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Relationship between sea surface temperature and surface air temperature over Arabian Sea, Bay of Bengal and Indian Ocean

A. K. Jaswal, Virendra Singh[1] and S. R. Bhambak

India Meteorological Department, Shivajinagar, Pune – 411 005
[1]India Meteorological Department, Lodhi Road, New Delhi-110 003
Email: jaswal4@gmail.com

ABSTRACT

Climatology and relationship of Sea Surface Temperature (SST) and Surface Air Temperature (SAT) over the Arabian Sea, Bay of Bengal and Indian Ocean north of 15°S are examined on annual and seasonal time scales using the Voluntary Observing Ships data for a period of 40 years (1961-2000). Seasonally, spatial patterns of climatological SST indicate large northward spread of temperatures greater than 28°C from winter to summer in the Arabian Sea and the Bay of Bengal. During monsoon season, there is appreciable cooling in the western half of the Arabian Sea while the entire Bay of Bengal still remains warm (>28°C). The SST and SAT correlation coefficients are quite high over the Arabian Sea and the Indian Ocean as compared to the Bay of Bengal, providing a good justification for using SST as an indicator of SAT variability over these regions. Relationship between SST and SAT indicates same variance over the Arabian Sea and large parts of the north Indian Ocean. But variance ratios of SST and SAT over the Bay of Bengal are quite high for all seasons, indicating a less energetic atmosphere causing smaller SAT variance as compared to SST variance over the area. The striking feature of the mean SST and SAT difference field is the change from strong winter patterns to weak monsoon patterns for sensible heat exchange over the Arabian Sea and the Bay of Bengal.

INTRODUCTION

Climate variability has become an important topic of scientific pursuit during the past few decades, intimately linking the economy of a nation with its climate-resources. Along with land and atmosphere, ocean is a fundamental component of the Earth's climate system. The ocean processes are slower and large scale changes in the ocean occur on monthly to multi-decadal time scales as compared to changes occurring in the atmosphere. India is surrounded by oceans and convection over these oceans plays a major role in the monsoon rainfall over India. A recent study by Barnett et al. (2005) has shown that oceans are not only becoming warmer at the surface, but there is also a penetration of human induced warming into the deeper parts of the oceans. An understanding of the important seasonal mean features of Sea Surface Temperature (SST) and Surface Air Temperature (SAT) and their relationship over the Indian Seas and adjoining Indian Ocean is therefore essential to know the variability and the seasonal movement of convective zones.

Lying on both sides of the Indian sub-continent, Arabian Sea and Bay of Bengal are having similar features but distinct characteristics (Shenoi et al., 2002). Several authors have studied the variation of meteorological parameters over the Arabian Sea, Bay of Bengal and Indian Ocean (Colon, 1964; Pisharoty, 1965; Bruce, 1968; Jambunathan and Ramamurthy, 1975; Anjaneyulu, 1980; Rao and Goswami, 1988; Ramesh Babu et al., 1989, Balakrishnan et al., 1993; Allan et al., 1995; Rajeevan et al., 2000). Using a simple numerical model, Shukla (1975) found that cold SSTs in the Arabian Sea reduce evaporation, increase surface pressure downstream and therefore reduce monsoon rainfall over India. At the same time, many observational studies have shown that positive SST anomalies over the Arabian Sea during the spring, preceding the monsoon season are precursors for above normal precipitation over India (Weare, 1979; Joseph and Pillai, 1984; Rao and Goswami, 1988; Clark et al., 2000). The intensity of warm pool over equatorial Indian Ocean in May and June was found to be positively correlated with good southwest monsoon rainfall (Balakrishnan et al., 1993). From observational study, Joseph et al. (1994) hypothesized that SST anomalies over the Indian and tropical west Pacific Oceans cause the inter-annual variability of the monsoon onset by affecting the timing of the northwestward movement of the equatorial convective maximum. Allan et al. (1995) examined the conditions of the Indian Ocean from 1900 to 1983 in boreal winter and found that overall SST displayed a warming trend. Rajeevan et al. (2000) have reported increasing trends in SST over the Equatorial Indian Ocean (EIO), Bay of Bengal and the Arabian Sea.

A large number of studies are available on the variability of SST over the Indian Ocean but less work has been done on SAT and the relationship between SST and SAT over the Indian Seas. The present study is an attempt to understand the mean seasonal features and relationship between SST and SAT, based on ship observations for the period of 40 years (1961-2000).

DATA AND METHODOLOGY

Though the Arabian Sea and the Bay of Bengal are located in the same latitudinal belt and receive the same amount of solar radiation, oceanographically these two basins exhibit remarkable differences. Bay of Bengal is much warmer than the Arabian Sea and more numbers of cyclonic storms develop over the Bay of Bengal as compared to that over the Arabian Sea. The Arabian Sea is dominated by a semi-annually reversing wind system called southwest monsoon. Bay of Bengal is partially linked with the Pacific Ocean and receives ~1.5x10^{12} m^{3} per year fresh water runoff from major rivers (Subramanian, 1993). These two basins merge with the EIO at their southern boundary, where interaction takes place with the rest of the Indian Ocean.

In this study, daily marine surface data recorded by the Voluntary Observing Ships (VOS) in World Meteorological Organization (WMO) standardized formats are utilized. These observations have been archived at India Meteorological Department (IMD), Pune from 1961 onwards. The SST and SAT data for the period 1961-2000 have been obtained from these observations. Annual and seasonal averages in the boxes of 5^{o} latitude by 5^{o} longitude over the Arabian Sea, Bay of Bengal and the Indian Ocean north of 15^{o}S have been prepared from the monthly means and their spatial patterns analyzed for winter

