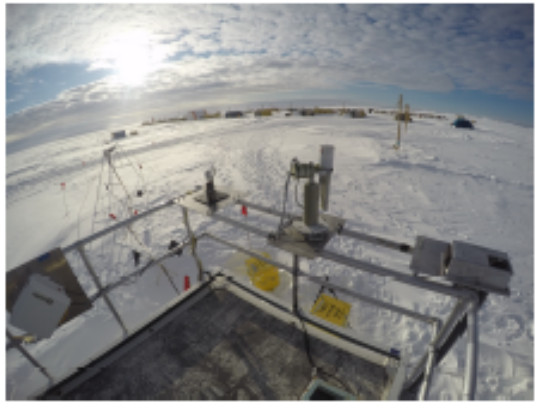
ARM West Antarctic Radiation Experiment

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

2017 ARM/ASR Joint User Facility PI Meeting
Tysons, VA 16 March 2017

Agenda

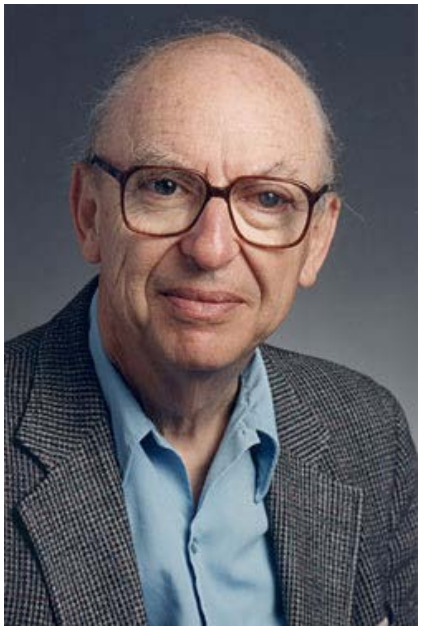
- Executive Summary
- Scientific Motivation
- Potential Case Studies for Modeling Community
  - A Monster Case Study from WAIS Divide – *January 2016 Surface Melt*
  - The Alien World of Ross Island – *fascinating cases in radar data*
- Concluding Remarks

An Early Career Mentor and Role Model:

James Arnold (1923-2012)

Founder of UCSD Chemistry Department

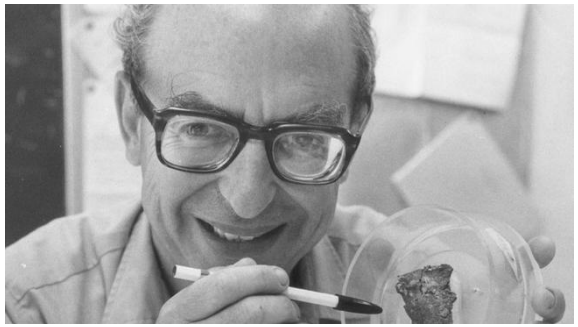
A great storyteller…



- 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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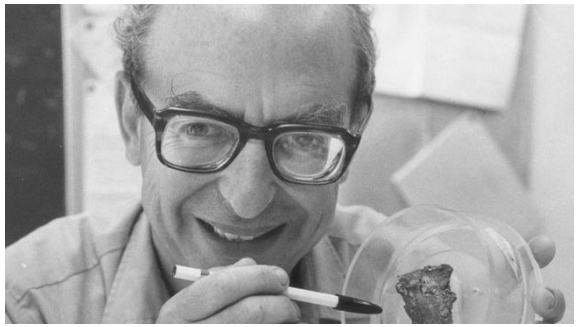

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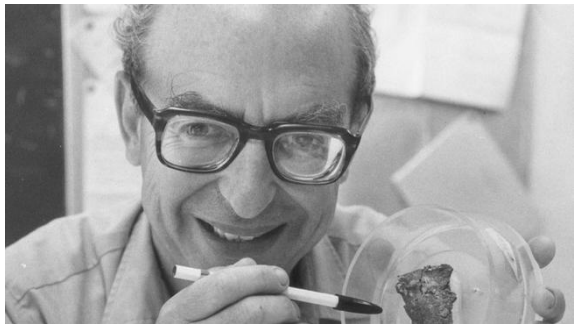
Astronauts all write in their notes

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.

