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WARM AND DRY SPELLS (WDS) IN AUSTRAL WINTER IN TROPICAL AND SUBTROPICAL SOUTH AMERICA

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1. INTRODUCTION

Vegetation fires in South America are among the worst ecological disasters of the world. The area of tropical forest and savannah burnt per year in the Amazon basin alone is ~150,000 km^2/year (Setzer 2005) and is larger than many smaller countries in the world. In a dry year the area burnt is ~50% higher and in a wet year the area is ~20% lower. Most of the vegetation fires are a result of wanton and criminal acts of a few greedy people. The area of the forest cleared by fires is growing year by year in South America (http://www.gvm.jrc.it/fire/gba200/index.html). This shows that the legislation in many countries is slack and the judiciary very soft on such issues.

Besides those anthropological and sociological reasons, the vegetation fires have a dependence on climatological and meteorological factors. A greedy landlord would set fire on the vegetation over the land around his property for expansion of pastureland. He does so when the atmospheric conditions are most suitable, especially after a dry and warm spell and when there is no rain forecast in the immediate future.

Biomass burning is the major source of greenhouse gases and tropospheric aerosols (Crutzen et al. 1979, Tarasoa et al., 1999, 2000). The dry biomass equivalent of a tropical rainforest is ~300 kg/m^2 and when burnt releases copious amounts of particulate matter and green house gases. According to the recent calculations by Cleber Salimon of the University of Sao Paulo in Brazil, the northwestern state of Acre in Brazil alone emits up to 240 X 10^6 tons of carbon per year into the atmosphere (Geraque 2005). Only 8 to 16% of this carbon is reabsorbed by the forest. These calculations show the devastation caused by vegetation fires to the forest and to the global environment.

In the central parts of Brazil and South America the winter and early spring months (June through September) present prolonged periods of warm and dry spells (WDS) called *veranicos* (literally ‘little summers’) locally. The veranicos can persist for one to several weeks. The atmospheric humidity in winter season in this region is low (~30%) and when the temperature raises a few degrees C above the monthly normal the relative humidity drops, sometimes to below 20%. During these periods the vegetation becomes dry and combustion becomes efficient. Such periods are chosen by the farmers for setting the vegetation on fire.

The frontal systems approaching from the south bring convection and rain to the central parts of Brazil in winter. During the veranicos the approach of frontal systems and the associated convective activity are inhibited and as a consequence the temperature raises and the humidity falls. Although the local meteorologists know the phenomenon, there have been no systematic studies of the veranicos in South America in the scientific literature. The objectives of this study are to understand the synoptic scale and regional scale flow characteristics associated with veranicos in the central parts of Brazil in winter half of the year and to check if there is an

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association between the veranicos and the vegetation fires in Brazil and in South America.

2. VERANICO (OR LITTLE SUMMER) IN THE CENTRAL PARTS OF BRAZIL

A target area bounded by 15°S, 25°S; 45°W, 60°W over the central parts of Brazil is considered for the identification of veranico episodes in the tropical and subtropical Brazil. The NCEP/NCAR analysis grid point data with 2.5° longitude by 2.5° latitude resolution is used for the study. The target area has 35 grid points in the horizontal. The average daily mean surface temperature (the 1000 hPa temperature) over the 35 grid points is designated T. The corresponding climatological value is designated T_c. If $T' \equiv T - T_c$, the mean surface temperature anomaly over the target area, is greater than 1.5°C for a period of 7 consecutive days or longer and is greater than 2.0°C during at least 4 consecutive days in this period of seven days or more, the episode is considered a veranico.

The temperature anomaly during a veranico in the period 31 May through 12 June 2002 is shown in Figure 1. This veranico had a duration of 13 days and the mean temperature anomaly was higher than 3.0°C on five consecutive days. This means that the temperature anomaly at some grid points in the target area could be higher than 3.0°C on some of those days. It can be seen that the mean temperature anomalies rose gradually from 30 May to 4 June, they remained high from 05 June through 10 June and had a rather sharp fall from 11 June to 13 June. This suggests that the veranico's life cycle has three phases: formation, maintenance and dissipation.

