Synoptic Patterns Associated with the Record Snowfall of 1960 in the Southern Appalachians

L. BAKER PERRY[1] AND CHARLES E. KONRAD II[2]

ABSTRACT

Record snowfall totals of up to 211 cm blanketed the Southern Appalachians between mid-February and late-March 1960. Snow was reported on average every other day in the higher elevations, and mean temperatures for the period were nearly 6 C below normal. Snow piled up to great depths, with Boone, NC, reporting a maximum depth of 112 cm. Snow drifts buried roads and made travel impossible, requiring food, fuel, and hay to be airlifted into the region. This paper analyzes the synoptic patterns associated with the record snowfall of February and March 1960. Snowfall events are identified using a combination of first order hourly observations and cooperative observer daily snowfall totals. The spatial patterns of snowfall are mapped using a GIS, while mean values for various synoptic fields (e.g. 850 hPa temperature, 500 hPa height) are calculated and compared to 50-year climatological means. Snowfall events during this period are then classified according to the pattern of cyclogenesis and prevailing flow direction.

Keywords: Synoptic patterns, snowfall, 1960, Southern Appalachians

INTRODUCTION

February and March 1960 continue to be remembered as the snowiest period on record in the Southern Appalachians. Snow was nearly a daily occurrence between 13 February and 26 March at higher elevations, with Boone, NC, reporting 211 cm and many other locations in excess of 175 cm. These snowfall totals are considerably greater than the current 30-year mean *annual* snowfall of 102 cm for Boone and approach the mean annual values of nearly 250 cm for the 2,000 m peaks (e.g Mt. Leconte and Mt. Mitchell) of the Southern Appalachians. Mean temperatures for the period were nearly 6 ºC below normal (Hardie 1960). The combination of frequent snowfall and low temperatures allowed the snow to pile up to great depths, with Boone, NC, reporting a maximum depth of 112 cm on 13–14 March (NCDC 2002). Considerable blowing and drifting of snow compounded problems, closing roads and requiring emergency distribution of food, fuel, and hay (Figs. 1 & 2). Although the impacts were greatest in the Southern Appalachians, the entire Eastern U.S. was adversely affected. March alone broke more records for cold and snow across the Eastern U.S. than any other March on record until then (Ludlum 1960a, Ludlum 1960b). It remains the coldest March on record for many locations in the Southern Appalachians (NCDC 2002.

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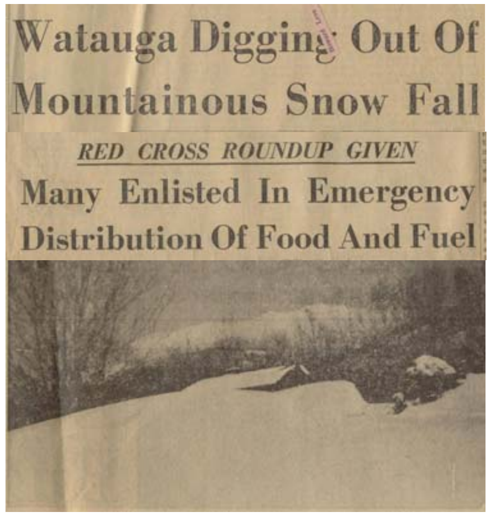

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Many Enlisted In Emergency
Distribution Of Food And Fuel

Figure 1. Headlines from the Watauga Democrat (Boone, NC) 10 Mar 1960 (Watauga 1960).

