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Behavior of droughts in Northern South America using the SPI as phenomenon's measure, and its relationship with ENSO

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INTRODUCTION

Widely-recognized as one of the most pressing issues that our planet faces today, climate change has given rise to an observed increase in world temperature, along with more frequent and more destructive extreme weather events (such as droughts). Consequently, water resources have negatively affected in a direct manner (Mishra and Singh 2010). Study of macro-climatic phenomena confirms that these changes could seriously impact the precipitation amount in a specific time period over vast regions. The purpose here is to identify tele-conections between precipitation anomalies in northern South America and the El Nino/Southern Oscillation (ENSO) macro-climatic phenomenon, based on Standardized Precipitation Index (SPI)

IDENTIFYING PRECIPITATION ANOMALIES USING SPI

SPI classifies the precipitation anomalies according to specific periods, in order to identify drought length and intensity (McKee, Doesken, and Kleist 1993). Gridded precipitation dataset from Delaware University (http://www.esrl.noaa.gov/psd/) allowed to calculate the SPI for the present study. The database includes observed rainfall data from 1900 to 2009, with 0.5º spatial resolution. SPI time series were created with several time scales (3, 6, 9 and 12 months) between 1950 and 2009, in order to quantify the precipitation deficits (or surpluses) in northern South America. Figure 1 shows the SPI12 average during "El Niño" strongest years (year "0"; average of strong "El Niño" years 1957, 65, 72, 82, 97) and two years after (year "1" and year "2"). Moreover, Figure 1 shows the extent of negative precipitation anomalies over several regions in northern South America during the last quarter of year "0" (warm colors). The maximum areal extension and intensity, are reached during the period February to July of year "1" . Then, SPI12 returns to "normal" values in January of year "2".

