12-1969

A Comparison of Climatic Elements at Four Elevations in the Great Smoky Mountains National Park

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To the Graduate Council:

I am submitting herewith a thesis written by Luther Allin Stephens Jr. entitled "A Comparison of Climatic Elements at Four Elevations in the Great Smoky Mountains National Park." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

E. E. C. Clebsch, Major Professor

We have read this thesis and recommend its acceptance:

H. A. Fribourg, H. R. DeSelm

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

December 3, 1969

To the Graduate Council:

I am submitting herewith a thesis written by Luther Allin Stephens, Jr., entitled "A Comparison of Climatic Elements at Four Elevations in the Great Smoky Mountains National Park." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Botany.

Edward E. C. Clebsch

Major Professor

We have read this thesis
and recommend its acceptance:

H. R. DeSelm

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Accepted for the Council:

[illegible]

Vice Chancellor for
Graduate Studies and Research

A COMPARISON OF CLIMATIC ELEMENTS AT FOUR ELEVATIONS IN THE GREAT SMOKY MOUNTAINS NATIONAL PARK

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Luther Allin Stephens, Jr.

December 1969

ACKNOWLEDGMENTS

For his suggestion of this study and helpful advice during the study, the author is indebted to Dr. E. E. C. Clebsch. Appreciation is expressed to Drs. H. R. DeSelm and H. A. Fribourg for their advice and criticism of the manuscript. Mr. Tom Elmore, of The University of Tennessee Computing Center, has also been of great service in an advisory capacity pertaining to the writing of the computer programs.

Appreciation also goes to the Tennessee Valley Authority, Hydraulic Data Branch, who cooperated by permitting the use of the data on which this study was based. Appreciation is also expressed to the National Science Foundation who partially supported the cost of computer operations through the NSF Research Grant No. GB-6103.

The author must acknowledge assistance given by his wife, Sarah Lee Stephens, who assisted in the preliminary typing and editing of the manuscript.

ABSTRACT

Between January 1, 1947, and December 31, 1950, hourly temperature and relative humidity and daily precipitation and cloud cover data were collected at the 1,460 ft., 3,850 ft., 5,000 ft., and 6,300 ft. elevations in the Great Smoky Mountains National Park. These four years were part of a period of data collection extending from January, 1946, through March, 1951. These data were processed by a digital electronic computer, IBM 7040, under the control of data summary and potential evapotranspiration programs. Selected statistical tests were employed to compare the similarity of variation in some monthly mean values or to determine the degree of variation between some of the climatic elements.

The findings showed that cloud cover increased with elevation and decreased in the warmer part of the year. Temperature decreased with elevation at a curvilinear rate. As altitude increased, the decrease in temperature per 1,000 ft. decreased. Lapse rate increased from a minimum in December-January to a maximum in July. Relative humidity also increased with altitude, except that microclimatic influences were strongly reflected in these data. Wind probably reduced the relative humidity at the 6,300 ft. elevation and lack of wind allowed atmospheric moisture build-up. Distribution of relative humidity had greater range in colder months than in the summer. Vapor pressure deficit decreased with elevation; however, the difference among the means of the three highest stations was small, reflecting the difference in

temperature and relative humidity at the different elevations. Precipitation increased with an increase in elevation; however, the two highest stations showed the results of microclimate and precipitation type on amounts collected. The 5,000 ft. station had the highest precipitation in the winter when precipitation was predominantly cyclonic. The 6,300 ft. station had the highest rainfall in the summer when much of the high-elevation precipitation was orographic.

Soil moisture balance, calculated by the Thornthwaite method, reflected only the variation in temperature and precipitation. When the assumptions were made that rooting depth was 6 feet and field capacity was 12.00 inches of water, soil moisture content increased and evapotranspiration decreased with an increase in altitude. Many other research workers have stated that these two climatic elements are not sufficient to calculate water balance and other factors were suggested for use in making such calculations.

The use of climate alone as the parameter for defining species distribution in the Smokies has been omitted because species ranges reflect a complex of environmental factors beyond those analyzed here.

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I. INTRODUCTION

The Great Smoky Mountains National Paɪk is an area with exceptional opportunities for ecological research. The diverse flora and fauna have made this area the object of many studies of organism-environment relationships. In spite of this, there has been no attempt to characterize the details of the climate of the area with data gathered over long time periods. Shanks (1954) dealt with the general climate pattern, Tanner (1963) with short term data, and Smallshaw (1953) with only one climatic element, precipitation.

There were four objectives to this study which attempted to fill a portion of the void in the climatological characterization of the Smokies:

1. To provide a detailed description of the climate of the Smokies, by elevation.
2. To provide a climatic description based on hourly and daily data summed to give monthly means of high precision.
3. To determine if climatological trends or relations exist between the elevations being studied.
4. To determine the feasibility of making predictions about upper elevation climatic conditions from conditions occurring at the base station (1,460 ft.).

This study used data originally collected in a cooperative program conducted by the U. S. Weather Bureau, the National Park Service, and the Tennessee Valley Authority. Stations were set up in Tennessee and North

Carolina to collect precipitation and at some station, to record relative humidity and temperature in addition to precipitation. The data used in this study were collected from January 1, 1947, to December 31, 1950. The total period of data collection was from January 1, 1946, to March, 1951, but the 1947 through 1950 period had the most complete data at the four stations of interest.

Three of the four stations were located in Sevier County, Tennessee. The four stations were located along a south to north line. The Park Headquarters station was located at the 1,460 ft. elevation. T. V. A. Station 209, which was operating prior to the time of data collection and is still operating, was used to collect data for the Park Headquarters station. The Alum Cave Bluff Parking Area station (3,850 ft.) was located in the draw through which the West Prong of the Little Pigeon River flows. The Newfound Gap station was located at 5,000 ft. in a gap along the crest of the mountains. The fourth, the Clingman's Dome station, was located in Swain County, North Carolina, at an elevation of 6,300 ft.

II. DESCRIPTION OF STUDY AREA

Geology

The major portion of the bedrock of the Great Smoky Mountains dates to the late Precambrian Period when the sediments now making up the Ocoee Series of rocks were originally deposited in an inland sea. A period of tectonic movement involving three major faults, the Greenbrier Fault of Paleozoic origin, the Great Smoky Fault of late Paleozoic origin, and the Gatlinburg Fault also of late Paleozoic origin, raised the relatively newly formed rocks high above sea level. There followed continuous erosion and uplift resulting in the mountains as they exist today (King, *et al.*, 1964).

The 1,460 ft. station was located on Roaring Fork Sandstone, a member of the Snowbird Group of rocks which were deposited in the later Precambrian. The 3,850 ft. and 6,300 ft. stations were located over Thunderbird Sandstone, a member of the Great Smoky Group of rocks. The Great Smoky Group was deposited in the later Precambrian. The other station, located at 5,000 ft. elevation, was situated over Anakeesta Formation rocks, also a member of the Great Smoky Group of later Precambrian rocks (King, *et al.*, 1964).

Vegetation

Each of the four stations was located in a different vegetation type. The 1,460 ft. station was located at the Park Headquarters on a lawn and received cold air drainage from higher elevations. Little of the original vegetation remained in the immediate vicinity of the

station, but remnants indicated that cove hardwood had existed in the area earlier (Shanks, 1954).

The 3,850 ft. station was situated in a relatively open stand of yellow birch (Betula lutea Michx. f.) and hemlock [Tsuga canadensis (L.) Carr]. A dense stand of Rhododendron maximum L. surrounded the instrument shelter and may have retarded wind flow through the area (Shanks, 1954; Whittaker, 1956).

The 5,000 ft. station was located near Newfound Gap which was at one time a beech gap dominated primarily by Fagus grandifolia Ehrh. On nearby slopes and ridges red spruce (Picea rubens Sarg.) occurred (Shanks, 1954; Whittaker, 1956; Russell, 1953).

The high station (6,300 ft.) was located on an exposed position at the edge of the Forney Ridge Parking Area near Clingman's Dome. The site originally was covered with Fraser fir [Abies fraseri (Pursh) Poir.] and red spruce. Due to clearing, secondary vegetation consisting of fire cherry (Prunus pennsylvanica L. F.) and yellow birch replaced the original spruce and fir (Shanks, 1954; Whittaker, 1956; Cain, 1934; Oosting and Billings, 1951).

Soils

The soil is an important part of the plant habitat and is the primary source of internal water and nutrients. However, due to the relatively small agricultural value of the soils of the Smokies, they have not been as extensively surveyed and mapped as had those in the rest of Sevier County, Tennessee (Hubbard, et al., 1956). Several studies have been conducted which described soils in limited areas such as the beech

and spruce-fir communities (Wolfe, 1967; McCracken, et al., 1962; Oosting and Billings, 1951).

The two high elevation stations (5,000 ft. and 6,300 ft.) were located on an area classified by Hubbard, et al., (1956) as rough mountainous land (Ramsey soil material). This is residual soil derived from quartzite, sandstone, or conglomerate parent material. It is highly acid and low in fertility. McCracken, et al., (1962) reported that the soils are higher in organic matter and browner than the Ramsey soil material. Soil texture at Clingman's Dome is a sandy loam and at Newfound Gap, a silt loam (Wolfe, 1967).

The 3,850 ft. station was situated on a valley deposit of alluvium derived from the Ramsey soil material upslope. Hubbard, et al., (1956) classified this as Barbourville stony fine sandy loam-rolling phase. This is a well drained, immature soil which has not yet developed distinct horizons.

The Park Headquarters station (1,460 ft.) was located on a typical level, bottom land soil, Staser fine sandy loam. This also is an alluvial soil derived from Ramsey soil material. In extensive areas along streams and in valleys, this soil is agriculturally important due to its high organic matter content, availability of nutrients, water-holding capacity, and position on the landscape (Hubbard, et al., 1956).

Climate

The climate of the region is influenced by different weather patterns in each of the four seasons. The climate of eastern Tennessee is characterized by maximum precipitation in late winter-early spring

with a secondary maximum in July. The winter precipitation results from depressions moving from northwestern North America into Texas after which they move northeastward. During the southern leg of the route this depression picks up moisture from the Gulf of Mexico which is deposited as it moves northeastward (Trewartha, 1966; Dickson, 1960).

The July secondary peak in precipitation results from midtropospheric troughs and ridges located over Florida. The effect of this condition is lessened in a northerly direction by a mid-continent pressure ridge resulting in July precipitation being characterized by showers and thunderstorms (Trewartha, 1966; Dickson, 1960).

The period of minimum precipitation, October, coincides with the return of the polar front, the major storm tracks, and the jet stream to their most northerly position. This is also coincident with the most western extension of the Atlantic high pressure system located east of North Carolina (Trewartha, 1966; Dickson, 1960).

In the Great Smoky Mountains National Park precipitation follows the same pattern as described above except that at higher elevations July-August is the period of primary maximum precipitation (Shanks, 1954; Smallshaw, 1953). The mean annual precipitation based on 42 years of data for the 1,460 ft. station is 55.54 inches per year and 83.71 inches per year at 6,300 ft. based on 28 years of data (T. V. A., 1967). The 42 and 28 years represent the length of time precipitation records had been kept for the 1,460 ft. and 6,300 ft. stations. The monthly precipitation means did not always show the steady increases of precipitation with altitude, since the 5,000 ft. station showed higher precipitation than the 6,300 ft. station in the winter months. This might have

been due to the position of the station in a gap in the crest of the mountains through which there is much turbulence and a funneling effect on advancing storm fronts (Russell, 1953; Smallshaw, 1953).

The annual average temperature decrease with altitude was 2.23° F per 1,000 ft. increase in elevation. The cooling gradient resulted in about a month's delay in the development of conditions suitable for the breaking of buds from the 1,460 ft. station to the 6,300 ft. station (Shanks, 1954). Long-term temperature data were not available for any station other than the one at the Park Headquarters. The coldest monthly mean temperature was January at 39.7° F, and the warmest was July at 74.4° F (Hubbard, et al., 1956).

According to the 1948 Thornthwaite climatic classification, the stations ranged from a mesothermal-humid at 1,460 ft. to microthermal-perhumid class at 6,300 ft. (Shanks, 1954). The spruce-fir zone of the Smokies was considered comparable climatically to the spruce-fir zone of the White Mountains of Vermont (Oosting and Billings, 1951).

III. METHODS

Data Collection

The equipment used in data collection was described by Shanks (1954). In addition to the data he described, notation was made by the original observers if precipitation had been snow or rain and if snow were on the ground. Snowfall was converted to equivalent rainfall so that a daily total of rainfall or equivalent rainfall was recorded. Sky conditions were recorded as clear, scattered clouds, partly cloudy, cloudy, overcast, or fog. The cloud cover was recorded once each day as the result of a visual observation. The observation for a station was usually 1 hour later than the observation at the preceding station. The observations were made in order from the 1,460 ft. station to the 6,300 ft. station.

Prior to data processing, the books in which temperature and relative humidity were logged were scanned to check for missing data. Since the stations were checked daily, missing data were usually limited to a few hours on a single day. In accordance with Conrad and Pollak (1950) the days immediately preceding and following the day with missing data were checked for trends such as time of maximum or minimum temperature, and with this in mind, values were calculated by interpolation to fit the missing hours. The gaps frequently were only 1 or 2 hours long but occasionally extended for 6 or 8 hours. These computed values were then inserted in place of the missing data.

Data Summary Program

The hourly temperature and relative humidity and daily precipitation data were punched onto cards for use with digital electronic computers. The program (see Appendix A) which compiled the data into daily,

weekly, and monthly values was written for the IBM 7040 computer. The computer output also included machine punched cards bearing the daily information to be used in a subsequent program for the calculation of potential evapotranspiration. The daily values computed were temperature maximum, minimum, range, mean based on 24 hourly values, mean based on maximum and minimum, and mean based on values taken at 4-hour intervals. The same data were computed for the relative humidity. The daily amount of precipitation was also printed. In addition, a value for mean daily vapor pressure deficit was calculated from temperature and relative humidity.

The weekly mean values were computed by summing daily mean values and dividing by seven except in the determination of temperature and relative humidity maximum, minimum, and range. The weekly values computed were maximum and minimum, mean maximum and minimum, range, and means based on maximum-minimum, hourly values, and 4-hour interval values. These were calculated for both temperature and relative humidity. Total precipitation and mean vapor pressure deficit were also determined on a weekly basis.

The monthly values were also computed by summation of daily mean values for the specified number of days and division by that number of days except for monthly maximum, minimum, and range for both temperature and relative humidity. In addition to those values, mean maximum, minimum, and range, and monthly means based on the three sets of values previously mentioned were calculated for both temperature and relative humidity. Total precipitation and a value for mean vapor pressure deficit were also included.

For each month the distribution of temperature and relative humidity data was studied. The distribution was derived by examining each hourly value and adding one to the number of values already in its class. For relative humidity each class had the range of 5 per cent points so

that there were 20 classes, from class 1 (0 per cent to 4 per cent) to class 20 (95 per cent to 99 per cent). The values of 100 per cent relative humidity were in class 21. Temperature values were also divided into similar classes; however, there were 22 classes instead of 21. This was done so that class 1 contained values of less than 0° F and class 22 contained values of 100° F or greater. A cut-off line was drawn onto the table showing these percentage values. The cut-off line encloses all values of 1 per cent or greater.

Potential Evapotranspiration Program

A computer program (see Appendix B) was written which computed daily potential evapotranspiration and the soil moisture balance based on the Thornthwaite (1957) method. The program used the data cards of daily values punched by the preceding program. The print-out included the date, station number, daily mean temperature, *i* value, correction factor for day-length, unadjusted and adjusted potential evapotranspiration, precipitation, precipitation minus potential evapotranspiration, soil moisture content, change in soil moisture content, moisture deficit or surplus, available gravitational water, gravitational water storage, and total soil moisture balance.

From daily information the following monthly values were computed: mean temperature, potential evapotranspiration, precipitation, precipitation minus potential evapotranspiration, mean soil moisture content, storage change from the preceding month, monthly moisture deficit and surplus, available gravitational water, gravitational water storage, and mean soil moisture balance.

When calculating soil moisture balance, a value must be considered as field capacity for the soils being examined. Since the field capacity was not known for the soils at the sites in this study, hypothetical

values were assigned to field capacity. This value was the one suggested by Thornthwaite for a mature forest on silt or sandy loam with a rooting depth of 6 feet. The value was 12.00 inches water in the soil at field capacity.

Data Analysis

After compilation of data into daily, weekly, and monthly values, monthly values were then graphed to examine visually the seasonal or elevational variation. Only monthly values were used because of the extensive nature of the accumulated data. More work remains to be done on the weekly and daily data to determine more precisely cycles that occur during the year, weather variations with movement of frontal systems into the area, and other information necessary for a complete climatic characterization of the Great Smoky Mountains.

Coefficients of determination (r^2) were calculated where there seemed to be correlation between climatic variables. Monthly mean temperature range was correlated with monthly mean precipitation and monthly mean vapor pressure deficit with monthly mean temperature range. Monthly mean, mean maximum, and mean minimum temperatures at the 3,850 ft., 5,000 ft., and 6,300 ft. stations were correlated with the corresponding values at the 1,460 ft. station. Coefficients of determination were also calculated for all possible station combinations for monthly mean precipitation. From the correlation calculations linear regression equations were calculated for the monthly mean, mean maximum, and mean minimum temperatures with the 3,850 ft., 5,000 ft., and 6,300 ft. stations as the dependent variables and the 1,460 ft. station as the

independent variable. Regression equations were also calculated to express the relationship between the 1,460 ft. station and each of the 3,850 ft., 5,000 ft., and 6,300 ft. stations, between the 3,850 ft. station and the 5,000 ft. and 6,300 ft. stations, and between the 5,000 ft. station, and the 6,300 ft. station.

Chi square values were computed to determine the significance of the difference between various means. Monthly temperature and relative humidity means calculated from daily max-min data and from 4-hour interval data were compared with the monthly means calculated from 24 hourly values. The 4-year monthly temperature means for the 1,460 ft. station were compared with the 42-year temperature means. Four-year monthly precipitation means for the 1,460 ft. and 6,300 ft. stations were tested against the long term monthly precipitation means. If the Chi square values were low, depending upon the degrees of freedom, the probability of getting greater difference between the means would be high.

The number of occurrences in the distribution tables for cloud cover types, relative humidity, and temperature were converted to percentage values (Conrad and Pollak, 1950; Barger and Nyhan, 1960; Brooks and Carruthers, 1953). The information given in the distribution tables is not the actual number of occurrences.

