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VARIATIONS IN MONTHLY PRECIPITATION OVER NORTH CAROLINA

by

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A revised version of Variations in Monthly Precipitation over North Carolina by Walter J. Saucier, Professor of Meteorology, North Carolina State University, Raleigh

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This research was carried out at North Carolina State University, Raleigh, North Carolina, in the Department of Marine, Earth and Atmospheric Sciences, School of Physical and Mathematical Sciences, with the assistance of the Geography Department, University of North Carolina, Chapel Hill.

INTRODUCTION

In 1973 the Water Resources Research Institute of The University of North Carolina published a technical report entitled "Precipitation Variability Over North Carolina". The authors were W. J. Saucier, A. H. Weber, and C. K. Bayne. One of the most useful features of this report was the maps showing the spatial distribution of mean monthly precipitation and variance across North Carolina. Unfortunately, because of the technical nature of this report, these maps have not been readily available to the public. Consequently, this revised version of that report was prepared with two major objectives in mind. First, the precipitation maps would be updated to reflect the new 1951-1980 normal period. Second, the report would be put in a form that would make it useful for both the general public and technicians in arriving at precipitation-related climatic decisions. The publication has purposely been kept short so that a large number of copies could be produced and distributed.

In this revised report the spatial and temporal variability of precipitation over North Carolina is examined through a statistical analysis of monthly normal precipitation data. Tables and maps derived from these data provide monthly precipitation means and standard deviations for 85 locations in North Carolina.

This revised version contains only a small portion of the total material available in the original report; consequently, the original report should be consulted if more detailed information is required. In addition, the Office of the State Climatologist, housed on the North Carolina State University campus, maintains an extensive collection of North Carolina climate data and should be consulted for additional information on the climate of the state.

DATA RESOURCES

Daily and total monthly precipitation data are published by the U.S. National Climatic Center in monthly publications entitled Climatological Data. An annual summary listing monthly precipitation as well as annual totals is also published as issue No. 13 in each volume. These data, as well as certain other hydrological information, were made available on the university computer system by the Water Resources Research Institute of The University of North Carolina in the Hydrological Information Storage and Retrieval System (HISARS) through the year 1980. This system provided convenient access to the data that were required for this study.

A total of 85 stations in North Carolina have complete or near complete data for the 30-year period 1951-1980. These data were used to analyze the precipitation variability over the state. Appendix A provides a listing of the stations that were used, along with the stations' latitude, longitude, elevation and the county in which the station is located. A station location map is also provided in Appendix B.

CAUSES OF NORTH CAROLINA PRECIPITATION

The spatial and temporal distribution of precipitation over North Carolina is partially controlled by the geographic position of the state relative to the global atmospheric circulation system. Superimposed on this system are physiographic controls imposed by the Appalachian Mountains in the western part of the state and the Atlantic Ocean to the east. The resulting precipitation patterns are quite complex. This section outlines, in a simplified form, the way in which the controls work, which hopefully will be useful conceptually in analyzing the temporal and spatial variations of precipitation over North Carolina.

The annual course of precipitation may be thought of as having two major components, A and B. The first, A, has a summer maximum and a winter minimum in precipitation. The annual cycle is dictated by the annual course of temperature, which in turn is tied directly to the annual course of the sun. The temperatures over land are usually lowest in January and highest in July, while ocean temperatures generally lag a month or two behind and exhibit a smaller annual range. Both the capacity of air to hold water and the rate of conversion of water vapor to precipitation within the atmosphere are controlled by temperature. Increasing the air temperature by 10°C (18°F) approximately doubles the capacity of air to hold water vapor. With saturated air and otherwise equal mechanisms producing rain, the rainfall rate is also roughly doubled as the temperature increases by 10°C. Furthermore, the tendency is for land temperatures to be warmer than the atmosphere in summer and cooler than the air in winter. As a result, we find that there is an annual cycle in convection which favors showers in the summer compared to winter. This simple seasonal trend is delayed near the coastline because of the modifying effects of the ocean. In the mountains, topographically forced uplifting of the air enhances summer convective showers, but reduces them over adjacent lower terrain, where compensating subsidence occurs. Finally, the annual course in temperature aloft lags behind that of the surface, leading to a higher frequency of convective showers in the spring than in fall because of stability factors.

These thermal controls exercised by the surface on water vapor capacity and convection lead to a simple annual cycle of precipitation much in phase with the temperatures: summer maximum, winter minimum, with spring convective showers more frequent than fall showers. This cycle is quite regular; it exhibits a dependable annual course and is the dominant component of the observed precipitation cycle over most of the state. If this component alone determined the annual course, the precipitation patterns would be rather simple. However, a second, more complex component also needs to be examined.

Superimposed upon component A, we find a second component, B, which adds to or subtracts from the first component by contributing its own precipitation patterns. This component involves the hemispheric system of atmospheric circulation, or more specifically, the broadscale patterns of upward and downward movements within the atmosphere which, by their geographic placements, give alternating rainy and fair weather. This component is more mechanical than thermal in nature, although it too is related ultimately to the annual cycle of the sun. Precipitation is derived mainly from cyclonic storms; consequently, storm frequencies and storm paths determine the the day-to-day and year-to-year variations. Such interannual variability makes one year's weather more or less different from the next. It is this component of the precipitation cycle which holds the major elements of variablity and unpredictability.

In the geographic setting of North Carolina, this second component, B, in the annual precipitation cycle may be viewed as being composed of two rather than one cycle per year. One of its precipitation-producing peaks is centered in February and the other about six months later, in August. Its minima in average precipitation occur at intermediate times, around May-June and October-November. The two cycles are not necessarily symmetrical or equal in length.

The spring and autumn minima in rainfall so characteristic of North Carolina, along with the winter and summer peaks situated between them in component B, are intimately related to the broadscale features in the pattern of global atmospheric circulation which shift erratically northward and southward in an annual cycle. These broadscale features are represented by three belts: the precipitation producing "belt of temperate westerlies" in the north, the equally active "belt of tropical easterlies" in the south, and between them the subtropical belt of high pressure, which on the whole inhibits rainfall because of its general subsidence within the atmosphere. North Carolina in winter is generally under the influence of the northern conditions and the storm paths of the westerlies. In mid-summer, the atmospheric circulation and rainfall are tropical in nature. Between these two periods, the subtropical conditions of lower precipitation predominate.

The winter rainfall peak is not uniform over the state. It is most prominent in the west, which is part of a geographical band that extends from Louisiana to the southern Appalachian Mountains. This band is supplied with moisture from the Gulf of Mexico. Here the yearly maximum monthly precipitation occurs in late winter, which contrasts with that of the east, which occurs in spring or summer. There is a decrease in the prominence of the winter precipitation peak eastward from the mountains to the Coastal Plain of North Carolina, which may be a rain-shadow effect produced by the Mountains. In coastal areas, the winter maximum again stands out clearly, in this case, the result of the influence exerted by the warm waters of the Atlantic Ocean. The late summer peak in the second component is hard to distinguish because of its close temporal proximity to the peak in the first component. It adds to the July amounts and often elevates the August and September rainfall to amounts comparable to July. This delay in the warm season peak is most pronounced in the southern coastal region.

Addition of the two components A and B, leads to the annual course of average monthly precipitation amounts. The resulting peaks in the annual profile generally occur in February-March and July-August. Minima generally occur in May-June and September-October, although variations of as much as a month are possible.

There are subtle aspects to the Atlantic Ocean's influence on spring and autumn rainfall. The ocean's spring coolness inhibits the capacity of marine air to contain, transport, and release water, as shown by the low spring rainfall amounts at the coast. Conversely, the ocean is comparatively warm in the late summer and fall, and the overlying air is moisture laden. Usually during this period (which by no coincidence is the tropical storm season), this moisture supply is kept offshore by the westerly (and northerly) flow that is predominant at this time of year; hence, conditions remain dry. But there are times when the westerly flow is sluggish and allows the marine tropical air to be drawn inland. Occasionally late in the year when surface temperature patterns are favorable, this may lead to a distinct "Cape Hatteras low pressure" region. This gives a slow inland movement of marine air, fed by the moist air overlying the Gulf Stream, and may produce large accumulations of precipitation in coastal regions and, on occasion, in inland areas. This phenomenon leads to months with rainfall totals that appear anomalously high in the general statistics from August into winter. Most of these storms lack the spatial and temporal consistency to allow accurate prediction of their occurrence and the resulting heavy precipitation.

THE DISTRIBUTION OF PRECIPITATION

The preceeding discussion has demonstrated that precipitation varies with time over North Carolina. This variation occurs not only from one month to another within a year, but also from one year to the next. When a single value is needed for the precipitation in a given month at a particular place, the most commonly used measure is the "normal" value, the average over a 30-year period. Normals for the 1951-1980 period at North Carolina stations are given in Table 1. This table also gives the standard deviation from the normal. This provides a simple measure of the variability of precipitation for a given month over the whole 30 year period. Approximately 68% of the actual monthly totals will fall within a range of plus or minus one standard deviation of the normal (See Appenix C).

The spatial variations of monthly precipitation across the state is shown in Figures 1-12, while the annual total is given in Figure 13. Each figure consists of two maps, one for the normal value and one for the standard deviation. This again emphasizes first the average conditions and then the variations about them. These maps, which were originally plotted by a minicomputer using a contouring program, were redrawn by hand using a tracing technique that allowed for interpolation and smoothing, thereby resulting in a more refined map. Although there are sufficient stations scattered across the state to reveal the general patterns, extreme caution should be used in interpreting the maps for the mountains. Topographic effects play a great role in determining the actual precipitation in rugged terrain, and rainfall totals may vary greatly in the space of a few miles. While the general patterns are likely to be realistic, values for individual locations may differ from those suggested by the maps.

A prevailing feature shown on the monthly precipitation maps, and therefore on the annual map, is the large spatial variability found in the Mountains of North Carolina. In this region one finds an area of maximum precipitation paralleling the North Carolina-South Carolina border, extending northeastward. The highest annual precipitation found in the eastern United States is located within this region, where Highlands averages over 82 inches annually. In contrast, Asheville, located only 50 miles away in a sheltered valley averages less than 40 inches per year. Profiles of these two stations (Figure 14) illustrate the extreme variability that topographic effects can impose upon precipitation distribution patterns.

Patterns observed in the Piedmont section of the state are much less complex than those found in the mountains. As a whole, the Piedmont is the driest of the three geographic divisions found in North Carolina, with some northern areas receiving less than 43 inches annually. Conversely, some areas in the southern Piedmont, most notably the Sandhills region, receive close to 50 inches annually. This contrast is shown in the monthly profiles provided for Raleigh-Durham and Pinehurst-Southern Pines (Figure 15).

Analysis of the precipitation patterns found in the Coastal Plain immediately reveals the dominating influence of the Atlantic Ocean. Monthly and annual precipitation averages increase steadily as one approaches the coast line from the west. This increasing gradient, while somewhat less noticeable in the north, is very pronounced along the southern coast. Precipitation profiles for Hoffman Forest, which averages almost 56 inches annually, and Edenton, which receives less than 49 inches yearly, illustrate this (Figure 16).

Seasonal examination of the precipitation patterns observed over North Carolina reveals the influence of the two distinct precipitation components discussed earlier. During the winter, the state's weather is dominated by the "belt of temperate westerlies," which provides precipitation of component type B. This broadscale flow results in the frequent passage of fronts and cyclones which are usually accompanied by large areas of steady precipitation. Average monthly precipitation generally increases across the state from January through March, as the frequency of fronts and cyclones increase. The one exception is found along the northern Coastal Plain, where monthly averages remain unchanged through this period.

As spring arrives in North Carolina, the westerlies weaken and retreat northward, resulting in a decrease in cyclonic activity. Subsequently, the trend toward increasing precipitation is reversed, and precipitation averages drop substantially statewide during April as spring continues. The dominance of component B is slowly replaced by component A (convective-type precipitation). Surface heating becomes sufficient by June to result in a statewide increase in monthly precipitation. The increase accelerates as the state enters the summer period , reaching a maximum during the months of July and August. Outside of a few mountain locations, this is generally the wettest period in North Carolina.

Close examination of the standard deviation patterns likewise reveals a summer maximum. This increase can be attributed, in part, to the direct proportionality that exists between the mean and the standard deviation. Any changes in the mean precipitation patterns will produce similar changes in the patterns of standard deviation. A more important contributor to the summer increase in standard deviation is the convective-type precipitation that dominates during this time of the year. Showers and thunderstorms are generally inconsistent temporally and spatially, resulting in weekly or monthly periods when little or no rainfalls in the state.

In response to decreasing surface heating during autumn, convective precipitation diminishes greatly. Both components of precipitation are near their minima during the months of September and October, resulting in the driest season of the year. Most sections of the state average less than 3 inches of rain during October. The coastal sections of the state are less affected by this decrease in average monthly precipitation, due in part to tropical storm influence.

By November, the "belt of temperate westerlies" begins moving south, resulting in the re-introduction of stratified, or component B-type precipitation to the state. This trend toward cyclonic and frontal type precipitation continues as we enter December and complete the yearly precipitation cycle.

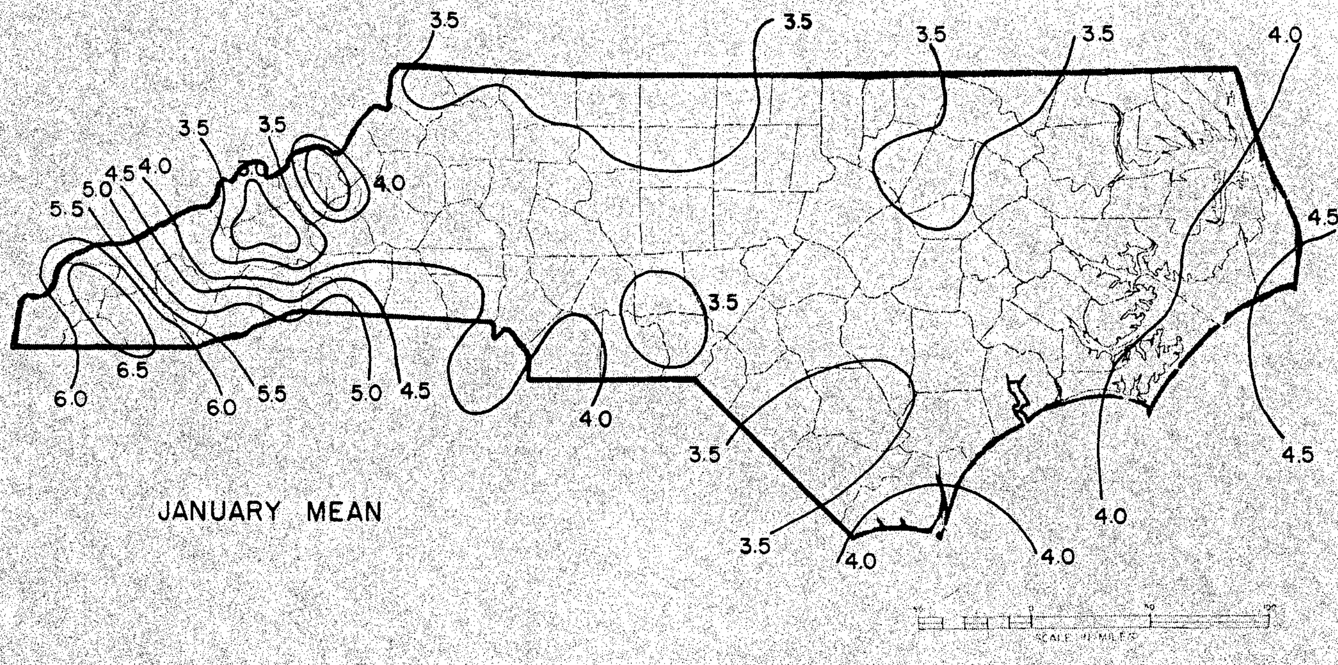
USE OF THE PRECIPITATION INFORMATION

The information presented here is intended to provide, in a form suitable for a wide variety of applications, a guide to the general conditions of precipitation and its variation across North Carolina. While an individual is free, of course, to use the information in any way, the variable nature of precipitation, both spatially and temporally, indicates that caution be used in interpreting the values. Consequently a few suggestions are offered here.

