

Relationship between Indian Ocean dipole mode and summer monsoon

INDU BALA and O. P. SINGH

India Meteorological Department, New Delhi, India

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e mail : opsingh@imdmil.gov.in

सार – इस शोध-पत्र में भारतीय महासागर द्विध्रुवीय मोड़ (आई. ओ. डी. एम.) और भारतीय ग्रीष्मकालीन मानसून वर्षा (आई. एस. एम. आर.) के 1960 से 2002 तक की अवधि के आँकड़ों का उपयोग करते हुए आई. ओ. डी. एम. तथा केरल में मानसून वर्षा का आरम्भ और देश में वर्षा के बीच के संबंधों का अध्ययन किया गया है। इस अध्ययन से यह पता चला है कि केरल में मानसून के विलंब से आने/शीघ्र आरम्भ होने का संबंध अप्रैल-मई के महीनों के दौरान के तीव्र/कमजोर पश्चिमी ध्रुव से है। मार्च अप्रैल के महीनों में तीव्र पूर्वी ध्रुव प्रायद्वीपीय भारत में मौसमी वर्षा (जून से सितम्बर) में बढ़ोतरी से संबंधित प्रतीत होता है। मानसून की वापसी के चरण अर्थात् सितम्बर के महीने में प्रायद्वीपीय भारत में जुलाई-अगस्त में आई. ओ. डी. एम. सूचकांक ग्रीष्मकालीन मानसून वर्षा की सक्रियता के अच्छे संकेत दे सकते हैं।

ABSTRACT. Utilizing the Indian Ocean Dipole Mode (IODM) and Indian Summer Monsoon Rainfall (ISMR) data for the period 1960-2002 the relationships between the IODM and monsoon onset over Kerala and rainfall distribution over the country have been studied. It has been found that stronger/weaker western pole during April-May is associated with delayed/early monsoon onset over Kerala. Stronger eastern pole during March-April seems to be associated with enhanced seasonal (June-September) rainfall over peninsular India. The IODM index of July-August can provide good indications of summer monsoon activity over peninsular India during the withdrawal phase of the monsoon, *i.e.*, during September.

Key words – Indian ocean dipole mode (IODM), Indian summer monsoon rainfall (ISMR), Western pole, Eastern pole, Sea surface temperature (SST).

1. Introduction

The meteorologists have made attempts to predict the monsoon rainfall over Indian subcontinent since the beginning of the past century (Walker, 1910; 1924) which are still being pursued (Gowariker *et al.*, 1991; Singh & Pai, 1996; Singh, 1998). The main focus of such studies was to identify the suitable predictors for the development of statistical methods for the monsoon prediction. The phenomenon for predicting planetary scale air-sea interactions represented by El-Nino-Southern Oscillation (ENSO) was discovered by Bjerknes (1969). The ENSO-monsoon relationship has been extensively studied by Sikka, 1980; Rasmusson & Carpenter, 1983; Shukla & Paolino, 1983; Chang & Krishnamurti, 1987; Singh *et al.*, 2000; Singh, 2001 and others. Webster & Yang, 1992; Wang, 1995 and Kripalani & Kulkarni, 1997 have shown that ENSO-monsoon connections are very complex though the general type of relationships between ENSO

and ISMR is known since long. Indian Ocean dipole mode (IODM) is the new focus of research (Webster *et al.*, 1999; Saji *et al.*, 1999; Behra *et al.*, 1999; Iizuka *et al.*, 2000; Kripalani and Kumar, 2004; Gadgil *et al.*, 2007) for regional climate variability over the Indian subcontinent. IODM has been defined as the SST difference between the Sea Surface Temperature (SST) anomalies over the tropical western Indian Ocean area bounded by 50° E - 70° E, 10° S - 10° N and the tropical southeastern Indian ocean area bounded by 90° E - 110° E, 10° S - equator (Ashok, *et al.*, 2001). Gadgil *et al.*, 2007 have introduced the atmospheric component of IODM as EQUINO and linked it to performance of monsoon. The IODM involves oscillation of SST between positive and negative phases. A positive phase means cooling of waters in the eastern Indian ocean which leads to droughts in Indonesian region and heavy rains in India whereas the negative phase of IODM brings warmer water and greater precipitation in the eastern near-equatorial

Indian Ocean region. The main objective of the present study is to examine the relationships of IODM, western and eastern poles with the monsoon onset over Kerala as well as monsoon rainfall distribution over India.

