5C.6

TROPICAL CYCLONE ENSEMBLE FORECAST PRODUCT DEVELOPMENT AND VERIFICATION AT THE MET OFFICE

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1. INTRODUCTION

For several years the European Centre for Medium Range Weather Forecasts (ECMWF) has run an Ensemble Prediction System (EPS) for areas outside of the tropics (Molteni et. al., 1996) which has become a useful operational forecasting tool at centres such as the Met Office. In recent years EPSs have been developed for tropical regions by organisations such as the National Centers for Environmental Prediction (NCEP) (Marchok et. al., 2002). In 2002 ECMWF introduced a targeted set of perturbations for the tropics and since then has run its EPS (as a non-operational system) to produce tropical cyclone (TC) forecasts. This paper briefly describes the ECMWF TC EPS, the products which have been developed at the Met Office to display the ensemble TC tracks and presents verification results for the period July 2002 to March 2003.

2. THE ECMWF TC ENSEMBLE SYSTEM

The system produces 51 ensemble members from two forecast runs per day using ECMWF's model at resolution T255L40 (compared to the operational deterministic model resolution of T511L60). A region around the Caribbean Sea and four other movable areas are targeted for TCs. The TC tracking system used is described by van der Grijn (2002).

3. EPS PRODUCTS PRODUCED BY THE MET OFFICE

3.1 Tropical cyclone tracks

Figure 1 shows an example of an ensemble TC tracks chart. TC tracks for each ensemble member and the ECMWF deterministic forecast are displayed up to 120h with the observed track added after the event. Symbols and lines are colour coded according to forecast time to enable the user to determine the speed of movement of the TC (reproduced in greyscale in this paper). This chart can be used to assess the spread of the TC tracks and gives an indication of the uncertainty of the forecast.

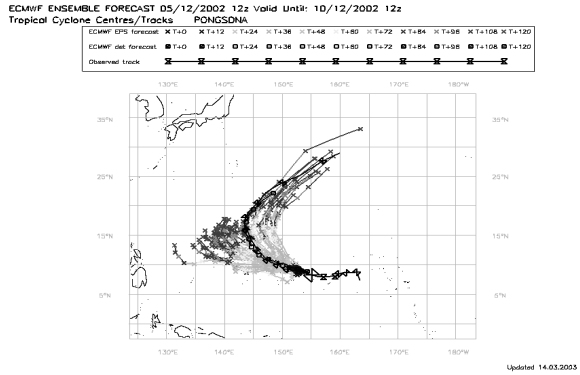

Figure 1. Ensemble TC tracks chart

This example from Typhoon Pongsona shows a marked bimodality between tracks which recurve rapidly to the north-east and those which move more slowly west-north-west. Ensemble spread varies from day to day giving some measure of predictability of TCs.

3.2 Tropical cyclone strike probabilities

Figure 2 shows an example of a strike probability chart with observed track added after the event. The probabilities are calculated by adding the number of ensemble forecast tracks that pass within 75 miles of each grid-point during the first 72 hours and dividing by the total number of forecasts. The data can be combined to produce a contoured map similar to those issued by the National Hurricane Center.

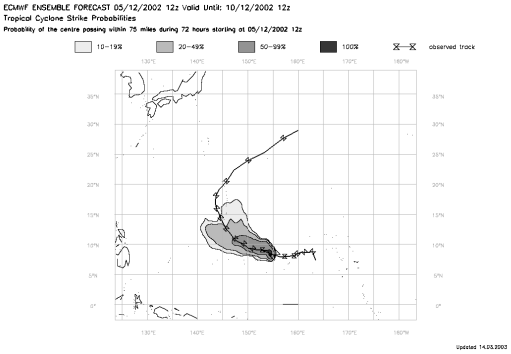

Figure 2. Ensemble strike probability chart

3.3 Tropical cyclone intensity charts

Two further ensemble products (not shown) indicate the forecast tendency of maximum 10m wind speed and minimum mean sea-level pressure. For each forecast time (at 12-hour intervals to 120h) a chart shows the TC position for each ensemble member. The symbols used are colour coded according to whether the TC has strengthened, changed little or weakened in the last 12 hours of the forecast. The thresholds between these categories have been empirically defined. Beneath each chart the probability of strengthening, little change and weakening is displayed.

4. TRACK FORECAST VERIFICATION

4.1 Verification of individual TC Tracks

The methodology described by Heming (1994) is used to verify the ensemble mean, ensemble control (unperturbed) member and ECMWF and Met Office deterministic forecast tracks for each case.