In addition to the calculation of daily potential evapotranspiration and the resultant monthly values, the water balance was calculated also in accordance with the Thornthwaite (1957) method using only mean monthly data. This was done to determine the significance of difference occurring between the monthly values of potential evapotranspiration,

soil moisture content, and total soil moisture balance when calculated by the two different methods. Chi square values were calculated for the comparison of potential evapotranspiration (daily basis) with potential evapotranspiration (monthly basis), soil moisture content (daily basis) with soil moisture content (monthly basis), and total soil moisture balance (daily basis) with total soil moisture balance (monthly basis).

IV. RESULTS AND DISCUSSION

Cloud Cover

The cloud cover data are presented in Tables I, II, III, and IV. The percentage of days with a certain type of cloud cover showed three general trends. First, February, May, and October were the months with least cloudiness. There was also a decrease in percentage of clear and scattered cloudy days with increase in altitude. Secondly, usually less than 10 per cent of the cloud cover occurred in the partly cloudy category. According to Griffiths (1966) conditions are usually either favorable or unfavorable for cloud formation, and 40 per cent to 60 per cent cloud cover is usually a transitional occurrence. Thirdly, the percentage of days with fog increased with elevation. The number of days with fog also showed a seasonal trend with a higher percentage of occurrences in the October to March period, but at the 5,000 ft. and 6,300 ft. stations there was a smaller maximum in July.

Temperature Relations

The growing season is sometimes defined as the number of days between the last occurrence in spring and the first occurrence in fall of a killing frost (Wang, 1963). However, photosynthesis and respiration may be minimal even though temperatures are above freezing (Conrad and Pollak, 1950; Peattie, 1936), and quite often the growing season may be considered the days between temperatures as high as 40° F (Burnett, 1964).

The number of consecutive days above various threshold temperatures (32° F, 36° F, 40° F) and the dates of the last occurrence in the

TABLE I

SUMMARY OF OCCURRENCE OF PER CENT CLOUD COVER FOR 1947-1950 AT THE 1,460 FT. STATION

Month	Clear	Scattered Cloudiness	Partly Cloudy	Cloudy	Overcast	Fog
Jan.	14.5	12.1	8.4	26.4	36.2	2.4
Feb.	23.2	23.2	5.4	5.3	42.0	0.9
Mar.	23.4	14.5	3.1	15.3	42.8	0.8
Apr.	30.8	18.3	4.2	20.0	26.7	0.0
May	40.3	21.8	3.2	21.8	12.9	0.0
June	25.8	22.5	9.2	23.3	19.2	0.0
July	33.9	27.4	4.8	16.1	17.8	0.0
Aug.	37.1	16.9	3.4	20.1	22.5	0.0
Sept.	32.5	25.8	0.8	15.0	24.2	0.0
Oct.	37.1	22.5	2.5	13.3	24.1	2.5
Nov.	29.2	21.2	1.6	21.9	26.7	2.6
Dec.	33.1	12.1	2.4	15.3	36.3	0.8

TABLE II

SUMMARY OF OCCURRENCE OF PER CENT CLOUD COVER FOR 1947-1950 AT THE 3,850 FT. STATION

Month	Clear	Scattered Cloudiness	Partly Cloudy	Cloudy	Overcast	Fog
Jan.	16.9	8.9	5.0	25.0	41.0	3.2
Feb.	28.6	18.8	0.0	18.7	33.9	0.0
Mar.	26.6	12.1	4.8	12.1	42.5	0.8
Apr.	25.8	17.5	4.3	20.0	31.6	0.8
May	29.3	19.4	2.2	24.2	24.1	0.8
June	11.6	27.5	8.5	25.8	26.6	0.0
July	18.5	22.6	5.6	29.3	24.0	0.0
Aug.	15.3	26.6	4.0	33.0	19.3	0.8
Sept.	23.3	31.1	5.8	24.9	14.1	0.8
Oct.	43.5	20.9	4.4	9.1	22.1	0.0
Nov.	33.3	14.2	2.5	17.5	30.0	2.5
Dec.	36.3	11.3	1.7	13.7	34.6	2.4

TABLE III

SUMMARY OF OCCURRENCE OF PER CENT CLOUD COVER FOR
1947-1950 AT THE 5,000 FT. STATION

Month	Clear	Scattered Cloudiness	Partly Cloudy	Cloudy	Overcast	Fog
Jan.	28.6	6.6	3.6	16.3	39.3	6.6
Feb.	26.8	15.2	2.7	14.3	34.7	6.3
Mar.	26.6	12.9	3.4	12.9	39.4	4.8
Apr.	26.6	15.8	7.0	18.3	30.7	1.6
May	25.8	23.4	4.9	18.5	18.5	1.6
June	12.5	30.8	6.0	30.0	17.4	3.3
July	12.9	23.4	8.9	23.4	29.8	1.6
Aug.	12.1	26.5	8.3	25.8	26.5	0.8
Sept.	22.5	21.6	6.0	30.8	17.5	1.6
Oct.	36.3	19.8	2.9	14.5	26.5	0.0
Nov.	35.0	15.8	2.7	11.6	33.3	1.6
Dec.	33.1	10.5	2.5	15.3	34.6	4.0

TABLE IV

SUMMARY OF OCCURRENCE OF PER CENT CLOUD COVER FOR 1947-1950 AT THE 6,300 FT. STATION

Month	Clear	Scattered Cloudiness	Partly Cloudy	Cloudy	Overcast	Fog
Jan.	23.4	7.3	2.5	18.5	39.5	8.8
Feb.	23.6	16.1	3.4	12.9	33.3	10.7
Mar.	17.8	11.6	6.6	16.0	38.3	9.8
Apr.	24.2	17.5	6.7	13.3	33.3	5.0
May	23.4	23.5	3.1	16.9	25.8	7.3
June	9.2	24.2	4.2	27.5	29.1	5.8
July	7.3	16.1	6.5	30.6	31.4	8.1
Aug.	8.9	19.4	4.8	36.3	27.4	3.2
Sept.	17.5	25.8	1.7	29.2	21.6	4.2
Oct.	28.2	20.9	1.0	14.5	28.1	7.3
Nov.	32.5	16.2	3.4	14.2	27.4	3.3
Dec.	34.6	13.7	2.5	11.3	31.4	6.5

spring and the first occurrence in the fall of these temperatures are recorded in Table V. For the 32° F and 36° F temperatures similar patterns appeared. Consecutive number of days declined with the increase in altitude, but the number of consecutive days at the 6,300 ft. station corresponded more closely to the number for the 1,460 ft. station than would be expected at 6,300 ft. The dates of last occurrence of 32° F and 36° F temperatures followed a trend similar to the consecutive days. As elevation increased, occurrence was later in the year except for the 6,300 ft. station where the date of last occurrence either preceded or was near the date for the 1,460 ft. station. The dates of first occurrence of 32° F showed that frost occurred earlier at higher elevations. The pattern for the first occurrence of 36° F was just as expected with that temperature having been reached earlier in the year except for the 6,300 ft. station which reacted similar to a lower elevation station.

The number of consecutive days above 40° F decreased with an increase in altitude and was accompanied by the corresponding date changes for the first and last occurrence of that temperature except for the 3,850 ft. station. The data for the 3,850 ft. station were more similar to the data for the 6,300 ft. station than to the data expected for a station that was located between the 1,460 ft. and 5,000 ft. stations.

Temperature lapse rate is defined by Conrad and Pollak (1950) as the amount of temperature change per a given elevational change. Shanks (1954) gave the lapse rate for the Great Smoky Mountains as 2.23° F/1,000 ft. To determine if lapse rate varied either seasonally or altitudinally, a lapse rate was calculated for each month using the monthly mean, mean

TABLE V

MEAN NUMBER OF DAYS BETWEEN THE LAST OCCURRENCE IN SPRING AND THE FIRST OCCURRENCE IN FALL OF 32° F, 36° F, AND 40° F AS MINIMUM TEMPERATURES AND THE AVERAGE DATE OF THE LAST AND FIRST OCCURRENCE OF MINIMUM TEMPERATURES

Temperature	Station	Number of Consecutive Days	Avg. Date of Last Occurrence	Avg. Date of First Occurrence
32°	1460	155.75	May 3	Oct. 7
	3850	152.25	May 4	Oct. 4
	5000	148.00	May 9	Oct. 4
	6300	152.25	Apr. 30	Oct. 2
36°	1460	135.50	May 3	Oct. 7
	3850	125.00	May 28	Sept. 30
	5000	116.75	May 31	Sept. 25
	6300	136.25	May 14	Sept. 27
40°	1460	122.25	May 18	Sept. 17
	3850	94.75	June 11	Sept. 13
	5000	104.50	June 3	Sept. 16
	6300	96.50	June 4	Sept. 8

maximum, and mean minimum temperatures over three altitudinal ranges (1,460 ft.-3,850 ft.; 1,460 ft.-5,000 ft.; 1,460 ft.-6,300 ft.). The lapse rate data are presented in Tables VI, VII, and VIII.

Lapse rate based on the monthly mean temperatures decreased with altitudinal range, indicating that the temperature-altitude relation was not linear. In addition, it was found that lapse rate increased at all altitudinal ranges to a peak in July and decreased to the lowest lapse rate in December. The lowest lapse rate was 1.28° F/1,000 ft. for December across the 1,460 ft.-6,300 ft. range, and the highest was 3.86° F/1,000 ft. for July across the 1,460 ft.-3,850 ft. range.

When lapse rates based on monthly mean maximum temperatures were examined, they were found to vary similarly to the variation that occurred in the monthly mean lapse rates. However, two exceptions were noted. The lapse rates for maximum temperatures were higher than the corresponding monthly mean lapse rates, and the increase in lapse rate with the approach of the hotter months was more rapid. As a result, the highest lapse rate was 5.85° F/1,000 ft. for the 1,460 ft.-3,850 ft. range in July and the lowest, 2.54° F/1,000 ft., occurred in December for the 1,460 ft.-6,300 ft. range.

The third set of lapse rates, based on monthly mean minimum temperatures, showed a different set of relations. The lapse rates did not show the consistent decrease with increase in elevational range. Several points overlapped between the values of the different rates. Also the increase in lapse rate toward July and the subsequent decrease was not as smooth as for the mean and maximum values although a general trend toward

TABLE VI

TEMPERATURE LAPSE RATES (DEGREES F) PER 1,000 FT. BASED ON MEAN, MEAN MAXIMUM, AND MEAN MINIMUM TEMPERATURES FOR 1947-1950 AT ELEVATIONS OF 1,460 FT. TO 3,850 FT.

Month	Mean Temp. Lapse Rate	Max. Temp. Lapse Rate	Min. Temp. Lapse Rate
Jan.	2.40	3.64	1.38
Feb.	2.82	3.55	1.25
Mar.	3.65	3.34	2.30
Apr.	3.23	3.47	1.67
May	3.65	4.47	1.88
June	3.65	5.35	1.75
July	3.86	5.85	2.21
Aug.	3.44	5.77	1.75
Sept.	3.02	5.52	1.67
Oct.	2.71	5.02	.62
Nov.	2.40	4.26	.75
Dec.	1.98	3.89	.62

TABLE VII

TEMPERATURE LAPSE RATES (DEGREES F) PER 1,000 FT. BASED ON MEAN, MEAN MAXIMUM, AND MEAN MINIMUM TEMPERATURES FOR 1947-1950 AT ELEVATIONS OF 1,460 FT. TO 5,000 FT.

Month	Mean Temp. Lapse Rate	Max. Temp. Lapse Rate	Min. Temp. Lapse Rate
Jan.	2.16	3.53	1.27
Feb.	2.61	3.47	1.27
Mar.	3.45	4.03	1.92
Apr.	3.24	4.03	1.41
May	3.10	3.95	1.27
June	3.10	4.32	1.18
July	3.95	4.60	2.34
Aug.	3.17	4.46	1.83
Sept.	2.74	4.29	1.63
Oct.	2.32	3.81	.22
Nov.	2.32	3.44	.84
Dec.	1.54	3.33	.28

TABLE VIII

TEMPERATURE LAPSE RATES (DEGREES F) PER 1,000 FT. BASED ON MEAN, MEAN MAXIMUM, AND MEAN MINIMUM TEMPERATURES FOR 1947-1950 AT ELEVATIONS OF 1,460 FT. TO 6,300 FT.

Month	Mean Temp. Lapse Rate	Max. Temp. Lapse Rate	Min. Temp. Lapse Rate
Jan.	1.64	3.03	1.11
Feb.	2.31	3.16	1.13
Mar.	2.68	3.51	1.42
Apr.	3.19	4.33	1.50
May	2.92	4.38	1.19
June	3.04	4.54	1.28
July	3.14	4.40	1.92
Aug.	2.83	3.98	1.69
Sept.	2.47	3.14	1.44
Oct.	1.85	3.57	.41
Nov.	1.64	2.93	.51
Dec.	1.28	2.54	.24

higher rates in late spring, summer, and early autumn did exist. The monthly minimum lapse rates were consistently lower than the mean lapse rates ranging from 0.5° F to 2.5° F lower.

Table IX shows the mean, absolute maximum, and absolute minimum, and mean maximum and mean minimum temperatures for the hottest and coldest months for all stations. February was consistently the coldest month and July the hottest.

Figure 1 illustrates the variation of mean monthly range with altitude and season. In general range decreased with altitude. A general gradient of decreasing range with increasing altitude existed but was not consistent throughout the year.

The data for mean monthly range appeared to vary inversely with the monthly amount of precipitation. The highest ranges corresponded to the months in which precipitation amounts were the lowest, and the range was lowest in the months in which the precipitation was highest. The r^2 values for a correlation of monthly range with monthly precipitation were .527, .053, .095, and .754, arranged from the 1,460 ft. to the 6,300 ft. station, respectively.

The monthly mean temperatures, as stated previously, were calculated on three different bases. The mean using 24-hourly readings per day was considered the true mean. As stated in the methods, the other two means were compared with the true mean to determine the significance of difference between the true mean and the other means. In all years and at all elevations the Chi square values obtained in each comparison showed that there was greater than a .995 probability of obtaining a

TABLE IX

MONTHLY MEAN, MEAN MAXIMUM AND MEAN MINIMUM, AND MAXIMUM AND MINIMUM TEMPERATURES (DEGREES F) FOR THE HOTTEST AND COLDEST MONTHS AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Hottest and Coldest Months	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Coldest Month	Feb.	Feb.	Feb.	Feb.
Mean Temp.	40.0	33.2	30.7	28.7
Mean Max. Temp.	53.0	44.5	40.7	37.7
Mean Min. Temp.	27.7	24.7	23.2	22.2
Abs. Max. Temp.	81	66	65	60
Abs. Min. Temp.	2	-5	-8	-12
Hottest Month	July	July	July	July
Mean Temp.	71.7	62.5	57.2	56.5
Mean Max. Temp.	86.5	72.5	70.2	65.2
Mean Min. Temp.	60.5	55.2	52.2	51.2
Abs. Max. Temp.	100	89	89	80
Abs. Min. Temp.	44	41	39	41

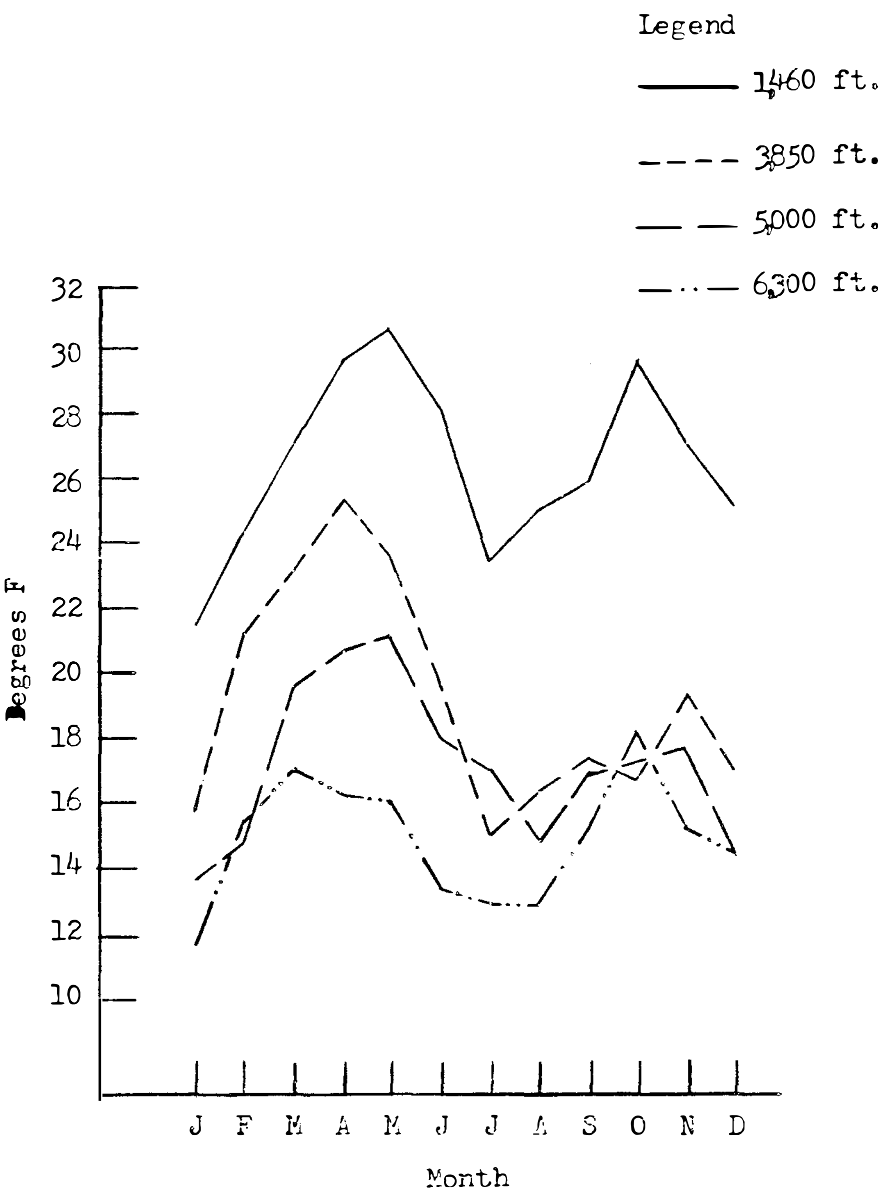

Figure 1. Monthly mean temperature range (degrees F) for 1947-1950 for the 1,460 ft., 3,850 ft., 5,000 ft., and 6,300 ft. stations.

larger Chi square. The data used in the comparisons of monthly temperature means are presented in Tables XL, XLI, XLII, and XLIII, Appendix C. The conclusion was that the relative ease in obtaining maximum and minimum temperatures for each day made this the preferred basis for computing a daily mean to be used in deriving a monthly mean. If the daily mean were to be used for purposes other than computation of monthly means, then the 24-hour mean would be preferable since variation of as much as 5 or 6 degrees occurred between the true and the max-min mean for 1 day. The mean based on 4-hour interval values was the same as the true mean 50 per cent of the time with deviation mostly of 1° F per day, occasionally 2° F per day, and very rarely 3° F per day.

