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# Thermal structure of the troposphere over Bangalore

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ABSTRACT. The paper presents monthly mean values of upper air temperatures over Bangalore at 5000, 10,000, ....., 50,000 ft a.s.l. based on the 00 Z radiosonde data for the period 1961–1965. The diurnal variation of temperature at these levels on the basis of 00 and 12 Z data is found to be generally less than 1°C, the evening temperatures being higher. Lapse rates are higher in the evenings below 10,000 ft but show little variation aloft.

## 1. Introduction

Primarily for suply of uppper air temperature data to the H.A.L. for test flights of their aircraft, a radiosonde station started at Bangalore in 1961. The monthly mean temperatures at pressure altitudes 5000, 10,000, ..... 50,000 ft worked out on the basis of these ascents are presented in this paper.

## 2. Discussions and results

In Table 1, the mean monthly morning temperatures at 5000, 10,000...., 50,000 ft are given. It will be seen from this table that the temperature at 5000 ft rises from the minimum of 287°A in January to the maximum of 293°A in April/May. The temperatures at 10,000 ft and above are more or less constant throughout the year. Thus, the chief characteristic feature of the thermal structure over Bangalore in the morning is that, except for variations in the lower levels upto 5000 ft, it undergoes very little change from month to month.

The highest temperatures in the morning upto 40,000 ft occur generally in the month of May which is considered as the hottest month in South India.

The changes between the evening and the morning temperatures $\triangle T = T\,(12Z) - T\,(00Z)$ are presented in Table 2. It is seen from this table that there is a general rise in the temperature in the evenings at all levels in all months except for a fall from morning to evening in the months of August, September and October at 45,000 ft and above, *i.e.*, towards the latter part of the southwest monsoon period and the beginning of the northeast monsoon period. It was also seen from the temperatures in the evening that significant changes in the thermal structure over Bangalore extends to 10,000 ft in the evenings, above which there is no appreciable change in the structure from month to month.

The mean monthly evening height-temperature curves of Bangalore as compared with Madras for the months of January, April, July and October are shown in Fig. 1.

Monthly mean lapse rates over Bangalore in the morning were calculated from the mean temperatures at Table 1 and presented at Table 3 for height intervals of 5000 ft upto 50,000 ft. It is seen from this table that there is a gradual rise of lapse rate till the maximum of 8·5°C/gpkm is reached between 30,000 and 40,000 ft and then a gradual fall thereafter (till about 100 mb when the lapse rate changes its sign abruptly). It was also noticed in the study that both in the morning and in the evening, the lapse rates above 10,000 ft were almost indentical; below 10,000 ft, they were however, higher in the evening throughout the year.

On a general perusal of the temperatures and lapse rates, it is seen that in the months of December and January, the effects of ground heating do not extend upto 5000 ft due to the minimum duration and intensity of solar radiation. In February and March, there is a rapid increase in the temperature upto 5000 ft and a corresponding increase in the lapse rates; the temperatures at 10,000 ft are, however, not affected to any appreciable extent indicating that in the afternoon in these months, the thermal convection and turbulence do not extend upto 10,000 ft. The temperatures in April and May are the highest in the year upto 10,000 ft with the corresponding high lapse rates enabling the easy vertical transport of air through the lower layers of the troposphere and thus conditions are very favourable for the occurrence of convective thunderstorms with a frequency of 9 and 13 in April and May respectively. From May to June, there is a fall in temperature and corresponding decrease of lapse rate at all levels in the lower troposphere upto 40,000 ft. This pattern more or less continued till September, after which, in October, consequent on the withdrawal of the southwest monsoon, there is fall in the temperature which continues in November.

