1. Publication Nº	2. Version	3. Date	5. Distribution
INPE-2994-PRE/446		*Jan., 1984*	☐ Internal ☒ External ☐ Restricted
4. Origin *DME/DPM*	Program *SINO*		

6. Key words - selected by the author(s)

BLOCKING
RAINFALL ANOMALIES

7. U.D.C.: *551.578.1(215-13)"1975/1979"*

8. Title *INPE-2994-PRE/446*

BLOCKING IN THE SOUTHERN HEMISPHERE, DURING 1975-1979

10. Nº of pages: *31*

11. Last page: *28*

12. Revised by

V.B. Rao

9. Authorship *Vernon E. Kousky*
Darci P. Casarin

Responsible author

13. Authorized by

Nelson de Jesus Parada
Director General

14. Abstract/Notes

Southern Hemisphere blocking situations are investigated, for 1975-1979. The Australia - New Zealand region is found to be the area with most frequent blocking followed in importance by the central and eastern Pacific. Blocking in these two regions has an average duration of about 11 days while in the remaining regions it has an average duration of eight days. Contrary to Northern Hemisphere blocking, certain regions of the Southern Hemisphere show a blocking maximum during the summer months. Two blocking events during FGGE are described. The January 1979 case illustrates the effects that summer blocking, in the vicinity of South America, may have on the rainfall distribution in Brazil.

15. Remarks *This work is being submitted for publication in Tellus.*

BLOCKING ACTION IN THE SOUTHERN HEMISPHERE, DURING 1975-1979

Vernon E. Kousky
and
Darci P. Casarin[1]

Instituto de Pesquisas Espaciais - INPE
Conselho Nacional de Desenvolvimento Científico e Tecnológico - CNPq
12.200 - São José dos Campos, SP, Brazil

[1] Present affiliation the Universidade Federal de Pelotas, Pelotas, Rio Grande do Sul, Brazil.

ABSTRACT

Southern Hemisphere blocking situations are investigated, for 1975-1979. The Australia - New Zealand region is found to be the area with most frequent blocking followed in importance by the central and eastern Pacific. Blocking in these two regions has an average duration of about 11 days while in the remaining regions it has an average duration of eight days. Contrary to Northern Hemisphere blocking, certain regions of the Southern Hemisphere show a blocking maximum during the summer months. Two blocking events during FGGE are described. The January 1979 case illustrates the effects that summer blocking, in the vicinity of South America, may have on the rainfall distribution in Brazil.

1. INTRODUCTION

Since the late 1940's, a great deal of attention has been given to blocking patterns and their effects on the weather. (For some of the earlier works see: Namias and Clapp, 1944; Elliot and Smith, 1949; Berggren et al., 1949; Rex, 1950a, 1950b, 1951; Namias, 1950; Sanders, 1953). Most of the observational studies have dealt with Northern Hemisphere blocking. These studies have shown that blocks generally form near the west coasts of continents (Rex, 1950b; Sumner, 1954) with the maximum frequency occurring during the late winter and spring months (Rex, 1950b; Brezowsky et al., 1951; Treidl et al., 1981).

In contrast to the Northern Hemisphere, relatively few studies have been performed on blocking in the Southern Hemisphere. A study by van Loon (1956) shows three distinct regions where blocks form in the Southern Hemisphere: 1) at longitudes just to the east of Africa; 2) just to the east of Australia and; 3) over and just to the east of South America. It should be emphasized that these regions are all to the east of continental land masses in contrast to the preferred areas of blocking in the Northern Hemisphere which are near the west coasts of continents. Due to data limitations, van Loon did not study the region of the central and eastern Pacific (85-150W). More recently, Wright (1974) analyzed data from the Indian Ocean (60E) eastward to 150W and found two areas of maximum occurrence of blocking: 1) 160-170E and 2) 90-100E. The first of these areas, which coincides with one of the regions detected by van Loon, was found to be the area of more frequent blocking. As in the Northern Hemisphere, Southern Hemisphere blocking is also more prevalent in the late winter and spring months (van Loon, 1956).

A severe limitation on observational studies in the Southern Hemisphere has been the lack of reliable data over oceanic areas. Since the advent of meteorological satellites, especially the geostationary satellites, analyses over these data sparse regions have greatly improved. In this paper we make use of these improved analyses to investigate Southern Hemisphere blocking giving special emphasis to the regions of the central and eastern Pacific and South America.

2. DATA AND ANALYSIS TECHNIQUE

The data used in this study were taken from the tropical grid analyses of the National Meteorological Center, obtained on magnetic tape from the National Center for Atmospheric Research. The data consist of the zonal and meridional wind components and temperature available for seven standard levels from 1000 to 200 mb. The east-west grid spacing is 5° of longitude while in the north-south direction there are 23 grid points between 48.1 N and 48.1 S chosen such that they are equidistant on a Mercator projection.

Since these data are in digital form, it was not feasible to inspect daily charts as has been done in other studies (e.g., van Loon, 1956; Treidl et al., 1981). Instead, we made use of Hovmöller, diagrams (Hovmöller, 1949) to depict various parameters, such as the meridional wind component, temperature (thickness) and vorticity, in the form of longitude-time sections for selected latitudes. Since the data contain high frequency transient disturbances as well as the lower frequency oscillations associated with blocking, we found it necessary to apply a Gaussian filter to attenuate oscillations at higher frequencies. The filter used reduced oscillations with periods of three days to 10% of their original amplitude,while oscillations with periods greater than 10 days retained more than 80% of their amplitude. Unfiltered as well as filtered data were used in determining blocking situations.

We define blocking situations as those having the following characteristics: a) the westerlies split into two branches; b) the total displacement of a block is less than or equal to 25° longitude during the period of its existence; c) a blocking pattern is maintained for a minimum period of six consecutive days. The initial and final positions of a block are the longitudes where the anticyclonic relative vorticity reaches a maximum within the polar branch of the flow. The initial date of each blocking pattern is determined by the appearance of condition a) while the final date is determined by the failure to meet conditions a) or c). Similar definitions of blocking situations have been provided by other authors (e.g. Rex, 1950a; van Loon, 1956; Wright, 1974).

3. CLIMATOLOGY OF BLOCKING (1975-1979)

A total of 183 blocking situations were encountered during the period 1975-1979. Their distribution by longitude is shown in Fig. 1. For future reference as well as to facilitate comparison with other studies, we have defined five regions in the Southern Hemisphere: the Indian Ocean (Region I), Australia - New Zealand (Region II), the central and eastern Pacific (Region III), South America (Region IV) and the Atlantic (Region V). In agreement with Wright's (1974) results, Region II is the region with the greatest number of blocks (Fig. 1 and the third from the last column of Table 1)followed by Regions III and I. Wright (1974) and van Loon (1956) found that the Indian Ocean Sector (Region I) is an important region for blocking, which again is consistent with our findings.

The region of the central and eastern Pacific (Region III, Fig. 1) shows very little variation in blocking occurrence with longitude. The distribution of blocking in Region IV is somewhat different from that observed by van Loon. Instead of a single maximum to the east of South America, we obtain two maxima, one just to the west of South America and the other over the Atlantic near 40^{o}W.

It can be seen from Table 1 that the average duration of blocking events varies from region to region. Blocking in the Indian Ocean, South American and Atlantic sectors (Regions I, IV and V) has an average duration of eight days, while blocking in the Australia - New Zealand and central and eastern Pacific regions (Regions II and III) has an average duration of 11 days.

The percent of days in which blocking was observed, on a month - to - month basis for each of the five regions, is shown in Table 1. In each region there is a great deal of variability from one month to the next, which may be due in part to the relatively short data sample used in our analysis. However, some information can be obtained about the seasonality of blocking in each region. Region I has a greater percent of days with blocking during the southern winter and spring months. Region II has a strong peak in late fall and another peak during summer. Blocking, in this region, is observed more than 50% of the time during May, June and January. Region II has a well-defined summer maximum with blocking observed on more than 50% of the days during December and January. Region IV shows a fall (March-April) maximum and Region V has a weak late winter or early spring maximum.

Blocking to the east of Australia and in the central Pacific is perhaps, in part, related to the South Pacific Convergence Zone (SPCZ), which has been noted in satellite cloud brightness data (Gruber, 1972) and in satellite outgoing longwave radiation (OLW) data (Heddinghaus and Krueger, 1981; Liebmann and Hartmann, 1982). The OLW data show that the SPCZ has a seasonal cycle in intensity and position. The SPCZ is farthest to the east (lying within Region III) and most intense during the southern summer (December-February) and farthest to the west (lying within Region II) during the southern winter (June-August). Table 1 indicates that the maximum in the percent of days on which blocking is observed follows a similar seasonal cycle, i.e., occurs in Region III during the summer and in Region II during the winter.

