Upgrade to Met Éireann's Forecast System April 2020

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Introduction

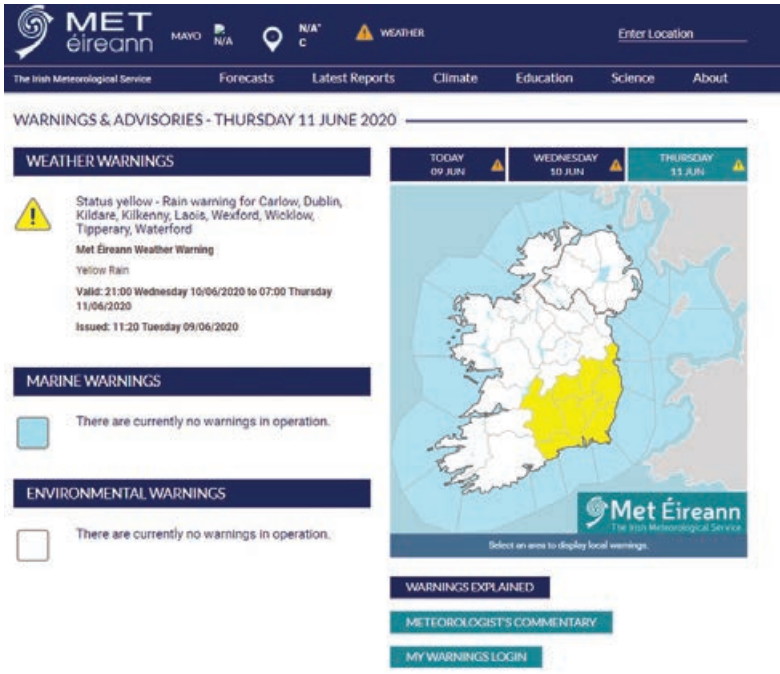
Met Éireann has launched a significant upgrade to the NWP system it uses for operational forecasts. This upgrade will increase the model data available to forecasters and open the way to providing earlier warnings for severe weather events. The system has been developed and tested by Met Éireann staff over the past several months, and it has been implemented as part of a new computing collaboration with the Dutch weather service, KNMI.

In 2018, Met Éireann developed its first ensemble-based NWP system, known as the Irish Regional Ensemble Prediction System (IREPS). Originally running twice per day, this system produced 11 forecasts (known as members) for weather conditions over the next 36 hours. On April 15th 2020, the IREPS system was upgraded to a 54-hour, 11-member ensemble which is run four times per day. This will help increase the frequency of model output available to forecasters which will help them monitor developing weather events and in turn increase the forecast length and warning times.

Weather and marine warnings now out to three days

Now that IREPS forecasts extend to 54-hours the duty forecaster in Met Éireann will have more confidence in the model output to extend warnings up to three days ahead. A new three tab display will enable the user to access the warnings over land and marine areas for: today, tomorrow and the day after tomorrow on https://www.met.ie/warnings.

Above is an example of a web display when Orange warnings are out for Tuesday and Wednesday but just limited to Yellow for Thursday. So when the user selects Thursday they get the appropriate warnings for that day only. This should go a long way to reduce people's confusion when there are multiple warnings in operation.



