Is This a Normal Winter?

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Introduction

Our perception of the environment is a construct of our life experiences. We remember a hot summer or a big blizzard. As we progress through each season we compare it to memories of past seasons: hot or colder, wetter or drier, early frost or major flooding.

We have developed an activity that spans standards in the hydrosphere (EH V.2 e-1, e-3), atmosphere (EAW V.3 e-1, e-2, m-1), data analysis and statistics (MIII.1, MIII.2, MIII.3), and the nature of science (C I.1 e-1, e-2, e-5, e-6, m-1, m-2, m-5, h-1, h-2, and R II.1 e-1, m-1, h-1). The activity is open-ended, easy to do, and timely (once a year starting on December 21st). It could be done in almost any grade but we recommend upper elementary or middle school.

Our goal is to answer a simple question: "Is this winter normal?" (if your are currently in the winter season) or, alternatively, you might look back and ask "Was last winter a normal winter?" To engage our students we ask a set of simple questions:

1. Is this winter normal?
2. How can we compare this winter to past winters?

In order to address these questions, students must first determine:

- How they want to define a "normal" winter.
- What data set(s) will be needed? Be specific.
- How the data can convincingly show that the winter was or was not normal.

Lastly, as the students work, you might ask them why the severity of the winter might be of interest and who might be impacted.

Method

What is a "normal" winter? Based on our memories we might say "not too much snow" or "it didn't get very cold" but these answers are hard to quantify. Fortunately, the National Weather Service (NWS) has kept weather data for over a century in numerous Michigan cities. We contacted our local National Weather Service office in Grand Rapids (www.nws.noaa.gov/) and requested a copy of the historic weather data for our location. For Grand Rapids the data set started in 1897. What data is most important? Although a long stretch of cloudy days can affect us, temperature and snowfall dominate our conversations and daily planning. The historic data included minimum temperature, average daily temperature, and the amount of snow fall. For each parameter the measurement was averaged over the number of years of observation.

There are two possibilities for gathering this year's data: students collect data from your school's weather station or "F6" climate data reported on NWS website. We suggest the students collect some weather data to better understand what their numbers represent. Because obtaining an accurate measurements for all three weather parameters can be difficult, we relied on the F6 data. F6 data is Local Climatological Data for a specific location. Essentially, it is the official weather data for a specific day at a specific location. The data includes high, low, and average temperature, amount and form of precipitation (including snow), wind speed and direction, amount of sunshine and sky cover, and types of weather (fog, etc.).

To simplify the exercise we define our conditions for winter as follows: Winter begins on December 21st. We consider this Day 1 in our data set and number subsequent days with consecutive numbers to March 20th. If you are interested in monthly patterns Day 12 is January 1st, Day 43 is February 1st, and Day 71 is March 1st.

Results

Historic data for the coldest temperature, average daily temperature and the amount of snowfall in Grand Rapids are presented in Table 1 and Figure 1 *(see page 6)*.

A set of questions is provided to guide student data interpretation (see end of lesson). Because the historic data are averaged for more than 100 years, the data for each parameter shows gradual change over a period of many days. For example, historically, the coldest days of winter extend from Day 26 to Day 45 (Mid-January to early February) when the temperature bottoms out at 15 ºF. Likewise, the snow fall data show gradual changes of 0.1 inch over many days with the his-