Table 1 shows all the veranicos in the period 1985 through 2003 detected from the surface temperature data for the months of May through September. The Table also shows the humidity and rainfall characteristics associated with the veranicos. The average duration of a veranico is about 10 days and the average temperature is 3.1°C. It is interesting to note that the relative humidity anomaly in the target area has been negative during all the episodes. The average negative anomaly of the relative humidity is 14%. In some episodes the negative anomaly was as high as 20% as in 1997 and 1999 cases. There were some veranico spells longer than two weeks, one in 1987, one in 1997, two in 1998 and one in 2002.

A nondimensional index for measuring the severity of the veranico (or WDS), taking into account both the temperature and humidity anomalies, T′ and U′ respectively, is defined here as

$$IS = (1/T_c)\sum T' - (1/U_c)\sum U' \qquad (1)$$

Where T_c and W_c are mean climatological values of temperature and humidity, respectively, over the target area. The summation is over the number of days of the veranico episode in question. The index is actually the sum of the normalized positive anomalies of the temperature in °C and normalized negative anomalies of the humidity in percentage points and is nondimensional. The normalization is with respect to the climatological value corresponding to the month of occurrence of the veranico. The last column in Table 1 shows the IS index values. As can be seen from the definition of the index, the longer the anomalies persist the higher is the index. The 1987, 1995, 1998, 1999 cases and the two cases in 2002 were the severest according to the index value (exceeding 5,0).

The monthly variation and the interannual variation of the veranico frequency over the period 1985-2003 are shown in Figure 2. The frequency of occurrence of veranicos is highest in the four-month period June through September (JJAS). Two veranicos per year is the average frequency. However, there is a large interannual variability of the frequency as can be seen from Figure 2. The year 1995 (La Niña) presented 5 episodes and the years 1989, 1990 and 1996 (neutral) did not present even a single episode. There is apparently no relation between the phase of the ENSO and the occurrence of veranicos. That is, the veranicos are not a result of the teleconnections, but are perhaps a result of the juxtaposition of regional and synoptic scale perturbations.

3. VERANICOS AND BLOCKINGS IN THE SOUTHEASTERN SOUTH PACIFIC

The veranicos have time scales of more than a week and less than a month, and it is natural to associate them with other phenomena having a similar time scale such as blocking episodes. Therefore, the 500 hPa geopotential data from the NCEP/NCAR analysis datasets are used to detect if there was a blocking situation in the southeastern South Pacific during the veranico and pre-veranico periods. For this purpose the definition of Kousky and Casarin (1982) for the blocking situations is used. According to the authors the criterion for blocking is the persistence for more than four days of the following flow conditions: (i) westerly current bifurcation around a positive geopotential anomaly of 200 gpm in the middle latitudes with a horizontal extension of more than 30° latitude, and (ii) the movement of the high pressure center less than 25° latitude in the whole blocking period. In the present study these flow conditions are verified in the latitude belt 30°S-50°S and in the longitude domain 80°W-180°W.

Table 2 shows the blocking episodes, their positions and durations. The table also shows the corresponding veranico cases shown in Table 1. Twenty-two out of thirty-five cases of veranico were associated with blocking and all the six severe veranicos (IS $\geq$ 5.0) were associated with blocking in the southeastern South Pacific and five of which happened when the blocking situation occurred in the longitude range of 110°W and 120°W. Most of the veranico episodes started a few days after the beginning of the blocking episode, especially so for the severe veranicos. Based on these observations one might conclude that there is a reasonably strong association between the blockings and the veranicos.

4. STRUCTURE AND SYNOPTIC EVOLUTION OF JUNE 2002 VERANICO

The synoptic structure and evolution of a veranico is minimally discussed in this section. Figure 3 shows the mean temperature and humidity anomalies for the period 31 May through 12 June 2002 over Brazil and adjoining countries. The positive temperature anomaly and the negative humidity anomaly cells occupied large areas centered over 22°S, 50°W. On the average the temperature was 4°C higher and the relative humidity was 15% lower than the June climatology over the central parts of South America. During the same period the Patagonia registered negative anomalies of temperature. The temperature distribution suggests a thermal wind anomaly from northwest to southeast over Paraguay and northern Argentina around 55°W which is in agreement with the 850 hPa wind anomaly (not shown).

