

Phytoplankton pigment/temperature relationship in the Arabian Sea

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A single date Coastal Zone Colour Scanner (CZCS) (onboard Nimbus 7 satellite) image of north west coast of India covering the area off Bombay and further south for March showed distinct patterns of pigment distribution. The single channel thermal data when density sliced shows resemblance with the pigment distribution pattern particularly in the offshore waters. The mean monthly pigment map derived from CZCS data showed seasonal change both qualitative as well as quantitative. The climatological oceanographic temperature data shows variation with season and different patterns at different depths are observed. However, when compared with the pigment distribution pattern the temperature contour at 50 m depth shows a close match with the pigment concentration contours of 0.2 mg. m^{-3} and 0.6 mg. m^{-3} particularly during March, September and October. The contours of 2 mg. m^{-3} and 0.6 mg. m^{-3} correlate with the temperature contours of 26°C and 24°C respectively. However, for other months no specific correlation is seen. It is observed that during these months which represents transition phase between northeast (March) and southwest (September, October) monsoon the MLD tends to be shallower. In the Arabian Sea the pigment distribution reflects the introduction of nutrients into the photic zone. The maximum annual pigment biomass in the Arabian Sea occurs when the mixed layer is relatively shallow. Therefore, at the time of sufficiently shallow MLD and less turbulent conditions the pigment and temperature pattern show covariation. For any modeling activity such understanding is crucial factor when inter-relationship of physical/biological oceanographic parameters is involved. This provides a useful input for modeling the coupling between physical and biological oceanographic parameters.

The variation in phytoplankton concentration regionally and seasonally in the oceanic waters is a known phenomenon. In the ocean the physical, chemical and biological processes are linked in an intimate manner. The biological and chemical flux are to a certain extent under physical forcing like winds, currents, mixed layer depth and temperature. The presence of phytoplankton is also known to affect the sea surface temperature (SST) by interception of the short radiation absorption and thereby increasing the SST¹. Thus the physical dynamics of ocean depends upon the local field of biological and chemical properties. The inverse relationship between temperature and nutrient concentration occurs seasonally in surface waters to varying degree depending on geographical location². The spatial and temporal characteristics of the depth distribution of temperature and plant nutrients combine to yield latitudinally specific relationship in plant nutrients vs temperature. Attempts have been made in this study to correlate the phytoplankton pigment distribution along with the sea surface temperature. In the analysis of satellite data it has been observed that the pigment information is from one attenuation length (~ from

1m to 35m) whereas the temperature is only skin depth. Therefore in the present study the satellite derived phytoplankton pigment information is compared with the temperature information at various depths at different periods of the year to understand the relationship between the two. Such understanding will help us for developing the coupled physical biological models.

Materials and Methods

The satellite derived ocean colour information pertains to the value at one attenuation length, which may vary from less than 1 meter in high turbid (pigment rich) area to 25-30 m in low pigment ($<0.1 \text{ mg m}^{-3}$) area³. The climatological atlas⁴ shows temperature distribution at sea surface and at various depths viz. 50 m, 100 m, etc. The phytoplankton pigment map derived from CZCS data is compared with satellite derived SST map of the same day. And the CZCS derived phytoplankton pigment maps for each month generated from using all available data for the particular month i.e. all scenes for the area from 1979 to 1986 which are cloud free have been used. This data has been obtained from DAAC, NASA,

USA. These monthly phytoplankton pigment maps were compared with the climatological temperature information for each month.

For single date CZCS data analysis the CZCS data of March 16, 1979 orbit No.1977 has been analysed. The area covered is a part of NW coast of India (area bounds: 50°-80°E and 5°-25°N). The ratio of channel 1 (443 nm $\pm$ 10 nm) and channel 3 (550 nm $\pm$ 10 nm) gives a sharp contrast and the features are very clear. The density sliced colour coded hard copy was generated on an in-house built PC-486 based image processing system "ISROVISION". The single channel thermal data (10.5-12.5 μ) was density sliced and the colour coded hard copy was generated.

