TECHNICAL MEMORANDUM

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Comparison of barotropic and baroclinic forecasts for verification

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1. INTRODUCTION

The experience with any forecast model is that the forecast quality varies from day to day. From a practical point of view it would be most useful to provide each forecast after its creation with a quality number indicating if it is reliable or not. This paper reports an attempt to find one such indicator. The idea is to compare forecasts made by an advanced baroclinic (ECMWF) model with those made by the simple filtered barotropic model for 24 hours. If the two forecasts are similar, the situation over the key area (Europe) is barotropic and easy to forecast in the sense that even the simple model could catch the basic features of the development. Consequently, the advanced model forecasts for days 3-7 could be more reliable than usual because of the good start. On the other hand, if the two forecasts differ much already at day 1, it may be expected that such a highly baroclinic development is difficult to forecast even for an advanced model, and the following forecasts for days 3-7 would be less reliable than usual. For four weeks the ECMWF 500 mb height forecasts over Europe were compared to barotropic forecasts to find out if this idea was working in practise.

2. THE MODELS

The barotropic model used for the experiments was based on the conservation of potential vorticity

$$\frac{d}{dt}\left(f + \zeta + f_o^2 \frac{\partial}{\partial p}\left(\frac{1}{\sigma}\frac{\partial\psi}{\partial p}\right)\right) = 0$$

where the baroclinic term was parameterized in the local change term by setting (Holton, 1979)

$$f_o^2 \frac{\partial}{\partial p}\left(\frac{1}{\sigma}\frac{\partial\psi}{\partial p}\right) = -\lambda^2\psi$$

This leads to the barotropic model equation:

$$(\nabla^2 - \lambda^2)\frac{\partial z}{\partial t} = J(\eta, z)$$

In the experiments λ^2 was fixed to $0{\cdot}75\ 10^{-12}\ m^{-2}$. The polar stereographic map projection was used with grid length of 300 km. With some optimization a 24 hour forecast of the 500 mb height field emerged in less than 3 seconds CDC CPU-time. Fig. 1 shows the calculation area and gives an example of the barotropic and baroclinic forecasts from 30 August 1980. The baroclinic model was the ECMWF operational 15 level N48 model with full physics.

