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14. Abstract/Notes

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LARGE SCALE PRECIPITATION VARIATIONS OVER SOUTH AMERICA DURING THE 1982-83 ENSO EVENT

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Abstract

The effects of 1982-83 ENSO EVENT over South America are reanalized mainly with respect to large-scale precipitation anomalies. Long lasting and very intense floods have occurred in the southern parts of Brazil, northern Argentina, Paraguay, Uruguay, Southern Bolivia, mainly during the period May-July 1983. Also, severe droughts have striken Northeast Brazil, including the Amazon region which was very dry during 1983. Ecuador and northwestern Peru suffered strong flood conditions from the end of 1982 until mid-1983. Somes GCM simulations reproduced the general aspects of the atmospheric circulation observed during last strong warming over Eastern Pacific. Theoretical results suggest that the precipitation anomalies observed over South America could be explained as the atmospheric response to the anomalous heating over the Eastern Pacific associated with the El Niño.

1. INTRODUCTION

It has been noted that most of the El Niño phenomena observed until recently have shown atmospheric and oceanic circulation patterns slightly distinct between themselves. Although much effort has been done in documenting the characteristics and effects of this event there still remain two basic questions: how does it iniciate; and what are the sequence of events that lead to an El Niño. It is known, however that once the El Niño is totally established the anomalous positive sea surface temperature (SST) at equatorial central Pacific acts as a heat source for the atmosphere with subsequent rainfall anomalies over large areas of the tropics and subtropics (Keshavamurty, 1982).

In this paper the effects of 1982-83 El Niño event over South America are reanalized mainly with respect to large-scale precipitation anomalies with special reference to Brazil. It is intended to compare the large-scale regional aspects of the El Niño related precipitation anomaly pattern with the results of previous diagnostic and theoretical works.

2. PRECIPITATION DATA

A total of 268 stations were used with monthly precipitation data obtained from various sources. Some Peruvian, Ecuadorian, Bolivian and Paraguayan series were obtained by personal contacts and most of these are long term series from the begining of the century up to 1984. Data given in the Monthly Climatic Data for the World (U. S. Department of Commerce) with series longer than 30 years were also used.

In order to have a better density of stations over the area, some stations were added for which only the monthly precipitation deviations were available and published in the Monthly Climatic Data for the World, based on 30 years averages. For some Brazilian stations the same procedure has been adopted, but using the data available in the Boletim Agroclimatológico of INEMET.

All stations are shown in Fig. 1, while Table 1 gives the station locations and the period of available data.

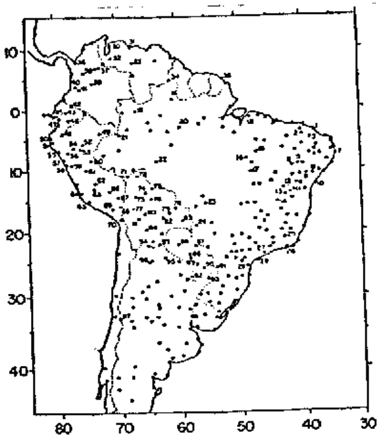

Fig.1. Locations of the pluviometric stations over South America. Full circles indicate station for which long series of precipitation data are available; empty circles indicate auxiliary stations for which only precipitation deviations were found (Monthly Climatic Data for the World or Boletim Agroclimatológico of INEMET).

TABLE 1

Locations of the pluviometric stations showing the record periods. Last column indicate the source of data where C means personal contact, M means Monthly Climatic Data for the World and A means Boletim Agroclimatológico of INEMET.

