Frequency Interactions to Explain Madden Julian Oscillations and Intra Seasonal Oscillations

S. A. Barr-Kumarakulasinghe
Brookhaven National Laboratory
Upton, New York

Deep convective activity as seen by outgoing longwave radiation (OLR) (< 180 wm^{-2}) is shown to occur at 20 to 60 periods in a more coherent manner during the boreal winters of El-Nino Southern Oscillation (ENSO) warm events. The coherent pattern is seen in the spectra of the TWP equatorial region closer to the date line. The frequency interaction of gravity waves, emanating from diurnal or 5- to 6-day convective activity is hypothesized to be the cause of the Madden Julian Oscillation (MJO) global wind pressure oscillations.

Introduction

The MJO is considered to be a global westward propagating 40 to 50 oscillations seen in the 850 mb zonal wind, and 700-150 mb temperatures (Madden and Julian 1971, Madden and Julian 1994). Large-scale convective episodes referred to as Intra Seasonal Oscillations (ISO) seen in the tropical Indian and western Pacific Oceans, with frequencies ranging from 20 to 60 days are also thought to be related to MJO's (Knutson 1987, Anyamba and Weare 1995, Dunkerton and Crum 1995).

Using a spectra of 20 years (July 1 1974 to August 20, 1996) of OLR 2.5° x 2.5° daily data (Liebmann and Smith 1996), we show the increased occurrence of the 30 to 60 periods in ISO during the boreal winters of ENSO warm events. Using simple interaction of periods we show that oscillations at diurnal periods can result in 5- to 6-day and 30- to 60-day beat periods.

Data and Methods

Five locations of daily OLR data from 5° x 5° boxes centered on the equator were extracted and averaged. Three of the locations from Africa (17.5°E-22.5°E), Papua New Guinea (137.5°E-142.5°E), and South America (57.5°W-62.5°W) were chosen to represent globally important deep convection regions over equatorial continental and island regions (Ramage 1968). The regions over Africa and South America were over the tropical rain forest regions of the Congo and the Amazon. The other two regions, Indian Ocean (57.5°E-62.5°E) and Tropical Western Pacific (TWP) (167.5°E-172.5°E), were chosen to represent oceanic convection over warm water. The winter months (November to February) during warm events (1977, 1983, 1987, 1991, 1992, 1993, 1994, 1995) were extracted from the data. There were 8 years of warm events in the data and resulted in 960 days of data. To assess the spectral signal during periods excluding warm events, we extracted the winter months of 1975, 1976, 1979, 1980, 1981, 1982, 1985, 1986. Daily averaged values greater than 180 wm^{-2} were set to zero, so that the data record contained only instances of large-scale deep convection. Fourier transform was then performed on both data sets to show the dominant frequencies.

Summation of cosine functions with different frequencies were used to examine the interaction of these frequencies. Each frequency was changed at random by a maximum of 10% during each time step of one day for 1095 days (3 years). The periods used to examine interactions were 0.5 and 1 day (diurnal and semi-diurnal); 1 and 2 days; 5 and 6 days; 0.5, 1, 2, 5, and 6 days; 20 and 50 days. The length of the integration was chosen to match the number of days used to analyze the OLR record. Fourier transform was then performed on the resulting data series to show the dominant frequencies. Similar to the OLR data, 10 to 80 and 2 to 10 periods were smoothed with respectively 10- and 30-point boxcar filters.

Results

OLR 30- to 60-day signals around the equator are stronger during the boreal winters of ENSO warm events (Figure 1) than in the years excluding warm events (Figure 2). This supports the idea that MJO related ISO's increase during warm events and explains the increases of WWB during warm years (Hartten 1996).

Qualitatively the frequency spectra of the OLR (Figure 1 and Figure 2) and the frequency interaction of one-day periods (Figure 3a) and 5-and 6-day periods (Figure 3b) look similar. Gravity waves can induce convection and

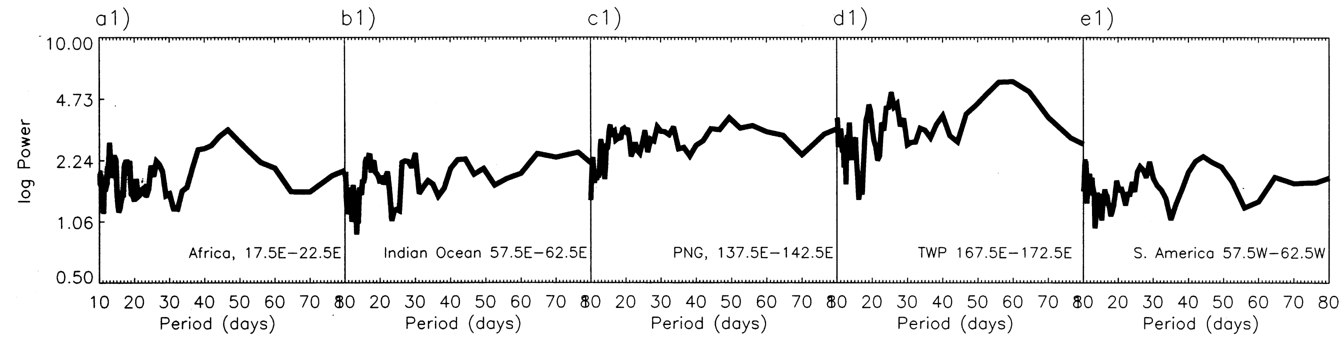

Figure 1. The OLR (< 180 wm-2) frequency spectra of ENSO warm events during boreal winters (1977, 1983, 1987, 1991, 1992, 1993, 1994, 1995) at different equatorial locations. Winters are defined as November of previous year to February of year.

