REQUEST FOR A SPECIAL PROJECT 2015–2017

MEMBER STATE: FRANCE……...…

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Olivier Bousquet, David Barbary, Marie-Dominique Leroux (CRC)

Project Title: Assessment of the AROME NWP model at sub-kilometre horizontal resolution over highly orographic terrain ("Arome-500")

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SP** _____	
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	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 (units)	14,450,000	7,000,000	
Data storage capacity (total archive volume) (gigabytes)	30,000	30,000	

*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: Alexandre MARY (Météo-France/CNRM)……

Project Title: AROME-500……

Extended abstract

A) Motivation

1. Motivations for assessing the behaviour of the AROME model at sub-kilometre scale

The goal of this project is to investigate the behaviour of the AROME forecast model at sub-kilometre scale in highly orographic regions.

AROME is a jointly developed NWP modelling system shared with the national met services of the ALADIN and HIRLAM consortia. Its code is to a large extent common with the IFS code. AROME is the operational NWP Limited Area Model (LAM) at Météo-France (Seity et al., 2011). Its present horizontal resolution is 2.5km (60 levels) and it will reach 1.3km by the beginning of 2015 (90 levels). The operational AROME model over France and part of Western Europe is coupled to ARPEGE. It is also planned to operationally implement AROME in French overseas regions, in replacement of the ALADIN model. These overseas models will have a horizontal resolution of 2.5km for the start, and they will be coupled to the IFS.

A 500m version of AROME has been extensively tested over Charles de Gaulle airport, i.e. over a fairly flat terrain in the Paris region (Hagelin et al, 2014). Improvements have been shown with respect to the 2.5km version mainly for the wind speed.

A sub-kilometre scale resolution potentially offers the possibility to obtain forecast fields that are adapted to finer scale local forcing and therefore should in principle be more realistic. The paradigmatic example probably is the dynamical adaptation of the wind field to a higher resolution orography over complex terrain, that can in return drive local weather effects. Fig. 1 shows the orography as seen by models of resolution ranging from 10km to 500m, for La Réunion island. It is stressed here that La Réunion holds several world records of rainfall. Fig. 1 illustrates the increasing realism of orography with increasing resolution. The increased realism however also induces new features such as a) locally steeper slopes; b) 3D effects at surface level; c) adaptation of turbulence schemes at sub-kilometre scale; d) triggering of convection. For the time being, little is still known about potential shortcomings of AROME with respect to such features. Furthermore, it is believed that some local effects should be implemented and evaluated, mostly via parametrized processes.

This special project aims at addressing by experimental means the properties of AROME for a typical resolution of 500m in mountainous regions both over inland France and over tropical islands (La Réunion or Tahiti). A specific attention will be paid to the four above mentioned issues. Details of these aspects are given in the following sections.

