Application and Verification of ECMWF Products 2019

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1.   Summary of major highlights

ECMWF output is widely used by the Met Office at many timescales, especially the week 2 period where the Met Office is particularly dependant on ECMWF output. The heaviest users of ECMWF output are the Chief and Deputy Chief Operational Meteorologists, who provide forecast guidance across the organisation, primarily for the UK but also for many other areas around the world and hydrometeorologists at the Flood Forecasting Centre. ECMWF output also forms part of 'BestData', a multi-model blend producing site-specific forecasts available, for example, on the Met Office public website. Meanwhile, the Met Office continues to be actively engaged in producing some novel and innovative tools to help operational meteorologists visualize ensemble output.

2.   Use and application of products

2.1   Direct Use of ECMWF Products

At the Met Office, ECMWF output is used alongside the Met Office's own model suite which includes hourly-cycling, convection-permitting deterministic and ensemble output (respectively UKV and MOGREPS-UK), the global model, run 4 times a day with horizontal resolution of approximately 10 km and an 18 member ensemble, MOGREPS-G.

Visualization of ECMWF output by operational meteorologists is via a number of mechanisms, primarily ecCharts and ingestion of a subset of ECMWF HRES into the Visual Weather forecaster workstations. Visualization is supplemented by use of ECMWF's main products web page, ecCharts and some internal web-based tools and diagnostics, for example a tool classifying ensemble members by synoptic type to objectively assess signals. This web-based tool is known internally as Decider and situations when it is of particular use includes identifying the threat of severe weather (Neal et al. 2016), or in downstream forecast applications to identify the risk of coastal flooding (Neal et al. 2018), fluvial flooding, or landslides. ECMWF ensemble data is also used to create multi-model ensemble products, for example in tropical cyclone forecasting. Meanwhile, ECMWF model data is blended with Met Office NWP to produce what is known in-house as 'BestData', a database of site-specific forecasts for thousands of sites used for many applications including, for example, forecasts on the Met Office public web site. In BestData, ECMWF data is the primary source of data for forecasts for week 2.

Regarding Met Office forecasting operations, over-arching, authoritative guidance for the shorter term (Days 1 and 2) is provided by the Chief Operational Meteorologist, who has ultimate accountability for forecast output and is responsible for operational delivery of National Severe Weather Warning Service (NSWWS) impacts-based warning service. The Chief Operational Meteorologist is supported, on shift, by three Deputy Chiefs. One focuses on UK weather on time scales from Day 3 onwards through the medium range and into monthly and seasonal time-scales. Another focuses on providing guidance on global forecast matters across multiple time-scales, operating in what is known as the Global Guidance Unit. Here customers include Met Office meteorologists working away from the UK, UK government departments, to whom support is provided during periods of severe weather and cross-European projects such as ARISTOTLE. Meanwhile, the third provides nowcasting guidance and support, mainly in the immediate build-up to and during severe convective events.

Other forecast teams, for example aviation, media and marine, then use this guidance to influence their own more customer-specific output. These forecast teams are spread across the UK with operational meteorologists based mainly at either UK military bases, the main Operations Centre in Exeter or in the Aberdeen office with a few meteorologists also embedded with clients, for example at some UK airports and transport agencies. In addition, there are a number of operational teams at locations around the world (e.g. Falkland Islands). The Flood Forecasting Centre, meanwhile, is a joint partnership with the Environment Agency set up in the wake of severe flooding over parts of the UK in 2007 and comprises of a team of dedicated hydrometeorologists providing advice on fluvial, pluvial and tidal flooding.

EFI and meteograms plotted with M-Climate are very popular with the Global Guidance Unit who require an efficient means of visualizing severe weather potential around the world and associated climatic context. Cyclone Database products (Hewson and Titley 2010) remain an effective means of visualizing extratropical cyclone details. Objective fronts and Dalmatian plots showing low pressure centres and intensity are two of the most popular elements used, especially in medium range forecasting. Meanwhile, diagnostics mentioned above classifying ensemble members by synoptic weather type are immensely useful in decision-making, allowing the operational meteorologist to quickly draw out the main themes and trends shown in ensemble output.

