5th Antarctic Meteorological Observation, Modeling, and Forecasting Workshop

BPRC Technical Report Number 2010-01

Byrd Polar Research Center
The Ohio State University
Columbus, Ohio, USA

12-14 July 2010

Byrd Polar Research Center 1960-2010 50th Anniversary
bprc.osu.edu

Preface

This workshop is meant to bring together those with both research and operational/logistical interests in Antarctic meteorology and forecasting. As in the past, the annual activities of the Automatic Weather Station (AWS) Project and the Antarctic Meteorological Research Center (AMRC) of the Space Science and Engineering Center at the University of Wisconsin-Madison,, and the Antarctic Mesoscale Prediction system (AMPS) project of the Mesoscale & Microscale Meteorology Division of the National Center for Atmospheric Research/Byrd Polar Research Center, Ohio State University will be addressed, as these affect a diversified group involved in and/or supporting Antarctic atmospheric and related science. Thus the status of, and developments in, the AWS, AMRC, and AMPS projects will be reviewed and an avenue for feedback and results from their user communities will be offered. The workshop will also serve more broadly as a forum for current results and ideas in Antarctic meteorology, NWP, and weather forecasting, from contributors to Antarctic efforts around the world. In addition, there will be general discussions on the relationships between the AWS, AMRC, and AMPS projects, other U.S., and international efforts and Antarctic forecasting, logistical support, and science. Topics of mutual interest to these programs, to Antarctic weather forecasters and modelers, and to the U.S. Antarctic Program and international programs will be considered.

This workshop is part of a year long celebration for the Byrd Polar Research Center, celebrating its 50th anniversary. This is also the 30th anniversary of the Antarctic Automatic Weather Station project and the 10th anniversary of AMPS!

Thank you to those who submitted papers, will make presentations and who will attend the meetings. We look forward to a productive and successful meeting.

On behalf of the Workshop Organizers, the hosts -the Polar Meteorology Group, and the Byrd Polar Research Center - Welcome to Columbus!

12 July 2010

5th Antarctic Meteorological Observation, Modeling, and Forecasting Workshop

Byrd Polar Research Center, Ohio State University, Room 240, Scott Hall

Monday July 12, 2010

Session 1: Antarctic Observations (1)

Chair: Ken Edele

8:30-9:00 a.m.	Matthew Lazzara, Nicole Schroeder, Lee Welhouse, George Weidner, and Jonathan Thom: Antarctic Automatic Weather Station Program: 2009-2010 field season overview
9:00-9:30 a.m.	Tamsin Gray: BAS Antarctic Peninsula Automatic Weather Station update
9:30-10:00 a.m.	Jonathan Thom, Matthew Lazzara, George Weidner, Linda Keller, and John Cassano: Antarctic Automatic Weather Station Program 2010-11 field plans
10:00-10:30 a.m.	Coffee Break

Session 2: Antarctic Observations (2)

Chair: David Reusch

10:30-11:00 a.m.	Steven Colwell: The meteorological capabilities of the British Antarctic Survey in Antarctica
11:00-11:30 a.m.	Marc de Keyser: Weather observations in East Antarctica: an expedition in 2011
11:30-noon	Steven Colwell and John Turner: The SCAR READER project
Noon-12:30 p.m.	Tom Lachlan-Cope: Antarctic airborne measurements
12:30-1:30 p.m.	Lunch

Session 3: Antarctic Observations (3)

Chair: David Bromwich

1:30-2:00 p.m.	George Weidner: Thirty years of automatic weather station measurements (New technology brings new challenges)
2:00-2:30 p.m.	Roundtable on reminiscences of the Antarctic AWS program plus Chuck Stearns' contributions
2:30-3:00 p.m.	Award of 2010 Goldthwait Polar Medal to Professor Charles R. Stearns (Posthumous). Accepting on his behalf: Jim Stearns. Preliminary remarks by David Bromwich. Formal award by BPRC Director Ellen Mosley-Thompson.
3:00-3:30 p.m.	Coffee Break

Session 4: Antarctic Observations and Applications

Chair: Neil Adams

3:30-4:00 p.m.	David Rasmussen, Linda Keller, and Matthew Lazzara: A 20 year assessment of the frequency and intensity of McMurdo area high wind events
4:00-4:30 p.m.	Shelley Knuth: Analysis of the atmospheric state of the Terra Nova Bay region of Antarctica
4:30 p.m.	Open Forum on the Future of Antarctic AWS
5:30 p.m.	Finish for the day.
6:30 p.m.	Group Dinner at Columbus Brewing Company

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Tuesday July 13, 2010

Session 5: Antarctic Data Distribution and Usage

Chair: Steve Colwell

8:30-9:00 a.m.	Elena Willmot, Matthew Lazzara, Linda Keller, and Nicole Schroeder: AMRC meteorological data distribution system part I: Data sources and archive
9:00-9:30 a.m.	Zachary Uttech, Matthew Lazzara, Elena Willmot, and Linda Keller: AMRC meteorological data distribution system part II: data services
9:30-10:00 a.m.	Matthew Lazzara, Richard Dworak, David Santek, Nick Bearson, Chris Velden, and Jeffrey Key: Composite satellite atmospheric motion vectors
10:-10:30 a.m.	Andrew Archer: Overview and status report on U.S.A.P. remote sensing systems
10:30-11: a.m.	Coffee Break

Session 6: Antarctic ENSO and SAM

Chair: Shelley Knuth

11:00-11:30 a.m.	Lee Welhouse, Matthew Lazzara, Greg Tripoli, and Linda Keller: Composite analysis of the surface effects on El Niño-Southern Oscillation teleconnections on Antarctica
11:30 a.m.-noon	David Reusch: Expressions of ENSO and SAM in modeled Antarctic surface temperatures
Noon-12:30 p.m.	Ryan Fogt, David Bromwich, and Keith Hines: Understanding the SAM influence on the South Pacific ENSO teleconnection
12:30-1:30 p.m.	Lunch

Session 7: Posters

Chair: David Bromwich

1:30-2:00 p.m.	Brief introduction to the 7 posters (listed at the end) – 5 minutes max. each.
2:00-3:00 p.m.	Poster viewing
3:00-3:30 p.m.	Coffee Break

Session 8: Antarctic Observational Studies

Chair: Tamsin Gray

3:30-4:00 p.m.	Irina Gorodetskaya, N. P. M. van Lipzig, M. R. van den Broeke, W. Boot, C. Reijmer, A. Mangold, S. Kneifel, S. Crewell, and J. Schween: Ground-based observations of cloud properties, precipitation, and meteorological conditions at Princess Elizabeth station in Dronning Maud Land, Antarctica
4:00-4:30 p.m.	Daniel Grovesnor: *In situ* observations of Antarctic Peninsula clouds
4:30-5:00 p.m.	Shelley Knuth: UAV observations of the wintertime boundary layer over the Terra Nova Bay polynya
5:00 -5:30 p.m.	Daniel Grosvenor: Examining a downslope warming wind event over the Antarctic Peninsula through modeling and aircraft observations: can mountain waves cause surface melting on the Larsen Ice Shelf?
5:30 p.m.	Finish for the day
6:30 p.m.	Causal dinner at Dave Bromwich's house

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Wednesday July 14, 2010

Session 9: Antarctic NWP and Forecasting (1)

Chair: Matt Lazzara

8:30-9:00 a.m.	Kevin Manning and Jordan Powers: AMPS update- July 2010
9:00-9:30 a.m.	Kevin Wilson: Software with a view of weather observation statistics
9:30-10:00 a.m.	Marc de Keyser: Operational forecasting in Patriot Hills with AMPS products
10:00-10:30 a.m.	Coffee Break

Session 10: Antarctic NWP and Forecasting (2)

Chair: Jordan Powers

10:30-11:00 a.m.	T. Bednarczk, W. Brown, B. Burden, J. Kramer, and R. Hennig: Aviation weather forecasting tools for South Pole.
11:30 a.m.-noon	Neil Adams: Verification of numerical weather prediction systems employed by the Australian Bureau of Meteorology over East Antarctica during the 2009-10 summer season
Noon-12:30 p.m.	Julien Nicolas, David Bromwich and Ian Thomas: Validating the moisture analyses and predictions of AMPS using ground-based GPS measurements of precipitable water.
12:30-1:30 p.m.	Lunch

Session 11: Antarctic Modeling

Chair: Kevin Manning

1:30-2:00 p.m.	Jordan Powers, Steven Cavallo, and Kevin Manning: Improving upper-level performance in AMPS: Longwave radiation
2:00-2:30 p.m.	Dan Steinhoff and David Bromwich: The effects of grid nudging on Polar WRF forecast in Antactica
2:30-3:00 p.m.	Melissa Richards and John Cassano: An analysis of the low-level wind field over the Ross Ice Shelf, Antarctica
3:00-3:30 p.m.	Coffee Break

Session 12: Antarctic Miscellaneous Items

Chair: Rolf Hennig

3:30-4:00 p.m.	Francis Otieno, David Bromwich, and Keith Hines: Short-term forecast performance of Polar WRF in the Antarctic
4:00-4:30 p.m.	Steve Pendlebury, Neil Adams, and Bruce Angle: Developments within the World Meteorological Organization concerning polar observations, research and services
4:30-5:30 p.m.	Open Forum: AMPS Feedback and Requests
5:30 p.m.	End of 2010 AMOMFW

Free evening

Posters

Neil Adams: Severe turbulence affecting helicopter operations over the Sørsdal Glacier south of Davis station

Martina Barandum and Christophe Genthon: Studies of Antarctic precipitation statistics (Presented by Irina Gorodetskaya)

Aurélie Bouchard, Florence Rabier, Vincent Guidard, Eric Brun, Fatima Karbou, Olivier Traulle, Alexis Doerenbecher, Christophe Genthon, and Delphine Six: The CONCORDIASI campaign (Presented by Irina Gorodetskaya)

Christophe Genthon, Mike Town, Delphine Six, and Vincent Favier: Extremely stable boundary layer on the Antarctic plateau (Presented by Irina Gorodetskaya)

Claudio Scarchilli, Massimo Frezzotti, Paolo Grigioni, Lorenzo De Silvestri, Lucia Agnoletto, and Stefano Dolci: Measurements of blowing snow transport in East Antarctica (Presented by Julien Nicolas)

Dan Steinhoff and David Bromwich: Polar WRF simulations of the McMurdo Dry Valleys

Michael Town, Irina Gorodetskaya, Hubert Gallee, Von Walden, and Christophe Genthon: An intercomparison of the surface energy budget over the South Pole between observations, ERA-40, and Modele Atmospherique Regional

ANTARCTIC AUTOMATIC WEATHER STATION PROGRAM: 2009-2010 FIELD SEASON OVERVIEW

Matthew A. Lazzara[*,1], Nicole M. Schroeder[1], Lee J. Welhouse[2] George A. Weidner[2], and Jonathan E. Thom[1]

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1. ABSTRACT

The 2009-2010 field season saw the servicing of approximately 14 Automatic Weather Station (AWS) sites around the Antarctic (See Figure 1 and 2). Poor weather conditions contributed to the failure of installing four new AWS sites, including three in West Antarctic near Pine Island Glacier and the Tall Tower AWS site on the Ross Ice Shelf. This presentation will review the AWS field season activities, repairs, servicing, and attempted installations. The presently known and verified network of all national and international AWS plotted on the map in Figure 3.

Figure 1. Pegasus North AWS being serviced by field team members Lee Welhouse and Nicole Schroeder.

Figure 2. The lead author servicing Windless Bight AWS.

2. ACKNOWLEDGEMENTS

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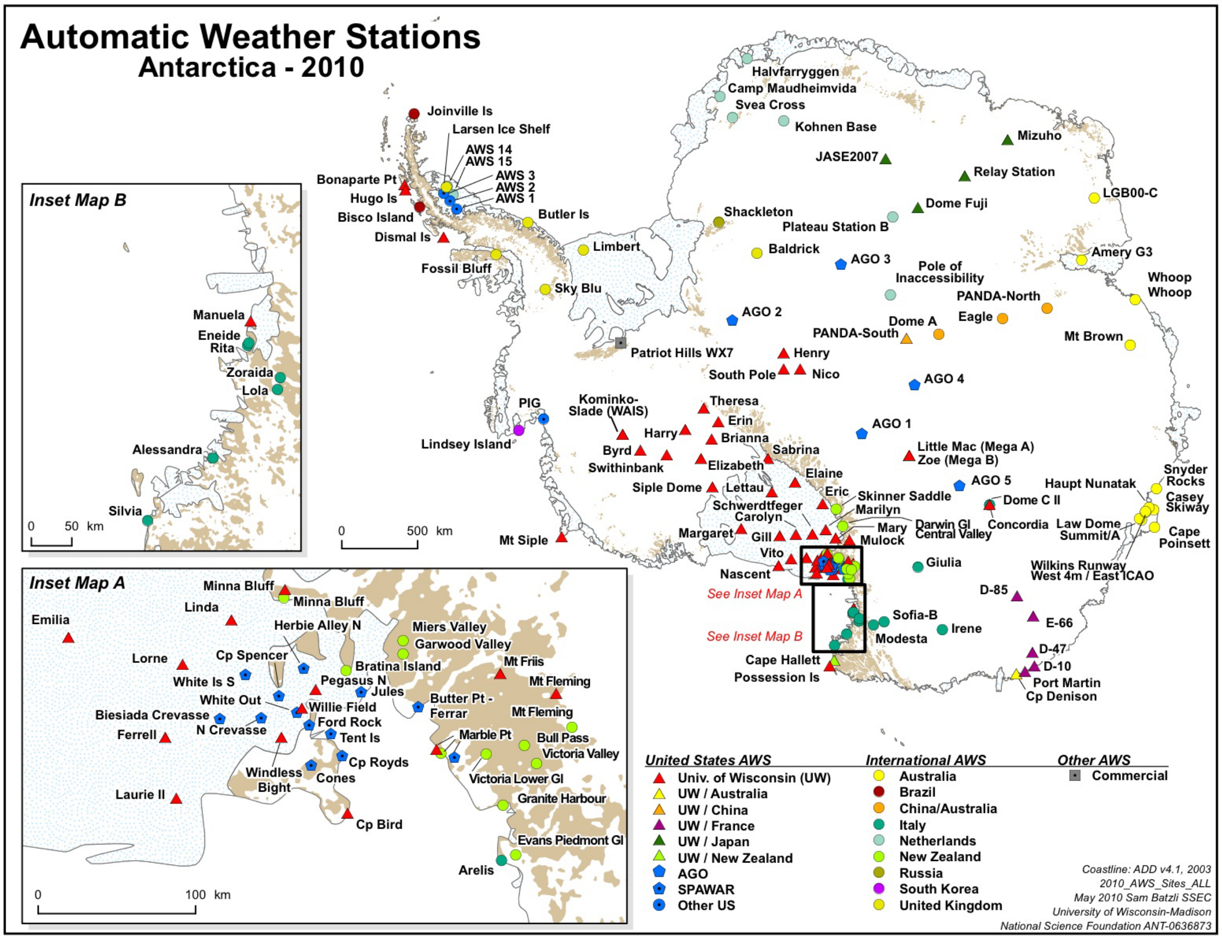


Figure 3. The 2010 draft Automatic Weather Station map of all verified AWS installed in Antarctica (as of June, 2010).

BAS ANTARCTIC PENINSULA AUTOMATIC WEATHER STATION UPDATE

Tamsin Gray

British Antarctic Survey, Cambridge, UK

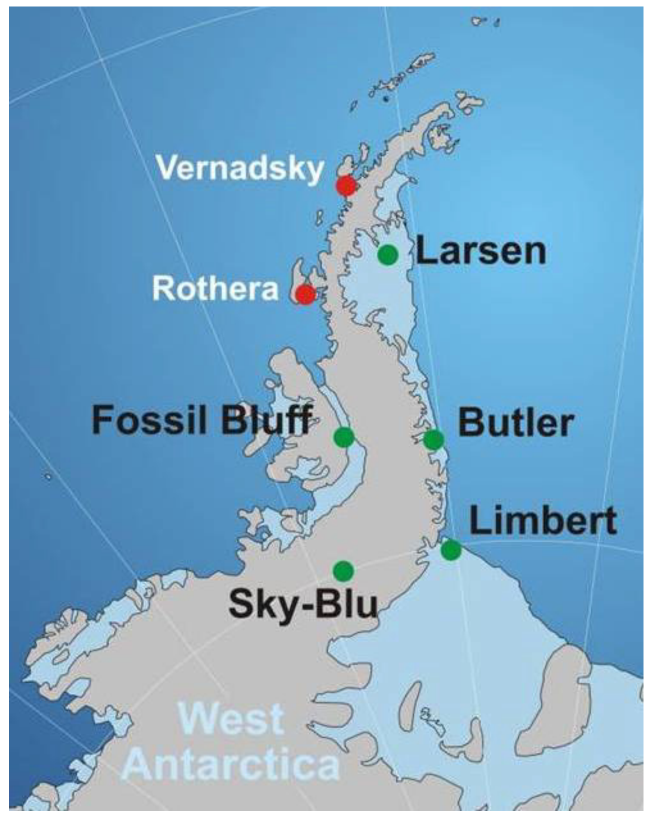
1 INTRODUCTION

During the past Antarctic field season, all 10 existing AWS sites maintained by BAS were serviced. We also installed one new station and carried out successful maintenance work at a USAP site on Dismal Island just south of Rothera. Next season we have plans to install 4 short term AWS across the Peninsula (see final map).

Servicing of existing AWS

There are currently six AWS located on the Larsen C ice shelf (although only the one originally installed by BAS is shown). A Dutch team led by Michiel van den Broeke of the University of Utrecht have one site collocated with the BAS AWS plus one approximately 40km to the south, details can be found at http://www.phys.uu.nl/~wwwimau/research/ice_climate/aws/antarctica_stations.html Konrad Steffen leads a joint US and Chilean team running 3 AWS further inland on the Larsen C. These sites were installed in summer 08/09 but were only partially functional until they were revisited this summer. All three stations are now transmitting weather, radiation and GPS data. All 6 Larsen AWS stations should continue running for at least another 2 years.

BAS also has stations located at Fossil Bluff, Sky Blu, Butler Island and on the edge of the Ronne Ice Shelf as shown. All stations are transmitting full datasets via iridium satellites, as well as real-time data via the Argos network. During summer 09/10 all sites were raised and the sonic snow depth sensors were replaced at Butler Island and Fossil Bluff.



Installation of 'Thomas' AWS

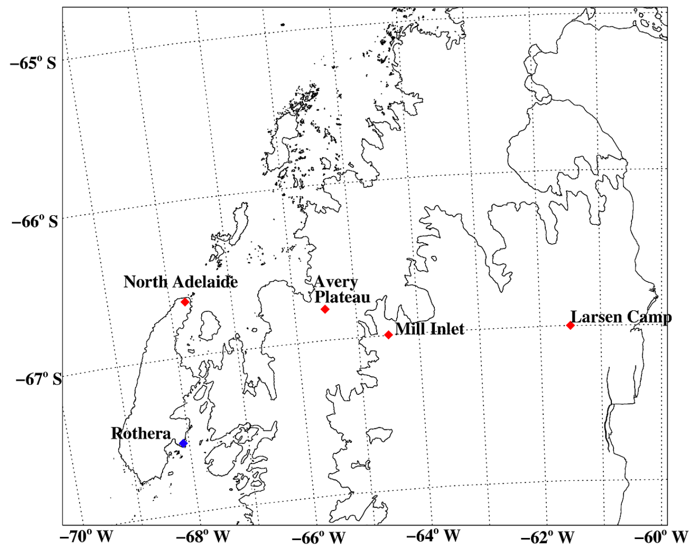
In December 2009 we installed a complete new AWS measuring temperature, humidity, pressure, wind speed and direction, and snow depth at 74°34.64S 086°54.26W. This AWS is currently transmitting data via iridium. Unfortunately, due to logistics this site is a temporary installation only and will be removed and relocated in the coming Antarctic summer. However, due to the location of the AWS in an area of West Antarctica with poor coverage, the data could be of interest.

Dismal Island Maintenance

In late March we were able to visit the USAP AWS located to the south of Rothera on tiny, but aptly named, Dismal Island. The wind vane, Argos antenna and power supply were replaced at this site and full data is now being received.

Planned AWS for 2011: OFCAP project

This summer, a group of scientists from BAS and the University of East Anglia will carry out a field campaign designed to study the impact of Orographic Flow on the Climate of the Antarctic Peninsula (OFCAP). As part of this initiative, 4 new AWS are planned covering a transect of the Peninsula as indicated on the map. These stations will be temporary installations, intended to collect data for one year only. They will transmit data via iridium and measure temperature, pressure, humidity, wind speed and direction.



ANTARCTIC AUTOMATIC WEATHER STATION PROGRAM 2010-11 FIELD PLANS

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1. Introduction

The United States Antarctic Program (USAP) Automatic Weather Station (AWS) network is an important resource for research and operations in Antarctica. The AWS network allows our group to pursue our scientific interests, but is valuable meteorological data resource for the greater Antarctic scientific community. This presentation outlines the general plans for the 2010-2011 field season and the short to mid-term future of the network. Technological changes to station systems will be discussed as well.

2. AWS 2010-2011 FIELD SEASON PLANS

Plans for the 2010-2011 field season activities include the work done by University of Wisconsin and work done by collaborators. This seasons University of Wisconsin work will include: (1) installation of a Tall Tower AWS ~100 miles southeast of McMurdo Station on the South Pole traverse route; (2) servicing and upgrading of AWS from McMurdo Station via fixed wing and helicopter; (3) servicing, upgrading, removal, and installation of stations in East Antarctica and the Southern Ross Ice Shelf while based from the CTAM field camp; (4) servicing, removal, and installation of AWS sites in West Antarctica; (5) removal of AWS sites near South Pole and servicing of Radiation shield test site at the Pole. The field season is ambitious and divided into an early season and late season. Due to weather, many events that were to occur in the 2009-2010 field season have been rescheduled for the 2010-2011 season. This includes three collaborative AWS installations in West Antarctica and the tall tower installation.

Some of the service work will include changes to the data telemetry for our AWS. We are converting some stations near McMurdo to Freewave radio modems to save Argos IDs for deep field locations. This will include the installation of a base station in McMurdo to collect data. The conversion of our old AWS stations to the new electronics platforms will continue.

3. FUTURE FIELD SEASONS

The AWS network will continue to evolve to reflect current economic realities, funding limitations, changes in policy, and logistical constraints. Overall, the AWS network will meet its primary role to support current and pending proposed NSF funded Antarctic research. Due to changes in accounting for Argos communication costs, the number of AWS units deployed will be reduced and we plan to operate a fixed number of Argos platforms (~50). Alternative data telemetry and on station recording will be explored.

The primary objective remains to optimize the research capabilities of the largest surface meteorological observing network in Antarctica. We continue to explore the option of adding new instrumentation to our stations and collaborating with other projects to better utilize USAP resources.

4. ACKNOWLEDGEMENTS

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THE METEOROLOGICAL CAPABILITIES OF THE BRITISH ANTARCTIC SURVEY IN ANTARCTICA

Steven Colwell

British Antarctic Survey, Cambridge, UK

1 INTRODUCTION

The British Antarctic Survey operates 4 year round stations in Antarctica and below will be detailed what meteorological measurements are made at each of these stations.

Rothera 67°34'S 68 °08'W

At Rothera we currently make most of our meteorological measurements, the main system for measuring the meteorological parameters is our JAWS (Just Another Weather Station) system which is based around a Campbell CR1000 logger it has a Druck pressure sensor, temperature is obtained via a PRT (Platinum Resistance Thermometer) in an aspirated radiation shield, humidity is obtained from a Vaisala HMP 45 probe also in an aspirated radiation shield. There are two wind sensors, a Vaisala WS 425 sonic anemometer is the primary source of the wind data but there is also an RM young aerovane as a backup if the sonic anemometer fails to give valid data which can happen in high wind conditions where there is a lot of blowing snow. There is also a CNR1 solar radiation sensor attached to the system that can measure incoming and outgoing long and shortwave radiation and finally there is a CSD1 sunshine detector attached. Data is logged every minute and software is run to allow a synoptic observation to be entered.

Radio-sondes are flow 4 times a week on Monday, Tuesdays, Thursday and Fridays using an MW31 ground station, RS92 radio-sondes and 350gram balloons.

A laser cloud-base recorder is also operated at Rothera and a real-time display is available that can be used to give information to aircraft. The data is also archived so it can then be used for research.

Precipitation is measured using a Biral LPS (Laser Precipitation Sensor) that uses a infra-red laser to measure water droplets and snow that pass between its sensor heads, it measures the reduction in the received signal and the length of time of the reduction and from this it can calculate the diameter of the particle and the fall speed, additional information can be found at http://www.biral.com/met/precipitation/lpm.htm.

Alongside this is a Biral VPF 730 combined precipitation and visibility sensor that operates using an infrared beam and looking at off axis scatter to calculate visibility and looking at backscatter to calculate precipitation type and intensity. Additional information about the VPF 730 can be found at http://www.biral.com/fog/visibilitysensors/vpf730visibiltyandpresentweather.htm#Measurement%20Principle.

There is also a heated tipping bucked snow gauge that is being trailed at the same site.

Atmosphere aerosol is measured using a Prede POM-01 sun photometer that looks at the sun in different wavelengths. It has an internal rotating filter wheel to measure radiation in seven narrow wavebands from 315 nm to 1020 nm. It measures the extent to which light from the Sun is scattered as it travels through the Earth's atmosphere, which allows the calculation of the size and density of the particles that are scattering the light (mainly things like sea salt, volcanic dust and man-made pollutants). More information can be found at http://www.kippzonen.com/?download/368392/POM-01+++POM-02+Sky+Radiometer+-+Manual.aspx.

A SAOZ (System d' Analyse par Observation Zenitale) instrument is run in the optical caboose at Rothera and this measures sunlight scattered from the overhead sky which allows the calculation of how much ozone and nitrogen dioxide the light has passed through.

Satellite images are received using our ARIES (Antarctic Reception of Images for Environmental Science) system, this has a 2.4m dish and the captured images are used in real-time by the forecaster and are also archived so that they can be used for research.

There is a Met Office forecaster based at Rothera in the summer and they use a HORACE system to display the data from the Met Office forecast model, the system can also take in and display the data from the satellite receiver system. The forecaster also has access to the AMPS output so this can be used alongside HORACE.

Halley 75°35'S 26°34'W

Halley is currently in a partial shutdown phase during the building of our new Halley 6 station, we are still making meteorological measurements using a Campbell AWS with a CR10X logger inside. The system measure pressure, temperature, humidity, wind speed and wind direction and this data is transmitted via a radio link back to the station so that hourly synoptic messages can be constructed.

Radio-sondes are flow 6 times a week (every day except Sunday) using an MW31 ground station, RS92 radio-sondes and 350gram balloons. During the Halley summer season (December to mid February) and the ozone hole period (Mid August to Mid October) daily flight are carried out

A cloud-base recorder is also operated at Halley and a real-time display is available that can be used to give information to aircraft, the data is also archived so it can then be for research.

Atmosphere aerosol is measured using a Prede POM-01 sun photometer.

Ozone is measured using a Dobson spectrophotometer.

King Edward Point (South Georgia) 54°17′S 36°30′W

Meteorological measurement are made at KEP using a Vaisala MILOS 520 which measures pressure, temperature, humidity, wind speed, wind direction and sunshine.

Precipitation is measured using a Biral LPS.

Bird Island (South Georgia) 54°00′S 38°03′W

Meteorological measurements are made at Bird Island using a Vaisala MILOS 520**.**

Automatic Weather Stations

BAS operates several AWS in Antarctica, details of these can be found in the abstract that is specifically about the BAS AWS.