The evolution of the temperature anomaly is presented in Figure 4 through the 300°K potential temperature isotherm position at the 925 hPa level. In panel (a) a rapid southward movement of the isotherm in the period 01 June to 05 June over Brazil is observed. During the next five days the isotherm remained in the state of Santa Catarina and in the third pentad from 11 June to 16 June the isotherm moved northward slowly to north of 21°S. This figure also suggests that the life cycle of the veranico consists of three stages mentioned in Section 2.

The 500 hPa geopotential and its anomalies (with respect the June climatology) for 02, 04, 07, 10, 13, and 15 June at 00GMT are shown in Figure 5. The high-pressure center anomaly in the Pacific moves very slowly from around 110°W to 75°W in two weeks. The pressure anomaly configuration in the pacific from 02 through 10 June was clearly characteristic of a blocking situation.

Figure 6 shows the 200 hPa streamlines and isotachs for the same days mentioned in the last paragraph. What is interesting is the presence of an anticyclonic circulation over Bolivia and a cyclonic vortex over the Northeast Brazil during the formative and maintenance stages of the veranico. This type of configuration is typical of austral summer. However, the anomalous warming in the subtropics of South America in the lower troposphere during this episode was responsible for the formation of an anomalous high over northern Amazon region and a low downstream. The veranico was associated with a summer like configuration in mid winter.

The jet-stream south of the anticyclone intensified from 02 to 07 June by the action of the anticyclonic circulation to the north, and lost its strength in the later half of the life cycle of the veranico.

5. ANNUAL VARIATION OF VEGETATION FIRES IN SOUTH AMERICA

The NOAA satellites detect hot spots. A hot spot is a pixel of the satellite imagery with average temperature in excess of 60°C. After discussions with satellite meteorology experts at the Center for Weather Prediction and Climate Studies (CPTEC) a reasonable idea about the hot spot detection is obtained. Usually, a vegetation fire front of 500 m extension with a ~1 m width and flames rising to 2 m high in a pixel of 4kmx4km (the resolution of the NOAA satellite infrared imagery) qualifies for a hot spot. The hot pixels (or hot spots) are counted, without any knowledge of the quantity of vegetation burnt per unit time. The smoke cloud that rises over the fire front is hot enough to be detected by the satellite. However, normal cloud cover does not permit the detection of a hot spot underneath. Therefore, the number of hot spots detected over a given region may be an underestimate of the actual situation.

The annual variation of the hot spots over South America obtained from the average of five years from 1999 - 2004 is presented in Figure 7. The month of maximum frequency (~60,000/month) is September, the last month of the dry season in the central parts of Brazil and South America. The month of minimum frequency (4600/month) is April, which coincides with the end of the rainy season. The preferred season for vegetation fires is really the winter season when the rains are scarce and the humidity is low to render the vegetation highly inflammable. It is interesting to observe a sudden fall in the frequency in November when the fires are inhibited by the pre-summer rains.

The interannual variation of the vegetation fire frequency is very high. This is due to changes in the legislation and inspection of fires in the South American countries.

6. VERANICOS AND VEGETATION FIRES IN SOUTH AMERICA

Figure 8 shows the pentad averages of hot spots in South America for six veranicos. Wherever possible the averages for one or two pentads before the veranico and one or two pentads after the veranico and during the veranico are plotted. In one case the weekly averages are plotted, because this veranico lasted for just 7 days. It is very clear from the figure that the frequency is significantly higher during the veranicos in comparison to the pentads before and after veranico. The veranico pentad averages are approximately twice as large as the average before veranico. Due to data problems the hot spot analysis is made for only those six cases. For other veranico cases the hot spot data was either not available or had many gaps. From the graphs it is evident that the veranicos have a significant influence on the hot spots or vegetation fires.