The basic, and consequently most accurate, data are presented in Table 1. Since these are point-specific values, information about areas or points without observations must be obtained with the assistance of the maps. For points without observations, the information can be obtained directly from the maps or, after checking the maps, by reference to data for a nearby observation station in similar conditions. In the mountains, the latter approach is strongly recommended, with particular care being taken to select as the reference station one that is in a similar topographic setting. Values of precipitation for an area can be obtained from the maps by visual estimate, plannimetry, or by more sophisticated techniques.

By presenting both normal (mean) and standard deviation values, the temporal variability of precipitation is emphasized. The mean may be the most appropriate value to use in many applications. However, its use in conjunction with the standard deviation allows consideration of a range of likely values. For example, rainfall totals for a particular month are likely to exceed the mean plus one standard deviation once every 6 years or so, while the mean plus two standard deviations is likely to be exceeded in about 1 year out of 40. While these figures are only approximate because of the difficulty of using simple statistics with rainfall records, they indicate the type of information that can be extracted from the information presented here.

Much more complex and sophisticated analyses of precipitation variability are possible. Particular application, for example, may need to emphasize extreme floods or droughts, or to consider daily rainfall values. Anyone with such needs is advised to contact the North Carolina Climate Program, Office of the State Climatologist, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, Raleigh, for advice and assistance.



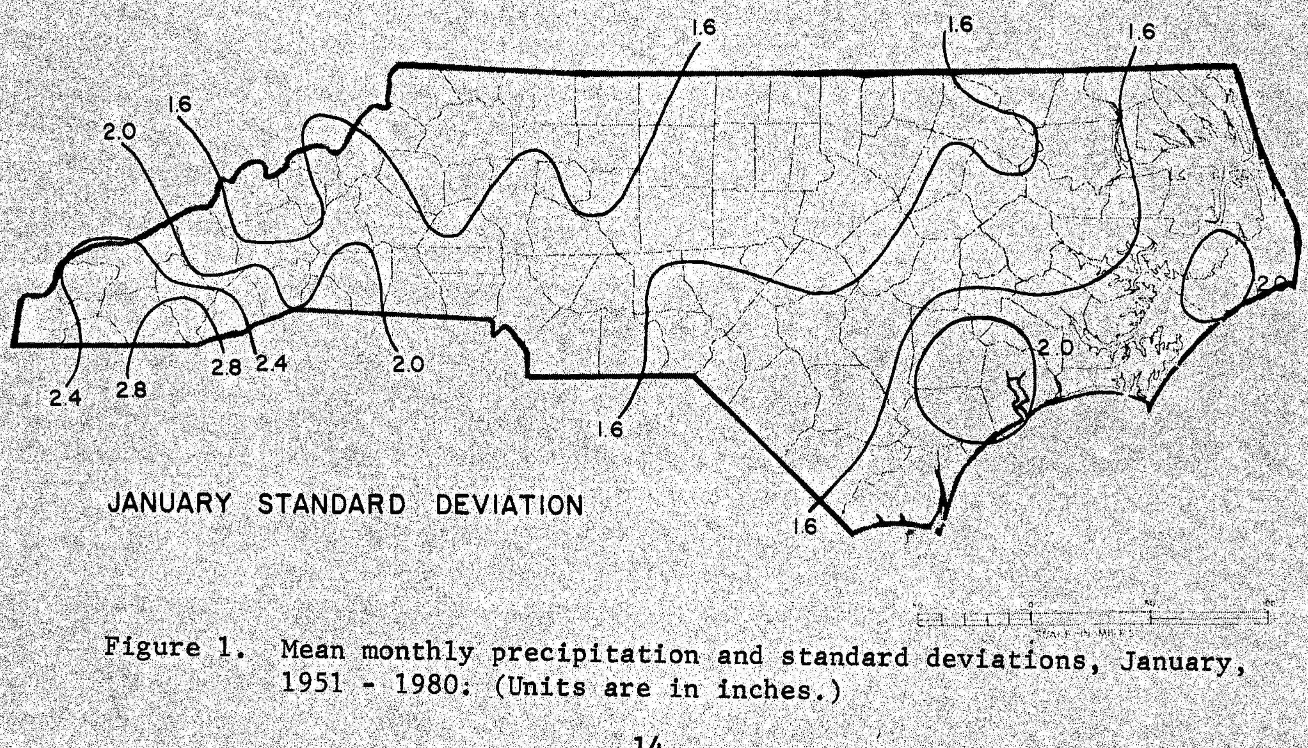
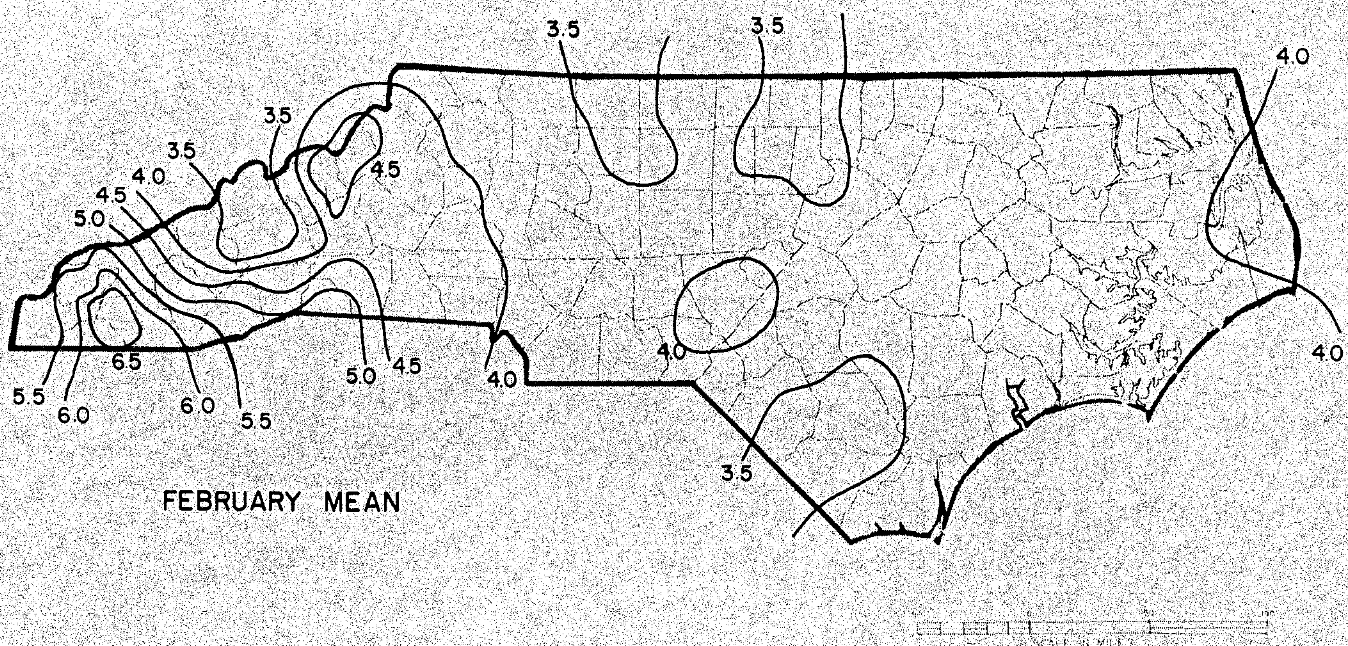


Figure 1. Mean monthly precipitation and standard deviations, January, 1951 - 1980. (Units are in inches.)



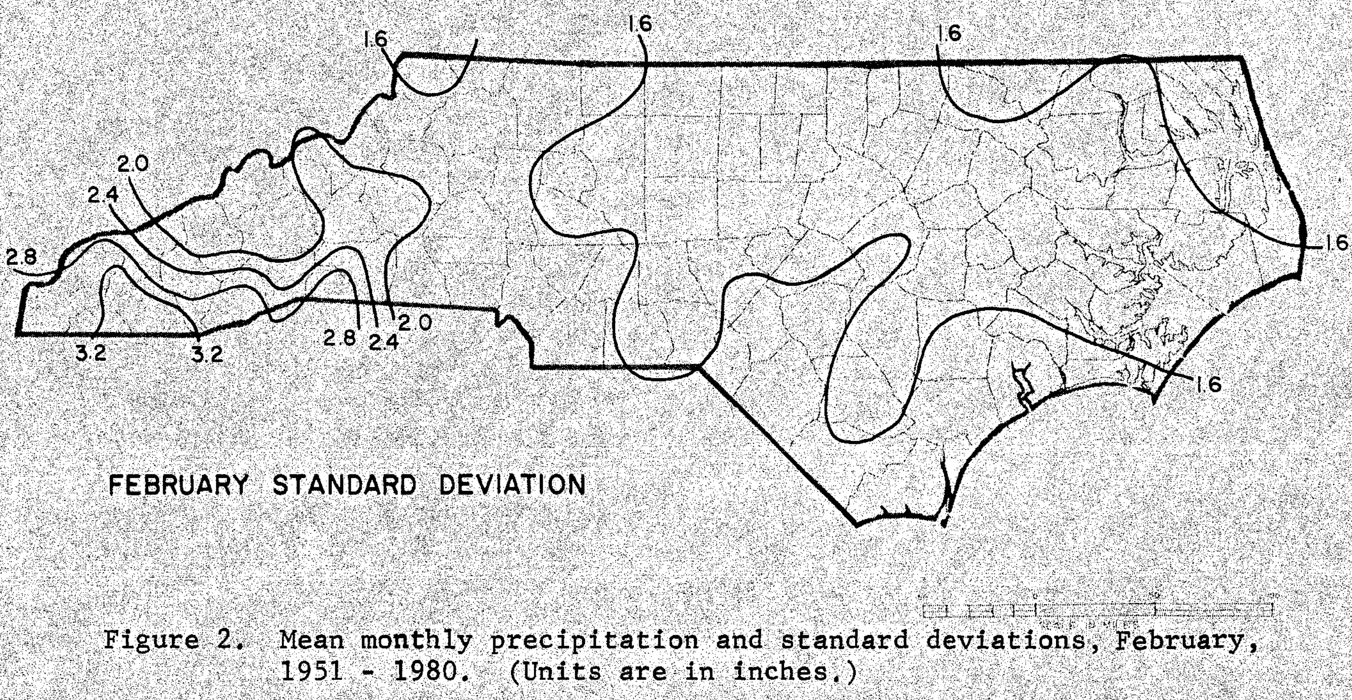
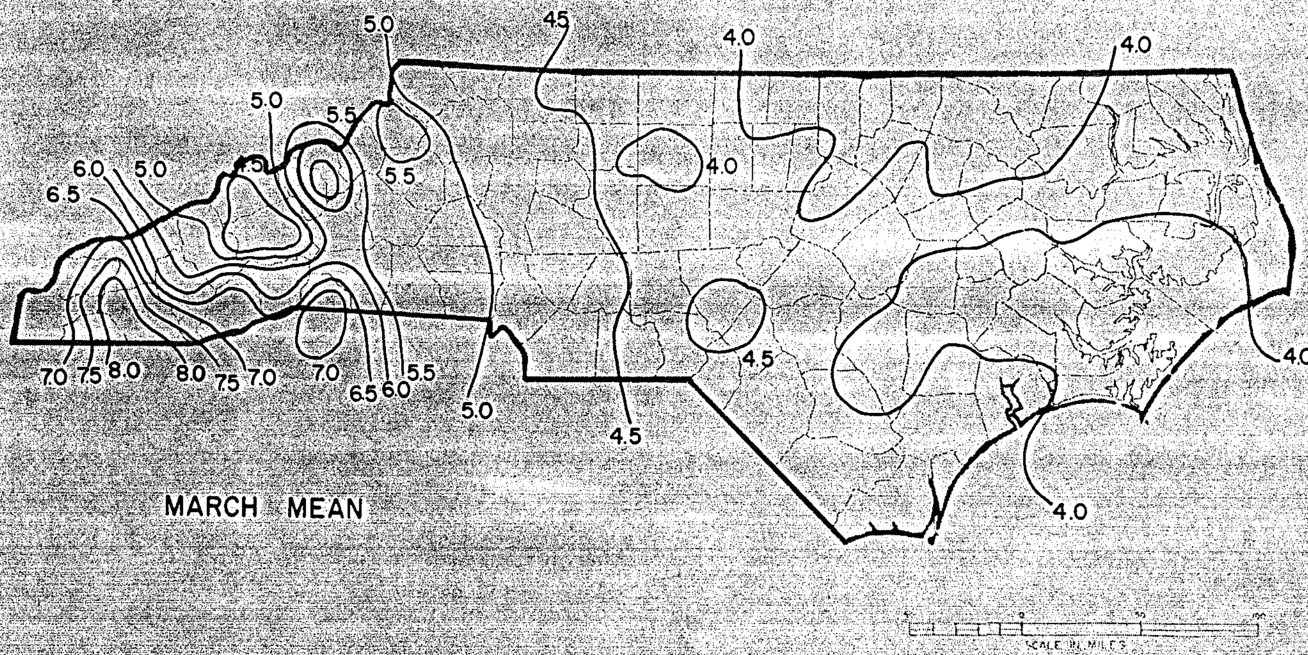


Figure 2. Mean monthly precipitation and standard deviations, February, 1951 - 1980. (Units are in inches.)