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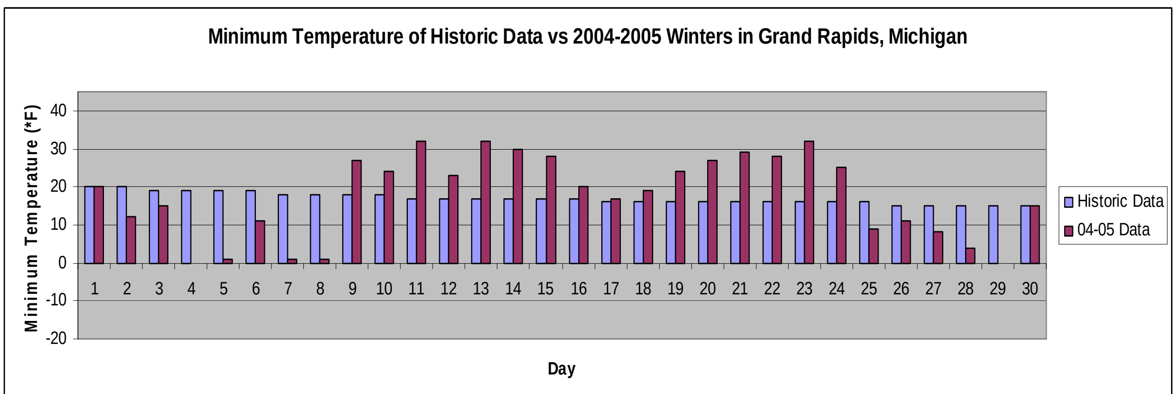
torically snowiest period from Day 4 to Day 19 (late December to early January). On the bar graphs (Figure 1) the historic data smoothly falls and rises as the days progress through the season.

Current data (December 21, 2004–March 20, 2005) for the coldest temperature, average daily temperature and the amount of snowfall are presented in Table 1 and Figure 1. The smooth patterns of the historic data are gone. For temperature, the current data rises and fall like a sine curve centered along the smooth gradient of the historic data. Periods of above or below historic values vary on a weekly or fortnightly period. Snowfall is episodic with weeks being graced with small, daily accumulations or individual one or two day events that that make up much of the accumulation for a 30-day (monthly) period. Interestingly, the first two 30-day periods both contain periods of about two weeks during which the minimum and average temperatures are above the historic values. In contrast, during the last 30-day period, the minimum and average temperatures stayed appreciably below the historic values for twenty days.

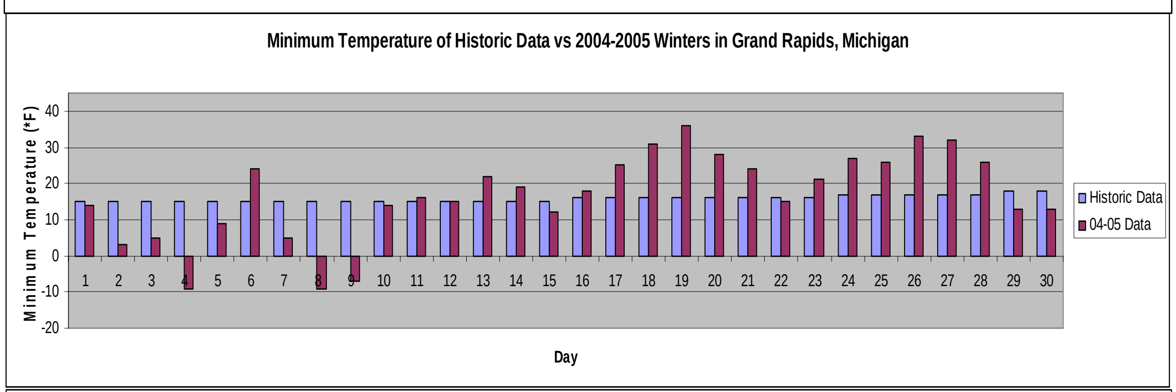
Although general observations might be useful for daily chats about the weather they lack the scientific reliability we glean from a more qualitative look at the data. Fortunately, the statistical methods we need are well within the limits of most students and consist of

Figure 1. Bar graphs comparing historic (light gray) to current (2004-2005 winter) data (dark gray) for coldest temperature, average daily temperature and the amount of snowfall in Grand Rapids

