Air Force Snowfall Statistics for Engineering Applications

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ABSTRACT

The United States Air Force Environmental Technical Applications Center recently compiled snowfall statistics for the Air Force Civil Engineering Support Agency (AFCESA). Specifically, AFCESA asked for the total snowfall and extreme daily snowfall for each of the last 10 snow seasons. USAFETAC also compared the data for the most recent 10 years with the entire period of record and for other 10-year periods.

AFCESA also asked for total snowfall during the worst storm at each location, as well as for the amounts that might be expected for a 50- and 100-year return period. We extracted data from summary of the day tapes for the maximum 1-, 2-, and 3-day period in each snow season, as well as for the total snowfall for the season. We defined a "season" as starting in July and ending in June.

The highest values for each season were entered in USAFETAC's "extreme value program," which is based on the double-exponential distribution. The result was a table of values for varying design lives and percent risks. We then extracted the 50- and 100-year return period values and furnished them to AFCESA. For locations without much snowfall, we furnished two sets of values: one based only on seasons in which there actually was snowfall, and another that included all seasons (i.e., those with snow as well as those with no snow at all).

INTRODUCTION

USAFETAC is an Air-Force controlled, named organization assigned to the USAF's Air Weather Service. We collect environmental observations from around the world and use them to create the world's largest computerized climatic database. We use quality-controlled and summarized data from that database, a comprehensive array of high-powered computer systems, and one of the largest atmospheric sciences libraries in the world to help solve environmental problems for planners, researchers, operators, and designers throughout the United States government.

For many years USAFETAC has supplied snowfall statistics to its customers. Last year AFCESA asked for two types of statistics that are not normally published in the literature. Although the statistics produced were provided for military customers, they could be used by other agencies. Total snowfall and maximum daily snowfall amounts will be used in determining allocations of snow removal equipment. Total snowfall amounts during the worst storms will help engineers design structures to last for long periods in various climatic regions. I will discuss these two requests in order.

TOTAL AND DAILY SNOWFALL AMOUNTS

This study was actually a request for an update of work the Engineering Meteorology Section had done several years earlier. (USAFETAC 1988) Although we had advised against it, AFCESA elected to base allocations of equipment on only the latest 10 years of data. We started by defining "snow season" as starting in July and ending the following June. We used data from our "summary of the day" database, which is compiled for both military and major civilian stations. It includes

daily values of temperature, precipitation (including snowfall), peak winds, and weather types. Since all stations were in the Northern Hemisphere, for many of them there was no snowfall data for the first 3 or 4 or last 2 or 3 months of the defined season. We compiled both total monthly snowfall and maximum monthly 1-day snowfall amounts for the full period of record (POR) available for each requested station reporting snowfall amounts. In many cases, we found that the latest 10-year period appeared to be very different from other 10-year periods or the full POR. Therefore, we decided to furnish the statistics shown in Tables 1 - 6.

The tables give total snowfall amounts for each of the last 10 seasons; the extreme daily amount and its date for each season; the extreme daily amount for the entire POR; and means and standard deviations for each 10-year (season) POR and for the entire POR.

Altus AFB, OK, (Table 1) is an example of a station with small snowfall amounts. Note that daily extremes vary from a trace to 7.6 inches (19.3 cm); seasonal values, from a trace to 16.4 inches (41.7 cm). However, seasonal means were only from 6.06 inches (15.4 cm) to 7.51 inches (19.41 cm).

Table 2 for Dover AFB, DE, is an example of a stateside station with moderate amounts of snow. Note that daily amounts vary from 0.4 inches (1.0 cm) to 17.9 inches (45.5 cm) (outside of the decade of interest), seasonal amounts from 1.8 inches (4.6 cm) to 33.6 inches (85.3 cm) and seasonal means from 15.16 inches (38.5 cm) to 24.87 inches (63.2 cm).

