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Analysis of the heavy precipitations during the summer 1997-1998 in southeastern South America and their relations with the summer 1982-1983

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RESUMEN

En este trabajo se estudia la situación sinóptica relacionada con las intensas lluvias del verano 1997-1998 bajo fuertes condiciones de El Niño.

La situación sinóptica media del verano 1997-1998, se caracterizó por una anomalía positiva en el Océano Pacífico en aproximadamente 55°S, 80°O en 500 y 1000 hPa, desplazada hacia el NE respecto a El Niño de 82-83. Este fenómeno de actividad bloqueante, junto con una franja de anomalías negativas entre los 30 y 40°S y 120 y 40°O en 500 hPa y la intensificación del flujo de masas de aire desde la Amazonia hasta el extremo norte de la Patagonia fueron las características comunes a ambos.

Luego se comparan las precipitaciones asociadas a los eventos El Niño del verano 1982-1983 y del verano 1997-1998, en el sur de Sudamérica.

En ambos casos, se registraron intensas precipitaciones que provocaron grandes avenidas en los ríos de la Cuenca del Río de la Plata. En el primer evento la máxima precipitación se observó en el Paraguay y Misiones (Argentina), mientras que en El Niño 97-98 se vio afectada una zona más amplia al sur de la anterior y hacia el centro de la Argentina.

ABSTRACT

In this paper the synoptic situation related to the intense rainfalls observed during summer 1997-1998 under strong El Niño conditions is studied.

The mean synoptic situation of the summer 1997-1998 was characterized by a positive anomaly in the Pacific Ocean at 500 and 1000 hPa, approximately located at 55°S,80°W, northeast of that corresponding to El Niño event of 1982-1983. This phenomenon of blocking activity, along with a band of negative anomalies between 30 and 40°S and 120 and 40°W in 500 hPa, and the intensification of the mass flux of air from the Amazonia to the northern limits of the Patagonia were the common characteristics of both cases.

Then a comparison is performed between the rainfalls associated to El Niño events corresponding to the summer 1982-1983 and 1997-1998, in the south of South America.

In both cases, intense rainfalls producing important flooding events within the Río de la Plata basin have been recorded. During the first event, the maximum precipitation was observed in Paraguay and Misiones (Argentina), while a much larger area located to the south of the latter extending towards the center of Argentina was affected during the second event.

1. Introduction

Several areas in Southern South America have been reported as presenting strong interannual precipitation variability associated with the El Niño event. The areas most frequently afected are southern Brasil, northeastern Argentina, Uruguay and Chile. Some authors have studied the relationships in this region between precipitation anomalies and sea surface temperature in the Pacific and Atlantic Oceans, the relationships between precipitation anomalies and the Southern Oscilation or with the composition of both (ENSO). More recently studies have been made by Diaz *et al.* (1998); González and Barros (1996); Grimm and Silva Dias (1996); Grimm *et al.* (2000); Ferraz and Gomes (1998); Pisciottano *et al.* (1994); Rutllant and Fuenzalida (1991); Rao *et al.* (1990).

The ENSO events are different from case to case, regarding intensity as well as duration and initiation (Trenberth, 1997), causing different impacts in the areas affected.

Taking into account the extraordinary climatic effects in northeastern Argentina of 1997 and 1998, Vargas *et al.* (1999) studied possible relations between anomalous sea-surface temperatures of the equatorial Pacific and the monthly precipitations in Argentina and concluded that effects of cold events are stronger that those of the warm ones.

Out of the seven El Niño events occurred from 1950 to the present, those of 1982-1983 and 1997-1998 presented extreme values for the multivariate ENSO index, according to the Climate Diagnostics Center of the Colorado University. Both events have a common maximum between the months of November(1982 and 1997) and April (1983 and 1998) approximately, with larger ENSO values for the first.

Beginning in October 1997 and until March 1998, intense and persistent rainfalls were registered producing flooding the rivers of the Río de la Plata basin, up to about 300% above the monthly mean, affecting the region socially and economically.

Renwick (1998) y Renwick and Rewel (1999) determined an association between El Niño events and blocking episodes in the southeastern Pacific Ocean, while others studied the relation of that blocking situations and precipitation in South America, see for instance Marques and Brahmanadarao (1999).

In a previous paper (Alessandro, 1999) the main characteristics of the mean synoptic situation associated to the rainfalls observed in Argentina, Uruguay, southeast of Brazil and Paraguay, during the event of 1982-1983 were described.

Though fluctuating from month to month in this case, the synoptic situation had some permanent characteristics consisting in a blocking situation in the Pacific Ocean about 110 W.

To the east of the Andes a frontal zone stronger and displaced to the north with respect to normal is observed together with an intensification of northerly winds from the Amazonian to the extreme north of the Patagonia.

These results are used for the comparison with the synoptic situations associated with the heavy rainfalls in northeastern Argentina during El Niño of 1997-1998.

2. Data and methodology

Daily 12 UTC analysis of the 500 and 1000 hPa geopotential heights of the period 1988-1998, were used. The National Weather Service provided them. The evolution and displacement of different synoptic systems were studied. The monthly mean fields were then obtained for both levels for the months from March 1997 to April 1998, corresponding to negative SOI values (Climate Diagnostics Bulletin), and those of their anomalies obtained as differences with the monthly mean of the heights for the decade 1988-1998. This last period could not be extended due to the lack of previous months analyzed with the same model. The months of November and December of 1997 and January, February and March 1998, were chosen in order to establish a comparison with the same months of the event of 1982-1983.

