P5.8 A CLIMATOLOGY OF SYNOPTIC CONDITIONS WHICH PRODUCED SIGNIFICANT TORNADOES ACROSS THE SOUTHERN APPALACHIAN REGION

David M. Gaffin* and Stephen S. Parker

National Weather Service, Morristown, Tennessee

1. INTRODUCTION

The frequency of significant tornadoes (F2 or greater) decreases markedly from west-to-east across the Tennessee River Valley and southern Appalachian region (Fig. 1). It's commonly thought that this decrease is mainly due to the increasingly complex terrain of the southern Appalachian region. The southern Appalachian region has terrain which generally stretches from southwest to northeast with three distinct features (Fig. 2): the Cumberland Plateau (around 450 to 900 m (1500 to 3000 ft) MSL), Great Tennessee Valley (around 150 to 450 m (500 to 1500 ft) MSL), and southern Appalachian Mountains (around 150 to 1980 m (1500 to 6500 ft) MSL). A need exists for a study to help local forecasters determine the synoptic conditions which affects the development of significant tornadoes across these different large-scale terrain features. The purpose of this study is to compile a 54 year climatology (1950-2003) of significant tornadoes across the southern Appalachian region in order to (1) examine the synoptic patterns which produced these tornadoes and (2) compare the similarities and differences to the large-scale terrain features.

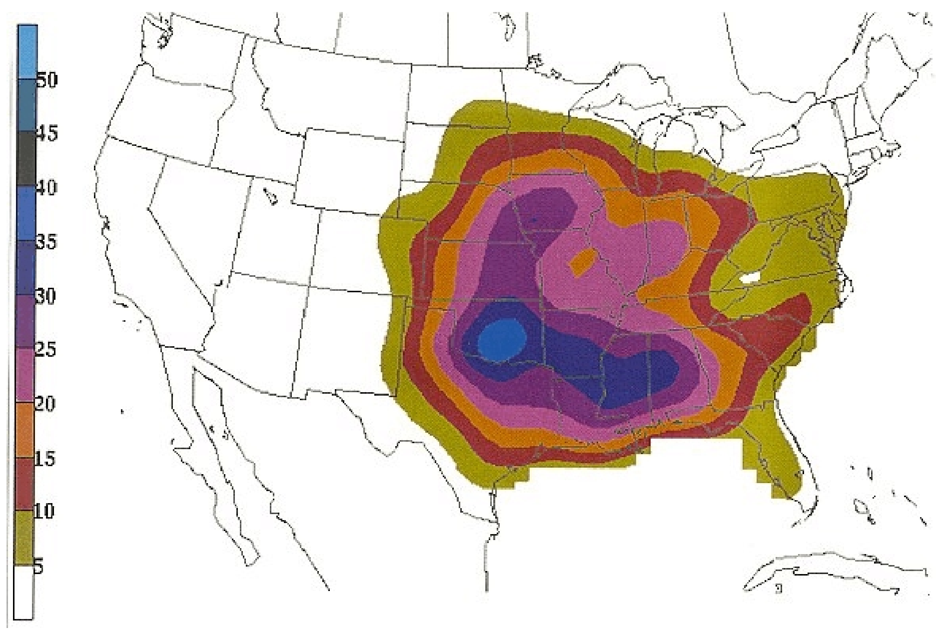

Figure 1. Mean number of days per century with at least one F2 or greater tornado from 1921 through 1995 (from Concannon *et al.* 2000).

2. METHODOLOGY AND DATA

Although significant tornadoes account for around 10% of the reported tornadoes across the United States, these tornadoes are responsible for most tornado deaths and are more likely to have been documented in the climatological record than weaker tornadoes (Concannon *et al.* 2000). Thus, only those events which produced a significant tornado were examined in this study. A tornado event was defined as a date when at least one significant tornado was documented in *Storm Data* within a hundred-county area of middle and east Tennessee, northeast Alabama, northern Georgia,

* *Corresponding author address*: David M. Gaffin, NWS, 5974 Commerce Blvd., Morristown, TN 37814; e-mail: David.Gaffin@noaa.gov

upstate South Carolina and western North Carolina (Fig. 3). If there was more than twelve hours of separation between tornado occurrences, then these occurrences were considered two separate events. Events were then classified according to whether they produced a tornado on the western side, southern side, or eastern side of the southern Appalachians. In this study, the western side was defined as eastern middle and east Tennessee, the southern side as northeast Alabama and northern Georgia, and the eastern side as upstate South Carolina and western North Carolina. Also, events were further classified into nine subgroups according to whether the tornado(es) occurred only west of the Cumberland Plateau, only on the Plateau, only in the Great Tennessee Valley, only in the southern Appalachian Mountains, on both the Plateau, Valley and/or Mountains, on both the Plateau and Mountains but not in the Valley, south of the Mountains (including near the opening of the Valley), east of the Mountains, and south and east of the Mountains. Outbreak events were also examined as a separate classification with an outbreak defined for this study as an event which produced five or more significant tornadoes. Five tornadoes per event seemed a reasonable threshold for an outbreak across the southern Appalachians, since a number higher than five would have resulted in too few cases for meaningful evaluation and a number lower than five may not have been an outbreak. An occurrence of two or three tornadoes during one event could have actually been the same tornado affecting multiple counties, since the number of documented tornadoes in *Storm Data* corresponded to how many counties were affected.

