# PREVIN - An Operational Display System for Ensemble Products

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## 1. Background

In 1997 the UK Met Office initiated a project to develop probability forecast products from the ECMWF Ensemble Prediction System (EPS). The principal aim of the project was to provide operational forecasters with a wide range of probability information from the ensemble, and thereby to create the facility for The Met Office to develop probability forecast services for customers. The major product of this project was a system named PREVIN (PREdictability VIsualisatioN), which presents this information to forecasters via the Met Office's internal web. In conjunction with this, the project also developed tools for the application of probabilities (Mylne, 1999) using the same forecast value techniques as described by Richardson (1998), and initiated a major programme of forecaster training in probability forecasting.

## 2. User Requirement

The PREVIN project was managed in a research department, but an important part of the work involved close collaboration with forecasters and product developers to produce a user requirement document. This guided the design of many of the displays produced, and was vital in ensuring that the final system met the needs of forecasters. Generation of the User Requirement was therefore run as a separate sub-project which was managed outside the research department to ensure independence. This policy meant that some requests had to be rejected as they were either technically impossible or not scientifically justifiable, but the end result was a system which is popular with forecasters, and initial usage has been high.

## 3. General Features

All PREVIN displays are generated automatically on a pair of dedicated workstations, and are available to forecasters through a site on the Met Office internal web. Most products are available for all lead-times from 0 to 240 hours at 12-hour intervals.

## 4. Chart Products

### 4.1 General Charts

Charts of model fields are presented in a range of ways designed to aid interpretation of the ensembles. The geographical regions covered by the charts depend on the expected applications, and the scales of the features they are intended to show.

An example of a 'spaghetti' chart is given in Figure 1, showing selected 500hPa height contours from all the ensemble members to give an estimate of the predictability of the broad-scale synoptic development. For this purpose the whole of the North Atlantic and Europe are shown. In this example three different contours are shown in different colours. Spaghetti charts are available for 850hPa wet-bulb potential temperature ($\theta_w$) as well as for 500hPa height, which allows assessment of low-level air-masses, and hence approximate most-probable frontal positions. Spaghetti charts are animated to present a movie sequence of the evolution through a forecast sequence.

'Postage Stamp' charts (figure 2) give forecasters a quick glance over all ensemble members' forecasts for a given time, to assess the range of synoptic solutions and their relative probabilities, and to identify any solutions liable to lead to severe or significant weather conditions. By contrast, ensemble mean charts (figure 3) for a series of times ahead give a quick view of the general synoptic evolution, with short-wave, unpredictable details averaged out. For both these products a smaller chart area covering the eastern N Atlantic and NW Europe was chosen to highlight the dominant synoptic patterns affecting the British Isles. Both these products are available for MSLP, 500hPa height, 850hPa $\theta_w$ and 1000-500hPa thickness; ensemble mean charts of 850hPa temperature are also available, and these may be viewed as a movie sequence with ensemble standard deviation also included as colour-shaded contours.

