Met Éireann Updates

Geoffrey Bessardon, Colm Clancy, Conor Daly, Rónán Darcy, Emily Gleeson, Alan Hally, Eoin Whelan

1 Introduction

Cycle 40h1 of HARMONIE-AROME has been operational at Met Éireann since May 2018, with the short-range Irish Regional Ensemble Prediction System (IREPS) running since October 2018. Details of this configuration may be found in a previous newsletter (Clancy et al., 2019). In August 2019, a technical upgrade to this operational NWP suite was carried out. This is described in detail in Section 2. In November, the SAPP system from ECMWF was made operational for the pre-processing of observations; details are given in Section 3. Recent work on model physiography is discussed in Section 4, while some information on MUSC development is provided in Section 5. Finally, updates on the MÉRA reanalysis project are given in Section 6.

2 Operational Upgrade

A technical upgrade to the operational suite (o-suite) was carried out in August 2019. The changes applied are summarised in Table 1 and are described in more detail below.

Table 1: Summary of changes in the technical upgrade

Model component	Description
Dynamics	Adjust vertical momentum equation
Dynamics	Change spectral grid from linear to quadratic
Data assimilation	Assimilate radiances from AMSU-A, MHS and IASI satellite instruments
Data assimilation	Assimilate METOP-C ASCAT winds
Ensemble	Update SLAF coefficients, SLAFLAG values and surface perturbations

2.1 Forecast model

During winter 2018/2019 noise patterns were observed in the MSLP forecasts produced by our operational HARMONIE-AROME. Investigations revealed that these could be removed by changing two parameters related to the form of the vertical momentum equation: i.e. changing {LGWADV, LRDBBC} from their default {FALSE, TRUE} to {TRUE, FALSE}. These latter values are already in use at Météo France and a number of ALADIN countries. The effects of these changes can be clearly seen from experiments shown in Fig. 1. Longer tests were carried out with these changes, and showed no significant differences in forecast quality.

A further dynamics change was also tested: replacing the default linear spectral grid with the quadratic grid. This results in a saving of approximately 13% in CPU time, which allows for more rapid forecast production. Experiments carried out during the period of a high-impact storm event (February 2014, with Storm Darwin) showed no significant reduction in accuracy.

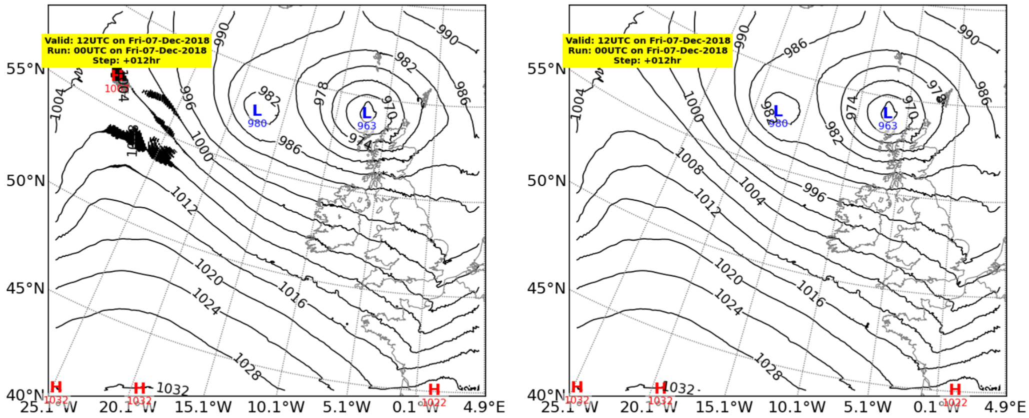

Figure 1: Plots of MSLP before (left) and after (right) the changes made to HARMONIE-AROME (40h1.1) following experiments with {LGWADV,LRDBBC} options. Left: default {FALSE,TRUE}. Right: {TRUE,FALSE}.