With these five last months, the mean fields of 500, 1000 hPa and that of 500/1000 hPa thickness were

obtained.

The daily precipitation values of Paraguay, Uruguay, south of Brazil and Argentina were used as well as the levels of the rivers of the River Plate basin. Then, the precipitation anomalies were determined, for the months of November 1997 to March 1998, as the difference between the monthly precipitation values and the mean precipitation of the period 1961-1990.

3. Flooding generated by the rivers within the river plate basin

The magnitude of the rainfalls is reflected by the levels of the rivers Paraguay, Paraná and Uruguay that exceeded their critical levels for months. See for example Camilloni and Castañeda (2000).

The mean monthly differences between hydrometric and critical levels(Δhmed), the dates corresponding to the maximum difference (Δhmax) of each analyzed month, as well as the period of days considered for the calculation of Δhmed (e. g. 1.33(2/4,6/21,23/30) meaning that 1.33 is the Δhmed calculated over the days 2 to 4, 6 to 21 and 23 to 30 of November), are given in Table 1 for some affected stations.

It can be seen that Iguazú (22°44′S, 54°28′W)presented the second largest anomaly of the selected points, but did not exceed the Δhmax of 82-83 (14 meters) neither its frequency as in 1982-1983 the critical height (hc) was exceeded during the five months considered.

In the new event, Rosario (26°12′S, 58°14′W) presented lower anomalies but an increased persistence compared to the preceding one.

The behavior of these two stations of the Paraná indicate that the maximum levels of the previous period were not reached, but the flooding was more persistent. Conversely, for the Uruguay river, Santo Tomé (28°32′S, 56°07′W), and Concordia (31°18′S, 58°01′W) presented the maximum Δh, were more affected compared to 0.90 and 1.85 of the preceding El Niño, respectively.

MONTH	STATION	Δhmed(m)(per.of days)	Δhmax(m)(date)
Nov.	Iguazú	1.33(2/4,6/21,23/30)	3.6 (17)
	Rosario	0.65(1/30)	0.93(29)
	Formosa	0.25(24/30)	0.38(30)
	Santo Tomé	1.6 (1/18)	2.86(10)
	Concordia	1.6(1/24)	2.24(1)
Dic.	Iguazú	------	------
	Rosario	1.06(1/31)	1.24(31)
	Formosa	0.74(1/25)	1.30(31)
	Sto. Tomé	------	------
	Concordia	------	------
Jan.	Iguazú	------	------
	Rosario	1.35(1/31)	1.42(18)
	Formosa	0.79(1/25)	1.40(5)
	Santo Tomé	------	------
	Concordia	1.5(7/13-29/31)	2.28(9 y 10)
Feb.	Iguazú	1.0(4/7-11)	2.10(4)
	Rosario	1.32(1/28)	1.40(5 y 6)
	Formosa	-----	------
	Santo Tomé	0.88(5/15)	1.10(14)
	Concordia	0.82(1-10/19)	0.98(13,14.15,16,18)
Mar.	Iguazú	2.02(2/9-18/31)	3.14(24)
	Rosario	1.33(1/31)	1.44(29)
	Formosa	0.41(2/31)	0.61(15)
	Santo Tomé	----	-----
	Concordia	1.7(4/4-8/11)	3.84(4)

Table 1. Mean differences between hydrometric and critical levels Δhmed (m) (periods of days of each month), the maximum differences attained Δhmax (m) (date) during the period November 1997-March 1998. (–) not exceeding critical levels.

Formosa (26°12′S, 58°14′W), located by the Paraguay river, exceeded the critical level (2 m) during the whole period 82-83, presented lower anomalies for the new event.

This analysis indicates that rainfalls most affected the Uruguay river basin, in a second term that corresponding to the Paraná river and third, the basin of the Paraguay river.

4. Development of 1997-1998 event

Below, a brief description is given, of the monthly synoptic characteristics in the period November 1997-March 1998, and the precipitation anomalies.

The height anomalies in 1000 and 500 hPa and those of the 500/1000 hPa thickness and the rainfalls anomalies for these five months are presented in Figures 1 to 5 respectively.

