THE IMPACT OF COLD SEA-SURFACE TEMPERATURES UPON AMAZON BASIN RAINFALL DURING THE NORTHERN WINTER

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INTRODUCTION

Buchmann et al. (1986) presented a series of global, real data integrations of a general circulation model which demonstrated that the influence of enhanced Pacific precipitation upon the rainfall of the Amazon Basin is predictable in a series of 10 day integrations. The results are in approximate agreement with observational studies that suggest remote influences over the Pacific Ocean and the North Atlantic may produce modifications in the rainfall of northeastern Brazil, and perhaps contribute to the severe droughts occasionally observed there (Walker, 1928; Namias, 1972; Kousky et al., 1984; Rogers, 1987).

The present study presents further general circulation model experiments designed to investigate the influence of atmospheric changes over the Pacific Ocean upon the precipitation of the Amazon Basin. Buchmann et al. (1986, hereafter also refered to as I) only performed experiments in which the tropical heating was increased over the eastern Pacific Ocean. They did not study whether the rainfall of tropical South America would be changed by Pacific heating enhancements that are imposed further to the west, nor did they investigate the consequences of low average east Pacific temperature (as typically occurs in "anti-El Niño" years). The latter question was partly answered in a series of Northern Spring experiments performed by Paegle et al. (1987), but that investigation focussed on other aspects of the response

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field, and it is of interest to ascertain whether the results of the winter season experiments are similar to those of the spring season.

In this paper we describe the sensitivity of Amazon Basin rainfall to heating imposed over the Western tropical Pacific (section 2) and to cooling imposed in the Eastern Pacific Ocean (section 3). The time evolution of the latter experiments is studied in section 4 in order to infer the South American response as a simple direct consequence of the Walker cell that propagates eastward from the Pacific heating modifications.

Buchmann et al. (1986) studied the strength of the Pacific-Amazon teleconnection in the National Center for Atmospheric Sciences Community Forecast Model (NCAR CFM) using an ensemble of then real-data cases selected from the Global Weather Experiment (GWE). One set of forecasts, constituting the "control" sample, was initialized with real data, and used the model physics in an unmodified form. Another set of forecasts was identical to the control sample, except that an extra heating term was added to the thermodynamic equation. This term maximized just south of the equator, approximately 3000 km west of Ecuador. Another set of experiments placed the same heating anomaly slightly north of the equator, and west of Central America.

These forecasts, and a similar set of experiments for the North Pacific (Paegle et al., 1987; hereafter also refered to as II), are consistent with the previously cited climatological studies in that they indicate suppressed precipitation of northern sections of tropical South America associated with enhanced heating and precipitation over the eastern Pacific.

Those experiments displayed the suppression of Amazon Basin rain within 5 days of Pacific heating onset. This rapid response was interpreted in terms of the eastward spread of subsidence in a region of equatorially trapped upper tropospheric westerlies that develop east of the heating modification. The subsiding forward edge of the westerlies propagate eastward at a rate of 30-40 m/s and possess a structure suggestive of an equatorially trapped Kelvin wave. The resulting eastern portion of the Walker cell response encircles more than half the globe after 10 days.

FAR WEST HEATING EXPERIMENT

The experiments use the NCAR CFM, which is described in more detail in Section 2 of I. This spectral model employs a rhomboidal truncation at wavenumber 15, and incorporates fairly complete physics parameterizations. It is initialized from 10 different initial winter dates starting in December 1978 and continuing into February 1979. The interval includes the first special observing period (SOP-I) of the GWE and provides an unusually high quality data set. The cases were originally selected on the basis of their rather distinct synoptic weather regimes (see Baumhefner, 1984). The availability of a number of distinct cases is important for present goals because of the sensitivity of tropical prediction to weather regime.

Figure 1 reproduces 10 day averages of precipitation fields for each of the 10 control cases studied in I. The figures display rather realistic distributions of tropical rainfall, with maxima over the Amazon Basin, tropical Africa and the western Pacific Ocean.

The heating field that was added to one of the experiments described in I is displayed in Fig. 2. This maximizes just north of the equator in a region of relatively warm sea surface temperature (SST). Although this is not a very common region for wintertime convective anomalies in the tropics it serves to illustrate the basic result that eastern Pacific heating enhancements suppress rainfall over the Amazon Basin, especially in the northern regions.

