

HEAT CONTENT VARIATIONS IN THE NORTHEASTERN ARABIAN SEA DURING A WEAK SPELL OF 1986 SUMMER MONSOON

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ABSTRACT: Based on time series measurements of temperature and surface meteorological parameters taken at a stationary location (19°N;67°E) in the northeastern Arabian Sea during a weak spell of 1986 monsoon from 29 th August to 5th September 1986, the changes in the heat content of the different layers upto 500m depth are examined. Under the environmental conditions in which the surface winds are in general less than 10 m/sec and cloud amounts are around 5 octas, the heat content variations in the upper 100m layer are found one order higher than those in the mixed layer (0-50m). The net surface heat exchange is mainly controlled by evaporation rates which are further related to wind fluctuations. On an average, the net surface heating is almost accounted for the general increase in the heat content (0.12 Kcal/cm²/day) of mixed layer below which the heat content changes are effected by the oscillations of thermocline. A net decrease in the heat content of the upper 500m and a net increase of the upper 100 m water columns indicate the dominance of upwelling and sinking processes below and above thermocline respectively.

INTRODUCTION

Though the onset and existence of the Indian summer monsoon are mainly due to the land sea differential heating effect, the energetics of the monsoon system are also dependant on the air-sea interactive processes modifying the air mass during its travel across the Indian Ocean. In the past many attempts have been made to understand the complex interaction over the Arabian Sea where anomolus summer cooling in the water body occurs (Sastry and Ramesh Babu, 1985). The summer cooling influences the fluxes of energy exchange after the onset of monsoon as pointed out by Saha (1970). Subsequently Rao (1984, 1986) and Ramesh Babu & Sastry (1984) have studied the summer cooling aspect on different time and space scales using the data sets of MONSOON-77 and MONEX-79 programmes. Mostly these studies cover the conditions just prior to and after the onset of monsoon in relation to some synoptic disturbances. The observed cooling has been attributed to various processes like heat exchange at the air-sea interface, advection, wind mixing and upwelling differently dominating in certain regions of the Arabian Sea. The energy input to the atmosphere from the ocean during disturbed weather conditions is almost doubled in contrast to that found during normal phase of the monsoon (Rao et al 1985). However, the thermal response of the upper ocean during either the relaxation period or the fog end of the monsoon season is not well understood as the earlier data sets are more or less confined to the onset and active phases of the monsoon. In this paper we have examined the variability of the heat content in the upper 500 m of the northeastern Arabian Sea in relation to air-sea surface exchange and ocean interior processes during a weak spell of 1986 monsoon.

DATA AND METHODS:

ORV SAGARAKANYA had occupied a stationary position at 19°N and 67°E in the northeastern Arabian Sea (Fig.1) for a period of about one week (29 August to 5 September 1986) to collect time series data on

temperature profiles using an Expendable Bathythermograph (XBT) (make: Sippican; Accuracy : $\pm 0.2^{\circ}\text{C}$). The surface meteorological and XBT data were collected at 3 hourly interval. The daily averages of temperature are only used in the present study in order to smooth out the effect of internal waves from the original data series.

The following equations are used to compute the heat fluxes at the air-sea interface:

$$R_N = R - (Q_e + Q_s) \quad \text{--- ①}$$

$$R = Q_a - Q_b \quad \text{--- ②}$$

$$Q_b = \epsilon \sigma T_s^4 (0.254 - 0.00495 e) (1 - 0.7 c) \quad \text{--- ③}$$

$$Q_e = \rho C_e L (e_s - e_a) U \quad \text{--- ④}$$

$$Q_s = \rho C_h C_p (T_s - T_a) U \quad \text{--- ⑤}$$

As the direct measurements on insolation were not made on board the ship, the same are obtained from the Smithsonian meteorological tables and corrected for albedo and cloud effects according to Stevenson (1982), to get the available insolation (Q_a) at the sea surface. Effective back radiation (Q_b) is computed following Reed (1976). The latent (Q_e) and sensible heat (Q_s) fluxes are estimated from the bulk aerodynamic formulae and the transfer coefficients C_e & C_h are taken from Kondo (1975). The rest of the symbols in the above equations have their usual meanings. The heat content (H) is estimated as follows:

$$H = \int_0^z \rho C_p \bar{T} dz \quad \text{--- ⑥}$$

for different layers: 0-50; 0-100; 0-300 and 0-500m assuming ρC_p constant ($0.977 \text{ cal/cm}^3/\text{deg C}$) as suggested by Bathen (1971).

