P1.57 EVIDENCE OF COOPERATIVE INTERACTIONS BETWEEN INTRASEASONAL OSCILLATIONS AND EQUATORIAL WAVES

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1. Introduction

The eastward propagating part of the Madden-Julian or Intraseasonal Oscillation (hereafter labeled the ISOe) and intraseasonal convectively coupled equatorial Rossby waves (hereafter labeled ISOw) cooperatively interact with and modulate each other (e.g. Roundy, 2003). For example, the ISOe modulates the amplitudes of convective and moisture anomalies of the ISOw. These two modes may also trigger or amplify one another through interactions with land.

In this work, I apply a multiple linear regression model that includes the first through fourth powers of an OLR time series index of the ISOe as predictors of precipitable water anomaly data (PW) filtered in wavenumber and frequency for two bands representing the ISOe and the ISOw. The ISOw modes are often characterized by somewhat higher frequencies than are the ISOe modes, so a linear regression model with only a linear predictor cannot diagnose the entire relationship.

Higher order regression models have been shown to be applicable in many fields of study as long as some simple caution is exercised. For example, in some applications of similar models, linear correlations between predictors may distort or otherwise invalidate the model results. For cases in which these collinearities are important, an orthogonal basis for the original set of predictors can be found and applied as a new set of predictors.

The purpose of this poster presentation is to describe how this technique can be applied to the study of atmospheric waves. I show that the application of the nonlinear terms improves the description of physical processes relative to a fully linear model. This is done by comparing both the results of this model and of a fully linear model to results from a much simpler composite averaging technique.

2. Data and Model Description

OLR and PW data were Fourier filtered for eastward and westward propagation in intraseasonal frequencies (including one band for the ISOe (wavenumbers 0-6 eastward and periods of 26-104 days) and another for the ISOw (wavenumbers 1-6 westward and periods of 15-104 days)).

The regression model is

$$y_{s,t+\tau} = a_{0,s\tau} + a_{1,s\tau}x_t^1 + a_{2,s\tau}x_t^2 + a_{3,s\tau}x_t^3 + a_{4,s\tau}x_t^4 + \varepsilon_{s\tau} \qquad (1)$$

where y is the dependent variable (for this case, y is ISOw band pass filtered PW) and x is the predictor variable (here, ISOe band pass filtered OLR at 90°E and 10°S, including only wavenumbers 1-4). The term ε represents the model residuals, τ represents a time lag, and s represents the spatial coordinate. The a_n coefficients are regression parameters that are determined by a simple matrix operation. An arbitrary value of two standard deviations below the mean of the base series is then input to the resulting equation to make a composite (e.g. Hendon and Salby, 1994).

Inclusion of the higher-power terms is not a new idea (Wilks, 1995; Draper and Smith, 1966). When examined in the context of a scatter-plot, it is easy to show that these terms help to model interactions that occur between processes in different frequency bands. Inclusion of these terms will be further justified in the poster.

3. Methodology

Three composites were developed for comparison. These included one from a fully linear model, the model given in equation 1, and an independent composite average. The independent composite of westward-moving anomalies was calculated by selecting a set of dates of minima of high amplitude ISOe OLR anomalies at a base point and by averaging the ISOw band pass filtered PW over lags from those dates. The base point was the same as for the regression models. The composite average exhibits responses to both linear and nonlinear interactions but it is more subjective than the statistical model because it uses only a small subset of the entire dataset and because the criteria used to select the set of dates are subjective.

In addition to the comparison of the three composites, the effects of collinearities on the multiple linear regression model was also estimated. This was done by recalculating the composite by using an orthogonal basis of the set of predictor terms, and examining the difference between it and the original result.

4. Results

The results of the fully linear model, the independent composite average, and the model from equation 1 (Figure 1) clearly show that the multiple linear regression model with nonlinear terms is more similar to

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the independent composite than is the simple linear model. For example, anomalies in both the independent composite and in the multiple regression composite tend to cluster along the heavy slanted lines in Figure 1 b and c. Such clustering is not apparent in the fully linear result.

