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A critical examination of the streamlines charts and conclusions of Dixit and Jones on (a) active and (b) weak monsoon conditions

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ABSTRACT. A critical examination has been made of the report of Dixit and Jones and it is shown that neither their drawings nor their conclusions regarding (*i*) the structure of the two cyclonic cells (the Gujarat low and the monsoon low) and the precipitation associated with them and (*ii*) the difference in the characteristics of the subtropical and subequatorial ridges can be accepted.

1. Introduction

Dixit and Jones (1965) have made a kinematic and dynamical study of active and weak monsoon conditions over India during June and July 1964. They have concluded that when the monsoon is active there are two distinct cyclonic cells, the eastern one called the monsoon low and the western one the Gujarat low; the former generally extends from surface upwards and is warm-cored, while the latter extends only from about 850 mb upwards and is cold-cored. It is stated that the Gujarat low at times descends right to the surface and can also change into a warm-core tropical depression or cyclone. Further, the Gujarat low is most effective in producing rainfall over Gujarat and much of the west coast, although hitherto it has not been generally recognised as a precipitation producing system distinct from the more persistent monsoon low of east central India.

According to Dixit and Jones weak monsoon conditions are characterised by a mid-tropospheric cold-core ridge over south and central India and that it is usually associated with a cold-core mid-tropospheric cyclonic cell over extreme south India and Ceylon. They have also stated that during such periods, the dual-cell monsoon trough is either absent over India or one cell is displaced to the northwest and the other to the northeast. Further, the sequence of events for the typical break situation can be characterised by a westward extension of the normal 500 mb easterlies over the south China Sea area into the Bay of Bengal and southeast India; for more marked breaks, these easterlies work downwards replacing the normal strong westerlies of the 700 and 850 mb levels between 10° and 17°N.

In what follows it is proposed to examine the streamlines charts and conclusions of Dixit and Jones with a view to see if the same can be accepted.

2. Discussion

(*a*) *Active monsoon conditions*

(*i*) *Cyclonic cells* — Dixit and Jones have selected 30 June 1964 to represent active monsoon conditions. In Figs. 1, 2 and 3 are given 12 GMT data of available upper winds (direction E as 09, S as 18, W as 27 and N as 36 and speed in knots in two figures) and temperatures (in degrees C to the 1st place of decimal) for 850, 700 and 500 mb respectively; in 850-mb level chart rainfall amounts of 1 cm and more between 03 GMT of 30 June and 1 July and the position of the trough axis at the surface at 12 GMT (broken line) are also indicated. Approximate positions of airmasses partitions and trough axis at different levels are indicated by broken lines and streamflow has been shown taking them into consideration. For comparative purposes, charts of Dixit and Jones given in Figs. 1 and 2 of their paper for 850 and 500 mb have been reproduced as Figs. 1(a) and 3(a) respectively. They have not given charts for 700 mb although in Fig. 15 of their paper, centres for 700 mb have been given; data of Fig. 15 have been given in Table 1. The positions of the centres and the temperatures given in Table 1 according to Dixit and Jones, are also indicated in a circle by a cross (x) and in whole degrees C respectively in Figs. 1, 2 and 3.

From the 03 GMT charts for June of the Bombay Regional Centre it is seen that the seasonal heat-low was well marked over West Pakistan and the trough of low pressure extended to the Orissa—West Bengal coast, there being a closed cyclonic circulation in it near 23°N, 84°E; the circulation in connection with the low extended

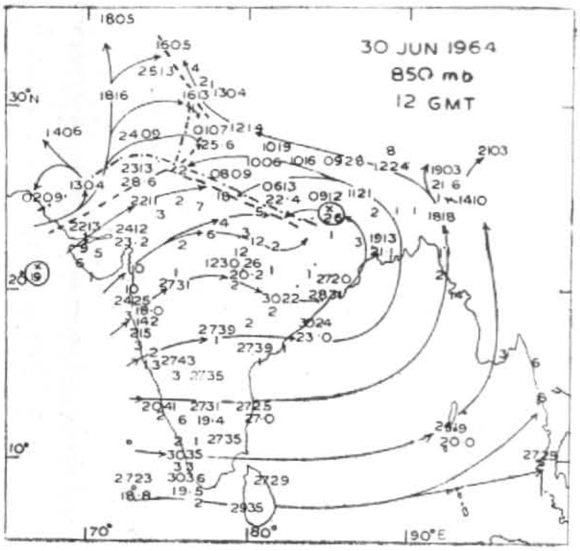

Fig. 1

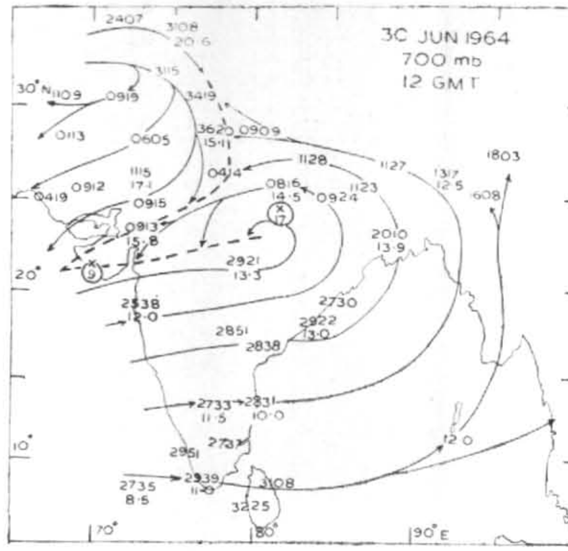

Fig. 2

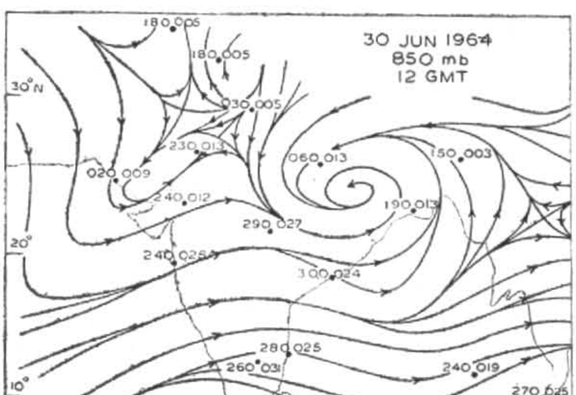

Fig. 1 (a)

