Objective verification of manual, automated and harmonised forecasts of cumulonimbus clouds from the World Area Forecast Centres

Andrew Mirza

1. Introduction

The two World Area Forecast Centres (WAFCs) are responsible for providing meteorological hazard forecasts to aviation customers around the world. The forecasts are presented in graphical format as Significant Weather (SIGWX) charts.

The desire from the international aviation community for a gridded product, more suitable for ingestion into flight planning systems, led to the development of automated gridded forecasts produced in gridded binary (GRIB) format. These have been distributed on a trial basis by the two WAFCs for a number of years [1,2].

During November 2011 a new trial product was made available: harmonised WAFC forecasts. These forecasts are a blend of the forecasts issued by each centre. The reason for this product is to improve the consistency and accuracy of the WAFC forecasts.

2. Harmonised Forecasts

Each WAFC uses a different numerical weather prediction model, consequently forecasts may arise where one centre predicts an event that the other does not. Therefore inconsistency between the forecasts will result. To address these occurrences the forecasts are blended using a simple algorithm. This technique is not new: it is often referred to as a multi-model or "the poor-man's" ensemble [4].

Both WAFCs use the same algorithm to blend the CB extent forecasts. The standard (unblended) forecasts are exchanged as soon as they are available. Where a forecast value exists at a grid point then the mean value is taken of the CB horizontal cloud extent; expressed as a cloud fraction. This is done at all pressure levels and forecast ranges. In the event that only a single value is present then this is taken directly. Furthermore, to improve consistency and reduce ambiguity the polar regions are excluded from the harmonised forecasts and their grid point values are set to the missing data indicator [5]. If for any reason the standard forecasts from one centre are not available then the harmonised forecast issued is set to be the same as the available unblended forecasts. This ensures that a consistent set of WAFC forecasts for CB Horizontal Extent are promulgated at the scheduled times.

To assess the benefits of the harmonised forecasts the objective verification scheme developed in 2010 was used [2].

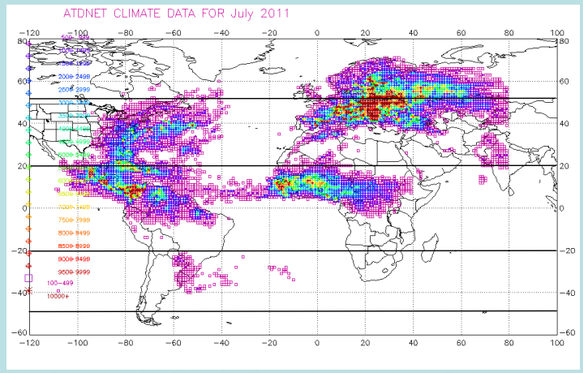


Fig. 1: Domain of the Met Office ATDNET lightning detection network. This plot summarizes the number of strikes per 1°box for July 2011. Only data between 40°S - 80°N and 110°W - 80°E are used, outside this area are often unreliable. Only boxes with values above 50 are plotted, any above 950 are assigned a dark red colour.

All Forecasts issued 2011-07-15 12Z, validity 2011-07-16 12Z

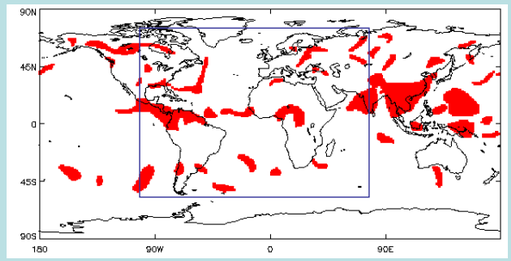


Fig. 2a: WAFC London Significant Weather Chart for Convection.

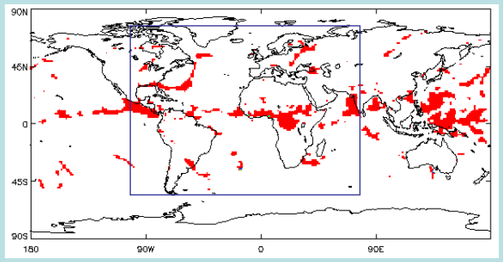


Fig. 2b: WAFC London Gridded Forecast for Convection.

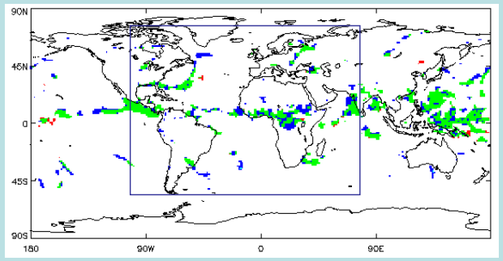


Fig. 2c: WAFC HARMONISED Gridded Forecast for Convection.

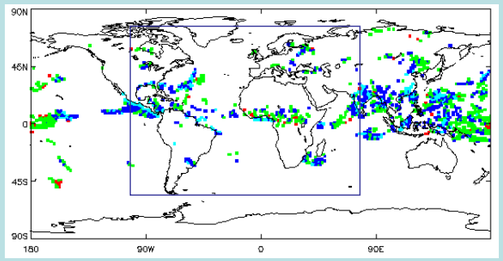


Fig. 2d: WAFC Washington Gridded Forecast for Convection.

