SPECIAL PROJECT PROGRESS REPORT

All the following mandatory information needs to be provided. The length should *reflect the complexity and duration* of the project.

Reporting year	2023
Project Title:	An evaluation of the advanced model physics in cycle 46/49 of HARMONIE-AROME
Computer Project Account:	SPIEGLEE
Principal Investigator(s):	Emily Gleeson
Affiliation:	Met Éireann
Name of ECMWF scientist(s) collaborating to the project (if applicable)	………………………………………………………….…… ………………………………………………………….……
Start date of the project:	2022
Expected end date:	2024

Computer resources allocated/used for the current year and the previous one

(if applicable)
Please answer for all project resources

		Previous year		**Current year**	
		Allocated	Used	Allocated	Used
High Performance Computing Facility	(units)	35M	35M	35M	1.6M
Data storage capacity	(Gbytes)	Used local	Used local	Using local	Using local

Summary of project objectives (10 lines max)

An evaluation of the advanced model physics in cycle 46/48 of HARMONIE-AROME with particular emphasis on the new microphysics, radiation and surface schemes.

Summary of problems encountered (10 lines max)

As is often the case in modelling, delays were encountered with model versions so that the nature of the testing has also changed from what I had originally planned to do.
For example, we still do not yet have a CY49 HARMONIE-AROME flavour of the modelling system and the versions of ecRad (radiation) and LIMA (microphysics) within CY46 are incomplete and cannot be used. The tests done in 2023 focussed on aerosol options and scale aware shallow convection.

Summary of plans for the continuation of the project (10 lines max)

I still have the bulk of the SBUs to use this year. My plan is to test CY46 options for operational use in the United Weather Centres West operational set-up. I plan to thoroughly test the aerosol configurations, options for fog/visibility forecasting and the use of the ICE-T microphysics scheme, which shows improvements in forecasting supercooled liquid.

List of publications/reports from the project with complete references

Martín Pérez, D.; Gleeson, E.; Maalampi, P.; Rontu, L. Use of CAMS near Real-Time Aerosols in the HARMONIE-AROME NWP Model. Meteorology 2024, 3, 161-190. https://doi.org/10.3390/meteorology3020008.

Emily Gleeson, Ekaterina Kurzeneva, Wim de Rooy et al., The Cycle 46 Configuration of the HARMONIE-AROME Forecast Model, ready to be submitted to Meteorology as a Technical Note.

Summary of results

Here I will focus on the results obtained during 2023 using the SBUs of this special project, mainly focussing on 1) aerosol testing and 2) scale aware shallow convection testing.

Aerosols:

Information on the aerosol options currently available in version of CY46 of HARMONIE-AROME is provided in the publications listed in the previous section. These options can be summarised as follows:

1) The Tegen aerosol climatology
2) CAMS near real-time (NRT) aerosols
3) The CAMS aerosol climatology

The Tegen climatology used by default in the radiation scheme in CY46 consists of vertically integrated aerosol optical depths (AOD) of land, sea, desert, and urban tropospheric aerosols at a wavelength of 550nm (AOD550), along with prescribed constant background tropospheric and stratospheric aerosols. A constant prescribed vertical profile of cloud droplet number concentration (CDNC) is used to calculate the cloud liquid droplet effective radius for the radiation scheme and is also used in the cloud microphysics.

Regarding CAMS near real-time aerosols, three-dimensional NRT aerosol mass mixing ratio (MMR) fields are introduced via the first guess and lateral boundary conditions (LBC) of the model, and advected by the model dynamics. 14 aerosol species are included: 3 sea salt species (fine, jet and spume drop modes), 3 desert dust (fine, coarse and supercoarse) 2 organic matter (hydrophilic and hydrophobic), 2 black carbon (hydrophilic and hydrophobic), one Sulfate, 2 Nitrate (fine and coarse mode) and Ammonium. For consistency three-dimensional AOD550 fields are obtained for the radiation calculations from the NRT aerosol MMR fields using the mass extinction (ME) coefficients. The AOD550s are grouped into the same general categories as the Tegen species, to enable these to be readily used by the radiation scheme.