**TABLE 1**

**Mean monthly morning temperatures (°A) over Bangalore** (3021 ft a.s.l.)

| Pressure altitude in ft and (mb) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | Range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 50,000 (116) | 198·6 (80) | 00·4 (83) | 00·3 (76 | 00·3 (50) | 99·1 (65) | 99·7 (78) | 99·7 (78) | 00·0 (80) | 99·3 (85) | 99·0 (89) | 99·2 (92) | 99·1 (67) | 99·6 | 1·8 |
| 48,000 (128) | 202·8 (83) | 03·8 (86) | 02·8 (84) | 02·9 (59) | 02·4 (67) | 02·5 (79) | 02·5 (75) | 03·3 (82) | 02·3 (88) | 02·1 (90) | 02·1 (97) | 02·3 (73) | 02·6 | 1·7 |
| 45,000 (147) | 207·3 (92) | 07·1 (91) | 07·2 (96) | 07·2 (64) | 07·3 (76) | 07·7 (83) | 06·7 (78) | 07·9 (87) | 07·2 (92) | 06·9 (97) | 06·3 (105) | 06·3 (80) | 07·1 | 1·6 |
| 40,000 (187) | 217·2 (98) | 17·3 (96) | 17·0 (103) | 17·5 (81) | 18·3 (86) | 17·8 (84) | 18·1 (77) | 18·0 (89) | 17·8 (87) | 17·5 (101) | 17·1 (107) | 17·1 (88) | 17·6 | 1·3 |
| 35,000 (238) | 229·3 (107) | 29·1 (106) | 29·0 (115) | 29·2 (87) | 30·9 (94) | 30·3 (95) | 30·0 (102) | 30·2 (99) | 30·1 (93) | 30·1 (104) | 29·1 (110) | 29·2 (104) | 29·7 | 1·9 |
| 30,000 (301) | 241·5 (112) | 41·8 (107) | 40·9 (127) | 42·0 (96) | 43·2 (108) | 42·7 (108) | 42·3 (108) | 42·6 (113) | 42·6 (110) | 42·2 (113) | 41·7 (118) | 41·5 (114) | 42·1 | 2·3 |
| 25,000 (376) | 253·4 (114) | 53·6 (107) | 52·8 (129) | 53·0 (103) | 54·9 (111) | 53·8 (110) | 54·2 (113) | 54·3 (115) | 54·3 (113) | 54·2 (116) | 53·6 (119) | 53·5 (118) | 53·8 | 2·1 |
| 20,000 (466) | 264·6 (116) | 64·3 (109) | 63·7 (137) | 63·9 (111) | 65·1 (112) | 64·5 (113) | 64·7 (116) | 64·9 (119) | 65·1 (115) | 64·9 (121) | 64·3 (119) | 64·4 (120) | 64·5 | 1·4 |
| 15,000 (572) | 273·7 (118) | 73·1 (11') | 73·1 (139) | 72·5 (125) | 73·5 (110) | 73·6 (112) | 73·5 (118) | 73·6 (121) | 73·9 (116) | 73·7 (121) | 73·4 (120) | 73·4 (121) | 73·4 | 1·4 |
| 10,000 (697) | 282·3 (119) | 81·3 (113) | 81·9 (143) | 82·8 (116) | 83·6 (113) | 82·8 (115) | 82·5 (119) | 82·8 (122) | 82·5 (117) | 82·0 (12') | 82·1 (120) | 81·7 (121) | 82·4 | 2·3 |
| 5,000 (843) | 287·4 (119) | 90·0 (113) | 91·4 (143) | 92·7 (117) | 92·5 (116) | 89·9 (115) | 89·3 (120) | 89·5 (122) | 89·3 (117) | 90·0 (122) | 87·6 (120) | 87·9 (122) | 89·8 | 5·3 |
| Surface (Normal) | 290·4 | 92·5 | 95·1 | 96·9 | 96·5 | 94·8 | 93·8 | 93·6 | 93·8 | 94·2 | 92·8 | 90·7 | 93·8 | 6·5 |

Note — 1. Hundred's figure of temperature omitted except in the 2nd column

2. No. of observations on which means for the different levels were computed are indicated in brackets just below the temperature values for each month

