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# The Radiation Error of Indian Radiosondes

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ABSTRACT. Based on the routine radiosonde ascents at two Indian stations, a statistical estimate of the radiation error of the sondes at upper tropospheric levels is attempted.

## 1. Introduction

Radiosonde ascents are taken in India at 00 and 12 GMT daily. Consecutive soundings at the same station often register large differences of temperature all of which cannot be attributed to real atmospheric causes. Some of these differences may be due to radiation errors of the instrument. Corrections for radiation error based on laboratory experiments being applied as a routine do not seem to be adequate. A statistical estimate of the additional correction required is attempted here.

## 2. Discussion

The corrections for radiation errors of both the Chronometric and Fan-type radiosondes used at Indian stations have been determined experimentally by a method similar to that of Scrase (1954) for various values of solar elevation angle and pressure levels (Curves A in Figs. 5 and 6). The method has been discussed with reference to the Fan-type radiosonde by Mani *et al.* (1959). These experiments involve certain assumptions to reduce the complexity of the problem. The only effect of solar radiation taken into account as contributing appreciably to errors in the instrument is the heating of the air passing across the element by the heated radiation shield. The direct solar radiation falling on the element, the short and long wave radiation from below and re-radiation from the shield to the element are some important factors not completely taken into account owing to experimental limitations.

The difference between day and night temperatures at any isobaric level must be due to (*i*) non-periodical changes due to dynamical causes, (*ii*) diurnal variations during the period, and (*iii*) instrumental errors due to radiation. The non-periodical changes are eliminated by averaging the data over a long period (Lugeon and Ackermann 1955). Diurnal variation may be appreciable at lower levels (Pant 1960) upto about 300 mb, owing to convection and other factors and at stratospheric levels owing to absorption of radiation by ozone. It is difficult to separate the real diurnal variation from instrumental errors at these levels. However, at upper tropospheric levels such as 200 mb, direct absorption of radiation is negligible and any postulates of dynamical mechanisms for diurnal variations at these levels are far-fetched and lead to inconsistencies, as pointed out by Kay (1951). Hence it may be safe to assume that at these levels the day-night differences are entirely due to radiation error of the radiosonde instrument.

In the present study only the 200-mb level has been considered, as data available for other possible higher levels, are meagre. Besides, these levels may not also be always below the tropopause. Fig. 1 shows a plot of the day-night temperature differences $T_{12}$—$T_{00}$ at the 200-mb level over Madras for the

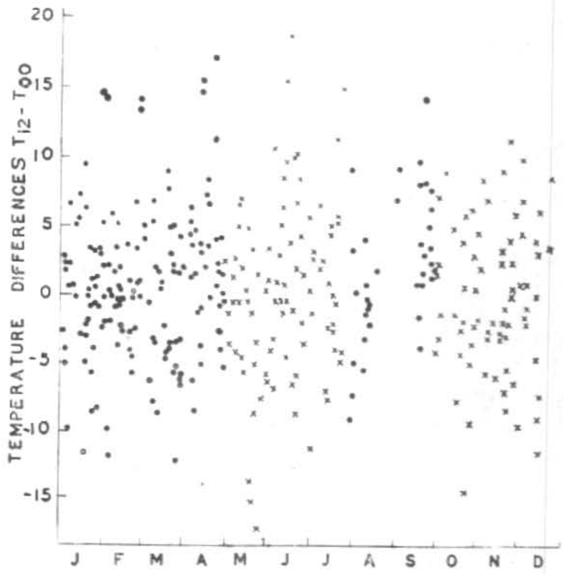

**Fig. 1. Scatter of day-night temperature differences (°C) of 200 mb at Madras during 1959**

Mean values of $T_{12}-T_{00}$ : Jan to Apr, Aug and Sep : + 1·3°C;
May, Jun and Jul : +0·4°C ; Oct to Dec : —0·1°C

