J1.21 HISTORICAL SEASONAL FORECASTS WITH A SIMPLE GCM

Hai Lin[1], Jacques Derome[1] and Gilbert Brunet[2]
[1] McGill University, Montreal, Canada
[2] Meteorological Service of Canada

ABSTRACT

A simple General Circulation Model (SGCM) driven by a time-independent forcing is used to perform a series of seasonal predictions. The predictions are made for 51 winter seasons (DJF) from 1948 to 1998. Ensembles of 20 forecasts are produced, with initial conditions of December 1st plus small perturbations. The model uses a forcing field that is calculated empirically from the National Centers for Environmental Prediction (NCEP) / National Center for Atmospheric Research (NCAR) reanalyses. The forcing used for a given winter is the sum of a climatological forcing plus an anomaly that is obtained from the preceding November NCEP data, and that is persisted through DJF. The forecast system does not use any data from the winter months (DJF) being predicted.

The ensemble mean prediction for each of the 51 winters is verified against the NCEP reanalysis. The system is found to have statistically significant skill in forecasting the DJF mean 500 hPa height field in areas of the globe that are nearly the same as those of a full GCM, albeit at somewhat reduced levels, but a very much lower computational cost. The skill is observed not only in zero-lead forecasts (for DJF) but also in one-month lead forecasts (for JF).

1. INTRODUCTION

Seasonal predictions are normally made either with statistical techniques (e.g., Palmer and Anderson, 1994) or with complex global dynamical models (e.g., Barnett et al., 1994; Derome et al., 2001). The purely statistical approach is hampered by the shortness of the observational record required to train the system. The complex global dynamical models do not suffer from that problem, but they are computationally much more expensive. The present study explores the usefulness of using a middle-ground approach, namely, a simple General Circulation Model (SGCM) driven by empirical forcing functions.

We mimic operational forecasting conditions in that the mean DJF conditions are predicted without using any information of the state of the atmosphere or oceans for that period.

* *Corresponding author address :* Hai Lin, Dept. of Atmospheric and Oceanic Sciences, McGill University, Montreal, QC H3A 2K6; e-mail: hai.lin@mcgill.ca

2. THE MODEL AND EXPERIMENTAL SETUP

The simple GCM used in this study is the same as described by Hall (2000). It is based on a dry global spectral primitive equation model with linear damping and diffusion, and an empirically derived, predetermined, time-independent forcing. The model integrates prognostic equations for vorticity, divergence, temperature and log surface pressure at a horizontal resolution of T21 with 5 equally spaced sigma levels. For each time tendency equation of the model, the forcing is obtained as a residual, after evaluating all the dynamical terms with NCEP data on a daily basis, and time-averaging over a period of one month or one season, to obtain a time-independent forcing. Thus, contrary to a full GCM, in which the “forcing”, such as the diabatic heating, is calculated at every time step, the SGCM uses a predetermined time-independent forcing, hence its much lower computational cost. More details can be found in Hall (2000) and Hall and Derome (2000). The model was shown by Hall (2000) to have a good Northern Hemisphere climatology, not only in terms of the mean zonal wind and standing waves, but also in terms of the transient eddy statistics.

All forecasts were made for the winter (DJF) season. We first computed the mean DJF forcing fields with NCEP data for each of the 51 winters (1948-1998) and the corresponding 51 mean-November forcing fields. When forecasting a given DJF we drove the model with a forcing constructed as follows. We first computed the anomaly in the November forcing of that particular year, defined as a deviation of that November forcing from the climatological forcing (the average over the 51 Novembers). We added this anomaly to the climatological DJF forcing (the average over the other 50 DJFs). The sum of these two forcings was then used throughout DJF. For each of the 51 winters, an ensemble of 20 forecasts was made. The initial conditions for the ensemble members were taken to be the December 1st analysis plus small perturbations.

3. RESULTS

The predictive skill is measured by the temporal correlation over the 51 winters between the predicted ensemble mean and observed seasonal averages. Fig.1 shows this skill for the 500 hPa geopotential height. The shaded areas have a significance level of 0.05 or better according to a Student-t test. Skilful DJF predictions are found over all the tropics and parts of the North Pacific, North America and eastern Asia.

