A Single Forecast Comparison Between the NCAR and GFDL General Circulation Models

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1. Introduction

The Numerical Weather Prediction Project at the National Center for Atmospheric Research (NCAR) has recently been comparing the relative skill of several General Circulation Models (GCM's) in predicting the evolution of large-scale features of the real atmosphere. The purpose of these studies is to identify the common errors associated with the various models and to ascertain the relative strengths and weaknesses of the individual models. The results of the intercomparisons may hopefully lead to a focusing of effort to extend the useful forecast range of large-scale models.

A detailed comparison is being performed at NCAR using results from the Goddard Institute for Space Studies (GISS), NCAR and National Meteorological Center (NMC) models for six forecasts during December 1972 and January 1973. In order to extend the results of these comparisons to another model, an NCAR GCM forecast was compared to a Geophysical Fluid Dynamics Laboratory (GFDL) published forecast (Miyakoda *et al.*, 1972). Only one individual forecast is displayed in this paper, the 17 January 1966 case; therefore, our comparison is limited to a single sample. The forecasts are compared using the published Hovmöller diagrams (longitude-time plots of forecast variables). These displays are given for various wavenumber ranges, thus facilitating easier understanding of the forecast error evolution. The standard deviation of error for the NCAR forecast is also compared to the GFDL results.

2. Models

The basic structure of the GFDL model is documented in the following papers: Smagorinsky *et al.* (1965), Manabe *et al.* (1965) and Miyakoda *et al.* (1969). This model has approximately 3° horizontal mesh and nine layers in the vertical. The NCAR model (Kasahara and Washington, 1971; GCM Steering Committee, 1975) uses a 2.5° horizontal mesh and six layers in the vertical. Both models contain extensive parameterizations of physical processes, have a mountainous lower boundary, and forecast over a hemispheric domain.

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The GFDL model was initialized with geopotential and moisture as analyzed by the NMC operational system. The wind field is calculated from the "balance" relationship (Miyakoda *et al.*, 1969). The same geopotential, converted to pressure, was used in the NCAR model, and the wind fields were obtained directly from the NMC analysis scheme. No filtering or balancing of the velocity field was performed. The initial moisture field for the NCAR model is simply a zonally averaged relative humidity inserted as a function of latitude.

3. Results

The forecasts at 500 mb are displayed in Fig. 1 in the form of Hovmöller diagrams for both models, together with the NMC analysis as verification. The GFDL forecast, as illustrated in Miyakoda *et al.* (1972), was transformed and reformatted to facilitate direct comparison. The complete field (all wavenumbers) at 500 mb (Fig. 1a) was not available for the GFDL forecast.

The spectral decomposition of the NMC analysis shows that the large-scale weather patterns are not in a state of transition. Only the smaller scale waves (6–10) show any significant movement during the period. There is, however, considerable change in amplitude at the lower wavenumbers. From a forecasting standpoint, this particular case should be relatively easy to predict since most of the waves need only to be held stationary to achieve forecast skill.

Both model forecasts hold waves 1–2 (Fig. 1a) stationary for the first three days with a general weakening in amplitude. The GFDL forecast shows a tendency toward progression in the latter stages of the period, especially in the Western Hemisphere, which does not occur in reality. The largest error of nearly 150 m occurs in the GFDL forecast at Day 7 associated with the destruction of the European ridge. The same tendency of weakening amplitude with time carries over to waves 3–5 (Fig. 1b), and the dominant stationary features are correctly forecast by both models. The NCAR model incorrectly retains the amplitude of the Asian wave system at the end of the forecast. Again, an unrealistic progression of the waves over the Atlantic and Europe is noted in the GFDL forecast. For the shorter waves

