REQUEST FOR AN EMI R&D PROJECT 2027–2029

Country/Organisation: Met Éireann, Ireland

Principal Investigator[1]: Dr. Markus Todt

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Project Title: Dynamical Downscaling of AMOC Storylines

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.		
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2027	
Would you accept support for 1 year only, if necessary?	YES **X**	NO

Computer resources required for project year:		2027	2028	2029
High Performance Computing Facility	[SBU]	90 million	90 million	
Graphics Processing Unit Cluster-A	[GBU]			
Graphics Processing Unit Cluster-B	[GBU]			
Accumulated data storage (total archive volume)[2]	[GB]	1,000,000*	2,000,000*	

[1] The Principal Investigator will act as contact person for this EMI R&D 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.

EWC resources required for project year:		2027	2028	2029
Number of vCPUs	[#]			
Total memory	[GB]			
Storage	[GB]			
Number of vGPUs[3]	[#]			

Continue overleaf.

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Extended abstract

All EMI R&D 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 EMI R&D 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 EMI R&D 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).

The Atlantic Meridional Overturning Circulation (AMOC) is an important driver of the climate of Northwestern and Northern Europe, in particular the mild climate of Ireland. Although considered a low-likelihood high-impact scenario, recent studies have suggested that a partial or full collapse of the AMOC may not be as unlikely as previously assumed (Rahmstorf, 2024, and references therein; Drijfhout et al, 2025; Portmann et al., 2026). A strong decline or collapse of the AMOC would not just affect Northwestern and Northern Europe via a reduced heat transport but also through changes in atmospheric circulation and sea level.

Ireland's national climate projections, standardised in Met Éireann's TRANSLATE project, consist of dynamically and statistically downscaled global climate model simulations with varying degrees of AMOC decline during the 21st century. This set of simulations is based on the global climate models used in Euro-CORDEX, currently based on simulations from the 5th phase of the Coupled Model Intercomparison Project (CMIP5) and soon to be updated to CMIP6, and covers the period up to 2100. However, a substantial AMOC decline and its impacts would manifest most strongly beyond the 21st century. This is highlighted by Drijfhout et al. (2025), who analysed simulations from CMIP6 that extend beyond 2100. They found a substantial AMOC decline, or AMOC shutdown, in simulations across Shared Socioeconomic Pathways (SSPs) as seen in Figure 1. Among them are two SSP1-2.6 simulations, neither of which is included in Euro-CORDEX (and therefore won't be included in TRANSLATE either). We identified these as suitable storyline simulations of extreme AMOC decline to supplement our national climate projections. They constitute the most extreme scenario from a temperature perspective, as the strong regional cooling from a substantial AMOC decline would only see a limited compensation from the comparatively weak global warming under SSP1-2.6. Despite similar magnitudes of decline in AMOC strength, impacts vary in magnitude between the two global simulations as indicated by winter temperatures over Ireland at the original model resolution (Figure 2). We therefore plan to dynamically downscale both of these simulations. While broad impacts and trends can be derived from the global simulations, dynamical downscaling is necessary to derive reliable projections of impacts on a regional and national scale.