	BRAZIL						
1	Fortaleza	03	43S	38	30W	1849 - 1984	C
2	Santa Quitéria	04	29S	40	10W	1912 - 1984	C-A
3	Quixeramobim	05	12S	39	17W	1896 - 1983	M-C
4	Flores	07	50S	37	59W	1911 - 1983	C
5	Casa Nova	09	24S	41	08W	1911 - 1983	C
6	Remanso	09	41S	42	04W	1911 - 1983	C-A
7	Recife	08	03S	34	54W	1875 - 1983	M
8	Araci	11	20S	38	57W	1911 - 1983	C
9	Queimadas	10	58S	39	38W	1911 - 1983	C
10	Salvador	12	59S	38	31W	1911 - 1983	M
11	Rio das Contas	13	34S	41	49W	1911 - 1983	C
12	Caetite	14	04S	42	28W	1911 - 1983	C
13	Palmas de Monte Alto	14	16S	43	10W	1911 - 1983	C
14	Januária	15	29S	44	22W	1912 - 1984	C-A
15	Carolina	07	20S	47	28W	1913 - 1983	M
16	Conceição do Araguaia	08	15S	49	17W	1948 - 1983	M
17	Porto Nacional	10	42S	48	25W	1949 - 1983	M
18	Belém	01	27S	48	29W	1948 - 1983	M
19	Uaupes	00	08S	67	05W	1931 - 1983	M
20	Manaus	03	07S	60	01W	1910 - 1983	M
21	Benjamin Constant	04	22S	70	02W	1961 - 1983	M
22	Porto Velho	08	46S	63	54W	1961 - 1983	M
23	Cuiabá	15	36S	56	06W	1901 - 1983	M
24	Corumbá	19	01S	57	40W	1931 - 1983	M
25	Juiz de Fora	21	16S	43	21W	1910 - 1983	M
26	Rio de Janeiro	22	54S	43	10W	1851 - 1983	M
27	São Paulo	23	30S	46	37W	1887 - 1983	M
28	Iguape	24	43S	47	33W	1895 - 1983	M
29	Curitiba	25	26S	49	14W	1885 - 1984	M
	VENEZUELA						
30	Maracaibo	10	34N	71	44W	1951 - 1983	M
31	Maracay	10	15N	67	39W	1951 - 1983	M
32	Merida	08	36N	71	11W	1951 - 1984	M
33	San Fernando	07	54N	67	25W	1951 - 1984	M
34	Santa Helena	04	36N	61	07W	1951 - 1984	M
	FRENCH GUIANA						
35	Cayenne	04	50N	52	22W	1951 - 1984	M
	COLOMBIA						
36	Turbo	08	06N	76	43W	1970 - 1983	M
37	Bucaramanga	07	08N	73	11W	1969 - 1984	M
38	Medellin	06	13N	75	36W	1969 - 1984	M
39	Bogota	04	42N	74	08W	1866 - 1984	C M
40	Buenaventura	03	53N	77	04W	1969 - 1984	M
41	Cali	03	24N	76	24W	1969 - 1984	M
42	Ipiales	00	50N	77	40W	1971 - 1984	M
	ECUADOR						
43	Quito	00	09S	78	29W	1891 - 1984	C
44	Porto Viejo	01	02S	80	26W	1931 - 1983	C
45	Isabel Maria	01	48S	79	32W	1930 - 1983	C
46	Ambato	01	15S	78	37W	1904 - 1983	C
47	Guayaquil	02	09S	79	53W	1915 - 1983	C
48	Loja	04	02S	79	12W	1930 - 1983	C

(continue)

