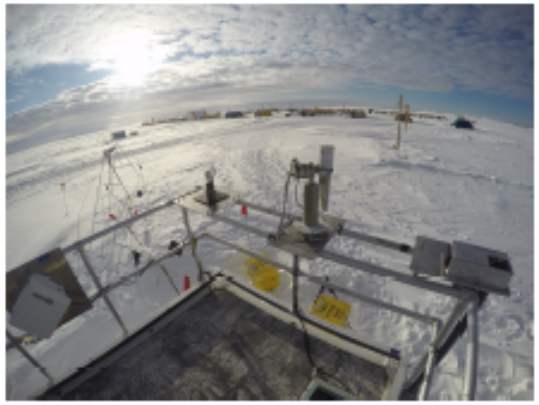
ARM West Antarctic Radiation Experiment

A Joint US NSF-DOE ARM Mobile Facility Campaign



Dan Lubin, Scripps
AWARE PI, Polar clouds and radiation

David Bromwich, Ohio State
Polar meteorology

Andrew Vogelmann, BNL
Polar clouds and radiation

Johannes Verlinde, Penn State
Radar meteorology

Lynn Russell, Scripps
Aerosol chemistry and physics

Ryan Scott, Scripps
WAIS Divide site scientist

12th Workshop on Antarctic Meteorology and Climate
National Center for Atmospheric Research
Boulder, CO 28 June 2017

AWARE Site Locations

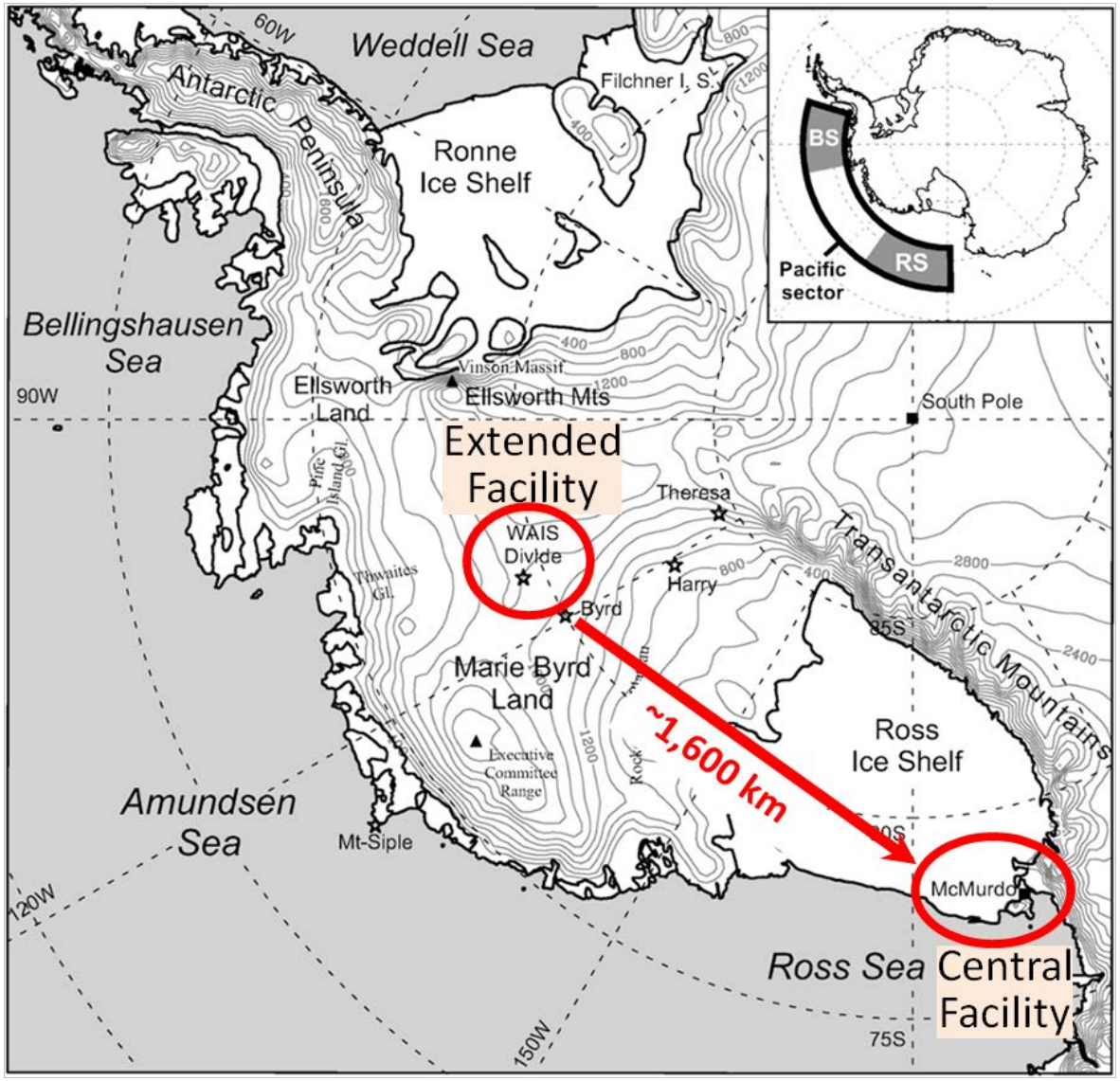


Figure adapted from
Nicolas and Bromwich (2011)

An Early Career Mentor and Role Model:

James Arnold (1923-2012)

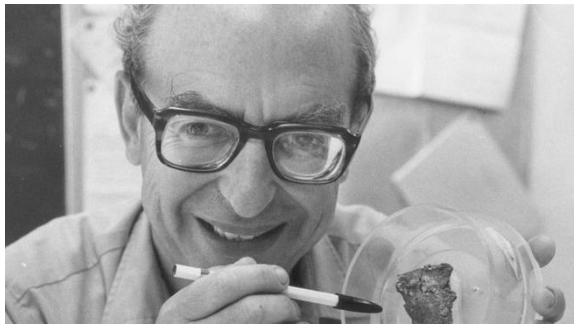
Founder of UCSD Chemistry Department

A great storyteller…

- Ph.D. work with Manhattan Project.
- Pioneer in Solar System Exploration.
- Established California Space Institute at Scripps Institution of Oceanography.
- 1969-72 advised NASA Apollo Program on lunar experiments and sample return, collaborating with astronauts.

Professor Arnold and NASA Apollo Missions

Gives astronauts detailed lecture on sampling strategies



- How lunar materials exposed at the surface should contain records of solar wind, solar-flare nuclei, galactic cosmic rays and micrometeorites.
- How contrasting ages of the rocks between 4.6 and 3 billion years should describe the various cataclysmic events shaping the lunar surface, and should provide evidence of when the moon separated from the earth.
- Differences expected between various samples such as basalts in the lunar maria; anorthositic plagioclase feldspar in the lunar highlands; and fragmental, granulitic versus mafic impact-melt breccias.

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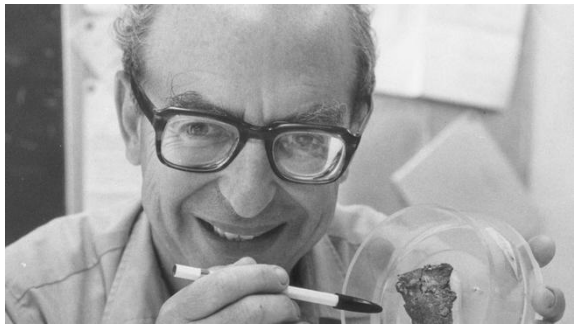

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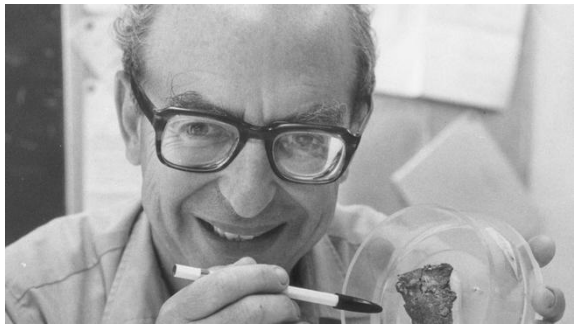
Astronauts all write in their notes

Professor Arnold and NASA Apollo Missions

Gives astronauts detailed lecture on sampling strategies



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Astronauts all write in their notes

Arnold: Bring back lots.

AWARE Executive Summary

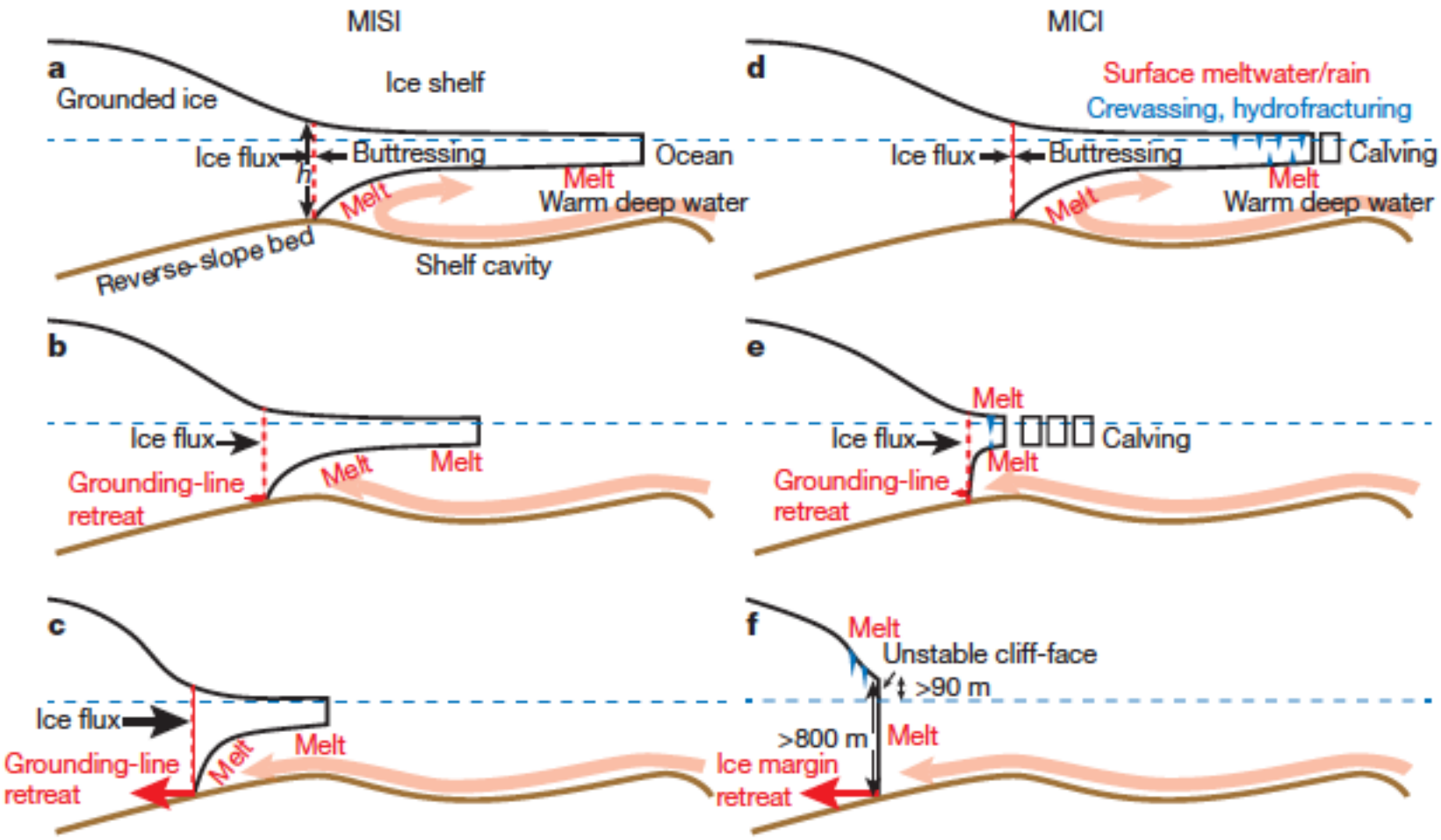
We went to Antarctica. We brought back lots.

AWARE Executive Summary

Fantastic collaboration over three years between DOE and NSF, Los Alamos National Lab and USAP Antarctic Support Contractor, and superb engineers from Australian Bureau of Meteorology.

