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CLIMATOLOGICAL SPATIAL AND TEMPORAL FEATURES OF THE MADDEN-JULIAN OSCILLATION

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1. INTRODUCTION

Since its discovery by Madden and Julian (1971), a comprehensive theory of the ~30–60-day Madden-Julian oscillation (MJO) has proven elusive. The MJO is characterized by an envelope of eastward propagating deep convective organization (cloud clusters) which appears to originate over the Indian Ocean and dissipates near the dateline. The perturbations in large-scale circulations, nevertheless, continue to propagate globally in the upper troposphere (Yanai et al., 2000). Numerical simulations of MJO with models with various degrees of complexity have difficulty in producing the right phase speed and periodicity. Recently, Grabowski (2003) performed an idealized simulation by implementing a two-dimensional cloud resolving model into a global model, suggesting that MJO-like structures with a reasonable propagation speed may be generated. As similar work progresses along the same lines, there is a practical need for statistical depictions of MJO from observations in order to validate the model results.

In this work, we examine climatological spatial and temporal characteristics of the Madden-Julian oscillation. Statistical features of the thermodynamic and dynamic fields as well as the coupling between convection and large-scale disturbances associated with MJO are obtained through a lagged regression method. The pronounced irregularity of MJO occurrence and periodicity is investigated by using a wavelet transform.

2. DATA AND ANALYSES

NOAA outgoing longwave radiation (OLR) and $2.5°$x$2.5°$, and 15-year (1979–1993) ECMWF reanalysis (ERA) products are the primary data sources for this study. Wind, vertical velocity, temperature, and humidity at 00 and 12 UTC are used to compute the apparent heat source (Q_1) and moisture sink (Q_2) (Yanai et al. 1973). Space-time filtered OLR retaining eastward wavenumbers 0-9 with periods of 30-96 days is used as a predictor. A lagged regression technique similar to that in Wheeler et al. (2000) is utilized to compose the climatological features of the dynamic and thermodynamic fields as well as how they interact with convection in the zonal wavenumber 30–96-day MJO band.

In addition, daily OLR from 1979 to 2003 is used to study the event-by-event variability of the MJO. A high-resolution continuous wavelet transform with the Morlet basis (Mallat 1999) is used to decompose the OLR time series along the equatorial band into the time-periodicity domain. An algorithm is developed to trace the maximum OLR variability in the ~ 27–~ 90 day range for each event that took place.

3. RESULTS

Figures 1 and 2 show the longitude-height sections of Q_1 anomalies associated with MJO. These are two snapshots on Day -9 and Day 0 in a series of 15-year all-season composites of Q_1 evolving with MJO in the Indian Ocean-Pacific region. The predictor used in deriving these is MJO-filtered OLR based at the equator. The plots are scaled to a -40 W/m^2 anomaly at the base point on Day 0. Figure 1 represents the composite of propagating convective heating associated with MJO. Deep convection is organized into an envelope of cloud clusters covering a longitudinal range of approximately 40°. Figure 1 suggests that there are often two significant regions of convective heating associated with the MJO as it propagates into the western Pacific. The first cluster (on the east side) appears to exhibit leading shallow convection, as suggested by lower vertical extend of the Q_1 anomalies. The shallower convection is possibly cumulus congestus. On Day 0 (Fig. 2), convection is at the brink of cooler SST around the dateline. Eastward propagation is very much diminished while semi-stationary convective heating reaches maximum strength.

Composite perturbation fields of ERA large-scale circulation, temperature, and vertical velocity associated with MJO are also produced and will be discussed at the meeting. Furthermore, statistical MJO profiles from radiosonde stations in the tropics will also be presented.

Figure 3 shows the MJO periodicity with maximum variance (PMV) at equator, 155° E, derived from the wavelet transform of OLR over ~24 years of time. There

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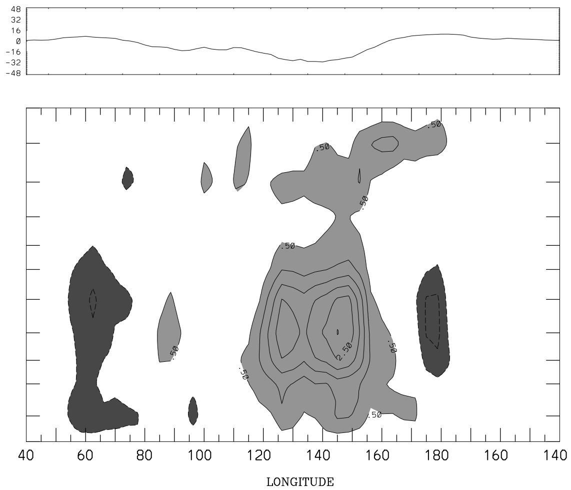

