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	2025
Project Title:	Improving cloud forecasting in 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:	01-01-2025
Expected end date:	31-12-2025

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)			35 M	16.75 M
Data storage capacity	(Gbytes)			N/A	N/A

Summary of project objectives (10 lines max)

The focus of this work is on improving the forecasting of clouds in the HARMONIE-AROME NWP model. The work involves considering the performance of the microphysics and shallow convection schemes, as well as the aerosol options available, both climatological and near real-time.

Summary of problems encountered (10 lines max)

So far, I have not encountered any major problems except that there were technical issues with the tsh to ATOS for several days, and that accessing MARS is very slow but I try to use boundary data stored locally to avoid MARS.

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

For the remainder of the project I will be focusing on evaluating radiation under clear skies, and tuning the background stratospheric aerosols, then moving to evaluating liquid clouds, using satellite products (radiation and LWP) and also CloudNet and radar profiles.

List of publications/reports from the project with complete references

None so far but there will be one on the shallow convection work.

Summary of results

I have used the SBUs so far to study shallow convection, and in particular missing precipitation from open cell convection. I have also used many SBUs to run experiments using the various aerosol datasets that we have implemented in HARMONIE-AROME cycle 46. A further set of experiments were run to test a new call to the microphysics scheme, code which has been refactored, but not previously tested for use in HARMONIE-AROME. Sample results from each of three separate suites of test topics are included below.

1. **Shallow Convection**

Starting with shallow convection, I focused on a case from December of last year where the precipitation from open cell convection near Ireland was missing in the reference version of HARMONIE-AROME (an issue that's been around for a long time). I also ran a 2-week summer period to check the integrity of a longer run containing days of deep convection, shallow convection and stratocumulus clouds. Sample results from the December case are included below.

Many, many options were tested. In the end the most viable options are: Use of LWTHRESHMOIST (switching off the moist updraft once a certain threshold in vertical velocity is reached), use of the dry mass flux at 70%, shut down the moist updraft when the subgrid evaporation and melting exceeds 1 mm/h. We decided against the tuning of ZLINF even though it is tunable. Apart from the changes above, it is proposed to re-introduce the momentum mixing by the convection scheme. It is known that mixing momentum, in the same way as temperature and humidity, overestimates the momentum mixing but as shown in https://doi.org/10.1175/JAS-D-23-0098.1, shutting down momentum mixing completely in HARMONIE-AROME underestimates the momentum mixing and leads to too much wind shear. We propose a 50% option. **Figure 1** shows a satellite image of the convection case. **Figure 2** shows the rain rate (mm/h) where you can see the impact of the various options on the precipitation. It is not that easy to gauge the full impact using such plots but the histograms in **Figure 3**, where an area over the Atlantic was used, really highlight the impact of the options on precipitation.