TABLE 1

Level (mb)	Centre	Gujarat low				Centre	Monsoon low			
		1	2	3	4		1	2	3	4
500	21°N, 70°E	4·96	328·1	—4·0	+1·7	24°N, 82°E	3·44	326·9	—5·0	—1·0
700	21°N, 70°E	4·93	312·4	+ 9·0	+2·5	24°N, 82°E	3·67	321·3	+17·0	—1·0
850	21°N, 67°E	3·84	306·0	+19·0	+2·0	24°N, 85°E	3·89	313·4	+26·0	—1·0
Surface	—	—	—	—	—	23·5°N, 85°E	6·00	—	—	—

Note — Columns 1 — Relative vorticity in units of 10^{-5} sec. $^{-1}$;

2 — Potential temp. in °K;

3 — Temp. °C;

4 — Gradient of temp. in °C per 100 km.

\+ Sign : temp. increasing outward and — sign : temp. decreasing outward.

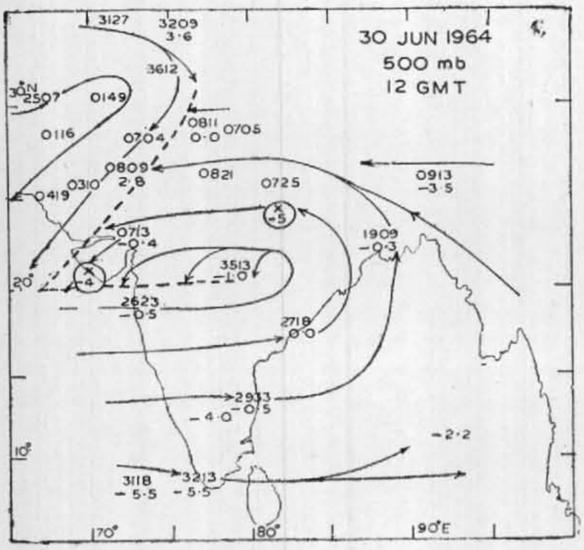

Fig. 3

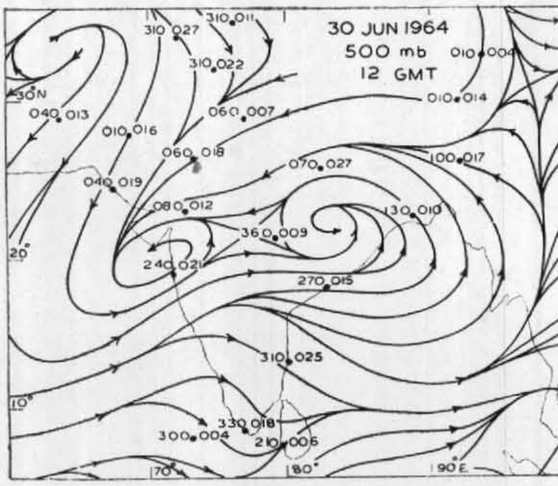

Fig. 3(a)

to about 6·0 km as seen from 00 GMT upper winds. This development was presumably associated with the eastern end of the seasonal trough being activated due to the passage of a low pressure wave from the east across upper Burma and the strengthening of the Bay monsoon after the 27th as judged from the rainfall on the Burma coast, the Arabian Sea monsoon having also strengthened at the same time on the Konkan coast. The monsoon was strong in the central Arabian Sea and the central and north Bay and widespread and locally heavy rain had fallen on the west coast between 17° and 23°N and on the Burma coast between Tavoy and Akyab between 03 GMT of the 29th and 30th; widespread rain with locally heavy falls had also occurred over the area from East Pakistan to northwest Orissa and east central Madhya Pradesh.

Surface — At 12 GMT of the 30th the surface centre of the low referred to above was near 23·5 °N 84°E (Fig. 1— in which surface trough axis from the centre is shown), *i.e.*, about a degree west of the centre given in Table 1. The heat-low continued to be over West Pakistan, the lowest pressure (M.S.L.) being 986·2 mb at Jacobabad.

850 mb — According to Fig. 1(a) and Table 1 there are two cells. From Fig. 1 it will be seen that there was *no* Gujarat low at all. For the other low, the available winds do not justify the centre at 24°N, 85°E; it might be near 23°N, 83°E, *i.e.*, near Ambikapur (Fig. 1).

In Table 1 the centre of the Gujarat low is given as 21°N, 67°E, while according to Fig. 1(a) there will not be any low at that location; even if the drawings in Fig. 1(a) are accepted, the centre of the so called Gujarat low would be only near 25°N, 70°E. Thus there is inconsistency in the centre of the Gujarat low in Fig. 1 (a) and Table 1.

On comparing Figs. 1 and 1 (a) it will be seen that Chhor and Jacobabad winds are not plotted in the latter; these two winds are against the streamlines over the area. Bikaner and Lahore winds (Fig. 1) which are not given in Fig. 1(a), are also against their streamlines. There might be a weak circulation with central region near 25°N, 69°E.