The 10-day averages of precipitation for each of the 10 cases with the heating enhancement at 6.6°N, 105°W (figure not shown) show a clear reduction of precipitation over northern portions of South America in each of the 10 cases, and particularly in those cases for which the controls have northward maxima. Fig. 7 of I shows rather similar results for an experiment with the heating enhancement centered at 6.6^{o}S, 135^{o}W.

One explanation of these results is that the Walker circulation emanating from the east Pacific heating regions suppresses rainfall over Amazonia in a way that appears to be rather insensitive to the particular placement of the heating anomaly.

We now describe the consequences of displacing the Pacific heating anomaly center far to west at 6.6^{o}S, 120^{o}E. The 10-day experiments is displayed in Fig. 3. Comparing these results with Fig. 1, it is evident that each of these cases shows a reduction of rainfall over the Amazon Basin with respect to the controls, although not as strongly as in the cases with the heating centered at 6.6^{o}N, 105^{o}N. The results generalize the conclusions of I in that heating enhancements anywhere above the tropical Pacific Ocean tend to reduce the rainfall over northern Brazil in the absence of other influences.

These conclusions are superficially inconsistent with observations of wetter than normal weather over Northern sections of South America during anti-El Niño phases of the Southern Oscillation-El Niño (ENSO) oscillation, because the latter also have positive heating anomalies over the western tropical Pacific Ocean. However, these cases are also characterized by cooler than normal SST over the eastern Pacific, a circumstance which promotes Amazon Basin rainfall in the northern spring CFM integrations presented in II. It is important to test the generality of these conclusions for other seasons.

EFFECT OF REDUCED SEA SURFACE TEMPERATURES

The purpose of the present section is to describe the influence of reduced Eastern Pacific during the northern winter.

The SST modification in Fig. 3 is centered near the equator somewhat further west than that imposed in II, and, following that study, we use a rather exaggerated anomaly which peaks at $-10^{\circ}C$ in order to completely suppress tropical rainfall over the region of maximum temperature drop.

Figs. 4 and 5 display the composite average of the precipitation at days 5, 10, 15 and 20 of the controls and experiment, respectively. The tropical rainfall over the eastern Pacific has clearly diminished as a consequence of the reduced SST. The effect over South America is not equally obvious, but close scrutiny of the diagrams suggests a northward shift in the experiments with respect to the controls. This shift is present at day 5, but is more obvious on days 10, 15 and 20.

The result may be compared with observations of Rogers (1987) which suggest increases/decrease of precipitation northward of approximately $8^{\circ}S$ in association with high/low indices of the Southern Oscillation. Since the high indices are more common in anti-El Niño years, that have relatively colder east Pacific SST, it appears that the present results are consistent with observations. Rogers'(1987) results have only marginal statistical significance over most of tropical South America. Present results are also consistent with this. Fig. 6 displays the T-test of the precipitation difference between the control and the experiment computed for the ensemble averaged over the 20 days of the integration. Although these results are significant at the 95% level only in a small region centered over Northern Brazil, they show a consistent precipitation enhancement ringing the entire zone of maximum SST reduction.

EVOLUTION OF CIRCULATION

The 200 mb flow field for the experiment at days 5, 10, 15 and 20 (figures not shown) indicates that pattern contains three equatorial wind maxima centered on the regions of maximum rainfall at day 5, and this gradually deforms with time to a broad band of easterly winds emanating from the western Pacific accross the Indian Ocean, Africa and South America. This produces a large inverted Walker circulation with respect to the forced cases that retain heating over the East Pacific.

Such a large-scale effect could produce rainfall modifications over broad areas. It is interesting to note that the rainfall over Africa also increased in the experiment (compare Figs. 4 and 5).

CONCLUSIONS

The present integrations, as well as those presented in I and II, show that the NCAR CFM tends to suppress rainfall over Brazil as a consequence of heating increase occuring either nearby or more remotely over the Pacific Ocean. The suppression is relatively weaker for more distant. Cooling the east-central Pacific sector produces marginally significant rainfall increases over the northeast sections of South America.