THE SCAR READER PROJECT

Colwell, S and Turner, J

British Antarctic Survey, Cambridge, UK

1 INTRODUCTION

READER (REference Antarctic Data for Environmental Research) is a SCAR (Scientific Committee on Antarctic Research) funded project that has the goal of creating a high quality, long term dataset of mean surface and upper air meteorological measurements from in-situ Antarctic observing systems. These data are of value in climate research and climate change investigations. Surface and upper air data have been collected and monthly means derived. Although monthly mean datasets already exist it was felt that this new dataset was needed because none of the other datasets had any information about how the mean values were calculated or how much data were used in the calculation. In READER we have included the percentage of observations used in brackets after the values. I will explain where the raw data were obtained from and the quality control procedures that were carried out on these data and where the data can be accessed. Other meteorological data that is available at the British Antarctic Survey will be shown along with the ways that these data can be accessed.

Thirty Years of Automatic Weather Station Measurements
(Advances in Technologies Brings New Challenges)

George Weidner

The last thirty years have seen dramatic advances in automatic weather station (AWS) capabilities. From the early days of a limited number of low power sensors and low sampling rates, we are today presented with an incredible array of sensor options and very fast sampling rates. Dataloggers offer onboard statistical analysis and Gigabyte storage capacities.

As with most advances, there are challenges in using the new AWS capabilities. Using the University of Wisconsin's AWS program as an example, I will present some of the challenges we faced during the last 30 years. These include accounting for varying measurement techniques in constructing data archives, the pros and cons of using commercial-of-the-shelf (COTS) components, software, and sensor interfaces, and especially how the trend to lower power , high sampling rate, small-signal capable measurement systems can present challenges to an in-house designed AWS.

A 20 YEAR ASSESSMENT OF THE FREQUENCY AND INTENSITY OF MCMURDO AREA HIGH WIND EVENTS

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ABSTRACT

Recent cases of increased structural damage have been reported throughout the McMurdo area. It has been hypothesized that this change may have been due to the increase in the frequency, duration, and magnitude of synoptic and mesoscale forced wind events in the region. This has led to our investigation in hopes of answering this question.

This study utilizes approximately 20 years of Automated Weather Station (AWS) wind data from four stations (Black Island, Cape Bird, Minna Bluff, and Pegasus North) around the McMurdo region. Both the University of Wisconsin Automatic Weather Stations Project and the United States Navy's Space and Naval Warfare (SPAWAR) Systems Center, based in Charleston, South Carolina, provided the AWS data. Each data set was examined for 'high wind events' that met a duration and intensity threshold. Wind speed intensity thresholds were unique to the distribution of winds at each AWS site and were also based upon the Beaufort Wind Force Scale to gage the extent of the theoretically possible structural damage. Our 'high wind event' duration requirements included wind events lasting at least 6, 12, or 24 hours. In order to be counted as a 'high wind event', at least half of the observations occurring within the 6, 12, or 24-hour duration had to meet our intensity thresholds. In addition, periods of missing data were recorded if they surpassed half of the observations in one month. In total, roughly 800 'high wind events' were found over the 20-year period from the available data at the four AWS sites.

Upon building a database of 'high wind events', a number of elementary statistical methods were utilized for each AWS location in an effort to answer the original hypothesis. These included: the frequency of the 6, 12, and 24-hour 'high wind events' occurring every year, the total seasonal frequency of 'high wind events' occurring over the historical period, the maximum wind speed occurring during a 'high wind event' in each year, and the overall wind direction frequency for all 'high wind events' occurring at each AWS location.

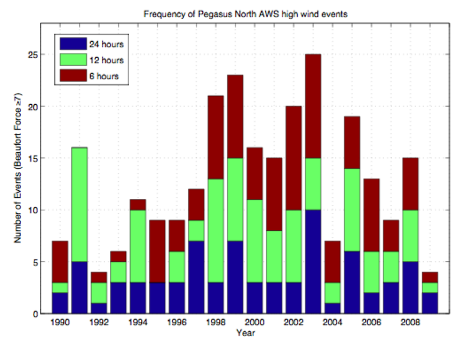

Figure 1. A sample histogram showing the annual distribution of 'high wind events' at Pegasus North AWS.

Based upon our initial analysis, we have found no clear trend in the annual maximum wind speeds at the four AWS sites in focus and no clear indication that El Niño Southern Oscillation (ENSO) influences the magnitude of the maximum wind speeds. However, it was found that the majority of the 'high wind events' have average wind directions ranging from SSE to SSW, with outlying events at Cape Bird AWS having wind directions in the area of NNE. In addition, it was found that the summer season experiences the smallest frequency of 'high wind events' at all AWS locations, and our initial examination also showed that there is disagreement between the other seasons as to which include the greatest number of 'high wind events'. Nonetheless, our analysis is continuing.

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Analysis of the Atmospheric State of the Terra Nova Bay Region of Antarctica

Shelley Knuth

In September 2009, four unmanned aerial vehicles (UAVs) were flown between McMurdo Station and Terra Nova Bay, Antarctica, to collect information on atmosphere-ocean interactions. Prior to the field season, wind and temperature data from a local automatic weather station (AWS) were collected from 1993-2007 and compared to an August-October 2006-2008 satellite cyclone climatology to place the September 2009 observations into a broader climatological context. AWS wind data revealed a strong tendency toward downslope flow in the region regardless of season, as the majority (55%) of winds were from the west to northwesterly directions. Most winds found at the site were less than 20 m/s, but 83% of the higher winds were from a direction consistent with downslope flow. Fifteen of 418 high wind events (greater than 20 m/s) occurred during the cyclone climatological period, with 100% of those events occurring in the presence of a Ross Sea cyclone. Winter experienced the greatest number of high wind events (68%), while summer had the lowest (4%). Most temperatures were found between -15 and -25ºC, with temperatures strongly influenced by wind fluctuations. The cyclone climatology revealed 64% of systems were comma-shaped, and most cyclones (84%) within the Ross Sea were mesocyclones. A comparison of AWS data for Septembers 1993-2007 and September 2009 showed fewer high wind events during 2009, while the cyclone climatology revealed a shift in cyclonic activity eastward. Reanalysis data comparing September 1993-2007 and September 2009 show an eastward shift in an upper-level trough, indicating September 2009 was an anomalous year.

In addition to the climatological data, preliminary wind data sampled during the UAV flights will be presented. Initial analysis suggests a strong topographical influence on local wind field from both Ross Island and local glacial streams west of Terra Nova Bay.

AMRC METEOROLOGICAL DATA DISTRIBUTION SYSTEM PART I: DATA SOURCES AND ARCHIVE

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1. INTRODUCTION

The University of Wisconsin collaborates with a variety of participants within the Antarctic meteorological community to collect, distribute and archive all meteorological data (Roth and Lazzara, 2002; Lazzara et al. 2008). Historically, the AMRC anonymous File Transmission Protocol (FTP) site has acted as an archive of various types of data collected from weather stations across Antarctica. Each month, the FTP site is updated and announcements of data are made available to the community through subscription e-mailing lists. Today, the creation of the new AMRC website and the utilization of additional tools will make the distribution of data simpler. Efforts are in progress to provide the AMRC meteorological data collection in a variety of user-friendly methods, with the goal of making much of this information available as self-service. This first part of this two-part series covers the data sources and the data archive that comprise the AMRC data collection, while the second portion will cover data services. Challenges that come with the management of Antarctic data are outlined here.

2. DATA SOURCES

Data sources internal to the AMRC, such as Automatic Weather Station (AWS) data and Antarctic satellite composites, constitute an important part of the overall AMRC data distribution system. A significant share of the meteorological data being archived and distributed comes from the University of Wisconsin's own AWS program. From these weather stations, the AMRC receives real-time and archive quality data sets in ten minute, one hour and three hour intervals. Satellite observations, primarily in the form of AMRC's signature infrared satellite composites are a key part of the collection as well (See Figure 1). These Antarctic composites were originally conceived by University of Wisconsin's Professor Charles R. Stearns in October 1992 (Lazzara, et al. 2003). The composites cover the South Pole region to about 40° South, and are created every three hours starting at 0 UTC every day. As technology developed, more sizes and types of composites were added to the collection including water vapor composites (introduced in May 2001) as well as visible, short and long wave composites.

Other satellite data, such as polar orbiting Local Area Coverage (LAC) observations from the Advanced Very High Resolution Radiometer (AVHRR) sensor onboard the National Oceanic and Atmospheric Administration (NOAA) satellite series are another part of the archive. Additional data sets over the Antarctic and adjacent Southern Ocean are collected from incoming data streams from Wisconsin's Space Science and Engineering Center (SSEC) Data Center. These include surface synoptic and Meteorological Aviation Report (METAR) observations along with Aircraft Reports (AIREP), Radiosonde Observations (RAOB) and Ship/buoy observations. Included in this stream are global numerical model outputs from the Global Forecast System (GFS) and the European Centre for Medium-Range Weather Forecasts (ECMWF), etc.

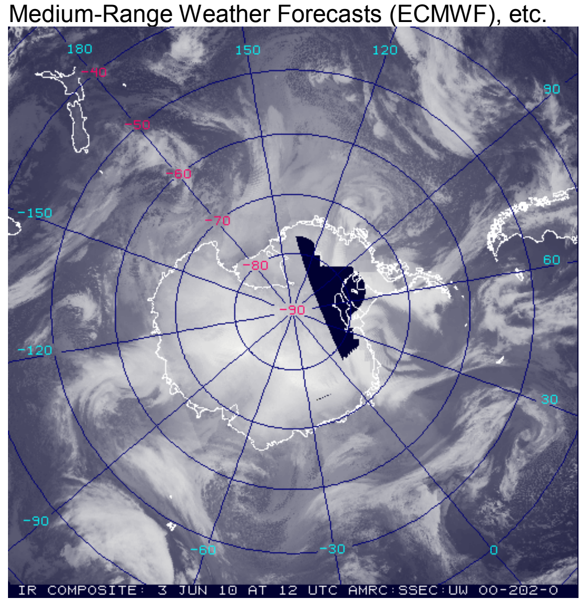

Figure 1. A sample Antarctic Infrared composite with color enhancements from June 3, 2010 at 12 UTC. Current composites can be found on the AMRC website.

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An equally important component of the distribution system involves data sources that originate external to the AMRC. Thanks to the participation of researchers, operational organizations, other United States Antarctic Program (USAP) participants, and international groups within the Antarctic meteorological community, AMRC is able to archive a variety of meteorological datasets. International AWS data, USAP research vessel observations, field experiment radiosonde observations as well as surface observations at Palmer Station, McMurdo Station, South Pole Station, and various other field camps are just a sample of the data sent to the AMRC on a routine basis and added to the ever-growing AMRC archive.

3. DATA ARCHIVE

Since October 1992, the AMRC has been archiving its data collection. A variety of media have been used over the years including magneto-optic disks, compact disks (CD), digital video disks (DVD), and a host of tapes (including 8 millimeter Exabyte, DDS3 and LTO). Presently, RAID/5 disk arrays host the primary archive with DVD and tape backups.

At the end of each month, new data sent to the AMRC from the various external sources (as well as internal sources) within the Antarctic community are organized and added to the archive. An announcement of the new monthly data is sent in a summary/notification email to one of AMRC's many subscription e-mailing lists, which serve as one of the main distribution systems for updating the community about newly available meteorological data.

4. DISTRIBUTION

One of the main goals of the AMRC group involves the distribution of data to fellow researchers, groups, and the general public. Some of the distribution services (to be discussed in greater detail in AMRC Meteorological Data Distribution System Part II: Data Services) include but are not limited to the FTP site, subscription e-mailing lists, and the website. The new AMRC website provides real-time displays in addition to the archive of the Antarctic meteorological data. Items such as the satellite composites are available and updated routinely. Information regarding the subscription e-mailing lists, AMRC mailing addresses, and supporting documentation and information will all be found on the new website. The AMRC will continue it's nearly 18-year-long tradition of archiving and distributing data to the Antarctic meteorological community in inventive and helpful ways.

5. CHALLENGES

As the system evolves into a semi-automated, self-service arrangement, there are several challenges to be addressed. One of the means by which AMRC receives external datasets is by way of FTP services. However, advancing security rules may force this method to be eliminated, and hence impel the need for another data access arrangement in the very near future. Interfacing with other external systems to acquire source data sets also poses challenges in an era with limited resources to establish and maintain automated links. Human resources to manually provide data are limited and expensive and not desired in an automated era. There is also the risk of loss of corporate knowledge due to a high turnover of personnel.

The AMRC also faces challenges regarding data access and quality from various third parties. Missing, corrupt, or low-quality data causes gaps in the archive. This, in turn, creates additional issues for AMRC: which data can be distributed as is and which requires extensive quality control? Finally, for this effort to continue, the AMRC requires the community to acknowledge the AMRC as a source of Antarctic observations and datasets as well as expertise.

6. ACKNOWLEDGEMENTS

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AMRC METEOROLOGICAL DATA DISTRIBUTION SYSTEM PART II: DATA SERVICES

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1. INTRODUCTION

The Antarctic Meteorological Research Center (AMRC), aims to provide real-time and archived meteorological data and observations to the community. A network of Automatic Weather Stations (AWS) in Antarctica and Antarctic satellite composite imagery provides a significant portion of AMRC data holdings. Historical means of data distribution, including File Transfer Protocol (FTP), and our current web site have needed modernization. A newer, improved, and organizationally restructured new website seeks to increase the efficiency of data acquisition by users.

2. NEW AMRC WEBSITE

Useful data and information are contained within the two rows of tabs located at the top of the homepage (Figure 1). The most commonly used information is contained within the AWS Network and the Data & Imagery sections.

The University of Wisconsin-Madison's Space Science and Engineering Center (SSEC) AMRC project supports an AWS network made up of approximately 63 stations. Due to the variety of meteorological data associated with this network, it became necessary to condense the archived station data into a more accessible central location. This was done with the creation of a dynamic AWS (click-able) map of Antarctica, with functionality that allows for the selection of any individual AWS. The most beneficial feature of the dynamic map is simultaneous access to the data of a selected station and the dynamic map itself: Users are able to navigate from one station to another with ease. In addition, the dynamic map has zooming and panning capabilities to aid in station identification and selection. With the selection of an individual station, the station is highlighted and the selected stations name, picture, and metadata are displayed underneath the dynamic map. Also located on this page are several sidebars containing additional information about the AWS.

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Figure 1. The layout of the AMRC's new homepage. All of our data and miscellaneous information is located in two rows near the top of this page.

The Data & Imagery section contains 9 separate categories of data: Antarctic surface observations, satellite imagery and composites, upper-air observations, models and forecasts, data fusion, aircraft observations, satellite navigation, archived surface and upper-air observations, and archived satellite imagery and composites (Figure 2). The thumbnail organizational layout of this page is a substantial improvement over the old AMRC website, which was simply an aggregation of text bullet points. The content within these categories is dynamically displayed and easily configurable, to keep the maintenance of the site to a minimum.

3. CURRENT DATA SERVICES

Currently five data services are used to provide real-time and archival data:

- File Transmission Protocol (FTP) server
- Rsync Service

- Antarctica-IDD (Internet Data Distribution) Local Data Manager (LDM)
- Abstract Data Distribution Environment (ADDE)
- E-mail distribution

The current FTP site stores archival data with minimal real-time datasets. The Antarctic-IDD system is a data-sharing network based on Unidata's Local Data Manager (LDM) software (Lazzara et al., 2006) with a focus on real-time data. The ADDE server contains both real-time and archived data. The ultimate goal is to provide self-serviceable data to reduce the effort to fill data requests.

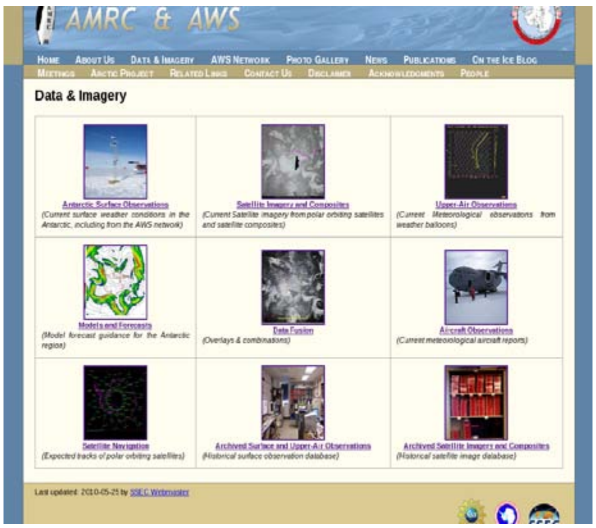

Figure 2. This is the layout of the AMRC's new "Data & Imagery" page. The "Data & Imagery" section is organized into 9 categories, which are represented by appropriate thumbnails.

4. FUTURE DATA SERVICES

Besides reconstructing the AMRC website to make data more accessible, efforts have also included experimenting with a data repository system called Repository for Archiving, Managing and Accessing Diverse Data (RAMADDA). RAMADDA is made up of a hierarchical collection of folders and entries (Yoksas et al. 2009) which can be accessed by the public via a Universal Resource Locator (URL) or a standard web address. The primary advantages of RAMADDA are its abilities to store any data type and make data easily accessible. Thus far, this has been an experimental effort testing RAMADDA's capabilities, and we have found it easy to load and manage new and old data entries (See Figure 3). A long-term goal is to have most - if not all - of AMRC's archived data ingested into RAMADDA (Seefeldt, et al. 2009a, 2009b).

PostGIS adds support for geographic objects to the PostgreSQL object-relational database. PostGIS spatially enables the PostgreSQL server, so it can be used as a backend spatial database for GIS (www.postgis.org). PostgreSQL is a powerful, open source object-relational database system (www.postgresql.org/about). Use of PostGIS, zigGIS, and PostgreSQL is desired to add tables that are not spatially referenced and to create a database that updates the AWS network map (and attendant metadata) on a near real-time basis. For example, managing information about the entire active Antarctic AWS network requires the use of a system like PostGIS. Furthermore, using the zigGIS extension in ArcGIS allows generation of maps of weather stations directly from the database. Another capability being explored is the ability to map any station-related (non-spatial) data through relational joins in the database.

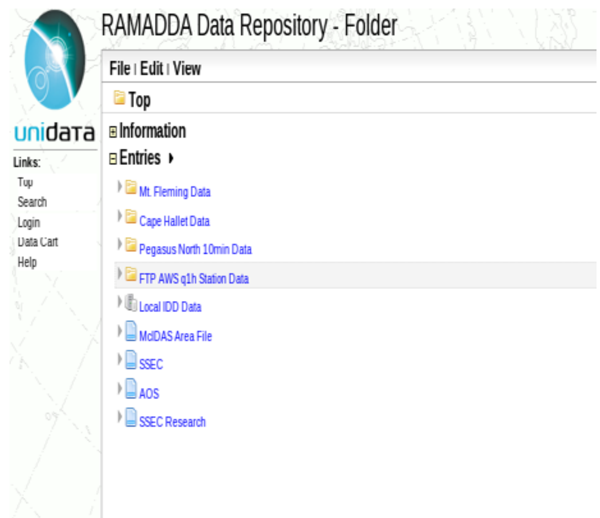

Figure 3 shows the organization of a RAMADDA File and Entry data repository.

5. ACKNOWLEDGEMENTS

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COMPOSITE SATELLITE ATMOSPHERIC MOTION VECTORS

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1. INTRODUCTION

Satellite observations of wind information have been estimated with geostationary satellite data (Velden et al., 2005) and polar-orbiting satellites (Key et al., 2003). However, from the point of view of the Antarctic and Arctic, there is a latitudinal gap in coverage between these two wind sets as depicted in Figure 1. This has inspired an investigation using Antarctic and Arctic composite imagery – a combination of geostationary and polar orbiting observations (Lazzara et al., 2003) – for the generation of atmospheric motion vectors (AMV).

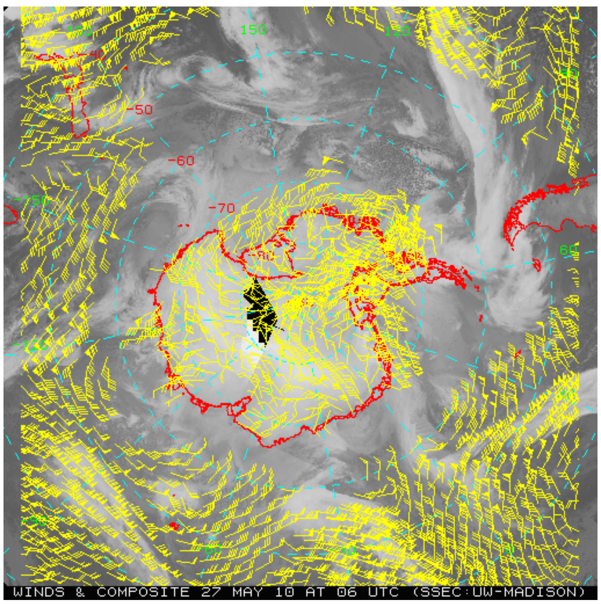

Figure 1. An Antarctic infrared satellite composite image, valid 6 UTC on 27 May 2010, depicting the gap in coverage of atmospheric motion vectors from the polar orbiting and geostationary satellite imagery.

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2. SATELLITE COMPOSITES

Satellite composites have been generated at the University of Wisconsin over the Antarctic for over eighteen years (Lazzara et al. 2003), and over the Arctic in the last few years (Lazzara and Knuth, 2009). These composites are a mosaic of satellite observations from both polar and geostationary orbit. The observational data once received at the University of Wisconsin is then cleaned up for any bad lines of data and remapped into a standard polar stereographic projection, The space background is removed from the data. Finally, the data are merged, with geostationary first and polar orbiting last via a conditional minimum method, to take into account limb darkening considerations (See Figure 2).

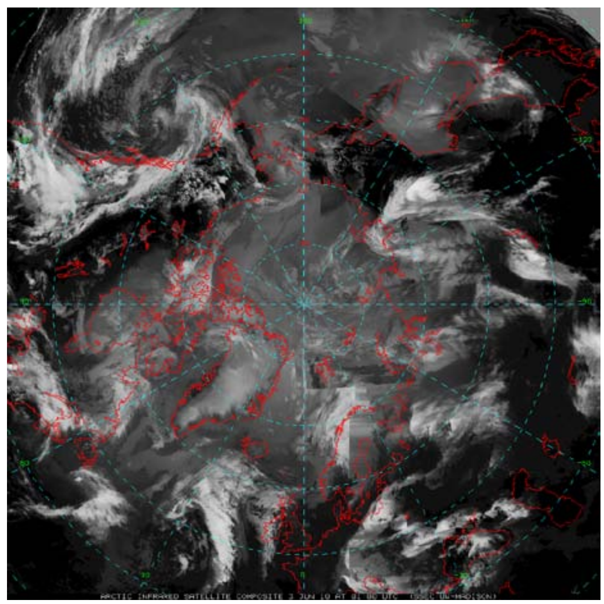

Figure 2. A sample hourly Arctic infrared composite image that is from 3 June 2010 at 1 UTC.

A variety of meteorological satellites are used in making up the composites, including GOES, MTSAT, METEOSAT, FY-2, Aqua/Terra and NOAA series. Additional satellites are added, as they are available, including GOES for South America. The composites are made in several spectral channels, including the infrared window channel, water vapor channel, shortwave infrared channel and longwave infrared channels (recently added for the Arctic, and will soon be for the Antarctic). Visible channel composites are under experimental investigation. The resolution of the resultant composite is a nominal five kilometers at the standard latitude of 60 degrees.

One requirement for this investigation was the increase of the temporal resolution of the composites from three-hourly to one-hourly, thereby providing wind information on the same temporal scale as with geostationary satellites. This change also benefits other research and operational users of the composite.

3. COMPOSITE CLOUD MOTION VECTORS

The Composite Cloud Motion Vectors (CCMVs) are developed using the same technique used in Key et al., 2003, and an example is given in Figure 3. In addition, we are running the CCMV derivation parallel on two machines to do sensitivity testing. This allows for the comparison of two different settings, for example two search box sizes to be validated against each other. By doing this, settings can be found that maximize the quality of the CCMVs.

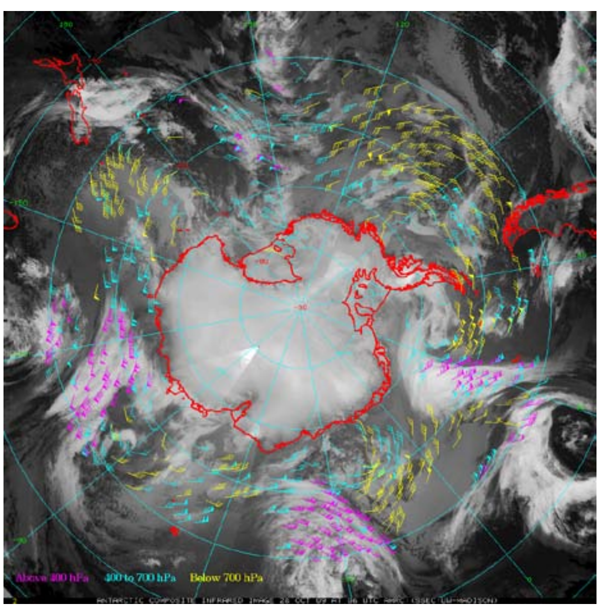

Figure 3. An hourly Antarctic composite imagery is displayed with corresponding atmospheric motion vectors from 6 UTC on 28 October 2009.

4. VALIDATION

AMVs are being derived routinely from the composite observations to build a dataset large enough to assess the quality of the winds on two different settings. While the composites have the strength of observations from both geostationary and polar-orbiting platforms, it is not yet clear how accurate the wind information is in the data void regions (Figure 1), given the very limited radiosonde and aircraft data in the aforementioned region that can be used for validation. Initial comparisons with radiosonde and limited aircraft wind observations indicate a vector root mean square (RMS) error of 7.91 ms^{-1}. Statistics given in Table 1 indicate an increase in average vector difference, vector and speed RMS with height for this same latitude band. The speed bias is negative or slow below 500 hPa, however, it becomes slightly positive or fast at higher levels. On the other hand, the normalized vector RMS or VNRMS indicates a slightly better quality overall above 500 hPa. This is especially seen when the ckcirrus routine is removed due to a 3 ms^{-1} decrease in Vector RMS, resulting in a 10% improvement in the CCMV's VNRMS above 500 hPa .

	>=850 hPa	***850> to 500 hPa***	***Above 500 hPa***
Vector RMS	***3.25***	***5.82***	***8.95***
Vector Diff.	***3.12***	***4.85***	***7.27***
Speed RMS	***2.54***	***3.45***	***6.21***
Speed Bias	***-0.23***	***-0.12***	***+0.30***
VNRMS	***.55***	***.54***	***.26***
Sample Size	***5***	***80***	***146***

Table 1*. Sample validation statistics of the CCMVs.*

However, it is important to mention that tests to optimize the quality of the AMVs are currently being worked on and show promise in improving the results seen in Table 1. While verification and validation activities are currently ongoing, it is expected that this activity will continue through the upcoming 2010-2011 field season. This includes aircraft reports (AIREPs) from US Antarctic Program associated aircraft (e.g. 109th New York Air National Guard LC-130s, Royal New Zealand Air Force C-130, US Air Force C-17) and other aircraft that fly missions between the middle latitudes and the Antarctic. Their observations of winds enroute has the potential to provide a significant set of validating observations in the all important wind data void region, needed to determine if the composite AMVs will be on the order of accuracy as its cousin polar-orbiting and geostationary wind sets (see Figure 4).

