The Temperature Profile In A Forest

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The author presents information on the air and soil temperature gradients in a mature mixed conifer stand in California.

THE temperature profile of a mature forest seldom has been observed. Temperatures at specific locations are of interest to the forester because they may help explain many phenomena, such as growth or death of seedlings and freezing of terminals and floral parts of trees. The opportunity to combine a vertical succession of such temperature measurements into a temperature profile was afforded the author by a battery of thermometers installed in a study of natural regeneration at the Stanislaus Branch of the California Forest and Range Experiment Station. This branch station is located on the west slope of the Sierra Nevada at latitude 38°11′ north, longitude 120°02′ west. One phase of the study was conducted in mature mixed conifer stand near the bottom of a east-facing slope at an elevation of 5170 feet. The stand is composed of the following species: ponderosa pine, sugar pine, Jeffrey pine, white fir, and California incense-cedar. This paper presents a summary of the temperatures observed therein.

Instrumentation

Maximum and minimum air temperatures were measured with Weather Bureau type thermometers in a weather shelter 4.5 feet above ground level and in thermometer shelters 30, 60, and 120 feet above ground level. The thermometer shelters were fastened to the north side of a Jeffrey pine about 175 feet tall and were reached by a ladder fastened to the bole. The shelter at 120 feet was within the tree's live crown, which started at about 100 feet up the bole.

Maximum and minimum soil temperatures were measured by "Six's" type thermometers at distances of ¼ inch, 3 inches, and 7 inches below the mineral soil surface. Humus and litter about 1½ inches deep covered the mineral soil. The thermometers were installed with the bulb extending into the soil horizontally at the depths stated and with scale in a soil box. With such an installation the thermometer need not be moved at all during the season.

Current soil temperatures were measured at depths of 12 inches and 18 inches by ordinary mercurial thermometers placed vertically in soil tubes. These temperatures were observed at 8:00 a.m. (P.S.T.). Maximum and minimum temperatures were not observed at these depths. A few records from soil thermographs at 12 inches indicated that the daily range of temperatures was about one degree, Fahrenheit. This observation is in accord with findings of Smith (*4*) who noted that in the hot Sacramento Valley of California there was little daily rise and fall of temperatures at 12 inches and none at 24 inches. The assumption that these current temperatures are very close to both the maximum and minimum temperatures is valid.

Temperatures were observed daily at each location during the field season, May to October, for three years, 1937-38-39. Temperatures were read to the nearest one-half degree, Fahrenheit,

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Table 1.—Average Maximum Temperatures, By Months, At The Location Indicated

Thermometer location	May	June	July	Aug.	Sept.	Oct.
	Average maxima by months					
			Degrees, F.			
120 feet above ground	64.9	71.2	79.4	80.4	75.2	62.8
60 feet above ground	65.0	71.7	80.1	80.8	75.2	62.8
30 feet above ground	65.7	71.8	80.4	81.5	76.1	63.0
4.5 feet above ground	66.9	72.9	82.0	83.6	78.0	65.6
¼ inch below mineral surface	70.6	75.9	94.6	98.8	88.7	60.3
3 inches below mineral surface	55.2	60.0	64.6	69.0	62.3	49.3
7 inches below mineral surface	51.5	55.3	61.6	62.4	57.7	47.9
12 inches below mineral surface	51.5	56.0	61.2	61.6	57.5	49.6
18 inches below mineral surface	50.2	53.6	58.9	59.9	56.8	50.2

and thermometers were checked against standards to provide any corrections necessary.

The Temperatures Observed

The average monthly maximum and minimum temperatures at the various heights and depths are summarized in Tables 1 and 2. For convenience, the 8:00 a.m. current temperatures at 12 inches and 18 inches soil depth are listed in both tables as being maximum and minimum.

The data in Tables 1 and 2 should not be interpreted to indicate that the maximum or minimum temperatures occur simultaneously at the different locations. Data presented by Johnson (*3*) show a lag of as much as 25 minutes from the time of maximum temperature at 1.2 meters to the time of maximum temperature at 17.1 meters above ground. Similarly he observed a lag in the time of occurrence of the minimum temperatures.

In the soil, the temperature lag is much greater. Thermographic records taken during the period of this study indicated that the lag at ¼ inch below mineral soil varied from ½ to 1½ hours. At 7 inches below mineral soil minimum temperatures lagged about 5 hours, maximum temperature about 7-½ hours. Smith (*4*) reported a lag of 4 hours at the 6 inch depth, 8 hours at 12 inches, and about 70 hours at 24 inches. Any perceptible daily amplitude at 12 and 18 inches probably would have occurred with a lag comparable to that reported by Smith. The data reported indicate, then, the maximum and minimum temperatures which might obtain from a given shelter temperature during the successive months including the growing season.

