F G G E FORECAST EXPERIMENTS FOR AMAZON BASIN RAINFALL

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RESUMO

No presente trabalho é investigado o padrão de precipitação, na Bacia Amazônica, da previsão de dez casos do Experimento do Tempo Global (GWE). A sensitividade deste modelo de previsão, para a presença de uma fonte de calor anômala no Pacífico leste, é investigada através de experimentos, em que um termo não adiabático é adicionado na equação da termodinâmica. Estes experimentos sugerem significativa supressão de precipitação sobre a Bacia Amazônica central, e especificamente sobre a parte nordeste do Brasil. Esta supressão está associada com o ramo descendente da Circulação de Walker cujo desenvolvimento é determinado por uma região de subsidência, a qual propaga-se para a direção este, vinda da região do Pacífico leste, uma razão de cerca de 30m/s. Esta evolução, que é consistente com a contribuição da onda de Kelvin para a célula de Walker, afeta o Brasil dentro de aproximadamente dois dias a partir da região da fonte.

INTRODUCTION

The climate of Northeast Brazil has been the subject of study by meteorologists who have been trying to explain the observed climatic anomalies that disrupt the lives of over 30 million people who live in the region. Two main lines of research have been followed. The first emphasizes local effects as the cause

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of the anomaly. Along this line, Gomes Filho (1979) studied local surface and topographical influences over Northeast Brazil, but these influences are not yet well determined. The second line of research emphasizes external mechanisms such as those invoked by Namias (1972), Hastenrath and Heller (1977), Kousky (1979), Moura and Shukla (1981), and Buchmann (1981).

Namias (1972) demonstrated a connection between the 700mb circulation pattern over the North Atlantic and the rainfall at Quixeramobin (state of Ceara). Hastenrath and Heller (1977) used a large number of observations to show that rainfall in the region of Ceara is closely linked to the meridional displacement of the equatorial trough zone. Kousky (1979) showed that: a) frontal systems penetrate the southern part of Northeast Brazil throughout the year; b) frontal incursion plays an important role in the December-January maximum in the monthly precipitation experienced in the southern part of Northeast Brazil; c) in certain periods the frontal incursions affect rainfall as far north as Ceara.

Moura and Shukla (1981) proposed that a possible mechanism for the occurance of severe droughts over Northeast Brazil is the establishment of a thermally direct local circulation which has the ascending branch at about 10°N and descends over Northeast Brazil and the adjoining oceanic region. Buchmann (1981) studied the occurance of drought and rain anomalies in Northeast Brazil, in relation to variations in the synoptic pressure systems located in middle and high latitudes of the Northern Hemisphere, through the mechanism of lateral forcing.

These previous studies represent idealized simulations based on models and concepts with different levels of complexity, and none are real-data integrations. It is useful to test such drought producing mechanisms with real data predictions in order to assess their relative importance in problems of tropical drought. A mechanism that produces a particular effect in isolation may be compensated, masked, or enhanced by other influences. Real-data integrations of realistic atmospheric models are required to investigate this possibility.

The purpose of this study is to describe the characteristics of real-data predictions of tropical rain and attendant circulations around South America during the Global Weather Experiment (GWE). The Community Forecast Model (CFM) of the National Center of Atmospheric research (NCAR) and the data used for this purpose are described in Section 2. The rain forecasts and related circulation features are described in Section 3. Although the model has rather crude horizontal resolution, it captures relatively detailed aspects of tropical rains over the Amazon Basin, including an apparent tendency for suppression of rain over the Northeast of Brazil by convection within the basin.

Section 4 explores the impact of heating anomalies in the South Pacific upon model produced rainfall over the Amazon Basin. This follow suggestions by Walker (1928) that enhanced rain over the tropical Pacific may induce subsidence over the Amazon Basin and so suppress rain there.

MODEL AND EXPERIMENT

The model used in this study is the Comunity Forecast Model (CFM) of NCAR. It employs sigma coordinates with nine vertical levels and uses a spectral representation in the horizontal, with a rhomboidal truncation at wavenumber 15. The semi-implicit time-differencing scheme uses a time step of 30 minutes, while the radiation and cloud routines are called every 12h. The physical parameterizations and non-linear operations are performed in grid point space, while the horizontal derivatives and linear operations are carried out in spectral space.