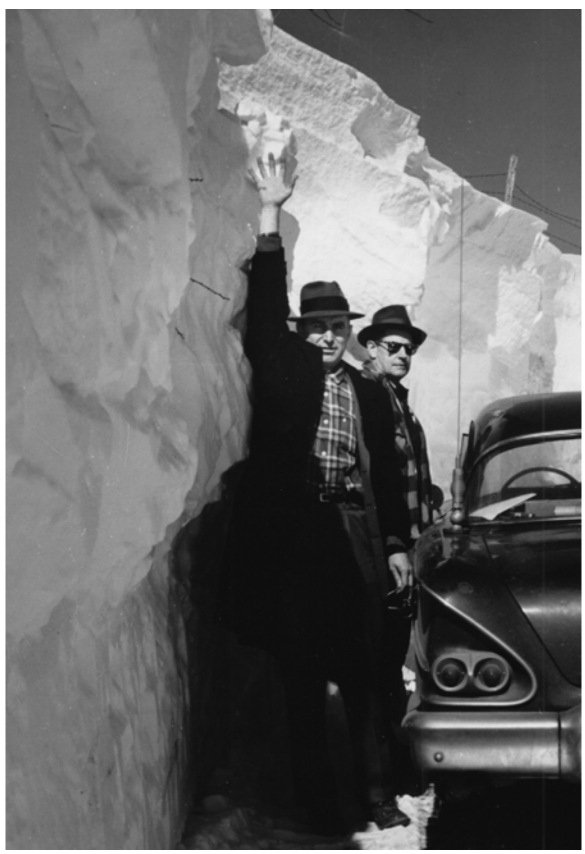

Figure 2. Snow depth on 17 Mar 1960 in Ashe County, NC (Photo courtesy of the NC DOT).

This paper analyzes the synoptic patterns associated with the record snowfall of February and March 1960 across the Southern Appalachians (Fig. 3). Three major questions serve to guide the research. 1) What were the spatial patterns of snowfall during the record-breaking period between 13 Feb and 26 Mar 1960? 2) What were the synoptic field values and map patterns for 1000 hPa height, 500 hPa height, and 850 hPa temperature during this period and how anomalous were these values? 3) What synoptic patterns were primarily responsible for the snowfall, and how did their relative importance vary across the region?

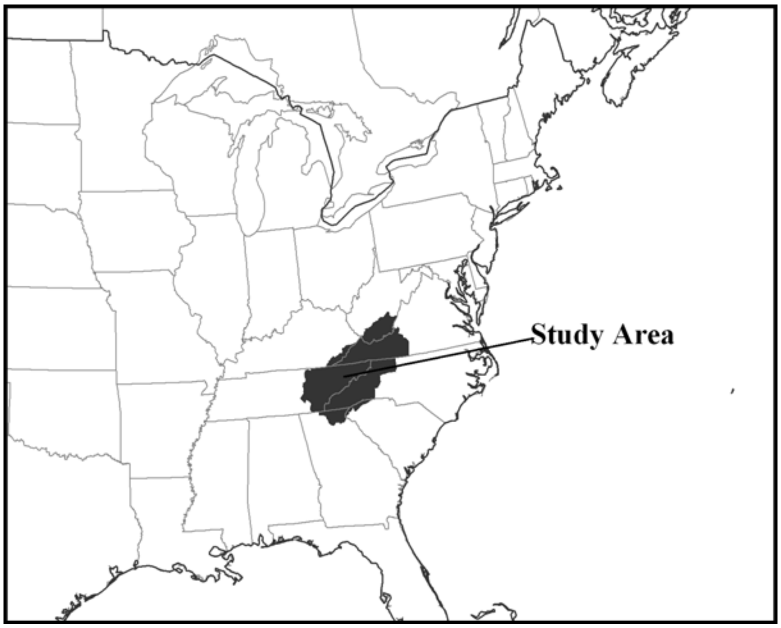

Figure 3. Location of study area.

DATA AND METHODS

Daily snowfall records for February and March 1960 served as the source of snowfall data. We extracted these data from the National Climatic Data Center's Cooperative Summary of the Day CD-Rom (NCDC 2002) for 121 cooperative observer (COOP) stations in the Southern Appalachian Region (Fig. 4). We restricted our analyses to 43 COOP stations that had complete coverage during the study period.

We defined a snowfall event as having occurred if at least one COOP station in the region reported snow accumulation on a given date. To improve the temporal resolution of each event, we referenced hourly surface observation summaries from four nearby first order stations (Fig. 4). From interpretation of these data, we were able to approximate the onset, maturation, and ending time as well as the duration of reported snowfall across the region. Assessment of the maturation time involved determining the hour in which the spatial extent of snowfall was greatest across the network of first-order stations. An event remained active if precipitation was reported during a six-hour period. When precipitation was no longer reported at any of the four first-order stations for more than six hours, we defined the event as having ended at the hour precipitation was last reported. Using this approach, we identified 17 snowfall events during the 43-day period between 13 February and 26 March 1960.