When monthly mean, mean maximum, and mean minimum temperatures for the 3,850 ft., 5,000 ft., and 6,300 ft. stations were tested for correlation with the 1,460 ft. station to determine the uniformity of variation among the stations, the r^2 values were all very high (above .900), indicating that the general pattern of seasonal temperature variation was the same for all stations. As might be expected, the r^2 values decreased as the distance between the base station and the other stations increased. Table X gives the r^2 values for these relations and the regression equations which express the relationship between the base station and each individual station.

Tables XI, XII, XIII, and XIV give the frequency of temperatures in groups of 5° F ranges. The values in the tables are in percentage of the total number of hourly readings for the month. The lines in each table enclose all values of 1 per cent occurrence or more. Two trends should be noticed. The bulk of each table (area between cut-off lines)

TABLE X

CORRELATION AND REGRESSION RELATIONS BETWEEN THE 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS AND THE 1,460 FT. STATION FOR THE MONTHLY MEAN, MEAN MAXIMUM, AND MEAN MINIMUM TEMPERATURES (DEGREES F) FOR 1947-1950

Temperature Group	X	Y	r^2	Regression Equation
Mean	1460	3850	.993	Y = -2.63 + .914X
Mean	1460	5000	.974	Y = -1.13 + .836X
Mean	1460	6300	.968	Y = -1.98 + .819X
Max.	1460	3850	.987	Y = -1.04 + .860X
Max.	1460	5000	.901	Y = -3.93 + .856X
Max.	1460	6300	.789	Y = 0.88 + .754X
Min.	1460	3850	.978	Y = -.809 + .930X
Min.	1460	5000	.973	Y = -.224 + .897X
Min.	1460	6300	.966	Y = .395 + .858X

TABLE XI

DISTRIBUTION OF HOURLY TEMPERATURES IN PER CENT OF TOTAL NUMBER OF HOURLY VALUES PER MONTH AT THE 1,460 FT. STATION FOR 1947-1950

Temp. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
$<0°$ F	0.1											
0° F - 4° F	0.1	0.2									0.1	
5° F - 9° F	0.6	0.1									0.6	0.7
10° F - 14° F	1.3	2.2	0.2								0.2	1.8
15° F - 19° F	3.0	3.5	2.2	0.1							1.6	4.6
20° F - 24° F	5.6	8.9	5.5	0.8						0.6	5.3	11.3
25° F - 29° F	8.5	10.0	8.7	3.3	0.2					1.3	12.4	15.0
30° F - 34° F	11.7	11.9	11.9	4.1	0.7				0.5	3.4	11.3	15.1
35° F - 39° F	10.3	12.6	9.1	5.4	2.0				1.9	5.2	10.4	11.6
40° F - 44° F	11.0	10.1	10.8	7.6	3.5	0.5			3.3	8.5	11.8	8.8
45° F - 49° F	11.9	7.6	10.0	10.9	6.8	2.5	0.5	0.1	5.0	9.6	12.5	8.4
50° F - 54° F	8.6	8.9	8.5	9.2	10.3	4.8	2.5	2.9	8.9	13.0	10.4	6.3
55° F - 59° F	7.7	8.7	9.1	12.2	13.1	7.5	4.9	7.7	13.7	15.7	8.1	6.3
60° F - 64° F	5.4	6.3	9.2	13.0	14.8	16.2	15.0	17.4	19.5	13.6	6.7	4.7
65° F - 69° F	7.2	3.6	6.4	10.9	10.9	17.2	21.8	22.8	14.0	9.4	4.7	3.0
70° F - 74° F	5.6	3.0	3.9	11.3	11.4	13.9	15.1	13.1	10.5	9.9	1.9	1.7
75° F - 79° F	0.6	0.4	2.4	6.1	11.6	11.9	11.6	11.8	7.7	6.2	0.8	
80° F - 84° F	0.1		1.2	3.6	9.1	11.5	12.2	12.7	7.3	2.1	0.2	
85° F - 89° F			0.2	0.7	4.2	8.8	9.8	8.2	5.6	0.6		
90° F - 94° F				0.1	0.6	4.6	5.3	2.2	1.3			
95° F - 99° F						0.5	0.6	0.5				
$\geq 100°$ F							0.03					

TABLE XII

DISTRIBUTION OF HOURLY TEMPERATURES IN PER CENT OF TOTAL NUMBER OF HOURLY VALUES PER MONTH AT THE 3,850 FT. STATION FOR 1947-1950

Temp. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0° F	0.2	0.5									0.8	
<0° F - 4° F	0.4	2.0	0.2								0.1	0.3
5° F - 9° F	1.4	2.2	1.2	0.06							0.1	1.1
10° F - 14° F	2.3	3.5	2.4	0.1							2.0	3.1
15° F - 19° F	4.2	5.6	5.4	0.7							3.5	6.2
20° F - 24° F	6.6	7.8	7.1	1.9	0.06					0.5	6.8	12.2
25° F - 29° F	10.2	11.2	12.5	4.7	0.7				0.1	1.8	14.2	18.0
30° F - 34° F	11.8	17.0	14.3	6.4	1.2				0.7	3.9	14.4	16.7
35° F - 39° F	11.9	12.5	13.3	7.1	3.3	0.3			1.5	7.9	11.7	13.7
40° F - 44° F	12.8	13.3	12.3	12.7	6.9	2.5	0.4	0.1	5.6	12.6	16.0	11.8
45° F - 49° F	14.2	11.2	11.1	16.9	14.0	4.7	2.2	2.3	8.7	13.5	13.6	9.2
50° F - 54° F	17.2	8.1	8.4	17.4	19.1	8.4	5.7	6.1	18.1	21.2	10.9	6.0
55° F - 59° F	5.6	3.3	5.7	13.0	19.6	19.6	19.0	21.1	23.0	22.5	3.5	1.2
60° F - 64° F	0.8	0.8	3.0	7.9	13.7	27.3	32.2	33.0	23.2	11.3	1.3	0.4
65° F - 69° F		0.2	1.5	4.8	10.2	19.5	21.9	23.8	11.9	3.8	0.4	
70° F - 74° F			0.6	3.6	6.9	10.9	11.7	10.8	5.0	0.5		
75° F - 79° F			0.1	1.5	2.7	4.9	4.9	2.4	1.4	0.06		
80° F - 84° F			0.03	0.3	1.0	1.8	1.4	0.06	0.2			
85° F - 89° F				0.06	0.1	0.03	0.3					

TABLE XIII

DISTRIBUTION OF HOURLY TEMPERATURES IN PER CENT OF TOTAL NUMBER OF HOURLY VALUES PER MONTH AT THE 5,000 FT. STATION FOR 1947-1950

Temp. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
$<0°$ F	0.3	2.1									0.9	
0° F - 4° F	0.7	1.2	0.4								0.2	0.2
5° F - 9° F	1.4	3.5	2.5	0.1							0.5	1.3
10° F - 14° F	2.9	4.3	3.6	1.2							3.6	3.8
15° F - 19° F	7.0	5.7	7.3	1.8						0.1	4.1	8.1
20° F - 24° F	10.3	8.3	9.0	2.2	0.06					0.4	7.1	10.7
25° F - 29° F	11.6	16.5	12.0	4.4	0.6				0.3	1.1	11.5	14.0
30° F - 34° F	15.3	16.6	13.8	6.7	2.4				1.2	5.7	13.0	17.4
35° F - 39° F	14.8	14.1	14.8	11.3	3.2	0.7	0.03		3.8	8.8	17.8	17.6
40° F - 44° F	14.4	16.1	13.3	17.1	8.0	1.3	0.3		7.2	21.1	17.0	13.7
45° F - 49° F	15.4	6.7	9.4	21.1	17.9	6.3	3.7	2.9	10.5	25.7	15.4	8.5
50° F - 54° F	4.8	3.5	7.8	15.3	26.0	14.1	10.0	15.5	23.1	20.3	5.5	3.7
55° F - 59° F	0.6	0.6	3.6	8.5	16.7	30.1	36.6	38.2	28.9	10.1	1.6	0.4
60° F - 64° F		0.03	1.4	5.2	11.4	24.2	24.4	25.4	13.4	4.5	0.8	
65° F - 69° F			0.3	2.7	7.0	12.6	13.5	10.4	7.0	1.3	0.4	
70° F - 74° F			0.1	1.4	4.8	6.5	7.1	5.2	3.6	0.2	0.2	
75° F - 79° F				0.3	1.3	2.9	2.9	1.5	0.5	0.05		
80° F - 84° F					0.2	0.7	0.6	0.2		0.05		
85° F - 89° F						0.03	0.1	0.3				

TABLE XIV

DISTRIBUTION OF HOURLY TEMPERATURES IN PER CENT OF TOTAL NUMBER OF HOURLY VALUES PER MONTH AT THE 6,300 FT. STATION FOR 1947-1950

Temp. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
<0° F	0.4	2.9	0.08								1.3	
0° F - 4° F	0.5	2.0	1.6								0.2	0.4
5° F - 9° F	1.0	3.2	3.7	0.5							0.6	2.0
10° F - 14° F	3.0	4.2	7.3	1.7							2.2	5.4
15° F - 19° F	8.8	5.3	7.6	2.1							5.1	5.3
20° F - 24° F	9.6	7.8	10.3	2.4	1.1					0.1	7.1	9.3
25° F - 29° F	12.9	14.5	18.1	4.1	3.3				0.1	1.0	9.0	16.3
30° F - 34° F	18.4	19.2	18.9	7.9	3.3				1.5	4.0	14.8	19.4
35° F - 39° F	25.8	20.1	14.6	17.8	12.1	0.4			5.6	6.2	19.9	21.7
40° F - 44° F	11.1	13.8	10.8	22.8	25.6	2.7	1.1	1.2	11.8	19.7	22.2	12.0
45° F - 49° F	1.0	5.3	4.7	22.6	29.0	9.8	5.1	5.6	20.1	31.3	9.1	5.4
50° F - 54° F	3.1	0.8	0.8	9.0	12.8	28.5	27.1	26.1	24.1	21.6	5.7	1.3
55° F - 59° F		0.1	0.2	5.3	8.7	35.5	34.1	39.5	23.1	8.6	1.4	0.7
60° F - 64° F		0.07		2.8	3.2	12.9	18.6	16.9	8.3	4.6	0.5	0.06
65° F - 69° F				0.3	0.6	7.3	9.1	7.3	3.4	1.6	0.3	
70° F - 74° F						2.1	3.3	2.3	1.4	0.5	0.03	
75° F - 79° F						0.2	1.0	0.6	0.03	0.03		
80° F - 84° F							0.1	0.06				

shifted slightly toward cooler temperatures as the elevation of the stations increased. Secondly, the minimum cut-off line varied 50 per cent to 100 per cent more than the maximum cut-off line as the bulk of temperatures varied seasonally. Because of this the cold months had a wider distribution of temperatures and the July hourly temperature values were concentrated into a smaller range.

Table XV gives monthly mean, mean maximum, and mean minimum temperatures for all stations. A consistent rise to a peak in July occurred for all three means. Table XVI shows that the extreme values for each month followed the same pattern as the means; however, the peaks for some of the values occurred in August instead of July.

When the monthly mean temperatures for the 4 years were tested against the long-term monthly means (norm) for the 1,460 ft. station, the difference was not significant, although the norm was higher 11 of the 12 months. The test showed a probability of obtaining a larger Chi square value to be greater than .995. This indicated that, although the 4 year means were consistently low, the difference was not significant.

Relative Humidity

Because of the nature of relative humidity, it is only briefly discussed. For instance, a relative humidity of 90 per cent at 68° F requires only half as much moisture to reach saturation as a 90 per cent relative humidity at 87° F. Relative humidity is used primarily as an indicator of atmospheric moisture saturation. For this reason vapor pressure deficit is calculated from temperature, relative humidity, and vapor pressure for a specific temperature.

TABLE XV

MONTHLY MEAN, MEAN MAXIMUM, AND MEAN MINIMUM TEMPERATURES (DEGREES F) AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

	Mean Temp.				Mean Max. Temp.				Mean Min. Temp.			
M	1460	3850	5000	6300	1460	3850	5000	6300	1460	3850	5000	6300
J	42.7	37.0	35.0	33.2	54.7	46.0	42.2	40.0	32.7	27.0	28.2	27.3
F	40.0	33.2	30.7	28.7	53.0	44.5	40.7	37.7	27.7	24.7	23.2	22.2
M	45.2	36.7	33.5	32.3	59.0	51.0	44.7	42.0	31.5	26.0	24.7	24.6
A	55.5	47.7	44.0	40.5	70.5	62.2	56.2	49.5	40.0	36.0	35.0	32.7
M	63.5	54.7	52.5	49.2	79.7	69.0	65.7	58.5	48.5	44.0	44.0	42.7
J	69.7	61.0	57.0	55.0	85.5	72.7	70.2	63.5	56.2	52.0	52.0	50.0
J	71.7	62.5	57.2	56.5	85.5	72.5	70.2	65.2	60.5	55.2	52.2	51.2
A	70.0	61.7	57.0	56.0	84.5	70.7	68.7	65.2	59.2	55.0	52.7	51.0
S	63.5	56.2	53.7	51.5	79.7	66.5	64.5	61.5	53.0	49.0	47.2	46.0
O	55.7	49.2	48.5	46.7	73.0	61.0	59.5	55.7	43.0	41.5	42.2	41.0
N	42.0	36.2	34.7	34.0	57.2	47.0	45.0	43.0	30.0	28.2	27.0	27.5
D	37.0	32.0	31.2	30.5	51.0	41.7	39.2	38.7	25.2	23.7	24.2	24.0

TABLE XVI

MONTHLY MAXIMUM AND MINIMUM TEMPERATURES (DEGREES F) FOR THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft.		3,850 Ft.		5,000 Ft.		6,300 Ft.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan.	80	-3	64	-4	60	-6	57	-8
Feb.	81	2	66	-5	65	-8	60	-12
Mar.	86	8	82	4	71	3	64	0
Apr.	91	17	85	9	79	9	67	6
May	94	27	87	24	82	23	74	25
June	99	42	85	35	86	35	77	38
July	100	44	89	41	89	39	80	41
Aug.	99	49	83	42	86	45	81	40
Sept.	93	30	83	29	77	27	75	29
Oct.	88	19	76	20	80	16	74	16
Nov.	82	3	69	-11	71	-11	70	-17
Dec.	74	5	61	2	57	2	60	1

The relative humidity information for the period 1947-1950 (Table XVII) shows that there was an annual cycle. January and August had the highest mean monthly relative humidities, and the lowest occurred in April. A secondary low occurred in November. The 1,460 ft. and 6,300 ft. stations were consistently the lowest with overlap between the two. The 3,850 ft. station had the highest set of monthly relative humidity means, but the 5,000 ft. station showed little difference from the 3,850 ft. station. Relative humidity means were high for all stations, with 14 of the 48 months involved being over 90 per cent, and 43 of the 48 being over 80 per cent.

The relative humidity frequency tables (Table XVIII, XIX, XX, and XXI) show that 42 of the 48 months had more than 50 per cent of the hourly readings at 100 per cent relative humidity. The cut-off lines (excludes frequencies of less than 1 per cent) follow approximately the same curve as the monthly mean values if they were plotted on a graph. This means that in July and August the range of relative humidity was not as large as in the other months with more of the hourly values concentrated at the higher end of the scale. The widest distributional range occurred in different months at the different stations.

When the max-min mean and the 4-hour interval mean were tested against the true relative humidity mean, the probability of getting a larger Chi square was greater than .995 for all stations using the 4-hour interval mean. However, there was a .500 probability of getting a larger Chi square value for the 1,460 ft. station, .750 at the 3,850 ft. station, .950 at the 5,000 ft. station, and greater than .995 at the 6,300 ft.

