PRELIMINARY ASSESMENT OF THE SOIL MOISTURE MEMORY ROLE ON SOUTHEASTERN SOUTH AMERICA SUMMER CIRCULATION

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1. INTRODUCTION

Previous studies showed the influence of surface processes on the circulation and precipitation patterns in South America. Fu and Li (2004), document how different soil moisture conditions may influence the rainy season to the south of Amazonia. Also, Grimm (2003) discusses the feedback between soil moisture and the monsoon activity over tropical South America.

More recently, Grimm et al. (2007) have shown how a reduction in soil moisture over central-east Brazil during spring may contribute to the formation of a low pressure anomaly that leads to more summertime precipitation over southeastern South America (SESA). Different mechanisms and/or circulation-land surface feedbacks have been proposed to explain land-atmosphere coupling over South America: Collini et al (2007) suggest that, in addition to the surface effects, there are changes in the boundary layer and, consequently, in the low level moisture transports, that result in further changes to the precipitation intensity. Also, Ferreira et al (2006) showed that land use changes leading to an augmented west to east temperature gradient, can modify the low level wind circulation leading to a southward shift of the precipitation area over SESA. Nevertheless, they find neither an enhancement nor a reduction in rain amounts associated with land use changes. These studies suggest that South America has regions where land-atmosphere interactions show up, and that the land conditions can contribute to the variability of seasonal precipitation, at least during some of its stages. Moreover, these results are consistent with those obtained by Dirmeyer et al (2008) who focus on possible controls of soil moisture memory on precipitation.

Soil states strongly influence the surface water and energy budgets, which in turn affect the boundary layer conditions that control weather and climate at different time scales. In particular, soil moisture acts as a strong control on the partitioning between sensible and latent heat flux at the surface (the Bowen ratio) modulating precipitation over a given basin. The stronger interactions between land surface conditions and the atmosphere occur in regions that are not too dry and not too wet (Koster et al. 2000). In such situations, it can be expected that the slowly varying soil moisture anomalies will persist over enough time to affect the overlying boundary layer. Seneviratne et al. (2006) have showed that it is important to study not only land-atmosphere coupling but soil moisture memory as well. The soil moisture (SM), as a prognostic tool, is greatest where both, memory and coupling are important. This points out to find possible controls to the atmospheric variability.

Combining these evidences it is proposed here to explore the relation between soil moisture and the regional circulation at particular phases of the South American Sea-Saw (SASS) pattern (Nogués-Paegle and Mo, 1997). SASS, the leading pattern of intraseasonal variability in South America, is characterized by a dipole-like structure associated with wet (/dry) conditions over the South Atlantic Convergence Zone (SACZ) and dry (/wet) conditions over southeastern South America (SESA).The overall objective is to determine whether it can be documented any influence of soil moisture anomalies on the strength and/or the duration of the SASS pattern, and evaluate whether SM memory can be used as a tool to improve predictability at medium ranges over SESA. To accomplish this, we first document SM memory over the region of interest and during our period of study and then try to relate circulation anomalies (quantified by a SASS index) with SM anomalies. This analysis has been performed on a daily basis given that we decided to focus on the intraseasonal variability during the SALLJEX warm season (Vera et al., 2006). It is expected that we will expand this study to other summer seasons.

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2. DATA AND METHODOLOGY

This study focuses on a portion of the 2002-2003 austral summer starting from December 15, 2002 and ending on February 14, 2003, which corresponds to part of the intensive observing period of the South America Low Level Jet Experiment (SALLJEX). This period has been selected because more precipitation data is available over the region of interest, and many studies have been devoted to analyze some of its characteristics.

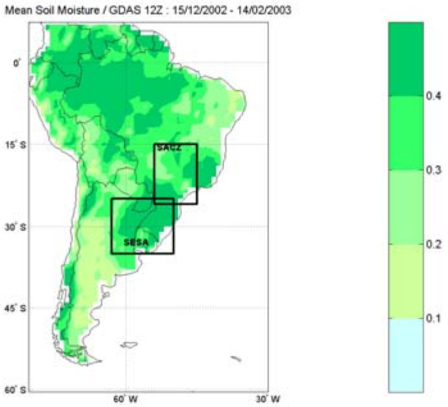


Figure 1: mean SM (in fraction) during the SALLJEX period

Daily accumulated precipitation from two data sets has been used for this study. The first belongs to the GPCP (Global Precipitation Climatology Project) and the second one has been constructed by Liebmann and Allured (2005), using an enhanced observational network gridded with a 1° horizontal resolution. This data set will be referred to as SA19, according to the version used here.