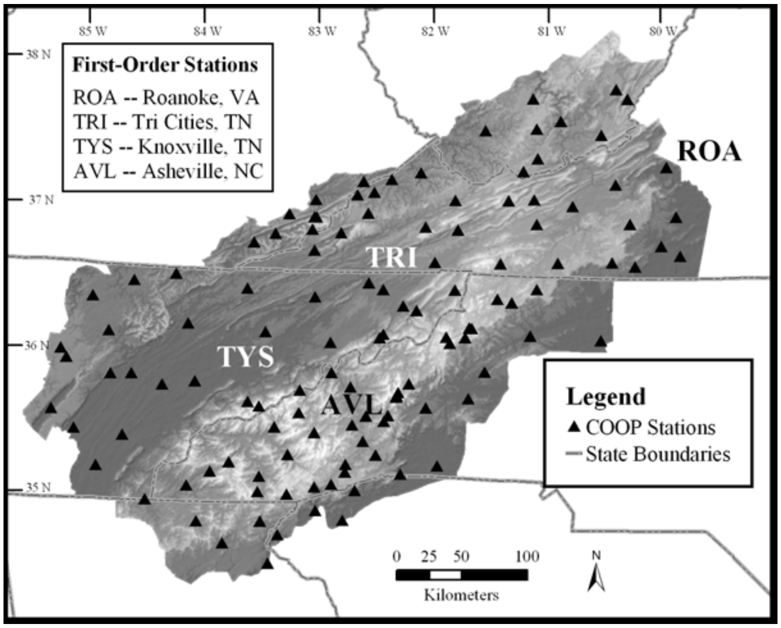

Figure 4. Topography of the region and weather stations used in this study.

We used gridded (2.5 by 2.5 degree latitude/longitude mesh), twice-daily synoptic fields that were extracted from CDs containing the National Center for Environmental Prediction (NCEP) Reanalysis dataset (Kalnay et al. 1996) to analyze the synoptic patterns during the period. These fields were spatially interpolated to the center of each snowfall event. Using the 0000 and 1200 UTC gridded synoptic fields, we undertook a temporal interpolation to estimate field values during the event maturation time. We employed an inverse distance technique to carry out all spatial and temporal interpolations. *Synoptic Climatology Suite* (Konrad and Meaux 2003) was used for compositing of synoptic fields and calculation of anomalies.

Each of the 17 snowfall events identified during the period was classified manually into one of five synoptic types (Table 1) according to the synoptic patterns identified from twice-daily surface analyses (NOAA 1960) and 850 hPa wind components (Kalnay et al. 1996). Miller Type A and Miller Type B cyclones are responsible for most of the big snowstorms across the Southern Appalachians, mid-Atlantic, and into the northeastern U.S. (Miller 1946, Kocin and Ucellini 1990, Keeter et al. 1995, Mote et al. 1997). In fact, all of the 20 major snowstorms in the northeastern U.S. analyzed by Kocin and Ucellini (1990) were of the Miller Type A or B variety. Miller Type A cyclones are characterized by the development of a surface cyclone along a frontal boundary in the Gulf of Mexico separating cold continental air from maritime tropical Gulf or Atlantic air. The surface low tracks northeastward out of the Gulf of Mexico, paralleling the Atlantic coastline and in some cases intensifying further. Miller Type B cyclones, however, initially track west of the Appalachians. As the primary low dissipates in the Ohio Valley, a secondary low develops along the Atlantic coast.

Table 1. Major synoptic types observed during February and March 1960.

