A Relationship Between Snowfall and Storm Tracks in the Greenville-Spartanburg County Warning Area

Thomas Winesett
Department of Atmospheric Sciences
University of North Carolina at Asheville
Asheville, NC

Laurence G. Lee
National Weather Service
Greer, SC

1. Introduction

Storm total snowfall varies greatly across the National Weather Service (NWS) Greenville-Spartanburg (GSP) County Warning Area (CWA) due to a number of factors, including the elevation differences across the mountains and Piedmont of the Carolinas and northeast Georgia. This study examines snowfall climatology among the three main climate sites (Fig. 1) in the GSP CWA: Greer Area, South Carolina (943 – 1,039 ft MSL), Charlotte Area, North Carolina (728 - 779 ft MSL), and Asheville Area, North Carolina (2,117 – 2,255 ft MSL). The goal is to identify general relationships between storm track and snowfall accumulation differences between the Asheville Area (a mountain valley location) and the Piedmont (Charlotte and Greer areas). Results can serve as a point of departure for more detailed investigations of the variability of event specific snow accumulations in the region.

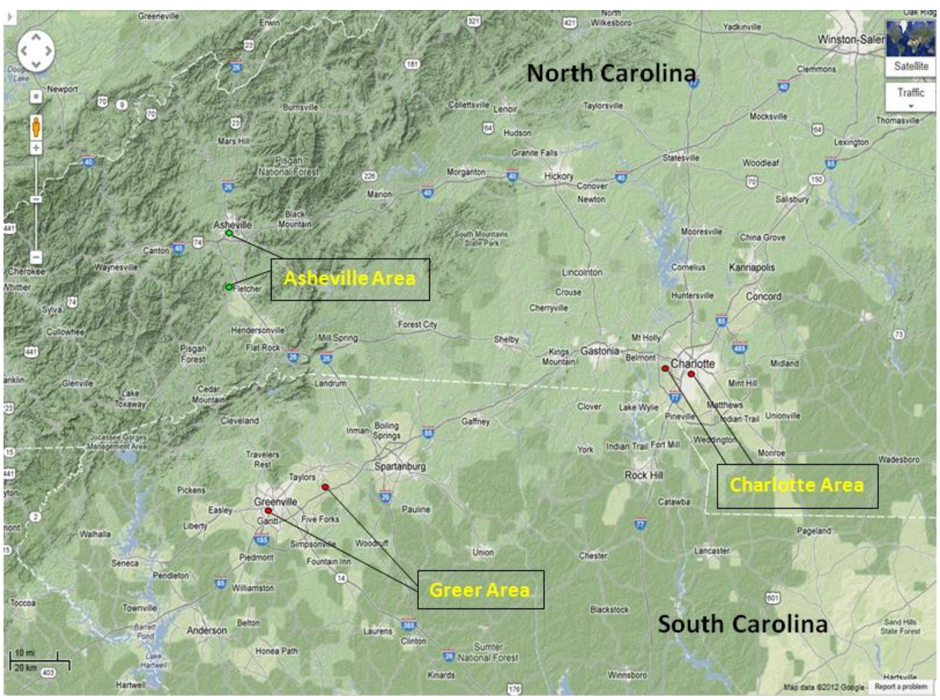

Fig. 1. Map of western North Carolina and western South Carolina showing the locations of Asheville Area, Charlotte Area, and Greer Area. Dots represent the geographic spread of observations in each data set.

2. Data Collection and Assessment

The xmACIS[1] threaded climatological record for each of the three observation sites was queried. The threaded data consisted of a combination of historical station records from the same general area that were linked to provide a more lengthy climatology than was available from a single station. Record keeping began in the Asheville, Charlotte, and Greer areas in 1869, 1878, and 1884, respectively. Individual station records that form the thread for each site were available from the National Climatic Data Center (NCDC).

Daily snowfall at each of the three sites from the beginning of record through the winter of 2011-2012 was inserted in a spreadsheet, sorted, and quality controlled. The quality of the data was determined by comparing the daily snowfall to data archived at the NCDC and original station climate records. A snowfall event was defined to be measurable snow that had a beginning and ending time on the same calendar day or measurable snow that fell continuously across midnight thus resulting in accumulation on consecutive days. A top ten list for each threaded data set was produced. A subset of the data was created to identify situations when at least two of the sites had measureable snow during the same event[2]. The list of snowfalls common to at least two of the sites revealed the interesting fact that there were a number of events during which one or both of the Piedmont locations (Charlotte and Greer areas) received more snow than the Asheville Area. Not surprisingly, there were also events during which the Asheville Area had more snow than the Piedmont locations.