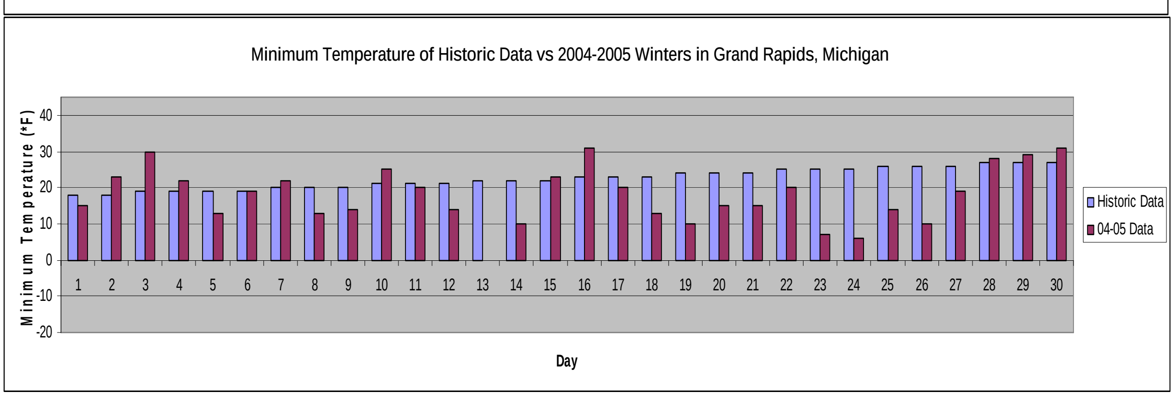
First Thirty Days



Second Thirty Days



Third Thirty Days



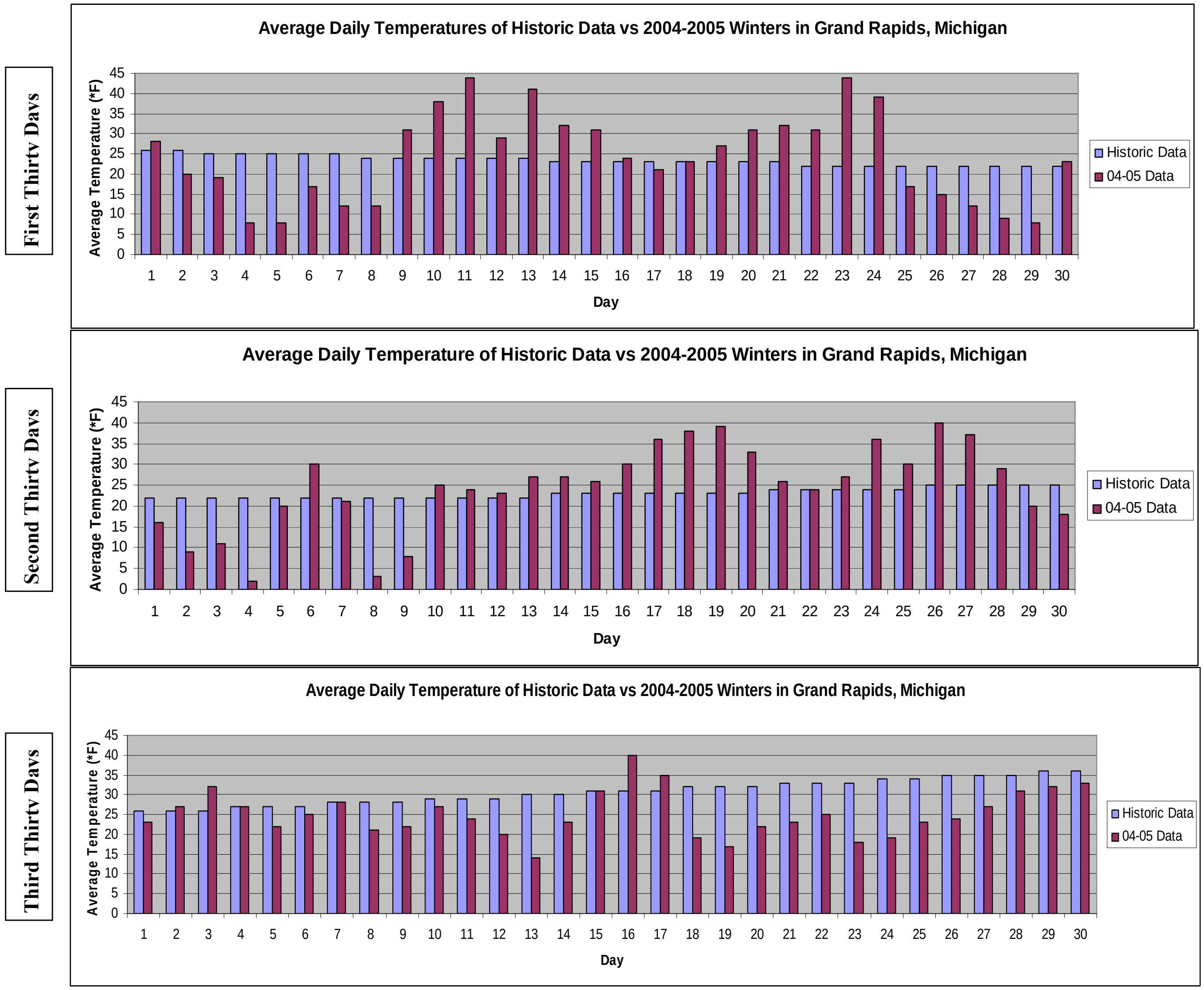


Figure 1. (***continued on page 8***)

averaging the data over different periods.

For each weather parameter, we calculate the difference between the historic value and the current (2004-2005) data (see Table 1). We summed these differences over the 30-day periods and for the entire season and averaged them over the 30-day periods (*see Table 2 on page 8*).

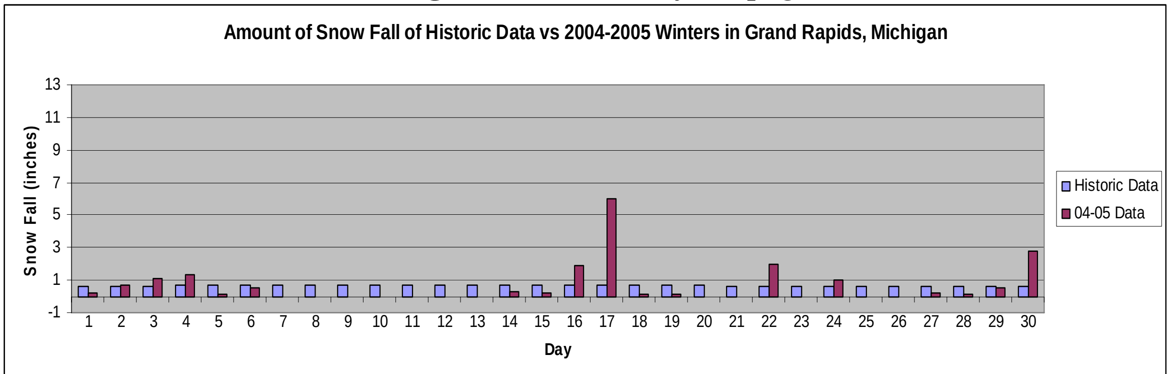
The results show that the first two 30-day periods were close to the historical averages in coldest and average temperature and in snowfall. In contrast, the last 30-day period, February 19 to March 20, the temperatures were about 5 ºF colder each day and an extra 15.7 inches of snow fell compared to the historic data. Interestingly, about 10.5 inches of the snow in March came when historic average temperatures are at or above freezing (i.e., commonly by that time in March temperatures are above freezing so the precipitation would have fallen as rain, not snow). The unseasonably cold temperatures allowed the precipitation to fall as snow instead of rain.

So, was last winter normal? Certainly the first two-thirds of the season were close to historic values. However, late February and early through mid-March were colder and snowier than normal, making a big impact on the psyche of Michigan residents seeking escape from "cabin fever." Quantitatively, averaged over the