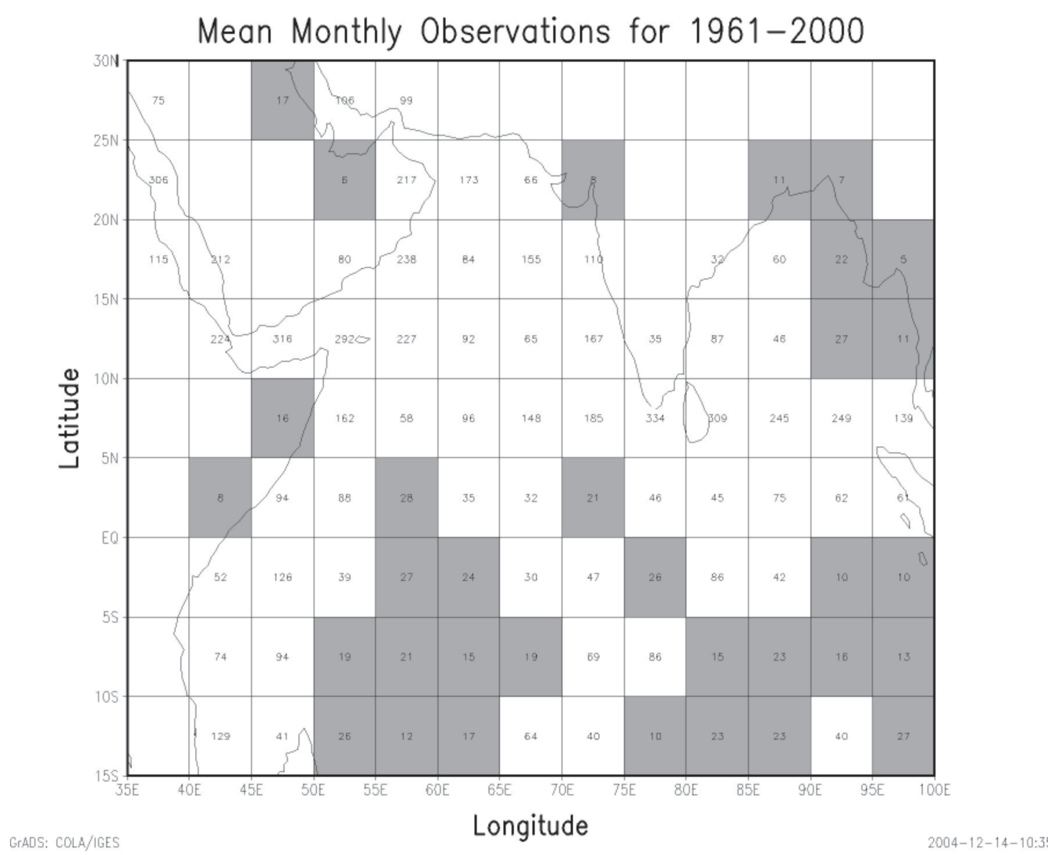

Figure 1. Mean monthly number of observations for each 5^{o} lat x 5^{o} long boxes for each month of a year for 1961-2000. Boxes having less than 30 observations in a month are shaded.

(January-February); summer (March-May); monsoon (June-September) and post monsoon (October-December) and annual (January-December) of the same calendar year. Fig. 1 gives average number of observations for each month in a 5° lat x 5° long box for the period 1961-2000. Boxes having mean observations less than 30 are shaded. Most of the boxes in the Southern Indian Ocean (SIO) are having less than 30 observations. Monthly means of SAT and SST over the Arabian Sea (8-25°N, 40-75°E), Bay of Bengal (8-25°N, 80-95°E), Western Equatorial Indian Ocean (WEIO) (10°S-10°N, 40-70°E) and Eastern Equatorial Indian Ocean (EEIO) (10°S-10°N, 80-100°E) are calculated and the annual march of these variables is shown in Figs. 2a and 2b respectively.

Distribution of annual and seasonal SST, SAT and SST-SAT differences are shown to illustrate the spatial and temporal variations of these parameters. Spatial patterns of climatological mean SST for the period 1961-2000 for annual, winter, summer, monsoon and post monsoon seasons are shown in Figs. 3(a-e), where contours are drawn at 0.5°C interval and boxes having SSTs greater than 28°C are shaded. Similarly, climatological mean SAT patterns are shown in Figs. 4(a-e). Patterns of climatological mean SST-SAT difference are shown in Figs. 5(a-e) where regions having difference values less than -0.5°C or greater than +0.5°C are shaded. To gain insight into the SST and SAT correlation, the spatial patterns of correlation coefficients for annual and four seasons are shown in Figures 6(a-e), where contours of correlation coefficients greater than +0.5 are shaded. Figs. 7(a-e) show spatial patterns of SST and SAT variance ratios ($\frac{\sigma^2_{SST}}{\sigma^2_{SAT}}$) for annual and four seasons, where boxes having variance ratios less than 0.5 or greater than 1.5 are shaded. The annual and seasonal maps of spatial variation (Figs. 3-7) allow comparison of climatological features of SST and SAT over the Arabian Sea, the Bay of Bengal and the Indian Ocean.

RESULTS AND DISCUSSION

Average numbers of observations in each 5° lat x 5° long boxes for each month for the period 1961-2000 are shown in Fig. 1, where boxes having observations less than 30 are shaded. It is clear from this figure that EIO, SIO and Andaman Sea areas are having