7. DISCUSSION AND CONCLUSIONS

The sequence of daily frequency of hot spots over the South American subtropics and tropics shows sudden jumps from small values to large values and vice versa (http://www.cptec.inpe.br/products/queimadas/queimavtemnoaa.html). These are mainly due to the deadlines for the imposition of government regulations. That is, just before the starting date of a certain prohibition on vegetation fires or immediately after the ending date of the prohibition period the farmer hurries up to set fire on his land (Setzer 2005).

As a consequence of the vegetation fires smoke concentration increases causing discomfort and respiratory problems to the population. On many occasions the airports in the southern Amazon region are closed for flights due to smoky or smoggy conditions provoked by vegetation fires, oftentimes uncontrolled.

Reliable forecasts of the veranico situations are necessary to enable the environment protection agencies to take preventive action and preparation for mitigating the effects.

Although the target area (15°-25°S; 45°-60°W) is smaller than the whole South American subtropical and tropical regions, the temperature and humidity anomalies averaged over the target area are regarded as good indicators of the widespread and prolonged dry conditions in the central parts of South America and especially the central parts of Brazil.

In this study, for the first time, a possible association between the blocking situations and veranicos in central South America is noticed. All the severest veranicos were associated with the blocking episodes in the eastern South Pacific. However, it is not verified if every blocking episode in that part of the globe provoked a veranico in South America. This will be investigated in a future study. The reason for the large interannual variability of the veranicos remains unclear and will be explored in future studies. Any relationship with blocking situations in the South Atlantic and the veranicos in central South America is also worth exploring.

The veranicos may have some relation with the migration of the South Atlantic subtropical high pressure center to the west and to the lower tropospheric cross equatorial winds into the Southern Hemisphere in the American sector, as most of the humidity for the Amazon and subtropical South American regions is provided by such winds.

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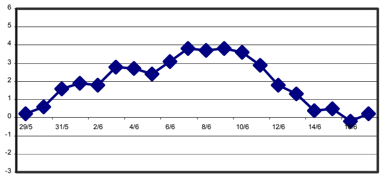


Figure 1. Aerial mean temperature anomaly variation during and around the veranico episode from 31 May through 12 June 2002 over central Brazil.

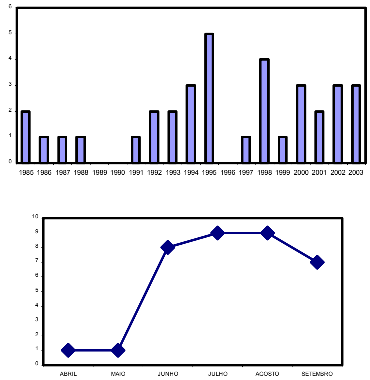


Figure 2. Interannual (a) and monthly (b) variations of veranico episode frequency.

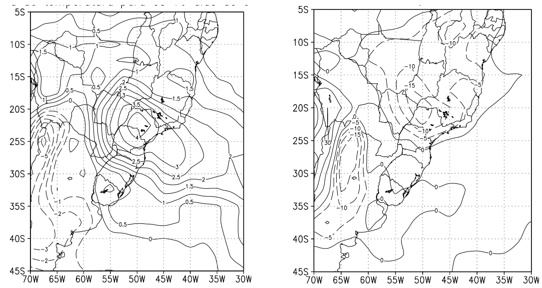


Figure 3. Temperature anomaly (left panel, °C) and the humidity anomaly (right panel, %) over South America and the adjoining Atlantic, averaged over the 13 days of the veranico episode from 31 May through 12 June 2002.

