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ABOUT THE NATURE OF THE RAINFALL EVOLUTION OVER CENTRAL SOUTH AMERICA DURING AUSTRAL SPRING

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1. Introduction

The annual cycles of precipitation and atmospheric circulation over tropical South America have characteristics of a monsoon (e.g., Zhou and Lau 1998; Gan et al. 2004). However, the South American Monsoon System (SAMS) exhibits somewhat less distinct features compared to the Southeast Asian monsoon, which appears to be related to weaker seasonal temperature differences over South America (Vera et al. 2005). SAMS and its counterpart in the Northern Hemisphere (known as the North American Monsoon System, NAMS) can be considered as extremes of the same cycle that exhibits a seasonal regularity and degree of symmetry with respect to the equator (Horel et al. 1989).

Portions of the SAMS region experience distinct wet and dry seasons, with many areas receiving more than 50% of the annual precipitation during the austral summer (Figueroa and Nobre 1990). In early austral spring, precipitation shifts southward from Central America and northwestern South America to the western Amazon, subsequently spreading eastward and southeastward to include central and southeastern Brazil by mid-spring (Kousky, 1988; Marengo et al, 2001; Gan et al., 2004). The onset of the wet season in central and southeastern Brazil typically occurs between the end of September and early October when deep convection covers most of central South America from the equator to 20°S, but is absent over the eastern Amazon Basin and Northeast Brazil (Sugahara 1991, Gonzalez and Barros, 1998, 2002). Intraseasonal oscillations may promote rapid onset over central Brazil (Vera and Nobre 1999) although the associated mechanisms are still not clear.

The timing of the rainy season in tropical South America is of relevance to many economic activities in the region, such as agriculture and hydroelectric energy generation. However, a lack of a dense coverage of daily precipitation observations with long records has limited to some extent the progress in the prediction of SAMS onset dates. Outgoing longwave radiation (OLR) has been used to describe the convection evolution as well as to determine rainy season onset dates (Kousky 1988). Marengo et al. (2001), Liebmann and Marengo (2001), and Gan et al. (2004) are the only papers that to our knowledge used precipitation data to provide objective onset date criteria over the Amazon region.

Recently Liebmann and Allured (2005) described a daily precipitation database for South America that allows for a more detailed study of the evolution of precipitation over tropical South America. The objective of this paper is to provide a more detailed analysis of the SAMS wet season onset based on that precipitation data set in order to better understand the nature of the evolution of rainfall over tropical South America.

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2. Data and Methodology

Historical daily rainfall data from stations in South America were used as individual stations and subsequently averaged onto 1°x1° gridded fields (Liebmann and Allured, 2005). OLR data interpolated by Liebmann and Smith (1996) are used. The average OLR and the accumulated precipitation were computed for each of the 73 pentads for each year.

3. Results and conclusions

The OLR fields for selected pentads in the South American sector are shown in Figure 1. As described by Kousky (1988), by the end of August (Figs. 1a-1b) convection shifts southward from the northwestern sector of the continent into