RESULTS AND DISCUSSION

During the period of present study a weak monsoon spell was prevalent as reflected from the large scale scanty nature of the rainfall distribution over India for the week ending on 3 September 1986 (Fig. 1). The wind speed varied between 4.7 and 9.6 m/sec whereas the cloudiness was around 5 octas during observational time. Figs. 2a-c. show the daily march of the various components of the heat budget and surface meteorological parameters. In general, there is an increasing trend in vapour pressure and temperature gradients (Fig. 2a). Winds are steady upto 2 September and thereafter a sudden increase is noticed nearly doubling in their intensity (Fig. 2b). The increase in the wind field is due to the presence of cyclonic circulation in the vicinity of the study area according to the weekly weather report of IMD. One could notice from Fig. 2c that the net radiation (R) is more or less steady during the entire period of study while the combined latent and sensible heat flux ($Q_e + Q_s$) increases suddenly from 2 September in a similar way like wind speed. The values of R and $Q_e + Q_s$ are around 340 and 160 $\text{cal/cm}^2/\text{day}$ respectively till 2 September showing a net heat gain at the sea surface. However a net heat loss from the ocean is seen on 4 September. On an average R_N is positive ($121 \text{ cal/cm}^2/\text{day}$) for the entire observational period indicating a net heat gain to the ocean from the atmosphere.

In order to understand the influence of the net surface heat gain in upper 0-500 m water column, the heat content variability for different layers is examined. Fig.3 shows a slight increase in the heat content in upper 50 m and further increase in the heat content is pronounced in 0-100 m layer. A general decreasing trend is seen in the heat content of 0-500m layer whereas the heat content of 0-300 m layer is nearly steady. The average rate of heat content increase in the upper 50m layer is found to be 120 cal/cm²/day which coincides well with the mean value of net heat gain at the surface. This suggests that the mixed layer warming during a weak spell of the summer monsoon is fully accounted due to net surface heat exchange which is mainly controlled by evaporation. In the upper 100m, there is an average increase at a rate of 885 cal/cm²/day in the heat content - maximum found in the entire water column. The mixed layer is slightly deep during later part of the observational period as compared to that during earlier part indicating the effect of wind revival (Fig.4). In addition to this momentarily wind forcing the negative wind stress curl which is a characteristic of this region helps in the development of mixed layer due to downward Ekman pumping. The average rate of heat content variation is around 180 cal/cm²/day in the 0-300m water column suggesting the diminishing influence of sinking process with depth. The dominance of upwelling process below 300 m depth is clearly seen from the net rate of decrease in the heat content of 0-500m water column which is on an average found to be -93 cal/cm²/day. These two opposing processes above and below thermocline result in the development of stronger vertical thermal gradients around 100 m with time. During the observational period, the thermocline gradient increases from 0.11 to 0.13 °C/m. Rao (1986) has observed a similar decrease in the heat content in the topmost 100 and 200 m layers of the eastern Arabian Sea during 1977 monsoon season. However the present study indicates upwelling between 300 and 500 m establishing that this is typical seasonal phenomenon.