**TABLE 2**

**Mean monthly changes between the evening and the morning temperatures (°A) over Bangalore**

| Pressure altitude in ft and (mb) | $\Delta T = T(12Z) - T(00Z)$ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
| 50,000 (116) | +1·3 | +0·5 | +0·5 | +1·7 | +0·5 | +1·1 | +0·6 | —0·4 | —0·4 | —0·4 | +0·2 | +0·4 | +0·4 |
| 48,000 (128) | +0·1 | +0·5 | +0·8 | +2·0 | +0·7 | +1·0 | +0·6 | —1·0 | —0·4 | —0·8 | —0·2 | +0·1 | +0·3 |
| 45,000 (147) | —0·3 | +0·8 | +0·7 | +2·1 | +1·4 | +0·6 | +0·4 | —1·0 | —0·3 | —0·8 | +0·5 | 0·0 | +0·3 |
| 40,000 (187) | —0·6 | +0·6 | +0·7 | +1·6 | +0·8 | +1·0 | —0·3 | +0·5 | +0·4 | —0·2 | +0·7 | —0·7 | +0·3 |
| 35,000 (238) | 0·0 | +0·6 | +0·5 | +0·9 | +1·3 | +0·6 | +1·0 | +0·6 | +0·6 | —0·3 | +0·8 | +0·4 | +0·6 |
| 30,000 (301) | +0·3 | —0·1 | +1·3 | +1·1 | +0·7 | +1·3 | +0·5 | +0·6 | +0·9 | +0·2 | +0·9 | +0·5 | +0·7 |
| 25,000 (376) | +0·1 | 0·0 | +0·8 | +1·1 | +0·3 | +0·9 | +0·5 | +1·0 | +1·0 | +0·2 | +0·9 | +0·4 | +0·6 |
| 20,000 (466) | +0·1 | —0·1 | +0·7 | +0·6 | +0·1 | +0·5 | +0·5 | +0·9 | +0·7 | +0·2 | +0·7 | +0·6 | +0·5 |
| 15,000 (572) | +0·1 | +0·2 | +0·4 | +0·6 | +0·2 | +0·1 | +0·3 | +0·3 | +0·2 | 0·0 | +0·6 | +0·4 | +0·3 |
| 10,000 (697) | —0·1 | +0·2 | +0·3 | +0·7 | +0·4 | —0·4 | 0·0 | —0·1 | +0·1 | +0·1 | +0·8 | +0·6 | +0·2 |
| 5,000 (843) | +3·8 | +3·4 | +5·2 | +4·8 | +4·9 | +3·7 | +3·4 | +3·4 | +3·4 | +2·7 | +4·0 | +2·8 | +3·8 |

**TABLE 3**

**Mean monthly lapse rate (°C/1000 ft) in the morning over Bangalore**

| Layer (ft) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 45— | 1·7 | 1·3 | 1·4 | 1·4 | 1·6 | 1·6 | 1·4 | 1·6 | 1·6 | 1·6 | 1·4 | 1·4 | 1·5 |
| 50,000 | (5·6) | (4·3) | (4·6) | (4·6) | (5·2) | (5·2) | (4·6) | (5·2) | (5·2) | (5·2) | (4·6) | (4·6) | (4·9) |
| 40— | 2·0 | 2·0 | 2·0 | 2·1 | 2·2 | 2·0 | 2·3 | 2·0 | 2·1 | 2·1 | 2·2 | 2·2 | 2·1 |
| 45,000 | (6·6) | (6·6) | (6·6) | (6·9) | (7·2) | (6·6) | (7·5) | (6·6) | (6·9) | (6·9) | (7·2) | (7·2) | (6·9) |
| 35— | 2·4 | 2·4 | 2·4 | 2·3 | 2·5 | 2·5 | 2·4 | 2·4 | 2·5 | 2·5 | 2·4 | 2·4 | 2·4 |
| 40,000 | (7·9) | (7·9) | (7·9) | (7·5) | (8·2) | (8·2) | (7·9) | (7·9) | (8·2) | (8·2) | (7·9) | (7·9) | (7·9) |
| 30— | 2·4 | 2·5 | 2·4 | 2·6 | 2·5 | 2·5 | 2·5 | 2·5 | 2·5 | 2·4 | 2·5 | 2·5 | 2·5 |
| 35,000 | (7·9) | (8·2) | (7·9) | (8·5) | (8·2) | (8·2) | (8·2) | (8·2) | (8·2) | (7·9) | (8·2) | (8·2) | (8·2) |
| 25— | 2·4 | 2·4 | 2·4 | 2·2 | 2·3 | 2·2 | 2·4 | 2·3 | 2·3 | 2·4 | 2·4 | 2·4 | 2·3 |
| 30,000 | (7·9) | (7·9) | (7·9) | (7·2) | (7·5) | (7·2) | (7·9) | (7·5) | (7·5) | (7·9) | (7·9) | (7·9) | (7·5) |
| 20— | 2·2 | 2·1 | 2·2 | 2·2 | 2·2 | 2·1 | 2·1 | 2·1 | 2·2 | 2·1 | 2·1 | 2·2 | 2·1 |
| 25,000 | (7·2) | (6·9) | (7·2) | (7·2) | (7·2) | (6·9) | (6·9) | (6·9) | (7·2) | (6·9) | (6·9) | (7·2) | (6·9) |
| 15— | 1·8 | 1·8 | 1·8 | 1·7 | 1·7 | 1·8 | 1·8 | 1·7 | 1·8 | 1·8 | 1·8 | 1·8 | 1·8 |
| 20,000 | (5·9) | (5·9) | (5·9) | (5·6) | (5·6) | (5·9) | (5·9) | (5·6) | (5·9) | (5·9) | (5·9) | (5·9) | (5·9) |
| 10— | 1·7 | 1·6 | 1·8 | 2·1 | 2·0 | 1·8 | 1·8 | 1·8 | 1·7 | 1·7 | 1·7 | 1·7 | 1·8 |
| 15,000 | (5·6) | (5·2) | (5·9) | (6·9) | (6·6) | (5·9) | (5·9) | (5·9) | (5·6) | (5·6) | (5·6) | (5·6) | (5·9) |
| 05— | 1·2 | 1·7 | 1·9 | 2·0 | 1·8 | 1·4 | 1·4 | 1·3 | 1·4 | 1·6 | 1·1 | 1·2 | 1·5 |
| 10,000 | (3·9) | (5·6) | (6·2) | (6·6) | (5·9) | (4·6) | (4·6) | (4·3) | (4·6) | (5·2) | (3·6) | (3·9 | (4·9) |

