may lead to development of new antibiotic(s) of high potency.

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Indian Ocean dipole mode and tropical cyclone frequency

The Indian Ocean dipole[1] is a coupled ocean–atmosphere phenomenon observed in the Indian Ocean (IO) in the form of an east-west dipole in the sea surface temperature (SST) anomalies. The Indian Ocean Dipole Mode Index (IODMI) is defined as the difference in SST anomaly between the tropical western IO (50–70°E, 10°S–10°N) and the tropical southeastern IO (90–110°E, 10°S-equator)[2]. Positive IODMI is associated with warm SST anomaly over the western tropical IO and cold SST anomaly over the southeastern tropical IO. Sign of the index reverses when SST anomalies swing to the opposite phase. The IODM phenomenon seems to play a key role in the occurrence of droughts (Tuarang) over the Indonesian region[3–5]. When IODMI is negative, it leads to drought over Indonesia and floods over East Africa and vice versa. Positive IODMI seems to correspond to more monsoon rains over India. The northeast monsoon rainfall (October–December) over south peninsular India and the IODM (September–November) are directly related, suggesting that the positive (negative) phase of the mode enhances (suppresses) the northeast monsoon activity[6]. A recent study has shown that the Indian summer monsoon has greater influence on the IODM, than vice versa[7]. In the present work, the relationship between the IODM and cyclone frequency in the Bay of Bengal (BOB) during the post-monsoon season (October–December), which is also known as the storm season in South Asia, has been investigated. The probable impact of IODM on the frequency of monsoon depressions and storms (which are significant rainfall-producing systems during the monsoon season from June to September) has also been looked into. Monthly time-series of IODMI[8,9] from January 1958 to December 2002 has been used to determine the correlation with cyclone frequencies. The cyclone frequency data have been obtained from IMD records.

As mentioned earlier, the post-monsoon season from October to December is known for maximum number of intense cyclones in the north IO[10]. Monthly frequency of severe cyclones (with maximum sustained wind speed exceeding 48 nmile per h) is highest during November. As about 80% of the north IO tropical cyclones form in the BOB, the focus of the present work is on the relationship between the IODM and the tropical cyclone frequency in the BOB.

The time-series of IODMI during September–October and the cyclone frequency in the BOB during November are presented in Figure 1. The aim is to demonstrate the lag relationships which have forecasting applications. It is evident from Figure 1 that the IODMI of preceding two months has an inverse relationship with the cyclone frequency in November. In other words, the negative IODMI during September–October corresponds to enhanced cyclone frequency during November. Therefore, colder SST anomalies over the western tropical IO and warmer SST anomalies over the southeastern tropical IO during September–October will correspond to enhanced cyclone activity in the BOB during November.

Figure 2 depicts the correlation coefficient (CC) between IODMI (September–October) and cyclone frequency (November). The CC between the September–October IODMI and November cyclone frequency is about –0.4, which is statistically significant at the 99% level. Thus the IODMI can provide useful indications of the November cyclone frequency two months in advance, which could be a potential tool in tropical cyclone forecasting. It is interesting to note that the simultaneous correlation between the November IODMI and the November cyclone frequency is less (–0.34) than the lag correlations, which implies that SST anomalies during the preceding two months play a more important role in the cyclogenesis in the BOB during November, than the anomalies during November.

The inverse relationship between the IODMI and the November cyclone frequency is consistent with the circulation patterns associated with the extreme dipole events during the post-monsoon season. A notable feature observed during the positive (negative) phase of the dipole mode is an anomalous anti-cyclonic (cyclonic) circulation over the BOB[6]. Thus the anomalous cyclonic circulation during the negative phase may support the formation of cyclones over the BOB as the anomalous cyclonic vorticity triggers the genesis of cyclones. This is the possible reason for the nega-