700 mb — According to Table 1, the centres of the Gujarat low and the monsoon low are at 21°N, 70°E and 24°N and 82°E respectively—positions indicated in Fig. 2. However, according to Fig. 2 there are only triple point conditions near 22°N, 68°E; the monsoon low is near 23°N, 81°E, *i.e.*, to the south of Umaria and about two degrees to the southwest of the centre of Dixit and Jones. The triple point conditions (meeting place of three airmasses—Desai 1967 a) have been wrongly taken as centres of depressions by some other workers also (Miller and Keshavamurthy 1965).

500 mb—According to Table 1, the centres of the Gujarat low and monsoon low are near Lat. 21°N, 70°E and 24°N, 82°E respectively; according to Fig. 3(a) the centre of the Gujarat low would appear to be near 20°N, 70°E and of the monsoon low near 22°N, 82°E.

According to Fig. 3, there is *no* Gujarat low; there might be triple point conditions near Lat. 20°N, 67°E. The monsoon low would appear to be near 21°N, 81°E.

On comparing the winds in Figs. 3 and 3(a) and from the *Indian Daily Weather Reports* it is seen that Dixit and Jones have given in the latter figure, wind directions for 6·0 km on 500 mb chart instead of for 5·4 km for some of the stations, *e.g.*, Calcutta, Delhi, Srinagar and Madras; for Quetta the wind direction given by them would appear to be that for 7·2 km.

From the foregoing discussion it will be seen that there is no consistency in all the cases between the centres for different levels given by Dixit and Jones in Figs. 1(a) and 3(a) on the one hand and in Table I (Fig. 15 of their paper) on the other, assuming that there were two lows. *There was actually only one low, i.e., the monsoon low and there was no Gujarat low.* Their streamlines are also not justified in all the cases.

(*ii*) *Temperature distribution in the low*—Dixit and Jones have given temperatures at the centre of the Gujarat and the monsoon lows as well as gradient of temperature in °C per 100 km from the centre outwards at different levels. The nearest stations for the Gujarat low are Ahmedabad and Bombay and for the monsoon low Nagpur, Calcutta and Allahabad. These stations are not sufficiently near the centres given in Table 1 to determine tempertures at and gradient of temperatures from the centres, presuming that both the lows existed. The following additional remarks might also be made regarding the actual values of temperatures at the centres given in Table 1 (also shown in Figs. 1, 2 and 3).

850 mb—The temperature at the centre of the monsoon low is given as 26°C. Temperature at none of the stations around the centres is more than 23°C as seen from Fig. 1. The basis on which higher temperature of 26°C has been taken is not mentioned by Dixit and Jones.

700 mb—Temperatures at the centre of the Gujarat low and the monsoon low have been taken as 9·0°C and 17·0°C respectively. As seen from Fig. 2, the lowest temperature in the area of the Gujarat low is 12·0°C and the highest temperature in the area of the monsoon low is 14·0°C. There is nothing to show that temperature at 21°N, 70°E would be lower by 3·0°C than at Bombay or that temperature at 24°N, 82°E would be higher by 3°C than at Allahabad (Fig. 2).

500 mb—Temperatures at the centre of the Gujarat low and the monsoon low have been taken as —4·0°C and —5·0°C respectively. As seen from Fig. 3 the lowest temperature in the area is —0·5°C at Bombay for the Gujarat low and —1·0°C at Nagpur for the monsoon low; the basis for taking lower temperatures than these values have not been indicated by them.

Dixit and Jones have stated "The respective cold core and warm core characteristics of the Gujarat and monsoon lows are clearly seen from Fig. 15, both with respect to a comparison of assessed central temperatures for each low and to the assessed horizontal temperature gradients about them". In view of what has been stated above one cannot accept their statement. It is also not necessary to discuss the distribution of potential temperatures given in Table 1 in view of the remarks about the estimated temperatures at the centres of the two lows. It would appear that they have presumed the Gujarat low to be cold-cored on the basis of the study of Miller and Keshavamurthy (1965) for the period 1 to 10 July 1963. Desai has examined the day-to-day conditions at different levels for 26 June to 10 July 1963 and shown* that the conclusions of Miller and Keshavamurthy cannot be accepted (also see Desai 1967 a, b).

They have also discussed the monthly mean temperatures at different levels during June and July on the basis of the data in Table 2 of their paper. Dixit and Jones have stated "The cold-core characteristics of the Gujarat low with its location over Gujarat and northeast Arabian Sea, may be attributed to the fact that it is a mid-tropospheric development in the southwesterlies over the Arabian Sea where the temperature decreases equatorward. The monsoon low on the other hand, being located well inland, has in its circulation westerlies (and easterlies) with trajectory over heated land and warm waters of the north Bay of Bengal". From Table 2 of their paper, it is seen that Veraval and Santacruz (Bombay) on the Arabian Sea coast have the same temperatures both in June and July at 850 and 700 mb, but at 500 mb Veraval is colder than Bombay by 2° and 1°C at 500 mb respectively in the two months. Bombay was warmer than Trivandrum at all levels. Lapse rate considerations in different airmasses, particularly near partitions between them, are very important as replacement of one airmass by the other above, *e.g.*, moist monsoon air by drier continental air above certain height, might mean type of temperature distribution noticed by Miller and Keshavamurthy (1965), *i.e.*, cold-core at 700 mb, neutral temperature field at 600 mb and warm-core at 500 mb (Desai 1967 a, b); it is not because the low near Bombay was a mid-tropospheric development considered by these workers that particular type of temperature distribution was noticed.

*Paper under publication

It is also seen from the same Table 2 that during both June and July, Calcutta was warmer than Port Blair at all levels. This is just as between Bombay and Trivandrum. It has been shown by Desai and Koteswaram (1951) that when fresh cold monsoon air reaches head Bay, one will get even Bay depressions with low temperatures (Desai 1967 a, b) ; when the fresh cold monsoon air gets repalced by warmer air—both westerly and easterly, there is a change in the structure of the depression and rain in the southwest sector begins. The monsoon low structure is of the latter type.