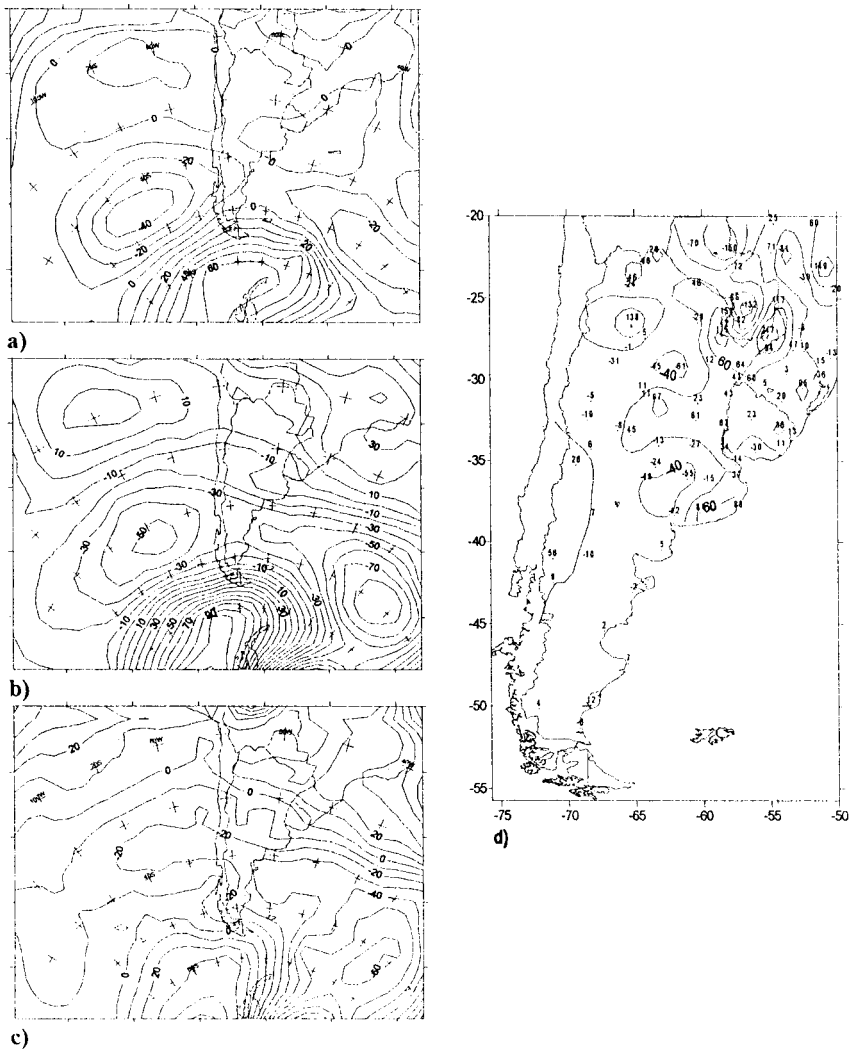

Fig. 1. Monthly anomalies corresponding to November 1997. Geopotential heights in 1000 hPa (a) and 500 hPa (b), 500-1000 hPa thickness (c), and precipitation (d).

a) November 1997

The fields (Figs. 1a, 1b and 1c), exhibit an important positive anomaly in the south of the continent at approximately 75°W, that since September was located in southeastern Pacific Ocean, denoting a long-wave ridge.

A zonally oriented band of negative values is observed between 40°and 50°S associated to a series of migratory depressions, and, positive values are observed in the subtropical region.

In particular, in 1000 hPa (Fig. 1a), a weak negative region is observed over the central and northern Argentina, with an slight increase of the northerly wind east of 65°W.

In the thickness field (Fig. 1c), there is over the continent an important decrease in the baroclinicity between 40°and 60°S and a strong increase of it between 25° and 40°S, generated by the frequent presence of fronts north of their normal position (35°S) for this season (Necco and Velasco, 1984), with some cyclogenesis cases over northeastern Argentina.

Associated to these conditions, positive values of the anomalies precipitation are observed within a region approximately bounded by the parallels 27° and 32°S, and the meridians 52° y 60°W (Fig. 1d), as well as in the center, northeast and south of Argentina and south of Paraguay. The maximum precipitation was 312 mm in Oberá (27°59′S, 55°08′W).

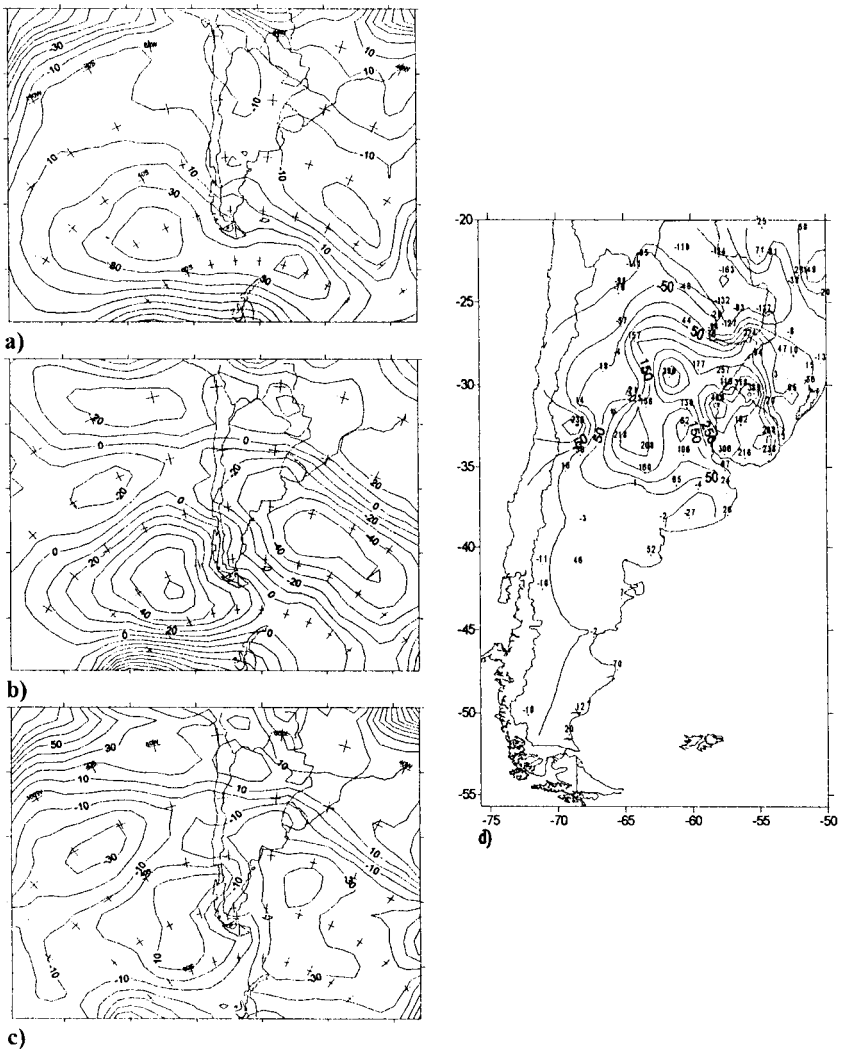

Fig. 2. Monthly anomalies corresponding to December 1997. Geopotential heights in 1000 hPa (a) and 500 hPa (b), 500-1000 hPa thickness (c), and precipitation (d).

b) December 1997

It is visible in the Figures 2a, 2b y 2c, that a strong positive anomaly in the south persists, it is located now at about 50°S and 90°W.

