JP2.5 ENSO-based forecasting of seasonal tropical cyclone trends from historical analyses of genesis and OLR oscillations

Colin K. Kennedy and David R. Smith.
U.S. Naval Academy
Annapolis, MD 21402

1. BACKGROUND

Low-frequency convective oscillations in both the tropics and the mid-latitudes have received quite a bit of attention in recently published literature. This is not the case for higher frequency activity known as intra-seasonal oscillations (ISOs). In contrast to the norm, while the few studies that have dealt with this subject do so in a highly quantitative fashion, this paper seeks to qualitatively describe ISOs by focusing on what they cause, rather than what causes them, based on their interactions with low-frequency interannual oscillations. The "tracer" chosen to accomplish this is the genesis of a tropical cyclone, a unique convective event that generally limits itself to regions north of the intertropical convergence zone (ITCZ) and south of the sub-tropical latitudes. This is placed against the backdrop of the Southern Oscillation (ENSO), a commonly studied interannual fluctuation caused by anomalous sea surface temperatures (SSTs) in the equatorial Pacific (Fuell, 1997; Kiladis, 1998; Lander and Guard, 1998; Vincent et al., 1998; Mandal, 1989; and many others). This paper will show that the inter-basin temporal variability of cyclogeneses—very much affected by large-scale phenomena—varies as well.

The primary goal of this research is to demonstrate a relationship, however variable, between seasonal atmospheric energetics and interannual climate features between basins. Here, we do so following the example of Pokrovskaya and Sharkov (1993, 1994), in which high- and low-frequency interactions are based on the analysis of individual cyclogeneses or "events" (as they will be known hereafter). With limited confidence a qualitative relationship will be verified to which future and more specific research can be applied. To this end, a complete 50-year data set of tropical events over the two basins of interest is analyzed.

In order to verify the technique established above, the second phase of this project was aimed at a more quantitative analysis of frequency interactions. A 25-year dataset of OLR is averaged and limited to match the spatial and temporal window used in the genesis technique. In terms of the genesis technique, it was observed during ENSO warm phases that inter-basin oscillations were usually suppressed. In effect, the tropical convection associated with genesis would "break out" at similar times. So, one would expect the OLR over the entire region to be minimized (convection maximized) during warm phases as well, providing evidence of the suppressed event oscillation.

Corresponding Author: David R. Smith, United States Naval Academy, Oceanography Department, 572M Holloway Road, Annapolis, Maryland, 21402; E-mail - drsmith@usna.edu.

2. METHODOLOGY

a) Genesis Technique

The first dataset employed in this study is the revised NCAR global tropical position dataset. The spatial limit of the two basins studied is 5-45°N, 10-140°W and the temporal limit is 01 June to 30 November. In order to ensure data continuity for the basins under investigation, some event removals are necessary within the two sets (as summarized in Table 1.)

Ocean Basin	**Non-Seasonal Events Removed (% total)**	**Events of Central Pacific Origin Removed (% total)**
East Pacific	21 (3.0)	33 (4.8)
North Atlantic	9 (1.8)	----------
Ocean Basin	**Events of Sub-tropical Origin Removed (% total)**	**Remaining Events (% total)**
East Pacific	----------	639 (92.2)
North Atlantic	19 (3.8)	469 (94.4)

Table 1. Summary of tropical position dataset adjustments.

The ENSO index values used in this study are derived from the regional ENSO monthly sea surface temperature (SST) anomaly data. Conveniently, this data also begins in 1950. . Of interest in this study is the seasonal region Niño 1+2, whose bounds lie closest to the active event areas of the East Pacific. "Seasonal" implies that only data from the six months that compose the tropical season are used. They are averaged to form a single tropical season value of SST anomaly for each season of the 50-year period. Seasons whose index absolute values are less than 0.5°C are classified as neutral seasons, while values greater than or less than ±0.5°C are classified as warm (+) or cold (-) seasons, respectively.

After time series are established, a lagged cross correlation is performed for each season. Peaks—representing oscillation lags between the two basins—are limited to 21 days in accordance with the precedent of earlier research. Strong signals near zero lag indicate high levels of coincident activity, while weak signals near zero were often accompanied by strong signals at higher lags, indicative of inter-basin oscillation. The lag findings are then compared graphically to the two corresponding seasonal ENSO values mentioned above. First, the principal spectral peaks for each season are compiled; the average lag is 7.58 days. The data series is then demeaned. Second, the ENSO data are demeaned in a similar fashion and then scaled up by a factor of five to compare more readily with the spectral peak series. Finally, a 6^{th} power polynomial regression is performed on both the spectral peak and ENSO series.

b) OLR analysis

The second principal dataset employed was the corrected global daily OLR dataset. The data were remotely sensed and placed on a 2.5° x 2.5° lat/long grid. Only the daily values from the tropical region of interest are included in the analysis and only for the tropical season, i.e. days 152-334. This yields 832 values per day which are averaged to form a single OLR value for each day. (It should be noted values for the season of 1978 were unavailable due to satellite failure.)