Duluth, MN, (Table 3), is an example of a station with heavier snowfall. Note that daily amounts vary from 3.2 inches (8.1 cm) to 23.2 inches (58.9 cm) (again, out of the decade requested by AFCESA); seasonal, from 36.5 inches (92.7 cm) to 119.1 inches (302.5 cm), and seasonal means, from 76.53 inches (194.4 cm) to 78.70 inches (199.9 cm).

Tables 4 - 6 are examples of small, moderate, and heavy amounts for overseas locations. Misawa, Japan, is a good example of heavy amounts even though we didn't have statistics for 5 of the last 10 seasons. The low mean value for the 1980-90 period is probably due more to the missing data than to a real change in snowfall climate. This low mean value has a high standard deviation that keeps it in line with the rest of the data, given the small sample size.

AFCESA forwarded these statistics to major commands for use in making decisions on how to allot types and amounts of snow removal equipment. We plan to publish data tables for the 100 plus stations in a revised USAFETAC technical note (USAFETAC 1992).

EXTREME ANALYSIS SNOWFALL

The second set of snowfall statistics we furnished AFCESA are a subset of another major project. These statistics include heating and air conditioning design temperatures, design freezing index, heating and cooling degree days, highest wind speeds, maximum 1-hour rainfall, and worst-storm snow accumulation for military locations in the CONUS, Alaska, and Hawaii. The data is to be used by AFCESA's Construction Cost Management Directorate to increase their capability to effectively estimate and analyze the multi-year cost of facility acquisition. It is expected that eventually we will need to furnish similar data for overseas locations.

After several discussions with the Staff Meteorologist at AFCESA, we decided to define "worst storm" as the maximum snowfall received in up to a 3-day period. We wrote a program to extract these values from our summary of the day data tapes. Table 7 shows this printout for Ft Leonard Wood, MO. Seasonal maximum 3-day values were then input into USAFETAC's extreme value program. The *Guide for Applied Climatology* (AWS 1977) explains extreme value analysis, and we decided to stick with the distribution described therein.

Table 8 is an example of this program's output. It shows the values input and the range of percent risk and design life values calculated. As you can see, these range from a design life of 1 year to 100 years and risks of 1 to 87%. We were asked to furnish values for 50- and 100-year return periods. These correspond to a 64% risk in a 50-year design life and a 1% risk in a 1-year design life. These values are highlighted and underlined in Table 8.

Maxwell AFB, AL, is a good example of a "problem station", or one that doesn't have snow every year. We had 47 years of data but only 10 years with any snow. If we used just the snow years, we obtained the results in Table 8. But if we input zeros for the years with no snow, the 50-year return period value became 1.67 inches (4.2 cm) versus 4.02 inches (10.2 cm) and the 100-year value became 1.99 inches (5.1 cm) versus 4.69 inches (11.9 cm). Since extreme value analysis using less than 10 years of data gives questionable results, our program requires a *minimum* of 10 years of data.

After more discussions with AFCESA we decided not to use any stations with less than 5 years of snow. If a station had at least 10 years of snow but less than half the total POR had snow, we ran the program twice; once with just snow like Table 8, and once including zeros for all the years with no snow. Including the zeros gave more realistic values for the 50 and 100-year return periods. We felt that customers would remember a heavy storm and question the results if we didn't also show what happened using only years with measurable snowfall amounts. All other stations were run with snow values including zeros for years with no snow.

Table 9 gives the POR, the worst storm amount, and the 50- and 100-year return period values for some representative stations. These are the statistics furnished to AFCESA. Of 217 stations, 31 had no snow and three had less than 5 years with measurable snow. For three stations, this table shows the values for all years (including zero amounts) and for only the years with values greater than a trace.

As you can see, the 50-year return period value is very close to the worst storm value in some cases; in others, it is quite different. The biggest differences are when stations had short PORs or had many years with no measurable snow. Most stations' PORs were longer than 30 years and, in many cases, close to 50 years. For the longer PORs the worst storm occasionally exceeded the 50-year return period value.