4.2 Brier skill scores

The Brier score is expressed as the mean value of the square of the difference between the forecast and observed probabilities of an event (Jolliffe and Stephenson, 2003). The Brier skill score (BSS) relates the Brier score of the ensemble members to that of a reference forecast (either the ECMWF or Met Office deterministic forecast). A positive score

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indicates that the ensembles show skill over the reference forecast.

4.3 Reliability diagrams

In an ideal probability forecasting system, events which have a forecast probability of *x*% actually occur on *x*% of occasions. In a reliability diagram (Jolliffe and Stephenson, 2003), the observed frequency is plotted against the forecast probability. The slope of a reliability diagram indicates the resolution capabilities of a forecasting system.

5. VERIFICATION RESULTS

During the trial period (July 2002-March 2003) a total of 76 cyclones of tropical storm strength and above were observed, 57 of which were forecast by the ECMWF EPS. The greatest number was in the North-West Pacific basin, followed by the North Atlantic and South-West Indian basin.

5.1 Tropical cyclone tracks

Figure 3 shows the mean positional errors during the trial period. This firstly indicates that the Met Office has the better deterministic forecasts up to 72h. Beyond this time the errors are similar to those from the ECMWF deterministic model. As far as ensembles are concerned, the results for the ensemble mean and control member are similar to each other and both have larger errors than the deterministic forecasts at all times except 120h when all results are very similar. 'Best48', 'Best72' and 'Best120' are the errors of the ensemble member with the lowest errors at 24h, 72h and 120h respectively. These are clearly better than all other forecasts indicating that there is useful information in the ensemble, but of course they cannot be identified in real time.

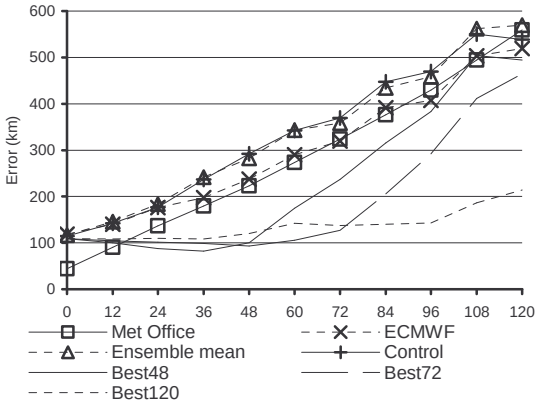

Figure 3. TC track forecast errors

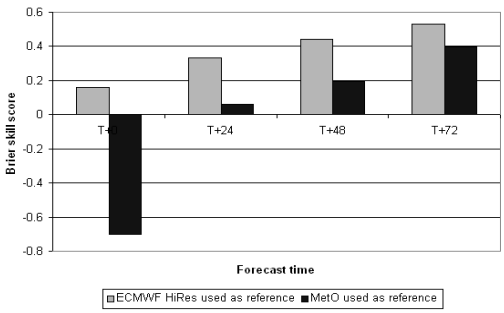

Figure 4. Brier skill scores

5.2 Tropical cyclone strike probabilities

Figure 4 displays the BSS calculated at 24-hourly forecast intervals. The large negative BSS at 0h, when the Met Office forecast is used as a reference, is as a result of the low analysis errors in the Met Office model achieved by use of a TC initialisation scheme (Heming et. al., 1995). However, the skill of the ensemble forecasts increases with lead time and is positive at 24h, 48h and 72h. The skill is higher when the ECMWF deterministic model is the reference.

Figure 5 shows the reliability diagram for the trial period. This firstly indicates that Met Office deterministic forecasts are more reliable than ECMWF. The ensemble forecast approaches perfect reliability at forecast probabilities less than 20%. At higher probabilities the observed frequency falls below the forecast probabilities. This is believed to be primarily due to positional errors in the early stage of the forecast. Nevertheless, at the 100% probability level the observed frequency is higher than both deterministic forecasts and the range of probabilities provides useful information not available from the deterministic forecasts.

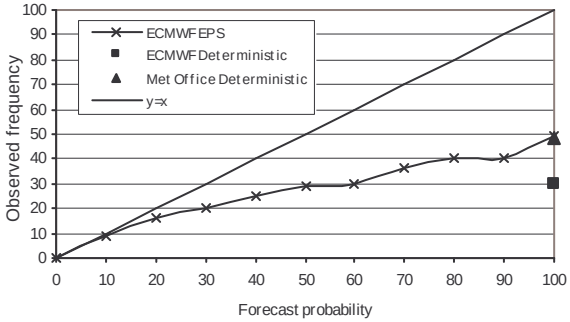

Figure 5. Reliability Diagram

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