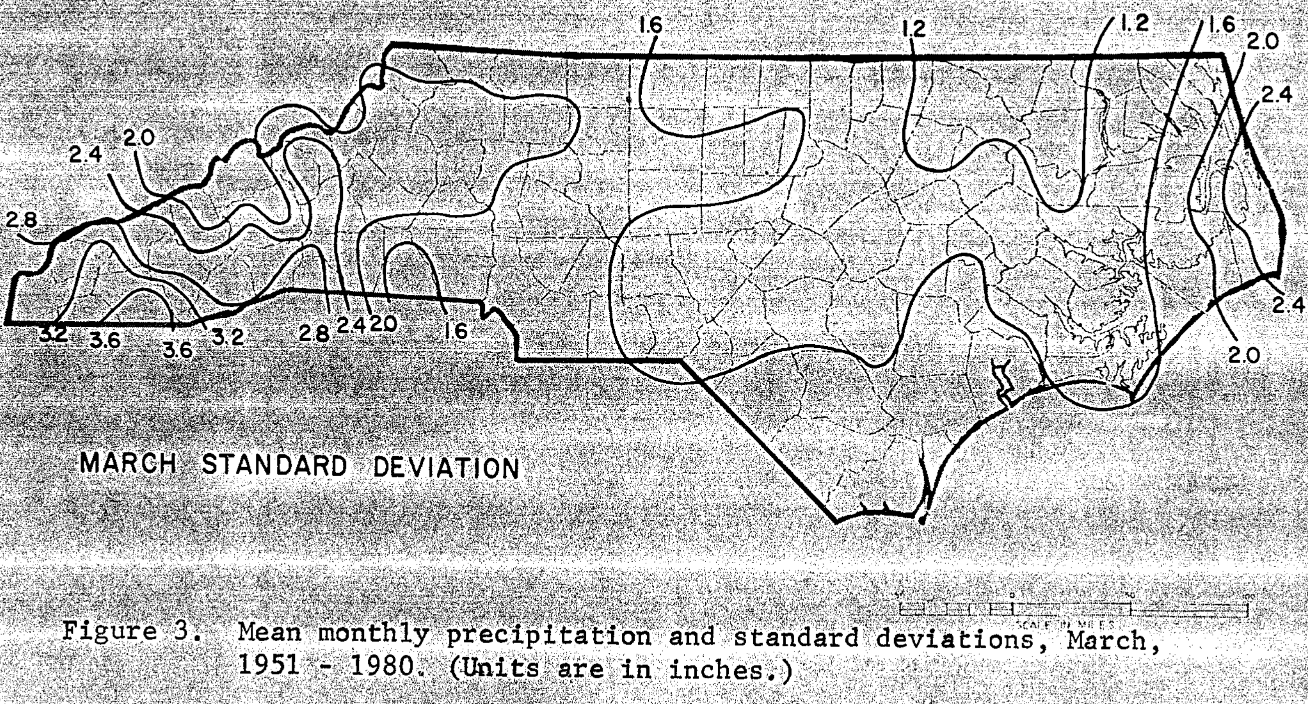
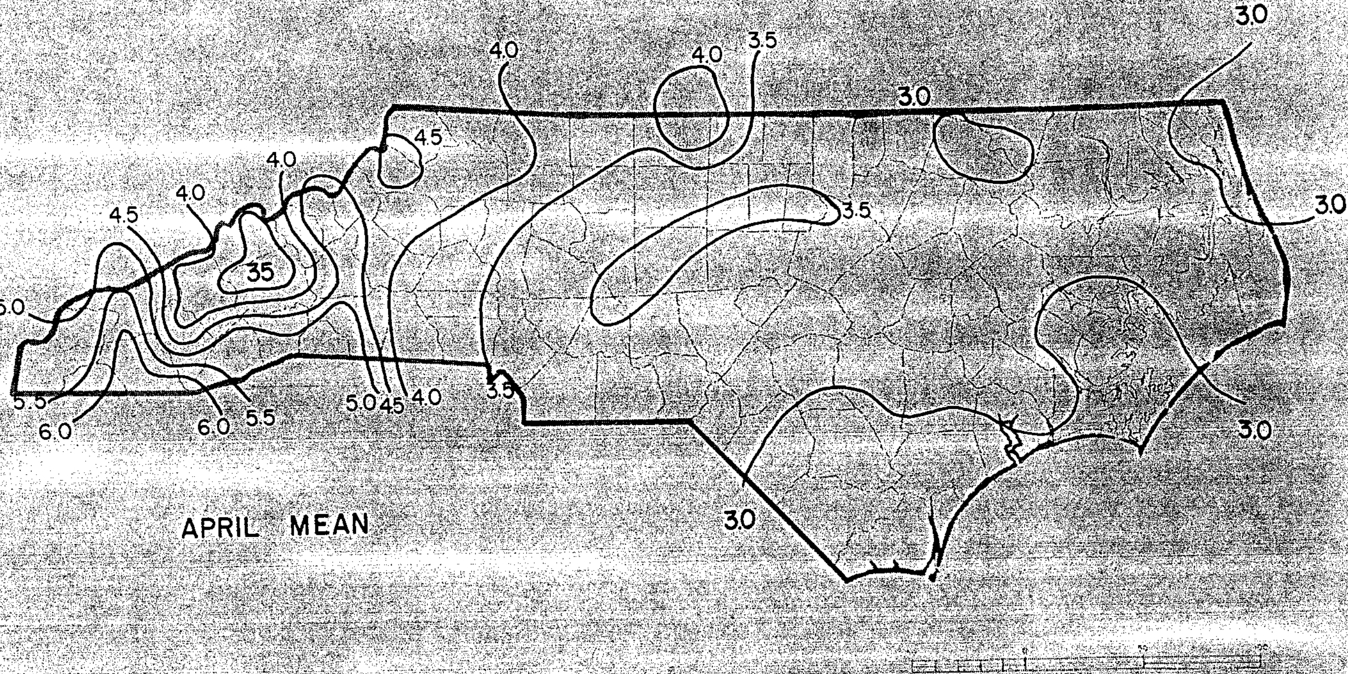


Figure 3. Mean monthly precipitation and standard deviations, March, 1951 - 1980. (Units are in inches.)



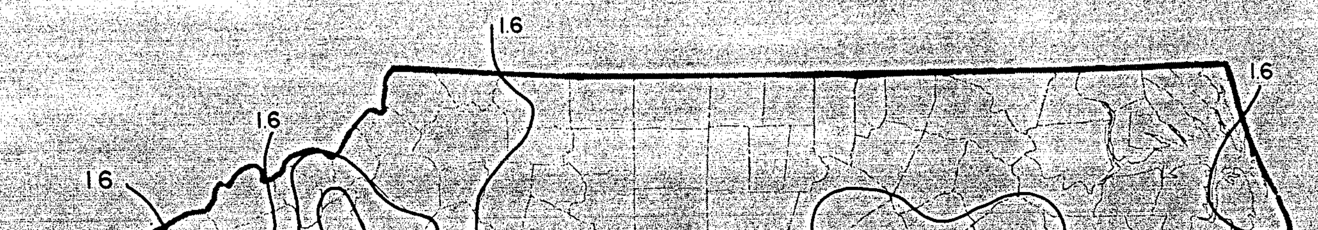
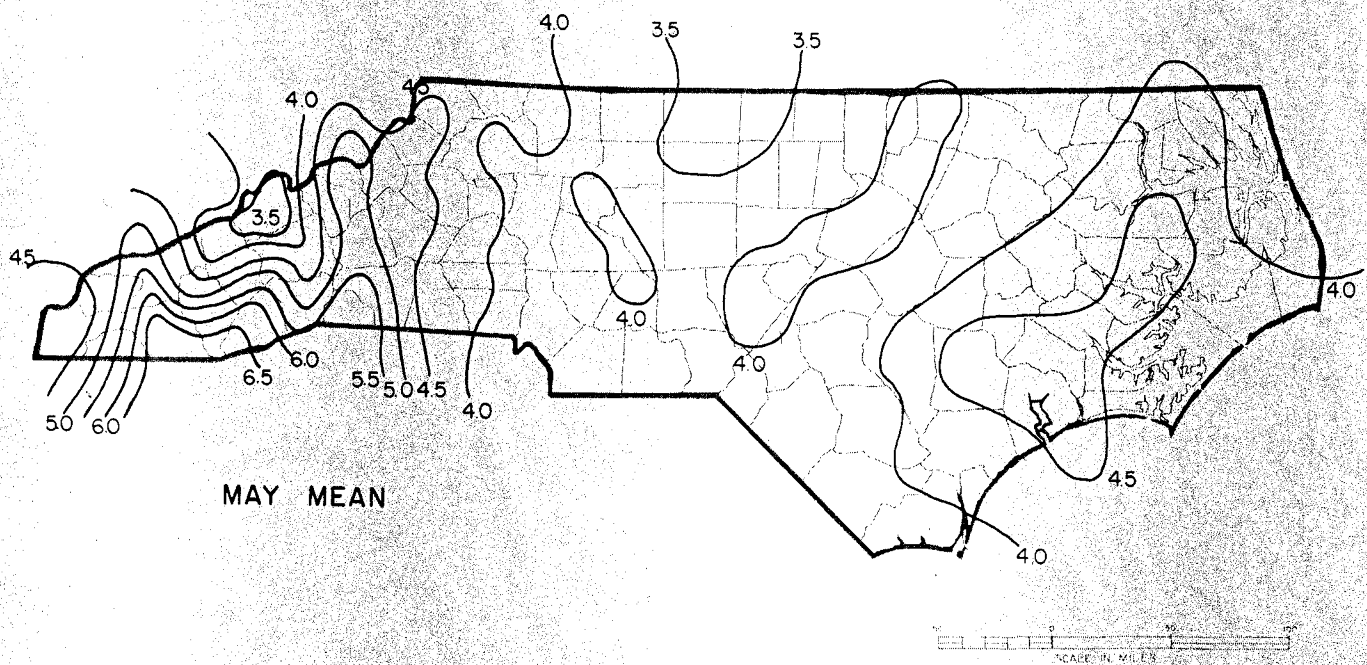


Figure 4. Mean monthly precipitation and standard deviations, April, 1951 - 1980. (Units are in inches.)



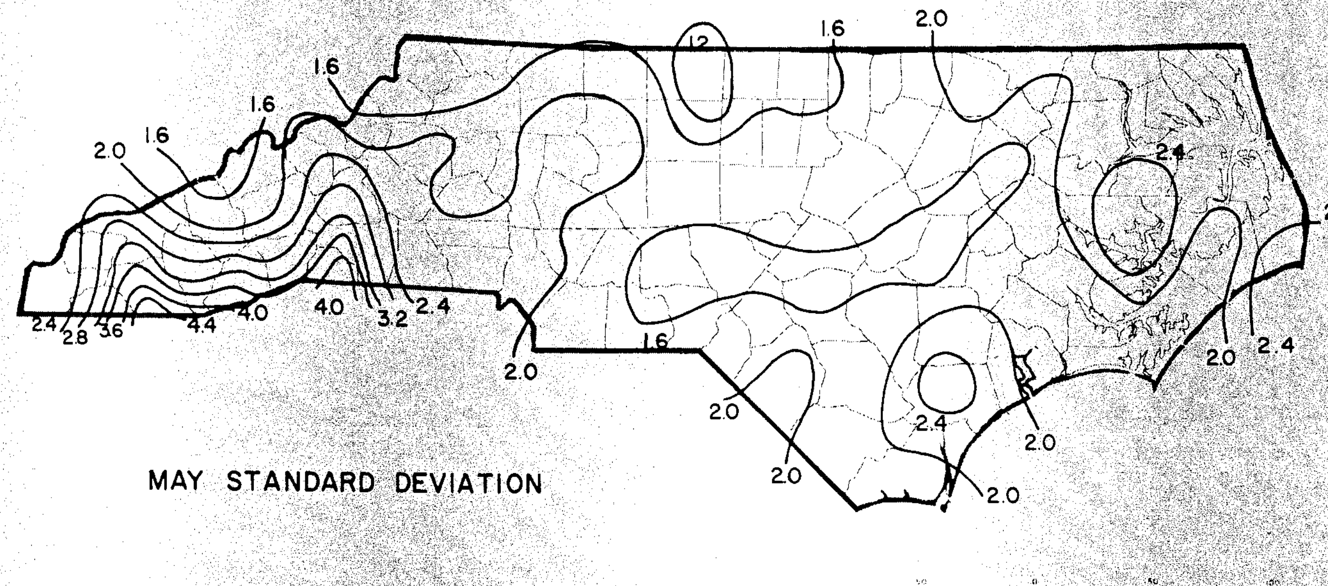
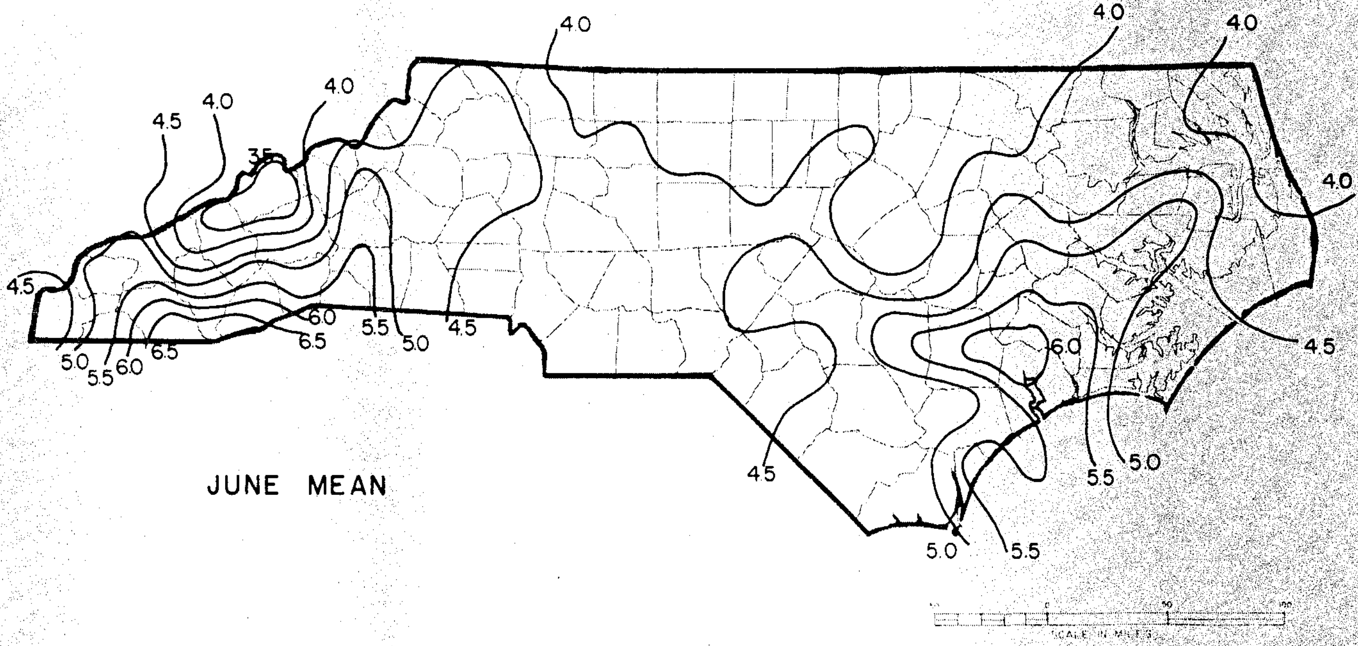


Figure 5. Mean monthly precipitation and standard deviations, May, 1951 - 1980. (Units are in inches.)



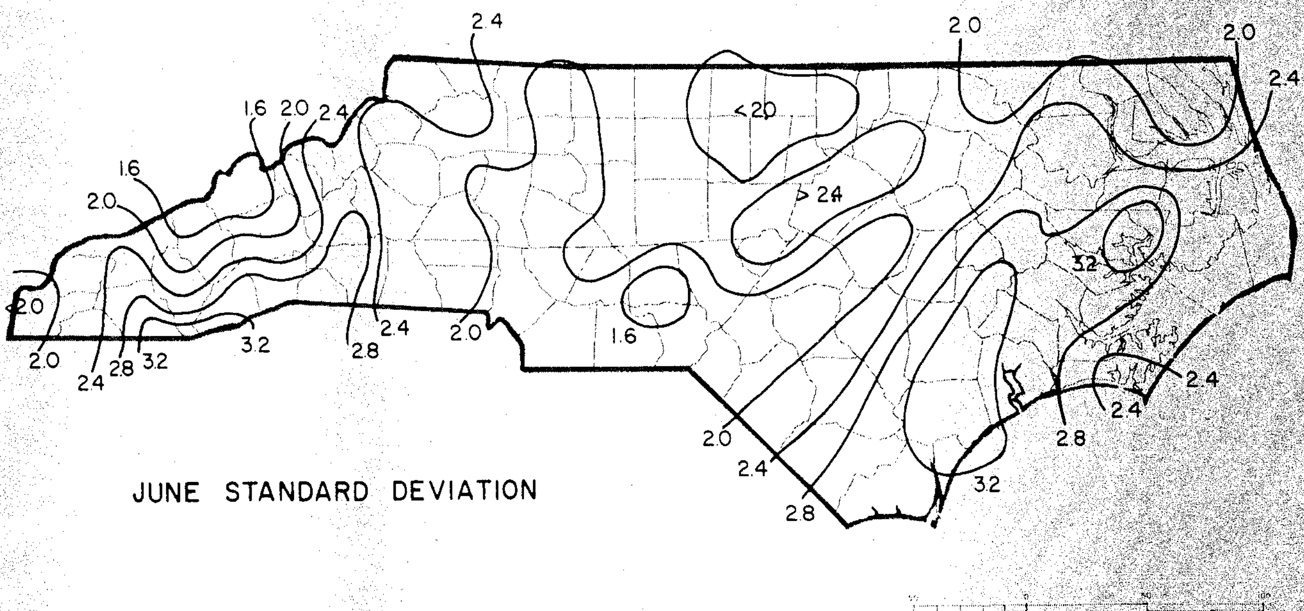
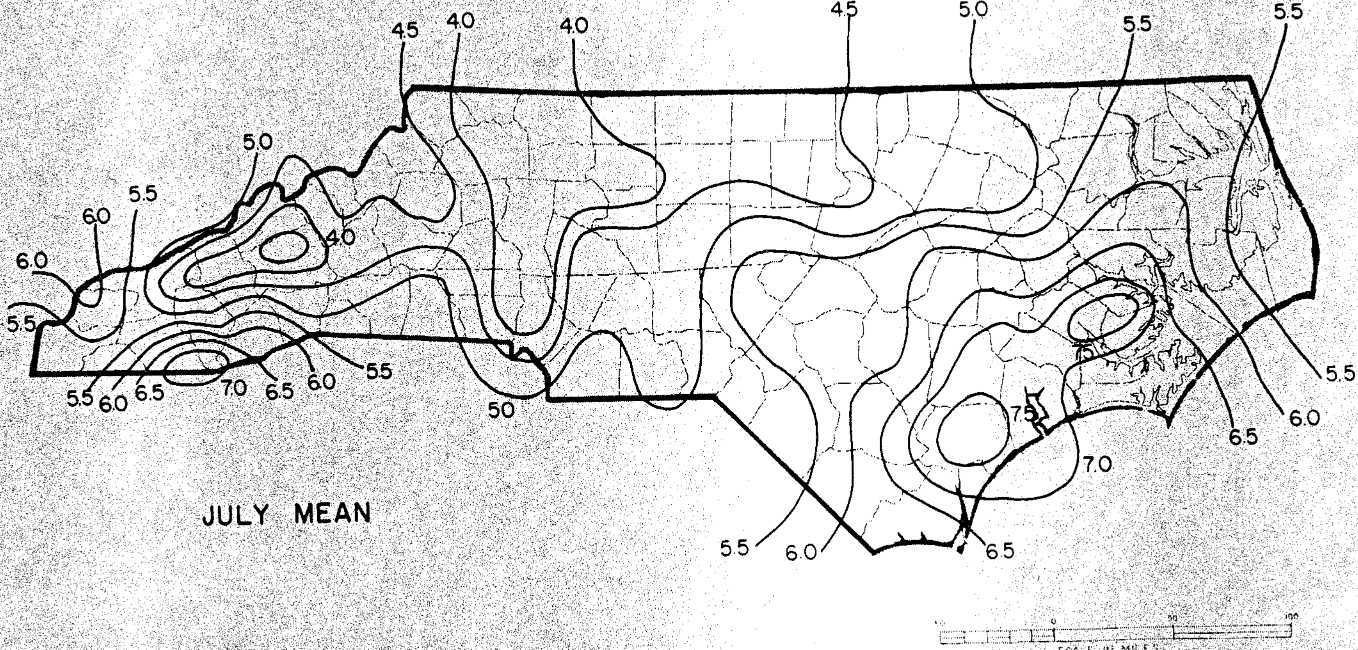