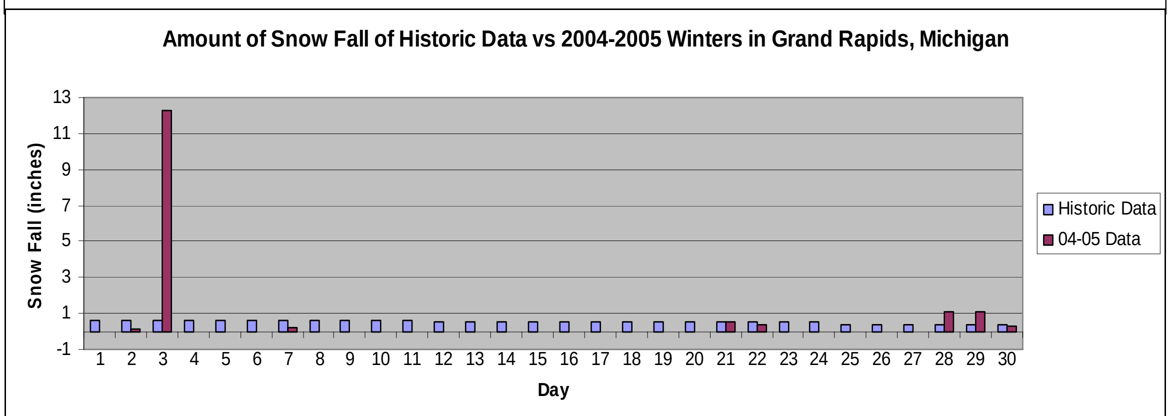
continued on page 8

Figure 1. (*continued from page 7*)

First Thirty Days



Second Thirty Days



Third Thirty Days

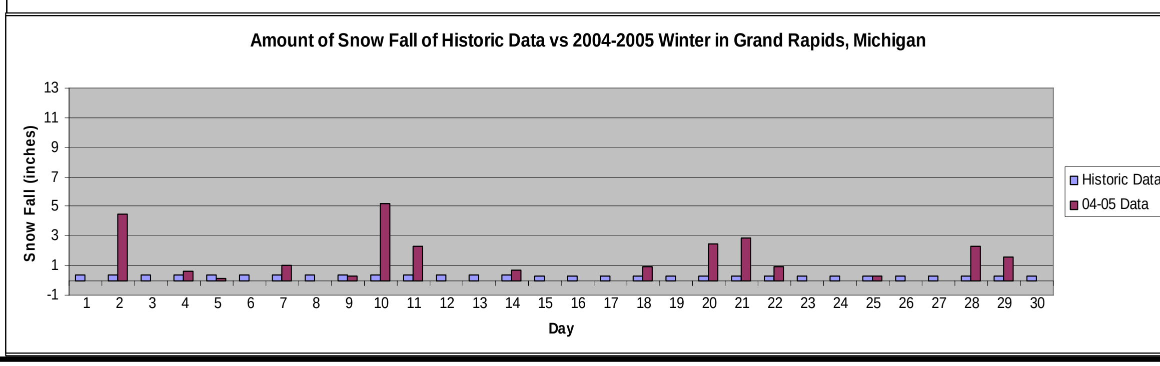


Table 2. Summary of temperature and snowfall data for 30-day periods and the winter of 2004-2005.

Period (days)	Coldest Temperature (ºF)	Average Temperature (ºF)	Snow Fall (inches)
1-30 December 21st to January 19th	∑ = +16 ºF or +0.5 ºF /day	∑ = +23 ºF or +0.7 ºF /day	∑ = -0.6 in or -0.02 in /day
31-60 January 20th to February 18th	∑ = +27 ºF or +0.9 ºF /day	∑ = +43 ºF or +1.4 ºF /day	∑ = 0.5 in or +0.016 in /day
61-90 February 19th to March 20th	∑ = -145 ºF or -4.8 ºF /day	∑ = -169 ºF or -5.6 ºF /day	∑ = +15.7 in or +0.5 in /day
0-90 December 21st to March 20th	∑ = -102 ºF or -1.1 ºF /day	∑ = -103 ºF or -1.1 ºF /day	∑ = 15.6 in or +0.2 in /day

Table 1. Historic data for the coldest temperature, average daily temperature and the amount of snowfall in Grand Rapids Note: t denotes days with a trace amount of snowfall.

