To the Graduate Council:

I am submitting herewith a thesis written by Linda Pasqua Marcus entitled "A Comparison of Local Precipitation Patterns to Synoptic Situations in the Southern Blue Ridge Mountains: Summer 1972." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geography.

James R. Carter

James R. Carter, Major Professor

We have read this thesis
and recommend its acceptance:

Edwin H. Hammond

Robert G. Long

Accepted for the Council:

Hilton A. Smith

Vice Chancellor
Graduate Studies and Research

A COMPARISON OF LOCAL PRECIPITATION PATTERNS TO SYNOPTIC SITUATIONS IN THE SOUTHERN BLUE RIDGE MOUNTAINS: SUMMER 1974

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Linda Pasqua Marcus

December 1974

ACKNOWLEDGEMENTS

The author is indebted to the members of her committee: Dr. James R. Carter, Dr. Edwin H. Hammond, and Dr. Robert G. Long. Their guidance in the preparation of this thesis is deeply appreciated.

The author also wishes to thank her husband for his sacrifices and encouragement during the period of research and writing.

1176341

ABSTRACT

The purpose of this study is to see whether recognizable synoptic weather types, in combination with the complex relief of the Southern Blue Ridge Mountains, produced distinctive local patterns of precipitation during the summer months of 1972. The study area consisted of the Holston River Basin, the French Broad River Basin, the Little Tennessee River Basin, the Hiwassee River Basin, and a portion of the Tennessee River Basin near Knoxville. These drainage basins extend from southern Virginia to north Georgia.

Two types of data were collected for this study--daily precipitation data and synoptic data. The daily precipitation data consisted of daily precipitation totals reported by TVA and hourly precipitation totals reported by the NWS. This data was used to classify local precipitation pattern types. The synoptic data consisted of North American Surface Charts, Moisture Composite Index Charts, and 500-Millibar Charts compiled by the NWS. The study of the synoptic data allowed for the formulation of causal factors that account for the precipitation patterns.

This investigation revealed that synoptic weather types, in combination with the complex relief of the Southern Blue Ridge Mountains, produce distinctly different patterns of precipitation. The various combinations of frontal activity, upper atmosphere stability/instability, precipitable water, 500 mb wind directions and speeds, and topography lead to the distinctive patterns of precipitation which were grouped into twelve classes.

TABLE OF CONTENTS

CHAPTER		PAGE
I.	INTRODUCTION	1
	Review of the Literature	2
	Study Area	7
II.	SOURCES OF DATA	13
	Precipitation Data	13
	Synoptic Data	16
III.	CLASSIFICATION AND EVALUATION OF PRECIPITATION PATTERNS	23
	Classification of Precipitation Patterns	23
	Classes of Local Precipitation Patterns	25
	Generation of Local Precipitation Patterns	63
IV.	CONCLUSIONS	83
	Problem of the Precipitation Gaging Network	83
	Problem of Data Comparability	83
	Findings	84
SELECTED BIBLIOGRAPHY		88
APPENDIX		91
VITA		94

LIST OF TABLES

TABLE		PAGE
1.	A Comparison of TVA and NWS Precipitation Reports Which Illustrates How Different Reporting Times Affect Daily Rainfall Totals - TVA Reported Through 7 A.M. and NWS Reported Through Midnight	17
2.	Classification of Daily Precipitation Patterns in the Southern Blue Ridge Mountains Based on Summer 1972 Rainfall Events.	27
3.	Precipitation Pattern Classes During June.	42
4.	Precipitation Pattern Classes During July.	43
5.	Precipitation Pattern Classes During August.	44
6.	Precipitation Pattern Classes During September	45

LIST OF FIGURES

FIGURES PAGE

1. National Weather Service Standard Rain Gage 4
2. Conceptual Model of the Processes Involved in Determining Rainfall with a Conventional Rain Gage. . . . 6
3. The Drainage Basins Delimiting the Study Area are the Holston River Basin, the French Broad River Basin, the Little Tennessee River Basin, the Hiwassee River Basin, and a Portion of the Tennessee River Basin near Knoxville. 9
4. Pattern of the Precipitation Gaging Network, September 1972. 10
5. Primary Sources of Moisture Enterning the Study Area. . . 11
6. Elevations in the Study Area. 12
7. Comparison of Precipitation Amounts Received at Two Rain Gages only Two Feet Apart, 209 and 209A in Gatlinburg, Tennessee; Illustrates Data Inconsistency due to an Eight Hour Difference in Gage Reading Times . . 15
8. The Four Sections Designated to Classify Local Rainfall Patterns. The Northeast-Southwest Boundary is the Major Ridgeline Between Tennessee and North Carolina. The Northwest-Southeast Boundaries are Drainage Basin Limits. 24
9. Example of Class A - September 5, 1972. 28
10. Example of Class B - July 15, 1972. 29
11. Example of Class N - July 5, 1972 31
12. An Example of Class NE - September 6, 1972. 32
13. An Example of Class E - July 21, 1972 33
14. Example of Class SE - August 12, 1972 34
15. Example of Class S - August 6, 1972 35
16. Example of Class SW - August 9, 1972. 37

FIGURE PAGE

17. Example of Class W - September 24, 1972 38
18. Example of Class WD - July 19, 1972 39
19. Example of Class ND - September 17, 1972. 40
20. Synoptic Charts for July 18 47
21. Synoptic Charts for July 19 48
22. Synoptic Charts for July 20 50
23. Synoptic Charts for July 21 51
24. Synoptic Charts for July 22 53
25. Synoptic Charts for July 23 54
26. Synoptic Charts for July 24 56
27. Synoptic Charts for July 25 57
28. Synoptic Charts for July 26 59
29. Synoptic Charts for July 27 60
30. Synoptic Charts for July 28 62
31. Characteristic Motion of a Cold Front with the Low Centered over the Great Lakes and Producing a Class A Pattern 65
32. Example of the Development of a Small Cyclonic System Producing a Class A Pattern. 66
33. Synoptic Charts for August 2 that Produced a Class A Pattern 68
34. Example of Class SP1 - July 2, 1972 70
35. Example of Class SP2 - September 25, 1972 73
36. Synoptic Charts for September 25. 74
37. Stalled Cold Front that Produces a Class N Pattern. . . . 76

CHAPTER I

INTRODUCTION

Precipitation is an important and vital process, for it is the primary manner in which "new" water enters an environmental system. Precipitation, along with the reception of solar energy, controls the world-wide growth of the biomass and the erosion processes working on the land surface. It is important to be familiar with precipitation characteristics in order to understand what is going on in an environment. Mountainous environments are especially intriguing since their complex topographic features lead to interesting precipitation characteristics. The purpose of this study is to see whether recognizable synoptic weather types, in combination with the complex relief of the Southern Blue Ridge Mountains, produce distinctive local patterns of precipitation.

The Southern Blue Ridge Mountains are located in the mid-latitudes, and the differences in seasonal processes become important when inspecting synoptic weather types and rainfall generation. "Winter rains, in general, are of the cyclonic type,"[1] while summer precipitation "is more dependent on local heating effects and is usually of the convective thunderstorm type."[2] This leads to more diverse precipitation developments in the summer than in the winter. It is for

---

[1]Tennessee Valley Authority, Division of Water Control Planning, Hydraulic Data Branch, Precipitation-Altitude Study: Snowbird Mountains, North Carolina, Report No. 0-5620, December, 1955, p. 15.

[2]Precipitation-Altitude Study, op. cit., p. 14.

this reason that the synoptic situations and local precipitation patterns are examined and compared for the summer months of 1972--June, July, August, and September. If patterns can be discerned one can gain a better understanding of where precipitation might be expected and how the gross relief affects its distribution in the Southern Blue Ridge Mountains.

Review of the Literature

Large amounts of precipitation data have been collected in the study region; however, only two studies have been published that use the data to examine precipitation relationships in part or all of the study area. The first study, Precipitation-Altitude Study: Snowbird Mountains, North Carolina, by the Tennessee Valley Authority (TVA), reviews the types of precipitation expected in a small part of this area, and focuses especially on the relationship of rainfall and elevation. It concludes that "there is a definite increase of precipitation with the increase in elevation when the precipitation results from cyclonic circulation."[3] The second study, Probable Maximum and TVA Precipitation for Tennessee River Basins up to 3000 Square Miles in Area and Durations to 72 Hours,[4] by TVA, is most pertinent to this investigation. It centers on massive storms which have occurred in the Tennessee Valley. The discussion of topographic

---

[3]Precipitation-Altitude Study, op. cit., p. 16.

[4]Francis K. Schwarz and Norber F. Helfert, Probable Maximum and TVA Precipitation for Tennessee River Basins up to 3000 Square Miles in Area and Durations to 72 Hours, Hydrometeorological Report No. 45, prepared for the Tennessee Valley Authority (Washington, D.C: Government Printing Office, 1969).

influences on intense storms, as well as, the dominant wind directions in the drainage basins are important considerations for this investigation.

An example of a study of this kind is an article by Russell D. Thompson that considers the influence of atmospheric circulations on rainfall and temperature distributions in New South Wales, Australia.[5] Thompson is concerned with the development of synoptic classifications of local rainfall patterns. He shows how rainfall and temperature distributions in his study area vary considerable with different air flow patterns.[6]

Besides the three studies mentioned above, the literature concerning rain gage placement is important in understanding the reliability of the precipitation data used for this study. TVA uses the National Weather Service (NWS) standard rain gage and has established a dense network of gages in its territory (Fig. 1). The station density is very high when compared to other sections of the nation. Although more compact, this arrangement of TVA monitored stations does not place the gages very close together, for there are only 275 gages in an area of over 17,000 square miles. The problem of gage placement and resultant networks has continually plagued climatologists. F. A. Huff and W. L. Shipp, among others, have written numerous articles on precipitation and gage sampling densities. In one study Huff determined

---

[5]Russell D. Thompson, "Some Aspects of the Synoptic Mesoclimatology of the Armidale District, New South Wales, Australia," Journal of Applied Meteorology, XII (June, 1973), pp. 578-88.

[6]Russell D. Thompson, op. cit., p. 587.



Figure 1. National Weather Service Standard Rain Gage.

how many gages are needed per square mile in order to get precipitation measurements of varied accuracies for given probabilities of storm detection. In one case he found that "if the user could limit his detection requirements to 99% detection of storms with areal means exceeding 0.05 inch, the summer curves for 0.06-0.10 inch show a required density of only 1 gage in 90 mi^2."[7] This density is much greater than the normal climatic network density for Illinois, which is about one gage per 225 square miles,[8] and less than the density in the study area, which is approximately one gage per 86 square miles.

A valuable study on the subject of measuring rainfall with rain gages is "The Assessment of Precipitation" by John C. Rodda.[9] A good way to see the many problems involved with a gaging system is to look at the conceptual model, which Rodda devised, of the processes involved in determining rainfall (Fig. 2). The model shows how features of the physical and human systems interact to affect the estimation of rainfall for some point. All facets of the model work against accurate values for rainfall estimations. Nevertheless, this method does allow establishment of basic rainfall trends for an area, especially those that occur time and again. When speaking of rain gage densities Rodda says:[10]

> It could be argued that networks designed for the same purpose would need to be more dense in mountainous areas than in flat country, because of

---

[7]F. A. Huff, "Precipitation Detection by Fixed Sampling Densities," Journal of Applied Meteorology, VII (October, 1969), p.837.

[8]F. A. Huff, op. cit., p. 134.

[9]John C. Rodda, "The Assessment of Precipitation," in Water, Earth and Man, ed. by Richard J. Chorley (London: Methuen & Co LTD, 1969).

[10]John C. Rodda, op. cit., p. 134.

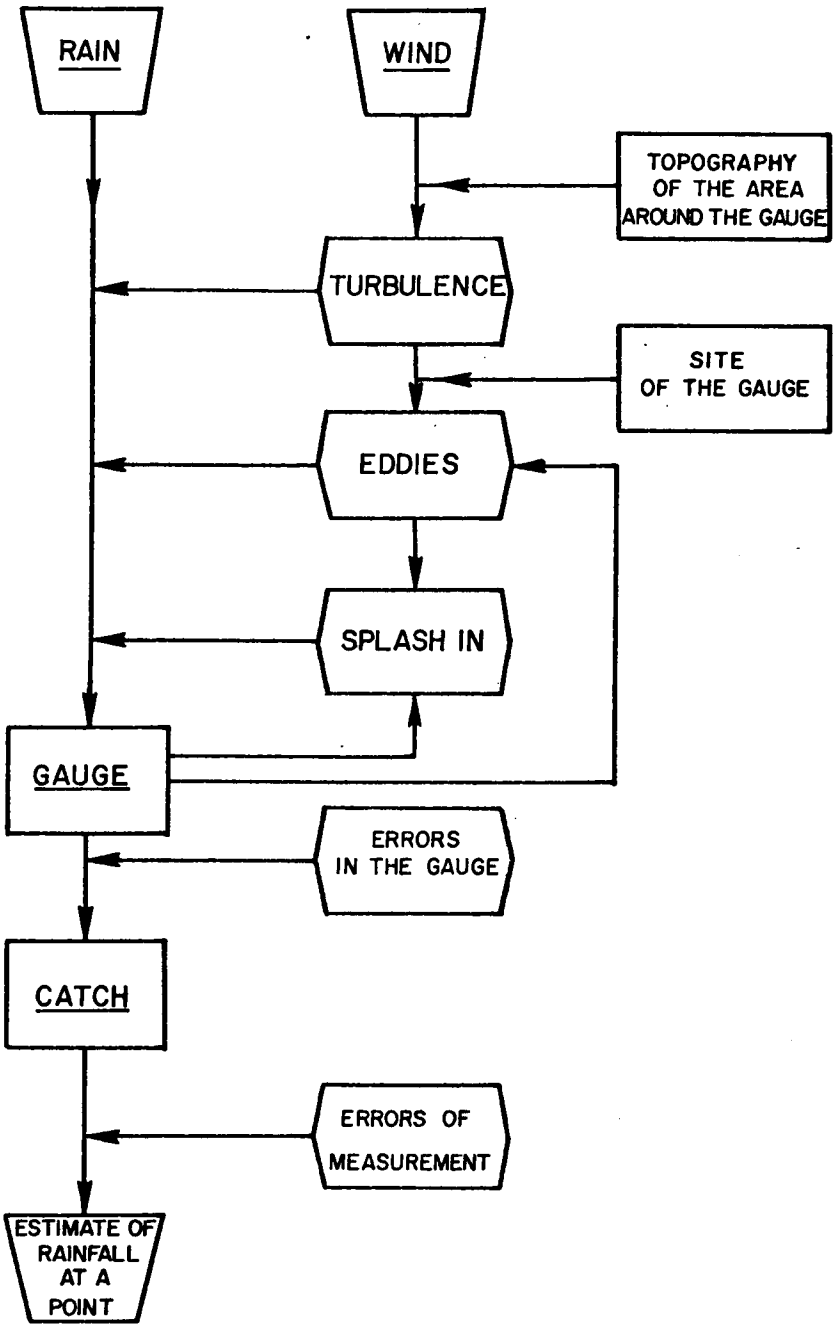


Figure 2. Conceptual Model of the Processes Involved in Determining Rainfall with a Conventional Rain Gage.

Source: John C. Rodda, "The Assessment of Precipitation," in Water, Earth and Man, ed. by Richard J. Chorley (London: Methuen & Co LTD, 1969), p.132.

> wider variations in rainfall that are found where differences in relief are most marked. However, this matter is not clear, because similar patterns of rainfall occur over mountainous areas, patterns which appear to be highly correlated with one another; as opposed to the more random distribution of rain that takes place in flat areas.

No gaging density is going to be perfect for observing precipitation. The one monitored by TVA is one of the most dense in the world over any sizeable area and therefore provides a better than average basis for evaluating the precipitation of the Southern Blue Ridge Mountains. That the network is less than desired should not detract from the study, but it should be realized that limits are imposed on the interpretation of the results.

The rugged topography of the area is hypothesized to influence precipitation amounts recorded at any station. The physical features, essentially, become a part of the recording station itself and ought to influence all weather systems of similar configuration in similar manners. When a weather system arrives in an area it is met with the same topographic arrangements that have met or will meet all previous and subsequent similar weather systems. The resulting patterns of precipitation should be much alike.

Study Area

The study area is located in the Southern Blue Ridge Mountains of east Tennessee, western North Carolina, north Georgia, southern Virginia, and northern South Carolina in the Southeastern United States. Four major drainage basins feeding the Tennessee River delimit the boundaries of the study area. The watersheds are those of the Holston River, the French Broad River, the Little Tennessee River,

the Hiwassee River, and a small portion of the Tennessee River basin near Knoxville (Fig. 3). Within the study area there were 275 rain gages under the auspices of TVA, that reported daily precipitation amounts in the summer of 1972 (Fig. 4).

This section of the country has a climatic classification of Subtropical Humid which is characterized by abundant precipitation occurring on the western limb of an oceanic subtropical anticyclone.[11] Moisture enters the area from the Atlantic Ocean, Caribbean Sea, and the Gulf of Mexico, primarily the latter two. Most moisture-laden air moves from the south or southeast[12] (Fig. 5).

Mixed broadleaf-conifer forests are the dominant vegetation type in the region. There is some cropland, especially on the western side. Cropland, however, is limited in extent because of the low soil fertility and rough topography. There are no large urban areas within the region that might influence precipitation generation.

The land surface form itself is an important aspect of the environment. Elevations range from 700 to over 6000 feet. Rugged mountains oriented from southwest to northeast, occupy the eastern portion of the region. The elevations of the western side of the study area are much lower and the terrain less mountainous than those of the eastern side (Fig. 6).

---

[11] Glenn T. Trewartha, Arthur H. Robinson, and Edwin H. Hammond, Fundamentals of Physical Geography (New York: McGraw-Hill Book Company, 1968), p. 109.

[12] Precipitation-Altitude Study, op. cit., p. 5.

STUDY AREA

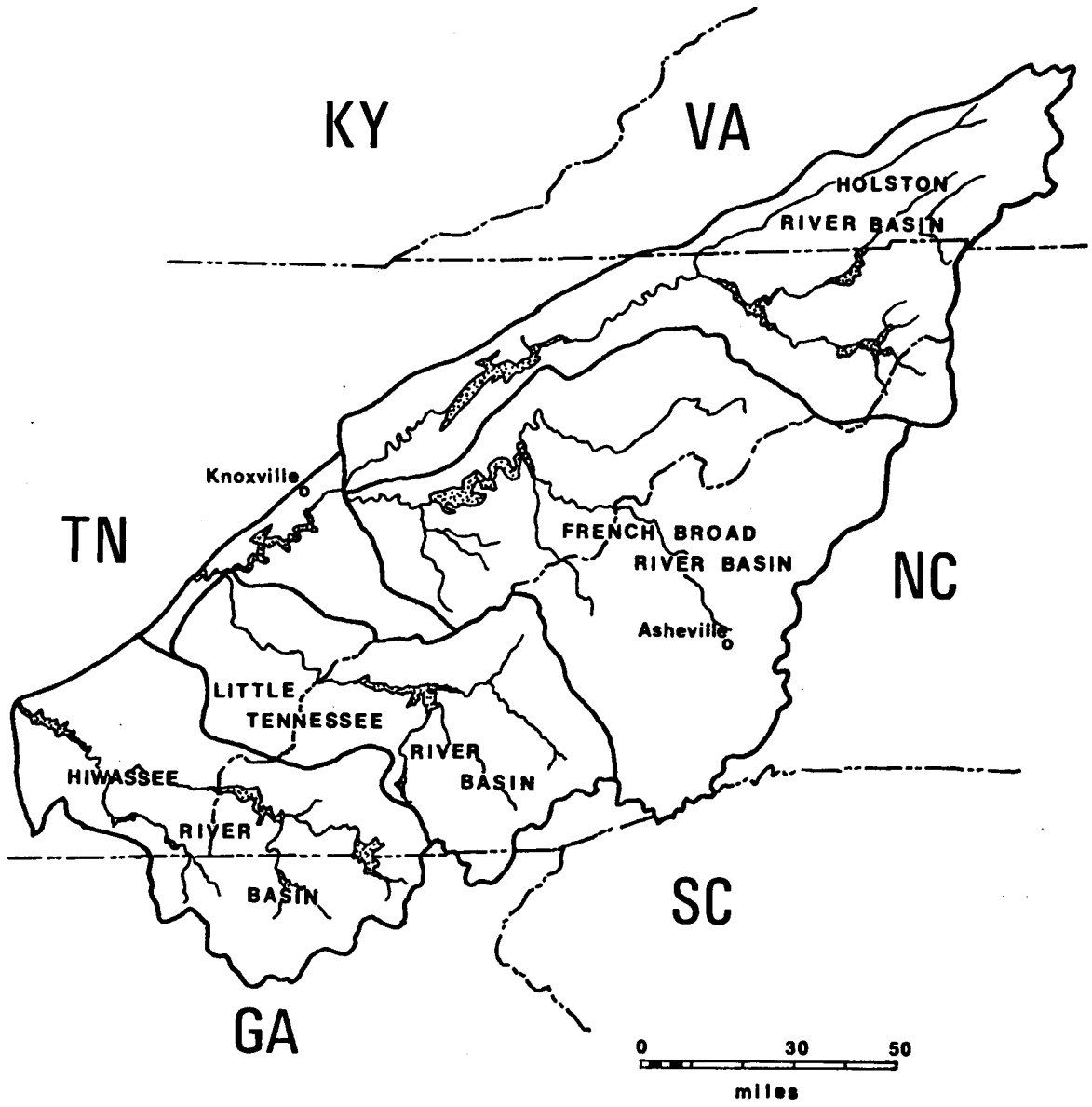


Figure 3. The Drainage Basins Delimiting the Study Area are the Holston River Basin, the French Broad River Basin, the Little Tennessee River Basin, the Hiwassee River Basin, and a Small Portion of the Tennessee River Basin near Knoxville.

PATTERN OF THE PRECIPITATION GAGING NETWORK, SEPTEMBER 1972

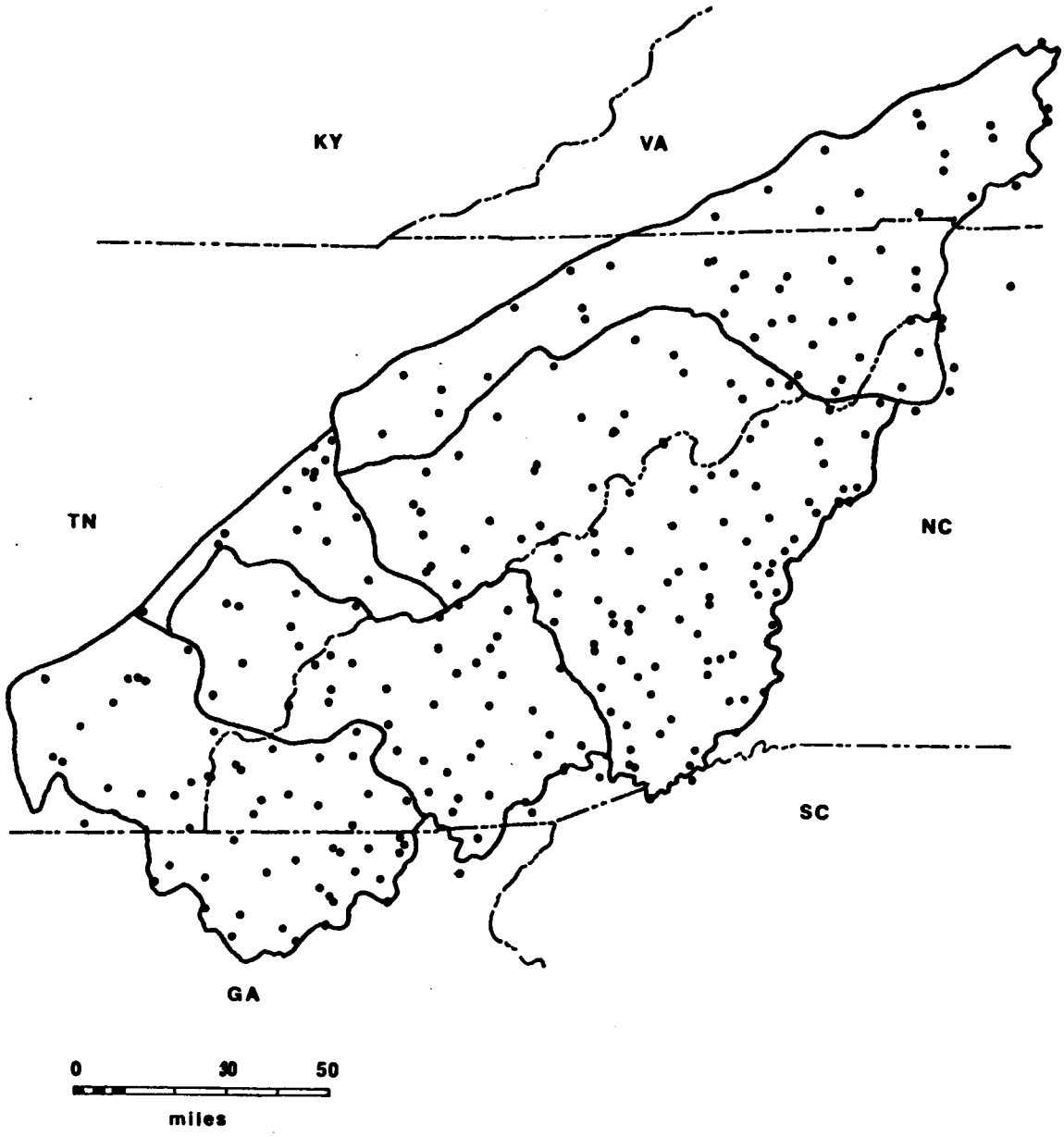


Figure 4. Pattern of the Precipitation Gaging Network, September 1972.