2.2 Data Assimilation

The technical upgrade also brought the assimilation of radiance data from the AMSUA-A, MHS and IASI instruments on board EUMETSAT and NOAA polar orbiting satellites. Met Éireann receives satellite data used in NWP via the EUMETSAT Advanced Retransmission Service (EARS) Regional Service. Figure 2 shows typical data coverage for AMSU-A and IASI observations.

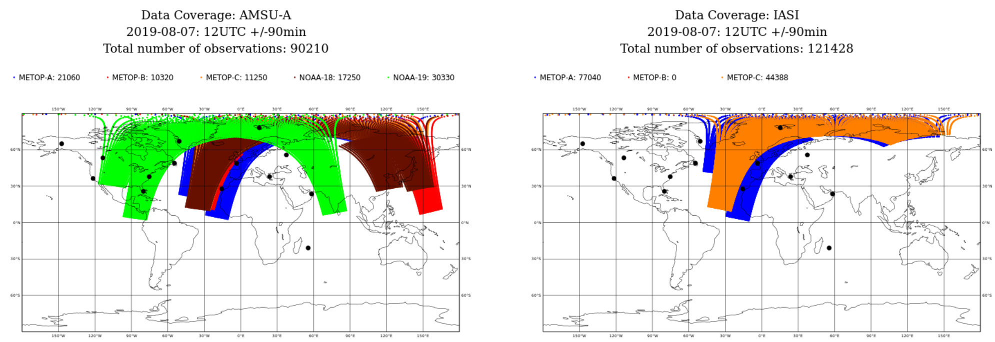

Figure 2: Data coverage of AMSU-A (left) and IASI (right) observations for 1200 UTC 7th August 2019. The black dots indicate the location of EARS receiving stations.

It is assumed by many data assimilation algorithms that observations have unbiased (Gaussian) errors. However, it is known that satellite observation errors have biases that must be corrected before use in NWP. HARMONIE-AROME uses a technique known as Variational Bias Correction (VarBC) (Aulígné et al., 2007) to correct satellite observation biases. VarBC coefficients are calculated over a suitable period (typically one month) and then corrections are applied to radiance observations as part of the HARMONIE-AROME 3D-Var minimization process. Further details on the application of VarBC in the HARMONIE-AROME system are available Arriola et al. (2016). VarBC coefficients for AMSU-A, MHS and IASI data assimilated in the operational domain were calculated during August 2018. Appropriate blacklisting of satellites was applied taking orbit times into account. As the operational domain is mainly ocean, radiance data over land was also blacklisted. Examples of time-series of the convergence of VarBC corrections applied to radiance data are shown in Fig. 3.

Following the calculation of VarBC coefficients for the operational domain a one month test period was used to validate model performance with the assimilation of AMSU-A, MHS and IASI observations in the HARMONIE-AROME 3D-Var data assimilation system. A control experiment (varbc_met_radass) assimilating only conventional and ASCAT observations ran for August 2018. An experiment (varbc_met_radass),

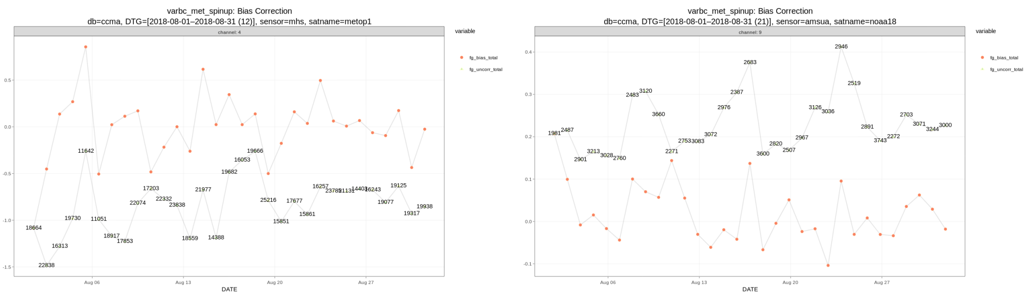

Figure 3: Time-series of average first-guess departures for Metop-B MHS Channel 4 (left) and NOAA-18 AMSU-A Channel 9 are show. "Raw" (green dots, numbers) and bias corrected (orange dots) departures are illustrate the benefits of applying VarBC to the data.

producing 24 hour forecasts at 0000 UTC and 1200 UTC, assimilating radiance data also ran for the same period. Forecasts produced by both experiment were then validated using SYNOP and TEMP observations. There was a slight positive improvement in scores MSLP and results for near-surface parameters were neutral, Fig. 4. There were improvements in forecasts of geopotential heights and humidity parameters in the middle atmosphere, Fig.5.

