How strong is the relationship between the MJO and the onset of the Australian monsoon?

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1. Introduction

Knowledge and understanding of the Australian monsoon advanced considerably through the era of the 1980's and 90's, stimulated partly by field experiments in the region such as Winter MONEX (1978-79), AMEX-EMEX (1987) and the subsequent establishment of the Darwin tropical experimental site. Significant papers of this era include those of Murakami and Sumi (1982), McBride (1983), Davidson et al. (1983), Holland (1986), Gunn et al. (1989), Keenan and Carbone (1992), Drosdowsky (1996), and McBride and Frank (1999). Parallel to this development, internationally there has been a recognition of the importance of variability on intraseasonal time scales in tropical weather and climate, and in particular the role of the Madden Julian Oscillation (MJO) as a large-scale control (e.g., Madden and Julian 1971, 1994; Wang and Rui, 1990; Hendon and Salby, 1994). Much of the emphasis of the above literature on the Australian monsoon has been on the phenomenon of active and break periods, which tend to be inherently on the intraseasonal time scale. Despite this, with the notable exception of the work of Hendon and Liebmann (1990a, b), the literature specific to the Australian monsoon has largely ignored or downplayed the influence of the MJO. Indeed, a great diversity of views about the importance of the MJO can be found. This is particularly evident in the case of monsoon onset, for which Hendon and Liebmann (1990a) implied that nearly all onsets result from the passage of a convectively-active MJO phase, while others have implied that the MJO has little or no impact (e.g., Davidson et al. 1983; Drosdowsky 1996).

Drawing on a recent review by the current authors (Wheeler and McBride 2004), the purpose of this short note is to reconcile these different viewpoints. Section 2 describes our methodology for defining monsoon onset and for monitoring the MJO. Section 3 describes some new results on the relationship between the two phenomena and addresses the contrasting views expressed in the earlier literature. A very short summary of our findings is given in Section 4.

2. Quantitative definitions of monsoon onset and of MJO activity

For definitions of monsoon onset we have used those in the published literature. The underlying concept is that of the monsoon being essentially a two-state system, with the monsoon (or monsoon "burst") state being characterised by a sustained wet spell accompanied by low level westerly winds, and that this relaxes periodically to a dry state accompanied by easterly low level flow. Following the seminal study of Troup (1961), various authors have defined monsoon onset as the beginning of the first "burst" or period of "wet westerlies". For some definitions, quantitative criteria on low-level (850 hPa) zonal wind and on northern Australian area-averaged daily rainfall or Outgoing Longwave Radiation (OLR), must be simultaneously satisfied for onset to have occurred (e.g., Hendon and Liebmann, 1990a; Hung and Yanai, 2004). Probably the most widely used definition within Australia is that of Drosdowsky (1996). Based on his experience as a Darwin forecaster, Drosdowsky defined the monsoon bursts as periods of sustained westerly wind extending from the surface up to 500 hPa, with the additional requirement that the upper tropospheric (300-100 hPa) wind be easterly. Despite the fact that Drosdowsky's criterion depended on wind only, whereas those of Hendon-Liebmann and Hung-Yanai were in terms of wind and either rain or OLR, all three definitions were based on the concept of the first intraseasonal burst of the monsoon. (Other frameworks for defining onset are possible, especially within agricultural impact studies. For example, Nicholls et al. (1982) defined onset as the date by which 15% of the long-term median seasonal rainfall had been accumulated).

To look at the association between onset and activity of the MJO, an index of the MJO is required that is calculated independently of the data used to define onset. The index used here is the Real-time Multivariate MJO phase space of Wheeler and Hendon (2004), defined in terms of the projection of daily data on to the two leading EOFs (RMM1, RMM2) of 15°S–15°N-averaged fields of OLR, 850-hPa zonal wind, and 200-hPa zonal wind over the entire globe (i.e., spanning all longitudes). As discussed by Wheeler and Hendon, and following earlier work by Hendon et al. (1999), Hall et al. (2001), and Waliser et al. (2003), structures akin to our current view of the MJO are well described by the leading EOF pair. Projection of the global data onto those EOFs extracts the large-scale, predominantly eastward-propagating, signal of the MJO.