The top ten lists were refined further to identify storms that resulted in an accumulation difference of three inches or more between the Asheville Area and at least one of the Piedmont areas. Events meeting that criterion exhibited noteworthy accumulation differences for the purpose of this study. Six storms did not meet the criterion, so they were removed from the list and replaced by the next storms that met the criterion. In this manner, noteworthy snowfall lists were created for the Asheville Area and the Charlotte and Greer areas (Tables 1 and 2).

Low pressure center tracks were plotted for each top ten noteworthy event that produced a snowfall maximum in the Asheville Area and a snowfall maximum at one or both of the Piedmont sites (Fig. 2). A second set of tracks was plotted for the events that fell in the original top ten but did not meet the noteworthy criterion (i.e., the snowfall difference between Asheville and the Piedmont locations was less than three inches; Fig. 3).

---

[1] xmACIS is a data query tool that allows National Weather Service offices access to climatological products in the Regional Climate Center database, Applied Climate Information System (Eggleston 2008).

[2] NWS (and predecessor agency) cooperative observers typically used an observation day that did not extend from midnight to midnight (e.g., 7:00 am to 7:00 am). Thus, precisely determining the day on which snow occurred was sometimes difficult. The day of the event was considered to be the day on which the measurement was entered on the observation form.

TABLE 1. Top snowfall events ranked by accumulation for the Asheville Area. Events in red did not meet noteworthy criterion.

Asheville Area Top Snowfall Events				
Asheville Area (in)	Charlotte Area (in)	Greer Area (in)	Dates	Event ID
18.2	1.6	9.8	3/12-14/1993	A1
16.7	T	7.7	1/26-28/1907	A2
16.3	7.5	11.4	12/3/1971	A3
16.0	2.9	8.0	3/2-3/1942	A4
15.8	13.2	5.9	2/15-17/1969	A5
14.0	12.1	12.0	1/7/1988	C1
13.0	2.7	0.8	1/29-30/2010	A6
11.5	0.0	0.3	4/3/1987	A7
11.3	3.0	4.7	1/6-8/1996	A8
11.0	7.6	4.1	3/9/1960	A9
10.7	9.5	5.2	3/2-4/1960	C2
10.3	3.5	4.2	3/10-11/1926	A10

TABLE 2. Top snowfall events ranked by maximum snowfall at Piedmont (Charlotte Area and Greer Area) locations. Events in red did not meet noteworthy criterion.

Piedmont Area Top Snowfall Events				
Charlotte Area (in)	Greer Area (in)	Asheville Area (in)	Dates	Event ID
17.4	15.0	8.4	2/14-18/1902	B1
13.3	9.7	7.1	3/1-2/1927	B2
13.2	5.9	15.8	2/15-17/1969	D1
13.2	8.3	5.5	2/26-27/2004	B3
12.1	12.0	14	1/7/1988	D2
11.0	10.5	0.0	12/2-3/1896	B4
10.4	14.4	9.0	12/17/1930	B5
10.3	9.3	2.6	3/24/1983	B6
10.2	6.1	5.5	1/15-17/1965	B7
10.0	8.2	8.6	2/18/1979	D3
9.5	5.2	10.7	3/2-4/1960	D4
8.7	11.0	5.0	12/28-30/1935	B8
8.5	3.0	1.0	1/23/2003	B9
8.1	6.0	3.6	2/24-26/1914	B10

3. Results

The envelope of tracks contained two clusters that subjectively were associated with the two accumulation scenarios: 1) Greater snowfall in the Asheville Area, or 2) Greater snowfall in the Piedmont. Most of the tracks displayed characteristics of Miller “A” cyclogenesis (Miller 1946). Two of the events (9 March 1960 and 15-17 January 1965) were associated with an initial low near, or just west of, the Appalachians and subsequent secondary development along the coast, sometimes termed Miller “B” cyclogenesis (Miller 1946). In general, the tracks are similar to those associated with major snowstorms that affected the northeastern United States (Kocin and Uccellini 2004a,b).

