Met Éireann Updates

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1 Introduction

Significant upgrades were made to the operational NWP suite at Met Éireann during 2018. Cycle 37h1.1 of HARMONIE-AROME had been in use since 2013. On the 1st of May 2018, Cycle 40h1 was made operational. This upgrade is detailed in Section 2. On the 15th of October, the new short-range high-resolution Irish Regional Ensemble Prediction System (IREPS) was implemented. Details are given in Section 3. ASCAT wind observations were added to the operational data assimilation. This is described in Section 4, while in Section 5 we discuss some of the new post-processing systems in use.

A new initiative in 2018 was the introduction of regular meetings between the model developers and the operational forecasters for the purposes of discussion and feedback on the performance of the HARMONIE-AROME model. This has proved successful and beneficial, and is discussed in more detail in Section 6.

Finally, an update on the Met Éireann Reanalysis project, MÉRA, is provided in Section 7.

2 Upgrade to Cycle 40

The HARMONIE-AROME configuration of the shared ALADIN-HIRLAM NWP system, hereafter HARMONIE-AROME, is the primary model used at Met Éireann for operational short-range forecasting and additionally as a research tool. Work on upgrading from cycle 37h1.1 to 40h1 began in 2017 and the new cycle was made operational for the 1200 UTC forecast on the 1st of May 2018. The major changes with the upgrade include the use of an enlarged domain (see Figure 1) and the introduction of 3D-Var data assimilation with 3-hour cycling. The background error covariances (structure functions) were estimated using downscaled IFS EDA forecasts and only conventional observations are assimilated. Table 1 outlines the changes in the new Met Éireann operational suite.

Table 1: HARMONIE-AROME operational configurations

	Previous 37h1.1	**New 40h1.1**
Horizontal domain	540×500, 2.5 km grid	1000×900, 2.5 km grid
Vertical levels	65 levels, 12 m up to 10 hPa	65 levels, 12 m up to 10 hPa
Timestep	60 s	75 s
Observations	SYNOP	SYNOP, SHIP, AIREP, BUOY & TEMP
Cut-off	45 min	45 min
Data assimilation	Surface OI analysis	Surface OI & 3D-Var
Forecast	54 hour forecasts at 0000, 0600, 1200, 1800 UTC	54 hour forecasts at 0000, 0600, 1200, 1800 UTC;
Boundaries	IFS	IFS

Figure 2 shows verification scores for a month-long period during the initial testing phase using cycle 40h1 with its default settings. This showed promising improvements in wind-speed forecasts (left). However, a significant

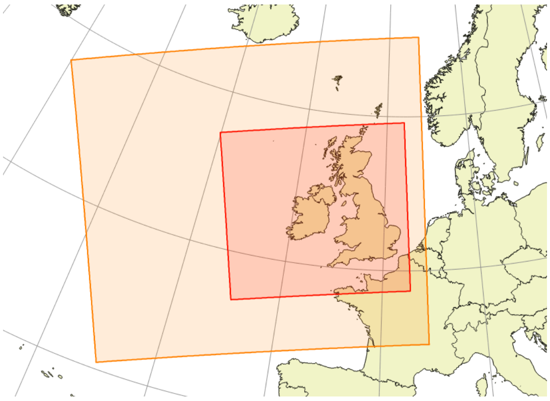

Figure 1: Previous operational (red) and new enlarged domain orange).

cold bias was noted in the 2 m temperatures (right), particularly during the night.

