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A SIMULATION OF THE MAINTENANCE OF THE MADDEN JULIAN OSCILLATION: USING SCALE INTERACTIONS AS A FRAMEWORK

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1. INTRODUCTION

The study of atmospheric energetics has long been related to the general circulation forecast issue discussed in numerous meteorological studies. Saltzman (1957) used formulations for major exchange processes which involve both available potential and kinetic energies - proposing a wavenumber spectral analysis of the energetics of atmospheric disturbances. The exchanges that Saltzman examined were an effort to discover the generation and transfer of energy among different wavenumbers.

The scale interactions formulation used in this study has its roots grounded in the work by Saltzman (1957) as well as the seminal mathematical framework of Hayashi (1980). Hayashi proposed a means of computing the nonlinear energy transfer spectra by using the Cross-spectral technique. There is a distinct advantage to the cross-spectral method in that it additionally allows for the application to the frequency spectra. This frequency spectra is the functional domain that all analyses herein constitute.

A fully involved and complete study of the generation and dissipation of eddy KE in an open system demands an examination of several components of the energetics cycle. Barotropic Processes; Baroclinic Processes; Frictional effects at the earth's surface; Frictional effects above the earth's surface; Boundary fluxes of eddy KE and Boundary fluxes of eddy potential energy.

The centerpiece of this study is the MJO and the scales of the atmosphere that help to maintain it. More than 30 years ago, Madden and Julian (1971, 1972) first discovered the global-scale, eastward-propagating zonal oscillation, that has a period between 30 and 60 days. The periods used in this study are

- *Synoptic (3-7 days)*
- *Semi-Annual (180 days)*
- *Annual (yearly)*
- *ENSO (3-7 years)*
- *Decadal and beyond (10 years +)*

We propose to answer the question: What scale of frequency interactions in the

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atmosphere contributes most prominently to the overall maintenance of the MJO, while adhering to a frequency domain scale interactions framework?

2. METHODOLOGY

Lorenz (1955) described a means of examining the cycle of energy transformation among wavenumbers by using a Fourier decomposition of the planetary field of motion in the atmosphere. This decomposition allowed 'scales' of motion to be described and the energy transformation between these scales to be examined. This study examines a similar decomposition of data, however our focus is toward the Hayashi (1980) method of Cross-Spectrum analysis of data in the frequency domain.

Hayashi (1980) decomposes the energy forms based on temporal scales, which takes a Fourier transform of the product of dependent variables that are multiplied at the grid points. This method is directly comparable to the computation of the spherical harmonic transforms for the nonlinear equations in spectral modeling (Orszag, 1970; Eliasen et al. 1970). This method for the computation of the net gain of energy between temporal scales is known as the Cross-Spectrum method (Hayashi, 1980).

2.1 Frequency Cross Spectra

Suppose a periodic, space-time dependent variable, can be represented by a discrete time-Fourier Series

$$u(t) = \sum_{n=0}^{N} U_n e^{i\frac{2\pi}{N}nt}$$

where N is the number of observations for each time series. Since u is assumed to be a real time series, we have the following relationship

$$U(-n) = U^c(n)$$

Where the right hand side is the complex conjugate of U. It should be noted that U(0) represents the time-mean value of the function U. Hayashi (1980) employed the sample frequency co-spectra and quadrature spectra,

$$P_n(u,v) = \frac{1}{2}Re(U^c(n)V(n)) \quad n = 1,2,...,M$$

and

$$Q_n(u,v) = \frac{1}{2}Im(U^c(n)V(n)) \quad n = 1,2,...,M$$

to compute the nonlinear transfer of kinetic energy among wavenumbers and frequencies. When summed, the co-spectra and quadrature spectra equal the sample cross spectra,

$$R_n(u,v) = P_n(u,v) + iQ_n(u,v)$$

which can be interpreted as the spectrum of the sample cross covariance.

2.2 SPECTRAL KE EQUATION

One can obtain an abbreviated form of the spectral kinetic energy equation by taking the co-spectrum between u & v and the zonal & meridional equations respectively, and while employing the continuity and hydrostatic equations, we can arrive at the spectral kinetic energy equation,

$$0 = < K \cdot K(n) > + < A(n) \cdot K(n) > + F(n) - D(n)$$

where

$$\langle K \cdot K(n) \rangle = \underbrace{\langle K(m) \cdot K(n) \rangle}_{A} + \underbrace{\langle K(0) \cdot K(n) \rangle}_{B}$$

is the partitioned kinetic energy transfer into frequency n, by nonlinear interactions among different frequencies excluding the time mean (term A), and the transfer of energy into frequency n, by interaction between the mean flow and frequency n (term B).

3. DATA

The data employed for this study was obtained from the ECMWF Re-Analysis data-set (ERA-40) at 2.5 degree resolution. This data is archived at the National Center for Atmospheric Research (NCAR) and covers the time period January 1958 through December 2001. Once daily data is used for this study, corresponding to a Nyquist frequency with a 2-day period. Thus, atmospheric transients with a period shorter than 2 days will be aliased to those with periods longer than 2 days. Data for the 200 hPa and 850 hPa levels were utilized for the global domain -90S to 90N, the tropics -30S to 30N and the respective mid-latitude regions -30S to -60S and 30N to 60N.

4. PRELIMINARY RESULTS

The maintenance of the MJO at 200 hPa illustrates some striking notions regarding regional and time-scale based exchanges. The nonlinear barotropic KE exchanges for the triad interactions illustrate (figure 1.) that globally, the MJO time-scale gains barotropic KE through nonlinear triad interactions (<K(m) . Kn)>) at the Annual, ENSO, and Decadal time-scales. At the Synoptic and Semi-Annual time-scales the MJO is prominently losing KE through these same interactions. Figure 1 illustrates similar results to that of Chen (1980) where the rotational components are significantly higher and dominate the the divergent component in their nonlinear triad maintenance of the MJO. Figure 1. indicates at what time-scales, over the 44 year period, act to provide energy to (and remove from) the MJO time-scale, for the nonlinear triad interactions.

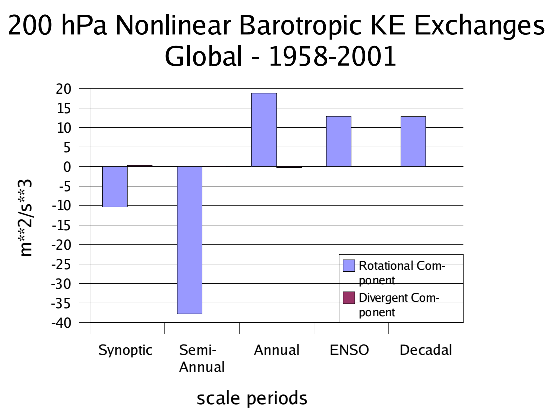

Figure 1. Nonlinear Barotropic KE triad interactions for the global domain for the period 1958-2001.

It will be shown that regional breakdowns of the MJO KE to KE maintenance can provide insight into the physical maintenance of this low frequency mode, in the tropics and mid-latitude regions. Further results will be illustrated for all terms in the spectral KE equation (time-mean time-transient and baroclinic conversion terms) with additional analysis of the mainentance in shorter temporal domains.

5. ACKNOWLEDGEMENTS

This research is supported by NSF Grant ATM 0241517, NOAA Grant NA16GP1365 and the FSU Research Foundation Grant 1338-831-45. We thank Dr. Chakraborty (IITM) for assistance with this project.

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