6.8 IMPACT AND INDICATOR BASED PERSPECTIVES OF ENSO INFLUENCE ON U.S. CLIMATE DURING WINTER

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1. INTRODUCTION

Traditional ENSO impact analysis is recast to investigate the teleconnections between wintertime U.S. climate and varying indicator regions of Sea Surface Temperature (SST) anomalies in the Tropical Pacific. This serves the dual purpose of finding a targeted indicator region for a particular impact zone (i.e. a localization of the teleconnection pattern) and indirectly assessing the viability of well-established ENSO indices (i.e. the Niño indices). Both air temperature and precipitation composites (anomalies) over the U.S. are computed as a function of U.S. grid point and indicator point (the SST time series in the Pacific), and are conditioned on SST phase (warm or cold events). The resulting space by space functions are analyzed from both impact and indicator perspectives. In addition, the space by space functions are decomposed using Empirical Orthogonal Function (EOF) analysis to isolate the leading impact-indicator pairs and provide modes that portray varying U.S. impacts based on different choices of an SST box in the equatorial Pacific Ocean

2. CREATING THE COMPOSITES

Monthly Pacific SST data are extracted from the ERSST data set (Smith and Reynolds 2003), which is constructed on a 2° X 2° grid, from 151°E to 81°W and 15°S to 15°N. The record length is 56 years, from 1946 through 2001. Monthly U.S. impact data consist of mean air temperature and precipitation data from the U.S. Historical Climate Network (USHCN, Karl et al. 1990), averaged to 2° X 2° grids using available data in each box. The resulting U.S. grid has 235 total grid points with data values. Local effects are not a focus of the current investigation. However, the target indicator regions can also be computed per station or grid point if a more localized assessment is desired.

SST indicator regions are varied across the equatorial Pacific Ocean, resulting in localized time series. Based on preliminary results, a 6° X 6° degree indicator region was selected. The 6° X 6° setting means that there are 806 (62 by 13) indicator regions that overlap each other. An additional timesaver is that impacts are only considered for December, January and February (DJF). Air temperature deviations are computed using composite analysis based on a local warm and cold phase, which is defined as when the local ENSO index is above or below the 80th or 20th percentile, respectively. For precipitation anomalies, percent deviations are computed.

For each SST indicator region, the monthly mean air temperature anomaly (T) composite is computed for both warm and cold events. These data arrays are denoted by $T_w(r,s)$ and $T_c(r,s)$, where w stands for the warm phase, c for the cold phase, r for the indicator location, and s for the impact grid point. A similar calculation is performed on the monthly precipitation (P), except that these are reported as composite percent deviations from the monthly climatology: $P_w(r,s)$ and $P_c(r,s)$. It is important to note that the data arrays are functions of indicator and impact locations only; the time dimension has been eliminated by the compositing process.

The fields are inspected from two perspectives: impact grid point and indicator region. The impact perspective is defined as the vantage point in which the anomalies for a given impact region are quantified as a function of indicator region – this results in a map over the Pacific Ocean that indicates the air temperature anomaly (for example) that would be

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experienced in a particular U.S. grid point based on various locations of the SST indicator region.

In the alternate perspective (the indicator perspective), air temperature and precipitation impacts are plotted as a function of indicator region location (U.S. grid points), allowing an inspection of the climate impacts associated with a single indicator region (much like the El Niño and La Niña impact maps that are readily available in the literature). Therefore, the indicator perspective is defined as the vantage point from which climate anomalies across a large impact zone are computed as a function of a given indicator region.

3. EOF ANALYSIS OF COMPOSITES

In order to simultaneously interpret both the impact and indicator perspectives described above, EOF analysis of the space-by-space data arrays is employed. Typically in geophysical applications, EOF analysis is used as a variance decomposition tool applied to a space by time field, reducing a cumbersome data array into a much smaller set of spatial patterns and associated time series. The time series is considered to be the loading vector, i.e. the time-varying weight (or amplitude) associated with a particular spatial signature. In the present case, the EOF modes represent temperature or precipitation signatures that are modulated by *the location* of the SST indicator region. In other words, the leading modes represent the most energetic impact-indicator pairs.

4. PRELIMINARY RESULTS

Preliminary results are presented for the impact perspective (Fig. 1), the indicator perspective (Fig. 2), and the EOF decomposition (Fig. 3) of the air temperature composites: $T_w(r,s)$ and $T_c(r,s)$. Bootstrapped composites, as well as EOF analyses of the bootstrapped composites, were utilized to ascertain statistical significance. Sign switching that is characteristic of EOF analysis was accounted for by using one-sided t-tests of absolute values when determining the p-values of the indicator weighting functions.

It is clear from Fig. 1 that the different U.S. grid points respond differently to varying indicator regions. Fig. 2 shows that the Niño regions generally agree in their air temperature impacts over the U.S., with the notable exception being the lack of a significant signal (and appearing to be of opposite sign) during the cold phase of Niño 1+2. EOF decomposition of $T_w(r,s)$ yields one significant mode that accounts for 84% of the variance – the impact amplitude map reveals the typical El Niño conditions experienced over the U.S. EOF decomposition of $T_c(r,s)$ results in 2 significant modes that explain 62% and 25% of the variance, respectively. While the leading mode depicts the typical La Niña conditions, the second mode is best characterized as anti-El Niño.

