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Activity of Madden Julian Oscillation during 2002 and 2006 – A comparative analysis

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सार – इस शोध पत्र में भारतीय ग्रीष्मकालीन मानसून को अत्याधिक उल्लेखनीय अन्तरा मौसमी भिन्नता द्वारा अभिलेखित किया गया है। मैडन– जूलियन दोलन (एम. जे. ओ.) भारतीय ग्रीष्मकालीन मानसून वर्षा के अन्तरा मौसमी भिन्नता की प्रमुख पद्धतियों में से एक है। भारत में वर्षा की सक्रियता और भूमध्यरेखीय क्षेत्र के निकट संवहन के पूर्वाभिमुखी प्रसरण के संदर्भ में अन्तरा मौसमी वर्षा की भिन्नता की विषमता के दो वर्षों की मानसून ऋतुओं के दौरान मैडन जूलियन दोलन की सक्रियता की जाँच की गई है। इस अध्ययन से विषम प्रवृति का पता चलता है अर्थात वर्ष 2002 की मानसून ऋतु में पूर्वाभिमुखी पद्धति का प्रभाव रहा है जबकि वर्ष 2006 में यह प्रवृति दबी हुई थी।

ABSTRACT. The Indian summer monsoon is characterized by very significant intra-seasonal variability. Madden-Julian Oscillation (MJO) is one of the dominant modes of the intra-seasonal variability of the Indian summer monsoon rainfall. The activity of Madden Julian Oscillation during the monsoon seasons of the two years of contrasting intra-seasonal rainfall variability has been examined in terms of rainfall activity over India and eastward propagation of convection in the near-equatorial region. The study shows the contrasting nature, *viz*., in the monsoon season of 2002, eastward mode dominated whereas in 2006, it remained suppressed.

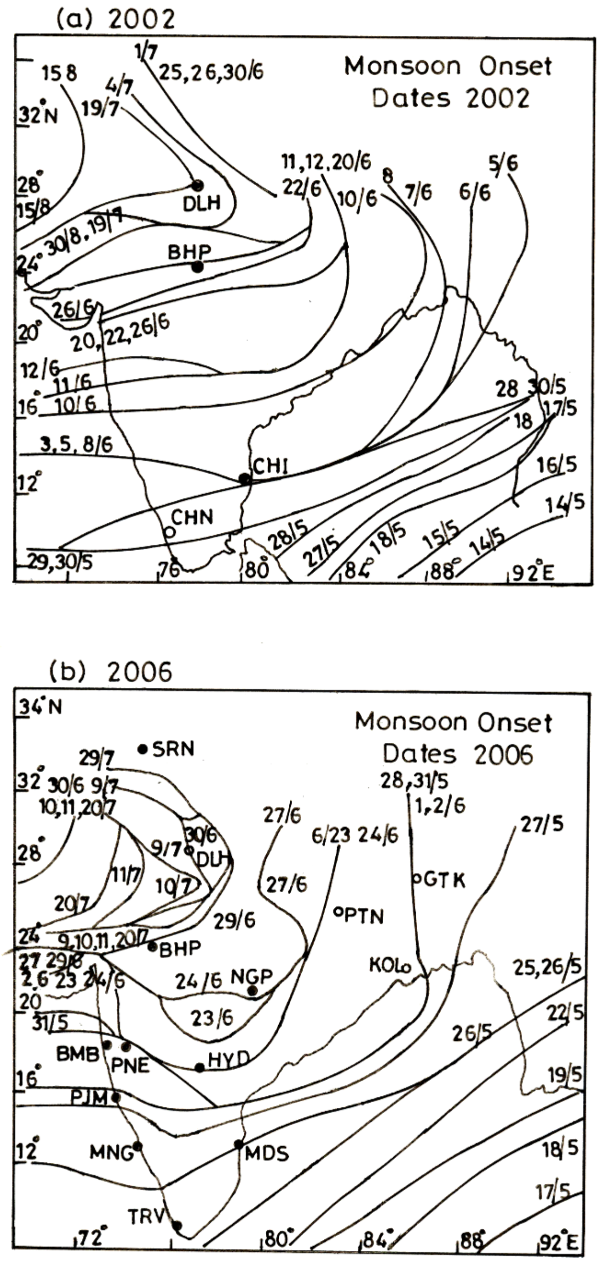
Key words – Madden Julian oscillation, Indian summer monsoon rainfall, Intra seasonal variability, Propagation of convection.