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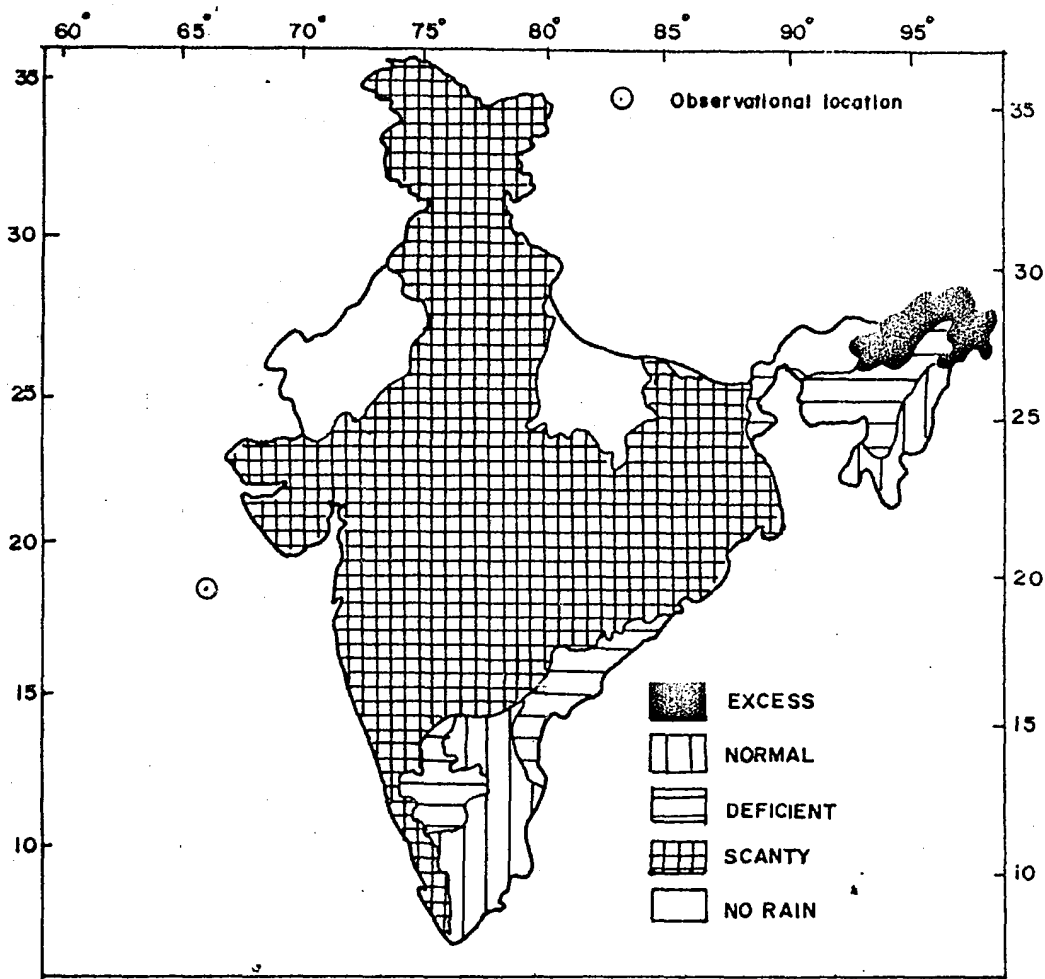


FIG-1 RAINFALL DEPARTURE OVER INDIA FOR THE WEEK ENDING 3 SEPTEMBER 1986
(WEEKLY WEATHER REPORT IMD)