Figure 6. Mean monthly precipitation and standard deviations, June 1951 - 1980. (Units are in inches.)



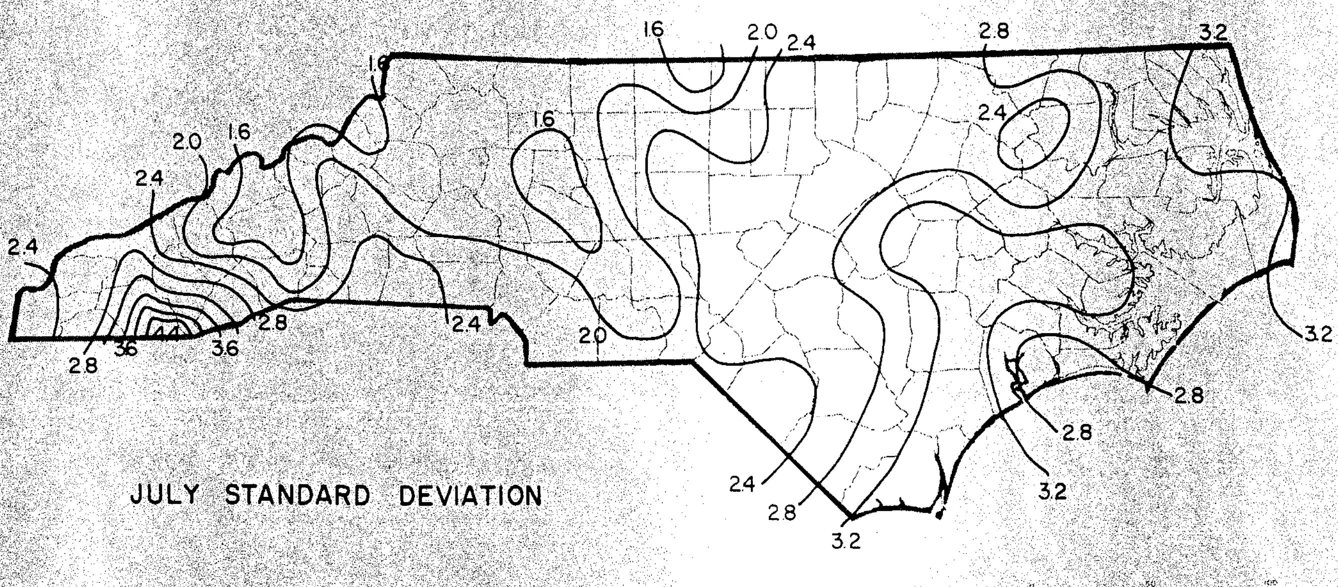
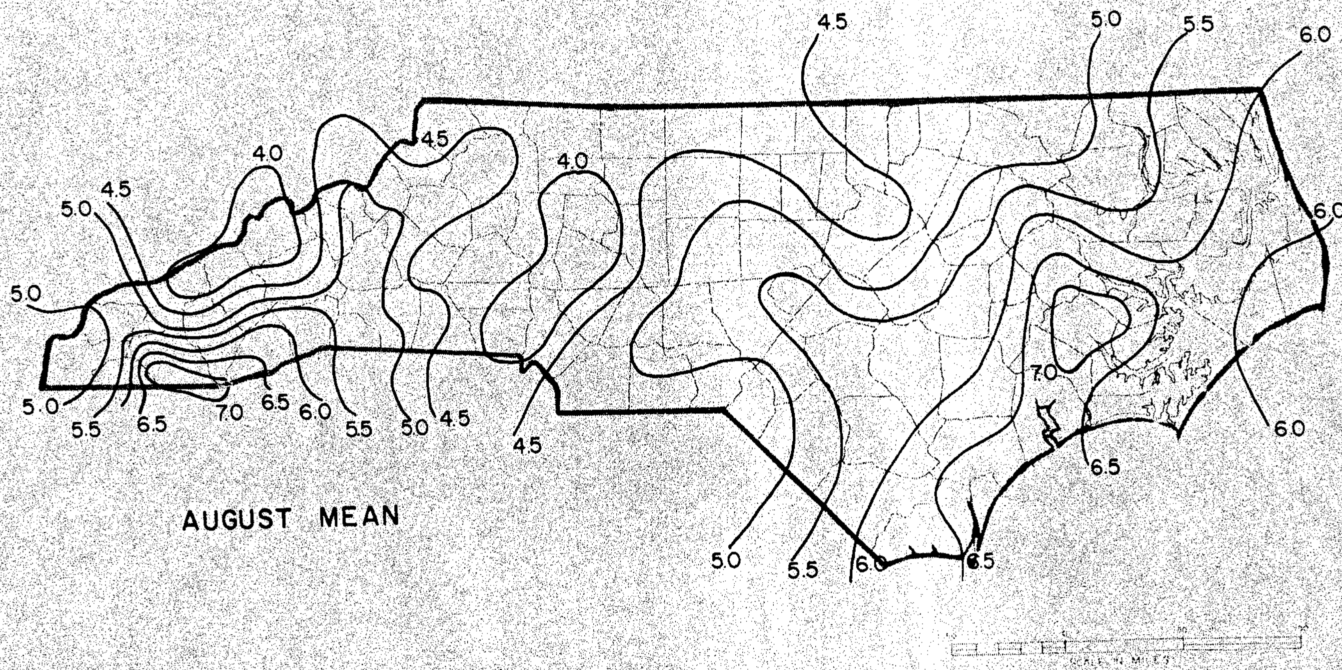


Figure 7. Mean monthly precipitation and standard deviations, July, 1951 - 1980. (Units are in inches.)



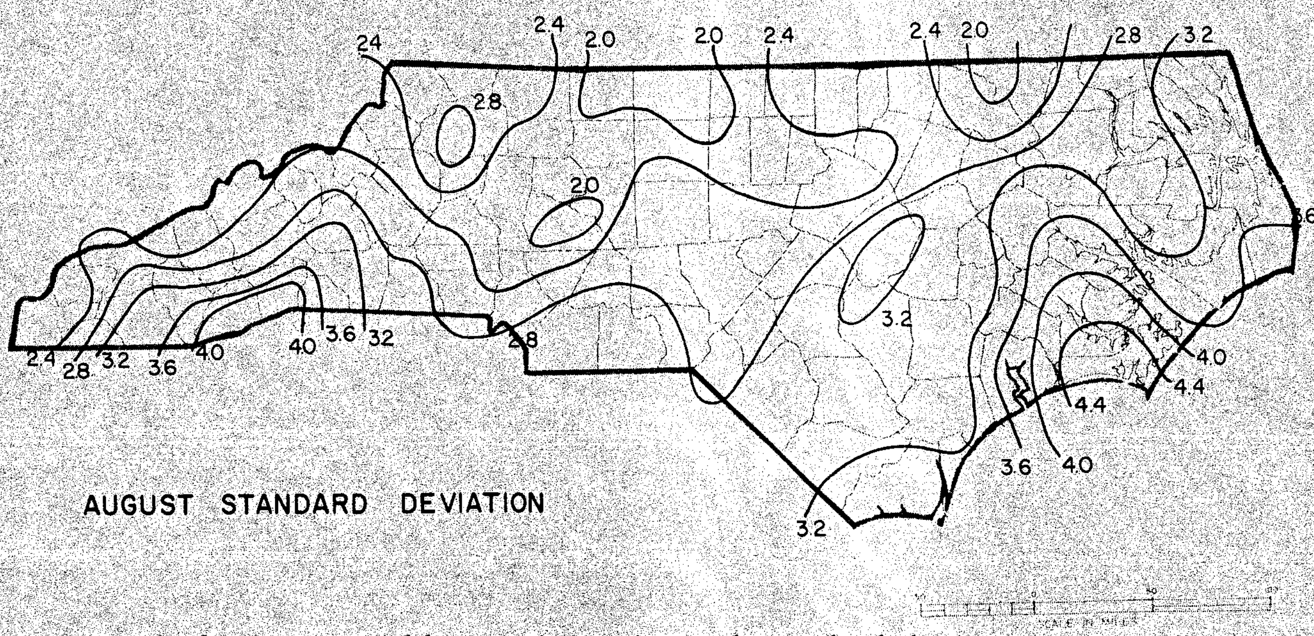
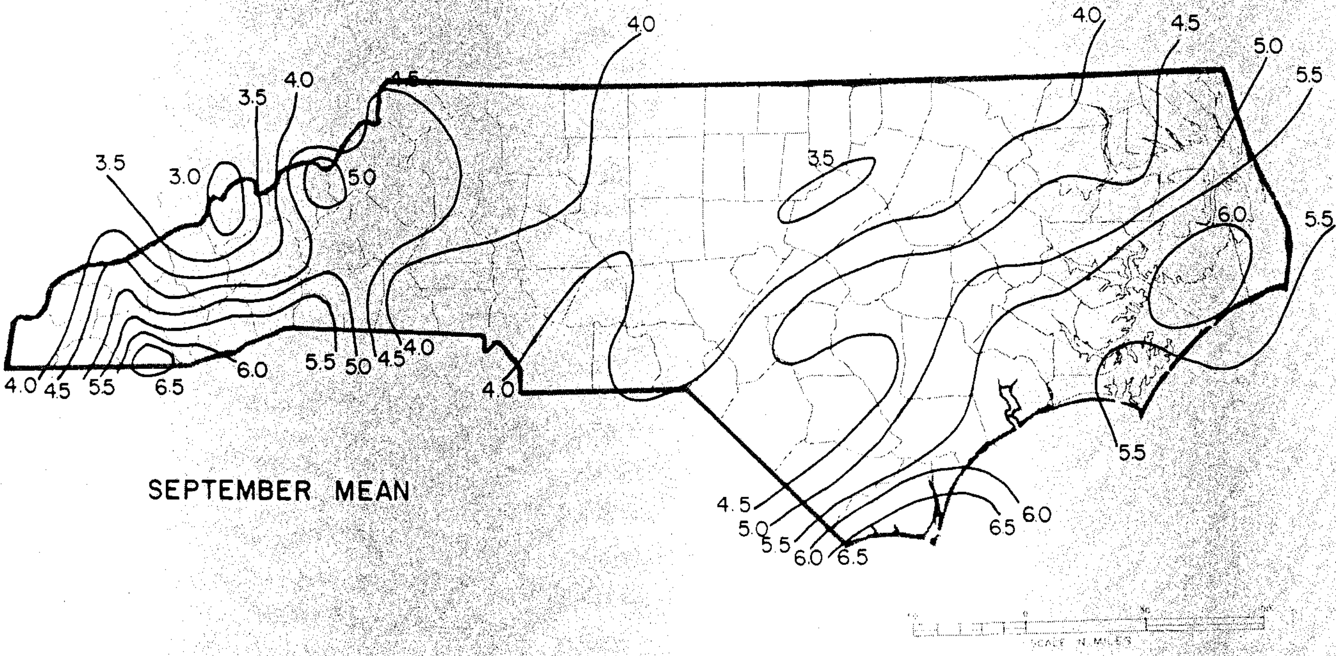


Figure 8. Mean monthly precipitation and standard deviations, August, 1951 - 1980. (Units are in inches.)