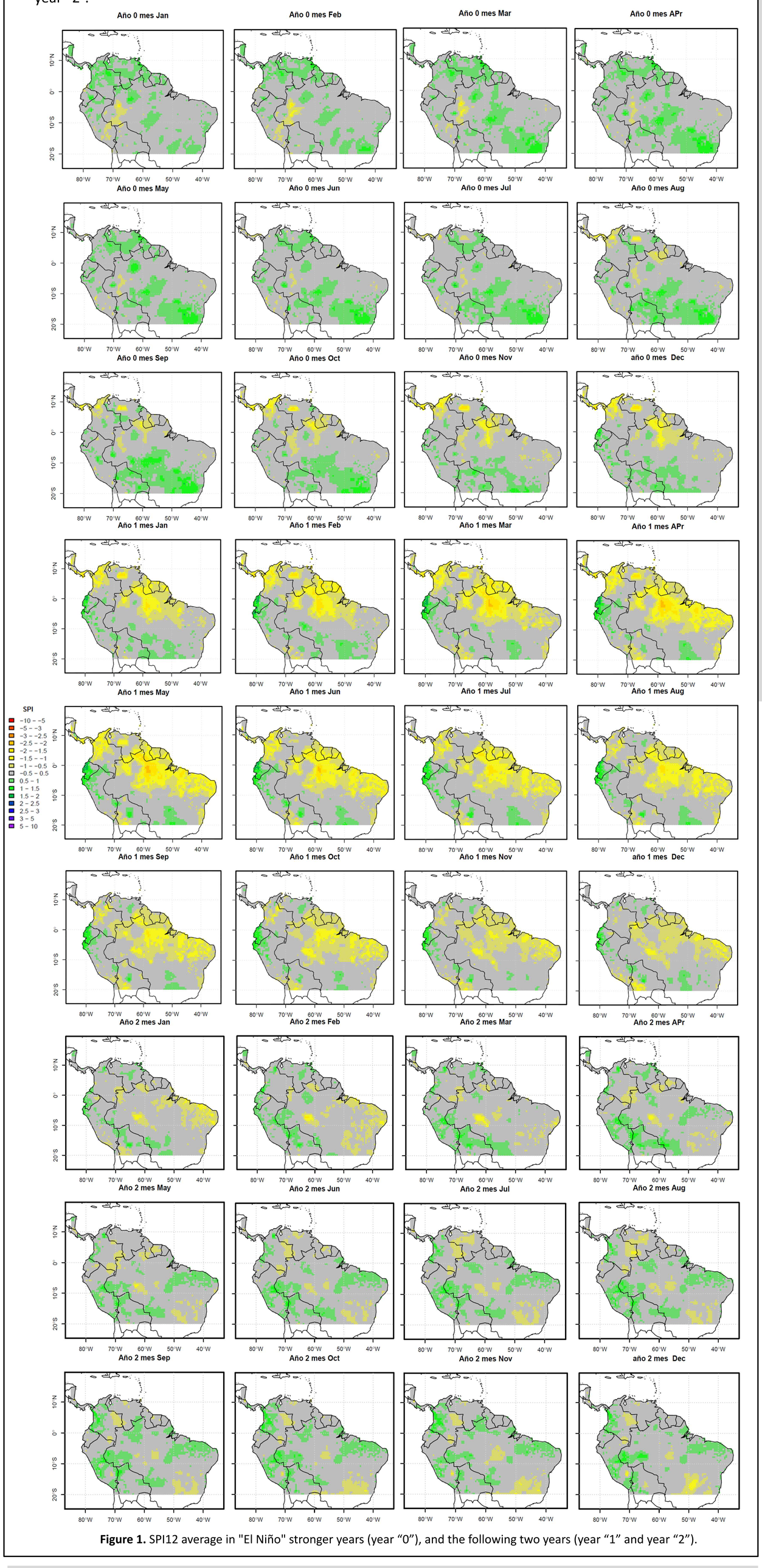

Figure 1. SPI12 average in "El Niño" stronger years (year "0"), and the following two years (year "1" and year "2").

PCA-EOF METHODOLOGY

Principal Component Analisys – Empirical Orthogonal Functions (PCA-EOF) analyzes spatial and temporal structure of geophysics fields. The reduction of the data dimensionality leads to principal components, which are supposed to explain an important percentage of the data variance (H. Björnsson and S. A. Venegas 1997).

Applying this methodology to SPI12 data, showed that the first eight EOF explain 51.31% of data variance (see Figure. 2).

For clarity's sake about the terminology, the spatial patterns obtained with the methodology are referred as EOF, while time series (or expansion coefficients), which describe the time evolution of these fields, are denominated PCA.

RELATIONSHIP SPI vs ENSO

The ENSO phenomenon has been recognized between the main drivers of South American climate (Grimm and Tedeschi 2009; Poveda, Waylen, and Pulwarty 2006). Then, the relationship between the time series of main vibration mode of SPI12 (PC1-SPI12), and the time series of the Multivariate ENSO Index (MEI; Wolter and Timlin, 2011), was studied. Figure 3 presents the results.

The cross-correlation function of MEI and PC1-SPI12 shows the maximum value at six-month lag (SPI12 after). The SPI12-EOF1 (associated with the expansion coefficient PC1-SPI12) shows negative values (depicted as warm colors in Figure 4) for western Colombia, and nearly the entire Amazonian basin (most prominently in the east). These regions would present negative precipitation anomalies (SPI < 0) after ENSO warm phases (MEI > 0).

Finally, a cross-correlation analysis of MEI time series and SPI12 reconstructed time series (using the firsts eight EOF; see Figure 5) yielded strong and spatially consistent negative correlations in the previously mentioned regions. These strong negative correlations are conspicuous at 3 to 8 months lag.

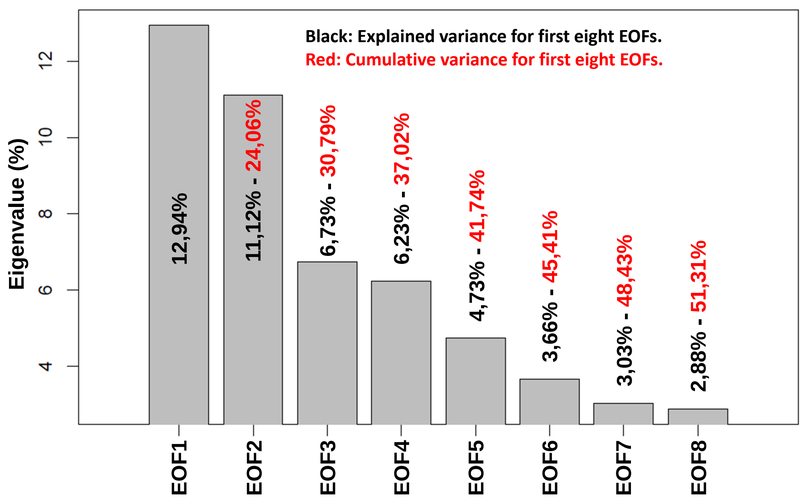

Figure 2. Explained and cumulative variance for the first eight SPI12 EOFs, computed on northern South America.