Physical parameterizations also simulate convective adjustment, vertical diffusion, surface fluxes and surface energy balance. Convective adjustment, which is of particular relevance to the present study, follows the approach of Manabe et al.(1965)

Baumhefner (1984) has performed a series of analysis and forecast intercomparisons using the GWE data for the same ten cases presently utilized.

The experiment in the present study is composed of two ensembles generated by integrating the NCAR CFM for 10 days. Each ensemble contains 10 cases initialized with 10 different GWE data sets, presented in Table 1. In the first ensemble, refered to as the control, the full physical parameterizations described above are employed. In the second ensemble, refered to as the forced case, an additional heat source is imposed into the model atmosphere by adding a heating term in the thermodynamic equation.

TABLE I

Initial Datas

CASE	INITIAL DATE			
1	10	DECEMBER	1978	COGMT
2	13	DECEMBER	1978	COGMT
3	6	JANUARY	1979	12GMT
4	9	JANUARY	1979	12GMT
5	13	JANUARY	1979	COGMT
6	16	JANUARY	1979	COGMT
7	19	JANUARY	1979	12GMT
8	21	JANUARY	1979	12GMT
9	12	FEBRUARY	1979	COGMT
10	17	FEBRUARY	1979	12GMT

The imposed heating field has a maximum of 8°C/day centered vertically at 400 mb, horizontally at 6.6° and 135°W. The column averaged heating at the center of the source is approximately 5°C/day, which is equivalent to the amount of latent heat released by the precipitation of 2.5 cm/day. The imposed heating induces rising motion that localy enhances rainfall and additional latent heating that approximately equals the imposed source. The net result is a local heating that is more characteristic of rather active individual events than it is of seasonal averages.

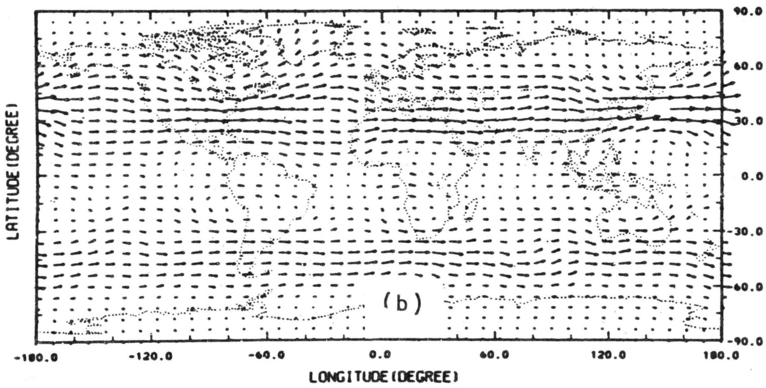

Fig. 1 - Ensemble averages of wind vectors at 200 mb for control at day 10.

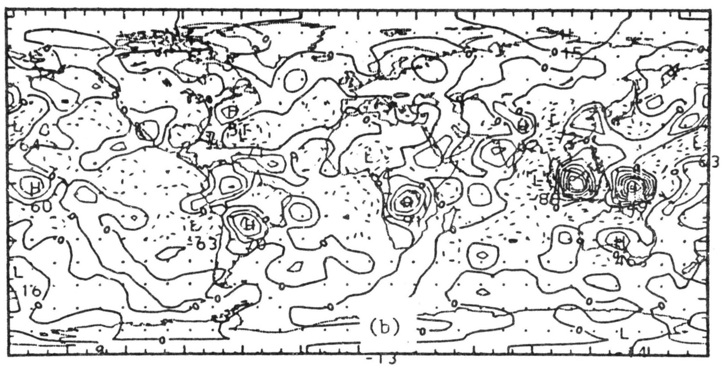

Fig. 2 - Ensemble averages of 200 mb divergence for the control with contour internal 2×10^{-6}/s and divergent wind vectors for day 10; maximum vector is 6.2 m/s.