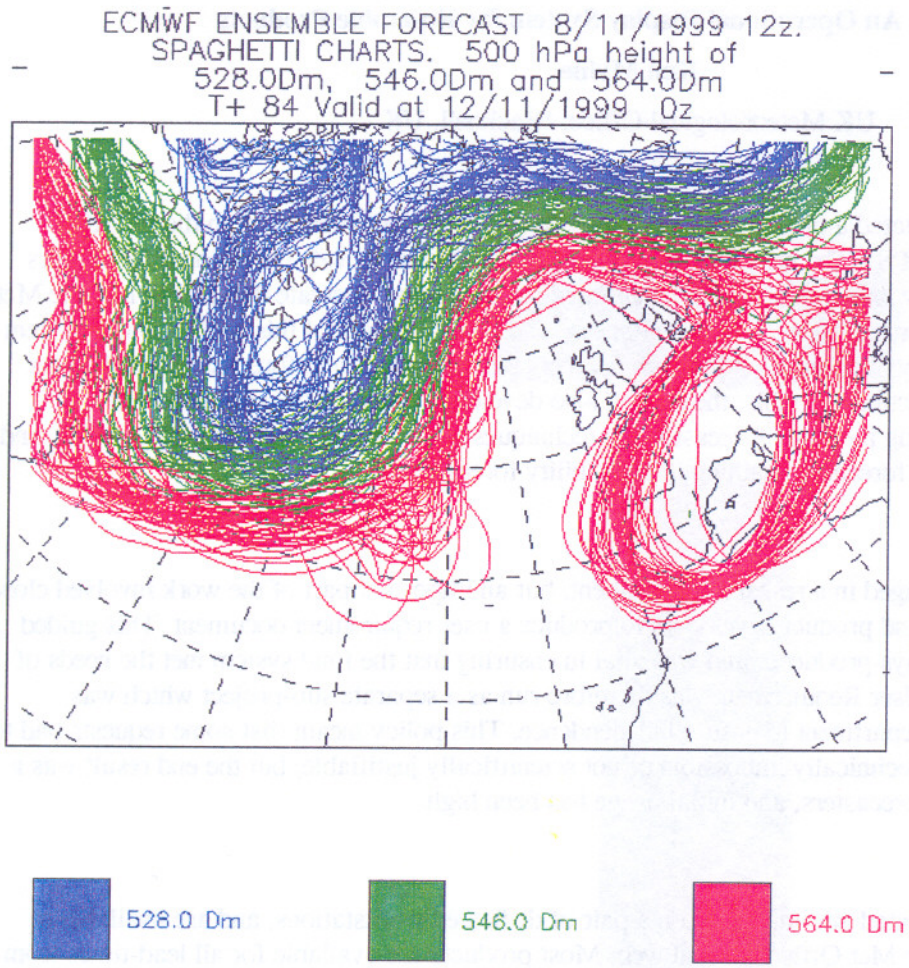


Figure 1: 'Spaghetti' chart showing 500hPa height contours at 528, 546 and 564Dm.

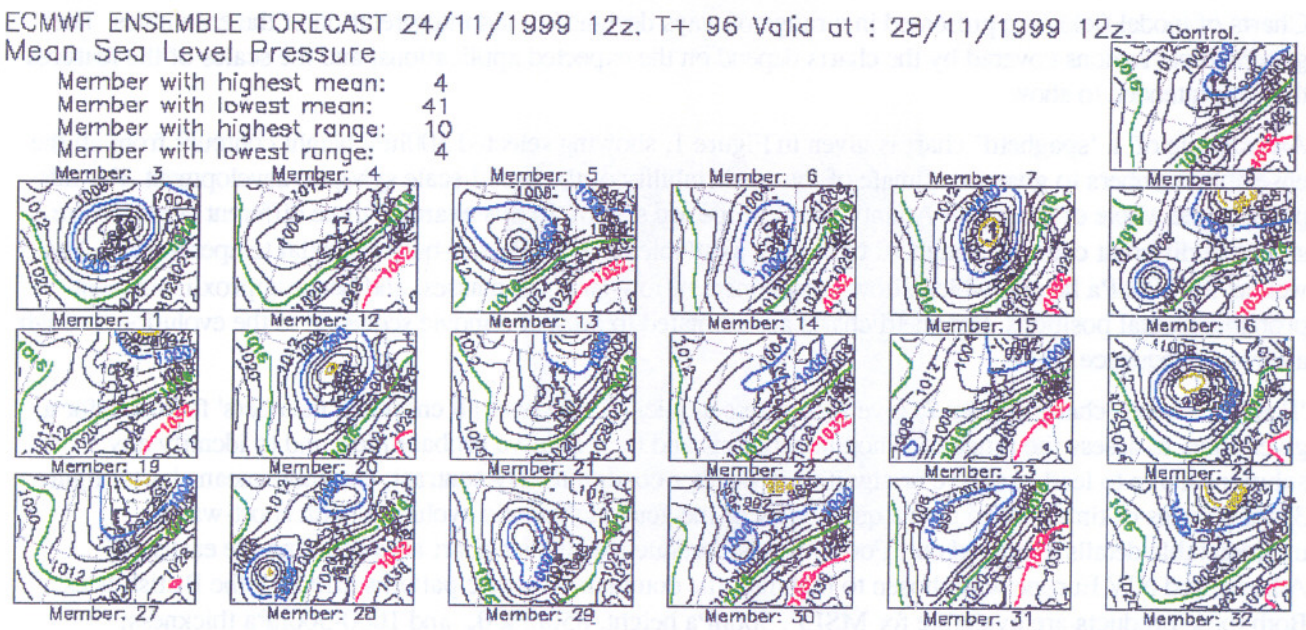


Figure 2: Part of a page of 'Postage Stamp' charts showing individual ensemble members' MSLP forecasts for a given time over the UK region. The full page displays all 51 members.