Monthly changes in phytoplankton pigment with respect to temperature have been studied using CZCS derived pigment information for each month (processed data source: DAAC, NASA) and climatological atlas data. The hard copy of colour composites of CZCS derived phytoplankton pigment map for each month (all available cloud free data for a particular month from 1979-86) has been used. The seasonal pattern of variation in phytoplankton pigment matches fairly well with the reported published values. The climatological atlas information for temperature at surface, 50 m and 100 m depth has been used.

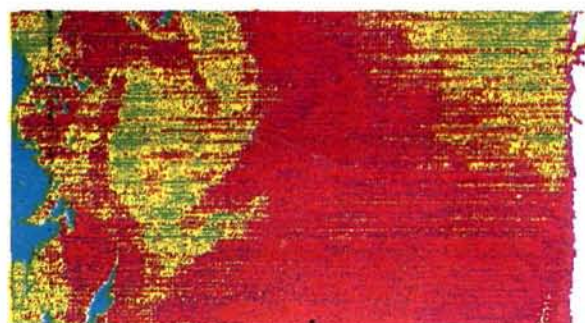
Results and Discussion

Single date CZCS scene shows distinct pattern of pigment distribution (Fig. 1a) and the single channel thermal data when density sliced shows resemblance to the pigment distribution pattern particularly in the offshore waters (Fig. 1b). The mean monthly pigment map shows seasonal change both qualitative as well as quantitative. The climatological temperature data shows variation with season and different patterns at different depths are observed. However, when compared with the pigment distribution pattern the temperature contour at 50 m depth shows a close match with pigment concentration, contour of 0.2 mg·m⁻³ and 0.6 mg·m⁻³ particularly during March, September and October (Figs 2-4). The contour of 0.2 mg·m⁻³ and 0.6 mg·m⁻³ correlated with temperature contours of 26°C and 24°C respectively.

An inverse relationship between pigment



(a)



(b)

Fig. 1—CZCS derived pigment (a) and thermal image (b) of March 16, 1979 (orbit#1977)

concentration and temperature may be due to the negative correlation between temperature and nutrient² which ultimately affects phytoplankton growth. Since the satellite derived information comes from one attenuation length rather than skin depth, the pigment concentration correlates better with temperature pattern at 50 m depth rather than at the surface.

During the months when mixed layer depth is about 50 m the pigment concentration will resemble better with temperature at 50 m depth. In the Arabian Sea the pigment distribution pattern reflects the introduction of nutrients into the surface. The maximum pigment biomass is seen when MLD is shallow⁵. Therefore, at the time of sufficiently shallow MLD and less turbulent conditions the pigment and temperature pattern show covariation. During the months which represent transition phase between northeast and southwest monsoon i.e. March, September and October, the MLD tends to be shallow. A close correlation is seen between the pigment and temperature at 50 m depth. The physical forcing

