14.4 LA NIÑA IMPACT ON SUMMER MONSOON IN BRAZIL

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1. INTRODUCTION

South America (SA) experiences consistent and strong precipitation anomalies associated with La Niña (LN) events (e.g. Ropelewski and Halpert 1989; Grimm et al. 2000). These events affect some important components of the South American summer monsoon (SASM) regime, as the South Atlantic Convergence Zone (SACZ), in view of their impact on tropical heat sources and global circulation. As summer is the rainy season in most of Brazil, and its interannual variability impacts significantly on very important economic activities, it is worth detailing the effect of those events.

The purpose of this paper is to give a consistent picture of the LN impacts on summer precipitation in Brazil and its sub-seasonal evolution, besides establishing connections between anomalies of precipitation, circulation and surface temperature.

2. DATA AND METHODOLOGY

The data used in this study include monthly precipitation totals from more than 1000 stations in the period 1956-1999, selected to span at least 5 LN events. These data were supplied by various sources, mostly by Agência Nacional de Energia Elétrica (ANEEL) and Instituto Nacional de Meteorologia (INMET). Also surface temperatures observed by INMET are used. Atmospheric circulation and thermodynamic structure are analyzed with NCEP/NCAR reanalysis monthly data from 1963 to 1992, because part of the radiosonde stations in SA started operating after 1963.

To detail the spatial and temporal variability of the LN impact, the LN-related median precipitation is calculated for each station and each month of austral spring and summer, from October of the year when the episode starts (0) through March of the following year (+). This amount is expressed as a percentile of the gamma distribution for each station, and a map of percentile isolines is generated.

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To assess the consistency of the anomalies during LN events a test is applied, based on the hypergeometric distribution. For example, to test the consistency of the relationship LN - dry (wet) conditions of a population that contains *r* LN episodes and *k* of them are wet (dry), the probability of obtaining more than *k* wet (dry) cases in a sample of *r* episodes taken at random from this population is computed (i.e., the cumulative probability of obtaining *k*+1, *k*+2, ..., up to *r* wet (dry) cases). This will give the significance level of this relationship.
The table below shows the year (0) of the LN episodes included in this study. When an event lasted for two years, only the first one was considered as year (0).

La Niña years	1964, 1967, 1970, 1971, 1973, 1975, 1985, 1988, 1999.

The way the atmospheric circulation anomalies act on precipitation is assessed through the analysis of the perturbations they impose on the essential ingredients of precipitation: moisture convergence, and the force to lift the moist air to the condensation level.

The alterations in the moisture convergence are analyzed through composites of anomalies of vertically integrated moisture flux, and its divergence.

The force to lift the air may be altered mainly through anomalies in the dynamic lift via upper-level winds (jet streams and advection of vorticity), or in the large scale divergence/convergence, or in the thermal forcing. The analysis is made using composites of LN-related anomalies of several parameters. The consistency of these anomalies is also assessed with the test based on the hypergeometric distribution, described above.

3. RESULTS

In spring (Oct (0) - Nov (0)) precipitation is consistently above median in northern, central, and eastern Brazil, and below median to the south. In these months the negative SST anomalies in eastern Pacific are already established and produce perturbations in the Walker circulation that enhance low-level convergence (and the corresponding high-level divergence) over parts of the Amazon an Atlantic ITCZ. Consistently, the anomalous rotational circulation shows pairs of upper-level anticyclones straddling the equator. An anomalous cyclonic center over southeastern SA dominates the subtropics, southwest of the precipitation anomalies in central-eastern Brazil. At low levels, weak cyclonic anomalies dominate tropical and subtropical regions, but in November and December an anomalous anticyclonic center starts developing over the subtropical highlands in southeastern Brazil, in the SACZ region. This circulation strengthens and becomes extensive and very consistent in January. In this month, the upper-level tropical anticyclonic anomalies split and displace westward and eastward, being replaced over central-eastern Brazil by a consistent cyclonic anomaly. The anomalies of divergent wind show very consistent low-level divergence and upper level convergence over that region, being oriented in a northwest-southwest band, like the SACZ. On the other hand, the region with strongest upper level divergence moved, from spring to summer, from the mouth of the Amazon northward, over the tropical North Atlantic. Consistent with this evolution of circulation anomalies, the above median precipitation of spring (OND) in the mouth of Amazon disappears and is replaced by below median precipitation. Likewise, Central, East and Southeast Brazil present dry conditions, particularly in the SACZ region. In southern Brazil, wet conditions prevail.

In February (+), the low-level anticyclonic center in the SACZ region has considerably weakened and the situation is similar to December in the tropics and extratropics over SA. The upper-level cyclonic center disappears and the anticyclonic centers to west and east are displaced toward Central Brazil. Above median precipitation returns to northern Brazil, and the dry anomalies over central-eastern Brazil weaken. In March (+), there are some consistent positive rainfall anomalies in central-western Brazil, but there are not anomalies as extensive as in the previous months.

The anomalous low-level anticyclone and subsidence over the SACZ region that appear consistently in January may be connected with the surface temperature anomalies caused by LN-related circulation and precipitation anomalies, and not with circulation anomalies remotely produced. An analysis of LN-related temperature anomalies in South and Central-East Brazil reveals very consistent negative anomalies between –1°C and –2°C in Central-East Brazil during spring, associated with anomalous southerly advection of temperature and above median precipitation. As this southerly advection weakens in December and reverses its direction in January, and the precipitation turns below median, the temperature anomalies turn consistently positive in January and February over Central-East Brazil, leading to the weakening of the low-level anticyclonic anomaly.

Besides the anomalous surface cooling and associated circulation anomalies, the dryness in the SACZ during summer is also caused by deficiency of moisture supply. The low-level anticyclonic anomaly centered over southeastern Brazil carries moisture from the SACZ region to Central-West and South Brazil and neighbor regions, like Paraguay. A region of moisture flux divergence is established over the SACZ, from December through February, being especially strong and consistent in January.

4. CONCLUSIONS

The impact of LN events on the SA summer monsoon is not uniform during the whole season and acts differently on different components of the summer monsoon system. While convection is enhanced in the eastern Amazon during most of the season, it is suppressed in January. On the other hand, it is enhanced in part of southern Brazil in this month. Convection over the SACZ region is suppressed, specially in January, probably due to the regional circulation response to surface cooling produced by rainfall and circulation anomalies in spring, and to the associated deficiency of moisture supply. Not only remote but also local influences seem to be important for the summer monsoon response to LN events.

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