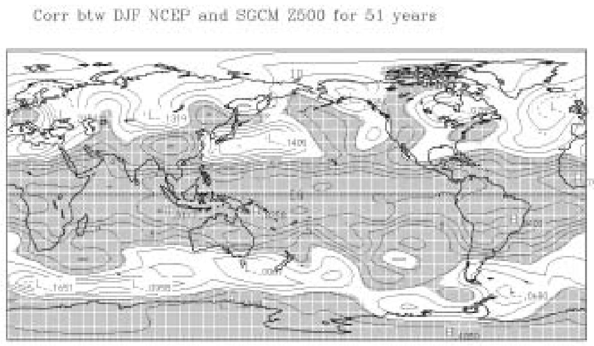

Fig. 1 Temporal correlation between the observed and SGCM-predicted 500 hPa height for 51 winters (DJF). Shaded areas indicate statistical significance at 5% level or better, as in the other figures.

Some of skill seen in Fig. 1 comes from the forcing and some of it from the initial conditions, since the figure refers to zero-lead forecasts. Figure 2 concentrates on the skill derived from the forcing by using only months 2 and three of the forecasts (JF). The skill is clearly reduced from that of zero-lead forecasts, but it is still statistically significant throughout the tropics and over some areas of the mid-latitudes.

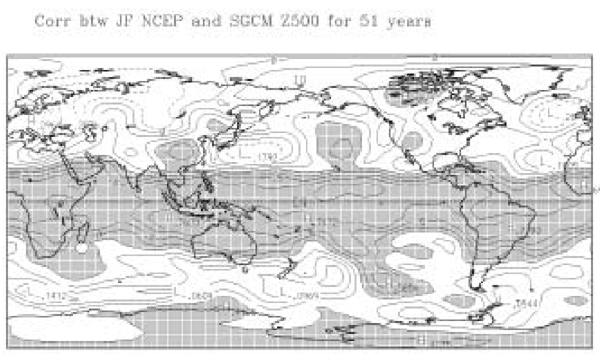

Fig. 2. As in Fig. 1 but for one-month lead forecasts (for JF).

Previous to the present study, the Canadian Climate Variability Research Group has conducted a project termed the Historical Forecasting Project (HFP). As part of that project, a General Circulation model developed at the Canadian Centre for Climate Modelling and Analysis, labelled GCM2, had been used to produce DJF forecasts over the 26 years 1969-1994. The GCM2 was run at a resolution of T32 with 10 levels in the vertical. The model details can be found in Boer et al. (1984) and McFarlane et al. (1992). The model was run with specified sea surface temperatures (SSTs), instead of a specified explicit forcing as in the case of the SGCM. The SST was specified to be the climatological SST for DJF plus the November SST anomaly. The latter was thus persisted through DJF. Thus, just as in the SGCM, no information about the DJF to be predicted was used in the prediction system, so that the GCM2 forecast protocol also mimicked an operational forecasting environment. The GCM2 experiments used 24 member ensembles, while the SGCM experiments used 20, but this small difference should have little influence on the results to be presented.

Figure 3 compares the forecast skills of the SGCM and the GCM2 over a common set of 26 winters, for JF forecasts of the 500 hPa geopotential. We first note that the SGCM skill is higher than that shown in Fig. 2, presumably because the 26 years of Fig. 3 (1969-1994) contain a higher percentage of strong ENSO winters than the 51 years of Fig.2 (1948-1998). Figure 3 shows that while the forecast skill of the SGCM is lower than that of the GCM2, its areas of skill in the Northern Hemisphere mid-latitudes are not radically different from those of the GCM2.

