—報告—
*Report*

# Automatic Weather Station (AWS) Program operated by the University of Wisconsin–Madison during the 2012–2013 field season: Challenges and Successes

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## ウィスコンシン大学マディソン校が実施している南極無人気象観測（AWS）計画の 2012–2013 年夏期の活動

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**要旨**: ウィスコンシン大学マディソン校で推進している南極無人気象観測計画（Antarctic Automatic Weather Station（AWS）program）の，2012–2013 年のフィールド調査および結果の概要を報告する．今期は AWS 観測網の歴史上，特異なシーズンであった．ロス島地域が温暖であったことは氷上滑走路の利用に影響を及ぼし，いくつかの設営面での制約に直面した． 柔軟な計画により，限られた条件下で AWS サービルを最大化し，自動観測ネットワークへの要求に対応する最善の手段をとることができた.

***Abstract***: This report reviews 2012–2013 field season activities of the University of Wisconsin–Madison's Antarctic Automatic Weather Station (AWS) program, summarizes the science that these sites are supporting, and outlines the factors that impact the number of AWS sites serviced in any given field season. The 2012–2013 austral summer season was unusual in the AWS network history. Challenges encountered include, but are not limited to, warmer than normal conditions in the Ross Island area impacting airfield operations, changes to logistical procedures, and competition for shared resources. A flexible work plan provides the best means for taking on these challenges while maximizing AWS servicing efforts under restricted conditions and meeting the need for routine servicing that

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maintaining an autonomous observing network demands.

## 1. Introduction

Surface meteorological and climatological observations in Antarctica require an autonomous platform, as there are very few year-round observing stations, and these are mostly constrained to the coastline. Since the 1980s, Automatic Weather Stations (AWS) have carried out this task of observing meteorological conditions across the Antarctic. (e.g., Allison *et al*., 1993; Lazzara *et al*., 2012; van den Broeke *et al*., 2004). Today, the international AWS network is the largest network on the continent (Figure 1). This report outlines the 2012–2013 field season to service and maintain the portion of the Antarctic AWS network managed by the University of Wisconsin–Madison with funding support from the United States' National Science Foundation (NSF). The Wisconsin AWS network includes segments managed directly by the University of Wisconsin. It also contains segments jointly overseen between the University and other nations including Japan, France, etc. The 2012–2013 field season saw several challenges not experienced previously (particularly in the prior seasons reported in Lazzara *et al*., 2013 and Mikolajczyk *et al*., 2013). This report reviews the field personnel, activities accomplished, challenges encountered, and offers some

