Antarctic Extremes:

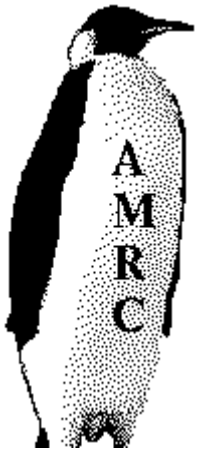
Support for the Next Generation Polar Weather and Climate Station

A technical report for engineer applications

Taylor P. Norton

Madison College

tpnorton@madisoncollege.edu



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This paper is dedicated to Dr. Matthew Lazzara for his encouragement and support of my meteorological passion in the past year and for the time ahead.

Table of Contents

Introduction

The Antarctic climate is very extreme, and scientists have been studying it for over 100 years. As time has passed by, more advanced technology needs to be invented to improve the accuracy of the climate observations taken. In order to get this data, the electronical pieces of Automatic Weather Stations (AWS) have to withstand the intensely cold temperatures and harsh environment. UW-Madison has a network of more than 60 AWS on the continent that dates back to the 1980's [e.g., Lazzara et al. (2012)]. The homemade manufactured electronic core the university had built can't be manufactured anymore and is outdated, and commercial off the shelf (COTS) stations aren't made for polar climates. The next generation automated polar weather and climate station needs an electronic design that can last longer and withstand the extreme environment.

This report goes through the extreme weather conditions that different AWS have observed around the continent, this includes record high and low temperatures, and wind speed (highs), long durations of cold temperatures, high relative humidity, and high wind speeds, and drastically rapid changes in temperature, relative humidity, and wind speed. These variables impact the effectiveness of the electronics, sensors, and towers of AWS.

Observational Data

The data from the rapid changes and long durations in this report comes from an analysis of seventeen different stations that provide a decent geographic difference around the continent. They show the various conditions that the AWS experience around Antarctica. Gill, Marilyn, and Margaret are on the Ross Ice Shelf, as well as Sabrina and Erin which are also near the Transantarctic Mountains. D-10 is on the Adélie Coast, Minna Bluff is near McMurdo, and Manuela is north of McMurdo along the coast on Inexpressible Island. Byrd and Harry are near the middle of West Antarctica, Henry and Harry are near the South Pole, and AGO-4, Relay Station, Dome C II, Dome Fuji, and Baldrick are scattered across East Antarctica on the high Antarctic Plateau. The time span looked through was from 2001-2016, although not all stations were running every year or all year.

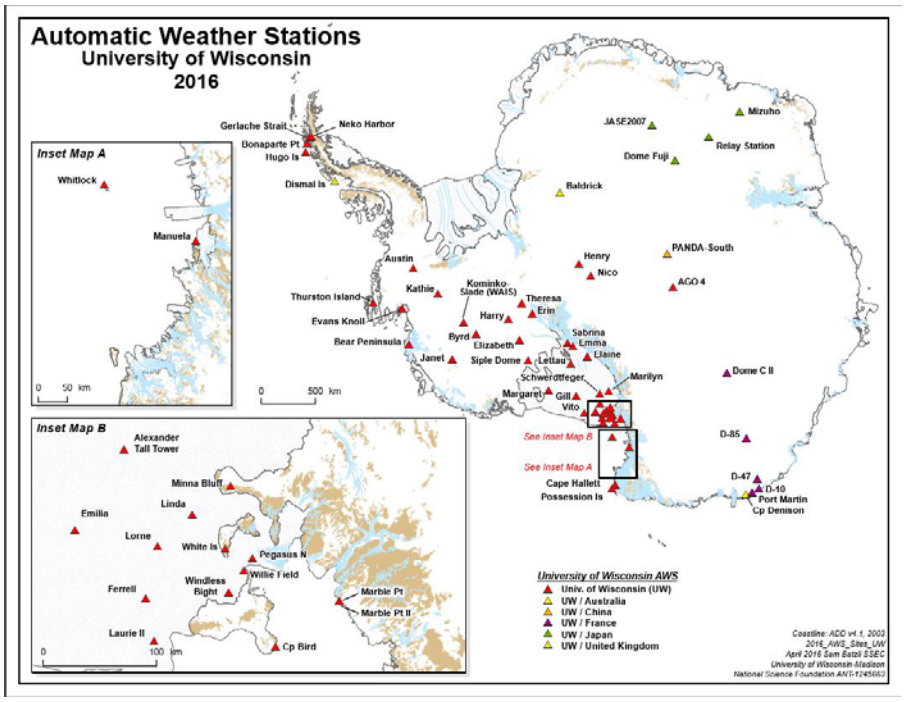

Figure 1. The figure above shows the map of UW-Madison Wisconsin AWS in Antarctica.

The variables researched were temperature, relative humidity, and wind speed. To find rapid changes, the data was graphed monthly to see significant jumps in a short amount of time, and then looked through to find the time period and exact details of the event. The graphs were also used to find long periods of extremely cold temperatures, high wind speeds, and high relative humidity percentages. Extreme values of temperature and wind speed were included from existing findings and the absolute records which date back to 1980.

