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Case study of a heat wave during July 1966

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ABSTRACT. A heat wave started affecting the southeastern and central parts of India due to a "break" in the southwest monsoon over the country during the first part of July 1966. The heat wave abated when the monsoon revived during the second week of July. Some stations recorded maximum temperatures which surpassed the previous highest maximum temperatures for July. This study deals with the synoptic situation, rainfall distribution and wind circulation over the country during the period of the heat wave. The thermal structure of the lower troposphere during the period of the heat wave has also been studied. It has been concluded that the heat wave was the result of a large defect in rainfall due to the prolonged "break" and the circulation pattern prevailing in the lower tropospheric levels over the central parts of the country during the heat wave period was more or less similar to that of May.

1. Introduction

A moderate heat wave affected the eastern parts of the Indian Peninsula during the first week of July 1966. While the heat wave abated over these areas by the end of the first week, the central parts of the country came under its grip and severe heat wave conditions persisted there during the second week of July, after which they abated. The heat wave was associated with a pronounced "break" in the monsoon which lasted from 2 to 11 July. A heat wave is considered to be "moderate" on occasions when the maximum temperature deviates by 6-7°C above the daily normal and "severe" when it deviates by more than 8°C. While it is not uncommon for maximum temperatures to rise and be appreciably (4-5° C) above normal during "breaks" in the monsoon, heat waves as such are very few in July. According to Raghavan (1966), the incidence of heat waves for the country during July is about 10 per cent of the total heat waves.

The mean monthly maximum temperatures over the region west of India and in north Africa show that they rise till June and remain more or less steady till August, after which they start falling. Over India, on the other hand, the temperatures start falling after May itself, due to the setting of the monsoon during the course of June. But for the monsoon, the maximum temperatures would have started falling only after August, as in the case of stations more to the west. Hence, abnormally high maximum temperatures occurring over major parts of India during July, should be attributed to the absence of the seasonal rains. Appreciably high temperatures over any part of the country during July however do not draw the serious attention of the synoptician, unless these conditions persist for a few days. In the present case, the maximum temperatures over the central parts of the country exceeded the daily normal values by as much as 10-12° C on a few days and surpassed the 40°C mark at many places. A heat wave of this magnitude persisting for more than a week in July has not occurred earlier in the last 70 years. It had also exceeded some of the highest maximum temperatures ever recorded in July, at many places. The study was, therefore, made to find out the probable causes of this unusual heat wave and the synoptic features associated with the same. The results of this investigation are discussed.

2. Synoptic situation

The southwest monsoon covered the entire country except west Rajasthan by the beginning of July 1966. By 30 June 1966, a cyclonic circulation in the extra-tropical westerlies in the upper troposphere moved over to Lake Balkash region (Lat. 45° N and Long. 75°E) and persisted there almost for about a week. A deep trough was seen extending southwards from this circulation on 3 July into the Indian latitudes, which moved away eastwards on 8 July. A low pressure area lying over east Uttar Pradesh on the morning of 30 June gradually moved eastwards across sub-Himalayan West Bengal and north Assam by 3 July. Concurrent with these developments, the axis of the monsoon trough shifted to the foot of the Himalayas and a "break" in the monsoon commenced from 2 July. During this period, rainfall activity over most of the country became very weak except in the northeastern and southeastern parts of the country. A general revival of the monsoon over the country took place after 11 July under the influence of a mid-tropospheric "low" (Koteswaram 1950) moving northwards along the west coast.

