Application and verification of ECMWF products 2014

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1. Summary of major highlights

This year there are contributions on the use of ECMWF for air quality applications and the first-guess warning system EPS-W.

2. Use and application of products

2.1 Post-processing of model output

2.1.1 Statistical adaptation

Nothing specific to report.

2.1.2 Physical adaptation

Operational Air Quality Forecasting

The Met Office provides the UK national Air Quality forecast. This is delivered using the AQUM configuration of the UM. AQUM is an on-line limited-area forecast configuration of the Met Office Unified Model which uses the UKCA (UK Chemistry and Aerosols) sub-model. AQUM has been developed to fulfil two purposes: (i) the operational delivery of daily air quality forecasts and (ii) to enable atmospheric modelling studies to address scientific and air quality policy-related questions. Model LBCs are a combination of chemistry and aerosol data from the MACC (and previously GEMS) global model and meteorological data from Met Office global weather forecast model. Use of MACC LBCs has enabled the Met Office to benefit from the considerable investment in data assimilation of composition at ECMWF and has also offered savings as the Met Office has not needed to develop or maintain a global Air Quality model. Verification of AQUM against observations and MACC forecasts is carried out as a routine part of the daily air quality forecast. This demonstrates clearly the added skill that AQUM offers over the UK and has also enabled the Met Office to feedback to ECMWF regarding MACC performance and thereby enhance the collaborative nature of this work.

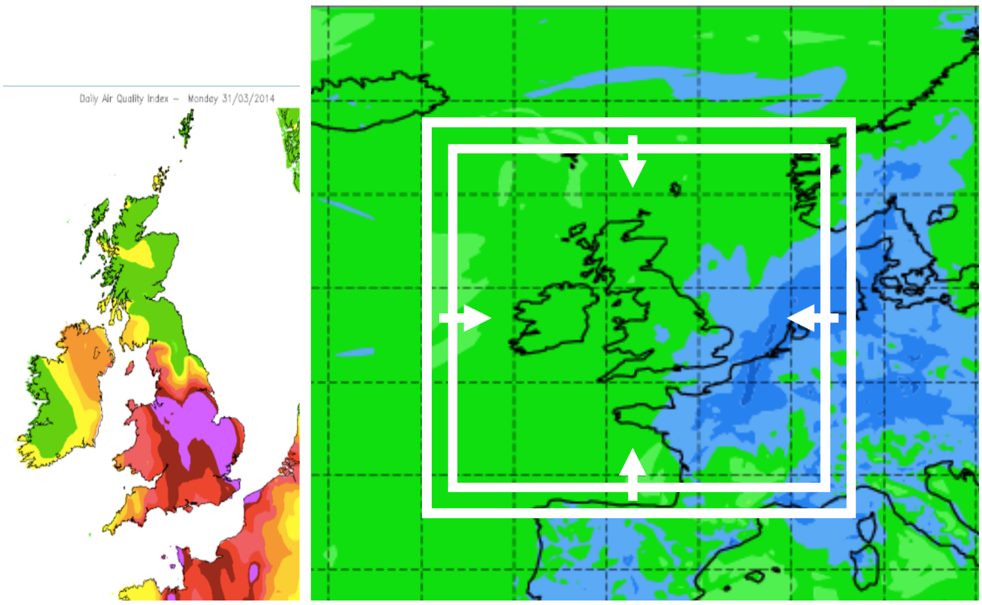

Fig. 1 : UK Air Quality forecast (left) and diagram of domain extent (right) and application of LBC.

Operational Dispersion Hazard Forecasting

The Met Office provides a range of national and international emergency response dispersion forecast services. These are delivered using NAME, the Met Office Lagrangian dispersion model, which operationally is driven by NWP data from the UM. Work is currently (2014) underway to add ECMWF deterministic forecast data to the NAME operational system thereby enabling the forecaster's the ability to select the most suitable NWP data for an event and also explore some of the effects of NWP forecast variability. Future plans will extend this to include NWP ensemble data.

Use of ECMWF data to model dispersion and deposition from Fukushima

In March 2011, the combined effects of an earthquake and a tsunami resulted in serious damage to the Fukushima Dai-ichi nuclear power plant on the east coast of Japan. Due to a combination of high release rates of radioactive material from the plant and precipitation, on the 15th March 2011 large amounts of radioactive Caesium-137 were deposited in Fukushima and neighbouring prefectures. Radionuclides deposited on the ground following a nuclear accident are an important contribution to the radioactive dose received by people in the area. Therefore any dispersion model which is to be used to provide activity fields for dose estimates must be able to provide a reasonable estimate of the amount and location of material deposited on the ground. To investigate the impact of the meteorology and the role of precipitation in setting the deposits ECMWF met data at a resolution of 0.125° by 0.125° was used within NAME to model the dispersion and deposition of Caesium-137 released from Fukushima Dai-ichi. The deposits predicted by the model run were compared to observed deposits and, as can be seen in Figure 1, the predicted deposits agreed well with the observed deposits. ECMWF meteorological data was also used to examine the sensitivity of the predicted deposits to the parametrization of wet scavenging within NAME. This work has been published in the Journal of Environmental Radioactivity (see reference below).