For this month, two wind maximum were detected (Fig. 2b), one at 65°S and the other at 25°S, a bifurcation typical of blocking situations. However, a blocking anticyclone was not observed in the above mentioned position, transited by a series of migratory anticyclones, therefore, the situation corresponds to a "blocking action".

A deepening of the Argentine Northwest Depression (DNOA) can be seen in Figure 2a, with stronger northerly winds, associated to this depression, transporting heat and humidity down to 38°S.

A displacement to the north of the subtropical baroclinic zone is visible in Figure 2c, with frontal systems similar to those of November. As shown in Figure 2d, practically the whole Argentine territory presents positive precipitation anomalies, with a maximum precipitation of 458 mm in Concordia. It is the month for which positive anomalies cover the largest area, including Brazilian stations located north of Uruguay and east of the Argentine Mesopotamia. Conversely in Paraguay they exhibit a deficit.

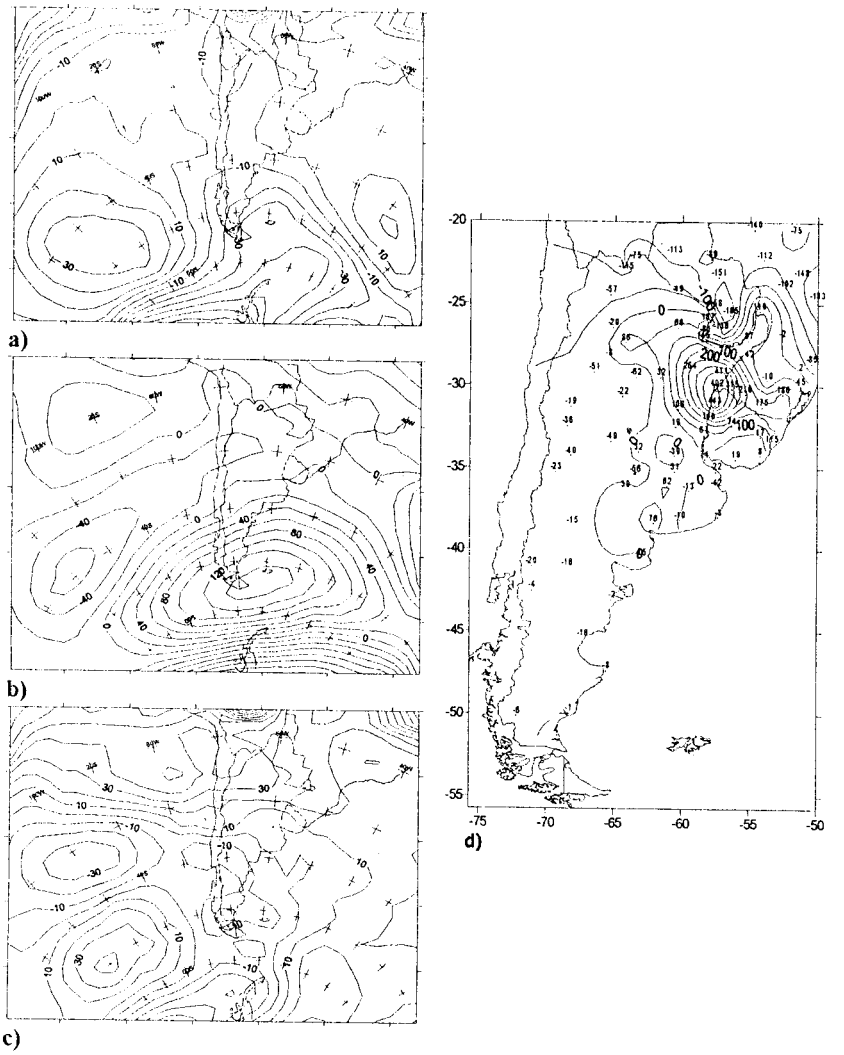

Fig. 3. Monthly anomalies corresponding to January 1998. Geopotential heights in 1000 hPa (a) and 500 hPa (b), 500-1000 hPa thickness (c), and precipitation (d).

c) January 1998.

It can be seen in the Figures 3a, 3b y 3c that the main positive anomaly is located in the Pacific at approximately 50°S and 110°W, displaced toward the west compared to the its position in November. At 500 hPa a negative center is visible at 32°S and 100°W.

The positive anomaly values over the east of the continent in the subtropical region are increased respect to those of the previous months due to an frequent passage of migratory highs and to the position of Atlantic Anticyclone, located closer to the continent.

In the Figure 3c, an intensification of the baroclinicity over the Pacific Ocean is observed, it is oriented WNW-ESE at approximately 30°S, crossing somehow weakened the Argentine territory in 32°S.

The humidity contribution from the northeast was important, associated to the mean position of the subtropical high of the Atlantic Ocean.

Precipitation excesses were concentrated in a smaller region (Entre Ríos province).