The author has studied* day-to-day synoptic conditions for the period 1 to 10 August 1964 and shown that there was nothing like the changing of the cold-cored Gujarat low into a warm-cored tropical depression or cyclones in the vicinity of Bombay as claimed by Dixit and Jones. That system was of the same type as that between 26 June and 10 July 1963 studied by the author and referred to above.

(*iii*) *Rainfall distribution*—In Figs. 9, 10 and 11 of their paper Dixit and Jones have given rainfall amounts recorded between 03 GMT of 30 June and 1 July 1964 (to represent effect of the conditions at 12 GMT of the 30th) along with vorticity data for 850, 500 and 200-mb levels; the rainfall amounts have also been given in Fig. 1. According to them the Gujarat cell appears to be the real cause for monsoon rainfall along much of the west coast and Gujarat; widespread rain with locally heavy falls on the west coast particularly north of 15°N upto Surat and in Saurashtra was due to the Gujarat low and from west Orissa to east Rajasthan due to the monsoon low. As shown earlier there was *no* Gujarat low. Rainfall on the west coast was mostly due to the Ghats' barrier; widespread and locally heavy rain in Saurashtra and the coast north of Bombay and over the area from west Orissa to east Rajasthan was due to the effect of the trough axis and partitions over the area from the surface to 500 mb including nearness of the triple point and perpendicular action conditions at 700 and 500 mb (Figs. 1, 2 and 3), the rainfall being mostly to the south of the trough axis at the surface as is to be expected. (Desai 1946, 1951, 1953, 1967 a, b; and Desai and Koteswaram 1951). The positions of the airmasses partitions in the upper air can be fixed accurately if there are sufficient upper winds data.

(*iv*) *Effect of divergence and vorticity on rainfall*—Dixit and Jones have stated that in general the computed divergence did *not* fit rainfall in the subsequent period and that the expected configuration of low level convergence superposed by high level divergence for good rainfall region was *not* obtained. The fit of the vorticity charts (Figs. 9, 10 and 11 of their paper) was much better according to them in the sense that a positive association of rainfall with cyclonic vorticity existed. Non-existence of good relation was possibly due to large percentage error in divergence computations; the percentage error in the vorticity computations according to them was much less than that of the divergence. The rainfall distribution, however, fits in well with the effect of the trough axis and airmasses partitions from the surface upto 500-mb level mentioned under (*iii*) above.

Dixit and Jones' statement that relation between the strengthening of the winds along latitudinal belt of west coast and the building up of a Bay depression is not one to one, may mislead forecasters. The place where the depression forms in the Bay is an important point to be considered in this connection. It may also be stated that Petterssen (1948) worked out the zonal index for the two seas, *i.e.*, the Bay of Bengal and the Arabian Sea and it appeared that there was a very high correlation of the two indices; the westerlies in the Arabian Sea most frequently strengthened at the same time as the westerlies in the Bay of Bengal. This happened in the present case after June as stated earlier.

It is also mentioned by Dixit and Jones that the relation between the strengthening of the westerly winds along the west coast and maximum rainfall is also not one to one. This is correct but the causes of it are not difficult to understand. It has been shown by Desai† while presenting results of the analysis of the IIOE data over the Arabian Sea that with the same strength and direction of winds over the coast, there would be more rain on the coast when about 500 km to the west of the coast there is characteristic airmass stratification (deflected trades in lower levels and drier unstable air above with an inversion between the two) than when there is westerly moist air with near saturation lapse rate above the deflected trades upto about 500 mb; if instead, there is westerly air of continental origin in all the levels, there will be little rain on the coast.

(*b*) *Weak monsoon conditions*

Dixit and Jones have selected 15 and 7 July 1964 to represent weak monsoon conditions. In Figs. 4, 5 and 6 are given details for 12 GMT for the 15th for 850, 700 and 500-mb levels and surface trough axis and rainfall recorded between the 15th and 16th mornings as in Figs. 1, 2 and 3; in Fig. 7 are given data for 500-mb level and rain-

