REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: FRANCE

Principal Investigator[1]: François BOUTTIER

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Project Title: Boundary layer model errors in the AROME ensemble prediction system

If this is a continuation of an existing project, please state the computer project account assigned previously.	SPFRBOUT	
Starting year: (Each project will have a well defined duration, up to a maximum of 3 years, agreed at the beginning of the project.)	2015	
Would you accept support for 1 year only, if necessary?	YES V	NO ☐

Computer resources required for 2015-2017: (The maximum project duration is 3 years, therefore a continuation project cannot request resources for 2017.)	**2015**	**2016**	**2017**
High Performance Computing Facility (MSBU)	6	7	8
Data storage capacity (total archive volume) (Tbytes)	5	5	5

*An electronic copy of this form **must be sent** via e-mail to:* *special_projects@ecmwf.int*

Electronic copy of the form sent on (please specify date): 30 June 2014

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 an annual progress report of the project's activities, etc.

Principal Investigator: François BOUTTIER

Project Title: Boundary layer model errors in the AROME EPS

Extended abstract

This project is a continuation of a 2012-2014 special project named "Continental winter weather prediction with the AROME ensemble prediction system" (see Bouttier et al 2014). The technical aspects will be similar i.e. the project will be based on experimental runs of the French and Hungarian AROME EPS preoperational testbeds. Here, the scientific objectives are updated in order to focus on a key issue of the system performance: the ensemble behaviour in the continental boundary layer, particularly its relationship with the representation of model errors. There will be an emphasis on stable wintertime situations, with investigations of boundary layer mixing, surface and cloud cover errors, and fog predictions.

Scientific Plan

The main tool will be AROME EPS (ensemble prediction system) which is a regional ensemble prediction system based on the AROME model (otherwise known as HARMONIE). AROME is operational in many NWP centres of the ALADIN and HIRLAM consortia. It is documented in Seity et al (2011): AROME is a non-hydrostatic limited area model with a 5-species microphysical scheme, prognostic turbulent kinetic energy subgrid mixing scheme, a detailed radiation scheme that includes the RRTM module, and the SURFEX model that includes schemes for various surface processes, including soil/vegetation, cities, lakes, sea/ice, and snow cover. AROME is designed to run at horizontal resolutions from about 400m to 4km. Here AROME is used at 2.5km resolution over two domains: mainland France and the Carpathian basin around Hungary. AROME EPS now includes the following features:

- perturbations of lateral and initial boundary conditions provided either by the French PEARP global ensemble, or by the ECMWF EPS. Optimal subsampling of the forcing ensemble members can be achieved by clustering.
- model perturbations using an SPPT stochastic scheme for the mid-level atmospheric part of AROME. SPPT has been adapted from its ECMWF EPS counterpart, with a retuning of amplitude and correlations for kilometric resolutions.
- surface perturbations for various prognostic and physiographic parameters of the SURFEX module, including SST and soil moisutre.
- the complete AROME EPS technical system has been installed on ECMWF computers, for research purposes. Plotting and scoring software runs on Meteo-France and HMS (Hungarian Meteorological Service) servers.

For some aspects of this Special Project, a 1D (one-column) version of AROME will be used to investigate the sensitivity of its PBL (planetary boundary layer) to various aspects of the physical parametrizations and of representations of model error. The generality of these results will be tested in 3D AROME EPS system, in situations and areas where the PBL evolution is expected to be dominated by local processes.

With these tools, the objective is to understand and improve the performance of AROME EPS in terms of low-level processes. The scientific workplan is as follows:

- The first step will be to run a few dozens of interesting cases over France and Hungary. The main phenomena of interest are: vertical mixing in the stable PBL, and the formation/dissipation of fog and low clouds (e.g. continental winter stratocumulus). The observational verification will be provided by low-level SYNOP reports (including dense national networks) of temperature, humidity, cloud cover and visibility; in the course of this project, verification using satellite cloud products will be investigated). The objective performance of AROME EPS will be assessed.
- Forecast performance will then be related to the model internal variables and fluxes, looking at the modelled PBL physics. Sensitivity experiments will be performed in 1D and 3D in order to identify the conditions that produce higher-than-average model errors.
- The surface and model perturbation schemes in the ensemble will then be modified in order to randomly perturb the model in these conditions, and the corresponding modification in ensemble spread and probabilistic performance will provide clues about the main sources of model errors. Hopefully, this will lead to improvements in the preoperational ensemble system, in the form of model perturbations that accurately represent the location and amplitude of model errors. Ensemble theory suggests that model perturbations that reflect genuine model errors should provide better ensemble performance than a brute-force injection of random noise all over the model (which is more or less what the current SPPT scheme does currently, though it does have a beneficial impact, see Bouttier et al 2012)
- A related problem is the robustness of the model with respect to SPPT activation. Experiment shows that SPPT generally produces a dry bias in the model forecasts, and that SPPT in the planetary boundary layer sometimes causes model crashes. These aspects will be studied in the course of this project so that the envisioned improved formulation of SPPT can be safely activated in the PBL (probably by acting on the mixing coefficients and surface fluxes, rather than on the physics tendencies).

This work is connected with a Ph.D thesis preparation by M. Szucs, and with the Meteo-France and ALADIN/HIRLAM plans for developing operational ensemble prediction systems based on the AROME model. There already is a lot of activity in the community on warm season ensemble predictions e.g. flash floods and thunderstorms, and on snow and windstorms. This project is one of a few that focus on settled-weather winter events, which can nevertheless have high societal impact e.g. on the transport or energy sectors.

Justification of computer resources requested

The verification of high resolution ensemble forecasts as envisioned here requires of the order of 30-60 independent forecast days (at least) in order to obtain significant objective scores. Each ensemble run will have about 12 members. To keep up with the evolution of the state of the art in the NWP modelling community, the AROME vertical resolution and domain extent will somewhat increase from what has been used in previous years: it will improve the physical realism and the spatial sampling of the experiments, but it will cause the SBU costs to increase over the years. The scientific plan will require the comparison of about 2 to 5 ensemble versions per year, which costs the computer resources (SBU) requested.

The storage resource evaluation takes into account that fact that only the most useful fields of the ensemble forecasts will be kept and sent them to external servers for plotting and scoring. Storage of the full 3D ensemble model states will be needed to a limited extent, in order to investigate the vertical structures of the boundary layer parameters, tendencies and fluxes.

Technical characteristics of the code used

The main code used will be the standard AROME/HARMONIE model (part of the IFS/ARPEGE software suite) optimized for the ECMWF supercomputers. The recommended job setup for deterministic AROME runs will be used in our ensembles. High parallelization efficiency will be sought by tuning the number of members that are submitted simultaneously, in relationship with the parallelization profile of each member.

References

Bouttier, F., B. Vié, O. Nuissier and L. Raynaud, 2012: Impact of stochastic physics in a convection-permitting ensemble. *Mon. Wea. Rev.*, **140**: 3706-3721. doi:10.1175/MWR-D-12-00031.1

Bouttier, F. amd M. Szucs, 2014: Final report of the SPFRBOUT project '*Continental winter weather prediction with the AROME ensemble prediction system*'. Sent to ECMWF in June 2014, available from francois.bouttier@meteo.fr

Seity, Y., Brousseau, P., S. Malardel, G. Hello, P. Bénard, F. Bouttier, C. Lac and V. Masson, 2011: The AROME-France convective scale operational model. *Mon. Wea. Rev.,* **139**, 976-99. doi: 10.1175/2010MWR3425.1