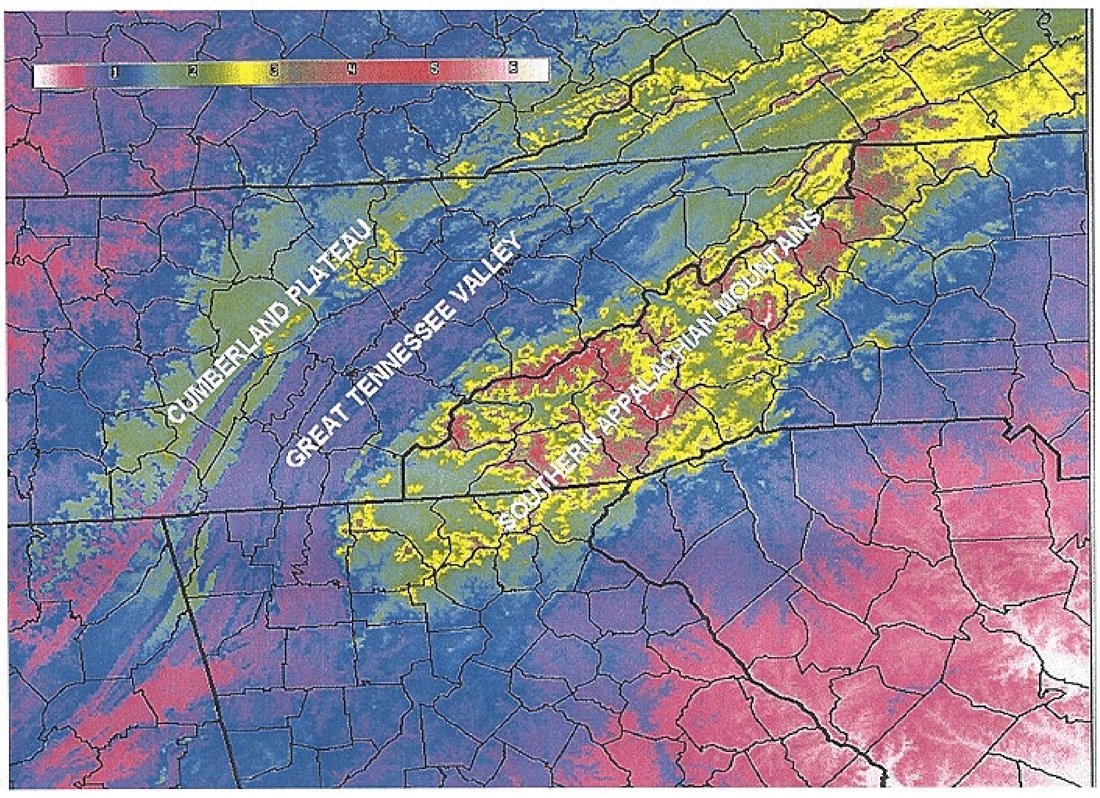

Figure 2. Image of terrain features across the southern Appalachian region (lines denote county boundaries; bold lines denote state boundaries).

Composite maps of all events, outbreak events, and events from the three regions (western, southern, and eastern) were constructed using the NCEP/NCAR reanalysis dataset (Kalnay *et al.* 1996) on the NOAA-CIRES Climate Diagnostics Center's website (http://www.cdc.noaa.gov/Composites/Hour/). The parameters analyzed with the composite maps included sea level pressure, surface temperatures, surface relative humidity (to determine dewpoints), surface wind speeds, 850 hPa geopotential heights, 850 hPa wind speeds, 850 hPa temperatures, 850 hPa relative humidity, 500 hPa geopotential heights, 500 hPa wind speeds, 250 hPa geopotential heights, and 250 hPa wind speeds.

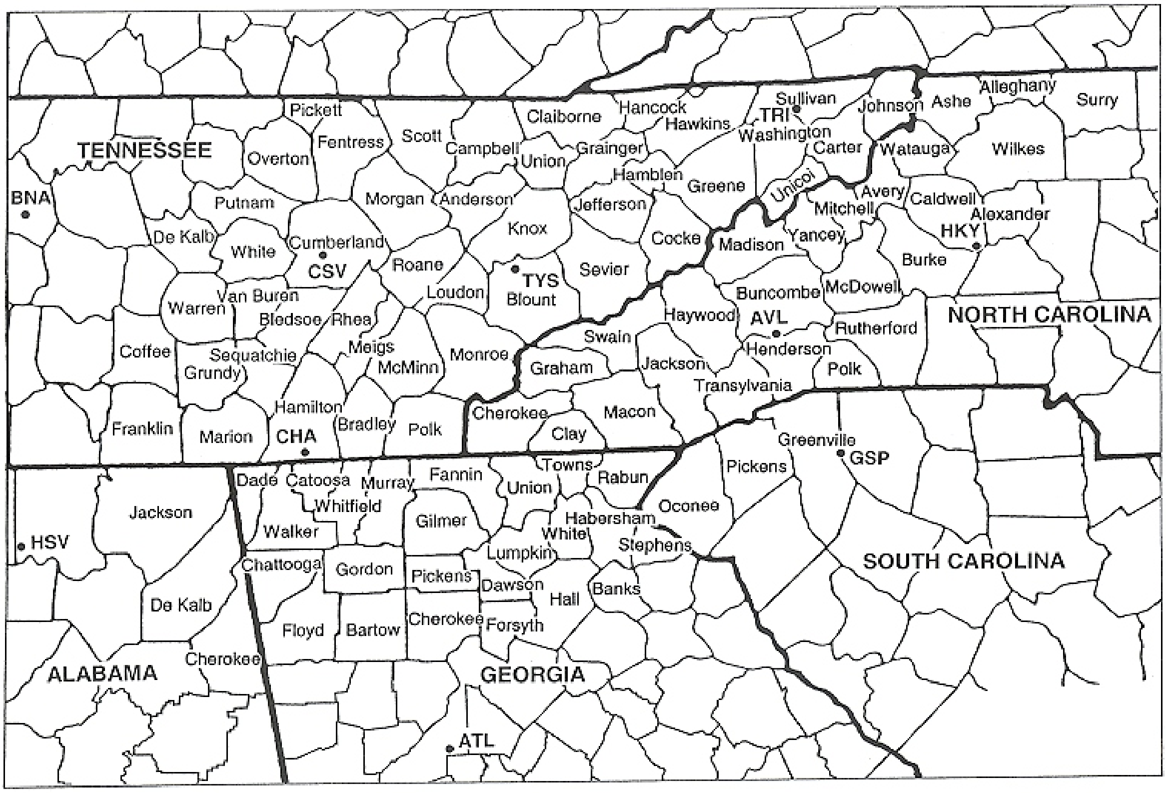

Figure 3. Counties and states used to comprise the southern Appalachian region and the locations of the surface observation sites (bold lines denote state boundaries).

Each individual event was analyzed using the three-hourly surface charts from the National Climatic Data Center (NCDC) closest to the time of tornado occurrence. Many of these surface charts contained illegible or missing surface observations, so the hourly surface observations at Nashville (BNA), Crossville (CSV), Huntsville (HSV), Atlanta (ATL), Chattanooga (CHA), Knoxville (TYS), Tri-Cities (TRI), Asheville (AVL), Hickory (HKY), and Greenville-Spartanburg (GSP) (Fig. 3) from the Web Search Store Retrieve Display (WSSRD) website (http://noaa.imcwv.com/login.asp) were used to supplement and enhance the information on many of the surface charts. If the observation at the time of the surface chart was considered unrepresentative of the tornado-producing airmass (primarily due to outflow from thunderstorms), then the previous hourly observation was used instead. Also, three events (18 February 1956, 6 April 1958, and 21 March 1974) had to be removed from consideration because the surface charts obtained were at the wrong time.

The twelve-hourly upper-air (850 hPa, 500 hPa, and 250 hPa) charts from NCDC closest to the time of tornado occurrence were also examined for each individual event. Missing upper-air charts were supplemented using the North American RAOB Upper Air Products on the Plymouth State University Weather Center's website (http://vortex.plymouth.edu/u-make.html). These charts were used to determine the isoheight patterns, winds, temperatures and dewpoints at the 850 hPa level, the winds and tilt of the isoheight troughs at the 500 hPa level, and the quadrant of any jet streak in relation to the southern Appalachians at the 300 or 250 hPa level. The southern Appalachians were considered near a 300 or 250 hPa jet streak if the region was generally within 500 km or 300 miles of the core of strongest winds. On the 500 hPa charts, a trough was considered negative-tilted if its axis was tilted west roughly 15^0 of a north-south orientation and positive-tilted if its axis was tilted east roughly 15^0 of a north-south orientation.