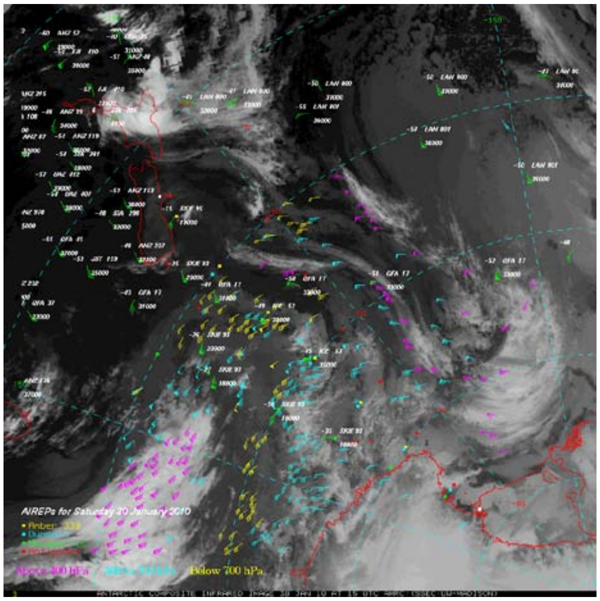

Figure 4. A display of aircraft meteorological report (AIREPs) along with composite atmospheric motion vectors in the flight corridor between New Zealand and Antarctica.

5. SUMMARY

Antarctic satellite composites have been used to demonstrate the ability to compute Atmospheric Motion Vectors, a derived quantity that is possible with the advent of hourly composites. These AMVs represent the first potential to fill in an observational gap left by geostationary and polar orbiting satellite AMV data sets. The resultant AMVs have been initially validated against weather balloon observations and aircraft reports in the Southern Hemisphere and Antarctic. The initial results show that the validation quality is much improved, especially above 500 hPa, when the software routine ckcirrus has been removed. Unfortunately, this has not been seen in the 60 to 70 degree South latitude band. This effort has revealed how important time stamping of the data is toward the resulting AMVs. Tests with Aqua and Terra MODIS imagery offer an example of the sensitivity the resulting AMVs can have with cross time stamps. While composite AMVs are not yet ready for model data assimilation, it is expected that the work in progress will lead to that in the near future.

6. FUTURE WORK

This effort continues, as additional satellites are being added to the composite. Arctic composite winds are now being generated and will expand the validation investigation to both polar regions. Focus will now turn toward testing techniques for optimal spatial and temporal resolution of the satellites. Time tracking of the satellite information to be used as auxiliary metadata information for computing the wind vectors is expected to improve the quality of the resulting AMVs. Issues such as parallax (at the time of wind vector generation) that are not being considered will be taken into account. All of these changes are expected to impact the AMV derivation software, and hence modifications will need to be made to incorporate these changes. Finally, validation efforts will continue, utilizing both traditional radiosonde observations and available aircraft observations.

7. ACKNOWLEDGEMENTS

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COMPOSITE ANALYSIS OF THE SURFACE EFFECTS OF EL NINO SOUTHERN OSCILLATION TELECONNECTIONS ON ANTARCTICA

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1. Introduction

Significant work has been done on identifying and understanding upper level height anomalies associated with El Nino Southern Oscillation (ENSO) events in the Amundsen and Bellingshausen Sea regions. (Turner 2004) This work focuses on the effect these teleconnections have on the Antarctic continent and adjacent Southern Ocean. Composites of ERA-40 (European Centre for Medium-Range Weather Forecasting Re-analysis) data from 1979-2002 of ENSO events, as determined by the Multivariate ENSO Index(MEI), illustrate how these events affect the surface variables (e.g. pressure, temperature, etc.). These composites consist of monthly averaged data compiled into three month seasons, with emphasis on December, January, and February as this is generally the period of maximum ENSO intensity. To ensure the accuracy of these findings regions with values exceeding the confidence intervals are compared with ground based Automatic Weather Stations (AWS) from the University of Wisconsin-Madison that have not been used in the reanalysis. Though the values vary considerably, during the strongest ENSO periods, we note significant warming (cooling) over much of the continent primarily focused in the East Antarctic during El Nino (La Nina) events. Significant high pressure anomalies are found during El Nino events focused in the Amundsen-Bellingshausen Sea regions, and extending to the Ross Ice Shelf and the Antarctic Peninsula. During La Nina events low pressure anomalies are evident throughout the continent.

2. Data

Throughout this study we have used the ERA-40 data set for surface temperature, pressure, wind, and humidity values due to it having higher correlations with observations (Bromwich 2004) during the post satellite era (1980-2002). We have also used the AWS dataset as a means to check the accuracy of the reanalysis during times when AWS stations weren't assimilated.

a. ERA-40

For our composite analyses we have created two different sets of composites, for both El Nino and La Nina events. The first of these composites consist of using all months during all events, as determined by the Trenberth defintion, to determine the overall affect these events have on the Antarctic continent. The second set of composites involves using three-month seasonal time sets. The timeframe of three months was chosen as it matches with the time frame used to calculate the ENSO indices used. These composites allow us to observe differences in the anomaly patterns between a variety of seasons. This study focuses on the peak months, though analysis has also been performed on non peak months. In all the monthly composites the events are compared against the average values.

b. AWS Network

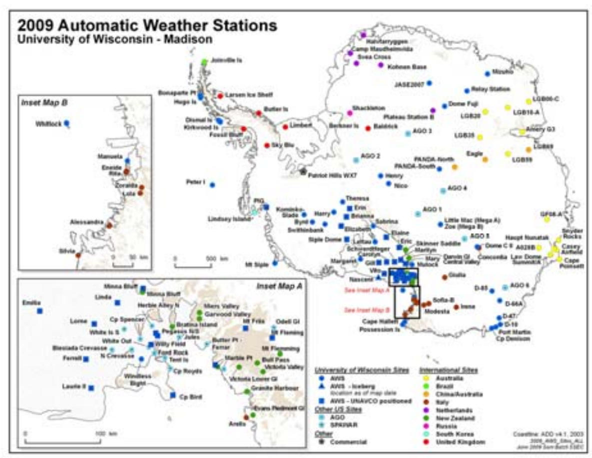

Figure 1: A map of the current AWS Network

Throughout this process the reanalysis is compared with the observational network (Figure 1) during times we are certain the weather station data has not been assimilated. As the reanalysis discontinued using AWS station data in 1998, a period of 44 months remains available in the ERA-40 dataset that we are able to compare with. We have also checked prior to this time for stations that have gone unused to ensure consistency between the Re-analysis and the

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observations. To compare between the grid points of the reanalysis and observation network the weighted average of the nearest four points in the reanalysis was used. Initial findings indicate there is a strong correlation, on the order of .95, between the two datasets.

c. ENSO Events

In this study we have chosen to use the Trenberth definition for ENSO events to ensure a conservative view of events. This indicates ENSO events as a deviation from the 5 month running mean sea surface temperature of .4 degrees centigrade in the Nino 3.4 region. (Trenberth 1997) We have also analyzed the Multivariate ENSO Index as a metric for determining ENSO events. This index utilizes the first principal component of the weighted average of sea surface temperatures, sea level pressures, surface wind speeds, cloudiness, and precipitation. (Wolter 1993) It seems to be a good representation of ENSO events. Composite analysis was performed on both metrics, as well as a Southern Oscillation index and all the metrics generally agree. The composites based on the Trenberth definition are shown below.

3. Analysis

This section will focus on understanding the effects ENSO has on Antarctic near surface temperature anomalies. Though our analysis extends to pressure, and will extend to wind speed and direction as well as relative humidity for this section we are focusing on temperature as seen in the yearly and seasonal composites.

a. Full Year

1. El Nino

This composite shows a general effect that remains consistent with prior understanding of the teleconnection in the Amundsen-Bellingshausen Sea with a few new, potentially important additions. In the case of the El Nino (Figure 2) event we note a relatively strong warming in the Amundsen-Bellingshausen sea region with the statistically significant warming extending somewhat into the Ross Ice Shelf. We also note a cooling just off the Antarctic Peninsula near the Weddell Sea. These two features make physical sense when you consider the teleconnection is generally expressed as an upper level height anomaly, and the associated flow can account for these temperature changes. Analysis of the pressure field indicates this as a likely cause. On the other hand the region of cooling in the Amery Ice Shelf seems disconnected from the upper level height anomalies, and because it is statistically significant it warrants further exploration.

2. La Nina

This composite is also consistent with prior work on the subject, with weaker warming being centered more closely to the Antarctic Peninsula and a region of cooling located north of the Ross Sea. These features seem to be linked to the upper level teleconnection in the same general area. We also see that much of East Antarctica has moderate cooling occurring. Much like the Amery Ice Shelf cooling this region warrants more study as to why this is occurring.

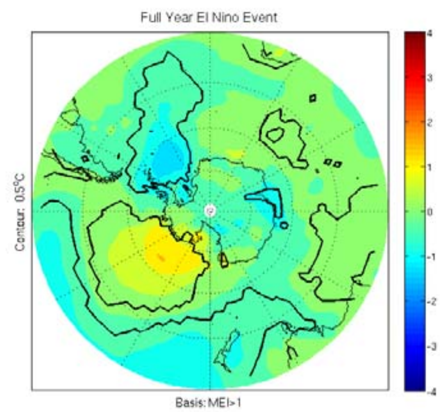

Figure 2: A composite of Full Year temperature anomalies during El Nino events with black lines indicating the 95% confidence interval.

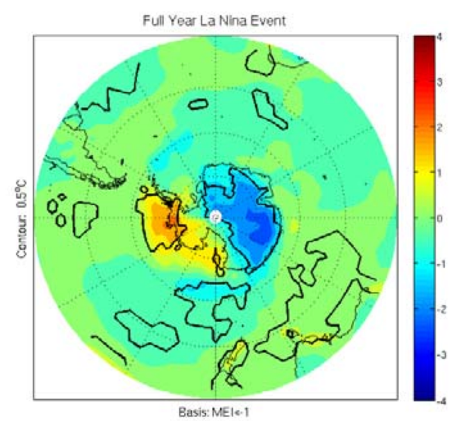

Figure 3: A composite of Full Year temperature anomalies during La Nina events with black lines indicating the 95% confidence interval.

b. Seasonal

1. El Nino

Throughout this section we will focus on two particular seasons, September-November and December-February. These two seasons are quite different. First we note September-November (Figure 4) is generally the beginning of the peak of an event event. In this composite we note the expected features associated with the teleconnection. This seems to be associated with advective effects of the teleconnection.. December-February (Figure 5) is moving toward the end of the peak months and potentially isn't the peak intensity in the Antarctic. We note considerably less surface temperature effects, with small regions of warming near the Antarctic Peninsula and cooling in the Ross Ice shelf along the Transantarctic mountains. Again this seems strongly linked to the teleconnection signature, but in this case it has shifted such that advection again may account for these temperature changes.

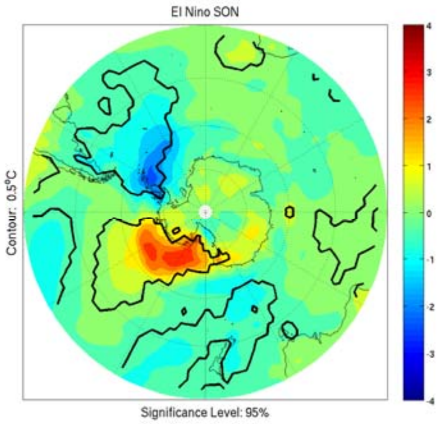

Figure 4: A composite of the September-November temperature anomalies during El Nino events with black lines indicating the 95% confidence interval.

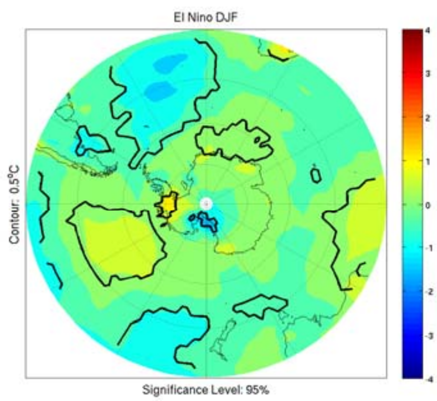

Figure 5: A composite of the December-February temperature anomalies during El Nino events with black lines indicating the 95% confidence interval.

2. La Nina

Again we focus on the September-November and November-January time periods. In September-November (Figure 6) we note moderate, significant warming in West Antarctica with regions stretching from the Ross Ice shelf to the beginning of the Peninsula. This feature seems connected with the teleconnection, and the advection associated with the changes in the height fields. Moving on to the December-February (Figure 7) season much has changed. There is less signal in the regions associated with the teleconnection in the West Antarctic, but the cooling in East Antarctic remains strong but has grown to cover most of the East Antarctic as well as much of the Ross ice shelf. This anomaly is connected to an upper level height anomaly in the region.

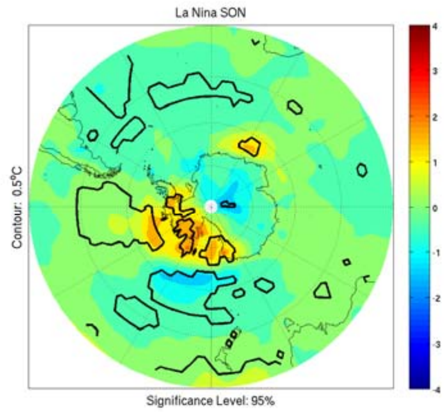

Figure 6: A composite of the September-November temperature anomalies during La Nina events with black lines indicating the 95% confidence interval.

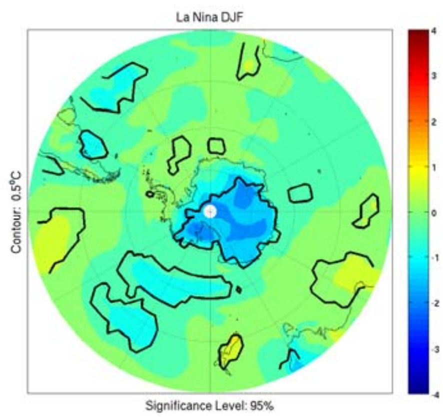

Figure 7: A composite of the December-February temperature anomalies during La Nina events with black lines indicating the 95% confidence interval.

4. Future Work

With the recent release of newer long-term Reanalysis products that extend through 2009 we hope to expand this study to capture more events, as well as finding means to expand the analysis to prior years as well. Expanding the analysis to view humidity as well as wind speed and direction is a necessary step toward understanding the full effects these events have. Also, recent research has shown that the Southern Annular Mode has a strong effect on the variability of the high latitude teleconnections associated with ENSO events.

(Fogt 2006) As such we hope to determine the effect including SAM events has on our findings.

5. Acknowledgements

The National Science Foundation Office of Polar Programs Grant # ANT-0636873 supported this research

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Expressions of ENSO and the SAM in Modeled Antarctic Surface Temperatures

David Reusch

Although many details remain uncertain, it is now well-established that West Antarctic climate is influenced by tropical events through a teleconnection with ENSO. However, similar El Niño events do not always produce similar surface temperature patterns suggesting a nonlinear relationship or additional dynamical influences, or, more likely, both. As seen in recent surface melt studies, for example, a likely additional modulator of the ENSO teleconnection is the Southern Annular Mode (SAM). Here we study this relationship through monthly and seasonal analyses of modeled daily near-surface temperatures.

Self-organizing maps (SOMs) provide a nonlinear, artificial neural networks-based approach to the analysis of complex geophysical datasets such as atmospheric circulation. Unsupervised classification of data into a fixed number of distinct, generalized SOM patterns, or modes, summarizes data variability into a two-dimensional, spatially organized (nonlinear) grid form. This set of patterns provides a concise summary of the input dataset as well as a foundation for further studies of dataset dynamics.

Annual frequency maps developed by tracking how often each generalized pattern appears let us use SOMs to study temporal changes: each year will have a unique signature based on which patterns are most prevalent. Using indices of ENSO (e.g., the Oceanic Niño Index) and the SAM with these maps, we examine how temperature patterns interact with these other climate influences.

Preliminary results show that the expression of El Niño in near-surface temperature patterns does vary with the state of the SAM. For example, the set of most common patterns for January in a high SAM year is noticeably different from the corresponding set for a low SAM year. Different extreme SAM years, however, do not necessarily show the same set of patterns, an indicator of the still unresolved complexity of this system.

Understanding the SAM Influence on the South Pacific ENSO Teleconnection

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The relationship between the El Niño – Southern Oscillation (ENSO) and the Southern Hemisphere Annular Mode (SAM) is examined, with the goal of understanding how various strong SAM events modulate the ENSO teleconnection to the South Pacific (45°-70°S, 150°-70°W). The focus is on multi-month, multi-event variations during the last 50 years. A significant (p<0.10) relationship is observed, most marked during the austral summer and in the 1970s and 1990s. In particular, the significant relationship is brought about by La Niña (El Niño) events occurring with positive (negative) phases of the SAM more often than expected by chance.

The South Pacific teleconnection magnitude is found to be strongly dependent on the SAM phase. Only when ENSO events occur with a weak SAM or when a La Niña (El Niño) occurs with a positive (negative) SAM phase are significant South Pacific teleconnections found. This modulation in the South Pacific ENSO teleconnection is directly tied to the interaction of the anomalous ENSO and SAM transient eddy momentum fluxes. During La Niña / SAM+ and El Niño / SAM- combinations, the anomalous transient momentum fluxes in the Pacific act to reinforce the circulation anomalies in the midlatitudes, altering the circulation in such a way to maintain the ENSO teleconnections. In La Niña / SAM- and El Niño / SAM+ cases, the anomalous transient eddies oppose each other in the midlatitudes, overall acting to reduce the magnitude of the high latitude ENSO teleconnection.

Ground-based observations of cloud properties, precipitation and meteorological conditions at Princess Elisabeth station in Dronning Maud Land, Antarctica.

I. V. Gorodetskaya[1], N. P. M. van Lipzig[1], M. R. van den Broeke[2], W. Boot[2], C. Reijmer[2], A. Mangold[3], S. Kneifel[4], S. Crewell[4], and J. Schween[4]

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Introduction

To understand the current and future evolution of the Antarctic ice sheet, a good knowledge of the surface mass balance is essential. Regional climate models have proven to be suitable tools for this purpose, but only if they realistically represent the meteorological conditions in the region of interest. It is important to evaluate not only the net accumulation in the models, but also the processes leading to precipitation. Clouds are of importance both for precipitation formation and for the surface radiative budget. As there is a lack of data on the clouds and precipitation processes in the Antarctic, the first goal of our project is to establish a new database that can be used for an in-depth model evaluation.

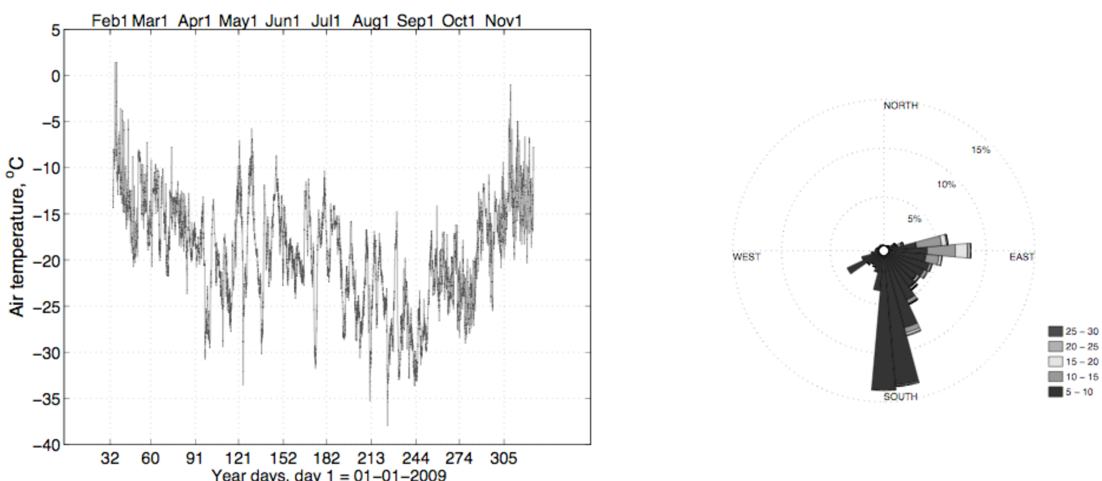
Instruments

The base for our measurements is the new Belgian Antarctic station Princess Elisabeth built on the Utsteinen Ridge in Dronning Maud Land, East Antarctica ($71^0$57'S and $23^0$20'E, ~1400 m asl, 180 km inland). Princess Elisabeth station is located in a nearly thousand kilometer wide "data gap", where no long-term measurements of the surface mass balance have been done up to date and where regional climate models show large differences in snow accumulation estimates. An automatic weather station (AWS) has been installed at Utsteinen in February 2009, providing continuous measurements of near-surface air temperature, humidity, pressure, wind, up and down broadband short-wave and long-wave radiative fluxes, snow height changes, and 1-m snow temperature profile (see: www.phys.uu.nl/~wwwimau/research/ice_climate/aws/). During the summer season 2010 (January-February), cloud and precipitation measurements were performed using a ceilometer, an infrared radiation pyrometer and a K-band radar. The Vaisala ceilometer CL31 employs pulsed diode laser (lidar technology) at near-infrared wavelength (910 nm). The measurement range is from the surface up to 7.5 km with 10 m resolution. The instrument gives a vertical backscatter profile, from which information about cloud height or vertical visibility is derived. The Heitronics infrared pyrometer is a passive radiometer, which measures the downward thermal emission from the clouds and from the air column during clear-sky conditions in the 8-13 μm atmospheric window. The radiation flux is converted to the equivalent blackbody brightness temperature. The

K-band radar, manufactured by METEK company, is a 24 GHz FM-CW Doppler radar used for hydrometeor detection (falling and drifting snow). This radar is designed to measure quantitatively raindrop size distributions and rainfall intensity, however it has recently also been used among other passive and active remote sensing instruments for snow measurements in Europe (Kneifel et al. 2010). Our project will be the first deployment of this type of radar for precipitation detection in Antarctica.

Results

The AWS measurements since February 2009 confirmed previous observations in the vicinity of the Utsteinen ridge (Pattyn et al. 2010) that the site is characterized by relatively mild meteorological conditions. During 2009, the minimum near-surface air temperature was -38 ^{0}C and the maximum wind speed was 30 m/s (Fig. 1). Low wind speeds occur from all directions influenced by complicated local topography including mountain ranges, glaciers, and nunataks. Wind speeds stronger than 5 m/s are restricted to the E-SE direction (Fig. 1b) and are mostly associated with cyclonic activity in the near-coastal ocean region near the station meridian. The mean winter SE direction of the near-surface wind at Utsteinen site results from the interaction between the large scale pressure forcing and katabatic wind forcing (van Lipzig et al. 2004), while the strong easterly winds are mostly associated with the passage and occasional blocking of cyclones in the 0-30^0 E meridional sector characterized by high cyclonic density (Simmonds and Keay 2000).

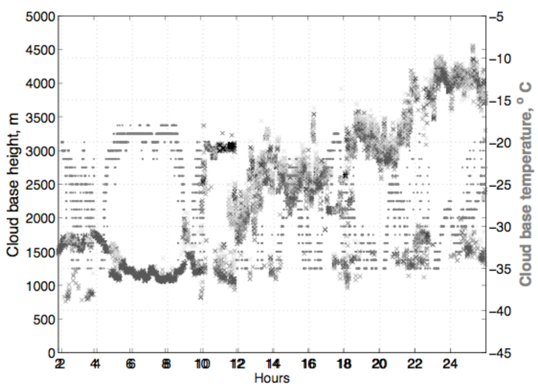


(a) (b)

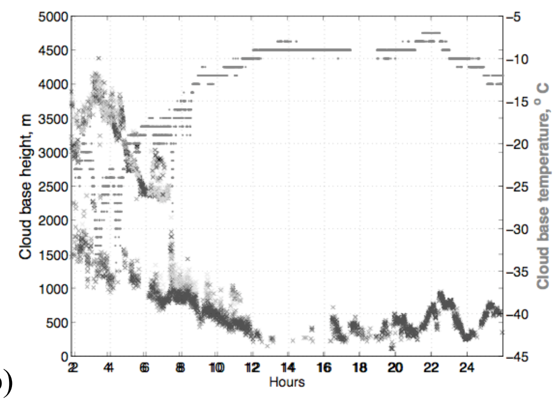
Figure 1. Near-surface air temperature (a) and wind rose (b) measured at Utsteinen from February 2 until November 21, 2009, at a height 3.5-4 m above the snow surface.

Sonic snow height meter measurements showed several strong step-wise accumulation events giving a total of 24 mm w.e. accumulation during 2009 at the AWS site (conversion to water equivalent accumulation is done using 1-m average snow density measured 1 km away from the AWS). Overall accumulation in the region is characterized by high spatial heterogeneity with alternating blue ice and positive accumulation areas.

Cloud and precipitation measurements during January-February 2010 showed frequent occurrence of mid-level clouds (2-4 km cloud base heights). During episodic cyclonic events, low clouds were also appearing together with an increase in cloud base temperature. Figure 2 shows cloud base height and temperature measured during February 6-7, 2010, demonstrating cloud conditions during a cyclonic event. On February 6, a large depression with low centre pressure of 961 hPa was located at 62 S, 13 E, moving southwest until it reached 67 S, 9 E on February 7, then weakening. Both mid level and low clouds were observed during the first day with shortly occurring light precipitation. The second day cloud bases lowered from 2.5-4 km in the morning to about 1 km in the early afternoon (Fig. 2b). Later during the day low cloud bases of about 500 m above ground level were detected by the ceilometer alternating with vertical visibility values instead of the cloud base values, which in this case indicated precipitation (we could detect precipitation events using the radar reflectivity plots, not shown here). On February 7, the radar detected snowfall starting from about 7 am local time until late evening. In the morning the snowfall occurred together with relatively strong near-surface wind speeds up to 15 m/s, while in the afternoon precipitation continued during quiet wind speeds. The depth of precipitating layer was from the surface up to 1 to 2.5 km high indicating continuous presence of midlevel clouds throughout the storm (not detected by the ceilometer).



a)



b)

Figure 2. Cloud base height (crosses) and cloud base temperature (dots) measurements during February 6 (a) and February 7, 2010 (b).

Summary and conclusions

The main objective of our project is to improve the understanding of the atmospheric branch of the hydrological cycle of Antarctica covering the chain from evaporation/sublimation at the surface via cloud formation to snowfall. As there is a lack of data on the clouds and precipitation processes in the Antarctic, the first part of the project is to establish a new database that can be used for an in-depth model evaluation. The base for our measurements is the new Belgian Antarctic station Princess Elisabeth built on the Utsteinen Ridge in Dronning Maud Land, East Antarctica. Measurements started in February 2009 with the installation of the AWS. Also cloud macro-physical properties and precipitation have been measured during the summer campaign of 2010.

The first results show high potential of such a set of instruments for understanding local meteorological conditions and cloud properties, synoptic-scale dependence of accumulation, and distinguishing the snowfall from drifting snow events. The collected data together with other existing and newly emerging data (both ground-based and satellite) will be used to evaluate and improve the regional atmospheric climate model RACMO/ANT2 after which an updated reconstruction of the climate of Antarctica will be performed.

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In Situ Aircraft Observations of Antarctic Clouds

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The microphysical properties of Antarctic clouds play a major role in determining the radiation balance of the atmosphere and hence knowledge of these properties is vital in order to model the Earth's climate. Yet, there have been very few in situ observations of Antarctic clouds. Satellite retrievals of Antarctic cloud properties have the potential to offer wide coverage. However, they currently rely on assumptions that are based on mid-latitude clouds, which need testing through in situ observations.

