THE IMPACT OF THE SOUTH ATLANTIC SEA SURFACE TEMPERATURE ON SUMMER PRECIPITATION IN CENTRAL-EASTERN BRAZIL

Rodrigo J. Bombardi and Leila M. V. Carvalho

Department of Geography, University of California, Santa Barbara

bombardi@umail.ucsb.edu

INTRODUCTION

The variability of the South Atlantic Ocean sea surface temperature (SST) changes the temperature gradient between land and ocean, generating significant changes in the climate of South America. Previous studies have shown that cold (warm) SST anomalies over the tropical South Atlantic are associated with dry (wet) years over northeastern Brazil (e.g. Uvo et al. 1998) and that the precipitation response to the South Atlantic SST is mostly confined to the ocean (e.g. Barreiro et al 2002; Robertson et al. 2003). However, ***we show that the variability of the South Atlantic SST not only changes precipitation over the Brazilian coast and adjacent ocean but also strongly impacts the monsoon regime over central-eastern Brazil.***

Central-eastern Brazil (Fig. 1) is a region with approximately 61% of Brazil's population and is responsible for approximately 73% of the Gross National Product. Most of the Brazilian production of sugarcane, coffee, cotton, and corn takes place in this region as well as the majority of cattle ranches (Source: Brazilian Institute of Geography – IBGE). In addition, 70% of electricity in Brazil comes from hydropower generation and most of the hydropower plants currently in use in Brazil depend on precipitation regimes that affect basins in that region (source: Brazilian National Agency of Water – ANA). Recently, over 700 people died due to floods and landslides resulting from above normal precipitation over southeastern Brazil. On the other hand, the 2001-2002 energy crises in Brazil were remarkable examples of the vulnerability of hydropower generation to climate variability. Therefore, ***the variability of the rainy season over central-eastern Brazil will have important social and economical impacts.***

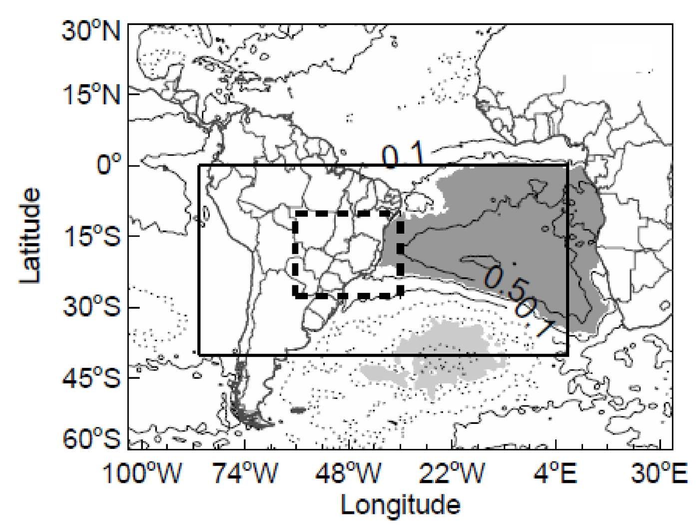

Figure 1 – First mode of Variability of the South Atlantic SST anomalies (trend and annual cycle removed). Solid lines show positive correlations and dotted lines show negative correlations. Shade indicates regions where the correlations are statistically significant at 5% level. The solid box indicates the domain selected for regional climate simulations and the dashed box presents the region of interest (Central-eastern Brazil).

OBJECTIVE

Previous studies have shown significant evidence of the influence of the South Atlantic SST on the precipitation over South America. For example, ***Bombardi and Carvalho (2011)*** observed that on interannual timescales, negative SST anomalies over the tropics and positive SST anomalies over the extratropics are associated with increased precipitation during the rainy season over central-eastern Brazil. Therefore, the objective of this study is to identify the mechanisms whereby the South Atlantic SST influences the climate of central-eastern Brazil. The proposed research is expected to improve our ability to predict the evolution of the South American monsoon, improving water management over central-eastern Brazil and, consequently, increasing global food security.

METHODOLOGY

We used SST data from the NOAA Optimum Interpolation 1/4 Degree Daily Sea Surface Temperature Analysis (Reynolds et al. 2007); station daily precipitation from ANA (Liebmann and Allured, 2005); and temperature, relative humidity, horizontal wind, and geopotential height from the NASA Modern Era Retrospective-Analysis for Research and Applications (MERRA) (Rienecker et al. 2011).

