551.525.5 : 631.421

RELATIONSHIP BETWEEN SOIL TEMPERATURES AT VARIOUS DEPTHS

1. In order to study the behaviour of soil temperatures during different seasons, regression/correlation studies have been carried out on the weekly normal values of soil temperatures recorded at 12 stations having different soil types and spread all over India.

2. *Data and method* — The selected stations (Fig. 1) are as follows :

Station	*State*	*Soil type*
Bhubaneswar	Orissa	Sandy loam fine, light coloured
Bikramganj	Bihar	Old alluvium
Dharwad	Karnataka	Black & red soil
Gwalior	Madhya Pradesh	Alluvial soil
Hisar	Haryana	Sandy loam
Jodhpur	Rajasthan	Dune & sandy plain
Nagpur	Maharashtra	Black soil
Pantnagar	Uttar Pradesh	Haldy loam fine texture, brownish in colour
Pattambi	Tamil Nadu	Laterite, reddish colour
Pune	Maharashtra	Black cotton
Rajahmundry	Andhra Pradesh	Black clay
Solapur	Maharashtra	Medium coarse texture, blackish brown in colour

52 means of weekly normal values (based on data for 30 years, 1951-80) of soil temperatures at 5, 15 and 30 cm depths recorded at 0700 and 1400 IST have been used. The values of correlation coefficient have been computed for the three pairs of depths, *viz.*, 5-15 cm (Layer L_1), 5-30 cm (Layer L_2), 15-30 cm (Layer L_3) and for all the stations separately by using the standard linear regression method. Surface layer data could not be used as the same was inadequate.

TABLE 1

Values of correlation coefficient between various depths for all seasons

Season	Layer	Stations											
		Bhuban-eswar	Hisar	Pant-nagar	Pat-tambi	Pune	Rajah-mundry	Sola-pur	Bikram-ganj	Gwalior	Jodhpur	Nagpur	Dhar-wad
I	L_1	0.999	0.978	0.986	0.986	0.981	0.985	0.987	0.957	0.994	0.984	0.997	0.884
	L_2	0.996	0.988	0.989	0.993	0.983	0.978	0.984	0.846	0.990	0.962	0.991	0.875
	L_3	0.997	0.989	0.990	0.973	0.987	0.992	0.992	0.916	0.980	0.984	0.998	0.994
II	L_1	0.990	0.996	0.996	0.902	0.822	0.939	0.942	0.997	0.997	0.995	0.992	0.804
	L_2	0.993	0.995	0.995	0.981	0.716	0.943	0.983	0.982	0.997	0.884	0.995	0.724
	L_3	0.996	0.994	0.999	0.905	0.966	0.989	0.947	0.993	0.998	0.999	0.995	0.944
III	L_1	0.978	0.943	0.949	0.980	0.931	0.881	0.976	0.962	0.983	0.881	0.983	0.967
	L_2	0.984	0.945	0.972	0.948	0.921	0.864	0.914	0.929	0.960	0.964	0.928	0.878
	L_3	0.984	0.981	0.974	0.982	0.979	0.730	0.959	0.931	0.987	0.889	0.972	0.949
IV	L_1	0.988	0.997	0.997	0.961	0.931	0.982	0.957	0.999	0.997	0.995	0.998	0.978
	L_2	0.986	0.997	0.998	0.874	0.947	0.932	0.940	0.981	0.996	0.938	0.994	0.987
	L_3	0.998	0.997	0.999	0.946	0.965	0.944	0.990	0.983	0.998	0.996	0.996	0.985
Annual	L_1	0.988	0.990	0.996	0.981	0.928	0.930	0.989	0.987	0.987	0.994	0.971	0.955
	L_2	0.974	0.984	0.993	0.991	0.916	0.930	0.927	0.975	0.980	0.970	0.939	0.942
	L_3	0.995	0.996	0.998	0.992	0.993	0.972	0.989	0.992	0.996	0.993	0.989	0.991

L_1 : Layer between 5 cm & 15 cm depths, L_2 : Layer between 5 cm & 30 cm depths L_3 : Layer between 15 cm & 30 cm depths