Figure 1. Equatorial longitude-height section of Q_1 anomalies on Day -9 in the life cycle of the composite MJO event over 40° E–140°W. Light (dark) shading indicates positive (negative) anomalies. Zonal equatorial OLR perturbation is shown along the top.

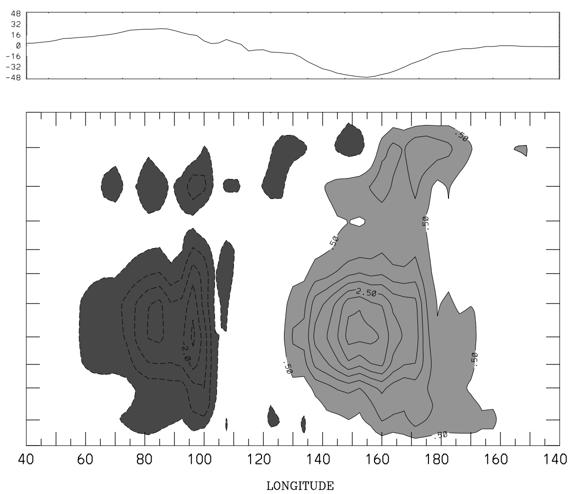

Figure 2. Similar to Fig. 1, for Day 0

are total 168 MJO events recorded. The PMV has a range from around 27 to 85 days, with a 40.11-day mean and 11.56-day standard deviation. In Fig. 3, the PMV shows behavior of a nonlinear dynamic system with abrupt changes of periodicity and possibly in some cases, sub-harmonic bifurcation and period doubling. Figure 4 plots the relative power of MJO signal corresponding to each PMV. PMV time series and its relative power around the equatorial belt are being generated, through which we can observe the longitudinal variation of variability as some MJO events propagate eastward. The same techniques are also applied to TRMM and other GPI calibrated daily rainfall from 1998 to 2003. Time series such as these can be used to study secular changes and interannual variability of the MJO associated with changes in the basic state.

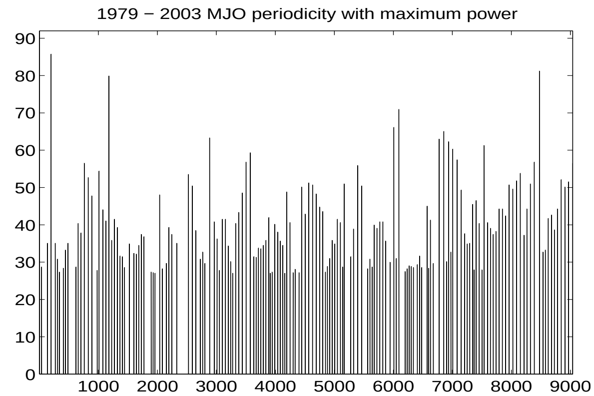

Figure 3. Time series of periods (in days) at which MJO exhibits maximum variability (PMV) in OLR from 1979–2003 at 0°, 155° E. Horizontal axis shows elapsed days from Jan. 01, 1979

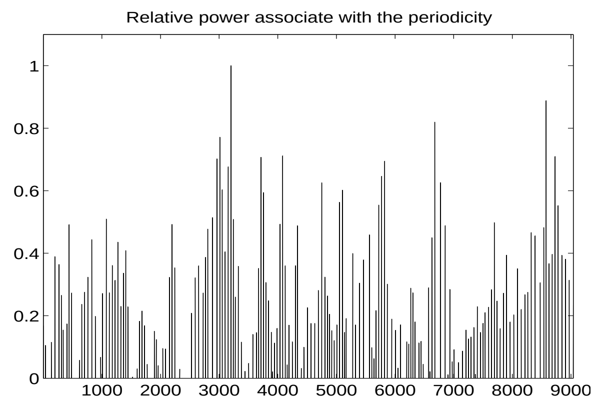

Figure 4. Relative power of MJO signals corresponding to the periods in Fig. 3.

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