PENTAD PRECIPITATION CLIMATOLOGY OVER BRAZIL AND THE ASSOCIATED ATMOSPHERIC MECHANISMS

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ABSTRACT

Using 24 years (1974 to 1997) of raingauge-based data covering most of the Brazilian territory, a pentad (5-day averages) climatology of the precipitation over Brazil was built. In addition, from the NCEP/NCAR reanalysis dataset for the same period, it was also computed the pentad climatology of the atmospheric circulation in the higher and lower troposphere over South America. Based on climatological precipitation fields over Brazil, were defined the indicative areas of the rainiest (driest) regime, which are represented by the spatial regions containing a threshold higher than 25 mm (less than 5 mm). Thus, a detailed comprehensive analysis concerning the pentad evolution of the areas containing such rainy and dry regimes occurring on regional level over Brazil along the year is described. In these analyses, the more relevant dynamic aspects related to the large- and synoptic-scale atmospheric patterns over the South American troposphere are also investigated.

RESUMO

Baseado em 24 anos (1974 a 1997) de observações provenientes de estações pluviométricas cobrindo a maior parte do território Brasileiro, foi construído uma climatologia pentadal (média de 5 dias) de precipitação para o Brasil. Além disso, usando os dados da reanálise do NCEP/NCAR para o mesmo periodo, foi também computada a climatologia pentadal da circulação atmosférica nos baixos e altos níveis da troposfera sobre a América do Sul. A partir dos campos de precipitação climatológica sobre o Brasil, foram definidas as regiões indicadoras do regime mais chuvoso (seco), as quais são representadas pelas áreas espaciais contendo o limiar de precipitação maior do que 25 mm (menor do que 5 mm). Assim, descreve-se uma análise detalhada sobre a evolução pentadal das áreas contendo tais regimes chuvosos e secos que se processam regionalmente sobre o Brasil ao longo do ano. Nestas análises, também são investigados os aspectos dinâmicos mais relevantes relacionados aos padrões atmosféricos de grande e escala sinótica sobre a troposfera sul-americana.

1. INTRODUCTION

Brazil has a continental area of about 8.548.000 km^2 (fifth largest country of the world) occupying most of the tropical area of the South America. It is well known that one of the main Brazilian economic activities is the agriculture. In spite of the fact that great progresses happened in this sector during the last years, it is still experimenting a substantial dependence of the precipitation occurrence in the form of raindrops (Rosseti, 2000). Moreover, activities related with hydroelectric power generation also depend on the rainfall occurrence for the water storage necessary in the energy generation process, which is distributed among the Brazilian cities. Therefore, the knowledge of the climatological precipitation aspects over Brazil is extremely important for these activities and also for other economic sectors.

The climatology of the precipitation over Brazil, in particular on seasonal and monthly timescales, has been well documented during the last three decades. Many works addressed climatological studies on these timescales. Contributions reported by Strang (1972), Ratisbona (1976) and Nimer (1979) are examples of pioneering works. Ratisbona (1976) presented a good survey of Brazilian climate based on monthly records of 515 stations for the 1912-1942 period. Nimer (1979) documented several regional studies (e.g., Serra and Ratisbona, 1942; Serra, 1960;

Nimer, 1972a,b; and others) concerning precipitation climatology and dynamic aspects observed in the Brazilian south, southeast, northeast and north regions. On the Brazil as a whole, Rao and Hada (1990) using 21 years (1958-1978) of monthly raingauge data determined the wet and dry stations, trying to identify the possible causal factors for these regimes. These authors commented that although the basic summer (wet) and winter (dry) regime was typical for a tropical country the details seem to be complicated and need further investigations. Figueroa and Nobre (1990) used 226 raingauge stations to analyse the precipitation distribution along western and central South America. In that study, the climatological rainfall patterns revealed influences of Andes and large-scale meteorological systems related to the Inter Tropical Convergence Zone (ITCZ) and South America Convergence Zone (SACZ) which were in agreement with the results obtained by Obregon and Nobre (1990). INMET (1992) computed the 30 years (1961-1990) monthly climatology of precipitation over Brazil and Quadro et al. (1996) published a detailed explanation of the meteorological mechanisms associated to the INMET climatology.

There have been relatively few studies that approached climatological aspects considering timescales less than a month. For example, using satellite-based outgoing longwave radiation (OLR) measurements as a proxy to tropical convective activity, Kousky (1988) presented a pentad (5-day averages) climatology (1979-1987) of some South American regions for which significant deep convection can be expected throughout the year. Kousky determined the starting and ending dates for tropical rainy seasons based on 240 Wm^{-2} threshold for convective rainfall. Based on 15-year record of OLR data, Horel et al. (1989) investigated interannual variability of onset and end of the rainy season, illustrating features of the upper-level atmospheric circulation in the vicinity of the tropical Americas. Recently, Marengo et al. (2001) using a dense network of raingauge stations for the 1979-96 period, determined onset and end dates of the rainy season in the Brazilian Amazon basin. The results found by Marengo et al, which were qualitatively consistent with Kousky (1988), showed that in general the onset progresses toward southeast during mid-October, and then toward the mouth of the Amazon basin near the end of the year. The end dates are earliest in the southeast and progress to the north but the withdrawal being slower than onset.

The purpose of the present work is to emphasize the annual variability of the climatological atmospheric circulation over South America and the rainfall within the Brazilian territory on pentad timescale. A pentad climatology of the precipitation over Brazil based on 24 years (1974 to 1997) of data obtained from raingauge stations will be used. Furthermore, the National Centers for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis data is also used to compute the pentad climatology of the atmospheric circulation over South America. Thus, based on these climatologies this paper provides a detailed comprehensive analysis of the dynamic aspects related to the rainy and dry regimes over Brazil and their associations with the large- and synoptic-scale atmospheric circulation patterns over South America.

2. DATA AND ANALYSIS PROCEDURE

a. Datasets

The main dataset used in this work is the daily precipitation records observed during the 1974-1997 period, which were derived from the raingauge stations that cover most of the Brazilian territory. The raingauge-based data was obtained from ″Instituto Nacional de Meteorologia″ (INMET), “Agência Nacional de Energia Elétrica” (ANEEL) of Brazil and also from some state meteorological centers. This dataset was checked for possible errors through a quality control that eliminates stations containing daily data with many flaws. Means and standard deviations were calculated for each station and the individual values higher or lower than three standard deviations were eliminated. After that, 193 stations were selected containing continuous observations for a total period of 24 years (1974-1997). Figure 1 displays the locations of these raingauge stations over Brazil, showing a good coverage in the northeast, southeast and south regions and part of center-west region. A poor coverage is mainly noticed in the north region, where is located the Amazonian basin. From these selected stations it was made a spatial interpolation from scattered data to a regular grid with horizontal resolution of 1 degree in latitude and longitude with the intention to extend the representation of the rainfall data for the whole Brazilian territory. To perform the spatial interpolation, the method known as inverse of the quadratic distances was used. The interpolated gridded precipitation values specifically located in the areas to the north of Amapá, south of Pará, south of Rondônia, and west and northeast of Mato Grosso should be analysed with care, since there are few stations available for the spatial interpolation in these narrow regions (see Fig. 1). Additionally, to represent the atmospheric circulation in the higher and lower troposphere over South America, the gridded daily dataset obtained from NCEP/NCAR reanalysis project was used. These data have a horizontal resolution of 2,5 degrees in latitude and longitude in the global domain (Kalnay et al., 1996). The variables used in this work were the zonal and meridional components of the wind vector at 850- and 200-hPa pressure levels and sea level pressure (SLP) for the 1974-1997 period.

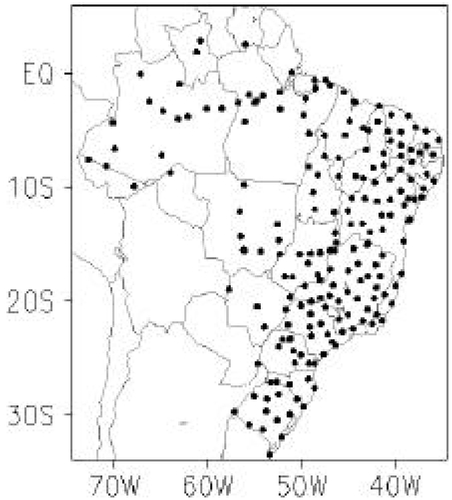

Fig. 1 - Geographical locations of the 193 raingauge stations over Brazil.

