Indian J. Met. Geophys. (1973), 24, 1, 27-30

551·573(267)

Evaporation over the Indian Ocean during the IIOE period

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(Received 2 April 1970)

ABSTRACT. The ship's data collected over the oceanic region bounded by 30°N to 40°S and 20°E to 140°E during International Indian Ocean Expedition (IIOE) period have been machine processed for the computation of various energy parameters of the heat budget across the air-sea interface. An attempt is made to evaluate the evaporation over the region for the months of January, April, July and October 1963 and 1964. Comparison with climatological values of evaporation as well as with earlier studies by other authors show that the evaporation computed for 1963 as well as 1964 is higher.

1. Introduction

Work on estimating the evaporation over Indian Ocean based on climatological data has been done by Venkateswaran (1956) and Privett (1959). Examining the water vapour flux data across the boundaries of the Arabian Sea during the SW monsoon of July and August, Pisharoty (1965) concluded that a large amount of the water vapour carried by the monsoon current over India is derived through evaporation over the Arabian Sea. The present study is attempted to assess the evaporation over the Indian Ocean based on a single year's collection (1963) and to compare them with the results of 1964 and the mean evaporation data.

2. Formula used for computation of evaporation

The following form of equation suggested by Jacob (1951) and Sverdrup (1951) has been used for the computation of evaporation (Q_e)

$$Q_e = K (e_s - e_a) V \qquad (1)$$

where e_s and e_a are the vapour pressures at the sea surface and at 10 metres above the sea surface respectively and V is the wind speed and K is the evaporation coefficient. K is, however, dependent upon the height, the wind speed and the roughness parameter etc. As is well known, computations of evaporation based on the above formula leads to certain uncertainties as strict theoretical considerations demand the eixstence of hydro-dynamically smooth sea surface. This constraint puts a serious limitation on the use of the equation and therefore the results obtained by different workers are often at variance in detail.

The value of K used in the present study is 81·9 where V is measured in knots and e_s and e_a are measured in inches of mercury. This value of the constant corresponds to $1 \cdot 62 \times 10^{-6}$ when the variables in (1) are expressed in C.G.S. units. It is well known that K may differ from area to area, depending upon the prevailing winds, roughness of the sea etc. For south Indian Oceanic region Venkateswaran (1956) and Privett (1959) used $2 \cdot 0 \times 10^{-6}$ and $1 \cdot 4 \times 10^{-6}$ respectively for K. Privett (1959) evaluated K for different oceanic areas and used an average value in his work. The value of the constant computed by him for the Indian Ocean belt (20-30°S and 70-90°E) is, however, 2/3 of his average value for the world ocean. The value of K used in the present study lies in between the values determined by Privett and Venkateswaran for the south Indian Ocean tropical belt.

From the consideration of wind stress on water surface K can be expressed as :

$$K = C_h \cdot \rho \qquad (2)$$

where C_h is a constant analogous to drag coefficient at a height h above the sea surface and ρ is the density of the moist air. Assuming ρ in C.G.S. units to be $1 \cdot 2 \times 10^{-3}$ the coefficient C_h works out to be $1 \cdot 35 \times 10^{-3}$ for the value of K used in this study. Several empirical relationships between the coefficient C_h and the wind speed have been suggested by different workers (Deacon 1962, Deacon and Webb 1962, Sheppard 1958, 1963). The value of the coefficient ($1 \cdot 35 \times 10^{-3}$) falls within the range of wind speeds 5 to 12 mps. The average prevailing speed throughout the year over the region under study lies within this range and hence the constant used in this study is considered to be suitable. However, it is noted that during the the southwest monsoon period wind strength exceeds this limit over parts of the Arabian Sea. As such the evaporation computed for July over the western Arabian Sea may be an underestimate.

3. Processing of the data

At the International Meteorlogical Centre, Bombay all efforts were made to collect ships' data from all possible sources which resulted on an average over 9000 reports per month from the Indian Ocean region, between 20°E to 140°E and 30° N to 40° S. The computer was programmed for checking of the format and all meterological parameters such as air, sea and dew point temperatures, wind and pressure etc. The checking was done against appropriate climatological values. The values which fell outside the acceptable range of the mean were printed out and later individually examined with regard to their acceptability. The checked data are subjected to final computations which include the monthly averages of the various quantities for each 5-degree latitude/longitude block. The programme then computes the evaporation. To estimate the evaporation from the climatological data, the various meterological parameters for each block were picked up from the *Dutch Marine Climatological Atlas*. The evaporation maps were prepared for the representative months of January, April, July and October for the years 1963 and 1964 as well as for the climatological data. The maps have not been shown to restrict space. The following discussion highlights the chief features.