For the soil moisture analysis, we have employed two alternative data sets, one used to construct anomalies for the SALLJEX season (http://www.cdc.noaa.gov/Composites/datasets.htm) and the other one has been taken from the operational GDAS (Global Data Assimilation System) analysis.

SA19 and GDAS soil moisture data at 12UTC have been area averaged over the boxes indicated in Figure 1, each one covering –approximately- the area where precipitation anomalies maximize at each phase of the SASS. The box to the north has been named "SACZ" and the one to the south "SESA".

The SASS index is used as an indication of the dipolar pattern state, as discussed by Gonzalez et al., 2008. To calculate this index they obtain the first rotated empirical orthogonal function of regional warm season filtered (10-90 pass band filter) OLR using a domain encompassing 40ºS–5ºN, 75ºW–32.5ºW. The associated SASS principal component is then used to assess the phases and intensity of the dipolar pattern. A time series of the standardized principal component was constructed and considered as the SASS index. Hereafter, SASS positive phase will refer to those periods associated with positive values of the principal component that indicate the occurrence of negative OLR anomalies (i.e. enhanced convection) over SESA and positive anomalies (i.e. inhibited convection) near the SACZ region.

3. DESCRIPTION OF SOILMOISTURE AND PRECIPITATION ANOMALIES DURING SALLJEX

A brief description of soil moisture (shown in Figure 1) and precipitation characteristics during SALLJEX is exposed in this section. Figure 2 depicts mean accumulated precipitation derived from SA19 (a) and from GPCP (b).

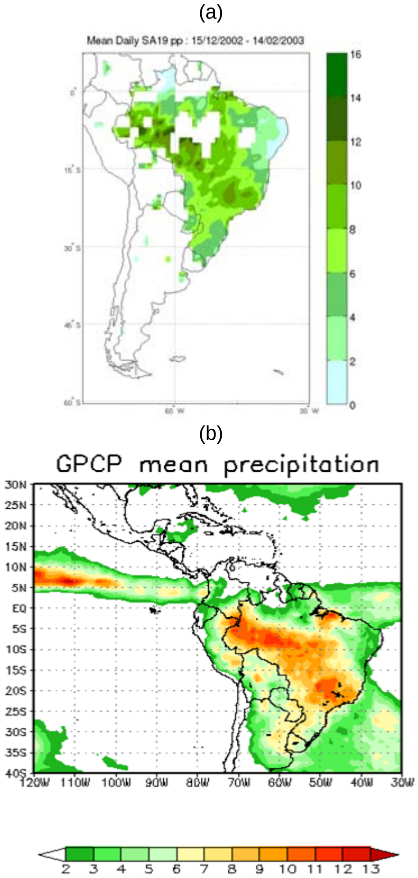
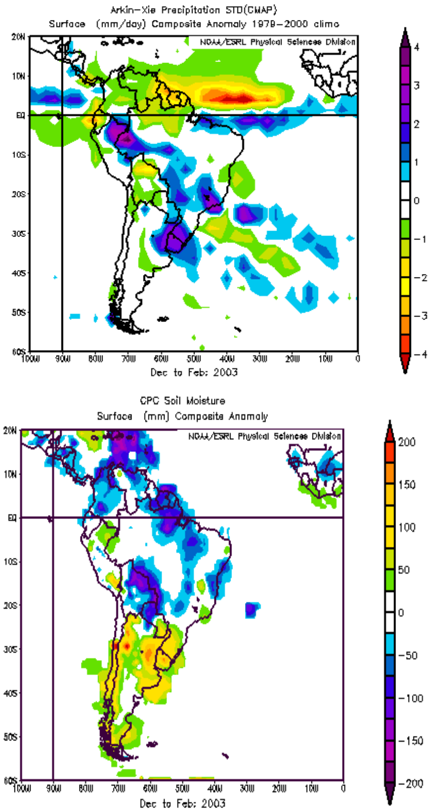


Figure 2: Daily mean accumulated precipitation in mm. (a)SA19 and (b) GPCP from 15 December 2002 to 14 February 2003.

Besides the evident lack of data over many regions, precipitation patterns seem to be well captured by GPCP estimations. As expected, SM mean field resemblances mean precipitation, with relative maximum values close to SACZ and SESA boxes. Compared with the climatology, Dec. 2002 - Feb. 2003 has been characterized by precipitation above normal over SESA and also over SACZ (Figure 3a). Over the ocean, it appears as if the SACZ has been shifted to the north. SM anomalies are consistent with precipitation anomalies over SESA, but not over SACZ, where the pattern is less coherent. From the comparison of Figures 3a and b, a signature of land-atmosphere coupling over SESA is suggested.