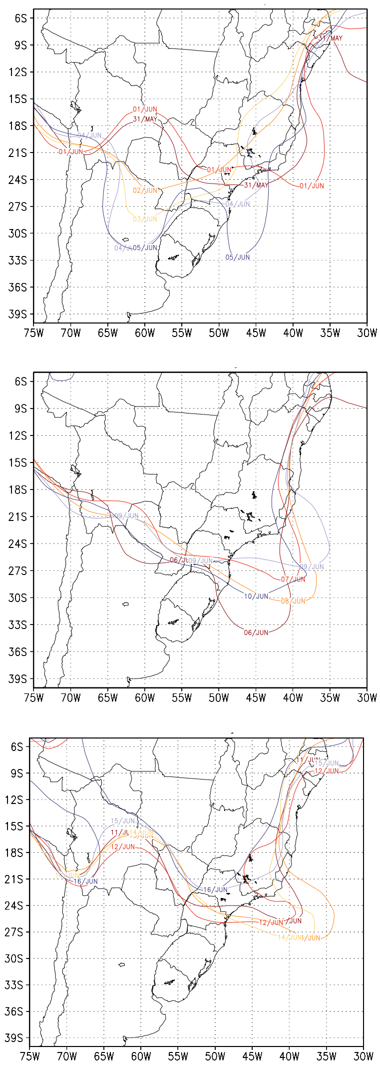


Figure 4. The 300°K potential temperature isotherm on the 925 hPa isobaric surface at 12 UTC over South America. Top panel: 31 May through 05 June. Middle panel: 06 through 10 June. Lower panel: 11 through 16 June. The dates are marked on the isotherms.

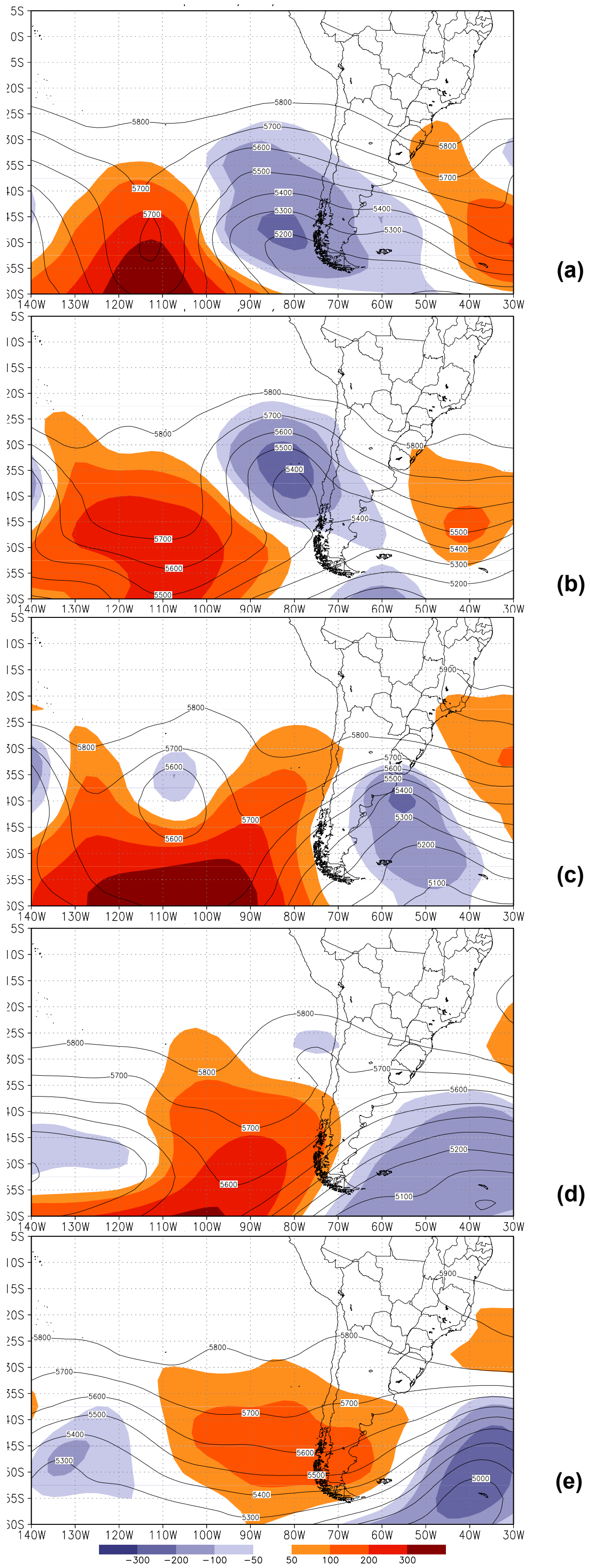
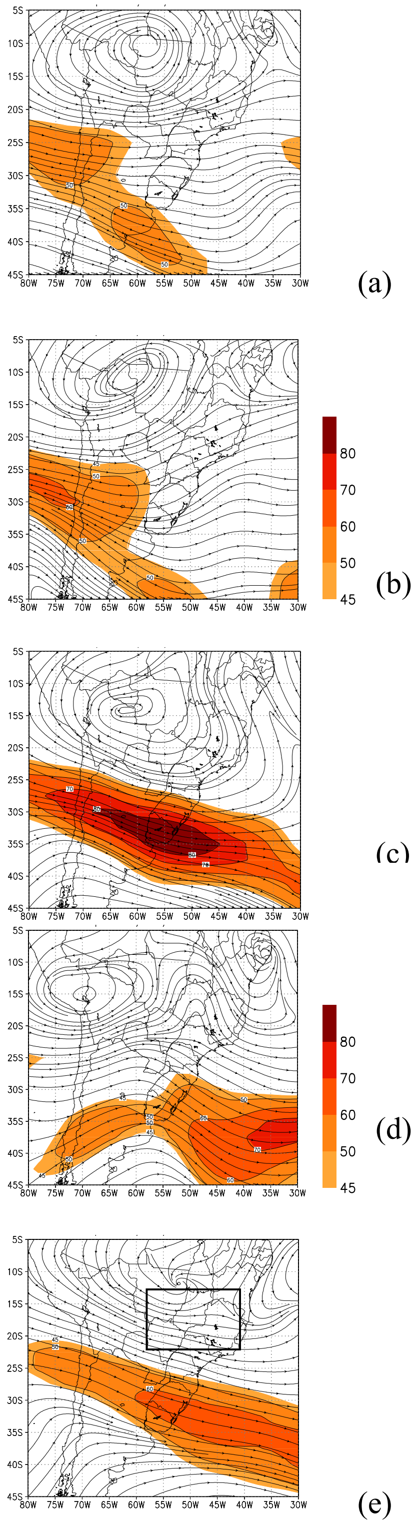


