USE OF ENSEMBLES IN MEDIUM RANGE FORECASTING AT THE UKMO

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INTRODUCTION

In its role as the weather forecasting guidance centre for the UK, the National Meteorological Centre (NMC) has, for many years, issued medium-range forecasts (taken to be the period 2-10 days ahead). Until a few years ago all medium range forecasting was essentially deterministic. For example, forecast synoptic charts out to 5 days ahead would be issued along with explanatory guidance, but with little or no reference to confidence levels or possible alternative evolutions. The advent of ensembles has had a major impact on the philosophy of medium range forecasting, reinforcing the notion of uncertainty. An important first step has been to assign confidence levels to deterministic products and to couch forecasts in more probabilistic terminology. In addition, a limited range of fully probabilistic products are now produced.

This paper will show examples of medium range forecast products and how ensembles are incorporated into the forecasting process. The paper will also show how the forecaster can add value to the model products.

MODIFICATION OF MODEL FIELDS

In producing medium range forecast charts, there has always been the option to modify UK Global Model (UKGM) fields in the light of products from other forecasting centres. More recently Field Modification software (Carroll 1997) provides a facility for the dynamically consistent alteration of model fields towards other centres' products, when deemed appropriate, which may often include the ECMWF ensembles.

In the following example, the 120-hr UKGM forecast valid 12UTC 28/9/99 (Fig 1) showed a marked surface ridge over the UK implying dry weather over much of the country. Most other forecast products suggested a southwesterly flow with fronts crossing the UK implying unsettled conditions. This idea was consistent with the

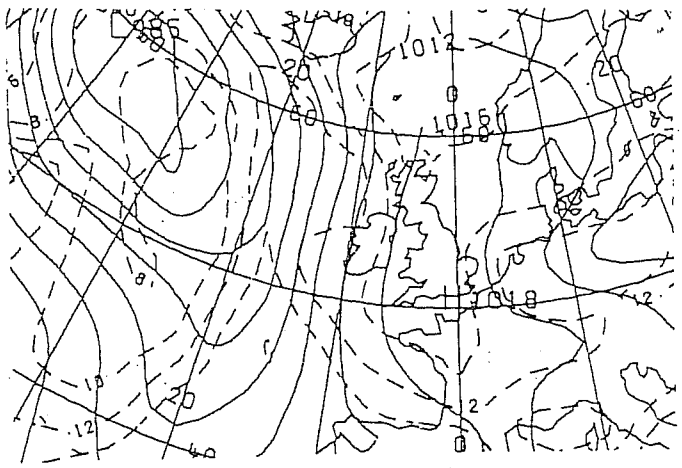


Figure 1 UKGM 120-hour forecast of sea-level pressure (continuous lines) and 850hpa wet-bulb potential temperature (dashed lines) valid at 12 UTC 28/9/99

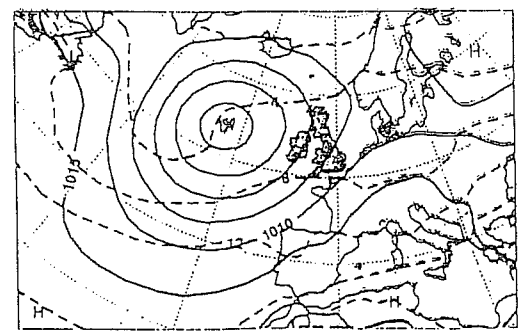


Figure 2 ECMWF ensemble central cluster - 144-hour forecast valid at 12UTC 28/9/99

ensemble central cluster (Fig 2) which suggested a major depression west of Ireland. At NMC the guidance products for 4 and 5 days ahead are (at the time of writing) issued once daily in the evening, often based on the 12UTC UKGM run. Since the UKGM was considered to be an outlier, the raw model fields were modified in line with other available products. The modified chart (Fig. 3) implied fronts affecting northern and some western parts and dry conditions in the southeast. A confidence of 70% was assigned, implying that the solution lay within a relatively limited range of synoptic patterns in the forecast data, but with possible timing errors of 24 hours. When the EC T319 model became available around midnight, their evolution was very different (Fig 4), culminating in a deep depression approaching Ireland by 12UTC 28/9/99. NMC forecasters have an option to issue additional charts to

