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Effect of cold wave on soil temperatures

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सार— पुणे की कपास उपजाऊ काली मृदा में जनवरी 1981 के साफ मौसम के दिनों में जिनमें मध्यम शीत लहर की अवधि भी शामिल है सतह से 150 सें० मी० गहराई तक की मृदा में गहन प्रेक्षण किए गए । देखा गया कि 30 सें० मी० से नीचे बहुत कम या न के बराबर दैनिक विचरण था । शीत लहर के चलने पर मृदा की ऊपरी परत तेजी से प्रभावित हुई और उसके तापमान में काफी गिरावट आई । लगभग दो दिनों तक चलने वाली मध्यम शीत लहर ने नीचे की गहरी परतों के तापमानों को भी प्रभावित किया । आंशिक मेघाच्छन्नता से मुख्यत: सतह और 5 सें० मी० की गहराई तक के तापमान प्रभावित हुए ।

सतह से 5 सें० मी० गहराई तक की तापीय विसरणशीलता 0.1029×10^{-2} सें० मी०^2/सें० रही, जबकि वह 15 से 20 सें० मी० की गहराई में 0.3043×10^{-2} सें० मी०^2/सें० थी । अवमंदन गहराई 7.6 सें० मी० पायी गई । ये दोनों प्राचल रेतीली मृदा की तुलना में कपास उपजाऊ काली मृदा में कम रहे, अत: उसमें दैनिक तापमान तरंग भी तेजी से मंद पड़ने लगी ।

ABSTRACT. Intensive observations from surface to 150 cm depth of soil on clear days in January 1981 covering the period of moderate cold wave were recorded in black cotton soils at Pune. There was a little or no diurnal variation below 30 cm. During the passage of cold wave upper layers of soil responded quickly and appreciable fall of temperatures were noticed. Persistence of moderate cold wave conditions for about two days influenced the deeper depths temperatures too. Partial clouding mainly affected the temperatures of surface and 5 cm.

Thermal diffusivity within surface to 5 cm was 0.1029×10^{-2} cm^2/sec while that in 15 to 20 cm was 0.3043×10^{-2} cm^2/sec. Damping depth was found to be 7.6 cm. Both these parameters being low in comparison to those for sandy soils diurnal temperature wave dampens at faster rate in black cotton soils.

1. Introduction

It is well known that there is a progressive lag with depth in times of occurrence of maximum and minimum soil temperatures because of the slow rate of energy transfer within the soil. The range of diurnal variation of soil temperature also decreases with increasing depth (Smith 1932, Flucker 1958, Kristensen 1959, Tripathi and Ghildyal 1979). What is not so well understood, however, is the manner in which subsoil temperatures would react to abrupt and large changes in surface temperature, such as those associated with a cold wave.

Keeping in view the above consideration, intensive soil temperature measurements were made from surface to 150 cm depth in the black cotton soil at Pune, the period of observations being so chosen as to coincide with the passage of a moderate cold wave. The results of the study are presented and discussed in this paper.

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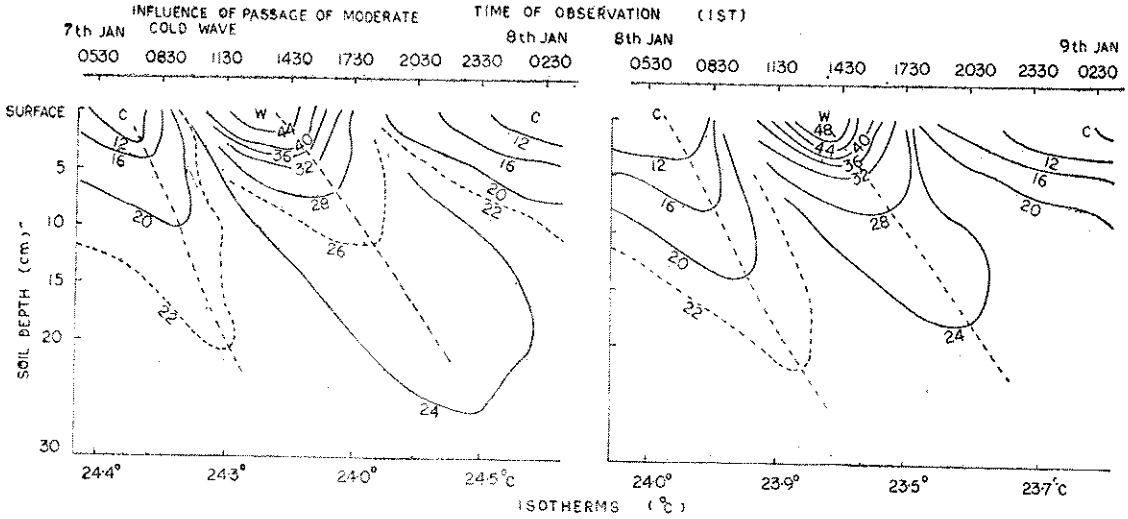
2. Instruments and observations