2. Data & methodology

The sub-divisionwise monthly and seasonal Indian summer monsoon rainfall data and the monsoon onset dates over Kerala for the period (1960-2002) published in the quarterly Journal Mausam in the article 'Weather in India' have been utilized. The time-series of monthly IODM index (IODMI) derived from GISST data have been used (Saji & Yamagata, 2003). SST data of western and eastern poles for the period 1960-1999 obtained from GISST data have also been utilized. The location of western and eastern poles of IODM are shown in Fig. 1.

Normally, the amplitude of IODM is maximum during spring (October-November). Thus the year-to-year variation in IODM index is maximum during October-November. During March-April the interannual variation is small which increases from May onwards and peaks in autumn. Three leadtime correlations between IODM indices & western and eastern poles' SSTs with monthly and seasonal monsoon rainfall of each sub-division of India have been computed. To establish the relationship of IODM & onset date over Kerala two leadtime correlations pertaining to April & May have been computed. Correlations between the SSTs in western pole during April-May and onset date over Kerala have also been computed. For this purpose 1st June is considered as the normal onset date for counting the onset date anomaly, *i.e.*, if onset date is 25th May the onset date anomaly is taken as -7 and if the onset date is 8th June it is taken as 7.

3. Results & discussion

3.1. Relationship between IODM and summer monsoon onset over Kerala

Fig. 2 shows that the correlations of onset date over Kerala with dipole index & western pole SST are positive which implies that the positive phase of dipole during April-May causes delayed onset of monsoon over Kerala. This is also supported by the correlations with SST in the western pole. Warmer SST anomalies in the western pole are associated with delayed monsoon onset. May SST of western pole is significantly correlated with monsoon onset having the Correlation Coefficient (CC) of +0.42, which is significant at the 99% level. It has been observed that SST anomalies in the western pole generally amplify during May (approximately two-third occasions).

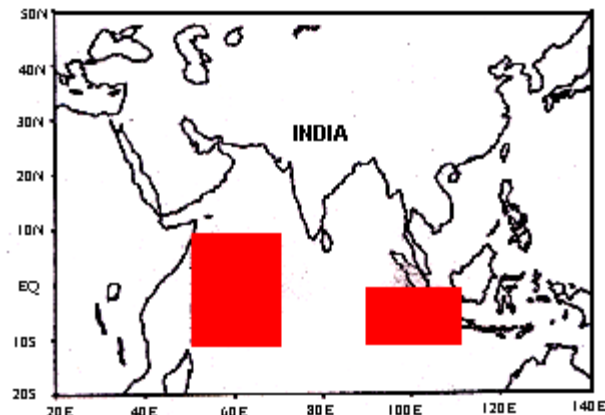


Fig. 1. Western and eastern poles of Indian Ocean dipole

3.2. Relationship between IODM and summer monsoon rainfall over different meteorological sub-divisions of India

To find out the relationships between IODM and summer monsoon rainfall over different sub-divisions, one/two/three months lag correlations between IODM indices and seasonal/monthly monsoon rainfall over each sub-division have been computed. However, the relationships between IODM and seasonal rainfall only have been emphasized and graphically presented.

3.2.1. Seasonal rainfall

3.2.1.1. 3 months lag relationships

It is seen from Fig. 3 that 3 months lag CC between IODM index and seasonal rainfall is highest for coastal Andhra Pradesh which is -0.5 (significant at the 99% level). The corresponding CCs for some other meteorological sub-divisions of peninsular India are: Rayalseema (-0.4) Telangana, Tamil Nadu & Pondicherry, north Interior Karnataka and south Interior Karnataka (-0.2). Outside peninsular India the significant CCs are for Marathwada and Vidarabha, west Rajasthan and Jammu & Kashmir (-0.3). Therefore, IODM Index of March can give indications of seasonal summer monsoon rainfall over the above mentioned meteorological sub-divisions of India.