Forecasting parameters found primarily from sounding data (such as CAPE and helicity) were not examined in this study since there were no sounding sites located within the southern Appalachian region. The closest sounding sites surrounding the area of study were generally more than 100 km (60 miles) away. Thus, it was decided that these soundings would not be representative enough to develop accurate conclusions.

3. DISCUSSION

a) Climatological statistics

An examination of the 94 significant tornado events across the southern Appalachian region (corresponding to 1.7 events per year) revealed that nearly two-thirds of the events occurred during the spring months of March, April, and May (Table 1) with April the most active month. Also, a secondary maxima with around a fourth of the events occurred from late autumn through the winter (November through February). This monthly distribution was similar to the Garinger and Knupp (1993) Interior Southeast subregion climatology. Another interesting statistic in this study involved the ratio of multiple tornado events compared to the total number of events for each month. Events which occurred in November and February were typically associated with multiple tornado occurrences (71% and 50% of the total events for each month respectively) while the number of outbreaks (5 or more tornadoes per event) in November was the second highest and nearly equal to those in April. The eight outbreak events in the southern Appalachian region included 15 April 1965 (7 significant tornadoes), 27 May 1973 (5), 3-4 April 1974 (45), 4 April 1989 (10), 22 November 1992 (5), 21 February 1993 (9), 27 March 1994 (22), and 10 November 2002 (11).

Table 1. Statistics of all tornado events by month across the southern Appalachians

All tornado events (1950-2003)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
6	6	20	23	18	3	3	1	0	1	7	6	94
Events with two or more tornadoes (percentage compared to all events)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
1	3	8	7	8	1	0	0	0	0	5	1	34
(17)	(50)	(40)	(30)	(44)	(33)	(0)	(0)	(0)	(0)	(71)	(17)	(36)
Events with five or more tornadoes (percentage compared to all events)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
0	1	1	3	1	0	0	0	0	0	2	0	8
(0)	(17)	(5)	(13)	(6)	(0)	(0)	(0)	(0)	(0)	(29)	(0)	(9)

Most tornado events across the southern Appalachians occurred on the southern and western sides (83%), while far fewer events occurred on the eastern side (Table 2). The secondary maxima in November and December can be seen best on the southern side. It is also apparent on the western side, but was non-existent on the eastern side. An examination of the surface charts from the thirteen November and December events revealed that drier air was located across the eastern side during nine of the events with a more than 3 ^{0}C (5 ^{0}F) dewpoint difference during five events. Also, the peak month for tornado events was found during the spring months (March, April, and May) on all three sides, but occurred later in the year (May) on the eastern side. During the summer months (June, July, and August), the western side experienced the most tornado events. The upper-air charts from the summer months revealed that west or northwest flow occurred during all summer events, which would suggest that the mountains helped to disrupt or change the environment of most tornadic thunderstorms as they moved from the western side to the southern and eastern sides. An examination of the eight outbreak events revealed that seven produced significant tornadoes on the southern side of the Appalachians, four on the western side, and three on the eastern side (some events produced tornadoes on multiple sides). The Super Outbreak of 3-4 April 1974 was the only event which produced significant tornadoes on all three sides of the southern Appalachians, and it also produced the largest number (45).

Table 2. Statistics of tornado events by month across the western, southern, and eastern sides of the southern Appalachians (some events overlapped categories)

Western side (eastern middle and east Tennessee)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
3	4	13	10	5	2	2	1	0	1	3	1	45
Southern side (northeast Alabama and northern Georgia)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
1	3	7	13	9	0	1	0	0	0	6	6	46
Eastern side (upstate South Carolina and western North Carolina)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot
2	0	2	5	7	2	0	0	0	0	0	0	18

b) Synoptic patterns of all events

Composite maps of all the tornado events (Fig. 4) revealed that an area of low pressure (~1007 hPa) was normally centered over the Mid West with an associated cold front extending south across west Tennessee and the lower Mississippi river valley. Southwest winds at the surface (averaging 5.5 to 6.5 m s^{-1} or 11 to 13 kt) normally occurred across the southern Appalachian region, with temperatures averaging between 16.5 and 18.5 ^{0}C (62 and 65 ^{0}F) and dewpoints between 15 and 17 ^{0}C (59 and 62 ^{0}F). The 850 hPa composites revealed a trough across the Great Lakes region with southwest winds (averaging 14 to 15 m s^{-1} or 28 to 30 kt) occurring across the southern Appalachian region. Temperatures at 850 hPa averaged between 11 and 13 ^{0}C (52 and 55 ^{0}F) with dewpoints between 8 and 9 ^{0}C (46 and 49 ^{0}F). Southwest winds (averaging between 26 and 28 m s^{-1} or 52 and 56 kt) were also normally observed at 500 hPa ahead of a neutral-tilted trough over the Mississippi river valley. At 250 hPa, the southern Appalachian region was normally located to the right of a jet streak (averaging 37.5 to 39 m s^{-1} or 75 to 78 kt) with southwest winds stretching from the southern Plains to the northeast United States.

When composite maps of the events on the western side (Fig. 5), southern side (Fig. 6), and eastern side (Fig. 7) of the southern Appalachians were compared, some similarities emerged such as a low pressure area over the Mid West. Also, some expected patterns emerged such as the thermal and moisture axes being located farther west for the western events, farther south for the southern events, and farther east for the eastern events. However, some interesting differences were also noted. For example, surface winds were weaker with the eastern side events (5.5 m s^{-1} versus 7.0 m s^{-1} on the western and southern sides) even though the surface low pressure area was slightly deeper (1006 hPa versus 1007 hPa on the western and southern sides). With the eastern side events, the 850 hPa trough was more shallow compared to the western and southern side events, resulting in weaker 850 hPa winds (14 m s^{-1} versus 16-17 m s^{-1}). The deepest 500 hPa trough was found with the southern side events while the most shallow trough was with the eastern side events. As a result, the 500 hPa winds with the eastern side events were the weakest, averaging around 24 m s^{-1}. Southern and western side winds were the strongest, averaging around 28.5 m s^{-1}. At 250 hPa, the western side events were normally located near the right-exit region of a jet streak (around 42 m s^{-1}), while the southern and eastern side events were located near the right-entrance region of a jet streak (around 42 m s^{-1} and 34.5 m s^{-1}, respectively).

