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Technical Attachment

# Great Smoky Mountain National Park Snowfall Analysis

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## 1. Introduction

The Great Smoky Mountain National Park is located across eastern Tennessee and western North Carolina (Fig. 1) and contains some of the most diverse terrain in the eastern United States. Elevations in the park range from 875 to 6,643 feet (Fig. 2). The Weather Forecast Office at Morristown, Tennessee has the responsibility for issuing forecasts for the Tennessee side of the park. The National Park is one of the most visited national parks in the United States with a variety of outside activities, such as hiking, camping, fishing, and sightseeing.

The main road across the park is U.S. highway 441, which crosses NewFound Gap at an elevation of 5048 feet MSL. The purpose of this study is to examine the differences in snowfall across the Great Smoky Mountain National Park, and to compare the average snowfall with the surrounding Automated Surface Observation Systems (ASOS) across eastern Tennessee and western North Carolina.

## 2. Data

The study will compare 15 years snowfall data from five daily reporting stations across the Great Smoky Mountains. The five stations are the following: Park Headquarters (elevation 1600 feet MSL), Cades Cove (1900 feet MSL), Oconaluftee (2040 feet MSL), Newfound Gap (5048 feet MSL), and Mount LeConte (6400 feet MSL). These stations report daily snowfall as of 7:00 am Local Standard Time (LST).

Approximately ten years of snowfall data, which is between March 1991 and February 2001, were obtained from the National Park archive. The Weather Forecast Office at Morristown, Tennessee has archived data from the National Park from 2001 to present. The 15 years of data were entered into a spreadsheet to generate graphs of annual, monthly, and daily snowfall comparisons between the stations.

Average snowfall for eastern Tennessee and western North Carolina ASOS sites were obtained from the National Climatic Data Center's Local Climatological Data. The three ASOS sites are: Knoxville McGhee Tyson Airport (elevation 981 feet MSL), Tri-City

Regional Airport (1519 feet MSL), and Asheville, North Carolina Airport (2165 feet MSL).

## 3. Annual Snowfall

The average annual snowfall (Fig. 3) varies greatly between the lower terrain stations, such as Park Headquarters, and the higher terrain stations, such as NewFound Gap and Mount LeConte. The difference between Park Headquarters and Mount LeConte is around 90 inches. The lower terrain receives an average annual snowfall around 12 inches, while Mount LeConte's average is nearly 100 inches. The average snowfall for the park's lowest elevations stations, which are Park Headquarters and Cades Cove, is only about 2 inches more than the Knoxville Airport.

The large temperature difference between the lower and higher elevations is likely a major reason for the enhanced average snowfall at NewFound Gap and Mount LeConte. Gaffin et al. (2002) concluded the differences between maximum temperatures were similar to the moist adiabatic lapse rate of $3.3^0$F per 1000 ft between Park Headquarters and NewFound Gap. The upslope lift into the higher terrain is also a contributor.

The annual snowfall graph does illustrate a fairly significant difference between the two higher elevation stations, NewFound Gap and Mount LeConte. It is interesting that the difference in annual snowfall is nearly 35 inches with only a 1400 feet MSL change in elevation. Perry and Konrad (2005) found that wind trajectories northwest from the Great Lakes into the windward slopes of the eastern Tennessee mountains, such as the Great Smoky Mountains, enhances snowfall. A relief map (Fig. 4) shows that Mount LeConte is in a very favored windward slope location to intercept the upslope moisture flowing from the Great Lakes. The relief map also shows that NewFound Gap is likely shadowed by the mountains to the west and northwest. This shadowing effect would block the deepest moisture from intercepting the windward slopes of NewFound Gap.

Mount LeConte average snowfall over the last 15 years is nearly 100 inches, but with large interannual variability (Fig. 5). Annual snowfall has varied from less than 45 inches in 1991 to over 160 inches in 2003.

There were several years in which the lower elevations stations received an inch or less of snow for the entire year (Table 1), with the least annual snowfall a trace at Cades Cove in 1992 and Oconaluftee in 2005.

The snowiest year for the entire park was 1993 -- the year of the so-called Super-Storm -- with an overall average snowfall for the five stations being almost 75 inches. The year with the least snowfall was 1991, with a five station average of less than 20 inches.

The average number of days per year with snowfall of one inch or more varied from four and five across the lower elevation stations to 26 at Mount LeConte (Fig. 6). The annual number of days of snowfall at NewFound Gap is 19, which is similar to the normal 18 snowfall days at Minneapolis Saint Paul, Minnesota.