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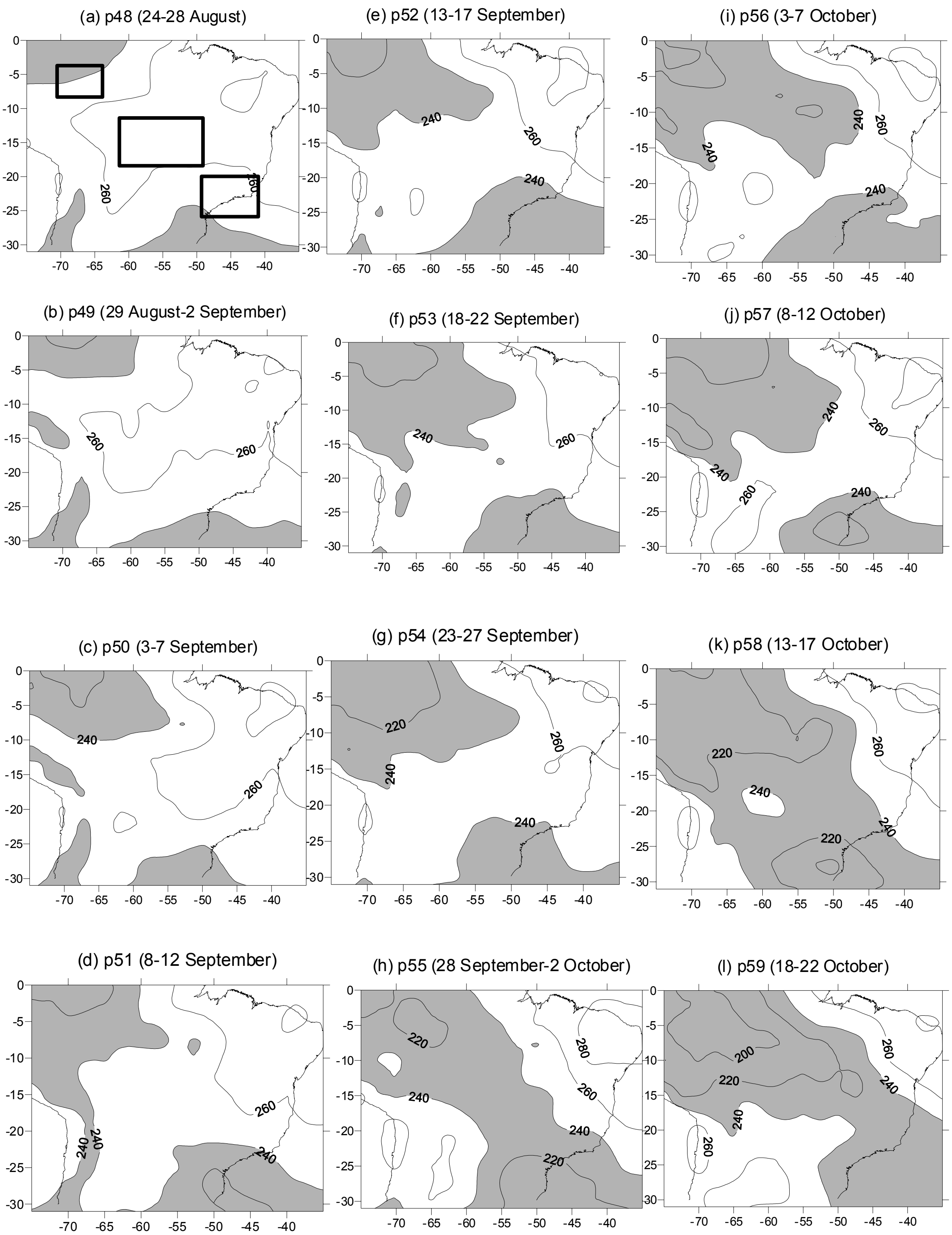

Figure 1: Climatological 5-day mean OLR from pentad 48 to 59. Contour interval is 20 W m^{-2}. Values less than 240 W m^{-2} are shaded. Boxes defining the regions NWA, CB, and SEB described in section 3, are denoted in Fig. 1a.

