Technical Attachment

A Single-Station Statistical Analysis of Measurable Snowfall Events in Mobile, Alabama

Jeffrey M. Medlin, SOO
WFO Mobile

Introduction

This paper will examine both the frequency and probability of occurrence of measurable snowfall events in Mobile over a 121.2 year period of record. The motivation to perform such an analysis stemmed from both a need to develop a local snowfall climatology, and persistent inquiries regarding the subject from the local media and general public during each winter season.

Data and Methodology

Before the analyses were performed, three assumptions were made:

Assumption #1	A measurable snowfall event is one that produces at least 0.1 in of snow. Although exceptions do occur according to airmass property, the 10:1 ratio of snow-liquid precipitation equivalent usually holds true in the US Deep South.
Assumption #2	In order to obtain the largest data set over the longest period of record possible, all past measurable snowfall events within the Mobile area were included in the study, regardless of whether they occurred at Bates Field in west Mobile or the old downtown observation site.
Assumption #3	The reliable date range used is 24 Jan 1881 to 15 Mar 2002 which is a 121.2 year period of record.

Table 1 lists the date of each measurable snowfall event, the amount and ranking. The events are ranked in increasing order of snowfall amount. Over the 121.2 year period of record, 19 observed measurable snowfall events occurred. The data range is 0.1 to 6.0 in. The mean, median and mode are 2.1, 1.6, and 0.5 in, respectively. On inspection, the first significant finding is that the average number of events per year is much less than one (as 19/121.2 = ~0.16). Second, it is important to note since there are so few events ($n < 30$) over such a long period of record, the data are given in terms of their “lowest common denominator.” In other words, it is apparent one should not attempt to stratify the data into sub-categories (e.g. monthly) in order to draw further statistical conclusions. However, using a statistical T-test (since n <30) one could more closely analyze the mean and nature of the mathematical distribution.

Table 1. Basic statistics on past measurable snowfall events in Mobile, Alabama 1881-2002.

Event Dates	Snowfall Amount (in.)		Rank (m)
14 - 15 Jan 1892	0.1		19
23 Feb 1901	0.2		18
30 Jan 1978	0.4		17
5 Dec 1886	0.5		16
18 Jan 1977	0.5		15
17 Jan 1893	1.0		14
23 Feb 1968	1.2		13
31 Jan 1977	1.4		12
12 Feb 1958	1.4		11
6 Mar 1954	1.6		10
5 Feb 1988	1.7		9
12 Feb 1899	2.0		8
12 - 13 Mar 1993	2.7		7
31 Dec 1963	3.0		6
18 Dec 1996	3.4		5
23 Jan 1955	3.5		4
9 Feb 1973	3.6		3
24 Jan 1881	5.0		2
14 - 15 Feb 1895	6.0		1
	Mean	**2.1**	
	Median	**1.6**	
	Mode	**0.5**	

Event Frequency

In order to analyze event frequency, the data were grouped into six class intervals according to the formula $5 \log_{10} n$, where n is the total number of events (19). Given the data range of 0.1 to 6.0 in, and six expected classes, the following intervals were established: 0.1-1.0, 1.1-2.0, 2.1-3.0, 4.1-5.0 and 5.1-6.0 in. Table 2 depicts class frequency, percent frequency and cumulative frequency. Additionally, Figs. 1 and 2 display relative and cumulative frequency histograms for the data given in the last two columns of Table 2.

Table 2 . Frequency distribution for measurable snow events in Mobile, Alabama 1881-2002.

Snowfall (in.) Class Interval	**Class Frequency**	**Percent Frequency (n/ *f)*100***	**Cumulative Frequency**
0.1 to 1.0	6	6 /19 = 31.6%	6/19 or .316
1.1 to 2.0	6	6 /19 = 31.6%	12/19 or .632
2.1 to 3.0	2	2/19 = 10.5%	14/19 or .737
3.1 to 4.0	3	3/19= 15.8%	17/19 or .895
4.1 to 5.0	1	1/19 = 5.3%	18/19 or .947
5.1 to 6.0	1	1/19 = 5.3%	19/19 or 1.0

The majority (12/19) of measurable snowfall events fell within the lowest two class frequency intervals. This is illustrated Fig. 2. The data in both Table 1 and Fig. 1 show that:

- # approximately 90% of all measurable snowfall events were $\leq$ 4 in.
- # greater than half (63.2%) of all measurable snowfall events were $\leq$ 2 in.
- # less than a third (~31.6%) of all measurable snowfall events were $\leq$ 1 in.

