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Distribution of Bowen ratio over the north Indian Ocean

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सार — उत्तरी हिन्द महासागर पर बोवन अनुपात का मासिक औसत अभिकलित किया गया है। जनवरी, मई और सितम्बर में तीन प्रतिरूपी स्थितियों को वर्तमान अध्ययन के लिए चुना गया है। अध्ययन वाले क्षेत्र में बोवन अनुपात में प्रत्येक दो मासों के बीच के अन्तर का अध्ययन महत्वपूर्ण पाया गया और उन पर ग्रीष्म ऋतु के साथ-साथ शीत ऋतु में भी मानसूनी रुख के संबंध में विचार विमर्श किया गया।

ABSTRACT. The monthly averages of Bowen ratio over the North Indian Ocean have been computed. Three typical situations in the months of January, May and September are taken for the present study. Month to month differences in the Bowen ratio over the study region are found significant and discussed in relation to the monsoonal behaviour of summer as well as winter.

1. Introduction

The ratio between sensible and latent heat fluxes over the water surface is called Bowen ratio which is one of the useful parameters to know the exchange of heat energy in the marine surface layer and to estimate the evaporation flux over the oceanic surface. It was assumed as constant by the earlier investigators (Mosby 1936, Mc Ewen 1938) due to lack of suitable data. The Bowen ratio is highly variable quantity both seasonally and latitudinally (Jacob 1942, 1951). Higher fractional values of Bowen ratio over an area indicate significant flux of sensible heat between the atmosphere and the ocean. The lower values of Bowen ratio signify the importance of latent heat flux which was found to be related to the rainfall activity over the west coast of India (Bhumralkar 1978). A negative value indicates that heat is conducted from the atmosphere to the ocean. In the present study, the authors have examined the month to month differences in the Bowen ratio over the North Indian Ocean and discussed in relation to the summer as well as winter monsoonal behaviour.

2. Data and method of analysis

Data on sea surface temperature, air temperature, wet bulb temperature and wind speed for all months for ten years (1955-64) over the North Indian Ocean have been taken from the marine section of India Meteorological Department. Mean monthly values of all the observations, available for different synoptic hours have been obtained for each grid of 2° latitude/longitude square, they also been linearly interpolated from the surrounding grid values for some grids where the ship observations are very much limited, and the Bowen ratio has been computed for all the squares. Mean monthly values of sensible and latent heat fluxes which are associated with Bowen ratio are well in agreement with that of Hastenrath and Lamb (1979).

The Bowen ratio is calculated on the basis of the formula given by Bowen (1926).

$$\text{Bowen ratio } (R) = \frac{Q_r}{Q_e} = 0.66 \frac{(T_s - T_a)}{(e_s - e_a)}$$

where, Q_r and Q_e are the sensible and latent heat fluxes over the water surface respectively

T_s is the sea surface temperature (°C)

T_a is the air temperature (°C) at 10 m level above the sea surface

e_s and e_a are the saturated vapour pressure and vapour pressures of the sea and air at 10 m level above the sea surface respectively (g/cm²).

3. Discussion of the results

The Bowen ratio over the North Indian Ocean is estimated for all the 12 months using the above mentioned method. Three typical months — January, May and September — which correspond to northeast monsoon, pre-monsoon and southwest monsoon seasons respectively are taken for a critical study.

The distribution of Bowen ratio over the region for the month of January is shown in Fig. 1(a). The Bowen ratio is maximum near the equator with a gradual decrease towards north reaching minimum around 15°N and a secondary maximum is observed over the head Bay in the Bay of Bengal.

During the months of February and March a general decrease is observed over the entire region, having negative values in the latter month over the northern parts of the Arabian Sea beyond 20°N. It is maximum in the month of April over the eastern equatorial part of the North Indian Ocean and decreases toward north reaching negative values over the extreme north.