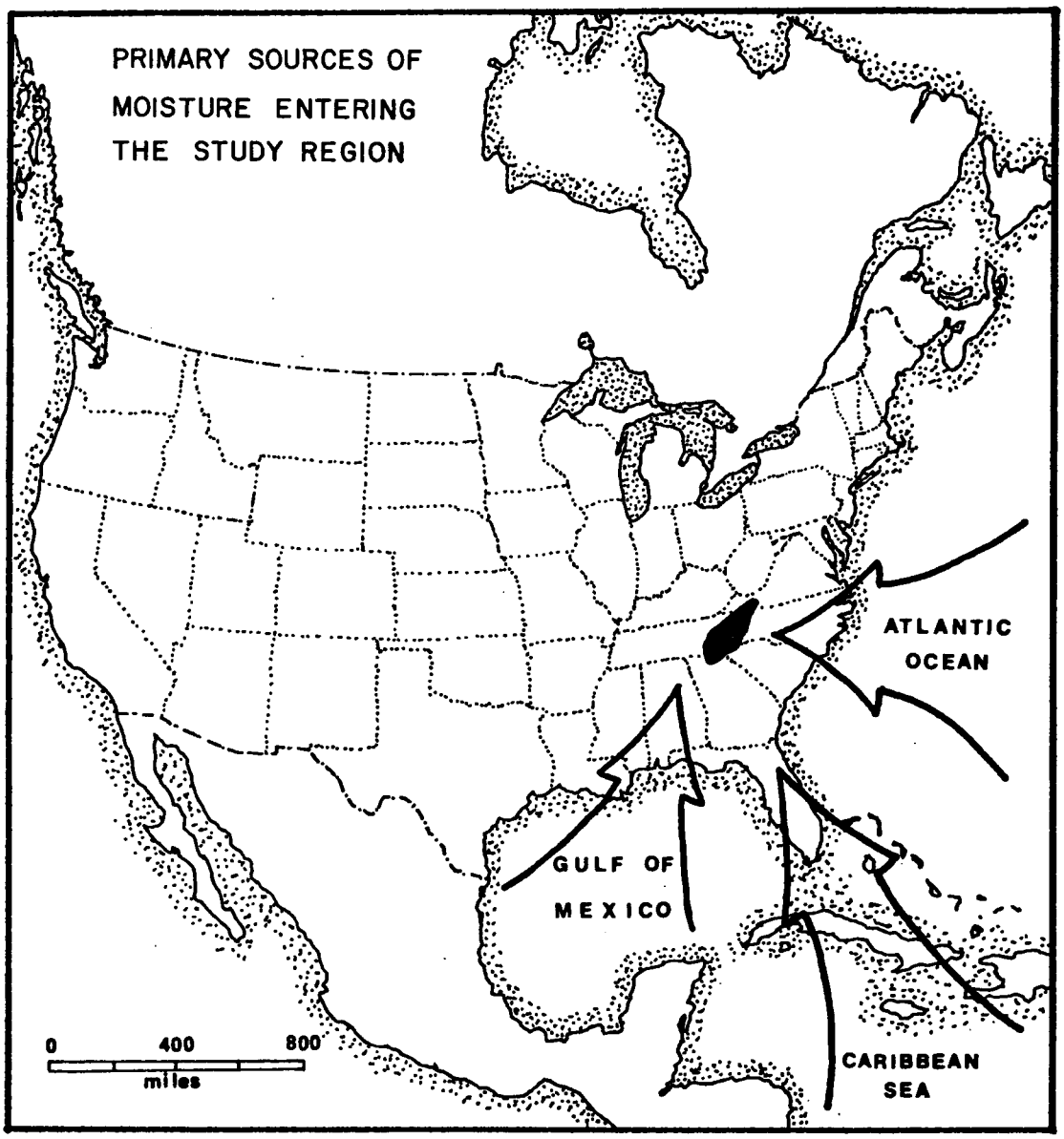


Figure 5. Primary Sources of Moisture Entering the Study Area.

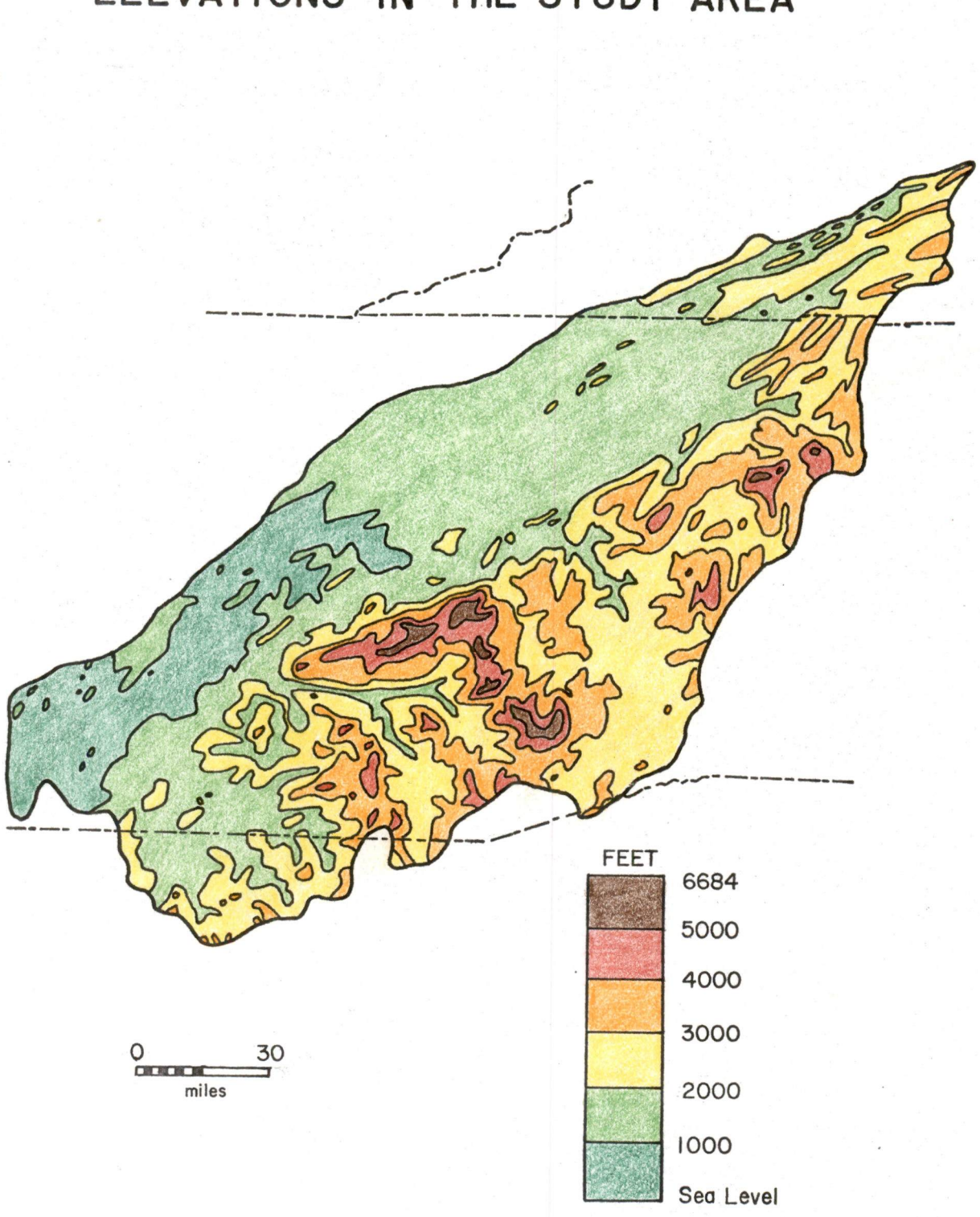


Figure 6. Elevations in the Study Area.

CHAPTER II

SOURCES OF DATA

For this study two types of data were collected--daily precipitation data and synoptic data. The precipitation records reveal patterns of rainfall, while the study of the synoptic data allow one to formulate causal factors to account for the precipitation patterns.

Precipitation Data

Daily and hourly precipitation data were used. Daily precipitation data are compiled monthly by TVA and published in Precipitation in Tennessee River Basin: [month, year].[13] Hourly precipitation data are published in Hourly Precipitation - [State]: [month, year][14] by the NWS.

Both the TVA and NWS precipitation data, as Rodda's model (see Figure 2) points out, are subject to errors of measurement by the station operators. An operator may read the gage incorrectly or interpolate rain amounts for days when a reading was missed. These erroneous data are then reported to the parent agencies, which have no way of knowing when and how often they are in error. For the purpose of this study and others involving data published by TVA and the NWS, the data must be accepted and assumed to be accurate except where gross differences

---

[13] Tennessee Valley Authority, Division of Water Control Planning, Hydraulic Data Branch, Precipitation in Tennessee River Basin: [month, year].

[14] U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service, Hourly Precipitation Data - [State]: [month, year].

between the two sources occur.

Precipitation data comparability also becomes a problem when the sampling times are not the same. A unique situation concerning gage reading times is found at the two Gatlinburg, Tennessee, rain stations. The two stations are situated side-by-side behind the National Park Headquarters, with one read at 7:00 A.M. and the other at 1:00 P.M.[15] On some days the differences in the amounts of precipitation reported are appreciable because the gages are not read at the same time (Fig. 7). Although the gage labeled 209 consistently records slightly higher amounts of precipitation than 209A, gross differences are noted on June 28-29, July 29-30, August 2-3, September 4-5 and 29-30. Those differences can be directly attributed to the differences in gage reading times. Each gage covers a 24 hour period of time 7 A.M. to 7 P.M. or 1 A.M. to 1 P.M. For example, any precipitation falling between 7 A.M. and 1 P.M. on June 20 is recorded as falling on June 20 by the 7 A.M. gage and on June 19 by the 1 P.M. gage. Such inconsistency of gage reading times becomes important when trying to establish relationships between local rainfall patterns and synoptic situations.

Most of the TVA stations are read at 7 A.M., E.D.T., and report precipitation for a 24 hour period.[16] Any rain falling between midnight and 7 A.M. is reported as having fallen on the previous day. The NWS reports the daily precipitation from midnight to midnight,[17] so that

---

[15]Conversation with National Park Ranger.

[16]Conversation with employee of Tennessee Valley Authority in Hydrolic Data Branch.

[17]Hourly Precipitation Data, op. cit., p. 2.

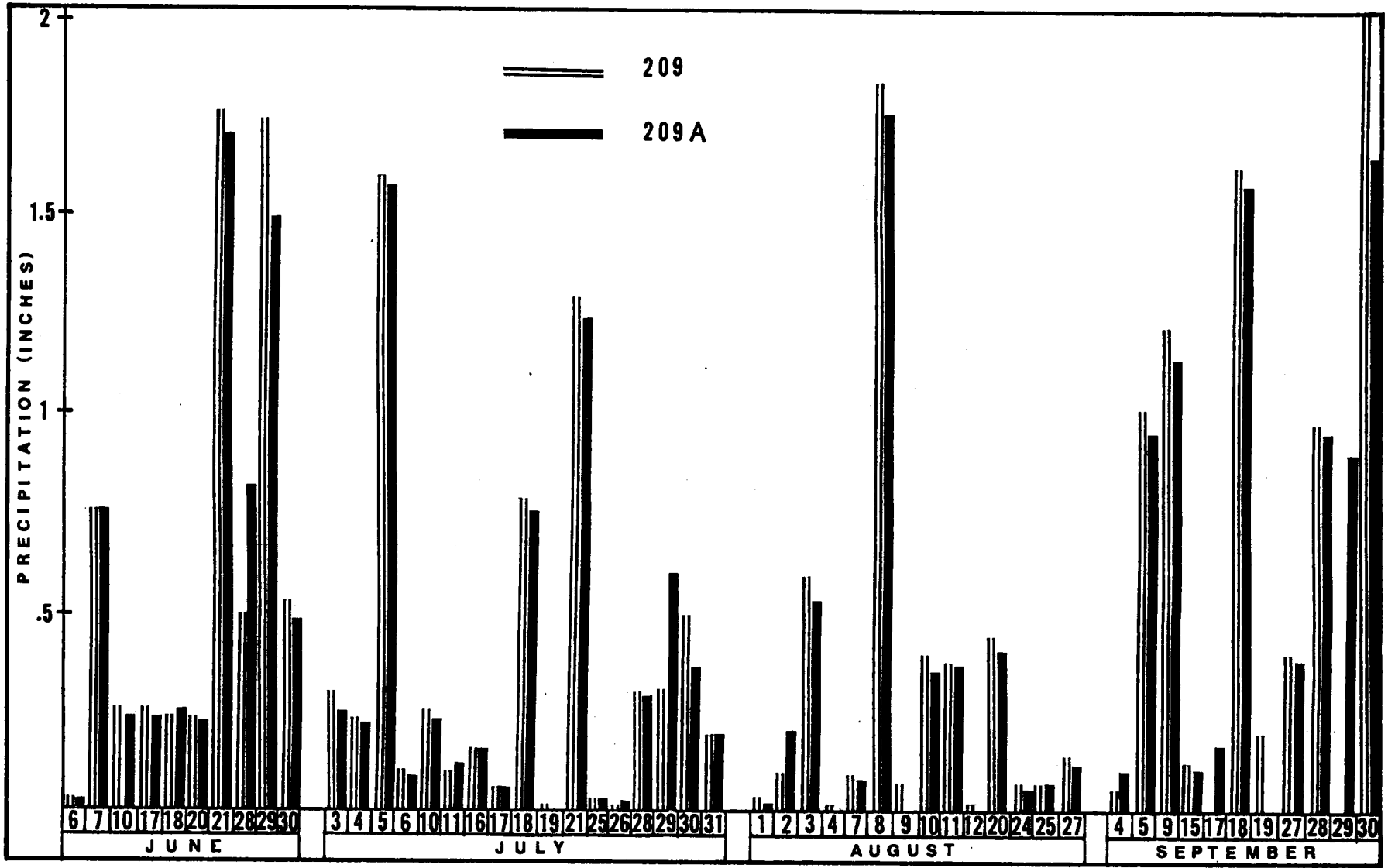


Figure 7. Comparison of Precipitation Amounts Received at Two Rain Gages only Two Feet Apart, 209 and 209A in Gatlinburg, Tennessee; Illustrates Data Inconsistency due to an Eight Hour Difference in Gage Reading Times.

their records correspond exactly with the day in question. When the daily TVA precipitation records are compared to the daily precipitation data published by the NWS, there are often differences in the daily amounts although the monthly totals are the same.

A number of stations in the study area report to both the NWS and TVA. These stations record hourly precipitation measurements which are published by the NWS in hourly increments. TVA, however, compiles the hourly data at the 7 A.M. reading and reports only the daily totals. Using the daily reports from both the NWS and TVA data, an example can be drawn from four days in July for seventeen stations which illustrates the reporting time problem (Table 1). Most of the rainfall during the four days fell between 1 A.M. and 6 A.M., making the TVA reports a day behind the NWS reports for 13 of the stations.

Because of this problem of lateness in the data, the hourly readings for the selected stations were checked to see at what times rain fell. On those days when rain fell between midnight and 7 A.M., the daily precipitation patterns were compared to the synoptic charts for the following day in order to get a more accurate picture of the weather system causing the precipitation.

Synoptic Data

Three types of synoptic data were utilized during this study--the North American Surface Charts,[18] the Composite Moisture Index Charts,[19]

---

[18] North American Surface Charts, MF-915-72B, April-June, 1972 and MF-915-72C, July-September, 1972.

[19] Composite Moisture Index Charts, MF-2532-72A, January-December, 1972.

TABLE 1

A COMPARISON OF TVA AND NWS PRECIPITATION REPORTS WHICH
ILLUSTRATES HOW DIFFERENT REPORTING TIMES AFFECT DAILY RAINFALL TOTALS
-TVA REPORTED THROUGH 7 A.M. AND NWS REPORTED THROUGH MIDNIGHT-

JULY	14		15		16		17		18	TOTAL	
	NWS	TVA	NWS	TVA	NWS	TVA	NWS	TVA	TVA	NWS	TVA
Wytheville	.17			.23						.17	.23
Groseclose	.30			.30	.04		.03	.07		.37	.37
Trout Dale	.11			.21						.11	.21
Abington	1.68		.02	1.70						1.70	1.70
Stanley Knobs			.03			.03				.03	.03
Bristol	.01	.01			.32	.32				.33	.33
Butler	.31		.10	.31	.45	.10		.45		.85	.85
Jefferson City	.10		.20	.22	.40	.09	1.00	.35	.63	1.70	1.30
Max Patch Mountain	.04	.04	.21		.07	.21	.50	.07	.50	.78	.78
Asheville	.20			T	.17	.17	.83		.99	1.04	1.10
Haywood Gap	.20				.16	.20	.28	.20	.24	.64	.64

TABLE 1 (continued)

JULY	14		15		16		17		18	TOTAL	
	NWS	TVA	NWS	TVA	NWS	TVA	NWS	TVA	TVA	NWS	TVA
Cedar Mountain	.20			.20	.05		.40	.05	.40	.65	.65
Blue Ridge Post Office			.19		.05	.19		.05		.24	.24
Spruce Mountain			.60	.20		.40	.17		.17	.23	.23
Bryson City	.35			.35	.10		.52	.10	.52	.97	.97
Conasauga						.05	.90	.03	.87	.90	.95
Knoxville					.40	.40	.09	.09		.49	.49

Source: Compiled from TVA daily precipitation records and NWS hourly precipitation records, July, 1972.

and the 500-Millibar Charts.[20] The North American Surface Charts are available for three hour intervals and give an excellent accounting of major pressure and frontal activity. These charts are drawn up by the NWS from data reported by major weather stations. Those stations within and bordering on the study area are Chattanooga, Knoxville, Tri-Cities, and Charlotte. Like all NWS stations, these four report such items as the amount of precipitation, time precipitation began or ended, present weather, surface wind speed and direction, cloud cover, barometric pressure and pressure change in three hours preceding observation, temperature, and dewpoint. Much of the information was not applicable to a study of this type or was not consistent enough to use. The information concerning precipitation was often missing from the synoptic charts and was derived much more easily from the hourly precipitation publication. Surface wind speeds and directions given on the Surface Charts are of value only in the immediate area of the station site. The major pressure and frontal organizations on the Surface Charts were largely depended upon for assessing the synoptic situations. Since there were eight charts per day, sequential movements of weather systems could be followed and daily trends established. The North American Surface Charts were especially important when frontal activity was involved, for they showed the major weather systems with which some types of local precipitation patterns are associated.

The second type of synoptic chart used was the composite Moisture Index Chart. This chart is published twice daily, at 7 A.M. and 7 P.M.

---

[20] Daily Weather Maps, Weekly Series, 500-Millibar Height Contours at 7:00 A.M. E.S.T., June-September, 1972.

E.D.T., and is comprised of charts of four indices which are especially useful in determining upper air conditions, the Lifted Index/K-Index, Precipitable Water, Freezing Level, and Average Relative Humidity. The first two indices, the Lifted Index/K-Index and Precipitable Water, proved most valuable in determining the stability of the upper atmosphere and the direction of moist air flow. The stations closest to the study area that report these indices are: Nashville, Tennessee; Huntington, West Virginia; Greensboro, North Carolina; and Athens, Georgia.

The Lifted Index is useful for the prediction of latent instability.[21] "It is compiled by lifting the mean moisture in the lowest 3000 foot layer of the atmosphere moist adiabatically to 500 mb and subtracting the resulting temperature at this point from the reported 500 mb free-air temperature."[22] Negative Lifted Index values indicate instability while positive values indicate stability.[23]

The K-Index is another measure of stability. According to the NWS:[24]

> The K-Index is a measure of thunderstorm potential based on the vertical temperature lapse rate, the

---

[21]Joseph G. Galway, "The Lifted Index as a Predictor of Latent Instability," Bulletin of the American Meteorological Society, XXXVII (December, 1956), p. 528.

[22]Maj. Gary D. Atkinson, USAF, Forecaster's Guide to Tropical Meteorology (Washington, D.C.: Air Weather Service, April 1971), p. 11-20.

[23]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Bureau, Technical Procedures Bulletin No. 28: The Lifted Index Computation (Washington, D.C.: Weather Analysis and Prediction Division, July 17, 1969), p.1.

[24]U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, Technical Procedure Bulletin No. 61: The K-Index Chart (Silver Spring, MD.: April 12, 1971), p. 1.

> moisture content of the lower atmosphere, and the verticle extent of the moist layer. The temperature difference between the 850 and 500 mb is used to parameterize the vertical temperature lapse rate. The 850 mb dewpoint provides information on the moisture content of the lower atmosphere. The vertical extent of the moist layer is represented by the 700 mb dewpoint depression. The combination of these parameters to yield the K-Index is performed as follows:
>
> K = (850 Temp - 500 Temp) + (850 dewpoint) - (700 dewpoint depression).

K values are especially applicable to the prediction of air-mass thunderstorms, and their interpretaion indicates thunderstorm probabilities. "Values of K less than 20 generally resulted in no air-mass thunderstorms while values greater than 35 resulted in numerous thunderstorms."[25] The following assignment has been suggested for determining thunderstorm probabilities:[26]

K value	Thunderstorm Probability
less than 15	0%
15 - 20	less than 20%
21 - 25	20 - 40%
26 - 30	40 - 60%
31 - 35	60 - 80%
36 - 40	80 - 90%
greater than 40	near 100%

While the Lifted and K-Indexes are indicators of atmospheric stability the Precipitable Water Charts are especially helpful in determining the direction in which moisture laden air is moving. Precipitable water vapor is defined "as the depth a layer of liquid water would assume if all water vapor in the atmosphere above a region were

---

[25] Technical Procedure Bulletin No. 61, op. cit., p. 2.

[26] Technical Procedure Bulletin No. 61, op. cit., p. 2.

condensed into a liquid layer on the surface....The greater the amount of precipitable water vapor, the greater the potential source of moisture to supply precipitation."[27] As previously mentioned, moisture laden air comes into the study region primarily from the Atlantic Ocean, Gulf of Mexico, and Caribbean Sea. By comparing the isohyets of precipitable water, the source of the moisture can be determined. For instance, charts with isohyets parallel to the east coast and precipitable water values decreasing westward indicate moisture coming from the Atlantic Ocean and suggest a greater probability for precipitation in the eastern portion of the study area. Both the surface charts and the moisture composite charts are extremely important in this study, as they help to establish cause for resultant local precipitation patterns.

The third type of synoptic chart used was the 500-Millibar Chart. It "represents the height contours and isotherms of the 500-millibar surface at 7:00 A.M."[28] as well as the wind direction and speed at the 500 mb level. The upper atmospheric wind directions and speeds can often be tied to the resultant pattern of local precipitation.

---

[27]Stanton E. Tuller, "The World Distribution of Annual Precipitation Efficiency," Journal of Geography, LXX (April, 1971), p. 219.

[28]Daily Weather Maps, op. cit., p. 1.

CHAPTER III

CLASSIFICATION AND EVALUATION OF PRECIPITATION PATTERNS

Classification of Precipitation Patterns

Once a large quantity of precipitation and synoptic data were amassed, some method was needed to correlate the two data types. An attempt was made to look for precipitation patterns and to classify them for greater understanding and convenience. When the precipitation patterns had been established, comparisons with the synoptic data revealed characteristics common to each class. This proved to be a successful method of investigation and comparison.

To facilitate classification of the local rainfall patterns, the study area was broken down into four distinct sections using the major ridgeline between Tennessee and North Carolina and the principal drainage divides as boundaries (Fig. 8). Each section was labeled according to its relative position--north, east, south, and west. A floating dot grid was used to calculate the area of each section, and subsequently to determine the areal extent of precipitation in each section on each rain day. The percentage of rain for each section was then figured according to the dot counts. For instance, a total of 59 dots are included within the south section. If only 46 dots are counted within the precipitation zone, 78% of that section is wet. Following this procedure for each section on every rain day led to the definition of cases such as on August 24 when the north had precipitation in 23% of its area, the east section in 31%, the south section in 57%, and the west in 35% of its area. Once the precipitation percentages for each day were found, a

SECTIONAL BREAKDOWN OF STUDY AREA

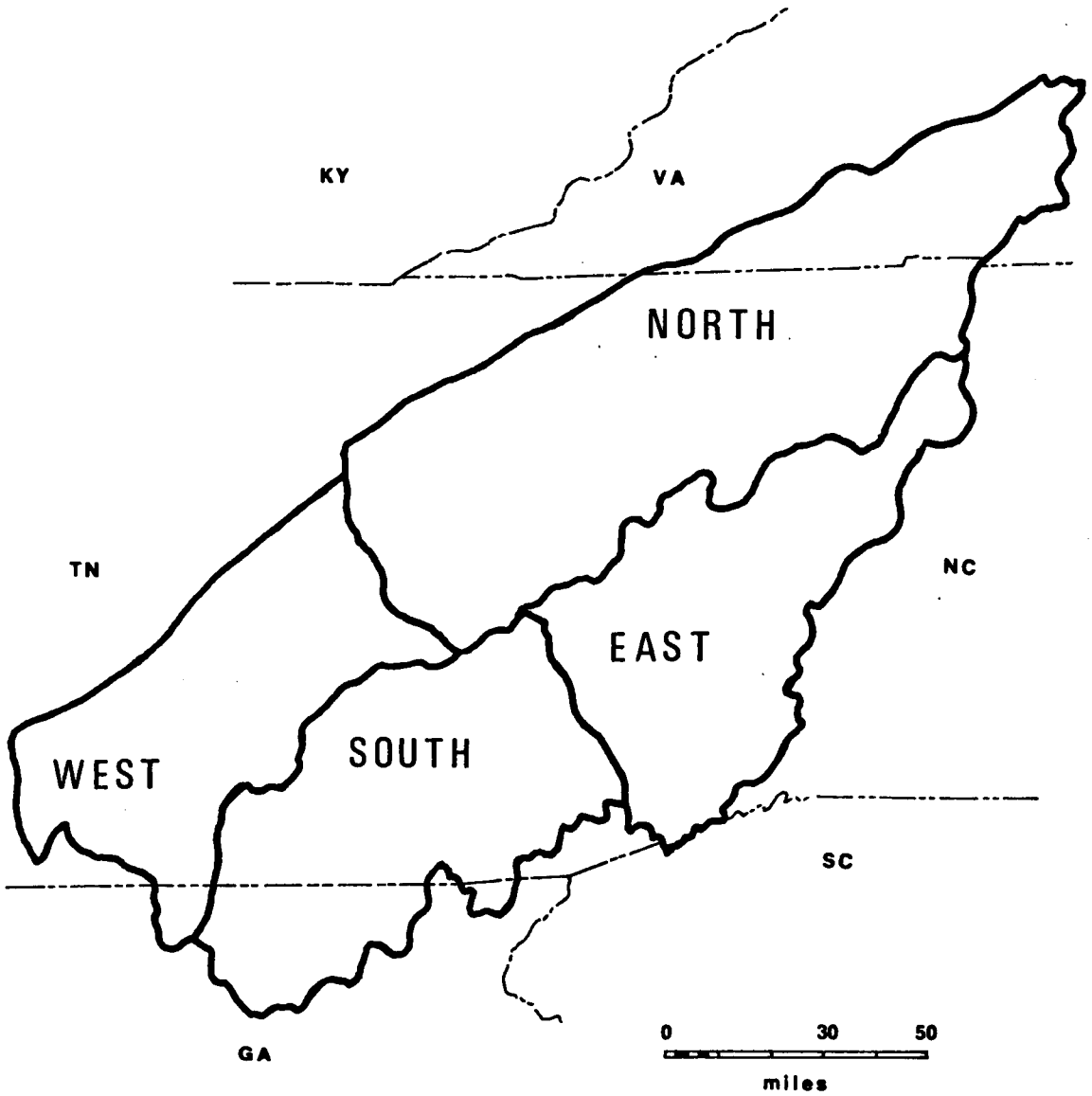


Figure 8. The Four Sections Designated to Classify Local Rainfall Patterns. The Northeast-Southwest boundary is the Major Ridgeline Between Tennessee and North Carolina. The Northwest-Southeast boundaries are Drainage Basin Limits.

classification system was developed which allowed each event to be placed in precipitation pattern classes.