3.2.1.2. 2 months lag relationships

It is seen from Fig. 3 that there exists a negative relationship between April IODM index and summer monsoon rainfall over peninsular India. The highest CCs are for Madhya Maharashtra, Rayalaseema and coastal Andhra Pradesh (-0.3) followed by Vidarabha, Telangana, Tamil Nadu & Pondicherry and Kerala (-0.2). Other

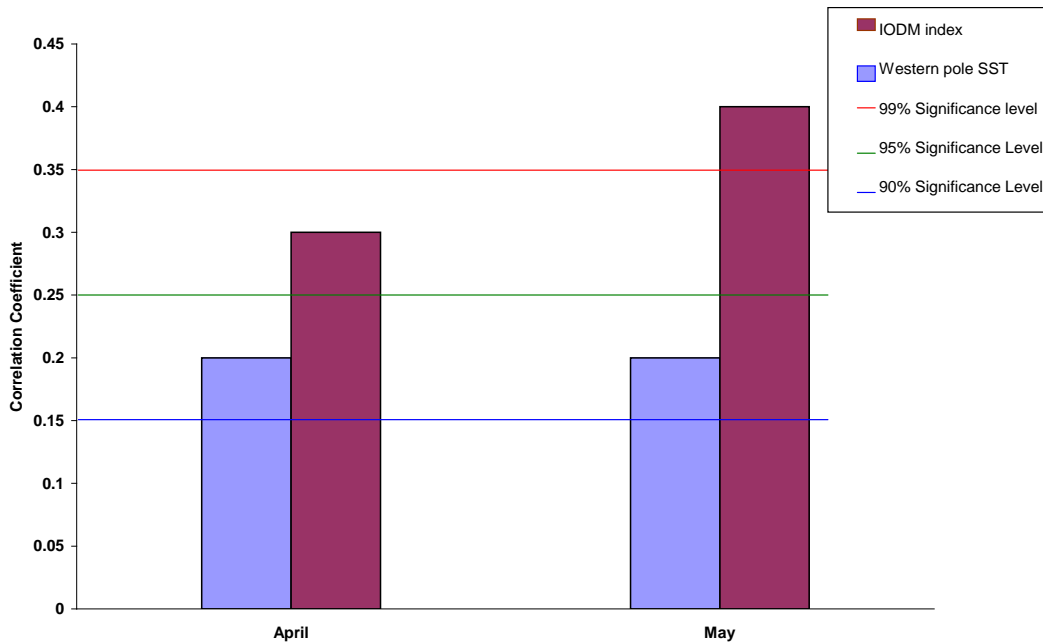


Fig. 2. Correlations between IODM index/western pole SST and monsoon onset over Kerala

significant CCs are for west Rajasthan, Jammu & Kashmir, Bihar, Uttar Pradesh, gangetic West Bengal & NMMT which is -0.2. These CCs are significant at the 95% significance level.

3.2.1.3. 1 month lag relationship

Most of 1 month lag correlations are significant at the 95% level. Some of these are: NMMT (-0.3), Andaman & Nicobar Islands and Arunachal Pradesh (-0.2). Over peninsular India CCs for sub-divisions of coastal Andhra Pradesh, Rayalaseema, Tamilnadu & Pondicherry are -0.2.

3.2.2. Monthly rainfall

Three months lag CC between IODMI & June rainfall is maximum for Saurashtra and Kutch which is -0.4. The CCs for south interior Karnataka, coastal Andhra Pradesh and Marathwada is -0.2. Positive significant correlation is seen for sub-divisions of SHWB & Bihar Plains which is 0.3 whereas for peninsular India and Andaman & Nicobar islands CCs are negative. For July rainfall almost similar pattern is observed.

Two month lag correlations are higher than 3 month lag values. Not only this, the area of significant

correlations is larger in the case of 2 months lag. The relations are consistent with 3 months lag. For July & August rainfall the correlations are not good except over peninsular India. For Andaman & Nicobar Islands all the three leadtime relations are consistent. The IODM indices of preceding 2 months can provide good indications of rainfall distributions over peninsular India during the withdrawal phase of the monsoon.