Once the gridded data are confined and averaged, an FFT power spectrum analysis is performed on the time series for each season. Spectral peaks arise that, although insignificant in appearance, are significant in reality. Even a small (i.e. < 1 W/m²) change in average OLR represents a significant change in the regional environmental conditions, hence the small but significant peaks.

3. RESULTS

Following the cross correlation analysis, it was determined by visual inspection of the cross correlation spectra that during ENSO cold events and neutral seasons, greater spectral peaks were evident away from zero. For some ENSO warm events, on the other hand, the spectral peak was near zero. This was the overall trend observed.

However, visual inspection alone is not expected to convince the reader of any significant correlations between oscillation lags and the phase of ENSO. Thus, graphical evidence was also created. As discussed earlier, both series were demeaned and the Niño 1+2 series was scaled so that both lines of data would have comparable magnitudes. Albeit that the annual progressions of both data series are highly variable and have little in the way of linear correlation, two polynomial regressions revealed the long term inverse relationship that the visual inspection of the data above suggested. (see Fig. 1). One can see that in the long run, as the value of the ENSO index increases (warm phase), the oscillation lag between the two basins decreases, or is suppressed.

In order to begin the process of eliminating the multitude of other atmospheric variables that could have an input into the oscillation phenomena, it was decided to analyze the atmosphere from the perspective of regional convection through the use of OLR data. Due to time constraints placed on this research, only the daily average values for the entire region in question were obtained, as opposed to one daily value for each basin.

Ideally, if convection oscillation is suppressed during an ENSO warm phase and convection in one basin occurs coincidentally with convection in another basin, spectral peaks in an FFT power spectrum would be more dramatic at periods of 14-21 days, the estimated periodicity of El Niño based convective flare-ups. Generally, this is what is observed.

4. SUMMARY AND CONCLUSIONS

Some work suggests that ENSO may be a forcing factor in this variability. The project completed here is an important first step in better understanding the inter-basin oscillations caused by these phenomena, an area of study that has been given little or no attention to date. Major findings in this study include:

a) During ENSO neutral and cold seasons, a marginal degree of inter-basin oscillation exists, while during warm seasons this oscillation may be absent and may stall or even be suppressed. Furthermore, a scaled overlay of ENSO and observed seasonal oscillation lags aids the reader in acknowledging the existence of an ENSO based restraint on inter-basin oscillation.

b) There were evenly spaced spectral peaks indicative of oscillation trains within certain seasons, in particular those with numerous events to analyze. Further studies of tropical convection proxies on more continuous timescales will show whether these occurrences are haphazard or are indicators of convective rains not resolved in quiescent seasons where cyclogeneses fail to form and provide signals.

All of the results made here are highly speculative and will need to be quantitatively verified in future research. However, the fact that even limited confidence of inter-basin oscillations can be demonstrated with so few variables leads to optimism that the door is wide open to future research on this subject from the standpoint of: similar techniques using different atmospheric variables, more statistical techniques and complex data analysis, and studies of other tropical ocean basins and the global-scale processes that govern them.

Ultimately a better ability to predict global cyclogenesis events in space and time as Pokrovskaya and Sharkov (1993, 1994) envisioned may be possible. This would be a benefit to commercial shipping, residents of coastal areas, emergency management organizations, and military forces operating at sea. In reference to the latter, at the 2000 Tropical Cyclone Conference hosted by the Joint Typhoon Warning Center the improvements to 7-14 day forecasts for purposes of exercise planning and improvements of numerical model performance for tropical cyclogenesis were specifically prioritized. The desire to “develop a graphical product that quantitatively describes the probability of tropical cyclone formation” was one of the conference’s five highlighted concerns. The ongoing research described in this paper has the potential to add to this effort.

5. ACKNOWLEDGEMENTS

The authors would like to thank the Data Support Section at the National Center for Atmospheric Research (NCAR) for making available the tropical position data and OLR data utilized in this study, and Mr. Joey Comeaux of the NCAR Data Support Section for his assistance in data acquisition. The authors also thank Mr. Bob Disque of the USNA Computer Aided Digital Design (CADIG) division for his assistance in programming to read and modify the very large OLR dataset. Also acknowledged is the National Climatic Data Center (NCDC) who made available through the Climate Prediction Center (CPC) website the ENSO SST anomaly data. Some financial support for this project was funded by the Office of Naval Research (ONR) and made available to the United States Naval Academy Midshipman Research Fund. Finally, the authors would like to thank Dr. Peter Guth who provided guidance on the computer-aided aspects of the experiment and his software primary data analysis platform of this project.