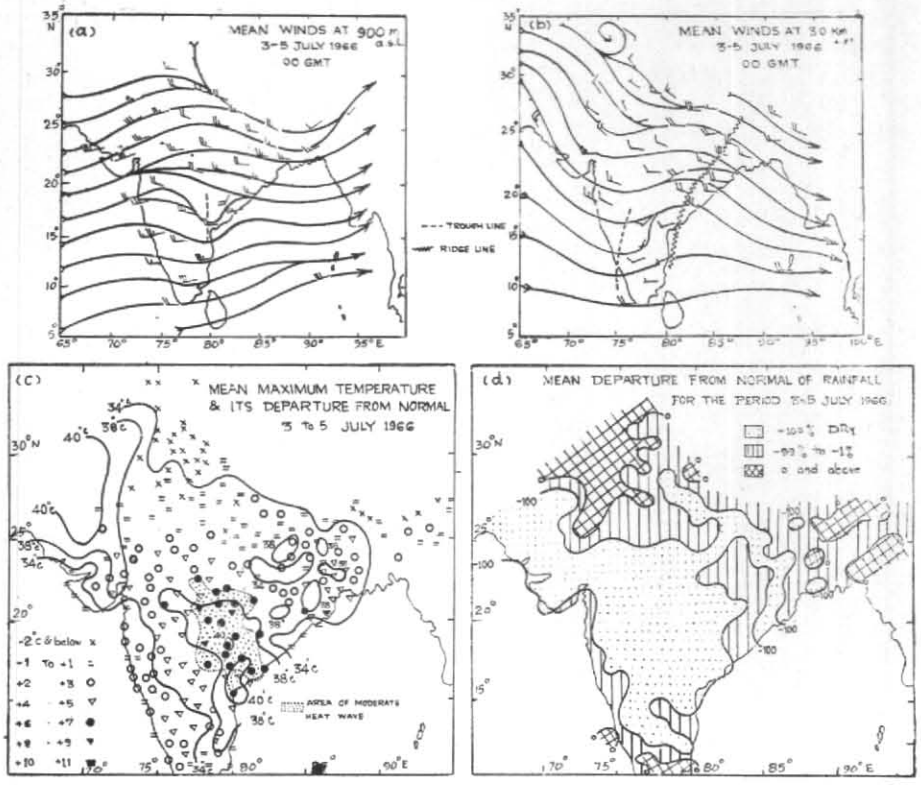
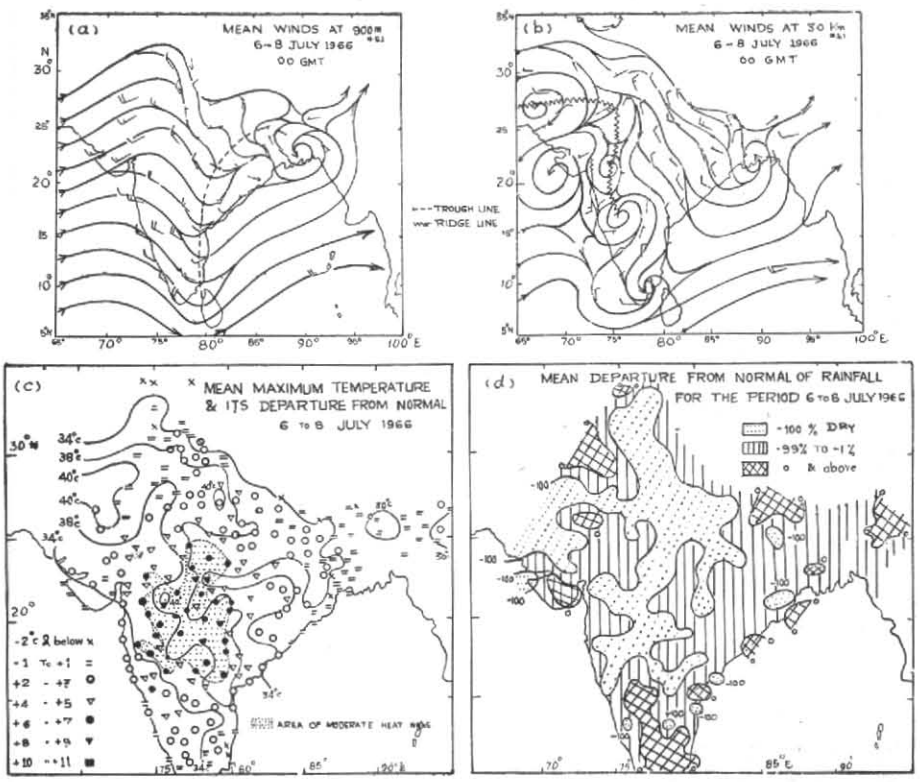

(a)
MEAN WINDS AT 900 m a.s.l.
3-5 JULY 1966
00 GMT
(b)
MEAN WINDS AT 30 Km
3-5 JULY 1966
00 GMT
TROUGH LINE
RIDGE LINE
(c)
MEAN MAXIMUM TEMPERATURE
& ITS DEPARTURE FROM NORMAL
3 to 5 JULY 1966
-2°c & below x
-1 To +1 =
+2 +3 O
+4 +5 ▽
+6 +7 ●
+8 +9 ▼
+10 +11 ■
AREA OF MODERATE HEAT WAVE
(d)
MEAN DEPARTURE FROM NORMAL OF RAINFALL
FOR THE PERIOD 3 to 5 JULY 1966
-100 % DRY
-99% TO -1%
0 and above