AWARE Site Locations

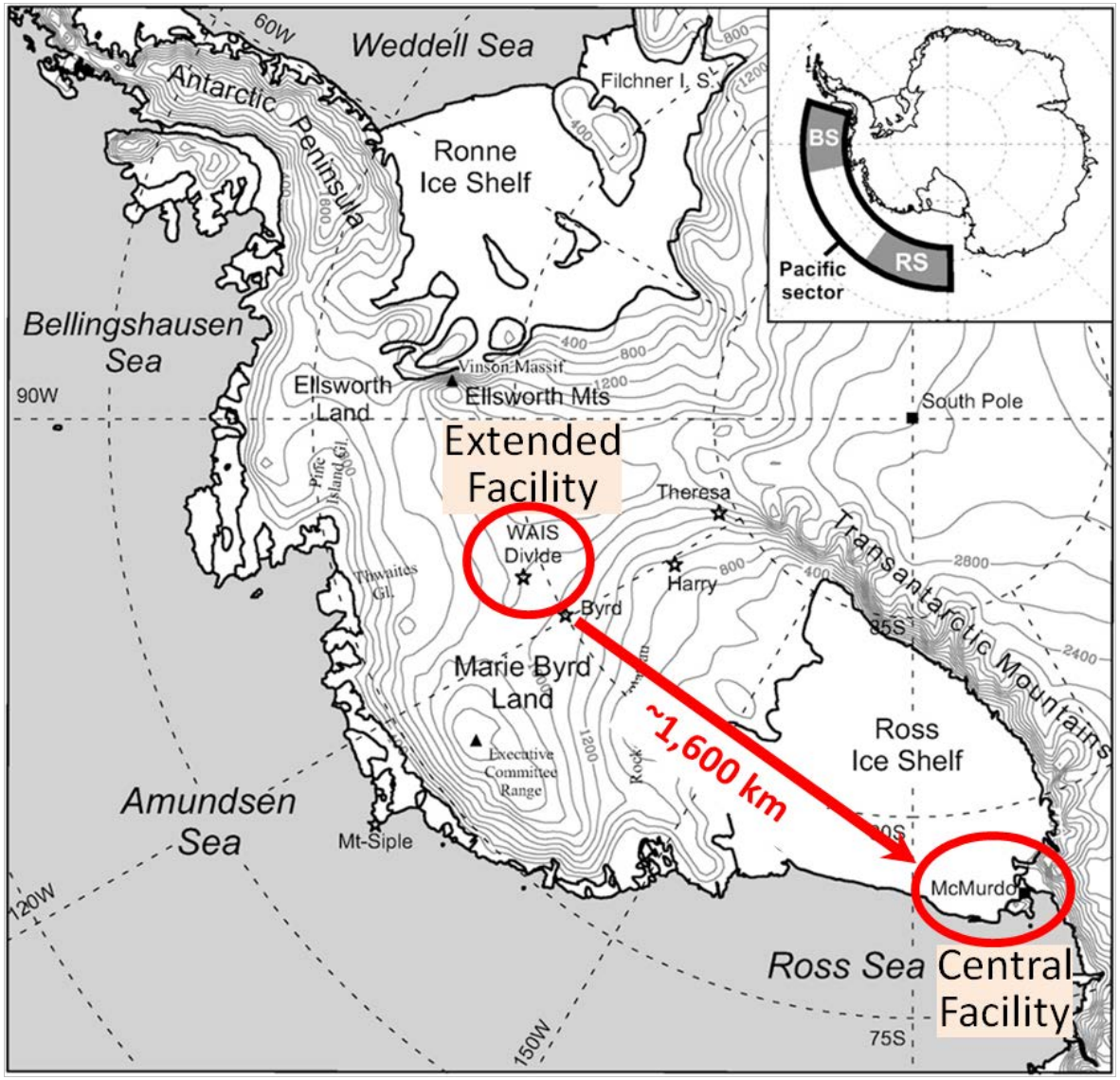