Figure 5. 500 hPa geopotential (gpm) and geopotential anomalies at 12 UTC over the eastern South Pacific and South American regions for some select days during the veranico episode shown in Figure 1. (a) 02, (b) 4, (c) 7, (d) 10, (e) 13, and (f) 15. Red shades indicate anomalous high. Blue shades indicate anomalous low. The anomaly values (m) are shown in the color code bar.



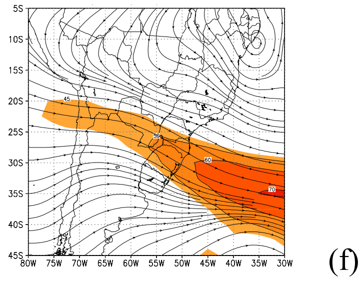
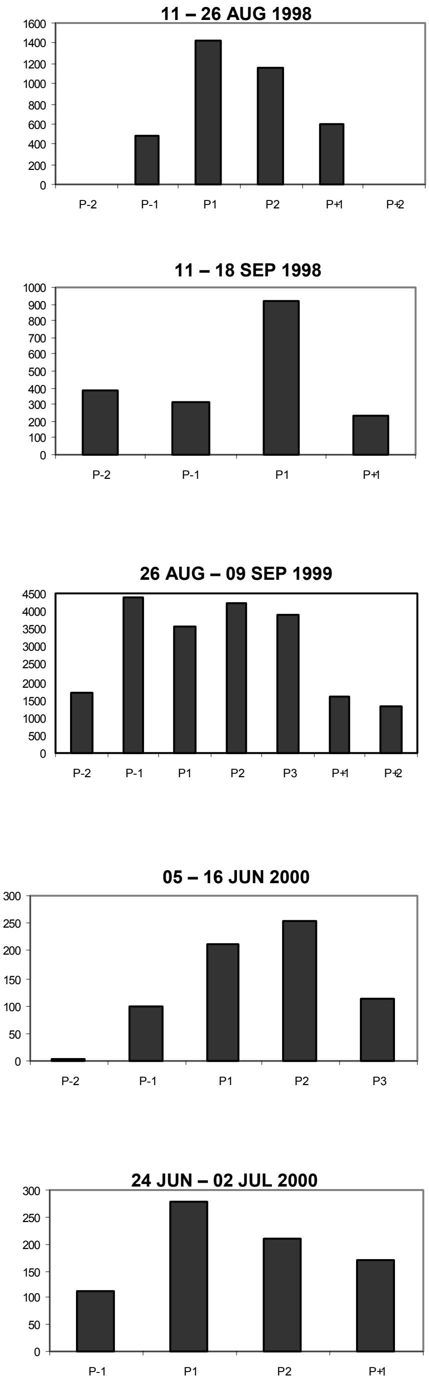