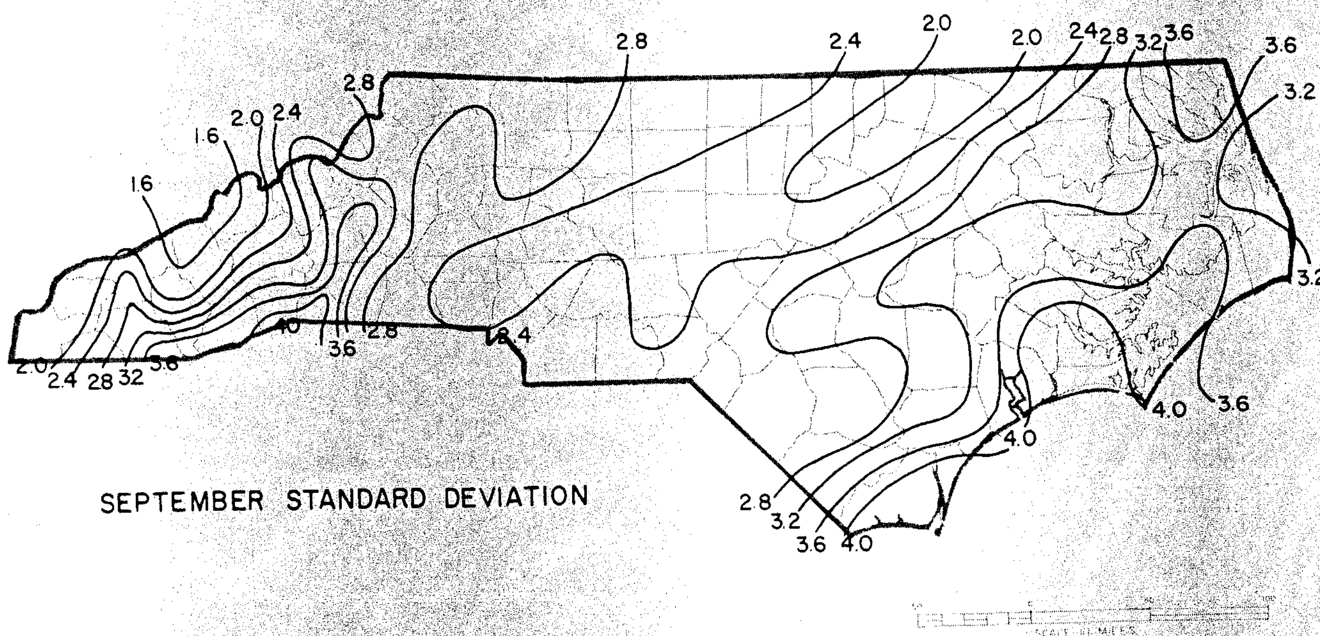
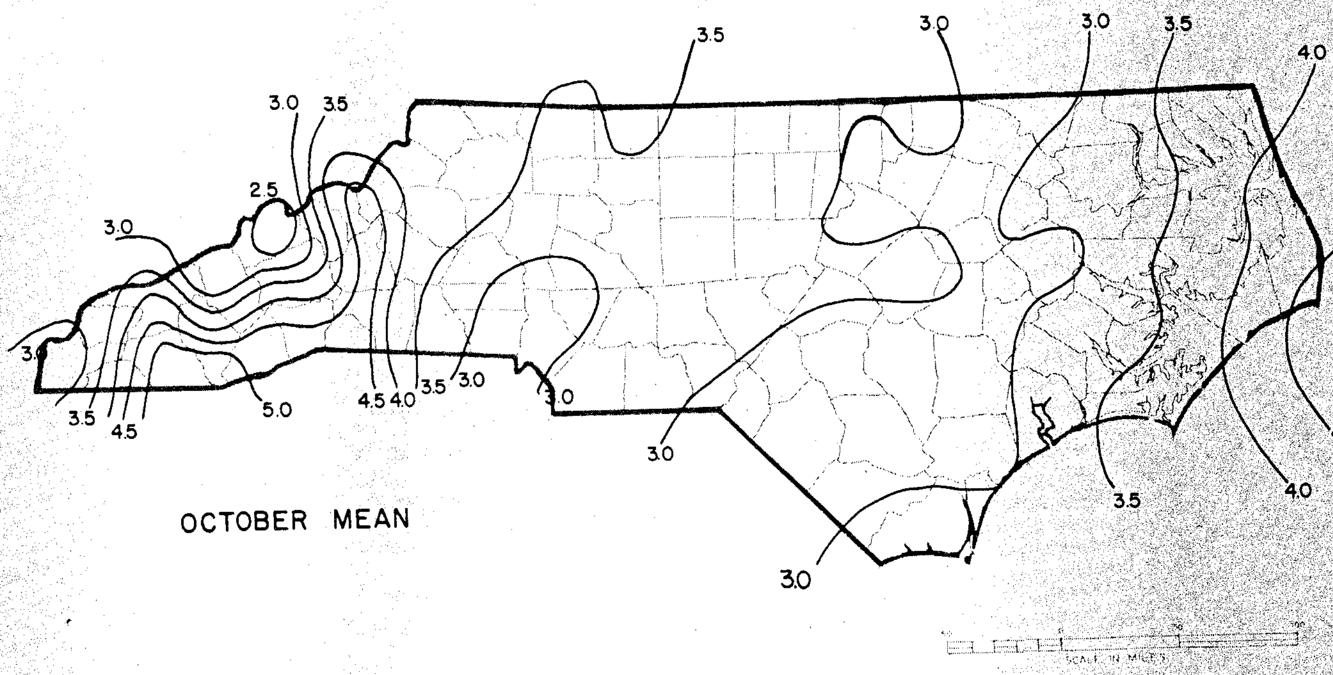


Figure 9. Mean monthly precipitation and standard deviations, September, 1951 – 1980. (Units are in inches.)



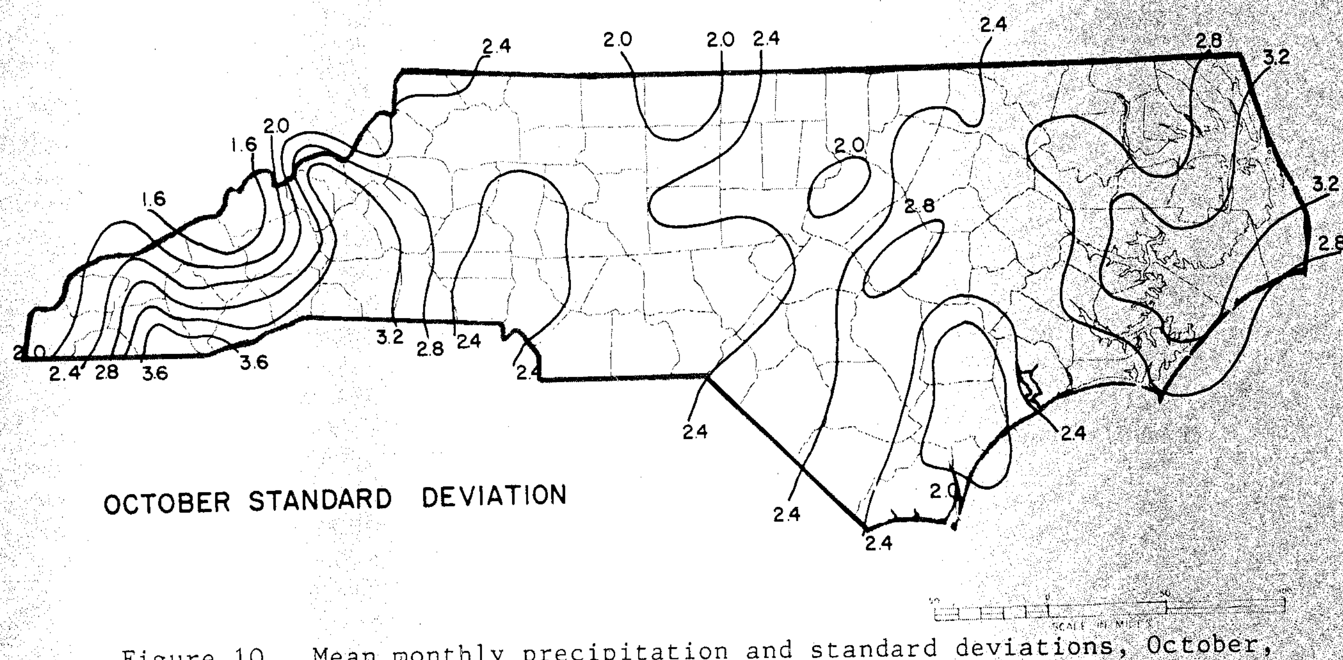
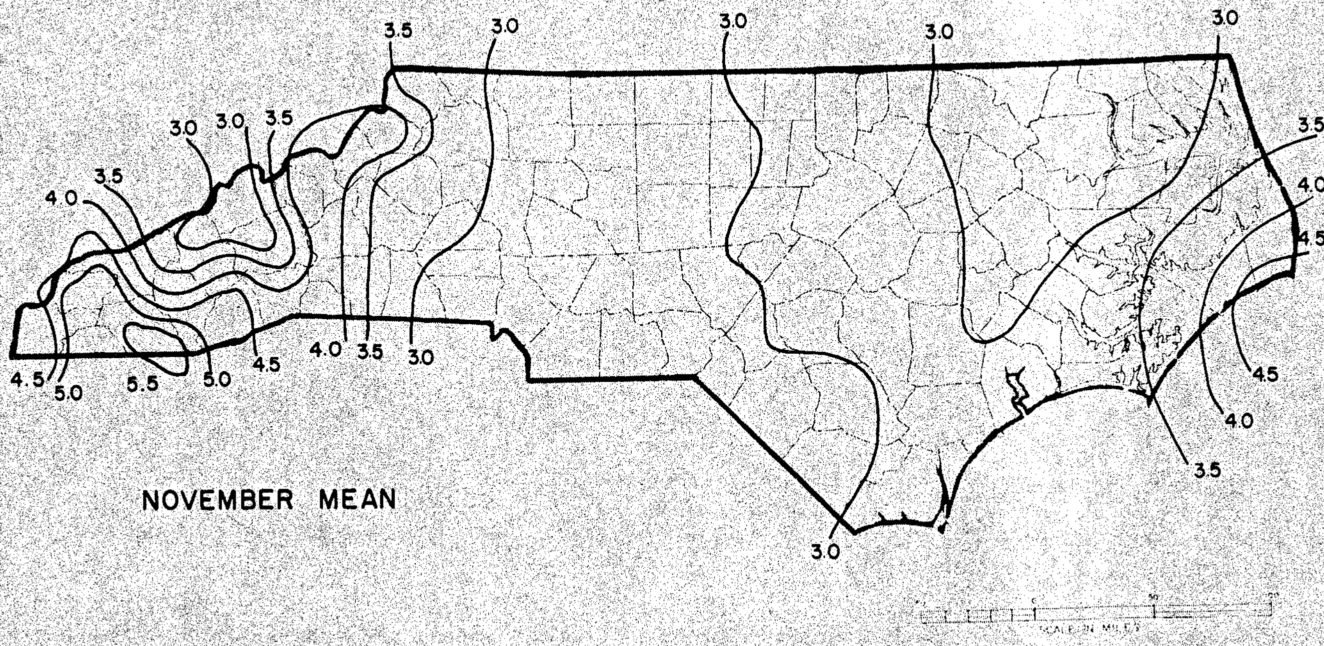


Figure 10. Mean monthly precipitation and standard deviations, October, 1951 - 1980. (Units are in inches.)



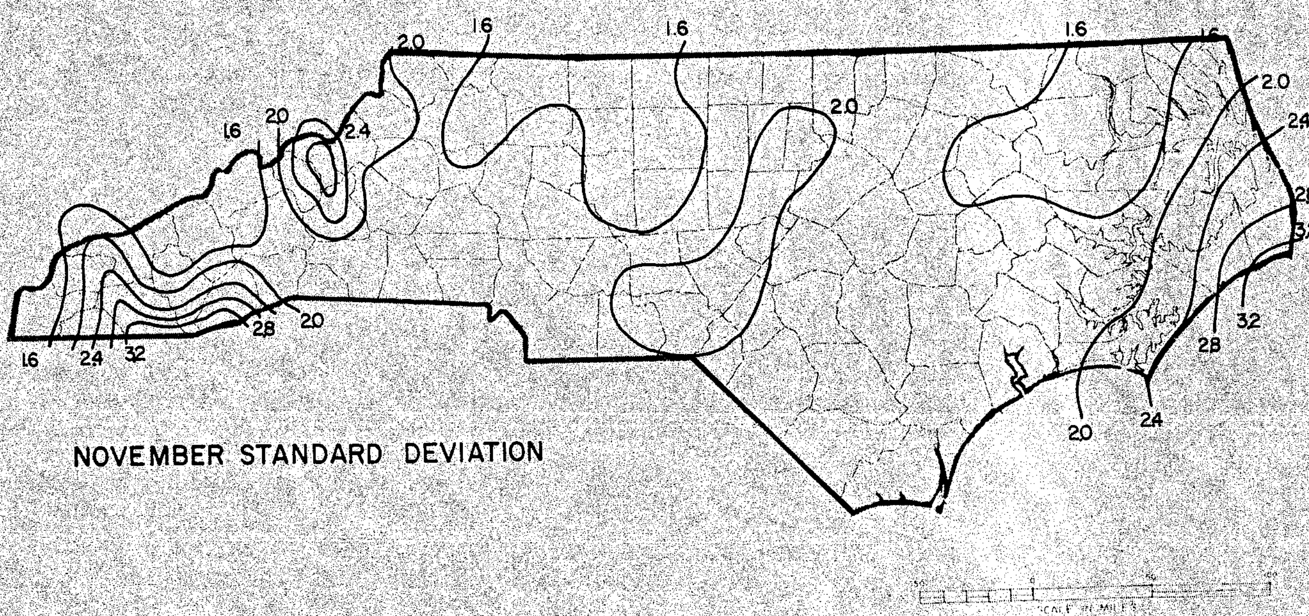
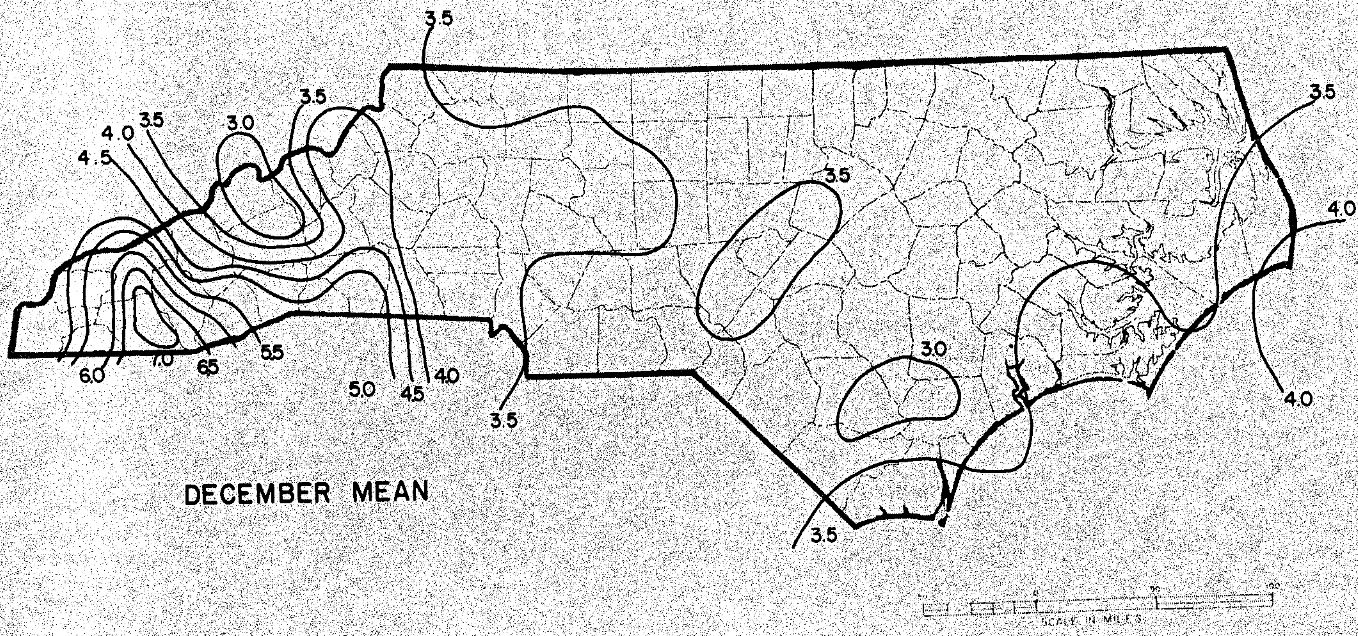


Figure 11. Mean monthly precipitation and standard deviations, November, 1951 - 1980. (Units are in inches.)



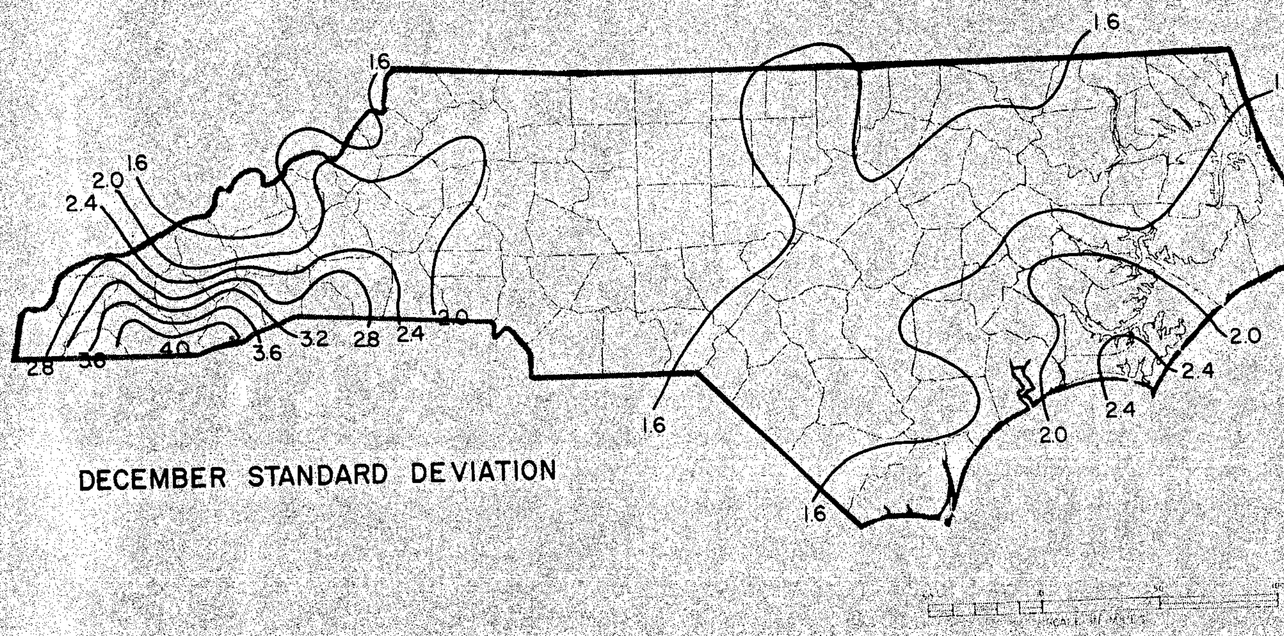


Figure 12. Mean monthly precipitation and standard deviations, December, 1951 - 1980. (Units are in inches.)

