

## THE LOWERING OF SEA SURFACE TEMPERATURE IN THE EAST CENTRAL ARABIAN SEA ASSOCIATED WITH A CYCLONE

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### ABSTRACT

An analysis of Thermal Structure in the East Central Arabian Sea associated with a moderate cyclone is presented. The heat storage and the heat budget components have been computed. Under the influence of the cyclone the Sea Surface Temperature (SST) decreased by 1.2°C. The study has revealed that the lowering of SST was primarily due to the downward heat flux (58%) and secondarily due to the evaporative cooling (33%). The fluxes of sensible heat and effective back radiation across the sea surface account for only 9% of the total loss from the surface layer.

*Key-words* : Sea surface temperature, heat flux, entrainment, upwelling.

The lowering of sea surface temperature (SST) in the Arabian Sea with the onset and advance of southwest monsoon season has been attributed to the processes of evaporative cooling, deepening of the surface mixed layer, advection of cold waters and convergences and divergences associated with the wind induced circulations (Colon, 1964 ; Colborn, 1975 and Rao, Sarma, Sastry and Premchand, 1976). In order to study the causative factors for the lowering of the SST and to parameterize the heat budget components, three oceanographic cruises were conducted on board R.V. *Gaveshani* during May-July, 1979, in the east Central Arabian Sea (Fig. 1). During 14-18 June, a depression passed over the study area and its track along with dates is also depicted in Fig. 1. This note presents an evaluation of the heat loss in the upper layers at 4 stations within a one-degree square grid and the consequent lowering of the SST associated with the passage of the depression from the observed thermal structure.

Vertical profiles of temperature obtained by a bathythermograph at four stations are presented in Fig. 2. The profile for station MX-10 represents premonsoon condition. Because of the late onset of monsoon during 1979, the temperature profile for station MX-80 also represented the premonsoon condition. Station MX-136 was occupied immediately after the depression had crossed the study area. The profile for station MX-144 represented a general monsoon condition. During May and early June, the surface layer was not well defined (MX-10 & MX-80). On the other hand, the profiles for stations MX-136 and MX-144 showed well defined isothermal layers down to the depths of 40 and 50 m respectively. The lowering of SST after the onset of the monsoon is clearly noticeable in Fig. 2. Further, the increase in the vertical temperature gradients at 40 m (MX-136) and at 50 m (MX-144) developed a

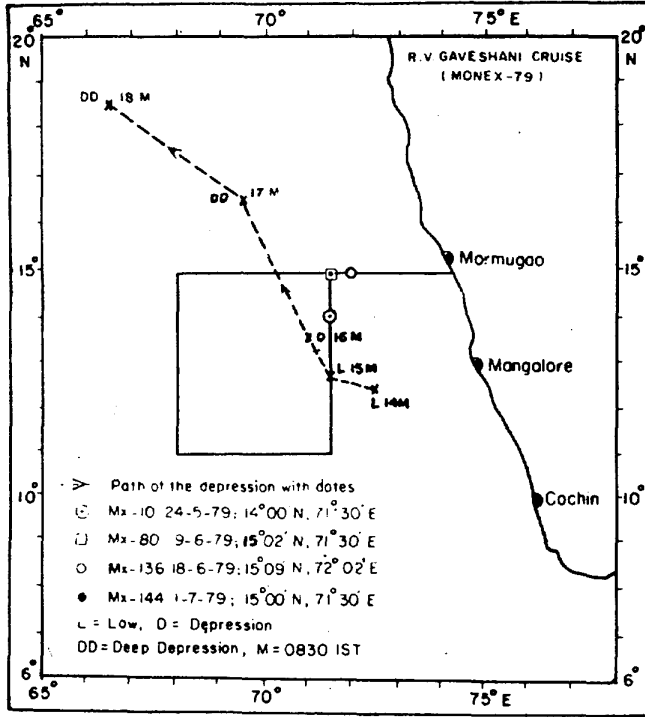


Fig. 1. Location of the stations and the track of the depression during 14-18 June, 1979.

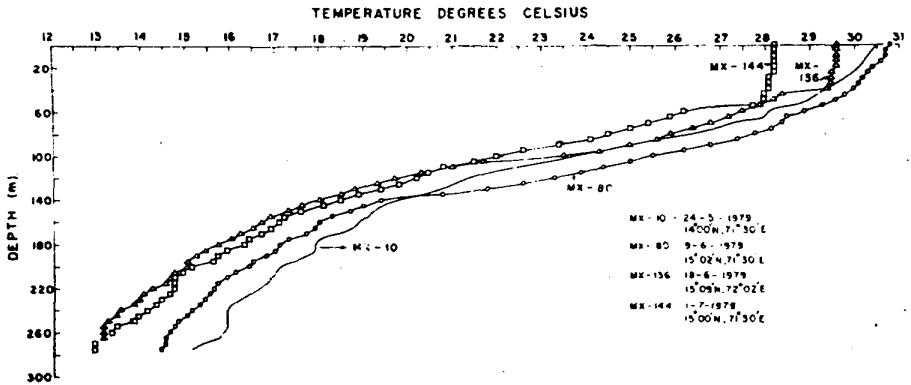


Fig. 2. Vertical profiles of temperature (°C).