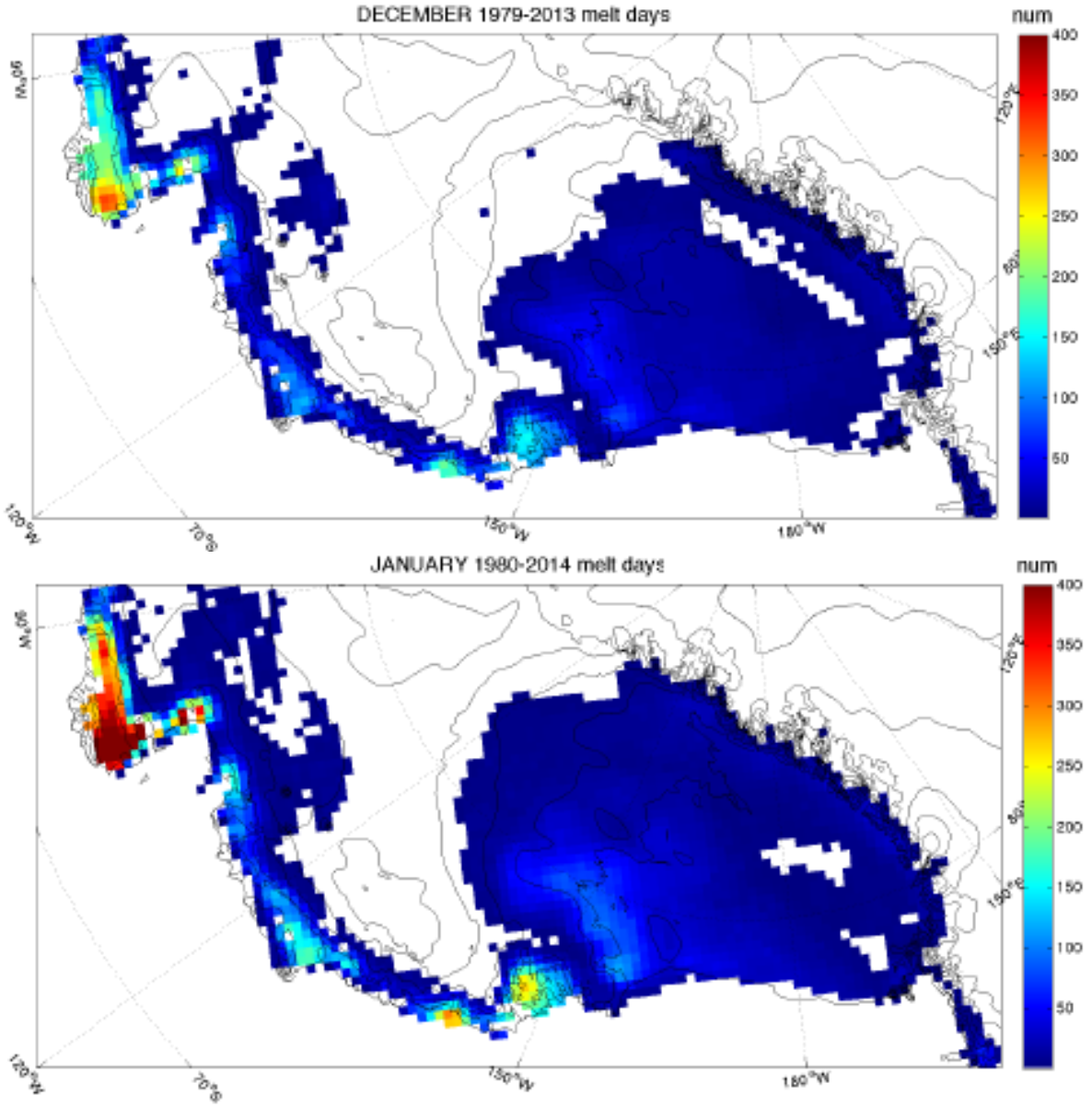
Marine Ice Sheet and Ice Cliff Instabilties

DeConto and Pollard 2016



Total Melt Days in West Antarctica

Since Start of Satellite Era (Passive MW)

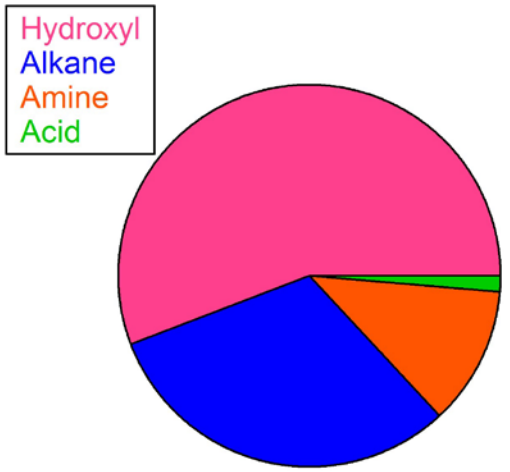


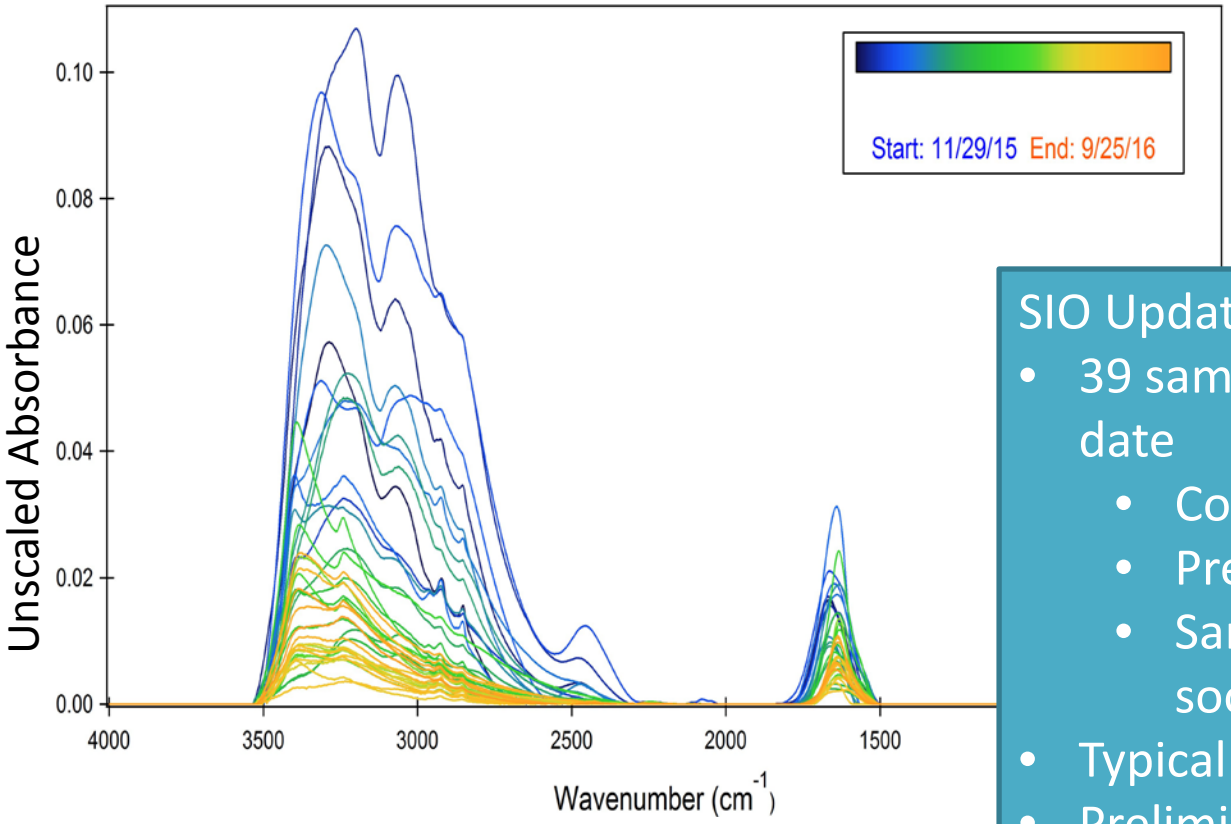
AWARE AMF-2 CosRay Site on Ross Island

Highlights of Full AMF-2 Deployment at Ross Island

- Official Campaign Start 01 DEC 2015, Campaign Ends 01 JAN 2017
  - Some instruments running earlier
- HSRL, AERI, MPL operated throughout campaign
- MWR: FEB-DEC 2016, GVRP: mid-JUN onward
- Aerosol Observing System data useful and valuable
  - Despite ~30% contamination from heavy vehicles on adjacent road (preliminary estimate from L. Russell's filters)
- Remarkable Success with Research Radars:
  - All four radars operated DEC 2015 – FEB 2016
  - MWACR went down by MAR 2016
  - KaSACR went down by SEP 2016
  - KaZR and XSACR operated throughout campaign

AWARE Aerosol Filter Collection
Organic Functional Group Composition





SIO Update 2/17/17:

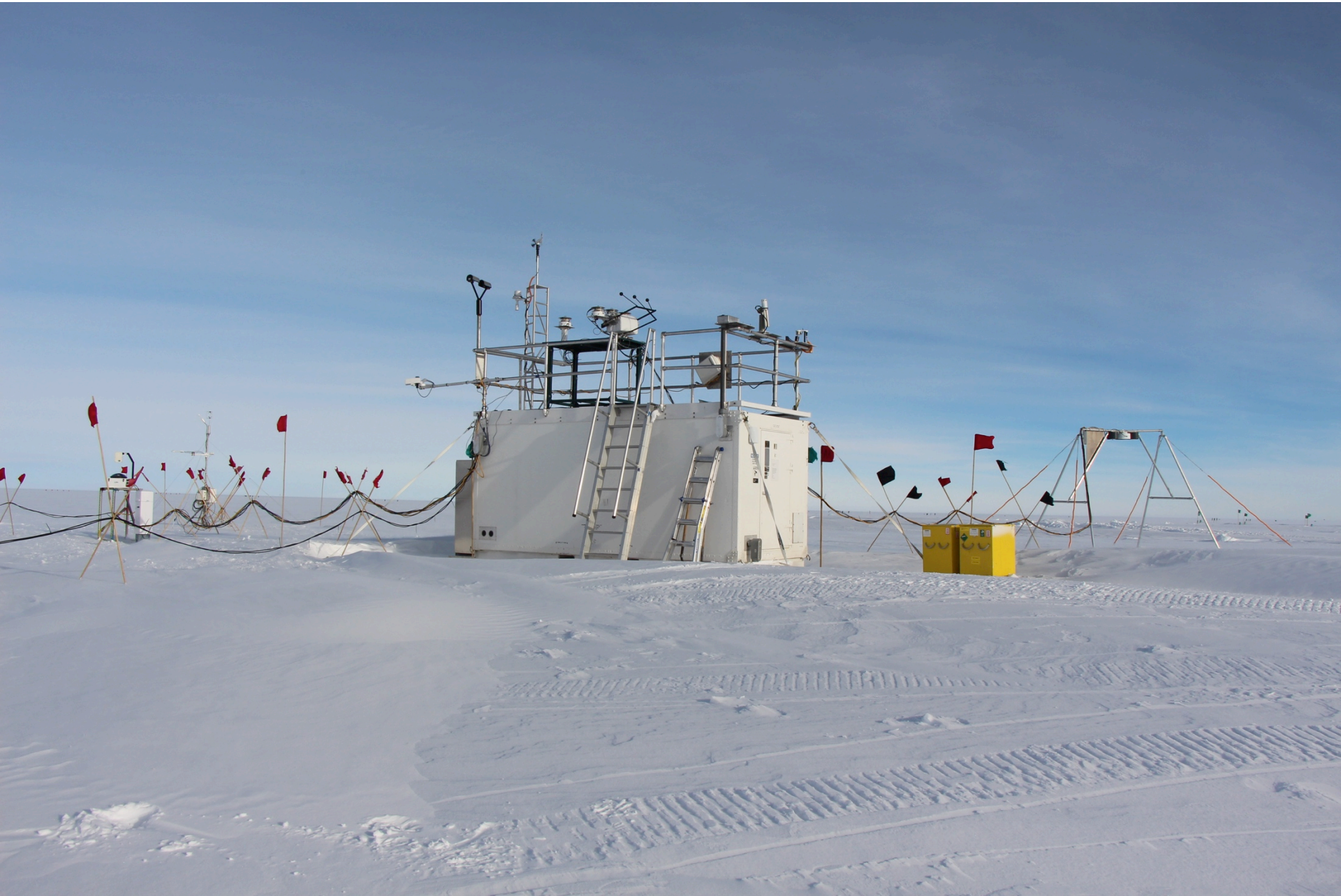
- 39 samples have been received to date
  - Completed FTIR;
  - Preparation for XRF underway;
  - Samples 10/1-12/31 expected soon.
- Typical OM ranges: 0.2 – 2 g/m^3
- Preliminary results
  - High alcohol group is likely marine;
  - Alkane group is partly anthropogenic

Savannah Lewis, Jun Liu, Lynn Russell (SIO)