	Coldest Tempera-tures (*F)					Average Temperatures (*F)					Snow Fall (inches)		
	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference
1	20	20	0		1	26	28	2		1	0.6	0.2	-0.4
2	20	12	-8		2	26	20	-6		2	0.6	0.7	0.1
3	19	15	-4		3	25	19	-6		3	0.6	1.1	0.5
4	19	0	-19		4	25	8	-17		4	0.7	1.3	0.6
5	19	1	-18		5	25	8	-17		5	0.7	0.1	-0.6
6	19	11	-8		6	25	17	-8		6	0.7	0.5	-0.2
7	18	1	-17		7	25	12	-13		7	0.7	0.0	-0.7
8	18	1	-17		8	24	12	-12		8	0.7	0.0	-0.7
9	18	27	9		9	24	31	7		9	0.7	0.0	-0.7
10	18	24	6		10	24	38	14		10	0.7	0.0	-0.7
11	17	32	15		11	24	44	20		11	0.7	0.0	-0.7
12	17	23	6		12	24	29	5		12	0.7	0.0	-0.7
13	17	32	15		13	24	41	17		13	0.7	0.0	-0.7
14	17	30	13		14	23	32	9		14	0.7	0.3	-0.4
15	17	28	11		15	23	31	8		15	0.7	0.2	-0.5
16	17	20	3		16	23	24	1		16	0.7	1.9	1.2
17	16	17	1		17	23	21	-2		17	0.7	6.0	5.3
18	16	19	3		18	23	23	0		18	0.7	0.1	-0.6
19	16	24	8		19	23	27	4		19	0.7	0.1	-0.6
20	16	27	11		20	23	31	8		20	0.7	0.0	-0.7
21	16	29	13		21	23	32	9		21	0.6	0.0	-0.6
22	16	28	12		22	22	31	9		22	0.6	2.0	1.4
23	16	32	16		23	22	44	22		23	0.6	0.0	-0.6
24	16	25	9		24	22	39	17		24	0.6	1.0	0.4
25	16	9	-7		25	22	17	-5		25	0.6	t	-0.6
26	15	11	-4		26	22	15	-7		26	0.6	t	-0.6
27	15	8	-7		27	22	12	-10		27	0.6	0.2	-0.4
28	15	4	-11		28	22	9	-13		28	0.6	0.1	-0.5
29	15	0	-15		29	22	8	-14		29	0.6	0.5	-0.1
30	15	15	0		30	22	23	1		30	0.6	2.8	2.2
		Total =	16				Total =	23				Total =	-0.6

Table 1. (***continued on page 10***)

Table 1. (*continued from page 9*)

	Coldest Tempera-tures (*F)					Average Tem-peratures (*F)					Snow Fall (inches)		
	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference
31	15	14	-1		31	22	16	-6		31	0.6	t	-0.6
32	15	3	-12		32	22	9	-13		32	0.6	0.1	-0.5
33	15	5	-10		33	22	11	-11		33	0.6	12.3	11.7
34	15	-9	-24		34	22	2	-20		34	0.6	t	-0.6
35	15	9	-6		35	22	20	-2		35	0.6	t	-0.6
36	15	24	9		36	22	30	8		36	0.6	t	-0.6
37	15	5	-10		37	22	21	-1		37	0.6	0.2	-0.4
38	15	-9	-24		38	22	3	-19		38	0.6	0.0	-0.6
39	15	-7	-22		39	22	8	-14		39	0.6	0.0	-0.6
40	15	14	-1		40	22	25	3		40	0.6	0.0	-0.6
41	15	16	1		41	22	24	2		41	0.6	0.0	-0.6
42	15	15	0		42	22	23	1		42	0.5	t	-0.5
43	15	22	7		43	22	27	5		43	0.5	0.0	-0.5
44	15	19	4		44	23	27	4		44	0.5	0.0	-0.5
45	15	12	-3		45	23	26	3		45	0.5	0.0	-0.5
46	16	18	2		46	23	30	7		46	0.5	0.0	-0.5
47	16	25	9		47	23	36	13		47	0.5	0.0	-0.5
48	16	31	15		48	23	38	15		48	0.5	0.0	-0.5
49	16	36	20		49	23	39	16		49	0.5	0.0	-0.5
50	16	28	12		50	23	33	10		50	0.5	t	-0.5
51	16	24	8		51	24	26	2		51	0.5	0.5	0
52	16	15	-1		52	24	24	0		52	0.5	0.4	-0.1
53	16	21	5		53	24	27	3		53	0.5	t	-0.5
54	17	27	10		54	24	36	12		54	0.5	0.0	-0.5
55	17	26	9		55	24	30	6		55	0.4	t	-0.4
56	17	33	16		56	25	40	15		56	0.4	t	-0.4
57	17	32	15		57	25	37	12		57	0.4	0.0	-0.4
58	17	26	9		58	25	29	4		58	0.4	1.1	0.7
59	18	13	-5		59	25	20	-5		59	0.4	1.1	0.7
60	18	13	-5		60	25	18	-7		60	0.4	0.3	-0.1
		Total =	27				Total =	43				Total =	0.5