Taken together, the two PC time series are used as the MJO index. In particular, the state of the MJO can be measured in the phase space defined by RMM1 and RMM2. Eight different phases are used for when the MJO is considered relatively strong, and a "weak MJO" phase for when the (RMM1,RMM2) vector has an amplitude of less than 1.0. When individual sequences of days of strong MJO activity are viewed in the phase space, their paths trace large anticlockwise circles. On average, each phase lasts for about 6 days, but there can be considerable variability in this number from event to event.

Given the description of the MJO by the (RMM1,RMM2) phase space, composites may be formed by averaging the observed anomaly fields occurring for the days that fall within each of the defined phases. Here, in Fig. 1 (located at http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/abstracts/McBrideW04.html#F1) we present such a composite for the December-January-February season focussed on the region of interest, showing the fields of OLR and the 850-hPa wind. Details of the composite are discussed in Wheeler and Hendon (2004) and Wheeler and McBride (2004). For the current discussion, it suffices to state the low-level westerly flow and enhanced convection (negative OLR anomalies) occur over the Australian longitudes during phases 4-7; and conversely, enhanced easterlies and positive OLR anomalies occur during phases 8-3. As is characteristic of the MJO, as time progresses from one phase to the next, the anomaly patterns are seen to move eastwards across the domain.

3. Association between onset and the MJO

An appreciation of the intraseasonal behaviour of the region can be obtained from the multiple panels of Fig.2. (http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/abstracts/McBrideW04.html#F2). The upper curve in each panel shows the time series of the satellite OLR field averaged over the indicated area encompassing a large section of the monsoon region. The lower curve shows rainfall averaged over a much smaller area in northern Australia. The only time smoothing that has been applied is that of a 3-day running mean. Superimposed upon the OLR curve is the climatological seasonal cycle (dashed curve) computed from the long-term mean and three harmonics, with shading to denote anomalies. Given that downward excursions of the OLR curve represent convectively active conditions, a reasonably close correspondence between the large-scale convective conditions, and the smaller-scale rainfall, is apparent. Also apparent are the characteristic monsoon bursts, many appearing in both the OLR and rainfall. For example, during the 1987/88 monsoon season there are three notable bursts in the OLR, all showing similarly-timed peaks in the rainfall. Much of the variance of these bursts can be identified as being within the range considered as intraseasonal, that is, having a time scale of about 10 to 90 days. The upward excursions correspond to breaks in the monsoon. Notably in at least half of the years, the mid-summer monsoon breaks are strong enough to fully negate the effects of the seasonal cycle (in the OLR), causing conditions equivalent to the dry season. The break of late February/early March 1988 is a good example. Following the framework of Hendon and Liebmann (1990a), Hung and Yanai (2004) and Drosdowsky (1996), onset is defined as the first burst of each wet season. The dates of onset according to the three definitions is indicated by arrows above the OLR time series for each year on Fig. 2. The main point portrayed is that for each of the years shown, all the defined onset dates coincide with a large-scale OLR-measured intraseasonal burst. Further, as the intraseasonal bursts have no apparent phase-locking to the seasonal cycle, they introduce an important interannual variation in the defined monsoon onsets. Indeed, in the 6 years shown, the onsets vary anywhere from early December to mid-January.