4. Discussion of results

The broad pattern of the evaporation over the Indian Ocean computed in this study agrees generally with the earlier studies of Venkateswaran (1956) and Privett (1959). The prominent features are : (*i*) the centres of maximum evaporation over west central Arabian Sea and Bay of Bengal during January and July and (*ii*) broad maximum region over the tropical belt of the south Indian Ocean between 10°S—20°S and a minimum near the equator. The maxima occur in all the months over the regions of trade winds or monsoonal winds and the minima near the equatorial region where the winds are weaker. There is a seasonal oscillation in the position of the centre of maximum over the south Indian Ocean which is due to the oscillations in the position of the subtropical anticyclone. As in the case of other oceanic regions, the maximum value of evaporation over south Indian Ocean also occurs in winter (July). The seasonal variation of the maximum evaporation isopleth is small over the south Indian Ocean, whereas it is quite large over the Arabian Sea and the Bay of Bengal. The maximum values over the Arabian Sea and Bay of Bengal are considerably smaller in autumn and spring in comparison to the values of the double peaks in July and January. Such seasonal variations over south and north Indian Ocean are chiefly determined by the variation in the wind speed and to a lesser extent by the variation in the moisture gradient near the sea surface. Over the south Indian Ocean the seasonal variations in the strength of the SE trade wind is not much whereas over the Arabian Sea and Bay of Bengal the winds in autumn and spring are much weaker in comparison to winter and summer.

The double peak in the seasonal values over the Indian Seas is a well known feature. Whereas the winter maxima are explained by dry trade winds and are connected with a considerable saturation deficit under the subsidence zone of the sub-tropical high pressure belt the summer maxima peculiar to the north Indian Ocean, are associated with the predominent effect of the strong southwest monsoon wind system which more than offsets the effect of reduction in the evaporation due to higher cloudiness and moisture content. The evaporation values over the Arabian Sea both in January and July were considerably higher than those over the Bay of Bengal whereas small differences occur between the western and eastern portion of the south Indian Ocean along the same latitudes. The existence of a zone of maximum evapora ion with highest values in July over the western Arabian Sea suggests that the SW monsoon picks up a considerable amount of water vapour while traversing the Arabian Sea.

The meridional variation of evaporation over the tropical parts of the Indian Ocean along the longitudinal block 60°—65°E during different months in 1963 is shown in Fig. 1. This block is selected on account of excellent data coverage. The peak evaporation over Arabian Sea during winter (January) occurs along about 17°N whereas it occurs further south (along 12°N) during summer (July). Over the south Indian Ocean the peak in winter (July) occurs along 22°S and in summer (January) along 12°S. In the transition months of April and October only one peak occurs in the meridional distribution which is found in the hemisphere progressing from winter towards the summer regime. The peak also occurs about 8-10°N/8–10°S in April/October respectively; the October peak being, however higher in magnitude.

Comparison of the evaporation charts for 1963 with the evaporation computed with the climatological data shows that the evaporation values for all the four months over almost all parts of the Indian Ocean are generally higher by 20—30 per cent in 1963. The regions of the maxima in 1963 also cover generally greater areal extent than in the climatological patterns. The data for the year 1964 also suggest somewhat higher values than the mean and greater agreement with 1963 results. Fig. 2 shows month to month variations

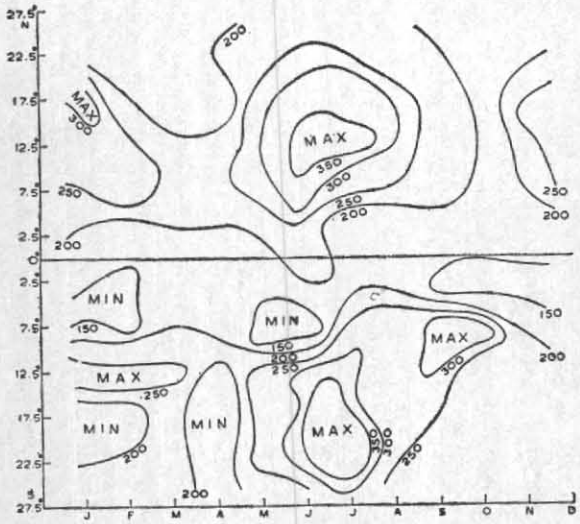

Fig. 1

Meridional distribution of Q_e (cal/cm^2/day) along the block 60-65°E during Jan-Dec 1963

