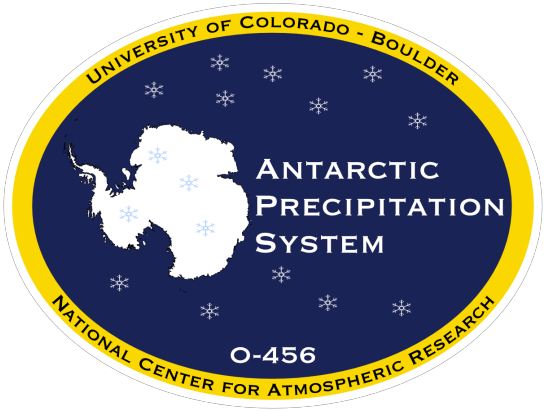
The Antarctic Precipitation Project: A Review of 2018-19 Field Season and an Initial Analysis of *In Situ* Precipitation Observations for the Northwest Ross Ice Shelf, Antarctica



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Cooperative Institute for Research in Environmental Sciences
UNIVERSITY OF COLORADO **BOULDER** and **NOAA**

Outline

- Introduction / Motivation
- Antarctic Precipitation System
- November 2018 Field Season
- Analysis of Events
- Precipitation vs Accumulation
- Sonic vs GPS-IR Measurements
- Comparison to Precipitation in NWP
- Future Work

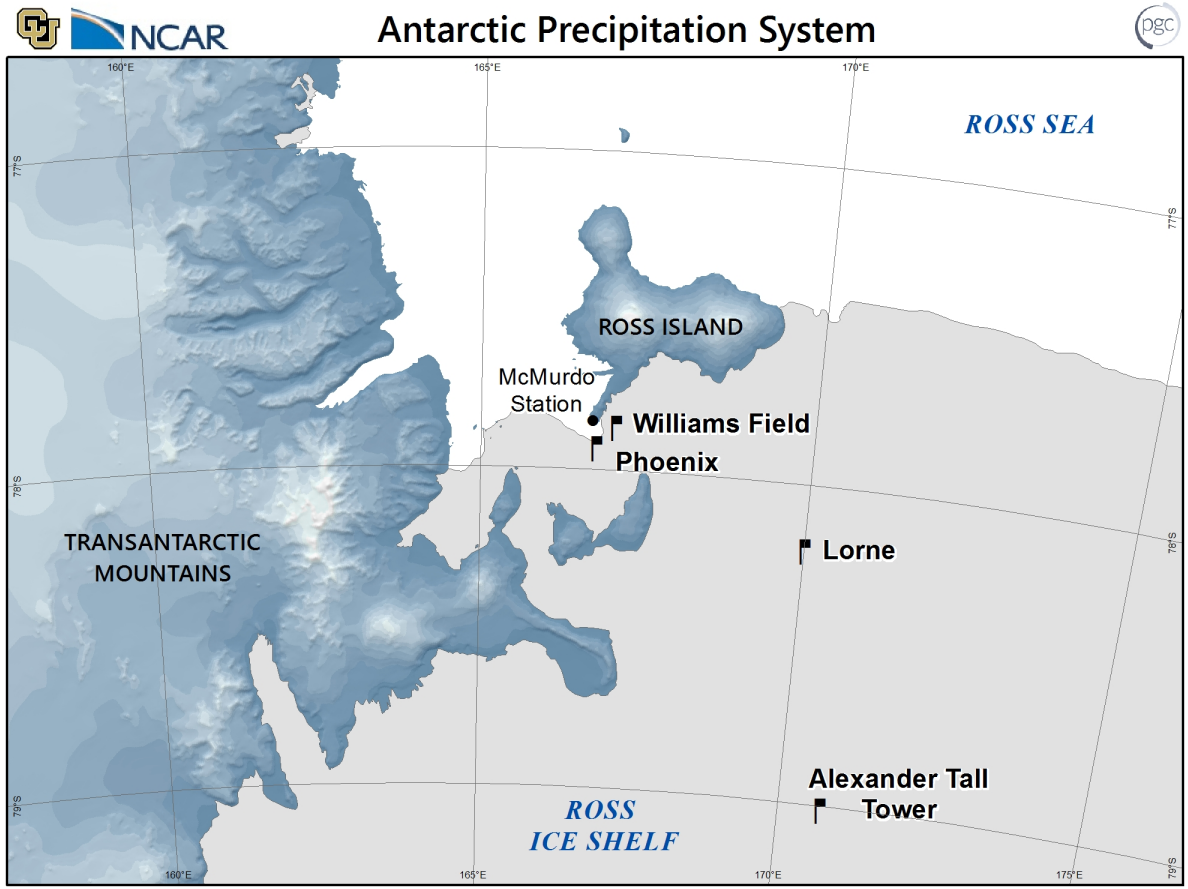
Motivation

Precipitation has been difficult to accurately measure due to:

1. The relatively small amount of annual precipitation (small signal)
2. Difficulty in distinguishing between falling snow (precipitation) and blowing snow (high noise)
3. The complexities in taking measurements in remote locations requiring low-power and autonomous instrument systems

Antarctic Precipitation Systems - Locations

- Premier APS Site
  - Willie Field AWS
- Standard APS Sites
  - Phoenix Airfield
  - Alexander Tall Tower
  - Lorne AWS

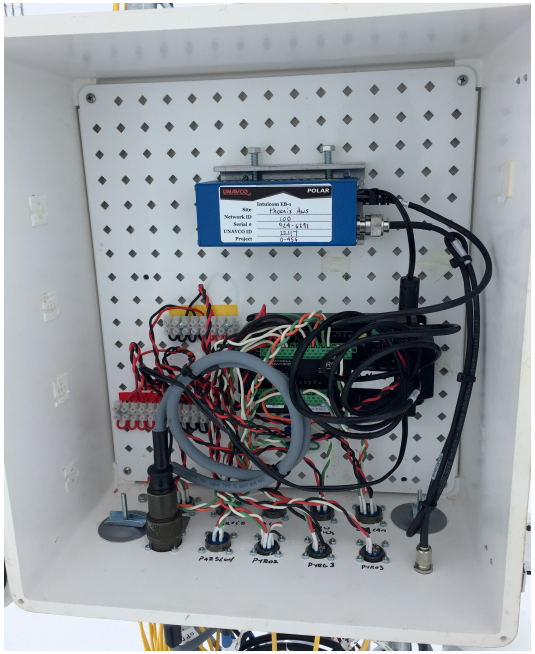


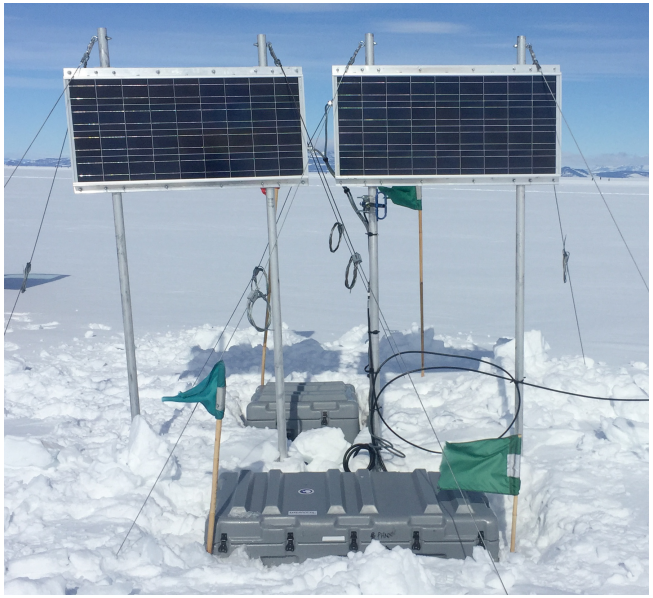
Antarctic Precipitation Systems – Instruments

- Primary:
  - Weighing Precipitation Gauge: Ott Pluvio^2
    - Installed inside a Double-Alter wind shield
  - Snow Height: Two Methods
    - Sonic Ranging Sensor
    - GPS Interferometry Reflectivity (GPS-IR)
- Supplementary:
  - Laser Disdrometer: Ott Parsivel^2 or Thies Laser Precipitation Monitor
  - Particle Counter: ETI Optical Precipitation Detector
  - Web Cam: Campbell Scientific - CCFC Field Camera
  - Wind Speed: Vaisala WAA151 3-cup Anemometer
- Installation of APS Sites in November 2017

APS Site – Datalogger / Comms / Power

- Campbell Scientific CR6 Datalogger
- Intuicom EB-1 radio Ethernet Bridge for radio communications
- 3 or 5 W power systems provided by UNAVCO