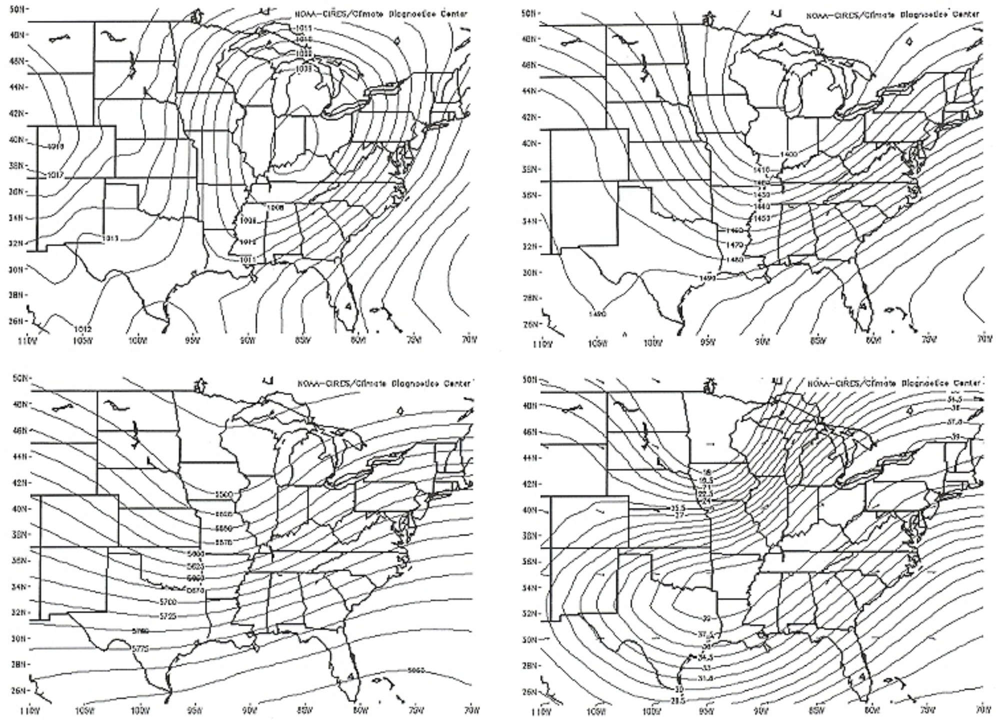

Figure 4. Composite maps of all significant tornado events across the southern Appalachian region with (top left) surface isobars (hPa), (top right) 850 hPa isoheights (m), (bottom left) 500 hPa isoheights (m), and (bottom right) 250 hPa isotachs (m s^{-1}).

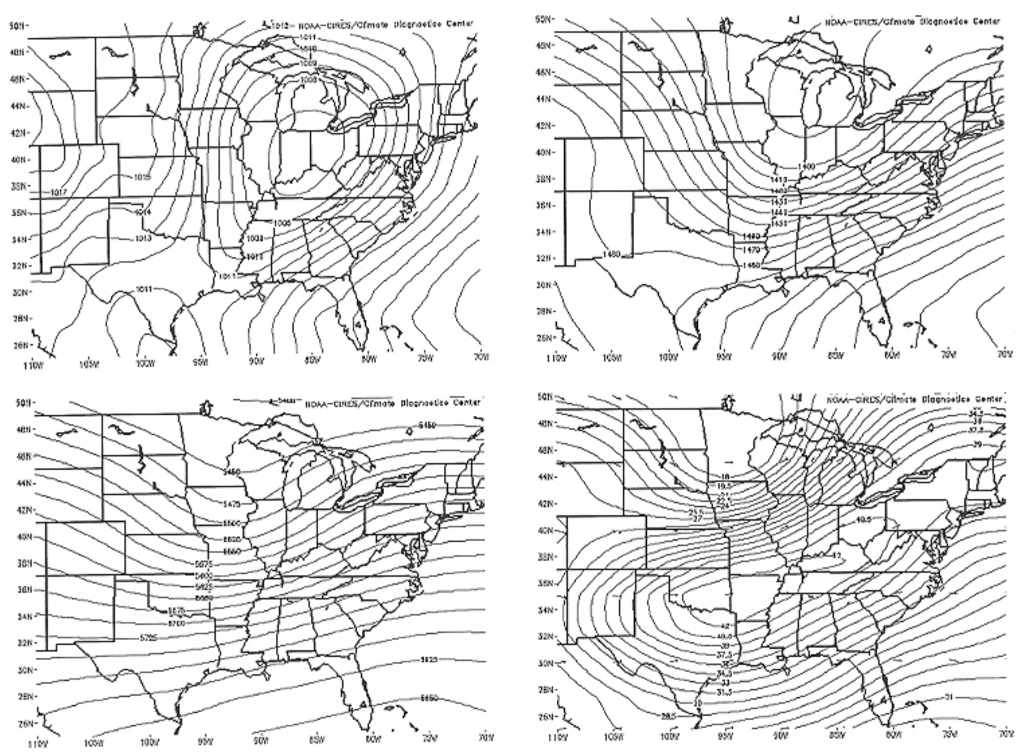

Figure 5. Same as Fig. 4, but for events on the western side of the southern Appalachians.

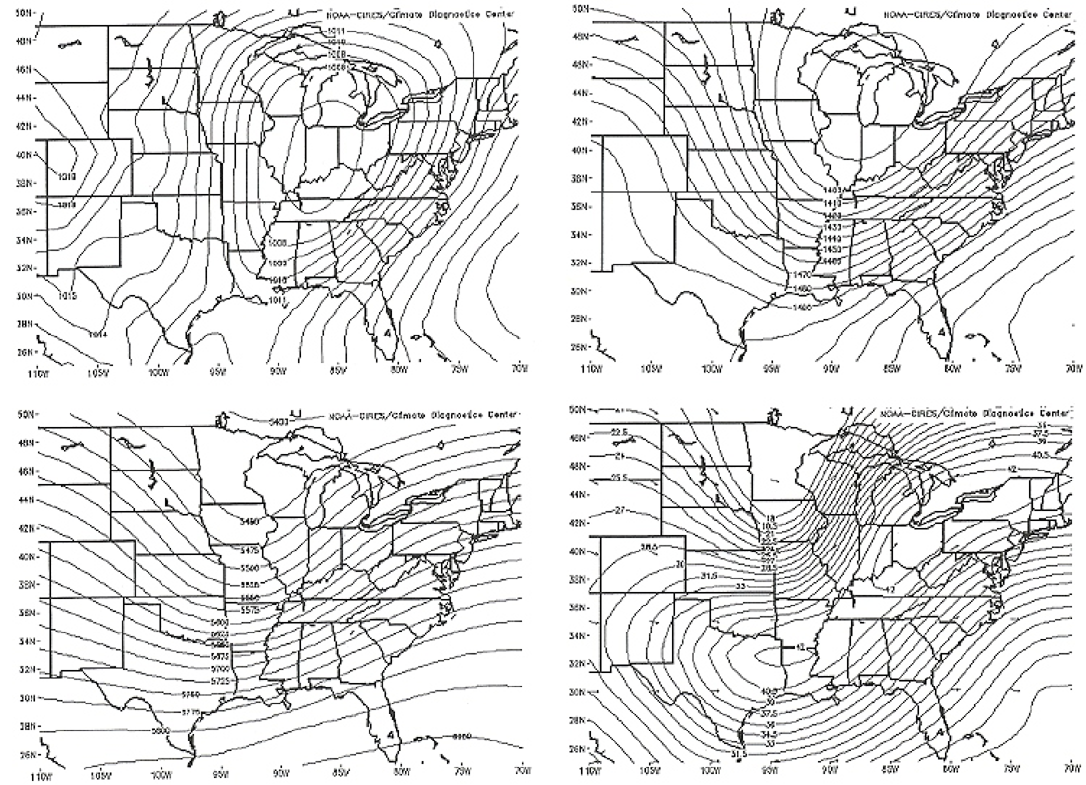

Figure 6. Same as Fig. 4, but for events on the southern side of the southern Appalachians.

