SOUTH AMERICAN PRECIPITATION REGIMES

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1. INTRODUCTION

The continent of South America exhibits a distinct geomorphology, with a large tropical land mass and the Andes cordillera that effectively blocks moisture advection from the Pacific Ocean. Surface conditions vary greatly both in the zonal and meridional direction, giving regional character to the seasonality and distribution of precipitation regimes (e.g. Vera et al. 2006 and references therein). The latter are also influenced by remote forcings from the adjoining oceans in a variety of time scales. As a result, the South American Monsoon System (SAMS) and summer rains over this continent present distinctive features summarized in Figure 1.

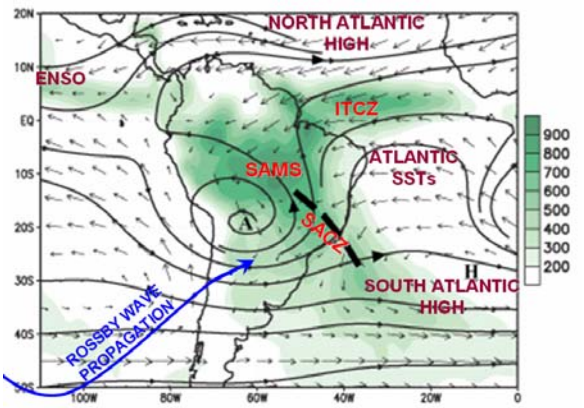

Figure 1: Schematic representation of the main elements and remote influences of the SAMS. Mean (1979-1995) 925-hPa vector wind (arrows) and 200-hPa streamlines (contours) from NCEP/NCAR reanalysis archive, and merged satellite estimates and station observations of precipitation (mm, shading) for December-February. The position of the Bolivian High is indicated by "A". The approximate axis of the SACZ is indicated by the heavy dashed line (based on CLIVAR transparencies available at www.clivar.org).

The orographic relief of South America (not shown), with the steep Andes Mountains to the West and two main gaps, the Orinoco valley to the north and the Amazon basin to the east open the north portion of the continent to moisture flux from the Atlantic Ocean. The narrow gap to the north is affected by air currents from the Caribbean Sea, and modulated by the variability of the North Atlantic High. The Intertropical Convergence Zone (ITCZ) has a strong influence in the weather and climate of Northeast Brazil, as well as providing a source of predictability on inter-annual time scales. The Atlantic Ocean is the main source of moisture for the South American Monsoon System (SAMS), moisture that enters the continent between the Guiana Highlands and the Brazilian Altiplano. Low level currents, represented by arrows in Figure 1, flow westward and are deflected southward by the Andes cordillera. These low-level jets link the Amazon basin circulations with those of the subtropical plains and the La Plata basin. As a result, during late November through late February (the mature phase of the SAMS), the main convective activity is centered over central Brazil and linked with a southeastward band of cloudiness and precipitation extending from southern Amazon region toward southeastern Brazil and the surrounding Atlantic Ocean. That convection band, known as the South Atlantic convergence zone (SACZ), is a distinctive feature of the SAMS. Also, the heavy rainfall zone extends over the Altiplano Plateau and the southernmost subtropical plains (Vera et al. 2006, and references therein).

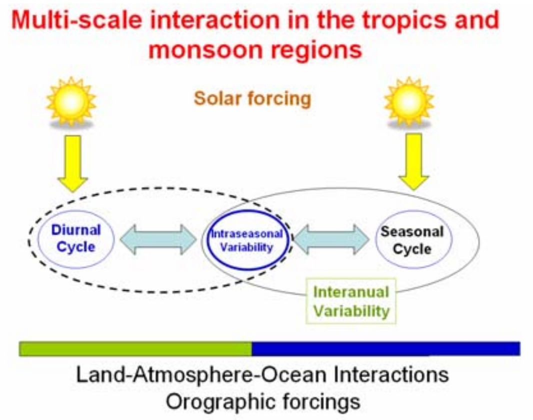

Figure 2: Summary of the multi-scale interactions that play a role on the climate of the monsoon regions (from Yasunari, 2008)