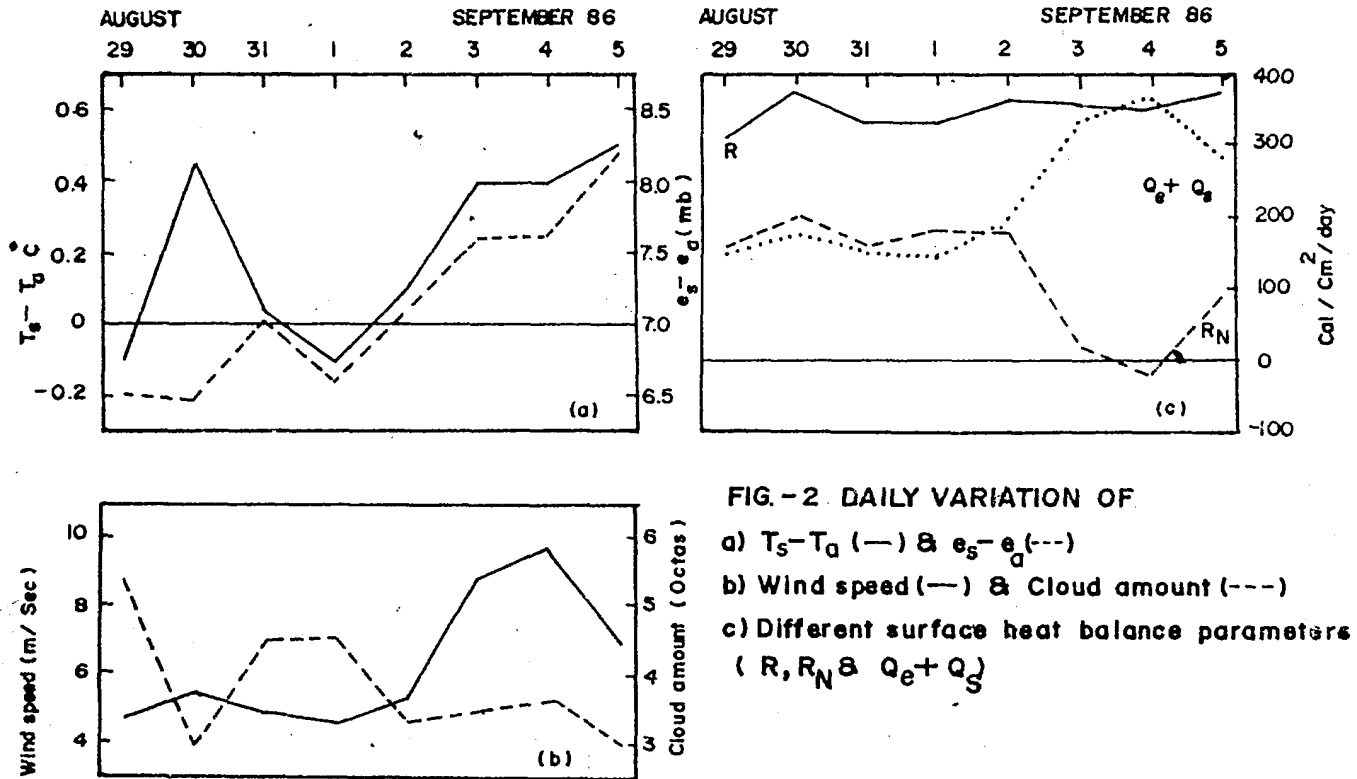


FIG - 2 DAILY VARIATION OF
 a) $T_s - T_a$ (—) & $e_s - e_a$ (---)
 b) Wind speed (—) & Cloud amount (---)
 c) Different surface heat balance parameters
 (R, R_N & $Q_e + Q_s$)