One novel product that has been developed during the last year by Andre Lanyon and Helen Titley is objective fronts probability maps with the Cyclone Database (Figs 1 and 2). These maps are created by counting the number of ensemble members which have fronts within one degree of any given point, and converting this to a probability field. For each lead time, a representative member can be highlighted by giving each ensemble member a score based on the position of their fronts on the probability field, the ensemble member with the highest score then being the 'representative member' for that lead time or across all lead times. Several forecast confidence measures are also calculated from the front probability information, which can be compared to both recent and all previous runs. The Cyclone Database is a Met Office system that is also used under licence at ECMWF. It is hoped that the current work at ECMWF to port to the latest Met Office python versions will help ongoing collaboration, e.g. facilitating multi-model ensemble front and feature plots.
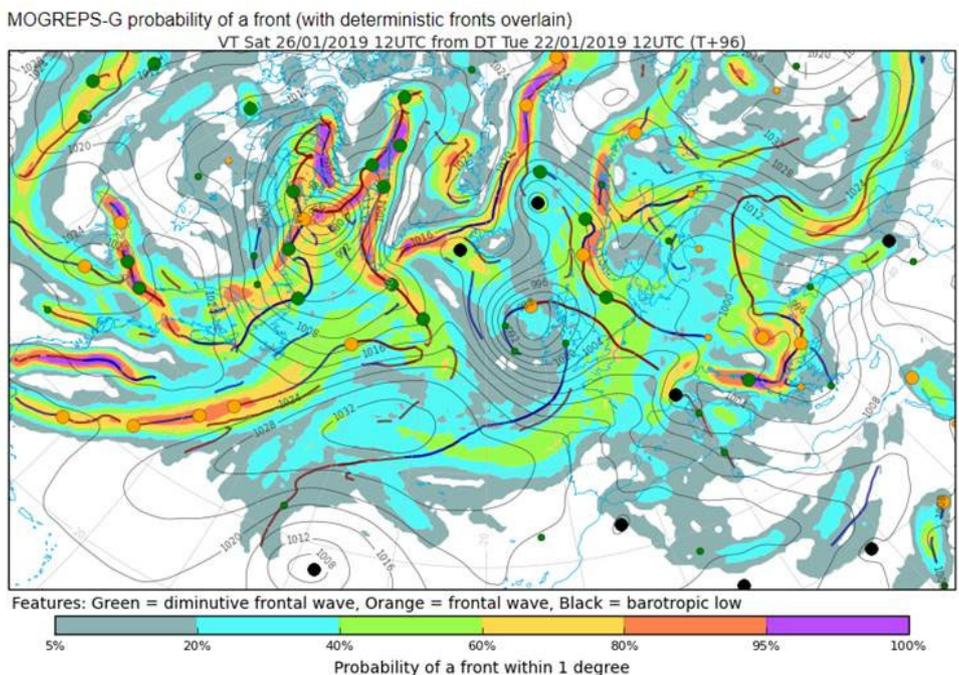

Fig.1   An example of the objective fronts probability maps in MOGREPS-G. Fronts from the deterministic model (represented by blue and red lines) can be seen to be an outlier compared to the ensemble consensus (coloured areas) over both the Atlantic Ocean and Northwest Europe.
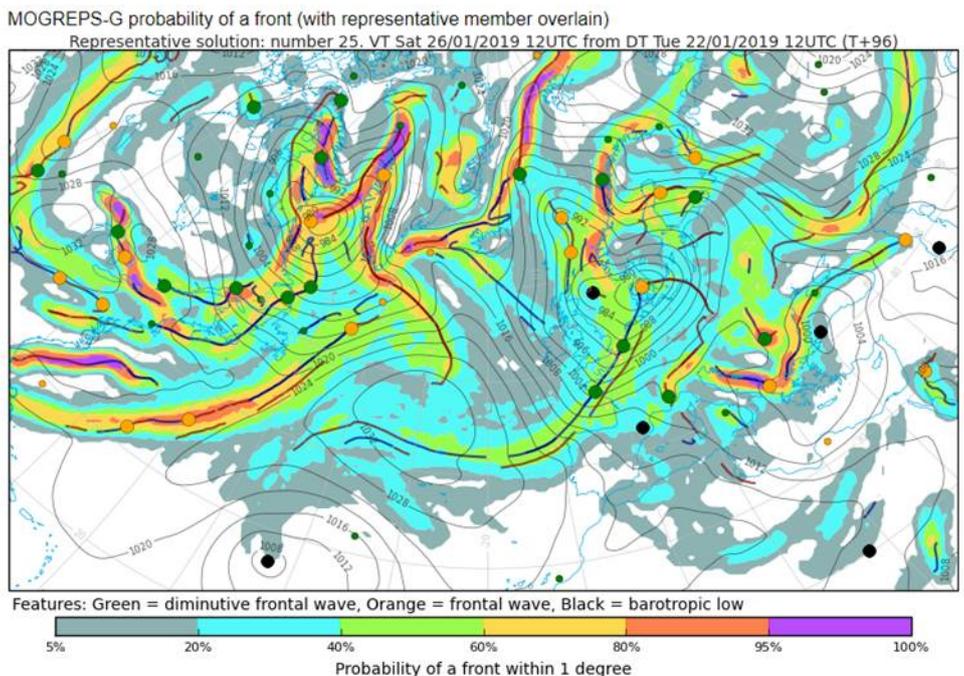