1. Introduction

The Indian summer monsoon is characterized by very significant intra-seasonal variability. It has been well established that, one of the dominant modes of the intra-seasonal variability of the Indian summer monsoon rainfall is governed by the eastward moving Madden-Julian Oscillation - MJO [Madden and Julian (1971; 1972; 1986; 1994), Lau and Chan, (1986), Lau, *et al*. (1988), Singh, *et al*. (1992), Jones and Weare (1996) and Saith & Slingo, (2006)]. It is one of the fundamental modes of low-frequency oscillations in the tropics. The Madden Julian Oscillation is manifested in the fields of surface winds, surface heat fluxes, sea surface temperature and ocean currents, on a time scale of about 30-60 days (Madden and Julian, 1994). MJO is characterized by an eastward progression of large regions of both enhanced and suppressed tropical rainfall, observed mainly over the Indian Ocean and Pacific Ocean. The anomalous rainfall is usually first observed over the western Indian Ocean, and propagates over the warm ocean waters of the western and central tropical Pacific. During winter season, eastward propagating MJO mode is dominant. But, in summer, as the eastward propagating MJO mode appears over the South-East (SE) Arabian Sea and the Bay of Bengal, a north ward moving convective organization is established with a frequency of 30-50 days [Sikka and Gadgil (1980) & Yasunari (1980)]. In recent times, 2002 and 2006 have been the years that have exhibited large scale intra seasonal variability of contrasting nature, in terms of all India area weighted rainfall. With this backdrop, an attempt has been done in this study to examine the activity of Madden Julian oscillation during the monsoon seasons of these two years of contrasting intra-seasonal rainfall variability.

2. Data and methodology

In order to examine the intra seasonal variability of Indian summer monsoon, the weekly All-India area



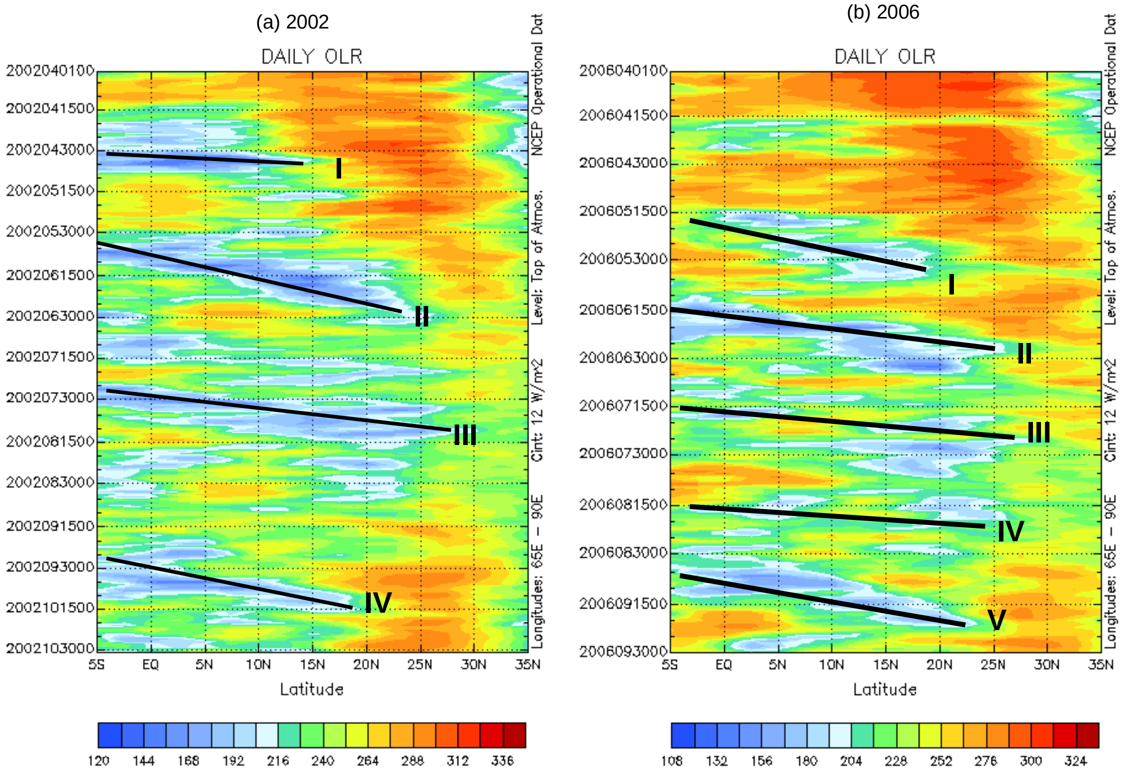
Figs. 1(a&b). Dates of advance of SW monsoon over various regions of India during (a) 2002 and (b) 2006

