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A note on the hot days of Madras (1875—1963)

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ABSTRACT. The incidence of heat waves over the city of Madras during the summer months March to June for the period 1875-1963 has been studied in this note. Delay in the onset of sea breeze by 2 to 3 hours, advective transfer of hot continental air from the Deccan plateau and warming by adiabatic descent of the prevailing northwesterly or westerly winds down the sloping terrain are shown to be the principal factors contributing to the occurrence of such hot spells over Madras.

1. Introduction

The city of Madras (Lat. 13°04′ N, Long. 80°15′E) situated on the east coast of India has relatively low mean daily maximum temperatures for the hot months of March (33°C), April (35°C) and May and June (38°C). Occasionally, during the hot season, however, moderate to severe heat waves pass over the city raising the day's maximum temperature by 6°C (9°F) and more above the normal values.

Apart from the northward migration of the sun and consequent shift of the thermal equator which renders May, the hottest of summer months at Madras, the probable causes for the occurrence of temporary hot spells over Madras would appear to be—(1) The delay in the onset of sea breeze, and (2) the advective transfer of hot continental air from the Deccan plateau and its further heating by adiabatic descent.

The incidence of such heat waves over Madras from March to June during the period 1875-1963 and the synoptic features associated with them are described in this note.

2. Data

The city observatory at Nungambakkam (Lat. 13°04′ N, Long. 80°15′ E) was founded by the East India Company in 1796 and is nearly four miles removed from the sea shore. This observatory was shifted in September 1943 to the airport at Meenambakkam (Lat.13°00′ N, Long. 80°11′ E) which is 14 miles from the coast and 8 miles southwest of the city observatory. The exposure of the instruments at both places is good. The Dine Pressure Tube Anemograph which was installed at the city observatory in 1938 was later shifted to the airport in 1951. The mean daily maximum temperature for the Madras City referred to already were based on the normals for the period 1881—1940.

For the purpose of this study, in conformity with the convention followed by the Department, a heat wave is reckoned as 'moderate' if the day's maximum temperature is 6°—7°C (9°—12°F) above the five-day normals and 'severe' if the departure is 8°C and more (13°F and more). The five-day normals were revised to suit the airport conditions after the shift of the observatory in 1943 and hence the departures of maximum temperature from the normals for both sites are comparable.

3. Occasions of heat waves

Tables 1 and 2 give details of moderate and severe heat waves that occurred over Madras during the months of March to June 1875—1963 and Tables 3 and 4 give the frequency of occurrence of heat waves during ten-year periods.

It will be seen that during the period of 89 years, there were 122 days of moderate heat waves over Madras (3 in March, 19 in April, 86 in May and 14 in June) and

TABLE 1

Moderate heat waves (i.e., 6° to 7°C above normal) over Madras (Mar-Jun 1875-1963)

		Date*	Max. temp.	
			Actual value	Departure from normal
1949	Mar	14	38	6
1953	Mar	27	40	6
		28	41	6
1875	Apr	24	40	6
		26	41	7
1879	Apr	15	40	7
1893	Apr	28	41	6
		29	41	6
		30	41	6
1895	Apr	29	42	7
		30	41	6
1908	Apr	28	41	6
1911	Apr	18	39	6
1922	Apr	22	41	7
1923	Apr	30	41	6
1928	Apr	18	41	7
		19	40	6
1936	Apr	23	40	6
		24	40	6
		25	41	6
1949	Apr	21	42	7
		22	41	6
1875	May	7	43	7
		8	42	6
		9	41	6
1876	May	14	43	6
1878	May	27	43	6
		29	43	6
		31	43	6
1880	May	1	41	6
1881	May	18	43	6
		19	43	6
		21	43	6
		22	44	6
		30	43	6
1886	May	8	42	6
1890	May	6	43	7
		7	42	6
		8	43	7
		9	42	6
		10	42	6
1892	May	27	42	6
893	May	1	42	7
894	May	8	42	6
		31	43	6
1895	May	17	42	6
		18	43	6
		20	43	6
1896	May	14	42	6
		16	43	6
		17	43	6
		18	43	6
		19	43	6