## 4. Monthly and Daily Snowfall

The monthly average snowfall shows a wide range between the ASOS sites, the National Park lower elevation stations, and the higher elevation stations (Table 2). Overall, the snowiest month across the park is January, with the highest monthly average snowfall around 25 inches at Mount LeConte. It is interesting to note that all of the park stations showed a slight decrease in average snowfall for February compared to January and March (Fig. 7). The slight decrease could be contributed to three fewer days in the month of February and the Super-Storm of March 1993.

Only NewFound Gap and Mount LeConte reported snowfall in the months of May and October. The earliest snowfall for NewFound Gap was October 25, 2005, with 1.5 inches. The earliest for Mount LeConte was October 19, 1996, with 0.1 inch. The latest snowfall for both NewFound Gap and Mount LeConte occurred on May 8-9, 1992 with four and 12.5 inches, respectively.

The latest first snowfall in the park occurred in Winter of 2001-2002. Mount LeConte did not receive its first measurable snow until December 24, 2001 with only 0.5 inch. NewFound Gap did not receive any measurable snow until January 7, 2002.

The greatest number of days with snowfall of one inch or more is at Mount LeConte, with an average of seven days for the month of January (Fig. 8). NewFound Gap's greatest number of days with snowfall of one inch or more is 4.9 for the month of January. This number is comparable to the normal number of days of snowfall for January at Minneapolis-Saint Paul, Minnesota, which is 4.5. The lower elevation stations, such as the Park Headquarters and Cades Cove, average between one and one and a half days of snowfalls of one inch or greater for January through March. This is comparable to those at the Tri-City and Asheville Airports.

The greatest daily snowfall for each of the park stations was reported during the March 13-14, 1993 Super-Storm. Mount LeConte received over 30 inches on March 14, 1993 (Fig. 9).

## 4. Concluding Remarks

The Great Smoky National Park has its own unique climatology with average snowfall varying greatly across the park. These variations are mainly due to elevation differences, upslope and downslope flow, and the capture of Great Lakes moisture along the windward slopes. It is crucial for the visitors of the National Park to understand these wide variations, especially the difference in average snowfall between Park Headquarters and the higher elevation locations, such as NewFound Gap and Mount LeConte.

Visitors to the National Park may get a false sense of security by the usually limited snowfall across the surrounding states, and then get surprised by the heavy snowfalls over the higher terrain. Travelers and hikers through the NewFound Gap should realize that

the average snowfall is 62 inches, which is greater than that at Boston, Mass., with an average of 43.8 inches or Chicago, Ill., with an average of 38 inches. The number of days per year with one inch or more of snowfall is also much greater at NewFound Gap with 19 days, than both Boston and Chicago, which each average around 12 days.

The snowfall climatology at Mount LeConte is similar to Caribou, Maine. Both locations have an average annual snowfall around 100 inches with the average number of days per year with one inch or more of snow around 26 at Mount LeConte and 29 at Caribou, Maine.

Additional research on heavy snowfall pattern recognition for the Great Smoky National Park would be beneficial. Also, as additional snowfall data are archived, a more complete snow climatology analysis of the park could be done.

**Acknowledgements**

The author thanks Jack Ramsden and Clayton Brantley of the National Park Service for providing the snowfall data used in this study. Thanks to David Gaffin, Senior Forecaster WFO Knoxville/Tri-Cities, Tennessee, for both the map of east Tennessee and the topographic map of the Great Smoky Mountain National Park. Also, I thank Jack Settelmaier, NWS Southern Region Headquarters, for reviewing the paper.

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Perry, B and C.E. Konrad, cited 2005: The Influence of the Great Lakes on Snowfall Patterns in the Southern Appalachians. *Proc. 62nd Eastern Snow Conference*, Waterloo, Ontario, Canada [Available online at http://www.easternsnow.org/proceedings/2005/perry.pdf.]