The concentrations and sources of Cloud Condensation Nuclei (CCN) and Ice Nuclei (IN) available in Antarctic clouds are, for example, very poorly understood. Such nuclei determine the initial concentrations of cloud droplets and ice particles in clouds and thus the starting conditions for other subsequent cloud microphysical processes. There is speculation that biogenic sources of IN may be of more importance in the clean Antarctic environment where there are likely to be few anthropogenic or (non-Antarctic) continental aerosols present. Marine sources of aerosol are likely to dominate in the coastal regions and there may be seasonal cycles associated with their formation (Alencar et al., 2010). There is evidence that their concentrations may also be a function of wind speed, which may have important consequences as a result of the changing circumpolar winds driven by variations in the Southern Annular Mode (Korhonen et al., 2010). It is likely that the situation is quite different deeper into the continent where the very cold temperatures can produce large areas that are supersaturated with respect to ice. Uncertainties in the concentrations and sources of IN means that predicting the degree of glaciation of clouds (or the ratio of ice to liquid cloud) is highly uncertain. However, this knowledge is vital as the presence of ice has a great effect on cloud radiative properties. Antarctic cloud dynamics are also likely to be somewhat different to clouds elsewhere because of, for example, interactions with sea-ice; interactions with the cold, high-albedo continental surface; the presence of often highly stratified air, etc. Thus, because of all these likely differences from clouds around the rest of the globe, there is a great need to characterize Antarctic clouds though in-cloud measurements.

In early 2010 the British Antarctic Survey performed 14 flights in the Antarctic Peninsula region during which clouds were sampled in situ with a Cloud and Aerosol Spectrometer (CAS) instrument, which measures the sizes and concentrations of aerosols and droplets with diameters between 0.61 and 50 μm and with a Cloud Imaging Probe (CIP) instrument, which takes images of ice crystals and large droplets with diameters between 25 and 1550 μm and can estimate particle mass and concentrations. Several different types of cloud were sampled that encompassed liquid, mixed phase and ice clouds.

The study of a train of lenticular clouds formed by gravity waves driven by an east-to-west flow across the Antarctic Peninsula has been focused on initially as such clouds provide a good way of characterizing the concentrations of CCN and IN. IN and ice concentrations only will be discussed here due to ongoing calibration issues with the CAS droplet measuring instrument. Lenticular clouds are short-lived and thus relatively simple in terms of the microphysical processes that occur within them. As such, they provide an ideal "natural laboratory" for studying CCN and IN concentrations since the numbers of droplets and ice particles observed are likely to reflect the numbers of CCN and IN as there are unlikely to be any other sources, nor any sinks, of droplet or ice number. One exception might be the aggregation of ice, although at the concentrations observed this seems unlikely. Bin resolved microphysical modeling of this case will be performed in the future in order to study such possibilities. Lenticular clouds may also allow the examination of any processing of CCN and IN that may occur in successive passes of the air through cloudy (wave crest) and evaporating (wave trough) regions.

The aircraft observations revealed the wavelengths (~9-10 km) and amplitude (2-5 ^{o}C) of the lee waves that formed the clouds (Figure 1). Liquid cloud was present at the peaks of most of the waves at mass concentrations peaking between 0.1 and 0.2 g m^{-3} (Figure 2). Droplet sizes were generally smaller than 20 μm in diameter and so were mainly non-precipitating. Ice particles were observed in some of the peaks, although many of the peaks were ice-free. Ice was also observed in some of the wave troughs. It is likely that this was ice that had formed in the wave crests and/or survived the descent or precipitated downwards. The ice in the troughs tended to be of a larger size. Ice concentrations were determined from the ice images taken by the CIP instrument (e.g. see Figure 3) and were found to number between 0.1 and 0.45 L^{-1}. The parameterization of combined deposition and condensation IN numbers used in the WRF model predicts a similar number for the temperature range observed (-11 to -14 ^{o}C) suggesting that the number concentrations of IN in this region might have been similar to those upon which the parameterization was based. Immersion and contact IN parameterizations from the WRF model predict lower numbers for the range of liquid water contents and temperatures observed, suggesting that these processes may not be as important for these clouds.

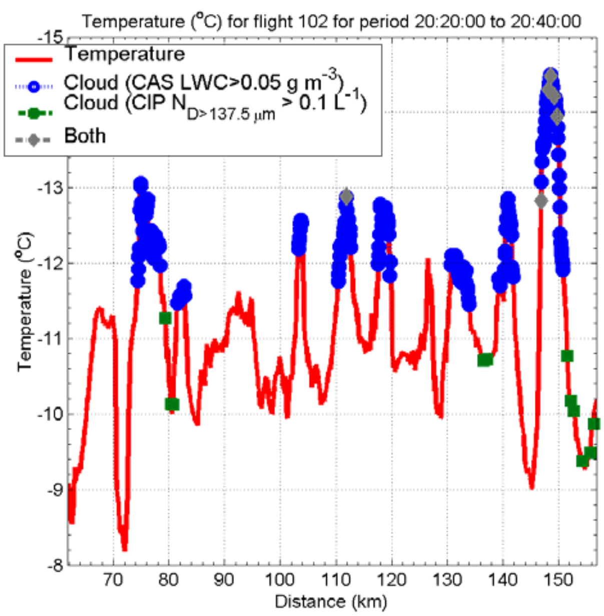

Figure 1 – The temperature oscillations experienced by the aircraft as it flew downwind through a section of the lenticular clouds as a function of distance along the flight path. The coloured markers indicate the presence of liquid water only regions (blue), ice only regions (green) and mixed phase regions (gray).

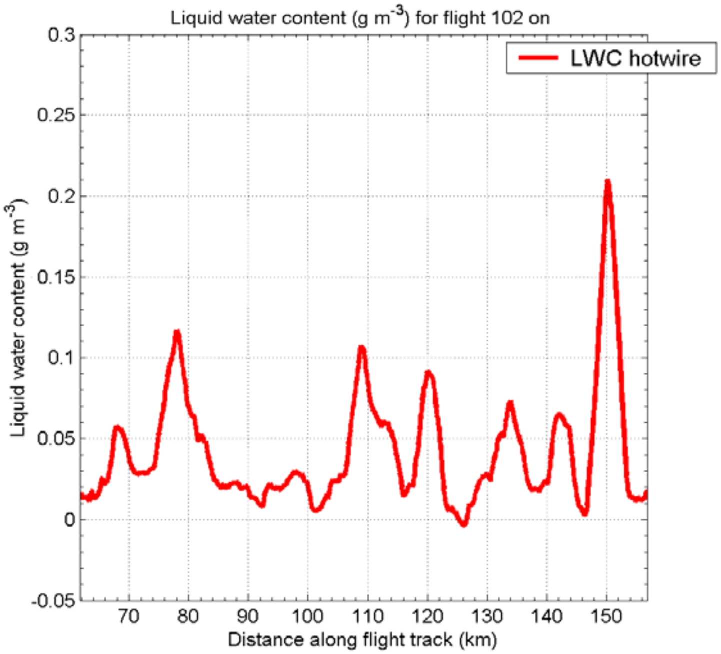

Figure 2 – As in Figure 1 except for liquid water content and the lack of cloud phase markers.

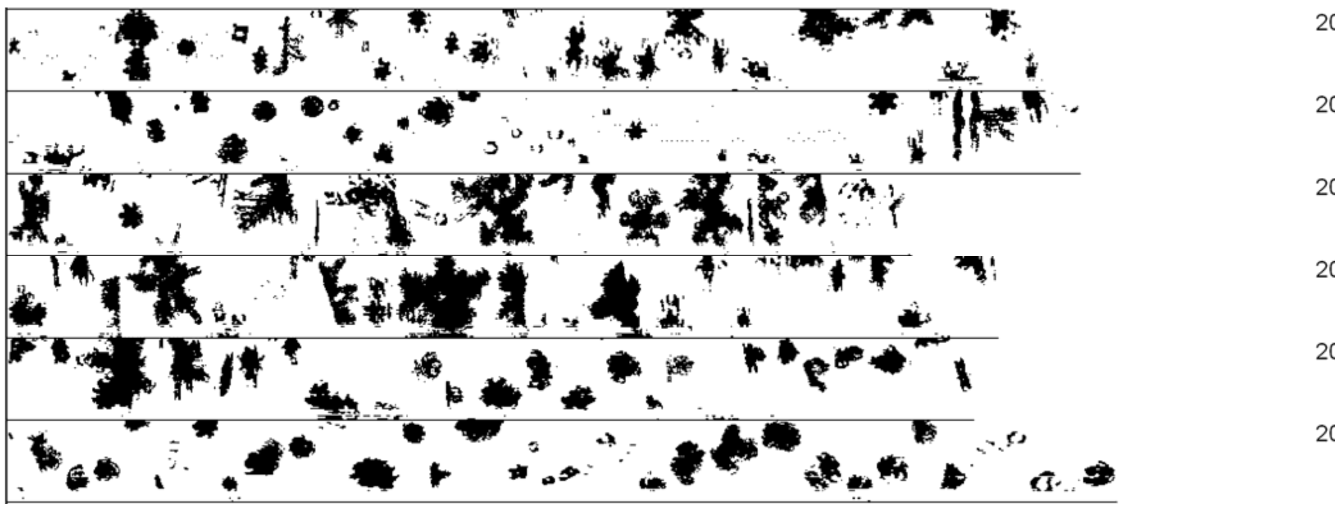

Figure 3 – Images of ice particles taken by the CIP instrument during a pass through the lenticular clouds.

There were periods during which very large ice concentrations (up to 60 L^{-1}) were observed. It seems likely that such high numbers were the result of contamination from the exhaust of the turbo-prop aircraft itself since the observations were made in close proximity to areas that had already been flown through. Thus, careful screening of the results is required in order to avoid this issue, which might be done through examination of the carbon dioxide readings from one of the on-board instruments.

Another flight over the ridge of the Antarctic Peninsula sampled clouds at colder temperatures (down to -20 ^{o}C) as well as clouds over the Larsen C Ice Shelf at warmer temperature ranges of around -2.5 ^{o}C. For the clouds at -20 ^{o}C the numbers of ice observed (<0.5 L^{-1}) were somewhat lower than those predicted by the ice parameterizations used in the WRF model (2.25 L^{-1} for deposition and condensation IN and ~ 20 L^{-1} for immersion IN). Thus, there is the suggestion that for these colder clouds the availability of Antarctic IN may be lower than for clouds elsewhere. However, the processes occurring in this cloud are likely to be quite complicated and may involve other processes, which is likely to mean that the number of ice particles observed does not directly reflect the number of IN. Detailed microphysical modeling of this cloud is required in order to make further progress. At -2.5 ^{o}C larger concentrations of ice were observed with values up to 3.5 L^{-1}. This is almost in the Hallet Mossop splinter production temperature range (approximately -3 to -9 ^{o}C) where riming of supercooled droplets onto ice particles can result in the shattering of the rimed ice and produce lots of small ice splinters. This can result in the rapid glaciation of a cloud and thus this process may play an important role in Antarctica where sources of heterogeneous IN may be rare.

The study of the these and the remaining flights will allow the examination of clouds covering the range of scenarios mentioned here with a view to better understanding the conditions in which ice forms in Antarctic clouds. This will allow the vital testing of cloud microphysics parameterizations and dynamical cloud formation processes in climate and regional models as well as the testing of the assumptions used in satellite retrieval techniques.

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UAV Observations of the Wintertime Boundary Layer Over the Terra Bay Polynya, Antarctica

Shelley Knuth

Aerosonde unmanned aerial vehicles (UAVs) were used during September 2009 to observe the atmosphere and ocean / sea ice surface state in the vicinity of the Terra Nova Bay polynya, Antarctica. These flights were the first wintertime UAV flights ever made in the Antarctic, and were also the longest duration UAV flights made to date in the Antarctic, with a maximum flight time of over 17 hours. A total of 130 flight hours were flown during September 2009, with a total of 8 science flights to Terra Nova Bay. The flights took place at the end of the Antarctic winter, in an environment characterized by strong katabatic winds and strong air-sea fluxes.

Observations of the boundary layer evolution of the katabatic winds propagating over the Terra Nova Bay polynya will be presented. The advantages of using UAVs for boundary layer observations in remote locations as well as the logistical challenges of operating UAVs in the Antarctic winter will also be presented.

The Examination of a Downslope Warming Wind Event Over the Larsen Ice Shelf Through Modeling and Aircraft Observations

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During the last 50-60 years temperatures over the Antarctic Peninsula region have increased more rapidly than anywhere else in the southern hemisphere, at several times the global average rate. At one station, the near-surface warming between 1951 and 2004 was 2.94 ^{o}C compared to a global average of 0.52 ^{o}C. However, the seasonal pattern of this regional warming has varied with location, with the east side having warmed more than the west in the autumn and summer seasons. This is important since the process of surface melting on the Larsen ice shelves, which are located on the east side, predominately occurs in summer. Crevasse propagation due to the weight of accumulated melt water is currently thought to have been the major factor in causing the catastrophic near-total disintegration of the Larsen B ice shelf in 2002, representing a loss of ice of area 3200 km^2. It may be possible that the larger and more southerly Larsen C ice shelf could also suffer a similar fate if the warming continues, with consequences for ecology and increased glacier flow, and thus sea level rise.

The difference in warming between the east and west side in these seasons is thought to have been driven by Southern Annular Mode (SAM) circulation changes that have led to increases in the strength of westerly winds. The high mountains of the Antarctic Peninsula provide a climatic barrier between the warmer oceanic air of the west and the cold continental air of the east. It has been suggested that increased westerlies allow warm winds to cross to the east side more frequently. The warming of westerly flow can also be enhanced by latent heat release on the upslope side and/or adiabatic descent of air from above, on the downslope side.

In January 2006 the British Antarctic Survey performed an aircraft flight over the Larsen C ice shelf on the east side of the Peninsula, which sampled a strong downslope warming wind event. Surface flux measurements over the ice shelf suggest that the sensible heat provided by the warm jets would be likely to be negated by latent heat losses from ice ablation. The main cause of any ice melting was likely to be due to shortwave radiation input. However, the warming from the jets is still likely to be important by acting as an on/off control for melting by keeping air temperatures above zero. In addition, the dryness of the winds is likely to prevent cloud cover and thus maximize exposure of the ice shelf to solar energy.

This case study has been simulated using the WRF mesoscale model. The modeling agrees with the results of the aircraft study in suggesting that solar radiation input is likely to provide the largest amount of energy for melting of the ice surface. Coriolis turning of the wind jets towards the north was predicted by the model (see Figure 1). It is possible that this will prevent the southern parts of the ice shelf from being exposed to the warm air and hence reduce the degree of melting there.

Generally a good match was found between the modelled and observed jet (Figure 2), especially for the predicted height of the jet maximum winds (~300 m), the rotation of the jet direction towards southerly at the height of maximum wind speed and the temperature profile of the jet. This indicates that the modelled positioning and structure of the jets (see Figure 1) accurately reflects the real jet and that the modelled Coriolis rotation of the jet also occurred in reality. However, the modelled jets died down after 15 UTC whereas the real jet was observed at 20:40 and 22:01 UTC (aircraft descent and ascent). AWS evidence (not shown) suggests that the synoptic situation of the ECMWF analysis used to drive the model changed prematurely so that the winds on the west side of the Peninsula no longer impacted perpendicularly to the ridge, thus causing the jets to cease prematurely. The lack of time available for jet development may explain why the modelled jet was weaker in terms of wind speed.

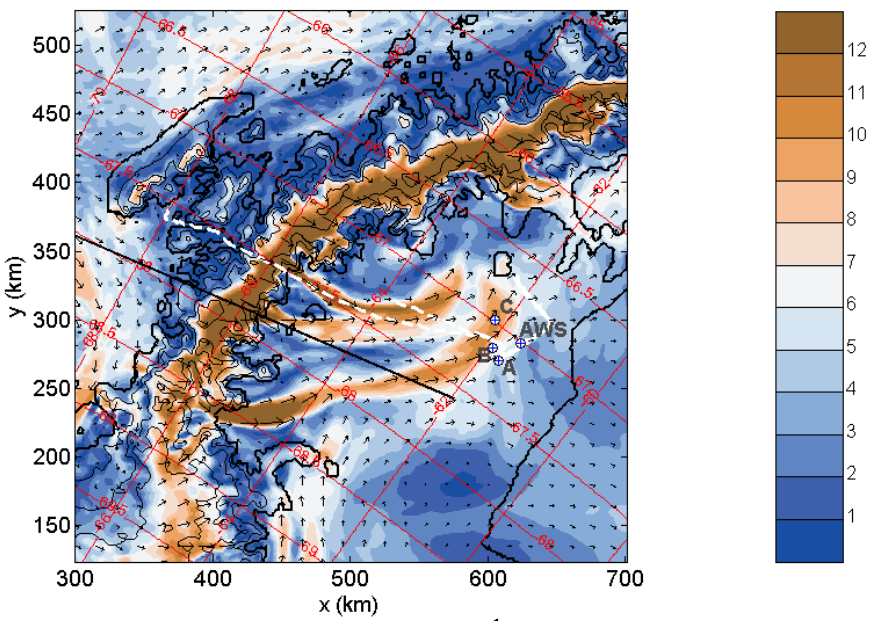

Figure 1 – Wind field (colours are speed in m s^{-1}) from the WRF model at 15 UTC on the 4th vertical model level, which was, on average, 293 m above the terrain.

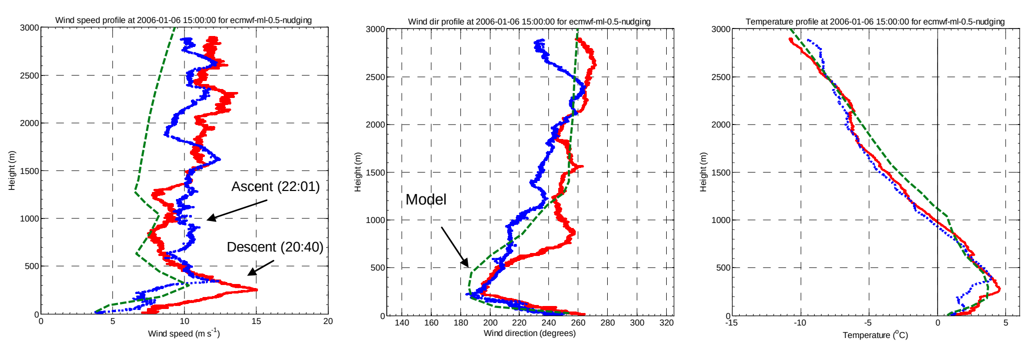

Figure 2 – Comparisons between the model profile at location C (see Figure 1 for the location markers) at 15 UTC and the aircraft profiles taken on the aircraft descent and ascent at locations A and B at 20:40 and 22:01 UTC, respectively. The left plot shows wind speed, the middle plot wind direction and the right plot temperature.

The simulation also provides insight into the physics of the downslope winds through examination of a cross section of the flow taken through one of the jets (Figure 3). They are found to be driven by descent of air from high above the mountain most likely caused by breaking mountain waves. The mechanism that is often perceived to occur in the region is that of air from below the mountain crest rising over the obstacle and descending on the lee side. However, this is somewhat different to the mechanism that the model predicts to be occurring in this case The case is also characterized by a large degree of upstream blocking, a situation in which the previous literature has tended to assume that such warming winds would not occur for this region. In fact, the application of downslope windstorm theories (based on hydraulic theory) suggest that the blocking may play a necessary role in producing the windstorm in this case and so examination of its causes could be of vital importance. It speculated that the presence of sea ice and/or the source of the upwind air may play a role. Upstream flow modification could also be occurring.

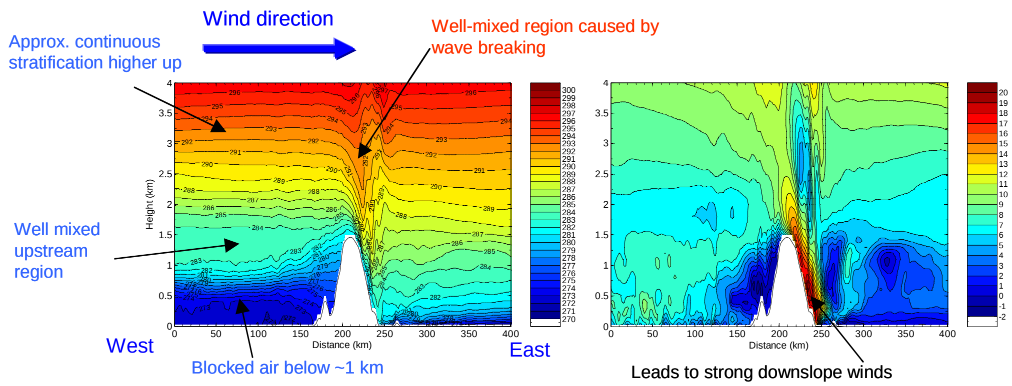

Figure 3 – Cross sections of potential temperature (left) and component horizontal wind speed (right) taken through the black line marked in Figure 1.

The production of warming on the east side of the Peninsula in blocked regimes is important as it would mean that it occurs at weaker low level upstream wind speeds than previously thought. The possible consequence of this are that the suggested increase in the frequency of warming events over the past 50 years in response to the changing SAM index might not be justified by consideration of the observed low level westerly wind speed increases alone. It may more strongly depend on other factors such as the wind speeds at levels near the ridge top, wind direction or the stability conditions. This work also shows that a high resolution model is likely needed to simulate the small scale wave breaking that seems to play a role in these events and thus the effect is not likely to be well captured at climate model resolution.

AMPS UPDATE – JULY 2010

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1 INTRODUCTION

The Antarctic Mesoscale Prediction System (AMPS) is an experimental real-time forecasting system offering high-resolution numerical weather prediction (NWP) products for Antarctic forecasters. Forecasts using the Weather Researching and Forecasting (WRF) model are run twice per day, with graphical and tabular forecast products posted to the web page. While the primary mission of AMPS is in support of forecasting for United States Antarctic Program (USAP) flight logistics, the real-time NWP products are freely available to the Antarctic community through the AMPS web page (http://www.mmm.ucar.edu/rt/amps).

This paper discusses the more significant changes and improvements to AMPS that have occurred over the past year.

2 AMSU-A RADIANCE ASSIMILATION

One goal for the current AMPS cycle has been the assimilation of AMSU satellite radiances. The WRF Data Assimilation package (WRFDA) has the capability to assimilate satellite radiances, using an adaptive bias correction technique (Auligne, et al. 2007) which uses the data assimilation procedure itself to identify and correct for biases in the satellite data. Working with T. Auligne, we tested WRFDA and WRF in a 2-domain AMPS configuration for the period of 28 Nov 2009 through 25 Jan 2010. Parallel experiments were set up: one experiment, the control setup, assimilated the usual set of surface, raob, and satellite-retrieved observations into the WRF initial conditions; the second experiment used those same observations, plus the AMSU-A radiances. Comparison of model results to sounding data over Antarctica (Fig.1) shows a small impact on the forecasts as averaged over the last month of the test period (after a "spin-up" period for the adaptive bias correction). The most noticeable effect is a slight increase in temperature (a few hundredths of a degree in the lower troposphere, to a few tenths of a degree around and above the tropopause) throughout the atmosphere.

We have turned on the radiance assimilation in the real-time AMPS forecasts beginning with the 00Z forecast cycle of 01 April 2010.

3 RRTM RADIATION CORRECTION

As described in more detail in Powers, et al. (2010), S. Cavallo has identified and fixed a problem with the implementation of the Rapid Radiative Transfer Model (RRTM) in WRF. Since AMPS currently uses the RRTM long-wave radiation scheme, we have applied Cavallo's correction in AMPS, beginning with the 00Z forecast cycle of 06 Apr 2010.

4 CAM RADIATION TESTS

At last year's workshop, J. Cassano and M. Seefeldt (2009) presented results of their extensive tests of physics options and combinations of physics options for WRF in a polar environment. One of the clearest signals from their results suggested that the radiation scheme from the Community Atmospheric Model (CAM), for both short-wave and long-wave radiation, produced better results in their simulations than the other radiation options available in WRF. While their tests were performed in the Arctic, their results were encouraging enough for us to test the CAM radiation scheme over Antarctica. For the months of Janu-

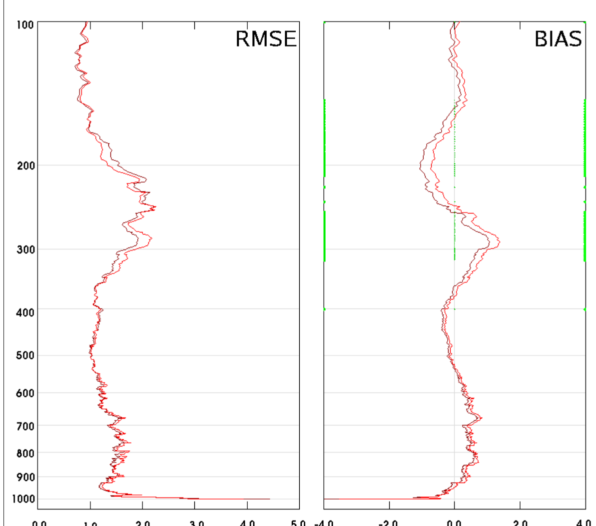

Fig. 1: Comparison of average temperature error profiles between 24-hour forecasts from forecasts initialized with and without AMSU-A radiances, for the period of 20 Dec 2009 through 20 Jan 2010. Dark red: Control RMSE and bias statistics. Bright red: AMSU-A Experiment RMSE and bias statistics.

* *NCAR is sponsored by the National Science Foundation*

ary and August 2009, we ran parallel tests of WRF in a 2-domain AMPS configuration. One experiment, our control simulation, used the Goddard shortwave radiation and the RRTM long-wave radiation schemes. The second experiment used the CAM radiation schemes for both shortwave and long-wave radiation. We compared model results to Automatic Weather Station (AWS) surface observations of temperature, pressure, and wind.

A first series of tests was encouraging with respect to the behavior of the model with the CAM radiation scheme. In particular, the occasional tendency for simulations to "wander" greatly from reality as the forecast progressed was quite evident in the control simulations, yet largely missing from the CAM tests. However, there were some systematic biases in the CAM results, with fairly large cold biases during summer over the higher elevations of Antarctica. These biases were not evident during the winter period. To address these biases, the surface albedo was further tuned in the CAM experiment to vary from 75% for terrain near sea level, to 80% for terrain above 2500 m. With this adjustment, the CAM tests performed noticeably better than the control simulations (Fig. 2).

Based on these results, we implemented CAM in AMPS. We soon began to have intermittent, mysterious, and unrepeatable model failures. Further tests confirmed that the use of the CAM option was triggering these failures. The nature of the failures suggested that the problem lay deep in the system level of the WRF code. Reluctantly, we reverted back to the prior configuration of the Goddard shortwave and RRTM long-wave radiation schemes.

We ran the CAM radiation scheme in the real-time AMPS system from 00Z, 17 Oct 2009 through 12Z, 18 Dec 2009.

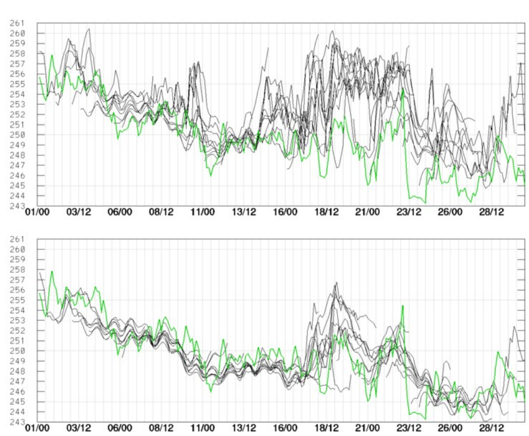

Fig. 2: Comparison of temperature forecasts from Control and CAM experiments for Jan 2009. Top panel: Control experiment. Bottom panel: CAM experiment. Individual forecast temperature traces are shown in black. Observations are in green.