Pentad number	Calendar dates	Pentad number	Calendar dates	Pentad number	Calendar dates	Pentad number	Calendar dates
1	*1-5 January*	*21*	*11-15 April*	*41*	*20-24 July*	*61*	*28Oct.-1Nov.*
2	*6-10 January*	*22*	*16-20 April*	*42*	*25-29 July*	*62*	*2-6 November*
3	*11-15 January*	*23*	*21-25 April*	*43*	*30July-3August*	*63*	*7-11 November*
4	*16-20 January*	*24*	*26-30 April*	*44*	*4-8 August*	*64*	*12-16 November*
5	*21-25 January*	*25*	*1-5 May*	*45*	*9-13 August*	*65*	*17-21 November*
6	*26-30 January*	*26*	*6-10 May*	*46*	*14-18 August*	*66*	*22-26 November*
7	*31Jan.-4Feb.*	*27*	*11-15 May*	*47*	*19-23 August*	*67*	*27Nov.-1Dec.*
8	*5-9 February*	*28*	*16-20 May*	*48*	*24-28 August*	*68*	*2-6 December*
9	*10-14 February*	*29*	*21-25 May*	*49*	*29Aug.-2Sep.*	*69*	*7-11 December*
10	*15-19 February*	*30*	*26-30 May*	*50*	*3-7 September*	*70*	*12-16 December*
11	*20-24 February*	*31*	*31May-4June*	*51*	*8-12 September*	*71*	*17-21 December*
12	*25Feb.-1Mar.*	*32*	*5-9 June*	*52*	*13-17 September*	*72*	*22-26 December*
13	*2-6 March*	*33*	*10-14 June*	*53*	*18-22 September*	*73*	*27-31 December*
14	*7-11 March*	*34*	*15-19 June*	*54*	*23-27 September*		
15	*12-16 March*	*35*	*20-24 June*	*55*	*28Sep.-2Oct.*		
16	*17-21 March*	*36*	*25-29 June*	*56*	*3-7 October*		
17	*22-26 March*	*37*	*30June-4July*	*57*	*8-12 October*		
18	*27-31 March*	*38*	*5-9 July*	*58*	*13-17 October*		
19	*1-5 April*	*39*	*10-14 July*	*59*	*18-22 October*		
20	*6-10 April*	*40*	*15-19 July*	*60*	*23-27 October*		

Table 1 - Listing of the pentads numbers and corresponding calendar dates.

b. Pentad climatology

To obtain the pentad precipitation climatology, we first calculated the pentads (sum of accumulated rainfall in 5 days) for each one of the 73 pentads for each individual year (1974 to 1997) following the calendar dates disposed in the Table 1. Subsequently, it was taken the average of the 24 years for each pentad along the year. The same procedure was applied for the NCEP/NCAR dataset to obtain the pentad (5-day averages) climatology of the atmospheric circulation at high and low levels over the South American region.

c. Climatological rainy and dry regimes definition

After the calculation of the 73 climatological precipitation pentads, an analysis of the spatial and temporal evolution of the rainiest and driest regimes areas along Brazil was made. An area defined as rainy (dry) regime occurs when the climatological precipitation is higher (less) than 25 mm (5 mm). The thresholds of 25 mm and 5 mm correspond approximately to 5 mm day^{-1} and 1 mm day^{-1}, respectively. A threshold of 4 mm day^{-1} was considered by Marengo et al. (2001) an indication of the onset of Amazonian rainy season, which corresponds to one unit below the threshold of the climatological rainy regime defined here for the Brazilian territory as a whole.

3. RESULTS AND DISCUSSIONS

Based on pentad climatological precipitation fields over Brazil (Figure 2), a comprehensive analysis of the pentad evolution and spatial distribution of the regions considered as having the climatological rainiest and driest regimes over Brazil along the year was carried out. In these analyses, the dynamic aspects of the large- and synoptic-scale climatological atmospheric circulation patterns at high (Figure 4) and low (Figure 3) levels of the South American sector are also investigated. In the next sub-sections the most significant results of the analyses are discussed and compared with findings in previous studies.

a. Pentad evolution of the regional rainy regimes

The time sequence of the 73 climatological precipitation pentads is shown in Figure 2. Regions that indicate the establishment of the rainiest regime (hereafter referred as RR) can be visualized by the spatial areas containing precipitation higher than 25 mm (regions with shaded contours in green until light purple). The analysis will start from the spring period, in order to identify the transition to the summertime regime which Zhou and Lau (1998) and Kousky (2001) denominated as South American Monsoon.

In the pentads corresponding to September (pentads 50 to 54 in Figure 2), one can notice the positioning of RR area (that is related with the large-scale tropical convection) confined to the northwest section of the Amazonian basin. In the pentad 55 it is clearly observed an abrupt shift of RR from northwestern to the southern Amazon basin, including sectors located in the south of Amazonas and Pará, and north of Rondônia and Mato Grosso. According to Silva Dias et al. (1983) the atmospheric circulation response to the tropical convection is related with the latent heat release, which originates the manifestation of an upper-level anticyclonic circulation. The response of the Amazonian deep convective activity in the superior tropospheric circulation pattern is initially deflagrated during September. In the pentads 53, 54 and 55 (Figure 2) the southward expansion of the rainfall maxima containing 20 mm (shaded contours in yellow that correspond to 4 mm day^{-1}, same threshold defined by Marengo et al., 2001) induce the beginning of the formation of a circulation with counterclockwise turning at 200-hPa level, exactly over central Amazon (see streamlines in the pentads 53 to 55 in Figure 4). This circulation will originate the so-called Bolivian high that together with the downstream cold-core trough form the distinctive features of the South American summertime circulation (e.g., Kousky and Kayano, 1981; Virji, 1981; Horel et al., 1989; Jones and Horel, 1990). Thus, after the abrupt shift of the RR in the pentad 55, such upper-level anticyclonic circulation and the downstream trough become well established during subsequent pentads. Around pentad 55 until 61 the RR region significantly increases with a gradual migration toward central Brazil (Figure 2). At the same time, the Bolivian high also intensifies and moves southward toward central Bolivia while the downstream trough tends to position over eastern Atlantic off the northeast Brazilian coast (see pentads 55 to 61 in Figure 4).

During mid-spring, a striking transition is verified from the pentad 61 to 62 (Figure 2) when occurs a rapid northward expansion of the RR area from southeast to the center-west region of Brazil. As a result, the RR dominates the southeast, center-west and north regions, acquiring an orientation northwest - southeast (NW-SE). This NW-SE oriented band of intense rainfall is frequently associated to the SACZ (e.g., Figueroa and Nobre, 1990; Quadro, 1994; Lenters and Cook, 1999).

Thus, based on this above climatological analyses there are two outstanding moments in the transition of spring to the summertime regime: the abrupt shift of the RR area to the central Amazon during pentad 55 (early October) - that originated the Bolivian high - and the rapid expansion of the RR area from southeastern towards central Brazil during the pentad 62 (early November) - from then onwards the SACZ related precipitation band was generated.

The large-scale characteristics associated to SACZ have been extensively investigated through observational and modeling studies. At low levels, there is a northwesterly flow along the Andes between 10S and 20S, which brings warm and moist air from the Amazon and reinforces the region of high convergence (SACZ axis) stretching diagonally over the South America (Kodama, 1992, 1993; Figueroa, 1997; Lenters and Cook, 1999; and others). At upper troposphere, the main circulation features are the Bolivian high, the associated trough to the eastern Brazil and the presence of the subtropical jet stream elongated over the subtropical South America around 30S (Kousky, 1985; Figueroa et al., 1995; Lenters and Cook, 1997; Marton, 2000; and others).

