OPERATIONAL ASPECTS OF ENSEMBLE FORECASTING FOR THE MEDIUM RANGE

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1. INTRODUCTION

Ensemble forecasting techniques offer the possibility of significantly increasing the skill of medium range forecasts. Within the Central Forecasting Office (CFO) of the UKMO a small team of medium range forecasters are considering the operational use of ensemble forecasting techniques for the medium range. They have identified some strengths and weaknesses in the current ECMWF Ensemble Predition System (EPS), considered areas in which ensemble forecasting may be used operationally in the near future, and instigated a subjective assessment of the EPS by the duty medium range forecaster.

2 THE NEED FOR ENSEMBLE FORECASTING

2.1 **Current problems with medium range forecasting**

Over recent years considerable effort has been made to further develop and improve numerical weather prediction models. Consequently the WMO standard scores for model 500hPa Geopotential Height rms error over Europe have shown over the years a gradual, though erratic, improvement at T+48. However at T+144 these scores, especially for the winter periods have shown no such improvement and may even have got slightly worse (figure 1). As models have become more sophisticated their climatologies have improved, and in particular newer models tend to have more realistic, and hence more intense, features by T+144. Unfortunately, synoptic scale predictability for this time scale remains low, and hence these features are often incorrectly forecast, which may have led to the apparent slight deterioration at T+144.

Within the UKMO deterministic forecasts showing the positions of fronts, isobars, and thickness lines for days 2 to 5 are routinely produced. A subjective assessment of the day 5 forecasts shows that, whilst for some periods the forecasts are predominantly very good, there are other periods in the which the majority of forecasts have major errors (for example timing errors of at least 24 hours).

The WMO standard scores, and the CFO subjective assessment together show that the performance of models for weather forecasting for days 5/6 outwards remains poor, with little improvement seen over several years.

2.2 **Are ensemble forecasts the solution**

If the relative failure of deterministic forecasting for the longer medium range is due to the atmosphere becoming effectively non-deterministic for synoptic scale features, then ensemble forecasting techniques offer a possible solution, and hence the prospect of some improvement in forecasting skill for the medium range. However, whilst the scientific case for ensemble techniques

is very strong there still appears to be no great weight of objective evidence to show that the ensemble forecasts currently available actually perform better than the best deterministic forecasts.

To use ensemble models fully for the medium range will involve a change in forecasting culture from essentially deterministic forecasting to essentially probabilistic forecasting. However, there will remain customers who prefer deterministic forecasts and are willing to accept their shortcomings. These customers should not be abandoned, and hence the ability to produce the highest possible quality deterministic forecast to day 10 should be retained. This may well involve keeping a separate higher resolution model.

3. THE CURRENT ECMWF ENSEMBLE PREDICTION SYSTEM (EPS)

3.1 **Six to Ten day forecasting**

There is an increasing demand for forecasts for the 6 to 10 day period and these are routinely produced by the UKMO for the UK area (e.g. figure 2). No attempt is made for this time scale to predict specific weather events, weather types are forecast instead. Essentially the forecaster is using his understanding of atmospheric predictability to interpret deterministic forecasts and produce a more generalised forecast of weather type.

If the EPS gives only some 'a priori' knowledge about atmospheric predictability, and hence the expected accuracy of an operational deterministic model, it would be very useful. However, using the EPS directly offers substantially greater possible benefits. Nine, day 8 ensemble forecasts, separated from each other by a week so that they are, approximately, independent, have been looked at for the period from 28th February to 24th April 1993. The sample size is probably too small for any objective assessment and the period covered too short. However, it is clear that during this period the EPS performed better than the T213 model in rms terms for these cases.

Table 1 compares day 8 forecasts from the T213 model with those from the EPS clustered over the normal 'European' area. The clusters formed over days 8 to 10 performed marginally better than the T213 according to this score. However, this small improvement may be in part, or wholly, due to the smoother fields produced by the clustering, and also perhaps to the use of the T63 model which has a smoother climatology. Table 1 also shows, that when the clustering was done for day 8 only, a greater improvement was achieved with rms scores better than for the T213 on all except 2 cases and substantially better on 3 cases (28th February, 13th March and 27th March). This shows that the EPS can produce better forecasts than the T213 for day 8 and that better results can be obtained by clustering for day 8 alone than by clustering for days 8 to 10.

