RESEARCH PAPER | Environmental Sciences | Volume : 4 | Issue : 11 | November 2014 | ISSN - 2249-555X

Dependence of Findlater jet intensities during Active and Break spells Rainfall of Indian Summer Monsoon

KEYWORDS: FLJ, Rainfall, Active and Break Spells

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ABSTRACT *Indian summer monsoon has a large inter-annual as well as intra-seasonal variability over temporal and spatial scales. One important synoptic feature associated with the onset of monsoon is the existence of a strong cross equatorial low level jet (LLJ), with its core around 850 hPa also known as Findlater jet (FLJ) over the Indian Ocean. In this article we studied the variation of FLJ intensities especially with respect to active and break spells of monsoon for the period 1997-2007. The active and break spells depends on monsoon intensity and rainfall over India. The FLJ intensities over Arabian Sea (AS) and the rainfall over Indian sub-continent are showing a clear idea of dependency on each other. FLJ intensities are higher during active spells than break spells and consecutive rainfall is also higher. The variations during El Nino and La Nina are also discussed.*

1. Introduction

The summer monsoon is inarguably an important facet of life in India, whether the aspect is economic (Webster et. al., 1998) or cultural (Zimmermann 1987). A remarkable feature of the summer monsoon over the Indian Ocean is the gradual formation of a LLJ over the western Indian Ocean (J. Findlater 1969). Joseph and Raman (1966) have established the existence of a westerly LLJ stream over peninsular India with strong vertical and horizontal wind shears. Later studies by Findlater (1969, 1971) have explained the importance of LLJ in the monsoonal activity over the Indian subcontinent. Findlater (1971) and Krishnamurti (1978) have found the major axis of the jet passes through the points 20°S, 60°E; 12°S, 48°E; 0°N, 40°E; 5°N, 42°E; 10°N, 50°E. At 12°N, 58°E the jet splits into two, the northward branch of major axis passes through 15°N, 60°E; 17°N, 72°E and Indian mainland. The southward branch (secondary axis) of the split moves south eastward, just south of India. Swapna and Ramesh Kumar (2002) have examined the role of low-level flow jet on monsoon activity using 850 hPa winds for the monsoon period June–September for the years 1987 and 1988. They found that during the active monsoon periods, the core of the jet is directed to the Indian subcontinent, producing heavy rainfall over India. But during the weak periods, the core of the jet is directed south of the Indian peninsula leading to weak monsoon conditions over India. P.V. Joseph and S. Sijikumar (2004) have done a detailed study of FLJ and have improved on the observations of Findlater.

The south west monsoon (SWM) rainfall varies in the form of 'active or wet' and 'break or weak or dry' spells. The inter-annual variability in the SWM is mainly due to the occurrence of long, dry spells in the later (Krishnamurti and Bhalme, 1976). Apart from intraseasonal variations which occur every year, a special situation traditionally known as 'break monsoon' occurs (Gadgil and Joseph, 2003). These breaks are periods when the monsoon trough is located close to the foot hills of the Himalayas which lead to a striking decrease in rainfall over most of India but increase along the Himalayas and parts of northeast India and the southern peninsula (Rao, 1976). Ramamurthy (1969) and by De et. al., (1998) observed characteristics of the breaks in the SWM and identified break as a day in which the trough of low pressure is not seen on the surface chart over India and easterlies are practically absent. Although interruption of rainfall is recognized as the most important feature of these 'breaks', the criterion used by the IMD for identifying break is the synoptic situation associated with such a rainfall anomaly and is defined by Rao (1976).

Webster et. al., (1998) use the term 'break (active) spells' to denote weak (strong) spells of convection and 850 hPa zonal winds over a large-scale region (65° E – 95° E, 10° N–20° N). On the other hand, Goswami and Mohan (2000) have defined breaks on the basis of the strength of the 850 hPa wind at a single grid point 15° N, 90° E. Anamalai and Slingo (2001) have used the term 'break' to denote weak spells of daily average rainfall. Gadgil and Joseph (2003) defined the break using the rainfall distribution in the monsoon zone and called it rain break. In the break spells the monsoon circulation is weak and the monsoon trough in Indo-Gangetic plane moves northward and the rainfall is restricted only to the foot hills of Himalayas. In the present study we have examined the variation in FLJ intensities over Arabian Sea especially during active and break spells and the consecutive rainfall over Indian subcontinent from 1997-2007. The authors have adopted the latest criteria of Rajeevan et al., (2010) for the months July and August.