Fig.2   As Fig 1 but showing the most representative member from this particular ensemble run.

Field modification software (Carroll 1997) is used by the Chief and Deputy Chief Operational Meteorologists to produce a graphical best estimate of weather conditions over the UK, a process which draws on a number of different elements of NWP, including ECMWF. Severe weather will be accompanied by the issue of National Severe Weather Warnings Service Warnings (NSWWS). This impacts-based warning service is aimed at both the general public and resilience/emergency services and makes use of a colour-coded 4x4 matrix to communicate a sense of both likelihood and severity of weather conditions. The range of elements for which warnings are issued was extended in summer 2018 from the original five elements (namely wind, rain, snow, ice and fog) to also include thunderstorms and lightning. These warnings can be issued out to seven days ahead. ECMWF data is used alongside Met Office data in the consideration of NSWWS, and a web-based tool using ensemble output, known as EPS-W (Neal et. al. 2014), can be used to generate first-guess warnings.

Regarding feedback on ECMWF initiatives, the vertical profiles tool has been an extremely welcome addition to ecCharts and much appreciated by the forecasting community at the Met Office. As for further development to this tool, the ability to perform Normand's point constructions on the HRES would be welcomed. The new extended range test products offer a novel and illuminating means of expressing the evolution depicted within the extended range ensembles and have been positively received. Feedback on products providing early warning for cold spells over Europe was submitted to Laura Ferranti during the winter whilst the stratospheric warning products provide a useful compliment to diagnostics from the Met Office's own seasonal model, GLOSEA5.

2.2   Other uses of ECMWF output

2.2.1   Post-processing
Nothing to add.

2.2.2   Derived fields
Nothing to add.

2.2.3   Modelling
Nothing to add.

3.   Verification of ECMWF products

3.1   Objective verification

A study was undertaken by Robert Neal, Ric Crocker and Thomas Bendall presenting the latest verification results for the Met Office's probabilistic weather pattern forecasting tool called Decider, using results from ECMWF, GEFS and GloSea5. Decider uses a set of 30 objectively derived weather pattern definitions produced by the Met Office (Neal et al. 2016) which represent climatological circulation patterns over the UK and surrounding European area.

The Decider forecasting tool assigns multiple ensemble members (forecast scenarios) from several global ensemble prediction systems to the closest matching weather pattern definition using this set of 30 weather patterns. Ensemble member assignments are carried out separately for each day in the forecast period, allowing short-lived/transitionary weather patterns to be identified. Forecast probabilities for each weather pattern are then based on the number of ensemble members assigned to each weather pattern definition. Probabilities for a reduced set of 8 weather patterns are derived by aggregating up probabilities from each of the 30 patterns, depending on which of the 8 patterns they are mapped to.

Weather pattern forecasts are verified against the Met Office global model analysis weather pattern assignment as defined at 1200 UTC daily. Four global ensemble models are verified. These are the ECMWF (15 day) and GEFS (16 day) models which cover the medium-range forecast period and the ECMWF (46 day) and GloSea5 (51 day) forecast models which cover the long-range forecast period. Results for the medium range (long-range) models are presented out to 15 (30) days to allow for an easier comparison between models which cover similar lead times.