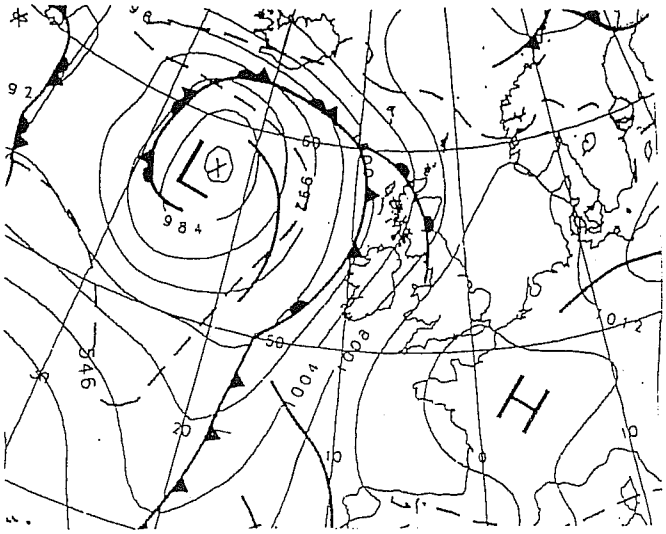


Figure 3 NMC 120-hour surface forecast valid 12UTC 28/9/99 based on modified UKGM fields

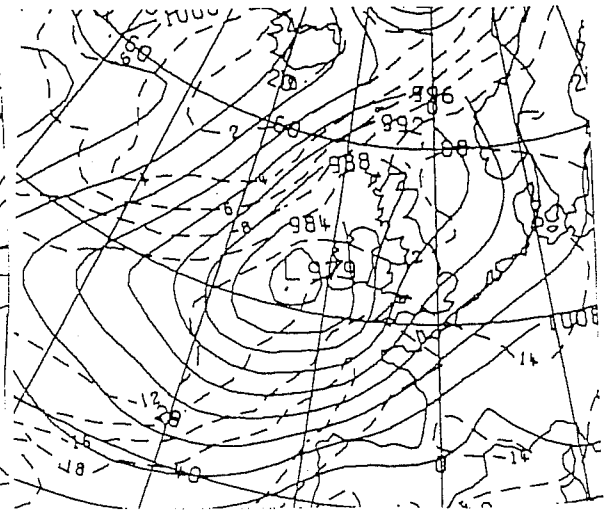


Figure 4 ECMWF T319 120-hour forecast valid at 12UTC 28/9/99. Symbols as in Fig 1

selected customers showing lower probability alternative scenarios. On this occasion the very different solution of the EC T319 was considered plausible and issued as a 20% alternative (Fig 5). When the ensembles became available later, they provided strong support for the T319 solution and so the probability of the alternative was increased, with proportionally less weight given to the earlier issued T+120 forecast chart.

The verifying analysis for 12UTC 28/9/99 is shown in Fig 6. Clearly the modified forecast (Fig 3), which benefited from a wide variety of products was superior to the raw T+120 UKGM in that it indicated potentially unsettled conditions. However, in this case, the alternative solution proved to be the better forecast, highlighting that the more probabilistic approach gave a better idea of the range of solutions in an uncertain situation, at 5-days ahead, than an individual UKGM forecast.