Arkin–Xie Precipitation STD(CMAP)
Surface (mm/day) Composite Anomaly 1979–2000 climo

CPC Soil Moisture
Surface (mm) Composite Anomaly

Figure 3: (a) Soil moisture (mm) and (b) Precipitation (mm) anomalies during December 2002-February 2003. Images provided by the NOAA/ESRL Physical Sciences Division, Boulder Colorado from their Web site at http://www.cdc.noaa.gov/

It should be mentioned that the area encompassed by the SACZ box has high topography. Given that SM datasets are strongly model dependent, and they can be less reliable where terrain inhomogeneities exist, we will put more emphasis in the analysis of the anomalies over SESA box.

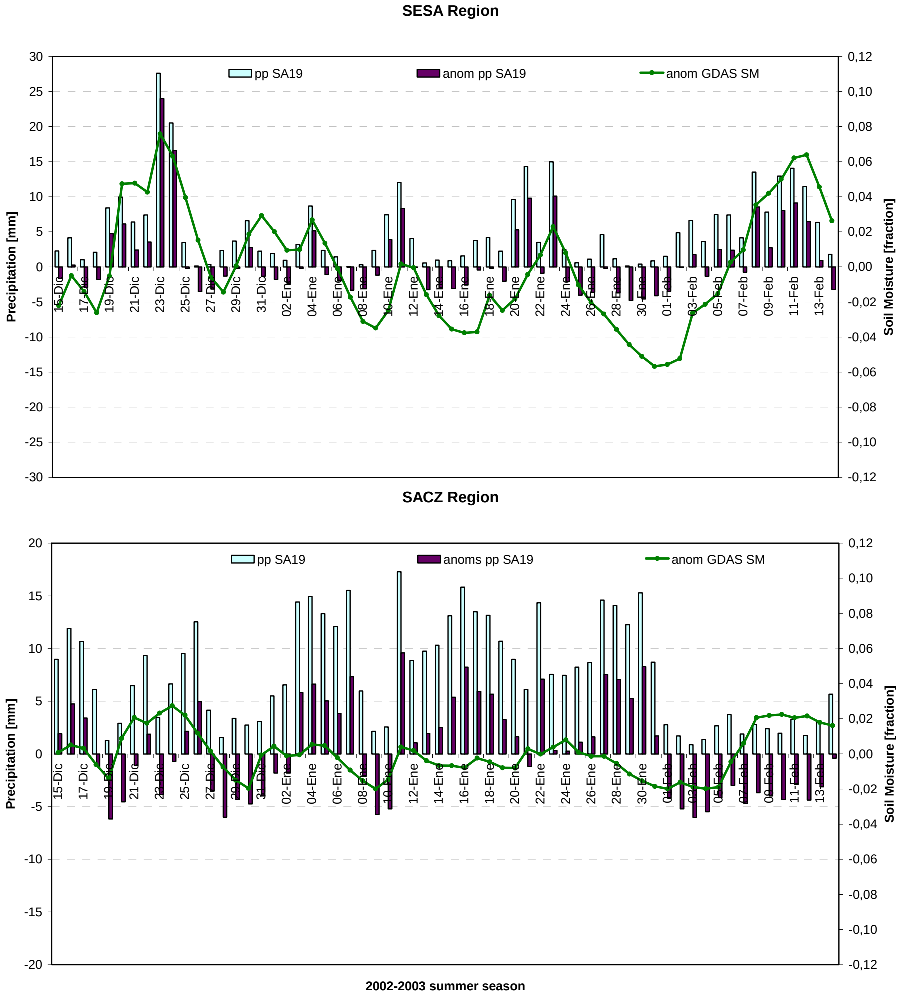
4. TEMPORAL EVOLUTION OF SOILMOISTURE ANOMALIES AND SASS.

The evolution of SM anomaly (with respect to the season mean) at 12UTC and precipitation area average inside the two boxes is showed in Figure 4. It can be seen that SM anomalies are more sensitive to precipitation variability over SESA than over SACZ, and also that the SM response shows up very fast. Moreover, there is a very high correlation between the anomalies of both variables, although precipitation anomalies have been constructed differently: they were obtained subtracting from each summer day the corresponding 1979-1999 mean climatological value. It is interesting to note that the system needs more days with rain to overcome a SM deficit stage than the time needed to progress from a positive SM anomaly to a negative one. SACZ box is characterized by a different behavior: precipitation occurs almost everyday and this might explain a weaker reaction of SM anomaly to precipitation changes.