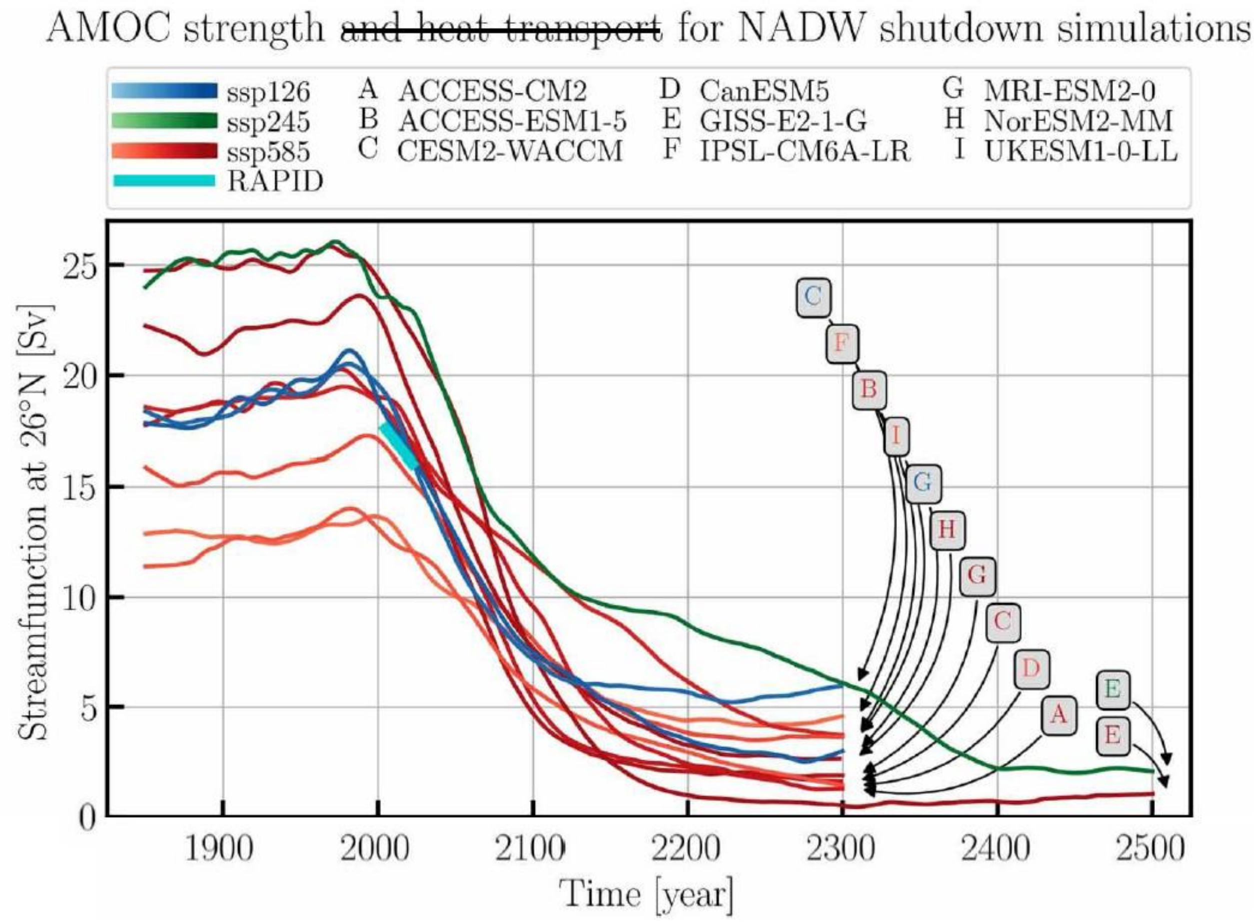

Figure 1: AMOC strength in CMIP6 simulations extending past 2100 that feature an AMOC shutdown (adapted from Drijfhout et al., 2025)

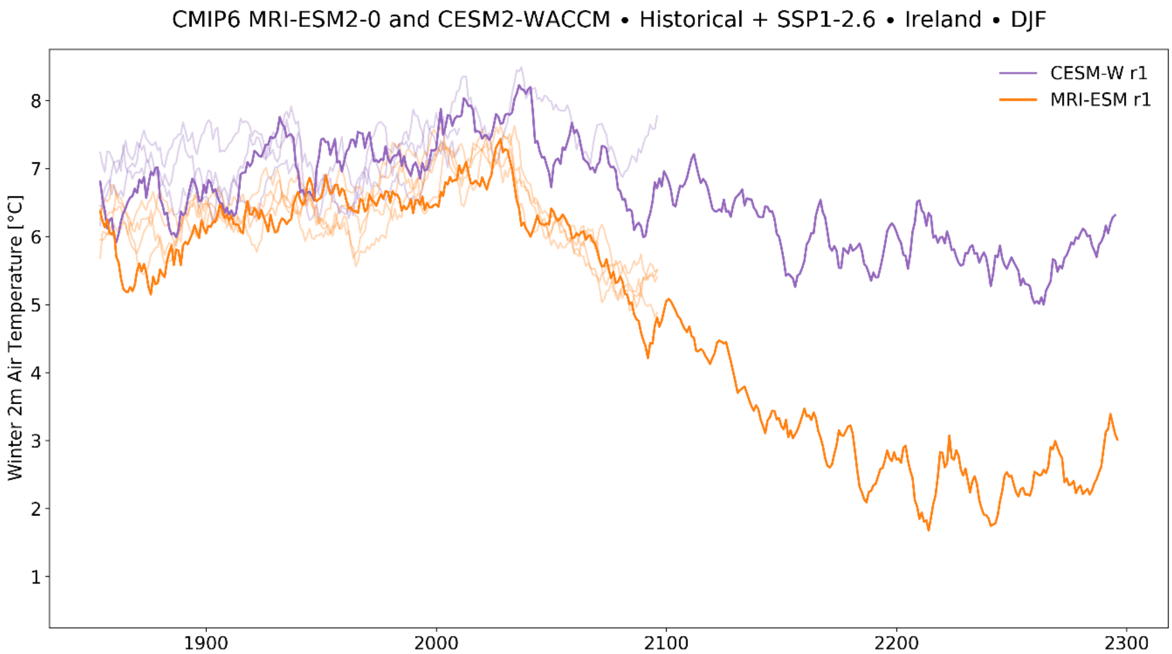

Figure 2: 9-year running average of winter temperatures over Ireland in the two SSP1-2.6 simulations shown in Figure 1

