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Analysis of Soil Temperatures at Waltair

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ABSTRACT. An analytical study of the depth and time variations of soil temperatures at Waltair has been made. Curves showing the diurnal variation of soil temperatures at different depths on certain representative days in different months have been presented and discussed. Several interesting features are brought out from the graphs depicting the seasonal variation of the daily temperature ranges at different depths as well as from seasonal variation of mean soil temperature in different months. Finally, emphasis is also laid on the tautochrones of mean daily temperature for various depths of observation in different months.

1. It is well-known that the amplitude of the surface diurnal wave varies considerably with latitude, season, nature of the surface and state of the sky. In the present note an analytical study of the depth and time variations of soil temperatures at Waltair is presented and discussed. The same set of soil and earth thermometers previously used for the heat flow work by the authors (1961) were employed also for this study and temperatures were recorded every hour continuously for 24 or 36 hours on representative occasions in different seasons. Curves presented in Fig. 1 show the diurnal variation of soil temperatures at different depths on certain representative days in different months. They confirm the general observation that the amplitude of the diurnal wave of temperature rapidly diminishes with depth and becomes very small beyond about 60 cm. This rapid decline in amplitude of the diurnal wave accounts for the existence of very steep temperature gradients in the uppermost layers of the ground. The time of occurrence of maximum surface temperature in all the curves is about an hour after the time of maximum solar radiation except on cloudy days and this observation is in agreement with Schreiber's (1910-1912) measurements in Dresden. The progressive phase shift in curves with depth indicates the slow rate of propagation of heat energy into the soil.

2. In Fig. 2, are presented curves showing the seasonal variation of the daily temperature ranges at different depths. It may be observed that the annual variation of soil temperature like the diurnal variation is the strongest in the surface layers only and in the deeper layers the ranges are very small. Further, the peaks and troughs in the curves, which are again of great interest, are features of the surface layers only and do not appear to be communicated to greater depths. The deep craterlike trough centred in July is clearly due to increased premonsoon and monsoon clouding which not only cuts down the incoming solar energy during day-time thus keeping the maximum temperatures low, but does not also allow the normal cooling of the earth's surface and thus raises the night minimum temperatures; with the clearing of the monsoon the troughs at all levels register secondary peaks in September. The second dip in October is again due to occasional clouding and slight rises in humidity resulting from the cyclonic activity of the post monsoon period.

3. Fig. 3 shows the seasonal variation of mean soil temperatures (means of the daily maxima and minima) in different months. The curves again indicate two peak values, analogous to range curves, in the premonsoon (March) and post monsoon (September) seasons. From the same graph it may be noticed

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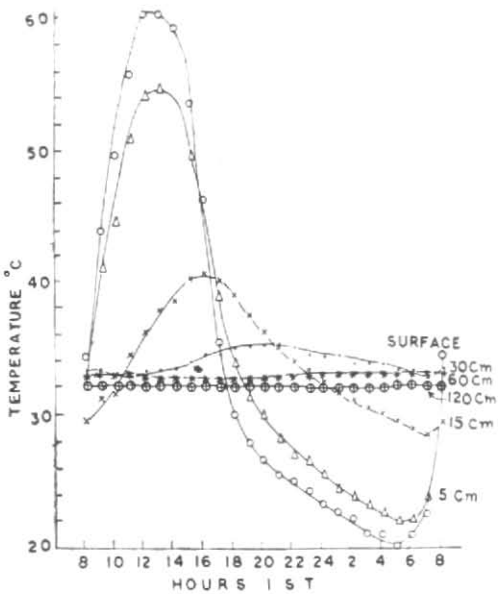

