REQUEST FOR A SPECIAL PROJECT 2023–2025

MEMBER STATE: Ireland

Principal Investigator[1]: Colm Clancy

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Project Title: Forecasting at sub-kilometre resolution with the HARMONIE-AROME model

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.)	2023	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2023-2025:
(To make changes to an existing project please submit an amended version of the original form.)

		2023	**2024**	**2025**
High Performance Computing Facility	(SBU)	20 M		
Accumulated data storage (total archive volume)[2]	(GB)	0 (National Allocation to be used)		

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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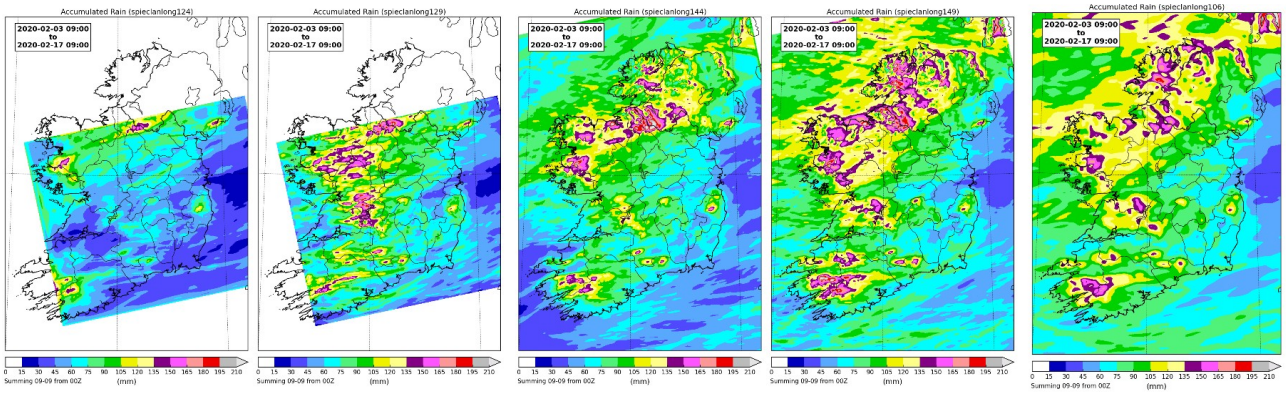
Extended abstract

Background

Met Éireann is a member of the ACCORD consortium and runs an operational Numerical Weather Prediction (NWP) suite using the HARMONIE-AROME canonical system configuration. 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). At Met Éireann, HARMONIE-AROME is the basis of the operational IREPS ensemble system, with a horizontal resolution of 2.5km and 65 vertical levels. Future operations within the United Weather Centres-West (UWC-W) cooperation will use a horizontal resolution of 2.0km with 90 levels.

There is increasing interest in operational centres in forecasting at sub-kilometre resolutions. This has been a research topic among the ACCORD partners for a number of years, with some experimental suites already in place (e.g. Yang, 2018). More recently, projects such as Destination Earth are driving the development of global NWP models at convection-permitting scales, and so are focussing more and more attention on the potential performance of our limited-area NWP models at resolutions on the order of hundreds of metres.

Met Éireann has been active in this area for a number of years. In 2021, the Special Project spieclan was used to extensively study the performance of HARMONIE-AROME at hectometric-scale over Irish domains in particular (Clancy et al, 2022). One key finding was that a 750m-resolution domain covering the whole of the country was a good compromise between performance and cost, and that careful choice and treatment of lateral boundary conditions (LBC) was essential when using necessarily-small domains (see Fig. 1 below). In 2021 and 2022, the Special Project spieharn was used to study the performance of hourly nowcasting range setups at 2.5km and 750m resolutions over Irish domains and, following the work of the spieclan, similar decisions must be made about the choice of LBCs. All of this work is guiding the development of high-resolution forecasting and nowcasting setups at Met Éireann which will begin as parallel e-suites in the second half of 2022.



(a) 500 m, L90, EIRL500W2 (b) 750 m, L90, IRL750 (c) 2.5 km, L90

Figure 1: Accumulated rainfall over a two-week test period in February 2020. The hectometric-resolution 500m and 750m test domains are shown in (a) and (b), respectively. The reference 2.5km run is shown in (c). In both (a) and (b), the simulations on the left use LBC from IFS-HRES, while on the right they are nested within a 2.5km HARMONIE-AROME experiment.

Scientific Plan

The aim in this project is to address some of the outstanding issues that were raised by the previous Special Projects. Specifically, two areas will be investigated:

- Lateral Boundary Conditions: as mentioned above, the choice and treatment of LBC was found to be important. Some benefit was seen when nesting within 2.5km HARMONIE-AROME simulations, as opposed to using LBC from IFS-HRES. However, the former used a HARMONIE-AROME host with the same analysis time. This would not be practical in an operational schedule, but instead 1-, 2- and 3-hour old boundaries would available from the proposed UWC-W EPS setup. Six-hour old IFS LBC would also be available, but now more testing is needed to ascertain the optimal "age" of HARMONIE-AROME boundaries.