3.2 **Clustering**

Clustering is done at ECMWF based on 500 hPa rms. height differences over Europe for days 5 to 7. Within the Central Forecasting Office of the UKMO forecasters have considered which individual ensemble members constitute good forecasts in the vicinity of the UK and to which cluster they belong, an example is shown in Table 2. Where an ensemble member was felt to give a good forecast (for an area centred broadly on the UK) then the number of the cluster to which the ensemble member belonged was entered into the table. In this example it is apparent that the 'good' forecasts are not concentrated in a single cluster, indeed for day 5 the 'good' forecasts are more or less evenly distributed between the first 3 clusters (there were 4 clusters in total). Also, cluster members do not stay consistently good, or bad, during the 5 to 7 day period. This, and other examples like it, cast some doubt on the current clustering technique, and on the wisdom of clustering over three days rather than on single days.

Clustering should ideally be done by the forecaster at his workstation, in an operational environment. He could then choose on a case by case basis how he wants to do the clustering. For example if he is interested in the 6 to 10 day period over the UK then he may normally want to cluster over the UK for days 6 and 7 and then separately for days 8 to 10. He may, however, wish to vary the clustering depending on the meteorological circumstances and for different forecasts he would want to do different clustering.

4. THE ASSESSMENT OF ENSEMBLE FORECASTS.

From January 1994 the duty medium range forecaster within the CFO will start probability forecasts for day 7 for three specific locations within the UK. Two forecasts are attempted. The first forecast is made without reference to the ensemble products, but allows the use of any other information available to the forecaster. The second forecast, for the same weather elements for the same places, additionally allows the use of ensemble products. Figure 3 shows an example of the form to be used. The ability of the forecasters to use ensemble products depends on the quality of the outputs they are given. In particular better clustering and the availability of point probability maps would greatly assist the forecasters in their interpretation of ensemble products.

This exercise has two main aims:-

(1) Firstly to familiarise the forecasters with the ensemble products and their usage in a real time forecasting environment. This will involve developing a better understanding of medium range predictability and gaining skill in the use of probability forecasting for the medium range.

(2) After (1) has been achieved then these forecasts can be used to demonstrate if the forecasters can achieve better results by using the EPS than by using deterministic models alone.

5. CONCLUSIONS

Ensemble forecasting techniques offer the prospect of a significant improvement in forecast skill for the medium range. However, this needs to be demonstrated by both objective and subjective assessment. Some subjective assessment of ensemble products starts within the CFO during January.

The six to ten day period has been identified as an area where ensemble forecasts can make a significant contribution and a number of case studies have indicated that the current ECMWF EPS may perform better than the T213 model at day 8.

A number of problems have been identified with the outputs currently received, especially with the clustering. The current clustering technique appears not to place 'good' forecasts together in the same cluster. Ideally clustering should be done by the forecasters at a work station on a case by case basis.

A move away from deterministic to probabilistic forecasting for the medium range involves a considerable change in forecasting culture. Education of both suppliers and customers for medium range products will be required and those customers who continue to prefer deterministic forecasts should not be abandoned.

Start Date	(a)	(b) rms.	(b) No.	(c) rms.	(c) No.
28/02	253	239	15	207	20
07/03	117	121	14	115	12
13/03	186	182	12	149	14
20/03	139	136	21	134	23
27/03	138	114	10	103	13
03/04	134	124	13	119	16
10/04	94	100	15	115	22
17/04	79	93	17	95	12
24/04	141	139	9	140	12
Av.	142	139	---	131	

Table 1. Rms. errors of 500 hPa height at day 8 for the European area:-

(a) The ECMWF T213 operational forecast.

(b) The largest cluster, clustered over days 8 to 10, and the number of elements in the cluster.

(c) Largest cluster, clustered for day 8 only and the number of elements in the cluster.

(a) No.	(b) Day 5	(c) Day 6	(d) Day 7
1			
2	3	3	
3		2	
4	3	3	
5			
6	2		
7			
8		2	
9	2		
10			
11	3	3	
12	2		
13			
14			
15	3	3	
16	1		
17			
18	3	3	3
19	1		
20	1		
21	1		
22	1		1
23	2	2	
24			
25			3

(a) No.	(b) Day 5	(c) Day 6	(d) Day 7
26	2		
27			
28			
29			
30	2		
31			
32	2		

Table 2. Subjective assessment of individual ensemble members for forecast with data time 03 October 1993.