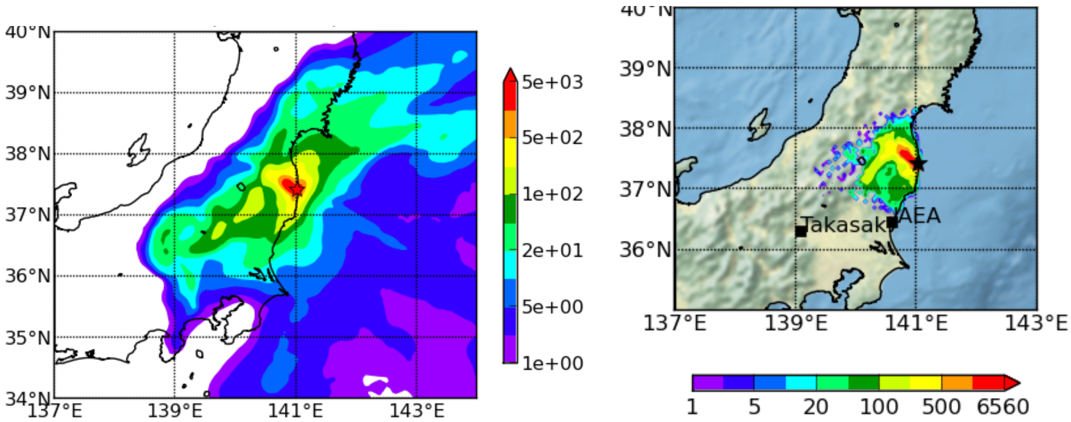

Fig. 2: Total (wet and dry) deposition of ^{137}Cs (in kBq/m^2) during March 2011 predicted using NAME model runs with ECMWF meteorological data (left) compared to observed deposits (right)

NWP resolved scales and the consequences for dispersion modelling

ERA Interim data has been used alongside MetUM data (of various resolutions) to assess the missing motions in the NWP data which lie in scale between the large-scale resolved motions and small-scale 3-dimensional turbulent motions. The information has been used to infer a suitable parameterisation for the Met Office's atmospheric dispersion model (NAME) based on the velocity variances and timescales of these missing mesoscale motions.

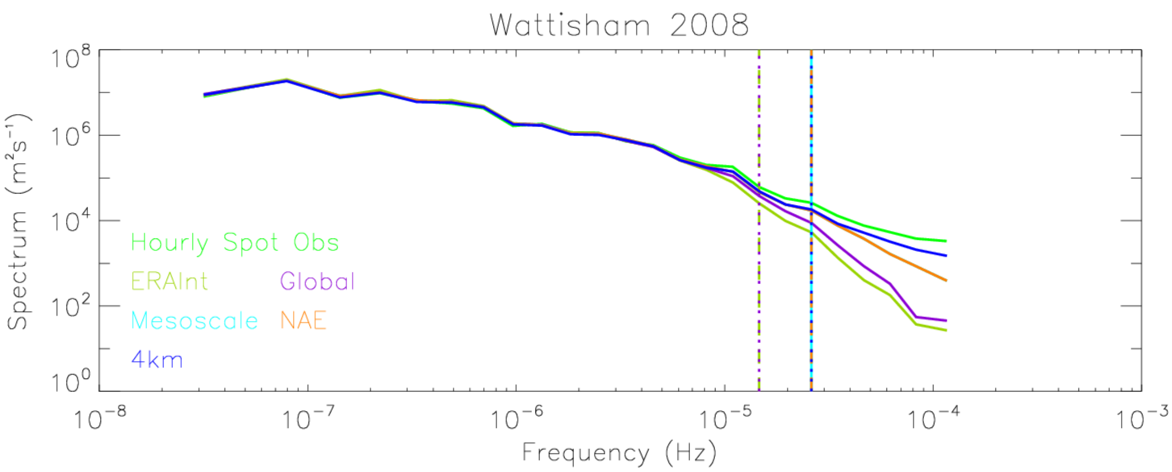

Fig. 3: Energy spectrum extracted from various NWP model configurations and observations for Wattisham over the entire year 2008.

2.1.3 Derived fields

An application of ECMWF ensemble output for warnings will be discussed in Section 3.1.3.

2.2 Use of products

Ensemble forecasting & 'Best Data'

The Met Office in-house system PREVIN (Predictability Visualisation) Ensemble Web Pages continues to receive ECMWF data via DART. This system is useful for identifying first order signals from ensemble data (e.g. summary maps).

The Met Office uses ECMWF data blended with Met Office model data to produce what it calls 'Best Data' for around 15,000 sites, approx. half of these are in the UK. The data being used includes: precipitation amount, screen temperature, 10m wind-speed and direction, wind-gust, dew point temperature, surface temperature, snowfall, total cloud amount, MSLP, min/max temperature. Our suite of models focuses on the first week of the forecast and the UK area in particular. However, we want to be in a position where ECMWF is the primary source for our week 2 forecasts, supplemented by other models where they add benefit.

