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The Atmospheric Circulation and the Major Drought and Flood of 1983 in Brazil

Minoru TANAKA* and Toshie NISHIZAWA**

Synoptic analysis of the atmospheric circulation associated with a large scale drought in Northeast Brazil (Nordeste) and a widespread flood in Iguacu/Parana river regions (Southern Brazil) in April 1983 are conducted. The rainfall in Northern Nordeste (north of 10°S) are concentrated in March-May. Hence, the 850 mb and 150 mb atmospheric circulation over Brazil in April 1983 were compared to that of April 1974, which was a wet month in Northern Nordeste. In addition, a brief historical survey of the drought in Northern Nordeste and its relationship to the El Niño-Southern Oscillation (ENSO) events was conducted.

It was shown that the two extreme climatological events in 1983 were associated with strong South Atlantic subtropical high at the 850 mb level which caused increased subsidence and decreased rainfall in Northern Nordeste. The atmospheric circulation around this anticyclone transported water vapor from the Atlantic Ocean toward the polar frontal zone in Southern Brazil. A brief historical survey of the drought in Northern Nordeste showed that the drought years are often observed in the ENSO event year or a year after an ENSO event. A 1983 drought was observed toward the end of a major ENSO event in 1982–1983.

I. Introduction

The Northeastern region of Brazil (hereafter called Nordeste) is a region which is subject to recurrent drought (TREWARTHA, 1961; RIEHL, 1979). HASTENRATH and HELLER (1977) identified the extreme drought years in the period 1912–1978 as 1915, 1919, 1942 and 1958. In 1983, the rainfall data from Brazil indicated a drought of extreme intensity in Nordeste.

The climatological studies on annual change in the rainfall regime in South America based on the surface data were conducted by RATISBONA (1976) and CAVIEDES (1981). These studies were focused on the drought in Nordeste. The rainfall regime in Nordeste are divided into Northern (north of 10°S) and Southern Nordeste by HASTENRATH and HELLER (1977). MOURA and SHUKLA (1981), and HASTENRATH (1984) linked the rainfall in Northern Nordeste to the sea surface temperature anomalies in the Atlantic Ocean. The atmospheric circulation over South America was investigated by NEWELL *et al.* (1972), VAN LOON *et al.* (1972), VIRJI (1981) and by CHUNG (1982).

The study on annual change in the tropospheric circulation and its relationship to the rainfall in South America was conducted by NISHIZAWA and TANAKA (1983). Similar survey on interannual change was conducted by TANAKA and NISHIZAWA (1983). Collectively, these recent studies show a trough at the 150 mb level over Nordeste which can be linked to regional subsidence and relatively small amount of the rainfall in Nordeste. In a current study, a synoptic survey of an extreme drought in Northern Nordeste (north of 10°S) and simultaneous flood in Southern Brazil (Iguacu/Parana river regions) during 1983 was investigated.

The main source of the data (1969 to 1983) for this study is *Monthly Climatic Data for the World* published by National Oceanic and Atmospheric Administration (NOAA). The upper air data for the 150 mb and 850 mb levels were also obtained from the same source. In addition, *Precipitation for the World* published by the Japan Meteorological Agency was used to obtain the rainfall data for Quixera-

* Numerical Prediction Division, Japan Meteorological Agency, Tokyo 100, Japan.
** Institute of Geoscience, University of Tsukuba, Ibaraki 305, Japan.

mobim (1896–1972) and Curitiba (1895–1972).

II. Rainfall and temperature anomalies in South America during 1983

Because the monthly total rainfall does not obey the normal probability distribution, the rank/frequency group called "Quintile" was taken from the data to analyze the rainfall anomalies. Table 1 shows the Quintile values defined by dividing the probability distribution by 5 equal appearance frequency. Since the boundary of each Quintile is based on the latest 30 year sample of the rainfall data, the observation of a record low (high) precipitation in a new sample of the data is given a rank of Quintile 0 (6).