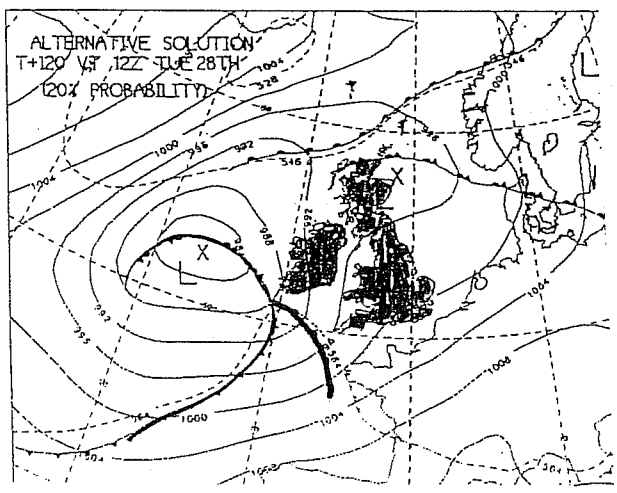


Figure 5 20% probability alternative solution for 12UTC 28/9/99 issued by NMC

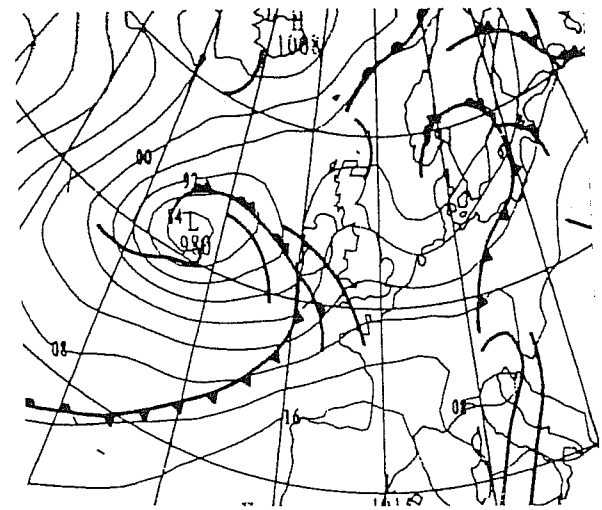
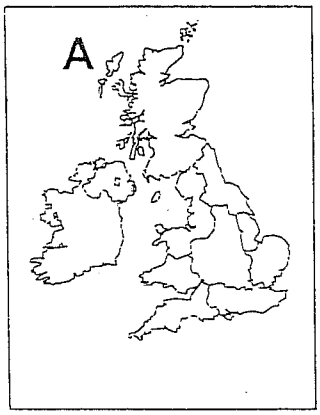


Figure 6 Surface analysis for 12UTC 28/9/99

The performance of the modified fields against the raw UKGM and ECMWF deterministic model is subjectively verified in the vicinity of the UK. During January to December 1999 (inclusive) 221 fields were significantly modified, of which 107 resulted in better forecasts, 80 neutral and 34 forecasts than the unmodified UKGM. In addition, during this period, the modified charts also marginally outperformed the ECMWF model with the same data time. This is particularly significant in that ECMWF is a high resolution model with a late data cut-off, and the output from this model is not available until some hours after issue of NMC 4 and 5 day forecasts. Currently, the ensembles are under-utilized, being over 24 hours old by the time these NMC forecasts are issued, but consideration is being given to an update of medium range charts in the morning to take advantage of later available ensemble data.

6-10 DAY FORECASTS

Ensembles are considered to be at their most useful relative to deterministic forecasts for periods of more than 5-days ahead. Fig. 7 is an example of a forecast product that relies heavily on ECMWF ensembles. It is issued as guidance to all UK regional forecasting offices and a wide variety of commercial customers involved in such areas as power distribution, retail and construction. Elements of the forecast include general weather conditions, temperatures and, very importantly, a statement of confidence level in the forecast.



Forecast for Days 8 to 10:- Fri 12 Nov to Sun 14 Nov 1999.

A:- Mostly dry with variable, often large amounts of cloud but also some bright or sunny intervals, the best of the brightness is mostly likely in the southwest. The far northwest and southeast may have a few light showers at times. Overnight fog patches, forming under prolonged clear spells, may linger well in to the day in places.

Temperatures:- In the northwest, near normal or mild, 10 to 13°C. Elsewhere, normal to rather cold, locally cold where fog lingers, 7 to 12°C.

Confidence:- HIGH for generally dry conditions but LOW for temperatures and cloud amounts. LOW to MEDIUM for cold E to NE winds setting in across the south.

Figure 7 Forecast for 8-10 days ahead, valid 12-14 November 1999 issued by NMC

Fig. 8 shows the ensemble mean of sea-level pressure through the forecast period covered in Fig 7. The most prominent feature in this case is the large anticyclone affecting the British Isles - this signal had been consistent over several runs of the ensemble suite. The so-called 'plume chart' (Fig 9) for Aughton (NW England) showed that for 500mb gph a significant number of members of the ensemble lay within a relatively narrow range. Given the situation, not surprisingly, the rainfall chart showed a strong dry signal. However, the trace of 850mb temperature indicated a considerable spread reflecting a wide range of positions of the high cell between individual ensemble members with resulting range of airmass characteristics. Forecasts based on the ensembles therefore emphasised the most confident aspect - i.e. the strong dry signal. However, more detail could be extracted from rainfall probability charts (Fig 10), indicating driest conditions in the southwest with greatest probability of any rain around the northern and southeastern peripheries of the UK. High confidence was assigned for dry conditions in view of the consistent strong signal from the ensembles. However, the low confidence for temperatures reflected the spread in the ensembles and the usual uncertainty in boundary layer structure in anticyclonic situations. A substantial minority of individual members showed a strong easterly component of surface flow across southern Britain, so this idea was incorporated as a lower probability alternative - the resulting coldness of such a pattern would be of potential interest to power generation customers for example.

