REQUEST FOR A SPECIAL PROJECT 2020–2022

MEMBER STATE: Ireland

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Project Title: HARMONIE Climate (HCLIM) Regional Downscaling Simulations for Ireland

If this is a continuation of an existing project, please state the computer project account assigned previously.	**spiemcgo**	
Starting year: (A project can have a duration of up to 3 years, agreed at the beginning of the project.)	2020	
Would you accept support for 1 year only, if necessary?	YES ☒	NO ☐

Computer resources required for 2020-2022:
(To make changes to an existing project please submit an amended version of the original form.)

		2020	**2021**	**2022**
High Performance Computing Facility	(SBU)	20M	18M	
Accumulated data storage (total archive volume)[2]	(GB)	35,000	45,000	

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.

Principal Investigator: Jonathan McGovern, jonathan.mcgovern@met.ie……………………………………

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Extended abstract

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

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.

Following submission by the relevant Member State the Special Project requests will be published on the ECMWF website and evaluated by ECMWF as well as the Scientific Advisory Committee. The evaluation of the requests is based on the following criteria: Relevance to ECMWF's objectives, scientific and technical quality, disciplinary relevance, and 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 asking for 1,000,000 SBUs or more should be more detailed (3-5 pages). Large requests asking for 10,000,000 SBUs or more might receive a detailed review by members of the Scientific Advisory Committee.

Aim:

The overall aim of the proposed project is to assess the future projections of Ireland by downscaling CMIP6 EC-Earth climate data, using the climate mode of HARMONIE model (Bengtsson et al., 2017), HCLIM. This will comprise an assessment of the quality of HCLIM at the 4km scale to provide insight into the added value of climate simulations in the grey zone near the kilometre scale. The future projections will be validated against observations, and will serve to update previous downscaled CMIP5 climate projections for Ireland, and provide a basis for analysis and further research of Ireland's climate.

1. Scientific Background

In a changing warming climate, small-scale effects of climate change, such as windstorms, high temperatures and heavy rainfall have a large impact on society.

Numerous studies have demonstrated that high-resolution RCMs improve the simulation of precipitation (Bieniek et al., 2016; Kendon et al., 2014; Lucas-Picher et al., 2012) and topography-influenced phenomena and extremes with relatively small spatial or short temporal character (Feser and Barcikowska, 2012; Flato et al., 2013). Another advantage is that physically based RCMs explicitly resolve more small-scale atmospheric features and provide better representation of convective precipitation (Rauscher et al., 2010) and extreme precipitation (Kanada et al., 2008). Other examples of the added value of RCMs include improved simulation of near-surface temperature (Di Luca et al., 2016), European storm damage (Donat et al., 2010), strong mesoscale cyclones (Cavicchia and von Storch, 2011), North Atlantic tropical cyclone tracks (Daloz et al., 2015) and near-surface wind speeds (e.g. Kanamaru and Kanamitsu, 2007).

The added value of RCMs in the simulation of cyclones is particularly important as cyclones are the main delivery mechanism for precipitation in Ireland. The International Panel on Climate Change (IPCC) have concluded there is 'high confidence that downscaling adds value to the simulation of spatial climate detail in regions with highly variable topography (e.g. distinct orography, coastlines) and for mesoscale phenomena and extremes' (Flato et al., 2013).

High-resolution 21st Century regional projections of Ireland's climate are important for policy-makers, farming and climate services. Ensemble climate projections for Ireland (e.g., Nolan, 2017) show an overall warming; an increase in mean annual temperature (1-1.6 degrees), and reduction in number of frost days by ~50% by the mid 21st Century (2041-2060), compared to the reference 1981-2000 period. A 20% increase in heavy precipitation events is also expected, while the number of dry periods is predicted to increase by between 12 and 40%. These projections were obtained by downscaling an ensemble of CMIP5 RCP4.5 and RCP8.5 global data. Representative Common Pathways (RCPs) are greenhouse gas concentration trajectories adopted by the IPCC in 2014.

Regional Climate Models (RCMs) such as WRF and COMSO-CLM (e.g. O'Sullivan, 2015; Nolan, 2017), and RACMO2 (e.g. Lenderink, 2015) have demonstrated improved skill in the simulations of small scale effects when compared with global climate model simulations. More recently, the climate mode of the HARMONIE NWP model (HCLIM) has been implemented and tested for downscaling (e.g., Lind, 2015).

The purpose of this project is to carry out the first downscaling projections of Ireland and Europe with HCLIM. This will serve to update the mid-century climate ensemble projections downscaled from CMIP5 data (e.g., Nolan 2017). These projections will also be a base for further study and analysis of the future Irish climate. Examples of this are the effects of climate change on the frequency and intensity of windstorms and heavy rainfall events in Ireland.