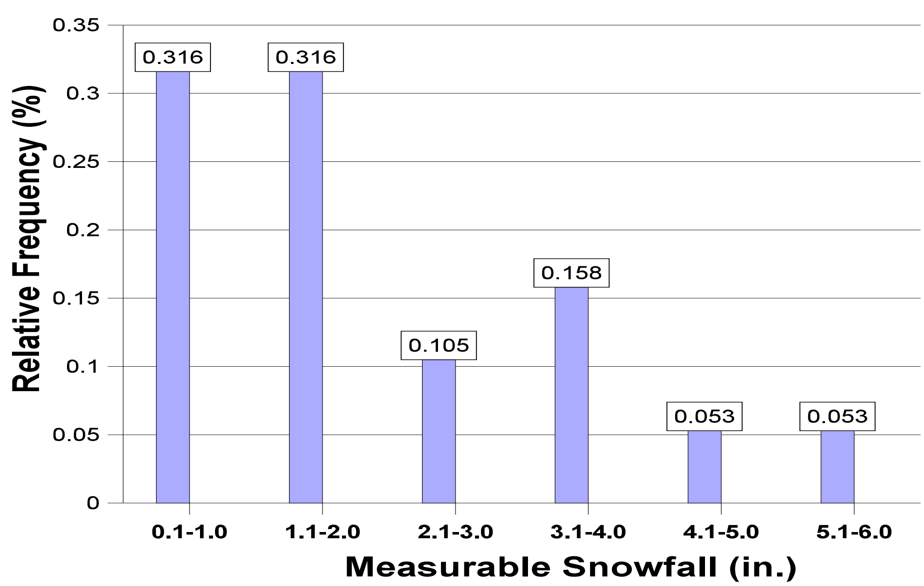

Figure 1 - Relative frequency histogram for all past measurable snowfall events in Mobile, AL from 1881-2002.

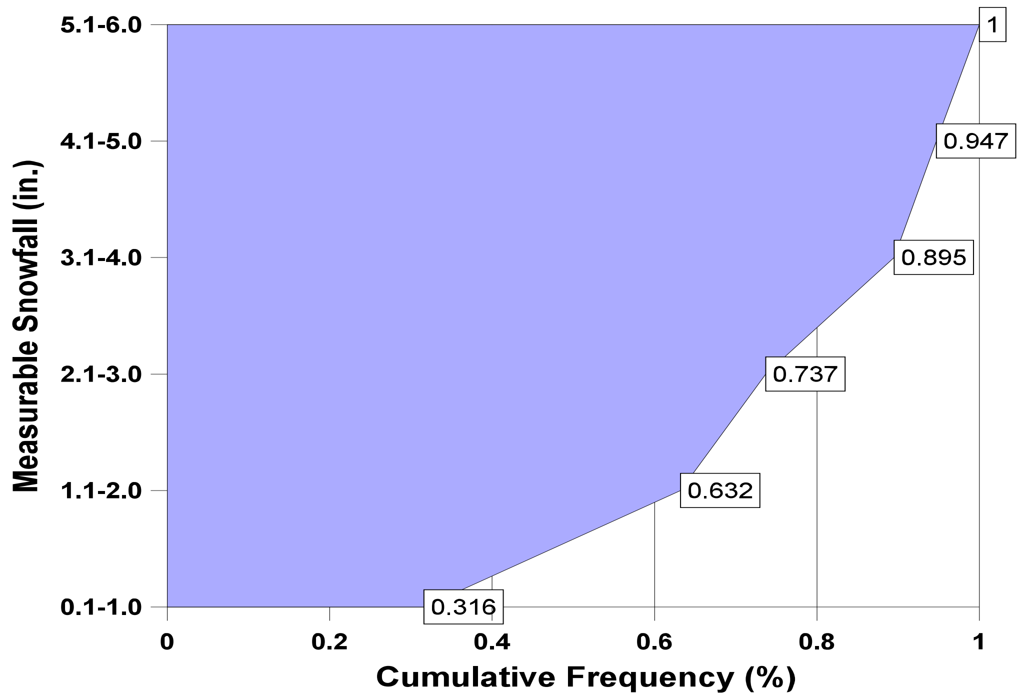

Figure 2 - Cumulative frequency histogram for all past measurable snowfall events in Mobile, AL from 1881-2002

Event Probability of Occurrence

It was previously mentioned that the mean number of measurable snowfall events per year was found to be much less than 1. Using basic probability statistics, additional insight may be gained if we attempt to answer the following three questions:

1) What is the probability of a snowfall event less than or equal to a certain value occurring within a given year?
2) What is the probability of a snowfall event equal to or more than a certain amount occurring within in a given year?
3) What is the average interval in years between snowfall events that equal or exceed a certain magnitude?