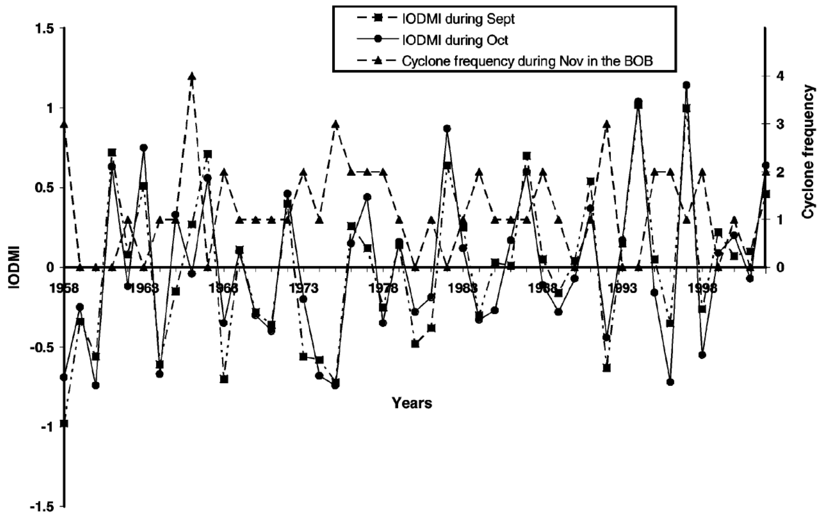

Figure 1. Time-series of Indian Ocean Dipole Mode Index (IODMI) during September–October and tropical cyclone frequency during November.

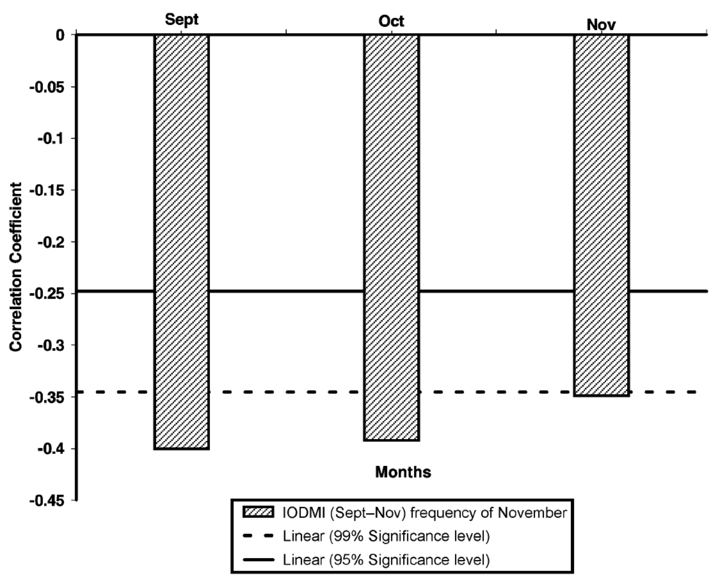

Figure 2. Lag and simultaneous correlations between IODMI (September–November) and cyclone frequency during November.

tive correlation between the IODMI and the November cyclone frequency.

It may be mentioned that the IODM peaks in autumn (September–November), and thus during the negative phase of IODM anomalous cyclonic vorticity would be present over the BOB during autumn[6]. As pointed out earlier, even simultaneous correlation between the IODM and cyclone frequency during November is good. The lagged correlations are slighty more because the impact of SST on the wind field is observed with a lag. The lagged correlations have been emphasized here because of their utility in forecasting.

When the seasonal frequency of tropical cyclones during the three months of the post-monsoon period from October to December is considered, the correlations get diluted. For instance, the lag correlation between the August–September IODMI and the post-monsoon cyclone frequency is approximately –0.2. Though this is not significant (significant level, 90% only), it can provide good indications of the seasonal tropical cyclone frequency in the BOB during the post-monsoon season.

Monsoon depressions and cyclones are important rainfall-producing systems in India during the monsoon season from June to September. Substantial percentage of monsoon rainfall over the central parts of India is associated with these monsoon systems. These systems generally form over the north and adjoining central BOB and move in a northwesterly direction along the monsoon trough. The IODMI of May has a correlation (–0.22) with the seasonal frequency of monsoon depressions and cyclones in BOB during the monsoon season. The correlation coefficient is almost significant at the 95% level. Therefore, with the lead time of one month, IODMI could be a predictor for the seasonal frequency of monsoon depressions and cyclones in the BOB.