One month lag relations yield positive correlations between IODM index and June rainfall which are highly significant over the west coast of India.

For September month all the leadtime correlations are significant at the 95% level. It is seen that all the leadtime correlations show consistent results over peninsular India.

Fig. 2 shows that the correlation coefficients having magnitudes more or equal to +0.35 are significant at the 99% level and those with magnitudes more or equal to 0.25 are significant at the 95% level. Thus as shown in Fig. 3 the correlation between IODM and the seasonal monsoon rainfall over two sub-divisions of peninsular India, *i.e.*, coastal Andhra Pradesh and Rayalaseema (about 25% of the peninsular India) are significant at the 99% level. The correlations are significant at the 95% level for about 50% of the peninsular India.

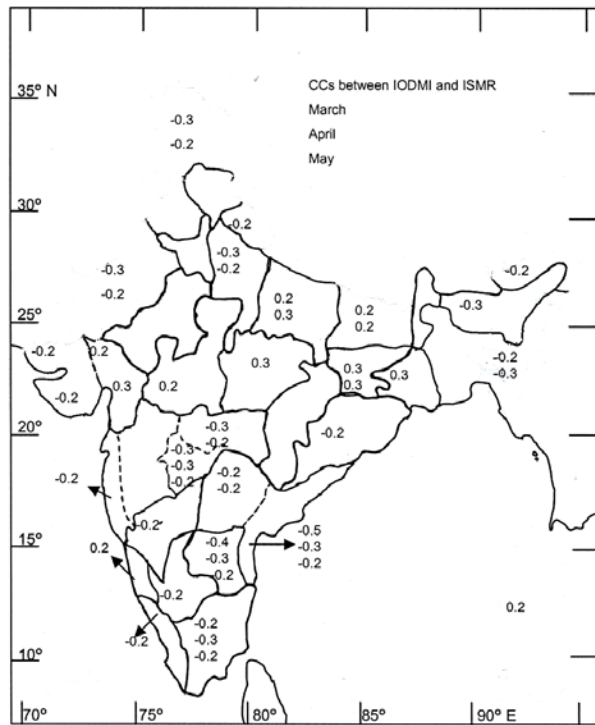


Fig. 3. Lag correlations between IODMI and seasonal rainfall

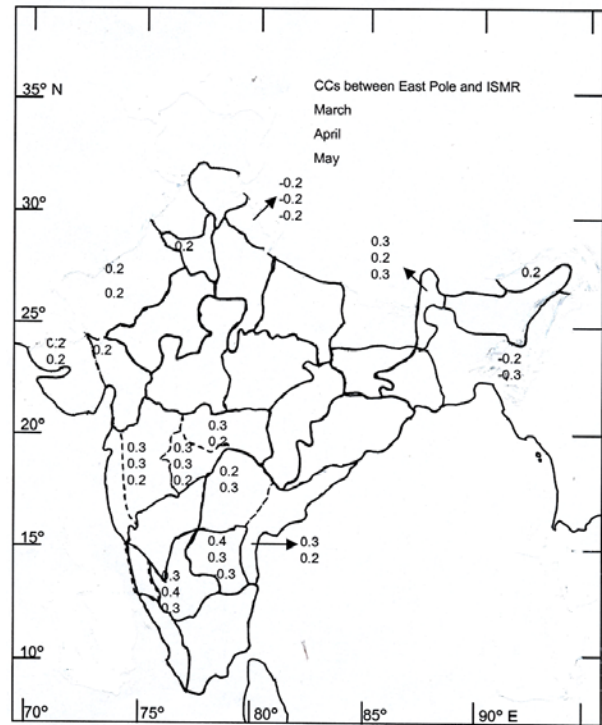


Fig. 4. Lag correlations between eastern pole and seasonal rainfall

3.3. Relationships between SST in the eastern pole and monsoon rainfall

3.3.1. Seasonal rainfall

It is seen from Fig. 4 that the SSTs in the eastern pole during April-May are positively correlated to ISMR over peninsular India. All the leadtime correlations are generally positive. The utility of relationships between SST in the eastern pole and monsoon rainfall seems to be limited to peninsular India only.