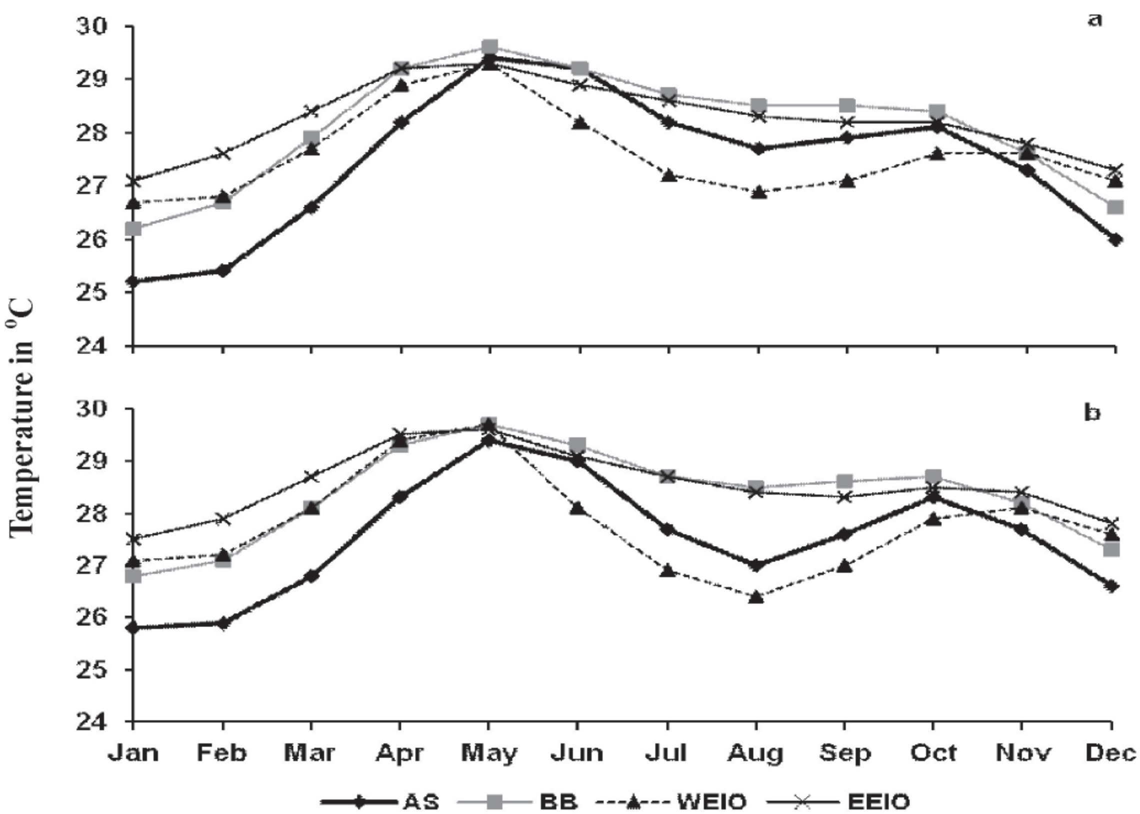

Figure 2. Monthly variation of a) Surface Air Temperature (SAT) and b) Sea Surface Temperature (SST) over Arabian Sea (AS: 08°-25°N, 40°-75°E), Bay of Bengal (BB: 08°-25°N, 80°-95°E), Western Equatorial Indian Ocean (WEIO: 10°S-10°N, 40°-70°E) and Eastern Equatorial Indian Ocean (EEIO: 10°S-10°N, 75°-100°E).

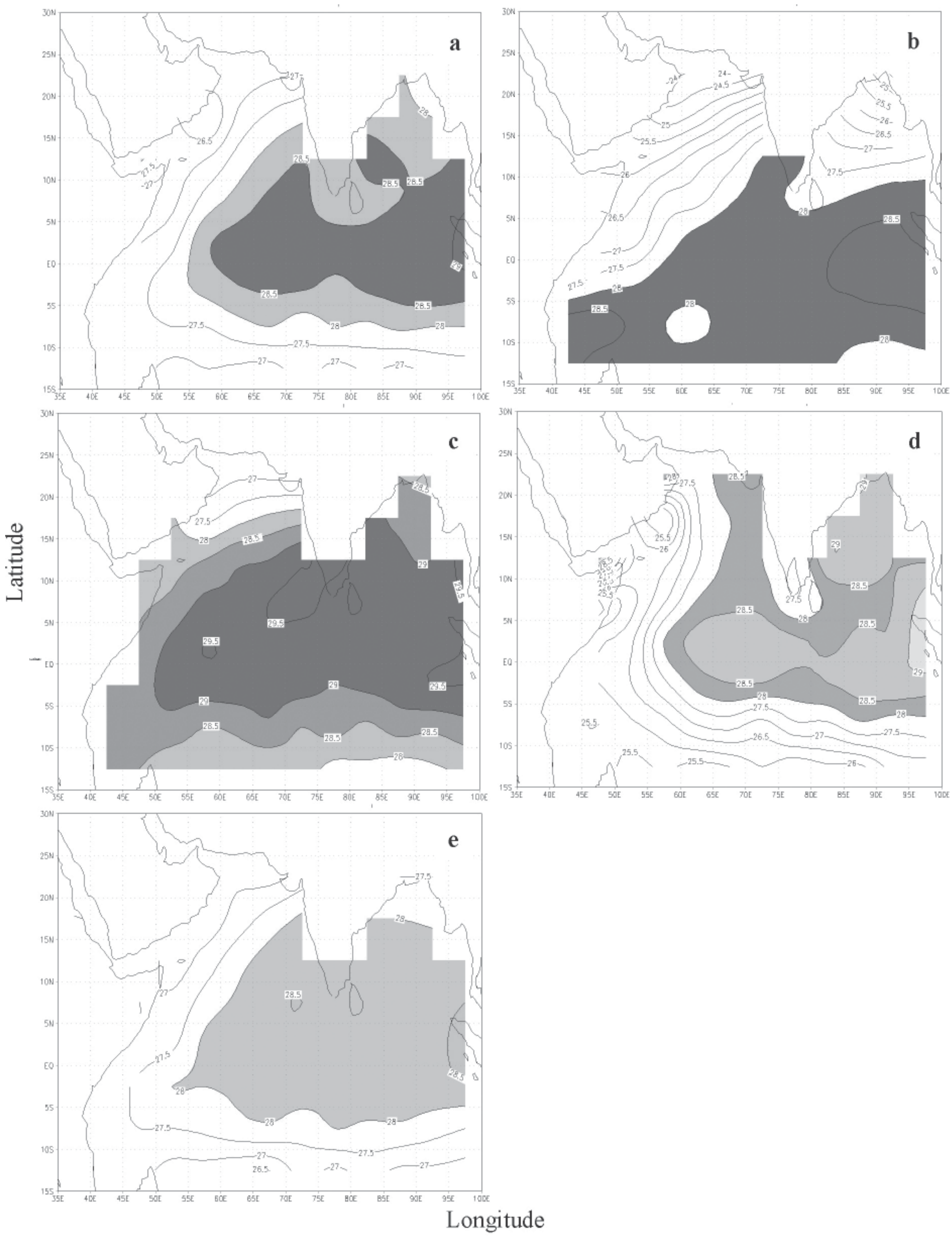

Figure 3. Spatial distribution of climatological mean Sea Surface Temperature (SST) for a) annual, b) winter, c) summer, d) monsoon and e) post monsoon based on ship observations for the years 1961-2000. Contours having temperature more than 28°C are shaded.