The third option is to use the CAMS aerosol climatology where climatological MMRs of 11 aerosol species are converted to the Tegen AOD550s for the radiation scheme and are used directly by the microphysics scheme. This has an advantage over the Tegen climatology in that the climatology is more up-to-date and representative and also that the climatology is used consistently in the radiation and microphysics.

Using the SBUs in this special project several technical tests were firstly run. Following these, experiments for 2-week periods (and a 5 day spin-up) were run for each of the four seasons. The domain used is the inner domain shown in Figure 1. The results of these experiments can be conveniently shown using an index known as the clear sky index (CSI), which is the global shortwave (SW) radiation divided by the clear-sky global shortwave radiation. For this purpose, station data for 20 sites around Ireland were used and the model data for the corresponding locations extracted. By default, clear sky fluxes are not output by the model and therefore an old Fortran route from HIRLAM was used for this purpose, where constant coefficients were used to account for aerosols and integrated water vapour – of course this can and will be improved upon. Sample CSI plots are shown in Figure 2, where lower values of the index are consistent with thick clouds and high values with clearer skies or thin Cirrus cloud.

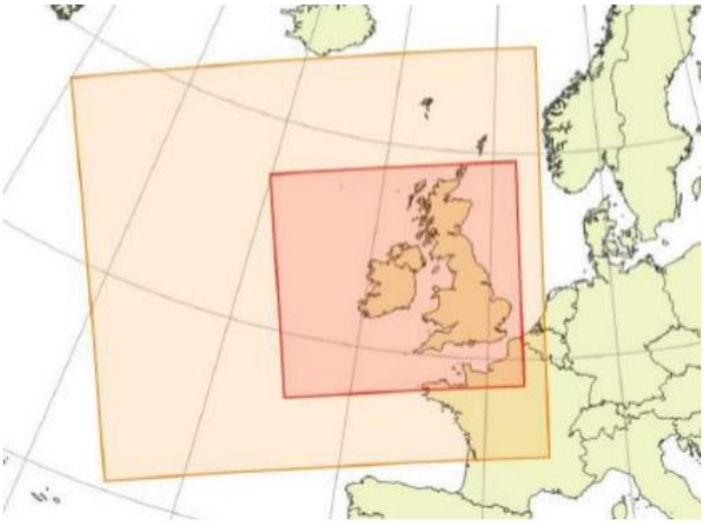

Figure 1. 2 old Irish operational domains in orange and red – the smaller red domain was used for my experiments.

Histograms of hourly averaged CSI are shown in Figure 2 for the (left) Summer period (June 1-14th 2018) and (right) Winter period (February 3-17th 2020). Observations and model data for 20 sites around Ireland are included in the calculation. In the figure CAMSMMR refers to the CAMS climatology. It can clearly be seen that the Tegen climatology is deficient at low CSI where we have seen that the lowest, thickest clouds contain too much cloud water compared to the MGS Seviri cloud water path for example. Low CSI are much better represented when the CAMS climatology is used – most of this improvement comes from the fact that the aerosol MMRs were used in the ICE3 microphysics scheme, instead of the constant vertical profiles assumed by default. Improvements are also shown for high CSI, especially evident in the Summer period shown in Figure 2. This is further shown in Figure 3 where the headline score of bias and standard deviation in T2m and low cloud are shown for the 00 Z runs using station data over the entire domain (top Summer, bottom Winter). The impact on cloud is showing up in the low cloud figure (lower bias when NRT aerosols are used), with the corresponding impact on T2m also evident (reduced negative bias).