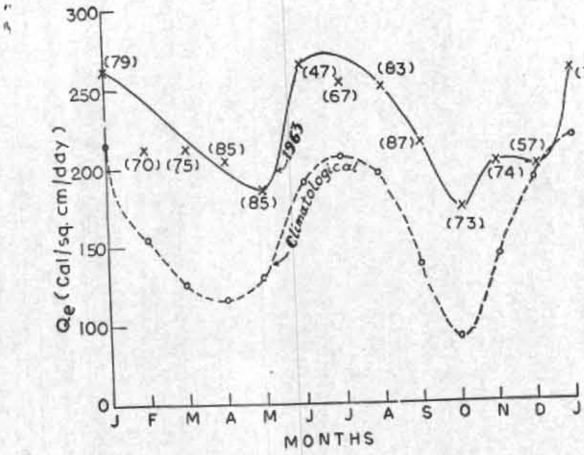

Fig. 2

Monthly variations of Q_e (cal/cm^2/day) for the 5-degree square centred 17·5°N, 72·5°E. Numbers in brackets indicate the number of observations on which the averages are based for the 5-degree block

in evaporation for the block centred at 17·5°N and 72·5°E in the Arabian Sea for 1963 as well as its comparison against normal evaporation in the same block.

Year to year variations in all the energy exchange parameters are well known in other oceanic areas. These variations may be due to the variations in the atmospheric general circulation features over the sea areas. In order to examine this aspect further over the Indian Ocean for our study, the average scalar wind speed distribution for the representative months of 1963 were compared with the climatologically derived values. The comparison indicated that the wind speed during January and July 1963 were generally 5—7 kt stronger than the climatological values whereas they were more or less the same during the other two months. Whereas it may be possible to explain the higher evaporation of January and July 1963 due to the higher wind speed, the higher evaporation in April and October is probably due to the variation from the mean of the other two factors controlling evaporation, *i.e.*, humidity content of the surface and air-sea temperature difference. Jagannathan and Ramasastry (1964) have also found somewhat higher values for evaporation in specified zones of the Arabian Sea and the Bay of Bengal as compared to the values of Venkateswaran. Though they could not attribute this to any definite change of the climate during the recent years, it only showed that large variations from year to year could occur. Comparing the charts of the present study with those of Venkateswaran we find that our values are about 20—30 per cent higher even though the constant K used by us is about 20 per cent lower. The feature being common to both the climatic data as well as for 1963 suggests that the difference may be due to longer period averaging (three months) done by Venkateswaran.

REFERENCES

Deacon, E. L. 1962 *J. geophys. Res.*, **67**, pp. 3167-3172.

Deacon, E. L. and Webb, E. K. 1962 Small scale interactions in 'The Sea', **1**, pp. 43-87.

Jacobs, W. C. 1951 Large scale aspects of the energy transformation over the oceans, *Compendium of Meteorology*, pp. 1057-1069

Jagannathan, P. and Ramasastry, A. A. 1964 *J. geophys. Res.*, **69**, pp. 215-222.

Pisharoty, P. R. 1965 Evaporation from the Arabian Sea and the Indian southwest monsoon, Symp. Meteorological Results of the IIOE, Bombay.

Privett, D. W. 1959 The exchange of energy between the atmosphere and the Oceans of the Southern Hemisphere, *Geophys. Mem.*, 104

REFERENCES (contd)

Roden, G. I. 1959 *J. mar. Res.*, **18**, pp. 36-61.

Sheppard, P. A. 1958 *Quart. J.R. Met. Soc.*, **84**, pp. 205-224.

1963 Momentum and other exchanges above a water surface. Proc. IUGG General Assembly, Berkeley. Publ. IAMAP No. 13, 117.

Sverdrup, H. U. 1951 Evaporation from the Oceans, *Compendium of Meteorology*, pp. 1071-1081.

Tabata, S. 1958 *J. Fish Res. B. Can.*, **15**, pp. 429-451.

Venkateswaran, S. V. 1956 *Indian J. Met. Geophys.*, **7**, pp. 266-283.