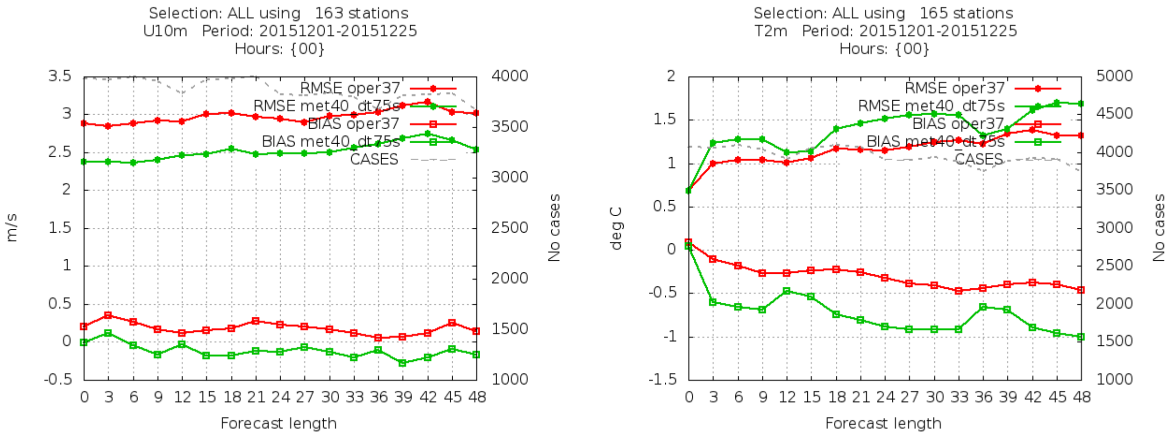

Figure 2: Point verification for December 2015 forecasts during the initial test phase of cycle 40h1.1, comparing the operational cycle 37h1.1 (oper37, red) and cycle 40h1.1 with default settings (met40_dt75, green) for 10 m wind-speed (left) and 2 m temperature (right).

Extensive testing was carried out in an attempt to improve the performance of the near-surface temperature forecasts. Eventually we found that the cold bias could be reduced by switching off the HARATU turbulence scheme and adjusting the temperature increment (ZTINER) in the surface analysis. Unfortunately, this then led to a degradation in 10 m wind forecasts. Further changes related to surface drag were needed in order to compensate. The changes made to create our 'optimal' pre-operational configuration are described in Table 2. Full details and results from the testing may be found in the Technical Note of Clancy et al., 2018.

Month-long tests on the new domain with 3D-Var data assimilation were then carried out. Five months in 2014 were chosen: Febrary, April, June, September and November. Verification scores for the five months combined are shown in Figure 3. In addition to long-term statistics such as these, a number of case studies were examined. Again, full details are available in the Clancy et al., 2018. In general, the testing showed neutral to slightly better results from the cycle 40 configuration.

3 Operational Implementation of IREPS

At 1200 UTC on the 15th of October 2018, Met Éireann implemented the Irish Regional Ensemble Prediction System (IREPS), Met Éireann's short-range high-resolution ensemble prediction system (EPS). IREPS is based

Table 2: Changes made to default cycle 40h1.1 for pre-operational testing

Change	**Affected file**	**Description**
HARATU=no	sms/config_exp.h	Turbulence scheme, i.e. use default instead of HARATU
ZTINER=2.0	src/surfex/ASSIM/oi_cacsts.F90	Temperature increment in surface analysis
ZH ← ZLAI/4 for grassland	src/surfex/SURFEX/z0v_from_lai.F90	Increased drag from grassland by increasing height ZH (default is ZLAI/6)
XCDRAG=0.05	nam/surfex_namelists.pm	Canopy drag coefficient (value used in oper37)

