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A note on the Hot Days of Bombay (1878—1955)

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1. Introduction

The city of Bombay (Lat. 18°54′ N, Long. 72°49′ E) located on the west coast of India enjoys a maritime climate. The long time observatory of this city is situated almost at the extreme southern end of the narrow ridge of land extending about three miles to the south-west of the Fort of Bombay. The observatory is practically at the water front, the eastern wall of the compound facing the sea; and the exposure is very good. The mean monthly maximum temperatures for the months of March, April and May recorded at this Observatory are 86°, 89° and 91°F respectively. It is interesting to observe that although the mean value is highest in May, there has been not a single occasion either before or after 1899 when the mercury touched 100°F during this month.

The India Meteorological Department has a convention of stating that an area is experiencing a moderate heat wave when the maximum temperature is 9° to 12°F above normal and of declaring a severe heat wave when the departure is 13°F or more above the normal. The incidence of such heat waves over Bombay during the recent years has been briefly referred to in the *Indian Journal of Meteorology and Geophysics* (1950, 1952, 1955). This note attempts a detailed survey of the "heat waves" over Bombay during the months of March, April and May for the period 1878—1955. A study of these individual days has shown—(1) that the onset of sea breeze is delayed by 2 to 3 hours on the days of heat waves, (2) that the early morning and dawn upper winds upto 1 km over Bombay and Poona have an *easterly* component of 4 to 14 knots on such days, while the normal winds have a *westerly* component. It is likely that the delay in the onset of the sea breeze is caused by the presence of the easterly component at the lower levels of the atmosphere on these abnormal days. It is also likely that the adiabatic descent of the air down the Western Ghats, associated with the easterly component, contributes to the heating of the surface air layers over Bombay on such days.

2. Occasions of heat waves

Table 1 gives the details about the moderate and severe heat waves experienced by Bombay during the months of March, April and May (1878—1955). During this period there were 52 days of moderate heat waves (37 in March, 9 in April and 6 in May) and 20 days of severe heat waves (14 in March, 1 in April and 5 in May). There were no heat waves over Bombay in the month of March for the years 1887, 1926, 1928, 1931, 1947, 1950 and 1955 and during the consecutive 12 years from 1889—1900 and during the consecutive 8 years from 1878 to 1885 and 1902 to 1909 and 1937 to 1944. There were similar breaks for March from 1911 to 1915 and from 1917 to 1922. There were also no heat waves in April during 1878 to 1951 that is for a period of 74 years except in 1908, 1941 and 1947. Neither were there any heat waves in May during the period under review but for those in 1899. The all time record of 105°F with a departure of 16°F above normal was recorded just before noon on 18 April 1955. There were only three occasions when the mercury touched or crossed 100°F in April during the present century. They were in 1908, 1952 and 1955.

3. Onset of sea breeze

The time of onset of sea breeze at Bombay (Colaba) during March and April is

TABLE 1

Moderate and severe heat waves over Bombay (March-May, 1878-1955)

Year	Month	Date*	Maximum temperature (°F)	Departure from normal (°F)
1886	Mar	12	95	10
		13	96	10
		14	95	9
1888	Mar	20	96	10
1899	May	3	101	11
		6	101	10
		7	101	10
		8	105	**14**
		9	105	**14**
		11	101	10
		12	101	10
		13	105	**14**
		14	103	**13**
		15	103	**13**
		16	100	9
1901	Mar	12	97	11
1908	Apr	14	100	12
1910	Mar	12	94	9
1916	Mar	2	94	10
1923	Mar	12	96	11
		13	94	9
1924	Mar	4	94	10
1925	Mar	5	95	11
1927	Mar	8	94	9
1929	Mar	20	96	10
1930	Mar	5	94	10
1932	Mar	3	94	10
		4	95	11
		6	96	11
		7	94	9
1933	Mar	15	100	**15**
1934	Mar	16	95	9
1935	Mar	8	100	**15**
		9	101	**16**
		10	101	**16**
		11	94	9
		12	97	12
		13	99	**14**
1936	Mar	12	101	**16**
		13	95	10
		14	96	11
		15	96	11
1941	Apr	8	99	11
		9	97	9
1945	Mar	9	100	**15**
		10	94	9
		23	103	**16**
1946	Mar	13	99	**14**
		14	99	**14**
		15	100	**15**
		28	98	11
1947	Apr	11	97	9
		14	99	11
		22	98	9
1948	Mar	1	95	11
		3	95	11
		4	94	10
1949	Mar	1	99	**15**
1951	Mar	2	97	**13**
		3	94	10
1952	Mar	4	95	11
		18	95	9
		19	100	**14**
		20	98	12
	Apr	13	100	12
1953	Mar	20	95	9
	Apr	2	97	9
1954	Mar	1	93	9
		2	93	9
		18	95	9
	Apr	22	97	9
1955	Apr	18	105	**16**

