

Exploiting ensemble members: forecaster-driven EPS applications at the met office

Introduction

Ensemble Prediction Systems (EPSs) have assumed a central role in the forecast process in recent years. The challenge is to allow forecasters to exploit fully the rapidly growing quantity of EPS data within the timescales of an operational environment.

As part of an ongoing review of usage of NWP products within the Met Office, new presentational techniques and automated analysis methods are being developed for use with model data. There is also a need to rationalise and unify EPS products used in the Met Office, thus simplifying usage and empowering the forecaster and other customers.

Uses of ECMWF data

Operations Centre Forecasters routinely access standard ECMWF EPS products such as ‘postage stamps’ and the Extreme Forecast Index (EFI) via the ECMWF website. Additionally, forecasters may make use of the ‘in-house’ suite of ensemble products derived from raw ECMWF data (accessed via a system known as PREVIN). Products from PREVIN include alternative clustering methods, meteograms, and a wide-range of probability charts for specific weather events affecting the UK. For example, an invaluable element of PREVIN is the First Guess Early Warning (FGEW) system, which uses the ECMWF EPS to automatically alert forecasters of upcoming potentially severe weather affecting the UK.

MOGREPS

In the last year, extensive trials have taken place using an EPS developed within the Met Office, known as MOGREPS (Met Office Global and Regional Ensemble Prediction System). MOGREPS uses an Ensemble Transform Kalman Filter (ETKF) to generate perturbations in initial conditions. Model physics perturbations are also introduced via random variation over time of key parameters within each EPS member.

	MOGREPS-G	MOGREPS-R
Model	UM6.1 (G38)	UM6.1 (E11)
Resolution	N144 (90km), 38 levels	24km, 38 levels
Run Times	00 and 12 UTC	06 and 18 UTC
Run Length	72 hrs	54 hrs
Availability Times	07:30 and 19:30 UTC	13:00 and 01:00 UTC
Ensemble Size	24 (CNTRL+23 perturbed)	24 (CNTRL+23 perturbed)

Table 1:
MOGREPS
configurations

MOGREPS runs in two main configurations (Table 1) based on the Met Office Global (GM) and North Atlantic & European (NAE) model domains respectively. An additional version of MOGREPS-G is run out to 15-days at ECMWF as a component of the THORPEX multi-model ensemble, TIGGE.

A wide variety of products are routinely generated using the MOGREPS output. As with PREVIN, these are accessed via the Met Office intranet. The website makes full use of web technology developed since PREVIN was originally implemented, displaying clickable and animated sequences of each EPS member, or products derived from them such as event probabilities and clusters.

Close liaison between forecasters and developers has resulted in a system with a high degree of flexibility: certain products or combinations of model fields have been requested depending on the synoptic situation, and developers can respond quickly to these requests. More formally, forecasters have been asked to evaluate the usefulness of each MOGREPS product via questionnaires, enabling developers to ascertain product priorities and to alter product generation schedules accordingly. Further surveys will be conducted, and continuous feedback encouraged, until an optimum set of forecast products is achieved.

New EPS applications

The Cyclone Database

PREVIN includes facilities for the tracking of extra-tropical cyclones based on matching and tracking MSLP minima. However these systems are often of limited use in identifying and tracking the precursors of cyclogenesis, prior to formation of well-defined low centres.

The Met Office Cyclone Database, CDB, (Hewson, 2007) has been running in real time on UK Global Model data for several years. This attempts to identify and display features using automated, objective techniques based on standard conceptual models of fronts and of cyclone development (Figure 1).

Having identified objective features at a given time, an attempt can be made to automatically identify the same features at later times. An important aspect of this tracking scheme is the consideration that an object may evolve into another type of object. For this type of transition, the probabilities have been derived empirically from historical data. Hence, for example, the natural development of a minor baroclinic feature into a frontal wave and finally a barotropic low can be tracked throughout its lifecycle using this system.

