ANNUAL CYCLE OF PRECIPITATION AND MOISTURE CHARACTERISTICS OVER BRAZIL

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ABSTRACT

Convective precipitation over tropical Brazil is characterized by strong annual variation of precipitation. This precipitation is associated with large scale features such as Intertropical Convergence Zone (ITCZ) over the northeast Brazil in austral autumn, and with South Atlantic Convergence Zone (SACZ) over the region from northwestern Brazil to the southeast. Over these regions convective activity begins in spring, at its peak in summer and seldom appears in winter. This sequence of events seen in the present study using the upper tropospheric wind data and the moisture parameters.

1. Introduction

Tropical Brazil is characterized by strong annual variation of rainfall, with heavy rainfall in austral summer and scanty rainfall in austral winter. In some parts of Brazil heavy rainfall occurs in autumn, such as in the northeast Brazil, whereas in the southeastern Brazil it occurs throughout a year (Rao and Hada 1995).

Summer precipitation is largely associated with broad and large zone of convection oriented from the northwest to the southeast Brazil and projecting into the Atlantic ocean, known as as South Atlantic Convergence Zone (SACZ) (Kodama 1992). This convective activity is seen over a large region of the northwestern South America in austral spring, and as the spring progresses this activity intensifies and spreads over Amazon Basin, central Brazil and then over the southeastern Brazil by summer (Horel et al. 1989). During austral autumn this large scale convective activity migrates northward and westward, and by austral winter it occurs a position that is over central America and adjacent waters of the Pacific. During austral spring the convective activity and the associated precipitation returns to the Amazon Basin. This sequence of events is referred to as the annual cycle.

The convective activity is largely connected to atmospheric circulation over South America. The principal features of the upper troposphere during summer are a closed anticyclone over Bolivia, known as Bolivian high, a downstream trough located to the east of it, and a subtropical trough located to the southeast of the high (Virji 1981; Lenters and Cook 1997). In order to understand the sources for the development and maintenance of these upper tropospheric features many linear and nonlinear modelling studies were done and concluded that as the summer progresses, strong latent heat release accompanying deep convcetion over the subtropical highlands and the southern portion of the Amazon Basin give rise to the Bolivian high (Silva Dias et al. 1983; Gandu and Geisler 1991; Lenter and Cook 1997). However, disgnostic studies reveal a predominant role of sensible heating in warming up the mid-troposphere over the central Andes during pre-rainy season (Rao and van de Boogaard 1989). In the present study we present the annual cycle of precipitation derived from the reanalysis of

National Center for Environmental Prediction (NCEP), and the corresponding upper atmospheric features and moisture characteristics over the South American region.

Data

The precipitation and the atmospheric circulation data used in the present study are the global analysis on a 2.5°×2.5° latitude-longitude grid from the NCEP reanalysis for the period 1982-94. The model used for the NCEP reanalysis is the medium range forecast T62 model, which is identical to the one used for the operational analysis of early 1994 at the National Meteorological Center (NMC), except for the horizontal resolution. The number of vertical levels available on pressure coordinates is 17, up to 25 hPa, but for the present purpose we used the data at 1000, 925, 850, 700, 600, 500, 400, 300 and 200 hPa levels only. The variables used for the present study are precipitation, precipitable water, specific humidity, and zonal and meridional horizontal winds.

Results and discussion

Figure 1 presents an annual cycle in terms of a series of bi-monthly mean precipitation over South America in mm/day. The climatological mean of the data are for the period 1982-94. Over the Amazon and the southeastern regions maxima precipitation are seen mainly in December and January, whereas over the northeastern region the maximum rainfall is seen around March and April. This difference could be due to different large scale activities causing rainfall over these regions. Other important features seen from these figures are that the length of rainy season over the Amazon region is much longer than over the other two regions, and monthly mean rainfall is much higher over the northeastern region during the rainy season, and lowest in the southeastern region.

In these figures one can see two well defined precipitation zones associated with large scale characteristics: one extends from the tropical South America toward the northeast, located close to the equator, which is a component of the Intertropical Convergence Zone (ITCZ), and the other extends toward the southeast, referred to as the SACZ. These precipitation zones experience large seasonal variations, as higher values of precipitation are seen in the austral spring, summer and autumn (September through April) than in winter (May through August) over the mainland of Brazil.