CONTROL CASE

The ensemble averaged 200 mb wind field forecast by the control for day 10 is displayed in Fig. 1. The northen mid-latitude troughs and subtropical jet maxima are located in their approximate climatological regions on the east coasts of the continents. Within the tropics, there appear three regions of easterly winds around the areas of divergent outflow maxima over the Amazon Basin, tropical Africa, and the tropical western Pacific Ocean (see Fig. 2.).

The Bolivian high is clearly evident in these diagrams and does not change markedly between days 5 and 10 of the composite. The divergence fields display far more variance from time to time, even in the composite. However, inspection of 200 mb forecasts at 12 h intervals shows a distinct tendency for weak convergence (implying subsidence) over Northeast Brazil. This typically flanks much more active divergent areas (implying rising motion) over interior Amazonia.

The precipitation maps averaged over each of the ten cases are displayed in Fig. 3. While there is a fair degree of variability between the centers of maximum precipitation over the Amazon Basin, only two of the 10 cases show analyzed contours extending over Northeast Brazil and most display precipitation maxima in Brazilian regions south of the equator. These patterns and similar fine-scale features over western tropical Africa and the western tropical Pacific Ocean are remarkably detailed, considering the rather course wave-number 15 resolution of the model.

SOUTHERN HEMISPHERE HEAT SOURCE

The convection over the tropical Pacific Ocean displays large re-arrangements on interannual time scales associated with El Niño Southern Oscillation (ENSO) phenomena (as reviewed by Kousky et al., 1984). It is also becoming increasingly clear that such re-arrangements occur on relatively shorter periods, as discussed in weekly, bi-weekly and montly averages of GWE data by Paegle and Baker (1982) and Paegle et al. (1983). The latter study shows that during two weeks of January 1979 the South Pacific Convergence Zone extended far east of its climatological position 200 mb divergent outlow in excess of 10 m/s from an active region east of the dateline. This convection subsequently disappeared, and the divergent circulation over the Amazon Basin appeared to strengthen upon this collapse.

