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# THE ROLE OF INTRASEASONAL WAVE ACTIVITY IN THE ONSET AND ACTIVE-BREAK PHASES OF THE INDIAN MONSOON

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## 1. Introduction

Predicting the timing of the onset and of active-break cycles of the Indian monsoon has long been a challenge. Much recent work has focused on the so-called Intraseasonal Oscillation (ISO), identified as essentially the northern summer manifestation of the Madden-Julian Oscillation (MJO), as being important in the distribution of monsoon rains, especially over India (see for example Lawrence and Webster, 2001, and references therein).

In many years there is a clear relationship between the passage of the MJO and monsoon onset over India. Flatau et al. (2001) implicated the MJO in so-called "double onsets" over India, when a first burst of rains, usually in early to mid-May, is followed by a prolonged dry spell before the real monsoon onset in June. In these cases the dry spell is frequently accompanied by a heat wave, and the real onset is often delayed when compared to normal.

In this study we examine the relationship between monsoon onset and active-break cycles with respect to the occurrence of not only the MJO, but other equatorially-trapped waves that are coupled to convection (Wheeler and Kiladis, 1999; hereafter referred to as WK). WK developed methodology to objectively identify signals of a variety of equatorial waves, many of which correspond to the normal modes of shallow water theory. We show that atmospheric Kelvin waves and equatorial Rossby (ER) waves, along with the MJO, often play roles in onset, double onsets, and active and break cycles over India.

## 2. Data and Methodology

Outgoing Longwave Radiation (OLR) data is space-time filtered as described in WK to isolate equatorial wave modes coupled to convection. In this approach, filtered OLR data corresponding to the MJO, Kelvin, and ER modes are produced to compare with monsoon indices. Monsoon onset and breaks are identified using the Hydrological Onset and Withdrawal Index (HOWI) index of Fasullo and Webster (2003). HOWI is based on the vertically integrated moisture transport over a sub-region of southern India. HOWI monsoon onset dates agree well with other criteria of onset, and have the advantage of being objectively derived from reanalysis data sets.

## 3. Results

Composite onset OLR fields based on HOWI from 1979-2001 have been constructed, and the mean progression of convection over India is quite well-defined. Fig. 1 shows a Hovmueller diagram of composite OLR anomalies, displaying a region of negative OLR from 50º-90ºE around and especially before the composite onset date (Day 0).
Fig. 2 shows Hovmuellers of OLR anomalies from 3 individual cases (1995, 1997, and 2002) of double monsoon onset identified by Flatau et al. (2001; 2003). Also shown in these figures are contours of space-time filtered OLR corresponding to the MJO and Kelvin waves (slow and fast eastward propagating signals, respectively) and the ER wave (westward propagation). In all three years eastward propagating convective activity in early May passes over the longitudes of India, followed by a prolonged dry spell later in the month, then followed by another period of convection in early June associated with the true monsoon onset according to HOWI. These May events do project onto MJO-filtered OLR, but in all cases much faster moving Kelvin wave activity is a prime contributor to these "false onset" convective episodes. In these diagrams, the MJO can be seen to be composed of a spectrum of higher frequency disturbances, including Kelvin waves and other waves propagating westward at various phase speeds. It is well known that in general the MJO convective envelope is characterized by a variety of other smaller scale disturbances (see Straub and Kiladis, 2003 for a review). The cases shown in Fig. 2 as well as those for most other years confirm that Kelvin modes are prime constituents of the MJO during the April-May time period, before climatological convection moves north of the equator after Asian monsoon onset. These Kelvin waves often transit the entire globe, and have been implicated in the initiation of individual MJO events over the Indian Ocean (Kiladis and Straub, 2003).

The potential role of Kelvin waves in the Indian monsoon onset can be inferred from Fig. 1. Despite being comprised of many different onset scenarios from 23 years of data, this composite shows that on average convection associated with onset over India occurs after the passage of eastward propagating convective activity across the entire Pacific and Atlantic basins, starting at around 100ºE on Day-35, followed by a suppressed mode of opposite sign. The phase speed of these signals is 17 m/s, matching that of the Kelvin in global OLR data (WK). Once this Kelvin pulse reaches the west coast of Africa at around 20ºW around Day-16, the convective envelope quickly spreads across the African longitudes and becomes nearly stationary, while nearly stationary convection develops farther east over the Indian Ocean with a gap of suppressed convection at 40ºE at Arabian longitudes. An analysis of total and filtered OLR shows that this onset convection is actually propagating more poleward than eastward over the Arabian Sea, and is made up of eastward MJO and Kelvin as well as westward ER components originating over western Pacific and southern Asia one-two weeks earlier. Some westward moving ER components can be seen in both the false and real onset cases shown in Fig. 2, as well as the tendency for Kelvin waves to propagate eastward out of Indian Ocean convection and into the Pacific, a signal shown to occur preferentially to the east of the MJO by Straub and Kiladis

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(2003). These results point to the importance of monitoring Kelvin and ER modes as well as the MJO with respect to monsoon onset, and as will be shown in the poster, active and break cycles as well.

