INTRASEASONAL ACTIVITY AND THE SACZ EPISODES DURING AUSTRAL SUMMER 2003/2004

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1. INTRODUCTION

The 2003/2004 austral summer was very rainy in central and southeastern Brazil. It was ranked into the five rainiest summers in the last 45 years. Five episodes of SACZ were registered during this summer. The SACZ is a climatological summer feature in South America. It is a very complex system not yet fully understood.

Nevertheless, important characteristics have been figured out in the last decades. One of them is that the SACZ usually presents a significant variability in the intraseasonal band. Paegle et al. (2000) and Mo and Paegle (2001) pointed out that precipitation over SACZ can be modulated by two oscillatory modes, one of them with period around 36-40 days and the other one with period around 22 to 28 days. Those modes appear as anomalous circulation (stream function) wave trains crossing the South Pacific Ocean and bending over South America. There are indications that those wave trains can be related to convection in Indonesia. The activity of these waves crossing South America from south to north modulates the spatial pattern of convective rainfall during an SACZ episode (Cunningham and Cavalcanti, 2006). Events associated with the strong convective activity over the South Atlantic Convergence Zone are associated with rainfall deficit over the subtropical plains of South America, whereas when the South Atlantic Convergence Zone weakens, precipitation over these plains tends to be abundant. One of the pioneers studies of this seesaw behaviour was done by Casarin and Kousky (1986). They showed that the two neighbour regions are intrinsically connected, with opposite behaviours.

In a higher frequency band, Liebmann et al. (1999) found Rossby wave trains impinging energy on the SACZ on the submonthly timescale (2-30 days). Probably most of this energy is due to cold fronts coming from the extratropical regions. Carvalho et al. (2004) and Cunningham and Cavalcanti (2006) have also suggested the presence of frontal systems during SACZ episodes. Analysing satellite image data, Siqueira and Machado (2003) discussed the influence of frontal systems on SACZ convection. However, the role of cold fronts or tropical convection on SACZ episodes needs more investigation.

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The objective of this work is to explore the effect of intraseasonal variability and high frequency associated with frontal systems on the occurrence of SACZ cases in the 2003/2004 summer.

2. DATA AND METHODS

The data set used in this study consists of daily NCEP/NCAR reanalysis of geopotential height and zonal and meridional component of wind at 200 hPa (Kalnay et al. 1996). Daily-interpolated OLR (Liebmann and Smith, 1996) was used as a proxy to convective rainfall. All data sets span over 2003 and 2004 years. We calculated the daily normalized anomalies using the daily mean and daily standard deviation, based on period of 1979–2004.

We performed wavelet analysis in time series (area averaged values) of daily anomalies of geopotential height at 200 hPa (hereafter refered as GHTA200) and Outgoing Long-wave Radiation (OLR) over South America to identify periods when the intraseasonal activity was present. Wavelet analysis is a useful tool to investigate time series with many different timescales or changes in variance. Decomposing time series into time-frequency space, we can determine both the dominant modes of variability and how those modes vary in time.

The wavelet analysis was done for a key region comprising Southern Brazil, Northeastern Argentina and Paraguay, and hereafter will be referred as SBNAP. The choice of the region over Southern Brazil followed Casarin and Kousky (1986) results. When SACZ is established, a region to the southwest of convective band presents suppressed convection (Nogués-Paegle and Mo, 1997). The SBNAP intends to represent this area. The limits of the region are 59^0W to 48^0W and 34^0S to 22^0S.

After the main band of intraseasonal variability was identified, we filtered out the remaining variability from the daily fields of anomalies of zonal and meridional component of wind, geopotential height and OLR. The objective was to investigate the intraseasonal features presented in this summer. The same fields were also filtered to enhance variability in the high frequency band (2 to 10 days).

3. ANALYSIS

The five episodes of SACZ that occurred during the summer presented very distinct characteristics.

Following the classification given by Carvalho et al. (2004) we can say that the first, fourth and fifth were oceanic episodes, whereas the third episode can be classified as a continental SACZ. The second belongs to the strong category. This study is focused on the three oceanic episodes.

The time-frequency diagram of geopotential height in SBNAP shows the predominance of intraseasonal periodicity, in January and especially in February (Fig.1a). The period of those oscillations was approximately 25 to 60 days.

The evolution of the geopotential height filtered in the 30 to 60 days band and averaged over SBNAP demonstrates that in December the geopotential anomalies oscillate - from positive to negative values (or vice versa) - with lesser amplitude than in January and February (Fig.1 a). The five SACZ episodes took place during these two months JF. This simultanous behaviour suggests that some amplitude threshold of the intraseasonal oscillations must be reached to affect a SACZ episode.