Class	Synoptic Type
1	Miller Type A
2	Miller Type B
3	Ohio Valley
4	Northwest Flow
5	Other

Cyclones that track west of the Appalachians through the Ohio Valley and do not undergo secondary cyclogenesis along the Atlantic coast constitute a third synoptic type responsible for producing snowfall during the period. These Ohio Valley cyclones (Knappenberger and Michaels 1993) typically result in minor snowfall accumulations as most of the region remains in the warm sector until the cold front passes. Northwest Flow Snow (NWFS) events result from the orographic ascent of a cold and moist low-level northwest flow, often in the absence of synoptic-scale lifting (Perry and Konrad 2005, Perry and Konrad 2006, Perry et al. 2006). In this study, NWFS were defined on the basis of a northwest (270 to 360 degrees) 850 hPa wind at event maturation. Other types of events (e.g. Alberta clippers, prolonged isentropic lift) were also classified during the period, but contributed minimally to snowfall totals.

RESULTS AND DISCUSSION

The greatest snowfall totals between 13 February and 26 March 1960 occurred in the North Carolina High Country, where Boone recorded 211 cm (Fig. 5). The 265 cm of snowfall recorded during the 1959–60 snow season in Boone still stands as the annual record, and only one other year (1967–68 at 215 cm) received more than the 211 cm that fell during the 43-day period in 1960. All of the higher elevations in the Southern Appalachians received considerable snowfall during the period, with many locations measuring two or three times as much snow during this period than they average in an entire year. As previously reported, the greatest snow depth measured was 112 cm, also in Boone, NC. The sustained cold, coupled with significant blowing and drifting snow, greatly increased the societal impacts. Residents would awake to find freshly plowed roads buried once again in newly drifted snow (Minor 1960).

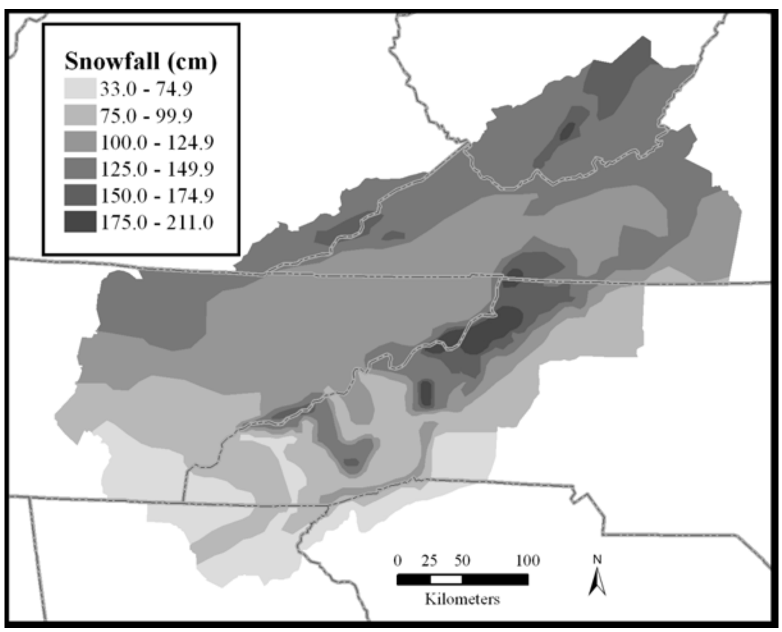

Figure 5. Total snowfall between 13 Feb and 26 Mar 1960.

