551.585.1 : 551.461.2

Relation between moisture transported across the equator and the west coast of the Peninsula during the southwest monsoon season

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ABSTRACT. Pisharoty's (1965) viewpoint has been examined and it is shown that evaporation from the Arabian Sea cannot explain double or more moisture (as deduced from flux computations) on the west coast of India when compared with that at the equator; it is observed on the basis of IIOE results that marked changes in the moisture content occur only within 200—300 miles of the coast and this can be understood according to the mechanism proposed by Desai (1965) taking role of the Western Ghats in converting the characteristic air mass stratification over the Arabian Sea into a more or less homogeneous air mass over the Peninsula.

1. Introduction

In the absence of upper air data over the Arabian Sea, it has been hitherto considered on the basis of ships' observations and the surface and upper air data over the Indian subcontinent and neighbouring areas that the monsoon current (the deflected southeast trades) is about 5·0 km deep. The dryness near the equator at Lat. 73°E was explained on the basis that the air will pick up sufficient moisture during its long travel over sea before entering India (Simpson 1921, Desai 1965). The IIOE observations during 1963 and 1964 have shown that the depth of the deflected trades is only about 5000 feet and higher up there is relatively drier unstable air probably from northeast Africa and Arabia side with an inversion between the two air masses (Colon 1963, Desai 1965) although over the Peninsula the depth of the moist current is about 5·0 km and the air mass is more or less homogeneous (Desai 1965).

Pisharoty (1965) has put forward the view that the high moisture content at all levels over the west coast of India when compared with the moisture values at the equator is probably due to contribution of water vapour through evaporation from (1) the Arabian Sea (significant contribution) and (2) droplets associated with breaking waves (appreciable contribution). The author considers that Pisharoty's viewpoint is based on inadequate appreciation of the facts of Indian weather, climatology and topography and a detailed discussion of the various points mentioned by him is given in this note.

2. Results and Discussion

Pisharoty (1965) has argued that as the air mass over the equator as well as over the west coast of the Arabian Sea bordering the Arabian desert is relatively dry, the main supply of the precipitable water for the monsoon has to be necessarily derived through evaporation from the Arabian Sea. He has made estimate of this evaporation by computing water vapour fluxes across the vertical walls of nearly rectangular box — Arabian Sea as its bottom, 450-mb level as its top, and four lateral boundaries— southern along the equator, the western along Long. 42°E, the eastern practically along 75°E and the northern practically along the Lat. 26°N; he has found that during July of 1963 and 1964, flux across the southern boundary was $2\cdot7\times10^4$ and $2\cdot2\times10^4$ million tons respectively of inflow per day, while the flux across the eastern boundary was $5\cdot9\times10^4$ and $5\cdot8\times10^4$ million tons respectively outflow per day. Thus the flux across the west coast of India in both the years is more than double of that across the equator; during strong or weak monsoon spells, the flux across the west coast would be considerably different. To account for these differences in flux across the equator and the west coast of India, Pisharoty calculated evaporation from the entire Arabian Sea and found it to be $1\cdot4\times10^4$ million tons per day, *i.e.*, it was significantly less than the evaporation called for by the flux computation. He has then considered evaporation from droplets associated with breaking waves and concluded that the same makes an appreciable contribution to the total evaporation from the Arabian Sea surface. As mentioned by Pisharoty himself his calculations of evaporation get considerably affected by the value of K which is the most debated element in the evaporation formula; one has, therefore, to conclude that while moisture will certainly be added due to evaporation from the Arabian Sea, one cannot be sure of its extent in view of a number of assumptions involved in the computations of the same.

In Table 1 are given data of moisture taken from Colon's paper (1963) for Arabian Sea and from Pisharoty's paper (1965) for the equator and for Bombay, Minicoy and Gan.

TABLE 1

Pressure (mb)	1*	2	3	4	5	6	7	8	9
1000	17·0	16·0	18·0	16·5	16·3	19·2	21·2	19·0	17·2
950	14·0	11·5	12·0	14·0	15·0	17·0	17·7	18·0	16·0
900	12·0	8·5	8·5	10·5	13·8	10·5	12·0	15·0	14·0
850	10·0	6·5	6·5	7·5	10·5	8·8	6·7	13·4	11·0
800	8·4	3·4	4·0	5·0	6·8	7·0	6·5	11·8	9·6
750	7·0	3·3	2·2	4·2	3·8	6·5	5·7	10·5	8·0
700	5·3	3·0	1·3	3·0	2·0	4·8	3·5	8·5	7·5
600	3·7	1·3		2·0	1·0	3·3	2·0	7·0	6·2
550	2·4							6·1	
500	2·0							5·4	

Note — Data in columns 1, 2, 3, 8 and 9 are taken from curves in Pisharoty's paper and those in columns 4, 5, 6 and 7 from curves in Colon's paper

*	Position	Date	Time GMT
1	Gan	July 64	1200
2	00° 00′N, 49° 20′E	29-6-63	0923
3	00° 02′N, 44° 36′E	29-6-63	1040
4	00·4°N, 45·3°E	1-7-63	0747
5	04·7°N, 48·7°E	1-7-63	0915
6	13·7°N, 56·9°E	2-7-63	0925
7	18·6°N, 63·5°E	2-7-63	1131
8	Bombay	July 64	1200
9	Minicoy	July 64	1200

It may be stated on the basis of moisture data in columns 1, 2, 3 and 4 that moisture differences at the equator upto about 900 mb are not so large at all the places, and higher up air is relatively drier at Long. 49° 36′, 45·3° and 44° 36′E, but further east at Gan there is not such marked dryness. Again if one compares data in columns 1 and 9 at Gan and Minicoy respectively, it will be seen that moisture at Gan is only 1 to 3 gm/kgm lower than at Minicoy. As shown by Desai (1965), Gan has more moisture than at stations at the equator to the west of Long. 50°E because of the presence of the trough just to the south of the equator between Long. 58° and 110°E. Pisharoty's statement for dryness of the air at the equator holds good only for stations west of Long. 50°E and that too only above about 900 mb.