The dominant mode of variability of the South Atlantic SST was identified by applying Empirical Orthogonal Function (EOF) analysis to SST anomalies over the domain [50S-0; 70W-10E]. The period considered is from September to May, which comprises the rainy season period of central-eastern Brazil (e.g. Bombardi and Carvalho 2009). The first mode of variability of the South Atlantic SST anomalies (EOF1) explains 12% of the total variability and is characterized by a dipole with a large tropical center and a small extratropical pole (Fig. 1).

The results we present here were based on the following methodology: We selected the dates when the EOF1 time coefficient was above 75th percentile ("high"), around 50th percentile ("neutral"), and below the 25th percentile ("low"). Then we compared periods when the EOF1 time coefficient was high and low with the period when it was neutral. The sign test was used to assess statistical significance.

OBSERVATIONAL RESULTS

EOF-1 < 25th percentile (*cold anomalies in the tropical Atlantic*)

EOF-1 > 75th percentile (*warm anomalies in the tropical Atlantic*)

Figure 2 – Precipitation anomalies during austral summer. EOF-1 below 25th percentile (left) and EOF-1 above 75th percentile (right).

When the tropical Atlantic is cold there is an increase in precipitation over tropical Brazil. When the tropical Atlantic is warm positive anomalies are observed over southern Brazil (Fig. 2). Figure 2 shows only stations where the differences are statistically significant at 5% level.

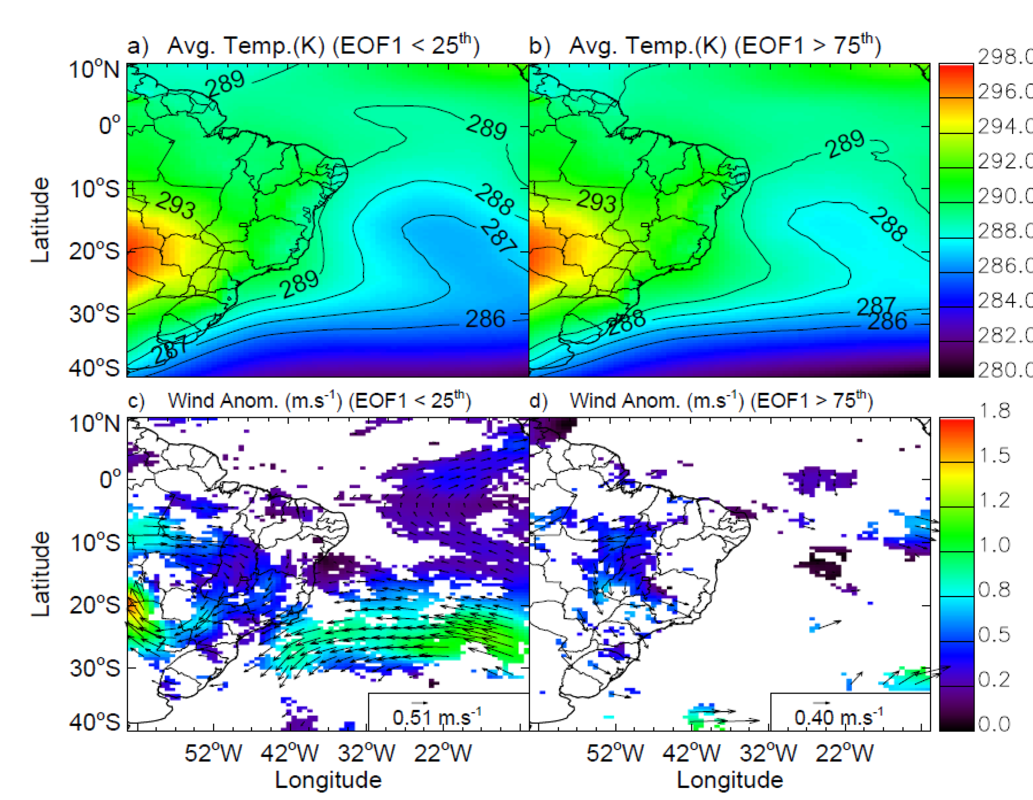

Figure 3 – Mean 850hPa temperature (Top) and 850hPa wind anomalies (bottom). EOF-1 below 25th percentile (left) and EOF-1 above 75th percentile (right).