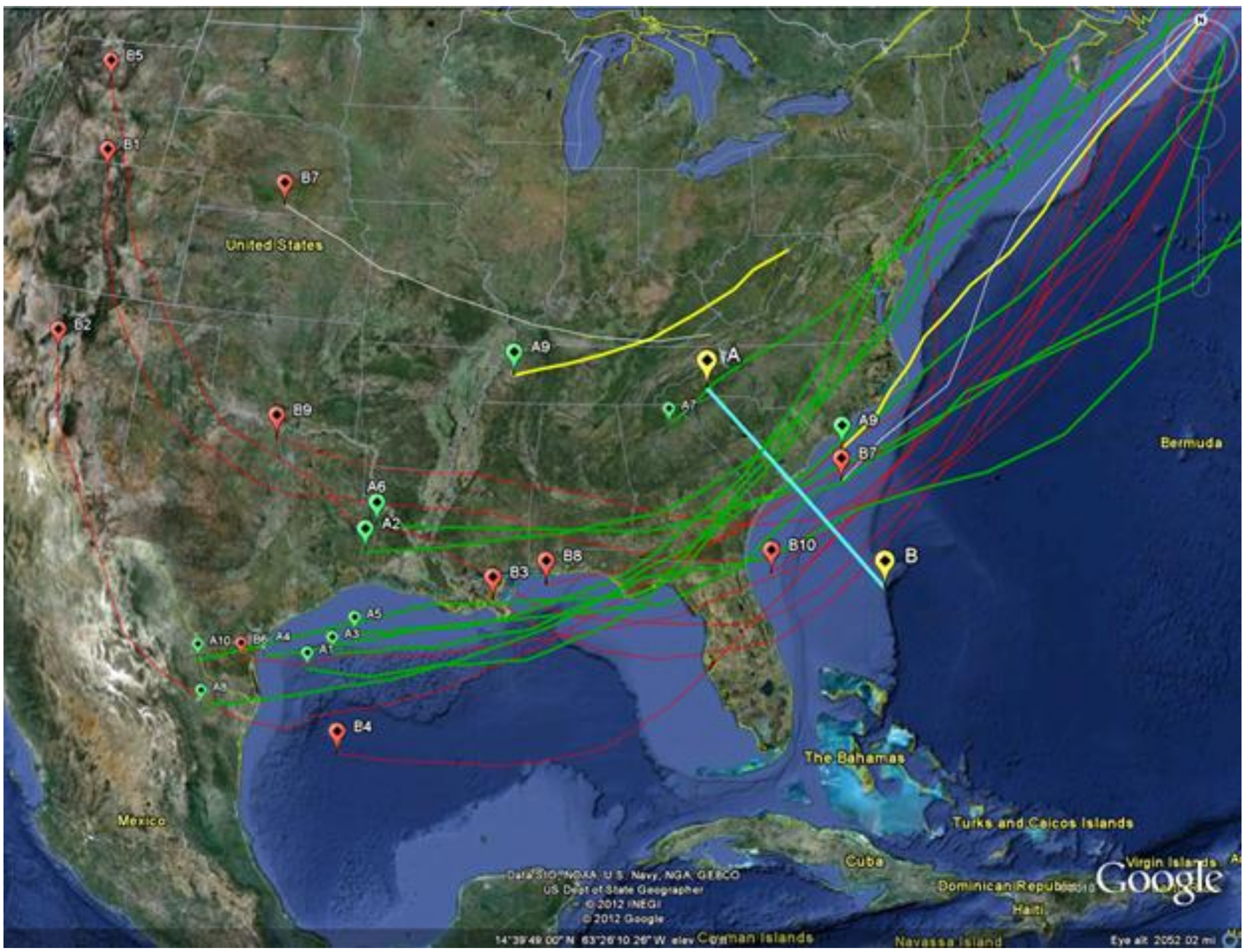

Fig. 2. Storm tracks for top ten noteworthy events in the Asheville Area (solid green and yellow lines) and at the Piedmont locations (solid red and white lines). Markers correspond to ID numbers in Tables 1 and 2. Line AB (light blue) defines the reference for measuring track distance from Asheville.

Events that produced more snow in the Charlotte and Greer areas than in the Asheville Area exhibited tracks that extended from the northern Gulf of Mexico and southern Gulf Coast states across north Florida and extreme southern Georgia to the Atlantic coast. Thereafter, the tracks curved to the northeast roughly parallel to the coast. When the Asheville Area had greater snowfall, the tracks were further west, generally slightly inland, after turning to the northeast.

Regardless of which site received more snow, cyclogenesis tended to originate in western portions of the Gulf of Mexico or along the Gulf Coast.

Proximity of the East Coast storm tracks to the GSP CWA was estimated by defining a line from Asheville through Charleston, South Carolina (Line AB). The distance of each track from Asheville when it intersected the line was calculated (Table 3). When the Asheville Area had at least three inches more snow than the Piedmont locations, the average distance from Asheville on Line AB was 209 miles. When the Piedmont locations had at least three inches more snow than Asheville, the distance from Asheville on Line AB was 352 miles.