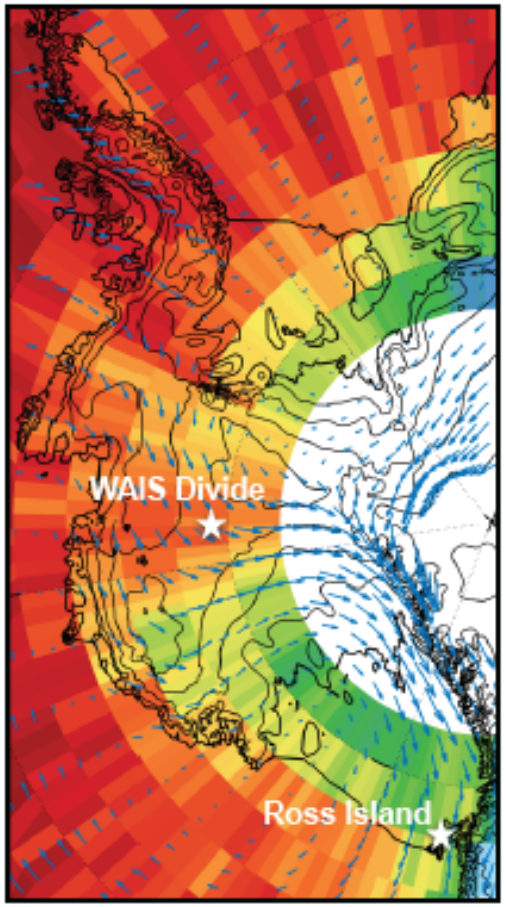
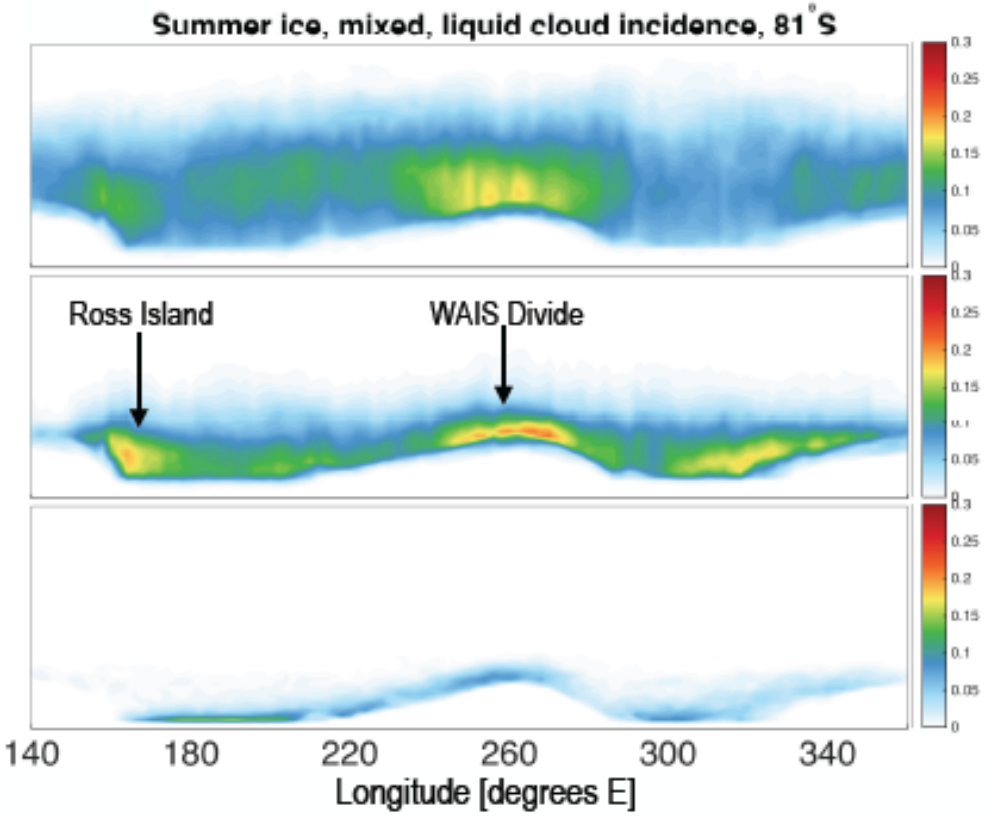


