REQUEST FOR A SPECIAL PROJECT 2024–2026

MEMBER STATE: Ireland

Principal Investigator[1]: James Fannon

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Other researchers: Colm Clancy

Project Title: Utilising the URANIE platform for sensitivity analysis and optimisation of ensemble perturbation methods in 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.	**SP** ………….	
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]	100 M		
Accumulated data storage (total archive volume)[2]	[GB]	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, as a member of the ACCORD consortium, runs an operational Numerical Weather Prediction (NWP) suite using the HARMONIE-AROME canonical system configuration of the shared ACCORD NWP system (further details can be found in Bengtsson et al., 2017). HarmonEPS is the ensemble realisation of HARMONIE-AROME and forms the basis for Met Éireann's operational Ensemble Prediction System (EPS), which currently utilises boundary, surface, upper-air, and multi-physics perturbations methods in a 1+15 member semi-continuous ensemble. Future operations within the United Weather Centres-West collaboration will introduce significant ensemble configuration changes, including the use of the Stochastically Perturbed Parameterizations (SPP) scheme and an expanded 1+30 member continuous ensemble.

The role played by these different perturbation schemes on overall ensemble performance is of course an ongoing area of interest within the HarmonEPS community, with recent studies highlighting the impact of soil moisture perturbations on ensemble member drying (Frogner, 2021) and the model spread generated by different stochastic perturbation schemes (Frogner et al., 2022). Moreover, the recent introduction of the SPP scheme in HARMONIE-AROME has emphasised the importance of appropriate perturbation parameter tuning to optimise performance. However, such parameter tuning can be a laborious and time-consuming exercise, and indeed may need to be repeated when new physics changes are implemented in the model.

Recent progress with a software platform known as URANIE, a sensitivity and uncertainty analysis tool developed at the Alternative Energies and Atomic Energy Commission, may help to address these issues. As part of the ESCAPE-2 deliverable D4.6, URANIE was successfully integrated within the HarmonEPS framework and applied to various EPS case studies. This included a sensitivity analysis of ensemble member biases on model perturbations and a perturbation parameter optimisation test (Van Ginderachter, 2021). Thus the statistical tools provided by URANIE may provide a promising approach for investigating known model issues in HARMONIE-AROME and optimising HarmonEPS performance in an efficient and robust manner.

Scientific Plan

The work carried out as part of ESCAPE-2 deliverable D4.6 has already been investigated at Met Éireann, with initial preliminary proof-of-concept experiments ongoing. The purpose of this special project is to extend this work to additional HarmonEPS cases, using the most recent version of HARMONIE-AROME, and ultimately to assess the feasibility of wider URANIE usage within the ACCORD community. The following two areas will be explored:

1. *Surface perturbations*

The role of different surface perturbation parameters on the prediction of high-impact weather events, such as thunderstorms and heat waves, will be investigated. In URANIE, this can be assessed by essentially sampling different perturbation amplitudes and using the Morris screening method to identify which parameters have the greatest impact on model performance (e.g. spread and CRPS). The parameters identified can subsequently be studied in more detail. Ireland has experienced both hot conditions and a period of intense convective activity in June 2023, which is a suitable test period for this study.

2. *SPP*

The SPP scheme in HarmonEPS currently contains 17 parameters in total, each of which has a number of tuning parameters for the parameter probability density function (PDF). The impact of each parameter will again be assessed through a sensitivity analysis (e.g. by iterating over the PDF standard deviation). We will also investigate how the URANIE framework can be used to suitably tune the SPP configuration settings, such as the SPP pattern spatial and temporal correlation length scales, and compare the results against settings previously obtained from manual tuning. Both the June 2023 convective period and a stormy February 2022 test period could be considered.

Justification of Computational Resources Requested

The latest available Cycle 46h version of HARMONIE-AROME will be used for this project. The majority of code changes required to incorporate URANIE into HARMONIE-AROME have already been carried out in a development branch of Cycle 46h1 and have been tested on the Atos HPC.

In order to reduce the significant computation costs associated with URANIE ensemble testing, runs will utilise single precision and the standard HARMONIE-AROME horizontal and vertical resolution of 2.5km and 65 levels, respectively, over an Irish domain. One 36-hour forecast at this resolution costs around 3K SBU. Typically 6 perturbed members are used for ensemble testing within the ACCORD community. In this project, we intend to initialise perturbed member forecasts from a previously run control member forecast in order to isolate the impact of model perturbations. Hence the costs associated with the control member and the data assimilation cycling for the perturbed members are avoided.

In order to perform sensitivity and optimisation analyses with URANIE, a relatively larger number of iterations over different perturbation parameter values need to be carried out. In the case of the Morris screening method (for sensitivity analysis), the number of URANIE iterations is given by R x (N + 1), where R is the number of trajectories and N is the number of parameters under consideration. Based on previous work, and to reduce computational costs, we take R=5 here. For parameter optimisation, the number of URANIE iterations is not known a prori, but can be estimated to be around 25 based on previous experience with the Efficient Global Optimization routine in URANIE. Note that one URANIE iteration consists of running the full ensemble over the entire test period, and thus URANIE experiments can quickly become quite expensive.

For the sensitivity analysis experiments, one week-long test period will be used for surface perturbations and two week-long periods for SPP. Two 36-hour forecasts will be run each day (at 00Z and 12Z), and we assume N=8 and N=9 for surface perturbation and SPP tests, respectively. Hence the costs of these analyses are estimated as follows:

Analysis	**Single forecast cost**	**Number of days**	**Cycles/day**	**Number of members**	**URANIE iterations**	**Total Cost (product)**
Surface	3K	7	2	6	5*(8+1)=45	11.3M
SPP	3K	14	2	6	5*(9+1)=50	25.2M

The optimisation experiments will be limited to parameters in the SPP scheme. The sensitivity analyses will inform which parameters to optimised, and here we assume approximately 5 in total. Optimisation will be carried out over the two test periods to assess dependence on meteorological conditions. Hence the costs of the optimisation tests are estimated as follows:

Number of parameters	**Single forecast cost**	**Number of days**	**Cycles/day**	**Number of members**	**URANIE iterations**	**Total Cost (product)**
5	3K	14	2	6	25	63.0M

Combining the two totals above gives around 100M SBU. In terms of storage, the complete model output will not require additional long-term archiving, and so the National Allocation will be sufficient.

References

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

Frogner, I. (2021). HarmonEPS developments, 1st ACCORD All Staff Workshop. http://www.umr-cnrm.fr/accord/?1st-ASW-12-16-April-2021-video-conference.

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Van Ginderachter M, 2021: D4.6: Full-system sized ensemble forecasts within the URANIE framework, ESCAPE-2 consortium, Work Package 4, Task 4.6. https://www.hpc-escape2.eu/resources/d46-full-system-sized-ensemble-forecasts-within-uranie-framework.