weighted rainfall (percentage departure from the normal) has been computed, for the SW monsoon seasons (June to September) of the years of 2002 and 2006 [Figs. 2(a&b)]. For analyzing the activity of Madden Julian oscillation, the daily values of operational data of Outgoing Longwave Radiation (OLR) obtained from the Climate Diagnostic Centre, National Centre for Environmental Prediction, have been utilized as proxy for convention. From these data, for examining the northward propagation of the convection, the time-latitudinal sections of the OLR are prepared, for the OLR values averaged over the longitudes from 65° E to 90° E, for the latitudes 5° S to 35° N, for the period 1st April to 30th September of the years of 2002 and 2006 [Figs. 3(a&b)] and analysed. Also, the time-longitude sections of OLR values have been prepared for examining the eastward propagation of the equatorial convection, for the same period. These sections are prepared for the longitudinal belt of 60° E to 120° W, for the OLR values averaged over the equatorial region, 5° S to 5° N (Fig. 4). Also, the vector wind anomaly values over the region 40° S to 60° N and 30° E to 60° W, as obtained from Earth System Research Laboratory, Physical Science Division, NOAA, are analysed to examine the lower tropospheric circulation features.

3. Discussion

In 2002, the onset of the southwest monsoon over Kerala occurred on 29th May, 3 days earlier to its normal date of 1 June. After 12th June, there was a hiatus in the advance of the monsoon for about a week. This hiatus was terminated on formation of a low pressure system over the north Bay of Bengal on 20th June, which moved across central India. In association with this, the monsoon advanced into central India and some parts of the Gangetic plains. However, with the weakening of the low on 28th June, there was a sudden weakening of the monsoon current. This situation prevailed almost till the end of July. Further, in association with a feeble low pressure that formed over northwest Bay on 17th July, the monsoon advanced up to Delhi and neighbourhood as a weak current on 19th July. However, there was another prolonged hiatus in the subsequent advance of monsoon and it covered the entire country only by 15th August [Fig. 1(a)]. The seasonal rainfall over the country as a whole was 81% of its long period average and thus it was an All-India drought monsoon year. The rainfall deficiency during July was the highest (-51%) in the 102 period from 1901 to 2002. During the entire monsoon season of 2002, not a single monsoon depression was formed. The monthly rainfall during June and August was normal and rainfall during September was near normal [Mausam, (2003)].

The All-India area weighted rainfall during 1st June to 30th September 2006, was 99.6% of the long period average. In 2006, the onset of monsoon over Kerala occurred on 26th May, six days prior to the normal date of 1st June. The advance of the monsoon occurred rapidly over the west coast, in association with an off-shore trough along the west coast, till 6th June. Further advance of the monsoon was characterized by two predominant epochs of hiatus, *viz.*, 7-22 June and 1-8 July. The monsoon covered the entire country on 24th July, nine days later than the normal date [Fig. 1(b)]. In contrast to the year 2002, eight monsoon depressions formed during the SW monsoon season of 2006. The tracks of most of



Figs. 2(a&b). Time latitude sections of OLR (W/m^2) showing northward propagation of convection during (a) 2002 and (b) 2006

these monsoon depressions were observed to have a higher westerly component rather than the climatological west-northwesterly direction. As a result, central and peninsular India received well distributed above normal rainfall, causing floods over these regions. The details of these depressions are listed in Table 1.

In addition to these depressions, seven low pressure areas/ well marked low pressure areas formed during the SW Monsoon season of 2006 [Mausam, (2007)]. Thus, the monsoons of 2002 and 2006 were clearly distinct in terms of the intra-seasonal variability. The monsoon of 2002 was characterized by spells of prolonged breaks, particularly in July, leading to seasonal rainfall deficiency. On the other hand, monsoon of 2006 was characterized by frequent active spells (Table 2).

