REQUEST FOR A SPECIAL PROJECT 2021–2023

MEMBER STATE: Ireland

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Project Title:
An Evaluation of the use of Near Real-time CAMS Aerosols in the HARMONIE-AROME NWP model over 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)	9.9 M		
Accumulated data storage (total archive volume)[2]	(GB)	10 TB		

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

1. Background

The shared ALADIN-HIRLAM numerical weather prediction system is used for operational weather forecasting by 26 national meteorological services in Europe and North Africa which form the HIRLAM (High Resolution Limited Area Model) and ALADIN (Aire Limitee Adaptation Dynamique Developpement International) consortia. The Irish Meteorological Service, Met Éireann, is one of the 26 members and has been using the HARMONIE-AROME canonical configuration of this system since 2011. We currently use cycle 40 of the system operationally (Bengtsson et al, 2017) with a set-up using a 1000 x 900 horizontal grid on a Lambert Conformal projection with 2.5 km spacing at the centre and 65 vertical levels. Further details about Met Éireann's implementation of cycle 40 are available in Clancy et al., 2018.

Cycle 43 of HARMONIE-AROME will be released in the coming months. This version uses version 8 of SURFEX (Le Moigne et al., 2018) containing more advanced surface physics schemes such as the 14-layer diffusion soil scheme, a multi-layer explicit snow scheme (Boone, 2000; Boone and Etchevers, 2001) and the ISBA Mutli-Energy-Budget Explicit Vegetation Scheme (Boone et al., 2017; Napoly et al., 2017), though these will not be implemented operationally in the first release. Another development within cycle 43 has been the testing of use of near real-time Copernicus Atmospheric Monitoring Service (CAMS) aerosols (Rontu et al., 2020) within HARMONIE-AROME. This implementation work, in various guises, has been carried out by researchers at the Finnish Meteorological Institute (FMI) and La Agencia Estatal de Meteorología (AEMET) (Rontu et al., 2020) where near real-time aerosols have been interfaced to the ICE3 microphysics scheme and the HLRADIA broadband radiation scheme. Mass mixing ratios of the aerosols are to determine optical properties for use in the radiation scheme and cloud condensation nuclei (CCN) and ice-forming nuclei (IFN) for the microphysics scheme.

The focus of this special project will be primarily on testing various implementations of near real-time CAMS aerosols in experiments under varying meteorological conditions over Ireland to investigate the impact. Aerosols are responsible for multiple direct, indirect and semi-direct effects on the radiative properties of the Earth’s atmosphere. The direct effects are related to how aerosols absorb and scatter shortwave and longwave radiation. The indirect effects of aerosols include their impact on cloud microphysics and involves changes in clouds radiative properties, their frequency and lifetimes. Aerosols act as cloud condensation nuclei so for example, more aerosols lead to clouds with a higher number of small water droplets than clouds formed in cleaner areas. Such clouds have a higher albedo; this effect is considered to be the first indirect effect of aerosols or the Twomey effect. The effect of aerosols on cloud height, lifetime and content is often referred to the second indirect effect while the effects induced by heating as a result of the absorption of solar energy by aerosols is considered to be a semi-direct effect.

An experimental version of HARMONIE-AROME contains three radiation schemes (an old IFS scheme from cy25r1 (ECMWF, 2015), ACRANEB2 by ALARO (Mašek et al., 2016; Geleyn et al., 2017) and HLRADIA from the HIRLAM model (Savijärvi et al., 1990; Rontu et al., 2017)). Currently, the CAMS near real-time aerosols have been interfaced to both HLRADIA and the ICE3 microphysics scheme in HARMONIE-AROME but interfacing them with the remaining two radiation schemes is a source of future work; such implementations will be tested during the course of the work to be carried out under this special project. It is important to note that the radiation scheme can operate with either an aerosol climatology (such as the default Tegen or newer CAMS climatology) or near real-time aerosols whereas the ICE3 microphysics scheme requires near real-time aerosols which are then advected (in the default version of the scheme land, urban and sea cloud condensation nuclei (CCN) concentrations are hardcoded as constants).