In the sequence of the climatological pentads shown in Figures 2, 3 and 4 it was possible to identify those aforementioned basic climatological characteristics related to the typical behaviour of the SACZ over South America. For example, from the pentad 62 to 9 of Figure 2 (early November to mid-February), the area represented by the RR includes most of the Brazilian territory, starting in the western Amazon (Acre, Amazonas, Rondônia and south of Pará), going through the center-west (Mato Grosso and Goiás) and reaching the southeast (Minas Gerais, Rio de Janeiro and São Paulo). This wide and long rainy area has a NW-SE orientation and is primarily associated with the SACZ. From the mid-November to early December, the low-level northerly winds turn to northwesterly over the eastern Andes, near 15S –20S and 65W-55W (see vectors wind in the pentads 64 to 67 of Figure 3). Since pentad 67 until around pentad 10 (Figure 3) the mean 850-hPa wind direction is predominantly northwesterly. In the same period, the 200-hPa wind pattern shows the Bolivian high, the downstream trough over the eastern Atlantic off coastal area of the northeast Brazil and the subtropical jet stream positioned around 35S, close to the southern sector of the SACZ-related intense precipitation band (see pentads 67 to 10 in Figure 4). These typical SACZ-related patterns are more evident in the December and January pentads (see Figures 2, 3 and 4).

During January, an interesting feature is observed from the streamlines of the pentads 4 and 5 (Figure 4). A closed cyclonic vortice appears at higher tropospheric levels in the vicinity of Brazilian northeast. This pattern is likely related to the coupling between the main summertime meteorological systems over South America, i.e., the simultaneous manifestation of the Bolivian high, upper-level vortice over northeast Brazil and the SACZ, as suggested by Figueroa (1997) and Chaves and Cavalcanti (2001). Indeed, Kousky and Gan (1981); Gan (1982); Ramirez (1996); and Kayano et al. (1997) documented the importance of the vortices episodes as the principal rainfall-producing system in the interior of the northeast Brazil before of the start of the rainy season (December and January) over this region.

During the peak of the SACZ (December and January) one can see the relatively low precipitation to the northeast and south of Brazil (note the low values in Figure 2, during pentads of the end and beginning of the year). Some authors suggested the existence of a compensatory descending branch over the north and south sides of the SACZ axis, which may lead to drought conditions to the Paraguay and southern Brazil (e.g., Casarin and Kousky, 1986; Nogues-Paegle and Mo, 1997; Gandu and Silva Dias, 1998).

The SACZ-related pattern shows signs of weakening around pentad 10 to 16 when it is observed a gradual break of the NW-SE oriented rainy band over the southeast and center-west regions (Figure 2). Also, during pentads 11 to 15 the wind at 850-hPa weakens over the eastern Andes and progressively changes its predominant direction from northwest to north (Figure 3). Thus, the RR area moves away from southeast region in the pentad 20 (mid-April) and from center-west region of Brazil during pentad 23 (end April), as noted in Figure 2. The withdrawal of summer circulation (Bolivian high and downstream trough) in the upper troposphere occurs around pentads 22 to 25 (Figure 4).

An interesting feature worthy of comment is the role of the slow-moving frontal systems during summertime. The high-frequency of the cold fronts crossing the Brazilian territory during this period, often produce precipitation in the south and southeast (Lemos and Calbete, 1996; Cavalcanti and Kayano, 1999) and eventually organize the tropical convection over Amazon and central Brazil (Oliveira and Nobre, 1985; Oliveira, 1986; Paegle, 1987). Kousky (2001) suggested that these transient frontal systems are also important mechanisms for maintenance and re-establishment of the rainfall band associated to the SACZ.

Another important meteorological system active in the South America during end-summer and autumn is the ITCZ. During March-April period, the ITCZ reaches its southernmost climatological location in the tropical south Atlantic (Hastenrath and Lamb, 1977; Nobre and Shukla, 1996; Zhou and Lau, 2001), modulating the rainy season in the eastern Amazon basin and specially in the north and interior of northeast Brazil (Uvo and Nobre, 1989; Hastenrath and Greischar, 1993; Souza et al., 1998; Souza et al., 2000; Xavier et al., 2000; Souza and Ambrizzi, 2002).

In Figure 2, the first indication of rainfall associated with the ITCZ can be noted in pentads 72 and 73 (end of the year), when the RR area reaches northern Brazil (south of Amapá and center-east of Pará). In January the RR area significantly increases over the whole eastern Amazon and progressively expands toward northeast region of Brazil, affecting the states of Maranhão and Piauí. From mid-February to early-April, the RR area covers most of interior of the northeast, which includes Ceará and western sector of Rio Grande do Norte, Paraíba and Pernambuco (see pentads 9 to 19 in Figure 2). Between pentads of mid-April and end-May, the RR migrates back to the equator, leaving the northeast Brazil and indicating the end of rainy season over that region (see pentads 21 to 30 in Figure 2). Thereafter, the ITCZ continues its seasonal cycle, returning to positions over tropical north Atlantic. Thus, the RR also moves to the north of Brazil, determining the ending of the rainy season in the eastern and central Amazon basin during pentads 31 to 40 (Figure 2).

During end-May, the migration of the RR area towards the northwestern Amazon, which is associated with the large-scale tropical deep convection, results in a complete dissipation of the wavy pattern over South America. As a consequence, an essentially zonal pattern establishes in the upper circulation over the vicinity of the South America, a typical feature of the Southern Hemisphere winter. This is clearly noticed in the pentads of June, July and August, when a zonally west flux covers most of the continent (see streamlines in Figure 4). In addition, the subtropical jet stream at 200 hPa moves equatorward and tends to stay around 25-35S (see shaded contours in Figure 4). During this period, the SLP fields from Figure 3 shows the inland penetration of a high pressure area with anticyclonic circulation originating from the South Atlantic semi-permanent high pressure center (see shaded contours in Figure 3). This pattern is typical of winter and it frequently acts as a blocking region for the frontal systems propagating towards the tropical areas of the South

America (Oliveira, 1986; Ito, 1999). These winter characteristics remain up to pentad 50 as it can be noticed in Figures 2, 3 and 4.

An important rainy regime observed during the winter happens in the eastern part of northeast Brazil. Actually, the RR area initially appears around mid-April (pentad 22 in Figure 2) over the eastern Bahia, Sergipe and Alagoas. In the subsequent pentads, this RR gradually extends along the regions known as “agreste”, “zona da mata” and coastal region of Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia. Such rainy regime is observed until the mid-July (see pentad 40 in Figure 2). The rainfall-producing mechanisms over those regions are closely related to the easterly winds blowing perpendicular to the coast (Rao et al., 1993), which favour the occurrence of a night convergence with the land breeze (Kousky, 1980). Other studies (e.g., Yamazaki and Rao, 1977; Shan, 1990; and Mota, 1997) found the existence of easterly waves around these regions whose manifestation is more frequent during the winter (Silvestre, 1996). In the 850 hPa wind fields shown in Figure 3, we can observe the easterlies flowing perpendicular to the eastern coast of northeast Brazil, which tends to have more intense values from June to August (see vectors in pentads 31 to 50 in Figure 3). These intense winds are driven by the subtropical high pressure center that occupies most of the tropical South Atlantic (see shaded contours in Figure 3).

A small region located in the far north of Brazil (state of Roraima) presents its rainy regime from pentad 23 until approximately pentad 48 (Figure 2). On the other hand, the RR area is observed over the northwestern Amazon basin all year long (Figure 2).

