Preface

The National Center for Atmospheric Research (NCAR) welcomes you to the 12th Workshop on Antarctic Meteorology and Climate (WAMC) in Boulder, Colorado, USA. The workshop brings together those with research and operational interests in Antarctic meteorology, weather forecasting, and climate. It serves as an international forum for current results and ideas on these topics and as a means for the community to share developments, discuss issues, and make plans. While the workshop has a meteorological focus, it welcomes others scientific disciplines with related Antarctic interests, such as glaciology and oceanography.

Prior to this year the WAMC was called the Antarctic Meteorological Observation, Modeling, and Forecasting Workshop (AMOMFW). The AMOMFW coalesced in 2006 from previously-separate annual meetings on the activities of the Antarctic Meteorological Research Center (AMRC), the Antarctic Automated Weather Station (AWS) program, and the Antarctic Mesoscale Prediction System (AMPS). The current workshop still covers the AMRC, AWS, and AMPS efforts, while having broadened to address international Antarctic activities and weather forecasting, logistical support, and related science. Presentations and discussions of interest to these programs, to Antarctic atmospheric researchers and weather forecasters, and to international Antarctic scientific efforts have been welcome. Over the years, workshop attendees have benefitted from the discussions on the shared issues and goals of the Antarctic meteorology and related communities.

We thank all of those who have submitted presentations and extended abstracts and who will attend the workshop. We look forward to active participation by all, in sessions that are informative and stimulating.

For this WAMC, special recognition is due to Ms. Kris Marwitz of NCAR for her handling of workshop support and logistics and to Ms. Yemaya Thayer and Ms. Terri Hamner of NCAR for their preparation of the workshop web pages.

The 12th Workshop on Antarctic Meteorology and Climate is locally organized and hosted by NCAR's Mesoscale and Microscale Meteorology Laboratory, which is supported by NCAR and the National Science Foundation. Travel funding has been provided by the Scientific Committee on Antarctic Research’s (SCAR) Expert Group on Operational Meteorology in the Antarctic (OpMet) and Standing Scientific Group for Physical Sciences (SSG-PS) and by the International Association of Meteorology and Atmospheric Sciences (IAMAS) through the International Committee on Polar Meteorology (ICPM). The WAMC committee worked over the year to plan and organize the workshop.

The Workshop on Antarctic Meteorology and Climate Committee
26 June 2017
WAMC Committee
Jordan G. Powers, National Center for Atmospheric Research (12th WAMC local host)
David H. Bromwich, The Ohio State University
Scott Carpentier, Australian Bureau of Meteorology
John J. Cassano, The University of Colorado
Arthur M. Cayette, Space and Naval Warfare Systems Center
Steven R. Colwell, British Antarctic Survey
Matthew A. Lazzara, Madison Area Technical College & The University of Wisconsin–Madison
12th Workshop on Antarctic Meteorology and Climate

National Center for Atmospheric Research, Foothills Laboratory
Boulder, Colorado, USA
June 26–28, 2017

Talks: 20 min (including time for questions)

Monday, June 26

0900–0910 Opening Remarks

Information: Jordan G. Powers, NCAR

Welcome: Dr. Christopher A. Davis, Director, Mesoscale and Microscale Meteorology Laboratory, NCAR

0910–1050 Antarctic Observational and Logistical Efforts 1

Chairperson: Jordan G. Powers

Carol A. Costanza¹, Lee Welhouse¹, David E. Mikolajczyk¹, Matthew A. Lazzara¹,³, George Weidner¹, and Linda M. Keller¹,²
¹Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin–Madison
²Department of Atmospheric and Oceanic Sciences, University of Wisconsin–Madison
³Department of Physical Sciences, Madison Area Technical College

British Antarctic Survey Automatic Weather Station Network 2017/18 Field Season Review
Rosey Grant, Steven R. Colwell, John Law, and Mairi Simms
British Antarctic Survey

The Challenges of Maintaining a Meteorology Program on a Floating Ice Shelf
Steven R. Colwell
British Antarctic Survey

Enhanced Year Round Observations at the Korean Jang Bogo Station, Terra Nova Bay
Taejin Choi, Sangbum Hong, Sangjong Park, Jaeill Yoo, Won-Seok Seo, and Seo-Hee Ahn
Korea Polar Research Institute

Thirty Years of Meteorological Data Observed at the Korean Antarctic King Sejong Station
Sang-Jong Park, Tae-Jin Choi, Bang-Yong Lee, and Seong-Joong Kim
Korea Polar Research Institute

1050–1105 Break
**1105–1225 Antarctic Observational and Logistical Efforts 2**  
Chairperson: Steven R. Colwell

*The Future Wisconsin AWS Field Season Plans*  
Matthew A. Lazzara¹,², Carol Costanza¹, Lee Welhouse¹, David Mikolajczyk¹, Marian Mateling¹, Andrew Kurth², and George Hademenos³  
¹Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin–Madison  
²Madison College  
³Richardson High School

*Remote and Autonomous Measurements of Precipitation in Antarctica*  
Mark W. Seefeldt¹, Scott D. Landolt², and Andrew J. Monaghan²  
¹University of Colorado–Boulder  
²National Center for Atmospheric Research

*The Madison Antarctic Automatic Weather Station: The Next Generation Polar Climate and Weather Station*  
Matthew A. Lazzara¹,², Andrew Kurth¹, Amy Limberg-Dzekute¹, Taylor Norton¹, Forbes Filip¹, Cris Folk¹, Joel Shoemaker¹, Alberto Rodriguez¹, Lee Welhouse², David Mikolajczyk², Carol Costanza², George Weidner², Linda Keller², and Rikki Decklever¹  
¹Madison College  
²Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin–Madison

*Exploring the Costs of UHF Transmissions in the UW–Madison AWS Network*  
David E. Mikolajczyk and Lee J. Welhouse  
University of Wisconsin–Madison

**1230–1400 Lunch**

**1400–1520 Antarctic Numerical Prediction and Modeling 1**  
Chairperson: Scott Carpentier

*Just Launched: The Year of Polar Prediction*  
Kirstin Werner, Thomas Jung, Helge Goessling, Winfried Hoke, and Katharina Kirchhoff  
International Coordination Office for Polar Prediction and Alfred Wegener Institute

*Antarctic Verification of the Australian Weather Forecast Model*  
Benjamin J. E. Schroeter¹, Phil Reid², Nathaniel L. Bindoff³, and Kelvin Michael⁴  
¹Institute for Marine and Antarctic Studies (IMAS), Antarctic Gateway Partnership (AGP), Australian Research Council Centre of Excellence for Climate System Science (ARCCSS)  
²Australian Bureau of Meteorology, Antarctic Climate & Ecosystems Cooperative Research Centre (ACECRC), AGP, IMAS  
³IMAS, ACECRC, ARCCSS, Commonwealth Scientific and Industrial Research Organisation  
⁴AGP, IMAS
AMPS Update 2017
Kevin W. Manning and Jordan G. Powers
Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research

Assessment of the Model for Prediction Across Scales (MPAS) in AMPS
Jordan G. Powers and Kevin W. Manning
Mesoscale and Microscale Meteorology Laboratory, National Center for Atmospheric Research

1520–1540 Break

1540–1700 Antarctic Numerical Prediction and Modeling 2
Chairperson: Kevin W. Manning

Testing the Impact of Assimilation of Additional Radiosonde and UAV Observations from the Southern Ocean in WRF
Qizhen Sun¹ and Timo Vihma²
¹National Marine Environmental Forecasting Center
²Finnish Meteorological Institute

Development of WRF-Ice for Surface Mass Balance Modeling over Antarctic Peninsula
Gian Villamil-Otero¹, Jing Zhang¹, and Yao Yao²
¹North Carolina A&T State University
²Nanjing University of Information Science and Technology

Verification of the Regional Climate Model CCLM in the Weddell Sea Region
Günther Heinemann and Rolf Zentek
Environmental Meteorology, University of Trier

Climate Change in Antarctica: On the Contribution of Global Climate Model with a High Regional Resolution
Julien Beaumet¹, G. Krinner¹, G. Le Normand¹, and M. Déqué²
¹Institut des Geosciences de l'Environnement, CNRS, UGA
²Météo-France

1700 Adjourn

Tuesday, June 27

0900–1020 Antarctic Observational and Modeling Studies 1
Chairperson: Mark W. Seefeldt

Meridional Moisture Transport in Antarctica as Seen by Satellite and a Regional Model
Tsukernik Maria¹ and Matthew A. Lazzara²
¹Brown University
Evaluating Precipitation in a Regional Climate Model Using Ground-Based Remote Sensing Measurements at Princess Elisabeth Station, Dronning Maud Land, East Antarctica
Irina V. Gorodetskaya1,2, Maximilian Maahn2, Hubert Gallée3, Niels Souverijns2, Stefan Kneifel3, Annick Terpstra1, Tiago Silva1, Susanne Crewell5, and Nicole P.M. Van Lipzig2
1Center for Marine and Environmental Sciences, Dept. of Physics, University of Aveiro, 2Katholieke Universiteit Leuven, Earth and Environmental Sciences 3NOAA/ESRL Physical Sciences Division 4Laboratoire de Glaciologie et Géophysique de l'Environnement 5University of Cologne, Institute for Geophysics and Meteorology

Role of Low-level Jets in the Enhanced Moisture Transport Towards Antarctica from Radiosonde Measurements at the Coastal Stations and Southern Ocean
Tiago Silva1, Irina V. Gorodetskaya2, Annick Terpstra2, Alfredo Rocha2, Pascal Graf3, Iris Thurnherr3, Heini Wernli3, Maria Tsukernik4, and F. Martin Ralph5
1Dept of Physics, University of Aveiro 2Center for Marine and Environmental Sciences, Dept. of Physics, University of Aveiro 3ETH Zurich 4Brown University 5Scripps Institution of Oceanography, UC San Diego

A Case Study of Intense Moisture Transport and Precipitation over the East Antarctic Ice Sheet and Southern Ocean
Annick Terpstra and Irina V. Gorodetskaya
University of Aveiro

1020–1100 Break and Poster Session

Poster: Mechanism of Record-Breaking Strong Wind Event at Syowa Station in January 2015
Kyohei Yamada and Naohiko Hirasawa
National Institute of Polar Research, Japan

Poster: Antarctic Extremes: Support for the Next Generation Polar Weather and Climate Station
Taylor P. Norton and Matthew A. Lazzara
Department of Physical Sciences, Madison Area Technical College

Poster: Measuring and Modeling Ice Supersaturation at Dome C
Jean-Baptiste Madeleine1, C. Genthon2, E. Vignon2, F. Hourdin1, F. Lemonnier1, H. Gallée2, and L. Piard2
1Laboratoire de Météorologie Dynamique/l’Institute Pierre Simon Laplace 2Institute des Géosciences de l’Environnement

Poster: Synergetic Study of the Radiative Properties of Antarctic Blowing Snow with CALIOP,
CERES, MODIS and Dropsonde Observations
Yuekui Yang, Manisha Ganeshan, Steve Palm, and Alexander Marshak
NASA/Goddard Space Flight Center

Poster: Antarctic Meteorology Broader Impacts with Students
Carol A. Costanza\(^1\) and Matthew A. Lazzara\(^{1,2}\)
\(^1\)Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin– Madison
\(^2\)Department of Physical Sciences, Madison Area Technical College

Poster: Antarctic-Wide and Long-Term Detection of the Atmospheric Rivers and their Relevance to Antarctic Precipitation
Irina V. Gorodetskaya, Rui Pedro Silva, and Annick Terpstra
CESAM–Center for Marine and Environmental Sciences, University of Aveiro

1100–1200 Community Discussion: Issues in the American Antarctic Meteorological Observation Effort
Chairpersons: Matthew A. Lazzara and Jordan G. Powers

USAP Meteorological Cyberinfrastructure
Matthew A. Lazzara and Carol Costanza
Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin– Madison

1200–1340 Lunch

1340–1500 Antarctic Forecasting and Event Studies
Chairperson: Michael D. Johnson

Meteorological Support for Air Drop Operation over the Argentinian Base Belgrano II
Marc de Keyser
Antarctic Logistics and Expeditions

Applying a Random Forest Classification Model for Fog at Pegasus Airfield
Joey Snarski
Scientific Research Corporation

Freezing Fog and Freezing Rain Events at Casey and Davis in 2017
Scott Carpentier
Australian Bureau of Meteorology

New Analysis of the Near-Surface Air Temperature in King George Island as Revealed by Frei Station
Jorge F. Carrasco
Universidad de Magallanes
1500–1520  Break

1520–1640  Antarctic Observational and Modeling Studies 2
Chairperson: Maria Tsukernik

_Tropical Drivers of the Antarctic Atmosphere_
Bradford S. Barrett and Gina R. Henderson
United States Naval Academy

