Conventional flood-management programmes such as embankment construction have mainly concentrated on the main channel and have provided limited relief in most flood-prone areas across the country. The main emphasis should now shift to management of the upstream area, where run-off generation and distribution take place. Recently, the basin-scale approach towards flood management has been strongly advocated[17]. Geomorphic characteristics of a river basin play a key role in controlling the basin hydrology.

The present investigation highlights the importance of morphometric studies in flood analysis. Effect of the geomorphometric parameters on the GIUH suggests that the length of channel of maximum order (L_Ω) and length ratio (R_L) have maximum control on the hydrological response of a river basin. The results of this communication are based on a wide range of morphometric parameters (Table 3) covering all natural river systems, and therefore, the conceptual understanding of geomorphic control on flood hazard is applicable to other river basins as well. In general, the tributaries with smaller length of channel of maximum order (L_Ω) and higher length ratio (R_L) would be characterized by higher peak of hydrograph. The outlets of these tributaries would therefore be potential flood-prone areas in a river basin. It is strongly recommended that the upstream flood-control efforts should be concentrated in such regions to reduce flood hazard.

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Equatorial East Indian Ocean sea surface temperature: A new predictor for seasonal and annual rainfall

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Here we examine the relationship of both the all India annual rainfall (AIAR) and the Indian southwest monsoon rainfall (ISWMR) with global sea ice sea surface temperature of the equatorial (EQ) East Indian Ocean along the grid 5S–5N, 85E–95E. A strong positive correlation (99%) exists between the April SST (sea surface temperature) in the region EQ–5N, 85E–95E and the AIAR, while a negative correlation (95%) exists between June SST in the region 5S–EQ, 85E–95E and the ISWMR. The SSTs in the grid could be used to predict the AIAR and the ISWMR prior to 8 and 3 months respectively.

THE Asian monsoon circulation influences most of the tropics and subtropics of the eastern hemisphere and more than 60% of the earth's population. Accurate long-lead prediction of monsoon rainfall can improve planning to mitigate the adverse impacts of monsoon variability and to take advantage of beneficial conditions[1]. The southwest (summer) and the northeast (winter) monsoons influence weather and climate between 30N and 30S over the African, Indian and Asian land masses[2]. As a first approximation, it can be said that the distribution of SST

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(sea surface temperature) in the Indian Ocean plays a crucial role in determining monsoon rainfall variability[3]. Several studies[4–8] have reported the empirical relations between Indian Ocean SST and the Indian southwest monsoon rainfall (ISWMR). The relationships between the ISWMR and SST anomalies over the equatorial Pacific Ocean associated with ENSO phenomena[9–15] and with the Indonesian–North Australian[16] region have also been documented. The impact of Arabian Sea SSTs on the ISWMR has been studied in detail[5,17–20]. It has been found that there exists a homogeneous region in the south eastern Arabian Sea where the March–April SST anomalies significantly correlate with the seasonal (June–September) rainfall[21]. The relationship between the South Indian Ocean SST and ISWMR has been addressed[13]. Also, it was found that SST anomalies over the equatorial Indian Ocean had also adversely affected the ISWMR during the 1987 El-Niño[14]. However, there are no studies that address the relationship of SST over the equatorial East Bay of Bengal with both ISWMR and all India annual rainfall (AIAR). The relationship between Indian rainfall and SST strongly suggests that it might be expected to continue[22]. Hence in this study, we have analysed the probable relationship of monthly SST (over a specific grid, 5S–5N, 85E–95E of the East Indian Ocean) of 70 years (1932–2001) with the ISWMR and for 25 years (1977–2001) with the AIAR. This specific grid has been chosen in our study, since a newly discovered phenomenon of a westward moving 'twin gyres'[21] is found to evolve in this grid during every southwest monsoon. It is found that the SST anomalies over the specified region could act as a useful predictor for both the ISWMR and the AIAR.