'Knee' at the respective depths where the temperature difference between pre-monsoon and monsoon profiles was a minimum.

The latent heat ( $Q_e$ ) and sensible heat ( $Q_s$ ) were computed using the standard bulk aerodynamic formulae (Malkaus, 1962) and the effective back radiation ( $Q_b$ ) was computed following Laevastu (1963). The following procedure has been adopted for their quantitative estimations and to derive the heat losses during the period of the depression.

The heat content or the heat storage of the water column (down to depth of 40 m from the sea surface),  $Q_{SL}$ , has been computed from the formula

$$Q_{SL} = \int_0^{40} \rho C_p T dz$$

Where  $\rho$  is density of the sea water,  $C_p$ , specific heat at constant pressure,  $T$ , 5 m-mean temperature and  $Z$ , depth.

The daily increase in heat storage was obtained from the difference in heat contents of the water column for MX-10 (24 May) and MX-80 (9 June). Assuming that no significant changes occurred in the general meteorological and oceanographic conditions during the period 9-14 June, the heat content at MX-80 for 14 June ( $Q_{SL-HY}$ ) was estimated by extrapolation. The depression crossed the study area during 15-17 June and the heat lost during the period was estimated at 4.37 Kcal (difference between  $Q_{SL-136}$  and  $Q_{SL-SY}$ ) (given in Table I).

Table I. Energy stored over a depth of 40 m water column around 15°00'N, and 71°30'E position.

Station No.	Date	$Q_{SL}$ Kcal. cm <sup>-2</sup>
MX-10	24.5.1979	119.23
MX-80	9.6.1979	121.70
MX-80 ( $Q_{SL-HY}$ )	14.6.1979	122.57
MX-136	18.6.1979	118.20
MX-144	1.7.1979	112.70

Fig. 3 shows the daily mean evaporation as well as the cumulative evaporation during 8-17 June. Between 8 and 14 June, the average rate of evaporation was uniform (0.5 cm. day<sup>-1</sup>) while the evaporation rate increased to about 1 cm. day<sup>-1</sup> from 15 June under the influence of cyclonic weather. During the period 15-17 June, overcast skies with predominantly low and medium clouds prevailed for most of the time and so the incoming solar radiation ( $Q_i$ ) was assumed to be negligible for the present computations. The heat fluxes  $Q_e$ ,  $Q_s$ , and  $Q_b$  from the sea surface, for the period 15-17 June, were estimated as 1.42, 0.27 and 0.129 Kcal, respectively, amounting to a total heat loss of 1.819 Kcal. Thus the difference of 2.551 Kcal (4.37-1.819 Kcal) was the net amount of heat lost either due to advection or due to the interior oceanographic processes. Assuming quasi-steady state conditions, i.e., the

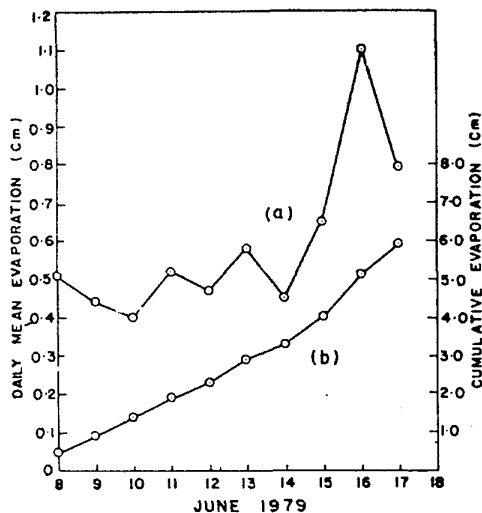


Fig. 3. (a) Daily mean evaporation,  
(b) Cumulative evaporation.

area sampled was subjected to the processes of cooling to the same degree, advective transport of heat can be neglected. However, the wind induced circulation associated with strong winds during the depression strengthened the surface circulation, developing a strong current shear zone at the 'Knee'. Entrainment of cold subsurface water into the warm surface layer takes place at the current shear zone and subsequent mixing lowers the sea surface temperature. Similarly, the warmer surface waters would mix with the cold subsurface waters, thereby transporting heat downwards. Thus, it can be visualised that a downward heat transport of 2.551 Kcal occurred during 15-17 June. The incoming solar radiation ( $Q_p$ ) reaching the surface, would result in a gain of heat to the surface layer. In such a case the quantum of the downward heat flux would be higher.

The lowering of sea surface temperature associated with the depression was partly due to increase in heat loss by evaporation and sensible heat transport and entrainment of the cold subsurface waters into the warm surface layer and the subsequent mixing. The study thus revealed that more than 50 per cent of heat loss from the surface layer was due to mixing processes across the thermocline causing the development of a 'Knee' at 40 m (MX-136) and the remainder accounted the heat loss across the sea surface. A secondary effect of the cyclone was the development of a surface isothermal layer.

Upwelling which can clearly be seen (Fig. 2) from the upward shift of the temperature profile of MX-136 when compared to the temperature profile of MX-80 between 40 m and 150 m is also the effect of the depression.

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