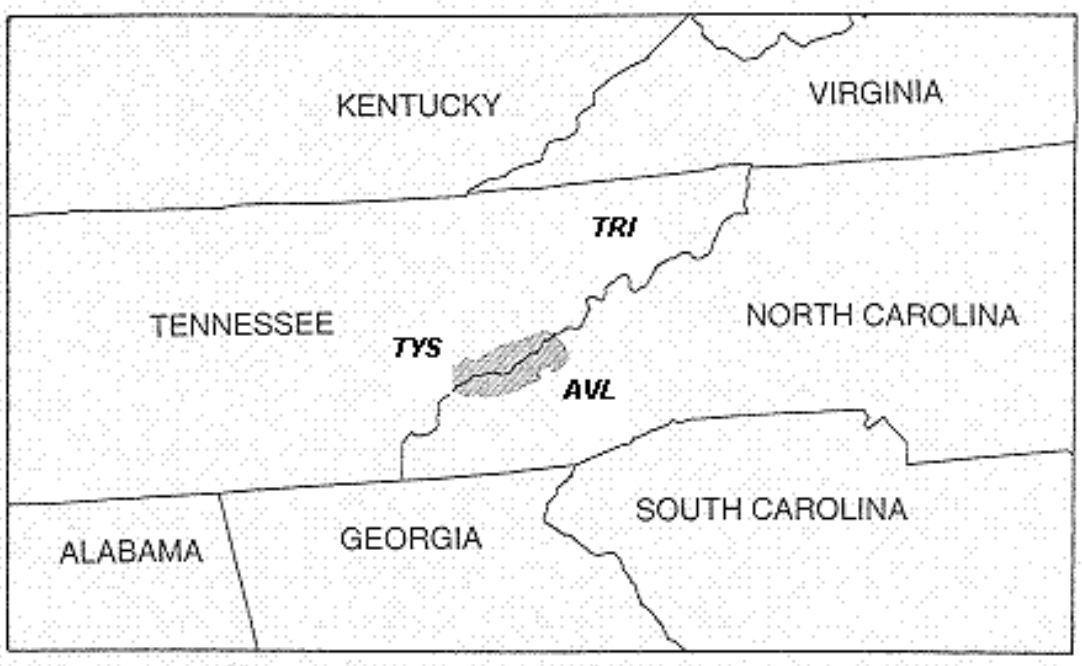


Figure 1. Map of the Southern Appalachians. The hatched area is the location of Great Smoky Mountain National Park. The three-letter ASOS identifiers denote the location of the Tri-City (TRI), Knoxville McGhee Tyson (TYS), and Asheville (AVL) airports.

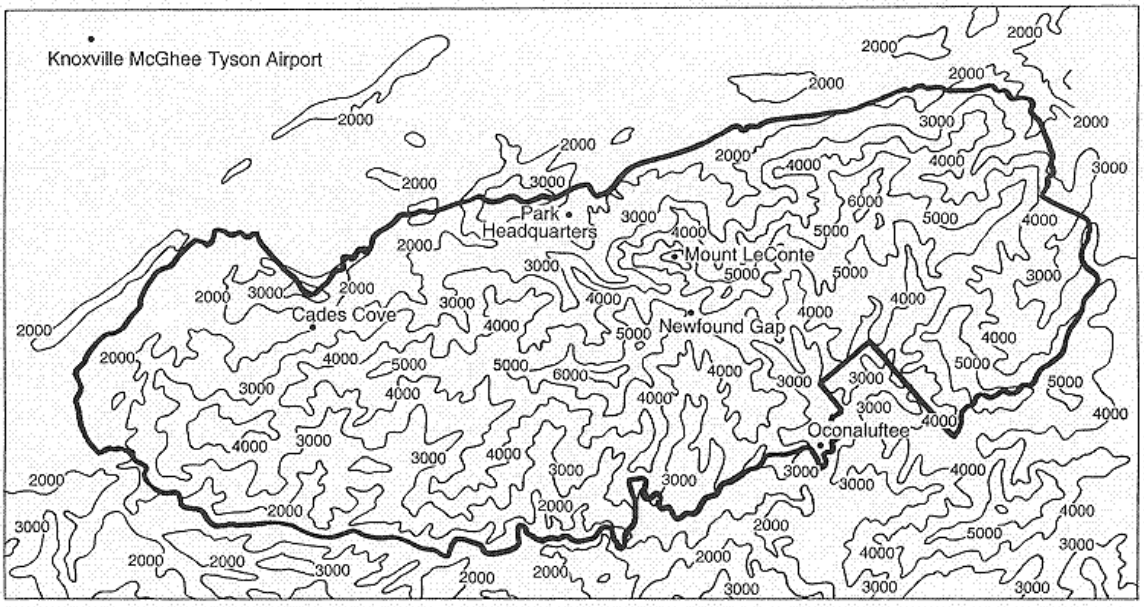


Figure 2. Topographic contour map (feet MSL) of the Great Smoky Mountain National Park. The bold line is the boundary of the park.