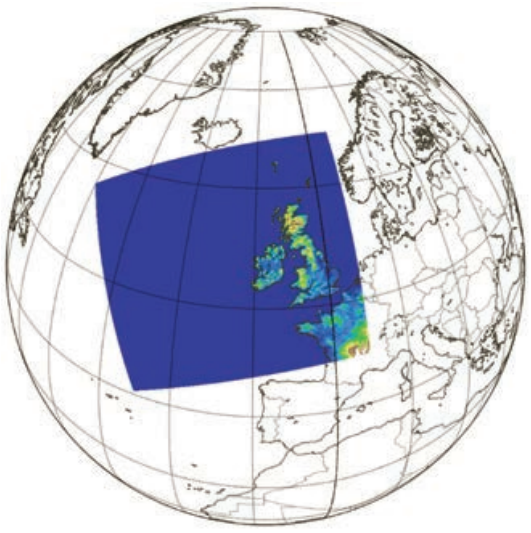
Technical details

Due to the vast amounts of calculations and data that must be processed to simulate the atmosphere large high performance computing (HPC) systems are required to run NWP models with the necessary accuracy and timeliness. Met Éireann uses computing resources on the HPC system of the European Centre for Medium Range Weather Forecasts (ECMWF) to run its NWP models. To meet the additional computing resources required to realise the latest upgrade to IREPS, Met Éireann has established a collaboration with the Dutch national weather service, KNMI. The newly acquired resources on the KNMI HPC system have been combined with the existing resources at ECMWF, providing enough computing power to run the enhanced system.

▲ *KNMI Supercomputer has a capacity of 50 trillion calculations/sec (50 teraflops). HARMONIE requires around 3 quadrillion calculations.*

IREPS is an ensemble which uses the HARMONIE-AROME model configuration (version 40h1.1) of the shared ALADIN-HIRLAM NWP system (hereafter HARMONIE-AROME). It consists of 10 ensemble members with 1 control member. The control member and the 10 ensemble members produce 54-hour forecasts and run four times daily at 00 Z, 06 Z, 12 Z, and 18 Z. IREPS runs with a horizontal grid spacing of 2.5 km, a spatial extent of 1000 x 900 grid points (see figure below), and 65 vertical levels. Both conventional (observations from weather stations, ships, buoys, balloons and aircraft) and scatterometer (satellite wind data) observations are assimilated into the model.

The ensemble members are constructed using a combination of initial and boundary condition perturbations and perturbations applied to surface parameters in the model. The initial and boundary condition perturbations follow the Scaled Lagged Average Forecasting (SLAF) technique whereby older boundary conditions valid at the current time are perturbed by a scaling factor which depends on their age with respect to the current time. Currently this initial and boundary condition data comes from ECMWF's Integrated Forecasting System (IFS)-HRES. However, using this data means the number of perturbed members is limited in the SLAF configuration and thus investigations are currently under way into moving to a system whereby initial and boundary conditions are supplied by IFS-ENS. This allows for a far larger number of potential ensemble members.



▲ *The geographical area over which Met Éireann runs its operational NWP forecasts is highlighted in colour.*

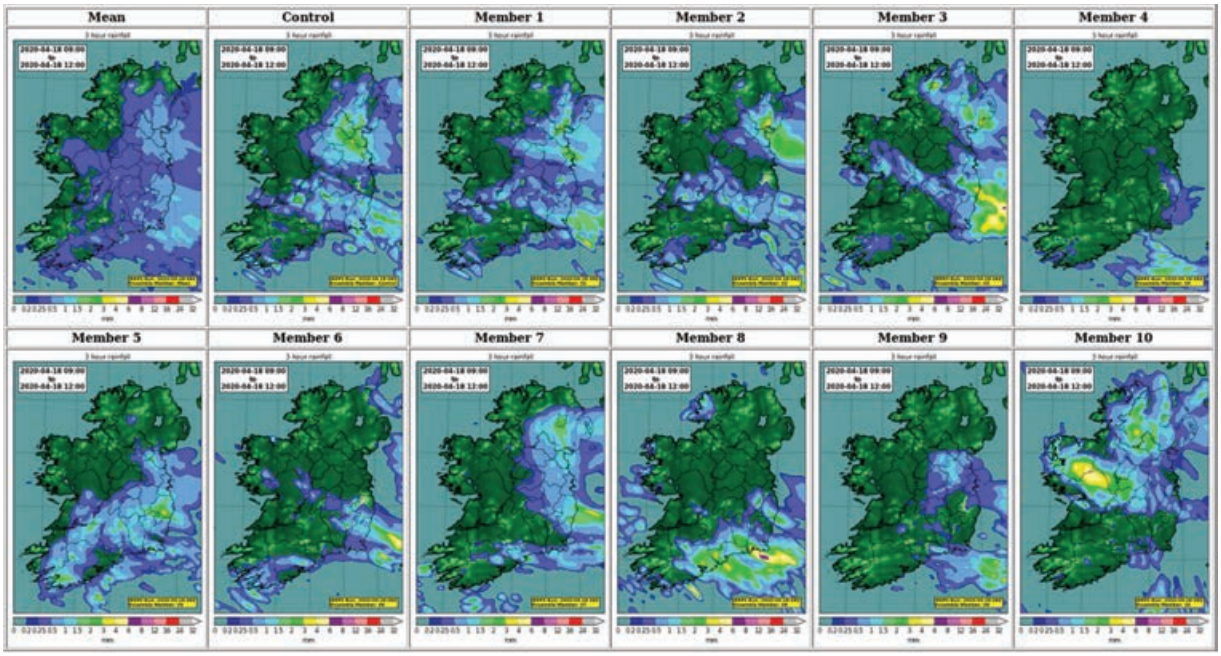
Surface perturbations are applied to some variables within the surface parameter code and in model initial conditions such as sea surface temperature and soil moisture. The perturbations are stochastic and clipped at upper and lower bounds in order to maintain physically sound values for the perturbed parameters. The stochastic nature of these perturbations accounts for uncertainty related to energy transfer from the model surface to the planetary boundary layer.

