Remote and Autonomous Measurements of Precipitation in Antarctica

Mark W. Seefeldt[1]
Scott D. Landolt[2] and Andrew J. Monaghan[2]

[1]Cooperative Institute for Research in Environmental Sciences (CIRES)
University of Colorado – Boulder

[2]Research Applications Laboratory (RAL)
National Center for Atmospheric Research

Background

- Snow accumulation is the primary mass input to the Antarctic ice sheets
  - Net result of: precipitation, sublimation/vapor deposition, drifting snow, and melt
- Long-term spatiotemporal variability of Antarctic snow accumulation is not well known
  - Results in uncertainty in mass budget estimates of the Antarctic ice sheets
- Precipitation dominates on the continental and regional scales in the understanding of snow accumulation

Background

- Precipitation has proven to be exceedingly difficult to accurately measure or otherwise estimate in Antarctica
  - Due to the relatively small amount of annual precipitation
  - Difficult to distinguish between falling snow (precipitation) and blowing snow
- The difficulties to measure precipitation are even more complex in remote locations requiring low-power and autonomous measurement systems
- Measurement on the high plateau is even more challenging due to even smaller accumulation and smaller precipitation particles

 (not addressed in this project)

Goals

- Design and install a system to accurately measure precipitation in Antarctica
  - The key is being able to distinguish between falling snow (precipitation) and blowing snow
- Install four Antarctic Precipitation Systems (APSs) in the Ross Island / Ross Ice Shelf region
  - Large variability in annual precipitation across this region
  - Logistical access and convenience of being adjacent to McMurdo Station
- Operate the APSs autonomously and remotely in the Antarctic environment over the entire year

Science Goals

- What are the differential contributions of falling snow, ice crystals and blowing snow to overall snow accumulation in the Ross Island region?

- How does precipitation accumulation (after removing the impact of blowing snow) vary seasonally and spatially?

- How well does WRF simulate the spatial and seasonal aspects of precipitation accumulation and where should efforts be focused to improve the model?

Field Observations

- The focus of the field observations is to use a suite of instruments to provide multiple simultaneous observations
- As precipitation is measured using a precipitation gauge, complementary observations will be used to identify if it is blowing or falling snow
- The additional complicating factor is to make the suite of instruments able to be low-power and autonomous for use at remote sites

Antarctic Precipitation Systems - Instruments

- Primary:
  - Ott Pluvio^2
  - Installed inside a Belfort Double Alter (BDA) shield
- Complementary:
  - Laser Disdrometer - Ott Parsivel^2 or Thies Laser Precipitation Monitor
  - Laser Disdrometer - ETI Optical Precipitation Detector
  - Campbell Scientific - Sonic Ranging Sensor
  - Campbell Scientific - CCFC Field Camera
  - Vaisala - WAA151 3-cup Anemometer
- Supplementary:
  - Snow Height by GPS Reflectivity