(a) Ensemble member No

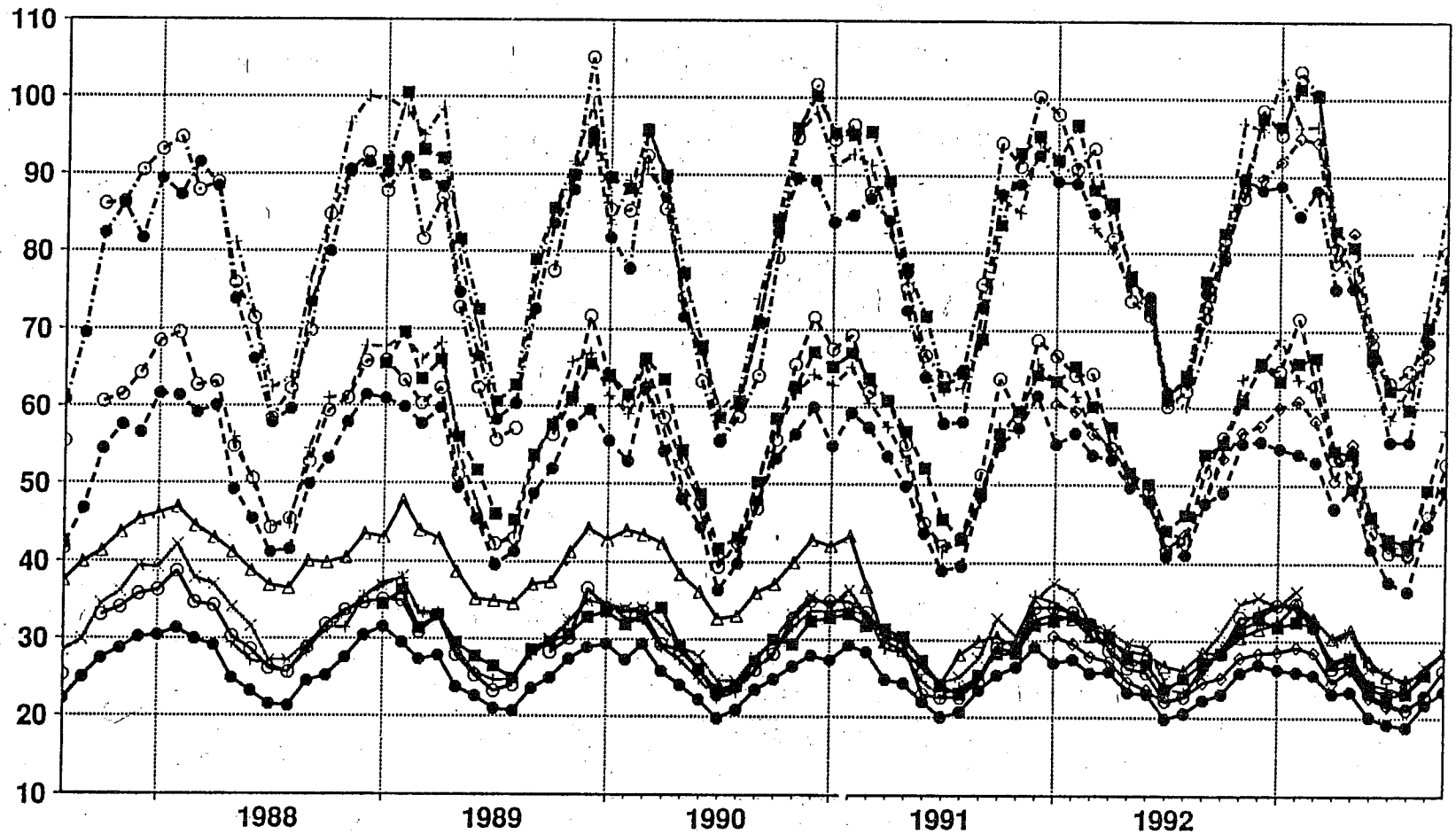
(b), (c), (d), Which cluster 'good' forecasts belonged to.