Tropical Cyclone Oscillation Lag vs. Niño 1+2 SST Anomalies

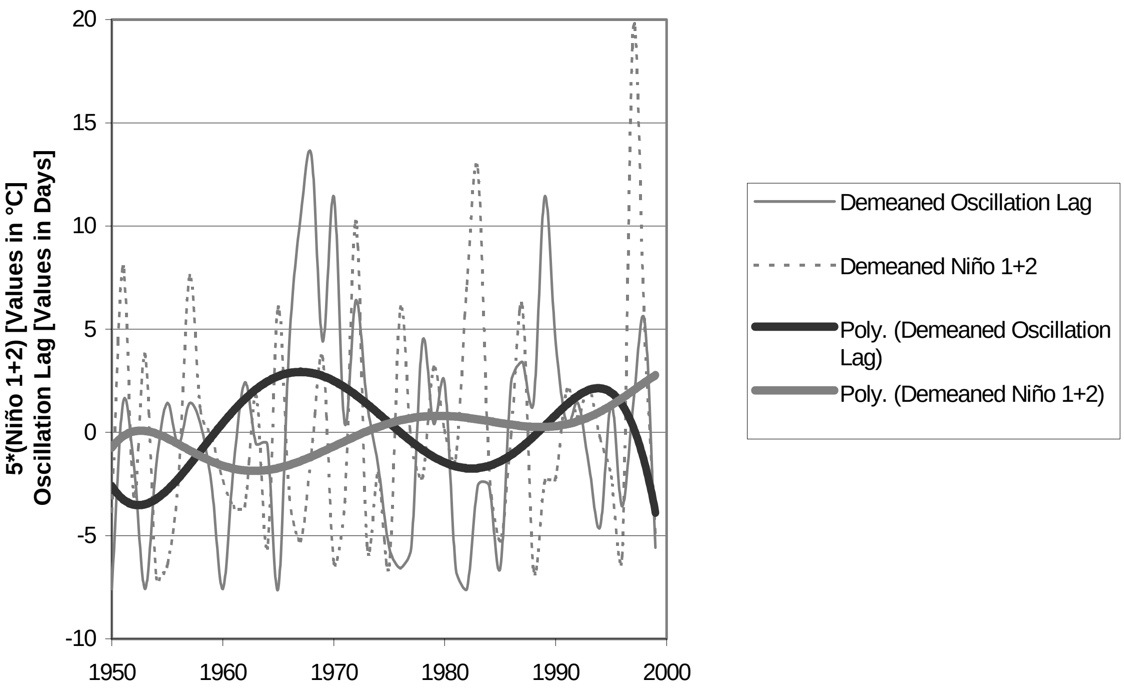

Figure 1. An illustration of the observed interaction between ENSO SSTs and cyclogenesis oscillations. When the ENSO index is high, representing a warm phase, the tropical oscillation is suppressed with respect to long-running averages, represented by the polynomial regression.

REFERENCES

Fuell, K., 1997, The annual cycle and interseasonal variability of synoptic (3-7 day) and intraseasonal (7-25 day) convective activity over the tropical eastern Pacific; M.S. Thesis, Department of Earth and Atmospheric Sciences, Purdue University, 78 pp.

Kiladis, G.N., 1998, Observations of Rossby waves linked to convection over the eastern tropical Pacific; *Journal of the Atmospheric Sciences*, 55, 321-339.

Lander, M.A., and Guard, C.P., 1998, A look at global tropical cyclone activity during 1995: contrasting high Atlantic activity with low activity in other basins; *Monthly Weather Review*, 126, 5, 1163-1173.

Mandal, G.S. 1989, Low frequency oscillations and seasonal variability of tropical cyclones within ocean basins; Proceedings of the Second WMO International Workshop on Tropical Cyclones (IWTC-II), Geneva, Switzerland, p. 67-76.

Pokrovskaya, I.V., and Sharkov, E.A., 1993, Global generation of tropical cyclones as a Poisson process; Transactions (Doklady) of the USSR Academy of Sciences, Silver Spring, MD, 333A, 9, 8-11.

Pokrovskaya, I.V., and Sharkov, E.A., 1994, Annual variability of global tropical cyclogenesis; Meteorology and Hydrology, Moscow, Russia, 4, 20-28.

Vincent, D.G., Fink, A., Schrage, J.M., and Speth, P., 1998, High- and low-frequency intra-seasonal variance of OLR on annual and ENSO timescales; *Journal of Climate*, 11, 5, 968-98.