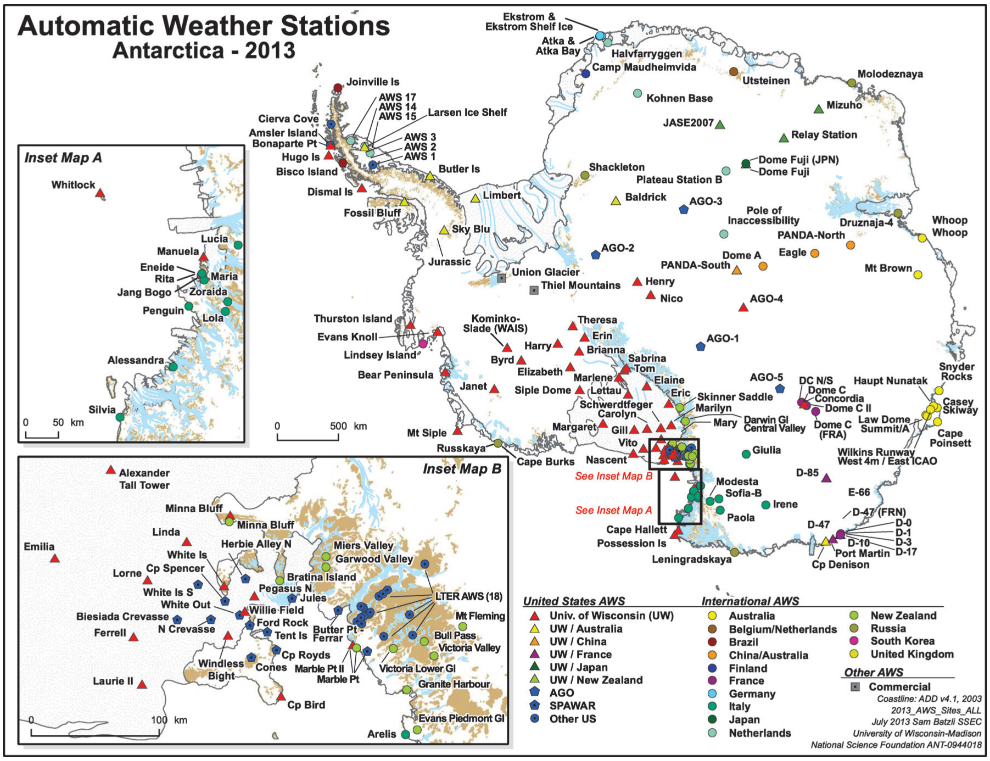



*Fig. 1. Map of all known Antarctic Automatic Weather Station (AWS) sites in 2013.*

concluding remarks on management of a large network in a physically challenging and logistically limited environment.

## 2. 2012−2013 Field Season Plans and Expectations

The original plans for the 2012−2013 field season called for visiting 11 sites in the Ross Island area, 6 sites on the Ross Ice shelf, 6 sites in West Antarctica, one on the Antarctic Peninsula, and one in East Antarctica for a total of 25 AWS site visits planned out of a network of 57 sites. Tasks planned included station repairs, operating system upgrades, and installation of a few new systems—some with newer communication systems. This season included limited collaborations with international collaborators, primarily with the Institut polaire français Paul-Emile Victor (IPEV) in Terre Adelie Land in East Antarctica. The 2012−2013 field season did not include any planned collaborations with the Japanese Antarctic Research Expedition (JARE); however, in future field seasons (likely the 2014−2015 season or beyond) joint field activities in that segment of the network are anticipated. During their traverse from Dumount D'Urville to Dome Concordia, IPEV visited/inspected the three AWS along the route. The only AWS that needed maintenance was D-10, which was raised.

## 3. Field Personnel

For the 2012−2013 field season, the field team consisted of Lee Welhouse, David Mikolajczyk, and Joseph Snarski from the University of Wisconsin−Madison's Antarctic Meteorological Research Center (AMRC), Space Science Engineering Center (SSEC), and Maria Tsukernik from Environmental Change Initiative (ECI), Department of Geological Sciences, Brown University. Lee Welhouse and David Mikolajczyk deployed to McMurdo Station on November 28, 2012 for the early portion of the season. David Mikolajczyk departed McMurdo Station on December 20, 2012. Maria Tsukernik arrived in McMurdo on December 30, 2012 to complete the final portion of the season along with Joseph Snarski, who arrived in McMurdo on January 3, 2013. Joseph departed on January 19 while Lee and Maria departed on February 9.

## 4. Field Activities

This field season focused on a series of tasks including the continued roll out of a very high frequency (VHF) modem communications network in the Ross Island/McMurdo Station region. Servicing and repairing AWS systems is the number one activity planned for most field seasons, therefore 2012−2013 was not unique. Continuing this year was the replacement of older AWS equipment, which is an effort that has been underway for some years. A primary goal was the removal of the older Campbell Scientific, Inc. (CSI) CR10X-based equipment as they can run into time-keeping issues, making the data observations more difficult to use. This older hardware is no longer supported by CSI. The replacement/

removal of all older Bendix/Belfort aerovanes was an additional priority, as refurbishment of these systems is no longer practical. RM Young systems are in wider use across the network (Lazzara *et al*., 2012). Finally, the older Wisconsin AWS2B systems were removed, especially if any were near failure or have failed. A final effort underway, which extends across multiple field seasons, is to run a series of multi-year tests of Wisconsin AWS2B systems side-by-side with the newer AWS-CR1000 CSI based hybrid/custom systems. A map of sites actually visited is shown in Figure 2.