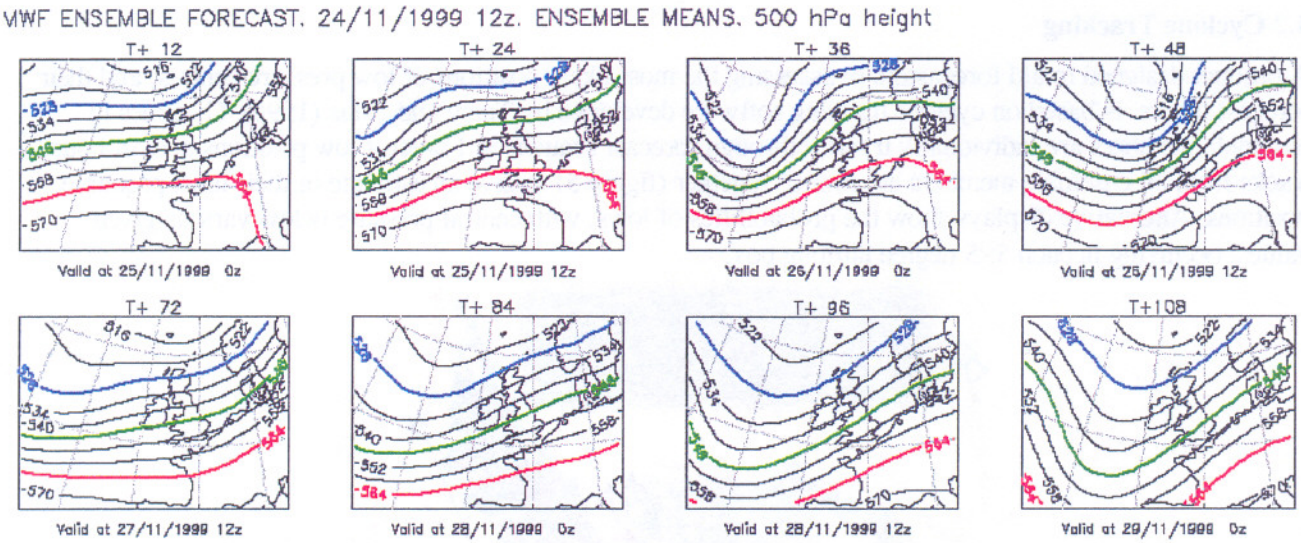


Figure 3: Part of a page of Ensemble Mean charts of 500hPa height fields. The full page shows all lead-times from T+12 to T+240 at 12-hour intervals.

One chart product specifically requested in the User Requirement is a summary page of the probabilities of various events, such as temperature anomalies, rainfall or snowfall accumulations and wind-speeds exceeding given thresholds on a selected day. This was designed to aid forecasters in considering the need for early warnings of severe weather conditions. An example of part of such a page is shown in figure 4.

Other chart products available include hemispheric maps of the initial perturbations used to generate ensemble members, and contour charts of 500hPa variance, indicating forecast uncertainty.