*The dates given here refer to the dates when the heat waves actually occurred and not to the subsequent day as is customary in the India Meteorological Department records

generally at 1000 IST (1943). The times of onset of the sea breeze at Bombay on the individual days of moderate and severe heat waves were worked out from the anemograms. The mean time of onset on the days of moderate heat waves works out to be 1208 IST while that time on days of severe heat waves works out to be 1255 IST. (The time at which a westerly component in the wind set in was taken as the time of onset of sea breeze). Thus it appears that the onset of sea breeze is delayed by about 2 hrs on the days of moderate heat waves and by about 3 hrs on days of severe heat waves. There are occasions of severe heat waves, when the sea breeze set in as early as 1058 IST or as late as 1543 IST. The delay in the time of onset of the sea breeze apparently permits the diurnal rise of temperature to continue even after 1000 IST, the usual time of onset of sea breeze, until such time as the sea breeze sets in.

4. Winds in the lowest kilometre

It was felt that the onset of the sea breeze was delayed on these abnormally hot days by the occurrence of a sufficiently strong easterly component in the airflow over Bombay upto about 1 kilometre, the approximate depth of a sea breeze in its early stages. In order to examine this point, the upper winds over Bombay on the days of heat waves were tabulated, and the mean values of the easterly components for these days obtained. These values are given in Table 2 separately for Bombay and Poona for the months of March and April for the levels of approximately 1500 and 3000 ft above ground level (a.g.l.). The corresponding normal values are also given in Table 2.

Table 2 shows that the *normal* upper winds over Bombay and Poona during these months at these heights, 1500 and 3000 ft a.g.l. have a *westerly* component ranging between 1 and 4 knots at Bombay and generally between 2 and 9 knots at Poona. On the other hand, the upper winds over Bombay and Poona about 6 and 12 ½ hrs prior to the occurrence of the abnormally high temperatures, when averaged, yield an *easterly* component between 3 and 15 knots at Bombay and between 3 and 14 knots at Poona. The easterly component of the winds measured during night, and 12 hours before the occurrence of the abnormally high temperatures are weaker than the corresponding values measured in the morning, about 6 hours before the occurrence of the abnormally high temperatures. In all cases the change from the normal value is the addition of an easterly component varying between 5 and 15 knots.

It thus appears that the occurrence of sufficiently strong easterly components upto 1 km above ground level over Bombay and Poona is probably responsible for the delay in the onset of the sea breeze at Bombay.

Table 3 gives an analysis of the number of occasions of heat waves examined and the number of occasions of the occurrence of easterly components in the winds.

If we confine our attention to the morning ascents, it will be seen that in March *all* the heat waves occurred on days having easterly components over Bombay at 1500 and 3000 ft a.g.l. while there was only one exception to this rule in April. In the case of Poona also, there has been only one exception each in March and April, for this rule of easterly components being present on days of heat waves. These moderate to strong easterly components at Bombay can occur either with a high over the north Konkan and the north Deccan (Desh), or with a low off the Malabar coast or the south Konkan coast. (If the low is located at a more northerly latitude, it is likely to cause an influx of moisture and consequent cloudiness over Bombay, which would prevent abnormal day time increase of temperature). Ganesan (1946) has pointed out that abnormally high temperatures occur over Karachi for a few days in some Octobers and that these spells of hot weather are invariably associated with a storm or depression over the central Arabian Sea or a trough of low pressure over the north Deccan,

TABLE 2

Mean value of the easterly components of upper winds at 1500 and 3000 ft above ground over Bombay and Poona during days of heat wave (1929—1955)