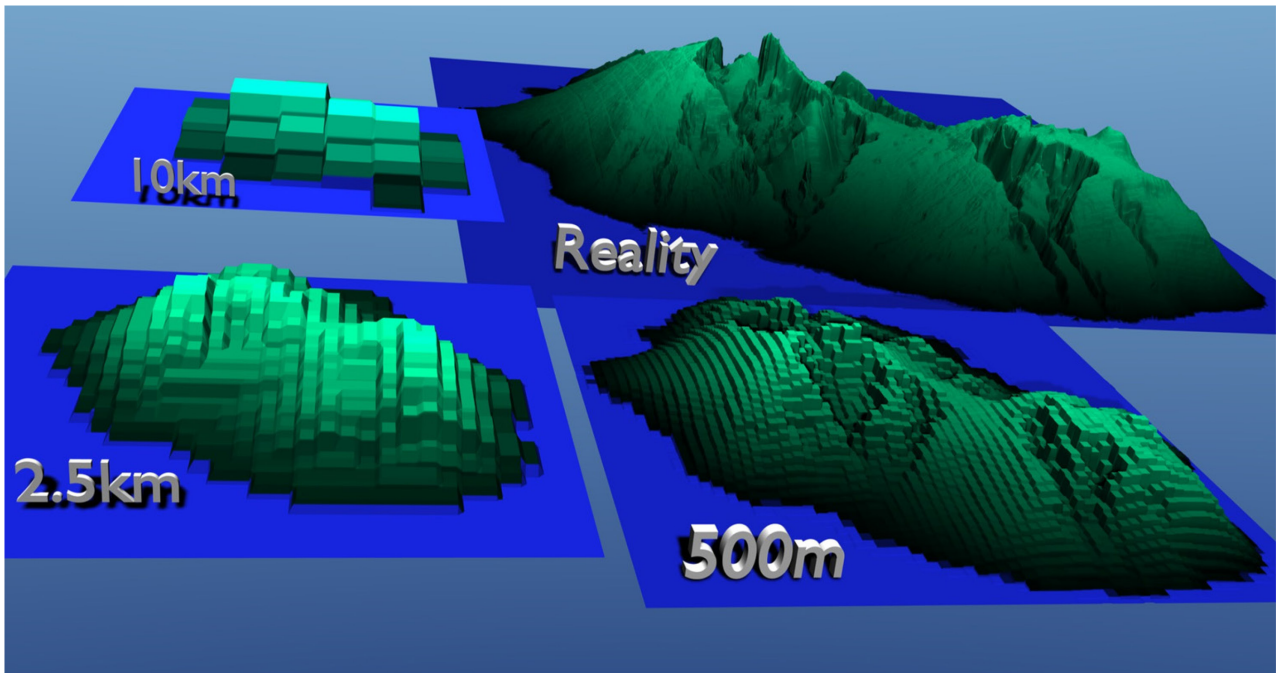

Fig. 1 : orography of La Réunion Island in the AROME grid for three horizontal resolutions ; “reality” is plot from SRTM 90m data

2. Flow in mountainous areas (for aspects not directly linked to moist processes)

Challenges for modelling the atmospheric flow in highly orographic terrain and with increasing horizontal resolution of the model are of various nature. As far as this special project proposal is concerned, three aspects will be studied. One aspect is the performance in terms of numerical precision and stability of the AROME non-hydrostatic dynamical kernel. Another aspect is the evaluation of the impact of significantly steeper slopes, deeper valleys and effects of shading (as compared with a 2.5km grid representation). Eventually, at hectometre scales, production of turbulent kinetic energy by terms involving horizontal shear is believed to become significant, in addition to vertical shear production. A first step to assess this aspect will be to evaluate the ability of AROME in explicitly representing thermal plumes in the model's planetary boundary layer.

More specifically, considering the AROME model, the investigations will concern :

- studies of the behaviour of the semi-lagrangian semi-implicit scheme with slopes reaching up to 50°. Possibly, these investigations might be pushed to an even further resolution, like 100m where slopes up to 70° can be obtained in the model grid.

- Investigations of the impact of various topological properties on the surface radiative budget. The topological features of concern include the steepness of slopes and their geographical aspect, the restricted sky view and the shading by neighbouring mountains (especially in low zenith angles, in winter). Recently proposed parametrized approaches for some of these features will be evaluated (Rontu et al. 2007, Manners et al. 2012).

- At first, experiments will be run for several horizontal resolutions (1km, 500m) over flat terrain, and the explicitly simulated plumes will be compared with LES data. In a second stage, experiments in flat and mountainous surface conditions will be performed, using several formulations of a turbulent scheme. In particular, one goal in these studies will be to assess the need for a 3D turbulent parametrization for a horizontal model resolution of 500m (Honnert et al., 2011).

