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The net energy exchange at the surface over the Arabian Sea during the summer monsoon

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सार — 1977 और 1979 के मई और जून महीनों के लिए अरब सागर के ऊर्जा बजट प्राचलों (निवल विकिरण, वाष्पन एवं संवेदी उष्मा अभिवाह) की गणना की गई है। समुद्री सतह के चारों ओर निवल उष्मा विनिमय के वर्षवार अन्तर सार्थक पाए गए। यहां उनकी मानसून की सक्रियता के संदर्भ में चर्चा की गई है।

ABSTRACT. The energy budget parameters (net radiation, evaporation and sensible heat fluxes) over the Arabian Sea have been computed for the months of May and June 1977 and 1979. The year-wise differences in the net heat exchange across the sea surface are found significant and discussed in relation to the activity of monsoon.

1. Introduction

One of the objectives of the Monsoon Experiment (MONEX) under the Global Atmospheric Research Programme (GARP) was to study the heat budget of the Indian Ocean in relation to the summer monsoon. Eventhough the existence of the Asiatic summer monsoon is primarily due to differential heating of land and sea, it is believed that, at least partially, the fluctuations in the monsoon activity may depend on the air-sea interaction processes which take place over the north Indian Ocean (Rao 1972, Saha 1970, 1974, Shukla 1975). In the present study, the authors have examined the exchange of heat energy across the surface of the Arabian Sea during the months of May and June for the years 1977 and 1979 and discussed the inter annual differences in relation to the activity of the monsoon.

2. Data and methods of study

Data on sea surface temperature, dry bulb temperature, dew point temperature, wind speed and cloud amount for this investigation have been taken from the ship data published in the *Indian Daily Weather Reports*. For 1979 period, the MONEX data set had also been considered. The area over Arabian Sea is divided into a number of grids separated by 5 deg. latitude and 5 deg. longitude. For each grid the monthly averages for all the above mentioned parameters have been computed and they also been linearly interpolated from the surrounding grid values for some grids where the ship observations are very much limited, for better continuity of drawing isopleths. The distributions of the total number of observations, average sea surface temperature and cloud amount in each grid for each month are presented in Fig. 1.

The net energy exchange (Q_N) at the ocean surface satisfies the equation :

$$Q_N = Q_I(1-R) - Q_B - Q_L - Q_S \qquad (1)$$

where, Q_I = the incident total solar radiation (ly/day),

R = albedo factor (%),

Q_B = the heat lost from the surface as effective back radiation (ly/day),

Q_L = the latent heat lost from the surface (ly/day),

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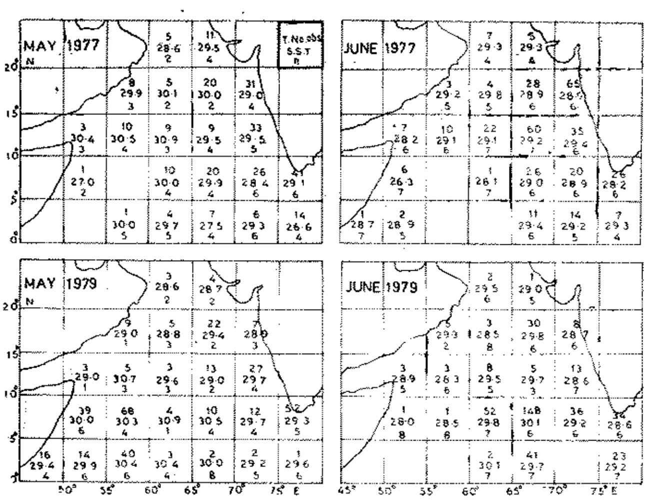

Fig. 1. Distributions of total number of observations, average sea surface temperature and cloud amount

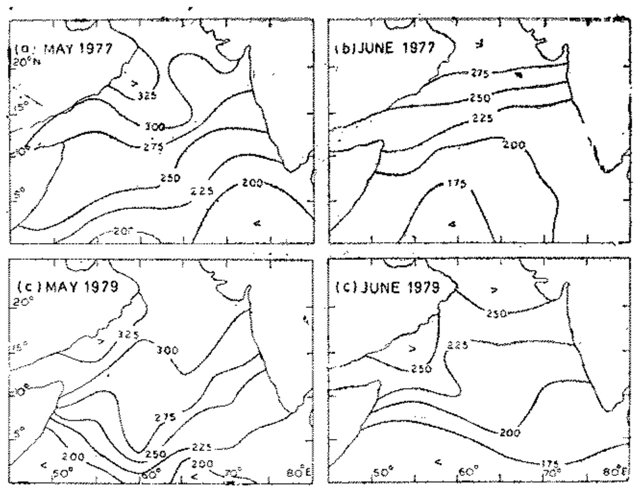

Fig. 2. Distribution of net radiation over Arabian Sea (ly/day)

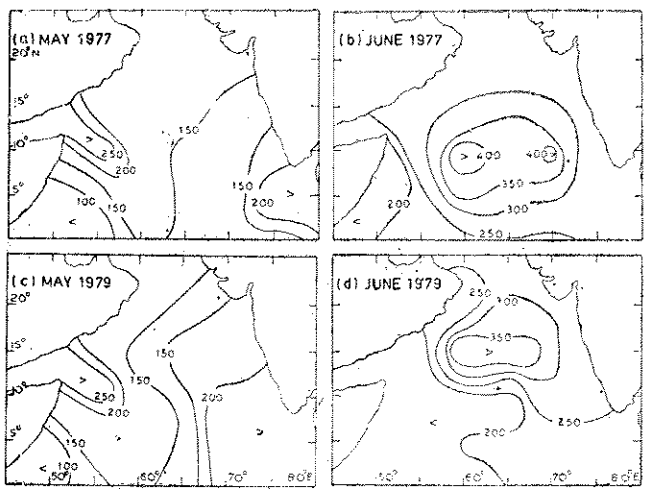

Fig. 3. Distribution of heat fluxes ($Q_s + Q_L$) over Arabian Sea (ly/day)

