ATMOSPHERIC PROCESSES ASSOCIATED WITH WET AND DRY EVENTS IN THE SOUTH OF BRAZIL

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Abstract

The characteristics of the persistent wet and dry events in Southern Brazil during all seasons are examined. The dataset used in this study include daily precipitation totals from several stations in the period 1979-2002, from the Agencia Nacional de Aguas (ANA). The raingauge stations are uniformly distributed over the three states of Southern Brazil. The atmospheric circulation is analyzed using the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis. From the precipitation data were selected 88 dry and 97 wet events. Composite charts based on these selected wet and dry events reveal some common atmospheric processes and circulation features according to the season. Basically, more precipitation over Southern Brazil is accompanied by less precipitation to the Southeast of Brazil. The vertically integrated horizontal water vapor flux for the wet events shows convergence over Southern Brazil associated with a decrease in the northwesterly flux intensity and with the curvature of the anticyclonic circulation anomaly whose center is located over South Atlantic Ocean. For the dry events a water vapor flux divergence over Southern Brazil is observed in association with an intense southerly flow. A significant precursor to wet events is the presence of an upper level cyclonic circulation anomaly over southern South America, in all seasons, except summer. During summer, this anomaly is observed displaced to south, over the South Atlantic Ocean. For dry events, the composite pattern is nearly opposite. The upper levels meridional component anomaly composites exhibit a wavelike pattern for all events. For winter, the signal is typical of the zonal wave number 4 or 5. The wavelike pattern over the Pacific-South American sector suggests the existence of a Rossby waveguide along the South Pacific jet and into the subtropics of the South Atlantic during all events. The wave energy propagates along a great-circle route, from Central South Pacific to southern South America, and turn to northward after cross the Andes. Composites also were created after a temporal filtering of the data by using a Lanczos digital filter. For the 06-14-pentads band (30-70-days), the signal, although weak, is wavelike and maintains the behavior observed in the non-filtered data.

1. Introduction

Persistent precipitation events such as floods and severe droughts have a large impact on many segments of the economy, including agriculture, industry and the water supply. A better understanding of the evolution of these events and their associated circulation features is important for climate monitoring and prediction. Persistent flood and drought episodes are usually accompanied by persistent atmospheric conditions and large-scale dynamical support.

Madden and Williams (1978) analyzed seasonal mean station data for North America and found negative correlation between temperature and precipitation. Chang and Wallace (1987) examined meteorological conditions during summer heat waves and droughts. They found that warm months were characterized by upper-level anticyclones over the central United States and a deep trough along the west coast of the United States. Tremberth (1988) hypothesized that extreme events are influenced by tropical convection through surface temperatures anomalies that set up a teleconnection pattern. Such mechanism with a persistent ridge over the Central United States caused the 1988 drought. Mo et al. (1997) examined persistent wet dry and wet events during summer over central United States. They found that a precursor to wet events is the enhancement of westerly flow over the eastern Pacific and western North America from 30^{o}N to 40^{o}N. For dry events, heating occurs in the tropical eastern Pacific associated with the northward shift of the ITCZ.

In addition to large-scale dynamical support, the local hydrological conditions are also important. Namias (1989) highlighted the importance of reduced soil moisture on the maintenance of warm and dry conditions during summer; reduced soil moisture leads to increased surface heating and reduced local evaporation.

For the past two decades, low frequency variability of the extra tropical upper troposphere has been an area of intense research. The importance of low frequency variability lies on the effect that it has on a wide range of scales of atmospheric motions from intraseasonal to annual variations. Although the large-scale flow of the atmosphere is significantly non-linear and displays chaotic behavior, the existence of teleconnection patterns (Wallace and Gutzler, 1981) presents evidence that the atmosphere differs from a purely turbulent system. Thus, extended range predictions are possible when specific low-frequency patterns prevail. The dynamical characteristic of the variability of low frequency disturbances of the extra tropical middle and upper troposphere associated with dry and wet periods in Southern Brazil is the general focus of this study.

2. Data and Methodology

For this study, the National Centers for Environmental Prediction (NCEP) global reanalysis data was used to represent the large scale circulation. Daily precipitation data from January 1979 to December 2002, of the Agência Nacional de Águas (ANA) for Southern Brazil region were used to select the dry and wet episodes.