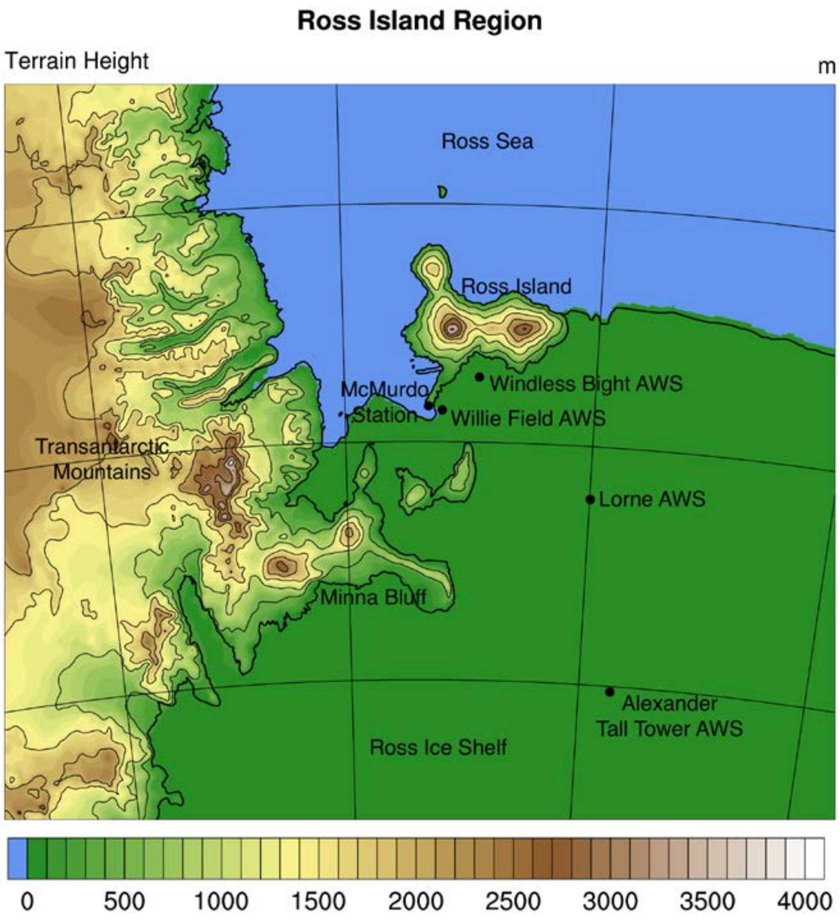
Antarctic Precipitation Systems - Schedule

- Initial deployment was originally scheduled for November 2016
  - Field work was deferred a year to provide more time to prepare the APS instrumentation
- Initial deployment will not be done in November 2017
- The goal is to get two years of observations
- Maintenance and adjustments will be completed in November 2018
- APS sites will be removed in November 2019
- Two-way communications will allow for real-time monitoring of the observations and adjustments to the measurement algorithms while installed

Antarctic Precipitation Systems - Locations

- Premier APS Site:
  - Willie Field AWS
- Standard APS Sites
  - Phoenix Runway (AWS)
  - Alexander Tall Tower
  - Elaine AWS

Note: Lorne AWS is being included in the field scheduling as a back-up site should the weather or Twin Otter resources eliminate Elaine.



APS Standard Site – Precipitation Gauge

- Ott Pluvio^2
  - All-weather weighing precipitation gauge
  - Original Pluvio^1 gauge is used by the NWS in the ASOS
  - Will be installed at an approximate height of 11 feet (3.3 m)

APS Standard Site – Precipitation Gauge

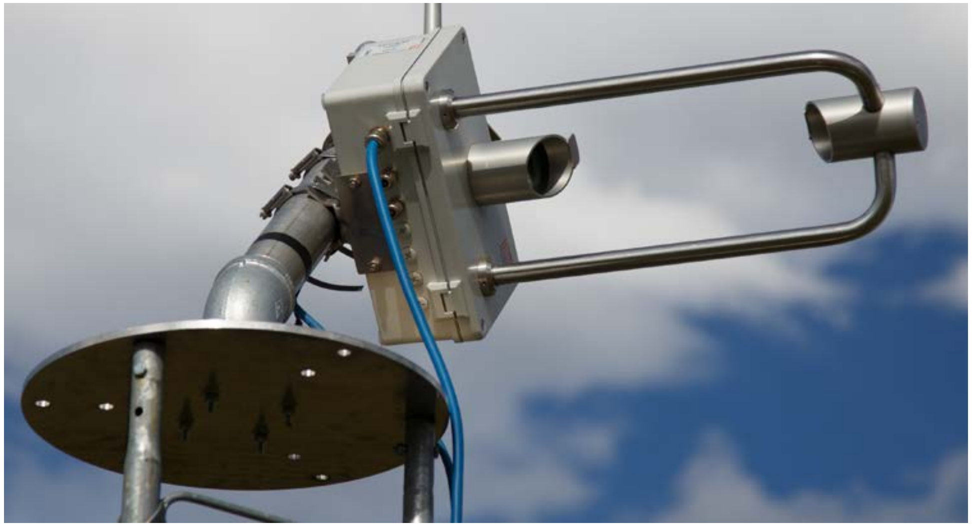
- Belfort Double Alter (BDA) Shield
  - The Pluvio^2 will be installed inside a BDA shield to improve snow collection on windy days
  - The actual shields used in Antarctica will be a slightly different design with modifications for the Antarctic environment