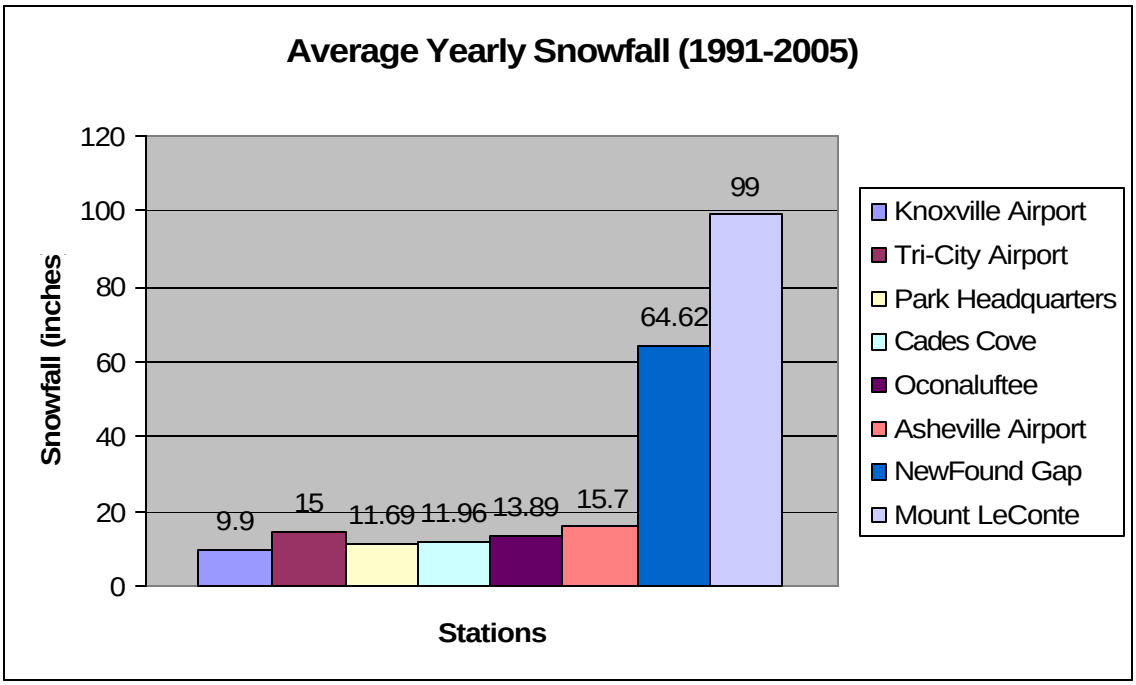


Figure 3. Average annual snowfall for the Great Smoky Mountain National Park stations and the eastern Tennessee ASOS sites.