To select events, we formed series of 5-day mean (pentad) precipitation averaged over a box that contain the southern Brazil region. Wet (dry) events are chosen when the pentad is above the 80^{th} percentile (below the 20^{th} percentile) for at least 2 consecutive pentads. Over the 24-yr period from 1979 to 2004, there are 97 wet and 88 dry events. Some events remain more than 4 pentads. For wet events there are 20 in summer, 26 in fall, 24 in winter and 27 in spring. For dry events there are 20 in summer, 23 in fall, 25 in winter and 20 in spring. Thus, both dry and wet events are fairly evenly distributed throughout along the year. We then obtained composite fields for wet and dry events by averaging over the duration over all the events. The statistical significance was assessed by using t-test at 95%.

The use of pentad data results in effectively removing high-frequency transients associated with individual weather events (Kousky and Kayano, 1994). Composites also were created after a temporal filtering of the data by using a Lanczos (Duchon, 1979) digital filter with 121 weights. Four our study on the intraseasonal oscillations (IO), we use a band pass filter where the weights are computed to separate 3 modes of intraseasonal variability (A,B and C). For the A mode, were used f_{c1}=1/2 pentads^{-1} and f_{c2}=1/6 pentads^{-1}.The B mode is determined with f_{c1}=1/6 pentads^{-1} and f_{c2}=1/14 pentads^{-1}. Finally, to the C mode, we used f_{c1}=1/2 pentads^{-1} and f_{c2}=1/18 pentads^{-1}.

The frequency response functions for the band pass filters are shown in Fig.1.

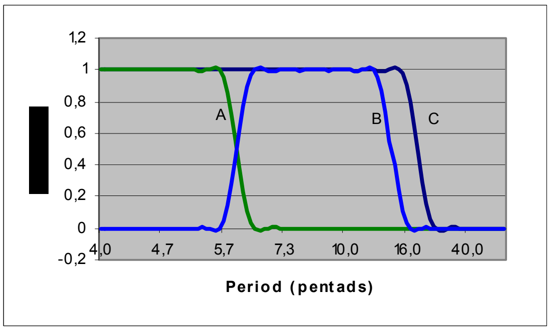
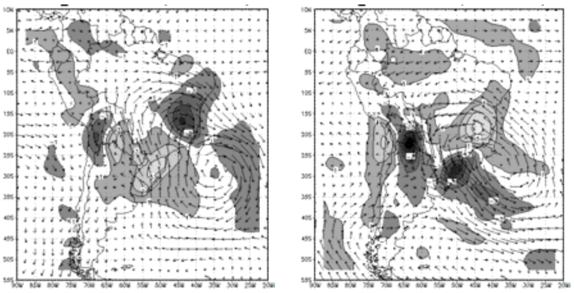


Fig.1 Lanczos filters response for intraseasonal band pass filters. A (2-6 pentads), B (6-14 pentads) and C (2-18 pentads).

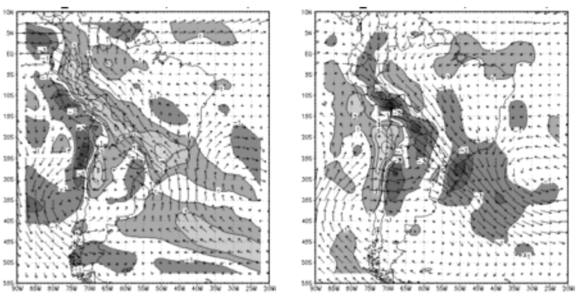
3. Moisture Flux Transport

The inspection of the events according to the season reveals some interesting characteristics. In the summer wet events composite (Fig. 2), there is an anomalous anticyclonic circulation over the Atlantic Ocean, around 35°W and 25°S. This circulation interacts with the northwesterly flow from the Bolivian region and converges over Southern Brazil. In the dry events, there is an anomalous cyclonic circulation over the South Atlantic Ocean around 35°W, 30°S. This anomalous cyclone drives the southerly flow to the negative rainfall anomalies regions over Southern Brazil. This southerly flow penetrates so far as 5°S over central Brazil and then turn to east. In the winter wet events (Fig. 3), there is only a little difference to the wet and dry events. In the wet events, the northwesterly flow starts in more low latitudes (around 10°S) while in the dry events, the southeasterly flux is tunneled from southern Brazil to northern South America along the Andes propagating to lower latitudes than in summer. During fall and spring seasons (Figs. 4 and 5, respectively), the pattern is more similar to the winter pattern only with small differences in the position of the anomalous circulation centers.