The study was conducted in Central Agricultural Meteorological Observatory located in Agricultural College, Campus, Pune. Soils at the observatory site are black cotton soils clayey in nature, of medium depth and medium class porosity. Field capacity (33 to 36% of the dry soil weight) of these soils is high in comparison to alluvial or sandy loam soils found in many parts of India.

For recording soil temperatures, standard mercury in glass thermometers are installed in soil and plot is kept free of grass or any other vegetation inside the observatory enclosure. Observations were recorded at depths : Surface, 5, 10, 15, 20, 30, 50, 100 and 150 cm and air temperature at 2 cm above ground surface at an hourly interval round the clock, starting at 0530 IST on 4 January 1981 to 0830 IST on 19 January 1981. Soil moisture at depths : Surface 7.5, 15, 22.5, 30 and 45 cm were determined on every third day by gravimetric method as percentage



Figs. 1&2. Penetration of diurnal temperature wave (Scalar analysis, Pune : 7/8 & 8/9 Jan 1981) [Influence of passage of moderate cold wave]

of dry soil. Daily significant weather observations like duration and amount of rainfall, dew deposition, state of sky, daily air (Stevenson screen) maximum and minimum temperature recorded at the observatory were also collected.

3. Local weather and soil moisture

Due to the passage of western disturbance, on 8 January, cold wave conditions with minimum temperature departures of the order 6 deg. C were prevailing over Saurashtra, west Madhya Pradesh and parts of Maharashtra. Minimum temperatures continued to be appreciably below normal on the 9th in these areas.

Local weather at Pune was clear from 1 January 1981. From 4 to 9 January, there was mist or haze in the early morning, with bright sunshine all through the day. Minimum temperature on 4th was 10.8 deg. C with small change over the next three days, but dropped to 5.8 deg. C on 8th morning. Maximum temperature showed a gradual fall from 30.4 deg. C on 4th to 24.6 deg. C on the 9th. After the passage of the cold wave, weather changed significantly. From the 10th onwards the sky was mostly cloudy and minimum temperatures were above normal or only slightly below normal. 4.2 mm of rain was recorded in the 24 hours ending 0830 IST of 18th. Prior to and during cold wave period, moisture content within surface to 7.5 cm of soil layer was nearly 10 per cent of the dry soil weight. At 15 cm depth moisture increased to 18 per cent and that at 30 cm and below to 20-21 per cent. In the course of observational period, soil moisture gradually decreased with time.

4. Results and discussion

4.1. *Scalar analysis*

With time along the X-axis and depth along negative Y-axis, hourly values of soil temperatures for surface to 30 cm depth were plotted for 7/8 and 8/9 January. Isotherms were drawn at 4 deg. C (or 2 deg. C) interval and are presented in Figs. 1 and 2. The dashed lines show the change in the time of occurrence of minimum/maximum soil temperature with depth.

Diurnal maxima and minima of soil temperatures at various depths from surface to 150 cm are presented in Table 1 while time lag of occurrence of these extremes are presented in Table 2. 6th and 7th represent the period prior to cold wave and 8th and 9th correspond to moderate cold wave.

4.2. *General features and influence of cold wave*

It may be seen from the results that prior to and in course of passage of cold wave minimum temperatures show progressive increase throughout the soil profile studied while maximum temperatures show decrease with depth upto 30 cm only. It is also observed that diurnal wave dies out very rapidly with depth. On 7th, range at the surface was 38.8 deg. C while at 30 cm it was only 0.2 deg. C. There was a little or no diurnal variation noticed at deeper depths. Thus, in normal winter period with small changes in screen minimum, diurnal temperature wave hardly penetrates below 30 cm.