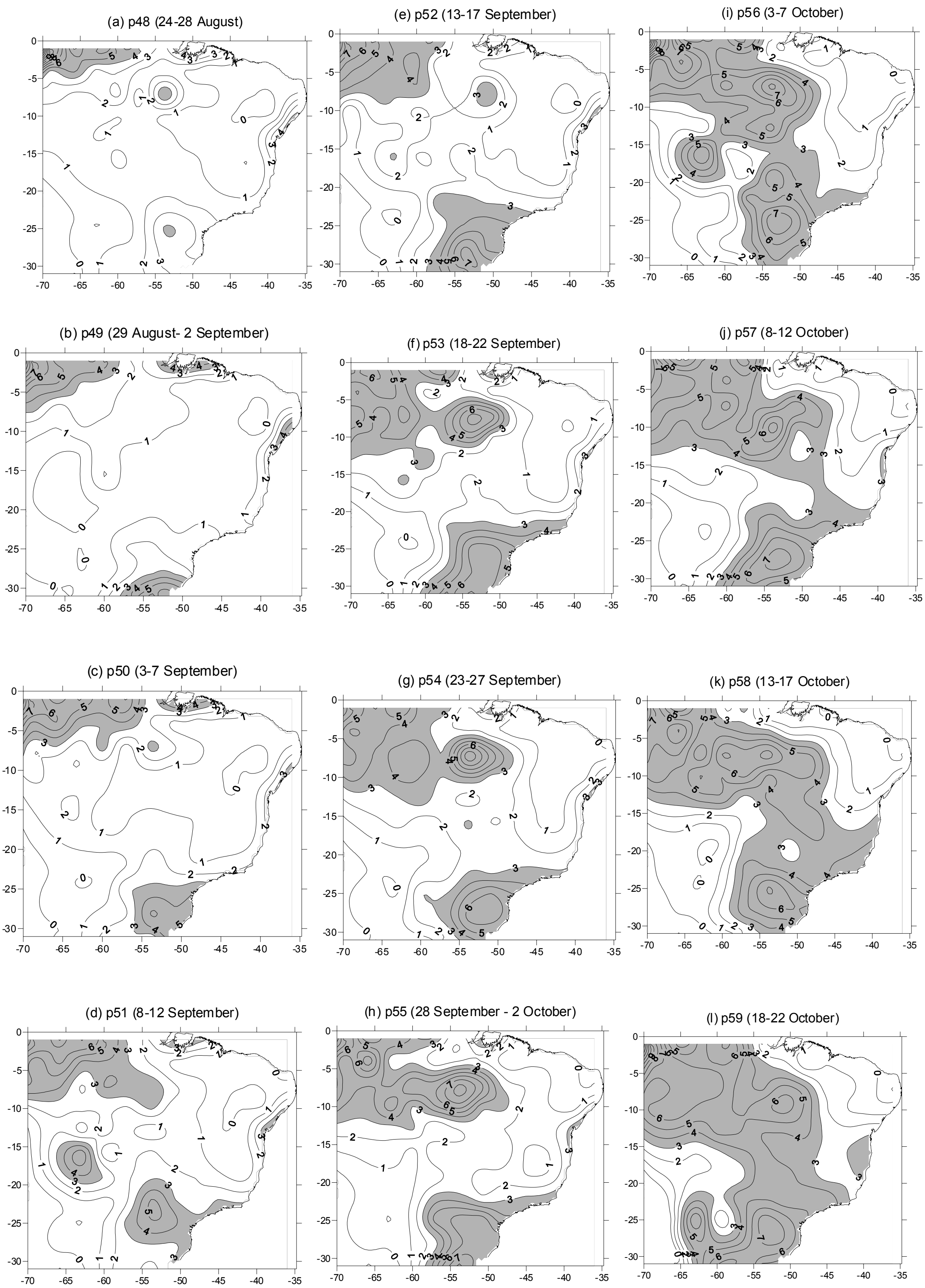

Figura 2: Idem Figure 1 but for rainfall data. Contour interval is 1 mm day $^{-1}$. Values larger than 3 mm day $^{-1}$ are shaded.

the Amazon basin. During September the convection over southeastern South America (SESA) intensifies and extends northwestward (Figs. 1c-1g). By the end of September (pentad 55, Fig. 1h), convection develops over central Brazil and intensifies over the entire region from the Amazon basin to SESA and southern Brazil, forming a NW-SE orientated band of intense convection. A increase of the climatological mean OLR values is evident during the first half of October (Figs. 1i-1j), followed by a decrease over the whole region by the end of the month (Figs. 1k-1l).

The climatological mean precipitation fields for the same pentads are displayed in Fig. 2. The southward intensification of the precipitation from northwestern South America (Figs. 2a-2g) is clear and agrees with the evolution shown in the OLR fields.On the other hand, the increase on rainfall over central Brazil occurs one pentad later (pentad 56) than indicated by the decrease in OLR (pentad 55, Fig. 1h). Souza and Ambrizzi (2003) presented a pentad climatology of precipitation over Brazil, and also show a precipitation increase over central Brazil around pentad 54-55 (Figs. 2g-2h). By pentad 57 (Fig. 2j) a decrease in the mean precipitation over central and eastern Brazil is evident, in agreement with that observed in OLR (Fig. 1j) and in the results presented by Souza and Ambrizzi (2003). By mid-October (Fig. 2k) precipitation re-intensifies over central Brazil a continuous rainfall increase is evident during the rest of the month (Fig. 2l, Souza and Ambrizzi, 2003).