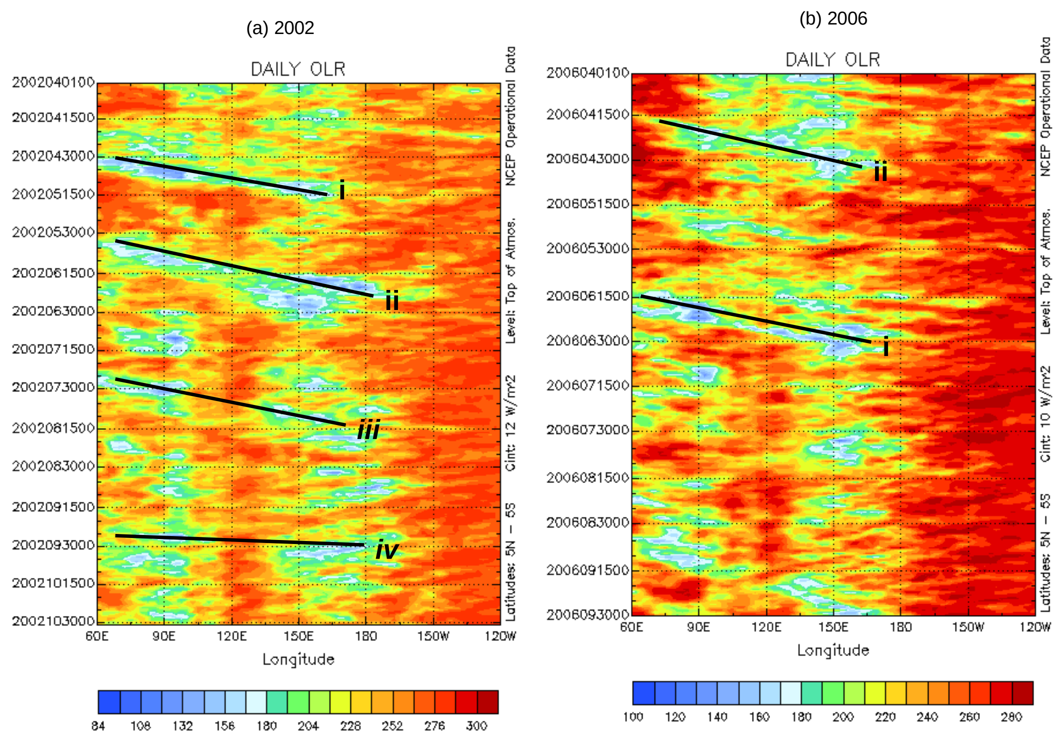
In 2002, there had been a significant eastward displacement of the west pacific warm pool during the northern hemispheric summer months. The Sea Surface Temperatures (SSTs) over the Indian Ocean were above normal. In contrast, during 2006, the west pacific warm pool was confined over that region; it did not extend east of the international date line (Figures not shown). In response to these SST conditions, during 2002, the

TABLE 1

Monsoon depression forming over the Indian region during 2002

S. No.	Place of origin	Duration (year 2002)
1.	North West Bay of Bengal	2-4 July
2.	North West Bay of Bengal	2-5 August
3.	North Bay of Bengal	12 August
4.	North Bay of Bengal	16-18 August
5.	North West Bay of Bengal	29 August-1 September
6.	North West Bay of Bengal	3-4 September
7.	Jharkhand (Land Depression)	21-23 September
8.	North West Bay of Bengal	28-29 September

eastward propagation of the convection zone was favoured in comparison with the northward propagation of the convection zone. However, during 2006, the northward propagation of the convection zone was favoured as compared to the eastward propagation of the convection, except for only one event during 15th to 30th June, during which, both, the northward and eastward propagations were dominant. During 2002, four distinct events of northward propagation of convection are evident, which



Figs. 3(a&b). Time latitude sections of OLR (W/m^2) showing eastward propagation of convection during (a) 2002 and (b) 2006

TABLE 2

Intra seasonal variability of weekly All-India area weighted rainfall during 2002 and 2006