The positive anomaly center of precipitation (Fig. 3d) is concentrated east of the position of previous month. The zone in Argentina is concentrated in the ENE and in Santa Fe, south of Córdoba, La Pampa and Buenos Aires. Uruguay, with Salto as an exception, presents lower positive anomalies when compared to those of December, Paraguay and Brazil, conversely, present a similar behavior to that of previous month.

The maximum precipitation value reached 443 mm in Salto (31°23′S, 57°57′W) and 551 mm in Paso de los Libres (57°09′S, 29°41′W).

d) February 1998

The important positive anomaly persists in the south at 55°S, 80°W, as can be seen in Figures 4a, 4b and 4c.

This zone is affected by the frequent passage and permanence of high pressure centers, that along with the negative anomalies in the north of this region, continue the blocking action.

It is noted that, the depression of northwestern Argentina (DNOA) is weakened and displaced toward the east respect to January (Fig. 4b).

The highest baroclinicity zone remains in the subtropical region (Fig. 5c), again displaced toward the north (20°S), with frequent stationary frontal systems.

In February (Fig.4d), only Argentina presents precipitation excesses, the most affected area is located west of that of the previous month. Maximum precipitation values were of 344 and 315 mm in Formosa (26°12′S, 58°14′W) and Resistencia (27°27′S, 59°03′W), respectively.

e) March 1998

The Figures 5a, 5b and 5c show a substantial atmospheric circulation change respect to the four precede months. It can be seen that the blocking action in the south of the Pacific has vanished, and weak positive anomaly is observed in the Atlantic Ocean at approximately 55°S, 35°W.

The thickness still exhibits an increase of the baroclinicity, but weaker than previously between 20 and 30°S (Fig. 5c).

March (Fig. 5d) presented a precipitation distribution similar to that of January.

Maximum precipitation values were of 453 mm in Irai (29°10′S, 53°23′W) and 440 mm in Concordia.

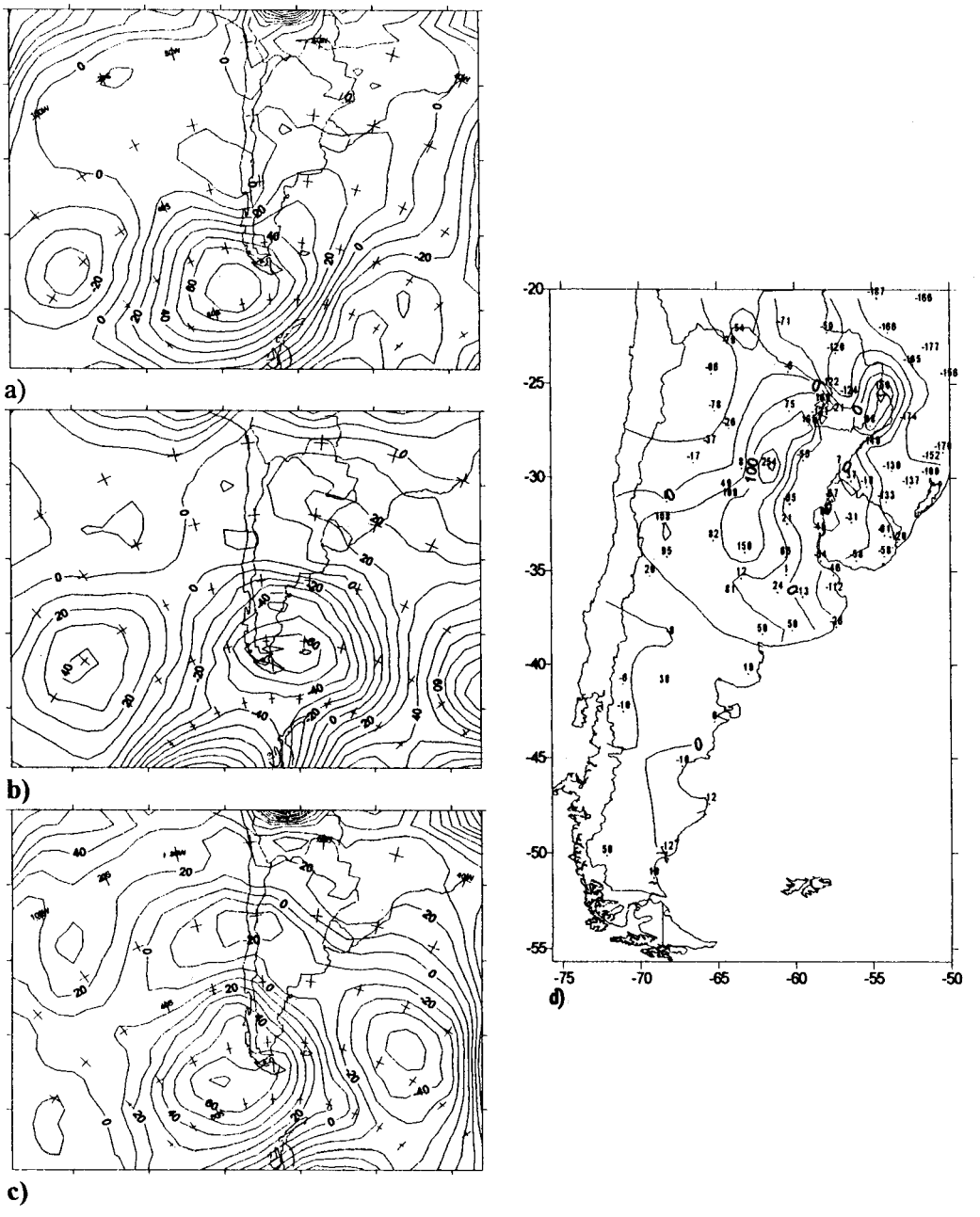

Fig. 4. Monthly anomalies corresponding to February 1997. Geopotential heights in 1000 hPa (a) and 500 hPa (b), 500-1000 hPa thickness (c), and precipitation (d).