What has been stated above for stations at the equator west of Long. 50°E also holds good for air masses off the African and Arabian coast as will be seen from data of moisture given in columns 5, 6 and 7 of Table 1. Further on comparing data at 900, 800, 700 and 600 mb in columns 4, 5, 6 and 7 it will appear that moisture differences at different places are not large and regular inspite of distances between different locations, which would indicate that length of travel does not appreciably change the moisture content (Desai 1965); thus one cannot with confidence make calculations regarding evaporation from the Arabian Sea during travel eastwards of air from the east coast of Africa and Arabia to about Long. 68°E or so. Pisharoty's explanation of associating dryness at the equator as being due to divergence there cannot be accepted as relative dryness above about 850 mb is also noticed in latitudes as far north as 18·6° (columns 5, 6 and 7); as stated by Desai (1965) the differences in moisture content below and above about 850 mb are due to differences in air masses — deflected southeast trades in the lower levels and westerly air from Africa and Arabia side higher up with an inversion or isothermal layer between the two air masses and not due to subsidence.

On comparing level for level data above 950 mb for the Arabian Sea in columns 5, 6 and 7 with those for Bombay and Minicoy in columns 8 and 9 respectively it is clear that at both the latter stations moisture is considerably more than at locations west of Long. 70°E. The question thus arises — what is responsible for the increase in moisture content within about 300 miles of the west coast of the Peninsula? Desai (1965) has stated that as a result of the barrier of the Western Ghats across the path of the monsoon current, the air is forced to rise within 200—300 miles of the coast and strong convection currents are set up leading to formation of large *Cu* and *Cb* clouds and precipitation and mixing of air due to *Cu* and *Cb* activity, thus raising the moisture content of the drier westerly current at all levels; this process gives rise to a more or less homogeneous air mass over the Peninsula with much higher moisture content at all levels upto 5·0 km or so when compared with places to the west of about Long. 68°E. The mechanism suggested by Desai (1965) would show that most of the additional moisture at all levels is that which is convected up from the lower 5000 feet or so, *i.e.*, the deflected trades due to their forced ascent because of the barrier of the Western Ghats; thus most of the moisture over the west coast is from the deflected trades increased in all levels due to forced ascent of air in the lower 5000 feet within 200 to 300 miles of the coast and not due to evaporation from the Arabian Sea as presumed by Pisharoty.

In point (6) of his paper Pisharoty has stated on the basis of the streamlines chart at 3 km for July that the Arabian Sea branch of the Indian southwest monsoon appears to be primarily a northern hemispheric trade wind system blowing from the equator northeastwards into Peninsular India, rather than the deflected southeast trades of the southern hemisphere. This is not justified as far as the layer about 1·5 km deep above the sea surface (deflected trades from the southern hemisphere) is concerned because it acts as a reservoir from which moisture can be convected upwards, the moisture content of the drier westerly current (above about 1·5 km) which is of northern hemispheric origin, getting considerably raised according to the mechanism of the southwest monsoon suggested by Desai (1965). Further, it is the experience of the Indian Meteorologists that during the periods of weak or break monsoon conditions, the flow of air across the equator from the southern hemisphere towards the west coast of India is either weak or practically absent and the northern hemispheric air is there right from the surface as in May. Thus it has to be recognised that the layer above sea surface about 1·5 km deep (deflected trades) acting as a reservoir is most important for getting precipitation on the west coast of the Peninsula.

It is stated in point (7) at the end of the paper that events occurring in the northern hemisphere leading to a strengthening of the winds over the Arabian Sea beyond a critical value, might help to obtain a greater insight into the vagaries of the monsoon activity over Peninsular India. While realising significance of events in the northern hemisphere for layers above 1·5 km one cannot disregard significance of events in the southern hemisphere for the layers below that height because without adequate flow of the deflected trades across the equator towards the west coast, the monsoon rainfall would be unsatisfactory. Regarding the strengthening of the winds beyond a critical or optimum value, it has to be stated that inspite of the winds being stronger than usual, rainfall has been below normal or even scanty in some years; hence the statement by Indian Meteorologists "strong winds, little rain".

It is relevant to refer here to the latest paper of Pisharoty (1966) regarding "The Southwest Monsoon — Some Recent Concepts". He has speculated "If due to some reason or other, an extensive patch of warm water moves over into the Arabian Sea, into an area of strong winds off the Somalia coast, the increased evaporation over that extensive patch, may give rise to a shallow low pressure area, which may be advected to the west coast of India and increase the rainfall activity there". While the role of sea surface temperature on the evaporation is important, it has to be stated that even according to Pisharoty's own remarks, the evaporation values are considerably affected by the value of K which one uses in the computations. It is considered that if we accept the fact of observation that the presence of the deflected trades about 1·5 km deep is essential for rainfall over the west coast of India because in their absence we do not get rain as in May or break periods, one would not have to make speculations for which one cannot give valid reasons.

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