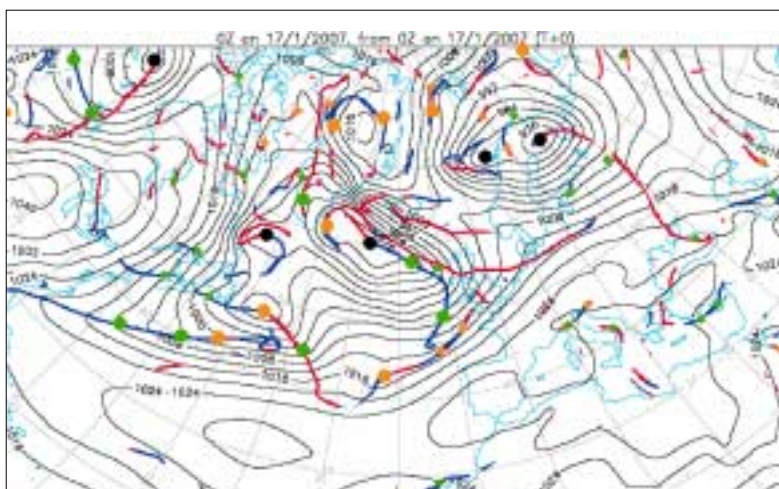


Figure 1: Example CDB analysis of UKMO Global Model T+0. Labelled features are Diminutive Waves (Green), Frontal Waves (Amber), and Barotropic Lows (Black) along with Warm (Red) and Cold (Blue) Fronts.

This formulation proves to be an excellent means of analysing large EPS datasets. The MOGREPS version of the CDB (adapted for THORPEX by Helen Watkin, Met Office) matches features in the MOGREPS-G CNTRL member at T+0 with the other ensemble members. Once common objects are identified, their tracks can be plotted, along with various other useful properties such as minimum MSLP and maximum wind at certain heights (Figure 2). Tracking plots for each object are displayed by clicking on the appropriate object in the T+0 CNTRL analysis (as in Figure 1).

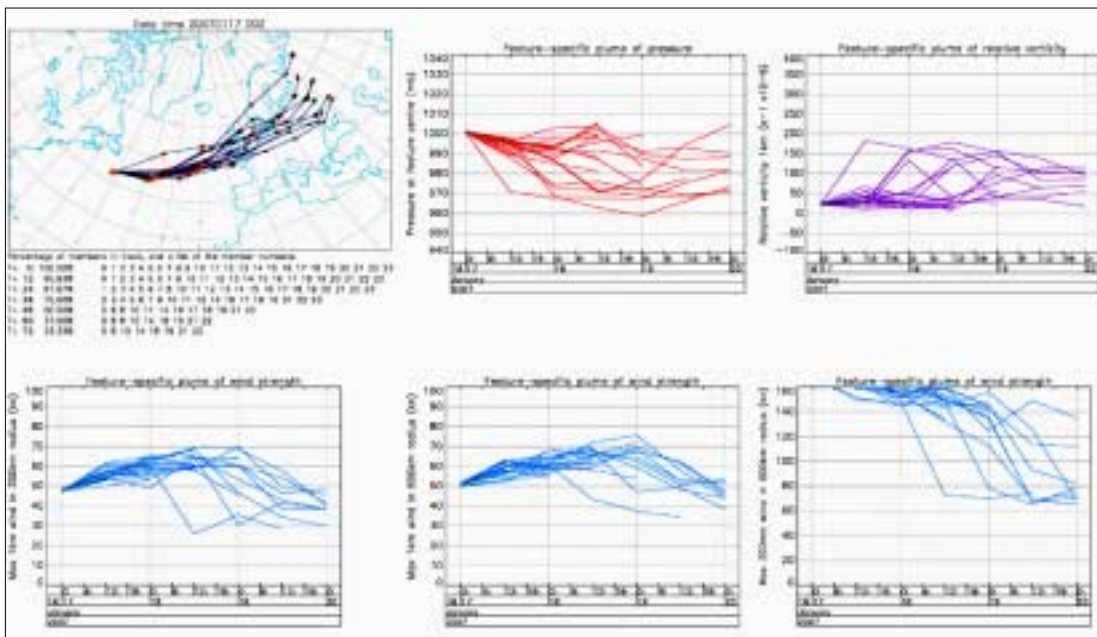


Figure 2: MOGREPS CDB plumes displayed by clicking on a given object identified in the CNTRL member at T+0

Objective-GWL: Synoptic Regime Analysis

As part of the THORPEX project, Paul James (of the Met Office's Hadley Centre) has developed applications to classify EPS members by synoptic type. Members of a MOGREPS-THORPEX dataset on a given day are clustered according to Grosswetterlagen (GWL) synoptic types over northwest Europe. The results are displayed in order to indicate quickly to the forecaster the dominant regimes in the medium-range period (see Figure 3 and Figure 4).