	PERU						
49	Iquitos	03	45S	73	15W	1947 - 1984	C
50	Talara	04	34S	81	15W	1961 - 1984	M
51	Piura	05	11S	80	36W	1961 - 1984	M
52	Yurimaguas	05	52S	76	07W	1950 - 1984	C
53	Tarapoto	06	31S	76	23W	1951 - 1984	C
54	Chachapoyas	06	14S	77	49W	1959 - 1984	C
55	Chiclayo	06	47S	79	50W	1961 - 1984	M
56	Cajamarca	07	08S	78	29W	1959 - 1984	C
57	Trujillo	08	06S	79	02W	1961 - 1984	M
58	Chimbote	09	10S	78	31W	1964 - 1984	M
59	Tingo Maria	09	08S	77	53W	1951 - 1984	M
60	Pucallpa	08	23S	74	32W	1950 - 1984	C
61	Huanuco	09	54S	75	25W	1962 - 1984	M
62	Huayo	12	02S	75	19W	1951 - 1983	C
63	Humanga	13	09S	74	13W	1964 - 1984	M
64	Pisco	13	45S	76	17W	1961 - 1984	M
65	San Juan	15	23S	75	10W	1961 - 1984	M
66	Cuzço	13	32S	71	58W	1945 - 1984	C
67	Juliaca	14	30S	70	09W	1962 - 1984	C
68	Puno	15	52S	70	00W	1964 - 1984	C
69	Arequipa	16	21S	71	34W	1943 - 1983	C
70	Tacna	18	04S	70	18W	1961 - 1984	M
	BOLIVIA						
71	Cobija	11	04S	68	44W	1943 - 1983	C
72	Riberalta	11	00S	66	05W	1943 - 1983	C
73	San Joaquim	13	03S.	64	49W	1943 - 1983	C
74	Santa Ana	13	43S	65	35W	1943 - 1983	C
75	Rurrenabaque	14	28S	67	35W	1946 - 1983	C
76	Trinidad	14	45S	64	48W	1943 - 1983	C
77	El Alto	16	30S	68	11W	1943 - 1983	C
78	San Ignacio de Velasco	10	22S	60	57W	1943 - 1983	C
79	Concepcion	16	15S	62	03W	1943 - 1983	C
80	Cochabamba	17	23S	66	10W	1943 - 1983	C
81	Oruro	17	58S	67	07W	1943 - 1983	C
82	Santa Cruz	17	47S	63	10W	1943 - 1983	C
83	Robore	18	19S	59	45W	1943 - 1983	C
84	Sucre	19	03S	65	10W	1946 - 1983	C
85	Yacuiba	22	01S	63	43W	1945 - 1983	C
	PARAGUAI						
86	Mariscal Estigarribia	22	02S	60	38W	1941 - 1984	C
87	Puerto Casado	22	02S	57	55W	1927 - 1984	C
88	Concepcion	23	27S	57	16W	1937 - 1984	C
89	Asuncion	25	21S	57	30W	1881 - 1984	C
90	Villarrica	25	45S	56	26W	1929 - 1984	C
91	Puerto Pres. Franco	25	32S	54	36W	1957 - 1984	C
92	Pilar	26	52S	58	23W	1939 - 1984	C
93	Encarnacion	27	20S	55	50W	1938 - 1984	C
	ARGENTINA						
94	La Quiaca Obs.	22	06S	65	36W	1903 - 1984	M
95	Rivadavia	24	10S	62	54W	1951 - 1984	M
96	Salto Aereo	24	51S	65	29W	1901 - 1984	M
	CHILE						
97	Santiago	33	26S	70	50W	1867 - 1984	M

3. SEASONAL ANALYSIS

Figures 2 to 6 show precipitation deviations from the mean normalized by the mean over South America for the three month periods from June-August 1982 up to June-August 1983.

By the middle of 1982 (June-August) global scale climatic fluctuations were developed and anomalous positive SST began to appear over the equatorial Eastern Pacific along the coasts of Peru and Ecuador (See Arkin et. al., 1983). However the precipitation anomalies over South America (Fig. 2) did not show yet the strong patterns which were observed six months later. At this time the anomalous warm waters were not intense enough and the weather of the South America was influenced by both Pacific and Atlantic low level highs which were quite strong and almost over the entire continent (See Arkin et. al., 1983). This fact could explain the presence of negative precipitation deviation areas over Ecuador and northwestern Peru, central South America (parts of Chile, Bolivia and Argentina), Northeast Brazil and a positive area in central South America (northern Argentina, Paraguay, Uruguay and southern Brazil). Further, the Amazon region looked somewhat dry in agreement with the divergent flow of low levels (See Arkin et. al.,1983).

Gradually dry and wet anomalies became stronger changing to the patterns found at mid-1983. Figs. 3 and 4 already show the areas of reported strong climatic anomalies characterized by devastating floods or droughts associated with the 1982-83 El Niño event. This was accompained by intensification of the anomalous positive SST at equatorial Eastern Pacific and changes in the atmospheric circulation.

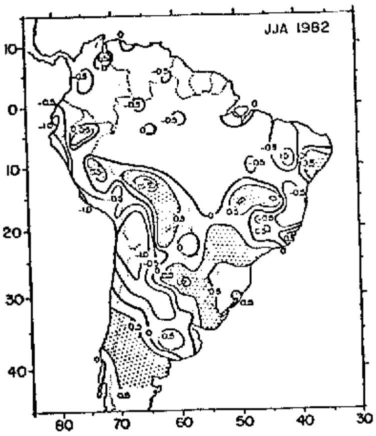

Fig.2. Seasonal precipitation departures normalized by the average for June-July-August 1982. Positive areas (values great than 0,5)are stippling.