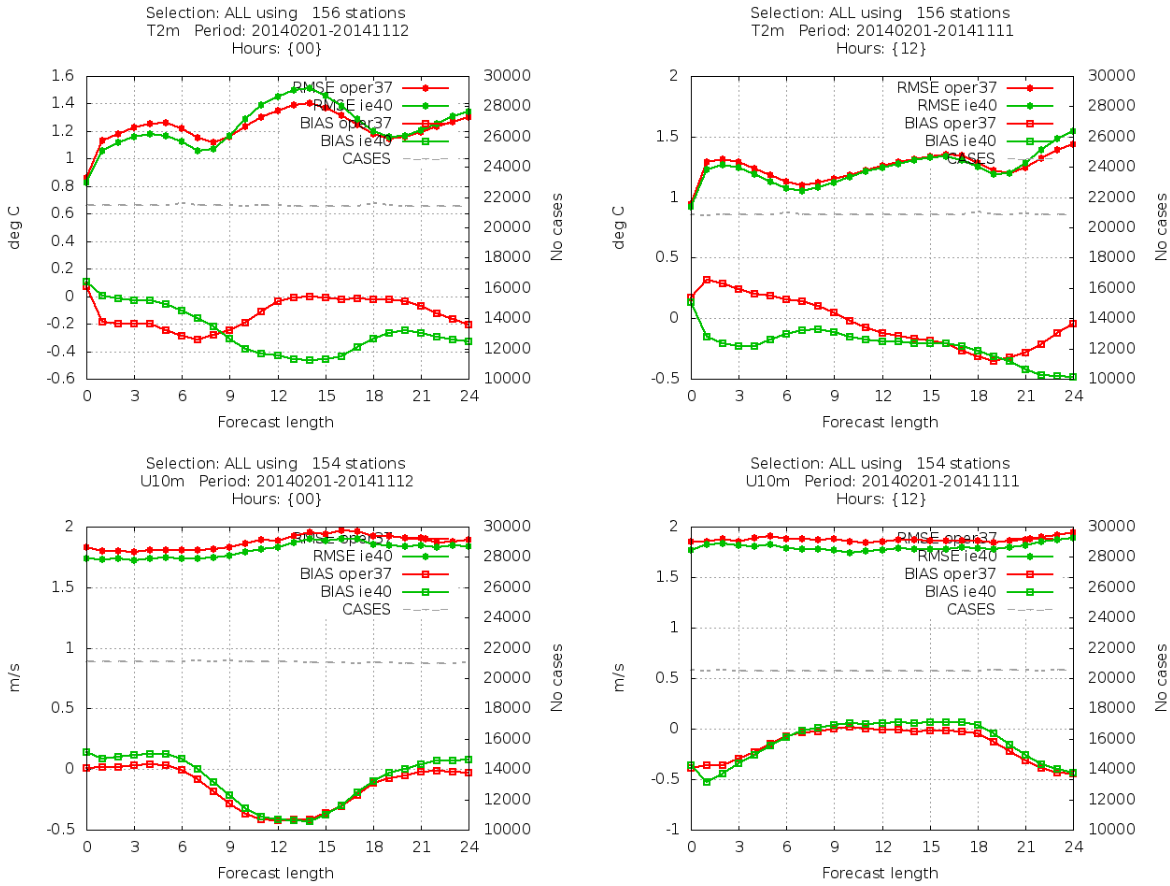

Figure 3: Point verification of 0000 UTC (left) and 1200 UTC (right) forecasts for all month-long tests combined, comparing the operational cycle 37h1.1 (oper37, red) and the new cycle 40 configuration (ie40, green). Parameters shown are 2 m temperature (top row) and 10 m wind-speed (bottom row).

on the MetCoOp setup of the HARMONIE-AROME-EPS branch of cycle 40h1.1. See Section 2 for details, and in particular Table 2 for local changes from the default configuration.

IREPS is composed of 10 perturbed members plus one control member and is run twice daily at 0000 UTC and 1200 UTC with a forecast length of 36 hours. The EPS members are constructed using the scaled lagged average forecasting (SLAF) method. This method uses Integrated Forecasting System (IFS) forecasts from previous runs, valid at the initialisation time, to provide initial and boundary conditions. The forecasts are tuned using a coefficient or scaling factor, with the size of the coefficient dependent on the age of the forecasts with respect to the initialisation time. More details can be found in Ebisuzaki and Kalnay, 1991. Perturbations are also applied to a number of surface parameters including sea surface temperature, the temperatures of the top two soil layers, surface moisture, vegetation fraction, leaf area index, soil thermal coefficient, roughness length over land, fluxes over the sea, albedo and snow depth. The perturbation strategy follows the method outlined in Bouttier et al., 2015.

Objective verification of IREPS versus the IFS ensemble (IFSENS) demonstrates the increased skill in the high-resolution limited-area-model EPS (IREPS) compared to the coarser resolution global EPS. Examples of this can be seen in Figure 4. The spread/skill ratios for 10 m wind speed and 2 m relative humidity are significantly improved. IFSENS continues to have an advantage in terms of MSLP for forecast lengths greater than 18 hours, but this is not an unexpected result as global EPSs generally capture larger-scale structures more accurately.