_Cloudy Windows: What GCM Ensembles, Reanalyses and Observations Tell Us about Uncertainty in Greenland’s Future Climate and Surface Melting_
David B. Reusch
New Mexico Institute of Mining and Technology

_Contribution of Foehn Effect to the January 2016 West Antarctic Melt Event_
Byrd Polar and Climate Research Center, The Ohio State University

_Observational and Model Based Analysis of Extreme Temperature Event in March 2015 in the Antarctic Peninsula_
Deniz Bozkurt¹, Roberto Rondanelli², René Garreaud², and Julio C. Marín³
¹Center for Climate and Resilience Research, University of Chile
²Center for Climate and Resilience Research, Department of Geophysics, University of Chile
³Department of Meteorology, University of Valparaiso

1700 Adjourn

1830 Workshop Dinner— B.J.’s Restaurant and Brewhouse

Wednesday, June 28

0900–1020  Measurement and Observation Applications
Chairperson: David H. Bromwich

_The Infrared Radiative Impact of Antarctic Clouds_
Penny Rowe¹, Von Walden², Christopher Cox³, and Steven Neshyba⁴
¹NorthWest Research Associates
²Washington State University
³NOAA Earth System Research Laboratory
⁴University of Puget Sound

_Improved Derivation of Ice Water Content and Particle Morphology from Cloud Particle Imagery and Future Application to Southern Ocean Clouds_
Saisai Ding¹, Greg McFarquhar¹, Joseph Finlon¹, Stephen Nesbitt¹, Paloma Borque¹, and Michael R. Poellot³
¹University of Illinois
New Possibilities for Climate Model Validation and Improvement in AWARE Data from WAIS Divide and Ross Island
Dan Lubin¹, Ryan Scott¹, Lynn Russel¹, Maria Cadeddu², Israel Silber³, Johannes Verlinde³, Andrew Vogelmann⁴, and David Bromwich⁵
¹Scripps Institution of Oceanography
²Argonne National Laboratory
³The Pennsylvania State University
⁴Brookhaven National Laboratory
⁵Byrd Polar and Climate Research Center, The Ohio State University

New Insights into the January 2016 West Antarctic Melt Event from the AWARE Campaign and Climate Model Simulations
Julien P. Nicolas¹, Andrew M. Vogelmann², Ryan C. Scott³, Aaron B. Wilson¹, Maria P. Cadeddu⁴, David H. Bromwich¹, Johannes Verlinde⁵, Dan Lubin³, and Lynn M. Russell³
¹Byrd Polar and Climate Research Center, The Ohio State University
²Brookhaven National Laboratory
³Scripps Institution of Oceanography
⁴Argonne National Laboratory
⁵The Pennsylvania State University

1020–1035 Break

1035–1155 Observational and Modeling Studies 3
Chairperson: Matthew A. Lazzara

Snowfall Microphysical Observations in the Antarctic Sea Ice Zone
Katherine Leonard¹,²,³, Ted Maksym⁴, Michael Lehning¹,³, Ernesto Trujillo¹,³, Yvonne Weber¹, Nander Wever¹,³, and Seth White²
¹École Polytechnique Fédérale de Lausanne
²University of Colorado, Boulder
³Swiss Federal Institute for Forest, Snow and Landscape Research SLF (WSL-SLF)
⁴Woods Hole Oceanographic Institution

Overview of the GABLS4 Model Inter-Comparison
E. Bazile, F. Couvreux, and P. Le Moigne
Météo-France/CNRS

Investigating Temperature Trends Across the Southern High-Latitudes
Megan E. Jones, David H. Bromwich, and Julien P. Nicolas
Byrd Polar and Climate Research Center, The Ohio State University

An Overview of the Activities and Resources Produced by the SCAR OpMet Expert Group
Steven R. Colwell
British Antarctic Survey

1200 Workshop Adjourn
12th Workshop on Antarctic Meteorology and Climate

Extended Abstracts
THE UW-MADISON 2016-2017 ANTARCTIC AUTOMATIC WEATHER STATION PROGRAM
FIELD SEASON: McMURDO AWS AND INTERNATIONAL COLLABORATION

Carol A. Costanza¹, Lee Welhouse¹, David E. Mikolajczyk¹, Matthew A. Lazzara¹,³, George
Weidner¹, and Linda M. Keller¹,²

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   College, Madison, WI

http://amrc.ssec.wisc.edu

1. OVERVIEW

The University of Wisconsin-Madison (UW-Madison) has overseen the Antarctic Automatic Weather Station (AWS) network since 1980. The AWS network currently consists of approximately 56 AWS (Figure 1). In this first year of the current AWS grant, a field team serviced 15 AWS from McMurdo. Lee Welhouse, David Mikolajczyk, and Carol Costanza were on the ice from November 2016 through mid-December 2016. Highlights from this field season include completing the conversion of Linda transmissions from UHF to Iridium, and installing new power systems at a variety of AWS. This season also included collaboration with the French, British, and USAP. Overall, the 2016-2017 field season was successful, albeit short.

2. UW-MADISON FIELD SEASON

Lee, Dave, and Carol arrived in Antarctica on 27 October 2016. Their first AWS visit was to Marble Point and Marble Point II on 5 November, where both the AWS were in great shape. On 7 November, they drove to Pegasus North to remove the enclosure to diagnose the problems with the temperature sensor. On 8 and 9 November, they took helicopter flights to White Island for inspection, and Cape Bird and Minna Bluff to replace their aerovanes. They continued to do field work out of McMurdo through November. They completed flights to Laurie II, Emma, Willie Field, and Schwerdtfeger to replace their power systems. Schwerdtfeger was difficult to find since we hadn’t been there for about 4 years, and the AWS also needed a raise. Finally, Windless Bight was raised and replaced with a new power system as well.

In the first week of December, Pegasus North was replaced after fixing the half bridge for the temperature sensor. At Alexander Tall Tower!, the power system and instrument booms were raised with help by the riggers. On 8 and 9 December, Linda was very successfully converted to Iridium transmissions, and Lorne had its pressure sensor replaced.

3. COLLABORATIVE FIELD SEASON

On 17 December 2016, D-10 was raised and fixed by Philippe Dordhain and his team. Then on 5 January 2017, D-47 was raised and the power system was also replaced by Philippe Dordhain and his team. After a few years of waiting, Rosey Grant and her team were able to get to Dismal Island on 5 February 2017 to replace the AWS with a CR1000 and new instrumentation. On 4 March 2017, UNAVCO and their team were able to remove Hugo Island while servicing their GPS station. Finally, on 26 April 2017,
the ASC staff from Palmer Station removed Bonaparte Point. Unfortunately, Dismal Island is now the only Wisconsin AWS on the Antarctic peninsula.

4. ACKNOWLEDGMENTS

The authors wish to thank the NSF, ASC, PHI, Ken Borek Air, PGC, NYANG, USAF and others within the USAP for their support of this field season’s efforts. This material is based upon the work supported by the National Science Foundation grant number ANT-1543305.

**Figure 1:** A map of UW-only AWS, as of the end of the 2016-17 field season.
THE FUTURE WISCONSIN AWS FIELD SEASON PLANS

Matthew A. Lazzara1,2, Lee J. Welhouse1, David E. Mikolajczyk1, Carol A. Costanza1, Marian Mateling1, Andrew J. Kurth1 and George Hademenos4

1Antarctic Meteorological Research Center, Space Science and Engineering Center, University of Wisconsin-Madison Madison, WI
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4Science Department, Richardson High School, Richardson, TX

http://amrc.ssec.wisc.edu/

1. OVERVIEW

The 2017-2018 field season for the Wisconsin Antarctic Automatic Weather Station (AWS) field season will have several facets to it, as most field seasons do (Lazzara et al., 2012; Lazzara et al., 2015). Work will be based out of West Antarctica and McMurdo Station, Antarctica. Deployment to South Pole to service stations near the Pole has not been approved for this coming season (See Map 1). With this, a rolling team of two members will be deployed on the ice at all times, with a group of two turning over to a new group of two throughout the season. This presentation will outline the team members deploying, the addition of a PolarTREC teacher to the group, and additional new participants. Work will focus on weather station repairs, raising AWS sites with high accumulation, and the installation of a new AWS site at Phoenix Airfield. Modifications will be made to run some tests at Willie Field AWS in support of the new MRI project. Community feedback and comments will be welcome during and after this presentation.

2. WEST ANTARCTICA

There are several AWS locations that need servicing this season. The newest AWS sites in the region, Austin and Kathie AWS (see Figure 1), are slated to be visited due to expected high accumulation. Servicing the coastal AWS in the region – specifically Bear Peninsula, Thurston Island and Evans Knoll – is also on the list. Raises are needed at Janet AWS site and Kominko-Slade (WAIS) AWS site. A visit to Harry AWS site is a possibility to investigate pressure sensor anomalies.

Figure 1. Kathie AWS from its Jan. 2016 installation.

3. ROSS ICE SHELF

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Several sites on the Ross Ice Shelf will be visited this season. Gill AWS site was not visited last year and will be important to check due to historical pressure measurement problems. Raisers will be conducted at Sabrina and Elaine AWS (See Figure 2) sites.

Alexander Tall Tower! AWS will be visited to have a check-up. Riggers will visit to confirm that the tower is properly guyed, etc. This visit may be done in conjunction with Mark Seefeldt’s precipitation project.

![Elaine AWS from its last visit in 2015.](image)

**Figure 2. Elaine AWS from its last visit in 2015.**

### 4. MCMURDO AREA

Standard servicing and check-ups will be conducted at Cape Bird, Marble Point, Minna Bluff, White Island, and Lorne. With help from the riggers, Windless Bight will have a new tower installed. A new station will be installed at Phoenix Airfield, in support of Mark Seefeldt’s precipitation project. Additional AWS testing equipment will be installed at Willie Field AWS test site in support of the new NSF MRI joint project between Madison College and UW-Madison.

### 5. FUTURE

Both Pegasus North AWS and new AWS at Phoenix Air Field will be running at the same time. After a 1- to 2-year test, Pegasus North AWS may be removed to avoid the station melting out. Comments on this are welcome from the community regarding plans to remove Pegasus North.

The general transmission scheme in the McMurdo Area is in flux due to challenges in the VHF transmissions. More on this will be presented at this workshop (Mikolajczyk et al., 2017).

### 6. ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation, Directorate for Geosciences, Office of Polar Programs, under Grant PLR-1543305.

### 6. REFERENCES


THE MADISON ANTARCTIC AUTOMATIC WEATHER STATION: THE NEXT GENERATION POLAR CLIMATE AND WEATHER STATION

Matthew A. Lazzara¹,², Andrew J. Kurth², Amy A. Limberg-Dzekute¹, Taylor P. Norton¹, Forbes A. Filip², Cris C. Folk², Joel B. Shoemaker², Alberto Rodriguez², Rikki Decklever¹, Joey Miller², Tristan L’Ecuyer⁴, Lee J. Welhouse³, David E. Mikolajczyk³, Carol A. Costanza³, George A. Weidner³,⁴, and Linda M. Keller³,⁴

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1. OVERVIEW

Madison Area Technical College (Madison College) has, within its over 100-year existence, a 25-year history of teaching weather and climate courses to the South-Central Wisconsin community. The College serves a 12-county district and hosts over 40,000 students. Enrollment since the mid-2000s has increased five-fold in freshman/sophomore level weather & climate, weather & climate laboratory, and climate & climate change course areas. In addition, the College offers a variety of program majors including, but not limited to areas such as electronics and electrical engineering technology.

The University of Wisconsin-Madison, a well-known hub for atmospheric sciences, satellite meteorology and climate science, has a long tradition as one of the centers of Antarctic meteorological study and research in the United States. With a 38-year emphasis on Antarctic Automatic Weather Stations (AWS) and with installations across the entire Antarctic continent at over 60 locations, the Wisconsin AWS network constitutes over half of the surface observing network in the Antarctic (Lazzara et al., 2012).

A synergy has arisen between the University of Wisconsin-Madison and Madison College with a focus on the development of the next generation Antarctic AWS at Madison College. With expertise in Antarctic meteorology, electronics, and field experiences spanning 4 decades, a partnership between students and young scientists are a central theme and at the forefront of the development of a next generation polar climate and weather station. This presentation will provide an overview of the polar climate and weather station where project goals, impacts for students directly involved in the project, and impacts for students in the classroom will be outlined.

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Implications for future community use and benefits will also be discussed.

2. ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation, Office of Integrative Activities, Major Research Instrumentation Program, Directorate for Geosciences, Office of Polar Programs, under Grant PLR-1625904.