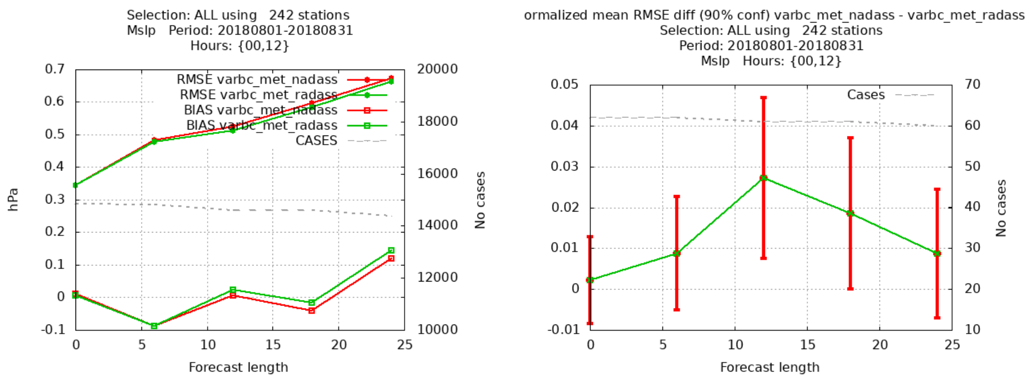

Figure 4: Validation of MSLP forecasts compared to SYNOP observations (right) and the significance of these results (right). Control (conventional + ASCAT) statistics are shown in red and radiance experiment statistics are shown in green.

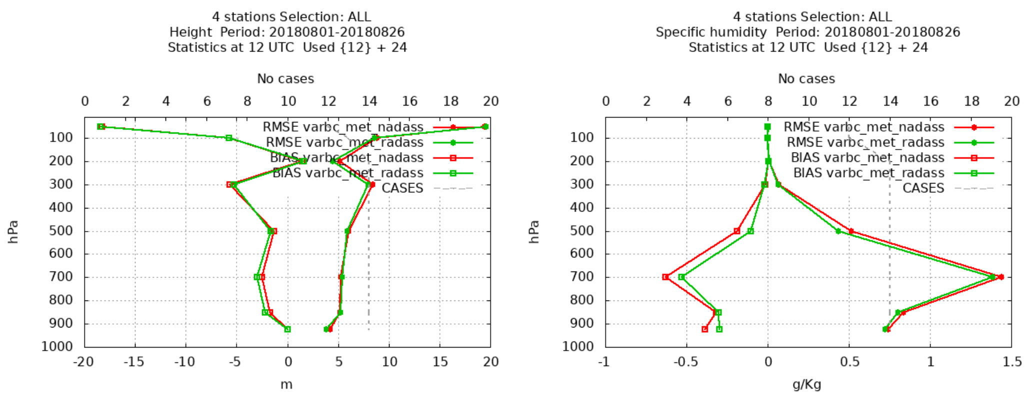

Figure 5: Validation of geopotential (left) and humidity (right) forecasts compared to TEMP observations. Control (conventional + ASCAT) statistics are shown in red and radiance experiment statistics are shown in green.

Metop-C was launched on the 7th November 2018. Data from Metop-C data are currently (August 2019) in trial dissemintaion mode. Radiance data (AMSU-A, MHS and IASI) have been blacklisted. ASCAT data will be assimilated as these data are considered to be unbiased. The assimilation of Metop-C radiances will be introduced at a later date.