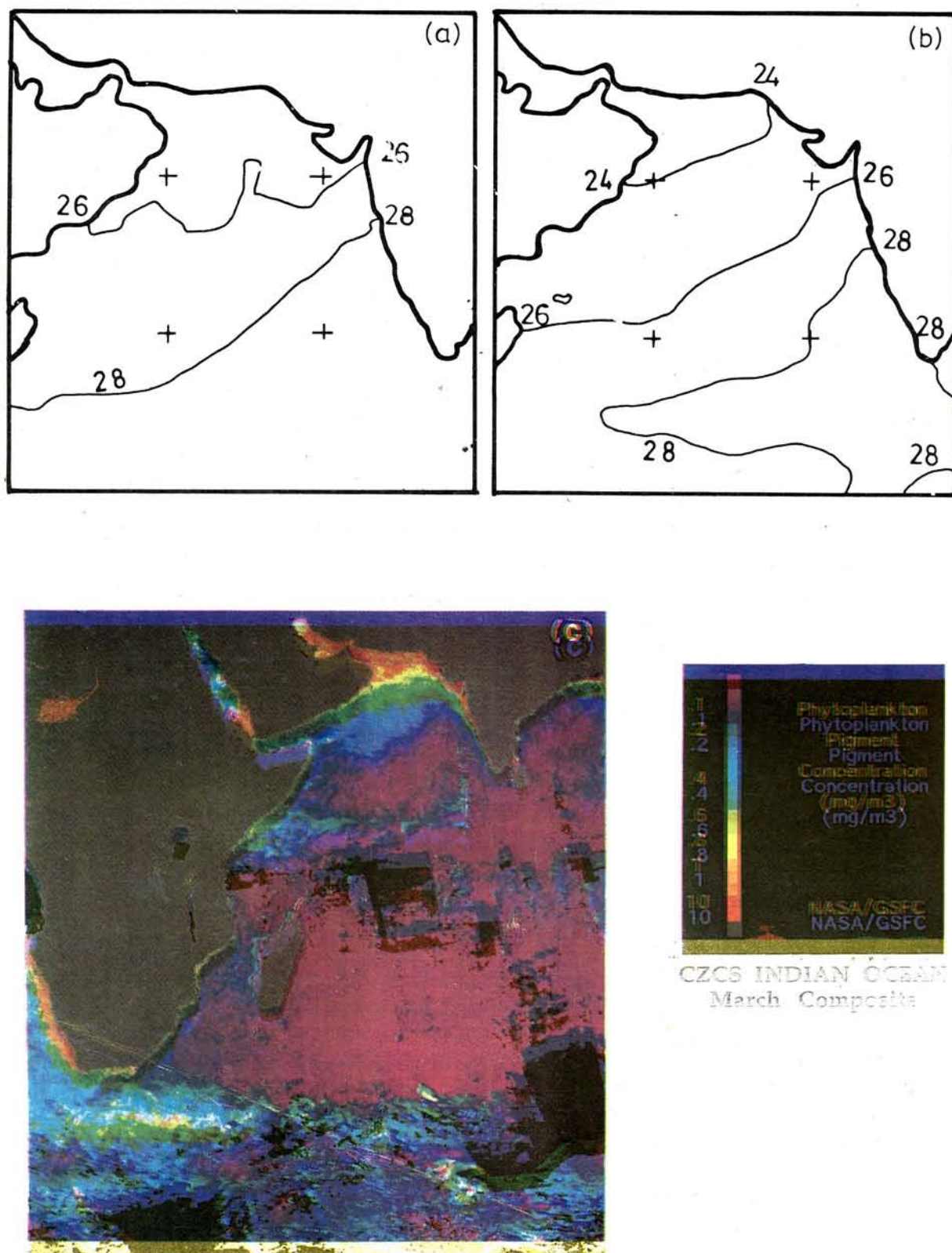


Fig. 2—Distribution of temperature at—a) surface, b) 50m and c) phytoplankton pigment for the month of March