APS Standard Site – Instrument Tower

- All other instruments and the datalogger will be installed on a second tower approximately 10 m upwind from the precipitation gauge

APS Standard Site – Laser Disdrometer

- Ott Parsivel^2 or Thies Laser Precipitation Monitor
  - Measures particle size and fall velocities
  - Will be used to detect particle size in an attempt to distinguish between precipitating snow versus blowing snow



APS Standard Site – Laser Disdrometer

- ETI Optical Precipitation Detector
  - Measures a count of particles
  - Mounted at a lower height than the Parsivel^2 / LPM units
  - Will be used to identify when events are occurring

APS Standard Site – Sonic Ranging Sensor

- Campbell Scientific SR50A (aka ADG)
  - Measures the snow height immediately beneath the sensor using acoustic signals
  - Will be used to track the accumulation at a given location
  - Includes a temperature sensor

APS Standard Site – 3-Cup Anemometer

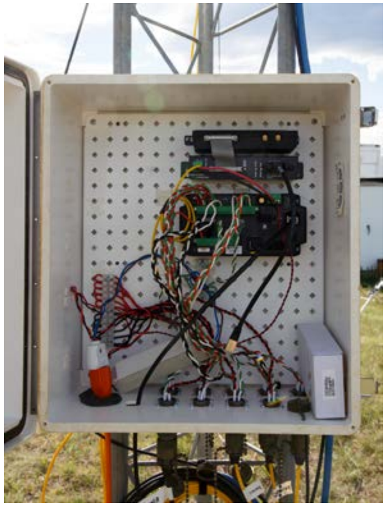
- Vaisala WAA151 3-cup Anemometer
  - Measures the wind speed at gauge height
  - Will be used in transfer calculations based on shielding efficiency
  - Will also be used in identifying blowing snow events

APS Standard Site – Camera

- Campbell Scientific CCFC Field Camera
  - Provide a visual picture of the conditions during a given event
  - IR LEDs are included for night photos
  - Will also be used to monitor the precipitation gauge and shield conditions

APS Standard Site – Datalogger/Comms/Power

- Campbell Scientific CR6 Datalogger
- Iridium (9522B) satellite communications for Tall Tower and Elaine
- Intuicom EB-1 radio Ethernet Bridge for Willie Field and Phoenix
- 3 or 5 W power systems provided by UNAVCO