One of the first uses of HCLIM was for downscaling on a Euro-CORDEX domain (Lindstedt, 2015) at two resolutions, 6 km – within the 'grey-zone' regime - and 15 km, over 10 years. The RCM was driven by ERA-interim lateral and surface boundary conditions, for the 1997-2008 period (Lindstedt 2015). HCLIM has a convection scheme designed to operate in the ‘grey-zone’ 3-8 km resolution regime, which increases realism and accuracy of the time and spatial evolution of convective processes compared to more traditional parametrisations. The 6 km resolution run was compared to other European RCMs run in Euro-CORDEX, and performed well.

Lind 2015 examined summer precipitation in the Alps with HCLIM, at 15 km and 6.25 km. The regional climate was represented very well and higher order climate statistics and smaller scale spatial characteristics of precipitation were in good agreement with observations. The 'grey-zone' 6-km resolution run reproduced the frequency and intensity of high-intensity precipitation events with higher skill compares with the 15 km resolution and is in closer agreement with observations. For the proposed project, the future climate of Ireland will be simulated at ~ 4-km resolution. As part of the project the quality of HCLIM at the 4km scale will be assessed and provide insight into the added value of climate simulations in the grey zone near the kilometre scale.

Met Eirean researchers will carry out the HCLIM by downscaling EC-Earth CMIP6 data. Analysis will also be carried out by researchers in the climate services ERA4CS project. These runs will allow differences between current and future climate to be examined.

EC-EARTH

The 6th phase of the Coupled Model Intercomparison Project (CMIP6) (Eyring, 2016) will play a key part in the 6th IPCC report. EC-Earth (Hazeleger et al., 2012) contributed to CMIP5, and is currently contributing to the CMIP6 project. EC-Earth consists of the ECMWF IFS atmospheric model, NEMO/LIM ocean and sea-ice model, a vegetation model and biogeochemistry model.

Met Eireann and ICHEC will carry out EC-Earth CMIP6 ScenarioMIP runs; with RCP 2.6, 4.5, 6 and 8.5, at T255L91-ORCA1L46 (80 km resolution in the atmosphere). CMIP6 also includes

HighResMIP runs, at T511-ORCA025L75 resolution (~39km resolution in the atmosphere). SSP -based RCPs are new CMIP6 versions of the RCPs based on the Shared Socioeconomic Pathways (SSPs; O'Neill et al., 2014). Five new SSPs have been developed to give descriptions of future societal conditions that serve as the basis, both for deriving forcing pathways and for characterizing vulnerability and mitigative capacity important for IAV (impacts, adaptation and vulnerability). EC-Earth data has been downscaled using a range of RCMs, such as RACMO (Lenderink, 2017), COSMO-CLM and WRF (Nolan 2017). To date, HCLIM has been used to downscale ERA-Interim data. It has also been used to downscale EC-Earth datasets, run at 20 km resolution with ALARO, and also at 2km with AROME. This project would downscale the new CMIP6 EC-Earth data using HCLIM.

HCLIM

HCLIM is the climate version of the NWP non-hydrostatic meso-scale HARMONIE model (Bengtsson et al., 2017). The HARMONIE model over Ireland has performed well, and this is promising for using the climate version of HARMONIE for downscaling. Part of this project will assess the quality of HCLIM at the 4km scale to provide insight into the added value of climate simulations in the grey zone near the kilometre scale. Work on this will start in the second half of 2019 (see section 3 timeline).

Cycle 38 is the present stable version used for downscaling, and will be used in this project. Development work on the next version HCLIM, cycle 43, is being carried out. The core of the model is similar to that in NWP mode, with some differences. The surface parametrisation in HARMONIE is taken into account in SURFEX model (Masson et al., 2013). HCLIM has been run with a diffusion scheme as standard soil scheme, for example at KNMI and SMHI. At SMHI, they have used diffusion as the surface model setup at all resolutions and turned on TEB (town energy balance model) for resolutions less than 4 km. The diffusion scheme will be used for these simulations.

In the context of HCLIM ALARO refers to the used physics in an otherwise unchanged non-hydrostatic core. It has generally been recommended not to use HCLIM-ALARO in cy38, because of problems with coupling to the surface model. SMHI, for example, do not use, nor recommend to use it.

HCLIM-ALADIN should generally be used for resolutions greater than 10 km, though some use it even at 5 km. HCLIM has been run with ALADIN and AROME to downscale to 3 km; ALADIN down to 12 km, AROME down to 3 km. In order to downscale global data, it is suggested to use a two stage downscaling. In the first step, EC-Earth 80 km resolution data would be downscaled down to 12 km using ALADIN physics, and in the second step, AROME physics to downscale further. Here it will to run at 4 km resolution and quality of HCLIM at the 4km scale to provide insight into the added value of climate simulations in the grey zone near the kilometre scale.