3. Heavy rain with orographic forcing

Small volcanic islands in tropical regions, with very complex orography, such as La Réunion in the Indian Ocean, and Tahiti in the Pacific Ocean, are areas well known for the outbreak of extremely heavy precipitation with orographic forcing. Yu et al (2014) have shown that increasing the horizontal resolution of the model can provide significant improvements for forecasting a specific heavy rainfall event on La Réunion island. In particular, a significant improvement of the AROME model behaviour was noticed between the resolutions of 2km and 1km.

Our goal is to determine if this improvement is consistent through several situations of heavy rain with orographic forcing, and to quantify any added value in the 500m resolution forecasts compared to the 1km and 2.5km ones. For the validation of these specific cases, La Réunion has a high density rain measurement network (raingauges, 2 radars), while Tahiti Island has been tested in hydraulic simulations.

It is furthermore planned to extend this investigation to similar events in mid-latitude regions.

This S.P. proposal is a joint request with scientists from the CNRM laboratory in Toulouse (joint Météo-France/CNRS research lab) and LACy/CRC “Laboratoire de l'Atmosphère et des Cyclones / Cellule Recherche Cyclone” of St-Denis/La Réunion (joint Météo-France/CNRS/Univ. De la Réunion lab).

B) Working plan

2014: 2nd semester: implementation of the impact of orography on the radiative budget in the AROME surface scheme SURFEX

by end of 2014: reference LES simulations will be ready; options in the turbulence scheme are coded.

2015:

- tuning, sensitivity tests, evaluation and validation of the modified surface scheme SURFEX at typically two horizontal scales (1km and 500m). This validation should be done over a long enough period so as to cover a variety of meteorological situations (21 days say), for both summer and winter periods (as the solar elevation is an important factor for shading), on representative orographic regions like the Alps, the Pyrénées and tropical volcanic islands (La Réunion, Tahiti). Estimated computing needs: 7,500,000 SBU // ~500 day-experiments. Note that the cost of an AROME 30h-forecast on a 750x750 domain was estimated to be around 15,000 SBU.

- Experiments with strong wind over orography (winter storms), at 500m-100m resolution, will be performed to test the robustness of the dynamical core over steep slopes. Estimated computing needs: 1,000,000 SBU.

- Extended simulations of AROME 1km and AROME 500m over Tahiti island ; these 2 models will have the same number of grid-points (600x600), with an estimated cost of 700,000 SBU each for a 3 week period (30h forecast 4 times a day) ; total annual cost ~ 5,600,000 SBU, which also includes the cost of the 2.5km model and its coupling files from IFS.

- A total set of about 10 experiments over flat terrain, then over a mountainous region, in order to sample the behaviour of simulated thermal plumes. The cost of each experiment is estimated to be about 35,000 SBU (~ 350,000 SBU)

2016:

- follow-on simulations of AROME 1km and AROME 500m both on La Réunion island and on a mid-latitude region, based on the tuned Surfex scheme and possibly including specific adaptations of the turbulence scheme ; total annual cost : ~ 5,000,000 SBU ;

- Re-run some heavy precipitation events with a two-moment micro-physical scheme in AROME (if the development phase of this scheme is completed). ~ 1,000,000 SBU.

- Comparison of Arome-500m with different versions of a parametrization of turbulence: ~ 1,000,000 SBU

C) Technical requirements

Code: AROME is the non-hydrostatic LAM version of the IFS-ARPEGE system, with separate physics. Hence it shares a large part of its source code with the IFS, especially parallel aspects. Porting of the code on ECMWF's CRAY HPC has already started, and it is expected that this porting will be regularly updated as a result of routine testing by system experts outside the framework of this special project.

Experiment User environment: the OLIVE web interface, used at Météo-France for build scripts for NWP experiments, is interfaced with the ECMWF HPC and job scheduler system..

Archive: storage volume is requested in order to store the AROME model input data (initial conditions and lateral boundary conditions). On the contrary, most of the produced data would be transferred to Météo-France's archive machine for diagnostic and post-processing purposes.

References

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