3. Weather Prediction (NWP) forecasts

For this study, WAFC CB Horizontal Extent fields (single centre and harmonised) are used in addition to the Aviation Forecaster's Weather Chart for Convection. Figure 2a shows the Significant Weather Chart issued by WAFC London for 15th July 2011 with a data time 12Z and a validity time of T+24 hours. The subsequent figures show the corresponding WAFC Gridded forecasts. Figure 2b is the WAFC London forecast, figure 2d is the WAFC Washington forecast while figure 2c is the harmonised forecast. The black rectangle is the verification domain which corresponds to the Met Office ATDnet lightning detection network. (The depiction of convective activity by colour is not significant.)

4. Verification methodology

For the purpose of verification all the data were interpolated onto a common grid, the Unified Model's Global Resolution grid (1024 x 769, ~ 25km). Linear interpolation was used to plot the forecaster's Convective Weather Chart (fig. 2a), the gridded Convective Cloud Amounts (fig. 2 b, c and d) and the accumulated total ATD observations for the thirty minutes either side of the forecast time for each grid point.

For each validity time, 2 x 2 contingency tables were computed for each forecast type against the ATD observations field. The computations were performed over the latitudinal zones within the domain of the Met Office's ATD Observations (shown in fig. 1), in addition to the whole ATD domain. The results were accumulated into seasonal totals from which Relative Operating Characteristic (ROC) Curves were obtained [6].

Computing a 2 x 2 Contingency Table

There are four possible outcomes of forecasting an event:

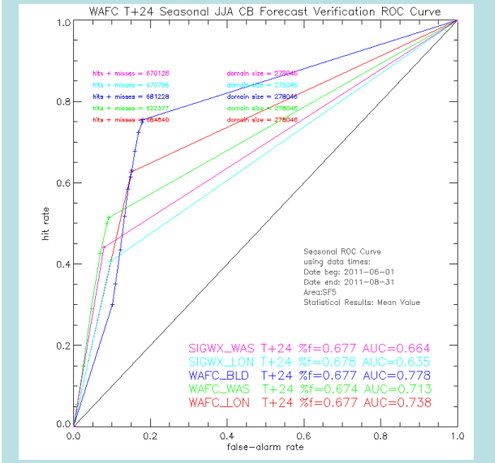
i) The event was forecast and it occurred (a hit);
ii) The event was forecast and it didn't occur (a false alarm);
iii) The event was not forecast but it occurred (a miss);
iv) The event was not forecast and it didn't occur (a correct rejection).

The number of occurrences of each of these outcomes in a set of forecast/observation pairs can be counted and then entered into a contingency table such as that illustrated in Table A1. Several statistical forecast accuracy measures can be calculated from such a contingency table

Table A1. Example of a 2x2 contingency table.

		Observed	
		Event occurred	Event did not occur
Forecast	Event occurred	**H**it	**F**alse alarm
	Event did not occur	**M**iss	**C**orrect rejection

n = total number of forecasts = H + F + M + C



The ROC Plot is a useful tool for analysis. The plot compares the probability of an incorrect forecast (False Alarm Rate) against the probability of a correct forecast (Hit Rate). A straight-line from the point (0.0) to the point (1,1) indicates the line of no-skill. A line that curves above this line of no skill is a measure of skill in obtaining a valid result using a defined methodology.

Fig. 3: ROC plot for all Convective Forecasts issued for the summer season of 2011 (JJA). The automated products are shown by the connected curves in blue, green and red; the manual products are the curves in pink and light blue.

5. Results

The ROC Plot for Summer 2011 is shown (fig. 3) for the forecast of convective activity. The performance of the automated products are shown by curves: red (WAFC London); green (WAFC Washington); blue (WAFC Harmonised). The forecaster generated charts are shown by the curves: pink (SigWx Washington) and light blue (SigWx London).

This analysis, while constrained to the ATDnet coverage, shows that the automated harmonised forecast provides added value over the automated forecast from each WAFC centre. The harmonised forecast captures more events than are forecast by only one centre. However, this analysis also shows that while the overall skill of the harmonised forecast is improved this is at the expense of increased false alarms when compared with either the forecaster generated charts or the single WAFC chart.

6. Further work

This study uses lightning observations recorded by the Met Office ATD network; which has limited coverage: mainly over the Atlantic and Tropical regions between West coast of Africa and East coast of the Americas.

While this domain accounts for much of the global air traffic, it would be useful to extend this study to include regions around Asia, China, Australia and the Pacific Ocean. A similar analysis will be undertaken using lightning observations from the Worldwide Lightning Location Network (WWLLN).

Furthermore this method of verification is being automated for the routine production of these ROC Charts; providing real time verification so that users' may gain confidence in WAFC automated forecasts, and provide research teams with an insight into the performance of parameterised convection schemes.

Met Office FitzRoy Road, Exeter, Devon, EX1 3PB United Kingdom
Tel: +44 (0)1392 885680 Fax: +44 (0)1392 885681
Email: andrew.mirza@metoffice.gov.uk

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