Table 1. Rank/frequency group for the monthly total precipitation (base period: latest 30 year normal).

Quintile	Rank
0	New record low precipitation
1	1 - 6 (lowest 6 years)
2	7 - 12
3	13 - 18 (6 years near a median value)
4	19 - 24
5	25 - 30 (highest 6 years)
6	New record high precipitation

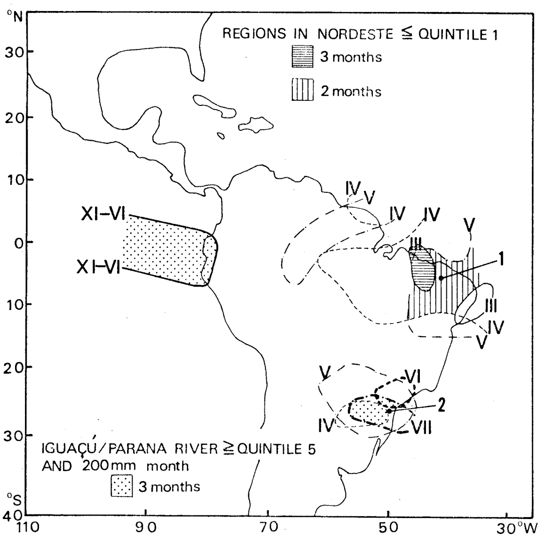

Figure 1. Rainfall Quintile over South America from March to July 1983.

Regions with less than Quintile 1 or greater than 5 (simultaneously over 200 mm) are shown by a line for each month (shown by the the roman numbers).
1. Quixeramobim 2. Curitiba

Figure 1 shows the rainfall Quintile over South America from March to July 1983. In Nordeste, the area which received less than Quintile 1 rainfall occupies a small region in the northern coast in March. In April and May, the rainfall was less than Quintile 1 in entire Northern Nordeste. Hence, the rainfall was well below the normal in most of Northern Nordeste in two out of three rainy months from March to May.

In Southern Brazil (Iguacu/Parana river regions), the areas which received more than Quintile 5 rainfall and simultaneously more than 200 mm per month are shown from April to July. It is important to note that the regions with heavy rainfall showed only a small month to month change on the location. The shaded regions near Curitiba received more than Quintile 5 for at least 3 months. Finally, a region near Ecuador, Peru and adjacent ocean near Galapagos Islands received heavy precipitation (more than Quintile 5) from November 1982 to June 1983. This rainfall was associated with a major El Niño-Southern Oscillation (ENSO) event.

Figure 2 shows the temperature departure in South America from April to July 1983.

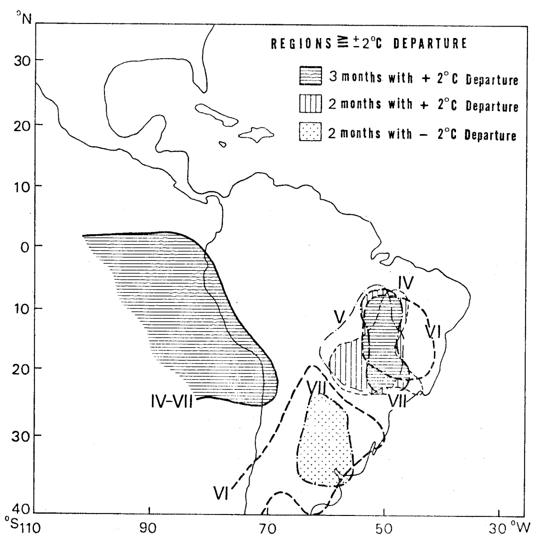

Figure 2. Temperature departures over South America from April to July 1983.

Regions with more than ± 2°C departure from the normal are shown by a line for each month (shown by the roman numbers).

From northern Chile, Peru to Ecuador, the temperatures were more than 2°C above the normal. This is a direct consequence of a major ENSO event. The temperature was above the normal near Brasilia and below the normal in northern Argentina. Hence, the temperature gradient was greater than the normal in Southern Brazil. This observation indicates an existence of the polar frontal zone over Southern Brazil which experienced heavy rainfall.