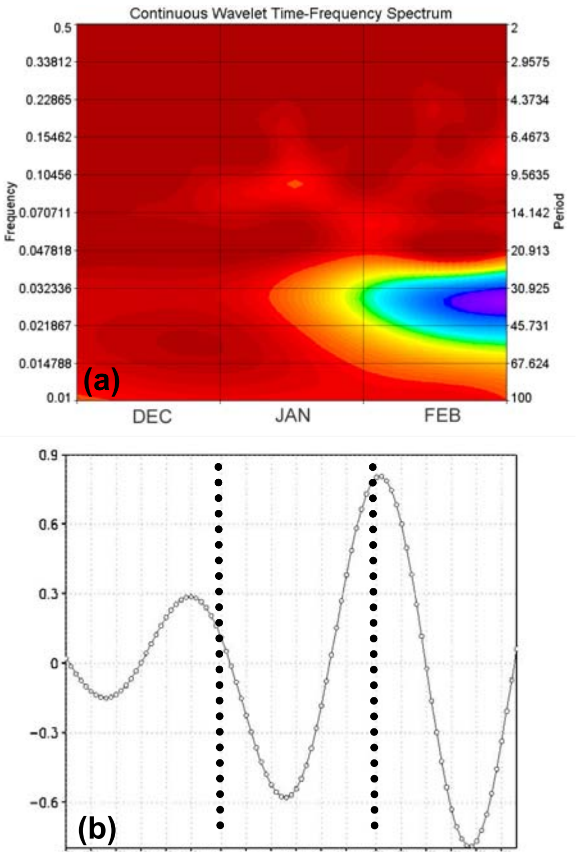


Figure 1 – a) Time-frequency diagram for GHTA200 in the SBNAP. Left axis shows the frequency and right axis the period. The values are the squared magnitude of the signal response. b) GHTA200 filtered to retain variations in the 30-60 days band and averaged over SBNAP area. The dashed line separates the three months: DEC, JAN and FEB.

The three oceanic episodes presented some common features. A composite of the mean vorticity field during the oceanic episodes shows that the band of convective clouds was positioned approximately along a region of maximum positive (anticyclonic) vorticity. This is consistent since anticyclonic vorticity is typically associated with an amplified ridge during a SACZ episode. To the south there was negative vorticity, associated with the typical trough during SACZ events (contours in Fig. 2a).

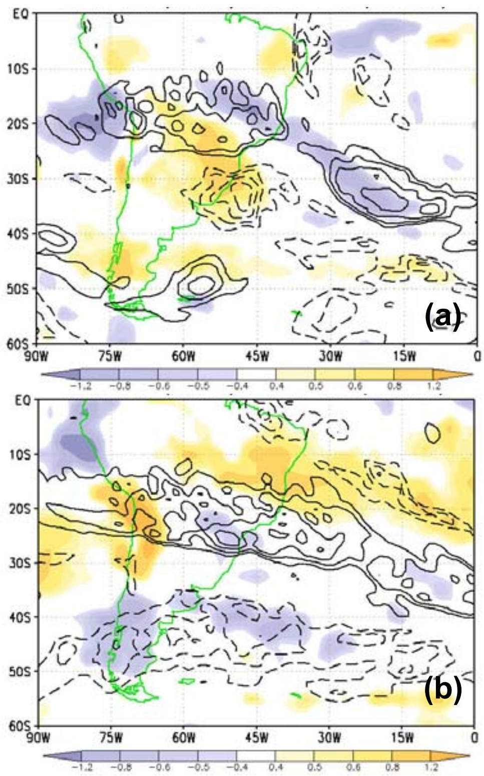
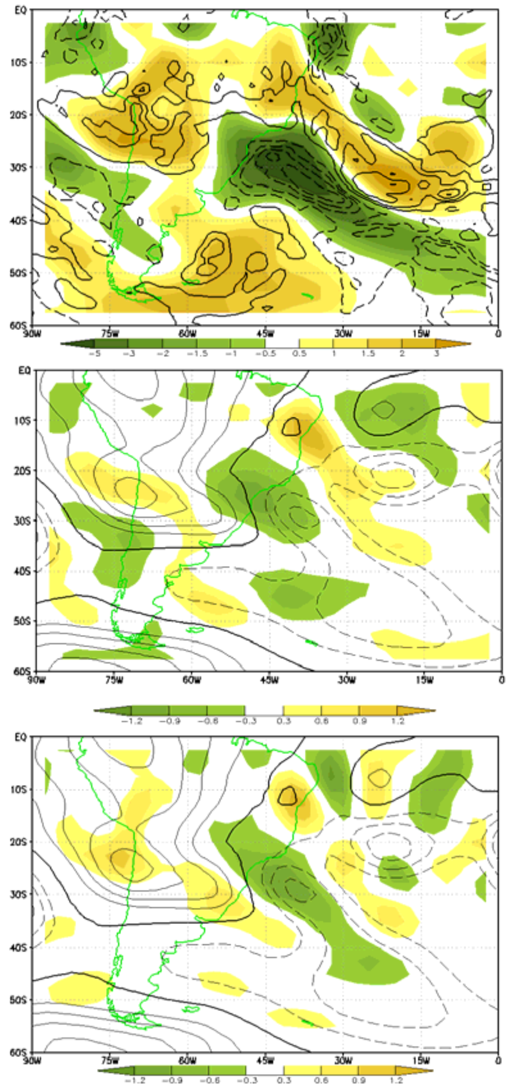