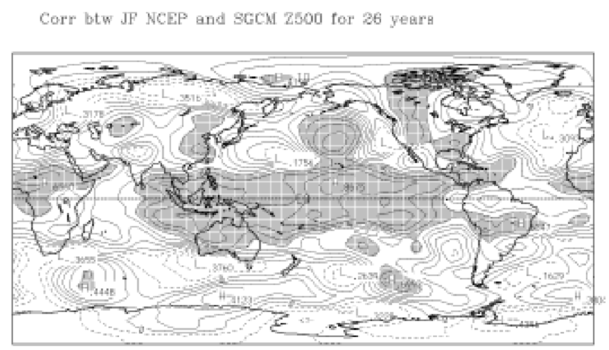

Fig. 3a. Temporal correlation between the observed and SGCM-predicted 500 hPa height for 26 winters (1969-1994). One-month lead forecasts (JF).

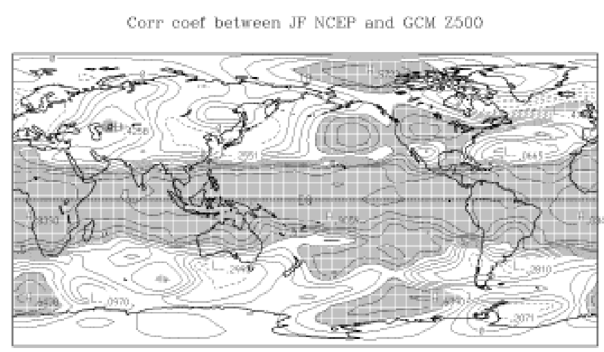

Fig. 3b. As in Fig. 3a, but for GCM2-produced forecasts.

4. DISCUSSION

A new approach to seasonal forecasting has been tested, in which a simple GCM is forced by a time-independent, specified forcing. The latter includes the forcing anomaly “observed” during the month preceding the forecast. The forecast system was shown to have skill in forecasting the 500 hPa height for months two and three not only over the tropics, but also over parts of the Northern Hemisphere mid-latitudes.

A full GCM used in seasonal forecasting must translate SST (and other lower boundary) anomalies into heating or cooling anomalies. Model deficiencies can lead to an incorrect specification of the corresponding forcing. With the approach used here, that step is by-passed, in that the heating/cooling anomalies themselves are specified. The obvious disadvantage with respect to a coupled GCM, on the other hand, is that the forcing anomaly must be predicted from past data. Here the simplest approach was used, in that the forcing anomaly of November was persisted through DJF. Tests (not shown here) have shown that when the "observed" forcing anomaly of DJF is used in the forecast, very much better forecasts are obtained. This suggests that our forecast procedure might be improved by better predicting the forcing anomaly. It may be possible, for example, to filter the forecast anomaly to keep only its more persistent components, such as the forcing associated with the tropical Pacific. Tests are under way to explore this possibility.

REFERENCES

Barnett, T. P., L. Bengtsson, K. Arpe, M. Flugel, N. Graham, M. Latif, J. Ritchie, E. Roeckner, U. Schlese, U. Schulzweida and M. Tyree, 1994: Forecasting global ENSO-related climate anomalies. *Tellus*. **46A**, 381-397.

Boer, G. J., N. A. McFarlane, R. Laprise, J. D. Henderson and J.-P. Blanchet, 1984: The Canadian Climate Centre spectral atmospheric general circulation model**.** *Atmos.-Ocean*, **22**, 397-429.

Derome, J., G. Brunet, A. Plante, N. Gagnon, G.J. Boer, F.W. Zwiers, S.J. Lambert, J. Sheng and H. Ritchie, 2001: Seasonal predictions based on two dynamical models. *Atmos.-Ocean*. In press.

Hall, N.M.J., 2000: A simple GCM based on dry dynamics and constant forcing. *J. Atmos. Sci.*, **57**, 1557-1572.

Hall, N.M., J., and J. Derome, 2000: Transience, nonlinearity and eddy feedback in the remote response to El Niño. *J. Atmos. Sci.*, **57**, 3992-4007**.**

McFarlane, N. A., G. J. Boer, J.-P. Blanchet and M. Lazare, 1992: The Canadian Climate Centre second-generation general circulation model and its equilibrium climate*. J. Climate*, **5**, 1013-1044.

Palmer, T. N. and D. L. T. Anderson, 1994: The prospects for seasonal forecasting: a review paper. *Quart. J. Roy.* Meteor*. Soc*., **120**, 755-793.