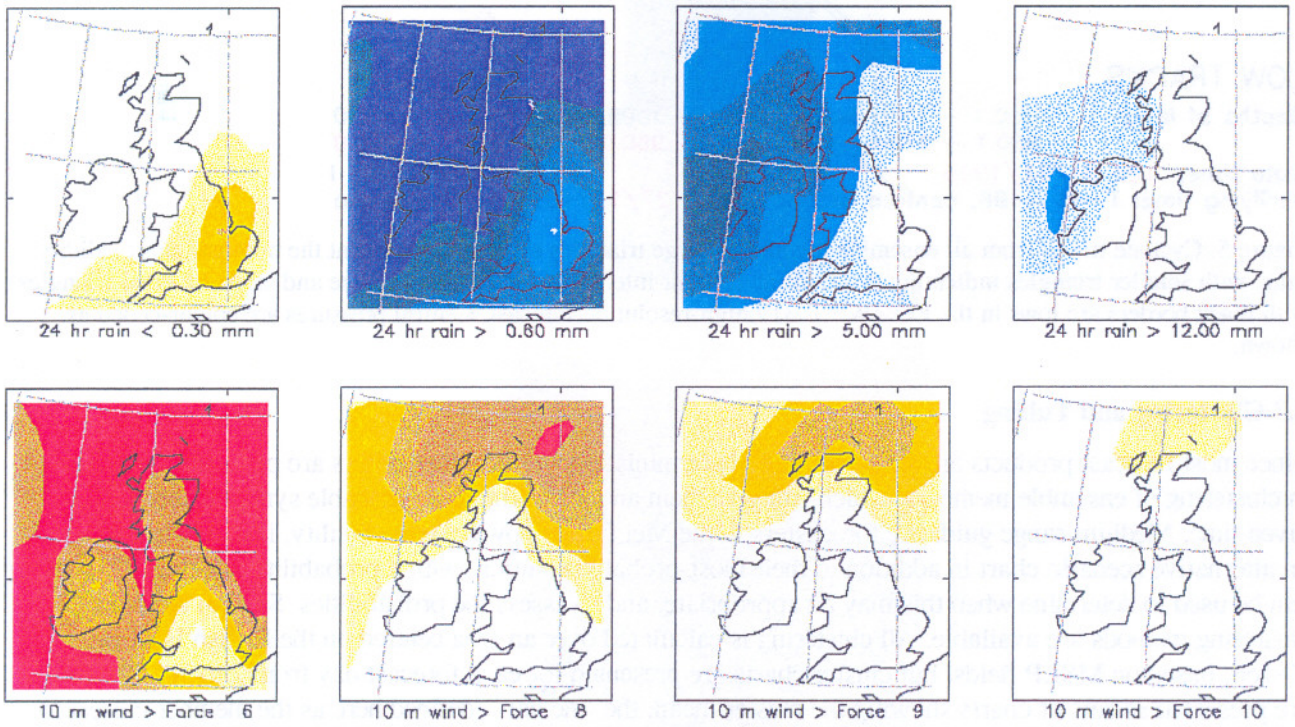


Figure 4: Part of a page of contoured probability charts summarising the probabilities of various events for a particular forecast day. Stronger, darker colours indicate higher probabilities of the events.

### 4.2 Cyclone Tracking

A product designed to aid forecasters in assessing the most likely positions of low pressure centres, and their forecast tracks, is based on cyclone tracking software developed by Terry and Atlas (1996). Cyclones in ensemble members are individually tracked through forecast sequences. Forecast low positions and 48-hour tracks from all ensemble members are plotted together (figure 5) to give an estimate of their most probable positions. Alternative displays show the probabilities of lows, with central pressure below various given values, occurring in each 5×5 degree lat/long box.