Table 1. (*continued on page 11*)

Table 1. (*continued from page 10*)

	Coldest Tempera-tures (*F)					Average Tem-peratures (*F)					Snow Fall (inches)		
	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference		Day	Historic Data	04-05 Data	Difference
61	18	15	-3		61	26	23	-3		61	0.4	t	-0.4
62	18	23	5		62	26	27	1		62	0.4	4.5	4.1
63	19	30	11		63	26	32	6		63	0.4	0.0	-0.4
64	19	22	3		64	27	27	0		64	0.4	0.6	0.2
65	19	13	-6		65	27	22	-5		65	0.4	0.1	-0.3
66	19	19	0		66	27	25	-2		66	0.4	t	-0.4
67	20	22	2		67	28	28	0		67	0.4	1.0	0.6
68	20	13	-7		68	28	21	-7		68	0.4	0.0	-0.4
69	20	14	-6		69	28	22	-6		69	0.4	0.3	-0.1
70	21	25	4		70	29	27	-2		70	0.4	5.2	4.8
71	21	20	-1		71	29	24	-5		71	0.4	2.3	1.9
72	21	14	-7		72	29	20	-9		72	0.4	t	-0.4
73	22	0	-22		73	30	14	-16		73	0.4	t	-0.4
74	22	10	-12		74	30	23	-7		74	0.4	0.7	0.3
75	22	23	1		75	31	31	0		75	0.3	0.0	-0.3
76	23	31	8		76	31	40	9		76	0.3	0.0	-0.3
77	23	20	-3		77	31	35	4		77	0.3	t	-0.3
78	23	13	-10		78	32	19	-13		78	0.3	0.9	0.6
79	24	10	-14		79	32	17	-15		79	0.3	t	-0.3
80	24	15	-9		80	32	22	-10		80	0.3	2.5	2.2
81	24	15	-9		81	33	23	-10		81	0.3	2.9	2.6
82	25	20	-5		82	33	25	-8		82	0.3	0.9	0.6
83	25	7	-18		83	33	18	-15		83	0.3	0.0	-0.3
84	25	6	-19		84	34	19	-15		84	0.3	t	-0.3
85	26	14	-12		85	34	23	-11		85	0.3	0.3	0
86	26	10	-16		86	35	24	-11		86	0.3	t	-0.3
87	26	19	-7		87	35	27	-8		87	0.3	t	-0.3
88	27	28	1		88	35	31	-4		88	0.3	2.3	2
89	27	29	2		89	36	32	-4		89	0.3	1.6	1.3
90	27	31	4		90	36	33	-3		90	0.3	t	-0.3
		Total =	-145				Total =	-169				Total =	15.7

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90-day period, temperatures were only about 1ºF lower (Table 2), easy enough to measure with a thermometer but hard for most of use to sense. In contrast, averaged over the 90-day period, we gained an extra 0.2 of an inch of snow each day. When daily historic values tend to be 0.6 or 0.4 inch this is an increase in snowfall of 30 to 50 percent. Unfortunately, nature does not behave in the smooth, gradual ways depicted by the historic data but rather provides 2 to 6 inches of snow in numerous events.

Extensions and Conclusions

Our goal is to provide opportunities for students to design scientific experiments or tests using data sets that they can construct or obtain, to manipulate the data in a statistically sound way, and to relate their results to their own lives. Weather phenomena provide excellent opportunities for these types of experiments.

We asked the students to contemplate on why the severity of the winter might be of interest and who might be impacted? Some potential impacts include energy supply and cost, delay and added cost to construction projects and farming, highway safety, and, to a lesser extent, delay of the onset of sports season and inclement weather during parades, etc.