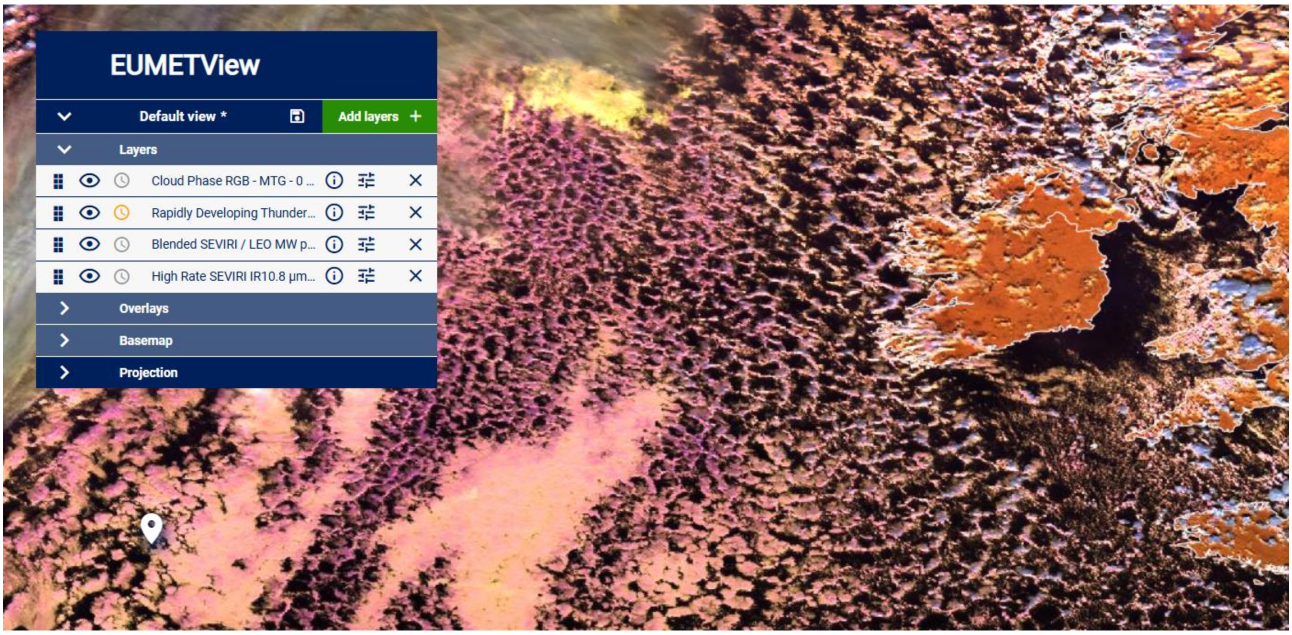

Figure 1: From the EUMETSAT portal. Shallow convection case for which the reference version of HARMONIE-AROME does not produce enough precipitation.