Figure 2 presents annual cycle of climatological streamlines and isotechs over South America at 200 hPa for the bi-monthly periods. In September-October (austral spring) the anticyclone over Bolivia and the trough over the northeast Brazil begin to develop. As the season advances, in the summer months the anticyclone and the trough are well established. The flow becomes more zonal over the continent during the winter season (May through August).

Figure 3 shows the precipitable water (PW) calculated over South America for the same six bi-monthly periods. It is calculated by using specific humidity, q:

$$PW = \frac{1}{g}\int_{p_t}^{p_0} q\,dp$$

Where pt is pressure at 300 mb, and p0 is at 1000 mb, and g is acceleration due to gravity. Higher PW is seen over the regions of intense convection such as the SACZ, ITCZ and the Amazon regions in summer months than in the winter months. Seasonal variations of PW over land areas are higher than over the ocean areas, due to the higher temperature variations. As higher PW does not necessarily lead to high precipitation over that area, we calculated vertically integrated moisture flux and its convergence over South America. Vertically integrated moisture flux, Q is calculated from:

$$Q = \frac{1}{g}\int_{p_t}^{p_0} qVdp$$

Where V is the horizontal wind vector. During the austral summer, the moisture flux is mainly westward from the tropical South Atlantic into the north South America due to the trade winds, and eastward in the higher latitudes in the higher latitudes (figure not shown).

Figure 4 shows divergence of vertically integrated moisture flux in mm/day. This is calculated by

$$D(Q) = \nabla.Q$$

Negative values indicate convergence and positive values indicate divergence. During the summer months convergence is seen over the Amazon region, the northeast and the southeast Brazil. During the winter months convergence is seen only over the northwestern part of South America, coinciding with the region of high convection as seen figure 2. Comparison of figures 2 and 5 show that they are well comparable over the tropical land areas. This suggests that the annual cycle of precipitation over South America can be well understood using the atmospheric data of NCEP reanalysis. However, spurious results over the mountainous regions show that they are still less reliable over there.

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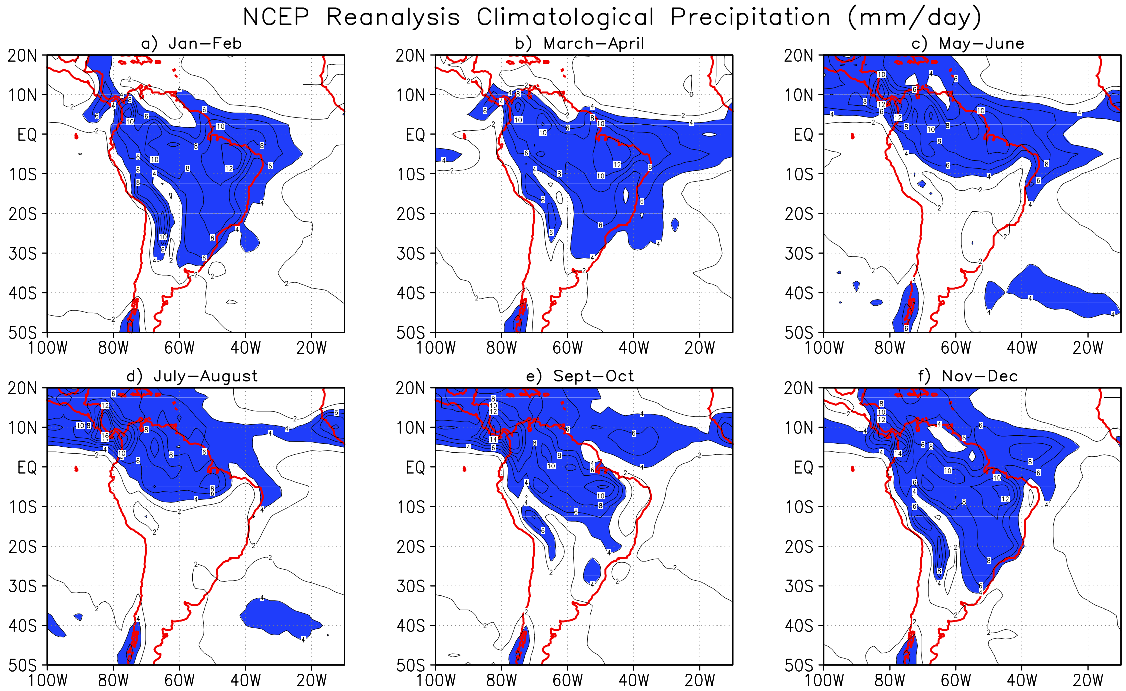

Fig. 1. Annual cycle of bi–monthly mean NCEP reanalysis climatological (1982–94) precipitation in mm/day: a) Jan–Feb, b) March–April, c) May–June, d) July–August, e) Sept–October and f) Nov–December.