The SAMS as the other monsoon systems of the world is manifested as a land-atmosphere-ocean coupled system, exhibiting a variety of time and space scales that are governed by complex physical processes and their interactions. It is quite evident that solar forcing induces at the monsoon systems distinctive and clear cycles at both diurnal and seasonal scales. Such distinctive cycles are strongly linked to intraseasonal and interannual variability generated by the land-atmosphere-ocean interaction. Therefore, monsoon systems possess a large range of variability from diurnal to decadal time scales and extreme weather events are found at times, when the different modes of rainfall variability coincide in a phase conducive to extended periods of favorable

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conditions. Considerable progresses have been made in understanding the associated processes and interactions (see review in Vera et al. 2006 for the American Monsoons). Nevertheless, they are not fully known yet and large uncertainties still exist in prediction of the monsoons on local, regional, and continental-scales. In that sense, we next review in more detail the characteristics of inter-annual and intra-seasonal variability over South-America.

2. SUB-SEASONAL VARIABILITY

The most distinctive pattern that characterizes intraseasonal rainfall variability over South America is a dipolar one (Nogues-Paegle and Mo, 1997). Figure 3 depicts this dipole as shown by satellite measurements of outgoing long wave radiation (OLR). Enhanced precipitation over the SACZ is accompanied by decreased rainfall in the subtropical plains while the opposite phase is associated with increased southward moisture flux from the Amazon region, and increased rainfall in the subtropical plains. The dipole activity is linked to Pacific convection by Rossby wave trains. Furthermore, the phase with SACZ rainfall maximum occurs mostly during the day, while rain falls preferably at night over South-east South America in the opposite phase.

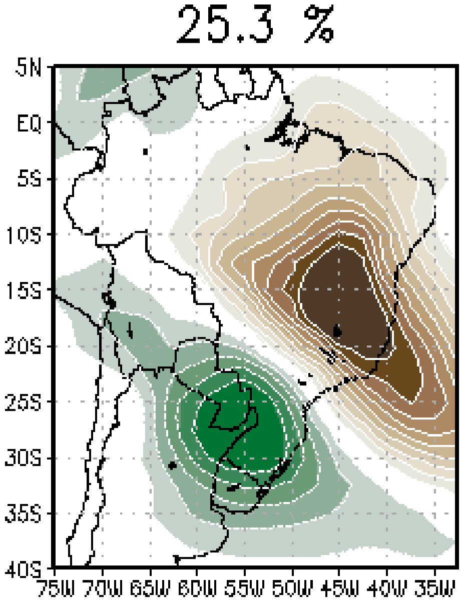


Figure 3: South American sub-seasonal dipole as represented by the 1st EOF leading pattern of 10-90 day filtered OLR variability.(From Gonzalez and Vera, 2009).

Singular spectrum analysis (Nogues-Paegle et al 2000) reveals two dominant time scales within the 10-90 day band: one at 36–40 days (mode 40) and another at 22–28 days (mode 22), with the faster mode (mode 22) leading the variability over the subtropical plains. Mode 40 is related to the Madden–Julian oscillation, as shown by outgoing long-wave radiation anomalies (OLRA) which propagate eastward from the western Pacific to the central Pacific with a period of 40–48 days. The 200-hPa streamfunction composite (Fig. 4) show a wavenumber 1 structure in the Tropics for mode 40 and a wave train propagating downstream from the convective area in the tropical Pacific.

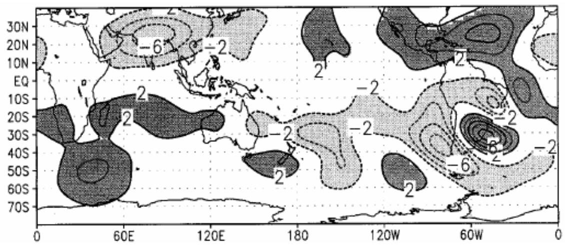


Figure 4: Composite of 200 mb stream-function difference between negative and positive OLRA phase for mode 40.

The development of the dipole pattern is also contributed by mode 22 (not shown), with meridional propagation of OLRA over South America from midlatitudes to the Tropics. The streamfunction composites for mode 22 show a wave train extending from the central Pacific eastward to about 60°S and curving toward the northeast over South America, similar to mode 40 over the western hemisphere.