Finally, in the south of Brazil (Rio Grande do Sul, Santa Catarina and part of Paraná) there are two predominant distinct periods of RR. They occur during spring (between pentads 52 and 65) and winter (between pentads 26 to 46). The frequent passage of cold fronts is the main meteorological system responsible for the rainfall maxima observed during these both rainy periods (Oliveira and Nobre, 1985; Satyamurti and Mattos, 1989; Lemos and Calbete, 1996; Cavalcanti and Kayano, 1999). However, other authors suggested that the manifestation of meso-scale convective complex (MCC) may play relevant role on the RR noted over that region (e.g., Guedes, 1985; Velasco and Fritsch, 1987; Figueiredo and Scolar, 1996; Silva Dias, 1996). MCC is preferentially formed in the night period over the Paraguay, northern Argentina and western south Brazil. During its mature phase, MCC tends to displace towards the south, southeast and center-west of Brazil bringing severe weather conditions to these regions (Guedes et al., 1994). During those rainiest periods over southern Brazil, the configuration of the atmospheric patterns in the lower and upper troposphere (Figures 3 and 4) resembles the typical features that contribute to the formation and maintenance of MCC. At 850 hPa level there is a predominance of northerly winds over the east of the Andes, between 15S and 20S (see vectors in Figure 3). Liebmann et al. (2001); Kousky (2001) and Marengo and Soares (2002) reported that this northerly stream brings Amazonian moist and warm air for the subtropical South America. At 200 hPa level the subtropical jet stream is positioned over subtropical South America around 35S, whose location is to the south of the region where MCC events are often observed (see shaded contours in Figure 4). These climatological patterns are similar to those reported by previous works (e.g., Guedes, 1985; Velasco and Fritsch, 1987; Sugahara et al., 1994; Silva Dias, 1996).

b. Pentad evolution of the regional dry regimes

In this section, the pentad evolution of the driest regime areas (hereafter referred as DR) occurring over Brazil along the year is described. This DR is visualized by the spatial areas containing rainfall less than 5 mm (areas with shaded contours in dark red in Figure 2).

In the pentad 25 (early-May), the beginning of the DR area is observed over the south of Bahia and north of Minas Gerais (Figure 2). In the subsequent pentads there is a gradual expansion of this DR area moving toward the interior of northeast and also to the southeast and center-west regions of Brazil. Around pentad 33 (mid-June), the DR area dominates part of the southeast, the whole center-west region and interior of the northeast Brazil. In the pentads 43 and 44 (early

August) the large spatial extension of the DR includes most of Brazil, characterizing the peak of the dry season on the country (Figure 2). The dynamic aspects related to the establishment of such dry regime are modulated by large-scale circulation patterns over South America. During June, July and August, the low level atmospheric pattern is characterized by the inland penetration of the high pressure area with associated anticyclonic circulation which is modulated by the South Atlantic subtropical high moving towards the interior of Brazil (see shaded contours in Figure 3).

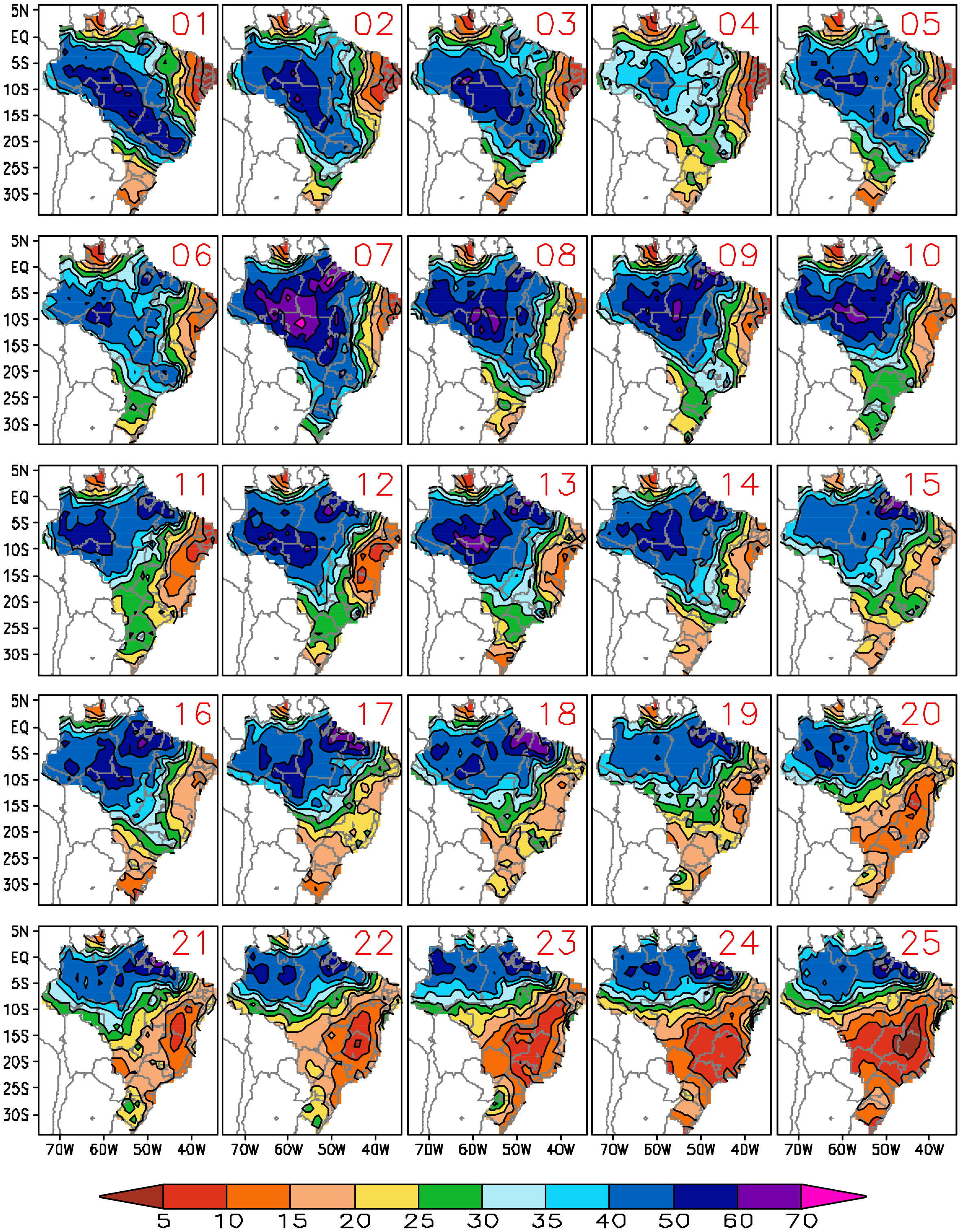

Fig. 2 - Pentad precipitation climatology (mm) over Brazil. The numbers above of figures correspond to the pentads 1 to 73 throughout the year, following the calendar dates disposed in the Table 1. The shaded contours interval is shown in the base colorbar.

At the same time, the upper-level circulation exhibits an essentially zonal westerly flow over South America below 15S (see streamlines in Figure 4). In this period, the low-level features and the positioning of the subtropical jet stream tend to favour the typically zonal displacement of the frontal systems towards South Atlantic (Oliveira, 1986; Ito, 1999). Therefore, the precipitation observed in the south of Brazil is primarily due to the passage of cold fronts while the remaining Brazilian regions acquire an essentially dry regime.