3. REFERENCES

1. OVERVIEW

The Antarctic climate and weather is one of the most extreme on Earth, and has been the focal point of study for decades. In order to capture those observations, the Automatic Weather Stations (AWS) have been built to withstand the intensely harsh environment. As time passes by, more advanced technology needs to be put into place to improve the observations of that extreme environment. The UW-Madison AWS network is one of several AWS networks on the Antarctic continent, and it is also one of the earliest installed that dates back to the 1980’s (Lazzara et al. 2012). Today, the original homemade manufactured electronic core from that original network can no longer be manufactured and is outdated. While the widespread use of commercial off the shelf (COTS) stations has been a good replacement for the homemade electronics, these COTS systems are not specifically made for polar climates and have their quirks. To aid in the electronic design of the next generation AWS, extreme weather conditions will be assessed from the existing AWS network. These findings will be applied toward the construction of polar climate and weather stations that can last longer and work better in this harsh environment.

2. EXTREMES

This poster presentation goes through the extreme weather conditions that different AWS have observed around the continent, including record high and low temperatures and wind speeds (highs); long durations of cold temperatures, high relative humidity, and high wind speeds; and dramatically rapid changes in temperature, relative humidity, and wind speed. Some of the major findings include a rapid change in temperature of 5.5°C in 10 minutes (see Figure 1), a rapid change in relative humidity of 54% in 50 minutes (see Figure 2), and a rapid change in wind speed of 34.6 m/s in 10 minutes (see Figure 3).

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3. FUTURE EFFORTS

Going forward, there needs to be more analysis done to more completely capture the extremes and rapid changes observed in historical observations. Future work will include looking through more years of observations 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.

5. ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation, Major Research Instrumentation, Directorate for Geosciences, Office of Polar Programs, under Grant PLR-1625904.

6. REFERENCES

EXPLORING THE COSTS OF UHF TRANSMISSIONS IN THE UW-MADISON AWS NETWORK

David E. Mikolajczyk¹,¹, Lee J. Welhouse¹, Matthew A. Lazzara¹,³, Carol A. Costanza¹, George Weidner¹,², Linda M. Keller¹,², and Jonathan E. Thom¹

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1. OVERVIEW

Beginning in late 2011, the University of Wisconsin-Madison (UW) Automatic Weather Station (AWS) Program (Lazzara et al. 2012) began switching their AWS in the McMurdo region from satellite transmissions to Ultra High Frequency (UHF) radio transmissions. Currently, there are 8 AWS that transmit using UHF (Fig. 1). This line-of-site option is cheaper to use than satellite relay methods and allows more bytes per transmission to be sent. Additionally, these AWS can report during periods when satellite data is unavailable in a timely manner for current weather conditions. Despite these advantages, numerous issues have been experienced since the inception of the UHF network. This presentation will explore these issues and take community input on future development of this segment of the network.

2. ISSUES

Some of the issues encountered with the UHF transmission system include multiple single-points of failure. Due to topography, White Island is used as a repeater site for Lorne, and Marble Point II is a repeater site for Cape Bird. If a repeater site fails, then the Antarctic Meteorological Research Center (AMRC) at UW is unable to receive data from downstream AWS. Other issues revolve around the need for the data to be sent via Local Data Manager (LDM) on a computer connected to the McMurdo internet. As has been experienced, disruptions in the McMurdo internet connection (power outages, etc.) disrupt the UHF data transmissions to UW, which can lead to missing data.

Anomalous pressure observations have been seen from some UHF AWS. Pressure “jumps” of 0.5 to 1 hectoPascal in 10 minutes have been observed at Minna Bluff, Willie Field, and Windless Bight. Since these jumps seem to coincide with powering on the UHF modem for transmission, it is hypothesized that powering on the modem can lead to anomalous pressure observations. Further investigation here is needed to determine the cause of this issue.

3. CONCLUSIONS

The cost-saving benefits and timeliness of UHF transmissions do not seem to outweigh the ongoing monitoring costs and burdens of maintaining the network. If it is wished to revert the UHF network back to satellite transmissions, however, this will invariably
incur a monetary cost in purchasing the necessary equipment and doing the necessary field work to install the equipment. Community input is encouraged here on future developments of this segment of the AWS network.

4. ACKNOWLEDGEMENTS

This material is based upon work supported by the National Science Foundation, Directorate for Geosciences, Office of Polar Programs, under Grant ANT-1543305.

5. REFERENCES

1. INTRODUCTION

The Antarctic Mesoscale Prediction System (AMPS) is a real-time numerical weather prediction capability that provides guidance for the forecasters of the U.S. Antarctic Program (Powers et al. 2012). AMPS also supports scientific field campaigns, researchers and students, and international Antarctic efforts. While AMPS has used the Weather Research and Forecasting (WRF) Model (Skamarock et al. 2008) for its forecasts and products since 2006, AMPS has begun running the Model for Prediction Across Scales (MPAS) (Skamarock et al. 2012). MPAS is an emerging global model that was designed to capture atmospheric evolution down to the cloud (i.e., nonhydrostatic) scales. It offers global coverage with either uniform or variable-resolution grids, with the latter achieved via mesh refinement over user-selected regions.

Unlike WRF with its rectangular grid, MPAS has an unstructured mesh composed of varied polygons (predominately hexagons). Figure 1 presents an example of an MPAS variable-resolution mesh with a finer grid over East Asia. NCAR supports the MPAS atmospheric model to the community, and the current version is 5.1. MPAS has been applied for research (Park et al. 2014) as well as real-time forecasting (e.g., Clark et al. (2012)).

AMPS’s implementation of MPAS not only provides the USAP forecasters with another source of NWP guidance, but also serves for testing and evaluation of this new capability over the high latitudes. This study pursues that, and here for varying seasons are analyzed and compared. Previous preliminary work (Powers and Manning 2016) looked at a limited span of MPAS runs that were available in 2016, when the model had not yet been running long in AMPS. Furthermore, the forecasts considered were not cleanly separated into summer and winter. With a year of MPAS operation completed in AMPS, however, the current work examines the seasonal differences and, for the first time, evaluates the upper-air performance of MPAS over Antarctica. Here MPAS and WRF forecasts are compared to inform the developers, forecasters, and Antarctic NWP community an idea of where MPAS stands for polar applications.

2. MODEL SETUPS AND FORECAST VERIFICATIONS

The WRF forecasts compared with those of MPAS are from AMPS’s regular five-domain nested setup. Figure 1 shows these domains. Since the nests are two-way, the WRF results reflect the finer-grid values for locations covered by a nest. In contrast, MPAS cannot be run with standalone, limited-area domains: it requires a global grid. MPAS does allow for regional refinement, however, so that a target area can have finer resolution (Fig. 1). Thus, here MPAS is run with a global 60-km mesh that decreases to 15 km over Antarctica. The MPAS forecast information verified over the continent therefore reflects a 15-km horizontal mesh.
Another model setup difference due to computing constraints is in the number of vertical levels. While WRF in AMPS has 60 half-levels, MPAS has 45. The model tops are about the same, however. For MPAS this is 30 km (~12 mb), while for WRF it is 10 mb (~31 km). Both models are run out to five days from 0000 UTC and 1200 UTC initializations.

Both models use the NCEP Global Forecast System (GFS) forecasts for their first-guess fields and for boundary conditions. However, as noted above, the WRF runs reflect a data assimilation (DA) step using a hybrid 3DVAR-ensemble approach, while no DA/reanalysis is done in MPAS.

The model codes used are WRF Version 3.7.1 and MPAS Version 4.0. WRF contains polar modifications (see, e.g., Hines and Bromwich 2008) to better capture the characteristics and conditions of the high latitudes, and these are available to both WRF and MPAS to the extent of the code version used. The physics schemes available in MPAS are a subset of those in WRF, as not all of the WRF physics are available in MPAS. For some processes the schemes are the same, although the scheme versions differ. For example, the WRF physics are from WRF Version 3.7.1, while the available packages in MPAS are from WRF Versions 3.3‒3.5. Table 1 lists the physics options used. The shared packages are the Noah land surface model, Kain-Fritsch cumulus parameterization, the RRTMG longwave radiation scheme, and the Eta/MYJ surface layer scheme.

To illuminate seasonal model performance and differences, austral winter and summer periods have been reviewed: July–August 2016 and December 2016–January 2017. For these, AWS and surface reports are used to verify surface temperature, pressure, and wind speed forecasts. For a third period, reflecting autumn (April–May 2017), upper-air verifications and error comparisons are performed. The upper-air verification was not done for the prior winter and summer periods because the capability for saving the upper-air profiles for the real-time WRF and MPAS runs was not in place when the operational runs were made.

3. RESULTS

a. MPAS and WRF—Forecast Behavior Overview and Model Consistency

Before digging into error statistics, it is important to begin with a wider view and consider the forecasts synoptically. To this end, and for verifying the basic
consistency of WRF and MPAS over Antarctica, forecasts have been subjectively compared on a regular basis from the real-time runs. As found in Powers and Manning (2016), MPAS and WRF evolve quite similarly through the first two days, with increasing divergence in the latter part of the forecast (day 3+). With some track record of operational implementation in AMPS, we begin by noting that MPAS is no longer an unknown. It has been providing consistent forecasts and is well-behaved/stable.

### Tab. 1: Physics options used in MPAS and WRF runs. While a number of schemes are the same, the versions of the schemes are not.

<table>
<thead>
<tr>
<th>WRF &amp; MPAS Physics</th>
<th>Shared</th>
<th>Different</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>• LSM Noah (MPAS V3.3.1, WRF V3.7.1)</td>
<td>• PBL WRF: MYJ MPAS: YSU</td>
</tr>
<tr>
<td></td>
<td>• Cumulus Kain-Fritsch (MPAS V3.5, WRF V3.7.1)</td>
<td>• Microphysics WRF: WSM-5 MPAS: WSM-6</td>
</tr>
<tr>
<td></td>
<td>• LW radiation RRTMG (MPAS V3.4.1, WRF, V3.7.1)</td>
<td>• SW radiation WRF: Goddard MPAS: RRTMG</td>
</tr>
<tr>
<td></td>
<td>• Surface layer (Eta) (MPAS V3.5, WRF, V3.7.1)</td>
<td></td>
</tr>
</tbody>
</table>

We present one case here as an example of how MPAS and WRF can compare. Figures 3(a) and 3(b) show WRF and MPAS forecasts from the 1200 UTC 1 June 2017 initialization. At hour 96, the WRF (Fig. 3(a)) and MPAS (Fig. 3(b)) SLP and 3-hourly precipitation fields parallel each other. First, all pressure centers in MPAS have counterparts in WRF—neither model is generating or evolving features absent in another. Second, in this example the depth and placement of all centers in and around the continent is consistent. There is a pair of lows in the northeastern Ross Sea and Amundsen Sea, marked L1 and L2. The depth of L1 is 963 mb in both, while L2 is 968 mb in WRF and 970 in MPAS. Compared with the AMPS analysis for this time (1200 UTC 5 June 2017) (Fig. 3(c)), both runs are accurate, with the analyzed depth of L1 at 958 mb. Similar correspondences can be seen in the other centers around the continent.

The third point to note is the similarity in accumulated precipitation associated with each system in the forecasts. The areas labeled A, B, and C are examples. The shading is consistent (scale to right), and thus the models are producing comparable amounts of precipitation.

**Fig. 3:** WRF and MPAS 96-hr forecasts for 1200 UTC 5 June 2017 (1200 UTC 1 June 2017 initialization) and analysis. Sea level pressure (contoured, interval= 4 mb) and 3-hourly precipitation (mm, scales to right) shown. Low L1 and L2 and precipitation areas A, B, and C referred to in text. (a) WRF. (b) MPAS. (c) AMPS analysis for 1200 UTC 5 June 2017.
### b. Verification Statistics

As noted in Sec. 1, for all three periods (Winter 2016, Summer 2016–2017, and Autumn 2017) verifications of surface parameters (temperature, pressure, and wind speed) are performed. These are based on AWS and station data from approximately 70 sites. For the first time for MPAS over Antarctica, we have also performed upper-air verification. We do this for the autumn 2017 period mentioned in Sec. 2, using the approximately 12 active radiosonde sites in Antarctica. For all parameters examined, statistical significance testing has been done on the differences in model bias errors.

![Figure 4](image-url)

**Fig. 4**: Surface temperature forecasts and error statistics for MPAS and WRF at McMurdo. Top panel: Observations (green), MPAS forecast (red) temperatures, and WRF forecast (blue) temperatures. Bottom left: Average errors per forecast hour (hrs 0–120)—WRF thick solid, MPAS thin solid. Blue= bias; red= RMSE; pink= bias-corrected RMSE; black= correlation. Dots in a given color indicate that the error differences for the corresponding statistic for the given forecast hour are statistically significant. Bottom right: Average forecast temperatures (°C) for a 24-hr daily period. (a) Jul.–Aug. 2016. (b) Dec. 2016–Jan. 2017.