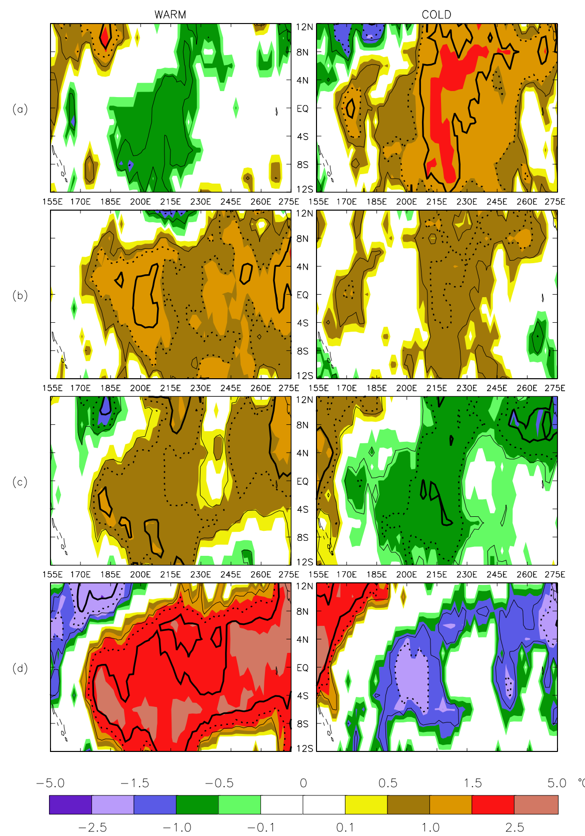

Figure 1: The Impact Perspective – Air Temperature. Mean winter air temperature anomalies (^oC) for impact grid points representative of (a) North Florida, (b) Eastern Pennsylvania, (c) Southwest Washington, and (d) Northeast Montana. The anomalies are contoured as a function of warm and cold phases of each 6° X 6° SST indicator box across the tropical Pacific. Anomalies where the statistical confidence is less than 60% (two-tailed) are not contoured. The two-tailed 75%, 90%, and 98% levels are depicted as solid, dotted, and heavy solid lines, respectively.

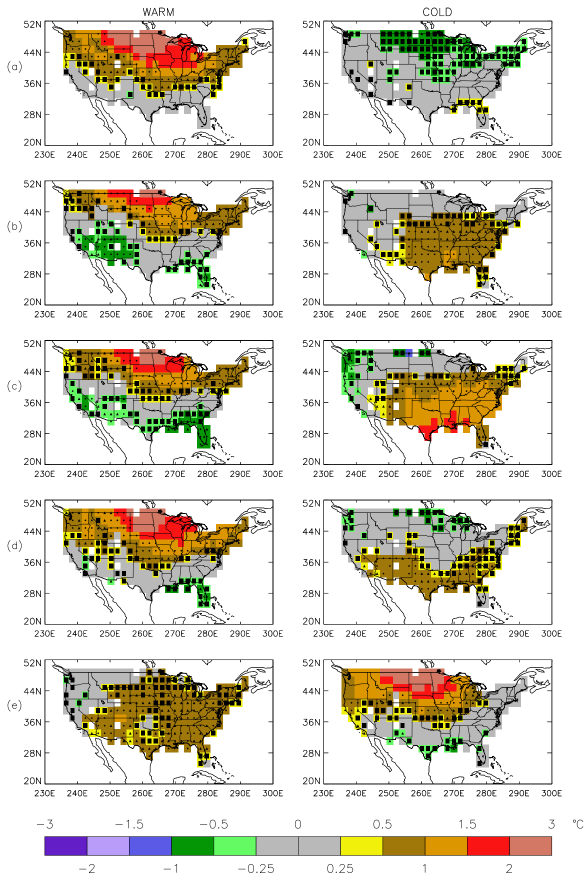

Figure 2: The Indicator Perspective – Air Temperature. Warm and cold phase air temperature deviations for 6° by 6° indicator regions centered on the equator. The longitudinal ranges straddle (a) 275°E, (b) 240°E, (c) 215°E, (d) 185°E, and (e) 155°E. The five SST regions are representative of Niños 1+2, 3, 3.4, 4, and the extreme Western Pacific, respectively. Anomalies where the statistical confidence is less than 50% (two-tailed) are not contoured. A grid point that fails the two-tailed 80%, 90%, or 98% confidence t-test is indicated by a rectangle, triangle, or circle, respectively. Grid cells without a black symbol exceed confidence at the 98% level.

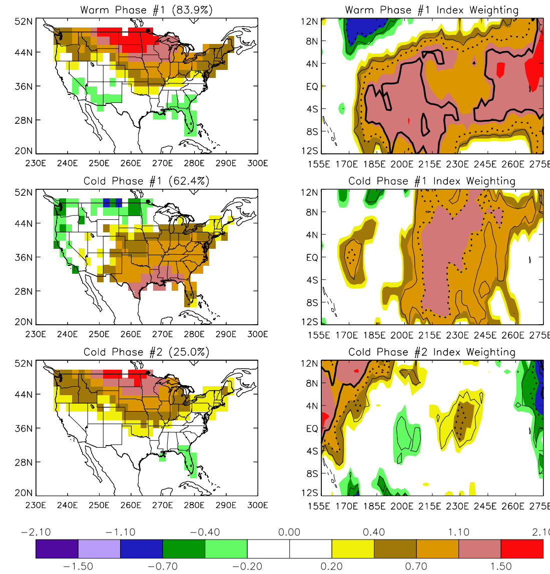

Figure 3: EOF Decomposition over U.S. – Air Temperature. EOF analyses of warm and cold phase air temperature anomalies as a function of indicator and impact regions for the entire United States. The left column represents the impact spatial signatures and the right column denotes the associated loadings for each 6° by 6° indicator region. The product of each mode pair is in degrees Celsius. Indicator weighting values where the statistical confidence is less than 60% (one-tailed) are not contoured. The one-tailed 75%, 90%, and 98% levels are depicted as solid, dotted, and heavy solid lines, respectively.

5. REFERENCES

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