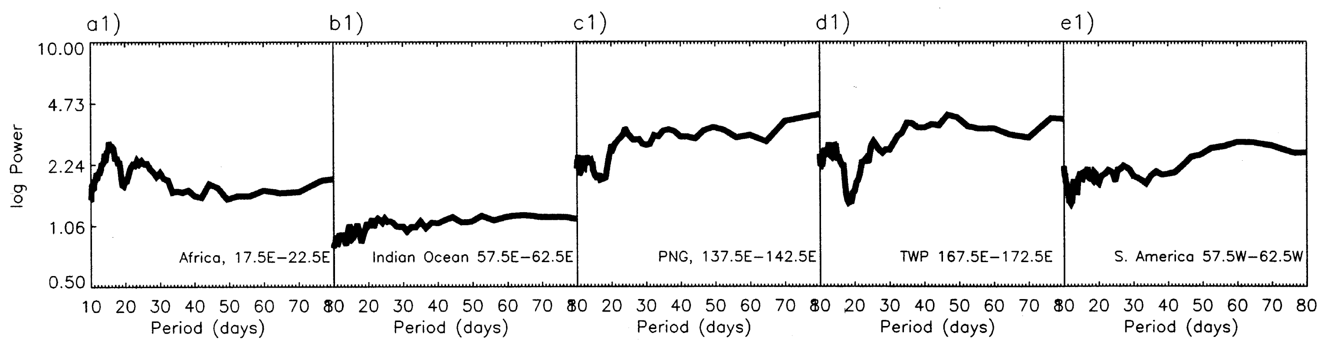

Figure 2. The OLR (< 180 wm-2) frequency spectra during "normal year" winters (1975, 1976, 1979, 1980, 1981, 1982, 1985, 1986) at different equatorial locations. Winters are defined as November of previous year to February of year.

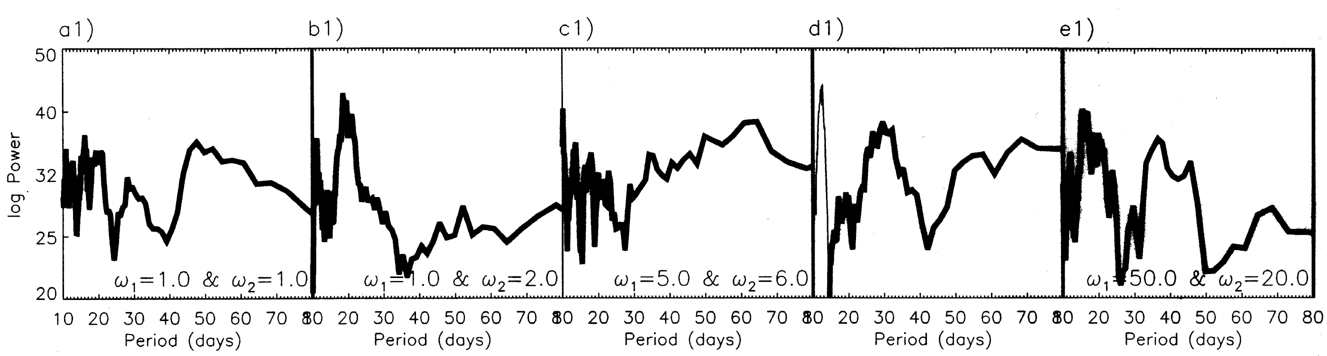

Figure 3. Frequency spectra resulting from interaction of different frequencies for 1095 days.

convection in turn can be a source of gravity waves. Gravity waves propagating away from a convective events can induce or trigger convection elsewhere (Mapes 1993, Matthews et al. 1996, Liebmann et al. 1997). Based on the similarity of the frequency interaction in Figure 3 to the wind spectra of Madden and Julian (1971), we propose that the wind spectra especially during non ENSO warm event winters are caused by the interaction of globally propagating signals from deep convection, occurring typically at diurnal time scales. There will be a preferential propagation to the east by Kelvin waves which are three times the speed of wave number one planetary waves (Gill 1980, Matsuno 1966).

In Barr-Kumarakulasinghe and Lwiza (1998) faster recycling of tropospheric humidity or "preconditioning" of the troposphere due to intense convection is used to explain why very large deep convective occurrences rarely occur over land and maritime continent compared to the open ocean. The location of the warm pool toward the central Pacific and the slow evolution of the upper tropospheric humidity over open ocean is used to explain why very large deep convective events at 30- to 60-day intervals are more likely to occur during ENSO warm events. The association of increased upper tropospheric humidity and large-scale deep convection over the TWP observed by Soden and Fu (1995) and Barr-Kumarakulasinghe and Lwiza (1998) also supports the notion that tropospheric preconditioning enhances very large scale deep convection.

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