Figure 4 shows the surface temperature results for McMurdo for the winter (Jul.–Aug. 2016 (Fig. 4(a)) and summer (Dec.–Jan. 2016 (Fig. 4(b))) periods. The top panel presents the MPAS (red) and WRF (blue) forecasts, along with the observations (green). The lower left panel shows the model bias (blue), RMSE (red), bias-corrected RMSE ("Stdv": pink), and correlation coefficient (black) averaged over the 120-hr forecast periods. WRF results are in the thick lines and MPAS results in the thin lines. The statistical significance of the differences in the metric between the two runs at the 95% level is indicated by colored dots for the given hour along the bottom axis. Lastly, the lower right panel presents the average forecast and observed temperatures over the diurnal cycle during the period, with MPAS and WRF the thin and thick traces, as in the lower right. For these diurnal view panels, only the model 0000 UTC runs have been used. The value for a given model hour reflects the averaged model forecast temperatures verifying for that local hour. Thus, for hour 12 it represents that day’s 0000 UTC forecast for hour 12, plus the previous day’s forecast for hour 36, etc.

For McMurdo, the main USAP Antarctic station, the top panel in Fig. 4(a) reveals that in winter both the WRF and MPAS forecasts are colder than observations. However, from the lower panels MPAS has a greater cold bias, and this is particularly apparent in the 24-hr plots in the lower right. WRF is statistically better than MPAS for hours 12–18 and after hour 39 (when the fine grid shuts off). Figure 4(b) presents the summer results, with both models again having a cold bias, but with MPAS’s of greater magnitude. The bias differences are significant for most of the forecast period. There is also a diurnal variation of T error/bias that emerges in both models, but is of higher amplitude in MPAS than WRF. The average bias (i.e., for both periods, as shown in lower left panel) here at McMurdo or WRF is -2.8°C, while for MPAS it is -4.0°C.
Figure 5 shows the temperature results for South Pole, the USAP’s other key base. For summer (Fig. 5(a)) MPAS’s warm bias is apparent when viewing its forecasts with the observations (top panel: MPAS—red, obs—green). WRF, in contrast, has a cold bias that is of lesser magnitude. This is brought out in the lower right panel of Fig. 5. In contrast, for the summer period (Fig. 5(b)), MPAS has, on average, a minimal temperature bias (-0.1 C), while WRF displays a warm bias (+1.6C). The difference is statistically significant for all forecast hours. Thus, model performance varies significantly with season.

The relative forecast performance of the models also varies by region. To see this, Tab. 2 presents the average surface temperature (T) forecast errors by region for the winter 2016 and summer 2016–2017 periods. The regions defined are: Ross Island, East Antarctica, Plateau/Pole, Queen Maud Land, West Antarctica, and the Antarctic Peninsula. Differing numbers of stations are grouped for each region, as the distribution of AWSs is diverse. Ross Is., for example, has many AWSs (about 11 in this analysis), while East Antarctica and Plateau/Pole have relatively few (3 each in this analysis). The values shown are averages of the given statistic over all forecast hours out to 120 hr. Areas of particular interest to the USAP are Ross Is., Pole, and the Antarctic Peninsula. For Ross Is., both WRF and MPAS have a cold bias. WRF’s is lower in the summer, while MPAS’s is lower in the winter. WRF, however, has lower yearly RMSEs. For Pole, the models are comparable for the summer, with WRF superior in winter. Around the Peninsula, WRF shows lower biases and RMSEs for both seasons. Lastly, one notable trend is that for both models, the T RMSEs are all greater for the winter season, and the biases are mostly of larger magnitude.

Table 3 presents the regional results for surface wind speed (WS). The Ross Is. biases for both models are very small (.5 ms⁻¹ or less) for both seasons, and this average reflects uniformly small values for individual sites (not shown) that for most stations are of magnitude 1.5 ms⁻¹ or less. The WS RMSEs for this region are comparable as well. For Pole, MPAS is slightly better than WRF for both bias and RMSE. Continent-averaged WS biases and RMSEs are slightly lower for MPAS than WRF.

As with temperature, there are higher WS biases and RMSEs for the winter for all regions. Thus, in both AMPS models, performance declines in winter. This may reflect weaknesses in the physics that are accentuated in the winter or the reduction in observations going into initialization (which will affect either the GFS first-guess or WRFDA reanalysis). It nonetheless is an area for forecast improvement.

Comparisons of surface variable biases and RMSEs across the continent are shown in Figs. 6-8. Here the circle color indicates which run is better at the given site, and the circle size is proportional to the magnitude of the improvement. As exemplified by the station highlights above, the results are mixed. For temperature bias, Fig. 6(a) presents the winter results. WRF is better over the Antarctic Plateau and the immediate Ross Is. region; MPAS is better over West Antarctica, Queen Maud Land, and the Ross Ice Shelf (RIS). For summer (Fig. 6(b)), WRF’s performance in the Ross Island region is enhanced and generally better than MPAS’s. This is important for USAP operations, as summer is the critical field season. MPAS, however, shows gains over the central Plateau (out to Dome C) and is better at Pole.
For T RMSEs, Fig. 7(a) shows that for winter the patterns follow those of biases. WRF is better over the Plateau and Ross Island region, with MPAS emerging over West Antarctica and the central part of the RIS. For summer (Fig. 7(b)), WRF widely outperforms MPAS. Although, the Plateau and Queen Maud Land show a mix of results.

For surface wind speed, MPAS has smaller biases than WRF over most areas for winter (Fig. 8(a)). These include the Plateau, East Antarctica, Queen Maud Land, and West Antarctica. The Ross Island region results vary, but MPAS has an edge. For summer (Fig. 8(b)) WRF outperforms MPAS for West Antarctica and the Antarctic Peninsula. The WS RMSE comparisons for both seasons (not shown) have patterns similar to the summer biases, with WRF presenting gains in West Antarctica and the RIS and the results being more mixed overall.

**Fig. 6:** Comparison of surface temperature biases (°C) for MPAS and WRF. Red = MPAS better; blue = WRF better. Circle size proportional to magnitude of improvement. (a) Jul.–Aug. 2016. (b) Dec.–Jan. 2016–2017.

**Fig. 7:** Comparison of surface temperature RMSEs (°C) for MPAS and WRF. Red = MPAS better; blue = WRF better. Circle size proportional to magnitude of improvement. Circles appearing in both red and blue are actually two locations near each other. (a) Jul.–Aug. 2016. (b) Dec.–Jan. 2016–2017.
Fig. 8: Comparison of surface wind speed biases (m/s) for MPAS and WRF. Red = MPAS better; blue = WRF better. Circle size proportional to magnitude of improvement. (a) Jul.–Aug. 2016. (b) Dec.–Jan. 2016–2017.

Upper-air verification has been done for the period April–May 2017 for the continental radiosonde sites operating. These are: McMurdo, South Pole (Amundsen-Scott), Neumayer, Marambio, Rothera, Novolazarevskaya, Syowa, Casey, Mawson, Davis, Mirnyj, and Dumont D’Urville. Fields verified have been temperature, zonal and meridional wind components, and wind speed.

Fig. 9: Error profiles for forecast hr 48 for McMurdo for period Apr.–May 2017. Pressure (mb) in (a) shown along vertical axis. Green bars mark levels at which model bias differences are statistically significant. (a) Temperature bias (solid, °C) and RMSE (dashed, °C). WRF red, MPAS blue. (b) Wind speed bias (solid, m/s) and RMSE (dashed, m/s). WRF red, MPAS blue.

Figures 9 and 10 show the results for forecast hour 48 for temperature and wind speed at McMurdo and Pole. For McMurdo temperature (Fig. 9(a)) note first the low magnitude of the biases through the column: the errors are mostly less than 1°C, except the near-surface layer for WRF (and in the tropopause layer). Statistically significant differences (marked by green bars) appear in the biases through 800 mb, with MPAS being better than WRF and having about half of WRF’s cold bias. Mid-tropospheric bias differences are negligible. Likewise, for the whole column, RMSE differences are minimal, and the values themselves are less than 2°C. For wind speed (Fig 9(b)), both models have positive biases through 500 mb, with WRF being significantly better in the near-surface and 700–800 mb layers. MPAS is better in the upper-troposphere and lower stratosphere, but the actual error magnitudes are small (<2 m/s). MPAS shows an overforecasting of WS in the lower troposphere in this autumn period, which is different from the summer and winter errors calculated for McMurdo (not shown, but incorporated in the Ross. Is. results in Tab. 3).
Fig. 10: Error profiles for forecast hr 48 for South Pole for period Apr.–May 2017. Pressure (mb) in (a) shown along vertical axis. Green bars mark levels at which model bias differences are statistically significant. (a) Temperature bias (solid, °C) and RMSE (dashed, °C). WRF red, MPAS blue. (b) Wind speed bias (solid, ms⁻¹) and RMSE (dashed, ms⁻¹). WRF red, MPAS blue.

For South Pole there are minimal T error differences for bias and RMSE through the column at hour 48 (Fig. 10(a)). However, the small bias differences are in WRF’s favor and are statistically significant. For wind speed (Fig. 10(b)), WRF shows smaller biases in the near-surface layer, with statistical significance seen. Both models display negative speed biases through the middle-troposphere to about 275 mb; these are quite small (<2 ms⁻¹), with MPAS better with significance. While for other sites there is more lower-tropospheric difference in the errors in T and, in particular, WS, the differences are generally small, and thus the models are performing similarly. Lastly, as forecast hour increases (not shown), errors do increase at almost all vertical levels, as would be expected.

4. SUMMARY

The Model for Prediction Across Scales (MPAS) is an emerging global model designed to capture scales down to cloud-resolving. To provide another source of NWP guidance for the USAP forecasters and to explore the value of MPAS in polar applications, MPAS has been implemented into AMPS. MPAS forecasts are produced twice daily with a global 60-km mesh that decreases to approximately 15 km over Antarctica. This study follows up from a preliminary look at MPAS over Antarctica from 2016 (Powers and Manning 2016). The aim here to show the WRF and MPAS communities the relative performance of MPAS in the high latitudes, and specifically Antarctica.

The MPAS and WRF forecasts reflect model configurations that are as similar as practicable, but with a number of differences. First, MPAS does not have the nesting structure of WRF and thus can only be set up with the single regional refinement. Second, MPAS does not have all of WRF’s physics options, and its schemes here reflect those from earlier versions of WRF. Third, the computational cost of MPAS limited the continental spacing to 15 km instead of 10 km, as in WRF.

Seasonal model performance has been assessed through verifications of (austral) winter and summer forest periods: July–August 2016 and December–January 2016–2017. Furthermore, for the first time, MPAS upper-air performance over Antarctica is assessed, using more recent forecasts from autumn 2017.

Subjective comparisons of MPAS and WRF forecasts show consistency of the models, even with their different setups. As illustrated, there is correspondence of synoptic and mesoscale features (pressure centers, fronts, precipitation) out to 3-4 days. No systematic differences in precipitation totals or structures associated with synoptic systems is seen. For the most part, divergence in the progs becomes apparent after 3–4 days, however. This is tied to the differences in the models (e.g., grids, topographic data) and the physics options used, and also to the different initializations (i.e., data assimilation) in the AMPS setting.

While only a limited sample of results can be shown here, from the surface verifications for all sites it is found that overall WRF still performs better
statistically than MPAS. Surface temperature forecasts are overall better (RMSE, bias) across the continent for WRF, while wind speed forecasts are mixed (MPAS better bias, WRF comparable in RMSE). With wind speed, biases are very low (<1.5 ms⁻¹) in summer, while these errors increase in winter. The primary USAP operation areas of Ross Island and South Pole have low errors in both models; while this was known for WRF, this is a good sign for MPAS. For both temperature and wind speed, both models have better forecast performance (lower errors) in summer than winter, a finding seen across the various continental regions examined. Thus, this seasonal performance loss is an area for improvement for both models.

For the first time for MPAS over Antarctica, we have done upper-air verification and comparisons with WRF. The period reviewed is April–May 2017. In temperature and wind speed, the largest differences between the models are in the lower troposphere (e.g., up to 750 mb, depending on the site). Temperature generally displays small errors (i.e., biases <2°C) through the troposphere, to about 350 mb. Overall, error differences between the models are small, with the better model varying with location. The tropopause level sees the greatest errors and differences between the models. As would be expected, as forecast hour increases, errors do increase at almost all vertical levels.

The key sites for the USAP are McMurdo and Pole. For McMurdo, both models show a low magnitude of forecast T biases through the column, but with MPAS having a statistical edge in the lower troposphere. As is the case continent-wide, mid-tropospheric bias differences are negligible. Wind speed error magnitudes are small (<2 ms⁻¹) for both models. At Pole we find minimal differences in both T bias and RMSE through the column, although the small bias differences are statistically in WRF’s favor. For wind speed, WRF has smaller biases in the near-surface layer, while MPAS is better above this, with error differences significant in both cases. For other sites, WS errors between the models are generally small, and thus the models are performing similarly across the continent.

