Abstracting ENSO Spatial Patterns' Impact on Atlantic Tropical Cyclone Seasonal Frequency

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Abstract

1 Introduction

Pacific Ocean sea surface temperatures (SSTs) have well documented global long-range teleconnections, including Atlantic TC activity [8, 2, 3, 4, 10]. The quasi-periodic cycle (2-7 years) of warming and cooling of the near equatorial Pacific Ocean, known as the El-Niño Southern Oscillation (ENSO), has been used as a staple variable to predict Atlantic TC activity for decades. However, due to the large amplitude variations in seasonal TC counts, the difference in Atlantic TC activity based on the various phases of ENSO is not obvious (see Figure 1).

ENSO has been quantified using warming-based indices where SST anomalies are averaged over regions in the Pacific. Such indices include the Nino 1+2 (0-10S, 90-80W), Nino 3 (5N-5S, 150-90W), Nino 4 (5N-5S, 160E-150W), and Nino 3.4 (5N-5S, 170-120W) regions. Some studies have suggested such indices do not capture ENSO's nature and evolution. Subsequently, more elaborate indices were developed some of which were linear combinations of the above-mentioned indices [14], while others have proposed indices using transformed data or nonlinear combination of indices [13]. Despite the varying degrees of complexity, the majority of works attempting to capture ENSO focus on the intensity of warming in a the tropical Pacific. While such indices might provide valuable insight into weather teleconnections, they were not designed to capture the physical pathways by which Pacific SSTs may impact the large-scale conditions over the Atlantic. Recent hurricane downscaling studies [11, 5] as well as genesis indices [12] have shown that the large scale environment over the Atlantic might play a dominant role in modulating Atlantic TC activity than precursor disturbances, since these simulations do not model such disturbances yet are able to reproduce Atlantic TC climatology with significant accuracy. Therefore, increasing our ability to predict the large-scale environment over the Atlantic could have significant scientific and societal value.

We propose a novel spatial ENSO index (S-ENSO) that is designed specifically to capture the physical pathways by which Pacific SSTs may influence Atlantic TC activity. Our approach introduces a distance-based ENSO index that tracks the location of maximum near-tropical Pacific warming anomaly instead of its absolute warming. We will demonstrate the performance of our index by comparing it to traditional warming-based ENSO indices in discriminating between the large-scale conditions that are favorable for Atlantic cyclogenesis.

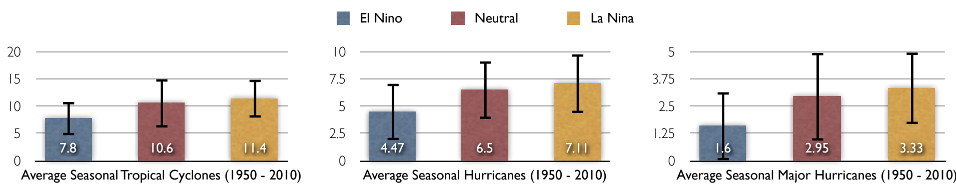

Figure 1: The 1950 – 2010 seasonal mean Atlantic tropical cyclones (a), hurricanes (b), and major hurricane (c) counts for El-Niño, neutral, and La Niña years. Vertical bars denote standard deviation. The overlap between between bars across categories makes distinguishing between Atlantic TC activity based on the phase of ENSO uncertain.

2 Spatial ENSO Index (S-ENSO)

An increasing number of studies have suggested changes in the spatial warming patterns of Pacific Ocean (SSTs) [15] and some have linked those changes to impact U.S. hurricane landfall probabilities [9]. We propose that based on such results, the spatial distribution of Pacific Ocean warming might provide better predictive insights into ENSO-Atlantic TC activity relationship than warming anomalies alone. We propose a distance-based ENSO index that tracks the longitudinal location of highest SST anomaly in the tropical Pacific. We also track the mean Outgoing Longwave Radiation (OLR) of the identified region to monitor atmospheric deep convection. The S-ENSO index is computed, by first averaging the SST anomalies over the March-October period. We then search the tropical Pacific (5S-30N) for a region with a size similar to that of traditional ENSO indices that has the highest mean SST anomaly over the March-October period (see figure 2). Once such a region is identified, we compute the mean OLR over that region. We repeat this procedure for each year from 1979 to 2010. The time series are then correlated with various quantities that communicate August-October Atlantic TC activity: number of tropical cyclones, number of major hurricanes, potential dissipation index (PDI) [6], accumulated cyclone energy (ACE) [1], and net tropical cyclone energy (NTC) [7].