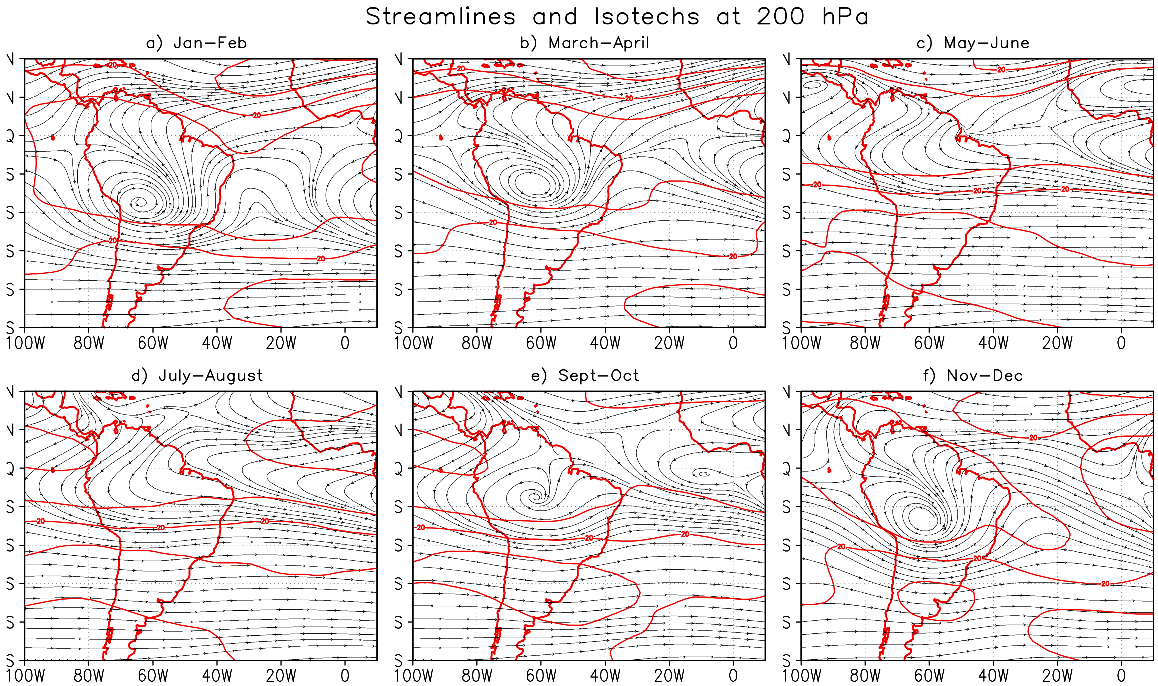

Fig. 2. Same as Fig. 1 except for the streamlines and isotechs at 200 hPa.