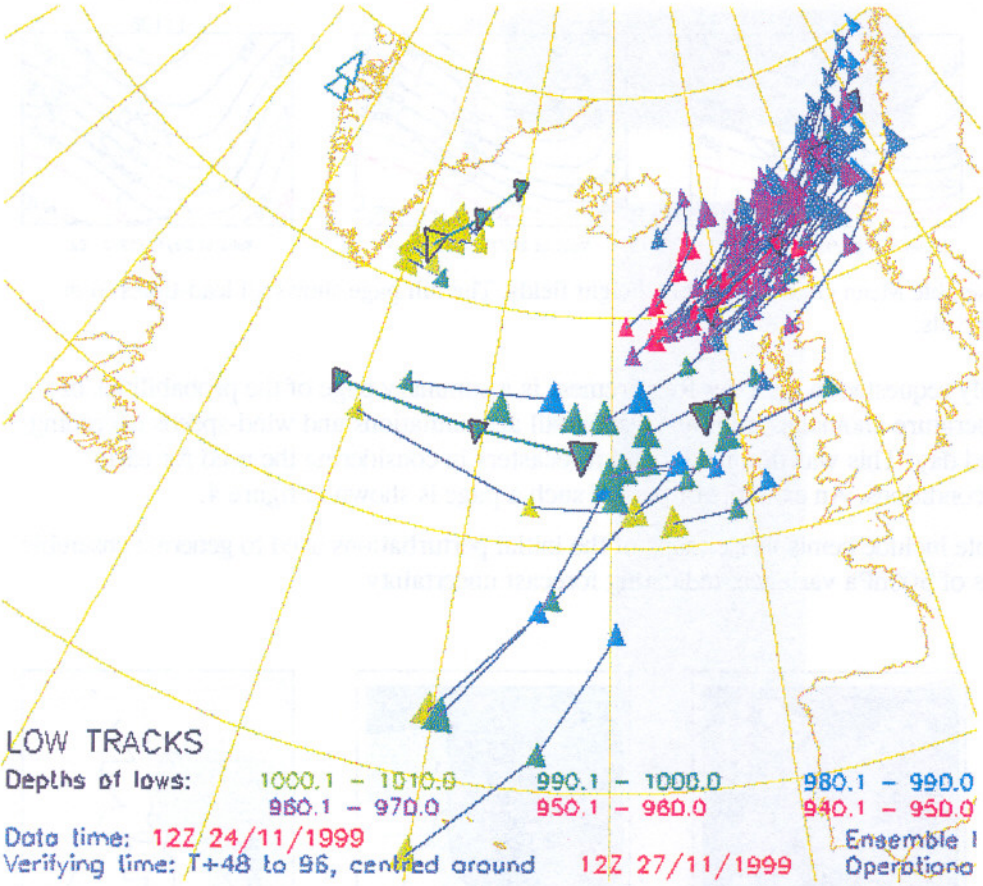


Figure 5: Cyclone tracks from all ensemble members. Large triangles show low centres at the nominal chart validity time, with smaller triangles indicating positions at 12-hour intervals over 24 hours before and after. Inverted triangles with black borders are lows in the ECMWF $T_L319$ high-resolution forecast. Central pressures are colour-coded as shown.

### 4.3 Clustering and Tubing

Since most forecast products are still essentially deterministic in nature, forecasters are particularly interested in clustering of ensemble members, which can give them an idea of the most probable synoptic solution at a given time. Medium-range guidance forecasters in the Met Office now have the facility, if they wish, to issue an alternative scenario chart in addition to their most-probable solution, with a probability attached. Clustering can be used to determine when this may be appropriate, and to assess the probabilities. Several different clustering methods are available. All clustering is calculated over an area centred on the British Isles at T+168, based on MSLP fields, but cluster charts are presented for each forecast day from 2 to 10. Clusters are presented as sets of charts showing the cluster mean, the 'median' (defined here as the member closest to the mean) and the cluster standard deviation for the following parameters: 500hPa height, MSLP, 850hPa $\theta_w$, 24-hour precipitation and 10m wind speed. An example is shown in figure 6. Charts are also produced based on the ECMWF tubing system (Atger, 1999) showing the mean of the central cluster and the tube extreme members (not shown).