Fig. 1(a). March 1960

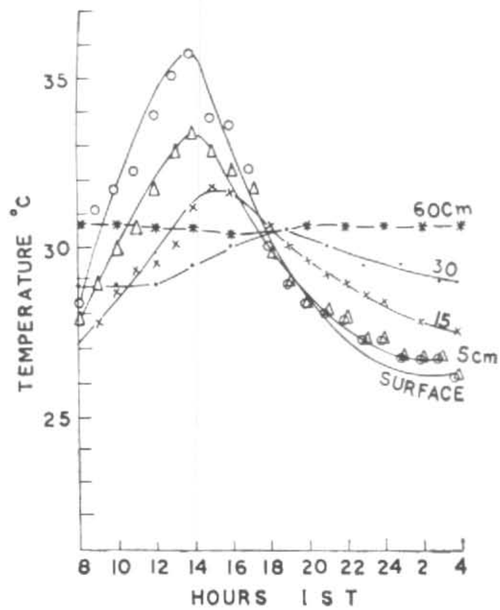

Fig. 1(b). July 1959

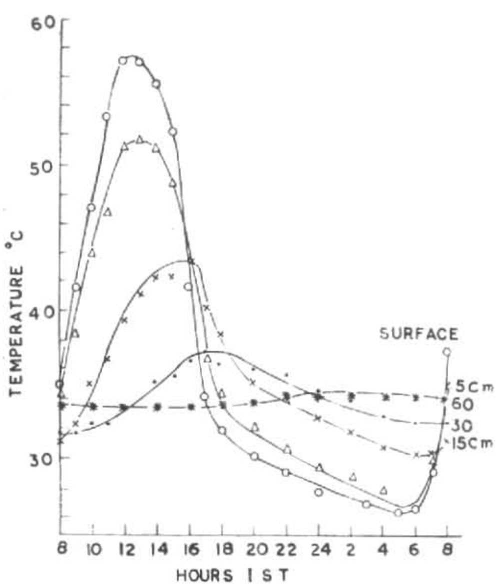

Fig. 1(c). September 1959

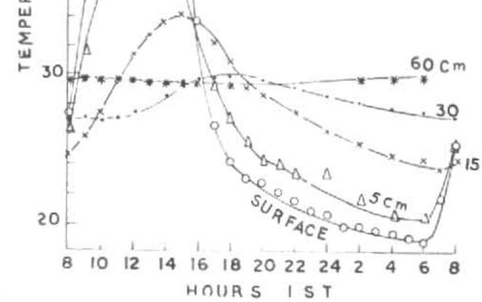

Fig. 1(d). November 1959

Figs. 1(a) to 1(d). Diurnal variation of soil temperatures

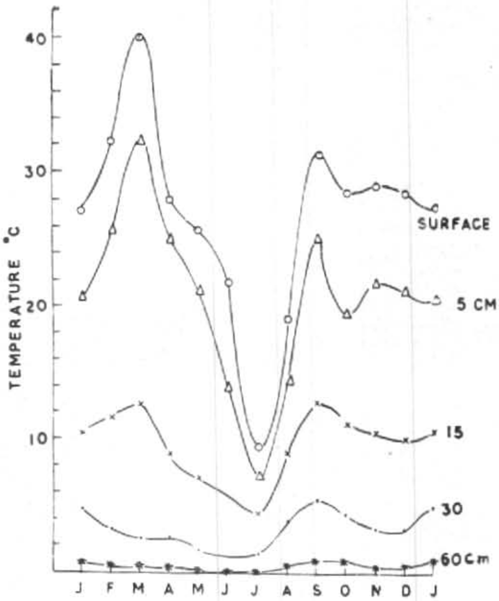

Fig. 2. Variation of temperature ranges in an year

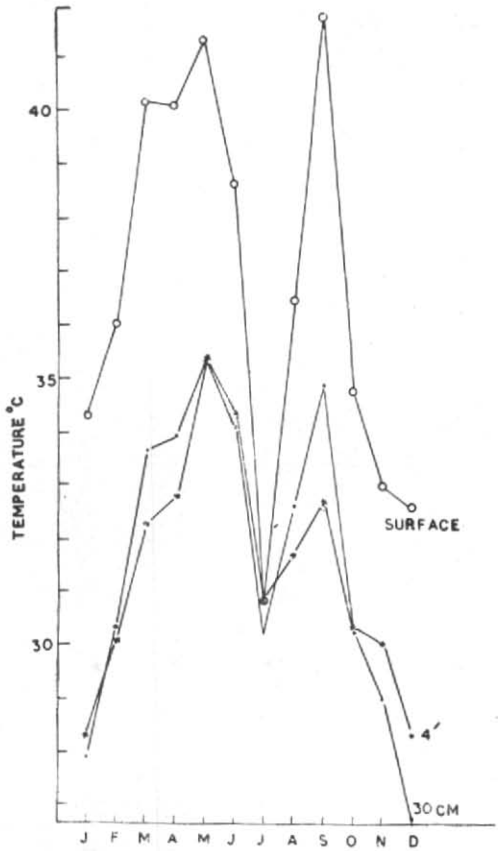

Fig. 3(a). Seasonal variation of mean soil temperatures

that the penetration of the annual wave is far deeper than the diurnal wave, for the reason that the amplitudes not only do not die out so rapidly but are quite appreciable even to a depth of 4 ft. The temperature gradients indicate that during the early summer period considerable amounts of heat must flow into the soil down to about 4 ft. With the establishment of the monsoon, temperature gradients become very weak in the entire soil column and heat fluxes are reduced to low values. A secondary period of higher heat flow occurs again in September after the monsoon season. These several features may also be observed from the heat flow curves presented earlier by the authors (1961).