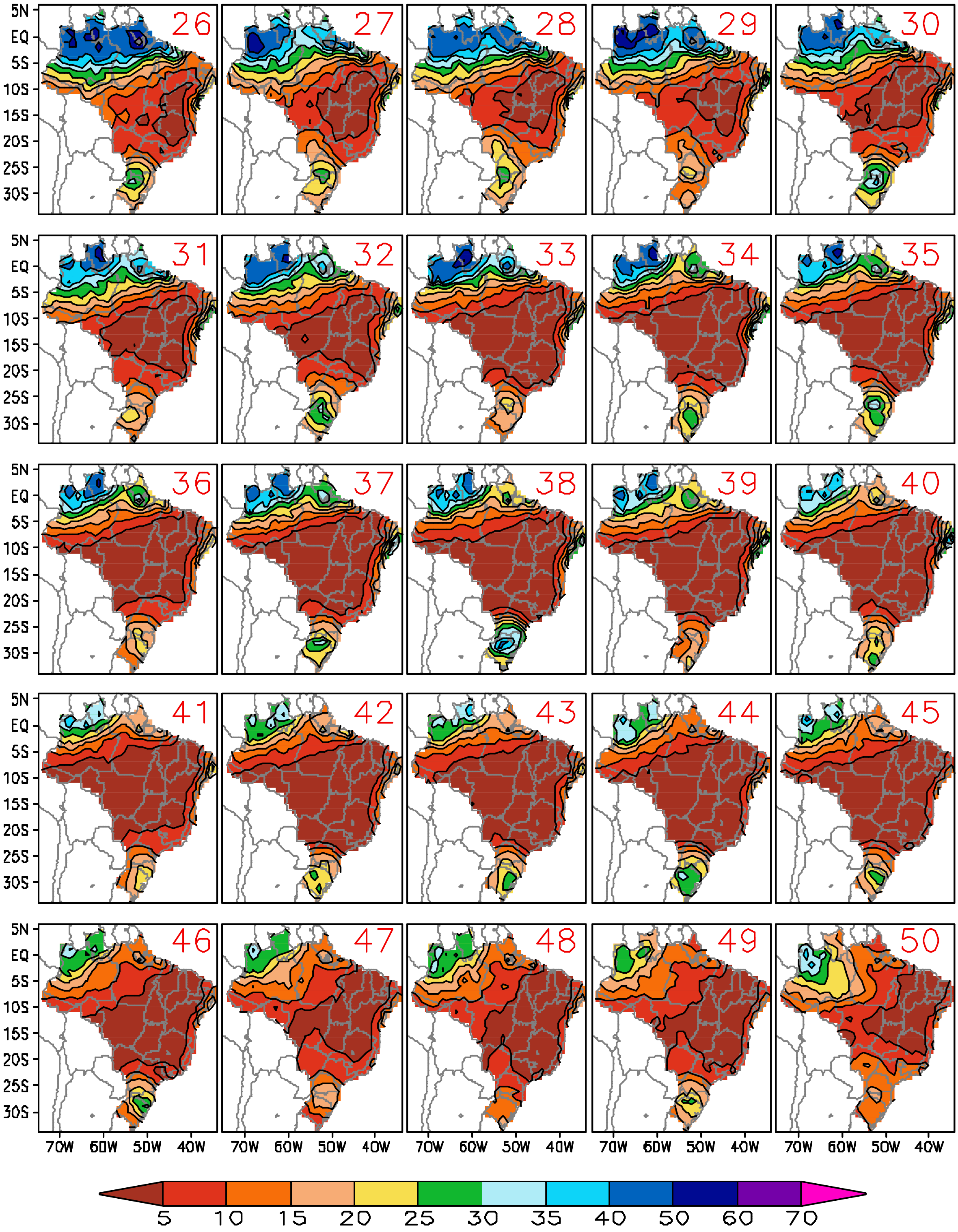

Fig. 2 – Continuation...

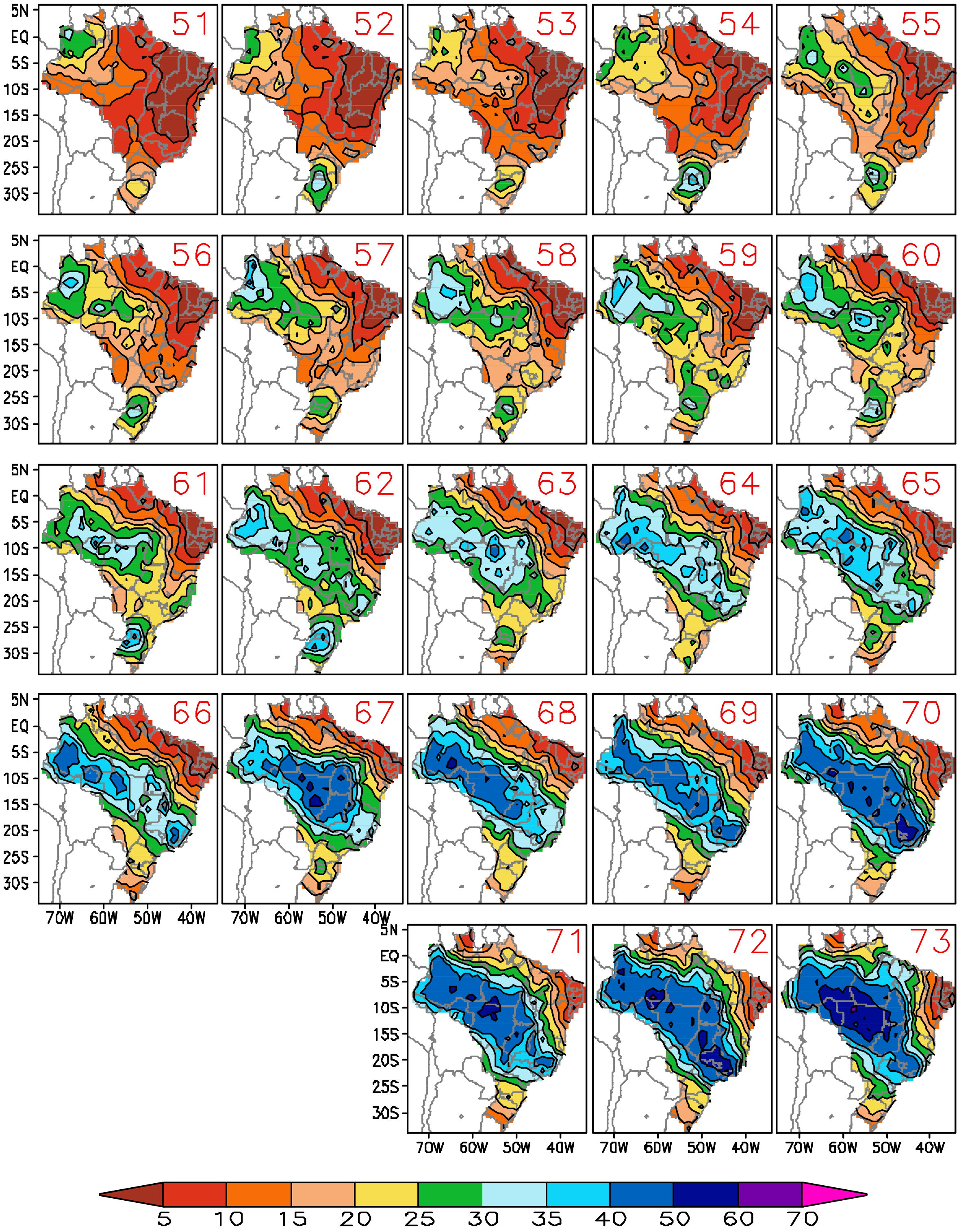

Fig. 2 – Conclusion.

Around pentads 50 and 53 (mid-September), a gradual northward expansion of the DR area is observed, indicating the end of the dry season over the southeast and center-west regions (Figure 2). Thereafter, the DR area acquires positions predominantly restricted to the northeast of Brazil, remaining there until pentad 66 (Figure 2). On the other hand, the far northwestern Amazon and the south region (Rio Grande do Sul, Santa Catarina and part of Paraná) do not present a DR area along the year.