The move from the older AWS2B and unsupported CR10X based AWS to a custom/hybrid AWS-CR1000 CSI based system provides the benefits of both using existing, proven and reliable sensors while taking advantage of more modern equipment that reduces time for design, assembly and testing. The newer AWS-CR1000 CSI systems enable the ability to have more sensors (e.g., acoustic depth gauge to measure snow accumulation at the station, incoming solar radiation, etc.) than was possible on the AWS2B (Lazzara *et al*., 2012). Communication options are more diverse on the AWS-CR1000, where Argos, Iridium or VHF methods are all options. AWS2B was enabled to work as an Argos enabled device only.

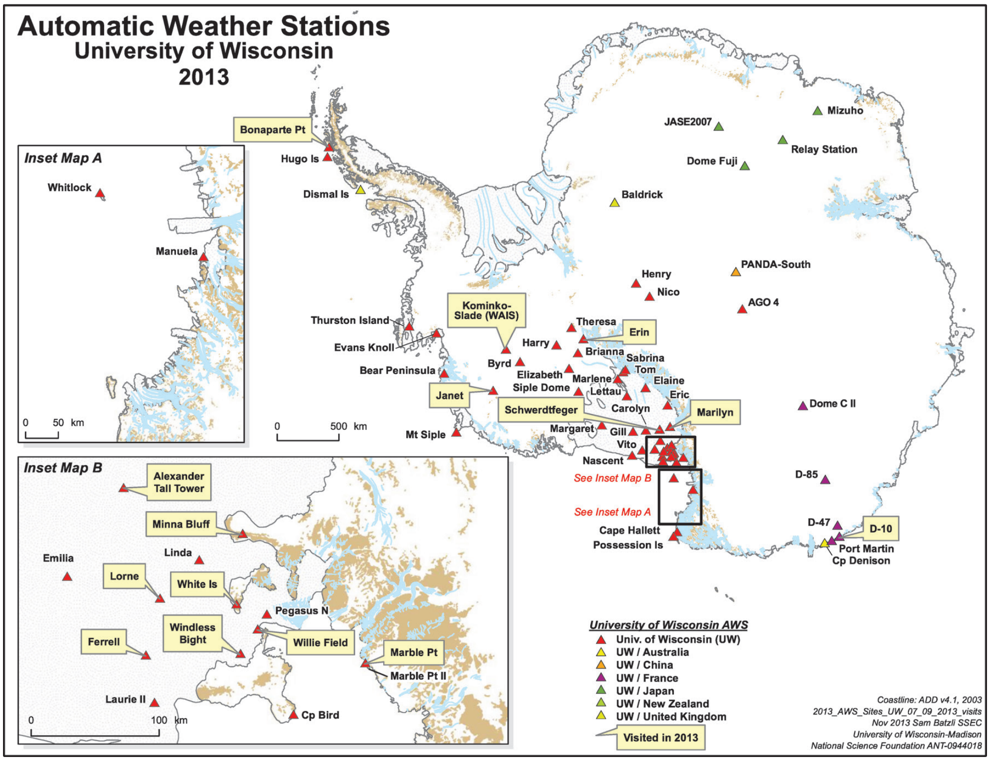



*Fig. 2.* *The UW-Madison AWS sites across the Antarctic, with those visited in the 2012–2013 field season highlighted by yellow text boxes that indicate the AWS name.*

## 5. Science Objectives and Sites Visited

### *5.1. Ross Island Region*

The AWS observing efforts in the Ross Island region are centered on several science focal points. First, the stations round out a regional network used for operational forecasting. The Wisconsin AWS are the first-line observations of incoming weather events to strike the area (See inset map B on Figure 1 and 2). Second, several of the AWS sites, including Cape Bird, Windless Bight, Lorne, Minna Bluff and Marble Point II, are used as a part of a tropospheric ozone study project (Kalnajs *et al*., 2013; Seefeldt *et al*., 2013). Third, many of the AWS in this area have been installed and maintained for over 25 years, and some for more than 30 years, allowing the observations to contribute to understanding the climatology of the region.