In conclusion, even with its coarser configuration, MPAS holds its own and shows statistically significant better performance at many sites and in different regions, depending on the variable. This is encouraging, as the grid and physics configuration of MPAS has not yet been refined for the AMPS Antarctic application as with WRF. MPAS will continue to be run in AMPS, and higher resolution and updated polar-modified physics are planned.

ACKNOWLEDGEMENTS

The authors thank the NSF Division of Polar Programs for its support of AMPS.

REFERENCES


<p>| Table 2: Averaged surface T errors (°C) for WRF and MPAS by region. |
| Jul.–Aug. 2016 | Bias | RMSE |
| WRF | MPAS | WRF | MPAS |
| Bias | RMSE | WRF | MPAS |</p>
<table>
<thead>
<tr>
<th>Region</th>
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<tr>
<td></td>
<td>WRF</td>
<td>MPAS</td>
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<tr>
<td>Antarctic Peninsula</td>
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</tr>
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</table>

Table 3: Averaged surface wind speed errors (ms⁻¹) for WRF and MPAS by region.
1. Introduction

The Antarctic Mesoscale Prediction System (AMPS) is an experimental forecast project to provide real-time numerical weather prediction (NWP) guidance to weather forecasters for the U.S. Antarctic Program (USAP). Sponsored by the U.S. National Science Foundation, AMPS has been in continuous operation since October of 2000.

Real-time graphical and textual NWP products are distributed through the AMPS web page, http://www2.mmm.ucar.edu/rt/amps. AMPS has also maintained an archive of its model output since Jan 2001.

While the priority of AMPS is to support forecasting for USAP operations and logistics, primarily regarding flights to and from McMurdo Station and the South Pole, the international nature of Antarctic research and the continental coverage of AMPS have led to other national Antarctic programs making use of AMPS forecast data as well. The AMPS archive has also proven useful for researchers and students investigating Antarctic weather and climate.

The principal tool of NWP for AMPS is the Weather Research and Forecasting model (WRF), which AMPS runs in several configurations. The primary AMPS run features a coarse-grid domain with 30-km grid spacing over Antarctica and the Southern Oceans, a nest with 10-km grid spacing over all of Antarctica, 3.3-km grids over Ross Sea and the Antarctic Peninsula, and a 1.1-km grid over Ross Island and the surrounding regions. An additional coarse-grid run (with 27-km grid spacing) is parent to 9-km grids over New Zealand and the Drake Passage. From these WRF forecasts, AMPS generates charts and tables for a number of regions of Antarctic interest.

In addition to these forecasts, AMPS also runs an ensemble of WRF forecasts, with individual ensemble members variously populated using the NOAA Global Ensemble Forecast System (GEFS) results, as well as using different initialization (data assimilation) strategies and different WRF physics parameterizations. The ensemble is useful in providing forecasters with multiple possible solutions that begin to represent the unpredictability of forecast situations and the uncertainty in the model itself. Additionally, the ensemble results are an important part of the data assimilation for AMPS initialization, which uses a hybrid Ensemble-3DVar assimilation system to incorporate the latest observations into AMPS initial conditions.

AMPS is also testing the Model for Prediction Across Scales (MPAS) for use in Antarctica. MPAS is a global model that makes use of an unstructured mesh of mostly hexagonal cells; the mesh can be configured to transition smoothly from low resolution on a global scale to higher resolution over regions of interest. AMPS has set up a 60-km global mesh which refines to 10-km over Antarctica.

2. Observations from BAS

At the 2016 AMOMFW, Steve Colwell of the British Antarctic Survey (BAS) noticed that according to AMPS observation usage reports, AMPS was consistently missing observations from a number of BAS stations. These observations are inserted by BAS into the GTS data stream, but they were not getting to AMPS. The common feature of these missing observations is that they were encoded in the BUFR format. For its GTS data ingest, AMPS relies on a distribution of real-time observations as provided by Unidata. Investigation suggests that this data feed is missing BUFR-coded surface stations.
Steve Colwell set up an ftp directory of real-time Antarctic surface observations as collected at BAS. These observations include several stations otherwise missing from the AMPS data feed, largely in the region of the Antarctic Peninsula. These data were tested for AMPS, and it was found that the inclusion of these additional station reports results in a reduction in forecast surface pressure bias in the region. Based on these encouraging results, beginning in September 2016 AMPS uses these data provided by BAS to supplement our observational data stream.

The surface observations for AMPS now come through three overlapping data sources: the GTS feed as provided by Unidata, AWS reports from the AMRC, and this new set of reports from BAS.

3. Field project support

AMPS has traditionally been able to support various field campaigns through customized NWP graphics produced from the AMPS forecasts. Such efforts are necessarily limited by resource availability (manpower, computing, software development, etc.) and AMPS priorities. This support has often taken the form of small plotting windows offering zoomed-in views of AMPS model results in regions of particular interest. In the 2016/17 season, AMPS support was requested for two ship-based expeditions: the Antarctic Circumnavigation Expedition (ACE) sponsored by the Swiss Polar Institute; and the Polynyas, Ice Production, and Seasonal Evolution in the Ross Sea (PIPERS) expedition sponsored by the U.S. Antarctic Program.

ACE featured a 3-month circumnavigation of Antarctica, with a variety of projects investigating the climatology, oceanography, biology, and meteorology of the southern oceans and Antarctica. AMPS was able to provide ship-following views from the 30-km and 10-km grids, views centered on the Russian icebreaker Akademik Tryoshnikov as it made its way around the continent.

PIPERS featured a 2-month expedition of the Nathaniel B. Palmer to the Ross Sea, with projects exploring air/sea/ice interactions in wintertime conditions. AMPS provided ship-following views primarily from the 10-km and 3.3-km grids.

4. New Computing Facilities

Beginning in June of 2017, AMPS has moved its principal computing to new hardware. The new machine, named "Cheyenne", is NCAR’s community supercomputer. NSF has provided additional funds to the acquisition of Cheyenne, for a special allocation for real-time AMPS computing on Cheyenne. This AMPS allocation results in approximately 2.5 times the computing power available for AMPS over the previous computer, the AMPS-dedicated "Erebus" machine.

Cheyenne represents the fifth generation of computing platforms used by AMPS over the years. For all but the initial platform, AMPS hardware has been managed by the supercomputing systems experts at NCAR’s Computational and Information Systems Lab (CISL). AMPS has benefited greatly from the experience and dedication of CISL staff, and their support of AMPS’ mission.

Currently, most of the changes to AMPS regarding the move to the new computer have been behind the scenes, with little visible change for end users. Taking advantage of the additional computing power, the AMPS team will begin upgrading AMPS, with higher resolution model grids, enhanced ensemble, and improved MPAS.

A grid configuration with cell sizes of 24/8/2.67/0.89-km is possible with the new hardware, which would bring 8-km grid spacing on the continental scale, and represent detailed flows on a sub-kilometer grid in the Ross Island/McMurdo region.

An expanded ensemble has the potential to offer forecasters a better sense of the predictability of forecast situations. It can also improve the hybrid 3DVar-Ensemble data assimilation step in AMPS, with a broader representation of model variability and model error. Additionally, the ensemble framework, based on multiple instances of model runs, is ideal for testing model physics options.

We have already begun expanding the AMPS ensemble, with new ensemble members added which vary the model physics options among members.

Improvements to MPAS as used in AMPS are underway. MPAS has been updated from version 4.0 to version 5.1. A higher-resolution mesh has been generated for AMPS, with 60-km global grid spacing.
mesh refined to 10-km over Antarctica. The new MPAS setup for AMPS now uses the RAMP2 DEM to better represent the geographic features of Antarctica. Finally, new postprocessing tools will allow us to easily make the same graphics from MPAS that the AMPS community is familiar with from WRF.

5. Conclusion

In its seventeenth year of ongoing operation, AMPS continues to develop and evolve, taking advantage of advances in computing hardware and software systems, model updates, new model developments, developments in ensemble and assimilation techniques, and other aspects of the ever-changing world of numerical weather prediction. AMPS has promoted development of model physics readily applicable to Arctic and Antarctic environments. Accurate weather forecasts are vital to the success of the ongoing research into Antarctic weather, climate, and ecosystems. AMPS continues to be a valuable part of the wide array of information that forecasters use to insure the success and safety of these Antarctic efforts.
TESTING THE IMPACT OF ASSIMILATION OF ADDITIONAL RADIOSONDE AND UAV OBSERVATIONS FROM THE SOUTHERN OCEAN IN WRF

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Abstract: A unique campaign of radiosonde and unmanned aerial vehicle (UAV) soundings was carried out during the RV Polarstern cruise in the Southern Ocean in winter 2013. The sounding data are assimilated into the Polar-optimized version of the Weather Research and Forecasting model (Polar WRF) to assess the impacts on short-range weather forecasts. The ERA-Interim reanalysis is applied to provide initial and boundary conditions for Polar WRF, in which the three-dimensional variational (3DVAR) data assimilation method is applied. The assimilation of data from both UAV and radiosonde soundings significantly corrects the local profiles of air temperature, wind speed, and humidity in the first-guess fields. Largest improvements in the first-guess field are detected in the lowermost 2 km layer, but some effects reach the height of 6 km. The largest effects are not always centered at the observation site. The assimilation of the two types of sounding data improves the vertical profiles in short-range forecasts, but the effect on the time series of near-surface variables along the ship track is limited. Assimilation of radiosonde data was more beneficial than UAV data in forecasting the sea level pressure and near-surface wind speed. This is likely due to the higher vertical extent of radiosonde data; the UAV measurements only covered the lowermost 1.7 km layer. The evaluation of forecasts against in-situ observations was only possibly at the site of RV Polarstern and a few coastal stations, but an evaluation of the forecast fields against analyses suggests that the data assimilation is most beneficial for the forecast skill in regions downstream of the observation sites.

Keywords: Data Assimilation, Antarctica, UAV, Radiosonde

1 INTRODUCTION

In recent years, plenty of atmospheric observations have been made both in Antarctic continent and over the surrounding ocean (Jones et al., 2016; Rintoul et al., 2012), and are promoting operational weather forecasting for Antarctica regions from several organizations worldwide (Turner et al., 2004). However, weather forecasting in Antarctica has been considered as a challenge with the fact that real-time observations for the surface and upper air, which can be assimilated into numerical forecasting models to improve the initial conditions, are far from enough. In addition, the verification of the numerical weather forecasting in such area suffers from a lack of in situ observations.

The harshness of the environment in Antarctica brings difficulty to conventional atmospheric measuring methods. Wind sensors could be damaged by the severe winds shortly after the installation, and precipitation measurement is almost impossible during snow storms, let alone the corrosion to the sensors due to the salty air and the unstable transfer of observation data via communication satellites at high latitudes and remote regions. Such situation appeals for new technology in the observation of Antarctic weather.

A unique observation campaign with unmanned aerial vehicle (UAV) flights in Southern Ocean took place from 21th Jun to 4th August 2013, when RV Polarstern cruised in the ice-covered Weddell Sea during its winter expedition ANT-XXIX/6 (Jonassen et al., 2015). During the cruise, three types of UAV were launched to measure the profiles of the atmospheric boundary layer (ABL) with different vertical range. Among these, a small unmanned meteorological observer (SUMO) had a relative better ability in the observation as it could ascend to a higher altitude (approximately 1700 m) than other types of UAVs.

To the authors’ knowledge, there has been no study testing the beneficial of assimilation of UAV observed data to short-range numerical weather forecast over Southern Ocean so far. The aim of this paper is to find out how much could the assimilation of the UAV and radiosonde observations benefits the short range forecast over the Southern Ocean in winter.
2 DATA AND STRATEGY

2.1 OBSERVATION DATA

The atmosphere profile observation with SUMO during the cruise of RV Polarstern started from 21st June 2013, following the Greenwich Meridian southwards, and ended on 4th August, near the tip of Antarctica peninsula (Fig. 1). The SUMO is based on a German-made commercially construction kit FunJet by Multiplex, and was equipped with meteorological sensors to measure vertical profiles of weather parameters (Jonassen et al., 2015). In this study of data assimilation, SUMO observations from two particular periods of time are used. The two particular periods of time are 11-14 July and 31 July to 4 Aug (hereinafter referred to as CASE 1 and CASE 2, respectively).

Each SUMO flight costs approximately 30 minutes and comprised two parts of ABL profile: the ascent and the descent. However, because of the time-lag existed when sensors of SUMO were measuring the atmosphere, only the descent data is used in the assimilation experiments as the descent rate is slightly slower than the ascent rate and thus had a better quality (e.g. Jonassen et al., 2015).