As we test the latest WRF release, WRF version 3.2, for use in AMPS, we will be testing the CAM radiation scheme again.

5 LARISSA ONE-WAY NEST

A one-way nest was implemented over the Larsen Ice Shelf, in support of forecasting activities for the Larissa field campaign. This nest replaced the Marie Byrd Land one-way nest which covered much of Western Antarctica. The grid (Fig. 3) was set up with a 2.5-km grid cell size, and ran out to 72 hours. As a one-way nest, it was run as a separate process after the integration of the principal AMPS grids, using the results from those grids as lateral boundary conditions. The Larissa grid ran from 04 Jan through 08 Mar 2010.

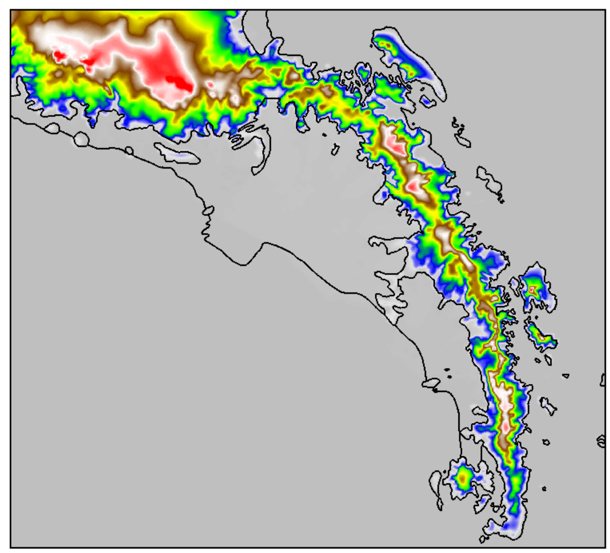

Fig. 3: Area of Larissa one-way nest, showing the terrain field in the grid.

6 AMPS PRODUCT CHANGES

The usual minor product adjustments have been implemented, following suggestions from forecasters. One entirely new product has been added to the AMPS product suite.

Ceiling plot details

Of the minor product adjustments this year, perhaps the most noticeable change is an increase in the resolution of the color scale at low levels for the cloud ceiling plot (Fig. 4). Formerly, all ceilings below 1000 feet were all filled in with a single color. The new color scheme adds several shades to distinguish variations variations in ceiling at greater resolution.

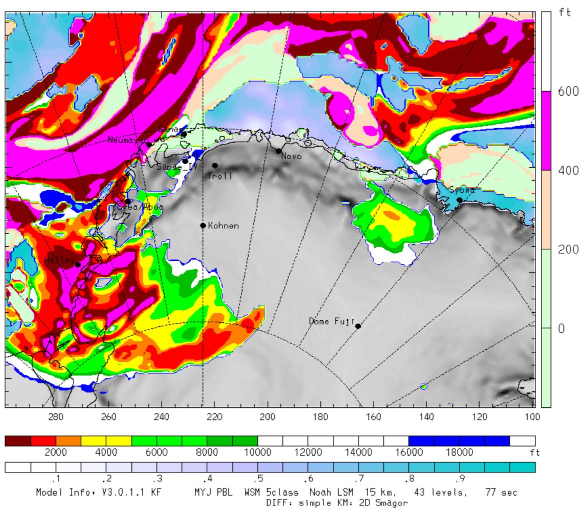

Fig. 4: Sample cloud ceiling product, showing new color scale that distinguishes lower ceiling values.

Self-Organizing Maps

At previous workshops, Cassano and Seefeldt (2008) and Seefeldt (2008) have described a pattern-recognition and grouping technique called the self-organizing map (SOM) as a powerful tool for evaluating model behavior in various forecast regimes. This season, we have begun offering to forecasters a SOM representation of AMPS model history (Fig. 5) from the analysis done by Cassano's group. The analysis focuses on summertime weather patterns over the Ross Ice Shelf and the Ross Sea as predicted by AMPS for past seasons. The statistics built up from past seasons may be used to help interpret current model results. For each forecast snapshot, the forecast pattern is matched to one of a set of identifiable patterns in the SOM. Statistics about how the model performed in past cases for similar events are presented to the forecaster in graphical form, as an aid to assessing confidence in the current forecast.

Because the SOM depends on a large database of forecasts, the current statistics have been developed using the past MM5 forecasts from AMPS. Statistics have not yet been computed using the history of WRF forecasts in AMPS.

The SOM products are available (for the Ross Sea region, in the summer season only) through the AMPS web page, using the "SOM" button.

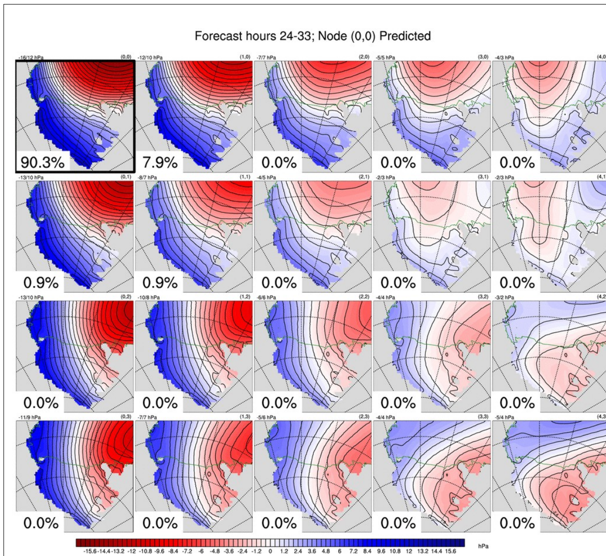

Fig 5: Sample SOM product

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Cassano, J. J. and M. W. Seefeldt, 2008. Comparison of AMPS MM5 and AMPS WRF forecasts using self-organizing maps. 3rd Antarctic Meteorological Observation, Modeling, and Forecasting Workshop. Madison, WI.

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SOFTWARE WITH A VIEW OF WEATHER OBSERVATION STATISTICS

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1. INTRODUCTION

As part of the model initialization for the Antarctic Mesoscale Prediction System (AMPS), observations are ingested by a variational data assimilation package, WRF-Var, to produce initial conditions for the WRF model integration. During previous Antarctic Meteorological Observation, Modeling, and Forecasting workshops it was suggested by various attendees that a statistical analysis of observations used by AMPS forecasts would be nice to have. NCAR then took on the task of building such an application. This paper describes that application, the Observations Statistical Software Package (OSSP).

Two files are needed as input data for the OSSP. These files are generated by the WRF-Var assimilation step. The first file is obs.ascii, and the second is the filtered_obs file. File “ob.ascii” contains a pre-processed file of all the observations that are provided to the data assimilation step. WRF-Var produces the filtered_obs file that is used by the OSSP. File “filtered_obs.ascii” contains the set of observations use by WRF.

2. SOFTWARE DEVELOPMENT

As of May 2010 the Observations Statistical Software Package was completed. The package consists of three programs (thus far): 'StatsObsDat', 'ObsPerPeriod', and 'StationStats'. Each of these components were written in Fortran 90.

StatsObsDat reads input from the obs.ascii and filtered_obs files. These are then parsed into comma-delimited files which remove the specific observation values. The process leaves the name of the observation, the type of observation, the date of the observation, the levels of the observation, and the latitude and longitude of the observation in the file. Matching between the observations in ob.ascii and filtered_obs files is performed to determine which observations have been discarded. This program is run for each of the AMPS forecasts, producing a single output file for each forecast. These files are then available as input to ObsPerPeriod of OSSP.

ObsPerPeriod reads the extracted files from the StatsObsDat and creates statistics with regard to the observations used, observations rejected, and percentages of all observations included, listed by observation category (that is, SYNOP, METAR, etc.). See Tab. 1.

StationStats the third component of the OSSP is used to find a particular station’s observations and to provide the same statistical output as ObsPerPeriod. Input to the program must include the name of the station to be found, the date of the forecast, and the number of days to be examined. See Tab. 2.

3. SUMMARY

In response to suggestions from users at previous Antarctic Meteorological Observation, Modeling, and Forecasting Workshops, NCAR has developed a capability to analyze the usage of observations in AMPS. This software suite consists of programs to gather, review, and compute statistics for observations in the AMPS domains. The suite provides capabilities for calculating the usage specific observation types on either an areal or individual station basis. Observation usage results are posted to the AMPS web site. The AMPS group encourages users to explore the utility and provide suggestions for future improvements.

ACKNOWLEDGEMENTS

The author would like to acknowledge the assistance of Michael Duda, Jordan Powers, and Kevin Manning in the development of this software. AMPS is funded by the National Science Foundation, Office of Polar Programs.

Table 1: Output file from ObsPerPeriod

```
Statistical report on observations used by WRF for a given period.
Date of Report: 20100401            , covering one week.
=====================================================================
Number of obs available for the forecast = 10811

Number of obs used in the forecast = 10359

Number of obs rejected in the forecast =   452

Percentage of obs used in the forecast =    95

Avg. obs used/forecast period =  0.0

Total number of input obs = 10811

Total number of rejected obs =   452

The percentage of rejected obs =  4.2

Incoming SYNOPs                         :   414
SYNOPs rejected                         :   180 ( 43.5%)
SYNOPs used in this analysis            :   234 ( 56.5%)

Incoming METARs                         :   137
METARs rejected                         :    67 ( 48.9%)
METARs used in this analysis            :    70 ( 51.1%)

Incoming SHIPs                          :    28
SHIPs rejected                          :     9 ( 32.1%)
SHIPs used in this analysis             :    19 ( 67.9%)

Incoming BUOYs                          :   139
BUOYs rejected                          :   139 (100.0%)
BUOYs used in this analysis             :     0 (  0.0%)

Incoming TEMPs                          :    20
TEMPs rejected                          :     0 (  0.0%)
TEMPs used in this analysis             :    20 (100.0%)
```

Table 2: Output file from StationStats

```
HALLEY station report for the following dates
20100404
20100405
20100406
20100407
20100408
20100409
20100410
20100411
=====================================================================

Number of HALLEY obs available for the forecast period =     5

Number of HALLEY obs used in the forecast period       =     5

Number of HALLEY obs rejected in the forecast period   =     0

Percentage of HALLEY obs used in the forecast period   = 100.0

Total number of rejected obs in the forecast period    =     0

The percentage of rejected obs in the forecast period  =   0.0

Total SYNOPs available for the forecast period       :      15
SYNOPs used in the forecast period                   :      13 (100.0%)
SYNOPs rejected in the forecast period               :       0 (  0.0%)

Total TEMPs available for the forecast period        :       5
TEMPs used in the forecast period                    :       5 (100.0%)
TEMPs rejected in the forecast period                :       0 (  0.0%)
```

AVIATION WEATHER FORECASTING TOOLS FOR SOUTH POLE

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1 INTRODUCTION

The Space and Naval Warfare Systems Center – Atlantic, Office of Polar Programs (SOPP) regularly issues aviation weather forecasts for the skiway at the Amundsen-Scott South Pole Station. These forecasts are issued by the SOPP Remote Operations Facility in North Charleston, SC during the austral summer to support United States Antarctic Program aviation operations at the South Pole skiway (ICAO identifier NZSP). The 24-hour forecast is issued as a Terminal Aerodrome Forecast three times daily, at 0700Z, 1500Z, and 2300Z, and disseminated via the Aeronautical Fixed Telecommunications Network.

There are three primary forecast tools used by the SOPP forecasters: observations and upper-air sounding analyses, meteorological satellite imagery, and the Antarctic Mesoscale Prediction System (AMPS).

2 FORECAST TOOLS

Manual METAR observations, upper-air soundings analyzed with the RAwinsonde OBservation Program application, and AMPS model output in the form of tables and meteograms are the quantitative forecast tools available for the forecast process. Qualitative tools such as satellite imagery and AMPS product animations complete the typical suite of forecast tools used as guidance in developing the forecast.

Upper-air soundings

South Pole meteorological personnel take and disseminate daily upper-air soundings at 0000Z and 1200Z during the austral summer USAP operating season. These sounding are analyzed with the RAwinsonde Observation (RAOB) Program application by the Remote Operations Facility. Other than the typical Skew-T diagram display generated by the application, several parameters analyzed by this application are used as guidance: inversion layers (radiation, subsidence, and frontal), fog stability index, mean winds (0-500 m), mean winds (0-6 km), cloud, contrail, clear air turbulence probability, and low-level wind shear.

Meteorological satellite imagery

Imagery from the TeraScan® system at its ground station at McMurdo is available to the SOPP Remote Operations Facility. TeraScan is a direct broadcast, dual X- and L- band reception and processing system for digital environmental satellite images. It is owned by the National Science Foundation, maintained by Raytheon Polar Services Company, and shared for joint operational and research use by forecasters and the science community.

The TeraScan system receives and processes digital imagery from the following programs:

- NOAA's Polar-orbiting Operational Environmental Satellite (POES) provides 1.2-kilometer (0.8mi) resolution imagery in both the visual and infrared spectrums
- Defense Meteorological Satellite Program provides 0.5-kilometer (0.3mi)

resolution visual imagery and 0.7-kilometer (1.7mi) infrared imagery during the austral summer. All DMSP data is transmitted unencrypted below 60°S.

- Two of NASA's Earth Observing System (EOS) satellites, Terra (EOS AM-1) and Aqua (EOS PM-1) employ the MODIS (Moderate-Resolution Imaging Spectroradiometer) instrument. MODIS has 36 channels; 11 channels in the visible range, 9 in the near-IR range, 6 in the thermal-IR range, 4 in the shortwave-IR range, and 6 in the longwave-IR range. Two channels have a spatial resolution of 250m, 5 have a resolution of 500m, and 29 have a resolution of 1000m.

Selected images are then transmitted via the TELECOM NZ 128K line to a Local Data Manager (LDM) computer at the USAP Campus in Christchurch, New Zealand, where it resides until polled by the Remote Operations Facility and the images then transferred via the Internet.

Antarctic Mesoscale Prediction System (AMPS)

Products from AMPS are available at http://www.mmm.ucar.edu/rt/wrf/amps/.
Grid 2 (15-km Continental grid) of AMPS is used to assess the synoptic situation over the continent, while Grid 4 (5-km South Pole grid) is used for determining mesoscale influences. The 5-km grid NZSP South Pole table and meteogram available from the product chooser page of the website are used, as well as these 15-km grid products viewed in the product animation window:

- 600hPa relative humidity (w.r.t. ice), geopotential height, and temperature
- 500hPa relative vorticity and geopotential height
- 300hPa relative vorticity and horizontal wind speed, and horizontal wind vectors
- cloud ceiling
- column-integrated cloud liquid water

The products listed above are also reviewed in the 5-km grid animation window, as well as these products specific for the 5-km grid:

- horizontal wind streamlines and speed (surface, 1k AGL, and 3k AGL)
- cloud ceiling (with 200 ft increments below 1000 feet)

3 SUMMARY

There is limited data available for developing forecasts for South Pole and the forecasting process for this site employs the single-station forecasting technique. However basic the forecast tools available for guidance in this process appear to be; high quality satellite imagery, observations, upper-air sounding analyses, and an excellent NWP model exemplified by the Antarctic Mesoscale Prediction System can provide an experienced polar weather forecaster with the requisite tools to generate a quality aviation forecast to support aviation operations at South Pole.

Verification of numerical weather prediction systems employed by the Australian Bureau of Meteorology over East Antarctica during the 2009-10 summer season.

Dr. Neil Adams*

June 1, 2010

1 Introduction

Every season the Antarctic Meteorological Section of the Australian Bureau of Meteorology organise for either direct streaming of Numerical Weather Prediction (NWP) data to weather forecasters stationed in Antarctica, or provide web based display systems to allow forecasters access to these data where data volumes are too large for transmission over the limited bandwidth into the Australian Antarctic stations. The available NWP systems include data from the European Centre for Medium Range Weather Forecasting (ECMWF), the United Kingdom Met Office (UKMO), the US National Centers for Environmental Prediction Global Prediction System (NCEP-GFS), the new Australian Community Climate and Earth-System Simulator (ACCESS) global NWP model (ACCESS-G), the Australian Antarctic polar-stereographic Limited Area Prediction System (PolarLAPS) and the US Antarctic Mesoscale Prediction System (AMPS). This paper provides a brief analysis of model performance over the later part of the 2009-10 austral summer and of a significant precipitation event at Casey in April 2010. The paper concludes with a discussion of the proposal to develop a polar prediction system within the Australian Bureau of Meteorology.

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2 NWP performance

In evaluating model performance over Antarctica the starting point for the analysis was output from the Antarctic multi-model ensemble system. These products are routinely generated from output from ECMWF[1], NCEP-GFS[2], UKMO[3], ACCESS-G[4], PolarLAPS (Adams 2006) and AMPS (Powers et al 2003). The ensembles are freely available[5] to the international community and include Antarctic stations, field camps and some sub-Antarctic islands. An example ensemble is shown in Figure 1 and the amalgamated ensembles output from +24 hour Casey forecasts for the period 25 January to 25 April 2010 shown in Figure 2, with model data from ECMWF, NCEP-GFS, ACCESS-G, AMPS and PolarLAPS. Casey Station is prone to significant blizzard events such as the event around 16 March 2010 (Figure 2). In such events the lower resolution global models tend to under-predict the wind strength with the higher resolution models such as AMPS performing significantly better. The coarser resolution models such as ACCESS-G and NCEP-GFS also typically over-forecast wind strength at Casey during the quieter between blizzard times. In Figure 2 the large discrepancies in surface pressure and air temperature fore-

[1] www.ecmwf.int/products/data/operational_system/description/brief_history.html
[2] wwwt.emc.ncep.noaa.gov/gmb/moorthi/gam.htm
[3] badc.nerc.ac.uk/data/um/umhelp.html
[4] www.bom.gov.au/nmoc/access/docs/ACCESS-G_raw.shtml
[5] cawcr.gov.au/projects/antarctic/ensembles.php

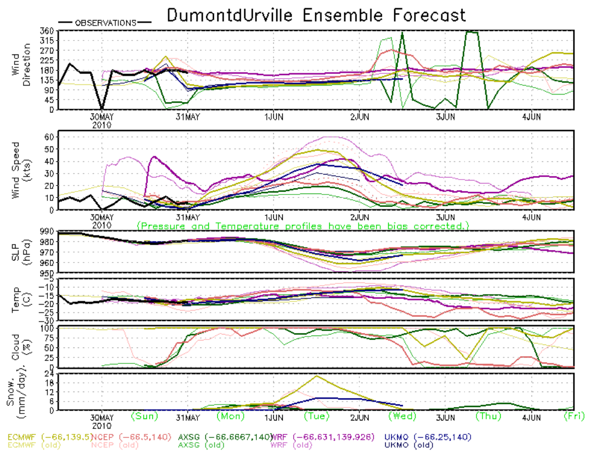

Figure 1: ***Example of Antarctic multi-model ensemble for Dumont d'Urville valid for a 6-day period from 29 May 2010. Top panel wind direction (0 - 360^o), second panel speed (0 - 60 kt), third surface pressure (950 - 990 hPa), fourth temperature (-30 - -5^oC), fifth cloud cover (0 - 100 %), bottom precipitation (0 - 24 mm/day).***

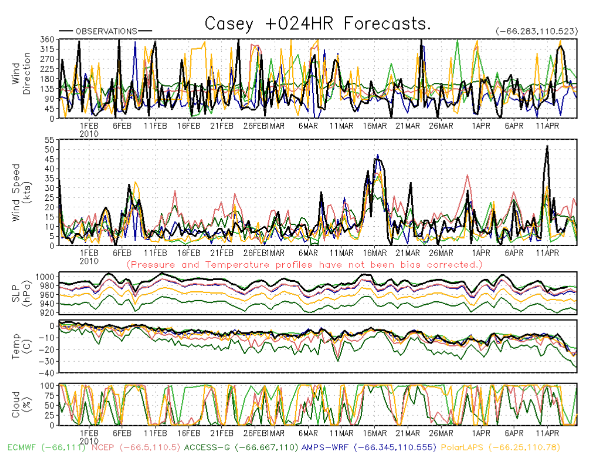

Figure 2: ***+24 hour ensemble output from all available models valid for the period 25 January to 25 April 2010. Top panel wind direction (0 - 360^o), second panel speed (0 - 55 kt), third surface pressure (920 - 1000 hPa), fourth temperature (-40 - 5^oC), bottom panel cloud cover (0 - 100 %).***

casts stem from the nearest-grid-point method used in building up the ensembles. The coarser resolution models typically have the closest grid-point some distance from the station which may be up or downslope, causing large biases in temperature and pressure. Some models also use mean sea level pressure (MSLP) rather than surface level pressure (SLP), and introduce another bias. Simple statistics may be generated from these ensembles including biases, Root Mean Square Errors (RMSE) and the RMSE from the bias corrected data (bcRMSE). Figure 3 shows the

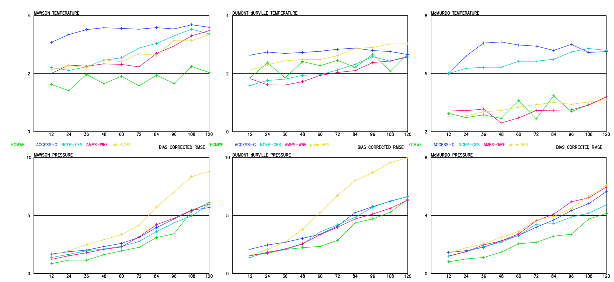

Figure 3: ***Bias corrected RMSE for temperature (top panel) and pressure (bottom panel) for Mawson (left), Dumont d'Urville (centre) and McMurdo (right) out to the 120 hour time-step. The lower the value the better the forecast. ECMWF - green, AMPS - purple, PolarLAPS - yellow, NCEP-GFS - cyan, and ACCESS-G - blue.***

bcRMSE statistics from Mawson, Dumont d'Urville and McMurdo for 25 January to 25 April 2010. From these statistics AMPS and ECMWF are clearly the strongest performers with NCEP-GFS and ACCESS-G generally performing poorly, and PolarLAPS lying somewhere in between.

The single-station statistics don't always highlight the relative merits of a particular model and don't adequately measure model performance where the forecast information may be good but the timing slightly in error. For example, wind forecasting at Casey is very important where conditions may rapidly change from the normally benign state with speeds typically less than 5 $ms^{-1}$to those in which the speed may exceed 40 ms^{-1}. A more useful gauge of model wind forecasting performance is the wind vector frequency diagram. Figure 4 is an example of such a diagram in direction-speed space and shows a comparison of the

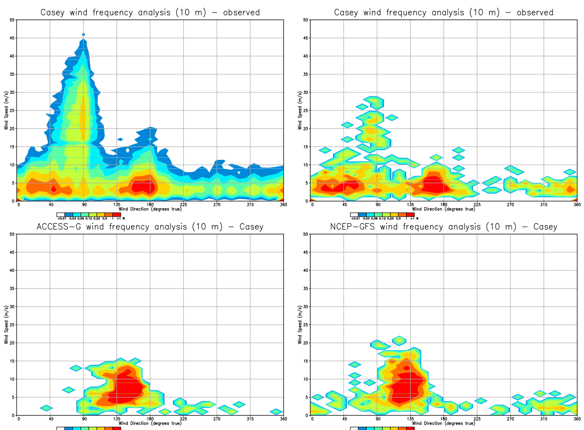

Figure 4: ***Wind speed-direction frequency analysis for Casey station with the long-term analysis covering the period from 1 January 1989 to the present (top left), the short term observed frequency for the period 25 January to 25 April (top right), and model analysis for the same period from ACCESS-G (bottom left) and NCEP-GFS (lower right). Wind direction is on the x-axis (0-360^o) and wind speed on the y-axis (0 - 50 ms^{-1}).***

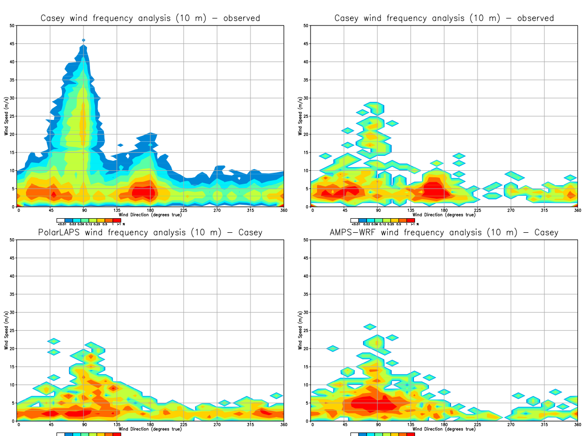

Figure 5: ***As for Figure 4 but displaying Casey model output from PolarLAPS (lower left) and AMPS (lower right). Wind direction is on the x-axis (0-360^o) and wind speed on the y-axis (0 - 50 ms^{-1}).***

long term Casey wind frequency analysis, the analysis over 25 January to 25 April 2010, and output from ACCESS-G and NCEP-GFS. At a resolution of 80 km ACCESS-G is the coarsest model under evaluation and the relatively poor agreement with the observed frequency analysis for the January to April period in both wind strength and direction is probably due to this. At 50 km resolution the NCEP-GFS model performs slightly better but still fails to replicate the bi-modal low wind speed signal with frequency peaks from the northeast and south to southeast directions. Figure 5 is the same as Figure 4 but compares output from PolarLAPS and AMPS. The AMPS wind modelling is clearly superior to that of PolarLAPS although there is more definition in the low speed bi-model signature in PolarLAPS than AMPS, however AMPS clearly performs better in modelling the strong easterly blizzards that are a feature of Casey.

3 Precipitation Forecasting

Forecasting precipitation is an important consideration in Antarctica due to the impact of snow on visibility and surface and horizon definition. Adequate modelling of precipitation is also a key requirement in Antarctic mass balance studies. Measuring precipitation is a challenge in Antarctica with Australia only measuring precipitation when there is no significant wind to contaminate the measurement with blowing or drifting snow. As a result, verifying model performance across all wind conditions becomes difficult, although some success was made in verifying precipitation output from ALAPS (Adams 2004a). In the 24 hours to 0300 UTC 20 April 2010 a significant fall of snow was reported at Casey during a period of light wind (see Figure 7). The water equivalent of this snow was measured at 34 mm. The accumulated precipitation values from the NWP systems initialised at 1200 UTC on 18 April 2010 and over the same 24 hour period are shown in Table 1. In general the higher resolution models performed better with the 0.125 km ECMWF model closest to the truth although still less than half the observed precipitation. The AMPS forecast performed worse than ex-

Model	Precipitation total (mm)
ACCESS-G	2.9
NCEP-GFS	5.0
ECMWF	16.0
PolarLAPS	12.8
AMPS	5.3
Observed	**34.0**

Table 1: 24 hour accumulated precipitation from ACCESS-G, NCEP-GFS, ECMWF, PolarLAPS and AMPS ending at 0300 UTC 20 April 2010 from the model runs initialised at 1200 UTC 18 April 2010.

pected, although the previous model run, initialised at 0000 UTC did forecast 8 mm over the 24 hours. The PolarLAPS forecast performed nearly as well as the ECMWF and inspection of the spatial distribution of the accumulated precipitation over the 24 hour period (Figure 6) showed a greater than 20 mm peak to the northwest and southeast of Casey. However, there is still a question mark over the effect of the local wind on the observed 34 mm fall. The microclimate around the station causes significant fluctuations in snow depth, as highlighted in a photo taken in the general vicinity of the precipitation gauge at the end of the event (Figure 7). Significant variations in snow depth are apparent over a relatively small area, throwing doubt on the accuracy of the measurement.