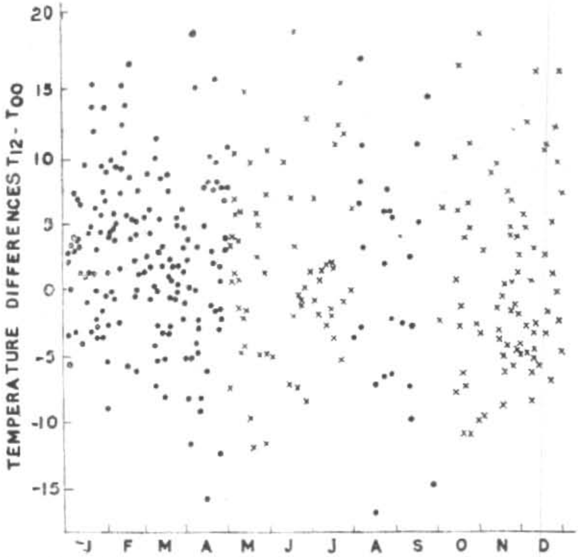

**Fig. 2. Scatter of day-night temperature differences (°C) of 200 mb at Madras during May 1960 to April 1961**

Mean values of $T_{12}-T_{00}$ ; Jan to Apr, Aug and Sep : + 2·2°C
May to Jul : + 1·0°C ; Oct to Dec : + 0·5°C

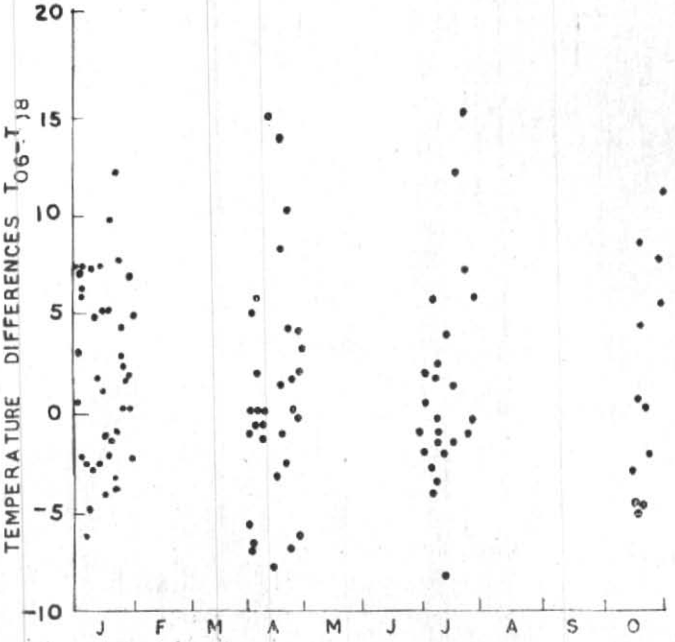

**Fig. 3. Scatter of day-night temperature differences (°C) of 200 mb at Madras during 1960-61**

Mean value of $T_{06}$—$T_{18}$ : Jan : +1·8°C ; Apr : +1·1°C; Jul : +1·7°C ; Oct : +1·9°C

period January-December 1959, $T_{12}$ and $T_{00}$ being the temperatures at 200 mb in the 12 and 00 GMT soundings respectively. The values at 00 GMT ascent immediately preceding and succeeding 12 GMT have been individually subtracted from the values at 12 GMT ascent and both the differences have been included. Since these ascents are close to sunset and sunrise, a few months of the year have one ascent in sunlight and the other corresponding ascent in darkness. The rest of the months have either both ascents in sunlight or both in darkness. To determine the above, the mean solar elevation of the 15th of a month is taken to represent the month. The balloon is assumed to reach the 200-mb level at 1752 and 0552 IST corresponding to mean times of launching of 1715 and 0515 IST and a rate of ascent 20 km per hour. While the day to day differences are substantial, the mean difference $T_1$ for the period October-December in Madras when both ascents are in darkness is almost zero (—0·1°).