The poster will include a discussion of the structure of the contribution of the nonlinear terms, showing that the nonlinear terms model interactions by which the ISOe modulates the amplitude and other behaviors of the ISOw. Results given in the poster will also clearly show that collinearities between the set of predictors do not significantly affect results for this application of the model form. The maximum difference between the original result and the result of the orthogonalized model was only 2 percent of the local composite value.

5. Conclusions

The multiple linear regression model produces physically valid analyses that reveal processes of partly nonlinear wave interactions that occur in the real tropical atmosphere. Similar relationships are also visible in a composite average of ISOw band pass filtered PW anomalies that is based only on a set of dates of active ISOe convective anomalies at a base point. Inclusion of the nonlinear terms in the regression improves the resolution of wave interactions relative to a purely linear version of the model. Correlations between the set of predictor variables do not significantly influence the model results for the case analyzed here.

Works Cited

Draper, N.R., and H. Smith, 1966: *Applied Regression Analysis*. John Wiley & Sons, Inc.

Hendon, H.H., and M.L. Salby, 1994: The life cycle of the Madden–Julian Oscillation. *J. Atmos. Sci.* **51**, 2225-2237.

Roundy, P.E., 2003: *Analysis of the climatology and interactions of waves in the equatorial region*. A thesis in Meteorology, Penn. State University, State College, PA. Contact the author for copy.

Wilks, D. S., 1995: *Statistical Methods in the Atmospheric Sciences*. International Geophysics Series, Vol. 59, Academic Press.

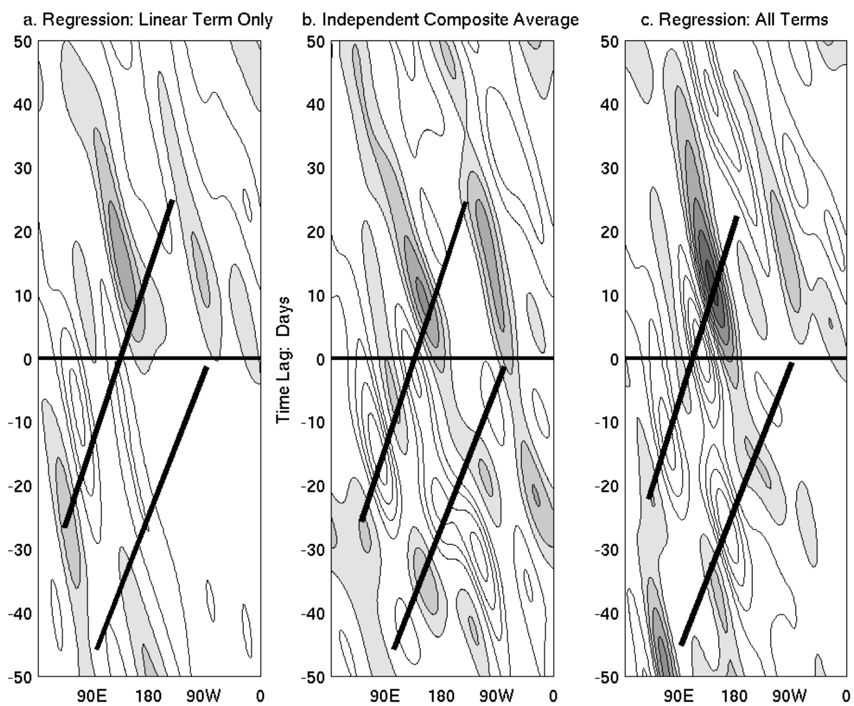

Figure 1 Regressed or averaged ISOw PW anomalies. Positive PW anomalies are shaded. a) Results for fully linear regression only, b) composite averaged based on dates of minima of the ISOe index, and c) multiple linear regression including nonlinear terms.