MOGREPS short-range ensemble forecasting and the PREVIEW Windstorms Project

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1 The MOGREPS Short-Range Ensemble

MOGREPS (Met Office Global and Regional Ensemble Prediction System) is an ensemble prediction system (EPS) designed specifically for short-range weather forecasting. As the name implies, MOGREPS provides both a global and a regional ensemble capability, but the main interest of our research and development is in performance of the higher resolution regional ensemble for high impact events. The 24-member regional ensemble is run twice daily (06 and 18UTC) to T+54h over the N. Atlantic and Europe at 24km resolution and 38 vertical levels. The global ensemble exists mainly to provide the lateral boundary conditions for the regional ensemble, but it also provides initial condition perturbations for the MOGREPS-15 day ensemble which runs at ECMWF as part of the THORPEX TIGGE research project.

Initial condition perturbations are calculated using the Ensemble Transform Kalman Filter (ETKF) (*Bishop et al.*, 2001). The perturbations are rescaled to ensure they are consistent with forecast errors using a variable inflation factor. The ETKF provides a set of perturbations which are added to the Met Office 4D-Var analysis to provide the initial states for ensemble members. Further details regarding the implementation of the ETKF in MOGREPS-G can be found in (*Bowler et al.*, 2007a). An important consideration in the design of the MOGREPS system was the issue of consistent perturbations across the lateral boundary between the global and regional ensembles. Until the end of May 2007 initial condition perturbations to the regional ensemble were interpolated from the global ensemble at T+6. Since May 2007 perturbations for the regional ensemble have been generated using a regional ETKF, which provides a better representation of shorter length scales and improved spread at upper levels. Some lack of spread in surface parameters is now evident, and future research is aimed at improving this.

Uncertainty due to model error is addressed in MOGREPS through stochastic perturbations to the model, mainly to the parameterised model physics. Three schemes are implemented in the global ensemble, but only the random parameters (RP) scheme is currently used in the regional ensemble. The RP scheme provides stochastic perturbations to nine of the tuneable parameters in parameterisation schemes within the Met Office Unified Model (UM) (for example, the gravity wave drag, convection, large scale precipitation and boundary layer schemes). Further details regarding the design of the MOGREPS ensembles can be found in *Bowler et al.* (2007a,b).

2 MOGREPS Products

A wide range of products are generated for forecasters and under pre-operational trials for customers. Figure 1a shows an example of a chart showing probabilities contoured on the model grid. Probabilities are also calculated for specific areas such as the sea areas used in the Shipping Forecast or regions used in UK weather warnings. A range of site-specific products such as EPS-Meteograms can also be generated for around 580 locations, mostly in the UK and Europe. A number of feature-based products have been developed which identify and track specific meteorological features, such as tropical or extra-tropical cyclones, to help identify potential high-impact weather events. Figure 1b shows an example graph of the central pressure of an extra-tropical cyclone tracked in different members of the MOGREPS ensemble. In another application developed under contract to the Environment Agency, a storm surge model is coupled to MOGREPS to estimate the uncertainty in storm surge events.

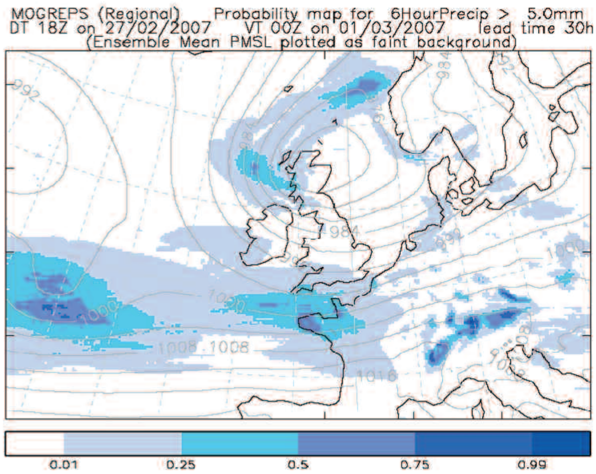


Fig. 1a Chart of the T+30 probability of 6h precipitation exceeding 5mm from the regional MOGREPS ensemble. The ensemble- mean MSLP is included as a reference.