- Stability and dynamics configurations: while previous work focussed on Irish domains, a few experiments were carried out in regions with more complex orography and extreme conditions. Tests at 500m over Greenland were found to be more challenging in terms of computational stability. Current development work on the UWC-W domain (which includes a part Greenland, Fig. 2) has revealed similar issues due to the proposed increase in vertical resolution.

Work on these topics will help both in the further development and improvement of the proposed very high-resolution short range and nowcast range operational suites at Met Éireann, and in the wider research and development of the HARMONIE-AROME model within the ACCORD consortium.

Justification of Computational Resources Requested

Cycle 43h2.2 of HARMONIE-AROME was officially released in April 2022, and will be used for the project. This has already been built and tested on the new Atos aa platform and is performing successfully. The tests on aa have indicated that a 48-hour forecast on the reference Irish 2.5km domain (red in Fig. 2) with 90 vertical levels will typically cost around 10k SBU, while a 36-hour short range forecast on the target 750m domain (purple in Fig. 2) costs around 30k SBU, with a 12-hour nowcast range on the 750m domain costing approximately 10k SBU.

February 2022 provides an ideal testing period, containing three named storms which impacted Ireland (Dudley, Eunice and Franklin). To reflect what will be available from the UWC-W EPS setup, a 14-day testing period will be considered with 3 suites of 8 cycles per day of the 2.5km reference, with the first suite running at hours 00/03/06/…, the second at hours 01/04/… and the third at 02/05/.... The three-hourly cycling is chosen to reflect options for LBC from the UWC-W EPS setup for the nested 750m domain, as discussed above.

The nested 750m simulations will target 4 cycles per day, out to a 36-hour forecast, so as to be able to use the various LBC. Four options for the LBC will be explored: IFS, and 1-,2- and 3- -hour old HARMONIE-AROME.

The same period will be used for the testing of the hourly nowcasting setup. The reference forecasts will be used for two experiments of an hourly 12 hour nowcast configuration.

The total approximate cost of the above experiments is detailed in the Table 1 below, and comes to roughly 16.7 M SBU. The remaining of the requested 20 M SBU will be used for shorter stability

tests, outlined previously, which do not require the longer cycling strategy, as well as any other necessary technical testing.

In terms of storage, the complete model output will not require additional long-term archiving, and so the use of National Allocation will be sufficient.

Setup	**Single forecast cost**	**Days**	**Cycles/day**	**Variations**	**Total Cost** (Single cost x Days x Cycles x Variations)
Reference 2.5km	10k SBU	14	8	3 (cycling suites)	3.3 M SBU
750m	30k SBU	14	4	4 (LBC options)	6.7 M SBU
Nowcasting	10k SBU	14	24	2 (LBC options)	6.7 M SBU
				Total Cost	**16.7 M** SBU

Table 1: Breakdown of the computational costs of the proposed set of experiments

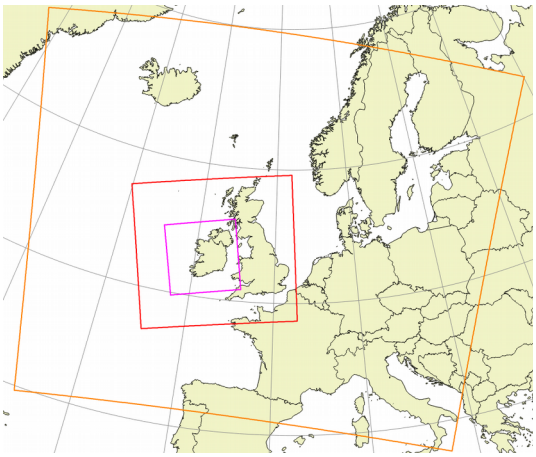


Figure 2: Domains to be considered in this project. Purple: 750m Irish domain. Red: 2.5km reference, used frequently for operational testing. Orange: 2.0km future UWC-W domain.

References

Bengtsson L., U. Andrae, T. Aspelien, Y. Batrak, J. Calvo, W. de Rooy, E. Gleeson, B. Hansen-Sass, M. Homleid, M. Hortal, K. Ivarsson, G. Lenderink, S. Niemelä, K.P. Nielsen, J. Onvlee, L. Rontu, P. Samuelsson, D.S. Muñoz, A. Subias, S. Tijm, V. Toll, X. Yang, and M.Ø. Køltzow, 2017: The HARMONIE–AROME Model Configuration in the ALADIN–HIRLAM NWP System. Mon. Wea. Rev. 145:5, 1919-1935

Clancy C., Fannon J., and E. Whelan, 2022: Hectometric-Scale Experiments at Met Éireann. ACCORD Newsletter 2, February 2022, 129-138

Yang X., 2018: Sub-km HARMONIE and on-demand setup for storm forecast. Aladin-Hirlam Newsletter No. 10, Jan 2018.