APS Standard Site

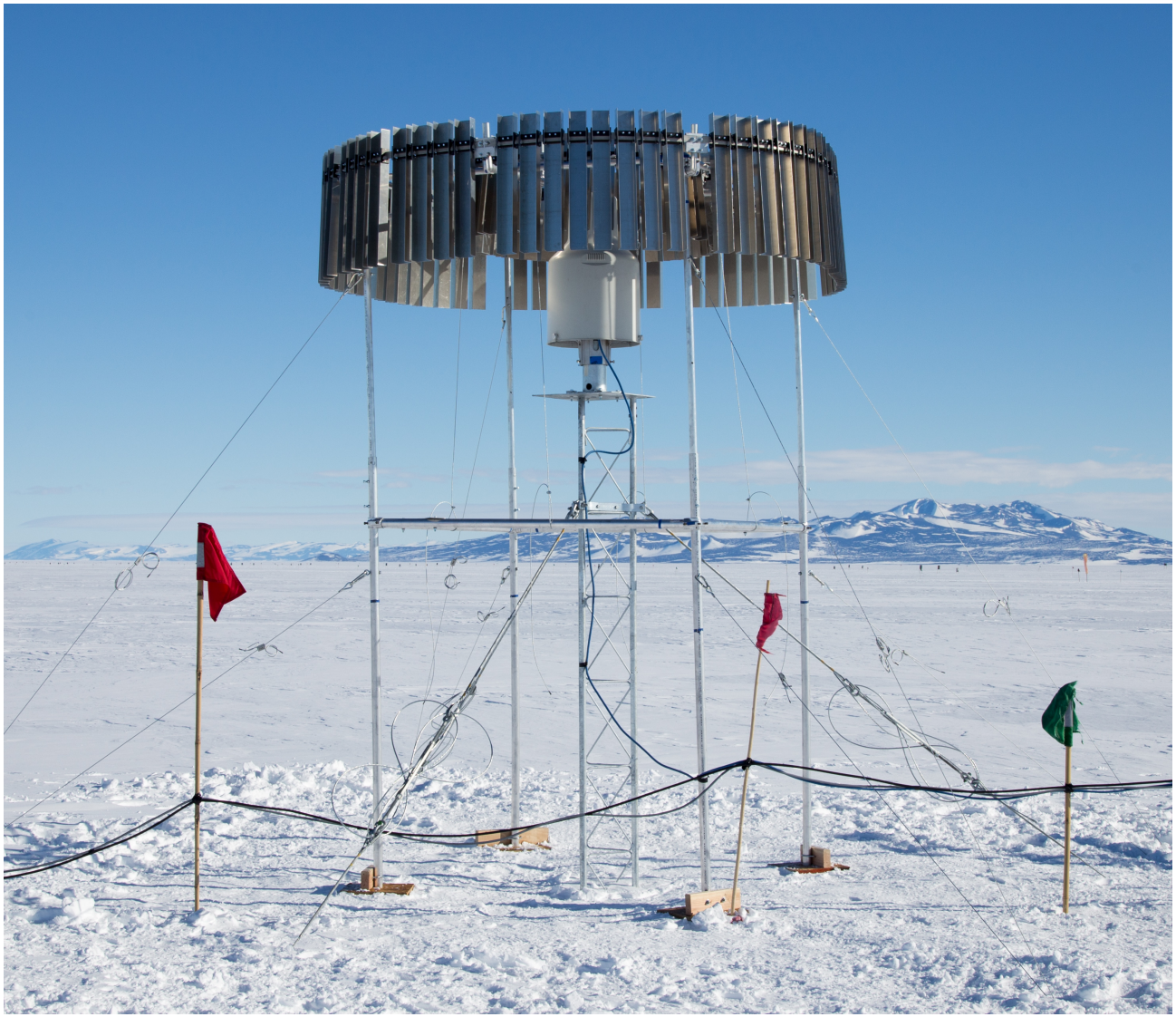
Pre-November 2018 Field Season Status

- All four APS sites remained in radio comms with data retrieval and ability to alter and upload new algorithms
  - Radio comms worked with Tall Tower – a distance of over 200 km transmission
- All data from the instruments are being downloaded to Boulder, Colorado daily
  - The webcam video files are not being actively retrieved due to bandwidth / battery limitations
- Issues with the disdrometers – software? or hardware?
- The UNAVCO power systems were in good condition and the batteries were sufficient for the polar night

November 2018 Field Season

- Goal: Perform maintenance and adjustments to the four APS sites
- In McMurdo: November 5 to December 7
- Visited Tall Tower and Lorne – twice each – by Twin Otter
- Accessed Phoenix and Willie Field numerous times by truck