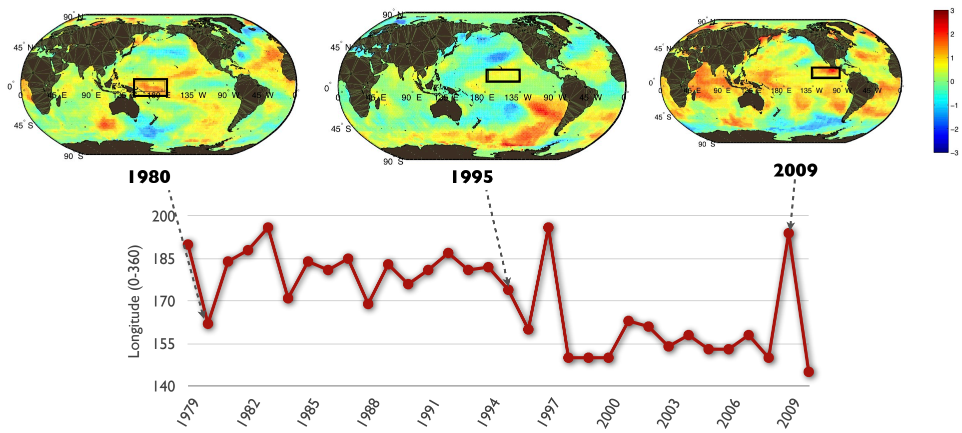

Figure 2: A schematic demonstrating how the S-ENSO index is built. First, SST anomalies over March-October are computed resulting in maps similar to those above. Next, we search the tropical Pacific for the region with the highest mean SST warming anomaly over March-October. Finally, we record the longitude of that region. We repeat this procedure for all years from 1979-2010.

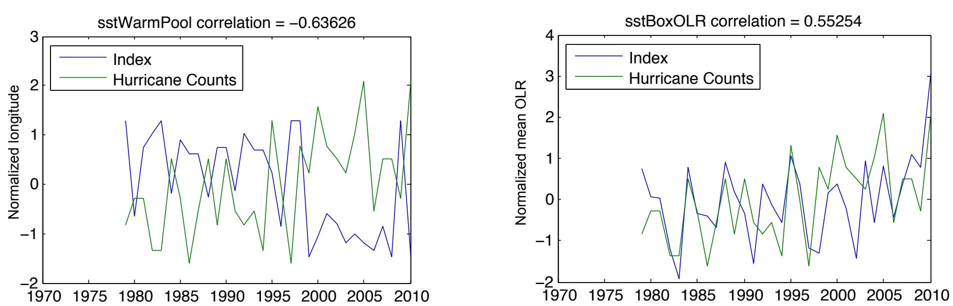

Figure 3: The time-series of our two indices with annual August-October Atlantic TC counts. Left: the normalized longitude to the warmest Pacific SST anomaly region and August-October Atlantic TC counts (-0.63 linear correlation). Right: the mean OLR of the the warmest Pacific SST anomaly region and August-October Atlantic TC counts (0.55 linear correlation). There is a notable shift in the SST anomaly signal after 1997.

	TCs	Major Hurricanes	NTC	PDI	ACE
maxSSTALon	**-0.64**	-0.5	**-0.55**	-0.44	**-0.49**
maxSSTABox-OLR	0.55	**0.57**	0.50	**0.46**	0.48
Nino1+2	-0.42	-0.42	-0.40	-0.3	-0.35
Nino 3	-0.44	-0.5	-0.44	-0.39	-0.40
Nino 4	-0.24	-0.41	-0.23	-0.2	-0.2
Nino 3.4	-0.42	-0.53	-0.42	-0.38	-0.40

Table 1: Linear correlation coefficients between various indices computed over the March-October period and August-October Atlantic TC activity. The highest score for each category is highlighted in **bold**