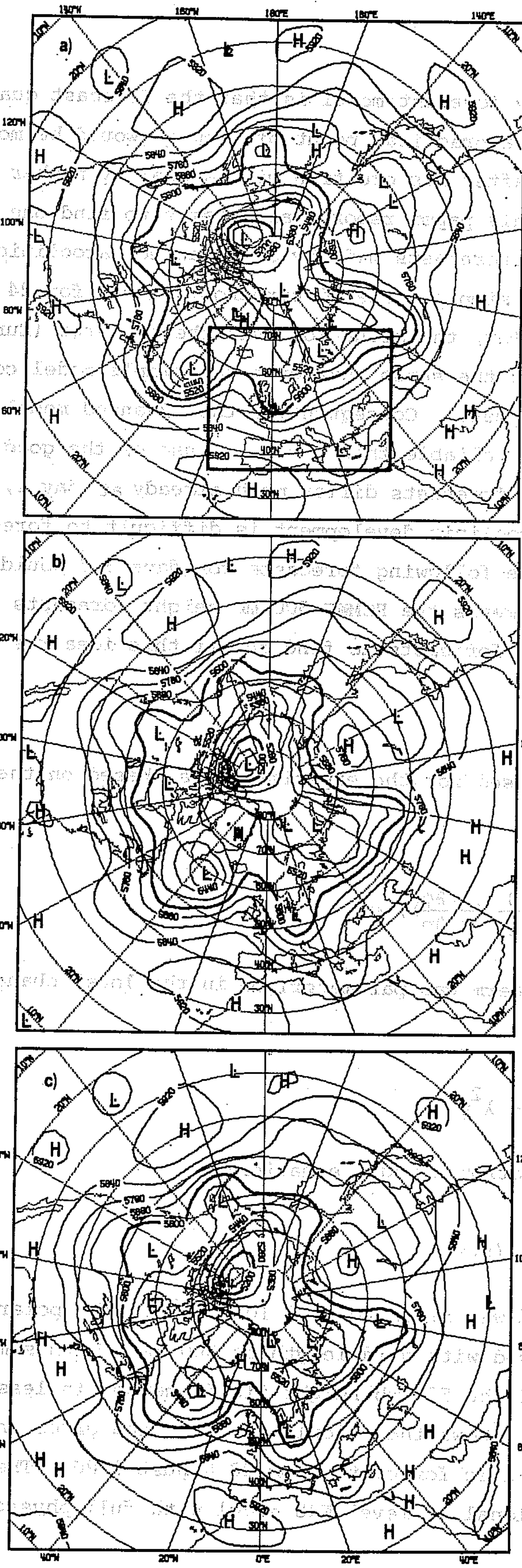

Fig. 1 An example of the barotropic (b) and ECMWF operational (c) 24 hour forecasts of the 500 mb height field starting from 30/8/1980 12GMT analysis (a). The deviation between the forecasts is calculated over the area indicated in (a).

3. RESULTS

For days 31 August - 25 September 1980 the 24 hour barotropic forecast was made daily starting from the analysed 12GMT 500 mb height field stored in EMOS polar stereographic database. This forecast was then compared to the ECMWF operational 24 hour forecast of the 500 mb height field (taken from the same database) by calculating the root mean square deviation between the two forecasts in the gridpoints covering Europe. This area is shown in Fig. 1. Also the rms deviation between the day 1 operational forecast and initial state (day 0) was calculated for the same area to simulate the observed change in the 500 height field during the 24 hour period.

These two rms deviations (bt vs bc and change) were then compared with the verification scores given by the ECMWF Operations Department for September 1980 (courtesy of R. Nieminen. The standard deviation of 500 mb height field forecast over Europe, defined and used in the ECMWF monthly forecast reports, was calculated for forecast days 1, 3 and 6. All these deviation measures are collected into Fig. 2. Fig. 2 shows also the subjective assessment of the operational forecasts as given by the analysts in the ECMWF Meteorological Operations section. This assessment, made in scores of good-moderate-poor, concentrates on the usefulness of the 4-6 day 500 mb forecasts over Europe when using them as synoptic guidance.

From Fig. 2 it can be seen that the correlation between the daily values of the rms deviation bt vs bc (curve a) and the change (curve b) is rather good, i.e. if the 24 hour change was large in the 500 mb height values over Europe, the deviation between barotropic and baroclinic forecasts was also large.

The deviations between models at day 1 (curve a) and the actual errors of the operational forecast at day 1 over Europe (curve c) do not correlate, however. There are forecasts (e.g. from 10 September), where the day 1 forecast error is large and yet the barotropic and baroclinic forecasts are near to each other while in other cases, (e.g. from 15 September) large difference in forecasts is accompanied by large error. For the longer operational forecasts there is no correlation, either, between the bt vs bc deviation at day 1 (curve a) and the forecast errors at day 3 and 6 (curves d and e, respectively). Thus, the deviation of simple and complex model forecasts in a short range prediction is not a reliable indicator of the errors in the succeeding medium-range forecasts. This indicates that for good medium-range forecasts the quality of the early forecasts (mainly determined by the