Classes of Local Precipitation Patterns

The local precipitation patterns for the summer months of 1972 have been broken down into twelve classes. A thirteenth class--that of no rain at any of the stations--could be added, as it does have synoptic characteristics of its own and appears 16 times during the four month period. On those days with no precipitation, high pressure cells were situated over the area, according to the surface charts. The upper air was extremely stable as indicated by the stability indices. Since this study is concerned with precipitation patterns, the days without rain are not given further attention.

The investigation was limited to only four months, and it is highly probable that additional local patterns would appear if other periods were studied. Nevertheless, the twelve patterns that are designated offer a beginning in categorizing precipitation patterns for the region.

In order to develop the precipitation pattern classification scheme the maps of precipitation patterns were laid out to identify class boundaries of wetness. The natural break points that were found are 70%, 40%, 15%, 15%, and 0%. Classes thus defined were then assigned a code number:

Percentage Wet	Code Number
greater than 70%	5
40 - 70%	4
25 - 40%	3
15 - 25%	2
1 - 15%	1
0%	0

Since the study area has been broken down into four sections and precipitation percentages found for each section, each day could be assigned a four digit code. All codes are arranged so that the first digit is assigned to the north section, the second to the east section, the third to the south section, and the fourth to the west section. August 14, just discussed, would then be assigned the number--2343. Another example is August 7 when the north was 69%, the east 29%, the south 41%, and the west 94% wet giving a code number of 4335. After determining the code for each rain day during the summer, a system of pattern classes was derived. The classes range from those in which the entire region is wet to those showing only spotty occurrences of precipitation (Table 2).

The first class--Class A--encompasses those days with the most extensive patterns of rainfall. Days in this class have code numbers with a minimum digit of 4 or 5. To belong to this class, a day can have a number that ranges from 5555 to 4444 or any combination of four's and five's. The maximum digit is five in 96% of the actual cases. Exemplifying a Class A pattern is September 5 which has a number of 5555 reflecting large expanses of precipitation (Fig. 9).

A number of days with pervasive rainfall fell short of the qualifications for the Class A pattern type. To accommodate these, Class B is established, in which no digit can be less than 3. A number such as 4344 or 3554 would fit in this class. July 15, 5443 (N - 77%, E - 63%, S - 60%, W - 33%), is an example of this class (Fig. 10).

The next set of precipitation patterns show concentration of rain in certain sections of the study area, with other sections being rather

TABLE 2

CLASSIFICATION OF DAILY PRECIPITATION PATTERNS IN THE SOUTHERN BLUE RIDGE MOUNTAINS BASED ON SUMMER 1972 RAINFALL EVENTS

CLASS	DESCRIPTION
	Region-Wide Precipitation
A	All wet - Code numbers have minimum digit of 4 or 5.
B	All wet, subset 1 - Code numbers have no digits less than 3.
	Sectional Patterns With Minimum Digit in Code Number of 0, 1, or 2
N	North section wet - First digit alone must be 3 or above and must exceed the minimum digit by two units.
NE	Northeast section wet - Has values of 3 or above in both the first and second digit, and both these digits exceed the minimum digit by two units.
E	East section wet - Has a value of 3 or above in the second digit alone which must exceed the minimum digit by two units.
SE	Southeast section wet - The second and third digits have values of 3 or greater and both those digits must exceed the minimum digit by two units.
S	South section wet - The third digit alone must be 3 or above and be greater than the minimum digit by two units.
SW	Southwest section wet - The values of the third and fourth digits are 3 or above and both must exceed the minimum by two units.
W	West section wet - The fourth digit alone must be 3 or above and exceed the minimum digit by two units.
WD	West section dry - The north, east, and south sections must show values of 3 or above, while the west section shows a value at least two units lower than any of those.
ND	North section dry - The east, south, and west sections must show values of 3 or above, while the north section shows a value at least two units lower than any of those.
SP	The maximum value in the code number is 1.

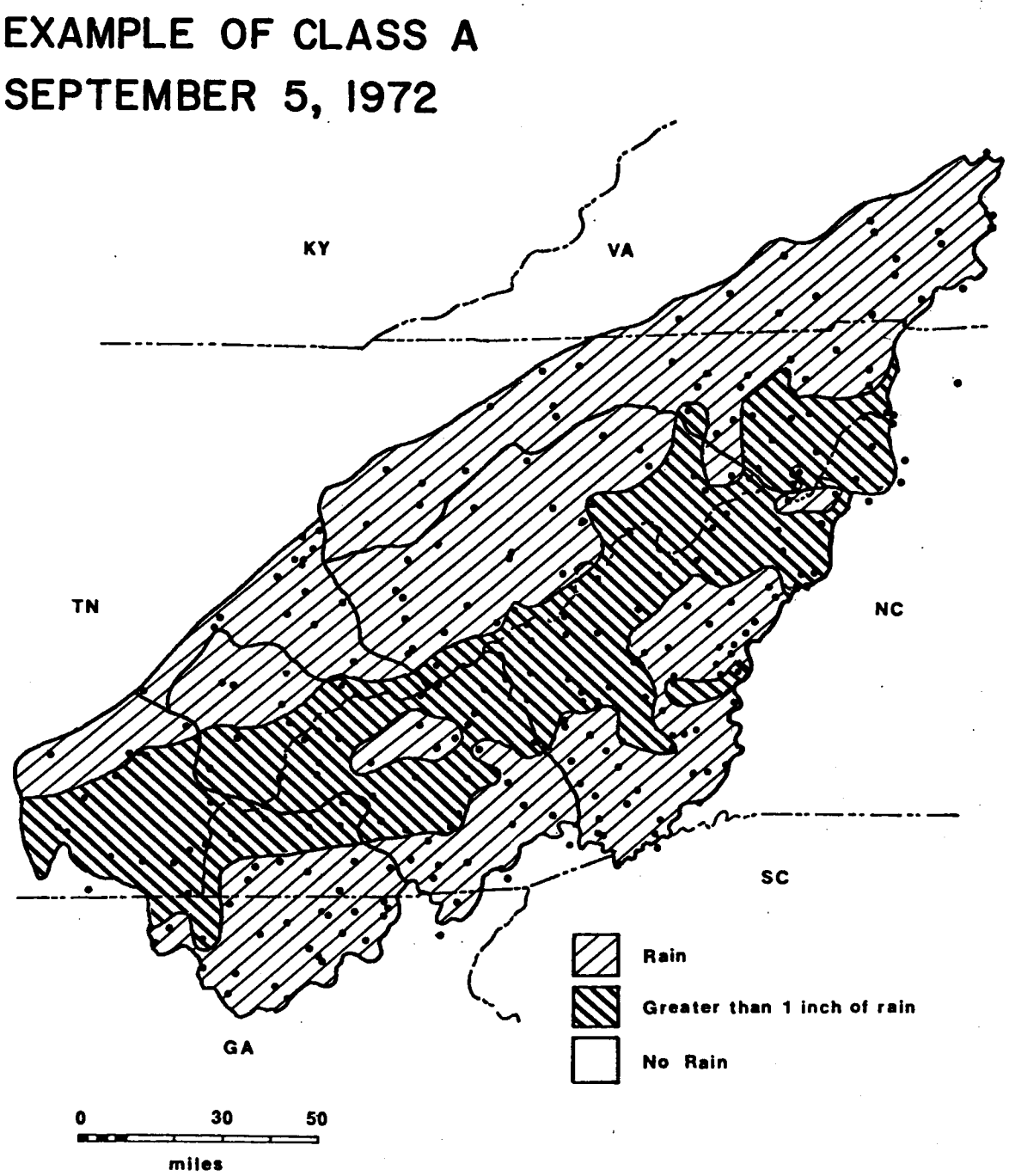


Figure 9. Example of Class A - September 5, 1972.

EXAMPLE OF CLASS B
JULY 15, 1972

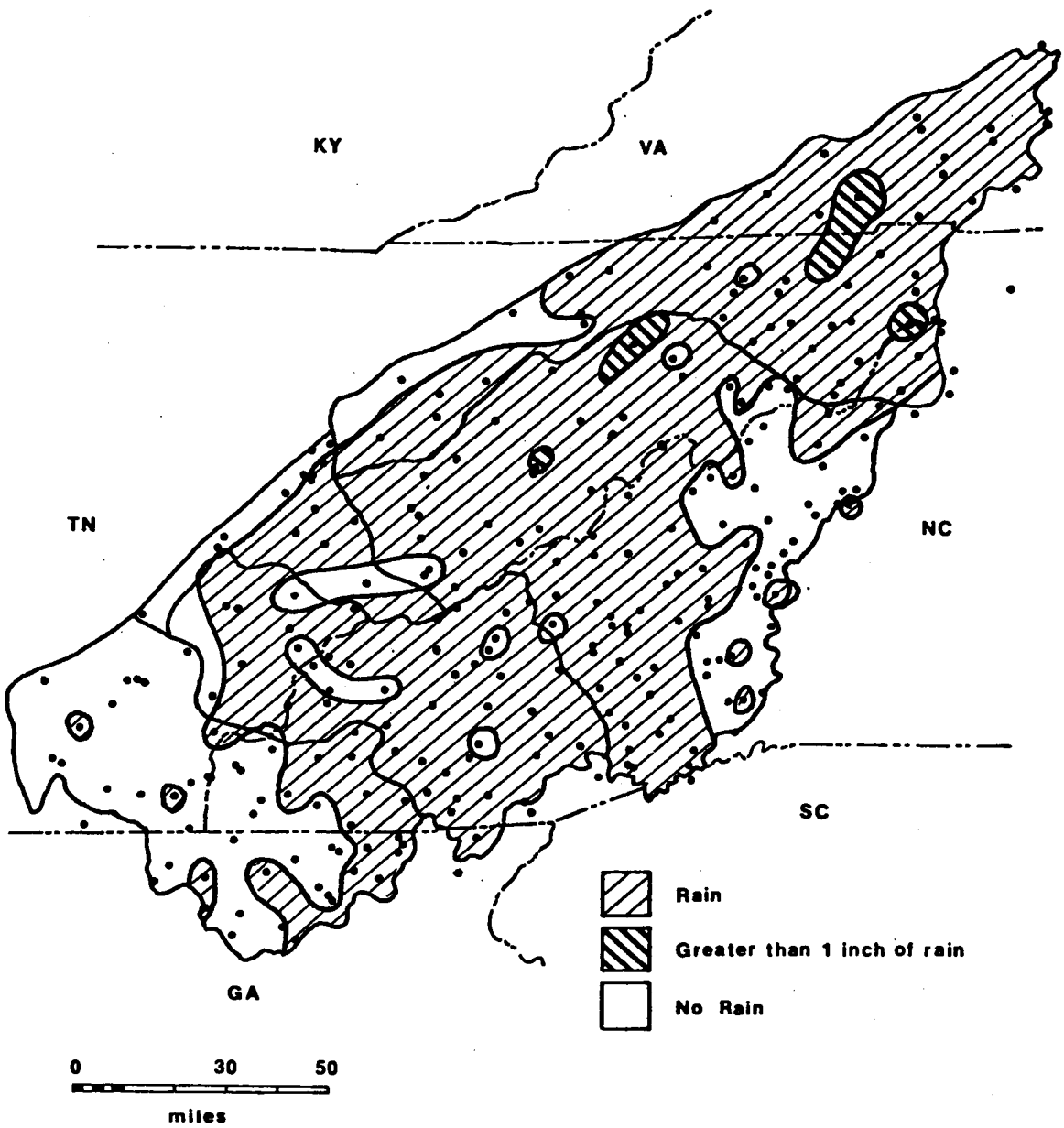


Figure 10. Example of Class B - July 15, 1972.

dry. To belong in this class, a number can have a minimum digit of 0, 1, or 2. Two subsets of this class are recognized. In the first, the maximum digit must be a 3 or above and must be two units above the minimum digit. By setting the limits in this manner ten sectional patterns of precipitation emerge from the rain days in the study. Since ten distinct patterns can be delimited, each one will be dealt with as a separate class.

In Class N, north, the first digit alone must be 3 or above and must exceed the minimum digit by two units. June 5 with the number 4100 is an example of a Class N (Fig. 11).

Class NE, northeast, has values of 3 or above in both the first and second digits, and both of those digits exceed the minimum digit by two units. On September 6 the number was 4421 which met the criteria for this class (Fig. 12).

Class E, east, has a value of 3 or above in the second position which must exceed the minimum digit by two units. July 21 with the number 2310 is an example of this class (Fig. 13).

In Class SE, southeast, the second and third digits have values of 3 or above and both of those digits must exceed the minimum digit by two units. On August 12 the precipitation pattern met the criteria of this class with a number of 2341 (Fig. 14).

In Class S, south, the third digit alone must be 3 or above and be greater than the minimum digit by two units. August 6 has the number 0130 and meets the qualifications of Class S (Fig. 15).

A Class SW, southwest, occurred once during the study. On August 9 the number, 1143, met the criteria of having the value of the third and

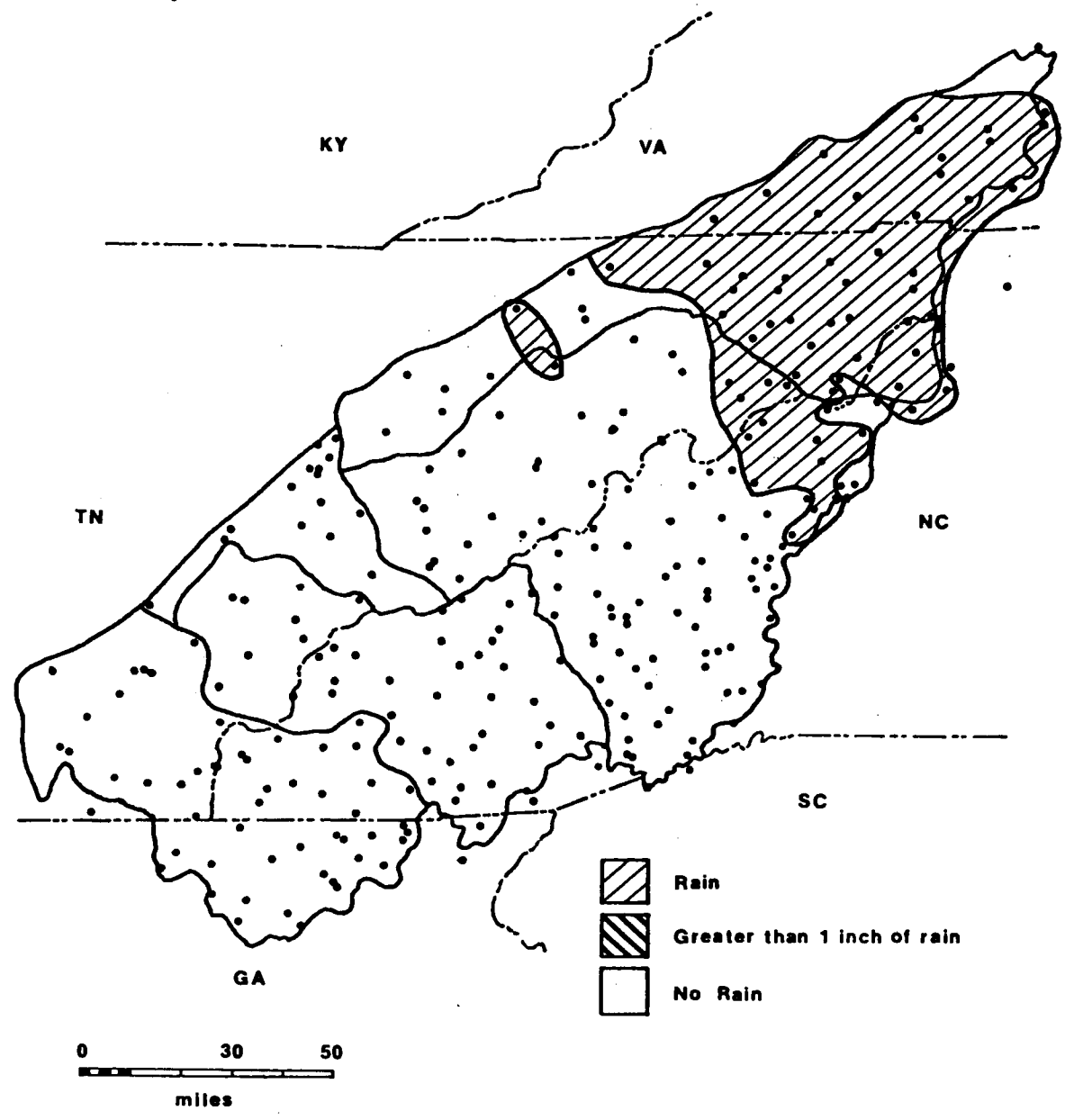


Figure 11. Example of Class N - June 5, 1972.

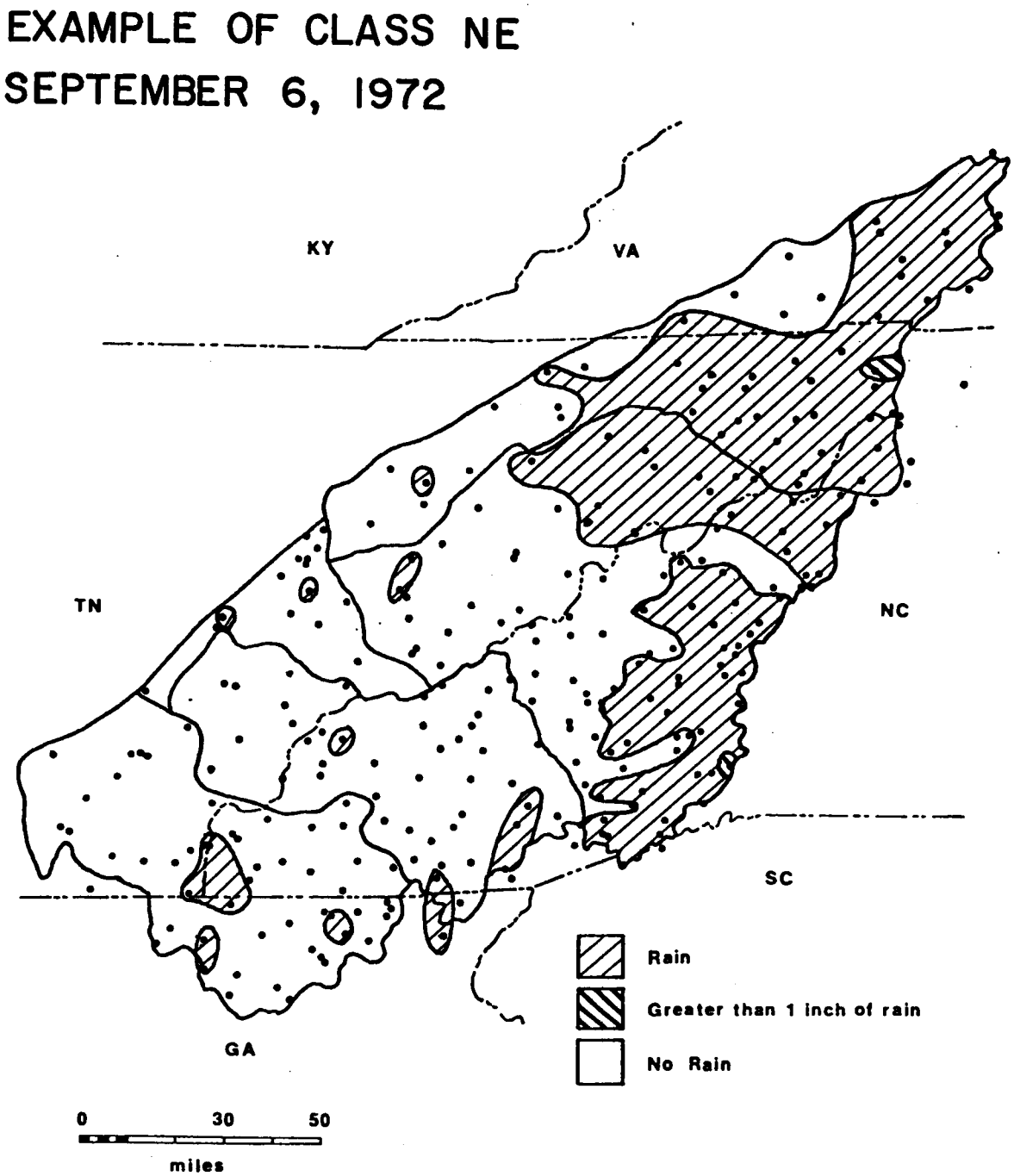


Figure 12. An Example of Class NE - September 6, 1972.

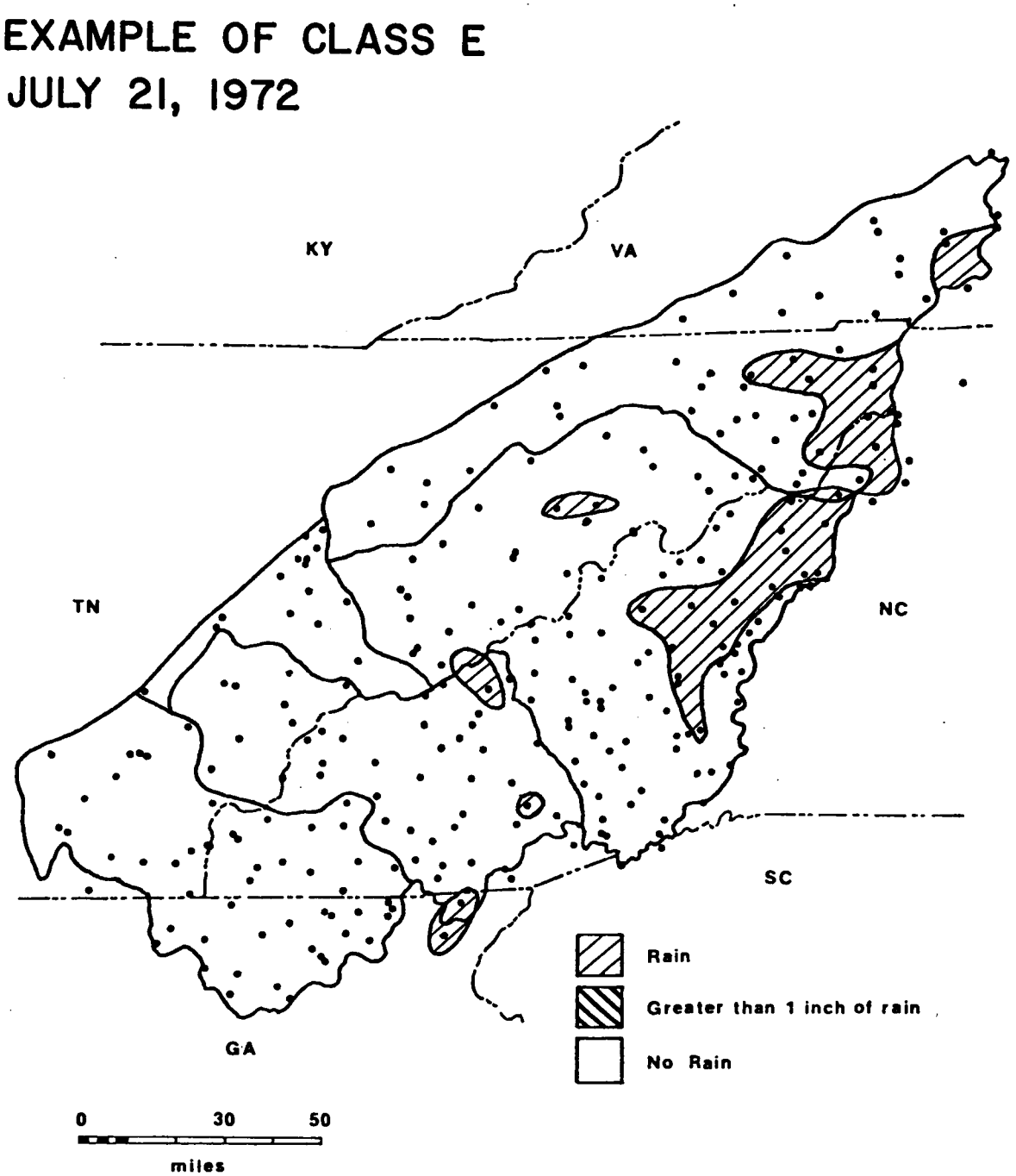


Figure 13. An Example of Class E - July 21, 1972.