2. Data and methodology

The following data over the period of 1997 to 2007 have been consulted for the present study. They are: (i) The daily rainfall collected over India during active and break spells using GPCP reanalysis data, which combines the data all over the world using different rain gauge data and satellite derived data (ii) Daily 850 hPa wind core intensity over the AS between latitudes 5°N to 20°N, and longitudes 50 and 75°E. In order to find out the daily geographical position of the LLJ core at 850 hPa level over the AS region, synoptic weather charts using the daily NCEP/NCAR reanalysis data have been consulted. The period of study is special for understanding the different events happening globally, which are particularly affected the Indian sub-continent rainfall during SWM. In this article authors attempted to observe the dependence of FLJ and rainfall, especially in active and break spells of SWM.

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3. Results and discussion

3.1 FLJ intensities in Active and Break spells

In the present article the criteria stipulated by Rajeevan, et. al. (2010) is followed and the authors have delineated the active and break periods. The periods of active and break spells and mean FLJ intensity in respective spells from 1997-2007 are given in table 1. It is interesting to note that there are two years without any active spell i.e. in 1999 and 2002. Similarly, it is observed from the data that the break spells are absent in the years 2003 and 2006. A prolonged break spell is observed in 2002.

During active spells the FLJ intensities are high and in break spells the FLJ intensities are relatively low. The maximum intensity observed during active spells is 30 m/s in the year 2005 and the minimum intensity is 16 m/s in the year 1997. In break spells the intensities vary between 13 m/s and 24 m/s and the intensities are lower compared to active spells. However, a maximum intensity of 33 m/s in July is observed in 1998 which is not in active spells and a minimum of 6 m/s is observed in 1997 and 2003 in June.

Table 1: Active and Break spell periods of the Indian summer monsoon according to M. Rajeevan, et. al., 2010 (There are no active or break spells observed in June as per M. Rajeevan, et. al., In the table the period J is July, A is August in the respective year).

Year	Active spell period	Mean FLJ intensities m/s in respective Active spells	Break spell period	Mean FLJ intensities m/s In respective Break spells
1997	30J-1A,20-26A	23, 21	11-15J, 9-14A	22, 20
1998	3-6J	23	20-26J, 16-21A	21, 16
1999	-------	----------	1-5J, 12-16A,22-25A	18,16,15
2000	12-15J,17-20J	24, 21	1-9A	17
2001	9-12J	25	31J-2A, 26-30A	21,19
2002	----------	----------	4-17J, 21-31J	18,19
2003	26-28J	23	------	-------
2004	30J-1A	24	10-13J,19-21J,26-31A	22,20,15
2005	1-4J, 27J-1A	23,25	7-14A, 24-31A	20,18
2006	3-6J, 8J-2A, 5-7A,3-22A	22,24,21, 22	----------	----------
2007	1-4J, 6-9J,69A	23, 22 ,21	18-22J, 15-17A	20,17

The duration of active and break spells by means of number of days; the number of break days is more than the number of days in active monsoon. But the exception is in the years 2003, 2006 and 2007. It has to be mentioned here that in entire period of study the number of active days are more during 2006. 1997 is the strong El Nino year, the number of days having active and break spells are 10 and 11 respectively, however the difference is not significant. The authors mentioned elsewhere that, this is the peculiarity of 1997 El Nino year (Pushpanjali, et. al., 2013). In 1997, which is a strong El Nino year the difference between the FLJ intensities between active (21.5 m/s) and break (21.0 m/s) spells is minimum. It is worth mentioning here that the year 2002, which recorded very high deficit rainfall over India, is not having any active spell. However the break spells are 2 and the duration is a maximum of 25 days. During La Nina years there is no active spell in 1999. The average FLJ intensity during active spells is 20.7 m/s and for break spells is 18.6 m/s. This clearly shows that the FLJ intensities are more during active spells than the break spells.