The remarkable changes in precipitation during September-November 1982 (Fig. 3) and December-February 1982-83 (Fig. 4) over Ecuador and Peru can be seen by comparing with Fig. 2 where negative deviations were replaced by positive ones. The corresponding SST anomalies (SSTA) maps (See Arkin et. al., 1983) show the spreading of positive SSTA westward from the west coast of South America and approaching the date line. The 850 mb wind vector anomalies (See Arkin et. al., 1983) show local changes in the atmospheric circulation linked with the persistence of this warm water in the equatorial Eastern Pacific, so that the Pacific high moved southward and therefore could not influence the atmospheric circulation over Ecuador and northwestern Peru. Thus, since this area is adjacent to the strong anomalous warm waters and without the mechanism that can inhibit the ascending motion, convection began to develop there. Such convective development can be confirmed by the negative out going long wave radiation anomalies (See Arkin et. al., 1983) and the increasing of precipitation over Ecuador from September-November 1982 (Fig. 3), with larger values during December-February 1982-83 (Fig. 4).

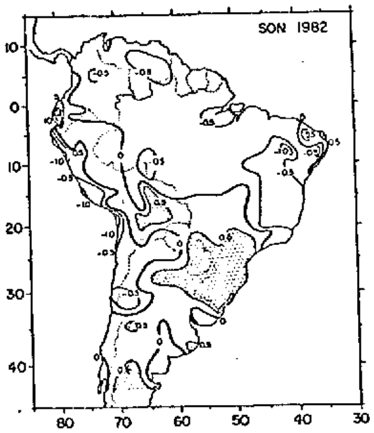

Fig.3. Same as Fig. 2, except for September-October November 1982.

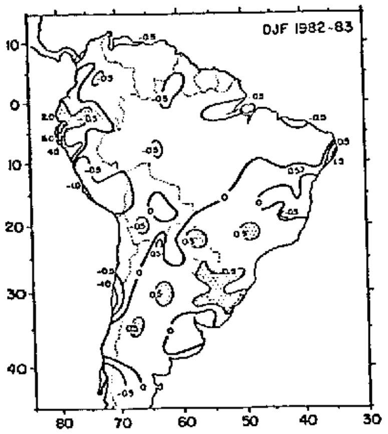

Fig. 4. Same as Fig. 2, except for December-January-February 1982-83.

The areas characterized by climatic disasters are well defined in the last two Figs. (5 and 6). These figures show two distinct flood areas, one over Ecuador and adjacent coastal lands of Peru and another one over southern parts of Brazil, northern Argentina, southern Bolivia, Uruguay and Paraguay. Very large positive precipitation deviations have been observed with values as high as +20.0 over Guayaquil (Ecuador).

It is interesting to note that the anomalous dry areas were situated over usual dry regions such as Northeast Brazil and the Atacama desert. (northern Chile and southwestern Peru).

The positive SSTA over equatorial Eastern Pacific were well developed during the period March to August 1983 (See Arkin et. al., 1983) while the 200 mb jet stream was also very strong. It was observed that during the 1982-83 El Niño the jet stream shifted eastward and northward from its normal position and was located over South America reaching velocities as high as 20 m s^{-1} above normal (ECLA, 1984).

The period from May to July 1983 was also characterized by the occurrence of blokings over South America. One of these blockings is shown in the GOES-5 satellite IR imagery on June 12, 1983 (Kousky and Cavalcanti, 1983).

Thus, floods on the central South America, droughts over Northeast Brazil and over the Atacama desert were related with both the occurrence of blocking and the associated 200 mb jet stream split which determined the atmospheric circulation characteristics over South America during March to August 1983.

The intense wet area over Ecuador and northwestern Peru is related mainly with the convective activity that occurred there and nearby regions.

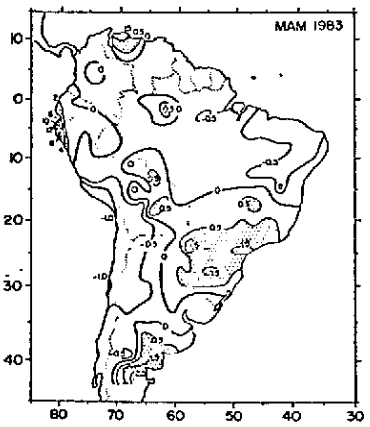

Fig. 5. Same as Fig.2, except for March-April-May 1983.