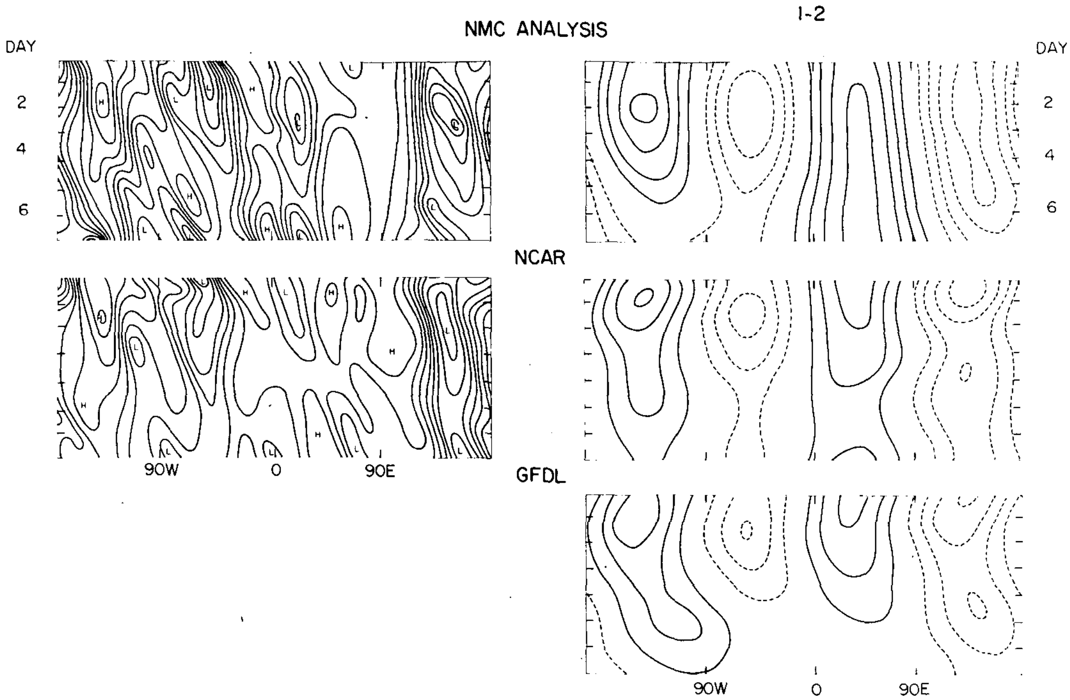

FIG. 1a. A longitude-time plot, averaged between 35–45°N, of 500 mb geopotential for NMC analyses (top), the NCAR forecast (middle) and GFDL forecast (bottom). Actual fields for NMC analyses and NCAR forecast are shown at left, contour interval = 60 m; spectral decomposition of wavenumbers 1–2 are shown at right, contour interval = 45 m. Solid lines are positive amplitude, dashed lines negative.

(6–10), both forecasts are too slow in moving the progressing systems in the eastern Pacific and the United States. The secondary system developments at Days 5–7 are not forecasted accurately by either model. Close examination reveals a phase error of about 180° for the predicted systems at Day 7 in both forecasts.

The standard deviation (SD) of error for the NCAR forecast and the range of SD for several GFDL cases,