It must be remembered that the ensemble mean should be used with great caution. If there is a broad spread of solutions, or a multi-modal distribution, then clustering techniques are much more relevant (e.g. Mylne Fig 6 in this volume).

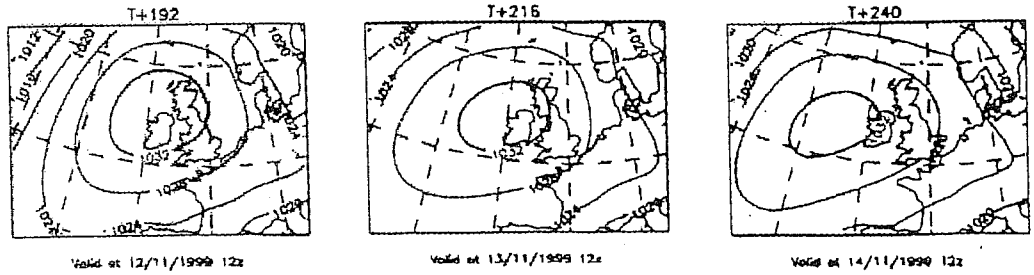
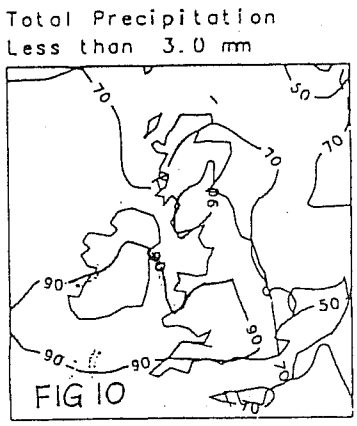


Figure 8 Grand ensemble mean forecast of sea-level pressure for 192, 216 and 240 hours ahead from data time 12UTC 4/11/99



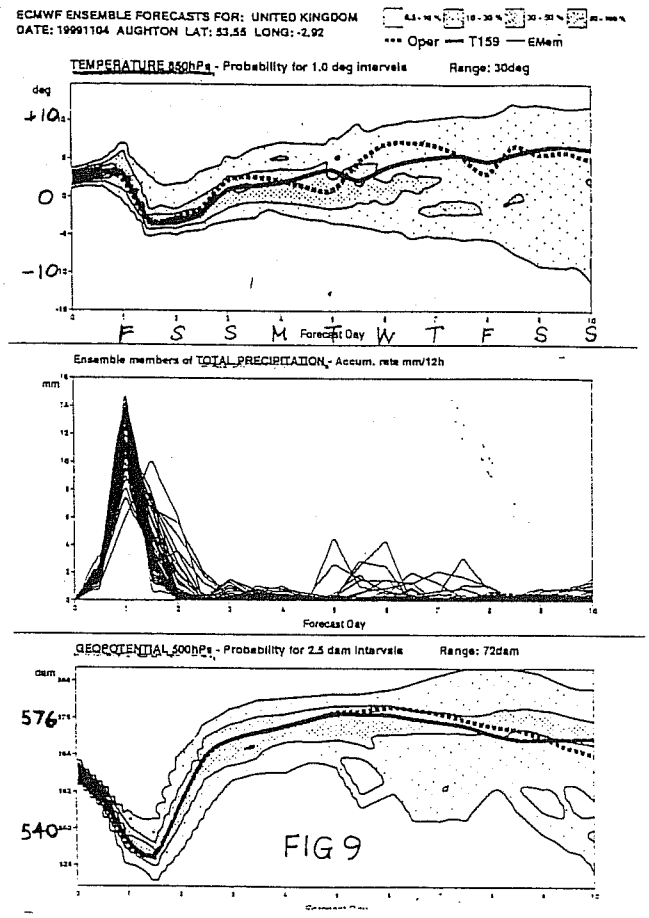


Figure 9 Forecast plumes of 850hpa temperature, 24-hour precipitation and 500hpa geopotential height for Aughton (NW England) derived from ECMWF ensembles data time 12UTC 4/11/99. Dashed line is EC T319 and continuous bold line is the control run of the ensembles