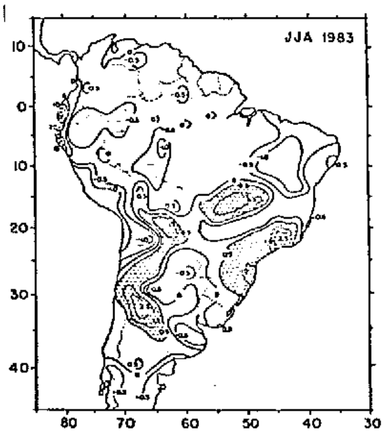

Fig. 6. Same as Fig.2, except for June-July-August 1983.

4. MONTHLY ANALYSIS

More detailed analysis can be seen in the individual monthly precipitation deviation maps (Not shown here). The anomalous precipitation features were basically similar to those observed at the corresponding three month maps. However, for May and July 1983 the anomalous values were more prominent, specially over the central South America where a very large and strong wet area was observed.

5. DISCUSSION

It is hoped that a comparison between observational results with findings from previous theoretical and diagnostic works might lead to some understanding of the physical mechanisms related with the El Niño phenomena.

Many GCM experiments have been conducted to investigate the atmospheric response to tropical SSTA over the Pacific (Rowntree, 1972; Julian and Chervin 1978; Keshavamurty, 1982; Shukla and Wallace, 1983; Fennessy et al. 1985). These works deal mainly with the El Niño phenomema and their associated atmospheric circulation. In addition, GCM experiments based on an equatorial Atlantic anomaly have also been done (Rowntree, 1976; Moura and Shukla, 1981).

Julian and Chervin (1978) using the NCAR, 6-level global primitive equation model simulated the atmospheric response to a positive SST anomaly at the Eastern Pacific near the coast of Peru and Ecuador. The greatest value of SST anomaly was 5°C. The distribution of 30 day average sea level pressure (anomaly minus control) shows positive values over both Northeast Brazil and Amazon and southward of this area there is a large negative anomalie.

Keshavamurty (1982) using the GFDL 9-level global spectral primitive equation model carried out an experiment with an idealized SSTA symmetric about the equator in which the greatest value was 3°C. The 90 day (June-July-August) average 830 mb wind anomaly shows an anticyclonic circulation over the Amazon region and Northeast Brazil and a strong cyclonic circulation centered approximately at (45°S; 100°W).

So, these simulation results are coherent with one another and also agree quite well with the precipitation deviation patterns observed (Fig. 6).

Fennessy et al. (1985) ran an experiment with the NASA/GLAS 9-level global, grid point, primitive equation model to simulate the mature phase of the 1982-83 event. One of their experiments consists of an insertion of observed initial condition on 16 December 1982 with the SST anomaly field on January 1983 obtained from Climatic Analysis Center. The 60 day average anomaly minus control precipitation differences (See Fig. 3b in Fennessy et al., 1985) show a good similarity with the observed precipitation deviations (Fig. 5).

Furthermore, Fennessy and Shukla (1985) using the same model (Fennessy et al., 1985) simulated the precipitation differences (anomaly minus control) for each month of the 1982-83 El Niño (May 1982 to October 1983). A month by month comparison of the simulation and observed precipitation deviation fields show that for most of the cases the agreement was very good. As an example the October 1982 case is shown in Figs. 7 and 8.

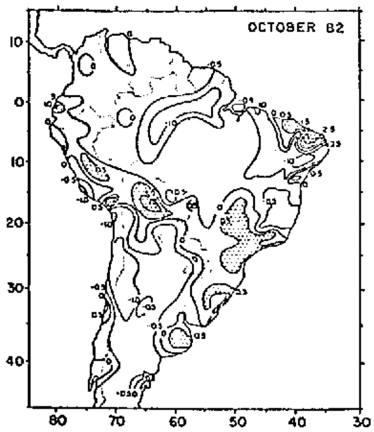

Fig.7. Monthly precipitation deviations for October 1982.