Warm (Cold) SST anomalies over the tropical South Atlantic are associated with weaker (stronger) than normal temperature gradient between land and ocean (Figs. 3a,b).

In addition, ***cold SST anomalies over the tropical Atlantic are associated with an intensification of the north flank of the South Atlantic High and cyclonic anomalies over the continent. (Fig. 3c)*** The opposite is not observed for the case when the tropical Atlantic was warm (Fig. 3d). Wind anomalies are shown only where differences are statistically significant at 5% level.

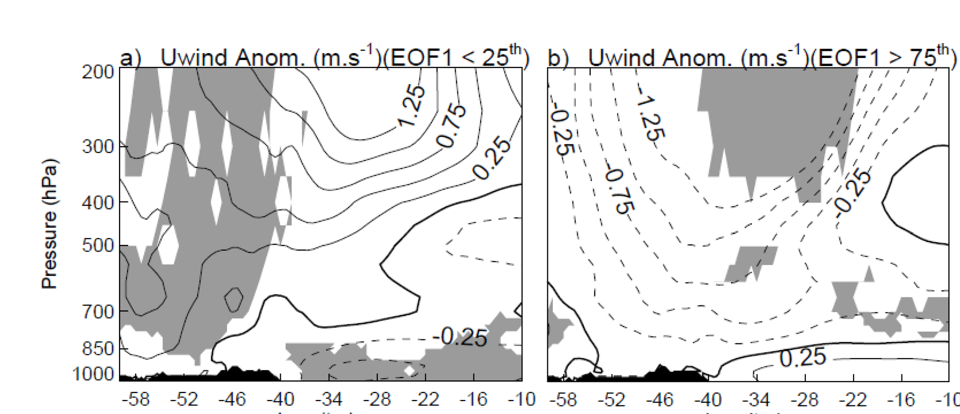

Figure 4 – Zonal wind anomalies (m.s^{-1}) when a) EOF-1 is below 25th percentile and b) EOF-1 is above 75th percentile. Average between 20ºS and 10ºS.

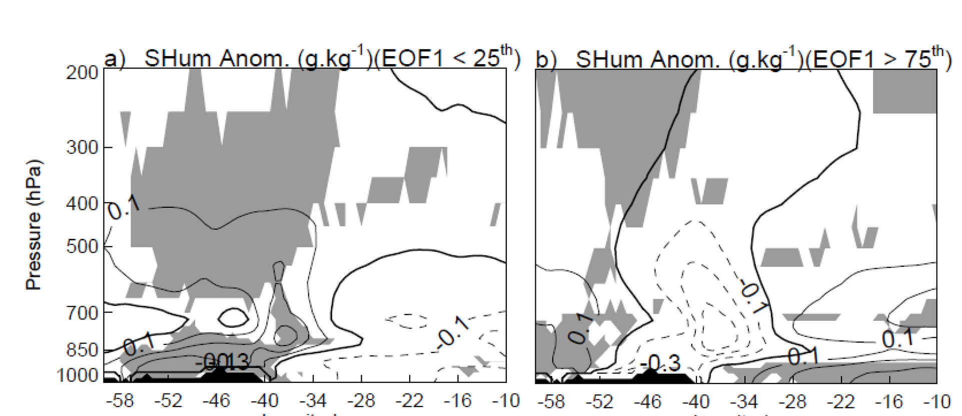

Figure 5 – specific humidity anomalies (g.kg^{-1}) when a) EOF-1 is below 25th percentile and b) EOF-1 is above 75th percentile. Average between 20ºS and 10ºS.

Cold tropical SST anomalies are related to convergence of the zonal wind and increased moisture over the plateau (Fig. 4,a - 5a).

REGIONAL ATMOSPHERIC SIMULATIONS

The regional climate simulations were performed using the Brazilian developments on the Regional Atmospheric Modeling System (BRAMS). BRAMS is a non-hydrostatic model with several components to represent cloud microphysics processes, radiative transfer, turbulence, and atmosphere–biophysics–hydrology interactions.