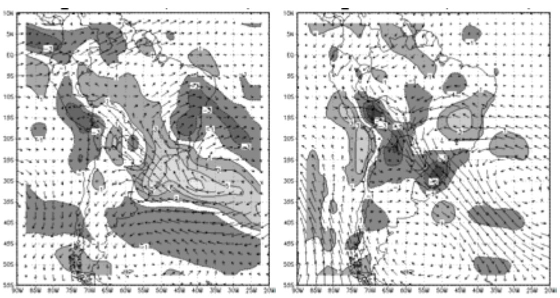
(a) (b)

Fig. 2. Composite of vertically integrated moisture flux (arrows) and flux divergence (shading) for (a) dry and (b) wet events in summer. The unity is $mm.day^{-1}$.



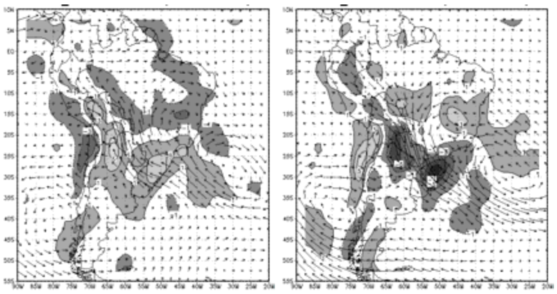
(a) (b)

Fig. 3. Same as Fig 2, but for Winter events.



(a) (b)

Fig. 4. Same as Fig 2, but for fall events.



(a) (b)

Fig. 5. Same as Fig 2, but for spring events.

4. Upper Levels Composites

The 300hPa meridional component anomaly for dry events during winter (Fig. 6a) shows a pattern that start in Australia and propagates zonally towards South America, turning to northeast after crossing the Andes. In the wet events (Fig. 6b), the pattern shows two trajectories for the anomalous flow. The first one propagates zonally around 30^{o}S from the Indian Ocean to South America, crossing the South Pacific Ocean along a great-circle route, from Australia to southern South America, and turning northward after crossing the Andes where it merges with the first one. In the fall, the composite shows a pattern with the anomalous centers more to south than in winter. In the dry events (Fig 6c), the energy propagates along a circle route that starts around 150E, 40S to South America. Apparently there is another track around 25^{o}S that start next Australia and propagates zonally to South America turning northward after crossing the Andes. For the wet events (Fig. 6d), the pattern is more robust than dry composite and also shows a wavelike structure with wave number 4. The composite to spring events is less statistically significant than in fall and winter. Apparently, there are various trajectories to anomalous centers, mainly in the dry events (Fig. 6e). To summer dry composites (Fig. 6g), the wavelike pattern starts around 100oE, 30oS and propagates to east. In these cases, the flow does not turn north after crossing the Andes Cordillera. In the case of the wet composite (Fig. 6h), the energy is concentrated more to south down to 40oS and start at around 150oE, 55oS, propagates nearly zonally to South America. In this case, wave number 5 is more robust.

5. Intra-seasonal composites

To examine circulation anomalies associated with intraseasonal variations, we filtered the data so that the modes of 2-6 and 6-14 pentads timescales are discussed here. In Fig.7a and 7b we show the composite to 2-6 pentads band pass filtered to winter dry and wet events, respectively. We note that the signal with the non-filtered composite (Fig. 6a) is stronger, indicating that the major part of signal is confined in this mode of variability. The Fig.7c shows the composite to 6-14 pentads band pass. We can see in this figure a wave train starting around Australia (150E, 30S) and propagating to South America, turning to the northeast after crossing the Andes Cordillera. In this season, the pattern is very defined and the main part of signal is confined to South Hemisphere. For wet events (Fig. 7d), the signal is diffuse and seems indicate that this variability mode (6-14 pentads) has not much impact over the mechanism that generate the events. For the fall season events (Fig. 8) we can highlight the wet composite to 6-14 pentads band (Fig.8d). In this case, the energy tracks a circle route and is statistically robust with a wave number 6. To 2-6 pentads band spring event composite (Fig. 9) the pattern is different compared to the dry events (Fig.9a) and more wavelike than the wet events (Fig.9b). To 6-14 pentads band, only dry events (Fig 9c) show a wavelike pattern with wave number 6. For the summer events (Fig. 10), we can highlight the 6-14 band pentads composite in the wet events (Fig. 10 d). In this case, a wavelike pattern that starts from New Zealand (around 175E, 35S) propagates to the South Pacific towards South America, turning to the northeast after crossing the Andes Cordillera