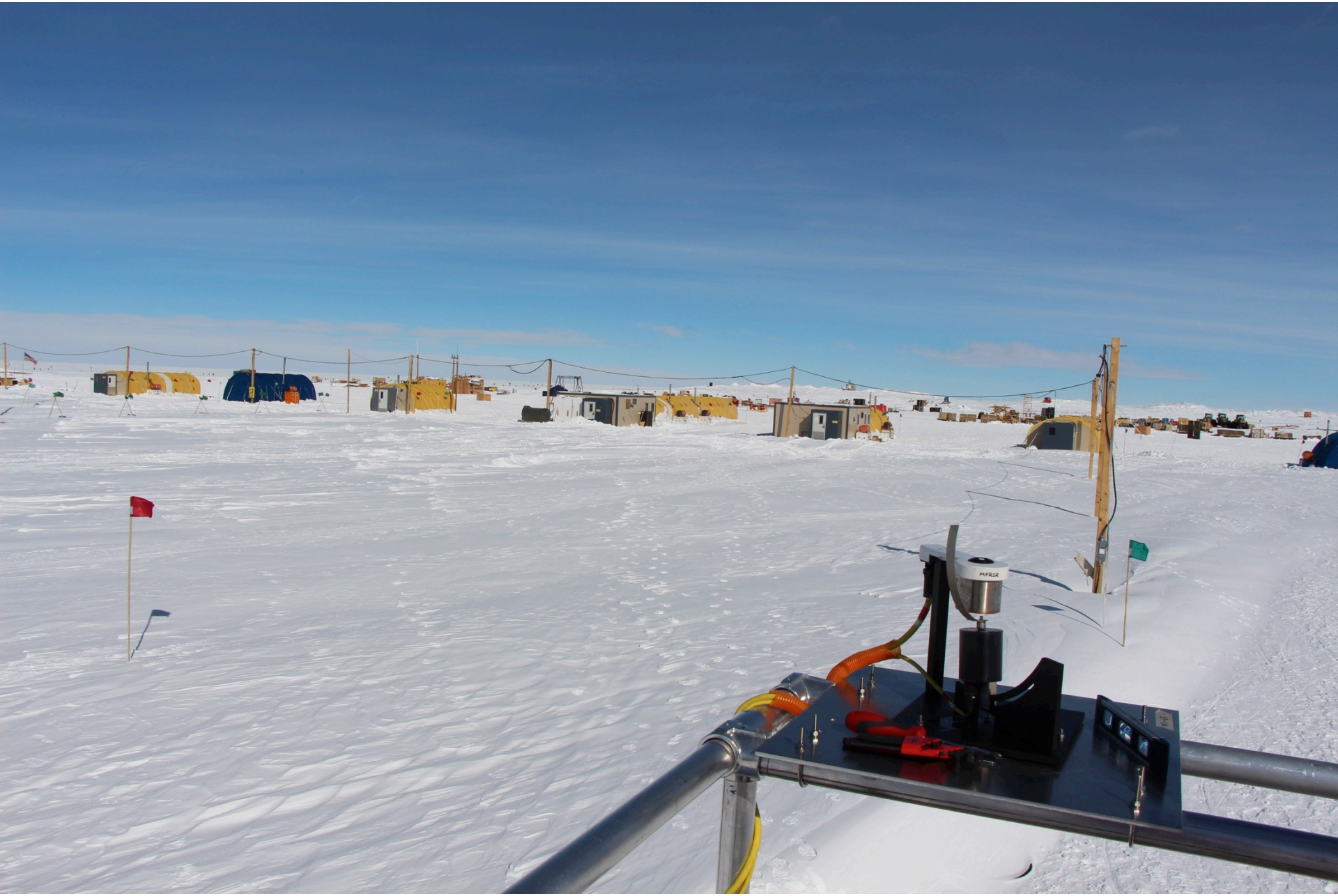
AWARE Arrival at WAIS Divide 02 DEC 2015

AWARE Logistics: One LC-130 Flight to WAIS

AWARE Skip Container at WAIS Divide



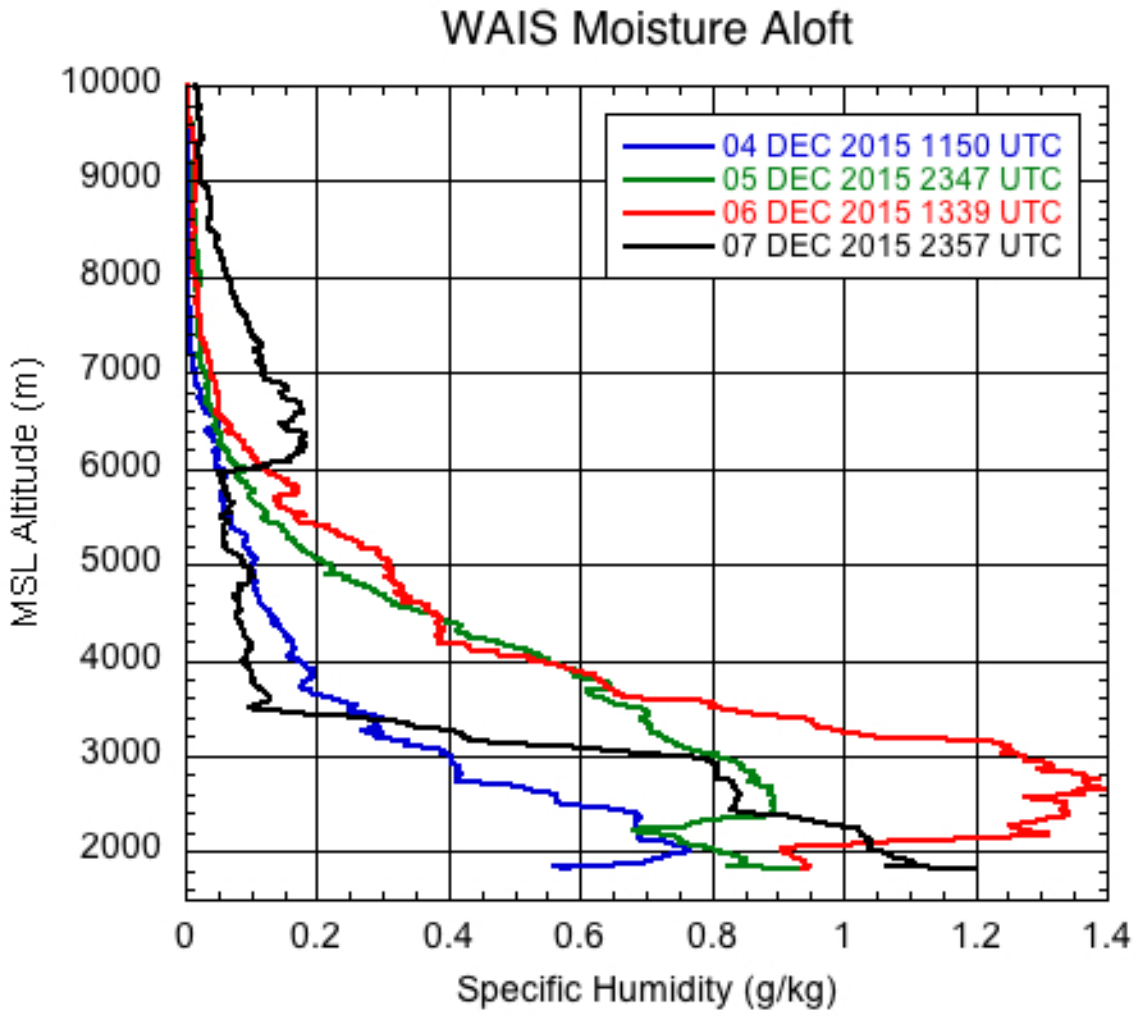
WAIS Divide Ice Camp – USAP Summer-Only Station



Equipment at WAIS Divide
(A USAP Summer-only Field Camp)

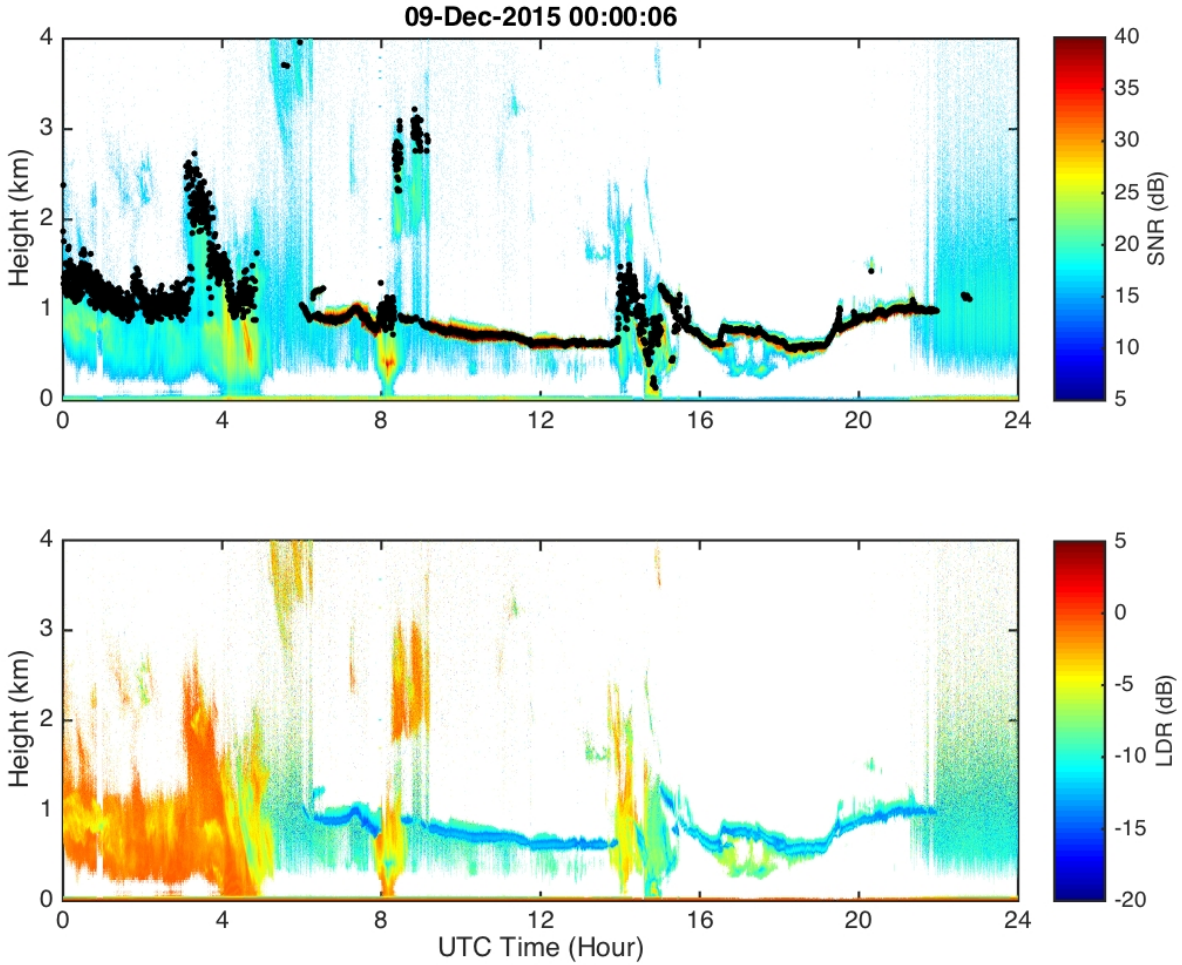
- Sondes 4 times daily
  - First in West Antarctica since 1967
- SKYRAD, GRDRAD, MFRSR, SEBS, MET, CSPHOT
- Micropulse Lidar (MPL) and Ceilometer
- G-band Vertical Profiling Radiometer (GVRP) and MWR
- Shortwave Spectoradiometer, 350-2200 nm
  - (ASD instrument from Scripps)
- Total Sky Imager (TSI)
- Campaign Start 4-7 December 2015
  - Sondes first, other instruments running later
  - Last day of measurements 18 January 2016

WAIS – First Sonde Data Since 1967



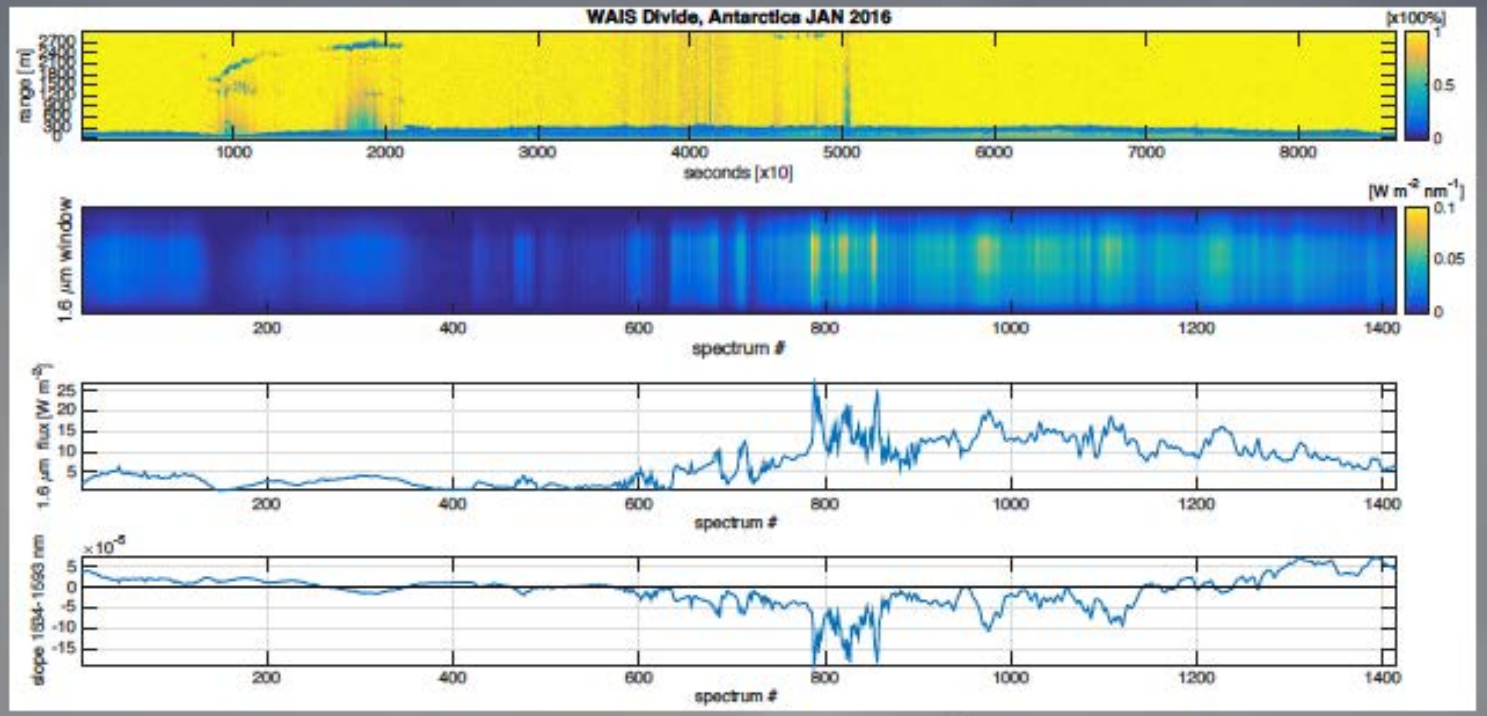
Storms in Amundsen-Bellingshausen Seas bring deep layers of warm air and moisture over West Antarctica – measured here during AWARE.