A VHF system, using FreeWave Technologies equipment (and henceforth referred to as Freewave), to communicate the weather observations has been employed to relay the weather observations from the AWS sites within line-of-sight of a base reception station, which is ultimately McMurdo Station. Some of the AWS sites on the network are acting as a relay node. For example, Cape Bird AWS, which is not within line-of-sight of McMurdo Station, relays its data to Marble Point II AWS, which is within line-of-sight. This method, employing VHF radio frequencies of roughly 900 MHz, enables the data to be made available in real-time to weather forecasters for operational support decisions, while not requiring the reoccurring costs associated with satellite communications. The data are then relayed from McMurdo Station back to the University of Wisconsin–Madison via Internet using the

*Fig. 3. White Island AWS with Mt. Erebus shown in the background.*

*Table 1. Summary of 2012–2013 AWS field season activity.*

| AWS Station | Work Accomplished | Date |
|---|---|---|
| White Island | New station installed – includes Freewave modem repeaters | December 9, 2012 |
| | Station Repair | December 20, 2012 |
| | Additional Station Repair | December 26, 2012 |
| Ferrell | The older AWS removed | December 12, 2012 |
| Windless Bight | Updated communications to Freewave modem | December 17, 2012 |
| Minna Bluff | Station inspection | December 26, 2012 |
| | Replaced wind direction sensor | February 5, 2012 |
| Lorne | Argos electronics removed | December 26, 2012 |
| | Install Freewave electronics | December 27, 2012 |
| | Repair Freewave electronics | December 29, 2012 |
| | Further repairs to Freewave modem | January 3, 2013 |
| Marble Point | Station inspection and data recovery along with electronics operating system update | December 29, 2012 |
| Janet | Raise station and replace batteries | January 15–16, 2013 |
| Erin | Station replaced with AWS-CR1000 system | January 20, 2013 |
| Kominko-Slade | Data recovered and operating system updated | January 24, 2013 |
| Alexander Tall Tower! | Lower instrument levels raised and tower inspection | January 30, 2013 |
| | Unsuccessful conversion to Iridium communications | February 2, 2013 |
| Marilyn | Aerovane replaced | February 2, 2013 |
| Schwerdtfeger | Station replaced with AWS-CR1000 system | February 2, 2013 |
| Willie Field | Electronic system replaced | February 3, 2013 |

Antarctic-Internet Data Distribution (Antarctic-IDD) system using the Local Data Management (LDM) system (Lazzara and Antarctic-IDD collaborators, 2008; Seefeldt *et al.*, 2009).

In the Ross Island region, one new AWS was installed at White Island (78.08°S, 167.45 °E) during the 2012–2013 season (Figure 3). This system is serving primarily as a relay for other AWS in the region on the new Freewave VHF communications network, as part of evolving this one segment of the AWS network away from a satellite-based communications network. A second visit was required to fix some minor issues with the power system. A third visit attempted to fix a problem with the acoustic depth gauge sensor, although that was not successful. Ferrell AWS (77.82°S, 170.82°E) was visited, where both a Wisconsin AWS2B system and a newer AWS-CR1000 system have been running side-by-side. The older AWS2B system was removed during the visit. An annual visit was required at Windless Bight AWS (77.73°S, 167.68°E) to raise the station due to the heavy snow accumulation at this location. However, a raise could not be accomplished this year due to the co-located ozone monitoring system installed. Accommodations for this will be arranged next season. Meantime, a newer CR1000 Freewave VHF transmitter was installed at the site. Minna Bluff AWS (78.56°S, 166.69°E) had its wind direction fail, and initial inspection was inconclusive as to the cause of the fault. Upon the arrival of a spare system at McMurdo Station, a second visit to Minna Bluff AWS was made to replace this sensor and fix the problem.