TABLE XVII

MEAN MONTHLY PER CENT RELATIVE HUMIDITY AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	86	94	89	83
Feb.	81	89	86	79
Mar.	74	86	84	80
Apr.	72	82	81	80
May	81	87	86	82
June	86	92	92	89
July	88	95	94	92
Aug.	89	96	94	93
Sept.	87	95	93	88
Oct.	86	95	87	82
Nov.	84	90	84	76

TABLE XVIII

DISTRIBUTION OF HOURLY RELATIVE HUMIDITY VALUES IN PER CENT OF THE TOTAL NUMBER OF MONTHLY VALUES AT THE 1,460 Ft. STATION FOR 1947-1950

R. H. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0%- 4%												
5%- 9%												0.06
10%-14%			0.2	0.1						0.1	0.3	0.1
15%-19%	0.1	0.1	0.7	0.7	0.2					0.4	0.3	0.2
20%-24%	0.3	1.0	2.7	2.0	0.6					1.8	1.1	0.7
25%-29%	0.3	2.3	3.3	3.5	1.5	0.1	0.4		0.1	0.9	1.5	1.3
30%-34%	1.0	2.1	5.3	4.2	1.9	0.7	0.2		0.6	1.6	2.0	1.1
35%-39%	1.3	2.4	3.5	3.8	3.7	1.3	0.8	0.2	1.3	2.2	1.8	1.7
40%-44%	1.9	3.5	4.0	4.3	4.0	2.5	1.2	1.6	2.7	2.7	3.1	1.9
45%-49%	2.6	3.1	3.9	4.1	3.5	2.9	2.2	2.5	3.8	2.8	2.9	1.9
50%-54%	3.3	3.8	4.0	4.6	3.5	3.3	3.4	2.8	3.2	3.0	2.7	2.6
55%-59%	3.7	3.6	4.1	3.5	3.7	3.8	3.6	3.4	3.3	2.2	2.6	2.9
60%-64%	4.2	3.4	3.9	4.1	3.4	3.4	4.1	2.9	3.1	2.7	3.4	3.1
65%-69%	4.2	3.1	3.9	4.0	2.3	3.7	3.8	3.1	3.0	2.3	3.0	3.7
70%-74%	3.7	3.1	3.1	4.7	2.5	4.3	3.4	2.5	2.6	2.2	2.1	3.2
75%-79%	2.4	2.7	2.8	3.2	2.7	3.2	3.1	3.3	2.6	1.5	1.7	2.3
80%-84%	3.0	2.6	3.1	2.3	2.9	3.1	3.1	2.8	2.3	1.5	2.1	3.1
85%-89%	2.4	2.4	2.3	2.2	2.1	1.9	1.8	2.3	2.3	1.3	1.8	2.7
90%-94%	2.0	2.5	2.3	2.3	2.1	2.5	2.1	2.9	2.2	1.6	2.2	3.4
95%-99%	3.0	2.4	2.1	1.9	2.4	1.7	2.1	2.2	1.8	1.3	1.5	2.6
100%	59.7	55.2	44.0	43.6	56.1	60.9	63.9	66.8	68.3	68.0	63.1	60.5

TABLE XIX

DISTRIBUTION OF HOURLY RELATIVE HUMIDITY VALUES IN PER CENT OF THE TOTAL NUMBER OF MONTHLY VALUES AT THE 3,850 FT. STATION FOR 1947-1950

R.H. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0%- 4%												
5%- 9%												
10%-14%												
15%-19%				0.1								
20%-24%	0.03	0.03	0.3	0.3						0.03	0.06	0.06
25%-29%	0.06	0.2	0.8	1.5	0.1					0.1	0.3	0.2
30%-34%	0.1	0.5	1.3	2.6	0.5					0.3	0.6	0.3
35%-39%	0.2	1.1	2.3	2.5	1.5	0.2				0.7	1.1	0.6
40%-44%	0.3	1.7	2.9	3.4	2.8	0.2			0.06	0.5	1.2	0.9
45%-49%	0.6	1.9	2.3	2.9	2.3	0.7	0.3	0.03	0.1	1.3	1.7	1.3
50%-54%	0.9	1.9	2.6	3.3	2.9	1.4	0.8	0.2	0.3	1.9	1.8	1.9
55%-59%	0.8	2.6	2.4	3.8	3.5	2.1	0.8	0.4	0.6	1.4	1.7	1.7
60%-64%	1.2	2.6	2.0	3.4	2.9	2.9	1.1	0.6	1.2	2.1	2.0	2.2
65%-69%	1.2	2.7	2.6	3.3	2.8	2.3	1.9	0.8	1.8	2.1	2.6	1.6
70%-74%	1.5	2.7	2.6	3.4	3.1	3.2	2.3	1.6	2.5	2.0	2.9	1.9
75%-79%	2.4	2.2	2.9	2.8	3.0	2.5	2.0	2.0	2.5	1.8	1.8	1.7
80%-84%	2.6	3.1	3.5	3.3	3.1	3.7	2.4	3.3	2.6	2.5	2.9	2.2
85%-89%	3.7	3.1	2.8	2.8	2.5	2.5	2.1	3.1	2.6	2.8	3.4	2.7
90%-94%	4.3	4.0	4.2	4.0	2.3	3.2	2.8	3.3	3.1	3.6	4.4	4.1
95%-99%	4.8	5.0	4.3	3.2	2.3	3.7	3.5	3.9	3.8	3.7	4.3	4.4
100%	74.6	63.3	59.5	52.2	63.6	70.5	59.4	80.4	78.3	72.8	66.6	71.6

TABLE XX

DISTRIBUTION OF HOURLY RELATIVE HUMIDITY VALUES IN PER CENT OF THE TOTAL NUMBER OF MONTHLY VALUES AT THE 5,000 Ft. STATION FOR 1947-1950

R. H. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0%- 4%												
5%- 9%												
10%-14%												
15%-19%	0.1									0.2		0.1
20%-24%	0.4									0.1	0.1	0.8
25%-29%	1.1	0.5	0.4	0.2						0.1	0.7	2.0
30%-34%	0.8	1.4	1.1	1.4	0.1				0.06	0.8	1.1	2.4
35%-39%	1.7	1.5	2.1	2.2	0.7	0.06			0.1	1.4	1.1	2.8
40%-44%	1.7	2.5	2.9	4.2	2.0	0.1			0.1	1.5	2.5	2.0
45%-49%	1.4	2.9	4.4	3.5	3.2	0.3	0.1	0.03	0.3	2.1	3.8	3.1
50%-54%	1.3	3.3	3.7	3.6	2.7	0.6	0.2	0.1	0.7	3.2	3.8	3.0
55%-59%	1.8	3.6	4.3	4.1	3.6	1.9	0.7	0.3	1.4	2.6	3.8	3.0
60%-64%	1.9	3.5	3.3	4.7	3.7	2.5	1.5	1.2	1.9	3.2	3.8	3.5
65%-69%	2.4	2.9	2.9	3.9	3.9	3.3	2.6	1.0	2.4	3.0	4.0	4.1
70%-74%	2.5	3.3	3.8	4.7	4.4	3.9	3.4	2.5	2.9	3.7	3.2	2.8
75%-79%	1.9	2.5	3.5	4.3	3.5	3.6	2.8	2.3	3.4	2.6	3.0	2.8
80%-84%	2.9	2.8	3.4	5.2	4.6	4.7	3.8	3.1	3.8	3.3	3.4	2.6
85%-89%	2.5	2.6	3.4	4.6	4.6	3.9	4.4	3.8	3.5	2.9	3.4	2.3
90%-94%	2.8	3.3	3.3	3.7	5.5	5.4	5.1	4.9	4.4	3.9	3.7	2.6
95%-99%	2.5	3.2	3.4	3.7	5.7	4.4	4.6	3.7	3.8	3.9	2.7	1.7
100%	69.3	59.3	53.3	45.1	51.2	64.7	70.2	76.5	70.5	61.2	55.2	57.5

TABLE XXI

DISTRIBUTION OF HOURLY RELATIVE HUMIDITY VALUES IN PER CENT OF THE TOTAL NUMBER OF MONTHLY VALUES AT THE 6,300 FT. STATION FOR 1947-1950

R. H. Class	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
0%- 4%		0.1									0.1	0.1
5%- 9%	0.4	0.4	0.1	0.2					0.03	0.06	9.9	0.6
10%-14%	0.7	0.6	0.5	0.3					0.09	1.0	2.0	0.8
15%-19%	1.3	1.3	1.4	1.3	0.3	0.03			0.1	2.0	2.0	3.7
20%-24%	1.6	1.8	1.4	1.7	0.5	0.2			0.2	2.0	2.6	5.7
25%-29%	2.1	2.5	2.0	1.6	1.2	0.2	0.1		0.6	1.8	4.0	6.2
30%-34%	2.6	3.0	3.5	2.0	1.8	0.3	0.1		1.4	2.1	3.8	5.9
35%-39%	2.4	3.7	4.0	2.5	1.6	0.5	0.06		1.1	2.5	3.4	4.9
40%-44%	2.5	3.5	3.6	2.7	2.4	1.0	0.09	0.1	1.6	3.1	3.7	4.7
45%-49%	2.5	2.8	3.2	2.8	4.0	1.0	0.2	0.5	1.4	3.0	3.2	4.5
50%-54%	2.7	2.6	4.4	3.1	3.7	2.3	0.8	0.8	2.0	2.1	3.2	2.8
55%-59%	1.6	2.3	5.7	2.9	3.8	2.3	0.9	1.1	1.5	2.7	2.8	2.1
60%-64%	1.8	2.4	3.4	3.4	4.9	2.5	1.9	1.9	3.0	2.9	2.9	3.3
65%-69%	1.7	2.3	2.7	3.3	3.5	2.9	3.1	1.9	2.7	3.8	3.0	1.6
70%-74%	1.5	3.3	2.9	3.1	3.9	4.5	3.6	3.1	2.9	2.3	3.3	1.7
75%-79%	1.6	2.3	2.5	2.9	3.9	3.7	4.1	3.5	3.1	3.2	2.6	1.0
80%-84%	2.0	2.3	2.2	3.9	4.7	4.6	4.9	4.1	3.8	2.6	2.1	2.5
85%-89%	2.2	1.8	1.7	3.1	1.3	4.0	4.2	4.6	2.7	3.1	2.2	2.9
90%-94%	1.7	1.8	1.9	3.0	2.4	4.4	4.7	5.6	4.2	4.4	2.0	3.0
95%-99%	3.1	3.4	2.6	2.2	2.4	8.0	7.8	7.6	5.1	3.2	4.0	3.2
100%	64.0	54.8	49.2	50.3	52.9	56.9	62.6	64.3	61.4	53.1	45.3	37.9

station when the max-min mean was compared with the true mean. There was a decrease in the significance of difference as the stations increased in elevation.

Vapor Pressure Deficit

Vapor pressure deficit is a better indicator of atmospheric moisture demand than relative humidity. A vapor pressure deficit value indicates the same atmospheric capacity for additional water regardless of the temperature (Anderson, 1936; Kittredge, 1948; Neumann, 1954).

The mean monthly vapor pressure deficits (Table XXII) for the 1,460 ft. station were consistently the highest of the four stations. The other three stations were considerably lower with very little difference among them. The 6,300 ft. station did have the highest deficit of the three stations during 9 of the 12 months. The annual variation showed that the months with greatest deficit were April and May with the least deficit occurring in January. Figure 2 is a graph of the data from all the stations.

Coefficients of determination were calculated to see if vapor pressure deficit correlated with factors that could be indicative of a wet month and a resultant high atmospheric humidity. The r^2 values for correlations between vapor pressure deficit and monthly total precipitation and between vapor pressure deficit and number of days per month with precipitation were below .250 for all stations. When vapor pressure deficit was correlated with monthly temperature range, there was little correlation at the 1,460 ft. station ($r^2 = .195$), but the r^2 increased as altitude increased (3,850 ft.: $r^2 = .473$; 5,000 ft.: $r^2 = .756$; 6,300

TABLE XXII

MONTHLY MEAN VAPOR PRESSURE DEFICIT IN mm Hg AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	1.31	.28	.46	.71
Feb.	1.32	.53	.64	.89
Mar.	2.30	.82	.84	1.03
Apr.	3.09	1.27	1.41	1.25
May	2.69	1.37	1.41	1.60
June	2.77	.97	.97	1.16
July	2.65	.65	.83	.90
Aug.	1.96	.45	.54	.79
Sept.	1.91	.50	.65	1.06
Oct.	1.49	.63	1.03	.97
Nov.	1.18	.53	.86	1.44
Dec.	.91	.36	.80	1.43

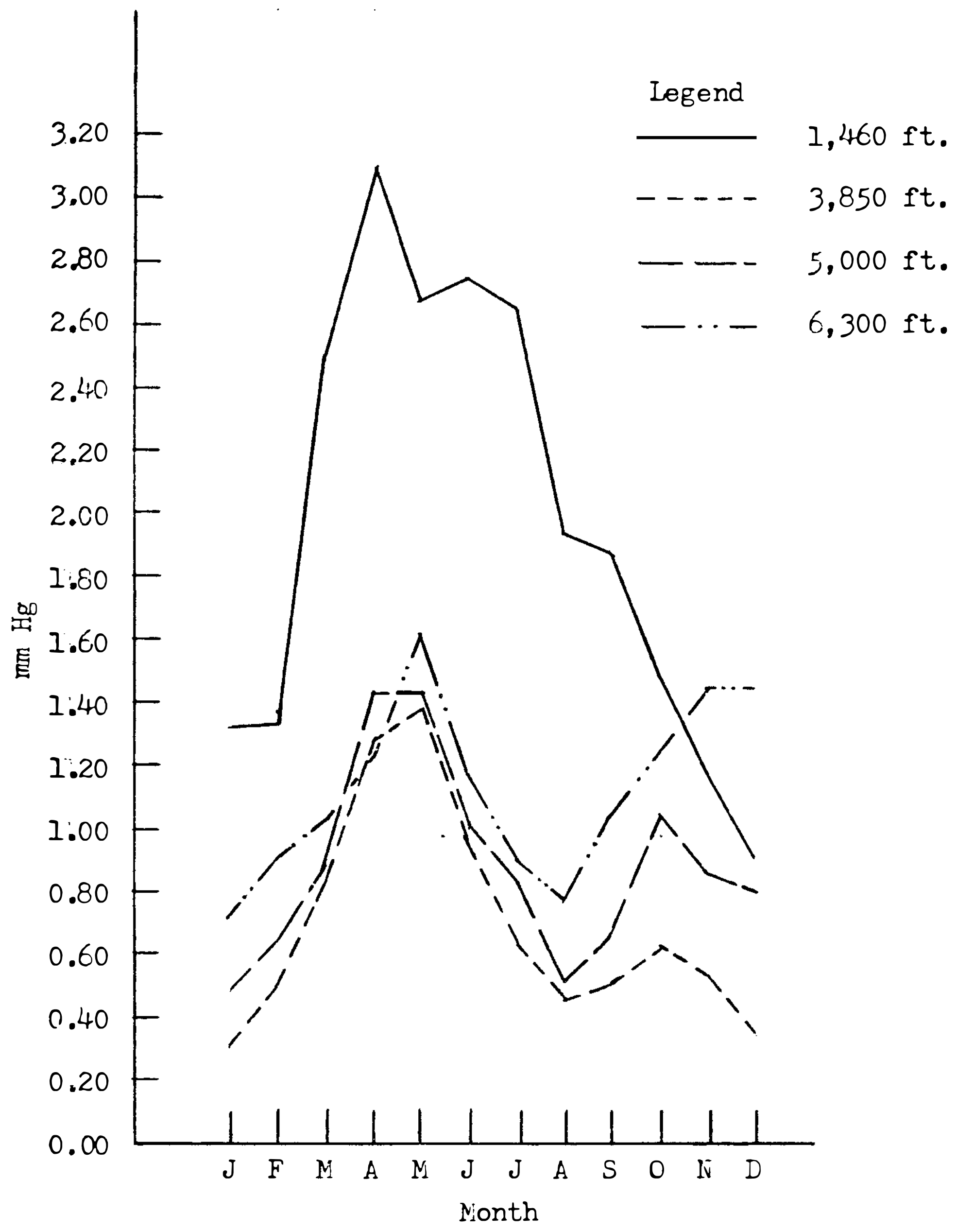

Figure 2. Monthly mean vapor pressure deficit (mm Hg) at the 1,460 ft., 3,850 ft., 5,000 ft., and 6,300 ft. stations for 1947-1950.

ft.: r^2 = .779). Graphically, there was indication of some correlation between vapor pressure deficit and temperature range; however, the reasons for it are not apparent.

Precipitation

Smallshaw (1954) showed that precipitation increased with elevation in the Smokies. The information presented here verifies this conclusion. The normal precipitation for the 1,460 ft. station and the 6,300 ft. station is 55.54 inches and 83.71 inches, respectively. The precipitation for the 4 years studied was 59.31 and 90.48 inches per year. The normal and study period precipitation followed the same patterns, except that the 1947-1950 January mean monthly precipitation was higher than the normal. The unusually high amount for January could be accounted for by a high amount of precipitation that fell in January, 1947. The amounts for that month ranged from 10.47 inches at the 1,460 ft. station to 17.47 inches at the 6,300 ft. station. Where the 4-year monthly precipitation means were compared with the norms, the probability of getting a larger Chi square was greater than .995 for the 1,460 ft. station and .500 for the 6,300 ft. station. Graphical comparison of the means is presented in Figures 3 and 4.

Microclimatic variation seemed to be best exhibited by precipitation. For the three highest stations (3,850 ft., 5,000 ft., 6,300 ft.) January was the wettest month, but August was the wettest at the 1,460 ft. elevation (Table XXIII). The second wettest month was August at the 6,300 ft. station, February for the 3,850 ft. and 5,000 ft. stations, and July for the 1,460 ft. station. The month of lowest precipitation

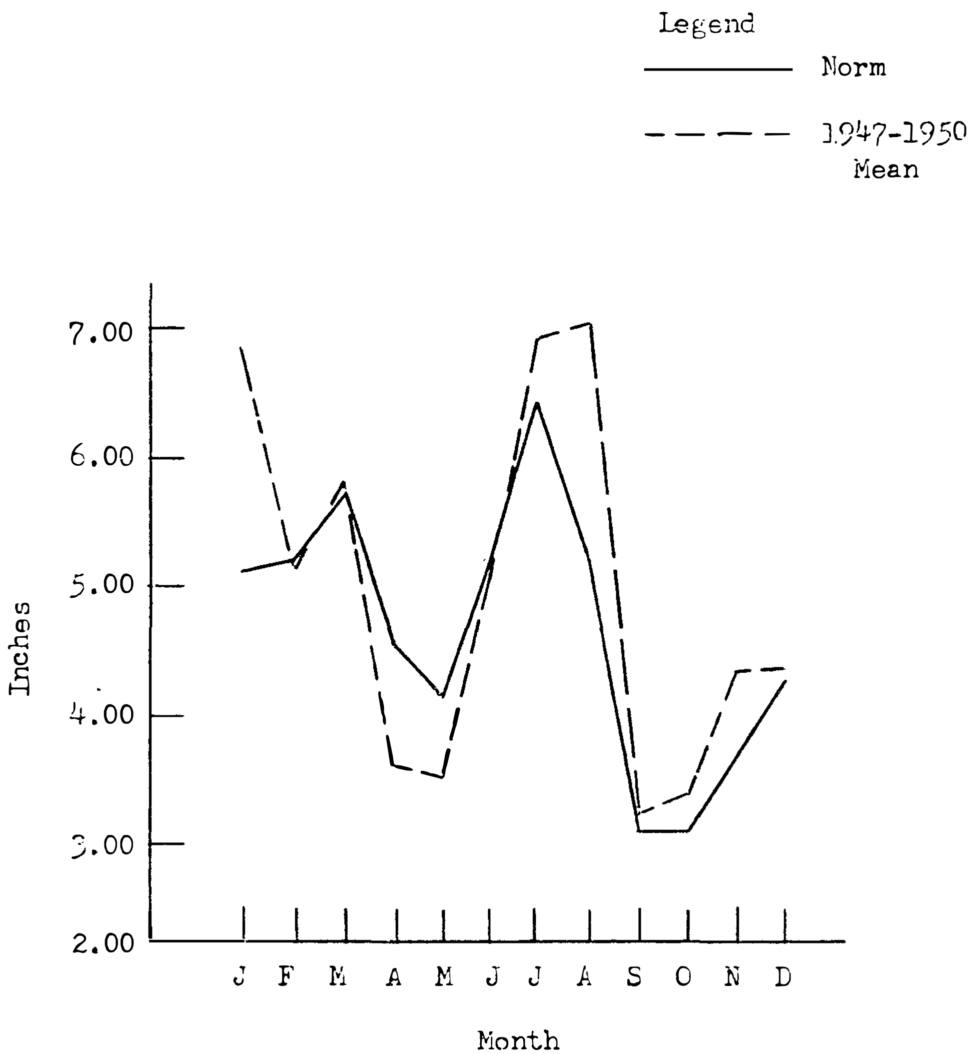

Figure 3. Comparison of the 1947-1950 mean monthly precipitation with the 42-year mean monthly precipitation at the 1,460 ft. station.