Figure adapted from
Nicolas and Bromwich (2011)

Meteorological connection between AWARE sites





Scott et al. 2017, Journal of Climate

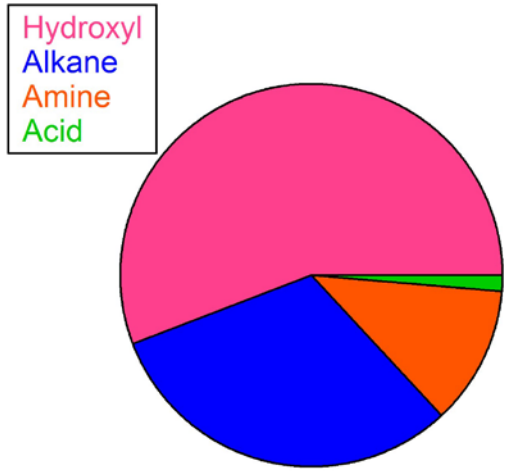
The first AWARE paper

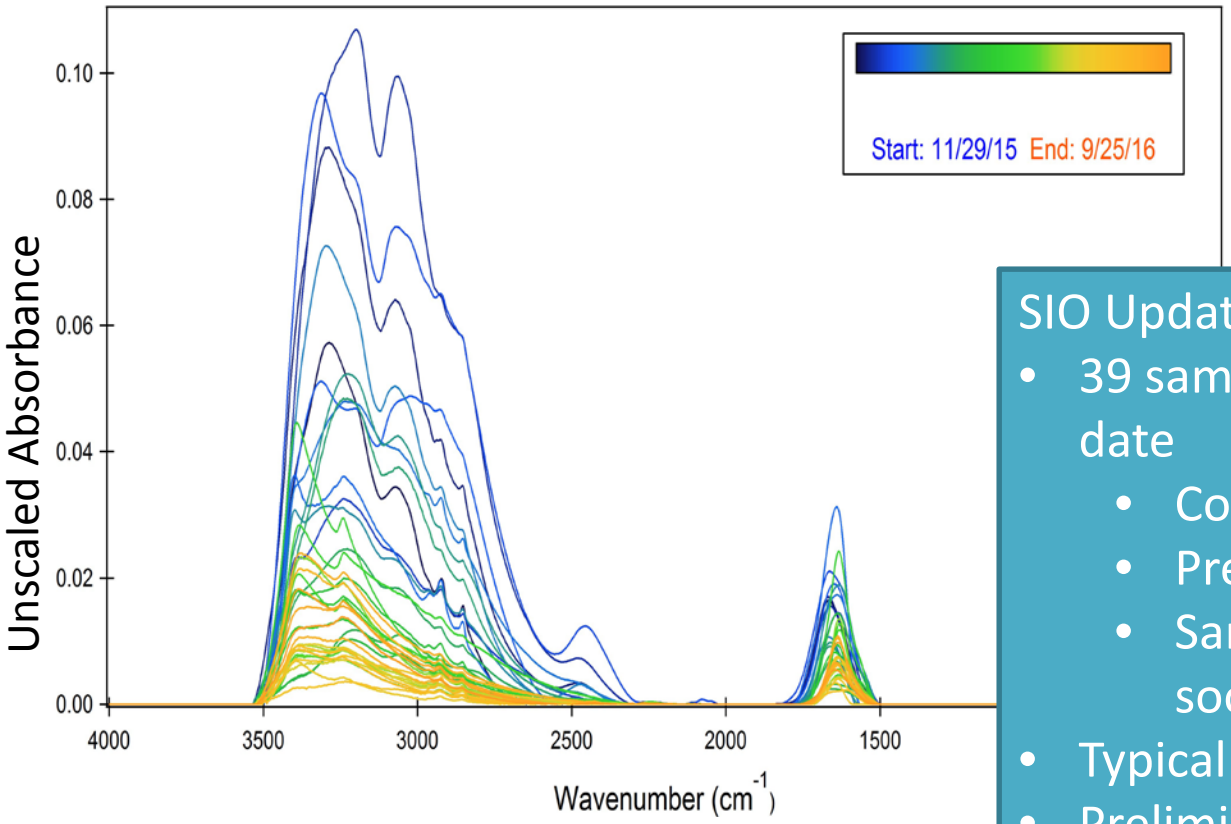
AWARE AMF-2 CosRay Site on Ross Island