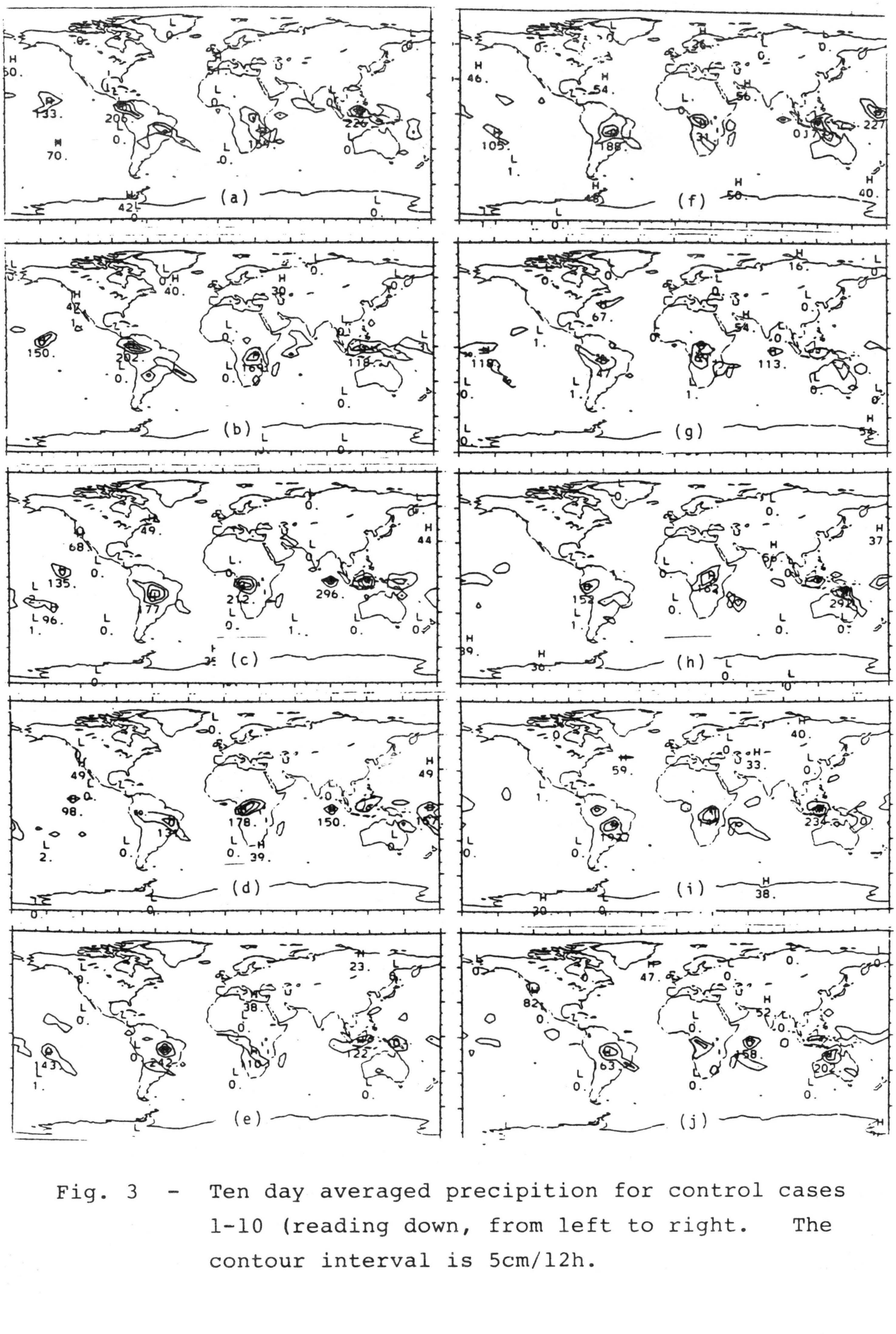

Fig. 3 - Ten day averaged precipition for control cases 1-10 (reading down, from left to right. The contour interval is 5cm/12h.

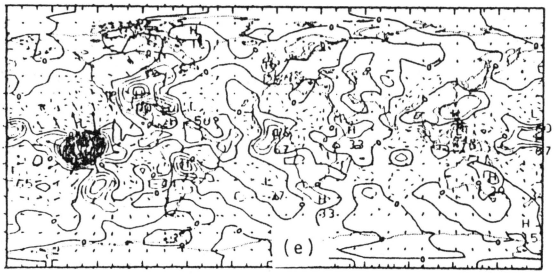

Fig. 4 - As in Fig. 2, but for the experiment with Southern Hemisphere forcing at 10 days, peak vector 15 m/s.

The events are compatible with the apparent suppression of Amazon Basin outflow and precipitation by an eastward displacement of the South Pacific Convergence Zone on interannual time scales (as first suggested by Walker, 1928; see also Kousky et al., 1984).

We now examine whether this remote influence may be perceived in 10 day model integrations by inserting an enhanceed hearting region centered at 135°W, 6.6°S as described in Section 2. This is somewhat east of the typical location of El Niño effects.

The composite averaged circulation at 200mb is displayed in Fig. 4. There is substantial variation in the divergence field with peak divergent winds ranging from 5.9 m/s at the beginning of the integration to as much as 25.2 m/s at day 5. The latter value is characteristic of the strongest observed divergent winds and is due to the positive feedback effect produced by the imposed heating.

Sinking motion is induced over much of tropical South America, and specially the eastern portions. The 10 day precipitation totals for the 10 cases are displayed in Fig. 5. There is a notable reduction of rainfall over the Amazon Basin in comparison with Fig. 3, suggesting a fairly rapid adjustment of the rain producting circulation. The reason for this is evident from the

