REQUEST FOR A SPECIAL PROJECT 2021–2023

(request for extension of existing project)

MEMBER STATE: Ireland

Principal Investigator[1]: Ewa McAufield / Emily Gleeson

Affiliation: Met Éireann

Address: 65/67 Glasnevin Hill
Dublin 9
D09 Y921

Other researchers: Colm Clancy
Fog machine learning postdoctoral fellow

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** IEMCAU	
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 (A ONE YEAR EXTENSION)	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	35M	
Accumulated data storage (total archive volume)[2]	(GB)	10	(will use national allocation)	

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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** Project Extension Request **

On March 23rd of this year Met Éireann upgraded its operational NWP suite to cycle 43 of HARMONIE-AROME and now uses a consistent value of 50 per cm^3 everywhere for the cloud droplet number concentration (CDCN) used in the microphysics calculations. Use of this lower value, in contrast to pervious defaults of 500/300/100 for urban, land and sea CDCNs, is the first step that we have taken in order to alleviate the issues we have been having with the prediction of fog.

We have already almost exhausted the 9.9 M SBUs we applied for 2021. These were used to run a comprehensive suite of physics tests (across 4 seasons – 4 x 2-week periods, each of which included some foggy cases) and 9 fog-specific case studies. An extensive progress report has been submitted on this. Longer runs for each season were carried out because we needed to be sure of the full impacts of any physics settings we tested to alleviate fog. The main physics-related parameters considered in relation to fog were: XRIMAX – the maximum Richardson number, RSMIN – the minimal stomatal resistance, RFRMIN(10) – control of precipitation release from the Kogan scheme, VSIGQSAT – saturation at lower levels, a new longwave cloud liquid optical property scheme by Kristian Pagh Nielsen (KPN) combined with consistent use of CDCNs in radiation and microphysics.

For most of the fog cases the use of a positive value for XRIMAX (which is also a physically better option than the unphysical use of XRIMAX=0 which is the current default) and the use of the KPN scheme and changes, provided the most benefit. However, one drawback of the KPN scheme is that it yields positive biases in near-surface temperatures in Summer in particular due to the fact that it makes clouds too transparent. This is as a result of lowering the CDCNs in the radiation scheme to the same value as used in microphysics (50 per cm^3).

We have run in excess of 100 tests using both this special project and SPIEGLEE (surface testing) which has really helped in our understanding of fog in HARMONIE-AROME. The model will soon be upgraded to include a positive value for XRIMAX. Work is still on-going on the CDCNs. We will soon test a profile for the CDCNs ranging from 50 per cm^3 near the surface (so that we get the benefits for fog) to 200 or 250 per cm^3 higher in the atmosphere to aid the transparency of clouds and need to decide whether to also use this profile in the radiation calculations.

While the above settings alleviate the problems with fog, there are still issues and a lot more testing is required to understand the problem further. There is a positive bias in dew point temperature and humidity over Ireland in Spring and Summer, most likely due to evaporation. This issue needs to be studied in detail and will have knock-on effects on any settings used for fog. Such investigations will be carried out in the extension of this project. In addition, testing has commenced with cycle 46 of HARMONIE-AROME which contains the more advanced LIMA scheme and the ECRAD radiation scheme and the fog cases studies will be thoroughly tested using this version of the model also. There are many other testing options available for microphysics that we did not yet get to trial and would like to do this testing for our suite of fog cases. Another bonus of cycle 46 is that work is on-going on interfacing it with near-real time CAMS aerosols. Tests using the near-real time aerosols will be carried out in relation to our fog cases as well as an investigation into the role of vertical resolution. Finally, we will have a postdoctoral researcher working with us on applying machine learning to fog prediction at airports. Machine learning can be used to improve the parametrizations used in the model and findings relevant to fog will be tested in this project extension also.

As Ireland is a member of United Weather Centres West (UWC-West) for operational weather forecasts, fog cases in other parts of our future domain (Denmark, the Netherlands, Iceland) will also be evaluated in this project.

- Note that the remainder of this document contains the original project proposal.

Extended abstract

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 Meteorological 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.

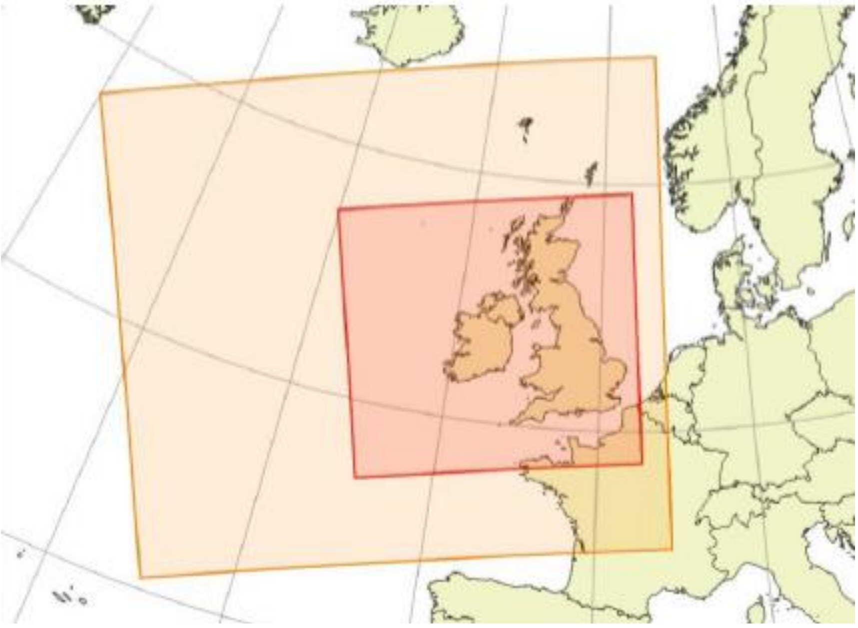

Fig 1. Irish operational domain in orange, old operational domain in red.

References

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