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Diurnal variability of heat fluxes and heat content at a few locations off central east coast of India during April 1989

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सार — अप्रैल 1989 के दौरान **आर. बी. गवेषणी** यान पर संग्रहित आकड़ों का प्रयोग करते हुए भारत के मध्य पूर्व तट से दूर तीन स्थानों अर्थात् स्टेशन ए (17° 59′ उ०, 83° 53.9′ पू०), स्टेशन बी (17° 00′ उ०, 82° 32.1′ पू०) और स्टेशन सी (16° 31.3′ उ०, 82° 21.8′ पू०) में सतह पवन गति, नेट उष्मा विनिमय, समुद्र सतह तापमान, उर्ध्वाधर उष्मीय संरचना और पूर्ण उष्मा की दैनिक परिवर्तनशीलता की व्याख्या की गई है।

ABSTRACT. Diurnal variability of surface wind speed, net heat exchange, sea surface temperature, vertical thermal structure and heat content at three locations, *viz.*, station A (17° 59′N, 83° 53.9′E), station B (17° 00′N, 82° 32.1′E) and station C (16° 31.3′ N, 82° 21.8′E) off central east coast of India is described making use of the data collected on board *R. V. Gaveshani* during April 1989.

Key words — Heat fluxes, Heat content.

1. Introduction

The coupling between the surface layers of the atmosphere and the ocean plays an important role in the dynamics of the atmosphere and ocean. Air sea interaction processes over the Bay of Bengal have been considered important for understanding the formation of cyclones and behaviour of monsoons. It is a well known fact that the frequency of cyclones is 3 to 4 times higher over Bay of Bengal as compared to the Arabian Sea (Rammohan Rao 1986).

Several studies (Varadachari 1958, Rao *et al.* 1981, Anto *et al.* 1982, Rao *et al.* 1983, Subbaramayya & Rammohan Rao 1984, Anto and Somayajulu 1985, Prabhakara Rao *et al.* 1987, Rao & Mathew 1988, Prabhakara Rao & Sadhuram 1989) have appeared in the literature dealing with meteorological and heat budget aspects of the Bay of Bengal. But studies on heat budget of the coastal waters on diurnal scale are meagre. This paper deals with the diurnal changes in the wind speed, SST, heat exchange and heat content, in the shelf waters off central east coast of India.

2. Data and methodology

Data on marine meteorological parameters and temperature profiles in the ocean column (0-50 m) have been collected at hourly intervals on board *R.V. Gaveshani* at three locations (shown in Fig. 1) during April 1989.

2.1. *Net heat exchange*

The net heat exchange across the sea surface (Q_n) can be estimated from the equation :

$$Q_n = Q_a - Q_b - Q_e - Q_s \quad (1)$$

$$Q_a = (1 - \alpha) Q_i \quad (2)$$

where, Q_a= net shortwave radiation, Q_b = effective back radiation, Q_e & Q_s= latent and sensible heat fluxes respectively, Q_i= total incoming radiation and α=albedo of the sea surface. The values of Q_n are estimated at hourly intervals. Values of Q_i are computed following Lumb's (1964) method. The value of α is assumed as 0.06 according to Payne (1972) and Q_b is computed following the procedure proposed by Reed (1976). Latent (Q_e) and sensible (Q_s) heat fluxes are determined by using bulk aerodynamic method. The equations are given below :

$$Q_e = \rho c_e L (q_s - q_a) U \quad (3)$$

$$Q_s = \rho c_h c_p (T_s - T_a) U \quad (4)$$

the bulk transfer coefficients for latent (c_e) and sensible heat (c_h) fluxes are evaluated following Kondo's (1975) method which takes care of the dependance of atmospheric stability and wind speed. The symbols have their usual standard notations.

