpoints	1250x750
Vertical levels	60
Time step	180 seconds
Forecast length	72 hours
Runs	00 and 12 UTC
Members	16+1
Initial condition perturbation	ESDA (surface) + spectral blending DFI (upper)
Model perturbation	ALARO-1 multi physics (4 clusters) + surface stochastic physics (SPPT)
LBC perturbation	ECMWF ENS

The A-LAEF system was moved to higher resolution and the finer scales. The horizontal and vertical resolutions increased to 4.8 km and 60 levels, respectively. Several other upgrades were implemented, such as new model version, and new physics parametrization schemes based on ALADIN System canonical model configuration ALARO (Termonia et al., 2018), as well as additional stochastic perturbation of physics tendencies for the surface prognostic fields.

The ALADIN-LAEF system runs operationally on the High Performance Computer Facility (HPCF) at the European Centre for Medium-Range Weather Forecasts (ECMWF) twice a day with the integration starting at 00 and 12 UTC producing 72 hour forecasts. The ensemble consists of 1 unperturbed control run and 16 perturbed members involving *initial condition uncertainty, model error simulation and coupled in lagged mode to perturbed lateral boundary conditions coming from the ECMWF EPS.*

Perturbation methods

Lateral boundary perturbation

The A-LAEF system uses forecast lateral boundary conditions coming from the operational global ECMWF EPS. The perturbed lateral boundary conditions (LBCs) are retrieved from the first 16 EPS members with a coupling frequency of 6h to account for the uncertainties at the domain boundaries. This is a natural choice for the LBCs perturbation, not only because of the similarity in model physics and dynamics among the ECMWF IFS (Integrated Forecast System) and ALARO (ALADIN), but also because of the quality of ECMWF forecasts and their operational availability at the same HPC where the A-LAEF system is run operationally.

Perturbatin of initial conditions: surface

The uncertainty of the initial conditions in A-LAEF is simulated by the ensemble of surface data assimilations (ESDA) (Belluš et al., 2016), where surface and soil prognostic fields are handled separately from the upper air. Each ensemble member has its own data assimilation cycle with randomly perturbed screen-level (near-surface) measurements of temperature and relative humidity.

Perturbations of initial conditions: upper air

Uncertainty of the upper-air fields in the initial conditions is simulated by upper-air spectral blending by digital filter initialisation (Derková and Belluš, 2007; Wang et al., 2014). The spectral blending method allows a sophisticated combination of uncertainties for different scales. While large ones are well simulated by the driving EPS, small ones are natively resolved by the target mesoscale system. It also ensures consistency between the initial conditions and lateral boundary conditions (LBC).

Perturbation of model physics

ALARO multi-scale physics has been run operationally on horizontal grids between one and ten kilometres (with several experimental configurations run on hectometric scales). It offers a wide range of tunable parameters and allows various choices in different parametrization schemes (as well as optional usage of the scale aware deep convection scheme), which makes it an ideal solution for a mesoscale ensemble like A-LAEF. Four different ALARO setups of micro-physics, deep and shallow convection, radiation and turbulence schemes are used to account for model uncertainty. This multi-physics approach is further supplemented by the stochastic perturbation of physics tendencies (SPPT) of surface prognostic fields for each individual ensemble member (Wang et al., 2019).

Description and objectives of the research planned for 2024

- upgrade of the model cycle to the cy46t1 (export version)

- related to the above, new definitions of perturbed physics

- updates in the surface data assimilation

- re-runs of extreme weather case studies (with different tunings)

- testing new software upgrades by ECMWF before their operational deployment

- Preparation of flow-dependent B-matrix using the A-LAEF 4.8km operational outputs.

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Duration of the project and estimated resource requirements

The SBU resources needed for the research and development in RC LACE is currently combined between the three ECMWF Members (Croatia, Slovenia and Türkiye) while there is considerable work done by developers from Co-operating countries (primarily Slovakia and Czech Republic). The resources assigned in the framework of this special project are primarily aimed at research done on the further A-LAEF development (as described above) by researchers from the co-operating member countries.

The current expenses of running and testing the A-LAEF suite (described in detail in the A-LAEF ecFlow TC-2 Suite document) are:

- about 188 000 SBU for one ensemble forecast of 16+1 members up to 72 hours

- 1.5 TB of storage space for the input and the output data per run

- the 15 M SBU would allow for approximately 80 such forecasts (and the storage was computed using the same number).

References

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