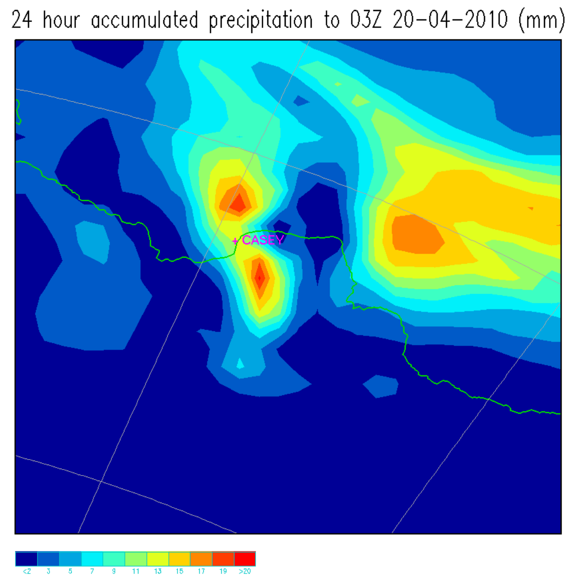

Figure 6: ***24 hour accumulated precipitation to 0300 UTC 20 April 2010 in the Casey area. Scale is less than 2 mm dark blue, to 20 mm or greater in red, colours graduate in steps of 2°C.***

Figure 7: Photo taken at Casey station showing the operations building at the time of the large snowfall event. The observations site is just out of the image to the right.

4 Future plans for polar prediction in Australia

Over the last three years the Australian Bureau of Meteorology (the Bureau) has been undertaking development of the UKMO Unified Model (UKMO-UM[6]) as the new atmospheric model for both operational weather forecasting and climate and weather research. The UKMO-UM forms part of the Australian Community Climate and Earth-Systems Simulator (ACCESS) suite of models and offers modern

[6] www.metoffice.gov.uk/research/modelling-systems/unified-model

non-hydrostatic dynamics with semi-lagrangian advection and semi-implicit time-stepping. It is a grid point model which can be run with a rotated pole and a variable horizontal grid. It can run either globally or as a limited area model, and can be coupled to land surface schemes, ocean, waves, chemistry and sea-ice models. The system also brings to the Bureau 4-D variational assimilation, providing a far more sophisticated analysis system. The old global model (GASP) and suite of limited area models (LAPS) are being phased out during 2010 as the new ACCESS suite of models are implemented on the new SUN supercomputer. PolarLAPS ceased in May 2010 with the de-commissioning of the old NEC-SX6 supercomputer.

With the demise of PolarLAPS a proposal has been submitted to develop an Australian Polar Prediction System (APPS) employing a polar version of the ACCESS system (ACCESS-P), initially running as a down-scaling system over an identical rotated grid to PolarLAPS. This will be followed by incremental upgrades introducing polar specific physics, including tiling over the sea-ice zone, 4-D variational assimilation of routine observations and satellite data, and a resolution increase from 0.25^o to around 0.15^o. An additional component of the APPS will be the development of a sea-ice forecasting system based around the Los Alamos Community sea-ice model (CICE) (Hunke et al. 2010). It is proposed to force the sea-ice model with output from ACCESS-P, and run an assimilation system utilising sea-ice concentration and ice motion observations. Sea-ice model output will also be used to initialise ACCESS-P with the expectation of improved modelling of atmosphere/sea-ice exchanges and an improvement in NWP forecast output in the five to seven day period.

5 Summary and Conclusions

The Australian Antarctic forecasting service continued to be well served by national and international NWP systems with forecasters heavily reliant on AMPS, ECMWF, NCEP-GFS and PolarLAPS output. High resolution regional models such as AMPS continue to provide the highest quality of NWP guidance and with the demise of PolarLAPS the Australian Bureau of Meteorology is looking ahead to developing the next generation Antarctic model based around the UKMO-UM model, and to further environmental monitoring and prediction with the introduction of a sea-ice analysis and forecasting system.

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Validating the moisture analyses and predictions of AMPS using ground-based GPS measurements of precipitable water

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1. Introduction

One important area of improvement in the numerical weather forecasts of the Antarctic Mesoscale Prediction System (AMPS) is the prediction of low-level cloud cover (Fogt and Bromwich, 2008; Steinhoff, 2009). Indeed, inaccurate cloud forecasts can significantly impact the aircraft operations at McMurdo, which require minimum conditions of cloud ceiling/visibility.

The assimilation of total precipitable water (PW) data derived from ground-based GPS measurements in Antarctica has been proposed as a way to improve the skill of AMPS forecasts, by providing a better constraint on the model low-level moisture. The tropospheric delay of the GPS signal varies as a function of the moisture content and temperature of the air above the GPS receiver (Bevis et al., 1992). Thus, assuming that the mean atmospheric temperature can be determined, it is possible to assess the vertically integrated moisture content of the atmospheric column. While providing a vertically integrated measurement, the GPS wet tropospheric delay is mainly influenced by the lower tropospheric layers (<700 hPa), where moisture is largely confined.

A number of GPS receivers have been recently installed in West Antarctica and south of McMurdo along the Transantarctic Mountains, especially as part as the Polar Earth Observing Network (POLENET) project (see Fig. 1 and http://www.polenet.org/maps/index.php). Persistent moisture convergence to Mary Byrd Land (West Antarctica), linked to the cyclonic activity over the Ross Sea, and the local wind pattern over the Ross Ice Shelf (e.g., Ross Ice Shelf Air Stream) make this region key to the moisture advection to the McMurdo area (Steinhoff et al., 2009).

Thomas et al. (2008) derived and analyzed 12 years (1995-2006) of PW estimates from ground-based GPS measurements at 12 Antarctic stations and reported good agreement of this dataset with radiosonde observations. Here, with a more operational focus, we compare AMPS forecast PW with GPS data and observations, focusing primarily on the McMurdo area. Based on our results, we also discuss the relevance and feasibility of assimilating GPS data into the AMPS forecasting model.

2. Data

The period investigated spans January 2007-June 2008. The AMPS data consist of the daily 0000 UTC initialized forecasts for the Antarctic domain (Grid 2) generated with the Polar WRF (version 2.2) mesoscale model and featuring a 20-km grid-spacing. Until July 2008, the primary model for AMPS forecasts was the Polar MM5 but the two models were run in parallel between March 2006 and June 2008, until the Polar MM5 was finally phased out in early July 2008. The Polar WRF model version/ configuration described above was used for AMPS forecasts until November 2008. The use of an earlier

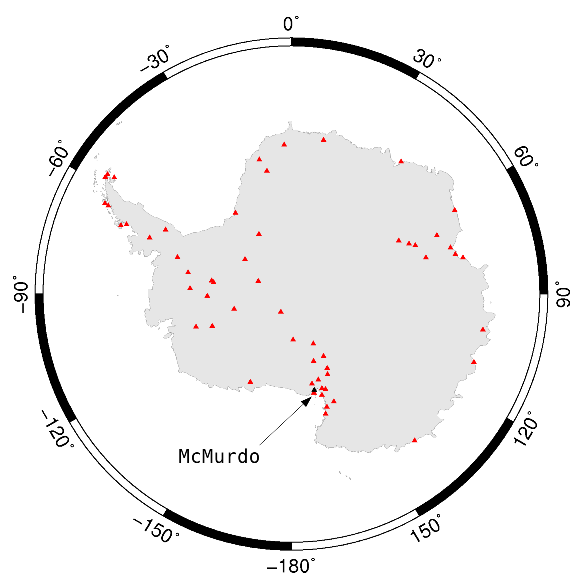

***Figure 1**. GPS sites in Antarctica. The map does not include the GPS receivers installed during the 09-10 field season.*

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model version in our study was dictated by the availability of GPS-derived PW data. AMPS gridded data were bilinearly interpolated to the McMurdo location.

Two-hourly time series of PW estimates derived from GPS measurements were provided by I. Thomas. To convert the zenith wet delay into PW, a mean tropospheric temperature is estimated based on surface temperature using the relationship from Bevis et al. (1994). It is noteworthy that Bevis et al. (1994) derived this relationship based exclusively on observations from the mid-latitudes of the Northern Hemisphere.

Observations from radiosondes at McMurdo are from the Integrated Global Radiosonde Archive of the National Climatic Data Center (http://www.ncdc.noaa.gov/oa/climate/igra/index.php). This dataset includes observations from 0000 UTC and 1200 UTC radiosoundings. However, the 1200 UTC soundings are only available during the Austral Summer between October-February.

3. Results

Figure 2 shows the time series of PW at McMurdo from observations, AMPS forecasts and GPS data. Figure 1a shows the observed PW together with PW estimates from the 6-h, 12-h, 18-h and 24-h AMPS forecasts. Fairly good agreement is seen overall between the two series, with the notable exception of a peak in AMPS PW around day 450. To a large extent, the model data reflect the observational constraint from assimilated radiosonde observations. In order to better describe the forecasting skill of the model, the AMPS series displayed in Fig. 2b is constructed from the 54-h, 60-h, 66-h and 72-h forecasts. While the degradation in the model performance can be clearly discerned, it must be noted that the model skill remains fairly high between days 240 and 440 (September 07-March 08), corresponding to the Antarctic operational season.

Figure 2c shows the observations together with the time series of GPS-derived PW. While a few large peaks likely indicate spurious values, the GPS data exhibit greater variability than AMPS. This is particularly marked between days 270 and 360 (October-December 2007), where the magnitude of the peaks and lows exceed that of the observations. As mentioned in Section 2, the empirical relationship used to estimate the mean tropospheric temperature and tuned for the northern mid-latitudes likely accounts for the observed discrepancies.

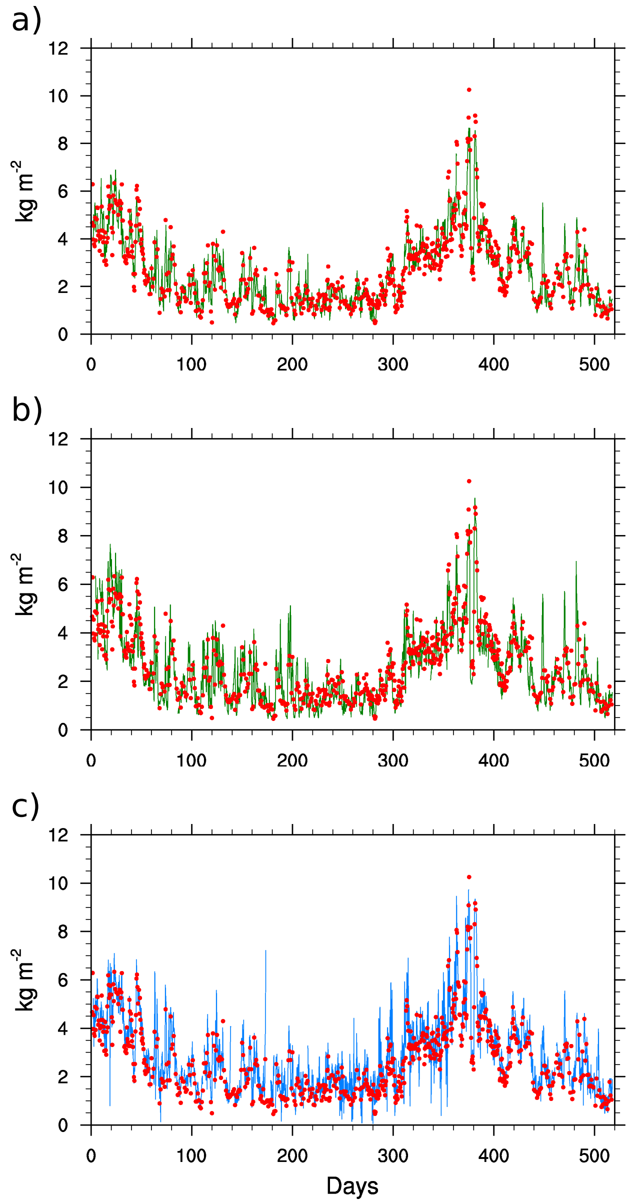

Figure 2. Total precipitable water at McMurdo in kg m^{-2} *from radiosonde observations (red dots), AMPS data (green line) and GPS data (blue line). Observations are compared with (a) AMPS 6-24h forecasts, (b) AMPS 54-72h forecasts, and (c) GPS data. The time axis, in days, spans 1 Jan. 2007 - 31 May 2008.*

A quantitative evaluation of AMPS and GPS-derived PW with respect to radiosonde data is presented in Table 1. The 24-h, 48-h and 72-h AMPS forecasts are compared with observations from 0000 UTC radiosoundings (throughout the year) whereas the 12-h, 36-h and 60-h forecasts are compared with observations from 1200 UTC radiosoundings (summer only). Because the time series of GPS-derived PW has data both at 0000 UTC and 1200 UTC, a significantly larger number of data is used. To allow for uniform comparison with AMPS forecasts, we also calculate and 72-h AMPS forecasts. The 24-h forecasts exhibit a small negative bias (~1%) in the lower tropospheric levels, which is amplified in the 48-h forecasts with a (negative) peak at 900 hPa. For the 72-h forecast, the bias is positive and comprised within 0-2%. In the upper levels (600-400 hPa), q is overestimated by 10-20% in the 24-h forecasts, but this bias tends to decrease as the forecast time moves forward. Fogt and Bromwich (2008) performed a similar analysis of the moisture vertical profile over McMurdo (their Fig. 2). They found a positive bias in relative humidity in the lower atmospheric layers for the 12-36h forecasts, in contrast with a negative bias shown in our Fig. 3 (for

__Table 1__. Bias, rmsd and correlation for GPS-derived and AMPS PW with respect to radiosonde observations calculated for the period Jan. 07-May 08. Mean, bias and rmsd are in kg m^{-2}. The last column shows the number of data used to compute the statistics. Note that for AMPS 12-h, 36-h and 60-h forecasts, only 1200 UTC radiosoundings are used.

	Mean	Bias	Rmsd	Correl.	Count
GPS*	2.87	0.22	0.69	0.92	632
GPS**	2.88	0.29	0.77	0.90	435
AMPS					
12-h	2.61	0.02	0.57	0.93	186
24-h	2.47	-0.06	0.61	0.91	482
36-h	2.42	-0.2	0.72	0.90	184
48-h	2.38	-0.16	0.85	0.84	481
60-h	2.45	-0.24	0.98	0.82	183
72-h	2.49	-0.05	0.87	0.83	480

* GPS data that coincide with all available radiosonde observations.

** GPS data that coincide with 0000 UTC radiosonde observations only. The data count is smaller than 482 because of missing data in the GPS record.

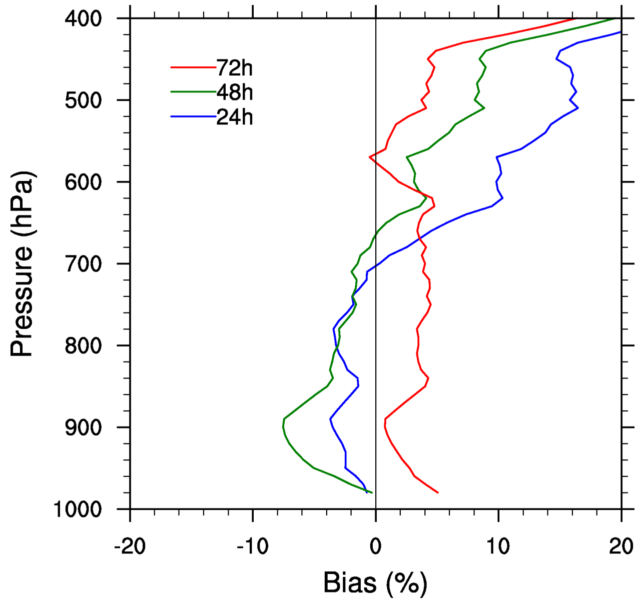

__Figure 3__. Vertical profile of the bias between AMPS and radiosonde data for the water vapor mixing ratio (q). The bias is shown as percentage with respect to the AMPS/radiosonde mean value at each pressure level.

statistics for the GPS-derived PW using only 0000 UTC radiosounding observations. The bias in AMPS PW estimates is found to be significantly lower for the 12-h, 24-h and 72-h than for the three other forecast times, which exhibit a negative bias of ~0.2 kg m^{-2}. AMPS exhibits gradually degrading rmsd and correlation values, except for the 72-h forecast, probably due to the difference in time sampling (year-long versus summer). As opposed to AMPS, the GPS data tend to overestimate PW by ~0.2-0.3 kg m^{-2}. Overall, the skill of the GPS-derived PW data is comparable to that of the AMPS 48-h forecasts, with biases of opposite sign.

Figure 3 shows the vertical profile of the bias in the water vapor mixing ratio (q) for the 24-h, 48-h the mixing ratio). Aloft, their is good agreement between the two studies. The differing model bias in the lower layers between the two studies may result from the change in the forecasting model (Polar MM5 versus Polar WRF).

4. Discussion

Our study reveals a tendency of the AMPS model to underestimate PW, especially in the 48-h forecasts. This underestimation of PW can be attributed to a negative bias in q, maximum around the 900-hPa pressure level. The GPS-derived PW data agree well with AMPS forecast and observed PW. The positive bias seen in the GPS data will likely benefit from a better tuning of the empirical relationship between surface temperature and mean tropospheric temperature for Antarctic conditions. In addition, it must be noted that comparison with AMPS is made where AMPS benefits from the constraint of observed atmospheric soundings. We can expect lower model skill in area distant from radiosounding observations, such as farther south on the Ross Ice Shelf or in West Antarctica. On the contrary, it can be hypothesized that the GPS-derived PW data exhibit comparable skill to that shown over McMurdo.

We conclude with remarks with regards to the prospects of assimilating GPS data. The WRF model allows for the assimilation of the PW retrievals and the GPS zenith wet delay. The direct assimilation of the zenith wet delay will likely yield better results as the model analysis temperature profile can be used to compute a more realistic mean atmospheric temperature than that derived empirically from surface temperature. The use of available GPS data would provide enhanced constraint for AMPS in the "atmospheric corridor" along the Transantarctic Mountains on the western Ross Ice Shelf. The prospect of assimilating GPS data should take into account the availability of GPS data in real-time for assimilation which, to our knowledge is still uncertain. The benefit of GPS data assimilation will also depend on the type of assimilation system. These benefits are maximized with a 4D-Var assimilation system (Poli et al., 2007) – not currently implemented in AMPS – but such a system would require additional computational resources.

Acknowledgments

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IMPROVING UPPER-LEVEL PERFORMANCE IN AMPS: LONGWAVE RADIATION

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1. INTRODUCTION

The Antarctic Mesoscale Prediction System (AMPS) (Powers et al. 2003) is a real-time, experimental, NWP system providing numerical guidance to forecasters of the United States Antarctic Program (USAP). In addition, it provides support for American and international research, field campaigns, and logistical needs over Antarctica. AMPS employs the Weather Research and Forecasting (WRF) model (Skamarock et al. 2008), producing twice-daily forecasts over the continent. AMPS forecasts may be found at http://www.mmm.ucar.edu/rt/amps

An ongoing aspect of the AMPS effort is the tuning of WRF physics to improve forecast performance over Antarctica/polar regions. Thus, the current work examines the performance of WRF at upper levels over Antarctica and its relation to the longwave radiation scheme used. The work is motivated in part by analyses of simulations in other regions that have revealed problems in WRF's behavior near the model top. The current study looks at the WRF upper-level performance in the context of AMPS and tests modifications to the longwave radiation package in the system. For the first time, the issues of WRF radiative flux errors and heating issues at high levels over the polar latitudes are addressed. Longwave scheme modifications are tested in summer and winter season AMPS forecast experiments. These are analyzed to determine the impacts and whether to implement the modified scheme operationally.

2. BACKGROUND AND MODEL CONFIGURATION

a. Motivation

Analyses of WRF simulations during the 2009 hurricane season in the Atlantic Basin brought to light the potential for radiation-induced problems near the model top. The results from simulated periods showed a distinct cooling at upper levels, and Cavallo et al. (2010) present the background on this work. As an example, Fig. 1(a) shows the evolution of potential temperature (θ) over time (mean removed) averaged over the Atlantic Basin domain from the 2009 season examination. Near the model top temperatures begin relatively warm and become progressively cooler. Here, WRF was run in cycling mode with data assimilation performed though an ensemble Kalman filter approach. Figure 1(b) presents the differences of WRF and the GFS (Global Forecasting System) analyses through the test period. Compared to the analyses, WRF displays a cool bias aloft, and this reaches close to -10K during this period (although the scale in Fig. 1 only reaches -4K). Cooling tendencies at the WRF model top in similar analyses by these investigations have also been found to be up to -10K/day.

The cool bias is a result of the approaches used in the longwave radiation scheme employed, the RRTM (Rapid Radiative Transfer Model) (Mlawer et al. 1997). Specifically, this scheme makes assumptions about the conditions above the model top to the top of the atmosphere (TOA) for the calculation of the radiative fluxes at the model upper boundary. The formulation leads to much of the error seen.

In making its flux calculations, the scheme internally uses one additional level between the model top and the TOA. In the new layer the temperature is assumed isothermal and the mixing ratios, except for that for O_3, are assumed constant. These assumptions can be inaccurate, however, for T and q_v for WRF with relatively low model tops (compared to the tops in global models for which the scheme was originally targeted). Actual temperatures in computational layers above 50–10 hPa (a region more commonly used for the top levels in most WRF applications) can vary significantly from those based on an assumed temperature equal to that of the model top. In addition, inaccurate assumptions in stratospheric relative humidity can produce conditions that are far too moist. That excessive moisture is then carried to the TOA through the buffer layer by the assumption.

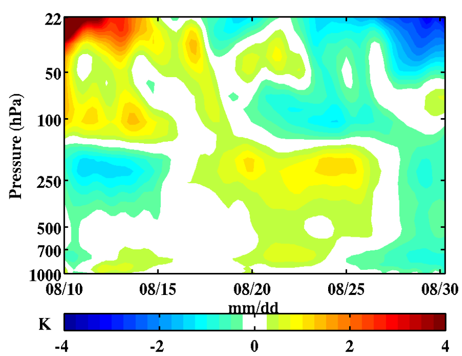
Thus, modifications have been developed to improve the RTTM scheme's treatment of buffer layer conditions and its calculations of longwave fluxes. The following changes to the scheme have been made and are tested in the experiments described below.

– Extra levels are added above the model top. Several levels are added in the RRTM layer from the model top to the TOA to serve as a buffer. The layer spacing is Δp= 2.5 hPa. Note that these levels only occur within the RRTM longwave package for its calculations and do not add to the number of WRF η-levels. Thus, the additional computation is not large, and the overall run time is not increased significantly.

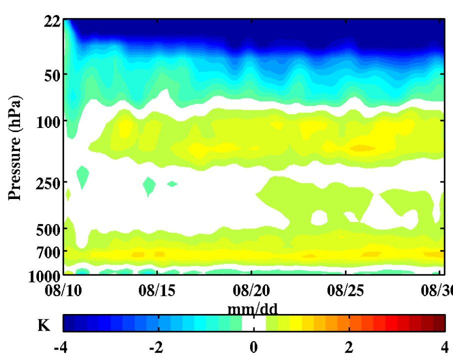
– Temperatures in the new levels are interpolated from an average observed temperature curve reflecting conditions in the stratosphere.

– The water vapor mixing ratio is set to a value of 1×10^{-6} kg/kg in buffer layers.

Figure 2(a) shows the additional levels and temperatures for calculation in the scheme. In this example, the new levels are at 2.5 hPa increments from the model top to the TOA. For the AMPS testing configuration (described below), this is from 10 hPa to the TOA. The temperatures at the additional levels are derived from a temperature profile composited from the observed profiles of different regions. Figure 2(b) shows the profiles for various regions (tropical, mid-latitude winter, mid-latitude summer, and sub-Arctic winter) (Ellingson et al. 1991) and the resultant average curve. The average is used for this version of the modifications to make the revised scheme applicable globally, instead of trying to produce regionally-tuned versions. The temperatures applied at the extra levels are based on the average profile and the difference from the average profile seen at the model top. The differences in the temperature at the various buffer levels can be seen in Fig. 2(a), which shows the temperature curve applied (solid) with the one that would have been used following an isothermal assumption (dashed).

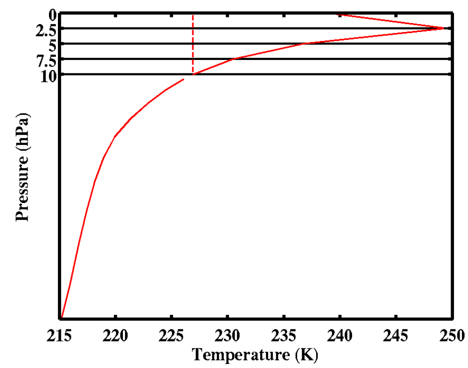


1(a)

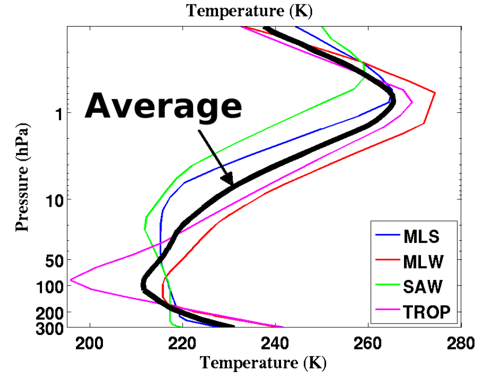


1(b)

Fig. 1: (a) WRF domain-averaged hr-6 θ perturbation (K; temporal mean removed at each level) from surface to model top for 10–30 August 2009 over the Atlantic Basin hurricane domain. (b) Domain-averaged WRF–GFS analysis θ (K) for 10–30 August 2009 over Atlantic Basin domain.



2(a)



2(b)

Fig. 2: Extra levels in modified RRTM longwave scheme and average temperature profile used. (a) Schematic of extra computational levels used in RRTM longwave scheme. Vertical spacing of levels is 2.5 hpa. Solid curve= Temperatures used at extra levels. Dashed curve= Temperatures reflecting original isothermal layer temperature assumption. (b) Regional observed temperature profiles and averaged profile used in modified scheme. MLS= mid-latitude summer; MLW= mid-latitude winter; TROP= tropical; SAW= sub-Arctic winter.

b. Model Configuration

WRF is tested in AMPS for summer and winter periods to diagnose the potential upper-level cooling and temperature biases. Shown in Fig. 3, the grid configuration features the two coarsest AMPS grids, with 45-km and 15-km horizontal spacings. The test periods are January 1–7, 2010 (austral summer) and July 1–7, 2009 (austral winter). Model heating/cooling rates for longwave and shortwave processes are compared against observed profiles for different global regions.

<u>AMPS Testing Setup</u>

2 domains: 45 km, 15 km
Vertical levels: 44 levels
Model top: 10 mb

IC/BC: GFS analysis/GFS forecast BCs
Simulation lengths: 6 hrs
Periods: January 2010 (summer), July 2009 (winter)
Radiation: RRTM longwave, Goddard shortwave

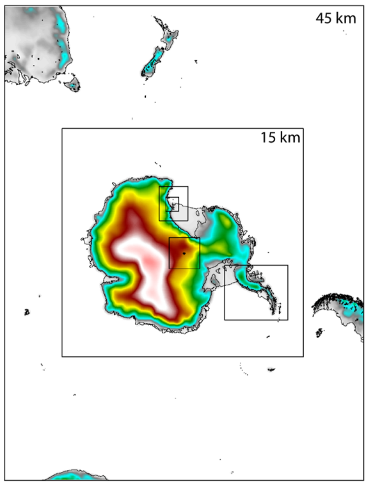


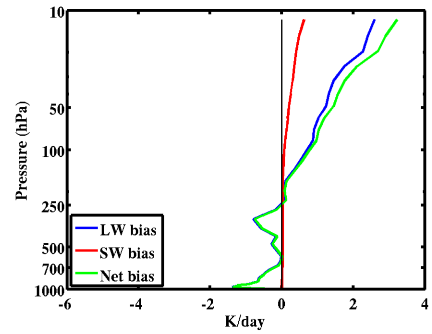
Fig. 3: AMPS WRF domains used for experiments. Outer grid: 45-km spacing. Inner grid: 15-km spacing. Grid outlines shown within 15-km grid are not run for the experiments.