The lesson could be extended or modified in several ways. Do some Michigan cities have "normal" winters when others do not (perhaps compare Muskegon to Lansing)? Is there a correlation between temperature and snowfall amounts in the data? Can the patterns in temperature and snowfall in the current data be correlated with the passing of cold and warm fronts or the influence of polar or tropical air masses? Could we do the same problem for summer instead of winter? We are sure you and your students will devise new experiments and extensions. We would enjoy hearing from you.

Student Data Interpretation

1. Describe, in general terms, the 90-day weather pattern defined by **historic data** for
   a. coldest temperature,
   b. average daily temperature, and
   c. the amount of snowfall.

2. Describe in general terms, the 90-day weather pattern defined by **current data** for
   a. coldest temperature,
   b. average daily temperature, and
   c. the amount of snowfall.

3. Is the gradual decline and rise shown in the historic data what we typically experience in our daily lives?

4. What is the value of the historic data?

5. Can you quantify (use numbers) your observations to convince your teacher that last winter was colder or snowier? Design a test to show if conditions were colder or snowier. After showing your test to your teacher, complete your calculations. Describe your results.

6. Describe how the severity of the winter might impacted you, your family, and your community.

Answers to Student Data Interpretation

1. *Describe, in general terms, the 90-day weather pattern defined by **historic data** for*
   a. *coldest temperature,*
   At the beginning of the historic data the coldest temperature starts out at 20 °F and gradually gets colder until days 26-45, which is middle of January the beginning of February. The coldest temperature is 15 °F. The coldest daily temperature then gradually begins to increase to 36 °F.

   b. *average daily temperature, and*
   At the beginning of the historic data of the average temperatures starts out at 26 °F and gradually get colder as winter progresses. Towards the middle of winter at days 26-45 the average temperature levels out at 22 °F followed by a gradual increase of average temperature. The ending average temperature is 36 °F.

   c. *the amount of snowfall*
   The maximum amount of snow fall from the historic data, 0.7 inch per day, is reached early in winter (day 4). After two weeks it shows a gradual decrease until the end of winter, ending with 0.3 inch per day of snow.

2. *Describe in general terms, the 90-day weather pattern defined by* ***current data*** *for*
   a. *coldest temperature,*
      The current data showing the coldest temperature does not display any distinct patterns. The lowest temperature is -9 °F and the warmest temperature is 39 °F.

   b. *average daily temperature, and*
      The current data showing the average temperature does not display any distinct patterns. There are dramatic increases and decreases in temperatures over short (1-2 day) periods. The lowest temperature is 2 °F and the warmest temperature is 40 °F.

   c. *the amount of snowfall*
      The current data showing the amount of snow fall shows a handful of days in which there was several inches of snow, ranging from 2 – 2.5 inches. However, the majority of the days experiences 1 inch of snow or no snow at all. There are several instances when there are two days in a row with a lot of snow, for example days 16 & 17, 80 & 81 and, 88 & 89. This could be due to a passing snow storm.

3. *Is the gradual decline and rise shown in the historic data what we typically experience in our daily lives?*

   In our daily lives we do not experience the gradual decline and rise that is shown by the historic data. The historic data has been average from 1897 to the present, which produce the gradual path shown in the data.

4. *What is the value of the historic data?*

   The historic data represents "normal" winter, because it is a compiling of winter data from 1897 to the present. The historic data can then be compared to the current winter data to determine what weather to expect.

5. *Can you quantify (use numbers) to convince your teacher that last winter was colder or snowier? Design a test to show if conditions were colder or snowier. After showing your test to your teacher, complete your calculations. Describe your results.*

   Student answers will vary. We present one possible solution in this paper.

6. *Describe how the severity of the winter might impacted you, your family, and your community.*

   Winters that have more snow fall means more shoveling of snow in the drive-way. More snow fall could also produce damage to the roof of the house, from the weight of the snow. Also with more snow fall means possible colder temperatures, which means the furnace in my house must be running more producing a higher energy bill. In the community more snow would be more snow plows on the roads, and the possibility of more car accidence because of the slick road conditions. Car accidence could lead to more medical expenses due to injuries. ■