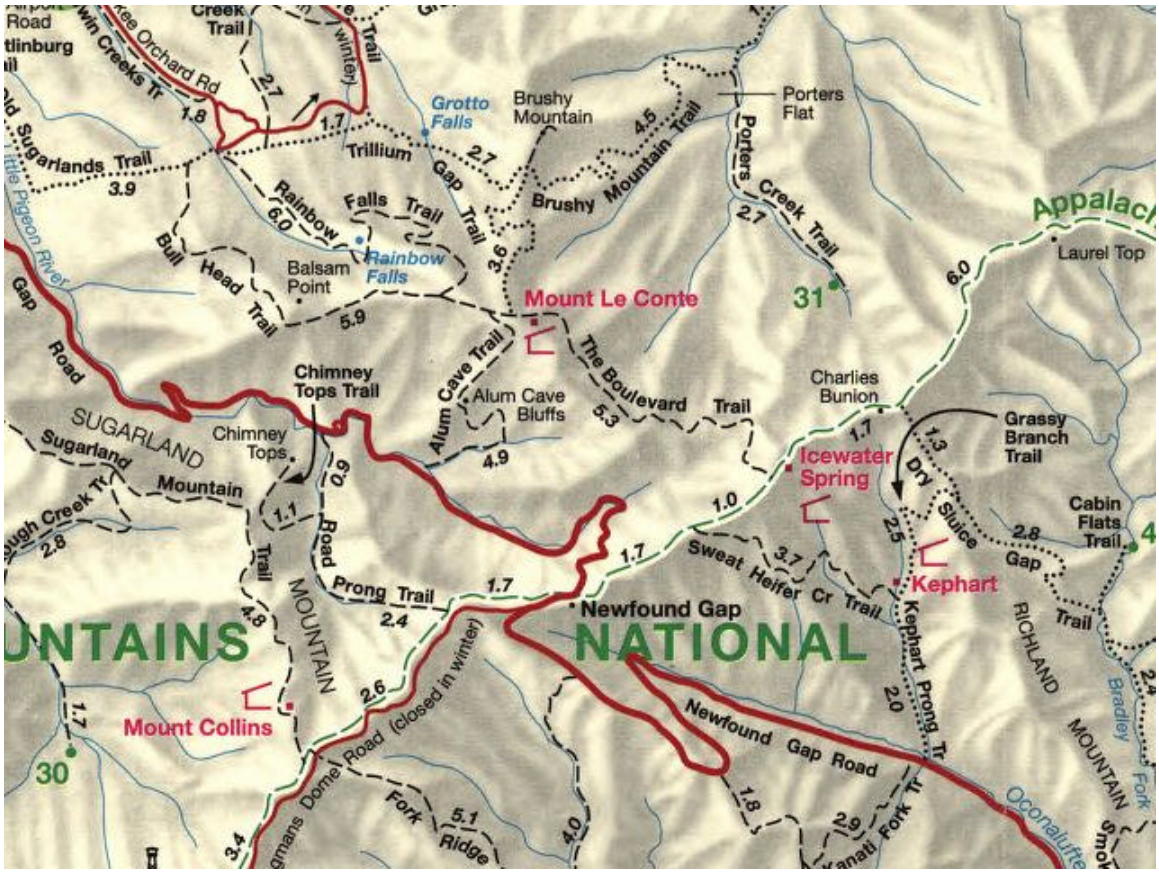


Figure 4. A relief map of the Mount LeConte and NewFound Gap areas of the Great Smoky Mountain National Park

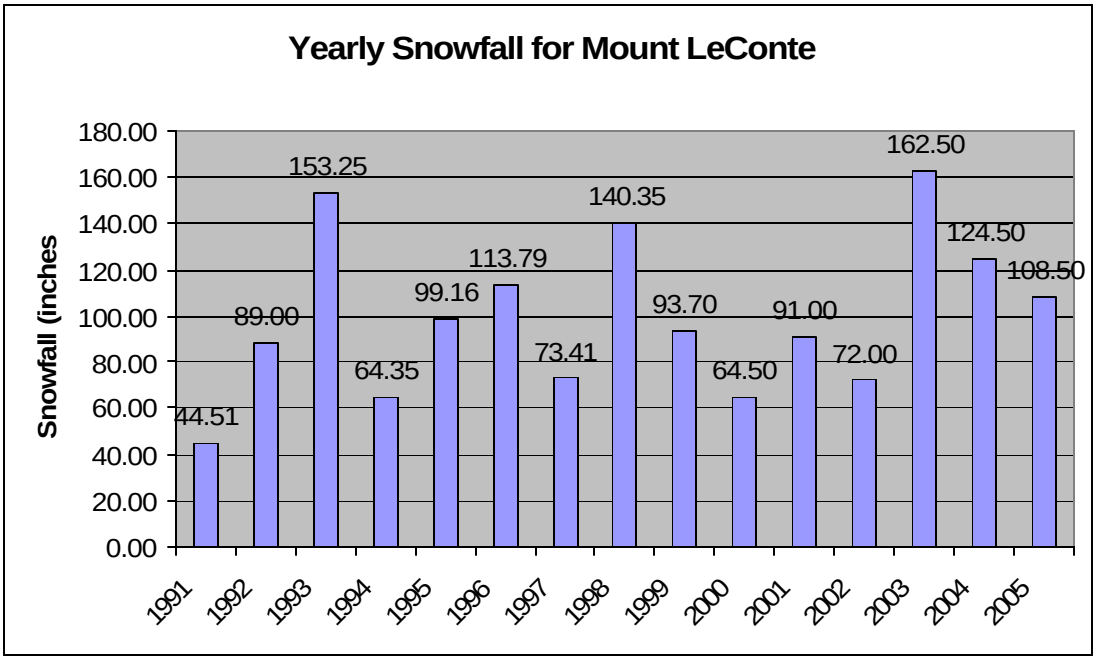


Figure 5. Annual snowfall for Mount LeConte from 1991 through 2005.