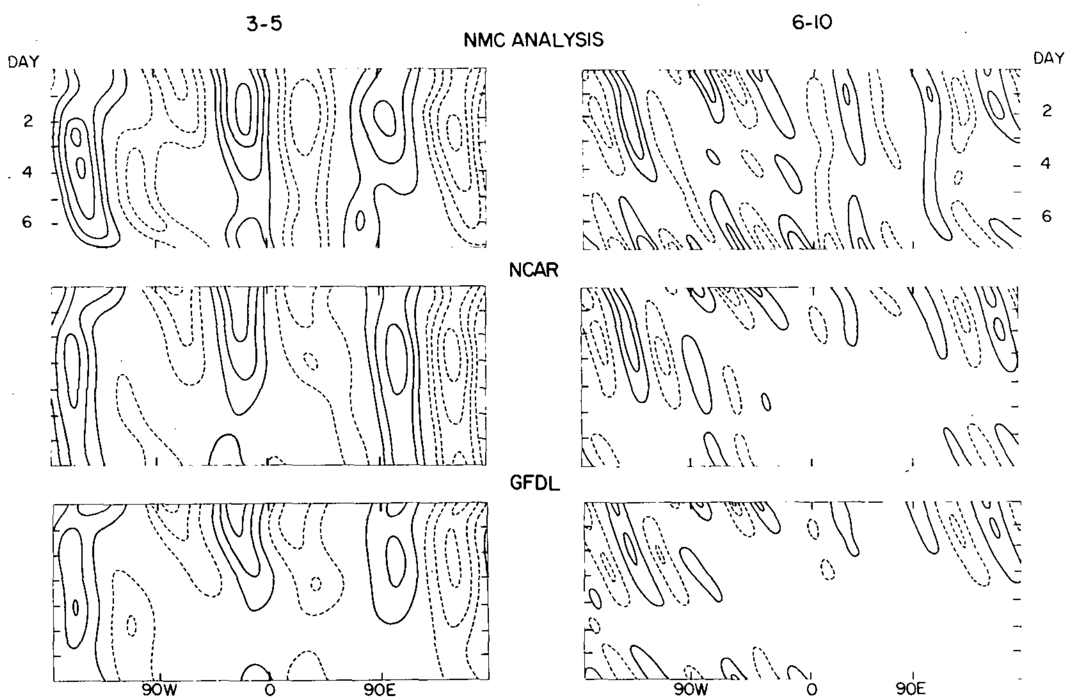

FIG. 1b. As in 1a except for spectral wavenumbers 3–5 and 6–10.

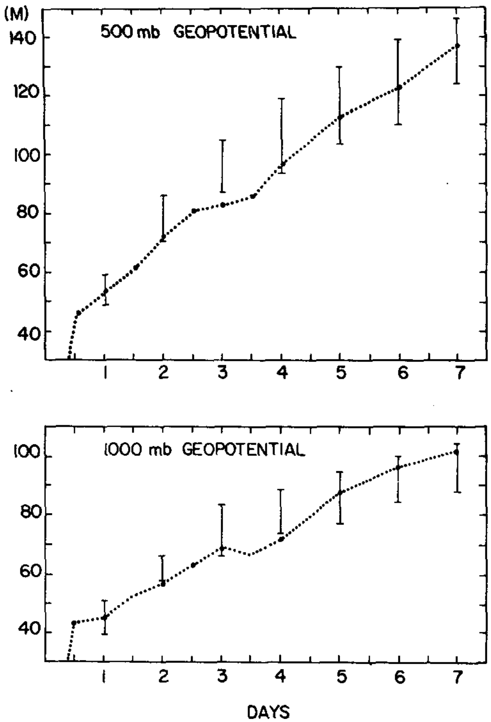

FIG. 2. Standard deviation of error (m) for 1000 and 500 mb geopotential, 25–90°N. Dashed lines represent NCAR forecast for 17 January 1966. Error bars show range of GFDL forecasts for 12 cases including 17 January 1966.

including that of 17 January 1966 (Miyakoda *et al.*, 1972), are presented in Fig. 2. The SD calculation method in the NCAR case included dropping points with elevations >1 km for the 1000 mb level. A similar adjustment is made for the GFDL values. The NCAR sd falls below the lowest GFDL value on several occasions in the middle of the forecast period.

4. Summary

From this single comparison, it is by no means possible to come to a definitive conclusion concerning the relative skill of the models; however, it appears that both models are comparable at the 500 mb level for this case. Some common problems do stand out—a loss of amplitude in all wavenumbers and a phase error in progressing small-scale systems. These errors are common to other models as well (see, e.g., Leary, 1971, and Druyan, 1974) and are largely attributable to inaccuracies in the numerical integration schemes (Kreiss and Oliger, 1972). It would be interesting to compare the two models in several more difficult situations to substantiate the preliminary results.

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