<u>LATE</u> REQUEST FOR A SPECIAL PROJECT 2019–2021

MEMBER STATE: Croatia……….…………………………………………........

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Project Title:

ALARO Limited Area Ensemble Forecast (A-LAEF)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** ___________________	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
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.)		**2019**	**2020**	**2021**
High Performance Computing Facility	(SBU)		10.000.000	
Accumulated data storage (total archive volume)[2]	(GB)		60.000	

Continue overleaf

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

[2] 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.

Principal Investigator: Martina Tudor

Project Title: ALARO Limited Area Ensemble Forecast (A-LAEF)

Extended abstract

A meso-scale ensemble system Aire Limitée Adaptation dynamique Développement InterNational - Limited Area Ensemble Forecasting (ALADIN-LAEF) based on the limited area model ALADIN has been developed in the frame of Regional Cooperation for Limited Area modelling in Central Europe (RC LACE) consortium, focusing on short range probabilistic forecasts and profiting from advanced multi-scale ALARO physics. Its main purpose is to provide probabilistic forecast on daily basis for the national weather services of RC LACE partners. It also serves as a reliable source of probabilistic information applied to downstream hydrology and energy industry.

The operational runs of ALADIN-LAEF system are performed on ECMWF HPCF supported by the SBU quotas of several ECMWF Members (currently: Turkey, Slovania, Croatia and Austria). The present request for the special project resources should cover testing, case studies and new developments.

The new configuration of ALADIN-LAEF operational run costs estimate are about 130 M SBU/year, for testing and development purposes in the framework of this special project, we ask for 13 M SBU.

The ALADIN-LAEF system

There is a number of limited area model – ensemble prediction systems (LAM-EPS) in Europe. Here we describe the system developed in frame of Regional Cooperation for Limited Area modelling in Central Europe (RC LACE, Wang et al. 2018). Aire Limitée Adaptation dynamique Développement 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).

The ALADIN-LAEF system is going to higher resolution and the finer scales. The horizontal and vertical resolutions are being increased to 5 km and 60 levels, respectively. As well as the use of higher resolution, several other upgrades are implemented, such as new model version, new physics parametrization schemes based on ALADIN System canonical model configuration ALARO (Termonia et al., 2018), additional stochastic perturbation of physics tendencies for the surface prognostic fields, etc. The ALARO CMC improvements are described in (Termonia et al., 2018) and this work focuses on the EPS improvement. The new ALADIN-LAEF system is defined on a slightly smaller domain, that keeps the benefit over the global EPS, but will reduce the large increase of computational cost.

The ALADIN-LAEF system runs operationally on the High Performance Computer Facility 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 (Wang et al., 2010b). The ensemble consists of 1 unperturbed control run and 16 perturbed members involving initial condition uncertainty, model error simulation and coupling to perturbed lateral boundary conditions rendered by ECMWF EPS.

Perturbation methods

Together with modelling higher spatial resolutions the appropriate simulation of the uncertainties becomes more important. That is because the atmosphere naturally behaves chaotically at the smaller spatial and temporal scales. In the ALADIN-LAEF system we use different 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.

Initial condition perturbation

The surface and soil prognostic fields' uncertainty in the initial conditions of ALADIN-LAEF system is simulated by the ensemble of surface data assimilations - ESDA (Belluš et al., 2016). This method replaced the former non-cycling surface breeding - NCSB (Wang et al., 2010a), which employed short-range surface forecasts driven by perturbed atmospheric forcing. The current ESDA profits from ALADIN surface data assimilation CANARI (Code d'Analyse Nécessaire à ARPEGE pour ses Rejets et son Initialisation), which is based on the Optimal Interpolation (OI) method. Each ensemble member has its own data assimilation cycle with randomly perturbed screen-level measurements. The amplitude and direction of the perturbations are defined by a Gaussian distribution function with zero mean and standard deviation equal to the usual errors of the observations.