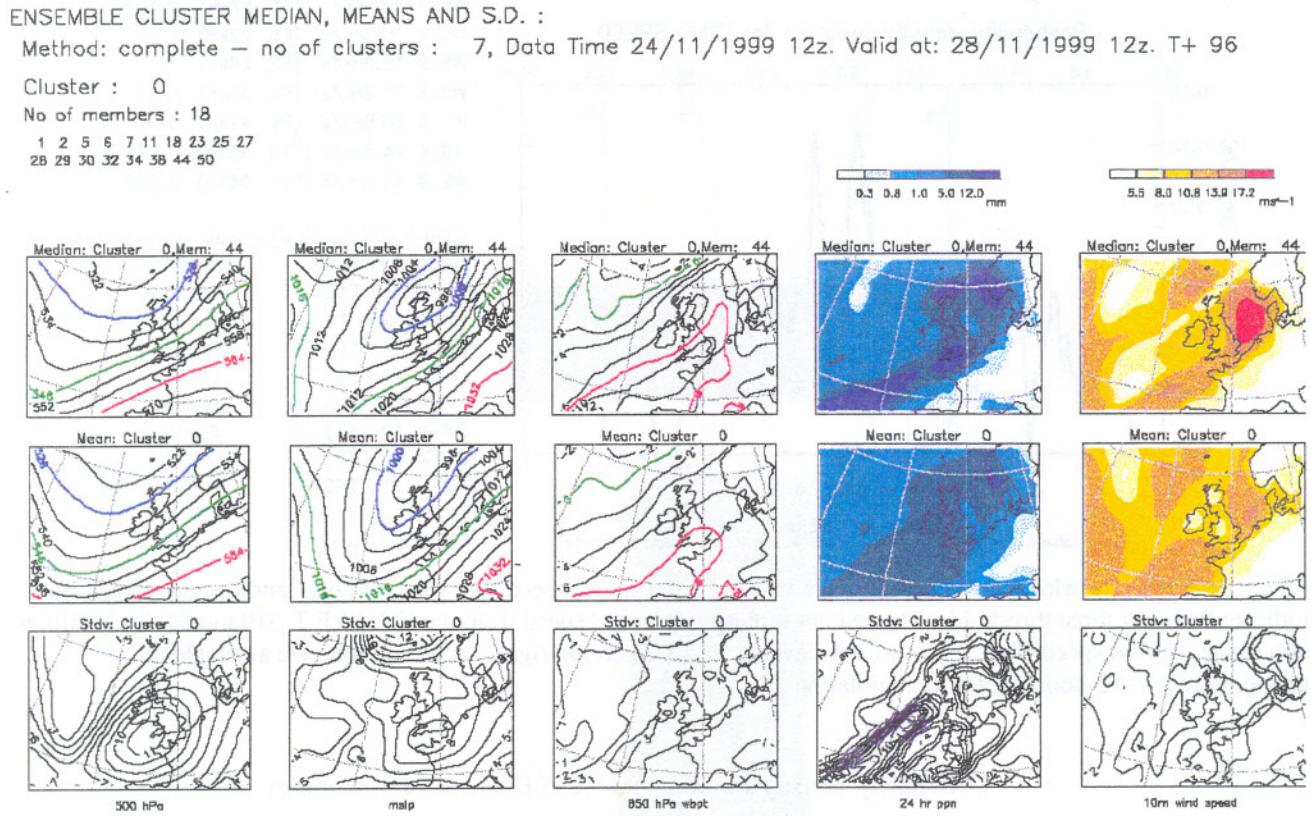


Figure 6: An example of output from clustering of ensemble members. A similar set of charts is produced for each cluster generated.

## 5. Site-Specific Products

Most probability forecasts for end-users are site-specific, so a range of probability forecasts are generated routinely for 41 sites in the UK. Probabilities are calculated for a range of events of temperature, windspeed and 12-hour rainfall accumulations, and also some combined events for snow (precipitation with low temperature) and wind-chill (low temperature with strong wind). Probabilities are displayed graphically as PDFs (probability density functions), and are also presented numerically (eg. figure 7).

Some probabilities are also presented in tables designed to aid forecasters in the production of specific end-products, and it is planned in the future to allow direct insertion of probabilities into customer forecasts.

Ensemble forecasts should avoid the large changes from run-to-run which are common in deterministic forecasts, although in practise they do not achieve this objective as well as might be hoped. It is therefore useful for forecasters to be able to view the evolution of probabilities through consecutive runs of the ensemble. Several such displays are provided (eg. figure 8).

## 6. Verification

A major component of the project comprised verification of the site-specific forecasts. A wide range of standard probabilistic diagnostics are automatically accumulated on a daily basis, including Brier Scores and Brier Skill Scores, Reliability Diagrams and Relative Operating Characteristics (ROC) (See Stanski et al (1989) for details of these diagnostics), and also Rank Histograms, sometimes referred to as Talagrand diagrams (Hamill and Colucci, 1997). All are presented graphically within PREVIN: some examples are given in figure 9. Results from equivalent forecasts from the ECMWF $T_L319$ high-resolution model are included for comparison. Different verification diagnostics have different applications, but the reliability diagram is of particular use to forecasters. A representative reliability diagram allows a forecaster to calibrate ensemble probabilities and provide customers with near-perfectly reliable probability forecasts, although it should be noted that such calibration reduces the probabilistic resolution of the forecast. Also included in PREVIN are forecast value calculations based on the ROC verifications, as described by Mylne (1999) (not shown). Value