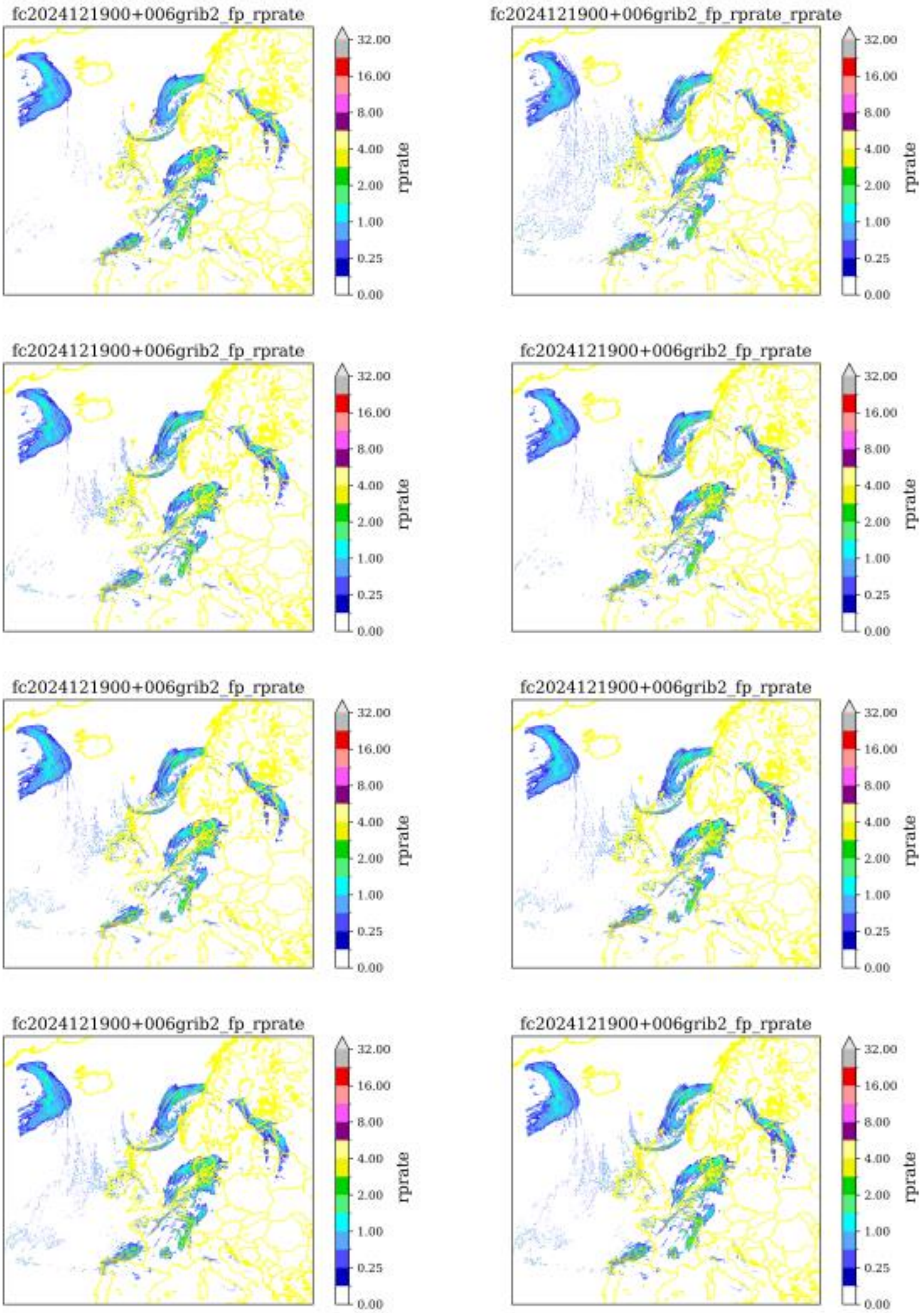

Figure 2: Rain rate (mm/h) at 06Z on 19/12/2024 for the following experiments: **1)** Reference **2)** No shallow convection scheme **3)** a formulation that limits the maximum cloud depth depending on the temperature **4)** LWTHRESHMOIST=TRUE, switch off the moist updraft when a threshold in vertical velocity is reached **5)** LWTHRESHMOIST=TRUE, ZLINF=100 (a tunable constant) Subgrid evaporation and melting > 1mm/h shuts down convection **6)** scale-aware shallow convection=TRUE (depends on boundary layer height), LWTHRESHMOIST=TRUE, ZLINF=200, Subgrid evaporation and melting >1mm/h **7)** LWTHRESHMOIST=TRUE, Subgrid evaporation and melting >1mm/h, dry

MF x 70% (use 70% of the dry mass flux once the threshold in vertical velocity is reached) **8**) same as 7) but with LMIXUV=TRUE (momentum mixing) and a 50% formulation used.