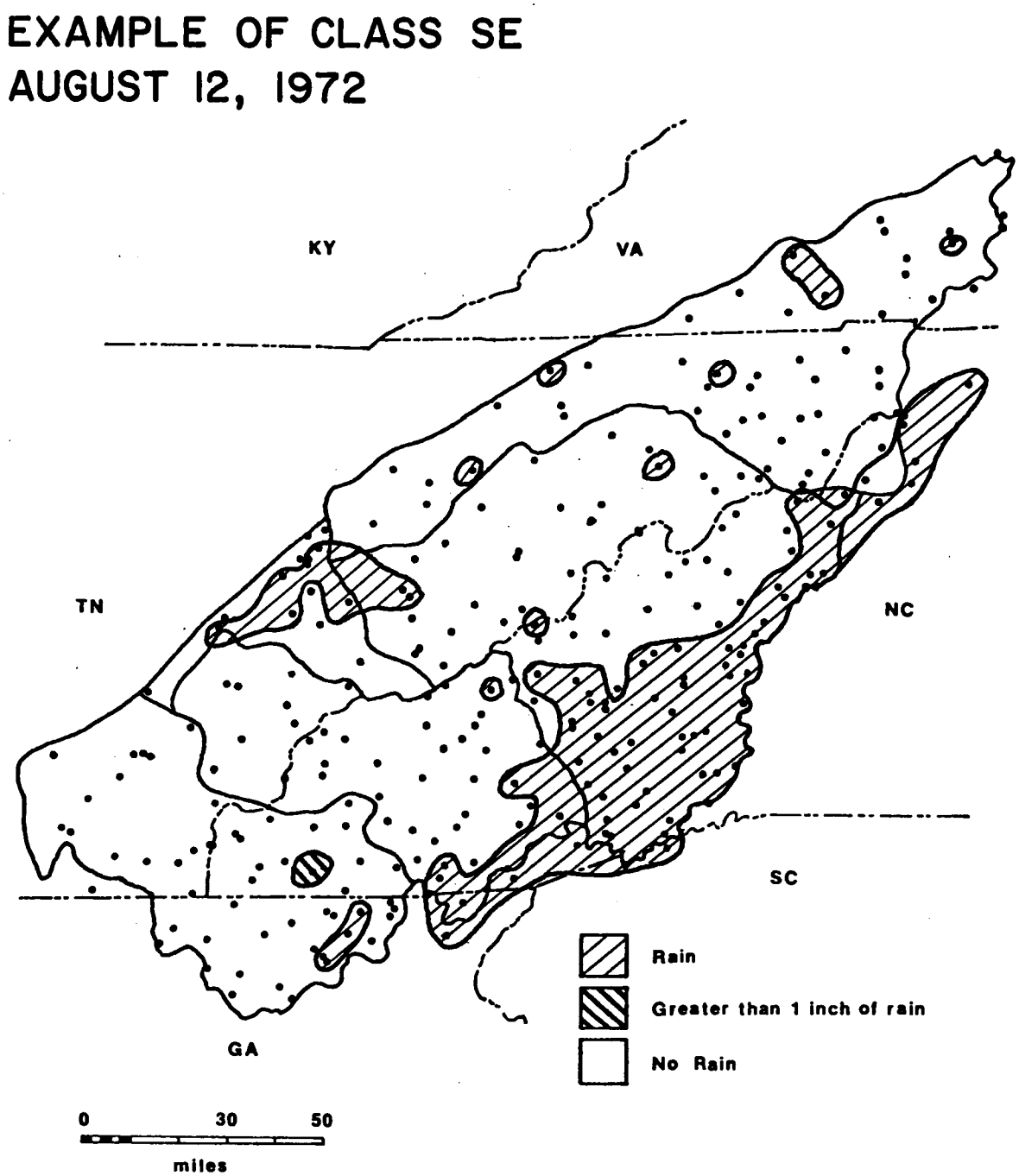


Figure 14. Example of Class SE - August 12, 1972.

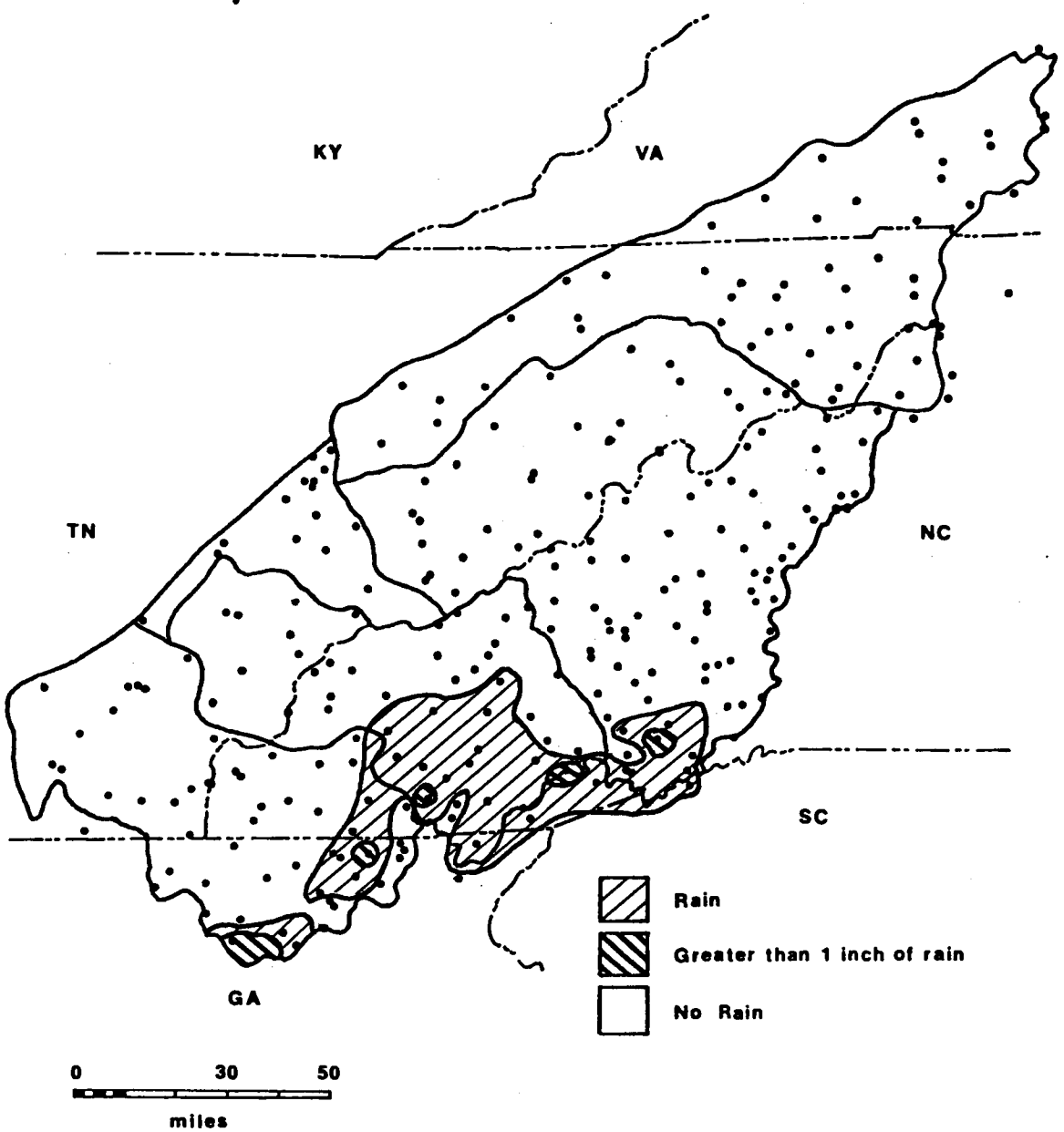


Figure 15. Example of Class S - August 6, 1972.

fourth digits 3 or greater and the minimum digit being at least two units less than both of these. The Class SW pattern is shown in Figure 16.

In Class W, west, the maximum digit of 3 or above is in the fourth digit alone and it must be two units above the minimum digit. With the number 1214, September 24 fills the requirements for this class (Fig. 17).

Class WD finds the west section relatively dry compared to the other three sections. The north, east, and south quadrants must show values of 3 or greater, while the west quadrant shows a value at least two units lower than any of those. July 19 with the number 4552 exemplifies this class (Fig. 18).

The final class in this set is Class ND, north dry. In this class the east, south and west quadrants must show values of 3 or above, while the north section shows a value at least two units lower than any of those. An example of this class is September 17 which has a number of 1335 (Fig. 19).

The next set with a minimum of 0, 1, or 2 has a maximum below 3. All days during the time span of the study meeting these qualifications have maximums of 1 and belong in Class SP. An SP class can be of two types. In one type the rainfall reception is seemingly random, equally likely to occur anywhere in the study region, and does not appear to be a function of elevation. The second type seems superficially random, but the rainfall occurrences associate well with the higher elevations. A listing of the rain days during the summer of 1972 and their code numbers can be found in Appendix A.

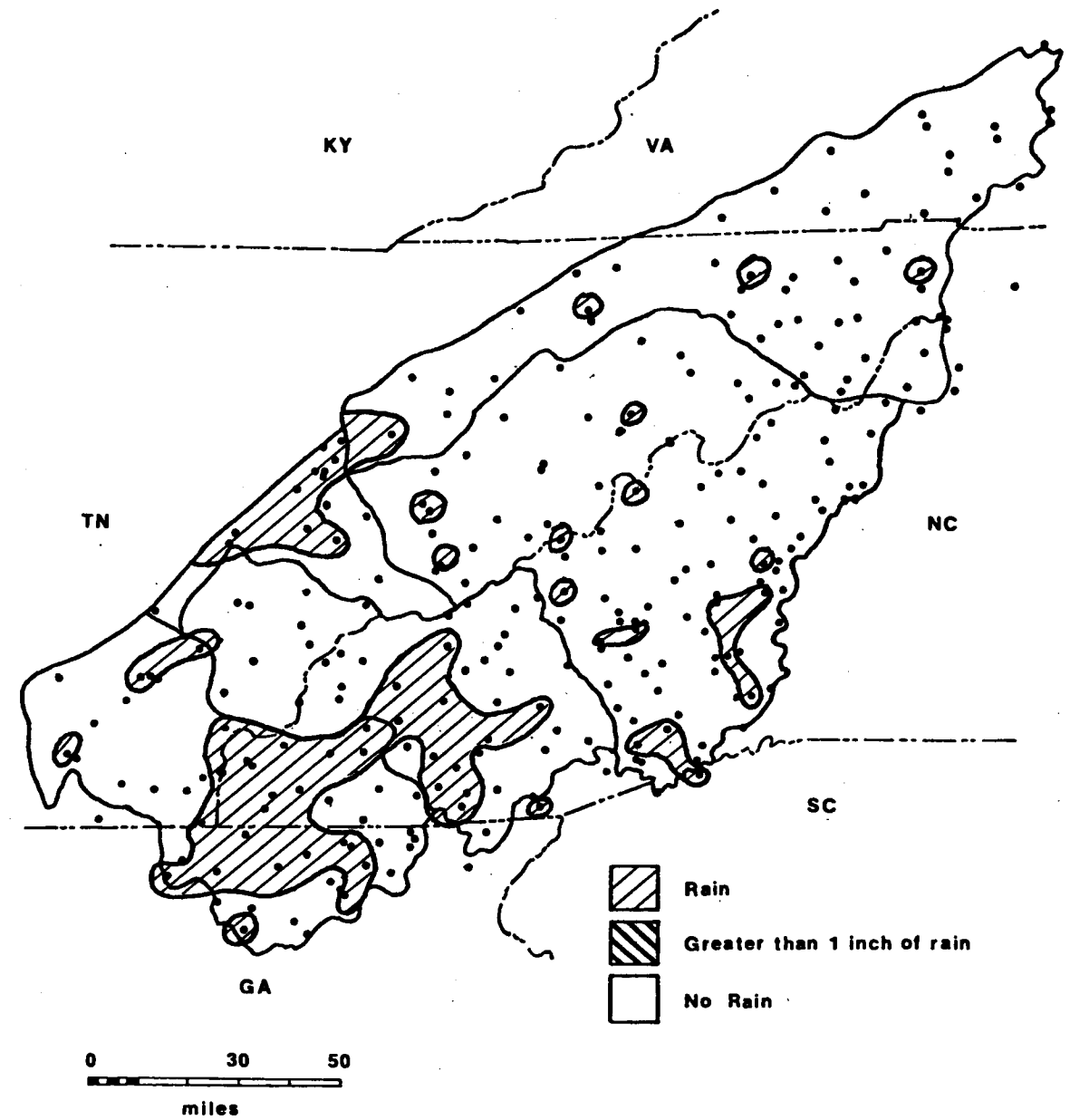


Figure 16. Example of Class SW - August 9, 1972.

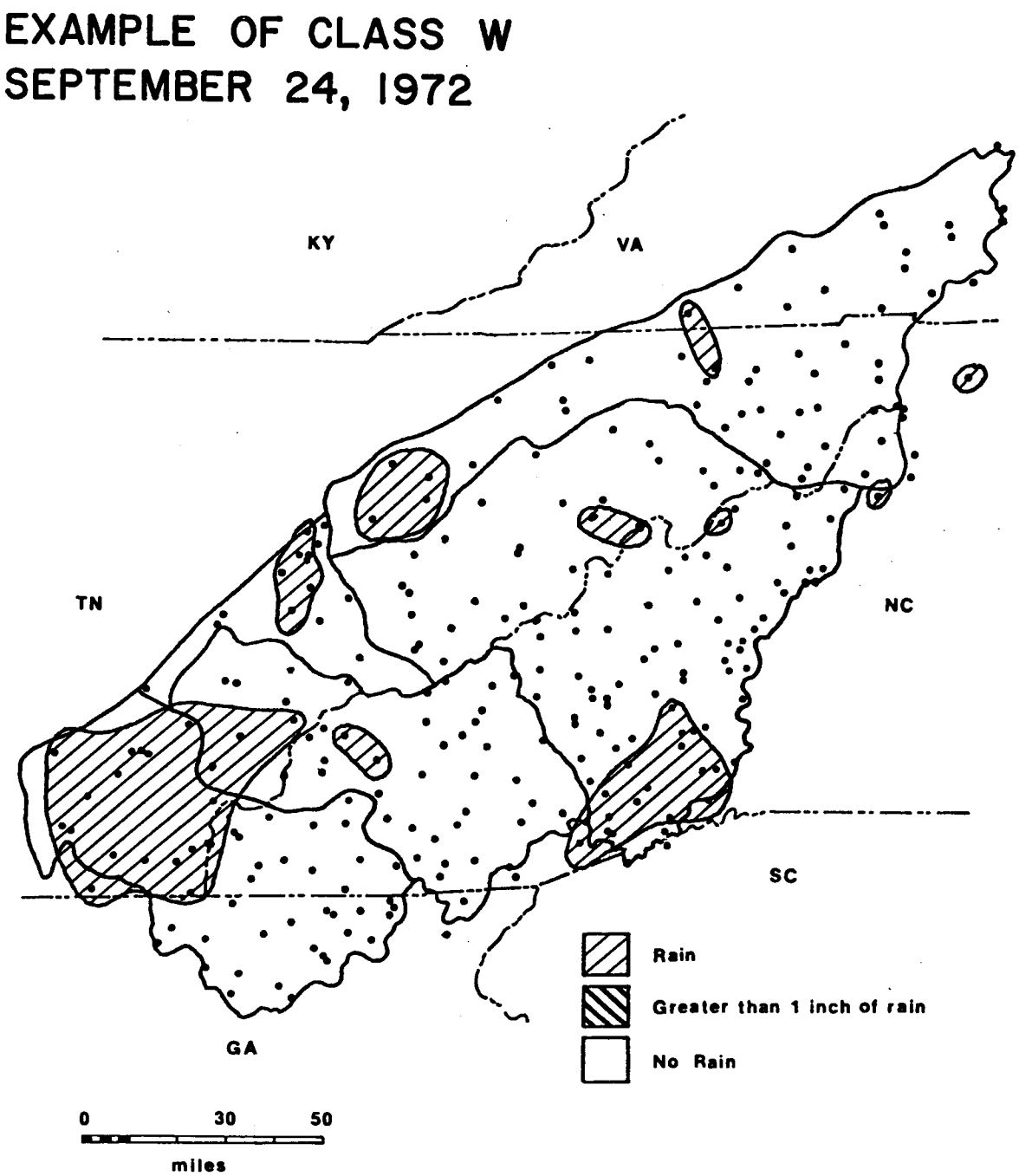


Figure 17. Example of Class W - September 24, 1972.

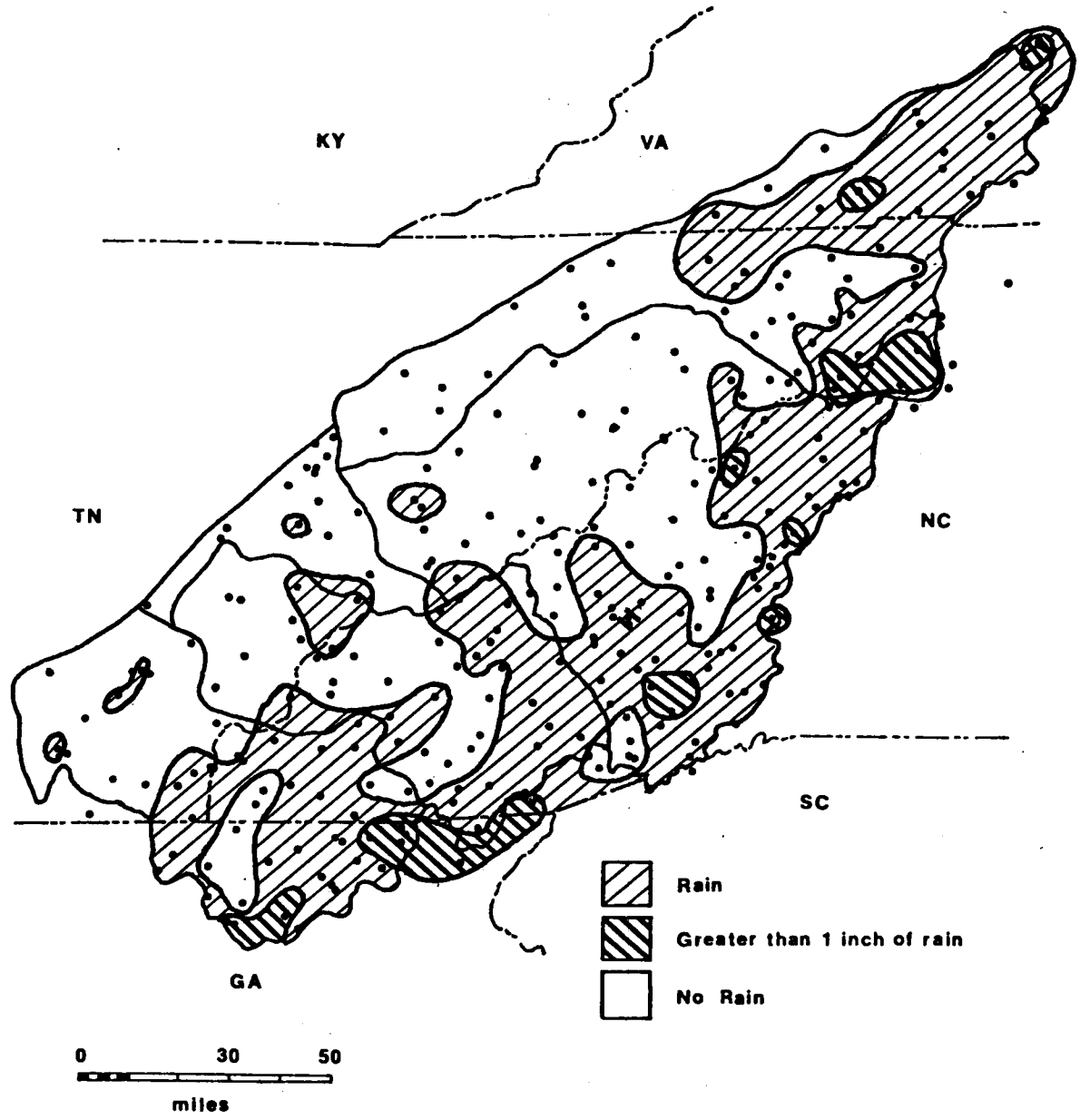


Figure 18. Example of Class WD - July 19, 1972.

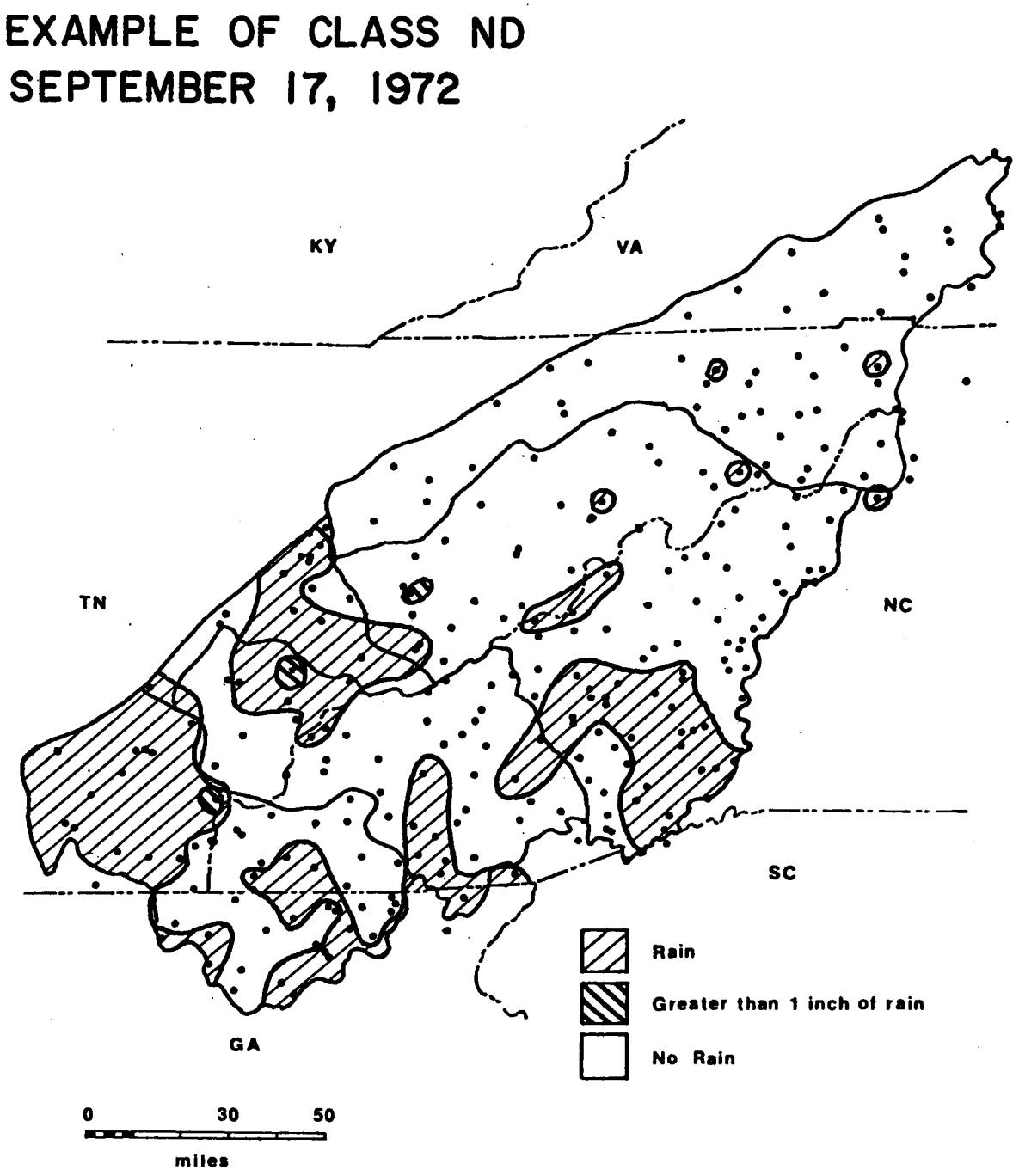


Figure 19. Example of Class ND - September 17, 1972.

Comparison of Local Precipitation Classes and Synoptic Situations

Correlating the twelve pattern classes with the rain days during the summer months leads one to suspect that distinctive synoptic situations create the different patterns (Tables 3, 4, 5, and 6). In some instances a given precipitation pattern occurs on successive days, suggesting that similar processes are going on. In other instances the local precipitation patterns vary systematically from day-to-day. A case study of this day-to-day precipitation pattern variation will help illustrate how synoptic situations lead to the different pattern classes.

Case Study: July 18 - 28

The climatic events of eleven consecutive days in July are presented in sequential maps. Seven of the local precipitation patterns are found between July 18 and 28. A thorough examination of the synoptic charts--Surface, 500 mb, K-Index, and Precipitable Water Charts--for each day demonstrates how daily changes effect the local patterns. The various charts are presented in a cluster for each of the eleven days. The reproductions include the wind directions and speeds of the 500 mb chart at its 7 A.M. reporting, the K-Index and Precipitable Water charts at their 7 A.M. and 7 P.M. reportings, a section of the surface charts at the 1 A.M., 7 A.M., 1 P.M., and 7 P.M. reportings, and the daily local precipitation pattern.

The local precipitation classification for July 18 is B as it has a code number of 3555 which almost qualifies the pattern as an A class. The hourly precipitation data indicate rain in the afternoon, and with very heavy amounts in localized areas a dominance of convective uplift

TABLE 3

PRECIPITATION PATTERN CLASSES DURING JUNE

Date	A	B	N	NE	E	SE	S	SW	W	WD	ND	SP
5			x									
6												x
7	x											
9												x
10		x										
11												x
14												x
15												x
16												x
17	x											
18	x											
19					x							
20	x											
21	x											
22			x									
23												x
24												x
26												x
27								x				
28												x
29												x
30												x

TABLE 4

PRECIPITATION PATTERN CLASSES DURING JULY

Date	A	B	N	NE	E	SE	S	SW	W	WD	NW	SP
1												x
2												x
3	x											
4		x										
5	x											
6				x								
9												x
10							x					
11												x
12												x
13												x
14						x						
15		x										
16	x											
17	x											
18		x										
19										x		
20		x										
21					x							
22						x						
23						x						
24										x		
25			x									
26	x											
27							x					
28	x											
29	x											
30	x											
31	x											

TABLE 5

PRECIPITATION PATTERN CLASSES DURING AUGUST

Date	A	B	N	NE	E	SE	S	SW	W	WD	ND	SP
1	x											
2	x											
3	x											
4												x
5			x									
6							x					
7		x										
8	x											
9								x				
10	x											
11						x						
12						x						
13												x
14								x				
15												x
16												x
17												x
18			x									
19				x								
20										x		
21							x					
22							x					
23												x
24							x					
25		x										
26	x											
27										x		
28												x
29												x

TABLE 6

PRECIPITATION PATTERN CLASSES DURING SEPTEMBER

Date	A	B	N	NE	E	SE	S	SW	W	WD	ND	SP
1												x
2												x
3												x
4				x								
5	x											
6				x								
8												x
9		x										
10												x
13												x
14												x
15										x		
16												x
17											x	
18	x											
19							x					
20												x
22												x
23												x
24									x			
25												x
26											x	
27	x											
28	x											
29	x											
30	x											

leading to thunderstorms is suggested. This dominance of thunderstorms is further substantiated with the examination of the surface charts (Fig. 20). Since a high pressure zone is situated over the study area, causal factors for precipitation cannot be discerned from the surface charts. The K-Indexes are all high, however, and imply a 60-80% chance of rain. At the 500 mb level the winds are very light (5-20 kts) and somewhat confused, but over the study area the wind flow is from the south-to-north, which ties in with the pattern of precipitation. With such a wind flow plus the unstable atmospheric conditions the majority of the region received rainfall with only a small portion of the north part of the study area being in a rain shadow.