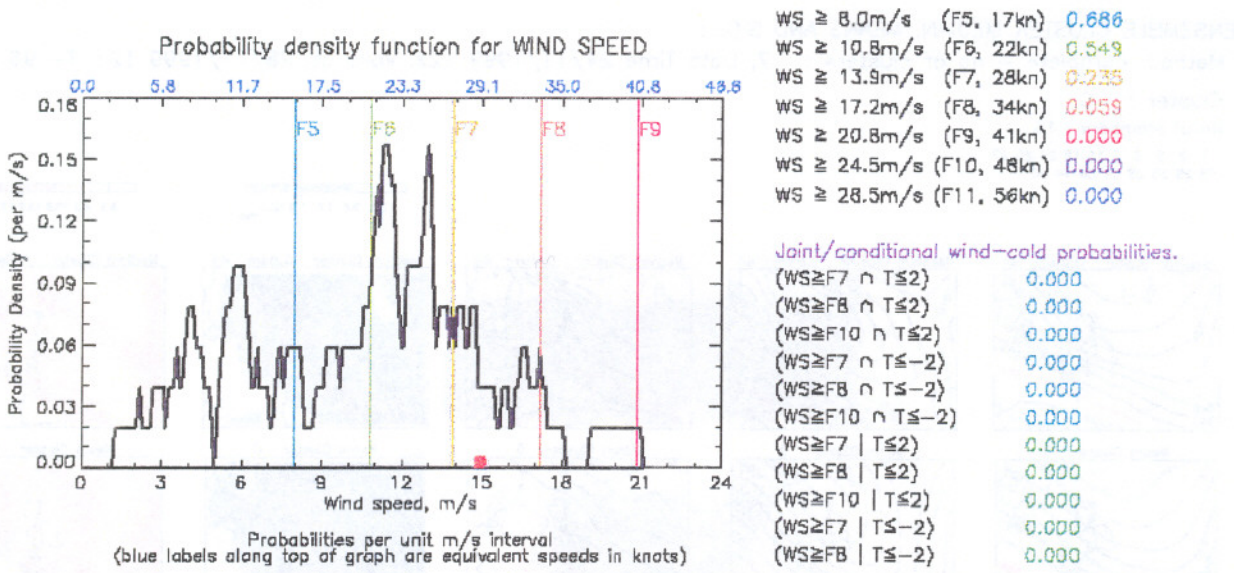


Figure 7: A PDF for windspeed at a site in the UK at T+216. Wind speeds are shown in $ms^{-1}$ and knots; vertical lines indicate Beaufort force thresholds. The red dot indicates the wind speed from the ECMWF $T_L319$ model. Probabilities of a range of wind speed (WS) and combined events are listed on the right. Similar graphs are available for temperature and 12-hour rainfall accumulations.

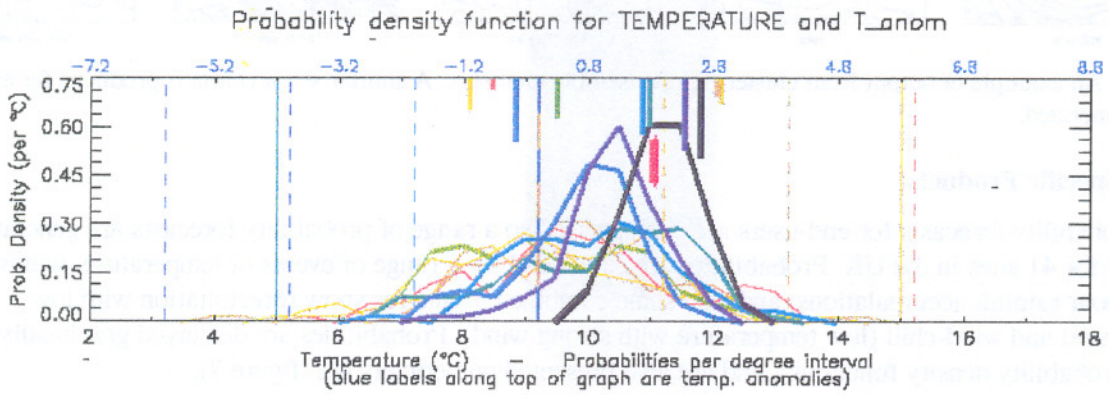


Figure 8: Overlaid PDFs from consecutive ensemble runs, showing the convergence of probability (decreasing uncertainty) towards decreasing lead-times (darker colours). Lines at the top indicate $T_L319$ forecasts, and in this example the red line indicates the verifying observation.