*Three papers under publication

†Paper under publication in the National Institutes of Sciences of India

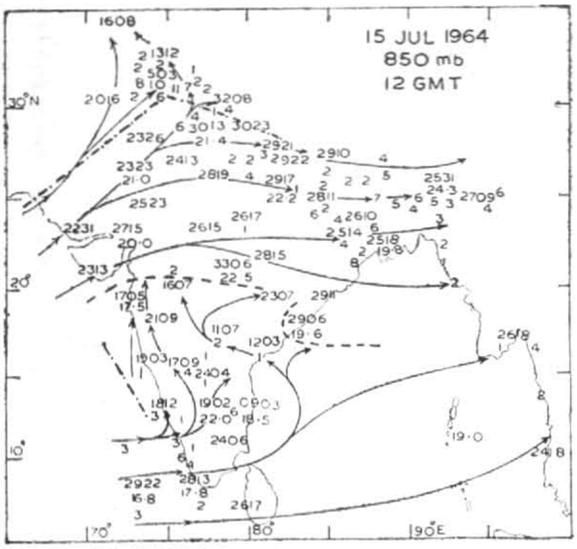

Fig. 4

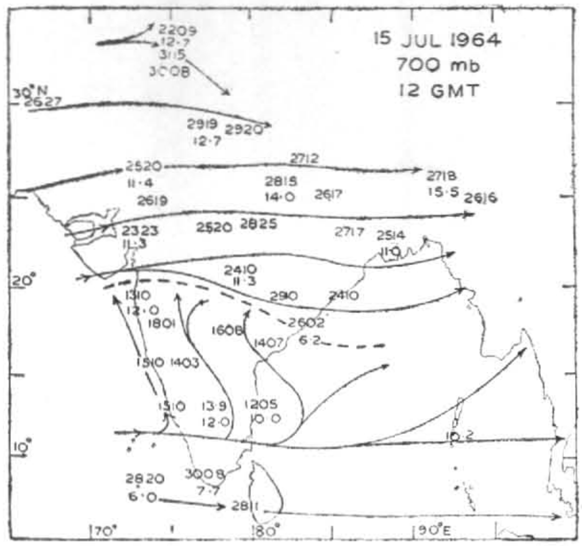

Fig. 5

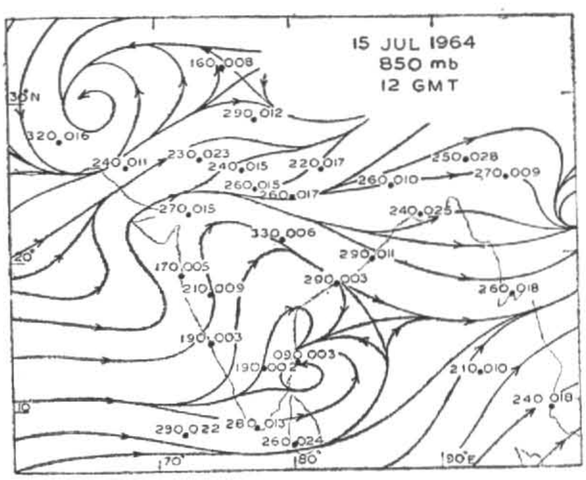

Fig. 4(a)

fall (in cm) recorded between 03 GMT of the 7th and 8th. Their Figs. 5 and 6 for 850 and 500 mb for 12 GMT of the 15th are given in Figs. 4 (a) and 6(a) respectively and their Fig. 7 for 500 mb in Fig. 7(a) for comparative purposes.

As seen from charts prepared by Bombay Regional Centre and mentioned in the active monsoon case discussed earlier, widespread rain with locally heavy falls occurred on the west coast between 30 June and 1 July mornings. Such conditions continued on the west coast upto the 13th morning with waxing and waning occasionally; rainfall on the west coast between the mornings of the 8th and 9th was the lowest of the period 1st to 13th in 24 hours. The monsoon low mentioned on 30 June moved northwestwards and merged into the seasonal trough on the 3rd. With the monsoon continuing moderate to strong in both the east Arabian Sea and the Bay of Bengal, a depression formed at the head Bay by the 3rd morning. Moving northwestwards and weakening at the same time, it lay near Agra on the 7th morning and merged into the seasonal low by the next morning. The Bay monsoon, however, weakened after the 5th. The departures of pressure from the normal became relatively high over the Bay between the 5th and the 10th. Thereafter the area of relatively high pressure departures shifted northwards and a trough appeared off the west coast at sea level between the 12th and 13th. The rainfall on the west coast between the 13th and 14th mornings was much less to the

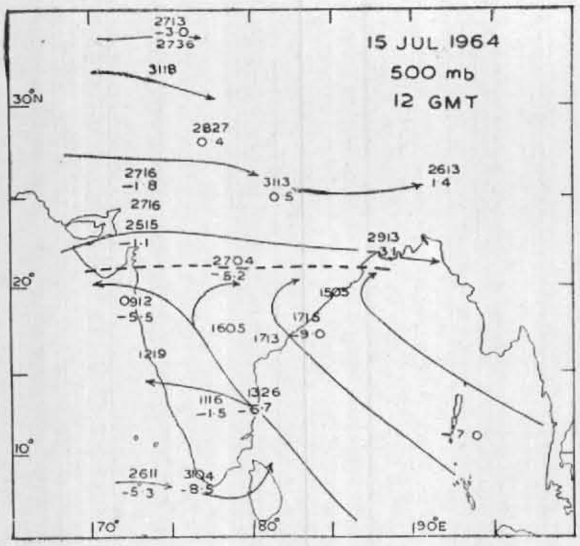

Fig. 6

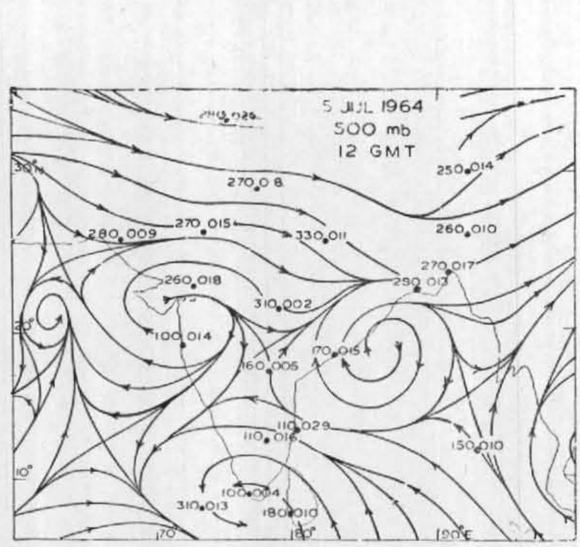

Fig. 6(a)

north of 12°N than in the previous 24 hrs. The sea level trough off the west coast persisted till the 14th evening after which it extended upwards and was noticeable even at 850 mb and 700 mb at 12 GMT of the 15th (Figs. 4 and 5). With the E'ly to S'ly winds over the Peninsula, showers began in the interior of the Peninsula. At 03 GMT of the 15th the area of relatively high pressure departures extended from the Arakan coast and the adjoining interior of Burma northwestwards to the west Madhya Pradesh, the same being relatively lowest off the west coast south of 13°N. The conditions for 12 GMT of the 15th may now be discussed.

