
The analysis of anomalies of surface meteorological field such as SST, wind speed and direction, sea level pressure and cloud cover for contrasting monsoons yielded interesting results. The SST anomalies during pre-monsoon or summer monsoon do not indicate the nature of monsoon in that year, as there are many good monsoon years with negative SST anomalies and positive SST anomalies over the Indian Ocean and Vice-versa.
• The negative SST anomalies over Indian Ocean are generally associated with La Nina.
• Positive SST anomalies with good monsoon rain fall (eg. 1983 and 1988) follow a severe El Nino and bad monsoon in the previous year.

The largest scale Indian Ocean SST anomalies are closely linked with ENSO events. Hence regions of warm SST may not be regions of negative OLR in the Indian Ocean (Webster et al, 1998). This could be one of the major reasons for any one to one direct relationship between Indian summer monsoon rainfall (ISMR) anomalies and SST in the Indian Ocean.

The anomalies of the surface wind suggests that

1) In general a strengthening of south westerlies (of over 3 to 5 m/s) in the Arabian Sea occurs during good monsoon years and weakening of SW take place during bad monsoon years. However 1983 remains as an exceptional case during early part of the monsoon.

2) Cross equatorial flow in the western Indian Ocean is weak in bad monsoon years compared to good monsoon years.

3) Some bad monsoon years are distinguished with the strengthening of south westerlies in the eastern part of the Bay of Bengal, eg. 1965.

4) The wind anomalies are strongest in the eastern equatorial Indian Ocean especially associated with EQUINOO or IOD.
SLP anomaly of monsoon months suggests that bad monsoon years have positive anomalies over the Indian seas and some part of South Indian Ocean. The positive anomalies indicate that SLP is high for bad monsoon months indicating high-pressure zones. The high pressure zone suppresses the air-sea interaction and convective activity reducing the moisture convergence in the boundary level. The pressure anomalies are positive in major part of northern Indian Ocean during bad monsoon years.

However, during good monsoon years, the pressure anomalies are negative indicating a fall in SLP during pre-monsoon and monsoon months. The condition is favourable for the updraft and moisture convergence in the atmosphere leading to an increased monsoon activity. Thus SLP anomalies can be used as a possible indicator to assess the performance of monsoon activity. This study also reveals that, in the pre-monsoon season and monsoon season, during excessive rain fall years, the cloud cover is more in the equatorial and north Indian Ocean compared to same period of drought years.

Of the four anomalies of surface meteorological parameters studied, the anomalies of wind were strongest in the eastern equatorial Indian Ocean compared to those of SST, SLP and cloud cover. In the wind anomaly, the zonal component was predominant. It is found to be the strongest between $0^\circ$ - $10^\circ$ S and $85^\circ$ – $95^\circ$ E. The study indicates that the IOD events can be better inferred from the index of zonal wind anomaly compared to SST, SLP or cloud anomalies. The filtered (periodicities up to one year removed) zonal wind anomaly during 1945 – 1993 shows that the oscillations were strongest in the 1950’s and 1960’s and the
amplitude decreased till the early nineties. FFT anomalies showed a periodicity of 2.5 years indicating QBO. Possibly IOD events are manifestations of QBO.

Having studied the anomalies of surface meteorological parameters the analysis of anomalies of net heat flux, short wave flux, latent heat and evaporation were carried out. This study showed the occurrence of large positive anomalies of latent heat flux and evaporation in the western tropical Indian Ocean during good monsoon years and large negative anomalies in bad monsoon years. The moisture flux from that region could be one of the main sources of moisture to the ISMR. Moreover, in the central and eastern equatorial Indian Ocean, the anomalies largely fluctuated in different years. The moisture transport in the equatorial belt associated with wind anomalies may also influence the patterns of rainfall over the Indian region. The tropical Indian seas are found to lose more heat during excess rainfall years compared to deficient rainfall years. This indicates that the air sea interaction prior to a good monsoon activity is more leading to increased exchange of fluxes of momentum, heat and moisture. Further, it can be seen that, prior to an excess rainfall year, tropical Indian seas lose more heat driving the convection activity in the atmosphere.

Recent studies (Gadgil et al., 2003) have shown that all the major ISMR anomalies during 1979 – 2003 can be explained in relation to favourable/unfavourable phase of EQUINOX or ENSO or both. This concept has been extended to the period 1945-1979. Though the phases of EQUINOX and ENSO explain most of the good and bad monsoon years, during the pre-
monsoon and monsoon phases of ENSO and EQUINOO, it is difficult to infer the intensity of monsoons of 1966, 1974 and 1979. In 1979 though the phases of EQUINOO and ENSO were unfavourable the signals were too weak. But in many years (1951, 1956, 1961, 1965, 1972, and 1975) there were very clean early indications of EQUINOO/ENSO effect on ISMR anomalies.

**Future scope of the study**

The interaction of the marine atmosphere with tropical Indian Ocean and its influence on ISMR continue to be an area of active research. There is still considerable uncertainty on the quantitative relationship between these. Though the effect of ENSO events on ISMR is qualitatively known, there is lot of uncertainty in this aspect also. With the recent discovery of IOD and EQUINOO much more advances have been made on the relationship between the Indian Ocean and ISMR. The combined effect of ENSO, EQUINOO, IOD, MJO etc on ISMR needs to be understood quantitatively for modelling and forecasting of ISMR well in advance. With the availability of near real-time information on several factors affecting ISMR with more accurate and real-time coverage over oceans employing satellites, buoys and Argo floats and with accurate analysis techniques, the relationship between the features in the Indian Ocean, ENSO and ISMR will soon be well understood.