Figure 2 – a) Mean OLR anomalies and mean vorticity field at 200 hPa for the three oceanic episodes. b) Mean OLR anomalies and mean vorticity field (200 hPa) during the first 15 days of December.

For comparison we averaged the relative vorticity field and anomalous OLR during December, when no SACZ episodes were registered (Fig. 2b). The general pattern is quite different. The band of anti-cyclonic (positive) vorticity is more zonally oriented, uninterrupted and it is not associated with convection. There is a region of cyclonic (negative) vorticity positioned far south, while during the SACZ episodes (Fig. 2a) the cyclonic (negative) vorticity region is positioned closer to the convective region.

The presence of cyclonic vorticity close to the SACZ position seems to be the crucial difference between a situation favourable or unfavourable to the formation of an SACZ event. It represents the presence of an amplified trough to the south of the convective band.



(a)

(b)

(c)

Figure 3 – Averaged fields during the fourth SACZ. **a)** Mean vorticity field at 200 hPa (contours) and mean anomalous vorticity field at 200 hPa (shaded). Contour interval for vorticity is 0.2, starting at –0.8. Negative contours are dashed. Zero contour is omitted; **b)** Contour: mean GHTA200, 30-60 days filtered. Contours levels are -0.5 -0.4 -0.3 -0.2 0.2 0.3 0.4 0.5. Shaded: mean anomalous vorticity field at 200 hPa 2-10 days filtered; **c)** Contour: same as (b). Shaded: mean anomalous vorticity field at 200 hPa 30-60 days filtered.

As in the composite for the three SACZ oceanic episodes, the fourth SACZ presented the same general characteristics, concerning the association between vorticity field and OLR anomalies. The band of convective cloudiness appears aligned at the same region of anticyclonic vorticity (not shown). Fig. 3a shows that a region of cyclonic vorticity lies in subtropical latitudes and close to the anticyclonic vorticity region. The anomaly field (shades in Fig. 3a) reveals that the vorticity patterns during this SACZ episode were exceptional. Negative anomalies are associated with cyclonic vorticity and positive anomalies with anticyclonic vorticity.

The high frequency perturbations however, present a different pattern, where the main center of negative anomaly is positioned over the continent. The GHTA200 mean field shows the negative center over the Southern Atlantic, in an elongated shape, characteristic of SACZ events. Negative anomalies in geopotential corresponds to anomalous cyclonic circulation, this in turns is associated to enhanced convection ahead during summer in South America (Liebmann et al., 1999; Paegle et al., 2000). Different from the high frequency disturbances, the flow perturbations in the 30-60 days band maintained a center of negative anomalies positioned off-shore, over the Atlantic Ocean and with an elongated shape in a well agreement with the GHTA200 field.
Therefore, both (high and intraseasonal) force the same signal in the vorticity field, suggesting that during a SACZ episode those disturbances could act in a cooperative way. Cunningham and Cavalcanti (2006) have already suggested that such coupling could play an important role on the SACZ convection.

Analyzing the synoptic evolution during the fourth SACZ episode, we noticed that only one cold front participate in the event. In February, 7th the cold front was positioned over the Southeast Region of Brazil (Fig. 5a). The band of convective clouds spreads mostly over the ocean, with a trough rearward. Over the central portions of South America (Northern Argentina and Chile, Paraguay and Southern Brazil) a great center of positive geopotential height anomalies (30-60 days) predominates, while negative anomalies spreads over the Atlantic. In the next 24 hours there is a great intensification of the trough associated with the SACZ convective band, in the Atlantic. Also the negative anomalies in the low frequency geopotential begin to spread over South America (Fig. 5b). This spreading continues until the last day of the SACZ occurrence (Fig.5e,f). An important feature that comes out from this sequence is that the presence of low (intraseasonal) anomalies of geopotential height contributes to the persistence of convection originally associated with the cold front. It is seen in Fig. 5 c (left panel) that the original frontal system which started the convection in SACZ, was not there anymore, however there is convection associated with a trough at upper level, maintained by the negative anomalies in the intraseasonal geopotential height.