2.3 Deterministic Verification

The deterministic configuration of the technical upgrade (e-suite) was put into parallel operational and cycled for a number of months to spin up the surface processes. The main parallel test period covered June and July 2019, with 48-hour forecasts beginning at 0000 UTC and 1200 UTC. Figure 6 shows sample surface verification scores for 10 m wind speed and 2 m temperature parameters. Some minor differences are visible but overall the average forecast quality is comparable, with no obvious degradation from the use of the quadratic grid. Verification of some vertical profiles is given in Fig. 7. Results are, again, broadly neutral. Perhaps the most notable feature is an improvement in upper level relative humidity (bottom panels), due to the assimilated radiance observations that provide information at these levels.

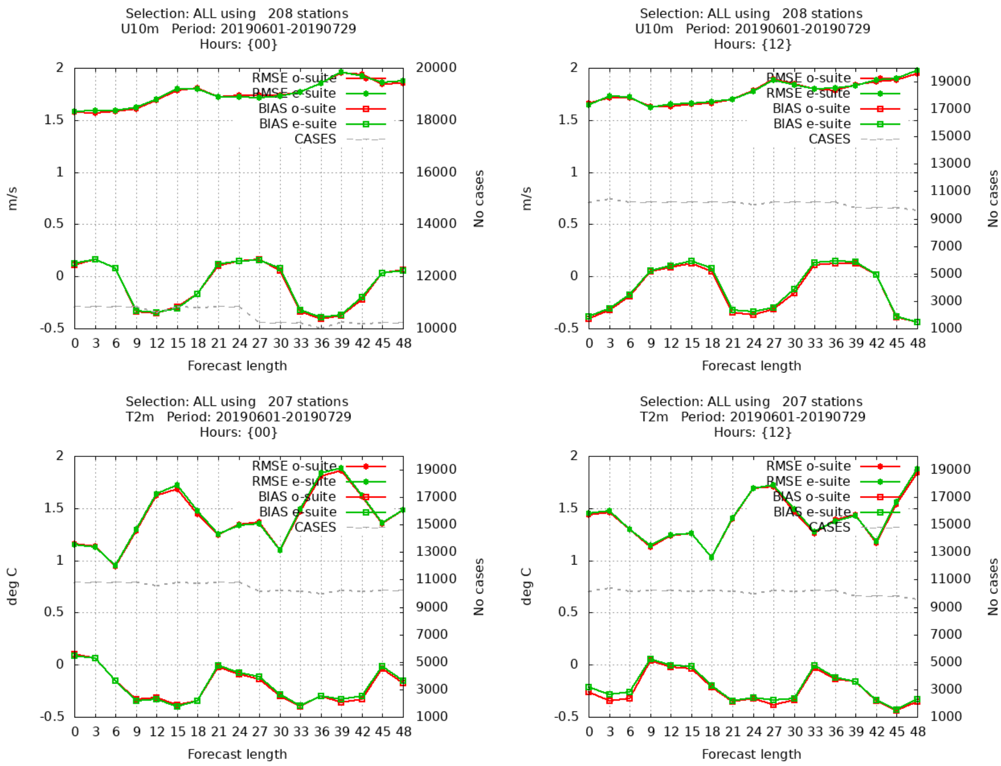

Figure 6: Point verification of the o-suite (red) and the e-suite (green) for the test period in June and July 2019. Forecasts begin at 0000 UTC (left) and 1200 UTC (right). Parameters shown are 10 m wind-speed (above) and 2 m temperature (below).

2.4 Ensemble System

Testing on a number of aspects related to the IREPS configuration was undertaken in order to pinpoint potential useful technical upgrades to the o-suite. The implementation of the perturbed analysis (PertAna) approach of representing initial condition uncertainty was investigated but discounted due to unacceptable noise patterns developing in the first few hours of the forecast.