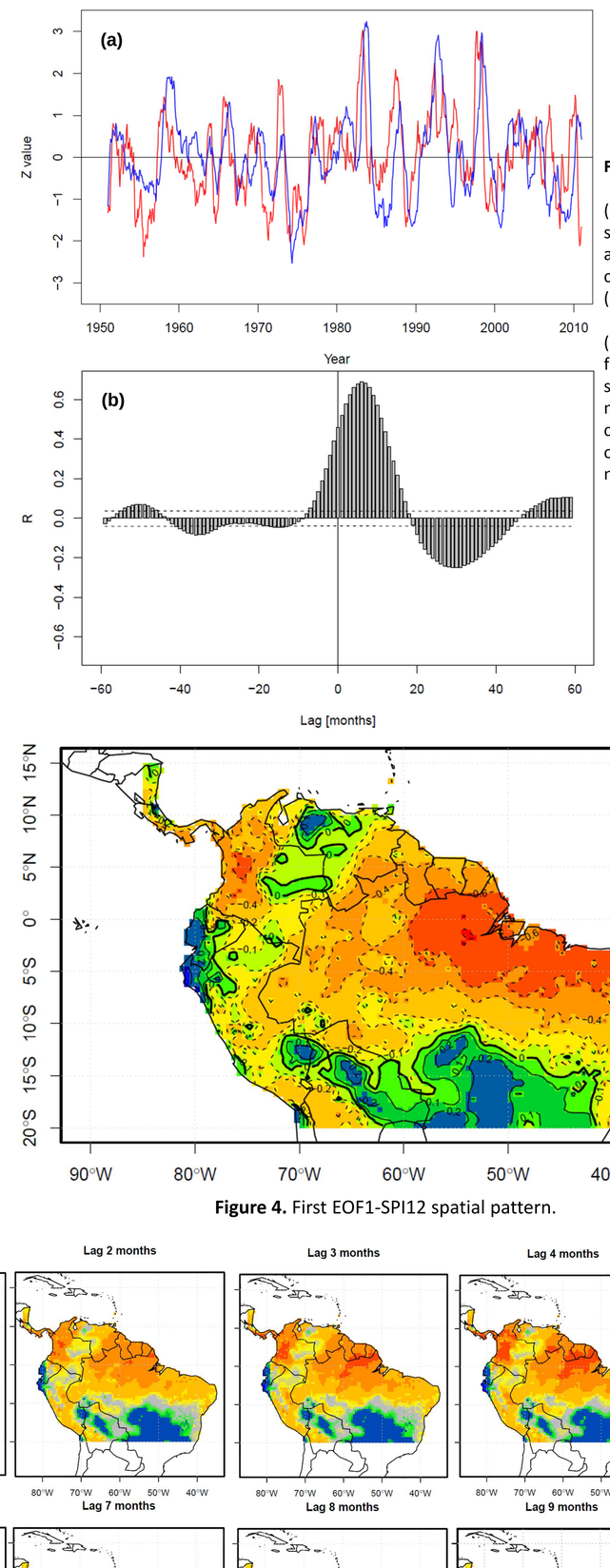

Figure 3.

(a) Standardized time series for MEI (red) and first principal component of SPI12 (PC1-SPI12, blue).

(b) Cross-correlation function of MEI time series and PC1-SPI12; maximum positive correlation is observed at six month lag.

Figure 4. First EOF1-SPI12 spatial pattern.

Figure 5. Cross-correlation function maps between MEI vs SPI12 (reconstructed at grid-points).

DISCUSSION

Evidence of temperature influence on precipitation anomalies on northern South America has been presented, based on SPI as a way to measure rainfall anomalies. The performed analysis show that precipitation anomalies are negatives in western Colombia and the Amazon basin. Looking more closely at the basin, the most negative and spatially spread anomalies are concentrated in the eastern half, near the mouth of Amazon river. These negative anomalies are strongest from 3 to 8 months following warming in the tropical region of the Pacific Ocean (from February to July of the following year at the beginning of warming phenomenon).

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