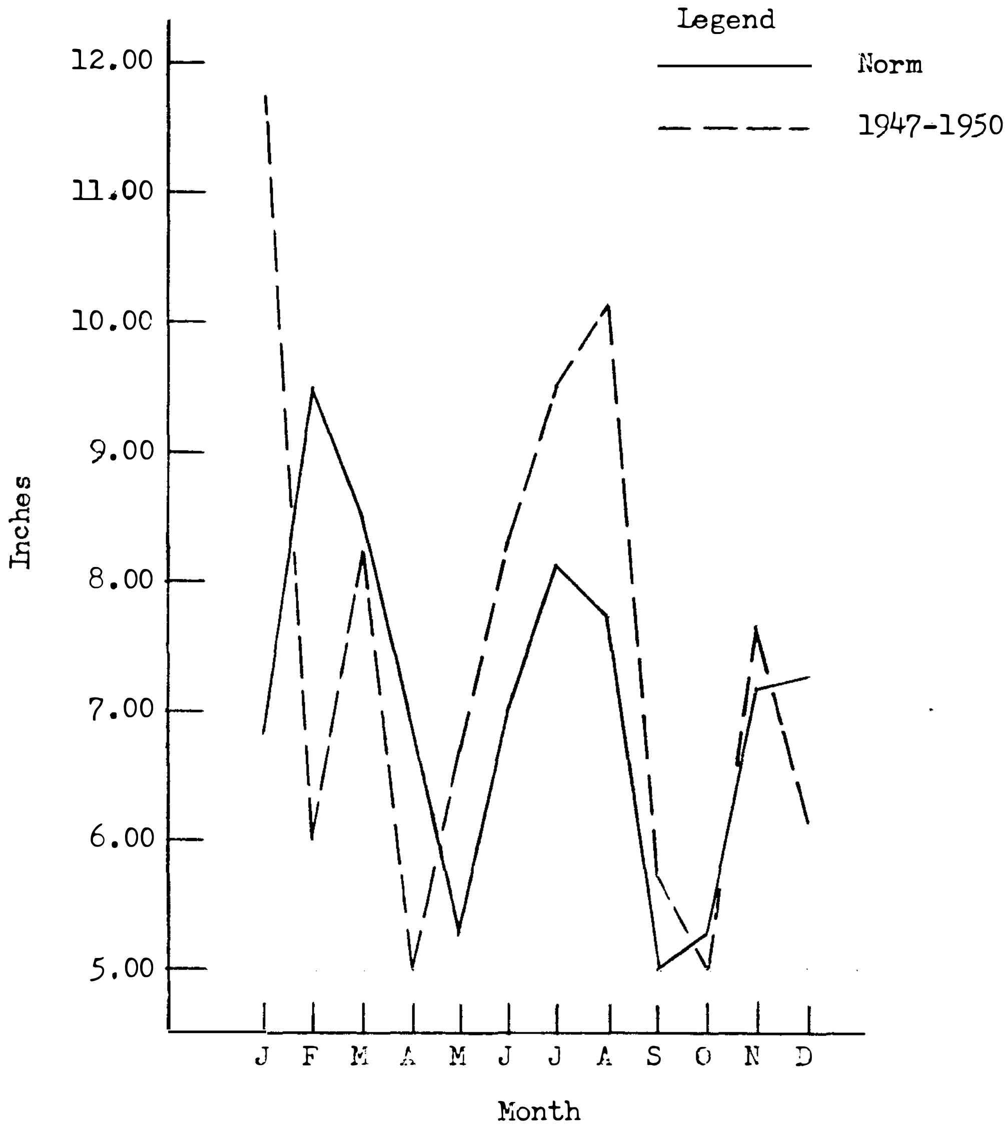

Figure 4. Comparison of the 1947-1950 mean monthly precipitation with the 28-year mean monthly precipitation at the 6,300 ft. station.

TABLE XXIII

MEAN MONTHLY INCHES OF PRECIPITATION AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	6.80	10.19	12.83	11.86
Feb.	5.09	6.57	8.12	6.05
Mar.	5.74	8.05	9.25	8.25
Apr.	3.69	4.52	4.71	5.01
May	3.60	5.83	6.04	6.76
June	5.03	4.89	5.74	8.36
July	6.93	6.79	7.67	9.59
Aug.	7.03	6.73	7.71	10.14
Sept.	3.09	3.95	5.21	5.71
Oct.	3.53	4.45	4.94	4.97
Nov.	4.39	7.51	8.13	7.66
Dec.	4.39	6.70	7.46	6.12

was September for the 1,460 ft. and 3,850 ft. stations, April for the 5,000 ft. station, and October for the 6,300 ft. station.

The increase of precipitation with increasing altitude in general held true except for the two highest stations (5,000 ft. and 6,300 ft.). From November through March the 5,000 ft. station had greater precipitation than the 6,300 ft. station. However, during the rest of the year the 6,300 ft. station exhibited the greater amounts of precipitation.

Results of the correlations between the mean monthly precipitation data for the four stations are presented in Table XXIV. Between the 1,460 ft. and 3,850 ft. stations and the 1,460 ft. and 5,000 ft. stations the r^2 values were very nearly the same (.503 and .505) and showed only a moderate correlation. The r^2 for the correlation between the 1,460 ft. and 6,300 ft. stations was considerably higher (.787). The r^2 between the 3,850 ft. station and the 6,300 ft. station was .582, and between the 5,000 ft. station and the 6,300 ft. station it was .601. However, the r^2 value for the correlation between the 3,850 ft. and 5,000 ft. stations was .959. This indicated that there was similarity in the variation of the 1,460 ft. and 6,300 ft. stations, and there was similarity in the variation of the 3,850 ft. and 5,000 ft. stations. However, there was a moderate amount of variation in the first pair of stations that was independent of the variation in the second pair of stations.

The number of days per month on which measurable precipitation occurred is an important indicator of the distribution of rain. Table XXV shows that precipitation occurred at some of the stations on at least

TABLE XXIV

COEFFICIENTS OF DETERMINATION AND REGRESSION EQUATIONS FOR THE MONTHLY MEAN PRECIPITATION FOR SIX COMBINATIONS OF STATIONS FOR 1947-1950

X	Y	r^2	Regression Equation
1460	3850	.503	$Y = 1.96 + .886X$
1460	5000	.505	$Y = 1.51 + 1.17X$
1460	6300	.787	$Y = .77 + 1.37X$
3850	5000	.959	$Y = -.88 + 1.29X$
3850	6300	.582	$Y = 1.56 + .942X$
5000	6300	.601	$Y = 2.26 + .723X$

TABLE XXV

MEAN NUMBER OF DAYS PER MONTH ON WHICH PRECIPITATION WAS MEASURED AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	16.25	17.25	18.25	17.25
Feb.	12.25	14.50	14.25	14.75
Mar.	13.25	15.25	15.75	15.00
Apr.	10.25	12.25	13.25	12.25
May	13.00	13.50	13.25	13.75
June	13.50	13.75	15.25	14.50
July	15.25	14.50	15.25	16.50
Aug.	14.00	13.00	17.25	18.00
Sept.	8.75	9.00	9.50	10.25
Oct.	9.00	10.00	10.25	10.75
Nov.	12.00	12.75	12.75	12.25
Dec.	12.00	12.00	12.50	12.00

33 per cent of the days in every month except September and October and occurred on 50 per cent of the days in 15 of the 48 months. Table XXV, page 52, also shows that there was a general increase in number of days with precipitation as the altitude increased except at the 5,000 ft. and 6,300 ft. stations. At those two stations, season was more important than altitude in determining the station with the highest number of days with precipitation.

The average amount of precipitation per day with precipitation (Table XXVI) varied with the other precipitation data. The average amount of precipitation per day generally increased with elevation, and it was less during the drier months and more during the wetter months. All daily averages were at least 0.25 inches or higher, and half of the total months involved had an average daily precipitation of 0.50 inches or more.

The average number of consecutive days with and without precipitation give a very good indication of the distribution of rainfall (Tables XXVII and XXVIII). The variation with altitude was not as pronounced as the change in monthly precipitation, but the trend did exist. In general the number of consecutive days with precipitation increased with altitude and the length of the period of time between periods of rain decreased. The shortness of the average time between periods of rainfall and of the time making up periods of rainfall along with the number of days per month on which rainfall occurred indicates the even distribution of precipitation in all months.

The average number of days on which snowfall was recorded and on

TABLE XXVI

AVERAGE INCHES OF PRECIPITATION PER DAY WITH MEASURABLE PRECIPITATION AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	.411	.585	.706	.681
Feb.	.417	.476	.587	.513
Mar.	.568	.527	.561	.594
Apr.	.357	.368	.357	.406
May	.278	.442	.457	.500
June	.372	.364	.388	.575
July	.454	.500	.506	.581
Aug.	.502	.448	.446	.565
Sept.	.353	.453	.548	.557
Oct.	.392	.445	.482	.460
Nov.	.394	.589	.614	.625
Dec.	.366	.558	.598	.603

TABLE XXVII

AVERAGE NUMBER OF CONSECUTIVE DAYS PER MONTH ON WHICH PRECIPITATION OCCURRED AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATION FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	2.87	3.50	3.63	3.45
Feb.	2.59	3.25	2.66	2.83
Mar.	2.07	2.30	2.40	2.35
Apr.	1.87	2.03	2.19	2.43
May	2.33	2.56	2.41	2.69
June	2.47	2.65	2.61	2.61
July	3.31	3.15	3.55	3.94
Aug.	3.04	2.79	2.80	3.26
Sept.	1.69	1.65	2.31	2.31
Oct.	2.62	2.05	2.42	3.35
Nov.	1.92	2.36	2.18	2.03
Dec.	2.24	2.10	2.00	1.97

TABLE XXVIII

AVERAGE NUMBER OF CONSECUTIVE DAYS PER MONTH BETWEEN PERIODS OF PRECIPITATION AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Month	1,460 Ft. Station	3,850 Ft. Station	5,000 Ft. Station	6,300 Ft. Station
Jan.	2.39	2.23	2.00	2.18
Feb.	2.76	2.52	2.08	2.06
Mar.	2.42	2.22	2.19	2.42
Apr.	2.88	2.50	2.52	2.90
May	3.28	3.25	3.00	2.95
June	2.73	2.45	2.00	2.00
July	3.21	3.05	3.26	2.78
Aug.	3.15	2.10	2.34	2.45
Sept.	3.24	3.59	3.61	3.08
Oct.	4.31	3.61	4.10	4.52
Nov.	2.51	2.54	2.44	2.50
Dec.	2.51	2.24	2.12	2.22

which snow was on the ground (Tables XXIX and XXX), being primarily temperature dependent, was very seasonal and altitudinal in distribution. The number of days with snowfall increased with altitude except for a slight drop from the 5,000 ft. station to the 6,300 ft. station. That followed the same pattern as total number of days with measurable precipitation. However, because of the generally lower temperatures at higher elevations snow persisted for greater lengths of time on the ground. Daily snowfall amounts were not recorded as such but were included in the total monthly precipitation as equivalent precipitation.

Soil Moisture Balance

Soil moisture balance was calculated in two different ways, both according to Thornthwaite (1957). The monthly calculations used monthly mean temperature, monthly total precipitation, and latitude (Tables XXXI, XXXII, XXXIII, and XXXIV). The daily calculations used daily mean temperature and daily precipitation. The daily values were then treated appropriately to get the desired monthly values (Tables XXXV, XXXVI, XXXVII, and XXXVIII).

Since potential evapotranspiration increased with increasing temperature, its curve followed the same pattern as the temperature curve with the low in February and/or December and the high in July. In Tables XXXI through XXXIV, which are based on monthly means, only 1 month of the 48 involved showed potential evapotranspiration to exceed precipitation. As a result only 1 month had soil moisture content departing from field capacity (May at Park Headquarters station). Actual evapotranspiration equalled the potential, a moisture deficit did not

TABLE XXIX

MEAN NUMBER OF DAYS PER MONTH ON WHICH SNOWFALL WAS RECORDED AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Station	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.
1,460	2.00	1.75	1.25	0.00	0.00	0.75	1.00
3,850	3.50	5.00	5.00	0.75	0.25	3.00	4.00
5,000	4.75	5.25	6.25	1.25	0.50	3.75	3.75
6,300	3.75	5.00	6.00	1.50	0.50	3.75	5.50

TABLE XXX

MEAN NUMBER OF DAYS PER MONTH WITH SNOW ON THE GROUND AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

Station	Jan.	Feb.	Mar.	Apr.	Oct.	Nov.	Dec.
1,460	2.75	4.00	1.00	0.00	0.00	0.75	1.00
3,850	7.00	9.50	9.75	1.75	0.25	3.25	6.50
5,000	8.00	13.00	12.25	2.50	0.50	5.00	8.25
6,300	7.25	13.25	13.25	3.00	0.75	4.00	10.25

TABLE XXXI

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 1,460 FT. STATION BASED ON MONTHLY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	42.7	.52	6.80	6.28	12.00	0	6.28	15.14
Feb.	40.0	.51	5.09	4.58	12.00	0	4.58	15.86
Mar.	45.2	.92	5.74	4.82	12.00	0	4.82	16.34
Apr.	55.5	2.31	3.69	1.38	12.00	0	1.38	14.91
May	63.5	3.63	3.60	-.03	11.97	0	0.00	13.48
June	69.7	4.75	5.03	.28	12.00	0	.25	12.83
July	71.7	5.20	6.93	1.73	12.00	0	1.73	13.28
Aug.	70.0	4.52	7.03	2.51	12.00	0	2.51	13.89
Sept.	63.5	3.09	3.09	0.00	12.00	0	0.00	13.89
Oct.	55.7	2.03	3.53	1.50	12.00	0	1.50	13.22
Nov.	42.0	.51	4.39	3.88	12.00	0	3.88	14.55

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXII

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 3,850 FT. STATION BASED ON MONTHLY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	37.0	.52	10.19	9.67	12.00	0	9.67	16.84
Feb.	33.2	.25	6.57	6.35	12.00	0	6.35	17.59
Mar.	36.7	.61	8.05	7.44	12.00	0	7.44	19.02
Apr.	47.7	1.98	4.52	2.54	12.00	0	2.54	16.28
May	54.7	3.26	5.86	2.57	12.00	0	2.57	15.42
June	61.0	4.02	4.89	.87	12.00	0	.87	14.15
July	62.5	4.46	6.79	2.33	12.00	0	2.33	14.24
Aug.	61.7	3.82	6.73	2.91	12.00	0	2.91	14.62
Sept.	56.2	2.78	3.96	1.17	12.00	0	1.17	13.85
Oct.	49.2	2.03	4.45	2.42	12.00	0	2.42	14.13
Nov.	36.2	.51	7.51	7.00	12.00	0	7.00	16.57
Dec.	32.0	0.00	6.70	6.70	12.00	0	6.70	17.58

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXIII

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 5,000 FT. STATION BASED ON MONTHLY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	35.0	.52	12.83	12.31	12.00	0	12.31	18.16
Feb.	30.7	0.00	8.13	8.13	20.13	0	0.00	23.21
Mar.	33.5	.30	9.25	8.95	12.00	0	8.95	24.52
Apr.	44.0	1.65	4.71	3.06	12.00	0	3.06	21.01
May	52.5	2.90	6.04	3.14	12.00	0	3.14	17.30
June	57.0	3.66	5.75	2.09	12.00	0	2.09	17.01
July	57.2	3.72	7.67	3.95	12.00	0	3.95	15.69
Aug.	57.0	3.48	7.71	4.23	12.00	0	4.23	17.15
Sept.	53.7	2.78	5.21	2.43	12.00	0	2.43	16.39
Oct.	48.5	2.03	4.94	2.91	12.00	0	2.91	15.15
Nov.	34.7	.51	8.13	7.62	12.00	0	7.62	17.38
Dec.	31.2	0.00	7.46	7.46	19.46	0	0.00	22.14

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXIV

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 6,300 FT. STATION BASED ON MONTHLY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	33.2	0.26	11.86	11.60	12.00	0	11.60	17.80
Feb.	28.7	0.00	6.05	6.05	18.05	0	0.00	20.95
Mar.	32.3	0.00	8.25	8.25	12.00	0	8.25	22.43
Apr.	40.5	1.32	5.01	3.69	12.00	0	3.69	19.82
May	49.2	2.54	6.76	4.22	12.00	0	4.22	17.81
June	55.0	3.29	8.36	5.07	12.00	0	5.07	18.78
July	56.5	3.72	9.59	5.87	12.00	0	5.87	18.31
Aug.	56.0	3.13	10.14	7.01	12.00	0	7.01	18.66
Sept.	51.0	2.47	5.71	3.24	12.00	0	3.24	16.95
Oct.	46.7	1.74	4.97	3.23	12.00	0	3.23	16.09
Nov.	34.0	0.25	7.66	7.41	12.00	0	7.41	17.75
Dec.	30.5	0.00	6.12	6.12	12.00	0	0.00	20.99