4. BLOCKING IN THE REGION OF SOUTH AMERICA

As evident in Table 1, blocking in the region of South America occurs throughout the year with a maximum occurrence during fall (March-April). Blocking patterns in this region are usually progressive and of fairly short duration (~8 days). In some instances, they have pronounced influences on the rainfall distribution over South America, even at equatorial latitudes. In this section we describe the characteristics of two blocking events which occurred during FGGE.

a) The April 1979 event

The blocking pattern which developed between 18 and 20 April 1979 evolved in a manner typical of many blocks in this region. The middle and upper tropospheric flow pattern was nearly zonal over the central and eastern Pacific on the 18th (Fig. 2a). The flow then became increasingly meridional as a series of troughs and ridges amplified first in the central Pacific then in the eastern Pacific and over South America (Fig. 2b). The flow split over the eastern Pacific with the polar branch passing over extreme southern South America. The crest of the middle and high latitude ridge, which developed over southern Argentina, remained between 55^{o} and 75^{o}W from the 20th to the 27th (Figs. 2c-2e). The subtropical branch of the flow, within this longitude range, was nearly zonal between the eastern Pacific and the western Atlantic. These characteristics typify split-flow blocks in the South American region. After the 27th, the block began to weaken and move eastward (Fig. 2f).

Frontal systems, which approached the west coast of South America during the period 20-27 April, decelerated, developed north-south orientations and either greatly weakened or completely dissipated as they entered the split-flow. These features are readily observed in the geostationary satellite images shown in Fig. 3. Most of Argentina and all of Paraguay, Uruguay and southern Brazil experienced an absence of frontal activity during the period of blocking.

The two main branches of the upper level flow merged over the western Atlantic, between 20^{o} and 30^{o}S. This region was characterized by frequent cyclogenesis and frontogenesis throughout the period of blocking. This activity was associated with the organization and eastward displacement of enhanced equatorial convection (Figs. 3a-3c), which has recently been discussed by Virji and Kousky (1983).

b) The January 1979 event

From 30 December 1978 to 19 January 1979 a split-flow in the middle and upper tropospheric circulation pattern existed in the central and eastern Pacific (130-150W). This pattern weakened on the 20th but intensified in the same region on the 21st and lasted until 6 February 1979. In contrast to the April 1979 case, the January 1979 split-flow pattern occurred at subtropical latitudes. The position of this block was such that downstream ridges and troughs entered in phase with the normal thermal distribution in the region of South America. As a result, both the upper tropospheric anticyclonic circulation over South America and the trough over the western Atlantic were quite vigorous (Fig. 4a). In addition, during the middle of January a blocking pattern became established at the longitude of the western Atlantic trough (~ 40^{o}W).

During all of January, a pattern of extremes in rainfall existed over many parts of Brazil. Southern Brazil remained under the influence of strong subsidence (Fig. 4b) with only 5-20% of normal rainfall. These abnormally dry conditions caused enormous losses to certain agricultural crops, such as soybeans, a major export crop in Brazil. Portions of southeastern and eastern Brazil, on the other hand, experienced rainfall departures that in some cases exceeded 300% of normal. Average rainfall totals and average percent of normal rainfall, during January 1979, for states in southeastern and eastern Brazil, are given in Fig. 5. Comparing Figs. 4b and 5 we note that areas of sinking motion over southern Brazil and maximum rising motion over eastern Brazil agree well with the areas of deficient and excessive rainfall, respectively.

5. CONCLUSION

Our results confirm those of van Loon (1956) and Wright (1974) in that the Australia-New Zealand and Indian Ocean regions are areas of frequent blocking. In addition, we have shown that the central and eastern Pacific is also an important blocking region second only to the Australia - New Zealand region.

Our results regarding the seasonality of blocking are somewhat different than those previously obtained, especially in regards to the summertime maxima observed in the Australia - New Zealand and central and eastern Pacific regions. It is possible that the South Pacific Convergence Zone plays an important role in block formation in these regions. Also, the high frequency of summertime blocking may be linked to the strong heating of major continental regions and the manner in which this heating distribution interacts with transient disturbances. The January 1979 blocking event near South America illustrates that summertime blocking may be highly persistent and lead to a rainfall pattern which is detrimental to agriculture.

ACKNOWLEDGMENTS

The authors are grateful to Dr. V.B. Rao for reviewing the manuscript. In addition, the first author wishes to thank Manuel A. Gan who helped prepare many of the figures. Thanks are also due to Sueli I.R. Ferreira who did the typing.

REFERENCES

Berggren, R., Bolin, B., and Rossby, C.G. 1949: An aerological study of zonal motion, its perturbations and break-down. *Tellus* 1, 14-37.

Brezowsky, H., Flohn, H., and Hess, P. 1951: Some remarks on the climatology of blocking action. *Tellus* 3, 191-194.

Elliot, R.D., and Smith, T.B. 1949: A study of the effects of large blocking highs on the general circulation in the Northern-Hemisphere westerlies. *J. Meteorol.* 6, 67-85.

Gruber, A. 1972: Fluctuations in the position of the ITCZ in the Atlantic and Pacific Oceans. *J. Atmos. Sci.* 29, 193-197.

Heddinghaus, T.R. and Krueger, A.F. 1981: Annual and interannual variations in outgoing long wave radiation over the tropics. *Mon. Wea. Rev.* 109, 1208-1218.

Hovmöller, E. 1949: The trough and ridge diagram. *Tellus* 1, 62-66.

Liebmann, B. and Hartmann, D.L. 1982: Interannual variations of outgoing IR associated with tropical circulation changes during 1974-1978. *J. Atmos. Sci.* 39, 1153-1162.

Namias, J. 1950: The index cycle and its role in the general circulation. *J. Meteorol.* 7, 130-139.

Namias, J. and Clapp, P.F. 1944: Studies of the motion and development of long waves in the westerlies. *J. Meteorol.* 1, 57-77.

Rex, D.F. 1950a: Blocking action in the middle troposphere and its effect upon regional climate. Part I: An aerological study of blocking action. *Tellus* 2, 196-211.

——— 1950b: Blocking action in the middle troposphere and its effect upon regional climate. Part II: The climatology of blocking action. *Tellus* 2, 275-301.

——— 1951: The effect of Atlantic blocking action upon European Climate. *Tellus* 3, 100-112.

Sanders, R.A. 1953: Blocking highs over the eastern North Atlantic Ocean and western Europe. *Mon. Wea. Rev.* 81, 67-73.

Sumner, E.J. 1954: A study of blocking in the Atlantic - European sector of the Northern Hemisphere. *Quart. J. Roy. Meteor. Soc.* 80, 402-416.

Treidl, R.A. Birch, E.C. and Sajecki, P. 1981: Blocking action in the Northern Hemisphere: a climatological study. *Atmosphere-Ocean* 19: 1-23.

van Loon, H. 1956: Blocking action in the Southern Hemisphere, Part I. *Notos* 5, 171-175.

Virji, H. and Kousky, V.E. 1983: Regional and global aspects of a low latitude frontal penetration in Amazonas and associated tropical activity. Preprints First International Conference on Southern Hemisphere Meteorology, 31 July - 6 August, 1983. São José dos Campos, Brazil, 215-219.

Wright, A.D.F. 1974: Blocking action in the Australian region. *Austr. Bur. Met. Tech. Rep.* No. 10, 29 pp.

TABLE LEGEND

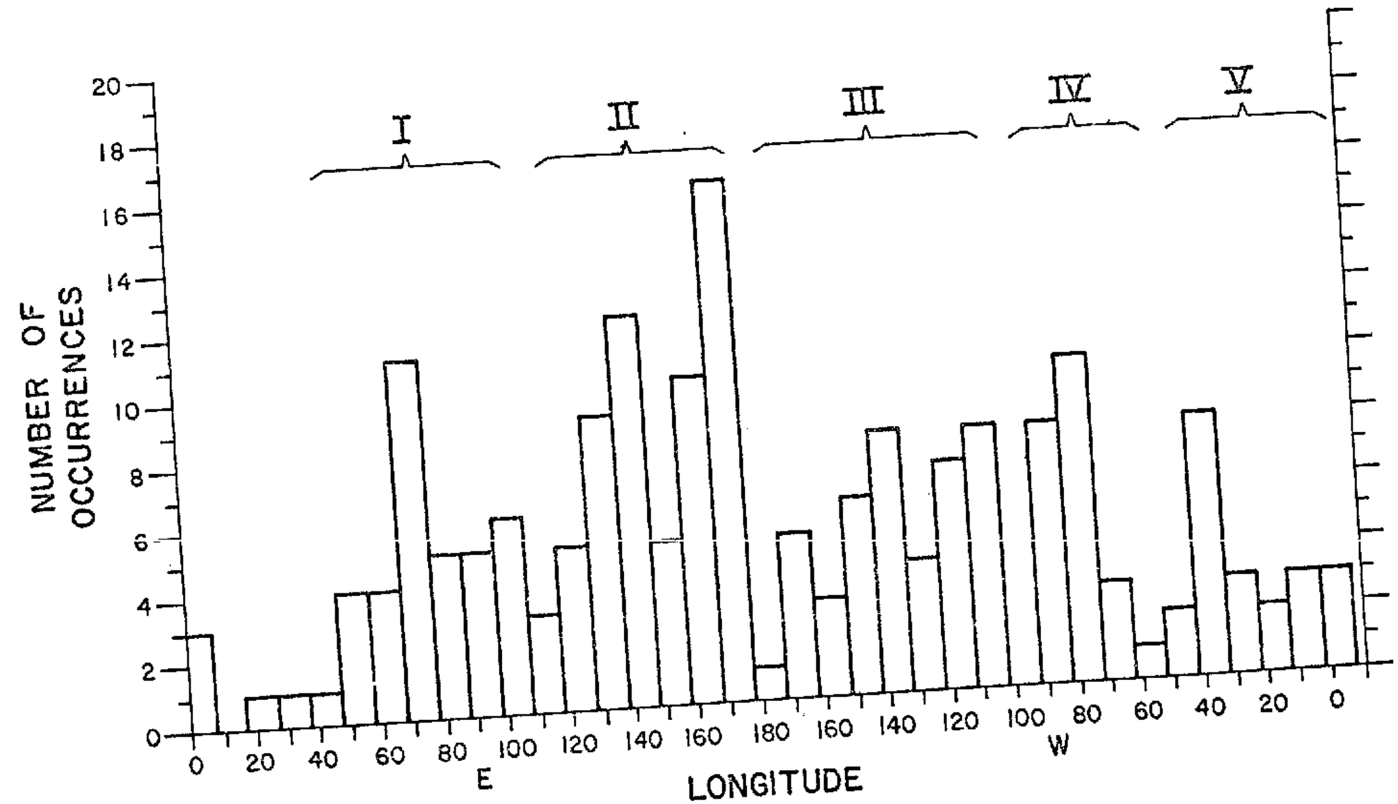
1 - Percent of days, for each month, in which blocking was observed during the period 1975-1979. The last three columns on the right give the total number of days on which blocking occurred, the total number of blocks and the average blocking duration (days).