3. RESULTS

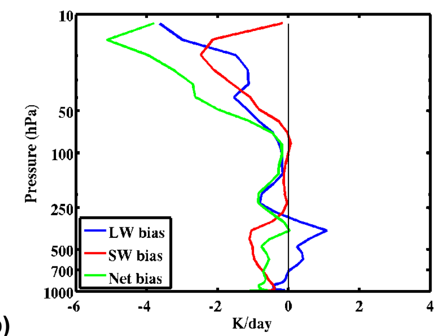
WRF is first run with the AMPS grids with the unmodified RRTM scheme to assess model behavior near the model top. Figures 4(a) and 4(b) show the heating rate biases in the winter and summer test periods. The heating rates are composited over the 15-km inner domain. Here, the comparison is between model heating profiles derived from averaged WRF 6-hr forecasts and heating profiles (not shown) for the sub-Arctic regions for winter and summer. The sub-Arctic profiles are used as the closest available that may be comparable to the southern high-latitude areas modeled.

The winter results show a net positive daily heating bias overall, with this being primarily due to the longwave component. Here this most likely reflects that the conditions in the southern polar vortex would be colder than those reflected in sub-Arctic winter heating/cooling profiles. As radiative emission (and cooling) is proportional to temperature, the longwave cooling over the colder (aloft) region covered by the AMPS grids would be less.

The summer results show a cooling bias above 100 hPa. The longwave contribution is maximized at the model top. The shortwave bias increases, too, above 100 hPa, but decreases at the model top level. Overall, WRF has net cooling aloft, as had been seen in the Atlantic Basin tests. In summary, WRF shows an upper-level/model top cooling bias in the Antarctic in the warm season, although the errors are not as large as in the mid-latitudes.



4(a)

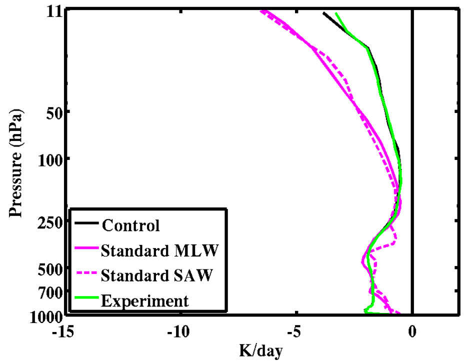


4(b)

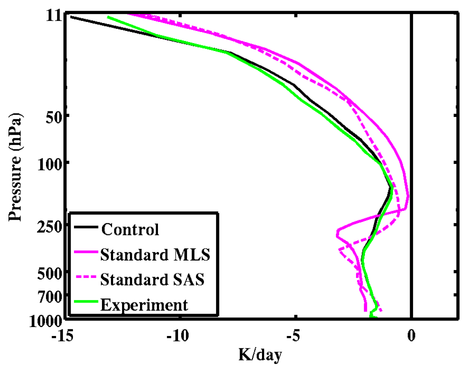
Fig. 4: AMPS WRF heating rate biases. Profiles of differences in heating rates from longwave (LW), shortwave (SW), and net (LW + SW) processes. (a) AMPS–SAW (Sub-Arctic Winter). (b) AMPS–SAS (Sub-Arctic Summer).

The experiment consists of runs the modified RRTM scheme in AMPS for the given seasons. Figure 5 compares heating rates for the control run (original RRTM) with the experiment (modified RRTM), along with standard profiles for mid-latitude and sub-Arctic regions. For the winter period (Fig. 5(a)) the control and experiment are largely similar: both have a bias toward warming (less cooling) (compared to the observations) at the model top. While both do have lower cooling rates than the given observations, it is noted that the standard profiles compared against are for the mid-latitudes and sub-Arctic, not for Antarctica.

For summer, both the control and the experiment show biased cooling above 75 hPa compared to the observations. However, the experiment shows decreased biases right at the model top. The model top bias reduction is 2 K/d.



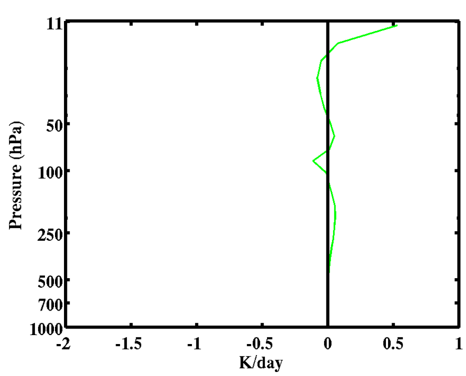
5(a)



5(b)

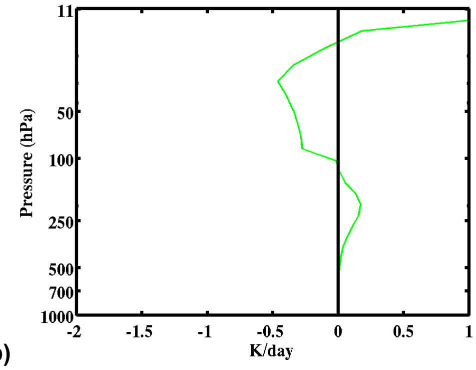
Fig. 5: Observed v. AMPS test heating rates. Control= Original RRTM scheme. Experiment= Modified RRTM scheme. (a) Winter (July 2009). MLW= Mid-Latitude Winter; SAW= Sub-Arctic Winter. (b) Summer (January 2010). MLS= Mid-Latitude Summer; SAS= Sub-Arctic Summer.

Figure 6 isolates the experiment differences. For the winter period (Fig. 6(a)) only slight differences are seen, except for the top model level, where the difference in rates is positive (+.5 K/d) (modified scheme cooling less than original). For summer (Fig. 6(b)), the experiment shows more cooling than the control below the model top (.5 K/d), but significantly less at the model top 2 K/d[1].



6(a)

[1] Note that scale in plot is capped at 1 K/d. Actual differences values reach 2 K/d at the model top level.

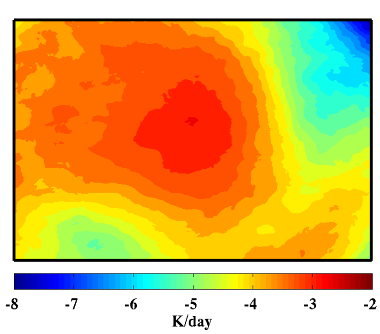


6(b)

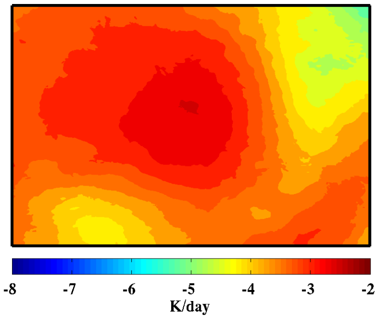
Fig. 6: Heating rate differences (K/day): Experiment–Control. (a) Winter (July 2009). (b) Summer (January 2010).

Figures 7 and 8 show the heating/cooling rates at the model top (top ½-η level) for the experiments. In winter, ∂θ/∂t from LW processes is negative in both runs, with the control showing greater cooling (Figs. 7(a), (b)). In these plots (including 7(a),(b),(c); 8(a),(b),(c)) the heating rates for LW processes are calculated as instantaneous rates averaged at hour 6 of the forecasts for the test periods. The change from the modified scheme averages about .5 K/d over the domain (Fig. 7(c)). The overall potential temperature change rate difference, ∂θ/∂t_total, averages .1-.2 k/d (Fig. 7(d)). Here, these ∂θ/∂t_total values reflect the rates of change as calculated over hrs 0–6 of the forecasts in the test periods.

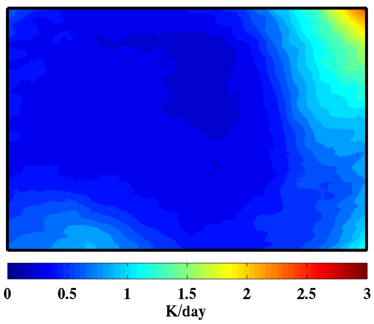
The summer differences are more substantial (Figs. 8(a),(b)). Over the continent, the original scheme rates are approximately -15.5 K/d, while the modified scheme rates are approximately -13.5 K/d. The LW cooling rates are 1.5–2 K/d less with the modified scheme (Fig. 8(c)). And, the overall potential temperature cooling rates at the model top are decreased up to .5 K/d over the continent (Fig. 8(d)). This can translate to differences in model top temperatures of about 2.5 K during the 5-day AMPS forecasts. Note, too, that the erroneous LW cooling rates seen as points in Fig. 8(a) and in the difference plot in 8(c), which reflect biases in radiosonde RH observations, are also corrected by the modifications.



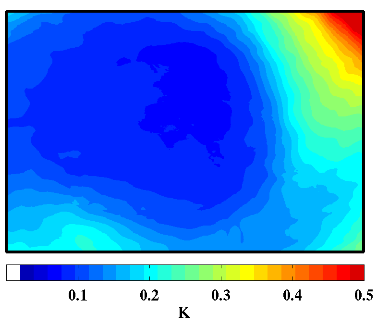
7(a)



7(b)

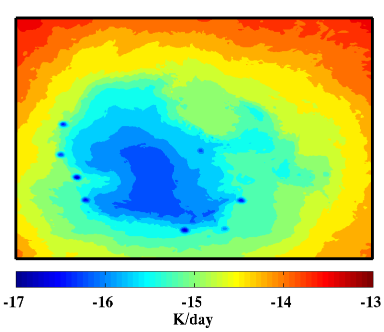


7(c)

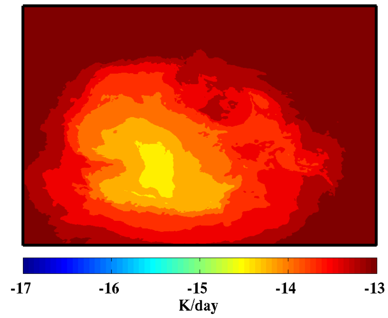


7(d)

Fig. 7: Heating rates from LW and total in AMPS WRF tests for winter (July 2010) period. $\partial\theta/\partial t$ LW rates ((a), (b), (c)) based on instantaneous values for forecasts at hr 6. Total $\partial\theta/\partial t$ rates ((d)) based on the average of the differences in the rates calculated from the change over hrs 0–6 in the forecasts in the given test period. (a) Control $\partial\theta/\partial t_{LW}$. (b) Experiment $\partial\theta/\partial t_{LW}$. (c) Experiment–Control $\partial\theta/\partial t_{LW}$. (d) Experiment–Control $\partial\theta/\partial t_{Total}$.



8(a)



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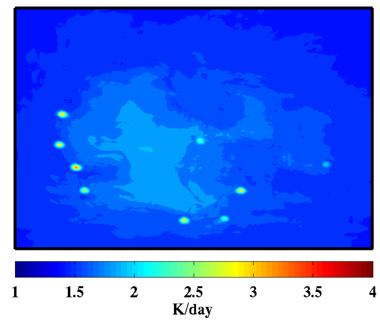
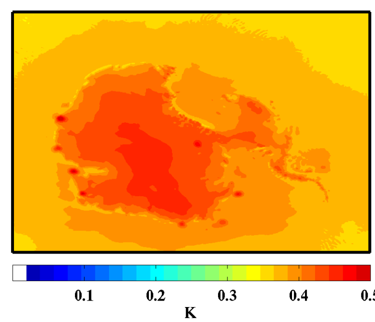


8(c)



8(d)

Fig. 8: Heating rates from LW and total in AMPS WRF tests for summer (January 2010) period. $\partial\theta/\partial t$ LW rates ((a), (b), (c)) based on instantaneous values for forecasts at hr 6. Total $\partial\theta/\partial t$ rates ((d)) based on the average of the differences in the rates calculated from the change over hrs 0–6 in the forecasts in the given test period. (a) Control $\partial\theta/\partial t_{LW}$. (b) Experiment $\partial\theta/\partial t_{LW}$. (c) Experiment–Control $\partial\theta/\partial t_{LW}$. (d) Experiment–Control $\partial\theta/\partial t_{Total}$.

5. SUMMARY AND CONCLUSIONS

Previous investigations by one of the authors had uncovered biases in WRF radiative heating rates near the model's top, leading to excessive cooling at upper levels. The problem stems from the RRTM longwave scheme's approach to calculating radiative processes at the model top and of assumptions of the temperature and moisture applied in the stratosphere. This problem is being investigated in the context of the Antarctic Mesoscale Prediction System (AMPS), a real-time implementation of WRF over Antarctica.

Experiments with a modified RRTM longwave package running in WRF in AMPS have been conducted. The RRTM modifications refine its computational buffer layer above the model top and implement more accurate profiles of temperature and moisture to the top of the atmosphere (TOA). The modifications reduce the excessive cooling in WRF for the given regions, with the impacts being greater in the summer. They also correct erroneous LW cooling that may result from biases in relative humidity values at high levels seen in some radiosonde data over Antarctica. The results indicate that the modified RRTM scheme will reduce upper-level temperature biases over the 5-day forecasts. Based on this study, the modified RRTM longwave package for WRF has been implemented in AMPS, and it is now running operationally.

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THE EFFECTS OF GRID NUDGING ON POLAR WRF FORECASTS IN ANTARCTICA

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1. INTRODUCTION

Nudging, or *Newtonian Relaxation*, is a method of data assimilation originally designed for dynamic initialization of numerical weather prediction models (Hoke and Anthes 1976) that forces a numerical solution towards observations. This technique is less complex and computationally demanding than full four-dimensional data assimilation. It is also used to improve the accuracy of forecasts during the nudging period (Stauffer and Seaman 1990). *Grid nudging* forces the solution to a gridded analysis point-by-point, and can be used to keep a long-term model simulation in line with the forcing dataset (Skamarock et al. 2008).

Grid nudging can therefore be an effective method to curtail model drift for extended simulations, where long-term forecasts can become unrealistic. Bromwich et al. (2009a) tested the effects of grid nudging on Polar WRF simulations for the Arctic. In comparing nudged and non-nudged extended forecasts simulations run in forecast mode for December 2007, the authors found that model performance (RMSD and correlation) began to significantly degrade after 3 days in the non-nudged extended simulations. Nudging improved the performance of extended simulations, especially when done for only the top few model levels.

This study presents similar comparisons of nudged and non-nudged 120-hour simulations against simulations run in forecast mode over Antarctica. It will be shown that grid nudging can improve the accuracy of 3-5 day operational forecasts in the high southern latitudes.

2. DATA AND METHODS

Polar WRF Version 3.1.1 is used for all simulations (Skamarock et al. 2008, Hines and Bromwich 2008, Bromwich et al. 2009b, Hines et al. 2010). A single domain is used with 331 x 313 gridpoints at 20 km grid spacing (identical to the previous AMPS domain setup). There are 35 vertical levels with the model top at 50 hPa, and vertical velocity damping in the top 8000 m. A 90 second timestep is used. Physics options include the WSM5 microphysics scheme, RRTMG shortwave and longwave radiation schemes, MYNN Level 2.5 PBL and surface layer schemes, the Noah land surface model, and the Grell-Devenyi cumulus parameterization scheme.

Three sets of simulations were run in this experiment. The first two sets, the *testing simulations*, were forced with NCEP GFS global 1.0° forecasts out to 120 hours. One set, named "NUDGE", was run with grid nudging every 6 hours through the duration of the forecast. Winds, temperature, and specific humidity are nudged for only the top 5 model vertical levels. Nudging involves an extra time tendency term in the solution for a given variable:

$$\frac{\partial \theta}{\partial t} = F(\theta) + G_\theta W_\theta (\hat{\theta}_0 - \theta)$$

where θ is a given variable, *F(θ)* is contributions from the normal forcing terms, G_θ is a time-scale parameter, W_θ is a weighting term, and $\hat{\theta}_0$ is the analysis field that the forecast is being nudged to. The time-scale parameter is typically set to the time scale of the slowest physical adjustment process in the model (Stauffer and Seaman 1990). A value of 3×10^{-4} s^{-1} is used here, corresponding to one hour, for all nudged variables. The second set of simulations, "NONUDGE", is identical to NUDGE except that grid nudging is turned off. The testing simulations are validated against Polar WRF simulations forced with NCEP FNL global 1.0° analyses for 48 hours, initialized every 24 hours. The setup for these simulations is otherwise identical to NONUDGE. All simulations feature lower boundary condition updates for SST using NOAA OI Daily 0.25° analyses (Reynolds et al. 2007) and for sea ice using 6-km resolution charts based on AMSR-E data from the University of Bremen (Spreen et al. 2008). Climatological values of sea ice thickness and snow thickness on sea ice are used, and taken from annual averages from the ASPeCT project (Worby et al. 2008). Terrain height is defined from the 200 m RAMP dataset (Liu et al. 2001).

Comparisons are done between each of the testing simulations and the validation simulation to determine the effect of nudging on forecast performance. For all simulations, the first 24 hours are discarded for model spin-up. Testing simulation forecasts are compared with

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validation simulations every 6 hours from 24-120 hours. Spatial plots and domain-averaged bias and RMSE are computed.

3. RESULTS

Here we present results from the average of six test runs, all initialized in September 2009 at 0000 UTC on the 5th, 10th, 15th, 20th, 25th, and 30th. Bias and RMSE values for surface pressure are averaged by forecast hour for these six test runs for both NUDGE and NONUDGE. Figures 1a and b show the average differences at 120 hours forecast compared to simulations initialized with FNL analyses every 24 hours for NUDGE and NONUDGE, respectively. While there are isolated regions of large positive and negative differences associated with misplacement of cyclones, forecasts for much of continental Antarctica are improved with nudging, as a positive bias in surface pressure is reduced.

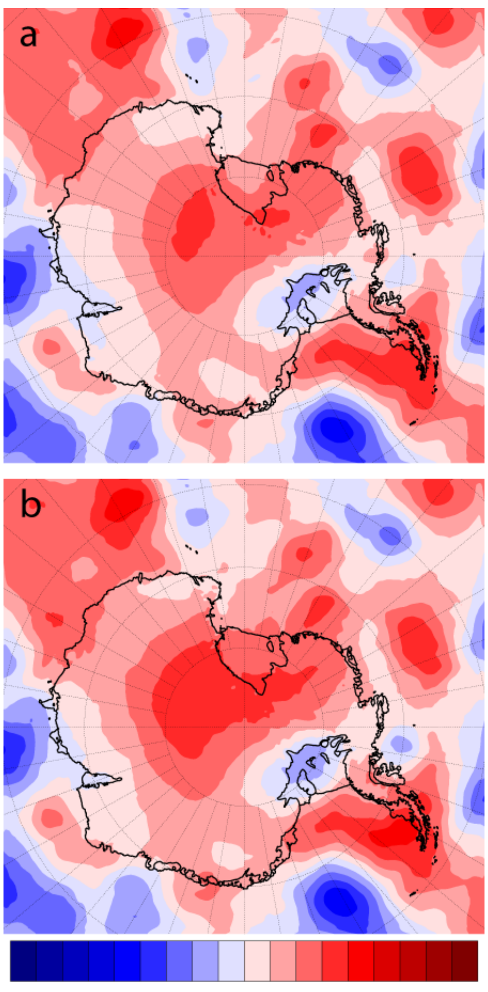

Figure 1. Bias (hPa) at 120 hours for (a) NUDGE and (b) NONUDGE compared to simulations forced with FNL in forecast mode.

To better gauge the magnitude of the differences between NUDGE and NONUDGE, Figs. 2a and b shows RMSE values at 120 hours, respectively. In both NUDGE and NONUDGE, there are isolated areas of large RMSE over the seas around Antarctica. These areas of large RMSE are generally displaced from areas of large bias in Figs. 1a and b, which implies random bias associated with the misplacement of cyclones. RMSE values are reduced over Antarctica with NUDGE, consistent with the reduction of bias in Fig. 1a and b.

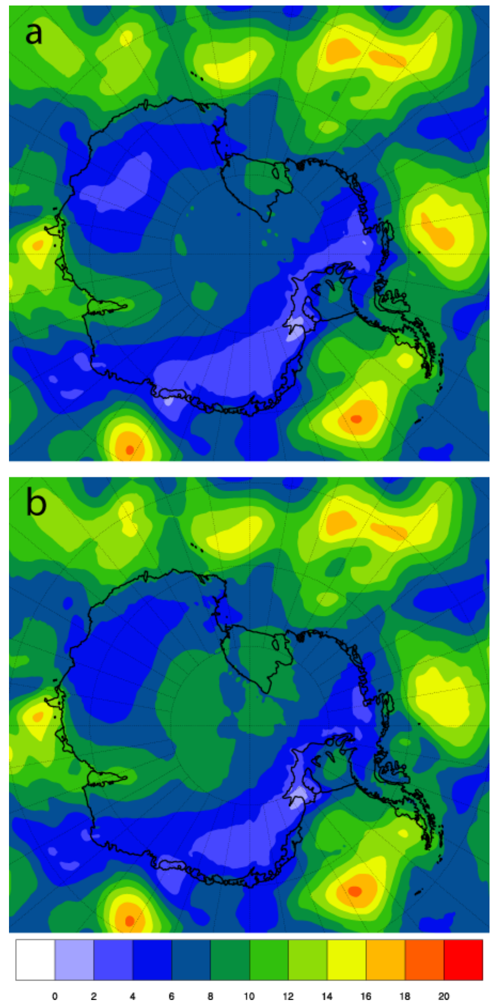

Figure 2. RMSE (hPa) at 120 hours for (a) NUDGE and (b) NONUDGE compared to simulations forced with FNL in forecast mode.

The difference between the RMSE values of NUDGE (Fig. 2a) and NONUDGE (Fig. 2b) are shown in Fig. 3. Negative (blue) values imply a reduced RMSE with NUDGE. This can be seen over almost all of Antarctica, particularly interior East Antarctica. Improvement can also be seen in the northern Ross Sea and extending to the west. Degradation of the forecast with NUDGE occurs over the Antarctic Peninsula and portions of the Bellingshausen Sea. This is associated with cyclone misplacement in GFS.

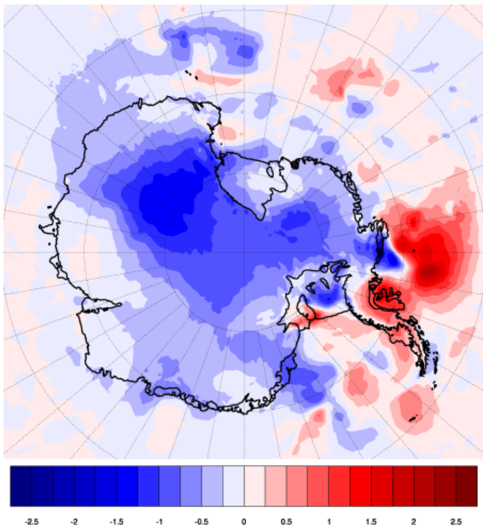

Figure 3. RMSE difference (NUDGE – NONUDGE) at 120 hours.

The evolution of biases and RMSE values for both NUDGE and NONUDGE with forecast hour, averaged over the entire computational grid, is shown in Figs. 4a and b. Averaged over the entire grid, the reduction of bias and RMSE with NUDGE is not very large. Biases for both NUDGE and NONUDGE are small and similar until after 72 hours, after which both steadily increase. Biases are reduced about 0.3 hPa by 120 hours in NUDGE compared to NONUDGE. RMSE values steadily increase from 24 hours to 120 hours forecast, with an improvement of 0.16 hPa at 120 hours.

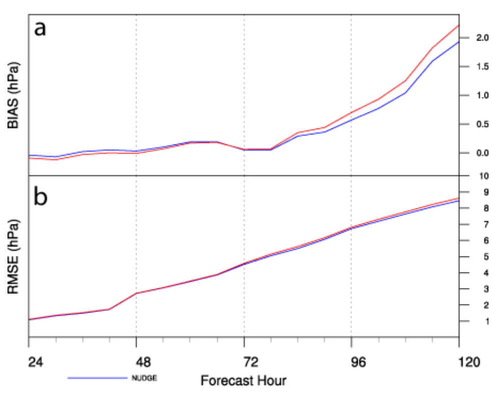

Figure 4. Evolution of (a) bias (hPa) and (b) RMSE (hPa) from 24 to 120 hours for NUDGE (blue) and NONUDGE (red).

4. CONCLUSIONS

Similar to the Arctic, benefits to long-term forecasts from the use of grid nudging in Polar WRF have been identified for Antarctica. Polar WRF experiments using nudging perform better than those without, compared to simulations forced by analyses. Forecast improvements are small for the grid average, but are more pronounced over the Ross Sea and continental Antarctica. Similar results can be shown for other variables and over a full field season. The findings of this experiment indicate that grid nudging would likely improve long-term forecasts over Antarctica in operational models like AMPS, providing extended lead time for forecasters and other operational personnel.

ACKNOWLEDGMENTS

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AN ANALYSIS OF THE LOW-LEVEL WIND FIELD OVER THE ROSS ICE SHELF, ANTARCTICA

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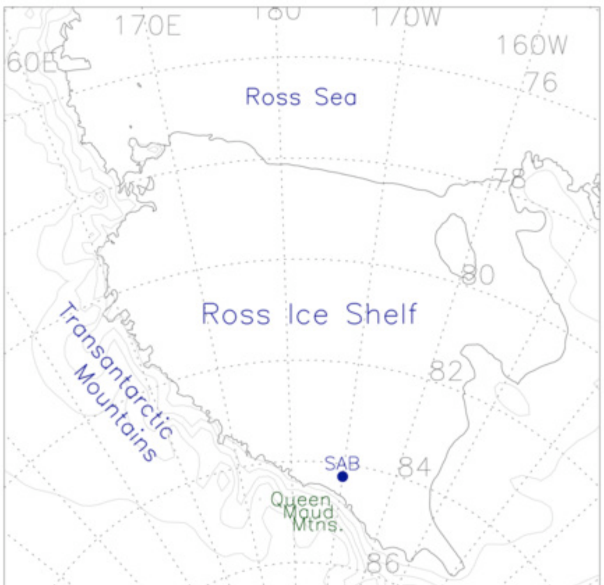

Figure 1: A map of the Ross Ice Shelf. The Sabrina AWS is shown and labeled as "SAB".

1 INTRODUCTION

There are many factors that influence the low-level wind field over the Ross Ice Shelf (RIS), Antarctica. For instance, katabatic drainage, synoptic scale and mesoscale cyclones, barrier winds and complex topography are just a few of the features that influence the low-level wind field. The interaction of two or more of these features can result in areas of very strong wind speeds. For instance, the wind speeds at the Sabrina automated weather station (AWS), located to the north of the Queen Maud Mountain (see Figure 1), are influenced by katabatic drainage out of both East and West Antarctica, the mesoscale cyclones that develop in the transition area between Siple Coast and the RIS, and the complex topography of the Queen Maud Mountains. This region experiences average yearly wind speeds of 7 ms^{-1} and high wind events that produce wind speeds up to 27 ms^{-1}. Therefore, studying the atmospheric dynamics in the region of the Sabrina AWS provides an opportunity to better understand the complex atmospheric dynamics that are associated with the low-level wind field over the RIS.