The evolution of these patterns agrees with the study by Walker (1928), suggesting that droughts in the northeast of Brazil are more common at certain phases of the Southern Oscillation. Others have identified these phases with El Niño episodes and increased North Pacific heating. Our results are also consistent with recent work of Rogers (1987). The relatively weak signal of the model precipitation response over the Amazon conforms with Kousky et al. (1984) finding that the El Niño mechanism explains only a relatively small fraction of Amazon rainfall variance and with Rogers'(1987) conclusion that the statistical significance of such correlations is only marginal.

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LEGENDA DAS FIGURAS

1 - Ten-day averaged precipitation for control cases 1-10 (panels a-j). The contour interval is 0.5 cm 12 h^{-1}.

2 - Spatial distributions of heating field. (a) Horizontal structure with a contour interval of 2 x 8^{o}C d^{-1}; (b) vertical structure.

3 - As in Fig. 1, but for the experiment with Western Pacific heating.

4 - Ensemble average precipitation for controls at (a) day 5, (b) day 10, (c) day 20. The maximum values are plotted and the unit is .01 cm/day;the contour interval is .5 cm/day.

5 - As in Fig. 4, but for the experiment with reduced SST in eastern tropical Pacific.

6 - T-statistic for the reduced SST experiment-control 20 day averaged precipitation rate. Only positive values are contoured values above 0.625 are significant at the 95% level.

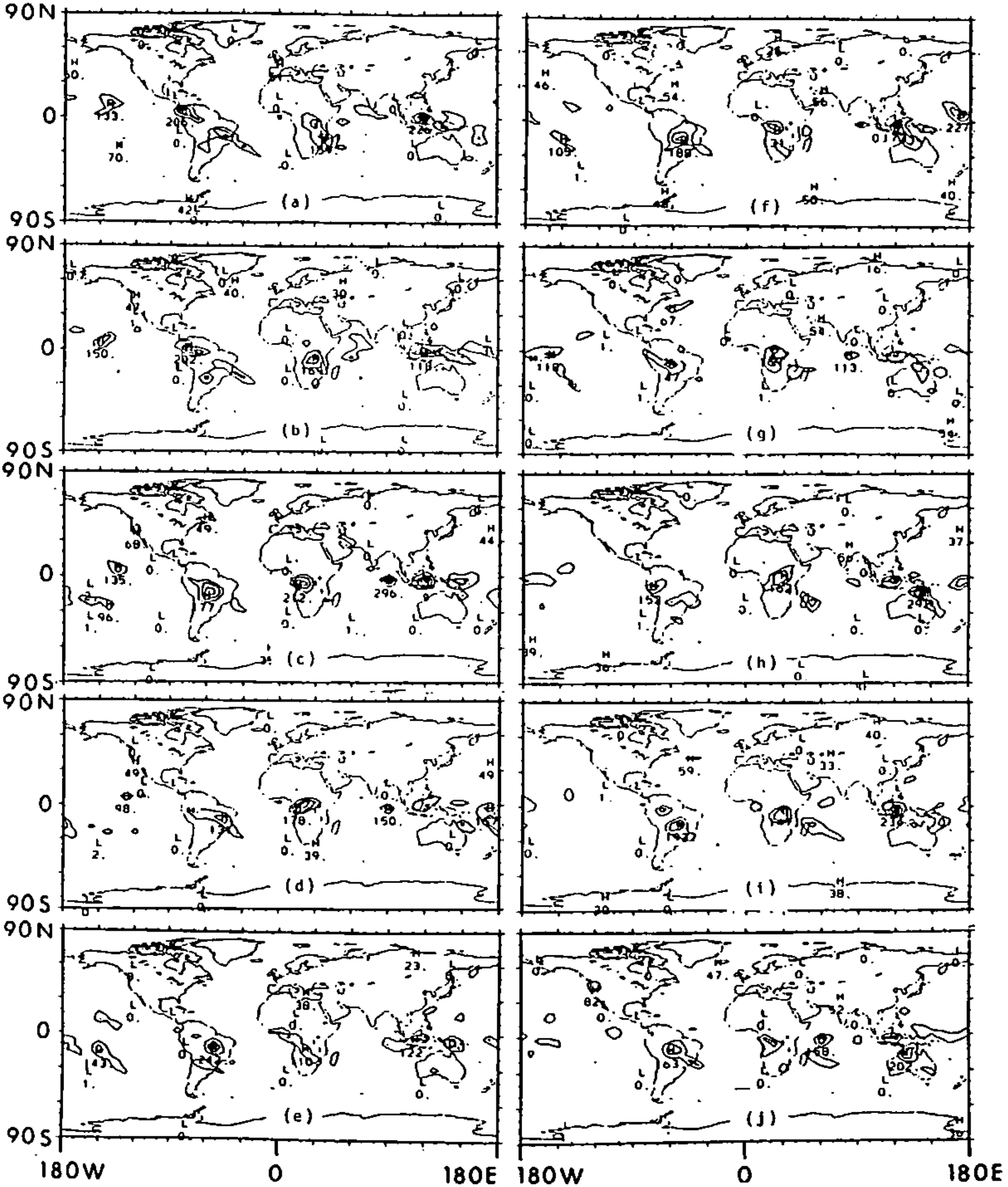
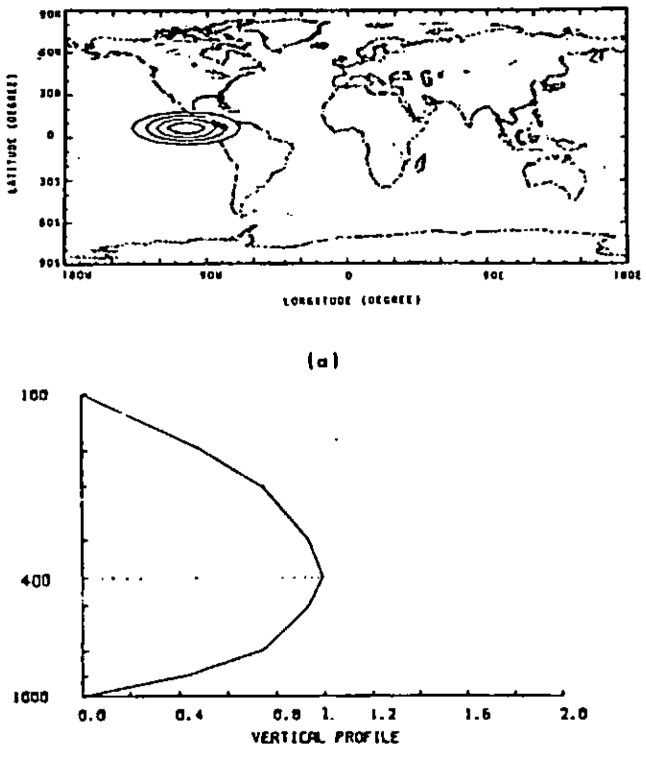