TABLE 1

REGION	PERCENT												TOTAL NUMBER BLOCKING DAYS	TOTAL NUMBER BLOCKS	AVERAGE BLOCKING DURATION
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC			
I	18	13	19	17	33	6	27	23	2	50	22	27	313	37	8.5
II	53	35	38	11	75	58	48	38	38	43	21	45	612	57	10.7
III	64	26	44	30	6	31	14	22	28	33	32	51	462	41	11.3
IV	12	5	26	28	15	13	5	5	12	0	10	13	175	23	7.6
V	10	11	6	9	11	12	11	9	29	1	5	15	158	19	8.3

LIST OF FIGURES

Fig. 1


NUMBER OF OCCURRENCES
0
2
4
6
8
10
12
14
16
18
20
I
II
III
IV
V
0 20 40 60 80 100 120 140 160 180 160 140 120 100 80 60 40 20 0
E
W
LONGITUDE

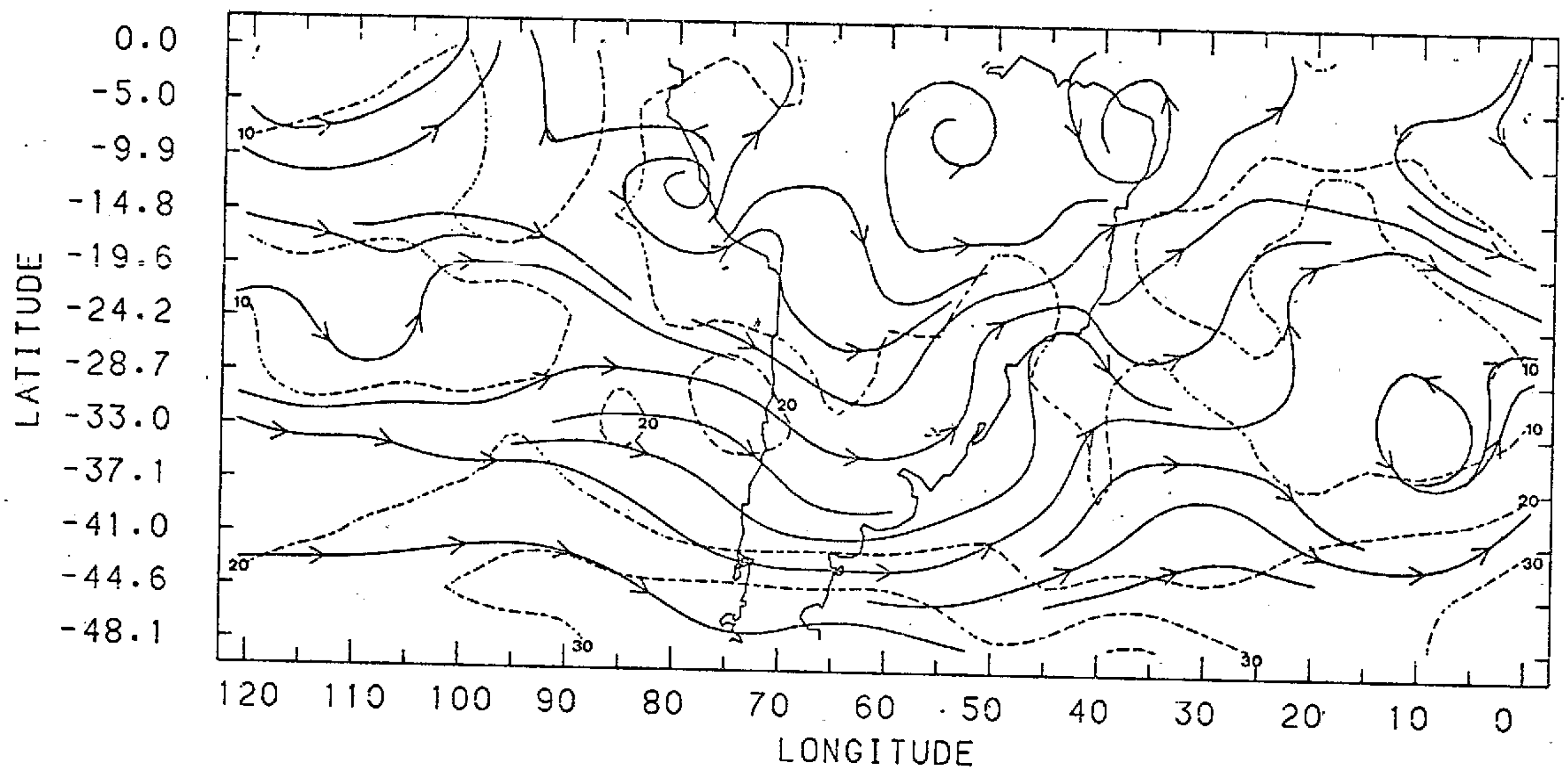
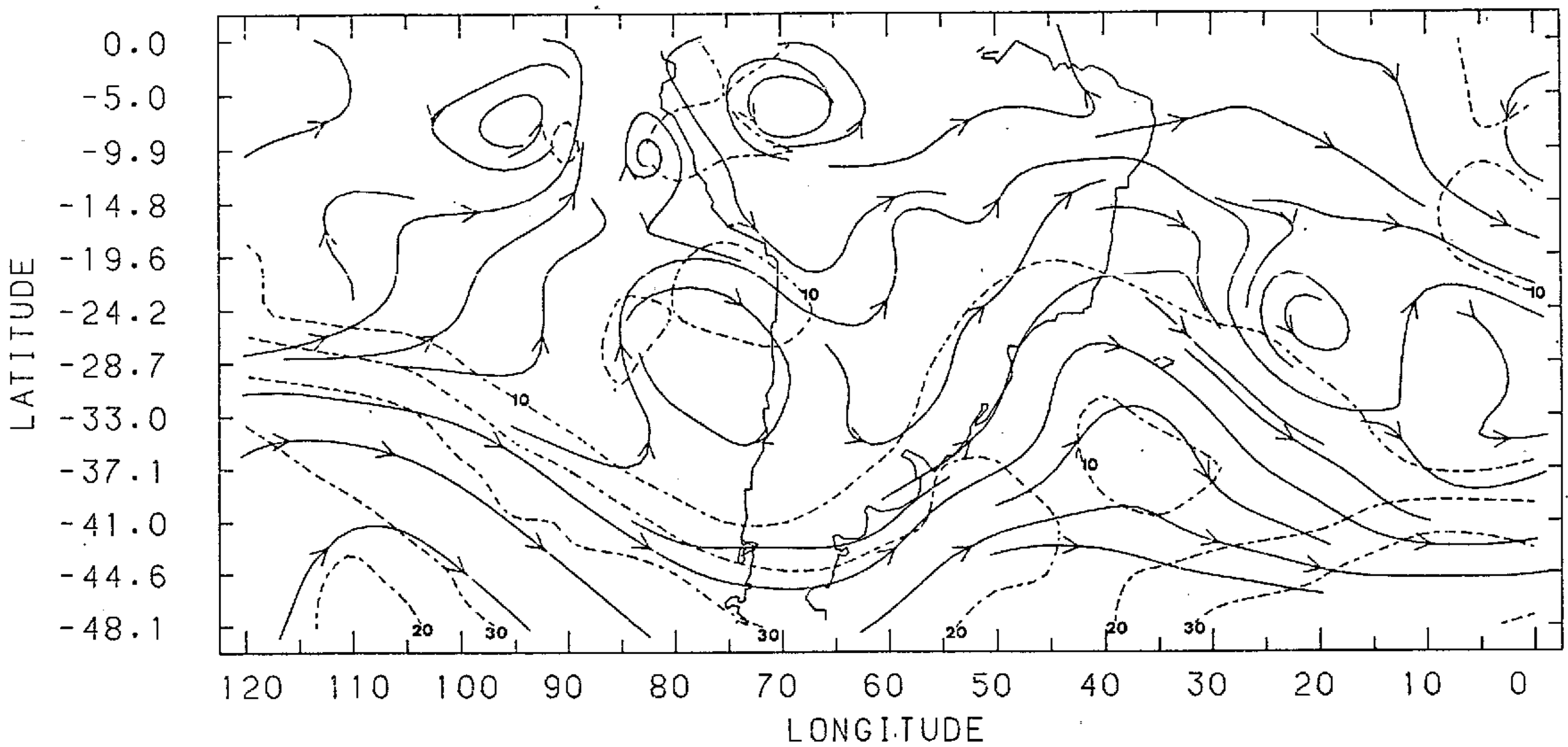
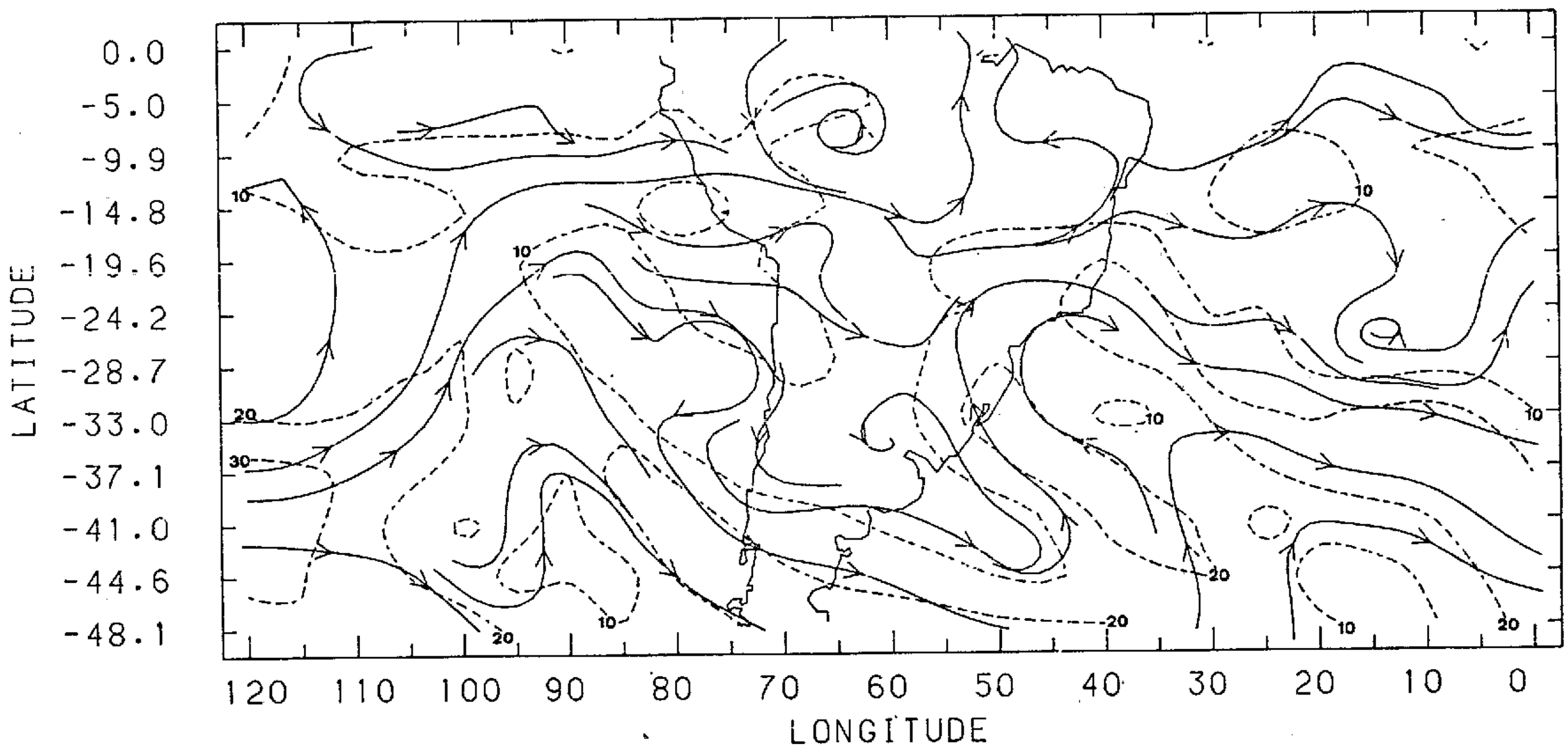

LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE
10
20
30

Fig. 2a



LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE
10
20
30

Fig. 2b



LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE

Fig. 2c

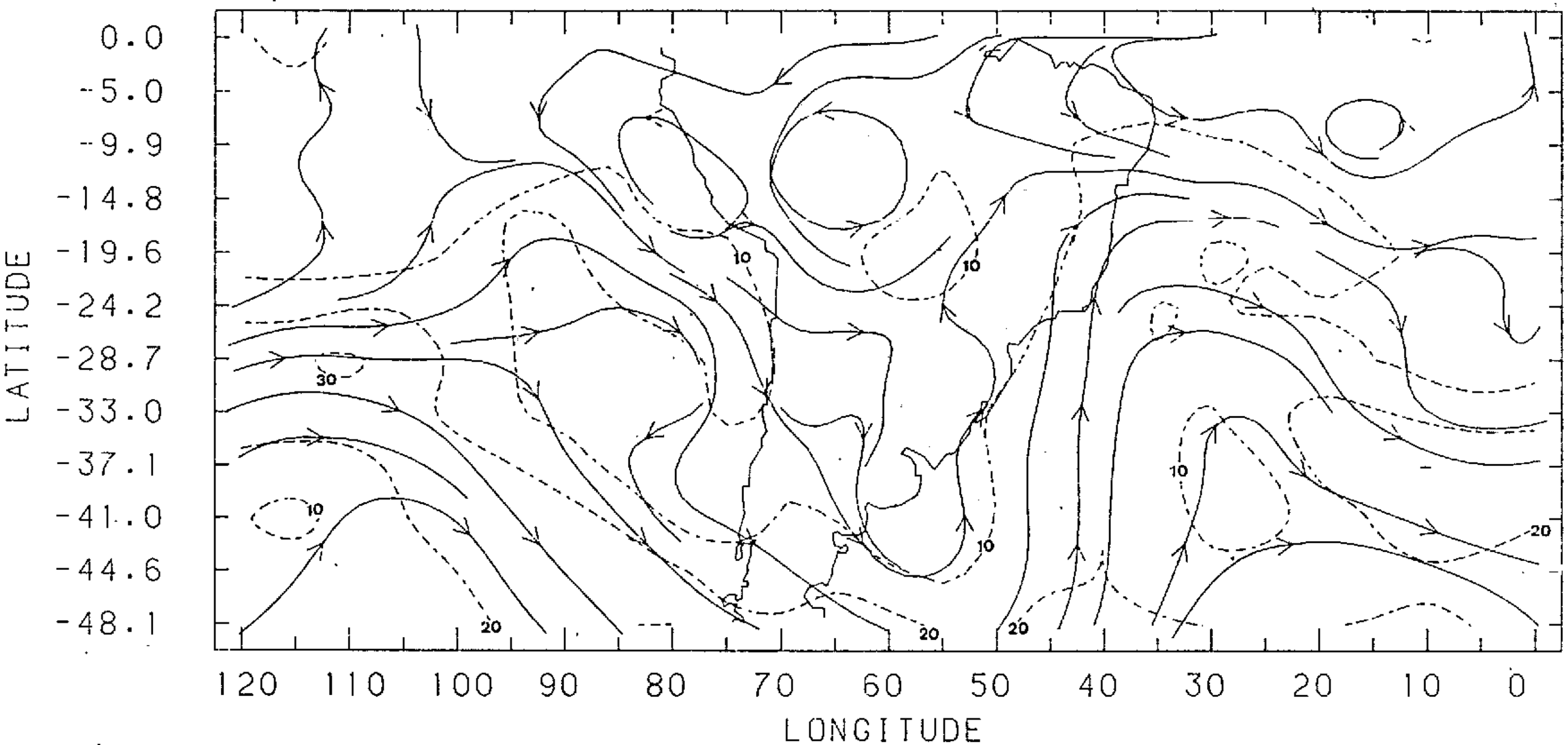

LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE
10
20
30

Fig. 2d

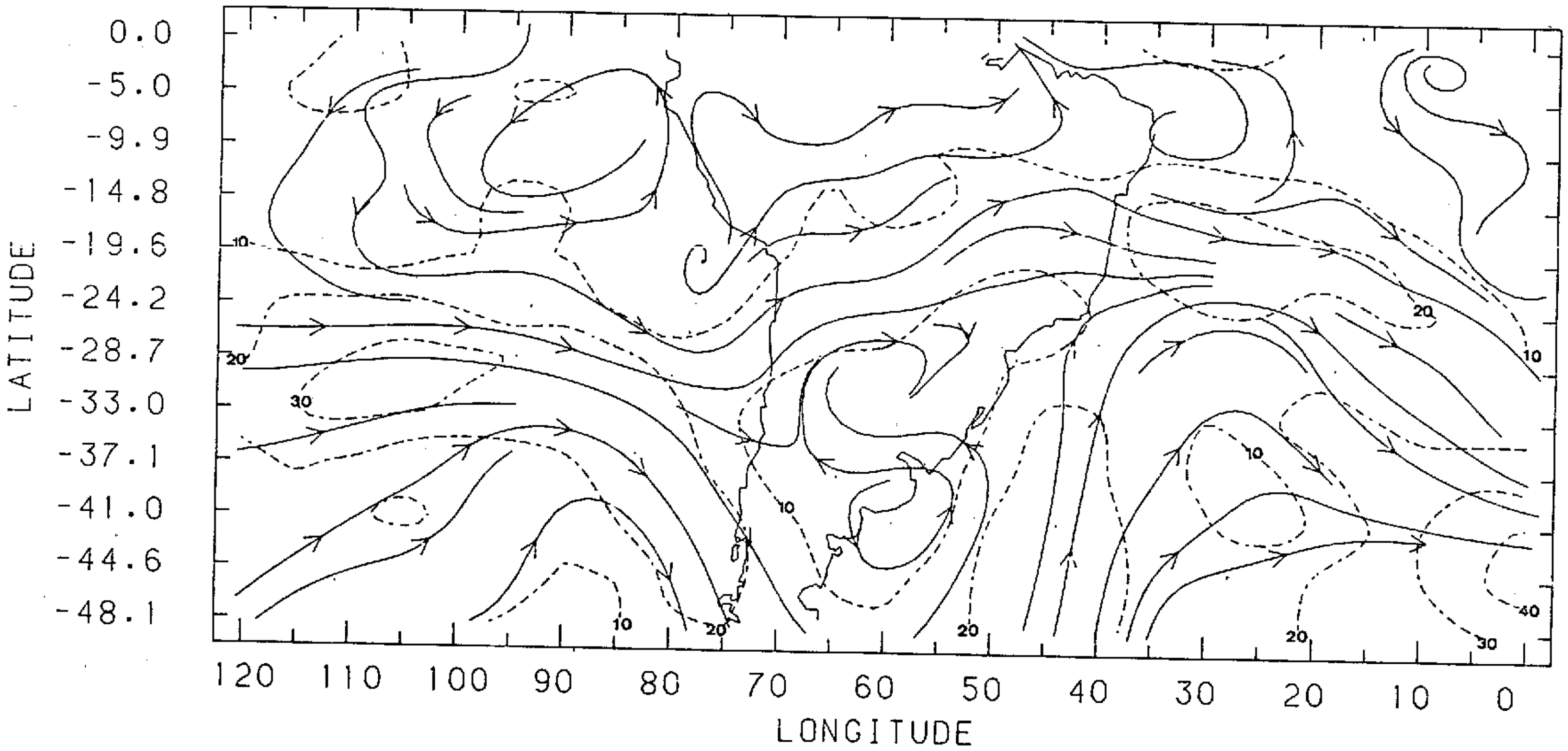
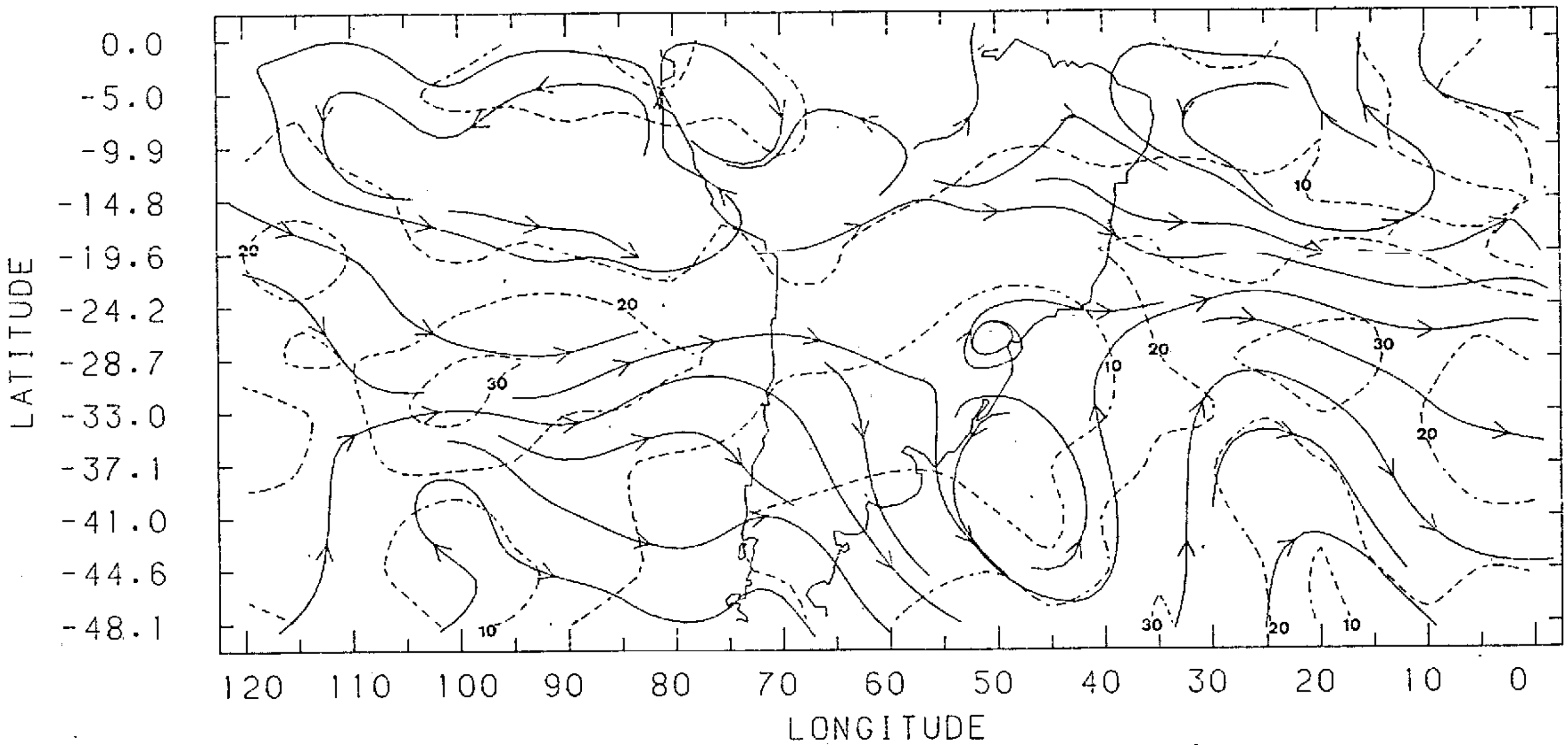

LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE
10
20
30
40

Fig. 2e



LATITUDE
0.0
-5.0
-9.9
-14.8
-19.6
-24.2
-28.7
-33.0
-37.1
-41.0
-44.6
-48.1
120
110
100
90
80
70
60
50
40
30
20
10
0
LONGITUDE

