

## SEASONAL VARIABILITY OF HEAT FLUX DIVERGENCE IN THE COASTAL WATERS OF VISAKHAPATNAM

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### ABSTRACT

Heat flux divergence ( $Q_v$ ) in the coastal waters of Visakhapatnam during different seasons, was estimated for the period February 1980 - January 1981. It is found that the water column (0-60 m) gains heat during winter and premonsoon seasons while it loses heat in the other seasons. The mean heat loss is found to be about  $19.8 \text{ W/m}^2$  annually. The magnitude of  $Q_v$  is comparable with the net radiation at the sea surface ( $Q_R$ ) during monsoon and post monsoon seasons, whereas  $Q_v$  is 56.8% and 28.5% of  $Q_R$  during premonsoon and winter seasons respectively.

### INTRODUCTION

Reversal of wind and current pattern in association with the northeast and southwest monsoons, causes both sinking and upwelling off the east coast of India. The process of upwelling and sinking, and the current pattern influence the heat content of the oceanic column significantly, on a seasonal scale. The thermal structure which is responsible for the heat content variations depends on several factors like advection of waters, radiation from the sun, mixing by wind, tidal current, internal waves, etc. (La Fond, 1954). The changes in the heat content due to advection (heat flux divergence/convergence) are difficult to estimate directly because it demands data on currents and temperature simultaneously which is not normally available. In the present study, an attempt has been made to indirectly estimate the heat flux divergence/convergence from the heat budget equation, making use of the data collected at a stationary location (Fig. 1) off Visakhapatnam during February 1980 - January 1981.

### DATA AND METHODS

Details on the collection of data have been presented earlier (Prabhakara Rao *et al*, 1987). The heat flux divergence ( $Q_v$ ) is obtained as a residual from the following equation:

$$Q_R = Q_E + Q_S + Q_T + Q_v$$

where  $Q_R$  = Net radiation at the sea surface;  $Q_E$  and  $Q_S$  = latent and sensible heat fluxes across the sea surface;  $Q_T$  = rate of change of heat storage;  $Q_v$  = heat flux divergence/convergence. The term,  $Q_R$  is computed following the procedure presented earlier (Sadhuram *et al*, 1989).

The terms,  $Q_E$  and  $Q_S$  have been estimated by bulk aerodynamic method and the exchange coefficients have been evaluated following Kondo (1975). The rate of change in heat storage ( $Q_T$ ) at the station is obtained from the equation:

$$\rho C_p \int_0^D \frac{\partial T}{\partial t} dz$$

where  $\rho$  = density of sea water;  $C_p$  = Specific heat of sea water at constant pressure;  $\bar{T}$  = water temperature at depth  $z$ ,  $t$  is the time,  $z$  is the vertical co-ordinate (positive downward).  $D$  is the depth (60 m) to which integration is carried out.