Results are available for all run dates using a verification period from April 2016 to February 2019. This near 3 year verification period was chosen as it is the longest period available within the Decider forecast archive which covers all models. ECMWF (15 day) forecasts are available for over 8 years within the Decider forecast archive and results for this period highlight the sensitivity of forecast skill on the specific verification period used.
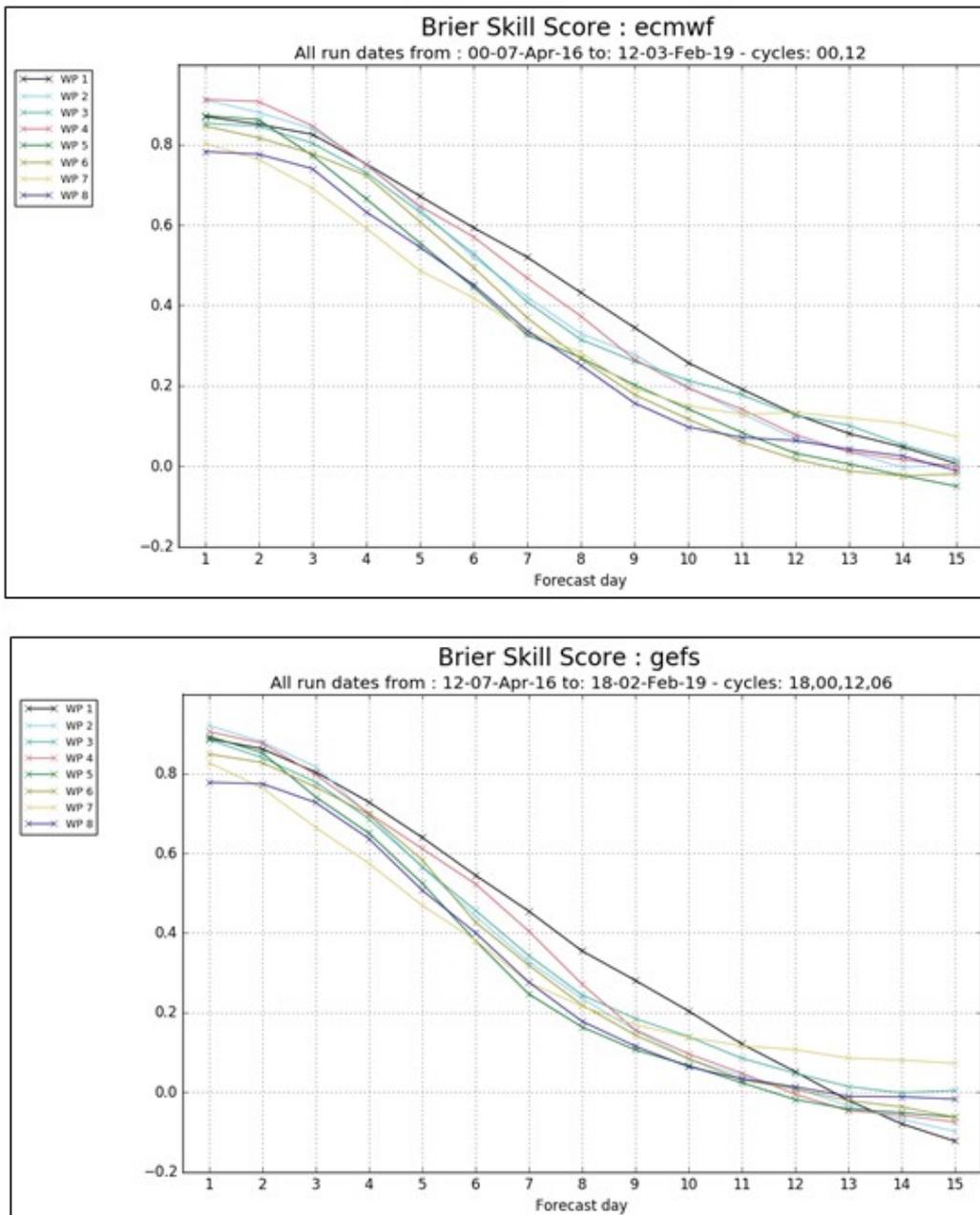
Fig.3   ECMWF (top) and GEFS (bottom) showing the Brier Skill Score for each weather pattern (using the set of 8 Met Office weather regimes) at each forecast lead time. Each weather regime also has a time-window of 3 days at each lead time (except Day 1 which use no time-window).