Phoenix Wind Shield – 26 November 2017

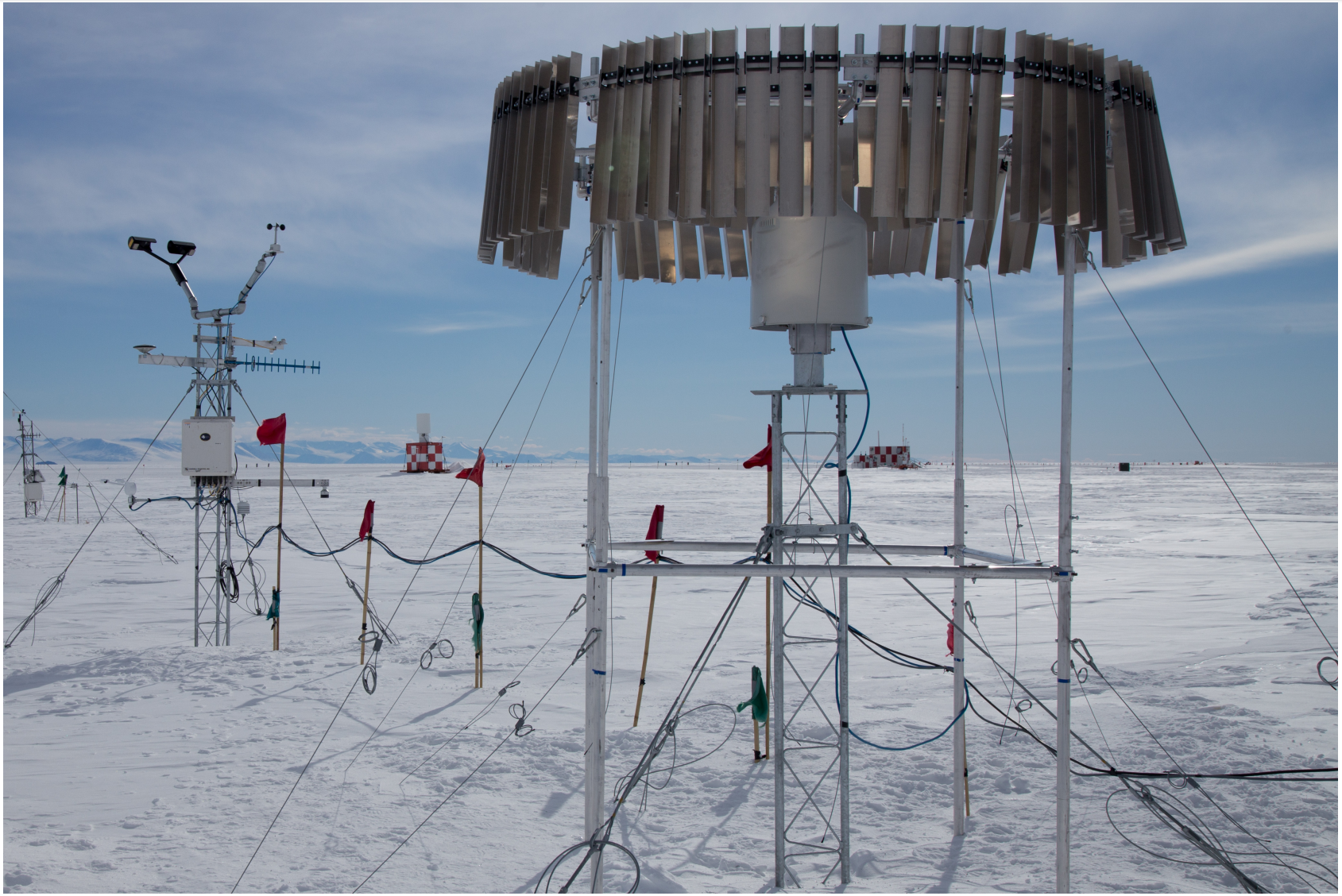


Phoenix Wind Shield – 3 September 2018

Phoenix Wind Shield – 17 September 2018

Phoenix Wind Shield – 9 November 2018

Phoenix Wind Shield – 21 November 2018

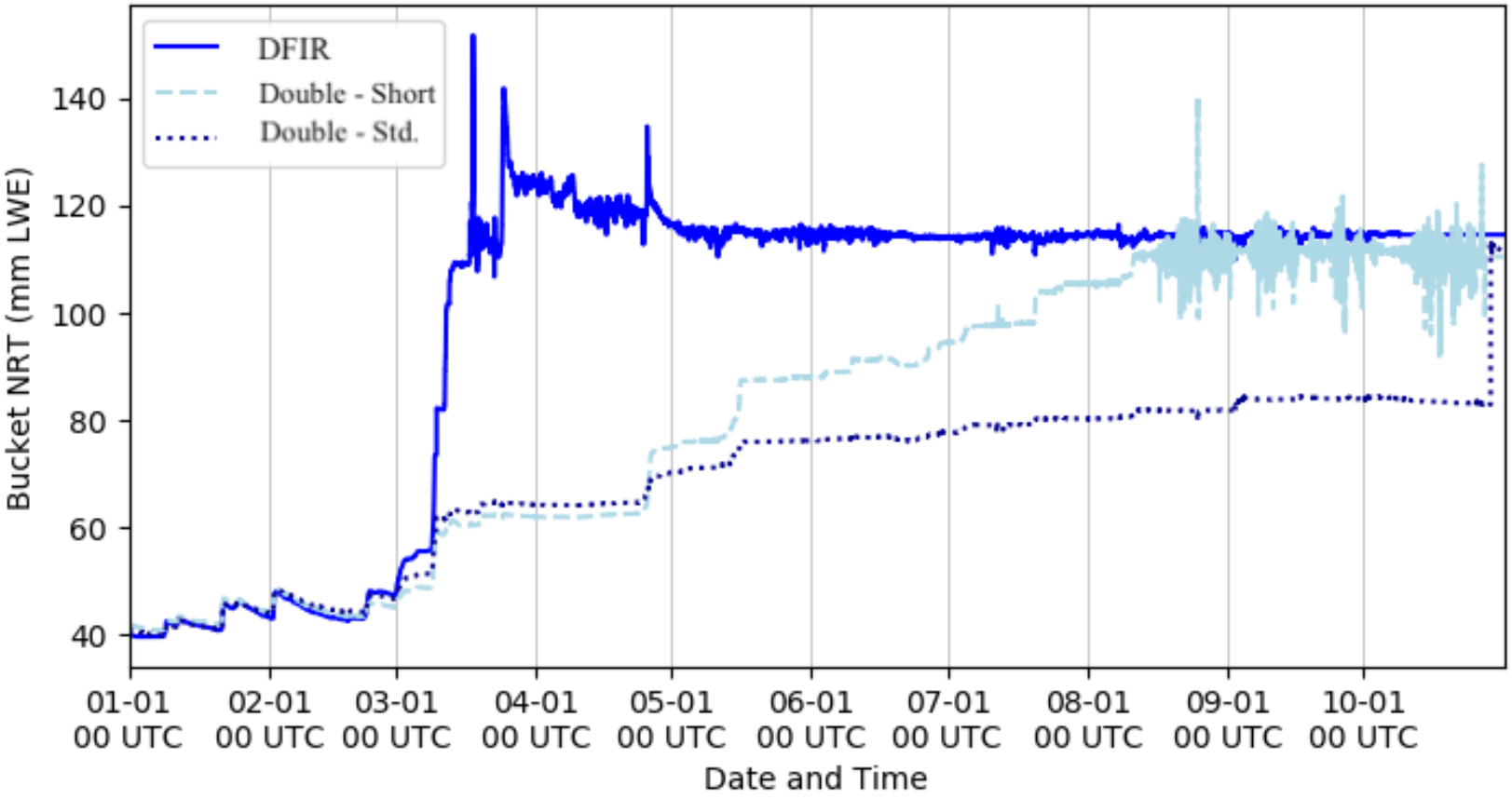


APS Premier Site – Willie Field Site

- Ott Pluvio^2 Precipitation Gauge installed inside a WMO solid precipitation standard Double Fence Intercomparison Reference (DFIR) wind shield

APS Premier Site – Willie Field Site

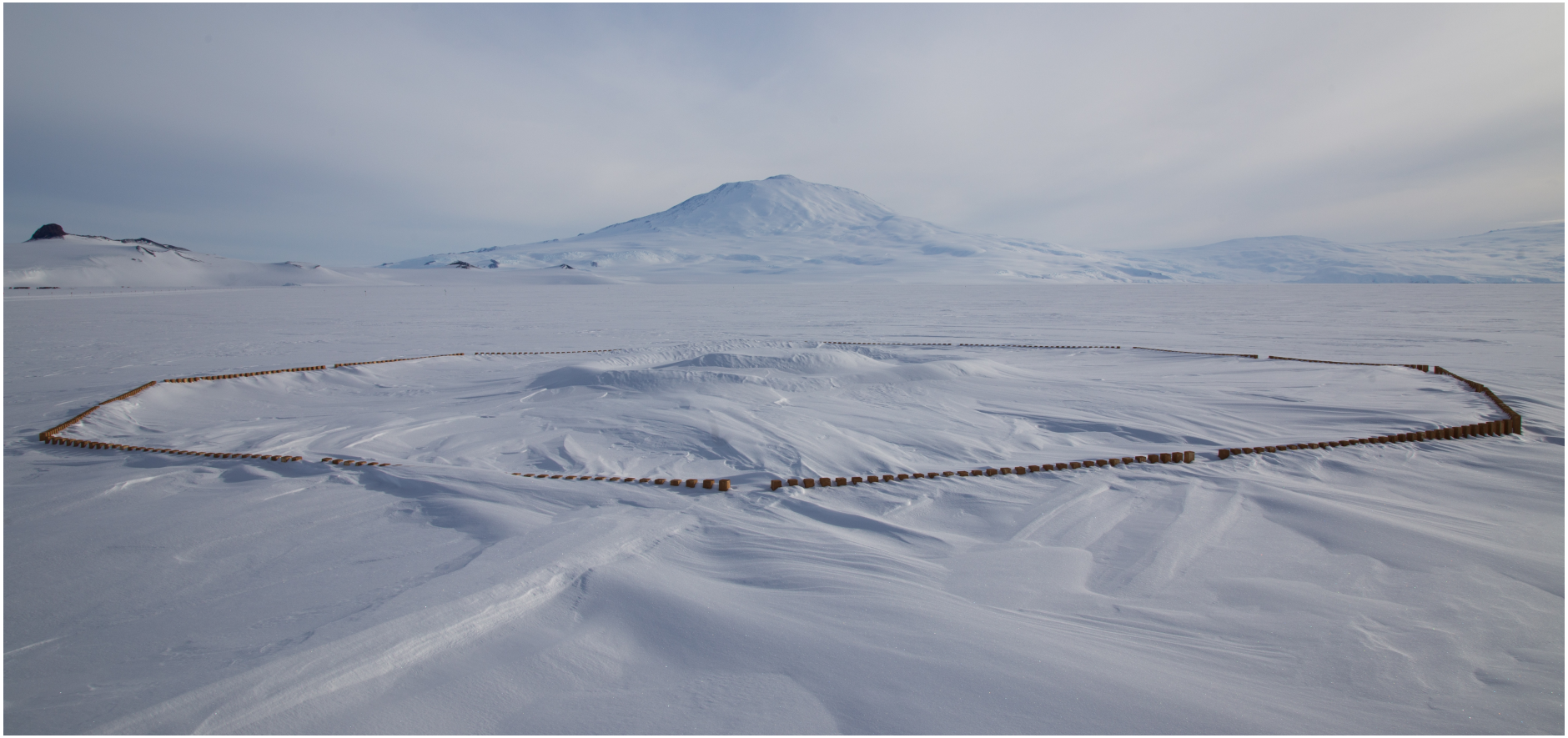
- The measurements from the Pluvio Precipitation Gauges at Willie Field did not make sense during the winter months