Fig. 1


(a)
MEAN WINDS AT 900m
6-8 JULY 1966
00 GMT
(b)
MEAN WINDS AT 30 Km
6-8 JULY 1966
00 GMT
TROUGH LINE
RIDGE LINE
(c)
MEAN MAXIMUM TEMPERATURE
& ITS DEPARTURE FROM NORMAL
6 to 8 JULY 1966
-2°c & below x
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+2 +3 O
+4 +5 ▽
+6 +7 ●
+8 +9 ▼
+10 +11 ■
AREA OF MODERATE HEAT WAVE
(d)
MEAN DEPARTURE FROM NORMAL OF RAINFALL
FOR THE PERIOD 6 to 8 JULY 1966
-100 % DRY
-99% TO -1%
0 & above

Fig. 2

The isobaric delineation at 0300 GMT on 2 July showed the axis of the monsoon trough to be just close to the foot of the Himalayas. The pressure gradient was normal along the west coast (about 6 mb between Mangalore and Surat). Surface pressures started rising over northwest India and the western parts of the country from 3 July and continued to do so till 8th, with the result, the pressure gradient over the country became very weak and a north-south trough started developing over the Peninsula. A moderate heat wave started affecting the southern parts of coastal Andhra Pradesh, Telengana, Vidarbha and adjoining parts of Madhya Pradesh from 3 July, where the maximum temperatures were rising steadily since 1 July. The heat wave conditions spread over to the central parts of the country subsequently and abated by 13 July.

3. Description of the heat wave and the associated synoptic features

For the sake of convenience, the entire period of the heat wave, *viz.*, 3-13 July has been split into four parts. These are (1) 3-5 July, (2) 6-8 July, (3) 9-11 July and (4) 12-13 July which broadly represent the beginning of the heat wave, the shifting of the heat wave to the central parts of the country, the severest period of the heat wave and the abating stage of the heat wave, respectively. These are discussed seriatim.

(1) *The first stage of heat wave (3-5 July 1966)*— Figs. 1 (a)-(d) show the 00 GMT mean upper wind flow pattern at 900 m and 3·0 km a. s. l., the mean maximum temperatures and their departure from normal and the mean percentage departure of rainfall from normal respectively for the period 3-5 July. Maximum temperatures of 38° C and more have occurred in south coastal Andhra Pradesh and adjoining Telengana, in most parts of Vidarbha and in west Rajasthan. The high temperatures over west Rajasthan are the seasonal feature. At 900 m a. s. l. a trough is developing over coastal Andhra Pradesh and neighbourhood with a pronounced ridge over the same area at 3·0 km a.s.l. There was no rainfall over most of the central parts of the country and in the interior Peninsula. Due to excess rainfall over northwest India, the temperatures were below normal there. The departure of maximum temperatures over south coastal Andhra Pradesh, Telengana, east Vidarbha and adjoining east Madhya Pradesh were of the order of 6-7°C above normal which could be termed as a "Moderate" heat wave.

(2) *The second stage of the heat wave (6-8 July 1966)* — Figs. 2 (a)-(d) show the 0000 GMT mean wind flow pattern at 900 m and 3·0 km a.s.l., the mean maximum temperatures and their departure from normal and the mean percentage departure from normal of rainfall respectively for the period 6-8 July. The area of nil rainfall during this period is confined roughly to the area between Long. 75° and 80°E north of Lat. 16°N. The area of high maximum temperatures (38°C and above) is also more or less confined to the area of nil rainfall. The trough which developed over coastal Andhra Pradesh and neighbourhood during the previous period (at 900 m a.s.l.) has become more pronounced and extends from Bihar Plains to Madras State. A ridge line at 3·0 km a.s.l. is running through Jacobabad, Jaipur, Malegaon and Bijapur with anticyclones over west Rajasthan and adjoining Sind, over south Gujarat region and adjoining north Madhya Maharashtra and over north Interior Mysore and adjoining south Madhya Maharashtra. The anticyclone over west Rajasthan and adjoining Sind is the extension of another anticylone situated further northwestwards which was gradually protruding into Indian latitudes in the rear of the westerly trough mentioned earlier. Departures of the order of 6-7°C above normal are obtained over Telengana, Marathwada, eastern parts of Madhya Maharashtra, Vidarbha and adjoining west Madhya Pradesh. The maximum temperatures which were falling during the previous epoch over the northern parts of the country have also started rising and the departures are already of the orders of 2-3° C above normal. The heat wave over the central parts of the country and the adjoining Peninsula is still a moderate one (departures of the order of 6-7°C above normal).