Table 1. Annual snowfall (inches) for the five park stations (1991-2005)

| | Park Headquarters | Cades Cove | Oconaluftee | NewFound Gap | Mount LeConte |
|---|---|---|---|---|---|
| 1991 | 2.50 | 7.50 | 9.75 | 33.87 | 44.51 |
| 1992 | 1.00 | 0.00 | 1.00 | 50.25 | 89.00 |
| 1993 | 24.00 | 34.00 | 57.00 | 106.55 | 153.25 |
| 1994 | 7.75 | 10.75 | 2.25 | 45.25 | 64.35 |
| 1995 | 12.13 | 9.15 | 9.79 | 58.27 | 99.16 |
| 1996 | 29.84 | 36.29 | 29.96 | 90.03 | 113.79 |
| 1997 | 15.00 | 12.45 | 12.52 | 47.76 | 73.41 |
| 1998 | 15.70 | 5.75 | 4.25 | 77.75 | 140.35 |
| 1999 | 7.55 | 3.00 | 11.75 | 62.10 | 93.70 |
| 2000 | 9.00 | 8.05 | 17.70 | 45.60 | 64.50 |
| 2001 | 10.00 | 10.00 | 6.00 | 54.50 | 91.00 |
| 2002 | 6.20 | 5.50 | 6.00 | 43.50 | 72.00 |
| 2003 | 18.00 | 15.00 | 23.00 | 98.00 | 162.50 |
| 2004 | 5.00 | 10.00 | 3.50 | 88.50 | 124.50 |
| 2005 | 4.50 | 1.00 | 0.00 | 58.50 | 108.50 |

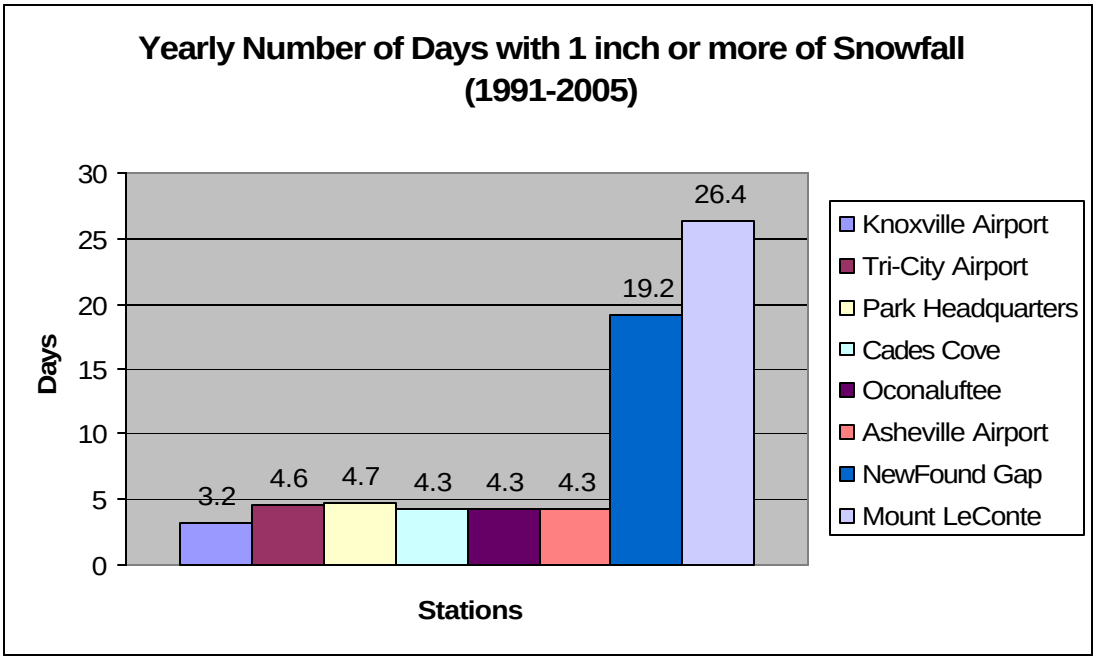


Figure 6. The average number of days with snowfall of one inch or more per year at the various study sites.