3 S-ENSO's impact on large-scale conditions over the Atlantic

To propose possible physical pathways by which our index impact Atlantic TC activity, we compute the composites for factors known to influence Atlantic TC activity: potential intensity (PI) and saturation deficit (also not shown we have composites for SST, central pressure, vertical wind shear, geo potential height and precipitable water). Each composite was for the August-October period - the peak hurricane season. To compare how well our index resolves the large-scale conditions that are critical to seasonal TC activity we compare our index' composites to those of the seasonal TC count composites (baseline) and those of the NINO3.4. The idea is that if our index is better able to distinguish between the large-scale conditions for active and inactive hurricane seasons its composites should closely resemble those of the baseline (i.e. active minus inactive hurricane years).

Figure 4 shows the PI composite. The mean OLR of the warmest SST anomaly region is able to reproduce nearly identical conditions to those of the TC count composite. In figure 5 a linear combination of the S-ENSO and OLR is also able to reproduce the large-scale saturation deficit in the lower and middle troposphere. These results show that monitoring the spatial warming patterns of the tropical pacific can significantly increase our ability to resolve the large-scale conditions over the pacific during the hurricane season. Furthermore, there seems to have been a phase shift in the warming patterns in the Pacific that coincided with the increased TC activity in the Atlantic.

4 Acknowledgments

We thank Prof. David Nolan for providing us with the MATLAB routines to compute potential intensity (PI) from reanalysis data.

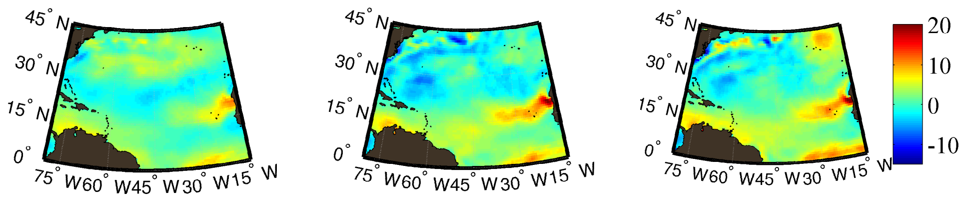

Figure 4: Potential Intensity (PI) composites for NINO3.4 (left), maxSSTABox-OLR (middle), and August-October Atlantic TC counts (right). The OLR index is able to reproduce the large-scale conditions over the Atlantic as they relate to PI.

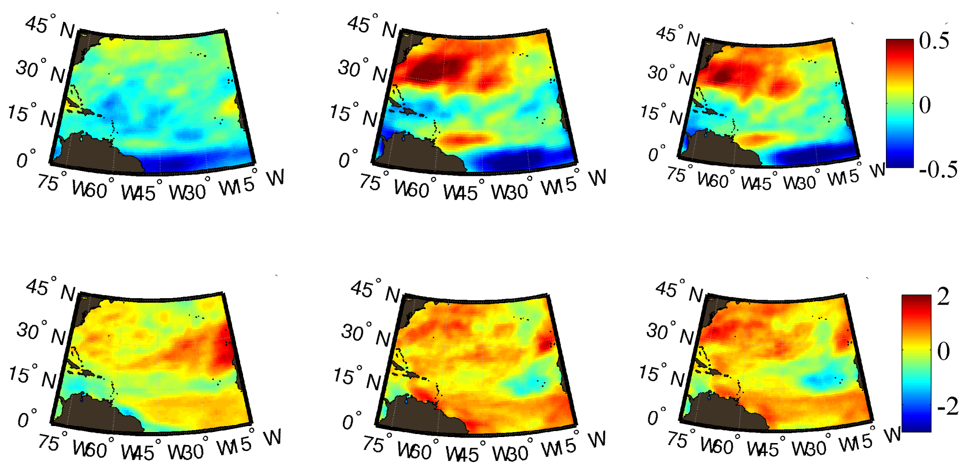

Figure 5: Saturation deficit composites at 500mb (top row) and 850 (bottom row). Left: NINO3.4 composite. Middle: the composite of a linear combination of the S-ENSO and OLR indices. Right: August-October Atlantic TC count composite. Our index is able to reproduce the saturation deficit the lower and middle troposphere over the Atlantic.

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