(3) *The third stage of the heat wave (9-11 July 1966)* — Figs. 3 (a)-(d) show the 0000 GMT mean wind flow pattern at 900 m and 3·0 km a.s.l., the mean maximum temperatures and their departure from normal and the mean percentage departure from normal of rainfall respectively for the period 9–11 July. Northwest India, Uttar Pradesh, Madhya Pradesh, Gujarat State, Vidarbha and some parts of Andhra Pradesh have had no rain during this period and the maximum temperatures are of the order of 38°C and above over these areas. At 900 m a.s.l., a cyclonic circulation lies over west Madhya Pradesh and another one over east Uttar Pradesh. An intense anticyclone lies at 3·0 km a.s.l. over the same area where there is a cyclonic circulation at 900 m a.s.l. (*viz.*, west Madhya Pradesh) which is a characteristic feature of a thermal low in the lower level diminishing with height and becoming anticyclone in the upper level. The anticyclone over west Rajasthan still persists (at 3·0 km a.s.l.) and the whole country north of Lat. 16° N is under the influence of an anticyclone. During July, when the monsoon is normally in full swing, the monsoon

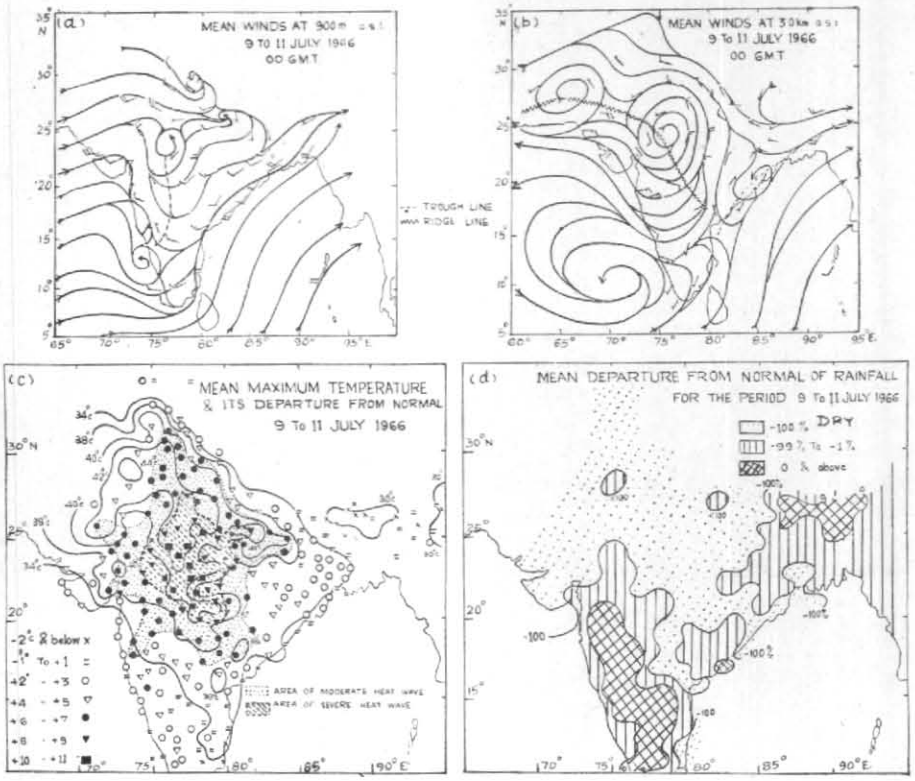
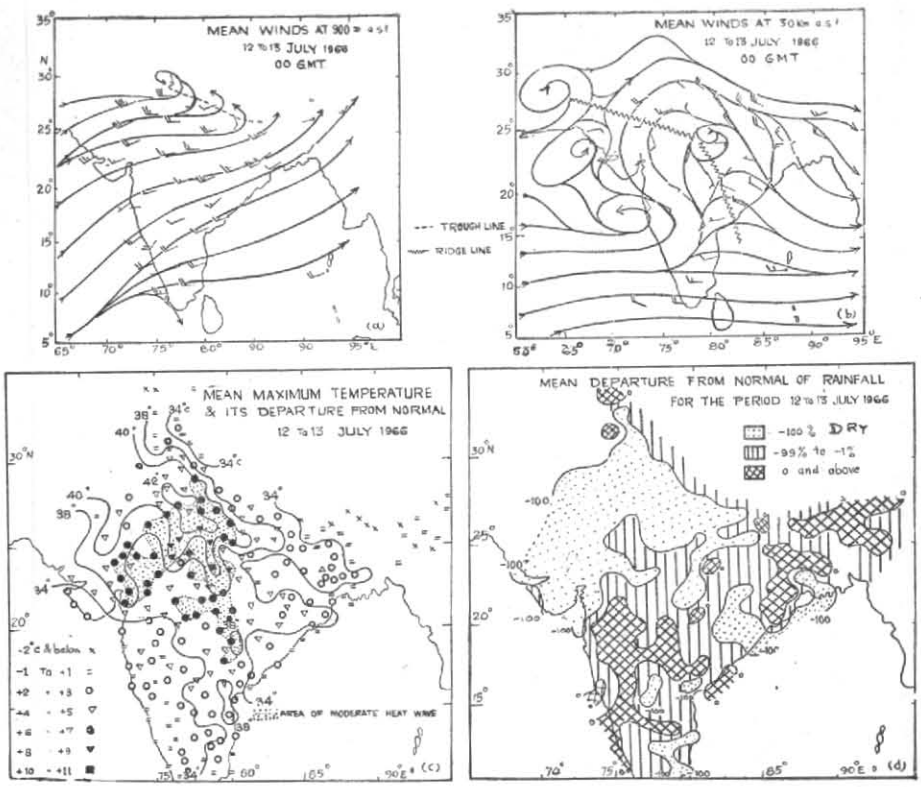