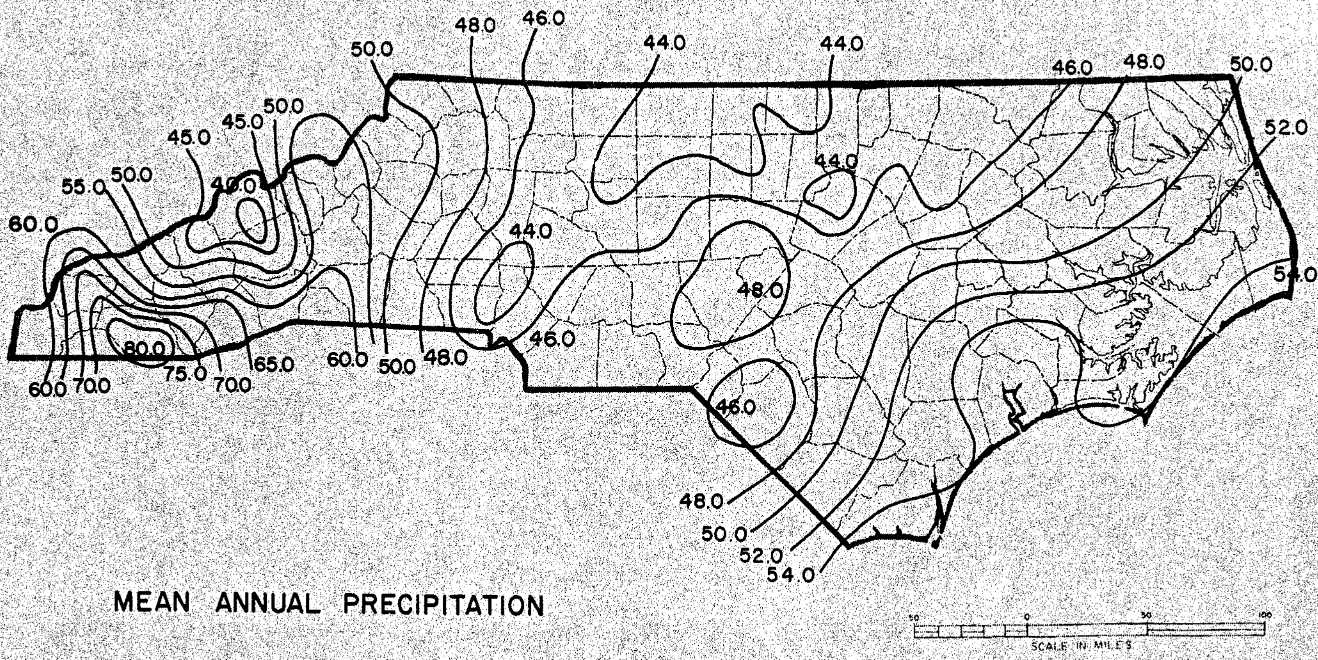


Figure 13. Mean annual precipitation. (Units are in inches. Note the change in the isohyet intervals.)

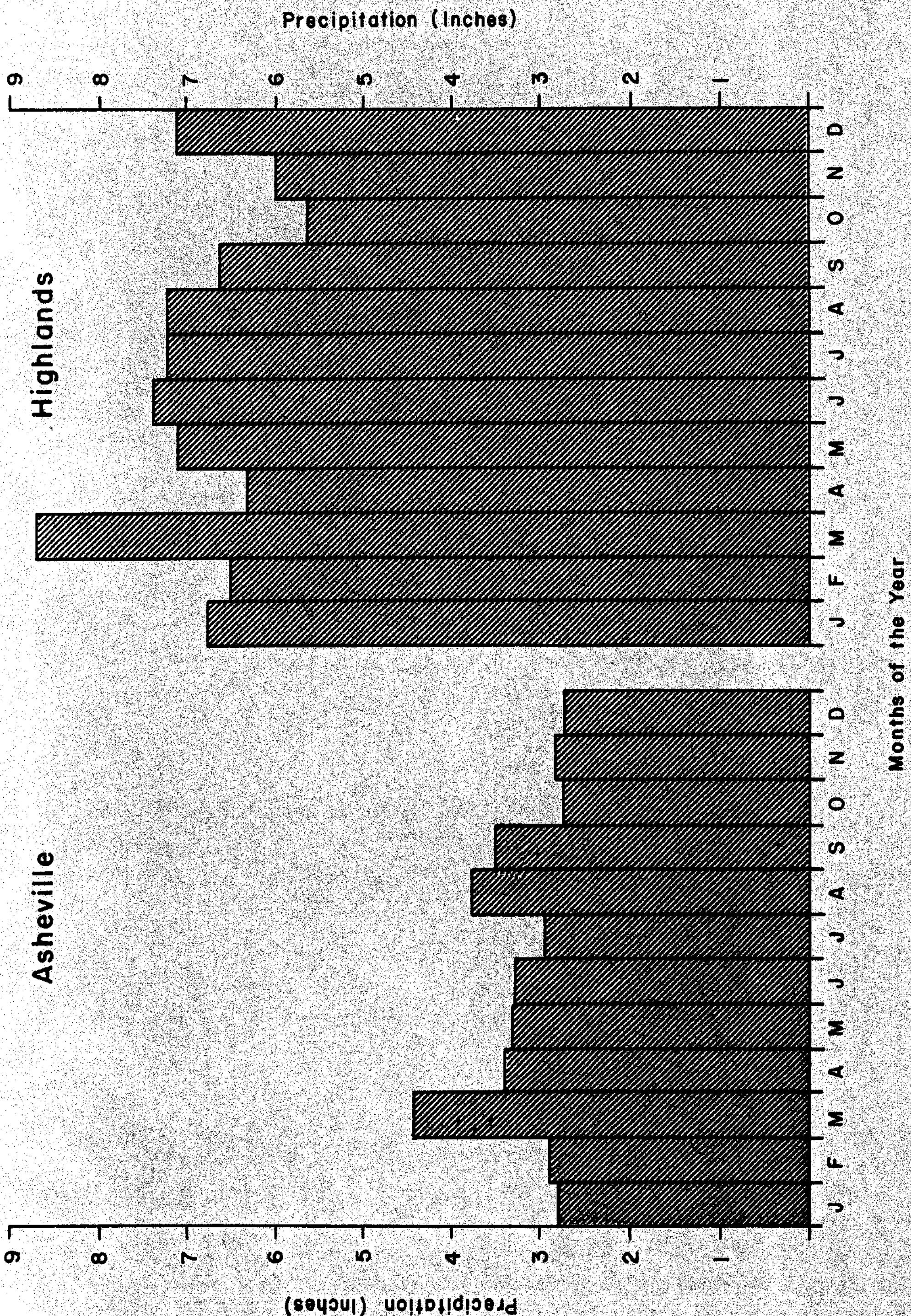


Figure 14. Monthly precipitation histograms for Highlands and Asheville.

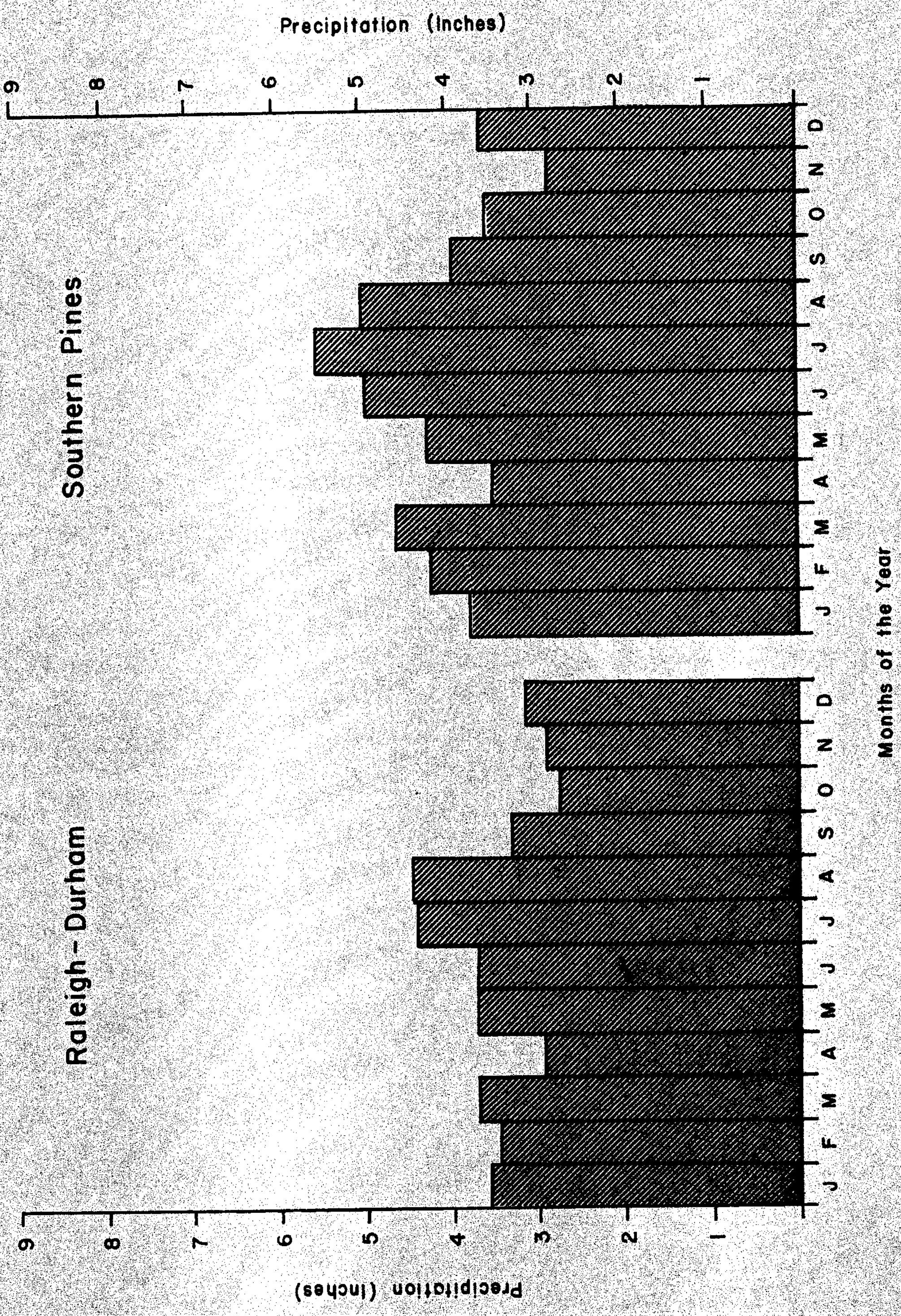


Figure 15. Monthly precipitation histograms for Raleigh-Durham and Pinehurst-Southern Pines.

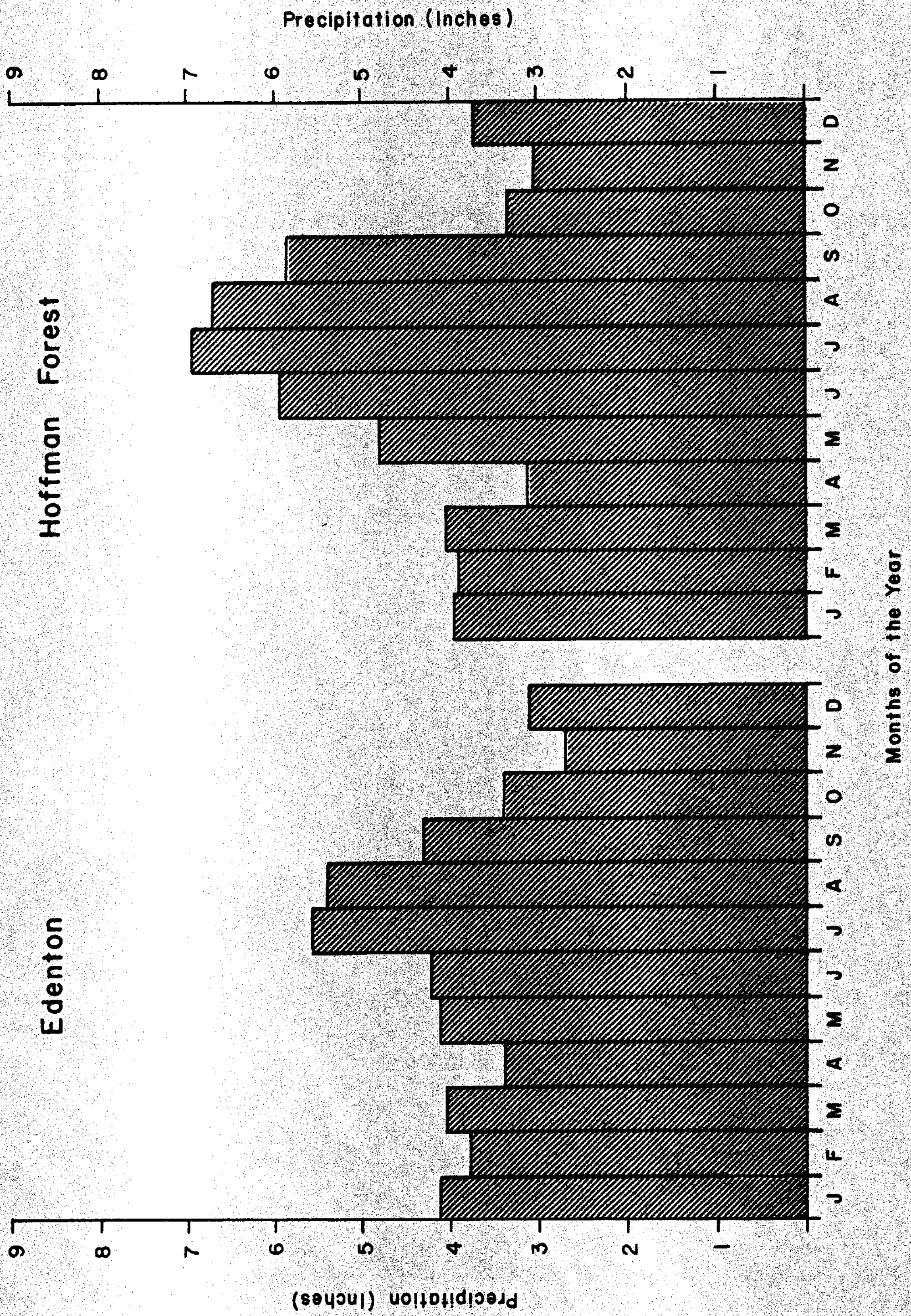


Figure 16. Monthly precipitation histograms for Hoffman Forest and Edenton.