SUMMARY

USAFETAC produced two types of snowfall statistics to answer specific requests from AFCESA. These statistics have been described and specific examples have been given. One set is being published as a USAFETAC technical note (USAFETAC 1992). It will be available from the National Technical Information Service. Agencies with a need for similar statistics, and who have access to summary of the day tapes, could produce them for their own use. U.S. military contractors may request such summaries from USAFETAC.

Table 1. Snowfall statistics for Altus AFB, OK, in inches.

Season	*Total Snowfall*	*Daily Extreme*	*Date of Extreme*
80-81	TRACE	TRACE	
81-82	4.8	3.0	Feb 82
82-83	7.7	3.0	Jan 83
83-84	4.5	1.0	Dec 83
84-85	6.0	2.4	Dec 84
85-86	15.9	4.4	Feb 86
86-87	10.2	6.5	Jan 87
87-88	16.4	7.6	Jan 88
88-89	5.0	2.9	Nov 88
89-90	TRACE	TRACE	
Daily Extreme for Entire POR:		7.6	Jan 88

	Seasonal Mean	*Standard Mean Deviation*
Ten-Season POR: Jul 60 - Jun 70	6.06	6.07
Ten-Season POR: Jul 70 - Jun 80	7.51	5.87
Ten-Season POR: Jul 80 - Mar 90	7.05	5.70
Entire POR: Jul 43 - May 90	6.72	5.34

Table 2. Snowfall statistics for Dover AFB, DE, in inches.

Season	*Total Snowfall*	*Daily Extreme*	*Date of Extreme*
80-81	1.8	0.4	Mar 81
81-82	22.9	3.3	Feb 82
82-83	19.2	8.4	Feb 83
83-84	5.5	1.7	Jan 84
84-85	11.3	3.5	Jan 85
85-86	17.8	4.0	Dec 85
86-87	33.6	8.4	Feb 87
87-88	9.7	6.2	Jan 88
88-89	11.2	6.2	Feb 89
89-90	18.6	5.2	Dec 89
Daily Extreme for Entire POR:		17.9	Feb 79

	Seasonal Mean	*Standard Deviation*
Ten-Season POR: Jul 60 - Jun 70	24.87	10.48
Ten-Season POR: Jul 70 - Jun 80	16.05	13.61
Ten-Season POR: Jul 80 - Jun 90	15.16	9.23
Entire POR: Jul 43 - Jun 90	17.12	10.71

Table 3. Snowfall statistics for Duluth, MN, in inches.

Season	*Total Snowfall*	*Daily Extreme*	*Date of Extreme*
80-81	36.5	3.2	Jan/Apr 81
81-82	95.7	12.0	Jan 82
82-83	96.5	11.6	Apr 83
83-84	107.3	16.5	Nov 83
84-85	68.2	12.0	Mar 85
85-86	89.3	10.3	Nov 85
86-87	40.6	4.4	Jan 87
87-88	53.8	7.1	Mar 88
88-89	119.1	11.6	Jan 89
89-90	58.3	5.1	Feb 90
Daily Extreme for Entire POR:		23.2	Dec 50

	Seasonal Mean	*Standard Deviation*
Ten-Season POR: Jul 50 - Jun 60	76.87	21.45
Ten-Season POR: Jul 60 - Jun 70	76.77	26.95
Ten-Season POR: Jul 70 - Jun 80	78.70	26.15
Ten-Season POR: Jul 80 - Jun 90	76.53	28.87
Entire POR: Jul 42 - Jun 90	77.72	27.00

Table 4. Snowfall statistics for RAF Alconbury, UK, in inches.