In Figure 1 the average temperatures for August, 1939, are plotted against the locations of the instruments to better portray the trend of maximum and minimum temperatures throughout the vertical distribution of locations.

No attempt has been made to connect the curves between the readings at 4.5 feet above ground and at ¼ inch below mineral surface. Measurement of maximum and minimum temperatures at the soil-air boundary was not possible with the equipment available. The difficulty of such measurements is pointed out by Daubenmire (*1*). His thermo-electric observations show that maximum temperatures occur at this exact soil surface. Depending on the type of soil surface,

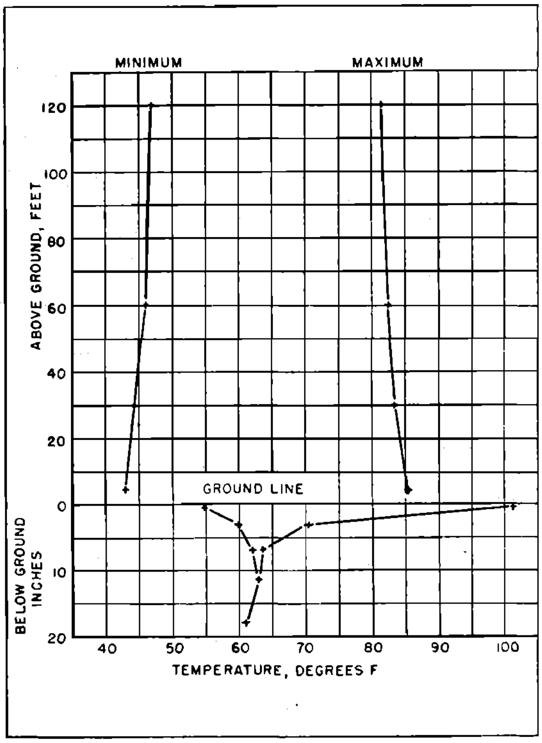

Fig. 1.—The vertical distribution of maximum and minimum temperatures in a forest.

Table 2.—Average Minimum Temperatures, By Months, At The Locations Indicated

Thermometer location	May	June	July	Aug.	Sept.	Oct.
			Average minima by months			
			Degrees, F.			
120 feet above ground	34.9	41.2	47.6	46.2	41.6	34.4
60 feet above ground	35.2	40.4	46.4	44.7	40.5	33.7
30 feet above ground	34.5	39.8	45.4	43.3	39.7	32.9
4.5 feet above ground	33.6	38.8	44.2	42.0	38.1	31.8
¼ inch below mineral surface	45.7	50.3	55.0	53.4	48.1	40.5
3 inches below mineral surface	47.2	51.5	57.7	58.2	52.2	42.2
7 inches below mineral surface	50.5	53.1	59.3	60.7	56.0	46.4
12 inches below mineral surface	51.5	56.0	61.2	61.6	57.5	49.6
18 inches below mineral surface	50.2	53.6	58.9	59.9	56.8	50.2

temperatures at this point were 4° to 15° F. higher than those at a depth of 5 mm. in the soil. Minimum temperatures also are known to be lowest at this point. Continuous maximum and minimum curves would then show highest and lowest temperatures at the ground surface.

The temperature gradient in the air closely follows the trend of maximum and minimum temperatures taken by Johnson (*3*) at 1.2, 7.1, and 17.1 meters above the ground. The vertical distribution of temperatures in the soil parallels that given by Geiger (*2*) who also shows distributions of air temperatures taken at lower heights above ground but similar in trend to that here presented.

The Application of Such Observations

A knowledge of the trends in climatic relationships can help the forester explain some of the forest phenomena which influence management. For example, seed crops are irregular and unpredictable, and the reasons for their irregular occurrence are not known. One factor may be the effect of freezing temperatures during the floral period. However, one cannot assume that freezing temperatures in the crowns of trees accompany such temperatures on the ground. The material presented in this paper indicates that minimum temperatures in the crown are several degrees higher than those observed in the conventional weather shelter. Occasional cold snaps in the spring with minimum temperatures in the shelter as low as 23° to 25° F., do produce killing temperatures in the crowns. The freezing of young cones of white fir has been observed several times. Without the knowledge that subfreezing temperatures had occurred in the crown, the reason for the loss of the cone crop might have been a pure guess.

The opportunity to make a series of measurements similar to those reported here would rarely occur. However, the relationships in the microclimate are more or less fundamental. In general, maximum temperatures decrease and minimum temperatures increase either above or below the soil surface at which the extremes occur. Some knowledge of this trend and of the order of the differences can help explain ecological observations in terms of forest management.

Literature Cited

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