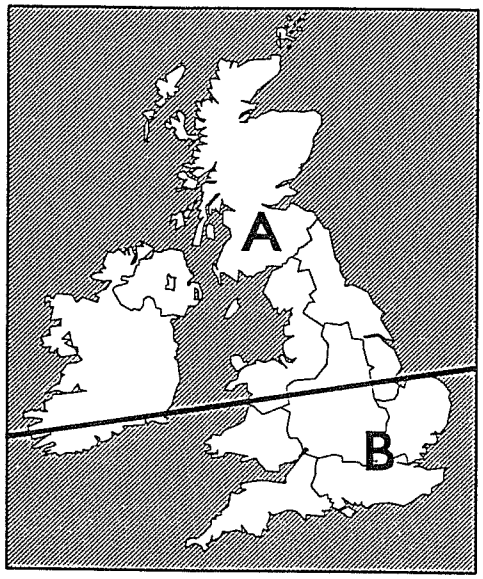
Fig. 1. **WMO STANDARD SCORES**

Northern Hemisphere

Verification against Analysis

500hPa Geopotential Height RMS Error (M)



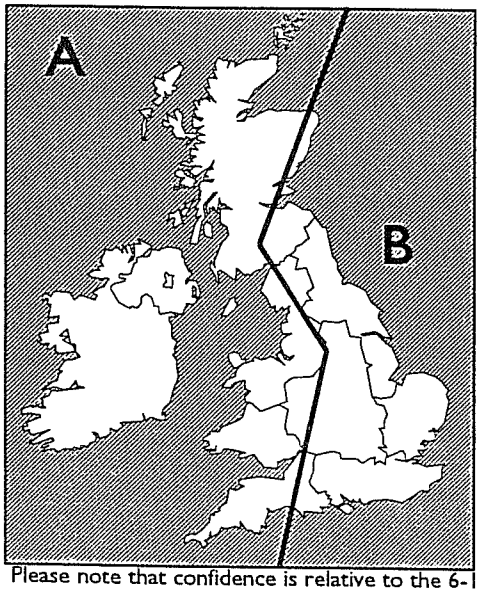


Day 6-7 Forecast: Wed 26/1/94 and Thu 27/1/94

A - Unsettled with showers or longer periods of rain, heavy at times. A few short-lived drier and brighter interludes. Windy with gales, perhaps severe in places.
Temperature - Near or a little above normal.

B - Dry and bright intervals with sunny spells alternating with unsettled weather with showers or spells of rain. Rather windy at times.
Temperature - Above normal, mild in places.

Confidence is high that the weather will be generally unsettled with temperatures not far from average, but low regarding detail.



Day 8-10 Forecast Fri 28/1/94 to Sun 30/1/94

A - Unsettled with showers or longer spells of rain alternating with drier and brighter interludes. Very windy with gales or severe gales at first in the northwest.
Temperature - Mild.

B - Rain or showers at first then generally dry and bright with sunny/clear intervals. Some mist/fog in southeast later. Becoming less windy.
Temperature - Mild or very mild

Confidence is medium that the weather will stay generally unsettled in the west and north but lower with regard to the drier trend in the east and southeast.

Please note that confidence is relative to the 6-10 day period, and last week's temperature refers to Mon to Sun of previous week.

Table of previous maximum temperatures expressed in °C

Region	10 yr mean	Last week	Region	10 yr mean	Last week
Scotland	07	06	East Anglia	07	08
Tyne-Tees, Yorkshire	07	07	London, S.England	08	09
North-West, N. Wales	07	07	South-West, S. Wales	09	09
Midlands	07	08	Northern Ireland	07	06

Fig. 2 Example of a 6 to 10 day forecast.

PROBABILITY FORECASTS FOR 0600 - 1800 ON _____
PREPARED ON _____
BY FORECASTER _____

1) FORECAST NOT INCLUDING ENSEMBLE PRODUCTS

	Rain ≥0.4mm	V. Wet ≥5.0mm	Snow Prob.	Wind ≥25kt	Max. AN	Temp BN
Stornoway 03026						
Score						
Manchester 03334						
Score						
Heathrow 03772						
Score						
Total Score						

2) FORECAST INCLUDING ENSEMBLE PRODUCTS

	Rain ≥0.4mm	V. Wet ≥5.0mm	Snow Prob.	Wind ≥25kt	Max. AN	Temp BN
Stornoway 03026						
Score						
Manchester 03334						
Score						
Heathrow 03772						
Score						
Total Score						

Fig. 3 Example of form used for probability forecasts for day 7.