III. Atmospheric circulation over South America in April 1983

The atmospheric circulation anomalies over South America at the 850 mb level (lower circulation of the Hadley cell) and at the 150 mb level (upper circulation of the Hadley cell) were analyzed to investigate the circulation pattern which contributed to the extreme rainfall distribution discussed in a previous section. The analyses were shown in this paper because this month is near the peak of the normal wet season in Northern Nordeste. In addition, an inspection of the atmospheric circulation in the other months showed a very similar pattern to that of April.

Figure 3 shows the 850 mb height and wind for April 1983. The southeast trade wind is strong near Fortaleza (3°45′ S, 38°31′ W). This wind blows counterclockwise around the South Atlantic subtropical high and becomes a northerly wind near Campo Grande (21°34′ S,54°55′ W). This moist northerly wind which originated over the tropical South Atlantic Ocean is forced to ascend in the polar frontal zone located over Southern Brazil and caused heavy rainfall.

Figure 4 shows the 850 mb height departure from the 1969–1978 (10-year) normal. The above normal height over Nordeste shows strong South Atlantic subtropical high and consequent subsidence and drought over Northern Nordeste. The moist northerly flow toward Southern Brazil is stronger than the normal. An inspection of the circulation in the other months shows that this northerly flow is stronger than the normal from April to July. Hence, persistent heavy rain was observed Southern Brazil.

Figure 5 shows the 150 mb height and wind. The upper tropospheric trough [which normally develops in December and January (Tanaka and Nishizawa, 1983) and are responsible for a dry period in Northern Nordeste] is still observed in April. This trough normally weakens in March and April and these months normally coincide with a brief wet season in Northern Nordeste.

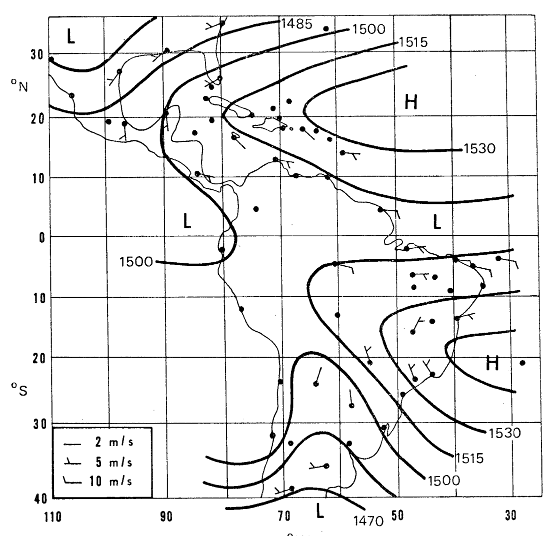

Figure 3. 850 mb height (gpm) and wind (m/s) for April 1983.

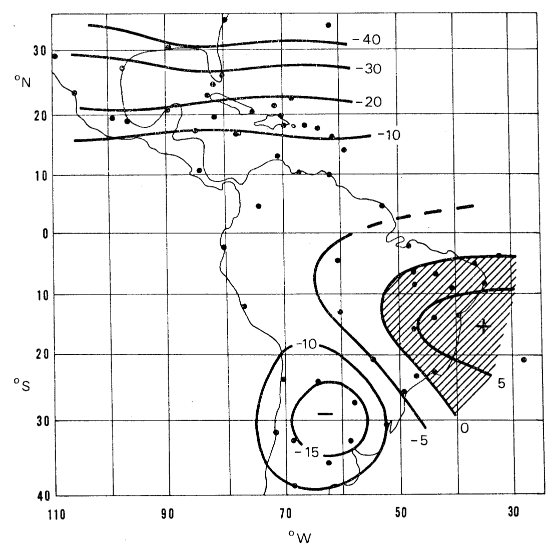

Figure 4. 850 mb height departures from the normal (1969–1978) for April 1983.