Modifications were restricted to changes in the SLAF perturbation coefficients, SLAFLAG values and surface perturbations. The SLAF coefficients control the scaling applied to the difference between the two lagged

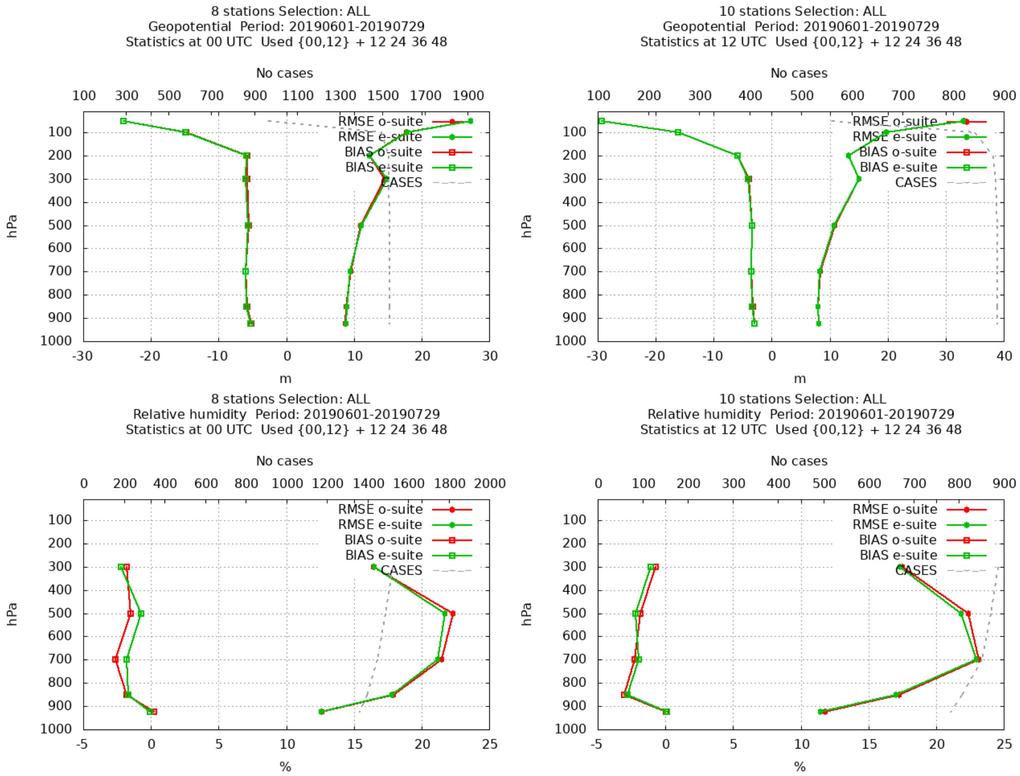

Figure 7: Vertical profile verification of the o-suite (red) and the e-suite (green) for the test period in June and July 2019. Verification is for forecasts valid at 0000 UTC (left) and 1200 UTC (right). Parameters shown are geopotential (above) and relative humidity (below).

forecasts which are valid at the same time. The SLAFLAG values determine the number of hours lag between the two forecasts. Table 2 shows the updates applied to the SLAF coefficients and SLAFLAG values.

Table 2: Previous and updated SLAF coefficient and SLAFLAG values for IREPS

Member	Old SLAF coeff	New SLAF coeff	Old SLAFLAG	New SLAFLAG
0	0.0	1.0	0	0
1	1.75	1.60	6	12
2	-1.75	-1.60	6	12
3	1.5	1.4	12	18
4	-1.5	-1.4	12	18
5	1.2	1.2	18	24
6	-1.2	-1.2	18	24
7	1.0	1.0	24	30
8	-1.0	-1.0	24	30
9	0.9	0.86	30	36
10	-0.9	-0.86	30	36

Perturbations of the snow depth parameter, vegetation fraction, leaf area index (LAI) and soil thermal coefficient were deactivated. The mean bias (Fig.8) in 2 m temperature, 10 m wind speed and 2 m relative humidity, shows the positive impact of these modifications. The 3 parameters result in a lower mean bias compared to the reference experiment. This is particularly important for 2 m temperature given that HARMONIE-AROME cycle 40h1.1 suffers from a negative 2 m temperature bias over Ireland.

IREPS continues to add significant value over IFSENS as demonstrated by the spread/skill score plot for 10m-wind in Fig.9.