Though the sixteen-parameter power regression model[23], generally used to predict the monsoon rainfall by the India Meteorological Department (IMD) uses various regional and global parameters up to May, it does not include SST from the eastern equatorial Indian Ocean. IMD had recently developed a new eight-parameter power regression model requiring data only up to March. However, data up to June will be used to issue update forecast by July for long-range forecast of the southwest monsoon rainfall. It is interesting to see that even in our study we use the SST of June for predicting the southwest monsoon rainfall. The grid 5S–5N, 85E–95E has been chosen for our study, because of the recently discovered twin gyre system[21] that has been noticed in this grid during the beginning (May) of every monsoon season. It is in this grid that the anticyclonic twin gyres evolve and subsequently move westward till the west equatorial Indian Ocean. It is also noted that in this grid SST drastically increases during May of every year, caused by the occurrence of the anticyclonic rotation of the twin gyres. This feature has also been noticed by an increase in the TOPEX sea surface heights in this grid apparently caused by these twin gyres; the complete features and dynamics of the twin gyres have already been explained[21]. Since these gyres have been found in this region, we tried to look into the SST over this region for the possible applications and correlations that would improve the predictive ability of the Indian monsoon and the Indian annual rainfall as a whole. Therefore, monthly mean averaged SST over this specific grid from April to June and its impact on the AIAR and ISWMR are investigated. This study correlates the April and June monthly means of global sea-ice sea surface temperature (GISST) (1° × 1°) averaged over the grid (5S–5N, 85E–95E) with the AIAR and the ISWMR, respectively. The seasonal and monthly rainfall data from 1871 to 2001 have been taken from the IITM rainfall series (www.tropmet.res.in). Though the correlations have been checked from 1871 to 2001, they are found to be of high significance level from 1977 for predicting the AIAR and from 1932 for predicting the ISWMR. The correlations were found to be coherent, as examined by various samples of 25 and 70 years for the two cases. It may be noted that the SST over this east equatorial region is not only related with the ISWMR but also with

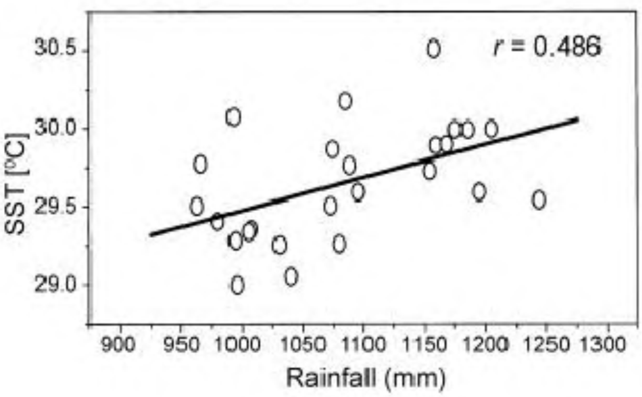

Figure 1. Positive correlation with 99% significance level between the SST and annual rainfall for 25 years (1977–2001) in the region 0–5N, 85E–95E.

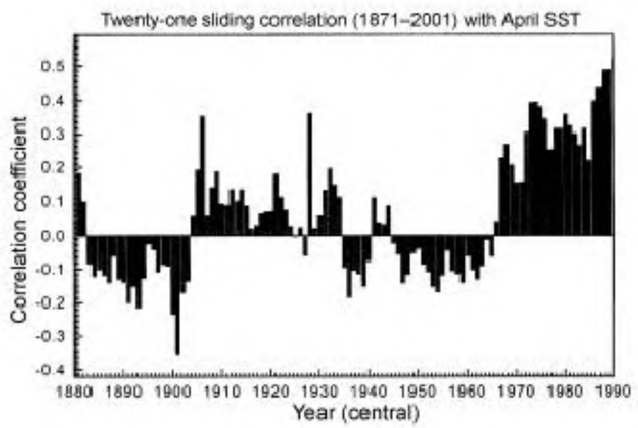

Figure 2. Twenty-one year moving correlation coefficient of annual rainfall with April SST over the grid, EQ–5N, 85E–95E. Values are plotted at the centre of the 21-year period.