Figure 6 shows the horizontal divergence of the wind field at the 150 mb level. The divergence values were calculated by the following methods: The wind vector at each upper air station was decomposed into zonal component (U) and meridional component (V). Based on these two scalar data, 5° latitude~5° longitude grid values for the U and V component of the wind over South America were obtained. The horizontal divergence was calculated by a continuity equation.

$$\mathrm{DIV}=\frac{\partial U}{\partial x}+\frac{\partial V\cos\phi}{\cos\phi\partial y}$$

where: $\partial x=R\cos\phi d\lambda$ and $\partial y=Rd\phi$

λ, ϕ: longitude and latitude

U, V: zonal and meridional component of wind

R: radius of the earth

In most of Nordeste, horizontal divergence of $-2\times10^{-6}\,\mathrm{sec}^{-1}$ was obtained. This convergent motion in the upper troposphere indicates subsidence in the middle troposhere (near the 500 mb level) over Nordeste.

The atmospheric circulation in April 1983

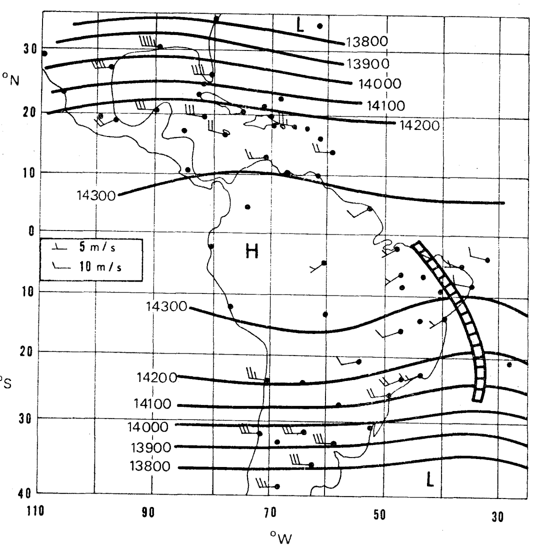

Figure 5. 150 mb height (gpm) and wind (m/s) for April 1983.

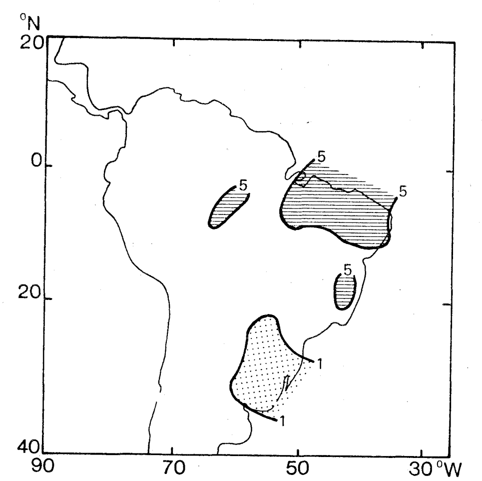

Figure 7. Same as Figure 1 but for April 1974.

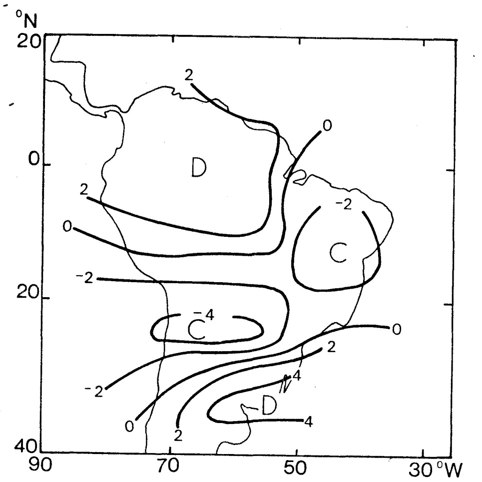

Figure 6. 150 mb divergence of the wind field for April 1983. (10^{-6} sec^{-1})