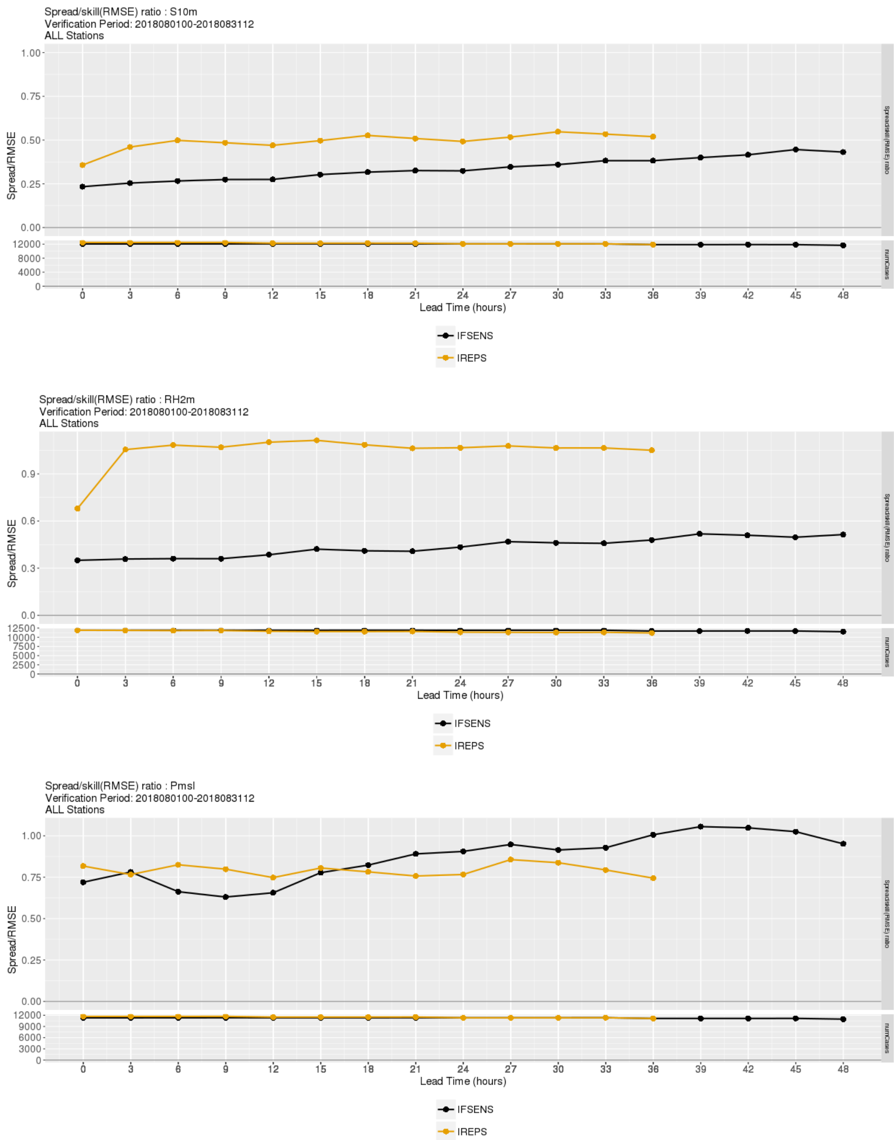

Figure 4: Spread-skill ratios for August 2018 for IREPS (orange) and IFSENS (black) for 10 m wind speed, 2 m relative humidity and Mean-Sea-Level-Pressure (MSLP).

Since IREPS became operational, and even during its pre-operational phase, it has been an important tool for forecasters at Met Éireann especially during high-impact weather events. One example of its usage was during the first significant wind storm of the 2018/2019 season, Storm Ali, which occurred on the 19th of September

2018.

4 Assimilation of ASCAT winds

The assimilation of ASCAT wind observations from the Metop-A and Metop-B satellites was evaluated for the Irish domain. Typical data coverage plots for ASCAT observations are shown in Figure 5. A three-week period in April 2018 was used to validate the usefulness of these observations. No changes were made to the default settings relating to the assimilation of these observations.