Week ending on	All India weekly area weighted rainfall (% departure from normal)	Week ending on	All India weekly area weighted rainfall (% departure from normal)
5th Jun 2002	15.4	7th Jun 2006	68.1
12th Jun 2002	-13.9	14th Jun 2006	-46.3
19th Jun 2002	-2.3	21th Jun 2006	-51.4
26th Jun 2002	31.2	28th Jun 2006	-15.3
3rd Jul 2002	-17.2	5th Jul 2006	13.8
10th Jul 2002	-62.3	12th Jul 2006	-16.7
17th Jul 2002	-66.1	19th Jul 2006	-32.0
24th Jul 2002	-22.0	26th Jul 2006	-12.9
31st Jul 2002	-62.0	2nd Aug 2006	26.2
7th Aug 2002	-22.2	9th Aug 2006	28.1
14th Aug 2002	25.1	16th Aug 2006	0.60
21st Aug 2002	-13.7	23rd Aug 2006	-2.45
28th Aug 2002	0.6	30th Aug 2006	-23.6
4th Sep 2002	1.7	6th Sep 2006	9.8
11th Sep 2002	8.3	13th Sep 2006	-25.7
18th Sep 2002	-25.2	20th Sep 2006	8.8
25th Sep 2002	-38.8	27th Sep 2006	11.5

correspond to the pre-monsoon rainfall activity (Event I) and the active phases of monsoon (Saith and Slingo, 2006) and these same events were also discernible in the equatorial eastward propagating mode of MJO [Fig. 2 (a) and Fig. 3(a)]. As seen from Fig. 3(a), during 2002, the eastward propagation of convection is very prominent, as discerned by events (*i*) and (*ii*). Also, another two events, event (*iii*) and event (*iv*), though, not as strong as event (*i*) and event (*ii*), are observed to influence the intra seasonal variability of the monsoon during the period July

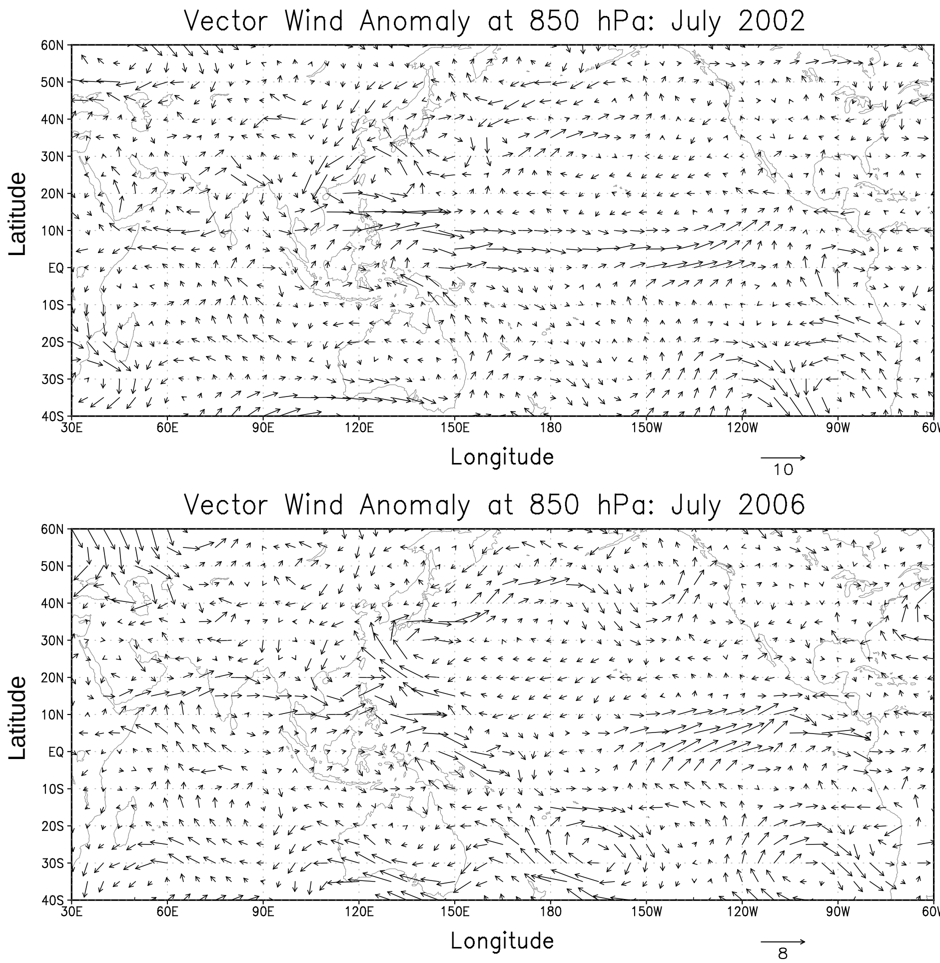


Fig. 4. Spatial distribution of vector wind anomalies during July 2002 and July 2006

to September. Such an eastward propagation of convection is not evident during 2006 [Fig. 3(b)].