In addition to SUMO, radiosonde equipment onboard RV Polarstern is used to carry out profile measurements of pressure, temperature, relative humidity and the wind vector around 11 UTC daily (König-Langlo et al., 2013). Data from an automatic weather station (AWS) onboard RV Polarstern is also obtained for the assimilation experiments. Table 1 gives a list of the observation data which is assimilated with the numerical model Polar WRF in this study.

The SUMO data is applied to a data quality control process before it is used in the assimilation. The process includes: (1) The time of the SUMO profile is the average time during the flight descent. During the landing, the SUMO was controlled manually, and its track was not as constant as when it was at higher levels. Hence, the lowest altitude of observations that is used in this study is 70 m above ground level. (2) In some SUMO flights, a difference of the temperature at lower levels between ascent and descent exceeds 2 °C. Such temperature data at lower levels is removed because it is regarded as unreliable. (3), As time-lag problem exists, profiles are corrected by shifting the ascent and descent profiles a bit in the vertical for them to match. The assumption is that the difference between the ascent and descent parts of the profiles is caused by sensor lag.

<table>
<thead>
<tr>
<th>Data source</th>
<th>Observation date and time (UTC)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11-14 July</td>
</tr>
<tr>
<td>Radiosonde</td>
<td>07/11 10:33</td>
</tr>
<tr>
<td></td>
<td>07/12 10:33</td>
</tr>
<tr>
<td></td>
<td>07/13 10:35</td>
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<tr>
<td></td>
<td>07/14 10:43</td>
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<tr>
<td></td>
<td>07/15 10:43</td>
</tr>
<tr>
<td></td>
<td>07/16 10:43</td>
</tr>
<tr>
<td>SUMO</td>
<td>07/11 14:28</td>
</tr>
<tr>
<td></td>
<td>07/11 18:27</td>
</tr>
<tr>
<td></td>
<td>07/11 21:11</td>
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<tr>
<td></td>
<td>07/12 23:50</td>
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<td></td>
<td>07/13 00:57</td>
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<tr>
<td></td>
<td>07/13 01:57</td>
</tr>
<tr>
<td></td>
<td>07/14 03:57</td>
</tr>
</tbody>
</table>

For radiosonde observations from RV Polarstern, data of near surface is neglected. Pressure, height, humidity, wind and temperature observations from radiosonde are used in the assimilation experiments. For both the SUMO and radiosonde observations, each of the profiles is averaged in 20-m height intervals.

2.2 EXPERIMENT STRATEGY

In this study, Polar WRF (version 3.7.1) is employed to conduct the data assimilation experiments. Polar WRF is a polar optimized model, which contains important modifications for a better presenting of physical processes in Polar Regions (Hines et al., 2008), that is being widely used by several organizations to provide operational weather forecast for Polar Regions, or to conduct Arctic and Antarctic weather and climate research.

The physical parameterizations of the model used in
this study follow the Antarctica Mesoscale Prediction System (AMPS, Bromwich et al., 2005). This group of parameter scheme has been tested by Bromwich et al. (2013) and showed a promising forecasting skill. The ERA-Interim reanalysis (Dee et al., 2011) is chosen as the initial and boundary conditions. This dataset has approximately 79 km spatial and 6 hours temporal resolution, assimilated with comprehensive types of observation including ship, radiosonde, buoys, and AWSs, and is a good background and forcing data for the Polar WRF model. The WRF three-dimensional variational (3DVAR) data assimilation system is used to assimilate the ABL profile measurement obtained from SUMO and radiosonde data from RV Polarstern.

Two different domains with a spatial resolution of 12 km are designed for each case in this study. The domains, with a spatial resolution of 9 km, are approximately centered by the locations of the RV Polarstern where the SUMO observations were taken place (Fig. 2).

To investigate how much the data assimilation of the observed profile data improves the forecast, a group of numerical model simulations is conducted. Fig. 3 shows the schematic of the simulation members taking CASE 2 as an example. There are three independent simulation members in each case: the control simulation (CTRL, without any observation assimilated), SUMO (with observations from SUMO assimilated) and PS (with observations from radiosonde of Polarstern assimilated). Both the SUMO and PS run in cycling mode in which the short-range forecast is used to blend with the next set of observations to start the cycle again. For each case, the simulation lasts for 5 days.

![Fig. 3. Schematic of the numerical modeling members and the cycling mode](image)

To understand how the assimilation process of sounding data modifies the analyses, the profiles extracted from analyses with or without data assimilation and profiles of observations are compared. The left part of Fig. 4 shows the comparison of PS assimilation while the right part shows that of SUMO assimilation. Temperature profiles with assimilation correspond with observations very well. This can be seen in both PS and SUMO assimilations. However, in the lowermost part of the temperature profiles when the observations differ too much from the analyses, assimilation does not successfully correct the analyses, either in PS or SUMO. In addition, the sheer of the observed temperature profiles at around 925 hPa on 11th July is not reflected after the assimilations.

![Fig. 4. Impact on local profiles from the assimilations at 1400 UTC 11th July and 1300 UTC 31th July 2013](image)

Comparing to temperature, the wind, and humidity profiles after assimilations lost details of the
observations. Anyway, they are able to capture the main characters of the observations. Among these, humidity profiles in analyses before assimilation and observation are generally further apart when compared with temperature and wind speed. Hence the largest benefit of assimilation to the local profiles is found in humidity. Further examining of the simulated profiles shows that the assimilation of the two types of sounding data improves the profiles in the short-range forecast (figures not included in this paper).

3.2 SPATIAL PATTERNS IMPACTS

Fig. 5 shows how the assimilations have an impact on local patterns of pressure and temperature at different levels, taking CASE 1 for example. The difference of air pressure between the analyses before and after assimilation reduces gradually from the surface to up to approximately 6 km above ground level (AGL) and the pattern remained stable with the increase of height. The largest difference of pressure brought by the assimilation is about 5 hPa, located at the surface level. Different from the pressure, the patterns of temperature difference deform significantly from the surface to upper levels, and the largest impact of the assimilation is not at surface level. In both the patterns of pressure and temperature, the largest difference is not necessarily always located at the observing position, which is centered in the domain shown in Fig. 5.

4 IMPACTS ON FORECASTS

4.1 TIME SERIES FORECAST

The impact of the assimilations on the short-range weather forecast is examined by comparing the time series of several variables on the track of the RV Polarstern. As showed in Fig. 1, the RV Polarstern voyages mainly northwestward against the westerly wind in the Southern Ocean. Thus, the sounding data assimilated in the model may not have a considerable impact on the following date and time when the vessel was upstream.

Fig. 6 illustrates the sea level pressure, surface air temperature and wind speed for each case. The forecast data from the three simulation members are interpolated to the locations of the vessel from the nearest four grid points of the model. In CASE 1, the pressure from PS corresponds better with observations than that from CTRL and SUMO. All the simulation members underestimate the air temperature in the first half of the simulation period but succeed in capturing the main feature the temperature evolution in the second half. Among the two cases, PS represents the peaks of the temperature better than the other two simulations. Generally, the wind speed is also underestimated in most of the time. PS and SUMO take a turn in a better simulation of the highest wind speed in the two cases. This means that the benefit of the assimilation from different sounding data varies from time to time and from case to case.

4.2 DOWNSTREAM EFFECTS

To find out how the assimilation of sounding data at single location affects the remote areas in the short-range forecast, comparison of sea level
pressure pattern from all the three modeling members is made. Fig. 7 shows the sea level patterns at 1800 UTC 11th July. Note that the location of the PS and SUMO observation are contacted at the center of the domain. Largest difference of the surface pressure between the three members is found the southeast of the domain center, namely the downstream of the vessel.

![Fig. 7. Patterns of sea level pressure from (a) CTRL, (b) SUMO, (c) PS at 1800 UTC 11th July, 2013.](image)

5 CONCLUSION

In this study, we tested the effect of sounding data from a UAV and radiosonde onboard RV Polarstern over the Southern Ocean to the short-range weather forecast with Polar WRF model. The simulation experiments employ ECMWF ERA-Interim reanalysis as initial and boundary conditions and 3DVAR as the assimilation method.

The result shows that the assimilation of those sounding data from both UAV and radiosonde significantly corrects the local profiles of air temperature, wind speed, and humidity in the analyses, and improves the profiles in the short-range forecast. Assimilation of radiosonde data is more beneficial than UAV data in forecasting the sea level pressure and near-surface wind speed. This is likely due to the higher vertical extent of radiosonde data; the UAV measurements only covers the lowermost 1.7 km layer.

Study of the remote effect of the data from single location shows that patterns of difference between analyses before and after assimilation differ between variables. For instance, the pattern of pressure difference shows the effect of assimilation decreases gradually from the surface to up to approximately 6 km above sea level. The largest difference is not necessarily always centered at the observing position. The evaluation of the forecast fields against analyses suggests that the data assimilation is most beneficial for the forecast skill in regions downstream of the observation sites.

REFERENCE

Wind LIDAR measurements on an icebreaker in the Antarctic

Günther Heinemann and Rolf Zentek

Environmental Meteorology, University of Trier

During a cruise of RV Polarstern (Alfred Wegener Institute, Germany) in the Weddell Sea a wind LIDAR was installed on the upper deck of the ship. The measurements were taken over six weeks (December/January 2015/2016). Measurements included horizontal and vertical scan programs that allow for the computation of different wind profiles. Since the lidar was not motion-stabilised, motion correction was done during postprocessing. Depending on weather condition data up to 1 km (and in single cases up to 2 km) height was collected. An evaluation of the derived vertical wind profiles was done by comparing them to onboard surface measurements and radiosoundings.

The mean bias of wind speed between the lidar and the radiosonde measurements was found as 0.7-1.2 m/s depending on data selection and height. Overall, the wind lidar is an excellent tool for the measurement of wind profiles with high spatial (10m) and temporal resolution (15min) and can be used for process studies and for the verification of models. A case study of a comparison with high-resolution model simulations (CCLM at 1km horizontal resolution) of a low-level jet is presented.

A lidar campaign during the YOPP period is planned in the Weddell Sea during Jan.-March 2018.
Antarctic-wide and long-term detection of the atmospheric rivers and their relevance to Antarctic precipitation

Irina V. Gorodetskaya, Rui Pedro Silva, and Annick Terpstra
(CESAM-Center for Marine and Environmental Sciences, Dept of Physics, University of Aveiro, Portugal)
Corresponding author: irina.gorodetskaya@ua.pt

Introduction

Atmospheric rivers (ARs) are narrow, elongated, corridors of enhanced water vapor transport usually observed in the pre-cold frontal zone of cyclones warm conveyor belt. ARs play an important role in the global hydrological cycle and regional weather and water resources. In East Antarctica, ARs have been related to several recent extreme snowfall events that strongly affected regional surface mass balance. The aim of our study is 1 - to apply and evaluate different algorithms of AR detection in application to the Antarctic ice sheet, and 2 - establish relationship between the ARs reaching the Antarctic ice sheet and associated precipitation in different regions of the ice sheet.

Data and Methods

Two automatic tracking algorithms are used for identifying atmospheric rivers: the global algorithm by Guan and Waliser (2015) (GW2015) and the algorithm developed specifically for a region in East Antarctica by Gorodetskaya et al (2014) (G2014). The former is a technique developed for objective detection of ARs on the global domain based on characteristics of integrated water vapour transport (IVT). The latter algorithm is based on finding a variable threshold for integrated water vapour amounts using Clausius-Clapeyron relationship. Both algorithms apply a set of geometric criteria indicative of AR conditions and identify the landfalling ARs. The algorithms are applied to 6-hourly ERA-Interim reanalysis data during 1979-2017.

Preliminary results and discussion

Figure 1a shows the amount of days with AR landfall at any location of the Antarctic ice sheet using the IVT-based algorithm by GW2015. Figure 1b shows the amount of the AR-days per year as detected by the two algorithms within the 20W-90E sector. A clear difference is seen between the algorithms with the IVT-based algorithm identifying many more AR cases compared to the IWV-based algorithm. This difference can be related to the fact that IWV-based algorithm is made to identify meridionally-oriented features. Also, the IVT-based thresholds provide a much smaller threshold on IVT compare to the IWV-based algorithm, where the IWV threshold varies as a function of latitude with the tropospheric moisture holding capacity. Interestingly, the amount of the days with an AR detected within 20W-90E sector using the IVT-based algorithm shows an increasing trend, which is not detected in the IWV-based AR detection.
Figure 1: Number of days per year when a landfalling AR was detected a) at any location of the Antarctic ice sheet coastline, and b) within the 20W to 90E sector.

Figure 2: AR case identified by both algorithms (top: 16 Feb 2011) and only by GW2015 (bottom: 6 Feb 2011). Left: the "object maps" showing the ARs and their landfall (red cross) around the world including Antarctica. Right: map of IWV (colors) and IVT (arrows) showing the landfall location identified by GW2015 algorithm (star).