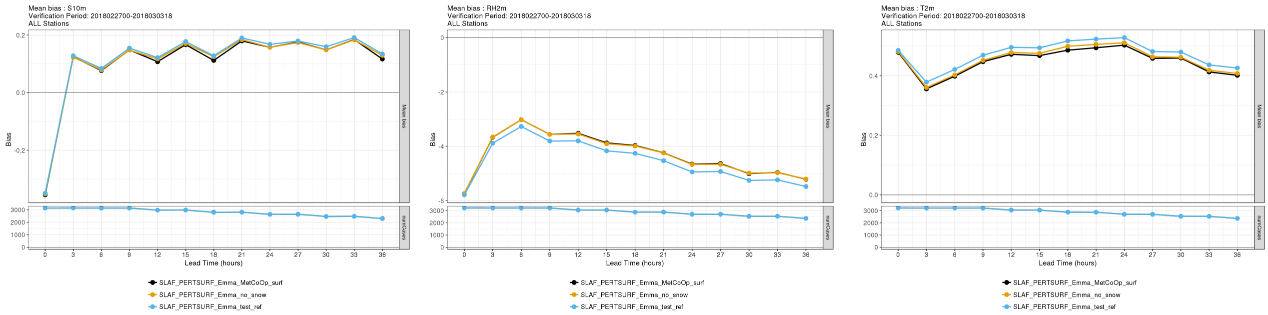

Figure 8: Mean bias in 10 m wind speed, 2 m relative humidity and 2 m temperature for experiments related to modifications in the surface perturbations. The updated surface perturbation set-up is shown in black, a reference experiment is in blue and an experiment with no perturbations to the snow depth parameter is in orange.

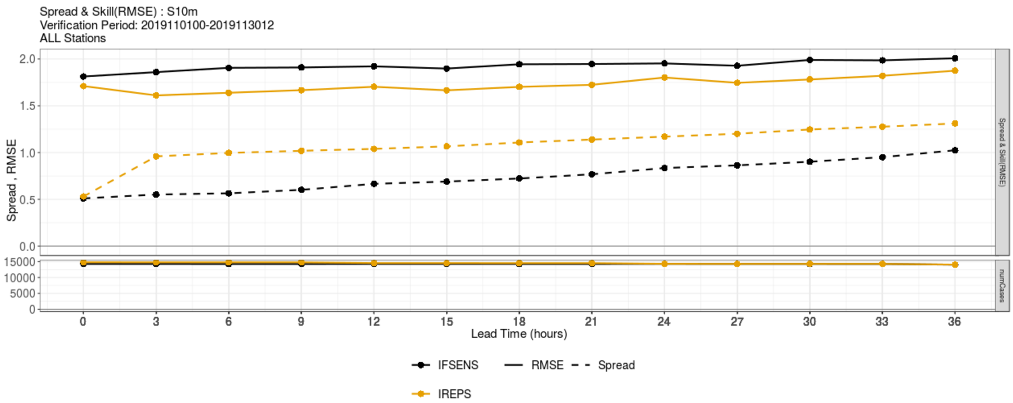

Figure 9: Spread-skill scores for IREPS (orange) and IFSENS (black) for 10m-wind speed for the month of November 2019.

3 Implementation of SAPP

3.1 Introduction

Met Éireann has used the Automatic Data Extraction system (ADE) to produce observational (BUFR) data readable by our operational NWP systems. The ADE was developed in the 1990's and is based on software developed by ECMWF supplemented by local adaptations and quality control functions. With the changes in formats used to transmit data on the GTS (TAC to BUFR) and the availability of new observational data streams the rigidity of the ADE design was apparent and was hindering progress with our operational NWP system development.

In May 2016 Met Éireann contacted ECMWF staff requesting access to a copy of their SAPP (Scalable Acquisition and Pre-Processing) System. A series of video meetings followed and Met Éireann hosted a SAPP workshop in 2017 which was attended by ECMWF staff and HIRLAM colleagues. In 2018 ECMWF Council approved a new Optional Programme to make SAPP available to Member and Co-operating States. During 2018 and 2019 Met Éireann staff (Eoin Whelan, Sarah Gallagher, Rónán Darcy and James Brennan) installed and developed the SAPP system for operational use.