WAIS – Never before this advanced!

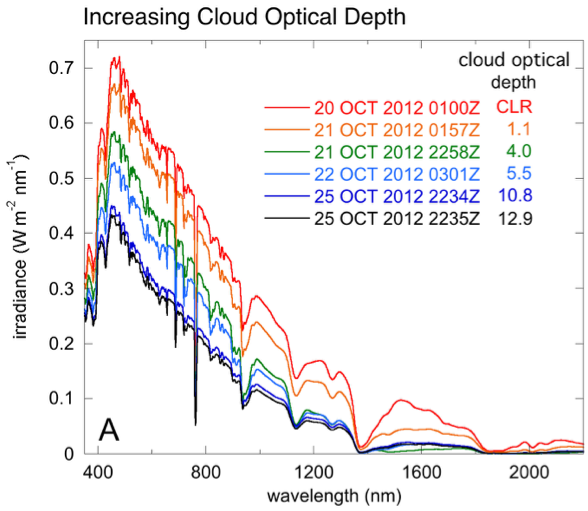


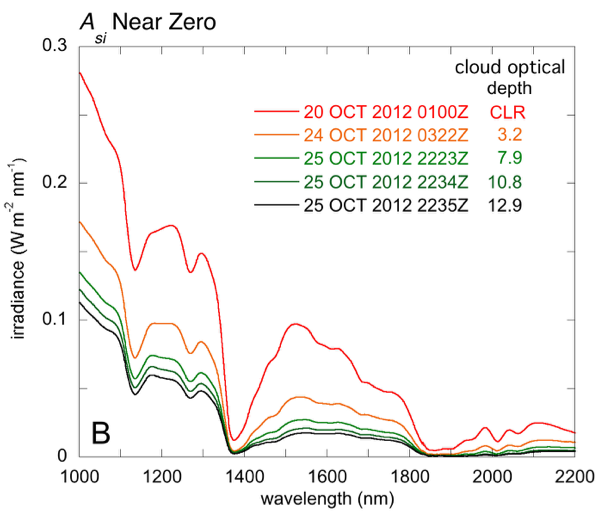
Micropulse lidar (MPL) polarized system shows cloud layer elevations along with their thermodynamic phase.

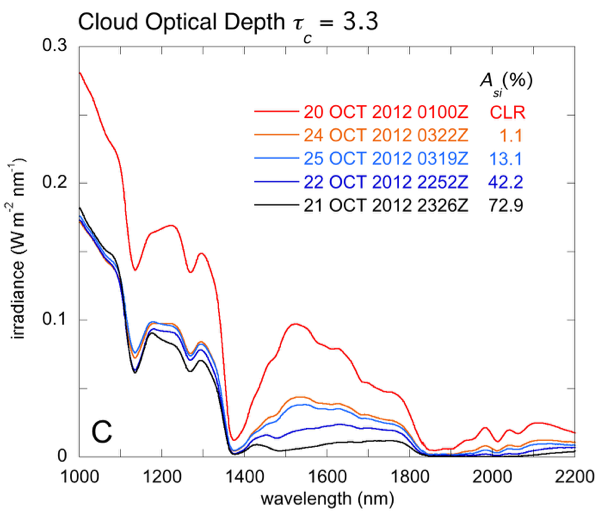
Then on 10 January 2016 a monster case study…

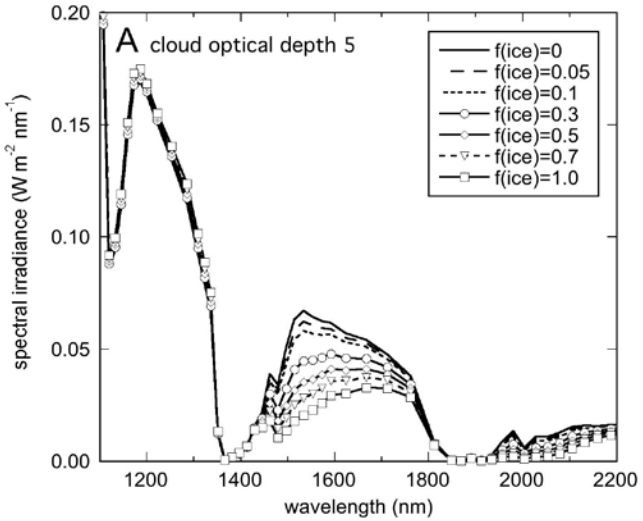

WAIS Divide, Antarctica JAN 2016
range [m]
seconds [x10]
[x100%]
1.6 μm window
spectrum #
[W m-2 nm-1]
1.6 μm flux [W m-2]
slope 1634-1593 nm
×10-5

Shortwave Spectroradiometer
Antarctic Data and RT Simulations



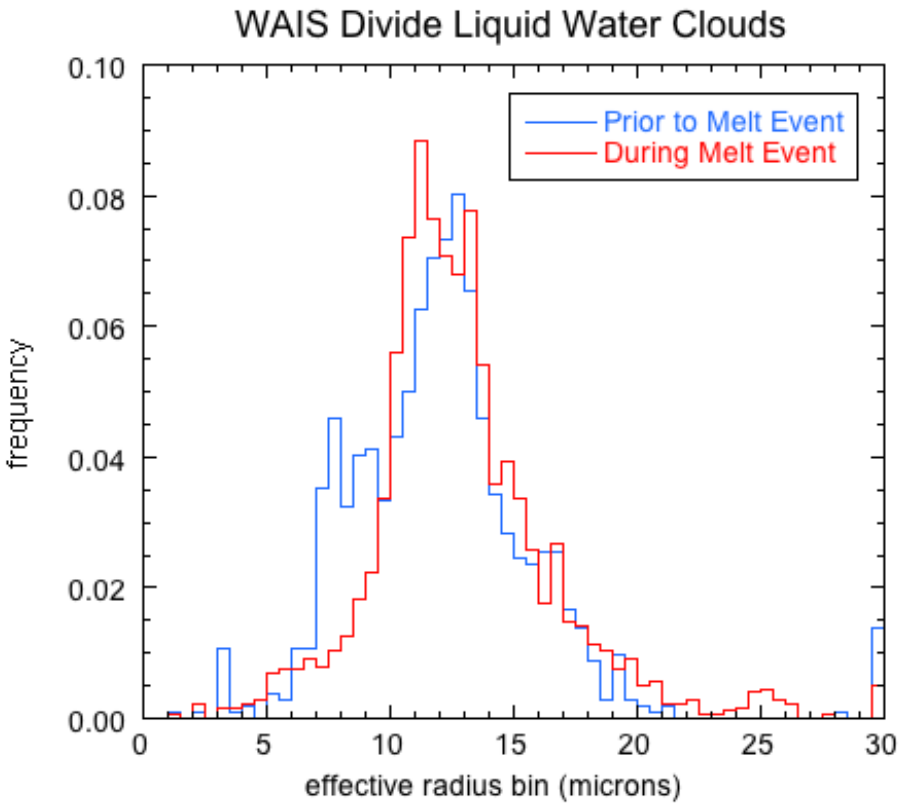


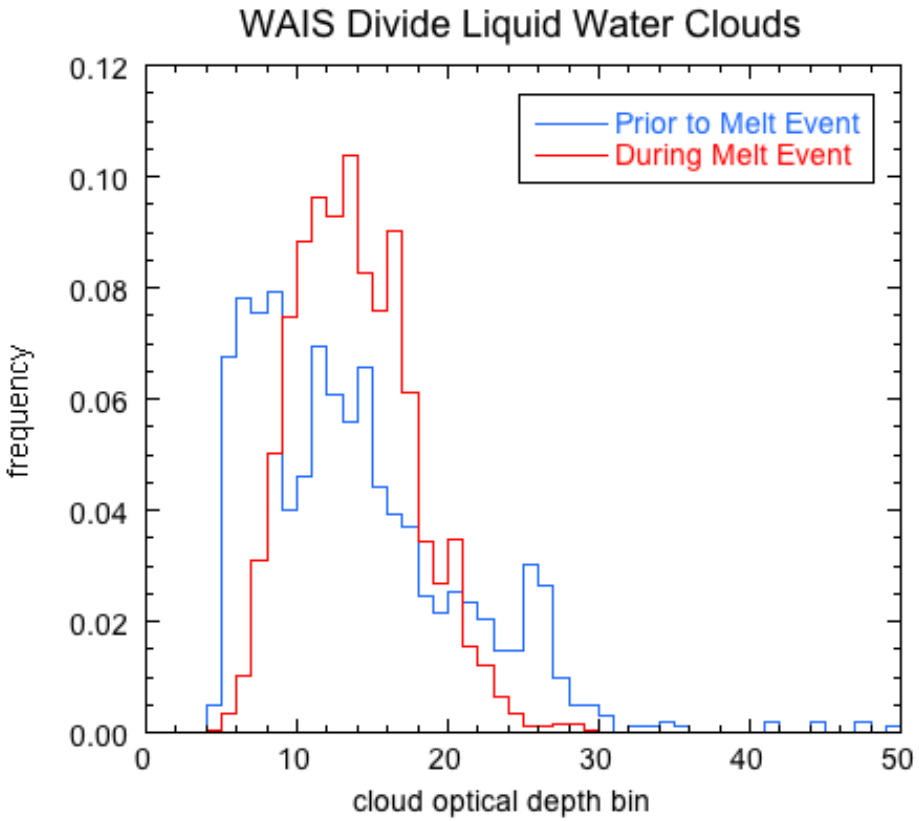




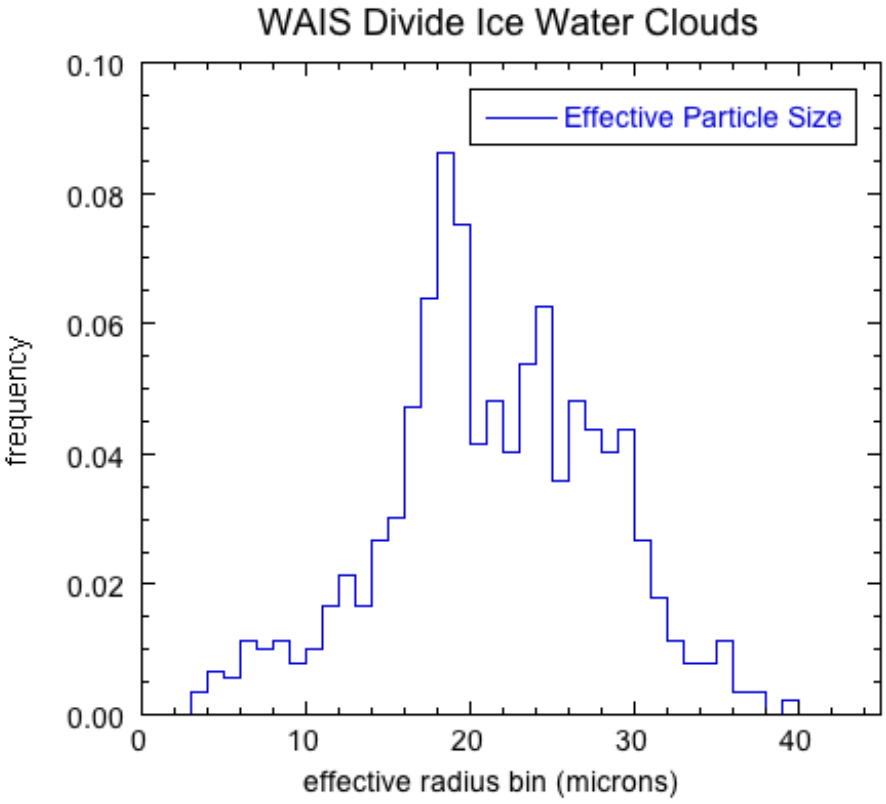
Simulation: Increasing ice fraction of the total optical depth.