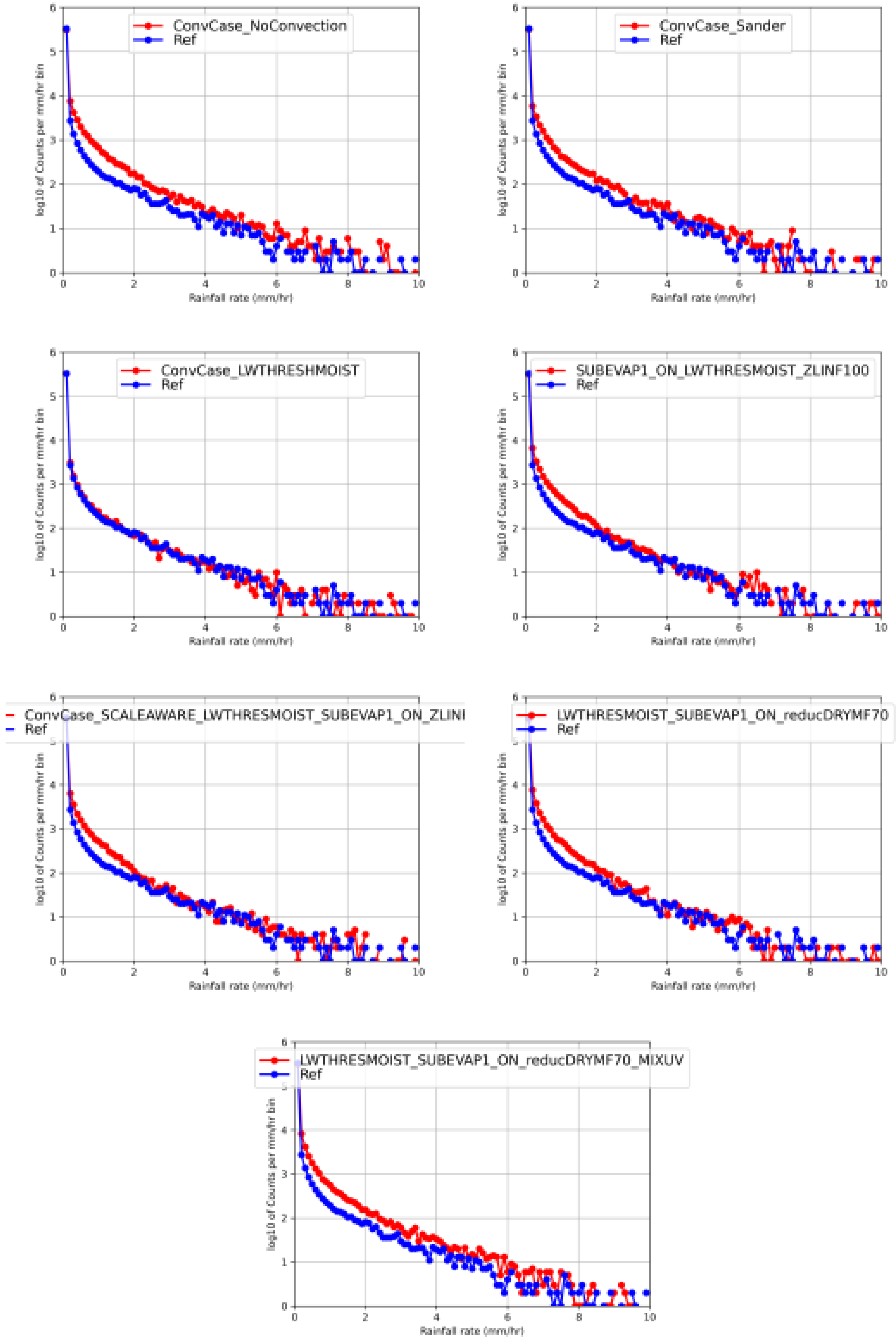

Figure 3: Histgrams of rain rate (mm/h) at 06Z on 19/12/2024 for the following experiments vs the reference. **1)** No shallow convection scheme **2)** a formulation that limits the maximum cloud depth depending on the temperature **3)** LWTHRESHMOIST=TRUE **4)** LWTHRESHMOIST=TRUE, ZLINF=100, Subgrid evaporation and melting > 1mm/h shuts down convection **5)** SA=TRUE,

LWTHRESHMOIST=TRUE, ZLINF=200, Subgrid evaporation and melting >1mm/h **6)** LWTHRESHMOIST=TRUE, Subgrid evaporation and melting >1mm/h, dry MF x 70% **7)** same as 6) but with LMIXUV=TRUE and a 50% formulation used.

2. Aerosols

Regarding aerosols, I tested the following options: **1)** The Tegen climatology, **2)** the CAMS climatology **3)** the CAMS climatology where the climatological mass mixing ratios are used to calculate the