LETTER TO THE EDITOR

On the instantaneous distribution of vertical velocity in the monsoon field and structure of the monsoon circulation.

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1. Introduction

In a paper published in this Journal on the subject, Saha (1968) has made various statements which would not appear tenable in the light of facts of topography and climatology as well as of observations on 7 July, 1963, the day selected by him for his study. It is proposed to draw attention in this note to some of the important points.

2. Discussion

I. *Figs. 2a, b and c of distribution of vertical velocity*

(*a*) There was widespread orographic rain on the west coast of the Peninsula. Yet ascending motion is seen only at 850 mb (Fig. 2 *a*); there is little ascending motion at 700 mb (Fig. 2 *b*) and there was actually descending motion over the coast south of 17° N at 500 mb (Fig. 2 *c*).

(*b*) There were soundings over the northeast Arabian Sea on 7 July, 1963 near 23° N, 68° E and 20° N, 70° E (Desai, 1967). Over these two locations ascending motion is seen both at 850 (Fig. 2 *a*) and 500 mb (Fig. 2 *c*) levels and descending motion at 700 mb level (Fig. 2 *b*).

The sounding data at 23° N, 68° E showed an inversion from 942 to 850 mb; there was dry air with adiabatic lapse from 850 to 586 mb and dry air with nearly saturation adiabatic lapse from 586 to 500 mb. Thus ascending motion at 850 and 500 mb (Fig. 2 *a* and *e*) would not be supported by the sounding data.

The sounding data at 20° N, 70° E showed (i) lapse rate between dry and saturation adiabatic with high humidity from surface to 716 mb, (ii) nearly isothermal layer with 90 to 100% humidity from 716 to 629 mb. (iii) nearly dry adiabatic lapse with high humidity from 629 to 574 mb, (iv) nearly saturation adiabatic lapse with humidity decreasing with height from 574 to 531 mb, and (v) isothermal layer with high humidity from 536 to 500 mb.

In view of the above descending motion at 700 mb (Fig. 2 *b*) was unlikely. The synoptic charts show that there was ascending motion at 20° N, 70° E due to convergence zones nearby.

Saha's view is that the low-level inversion over the Arabian Sea is due to subsidence. It is considered that the same is an airmass one (Desai, 1970 *a*, *b*) as over other parts of the Arabian Sea.

At 20° N, 70° E there was also the same type of airmass stratification as at 23° N, 68° E i.e. cool moist air in the surface layers and dry unstable continental air above, but the same was disturbed due to presence of convergence zones nearby at different levels and the low-level inversion was destroyed. The dry air was cooled and humidified by rain falling through it; Veraval near 20° N, 70° E had 4 cm rain between the 7th and 8th mornings.

From the above discussion it would appear that vertical velocity patterns of Saha are not suppported by the rainfall over the west coast and available soundings over the northeast Arabian Sea in all the cases.

II. *Fig. 8 regarding distribution of absolute vorticity at 850 mb and 24 hr rainfall between 7th and 8th mornings and Fig. 9 of July normal rainfall*

From a study of synoptic charts during the monsoon season, it is seen that patterns of circulation and associated rainfall are significantly different from day to day. The normal July rainfall given in Fig. 9 is a mean based on days of little rain and copious rain besides rainfall of days when it was about the same as normal. The authors have given in their papers under publication in the *Indian Journal of Meteorology and Geophysics* contour patterns at 500 mb level from 26 June to 10 July, 1963 and for 850 and 500 mb levels for 26 June, and 1 and 10 July, 1963, 4 and 5 July, 1962 and 12 and 13 August, 1964 with 24 hour rainfall on 850 mb level contour chart; it is seen from those charts that circulation patterns and associated rainfall varied significantly from day to day.

Miller & Keshavamurthy (1967) have given divergence patterns for 700 and 500 mb level respectively in their Figs. 43 *B* and *C* for July, Figs. 31 *B* and *C* for 2 July, 1963, and composited Figs. 43 *B* and *D* for 2, 4 and 7 July, 1963. Examination of their divergence patterns shows how different they are when taken for a single day, for 3 days together and for the whole month; the associated rainfall distribution for the cases was also different as seen from our study.

It would thus appear that it is not advisable to draw conclusions about monsoon circulation from analysis for a single day as done by Saha.

III. *Transport of air across the equator*

The transport of air across the equator in the western Indian Ocean during the northern summer monsoon iv very large. It is seen from the computed values of meridional transport across the equator between longitudes 35 and 75° E in the layer surface to 600 mb during July given in Table 1 of Findlater (1969 *b*) that 7.68×10^{12} metric tons of air is transported per day, this value being nearly half of the total transport across the *whole* equator; the bulk of the transport takes place between longitudes 38 and 45° E as seen from Fig. 2 of Findlater (1969 *b*), the maximum being between 950 and 750 mb or in the layer 0.6 to 2.4 km in which the low-level southerly jet occurs (Findlater, 1969 *a*, Figs. 10 and 11).

The cross-equatorial flow west of about 60° E constitutes the Arabian Sea monsoon current (Desai, 1967, 1968; Rao & Desai, 1969, 1970) and its depth increases to about 6.0 km over the Peninsula. The moist air which crosses the Peninsula constitutes the bulk of the Bay monsoon current north of about 10° N, only a small portion of the southern hemisphere air entering the Bay south of 10° N either from the south Arabian Sea side or directly across the equator east of 60° E.

IV. *The westerly and easterly jet-streams*

The westerly and easterly jet streams would not appear a part of the monsoon circulation below about 500 mb (Desai, 1969; Rao & Desai, 1970). The warm anticyclone over Tibet in the upper levels develops independently of the trough over the Gangetic Valley in the lower levels and which is of dynamic origin although the flow of moist air from across the equator is influenced by the heat-low over northwest of the Indian subcontinent. In fact one would be justified in considering 600–500 mb layer as transition layer in the mean between the lower monsoon and the upper easterly circulations as far as the Indian summer monsoon area is concerned.

3. Concluding remarks

From the foregoing discussion it would appear that it is not correct to base model of monsoon circulation on a single day's data as there are ordinarily significant day-to-day variations in the circulation patterns and the associated rainfall over the subcontinent. With an open network of stations reporting upper air data over land and only a few reports from the sea areas, the vertical velocity computations will not help to explain or forecast rainfall satisfactorily over different areas. The low-level inversion over the Arabian Sea is an airmass one and not due to subsidence. The monsoon circulation upto about 600 mb and the easterly circulation above 500 mb can develop independently, there being no cause-effect relation between the two. The massive flow of air across the equator between about 38 and 45° E in the levels upto about 600 mb is considered vital for setting up the monsoon circulation over the Indian subcontinent. The monsoon trough over the Gangetic Valley is produced as a result of influence of topographical features of the subcontinent on the air flow, the Indian summer monsoon being peculiar in this respect when compared with monsoons in other parts of the world.

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