(a)
MEAN WINDS AT 900m a.s.l
9 TO 11 JULY 1966
00 GMT
TROUGH LINE
RIDGE LINE
(b)
MEAN WINDS AT 30km a.s.l
9 To 11 JULY 1966
00 GMT
(c)
MEAN MAXIMUM TEMPERATURE
& ITS DEPARTURE FROM NORMAL
9 To 11 JULY 1966
-2°C & below x
-1 To +1 =
+2 - +3 O
+4 - +5 ▽
+6 - +7 ●
+8 - +9 ▼
+10 - +11 ■
AREA OF MODERATE HEAT WAVE
AREA OF SEVERE HEAT WAVE
(d)
MEAN DEPARTURE FROM NORMAL OF RAINFALL
FOR THE PERIOD 9 To 11 JULY 1966
-100 % DRY
-99 % To -1 %
0 & above

Fig. 3


MEAN WINDS AT 900m a.s.l
12 To 13 JULY 1966
00 GMT
TROUGH LINE
RIDGE LINE
(a)
MEAN WINDS AT 30km a.s.l
12 To 13 JULY 1966
00 GMT
(b)
MEAN MAXIMUM TEMPERATURE
& ITS DEPARTURE FROM NORMAL
12 To 13 JULY 1966
-2°C & below x
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+6 - +7 ●
+8 - +9 ▼
+10 - +11 ■
AREA OF MODERATE HEAT WAVE
(c)
MEAN DEPARTURE FROM NORMAL OF RAINFALL
FOR THE PERIOD 12 To 13 JULY 1966
-100 % DRY
-99% To -1%
0 and above
(d)

Fig. 4

trough is well pronounced with strong westerlies in the Peninsula and easterlies over northern parts of the country in the lower and middle troposphere. The flow pattern at 3·0 km a.s.l. during the period 9-11 July 1966 is strikingly the opposite. The anticyclone over west Rajasthan and adjoining West Pakistan extends to as far as the Caspian Sea as could be seen from the working charts. Practically two-thirds of the country has come under the grip of a heat wave — very severe over west Madhya Pradesh and adjoining east Rajasthan and moderate to severe over the surrounding areas — during this period.

(4) *The fourth stage of the heat wave (12-13 July 1966)* — Figs. 4(a)-(d) give the 0000 GMT mean wind flow pattern at 900 m and 3·0 km a.s.l, the mean maximum temperatures and their departure from normal and the mean percentage departure from normal of rainfall respectively for the period 12-13 July. At 900 m a.s.l. the trough and the cyclonic circulation over the central parts of the country have disappeared. The winds are having a zonal flow from west to east. Westerlies at this level over the south Peninsula have strengthened to 20-25 kt indicating the revival of the monsoon. The anticyclone at 3·0 km a.s.l. over west Madhya Pradesh has become somewhat diffuse and has shifted eastwards. Monsoon westerlies at this level are prevailing upto Lat. 15°N and these moist winds are circulating around the anticyclone over Madhya Pradesh. Maximum temperatures have generally fallen over most parts of the country under the influence of rainfall activity which has extended upto Lat. 25°N. The only area which is still free from rainfall during this period is Gujarat State, Rajasthan, Punjab, Haryana and most of Uttar Pradesh. The departures of maximum temperatures are of the order of 6-7°C above normal over north Vidarbha, Gujarat region, east Rajasthan, northwest Madhya Pradesh and west Uttar Pradesh. Only, portions of east Rajasthan and northwest Madhya Pradesh are having departures of about 8°C above normal. On 13 July, the axis of the monsoon trough had moved southwards, running from north Rajasthan to Gangetic West Bengal. The pressure gradient along the west coast had also built up (6 mb between Calicut and Ratnagiri). On the 14th, there was further fall of maximum temperatures over the country which ranged from 3-8°C from Long. 70° to 80°E and from Lat. 15° to 26°N.