Figure 10 Forecast probablility of total precipitation less than 3.0mm over the period 12-14 November 1999 derived from ECMWF ensembles, data time 12UTC 4/11/99

SPOTTING THE 'ROGUE' MODEL RUN

It is frequently observed that after several consecutive model runs (from one or more forecasting centres) showing a similar evolution, an individual forecast based on more recent data produces a completely different evolution. Whether or not to accept this so-called 'rogue' run is a dilemma. The problem, which can assume special importance for a high-profile occasion, is illustrated by the case below.

Fig.11 shows a 96-hr forecast from the UKGM valid 12UTC 30/8/99, the day of a major Public Holiday in England and Wales. The dominant feature over England and Wales is the strong surface ridge of high pressure. This

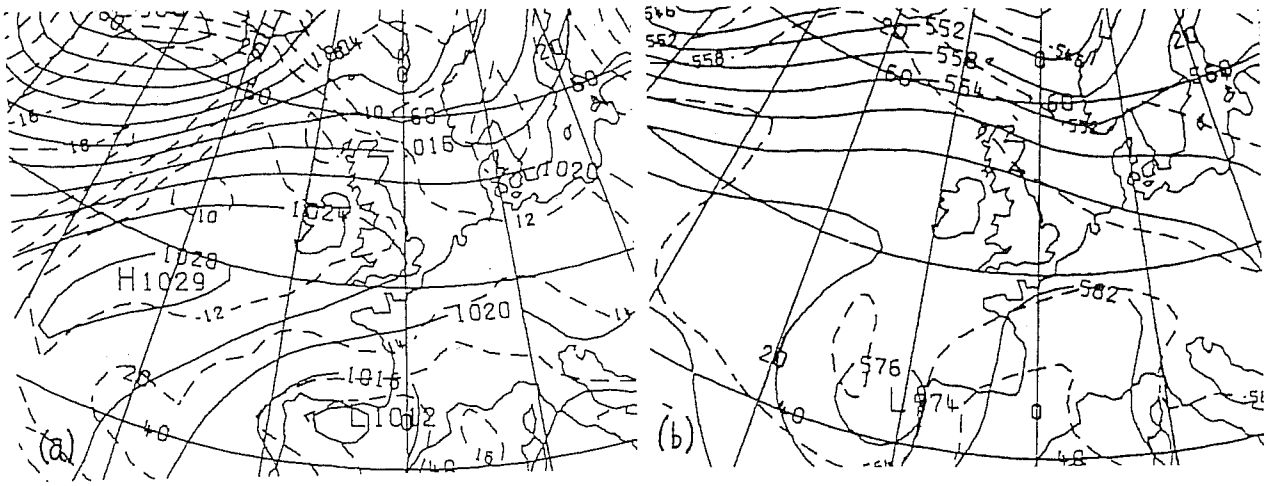


Figure 11 UKGM 96-hour forecasts valid 12UTC 30/8/99 showing (a) sea-level pressure (continuous lines) and 850hpa wet-bulb potential temperature (dashed lines) and (b) 500hpa geopotential height (continuous lines) and 1000/500hpa thickness (dashed lines)

evolution had been reasonably consistent with earlier model runs, although some forecasting centres had the ridge axis somewhat further north with fronts approaching from the south. Therefore a reasonably optimistic weather picture was suggested for this day. When the equivalent run of the EC T319 became available, a totally different handling of a trough disruption over the Atlantic led to an upper cut-off vortex and associated surface low over southern Britain implying unsettled, wet conditions (Fig. 12). Should the emphasis of the previously optimistic forecast be changed in the light of this new guidance? When compared with the new run of the ensembles, the trace of 500mb gph from the T319 (Fig 13) fell to near the lower limit of the ensemble range by 12UTC 30/8/99 (day 4) due to formation of the upper cut-off vortex. This implied that the T319 solution was very unlikely and so the original story was retained with the T319 evolution treated as a low probability alternative. Subsequent verification (Fig.14) showed that the more optimistic UKGM story was justified, with a surface ridge across southern Britain.