During 2006, five distinct (I, II, III, IV, V) events of northward propagation of the convection can be identified in the field of daily Outgoing Long wave Radiation (OLR) [Fig. 2(b)]. Event I, (during 15^{th} -30^{th} May) and Event II, (with about 30 days periodicity, appeared during the period 15^{th}-30^{th} June), correspond to the onset of monsoon over Kerala and the subsequent rapid advance of the monsoon along the west coast of India. It was followed by another Event III, during 15^{th}-25^{th} July (again with a periodicity of about a month), which was associated with further advance of the monsoon to cover the entire country. Event IV occurred during 15-25^{th} August, coinciding with an active phase of the monsoon characterized by two depressions moving across India in west-northwest direction. The final event occurred during 1^{st}-25^{th} September, which again coincided with two depressions (including one land depression) moving across India in west-northwest direction. However, as seen from Fig. 3 (b), there was only one distinct event [event (*i*)] of eastward propagation of the convection, which occurred during 15^{th} - 30^{th} June 2006, simultaneously with the event II of the northward propagation of the convection. Apart from this event, there is another event [event (*ii*)] of prominent eastward propagation during the period, 15^{th} April to 30^{th} April 2006. However, this does not pertain to the propagation of convection during the SW monsoon season and may be associated with the convective activity during the pre-monsoon season. Unlike in 2002, [Fig. 3(a)], there has been clear absence of eastward propagation during 2006, particularly after the onset and advance phase of the monsoon was completed. As such, with the absence of this eastward convection and dominance of systematic northward propagation of convection with the periodicity of about 30-40 days, there was no any major break during 2006. The active phases of the monsoon clearly coincided with the systematic northward propagation of convection from 5° S to as north as 25-27° N. Thus, the dominance of eastward mode of MJO, affecting the intra-seasonal variability of the summer monsoon was totally absent in 2006.

It is evident form Table 2 that, following are the major prolonged spells of below normal All India rainfall activity during the years 2002 and 2006:

2002 : *Spell I* – 3rd July to 7th August-Spell of 34 days of below normal All India rainfall.

Spell II – 18th September to 25th September-Spell of 8 days of below normal All India rainfall.

2006 : *Spell I* – 14th June to 28th June-Spell of 15 days of below normal All India rainfall.

Spell II – 12th July to 26th July-Spell of 15 days of below normal All India rainfall.

It is observed from Fig. 2(a) and Fig. 3(a) that, during 2002, during the spell from 30th June to 25th July, the eastward mode of propagation of convection, was highly suppressed. Also, the northward propagation of convection during this spell is not significant. This spell corresponds to the prolonged spell of below normal All India below normal rainfall activity from 3rd July to 7th August. Also, during the period 18th September to 25th September, the mode of northward propagation of convection was insignificant; however, the eastward propagation of convection was dominant.

It is also evident from Fig. 2(b) and Fig. 3(b) that, during 2006, during 14th June to 28th June, there was a northward propagation of convection from 5° S to 25° N. During the same period, the eastward propagating mode of enhanced equatorial convection was also dominant. Despite of this, the All India rainfall activity was below normal for a period of 15 days. During another spell of below normal All India rainfall activity for 15 days (12th July to 26th July), the northward propagation of convection from 5° S to 25° N is clearly evident [Fig. 2(b)]. However, during the same period, no eastward propagation of equatorial convection is observed [Fig. 3 (b)].

The lower tropospheric wind anomalies during July 2002 (Fig. 4) clearly show predominant anticyclonic wind flow over the Indian region, suggesting thereby, an anomalous sinking over these areas and hence, suppressed convection. During July 2002, the rainfall over India was highly deficient, 49% lower than the respective normal. Also, enhanced strength of cross-equatorial flow during July 2006 is evident in contrast to the easterly wind anomalies (weak cross-equatorial flow) during July 2002.

4. Conclusions

(*i*) During 2002, the eastward mode of the Madden Julian Oscillation and associated propagation of the convection eastwards were dominant over the northward propagation of the convection. This led to major breaks in Indian summer monsoon in 2002, particularly in the month of July.

(*ii*) In contrast, during 2006, the northward mode of propagation of convection was more predominant, with suppressed eastward propagating mode, leading to absence of any major break during the Indian summer monsoon season and frequent spells of active monsoon.

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