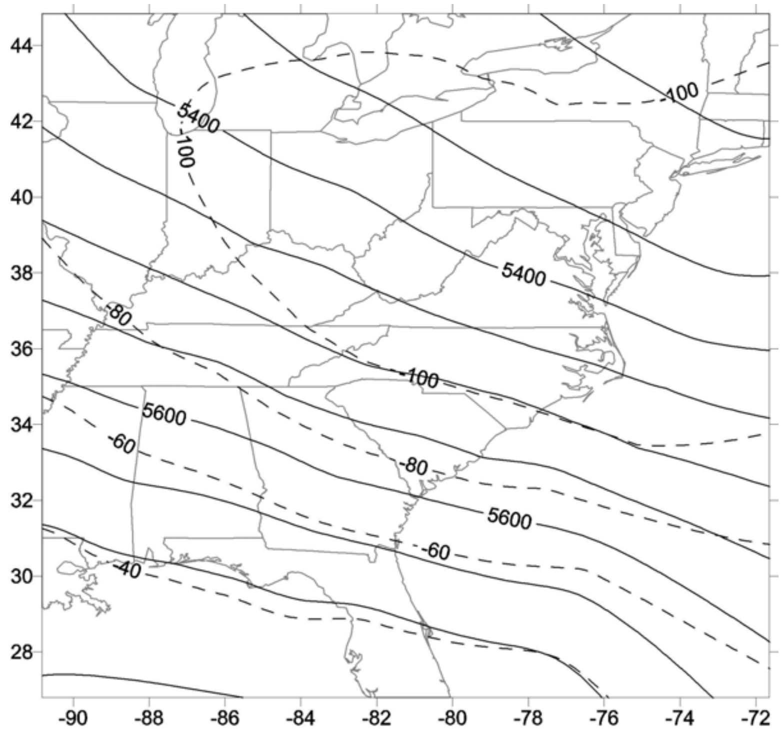

Figure 6. 500 hPa height (m) and anomaly for 13 Feb to 26 Mar 1960 (reference period 1951–2000).

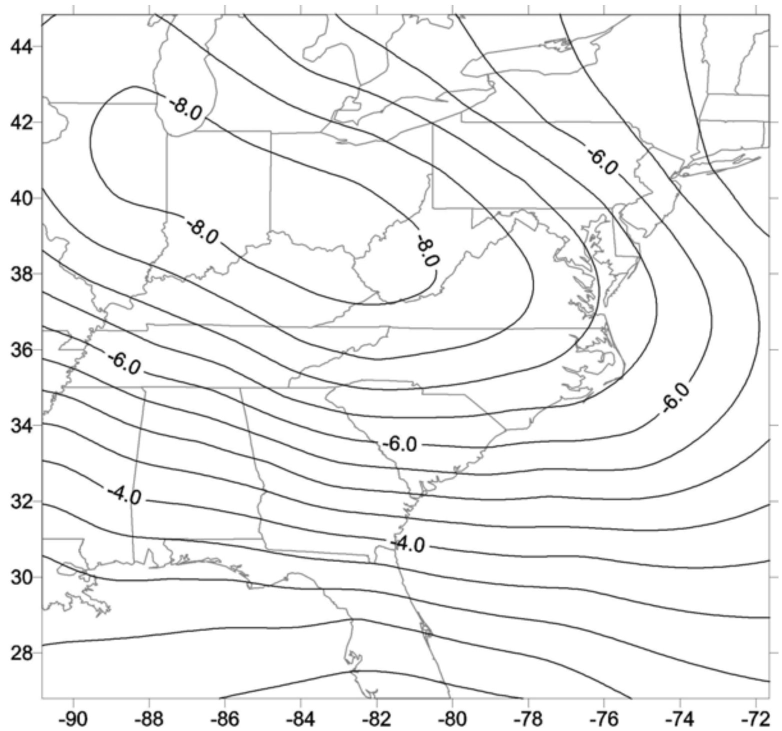

Figure 7. 850-hPa temperature anomaly (ºC) for 13 Feb to 26 Mar 1960 (reference period 1951–2000).

The synoptic-scale atmospheric circulation was highly anomalous during this period. The 500-hPa height, for example, was considerably below the 50-year mean for the Southern Appalachians (–2.29 z) and throughout eastern North America. A 500 hPa trough dominated eastern North America throughout this period, providing an active, southeasterly displaced storm track that allowed frequent intrusions of cold continental air (Fig. 6). The 850 hPa temperature anomaly was even more extreme, registering nearly 8.0 C cooler (–3.46 z) than the 50-year mean over northern portions of the study area (Fig. 7). Again, the highly anomalous values were not restricted to the Southern Appalachians, but covered the entire eastern U.S. As a result, March 1960 was the coldest March on record across much of the eastern U.S. (Ludlum 1960b).