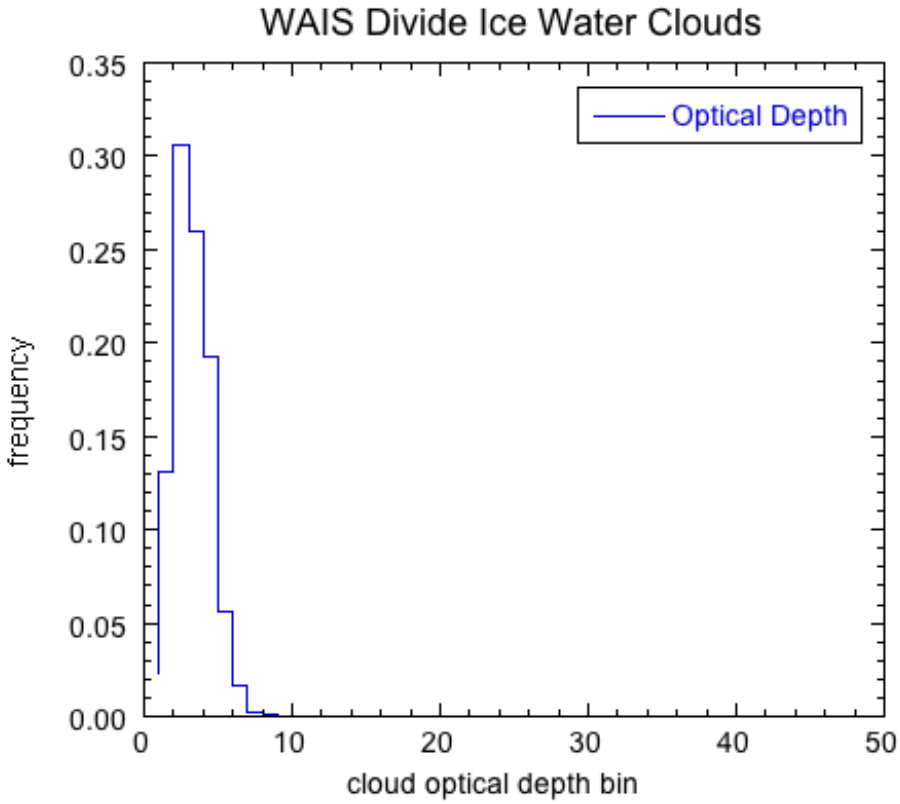
Shortwave Spectroradiometer Retrivals from WAIS Divide



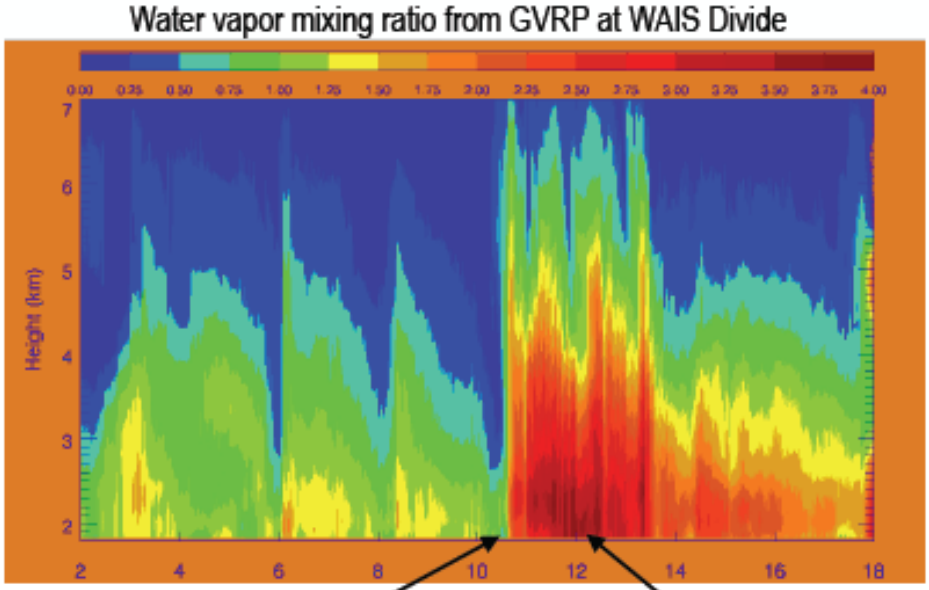


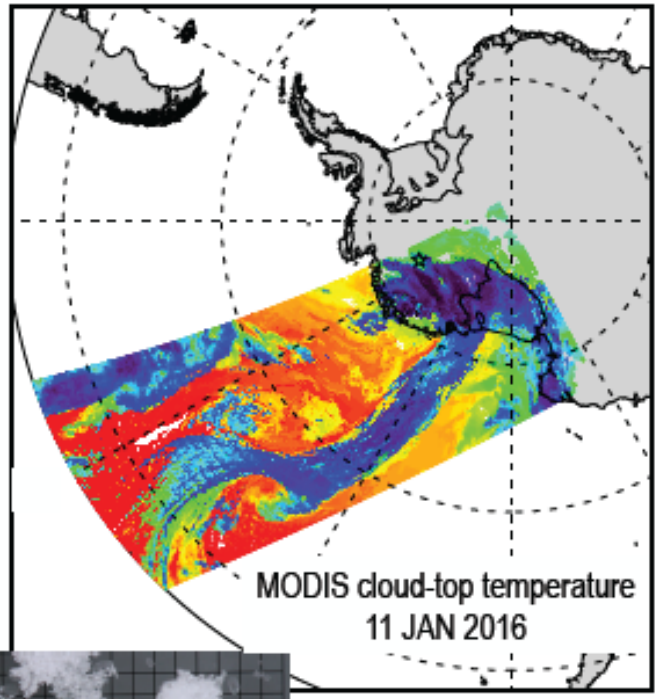
Shortwave Spectroradiometer Retrivals from WAIS Divide

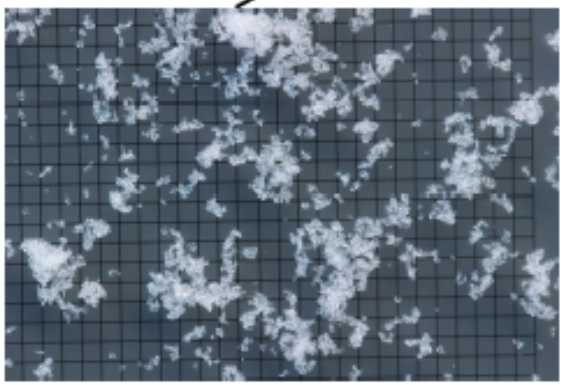




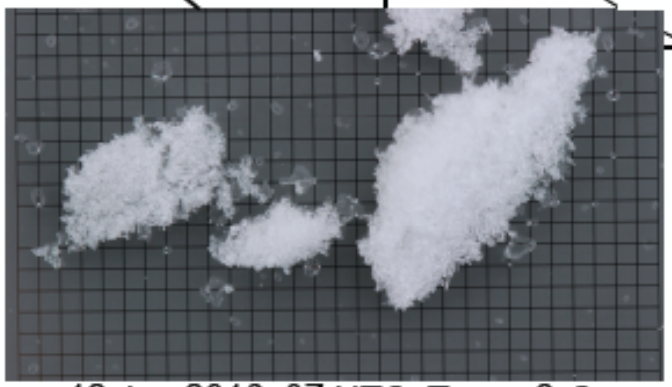
January 2016 surface melt driven by atmospheric river