Lorne AWS (78.22°S, 170.02°E) was visited several times during the season. The initial visit could not be completed due to a laptop computer failure in the cold conditions. To allow the work to be completed, the electronics were recovered from the site, and work was completed in the lab at McMurdo Station. A second visit re-installed the electronic system, along with a new Freewave VHF modem communications system. Transmission failures prompted additional visits to optimize the relay of the observations from Lorne AWS through White Island AWS. These repairs were successful until White Island lost power during the winter-over period. Complications associated with a failure of transmissions from a station acting as a relay (such as White Island) raises a question of reliability of Freewave VHF communication. It is important to note that the newer AWS-CR1000 system, such as the Freewave network uses, are equipped with compact flash memory cards to log the observations in an effort to prevent the loss of data during communications outages. Marble Point AWS (77.44°S, 163.75°E) was visited, primarily to check on the new Marble Point II CR1000 system. Data was retrieved from the system, and an update was completed to the data logger operating system. Willie Field AWS (77.87°S, 166.95°E) was having electronic difficulties and was replaced as a result.

## *5.2. Ross Ice Shelf*

The AWS throughout the Ross Ice Shelf region are being primarily used to understand the wind flow and dynamics including the Ross Ice Shelf air stream, corner jets, etc. (Nigro

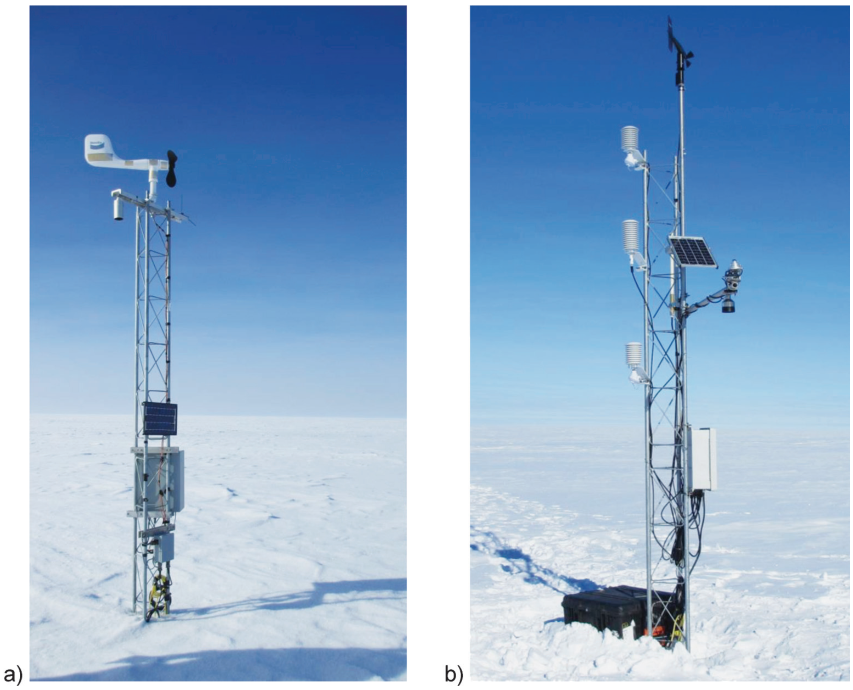
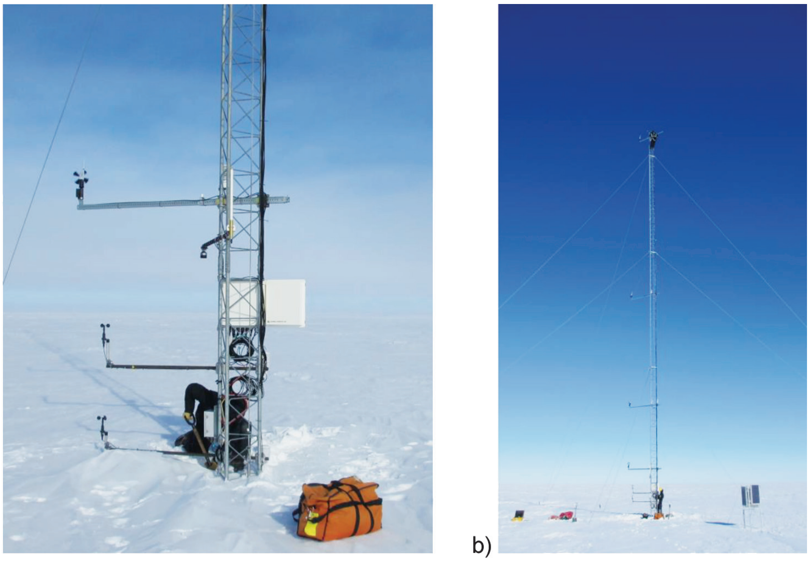



