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ANNUAL CYCLE OF THE SOUTH AMERICAN MONSOON SYSTEM

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1. INTRODUCTION

The South America monsoon system plays an important role on the precipitation and circulation regimes over the continent. Over several areas of the monsoon region there is a quick increase of precipitation during spring (SON) and a reduction in March and April. The austral summer, DJF, is the rainy season in these areas, with maximum observed precipitation (Paegle et al., 2002). The monsoon onset and duration affect several economic and social activities, as agriculture planning and management of hydrological resources. Although the South American continent does not present a classical typical wind monsoon characteristic, like in Asia or India, several studies have indicated monsoon features over South America. Removing the annual mean of the low level wind, it is possible to identify the wind reversion, as shown by Zhou and Lau (1998). The seasonal cycle has a strong contrast between summer and winter, discussed in several studies, as Rao et al. (1996), Gan et al. (2004). The rainy season in central and southeastern South America regions are closely linked to the monsoon lifecycle. The initial phase of the South America Monsoon System (SAMS) occurs during SH spring (sep-nov), when there is a migration of the convection from the extreme NW South America towards central Amazonia. This migration has been associated with the intense atmospheric heating from the surface (Nogués-Peagle et al. 2002). The SAMS reach the maximum intensity during the SH summer, when there is a change in the atmospheric circulation and maximum precipitation over central Amazonia and Southeastern Brazil, associated with the Bolivia High, South Atlantic/Northeast Upper Level Cyclonic Vortice, and South Atlantic Convergence Zone (SACZ), (Grimm, 2005).

The onset and demise of the rainy season over these regions have been analyzed using OLR, precipitation and wind components (Kousky, 1988; Marengo et al., 2001; Gan et al., 2004, Zhou and Lau, 1998). Fasullo and Webster (2003) used another criterion to identify the onset of the Indian monsoon, based on variables of the hydrological cycle of a certain region in India. Therefore, in this study, atmospheric features associated with the onset and demise of the South America Monsoon System (SAMS) are analyzed based mainly on the vertically integrated humidity transport. The SAMS lifecycle is analyzed discussing the relations with precipitation, humidity and wind field at low and high levels.

2. DATA AND METHOD

Daily reanalysis data of wind components and specific humidity are obtained from the NCEP/NCAR reanalysis (Kalnay et al, 1996). Monthly precipitation data are obtained from CMAP (Xie and Arkin, 1997). The analyzed period is 1988 to 2004. The analyses were performed based on the time averaged vertical (1000-700) integrated specific humidity (VISH), time series of zonal and meridional wind components at low and high levels, specific humidity and precipitation, and the Fasulo and Webster index, for several key areas of South America. The former analysis considers the index between –1 and +1, and the criteria that the monsoon onset occurs when the index changes from negative to positive and the opposite to the demise. In the present analysis only the mean behaviour is analyzed. The interannual variability will be shown in a more detailed discussion in a complete paper.

3. RESULTS

There is a distinct difference in the vertically integrated moisture flux from the winter to the summer months over South America (Fig.1). During the winter months, the strongest moisture flux occurs over Northeast Brazil, from southeast to northwest. In the summer months, the strongest flux occur over Amazonia (from Northeast to Southwest) and also over the South America Low Level Jet (SALLJ) region (from Northwest to Southeast). The annual cycle of moisture and wind flow over the northern sector of the La Plata basin, in South America, shows large seasonal

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differences (Rodrigues and Cavalcanti, 2006). The precipitation in this sector is related to the SACZ and to the monsoon behavior in the summer months.