Fig. 2f

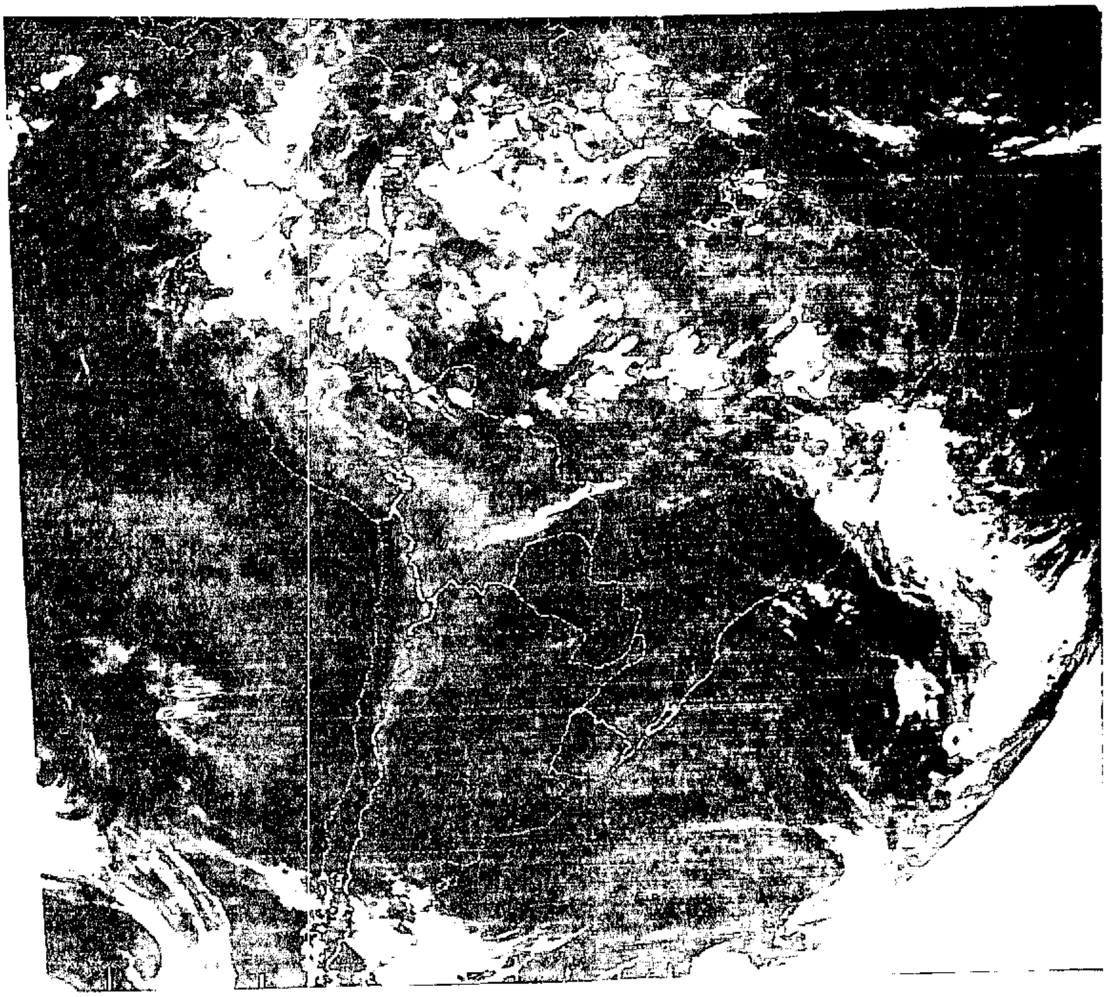


Fig. 3a

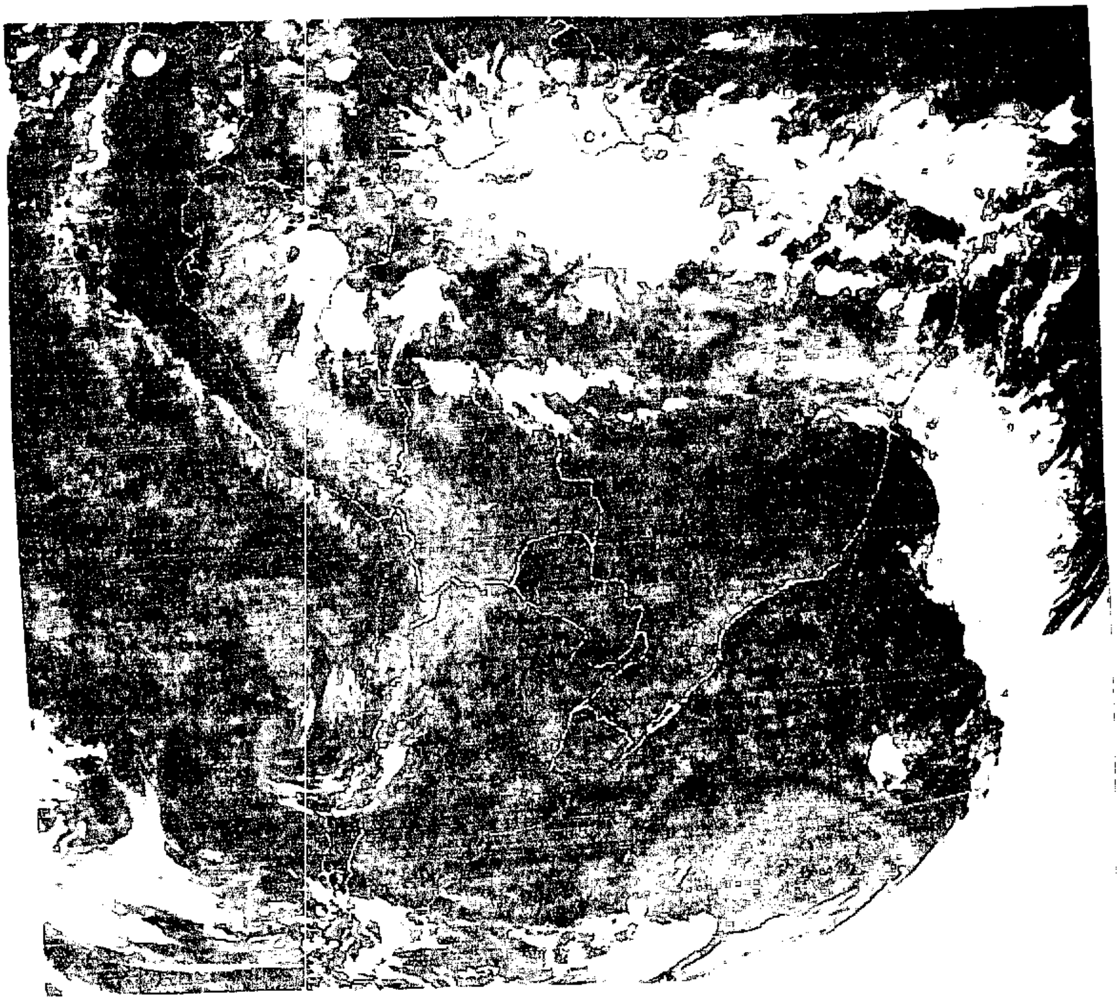


Fig. 3b

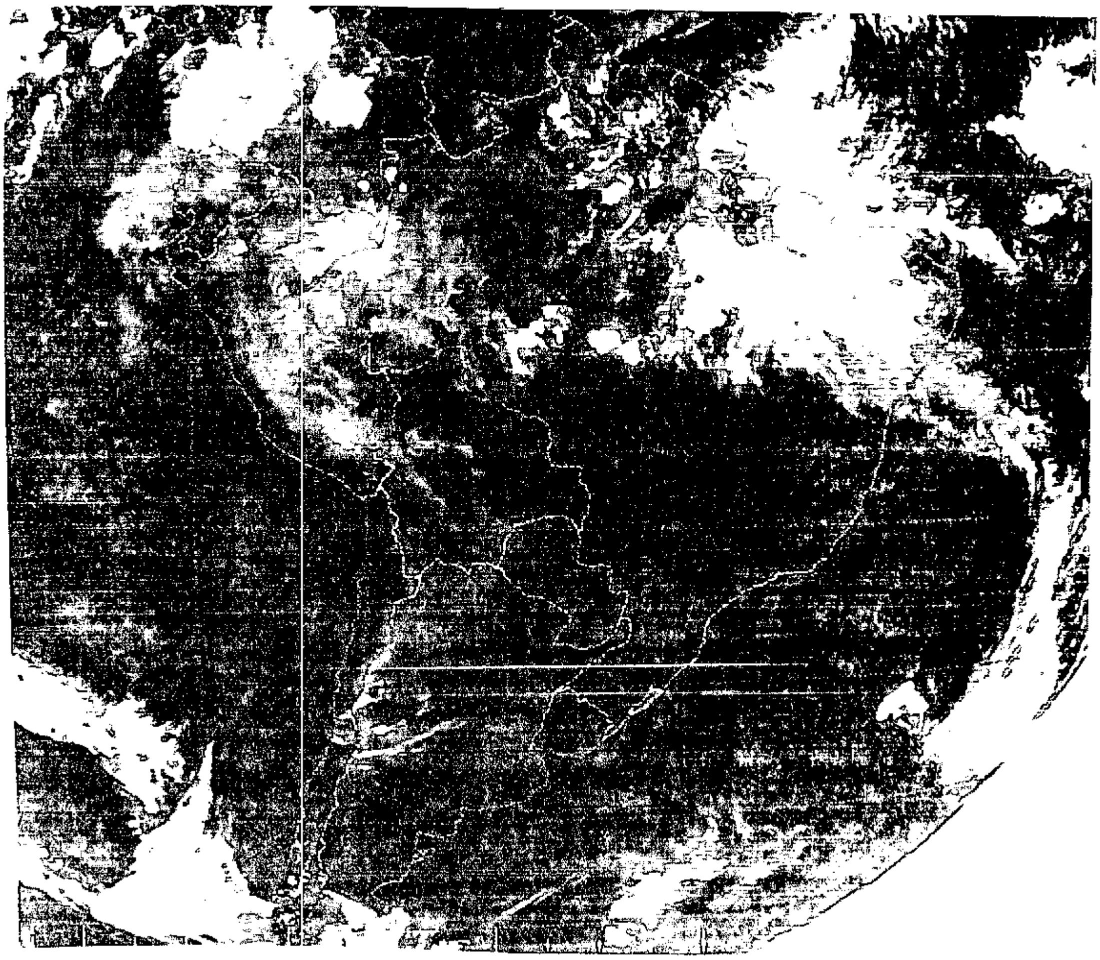


Fig. 3c

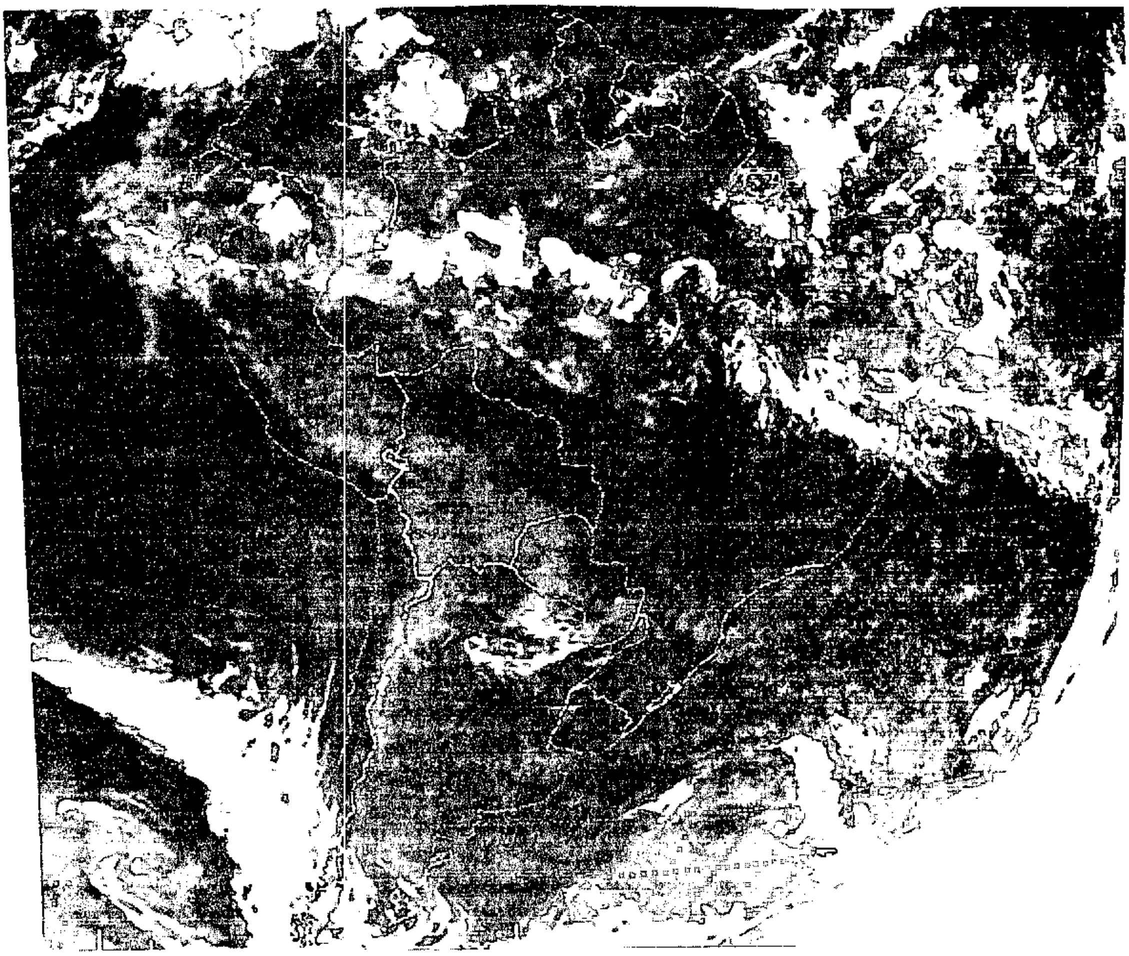


