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SHORT-TERM CLIMATE VARIABILITY IN THE SOUTHEASTERN SOUTH AMERICA

C A D Lentini *, R A F De Almeida b, L P Pezzi c and R B Souza a

National Institute for Space Research (INPE) * a c
Remote Sensing Division (DSR) *
Oceanographic Institute of the University of São Paulo (IO-USP) b
Center for Weather Forecast and Climate Studies (CPTEC-INPE)* c

1. Introduction:

Due to the southeast South America (SESA) proximity to the Brazil-Malvinas Confluence (BMC) region, the influence of offshore sea surface temperature (SST) anomalies in the southwestern Atlantic (SWA) and the confluence position on the SESA regional climate might be expected (Lentini, 2002). Some effort has been done recently in order to understand the air-sea interaction at BMC region, using *in situ* and ship-borne meteorological observations (Pezzi et al, 2005). This region, which comprises southern Brazil, part of Argentina, and Uruguay, corresponds to the subtropical zone east of the Andes between 25°-40°S and 65°-45°W (Fig. 1). This study explores changes in the variability of the confluence during ENSO-related events and the potential relationship between the atmosphere and the ocean in the SESA.

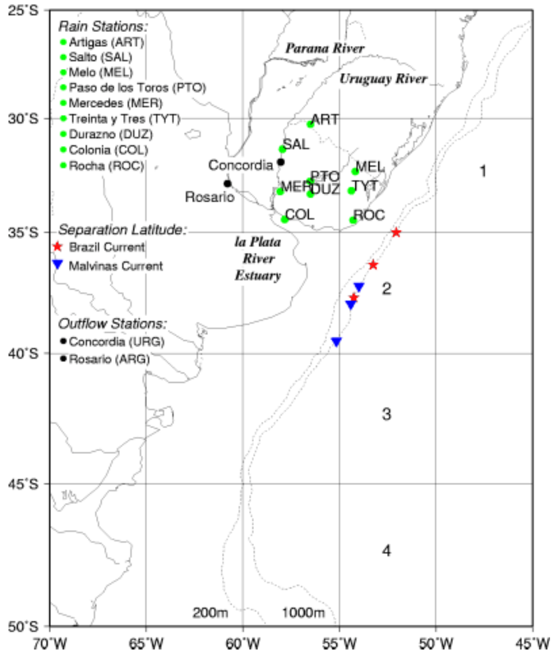

Figure 1. The southeast South America (SESA). SST time series were extracted from boxes 1 - 4. The stars (inverted triangles) corresponded to the mean latitude of separation of the Brazil (Malvinas) Current from the 1000-m isobath seen in satellite SST images ± one standard deviation. The two black dots represented the river outflow gauging stations.

marologo@gmail.com

2. Datasets

2.1. SST

SST data consisted of weekly NCEP Reynolds Optimally Interpolated data with a 1 x 1 degree resolution for the period of January 1982 to May 2002. This data was pulled out for four different 5 x 5 sub-regions (see Fig. 1), binned together, and then averaged to create the monthly mean SST time series. Each box had been selected according to different oceanographic regimes.

2.2. Position of the Confluence

Sixteen years (Aug 1984 - Dec 2000) of 5-day infrared maps of AVHRR HRPT digital data were used to extract the position where the Brazil (BC) and Malvinas (MC) currents separate from the coastline (e.g., Olson et al, 1988). This position was visually digitized where the cores of the BC and MC jets crossed the 1000-m isobath.

2.3. River discharge at Rosario Station

The Paraná river discharge time series covered the period from January 1931 to December 2001 recorded at Rosario station and provided by the Instituto Nacional del Agua (INA), Argentina.

3. Methods

The original datasets were converted into normalized monthly mean anomalies and set for the period of August 1984 to December 2000. These anomalies were the basis of all subsequent analyses.

3.1. ENSO composites

Normalized monthly mean anomalies of each of the three datasets were composited into a 12-month period starting in July of the year when an ENSO-related event begins, Year(0), and ending in June of the following year, Year(+1), to address the potential influence of ENSO-like events.

3.2. Squared coherency

Squared coherency was carried out to explore the possible relationship between SST anomalies (SSTAs) and the confluence position on the river discharge over the SESA. Due to the number of coherent peaks at different time scales, they were divided into 3 sub-sets: 1 year, 2 years, 3 years and longer. Only signals above the 95 % confidence level were considered.

4. Results

4.1. ENSO composites

4.1.1. SSTAs

Positive SSTAs associated with El Niño (EN) can normally be observed from July to August of Year(0) and from May to June of Year(+1). SSTAs associated with La Niña (LN) episodes showed more changes along the ENSO composites than did the EN-related SSTAs on a month-to-month basis, although both phases switched from positive to negative anomalies throughout the composite (Fig. 2 - top). Notably, it was during Neutral Years (NT) that relatively large anomalies took place. They were predominantly observed during the first half of the ENSO composite, which corresponded to the period from July(0) until December(0). Although it did not show a well-defined bi-polarity as observed in the EN-LN curves, the NT behavior associated with the SSTAs of all four sub-regions showed amplitude anomalies that were as large as any other amplitude observed during EN and LN events.