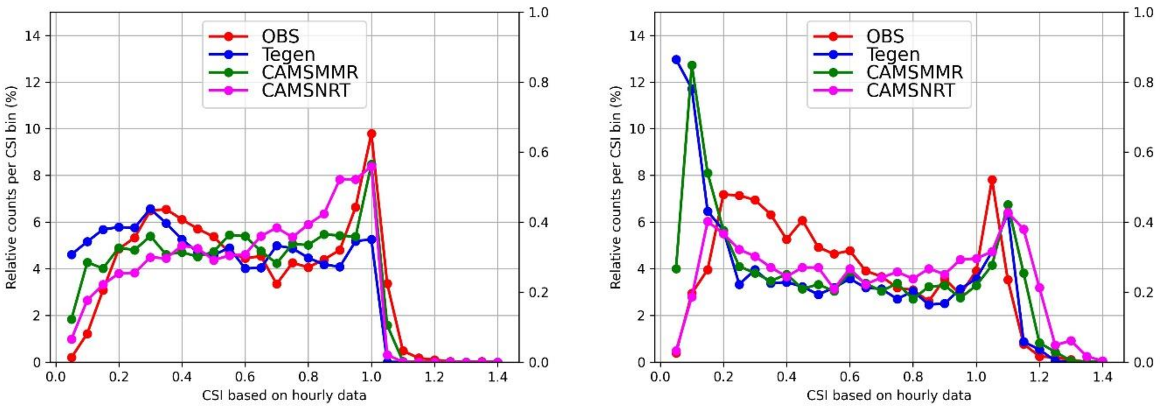

Figure 2. Histograms of hourly averaged CSI for the (left) Summer period (June 1-14th 2018) and (right) Winter period (February 3-17th 2020). Observations and model data for 20 sites around Ireland are included in the calculation.