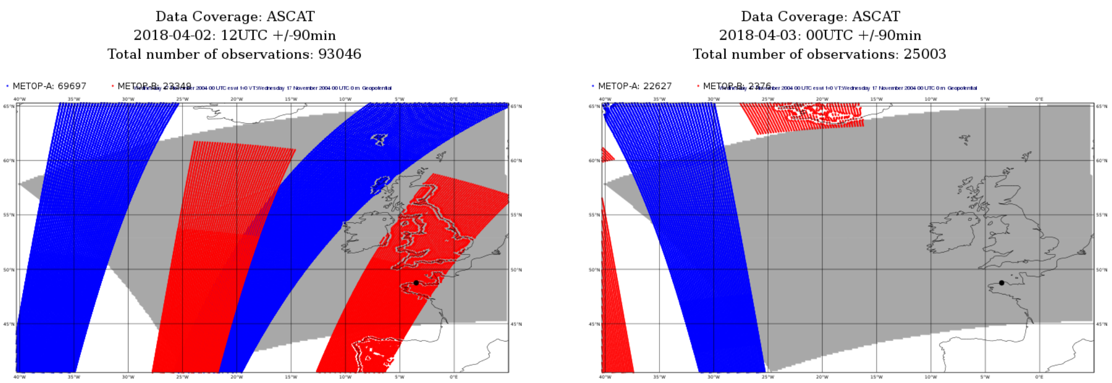

Figure 5: ASCAT data coverage for 1200 UTC April 2nd 2018 (left) and 0000 UTC April 3rd right. The operational HARMONIE-AROME domain is shown in dark grey.

Forecasts produced (April 1st - April 19th) at 0000 UTC and 1200 UTC each day were verified against SYNOP and TEMP observations. Verification scores (mean bias and RMSE) for the period indicated a neutral impact on forecast quality when averaged over the test period. Figure 6 shows average scores for forecasts of MSLP compared with SYNOP observations and forecasts of geopotential compared with 1200 UTC TEMP observations.

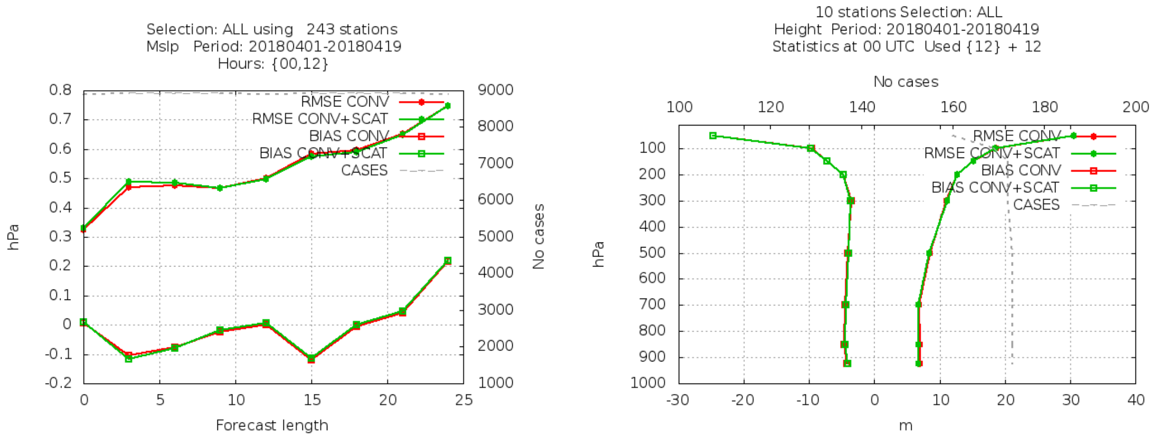

Figure 6: Verification scores comparing conventional only (CONV, red) and conventioal plus ASCAT (CONV+SCAT, green) experiments. MSLP forecasts from both experiment (left) are verified against SYNOP (no SHIP) observations. Forecasts of geopotential (right) are verified against TEMP (land only) observations.

The relative usefulness of ASCAT observations was further evaluated using the moist total energy norm approach, MTEN, as descibed in Stort & Randriamampianina, 2010. Data denial experiments were executed for two typical cycles (20180402 1200 UTC and 20180404 0000 UTC). The forecast sensitivity to the assimilation of different observation types (SYNOP including SHIP, AIREP, BUOY, TEMP and SCATT) is measured using the MTEN norm. Assuming forecasts produced by the control with all observations assimilated, MTEN values provide a measure of the negative impact of the denial of each observation type. For 1200 UTC (Figure 7 left) MTEN values suggest that ASCAT observations are as important as AIREP observations. For 0000 UTC, with fewer ASCAT (and AIREP) observations, forecasts are less sensitive to the denial of these observations. The assimilation of ASCAT observations was implemented operationally with the introduction of IREPS.