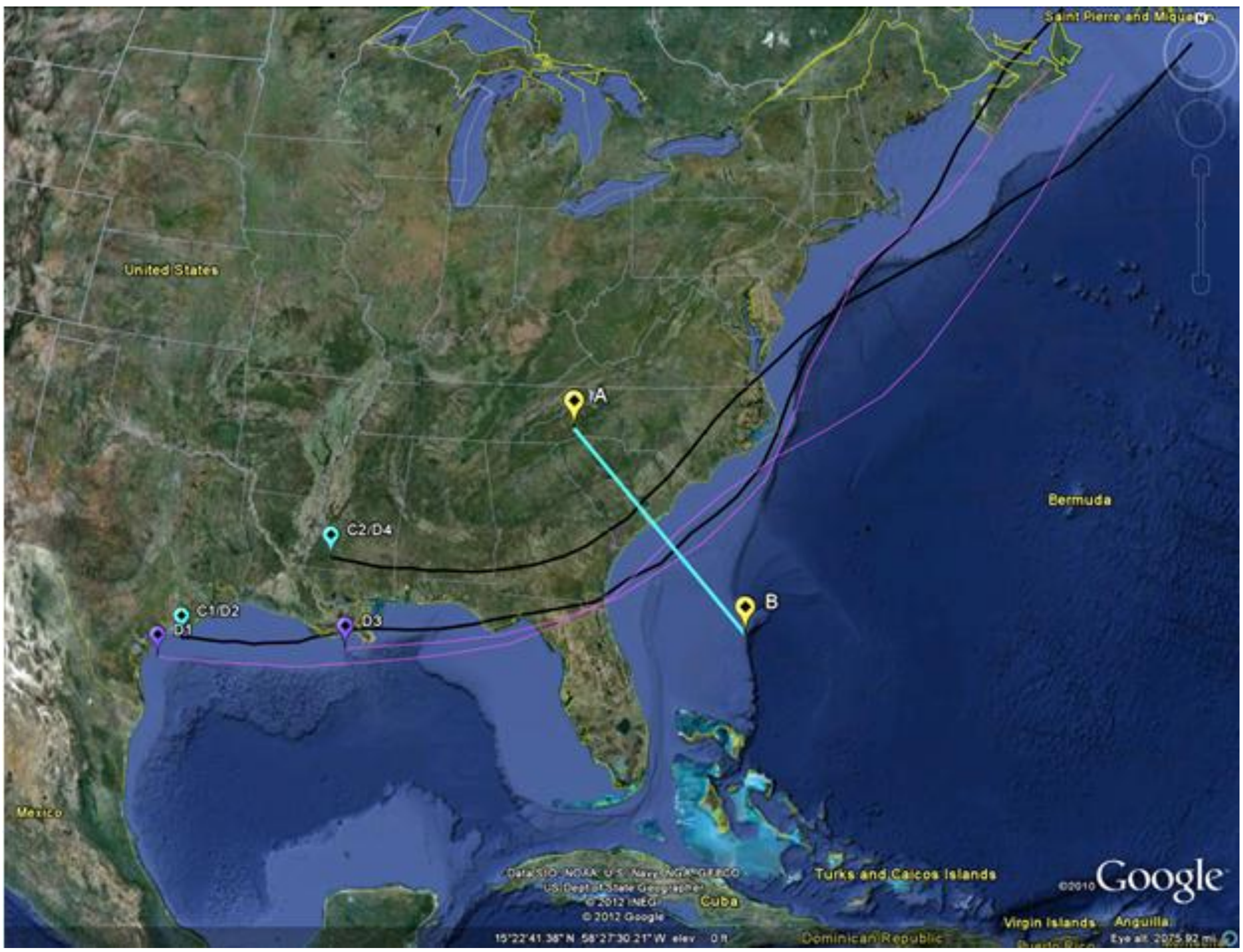

Fig. 3. Storm tracks for events not meeting noteworthy criterion in the Asheville Area (solid black lines) and at the Piedmont locations (solid purple lines). Line AB (light blue) provides the reference for measuring track distance from Asheville.

During the study period, six storms resulted in accumulations that did not differ by three or more inches between the Asheville Area and at least one of the Piedmont locations. The average distances from Asheville on Line AB for the storm tracks that did not meet the noteworthy criterion at Asheville and at one or both of the Piedmont locations were 251 and 278 miles, respectively (Table 3).

TABLE 3. Storm track distance from Asheville for noteworthy events in the Asheville Area (A1 through A10) and in the Piedmont areas (B1 through B10). Non-noteworthy Asheville Area (C1 and C2) and Piedmont area events (D1 through D4) in red.