The Best Data group receives and is looking to make use of other parameters such as convective/dynamic rain amounts, 100m U and V or model level data and wind speed forecasts at height. It is developing a gridded best data prototype using the following ECMWF data out to 7 days: 10m wind speed and direction, PMSL, maximum 10m gusts, total precipitation, total snowfall, 2m temperature, maximum and minimum temperatures.

An enhanced weather regime website has been developed by the Met Office and this uses ECMWF 500 hPa GPH, 10m U and V, PMSL, surface and 1.5m temperature, T850hPa out to 15 days.

Operational Meteorologists (general) & Guidance Unit

ECMWF products remain well-respected and are widely used along with output from other centres as a comparator against our own model output. The following ECMWF products are accessed via EC Charts:
ECMWF Global GRIB - Td, gph, height, Tmax, Tmin, WBPT, MSLP, P, RH, Specific Humidity, T, T 2m, Cloud cover, total precip, total snow, theta-w, CAPE/CIN, Vert Velocity, wind u, wind v (T+0 - T+240). Ensemble GRIB - Sig wave height, total precip, prob of precip, wind gust (T+0 - T+120). EC wave data both deterministic and ensemble is also used.

EC EFI output is frequently used along with EFI EPS meteograms, model climatology and the basic EPS meteograms for a wide variety of locations globally. Deterministic data from the EC website for various global regions provides useful information beyond T+144. EC tropical cyclone pages and database, 'Dalmation plots' and fronts animations are widely used for the guidance assessments.
EC Meteograms (both 10 and 15 day) containing max/min temperature, 10m wind speed and total precipitation (mm/6hr) continues to be used for a small number of Open Road customers.

The Guidance Unit look at a number of ECMWF products via the main website but also EC Charts (available to member states). There is also access to post-processed info via Met Office systems such as PREVIN. EC gridded data is also available and well used on Visual Weather. All of these are visualised but some are included in guidance. The actual data does not drive any products directly in the Guidance Unit.

Flood Forecasting/extreme weather

The EC Charts application is used extensively in the Flood Forecasting Centre (FFC) in the Met Office where ECMWF data in visual weather used as comparison against Met Office UM data. Precipitation and wind fields are of particular interest. The FFC also use EFAS products.

The ECMWF EFI output is also used and accessed both from the ECMWF website and EC Charts. ECMWF ensemble precipitation forecasts, wave data (deterministic and ensemble are used. ECMWF ensemble postage stamp forecasts are viewed from PREVIN pages and longer range anomaly maps. EPS meteograms are used when required alongside the EFI output to provide additional confirmation of severe weather.

Climate applications

The Met Office Climate Applications team are using products from the following ECMWF systems: VarEPS/monthly system, the seasonal system and EUROSIP. From these monthly rainfall and temperature products for East, West and southern Africa are made available to African collaborators. ECMWF and EUROSIP visualised seasonal forecast products are also used to help generate consensus seasonal outlooks at Regional Climate Outlook Forums in East, West and southern Africa. The main products used are probabilistic rainfall products and ENSO plumes. Digital forecast and hindcast data from the ECMWF system is also used in capacity training and forecast generation.

Monthly and seasonal forecasting: Public Weather Service (PWS)

ECMWF data is used to generate products (e.g. the monthly outlook) for the UK and other regions globally with predictions made weekly. Parameters used: Temp mean, Temp max, Temp min, precipitation, windspeed (10m), PMSL and Z500.

The EC Var EPS/monthly system is utilised for monthly forecasts for Africa (International Aid Programme)
The 3 month outlook (primarily for contingency planners) uses data for the UK. For other regions, including Africa etc., products (related to tropical storm activity over the next 6 months) are created using multi-model combinations. The EC seasonal pages are also used to compare with other Met Office outputs.

Future requests for new and enhancement of existing products and data

Met Office users of EC data and services have the listed the following items which they believe would add value to the data and products they currently receive from the Centre:

- Severe weather products to help provide longer lead times (3-5 days)
- Access to higher resolution EC Website data
- Use of high resolution for **regime change:** 6-15 day lead times.
- Additional thresholds/parameters to support weather regime products
- EC Charts - Omega equation components, precip rates
- More EC Fields on SWIFT/VISUAL weather
- Training for operational meteorologists on how EC products can be used to assist their work
- Extend windstorm concept to cover rainstorms and snowstorms
- Postage stamps type displays for other parts of the world

3. Verification of products

3.1 Objective verification

3.1.1 Direct ECMWF model output (both deterministic and EPS)

Nothing to report.

3.1.2 ECMWF model output compared to other NWP models

The use of ECMWF analyses for gridded verification of fields such as mean sea level pressure, winds etc continues, with the analyses forming the basis for most of the evaluation of the new dynamical core of the Met Office Unified Model, ENDgame (Even Newer Dynamics) which went operational on 15 July 2014.

3.1.3 Post-processed products

Verification of probabilistic severe weather forecasts from the ECMWF medium range ensemble

Ensemble Prediction System first-guess Warnings (EPS-W) is a Met Office system which routinely post-processes ensemble data from MOGREPS and ECMWF using criteria from the National Severe Weather Warning Service (NSWWS). Recent verification results using the ECMWF medium range ensemble are presented here and cover the two year period from 1 March 2012 to 28 February 2014.