850 mb — On comparing Figs. 4 and 4(a) it would be seen that in the latter, Dixit and Jones have not given winds of Gannavaram (16·5°N, 81°E), Hyderabad, Anantpur, Gadag, Chikalthana and Veraval; winds of Veraval, Hyderabad and Gannavaram are against the streamlines in Fig. 4(a). The main feature of this chart is the weak wind field over the Peninsula with little westerly component and trough off the west coast between 10° and 20°N.

700 mb — The conditions at this level were about the same as at 850 mb as will be seen by comparing Figs. 4 and 5.

500 *mb* — The trough is over the south of the Peninsula, the winds over the Bay south of 18°N being mainly SE'ly (Fig. 6). On comparing this figure with Fig. 6(a) from Dixit and Jones' paper it will be seen that the winds of Gopalpur and Vengurla which are not given in the latter figure, are against their streamlines.

It is also seen from the *Indian Daily Weather Reports* that Nagpur, Ahmedabad, Trivandrum and Minicoy winds in Fig. 6 (a) are for 6·0 km and not for 5·4 km; one is not justified to plot both 5·4 and 6·0 km winds on the 500-mb level chart.

The streamlines over the Bay between 15° and 20°N and over the northwest of the Peninsula and Saurashtra cannot also be accepted.

It will be seen from Figs. 6 and 6 (a) that there is nothing to show that the two cells (the Gujarat low and the monsoon low) had merged into one over Rajasthan and its moving away westward or northward. Further, from Figs. 4, 5 and 6 it cannot be said that the trough off the west coast upto 700 mb and over the south of the Peninsula at 500 mb had developed as a result of the establishment of the mid-tropospheric ridge over central India. The correct position would appear to be somewhat as follows.

The monsoon being weak, the seasonal trough of low pressure over the Gangetic Valley and the associated easterly flow was absent; the pressure departures also become above normal over the area and further south, a condition opposite to that when the monsoon is active or strong. When the monsoon is weak and with it the westerly flow, the easterlies from the south China Sea side begin to extend into the Bay (Fig. 6). The easterly flow occurs first in higher levels and later in the lower levels as normally the westerly wind flow is stronger in the lower than in the higher levels. Thus the change of winds when strong monsoon conditions are replaced by weak monsoon

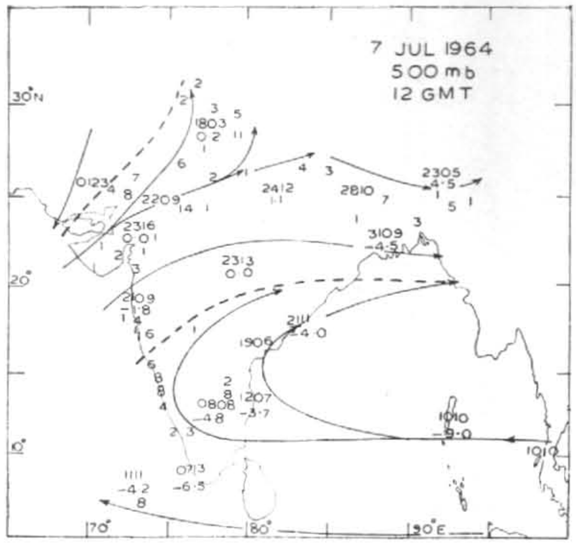

Fig. 7

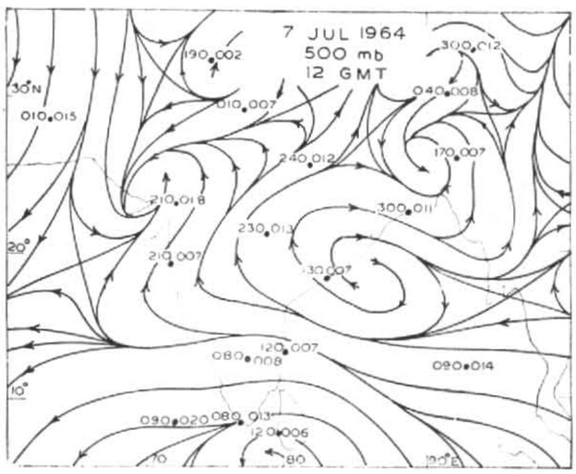

Fig. 7(a)

conditions is not difficult to understand. The easterly flow over the Peninsula at 850 and 700 mb in Figs. 4 and 5 was not from the China Sea side.

Regarding the rainfall amounts recorded between the 15th and 16th mornings given in Fig. 4, the following remarks will be relevant —

The trough of low pressure over the Gangetic Valley began to weaken after the 12th and with it the easterly flow from the upper to the lower levels over the area, the westerly winds replacing the easterlies at the same time, the process being completed last at the surface; the moist westerly winds from the Arabian Sea side also strike the orographic barrier of the Himalayas in such situations. With this type of distribution instability conditions also develop due to moist air in the lower levels and drier unstable air in the upper levels. Under such conditions, widespread and locally heavy rain accompanied by thunderstorms occurs over the area from the east Punjab to Assam, rainfall spreading from west to east. When the monsoon is weak showers also occur in the interior of the Peninsula, there being E'ly to S'ly winds there as it happens in the premonsoon months of April and May. The rainfall on the west coast was mostly due to the barrier of the Ghats.

It is not possible to accept the statement of Dixit and Jones that the surface and the lower trough along 32°N in the extreme north of India in the Punjab resulted in good rainfall in that region. The low at the surface and 850 mb was due to heat and it was over about the same area even on the 14th, 13th and 12th and the easterly flow was also present on those days; the low was not there either at 700 or 500 mb on the 15th as mentioned earlier. Widespread and locally heavy rain occurred in and near the Punjab-Kumaon hills, only with the replacement of the easterly flow over the area by the westerly flow.