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXV

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 1,460 FT. STATION BASED ON DAILY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	42.7	0.87	6.80	5.92	11.96	0.01	6.33	13.18
Feb.	40.0	0.62	5.09	4.46	11.97	0.00	4.79	13.69
Mar.	45.2	1.18	5.74	4.55	11.95	0.01	5.24	13.27
Apr.	55.5	2.26	3.69	1.87	11.77	0.02	2.96	12.82
May	63.5	3.64	3.60	-0.04	11.31	0.13	2.41	12.06
June	69.7	4.70	5.03	1.19	10.66	0.32	3.33	11.55
July	71.7	5.07	6.93	2.05	10.60	0.21	4.66	11.83
Aug.	70.0	4.55	7.03	2.46	11.13	0.20	5.26	12.47
Sept.	63.5	3.15	3.09	-0.06	10.93	0.19	2.18	11.92
Oct.	55.7	2.02	3.53	2.16	10.60	0.13	2.94	11.18
Nov.	42.0	0.68	4.39	3.95	11.77	0.02	4.33	13.00
Dec.	37.0	0.40	4.39	3.98	11.98	0.00	4.18	13.22

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXVI

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 3,850 FT. STATION BASED ON DAILY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	37.0	0.72	10.19	9.47	11.97	0.01	9.70	13.93
Feb.	33.2	0.43	6.57	6.13	11.97	0.00	6.27	14.26
Mar.	36.7	0.78	8.05	7.26	11.97	0.00	7.68	13.95
Apr.	47.7	1.84	4.52	4.88	11.87	0.01	3.82	13.37
May	54.7	2.93	5.86	2.89	11.65	0.05	4.79	12.81
June	61.0	3.79	4.89	1.10	11.44	0.10	3.49	12.68
July	62.5	4.04	6.79	2.74	11.61	0.08	5.02	13.22
Aug.	61.7	3.70	6.73	3.03	11.56	0.08	5.09	12.91
Sept.	56.2	2.68	3.95	1.27	11.25	0.12	3.17	12.47
Oct.	49.2	1.79	4.45	2.65	11.34	0.05	3.79	12.04
Nov.	36.2	0.54	7.51	6.94	11.96	0.01	7.23	13.96
Dec.	32.0	0.29	6.70	6.39	11.99	0.00	6.53	13.95

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXVII

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 5,000 FT. STATION BASED ON DAILY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	35.0	0.65	12.83	12.19	11.98	0.01	12.31	14.49
Feb.	30.7	0.36	8.13	7.76	11.98	0.00	2.86	14.85
Mar.	33.5	0.64	9.25	8.61	11.97	0.00	8.94	14.35
Apr.	44.0	1.63	4.71	3.08	11.87	0.01	4.07	13.53
May	52.5	2.84	6.04	3.19	11.67	0.05	4.97	12.87
June	57.0	3.66	5.75	2.26	11.64	0.05	4.40	13.10
July	57.2	3.80	7.67	3.86	11.70	0.06	6.08	13.43
Aug.	57.0	3.49	7.71	4.21	11.69	0.07	5.87	13.31
Sept.	53.7	2.52	5.21	2.68	11.59	0.05	4.43	13.04
Oct.	48.5	1.85	4.94	3.08	11.69	0.03	4.30	12.55
Nov.	34.7	0.56	8.13	7.56	11.97	0.01	7.84	14.11
Dec.	31.2	0.34	7.46	7.11	11.99	0.00	7.28	14.14

[1]PET = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

TABLE XXXVIII

ANNUAL SOIL MOISTURE BALANCE IN INCHES AT THE 6,300 FT. STATION BASED ON DAILY MEANS FOR 1947-1950

Month	Temp.	PET[1]	Prec.	P-PET[2]	SM[3]	MD[4]	MS[5]	SMB[6]
Jan.	33.2	0.57	11.86	11.29	11.98	0.00	11.40	14.68
Feb.	28.7	0.44	6.05	5.78	11.98	0.00	5.91	14.28
Mar.	32.3	0.60	8.25	8.31	11.97	0.00	8.62	14.04
Apr.	40.5	1.34	5.01	4.01	11.88	0.01	4.87	13.46
May	49.2	2.61	6.76	3.89	11.72	0.04	5.53	13.17
June	55.0	3.37	8.36	4.83	11.78	0.02	6.81	13.78
July	56.5	3.65	9.59	6.55	11.72	0.05	8.50	14.17
Aug.	56.0	3.41	10.14	6.22	11.69	0.05	11.69	13.92
Sept.	51.0	2.52	5.71	3.07	11.53	0.06	4.82	13.41
Oct.	46.7	1.83	4.97	3.37	11.59	0.04	4.55	12.53
Nov.	34.0	0.64	7.66	6.77	11.94	0.01	7.19	13.87
Dec.	30.5	0.34	6.12	6.31	11.98	0.00	6.44	13.99

[1]P.E.T = Potential evapotranspiration.

[2]P-PET = Precipitation minus potential evapotranspiration.

[3]SM = Soil moisture content.

[4]MD = Moisture deficit.

[5]MS = Moisture surplus.

[6]SMB = Soil moisture balance.

occur, and a soil moisture surplus was common. As a result, the total soil moisture balance was high, always exceeding field capacity and increasing with elevation except at the two high elevation stations. The soil moisture balance at the 5,000 ft. station was higher than that of the 6,300 ft. station from November through March. The reverse was true from April through October.

Tables XXXV through XXXVIII, pages 64 through 67, giving the information calculated on a daily basis, should give a more accurate evaluation of the soil moisture balance. The total monthly potential evapotranspiration showed the same pattern of distribution when calculated by either method. The main difference occurred during months with a mean temperature of 32° F or less. The potential evapotranspiration calculated on a monthly basis was zero, but it was as much as 0.50 inches greater for the month when calculated on a daily basis than when calculated on a monthly basis. The month, even though it had a mean temperature of less than 32° F, still had days above the temperature at which evapotranspiration could occur. The 6,300 ft. station showed no potential evapotranspiration during March using the monthly data, but showed 0.60 inches potential evapotranspiration using the daily data.

Soil moisture content also exhibited differences when calculated by the two different methods. The 1,460 ft. station showed only one month (May) with a soil moisture content (11.97 inches) of less than field capacity (12.00 inches). Soil moisture when calculated on the daily basis was continually below field capacity during all months, dropping as low as 10.60 inches at the 1,460 ft. station, 11.25 inches at the 3,850 ft. station, 11.59 inches at the 5,000 ft. station, and 11.53

inches at the 6,300 ft. station. These low values all occurred in September which combined moderately high temperatures and low precipitation to result in soil moisture depletion greater than in any other month. In spite of the consistent difference between the monthly and daily derived soil moisture contents, there was still a greater than .995 probability of getting a larger Chi square based on the difference of the means.

According to the calculations based on monthly data, no moisture deficit occurred during any month, and a moisture surplus occurred in 42 of the 48 months. The daily information, however, showed moisture deficit occurring in 36 of the 48 months, but a surplus occurred in the same months. That happened when there was a period of several rainless days with simultaneously occurring evapotranspiration. If the rainfall oocurring at the end of the rainless period was more than sufficient to recharge the soil, then a surplus occurred.

Soil moisture deficit was highest in the same months when potential evapotranspiration was highest (June-September) and decreased with altitude. Moisture surplus, in general, increased as altitude increased. Moisture surplus was not as dependent on potential evapotranspiration as moisture deficit but was more precipitation dependent. The curve of moisture surplus was similar to the precipitation curve.

Table XXXIX gives the one day values of maximum and minimum soil moisture content. The maximum values were in evidence many times during each month, but the minimum occurred only once. All stations reached field capacity in all months. The minimum values followed a curve similar to the inverse of the temperature mean curves. The minimum

TABLE XXXIX

SOIL MOISTURE MAXIMUM AND MINIMUM IN INCHES FOR EACH MONTH AT THE 1,460 FT., 3,850 FT., 5,000 FT., AND 6,300 FT. STATIONS FOR 1947-1950

	1,460 Ft. Station		3,850 Ft. Station		5,000 Ft. Station		6,300 Ft. Station	
Month	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan.	12.00	11.64	12.00	11.74	12.00	11.79	12.00	11.76
Feb.	12.00	11.71	12.00	11.84	12.00	11.89	12.00	11.93
Mar.	12.00	11.44	12.00	11.76	12.00	11.76	12.00	11.78
Apr.	12.00	10.99	12.00	11.05	12.00	11.08	12.00	11.08
May	12.00	10.13	12.00	10.62	12.00	10.69	12.00	10.65
June	12.00	8.82	12.00	10.59	12.00	10.79	12.00	11.21
July	12.00	8.74	12.00	10.51	12.00	10.82	12.00	10.77
Aug.	12.00	9.25	12.00	9.96	12.00	10.20	12.00	10.63
Sept.	12.00	8.34	12.00	9.66	12.00	9.90	12.00	10.34
Oct.	12.00	8.03	12.00	10.05	12.00	10.88	12.00	10.57
Nov.	12.00	8.88	12.00	11.52	12.00	11.47	12.00	11.37
Dec.	12.00	11.85	12.00	11.81	12.00	11.88	12.00	11.91

monthly value was usually highest in February and lowest in September. There was a lag between the highest monthly temperature mean and the lowest soil moisture content, because July, the hottest month, was also one of the wettest. The minimum value reached by any station was 8.03 inches in October at the 1,460 ft. station. The 8.82 inches, 8.72 inches, 9.25 inches, and 8.34 inches of June, July, August, and September occurred either in 1947 (June and July) or 1948 (August and September). In each situation the lows occurred during a dry period overlapping the two months. Two periods, one of 25 days in June and July, 1947, and one of 64 days in August, September, October, and November, 1948, were the only periods with soil moisture content as low or lower than 10.00 inches. Both occurred at the 1,460 ft. station. At the other three stations, soil moisture was consistently above 10.50 inches with 19 of the 36 months shown for the three stations being above 11.00 inches. These were extreme values which were rarely approached during the 4 years of study, and it is quite obvious that soil moisture content remained at high levels throughout the year.

The total soil moisture or soil moisture balance is the sum of the soil water being held by the soil until lost by evapotranspiration and runoff. These values were quite different for the total soil moisture balance calculated by the two methods. The soil moisture balance computed on a daily basis was considered to be the true value, and the total soil moisture calculated on a monthly basis was tested against it. The probabilities of getting a larger Chi square were .975, .850, less than .005, and .010 for the 1,460 ft., 3,850 ft., 5,000 ft., and 6,300 ft. stations, respectively. The difference between the two values resulted

because the entire precipitation surplus was added to the soil moisture balance at one time when calculated on a monthly basis. However, moisture was added to the soil in small increments, and runoff and evapotranspiration occurred between moisture additions when computed on a daily basis. As a result, the soil moisture build-up was never as great in the daily values as in the monthly.

Soil moisture balance was much less when computed on a daily basis and did not show as wide a range of variation as the monthly derived values. True soil moisture balance showed fluctuation similar to that shown by precipitation; however, since temperature was a variable also affecting soil moisture balance, there was some deviation of soil moisture balance from the curve followed by precipitation. The February-March period was the period of peak soil moisture with a sub-peak in July. The period of lowest moisture was October with a sub-minimum occurring in the May-June period.

V. GENERAL DISCUSSION

When evaluating and interpreting the data previously presented, three factors must be kept in mind which limit the use of the derived information as true elevational means. A climatic data collecting station should be in a location representative of the area which the data will describe (Conrad and Pollak, 1950). Because of changing vegetation, elevation, angle of slope, aspect, and other site factors, a myriad of microclimates is present (Rumney, 1968) in the mountains. To represent appropriately an area such as an elevational zone, a network of stations must be used to determine a "norm." From this network one or a few stations which are representative of the area will become permanent (Wilm, et al., 1939). In this way extreme values such as the effect of cold air drainage on a daily mean temperature (Geiger, 1965) or a rainshadow resulting from topographic variation (Corbett, 1967) average out to give a climatic value representative of the area of interest. In this study only one station was located at each altitude. Because of this, it was impossible to tell how much of the variation in the data was due to change in elevation and how much was due to microclimatic variation resulting from topographic diversity.

Geiger (1965) and Peattie (1936) described in detail the microclimatic variation that occurred from the north to south facing slopes. Depending on the angle of the slope, exposure related to nearby slopes, and aspect, the variation between the two slopes could be significant. The stations involved in this study were located on a mountain crest, on

north-facing slopes, and at the base of north-facing slopes. In view of this, the values that resulted from this study were not applicable to the general climatic characterization of the Great Smoky Mountains.

Thirdly, in many areas extreme values are more important than mean values in evaluating plant-environment relationships because of the tolerance limits for many species of plants (Daubenmire, 1968; Wang, 1963). Mean values hide or smooth over extremes so that areas with large ranges of climatic variables and resulting severe climates are considered similar to climates with smaller ranges but similar means.

Cloud cover is very important in the energy balance of any area (Pochop, et al., 1968). In an area with a high percentage of cloud cover, slope effects can be reduced by having received equal amounts of diffuse radiation on both the north- and south-facing slopes (Geiger, 1965) or by having diurnal temperature ranges reduced (Sellers, 1965). Because of the rapid change of cloud cover and its irregularities, standards set up by the International Meteorological Organization requiring a minimum of three observations per day, evenly distributed, must be met to obtain meaningful daily cloud cover values (Conrad and Pollak, 1950). The cloud cover data for this study were collected by visual observation once each day. Also the observations were made at a different time each day. Although the data did reflect altitudinal and seasonal trends, their primary usefulness lay in the indication of trends for which verification is needed.

Temperature normally decreases with an increase in elevation (Peattie, 1936; Geiger, 1965). This was evident from the data presented here. However, gradients could be modified by microclimatic effects

associated with topography. Monthly means, mean maxima, and mean minima generally decreased with altitude. The monthly mean minima, however, did not show the pronounced decrease with altitude that the mean and mean maximum temperatures did. This could probably be accounted for by cold air drainage from the higher elevations through the valley of the West Prong of the Little Pigeon River. The 3,850 ft. station was located in a narrow, steep-sided part of the valley where cold air drainage was probably significant. The 1,460 ft. station was also located in an area that would have received cold air drainage, but the effect was lessened by an outlet in the valley so that cold air pooling would not result. Geiger (1965) stated that cold air drainage may in fact cause low elevation stations to have colder minimum temperatures than higher stations. This was particularly in evidence in the lengths of time between the different threshold temperatures. The occurrence of a low threshold temperature was dependent on the last and first occurrence of the threshold temperature as a minimum. In this study the 6,300 ft. station showed length of time between threshold temperatures to have varied similarly to stations at lower elevations. The reason for this was probably the effect of cold air drainage on the lower elevation stations causing the last and first occurrence of the various threshold temperatures to occur later and earlier, respectively.

In the Rocky Mountains temperatures do not decrease with altitude on a straight line basis. As the elevation increases, the lapse rate becomes smaller (Daubenmire, 1956). The same was found to have been true in the Smokies. The lapse rate from the 1,460 ft. station to the 3,850 ft. station was greater than the lapse rate from the 1,460 ft.

station to the 5,000 ft. station. This indicated that each additional 1,000 ft. increase in elevation was accompanied by a smaller change in temperature than occurred in the previous 1,000 ft. The minimum lapse rate helped to show the effect of cold air drainage on minimum temperatures. The low minimum temperature lapse rate to all stations indicated that the lowest station may in some months have had a minimum temperature less than 4° F higher than the highest elevation station. Not only was the lapse rate different depending upon altitudinal range, but lapse rate was greater in the summer than in the winter. This indicated that in winter there was a moderating influence to reduce the effect of altitudinal change on temperature change.

With an increase in altitude the monthly temperature range decreases (Peattie, 1936). The temperature range date for this study showed this to be true in the Great Smoky Mountains. Temperature frequency tables showed that as altitude increased there was more concentration of temperatures into a smaller distribution range. This could be attributed to three factors:

1. A moderating effect on temperature by greater humidity at higher elevations.
2. A moderating effect on temperature by greater cloud cover at higher elevations.
3. The inability of the less dense atmosphere to gain and lose significant amounts of heat (Geiger, 1965).

Although there were microclimatic effects reflected in the temperature data, all elevational zones varied similarly through the year as the r^2 values in Table X, page 29, indicated. Even though the different

areas did not react exactly as would have been expected, the general temperature changes for all stations showed no signs of influence on any one station to cause its annual pattern of temperature to be significantly different from the pattern of adjoining stations, and as change occurred at the lowest station, a similar but smaller change occurred at the higher stations (Tanner, 1963).

Relative humidity is the percentage of the moisture needed to saturate the atmosphere which is actually present in the atmosphere (Anderson, 1936). Relative humidity in stable conditions varies inversely with air temperature (Foster, 1948). This could be seen in the hourly relative humidity data. As the hottest portion of the day approached, relative humidity dropped, and as the day began to cool, the relative humidity rose. This was subject to modification as a result of moist or dry winds. The relationship of relative humidity to temperature indicated that summer values should be lower than the winter ones, but such was not true in the Smokies. The relative humidity frequency tables show that relative humidity values were more concentrated toward the saturated end of the scale in the summer. In the colder months relative humidities were distributed over a broader range. In the summer the moisture capacity of the atmosphere is much greater than in the winter. The combination of high relative humidity and increased atmospheric moisture capacity indicated that there was a greater supply of moisture in summer than in the winter. This greater moisture supply might have been the result of increased evapotranspiration.

Daubenmire (1943) and Peattie (1936) stated that there is no

relation between relative humidity and elevation. This appeared to be untrue in this study. There was a general trend toward increasing monthly relative humidity means as altitude increased through the 5,000 ft. station. The 6,300 ft. station had relative humidity values similar in magnitude to the 1,460 ft. station. This was probably a microclimatic effect. The 6,300 ft. station was on an exposed peak without protection from the wind. The high wind movement across the peak probably lowered the relative humidity by transporting the atmospheric moisture away from the station to an area of a lower moisture concentration. The 5,000 ft. station was also subject to wind movement (Russell, 1953), but frequently clouds and moisture picked up from the valley below were funnelled through the gap. This kept relative humidities high at the 5,000 ft. station.

Vapor pressure deficit is a much better indicator of atmospheric moisture demand than relative humidity (Anderson, 1936; Kittredge, 1948) and is important in determining the magnitude of moisture stress in a plant (Shaw and Laing, 1965; Kozlowski, 1968; Weatherly, 1965; Slatyer, 1967). The altitudinal and seasonal variation in vapor pressure deficit was based on the combined relations of temperature and relative humidity. The 1,460 ft. station, which had the highest temperature and lowest relative humidity, had the highest vapor pressure deficit. The 6,300 ft. station had the second highest saturation deficit. Even though temperatures were lower at 6,300 ft., the relative humidity was also low enough so that a higher saturation deficit occurred than at the 3,850 ft. and 5,000 ft. stations. The 3,850 ft. station had the lowest vapor pressure deficit of the four stations. This resulted from the

combination of high relative humidity and cool temperatures. Conditions at this station might have been influenced by the data collecting site. Thick vegetation probably retarded the wind flow through the area and permitted atmospheric moisture build-up (Shanks, 1954).