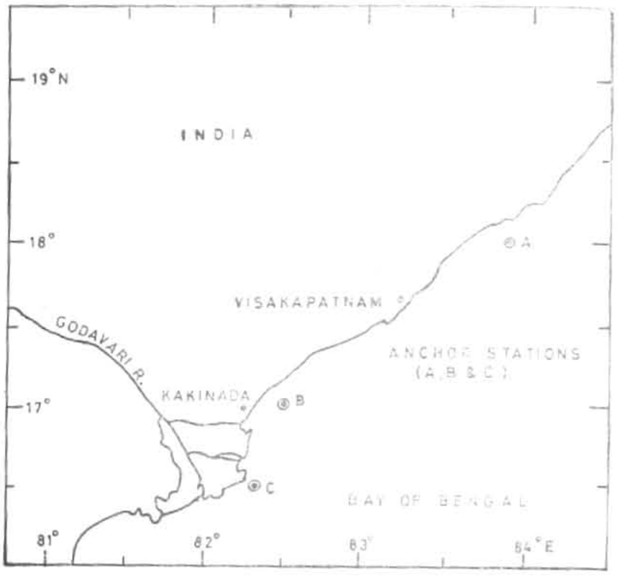

Fig. 1. Location map

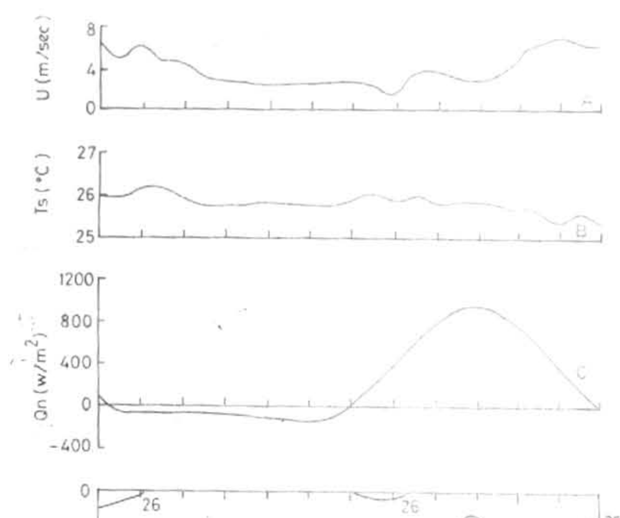

Fig. 2. Diurnal variability of wind speed (A), sea surface temperature (B), net heat exchange (C), thermal structure (D) and heat content (E) at station A

2.2. *Heat content (H)*

Heat content (H) of the upper oceanic column can be estimated from the following equation making use of the observed temperature profiles.

$$H = \rho_0 \, c_p \int_0^D \bar{T} \, dz \qquad (5)$$

where, ρ_o = density of sea water (obtained from the historical temperature and salinity data sets collected in the region), c_p = specific heat of water at constant pressure, $\bar{T}$ is the mean temperature of the layer and D is the depth up to which integration is carried out. In the present study, D is fixed as the bottom depth at respective stations A, B & C.

3. Results and discussion

Diurnal variability of wind speed (U), sea surface temperature (T_s), net heat exchange (Q_n) and heat content (H) at the stations A, B & C (shown in Fig.1) have been presented in the Figs. 2 to 4.

At station A, wind speed is found to be maximum during afternoon with an intensity of 6 m/s and minimum is noticed during mid-day [Fig. 2(a)]. The sea surface temperature (T_s) is almost stable during night time and gradually increased during day time due to solar heating [Fig. 2(b)]. The values of Q_n are negative and low during night time while they reached maximum ($\approx$ 900 W/m^2) during noon. This is mainly due to the fact that the input solar radiation is very high at noon due to clear sky conditions and the heat losses due to Q_b, Q_e and Q_s are low. The values of heat content (H) varied between 3.8 and 4.0 (10^9 J/m^2) on diurnal scale [Fig. 2(e)]. The fluctuations noticed in the thermal structure are due to the presence of internal gravity waves. Earlier studies (LaFond 1959, Antony *et al.* 1985) indicated the presence of internal gravity waves off the east coast of India. At station B, a steep rise in wind speed is observed from 1000 to 1600 IST on 14 April and gradual decreasing trend is noticed afterwards [Fig. 3(a)]. T_s is found to be maximum around 1300 IST and stable during 2200-0300 IST [Fig. 3(b)]. Q_n is positive during day time and negative during night time which is quite obvious. Maximum value is observed at 1100 IST. Stronger winds and the decreasing trend in Q_n observed during 1000-2000 IST might be responsible for the lowering trend in SST observed from 1200 IST onwards [Figs.3(a & c)]. Heat content (H) varied between 3.8 and 4.2 (10^9 J/m^2) [Fig. 3(e)] which could be due to the large fluctuations caused by internal waves noticed in the thermal structure [Fig. 2(d)].

Fig. 4 shows the variability of wind speed, T_s, Q_n, thermal structure and H, observed at station C. It may be mentioned here that sky is clear during the period of observations at stations A & B, whereas at station C, cloud amount varied between 2 & 7 octas. In general, winds are stronger and steady at station C compared with those at other stations. Maximum wind speed is found to be about 10 m/sec [Fig. 4(a)]. It is interesting to note that SST is almost stable around 29° C throughout the observational period except for a small duration [1200-1800 IST — Fig. 4(b)]. This is, perhaps,