500 mb chart for 7 July (Figs. 7 and 7a) may now be discussed. Rainfall recorded between 03 GMT of the 7th and 8th is also given in Fig.7. It can be stated that in spite of the easterly flow south of 15°N over the Bay and the Peninsula at 500 mb, the monsoon was strong on the west coast between Calicut and Devagadh and active further north as seen from rainfall. From the upper winds it is seen that the westerly flow was there even south of 15°N upto 700 mb except in the extreme south where its depth was about 2·0 km. As such, it is not correct to consider this day as of weak monsoon, the strength of the monsoon current had waned on this day and the depth of the westerly moist layer consequently decreased. The rainfall over the Punjab, the Uttar Pradesh, Rajasthan, Saurashtra and Gujarat was associated with the trough axis and the airmasses partitions from the surface upto 500 mb over the area and the low from the Bay which was near Agra on the 7th morning and had merged into the seasonal trough by the 8th as mentioned earlier.

It is also seen on comparing wind data given in Figs. 7 and 7(a) that Gauhati, New Delhi and Visakhapatnam winds in the latter figures are not for 5·4 km; they were for a higher level as seen from the *Indian Daily Weather Reports*. These winds (Fig. 7) do not fit in with the streamlines over those areas given in Fig. 7 (a). There was no low over northwest India; there was only the southern end of partition as seen from Fig. 7. The low over northeast India shown in Fig. 7(a) cannot be accepted in view of Gauhati wind at 500 mb (Fig. 7).

3. Comparison of a monsoon rain with a monsoon lull

In Fig. 16 of their paper Dixit and Jones have given differences of temperatures of 30 June and 15 July 1964 (Temps. on 30th—Temps. on 15th) for 500, 300 and 200 mb. As stated earlier there were active monsoon conditions on the 30th and weak monsoon conditions on the 15th . It is presumably on the basis of this figure that Ramage (1966) has stated "Dixit and Jones (1965) in comparing a monsoon rain with a monsoon lull along the west coast of India located by far the greatest middle and upper tropospheric temperature differences above the heat low, with the rain situation 2°-6°C warmer than the lull situation". The following remarks might be made regarding the statement.

(1) From Figs. 3 and 6 for 500 mb for the 30th June and 15th July respectively, it will be seen that the nature of airmasses over the subcontinent was quite different on the two days. The highest temperatures and differences in temperatures at 500, 300 and 200mb, cannot, therefore, be taken as evidences of subsidence over the heat low as done by Ramage.

(2) On 30 June–1 July there was rain over Kutch Saurashtra and the West coast upto Surat (Fig. 1), while on 15–16 July there was no rain over the area (Fig. 4). The causes of the rainfall on 30 June–1 July and absence of rain on 15–16 July have been given earlier. The highest temperatures and differences in temperatures were over West Pakistan (Fig. 16); from the wind directions at 500 mb over West Pakistan on the 30th (Fig. 3), it can be stated that the latent heat released due to condensation of water vapour over the area of heavy rain, could not have been transported to Baluchistan.

(3) In Table 2 are given differences in temperatures (°C) for different stations at 500, 300 and 200 mb for 12 GMT of 30 June and 15 July taken from the data given in the *Indian Daily Weather Reports* for monsoon rain (30 June) and monsoon lull (15 July) along the west coast of India. The values given in Fig. 16 of Dixit and Jones have also been given in brackets. They have not taken available values for all the stations, not given values for two cases where they are available and given values in five cases where data are available according to the *Indian Daily Weather Reports* only for one of the two days. It will appear from Table 2 that the values given from the *Indian Daily Weather Reports* do not agree with those given from Fig. 16 of Dixit and Jones.

In view of the above considerations Ramage's utilising Fig. 16 of the paper of Dixit and Jones to support his interpretations of the IIOE results and his model for the Arabian Sea monsoon is not justified. In fact Desai (1967 a, b) has shown that most of the interpretations of the IIOE results by Ramage and his models for both the Arabian Sea monsoon (1966) and the Bay of Bengal monsoon (1964) cannot be accepted.

From the above discussions it would appear that the streamlines charts of Dixit and Jones for the active and weak monsoon conditions and their conclusions from the same, cannot be of use to the forecasters.

TABLE 2

Differences in temperatures (°C) for 12 GMT

30 Jun 1964 monsoon rain west coast India *minus* 15 Jul 1964 monsoon lull west coast India

Station	Level		
	500	300	200
Ahmedabad	+0·7	+6·9	+8·4
Allahabad	— (+0·8)	+2·0 (+1·6)	— (+0·3)
Bangalore	—2·5	—1·3	—1·1
Bombay	+5·0 (+1·0)	+9·8 (+3·0)	+2·9 (+0·9)
Calcutta	+2·8 (—0·3)	+0·9 (—0·2)	—2·2 (—0·2)
Gauhati	—4·9 (—0·7)	—7·0 (+1·0)	— (—0·3)
Jodhpur	+4·6 (+3·6)	+1·4 (+4·7)	+5·8 (+5·8)*
Madras	+6·2 (+2·2)	+2·0 (—1·4)	— (+2·3)
Minicoy	—0·2	+4·6	+5·7
Nagpur	+4·2 (+1·9)	+7·9 (+1·6)	+3·9 (+1·0)
New Delhi	—0·4 (+0·6)	— (+3·3)	— (+1·7)
Port Blair	+4·8 (+2·6)	—0·5 (+2·7)	— (+3·9)
Srinagar	+6·6	+4·4	+4·9
Trivandrum	+3·0 (+1·4)	+7·2 (—1·5)*	+4·9 (—0·6)
Visakhapatnam	+9·0 (+3·0)	+4·2 (+3·9)	+1·5 (+4·5)

NOTE — (*i*) *Taken from curves in Fig. 16 of Dixit & Jones

(*ii*) Differences are not given where temperatures for both the days are not available in the *Indian Daily Weather Reports*

4. Concluding Remarks

Dixit and Jones have considered that (1) the monsoon trough has two cyclonic cells which are different in dynamic and thermal structures and (2) the establishment of anti-cyclonic conditions in the mid-troposphere (around 500 mb) over central India (about 23°N) leads to sustained breaks in precipitation over the area. Their suggested model for the active and weak monsoon regimes and qualitative forecast scheme for commencement of "breaks" and re-establishment of active monsoon conditions, are based on the above two considerations. As these are important from the point of forecasters, it is proposed to discuss in brief the same.