Figures in brackets : °C/gpkm

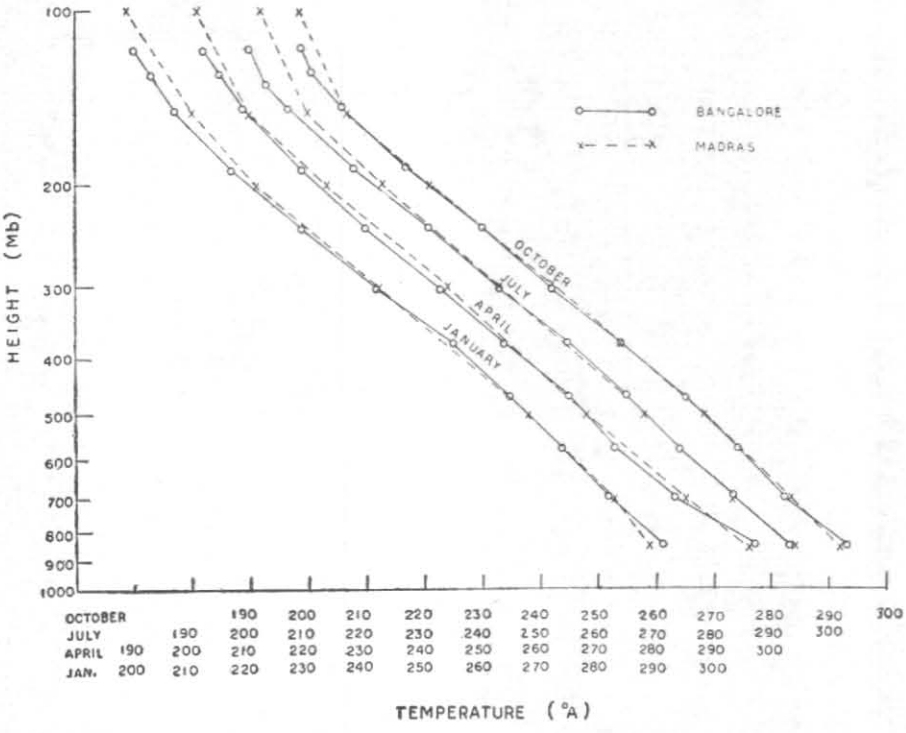


**Fig. 1. Mean monthly temperatures over Bangalore compared with those of Madras (evening)**