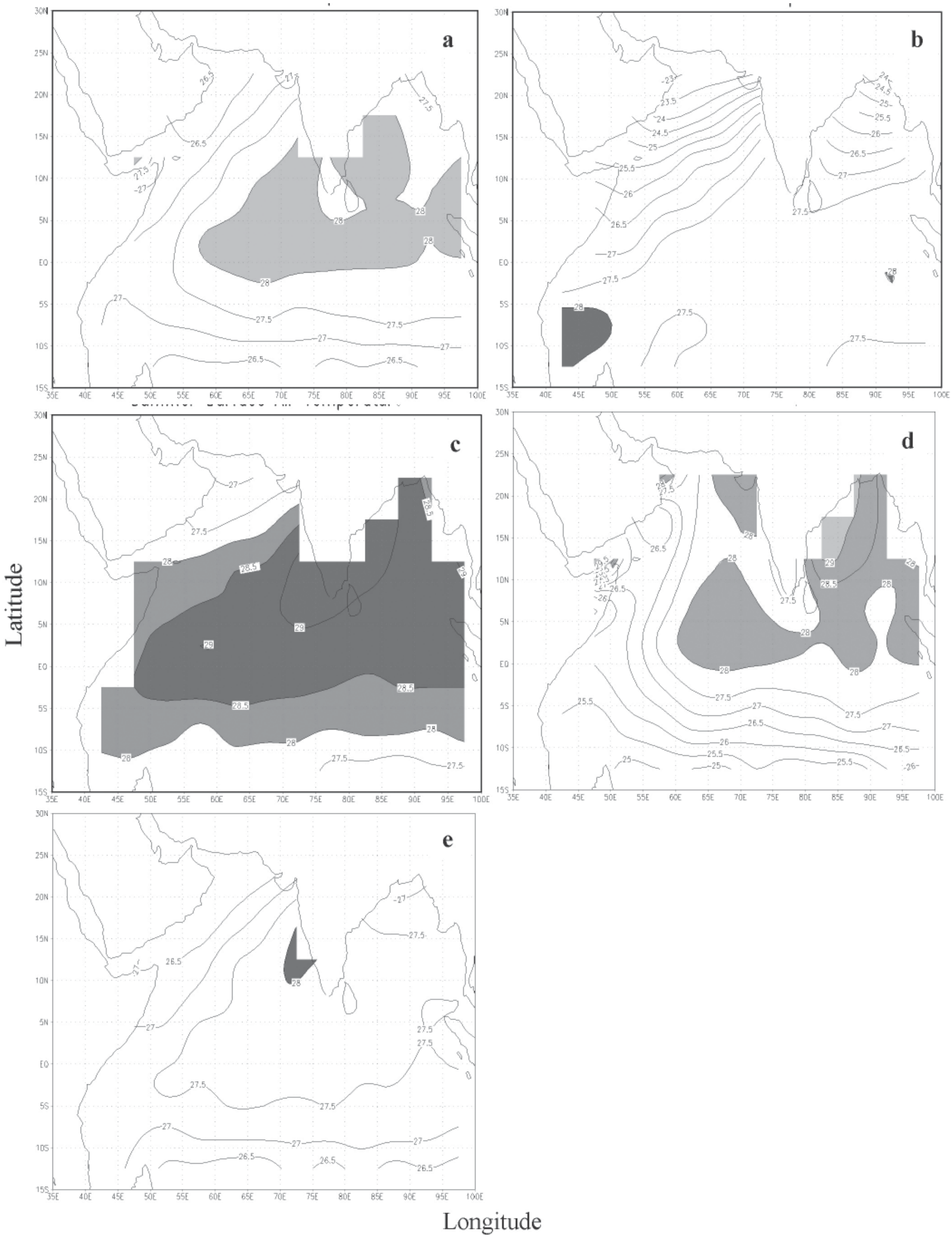

Figure 4. Spatial distribution of climatological mean Surface Air Temperature (SAT) for a) annual, b) winter, c) summer, d) monsoon and e) post monsoon based on ship observations for the years 1961-2000. Contours having temperature more than 28°C are shaded.

lesser numbers of ship observations. Nevertheless, the number of observations are considered adequate to prepare monthly climatology of SST and SAT over these regions. One of the most prominent features of the tropical oceans is the existence of warm pools, which are vast areas of water with relatively homogenous temperatures more than 28°C. Annual variations of mean SST and SAT over Arabian Sea, Bay of Bengal, WEIO and EEIO are shown in Fig. 2. While the Arabian Sea is warmer than the overlying surface air except during monsoon, Bay of Bengal SST remains higher than SAT throughout the year indicating more positive sensible heat flux. Since WEIO also comes under the influence of strong monsoon winds, it also behaves similar to the Arabian Sea. EEIO, which is partially connected to the Pacific Ocean remains warmer than the prevailing surface air indicating positive sensible heat exchange throughout the year over these regions, as shown in Fig. 2. The SST evolution is determined by the latent heat flux and the net energy balance available at surface of the ocean. The available climatologies (Hastenrath and Lamb, 1979) suggest that the skies over the Arabian Sea are clear prior to the onset of the summer monsoon, implying that it receives a large amount of heat through solar radiation. The winds are weak and hence latent heat loss is small, causing large heat gain by the Arabian Sea (Rao and Sivakumar, 2000). The north Indian Ocean SST reaches a maximum in April-May before cooling slightly, while with the arrival of summer monsoon and due to mixing and enhanced Ekman transports there is substantial cooling in the Arabian Sea.

Climatological patterns of Sea Surface Temperature, Surface Air temperature and Sea-Air Temperature difference

Throughout the world's oceans, a significant transfer of heat and water vapour occurs at the air-sea interface, which then drives atmospheric and oceanic processes such as the redistribution of heat and water vapour. The seasonal cycle of SST in the Arabian Sea is marked by a cooling in May to August when rest of the oceans in the northern hemisphere is in a warming phase. Spatial patterns of mean SAT are similar to SST patterns but lesser in magnitude except in summer season when most of the regions have SAT above 28°C.