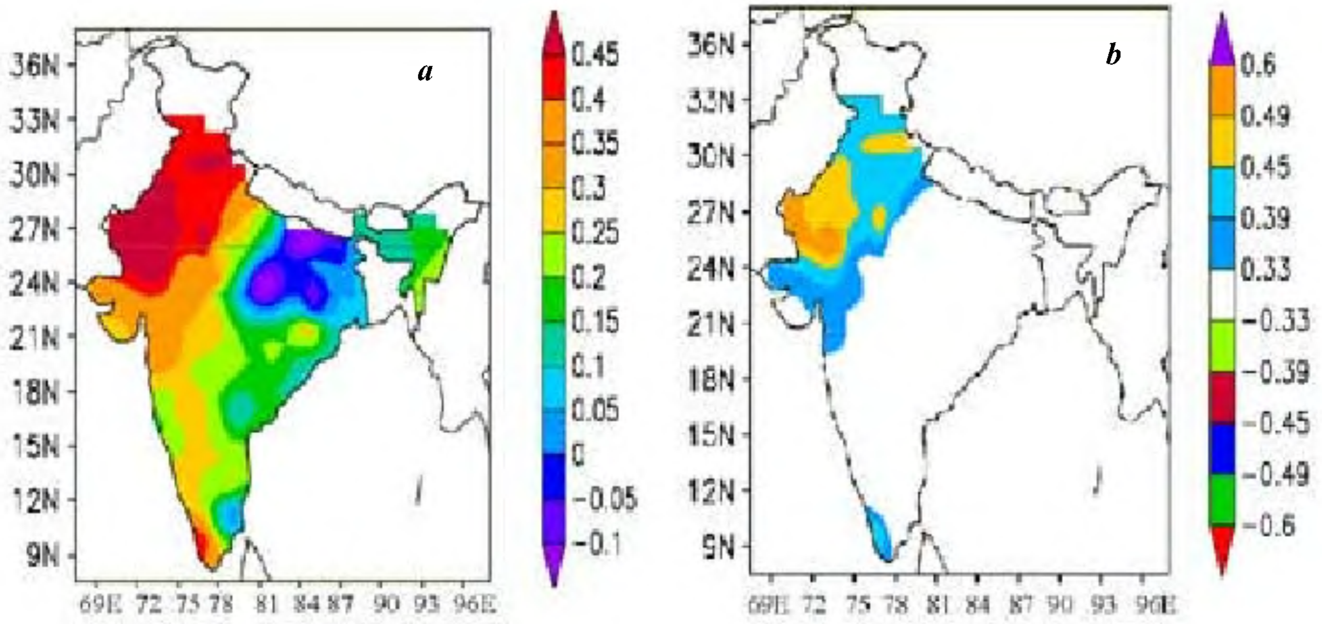

Figure 3. Spatial distribution of correlation coefficient of all India subdivisional annual rainfall with April SST over the grid EQ–5N, 85E–95E (***a***) and areas of significance levels at 97–99.99% (***b***).

AIAR, whereas in most of the earlier studies Indian Ocean SST has always been related with the ISWMR alone.

In order to quantify the results obtained, it is seen that a strong positive correlation is found between April SST over the region 0–5N, 85E–95E and the AIAR. The correlation is as good as 0.48 for a period of 25 years (1977–2001), corresponding to a significance level of 99%. This gives an indication that the April SSTs over the region 0–5N, 85E–95E could help predict eight months ahead, the all India rainfall that would occur by the year end. Studies available in the literature had focused on predicting the Indian rainfall during the southwest monsoon, as it occurs for only four months but contributes maximum to the all India rainfall. However, in this study we looked into the possibility of predicting the annual rainfall as well. It is interesting to note that the April SST provides clues to the amount of total annual rainfall, which includes the rainfall occurring during the northeast monsoon also. One can infer from Figure 1, that warmer the SSTs in this grid, more the rainfall that year and vice versa.

The secular variations of the relationship of these SST indices with the AIAR are further investigated by calculating the 21-year sliding correlations from 1871 to 2001. The results given in Figure 2 consistently show significant correlations from 1970s and are more profound from 1977. The correlation is seen to become stronger (0.48) at 99% significance level during the last decade and is still continuing to do so. The shift observed in the Indian Ocean after 1976 may be because of the climate change/global warming observed after mid-1970s (ref. 24).