Table 2. Monthly average snowfall (inches) for the Great Smoky Mountain National Park stations and the eastern Tennessee ASOS sites (1991-2005).

| | Knoxville Airport | Tri-City Airport | Park Headquarters | Cades Cove | Oconaluftee | Asheville Airport | NewFound Gap | Mount LeConte |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| **Jan** | 3.70 | 5.50 | 4.36 | 3.99 | 3.03 | 4.30 | 17.99 | 25.28 |
| **Feb** | 3.00 | 4.10 | 2.13 | 1.90 | 1.90 | 4.10 | 13.16 | 20.42 |
| **Mar** | 1.60 | 1.90 | 3.15 | 3.51 | 4.82 | 3.10 | 15.57 | 24.80 |
| **Apr** | 0.80 | 0.90 | 0.40 | 0.13 | 0.00 | 1.00 | 2.92 | 7.46 |
| **May** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.83 |
| **Jun** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Jul** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Aug** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Sep** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| **Oct** | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.43 |
| **Nov** | 0.10 | 0.30 | 0.20 | 0.30 | 1.37 | 1.00 | 3.28 | 6.15 |
| **Dec** | 0.70 | 2.20 | 1.47 | 1.50 | 1.98 | 2.20 | 11.49 | 15.28 |

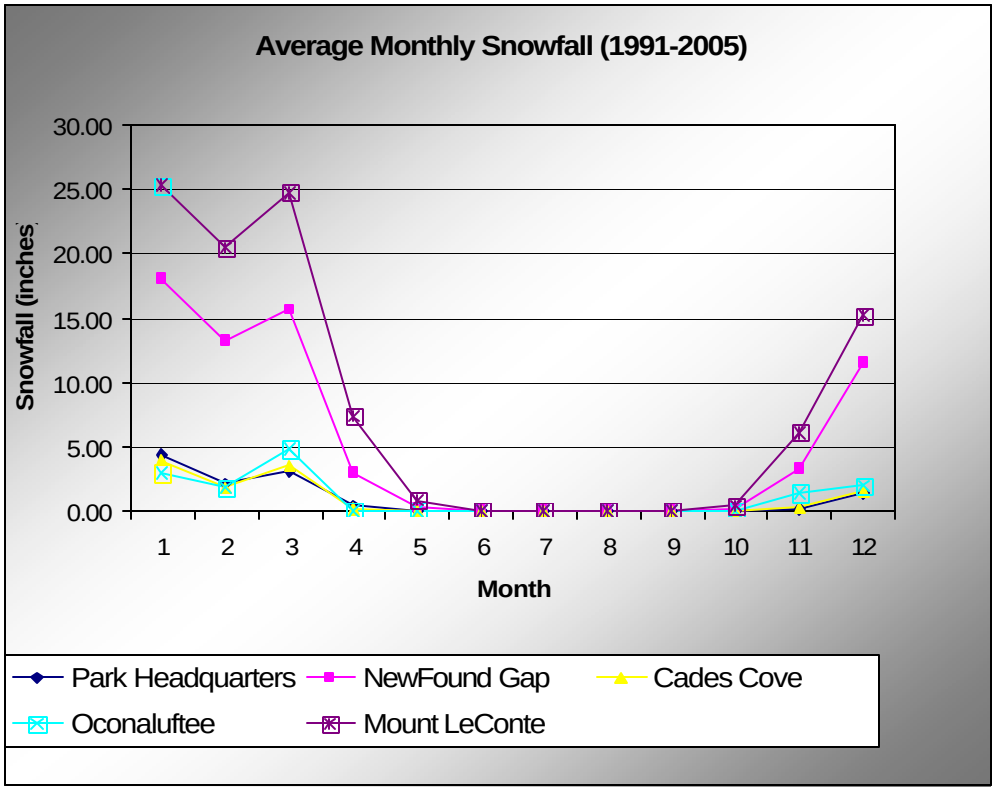


Figure 7. Average monthly snowfall for the park stations for 1991 through 2005.