Sea Surface Temperature

Annual climatological SSTs (Fig. 3a) over the Arabian Sea have strong south–north gradient with predominant cold region (<26.5°C) along Somalia-Arabia coast and warm region (>28.5°C) in the southeast part of the Arabian Sea. In the Bay of Bengal the variation in SST is south to north with a flat gradient varying between 28.0° and 28.5°C. A region of highest SSTs of (>28.5°C) lies in southwest Bay of Bengal. The thermal ridge runs along the equator up to 60°E and thereafter sloping south-westwards west of 60°E. The thermal high of SST greater than 29°C can be seen east of 95°E along the equator, which shows an influence of equatorial Pacific waters in the Indian Ocean area. During winter season (Fig. 3b), the SSTs in the Arabian Sea have south-north gradient with region of cold waters (<24°C) lying in the north Arabian Sea. The thermal ridge runs from southwest to northeast along 7°S up to 70°E and thereafter along the equator west of 70°E. In summer season (Fig. 3c) there is northward movement of warm waters from equator and regions of SSTs greater than 28°C increase and cover almost whole of the Arabian Sea, Bay of Bengal and north Indian Ocean. Even though, the gradient is still south to north, the magnitude of variation becomes small. A well marked southwest to northeast thermal ridge appears during summer season having a pronounced warm pool of SST greater than 29.5°C from Kerala coast to the Indian Ocean up to 67°E, along the thermal ridge enveloping the south western tip of the Indian peninsula. Even though, both the Arabian Sea and the Bay of Bengal show south-north temperature gradient, the SST gradient in the Bay of Bengal has become less with entire Bay of Bengal having SSTs above 28°C. South of equator, the Indian Ocean is having north-south SST gradient. As summer season progresses, SSTs in the Indian Ocean increase and the warmer region occupies larger areas towards the Arabian Sea and the Bay of Bengal. It is the warmest area of the world oceans during April-May and has also been referred to as the Indian Ocean Warm Pool (Joseph, 1990 and Shenoi, 1999).

During monsoon season (Fig. 3d), the Arabian Sea starts cooling and has coldest regions (SST<25.5°C) along Somalia and Arabia coast. SST gradient over the Arabian Sea changes from south-north to east–west. Climatological thermal high, which was south of the equator in summer, shifts northwards during monsoon season and lies between 65-75°E. A cold region (<27.5°C) along the Kerala coast is also observed, indicating a region of upwelling during monsoon season. In contrast, SSTs all over the Bay of Bengal remain above 28.5°C and some pockets even have temperatures above 29°C. However, the temperature gradient remains south to north. The vast area of warm SSTs could be one of the factors for

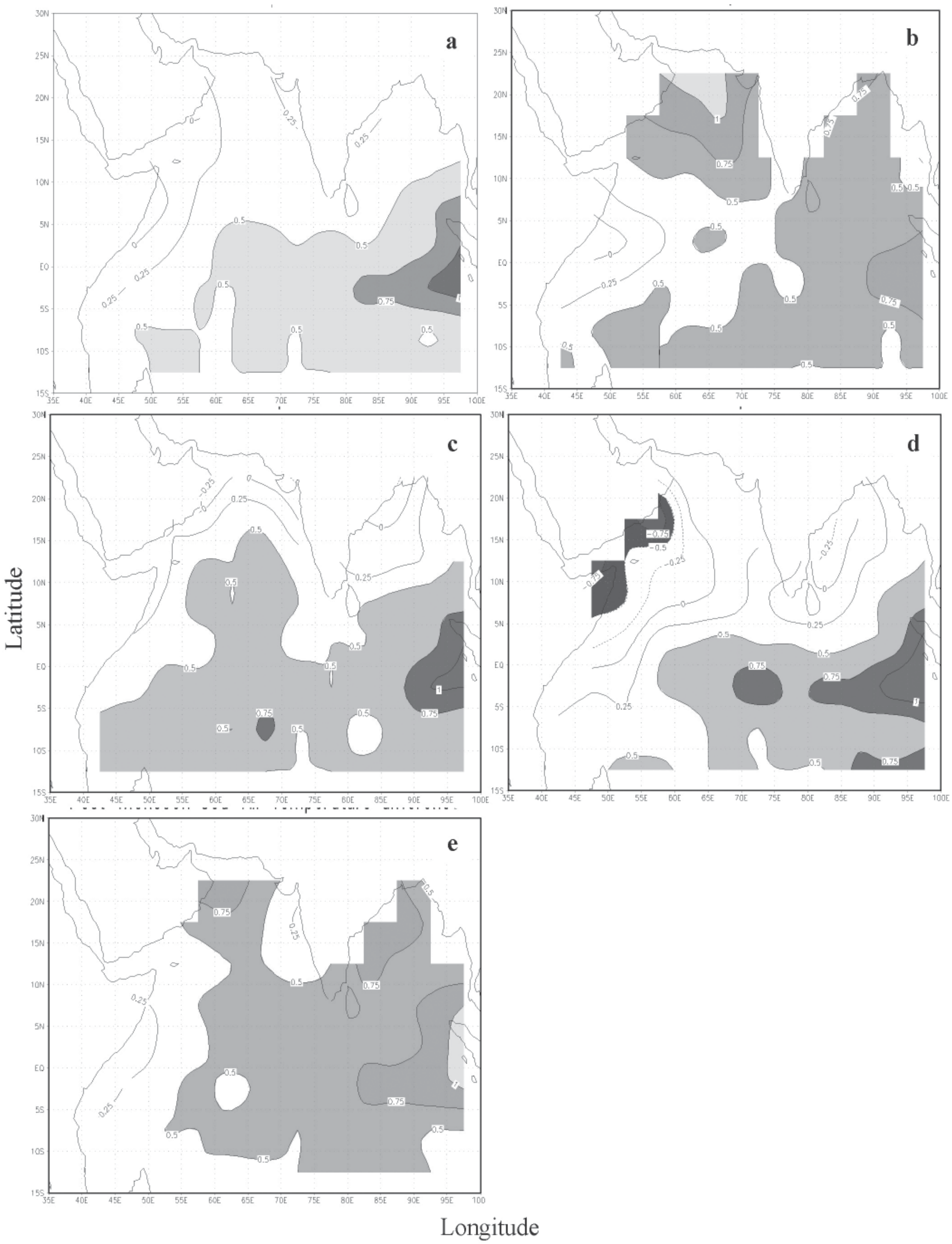

Figure 5. Spatial distribution of climatological mean Sea Surface Temperature (SST) and Surface Air Temperature (SAT) difference for a) annual, b) winter, c) summer, d) monsoon and e) post monsoon based on ship observations for the years 1961-2000. Contours having temperature difference < -0.5^{0}C or > +0.5^{0}C are shaded.

