REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Ireland

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Project Title: Investigation of the impact of the different parametrizations on the fog development in HARMONIE-AROME for NWP forecasting for Ireland

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.)	2021	
Would you accept support for 1 year only, if necessary?	YES X	NO ☐

Computer resources required for 2021-2023: (To make changes to an existing project please submit an amended version of the original form.)		**2021**	**2022**	**2023**
High Performance Computing Facility	(SBU)	9M		
Accumulated data storage (total archive volume)[2]	(GB)	10		

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

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.

1. Background

Fog is a boundary layer phenomenon which can have a strong impact on aviation, land and marine transportation (Pagowski et al. 2004). Because of a large number of processes that influence fog dynamics (including the turbulence, microphysics, radiation and surface fluxes), fog formation and evolution is still not well understood (Gultepe et al. 2007). Therefore, more research and testing of various parametrizations is needed to get a better understanding of the physics of fog, which may lead to improvements in fog forecasts.

Recently, the European Numerical Weather Prediction (NWP) community has begun progressively focusing on improving fog forecasts in the HARMONIE-AROME model (Bengtsson et al. 2017) since it became a noticeable issue for many countries. The countries that are mostly affected are the northern countries, where fog occurs more frequently (i.e. Netherlands, Denmark, Ireland, Finland, Sweden, Norway).

For instance, it has been recently shown by the Royal Netherlands Meteorological Institute (KNMI) that the decrease in the coefficient used in the emissivity calculation (introduced by Stephens (1978) and used in the radiation scheme of the HARMONIE-AROME model) reduces the long wave cooling of fog (personal communication). In addition, the study by KNMI has also shown that the cloud droplet number concentration has a significant impact on the development and evolution of fog. Decreasing the cloud droplet number concentration improves the visibility forecasts. Furthermore, the impact of Richardson's coefficient on surface fluxes, hence on fog, has been recently studied by the HIRLAM and ALADIN consortia. Although many tests have been already performed, the choice of the coefficient seems to impact model domains in different ways. Therefore, more testing specific to the Irish domain has to be performed.

An aspect that also has to be considered when aiming for an improvement in the fog forecasts, is the fact that the visibility parametrization in the HARMONIE-AROME model is based on Kunkel relation (Kunkel 1984). The Kunkel relation is a power-law relationship between Liquid Water

Content of fog and its associated extinction coefficient, but has no information on the droplet size distribution. However, the study by Gultepe et al. 2006 showed that visibility forecasts are improved when the droplet number concentration is included in the visibility calculation.

The Irish Meteorological Service, Met Éireann, is currently using cycle 40 of the HARMONIE-AROME model. In this cycle an improved turbulence scheme, HARATU (Bengtsson et al. 2017), was introduced in order to improve the fog and low level clouds forecasts. Although it improved the wind speed and cloud cover forecasts, fog and low level clouds were still significantly overpredicted.

In cycle 43, many changes were introduced, also for testing purposes, (including changes to roughness parameter, Richardson coefficient and cloud droplet number condensation) which caused a significant reduction of fog in many cases. However, in some cases it also led to underprediction of fog. This shows that the understanding of the physics of fog is still incomplete. Therefore, research and model development is needed for better fog forecasts.

In cycle 46, an improved microphysics scheme, LIMA (Bengtsson et al. 2017), is going to be introduced. It includes a prognostic variable for the droplet number concentration, which is an important parameter in fog evolution. It decreases the amount of cloud water and hence may lead to an improvement in fog forecasts. Lowering the cloud droplet number concentration showed to improve the current operational model forecast. In general, a significant difference was noted between the land and sea fog forecasts and therefore more investigation is needed to understand the impact of the cloud droplet number concentration and other parameters on the model performance.

2. Scientific Plan and Computer Resources

The HARMONIE-AROME model is a configuration of the ALADIN-HIRLAM (High Resolution Limited Area Model - Aire Limitee Adaptation Dynamique Developpement International) NWP system (Bengtsson et al. 2017). In the configuration used in the Irish Meteorologica Service, Met Éireann, ALADIN non-hydrostatic dynamics (Benard et al. 2010), non-hydrostatic mesoscale (MesoNH) physics (Lafore et al. 1998) and the SURFEX (Surface Externalisee) externalised surface scheme (Masson et al. 2013) are used. In this work, cycle 43 of the HARMONIE-AROME model is going to be utilised in order to better understand and improve the fog forecasts in the Irish domain. The work will involve running sensitivity tests by making changes to various parametrizations.

The operational domain for Ireland covers an area of 1000 x 900 points (Fig.1, orange domain) with a horizontal grid spacing of 2.5 km and 65 vertical levels. Running this domain for one 24-hour forecast cycle costs approximately 13000 SBUs. Our previous operational domain (Fig.1, red domain) covered an area of 500 x 540 grid points. Running this domain for one 24-hour forecast cycle cost approximately 4000 SBUs.

The requested resource of 9MSBUs will be spent as follows:

1. Run a set of few days long control experiments (using smaller domain) for the past winter and summer months, in order to simulate fog development under different conditions (including the sea fog). SBU cost: ~ 1MSBU.

2. Run sensitivity experiments that will assist in tuning of various parametrizations (e.g. changes made to CCNs, Richardson coefficient, roughness length, visibility parametrization and vertical

resolution). Sensitivity tests will also be carried out using 1-D experiments to support the analysis of the impact of different parametrization schemes on the development and evolution of fog. SBU cost: ~ 5MSBU.

3. Run some experiments using a large model domain for comparison purposes. SBU cost: ~ 3MSBU.

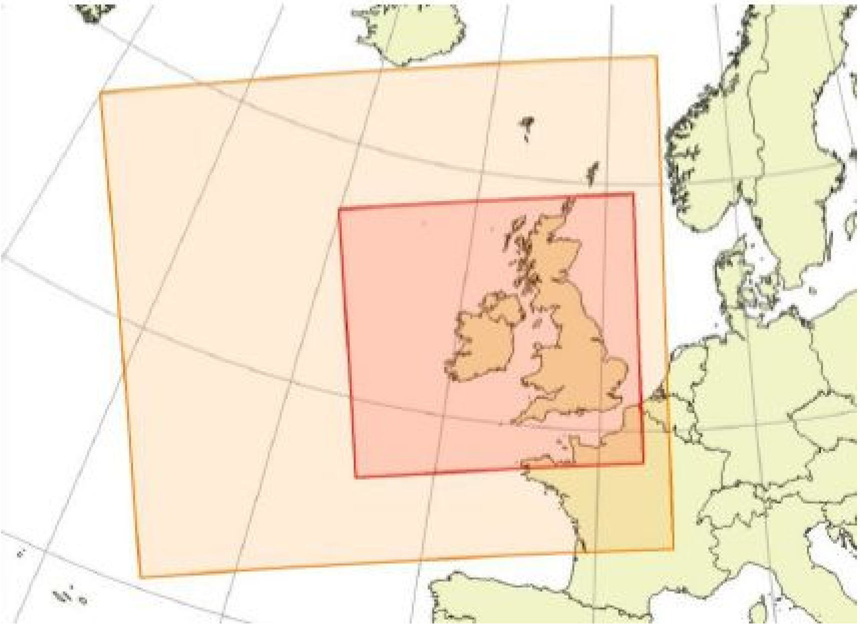

Fig 1. Irish operational domain in orange, old operational domain in red.

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