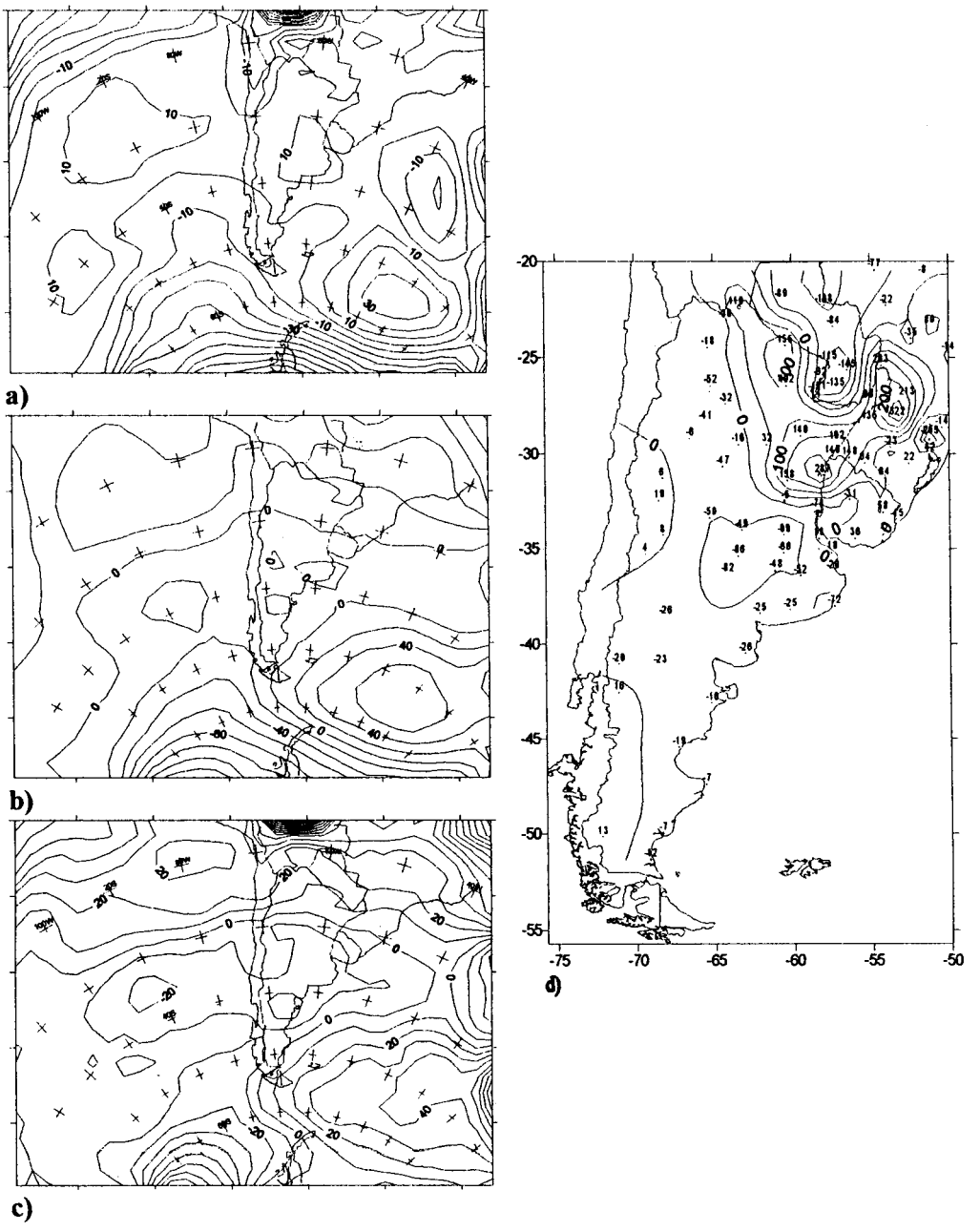

Fig. 5. Monthly anomalies corresponding to March 1998. Geopotential heights in 1000 hPa (a) and 500 hPa (b), 500-1000 hPa thickness (c), and precipitation (d).

5)Comparison of the events corresponding to the summer 1982-1983 and 1997-1998

a) Differences between persistent features of the atmospheric circulation

The mean anomaly fields of 1000, 500 and 1000/500 hPa (Figs. 6a, 6b and 6c) of the period 1997-1998, have been analyzed in order to detect common characteristics of the five considered months.

A positive anomaly southeast of the Pacific and south of the Chilean Argentine territory are visible in Figures 6a, 6b and 6c.

In the thickness field, a baroclinic zone is detected at about 20°S, and a band of negative anomalies extends zonally at 35°S at 500 hPa also.