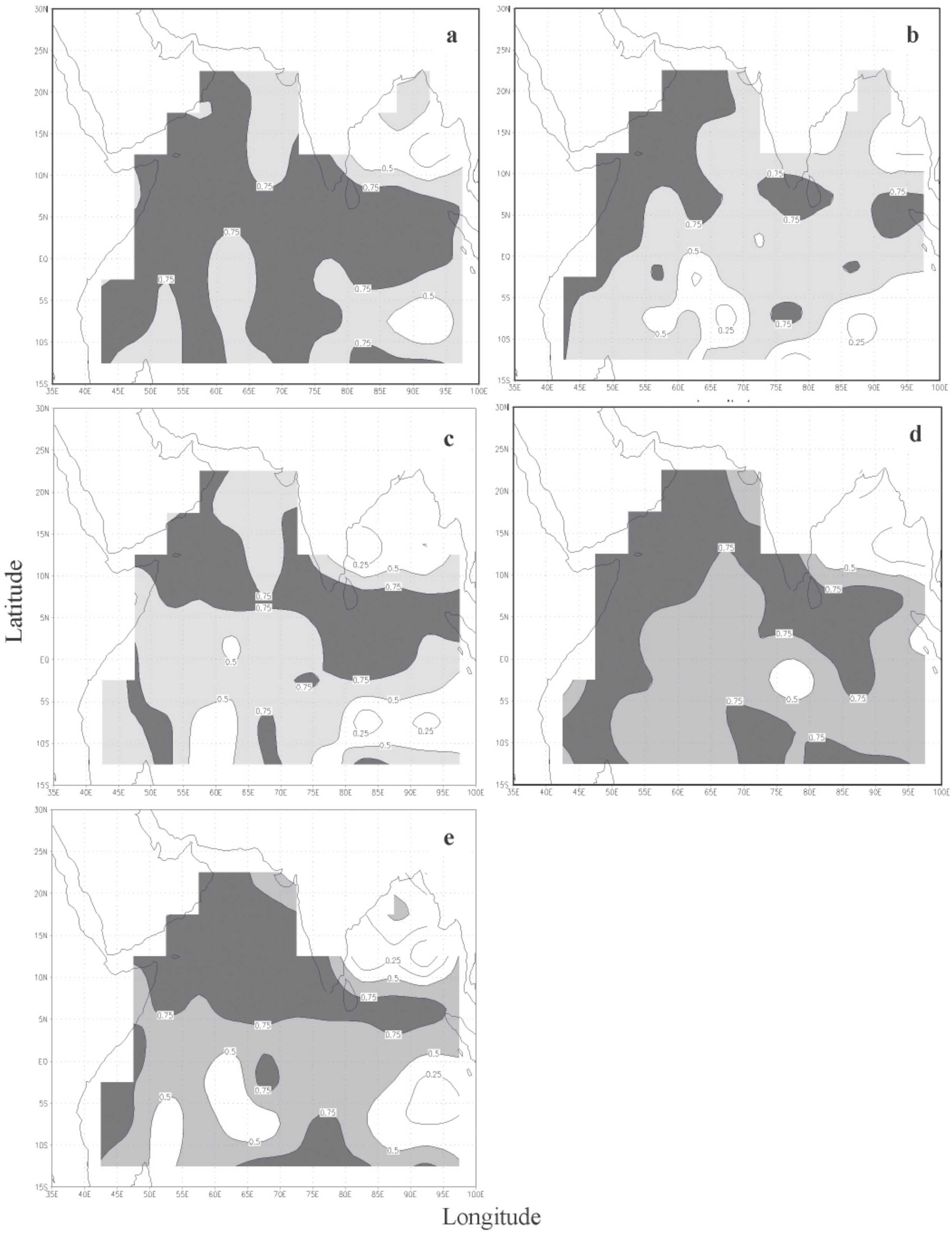

Figure 6. Spatial distribution of coefficients of correlation between Sea Surface Temperature (SST) and Surface Air Temperature (SAT) for a) annual, b) winter, c) summer, d) monsoon and e) post monsoon based on ship observations for the years 1961-2000. Contours having correlation coefficients > +0.5 are shaded.

the formation of more number of weather systems in the Bay of Bengal, as compared to the Arabian Sea. After the withdrawal of monsoon, the SST gradient becomes flat over the Arabian Sea (Fig. 3e). A large area in the Bay of Bengal, south of 17°N is still having SSTs greater than 28°C, which is conducive for the formation of tropical systems in the south Bay of Bengal.

Surface Air temperature

Fig. 4a shows annual mean surface air temperature (SAT), where regions having temperatures greater than 28°C are shaded. Over the Arabian Sea, it has south-north gradient with colder air temperatures along Somalia-Arabia coasts. The thermal ridge emanating from the warmest SAT area is tilted south-westwards to the east African coast. Along the equator east of 60°E, there is a region of warm SAT, which encircles the southern peninsula. Winter SATs over the Arabian Sea and the Bay of Bengal have strong south-north gradient, as shown in Fig. 4b. With the intrusion of cold dry air from north during winter season, northern parts of the Arabian Sea and the Bay of Bengal have coldest SAT values. Indian Ocean exhibits flat temperature gradient during this season, as the SAT values remain around 27.5°C. The warmest SAT area (>28°C) lies south of the equator along east African coast (5-10°S, 40-50°E). Summer SATs over the Arabian Sea (Fig. 4c) have south-north gradient and a large area of warm air (>29°C) surrounds the Indian peninsula. The thermal ridge emanating from it, slopes south-westwards to the east African coast. Surface air temperatures along the entire Indian coastline are above 28°C.

During monsoon season SATs show east–west gradient with regions of cold air temperatures off Somalia-Arabia coasts, as shown in Fig. 4d. A region of warm SAT (>28°C) lies in the northeast Arabian Sea along west coast. Entire Bay of Bengal have SATs above 28°C, with the warmest region (>29°C) along the Indian coast. SAT gradient becomes east-west in the Arabian Sea as well as in the Bay of Bengal. In the Indian Ocean, a large pool of warm air (>28°C) lies around 0-10°N, 60-75°E, while south of the equator, temperature gradient becomes south-north. During post monsoon season, Arabian Sea has southwest-northeast temperature gradient with a region of warm air (>28°C) off western coast (Fig. 4e).

Sea-Air Temperature difference

Sea-air temperature difference (SST-SAT difference) can be taken as a measure of vertical stability near the ocean surface. Flux of heat and moisture are strongly determined by the surface wind speed and to a lesser extent on the stability of the atmosphere. A positive difference between SST and SAT indicates sensible heat flux exchange from ocean to the atmosphere, while a negative difference indicates sensible heat exchange from atmosphere to the ocean surface.

