REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Ireland

Principal Investigator[1]: Colm Clancy

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

To make changes to an existing project please submit an amended version of the original form.)

If this is a continuation of an existing project, please state the computer project account assigned previously.	**SPIECLA2**.	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2024	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for project year:		**2024**	**2025**	**2026**
High Performance Computing Facility	[SBU]	30 M	30 M	
Accumulated data storage (total archive volume)[2]	[GB]	0	0	

EWC resources required for project year:		**2024**	**2025**	**2026**
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

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.

[3] The number of vGPU is referred to the equivalent number of virtualized vGPUs with 8GB memory.

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Extended abstract

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

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF and its Scientific Advisory Committee. The requests are evaluated based on their scientific and technical quality, and the 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.

Requests exceeding 5,000,000 SBU should be more detailed (3-5 pages).

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 forecasting at sub-kilometre resolutions. This has been a research topic among the ACCORD partners for a number of years and now the Destination Earth project, and in particular the On-Demand Extremes contract, is focussing more and more attention on the performance of our NWP models at resolutions on the order of hundreds of metres.

Met Éireann is currently running a parallel experimental suite named HECTOR, at 750m resolution. This is the result of work carried out in recent Special Projects, notably spieclan in 2021 (Clancy et al, 2022) and spiecla2 in 2023. The former examined the optimal configuration settings for Ireland, while the latter further investigated the options for lateral boundary conditions and coupling.

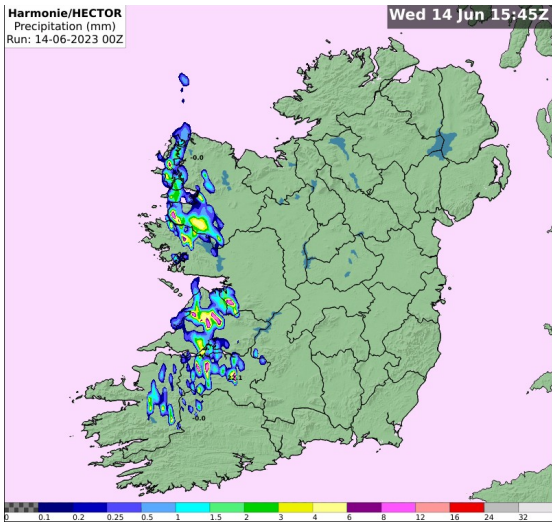

Figure 1:
The HECTOR e-suite at Met Éireann

Scientific Plan

The aim of this project is to continue and expand on work done in the previous projects. Two areas will be explored.

1. Resolution
As mentioned, the HECTOR e-suite at Met Éireann runs at 750m horizontal resolution. We will test further at 500m and also at 250m. The stormy February 2022 test period from the previous spiecla2 will be used again, to investigate any added benefit from the resolution in the case of extreme winds. As a second test period, Ireland has experienced hot conditions with some days of intense convective activity in June 2023. This is a situation where we may hope to gain accuracy in terms of extreme precipitation.

While 500m resolutions have been tested successfully before, the 250m poses more of a challenge. This is not only in terms of model stability, but also in terms of the validity of the current physics parameterisations in HARMONIE-AROME. A scale-aware convection scheme has been developed within the community, and this is something which will be tested.

As always, verification at very high resolution remains a challenge. Within the current spiecla2 project in 2023, work has been done with the FSS for rainfall. This work will be continued.

2. Ensemble Forecasting
As resolutions increase, it becomes less and less appropriate to rely on a deterministic forecast, particularly for the kind of convective conditions mentioned above. The obvious challenges with this are the computational cost and the ability of current perturbation techniques to suitably capture model uncertainty at such high resolutions. We will carry out some preliminary tests with a small 750m-resolution ensemble to assess the feasibility and benefit.

Justification of Computational Resources Requested

Cycle 43h2.2 of HARMONIE-AROME has been used for the spiecla2 testing so far. We will likely switch to the latest available Cycle 46h version, in order to use the convection options mentioned. A number of development branches of Cycle 46h1 are already in use on the Atos HPC.

Our previous testing has shown that our standard reference 2km HARMONIE-AROME 36-hour forecast on Atos costs around 10k SBU, while for the 750m using single precision, this is around 15k. Typically we test for two-week periods with 4 long forecasts per day at 00/06/12/18 for the 750m, with 8 for the reference to produce the boundary files for nesting.

If we keep the same region as the 750m experiments (the island of Ireland), but increase to 500m, we will get a rough increase in cost by a factor of (1.5 x 1.5 x 1.5)=3.375.
A 250m resolution for the same region would quickly become prohibitively expensive. Instead we would test a sub-domain with similar number of grid-points to the others; thus the cost factor would be 3 times the 750m, i.e. just the time-step.

As mentioned, two test periods will be used. For the hectometric domains, we can further choose nesting directly with IFSHRES LBC, or using the intermediate HARMONIE-AROME reference. This may become particularly important with the resolution jump to 250m.

Using these values, we compute the overall approximate cost of these deterministic tests in the table below.

Resolution	Single forecast cost (SBU)	Days in test period	Cycles/day	Variations	Total cost (product)
2km ref	10 k	14	8	2 (test periods)	2.2 M
750m	15 k	14	4	4 (2 test periods, 2 LBC)	3.4 M
500m	50 k	14	4	4 (2 test periods, 2 LBC)	11.2 M
250m	45 k	14	4	4 (2 test periods, 2 LBC)	10.1 M
				TOTAL	**26.9 M SBU**

For the ensemble tests, we typically test with a 6-member ensemble. The initial focus will be on a 750m configuration using IFSHRES boundaries. The costs will then be:

Resolution	Single forecast cost (SBU)	Members	Days in test period	Cycles/day	Variations	Total cost (product)
2km ref	10 k	6	14	4	2 test periods	6.8 M
750m	15 k	6	14	4	2 test periods, 2 configurations	20.2 M
					TOTAL	**27.0 M SBU**

Combining the two totals above gives around 54 M SBU. Allowing for extensive technical testing e.g. of the physics options, as well as the ensemble perturbations, will bring the total up to 60 M SBU, and we propose to carry this out over two years.

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.

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.
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Clancy C., Fannon J., and E. Whelan, 2022: Hectometric-Scale Experiments at Met Éireann.
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