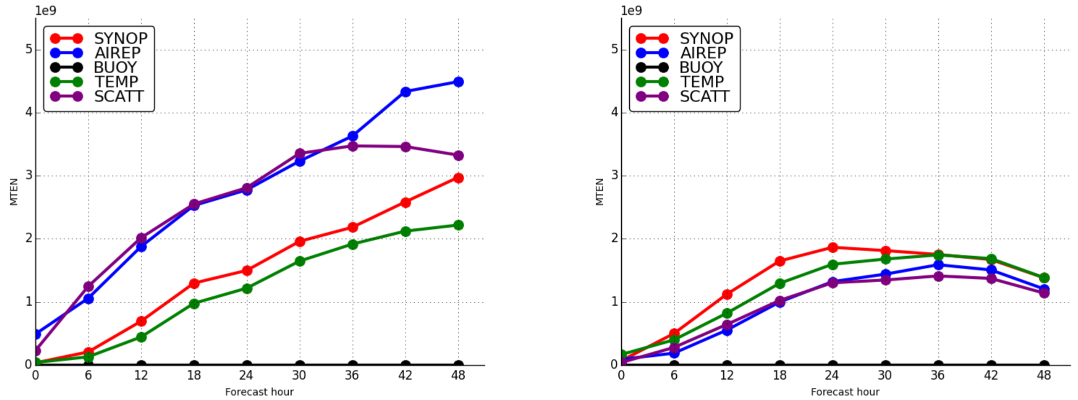

Figure 7: MTEN for forecasts based on data denial experiments for 20180402 1200 UTC (left) and 20180403 0000 UTC (right). SYNOP (red) indicates SYNOP observations have not been assimilated, AIREP (blue) and so on.

5 Postprocessing

Postprocessing of 2 m air temperature is done by downscaling the HARMONIE-AROME data to a 500 m grid with orographic correction from HARMONIE-AROME orography to a 60 m DEM over the island of Ireland. Further adjustment is then done by use of a Kalman filter on observed temperatures followed by kriging with a 30 km influence radius. These data are made available for verification with some measure of success seen. Figure 8 shows the effect of Kalman filtering on points which contributed to the adjustment (right) and the effect of orographic correction on points which did not contribute to the Kalman filter (left).

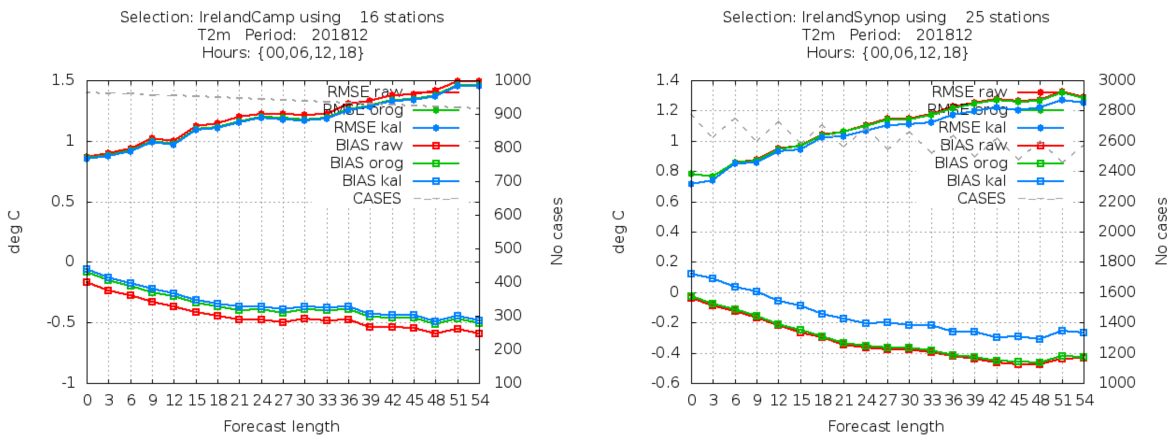

Figure 8: Point verification of orographic correction (left) and Kalman filtering (right). Parameter shown is 2 m temperature. Raw forecast is shown in red, orographic correction in green and Kalman filter in blue.