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





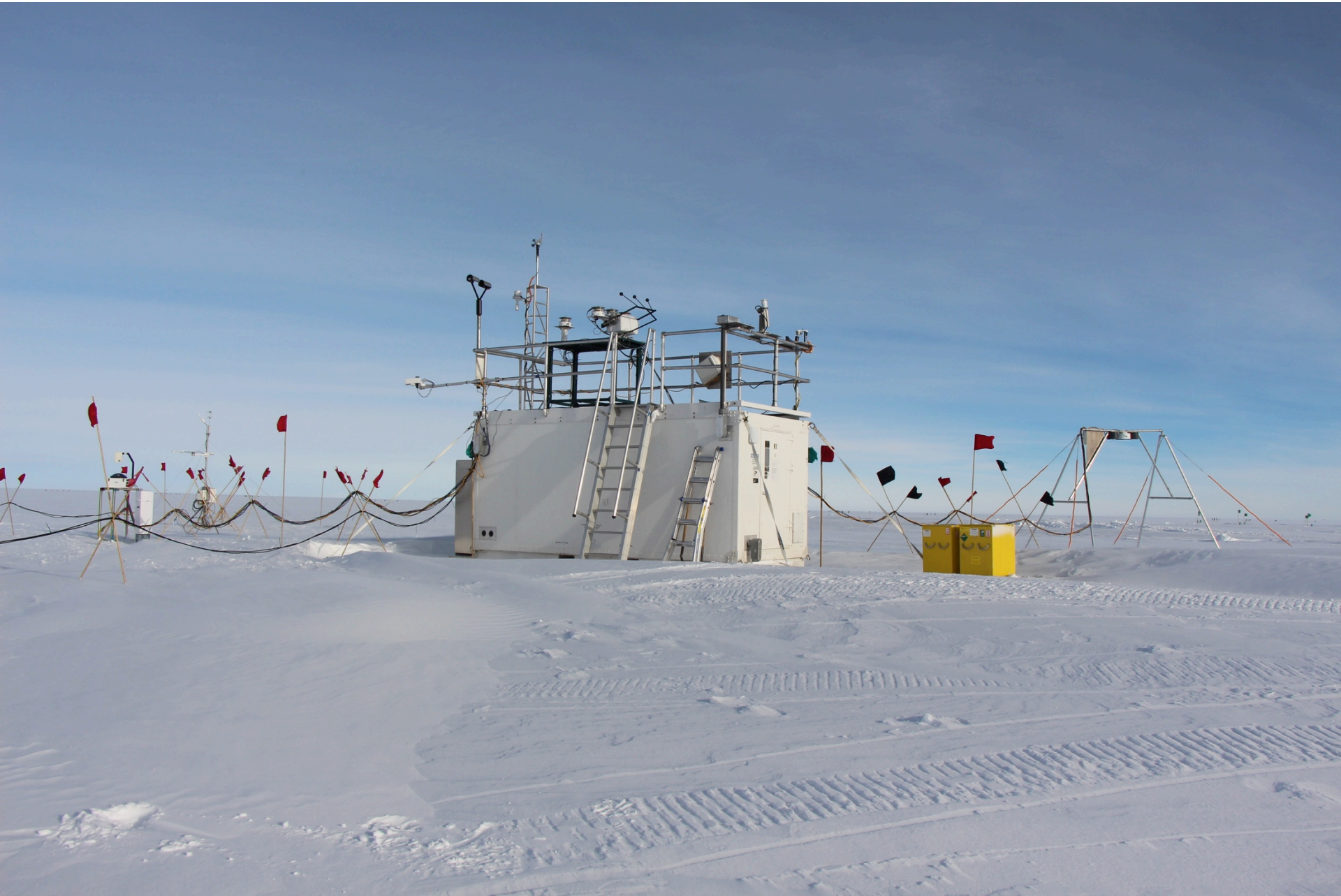
SIO Update 2/17/17:

- 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 Skip Container at WAIS Divide

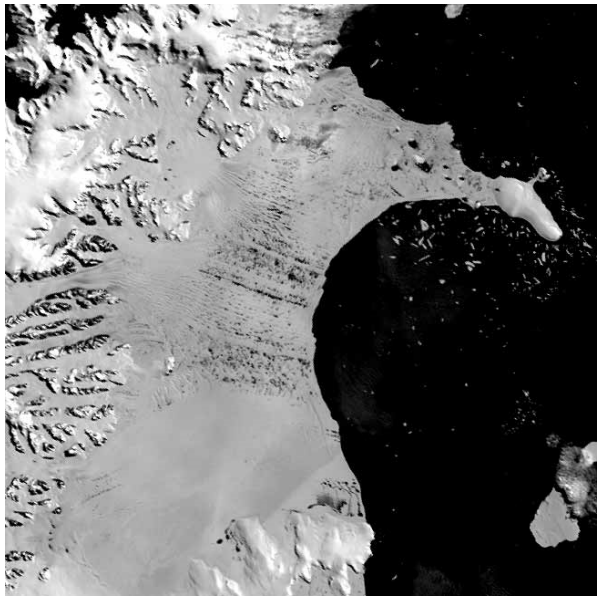


Equipment at WAIS Divide
(A USAP Summer-only Field Camp)