Running such a system 4 times daily produces a phenomenal amount of data. In order to reduce data transmission times and data storage needs, only high-impact parameters are currently produced for the perturbed ensemble members (e.g. wind gusts, precipitation, lightning, temperatures). This also allows for a rapid dissemination of files to Met Éireann and IREPS products are generally available within 3 hours of run time.

To summarize: The observations (initial conditions) and the model are not perfect. Small errors in the initial conditions of a forecast grow rapidly and affect predictability. The ensembles can provide forecasters with an objective way to predict the skill of a forecast and to estimate the most likely scenario. This will improve forecasts, warnings and enhance support for impact-based decision making for weather events and contribute to the safety of citizens and property.

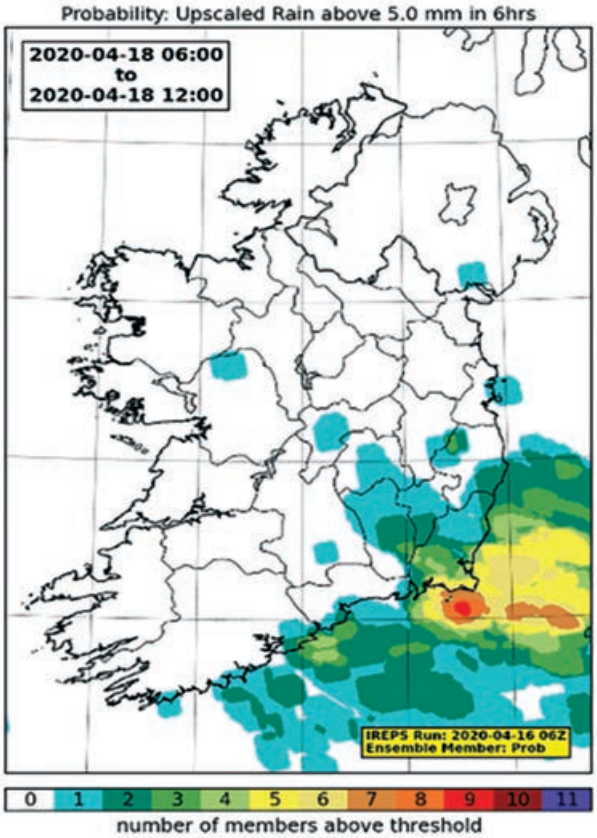
What does output from IREPS look like?

The output of an ensemble prediction system may be displayed in many ways, each with their own purpose. Plots of all members are displayed side-by-side (called "postage stamps") to give an indication of the spread in the range of possible solutions over a large area at a given time. In the above



▲ *Postage stamps from the 06 Z IREPS on 16th April 2020 showing rainfall predicted up to 54 hours later - between 09 Z (10:00 local) and 12 Z (13:00 local) on the 18th April 2020. All eleven members (1 control + 10 perturbed) are plotted, as well as their mean.*

image, postage stamps for the 06 Z forecast from 16th April indicate rainfall is likely to occur in the south-east, but the north-east is more uncertain with some solutions suggesting relatively dry conditions.