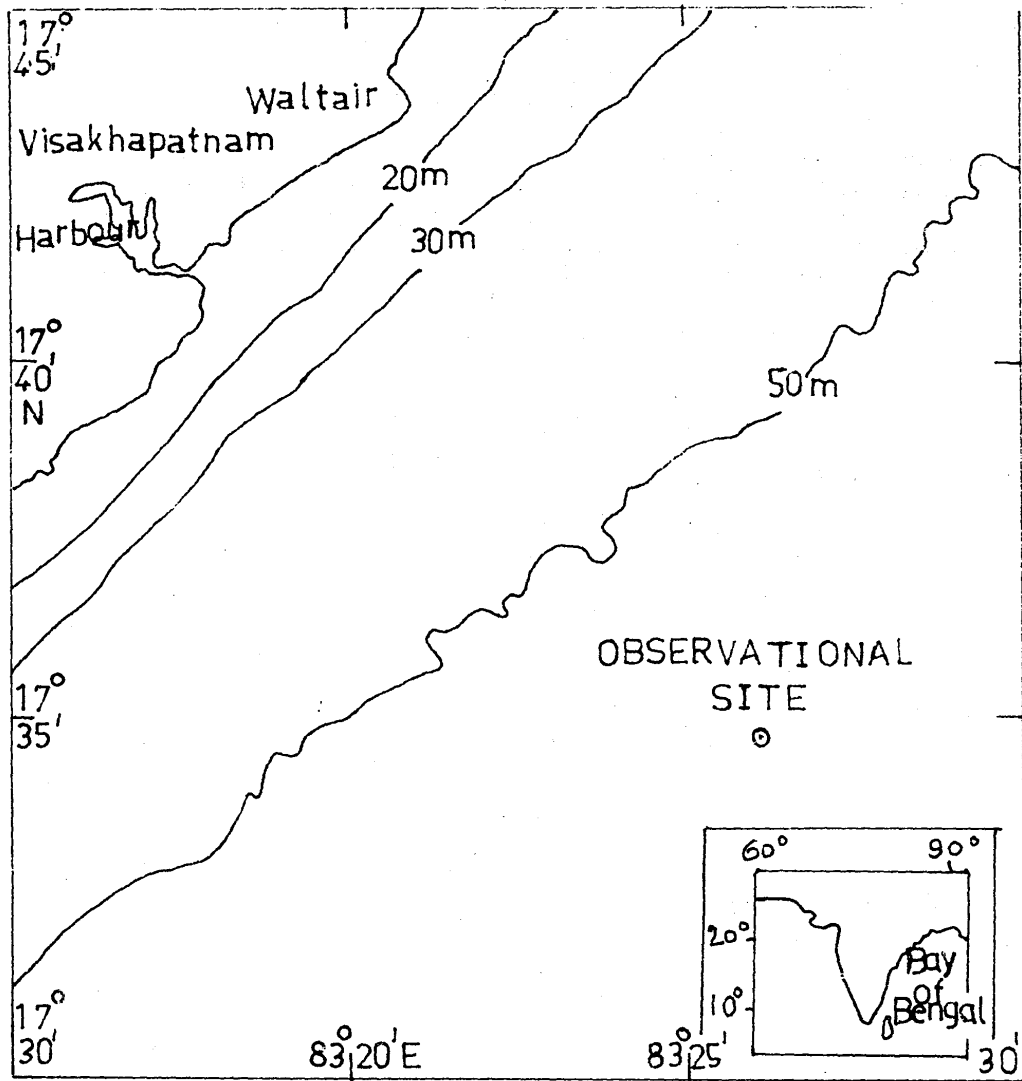


Fig. 1. Location map.

## RESULTS AND DISCUSSION

### a) Thermal Structure:

The thermal structure based on monthly mean data is presented in Fig. 2. It is seen that the sea surface temperature is minimum ( $<25^{\circ}\text{C}$ ) in January and maximum