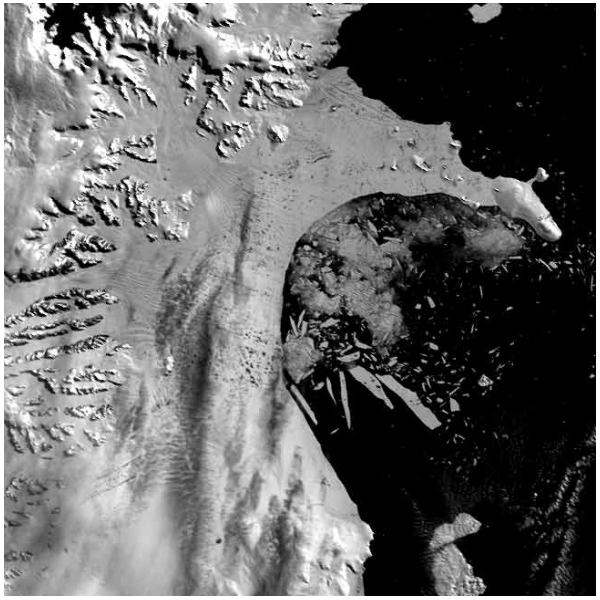
- Sondes 4 times daily
  - First in West Antarctica since 1967
- SKRAD, GRDRAD, MFRSR, SEBS, MET, CSPHOT
- Micropulse Lidar (MPL) and Ceilometer
- G-band Vertical Profiling Radiometer (GVRP) and MWR
- Shortwave Spectoradiometer, 350-2200 nm
  - (ASD instrument from Scripps)
- Total Sky Imager (TSI)
-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