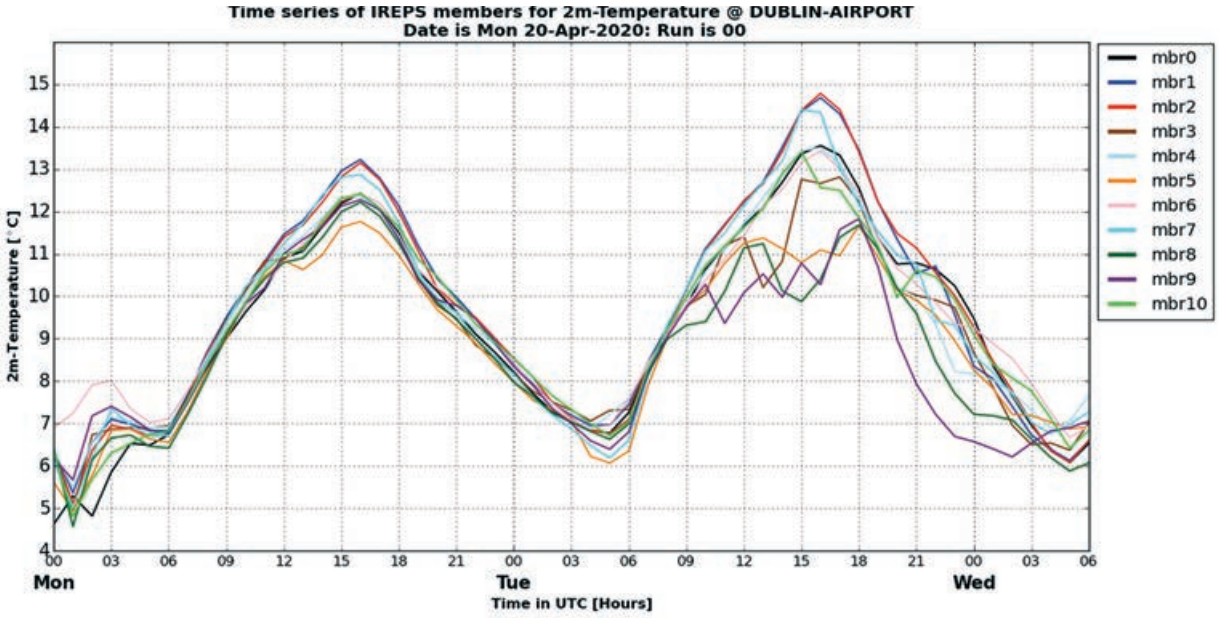
▲ *A pseudo-probability plot for rainfall totals exceeding 5 mm in a 6 hour window. The raw data has been upscaled to 5x5 grid points to avoid the double-penalty issue seen with high-resolution ensemble prediction systems.*

Another method combines all members together to form a single pseudo-probability plot based on a threshold. In the image below, the number of members exceeding 5 mm of rainfall in 6 hours are counted, giving an indication of the probability of this threshold being exceeded over the area plotted.

