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The 2014 Primera Drought over Central America

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1. Introduction

In Central America, the Primera or first rainfall season begins in May and ends roughly in August. In 2014, the Primera was well below-average and led to drought, which severely impacted many countries. By mid-September, the livelihoods of more than 2 million people were jeopardized by food insecurity, according to the United Nations World Food Programme (Bonifacio 2014). Past studies have identified relationships between sea-surface temperatures (SST) over the Pacific and Atlantic and rainfall anomalies over Central America (Ropelewski and Halpert 1987; Waylen and Quesada 2002; Magana *et al.* 2003). Studies have also associated the mid-summer drought, a period with reduced rainfall in July, with a strong Caribbean low-level jet over the Intra-Americas Sea. This surge is linked to an amplification and westward extension of the North Atlantic subtropical high (Romero-Centeno *et al.* 2007; Wang and Lee 2007; Wang 2007; Small *et al.* 2007; Munoz *et al.* 2008). Understanding drought still poses a challenge, particularly over such a complex and narrow land as Central America. The main goal of this study is to investigate the underlying mechanisms, governing the Central America drought during May-August, 2014, with a particular emphasis on the role played by SST and its coupling with the atmosphere. A better understanding of the forcing associated with this particular drought may help improve prediction of such extreme climatic event in the future.

2. Data and methods

We used the National Centers for Environmental Information monthly extended reconstructed sea-surface temperatures version 3b (ErSSTv3b) (Smith et al. 2008) for the period 1979-2012 and optimum interpolation SST (OI-SST) (Reynolds *et al.* 2002) for the period 1982-2014. We applied an empirical orthogonal function (EOF) analysis similar to the method used in Messie and Chavez (2011) to ErSSTv3b to explore the dominant modes of variability of global SST. We then applied regression to the Climate Prediction Center Merged Analysis of Precipitation (CMAP) (Xie and Arkin 1997) onto the principal components (PC) of SST. We used the National Aeronautics and Space Administration (NASA) daily Tropical Rainfall Measurement

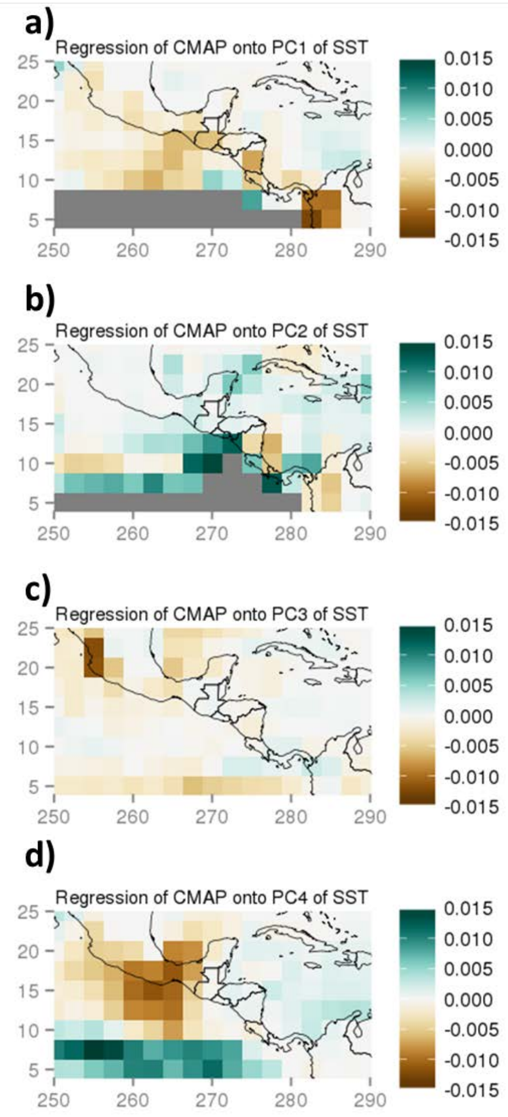

Fig. 1 Regression of the May-August CMAP rainfall onto each of the first four (a-d) PCs of SST.

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Mission 3B42 version 7 (TRMM 3B42 v7) and monthly TRMM 3B43 v7 (Huffman et al. 2007) to quantify anomalies during 2014. The climatology was calculated from 1998-2014. We used the NASA Global Land Data Assimilation System (GLDAS) version 1 (Rodell *et al.* 2004) soil moisture content in the 0-10cm layer from the NOAH land surface model to quantify soil moisture anomalies. Climatology used was 1981-2010. We used the National Centers for Environmental Prediction-National Center for Atmospheric Research (NCEP-NCAR) reanalysis (Kalnay *et al.* 1996) monthly zonal and meridional components of the wind, vertical velocity, and specific humidity to examine large-scale atmospheric circulation and moisture transport. Climatology was computed for the 1981-2010.

3. Results

3.1 Sea-surface temperatures and rainfall

The dominant mode (EOF1) explains 19.3% of the total variance and exhibits ENSO patterns. The first principal component (PC1) strongly correlates with the Oceanic Nino Index (ONI), with a correlation coefficient of 0.82. Regression of CMAP onto PC1 displays negative anomalies across Central America, with the largest deficits over Guatemala, western El Salvador, Nicaragua, and western Costa Rica (Fig 1a). This means El Nino conditions likely result in below-average Primera rainfall. In contrast, regression of rainfall onto PC2 shows positive rainfall anomalies over much of Central America, (Fig 1b). Regression of rainfall on PC3 indicates near-neutral conditions (Fig 1c), whereas its regression on PC4 displays substantial negative anomalies over southern Mexico and western Guatemala (Fig 1d).