Month	Time	Height above ground (approx.) (ft)	Normal easterly component (kt)	Average easterly component on days of heat wave (kt)
		BOMBAY		
March	Night	1500	—1·5 (*351*)	6·5 (*11*)
		3000	—0·8 (*345*)	9·3 (*21*)
	Morning	1500	—2·3 (*235*)	14·6 (*19*)
		3000	—2·3 (*295*)	13·5 (*29*)
April	Night	1500	—3·8 (*335*)	0·2 (*4*)
		3000	—2·3 (*329*)	3·2 (*8*)
	Morning	1500	—0·6 (*257*)	3·6 (*5*)
		3000	—2·1 (*316*)	6·8 (*9*)
		POONA		
March	Night	1500	—5·6 (*217*)	6·5 (*21*)
		3000	—2·2 (*217*)	13·9 (*21*)
	Morning	1500	1·3 (*585*)	11·2 (*29*)
		3000	1·0 (*587*)	12·8 (*28*)
April	Night	1500	—9·0 (*209*)	3·2 (*7*)
		3000	—6·6 (*208*)	4·5 (*7*)
	Morning	1500	—3·7 (*567*)	7·0 (*9*)
		3000	—1·8 (*570*)	9·4 (*9*)

NOTE—While Bombay is practically at the sea level, the height of Poona is nearly 1800 ft above mean sea level

Figures in brackets indicate the number of observations on which the values of components are based

TABLE 3

Frequency of occurrence of easterly component of upper winds at 1500 and 3000 ft a.g. over Bombay and Poona on days of heat waves

Month	Time	Height a.g. 1500 ft (a)	Height a.g. 1500 ft (b)	Height a.g. 3000 ft (a)	Height a.g. 3000 ft (b)
		BOMBAY			
March	Night	11	10	21	20
	Morning	19	19	29	29
April	Night	4	2	8	5
	Morning	5	4	9	8
		POONA			
March	Night	21	18	21	21
	Morning	29	28	28	27
April	Night	7	5	7	5
	Morning	9	8	9	8

NOTE— (a) = Total No. of available observations
(b) = Total No. of observations with easterly components

TABLE 4

Easterly component of upper winds on the day of severe heat wave over Bombay (Colaba), 18 April 1955

Time	Bombay Height a.g.l. (approx.) (ft)	Bombay Speed (kt)	Poona Height a.g.l. (approx.) (ft)	Poona Speed (kt)
Night	2000	12·2	1500	9·8
	3000	12·3	3000	17·2
Morning	2000	20·7	1500	20·8
	3000	17·4	3000	29·9

5. The record heat wave on 18 April 1955

The severe heat wave that occurred on 18 April 1955 over Bombay (Colaba) perhaps deserves special mention. For on that occasion the maximum temperature shot up to 105°F (dep.+16°F) which was an all-time record for Colaba for any month during a period of well over a century (*i.e.*, since 1846). Santacruz, 16 miles to the north of Colaba also recorded an unusually high temperature of 106°F (dep.+16°F) on the same day.

Table 4 gives the values of easterly components of upper winds over Bombay and Poona on this day.

While the east-west component of the normal wind at Bombay at 1 km a.g. is westerly 2 knots, the winds on this date had an easterly component of 12 and 17 knots for the respective night and morning ascents. At Poona the normal wind for the night has a westerly component of 7 knots and for the morning a westerly component of 2 knots; the actual wind on this day had an easterly component of 17 knots for the night and of 30 knots for the morning. Apparently the building up of relative high over north Konkan and north Deccan Desh, behind an active western disturbance, was responsible for these strong easterlies over Poona and Bombay on this day.

6. Adiabatic descent down the Western Ghats

The normal lapse rate over this part of India in March and April is 1°F per 300 ft. Assuming that descending air gets warmed at the dry adiabatic rate of 1·6°F per 300 ft the descent of air through 2000 ft from the east down the Ghats will lead to a warming of the air over Bombay by nearly 4°F. Apparently the relatively strong and seasonally unusual easterly wind over the Deccan plateau plays a double role in causing unusually large maximum temperatures over the city of Bombay (a) by causing a delay in the setting of sea breeze and (b) by making the air over Bombay about 4°F warmer by adiabatic descent down the Western Ghats over and above what the local insolation does.

7. Conclusion

The above study of the abnormally hot days of Bombay shows that they are invariably associated with delayed onset of sea breeze and the consequent increased insolational heating. The upper winds upto about one kilometre above ground level at Bombay and Poona, on these abnormal days show a

distinct easterly component, which has an average value ranging between 4 and 14 knots, while the normal wind is a westerly component. Such easterly components may be brought about by the existence of either (a) a low off the south Konkan or Malabar coast, or (b) a relatively high over the north Konkan and north Deccan Desh, behind an active western disturbance. It is also likely that the adiabatic descent of air down the Western Ghats, when the airflow has a distinct easterly component, contributes nearly a 30 per cent share to the heating of the surface air layers over Bombay on such days.

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