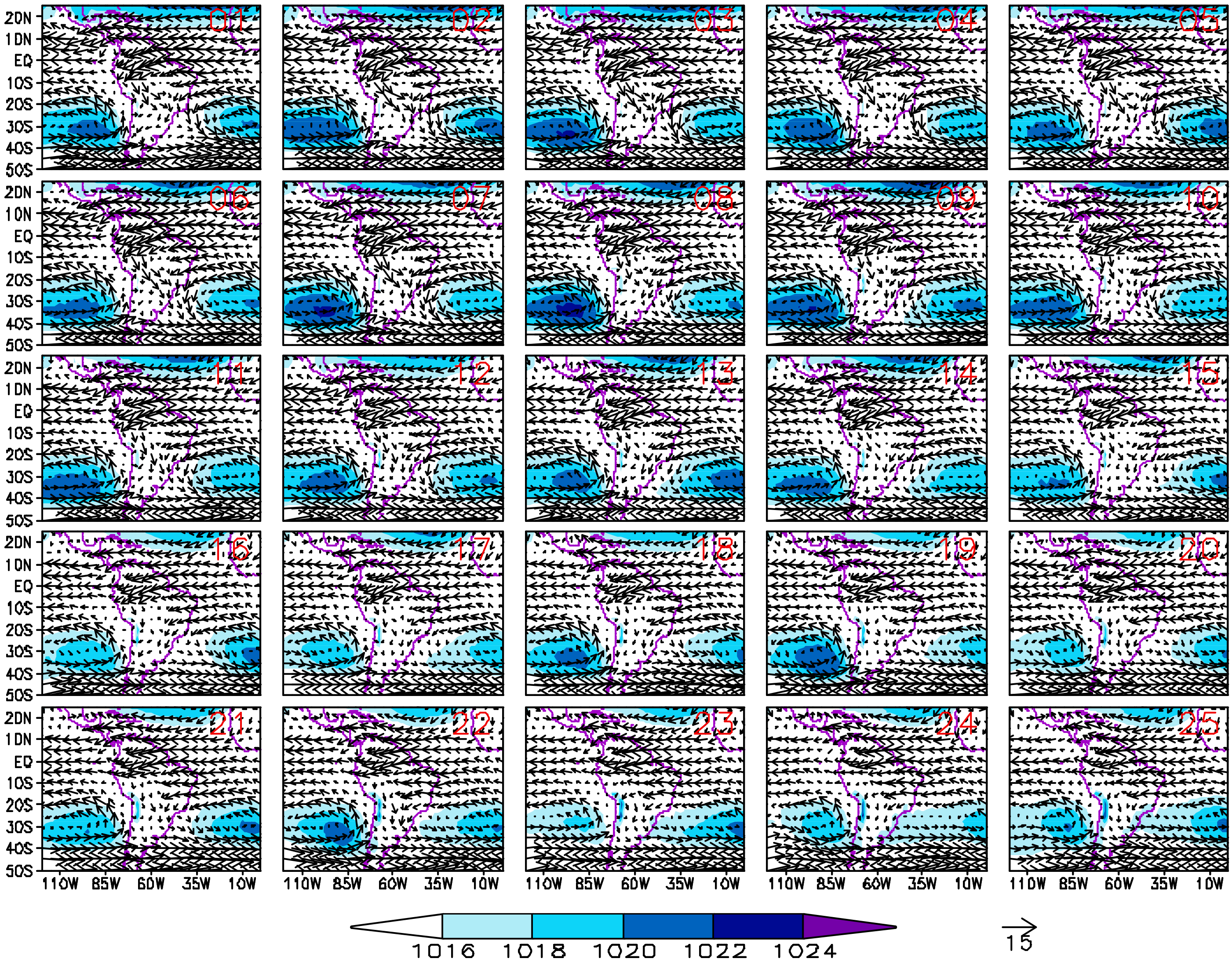

Fig. 3 - As in Fig. 2, but for the low-level (850 hPa) atmospheric circulation (wind vectors in m/s) and sea level pressure - SLP (shaded contours in hPa) over South America. The SLP shaded contour interval is shown in the base colorbar.

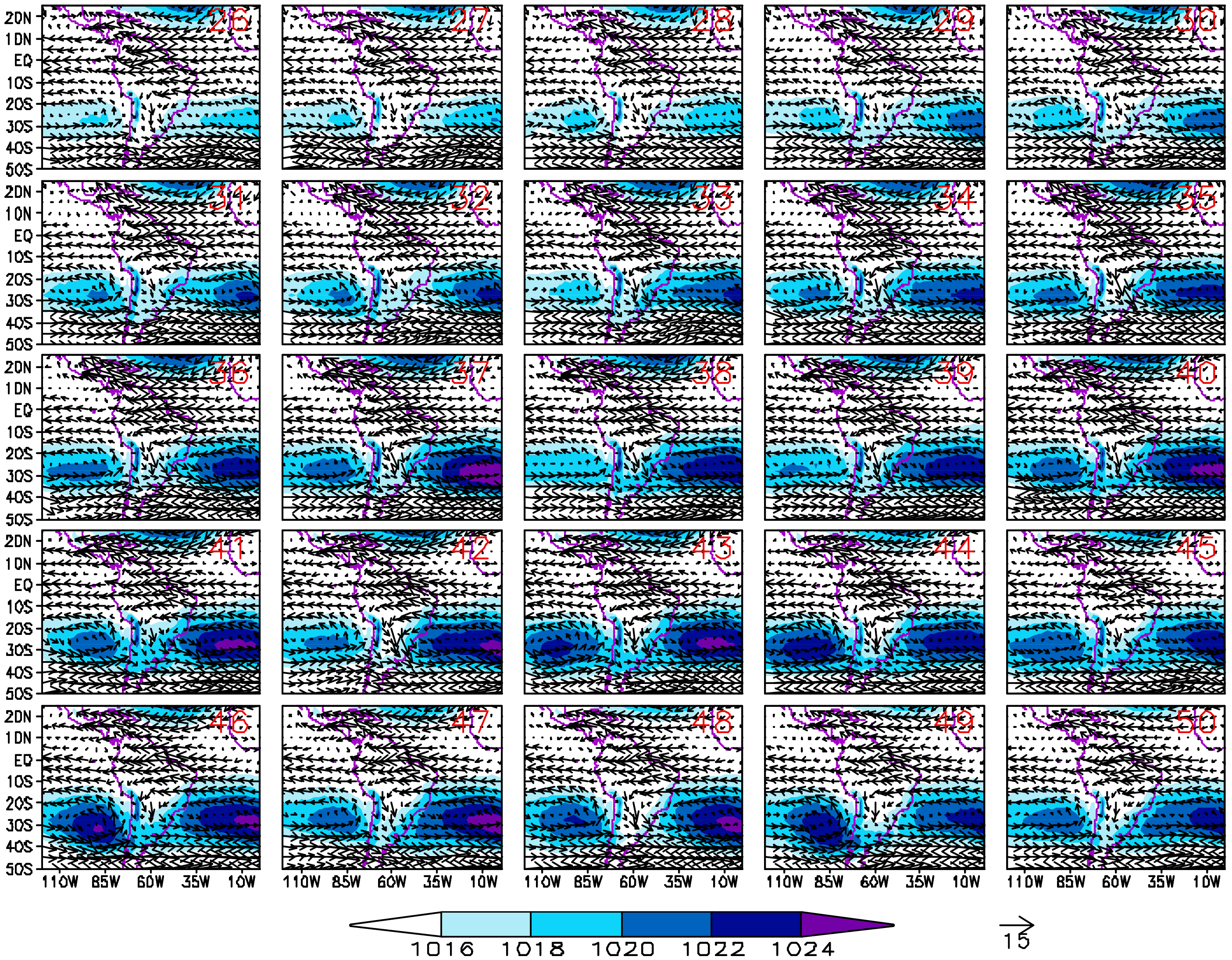

Fig. 3 – Continuation...