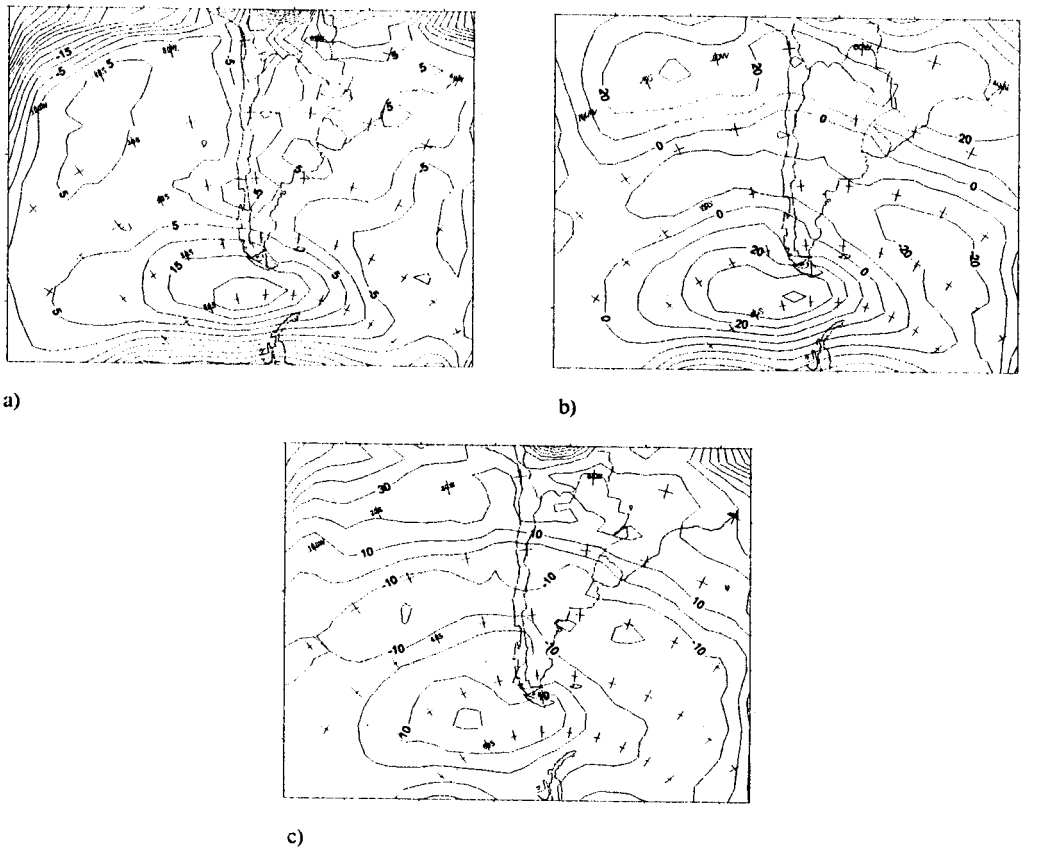

Fig. 6. Monthly anomalies for the period November 1997-March 1998. Geopotential heights in 1000 hPa (a) and 500 hPa (b), and 500-1000 hPa thickness (c).

The mean fields of anomalies of the period 1982-1983 (Alessandro, 1999) are reproduced in Figures 7a, 7b and 7c.

The presence of a positive anomaly in the southeast of the Pacific Ocean in another common feature of both periods, but for the first event it was located at about 70°S, 120°W, while for the new event it was located much closer to the continent (55°S, 80°W). This characteristic is consistent with the results of Renwick and Rewel (1999), Renwick (1998) above mentionaned and Grimm *et al.* (2000) who studied statistically the differences between El Niño y La Niña events of the higth anomalies of 200 and 850 hPa which are positive for the months here considered.

In 1000 hPa (Fig. 6a) greater differences can be observed. In the period 1982-1983, the Trade winds were weakened north of 30°S, a feature generally associated to El Niño conditions detailed by Philander (1990), condition that was not observed for the period 1997-1998, where the intensity of the Pacific anticyclone was enhanced (Minetti and Vargas, 1983; Minetti *et al.*, 1993).

In this level, similarly to 500 hPa, a positive anomaly is visible to the southwest of the continent, displaced toward the east when compared to its position during the previous event.

The position of this anomaly is reflected in the 500/1000 hPa thickness field (Fig. 6c), where a lack of baroclinicity associated to a blocking activity in the region can be noted, impeding in this way, the normal movement of the systems.

In this field, a baroclinic zone is observed at approximately 28 and 32°S for most of the months of 1997 and up to March 1998. This characteristic was not so visible for the previous case, for which the heating was lower north of this latitude (ΔT=1°C) and around 40°S the cooling was lower (ΔT =-2°C).

The presence of this positive anomaly in the south of Argentina, suggests that the anomalous circulation from the southeast to the northwest in the Atlantic caused an increased frequency of cold air masses that generated a cooling around 40°S.

The depression of northwestern Argentina Lichtenstein (1981) was less pronounced than in 1982-1983.

The displacement toward the south and the greater intensification of the baroclinicity around 30°S for the last event El Niño, generates a displacement of the maximum precipitation to the south (Velasco, 1994), and an increase of the anticyclonic circulation at 500 hPa over the south of Brazil and Paraguay is associated to the displacement of the rainfalls to the west.