Rainfall is upscaled by statistical analysis of a 7x7 gridbox producing 20, 50 and 80th percentile figures.

Postprocessed data is used to drive a point forecast system accessible at `https://www.met.ie`.

6 NWP developer/user Working Group at Met Éireann.

In March 2018 we held a workshop to exchange knowledge and enhance communication between users and developers of NWP at Met Éireann. Since then we have held monthly meetings which involve discussions on successful and unsuccessful HARMONIE-AROME forecasts, known issues in the model, model evaluation and verification, what is required to make a model operational, physical parametrizations, the IREPS ensemble and many other topics. Feedback from NWP users (i.e. forecasters at Met Éireann) has been very positive and overall the meetings have vastly improved the flow of information and feedback between the two groups.

Figure 9: Some of the topics discussed at the NWP user/developer monthly meetings at Met Éireann!

7 MÉRA - Met Éireann Reanalysis

The production of the Met Éireann regional reanalysis (MÉRA, Whelan et al., 2018) is still ongoing. We currently have output spanning 1981 to February 2018. MÉRA production will cease later in 2019 when ERA5 supercedes ERA-Interim and ECMWF stop the production of ERA-Interim.

A successful workshop for users and stakeholders of the MÉRA dataset was held in May 2018 (`https://www.met.ie/science/events/mera-workshop`) and consisted of 15 talks on topics ranging from wind/solar energy to potato and tomato blight to air quality monitoring. The workshop attracted speakers from Canada, the UK and the Netherlands. Extended abstracts have been published in Gleeson and Whelan, 2018. A second workshop will be held on May 2nd 2019.

An analysis of the global radiation outputs from MÉRA is included in Nielsen and Gleeson, 2018 and an analysis of extremes of winds and precipitation is presented in Whelan et al., 2018. There are currently over 200 known users of the dataset across Europe and North America. Some preparations will be made this year regarding the production of an updated reanalysis for Ireland. Ideas include the use of ERA-5 boundaries, improved use of observations similar to the CARRA (Copernicus Arctic Regional Re-Analysis) project, coupling to ocean and wave models, a greater focus on surface processes.

Figure 10: First MÉRA Workshop held in May 2018.

8 Summary and Outlook

The past year has seen many operational NWP developments that have put Met Éireann in a better position to provide the best short-range forecasts of high impact weather for the Ireland. The use of 3D-Var and the assimilation of non-conventional observations coupled with the implementation of a high resolution EPS would not have been possible without the scientific and technical developments undertaken by HIRLAM-C, ALADIN and Météo France. Met Éireann's operational NWP capabilities will be enhanced further with future collaboration and cooperation. In 2018 Met Éireann signed a memorandum of understanding, along with 9 other European countries, regarding joining forces for operational weather forecasting. The new collaboration is known as United Weather Centres (UWC). Ireland will initially join Denmark, Iceland and the Netherlands to form UWC-West in 2022 and will merge with UWC-East (MetCoOp, Estonia, Latvia and Lithuania) in 2027. Further information on UWC is available in the following article by Dick Blaauboer and Jørn Kristiansen: https://www.emetsoc.org/uwc-short-range-weather-forecasts/.

A minor suite upgrade is planned in spring 2019. There will be an update to IREPS to introduce initial condition perturbations using the PertAna approach. This approach involves adding perturbations to the analysis of each ensemble member. The assimilation of AMSU-A, MHS and IASI radiance observations will be enabled. Tests have also been carried out with a quadratic spectral grid. No significant reduction in accuracy has been found, and so it is planned to implement this for the benefit of computational efficiency.

The assimilation of Mode-S aircraft derived observations retrieved from locally installed receivers and GNSS observations produced by E-GVAP will also be evaluated in the coming year. Nowcasting activities in Met Éireann have started with the recruitment of a dedicated Nowcasting scientist. Nowcasting techniques and the use of crowd-source observations will be investigated. The operational implementation of CY43 is planned for later in 2019. Following the decision by ECMWF Council to make the SAPP (Scalable Acquisition and Pre-Processing) system available by means of an Optional Programme, Met Éireann plan to make the system operational during 2019.

The coming year will bring many exciting challenges for the Irish NWP team!

9 References

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