*Fig. 4. Schwerdtfeger AWS as seen a) before servicing and b) after install of the newer equipment and sensors.*



a) b)

*Fig. 5. The raising of sensors is the most common activity required at many AWS sites as seen here, with a) Tall tower before the raise and b) Tall Tower after the raise with the entire station pictured.*

and Cassano, 2014; Nigro *et al*., 2012) and to characterize the climatology of the region (work currently in progress Costanza *et al*. in preparation). Weather forecasting is another use of these observations, as they are utilized to monitor incoming weather systems that affect both the McMurdo Station/nearby airfields and flight operations between the McMurdo area toward other field camps in the region and toward South Pole Station. The AWS network is the only routine weather observing system available in the Ross Ice Shelf region.

At Schwerdtfeger AWS (79.88°S, 170.11°E), the Wisconsin AWS2B was replaced with a CR1000-based AWS (Figure 4). Issues with the battery system were fixed while at the site. A new instrumentation boom was installed at Marilyn AWS to improve issues with data transmissions. Alexander Tall Tower! AWS* (79.04°S, 170.65°E) was visited to raise the lowest two sensor levels (Figure 5). Additionally, the communications system was upgraded to Iridium. Difficulties doing this on the first attempt, however, required a second visit to fix, which was not completely successful as the system data transmissions are incorrect. The station is collecting data, but not currently transmitting in real-time.

### *5.3. West Antarctica*

With recent research on the significant climate changes seen in West Antarctica, the principal use of the AWS network in this region is to continue to capture observations to further understand the climate of the region and how it is continuing to change. In particular, warming on the order of 2.18 ± 1.25℃ from 1958 to 2010 has been observed using a combination of staffed station and AWS temperature observations from Byrd Station and Byrd

* The exclamation mark (!) is a part of the name of this AWS, included by the support staff who worked at the many attempts to install this AWS over two field seasons (2009–2010 and 2010–2011).

AWS (Bromwich *et al*., 2013). The annual trend over this period is 0.42 ± 0.24℃ and is statistically significant at the 99 % level. This ranks central West Antarctica as one of the rapidly warming sites on Earth. Some of the AWS in the region are also used for weather forecasting, as no other long-term, year-round observations exist for the region.

Three stations were serviced this season. Janet AWS (77.17°S, 123.39°W) was raised and a new power system installed to replace the failed system on site. A problem with a charge controller required a second visit to make the site fully operational. The AWS at the West Antarctic Ice Sheet (WAIS) —Divide field camp, known as Kominko-Slade (79.47°S, 112.11°W), was visited to collect data recorded on a memory card as well as to upgrade the operating system on the datalogger. Power and instrumentation issues at Erin AWS (84.90°S, 128.85°W) necessitated replacing the Wisconsin AWS2B with a CR1000-based AWS at this site.

### *5.4. East Antarctica*

The AWS network in East Antarctica between Dumont D'Urville Station and Concordia Station has been used in a variety of studies including katabatic wind events (e.g., Parish *et al*., 1993; Wendler *et al*., 1993), blowing snow studies (Gallée *et al*., 2012), and temperature studies (Genthon *et al*., 2011). These AWS are jointly managed by the UW-Madison and IPEV. The interest in these sites, in addition to supporting science activities, includes gathering weather data for an alternative emergency landing site at D-85. As with many AWS observations across the Antarctic, the observations are made available on the GTS for insertion into real-time global numerical forecast models.