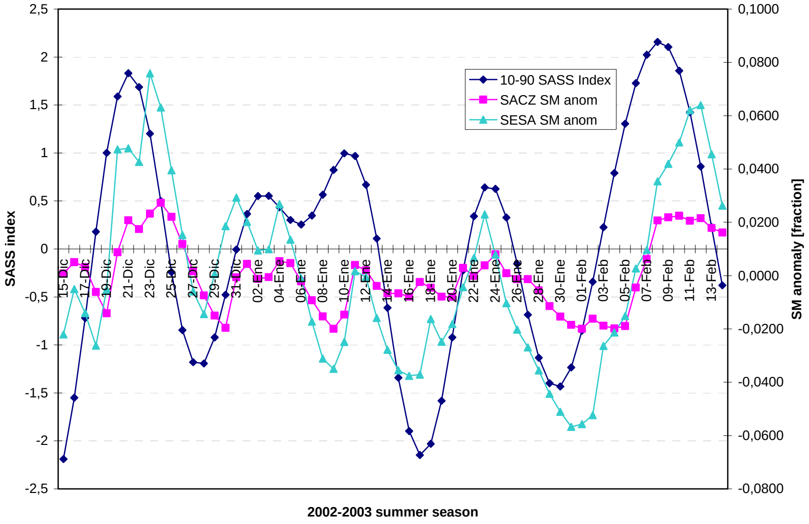
Given that the main signature of the South American Monsoon System' intraseasonal variability shows up as a sea saw pattern (SASS) in precipitation, it is interesting to show its evolution through an index that synthesizes this feature and analyze it together with SM anomalies. Their combined evolution can aid in answering the following questions: can SM anomalies drive or explain in some way the SASS?, do they lead the phase change? or is it the opposite way?. A first inspection of this relationship can be done with the aid of Figure 5. Remind that SASS index is positive when enhanced convection occurs over SESA (and it is inhibited near the SACZ region).

Although SASS index provides an "integrated view" of the dipole, it can be seen that it is more closely related to SM anomalies over SESA than to SACZ SM anomalies. In general, SASS leads SM anomaly changes over SESA, except from Dec. 28 to Jan. 4 when SM anomalies slightly lead SASS and between Jan. 17 and Jan 28, when they seem to vary almost at the same time. Currently an analysis of the synoptic evolution is being done in order to better understand what could be happening during these particular periods. It should be noted, however, that SASS is an index where short frequency variability has been removed (higher than 10 days), while SM anomalies have been directly calculated. In this sense this figure denotes that SM variability is slower than atmospheric variability, what is in agreement with previous studies.

Finally, in order to document SM memory over SACZ and SESA, an autocorrelation analysis has been performed and is showed in Figure 6.



<u>Figure 4</u>: Area average evolution of observed daily accumulated precipitation in mm –light blue columns-, its anomaly –violet columns- and SM anomaly (m^3m^{-3}) over SESA (a) and SACZ (b) –green line-.



<u>Figure 5</u>: SASS Index and Soil moisture anomaly evolution for SESA and SACZ

In agreement with previous results (Dirmeyer et al. 2008), it can be seen that SM memory is relatively short –below a week-, and slightly longer for SESA. However there appears a significant anti-correlated signature in SACZ between 13 and 18 days and then another one after 23 days for both regions. Still the longer period memory should be considered with caution, since the period under study is too short (61 days).

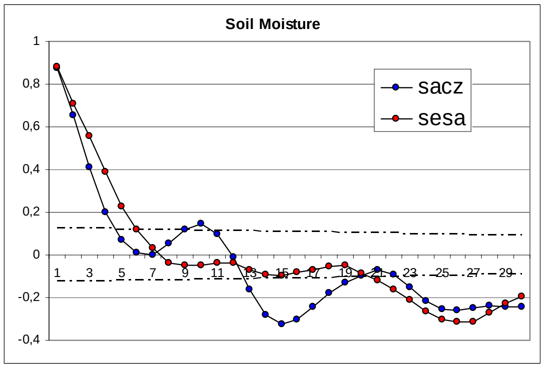


Figure 7: Soil Moisture lagged autocorrelation for SESA and SACZ. Dot-dashed lines denote confidence limits.x-axis represents days

5. CONCLUDING REMARKS

Soil moisture, precipitation and SASS evolution have been explored during a particular warm season. The underlying idea has been to identify if it can be established a relationship between soil conditions and precipitation, and ultimately, if land surface processes exert some control on the regional circulation. This preliminary analysis suggests that SESA region may be more clearly affected and modulated by soil moisture changes than SACZ region. On the other hand, it seems that remote scale forcing (i.e. that driving the SASS) is the most effective control on the precipitation variability over the area of interest. Still, a deeper analysis of the role of surface processes has to be done in order to understand particular responses observed when the larger scale forcing is not so strong. Also, it will be of interest to analyze a longer period in order to detect if SM variability exhibits significant signals at lower frequencies, and to quantify their strength compared with that detected at synoptic time-scales. This could be relevant to assess if SM can provide enhanced predictability over the region.

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