4. Some striking features of the heat wave

1. The heat wave was at its severest intensity on 11 July. The highest maximum temperature recorded during this heat wave was 46° C at Anupgarh (west Rajasthan) on this day. The highest departure of 13°C above normal (maximum temperature 43°C) was recorded at Hoshangabad (west Madhya Pradesh) on the same day. Maximum temperatures of 40°C and more were prevailing over most of the country north of Lat. 20°N on the 11th. The departures from normal were of the order of 8°C and more (severe heat wave) over the area comprising of Uttar Pradesh, Madhya Pradesh, Vidarbha, north Madhya Maharashtra, Gujarat region and south Rajasthan.

2. It has been confirmed from records that maximum temperatures exceeding 42°C were never earlier recorded during July south of Lat. 25° N except over the coastal belt of Andhra Pradesh. It was only in July 1966 that many places in west Madhya Pradesh and southeast Rajasthan recorded temperatures exceeding 42°C. Raghavan (1966) has also concluded that during July practically the whole of the Peninsula is free from heat waves. The heat wave under study has extended into Vidarbha and the northern parts of Andhra Pradesh.

3. The highest maximum temperatures recorded during the heat wave under study are given in Table 1 along with their departure from normal, the earlier highest maximum temperature for the same station and the departure from normal.

It will be seen from Table 1 that the heat wave which affected major parts of the country during the first fortnight of July 1966 was the severest on record for the month. During this heat wave period as many as 25 contiguous stations recorded maximum temperatures which either exceeded or equalled the highest maximum temperatures ever recorded earlier for the concerned station.

5. Comparison of mean upper wind flow patterns during May and during the heat wave period in July 1966, in the lower troposphere

Since a cursory glance at the flow patterns in the lower tropospheric levels during the heat wave period showed that they were similar to that of May, it was thought worthwhile to verify the same by comparison with May flow patterns for the lower levels. Figs. 5 (a) - (d) give the mean 0000 GMT upper winds flow patterns for the levels 900 m and 3·0 km a.s.l. for the month of May and for the period 3-11 July 1966 (during which period the heat wave built up and persisted). It is interesting to note that the 900 m a.s.l. mean wind flow pattern for this period is strikingly similar to the mean flow pattern for May for this level. The Peninsular trough line is running more or less similar to the position in May. The only difference is that the east-west wind discontinuity at 900 m a.s.l. which runs from north Assam to east Uttar Pradesh in May is absent in the mean chart

TABLE 1

Station	Highest recorded during July 1966			Previous highest record during July		
	Max. Temp. (°C)	Day	Dep. from normal	Max. Temp. (°C)	Day (Yr.)	Dep. from normal
West Rajasthan						
Anupgarh	46·0	11	—	Observatory started in Feb 1961		
Mahajan	45·5	11	—	Not available		
East Rajasthan						
Jhalawar	43·9	11	+11·9	42·2	1(1931)	+ 8·2
Udaipur	39·3	11	+ 8·3	37·8	8 (1948)	+ 6·8
Pilani	43·5	11	+ 6·5	43·3	6 (1963)	+ 5·3
West Madhya Pradesh						
Betul	38·6	9	+ 9·6	35·6	4 (1959)	+ 5·6
Bhopal	41·2	11	+11·2	40·6	2 (1931)	+ 8·6
Guna	43·0	10,11	+12·0	41·7	1 (1931)	+ 8·7
Hoshangabad	43·2	11	+13·2	41·4	24 (1960)	+11·4
Indore	39·9	11	+10·9	38·3	1 (1931)	+ 7·3
Khandwa	41·4	10	+10·4	40·0	2 (1900)	+ 8·0
Rajgarh	43·6	11	+11·6	41·2	6 (1957)	+ 8·2
Sheopur Kalan	43·3	11	+ 9·4	42·3	1 (1965)	+ 5·3
Ujjain	41·1	11	—	39·8	15 (1965), 1 (1962)	—
Vidarbha						
Nagpur	40·6	9,11	+ 8·6, + 9·6	40·6*	4 (1897)	+ 7·6
Yeotmal	39·5	9	+ 9·5	38·3	4 (1950)	+ 6·3
Amraoti	40·2	10	+10·2	39·4	1 (1931)	+ 8·4
Madhya Maharashtra						
Ahmednagar	37·7	10	+ 8·7	37·2	9 (1955)	+ 7·2
Jalegaon	40·4	7,11	+ 8·4	39·9	1 (1962)	+ 6·9
					5 (1962)	+ 7·9
Marathwada						
Parbhani	39·1	11	+ 7·1	38·2	2 (1962)	+ 5·2
Coastal Andhra Pradesh						
Gannavaram	41·0	6	+ 8·0	39·4	9 (1952)	+ 6·4
Nidadavole	40·4	5	+ 8·4	36·4	1 (1962)	+ 3·4
Ongole	41·2	5	+ 7·2	40·0	9 (1962)	+ 6·0
Telengana						
Khammam	40·6	6	+ 7·6	39·4	9 (1952)	+ 6·4
Hanamkonda	39·6	6	+ 7·6	38·9	2 (1920)	+ 6·9
Ramgundam	41·0	5	+ 8·0	40·0	1 (1950)	+ 7·0
Badrachalam	40·8	6	+ 7·8	39·4	8 (1952), 9 (1952)	+ 6·4