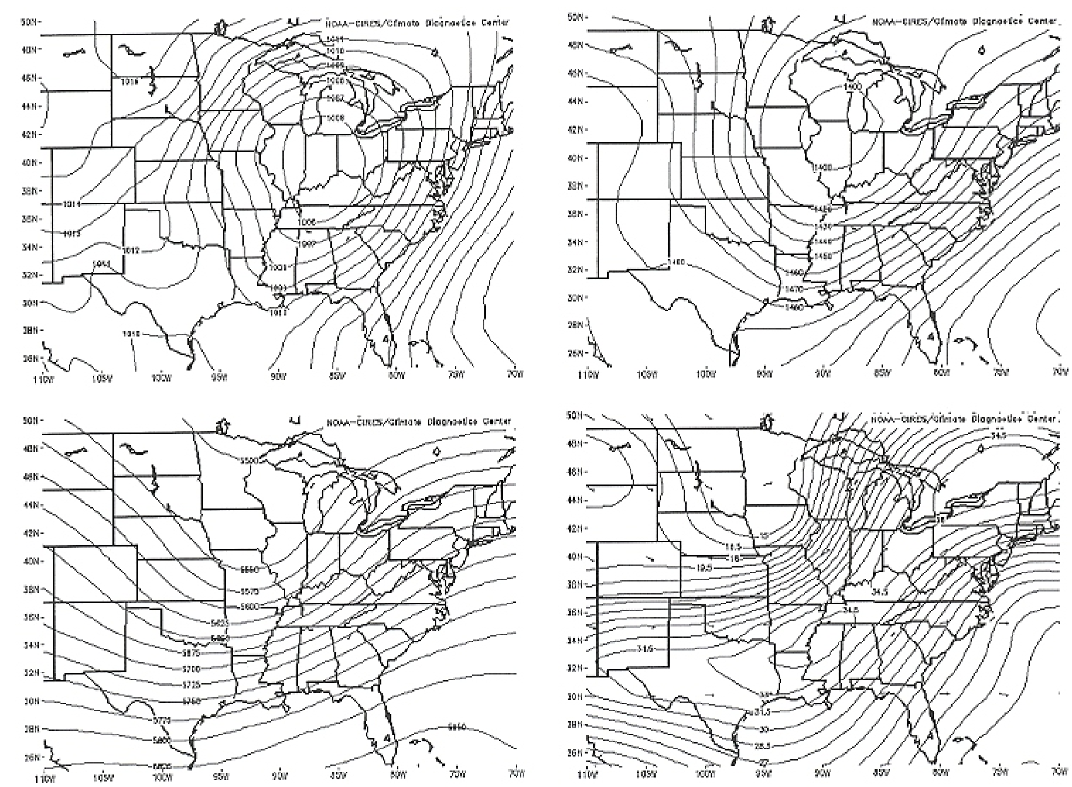

Figure 7. Same as Fig. 4, but for events on the eastern side of the southern Appalachians.

Surface charts of individual events were then examined to determine whether an event had a tornado occurring near a boundary including cold fronts, warm fronts, stationary fronts, pre-frontal troughs, or troughs north of an area of low pressure. Rogash (1995) found that an overwhelming majority of F2 or greater tornadoes developed within 100 km of a surface thermal or moisture boundary. In this study, a tornado was also considered near a boundary if it occurred within 100 km (60 miles) of the boundary. Of the 91 events with available surface charts, 28 events had tornadoes occurring near a pre-frontal trough, 24 near a cold front, 21 near a warm front, seven near multiple boundaries, four near a stationary front, and three near a trough north of a low pressure area. In addition, there were 18 events where the tornadoes were not near a boundary. Cold fronts were the most common boundary observed with the western side events (10 out of 44 events), while pre-frontal troughs were the most common boundary observed with the southern side events (18 out of 44 events) and eastern side events (8 out of 18 events). Cold fronts were observed most often with the western side events (50%), warm fronts with the western side events (40%), stationary fronts with the eastern side events (50%), pre-frontal troughs with the southern side events (51%), multiple boundaries with the western side events (55%), and troughs north of a low pressure area exclusively with the western side events. When the surface boundaries were compared to the terrain features, it was discovered that only 25% of the pre-frontal trough events on the western side produced tornadoes in the Great Tennessee Valley with most pre-frontal trough tornadoes occurring either on the Cumberland Plateau (50%) or west of the plateau (25%). Dewpoints from the most representative observation sites at the time closest to tornado occurrence were found for each event. Around 85% of the dewpoints were found to be between 14 and 21 ^{0}C (58 and 70 ^{0}F), while around 54% were between 16 and 19 ^{0}C (60 and 66 ^{0}F). The lowest dewpoint observed was 9 ^{0}C or 49 ^{0}F (on 26 March 1955) and the highest was 24 ^{0}C or 75 ^{0}F (on 12 August 1964).

Upper-air charts of each individual event (with the exception of the 18 February 1956 charts which were missing) were examined for any interesting similarities or differences. Also, five 850 hPa charts were also unavailable or unreadable including the 1 March 1952, 10 May 1952, 21 January 1953, 7 March 1956, and 23 January 1957 events. Most events had 850 hPa temperatures between 10 and 15 ^{0}C (72 %) and dewpoints mainly between 8 and 13 ^{0}C (74 %). The lowest 850 hPa temperature observed was around 7 ^{0}C on 8 April 1974 and 28 April 1980, while the highest was around 23 ^{0}C on 10 July 1980. As for the 850 hPa dewpoints, the lowest observed were around -1 ^{0}C on 13 March 1961 and 8 March 1961 (although these are suspect since they are 7 ^{0}C outliers) while the highest were around 15 ^{0}C on 28 May 1973, 18 May 1984, and 27 June 1994. The 500 hPa charts revealed that most events were associated with southwest flow (65%). The other events observed flow from the west (25%), south (6%), and northwest (4%). Northwest flow events were mainly during the summer months (three out of the four events) and mainly produced tornadoes in the southern Appalachian mountains (three of the four events). Previous research (Giordano and Fritsch 1991, Johns 1982) has also shown that northwest flow events are primarily a summer phenomena with a major axis stretching from the upper Mississippi Valley to the Mid-Atlantic region. Another interesting finding in this study was that four of the six tornado events in the southern Appalachian mountains were associated with west or northwest flow at 500 hPa. Of the 93 500 hPa charts, 68 (73%) observed troughs with most (40) neutral-tilted (43%), 15 positive-tilted (16%), and 13 negative-tilted (14%). Of the 90 total events with available 300 or 250 hPa charts (three events had charts that were unreadable), 83 events (92%) were located near a jet streak (generally within 500 km or 300 miles of the core of strongest winds). Of the 80 events where it was determined that the southern Appalachian region was located near a particular quadrant, 63 events (79%) were found on the right side of the jet streaks with 31 events near the entrance region and 32 events near the exit region. Only 17 events (21%) were found on the left side of the jet streaks with 16 near the exit region and only one near the entrance region. Around 53% of the tornado events in the southern Appalachian region (or 60% of those near jet streaks) occurred near the exit region of an upper-level jet streak. This was similar to Rose *et al.* (2004) who found that tornadoes occurred primarily under the exit regions of upper-level jet streaks with a significant number occurring under the right-exit region (although less than the left-exit region).