6. Summary and discussion

We investigated the evolution of the circulation pattern and moisture transport during the wet and dry persistent precipitation events over southern Brazil. These events were chosen based on observed rainfall at the surface. After determining events, composites over all dry and wet events for each season were computed in order to study the evolution and circulation features during extreme precipitation patterns. The observational results suggest that Rossby wave energy that reach South America originates primarily in the South Pacific. These results were also found by Marengo et al (2002) in cold-air outbreaks over Southeastern Brazil during wintertime. During summer, the vertically integrated horizontal water vapor anomalous flux for the wet and dry events shows a very distinct opposite pattern. For the wet events, the northwesterly moisture flux from the continental area around 10^{o}S converges with the mid-latitude westerlies over the Atlantic Ocean at 40^{o}S. In these cases, there are positive rainfall anomalies centered over southern Brazil, just along the main stream of the low-level moisture transport (associated with a low level jet). For the dry events an anomalous cyclonic circulation is observed over the Atlantic Ocean around 25^{o}S that maintains intense the southeasterly anomalous flow with divergence of the water vapor over Southern Brazil. Negative precipitation anomalies in northeastern Argentina and Southern Brazil are due the compensating subsidence associated with a more active South Atlantic Convergence Zone (SACZ) over Southeast of Brazil and the suppression of the important water vapor transport from the tropical continent in the summer. The upper levels meridional component anomaly composites exhibit a wavelike pattern for all events. During winter, the signal is typical of the zonal wave number 4 or 5 (Fig. 5). The wavelike pattern over the Pacific-South American sector suggests the existence of a Rossby wave guide along the South Pacific jet and into the subtropics of the South Atlantic during all events. The wave energy propagates along a great-circle route, from Central South Pacific to southern South America, and turn northward after crossing the Andes. Composites also were created after a time filtering of the data by using a Lanczos digital filter. For the composites to filtered data we note that the main part of signal is confined to 2-6 pentads band and approach to non-filtered composites. The 6-14-pentads band (30-70-days), is characterized by a wavelike signal that is more robust in the fall and summer wet events. These features are associated with the 30-60 day (Madden-Julian) oscillation.

Acknowledgments. This investigation was supported by Fundacão de Amparo a Pesquisa do Estado de São Paulo (São Paulo State Foundation to Support Research) – FAPESP (2001/13816-1) and by the Brazilian Council for the Development of Research (CNPq) and constitutes part of D. L. Severo's Doctorate Thesis at Instituto Nacional de Pesquisas Espaciais (INPE).