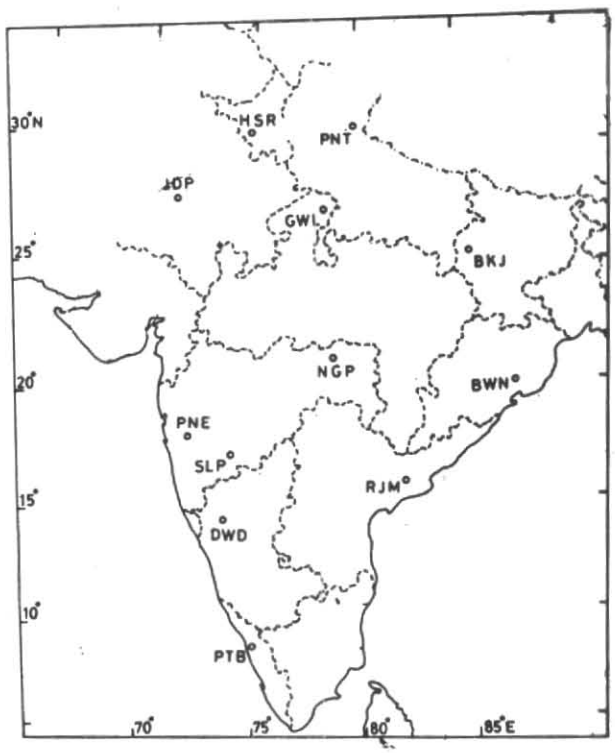

Fig. 1. Location of stations considered for analysis of soil temperature

Correlation coefficients and regression constants A and B in the regression equation $Y = AX + B$ have been computed by taking X and Y as the shallower and deeper depth temperatures respectively for the above mentioned layers for year as a whole and also for four nearly homogeneouos seasons, *viz.* :

Season I : January-February (weeks 1-9).

Season II : March-May (weeks 10-22),

Season III : June-September (weeks 23-39),

Season IV : October-December (weeks 40-52).

The values of correlation coefficient for different soil layers for all seasons are given in Table 1.

The following observations are noticed :

Season I (January-February)

(i) In 91% of the cases, the value of CC is > 0.9 for all the pairs of depths taken together which points out to an extremely good correlation. The remaining 9% cases consist of only 3 cases—two at Dharwad and one at Bikramganj.

(ii) The range of CC values is from 0.999 to 0.846. The highest value is 0.999 for the layer L_1 at Bhubaneswar. Considering the layers individually. Bhubaneswar shows highest values for L_1 and L_2 layers whereas for L_3 layer. Nagpur shows a marginally higher value than Bhubaneswar.

(iii) Bikramganj shows lowest CC for the two layers out of three, *viz.*, L_2 (0.846) and L_3 (0.916). The lowest value for L_1 layer (0.884) is observed at Dharwad.

(iv) The respective ranges of CC for the three layers L_1, L_2 and L_3 are 0.115, 0.150 and 0.082.

Season II (March-May)

(i) In 83% of the cases, the value of CC is > 0.9 for all the pairs of depths taken together showing quite a good correlation.

(ii) The range of CC values is from 0.999 to 0.716. The highest value of CC is 0.999 at Jodhpur for the layer L_3. For the other layers, highest values are, 0.997 at Bikramganj and Gwalior for L_1 layer and 0.997 at Gwalior for L_2 layer.

(iii) It is observed that cases pertaining to CC < 0.9 are more in the layer L_2 as compared to the other two layers.

(iv) The lowest value 0.716 of CC is observed at Pune in the layer L_2. Dharwad station shows lowest value in the layer L_1 (0.804) and significantly low in the layer L_2 also (0.724). However, the lowest value in L_3 layer (0.905) is observed at Pattambi.

(v) The respective ranges of CC for the layers L_1, L_2 and L_3 are 0.193, 0.281 and 0.094.

Season III (June-September)

(i) In 83% of the cases, the value of CC is > 0.9 for all the pairs of depths taken together showing quite a good correlation.

(ii) The range of CC values is from 0.987 to 0.730. The highest value is 0.987 at Gwalior for L_3 layer. Gwalior again exhibits the same behaviour with a value of 0.983 for the layer L_1 while Bhubaneswar shows the highest value of 0.984 in the layer L_2.