c) Synoptic patterns of outbreaks

Composite maps of the eight outbreak events (Fig. 8) revealed that a deeper area of low pressure (~1000 hPa) normally occurred over the Mid West (compared to the composites of all events). This deeper low produced stronger southwest winds at the surface with wind speeds averaging 8.5 to 9.5 m s^{-1} or 17 to 19 kt across the southern Appalachian region. Surface temperatures were only slightly warmer, averaging between 18 and 20 ^{0}C (64 and 68 ^{0}F) with dewpoints between 16 and 18 ^{0}C (61 and 65 ^{0}F). A deeper and positive-tilted 850 hPa trough was normally observed with the outbreak events across the western Great Lakes region resulting in stronger southwest winds (averaging 18 to 20 m s^{-1} or 36 to 40 kt) across the southern Appalachian region. Slightly warmer temperatures at 850 hPa averaged between 12 and 14 ^{0}C (54 and 57 ^{0}F) with dewpoints between 10 and 12 ^{0}C (50 and 53 ^{0}F). A deeper and slightly positive-tilted 500 hPa trough was also normally observed west of the Mississippi river valley producing stronger southwest winds (averaging between 32.5 and 37.5 m s^{-1} or 65 and 75 kt) across the southern Appalachians. At 250 hPa, the southern Appalachian region was normally located near the right-exit region of a jet streak (averaging 47.5 to 50 m s^{-1} or 95 to 100 kt) over the southern Plains and lower Mississippi river valley.

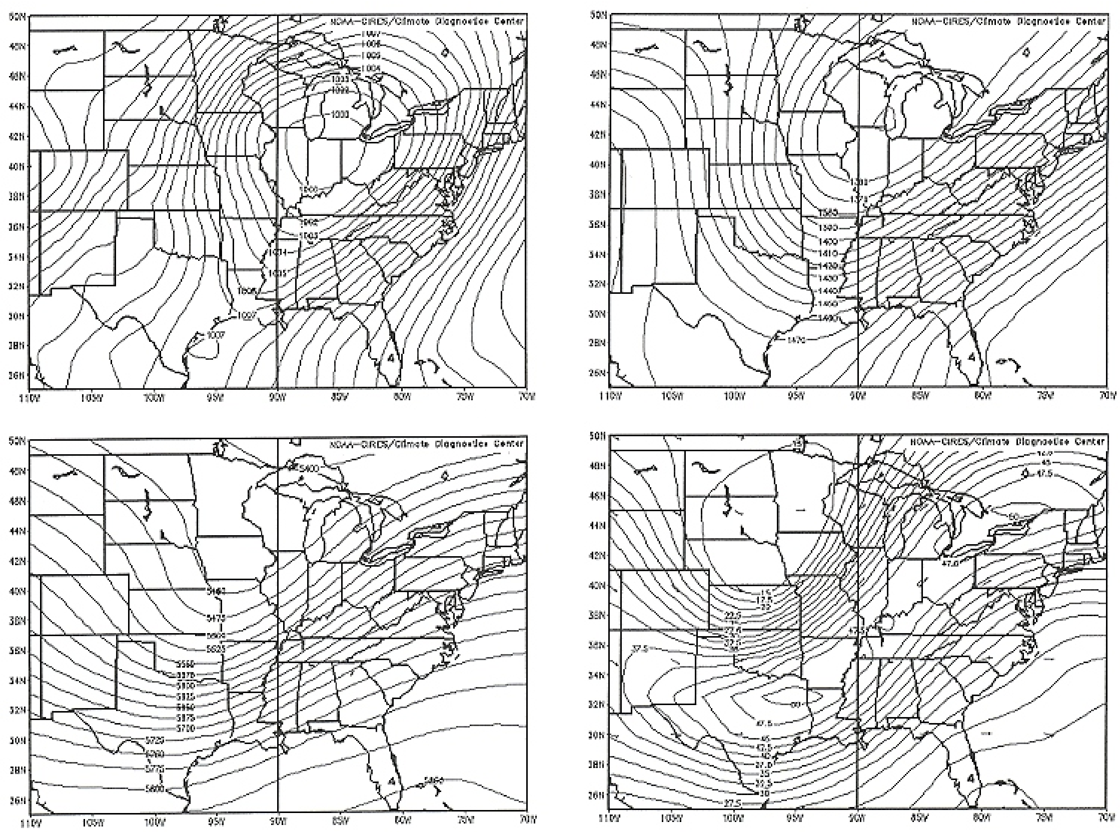

Figure 8. Same as Fig. 4, but for outbreak events (5 or more significant tornadoes).

Individual surface charts of the eight outbreak events revealed that six events (75%) had tornadoes occurring near a pre-frontal trough, three events (38%) near a cold front, and two events (25%) near a warm front (three events had tornadoes near multiple boundaries). Of the six pre-frontal trough events, six produced tornadoes across the southern side, four across the eastern side, and two across the western side. Of the three cold front events, three produced tornadoes across the southern side, two across the western side, and only one across the eastern side. Of the two warm front events, two produced tornadoes across the western side, one across the southern side, and none across the eastern side. Dewpoints during the outbreak events were typically between 16 and 21 ^{0}C (in the 60s ^{0}F) with the exception of the 21 February 1993 outbreak where dewpoints were between 12 and 15 ^{0}C (in the mid to upper 50s ^{0}F).

Examination of the upper-air charts from each individual outbreak event revealed that 850 hPa temperatures were typically between 13 and 18 ^{0}C (75% of the events) with dewpoints typically between 10 and 15 ^{0}C (75% of the events). The outbreak events on 21 February 1993 and 4 April 1989 were the only two events that observed 850 hPa temperatures and dewpoints outside of the typical range with 850 hPa temperatures around 10 ^{0}C and dewpoints around 8 ^{0}C. Wind flow at 500 hPa with the outbreak events was typically from the southwest (five events), while two events had winds from the south (southern and eastern side events) and one event had winds from the west (western side event). Most outbreak events (63%) were associated with 500 hPa troughs with three positive-tilted, one negative-tilted, and one neutral-tilted. However, three events (including the Super Outbreak) observed a closed 500 hPa low over the southern or central Plains. All eight outbreak events were located near a 300 or 250 hPa jet streak with seven events found on the right side of the jet streaks and only one on the left side. Four events occurred near the right-exit region, three events near the right-entrance region, one event near the left-exit region, while none occurred near the left-entrance region.