Figure 2 shows two cases - one when an AR hitting DML was detected by both algorithms (15-16 February 2011), compared to the case when only GW2015 algorithm detected an AR (6 February 2011). Case 1 is an illustration of a typical meridionally-oriented AR, while in case 2 GW2015 algorithm identifies a much weaker moisture transport, without an AR signature in IWV values. Our presentation will discuss the AR detection by the two algorithms highlighting the differences between them. We will discuss particular features of the ARs affecting Antarctic precipitation compared to other continents, which have to be taken into account when applying automatic (global) AR detection algorithms to Polar Regions.
Role of low-level jets in enhanced moisture transport towards Antarctica from radiosonde measurements at the coastal stations and Southern Ocean

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Introduction

The Antarctica continent is a highly complex and critically important component of the global climate system that remains poorly understood, especially due to data sparse and remote regions of difficult human access. Large precipitation events associated with enhanced poleward moisture transport (MT) towards Antarctic ice sheet can strongly affect the total ice sheet mass balance and thus its input to global sea level [Boening et al 2012; Gorodetskaya et al. 2014].

In this study, we use radiosonde measurements available via Integrated Global Radiosonde Archive (IGRA) and from Antarctic Circumnavigation Expedition (ACE) to:
1) identify cases with enhanced MT towards the ice sheet, in some cases related to atmospheric rivers (ARs);
2) study their association with the low-level jet (LLJ) presence;
3) evaluate ERA-Interim (ERA-I) re-analysis MT vertical profiles using radiosonde data.

Data and Methods

The analysis is based on radiosonde data from three research Antarctic stations located in the coastal region of Dronning Maud Land (DML), East Antarctica, namely Neumayer (NEU), Novolazarevskaya (NOVO) and Syowa (SY). NEU is located on an ice shelf, while the other stations are placed around a more complex topography.

For this study we used data during 2009, 2011 and 2012 and only during the months when ARs intersected DML as defined by Gorodetskaya et al [2014]. Here we detected other events of the enhanced moisture transport, in addition to the ARs considered in the above study. The following criteria were applied to ERA-Interim reanalysis data at the nearest grid point to the stations:
1) the integrated water vapor transport (IVT) larger than 100 kg m\(^{-1}\) s\(^{-1}\);
2) maximum of the moisture flux in the vertical profile larger than 50 kg m\(^{-2}\) s\(^{-1}\).

We analyzed the available sounding data from IGRA during the enhanced MT events at DML coastal stations. Further, we compare to the radiosonde measurements made within an AR over the Indian sector of the Southern Ocean during ACE on 3-4 January 2017. The timing of radiosonde launches during this and other AR cases during ACE was decided based on the ECMWF operational forecasts and AR detection with the aid of the IVT and integrated water vapor maps.

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Email: irina.gorodetskaya@ua.pt
Results and Discussion

1) DML coast

Figure 1 shows the vertical profiles of specific humidity, wind speed and moisture flux at SY station during December 2011. It demonstrates significant changes in all parameters during the enhanced MT event in the middle of the month. Figure 2 shows vertical profiles of the same three parameters during this enhanced MT event, defined as an AR event, on 17 December 2011, both from the radiosonde measurements and ERA-I reanalysis.

Reanalysis only slightly underestimated the LLJ intensity and humidity inversion. The resulting moisture flux profile is also well captured, with only a small underestimation near the surface. Same is true for the IVT values, which are almost identical.

Further, we analyzed average profiles for all the events with enhanced MT. For comparison, the ERA-I averaged profiles were interpolated onto the radiosonde measurements levels (25 pressure levels from 990 until 510 hPa).

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while specific humidity shows elevated but more irregular values.

2) Southern Ocean profiles
On 3–4 January 2017, an AR intercepted the ACE research vessel located at that time in the Indian sector of the Southern Ocean. Frequent soundings were made to understand the vertical profile evolution inside this AR. This case, when an atmospheric river resulted in an intense precipitation over the Southern Ocean without reaching Antarctica, provides an interesting comparison to the atmospheric river cases occurring in the same sector and reaching the Antarctic coast as detected by the coastal stations.

The profiles showed a well-defined q inversion, while wind speed did not show a clear maximum typical of a LLJ. The maximum in the moisture flux in this case is more influenced by the q maximum compared to the coastal sites.

Much larger differences are obtained between observations and reanalysis compared to the coastal stations, with ERA-I profiles underestimating the q-inversion and slightly overestimating the wind speed increase with height. These differences can be due to the fact that ACE sounding data were not reported and consequently not assimilated by the ECMWF model, while radiosondings made at coastal stations are regularly reported and assimilated.

Conclusions
Radiosonde profiles at the DML coastal stations during the enhanced MT events always showed the presence of the LLJ with maximum wind speeds below 850 hPa. Maximum in specific humidity was typically found below 950 hPa. The maximum in the moisture flux (>50 kg m⁻² s⁻¹) was typically observed at the same level as the LLJ.

Despite the three DML coastal stations are located at orographically different places, the radiosondes vertical shape showed always some identical aspects and patterns. However, the sample in study should be extended in time and space in order to generalize vertical profiles typical of an enhanced MT pattern.

Profiles obtained over the Southern Ocean right in the core of the AR, show different patterns of q and WS compared to DML coast with a well-defined q inversion. We find that while LLJ drives moisture flux around DML coast, it is humidity inversion that determines the magnitude of the moisture flux during the Southern Ocean AR case.

References

A case study of intense moisture transport and precipitation over the Southern Ocean and East Antarctic ice sheet

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Introduction

During the last decade Antarctica experienced a net loss in ice-mass. However, the spatial distribution of the ice-mass changes exhibits a stark contrast, in particular East Antarctica likely encountered an increase in ice-mass thereby counterbalancing the overall ice-sheet mass loss (e.g. Shepherd et al. 2012). Local ice mass changes depend on both the accumulation and ablation, with precipitation as the only significant source term for the ice mass budget (e.g. Bromwich 1988). Boening et al. (2012) showed that recently precipitation significantly increased over the Droning Maud Land (DML) region of East Antarctica, and consequently snow-accumulation significantly increased over this area. Furthermore, they showed that the majority of the accumulation occurred during a few episodic snowfall events. Gorodetskaya et al. (2014) confirmed the episodic nature of the precipitation contributing to snow accumulation and related the episodic precipitation events over the DML region to so-called atmospheric rivers (ARs). Hence, to gain insight in the processes resulting in episodic snow accumulation events, it is essential to understand the evolution, sources and underlying dynamical pathways of anomalous moisture transport events reaching the Antarctic coastal region.

Data and Methods

To investigate the role of anomalous moisture transport on ice-sheet accumulation we consider one of the episodic precipitation events over the DML-area identified by Gorodetskaya et al. (2014). The selected event occurred between 14-18 February 2011. We use ERA-Interim Reanalysis data (Dee et al. 2011) which provides a best-guess of the state-of-the-atmosphere during the event by combining observations and numerical modelling. For the identification of anomalous moisture transport we adopted a similar method as used by Guan and Waliser (2015) to detect ARs. The algorithm is based on vertically integrated water vapour transport (IVT) deviations from the monthly mean, where we used the 85th percentile as the threshold value to identify anomalous moisture transport. Analogous to Guan and Waliser (2015) we will refer to filamentary, coherent areas of anomalous moisture transport as AR-areas, and consider all precipitation within such an area as precipitation associated with that particular AR.

Results

a) synoptic evolution and structure

The synoptic situation several days prior to the landfall of the AR is characterised by a quasi-steady, but intensifying cyclone located over the Southern Ocean slightly to the east of the

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DML region. The circulation associated with this cyclone extracts moist, warm air from lower latitudes (down to 30S) into the warm-sector of the cyclone (Fig.1). When the atmospheric river area makes landfall this synoptic scale cyclone decreases in intensity, whereas around the same time a meso-scale cyclone develops in the cold side of the AR-area. During the development, at upper levels there is a strong trough more or less co-located with the surface pressure field of the cyclone. The AR-area exhibits an intense (>30 m s\(^{-1}\)) low-level jet in a troposphere deep baroclinic zone (Fig.2). This baroclinic zone is tilted backward with height (with respect to the AR propagation direction) and comprises a meridionally orientated upper-level jet parallel to the low-level jet. The maximum intensity of moisture transport is located in the lower-troposphere (around 900hPa), about 100 km towards the cold side relative to the maximum of the IVT. Within the AR-area cloud-structures occur close to the surface, indicated by the high values of relative humidity. The cloud-structure extends to the tropopause and is tilted with height away from the upper level jet, which is consistent with rising air in a warm conveyor belt.

\[ qu_{perp} \ (kg \ kg^{-1} \ m \ s^{-1}) \]

**Fig.2** Vertical cross-section on 15 February 2011 00:00UTC at the maximum of IVT within the AR-area (for location see Fig.1). Moisture flux perpendicular to the plane (shading, units: kg kg\(^{-1} \ m \ s^{-1}\)), wind-speed perpendicular to the plane (dashed lines, units: m s\(^{-1}\)), and dynamical tropopause (solid line, value: 2PVU). Distances on the horizontal axis are in km, on the vertical axis in hPa.

**b) precipitation**
The onset of precipitation over land co-occurs with the landfall of the AR-area. The bulk of the precipitation associated with the AR-area occurs over the ocean, whereas local peak-values are found in the coastal areas over land. The temporal evolution of the precipitation clearly shows a signature of the landfall of the mesoscale cyclone, since during this period (around 16 February 12:00UTC) enhanced values of precipitation occur both over land and sea-ice. The land-based precipitation is mainly located in the coastal area, hinting at a dominant role of orographic forcing in producing this precipitation. Note that the AR-precipitation signature is already very prominent over the sea-ice edge and ocean, pointing to the existence of a additional forcing mechanisms for precipitation.

**Fig.3** Temporal evolution of the precipitation associated with the AR event (units: m w.e.), separated in total precipitation (columns) and over ocean/land/sea-ice areas (see legend).

**c) moisture sources**
Several mechanisms/sources can contribute to the moisture in the AR-area. In mid-latitudes, moisture recycling (i.e. local evaporation and precipitation) along AR-areas is common (e.g. Dacre et al., 2015). In the selected case of anomalous moisture transport at high-latitudes, the moisture transport is more-or-less perpendicular to the SST-gradient, and the warm, moist air comprising the AR-area is experiencing a reduction of SST during its meridional extension. Turbulent air-sea exchange results in a constant cooling of the

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low-level air south of approximately 40S, and since the air is already (almost) saturated, the cooling results in super-saturation, thereby suppressing surface latent heat fluxes. Hence, there is virtually no local evaporation along the AR-area, indicating that the moisture has to be either from long-range transport or from local convergence. Local moisture convergence mainly occurs in the cloud-area (Fig. 4), with peak values close to the surface, along the strongest thermal gradient (frontal zone). However, similarly large values of moisture divergence are found on the cold side of the AR-area. Thus the AR-area is composed of two contrasting air-masses, with on the one hand zonally directed cold, dry air advection behind the cold front, and on the other hand meridionally directed warm, moist air-advection.

**Discussion**

In this study we analysed an anomalous moisture transport event over the Southern Ocean, which significantly contributed to regional ice-sheet accumulation over the DML-region. Compared to similar events at mid-latitudes, this particular event exhibits a more meridional directed elongation, and much weaker local moisture recycling (due to the low SST values at high latitudes). Furthermore the AR-area was associated with a rather stationary cyclone, as opposed to cyclone trains commonly found during AR-events at mid-latitudes. These differences indicate that both features (strong evaporation and cyclone-trains) are not necessary for ARs to occur. Furthermore, it is noteworthy that in this particular event a mesoscale cyclone played a prominent role in enhancing moisture transport and precipitation rates.

**Acknowledgements**

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**References**


**Fig.4** Vertical cross-section on 15 February 2011 00:00UTC at the maximum of IVT within the AR-area (for location see Fig.1). Moisture flux divergence (shading, units: kg kg$^{-1}$ s$^{-1}$ *10$^{-7}$), wind-speed (dashed lines, units: m s$^{-1}$), and specific humidity (solid lines, units: gr kg$^{-1}$). Distances on the horizontal axis are in km, on the vertical axis in hPa.

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1. OVERVIEW

A large focus of the Antarctic Cyberinfrastructure grant is to engage in outreach projects with a variety of schools all over the United States. Upon talking with a few teachers, plans were set to work with teachers in Wisconsin, Illinois, Iowa, and Massachusetts. The focus of these projects was to access, analyze, graph, etc., Antarctic meteorology data with a goal of teaching skills in data and analysis with the exciting Antarctic observational data rather than canned data. These presentations also provided background about the AMRC/AWS project and paths to a career in Science, Technology, Engineering, and/or Mathematics including Antarctic meteorology.