For the period January-April and August-September when one ascent of the day is in darkness and the other in sunlight, the mean difference $T_2$ (1·3°) is quite appreciable, and is also significant at 1 per cent level over $T_1$. The results for 1960-61 (Fig. 2) are similar. This is not a fortuitous coincidence as the data of New Delhi at a different latitude by a different sonde (Fig. 4) show the same result. The mean difference $T_{06}$—$T_{18}$ between the 200-mb temperatures at 06 and 18 GMT at Madras (Fig. 3) is also consistent with the above results. It is difficult to postulate a mechanism for diurnal variation of the order of 2° in the period when one ascent is in darkness and the other in sunlight, and for practically no diurnal variation when both ascents are in darkness. The conclusion that is

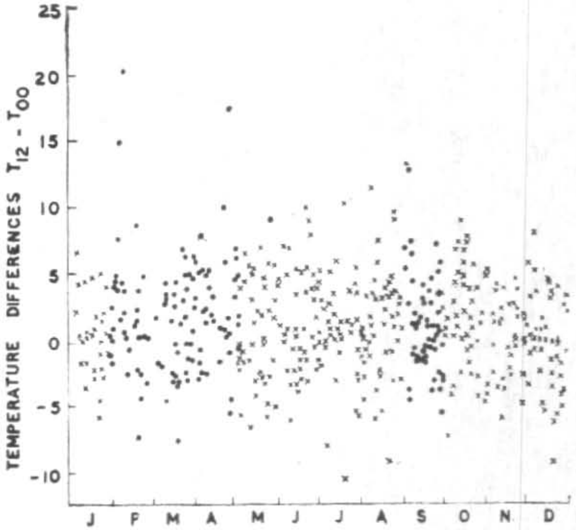

Fig. 4. Scatter of day-night temperature differences of 200 mb at New Delhi during 1959

Mean values of $T_{12}—T_{00}$ : Feb to Apr and Sep : +2·0°C;
May to Aug : +0·9°C ; Oct to Jan : +0·6°C

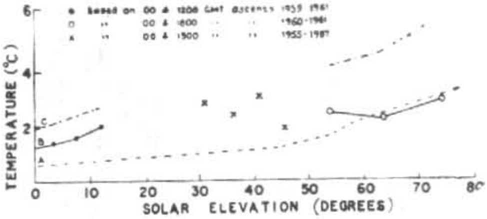

Fig. 5. Radiation correction at 200-mb level for Madras

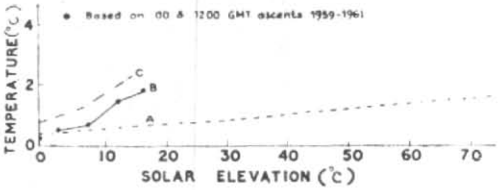

Fig. 6. Radiation correction at 200-mb level for New Delhi

A—Radiation correction applied in routine ascents
B—Mean $T_s—T_d$
C—Total radiation correction required (sum of curves A and B)