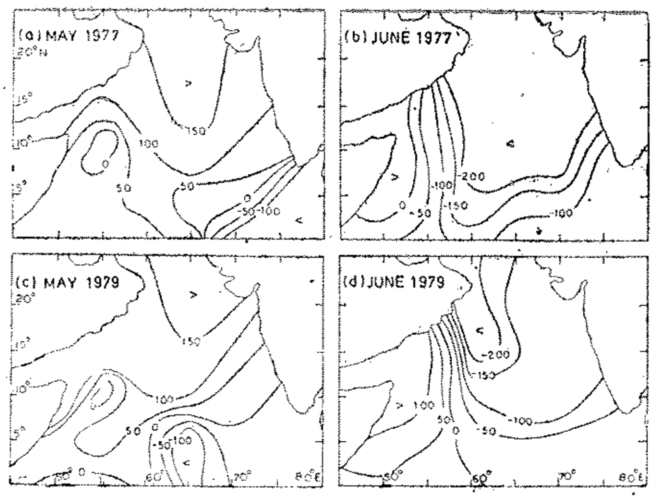

Fig. 4. Distribution of net energy exchange across the surface over Arabian Sea (ly/day)

Q_S = the sensible heat lost from the surface (ly/day).

The total incoming radiation (Q_{I0}) under cloudless conditions has been taken from the table given by Bodyko (1963). Further it is corrected for cloudiness using Savino-Angstorm formula given by :

$$Q_I = Q_{I0}(1-0.071\,n) \tag{2}$$

where, n is cloud amount in octas.

The albedo values for the region of present study are taken from Payne (1972) and it is 0.06 (*i.e.*, 6%).

The back radiation under cloudless conditions (Q_{B0}) is determined from the diagram given by Sverdrup (1946) and corrected for the cloudiness using the following equation :

$$Q_B = Q_{B0}(1-0.083\,n) \tag{3}$$

The sensible and latent heat transfers from the sea surface have been estimated using the Bulk aero-dynamic formulae given by :

$$Q_S = \rho\, c_p\, C_H\, (\overline{T_0}-\overline{T_a})\, \overline{U_a} \tag{4}$$

$$Q_L = \rho\, L\, C_E\, (\overline{e_0}-\overline{e_a})\, \overline{U_a} \tag{5}$$

where, ρ is the density of the air ($\rho = 1.2\times10^{-3}$ g cm^{-3}),

c_p is the specific heat of air at constant pressure (c_p=0.24 cal g^{-1} deg^{-1}),

$\overline{U_a}$ is the average wind speed at 10 m over the sea surface,

$\overline{T_0}$ and $\overline{T_a}$ are the average temperatures of the sea surface and the air at 10 m over the sea surface respectively,

$\overline{e_0}$ and $\overline{e_a}$ are the saturated vapour pressures and vapour pressures of the sea and air respectively,

C_E and C_H are the exchange coefficients of water vapour and sensible heat respectively. These coefficients are obtained from the table given by Bunker (1976).

3. Results and discussion

3.1. *Net radiation*

The distributions of net radiation during May and June of 1977 are presented in Figs. 2(a) & 2(b) respectively. They show a general northward increase from the equator with a maximum values of more than 325 ly/day observed off the Arabia coast during May and more than 275 ly/day in the northern Arabian Sea during June. Similar northward increasing trend is also noticed in the year 1979 with some differences in maximum values [Figs. 2(c) & 2(d)]. These distributions are in close agreement with the patterns given by Hastenrath and Lamb (1978). The reduction in net radiation from May to June is most remarkable in both the years as a result of monsoon activity.

3.2. *Latent heat and sensible heat fluxes*

Figs. 3(a) & 3(b) show the distributions of the total heat flux from the Arabian Sea in the form of both latent and sensible for the months of May and June 1977 respectively. A maximum value of generally high fluxes with more than 400 ly/day is encountered over central portions of the Arabian Sea during monsoon whereas in the pre-monsoon the values are ranging only between 100 and 200 ly/day except with a high value of more than 250 ly/day in the Gulf of Aden. For the monsoon period of 1979, the total flux from the sea is somewhat lower as seen from Fig. 3(d). This could be related to the activity of summer monsoon which in fact has set early over the Arabian Sea in 1977 than in 1979.

3.3. *Net heat gain or loss at the surface*

Figs. 4(a-d) show a general net heat gain over most of the area in May and a net heat loss over most of the area in June. However, in 1979, the net heat loss in June is confined to the central and the eastern Arabian Sea only whereas in 1977 almost the entire area of the Arabian Sea except the region of Somalia and Gulf of Aden has experienced a net heat loss (more than —200 ly/day). This again reflects the influence of relatively stronger monsoon activity in 1977. The surplus energy in the western Arabian Sea as seen in June 1979 [Figs. 4(c) & 4(d)] is due to the delay in the onset of the monsoon over the area.

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