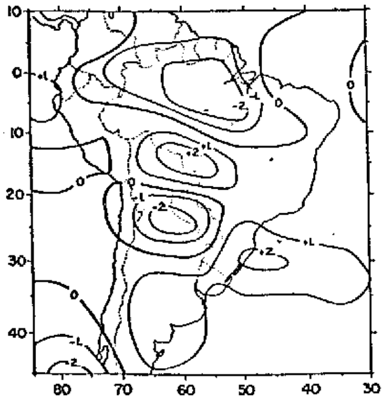

Fig. 8. Precipitation difference (anomaly minus control) in mm day^{-1} for October 1982, from an experiment using the NASA/GLAS GCM

[Cortesy of Fennessy and Shukla, 1985 (adapted)]

This comparison between simulated and observed fields suggests that the occurrence of a strong El Niño phenomenon does affect the precipitation over South America mostly the way it is observed.

Thus, regarding the use of GCM's for a dynamical prediction of monhtly or seasonal means (rainfall) it is clear that the general aspects of the atmospheric circulation are well reproduced and that modelling results present a hope for prediction.

Finally, the observational results are discussed in the light of some previous theoretical results.

Gill (1980) constructed a simple analytical model to investigate some features of the tropical atmosphere response to a diabatic heating. The symmetric heating about the equator induces an ascending motion over the heating area and subsidence elsewhere. The heat source also generates two low level cyclones northwest and southwest of the forcing region. Hoskins and Karoly (1981) used a linearized steady-state five layer baroclinic model to study the response of a spherical atmosphere to thermal and orographic forcing. They found that on the upper troposphere the low latitude heat source generates wavetrains with long wavelengths propagating polewards and eastwards. They also found upward motion over the forcing area.

So, floods over Peru and Ecuador and drought over Amazon region and Northeast Brazil seem to be associated with a Walker type circulation with upward motion at the heating area and descending motion east of this forcing region (Kousky et al., 1984). Further, the anomalous wet region in Peru and Ecuador, the dry region on the Atacama desert and wet region in central South America are orientated in a southeast direction. Thus, these precipitation anomalies could be linked with the upper tropospheric wavetrains which are generated by the low latitude heat source in a way similar to the theoretical results of Hoskins and Karoly (1981), applied to southern hemisphere. In this case the wet and dry regions could be associated with upper level patterns on which there are alternating highs and lows in a southeast orientation.

During May-July 1983 the intense floods reported over southern Brazil, southern Bolivia, northern Argentina; Uruguay and Paraguay were caused by some frontal systems and cloud clusters which remained quasi-stationary due to an atmospheric blocking (Nobre and Rennó, 1985; Kousky and Cavalcanti, 1983). These authors suggest that the occurrence of blocking can be related with the strong jet stream located in that region. However, it is possible that the blocking can also be related with the upper level disturbances as those described by Hoskins and Karoly (1981) which are generated by the strong SSTA over Eastern Pacific.

6. CONCLUSIONS

During the 1982-83 El Niño event remarkable precipitation anomalies have been reported all over South America. Ecuador and northwestern Peru were affected by severe floods; over the Amazon region, Northeast Brazil, northern Chile and southwestern Peru negative precipitation deviations were observed, while over southern Brazil, northern Argentina, southern Bolivia, Uruguay and Paraguay positive precipitation deviation were noted.

The general aspects of the atmospheric circulation associated with the strong warming observed over Eastern Pacific during 1982-83 have been well reproduced by GCM simulations (Julian and Chervin, 1978; Keshavamurty, 1982: Fennessy et al., 1985). GCM simulations of monthly or seasonal means show considerable agreement with observations.

Further, some previous theoretical results suggest that the precipitation anomalies observed over South America during 1982-83 could be explained as the atmospheric response to an Eastern Pacific heat source. A Walker type circulation could explain the floods observed over Peru and Ecuador and also the negative precipitation deviations verified over the Amazon and Northeast Brazil.

The anomalous wet area in Ecuador and Peru, the stronger droughts in the Atacama desert and the very wet areas over southern Brazil and adjacent regions show a southeast orientation suggesting a possible existence of an upper tropospheric wavetrain generated by the low latitude heat source (Hoskins and Karoly, 1981).

The occurrence of blockings during May-July 1983, which were related with floods in southern Brazil and adjacents areas, the strong jet stream which organized the convective activity (Kousky and Cavalcanti, 1983) and the upper level disturbances generated by heating over the Eastern Pacific which propagated southeastward probably are several closely connected parts caused by physical mechanisms that form a complex chain of events related with atmospheric - oceanic circulations during a El Niño episode.

7. ACKNOWLEDGEMENTS

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