Due to sampling limitations associated with severe (and rare) events, a range of precipitation accumulation and wind gust thresholds have been verified. These range from the moderate threshold of 18mm in 24 hours and 35 knot gusts, to the more severe thresholds of 25mm in 24 hours and 45 knot gusts.

Verification is done on the UK county and unitary authority basis, with there being 147 such areas in the UK. EPS-W derives probabilities for an individual area by taking the 95th percentile of grid-point probabilities in that area. This means that a forecast probability applies to ≥ 5% of the area. Probability forecasts are placed into one of 10 evenly distributed probability bins (with an additional bin for all 0% forecasts) before verification takes place.

Forecasts have been verified against a Met Office 2km resolution analyses. An event is considered to have occurred in a county or unitary authority if ≥ 5% of the 2km resolution analysis grid-points meet or exceed the warning threshold in that area.

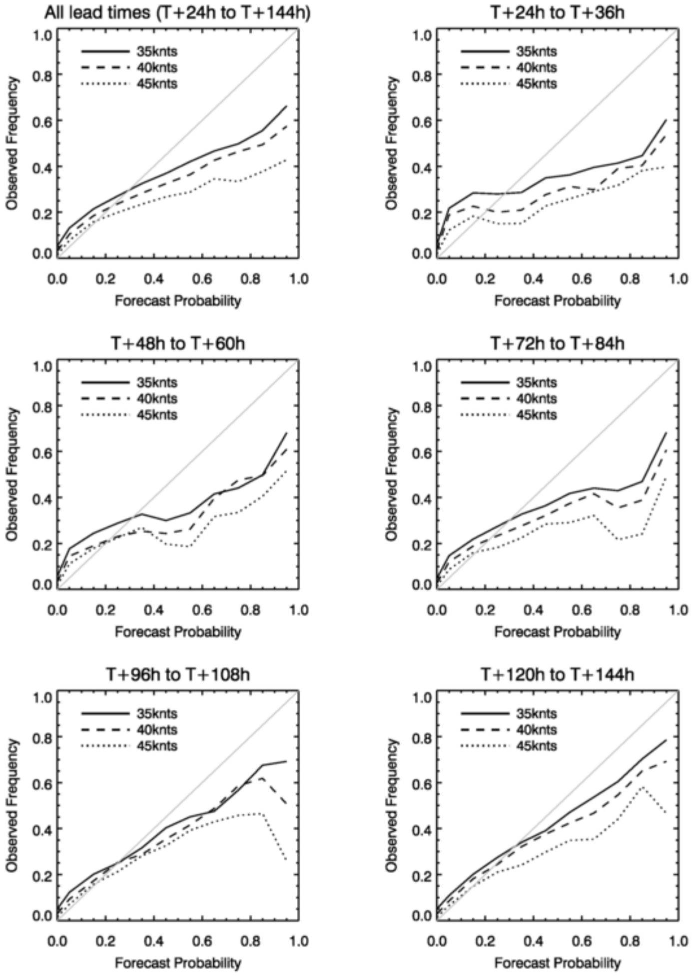

Fig. 4 ECMWF reliability diagrams for 10m wind gusts ≥ 35, 40 and 45 knots shown for all lead times combined and broken down into separate forecast lead times.

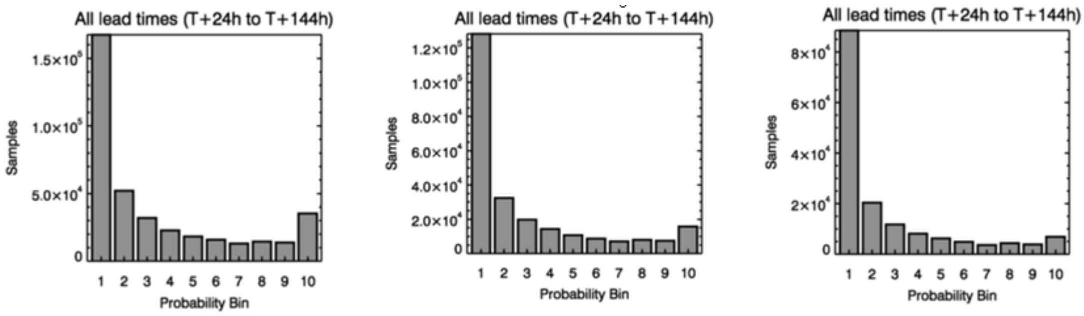

Fig. 5. ECMWF sharpness diagrams for 10 wind gusts ≥ 35 knots (left), 40 knots (middle) and 45 knots (right) for all lead times combined.