From 7 to 8 January, with the incursion of cold continental air soil temperature minima registered a clear fall at all depths upto 30 cm. Even at 50 cm, a slight fall (—0.3 deg. C) was noticed. Maximum temperatures also decreased at all depths. However, the fall was more significant in the 10-20 cm layer than in the soil above and below it. At the deeper depths of 100 and 150 cm, there was no appreciable change on 8th, but a fall (—0.2 deg. C) was observed on the 9th. These observations clearly show that the passage of cold wave greatly influences the soil temperatures in the 0-30 cm layer and to a lesser degree, the temperatures of the deeper depths.

TABLE 1

Diurnal soil temperature minima and maxima along with their range on days prior to and in the course of passage of moderate cold wave at Pune

Date	Surface	5	10	15	20	30	50	100	150	Screen
		Soil depth (cm)								
					Minimum temperature (°C)					
6	10.1	16.0	20.1	21.6	22.1	23.9	25.0	25.6	26.2	9.4
7	11.0	17.0	19.7	21.2	21.9	24.1	25.0	25.6	26.2	10.8
8	6.3	14.0	18.9	20.5	21.3	23.5	24.7	25.6	26.2	5.8
9	5.9	13.9	18.5	20.8	21.7	23.1	24.5	25.4	26.0	6.2
					Maximum temperature (°C)					
6	48.3	31.2	27.2	25.4	24.5	24.3	25.0	25.6	26.2	29.8
7	49.8	32.0	26.5	25.0	24.4	24.3	25.0	25.6	26.2	27.2
8	50.0	31.8	25.7	24.1	23.6	23.8	24.9	25.6	26.2	25.3
9	46.4	29.1	24.1	23.4	22.8	23.6	24.7	25.5	26.1	24.6
					Range (°C)					
6	38.2	15.2	7.1	3.8	2.4	0.4	0.0	0.0	0.0	20.4
7	38.8	15.0	6.8	3.8	2.5	0.2	0.0	0.0	0.0	16.4
8	43.7	17.8	6.8	3.6	2.3	0.3	0.2	0.0	0.0	19.5
9	40.5	15.2	5.6	2.6	1.1	0.5	0.2	0.1	0.1	18.4

TABLE 2

Time lag of occurrence of minima and maxima of soil temperatures in shallow depths with reference to that at the surface

Date	Surface	5	10	15	20	30
	Soil depth (cm)					
			Time lag (hr-min) for min. temp.			
7	—	1-35	2-40	3-55	5-25	—
8	—	1-25	2-35	4-05	5-35	—
			Time lag (hr-min) for max. temp.			
7	—	2-20	4-10	6-10	8-00	—
8	—	2-10	4-15	6-10	8-05	—

TABLE 3

Thermal diffusivity values based on amplitude variation (K) and phase variation (K_L) along with ratio of amplitudes (A_1/A_2) at depths Z_1 and Z_2 and their relative time lag (t_2-t_1) and moisture for each soil layer

Soil layer (Z_1 to Z_2) (cm)	Moisture (%)	A_1/A_2	$K\times 10^2$ (cm²/sec)	Time lag (t_2-t_1) (min)	$K_L\times 10^2$ (cm²/sec)
0-5	8.2	2.59	0.1029	140	0.2436
5-10	11.0	2.20	0.1452	110	0.3946
10-15	15.5	1.79	0.2684	120	0.3316
15-20	18.3	1.73	0.3043	110	0.3946

4.3. *Post-cold wave period*

After the passage of the cold wave, the sky conditions changed from clear to cloudy. The hours of bright sunshine was 5.4 on 11th compared to 10.4 on the 8th. There was also appreciable reduction in total solar radiation (19.44 Mega Joules/m² on 8th against 13.53 MJ/m² on 11th). On the 11th, *Sc* and *Ac* clouds were present in the forenoon and *Cu* developed in the afternoon, the cloud amount being about 6 oktas most of the time. The patterns of soil temperature variation are shown in Figs. 3 and 4. At the surface compared to 8th, the soil temperature maximum decreased by 5.9 deg. C while the minimum increased by 5.2 deg. C. Very little or no fluctuations in hourly soil temperatures were seen below 10 cm. Diurnal range of temperature became insignificant even at 30 cm depth. The time lags in the occurrence of minima did not show any change. Maximum of surface and 5 cm, however, was not recorded at the same hour as that on clear days. Thus, partial cloud cover influences the soil temperature pattern mainly in surface to 10 cm while lower depths do not exhibit any major change.