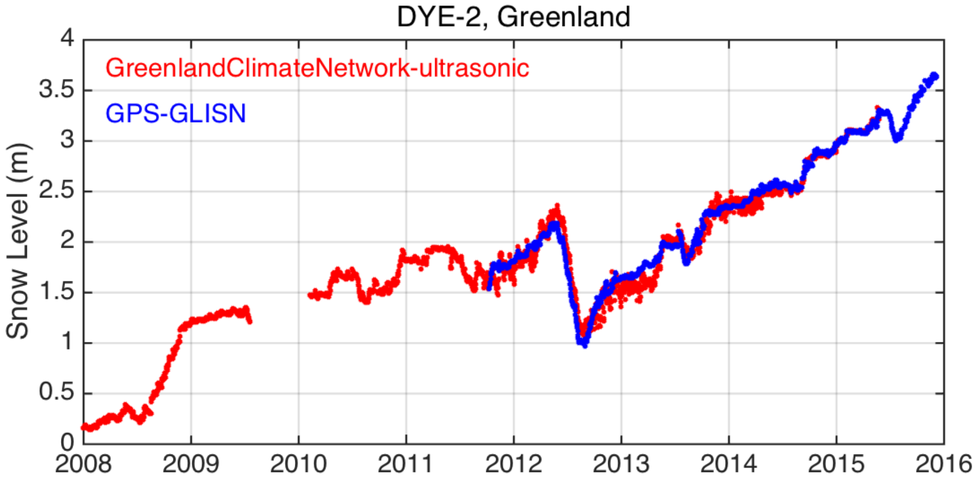
APS Standard Site – Instrument Tower

APS Premier Site – Willie Field AWS

- Includes all of the instruments from a standard sites
- Will also include the following:
  - A second precipitation gauge shielded by a Double Fence Intercomparison Reference (DFIR) shield
  - A third precipitation gauge with a BDA shield at the DFIR shield height (~ 6 feet / 2 m)

APS Supplementary – Snow Height by GPS

- Christine Larson (CU-Boulder) has developed a methodology that measures snow height over an area using a GPS receiver
  (Larson et al., 2009; Larson et al., 2015; Larson et al., 2016)
- Measures snow height through multipath observations using interferometry of the dual frequency GPS signals to examine the dominant height that occurs within 5 degree azimuthal bins
- Comparison to an ultrasonic sensor at DYE-2, Greenland:



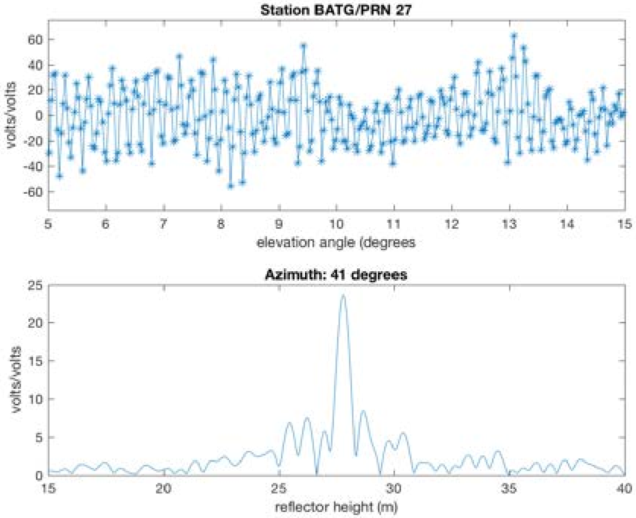
APS Supplementary – Snow Height by GPS

- An installation of a GPS receiver was completed at Alexander Tall Tower during the 2016-17 field season
- Thanks goes to the University of Wisconsin AWS team and UNAVCO for completing this installation

APS Supplementary – Snow Height by GPS

Tall Tower, Ross Ice Shelf

kristinem.larson@gmail.com



Top: GPS signal to noise ratio (SNR) data; Bottom: periodogram of SNR data, yielding vertical height of the GPS above the snow surface

Footprint of the technique

800 meters

Antarctic Precipitation Systems – Challenges

- Continually battling efforts to keep the system low power
  - Manufacturers have no appreciation of the necessity low power requirements (e.g. laser snow-height sensor)
  - Most all of the instruments include a heating method that will not be able to be used
- Will need to create measurement algorithms to sample for events yet minimize power requirements
- Uncertainty with how the instruments will handle being turned on/off routinely during the Antarctic winter
- Difficulties in designing and developing a suite of instruments for installation in the Antarctic environment

Email:

Mark Seefeldt mark.seefeldt@colorado.edu

Scott Landolt landolt@ucar.edu

Acknowledgments:

- Project supported by the National Science Foundation PLR 1543377
- Field and instrument design assistance from the University of Wisconsin AWS project and UNAVCO