A comparison of climatic wind and sea surface temperature data sets using a numerical model

Charles E. Tilburg[1] and James J. O'Brien[2]

[1]Graduate College of Marine Studies, University of Delaware, Newark, Delaware
[2]Center for Ocean Atmospheric Prediction Studies, Florida State University, Tallahassee, Florida

Email: tilburg@udel.edu

The examination of interdecadal variations in ocean dynamics frequently requires the use of different historical data sets that can suffer from inadequate spatial and/or temporal resolution as well as inaccuracies and biases due to varying sampling techniques. Consequently, much effort has been invested in both the development and validation of reconstructed observational data sets. Recently, two studies have used empirical orthogonal functions (EOFs) to reconstruct historical surface wind stress (Shriver and O'Brien, 1995) and sea surface temperature (SST) (Meyers et al., 1999) of the tropical Pacific Ocean.

We compare the SST and the wind stress data sets using a simple reduced gravity model. The model domain (shown in the top two panels of the figure) encompasses the equatorial Pacific Ocean from 124ºE to 80ºW. The use of the numerical model driven by the reconstructed winds allows a direct comparison between two related quantities: SST and upper layer thickness (ULT) of the model, which is a proxy for the depth of the pycnocline. Changes in equatorial SST are associated with the dynamics of equatorial Kelvin waves triggered by the variation in trade winds. The warm phase, or El Niño, is initiated by the relaxation of trade winds, which force a series of downwelling Kelvin waves that propagate west to east across the equatorial Pacific Ocean. The downwelling Kelvin waves increase the pycnocline depth and inhibit the deeper colder waters from mixing with the warmer surface waters, resulting in warm SST anomalies in the eastern Pacific Ocean. The cold phase, or La Niña, is characterized by a series of upwelling Kelvin waves that are triggered by an increase in the trade winds. The upwelling Kelvin waves decrease the depth of the pycnocline, enhance the mixing of colder deep waters with surface waters, and result in cold SST anomalies in the eastern Pacific Ocean.

EOF analysis of the modeled ULT field from 1930-1998 (Top panel) and the SST field from 1930-1993 (Middle panel) demonstrates that the largest single component of variability (1^{st} EOF mode) for both data sets is dominated by the ENSO cycle. The spatial structure of the 1^{st} EOF mode (containing 21% of the variance) of the modeled ULT field is comprised of a horizontal bipolar structure centered on the equator. The regions of largest variation in the eastern Pacific are along the equator and along the coastal regions and are related to downwelling or upwelling equatorial and coastal Kelvin waves. The largest variations in the western Pacific extend to 180º and are out of phase with those of the eastern Pacific. These are related to the ocean's response to the shift in the trade winds associated with the onset of an El Niño or La Niña. The spatial structure of the 1^{st} EOF mode (containing 40% of the variance) of the SST anomalies consists of a maximum constrained to the equator in the eastern equatorial Pacific extending from 180º to the coast of South America. The amplitudes of the two EOF modes (Bottom panel) are highly correlated (r=0.72), demonstrating that upwelling and downwelling within the equatorial region caused by the reconstructed winds are evident in the equatorial SST.

Acknowledgments:

Charles Tilburg receives financial support from NSF Grant OCE-0002375 and Sea Grant NA96RG0029. COAPS receives its base funding from the ONR Secretary of Navy Grant to James O'Brien.

References:

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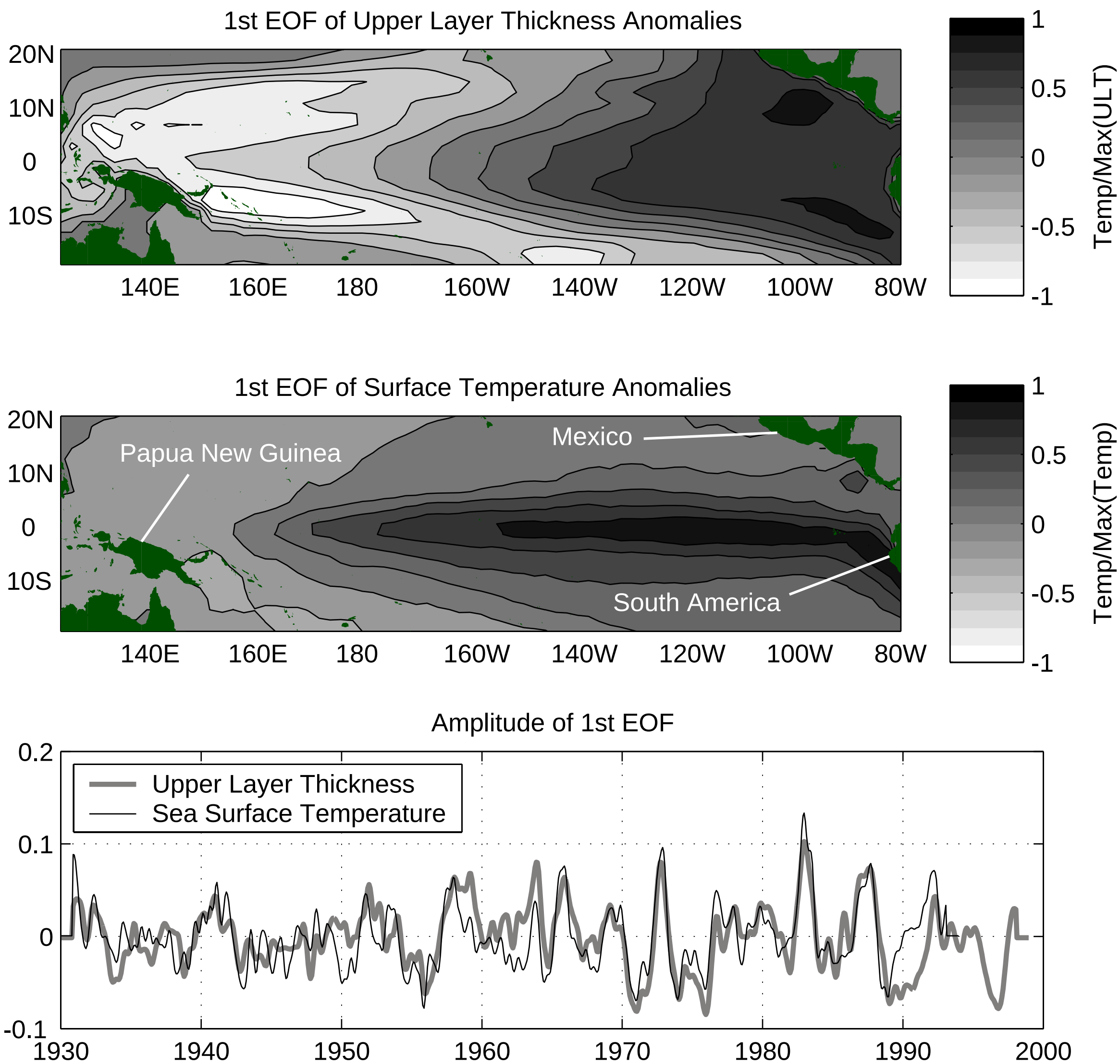

(Top Panel) Spatial structure of the 1st EOF of the upper layer thickness anomalies of the numerical model forced by the winds from Shriver and O'Brien (1995). **(Middle Panel)** Spatial structure of the 1st EOF of the sea surface temperature anomalies from the analysis by Meyers et al. (1999). **(Bottom Panel)** Amplitudes of the two EOF modes as functions of time.