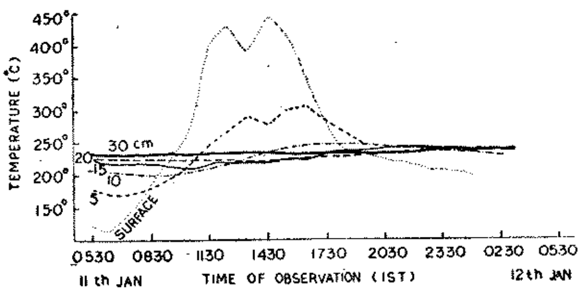


Fig. 3. Diurnal variation of soil temperature (cloudy day : Pune 11/12 Jan 1981)

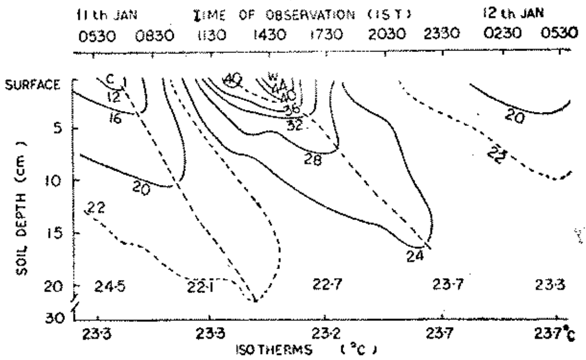


Fig. 4. Penetration of diurnal temperature wave (Scalar analysis) [Cloudy day: Pune 11/12 Jan 1981]

4.4. *Thermal diffusivity*

Thermal energy is transported in soil by conduction on a molecular scale. Assuming that the soil is homogeneous medium and soil temperature variation is periodic function of time, thermal diffusivity of soil may be computed from the relationship :

$$K = \frac{(Z_2 - Z_1)^2}{P\{\ln(A_1/A_2)\}^2} \quad (1)$$

or

$$K = \frac{P}{4\pi} \times \frac{(Z_2 - Z_1)^2}{(t_2 - t_1)^2} \quad (2)$$

where, K=Thermal diffusivity of soil (cm²/sec)

Z_1, Z_2 = Depth of upper and lower boundary of soil layer.

A_1, A_2 = Amplitudes of soil temperatures at depths Z_1 and Z_2 respectively.

t_1, t_2=Time lags of occurrence of maxima at depths Z_1 and Z_2.

P=Periodic time.

In present case amplitudes and time lags correspond to diurnal cycle (P=24 hours).

A description of assumptions involved and method of computation are given elsewhere (Bhandari 1981). Since soil moisture content varied with depth thermal diffusivity values were computed from data of 7 January for soil layers 0-5, 5-10, 10-15 and 15-20 cm using both the amplitude (Eqn. 1) and phase variation (Eqn. 2). These are presented along with soil moisture values, in Table 3. Moisture content of each layer was estimated from the soil moisture observations recorded at surface, 7.5, 15 and 22.5 cm depth. The time of occurrence of maxima and minima are not sharply defined. The ambiguity involved in the estimation of time lag may result in error in computation of K by time lag method. Thus out of two sets of values (K and K_L) those computed from amplitude variation should be more accurate.

Predetermined values of thermal diffusivity may be used for computation of damping depth from the relationship.

$$D = \sqrt{\frac{KP}{\pi}}$$

where D is the damping depth. Substituting the value for K=0.1029×10⁻² cm²/sec based on amplitude variation in surface layer D works out to be 5.24 cm. Taking average value of K=0.21×10⁻² cm²/sec damping depth is 7.6 cm for black cotton soil at Pune. Average damping depth for sandy soil is about 12 cm (Van Wijk and Vries 1963). This indicates that diurnal soil temperature cycle in Pune soils penetrates to relatively shallow layers, *i.e.*, the soil temperature wave dampens very rapidly.

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