Table 1

Mean Monthly and Mean Annual Precipitation (Inches)
and Standard Deviations in Monthly Precipitation

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Albemarle 4N	3.74	3.92	4.74	3.53	4.07	4.12	4.96	4.56	4.36	3.06	2.84	3.57	47.47
	1.80	1.86	2.07	1.61	1.82	2.43	2.75	2.67	2.51	2.41	1.77	1.77	
Andrews 2E	6.97	5.93	7.34	5.33	4.61	5.06	5.54	4.76	3.67	3.29	4.74	5.92	63.16
	2.75	3.00	3.01	1.92	2.00	2.18	2.43	1.93	1.75	1.99	1.52	2.60	
Asheboro 2W	3.76	3.59	4.18	3.33	4.07	3.89	4.89	4.84	3.85	3.16	2.67	3.39	45.62
	1.92	1.54	1.54	1.34	1.99	2.36	3.11	2.95	2.25	2.53	1.54	1.64	
Asheville	2.80	2.90	4.45	3.36	3.31	3.27	2.91	3.76	3.53	2.72	2.79	2.75	38.55
	1.24	1.35	1.73	1.43	1.70	1.62	1.14	2.18	1.89	1.73	1.48	1.40	
Banner Elk	3.99	3.90	4.97	4.46	4.44	4.38	4.81	4.56	4.20	3.43	3.62	3.42	50.18
	1.24	1.64	1.75	1.60	1.46	2.31	1.47	2.26	2.36	1.99	1.80	1.51	

Table 1 (Continued)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Belhaven	3.98	3.54	3.92	3.04	4.54	5.04	6.35	5.69	5.56	3.54	3.13	3.36	51.69
	1.61	1.56	1.29	1.42	2.66	3.34	3.11	3.11	3.24	3.44	1.60	1.55	
Boone	4.20	4.63	5.96	4.64	4.59	4.63	4.64	4.39	4.75	4.07	4.06	3.88	54.44
	1.58	2.05	2.31	2.08	1.77	2.42	1.94	2.34	3.35	2.58	2.12	1.74	
Brevard	5.59	5.47	7.23	5.40	5.86	5.83	5.86	6.57	5.40	4.88	4.57	5.37	68.03
	2.14	3.12	2.64	2.49	3.13	2.96	2.72	4.01	3.36	3.39	2.14	3.36	
Bryson City 2	4.86	4.96	6.05	4.24	3.74	3.75	3.85	3.65	3.38	2.76	3.63	4.79	49.66
	2.28	2.29	2.37	1.68	2.08	1.60	1.87	1.86	1.41	1.75	1.26	2.24	
Canton 1SW	3.30	3.20	4.68	3.53	3.56	3.38	3.84	3.83	3.32	2.54	2.68	3.03	40.89
	1.36	1.47	1.90	1.53	1.66	1.62	1.53	1.78	1.82	1.55	1.44	1.49	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Celo 2S	4.84	4.78	6.91	4.94	5.20	4.48	4.84	4.70	5.28	4.61	4.36	4.32	59.26
	2.02	2.33	2.75	2.14	2.35	2.43	2.15	2.34	3.58	3.28	2.88	1.98	
Chapel Hill 2W	3.74	3.84	4.29	3.64	3.92	4.02	4.26	4.61	3.72	3.08	3.15	3.35	45.62
	1.84	1.53	1.61	1.48	1.62	2.10	2.16	2.37	2.22	2.15	2.13	1.50	
Charlotte WSO AP	3.80	3.81	4.81	3.27	3.64	3.57	3.92	3.78	3.59	2.72	2.86	3.40	43.17
	1.68	1.77	1.88	1.49	2.08	1.75	1.95	2.30	2.30	2.20	1.64	1.57	
Clinton 2S	3.76	3.51	3.95	3.29	4.08	5.21	5.82	5.53	4.26	2.89	3.01	3.32	48.63
	1.37	1.49	1.46	1.74	1.86	2.30	2.70	2.90	2.47	2.64	1.79	1.58	
Coweeta Exp. Station	7.01	6.91	8.47	6.34	5.92	5.35	5.06	5.56	5.28	4.51	5.38	7.05	72.84
	2.53	3.45	3.51	2.62	3.98	2.60	2.78	2.80	2.69	3.02	2.29	3.32	

Table 1 (Continued)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Cullowhee	4.63	4.38	5.87	4.02	4.38	4.24	4.42	4.10	3.51	3.11	3.46	4.50	50.62
	1.94	2.08	2.32	1.84	2.49	1.88	2.48	2.58	1.74	1.86	1.48	2.20	
Danbury 1NW	3.32	3.34	4.47	3.90	3.54	4.00	4.19	4.11	3.98	3.73	2.90	3.23	44.71
	1.61	1.62	2.02	1.49	1.81	2.18	2.12	1.82	2.95	2.75	1.60	1.86	
Durham	3.94	4.06	4.17	3.46	4.00	4.31	4.57	4.61	3.75	3.18	3.28	3.48	46.81
	1.96	1.63	1.64	1.68	1.79	2.41	2.68	2.71	2.57	2.08	2.09	1.57	
Edenton	4.11	3.77	4.05	3.39	4.13	4.24	5.56	5.42	4.32	3.42	2.72	3.12	48.25
	1.70	1.58	1.21	1.48	2.13	1.97	3.20	3.22	2.78	2.65	1.41	1.49	
Elizabeth City	4.05	3.79	4.14	2.96	3.96	3.96	5.73	5.81	4.81	3.98	3.02	3.10	49.31
	1.73	1.63	1.58	1.32	2.12	1.84	3.22	3.20	3.79	3.13	1.85	1.37	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Elizabethtown Lock 2	3.47	3.37	4.23	2.90	3.79	4.61	6.07	5.66	4.09	2.88	2.82	2.95	46.84
	1.45	1.56	1.66	1.74	1.64	2.30	2.71	3.23	2.46	2.61	1.64	1.52	
Elkin	3.67	3.65	4.75	4.05	4.28	4.35	3.68	4.64	4.53	3.50	2.95	3.48	47.53
	1.67	1.77	2.00	1.65	1.56	2.40	1.96	2.44	3.03	2.44	1.48	1.81	
Enfield	3.63	3.70	3.87	3.09	3.70	3.45	4.82	4.33	3.66	2.71	2.93	3.16	43.05
	1.75	1.41	1.09	1.54	2.09	1.85	2.67	2.51	1.97	2.34	1.60	1.67	
Enka	3.13	3.33	4.59	3.44	3.87	3.48	3.93	4.53	3.61	3.08	3.00	2.84	42.83
	1.38	1.38	2.18	1.55	2.03	1.79	1.86	2.53	2.28	2.00	1.76	1.55	
Fayetteville	3.65	3.77	4.22	3.02	3.50	4.66	5.66	5.55	4.71	2.76	3.08	3.22	47.80
	1.24	1.74	1.45	1.49	1.37	1.98	2.61	2.79	2.92	2.22	1.86	1.33	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Gastonia	4.16	4.10	5.12	3.57	4.08	4.11	4.16	4.42	3.98	2.82	2.87	3.74	47.13
	1.78	1.93	2.08	1.79	2.22	2.05	2.34	2.77	2.30	2.17	1.64	1.76	
Goldsboro 1SSW	4.07	3.37	4.06	3.45	4.01	4.42	6.40	5.77	4.77	2.84	3.25	3.46	50.23
	1.59	1.55	1.55	1.61	1.46	2.37	2.91	2.74	3.45	2.41	1.96	1.49	
Graham 2ENE	3.67	3.46	4.01	3.25	3.77	3.64	4.21	4.46	3.84	3.04	2.67	3.28	43.30
	1.86	1.42	1.75	1.33	1.76	1.74	2.34	2.00	2.59	2.26	1.53	1.67	
Greensboro WSO AP	3.51	3.37	3.88	3.16	3.37	3.93	4.27	4.19	3.64	3.18	2.59	3.38	42.47
	1.62	1.33	1.64	1.11	1.64	2.14	2.71	2.29	2.74	2.55	1.48	1.61	
Greenville	4.06	3.78	3.92	3.47	4.12	4.31	5.59	6.06	4.77	2.95	3.03	3.24	49.30
	1.55	1.61	1.36	1.77	1.99	2.65	3.07	3.29	3.28	2.50	1.74	1.53	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Hatteras	4.82	3.96	4.07	3.05	4.09	4.30	5.33	5.90	5.45	4.61	4.79	4.29	54.66
	1.95	1.53	2.03	1.56	2.54	2.73	3.27	3.74	3.30	2.65	3.31	1.86	
Henderson 2NNW	3.70	3.54	3.88	3.04	4.04	3.75	4.79	4.93	3.81	3.13	3.14	3.34	45.09
	1.69	1.41	1.44	1.52	1.88	2.28	3.12	2.60	2.23	2.37	1.74	1.47	
Hendersonville 1NE	4.15	4.30	6.14	4.52	4.67	4.98	4.65	5.79	4.49	4.18	3.95	4.33	56.15
	1.81	2.19	2.61	2.15	2.48	2.56	1.72	3.93	2.59	2.88	1.84	2.43	
Hickory FAA AP	3.87	4.58	5.05	3.96	4.67	5.00	4.03	4.87	3.91	3.31	2.98	4.18	50.41
	1.66	1.61	2.34	1.95	2.15	2.60	1.87	2.78	2.51	2.57	1.56	2.20	
Highlands 2S	6.74	6.49	8.68	6.32	7.09	7.37	7.22	7.22	6.60	5.62	5.96	7.12	82.43
	3.06	3.39	4.06	2.83	4.86	3.23	4.53	3.56	3.94	3.98	3.43	4.37	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
High Point	3.52	3.51	4.05	3.37	3.72	4.00	3.81	4.97	3.74	3.18	2.76	3.52	44.15
	1.68	1.47	1.82	1.26	1.89	2.39	2.07	2.57	2.50	2.37	1.42	1.68	
Hoffman Forest	3.97	3.92	4.09	3.11	4.84	5.97	6.99	6.75	5.90	3.36	3.08	3.77	55.75
	1.73	1.68	1.71	1.55	1.85	3.05	2.51	3.94	4.39	2.69	1.63	1.76	
Hot Springs 2	3.54	3.23	4.71	4.01	4.01	3.92	5.26	4.34	3.55	2.53	2.99	2.93	45.02
	1.68	1.66	2.00	1.27	1.43	1.43	1.79	1.38	1.56	1.42	1.21	1.28	
Jefferson	3.56	3.56	4.84	4.05	4.36	4.46	4.43	4.20	4.44	3.67	3.44	3.42	48.43
	1.39	1.51	1.84	1.63	1.88	2.52	1.71	2.44	2.77	2.31	1.91	1.68	
Kinston 5 SE	4.11	3.66	3.95	3.39	4.42	5.39	6.20	5.76	5.30	3.06	2.92	3.42	51.58
	1.50	1.58	1.66	1.58	1.87	3.23	3.02	2.99	3.13	2.47	1.65	1.59	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Lenoir	3.65	4.01	5.04	4.20	4.11	4.56	4.87	4.26	4.59	3.79	3.26	3.63	49.97
	1.24	1.92	2.36	1.90	2.13	1.98	2.39	2.37	2.70	2.57	1.99	1.94	
Louisburg	3.50	4.08	4.19	3.17	3.90	3.95	4.87	4.75	3.96	3.13	3.33	3.43	46.26
	1.84	1.62	1.50	1.53	1.55	2.53	2.65	2.39	2.23	2.48	2.01	1.82	
Lumberton 6NW	3.48	3.40	4.28	2.94	3.73	4.91	5.30	4.96	4.28	2.87	2.73	3.00	45.88
	1.37	1.63	1.91	1.62	2.09	2.08	2.20	2.76	2.82	2.34	1.83	1.38	
Manteo 2WNW	4.20	4.25	4.08	3.06	3.78	3.95	5.24	6.86	5.64	4.30	3.70	3.69	52.75
	1.95	1.72	2.37	1.72	171	2.64	2.87	3.43	2.70	3.54	2.34	1.69	
Marion	4.19	4.53	5.97	4.71	4.80	5.36	4.54	5.41	4.34	4.69	4.19	4.16	56.89
	1.92	2.42	2.66	2.50	2.71	2.88	2.20	3.11	2.91	3.49	2.03	2.35	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Marshall	3.30	3.38	4.48	3.44	3.36	3.50	4.33	3.64	2.97	2.40	2.83	2.89	40.52
	1.45	1.63	1.86	1.34	1.39	1.35	1.90	1.86	1.67	1.37	1.37	1.23	
Mocksville	3.81	3.62	4.76	3.42	4.05	4.36	3.64	3.87	4.33	3.39	2.81	3.58	45.64
	1.55	1.50	1.96	1.33	2.01	2.11	1.54	2.06	2.97	2.40	1.62	1.82	
Moncure 3SE	3.86	3.79	4.24	3.28	4.02	4.31	5.67	5.32	3.77	3.32	3.14	3.66	48.38
	1.92	1.45	1.28	1.47	1.55	2.63	2.83	2.64	2.26	2.42	2.00	1.64	
Monroe 4SE	4.11	3.91	4.68	3.21	3.61	3.96	5.10	4.74	4.19	3.22	2.78	3.42	46.93
	1.76	1.80	1.79	1.44	1.82	1.84	2.42	3.16	2.86	2.79	1.87	1.80	
Morehead City 2WNW	4.13	3.97	3.68	2.90	4.27	4.57	6.57	6.08	5.32	3.77	3.39	3.99	52.64
	2.03	1.76	1.40	1.54	1.84	2.33	2.80	4.57	3.55	2.75	2.03	2.42	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Morganton	3.99	4.22	5.07	4.04	4.62	4.60	4.13	3.90	4.99	3.81	3.19	3.72	50.28
	1.66	2.09	2.18	1.93	2.14	2.18	1.92	2.50	3.27	2.88	1.80	2.15	
Mount Airy	3.37	3.50	4.46	3.95	3.96	3.87	4.02	4.36	4.22	3.35	2.91	3.47	45.44
	1.46	1.68	1.70	1.50	1.52	1.85	2.20	2.52	2.93	2.40	1.41	1.79	
Mount Holly 4NE	3.80	4.10	5.01	3.41	3.76	4.03	3.94	3.92	3.57	2.93	2.87	3.64	44.98
	1.65	1.58	1.90	1.55	2.37	2.05	2.11	2.48	1.84	2.19	1.75	1.85	
Murphy	5.36	5.40	6.43	5.02	4.24	4.39	5.23	4.67	3.75	2.85	3.98	4.76	56.08
	2.23	2.77	2.93	1.83	1.94	1.97	2.01	2.54	1.77	1.86	1.43	2.49	
Nashville	3.46	3.70	3.96	3.11	3.93	3.86	4.70	4.46	3.74	2.95	3.15	3.18	44.20
	1.55	1.37	1.19	1.16	1.94	1.86	2.84	2.80	2.34	2.55	1.99	1.47	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Neuse 2NE	3.75	3.79	4.08	3.23	3.97	3.98	4.27	4.33	3.59	2.99	3.29	3.53	44.80
	1.86	1.57	1.33	1.52	1.60	2.33	2.44	2.26	2.02	2.04	2.02	1.62	
New Holland	4.17	3.91	3.61	3.31	4.25	4.41	6.25	6.45	5.62	3.90	3.69	3.33	52.90
	2.11	1.51	1.67	1.45	1.84	2.51	2.89	3.20	3.82	3.25	2.37	1.70	
North Wilkesboro	3.76	3.91	4.92	4.20	3.94	5.01	3.95	4.75	4.18	3.71	3.17	3.70	49.20
	1.54	2.01	2.10	1.77	1.60	2.46	1.72	2.83	2.75	2.65	1.55	1.86	
Oxford 2SW	3.51	3.59	3.92	3.09	3.94	3.93	4.64	4.70	3.54	2.97	3.13	3.28	44.24
	1.83	1.52	1.63	1.49	1.62	2.07	3.07	2.46	2.24	2.04	1.93	1.45	
Pinehurst Southern Pines	3.75	4.20	4.59	3.46	4.22	4.94	5.50	4.97	3.92	3.53	2.83	3.60	49.51
	1.64	1.61	1.74	1.59	1.97	2.12	2.82	2.85	2.63	2.73	2.09	1.63	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Raleigh-Durham WSO AP	3.55	3.43	3.67	2.91	3.67	3.66	4.38	4.44	3.29	2.73	2.87	3.14	41.74
	1.72	1.28	1.26	1.42	1.56	1.97	2.15	2.27	1.72	1.78	1.85	1.39	
Raleigh 4SW	3.79	3.75	4.19	3.36	4.44	3.93	5.09	4.58	3.83	3.12	3.40	3.34	46.82
	1.72	1.44	1.48	1.62	2.03	1.96	2.85	2.59	2.19	2.03	2.12	1.54	
Randleman	3.80	3.65	4.08	3.54	4.01	4.15	4.59	4.70	3.91	2.93	2.63	3.49	45.48
	1.85	1.64	1.58	1.36	1.70	2.29	3.12	2.24	2.32	2.30	1.45	1.59	
Red Springs	3.60	3.71	4.05	3.09	3.66	4.76	5.26	4.50	4.31	2.59	2.88	3.31	45.72
	1.36	1.72	1.43	1.54	1.92	1.92	2.41	2.79	2.53	2.21	2.01	1.56	
Rocky Mount 8 ESE	3.77	3.74	4.12	3.05	3.65	4.50	5.14	5.04	4.07	2.98	2.95	3.25	46.26
	1.52	1.47	1.25	1.35	1.65	2.46	2.83	2.77	2.66	2.63	1.56	1.44	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rougemont	3.79	3.54	4.10	3.35	3.96	3.98	4.37	4.34	3.67	3.14	3.17	3.27	44.68
	1.86	1.44	1.61	1.44	1.73	1.82	2.69	2.50	2.07	2.17	2.08	1.50	
Roxboro	3.65	3.36	3.75	3.25	3.74	3.95	4.34	4.50	3.78	3.21	3.08	3.18	43.79
	1.67	1.51	1.42	1.37	1.50	2.11	2.58	2.43	2.83	2.27	1.84	1.68	
Salisbury	3.72	3.78	4.61	3.38	3.66	4.20	4.61	3.97	3.64	3.21	2.92	3.56	45.26
	1.66	1.56	1.99	1.32	1.77	1.96	1.89	1.95	2.26	2.60	1.60	1.72	
Scotland Neck	3.92	3.90	3.99	3.01	3.90	4.50	5.21	4.77	4.29	3.42	3.00	3.37	47.28
	1.70	1.45	1.20	1.23	1.93	2.59	2.88	2.65	2.99	2.94	1.63	1.59	
Shelby 2NNE	4.18	4.03	5.35	3.91	4.12	4.57	4.35	4.71	4.04	3.35	3.15	3.98	49.74
	1.77	1.78	2.15	2.29	2.31	2.17	2.44	2.96	2.43	2.89	1.90	2.22	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Siler City 2NW	4.05	3.85	4.34	3.45	4.00	3.97	4.87	5.19	3.89	3.30	2.91	3.44	47.26
	1.98	1.65	1.51	1.43	1.74	2.12	2.68	2.66	2.32	2.44	1.84	1.68	
Sloan 3S	4.11	3.78	4.43	3.28	4.69	4.08	7.26	5.88	5.22	2.54	3.10	3.38	53.75
	1.77	1.66	1.78	1.42	2.00	3.25	3.30	2.96	3.11	1.78	1.81	1.79	
Smithfield	3.88	3.98	4.18	3.40	3.78	3.74	5.65	4.64	4.65	3.15	3.03	3.27	47.35
	1.52	1.62	1.29	1.94	1.61	1.95	3.37	3.47	2.73	3.00	1.83	1.45	
Southport 5N	4.32	3.89	4.40	2.74	3.87	4.86	6.43	6.63	7.08	3.47	3.13	4.04	54.86
	2.08	1.98	2.0	2.05	1.89	2.86	3.39	3.57	4.19	2.75	1.96	1.92	
Statesville 2NNE	3.80	3.90	4.82	3.52	3.85	4.52	3.62	4.37	4.12	3.15	2.98	3.85	46.50
	1.84	1.69	2.00	1.46	1.85	1.92	1.73	2.17	2.87	2.25	1.72	1.97	