Three primary synoptic types contributed the bulk of the snowfall across the Southern Appalachians (Fig. 8). The majority of the snowfall across the region occurred in association with Miller Type A and Miller Type B cyclones (Fig. 9). The two Miller Type A cyclones occurred in February, whereas the three Miller Type B storms moved by in March. Interestingly, the greatest accumulations in association with the Miller Type A cyclones were in the western and northern portions of the study area, while areas in the southeast of the study area received mostly rain (NCDC 2002). Miller Type B cyclones contributed the greatest amount to snowfall totals during the period at all but two of the regions across the study area. In the south and east, these three storms contributed nearly all of the snowfall, occurring during a two-week period in early March. In the higher elevations and along northwestern slopes, NWFS contributed substantially to snowfall totals, constituting as much as 35 percent of the total. Interestingly, none of the NWFS events were tied to 500 hPa cutoff lows, which were responsible for the extremely heavy spring snow events in April 1987 and May 1992 (NWS 1987, Fishel and Businger 1993). The NWFS events were more numerous than the Miller Type A and B cyclones, but the snowfall was limited in spatial extent. Mainly as a result of the NWFS events, the cumulative percentage of total snowfall during the period contributed by each event displayed considerable variability across the Southern Appalachians (Fig. 10). At lower elevations, particularly in the southeast, only two or three exceptionally heavy events occurred during the period. Elsewhere, and particularly at higher elevations and along northwestern slopes, lighter NWFS events were interspersed with the big Miller Type A and B cyclones, reflecting a greater diversity of synoptic types responsible for the snowfall totals.

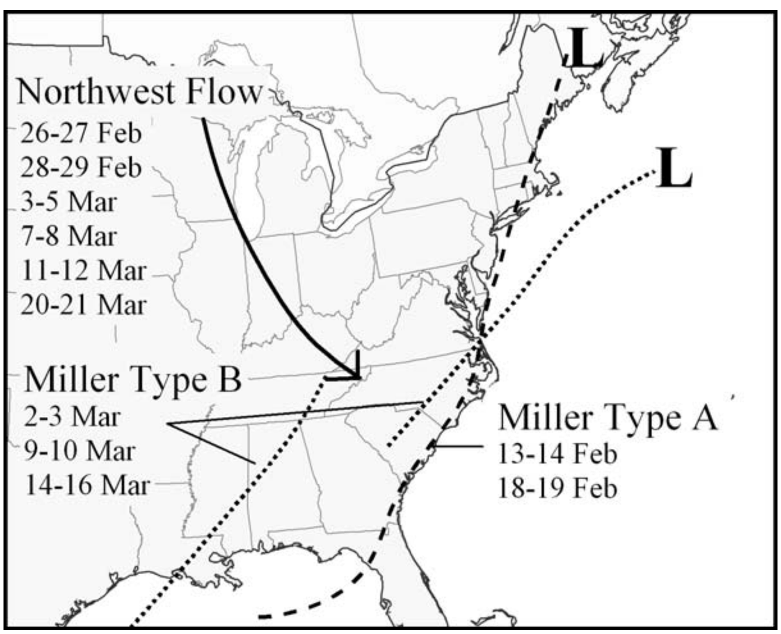

Figure 8. Three primary synoptic patterns responsible for the record snowfall and associated dates.