3.3.2. Monthly rainfall

For June rainfall over peninsular India positive correlations are observed. All the three lead time correlations are consistent for peninsular India. Interestingly, July rainfall shows negative correlation with SST in eastern pole. Two months lag relations are more prominent for August rainfall. SST in the eastern pole yields a uniform pattern of relationship with rainfall over the sub-divisions of Madhya Maharashtra, Vidarabha, Marathwada, Telangana, north Interior Karnataka, south Interior Karnataka and Rayalaseema.

As shown in Fig. 4, the correlations between eastern pole of the dipole and the seasonal monsoon rainfall are significant at the 95% level for about 40% of the peninsular India.

3.4. Relationship between SST in the western pole and monsoon rainfall

It is seen from Fig. 5 that the SST in the western pole is positively correlated to seasonal monsoon rainfall over peninsular and western India (except Tamilnadu). March SSTs in the western pole can provide good indications of seasonal rainfall over Maharashtra.

Good correlations exist between SST in the western pole during June and rainfall over west coast & interior parts of peninsular India. During the strong western pole phase though the onset date over Kerala is delayed the monsoon activity during June is good over west coast and peninsular India.

Fig. 5 shows that the correlations between the western pole of dipole and seasonal monsoon rainfall are significant at the 99% level for Andaman & Nicobar

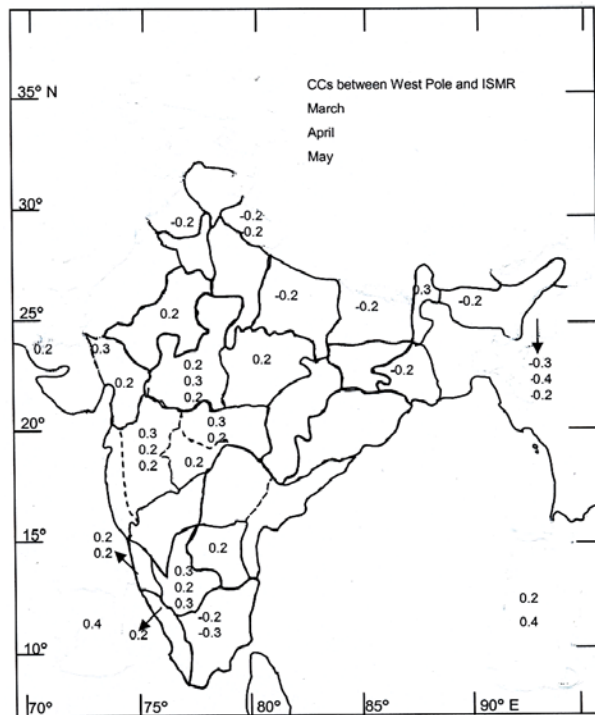


Fig. 5. Lag correlations between western pole and seasonal rainfall

Islands and Lakshadweep whereas they are significant at the 95% level for Tamilnadu and north Interior Karnataka.

4. Conclusions

The study has brought out the following results :

(i) Positive/negative phase of Indian ocean dipole mode and warmer/colder SSTs in the western pole during April-May cause delayed/early onset of monsoon over Kerala.

(ii) The Indian ocean dipole phenomenon seems to influence the summer monsoon activity over the peninsular India more as compared to that over the central and northern parts of India. Negative phase of IODM during March-April, *i.e.*, stronger eastern pole is associated with enhanced seasonal summer monsoon rainfall over peninsular India. The correlations are significant at the 99% level for about 25% of the peninsular India.

(iii) The Indian ocean dipole mode index of preceding one/two months, *i.e.*, July and August can provide good indications of summer monsoon activity over peninsular India during the withdrawal of monsoon, *i.e.*, September.

(iv) Sea surface temperatures in the western pole during March-April are associated with enhanced monsoon rainfall over Kerala, Karnataka and Andhra Pradesh

during the onset phase of monsoon, *i.e.*, June. The correlations are significant at the 99% level for Andaman & Nicobar islands and Lakshadweep and at the 95% level for Tamilnadu and north Interior Karnataka.

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