(iii) The lowest values (all < 0.9) in all the three layers are observed at Rajahmundry, the least of them being 0.730 in the L_3 layer.

(iv) It is observed that in almost all the layers, only two stations out of 12, *viz.*, Gwalior and Rajahmundry, exhibit the extreme values.

(v) The respective ranges of CC for the layers L_1, L_2 and L_3 are 0.102, 0.120 and 0.257.

Season IV (October-December)

(i) In 97% of the cases, the value of CC is > 0.9 for all the pairs of depths which shows an extremely good correlation. Even the lowest CC value is 0.874 at Pattambi for the L_2 layer.

(ii) The range of CC values is from 0.999 to 0.874. The highest value of CC is 0.999 at Pantnagar for the layer L_3. For the layers L_1 and L_2 the highest values are 0.999 at Bikramganj and 0.998 at Pantnagar.

(iii) The respective ranges of CC for the layers L_1, L_2 and L_3 are 0.068, 0.124 and 0.055.

3. *Annual*

(i) At all the stations and in all the three layers, the CC values are > 0.9 indicating an extremely good correlation.

(ii) The range of CC values is from 0.998 to 0.916. Highest CC values in all the layers are observed at Pantnagar — the highest being 0.998 for the L_3 layer.

(iii) Lowest CC value (0.916) is seen at Pune in the L_2 layer. In the layer L_1 also, Pune has the lowest value (0.928) while for the L_3 layer, lowest value is 0.972 observed at Rajahmundry.

(iv) In almost all the cases, CC values are higher in the L_3 layer as compared to the other two layers.

(v) The respective ranges of CC for the layers L_1, L_2 and L_3 are 0.068, 0.077 and 0.026.

4. *Discussion*—Soil temperature variations at different depths for different soils under study may be attributed to variation of thermal conductivity of the soil. Conduction of heat through earth's layers is a relatively slow process so that the temperatures at deeper depths do not follow the same pattern as the temperatures at shallower depths (Bhandari 1980). It has also been shown that the soil temperatures at various depths are harmonic functions (Lamba and Khambete 1991).

As the soil between 15 cm and 30 cm depths by and large remains undisturbed from soil manipulation, *viz.*, tilling and fertilization, it can be considered as a homogenous soil layer under consideration. This, perhaps, explains as to why the correlation between the 15 cm and 30 cm depths is the highest.

Pantnagar is located in a submontane area. It has a haldy loamy fine textured wet soil. The soils of this region lie as a belt below and a few kilometres south of the foothills of the Himalayas on a gently sloping outwash plain. These soils are classified as Mollisols and are characterised by high water table conditions (Tripathi and Ghildyal 1979). It is, perhaps, due to these characteristics of its soil that Pantnagar shows highest values of the correlation coefficient between the temperatures of the layers under consideration.

5. *Conclusions* — The following conclusions are drawn :

(i) All types of soils experience linear regression relationship between different layers. As such, it would be possible to determine deeper depth temperatures from shallower depth (or surface) temperatures and *vice versa*.

(ii) Correlation coefficient values are ≥ 0.9 on 91% of the occasions for all the seasons and the year taken together but the score is cent/percent for annual values.

(iii) The correlation between soil temperatures at 15 cm and 30 cm depths is the highest for all the seasons as well as the year as a whole.

(iv) Correlation values during summer monsoon season (June-September) are the lowest among the three layers considered indicating that the soil heating gets disturbed during the rainy season.

(v) The ranges of CC for all the three layers are lowest in case of the annual values.

(vi) During winter, a coastal station (Bhubaneswar) shows highest correlation in two of the three layers; during pre-monsoon and monsoon seasons, a central station (Gwalior) and during post-monsoon season and year as a whole, a station in submontane area (Pantnagar) exhibit the same behaviour.

(vii) Pantnagar shows highest CC values in 33% of the cases while Bhubaneswar and Gwalior exhibit the same in 20% of the cases. However, the stations Pune, Dharwad, Pattambi, Rajahmundry, Hisar and Solapur do not show such a behaviour even on a single occasion.

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