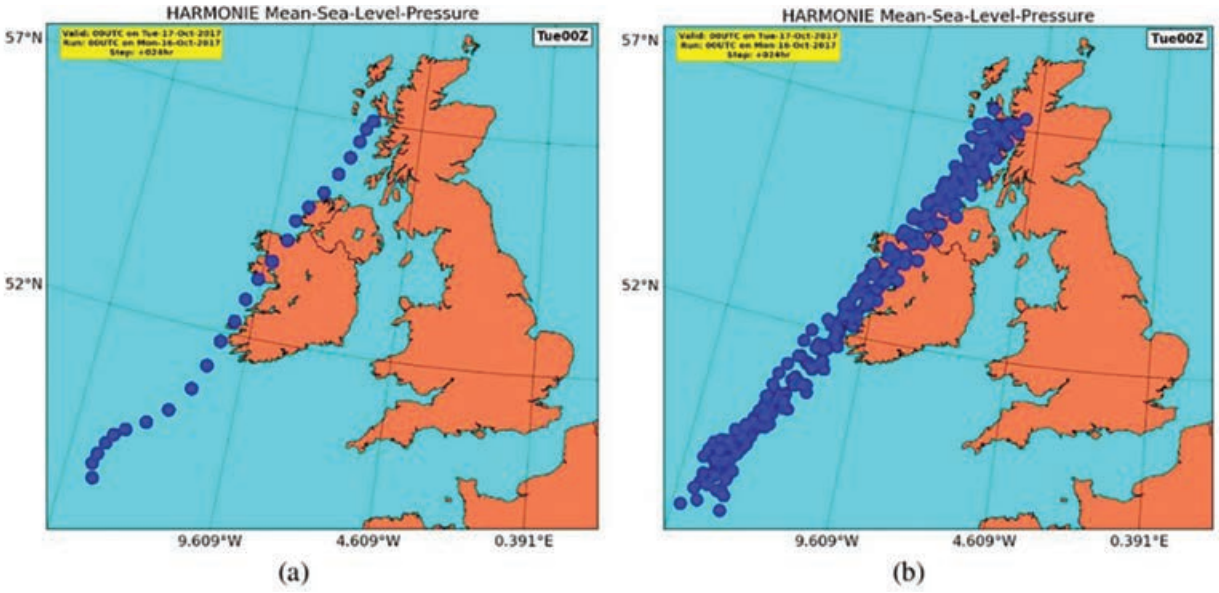
Yet another method is the use of meteograms. Here, a time-series plot is produced for a specific parameter at a single location to visualise how each of the ensemble members progress. This gives an indication of the spread, and identifies “clustering”, where several members may bunch around a particular solution.

Case study 1: Ophelia Monday 16th October 2018

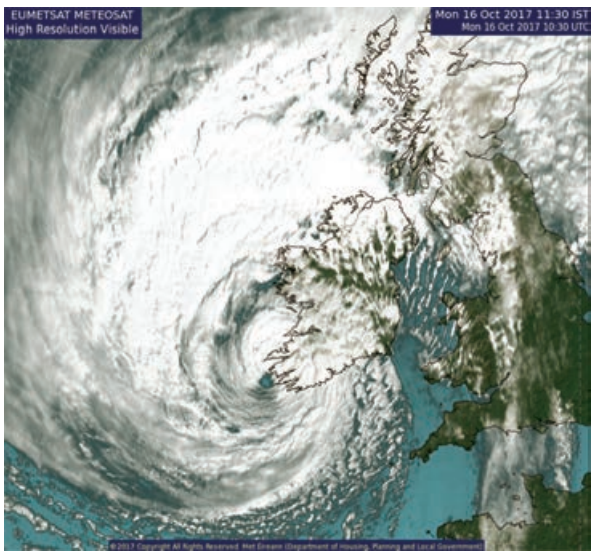
Prior to Ophelia only the deterministic forecast (figure a) was available from Harmonie. The track of Ophelia was re-run using the 10-member ensemble system (b). While the deterministic track was very close to the observed track, had the IREPS been available 54-hours ahead it would have given more certainty to the forecasters particularly in helping to provide a longer lead-in time in the issuing of the Status Red wind warnings.