Figure 6. 200 hPa Stream lines and isotachs (colored areas) for some select days during the veranico episode shown in Figure 1. (a) 02, (b) 4, (c) 7, (d) 10, (e) 13, and (f) 15. Red shades indicate the jet stream postion. Wind magnitude (m s^{-1}) is shown in the color bar.



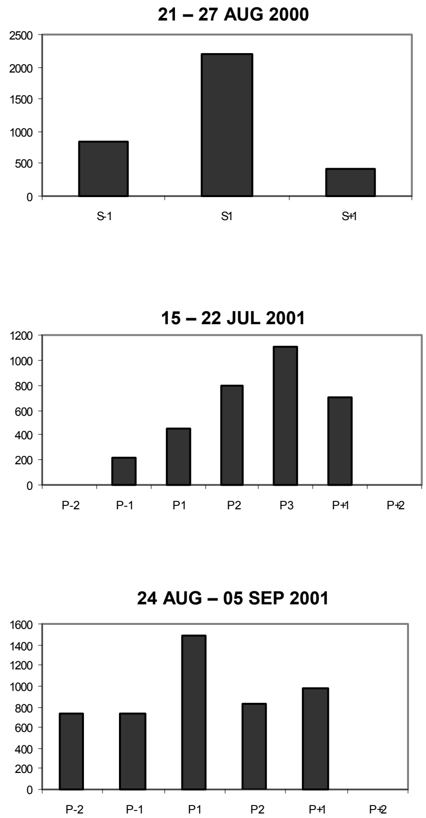


Figure 7. Mean frequency of vegetation fires in the pre-veranico (P-2 and P-1), veranico (P1, P2 and P3) and post-veranico (P+1 and P+2) pentads over the target area for several veranico episodes. In the last panel weekly means (S-1, S, S+1) are used instead of pentad means.

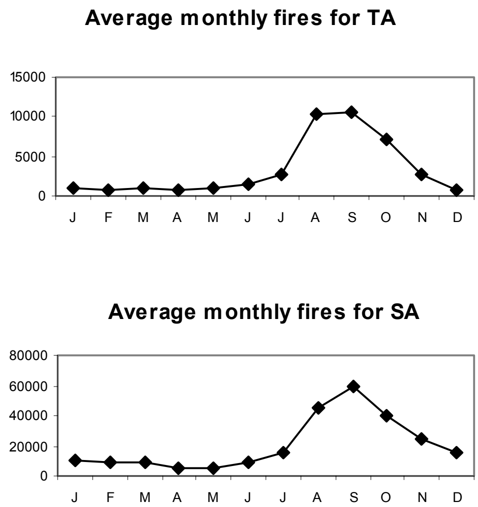


Figure 8. Monthly variation of the vegetation fires in South America (a) and in the target area over the central parts of Brazil (b) based on 5 years data.