Willie Field DFIR – 27 November 2017

Willie Field DFIR – 9 November 2018

- DFIR wind shield w/Pluvio^2 one year after installation



Willie Field DFIR – 26 November 2018

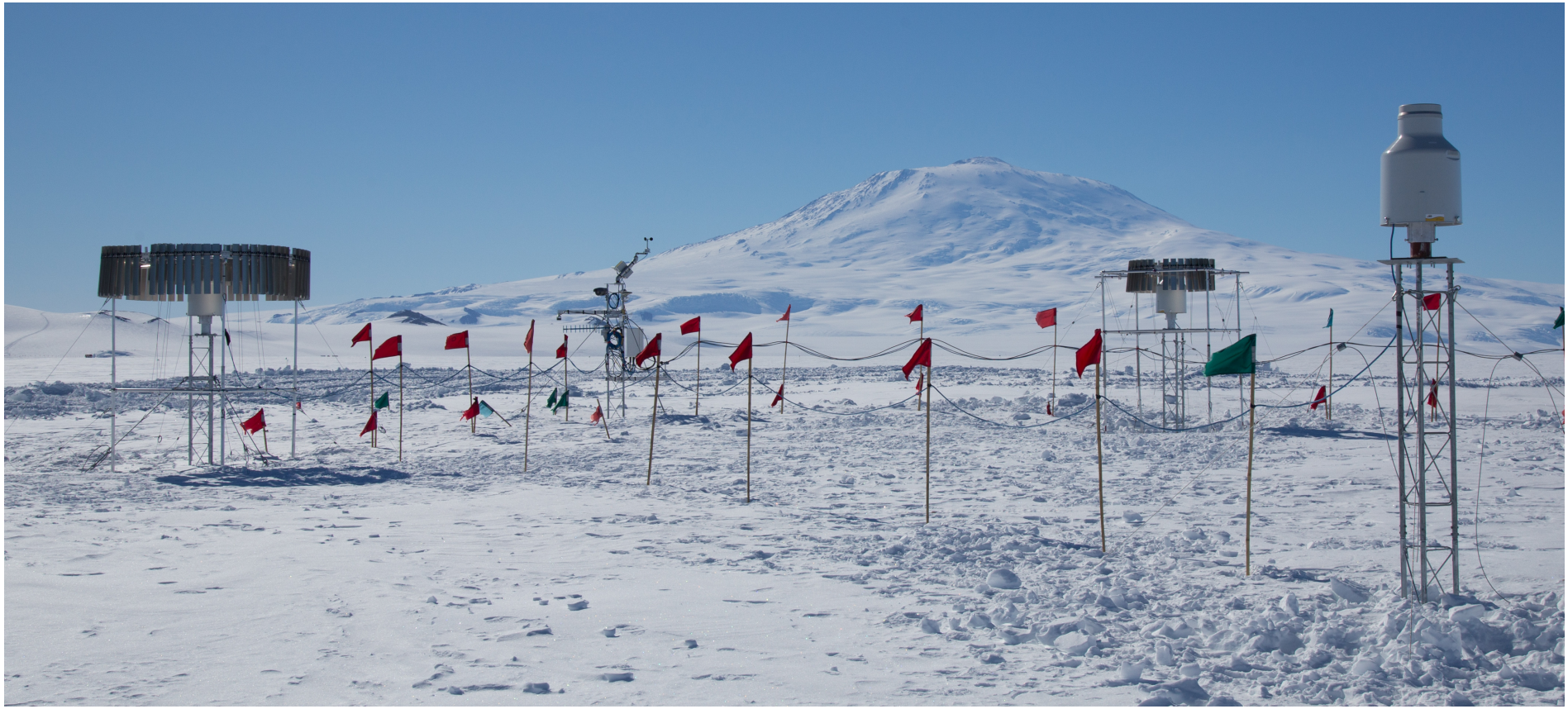
- It took a bigger shovel to remove the DFIR

Willie Field DFIR – 27 November 2018

- Thanks to NSF and ASC for providing the additional support

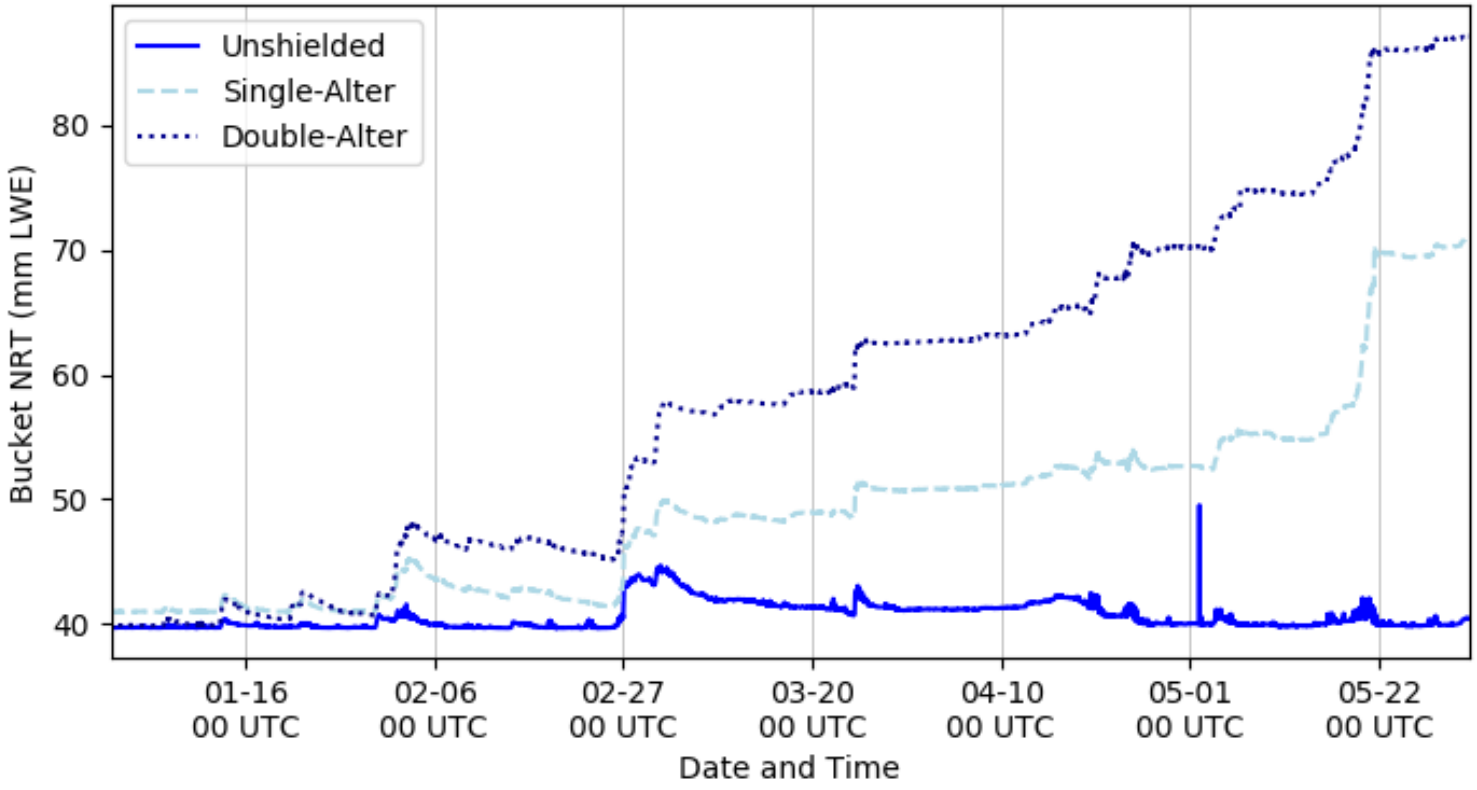
APS Premier Site – Willie Field Site

- Modified experiment: Ott Pluvio^{2}s installed in a Double-Alter, Single-Alter, and unshielded configurations