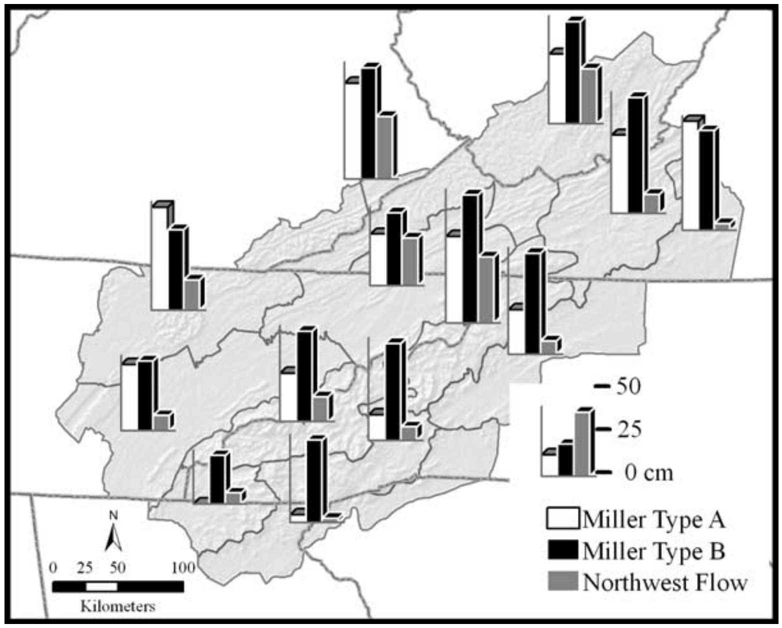

Figure 9. Total snowfall between 13 Feb and 26 Mar 1960 by synoptic pattern.

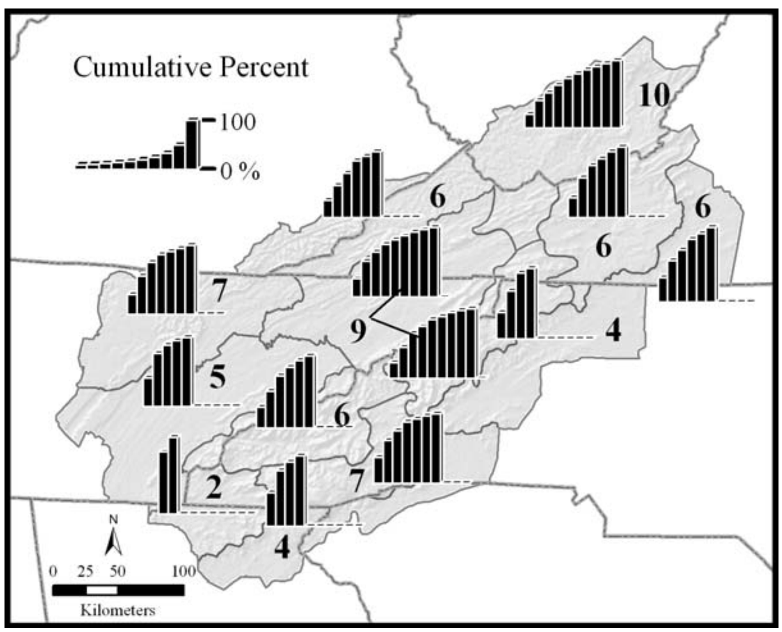

Figure 10. Cumulative percentage of total snowfall contributed by each event (from heaviest to lightest) and number of events needed to reach 90%.

CONCLUSIONS

The record snowfall in February and March 1960 across the Southern Appalachians occurred in association with highly anomalous 500 hPa circulation and 850 hPa temperatures. The persistence of a 500 hPa trough over the eastern U.S. was associated with a southeasterly displaced storm track that kept temperatures well below normal. As a result, the 1959–60 snow season still holds the annual snowfall record (265 cm) and maximum snow depth record (112 cm) for Boone, NC, and countless other locations across the region. Miller Type A cyclones, Miller Type B cyclones, and NWFS events were responsible for nearly all of the total snowfall across the region. However, NWFS made the greatest contribution to snowfall totals across the higher elevations and along northwestern slopes, where snow fell on average every other day during the period. A small number of exceptionally heavy events produced the record snowfall in the Georgia and Carolina foothills in contrast with the elevated areas to the north and west where numerous, relatively light NWFS events contributed substantially to the total snowfall. Unanswered questions include the causes of the anomalous and persistent 500 hPa circulation pattern. In particular, the role of hemispheric teleconnections versus persistent snow cover across the region in forcing this pattern needs to be explored. The influence of favorable air trajectories extending downwind from the Great Lakes in periods of NWFS also deserves further scrutiny, particularly since these have been tied to enhanced snowfall in the Southern Appalachians (Perry and Konrad 2005). Lastly, given the deep snowpack and reports of flooding during rapid melting at the end of March (Ludlum 1960b), an investigation of the hydrological significance (e.g. SWE estimations and flooding reports) of February and March 1960 is also warranted.

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