Desai (1967 d) has shown that the low over West Pakistan is due to heat and is shallow, while the monsoon trough over the Gangetic Valley which extends southeastwards from near Delhi to the head of the Bay and is joined with the former, is *not due to heat* but due to dynamical causes, the topographical features of the subcontinent playing an important part in its formation; this trough is deep extending to about 500 mb and its axis is displaced equatorwards with height, it being along about 21°N at 3·0 km and 19°N at 6·0 km (Desai 1967 a, d). This trough gives rainfall over the area to the south of the axis at the surface even without a low; its activity waxes and wanes in unison with the strength of the monsoon current. The lows from the Bay move northwestwards along the axis of the trough; lows also develop over land in this trough when low pressure waves move from the east or from the head of the Bay when the monsoon is strong and even without a depression. When the monsoon is weak or there are break conditions, the trough of low pressure is weak and further north of its normal position or it may be even absent, the shallow heat low over West Pakistan however continuing to be present (Desai 1967 a, d) all the time.

The author has examined the day to day synoptic conditions for the periods 26 June to 10 July 1963 and 1 to 10 August 1964 and also discussed synoptic climatology of the Indo-Pakistan subcontinent* and shown that the presence of the Western Ghats and the normal upper winds distribution give rise to lows over the Bombay area at 700 mb and above; the lows appear even below 700 mb and extend to the surface when the monsoon in terms of rainfall is strong or vigorous and a trough develops off the west coast (Desai 1967 a, b). It is also known that in the case of the depressions in the northeast Arabian Sea off the coast, the warmer and drier continental air is involved along with the moist monsoon air. As a result of the differences in the lapse rates in the two airmasses—near dry adiabatic in the continental air and near moist adiabatic in the monsoon air, the former which is warmer at the surface, becomes colder than the latter above a certain level—reversal level. As a result of this peculiar temperature distribution from the surface upto the reversal level, the lows do not appear or are weak in the lower levels; even when the cyclonic circulation appears at the surface, its extent is small as it also happen in the premonsoon depressions and cyclones. When the continental air is colder than the moist air right from the surface, the extent of the cyclonic circulation is large even at the surface as in the post-monsoon depressions and cyclones. In view of the foregoing discussions, it is not correct to compare the so-called Gujarat low with the Kona storm in the eastern Pacific or the cyclones of the western Pacific and Atlantic Oceans with a cyclone near Bombay as the one towards the end of the first week of August, 1964 as done by Dixit and Jones.

During the weak or break monsoon conditions the easterlies to the north of 20°-23°N are absent upto about 500 mb, the trough being also absent and the easterly air is replaced by the westerly air; the troughs in the westerlies also take a more southerly course. Pisharoty and Desai (1956) have mentioned that during July 1964 when there were severe floods in Assam, north Bengal and Bihar, mean monthly upper air contours for 500 mb showed a low to the north of the Himalayas instead of the usual high or the ridge of high. The disappearance of the trough and the appearance of the westerlies over the area of the usual easterlies is due to the weakness of the monsoon current; as a result there comes into existence premonsoon months' circulation over the south Bay of Bengal due to extension of the easterlies of the western Pacific across the south China Sea and southeast Asia and low pressure waves move from east to west across Tenasserim and the south Bay instead of through upper Burma north of 15°N as happens when the monsoon current is active or strong.

*Paper under publication

It is felt that during the southwest monsoon season, the most important factors to be considered are those pertaining to levels upto 500 mb, the factors above that level being not as important. This view would also appear to be supported by the statement of Dixit and Jones 'Figure 8 depict the streamlines analysis for 200-mb level of this particular break situation which differs little from the conditions of 30 June with respect to the generally easterly flow and the position of the upper tropospheric ridge line over the Himalayas, along 30°N'. It has been also shown by Desai (1966, 1967 c) that the partition between the westerlies and easterlies at 9·0 and 12·0 km lies along about 30°N during normal, active or strong and weak monsoon conditions. The differences in the isotach field of 30 June and 15 June for 200 mb, the presence of the middle latitude troughs at 65° and 110°E on 15 July and their absence on 30 June and existence of rather strong westerlies north of 40°N on 30 June and their non-existence on 15 July, are not specially significant from the point of explaining rainfall distribution and systems upto 500 mb. It may also be stated that as shown by Flohn (1965), during the monsoon season there are two troughs in the westerlies one to the west and the other to the east of the Tibetan plateau. The streamlines of Dixit and Jones for 200 mb for 30 June which do not show trough at 65°E cannot be taken seriously as there are no observations between 50° and 75°E and 35° and 50°N; there is evidence in their chart of a trough just to the east of 100°E although they have not taken notice of the same. Absence of strong westerlies north of 40°N on 15 July has no special significance from the point of performance of the monsoon because as stated by Petterssen(1953) the westerly jet which is to the north of about 40°N, is not a part of the monsoon circulation.

Due to inadequate appreciation of the climatic and topographical features of the subcontinent, Dixit and Jones have drawn conclusions which are not tenable as would appear from detailed discussions in this paper of the types associated with the active and weak monsoon conditions mentioned by them.

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