Two preliminary simulations were carried out for the austral summer of 2005/2006. The summer of 2005/2006 was selected because it was a period when both Pacific and South Atlantic Oceans presented neutral conditions (not shown). The first experiment was the ***Control experiment , which is forced with the MERRA reanalysis fields and observed daily SST*** for the austral summer of 2005/2006. The second experiment was the ***SST experiment***, which was performed using the same driving field as the Control experiment but with ***observed daily SST plus prescribed SST anomalies***. SST anomalies were identified as the composite of SST anomalies for the cases when ***EOF-1 was below the 25th percentile*** (cold tropical SST anomalies). Prescribed anomalies were included only over the South Atlantic Ocean.

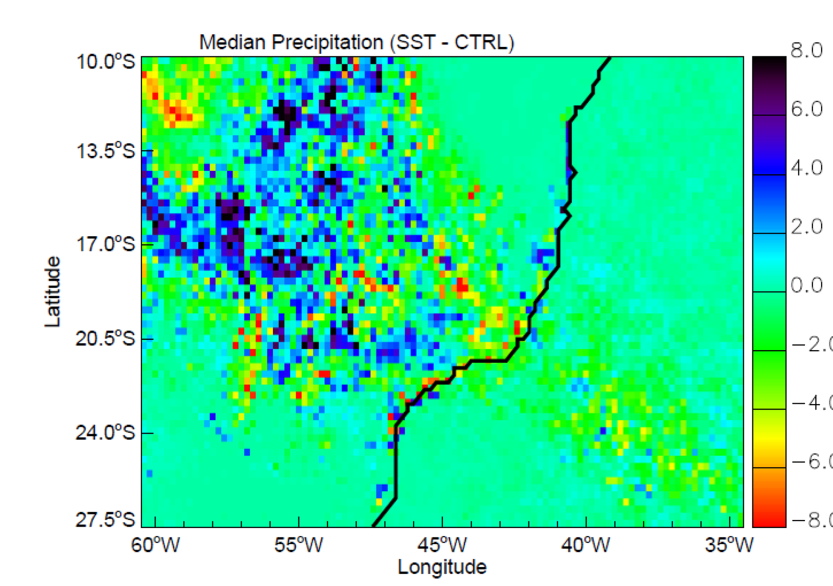

Figure 6 – Median precipitation difference (mm.day^{-1}) between SST and Control Experiments.

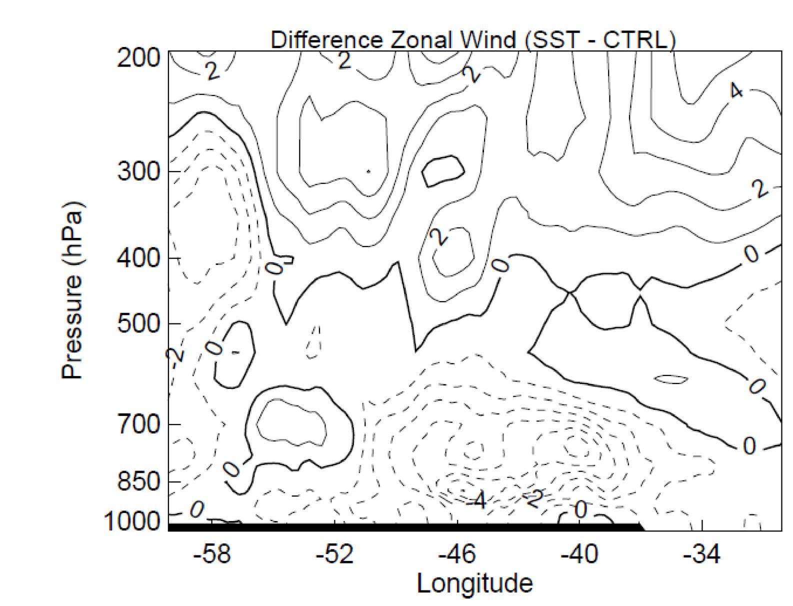

Figure 7 – Zonal wind difference (m.s^{-1}) between SST and Control Experiments. Average between 20ºS and 10ºS.

Preliminary regional atmospheric simulations are consistent with observations. ***Cold SST anomalies over the tropical South Atlantic increase precipitation over Central – eastern Brazil*** (Fig. 6) and ***are associated with the enhancement of westward anomaly wind over the region*** (Fig. 7).

CONCLUSION

Observations and regional atmospheric simulations indicate that ***cold SST anomalies over the tropical South Atlantic intensify the temperature gradient between land and ocean, increasing the transport of moisture onshore and increasing precipitation over central-eastern Brazil during the South American summer monsoon.***

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