When comparing medium-range models with a 3-day time-window and using 8-regime groups, ECMWF has slightly better forecast skill than GEFS where there are similar characteristics in forecast skill for specific regime groupings between models (Fig 3). For example, WP1 (blocked –NAO) consistently performs the best and WPs 5 (Scandinavian blocking high) and 8 (anticyclonic westerly with Azores high extension) consistently perform among the worst.
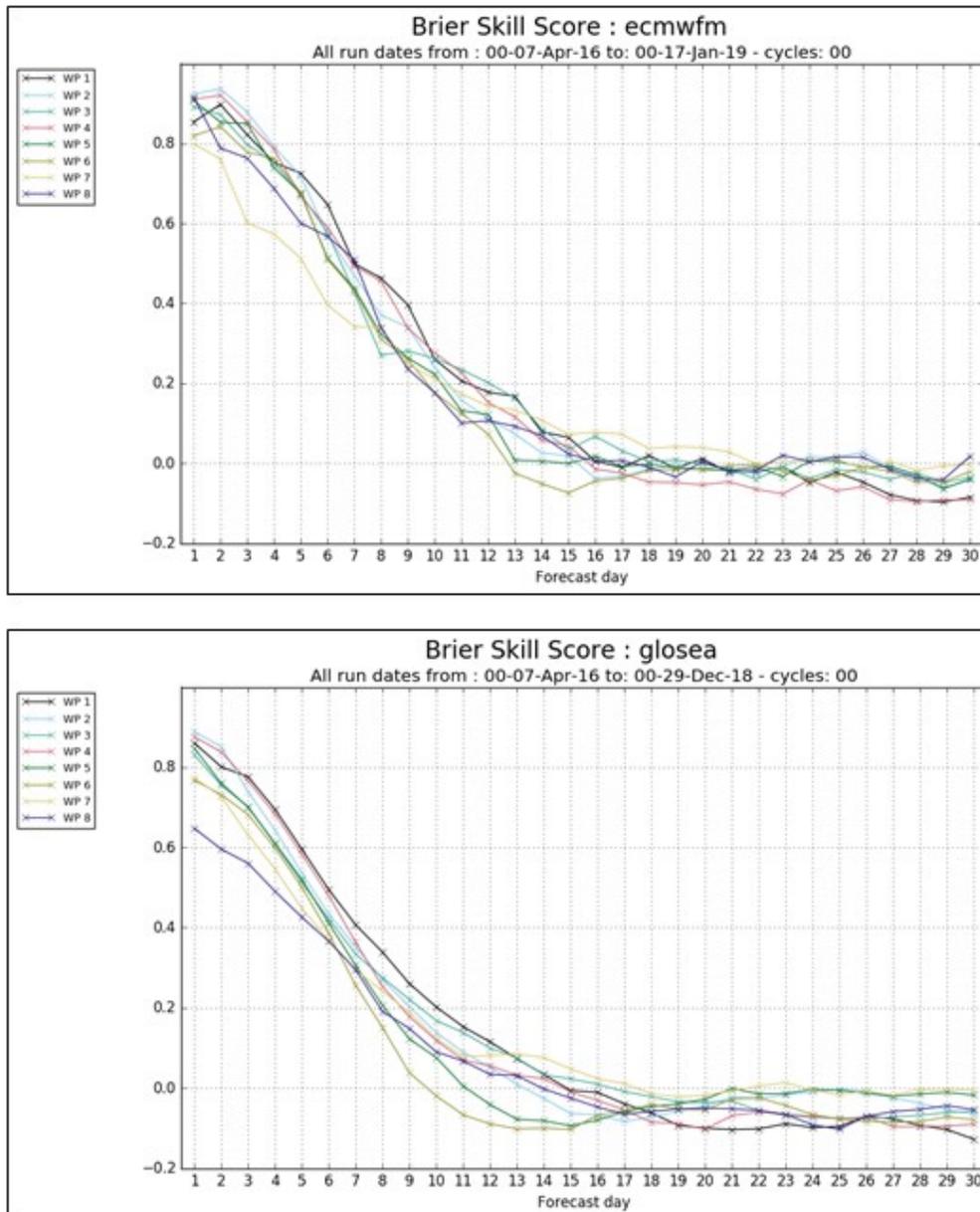
Fig.4   ECMWF (top) and GloSea5 (bottom) showing the Brier Skill Score for each weather pattern (using the set of 8 Met
           Office weather regimes) at each forecast lead time. Each weather regime also has a time-window of 5 days at each
           lead time (except Days 1 and 2 which use no time-window).