These questions can be answered through an examination of the following basic statistics: cumulative probability, exceedence probability and return period, respectively. These statistics are defined in Table 3 whereby n = number of data points (in our case 121.2 years).

Perhaps one of the most simplistic and useful findings is that the probability of any amount of measurable snow occurring at least once in any given year is a meager 15%. Recall, this is an exceedence probability (p). Exceedence probabilities for other significant snowfall thresholds, rounded to the nearest percent, are:

$\geq$ 1 in	p ~ 11%
$\geq$ 2 in	p ~ 7%
$\geq$ 3 in	p ~ 5%
$\geq$ 4 in	p ~ 3%
$\geq$ 5 in	p ~ 2%
$\geq$ 6 in	p ~ 1%

While the exceedence yields the probability that a certain amount (or more) of measurable snowfall will occur in any given year, the cumulative probability (not shown in Table 3) is the probability that the snowfall will be less than or equal to a given amount. To do this, simply use the formula ($1-p$), where p is the exceedence probability. Admittedly, when it comes to measurable snowfall, most people will generally be interested in receiving "at least that much" as some stated amount of snow. Thus, exceedence probabilities are more applicable than cumulative probabilities in these events. The NWS defines heavy snow as 4 inches falling within 12 hours. Using the closest event statistic (3.6 in, occurring on 9 Feb 1973) the exceedence probability is ~2.4% (which is just under half as likely to occur as 3 in), thus making "heavy snow" exceedingly rare in Mobile, Alabama !

Table 3. Probability of occurrence statistics for snow events in Mobile, Alabama 1881-2002.

Date	Snowfall Amount (in.)	Rank (m)	Exceedence Probability p = m / (n+1)	Return Period (yrs.) T = 1/p
14-15 Jan 1892	0.1	19	.1542 or 15.42%	6.5
23 Feb 1901	0.2	18	.1461 or 14.61%	6.8
30 Jan 1978	0.4	17	.1380 or 13.8%	7.2
5 Dec 1886	0.5	16	.1299 or 12.99%	7.7
18 Jan 1977	0.5	15	.1218 or 12.18%	8.2
17 Jan 1893	1.0	14	.1136 or 11.36%	8.8
23 Feb 1968	1.2	13	.1055 or 10.55%	9.5
31 Jan 1977	1.4	12	.0974 or 9.74%	10.3
12 Feb 1958	1.4	11	.0893 or 8.93%	11.2
6 Mar 1954	1.6	10	.0812 or 8.12%	12.3
5 Feb 1988	1.7	9	.0731 or 7.31%	13.7
12 Feb 1899	2.0	8	.0649 or 6.49%	15.4
12-13 Mar 1993	2.7	7	.0568 or 5.68%	17.6
31 Dec 1963	3.0	6	.0487 or 4.87%	20.5
18 Dec 1996	3.4	5	.0406 or 4.06%	24.6
23 Jan 1955	3.5	4	.0325 or 3.25%	30.8
9 Feb 1973	3.6	3	.0244 or 2.44%	41
24 Jan 1881	5.0	2	.0162 or 1.62%	61.6
14-15 Feb 1895	6.0	1	.0081 or 0.81%	121.2