Currently, the Irish operational NWP domain exhibits large negative biases in shortwave (SW) irradiance due to the over-prediction of cloud condensate. Part of the reason for this over-prediction is that the CCNs are fixed within the model, rather than being a prognostic variable like in the more advance LIMA scheme, which will be available in cycle 46. The use of CAMS aerosols should alleviate this problem to some extent. In addition, the Irish domain suffers from negative shortwave irradiance biases on clear-sky days. This is also considered to be due to an over-estimation of aerosols in the Tegen aerosol climatology (Tegen et al., 1997) currently used in the model. As well as the biases in SW irradiance, the use of CAMS aerosols will also be tested using fog cases. In general HARMONIE-AROME has a problem regarding the over-prediction fog; this is also strongly related to the hardcoded constant values of cloud droplet number concentration.

2. SBU Justification for Various Experiments

The operational domain for Ireland covers an area of 1000 x 900 points (figure 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 (Figure 1, red domain) covered an area of 500 x 540 grid points. Running this domain for one 24-hour forecast cycle costs approximately 4000 SBUs.

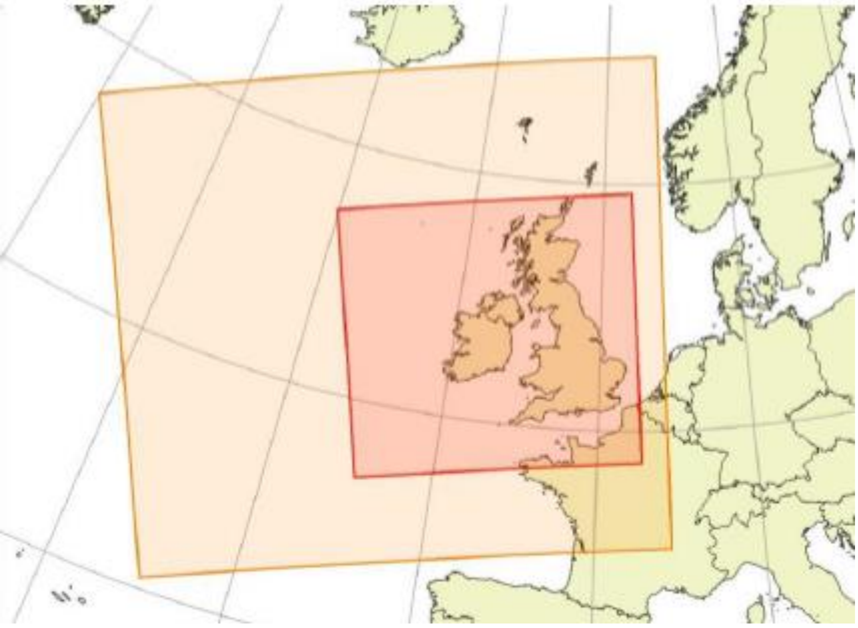

Fig 1. Irish operational domain in orange, old operational domain in red.

The requested resource of 9.9 MSBUs will be spent as follows:

- Systematic testing of a series of clear-sky, thick frontal cloud and fog cases using CAMS aerosols compared to the reference Tegen dataset. SBU cost (using the smaller domain) ~ 3M SBUs.

- Four month-long (all seasons) experiments using HARMONIE-AROME cycle 43 with CAMS aerosols implemented in the HLRADIA radiation scheme and also 4 month-long reference experiments with HLRADIA for comparison. SBU cost (using the smaller domain) ~ 3M SBUs.

- Similar experiments to the above but using the ACRANEB2 radiation scheme. This is a broadband scheme, like HLRADIA, but is much more advanced particularly in its treatment of clouds and gases etc. SBU cost (using the smaller domain) ~ 3M SBUs.

- Prior to testing with ACRANEB2, CAMS near real-time aerosols will need to be implemented in the scheme. This will require a series of tests, of shorter length. SBU cost (using the smaller domain) ~ 0.9 SBUs.

3. Benefits of the Project

The use of near real-time, rather than climatological, aerosols has already shown to be of benefit, particularly in cases where aerosol pollution is high (e.g. Gleeson et al., 2016). An example of the benefits of using near real-time aerosols is shown in Figures 2 and 3. In figure 2 the peak at the high end of the histogram of CSIs (clear sky index) shows better agreement with observations when realistic aerosols are used. This is complemented by the increase in SW irradiance as shown in Figure 3 which helps alleviate the known negative bias in SW irradiance over Ireland.

This area of work, i.e. use of realistic aerosols in the radiation and microphysics parametrizations and in making the schemes consistent in that regard, is a high priority on the joint ALADIN-HIRLAM workplan for 2021. A thorough analysis of the benefits of using near real-aerosols under a range of meteorological conditions is needed and this special project will enable an evaluation to be done over the Irish domain.