* The highest temperature was equalled in July 1966 only

for 3-11 July. The mean 3·0 km a.s.l. flow pattern is also more or less similar to the mean May flow pattern except for the fact that a cyclonic circulation lies over south Peninsula, which is free from the heat wave.

6. Thermal structure of the atmosphere during the heat wave period

Since the lower tropospheric flow patterns were fairly similar to each other during the heat wave period of July and May, it was thought fit to see whether the thermal structure of the atmosphere during the period of the heat wave (at stations in the central parts of the country) had also any resemblance to that which normally prevails during May over the northern and central parts of the country.

According to Roy (1945), the air that circulates over most of the country during May is the Tropical Continental Air (*Tc*) with its source region in Southwest Asia. The warm dry air develops nearly adiabatic lapse rate upto a considerable height with a super-adiabatic lapse rate prevailing in the afternoons in the lowest half to one km. The Tephigrams of Jodhpur, Delhi, Allahabad and

Nagpur have been depicted in Figs. 6 (a)-(d) respectively. In each of these tephigrams, the mean dry bulb and dew point curves for the month of May and July have been shown along with the ascent curve for 1200 GMT of 5 July 1966 in respect of Jodhpur, of 6 July in respect of Delhi, of 11 July in respect of Allahabad and of 7 July in respect of Nagpur. The ascent curve for each station for the representative date in July 1966 shows striking resemblance to the ascent curve for May for that station with near dry adiabatic lapse rate, suggesting that the lower tropospheric thermal structure of the atmosphere during the first fortnight of July 1966 was more or less similar to that of May.

7. Causes for the "break" in the monsoon

Conditions in the northern parts of India and neighbourhood — It is evident from the foregoing that the heat wave gradually built up itself due to the prolonged "break" in the monsoon which resulted in very poor rainfall activity in the central parts of the country. Such prolonged "breaks" during July are rare. "Breaks" of 10 days duration and more form only 10 per cent of the total "breaks" during July (Ramamurthy 1969). A low pressure area lying over east Uttar Pradesh on the morning of 30 June gradually moved eastnortheastwards across north Assam by the 3rd morning, and the monsoon trough shifted to the foot of the Himalayas. As mentioned in para 2 a deep trough in the mid-latitude upper tropospheric westerlies began to extend to Indian latitudes from 3 July. Concurrent with these developments, the "break" in the monsoon set in over the country and persisted till 11th. Fig. 7 (a-d) shows the wind flow pattern at 300 mb over Central Asia on 30 June, 3, 6 and 8 July 1966 respectively. The trough in the westerlies persisted over northwest India till 8th without any movement. As a result of the extension of the trough over the northern parts of the country, the subtropical ridge at 300 mb moved southwards and was around Lat. 25-26°N. Winds which should normally be easterlies at Lat. 25-28° N during the active monsoon period were replaced by the westerlies. Delhi recorded westerly wind of 55 kt at 1200 GMT of 5 July at 200 mb and southwesterly wind of 50 kt on 4 and 5 July at 300 mb.

Conditions in the West Pacific — The position of the surface ridge over the West Pacific was about six degrees south of the normal position (around Long. 130°E). It moved to its normal position only on 9th. The mean position of the surface ridge in the West Pacific during July is around Lat. 28-30°N. The ridge at 850 and 700 mb levels was also very much (as much as 8 degrees)