effective radius (an option called LAEROMIC) **4)** Like 2 but without background stratospheric aerosols. **Figures 4** and **5** show 2D and 1D histograms of clear sky index (CSI) using stations in Ireland, where CSI = global shortwave radiation divided by the global clear sky shortwave radiation. You can see the issue of too much liquid in front clouds (too many low CSI values in the model and **Figure 6**). In addition, the LAEROMIC option is not optimized and needs to be checked further. These results are for Ireland where the Tegen and CAMS climatologies are similar. I plan to run over a larger area where reduction in aerosol optical depth in CAMS will have a higher impact.

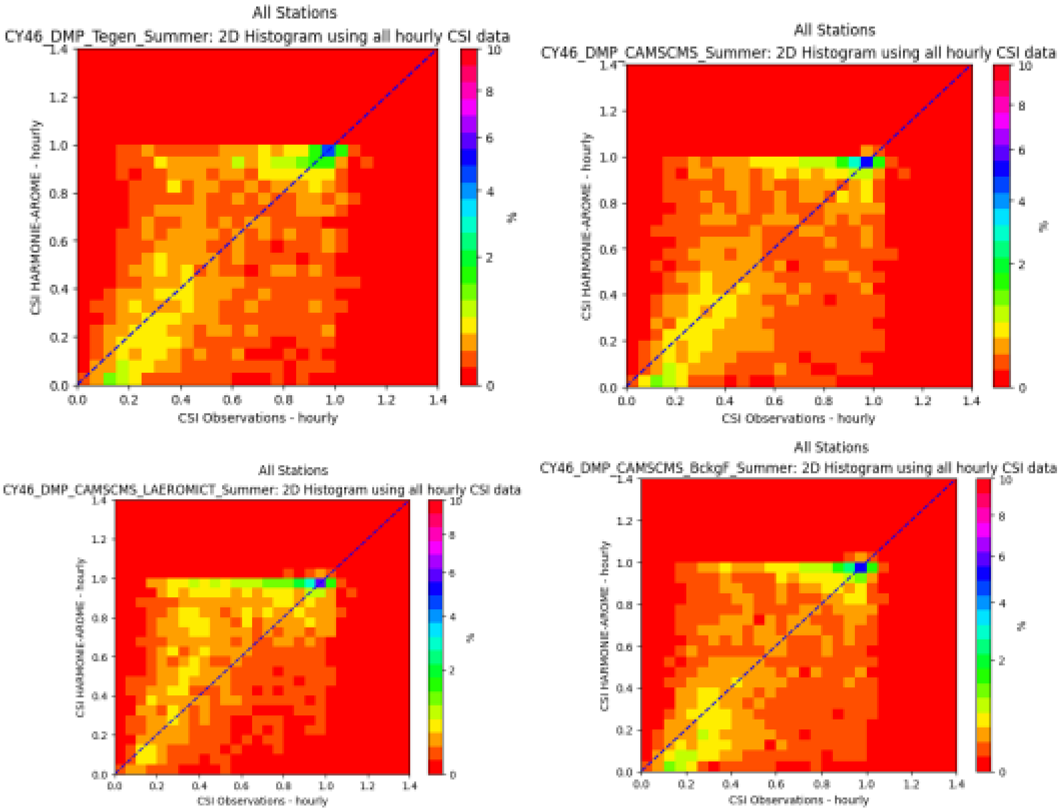

Figure 4: 2D Histograms of clear sky index for the following experiments: Tegen, CAMSCMS+BCK, CAMSCMS+BCK+LAEROMIC=T, CAMSCMS+BCK