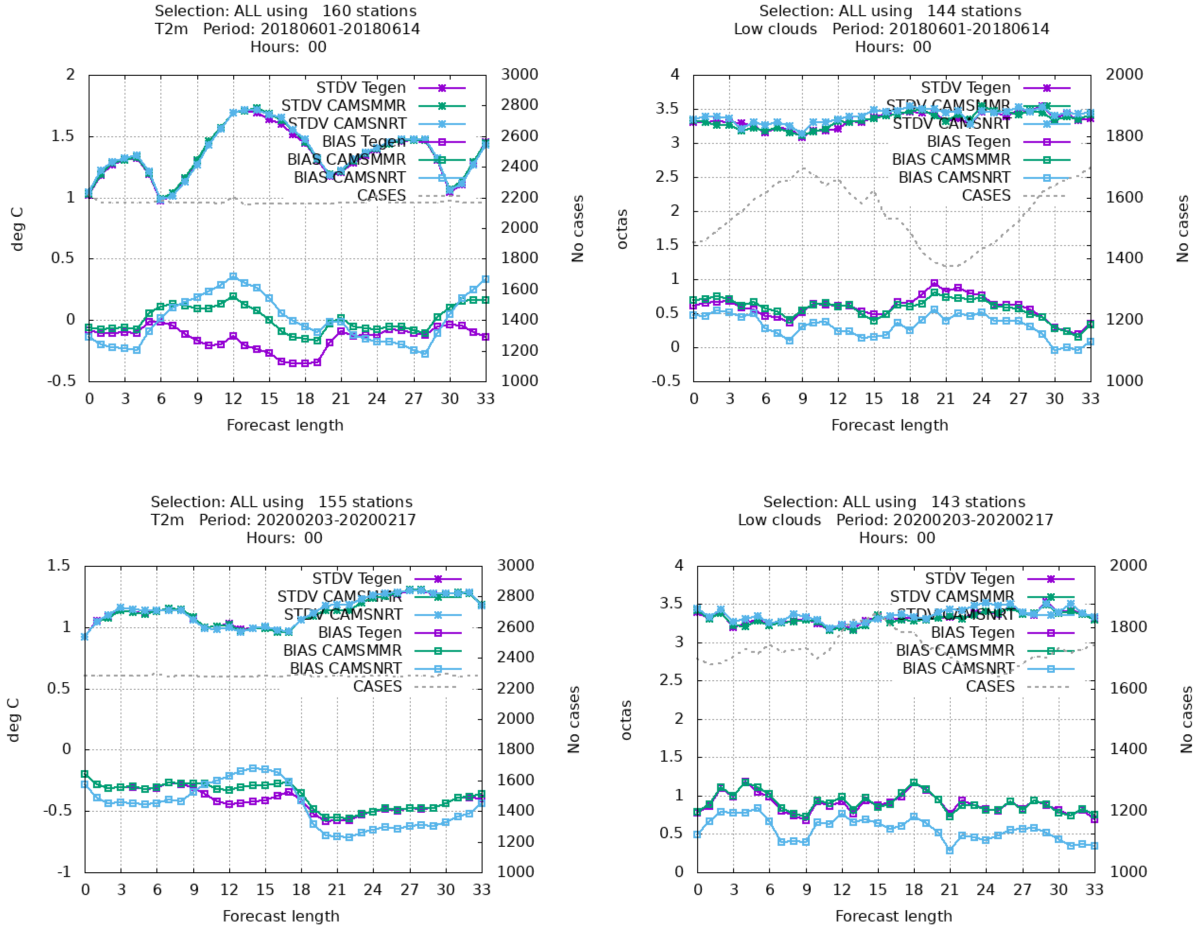

Figure 3. Bias and standard deviation in T2m and low cloud cover for (top) Summer period and (bottom) Winter period. Only data from the 00Z runs are included in order to highlight the impact on daytime temperatures for example. The bias in low cloud is clear better when NRT aerosols are employed.

Shallow Convection:

The next suite of tests that the SBUs were used for concerned experimenting with options in the shallow convection scheme, in particular testing on options that could be used to make the scheme scale aware. The following options were tested:

1) Shallow Convection (mass-flux scheme) on
2) Shallow Convection (mass-flux scheme) off
3) A scale-aware option developed by Rachel Honnert, Météo France.
4) A more advanced scale-aware option based on the vertical velocity threshold (moist updraft) i.e. the shallow convection scheme is switched off once the model starts to build it for itself, based on a threshold for the vertical velocity. The mass flux shallow convection scheme in HARMONIE-AROME has both dry and moist updrafts, which enables the threshold to applied to only the moist for example.

In particular, the following 5 permutations were tested at 2.5km and 750m grid spacing. Note that the 750m simulations used 90 as opposed to 65 vertical levels so the comparisons made are not only with respect to horizontal resolution. In the permutations SC = shallow convection, SA = scale aware and Wopt is the SA option based on the moist updraft.

1) Wopt = F, SC = T, SA = F

2) Wopt = F, SC = F, SA = F
3) Wopt = F, SC = T, SA = T
4) Wopt = T, SC = T, SA = F
5) Wopt = T, SC = T, SA = T

Sample headline scores are shown in Figure 4, but further details are not included here as a paper will be published by Wim de Rooy et al. firstly and additional results will therefore be included in my final report for this special project. There is a lack of non-local mixing in the sub cloud layer with the simple w threshold option and more work will be done on this.

Sample results for 2.5km vs 750m grid spacing can be viewed at:
https://emilygleesonmeteireann.github.io//SUMMER_2500v750_DEFAULT/ (just SC on)
https://emilygleesonmeteireann.github.io///SUMMER_2500v750_WOPTMOIST/ (W threshold moist)
https://emilygleesonmeteireann.github.io/SUMMER_2500v750_NoWOPTNoSC/ (no SC or W threshold)
https://emilygleesonmeteireann.github.io/SUMMER_2500v750_WOPT/ (W threshold not just moist)