Scientific Motivation: Larsen-B Ice Shelf Collapse

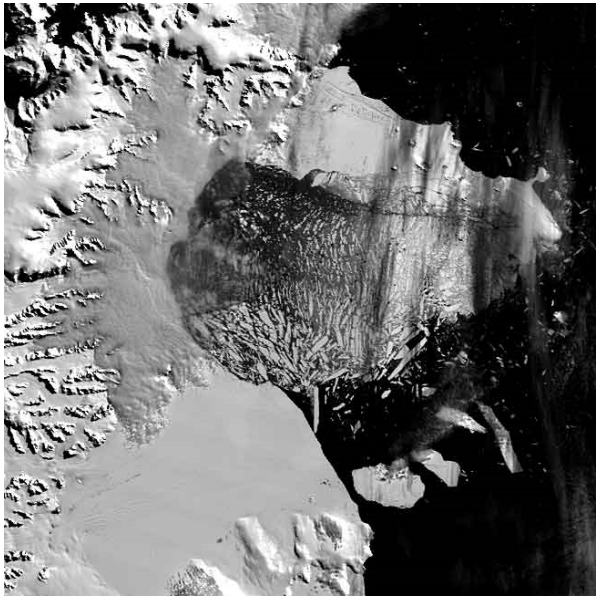
31 JAN 2002



23 FEB 2002



05 MAR 2002

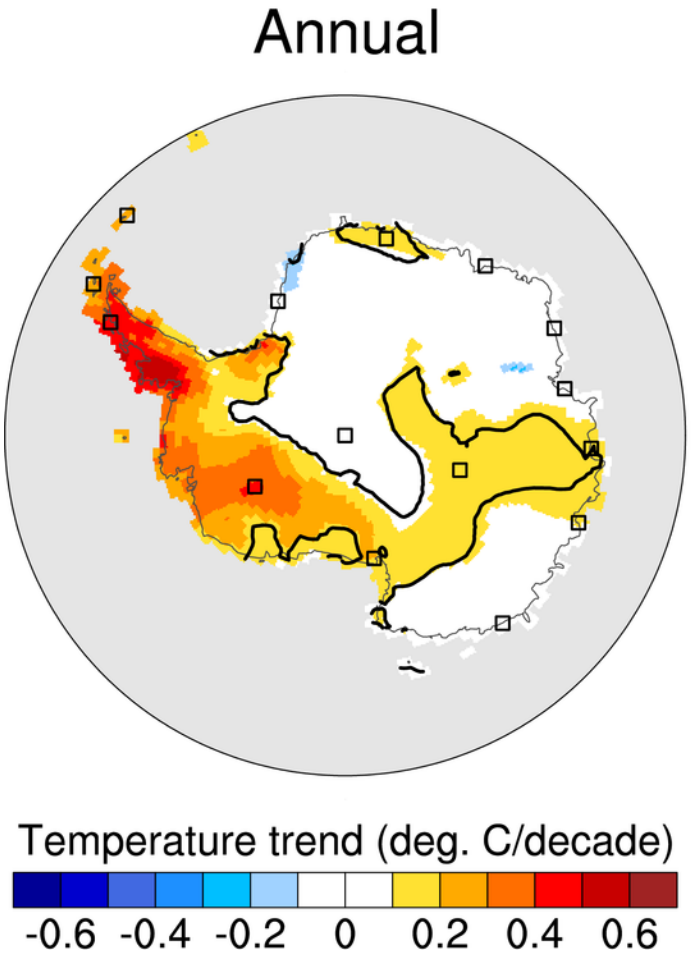


- Automatic Weather Station (AWS) data analysis links Larsen-B Ice Shelf collapse to warm air anomaly (van den Broeke, GRL, 2005), similar to Greenland.
- Antarctic Peninsula and Greenland known to be impacted primarily by atmospheric forcing.

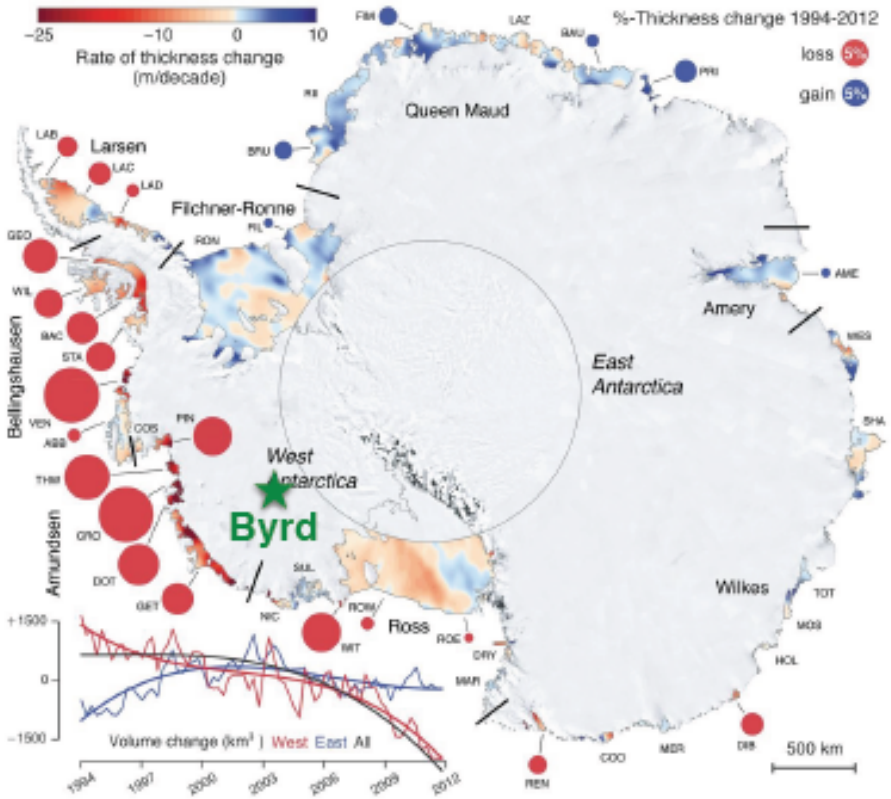
West Antarctica is One of the Most Rapidly Warming Regions on Earth

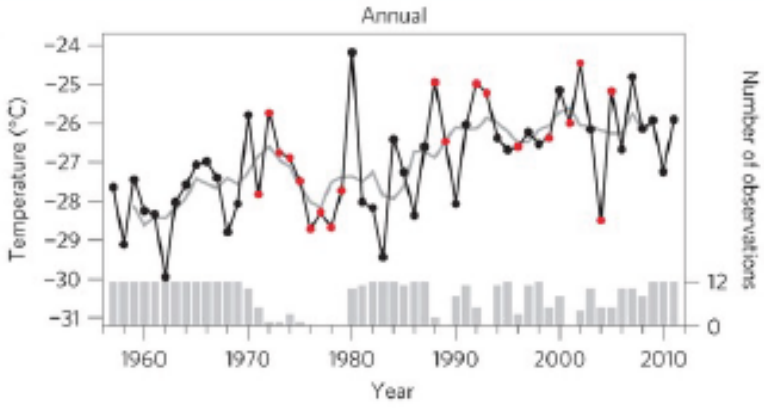
Linear Trends in Antarctic Near-Surface Temperature 1958-2011

- Steig et al. (2009) showed persistent West Antarctic warming, in contrast to the "SAM paradigm" involving only Peninsula warming with some high plateau cooling.
- Nicolas and Bromwich (2014) have extended this warming trend as far as Ross Island and part of East Antarctica.