The uncertainty of the upper-air part of the initial conditions used in ALADIN-LAEF system is currently simulated by the breeding-blending cycle (Wang et al., 2014). It combines the large-scale perturbations provided by the driving global ensemble (ECMWF EPS), with the small-scale perturbations generated by ALADIN-LAEF breeding vectors within the pseudo-assimilation cycle. The upper-air spectral blending (Derková et al., 2007) by digital filter initialization is used, profiting from the spectral character of ALADIN model. An obvious disadvantage of such method is the absence of data assimilation for the upper atmosphere. The ensemble BlendVar technique combines the ensemble of 3D variational data assimilations (with perturbed observations like SYNOP, TEMP, AMDAR, GEOWIND and GNSS ZTD) and the upper-air spectral blending. Therefore, the implementation of the ENS BlendVar procedure is underway, to obtain more truthfulcontrol analysis and consequently the perturbed members with less initial bias. The novelty of ENS BlendVar utilization within the LAM EPS is that it can serve as the method for generating the background error statistics (B-matrix) that can be used for operational 3D-Var in member services.

Model perturbation

During its lifetime, the meso-scale ensemble system ALADIN-LAEF has undergone many changes and upgrades. The forecast model uncertainty is currently simulated by several combinations of different micro-physics, deep and shallow convection, radiation and turbulence schemes. It largely profits from the multi-scale properties of the ALARO physics package used by the system (such as the modular multi-scale microphysics and transport scheme for convection). The stochastic perturbation of physics tendencies (SPPT) is another approach which has been successfully tested in order to enhance the model uncertainty simulation for the surface prognostic variables, but also for the upper-air fields.

The stochastic physics method can randomly disturb the model tendencies computed by the parametrization schemes and hence addresses the model accuracy at its source. In our experiments the surface prognostic fields like temperature, liquid soil water content, frozen soil water content, snow albedo, snow reservoir water content, snow density and water intercepted by vegetation were perturbed. We intentionally avoided the perturbation of deep soil prognostic fields (e.g. deep soil temperature), because such fields are naturally changing very slowly in time. On the other hand, we found the perturbation(skin) surface prognostic fields very important for generating enough spread for screen-level variables in LAM EPS.

The surface temperature is perturbed by assimilating perturbed screen-level measurements, while its effect is measured through the spread of the screen-level temperature forecast. The multiphysics perturbation method yields dominantly positive or negative perturbations over the vast geographical areas, while the stochastic physics tendency perturbation yields small disturbances over the Central Europe in comparison to ESDA perturbations (for this example).

Lateral boundary perturbation

The ALADIN-LAEF system is driven by the 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 ALADIN, but also because of the quality of ECMWF forecasts and their operational availability.

Technical implementation

Each of the 16 LAEF members uses different LBCs, different surface initial conditions from ESDA and different upper air initial conditions from blending. During the forecast, the surface fields are subject to SPPT and upper air fields are treated by multiphysics (4 different tunings of ALARO). Higher spatial resolution and more complex and advanced physics has led to considerable increase in the computational cost of the new ALADIN-LAEF system.

The new ALADIN-LAEF suite uses a complex system of scripts written under the ecFlow environment (ecFlow isworkflow package developed in ECMWF that serves as a job scheduler). Suite definition file is generated by Python code, while all tasks, include files and configuration modules are written in Perl. Such system should replace the obsolete one based on the SMS scripting as a Phase I of planned operational upgrade. It will be followed by Phase II upgrade later2019, with the inclusion of ENS BlendVar for more advanced uncertainty simulation of the upper-air initial conditions.

Current results, validation and conclusions

The main motivation for running an operational version of a regional EPS is its added value over the global ensemble. Therefore, we have verified new ALADIN-LAEF Phase I against the downscaling of corresponding 16 ECMWF EPS members for surface as well as for the upper-air parameters. For the surface parameters the statistical scores show larger spread, lower root mean square error (RMSE), bias and a reduced number of outliers for new ALADIN-LAEF system compared to the downscaled ECMWF EPS. Very positive result is also the significant damping of a diurnal cycle of errors, mostly for temperature and relative humidity. On the other hand, the impact on upper-air fields is rather neutral as it was expected.

Description and objectives of the research planned for 2020

- Research and development concerning the regional ensemble forecasting system A-LAEF in order to sustainably improve its operational implementation, but the methods that are to be tested and possibly implemented are applicable in the wide scientific community while the results are to be shared and published in scientific papers (the development of the A-LAEF system has already lead to a number of published scientific papers and this practice is intended to continue in the future).

