FURTHER EXPERIMENTS ON THE EFFECT OF TROPICAL ATLANTIC HEATING ANOMALIES UPON GCM RAIN FORECASTS OVER THE AMERICAS

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INTRODUCTION

The purpose of this paper is to describe the sensitivity of the response of a general circulation model to variations in the structure and magnitude of the tropical forcing. This work builds upon a series of real data experiments incorporating tropical heating modifications with the National Center for Atmospheric Research (NCAR) general circulation model (GCM). Zhang (1985), Buchmann et al. (1986), Paegle et al. (1987), Buchamnn et al. (1989a) and Buja (1989) describe experiments in which the tropical heating of East Pacific is modified within integrations of 10-36 day duration. Buchmann et al (1989b) and Buja (1989) study the effect of varying tropical Atlantic heating in 30 days predictions.

The principal conclusions were that strong tropical latent heating events influence the regional tropical and extra tropical circulation on time scales of 5 days and 10 days, respectively, and are evident globally after 30 days. In particular, modifications of Tropical Atlantic heating have supresingly strong and repeatable effects upon rainfall forecasts over North America, Buchmann et al. (1989b), but probably used unrealistically large tropical heating modifications. Two of our present goals are to investigate the typical strenght of model tropical heating, and the model response to variations of the heating.

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The selection of a series of different real-data cases allows statistical evaluation of response in forecasts that retain some of the variability characterizing the actual atmosphere. The 36 days forecasts made by Buja (1989) are sufficiently short that their temporal average has still not drifted completely into the model climate, and sufficiently long that they may be relevant to outlooks of monthly trends. The relatively short durations of these integrations have also justified our previous imposition for large heating anomalies, peaking at 8°C/day in the mid-troposphere. Such heating rates are probably excessive with respect to latent heating occurring naturally in the NCAR GCM on seasonal time scales, and it is not clear how relevant they may be for shorter periods. This complicates the interpretation of the earlier results. Sections 2 describes the response of the NCAR GCM when the magnitude of the imposed tropical heating is reduced to 33% of the values imposed by Buchmann et al. (1989b). The resulting heat input is less than the values produced naturally by the model. The integrations also include modifications of East Pacific SST to determine whether East Pacific events modify the Atlantic influence significanlty.

RAINFALL RESPONSE TO TROPICAL HEATING

The experiments of the present study are composed of four ensembles, each consisting of eight cases initialized from eight different dates starting on 1 January of each year from 1977 to 1984. The first ensemble is the control, in which the model is run in an unmodified form for 30 days for each of the eight searche cases. In the second, third, and fourth ensembles, a heating term is added to the thermodynamic equation. In the case of the second and third ensembles this heating term maximizes at 6.6 N, 30 W, and in the case of the fourth ensemble, the heating is strongest at 6.6 S and 30 W. The term decreases radially outward with a Gaussian profile that has a half width of approximately 8 in latitude and 16 in longitude. It is strongest at 400 mb in both cases, with a local maximum of 8°C/day in ensemble 2 and 2.6°C/day in ensembles 3 and 4. The column averaged heating rate is 5°C/day in ensemble 2 and 1.7°C/

/day in ensembles 3 and 4.

As additional modification of each of the experimental ensembles (two, three and four) is decreased East Pacific SST as done by Buchmann et al. (1989a). In the case of ensemble 2, this decrease is rather extreme, peaking at - 10°C (used by Buchmann et al. (1989a)), and in ensembles 3 and 4 it peaks at a more realistic value of - 3.3°C. Another experiment, designed to study the influence of the East Pacific heating, acting alone, was also run for each of the eight cases. These results will not be emphasized here, but were useful to substantiate claims of the relative influence of Atlantic and Pacific modifications.

Figure 1a displays the time averaged precipitations response of the second ensemble in the vicinity of South America. This can be compared with Fig. 1 of Buchmann et al. (1989b), which shows a similar case that lacks Pacific cooling, and Fig. 4 of Buchmann et al. (1989a), which is similar to the present cases, but lacks Atlantic heating. The increased Amazon Basin rainfall of Fig. 1 is more in agreement with Buchmann (1989a) than with Buchmann (1989b), suggesting that the Pacific influence dominantes the rainfall of the Amazon Basin. However, in contrast to the situation with only Pacific cooling, the T statistics of the present case is not significant at the 95% level anywhere in the vicinity of the Amazon Basin. Reduction of the Atlantic heating and the Pacific cooling by a factor of 3 (ensemble 3) reduces the response substantially (see Fig. 2), although its pattern is similar to the strongly forced case exhibited in Fig. 1. In summary, the presence of Pacific cooling is sufficient to strongly modify the South American response to tropical Atlantic heating, and reduction of both forcings shrinks the region of statiscally significant response markedly.

Figures 3 and 4 display the precipitation response, the T statistic, and significance analyses over North America for ensembles 2 and 3, respectively. Both strong (Fig. 3) and weak (Fig. 4) forcings produced statistically significant rainfall reductions over North America. The drying effects are more pronounced in the strongly forced case than the weakly forced case, but each produces responses that are significant at more than a 95% confidence level over eastern sections of the United States.

The responses for ensemble 4 are similar to those for ensemble 3 and not shown. Comparasion of these cases with the experiment in which only the East Pacific tropical SST was changed (not shown) suggest that the tropical Atlantic heating provides the principal influence on the Eastern North American rainfall response of Fig. 3 and 4.