When the SACZ is enhanced, these two modes become meridionally aligned locally. Such episodes are characterized by a wave train propagating northeastward from southern South America towards the Tropics. Composites based on the SSA decomposition indicate that the dominant periods of variability (22 and 40 days) cancel out over the Pacific region and reinforce each other over the SACZ for times close to onset of the enhanced SACZ episodes.

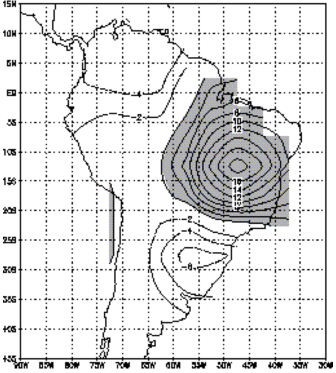
3. INTERANNUAL VARIABILITY

Previous studies have considered five factors for the interannual variability of American monsoon precipitation: SST anomalies, land surface conditions, the position and strength of the tropical convergence zones, water vapor transport, and large-scale circulations (Vera et al. 2006). In particular, remote forcings from the Pacific Ocean modulate atmospheric conditions in the continent from at interannual time scales, through longitudinal over-turnings, and Rossby-wave propagations that connect the upper atmospheric levels over the Pacific Ocean with those over South America. Specially, El-Nino-Southern Oscillations (ENSO) regulate patterns of rainfall variability over South America on interannual time scales as indicated in Figure 1, with the positive phase of ENSO associated with rainfall deficits on the north-east and positive anomalies over the south-east of the continent.

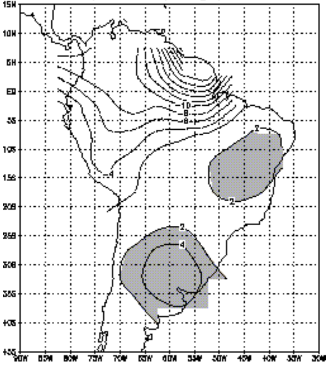
Nogues-Paegle and Mo (2002) isolated the main modes of interannual variability through rotated empirical orthogonal functions of the seasonal rainfall anomalies using reconstructed rainfall data based on gauge observations from 1948 to 2000 (Chen et al.

2002). They found three fundamental patterns of variability shown in Fig. 4 for summer. The dominant mode (REOF1) is associated with ENSO, and they showed that negative rainfall anomalies during warm ENSO events in northern South America are due to longitudinal overturnings, with sinking motions over the continent, while positive anomalies south of 25 S are associated with a wave train that extends from the equatorial Pacific southward to the southern tip of South America and then turns northward into the continent. This is consistent with other studies.

(a) REOF 1



(b) REOF 2



(c) REOF 3

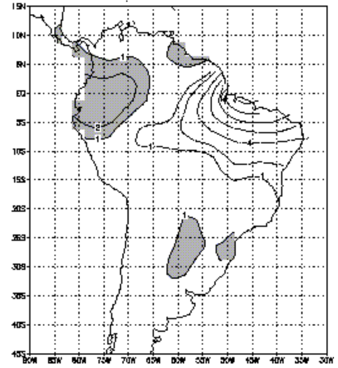


Figure 5: REOF1 through REOF3 for DJF rainfall over South America, explaining 12%, 10.8% and 7.2% of the total variance by each REOF respectively. Contour interval is 2 non-dimensional units. Zero contours are omitted. Contours -1 and 1 are added in the middle panel.

REOF2 is influenced by Atlantic sea surface temperatures, with warm tropical South Atlantic SST associated with positive rainfall anomalies in the eastern half of the continent centered at the Equator.

Both the Atlantic and the Pacific Ocean influence the third REOF shown in the figure. The pattern is similar to that of REOF2, but anomalies are displaced about 10°S and there is an additional center at about 30 S. Between 1950 and 1962 and from 1983 to 1993, these two patterns were in phase with a dominant Atlantic influence during those years. The amplitude of these two modes were both small during mid- 50s to mid-60s and out of phase from 1968 –70 resulting in persistent dry conditions over the upper basin of La Plata River.

4. REFERENCES

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