GWL	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	Description	Max. Freq. (%)	All Time
W1				1	1	1	1	1								Anticyclonic weather	1.5	11.9
W2																Cyclonic weather	9.1	18.9
W3																Disturbance weather	9.1	18.9
W4																Anticyclonic weather (West of Europe)	9.8	1.4
W5																Anticyclonic weather	9.8	6.5
W6																Cyclonic weather	9.8	4.2
W7																Anticyclonic weather	9.8	9.7
W8																Cyclonic weather	9.8	9.8
W9																High and cold weather	7.8	1.8
W10																Disturbance weather	7.8	9.3
W11																Anticyclonic weather	9.8	1.1
W12																Anticyclonic weather	7.7	9.8
W13																Cyclonic weather	13.7	1.9
W14																Anticyclonic weather	1.7	1.9
W15																Anticyclonic weather	1.8	1.8
W16																High and cold weather	10.5	2.3
W17																Disturbance weather	9.7	1.3
W18																Anticyclonic weather	9.8	9.3
W19																Cyclonic weather	9.3	4.2
W20																Disturbance weather	9.8	1.3
W21																Anticyclonic weather	9.8	1.8
W22																High and cold weather	9.3	1.8
W23																High and cold weather	9.8	1.8
W24																Anticyclonic weather	9.8	1.8
W25																Disturbance weather	9.7	1.8
W26																Anticyclonic weather	9.8	1.7
W27																Disturbance weather	9.7	1.8
W28																High and cold weather	9.8	1.3
W29																Disturbance weather	9.2	1.4

Figure 3: MOGREPS-THORPEX Objective-GWL output displaying the number of EPS members of each GWL synoptic type on a given day.

The analysis can also be performed on either ECMWF or GFS ensemble data. Additionally, the data can also be classified by Lamb Synoptic Type, which is perhaps more familiar to UK forecasters.

Cluster	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7
1	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ
2	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ
3	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ
4	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ
5	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ	NZ

Figure 4: Objective GWL clustering. Cluster 1 represents the most probable GWL regime sequence. Cluster 2 is the next most probable sequence, having removed the first set of regimes, and so on.

These products have recently become widely used by the Medium Range forecasters in the Met Office. In the past, forecasters have derived similar results subjectively, usually by inspection 'by eye' of EPS 'postage stamps'. Anecdotal evidence already suggests that such automated output is extremely useful, and is already saving considerable time and effort.

Future Projects

Though ensembles are in continuous use by forecasters, the recent survey of their usage has highlighted a need for consistent methodology and for standard working practices. At present, each forecaster relies on the particular products with which they have become familiar, and the very large amount of data available can make it difficult to assimilate additional information on the timescales required operationally.

The amount of available EPS data has increased substantially in recent years. Clearly it is advantageous to have access to a wide range of products, and also a range of different models, each with known characteristics. However, this profusion of data from different sources (often in different formats and available at different times) makes objective and quantitative comparison difficult for the operational forecaster. At present, much of this evaluation is made subjectively after examination of a combination of screen-displayed and printed charts.

It is hoped that, by developing standardised products and procedures, the comparison of data may be made more rigorous and more objective, and considerable time and effort can be saved during the forecast process. There is already work underway within the Met Office to attempt to standardise the presentation of 'in-house' EPS output: PREVIN products are soon to be accessed via the MOGREPS webpages and displayed in a similar format. New products, such as those described above, show the merits of developing automated analysis and comparison techniques, and will be absorbed by the unified display system. In addition, EPS products will be incorporated into the new Met Office forecaster workstation, SWIFT, further enabling detailed analysis of Ensemble data.

Having established standardised display formats, the next logical step is to enable quantitative comparison between the different models themselves. For example, the behaviour of an EPS relative to its 'parent' deterministic model can be an important indicator of forecast confidence if correctly interpreted. Work at ECMWF (the 'Combined Prediction System') suggests that statistically, the ECMWF operational deterministic model has very high average weighting at short lead-times, if considered as a member of its own ensemble. It is expected that these results can be generalised, enabling forecasters to quantitatively assess the most probable solution via comparison of all the models.