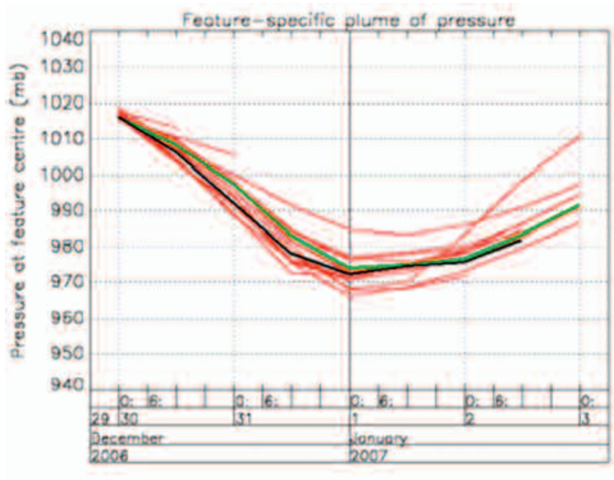


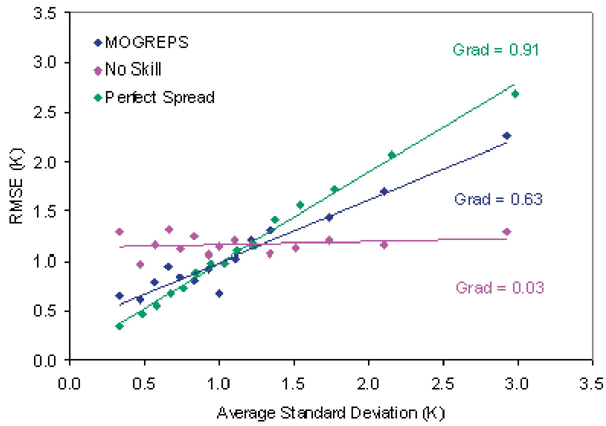
Fig. 1b Plume graph of the central pressure of an extra-tropical cyclone tracked in members of the MOGREPS global ensemble.

3 MOGREPS Verification

The MOGREPS ensembles have been run in semi-operational mode since August 2005 and the aim of verification presented here is to objectively assess the quality of the products that are generated from the MOGREPS system. The results are focussed on forecasts of surface parameters from the regional ensemble. It is only possible to show a small sample here, and further results are presented in *Bowler et al.*, (2007a,c).

One of the key aims of an ensemble from a forecaster's perspective is to predict the skill of the deterministic forecast. Ideally, when the spread of the ensemble is small then the forecaster can have confidence that the deterministic forecast will be reliable, whereas when the spread is large it is more important to express uncertainty and make allowance for errors. Figure 2 shows an example of the spread-skill relationship for MOGREPS forecasts of surface temperature at T+30. To help evaluate the spread-skill relationship, results are compared with two other, artificially generated ensembles. The first is an ensemble which had no spread-skill relationship and is referred to as the 'no skill' ensemble. The second is an ensemble which had 'perfect spread' which means the observation was always contained within the ensemble distribution. The comparison illustrates that MOGREPS manages to achieve a large proportion of the spread possible for an ideal ensemble.

Verification of forecasts for specific locations against observations allows us to compare MOGREPS forecasts from those which can be generated in the same way from ECMWF data. It should be noted that the ECMWF forecasts that are presented to forecasters and used for verification purposes are disseminated to the Met Office at 1.5 degree resolution. Therefore the results will not reflect the performance of the ECMWF model at its full resolution and the results should be viewed in this context. Figure 3 shows Brier Skill Score and its decomposition into reliability and resolution components for forecasts of surface temperature exceeding 10 Celsius at 79 sites around the UK and Europe. The Brier skill score and its decomposition into reliability and resolution components, as detailed by *Bowler et al.*, (2007b), are calculated from reliability tables that have been generated for each day of the verification period. The reliability tables were bootstrap re-sampled, using the percentile method, to provide 90% confidence intervals on the statistics calculated. The regional MOGREPS (green) is the most skilful, and the global MOGREPS (red) the next most skilful. The differences are significant at the 0.05 level for all distinctions, except for the difference between the global and ECMWF ensembles.



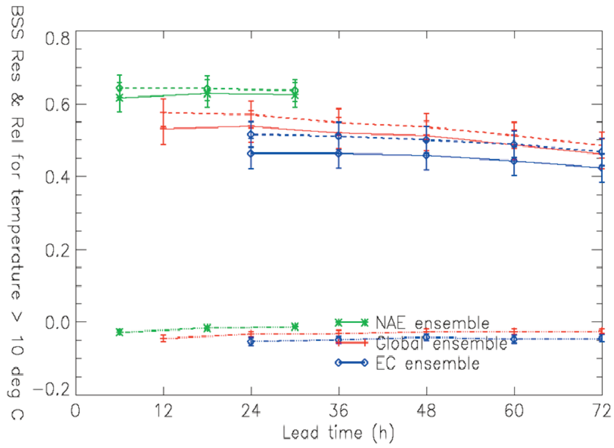
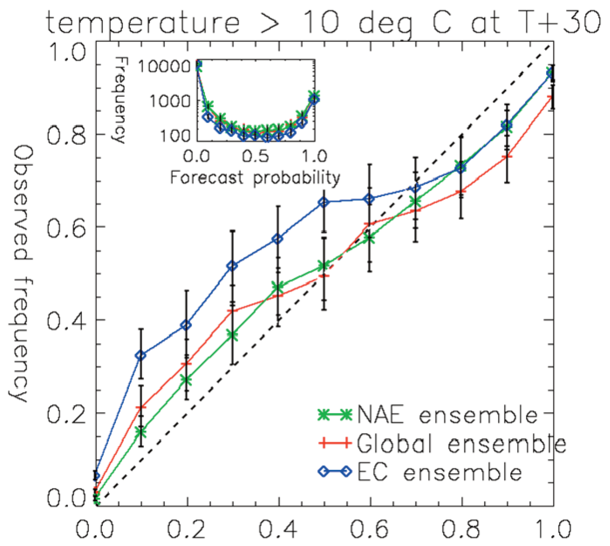