3.2 Variation of rainfall during active and break spells

Variation of FLJ intensities and rainfall during 1997-2007 with number of days in active and break spell are illustrated in the figure1. Normally during the active spells, rainfall is higher than break spells. The maximum FLJ intensity can be observed during 2001 and the number of active spells is lower. Number of break spells is higher during 2002, the intensities are normal. From figure it is observed during active spells, the FLJ intensities are higher with higher rainfall. During the break spells we can observe almost no rainfall, i.e. in 1999 and 2002. The detailed discussion during El Nino and La Nina are given below.

During the period of study, the number of spells in active and break are the same in El Nino years i.e. 7, but the amount of rainfall differs. During El Nino event, Indian sub-continent is experiencing drought condition to normal rainfall (Subrahmanyam et. al., 2013). In the study period, 1997 a strong El Nino year during active spells the average rainfall over India is 339 mm i.e. normal rainfall. Normally one expect during the strong El Nino year there will be more break spells, but 1997 is a strongest El Nino, there are active spells almost similar to break spells, however the monsoon rainfall is near normal during 1997. There are no active spells in 2002 but experienced more break spells. The year 2002 is a moderate El Nino but Indian Ocean Dipole (IOD) is in phase leads to drought condition over Indian sub-continent. So the synergistic effect of El Nino and IOD is much more and resulted in very much deficit rainfall (Subrahmanyam, et. al., 2013). This is also collaborated by the fact that in 2002 number of active days is zero and the number of days during break spells is 25, which is more during the study period. The number of active and break spells in La Nina periods are 6 and 8 respectively.

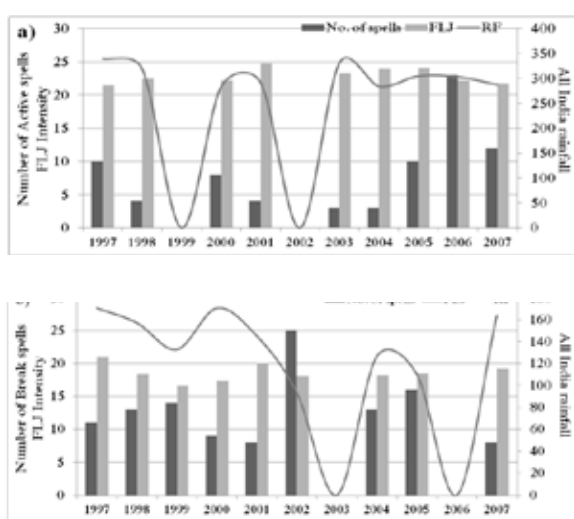

Figure 1. Variation of FLJ intensities and rainfall during 1997-2007: a) active spells and b) break spells.

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This study concludes that FLJ plays an important role in determining the rainfall variability over India. It is seen that during the active phase of monsoon, the LLJ is elongated in west-east direction over the Indian peninsula. Prior to the break, splitting of the LLJ takes place due to forced flow from the north; the northern branch of the LLJ disappears and southern branch passes through the south of the Indian subcontinent taking all the moisture towards the equator. LLJ is a good indicator of active and break phases of monsoon over the country. Keeping a constant watch on LLJ, one can get the information regarding break and active phases of the monsoon well ahead of time.

4. Conclusions:

From this study the following conclusions can be drawn

- During active (break) spells the FLJ intensities are higher (lower) with higher (lower) rainfall.
- There are no active spells during 1999 and 2002, and no break spells during 2003 and 2006. During 2002, the break spells are higher (25 days) and no active spells. In 2006 experiences higher active spells (23 days) and no break spells.
- The rainfall is higher (339 mm) during active spells of 1997, even though it is a strong El Nino year.
- During study period FLJ intensity is higher than 24 m/s during active spells and during break spells FLJ intensity is lower than 20 m/s except in 1997 and 2001.

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