The regional differences identified in the precipitation and OLR evolution over tropical South America were further analyzed by defining the following the regions: Norwthwestern Amazon (NWA, 65°W-70°W, 6°S-5°S)Central Brazil (CB, 50°W-60°W, 12°S-18°S) and southeastern Brazil (SEB, 50ºW-42ºW and 25ºS-20ºS).This regions are illustrated in figure 1a. Due to the fact that the precipitation data series over the region are affected by several missing observations over the study period, a group of 7 in CB and 6 in SEB, with the more complete records were selected. The time series of the precipitation and OLR departures (from the annual mean), averaged over the selected stations considered for each of the regions, are displayed in Figure 3. The series were normalized by their respective standard deviations in order to better compare the changes in both variables. Mean precipitation in CB (Fig. 3a) shows an almost negligible increase until mid-September (around pentad 54), when an abrupt positive change of 1 standard deviation is observed. After that, the rainfall remains quite high. By the beginning of September (pentad 50) the OLR in CB starts to increase earlier than precipitation, and normalized OLR values remain generally larger than those of precipitation during the rest of the study period. Furthermore, the abrupt increase observed in precipitation by the end of September is not observed in the evolution of OLR. The evolution over SEB region (Fig. 3b) is characterized by a moderate increase rate of precipitation between the end of August (pentad 48) and middle October (pentad 58). A rapid precipitation increase of around one standard deviation occurs in 2 pentads by pentad 59. After that, precipitation continues increasing at a moderate rate similar to that observed at the beginning of the period. The OLR for this particular region exhibits values and rates comparable to those of precipitation until mid-October, while after that OLR standardized departures (multiplied by -1) are larger than those of precipitation. In order to better understand the abrupt positive change observed in mean rainfall evolution in CB on pentad 55, a *rainfall jump* index, defined as the maximum rainfall difference between two consecutive pentads over CB, was applied to the rainy season onset period between 15th July and 1st November (pentads 40 and 61). This jump was calculated for each year during 1975-1998. The jump occurs on average in pentad 57 (8-12 October) with a variability of around 3 pentads, with a mean rainfall rate of 7.7 mm day^{-1} and a standard deviation of 3 mm day^{-1}. Meanwhile, the onset date of the monsoon was calculated for the OLR fields using the onset date definition by Kousky (1988) for each one of the years, showing that the mean onset date occurs in pentad 54 (23-27 Sept) with a standard deviation of 2.7 pentads.

The rainfall jump tends to occur in general after the rainfall onset and in a few cases they occur simultaneously or before.

Figure 4a shows the time series of normalized rainfall and OLR averaged over the CB region, relative to the *rainfall jump*. While rainfall values increase slowly before the jump pentad, soon thereafter an increase of the precipitation rate as well as of its variability is noticeable but there is no abrupt change in OLR series.

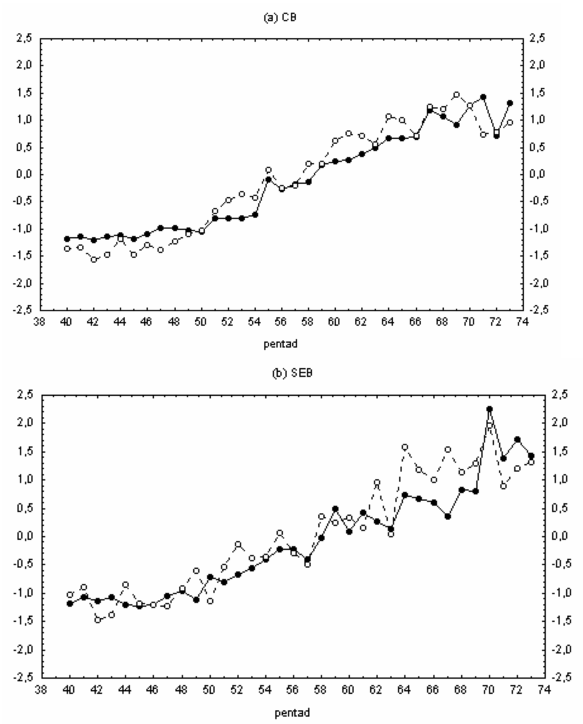

Fig 3. Temporal series of standardized climatological means of OLR (multiplied by -1, open circles) and rainfall (full circles) for (a) CB, and (b) SEB regions.

Figure 4b shows the time series of both normalized rainfall and OLR averaged over the CB region, now relative to onset (as defined by Kousky 1988). A precipitation increase is noticeable since pentad 0 that is more pronounced than that displayed in Figure1b. A comparison between Figures 4a and 4b confirms that the occurrence of the *rainfall jump* is associated with a change in the way that it rains rather than to the beginning of the rainy season. The composites of 5-day rainfall averages relative to *rainfall jump* and to onset (not shown), respectively were analyzed. It was found that composites relative to either convection onset date or rainfall jump date are able to reproduce the experience that indicates that usually first rains occur before the actual rainy season onset starts.