Fig. 2 The average standard deviation in each bin plotted against the RMSE in each bin, corrected for observation error. Values for temperature (K) in DJF 2006/07 at T+30.

Fig. 3 Brier skill score (solid), and reliability (dash-dot) and resolution (dashed) components for the MOGREPS regional, MOGREPS global and ECMWF ensembles for forecasts of screen level temperature greater than 10oC. The verification period is from 6 November 2006 to 28 February 2007.



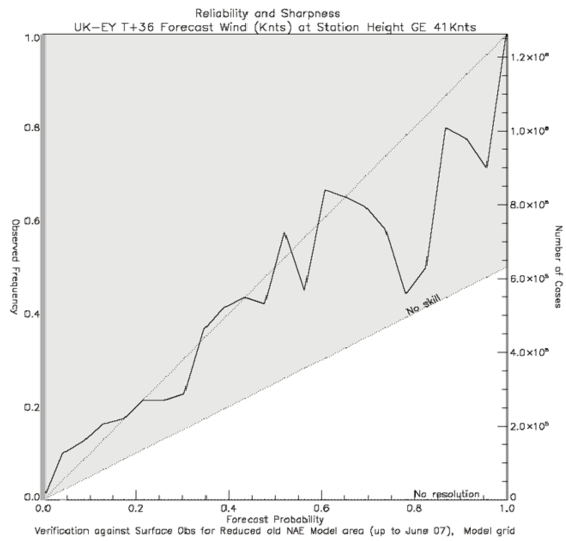


Fig. 4 Reliability diagram for the same forecasts as illustrated in figure 3 at T+30

Fig. 5 Reliability diagram for 36h MOGREPS forecasts of 10m wind speed exceeding 41kt at observation sites across the regional model domain.

Reliability and sharpness diagrams for the same forecasts at T+30 are shown in figure 4, which shows that the greater skill of the MOGREPS regional ensemble comes from a better reliability in particular. As noted above a particular interest of MOGREPS verification is the skill of the system for more extreme events which are commonly the more high-impact events. As with most forecast systems it is generally found that the quality of the forecasts decreases for more extreme events. However figure 5 provides an example of a reliability diagram for 10m wind-speed exceeding Beaufort Force 9 (41kt) at T+36, which is quite a rare event at most sites. In this case the regional MOGREPS forecasts show a good reliability with considerable skill, which is very encouraging. Even at Force 10 (not shown) the reliability diagram shows good indications of useful skill, although the verification is limited by small sample size.

It has only been possible to show a very small sample of verification results here. Much more detail is given in a MOGREPS verification report by *Bowler et al* (2007c) available from the Met Office website. Overall it has been shown that having a higher resolution regional ensemble designed specifically for short-range use provides significant benefit which complements the use of the ECMWF ensemble for medium-range prediction, and work is underway to make MOGREPS fully operational in the summer of 2008.

4 The PREVIEW Windstorms System

PREVIEW is an integrated project of the EU Commission providing services to aid with risk management for a wide range of environmental and man-made hazards. The Windstorms Service has been developed by a group of European Met Services using a multi-model ensemble approach to provide the best available automatic alerts to strong wind events. Project partners in civil protection have helped assess the usefulness of the service. Forecasts are provided for periods of 1-2 days and 3-5 days ahead using different combinations of ensemble inputs. Forecasts for 3-5 days ahead use the ECMWF ensemble and two versions of the COSMO-LEPS ensemble run by ARPA-SIM in Bologna. Forecasts for 1-2 days use a larger set of short-range ensembles comprising the MOGREPS ensembles from the UK Met Office, the PEACE ensemble of Meteo-France, the COSMO-LEPS ensembles, the LAMEPS ensemble of the Norwegian Met Institute (met.no) and the multi-model "Poor-Mans" ensemble SRNWP-PEPS run by the German Met Service (DWD) for Eumetnet. Forecasts from all these systems are collected for a large set of sites around Europe on the site-specific forecast database at the UK Met Office and used to generate multi-model ensemble forecasts and alerts.