Vapor pressure deficit also followed an annual trend. Deficits were largest in the summer months in spite of high relative humidities. This resulted from the higher temperatures which were accompanied by a higher moisture demand to reach saturation. In the winter when relative humidities were not as high as in summer, the saturation vapor pressure of the atmosphere was small enough so that the difference between vapor pressure and saturation vapor pressure was a smaller value than the corresponding value for summer.

Precipitation in the Great Smoky Mountains can generally be classified as either cyclonic or orographic (Donley and Mitchell, 1939; Dickson, 1959; Smallshaw, 1953). Orographic precipitation results from moist air being lifted into a cooler zone where condensation occurs to form droplets large enough to react to gravity and fall as rain (Burns, 1953; Elliot and Shaffer, 1962). This is characteristic of higher elevations. Cyclonic rainfall is associated with frontal systems. Elevation is not important in rainfall amounts unless a landform is high enough to interfere with the movement of a system (Foster, 1948). Both types of precipitation were common in the Smokies and each type probably brought about different results.

Precipitation normally increases with altitude until an altitude is reached at which the atmospheric moisture begins to diminish and

precipitation amounts decrease (Donley and Mitchell, 1939). The Smokies are not high enough in elevation so that there is a decrease in precipitation above a point of maximum precipitation. There was an exception to this which was probably a result of precipitation type and local topography. In the winter months the 5,000 ft. station had greater precipitation than the 6,300 ft. station. Winter precipitation was primarily of the cyclonic type. As the front approached the mountains, it might have been temporarily slowed or stopped by them. While the front was moving across the mountains, a compression in the draws leading to gaps might have occurred. As the front gained altitude, there was a certain amount of funnelling effect through these gaps and higher amounts of precipitation fell near the gaps than on nearby peaks. In the summer much of the precipitation was orographic, and the highest stations received the highest amounts. As a result the 6,300 ft. station had higher precipitation in the warmer months than did the 5,000 ft. station.

When considering the precipitation amounts of the 6,300 ft. and 5,000 ft. stations, it must be kept in mind that wind is an important factor in the measurement of true precipitation (Helmers, 1954; Corbett, 1967; Brown and Peck, 1962). The precipitation gauges used in this study were equipped with alter shields which helped to compensate for wind effect. However, the 5,000 ft. station, located in Newfound Gap, was associated with much air turbulence. This may have affected the winter precipitation amounts which were the highest among the four stations. The data collecting station at 6,300 ft. elevation was also in an exposed and windy site. This might have affected precipitation measurements.

Total precipitation was measured in this study. This was necessary to compare stations without corrections of amounts collected depending upon the possible sources of variation. In discussing plant habitats, effective rainfall might be more important than the total. Effective rainfall is the precipitation that reaches the soil. The difference between the total and effective rainfall is accounted for by interception, trapping, storing, and disposition of water without its reaching the litter (Zinke, 1967). Litter may also intercept appreciable amounts of moisture (Eschners, 1967). Rogerson and Byrnes (1968) stated that throughfall occurred only after .05 inches of precipitation in Pennsylvania hardwood forest and that only 80 per cent of the summer precipitation reached the soil. Slatyer (1967) reported a 25 per cent loss of rainfall due to interception by spruce and fir and a 7 per cent loss in beech. In considering the soil moisture regime of an area, all intercepted precipitation is not lost to the soil since soil moisture losses due to evapotranspiration are reduced as long as moisture is on the leaves. However, reductions in evapotranspiration do not equal the amount of moisture intercepted (Thorud, 1967). Comparisons among stations in this study could be made because of uniform precipitation sampling methods and equipment. Soil moisture calculations may be inaccurate because total rather than effective precipitation was used in the calculations.

The soil moisture balance showed an increase in soil moisture and a decrease in potential evapotranspiration with increasing altitude. The use of this method may result in criticism for several reasons,

although Fitzgerald and Rickard (1960) and Zahner (1955) found good agreement between computed and observed conditions using the Thornthwaite method. To the contrary, Daubenmire (1956) said that this method used mean climatic values when extremes might be of more importance in the plant environment. Dickson (1959) stated that in the Southern Appalachians evapotranspiration decreased with an increase in elevation, but Daubenmire (1968) said that evapotranspiration at 6,300 ft. was generally 2.5 times as high as at sea level because of reduced atmospheric pressure. Daubenmire (1943) also stated that because of other factors influencing evapotranspiration elevation was not a good predictor of soil moisture.

The Thornthwaite method uses only temperature, precipitation, and a correction factor for latitude to compute potential evapotranspiration and the soil moisture balance. Other researchers found other climatic variables to be significant in determining soil moisture relations. Knoerr (1961), Bethlahmy (1953), Kittredge (1948), Kucera (1954), and Neumann (1954) found vapor pressure deficit to be related to evapotranspiration. Johnston (1919), Kucera (1954), and Neumann (1954) found that the combination of vapor pressure deficit and wind gave a higher correlation with evapotranspiration. Johnston (1919) also found that as vapor pressure deficit decreased, wind became more important. To the contrary, Thornthwaite and Holzman (1939), Deacon (1958), and Budyko (1963) stated that vapor pressure deficit was unimportant in determining evapotranspirational rates. Evapotranspiration can still occur in an area of low vapor pressure deficit as moisture is removed from the area by wind or by diffusion (Budyko, 1963).

Instead of determining evapotranspiration from temperature or vapor pressure deficit data, Slatyer (1967), Foster (1948), and Budyko (1963) stated that evapotranspiration is determined by:

1. Energy used in evaporation and transpiration.
2. A water vapor gradient allowing diffusion from the surface of evaporation and transpiration.
3. Wind acting as the transporting agent.

Stearns and Carlson (1960) added soil and air temperature to energy, wind, and vapor pressure gradient and got a .84 value for R^2 using the multiple regression method. Nash (1963) found that vegetation characteristics were also to be added to the other climatic factors to get good agreement between observed and calculated soil moisture as a result of evapotranspiration.

If the assumption were made that vapor pressure deficit was a significant variable in determining evapotranspirational rates, then it would be necessary to revise the figures for the upper three stations in the Smokies to account for very low vapor pressure deficits and their effect. On the other hand, since wind was an important transport mechanism of water vapor, it required a raising of evapotranspirational rates at the 5,000 ft. and 6,300 ft. stations because of the windy nature of the environment. From this discussion it could be seen that the potential evapotranspiration and soil moisture balance values obtained in this study were primarily important as values which integrated available climatic variables, temperature and precipitation, to give comparable composite values for the four stations rather than true soil moisture data.

Associated with the soil moisture balance is moisture stress on a plant. Moisture stress occurs when water loss due to transpiration is greater than water gain due to absorption (Zahner and Stage, 1966; Kozlowski, 1968; Weatherly, 1965). This condition can occur when soil moisture is low and does not move to the roots (area of lowest soil moisture content) fast enough to keep up with the rate of absorption. Moisture stress can also occur in well watered soils because of very high transpiration rates due to a high atmospheric moisture saturation deficit (Shaw and Laing, 1965; Kozlowski, 1968).

If the assumption were made that the soil moisture values computed in this study were useful in evaluating the moisture balance of the Smokies, there was agreement with Helvey and Hewlett (1962). They stated that in the high rainfall region of the Southern Appalachians, soil moisture was seldom, if ever, low enough to be limiting to the vegetation. Patric, et al., (1965) and Zahner (1967) stated that in humid forest regions the shallow root zone was frequently supplied with precipitation. Data from this study verified that rainfall was distributed evenly among the stations and at frequent intervals in the Smokies. The combination of high soil moisture, frequent wetting of the surface horizons, and low vapor pressure deficits suggested that moisture stress was infrequent at the three upper stations in the Smokies and might be of no consequence to the vegetation.

Much climatic research remains to be done in order to verify or deny the implications of this study. The high elevations of the Great Smoky Mountains provide a unique area of study into evapotranspiration. According to some authors, evapotranspiration should be high because of

low atmospheric pressure and high wind, and others suggest it should be an area of low evapotranspiration because of low vapor pressure deficits and low temperatures. The true value probably lies in the integration of these different climatic variables.

According to Fowells (1965) most of the tree species in the Great Smoky Mountain National Park occur in other areas characterized by greater climatic extremes than occurred in the period involved in this study. This leads the plant ecologist to question the validity of microclimate as a sole parameter in the distribution of vegetation. Actually climate is a factor in an integration of variables such as soil, history, slope, aspect, parent material, etc., which determines the range of a species. In the Smokies a group of species such as cove hardwoods may correlate well with a group of climatic factors, but since those species are not the only ones occurring in that climatic zone, other limiting factors must be sought to help in the definition of species range. The integration of these interrelating factors is a complex problem which the ecologist is attempting to achieve.

VI. SUMMARY

Between January 1, 1947, and December 31, 1950, hourly temperature and relative humidity and daily precipitation and cloud cover data were collected at the 1,460 ft., 3,850 ft., 5,000 ft., and 6,300 ft. elevations in the Great Smoky Mountains National Park. These four years were part of a period of data collection extending from January, 1946, through March, 1951. These data were processed by a digital electronic computer, IBM 7040, under the control of data summary and potential evapotranspiration programs. Selected statistical tests were employed to compare the similarity of variation in some monthly mean values or to determine the degree of variation between some of the climatic elements.

The findings showed that cloud cover increased with elevation and decreased in the warmer part of the year. Temperature decreased with elevation at a curvilinear rate. As altitude increased, the decrease in temperature per 1,000 ft. decreased. Lapse rate increased from a minimum in December-January to a maximum in July. Relative humidity also increased with altitude, except that microclimatic influences were strongly reflected in these data. Wind probably reduced the relative humidity at the 6,300 ft. elevation and lack of wind allowed atmospheric moisture build-up. Distribution of relative humidity had greater range in colder months than in the summer. Vapor pressure deficit decreased with elevation; however, the difference among the means of the three highest stations was small, reflecting the difference in

temperature and relative humidity at the different elevations. Precipitation increased with an increase in elevation; however, the two highest stations showed the results of microclimate and precipitation type on amounts collected. The 5,000 ft. station had the highest precipitation in the winter when precipitation was predominantly cyclonic. The 6,300 ft. station had the highest rainfall in the summer when much of the high-elevation precipitation was orographic.

Soil moisture balance, calculated by the Thornthwaite method, reflected only the variation in temperature and precipitation. When the assumptions were made that rooting depth was 6 feet and field capacity was 12.00 inches of water, soil moisture content increased and evapotranspiration decreased with an increase in altitude. Many other research workers have stated that these two climatic elements are not sufficient to calculate water balance and other factors were suggested for use in making such calculations.

The use of climate alone as the parameter for defining species distribution in the Smokies has been omitted because species ranges reflect a complex of environmental factors beyond those analyzed here.

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APPENDIXES

APPENDIX A

DATA SUMMARY PROGRAM

```
      INTEGER MMTR, MMRR, MRRN, TMN6, TSUM, RSUM, RMAX, RMIN
      INTEGER RMN, RRNG, TSM6, RMN2, RSM6, STAT, DATA, DATE
      INTEGER VP, VPD, TMAX, TMIN, TMN, TRNG, TMN2, RMN6
      INTEGER WTMA, WTMI, WTMN, STMN, WTM2, STM2, WTM6, STM6
      INTEGER WRMI, WRMA, WRMN, SRMN, WRM2, SRM2, WRM6, SRM6
      INTEGER WTRN, WRRN, WTMX, STMX, WTMM, STMM, WRMX, SRMX
      INTEGER WRMM, SRMM, PREC, WPRE, WVPD, SVPD, FTEQ, FREQ
      INTEGER DAY, DAYS, MONT, YR, MTMI, MTMX, MRMI, MRMX
      INTEGER MMTX, MMTI, MTMN, MTM2, MTM2, MMRX, MMRI, MRMN
      INTEGER MRM2, MRM6, MVPD, MPRE, JP
      DIMENSION FTEQ(22), FREQ(21), DATA(48), VP(101)
      J=8
   80 READ 81, (VP(K),K=1,100)
   81 FORMAT (26I3/26I3/25I3/25I3)
  136 YR=0
  137 YR= YR+1
   95 MONT=0
  106 MONT=MONT+1
   84 IF( MONT .EQ. 1) DAYS=31
      IF(MONT  . EQ. 2) DAYS=28
      IF(MONT .EQ. 3) DAYS=31
```

```
      IF(MONT .EQ. 4) DAYS=30
      IF(MONT .EQ. 5) DAYS=31
      IF(MONT .EQ. 6) DAYS=30
      IF(MONT .EQ. 7) DAYS=31
      IF(MONT .EQ. 8) DAYS=31
      IF(MONT .EQ. 9) DAYS=30
      IF(MONT .EQ. 10) DAYS=31
      IF(MONT .EQ. 11) DAYS=30
      IF(MONT .EQ. 12) DAYS=31
   76 DO 77 N=1,22
   77 FTEQ(N)=0
   78 DO 79 M=1,21
   79 FREQ(M)=0
   96 DAY=0
      IF(J .LT. 8) GO TO 107
   30 PRINT 31
   31 FORMAT (1H , 6H DATE , 4HSTAT, 5H TMAX, 5H TMIN, 5H TRNG, 5H TMN ,
     1 5H TMN2, 5H TMN6, 5H RMAX, 5H RMIN, 5H RRNG, 5H RMN , 5H RMN2,
     2 5H RMN6, 5H PREC, 5H VPD)
      J=1
  107 DAY=DAY+1
   10 READ 11, (DATA(I),I=1,48)
   11 FORMAT (6X, (24I3/6X, 24I3), 2X)
      TMAX=0
      TMIN=0
```

```
      TRNG=0
      TMN=0
      TSUM=0
      TSM6=0
      TMN6=0
      RMAX=0
      RMIN=0
      RRNG=0
      RMN=0
      RSUM=0
      RMN2=0
      RSM6=0
      RMN6=0
    1 DO 2 I=1,48
    2 DATA(I)=DATA(I)*10
      TMIN=DATA(1)
      RMIN=DATA(2)
      DO 14 I=1,47,2
   12 IF(TMAX .LE. DATA(I)) TMAX=DATA(I)
   13 IF(TMIN . GE. DATA(I)) TMIN=DATA(I)
  150 IF(DATA(I) .LT. 0) GO TO 154
  151 IF(DATA(I) .GE. 1000) GO TO 156
  152 N=(DATA(I)/50)+2
  153 GO TO 158
  154 N=1
```

```
155 GO TO 158
156 N=22
157 GO TO 158
158 FTEQ(N)=FTEQ(N)+1
 14 TSUM=TSUM+DATA(I)
 15 TRNG=TMAX-TMIN
 16 TMN=TSUM/240
 17 TMN2=(TMAX+TMIN)/20
    DO 20 I=2,48,2
 18 IF(RMAX .LE. DATA(I)) RMAX=DATA(I)
 19 IF(RMIN .GE. DATA(I)) RMIN=DATA(I)
 68 M=(DATA(I)/50)+1
 69 FREQ(M)=FREQ(M)+1
 20 RSUM=RSUM+DATA(I)
 21 RRNG=RMAX-RMIN
 22 RMN=RSUM/240
 23 RMN2=(RMAX+RMIN)/20
 24 DO 25 I=1,41,8
 25 TSM6=TSM6+DATA(I)
 29 TMN6=TSM6/60
 26 DO 27 I=2,42,8
 27 RSM6=RSM6+DATA(I)
 28 RMN6=RSM6/60
 36 READ 37, DATE, STAT, PREC
 37 FORMAT (I6, I1, I4)
```

```
141 IF(PREC .EQ. 2000) PREC=0000
    IF(PREC .EQ. 3000) PREC=0000
 85 IF(TMN-0) 86, 87, 87
 86 K=1
    GO TO 90
 87 K=TMN
 88 IF(100-RMN) 89, 89, 90
 89 VPD=0
    GO TO 3
 90 VPD=(100-RMN)*VP(K)
  3 TMAX=TMAX/10
  4 TMIN=TMIN/10
  5 TRNG=TRNG/10
  6 RMAX=RMAX/10
  7 RMIN=RMIN/10
  8 RRNG=RRNG/10
  9 VPD=VPD/10
 71 IF(J .EQ. 1) GO TO 73
 72 IF(J .GT. 1) GO TO 39
 73 WTMA=0
    WTMI=0
    WTM2=0
    WTM6=0
    WRMI=0
    WRMA=0
```

```
      WRMN=0
      WRM2=0
      WRM6=0
      WTRN=0
      WRRN=0
      WTMX=0
      WRMX=0
      WRMM=0
      WPRE=0
      WVPD=0
      WTMM=0
      WTMN=0
      STMN=0
      STM2=0
      STM6=0
      SRMN=0
      SRM2=0
      SRM6=0
      STMX=0
      STMM=0
      SRMX=0
      SVPD=0
   75 SRMM=0
   39 IF(DAY .EQ. 1) GO TO 82
      IF(DAY .GT. 1) GO TO 123
```

```
 82 MTMI=0
    MTMX=0
    MRMI=0
    MMTX=0
    MMTI=0
    MMRX=0
    MMRI=0
    MTRN=0
    MRRN=0
    MTMN=0
    MTM2=0
    MTM6=0
    MRMN=0
    MRM6=0
    MRM2=0
    MVPD=0
    MPRE=0
    MRMX=0
    MMTR=0
    MMRR=0
123 IF(J .EQ. 1) GO TO 58
124 IF(J .GT. 1) GO TO 50
 58 WTMI=TMIN
 60 WRMI=RMIN
 50 IF(WTMA .LE. TMAX) WTMA=TMAX
```

```
51 IF(WTMI .GE. TMIN) WTMI=TMIN
61 IF(WRMA .LE. RMAX) WRMA=RMAX
62 IF(WRMI .GE. RMIN) WRMI=RMIN
40 STMX=STMX+TMAX
41 STMM=STMM+TMIN
42 STMN=STMN+TMN
43 STM2=STM2+TMN2
44 STM6=STM6+TMN6
45 SRMX=SRMX+RMAX
46 SRMM=SRMM+RMIN
47 SRMN=SRMN+RMN
48 SRM2-SRM2+RMN2
49 SRM6=SRM6+RMN6
91 WPRE=WPRE+PREC
92 SVPD=SVPD+VPD
   IF(DAY .EQ. 1) GO TO 57
   IF(DAY .GT. 1) GO TO 59
57 MTMI=TMIN
   MRMX=RMAX
   MRMI=RMIN
   MTMX=TMAX
59 IF(MTMI .GT. TMIN) MTMI=TMIN
   IF(MTMX .LT. TMAX) MTMX=TMAX
   IF(MRMI .GT. RMIN) MRMI=RMIN
   IF(MRMX .LT. RMAX) MRMX=RMAX
```

```
74 MMTX=MMTX+TMAX
   MMTI-MMTI+TMIN
   MTMN=MTMN+TMN
   MTM2=MTM2+TMN2
   MTM6=MTM6+TMN6
   MMRX=MMRX+RMAX
   MMRI=MMRI+RMIN
   MRM2=MRM2+RMN2
   MRM6=MRM6+RMN6
   MVPD=MVPD+VPD
   MPRE=MPRE+PREC
   MMTR=MMTR+TRNG
   MMRR=MMRR+RRNG
   MRMN=MRMN+RMN
32 PUNCH 33, DATE, STAT, TMAX, TMIN, TRNG, TMN2, TMN6,  RMAX, RMIN, RMN,
  1  RRNG, RMN2, RMN6, PREC, VPD
33 FORMAT (I6, I1, 14I4)
34 PRINT 35, DATE, STAT, TMAX, TMIN, TRNG, TMN, TMN2,  TMN6, RMAX, RMIN,
  1  RRNG, RMN, RMN2, RMN6, PREC, VPD
35 FORMAT (1H , I6, 2X, I1, I6, 13I5)
   J=J+1
142 IF(J .EQ. 8) GO TO 99
   IF(J .LT. 8 .AND. DAY .LT. DAYS) GO TO 107
   IF(J .LT. 8 .AND. DAY .EQ. DAYS) GO TO 83
99 WTRN=WTMA-WTMI
```

```
100 WRRN=WRMA-WRMI
 93 WVPD=SVPD/7
 52 WTMX=STMX/7
 53 WTMM=STMM/7
 54 WTMN=STMN/7
 55 WTM2=STM2/7
 56 WTM6=STM6/7
 63 WRMX=SRMX/7
 64 WRMM=SRMM/7
 65 WRMN=SRMN/7
 66 WRM2=SRM2/7
 67 WRM6=SRM6/7
 97 PRINT 98
 98 FORMAT (1H , 5H WTMA, 5H WTMI, 5H WTRN, 5H WTMX, 5H WTMM,  5H WTMN,
   1  5H WTM2, 5H WTM6, 5H WRMA, 5H WRMI, 5H WRRN,  5H WRMX, 5H WRMM,
   2  5H WRMN, 5H WRM2, 5H WRM6, 5H WPRE,  5H WVPD)
120 PRINT 121, WTMA, WTMI, WTRN, WTMX, WTMM, WTMN, WTM2,  WTM6, WRMA,
   1  WRMI, WRRN, WRMX, WRMM, WRMN, WRM2, WRM6,  WPRE, WVPD
121 FORMAT (18I5)
    IF(DAY .LT. DAYS) GO TO 30
 83 MMTX=MMTX/DAYS
    MMTI=MMTI/DAYS
    MTMN=MTMN/DAYS
    MTM2=MTM2/DAYS
    MTM6=MTM6/DAYS
```

```
      MMRX=MMRX/DAYS
      MMRI=MMRI/DAYS
      MRMN=MRMN/DAYS
      MRM2=MRM2/DAYS
      MRM6=MRM6/DAYS
      MVPD=MVPD/DAYS
      MMTR=MMTR/DAYS
      MMRR=MMRR/DAYS
      MTRN=MTMX-MTMI
      MRRN=MRMX-MRMI
  101 CONTINUE
  129 PRINT 133
  133 FORMAT (1H , 5H MTMX, 5H MTMI, 5H MRMX, 5H MRMI, 5H MMTI, 5H MMTX,
     1 5H MMRX, 5H MMRI, 5H MMTR, 5H MMRR, 5H MTMN, 5H MTM2, 5H MTM6,
     2 5H MRMN, 5H MRM6, 5H MRM2, 5H MVPD, 5H MTRN, 5H MRRN, 5H MPRE)
  134 PRINT 135, MTMX, MTMI, MRMX, MRMI, MMTI, MMTX, MMRX, MMRI, MMTR,
     1 MMRR, MTMN, MTM2, MTM6, MRMN, MRM6, MRM2, MVPD, MTRN, MRRN, MPRE
  135 FORMAT (1H , 20I5)
  161 PRINT 162
  162 FORMAT (4HFT1 , 4HFT2 , 4HFT3 , 4HFT4 , 4HFT5 , 4HFT6 , 4HFT7 ,
     1 4HFT8 , 4HFT9 , 4HFT10, 4HFT11, 4HFT12, 4HFT13, 4HFT14, 4HFT15,
     2 4HFT16, 4HFT17, 4HFT18, 4HFT19, 4HFT20, 4HFT21, 4HFT22)
  163 PRINT 164, (FTEQ(N), N=1,22)
  164 FORMAT (22I4)
  165 PRINT 166
```

```
166 FORMAT (4HFR1 , 4HFR2 , 4HFR3 , 4HFR4 , 4HFR5 , 4HFR6 ,  4HFR7 ,
   1  4HFR8 , 4HFR9 , 4HFR10, 4HFR11, 4HFR12, 4HFR13,  4HFR14, 4HFR15,
   2  4HFR16, 4HFR17, 4HFR18, 4HFR19, 4HFR20,  4HFR21)
167 PRINT 168, (FREQ(M), M=1,21)
168 FORMAT (21I4)
138 IF(MONT .EQ. 12 .AND. YR .LT. 3) GO TO 137
139 IF(MONT .EQ. 12 .AND. YR .EQ. 3) GO TO 105
160 CONTINUE
    GO TO 106
105 CONTINUE
    CALL EXIT
    END
```