4.1.2 Confluence

ENSO composite for the BC showed that during EN (LN) the current's anomaly latitude of separation was usually large (small) and positive (negative) after August (0) until January (+1) (Fig. 2 - bottom). The MC composite did not show the same mirror image as observed in the BC, although positive (negative) anomalies associated with ENSO phases also occurred after August (0) until January (+1). Here, "positive" ("negative") monthly anomalies meant that the currents separated at latitudes lower ("higher") than their long-term means (not shown). NT episodes showed amplitude anomalies that were as large as any other amplitude observed during EN and LN events. After December (0) the NT mean curve changed its polarity, which was usually negative during Year (0) to positive during Year (+1). This particular pattern indirectly implied that the confluence's position may be forced by another source other than ENSO.

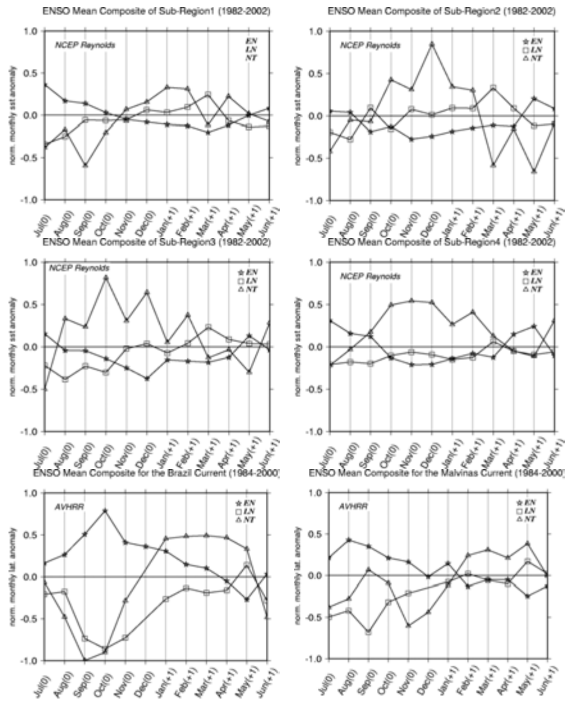

Figure 2. ENSO composites for the SSTAs for each box (1-4), the BC and MC.

4.2. Squared coherency

4.2.1 SSTAs and Paraná river discharge at Rosario Station

One-year period:

The squared coherency between SSTAs of Box 1 and the Paraná river discharge showed two significant peaks: one at ~6 and another at 3-4 months (Fig. 3). These two peaks were characterized by positive phases suggesting that SSTAs led the Paraná river outflow by a temporal lag of 1-2 months. No statistically significant coherency was found between SSTAs of Box 2 and the river flow (not shown). Box 3 and the river flow anomalies were coherent at 8, 4, and 3 months. Phases associated with these frequencies suggested that the river runoff led SSTAs by approximately one month, except at the 8-month peak, where it was led by

SSTAs by ~one week. Box 4, which was located in the sub-polar sector, had basically four statistically significant frequency bands. These peaks corresponded to 9, 6-5, 4, and 3 months.

The above results suggested a general tendency for atmospheric to oceanic forcing perturbations in the river discharge on annual time scales, especially for the SSTAs of Boxes 2 and 3. An exception to this rule was observed in Box 1, which suggested an oceanic forcing for the river discharge.

Two-year period:

For the 2-yr period, SSTAs of Box 1 were statistically significant and coherent at the 16-17-month period. A negative phase associated with this indicated that the river discharge led SSTAs by a temporal lag of 5 months. SSTAs of Box 2 were not coherent with the river flow anomalies (not shown). Sub-regions 3 and 4 were not coherent with the Paraná river. In the 2-year period frame, river discharge anomalies consistently led SSTAs in the SWA, which undoubtedly suggested that the atmosphere was forcing the ocean at this particular period.

Three-year period and longer:

The Paraná outflow, which was statistically significant for sub-regions 1 and 4, was coherent at 60 months. Positive phase associated with sub-region 1 indicated that the river was led by SSTAs with a lag of 26 months.