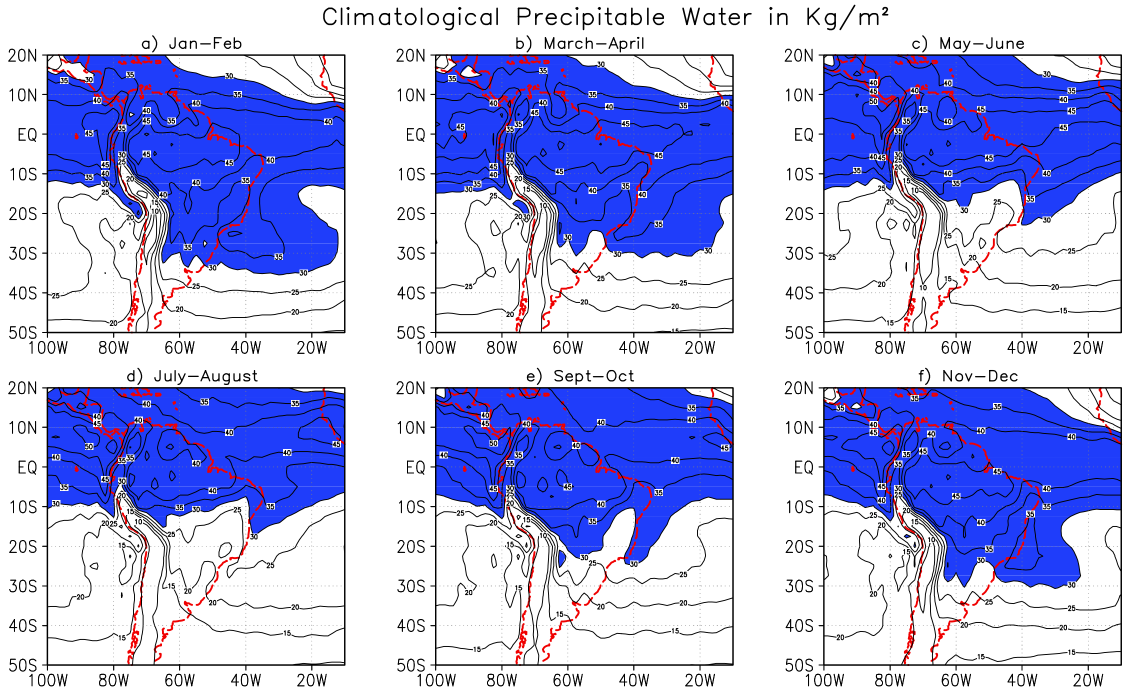

Fig. 3. Same as Fig. 1 except for the precipitable water (Kg/m²). Values greater than 30 are shaded. Contour interval is 5 Kg/m²

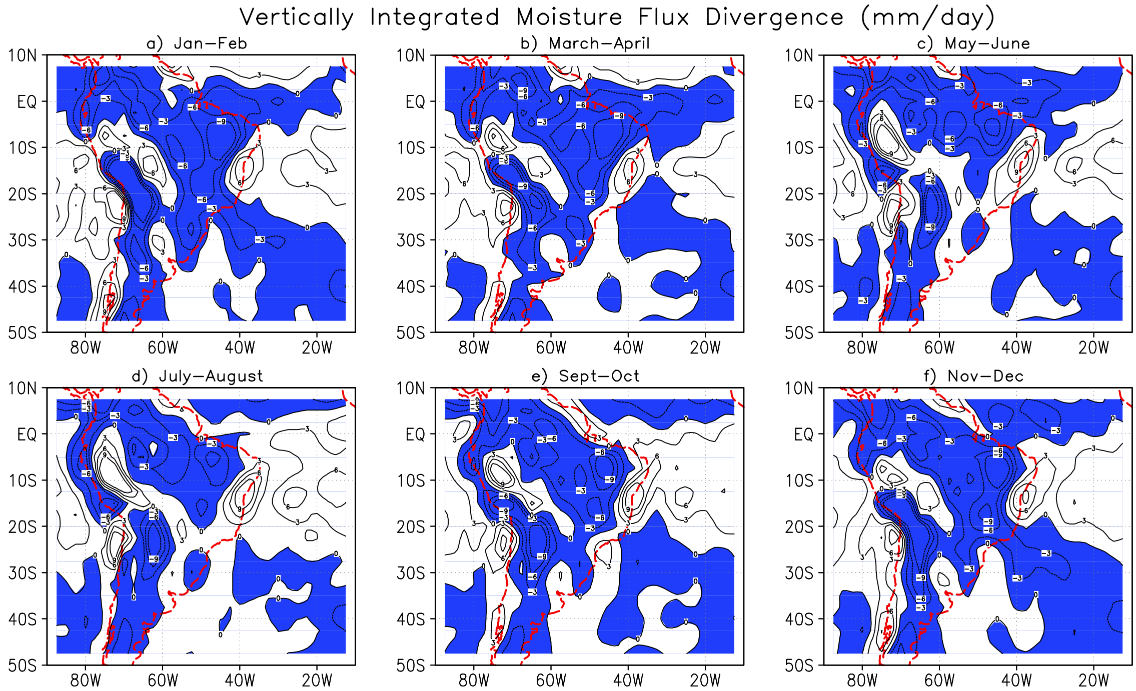

Fig. 4. Same as Fig. 1 except for the vertically integrated moisture flux divergence (mm/day). Negative values (convergence) are shaded. Contour interval is 3 mm/day