The SAPP system has provided Met Éireann a robust flexible framework for processing and monitoring observations used in NWP. With SAPP more conventional observations are now available for operational data assimilation. New observation types, such as wind profiler and GNSS, are also available for testing and planned use in the next version of IREPS.

3.2 Operational implementation

ECMWF have provided the SAPP system as a virtual machine (VM). Two instances of SAPP (vsapp02a/b) have been installed in Met Éireann's virtual environment and have been running in pre-operational mode since June 2019. Both VMs process conventional observational data received from the GTS. The extraction of data for use in operational NWP has been tailored to Met Éireann's needs. A "*short cut-off*" (sc) stream has been implemented for use by IREPS and "*nowcast*" (nc) data stream has been implemented for a planned HARMONIE based nowcasting system to be developed in 2020. The use of BUFR data produced by SAPP was made operational for the 1200 UTC forecast on 19 November 2019.

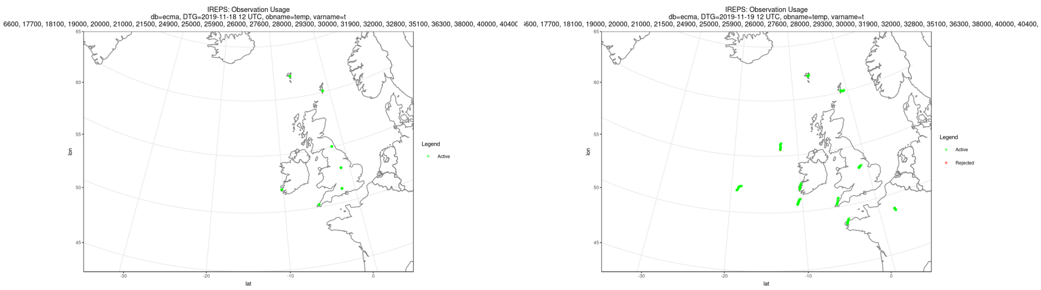

Figure 10: Radiosonde temperature observations assimilated by IREPS on the 18th (left) using ADE BUFR and (right) on the 19th using SAPP BUFR

4 Surface

A summary of recent preliminary work in the area of physiography, carried out by staff working at Met Éireann may be found at: https://hirlam.org/trac/attachment/wiki/Meetings/Surface/Surface201911/nwp-note-201907.pdf

As this is the first time we have looked at the physiography-related datasets over Ireland, we began by comparing the sand and clay maps in HARMONIE-AROME Cycle 43 FAO, SOILGRIDS, HWSD) with a locally available dataset created by an Irish organisation called Teagasc. As the local dataset only covers the Republic of Ireland, with Northern Ireland excluded, it was necessary to blend the local dataset with the maps available over the HARMONIE-AROME experiment area for our tests. We also looked at the ECOCLIMAP-SG land cover dataset and LAI input.

A brief summary of our findings to date is given below. More extensive testing is planned for the coming months using off-line SURFEX. We are also looking for other local datasets that could potentially be of use and we are investigating the possibility of using machine learning to extract useful parameters from mapping imagery such as Google Street View and OpenStreetMap.

1. Soil & Clay: A the SOILGRID and SOILGRID-BLEND (where SOILGRID-BLEND = SOILGRID + local data) soil and clay maps are similar, and significantly different to the lower resolution FAO maps, the SOILGRID maps can be considered to be of superior quality. The SOILGRID-BLEND maps provide additional local information, not included in SOILGRID, and are therefore the preferred choice. Testing using SURFEX in offline mode has commenced to get a better handle on sensitivities.