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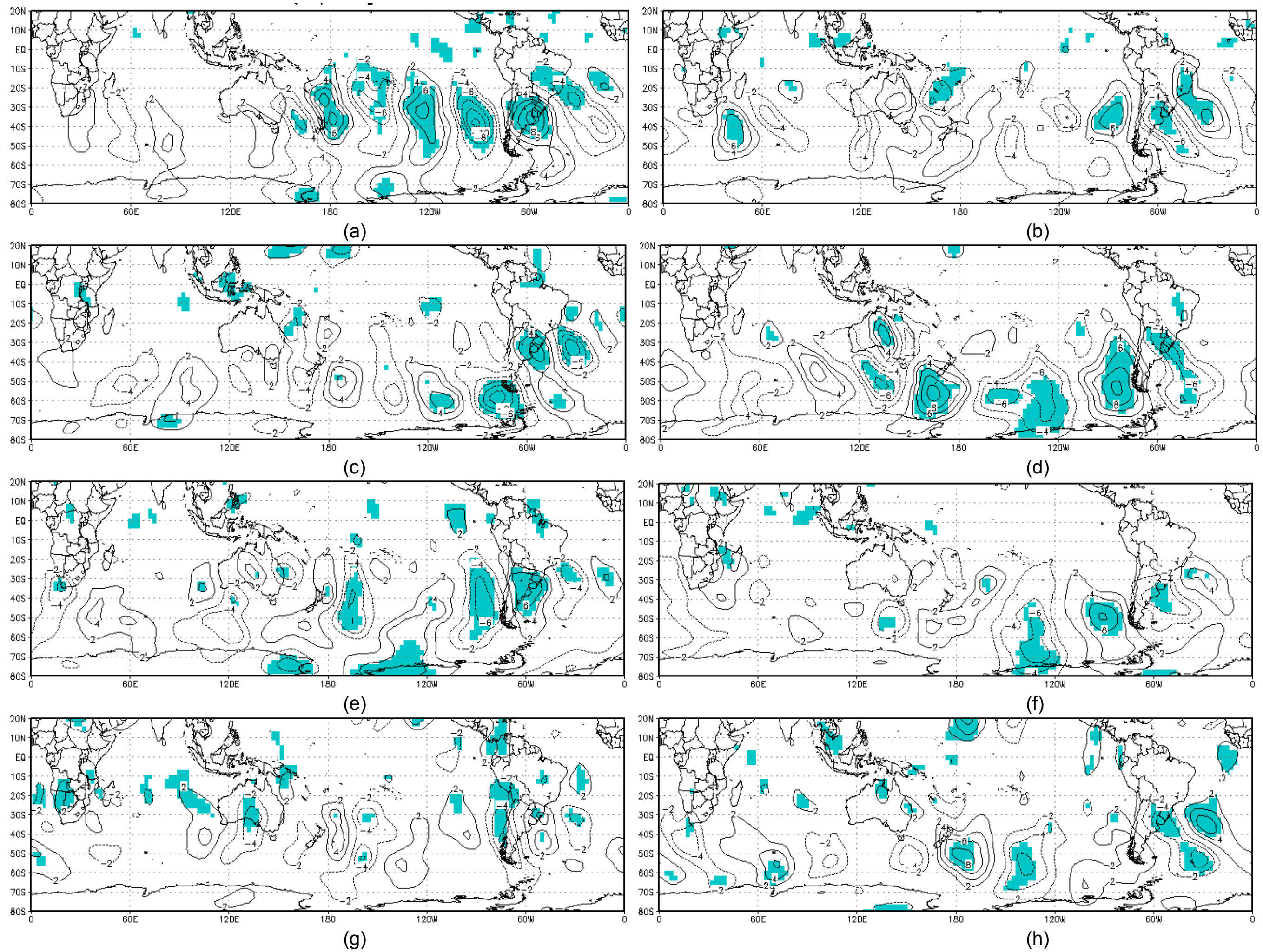

Fig. 6. Composite of anomalous 300-hPa meridional component for (a) dry and (b) wet events in winter, (c) and (d) for fall, (e) and (f) for spring and (g) and (h) for summer. Anomalies statistically significant at the 95% are shaded.