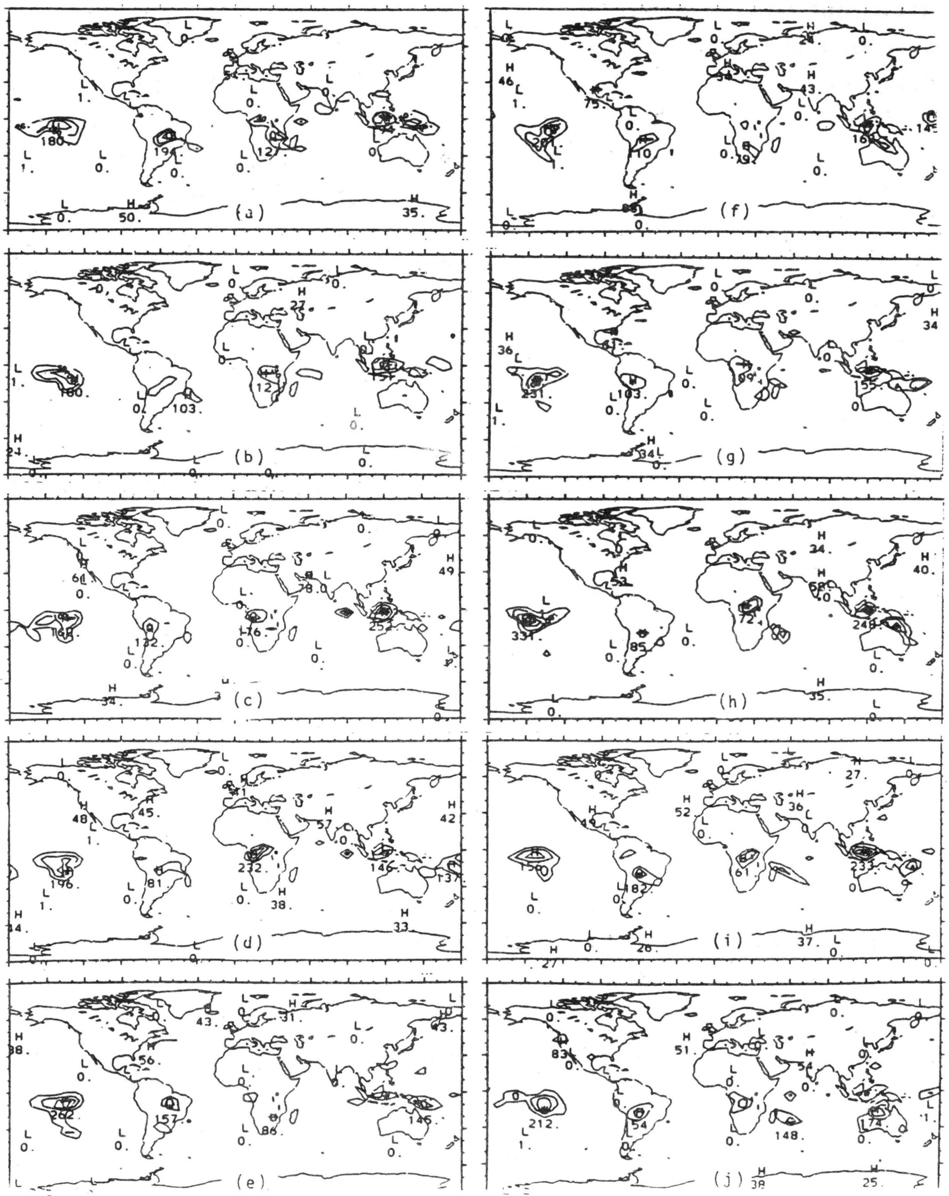

Fig. 5 - As in Fig. 3, but for the experiment with Southern Hemisphere forcing.

different of the zonal evolution at 200 mb between the present case and the control discussed in the previous section. This difference field suggests a prominent Walker circulation, propagating eastward at about 30 m/s from the eastern Pacific source. This rate of propagation is similar to that of the Kelvin waves that influence the eastern Pacific source. This rate of propagation is similar to that of the Kelvin waves that influence the eastern subsiding branch of the Walker circulation (Geisler, 1981). In the present example, this begins to influence the Amazon in about 3 days.

CONCLUSION

Our results support the hypothesis of Walker (1928) regarding suppression of Amazon Basin rain by east Pacific heating. More importantly, these calculations suggest that this suppression begins to act on a time scale of a week or less in real data predictions.

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