As discussed, the research literature pertaining to the region's monsoon onset gives the impression of widely differing roles for the MJO. On the one hand, Hendon and Liebmann (1990a) suggested that the monsoon onset in each year is "strongly influenced by the 40-50 day oscillation", and that in 27 out of 30 years the onset fell within 4 days of the passage of the oscillation. In contrast, Davidson et al. (1983) examined the evolution of the large-scale flow at monsoon onset in six years. Although they suggested an important role for a number of different triggers, no relationship was suggested with the propagation of MJO-like perturbations from the Indian Ocean. Part of the reason of the omission of the MJO in the Davidson et al. study was that, although the original Madden and Julian (1971, 1972) studies long-proceeded their work, the MJO was still relatively unknown among researchers at the time. Yet, the much later study of Drosdowsky (1996) stated: "in contrast to a number of recent studies that have highlighted the so-called 40-50-day oscillation in the Australian summer monsoon, no dominant timescales are found in the length of the active periods or in the recurrence time between active phases". Given that Drosdowsky defined onset as the beginning of the first active period each wet season, it is difficult to reconcile this statement with the earlier work of Hendon and Liebmann (1990a).

A recent re-evaluation of the onset/MJO relationship has been made by Wheeler and Hendon (2004), based on the information as presented here in Fig.3 (http://www.bom.gov.au/bmrc/clfor/cfstaff/matw/abstracts/McBrideW04.html#F3). Using the objective, independent, wind-only, monsoon onset definition of Drosdowsky (1996), the figure shows the relationship of the onset dates to the globally-defined MJO, as determined in the (RMM1,RMM2) phase space. A definite relationship with Drosdowsky's onset dates appears. Considering only the dates that lie outside the central unit circle (i.e., those occurring when the MJO is non-weak), more than 80% (15) of the dates occur in Phases 4-7 (when MJO low-level westerlies are in the vicinity of northern Australia, Fig.1). Less than 20% (3) of the onset dates occur in the other phases (when northern Australia is under the influence of MJO easterlies). Further, given all 28 years presented in the figure, in more than 60% (>17) of years the MJO appears to be having a positive impact. Yet the spread of onsets from Phases 4 to 7 covers a time window of half the period of the MJO (i.e., about 20 to 30 days), a signficantly greater spread than the 14 days found by Hendon and Liebmann (1990a).

We also examined the phase portrait of monsoon onsets (i.e., as in Fig. 3) using the onset dates of both Hendon and Liebmann (1990a) and Hung and Yanai (2004). Although there were fewer points to examine, the general appearance of a large spread of the onset days across a number of MJO phases was still apparent.

How then did Hendon and Liebmann (1990a) get a much closer correspondence of the MJO and Australian monsoon onset? The reason is because of their less stringent definition of monsoon onset, and especially that for the MJO. For monsoon onset they used a 1-2-3-2-1 low-pass filter of Darwin winds and northern-Australian rainfall, and for their "40- to 50-day oscillation" they used a 30- to 60-day filtered series of the same winds and rainfall, that is, a very local MJO definition. Obviously, dates defined from such similar series are likely to have a closer correspondence than those coming from unfiltered winds (as in the case of Drosdowsky's onset dates), and a series using information from planetary-scale fields of winds and OLR (as in the case of the RMM MJO index). Thus while the MJO was a notable oversight as a potential onset mechanism in Davidson et al.'s (1983) work, its dominance, we feel, was overstated by Hendon and Liebmann (1990a).

4. Summary

From the 3-day running mean representation of OLR for the individual years (Fig.2), it is clear that monsoon onset never occurs during a large-scale break period of the monsoon. From the plot of the Drosdowsky onsets in the (RMM1, RMM2) phase diagram (Fig.3), monsoon onset is seen to virtually never appear during the easterly/suppressed phase of the MJO either. This can be considered a strong association. Still, monsoon onset occurs in all years even though there are some seasons when the MJO is inactive (e.g., Hendon et al. 1999). Further, when a westerly phase of the MJO is present over Australian longitudes, onset can occur at almost any time in that half-cycle, i.e., over a time window of 20 to 30 days. Thus it appears that while the globally-defined MJO is limiting monsoon onset to be within its active half-cycle, as lasting for a few weeks, the actual day of onset (as defined at the point location of Darwin) is often being set by other phenomena. This view is in essence the same as that of Hung and Yanai (2004) and the much earlier study of Hendon et al. (1989), both of whom found the influence of the MJO to be only one of a number of factors that determine monsoon onset.

5. References

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