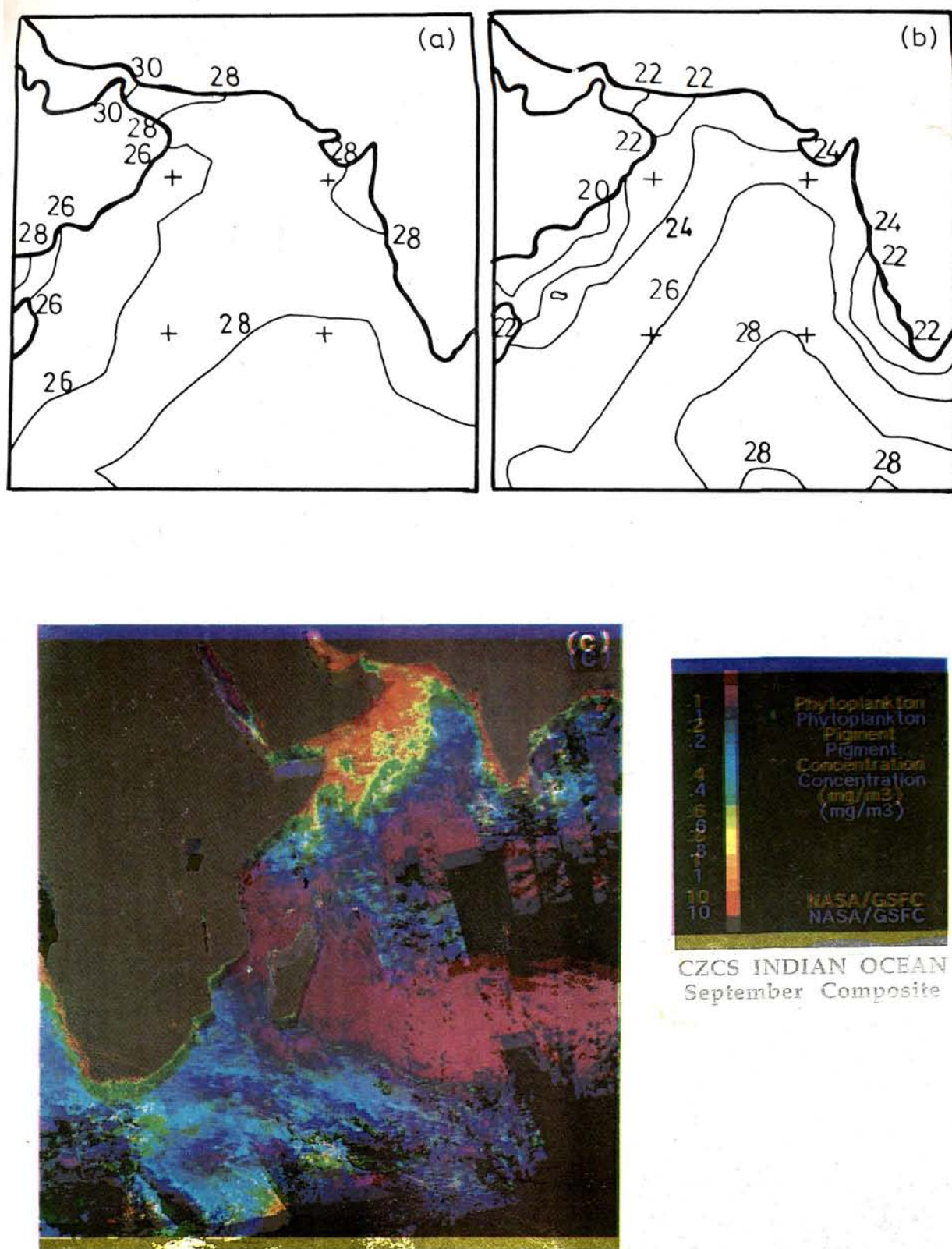


Fig. 3—Distribution of temperature at—a) surface, b) 50m and c) phytoplankton pigment for the month of September