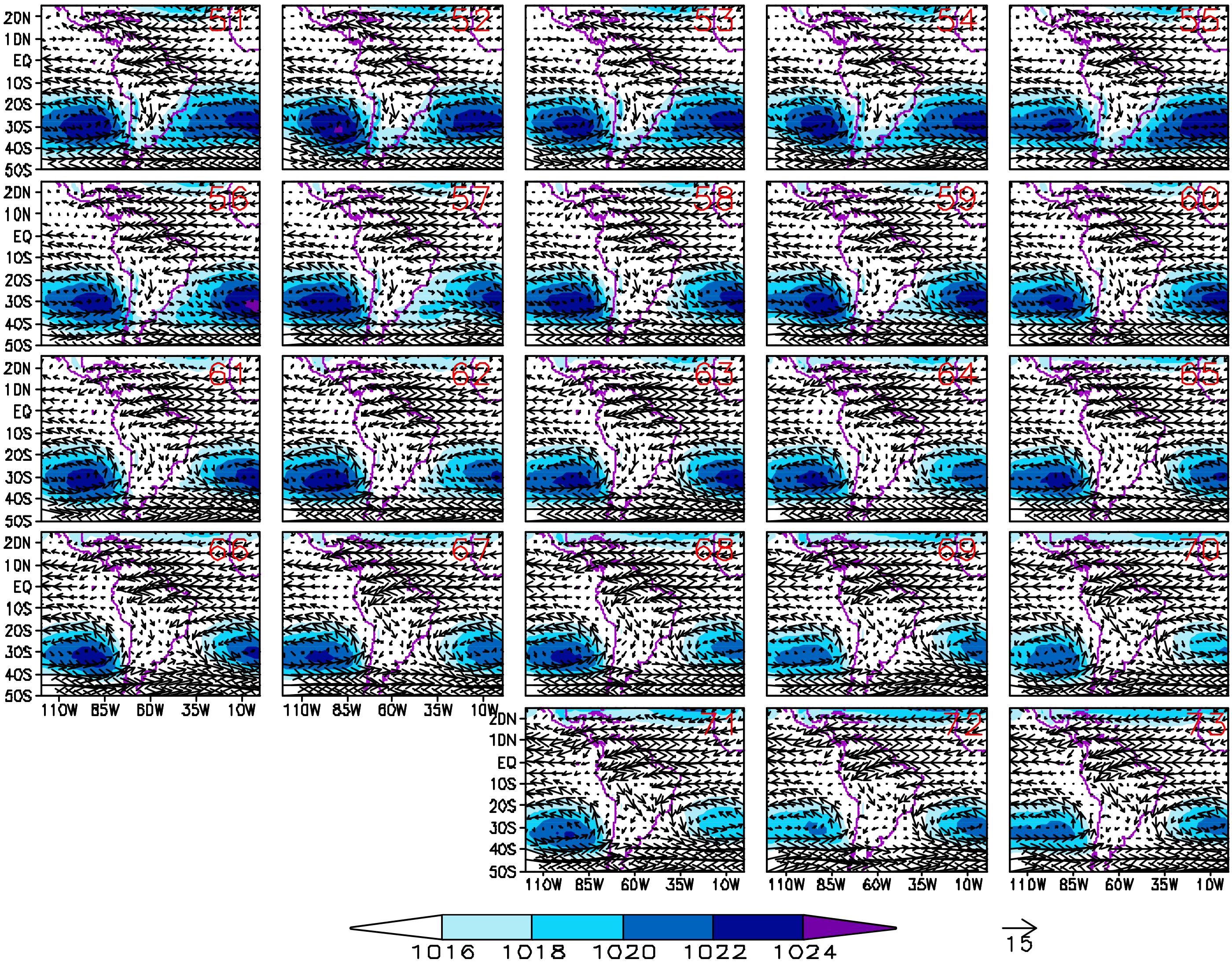

Fig. 3 – Conclusion.

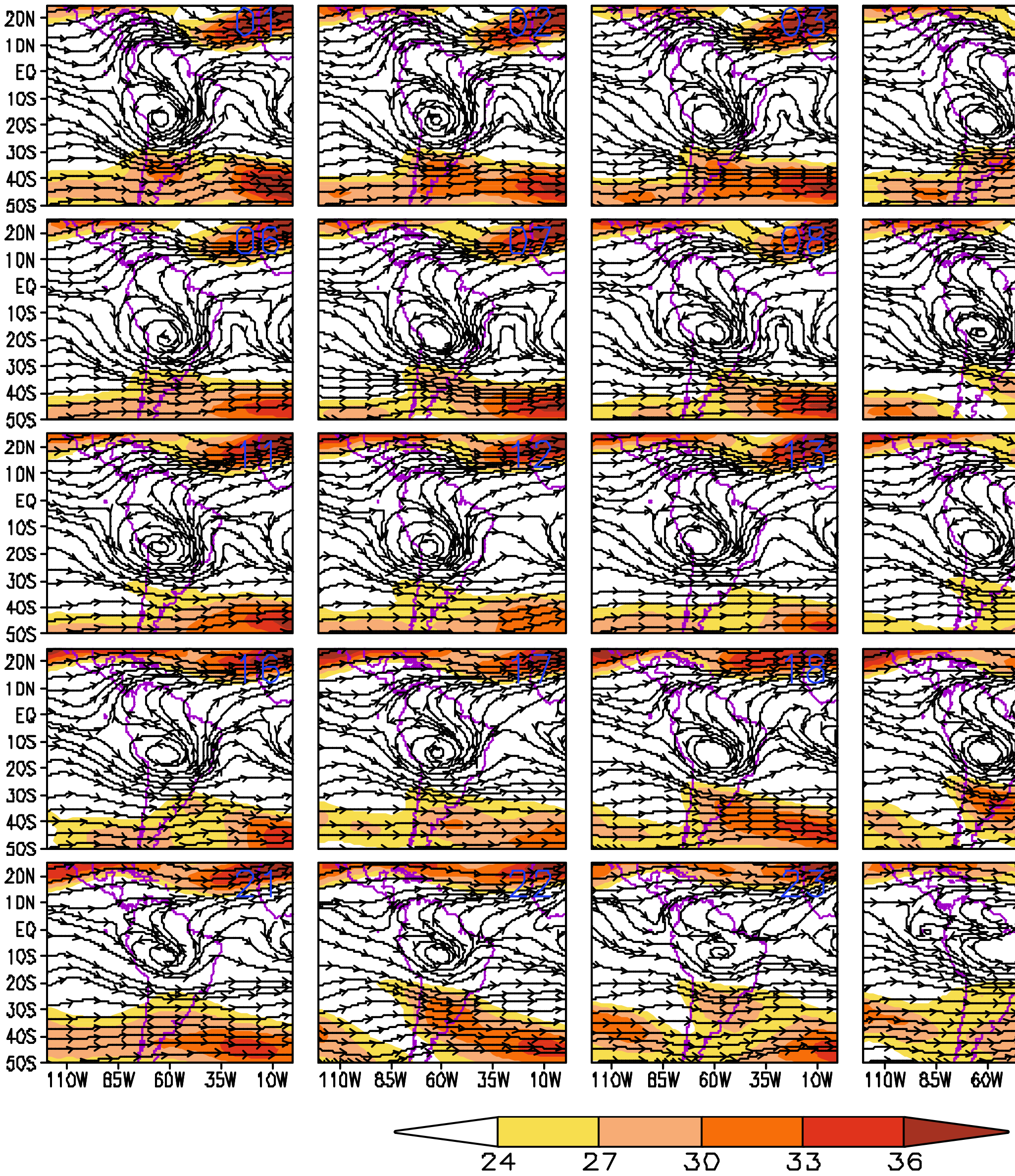

Fig. 4 - As in Fig. 2, but for the high-level (200 hPa) atmospheric circulation (streamlines in m/s) and intensity of the wind (shaded contours in m/s) over South America. The shaded contour interval is shown in the base colorbar.