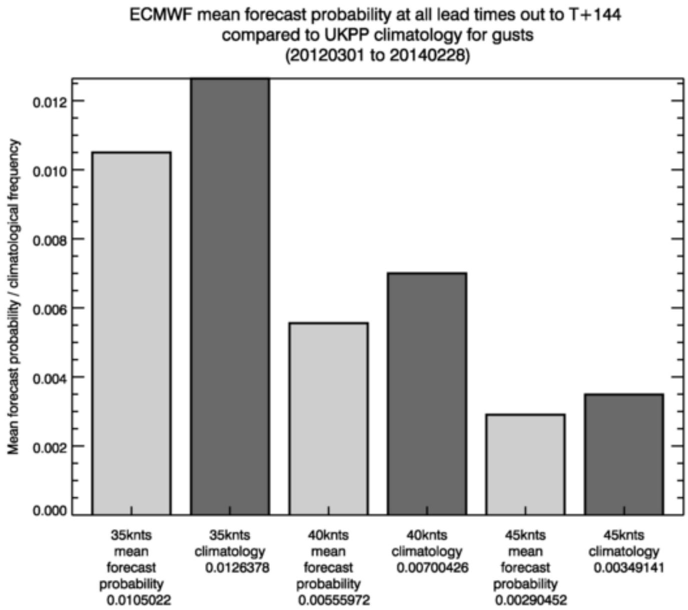

Fig. 6. ECMWF mean forecast probability compared to sample climatology for 10m wind gusts ≥ 35, 40 and 45 knots shown for all lead times combined and broken down into separate forecast lead times.

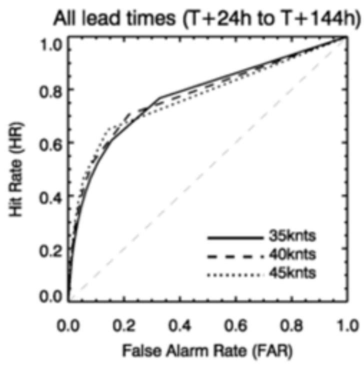

Fig 7. ECMWF ROC curves for 10m wind gusts ≥ 35, 40 and 45 knots shown for all lead times combined.

Reliability diagrams (Figure 4) show under-forecasting at the lower probability thresholds and over-forecasting at the higher probability thresholds. The lower wind gust thresholds (35 and 40 knots) appear closer to the diagonal at most probability thresholds and therefore may have better forecast reliability overall. Reliability improves with forecast lead time as ensemble spread increases.

The sample sizes (Figure 5) are typical for severe (and rare) events with there being plenty of low probability forecasts and very few medium and high probability forecasts. There is however a slight rise in samples for the very highest probability bin. A breakdown of samples with forecast lead time shows that these higher probability forecasts tend to occur at shorter lead times when the model is more confident and ensemble spread is lower (plot not shown).

In an unbiased forecast system the mean forecast probability should equal the sample climatology. However, Figure 6, which takes account of all samples over all lead times and counties, shows under-forecasting at all wind gust thresholds. These forecast biases will be heavily dominated by the performance of ECMWF at the lower probability thresholds where samples are very high (Figure 5).

The ROC curves (Figure 7) show curves well above the diagonal suggesting forecast skill, with the forecast system able to discriminate between events and non-events.

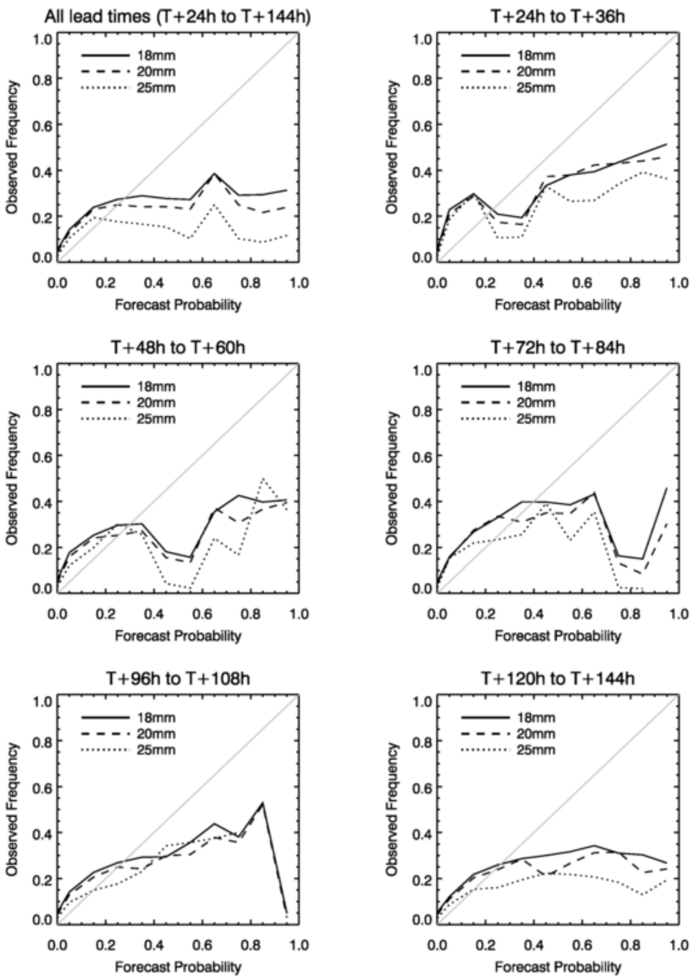

Fig 8. ECMWF reliability diagrams for 24 hour precipitation ≥ 18, 20 and 25mm shown for all lead times combined and broken down into separate forecast lead times.