CONCLUSIONS

The present study of tropical Atlantic influences upon North America was motivated by our last investigation (Buchmann et al., 1989b) which demonstrated that this teleconnection is one of the strongest tropical-extratropical teleconnections produced in a rather extensive series of real data, medium to extended range forecasts we have performed with the NCAR GCM. Other investigatiors have studied teleconnections over the Atlantic sector (e.g., Namias, 1972 and Moura and Shukla, 1981), but most of these have been concerned with the rainfall response over South America. Our interest in real-data deterministic forecasting over South America prompted our earlier studies of the influence of Atlantic anomalies upon rainfall in the western hemisphere. Unexpectedly, these showed that the most significant response to tropical Atlantic heating anomalies resides in Eastern North America.

The major simplification in these earlier studies was imposition of rather strong heating anomalies relative to those that may occur in nature, or those which characterize the climate of the NCAR GCM. The results of Section 2 suggest that these prior heating rates were large by approximately a factor of two, compared to naturaly occuring rates within the tropics over similar time intervals in extended integrations. In order to cover the range of possible results, we have repeated the integrations of Buchmann et al. (1989b) using their unrealistically strong heating, as well as values that are approximately one third of those rates. The latter produce weaker net heating than peak values that characterize the unmodified model tropics, and these different sets of experiments should bracket the range of likely response to positive Tropical Atlantic heating anomalies. In order to further broaden the range of experimental conditions we have also lowered the SST of the Eastern Tropical Pacific Ocean.

A total of 24 new 30 days experiments were run: one set of eight cases utilized strong Tropical Atlantic forcing centered north of the equator, another set of eight cases utilized moderate tropical forcing here, and the final set of eight cases utilized moderate Tropical Atlantic forcing centered south of the equator. Twenty of these cases predicted reduced rainfall over eastern sections of the United States. The T statistic suggestes less than a 5% chance that the drying is a sampling fluctuation unrelated to the tropical heating modifications. A separate set of eight cases in which only the East Pacific SST cooling was imposed indicates that this supports the drying influence over eastern North America, but is not the dominant effect.

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Figure Captions: **Fig. 1a** - Ensemble and time averaged precipitation response for ensemble 2. Contour interval is 2 x 10**-8 m/s. **Fig. 1b** - T-statistic for response depicted in Fig. 1a. Contour interval is 1/2. **Fig. 1c** - Probability that the response depicted in Fig. 1a is statisticaly significant. Contour interval is 3% and only values of 95% and higher are analyzed. **Fig. 2** - As in Fig. 1 for ensemble 3. **Fig. 3** - As in Fig. 1 for North America. **Fig. 4** - As in Fig. 3 for weaker forcing, ensemble 3.

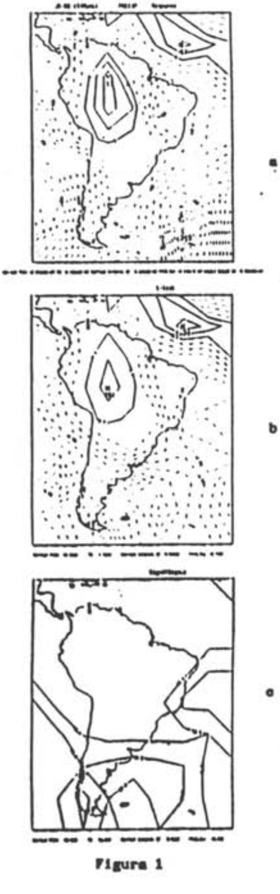

Figura 1

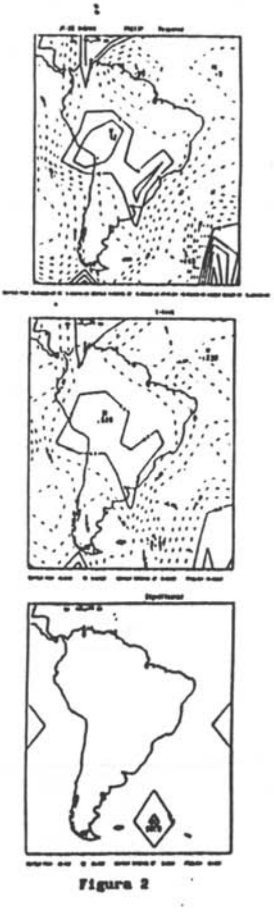

Figura 2

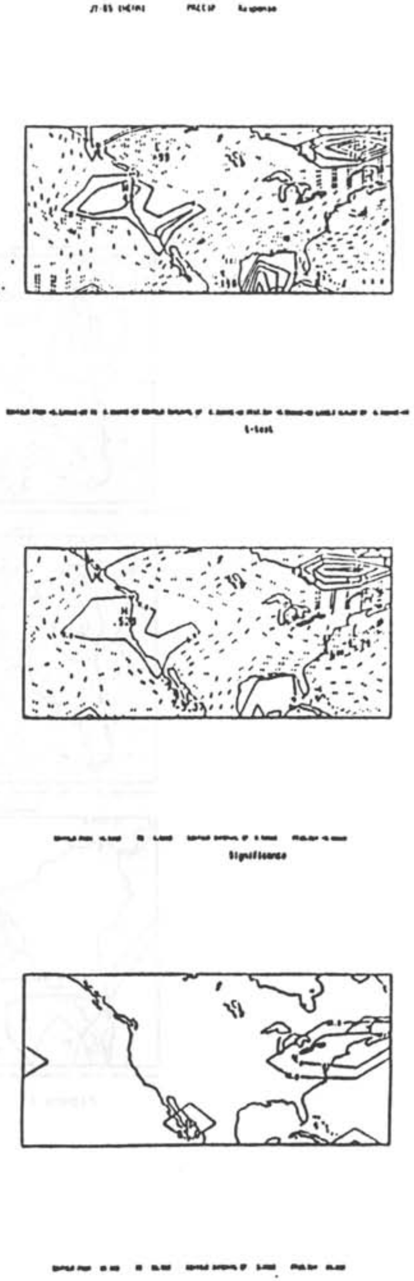

Figura 3

Figura 4