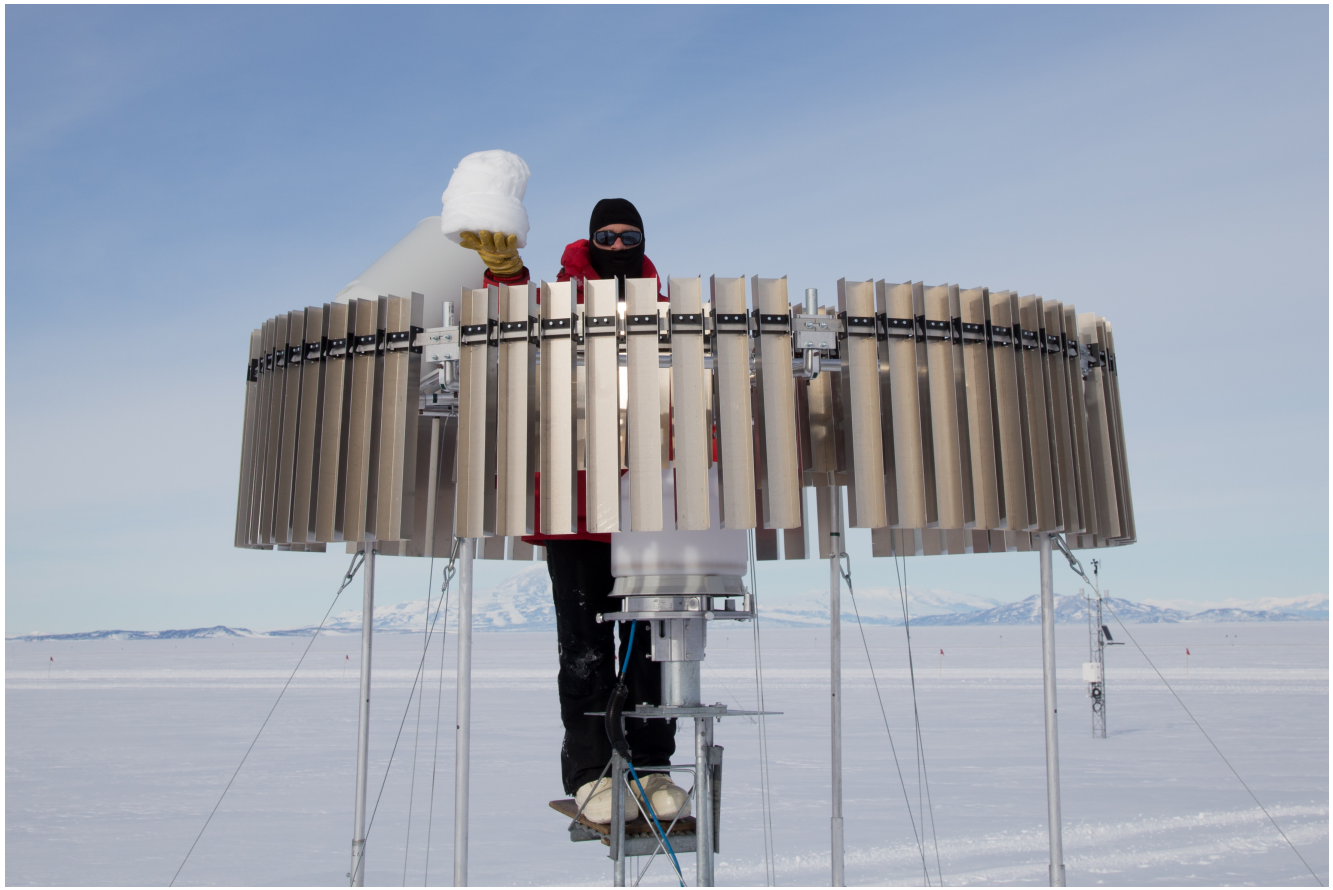
APS Premier Site – Willie Field Site

- The double-alter catches significantly more snow than the single-alter
- The unshielded gauge has minimal effectiveness

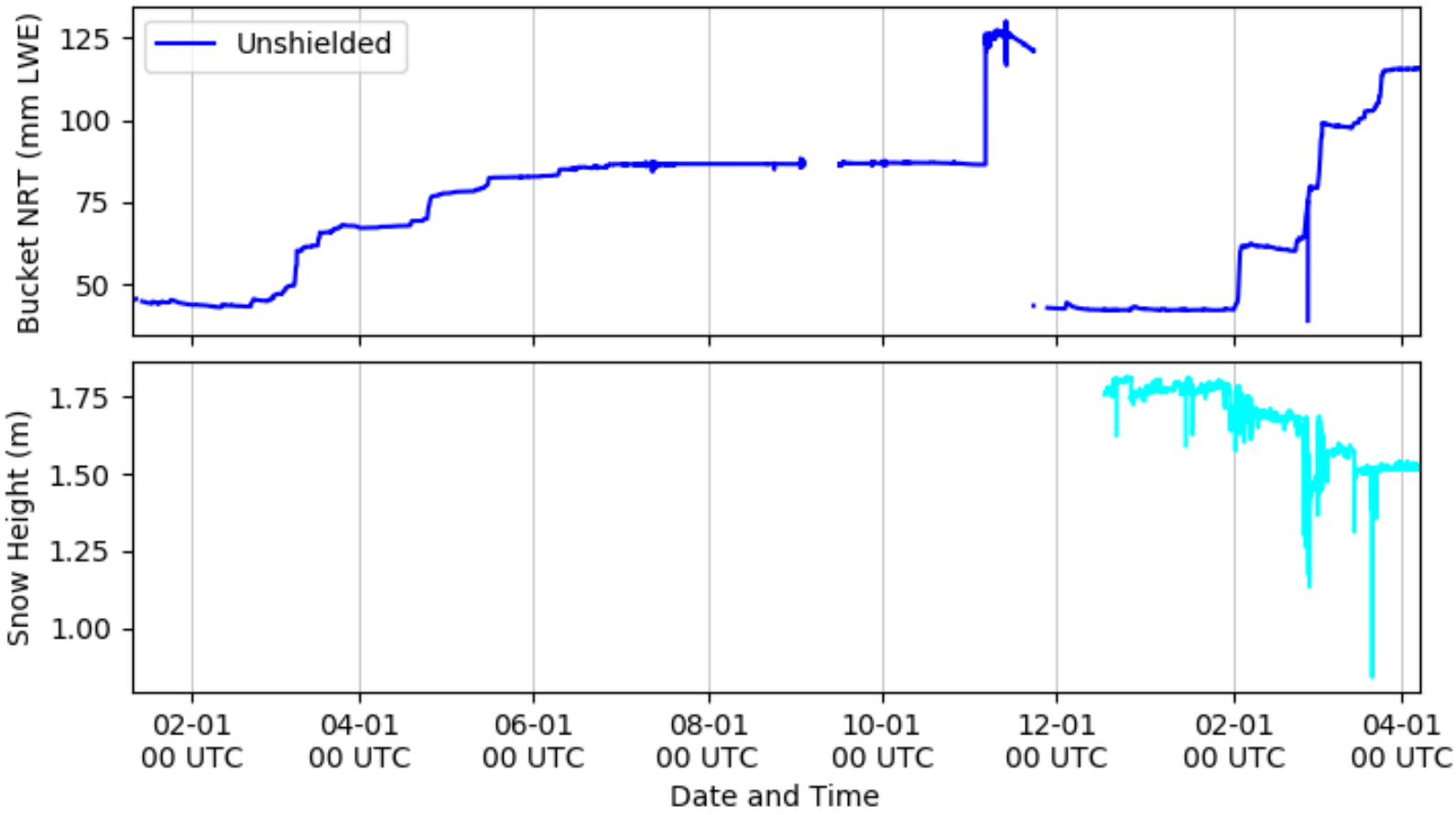


All APS Sites – Ice Bridging

- An issue has emerged that needs to be addressed related to ice bridging – the top of the gauge becoming capped