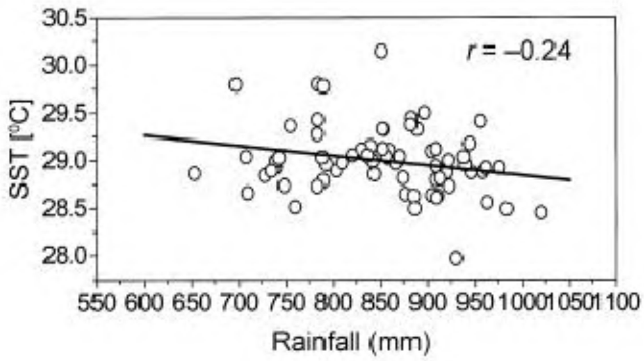

Figure 4. Negative correlation with 95% significance level between June SST and the rainfall for 70 years (1932–2001), EQ–5S, 85E–95E.

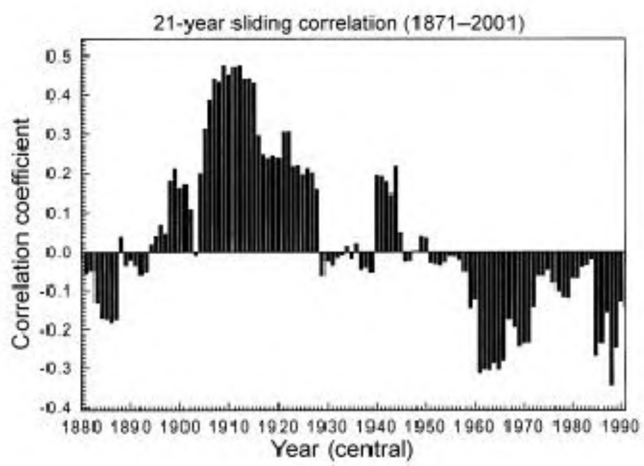

Figure 5. Twenty-one-year moving correlation coefficient of seasonal rainfall with June SST over the grid, EQ–5S, 85E–95E. Values are plotted at the centre of the 21-year period.

We have further carried out a spatial distribution of correlation coefficients to examine the utility of these indices for long-range forecasting of the AIAR. Correlations of the April SST over the grid EQ–5N, 85E–95E with the all India subdivisional annual rainfall are shown in Figure 3. The correlation coefficients for all the subdivisions are shown in Figure 3 *a* and for subdivisions which are significant at 98 and 99% levels are shown in Figure 3 *b*. The results bring out strong correlations of +0.52, +0.52 at 99.99% significance level, in particular over the northwestern parts of India and also southeast parts. It is seen from the results that the SST over this grid could possibly be used as a predictor for long-range forecasting in the northwest part of India and also for Kerala in southern India.

Similarly, we have looked for a possible predictor that would be useful in predicting the ISWMR. A negative correlation is found between June SSTs over the region 0–5S, 85E–95E and the Indian southwest monsoon rainfall (July–September). The correlation is –0.24, as seen in the Figure 4 for a period of 70 years (1932–2001), corresponding to a statistically significant level of 95%. This relationship has been persistent since the past 70 years and so would be useful to predict the total monsoon rainfall, though we may require the SST of June, i.e. after the onset of the monsoon.

We also worked out the 21-year sliding correlations from 1871 to 2001. However it is seen that a consistent negative correlation builds up after 1932. The results shown in Figure 5 indicate that a negative correlation continues from 1932 and attains strong values during the period 1960–1970. The pattern continues till 2001, though the correlation become lesser in magnitude but with corresponding significance levels at 90, 95 and 98%. Such secular variations between the ISWMR and several other predictors have been observed earlier[25,26].

We also plotted the spatial distribution of correlation coefficients to examine the utility of these indices for long-range forecasting of the ISWMR. The results given in Figure 6 represent the correlations of all the subdivisions with SST (Figure 6 *a*) and those that correspond to significance levels of 90 to 98% with the SST (Figure 6 *b*). It is seen from the Figure 6 *b* that Central and South India bear correlations of –0.27, –0.25 at 98 and 95% significant levels respectively.

Similar spatial correlation structures as seen in Figure 6 are also observed with other predictors[27].

The correlations obtained between the AIAR and ISWMR with SST suggest that lower (higher) April SST compared to the previous year would indicate a lower (higher) annual rainfall, and higher (lower) June SST compared to the previous year would indicate lower (higher) seasonal rainfall during that year. Rainfall prediction during the northeast monsoon has not been clearly focused over the past years. Therefore, the present study adds to the predictability of the northeast monsoon rainfall along with the southwest monsoon.