July 19 is classed WD--west dry--as it has a code number of 4552. There is a definite pattern of rainfall on the southeast side of the main ridge line. Again the surface charts show the dominance of the high pressure system and no frontal controls of rainfall (Fig. 21). There is an extremely high level of precipitable water within the study area, however, and the atmosphere is also highly unstable. This is especially true at 7 A.M. in the Nashville area. The 500 mb chart shows a weak upper air flow that has a definite trend from east-to-west. This upper air flow appears to have interacted with the mountains to produce rain on the windward side and dry to the lee, or in this case, the west section of the study area. The high chance of rain over Nashville would be expected to show up in precipitation to the northwest of that area since that is the way the air flows.

July 20 falls into the B class. The overall precipitation

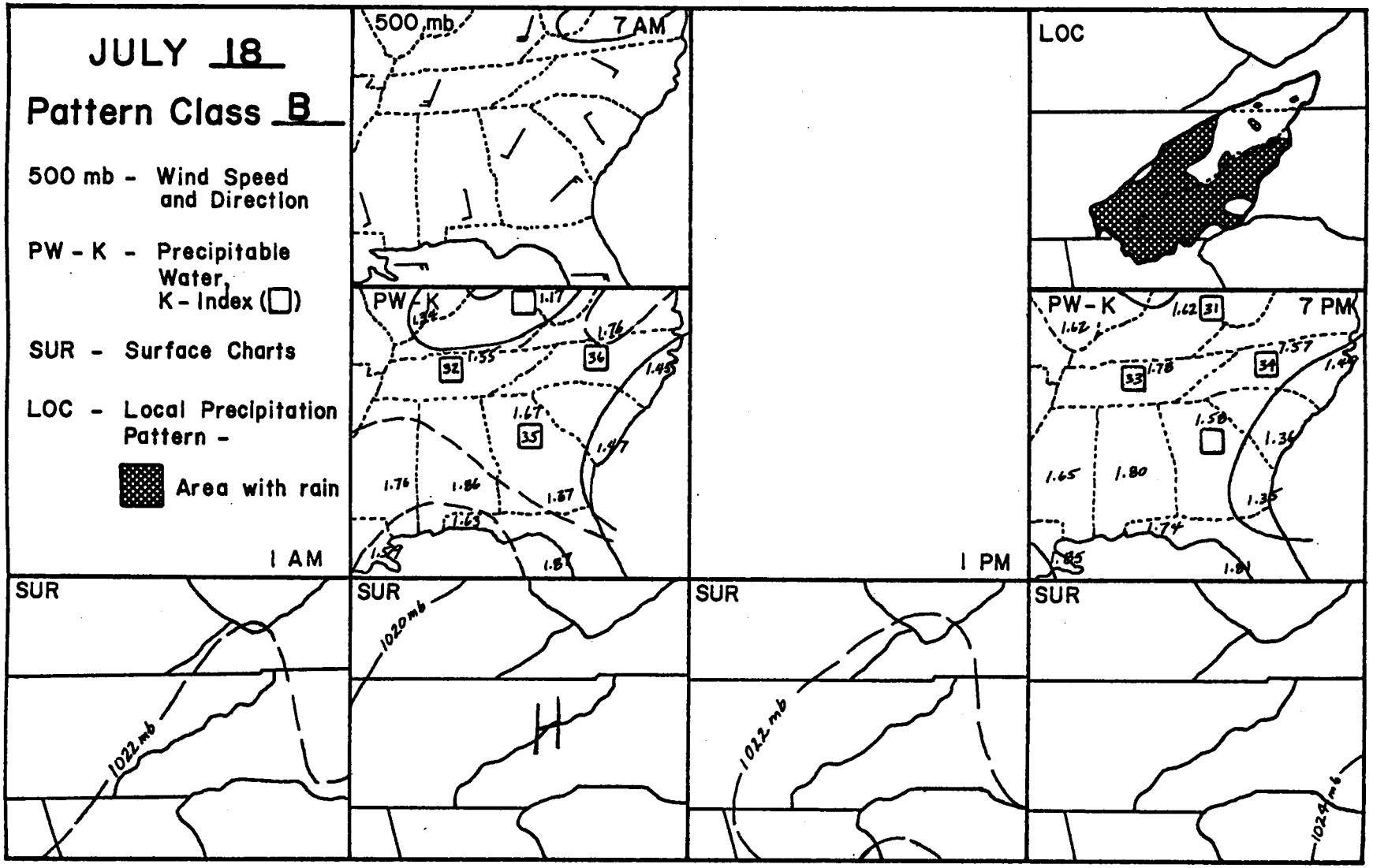


Figure 20. Synoptic Charts for July 18.

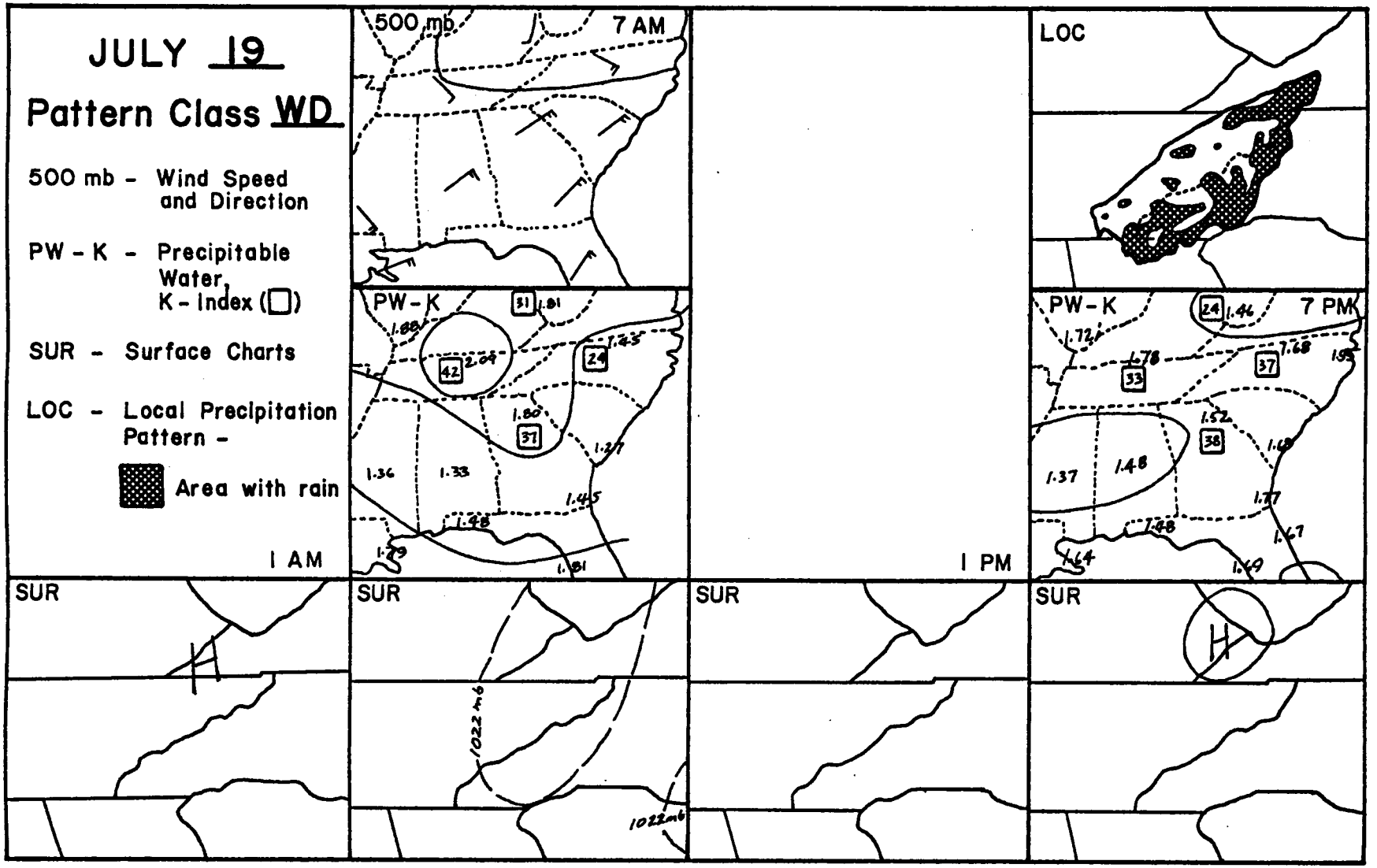


Figure 21. Synoptic Charts for July 19.

pattern is nearly random. The precipitation is spread throughout the study area. It is fairly light, however, with only a few places of high elevation receiving more than .75 inch of rain. As on July 18, the northern section received less rain, with only 27% of its area wet, while the south, west, and east sections were 73%, 69%, and 71% wet respectively. As on the previous days, no causal factors for precipitation are seen on the surface charts (Fig. 22). It cannot be stated readily that the precipitation that fell was convective as it was on the 18th. The hourly precipitation data are of little use in establishing the time of day precipitation fell, since there was rain at only one station within the study area that reports hourly rainfall. The rainfall at this station did occur during the afternoon. Nevertheless, both the precipitable water and K-Indexes are quite low at 7 P.M. in the southern portion of the region in comparison to the 7 A.M. values. This is presumably a result of precipitation earlier in the day removing a large proportion of the moisture from the atmosphere.

At 500 mb the air continues to flow from east-to-west, contributing to the higher precipitation amounts in the east section of the study region. This upper air flow configuration also tends to have a shearing effect as the fast-moving east-to-west winds to the south of the region run parallel to these flowing across the region and generate precipitation throughout the southern portion.

Class E is the rainfall pattern type of July 21. Rain is very light and only averages about .20 inch. The pattern of precipitation shows the eastern fringe of the study area wet. The surface is still under the weak high-pressure cell (Fig. 23). The low precipitable

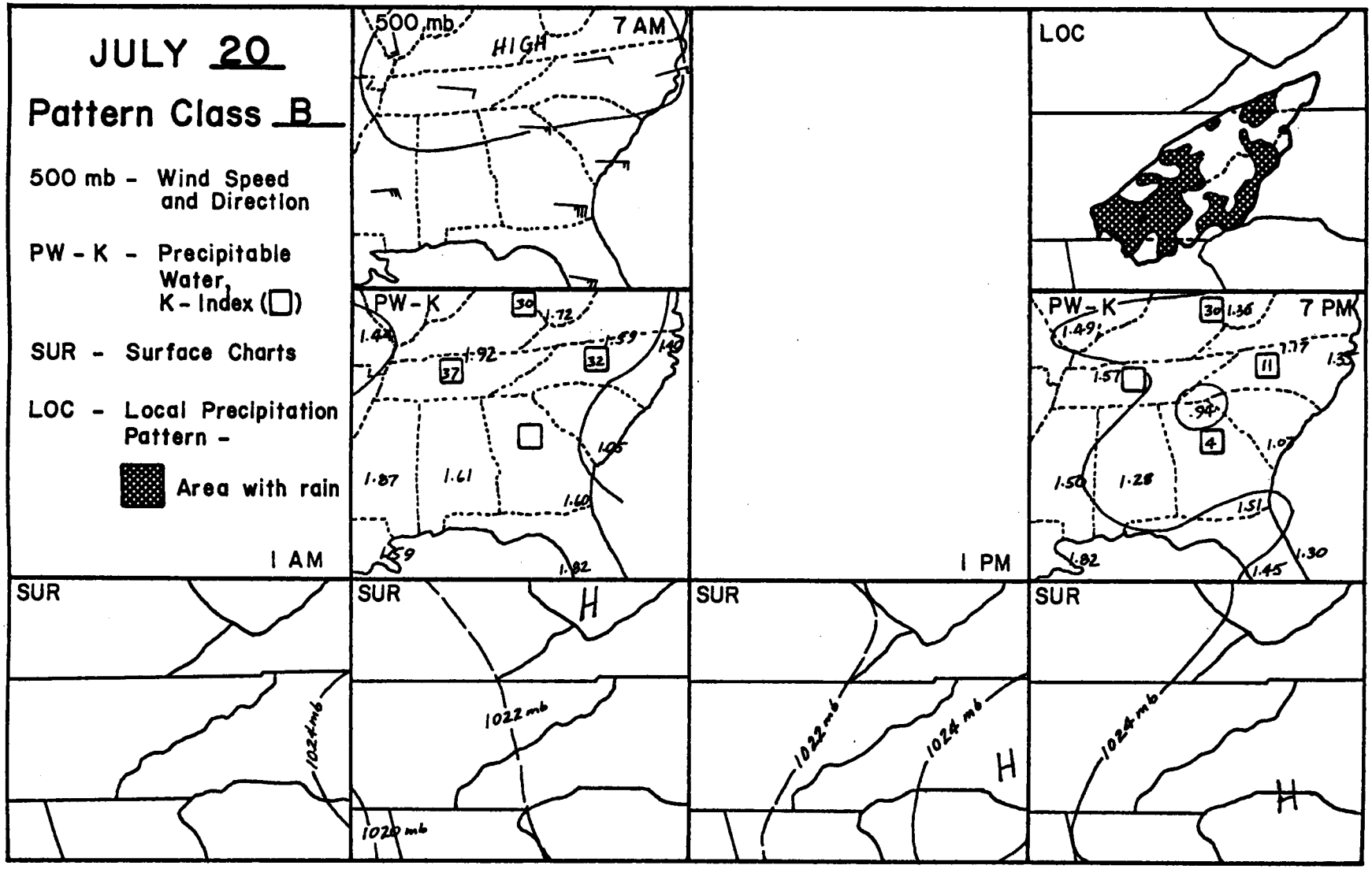


Figure 22. Synoptic Charts for July 20.

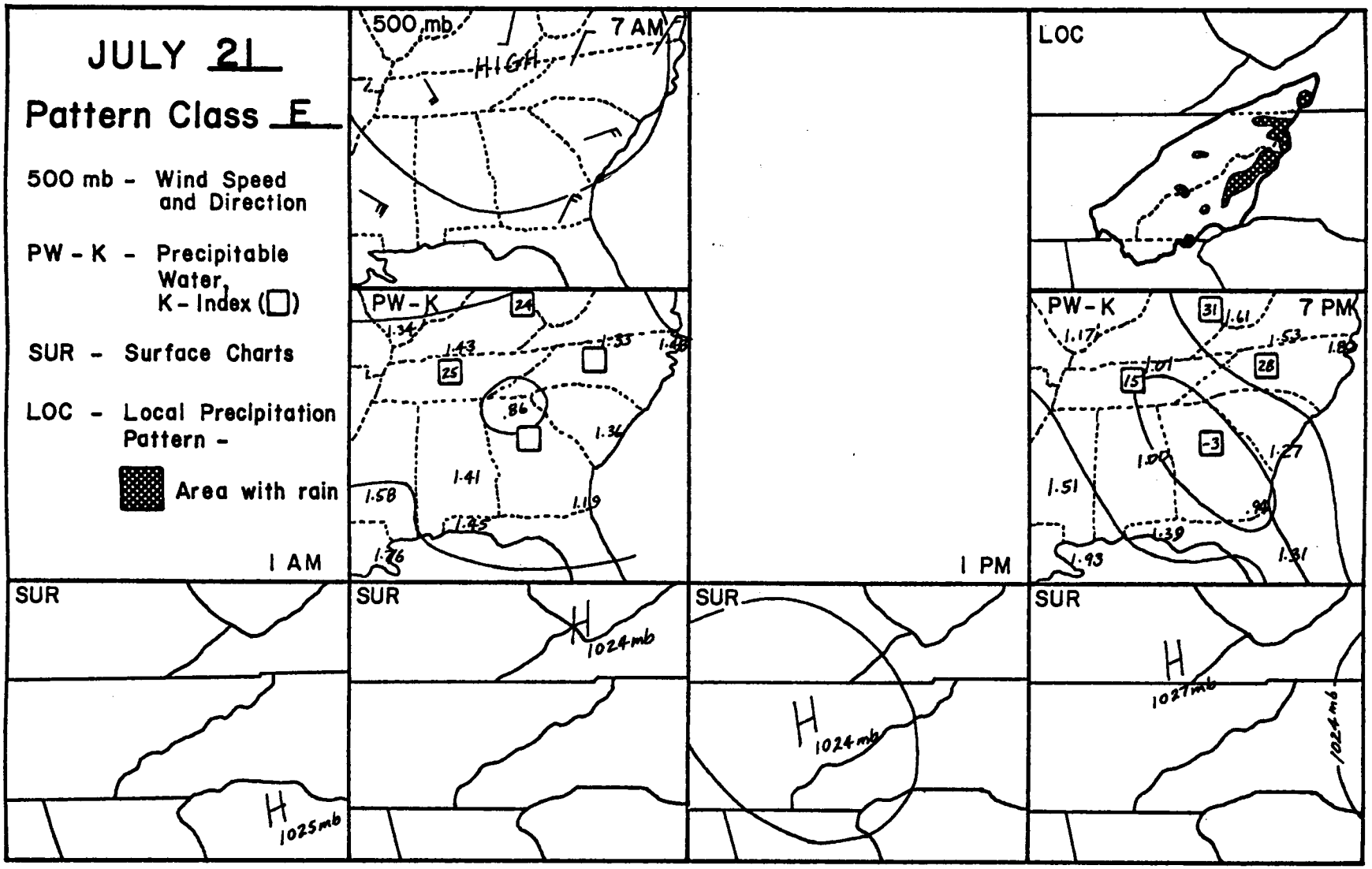


Figure 23. Synoptic Charts for July 21.

water values and stable atmospheric conditions at and around Athens on the 20th still persist throughout the 21st. There is no particular explanation for the precipitation on the east side of the area other than convection, for the precipitable water and K-Indexes were not extremely high. The K-Indexes at Huntington and Greensboro indicate thundershower probabilities of 40-60% when in actuality the north and east sections had only 18% and 27% of their areas wet. This E pattern seems directly related to the dry air over the south end of the region and the lack of any significant advection at all levels.

July 22 is characterized by rainfall in the south and east sections, a shift southward from the previous day. Rain is more widespread and greater in amount in the southeast, while the west section is completely dry. The center of the high shifts off to the west at the surface, but it still dominates (Fig. 24). The upper air flow is stronger and still comes from the east. It is especially strong in the southeast. This eastern flow of upper air, as seen on July 19, concentrates precipitation on the eastern side of the region, leaving the west section dry in both cases. Unlike the pattern on the 19th, the precipitable water is low and the upper atmosphere stable during the morning of the 22nd in the western area. As a result, precipitation is concentrated in the southeast.

The precipitation is again concentrated in the southeast on July 23. Compared with the 22nd, the extent of precipitation as well as the amount of precipitation is greater. The high pressure cell is still dominant on the surface charts, although it has shifted northward (Fig. 25). The upper air flow is still from east-to-west, which,

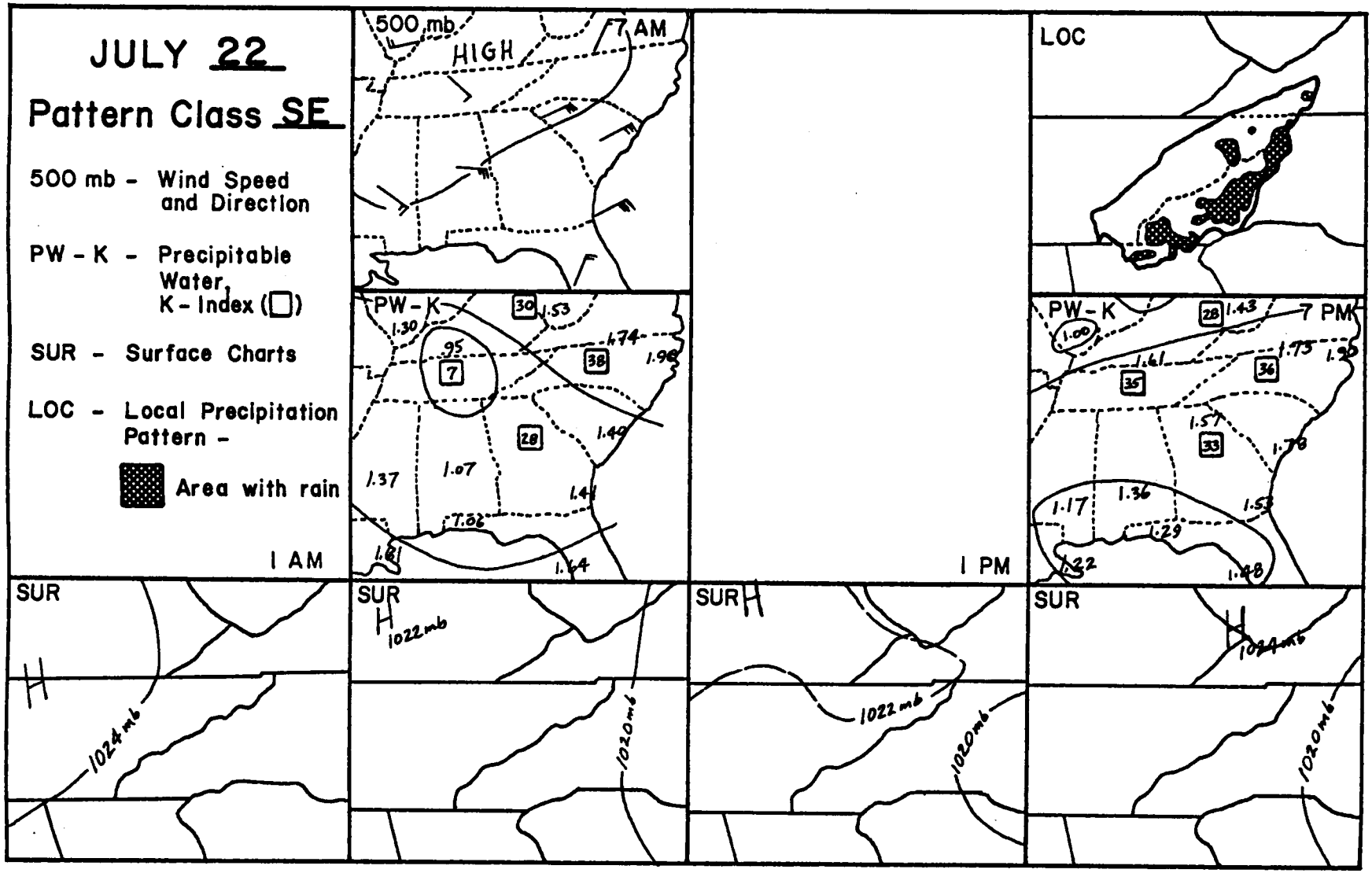


Figure 24. Synoptic Charts for July 22.

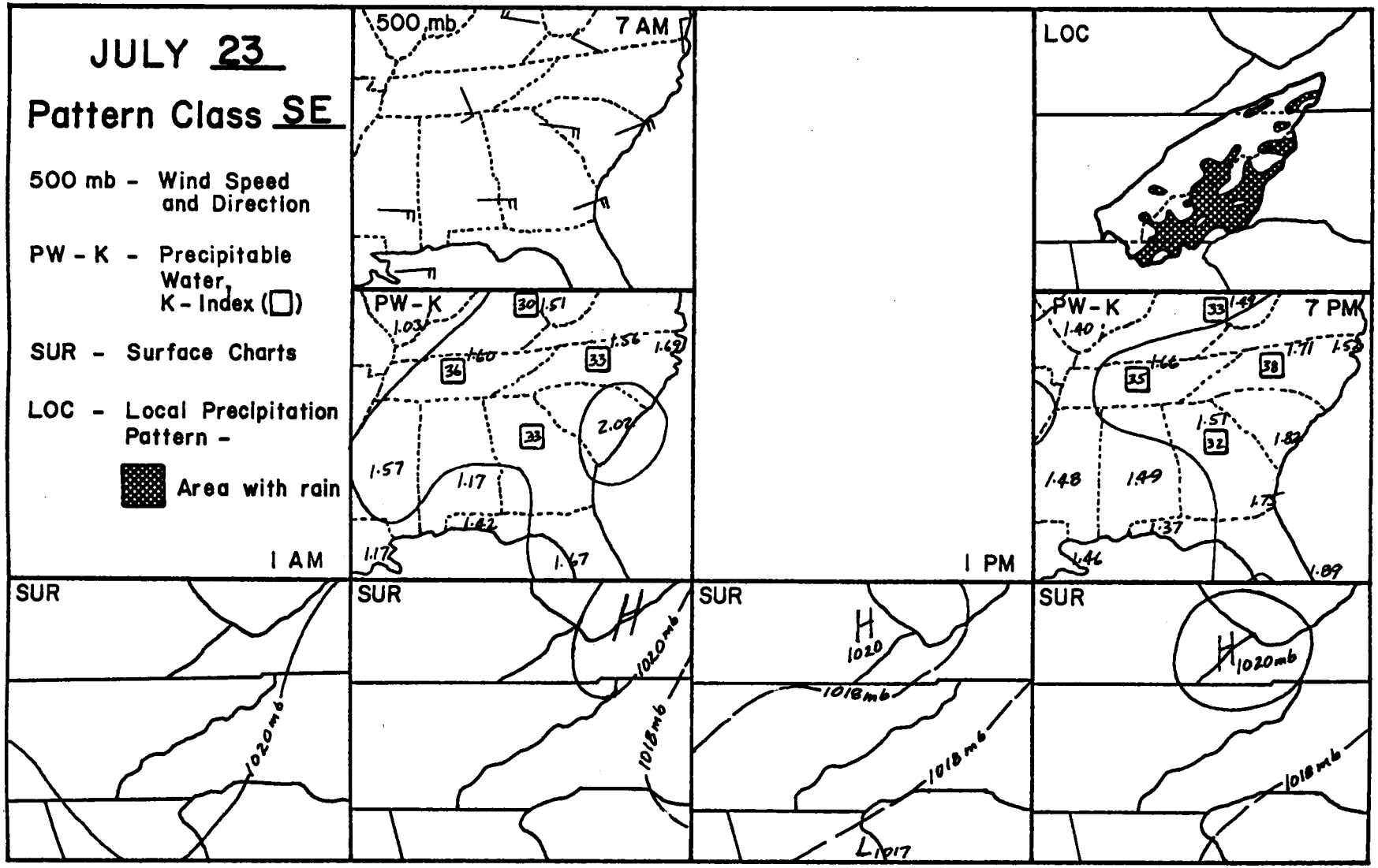


Figure 25. Synoptic Charts for July 23.

as seen on the previous day, led to precipitation on the eastern side of the region. There is also a large concentration of precipitable water in the southeast. This coulped with high probabilities of thunderstorms, caused afternoon precipitation, as substantiated by the hourly precipitation data, predominantly in the south and east sections.