4. SUMMARY AND CONCLUSONS

We used NCEP/NCAR Reanalysis (Kalnay et al., 1996) and interpolated OLR (Liebmann and Smith, 1996) to investigate the interaction between high frequency perturbations (2-10 days) and the intraseasonal variability (30-60 days) in the SACZ episodes that occurred during 2003/2004 austral summer.

The intraseasonal activity was detected through a wavelet analysis in the geopotential height at 200 hPa in a key area over South Region of Brazil and surroundings. Variations in the geopotential height with strong signal in the intraseasonal band (30 to 60 days) revealed the presence of intraseasonal activity. The strongest signal was detected in January and February, when there was occurrence of SACZ episodes. There are indications that while the intraseasonal oscillation did not reach appropriate amplitude, no favorable conditions for an SACZ episode were established. December, for instance, was a month plenty of cold fronts reaching South America, however the intraseasonal signal was weak and no SACZ episodes were registered.

The five episodes of SACZ in january and february presented different positioning and strength. Nevertheless, three of them presented similar positioning and could be grouped in one category. Obeying Carvalho et al. (2004), they were classified as oceanic episodes.

During the SACZ episodes there were contributions of high and intraseasonal bands, seen in the vorticity and geopotential anomaly fields. This suggests that high frequency transients and intraseasonal variability act cooperatively in a SACZ episode. The analysis of the evolution of a SACZ episode indicates that a cold front initiates the convection, but the maintenance of the episode was due to the presence of anomalous intraseasonal low geopotential height, southwestward of the convective band, which was responsible for the persistence of the trough.

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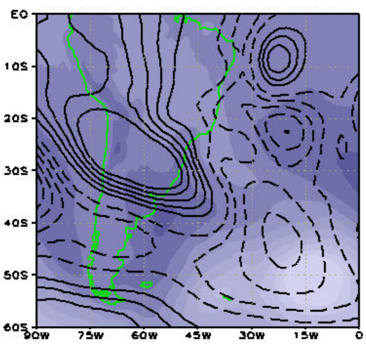

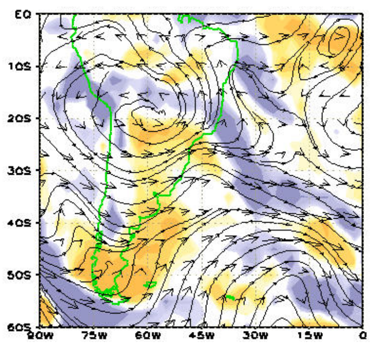

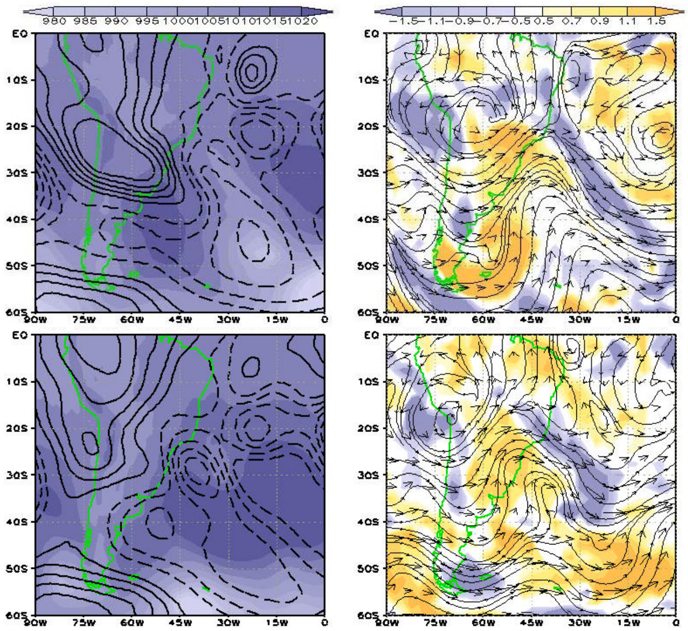

Figure 4 – Left panel: GHTA200 filtered in the 30-60 days band (contour) and sea level pressure (shaded). Right panel: anomaly of OLR (no filtering) and flow at 200 hPa. Contour interval for GHTA200 is 0.1, starting at –0.5. Negative contours are dashed. Zero contour is omitted; a) February 07th , 2004; b) February 08th , 2004; c) February 11th .