3.2 The 2014 Primera drought

Large seasonal deficits exceeding 3mm day-1 were observed over western and southern Nicaragua and northwestern Costa Rica. An analysis of the area-averaged (92ºW-83ºW; 10ºN-16ºN) daily rainfall during 2014 relative to the average daily rainfall displays an early onset and extended mid-summer drought. The mid-summer drought began mid-June and ended in late July. This corresponded to a reduction in rainfall by roughly 50%. In terms of interannual variability, seasonal rainfall shows no significant trend over the past seventeen years. However, a declining trend was observed since 2010. With the exception of 2001, 2014 was the second driest years since 1998, with seasonal rainfall falling more than one standard deviation below the mean.

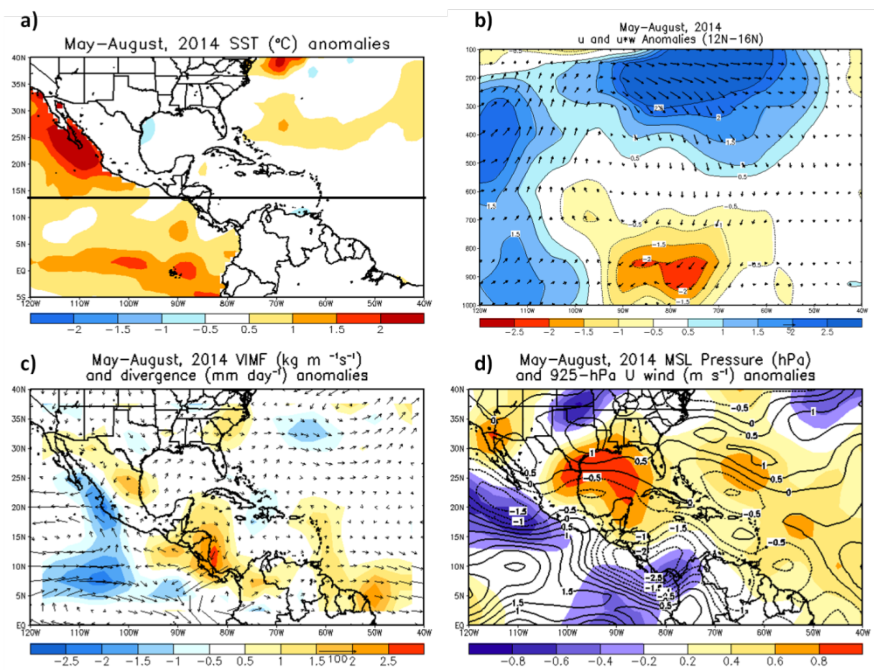

Fig. 2 a) SST anomalies during May-August, 2014 in the OI-SST. b) Longitude-height cross section of the zonal component of the wind coupled with vertical velocity (vectors) anomalies and zonal component of the wind (shaded and contours) anomalies. c) Vertically-integrated (850 hPa-200 hPa) of moisture flux (vectors) anomalies and moisture divergence anomalies (shaded). d) Mean sea-level pressure (shaded) anomalies and 925-hPa zonal component of the wind (contours) anomalies.

3.3 Atmospheric circulation and moisture transport

Well above-average SST was observed across the equatorial eastern Pacific, while the western Atlantic and Caribbean Sea remained near-neutral (Fig 2a). A longitude-height cross section of zonal wind coupled with vertical velocity anomalies averaged between 12°N and 16°N indicates a vertical circulation, with its ascending branch over the northeastern Tropical Pacific (Fig 2b). Conversely, the associated descending branch is observed over the longitudes of Central America. Stronger than average easterlies, with anomalies larger than 2 m s^{-1} were observed at 925 hPa and correspond to strong Caribbean low-level jet (Romero-Centeno *et al.* 2007; Wang and Lee 2007; Small *et al.* 2007; Munoz *et al.* 2008). Strong moisture flux anomalies exited the Pacific Basin of Central America, thus removing moisture from the region (Fig 2c). Positive divergence anomalies were also observed over Central America. Figure 2d shows stronger than average Caribbean low-level jet across the southern portions of Central America. Mean sea-level pressure anomalies exhibits anomalous cut-off high over the Gulf of Mexico and a westward extension of the North Atlantic subtropical high.

4. Concluding remarks

We have examined the influence of SST, observed features, atmospheric circulation, and moisture transport to better understand the governing mechanisms associated with the drought over Central America during May-August, 2014. An EOF analysis was applied to the global SST. Seasonal rainfall was projected onto the PC's of SST. Anomalies in various flux and atmospheric fields were also analyzed. The following results stand out. First, ENSO was found to be the dominant mode of variability in global SST and it tends to suppress the Primera, May-August season, over Central America. The fourth leading mode resembles central Pacific ENSO and can lead to rainfall deficits in southern Mexico and western Guatemala. Second, the 2014 drought was characterized by an early onset and extended mid-summer drought, with a reduction in rainfall by roughly 50 percent. The 2014 Primera season was among the top driest years since 1998. Third, warmer eastern Pacific and relatively colder Atlantic drive vertical circulation, with an ascending branch that enhances convection over the northeastern Tropical Pacific and a descending branch, which suppresses rainfall over Central America. Enhanced anomalous moisture divergence and moisture flux contributed to the reduction in atmospheric humidity. Lastly fourth, in line with previous studies, large-scale remote forcing contributed to the drought over Central America.

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