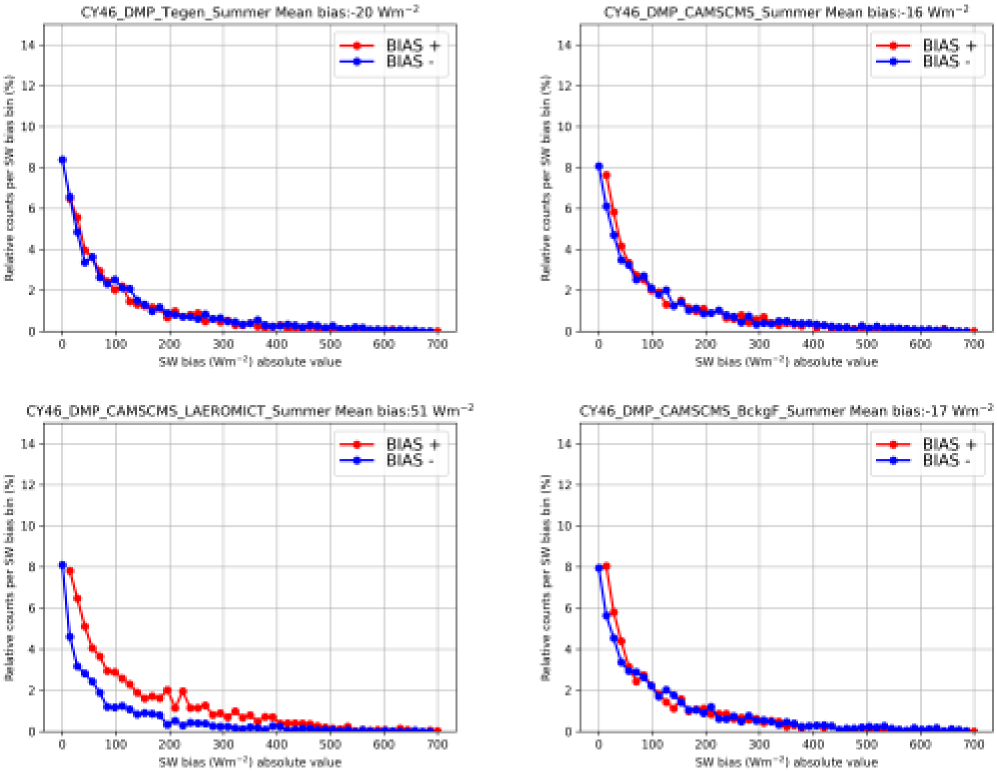

Figure 5: Histograms of SWD bias for the following experiments: Tegen, CAMSCMS+BCK, CAMSCMS+BCK+LAEROMIC=T, CAMSCMS+BCK=F.

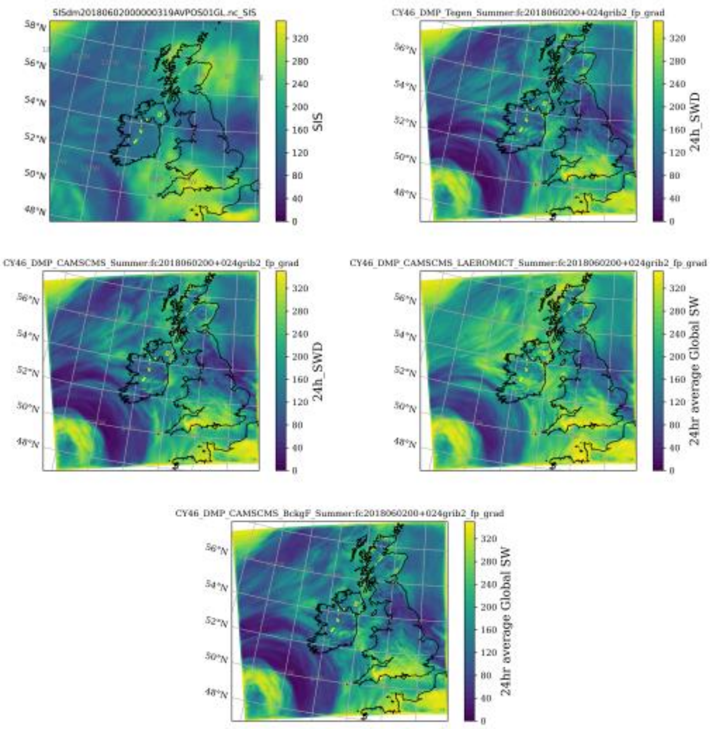

Figure 6: Daily mean global SW (W/m−2) for the June 3rd 2018 as an example for the following: MSG SEVIRI, Tegen, CAMSCMS+BCK, CAMSCMS+BCK+LAEROMIC=T, CAMSCMS+BCK=F.