Fig. 3d

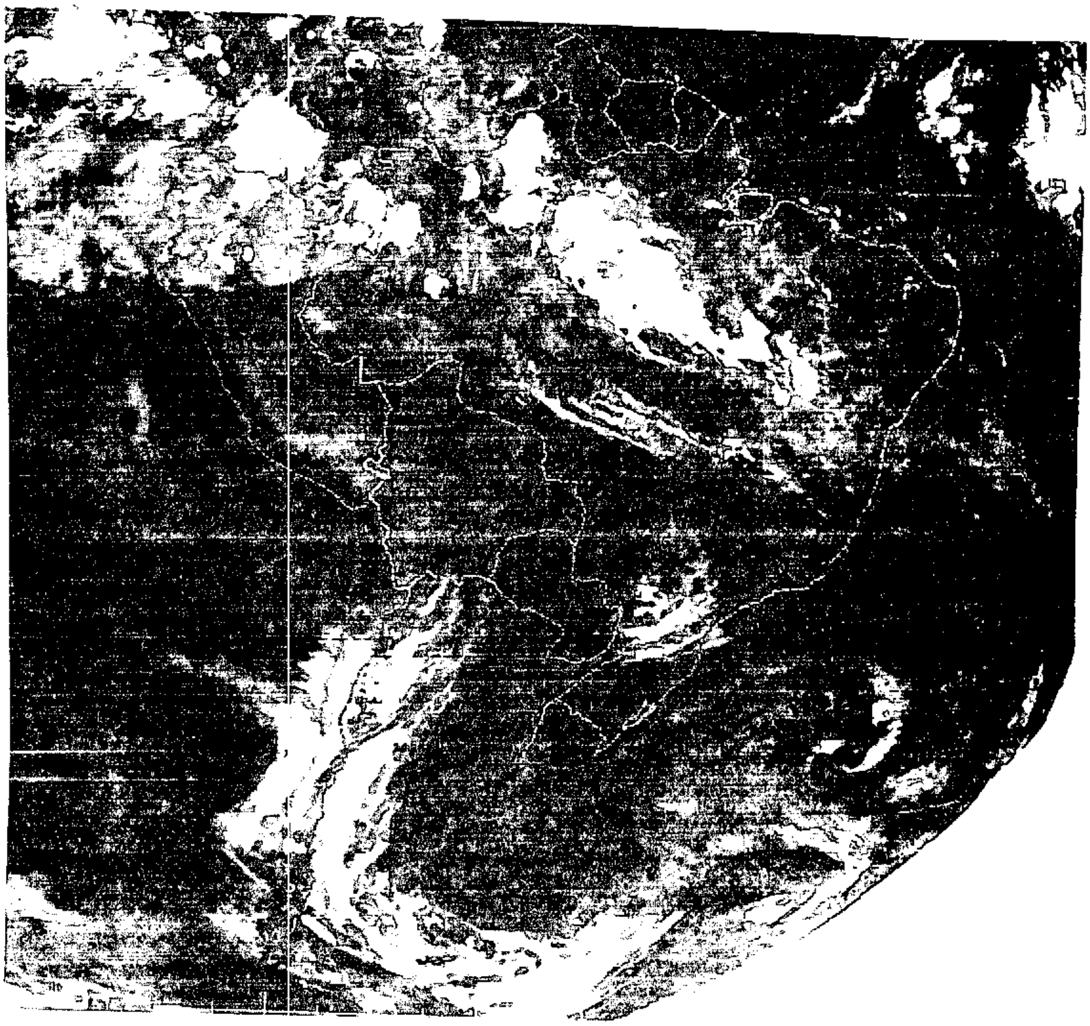


Fig. 3e

YEAR: 1979 LEVEL:200. MB

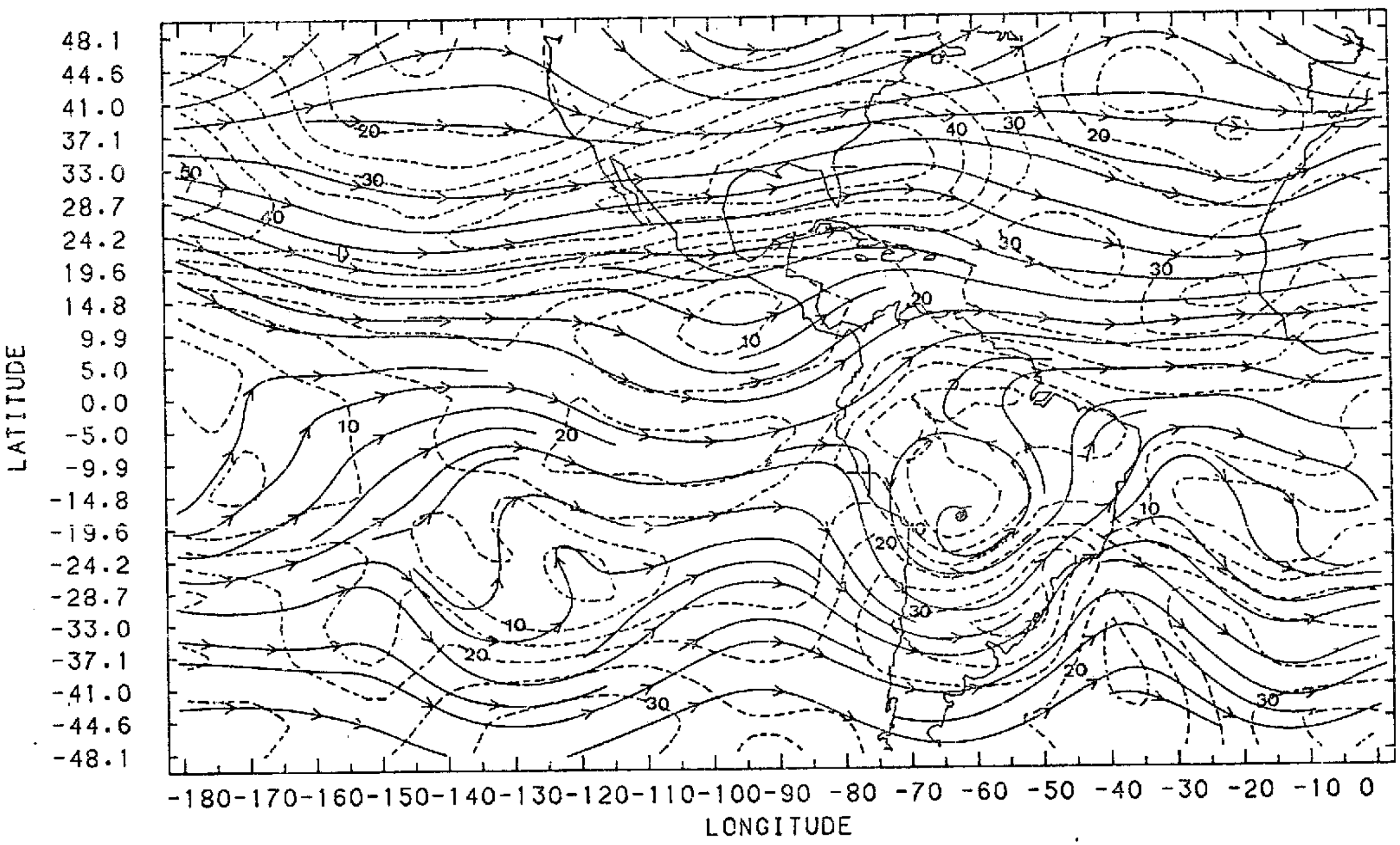


Fig. 4a

YEAR: 1979 LEVEL:500. MB

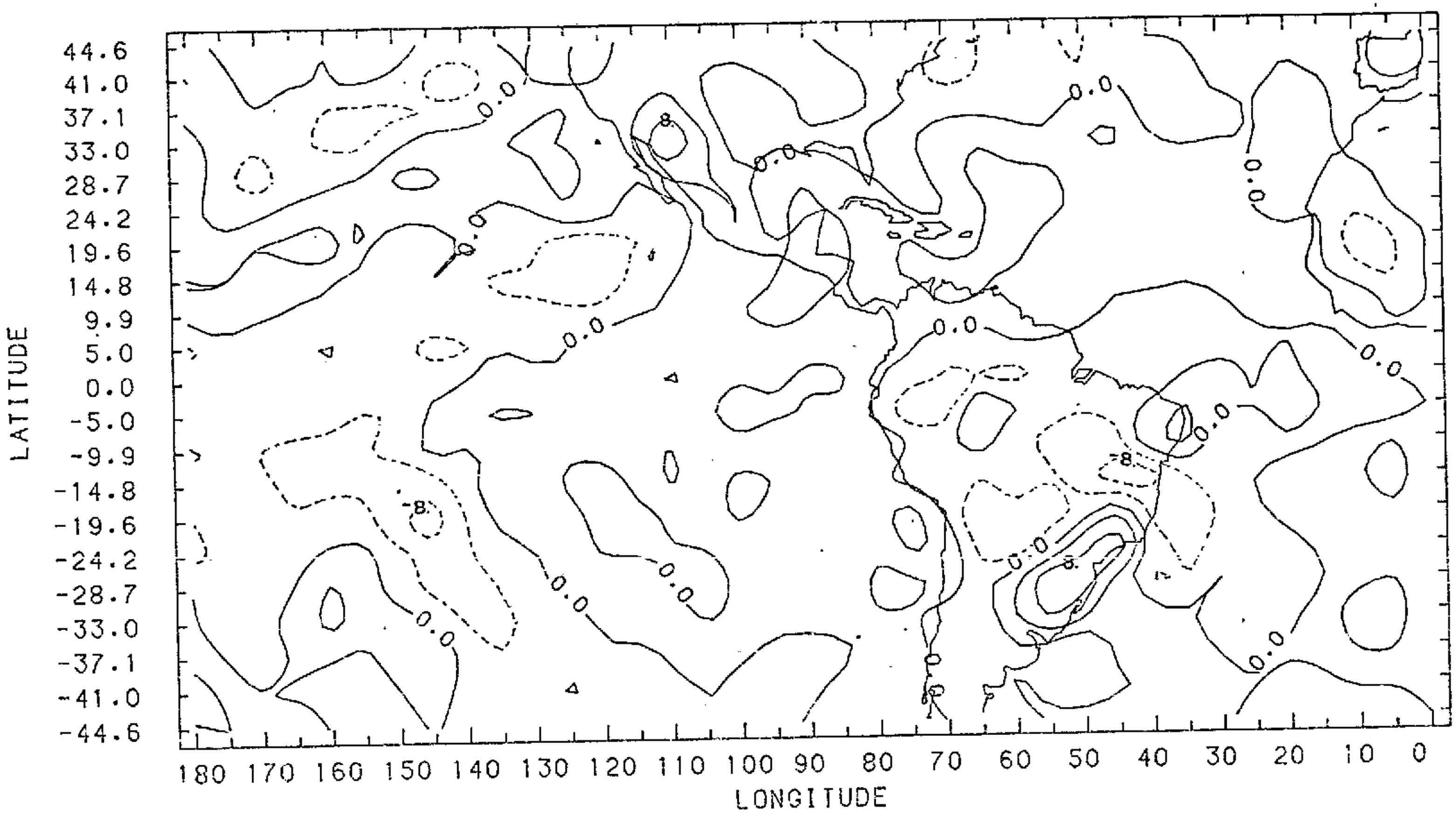