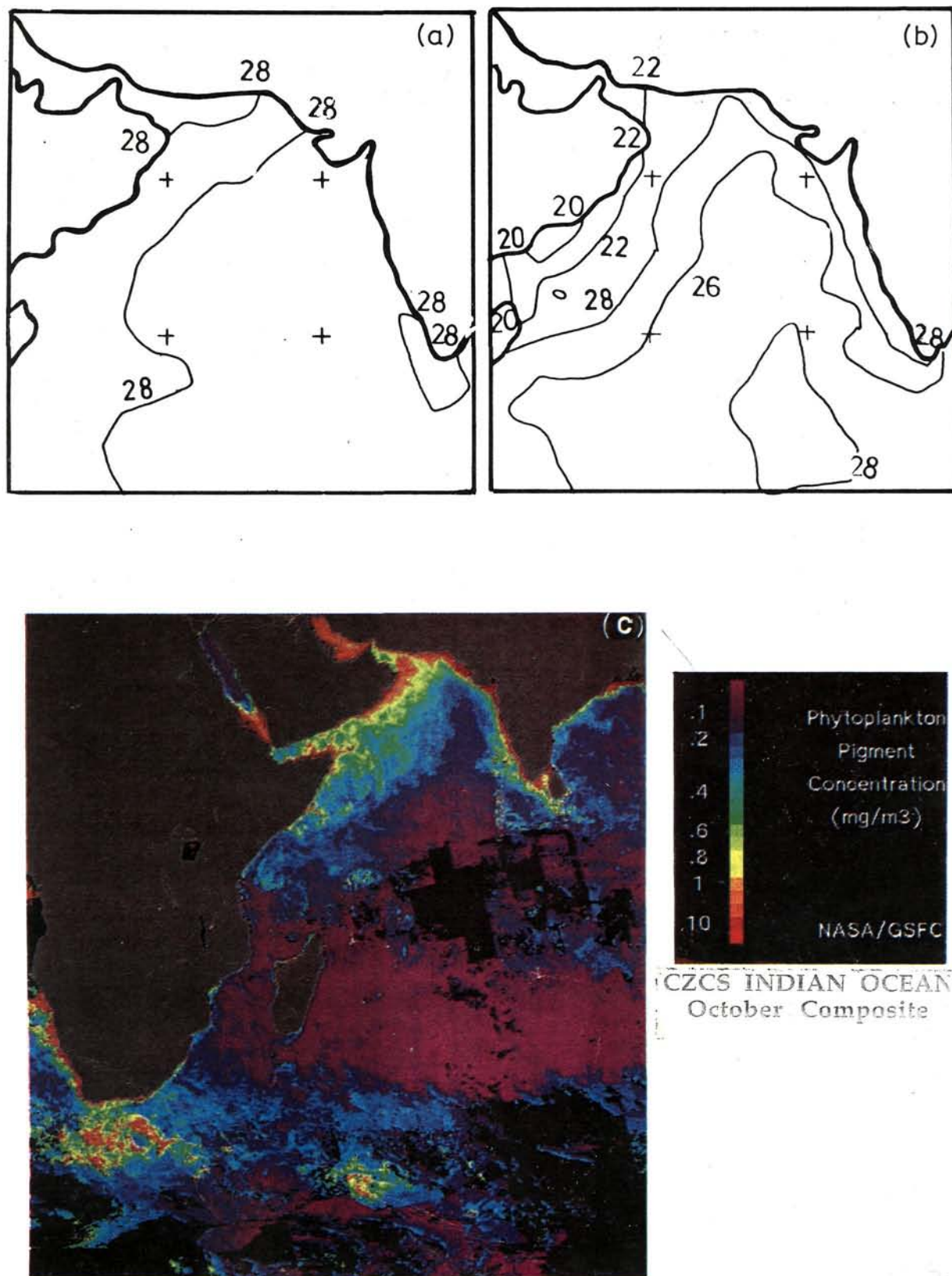


Fig. 4—Distribution of temperature at—a) surface, b) 50m and c) phytoplankton pigment for the month of October

due to winds and currents, is the primary factor influencing the spatial pattern of mixed layer depth and pigment biomass during the monsoon seasons in the Arabian Sea⁵. Reversal of winds and changes in the magnitude of wind speed affects mixed layer depth and nutrient availability, in addition to this upwelling as well takes place at south west coast of India and some other parts. All these factors influence phytoplankton distribution and growth.

In order to develop any model for bio-physical coupling the study of relationship of parameters at temporal and spatial basis is a pre-requisite. This study shows the variation in relationship when a single parameter is considered on monthly basis. Therefore, more related parameters have to be considered and spatial variation have also to be observed before making any conclusive statement. But one point comes out very clearly that the satellite derived pigment concentration cannot be directly compared with the satellite derived sea surface temperature unless one is sure as to how the temperature is distributed at different depths.

Muller-Karger *et al.*⁶ used CZCS derived pigment maps and AVHRR derived SST maps of the Gulf of Mexico region on monthly basis and found that the algal biomass is not directly related to the temperature of the water. This may be true if only sea surface temperature (SST) is considered.

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