TABLE 1 (*contd*)

		Date*	Max. temp.	
			Actual value	Departure from normal
1897	May	6	42	6
1898	May	8	42	6
		9	43	7
		10	42	6
		11	43	6
		13	43	6
		14	43	7
1901	May	7	42	6
		9	42	6
1902	May	8	42	6
1905	May	2	42	7
		3	41	6
		21	43	6
		22	44	7
		28	43	6
1906	May	27	44	7
		28	43	6
1907	May	4	42	7
1908	May	10	42	6
		13	42	6
		17	43	6
		27	43	6
		30	43	6
1910	May	19	43	6
		21	43	6
		24	44	6
		26	43	6
		27	43	6
1912	May	17	43	6
		19	44	7
		20	43	6
1913	May	12	42	6
1915	May	12	42	6
1920	May	6	43	7
1921	May	7	42	7
		13	44	7
		25	44	7
		26	43	6
		28	43	6
		29	43	6
1922	May	6	42	6
1923	May	1	42	6
		4	42	6
		6	42	6
		7	42	6
1926	May	31	43	6
1927	May	26	43	6
		30	43	6
1928	May	25	43	6
		26	43	6
		30	43	6
1934	May	29	43	6
		30	43	6
1935	May	26	43	6
		27	43	6

* The dates given here refer to the dates when the heat waves actually occurred

TABLE 1 (*contd*)

	Date*	Max. temp.	
		Actual value	Departure from normal
1878 June	1	43	6
	2	43	6
1894 June	1	43	6
1900 June	1	43	6
	3	43	6
1912 June	2	43	6
1914 June	1	43	6
1923 June	7	43	6
	8	43	6
	9	43	7
1926 June	3	43	6
1927 June	1	43	6
1939 June	1	43	6
	2	43	6

* The dates given here refer to the dates when the heat waves actually occurred

TABLE 2

Severe heat waves (i.e., 8°C above normal) over Madras

(March to June 1875—1963)

	Date*	Max. temp.	
		Actual value	Departure from normal
1875 April	25	43	8
1879 April	14	42	9
1908 April	26	43	8
	27	43	8
1881 May	20	45	8
1896 May	15	45	8
1910 May	20	45	8
1922 May	4	43	8
1923 May	3	43	8

* The dates given here refer to the dates when the heat waves actually occurred

TABLE 3

Frequency of occurrence of moderate heat waves over Madras during ten-year periods (1875—1963)

	Total No. of heat waves	1875 to 1880	1881 to 1890	1891 to 1900	1901 to 1910	1911 to 1920	1921 to 1930	1931 to 1940	1941 to 1950	1951 to 1960	1961 to 1963
March	3	—	—	—	—	—	—	—	1	2	—
April	19	3	—	5	1	1	4	3	2	—	—
May	86	8	11	19	21	6	17	4	—	—	—
June	14	2	—	3	—	2	5	2	—	—	—

TABLE 4

Frequency of occurrence of severe heat waves over Madras during ten-year periods (1875—1963)

	Total No. of heat waves	1875 to 1880	1881 to 1890	1891 to 1900	1901 to 1910	1911 to 1920	1921 to 1930	1931 to 1940	1941 to 1950	1951 to 1960	1961 to 1963
March	—	—	—	—	—	—	—	—	—	—	—
April	4	2	—	—	2	—	—	—	—	—	—
May	5	—	1	1	1	—	2	—	—	—	—
June	—	—	—	—	—	—	—	—	—	—	—

9 days of severe heat waves (4 in April and 5 in May).

It is very interesting to note that since 1923 there was no severe heat wave over Madras City.

During the period under review, the hot spells have occurred between 14 March and 9 June.

The all-time record of the highest departure of 9°C (17°F) above the normal with a day's maximum temperature of 42°C (108°F) occurred on 14 April 1879.