Fig. 4b

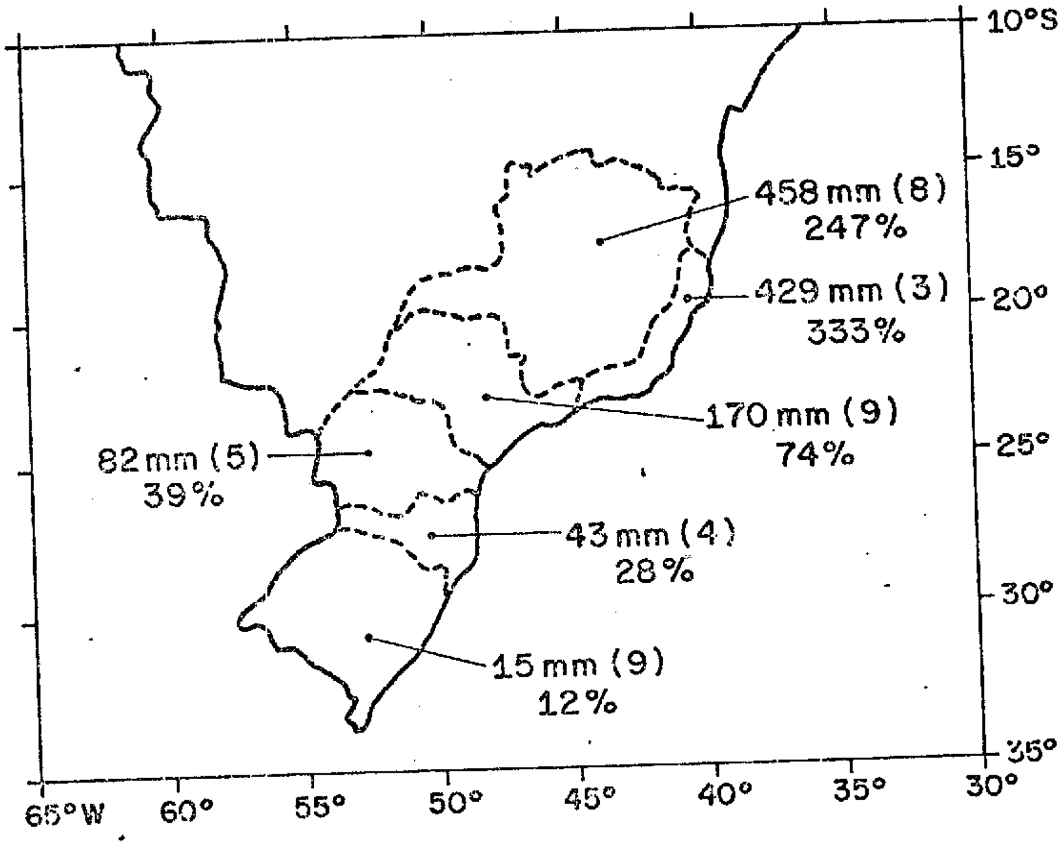

10°S
15°
20°
25°
30°
35°
65°W
60°
55°
50°
45°
40°
35°
30°
458 mm (8)
247%
429 mm (3)
333%
170 mm (9)
74%
82 mm (5)
39%
43 mm (4)
28%
15 mm (9)
12%

Fig. 5