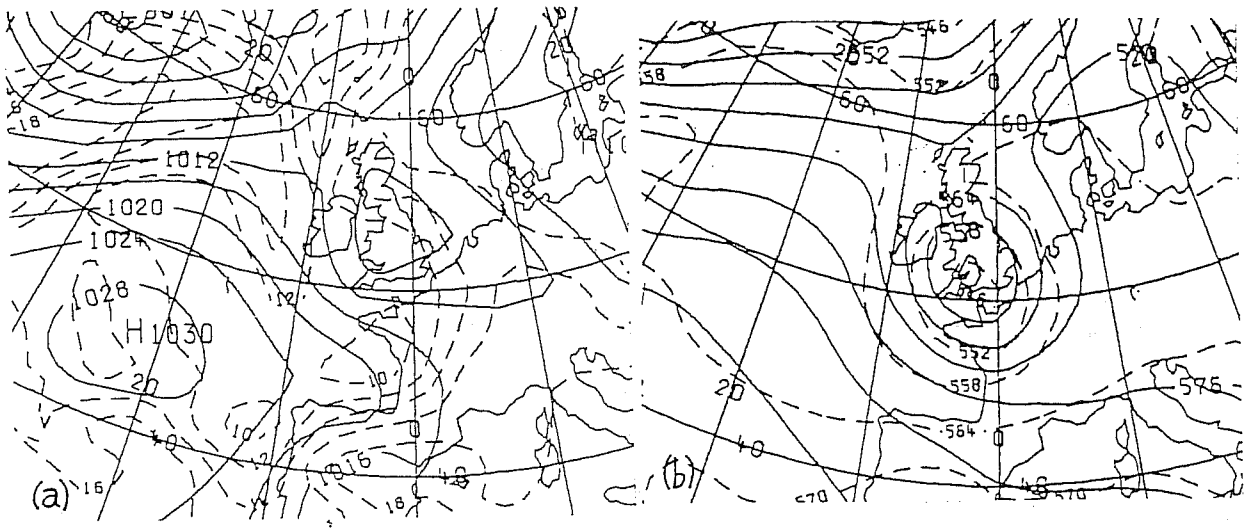


Figure 12 ECMWF T319 96-hour forecasts valid 12UTC 30/8/99. (a) and (b) as in Fig 11

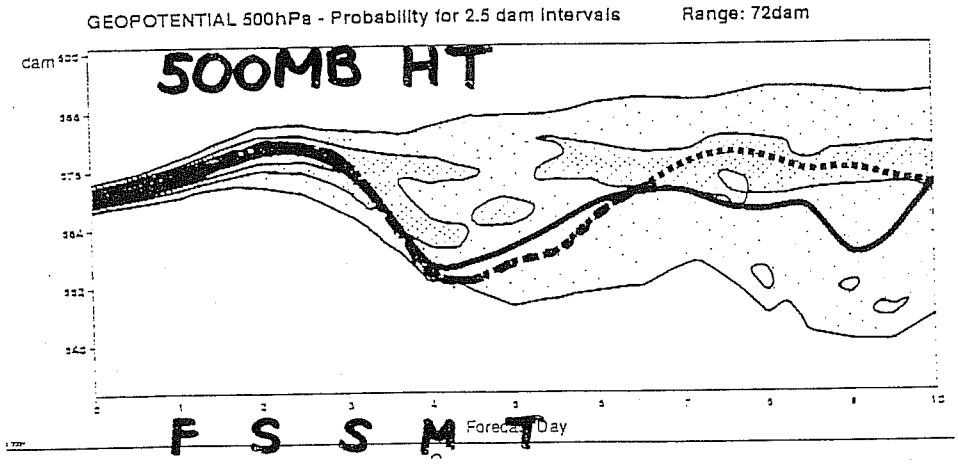


Figure 13 Forecast plume of 500hpa geopotential height for Herstmonceux (SE England) data time 12UTC 26/8/99. Symbols as in Fig 9

A problem for forecasters is knowing when to start putting more weight on a 'rogue' or 'outlying' run. It may be that this run is providing an early indication of a different evolution in a finely balanced situation. Experience has shown that if later runs of deterministic models repeat the 'rogue' solution initially discounted, then it must be taken more seriously. This problem becomes particularly relevant when the outlying run suggests a possibility of severe weather conditions.