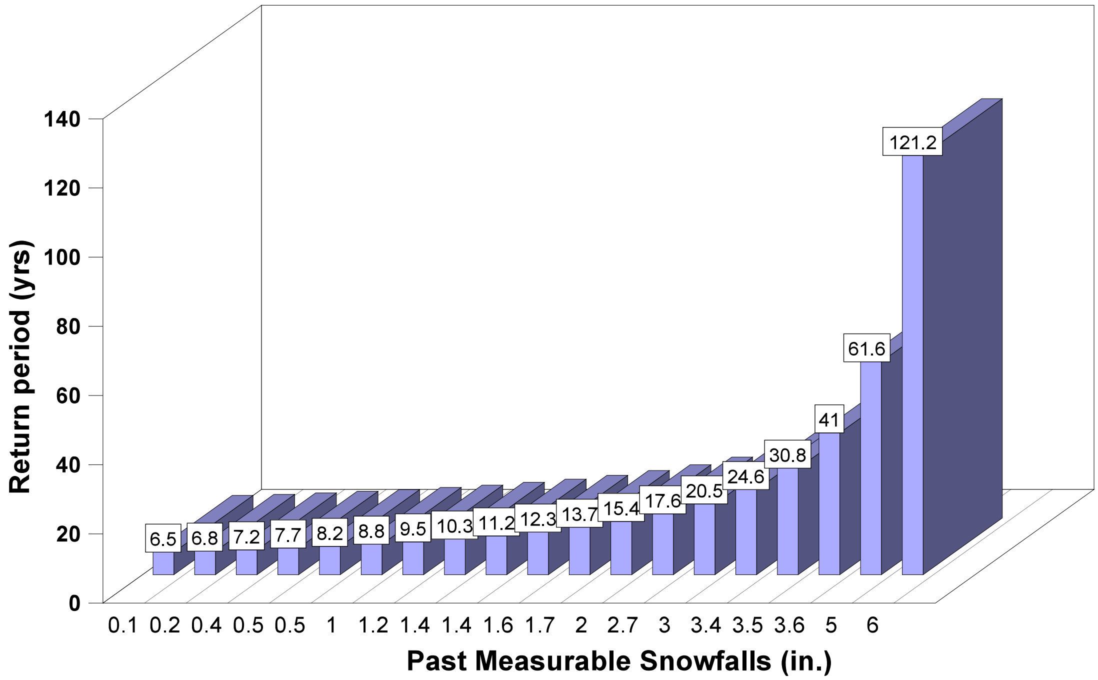

Figure 3 - Return period for all past measurable snowfalls events in Mobile, Alabama from 1881-2002.

Before revealing the return period results, it is worth noting most people inquiring about the probability of occurrence of certain events can easily relate to the concept of return period (*T*). It is easy for the media and planners to think in terms of an event of a given magnitude returning every *X* years. However, caution must be used in the interpretation of return period. Due to the fact measurable snowfall events occur more or less randomly over a long period of record in a location such as Mobile, statistical misinterpretation could result. For example, the event could occur over several consecutive years in a row and then never again, thus providing a misleading interpretation of the results.

Figure 3 is a plot of the computed return period versus each past measurable snowfall event. The curve is highly exponential. Beginning with the basics, note the return period for *any measurable* snow event ~ 6.5 years. The nature of the return period in this case is such that it nearly doubles (12.3 years) as the past events approach 1.6 inches. For those events with return periods greater than 30 years (the top four event rankings of 6.0, 5.0, 3.6 and 3.5 in) it can be understood just how exceedingly rare such events are when one considers the fact that the NWS computes moving 30 year averages for such statistics each decade. Thus, events of those magnitudes may or may not make it into any given 30 year measurable snowfall average.

Summary and Future Plans

This paper has examined both the frequency and probability of occurrence of past measurable snowfall events in Mobile over a 121.2 year period of record. Significant findings include :

- Measurable snow fell in Mobile 19 times during the period of record. This equates to .157 events per year.

- The range of the data set is 0.1 to 6.0 in, and the mean, median and mode are 2.1, 1.6 and 0.5 in, respectively. Approximately 90% of all measurable snowfall events were $\leq$ 4 in; 63.2% of events were $\leq$ 2 in; and ~31.6% of all events were $\leq$ 1 in.

- Exceedence probabilities show that for any given year, the probability of receiving at least 1 in of measurable snow is about 11%, and this falls to a meager 5% for $\geq$3 in.

- The exceedence probability for heavy snow (4 in/12 hr) at Mobile is ~2.4% (which is just under half as likely to occur as 3 inches) making the event exceedingly rare. This finding would certainly advocate and support a regional lowering of the definition of heavy snowfall based on climatology, as has been done in the past.

- An analysis of all event return periods shows the top four highest snowfall totals of 6.0, 5.0, 3.6 and 3.5 in, each had return periods greater than 30 years. This is significant since, due to the random nature of past snowfall events in Mobile, such extreme events may not even be included in any given 30 year climatological average, which are computed each decade.

It is anticipated these results will later be incorporated into a more comprehensive analysis of measurable snowfall of all National Weather Service cooperative observation stations within the NWS Mobile county warning and forecast area. In this manner, return period contours for given snowfall amounts can be generated geospatially.

Acknowledgments

The author would like to thank the SRH Scientific Services Division for providing helpful comments and suggestions.

References

Winkler, R.L. and W.L. Hays, 1975: *Statistics: Probability, Inference and Decision, 2nd Edition.* Holt, Rinehart and Winston, Inc., New York, NY.