Besides the differences already mentioned, in the position of maximum moisture flux, between summer and winter, there are differences in the flux direction, in areas 1 (0-10S/70-60W), 2 (0-10S/60-50W) and 3 (10-15S/60-55W). Areas 1, 2 and 3 present zonal flux westward in the winter, while in the summer, the flux is mainly southwestward over areas 1 and 2, turning to southeastward over area 3. Besides the seasonal changes in these areas, there are differences also in other areas of the SAMS. Over the southern sector of Northeast there are changes from northwestward flux in the winter to southwestward flux in the summer. Over the northern sector of Northeast, the flux is also northwestward in the winter, turning to westward in the summer. The flux also changes from eastern to southwestern over the northern sector of Southeast. Seasonal differences are also seen over the extreme northern South America. The flux is strong in the summer toward Amazonia, while in the winter it is weak and westward. Therefore, the seasonal changes of moisture in the monsoon region are related to the moisture flux contributions from these several areas around the core of the SAMS, which was considered as area 3.

The lifecycle is discussed based on wind components, magnitude of specific humidity and vertically integrated moisture flux averaged in area 3. The maximum magnitude of specific humidity occurs from middle November to middle April, when there is a reduction to minimum values in July and August (Fig.2). This behaviour is consistent with the increase of precipitation in November, indicating the beginning of the rainy season in the core of the SAMS, that continues up to march, with the highest values in DJF (SH summer) (Fig.3). There is minimum precipitation in JJA and a considerable increase from September to November. This lifecycle is also consistent with the vertically humidity transport previously mentioned. The changes in the zonal wind component at low levels, from positive values (end November to March) to negative values (April to beginning November) (Fig.4), the VISH index (positive from end-November to March and negative from April to end November) (Fig.5 and Fig.6) can represent the climatological mean onset and demise of the SAMS.

4. CONCLUSION

This preliminary study shows the seasonal variability of moisture flux in several regions of SAMS, and that the moisture flux and the zonal wind component in the core of SAMS can indicate the lifecycle of the rainy season in the region**.** A similar analysis considering the interannual variability in pentadal scale is in progress to establish the range of the lifecycle variability. Analysis of pentadal precipitation variability in areas of southeastern Brazil in connection with the monsoon life cycle is also in development.

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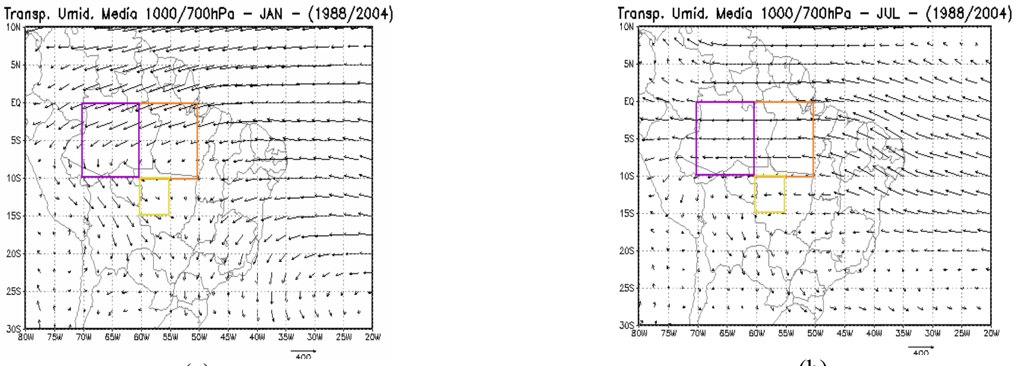

(a) (b)

Fig 1 - Vertically integrated moisture flux between 1000 and 700 hPa over South America: (a) January and (b) July

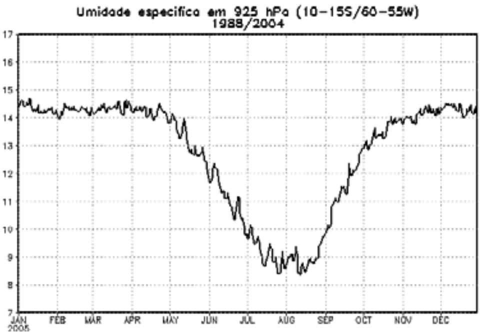

Fig 2 – Specific humidity (kg/g) at 925 hPa over area 10-15S/60-55W.