## 4. References


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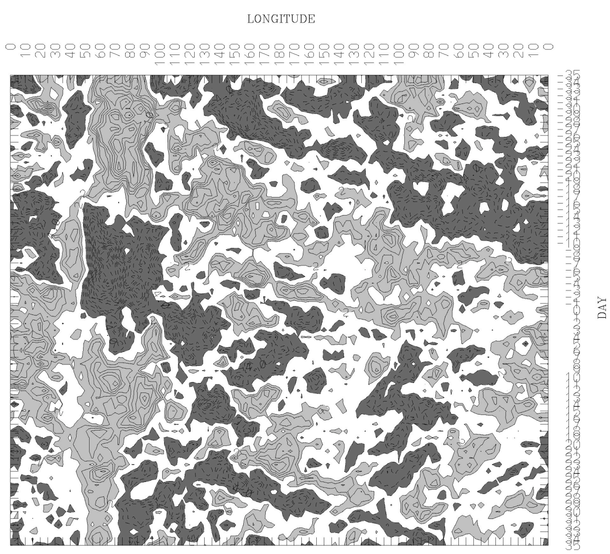


Fig. 1. Time-longitude OLR anomalies between 5ºS and 15ºN composited based on the date of monsoon onset (Day 0). Contour interval is 2 W/m$^2$ and dark (light) shading corresponds to negative (positive) perturbations.

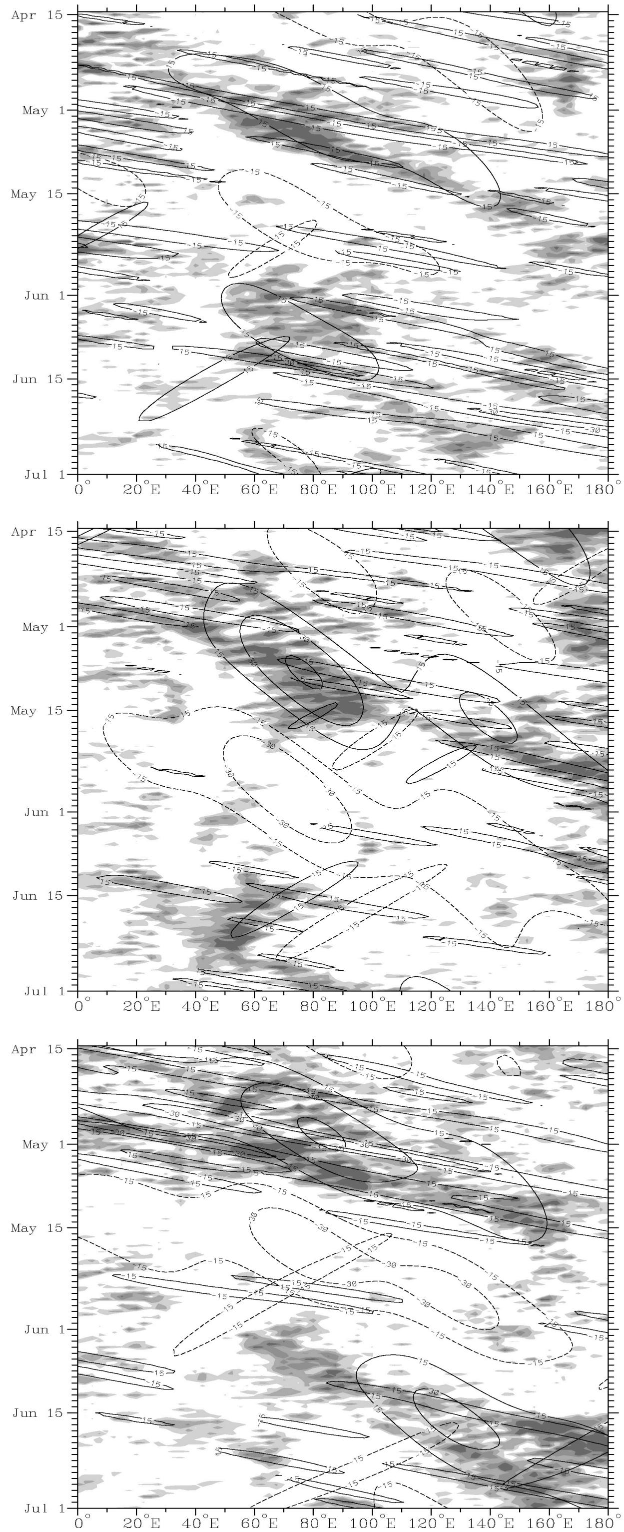


Fig. 2. Time-longitude negative OLR anomalies between 5ºS and 15ºN for April 15-July 1 1995 (top), 1997 (middle), and 2002 (bottom). Shading intervals of are at 20 W/m$^2$ starting at -10 W/m$^2$. Contours are of MJO and Kelvin-filtered OLR (slow and fast eastward propagation, respectively) and ER waves (westward propagation). Contour interval is 15 W/m$^2$.