2. **Simulations**

This project will serve to update the mid-century climate ensemble projections carried out with CMIP5 data (e.g., Nolan, 2017), and to examine local climate change effects. The projections will also be useful for climate services for Ireland, and will be made available to third level institutions, policy makers, researchers and climate services (e.g. ERA4CS).

The domain of the proposed 4-km simulations will include UK and Ireland (see Fig. 2).

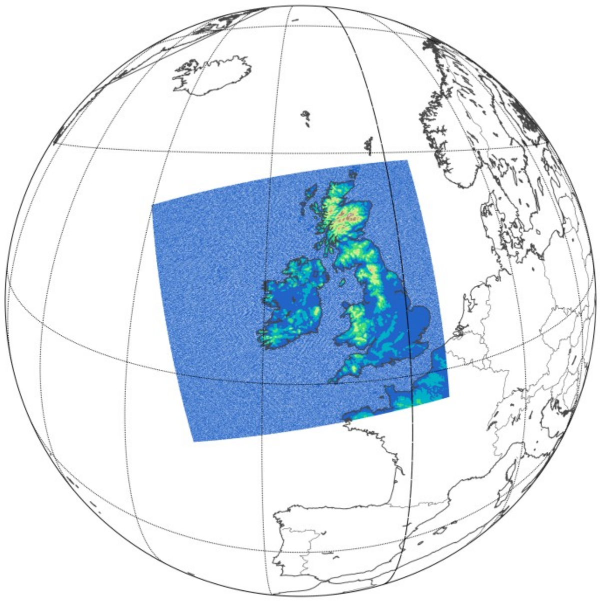

Fig.2 *Ireland HARMONIE domain.*

These simulations will consist of an ERA-5 boundary condition run to validate the present-day climate, a present-day run using Historical EC-Earth data as input, and Future runs using RCP4.5 and RCP8.5 EC-Earth data as input.

In order to run the EC-Earth data simulations, preparations for HCLIM for EC-Earth have been and are taking place. Config files are being adapted. EC-Earth data needs to be compatible with HCLIM; working scripts are used to post process the data to make it compatible with HCLIM. The runs to be carried out are:

Experiment 1: ERA 5
The lateral boundary conditions for HCLIM are taken from ERA 5, 1981-2000. This run will be used to validate the present-day run.

Experiment 2: Present day
Run with as input EC-Earth data over the 1981-2000 20-year reference period, from the historical EC-Earth run. This run will be used for comparison with the future runs.

Experiment 3: Future 21st century
Two future (2015-2100) HCLIM runs will be carried out at RCP4.5 and RCP8.5.

2. 1 Validation
Experiment 1 will be validated against the gridded E-OBS observation dataset. Downscaled ERA5 will be compared to E-OBS temperature data. Experiment 2 will be validated with respect to the ERA5 run. Once experiments 1 and 2 are validated, mid- 21st century HCLIM runs will be carried out (exp 3).

3. **Timeline**

Work on this project was expected to start in 2019. As the EC-Earth simulations have been delayed to later than previously thought, however, I have focused on preparing for this up to now (monitoring, cmorisation...). It is thus expected the HCLIM work will commence over the summer, and continue in the latter half of this year and 2020; I will focus on the HCLIM work then.

As was suggested by the reviewers, it is proposed to first simulate Exp1 and 2 and make availability of the resources for Exp 3 dependent on explicit expectations and evaluations of these experiments.

4. **Justification of computational resources**

HCLIM will be used to downscale EC-Earth CMIP6 data. CMIP6 simulations have been delayed until June, later than previously thought, due to issues with the latest version of EC-Earth. In light of this in 2019 I have thus been working on EC-Earth, analysing EC-Earth data for validation & preparing (monitoring, cmorisation) the global data for downscaling with HCLIM.

I am keeping my account SBUs for the HCLIM work which will commence over the summer, and continue in the latter half of this year and 2020. I will focus on the HCLIM work then.

Experiments 1 and 2 will be performed in the second half of 2019, and it is envisaged that experiment 3 to start end 2019 or start 2020. Once Experiments 1 and 2 are carried out, an update will be made regarding the availability of the resources for Exp 3 in 2020.

A model run on an Ireland domain at 2.5 km resolution costs ~ 70 kSBU per month. This results in ~ 5 MSBU for 20 years at 4 km resolution, ~ 9 MSBU for 34 years, and ~ 23 MSBU per 85 year run.

The corresponding amount of output data is 15 TB

	Description	Simulation yrs.	Total SBUs	Total Archive
Experiment 1 (2019-20) ***	ERA-5	20	5 million	5 TB
Experiment 2 (2019-20) ***	Present day	34	9 million	10 TB
Experiment 3 (2020)	Future	170	46 million	30 TB
Total			60 million	45 TB

*** Once Exp 1 and 2 are carried out, an update will be made regarding the availability of the resources for Exp 3 in 2020

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