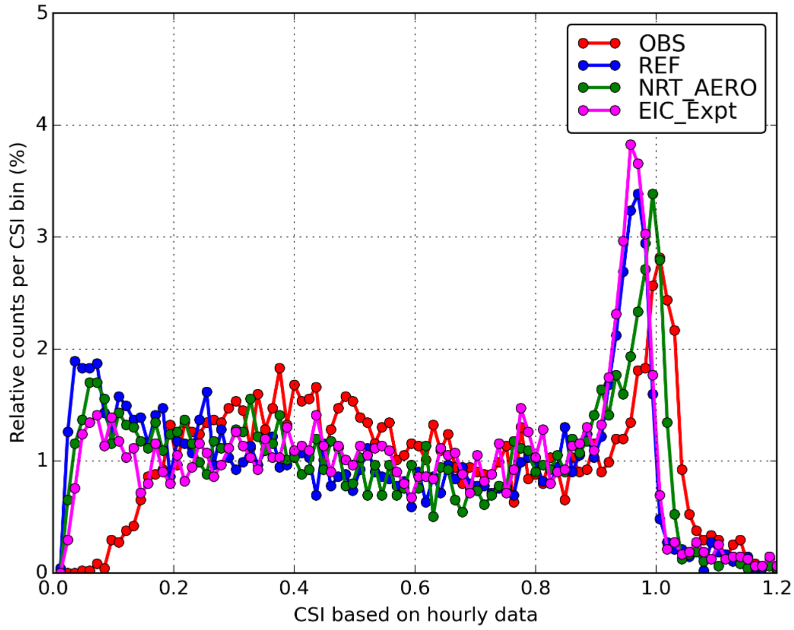

Fig 2. Histograms of clear sky index (SW irradiance divided by clear-sky SW irradiance) based on observation data in Ireland (red), a reference HARMONIE-AROME cycle 43 experiment (blue), a HARMONIE-AROME cycle 43 experiment with near real-time CAMS aerosols (green) and an experiment using 50 rather than 100 CCNs/cm^3 for land aerosols in ICE3 (magenta).

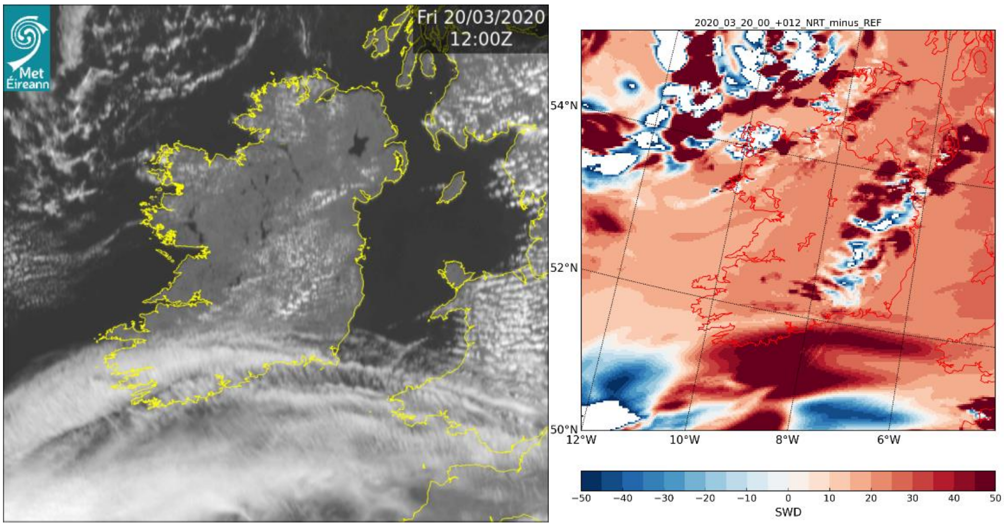

Fig 3. MSG visible satellite image over Ireland at 12 Z on the 20th March 2020. The corresponding increase in SW irradiance over Ireland when near real-time CAMS aerosols were used in place of the Tegen climatology for the radiation calculations and were also interfaced to the ICE3 microphysics scheme. In practical terms, in the radiation scheme the Tegen AOD550nm climatology was replaced with corresponding CAMS near real-time values. In this case, the increase in SW under clear skies can be seen in the right-hand image.

