A Climatology of the Madden-Julian Oscillation

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Introduction

The Madden-Julian Oscillation (MJO) is the leading mode of atmospheric variability on the intraseasonal time scale in the tropics. It is characterized by the location of enhanced convection In the equatorial Pacific (Fig. 1) and is defined by 8 eastward propagating phases with a generally defined period of 30-120 days (Madden and Julian 1974).

The MJO has a global impact to include influences on rainfall, genesis of tropical cyclones, and equatorial surface winds in the Atlantic Ocean (Zhang 2005). It has also been shown to affect Arctic atmospheric and cryospheric parameters (Henderson et al. 2013).

Izumo et al. (2009) found the MJO period to vary in DJFM between 55-100 days and 30-50 days. Yoo et al. (2012) defined MJO activity as RMM amplitude greater than or equal to 1.5 and found roughly 30% of NDJFM to meet this criterion from 1979-2008. In 2004, Wheeler and Hendon defined a "more active" MJO as one in which the square of the amplitude of the RMM index was greater than 2. However, a direct climatological look at daily seasonal variation of the MJO using the RMM Index has not been studied.

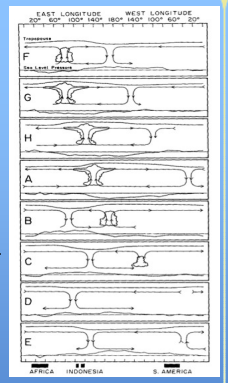

Figure 1: A schematic diagram of the eastward propagating Madden-Julian Oscillation. (Madden and Julian, 1972)

Data and Methods

The purpose of this study was to explore MJO activity by extending the WH04 definition of activity to two additionally defined thresholds.

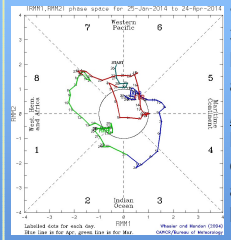

Figure 2: Phase of MJO as defined by RMM21 and RMM2 for 25Jan14 through 24Apr14 (Wheeler and Hendon, 2004)

Data:

- Daily MJO index values (01Jun1974 – 31Mar2014) from the Real-time Multivariate MJO Index (RMM, Wheeler and Hendon 2004) were used.

Methods:

MJO activity was subdivided into four categories: inactive (*IA*), active (*A*), very active (*VA*), and extremely active (*EA*) based on the RMM Index. Thresholds for *VA* and *EA* occurrences were varied such that *VA* events occurred roughly 30% and *EA* events occurred roughly 5% of the time period.

These thresholds were then used to examine seasonal variation in phase occurrences and daily progression of the MJO.

Results

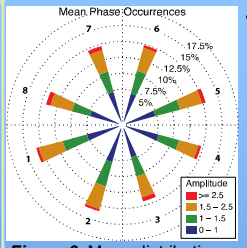

Figure 3: Mean distribution by phase and activity level. Length of flag represents percent of time spent in that phase. Flags are comprised of activity level breakdown.

Table 1: Mean annual percent occurrence by MJO activity level

Season	Activity Levels	Percentage
Annual	Inactive (Amp < 1.0)	38.8
	Active (Amp ≥ 1.0)	60.7
	Very Active (Amp ≥ 1.5)	32.6
	Extremely Active (Amp ≥ 2.5)	4.3

- Mean MJO phase distribution was relatively equal (Fig. 3). For example, Phase 1 occurred the most often (13.2%) compared to the least occurring phase: Phase 3 (11.7%)
- Activity levels (*IA*, *A*, *VA*, *EA)* were also evenly distributed across the eight phases during the year.
  - Daily MJO was *A* for ~60% of the past 40 years (Table 1)
  - *VA* events occurred roughly 32% of the time period and *EA* occurred roughly 4.3%`

Results

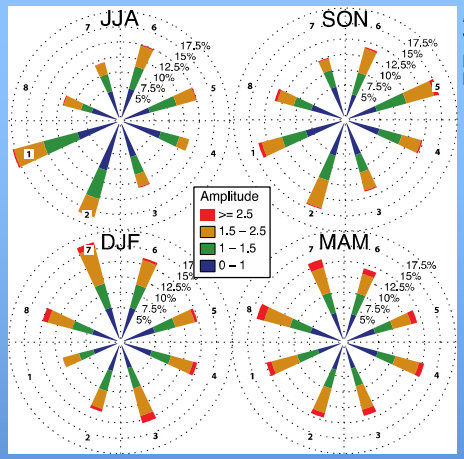

Figure 4: Seasonal variability by MJO phase and activity level

- MJO occurrence by both phase and level of activity varied substantially between seasons (Fig. 4).
- There was an increasing trend in activity level from JJA through MAM.
- MAM was the most active season with 65.2% of MJO events *A*; 8% of MAM events were *EA*
- JJA was the least active season with 55.5% Active MJO events; only 1% of JJA events were *EA*
- JJA and DJF phase distributions were more variable (evident from varied length of phase flags) than SON and MAM

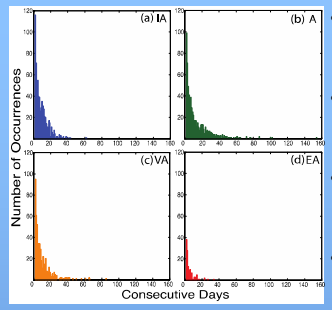

Figure 5: Consecutive MJO occurrences for the four activity levels

- Consecutive MJO events of the same activity level were most common for short periods (Fig. 5)
- For example, there were only 3 occurrences of *A* MJO periods longer than 90 days (Fig. 5d).
- Similarly, there were only 4 *EA* periods longer than 20 days. These events were concurrent with strong El Niño events.
- MJO rarely transitioned from *VA* to *IA* in 2 days

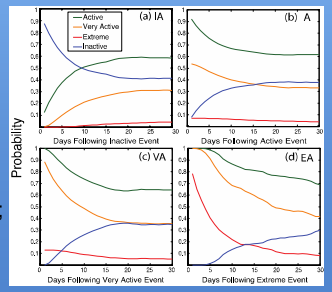

Figure 6: Probabilities of MJO activity levels for subsequent events following a given MJO event

- For a given day, the probability of the following days being the same activity level or greater tended to decrease exponentially and behaved asymptotically (Fig. 6)
- For a given inactive day (Fig. 6a), the odds were higher that the following day was *IA* up to 9 days following. After the 9th day, an *A* event was more likely to occur.
- MJO rarely transitioned from a *VA* day to an *IA* day in 2 days.

Conclusions

- The MJO has been significantly more active than inactive in the past 40 years (Table 1).
  - *IA* events occurred 38.8% of the time compared to 60.7% *A* events.
  - *VA* events occurred 32.6% of the time; *EA* events occurred 4.3%.
- There was weak mean variation (Fig. 3)
  - Only a 2% difference between the most occurring and least occurring phases.
- There was strong seasonal variation
  - Phase occurrences (flag lengths) were significantly more variable in JJA and DJF than the transition months of SON and MAM.
  - MAM was the most *A* and *EA* season; JJA was the least *A* and *EA* season
  - Prolonged periods of each level of activity were rare.
  - Four of these *EA* periods lasted more than 20 consecutive days (Fig. 5d). These four events were followed by an onset of El Niño events within a year.
  - *IA* days were more likely to be followed by an *IA* day up to 9 days after (Fig. 6a).

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