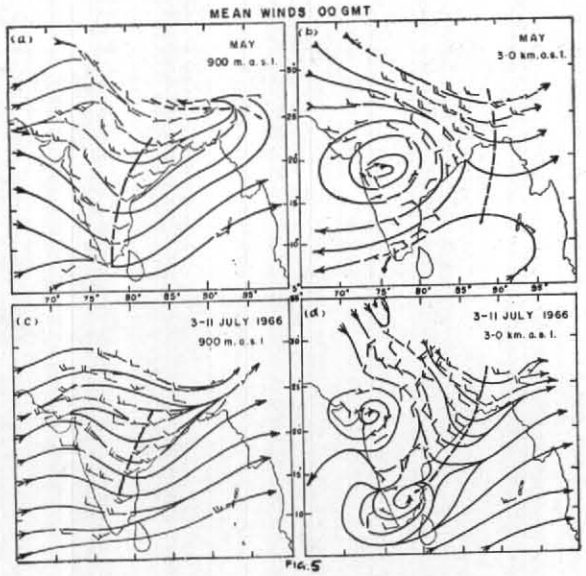

Fig. 5

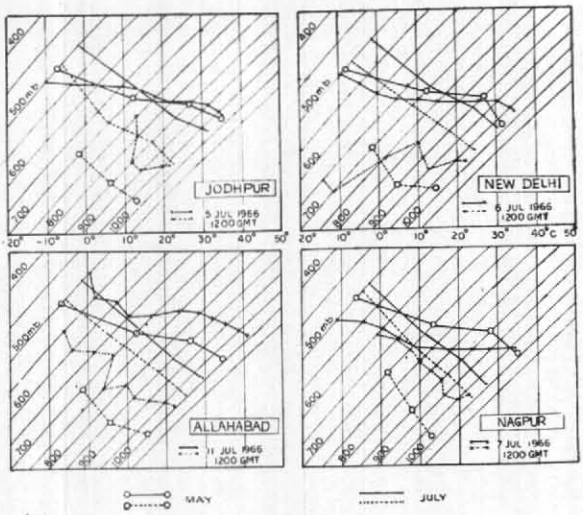

Fig. 6

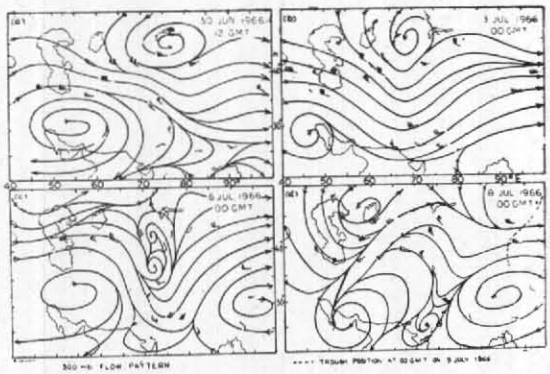

Fig. 7. 300 mb flow pattern

..... Trough position at 00 GMT on 9 July1966

south of the normal position upto 10 July. At 300 mb also the ridge was running around Lat. 27°N and the mean position for July is Lat. 30°N. Posey (1966) has commented that over Asia and most of the Pacific, the major westerlies were slightly south of their normal position during July 1966.

On an average about 4 tropical storms form in the West Pacific during July (Ramanna 1969). Though four tropical storms did develop in the West Pacific during July 1966, none of them formed before 11 July. The absence of any tropical storms over this area during the first fortnight of July contributed to some extent for the non-formation of any depression or low pressure area over the head Bay of Bengal. The belt of low pressure which stretches across South Asia and Southwest Pacific was ill-defined during this period.

8. Revival of the monsoon

The "break" did not terminate till about 11 July as no systems formed in the Bay of Bengal. No wave in the upper tropospheric easterlies also moved across the north Bay of Bengal during this period. However, a circulation at 6·0 km a.s.l. which was over the south Bay of Bengal moved across the south Peninsula to Kerala and adjoining coastal Mysore on 8th. On this day, the circulation could be seen at 1·5 km a.s.l. also. The circulation gradually moved over to south Gujarat coast by 14th. On the 11th and 12th, the system was also seen on the surface as a low pressure area. Under the influence of this system, the monsoon revived on 12th over the Peninsula. The southern end of the monsoon trough was well marked on 15th and a depression formed over the head Bay of Bengal on 17th.

9. Conclusions

In the light of the facts presented in the foregoing paragraphs, the following broad conclusions are arrived at:

The heat wave which prevailed over the central and southeastern parts of the country during the first fortnight of July 1966 was due to a pronounced "break" in the monsoon, when rainfall over these parts was either nil or far below normal. Due to the absence of the normal rain and clouds over these areas, the surface temperatures rose abnormally. The air that circulated over most of the country (outside the south Peninsula and northeast India) was the dry Tropical Continental Air and the circulation pattern was more or less similar to that of May. This study also gives an idea as to the limits to which the normal monsoon circulation during July (when the monsoon should be at its peak) could change completely leading to its virtual collapse (in the lower levels) and mid-summer (pre-monsoon) conditions setting in.

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