- Implementation of new random number generator (SPG) suitable for LAM EPS environment in A-LAEF 5km.

- Investigate the possibilities of stochastic perturbation of fluxes instead of tendencies. This should be beneficial with respect to the energy balance preservation in perturbed model.

- Preparation of flow-dependent B-matrix using the A-LAEF 5km operational outputs.

- Implementation of A-LAEF 5km Phase II configuration involving ENS BlendVar to improve the simulation of upper-air ICs uncertainty.

- Calibration of precipitation. Methodology for post-processing over the river catchments according to the needs of hydrological models.

Duration of the project and estimated resource requirements

The RC LACE MoU is currently extended until 31st December 2020. However it is expected that the cooperation will continue under the new MoU after that date.

The SBU resources needed for the research and development in RC LACE is currently combined between the three ECMWF Members (Austria, Croatia and Slovenia) while there is considerable work done by developers from Co-operating countries (primarily Slovakia and Hungary). 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:

- 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 10 M SBU would allow for approximately 53 such forecasts (and the storage would limit that to 30 experiments but we assume that different experiments would use the same input data)

References

Bellus, M., Y. Wang, F. Meier, 2016: Perturbing surface initial conditions in a regional ensemble prediction system. Mon. Wea. Rev. 144:3377-3390.

Derkova, M., M. Bellus, 2007: Various applications of the blending by digital filter technique in the ALADIN numerical weather prediction system. Meteorologicky casopis, 10, 27–36.

Termonia, P., Fischer, C., Bazile, E., Bouyssel, F., Brožková, R., Bénard, P., Bochenek, B., Degrauwe, D., Derkova, M., El Khatib, R., Hamdi, R., Mašek, J., Pottier, P., Pristov, N., Seity, Y., Smolíková, P., Spaniel, O., Tudor, M., Wang, Y., Wittmann, C., Joly, A., 2018. The ALADIN System and its Canonical Model Configurations AROME CY41T1 and ALARO CY40T1. Geoscientific Model Development. 1–45. doi: 10.5194/gmd-2017-103

Wang, Y., M. Bellus, C. Wittmann, M. Steinheimer, F. Weidle, A. Kann, S. Ivatek-Šahdan, W. Tian, X. Ma, S. Tascu, and E. Bazile, 2011: The Central European limited-area ensemble forecasting system: ALADIN-LAEF. Quart. J. Roy. Meteor. Soc., 137, 483–502.

Wang, Y., M. Bellus, J. Geleyn, X. Ma, W. Tian, and F. Weidle, 2014: A new method for generating initial perturbations in regional ensemble prediction system: blending. Mon. Wea. Rev. 142: 2043-2059.

Wang, Y., A. Kann, M. Bellus, J. Pailleux, and C. Wittmann, 2010a: A strategy for perturbing surface initial conditions in LAMEPS. Atmos. Sci. Lett., 11, 108–113.

Wang, Y., M. Bellus, G. Smet, F. Weidle, 2010b: Use of ECMWF EPS for ALADIN-LAEF. ECMWF Newsletter, 126, Winter 2010/2011, 18-22.

Wang, Y., M. Bellus, A. Ehrlich, M. Mile, N. Pristov, P. Smolikova, O. Spaniel, A. Trojakova, R. Brozkova, J. Cedilnik, D. Klaric, T. Kovacic, J. Masek, F. Meier, B. Szintai, S. Tascu, J. Vivoda, C. Wastl, Ch. Wittmann, 2018: 27 years of Regional Co-operation for Limited Area Modelling in Central Europe (RC LACE). Bulletin of the Am. Met. Soc., Vol. 99 Issue 7, 1415-1432.

The completed form should be submitted/uploaded at https://www.ecmwf.int/en/research/special-projects/special-project-application/special-project-request-submission.

All Special Project requests should provide an abstract/project description including a scientific plan, a justification of the computer resources requested and the technical characteristics of the code to be used.

Requests asking for 1,000,000 SBUs or more should be more detailed (3-5 pages).

Following submission by the relevant Member State the Special Project requests the evaluation will be based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and justification of the resources requested. Previous Special Project reports and the use of ECMWF software and data infrastructure will also be considered in the evaluation process.

All accepted project requests will be published on the ECMWF website.