4. References

Bengtsson, L., U. Andrae, T. Aspelien, Y. Batrak, J. Calvo, W. de Rooy, E. Gleeson, B. Hansen-Sass, M. Homleid, M. Hortal, K. Ivarsson, G. Lenderink, S. Niemelä, K.P. Nielsen, J. Onvlee, L. Rontu, P. Samuelsson, D.S. Muñoz, A. Subias, S. Tijm, V. Toll, X. Yang, and M.Ø. Køltzow, 2017: The HARMONIE–AROME Model Configuration in the ALADIN–HIRLAM NWP System. Mon. Wea. Rev., 145, 1919–1935, https://doi.org/10.1175/MWR-D-16-0417.1

Boone, A., Modelisation des processus hydrologiques dans le schema de surface ISBA: Inclusion d’un reservoir hydrologique, du gel et modelisation de la neige. PhD thesis, University Paul Sabatier, Toulouse, France, 2000.

Boone, A. and P. Etchevers. An intercomparison of three snow schemes of varying complexity coupled to the same land surface model: Local-scale evaluation at an alpine site. J. Hydrometeorol., 2(4):374–394, 2001.

Boone, A., P. Samuelsson, S. Gollvik, A. Napoly, L. Jarlan, E. Brun, and B. Decharme. The interactions between soil-biosphere-atmosphere (isba) land surface model multi-energy balance (meb) option in surfex - part 1: Model description. Geosci. Model Dev., 30:1–30, 2017.

Clancy, C., Darcy, R., Gleeson, E., Hally, A. and Whelan, E., 2018. HARMONIE-AROME 40h1.1 Upgrade. Technical Note No. 66, Met Éireann. http://edepositireland.ie/handle/2262/86034

ECMWF. IFS Documentation, Chapter 2, 2015. Available online: http://www.ecmwf.int/sites/default/files/elibrary/2015/9211-part-iv-physical-processes.pdf

Geleyn, J.F.; Mašek, J.; Brožková, R.; Kuma, P.; Degrauwe, D.; Hello, G.; Pristov, N. Single interval longwave radiation scheme based on the net exchanged rate decomposition with bracketing. Q. J. R. Meteorol. Soc. 2017.

Gleeson, E.; Toll, V.; Nielsen, K.P.; Rontu, L.; Mašek, J. Effects of aerosols on clear-sky solar radiation in the ALADIN-HIRLAM NWP system, Atmos. Chem. Phys. 2016, 16, 5933–5948.

Le Moigne, P., and Coauthors, 2013: SURFEX (8.1) Scientific Documentation, 2018. Masson, V., and Coauthors, 2013: The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes. Geosci. Model Dev., 6 (4), 929–960, doi:10.5194/gmd-6-929-2013.

Mašek, J.; Geleyn, J.F.; Brožková, R.; Giot, O.; Achom, H.O.; Kuma, P. Single interval shortwave radiation scheme with parameterized optical saturation and spectral overlaps. Q. J. R. Meteorol. Soc. 2016, 142, 304–326.

Napoly, A., A. Boone, P. Samuelsson, S. Gollvik, E. Martin, R. Seferian, D. Carrer, B. Decharme, and L. Jarlan. The interactions between soil-biosphere-atmosphere (isba) land surface model multi-energy balance (meb) option in surfex - part 2: Model evaluation for local scale forest sites, 2017.

Rontu, L.; Gleeson, E.; Räisänen, P.; Nielsen, K.P.; Savijärvi, H.; Sass, B.H. The HIRLAM fast radiation scheme for mesoscale numerical weather prediction models. Adv. Sci. Res 2017, 14, 195–215.

Rontu, L.; Gleeson, E.; Martin Perez, D.; Pagh Nielsen, K.; Toll, V. Sensitivity of Radiative Fluxes to Aerosols in the ALADIN-HIRLAM Numerical Weather Prediction System. Atmosphere 2020, 11, 205.

Savijärvi, H. Fast Radiation Parameterization Schemes for Mesoscale and Short-Range Forecast Models, J. Appl. Meteorol. 1990, 29, 437–447.

Tegen, I.; Hoorig, P., Chin, M.; Fung, I.; Jacob, D.; Penner, J. Contribution of different aerosol species to the global aerosol extinction optical thickness: Estimates from model results. J. Geophys. Res. 1997, 102, 23895–23915.