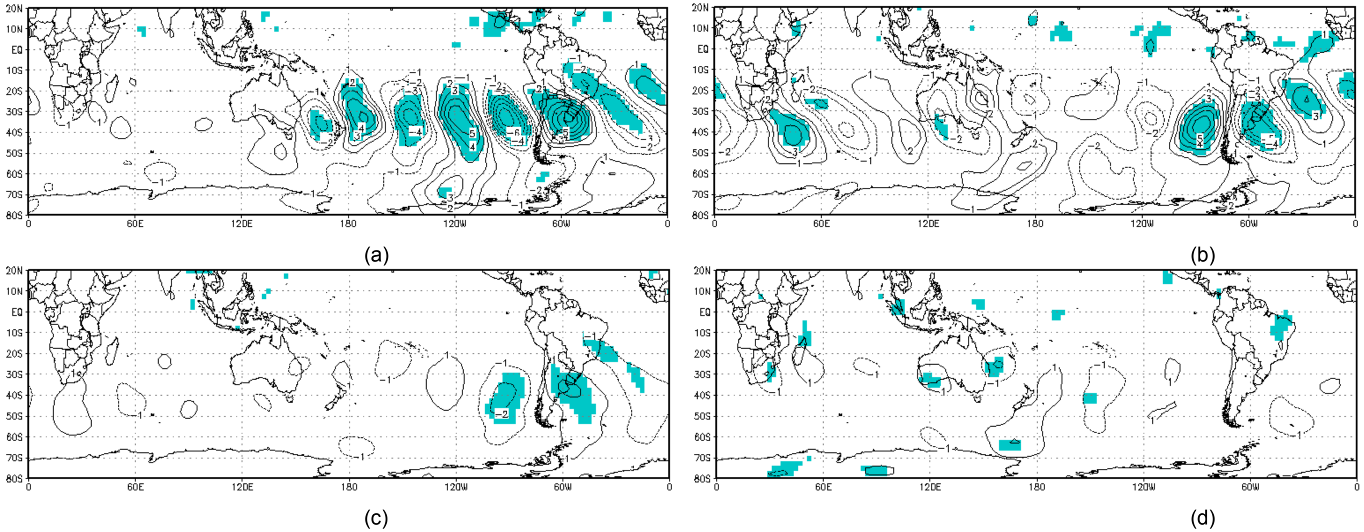

Fig. 7. Composite of 300-hPa meridional component for (a) 2-6 band pass winter dry events, (b) same as (a) but for wet events, (c) same as (a) but for 6-14 band pass and (d) same as (d) but for 6-14 band pass. Anomalies statistically significant at the 95% are shaded.

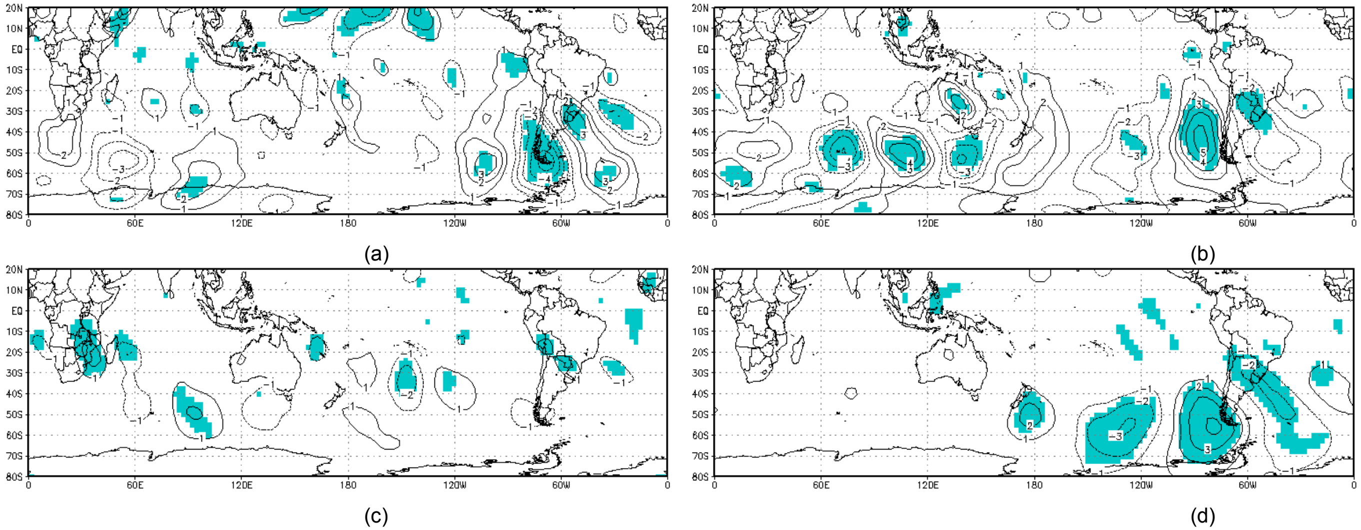

Fig. 8. Same as Fig.10 but for fall events.