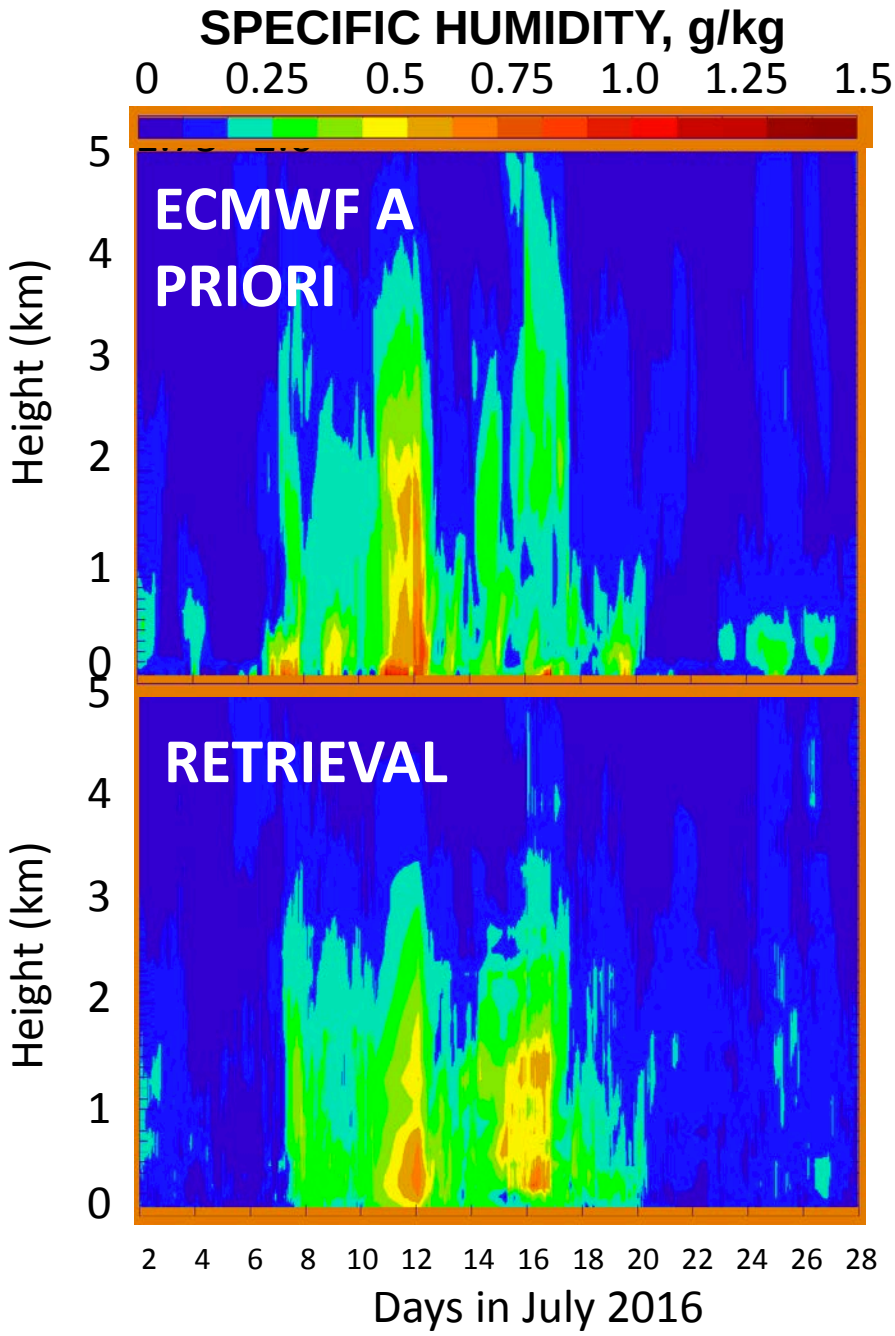
10 Jan 2016, 08 UTC, T_{2m} = -18°C



12 Jan 2016, 07 UTC, T_{2m} = -3°C

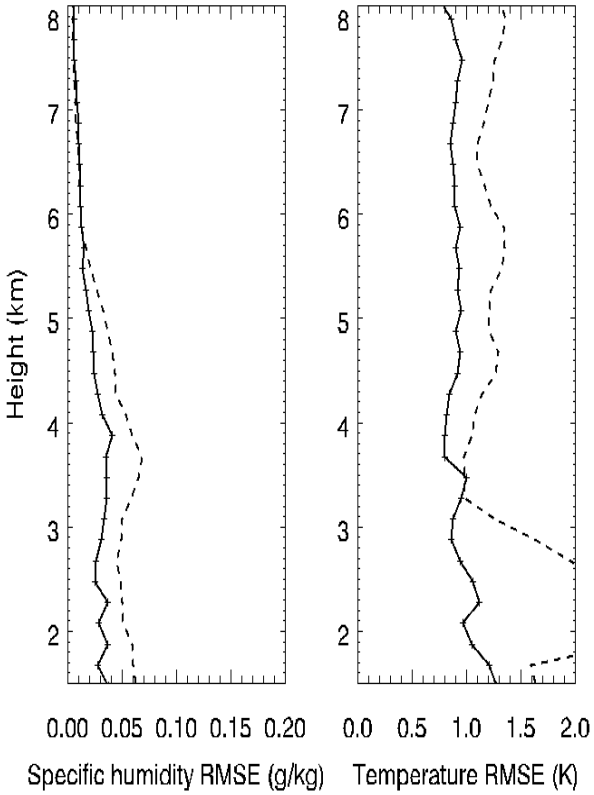
Daily snow grain macrophotographs

GVRP work from Maria Cadeddu, ANL

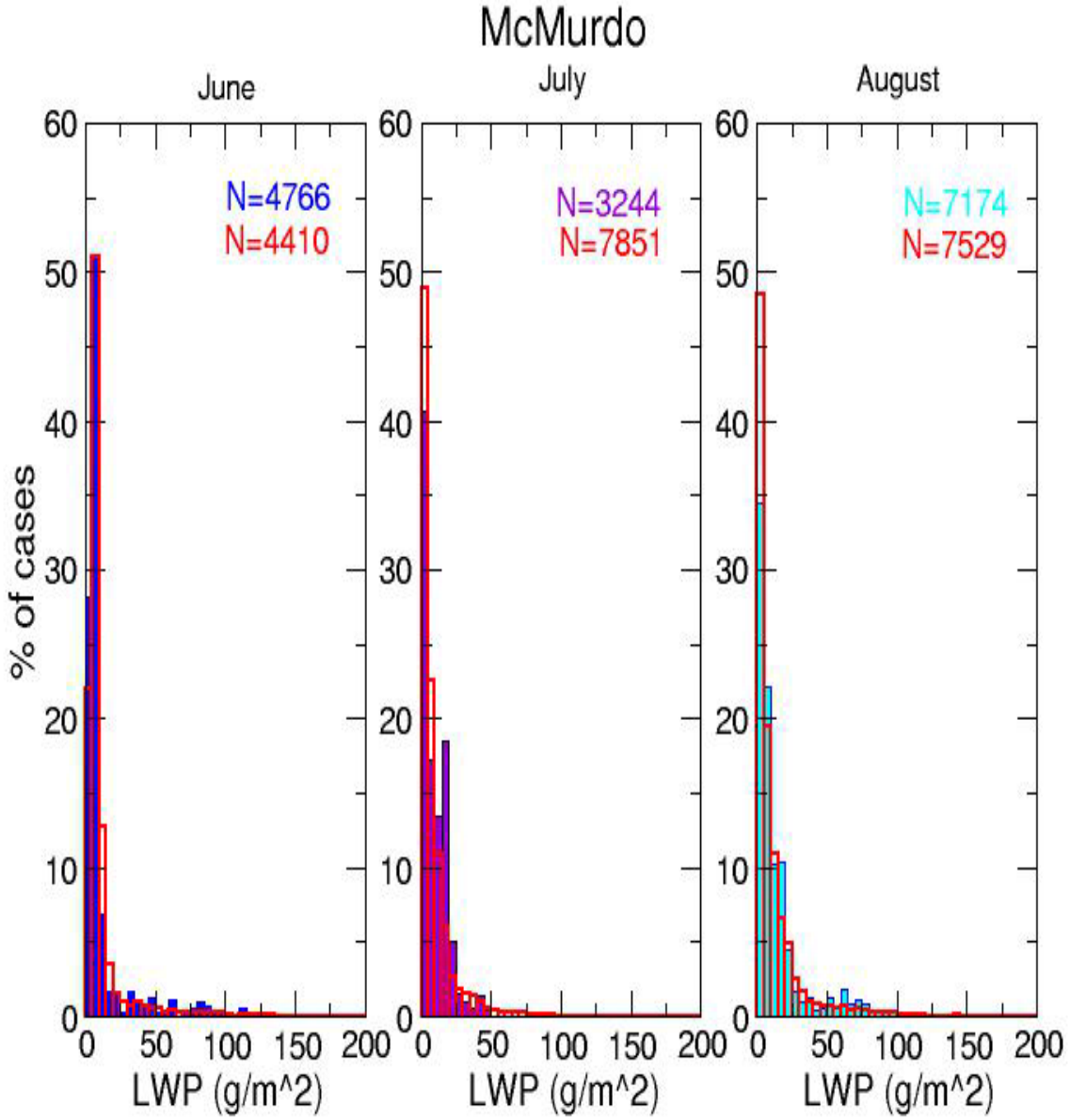


RMS ERROR

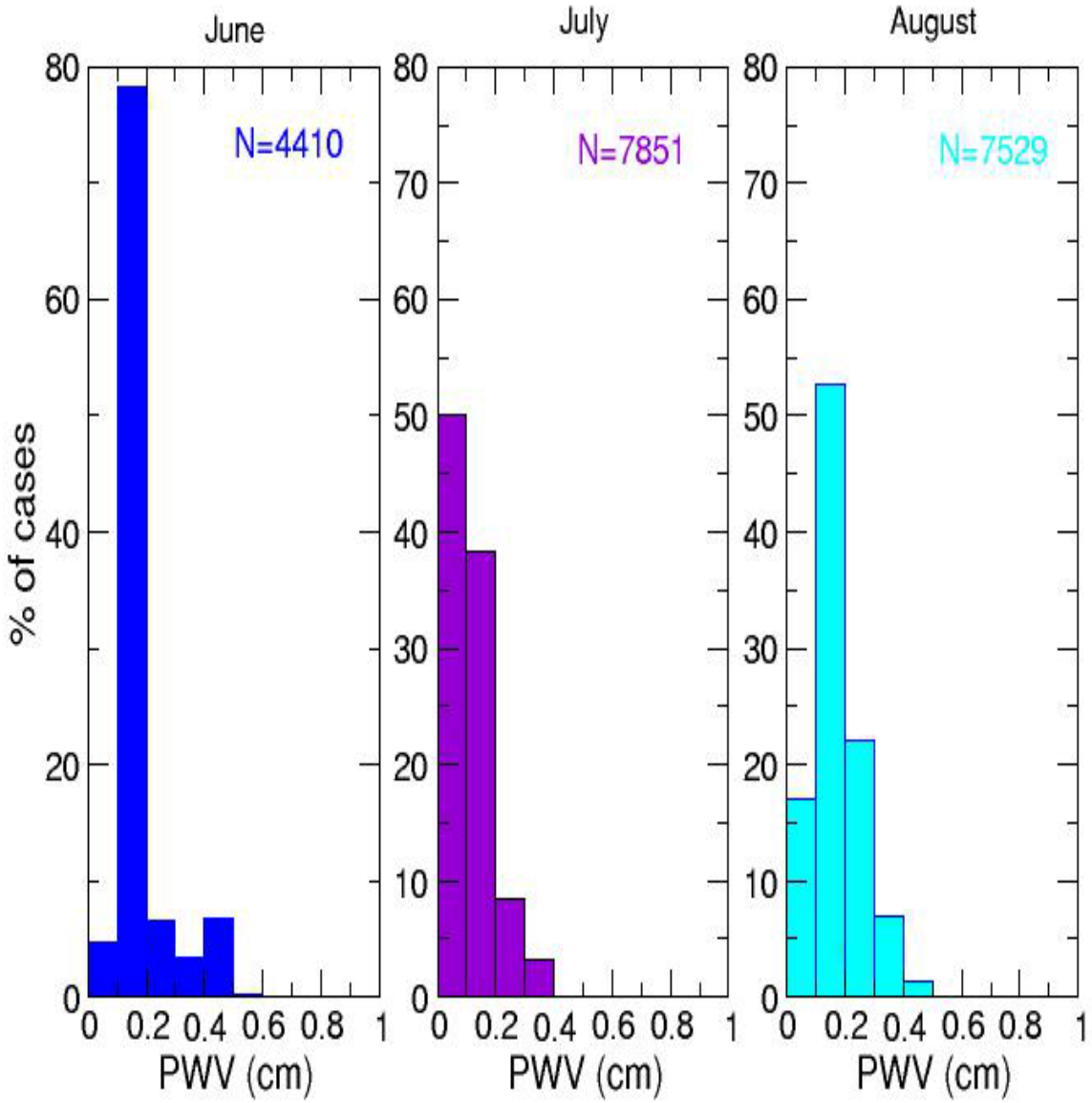
SOLID: RETRIEVAL
DASHED: A PRIORI



LWP occurrence at McMurdo June-August 2016
(GVRP work from Maria Cadeddu, ANL)

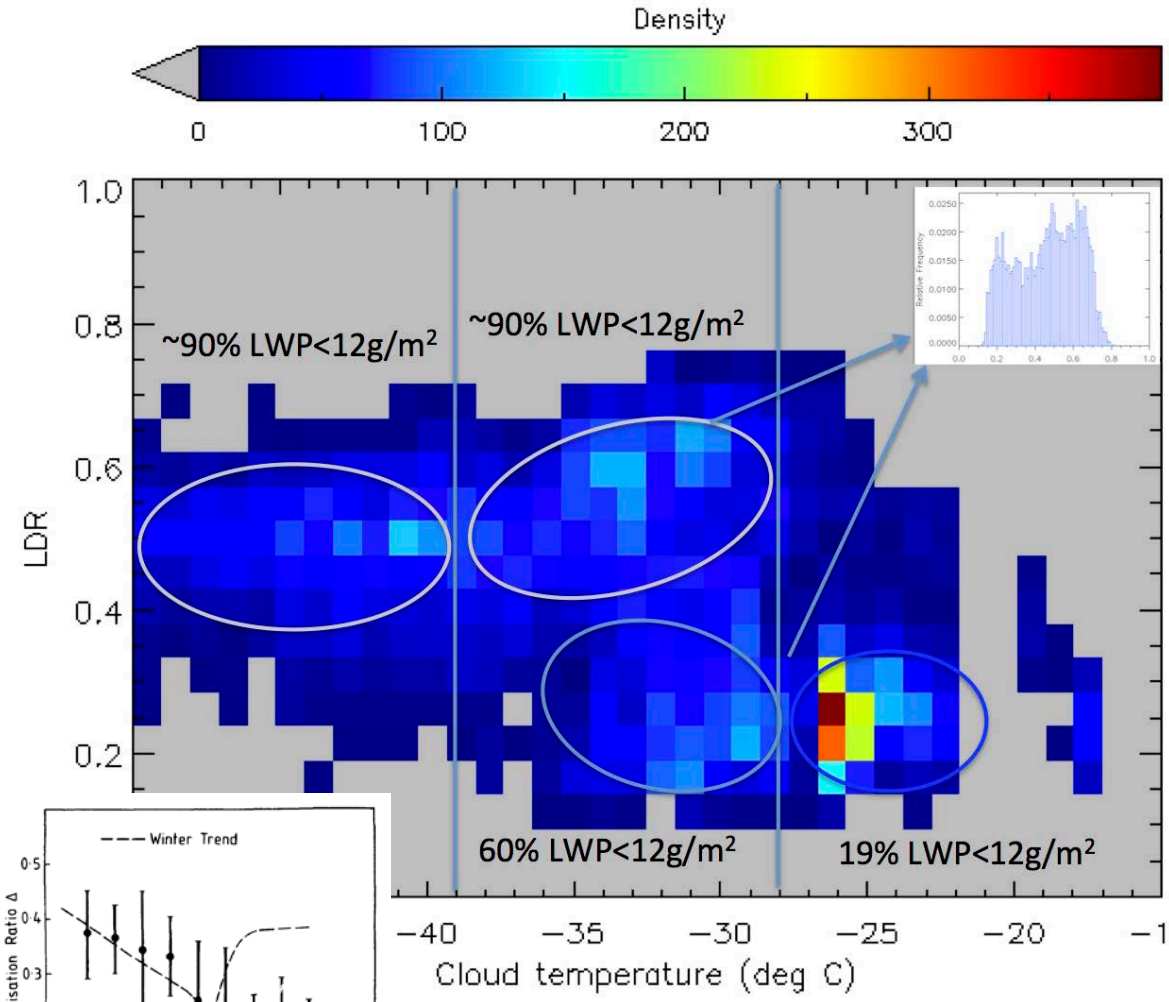


PWV occurrence at McMurdo June-August 2016
(GVRP work from Maria Cadeddu, ANL)



Cloud Phase from GVRP and MPL

Maria Cadeddu, ANL

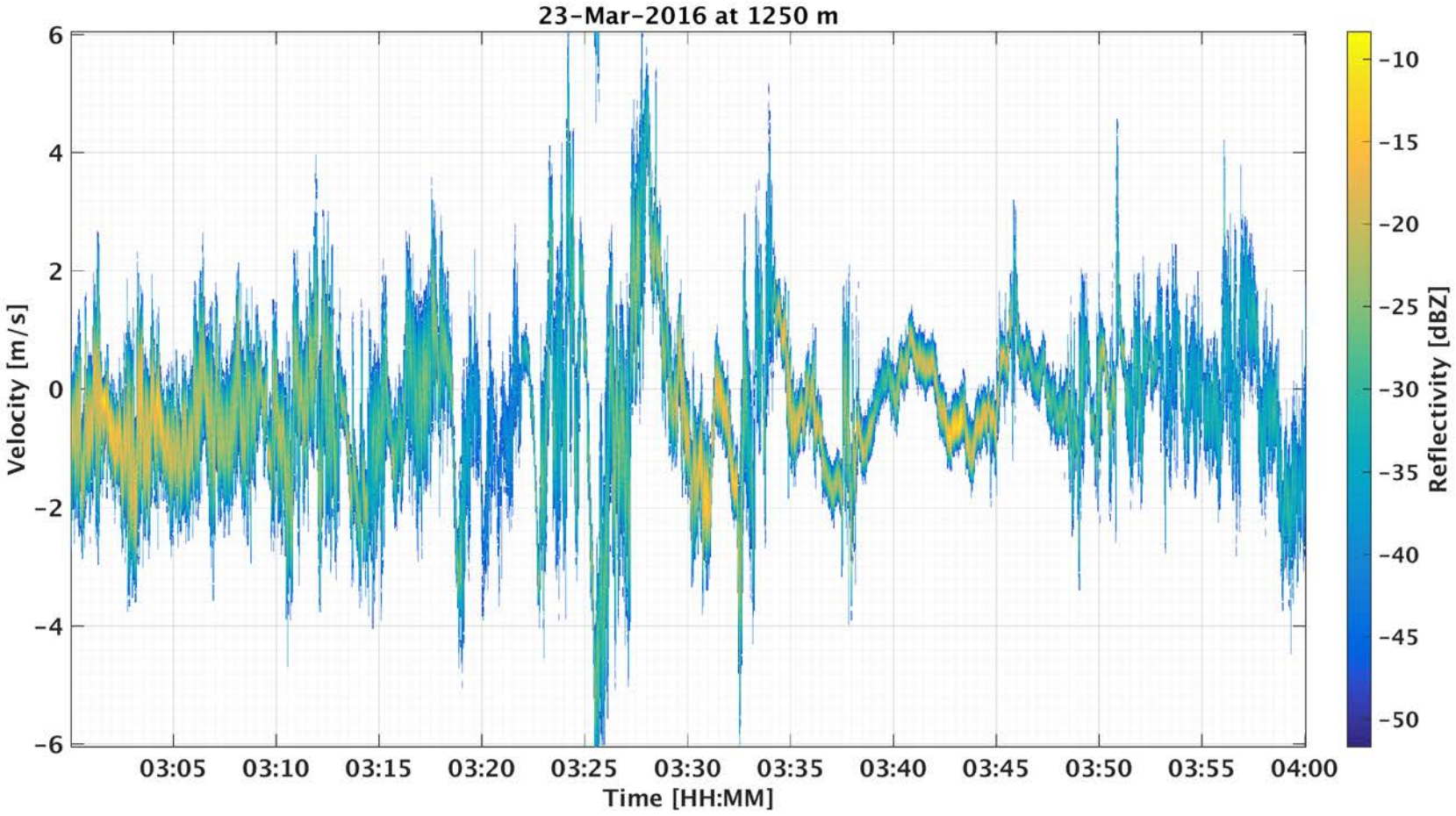


The bimodal distribution is similar to what is reported in Sassen, 1991, but at lower temperatures