Prior studies have investigated the complex atmospheric dynamics in the region to the north of the Queen Maud Mountains. For instance, *Seefeldt and Cassano* [2008] identified the presence of a low-level jet that travels along the Transantarctic Mountains in this area. The study found that the Queen Maud Mountains protrude into the flow of the low-level jet, causing an accelerated tip jet over the protruding mountains. Additionally, *Steinhoff et al.* [2009] studied the dynamics of the flow around the Queen Maud Mountains. This study identified the flow around the Queen Maud Mountains as a "knob" flow, arguing that the flow is primarily around, not over, the protrusion of the Queen Maud Mountains. As described by *Dickey* [1961] and *Kozo and Robe* [1986], a "knob" flow, or corner effect, occurs when stably stratified airflow is forced around an orographic protrusion. Each of these studies mention that additional analysis of the dynamics in the region is necessary in order to fully understand the mechanisms responsible for strong winds in the region. The goal of the research for this presentation is to build on the findings of these studies and to determine the presence and magnitude of the specific forcing mechanisms that are associated with the strong wind speeds that occur in the region of the Queen Maud Mountains.

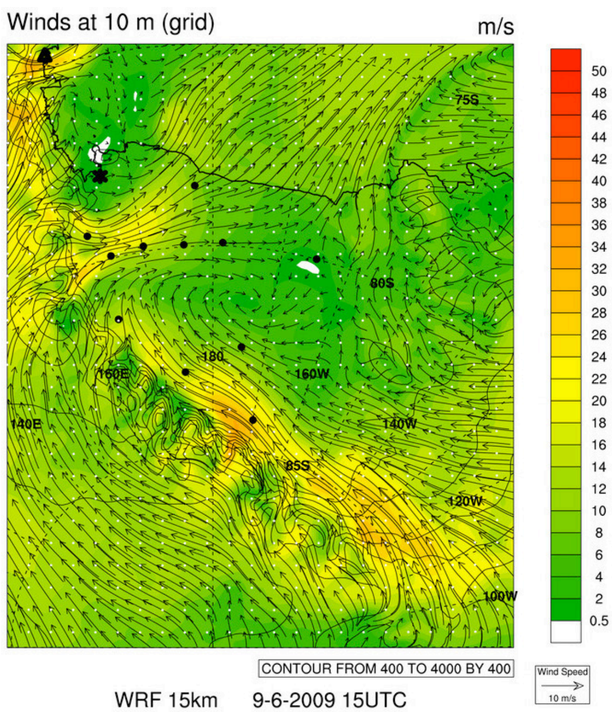

Figure 2: Spatial plot of AMPS 10-meter winds for 15:00 UTC on September 6, 2009. The black dots represent various AWS locations.

2 CASE STUDY

In order to understand the specific forcing mechanisms associated with the strong wind speed at the Sabrina AWS, a case study of a high wind event was used. The high wind event occurred during the timeframe of September 6, 2009 through September 8, 2009 (Figure 2 shows the 10-meter winds at 15:00 UTC on September 6, 2009). During this time, the Sabrina AWS took observations of wind speed, wind direction, temperature and pressure at 10-minute intervals. These observations have been compared to output from the Antarctic Mesoscale Prediction System (AMPS) in order to understand the performance of the model in this region during the timeframe of the case study. The results indicate that the model output for the 12-21 hour and 24-33hr forecasts were able to accurately capture the magnitude and timing of the wind speed increase and subsequent decrease during the high wind event. Additionally, the model was able to predict the surface temperature, pressure and wind direction with reasonable accuracy. Due to the ability of AMPS to capture the high wind event at Sabrina AWS, the model was used to analyze the atmospheric dynamics of the surrounding region for the case study. Preliminary results from this analysis and future steps that will be taken to determine the forcing mechanisms that cause the strong wind speeds in this region will be presented.

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Short-term forecast performance of Polar WRF in the Antarctic

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1.0 Introduction

Contemporary forecast models primarily developed for the mid latitudes in the Northern Hemisphere have demonstrated significant skill in the Arctic (e.g. Wilson 2010). Their forecast performance in Antarctica is now rigorously being examined. At present they provide the only detailed four dimensional structure of the Antarctic atmosphere and have become invaluable tools in providing forecasts needed in support of Antarctic operational activities. In the 2009-2010 field season, 400 LC-130 missions were conducted by USAF on the continent (NSF 2010). These flights would normally be halted for safety reasons under unfavorable weather as well as during the extremely cold winter darkness. Accurate forecasts have played a critical role in previous evacuations from the continent and will continue to do so as the number of tourist visits increase.

The Antarctic Mesoscale Prediction System (AMPS) project previously used Polar MM5 until June 2008 to make the forecasts but is currently using the new mesoscale model (Polar WRF). The model is continuously becoming very sophisticated with new changes every year. Since Polar WRF has seen extensive tests in the Arctic and is rapidly evolving, it is very important to periodically assess the skill of the model as the safety of personnel and operations in Antarctica depend on the accuracy of its forecasts.

2.0 Methods

Building on the success with Polar MM5 in the Arctic, the Polar Meteorology group at The Ohio State University developed Polar WRF (Hines and Bromwich 2008). As with Polar MM5, Polar WRF has seen extensive tests almost exclusively over a range of Arctic surfaces (Bromwich et al 2009). On the other hand a detailed evaluation of model performance in the Antarctic is nearing completion. This study uses the polar-optimized version of WRF3.0.1.1 (Skamarock et al. 2005) which has shown skill in the Arctic. A single domain (Fig. 1) centered at the South Pole (90°S, 0°E) and divided into 120x120 latitude/longitude grid at 60 km resolution in the horizontal with 39 eta levels in the vertical is used. The model is re-initialized every 48 hours. The first 24 hours allow the model to spin up and the last 24 hours from each forecast are strung together for analysis. Radarsat Antarctic Mapping Project Digital Elevation Model (RAMP-DEM: Liu et al 2001) at 200m is used to specify model surface elevation.

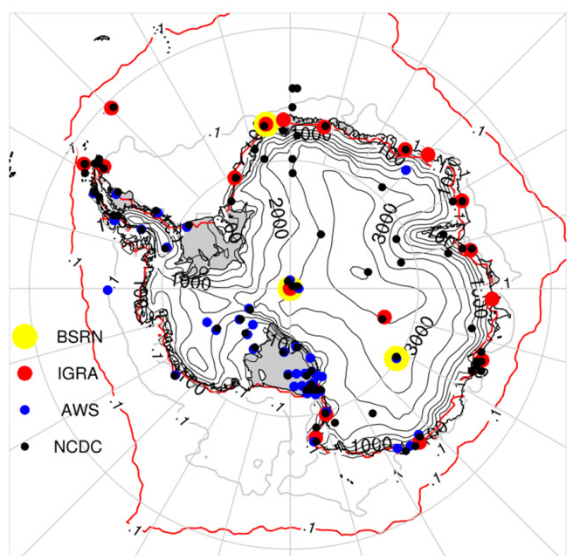

Fig. 1: Region of study showing the terrain elevation and location of stations. Red contour marks 0.1 fractional sea ice and shows the winter extent.

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Sea ice concentrations are derived from measurements of the Special Sensor Microwave Imagers (SMM/I) on board the Defense Meteorological Satellite Program (DMSP) polar orbiters available from the National Snow Ice Data Center (NSIDC: Comiso 1999). The GFS lateral boundary conditions and global real time SSTs (RTG) are taken from the National Centers for Environmental Prediction (NCEP).

The permanent ice cover produces a very stable atmosphere over Antarctica and thus the temperature at the lower boundary (ice temperature) is very close to that of the surface air. Reconstructed mean surface air temperature (Monaghan et al. 2008) is therefore used to provide the ice temperatures at depth.

Some similarities exist between the ice sheet environments in Antarctica and those in Greenland where the model has shown significant skill (Hines and Bromwich 2008). Antarctica lacks the dense data network needed to provide Polar WRF with an accurate representation of the large scale circulation. The large expanse of elevated permanent land ice likely degrades the model skill. For skillful forecasts the model must accurately represent the Antarctic katabatic winds (Bromwich and Liu 1996, Parish and Bromwich 1998, Cassano and Parish 2000) that are governed by the balance of gravity, thermal stability and synoptic forcing.

3.0 Data

Until recently, inadequate observations made it difficult to verify forecasts routinely provided by the AMPS. This is in part due to the complex terrain and extreme climatic conditions on the continent. Efforts toward large-scale meteorological instrumentation of the Antarctic continent utilizing automatic weather stations (AWS) started in 1980 (Stearns and Wendler 1988). From 37 AWS in 1987 there are now more than 100 units deployed by several countries including the United States, Australia, United Kingdom, France and China. However not all the units provide high quality measurements. Figure 1 shows stations that meet our quality criteria, less than half of the AWS deployed. Surface observations have been augmented using NCDC and Baseline radiation network (BSRN) archives (Fig. 1). The Integrated Radiosonde Archive (IGRA: Durre and Yin 2008) at NCEP provides upper air observations for this study. The model is verified using forecasts for 2007.

4.0 Results

Preliminary results show that Polar WRF has a skill level in Antarctica that is comparable to that previously found in the Arctic. Table 1 show an overall cold bias in forecast surface air temperatures but the variability in both July and January is captured with correlation of ~0.6. The verification at the surface is not complete as each station needs careful consideration to correct for model surface type inconsistency, elevation errors and also to delineate stations that represent synoptic rather than local scale behavior.

Table 1: Surface temperature statistics. The number of stations used is shown in parenthesis after the month.

	Bias	RMSD	Corr
January (18)	-2.1	3.4	0.61
July (25)	-1.1	3.8	0.64

Table 2 summarizes the upper air annual statistics from the 9 IGRA stations used. On the annual time scale shown, the temperature biases are much smaller than those at the surface (seasonal biases are comparable). Except at 300 hPa the wind speeds in the model are slightly stronger than observed. The difficulty of simulating wind speed is evident in the lower correlations and higher root mean square differences.

Table 2: Temperature and wind speed statistics (RMSD-root mean square difference; CORR-correlation) during 2007.

	Temperature			**Wind Speed**		
	BIAS	**RMSD**	**CORR**	**BIAS**	**RMSD**	**CORR**
850	1.04	2.57	**0.94**	1.42	5.44	**0.69**
700	0.87	2.46	**0.92**	1.27	4.78	**0.68**
500	0.03	1.77	**0.96**	0.51	4.95	**0.77**
400	0.07	1.7	**0.88**	0.38	5.93	**0.77**
300	0.9	2.01	**0.65**	-0.24	6.5	**0.80**
250	0.76	2.28	**0.86**	0.04	5.48	**0.83**
200	0.04	1.96	**0.93**	0.45	4.19	**0.86**

The variability and amplitude of the downwelling longwave radiation which is responsible for surface heating during the long Antarctic winters is forecast well (Fig. 2). But the Model allows excessive downwelling shortwave (~40 Wm^{-2}) at the surface during the Austral summer (Fig. 3).

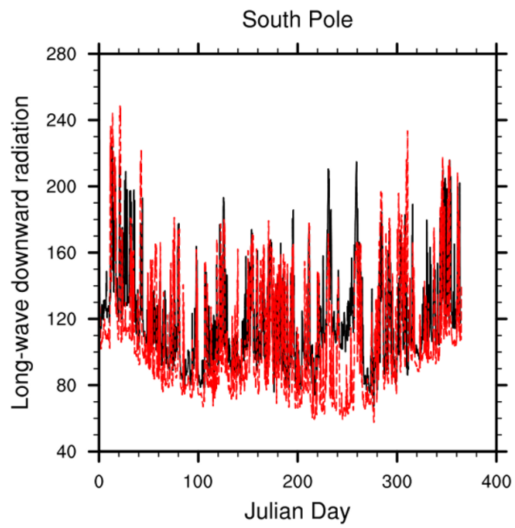

Fig.2: Downwelling longwave radiation Wm^{-2} at the South Pole (red model, black observed).

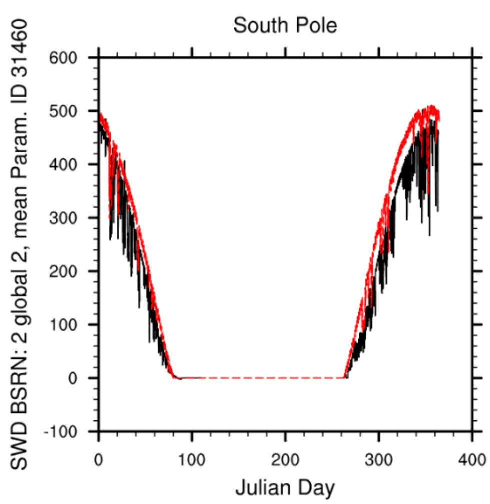

Fig.3: Downwelling shortwave radiation Wm^{-2} at the South Pole (red model, black observed).

The forecast variability of the downwelling shortwave is also smaller than the observed particularly at the South Pole but is evident at both Neumayer and Dome C. The excess shortwave appears in the hours following the local noon (Fig. 4).

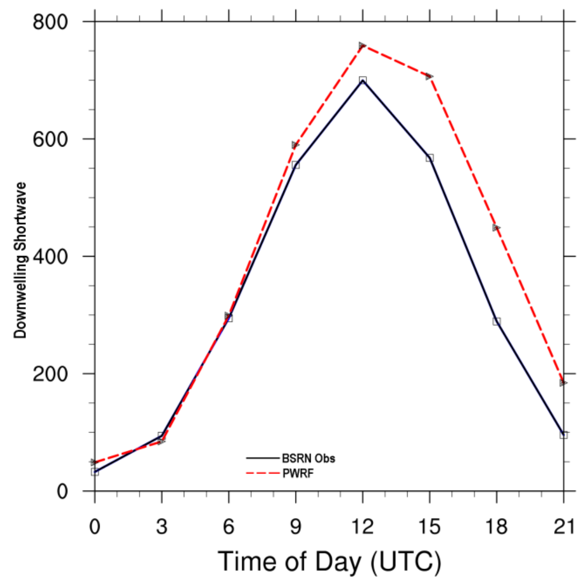

Fig. 4: Diurnal cycle of downwelling shortwave (Wm^{-2}) at Neumayer.

Acknowledgments

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Developments within the World Meteorological Organization concerning Polar Observations, Research and Services

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1.0 Introduction

The Antarctic Meteorological Observation, Modeling, and Forecasting Workshop (AMOMFW) forums, and the World Meteorological Organization's (WMO) Executive Council Panel of Experts on Polar Observations, Research and Services (EC-PORS) share common goals for Antarctic meteorological and related sciences. Here we explore some of these goals, by bringing to the attention of AMOMFW participants an overview of the work of EC-PORS.

2.0 Arctic and Antarctic combine in 'WMO-space'

2.1 International Polar Year 'steers' WMO

The International Polar Year 2007–2008 (IPY) produced many outcomes, one of which was a decision by the 15th Congress of WMO to subsume the pre-existing WMO Executive Council Working Group on Antarctic Meteorology into a group which focussed relevant outcomes in the polar regions of *both* hemispheres — this new group is EC–PORS.

2.2 EC–PORS structure

Eighteen of the relevant WMO Member states nominated a group of experts to participate in EC–PORS, including representation from the European Space Agency and the International Arctic Social Sciences Association. Countries/Agencies directly represented on EC-PORS as at October 2009 were (WMO, 2010a): Members include;

Argentina, Australia, Canada, Chile, China, Finland, France, Germany, Iceland, Italy, New Zealand, Norway, Russian Federation, South Africa, United Kingdom of Great Britain and Northern Ireland and the United States of America. Also, the European Space Agency is represented via The Netherlands and the International Arctic Social Sciences Association is represented via Switzerland.

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2.3 EC–PORS *modus operandi*

EC–PORS is in its formative stages but is making excellent progress towards achieving its goals and while fine tuning its Terms of Reference (WMO, 2010b). The first session of EC–PORS was held in Ottawa, Canada, 13–15 October 2009. An 'Executive Summary', and a 'Final Report' of the outcomes of this meeting is available from WMO, 2010c.

The second session of EC–PORS will be in Hobart 18–20 October 2010. In the period between these sessions the core activities of the panel has been divided into three 'Frameworks': Services; Observations; and Research as outlined in the following section. A small team of Antarctic specialists continues to address matters related to telecommunications and monitoring networks given the unique nature of Antarctic governance.

3.0 Outcomes sought from EC-PORS

3.1 Services drive the work of EC-PORS

"Services' are the driver of what EC–PORS aims to achieve. For example, are Polar-related needs of the Global Maritime Distress Safety System (GMDSS) being met? In this regard, two of the gaps noted were the lack of a comprehensive sea-ice monitoring and prediction for the Southern Ocean; and a lack of robust satellite communications coverage over the entire Arctic. And so there is a "Services Framework" for which a small sub-team is aiming to:

- complete a high-level, standardized survey of products and services currently available in the polar regions
- collect requirements through members' interaction with user and customer groups

- assess current capabilities against user requirements to determine unmet needs/gaps
- examine strategies to fill gaps.

3.2 Observations support Services

The "Observations Framework" within EC–PORS has activities which:

- includes observations from research and observational networks, satellite, in-situ and new technologies
- monitors effectiveness of basic observing system, and provides feedback
- supports standardization of observing practices for Polar Regions

Two key tasks addressed under this framework will be:

- re-establishing a Space Task Group, with a new mandate, in post-IPY (i.e. after June 2010).
- develop proposals for a Global Cryosphere Watch (GCW) under the auspices of WMO.

3.3 Research supports Services & needs/supports Observations

It is almost axiomatic that research and development underpins progress in service delivery in the 21st Century. A key focus for the EC–PORS' "Research Framework" is to encourage the transfer of research into operations/services while encouraging appropriate feedback/interaction from the observations/services areas. For example, what observations can the real-time National Observing Systems provide to support research? Conversely, how can research assist in optimizing the real-time networks?

A vision for EC–PORS is that there be a 'Polar Prediction System' that delivers service-focused Numerical Weather Products (NWP) tuned for both polar regions. To this end EC–PORS welcomes the WMO-Commission for Atmospheric Sciences (WMO-CAS) initiative to develop a THORPEX Polar Prediction Research Project, and hold a related workshop in Norway 6–8 October 2010 (WMO, 2010e). It is hoped that co-author Adams will attend this workshop, then report first-hand to the EC-PORS October 2010 meeting in Hobart.

4.0 Synergies/Opportunities

The EC–PORS group recognizes that there is a wide range of groups, agencies, commissions etc that (i) contribute to the welfare of people operating in both polar areas, and/or (ii) seek to assess the impact of polar regions on the global climate. As a result, there is a strong focus within EC-PORS in maintaining engagement not only within the WMO system but with the broader global services, operations, and research communities.

A particular 'project' that the EC-PORS group is exploring on behalf of WMO is to further develop the concept of an International Polar Decade (IPD) during which multi-disciplinary and multi-agency efforts would combine to better address Polar issues. Where this might lead may well be determined by considerations at WMO Congress in 2011, but the IPD is unlikely to start before the middle of the current decade.

5.0 Conclusion

It is clear that, in the Antarctic context, the synergies between the short to medium-term ambitions of the AMOMFW forums and EC-PORS are closely aligned, and it would seem advantageous to both groups that strong inter–group linkages be developed.

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Severe turbulence affecting helicopter operations over the SØrsdal Glacier south of Davis Station. (poster)

Dr. Neil Adams*

June 1, 2010

1 Introduction

On 31 December 2009 at around 0500 UTC two helicopters travelling from Davis Station to the Rauer Islands encountered strong vertical velocities with rapid loss of altitude over the SØrsdal Glacier. At the time Davis Station experienced only a light and variable wind with little in the way of a synoptic scale pressure gradient over the area. However, a 55 ms^{-1} southerly jet was observed over Davis at around 8300 m from the 0000 UTC radiosonde flight on that day. The poster provides an analysis of the situation and makes the argument that the severe turbulence was in response to a hydraulic jump, typically situated well inland on the Antarctic plateau, being advected westward out over the SØrsdal Glacier in response to the developing upper level southerly Jet.

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Studies of Antarctic Precipitation Statistics

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LGGE, France

Climate models predict a significant increase of Antarctic precipitation with global warming, with a negative contribution to sea-level. Direct observation of precipitation on the field is very difficult in Antarctica, and there are very few such observations available. Accumulation, i.e. surface mass balance that can be evaluated using glaciological rather than meteorological methods, is only a first order proxy. Even for accumulation, there are very few observations that can characterize the variability at the time scale of the precipitation events. However, detecting precipitation events and their statistics may be significantly more accessible than measuring quantities and their variability. We show that different climate models simulate significantly different statistics of precipitation events (e.g. number of events per year) over Antarctica. We show that preliminary observations of precipitation events on the field, using disdrometers and ultra-sonic snow gauges, only partially agree with the models. While satellite remote sensing of Antarctic precipitation quantities is less than convincing, detection of precipitation events may be possible, thus offering a large scale sensitive constraint on models ability to simulate and predict Antarctic precipitation.

The CONCORDIASI Campaign

Aurélie Bouchard [1], Florence Rabier [2], Vincent Guidard[2], Eric Brun [2], Fatima Karbou [2], Olivier Traulle[2], Alexis Doerenbecher[2], Christophe Genthon[3], Delphine Six[3]

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In the framework of the International Polar year, the Concordiasi field campaign, part of the IPY-THORPEX cluster, takes place in Antarctica in order to validate satellite data assimilation in Numerical Weather Prediction models at high latitudes. Our focus of interest is the hyperspectral IASI sensor onboard the European MetOp platform. The campaign is made up of three parts, each one during austral spring (2008, 2009, 2010). In spring 2008 and 2009, additional sondes have been launched at DomeC and Dumont d'Urville, measuring the atmospheric profiles together with surface parameters, synchronised with the MetOp track over these stations. Next austral spring, stratospheric balloons will bring complementary information on satellite data assimilation but also on chemical and stratospheric dynamical processes.

Difficulties are associated with data assimilation over high latitudes, mainly due to the estimation of surface parameters and to the cloud detection, important for infrared measurements. To improve our understanding of such parameters, the radiosoundings obtained after the first two parts of the campaign are compared to the outputs of the meteorological model of Meteo-France, especially adjusted for Antarctica. The model has been tuned in order to increase the resolution for these latitudes. Moreover, improvements of the calculation of microwave emissivity and the assimilation of infrared satellite data over high latitudes have shown positive results, as they resulted in a better fit of the model to radiosoundings.

After these first positive results obtained in this context, work on cloud detection and retrieval of surface properties has been continued to further improve the assimilation. In particular, over the Concordia station, the available in-situ observations from the campaign helped to evaluate the satellite data bias correction and to calibrate a better use of satellite data using more accurate surface information. In parallel, work is being performed on surface properties simulation.

Extremely Stable Boundary Layer on the Antarctic Plateau

Christophe Genthon[1], Mike Town[1], Delphine Six[1], Vincent Favier[1], Laura Genoni[2], Cyprien Pouzenc[3] and Andrea Pellegrini[4]

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[2] DiSGAM, Italy
[3] SIRENE, France
[4] ENEA, Italy

Surface-based inversions are a major characteristic of polar meteorology. Meteorological models suggest that the steepest and most durable surface-based inversions occur in the austral winter on the Antarctic plateau. However, there are very few places were such inversions can be sampled with more details than sporadic fast-cruising balloon-borne radiosondes may provide. Meteorological instruments have been deployed along a 45-m tower at Dome C (74°06' S, 123°20' E, 3233 m a.s.l.) on the Antarctic plateau. Observations and comparisons with meteorological analyses have been recently published for the summer of 2008 (Genthon et al., J. Geoph. Res., doi:10.1029/2009JD012741). In the winter of 2009, the temperature inversions have locally reached extreme values of more than 2°C per meter (figure below). The winter data recorded along the tower will be presented along with comparisons with models and meteorological analyses, showing that the extreme Antarctic environment is a stringent test-bed of the robustness of atmospheric boundary layer parametrizations and thus of a major aspect of polar meteorology.

Polar WRF Simulations of the McMurdo Dry Valleys

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[3]Research Applications Laboratory, National Center for Atmospheric Research, Boulder, Colorado

The McMurdo Dry Valleys (MDVs) feature the largest ice-free region in Antarctica, extensive biological activity during the summer melt season, and a strong sensitivity to small climate fluctuations, perhaps being a bellwether of climate change. However, the meso- and microscale atmospheric processes, variability and controlling features of the climate, and the paleoclimate of the MDVs are not well understood. Regional-scale modeling is the best approach towards studying the meteorology and climate of the MDVs. Here we present results from several test simulations of the MDVs using Polar WRF. Results from two case studies show that Polar WRF can simulate the controlling features of MDVs summer climate: foehn winds and sea breezes. Special modifications to model settings and input conditions (e.g, land use, snow cover, surface and soil properties) have to be made for proper representation of atmospheric conditions of the MDVs.

International Workshop on Antarctic Clouds

Byrd Polar Research Center, Ohio State University, Room 240 Scott Hall

Day 1 – Invited Talks

8:00-8:45 a.m.	What do we know and don't know about Antarctic clouds? David Bromwich, The Ohio State University.
8:45-9:00 a.m.	Discussion
9:00-9:45 a.m.	Surface-based remote sensing. Erica Key, National Science Foundation.
9:45-10:00 a.m.	Discussion
10:00-10:30 a.m.	Coffee Break
10:30-11:15 a.m.	Satellite-based remote sensing. Dan Lubin, Scripps Institution of Oceanography.
11:15-11:30 a.m.	Discussion.
11:30 a.m.-12:15 p.m.	Airborne Measurements of Clouds and Aerosols during ISDAC and M-PACE. Greg McFarquhar, University of Illinois-Urbana Champaign.
12:25-12:30 p.m.	Discussion.
12:30-1:30 p.m.	Lunch
1:30-1:45 p.m.	Ground based remote sensing of clouds and precipitation at the Princess Elisabeth station, Dronning Maud Land. Irina Gorodetskaya, K.U. Leuvin
1:45-2:30 p.m.	Airborne measurements: Antarctic experience. Tom Lachlan-Cope, British Antarctic Survey.
2:30-2:45 p.m.	Discussion
2:45-3:00 p.m.	In situ aircraft observations of Antarctic Peninsula clouds. Daniel Grosvenor, University of Manchester
3:00-3:30 p.m.	Coffee Break.
3:30-4:15 p.m.	Regional modeling of Antarctic clouds. Keith Hines, The Ohio State University.
4:15-4:30 p.m.	Discussion
4:30-5:15 p.m.	Global modeling status. Tom Lachlan-Cope and Keith Hines
5:15-5:30 p.m.	Discussion
6:30 p.m.	Social activity

International Workshop on Antarctic Clouds

Byrd Polar Research Center, Ohio State University, Room 240 Scott Hall

Day 2 – Working Groups

8:30-9:00 a.m.	Preliminary integrated discussion. Charge to Working Groups. Identify needed research and potential synergies between approaches.
9:00-10:30 a.m.	Working Groups meet: 1 – Surface-based remote sensing 2 – Satellite-based remote sensing 3 – Airborne studies 4- Modeling
10:30-11:00 a.m.	Coffee Break
11:00 a.m.-12:30 p.m.	Working Groups continue to meet. Circulation to other groups is encouraged.
12:30-1:30 p.m.	Lunch.
1:30-2:10 p.m.	Working Group Reports – 10 minutes each.
2:10-3:30 p.m.	Desirable research projects and plans for a workshop report.
3:30 p.m.	Adjourn

5th Antarctic Meteorology Observation, Modeling, & Forecasting Workshop
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