Annual SST-SAT difference (Fig. 5a) in the Arabian Sea and the Bay of Bengal are small in magnitude, while in the Indian Ocean south of equator from 90° to 100° E the difference increases to 1°C. With cold northerly winds prevailing over the north Arabian Sea, the SST-SAT difference shows a large north-south gradient during winter season (Fig. 5b). Bay of Bengal and Indian Ocean are having flat gradient having maximum SST-SAT difference values greater than 0.75°C over the north Bay of Bengal and south of equator east of 90°E. The advent of summer brings hot dry air from land to the Arabian Sea and the Bay of Bengal, reversing the SST-SAT difference to south-north (Fig. 5c). Large areas in the Indian Ocean have SST-SAT difference greater than 0.5°C, with a region of maximum difference lying south of equator, east of 90°E. With the onset of monsoon and cooling of the Arabian Sea and north Indian Ocean, large areas exhibit strong negative SST-SAT difference (Fig. 5d). Jambunathan and Ramamurthy (1975) have observed that sea is warmer than the air over east Arabian Sea during active monsoon and the east Arabian Sea is colder than the air during weak monsoon. In the Bay of Bengal, there is a region of negative SST-SAT difference along eastern coast. The region of higher difference shifts to south of equator in the Indian Ocean, with highest difference east of 90°E. SST-SAT difference in the post monsoon season are 0.5 to 0.75°C having north-south gradient over the Arabian Sea and the Bay of Bengal, as shown in Fig. 5e. The striking feature of the average difference field is the change from strong winter patterns to weak summer patterns, indicating the predominance of the winter and post monsoon season for sensible heat exchange.

SST AND SAT CORRELATIONS

Annual SST and SAT correlations are positive and quite high over the Arabian Sea and the Indian Ocean region (Fig. 6a). Majority of boxes are having correlation values exceeding +0.75, indicating the high level of thermal communication at the interface on large time and space scales. In contrast, SST and SAT correlations are small in the Bay of Bengal, except north Bay of Bengal where it is +0.5. During winter season (Fig. 6b), SST and SAT correlations

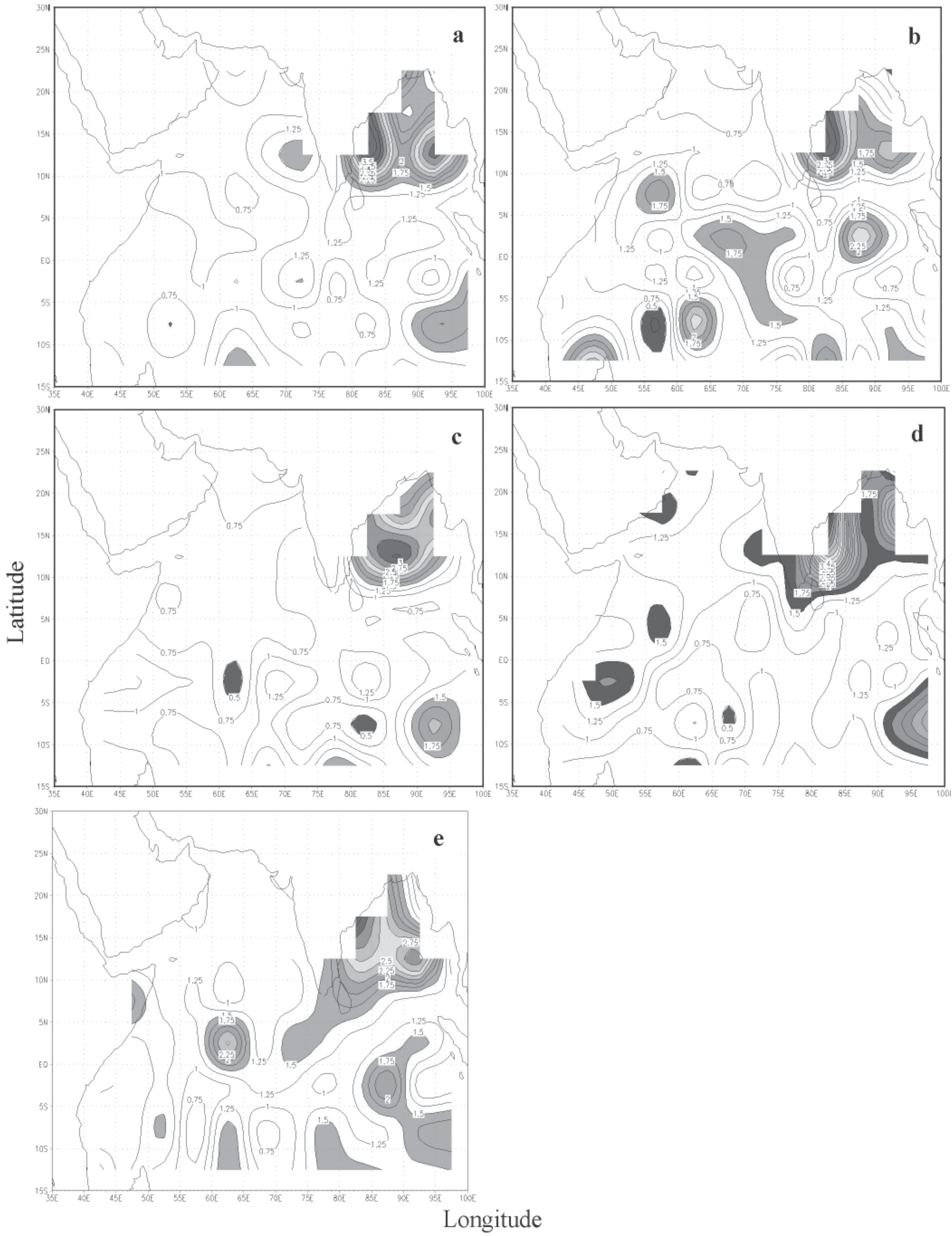

Figure 7. Spatial distribution of Sea Surface Temperature (SST) and Surface Air Temperature (SAT) variance ratios for a) annual, b) winter, c) summer, d) monsoon and e) post monsoon based on ship observations for the years 1961-2000. Contours having variance ratio <0.5 or >1.5 are shaded.

over the Arabian Sea and the Indian Ocean north of equator are positive and above +0.5. In the Bay of Bengal, except north and extreme south Bay of Bengal all other areas are having lower correlation values. Summer season SST and SAT correlations in the Arabian Sea and Indian Ocean north of equator are positive and above +0.5 (Fig. 6c). Entire Bay of Bengal north of 10°N is having least correlation values. During monsoon and post monsoon seasons (Figs. 6d and 6e), SST and SAT correlations over most of the Arabian Sea and the Indian Ocean are positive and above +0.5, while in the Bay of Bengal correlations are positive but below +0.5.