Table 1 (Contined)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Swannanoa 2E	3.28	3.11	4.54	3.69	4.13	4.05	3.86	4.13	3.93	3.30	3.34	3.04	44.40
	1.47	1.62	1.89	1.67	2.16	1.61	1.69	2.43	2.27	2.11	1.82	1.51	
Tapoco	5.72	5.13	6.74	4.86	4.61	4.88	6.13	5.30	3.77	3.16	4.41	4.94	59.65
	2.32	2.64	2.64	1.69	2.04	2.26	2.83	2.61	1.70	1.89	1.89	2.37	
Tarboro 1S	4.03	3.84	4.25	3.02	3.75	4.41	4.91	5.78	4.54	3.14	2.98	3.32	47.97
	1.53	1.62	1.28	1.39	1.56	2.17	2.40	3.37	3.02	2.74	1.53	1.46	
Tryon	5.32	5.52	7.14	5.31	5.86	5.67	5.14	5.23	5.56	4.77	4.15	5.16	64.83
	2.27	2.93	3.00	2.64	3.48	2.97	2.31	3.29	4.08	3.57	1.88	2.85	
Waynesville 1E	4.37	4.05	5.63	3.96	3.87	3.56	4.05	3.87	3.48	2.79	3.14	4.06	46.83
	1.90	1.98	2.36	1.79	1.64	1.67	1.64	1.81	2.03	1.71	1.60	1.89	

Table 1 (Contined)

Station		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Willard 4SW		3.95	3.81	4.03	2.88	4.33	5.76	7.53	6.08	5.32	2.71	3.17	3.21	52.78
		1.81	1.78	1.59	1.25	2.52	3.18	3.31	2.95	2.78	1.95	1.99	1.47	
Williamston 1ENE		3.86	3.66	4.02	3.28	4.39	4.26	5.74	5.42	4.57	3.42	2.72	3.02	48.36
		1.43	1.59	1.19	1.36	2.17	2.72	2.89	3.72	3.18	3.03	1.57	1.51	
Wilmington WSO AP		3.64	3.45	4.05	2.99	4.23	5.62	7.44	6.67	5.71	2.97	3.19	3.43	53.39
		1.64	1.47	1.73	1.90	2.02	3.30	3.34	3.18	3.68	2.33	1.96	1.58	

Appendix A -
STATION INDEX

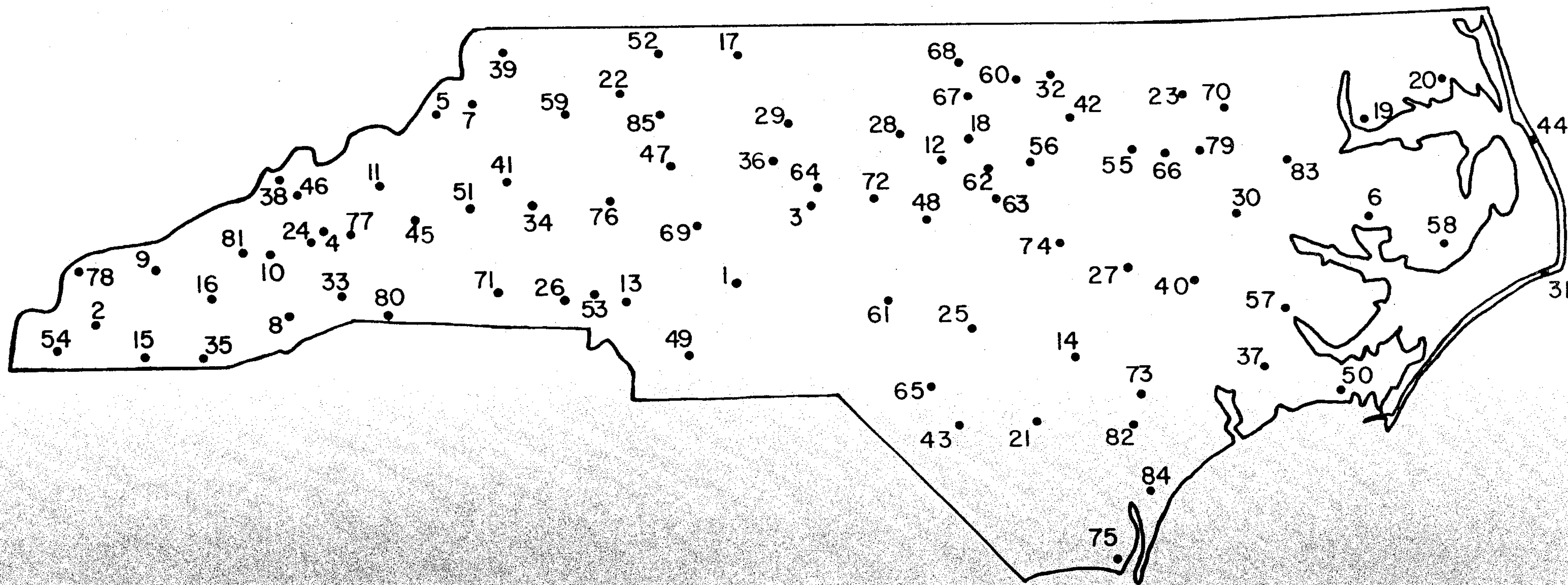
Station	County	Longitude (Degrees,	Latitude Minutes)	Elevation (Feet)	Station Number
Albemarle 4N	Stanly	35 21	80 12	500	1
Andrews 2E	Cherokee	35 12	83 48	1827	2
Asheboro 2W	Randolph	35 42	79 50	870	3
Asheville	Buncombe	35 36	82 32	2203	4
Banner Elk	Avery	36 10	81 52	3750	5
Belhaven	Beaufort	35 33	76 38	10	6
Boone	Watauga	36 13	81 41	3360	7
Brevard	Transylvania	35 14	82 44	2155	8
Bryson City 2	Swain	35 25	83 27	2000	9
Canton 1SW	Haywood	35 32	82 51	2662	10
Celo 2S	Yancey	35 50	82 11	2700	11
Chapel Hill 2W	Orange	35 55	79 06	500	12
Charlotte WSO AP	Mecklenburg	35 13	80 56	725	13
Clinton 2S	Sampson	34 58	78 19	150	14
Coweeta Exp. Stat.	Macon	35 04	83 26	2249	15
Cullowhee	Jackson	35 19	83 11	2100	16
Danbury 1NW	Stokes	36 25	80 13	840	17
Durham	Durham	36 02	78 58	406	18
Edenton	Chowan	36 03	76 37	20	19
Elizabeth City	Pasquotank	36 18	76 13	8	20
Elizabethtown Lock 2	Bladen	34 38	78 35	60	21
Elkin	Surry	36 14	80 51	880	22
Enfield	Edgecombe	36 09	77 41	111	23
Enka	Buncombe	35 33	82 39	2050	24
Fayetteville	Cumberland	35 03	78 51	96	25
Gastonia	Gaston	35 16	81 11	810	26
Goldsboro 1SSW	Wayne	35 21	78 01	82	27
Graham 2ENE	Alamance	36 04	79 24	656	28
Greensboro WSO AP	Guilford	36 05	79 57	897	29
Greenville	Pitt	35 37	77 22	25	30
Hatteras	Dare	35 13	75 41	5	31
Henderson 2NNW	Vance	36 19	78 26	510	32
Hendersonville 1NE	Henderson	35 20	82 28	2153	33
Hickory FAA AP	Catawba	35 45	81 21	1165	34
Highlands 2S	Macon	35 01	83 12	3350	35
Highpoint	Guilford	35 57	80 00	912	36
Hoffman Forest	Onslow	34 50	77 18	44	37
Hot Springs 2	Madison	35 54	82 50	1480	38
Jefferson	Ashe	36 25	81 29	2900	39
Kinston 5SE	Lenoir	35 13	77 32	55	40
Lenoir	Caldwell	35 55	81 32	1294	41
Louisburg	Franklin	36 06	78 19	260	42
Lumberton 6NW	Robeson	34 42	79 04	132	43
Manteo 2WNW	Dare	35 56	75 42	10	44
Marion	McDowel	35 41	82 01	1425	45
Marshall	Madison	35 48	82 40	2010	46
Mocksville	Davie	35 53	80 34	814	47

Appendix A -- (Continued)

Station	County	Longitude (Degrees,	Latitude Minutes)	Elevation (FEET)	Station Number
Moncure 3SE	Chatham	35 35	79 03	202	48
Monroe 4SE	Union	34 58	80 31	586	49
Morehead City 2WNW	Carteret	34 44	76 44	10	50
Morganton	Burke	35 45	81 41	1110	51
Mount Airy	Surry	36 31	80 37	1090	52
Mount Holly 4NE	Gaston	35 19	80 59	700	53
Murphy	Cherokee	35 06	84 02	1575	54
Nashville	Nash	35 58	77 58	205	55
Neuse 2NE	Wake	35 54	78 34	281	56
New Bern 3NW	Craven	35 08	77 05	12	57
New Holland	Hyde	35 27	76 11	2	58
North Wilkesboro	Wilkes	36 10	81 09	1118	59
Oxford 2SW	Granville	36 17	78 37	500	60
Pinehurst-Southern Pines	Moore	35 12	79 28	548	61
Raleigh-Durham WSO AP	Wake	35 52	78 47	434	62
Raleigh 4SW	Wake	35 44	78 41	420	63
Randleman	Randolph	35 48	79 49	810	64
Red Springs	Robeson	34 49	79 12	204	65
Rocky Mount 8ESE	Edgecombe	35 54	77 43	110	66
Rougemont	Durham	36 13	78 55	549	67
Roxboro	Person	36 24	78 58	690	68
Salisbury	Rowan	35 41	80 29	700	69
Scotland Neck	Halifax	36 08	77 25	102	70
Shelby 2 NNE	Cleveland	35 20	81 32	915	71
Siler City 2NW	Chatham	35 43	79 27	625	72
Sloan 3S	Duplin	34 47	77 49	50	73
Smithfield	Johnston	35 31	78 21	146	74
Southport 5N	Brunswick	33 55	78 01	15	75
Statesville 2NNE	Iredell	35 49	80 53	950	76
Swannanoa 2E	Buncombe	35 36	82 22	2230	77
Tapoco	Graham	35 27	83 56	1110	78
Tarboro	Edgecombe	35 54	77 32	50	79
Tryon	Polk	35 13	82 14	1075	80
Waynesville 1E	Haywood	35 29	82 57	2638	81
Willard 4SW	Pender	34 43	77 59	51	82
Williamston 1ENE	Martin	35 51	77 02	20	83
Wilmington WSO AP	New Hanover	34 16	77 55	30	84
Yadkinville 6E	Yadkin	36 08	80 31	860	85

Notes: Figures and letters following the station name indicate the distance in miles and direction from the post office or town center.

STATION LOCATION MAP



Appendix B.

The present calculations assume a normal data distribution. For fitting precipitation totals for periods of a month or less, the gamma distribution has been widely used. It should be considered for fitting any variable bounded by zero on the low end and unbounded on the upper end. For precipitation data it is ideal since for periods on the order of one or two weeks there will be a high frequency of zero values; however, there is also a possibility of large precipitation amounts from thunderstorms. In the gamma distribution the mean is weighted toward the larger amounts and is larger in value than the median for short-period precipitation summaries.

Precipitation totals approach a normal distribution as the length of the period over which precipitation is summed increases. In wetter areas even monthly totals may be near normal; however, in desert areas even the annual totals may be skewed.

The figure below shows three November precipitation frequency distributions for Piracicaba, Sao Paulo, Brazil, for the period 1941-1970. The gamma distribution fits the empirical distribution better than the normal distribution. Goodness of fit can be tested statistically, which is currently being undertaken for the North Carolina data. This information on the gamma distribution was provided by courtesy of Professor Robert F. Dale, Department of Agronomy, Purdue University.