4. CONCLUSIONS

An examination of the 94 events which produced significant tornadoes across the southern Appalachian region (corresponding to 1.7 events per year) revealed many interesting differences among their synoptic patterns in relation to the large-scale terrain features. Most tornado events across the southern Appalachians occurred on the southern and western sides (83%), while far fewer events occurred on the eastern side. The peak season for tornadoes was during the spring on all three sides of the southern Appalachians, but a secondary maxima also occurred during November and December only on the southern and western sides. Surface charts from the November and December events revealed that drier air was typically located across the eastern side which may account for the lack of tornadoes on the eastern side. Events during November were typically associated with multiple tornado occurrences (71% of its total events). Most tornado events during the summer months (June, July, and August) occurred across the western side of the southern Appalachians and with west to northwest upper-level flow. This would suggest that the mountains helped to disrupt or change the environment of most tornadic thunderstorms as they moved from the western side to the southern and eastern sides.

Composite maps of all three events revealed that the surface winds as well as the upper-level troughs and winds were weakest with the eastern side events, but were fairly similar with the western and southern side events. The western side events were normally located near the right-exit region of a 250 hPa jet streak, while the southern and eastern side events were located near the right-entrance region. Individual surface charts revealed that most events across the southern Appalachians occurred near a pre-frontal trough, especially across the southern and eastern sides. Cold fronts were the most common boundary observed with the western side events, while most pre-frontal trough tornadoes on the western side occurred either on the Cumberland Plateau or west of the plateau (but not in the Great Tennessee Valley). Most surface dewpoints were between 14 and 21 ^{0}C (58 and 70 ^{0}F) and especially between 16 and 19 ^{0}C (60 and 66 ^{0}F), while the lowest dewpoint was 9 ^{0}C (49 ^{0}F) and the highest 24 ^{0}C (75 ^{0}F). Individual upper-air charts revealed that most events had 850 hPa temperatures between 10 and 15 ^{0}C (72 %) and dewpoints between 8 and 13 ^{0}C (74 %). The lowest 850 hPa temperature and dewpoint observed were around 7 and -1 ^{0}C (although this dewpoint is suspect) while the highest were around 23 and 15 ^{0}C. Most events were associated with southwest 500 hPa flow ahead of a neutral-tilted trough, but west to northwest flow dominated during the summer months and produced most of the tornado events in the mountains. Most of the tornado events were located near a 300 or 250 hPa jet streak (92%) with most occurring on the right side (79%) and evenly split between the entrance and exit regions. Only 17 events (21%) were found on the left side of a jet streak with only one near the entrance region.

As for the eight outbreak events, there were nearly always tornadoes observed on the southern side. Composite maps of the outbreak events revealed a deeper surface low pressure area and a deeper and positive-tilted 850 and 500 hPa trough compared to the composites of all events. As a result, stronger southwest winds at the surface, 850 hPa, and 500 hPa were observed with the outbreak events. At 300 or 250 hPa, the southern Appalachians were normally located near the right-exit region of a jet streak over the southern Plains and lower Mississippi river valley. Individual surface charts of the eight outbreak events revealed that most tornadoes occurred near a pre-frontal trough. Surface dewpoints during the outbreak events were typically between 16 and 21 ^{0}C (in the 60s ^{0}F) with the exception of the 21 February 1993 outbreak where dewpoints were between 12 and 15 ^{0}C (in the mid to upper 50s ^{0}F). The individual upper-air charts revealed that 850 hPa temperatures were typically between 13 and 18 ^{0}C with dewpoints typically between 10 and 15 ^{0}C. Southwest 500 hPa flow was observed with most outbreak events along with a positive-tilted 500 hPa trough. All eight outbreak events were located near a 300 or 250 hPa jet streak with only one event on the left side. Most events occurred near the right-exit region or right-entrance region with only one event near the left-exit region.

5. ACKNOWLEDGMENTS

The authors would like to thank Scott Stephens at NCDC for providing the numerous surface and upper-air charts and access to the WSSRD website. Also, thanks to Howard Waldron for his help in retrieving the *Storm Data* information.

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APPENDIX

Tornado dates (F2 intensity or greater) since 1950 across the southern Appalachian region

Date	Time (UTC)	F-scale (#)	Counties Affected	Geographic Area
February 14, 1952	04:40	3 (1), 4 (1)	Franklin TN, Grundy TN	west of plateau / plateau
February 29 - March 1, 1952	23:00-01:30	2 (3), 3 (1)	McMinn TN, Warren TN, DeKalb AL, Banks GA	plateau / valley / east of mtns
May 10, 1952	20:00	3 (1)	Greenville SC	east of mtns
January 20, 1953	23:41	2 (1)	Warren TN	west of plateau
May 2, 1953	08:15	2 (1), 4 (2)	Anderson TN, McMinn TN, Meigs TN	valley
December 5, 1954	21:00	2 (1)	Bartow GA	opening of valley
March 6, 1955	01:00	2 (1)	Hawkins TN	valley along Clinch Mtn
March 25, 1955	23:30	2 (1)	Jefferson TN	valley
February 18, 1956	06:30	2 (1)	Walker GA	opening of valley
March 7, 1956	16:30	2 (1)	Overton TN	west of plateau
January 23, 1957	04:30	2 (1)	Coffee TN	west of plateau
April 8, 1957	12:00-21:30	2 (3)	Cumberland TN, Washington TN, Gordon GA	plateau / valley / opening of valley
November 18, 1957	22:30-22:45	2 (2)	Fentress TN, Chattooga GA	plateau / opening of valley
April 6, 1958	06:03	3 (1)	Jackson AL	start of plateau
March 27, 1959	00:10	3 (1)	Coffee TN	west of plateau / plateau
March 8, 1961	07:45	2 (1)	Catoosa GA	opening of valley
March 13, 1961	22:40	3 (1)	Warren TN	west of plateau
March 21, 1962	08:20	3 (1)	Cherokee GA	south of mtns
April 11, 1962	13:30	2 (1)	Cherokee GA	south of mtns
March 12, 1963	00:00-03:00	2 (3)	Cocke TN, Marion TN, Warren TN	valley / Sequatchie valley / west of plateau
March 20, 1963	00:15	2 (2)	Bradley TN, McMinn TN	valley
January 25, 1964	03:00	2 (1)	DeKalb AL	start of plateau
April 7, 1964	15:10	2 (1)	DeKalb AL	start of plateau
August 12, 1964	09:30	2 (1)	Sequatchie TN	Sequatchie valley
April 9, 1965	08:45	2 (1)	Avery NC	mtns
April 15-16, 1965	19:50-01:00	2 (3), 3 (4)	Bradley TN, Cumberland TN, Fentress TN, Knox TN, DeKalb AL, Jackson AL, Pickens GA	plateau / valley / south of mtns
April 26, 1965	18:30	2 (1)	Cherokee GA	south of mtns
December 10, 1966	09:30	2 (1)	Stephens GA	south of mtns
March 12, 1967	11:30	2 (1)	Greene TN	valley
April 22, 1967	13:05	2 (1)	Greene TN	valley
May 3, 1967	00:10	2 (1)	Greenville SC	south of mtns
December 18, 1967	22:15	2 (1)	Floyd GA	opening of valley