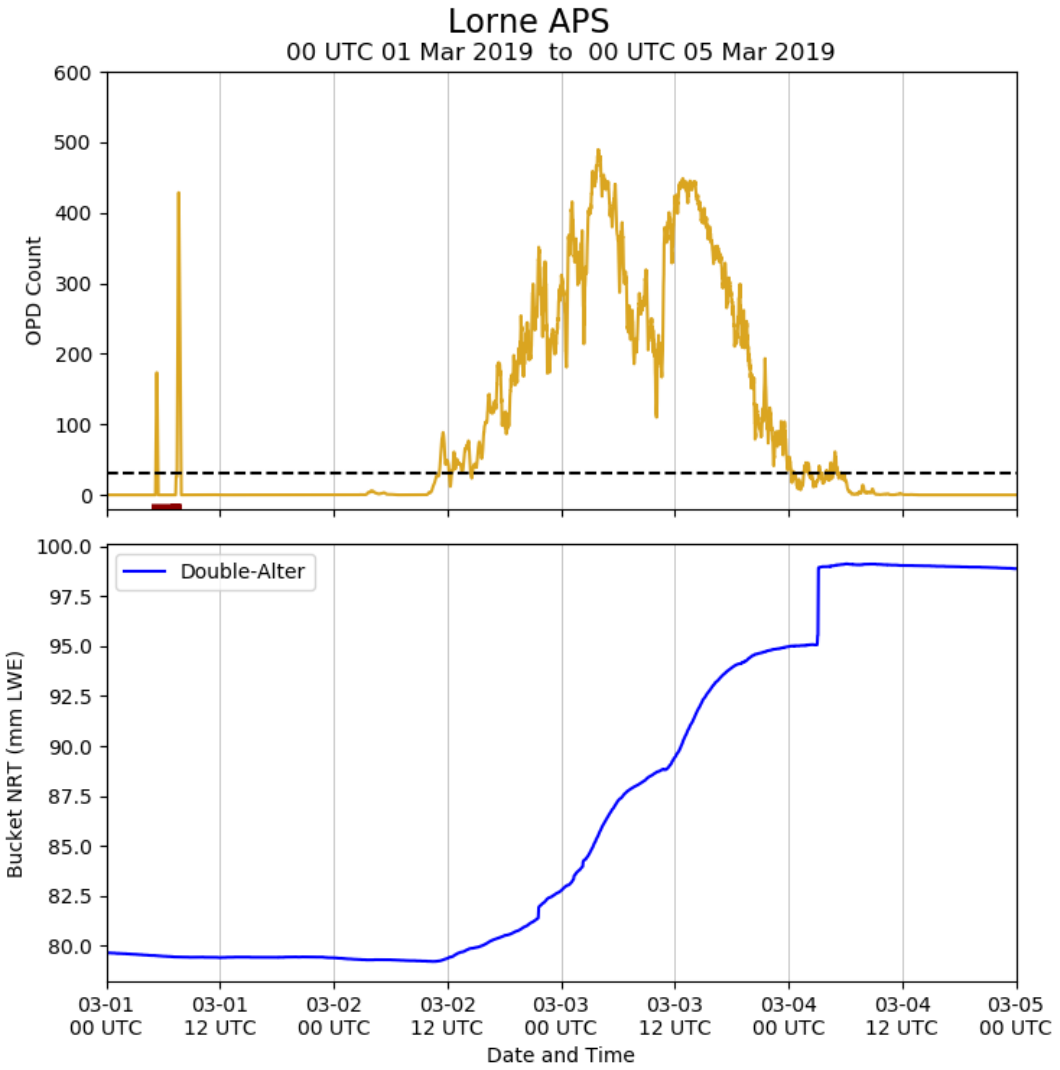


All APS Sites – Ice Bridging



All APS Sites – Ice Bridging

- With experience, the accumulation of snow at the orifice of the gauges has been identified.



Classification of Precipitation Events – Year 1

- The valid observations range from roughly mid-January to mid-June, varying by site

- The observations were reviewed to identify a precipitation "event" defined primarily by precipitation accumulation

- Event classifications:
  - Mild: 0.1 to 2 mm LWE
  - Moderate: 2.0 to 10 mm LWE
  - Extreme: > 10 mm LWE

Events – Year 1

Events by site for Year 1:

- Lorne APS – 30 events
- Phoenix APS – 30 events
- Tall Tower – 32 events
- Willie Field APS – 39 events

Case Study Events:

- Accumulation greater than 1 mm at least at one site
- Typically, accumulation occurring at more than one site
- 20 events

Antarctic Precipitation Systems – Year 2

- All sites have been operating since mid to late November

- Lorne site has either ice-bridged, or the bucket is filled, since mid-May
- Tall Tower appears questionable since early June
- Phoenix is still operating as expected

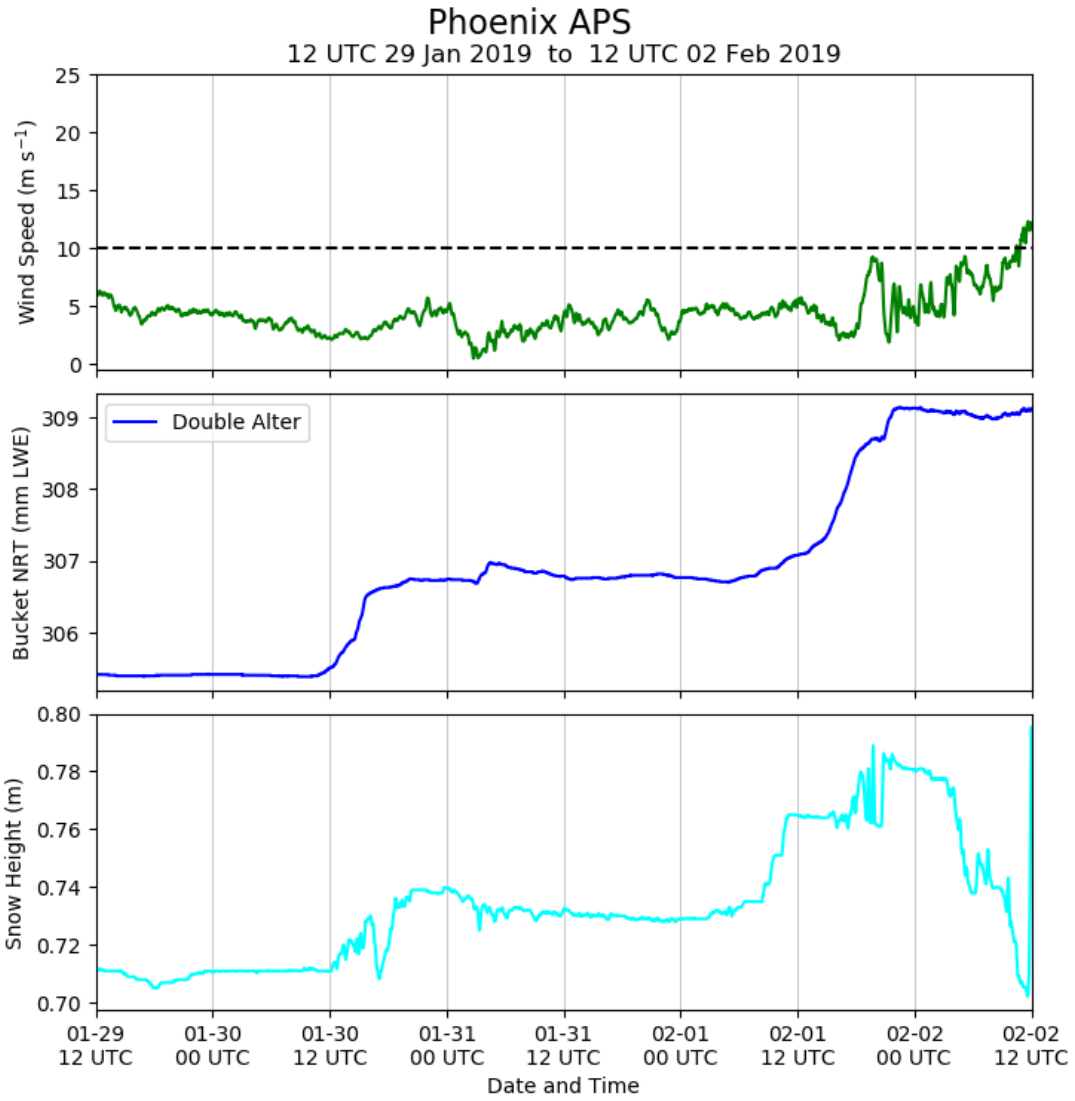
- Still evaluating the observations for the classification of events

Precipitation vs Accumulation

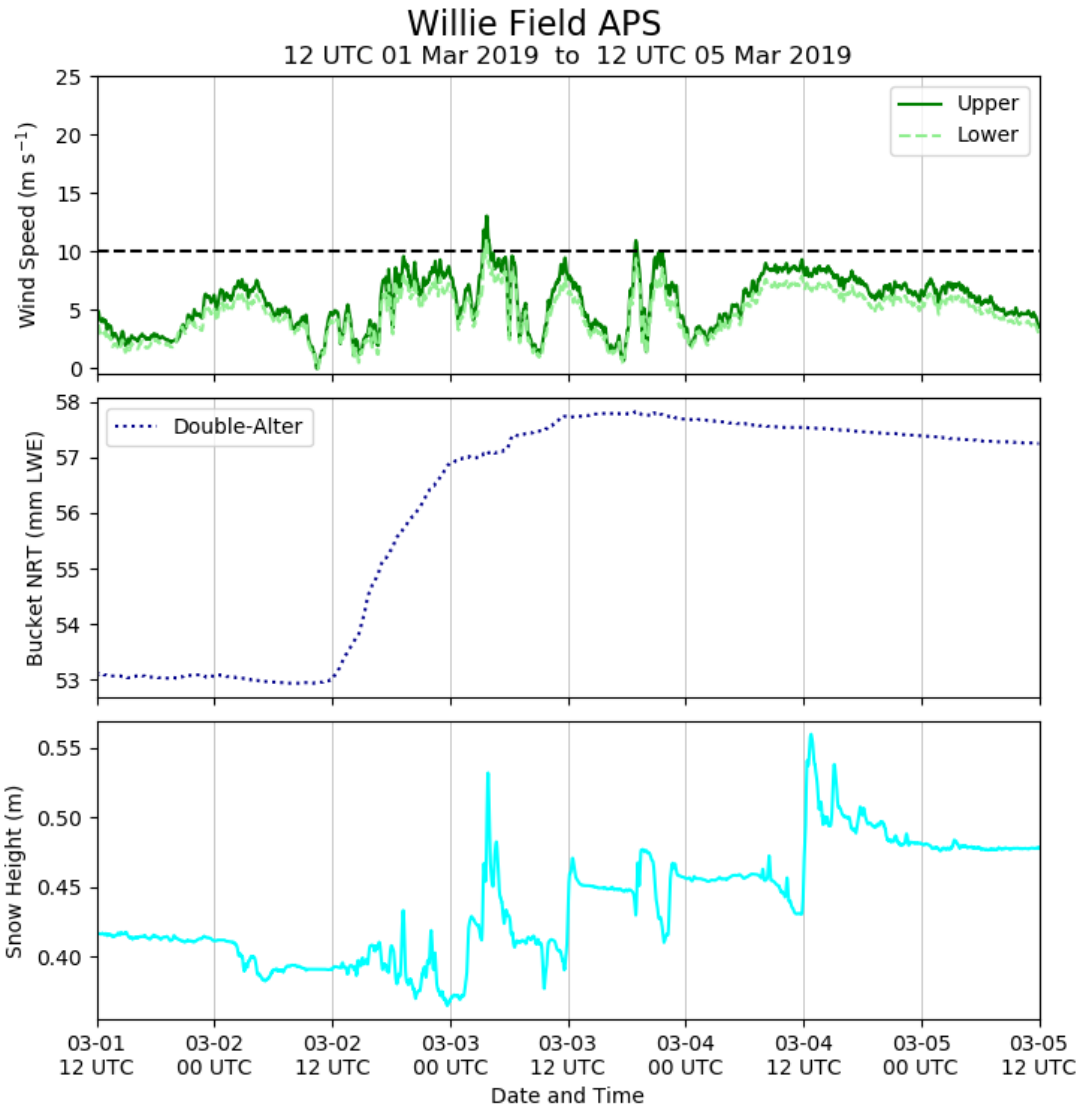
- The liquid water equivalent (LWE) will be compared to the snow height measurements, using the sonic