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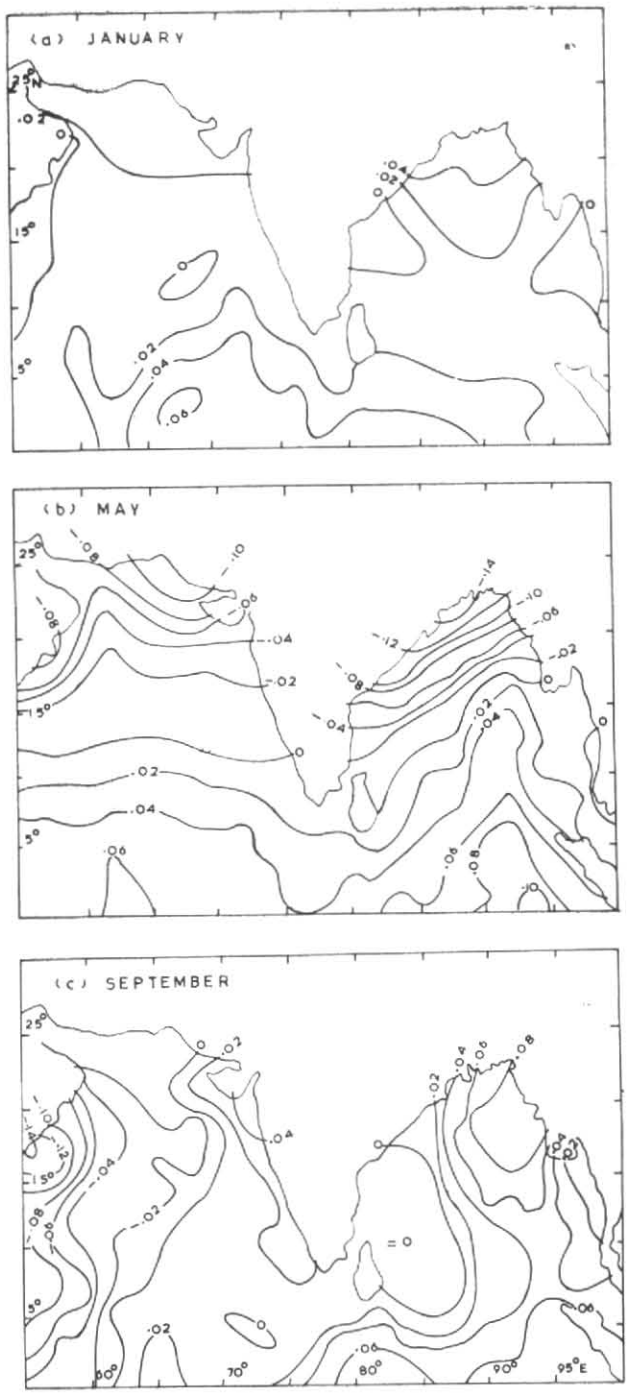

Fig. 1. Distribution of Bowen ratio during : (a) January, (b) May and (c) September

During the months of June, July and August, positive is active over the southern parts of the region. The distribution of Bowen ratio during May is shown in Fig. 1(b). Over the equatorial region the Bowen ratio is maintaining maximum and it is 0.10 in the eastern equatorial region. As in the previous month a decrease is observed towards north reaching a minimum of —0.14 near the head Bay.

During the months of June, July and August, positive values over the equatorial region and negative values over the northern parts of the Arabian Sea and Bay of Bengal are observed. In July maximum negative values are observed over the western parts of the Arabian Sea with relatively lower values towards east. In August a large variation of Bowen ratio is noticed with negative values over the entire North Indian Ocean excluding the regions of equatorial Arabian Sea and eastern Bay of Bengal.

Fig. 1(c) shows the distribution of Bowen ratio over the region for the month of September. During this month the equatorial region is maintaining its maximum Bowen ratio. A general trend of increase of Bowen ratio from western to eastern region is observed. A maximum negative Bowen ratio of —0.14 in the northwestern part over the Arabian Sea and a maximum of 0.08 in the northeastern part over the Bay of Bengal are noticed.

During the period from October to December, it is observed that positive values of Bowen ratio are noticed over the entire region with a maximum of 0.1 over the southeastern Bay of Bengal.

4. Conclusions

During the northeast monsoon period (October to February) practically the entire region is supplying heat energy to the atmosphere. During this season cold wind is blowing over the warm water and this is mainly responsible for positive values of Bowen ratio over the region which is typical for monsoon climate. The maximum ratio of 0.10 is observed over the southeastern region of the Bay of Bengal in the month of November.

During the pre-monsoon period (March to May) the Bowen ratio is negative, indicating the transfer of sensible heat from the atmosphere to the sea surface over the northern region of the Arabian Sea and it is positive for the rest of the region. In the Bay of Bengal the ratio is positive during March and in the months of April and May it is positive in the southern region and negative in the northern region. During this season the range of Bowen ratio is observed as 0.10 to —0.14.

During the southwest monsoon period (June to September) the same trend as in the pre-monsoon is continued over the Arabian Sea. In the month of July, the northern half of the Arabian Sea is showing negative values with maximum of 0.19 over the region off Arabia coast. This may be mainly due to intense upwelling off the Arabia coast. But in the Bay of Bengal Bowen ratio is positive over most of the region during this period with a maximum of more than 0.16 over the head Bay in the month of July.

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