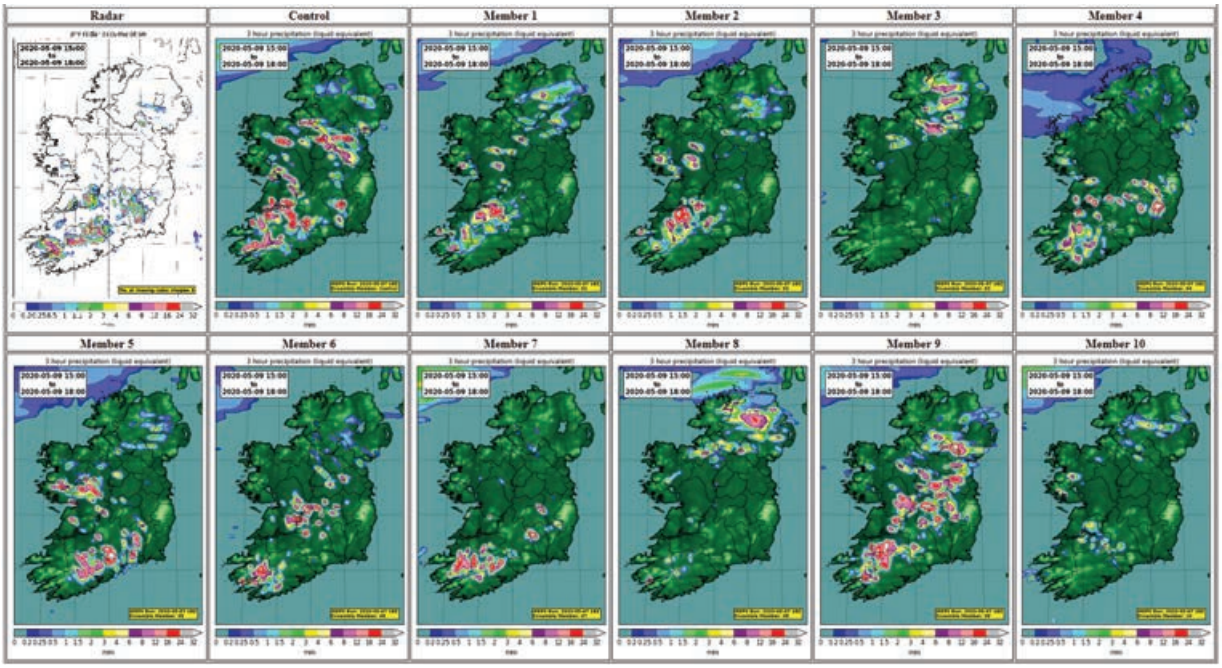


▲ *A meteogram time-series plot demonstrating the evolution of the temperature forecast at Dublin Airport for each of the 11 members of an IREPS forecast.*



▲ *(a) Projected track of the central low pressure of Ophelia over a 24-hour period from the operational run of HARMONIE-AROME at 0000 UTC on the 16th of October.*
(b) Projected track of the central low pressure of Ophelia over the same period for each of the ensemble members of IREPS – this illustrates the confidence we could have in the track of Ophelia.





Case study 2: Thunderstorms, Saturday 9th May 2020

Saturday the 9th May was a warm, humid day with temperatures up to 24 degrees C. Thunderstorms developed in the afternoon and hail and waterspouts were observed. The white map of Ireland shows the afternoon radar on the 9th showing intense showers/thunderstorms. The other 11 green maps are the showers as forecast by our new 54-hour IREPS from a forecast on the evening of Thursday the 7th, each one being a possible outcome. The overall IREPS forecast was judged to be excellent. However the 10 ensemble members show the different locations possible, illustrating how difficult it is to pinpoint exactly where showers will develop and how difficult it still is to give thunderstorm warnings for exact locations two days ahead.

You can listen here to Dr Rónán Darcy and Dr Alan Hally talking about setting up IREPS and its benefits for weather forecasting:

https://www.met.ie/cms/assets/uploads/2018/10/IREPS.mp4?_=1

Further plans to 2023

The upgrade to IREPS is thanks to the development of the system by our Met Éireann NWP team led by Eoin Whelan and the substantial installation and testing work performed by them over the last several months. In addition, personnel from Technology, Forecasting, and Business Services Division were involved in implementing the necessary technical changes and in managing the agreements and approvals required for our collaboration with KNMI.

▲ *Alan Hally, Liz Walsh and Noel Fitzpatrick discuss the wonderful complexities of weather forecasting in the Met Éireann Podcast (monthly).*

The next stage in Met Éireann's HPC projects will see us collaborate with Denmark, Iceland, and the Netherlands to develop a common numerical weather prediction system. Known as UWC-West, this project is due to go operational in 2023 and preparations are well underway with most non-operational staff in Met Éireann remote working.