A very limited set of work was planned for this portion of the continent in the 2012–2013 field season. The IPEV traverse from Cape Prudhomme, near Dumont D'Urville Station, to Concordia Station goes past several AWS sites. The traverse visited D-85 AWS (70.43°S, 134.15°E) and D-47 AWS (67.40°S, 138.73°E) sites, but they did not require any maintenance. The D-10 AWS (66.71°S, 139.83°E) was visited and raised. Dome C II AWS (75.12°S, 123.37°E) was also briefly visited; however, no servicing work was accomplished this season.

## 6. Challenges and Successes

### *6.1. Challenges*

Challenges faced this season can be classified as those that were unexpected/unplanned, weather related, and programmatic constraints. Many of the revisits to some sites were unplanned due to unexpected failure, while some revisits were originally planned due to the complexity of maintenance efforts (such as to Alexander Tall Tower! AWS). Planned visits typically include routine maintenance, raising sensors to maintain a constant height above the snow surface, and established repairs. Unexpected visits are made to mitigate any failures to AWS sites that occur during the field season that can be fixed with the available logistics to visit the sites. Considering other complications affecting the 2012–2013, these unplanned revisits had a small impact on the overall outcomes.

Weather often impacts most field seasons, some more than others. This season Pegasus North AWS (77.96°S, 166.52°E), located at the Pegasus Airfield, had the fifth warmest

*Table 2. Field season temperatures and statistics from Pegasus North AWS 1990–2012/2013 (a few years of data are missing from the record over the 23-year record due to occasional periods when the AWS was not working).*

| Month | 2012/2013 Field Season Monthly Average | Mean Monthly Average (1990–2012/2013) | Comments |
|---|---|---|---|
| November | −12.0°C | −10.3°C | |
| December | −2.4°C | −3.7°C | Tied for 5th warmest with Dec. 1990 |
| January | −3.9°C | −4.6°C | Tied for 6th warmest with Jan. 2002 |
| February | −11.9°C | −11.8°C | |

December, tied with December 1990, over a 23 year observing period (1990–2012) followed by the sixth warmest January, tied with January 2002 (See Table 2). The mean temperatures were warmer than the long term running mean over the observing period in both December (1.4℃) and January (0.7℃), when observations were available during the period. These warmer conditions combined with volcanic dust blown over the snow surfaces created melted snow surface conditions that impacted logistical operations. We are currently investigating the meteorological significance of such a melt event in a follow up study. The poor runway conditions, combined with programmatic constraints (e.g., limited resources and logistics in the field), made it difficult to complete all of the fieldwork aimed for in the season.

### *6.2. Successes and Lessons Learned*

Despite all of the challenges encountered,, this field season met a threshold of visiting 50 % of planned AWS sites, a modest level of serviced and repaired AWS sites and one new AWS installed. Lessons learned included a reminder of the necessity of patience and flexibility in Antarctic fieldwork. Upcoming field seasons aiming for more definitive scheduling, will keep primary goals in mind, with secondary ones planned. Targeting a visit to at least one AWS per region of the continent per field season for needed fieldwork allows at least one AWS to be working to capture the climate of the region. Being able to maintain regional measurements with at least one recently serviced and working AWS in the area can be important for filling any gaps in nearby AWS time series if failures occur (e.g., Reusch and Alley, 2004). From an operational standpoint, maintaining some AWS sites is crucial for providing accurate weather forecasts. From a climatological standpoint, gaps in data records cause significant difficulty in applying the data to various research problems. At specific AWS sites, maintaining AWS sensor heights above the snow surface is vital as well (Ma *et al.*, 2011).

## 7. AWS Data Availability and Applications

### *7.1. AWS Data Availability*

Observations made by the AWS network are available via two temporal periods: real-time and archive. Real-time observations are made available via a series of methods. Observations are placed on the World Meteorological Organization's (WMO) Global Telecommunications System (GTS), as a subset of the network is designated as WMO stations. The British Antarctic Survey places the remaining AWS observations on the GTS as synoptic mobile messages. Real-time observations are decoded by the AMRC at the University of Wisconsin as well as on site at Palmer Station and McMurdo Station where direct broadcast facilities and data streams are available. The data are then posted to the AMRC web site (http://amrc.ssec.wisc.edu/). The observations are displayed as text listings, time series meteorograms and plotted on maps. Other methods used to distribute the real-time observations include the Abstract Data Distribution Environment (ADDE) data server, accessible by a variety of meteorological analysis software. Also, the data are relayed over the Antarctic-IDD using the LDM software.