The data examined comes from the Antarctic Meteorology Research Center's (AMRC) directory of quality-controlled AWS records. In order to look at the data most efficiently, a copy of the data of an entire year is acquired, separated by month, for each station, into an excel spreadsheet for each year. A graph is created separately for the temperature, relative humidity, and wind speed. From there, the graphs are analyzed for rapid changes or long durations. These are inspected more closely by looking directly at the data at the times of interest. Certain values for each variable are used when it comes to duration and rapid changes. Long durations of cold temperatures are -40 °C or colder for at least 5 months, wind speed of 20 m/s or stronger for more than 3 days, and a relative humidity of 70% or higher for more than 100 days. These values were chosen because most electronics used in an AWS operate down to -40 °C, but the temperatures in Antarctica regularly drop below that. Gale force winds are 20 m/s, so the station needs to be able to stay up while constant strong winds blow, and the electronics could be affected by the vibrations caused by long duration strong wind speeds. Relative humidity of 70% and higher equates to higher moisture contents which can affect the effectiveness of the electronics core. A rapid change in temperature includes at least 8°C in 10 minutes and 25°C in 6 hours, a wind speed difference of 20 m/s in 10 minutes, and a difference in relative humidity by

30% in 10 minutes and 50% in one hour. Rapid changes in time spans in between are also counted when the change is in between baselines for each amount of time.

Data Analysis

Extremes

In the Antarctic, which includes latitudes 60°S or higher, the record high temperatures are found from three different regions: Antarctic Region, Antarctic Continent, and Antarctic Plateau. In the Antarctic Region, the highest temperature ever recorded was 19.8°C on January 30,1982 at Signy Research Station. On the continent, the highest recorded temperature was 17.5°C on March 24, 2015 at the Esperanza Station. On December 28, 1989, AWS D-80 hit -7.0°C which is located on the Adelie Coast on the Antarctic Plateau (e.g., Skansi et al. 2017). The coldest temperature ever recorded in Antarctica was -89.2°C on July 21, 1983 at the Russian Vostok Station (e.g., Turner et al. 2009).

For the Wisconsin AWS, the warmest recorded temperature was tied at 11.9°C at D-10 on December 11, 2010 and Bonaparte Island on March 8, 2010. The lowest recorded temperature was on August 26, 1982 at -84.6°C at Dome C. Minna Bluff had the highest recorded wind speed, maxing out at 61.3 m/s on July 10, 2001.

Station	Max. Temp. (°C)	Date	Min. Temp. (°C)	Date	Max. Wind Speed (m/s)	Date
Gill	3.9	12/25/2005	-65.4	8/14/2001	25	6/12/2007
D-10	11.9	12/11/2010	-42.3	9/1/1992	41.8	7/11/2002
AGO-4	-21.7	1/3/2014	-78.4	9/7/2016	16.8	3/31/2014
Byrd	1.6	1/6/2005	-64.4	7/18/1985	33.2	8/8/1997
Manuela	7.3	1/6/2014	-42.4	9/1/1992	55	5/19/2016
Harry	4.5	1/7/2005	-60	9/22/2011	30	4/11/1996
Marilyn	4.9	12/31/2011	-58.5	9/2/2009	33.8	7/1/1988
Sabrina	1.7	1/10/2010	-57.8	9/2/2009	35.4	7/27/2011
Henry	-8.4	12/25/2011	-75.4	6/7/2013	19.7	9/21/2011
Nico	-8.2	12/25/2011	-78.6	9/2/1995	20.3	6/16/1993
Baldrick	-9	12/26/2012	-66.3	5/21/2012	24.3	6/2/2013
Relay Station	-7.7	1/10/2013	-75.5	7/18/2004	24.4	11/29/2001
Erin	5.8	1/4/2001	-53.2	7/16/2010	40.9	9/18/2007
Minna Bluff	1.1	12/24/1996	-48.1	8/24/1993	61.3	7/10/2001
Margaret	1.8	1/12/2016	-63.9	7/17/2010	23	9/18/2015
Dome C II	-10	1/2/2002	-83.2	8/13/2010	22.5	8/30/2004
Dome Fuji	-13.2	12/23/2016	-82.9	7/27/2014	45.2	5/23/1998

Table 1. The table above shows the extremes found at the seventeen stations that were researched from their entire history of being in service, including maximum temperature, wind speed, and pressure, as well as the minimum temperature and pressure.

Temperature

The most rapid change in temperature in 10 minutes was an increase of 11.4°C at Sabrina June 14, 2014. In 5 hours, there was an increase of 36.5°C at Sabrina on September 5, 2009. The longest duration of cold temperatures below -40°C lasted 265 days, 16 hours, and 20 minutes at AGO-4 from February 12- November 4, 2012.

Relative Humidity

The most rapid change in relative humidity (RH) in 10 minutes was a decrease of 44.9% at Marilyn December 26-27, 2013. In 40 minutes, there was an increase of 70.0% at Minna Bluff

November 27, 2016. The longest duration for RH above 70% lasted 127 days, 1 hour, and 30 minutes at Erin from April 21- August 26, 2011.

Wind

The most rapid change in wind speed was investigated, but further analysis proved more exploration is necessary as unlikely circumstances may have escaped traditional quality control. The longest duration of a wind speed greater than 20 m/s lasted for 6 days, 13 hours and 40 minutes at Manuela from May 17-24, 2016.

Summary

From these extreme values, changes, and durations, it can be found what the electronic core of the weather station needs to withstand. A change in temperature of 11.4°C in 10 minutes and a duration of 266 days below -40°C; a change in RH of 44.9% in 10 minutes and a duration of 127 days above 70% RH; and a duration of winds above 20m/s for 6.5 days.

This will allow the next generation polar climate and weather station to be able to withstand the extreme Antarctic environment. It is also important to understand how these events could occur and to realize they could happen again. Antarctic meteorology is complicated, but the more research is done, the more information we can learn about it and share with others, impacting people's safety, as well as understanding this remote part of the globe more in depth.

Future Efforts

Going forward, there needs to be more work done to create a more concrete claim. Future work will include looking through more years of the stations with an aim to get their entire history of data analyzed. Examining more stations to get the most coverage of the continent to find the most extreme events is desired.

Acknowledgements

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