REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Ireland

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Project Title:
Investigating the optimal configuration of the HARMONIE-AROME NWP model for hectometric-scale forecasting over Ireland

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.)	2021	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2021-2023:
(To make changes to an existing project please submit an amended version of the original form.)

		2021	2022	2023
High Performance Computing Facility	(SBU)	9M		
Accumulated data storage (total archive volume)[2]	(GB)	10TB		

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

Background

Met Éireann, as a member of the HIRLAM consortium, runs an operational Numerical Weather Prediction (NWP) suite using the HARMONIE-AROME configuration of the shared ALADIN-HIRLAM NWP system (hereafter referred to as the HARMONIE-AROME model). This is a limited-area, non-hydrostatic, convection-permitting model developed within the frameworks of ARPEGE and IFS software (further details may be found in Bengtsson et al., 2017). HARMONIE-AROME is currently run by HIRLAM members at an operational horizontal resolution of 2.5km with 65 vertical levels, while Météo France runs AROME at 1.3km with 90 levels.

Increasingly, operational centres are aiming for higher and higher resolutions, with the ECMWF targeting global forecasts at resolutions of around 5km by 2025. There is considerable interest in a corresponding increase in the resolutions of limited-area models to sub-kilometre levels. To this end, a number of workshops have been held among the HIRLAM and ALADIN consortia members to address this, the most recent being in December 2019.

Figure 1 below shows an example from preliminary studies of the increased level of detail available as the grid-size used in simulations is decreased from 2.5km to 750m. It is also hoped that increased resolution may give a better forecast of extreme events such as wind storms (Yang, 2018).

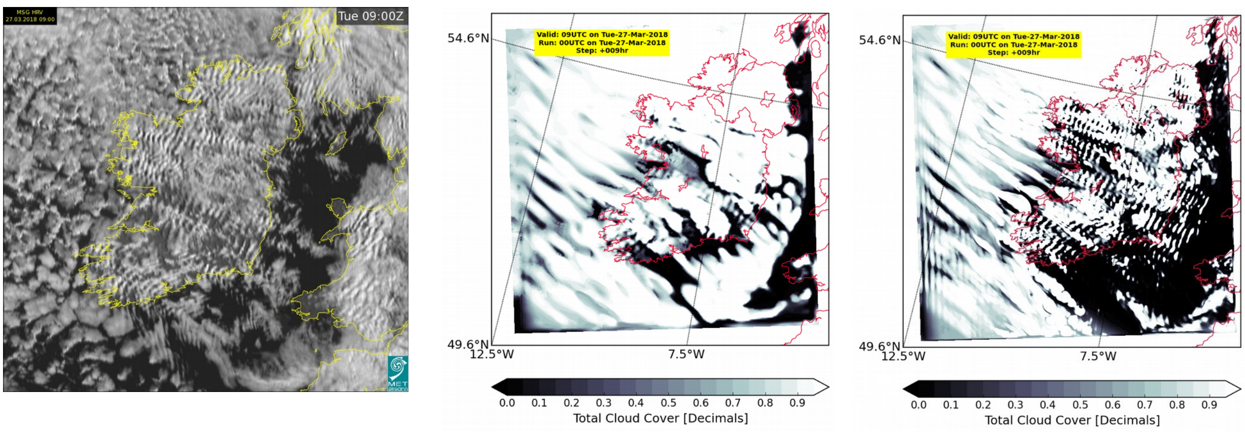

Figure 1: Satellite image (left) of gravity waves over Ireland, along with simulations using HARMONIE-AROME at 2.5km (middle) and 750m (right) resolution.

Although higher resolutions have the potential to provide more accurate forecasts, a naive approach of simply reducing the grid size and the time-step accordingly will not be sufficient. As an example, Figure 2 below shows the results of a 750m simulation of Storm Ophelia in October 2017; while remaining computationally stable throughout the integration, the forecast suffered from grid-scale noise, particularly visible in the MSLP fields.

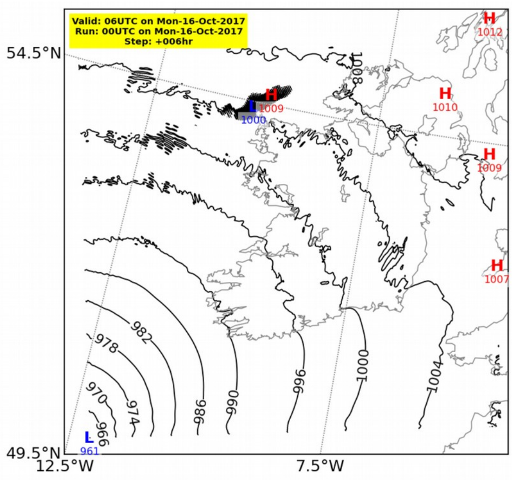

Figure 2: MSLP field from simulation of Storm Ophelia over Ireland using HARMONIE-AROME at 750m horizontal resolution.