Historical and official archived AWS data are available primarily from the AMRC file transfer protocol (FTP) site (ftp://amrc.ssec.wisc.edu/pub/aws). The data are provided in quality controlled and raw formats. Raw observations are available with a temporal spacing of 10 minutes. Quality controlled observations are made available with a temporal spacing of 3 hours, and in most cases since 2010 in 1 hour and 10 minute time spacing. An e-mailing list is used to notify the community of updates and changes to the archive collection. Anyone can subscribe to the mailing list—found at the bottom of the AMRC Contact Us web page (http://amrc.ssec.wisc.edu/contactus.html). Additional means for providing the archive quality AWS observation have been tested, including AMRC's repository for archiving, managing and accessing diverse data or RAMADDA server. Unfortunately at the time this paper was submitted, this server system was not operational at the AMRC, but a version of this or something like this may be in the coming year. Plans include releasing an AWS observational data gateway to provide the community easy access to the AWS observational collection.

### *7.2. Sample AWS Applications*

There is a range of applications for AWS observations among the community. Real-time weather forecasting is the number one operational use of the network. A variety of research utilizes observations from the network as well. In the past two years, approximately 15 peer-reviewed papers and a PhD thesis were published on projects have used AWS observations. Projects employing AWS observations included remote sensing of melt (e.g., Steiner and Tedesco, 2014) and validation of satellite observations (e.g., Das *et al*., 2014; Picard *et al*., 2013). Aspects of glaciological studies related to sediment transport and deposition utilized the AWS observations (Chewings *et al*., 2014). Wind systems were a focus of some papers including those in the McMurdo Dry Valleys (Speirs *et al*., 2013), and strong wind events at McMurdo Station (Chenoli *et al*., 2013). Boundary layer studies, with some centered on Dome C Antarctica (Champollion *et al*., 2013; Macelloni *et al*., 2013; Pietroni *et al*., 2014) and some in Adelie Land (Preunkert, *et al*., 2013), make use of the AWS. Other boundary layer studies using both AWS and unmanned aerial vehicles have also been published (Cassano, 2013). AWS observations have been used to gauge numerical model performance (Bromwich *et al*., 2013). Other publications included studies of the synoptic climatology of the Ross Ice Shelf and Ross Sea regions (Coggins *et al*., 2013); the impact of synoptic scale features on warming and precipitation at Dome Fuji Station (Hirasawa *et al*., 2013); and the synoptic variability of the Ross Sea region (Cohen, 2013; Cohen *et al*., 2013).

## 8. Summary and Concluding Remarks

One of the unique aspects of maintaining the AWS observational network is the necessity of fieldwork. A full time job in and of itself, keeping a network of 50 to 70 AWS systems operating even with international partners, requires a devoted effort of AWS fabrication and assembly team members doubling as repair and field personnel. Flying to remote places around the Antarctic continent and dealing with polar weather conditions makes maintenance a challenge. In summary, a partial season is counted as a successful season in Antarctica. Flexibility is key. One of the biggest needs for the AWS network is attempting to have a routine service and maintenance schedule. This is taken for granted at many mid-latitude automated weather stations, but very difficult to accomplish in remote locations such as the Antarctic continent. The two prior seasons were very successful efforts. In 2011–2012, goals of servicing were nearly fulfilled, with 21 of 25 planned sites visited/serviced. The season prior, 2010–2011, had a phenomenal success rate making all 27 planned AWS site visits (Lazzara *et al*., 2013). The 2012–2013 field season contrasts with only 15 of 25 sites visited due to weather and logistics. As indicated by the last three field seasons, not every field season can be as successful as the last, and planning for unexpected complications is important as we look forward to 2013–2014 field season.

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