4. Tautochrones of mean daily temperature for various depths of observation in different months are shown in Fig. 4. The profiles again indicate, as expected from the above discussions, steep temperature gradients in the top layers in all seasons and weak gradients or isothermal layers at greater depths. The regular variations of the mean temperature of the soil column can also be clearly observed from the gradual bodily displacement of the curves in different months.

5. A preliminary analysis of the diurnal curves was made to evaluate the thermal diffusivity of the soil in a dry period as suggested by Coutts (1955). The formula employed was—

$$K = \frac{\pi}{T}\left[\frac{(x_1 - x_2)}{\ln \theta_1/\theta_2}\right]^2$$

where T=86,400 seconds and θ_1 and θ_2 diurnal amplitudes at depths x_1 and x_2. The value of K came out to be $6 \cdot 134 \times 10^{-3}$ cm^2/sec which is almost of the same magnitude as reported by Coutts (1955) and Subba Rao

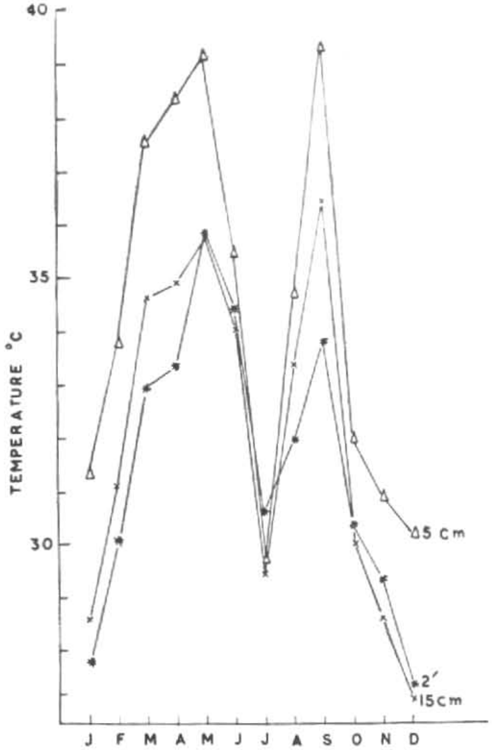

Fig. 3(b)

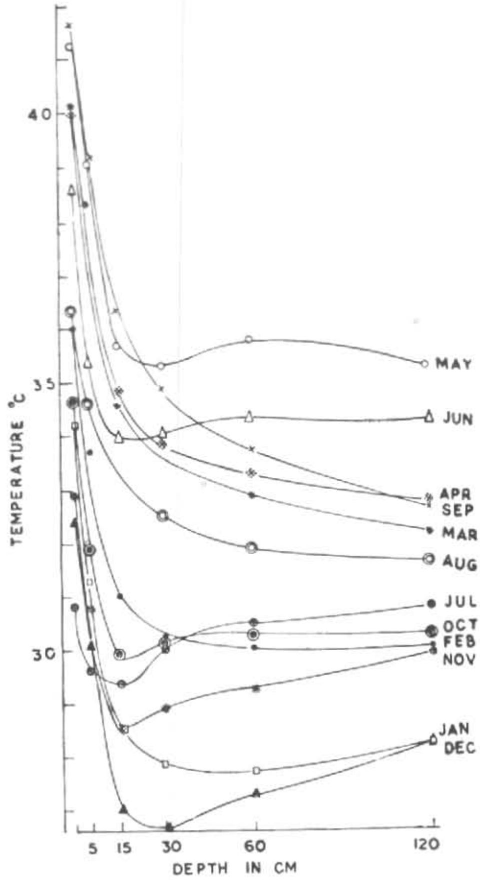

Fig. 4. Tautochrones

and Subrahmanyam (1957). Further studies on thermal properties of soils are in progress.

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