CASE	BEGINNING	END	DURATION	T´ (°C)	U´ (%)	IS
1	25/8/1985	1/9/1985	8	3,9	-6	2,3
2	12/9/1985	23/9/1985	12	3,2	-9	3,6
3	11/6/1986	17/6/1986	7	2,2	-8	1,5
4	7/7/1987	29/7/1987	23	3,6	-5	5,9
5	20/9/1988	28/9/1988	9	4,7	-15	4,1
6	24/8/1991	1/9/1991	9	3,0	-11	3,0
7	3/6/1992	9/6/1992	7	3,2	-1	1,2
8	23/6/1992	1/7/1992	9	2,1	-10	2,1
9	26/6/1993	6/7/1993	11	3,4	-6	2,8
10	18/7/1993	25/7/1993	8	2,2	-7	1,7
11	2/5/1994	11/5/1994	10	2,3	-4	1,7
12	20/8/1994	1/9/1994	13	3,5	-12	4,9
13	19/9/1994	26/9/1994	8	3,5	-12	2,8
14	10/6/1995	17/6/1995	8	2,9	-6	1,8
15	10/7/1995	17/7/1995	8	2,6	-1	1,2
16	24/7/1995	31/7/1995	8	3,5	-11	2,8
17	8/8/1995	16/8/1995	9	3,3	-8	2,6
18	22/8/1995	3/9/1995	13	3,5	-13	5,1
19	27/8/1997	10/9/1997	15	2,7	-20	7,0
20	29/6/1998	8/7/1998	10	2,2	-2	1,5
21	17/7/1998	31/7/1998	15	3,3	-11	5,1
22	11/8/1998	26/8/1998	16	3,0	-1	2,4
23	11/9/1998	18/9/1998	8	3,3	-6	1,9
24	26/8/1999	9/9/1999	15	3,3	-20	7,3
25	5/6/2000	16/6/2000	12	2,4	-9	3,0
26	24/6/2000	2/7/2000	9	2,5	-12	2,6
27	21/8/2000	27/8/2000	7	3,8	-15	3,1
28	15/7/2001	22/7/2001	8	3,6	-9	2,6
29	24/8/2001	5/9/2001	13	3,6	-7	3,7
30	31/5/2002	12/6/2002	13	2,8	-10	3,7
31	12/8/2002	29/8/2002	18	2,8	-9	5,4
32	10/9/2002	20/9/2002	11	2,4	-7	2,4
33	25/4/2003	2/5/2003	8	2,6	-12	2,0
34	10/6/2003	22/6/2003	13	2,7	-14	4,2
35	19/7/2003	25/7/2003	7	2,2	-14	2,3

Table 1. Veranico episodes in the austral winter half of the year in the period 1985 through 2003. T′ and U′ are the aerial mean temperature and relative humidity anomalies for the target area over central Brazil, averaged over the duration of the episode.

BLOCKING			VERANICO		
D_0	D_f	LONG	CASE	D_0	D_f
04/06/86	19/06/86	130°W	3	11/06/86	17/06/86
03/07/87	20/07/87	110°W	4	07/07/87	29/07/87
11/06/92	29/06/92	120°W	8	23/06/92	01/07/92
30/06/93	03/07/93	90°W	9	26/06/93	06/07/93
19/08/94	23/08/94	100°W	12	20/08/94	01/09/94
10/06/95	14/06/95	100°W	14	10/06/95	17/06/95
14/07/95	31/07/95	120°W	15	10/07/95	17/07/95
14/07/95	31/07/95	120°W	16	24/07/95	31/07/95
20/08/95	28/08/95	110°W	18	22/08/95	03/09/95
22/08/97	30/08/97	150°W	19	27/08/97	10/09/97
12/07/97	17/07/97	120°W	21	17/07/98	31/07/98
10/09/98	16/09/98	100°W	23	11/09/98	18/09/98
24/08/99	04/09/99	100°W	24	26/08/99	09/09/99
23/06/00	29/06/00	80°W	26	24/06/00	02/07/00
19/08/00	24/08/00	100°W	27	21/08/00	27/08/00
12/07/01	21/07/01	100°W	28	15/07/01	22/07/01
21/08/01	30/08/01	140°W	29	24/08/01	05/09/01
01/06/02	12/06/02	120°W	30	31/05/02	12/06/02
12/08/02	16/08/02	110°W	31	12/08/02	29/08/02
11/09/02	14/09/02	80°W	32	10/09/02	20/09/02
24/04/03	29/04/03	100°W	33	25/04/03	02/05/03
08/06/03	13/06/03	100°W	34	10/06/03	22/06/03

Table 2. Blocking situations in the veranico and preveranico periods. Di and Df are initial and final dates of the blocking situation in the eastern South Pacific. The longitude is the mean longitude of the blocking high during the episode.