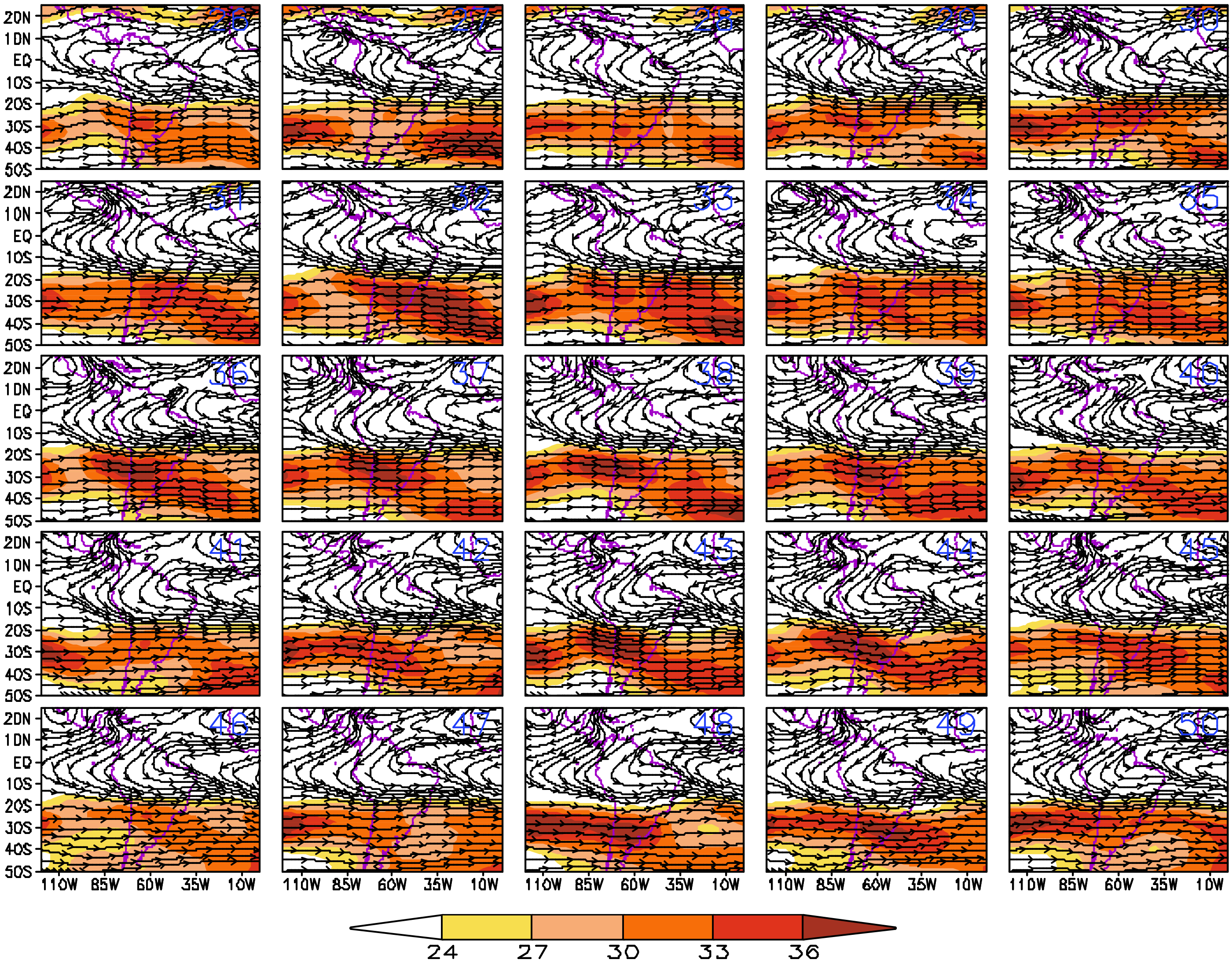

Fig. 4 – Continuation...

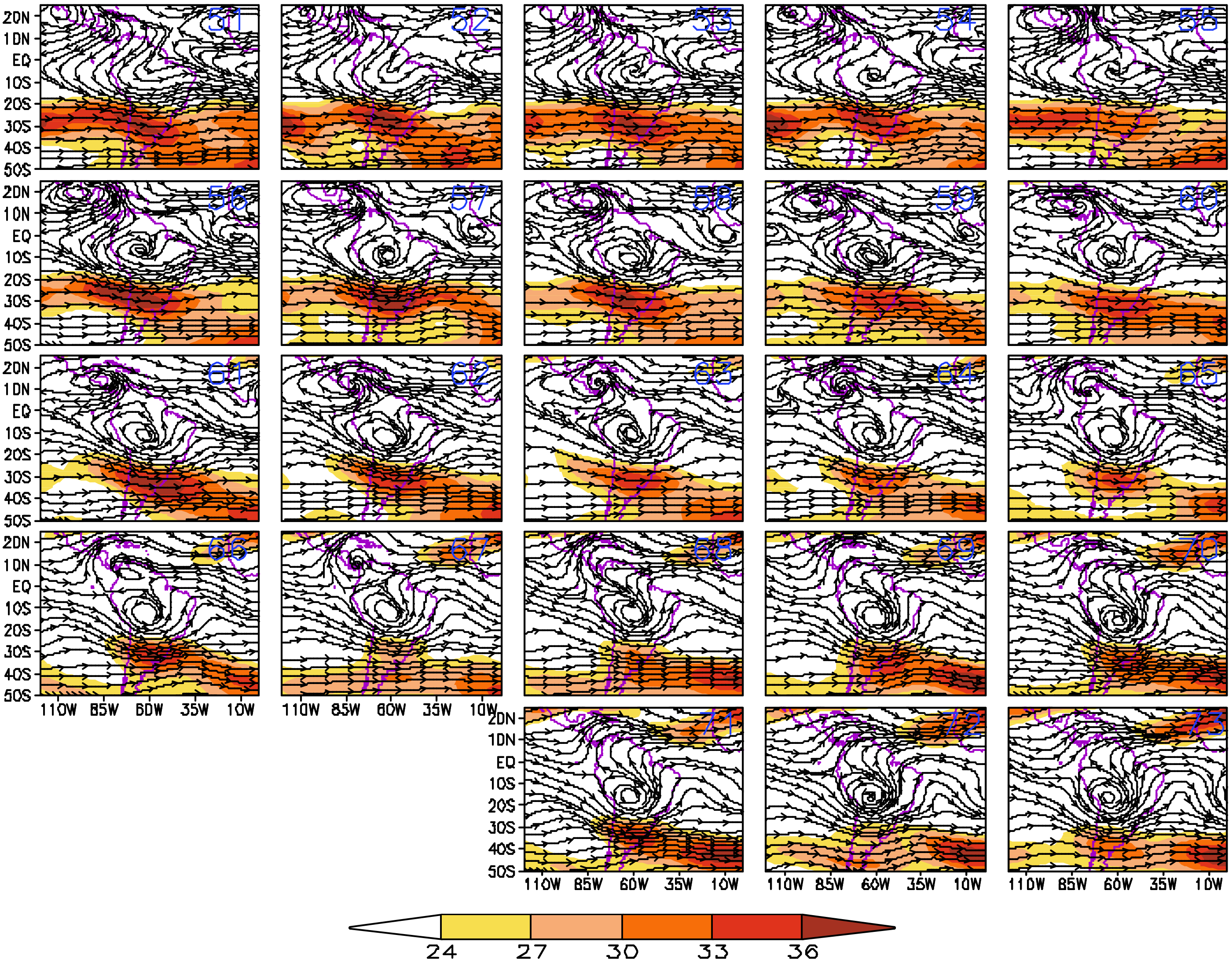
Fig. 4 – Conclusion.

4. CONCLUDING REMARKS

This work presented a pentad precipitation climatology over Brazil calculated from 24-years (1974-1997) of raingauge-based data covering most of the Brazilian territory. The NCEP/NCAR reanalysis data for the same period was used to compute the pentad climatology of the atmospheric circulation over South America.

Based on climatological precipitation fields over Brazil, we have defined the areas of the rainiest (driest) regime, which are represented by the spatial regions containing a threshold higher than 25 mm (less than 5 mm). Thus, a detailed comprehensive analysis concerning the pentad evolution of the areas containing such rainy and dry regimes occurring on regional level over Brazil along the year was described in this paper. The analyses focused on more relevant dynamic aspects related to the different precipitation regimes over Brazil and their associations with the large- and synoptic-scale atmospheric circulation patterns in the lower and upper troposphere over South America. A brief but consistent discussion of the main patterns related to the pentad climatological cycle of the SACZ; ITCZ; low-level features associated with the northerly winds along the eastern Andes, tropical easterlies and the subtropical high pressure centers in the Atlantic; and the high-level features associated with the Bolivian high, downstream though and subtropical jet stream in the vicinity of the South American continent is presented.

This work is a first step to a better understanding of the Brazilian precipitation regime on pentad timescale. The knowledge of such pentad climatologies can provide additional informations for the management and decision-makers of the agriculture and hydrology activities. Furthermore, these climatologies may help future studies of interannual and intraseasonal climate variability.

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