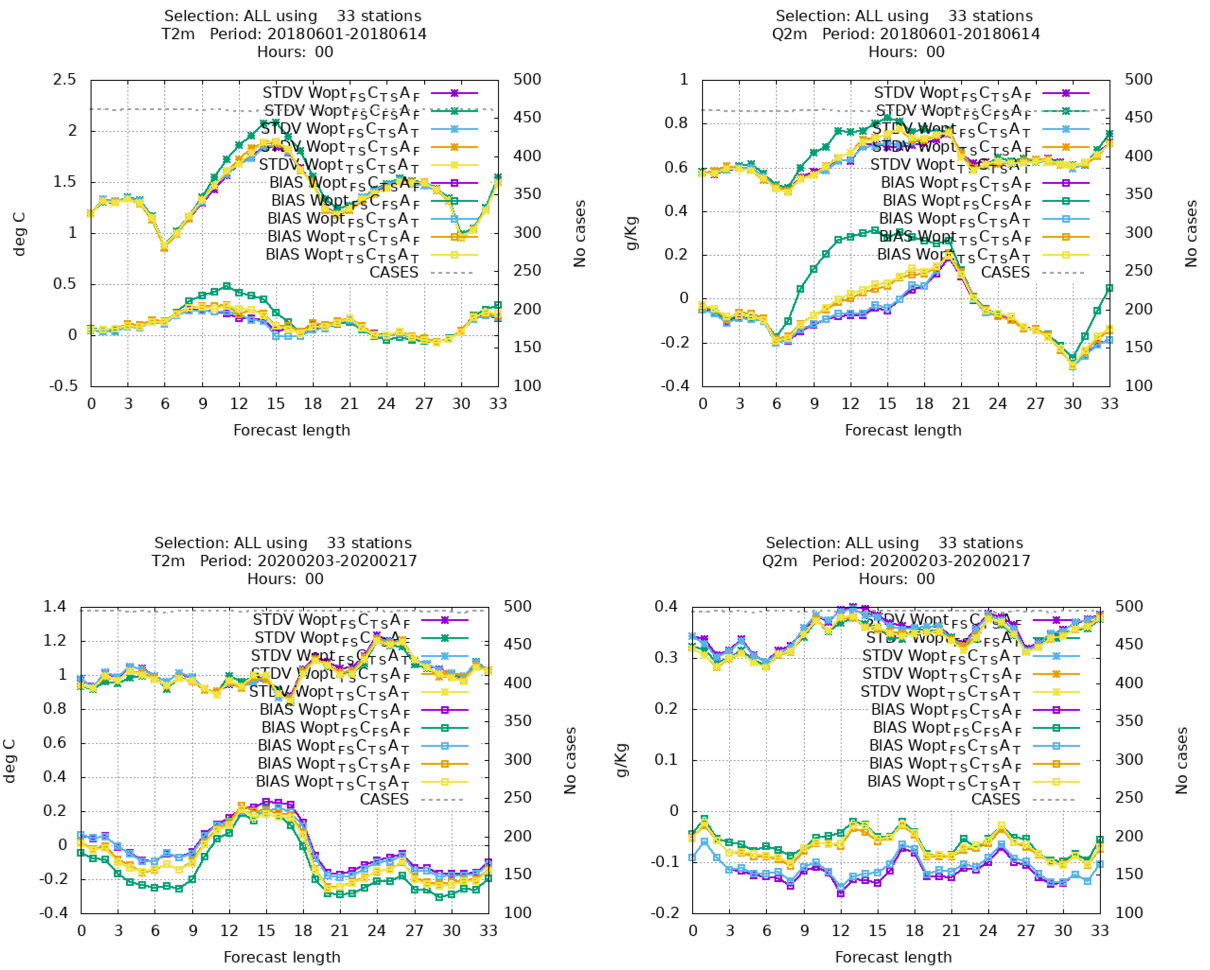

Figure 4. Sample Summer (top) and Winter (bottom) plots of bias and standard deviation in T2m and Q2m for the 5 shallow convection permutations mentioned above.