Some PREVIN and MOGREPS products (such as meteograms) are generated on demand, and as computing power increases, it is anticipated that many other EPS products may be created in this way. The development of an interactive EPS system would also allow the forecaster to specify key parameters for various analysis techniques. At present, the full power of clustering is rarely demonstrated. However, by letting the forecaster specify the domain, time and fields over which to cluster the data according to the synoptic situation, a powerful tool could be generated. This flexibility is far more important than the actual clustering methods used, which can be made as simple as possible in order to minimise computing time.

Best member selection

A standard method of model verification is by subjective comparison of appropriate fields with observational data, most notably with IR or WV satellite imagery. Evaluation of a model's handling of upstream features at, say, T+6 (see Fig 5) provides a key measure of confidence in its later performance.

We can also use this idea to assess performance of each EPS member, thus identifying the current 'Best' and 'Worst' performers in the ensemble. As with the products above, it is essential to automate the process of comparison in order to examine the large EPS datasets on operational timescales. Comparison techniques in this case will be similar to those used in the CDB matching algorithms.

Initial efforts will focus on identifying 'Worst Members' – poor performers – which may be discarded from the ensemble. This is a much simpler process, as often model deviations from reality are clear from comparison of single model fields with imagery. The Best Member could then be obtained by process of elimination, or a set of updated probabilities could be calculated based on the remaining members. Though lacking the statistical rigour of the probabilities derived from the full sample, these recalculated probabilities would help forecasters assess weightings of particular members or clusters given recent observations.

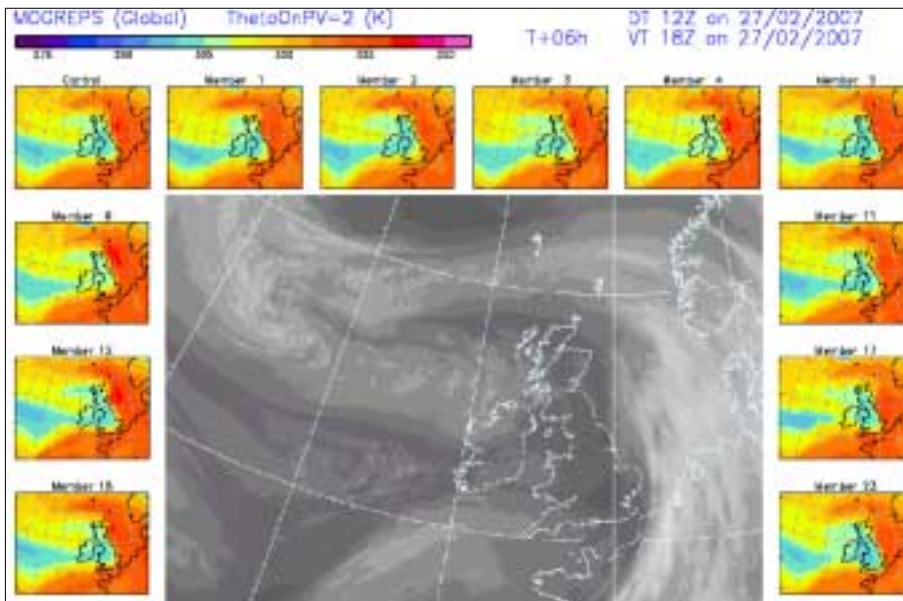


Figure 5:
Example comparison between MSG WV imagery and MORGREPS fields. Comparison can be automated, and used in Best/Worst Member selection scheme.

In the future, it is anticipated that the configuration (eg. resolution and physics schemes) of EPS members will be equivalent to their 'deterministic' parent model. This may open up a scenario whereby a Best Member could be chosen to drive products further down the forecast chain if deemed likely to perform better than the parent model run. This option is being considered as an alternative to complex field modification techniques that are currently being used when larger-scale errors are anticipated in the parent model run.

Summary

The proliferation of EPS data requires that new presentation and analysis techniques are developed in order to keep full data comparison viable on operational timescales.

The Met Office is moving to standardise its EPS output as new ensemble products become operational.

It is hoped that these developments will be the first steps towards a unified and interactive system for quantitative comparison between observations and both EPS and deterministic model data. This will allow EPS data to play an increasingly pivotal role in the everyday forecast process.

References

Hewson, T. 2007. "Objective Identification of Cyclonic Features, from Initiation Through to Decay". To be submitted to Meteorological Applications.