May 30, 1968	01:00	2 (1)	Floyd GA	opening of valley
April 2, 1970	10:00	3 (1)	Forsyth GA	south of mtns
July 19, 1970	19:00	2 (1)	Bartow GA	opening of valley
May 15, 1972	02:30	2 (1)	Fentress TN	plateau
June 28, 1972	19:00	2 (1)	Cumberland TN	plateau
March 15, 1973	08:00	2 (1)	White TN	west of plateau
March 16, 1973	19:25-19:37	2 (2)	Chattooga GA, Gordon GA	opening of valley
April 1, 1973	01:00	2 (1)	Pickens SC	east of mtns
May 8, 1973	10:10	2 (1)	DeKalb AL	start of plateau
May 19-20, 1973	22:15-00:45	2 (2), 4 (1)	DeKalb AL, Jackson AL	plateau
May 27-28, 1973	20:15-03:30	2 (4), 3 (1)	Jackson AL, Greenville SC, Oconee SC, Pickens SC	start of plateau / east of mtns
November 21, 1973	14:30	2 (1)	Stephens GA	south of mtns
December 13, 1973	13:50-17:20	2 (1), 3 (1)	Polk TN, Hall GA	valley / south of mtns
December 29, 1973	23:15	2 (1)	DeKalb AL	start of plateau
March 21, 1974	06:40	2 (1)	Polk TN	valley
April 3-4, 1974	18:00-13:00	2 (15), 3 (14), 4 (15), 5 (1)	Blount TN, Bradley TN, Cherokee AL, Coffee TN, Cumberland TN, DeKalb TN, Fentress TN, Franklin TN, Jackson AL, Loudon TN, McMinn TN, Monroe TN, Morgan TN, Overton TN, Pickett TN, Polk TN, Putnam TN, Scott TN, Warren TN, White TN, Bartow GA, Cherokee GA, Dawson GA, Fannin GA, Gilmer GA, Gordon GA, Lumpkin GA, Murray GA, Pickens GA, Rabun GA, Whitfield GA, Cherokee NC, Graham NC, Swain NC, Caldwell NC	valley / plateau / mtns
April 8, 1974	17:15	3 (1)	McMinn TN	valley
January 11, 1975	02:30	2 (1)	Transylvania NC	eastern mtns
April 24, 1975	21:30	2 (1)	Cumberland TN	plateau
May 18, 1975	07:00	2 (1)	Rutherford NC	east of mtns
February 18, 1976	19:07	2 (1)	Cocke TN	valley
May 15, 1976	03:10-03:15	2 (2)	Banks GA, Habersham GA	south of mtns
June 29, 1976	00:30	2 (1)	Jackson NC	mtn valley
March 30, 1977	14:15-16:30	2 (3), 3 (1)	DeKalb AL, Gilmer GA, Gordon GA	plateau / opening of valley / mtns
April 4, 1977	18:20-21:15	2 (1), 3 (1)	Jackson AL, Floyd GA	opening of valley
March 23, 1979	21:30	2 (1)	Greenville SC	east of mtns
May 24, 1979	21:57	2 (1)	Burke NC	mtns
April 13, 1980	23:58	2 (1)	Greenville SC	east of mtns

April 28, 1980	23:05	2 (1)	Monroe TN	mtns
July 6, 1980	19:00	2 (1)	Hancock TN	valley
July 10, 1980	18:30	3 (1)	Unicoi TN	mtns
April 26, 1982	22:15	2 (1)	Bartow GA	opening of valley
May 19, 1983	22:15	3 (1)	DeKalb AL	start of plateau
May 7, 1984	23:20	2 (1)	Loudon TN	valley
April 6, 1985	00:35-01:05	2 (2)	Cherokee GA, Pickens GA	south of mtns
February 6, 1986	22:18-22:38	3 (3)	Bradley TN, McMinn TN, Polk TN	valley
May 10, 1988	00:25-00:33	2 (2)	DeKalb AL, Jackson AL	Sequatchie valley / plateau
April 4, 1989	18:22-21:55	2 (10)	Greenville SC, Oconee SC, Banks GA, Bartow GA, Cherokee GA, Floyd GA, Habersham GA, Hall GA	south and east of mtns
May 5, 1989	21:00-23:28	2 (2), 4 (1)	Stephens GA, Caldwell NC, Rutherford NC	east of mtns
November 16, 1989	00:05-00:30	2 (1), 3 (1)	Floyd GA, Habersham GA	opening of valley / mtns
November 22, 1992	14:00-18:10	2 (3), 3 (1), 4 (1)	DeKalb AL, Cherokee GA, Lumpkin GA	start of plateau / south of mtns / mtns
February 21, 1993	21:35-22:45	3 (9)	Anderson TN, Blount TN, Cherokee AL, Knox TN, Loudon TN, McMinn TN, Monroe TN, Putnam TN, Roane TN	west of plateau / valley / mtns
March 27-28, 1994	17:30-00:03	2 (1), 3 (16), 4 (5)	Cherokee AL, DeKalb AL, Oconee SC, Bartow GA, Cherokee GA, Dawson GA, Floyd GA, Gordon GA, Habersham GA, Lumpkin GA, Pickens GA, Rabun GA, White GA	south and east of mtns
April 15, 1994	16:30-16:36	3 (3)	Bradley TN, Hamilton TN, McMinn TN, Meigs TN	valley
June 27, 1994	00:30-04:30	2 (3)	Sequatchie TN, Grundy TN, Oconee SC	plateau / eastern edge of mtns
February 16, 1995	11:31	2 (1)	DeKalb AL	start of plateau
April 21, 1995	18:25	2 (1)	Hamilton TN	valley
May 18, 1995	23:21	3 (1), 4 (1)	Cumberland TN, Jackson AL	plateau
March 16, 1996	22:05	2 (1)	Overton TN	west of plateau
November 7, 1996	22:00	2 (1)	Franklin TN	west of plateau
January 24, 1997	23:23-23:54	2 (2)	DeKalb TN	west of plateau
March 29, 1997	03:55-07:00	2 (2), 3 (2)	Overton TN, Sequatchie TN, Hamilton TN, Bradley TN	west of plateau / plateau / valley
April 22, 1997	20:53	2 (1)	DeKalb AL	start of plateau

May 2, 1997	23:00	2 (1)	Franklin TN	west of plateau
January 8, 1998	03:10	2 (1)	Pickens SC	east of mtns
March 20, 1998	12:25-12:40	3 (2)	Hall GA, White GA	south of mtns
April 16, 1998	22:35	3 (1)	Pickett TN	west of plateau
May 7, 1998	22:49-23:03	2 (1), 4 (1)	Caldwell NC, McDowell NC	east of mtns
December 16, 2000	20:59	3 (1)	Cherokee AL	south of plateau
October 25, 2001	04:28	2 (1)	Coffee TN	west of plateau
November 24, 2001	20:25-21:18	2 (2)	DeKalb AL, Cherokee AL	start of plateau
November 10-11, 2002	23:50-07:25	2 (9), 3 (2)	Cherokee AL, Coffee TN, Van Buren TN, Cumberland TN, Anderson TN, Bartow GA, Cherokee GA, Pickens GA, Dawson GA	west of plateau / plateau / opening of valley / south of mtns