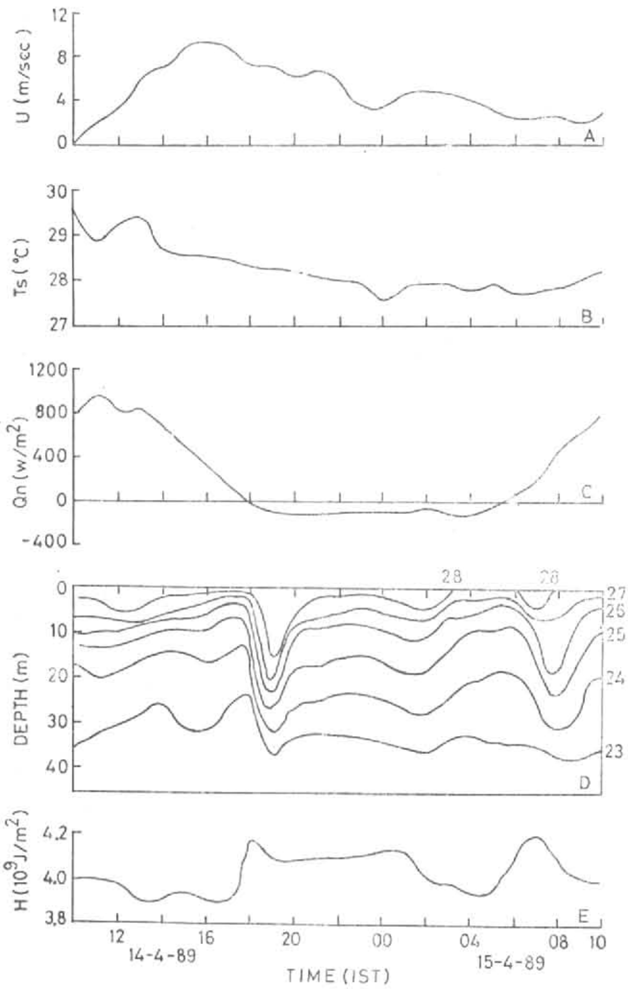

Fig. 3. Same as Fig.2 but for station B

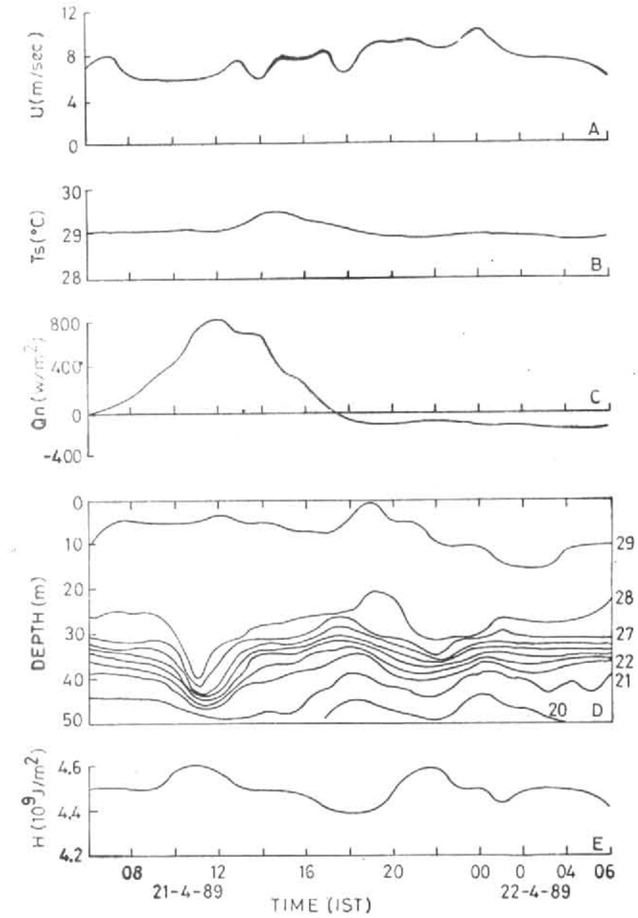

Fig. 4. Same as Fig. 3 but for station C

due to presence of cloud and steady winds. Due to the presence of clouds the maximum Q_n observed at station C is lower compared with those observed at stations A & B [Fig. 4 (c)]. H varied between 4.4 and 4.6 (10^9 J/m^2) at station C [Fig. 4(e)]. The mean wind speed is low at stations A & B and it is steady and stronger at station C. The noticeable feature in thermal structure is that the gradients are weaker in the bottom layer (30-50 m) at station A and stronger at stations B & C. As a result of steady and strong winds, the depth of mixed layer is higher ($\approx$25 m) at station C. The oscillations in the thermal structure are due to the presence of internal gravity waves. The heat content (H) varied between 3.8 and 4.0 (10^9 J/m^2) at station A and 4.4-4.6 (10^9 J/m^2) at station C.

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