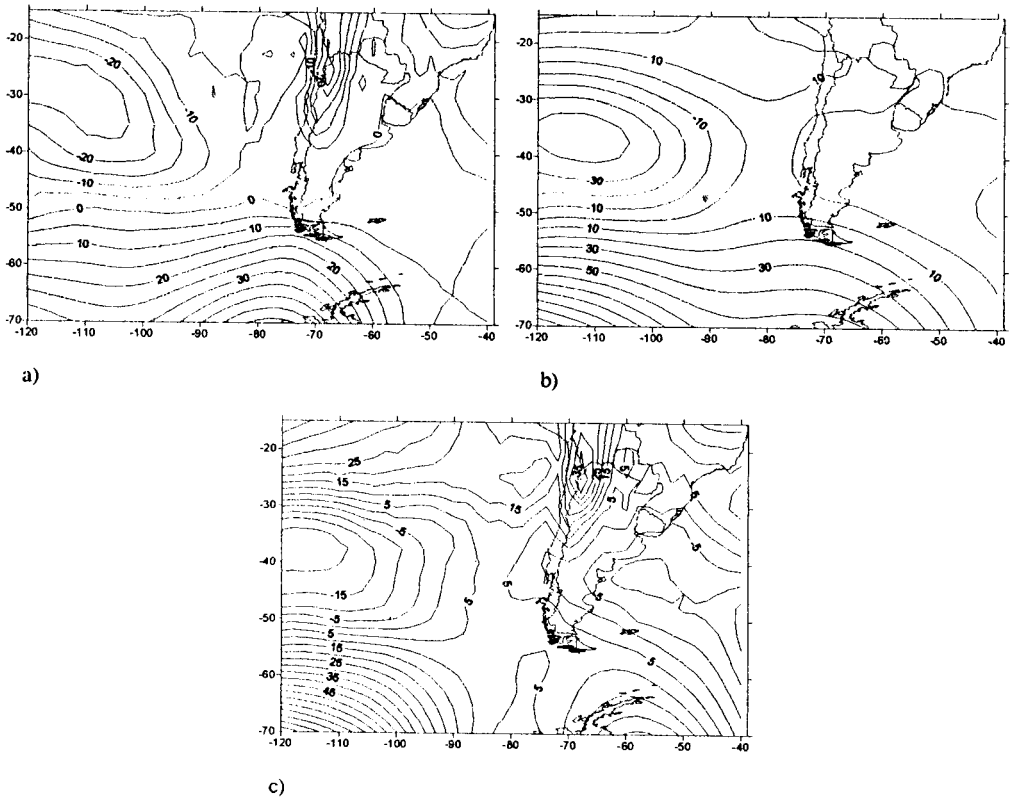

Fig. 7. Monthly anomalies for the period November 1982-March 1983. Geopotential heights in 1000 hPa (a) and 500 hPa (b), and 500-1000 hPa thickness (c).

b) Differences between the precipitation anomalies

From the comparison of the precipitation anomalies of the events occurred from November 1982 to March 1983 (Alessandro, 1999) and those of the same period in 1997-1998 it may be observed that: Both months of November present similar characteristics, although the maximum anomaly of +384 mm in El Niño 1982-1983 was not reached.

Uruguay and the Brazilian stations around 30°S presented excesses, and deficits for the previous case.

In December 1997, the whole Argentine territory is considerably affected, while for the previous case Paraguay was specially affected

Even when January 1998 and 1983 present more intense rainfalls in the northeast of Argentina and Uruguay, for the first the center of Argentina was not affected as it was in 1983.

In February 1998 the center of the Argentine territory was much more affected than in the previous period. The stations of Uruguay, Brazil and Paraguay were less influenced.

In March, for these last mentioned stations and for the northeast and center of Argentina the detected excesses were larger than those of 1983.

From the precipitation characteristics previously considered it can be noted that, with January 1983 as an exception (even when the value of 443mm was not reached), the intensity of rainfalls over the Argentine territory was greater during the period 1997-1998, covering a larger area of its center and its northeast.

Excepting February, Uruguay presented strong positive anomalies differing from the previous period, opposite results were obtained for Paraguay.

During the last event El Niño, only the considered stations in the southwest of Brazil (south of 20°S and west of 50°W) near Argentine and Uruguayan borderlines, were affected by the intense rainfalls, while during the old period, the precipitation excess was more general.

A large increase of the precipitation excess over the Argentine Mesopotamia can be observed during both events. Considering the months of November through March of the seven most intense events since 1950 above mentioned, 80% of the station in northeastern Argentina have positive precititation anomalies. The precipitation quantities differ from event to event and the meteorological station considered. In the two cases analized in this paper the rainfalls were heavier with respect to the others at Formosa (26°12′S, 58°14′W), Posadas (27°22′S, 55°59′W), Oberá (27°59′S, 55°08′W) and Iguazú (22°44′S, 54°28′W).

6. Conclusions

During El Niño events 1982-1983 and 1997-1998 the most prominent common synoptic situation consists of a strong positive anomaly in the southeastern Pacific Ocean near the southern extreme of the continent, associated to a blocking action.

In a second place, the presence of a negative anomaly at 500 hPa, approximately located between 30 and 40°S, over and out of the continent. Also there is a strong increase of baroclinity in the continental subtropical region.

Some interesting differences may be noted as follows. The blocking situation in the southern Pacific is displaced towards the east during the 1997-1998 event respect to the former one, causing a stronger southerly flow and lower temperatures over the Patagonia.

In 1997-1998 the subtropical baroclinic zone is situated to the south respect to the previous event, with a stronger northerly flow over the central and northern Argentina. On the other hand there is an increased anticyclonic circulation in 500 hPa over the south of Brazil and Paraguay associated to the displacement of the precipitation toward the west.

According to these considerations, during the 1997-1998 period, the zone of maximum rainfalls covered a larger area in the center and west of Argentina. Uruguay resulted more affected, as it presented values of deficit for most of the months of El Niño 1982-1983. Opposite results were obtained for Paraguay.

During the last El Niño, only the stations in the southwest of Brazil, near Argentine and Uruguayan borderlines, were affected by the intense rainfalls as mentioned above, while during the old period, the precipitation excess was more general.

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