The local precipitation pattern on July 24 is WD--west dry. The overall precipitation pattern is very light with the west section receiving less rain (12%) than the other three sections (36%, 26%, and 37%). The high pressure zone still dominates the surface charts, and there is no strength or organization in the air flow aloft (Fig. 26). The hourly precipitation data indicate rain fell during the afternoon, which implies convective uplift. The explanation for the lack of precipitation in the west section is tied to the low precipitable water values and more stable atmospheric conditions in that area.

July 25 is classed as having an N precipitation type with an assignment of 4323. According to the hourly precipitation data, rainfall occurred during the afternoon. This plus the fact that areas of heavy rainfall amounts occurred in the area, implies that convective thunderstorms are the cause of precipitation. The precipitable water values are fairly uniform throughout the area, and there are high levels of instability in the upper atmosphere (Fig. 27). The most dominant factor in the resultant precipitation pattern is the light air flow coming out of the northwest and flowing southeast. This causes more convective showers in the northern section of the study area.

On July 26 the local precipitation has become so widespread that it is classed as an A type. This pattern is much like that of the

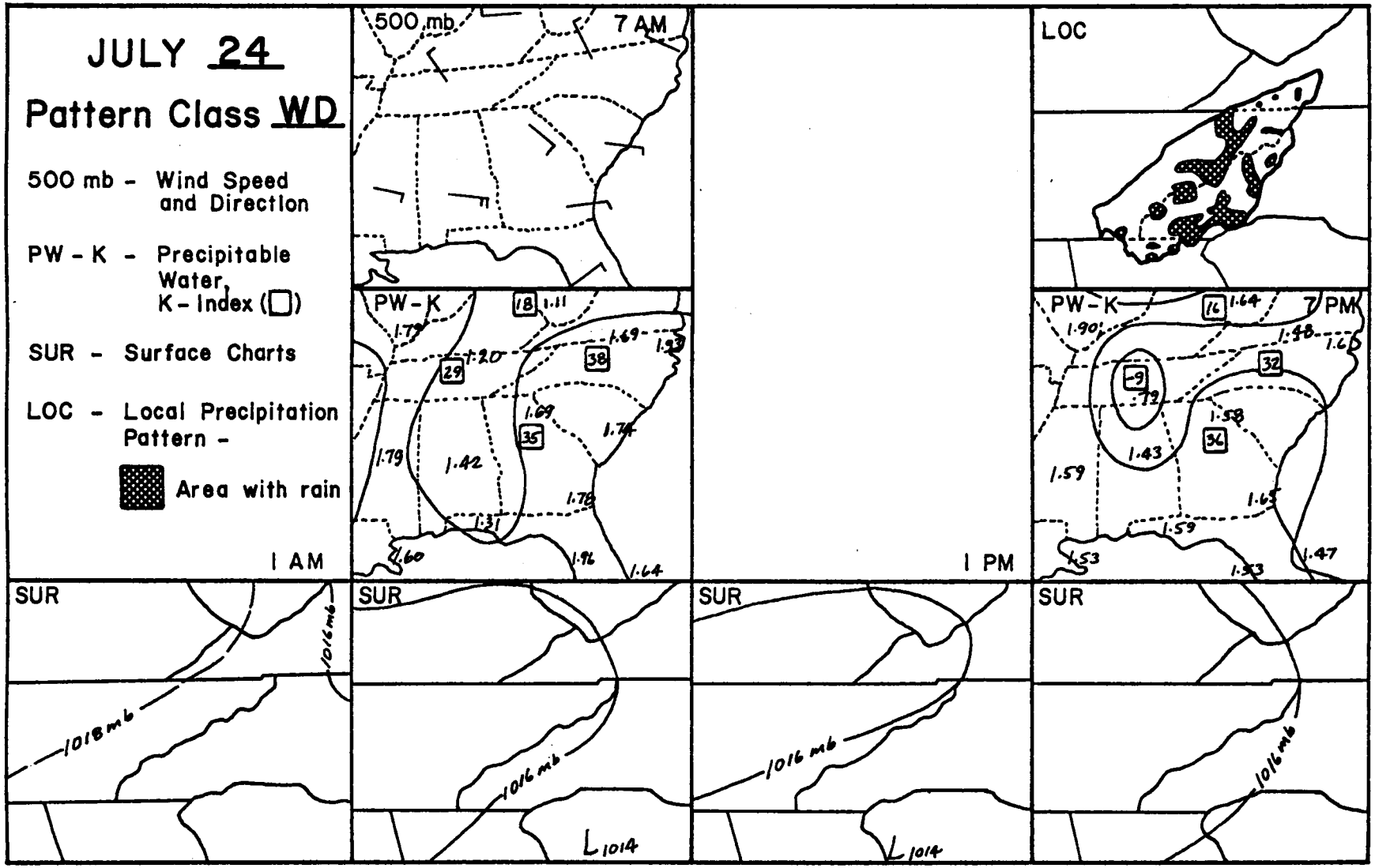


Figure 26. Synoptic Charts for July 24.

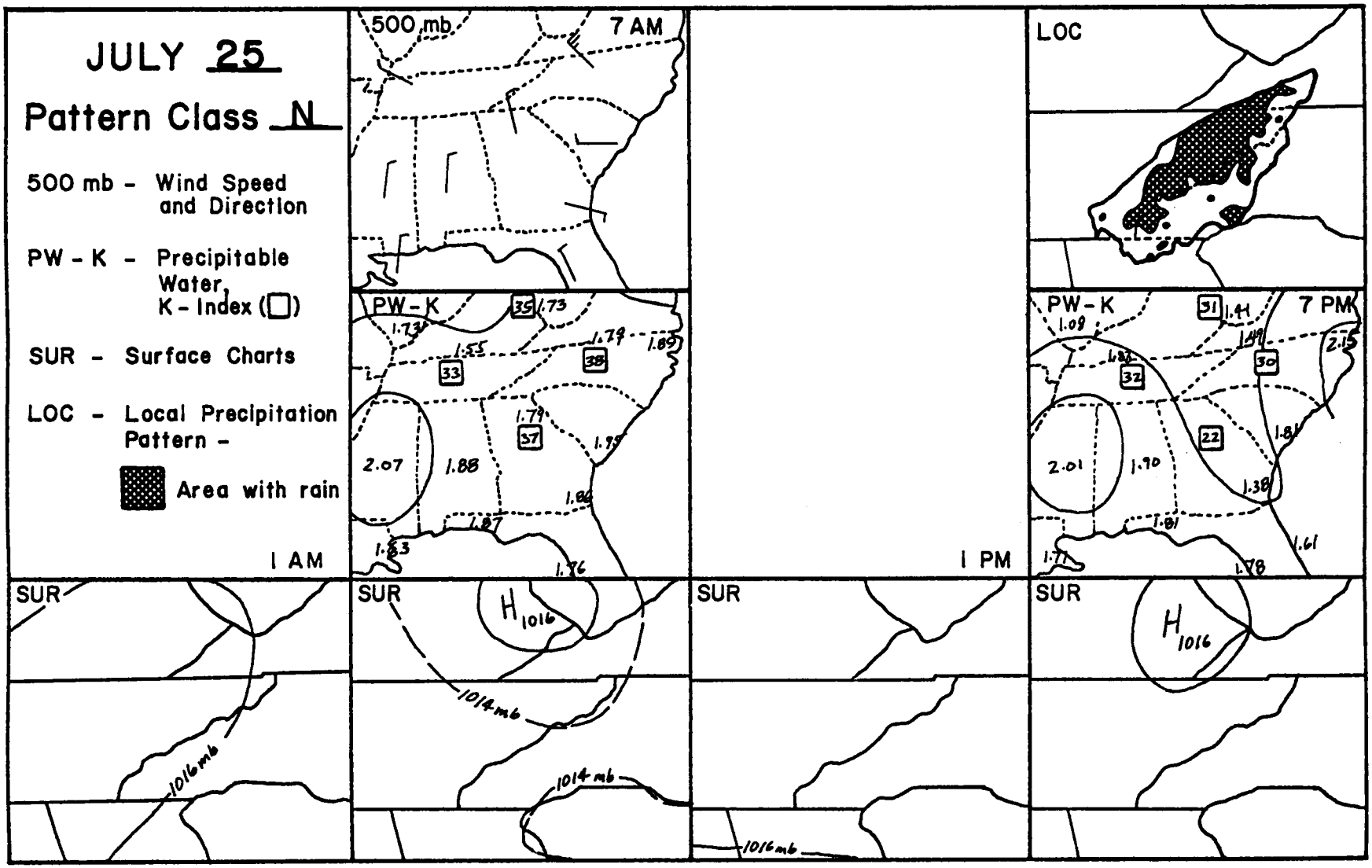


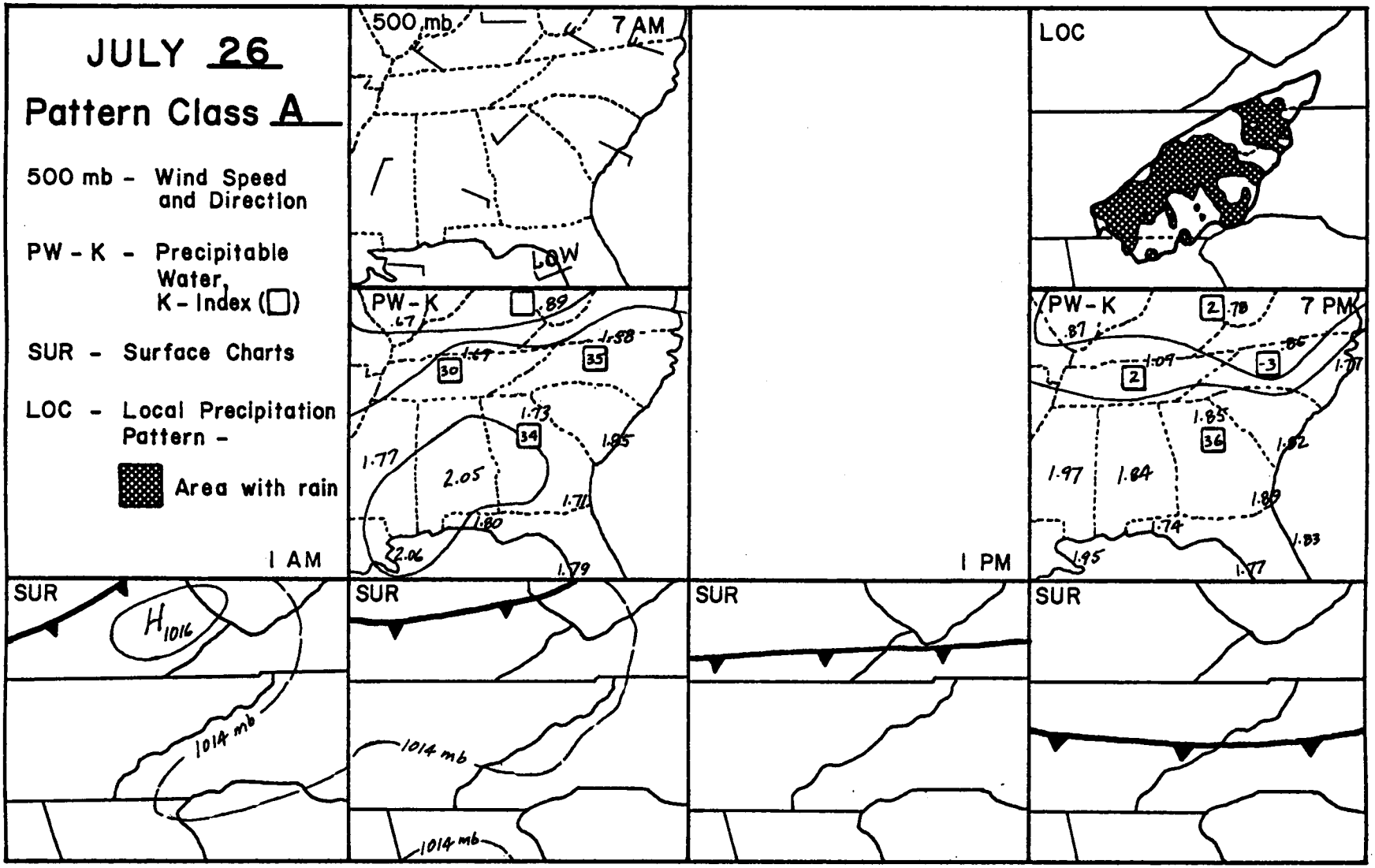
Figure 27. Synoptic Charts for July 25.

of the previous day, but more rain is involved. The west quadrant was 94% wet, the south 78%, the east 52%, and the north 58%. The cause of the increase in precipitation is seen on the surface chart in the form of an east-west frontal system that moves into the region from the north (Fig. 28). Not only can this front be seen on the surface charts, but the isolines of precipitable water and the K-Indexes show its passage. The passage of the front resulted in a large amount of precipitation throughout the study area.

The front was still present on July 27 and resulted in rain concentrated in the southern portion of the region. From the surface charts on Figure 29, the cold front that moved southward through the area on the 26th was converted into a warm front near Chattanooga. The warm front began moving northward around 7 A.M. and had become stationary in Kentucky and Virginia by 1 P.M. The resultant pattern of precipitation generated by the warm front at all stations is dependent upon "the nature of the overrunning warm air. If it is dry and stable, considerable ascent will be necessary to produce any condensation, and precipitation will be light if it occurs at all. On the other hand, if the warm air is conditionally or convectively unstable ascent over the cold wedge may be vigorous enough to trigger showers."[29] At 7 A.M. the upper air in the southern portion of the region was extremely unstable, while the upper air in the rest of the region was quite stable. As the warm front encountered the unstable air in the southern portion of the region rain fell, while the more stable

---

[29]Glen T. Trewartha, An Introduction to Climate (New York: McGraw-Hill Book Company, 1968), p. 203.



Figrue 28. Synoptic Charts for July 26.

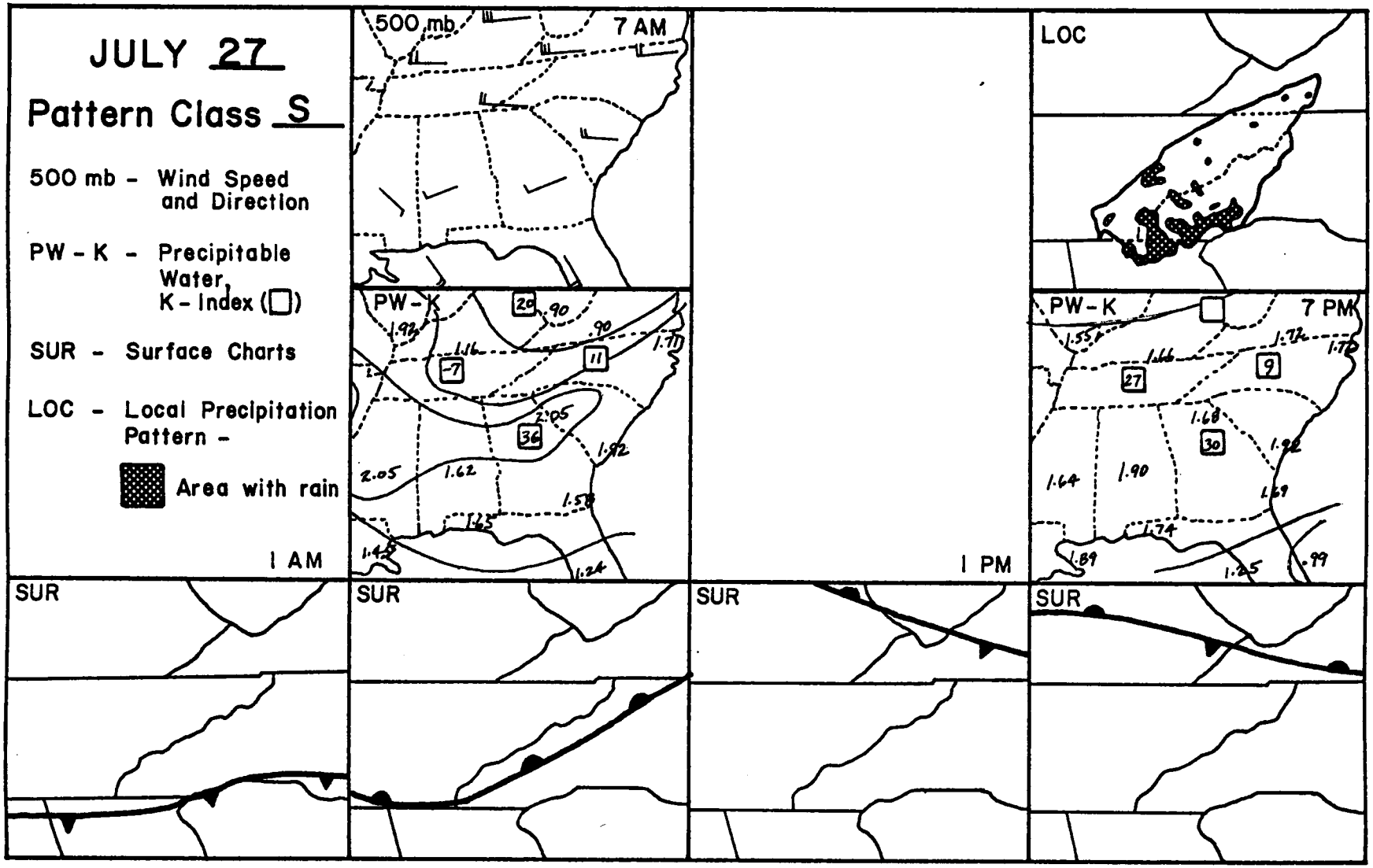


Figure 29. Synoptic Charts for July 27.

conditions over the remainder of the region retarded precipitation there. Because of the synoptic conditions rainfall was concentrated in the southern portion of the region.

The frontal system that became stationary on July 27 remained in the same place throughout the next day. This can be seen on both the surface charts and the precipitable water charts (Fig. 30). Every station within the study area received rain on the 28th giving it an A type pattern. Since the stationary front is located north of the study region, its direct effect upon the region-wide precipitation is minor. The rainfall seems to be associated more with thunderstorm activity. The K-Indexes indicate 60-80% chances of thunderstorms throughout the day, and the precipitable water values are high. According to the hourly precipitation data, the precipitation exhibited thunderstorm characteristics, as short, intense occurrences of rainfall were recorded. The presence of the stationary front may have acted as a triggering agent for the extensive thunderstorm activity found in the region.

From the analysis of this eleven-day period, the sequential movement of synoptic situations can be related to the development of the local precipitation patterns. Those days with similar precipitation patterns had similar synoptic situations controlling precipitation.

Each day during the summer of 1972 was scrutinized in a like manner. The synoptic conditions discussed in the case study from July 18 - 28 are not the only ones that generate local precipitation patterns. There is not one set of circumstances for each pattern, but different synoptic combinations can be responsible for the same pattern.

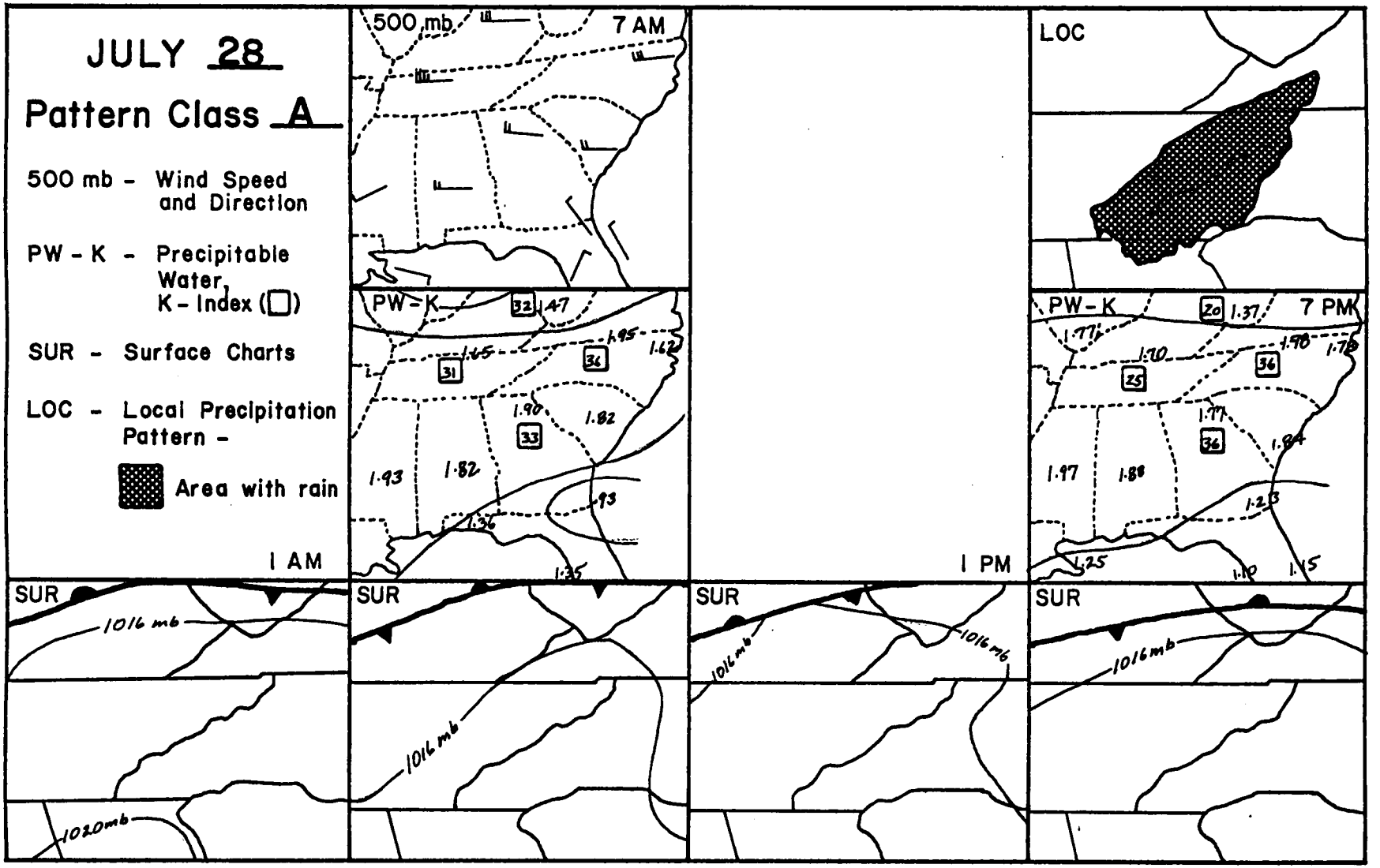


Figure 30. Synoptic Charts for July 28.

Nevertheless certain overriding synoptic characteristics prevail for each local precipitation pattern class.

Generation of Local Precipitation Patterns

The two most frequent classes are the A and SP patterns, occurring on 29 and 35 days respectively. These two classes are different in terms of intensity or extent as Class A has rainfall over nearly the entire region, while Class SP is characterized by spotty, random precipitation restricted to isolated nodes.

Class A

Class A is almost entirely due to frontal systems that move across the region. Twenty-four of the twenty-seven Class A days are associated with large weather systems of some type. Even in this class, where there is rainfall over the majority of the region, there are gradients within the precipitation patterns in which one area is far wetter than another.

One non-frontal weather system that caused precipitation over the entire region was a hurricane. During the summer there were three hurricanes indicated on the North American Surface Charts. Two of them, Carrie (August 31 - September 5) and Dawn (September 5-11), developed in the Atlantic Ocean off the Florida Coast and did not advance far enough landward during their trip north to affect the study area. The third, Hurricane Agnes, began in the Gulf of Mexico and hit the Gulf Coast of Florida on June 19. By June 20 the effects were noticed in the Blue Ridge Mountains, where huge amounts of rain fell on the south end and eastern side. As the hurricane neared

Chattanooga from the south, it veered toward the east and continued moving north along the eastern edge of the mountains. The next day, June 21, saw a great deal of water vapor being moved westward toward Tennessee until most stations in the study area were experiencing some precipitation. One interesting note is that Knoxville did not receive any rain during the invasion of this massive storm system.

The primary weather system causing a Class A pattern is a cold front that moves from west-to-east across the region. Such fronts may be divided into fast and slow-moving systems. The first appears as a large cyclonic system centered in the Great Lakes area, with a southwestward trailing cold front that moves across the region (Fig. 31). The speed of the front has a definite effect upon the area that receives precipitation in one day and the amount of precipitation that falls. Fast moving fronts have greater daily station totals than do the slower moving ones. Often the slow-moving fronts cause daily patterns to be classed as other than A, because precipitation is centered along the front and only the west side or east side of the region may be wet.