The study suggests that careful monitoring of the SST in this grid would be worthwhile in developing an accurate method for the long-range prediction of the Indian monsoon rainfall. This study helps to identify a 5° × 10° grid whose SST could be used to predict both the all Indian monsoon rainfall (5S–0, 85E–95E) and the Indian summer monsoon rainfall (0–5N, 85E–95E). A 5° × 10° grid

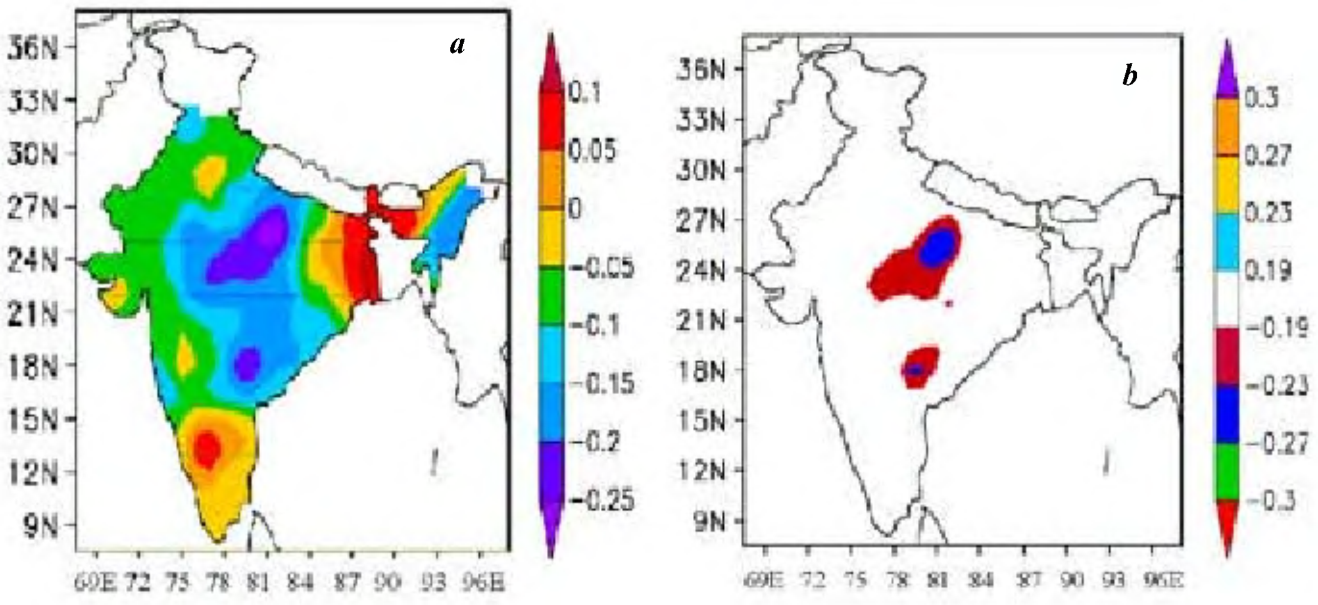

Figure 6. Spatial distribution of correlation coefficient of all India subdivisional annual rainfall with June SST over the grid EQ–5S, 85E–95E (***a***) and areas of significance levels at 90–98% (***b***).

is small compared to the spatial scales of the ocean, but this would certainly add more clarity to understanding the Indian Ocean SST relation with the Indian rainfall.

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Prevalence of abnormal haemoglobin E gene in the Dhelki Kharia tribal population

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Tribal communities in India are vulnerable to many hereditary blood disorders. The sickle cell haemoglobinopathy and glucose-6-phosphate dehydrogenase (G-6-PD) deficiency are the most common haemolytic disorders of blood prevalent among the aboriginal or autochthonous people of India. In the present study out of 335 Dhelki Kharia tribals screened following the probability proportionate to size cluster sampling procedure, eleven cases of haemoglobin E gene (ten cases of haemoglobin E trait and one case of haemoglobin E disease) were detected for the first time from Sundargarh district of Western Orissa. The present

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