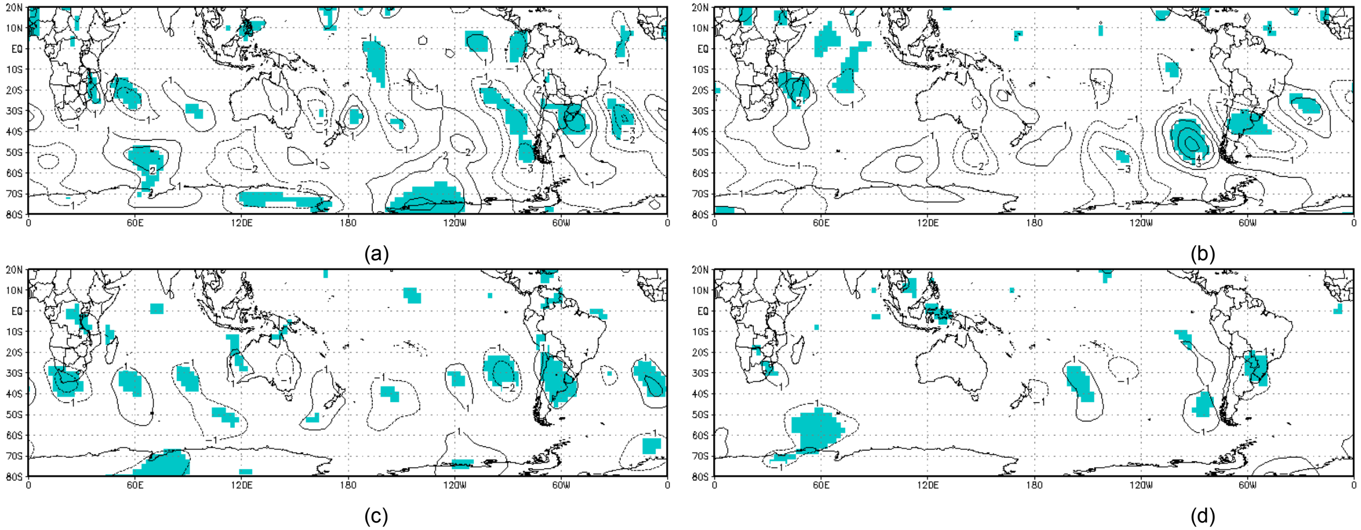

Fig. 9. Same as Fig.10 but for spring events.

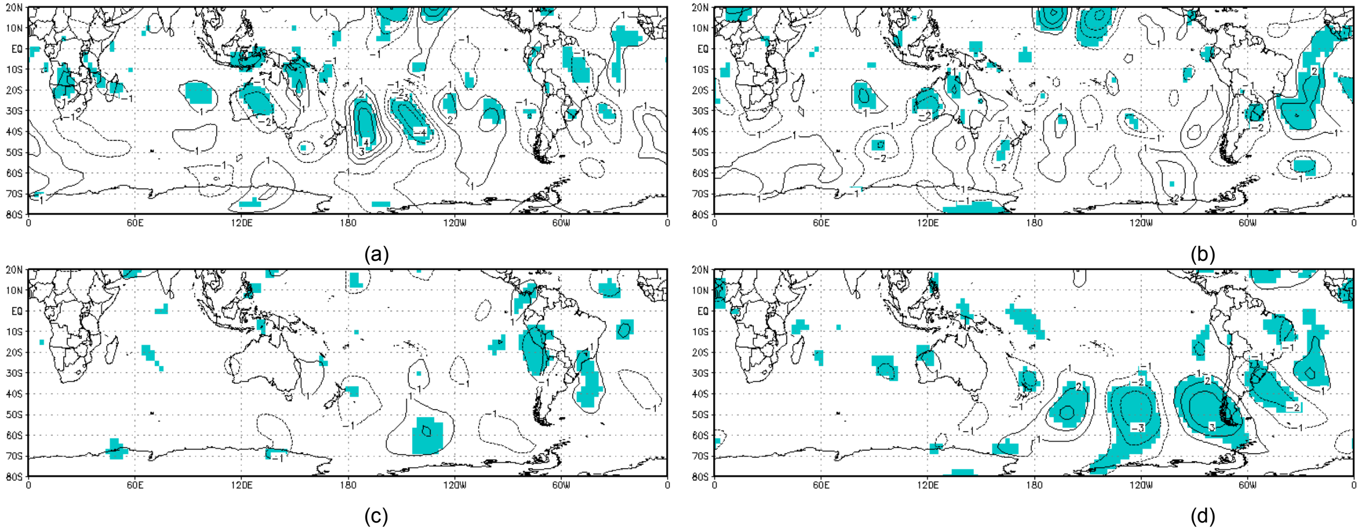

Fig.10. Same as Fig.10 but for summer events.