2. Land Cover: The water, urban and nature fractions in the ECOCLIMAP-SG land cover dataset are much more realistic than in ECOCLIMAP2.5plus. For instance, in SG the Shannon Estuary is now clearly accounted for. All of Ireland's cities are larger than before, consistent with the growth that has taken place over recent decades. The land-sea mask seems to be much improved in general with more of the islands around the coast being resolved. Initial comparisons between SG and a small subset of the Ordnance Survey Ireland Prime 2 dataset have been made but so far no 3D or offline SURFEX runs have been made. It is not trivial to map the cover types in Prime 2 to those in SG to aid comparisons so this work is on-going.

3. Leaf Area Index: The climatologies of LAI used in HARMONIE-AROME are not sufficient for years that vary greatly from normal. An example of this occurred during the summer of 2018 when Ireland suffered a serious drought which resulted in the normally green island, turning a shade of brown. Figure 11 shows the large difference between the LAI in July 2018 and that of the climatologies used in HARMONIE-AROME and highlights the need for assimilating LAI data rather than using climatologies. Offline experiments are underway to investigate the differences between using satellite LAI for 2018 compared to multiyear climatologies.

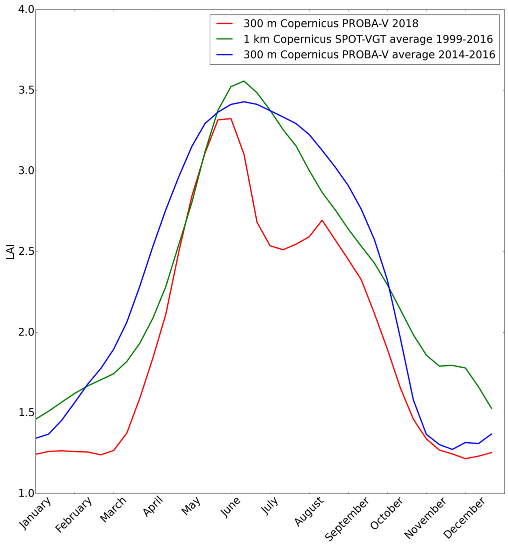

Figure 11: Annual cycle of mean LAI over Ireland plotted using: 300 m LAI data for 2018 from the Copernicus PROBA-V satellite (red), the Copernicus satellite SPOT-VGT LAI data averaged over the period 1999-2016 (green), the Copernicus satellite 300 m LAI data averaged over the period 2014-2016 (blue).

5 MUSC

The scripts that we have developed to run test cases of MUSC in HARMONIE-AROME Cycle 43 are document on the hirlam.org wiki under https://hirlam.org/trac/wiki/HarmonieSystemDocumentation/MUSC. Stephen Outten, who works at NERSC in Norway, developed a virtual box version of MUSC. Details about the installation of this are also provided on the MUSC wiki page. Further test cases will be added over the coming months.

6 MÉRA

With the completion of ERA-Interim in late 2019 the production of the MÉRA high resolution reanalysis for Ireland (Whelan et al. 2018, Gleeson et al. 2017) completed in early 2020. The dataset extends from January 1981 to August 2019. A user workshop was hosted by Met Éireann (https://www.met.ie/science/events/meraworkshop-2019) last May and invited presentations by representatives from Copernicus reanalysis projects were included on the programme. Presentation slides and the workshop proceedings are available on the website.

A new Irish reanalysis project, MÉRA-2, is planned for the coming years which will involve use of ECMWF ERA5 boundary conditions, a new version of HARMONIE-AROME and other useful upgrades.

Figure 12: MÉRA users workshop May 2019, National Botanic Gardens, Dublin.

7 Summary and Outlook

The past year has seen some significant NWP developments at Met Éireann. Significant work in the area of NWP during 2019, including the assimilation of radiance data and the operational implementation of SAPP, should put Met Éireann on a good footing for the coming years.

Early in 2020 five members of IREPS will start to run operationally on KNMI's HPCF with the other members continuing to run at ECMWF's HPCF. The operational version of HARMONIE-AROME will be upgraded from cycle 40h1.1 to 43h2.1 in the third quarter of 2020. Other planned NWP developments include the implementation of an NWP based nowcasting system, the assimilation of GNSS data and the evaluation of locally received Mode-S observations.

8 References

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