When the lead time was increased and the correlation between the April IODMI and the frequency of monsoon depressions and cyclones was computed, it was found that the two were not related. Thus in case of monsoonal cyclogenesis, the IODMI of only the preceding month (i.e. May) has prognostic utility, whereas in case of the November (post-monsoon) cyclogenesis, the IODMI of preceding two months is significantly correlated with the cyclone frequency.

During the pre-monsoon season (March–May), cyclone frequency is maximum in May. The lag correlations between the IODMI and the cyclone frequency during pre-monsoon are insignificant, implying that IODMI cannot provide any predictive indications of the cyclone frequency during the pre-monsoon season. This may be due to the fact that the dipole mode is normally initiated in summer (June–August) and peaks in autumn (September–November). Thus the correlations between the IODMI and pre-monsoon cyclone frequency are poor.

The IO dipole can provide good indications of the tropical cyclone frequency in the BOB during November with a lead time of two months. It could be a potential tool in the forecasting of the November tropical cyclone frequency. The IODMI of May is correlated with the frequency of monsoon depressions and cyclones during the monsoon season. It can provide predictive indications of the seasonal monsoon depression and cyclone frequency. However, the IODMI of preceding months cannot provide indications of the tropical cyclone frequency during the pre-monsoon season.

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‘Orange sand’ – A geological solution for arsenic pollution in Bengal delta

Arsenic pollution in the Bengal delta is considered to be the most hazardous environmental problem in recent years, affecting millions of people residing in West Bengal, India and adjoining Bangladesh. Several studies have been carried out over the last few decades to address this problem. These studies were based on reports of arsenic incidences[1,2], genetic aspect of arsenic entrapment and its consequent release into groundwater[3,4]; some have come up with suggested measures mostly based on surface filtration of the contaminated water[5,6]. Tubewells in the depth range 20–50 m yield maximum arsenic concentration in groundwater; the values may exceed 500 ppb compared to the maximum permissible limit of 50 ppb in potable water[7,8]. On the basis of knowledge of low arsenic in deeper aquifers[9], tubewells were also made in the depth range 120–140 m. But in the affected areas[6], some of these (30–40%) are also found to yield arsenic greater than 50 ppb. Thus people are forced to use costly surface filters either at domestic level or community level. In the long run, majority of the filters are also found to be non-functional in reducing arsenic and people have no other alternative than to drink the contaminated water and consequently become a recurring victims of arsenic toxicity. The present work enumerates a geological solution for this pollution problem, simply by tapping groundwater from a specific aquifer which would yield arsenic-free groundwater.

The Bengal delta, covering the eastern part of West Bengal up to Bangladesh, represents the Quaternary deposit of the Ganga–Padma–Brahmaputra river system. The deposits are relatively younger compared to the deposit of Damodar flood plain in the western part of West Bengal or its equivalent in Bangladesh[10–12]. In the affected areas there are multiple aquifers at different depths; each is semiconfined to leaky-confined, or confined by a variety of overlying clays[13]. The clays vary from light grey to dark grey and soft to hard in nature, whereas the sands are mostly grey and fine-to-medium in size. Each sand–clay fining upward unit represents a single cycle of fluvial deposit, superposed on each other to form a stack of multiple aquifers. In the Bengal delta, groundwater is tapped by people from the leaky-confined, grey, fine sand in the depth range 20–50 m. Community wells are also made in these localities by the local administration, tapping groundwater from the deeper grey, fine sand aquifers in the depth range 60–140 m. The aquifers of grey, fine sand with an overlying grey, soft clay, enriched in organic matter occurring at different depths yield high arsenic in groundwater[14]; their regional extent along with depth consistency thus has resulted in severe geogenic health hazards of toxic arsenic in these areas.

The groundwater in Damodar flood plain is free from arsenic, except in a few localities[15]. The aquifer sand of this plain and its equivalent in Bangladesh[11,12] is yellowish-brown in colour and is known as orange sand. However, orange sand was not reported earlier within the younger

Figure 1. Stratigraphic position of orange sand unit yielding arsenic-free groundwater. This unit is sandwiched between the overlying and underlying grey sands, both yielding high levels of arsenic in groundwater.