APPENDIX B

POTENTIAL EVAPOTRANSPIRATION PROGRAM

```
      INTEGER IND, UDPE, CF, UADP, SMRT, DATE STAT, T, P
      INTEGER DIN, YIN, DPE, PMPE, ACT, STC, MOD, MOS, TERM
      INTEGER GRWS, AGW, SMB, MONT, DAY, YR, DAYS,
      DIMENSION LLM(365), LIM(365), KLM(365), IND(68),
      DIMENSION UDPE(24,47), CF(365), UADP(20), SMRT(500)
      DIMENSION DATE(365), STAT(365), T(365), P(365), DIN(365)
      DIMENSION DPE(365), PMPE(365), ACT(365), STC(365)
      DIMENSION MOD(365), MOS(365), GRWS(365), AGW(365)
      DIMENSION SMB(365)
    1 READ 2,(IND(J), J=1,68)
    2 FORMAT (17I4/17I4/17I4/17I4)
    3 READ 4, ((UDPE(K,L), K=1,24), L=1,47)
    4 FORMAT (24I2)
    5 READ 6, (CF(I), I=1,365)
    6 FORMAT (26I3/26I3/26I3/26I3/26I3/26I3/26I3/26I3/26I3/26I3/26I3/
     1  26I3/26I3/26I3/26I3/26I3)
    7 READ 8, (UADP(N), N=1,20)
    8 FORMAT (20I2)
    9 READ 10, (SMRT(M), M=1,500)
   10 FORMAT (20I4/20I4/20I4/20I4/20I4/20I4/20I4/20I4/20I4/ 20I4/20I4/
     1  20I4/20I4/20I4/20I4/20I4/20I4/20I4/20I4/20I4/ 20I4/20I4/20I4/
     2  20I4/20I4)
```

```
92 YR=YR+1
11 YIN=0
36 M=1
12 DO 13 I=1,365
13 READ 14,DATE(I), STAT(I), T(I), P(I)
14 FORMAT (I6, I1, 8X,I4, 36X, I4)
15 DO 19 I=1,365
16 IF(T(I) .LT. 33) J=1
17 IF(T(I) .GE. 33) J=T(I)-31
18 DIN(I)=IND(J)
19 YIN=YIN+DIN(I)
20 YIN=YIN/30
33 DO 35 I=1,365
22 IF(T(I) .LT. 34) GO TO 27
23 IF(T(I) .GE. 34 .AND. T(I) .LT. 81) GO TO 29
24 IF(T(I) .GE. 81) N=T(I)-80
25 DPE(I)=UADP(N)
26 GO TO 32
27 DPE(J)=0000
28 GO TO 32
29 K=((YIN-2500)/250)+1
30 L=T(I)-33
34 DPE(I)=UDPE(K,L)*CF(I)
32 CONTINUE
   IF(T(I).LT. 34) LIM(I)=0
```

```
      IF(T(I) .LT. 34) LIM(I)=0
      IF(T(I) .GE. 81) LIM(I)=UADP(N)
      IF(T(I) .GE. 34 .AND. T(I) .LT. 81) LIM(I)=UDPE(K,L)
86    P(I)=P(I)*100
      PMPE(I)=P(I)-DPE(I)
      IF(PMPE(I) .GE. 50 .AND. PMPE(I) .LE. 100) PMPE(I)=100
35    CONTINUE
37    DO 90 I=1,365
      LM=0
      LM=LM-PMPE(I)
      LM=LM/100
      LLM(I)=LM
      M=M-LM
39    IF(M .LT. 1) M=1
      KLM(I)=M
40    ACT(I)=SMRT(M)
71    IF(I .EQ. 1) GO TO 72
41    STC(I)=ACT(I)-ACT(I-1)
73    GO TO 42
72    STC(I)=0
42    IF(PMPE(I) .LT. 0) GO TO 45
43    IF(PMPE(I) .GT. 0) GO TO 48
44    IF(PMPE(I) .EQ. 0) GO TO 56
45    MOD(I)=(PMPE(I)/100)-STC(I)
46    MOS(I)=0
47    GO TO 58
```

```
 48 TERM=PMPE(I)+ACT(I)
 49 IF(TERM .GT. 1200) GO TO 53
 50 MOD(I)=0
 51 MOS(I)=0
 52 GO TO 58
 53 MOS(I)=TERM=1200
 54 MOD(I)=0
 55 GO TO 58
 56 MOS(I)=0
 57 MOD(I)=0
 58 IF(MOS(I) .GE. 50 .AND. MOS(I) .LE. 100) MOS(I)=100
    MOS(I)=MOS(I)/100
 90 CONTINUE
120 PRINT 121, YIN
121 FORMAT (1H, I10)
 59 DO 66 I=1,365
 60 IF(I .EQ. 1) GO TO 63
 61 AGW(I)=MOS(I)
 62 GO TO 65
 63 AGW(I)=MOS(I)
 64 GO TO 65
 65 GRWS(I)=(AGW(I)*9)/10
 66 SMB(I)=ACT(I)+GRWS(I)
    DO 85 I=1,365
    P(I)=P(I)/100
 83 PRINT 84, DATE(I), STAT(I), T(I), DIN(I), CF(I), LIM(I), DPE(I),
```

```
      1 P(I), PMPE(I), ACT(I), STC(I), MOD(I), MOS(I),  AGW(I), GRWS(I),
      2 SMB(I), KLM(I), LLM(I)
   84 FORMAT (1H , 18I6)
   85 CONTINUE
  105 MONT=0
  104 MONT=MONT+1
      IF(YR .LT. 8) GO TO 131
      IF(YR .EQ. 8) GO TO 132
  131 IF(MONT .EQ. 1 .OR. MONT .EQ. 3) DAY=31
      IF(MONT .EQ. 2) DAY=28
      IF(MONT .EQ. 4 .OR. MONT .EQ. 6) DAY=30
      IF(MONT .EQ. 5 .OR. MONT .EQ. 7) DAY=31
      IF(MONT .EQ. 8 .OR. MONT .EQ. 10) DAY=31
      IF(MONT .EQ. 9 .OR. MONT .EQ. 11) DAY=30
      IF (MONT .EQ. 12) DAY=31
  133 GO TO 130
  132 IF(MONT .EQ. 1 .OR. MONT .EQ. 2) DAY=31
      IF(MONT .EQ. 3 .OR. MONT .EQ. 5) DAY=30
      IF(MONT .EQ. 4 .OR. MONT .EQ. 6) DAY=31
      IF(MONT .EQ. 7 .OR. MONT .EQ. 9) DAY=31
      IF(MONT .EQ. 8 .OR. MONT .EQ. 10) DAY=30
      IF(MONT .EQ. 11) DAY=31
  130 IF(MONT .EQ. 1) GO TO 122
      IF(MONT .GT. 1) GO TO 125
  122 KAP=1
```

```
123 LOT=31
    GO TO 127
125 KAP=LOT+1
126 LOT=LOT+DAY
127 MACT=0
    MSTC=0
    MT=0
    MSMB=0
    MGRW=0
    MAGW=0
    MP=0
    MMOD=0
    MMOS=0
    MPE=0
    MPMP=0
    DO 110 I=KAP,LOT
    MT=MT+T(I)
    MPE=MPE+DPE(I)
    MP=MP+P(I)
    MPMP=MPMP+PMPE(I)
    MACT=MACT+ACT(I)
    MMOD=MMOD+MOD(I)
    MMOS=MMOS+MOS(I)
    MSTC=MSTC+STC(I)
    MAGW=MAGW+AGW(I)
    MGRW=MGRW+GRWS(I)
```

```
100 MSMB=MSMB+SMB(I)
110 CONTINUE
    MSTC=MSTC/DAY
    MACT=MACT/DAY
    MT=MT/DAY
    MSMB=MSMB/DAY
    MGRW=MGRW/DAY
    MAGW=MAGW/DAY
101 PRINT 102, MT, MPE, MP, MPMP, MACT, MSTC, MMOD, MMOS,  MAGW, MGRW,
   1  MSMB
102 FORMAT (1H , 11I6)
    IF(MONT .LT. 12) GO TO 104
    IF(MONT .EQ. 12) GO TO 103
103 CONTINUE
    IF(YR .EQ. 8) GO TO 91
    IF(YR .LT. 8) GO TO 92
 91 CONTINUE
    CALL EXIT
    END
```

APPENDIX C

TABLE XL

MONTHLY MEAN TEMPERATURES (DEGREES F) CALCULATED FROM 24-HOURLY VALUES, DAILY MAXIMUM AND MINIMUM, AND 4-HOUR INTERVAL VALUES AT THE 1,460 FT. STATION FOR 1947-1950

Month	24-Hour Mean	Max-Min Mean	4-Hour Interval Mean
Jan.	42.7	43.5	42.7
Feb.	40.0	40.5	40.0
Mar.	45.2	45.7	45.0
Apr.	55.5	54.0	54.7
May	63.5	63.7	63.5
June	69.7	70.5	69.7
July	71.7	73.2	72.0
Aug.	70.0	71.7	70.2
Sept.	63.5	65.2	64.0
Oct.	55.7	58.0	56.0
Nov.	42.0	43.0	42.0
Dec.	37.0	38.0	36.7

TABLE XLI

MONTHLY MEAN TEMPERATURES (DEGREES F) CALCULATED FROM 24-HOURLY VALUES, DAILY MAXIMUM AND MINIMUM, AND 4-HOUR INTERVAL VALUES AT THE 3,850 FT. STATION FOR 1947-1950

Month	24-Hour Mean	Max-Min Mean	4-Hour Interval Mean
Jan.	37.0	37.7	47.2
Feb.	33.2	34.5	33.2
Mar.	36.7	39.0	37.7
Apr.	47.7	49.0	47.7
May	54.7	56.5	55.2
June	61.0	62.0	61.2
July	62.5	63.7	62.5
Aug.	61.7	62.7	62.0
Sept.	56.2	57.5	56.7
Oct.	49.2	51.0	49.5
Nov.	36.2	37.2	36.2
Dec.	32.0	32.7	32.0

TABLE XLII

MONTHLY MEAN TEMPERATURES (DEGREES F) CALCULATED FROM 24-HOURLY VALUES, DAILY MAXIMUM AND MINIMUM, AND 4-HOUR INTERVAL VALUES AT THE 5,000 FT. STATION FOR 1947-1950

Month	24-Hour Mean	Max-Min Mean	4-Hour Interval Mean
Jan.	35.0	35.2	35.0
Feb.	30.7	31.7	30.7
Mar.	33.5	34.2	33.7
Apr.	44.0	45.2	44.2
May	52.5	54.2	54.7
June	57.0	61.0	58.5
July	57.2	61.2	59.5
Aug.	57.0	61.0	58.7
Sept.	53.7	55.7	53.7
Oct.	48.5	50.5	48.5
Nov.	34.7	35.5	35.0
Dec.	31.2	31.5	31.2

TABLE XLIII

MONTHLY MEAN TEMPERATURES (DEGREES F) CALCULATED FROM 24-HOURLY VALUES, DAILY MAXIMUM AND MINIMUM, AND 4-HOUR INTERVAL VALUES AT THE 6,300 FT. STATION FOR 1947-1950

Month	24-Hour Mean	Max-Min Mean	4-Hour Interval Mean
Jan.	33.2	32.5	32.2
Feb.	28.7	29.5	28.7
Mar.	32.3	33.0	32.6
Apr.	40.5	41.0	40.5
May	49.2	50.2	49.2
June	55.0	56.5	55.0
July	56.5	58.0	56.7
Aug.	56.0	58.0	56.2
Sept.	51.5	53.5	52.0
Oct.	46.7	48.5	46.5
Nov.	34.0	35.0	34.5
Dec.	30.5	31.0	30.5

VITA

The author was born on July 4, 1940 in Chattanooga, Tennessee. In January, 1945, he moved to Oak Ridge, Tennessee, where the first nine years of his education were completed in the Oak Ridge City Schools. In October, 1955, the author moved to Knoxville, Tennessee, and completed his secondary education in the Knox County Schools. The author attended The University of Tennessee, Knoxville, Tennessee, from September, 1958, to June, 1960, and Maryville College, Maryville, Tennessee, from September, 1960, to June, 1961. In October, 1961, the author became an employee of Union Carbide Corp., Nuclear Div., Oak Ridge, Tennessee. In September, 1964, he returned to The University of Tennessee and received the Bachelor of Science Degree in December, 1965. Again, the author became an employee of Union Carbide Corp., Nuclear Div., at Oak Ridge as a mechanical draftsman. In January, 1967, he began part-time work toward the Master of Science Degree in Botany at The University of Tennessee, while continuing as an employee of Union Carbide Corp.