The Windstorms service is designed to allow users to gain a quick alert to any risk of a windstorm event for their region of interest, and then to access a more detailed forecast when an alert situation is identified. On entering the website the user is presented with a "Traffic Light" map of Europe for the 1-2 day forecast (figure 6). A similar map is available for the day 3-5 forecast. For any site where a raised alert level is presented (any colour other than green), the user can click directly on the site to gain access to more detailed ensemble forecasts for that site. The primary ensemble product is an enhanced meteogram as shown in figure 7, which presents both the mean speed and the gusts in different styles on the same graph. Wind-roses showing the probabilities of different combinations of speed and direction are also available.

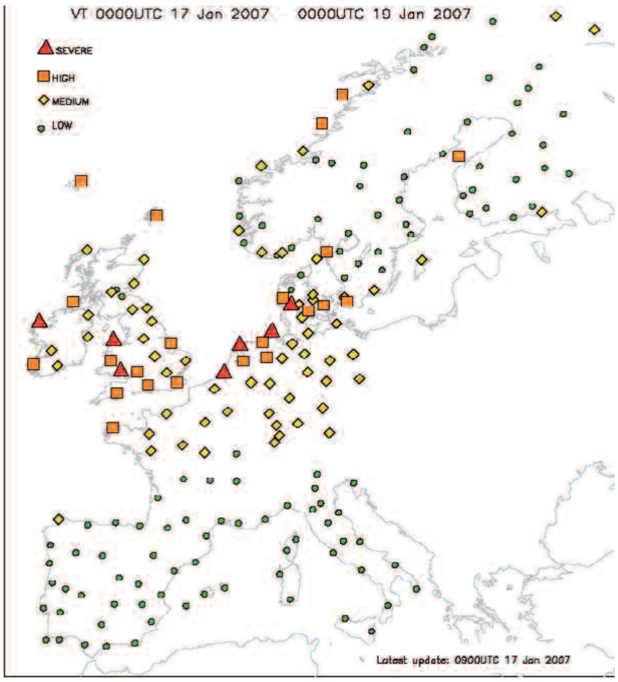


Fig. 6 Example of a Traffic Light alert map spanning the first two days of the forecast from the PREVIEW Windstorms system.

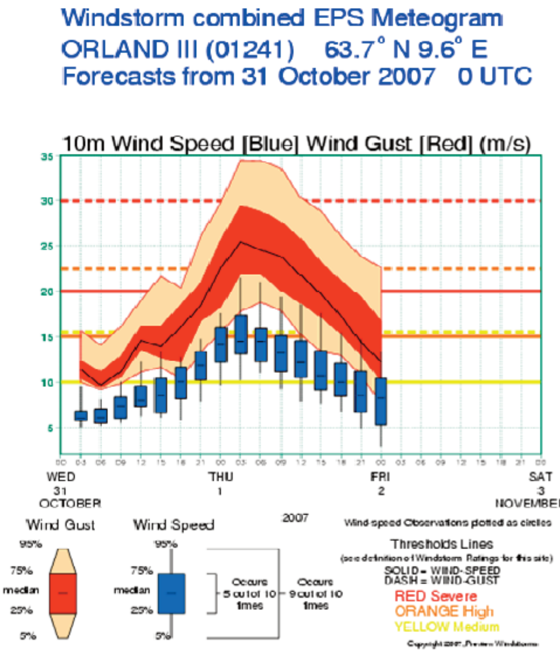


Fig. 7 Example of a combined EPS meteogram from the PREVIEW Windstorms service, showing a multi-model ensemble forecast of both windspeed (blue box-whiskers) and gusts (orange/red fan)

In addition to the forecast service, the Windstorms service also provides access to climatological information on windstorm events based on an analysis of the ERA-40 reanalysis dataset which was conducted by the Swedish Met Service (SMHI). This provides gridded maps of the frequency of windstorm events across Europe, and wind-roses for the frequency of strong wind events at each of the sites used in the forecast system.

Feedback from users of the Windstorms warning service in several countries has been very positive, with the traffic-light map presentation proving popular. It is recognised that there are some limitations of the use of ERA-40 data for providing a climatology of extreme wind events, as some events are missed between locations or the 6-hourly analyses, but the data nevertheless provide a basic summary of the frequency of strong-wind events in different locations across Europe.

Access to the Windstorms website is restricted by password as it is not available for commercial use. For access please contact the author at the email address given above.

5 References

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The above Technical reports can be found at
http://www.metoffice.gov.uk/research/nwp/publications/papers/technical_reports/