The second case of a cold front moving from west-to-east is associated with a small cyclonic system. A low is situated north of Tennessee, with a quasi-stationary front oriented east-west. Gradually a small frontal wave forms, with a southwesterly-directed cold front which moves across Tennessee and the study region (Fig. 32). When this occurs there is a tendency for heavier amounts of rain to fall across the entire region.

There were six days with Class A precipitation that are not

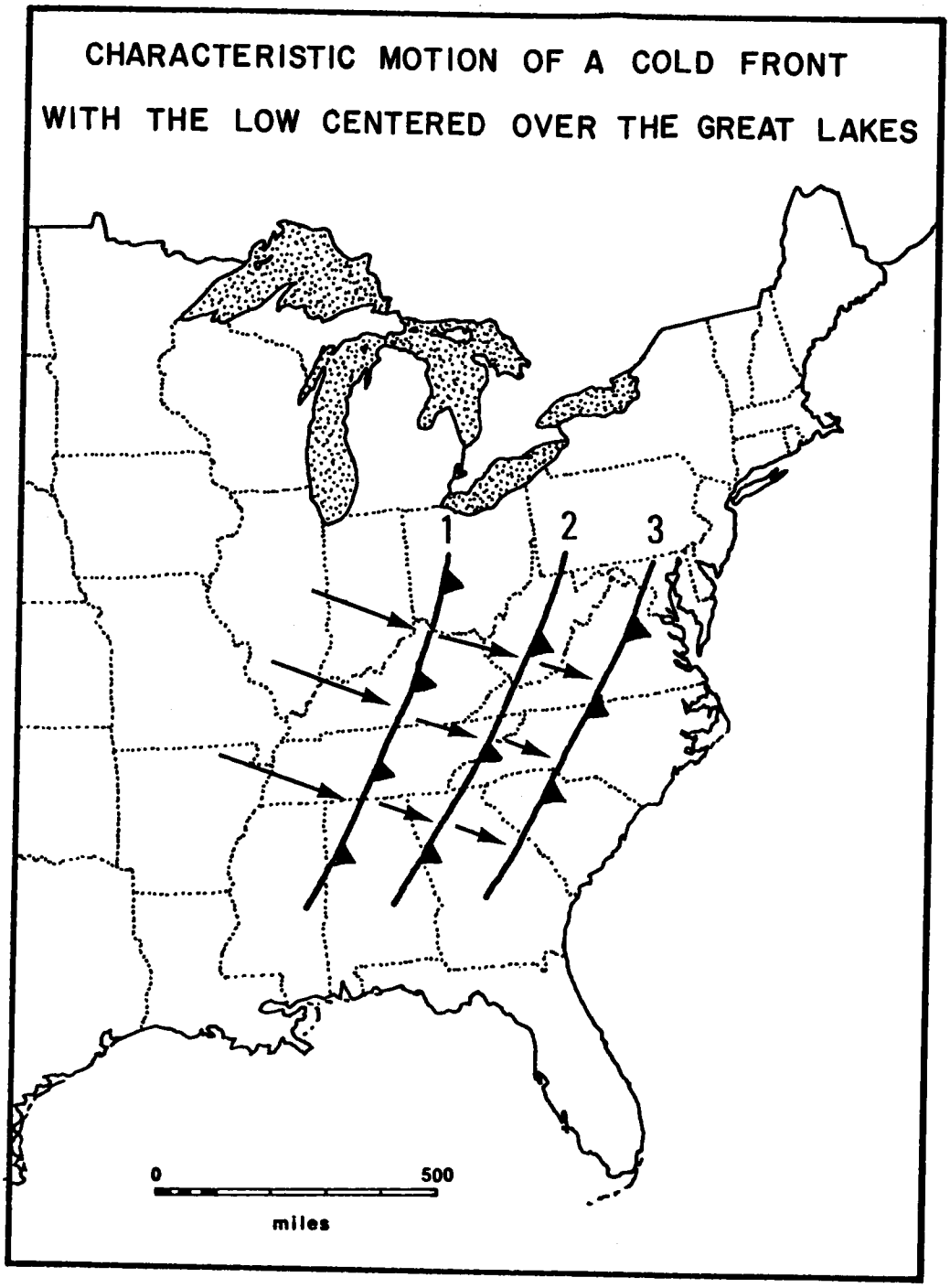


Figure 31. Characteristic Motion of a Cold Front with the Low Centered over the Great Lakes Area and Producing a Class A Pattern.

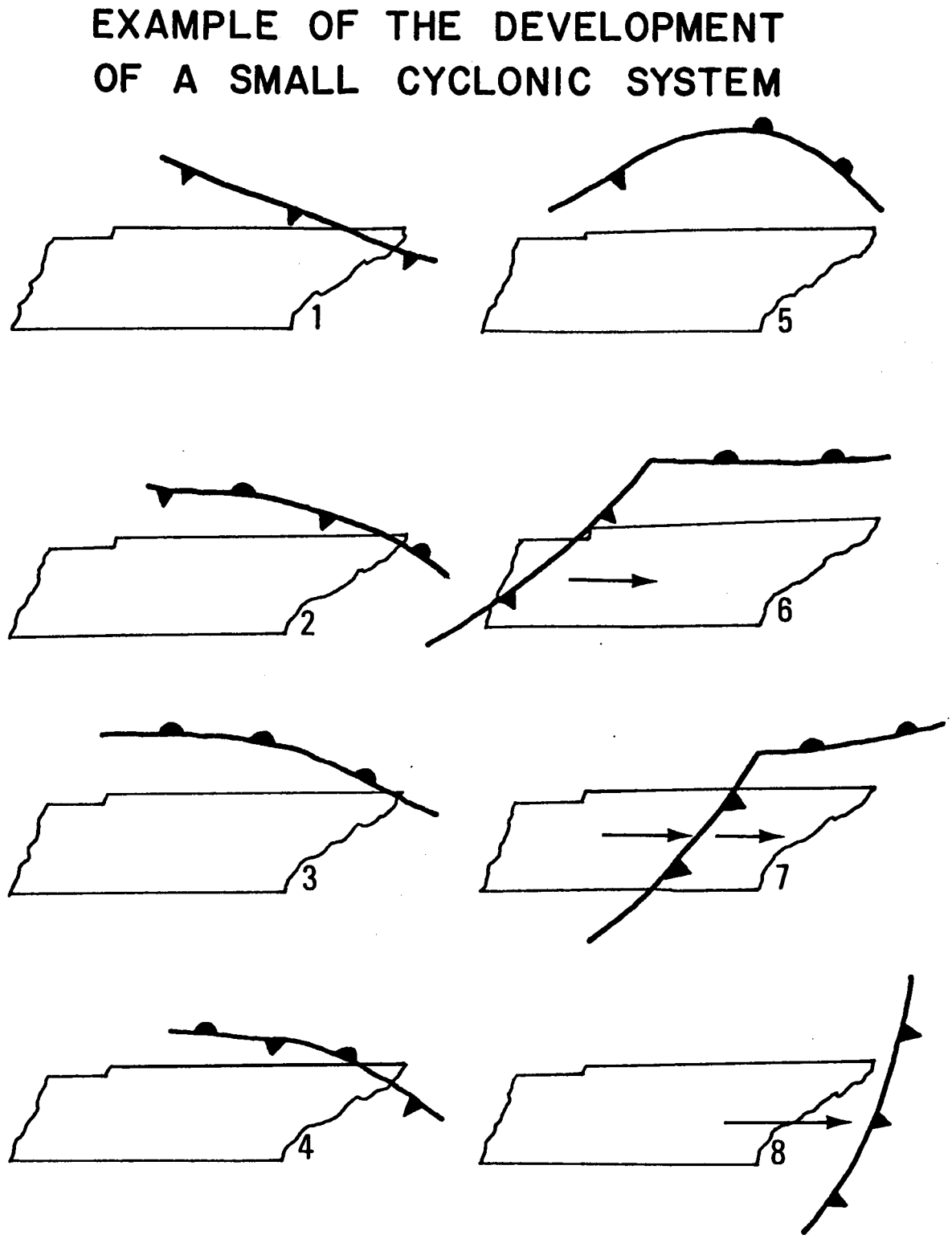


Figure 32. Example of the Development of a Small Cyclonic System Producing a Class A Pattern.

associated with frontal activity of some sort or a hurricane. They do, however, have two important aspects in common: they are associated with extremely unstable upper air conditions, and the upper air at 500 mb is shown to be moving from the west. On two of the days a 100% chance of thunderstorms existed and on the other four days each was assigned a greater than 60% chance of showers in one of the K-Indexes. August 2 is an example of an A class precipitation pattern where there is no frontal activity associated with the widespread rainfall (Fig. 33). As on most days exhibiting an A class pattern, the winds aloft flowed eastward across the region. This plus a relatively high level of precipitable water that was evenly distributed across the region and very unstable atmospheric conditions led to widespread precipitation which at most places was less than .75 inch. With thunderstorms probable in more than 60% of the area on the six days in question, it is not unexpected that a type A pattern develops.

Class SP

While Class A is basically due to frontal activity and can be related to the synoptic features shown on the North American Surface Charts with ease, Class SP proved to another case entirely. There is nothing on the surface charts that would indicate there should be precipitation in the region, especially rainfall of so spotty a pattern. Further inspection of the maps classed as SP permitted them to be divided into two subclasses. In the SP1 type rainfall reception seemed to be random over the entire area. Rainfall with an SP2 pattern also appears to be random in terms of scattered nodes but is clearly associated with higher elevations. These two subclasses are almost equally

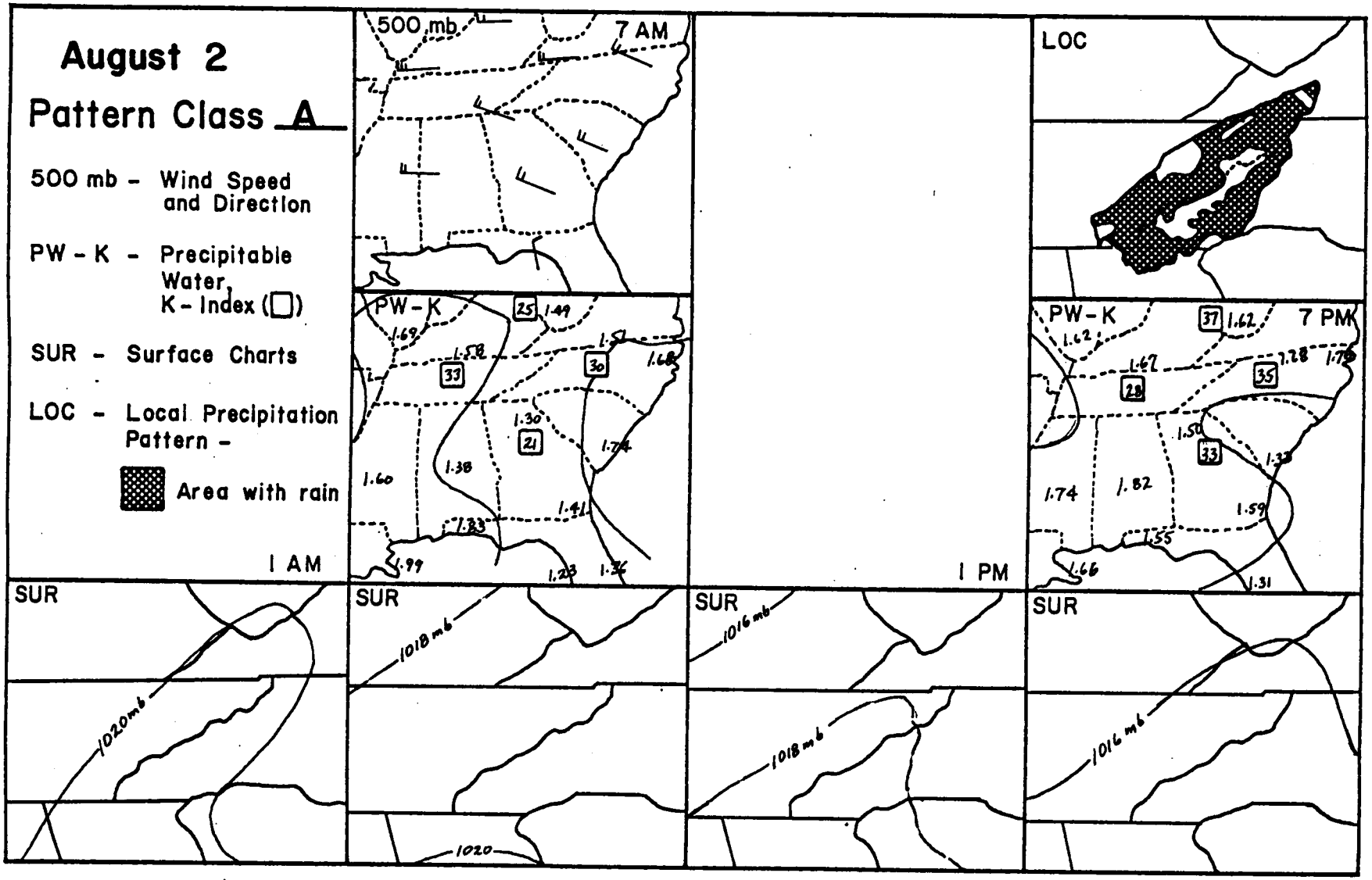


Figure 33. Synoptic Charts for August 2 that Produced a Class A Pattern.

frequent, as there are 17 days of SP1 patterns and 18 days of SP2 patterns.

The surface charts do not reveal what is causing the spotty precipitation pattern. Local convection showers are frequent during the summer months, and the SP1 class is probably dependent upon them. The fact that the SP1 type is not selectively associated with higher elevations seems especially indicative of convective precipitation as described by Glenn T. Trewartha;[30]

> Rainfall associated with convective overturning has certain distinctive characteristics. Since a single convective unit is composed of several columns of cells of rapidly ascending air, each often capped by a cumulus or towering cumulonimbus cloud, cooling is rapid, and the resulting rain commonly falls as a pelting downpour. But since the ascending chimneys of air and their cumulonimbus clouds are not horizontally extensive, the rain is often spotty, local, and brief for the raincloud quickly drifts by.... Much convective shower activity has a seasonal and diurnal periodicity reflecting the influence of solar heating. It tends to follow the sun and occurs at the time of greatest heat and greatest atmospheric instability.

The brevity, localness, and spottiness of convective showers effectively describe the SP1 pattern class. From the Lifted Index Chart on the Moisture Composites all 17 SP1 days show upper air instability. On some days there is only a 20% chance of rain while on others there is an 80-100% chance. July 2 is a good example of the SP1 class (Fig. 34). The rainfall is both spotty and sparse. It occurs in each of the four sections, and there is little correlation with high elevation. The 7 A.M. chart shows K-Indexes of 25 at Nashville, 4 at Huntington, 22 at

---

[30]Glenn T. Trewartha, op. cit., p. 150.

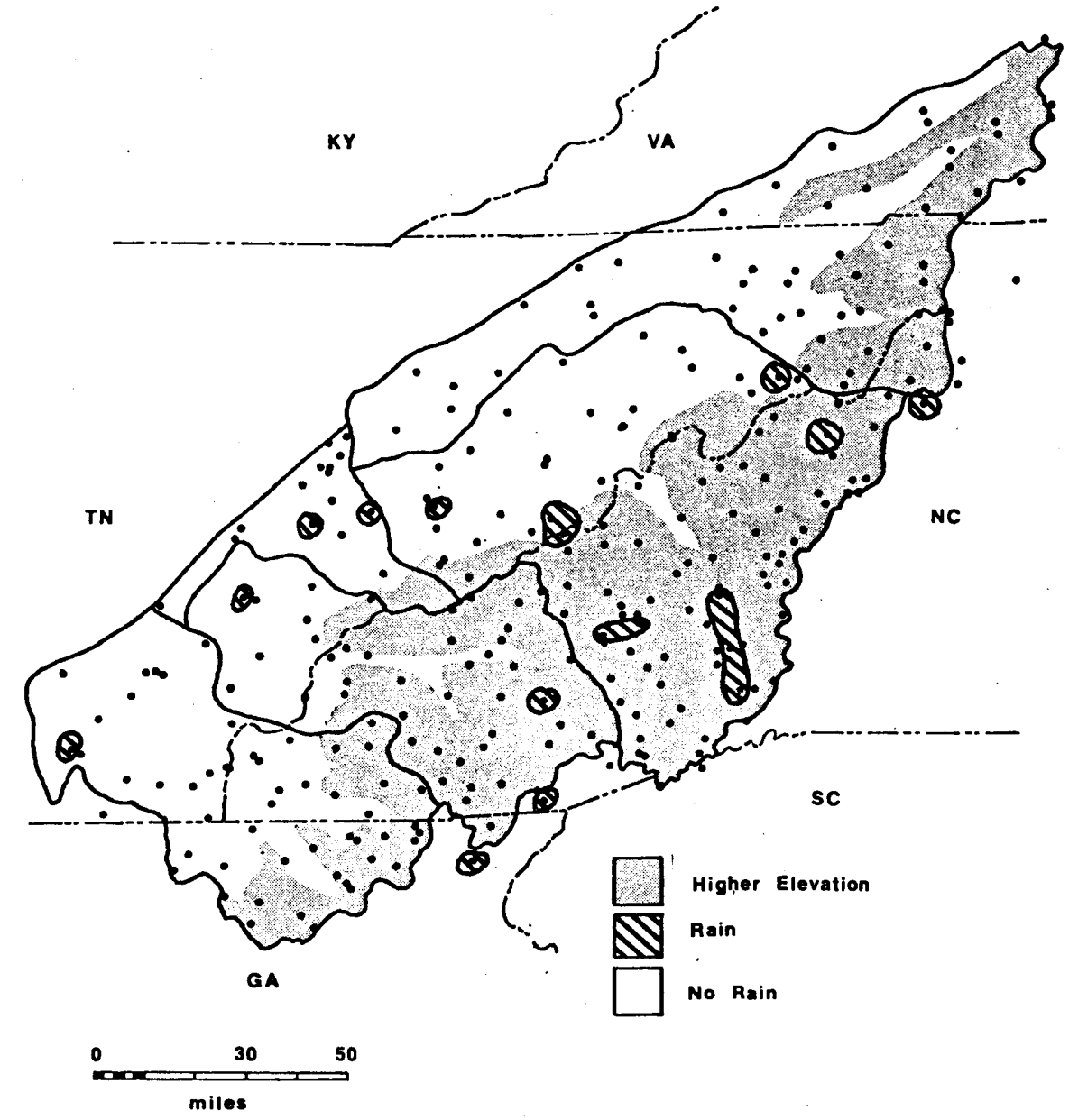


Figure 34. Example of Class SP1 - July 2, 1972.

Athens, and 11 at Greensboro, which point to a 20% chance of showers in the north and west parts of the region. The 7 P.M. readings have K-Indexes of 35 at Nashville, 33 at Huntington, 30 at Athens, and 11 at Greensboro. The K-Indexes have increased substantally, so that there was then a 60% chance of thunderstorms in most of the region. With such instability in the atmosphere, widespread local convective showers are predictable.

Circumstances for the SP2 class are much like those of the SP1 class. For the most part, there is nothing on the surface charts to suggest such spotty rainfall. Five of the days, however, are associated with frontal systems. On these five days the rain might be due to orographic precipitation caused as the air ascends a mountain barrier. The rest of the SP2 days show no reason for rain at the higher elevations. Trewartha again gives an indication of what might be happening:[31]

> It seems likely, though, that a considerable part of the increased precipitation associated with highlands is not solely the result of forced upslope ascent of prevailing winds, but is complex in origin. Other indirect effects of highlands are also important; (1) their production of strong turbulence of both a mechanical and a convective nature; (2) their obstructing and slowing effect upon the progress of cyclonic storms; (3) orographically conditioned convergence in horizonal currents; and (4) the trigger effect of highlands that gives the initial upthrust to conditionally or convectively unstable air masses. Sometimes only a slight amount of lifting is necessary to bring unstable air masses to the condensation level. After that, added heat of condensation makes them unstable and bouyant and causes them to continue rising, yielding abundant showery convective rainfall.

There is a complexity of reasons why rainfall might occur at the higher

---

[31]Glenn T. Trewartha, op. cit., p. 151.

elevations as characterized by the SP2 class. On most days the K-Index shows a greater than 40% chance of showers, and some days have as high as an 80% chance. Again as in the SP1 case, the upper air is unstable and the barrier imposed by the mountains is enough to trigger precipitation at the high altitudes. September 25 is an example of Class SP2 (Fig. 35). Rain fell at 13 stations with higher elevations while none was recorded elsewhere. The upper atmosphere is quite unstable as there is a 60% chance of thunderstorms over the eastern portion of the region (Fig. 36). As the eastward-flowing upper air crosses the mountains the higher altitudes and unstable atmospheric conditions of the North Carolina side trigger precipitation at the higher elevations giving a spotty daily precipitation pattern.

Class B

Class B has rainfall in all four sections but the area of rainfall is not as extensive as in Class A. Frontal passage is a primary synoptic feature behind this pattern. On one occasion, June 10, a front moved southward across the region and wetted a large percentage of all four sections. A similar front became stationary in the southern portion of the region on July 4 and widespread precipitation occurred. On August 7 a front moved slowly from west-to-east. The remaining five days in this class, July 15, 18, and 20, August 25, and September 9, are not related to frontal activity. July 18 and 20 have been discussed in detail in the case study (see pages 46 and 49). As the precipitation patterns suggest, July 15 and August 25 are quite similar to July 20. The precipitation amounts are sparse on these days, and only a few stations exceed .75 inch of rain. All five days did have

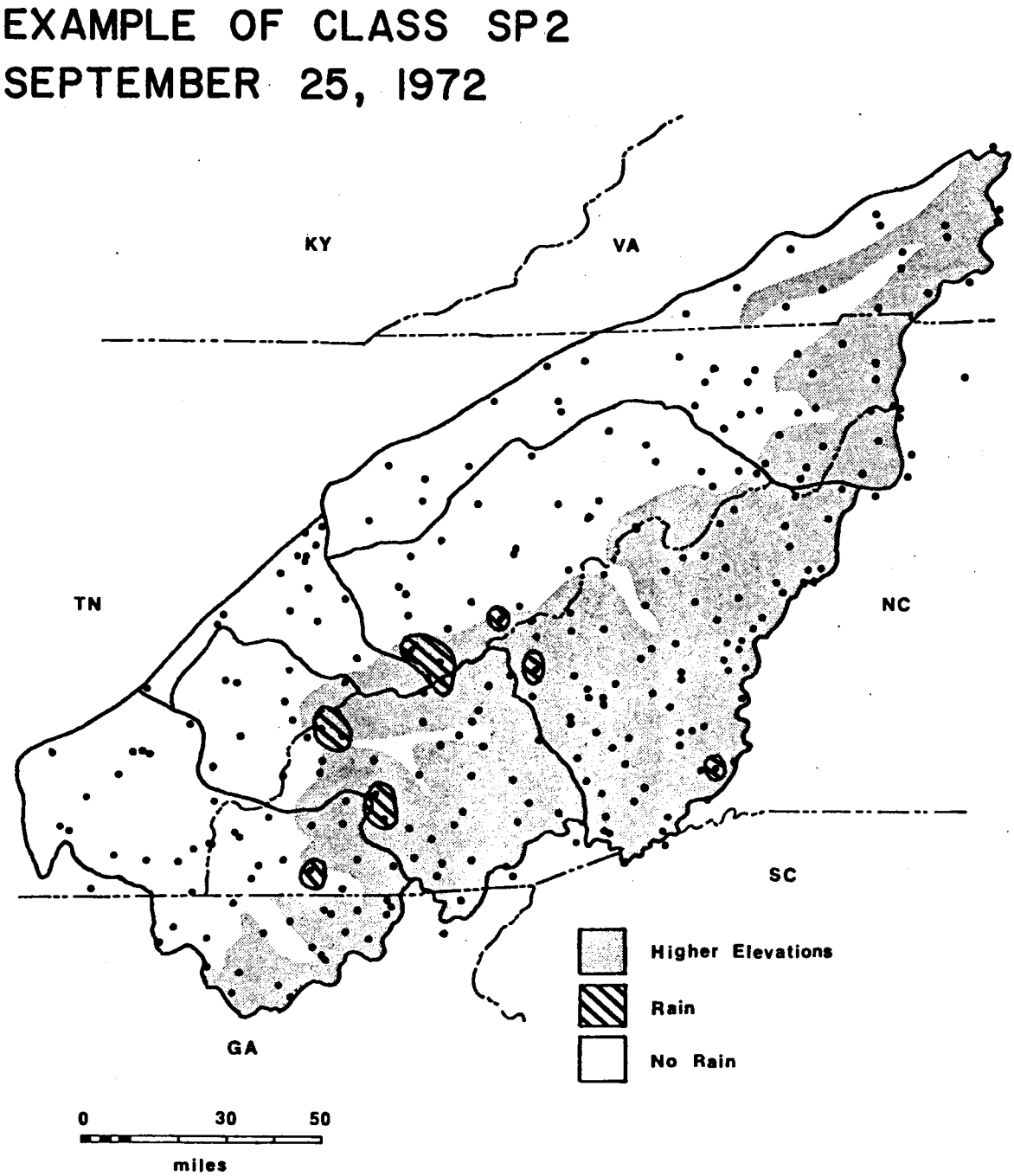


Figure 35. Example of Class SP2 - September 25, 1972.