A lesson plan, developed for students to understand the relationship between station pressure and elevation, was used by a few of the teachers. The lesson plan used the topography of the US as an example for students to try and understand the topography of Antarctica by comparing station pressure values and their contours over the US and Antarctica. Another lesson plan was created by Jody Baty to show the photoperiod, the duration of daylight in a day, in Antarctica versus other regions of the world. An additional informal activity as a part of this effort was providing moral support for the collaborating teachers in their struggles in today’s classroom. Finally, the outreach efforts were extended to the Madison community schools and science events.

2. OUTREACH EVENTS

Carol Costanza presented to about 200 middle school students in March of 2017 at Emerson Middle School in Park Ridge, IL.

Dr. Matthew Lazzara, Peter Voytovich, and Dave Mikolajczyk (from left to right) present information about the Antarctic Meteorological Research Center to UW-Madison Chancellor, Rebecca Blank, and her husband. Photo credit: Tim Schmidt

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**NEW ANALYSIS OF THE NEAR-SURFACE AIR TEMPERATURE IN KING GEORGE ISLAND AS REVEALED BY FREI STATION**

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**Introduction**

The Antarctic Peninsula (AP) is one of the regions on Earth where air surface temperatures have experienced substantial warming at higher rate than global average (Vaughan et al. 2001, 2003, Turner et al. 2005, Din et al. 2011, Bromwich et al. 2013) during the second half of the 20th century, although during the last 15 years or so, this warming has declined or even a slight no significant cooling has been detected (Carrasco 2013, Turner et al. 2016, Oliva et al. 2017). Most of the studies dealing with air temperature analyze this parameter on the daily, monthly, seasonal and annual basis and their lineal tendency over a given period. Averages of the mean and extremes air temperature (minimum and maximum) are usually analyzed for climate change studies. Here, a different approach is introduced for studying the air temperature behavior recorded at Frei Station located in King George Island (62º12’0”S, 58º57’51”W), in the northern tip of the AP.

**Materials and Methods**

Daily weather observations carry out at the Chilean station Eduardo Frei allow a detail analysis of the behavior of meteorological variables at different timescales. In this occasion, near-surface minimum and maximum air temperatures (Tmin and Tmax) data are analyzed from 1970 to 2015. The daily data also allow estimating the starting and ending freezing season. This period is defined as all days when the Tmax is permanently below zero degree, after filtering out the daily variability. Therefore, to determine this period, the original daily Tmax were smoothed by applying an exponential filter (Rosenblüth et al. 1997) given by:

\[
y_t = cx_t + (1-c)y_{t-1} \quad t = 2,3,\ldots,n \quad (1)
\]

and

\[
z_t = cy_t + (1-c)z_{t+1} \quad t = (n-1),(n-2),\ldots,1 \quad (2)
\]

where equations (1) and (2) are respectively the first forward and second backward smoothing. The first value \(y_t\) is the average of the first 10 values of the series and \(z_t\) corresponds to the final value of the first smoothing. The degree of smoothing \(c\) can range from 1 (maximum, reproduced the original data) to 0 (it gives a straight line). Here, we used \(c = 0.11\) and \(c = 0.2\) for filtering the high frequency inter-daily and annual variability, respectively, but keeping the longer term behavior. Figure 1 shows an example of the procedure used for determining the freezing season, in this case for 1975. By applying the filter, the longer (weekly or monthly) behavior stand out and, an initial and final days of the freezing season can be determined.

![Figure 1. Maximum air temperature behavior for 1975.](image-url)
Results

Firstly, the usual analysis indicates an overall warming in the annual mean temperature ($T_{\text{mean}}$), mainly during the eighties and nineties and a cooling during the last fifteen years (Figure 2 and 3). An overall positive trend took place until around 2000 and a slight negative trend afterward. The $T_{\text{min}}$ is the one that shows significant warming (higher than the $T_{\text{max}}$) mainly until around 2000 and a cooling afterward (Figure 3). This results in an overall negative trend of the average diurnal temperature range (DTR) during the 1970-2015 period. Table 1 shows the annual and seasonal decadal trends of the extremes and mean air temperature and for the DTR for the analyzed period.

<table>
<thead>
<tr>
<th>Season</th>
<th>$T_{\text{min}}$</th>
<th>$T_{\text{max}}$</th>
<th>$T_{\text{mean}}$</th>
<th>DTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>-0.02</td>
<td>-0.26</td>
<td>-0.14</td>
<td>-0.24</td>
</tr>
<tr>
<td>Autumn</td>
<td>0.03</td>
<td>-0.03</td>
<td>0.14</td>
<td>-0.35</td>
</tr>
<tr>
<td>Winter</td>
<td>0.47</td>
<td>0.00</td>
<td>0.23</td>
<td>-0.47</td>
</tr>
<tr>
<td>Spring</td>
<td>0.08</td>
<td>-0.28</td>
<td>-0.10</td>
<td>-0.36</td>
</tr>
<tr>
<td>Annual</td>
<td>0.21</td>
<td>-0.15</td>
<td>0.03</td>
<td>-0.35</td>
</tr>
</tbody>
</table>

Secondly, Figure 4 shows the annual duration of the freezing season and the starting and ending day. Results indicate no significant change in the starting freezing season, which occur around mid-April; while, the ending freezing season reveals a significant change of about one month, from the late October to late November. This implies that the number of freezing (non-freezing or melting) days has increased (decreased) mainly during the last 15 year (Figure 5). Also, the annual number of days with $T_{\text{max}}$ below zero degrees Celsius (above 1°C = $T_{\text{mean}} – 1$ standard deviation) has increased (decreased) over the 1970-2015 period. The long-term tendency showed that significant changes occurred from early 90’s onward, before that, non-significant changes are observed.
Discussion

Traditionally analysis of the air temperature behavior is carried out by calculating the mean and the long-term tendency. By doing this, it has been found a significant warming in the AP during the second half of the 20th Century. Frei station reveals the same behavior but also indicates the cooling observed during the last 15 years (Carrasco 2013, Turner et al. 2016, Oliva et al. 2017). Also, the analysis resolves that the significant warming is taking place during the winter (June-July-August) and in the Tmax, while the Tmax showed less warming until the 2000 and significant cooling afterward mainly in the spring and summer seasons. This results in an overall cooling of the Tmax over the 1970-2015 period and a corresponding negative trend in the DTR.

Another approach for analyzing the air temperature behavior is examined. This consists in determining the freezing season which corresponds to the time when Tmax is, on average, permanently below zero degrees Celsius, therefore no melting is expected during this period. This means that there is a starting and an ending day for each season over the years, which is determined after filtering out the inter-daily variability (Figure 1). At Frei station, the result indicates that the freezing season has extended about one month, from the late October to late November, resulting also in a shortening of the non-freezing period or “warming day season”, which can be defined as the time when the Tmax is above zero degrees, which mainly concurs with the summer season. Therefore, the results reveal an overall warming during the last quarter of the 20th Century, but a slight cooling afterward, this mainly due to the changes in the winter Tmin; however at the same time, there has been an increase of the freezing season duration.

To expand the analysis, the same procedure was carried out with Rothera (67°35’08”S, 68°07’59”W) and Faraday/Vernadsky (65°14’44”S, 64°15’28”W) stations, located to the south of Frei station on the western side of the AP. Figure 6 graphs the freezing season for Rothera station for the 1977-2015 period, while Figure 7 corresponds to Faraday/Vernadsky station for the 1970-2015 period. Both locations present different results from that found at Frei. They do not show an increase of the freezing season although Rothera does reveals an increase during the 2000-2015 period (Figure 6). On the other hand, the shortening of the freezing season at Faraday/Vernadsky can clearly be observed in Figure 7, which also reveals that the starting day have becoming later in the year, from mid-April to early-May. This means a longer summer melting season. To complement this analysis, the annual number of days for which the Tmax was above zero degrees Celsius (ANPD), were calculated for the three stations (Figure 8). Faraday/Vernadsky shows a significant positive trend over the 1948-2015 period, even during the last 15 years. Positive trend takes place at Rothera station between 1977 and 2000, and negative trend afterward. Non changes are observed at Frei station between 1970 and 1990, but afterward a negative trend can be observed, which is more significant after 2000.
Conclusion

The overall result at Frei station indicates a warming until 2000, mainly driven by the Tmin in winter, and a slight cooling afterward. Also, the duration of the freezing season has increased due to that the ending day has changed from the late October to late November during the 1970-2015 period. However, Rothera only shows a slight increase of the freezing season after 2000, while Faraday/Vernadsky reveals a decrease over 1970-2015 period. These behaviors concur with the behaviors of the ANPD, at each station. The analysis indicates that Faraday/Vernadsky station is the one that consistently shows a warming over the observed period (1948-2015), even during the last 15 years when the station located to the north (Frei) and south (Rothera) of it, a cooling has been taking place. This might suggest different north-south environmental and biophysical responds to the variability of the freezing season. For example, Petlicki et al. (2017) indicates that the reduction of ice mass loss in Ecology Glacier at King George Island is probably related to the decreasing summer temperature. The increase of the freezing season and the decreasing ANPD at Frei also support the Petlicki et al.’s conclusion (see Figures 4, 5 and 8). Cook et al. (2014) found an increasing ice loss from north to south in the western side of the AP. This might concur with the fact that Faraday/Vernadsky and Rothera stations show an overall decrease of the freezing season, mainly at Faraday/Vernadsky, which also experienced a significant increase of the ANPD. Further analysis is needed on this different temperature behavior in the western AP and its impacts.
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References


Observational and model based analysis of extreme temperature event in March 2015 in the Antarctic Peninsula

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Between 18 and 27 March 2015, northern, central, and southern Chile as well as the Antarctic Peninsula experienced a series of extreme hydrometeorological events just at the beginning of the austral fall. Within these dates, a record high-temperature of 17.5 °C occurred on 24 March 2015 on the continent of the Antarctic Peninsula at the Esperanza research base. The extreme temperature event is examined from a synoptic perspective with the goal of identifying large-scale forcing mechanisms. For that aim, we use ERA-Interim reanalysis, surface station data, sounding observation. To further investigate the event from a local scale perspective such as orographic effects, we have carried out a couple of regional climate model simulations with different configurations. Based on the synoptic-scale evaluation, it is shown that an anomalous northwest-southeast midlevel ridge and surface anticyclone stretched from higher latitudes over the South Pacific towards the Antarctic Peninsula before the event. Following the stretching and northwesterly warm air advection towards the Antarctic Peninsula, foehn wind events occurred on the lee of the mountain ranges in the Antarctic Peninsula resulting in extreme temperatures. We have applied the hydrostatic version of ICTP-RegCM4 model at 10 km grid size and 23 pressure levels driven by ERA-Interim reanalysis with different physical schemes to further investigate the local scale changes during the event. Preliminary results indicate that the model captures the above-defined synoptic conditions as well as the rapid increase in the temperature on the lee of the mountain ranges reasonably well. However, the amplitude and exact locations of the temperature spike are not captured well in the model simulations. The non-hydrostatic version ICTP-RegCM4 will be applied in a nested configuration with two domains at 10-km and 2-km resolutions together with increased vertical resolution in order to investigate the impact of resolution on the local scale mechanisms controlling the extreme temperature event. We will also use simulation results of non-hydrostatic WRF model for further comparisons.
New insights into the January 2016 West Antarctic melt event from the AWARE campaign and climate model simulations

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Episodes of widespread summer melt have been sporadic in West Antarctica since the beginning of satellite observations in the late 1970s. The various aspects of these melt events from the large-scale atmospheric drivers to the role of clouds and surface albedo remain poorly understood. At the peak of the Antarctic summer, surface temperatures over the Ross Ice Shelf and other low-lying areas of West Antarctica already commonly approach zero Celcius. And it is relatively common for the fringe of ice shelves along the Amundsen Sea to experience summer melting. This suggests that it may take only relatively modest atmospheric warming to make widespread surface melting more common in a not-so-distant future. In addition, the Southern Annular Mode (SAM) and the El Niño–Southern Oscillation can periodically cause important disruptions of the regional atmospheric circulation, which can create conditions favorable to extensive surface melt.

As discussed previously, a prominent surface melt event occurred in January 2016 and affected a large portion of the Ross Ice Shelf. Our presentation will provide further insight into what happened based on observations from the Atmospheric Radiation Measurement West Antarctic Radiation Experiment (AWARE) at WAIS Divide and idealized climate model simulations conducted with the Community Atmosphere Model version 4 (CAM4). The AWARE observations highlight in particular the presence of low-level liquid-water clouds during the event, which may have aided the radiative heating of the snow surface. The CAM4 simulations, forced with permanent El Niño conditions in the tropical Pacific, suggest that the strong 2015–16 El Niño event was an important factor in creating sustained warm air advection to the Ross Ice Shelf during the event. These model simulations also show that the positive SAM which prevailed before and during the event partly counteracted the El Niño influence and thus likely mitigated the overall magnitude of the melt.