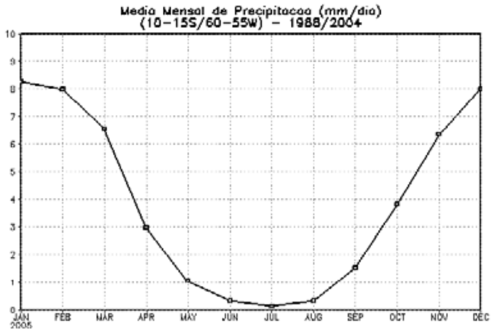

Fig 3 – Precipitation (mm/day) over area 10-15S/60-55W.

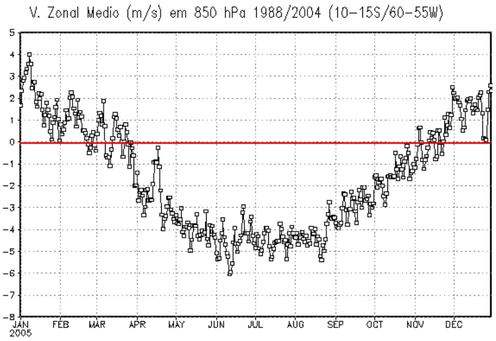

Fig 4 – Zonal wind component (m/s) at 850 hPa over area 10-15S/60-55W.

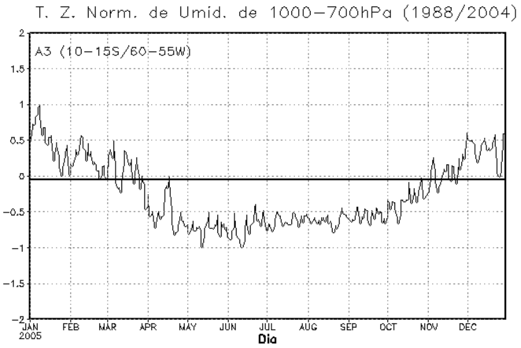

Fig 5 – Index VISH for zonal componentover area 10-15S/60-55W.

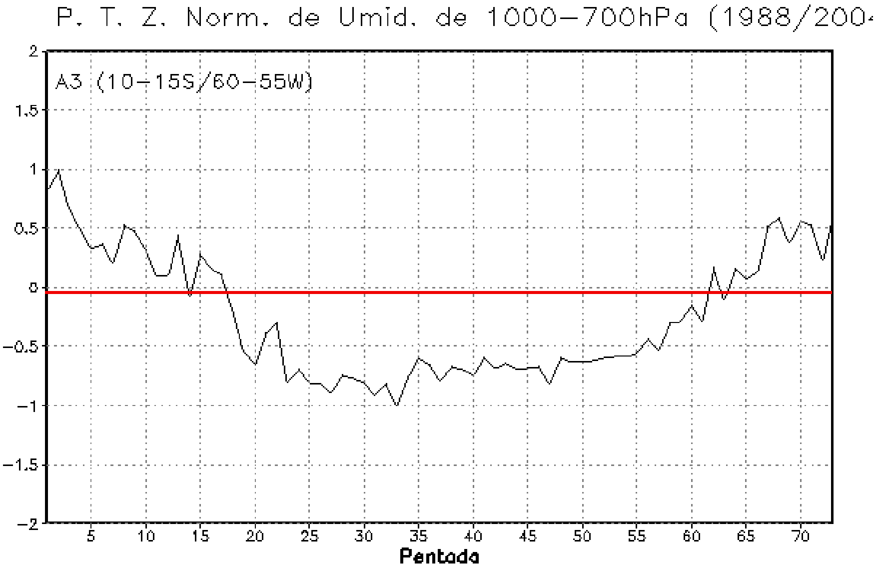

Fig 6 – Zonal component index VISH over area 10-15S/60-55W (1988/2004).