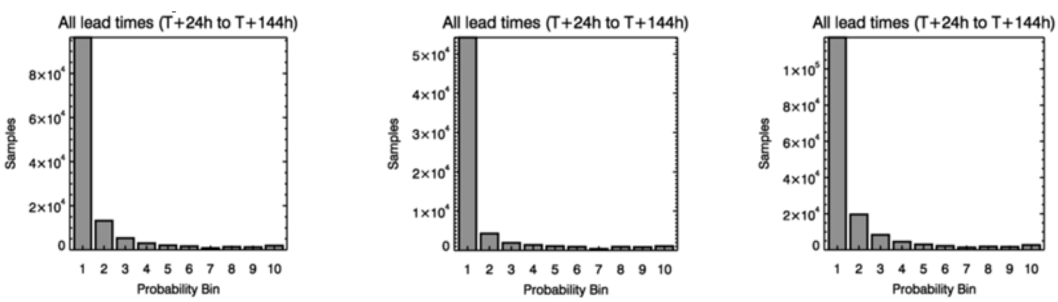

Fig 9. ECMWF sharpness diagrams for 24 hour precipitation ≥ 18mm (left), 20mm (middle) and 25mm (right) for all lead times combined.

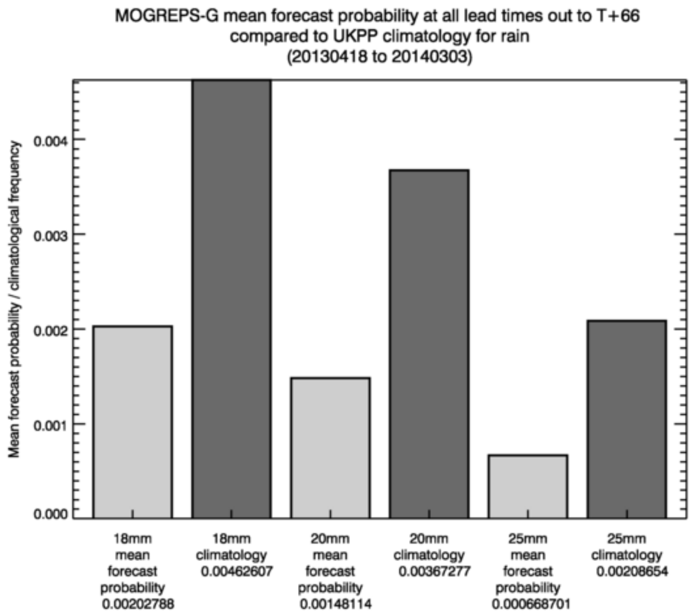

Fig 10. ECMWF mean forecast probability compared to sample climatology for 24 hour precipitation ≥ 18, 20 and 25mm shown for all lead times combined and broken down into separate forecast lead times.

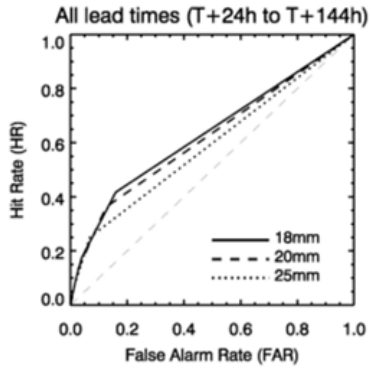

Fig 11. ECMWF ROC curves for 24 hour precipitation ≥ 18, 20 and 25mm shown for all lead times combined.

The reliability diagrams (Figure 8) show under-forecasting at the lower probability thresholds where sample are high and over-forecasting for probability thresholds > ~20% where samples are low. Lower precipitation accumulation thresholds have better reliability. Reliability improves very slightly with forecast lead time as ensemble spread increases.

The mean forecast probability compared to sample climatology (Figure 9) shows significant under-forecasting at all thresholds. This is in contrast to the reliability diagrams which show over-forecasting at most probability thresholds. However, given the low number of samples in the higher probability bins (Figure 9), the under-forecasting shown in Figure 10 is a fair representation of the overall forecast bias.

The ROC curves (Figure 11) show all lines just above the diagonal indicating forecast skill. Unlike with wind gusts (Figure 7), the lower thresholds have better forecast discrimination between events and non-events. The ROC areas are also much smaller compared to wind gusts forecasts, suggesting there is more skill at forecasting severe wind gusts than severe precipitation.

A range of wind gust and precipitation accumulation thresholds have been verified due to sampling limitations associated with the most severe (and rare) events. The most severe thresholds in particular have a very low number of samples and so these results should be interpreted very carefully.

Making confident conclusions about these results is difficult, but it has been shown that there is skill in forecasting both severe winds gusts and heavy precipitation. Wind gust forecasts tend to perform better than precipitation forecasts, with both parameters showing an overall under-forecasting bias.

3.1.4 End products delivered to users

Nothing to report.

3.2 Subjective verification

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

Nothing to report.