TABLE 1

**Relation between solar elevation angle and day-night temperature differences at 200 mb**

| | Solar elevation angle ($\theta_s$) interval | Weighted mean $\theta_s$ | Total of differences ($T_s - T_d$) (°C) | No. of observations | Mean ($T_s - T_d$) (°C) | Remarks |
|---|---|---|---|---|---|---|
| | | | (*a*) MADRAS | | | |
| A | 1—5 | 3·5 | 428·1 | 93 | 1·4 | Based on 00Z and 12Z observations in 1959-61 |
| | 6—10 | 7·9 | 287·5 | 175 | 1·6 | |
| | 11—16 | 12·5 | 82·4 | 42 | 2·0 | |
| B | 25—34 | 32·1 | 259·2 | 92 | 2·8 | Based on 03Z and 15Z observations in 1955-57 ; Radiation correction not applied to data |
| | 35—39 | 37·2 | 270·4 | 112 | 2·4 | |
| | 40—44 | 42·0 | 232·0 | 75 | 3·1 | |
| | 45—49 | 47·0 | 90·8 | 48 | 1·9 | |
| C | 50—59 | 55·0 | 99·9 | 40 | 2·5 | Based on 06Z and 18Z observations in 1960-61 |
| | 60—69 | 65·1 | 92·5 | 40 | 2·3 | |
| | 70 and above | 76·2 | 72·5 | 28 | 2·9 | |
| | | | (*b*) NEW DELHI | | | |
| | 1—5 | 2·6 | 16·9 | 31 | 0·5 | Based on 00Z and 12Z observations in 1959-61 |
| | 6—10 | 8·0 | 42·3 | 63 | 0·7 | |
| | 11—15 | 13·0 | 160·9 | 105 | 1·5 | |
| | 16—21 | 17·2 | 60·5 | 34 | 1·8 | |

inescapable is that the sondes still need correction for radiation, presumably due to the assumptions in the experimental determinations.

### 3. Evaluation of the error

A method similar to that of Teweles and Finger (1960) was adopted for making a quantitative assessment of this additional correction for radiation. The 200-mb temperature differences of the days when one ascent was in sunlight and the other in darkness were tabulated against $\theta_s$, the solar elevation angle at the time when 200 mb is reached in sunlight on the day. A rate of ascent of 20 km per hour was allowed over the actual time of launching of the balloon on *each* day for calculating the time at which 200 mb is reached. Actual time of launching on each individual day and the corresponding solar angle were considered to avoid any errors due to approximations. To eliminate the possibility of direct sunlight falling on the sondes during the ascent in darkness all the days with $\theta_d$ (solar elevation angle at 200 mb, reached in darkness) greater than –3° were omitted. The results for the range of solar elevations 1–16° covered by the routine ascents at Madras (Table 1a) are plotted in Fig. 5 as curve B. Radiation correction as in curve A is already being applied in routine ascents. The sum of the ordinates of the curves A and B is given by curve C. This is the curve of total radiation correction required for the sonde. The correction is of the order 2—2·5° for the range of low angles and the same trend with lesser corrections appears in the curve C for ascents at New Delhi (Fig. 6 and Table 1 b) with the C-type sonde. The plots for the curves B and C (Fig. 5) for angles of 50° and above for Madras were obtained from the data of special 06 and 18 GMT ascents made in the months of July, October 1960, and January, April 1961. The corrections for higher angles from this moderate amount of data are of the order of 4 to 6° which do not appear inconsistent with the figures for lower angles. Similar computations for higher solar angles for New Delhi could not be carried out as the checked data for 06 and 18 GMT observations are not yet available.

For the range of solar angles 25° to 60° mean differences $T_{03}$–$T_{15}$ for the period May 1955—March 1957 from the data of 03 and 15 GMT soundings at Madras were calculated. No corrections for radiation used to be applied during the period and hence the plot of these values should represent the total radiation correction curve and the data fit in curve C fairly. Similar computation for the C-type sonde (New Delhi) for this range of solar angles could not be carried out, as the sonde in use prior to July 1957 was not the same as the sonde used subsequently.

## 4. Acknowledgement

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## *REFERENCES*

| | | |
|---|---|---|
| Kay, R. H. | 1951 | *Quart. J. R. met. Soc.*, **77**, pp. 427-434. |
| Lugeon, J. and Ackermann | 1955 | *Ann. Sta. cent. Suisse Met.* |
| Mani, A., Venkataraman, C. N. and Huddar, B. B. | 1959 | *Indian J. Met. Geophys.*, **10**, 2, pp. 189-198. |
| Pant, P. S. | 1960 | *Ibid.*, **11**, 4, p. 371. |
| Scrase, F. J. | 1954 | *Quart., J. R. met. Soc.*, **80**, p. 565. |
| Teweles, S. and Finger, F. G. | 1960 | *J. Met.*, **17**, p. 177. |