Storm Track Distance from Asheville			
Noteworthy Events		**Non-Noteworthy Events**	
Event ID	**Distance from Asheville (mi)**	**Event ID**	**Distance from Asheville (mi)**
A1	178	C1	306
A2	160	C2	196
A3	352	**C1…C2**	**251 (Average)**
A4	159	D1	286
A5	287	D2	306
A6	244	D3	325
A7	3	D4	196
A8	257	**D1…D4**	**278 (Average)**
A9	258		
A10	191		
A1…A10	**209 (Average)**		
B1	341		
B2	271		
B3	463		
B4	379		
B5	434		
B6	378		
B7	302		
B8	258		
B9	332		
B10	365		
B1…B10	**352 (Average)**		

4. Summary

Daily snow accumulations for the Asheville, Charlotte, and Greer areas were extracted from the threaded xmACIS database. The data extended from the beginning of record (Asheville Area, 1869; Charlotte Area, 1878; Greer Area, 1884) through the winter of 2011-2012. Event total snowfalls were derived from the daily snowfall observations at each site. Events during which snow was measured at more than one of the sites were identified. A noteworthy event was defined to be one characterized by a three inch or greater accumulation difference between the Asheville Area and at least one of the Piedmont locations (Charlotte and Greer areas).

Tracks of the low pressure systems that produced the top ten noteworthy snowfalls in the Asheville Area and in the Piedmont areas were plotted along with the tracks that did not meet the three inch criterion. The tracks indicated that all three sites received significant snowfall from low pressure centers that traveled from the Gulf Coast region to the Florida and Georgia coast where they curved to the northeast generally parallel to the East Coast. Although quite a bit of spread existed in the ensemble of tracks, low pressure systems that produced heavier snow in the Asheville Area tended to be slightly inland along the Atlantic coast. Tracks associated with heavy snow in the Greer and Charlotte areas were offshore after turning to the northeast.

This study evaluates only the relationship of storm track to snowfall occurrence and snow accumulation difference among the three primary climate stations in the WFO GSP CWA. Many other factors, such as elevation, also should be considered when assessing the variability of snow accumulation across the region during a particular event.

Acknowledgments. Zachary Hargrove assembled the Asheville Area daily snowfall database. Low pressure center tracks were extracted from NOAA/NWS/Hydrometeorological Prediction Center Daily Weather Maps and the U.S. Daily Weather Map Project at the following link: http://docs.lib.noaa.gov/rescue/dwm/data_rescue_daily_weather_maps.html. Patrick Moore provided a helpful review that improved the quality of the document.

APPENDIX

Threaded Databases

The threaded databases used in this study are the product of collaboration among NOAA's National Climatic Data Center, NOAA's National Weather Service, and the Northeast Regional Climate Center. Project information is available at: http://threadex.rcc-acis.org/.

Station Thread for Asheville Area, NC	
Station Name	**Period in Thread**
Asheville Regional Airport	09/1964 to Present
Asheville City	01/1947 to 08/1964
Asheville City (Climate Record Book)	08/1902 to 12/1946
Asheville City	08/1876 to 03/1902
Asheville Aston	03/1869 to 07/1876

Station Thread for Charlotte Area, NC	
Station Name	**Period in Thread**
Charlotte-Douglas International Airport	09/1948 to Present
Charlotte City	01/1893 to 08/1948
Charlotte City (Climate Record Book)	10/1878 to 12/1892

Station Thread for Greer Area, SC	
Station Name	**Period in Thread**
Greer Greenville-Spartanburg Airport	10/15/1962 to Present
Greenville Downtown Airport	12/11/1941 to 10/14/1962
Greenville Downtown	01/1930 to 12/10/1941
Greenville Downtown (Climate Record Book)	11/1917 to 12/1929
Greenville Downtown	04/1884 to 10/1917

REFERENCES

Eggleston, K.L., 2008: The xmACIS User's Guide, Northeast Regional Climate Center, Cornell University, Ithaca, NY, 16 pp.

Kocin, P.J., and L.W. Uccellini, 2004a: *Northeast Snowstorms of the Twentieth Century. Vol 1: An Overview, Meteor. Monogr.*, Vol. 32, No.54, Amer. Meteor. Soc., 296 pp.

________, and ___________, 2004b: *Northeast Snowstorms of the Twentieth Century. Vol 2: Case Studies, Meteor. Monogr.*, Vol. 32, No. 54, Amer. Meteor. Soc., 522 pp.

Miller, J.E., 1946: Cyclogenesis in the Atlantic coastal region of the United States. *J. Meteor.*, **3**, 31-44.