4. Delayed onset of sea breeze

It was pointed out by Ramakrishnan and Jambunathan (1958) that the average interval between the incidence of the sea breeze at Nungambakkam (city) and Meenambakkam (airport) is generally 45 minutes and that the difference in the maximum temperatures recorded at the two places generally is of the order of 2 to 3°F during March to July, Meenambakkam recording always a higher maximum than Nungambakkam.

The mean time of onset of sea breeze on the days of moderate heat waves was calculated from the available anemograms, thermograms and hygrograms from 1938. The *normal* times of onset of sea breeze at Madras during March to May is 1100 IST (India met. Dep. 1943). The normal time of onset of sea breeze for June is given as 1500 IST in this publication. However, it is assumed to be same as for May, that is, 1100 IST, since the available data for actual onset of sea breeze are for 1 and 2 June only, the dates being very close to May . On the six days of moderate heat waves, for which data were available, the mean time of onset of sea breeze worked out to be 1255 IST for Madras City (Nungambakkam) and 1355 IST for the Airport (Meenambakkam) indicating an average delay on the onset of sea breeze of about 2 and 3 hours respectively at the two places.

There are, however, a few exceptional days of moderate heat waves when the sea breeze set in as early as 1045 IST at Nungambakkam and 1310 IST at Meenambakkam and as late as 1540 IST and 1600 IST at these two places respectively.

However, no data for the times of onset of sea breeze on days of severe heat waves, which occurred only prior to 1923, are available.

The delay in the onset of sea breeze obviously contributes to a sustained heating of the surface air layers leading to the incidence of hot spells over Madras.

5. Winds in the lowest kilometre

The *mean* values of the westerly components of available winds for the morning of hot days over Madras in March, April, May and June are given in Table 5 for the levels, surface, 1000, 2000 and 3000 ft a.s.l. The corresponding normal values, the total number of available observations together with the frequency of occurrence of westerly components at those levels and their changes in speed from the normals are also given in this table.

It will be seen that in *March*, the normal upper winds over Madras at all levels have *easterly* components ranging between 2 and 5 knots while the actual upper winds six hours before the hot spells show a *westerly* component of speed between 6 and 15 knots on an average. In all cases, the change of actual wind from the normal is an addition of a westerly component varying between 11 and 16 knots.

In *April*, the normal upper winds have weak westerly components of speed of one knot. However, the actual upper winds over Madras on days of hot spell in April show a westerly component of speed of 12 to 17 knots, the change of speed of the actual westerly components from the normal values being an addition of speed of 11 to 16 knots.

In *May*, the normal and the actual upper winds show westerly components. While the speed of the normal westerly component ranged between 9 and 13 knots, the speed of the actual westerly components for the

TABLE 5

Frequency and mean value of the westerly components of winds at surface, 1000, 2000, 3000 feet a.s.l. over Madras during days of heat waves (1875—1963)

	Time	Height (ft. a.s.l. approx.)	Normal westerly compo-nents (kts)	No. of observa-tions	Average westerly compo-nents on days of heat waves (kts)	Total No. of available observa-tions	Total No. of observa-tions with westerly compo-nents	Change in speed of westerly compo-nents from normal value (kts)
March	Morning	Surface	— 0·9	403	— 3·4	3	3	— 2·5
	0730 IST	1000	1·8	153	—14·5	3	3	—16·3
		2000	2·7	153	—12·8	3	3	—15·5
		3000	4·9	670	— 6·1	3	3	—11·0
April	Morning	Surface	— 1·0	420	— 5·0	2	2	— 4·0
	0730 IST	1000	— 1·0	180	—12·3	2	2	—11·3
		2000	— 1·1	180	—13·4	2	2	—12·3
		3000	— 0·7	706	—16·5	2	2	—15·8
May	Morning	Surface	— 1·7	434	*	—	—	*
	0730 IST	1000	—10·6	185	*	—	—	*
		2000	—12·7	185	—30·0	4	4	—17·3
		3000	— 8·5	736	*	—	—	*
June	Morning	Surface	— 4·8	420	— 7·8	1	1	— 3·0
	0730 IST	1000	—21·0	150	—21·7	1	1	— 0·7
		2000	—22·9	150	—32·5	2	2	— 9·6
		3000	—21·7	717	—31·0	2	2	— 9·3

* Data not available

available level was 30 knots showing an addition of 17 knots to the normal wind.