3.2.2 Synoptic studies

Rapid Assessment Reports (RAR) are intended as a concise and rapid assessment of a Global Model forecast error which is significantly larger than that normally observed. They are normally produced soon after the event. The intention is that they will provide:

- a description of the degree and nature of the error.
- a basis from which it may be judged whether further investigation is necessary.
- guidance on Global Model and MOGREPS-G performance
- case studies for suite upgades

Rapid Assessment Report 8 (Semple, 2014) documents an investigation into the forecast from 00UTC 13th June 2014 in which the Parallel Suite (PS) Global Model (PS34, ENDgame 17 km) is of significantly higher skill than the operational Global Model (GM, New Dynamics 25 km). The skill of the GM forecast is that of forecast bust.

Error assessments for the GM forecast show that the errors are associated with the difficulty in modelling an upper trough which is located near the Great Lakes at the forecast data time and that this upper trough is instrumental to the development of thesynoptic pattern across the whole of the North Atlantic and across the UK and also eventually on the change of weather regime from anticyclonic to more mobile westerly.

The investigation shows that the PS forecast more readily extends the upper trough early in the forecast resulting in a trough disruption in the western North Atlantic, whilst the GM forecast incorrectly maintains a more mobile upper trough and delays the disruption. The skill of the GM forecast in this case is such that it is 24 hours behind forecasts from the PS and also those from ECMWF and GFS.

Fig. shows the 00UTC 13th June T+72 250hPa gph errors over eastern North America, the North Atlantic and Europe for the GM, PS, EC and GFS. It is immediately clear from this comparison that the operational GM errors are significantly worse than any of the three other models for the upper trough over Nova Scotia at the verification time. The PS at this time not only shows a significant reduction in the magnitude of the errors relative to the operational GM but also shows greater consistency with the models from the other forecasting centres.

The assessment continues to consider the forecasts immediately after the PS success. Here it is found that the PS skill is significantly lower than that of the GM for a period of about 24 hours. The PS errors are found once again to originate from the model more readily amplifying the Great Lakes upper trough – this time erroneously. It is suggested that this may be an indication of a model characteristic for the new model configuration which it would not only be prudent to monitor but also to raise awareness of it’s possible existence for operational meteorologists.

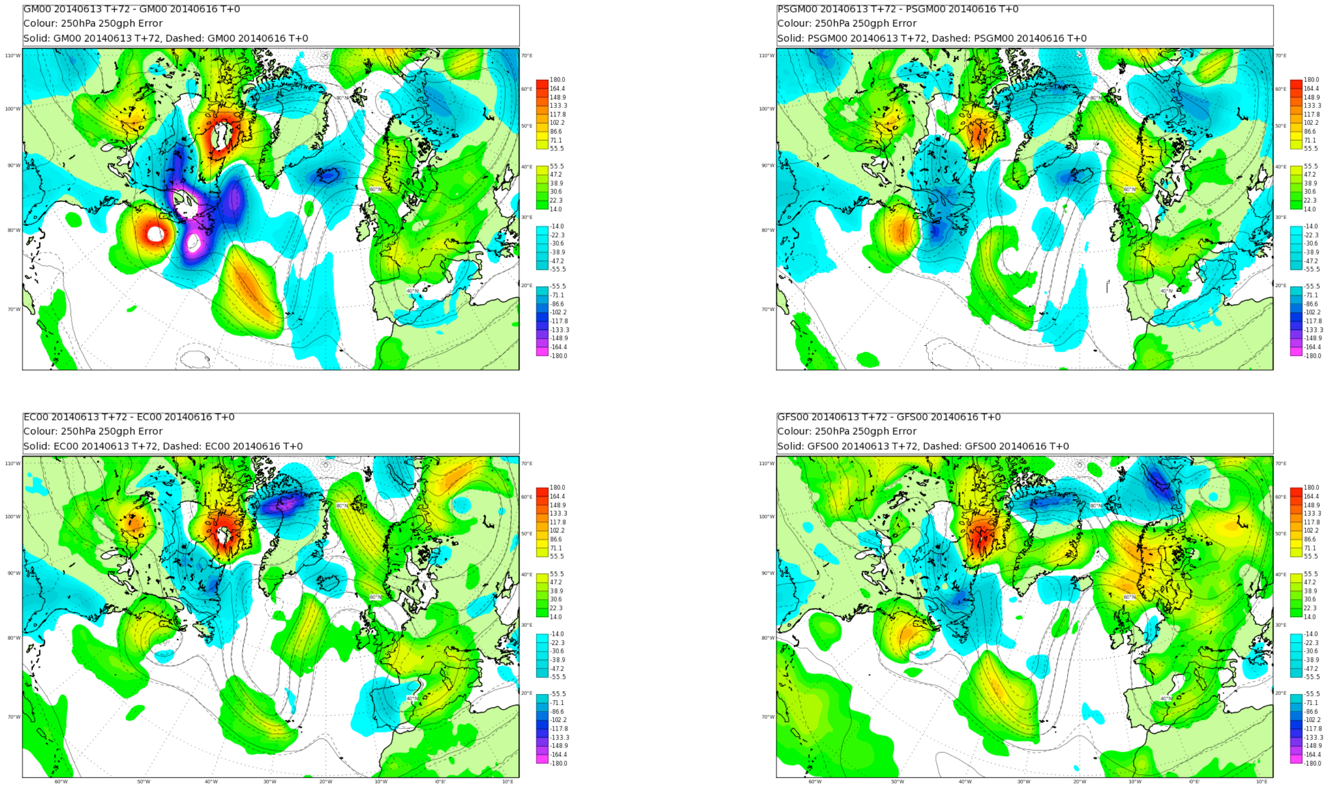

Fig. 12: 250hPa gph Errors for the 00UTC 13th June 2014 T+72 forecast, verification time 00UTC 16th June 2014 for GM, PS, EC and GFS.