3. Testing the calls to the microphysics scheme

In Cycle 46 and 49 of HARMONIE-AROME there are two call routes to the microphysics scheme, rain_ice (RI) and rain_ice_old (RIO). In cycle 46 not all parts of the HARMONIE-AROME microphysics have been implemented under rain_ice. In cycle 49, the rain_ice code has been refactored. The main difference between the calls is that rain_ice includes some small bug fixes. The HARMONIE-AROME flavour of the microphysics scheme comes under the namelist switch LOCND2. For cycle 46 I could only test RI with LOCND2 off. For cycle 49, I tested RI and RIO for LOCND2 on and off. Some interesting points: mean biases in global shortwave radiation seem to be lower when LOCND2 is off (**Figure 7**). We seem to have less of an issue at low CSI with LOCND2 off, and high CSI looks better with DA off (**Figure 8**). Further investigation is needed. Regarding integrated cloud liquid, cloud ice, rain, snow and graupel path, CY46 and CY49 RI-RIO differences look quite similar with LOCND2 off (can't run RI in CY46 with LOCND2=TRUE). With LOCND2 on in CY49, the differences in the snow path for RI-RIO are higher and of opposite sign (**Figure 9**). We don't have the option of doing the same comparison in CY46 unfortunately.

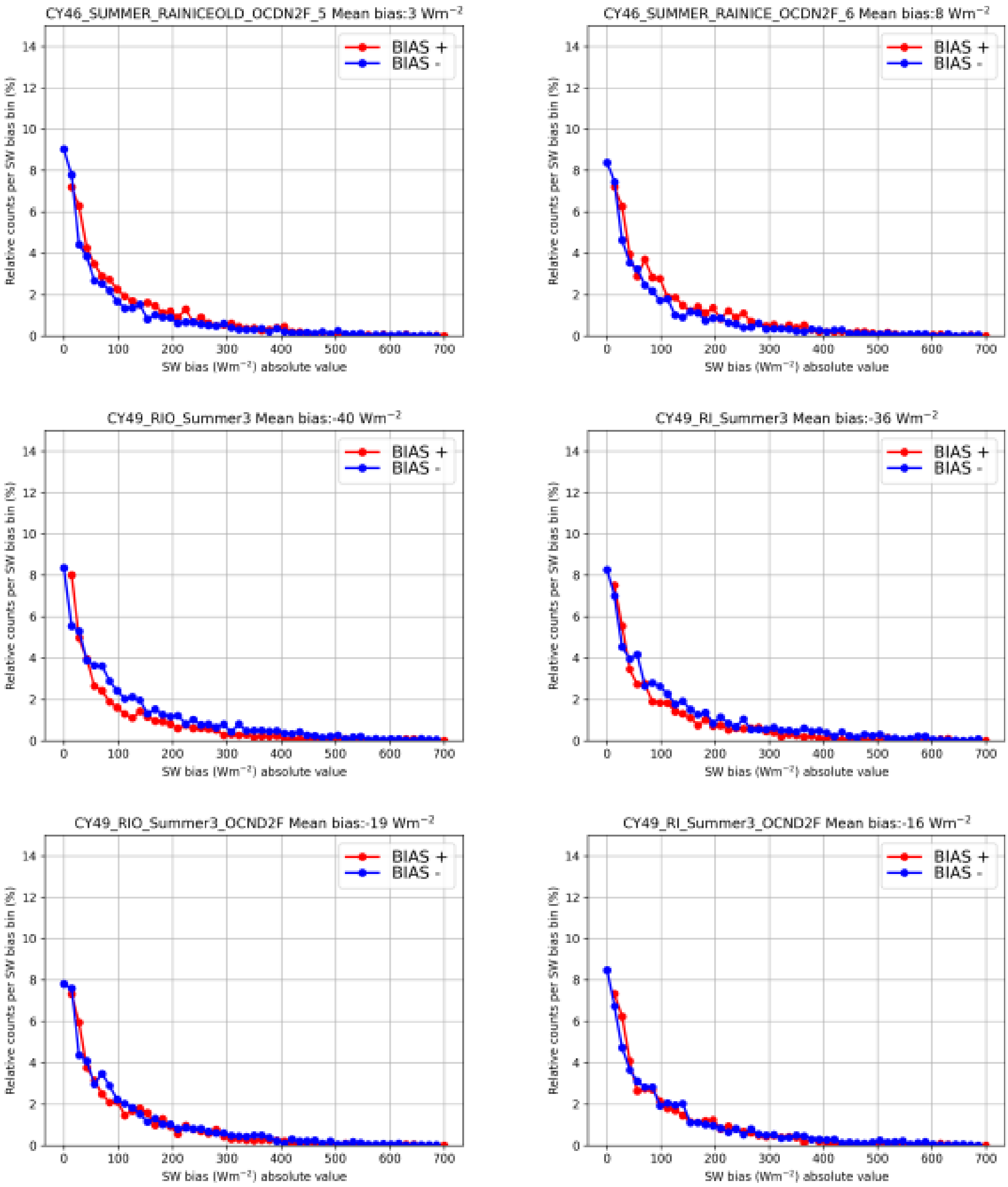

Figure 7: left: RIO right: RI. Top CY46 OCND2=F, middle CY49 OCND2=T, bottom CY49 OCND2=F.

