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Letters to the Editor

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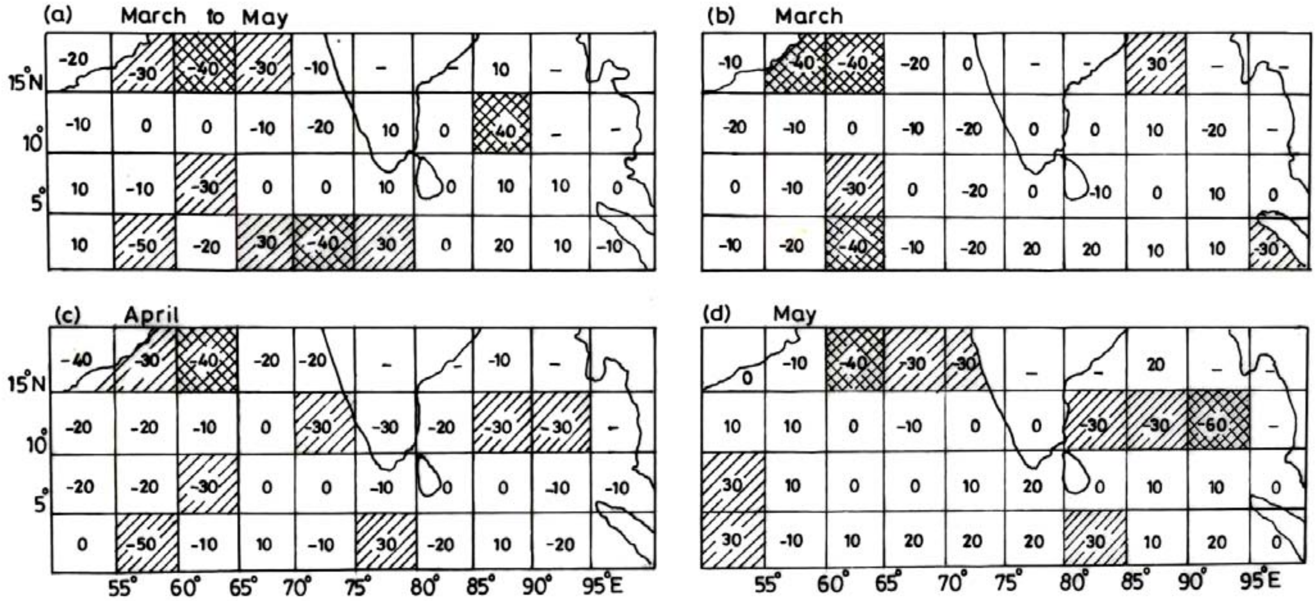
ASSOCIATION BETWEEN THE MONSOON ONSET OVER KERALA (MOK) AND SEA SURFACE TEMPERATURE (SST) OVER NORTH INDIAN OCEAN

1. The summer monsoon over India is the principal rain giving system for India. The normal date of monsoon onset over Kerala (MOK) is 1 June, with a standard deviation of 8 days. However, large year-to-year variations are observed in respect of the dates of MOK. Although the correlation between the dates of MOK and the total seasonal rainfall during ISM season is very weak [Joseph *et al*. (1994), Dhar *et al*. (1980)], the timely arrival of monsoon is of utmost significance. If the date of MOK is delayed considerably, it may affect the crucial agricultural operations like sowing of kharif crops. The late MOK, if combined with sluggish than normal advance of monsoon, may create a severe water crisis over several parts of Indian mainland. The MOK, though a regularly occurring one, is a very complex phenomenon. It is non-linearly linked with many a factors like surface and upper air winds and temperatures, pressures, Sea Surface Temperature (SST), etc. The role of SST over Indian Ocean (IO) in the phenomenon of MOK is quite important, considering the geographical location of India. Joseph *et al*. (1994) have studied the inter-annual variability of MOK in relation to the global SST field and other atmospheric features. They have observed that the delayed MOK is associated with El-Nino (anomalous warming over central and eastern equatorial Pacific Ocean), particularly, in the year (+1) of the El-Nino. Vernekar and Ji (1999) have related the monsoon onset to the pre-monsoon and mid-tropospheric meridional temperature gradient and the strength of the east-west pressure gradient in the equatorial IO. This study also highlights the role of SST over IO during the MOK.

With this backdrop, an attempt has been done in this study, to examine the association between the dates of MOK and the SSTs over North Indian Ocean. For this purpose, monthly SST data obtained from ships' observations, archived by India Meteorological Department, for the period 1961-1998, are used. These data are grouped in the 5° × 5° latitude – longitude grid over the region of North Indian Ocean bounded by 0-20° N, 50° E – 100° E. The dates of MOK are collected from various IMD publications. For each grid, the values of anomaly of SST are computed from the average for the period 1961-98, for the months of March, April, May and the season (MAM), for each year during 1961-98. The coefficients of correlation (CCs) between the dates of MOK and the anomaly of SST during the months, March, April, May and the season, March-April-May (MAM), are computed for each of the grids described above. The CCs are used in order to identify the regions of North Indian Ocean, contributing significantly to the variability of MOK.

2. *Correlation between the dates of MOK and SST over north Indian Ocean during March, April, May and March-April-May (MAM) (1961-98)* – Fig. 1 shows the Coefficients of Correlation (CCs) between the dates of MOK and the anomaly of SST for each, 5° × 5° latitude - longitude grid over north Indian Ocean bounded by 0-20° N and 50 – 100° E. It is observed that, in general, these CCs are negative for the March, April, and May SST anomaly. Statistically significant (at 95% significance level) CCs are observed over the region north of 10° N, during April. The CCs between the dates of MOK and the seasonal (MAM) SST anomaly are relatively weak.

Thus, generally MOK is observed to be negatively correlated (though with not high statistical significance) with the anomaly of SST over north Indian Ocean during March, April, May and MAM, over some grids over north Indian Ocean as shown in Fig.1. However, a continuous area in north Indian Ocean (combination of two or more grids), over which the correlation is uniform, statistically significant and of higher value, is not evident from Fig. 1. This is only expected, considering the very small interannual variability of SST over a 5° × 5° latitude - longitude grid over north Indian Ocean. The MOK can be thought of as being associated with warm SSTs - causing large-scale moisture convergence, which, in turn, leads to building up of active and strong Inter Tropical Convergence Zone (ITCZ) with the associated convective clouds and strengthening of the lower-tropospheric south-westerly winds. In the seasonal cycle, during mid-May, the warmest area of the Indian Ocean warm pool lies in the north Indian Ocean. This facilitates the northward propagation of Equatorial Convective Cloud Maximum (ECCM) from the western Pacific warm pool region, heralding the MOK [Joseph, *et al.* (1994]. The negative correlation between the dates of MOK and the Arabian



Figs. 1(a-d). Coefficients of correlation (× 100) between the date of MOK and the normalized SST anomaly over north Indian ocean (0° - 20° N/ 50° - 100° E) (5° × 5° Lat. – Long. Boxes) for (a) March to May, (b) March, (c) April and (d) May, during 1961-98. The hatched (crosshatched) boxes indicate the regions where the CC is significant at 95% (99%) level

Sea SST anomalies indicates that if the Arabian Sea SSTs during MAM are colder (warmer) than normal, then the MOK will be delayed (earlier) than normal date. This can be attributed to non-building of the north Indian Ocean warm pool of sufficient strength so as to build the convection over the pre-monsoon season warm pool of the Arabian sea.

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