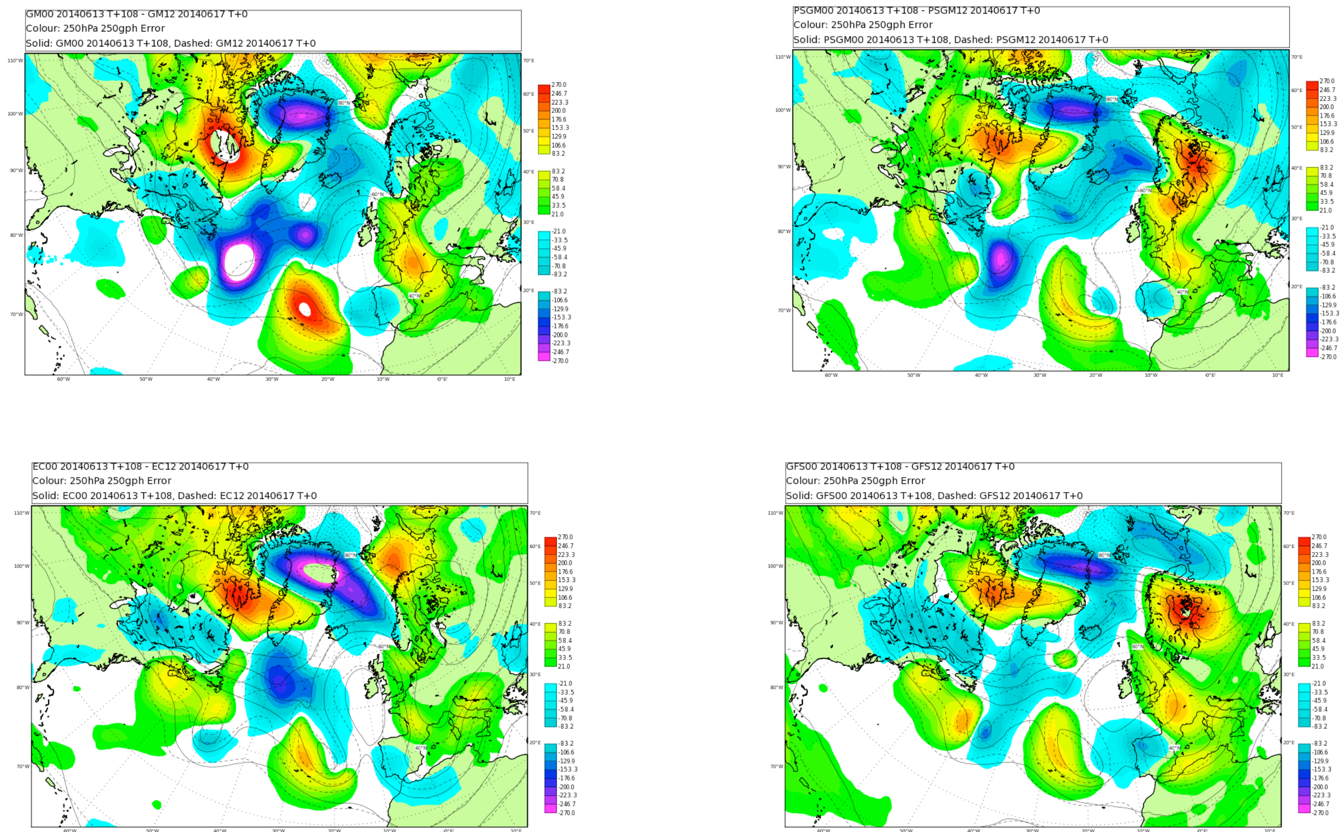

Fig. 13: 250hPa gph Errors for the 00UTC 13th June 2014 T+108 forecast, verification time 12UTC 17th June 2014 for GM, PS, EC and GFS.

4. References to relevant publications

Leadbetter S.J., **M.C. Hort**, **A.R. Jones**, **H.N. Webster** and **R.R. Draxler**, 2014: Sensitivity of the modelled deposition of Caesium-137 from the Fukushima Dai-ichi nuclear power plant to the wet deposition parameterisation in NAME. *J. Env. Rad.,* (in press).

Savage, **N. H., P. Agnew**, **L. S. Davis**, **C. Ordonez**, **R. Thorpe**. **C. E. Johnson** and **M. Dalvi**, 2013: Air quality modelling using the Met Office Unified Model (AQUM OS24-26): model description and initial evaluation. *Geosci. Model Dev*. **6**, 353–372.

Semple A., 2014: Relative Performance of PS34 and the Operational GM for the Significant Forecast Period of 12th-14th June 2014. *Rapid Assessment Report* **8**, 8 July 2014, 25pp (on request)