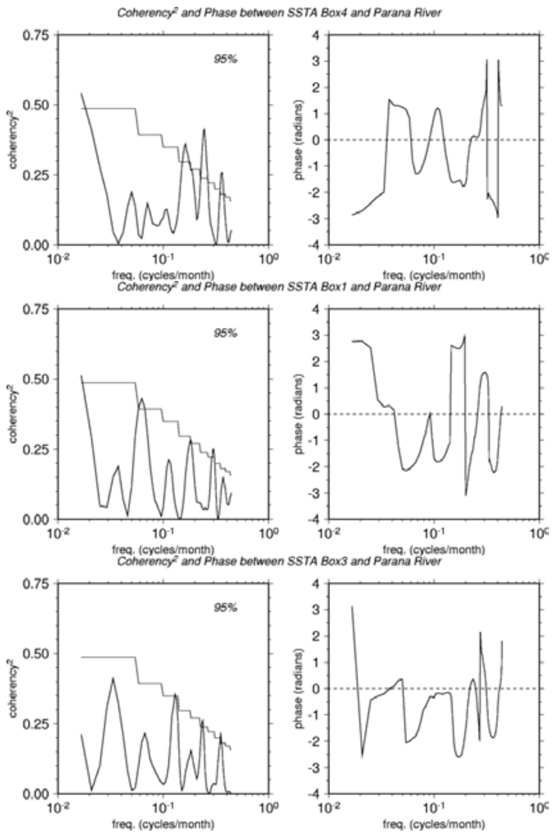

Figure 3. Squared coherency and phase between SSTAs (Box 1, Box 3 and Box 4) and the Paraná river discharge. SSTA of sub-region 1 and the Paraná outflow (upper panel) were coherent at 60(26), 16(-5), 6(2), and 3(1) months. SSTA of sub-region 3 and the Paraná outflow (upper panel) were coherent at 8(- one week), 4(one week), and 3(1) months. SSTA of sub-region 4 and the Paraná outflow (lower panel) were coherent at 60(-27), 6(-2), 4(one week), 3(-1) months. The numbers in parentheses corresponded to their phases.

4.2.2 Confluence and river discharge

One-year period:

The squared coherency between the BC and the river flow had only one peak statistically significant at ~5 months. A negative phase was associated with this peak, suggesting that the river flow led the current latitude of separation anomaly by 2 months (Fig. 4, top). The squared coherency between the Malvinas and the Paraná flow had four significant peaks, at 8, 6, 4, and 3 months (Fig. 4 - bottom).

Remarkably, all the first three peaks had negative phases, which indicated that the point where the current separated from the coastline was led by the Paraná outflow by 1 to 2 months. The last peak (i.e., at 3 months) showed a positive phase suggesting that the Malvinas latitude of separation variability led the river flow by ~one week. In fact, this result supported the idea that the Brazil-Malvinas confluence geometry had a direct relationship to the river discharge, at least on annual time scales (Lentini, 2002).

Two-year period:

Both currents showed four coherent peaks above the 95% confidence level, corresponding to periods between 13 and 19 months. These frequencies were associated with negative phases, which suggested an atmosphere-to-ocean forcing as the river flow led the currents' latitude of separation by 5 to 8 months.

Three-year period and longer:

The squared coherency between the BC and the river flow had one significant peak at 47 months. Surprisingly, a positive phase was associated with this frequency band, indicating that the current led the river flow by a temporal lag of 19 months (Fig. 4, top). Conversely, the squared coherency for the MC and the river flow had no significant peak.

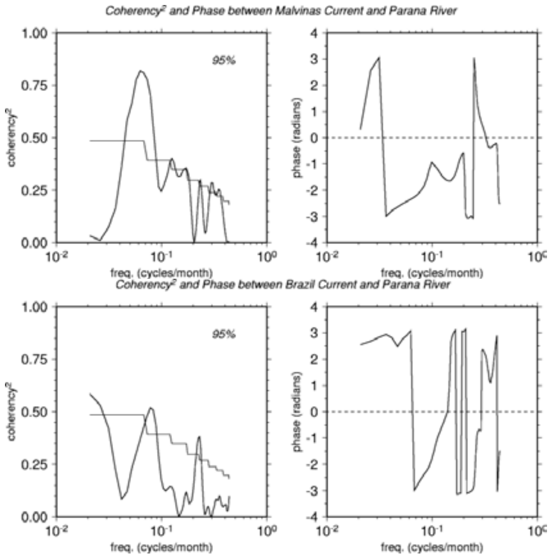

Figure 4. The BC and Paraná flow anomalies (top) were coherent at 47(19), 13(-5), and 5(-2) months, whereas the MC was coherent at 16(-6), 8(-2), 6(-1), 4(-2), 3(one week), and 3(- one week) months (bottom). The numbers in parentheses corresponded to their phases.

5. Summary and Final Remarks

ENSO composites showed that SSTAs observed during EN episodes were always positive and mostly larger than those observed during LN events. NT years, in general, departed less from the average EN-LN episodes, although they showed a relatively high month-to-month variability along the composite. The difference in the timing between the latitude of separation of the Brazil and Malvinas currents suggested that they responded distinctly to an ENSO event. NT episodes showed amplitude anomalies that were as large as any amplitude observed during EN and LN events, which indirectly implied that the position of the confluence may be forced by a source other than ENSO.

Squared coherency computations between the SSTAs, the position of the confluence, and the monthly river discharge anomalies indicated a high level of complexity between atmospheric and oceanic forcings. For instance, Boxes 2 and 3 showed an atmospheric to oceanic type of forcing with the river discharge leading the SSTAs. On the other hand, Boxes 1 and 4 suggested a different scenario, where the river discharge was now led by SST anomalies. Like the SSTAs, the position of the confluence was also associated with the river discharge anomalies and showed that both types of forcing occur at 1-yr and 3-5-yr periods. Despite the results suggested a slightly general tendency for an atmospheric type of forcing, they also revealed that the SSTAs and the confluence position had some influence in the river discharge on ENSO time scales (Mianzan, personal communication, 2004).

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