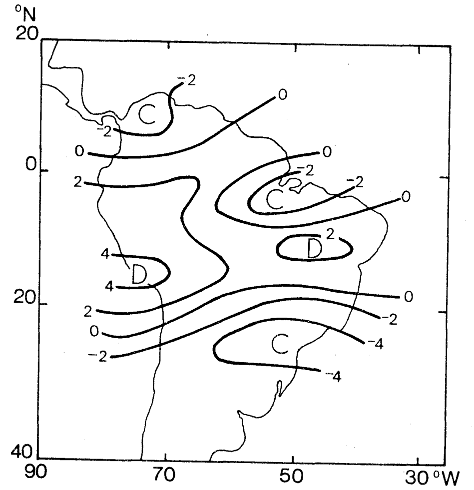

Figure 8. Same as Figure 6 but for April 1974. (10^{-6} sec^{-1})

was then compared to the circulation in April 1974, a wet month in Northern Nordeste. Figure 7 shows the rainfall Quintile over South America in April 1974. Most of Northern Nordeste observed more than Quintile 5. An inspection of the monthly total precipitation for the same month showed that most region in Northern Nordeste received 200 to 400 mm of the precipitation in April 1974. It is also interesting to note that a dry region (less than Quintile 1) is located in Southern Brazil. Figure 8 shows divergence of the wind field at the 150 mb level for April 1974. The values of divergence over Nordeste are opposite to those of 1983. This indicates ascending motion which favors cloud formation in the middle troposphere over Nordeste.

IV. Relationship between the drought in Northern Nordeste and ENSO

Finally, a brief historical survey of the drought in Northern Nordeste based on the rainfall at Quixeramobim (5°12′ S, 39°18′ W) and heavy rain in Southern Brazil based on the rainfall data at Curitiba (25°26′ S, 49°16′ W) was conducted. The relationship to ENSO was also investigated. Figure 9 shows inter-annual change in the rainfall at Quixeramobim from 1897 to 1983 (January year). Because 96.6% of the annual rainfall is observed during eight month period from December to July, this graph shows essentially the rainfall total for the annual period. Therefore, the eight month period was taken to reduce the number of the years with the missing data. Four years with missing observation are shown by the dashed line which shows the total precipitation excluding the missing months. Fourteen triangles shown at the bottom of graph indicate the drought years arbitrarily defined as less than 400 mm during the eight wet month. An inspection of this graph shows that the drought years were frequent until 1920. The drought in 1983 was the first major drought since 1958.

Table 2 shows the major El Niño and/or large Walker Circulation Index (ENSO year in this paper) years based primarily on Quinn and Burt (1970) and supplemented by Tanaka (1976). These years are shown on the left hand column. The middle column shows the drought years at Quixeramobim taken from Figure 9 (and two additional probable drought years in 1907 and 1931) and the wet years at Curitiba defined here as more than 700 mm during five months from May to September.

This tables shows that the drought years have a strong tendency to be observed in the year with ENSO event or a year after this event. The unusually heavy rain at Curitiba also follows a similar tendency. A 1983 drought was one of the five extreme drought (defined here as less than 290 mm in the eight wet month) at Quixeramobim since 1897.

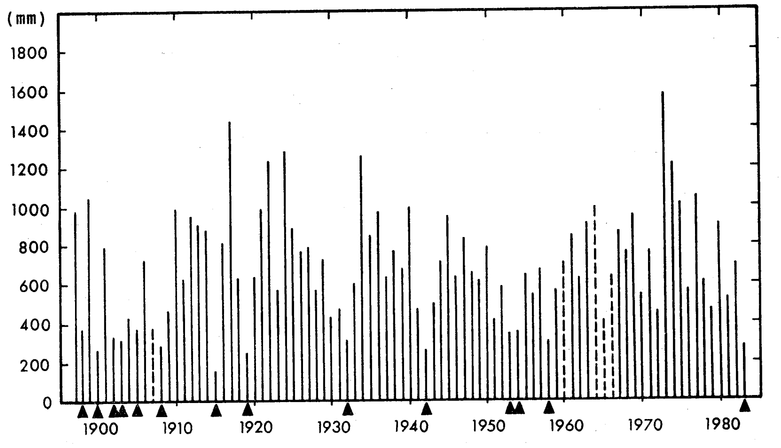

Figure 9. Precipitation at Quixeramobim for 8 months' total from December to July (shown by January year).