Met Éireann is part of the regional-climate-modelling consortium HCLIM (Belušić et al., 2020). In order to dynamically downscale from global climate simulations, which typically feature resolutions of around 100km, to regional projections with convection-permitting climate models at 3-4km resolution, a two-step (or nested) approach is required. This consists of firstly running a regional, convection-parameterised climate model forced by the global climate model at the boundaries, and secondly running a convection-resolving climate model on a smaller domain forced at the boundaries by the first regional climate simulation. Within the HCLIM consortium, this is typically done with HCLIM-ALADIN at a resolution of about 12km and with HCLIM-AROME at a resolution of around 3km. We intend to dynamically downscale both of the identified global climate simulations with HCLIM-ALADIN on a Pan-European domain over the period 1980-2300 and subsequently nest HCLIM-AROME for individual 30-year periods over smaller domains within the HCLIM-ALADIN simulation. This requires storing and archiving the full output from the HCLIM-ALADIN simulation in order to drive the nested HCLIM-AROME simulation. We also intend to share the Pan-European HCLIM-ALADIN simulation within the HCLIM consortium, enabling partners to run nested HCLIM-AROME simulations for their own domains.

Potential technical issues:

Regional climate models are typically driven with model-level data from the global climate models. However, model output from at least one of the two identified global simulations is only available on pressure levels beyond 2100. We therefore need to set up HCLIM to be forced with pressure-level data, for which we will rely on experience within the HCLIM consortium as well as by colleagues working in Numerical Weather Prediction using the same model core as in HCLIM.

Schedule:

2027 – Setting up HCLIM-ALADIN driven by pressure-level data. Downscale MRI-ESM2-0 global simulation over Pan-European domain with HCLIM-ALADIN and run nested HCLIM-AROME simulations within HCLIM-ALADIN simulation for MRI-ESM2-0
2028 – Downscale CESM2-WACCM global simulation over Pan-European domain with HCLIM-ALADIN and run nested HCLIM-AROME simulations within HCLIM-ALADIN simulation for CESM2-WACCM.

*Computational resources:

Our intention with this special project is to supplement our national computational resources used for regional climate projections. The numbers of SBUs given in the table on page 1 are representative of the resources required for the nested HCLIM-AROME simulations, while we intend to use our national resources for the HCLIM-ALADIN simulations. In contrast, the total archive volume given in the table covers all simulations. We are aware of the maximum storage volume for special projects and will cover the difference between requested storage volume and granted storage volume with our national resources.

References:

D. Belušić, H. de Vries, A. Dobler, O. Landgren, P. Lind, D. Lindstedt, R. A. Pedersen, J. C. Sánchez-Perrino, E. Toivonen, B. van Ulft, F. Wang, U. Andrae, Y. Batrak, E. Kjellström, G. Lenderink, G. Nikulin, J.-P. Pietikäinen, E. Rodríguez-Camino, P. Samuelsson, E. van Meijgaard, and M. Wu, *HCLIM38: a flexible regional climate model applicable for different climate zones from coarse to convection-permitting scales*, Geosci. Model Dev., 13, 1311–1333, 2020, https://doi.org/10.5194/gmd-13-1311-2020

S. Drijfhout, J. R. Angevaare, J. Mecking, R. M. van Westen, and S. Rahmstorf, *Shutdown of northern Atlantic overturning after 2100 following deep mixing collapse in CMIP6 projections*, Environ. Res. Lett., 20, 094062, 2025, https://doi.org/10.1088/1748-9326/adfa3b

V. Portmann, D. Swingedouw, O. Khattab, and M. Chavent, *Observational constraints project a ~50% AMOC weakening by the end of this century*, Sci. Adv. 12, eadx4298, 2026, https://doi.org/10.1126/sciadv.adx4298

S. Rahmstorf, *Is the Atlantic overturning circulation approaching a tipping point?*, Oceanography, 2024, https://doi.org/10.5670/oceanog.2024.501