Season	*Total Snowfall*	*Daily Extreme*	*Date of Extreme*
80-81	3.0	1.2	Feb 81
81-82	18.9	4.3	Dec 81
82-83	8.6	3.1	Feb 83
83-84	5.8	2.6	Jan 84
84-85	15.7	3.9	Feb 85
85-86	8.8	4.0	Feb 86
86-87	3.4	1.7	Jan 87
87-88	3.2	2.7	Jan 88
88-89	3.1	TRACE	Nov 89
89-90	18.3	6.0	Dec 89
Daily Extreme for Entire POR:		7.4	Dec 61/Dec 62

	Seasonal Mean	*Standard Deviation*
Ten-Season POR: Jul 60 - Jun 70	11.70	8.68
Ten-Season POR: Jul 70 - Jun 80	4.61	6.72
Ten-Season POR: Jul 80 - Jun 90	7.05	6.07
Entire POR: Jul 43 - Jun 90	7.53	7.24

Table 5. Snowfall statistics for Bitburg AB, West Germany, in inches.

Season	*Total Snowfall*	*Daily Extreme*	*Date of Extreme*
80-81	52.2	13.6	Apr 81
81-82	31.6	4.4	Nov 81
82-83	27.9	4.8	Jan 83
83-84	37.3	4.3	Jan 84
84-85	35.5	5.9	Jan 85
85-86	28.5	3.7	Nov 85
86-87	33.6	8.4	Dec 86
87-88	32.7	5.0	Feb 88
88-89	5.2	2.8	Nov 88
89-90	5.4	1.9	Feb 90
Daily Extreme for Entire POR:		13.6	Apr 81

	Seasonal Mean	*Standard Deviation*
Ten-Season POR: Jul 60 - Jun 70	30.24	13.39
Ten-Season POR: Jul 70 - Jun 80	19.96	7.05
Ten-Season POR: Jul 80 - Jun 90	28.99	14.20
Entire POR: Jul 52 - Jun 90	24.77	11.83

Table 6. Snowfall statistics for Misawa AB, Japan, in inches.

Season	*Total Snowfall*	*24-Hour Extreme*	*Date of Extreme*
80-81	MISSING	MISSING	
81-82	MISSING	MISSING	
82-83	MISSING	MISSING	
83-84	MISSING	MISSING	
84-85	MISSING	MISSING	
85-86	165.5	10.6	Nov 85/Feb 86
86-87	129.7	14.2	Feb 87
87-88	122.3	10.3	Dec 87
88-89	89.1	9.5	Nov 88
89-90	53.5	7.5	Jan 90
24-Hour Extreme for Entire POR:		43.1	Mar 52

	Seasonal Mean	*Standard Deviation*
Ten-Season POR: Jul 50 - Jun 60	128.40	39.84
Ten-Season POR: Jul 60 - Jun 70	127.60	26.55
Ten-Season POR: Jul 70 - Jun 80	112.90	24.51
Ten-Season POR: Jul 80 - Jun 90	93.48	59.22
Entire POR: Jul 48 - Jun 90	115.30	40.84

Table 7. Snowfall data for Ft Leonard Wood, MO, in inches.

YEAR	*MAX1DAY*	*MAX2DAY*	*MAX3DAY*	*SEASON*
63	9.4	11.0	11.0	22.5
64	5.9	8.9	8.9	20.8
65	4.3	7.2	7.2	16.9
66	3.0	3.7	3.7	9.3
67	3.3	6.3	6.3	21.2
68	6.6	6.6	6.6	8.6
69	5.1	8.8	8.8	32.4
70	3.3	5.5	6.8	22.2
71	4.0	4.0	4.0	7.9
72	3.5	5.1	5.1	14.8
73	8.1	8.1	8.1	27.7
74	5.0	6.5	7.8	28.5
75	10.3	10.3	10.3	16.1
76	6.3	6.6	6.6	13.0
77	3.7	5.7	6.3	27.5
78	6.0	6.4	6.4	22.8
79	11.6	11.9	11.9	26.3
80	4.3	5.5	5.9	11.9
81	6.9	6.9	6.9	15.6
82	2.6	3.6	3.6	4.4
83	11.0	11.0	11.0	24.8
84	5.0	6.1	7.1	22.9
85	4.7	4.7	4.9	11.6
86	5.6	5.8	6.2	13.9
87	5.3	6.3	6.3	23.5
88	9.0	11.2	11.2	24.8

Table 8. Extreme analysis program output example.