In *June*, both the normal and the actual upper winds have westerly components. While the speed of the normal westerly component varied between 21 and 23 knots, the speed of the actual westerly component ranged between 22 and 33 knots giving an addition of 10 knots as the change of the actual from the normal values.

At the surface, the normal westerly component increased from 1 to 5 knots as the season advances from March to June. However, the westerly component of actual surface winds measured 6 hours prior to the occurrence of heat waves increased during all the months by 2 to 3 knots from the normal wind speeds.

Relationship, if any, between the change in the strength of the westerly components of winds in the lowest kilometre from the normals and the delay in the onset of sea breeze at Madras on days of heat waves, could not however, be given with the meagre data available.

It is apparent that the systematic occurrence of westerly components of winds with speeds varying between 9 and 17 knots exceeding the normal values up to a depth of 1 km (the approximate depth of sea breeze in its early stages) just 6 hours before the heat waves occurred over the city probably explains the delay in the onset of sea breeze at Madras.

The synoptic features that induce a moderate to strong westerly components of winds to oppose the inflow of sea breeze on hot days over Madras were seen to be—(1) Strong pressure gradient causing strong west or northwest off-shore winds, (2) Orientation of the trough at sea level over central Bay instead of the adjoining southwest Bay

off Coromandel—Circars coast during the morning hours; and (3) formation of unsettled conditions or depression over north Andaman Sea with associated trough extending over central Bay up to the Coromandel coast.

6. Advective transfer of heat from the Deccan plateau

The seat of the highest mean temperature lies over the Deccan plateau in the month of March; this region of high temperature progressively shifts northwards across Vidarbha to northern India through April and May. In the mid-summer month of April, there are two distinct regions of highest mean temperature, exceeding 32·5° C, one over Rayalaseema, at the southeastern part of the Deccan plateau and the other over Vidarbha, slightly to the north of the Deccan plateau.

As Madras lies at the outer periphery of this region of highest surface temperature over Rayalaseema, abnormally high temperatures should, occur normally at Madras when the wind flow over south Peninsula in the lower levels, below 3000 ft (or in individual cases, below 5000 ft) is predominantly NW/N under favourable synoptic conditions. This will bring in a continuous supply of dry continental air from the north. An examination of the weather charts for the period 18-25 April 1949, has shown that—

(*i*) Maximum temperature was 5-6°F above normal over Madras and neighbourhood on 18 April 1949, became 8-13°F above normal on 22nd and continued to be so till the next day. By the evening of 24th, the hot spell abated, the temperature being only 5—7°F above normal.

(*ii*) Commencing from 20 April 1949, the upper wind flow at 1·5 km (5000 ft) and below was predominantly NW/N. On the morning of 22nd, the wind flow at 1·5 km was mainly northerly and continental in origin and character.

(*iii*) A depression was forming in the central Bay of Bengal on and around 22 April 1949.

It will thus be seen that the pronounced northerly wind flow bringing in dry continental air from the north and adiabatically descending down the sloping terrain of the Deccan plateau to the Madras coast resulting in its further heating, was directly responsible for the abnormally high temperature over Madras and neighbourhood during the period.

7. Conclusion

The above study has shown that the hot days of Madras are invariably associated with the delayed onset of sea breeze. The occurrence of a moderate to strong westerly components of upper winds in the lowest kilometre varying between 9 and 17 knots from the normal wind prevented the sea breeze from setting in, in time, thereby contributing to the sustained heating of the surface air layers. Advective transfer of hot continental air combined with the adiabatic descent of air down the Deccan plateau when the air flow has distinct northwesterly or westerly components also contributed to the heating of the air layers over Madras on such hot days.

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