If we combine the LDR-T scatterplot with LWP information we can identify the following regions:

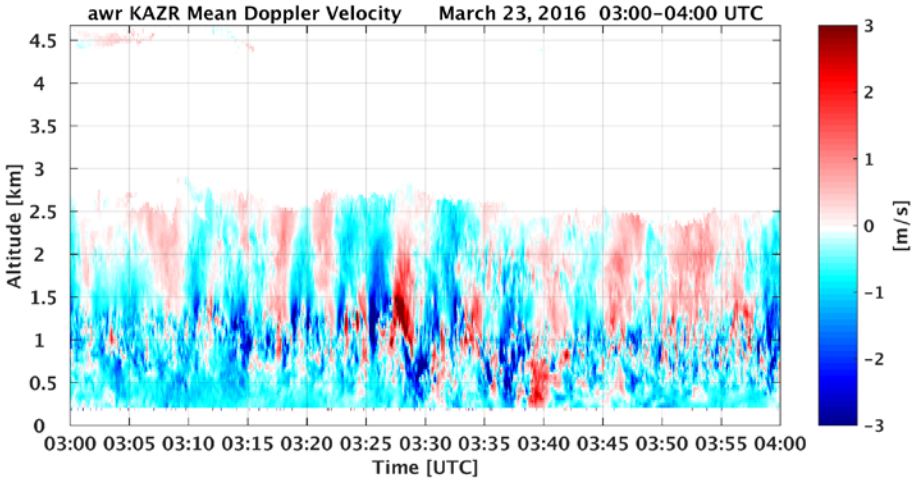
- T<-40 C: Has high LDR (~0.5) and very low LWP- mostly ice clouds.
- -38 < T < -28 C: It shows a bimodal distribution of LDR with very high LDR values (> 0.5) and very low LWP. This region may be mostly ice clouds, but it appears to have higher LDR than the clouds with T< -40 C. In the same T region clouds with LDR < ~0.4 appear to have higher LWP (may be mixed-phase clouds).
- T>-28 C: This region has mostly LDR< 0.4 and higher LWP values.

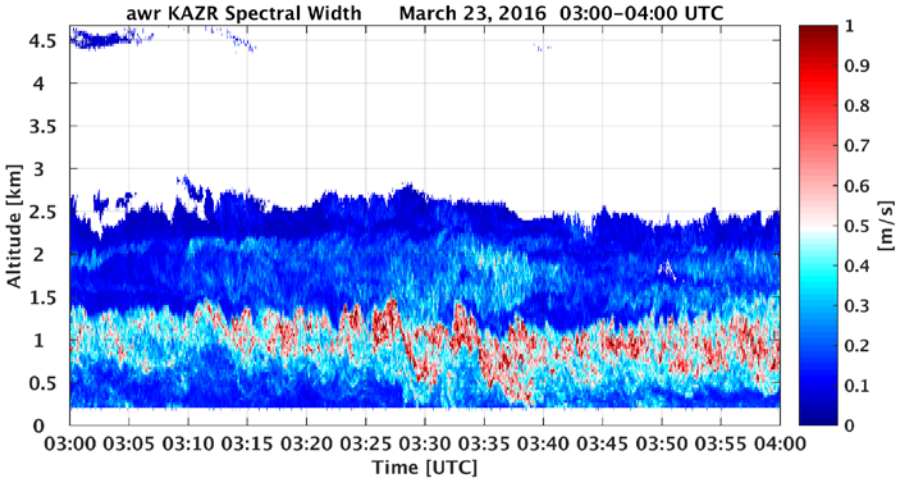
Alien World:
Penn State Preliminary Wave Activity Cases

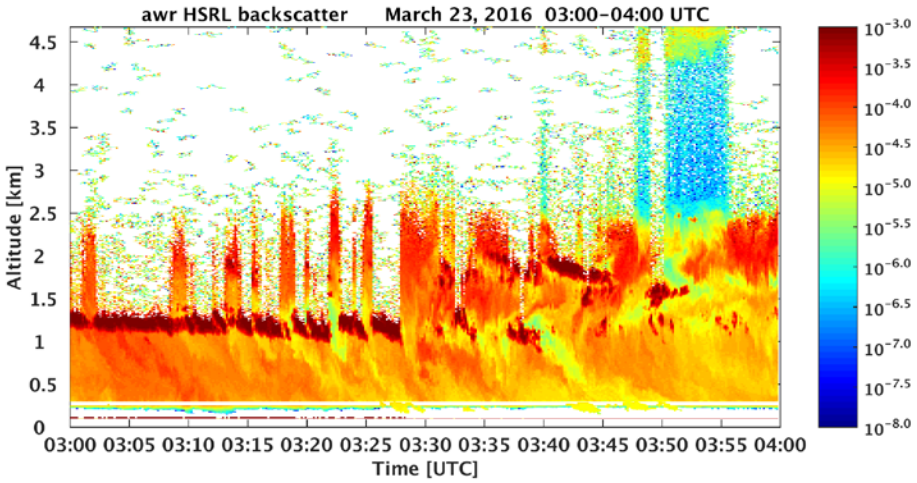


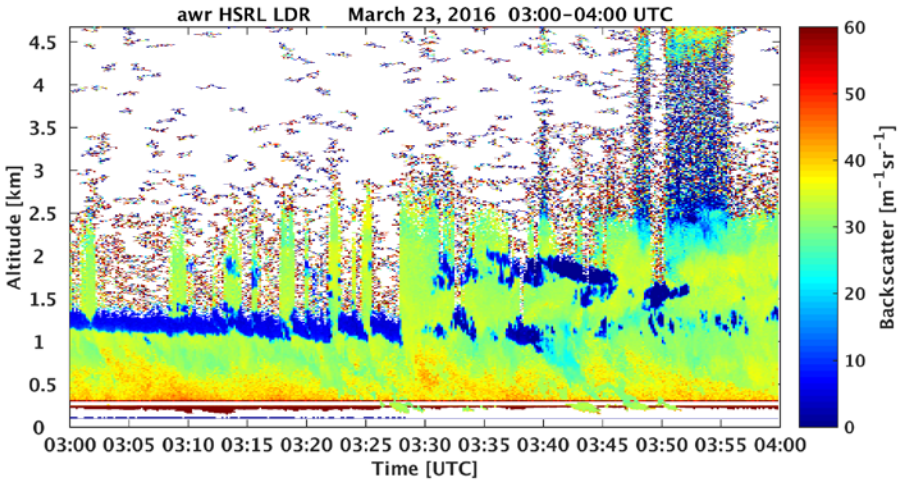
Ross Island is not Barrow!

Penn State Preliminary Wave Activity Cases









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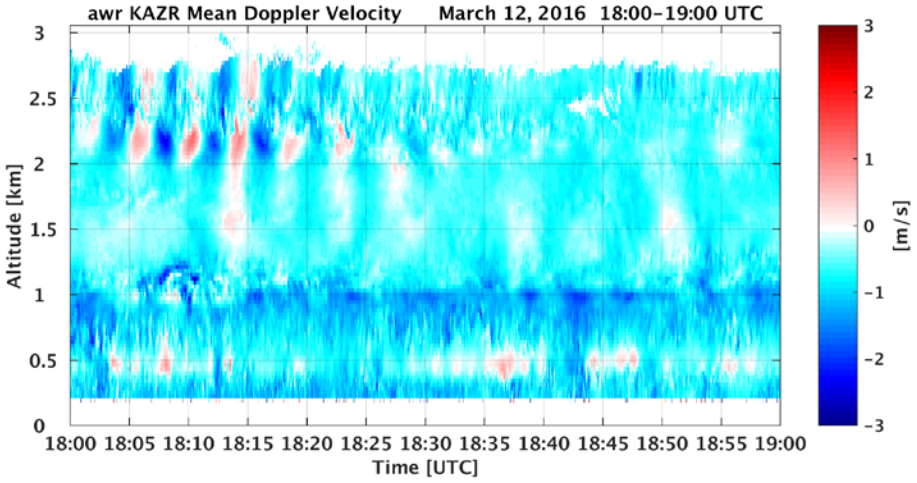
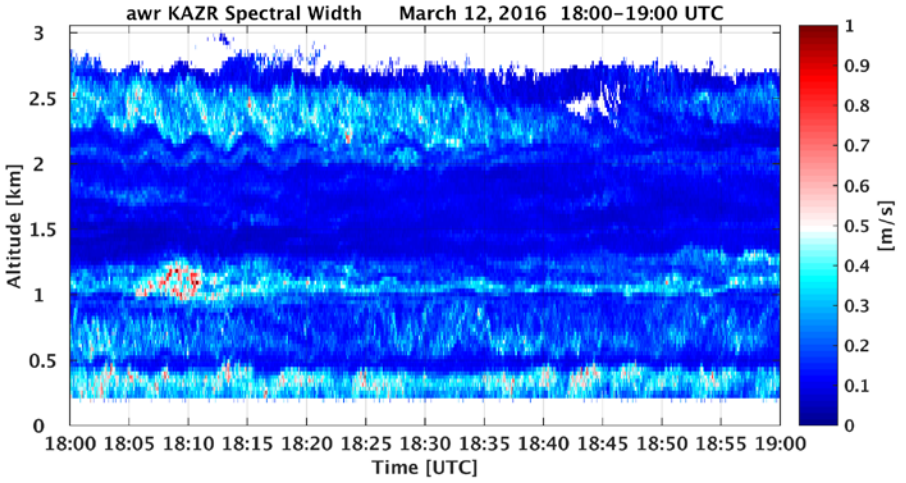
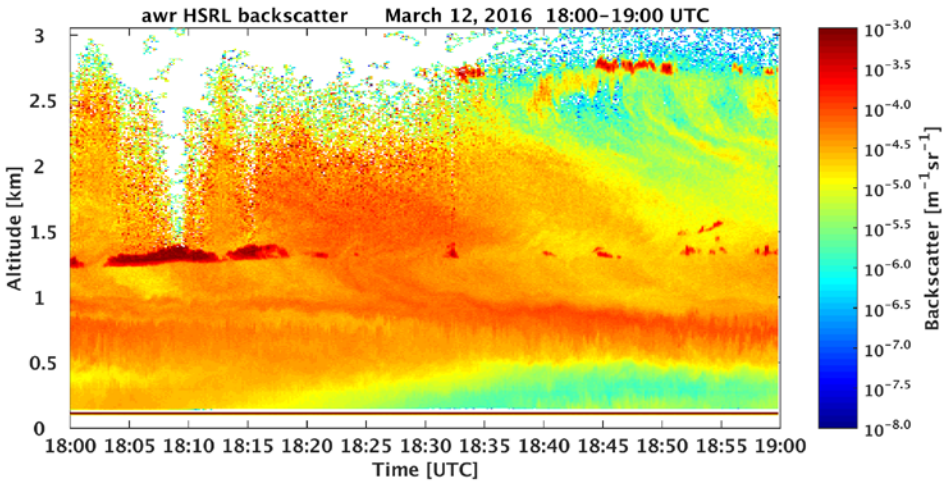
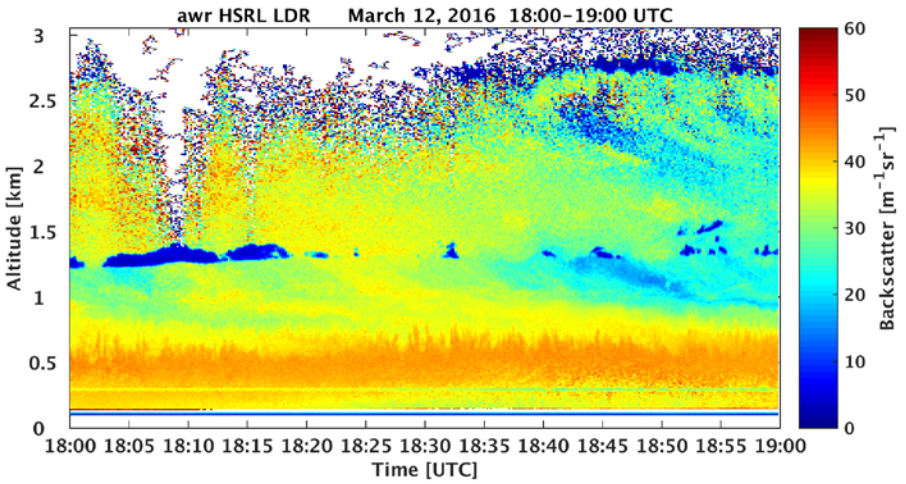
Penn State Preliminary Wave Activity Cases