Figura 1


90N
60N
30N
0
30S
60S
90S
LATITUDE (DEGREE)
180W
90W
0
90E
180E
LONGITUDE (DEGREE)
100
400
1000
HEIGHT(MB)
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0.4
0.8
1.
1.2
1.6
2.0
VERTICAL PROFILE

(a)

(b)

Figura 2

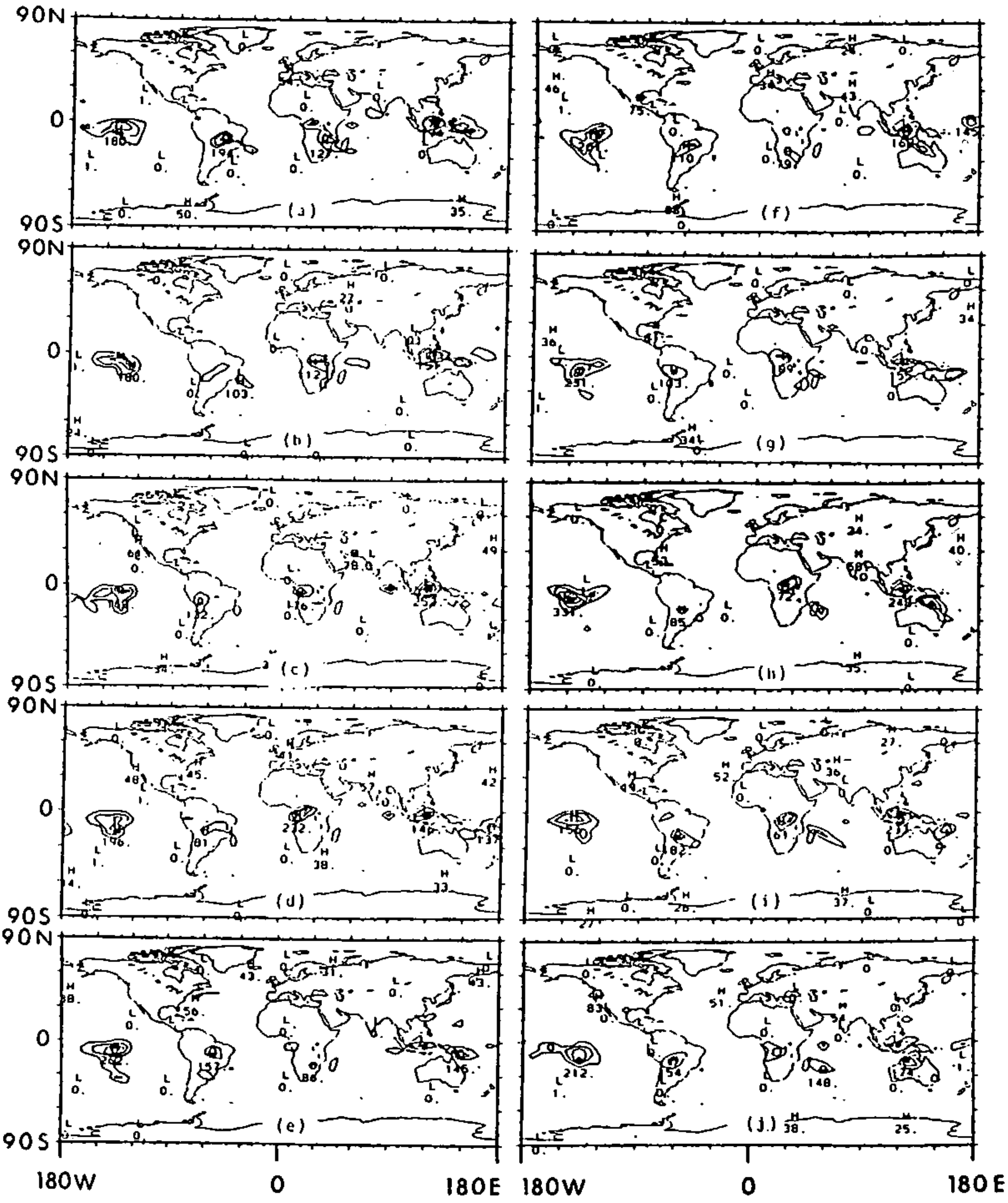
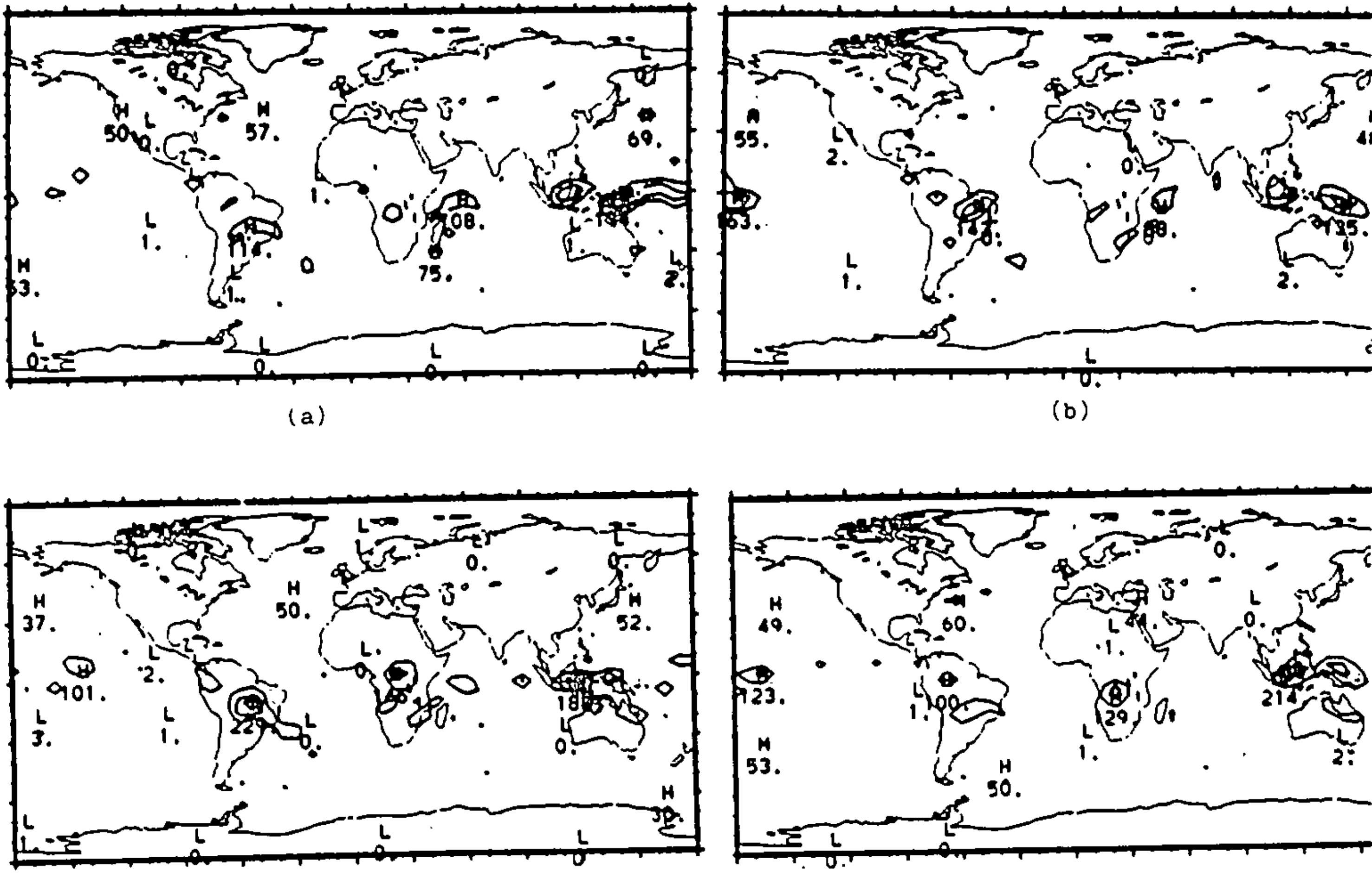