Scientific Plan

In this project, we aim to address some of the scientific and technical challenges relating to hectometric resolutions within the HARMONIE-AROME model. The ultimate goal is to arrive at an optimal model configuration using a 750m grid, and assess the performance benefits of such a forecasting system over Ireland, particularly for extreme events.

Specific issues to be investigated include the following:

- Domain and grid: the trade-off between domain size and increased computational cost will be addressed. Figure 3 shows some possible 750m grids over Ireland. However, smaller domains will suffer more from boundary effects, which were evident to the west in the simulation on the right-hand panel of Figure 1 above. The option of quadratic or cubic spectral truncation as a means to save on computation will be explored. Finally, the choice of lateral boundary conditions and nesting strategy will be investigated; that is, examining the effect of direct nesting within IFS-HRES, or using 2.5km HARMONIE-AROME as an intermediate host.

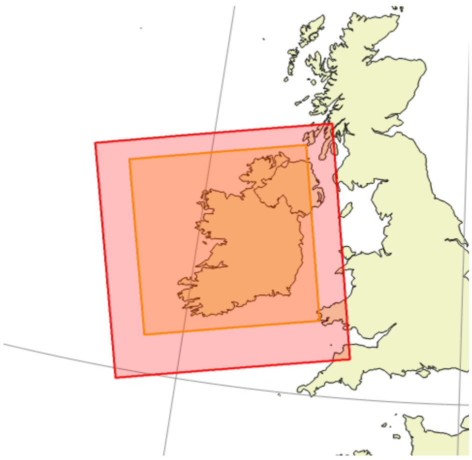

Figure 3: Possible domains over Ireland at 750m horizontal resolution, using 800x800 (red) and 600x600 (orange) grid-points.

- Vertical resolution: as mentioned at the beginning, HIRLAM members presently use 65 vertical levels with HARMONIE-AROME. The effect of increasing to the 90 levels used operationally by Météo France will be explored, along with any additional stability concerns.
- Time-scheme: HARMONIE-AROME uses a semi-implicit semi-Lagrangian time-scheme, allowing stable integrations at long time steps. There is an option to use an iterative centred implicit scheme, which may be necessary for stability as resolutions increase (Bénard et al., 2010).
- Diffusion: at higher resolutions, small-scale noise such as that seen in Figure 2 could, of course, be removed by adding excessive levels of diffusion to the set-up. However, this is clearly not an ideal or accurate approach. In addition to standard spectral horizontal diffusion, there is a flow-dependent semi-Lagrangian horizontal diffusion scheme (SLHD: Váňa et al., 2008) available in HARMONIE-AROME, and the optimal balance of both schemes remains to be found.
- Physics paramterisations: the above issues discussed so far mostly concern the dynamics and stability of the model. While a dynamically robust configuration is essential, it may not be sufficient for accurate simulations at hectometric scales. The behaviour and tuning of various parameterisation schemes within the model, in particular the turbulence and convection, will need investigation. Time permitting, this aspect of the model will also be considered.
- Verification of results: it is generally acknowledged that, while increasing resolution leads to more realistic-looking forecasts, it can be difficult to objectively prove this using traditional point-verification methods (Mass et al., 2002). A range of supplementary spatial-based methods will be needed to fully assess the quality of the simulations (e.g., Mittermaier, 2014).

Justification of Computational Resources Requested

Cycle 43 of HARMONIE-AROME will be used for this project. This model cycle is currently under testing, with an official release planned in the second half of 2020.

A single 24-hour forecast using a 750m resolution domain, similar to those shown in Figure 3 above, has been found to typically cost around 15000-20000 SBU (depending on exact domain size, vertical resolution etc). The first stage of the project will involve a series of single forecasts to test various technical settings and address issues such as stability, domain size etc, as discussed above. Additionally, sensitivity tests will be carried out, experimenting with convergence with reduced time-step, and comparison with even finer 500m resolution simulations. While the exact number will depend on the results being obtained, it is envisaged the total cost of this first stage, including the extra fine resolution experiments, will be an order-of-magnitude approximation of 1M SBU.

These experiments will suggest a number of candidate configurations, which will then need to be evaluated and compared meteorologically using longer cycling experiments. Moving to more operationally-appropriate 48-hour forecasts, we can calculate the approximate cost upper-bound of a month-long experiment with three-hour cycling and 48-hour forecasts at 00Z and 12Z as: 30 x 2 x (2 x 15000) ~ 2M SBUs. This would allow roughly 4 such month-long experiments in the second stage of the project, to give the total of (1 + 4 x 2) ~ 9M SBUs requested.

These long experiments would allow meaningful statistical comparison between the promising candidates identified during the first phase, and would be carried out over periods of interest in terms of extreme weather and high-impact events over Ireland; for example, the numerous named storms during February 2020, and heavy convective events experienced in July 2019 and June 2020.

References

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