Remote and Autonomous Measurements of Precipitation in Antarctica

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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 Pluvio²
  – Installed inside a Belfort Double Alter (BDA) shield

• Complementary:
  – Laser Disdrometer - Ott Parsivel² 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
• 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.
• Ott Pluvio²
  – All-weather weighing precipitation gauge
  – Original Pluvio¹ gauge is used by the NWS in the ASOS
  – Will be installed at an approximate height of 11 feet (3.3 m)
• **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
• All other instruments and the datalogger will be installed on a second tower approximately 10 m upwind from the precipitation gauge.
• 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
• 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
• 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
• 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
• 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)
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:
• 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

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
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