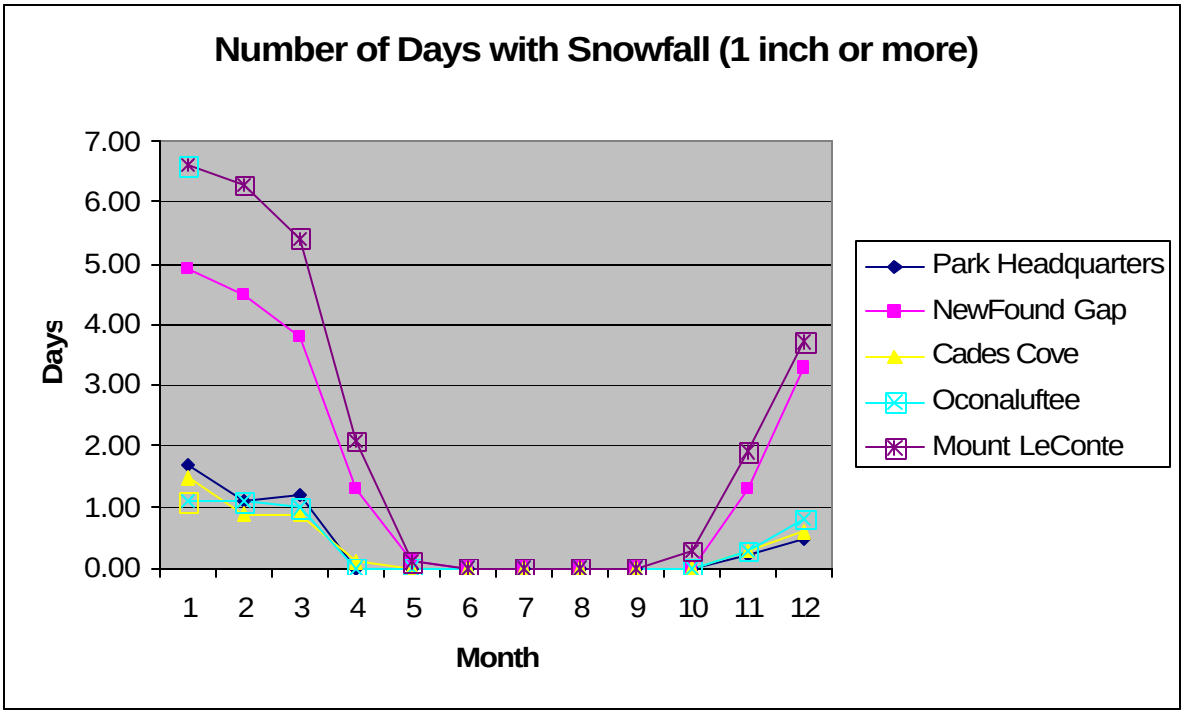


Figure 8. Number of days with snowfall (one inch or more) by month across the Great Smoky Mountain National Park from 1991 through 2005.

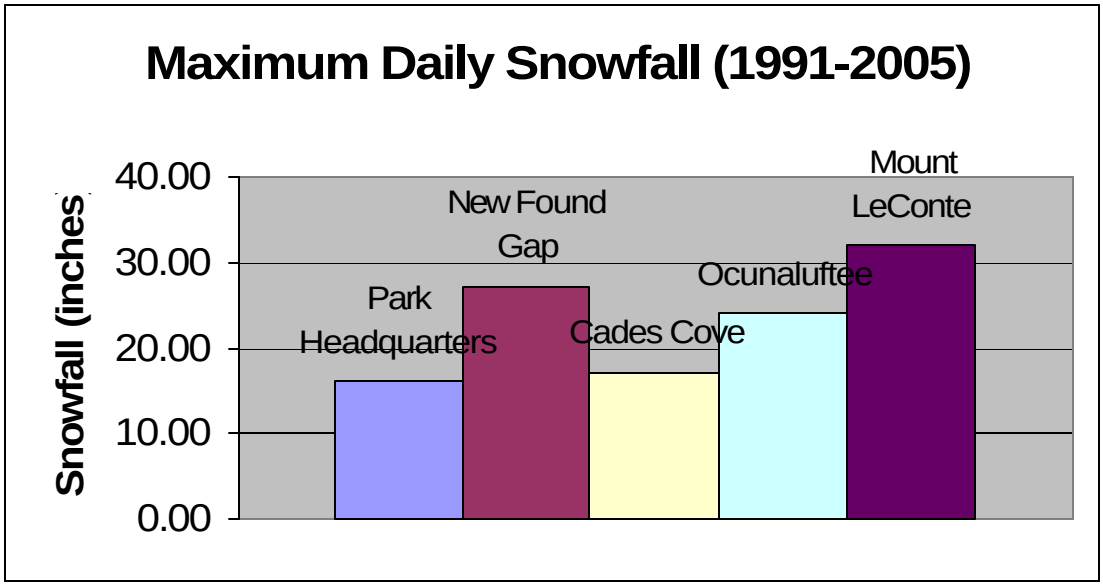


Figure 9. Maximum daily snowfall from 1991 through 2005.