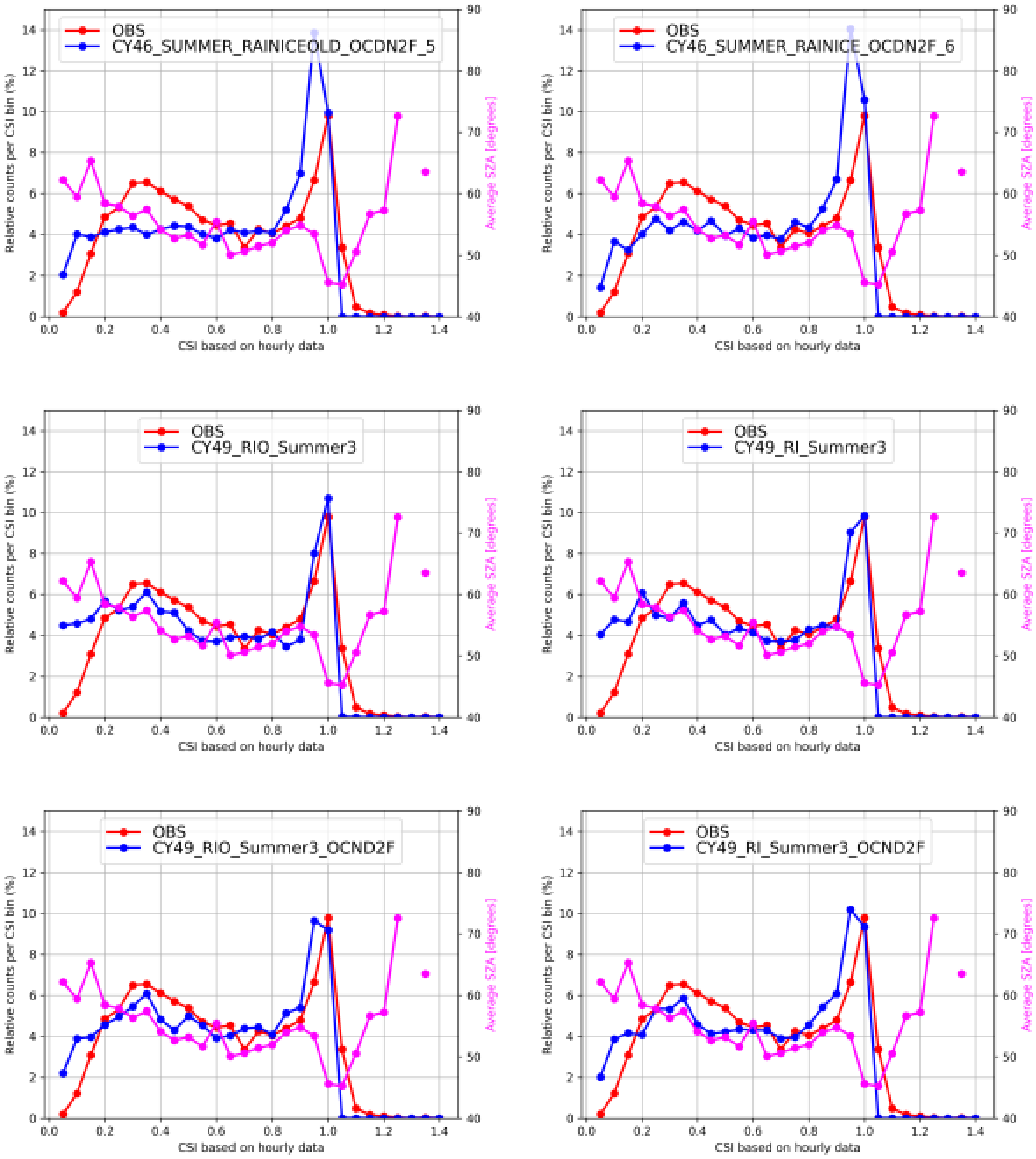

Figure 8: left: RIO right: RI. Top CY46 OCND2=F, middle CY49 OCND2=T, bottom CY49 OCND2=F.

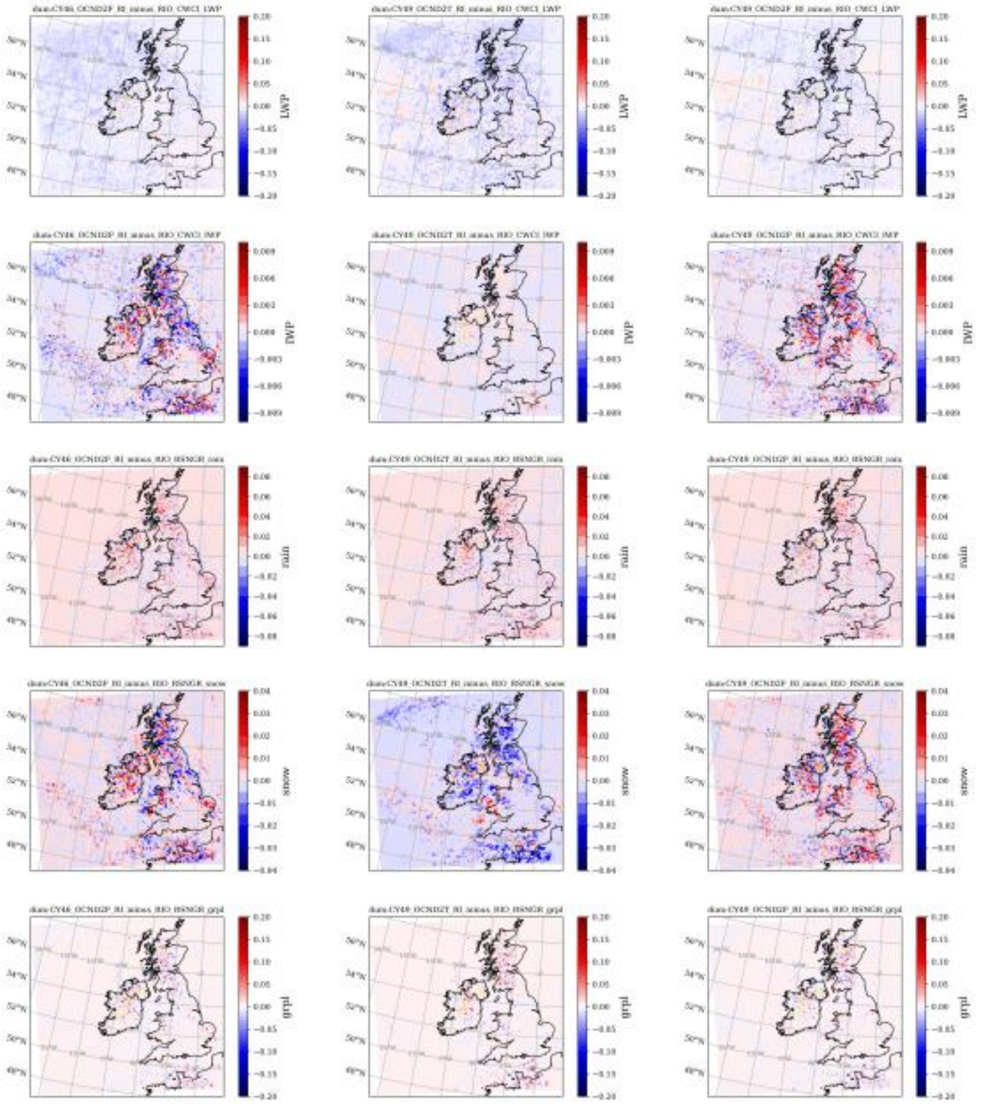

Figure 9: left to right: CY46 OCND2=F, CY49 OCND2=T, CY49 OCND2=F (RI-RIO). Rows: LWP, IWP, integrated rain, snow and graupel.