- Investigating to see if the correlation of precipitation to changes in snow height is different for occurrences of high wind speed and low wind speed events

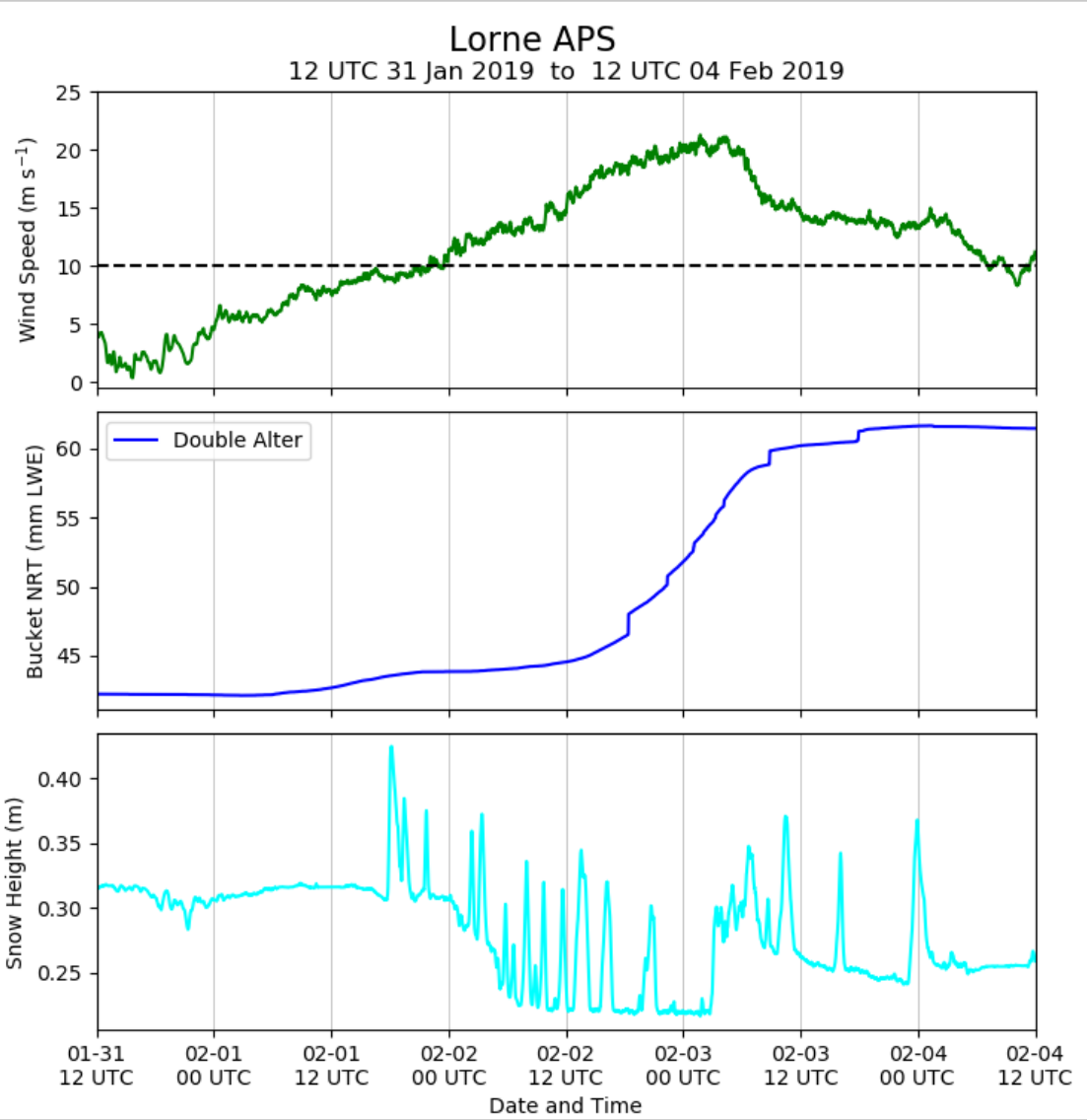
Precipitation vs Accumulation – Low Wind



Precipitation vs Accumulation – Medium Wind



Precipitation vs Accumulation – High Wind



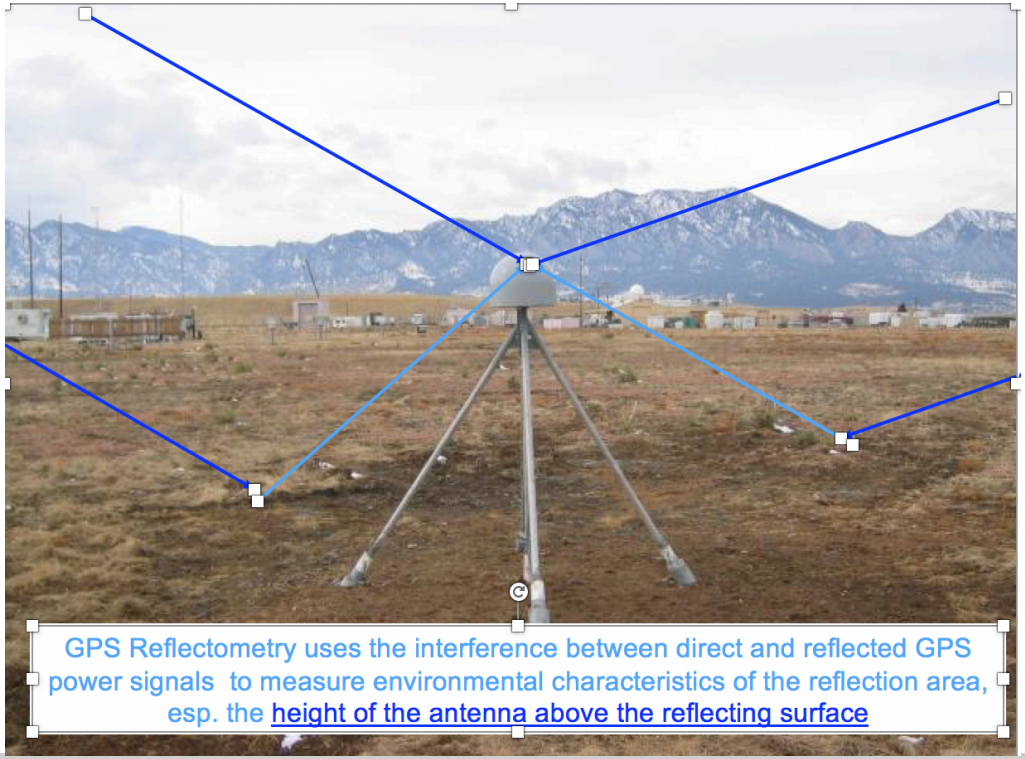
Sonic vs GPS-IR Snow Height Measurements

- The APS sites are equipped to measure snow height using two methods
  - Sonic Ranging Sensor (Campbell Sci. SR50A)
  - GPS Interferometry Reflectivity (GPS-IR)

- Early analysis is showing a similar general pattern between methods but different characteristics

Snow Height by GPS-IR

- Kristine Larson (CU-Boulder) has developed a methodology that measures snow height over an area using a GPS receiver
- 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