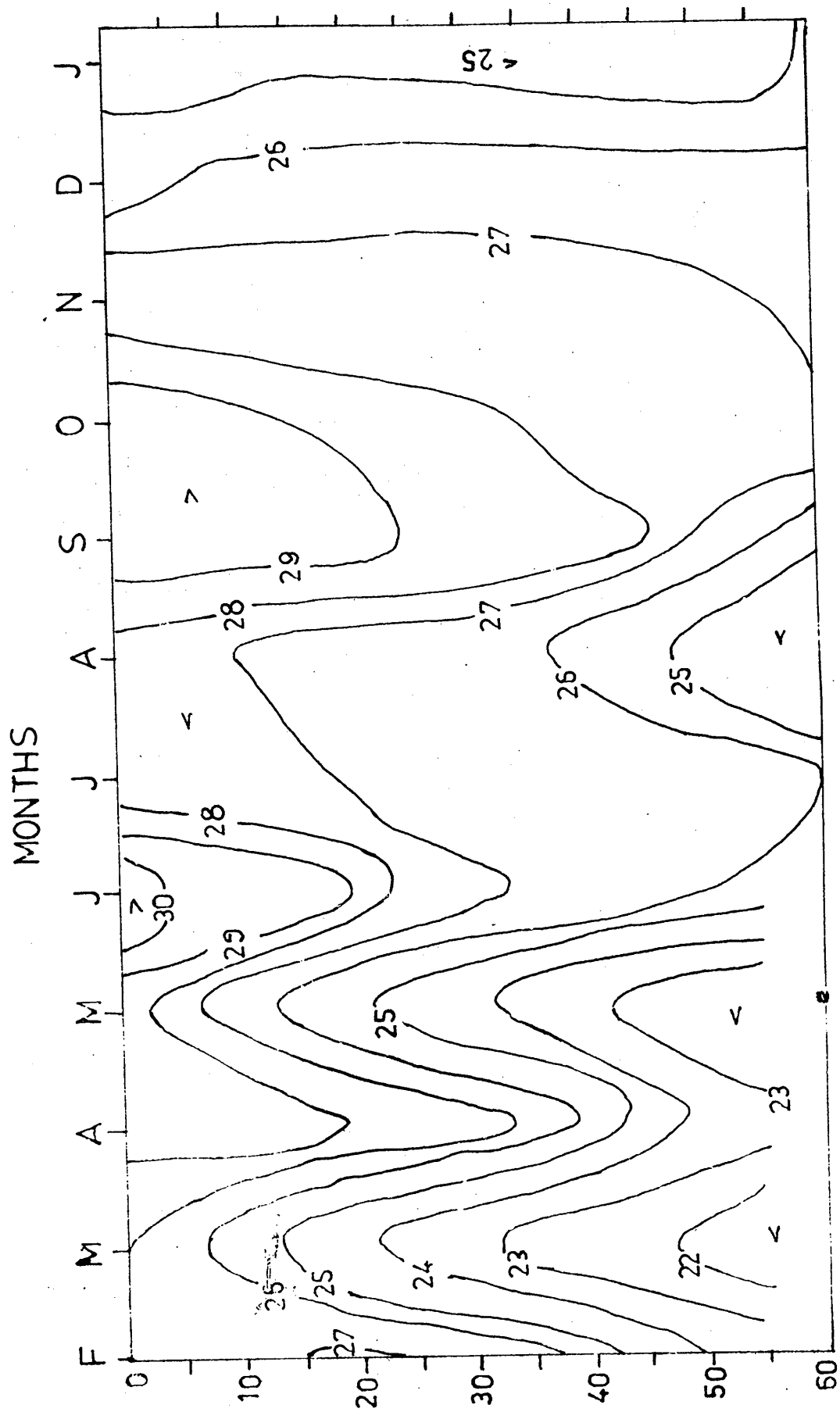


Fig. 2. Monthly variation of temperature in the coastal waters of Visakhapatnam.

(30°C) in June. The gradients are very strong during premonsoon season (March-May) throughout the water column and very low temperatures (22-23°C) prevail at the bottom. The temperature gradients are very weak during monsoon (June-August) and postmonsoon (September-November) seasons. During the period from November to January, isothermal layers are present throughout the water column. There is a rapid increase in the temperature of the bottom layer (50-60 m) from February to November, which varies from 22°C to 27°C.

*b) Heat flux Divergence/Convergence (QV):*

The mean meteorological data and the estimates of heat budget terms have been presented in the Tables 1 & 2. The net radiation (QR) is found to be maximum during premonsoon season and minimum in winter season (Table 2). QE is found to be maximum in winter due to higher vapour pressure gradient whereas it is almost stable in the other seasons. Qs is negative and one order lower than QE in all the seasons except in monsoon season. The large temperature gradient and higher winds (Table 1) of monsoon are responsible for the maximum Qs. The rate of change of heat storage, obtained from the monthly mean data presented in Fig. 2, is positive and one order lower in winter and premonsoon compared with those in the other seasons. There is a mean heat loss of 19.8 W/m<sup>2</sup> from the water column annually. The residual term Qv, is positive throughout the year indicating a net heat flux divergence from the region under consideration. It is interesting to

Table 1. Mean meteorological parameters at the location

Season	C	U	Ta	Td	Tw	es-ea	Tw-Ta
Winter	2.5	4.0	26.0	23.1	25.8	4.6	-0.2
Premonsoon	3.7	5.2	28.1	27.1	28.0	2.0	-0.1
Monsoon	6.1	6.2	30.0	28.1	28.4	2.0	-1.6
Postmonsoon	4.2	4.6	29.2	27.7	28.8	2.4	-0.4

C = cloud amount (in octas); U = wind speed (m/sec); Ta = dry bulb temperature (°C); Td = Dew point temperature (°C); Tw = sea surface temperature (°C); es-ea = vapour pressure gradient (mb); Tw-Ta = sea-air temperature difference (°C).

Table 2. Estimates of heat budget parameters at the location

Unit: W/M<sup>2</sup>

Season	QR	QE	Qs	Qt	Qv
Winter	207.4	88.3	- 2.6	62.5	59.2
Premonsoon	304.9	50.0	- 1.6	83.3	173.2
Monsoon	282.8	59.5	-30.7	-125.0	379.0
Postmonsoon	244.2	52.8	- 5.8	-100.0	297.2
Mean	259.8	62.6	-10.2	- 19.8	227.2

note that the magnitude of  $Q_v$  is comparable with  $Q_R$  during monsoon and postmonsoon seasons while  $Q_v$  is 56.8% and 28.5% of  $Q_R$  during premonsoon and winter seasons respectively. From this, it may be inferred that  $Q_v$  plays an important role in controlling the heat content of the coastal waters.

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