Variance ratios of SST and SAT

Annual SST and SAT variance ratios in the southeast Arabian Sea close to west coast of India are greater than 1.5, as shown in Fig. 7a. In the entire Bay of Bengal the variance ratios are quite high and a region of maximum ratio (>3.75) lies in the central Bay of Bengal. In the Indian Ocean, except a small region in the eastern part where it is greater than 2, SST and SAT variance ratios are around 1. During winter season (Fig. 7b) the variance ratios in the Arabian Sea are small. Bay of Bengal is having highest variance ratio (>3.5) in the central Bay off Andhra-Tamilnadu coast. Indian Ocean regions bound by 0-5° N, 85-90°E and 5-10° S, 60-65° E are showing high variance ratio (>2.25). During summer season, variance ratios are large in the south-central Bay of Bengal (>3.25), while during monsoon season there are two regions of largest variance ratios, one near Andhra-Tamilnadu coast (>5.5) and the other near Bangladesh-Myanmar coastline (>3.25), as evident from Figs. 7c and 7d. Post monsoon variance ratios (Fig. 7e) are large in the central Bay of Bengal and the Indian Ocean areas bound by 0-5°N, 60-65°E and 0-5°S, 85-90°E. The increased near surface stratification, owing to warm SST and large freshwater influx together with less stronger winds in comparison to the Arabian Sea, inhibits the turbulent vertical mixing to a shallow depth in the Bay of Bengal. This leads to large variance ratios over the Bay of Bengal as compared to the Arabian Sea.

Overall, the ratio maps shown in Figs. 7(a-e) indicate that the variance of SST and SAT are roughly equal in the Arabian Sea and the Indian Ocean (except small pockets) while SAT variance is smaller than the SST variance in the Bay of Bengal, where the smallest ratios are less than 0.5 and the largest are slightly greater than 5.5, with a majority of them falling in between 0.5 to 1.5. The similarity of the SST and SAT patterns of variance and the closeness of their amplitudes on the seasonal to annual time scales is clearly indicated by these maps.

The feedback cycles in the Arabian Sea and the Bay of Bengal work in opposite directions, as is evident from correlations and variance ratios of SST and SAT (Figs. 6 and 7), justifying the distinct characteristics of the two important basins of Indian Ocean. While SST and SAT correlations are higher in the Arabian Sea as compared to the Bay of Bengal, SST and SAT variance ratios are higher in the Bay of Bengal as compared to the Arabian Sea. Shenoi et al. (2002) have suggested that during the summer monsoon, a positive feedback mechanism works in both the Arabian Sea and the Bay of Bengal through the ocean-atmosphere interaction. In the Arabian Sea, the feedback cycle consists of strong winds, strong vertical transport in the ocean, cool SST, weak convective activity, negative value of precipitation minus evaporation and weak near-surface stratification. On the other hand, in the Bay of Bengal the feedback cycle consists of weak winds, weak vertical transport, warm SST, strong convective activity, positive value of precipitation minus evaporation and strong near-surface stratification. Copious rainfall and river water discharge freshen the upper layers of the Bay of Bengal and stabilizes the water column making it more difficult for the winds to mix the warm, stable surface layer with the cooler waters below. This leads to a strongly stratified surface layer in the Bay of Bengal as compared to the Arabian Sea, where there is no such stabilizing effect. As a consequence, the mixing with the cooler waters below is more vigorous in the Arabian Sea. Since a SST of about 28°C is necessary for convection to take place in the atmosphere, this condition is satisfied in the Bay of Bengal but not in much of the Arabian Sea.

CONCLUSIONS

Based upon VOS observations for the period 1961-2000, climatology and relationship between sea surface temperature and surface air temperature have been studied over the Arabian Sea, the Bay of Bengal and the Indian Ocean. The results of this study are summarized as below:

i) Seasonal mean sea surface temperatures over the Arabian Sea are highly variable from one season to the other as compared to the Bay of Bengal and the Indian Ocean. This could be attributed to different phases of monsoon, high surface winds during monsoon season, vertical mixing due to upwelling and Somali current in the Arabian sea and presence of stratified surface layer of fresh water received from the peninsular rivers and weak winds over the Bay of Bengal.

ii) During winter season, mean sea surface temperatures over the Bay of Bengal are lowest and have strong gradient (25 to 28^{o}C) but in all other seasons they remain steadily in the range 28.5 to 29.0^{o}C with a flat gradient indicating the prominent role played by copious rainfall, river water discharge and weak winds in stabilizing the water column and making it more difficult for the winds to mix the warm, stable surface layer with the cooler waters below.

iii) There is strong evidence of influence of warm equatorial Pacific waters on the adjoining equatorial Indian Ocean through Indonesian through flow in sustaining the Indian Ocean warm pool.

iv) The spatial and seasonal changes in the sea surface temperature and surface air temperature difference over the Arabian Sea and the Bay of Bengal indicates strong regional and seasonal preferences in the sensible heating regime. Average sea surface temperature and surface air temperature difference field indicates the predominance of the winter and post monsoon seasons for sensible heat exchange over the Indian Seas.

v) The sea surface temperature and surface air temperature correlations are generally high for all averaging periods and seasons indicating the high level of thermal communication at the interface. There seems to be a seasonal preference for the correlations to be greater in annual, monsoon and post monsoon periods over the Arabian Sea and Indian Ocean. In the Bay of Bengal, the sea surface temperature and surface air temperature correlations are low for all seasons except winter. It appears that there is very less thermal adjustment between the upper layers of ocean and lowest atmosphere over the Bay of Bengal.

vi) The variance ratios are quite large in the Bay of Bengal as compared to the Arabian Sea and the Indian Ocean for all seasons. Large increase in variance ratios in the Bay of Bengal are due to less surface air temperature variance as compared to sea surface temperature variance. This may result from a less energetic atmosphere over the Bay of Bengal causing lower surface air temperature variances.

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