Sonic vs GPS-IR Snow Height Measurements

- Green: GPS-IR Blue: Sonic
- 1 April 2018 to 1 November 2018

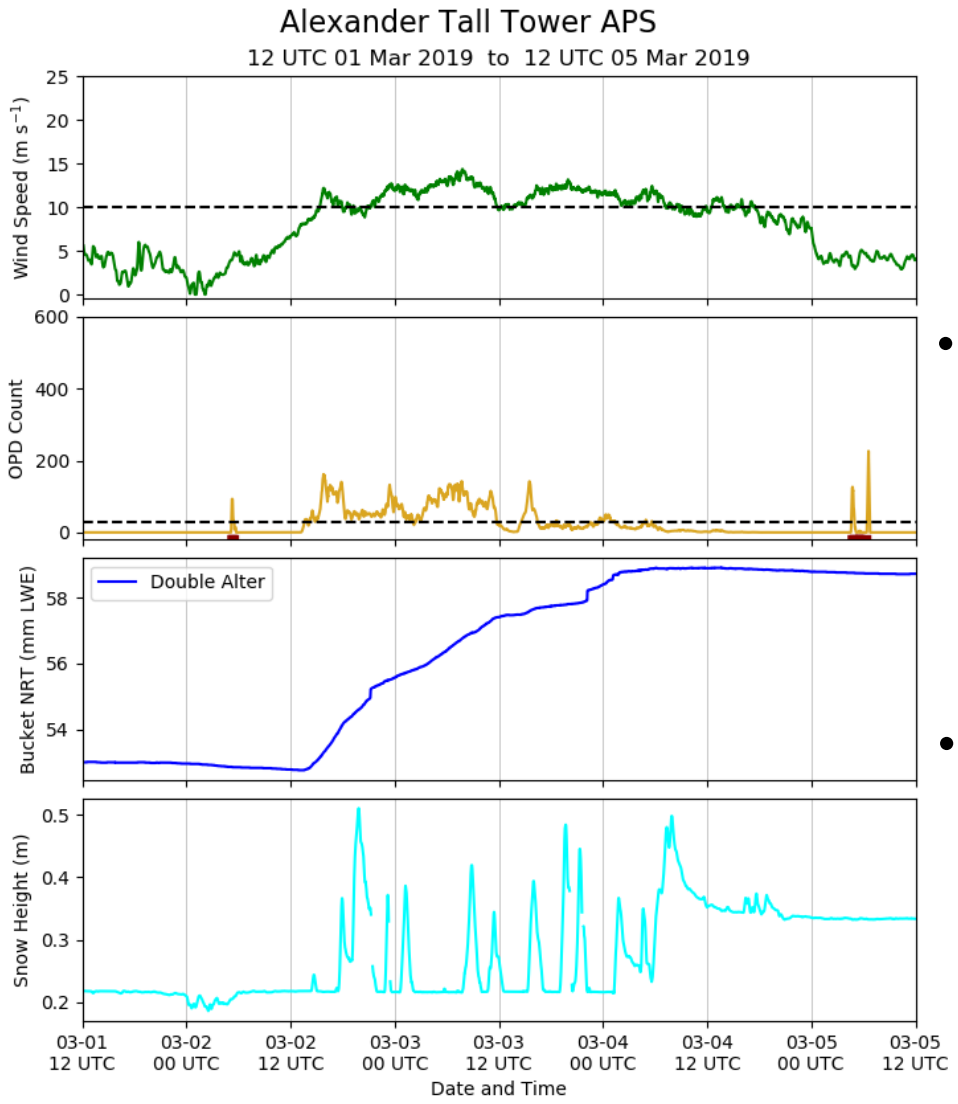
Comparison to Precipitation in NWP

- The results of the observations can be used in comparison to NWP, reanaylses, and RCMs to evaluate the accuracy of the modeled precipitation on an event-by-event basis

- The Antarctic Mesoscale Prediction System (AMPS) provides real-time NWP forecasts of Antarctica for the USAP

Case Study Event: 2 - 4 March 2019 – ATT

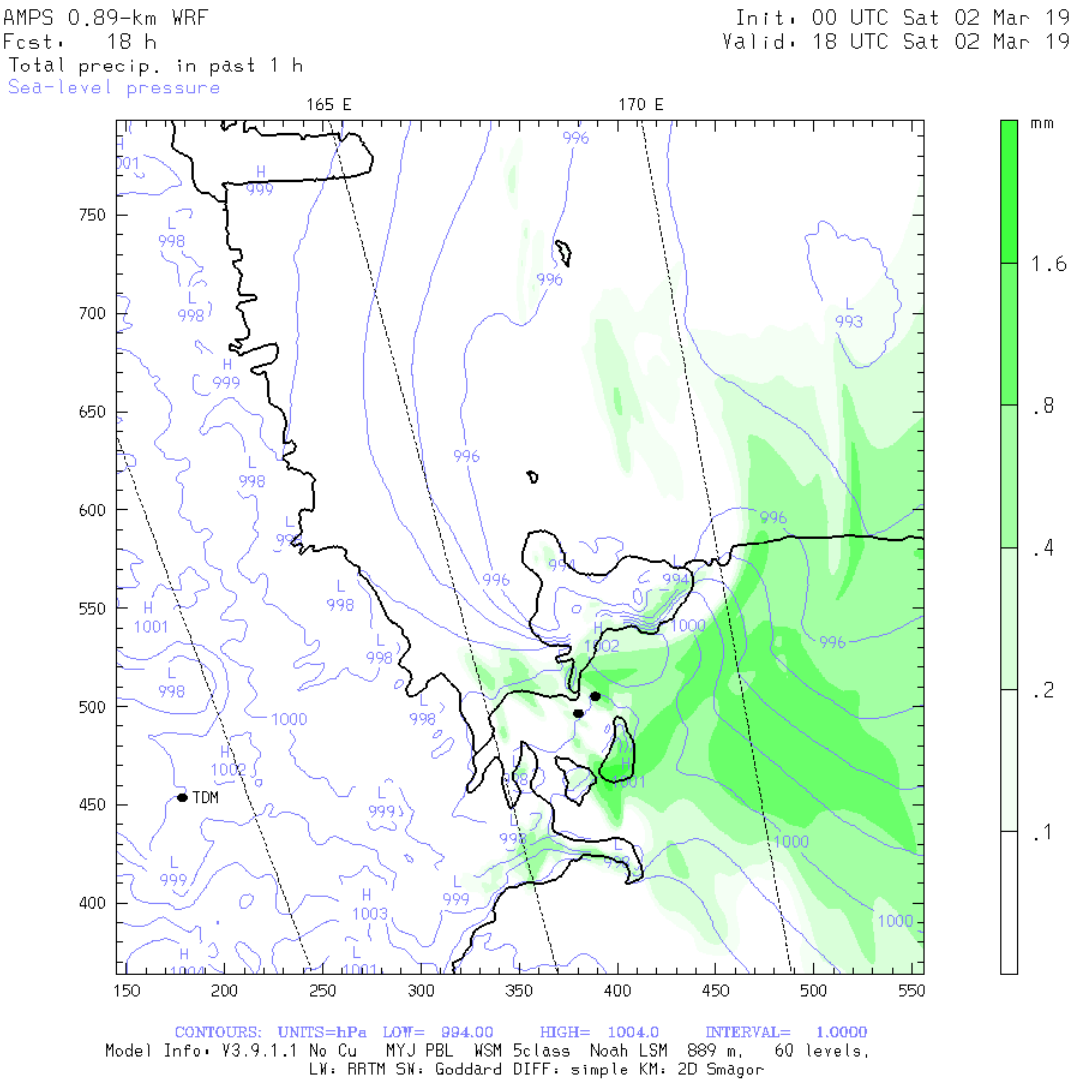
- Moderate to high winds throughout the event
- Accumulation of approximately 6 mm LWE



- OPD count is not as large with the winds not lofting as much snow at LRN
- Variable snow height during the event, ending with about an 11 cm increase in snow height

Observations and Modeling

- Antarctic Mesoscale Prediction System (AMPS)
- 0.89 nested domain – 18h forecast valid 18 UTC 25 April 2018
- SLP and 1h accumulated precipitation



Future Work

- The APS systems will be removed in November
- A full compilation and analysis of the number and magnitude of the observed events
- The precipitation observations will be quantitatively compared to numerical model (NWP and renanalyses)
  - Spatial analysis – highlighting the meteorology of the different events
  - Time series analysis – comparing modeled precipitation to observations
- A more in-depth and comprehensive comparison of accumulation vs precipitation will be completed
- A great understanding of the characteristics, strengths, and weaknesses of GPS-IR vs Sonic snow height

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