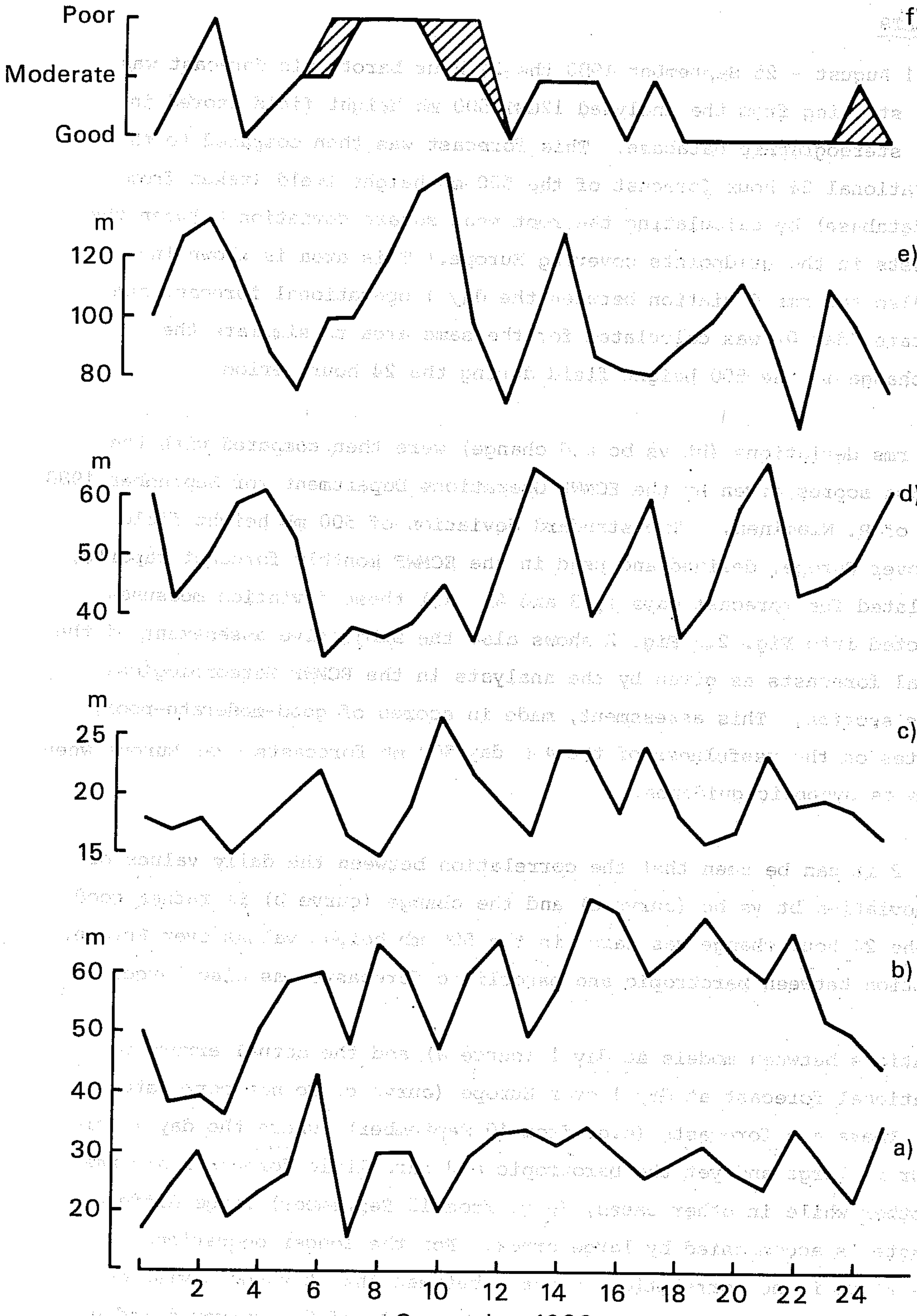

Fig. 2 The time evolution of error scores. EC forecast = ECMWF operational 500 mb height forecast over Europe

a) rms deviation between barotropic and EC forecast for day 1
b) rms deviation between initial state and EC forecast for day 1
c) standard deviation of EC forecast error for day 1
d) standard deviation of EC forecast error for day 3
e) standard deviation of EC forecast error for day 6
f) subjective assessment of the forecast set starting from the day indicated

accuracy of the initial state) is less important than the complex model's ability to simulate accurately the baroclinic developments through energy conversions and sub-grid scale parameterizations. This can also be seen in the error scores for days 1, 3 and 6, which do not correlate with each other. Thus, day 1 forecast can be bad in the sense of relatively large standard deviation and yet day 3 or day 6 forecasts from the same initial data can be good. An example is given in Fig. 2 by the forecast starting from the 6th of September 1980.

Even if the statistical error measures are large the forecast could still be useful for the meteorologist. A weak daily correlation between subjective and objective forecast quality indicators was pointed out in a study made in the Finnish Meteorological Institute (Bengtsson, 1978), and it can be seen also in Fig. 2 that the subjective assessment (curve f) does not coincide completely with the standard deviation of error for day 6. However, except for the first six days of the sample, there is little correlation between the model deviations (curve a) and subjective assessment (curve f). We conclude that the deviation between a simple barotropic and advanced barotropic short-range forecast is not a reliable indicator of the quality of the medium-range forecasts.

4. CONCLUDING REMARKS

An attempt to forecast the quality of the forecasts was made by comparing the deviation between day 1 forecasts, made by an advanced baroclinic model and by a filtered barotropic model, with subjective and objective error scores. No significant correlation was found in the short sample studied, neither did the error scores correlate well with each other. This negative result is still encouraging in the sense that even after a relatively bad short-range forecast an advanced model is able to reproduce good medium-range forecasts. An essential element in such a model is the baroclinic energy transformation between potential and kinetic energies and care should be taken to find the optimum finite difference scheme for it.

References

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