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SEPTEMBER 1986

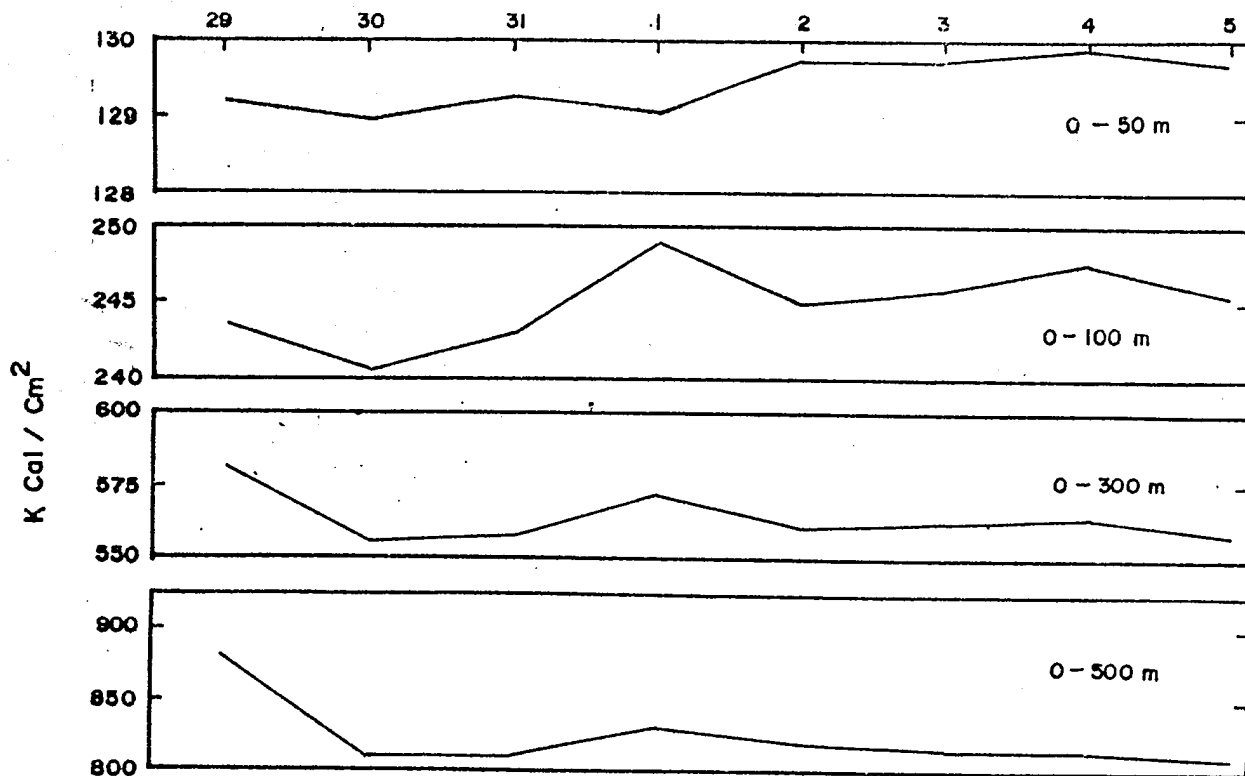


FIG. 3 VARIATION OF DAILY AVERAGE HEAT CONTENT IN DIFFERENT LAYERS

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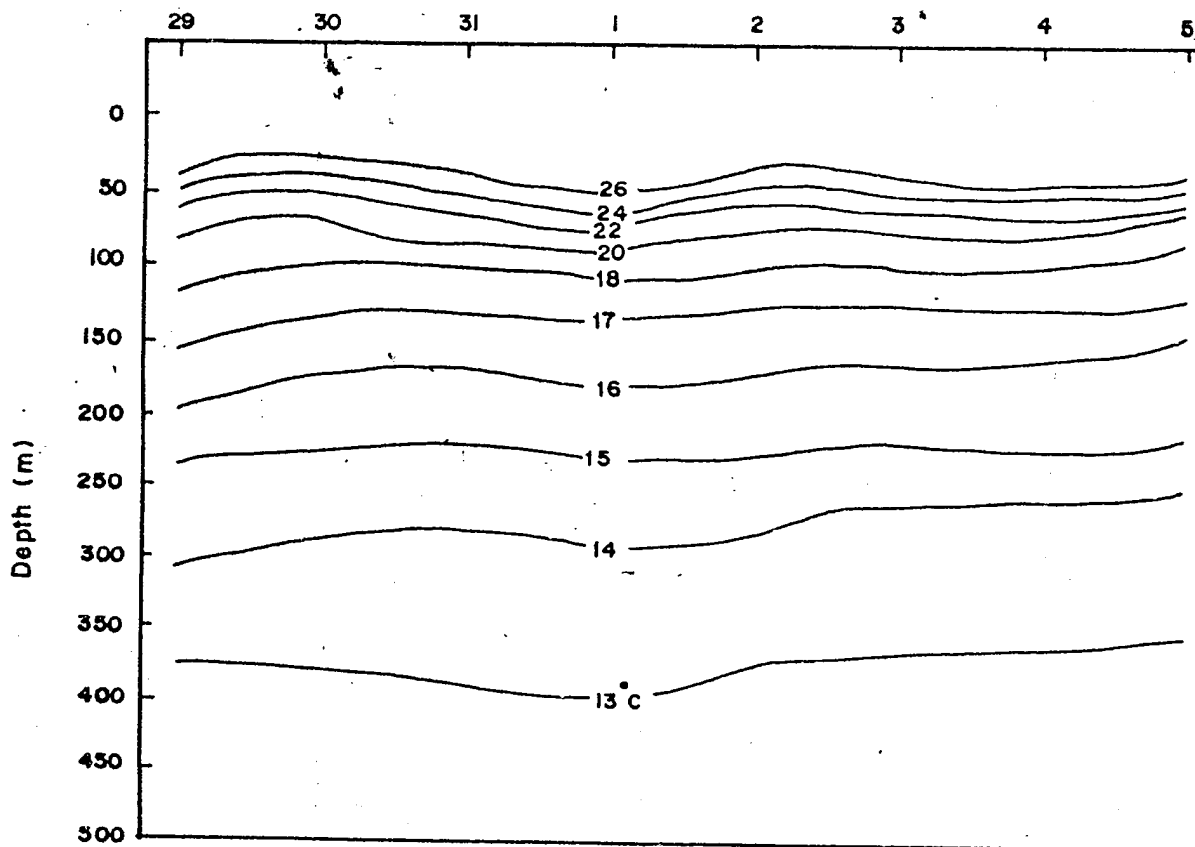


FIG. 4 DAILY EVOLUTION OF AVERAGE THERMAL STRUCTURE AT 19°N & 67°E