LOCATION	*OPTION*	*LATITUDE*	*LONGITUDE*	*ALTITUDE*
* MAXWELL AFB AL	3DAYSN	3223° N	08622° W	167 FT

3DAYSN INPUT DATA IS:

0.20	1.00	0.40	0.20	0.40	1.50	3.00	0.20	0.10	1.00

YRS DATA	*MEAN*	*STANDARD DEVIATION*
10	0.80	0.90

DESIGN LIFE	**1%**	**5%**	**10%**	**20%**	**25%**	**34%**	**40%**	**50%**	**64%**	**87%**
1	**4.69**	3.15	2.46	1.75	1.51	1.16	0.97	0.67	0.31	0.05
5	6.22	4.67	3.99	3.28	3.04	2.69	2.49	2.20	1.84	1.18
10	6.88	5.33	4.65	3.94	3.70	3.35	3.15	2.86	2.49	1.84
15	7.26	5.72	5.03	4.32	4.08	3.73	3.54	3.25	2.88	2.22
20	7.53	5.99	5.31	4.59	4.35	4.00	3.81	3.52	3.15	2.50
25	7.75	6.20	5.52	4.81	4.56	4.22	4.02	3.73	3.36	2.71
50	8.40	6.86	6.17	5.46	5.22	4.87	4.68	4.39	**4.02**	3.36
100	9.06	7.51	6.83	6.12	5.88	5.53	5.33	5.05	4.68	4.02

THIS DATA WAS RUN ON 5 SEP 1991:
* MAXWELL AFB AL 3DAYSN 3223° N 08622° W 167FT

Table 9. Snow statistics for representative stations.

SITE	POR YEARS	WORST STORM IN	WORST STORM CM	50-YEAR RETURN PERIOD IN	50-YEAR RETURN PERIOD CM	100-YEAR RETURN PERIOD IN	100-YEAR RETURN PERIOD CM
MAXWELL AFB AL	47	1.5	3.8	1.7	4.3	2.0	5.1
	10	1.5	3.8	4.0	10.2	4.7	11.9
ELMENDORF AFB AK	45	30.0	76.2	27.9	70.9	31.1	79.0
CASTLE AFB CA	46	1.0	2.5	0.7	1.8	0.8	2.0
DOVER AFB DE	39	20.1	51.1	19.2	48.8	21.8	55.4
SCOTT AFB IL	43	18.0	45.7	18.5	47.0	21.0	53.3
BARKSDALE AFB LA	44	7.7	19.6	8.0	20.3	9.4	23.9
BRUNSWICK NAS ME	37	22.5	57.2	27.3	69.3	30.1	76.5
ANDREWS AFB MD	44	19.8	50.3	22.1	56.1	25.0	63.5
K.I.SAWYER AFB MI	30	33.5	85.1	40.5	102.9	44.9	114.1
DULUTH MN	41	33.1	84.1	30.2	76.7	33.7	85.6
FT LEONARD WOOD MO	26	11.9	30.2	14.4	36.6	15.9	40.4
MINOT AFB ND	31	20.0	50.8	22.3	56.6	25.2	63.6
ALTUS AFB OK	36	9.4	23.9	11.4	29.0	13.0	33.0
CHARLESTON AFB SC	44	7.1	18.0	4.1	10.4	4.9	12.4
	16	7.1	18.0	7.2	18.3	8.4	21.3
FT HOOD TX	26	8.2	20.8	7.5	19.1	8.8	22.4
	12	8.2	20.8	10.9	27.7	12.7	32.3
F.E.WARREN AFB WY	41	25.6	65.0	23.9	60.7	26.9	68.3

REFERENCES

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