calculations allow probability forecasts to be optimised as decision-making tools for forecast end-users. In general, results demonstrate that probability forecasts have greater skill, and user value, than equivalent deterministic forecasts. However, site-specific biases are severe in many cases, degrading the absolute skill of the forecasts. Ensemble spread is generally found to be too small, which means that probabilities are over-confident and too frequently change dramatically from run-to-run of the ensemble.

### Future Developments

The PREVIN system has been developed as an initial facility to give forecasters access to ensemble information and allow the production of probability forecasts. A number of enhancements are planned for the future. In particular there is currently no statistical post-processing to optimise the site-specific data extraction from the models, which leads to rather poor absolute skills as reflected in the verification. It is therefore planned to incorporate some post-processing, probably using a Perfect-Prognosis approach. It is also planned to put probability forecasts into a database to allow incorporation directly into products for customers.

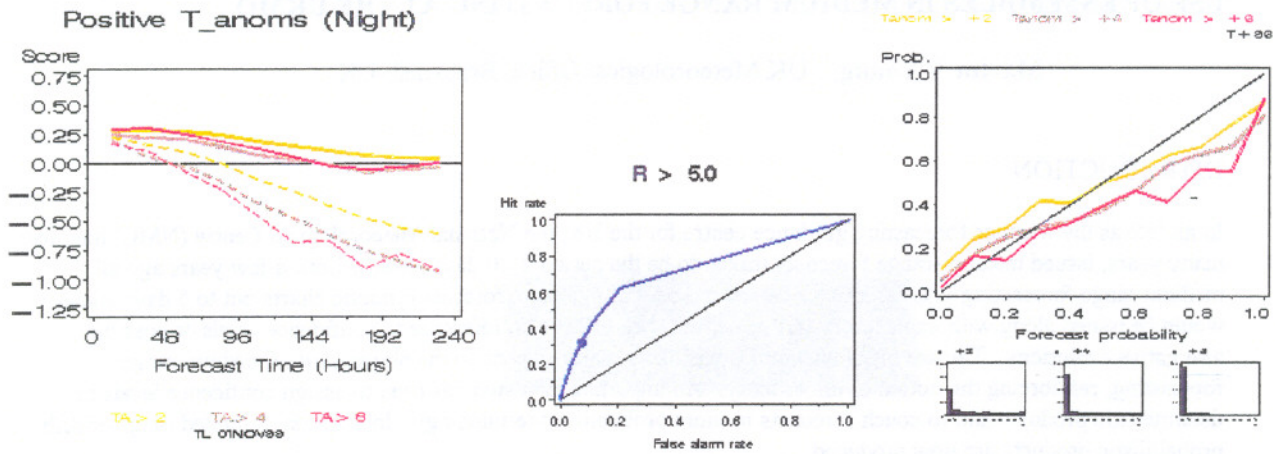


Figure 9: Examples of verification graphics from PREVIN. All are based on approximately 2 years data from 41 stations around the UK, although results for individual 3-month seasons are also available. Left: Brier Skill Scores for positive temperature anomalies of 2, 4 and 6 degrees. Solid lines give the skill, relative to climatology, of ensemble forecasts; dashed lines give equivalent skill for $T_L319$ deterministic forecasts. Centre: ROC (Relative Operating Characteristics) for ensemble forecasts of rainfall accumulations exceeding 5.0mm. The dot represents the $T_L319$ deterministic forecasts. Right: Reliability diagram for probability forecasts of positive temperature anomalies of 2, 4 and 6 degrees. Small histograms under the graph are sharpness diagrams showing the frequency of usage of each probability band in the forecasts (in intervals of 10% probability).


## Acknowledgements

The project which generated the PREVIN system involved many staff from different areas of the Met Office. Particular credit is due to Mike Harrison (now at WMO, Geneva) who provided the original inspiration for the project; Tim Legg and Caroline Woolcock designed many of the graphics and developed the software; and Don Hewitt headed the team producing the User Requirement.


## References


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