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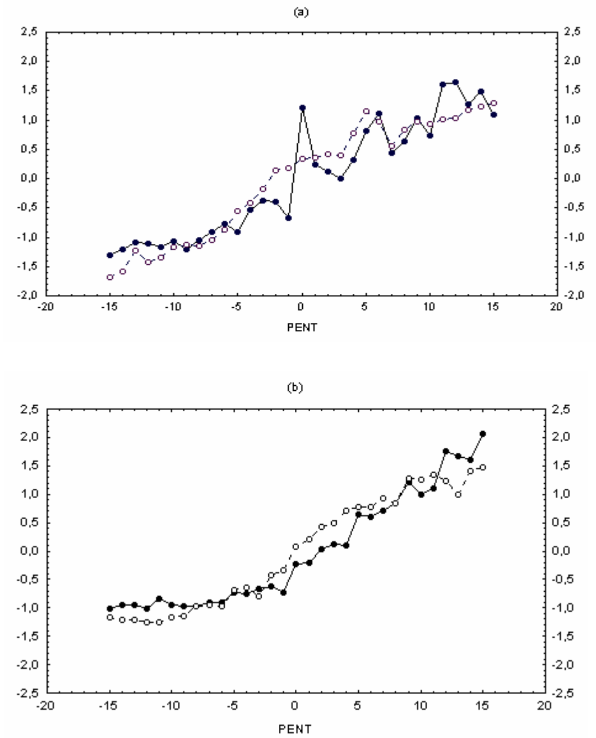

Fig 4. Standardized time-series of composite OLR (multiplied by -1, open circles) and rainfall (filled circles) relative to (a) *rainfall jump*, and (b) onset date.

References

Figueroa SN, and, Nobre C. 1990. Precipitation distribution over central and western tropical South America. Climanalise 5: 36-44.

Gan MA, Kousky VE, and Ropelewski CF. 2004. The South America monsoon rainfall over west-central Brazil. J. Climate 17**:** 47-66.

González M and Barros V.1998. The relation between tropical convection in South America and the end of the dry period in subtropical Argentina. Int. J. Climatol. 18 (15):1669-1685.

González M and Barros V. 2002. On the forecast of the onset and end of the convective season in the Amazon. Theor. Appl. Climatol. 73: 169-187.

Horel JD, Hahmann AN and Geisler JE. 1989. An investigation of the annual cycle of convective activity over the tropical Americas. J. Climate 2: 1388-1403.

Kousky VE. 1988. Pentad outgoing longwave radiation climatology for the South America sector. Revista Brasilera de Meteorología 3*:* 217-231.

Liebmann, B, and Marengo, J. 2001. Interannual variability of the rainy season and rainfall in the Brazilian Amazon Basin. J. Climate 14: 4308-4318

Liebmann, B and Smith C. 1996. Description of a Complete (Interpolated) Outgoing Longwave Radiation Dataset. Bulletin of the American Meteorological Society 77:1275-1277.

Liebmann, B., and Allured D. 2005. Daily precipitation grids for South. America. Bulletin of the American Meteorological Society (in press).

Marengo J, Liebmann B, Kousky V, Filizola N and Wainer I. 2001. Onset and end of the rainy season in the Brazilian Amazon basin. J. Climate 14: 833-852.

Souza, E and Ambrizzi, T. 2003. Pentad Precipitation climatology over Brazil and the associated Atmospheric Mechanisms. Climanalise 12 nº1 Electronic Version at http://tucupi.cptec.inpe.br/products/climanalise/artigos/artcien2.shtml

Sugahara S. 1991. Fluctuacoes interanuais, sazonais e intrasazonais da precipitacao no estado de Sao Paulo. Tese de Doutorado. Departamento de Ciencias Atmosfericas. Universidade de Sao Paulo, Brasil, 140 pp.

Vera C, Higgins W, Amador J, Ambrizzi T, Garreaud R, Gochis D, Gutzler D, Lettenmaier D, Marengo J, Mechoso CR, Nogues-Paegle J, Silva Dias PL, and Zhang C. 2005. A Unified View of the American Monsoon Systems. J. Climate . Acepted for publication.

Zhou J and Lau KM. 1998. Does a monsoon climate exist over South America? J. Climate 11: 1020-1040.