Table 2. ENSO event years and drought years at Quixeramobim and flood years at Curitiba from 1891 to 1983.

Large WCI El Niño	Dec.–Jul. Rainfall (<400 mm) in Quixeramobim	May–Sept. Rainfall (>700 mm) in Curitiba
1891	(1898)	1891
1899	1900 #	—
1902	{1902 1903	—
1904	1905 (1907, 1908)	1905
1914	1915 #	1915
1918	1919 #	—
1925	—	1926
1930	(1931) 1932	—
1940 1941	1942 #	—
1946	—	—
1951	*	—
1953	{1953 1954	—
1957	1958	1957
1965	*	—
1969	*	—
1972	*	—
1976	*	—
1982 1983	1983 #	1983

(# ; <290 mm, * <693 mm = normal)

V. Conclusion

The synoptic analyses of the atmospheric circulation during a large scale drought in Northern Nordeste and the large scale flood in Southern Brazil in 1983 were conducted. It was shown that the two extreme events in 1983 were associated with a strong South Atlantic subtropical high at the 850 mb level which caused increased subsidence and decreased rainfall in Northern Nordeste. The strong circulation around this anticyclone transported water vapor from the Atlantic Ocean toward the polar front zone in Southern Brazil. A 150 mb trough which normally produces dry period in Nordeste in December and January was observed in April 1983. The comparison of the horizontal divergence at the 150 mb level between the two April in 1974 and 1983 showed the contrasting pattern which favors subsidence at the 500 mb level and consequent drought in 1983 and upward motion and increased rainfall in 1974. A historical survey on the drought in Northern Nordeste showed that the drought years are often observed in the ENSO year or a year after ENSO event. The 1983 drought in Northern Nordeste was the first extreme drought since 1958 and was observed toward the end of the largest ENSO event (1982–1983) in the 20th century. Hence, our study shows that the influence of the ENSO event is an important factor leading toward development of the drought in Northern Nordeste.

It is suggested that the local Hadley Circulation over the Equatorial Pacific Ocean and adjacent South America intensifies during the ENSO event. The South Atlantic subtropical high also intensifies as a part of this circulation and consequent subsidence and drought over Northern Nordeste. The time lag between the ENSO event and the drought may be explained by delay in the response of the air-sea circulation over the Atlantic Ocean.

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1983年のブラジルにおける干ばつと大雨を伴った大気の循環

田中　実*・西沢利栄**

1983年に観測されたブラジル北東部（ノルデステ）の干ばつと南ブラジル（イグアス・パラナ川流域）の大雨をもたらした大気循環について解析を行った．

北部ノルデステ(10°N より北)地方の雨季は，3月から5月に集中しているので，1983年の4月の大気循環を中心に解析を行った．また，北部ノルデステ地方に雨の多かった1974年についても，4月の大気循環の比較解析を行った．さらに，1891年以降の北部ノルデステ地方の干ばつおよび南ブラジルの大雨とエルニーニョとサウザンオッシレーション (ENSO) との対応について調査した．

1983年の干ばつと大雨を伴った循環は，850 mb では南大西洋高気圧が平年より強くノルデステ地方へ張り出し，この高気圧を反時計廻りに回る北よりの風が，南ブラジル上空の前線帯で上昇し大雨を降らせた．また，観測時代における北部ノルデステ地方の干ばつは，ENSO の年か，その翌年に出現しやすいことがわかった．1983年の大干ばつも1982年から1983年にかけての大きな ENSO の後半に観測された．

* 〒100 東京都千代田区大手町　気象庁数値予報課
** 〒305 茨城県新治郡桜村　筑波大学地球科学系