Figura 3



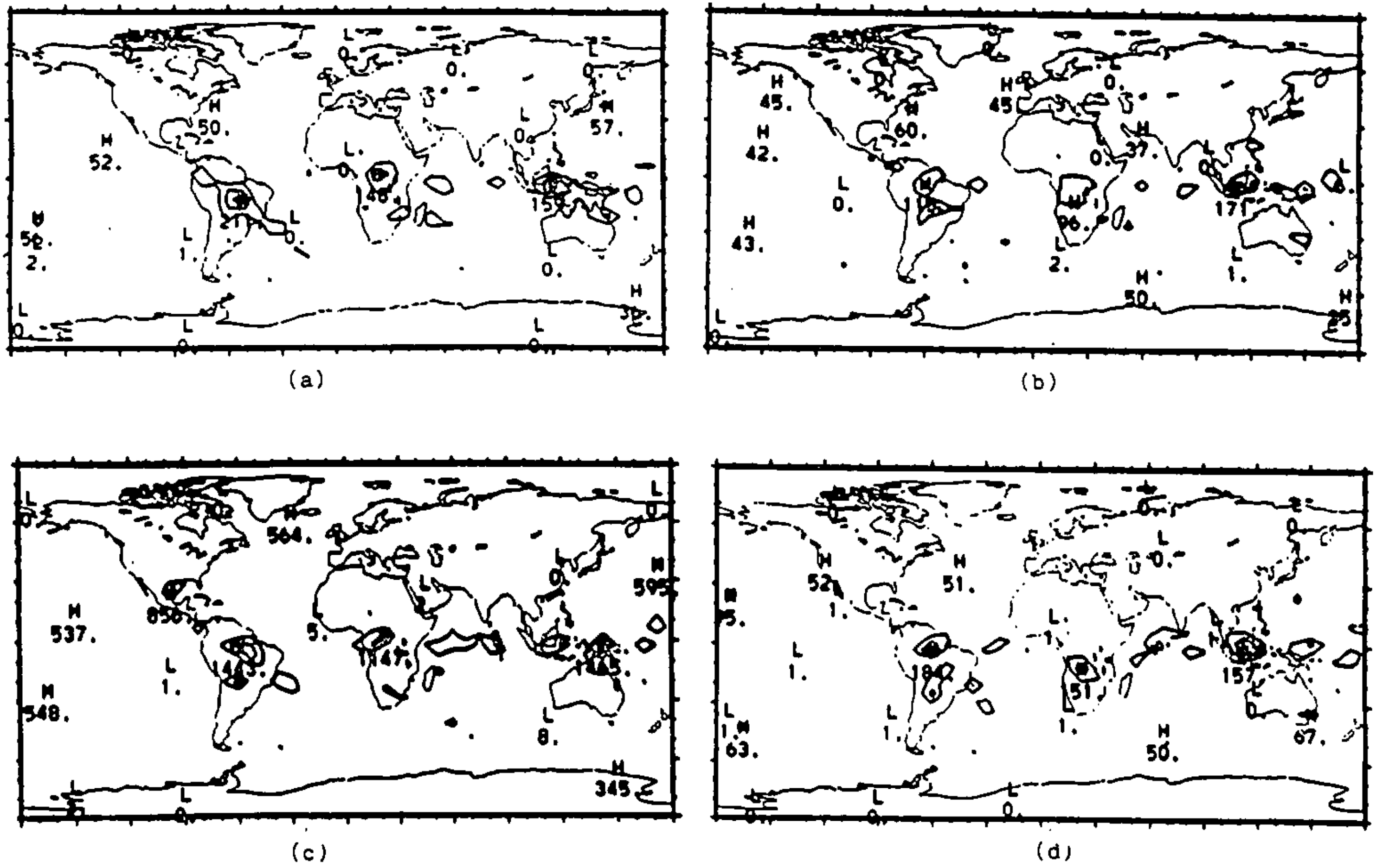
(a)

(b)

(c)

(d)

Figura 4



(a) (b)

(c) (d)

Figura 5

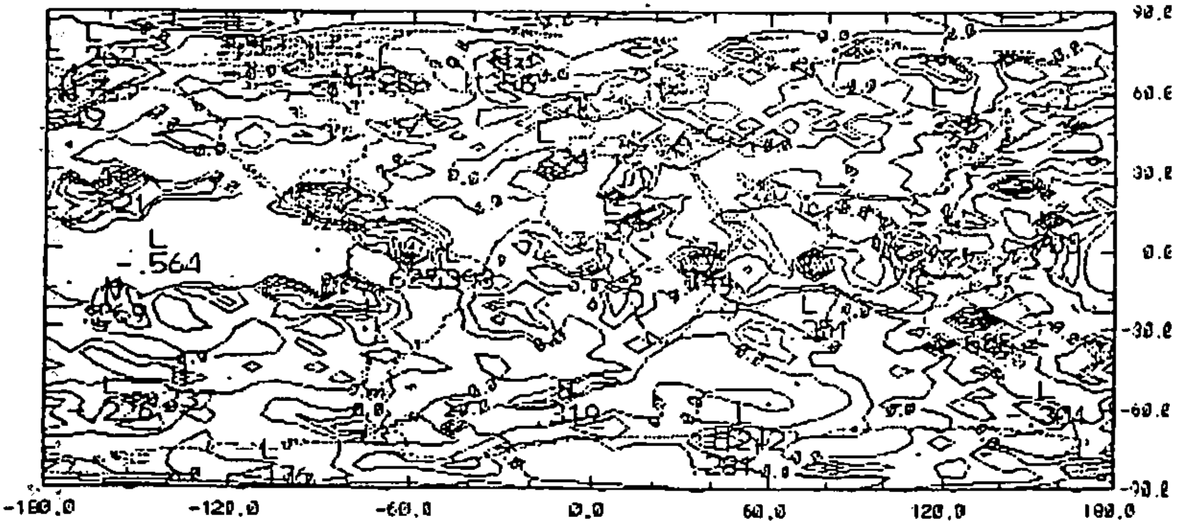


Figura 6