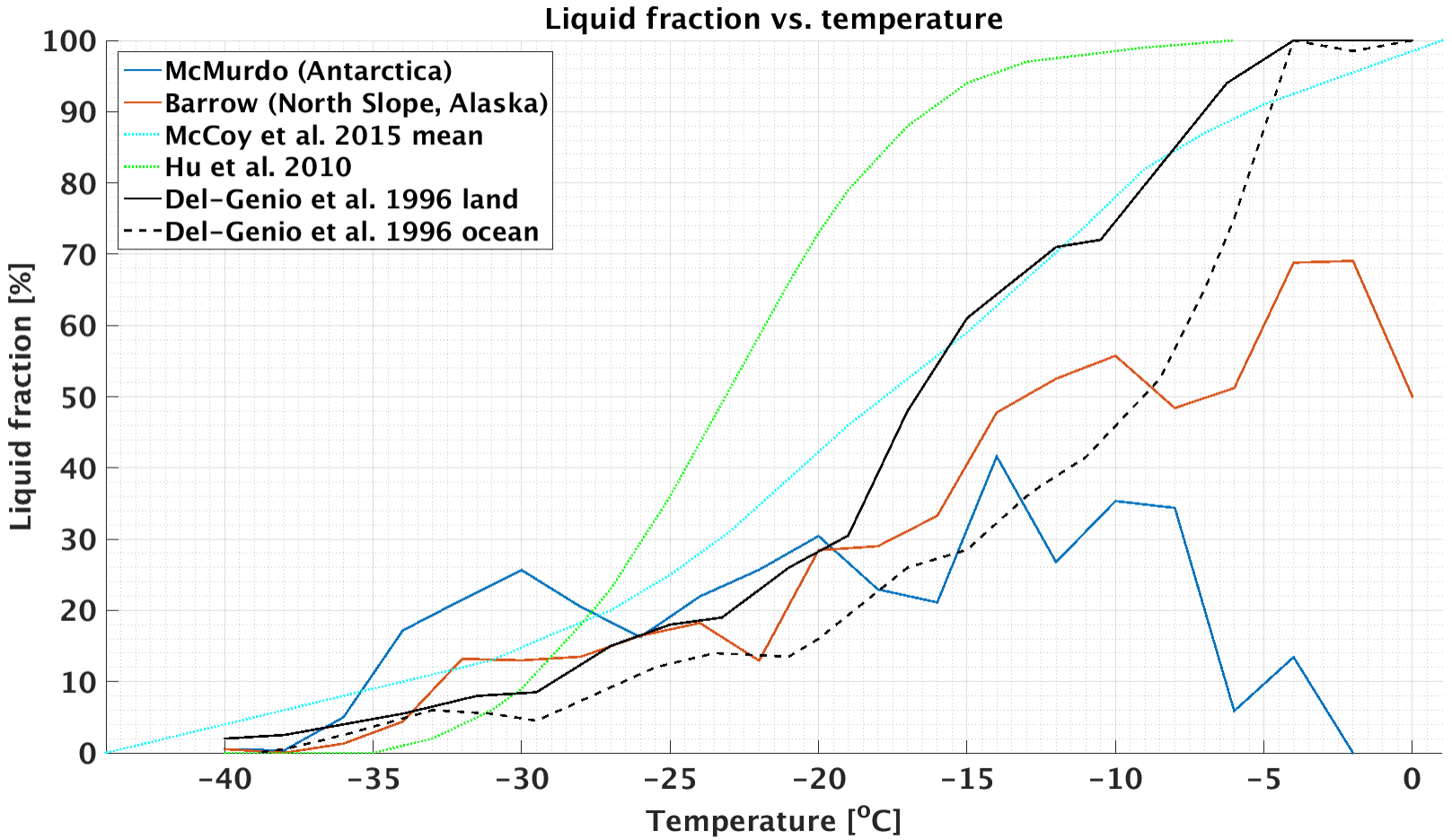




Ross Island is not Barrow!

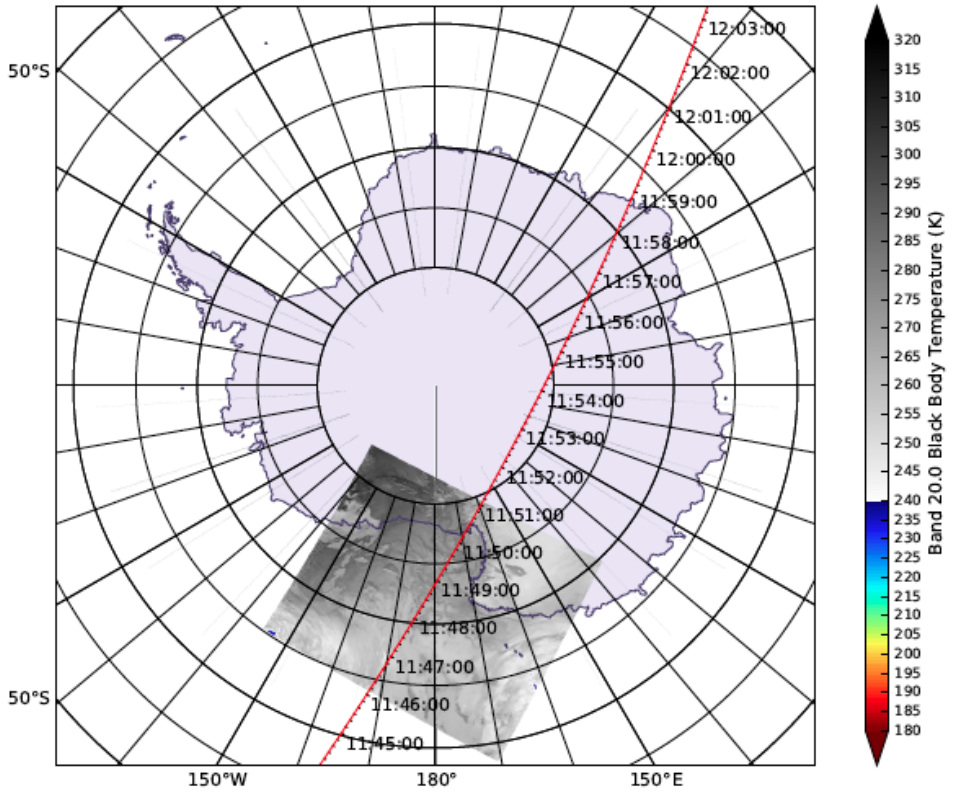
Penn State's First CosRay Results

from HSRL, Silber & Verlinde 2017 in prep.

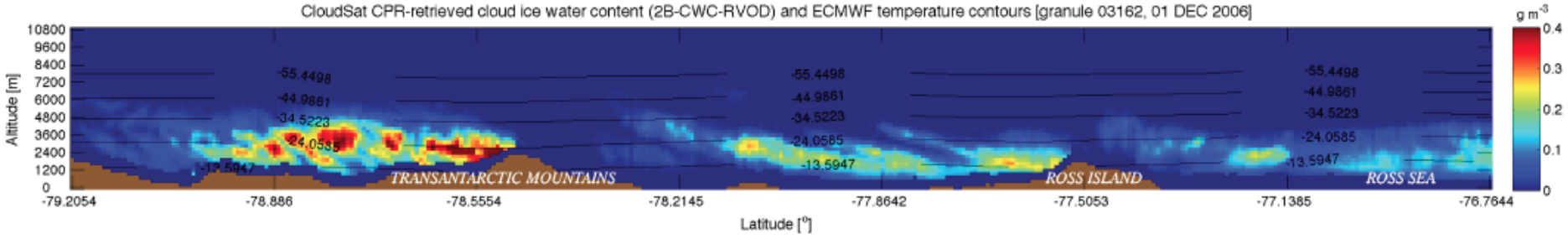


NASA CloudSat Comparison: Ross Island with Arctic Sites

(Scott & Lubin 2016, GRL)

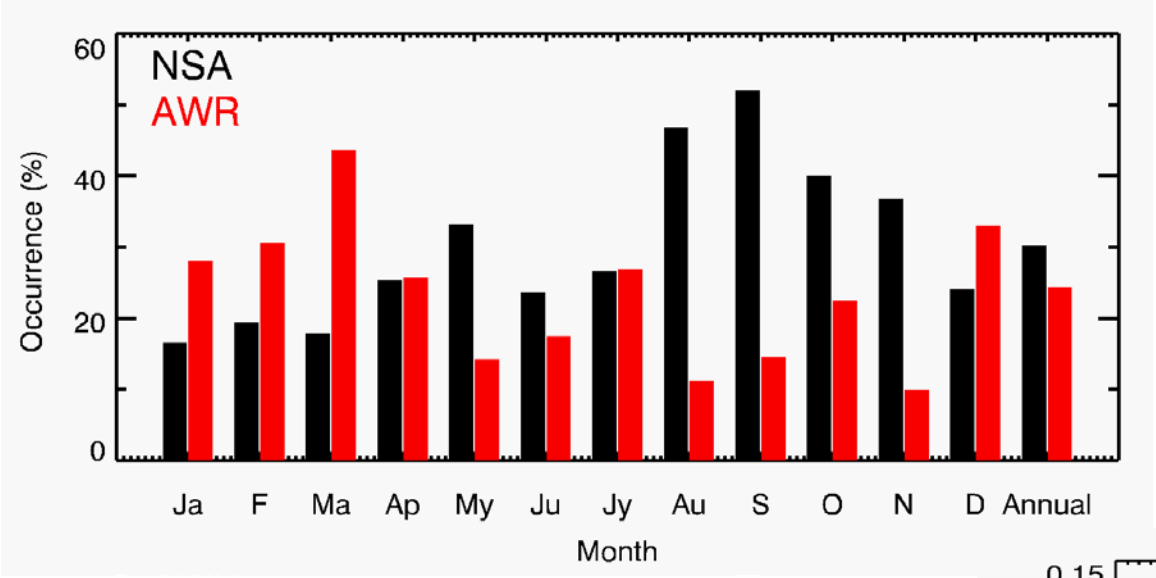


- CloudSat/CALIPSO data reveal that orographic forcing of cloud cover and high IWC is pervasive around the Antarctic coast.
- Ross Island has unique manifestations of polar cloud microphysics, very distinct from the Arctic.
- Studies of these contrasting clouds are very relevant to Antarctic climate modeling needs.



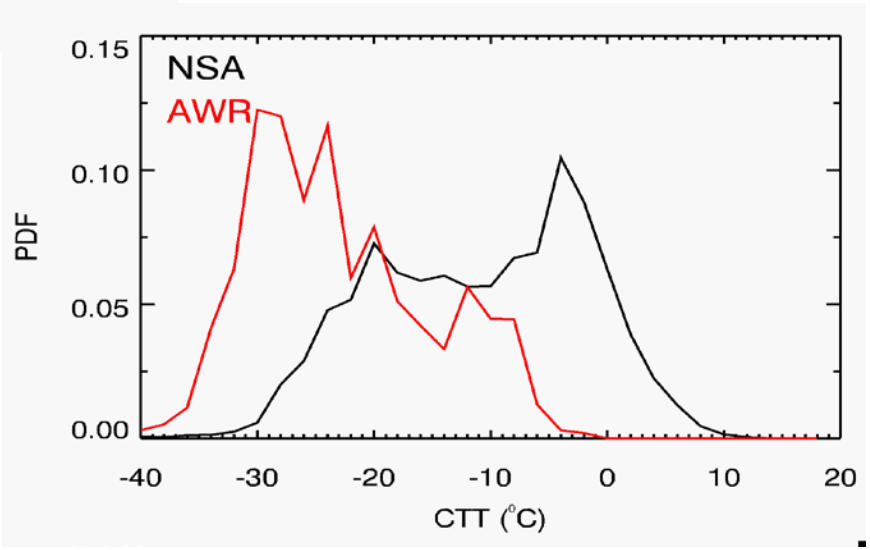
Stratiform Cloud Occurrence

See Damao Zhang's poster



Ross Island is not Barrow!

- Annual stratiform cloud occurrence of 30% at NSA and 24% at AWR.
- Maximum occurrences during the Summer season at both NSA and AWR.
- Most stratiform clouds are within the temperature range between -40 and 0 ^{o}C.



Concluding Remarks: Science Team Current Activities

- D. Lubin (SIO), A. Vogelmann (BNL), M. Cadeddu (ANL)
  - Surface radiation & energy budget, and cloud optical properties from *some* instruments (SW radiometer, MPL, GVRP, SKYRAD).
- J. Verlinde and I. Silber (Penn State)
  - Physical meteorology and empirical cloud microphysics in radar and HSRL case studies.
- D. Bromwich and J. Nicolas (Byrd Polar)
  - Synoptic and mesoscale meteorology for understanding context of AWARE data (e.g., WAIS melt event completed).
- L. Russell (SIO)
  - Characterizing Ross Island aerosol annual cycle from AOS and weekly filter samples.
- Team – Pending ASR/ARM Award late 2017
  - Evaluation of current cloud microphysical parameterizations for Antarctic conditions using Polar WRF.

Most Important Slide of All

- ★ AWARE is the most complete and advanced atmospheric and climate science experiment yet fielded in Antarctica.
  - Should have great relevance for polar process study and model improvement but going forward in Antarctica:
  - Don't wait for the next big AWARE-type campaign,
  - Instead consider upgrading capability all around the continent with moderate-cost remote sensors (e.g., SW spectral, MPL, MWR, zenith radar) – Some very powerful techniques available!
- ★ AWARE data are *YOUR* data…
  - AMF2 and WAIS Divide data go into ARM archive as soon as they are quality-controlled by ARM instrument mentors.
  - Publicly available worldwide with *no* proprietary period for AWARE PIs.
  - No need to "collaborate" with AWARE Science Team when using AWARE data.
  - Interested in Antarctic atmospheric science - go for it! (Just acknowledge ARM per archive website instructions).
  - Archive website: www.arm.gov