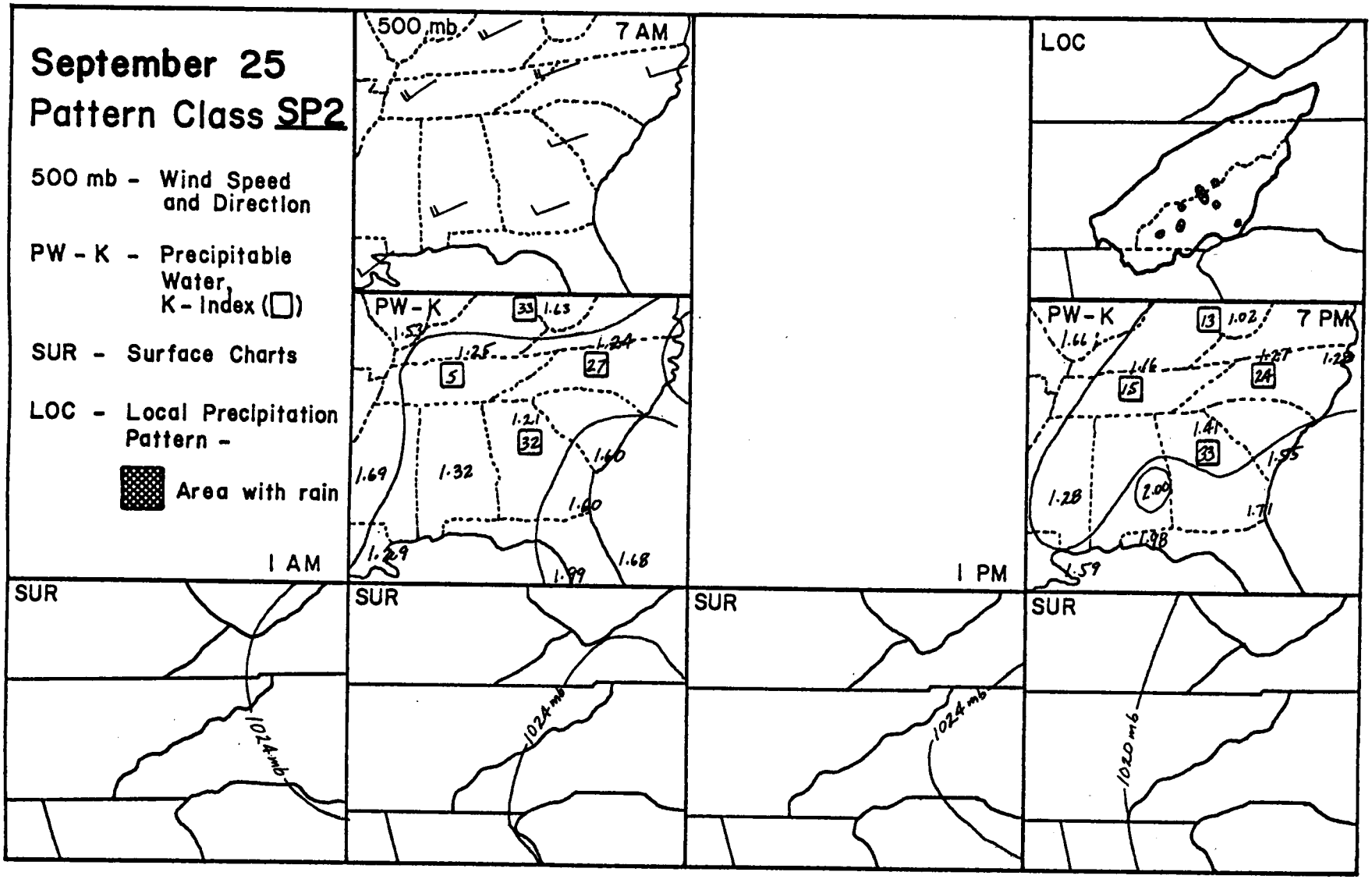


Figure 36. Synoptic Charts for September 25.

extremely unstable upper air (over 60% probability of thunderstorms on July 15 and August 25). September 9 is also characterized by very unstable upper air. This instability coupled with the precipitable water in the air caused extensive thunderstorms across the entire region. Approximately 60% of the region received rainfall on all five days.

Synoptic conditions leading to a Class B pattern vary a great deal. On two occasions frontal systems moved from north-to-south, on another occasion a slow-moving front traveled eastward across the region, and on five occasions extremely unstable upper air led to the widespread precipitation.

Class N

The remaining nine precipitation patterns are regional and do not contain as many daily examples as the A and SP classes. Each class, however, has certain characteristics which set it apart from the others. The rainfall was too limited in areal extent in each of these classes to fit the A class yet it was more extensive than the nodal patterns characterizing the SP class. In Class N not only is precipitation primarily in the north quadrant, it is on the northern fringe of this section. This rainfall pattern on one occasion resulted when a cold front moved southward through the Tri-Cities area and stalled between there and Knoxville (Fig. 37). The pattern on June 5 was formed by this process. The northern section can also be influenced by other weather systems lying to the north. On June 22, this area received slight amounts of rain from the influence of Hurricane Agnes, which was stalled over Pennsylvania at that time.

The other three days with an N type pattern are July 25, August 5,

STALLED COLD FRONT THAT PRODUCES A CLASS N

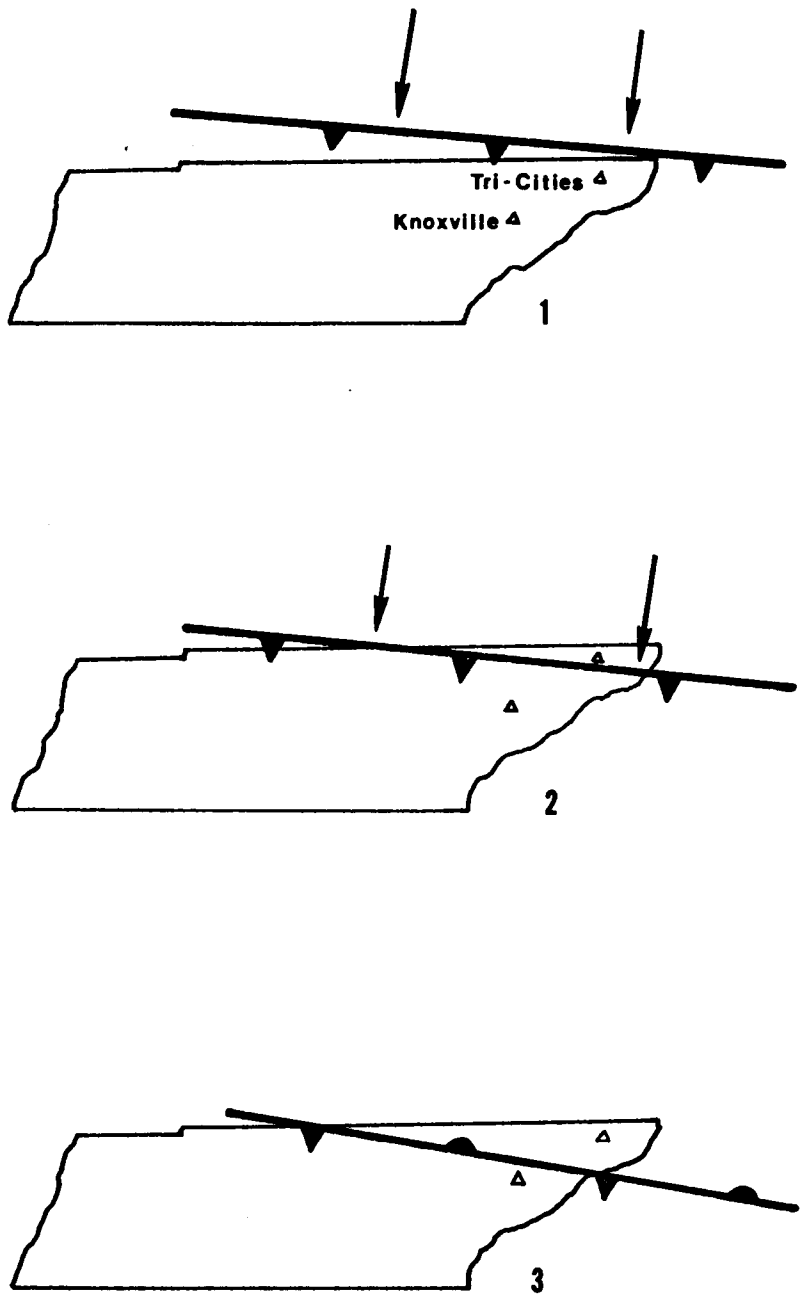


Figure 37. Stalled Cold Front that Produces a Class N Pattern.

and August 18. As frequently occurred in the case study, there are no obvious precipitation controls indicated on the surface charts for those days. July 25 has been discussed in the case study (see page 55). The most important indicator of where precipitation was to fall is the K-Index chart. On August 5 and 18 the K-Indexes for Greensboro and Huntington indicate that the upper air conditions over the northern portion of the area are very unstable, while elsewhere stable conditions exist. The upper air flows from the northwest, which leads to the concentration of rainfall in the northern part of the region. The combination of the upper air flow and the unstable atmosphere in the northern part of the region led to a rainfall pattern type of N on both August 5 and 18.

A Class N precipitation pattern is well defined and can be related to three synoptic conditions: (1) weather systems affecting the area to the north and overlapping the boundary; (2) a stationary front stalled between Knoxville and Tri-Cities; and (3) very unstable upper air conditions over the northern portion of the area and upper air flows from the northwest.

Class NE

Two kinds of synoptic situations led to the occurrence of an NE pattern class. The first cause is associated with frontal acitvity. Slow-moving fronts can cause precipitation to be spread over a series of days, with a different pattern classification for each day. Precipitation on September 4 and 6 was due to slow-moving cold fronts traveling eastward across the region. The rest of the region had received rain on previous days, and the slow speed of the cold front caused rain to

fall in the east as it left the region. The rainfall on August 19 was also due to a slow frontal system. This cold front came from the northern section, instead of being on the end of a frontal passage, was at the beginning.

The second synoptic situation is found on July 6. The surface charts show no obvious controls for precipitation, and the primary explanation for the precipitation is convection. Atmospheric conditions were most unstable near Greensboro and on the eastern slope, with thunderstorm probabilities greater than 60%. The NE pattern seems directly related to the unstable atmospheric conditions in the north and east sections of the study area.

There are two types of synoptic situations resulting in a NE pattern class. Slow-moving fronts that are active for a series of days cause a NE pattern as they pass through the north and east sections. This pattern is also related to unstable atmospheric conditions in the northeast portion of the study area.

Class E

There are two examples of an E pattern class. July 21, as seen in the case study, is characterized by greater K-Index values at Huntington and Greensboro which led to convective showers on the eastern edge of the study region (see page 52). The directional component of the 500 mb winds led to an E pattern on July 19. The higher elevations in the east induced precipitation as moist air flowed northward across the region.

Class SE

On five days, twice as much rain fell in the south and west sections

as in the other two sections. There was nothing on the surface charts on those days which would indicate the cause of an SE pattern class. In the case study two of the days in this class were discussed (see pages 52 and 55). On the 22nd of July the direction of the 500 mb winds and the stable conditions in the west section resulted in the SE pattern. On the 23rd the upper air flow is still important, but the high probability of thunderstorms in the south and the amount of precipitable water take precedence. The other three days in this class, August 11, 12, and 14, exhibit much larger thunderstorm probabilities in the southern and eastern portions of the region than toward the north and west. The concentration of precipitable water in the south, and either the direction of the 500 mb winds or the instability of the upper atmosphere, lead to the concentration of precipitation in the south and east sections of the study area.

Class S

Eight days are classed as an S pattern type. The patterns on July 27 and August 19 and 21 are examples of days at the end of a frontal passage. Fronts moved across the region from north-to-south, so that only the southern portion received rain on the 27th, 19th, and 21st. Two days with this pattern, August 6 and 22, both have K-Indexes which point to unstable atmospheric conditions in the southern portion of the region and stable conditions elsewhere. The greatest amount of precipitable water is concentrated in the south. The concentration of moisture in the south plus the unstable upper air there leads to local precipitation patterns of the S type. July 10 and August 24 both had extremely unstable atmospheric conditions and

concentrations of moisture in the south which led to convective rainfall in the south section. The last day, August 14, had winds aloft from the south contributing to higher precipitation concentrations in the south section.

Frontal systems passing southward through the study area and either north flowing 500 mb winds or a concentration of moisture plus unstable atmospheric conditions in the southern portion of the region lead to a Class S precipitation pattern.

Class SW

There is only one example of the SW class, and it is due to a front that became stationary in the southern part of the region on August 9. Fronts temporarily stalled in the southern portion of the region and unstable atmospheric conditions in the south and west sections lead to a SW class.

Class W

June 27 and September 24 are both characterized by extremely unstable atmospheric conditions. The K-Index values in the west were greater than those in the east and contributed to the precipitation concentrations in the west. The 500 mb wind direction is also important in producing this pattern. On September 24 the upper air flowed from the southwest and brought in moist air that was precipitated on the western section; while on June 27 the winds were from the northwest, which also resulted in the majority of the rain falling in the west section. The combination of the unstable atmospheric conditions in the west and the directional component of the 500 mb winds lead to a W pattern class.

Class WD

Class WD, west dry, is characterized by one section being considerably drier than the other three. Three WD days show the effects of frontal activity. September 15 has a front stationary in the southeast portion of the region. For the August 20 occurrence, a cold front moved from northeast-to-southwest. Since the front traveled into the region on August 20, the west section remained dry as the front had not gone far enough southwest. The west section was dry on August 27, because a slow eastward moving front had already gone through that section on the previous day. The other two cases have extremely unstable atmospheric conditions, and the terrain is most important in the pattern. The west section has the lowest elevations, and most of the precipitation fell at the higher elevations of the other three sections. This is seen in the case study of July 19 (see page 46). July 24 has also been discussed in the case study, and the characteristics of low precitable water values and more stable atmospheric conditions in the west are emphasized (see page 55).

Class WD is associated with a variety of synoptic situations. Slow-moving fronts can cause other sections of the region to be wet while the west quadrant is dry. More stable atmospheric conditions and lower elevations in the west section also lead to a drier western zone.

Class ND

Like Class WD, Class ND is characterized by one section being much drier than the other three. Here it is the north section. The two days in the ND class possess characteristics which tend to put the northern part of the study area in a rain shadow. September 17 and 26 had high

instability indices in the southern portion which generated precipitation in the three southernmost sections. It seems reasonable to assume that by the time the air masses reached the northern section the level of precipitable water was low, leaving the north section relatively dry. The most prominent synoptic situation which generated this pattern was the movement of moist air from the south creating a rain shadow-like effect in the northern part of the region.

Summary

Each day's rainfall is assigned a code number before its pattern type can be designated. Once a class has been found, its corresponding synoptic pattern must be evaluated in order to determine factors behind its generation. The generation of patterns is not always easy to determine. None of the classes has a single set of synoptic characteristics that invariably lead to its development, and several synoptic situations may produce the same daily rainfall pattern.

CHAPTER IV

CONCLUSIONS

Synoptic weather types, in combination with the complex relief of the Southern Blue Ridge Mountains, produce distinctly different local patterns of precipitation. This investigation led to the classification of eleven precipitation types which recurred throughout the region during the summer of 1972. Prior to developing the classification scheme two issues had to be dealt with--the density of the precipitation gaging network and the problem of data comparability.

Problem of the Precipitation Gaging Network

The density of the precipitation gaging network in the Southern Blue Ridge Mountains is high when compared to other sections of the country, yet there is still only about one gage for ever 86 square miles. This gaging network is less than optimal, but it does allow the establishment of basic precipitation patterns for the study area. Ideally a more dense system of gages could be designed to give a more accurate picture of the precipitation variations. The physical placement of the gages could also be improved upon. More gages need to be placed along ridge tops and sides, rather than in valley settings, to get a more complete picture of precipitation occurrence. The gaging system utilized in this study did provide sufficient coverage to permit construction of daily precipitation maps which were used to see how the gross relief of the mountains effect its distribution.

Problem of Data Comparability

Inherent in a study of this type is the problem of data compara-

bility. Precipitation data used to make maps of precipitation patterns are reported on a daily basis and are subject to several kinds of error. Synoptic weather charts that establish causal factors for precipitation occurrences are reported at three, twelve, and twenty-four hour intervals. The sequential movements shown on the synoptic charts give an important temporal picture of the weather systems affecting the study area, an aspect the daily precipitation reports fail to do. The daily precipitation data, owing to station reporting times, occasionally cause appreciable differences in daily rainfall amounts; and only hourly precipitation records, taken at a portion of the stations, allow daily discrepancies to be adjusted and compensated for. The ability to overcome the shortcomings of the daily precipitation data led to explanations for the pattern types through comparisons with the synoptic data.

Findings

Explaining the synoptic factors that generate the various precipitation patterns was not always easy. Each day's local precipitation pattern hinges upon the strength of the synoptic forces that induce rainfall. The intensity of frontal systems, the directional component of winds aloft, the amount of precipitable water available, and the instability of the upper atmosphere interact with the topographic configuration of the study region to produce the daily local precipitation patterns. Any or all of these factors can influence the precipitation pattern in such a manner as to bring about expected, and sometimes unexpected results. None of the precipitation patterns has a single set of synoptic characteristics that invariably lead to its development, and it was seen that several synoptic situations produced the same daily

rainfall pattern. Although the study was limited to one summer, some conclusions can be drawn from this research:

1. Area-wide precipitation patterns are almost entirely due to well defined frontal systems that travel eastward across the region.
2. Fronts that move southward through the region are weaker than west-east moving fronts and result in more sectional precipitation patterns due to their slower movement and stalling tendencies.
3. Slow-moving fronts tend to produce sectional precipitation patterns (i.e., a slow-moving west-east front wets the western side of the region on the first day of its passage, while on the second day of its passage the west section is dry and the east section is wet).
4. Small and scattered patches of precipitation are caused by convective showers and are commonly associated with weak upper air circulation.
5. When a portion of the region has unstable atmospheric conditions, while the remainder of the region has stable upper air aloft, sectional patterns will be generated (i.e., if unstable conditions exist at the Huntington and Greensboro stations while the Athens and Nashville stations have stable atmospheric conditions, the northeast corner of the study area is likely to receive rain).
6. When high atmospheric instability exists across the entire region and thunderstorms develop, any one of the eleven

classes may result, depending upon the direction and strength of the upper air flow.

The ability to draw these conclusions is a reflection of the classification scheme devised for this investigation. The development of a classification system and the evaluation of the factors causing the patterns is a plausible method for investigating the precipitation occurrences in the study area. The method of classification was arbitrary in many ways, but it was based on empiricism which resulted in the production of distinctive local patterns of precipitation.

To investigate this subject further, one would first need to expand the time span of the study. Limiting this study to only four months of 1972 narrowed its scope. The summer of 1972 was assumed to be representative days of the synoptic weather types effecting the study area, but an expansion of the study through the winter months and other summer situations would strengthen the investigation.

This study would be more cohesive if hourly precipitation data was available for all of the reporting stations, eliminating the lag problem in daily totals. This would facilitate the comparisons of the daily precipitation patterns to the synoptic charts. As far as the synoptic charts are concerned there are several ways that the data could be supplemented to improve analysis. The surface charts are often incomplete as many of the indices which should appear on the charts are missing. The Moisture Composite Charts would have been much more helpful if they were reported at three hour intervals, like the Surface Charts, rather than twice a day. The addition of more Lifted Index/ K-Index reporting stations (especially some in the study region) would

have been particularly helpful in determining atmospheric instability in the study area. Different levels of upper air data, especially lower than 500 mb, would also have been helpful.

This investigation might be termed a broad scale study. It has been shown that synoptic situations generate different precipitation patterns across the entire study region. How these same synoptic situations might effect small scale studies concerning adjacent stations with different topographic configurations remains to be seen. The impact station orientation and elevation have upon rainfall reception as various storm types move into the area offers an entirely different view from the broad scale approach. Precipitation patterns exist on a broad, region-wide scale, while their existence on a small scale is open for inspection. The rugged terrain and complex relief in the Southern Blue Ridge Mountains constitute an area where climatological studies with various scopes could be conducted. Some intriguing climatological processes take place in the mountainous environment, and studies examining them are important.

SELECTED BIBLIOGRAPHY

SELECTED BIBLIOGRAPHY

Atkinson, Maj. Gary D., USAF. Forecaster's Guide to Tropical Meteorology. Washington, D.C.: Air Weather Service, 1971.

Barry, R. G., and Perry, A. H. Synoptic Climatology: Methods and Applications. London: Methuen & Co. LTD, 1973.

Composite Moisture Index Charts. MF-2532-72A. January-December, 1972.

Daily Weather Maps. Weekly Series. 500-Millibar Height Contours at 7:00 A.M. E.S.T. June-September, 1972.

Galway, Joseph G. "The Lifted Index as a Predictor of Latent Instability." Bulletin of the American Meteorological Society, XXXVIII (December, 1956), pp. 528-9.

Huff, F. A. "Precipitation Detection By Fixed Sampling Densities." Journal of Applied Meteorology, VII (October, 1969), pp. 834-7.

_____. "Sampling Errors in Measurement of Mean Precipitation." Journal of Applied Meteorology, IX (February, 1970), pp. 35-44.

Huff, F. A., and Shipp, W. L. "Rainfall Variability Relations on Small Areas." Transactions: Illinois State Academy of Science, LXI, No. 2 (1968), pp. 157-64.

_____. "Spatial Correlations of Storm, Monthly and Seasonal Precipitation." Journal of Applied Meteorology, VIII (August, 1969), pp. 542-50.

Johnston, R. J. "Choice in Classification: The Subjectivity of Objective Methods." Annals of the Association of American Geographers, LVIII (1968), pp. 578-89.

Lund, Iver A. "Map-Pattern Classification by Statistical Methods." Journal of Applied Meteorology, II (February, 1963), pp. 56-65.

Miller, Albert, and Thompson, Jack C. Elements of Meteorology. Columbus, Ohio: Charles E. Merril Publishing Co., 1970.

North American Surface Charts. MF-915-72B. April-June, 1972.

_____. MF-915-72C. July-September, 1972.

Rodda, John C. "The Assessment of Precipitation." Water, Earth, and Man. Edited by Richard J. Chorley. London: Methuen & Co. LTD, 1969.

Schwarz, Francis K., and Helfert, Norber F. Probable Maximum and TVA Precipitation for Tennessee River Basins up to 3000 Square Miles in Area and Durations to 72 Hours. Hydrometeorological Report No. 45. Prepared for the Tennessee Valley Authority, May, 1969. Washington, D.C.: Government Printing Office, 1969.

Showalter, A. K. "A Stability Index for Thunderstorm Forecasting." Bulletin of the American Meteorology Society, XXXIV (June, 1953), pp. 250-2.

Stackpole, John D. "Numerical Analysis of Atmospheric Soundings." Journal of Applied Meteorology, VI (June, 1967), pp. 464-7.

Stall, John B., and Huff, F. A. The Structure of Thunderstorm Rainfall. Meeting Preprint 1330. ASCE National Water Resources Engineering Meeting, Phoenix, Arizona, January 11-15, 1971.

Tennessee Valley Authority. Division of Water Control Planning. Hydraulic Data Branch. Precipitation-Altitude Study: Snowbird Mountains, North Carolina. Report No. 0-5620, December, 1955.

_____. Precipitation in Tennessee River Basin: [month, year].

Thompson, Russell D. "Some Aspects of the Synoptic Mesoclimatology of the Armidale District, New South Wales, Australia." Journal of Applied Meteorology, XII (June, 1973), pp. 578-88.

Trewartha, Glenn T. An Introduction to Climate. New York: McGraw-Hill Book Company, 1968.

Trewartha, Glenn T.; Robinson, Arthur H.; and Hammond, Edwin H. Fundamentals of Physical Geography. New York: McGraw-Hill Book Company, 1968.

Tuller, Stanton E. "The World Distribution of Annual Precipitation Efficiency." Journal of Geography, LXX (April, 1971), pp. 219-23.

U. S. Department of Commerce. National Oceanic and Atmospheric Administration. Environmental Data Service. Hourly Precipitation Data - [State]: [month, year].

_____. National Weather Bureau. Technical Procedures Bulletin No. 28: The Lifted Index Computation. Washington, D.C.: Weather Analysis and Prediction Division, July 17, 1969.

_____. National Weather Service. Technical Procedure Bulletin No. 61: The K-Index Chart. Silver Springs, Md.: April 12, 1971.

APPENDIX

APPENDIX A

CODE NUMBERS OF THE RAIN DAYS DURING THE SUMMER 1972 BY CLASSES

CLASS A

June 7	5555
June 17	5555
June 18	5554
June 20	5555
June 21	5555
June 28	4555
June 29	5555
June 30	5555
July 3	4555
July 5	5555
July 16	5545
July 17	5555
July 26	4455
July 28	5555
July 29	5555
July 30	5555
July 31	5555
August 1	5555
August 2	5455
August 3	5555
August 8	5554
August 10	4555
August 26	4444
September 5	5555
September 18	5555
September 27	5555
September 28	5555
September 29	5545
September 30	5555

CLASS B

June 10	5443
July 4	3345
July 15	5443
July 18	3555
July 20	3444
August 7	4345
August 25	3544
September 9	4334

CLASS SP

June 6	1101
June 9	1101
June 11	1100
June 14	0100
June 15	1001
June 16	1111
June 23	1010
June 24	1000
June 26	0010
July 1	1100
July 2	0101
July 9	1110
July 11	0011
July 12	1100
July 13	1100
August 4	1010
August 13	1111
August 15	0110
August 16	1110
August 17	1111
August 23	1111
August 28	1110
August 29	0000
September 1	0011
September 2	0010
September 3	1001
September 8	0001
September 10	1000
September 13	0000
September 14	1000
September 16	0011
September 20	0010
September 22	0010
September 23	0111
September 25	1110

CLASS N

June 5	4100
June 22	3100
July 25	4323
August 3	4211
August 18	4100

CLASS NE

July 6	3411
August 19	5432
September 4	4311
September 6	4421

CLASS E

June 19	1421
July 21	2310

CLASS SE

July 14	2331
July 22	1440
July 23	2451
August 11	1452
August 12	2341

CLASS S

July 10	2342
July 27	1241
August 6	0130
August 21	0030
August 22	0031
August 24	2343
September 19	1232

CLASS SW

August 9	1143

CLASS W

June 27	1123
September	1214

CLASS WD

July 19	4552
July 24	3331
August 20	4441
August 27	3441
September 15	4431

CLASS ND

September 17	1334
September 26	1554

VITA

Linda Louise Pasqua Marcus was born in Evanston, Illinois on June 16, 1949. She moved to Alcoa, Tennessee in 1952, attended elementary school in that city and graduated from Alcoa High School in 1967. The following August she entered the University of Kentucky, and in May 1971, she received a Bachelor of Science degree in Mathematics.

She entered the Graduate School at the University of Tennessee in September, 1971, and received a Master of Science degree with a major in Geography in December, 1974.

She is married to Kermit Marcus, Jr. of Whittier, North Carolina.