When comparing long-range models with a 5-day time-window and using 8-regime groups, ECMWF has slightly better forecast
skill than GloSea5 (Fig 4). Both models see forecast skill drop close to zero by day 15, but ECMWF has higher skill score values
(including better reliability and resolution – not shown) in the days leading up to this. However, this is not a like-for-like
comparison as ECMWF has 51 new members for each run, but only two runs per week, whereas GloSea5 has 4 new members
for each run which provide daily updates to a time-lagged (up to 40 member) ensemble. A benefit of the GloSea5 approach is
that the forecasts is likely to be less jumpy between successive runs, however, some of the older members which may include
an old forecast signal could be contaminating the forecast.

Key results of this study are:

1. ECMWF has better forecast skill than the GEFS at similar time ranges.

2. ECMWF has better forecast skill than GloSea5 at similar time ranges.

3. GloSea5 forecasts verify better when the number of time-lagged ensemble members increases gradually with forecast lead time.

4. Forecast skill is better in winter than summer for all models.

5. Changing the verification period does not affect the maximum lead time of useful forecast skill (around 15 days) but does change the regimes or weather patterns which verify the best.

6. The longer-range forecasts provided by ECMWF and GloSea5 have forecast skill which is similar to using climatology beyond 15 days. This is due to forecast probabilities often being very low at these time ranges which can lead to a weak forecast signal. However, results for circulation trend indicators (using fewer regime groups) perform slightly better at these lead times. In addition, case study analysis of the 2018 "Beast from the East" (Mylne and Neal 2018) shows that it is possible to get an accurate forecast signal 3 to 4 weeks in advance, although more case study analysis is need to be conclusive.

3.1.1 Direct ECMWF model output (both HRES and ENS), and other NWP models

Nothing to add.

3.1.2 Post-processed products and end products delivered to users

Nothing to add.

3.1.3 Monthly and Seasonal forecasts

Nothing to add.

3.2 Subjective verification

3.2.1 Subjective scores (including evaluation of confidence indices when available)

Nothing to add.

3.2.2 Case studies

Nothing to add.

4.   Requests for additional output

Feedback from the Met Office forecasting community is dominated by requests for faster performance of ecCharts, though it is also acknowledged that the Beta system being trialled offers some improvement here. One of the main foci for product development at the Met Office using ECMWF output remains the use of multi-model ensembles and tools to identify impacts. Significant work is underway to develop a multi-model blended probabilistic post-processing system and any products aiding this effort would clearly be of use. Other areas where input from ECMWF is sought include developing tools and products to monitor ongoing and developing hazards, improved or novel methods to get better statistics of extremes to contextualise weather events and further developments to reanalysis and/or reforecasts for climate context and calibration.

Regarding some more specific requests, feedback included adding 500 hPa geopotential height anomalies into the parameters offered in the 'Weekly anomaly - Extended range forecast' product, developing a means of comparing model time frames to current satellite imagery to aid model assessment and offering a facility to easily compare two or three models runs in a single product to assess differences between model runs and where they stem from. Meanwhile, hydrometeorologists at the Flood Forecasting Centre are investigating driving the NEMO surge model with ECMWF wind and pressure data to generate ECMWF-driven surge output to supplement the existing Met Office surge model. With this in mind, storm surge output would be welcomed by the Flood Forecasting Centre.

5.   Feedback on ECMWF "forecast user" initiatives

The creation of the Forecast User Portal is welcomed by the forecasting community at the Met Office. Of particular use are the pages on forecasting issues and changes to the forecasting system, and this portal has also proved a useful means of learning about new products, such as the new Point Rainfall product in ecCharts.

6.   References to relevant publications

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(7.   Structure of these Reports)

Nothing to add.