Scientific Motivation for AWARE



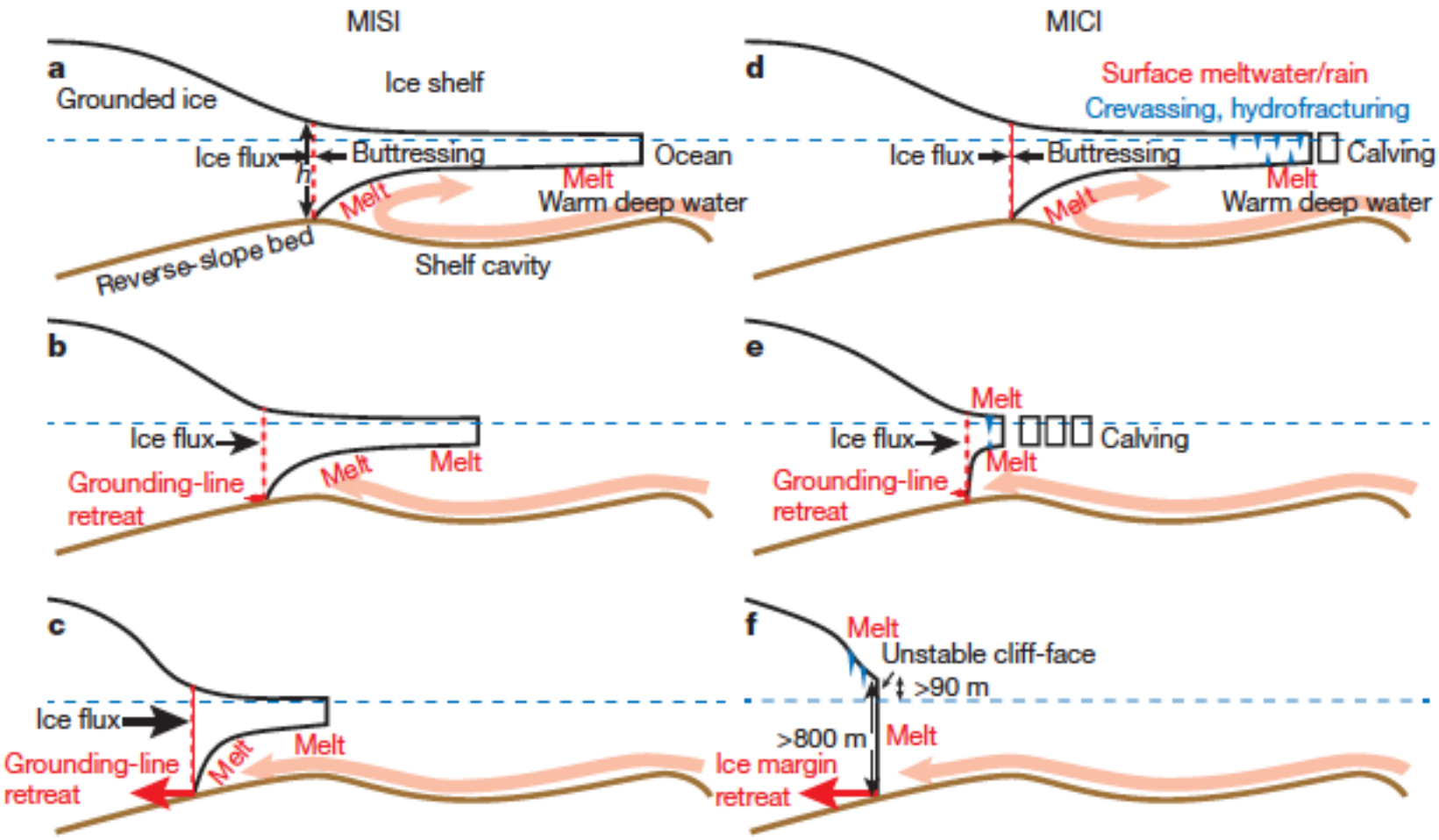


(**above**) Annual-mean air temperature time series from the **Byrd AWS** in central West Antarctica (Bromwich et al. 2013)
Trend: 0.42±0.24°C/decade

(**left**) Antarctic ice shelf thickness change from 1994-2012 (Paolo et al. 2015)

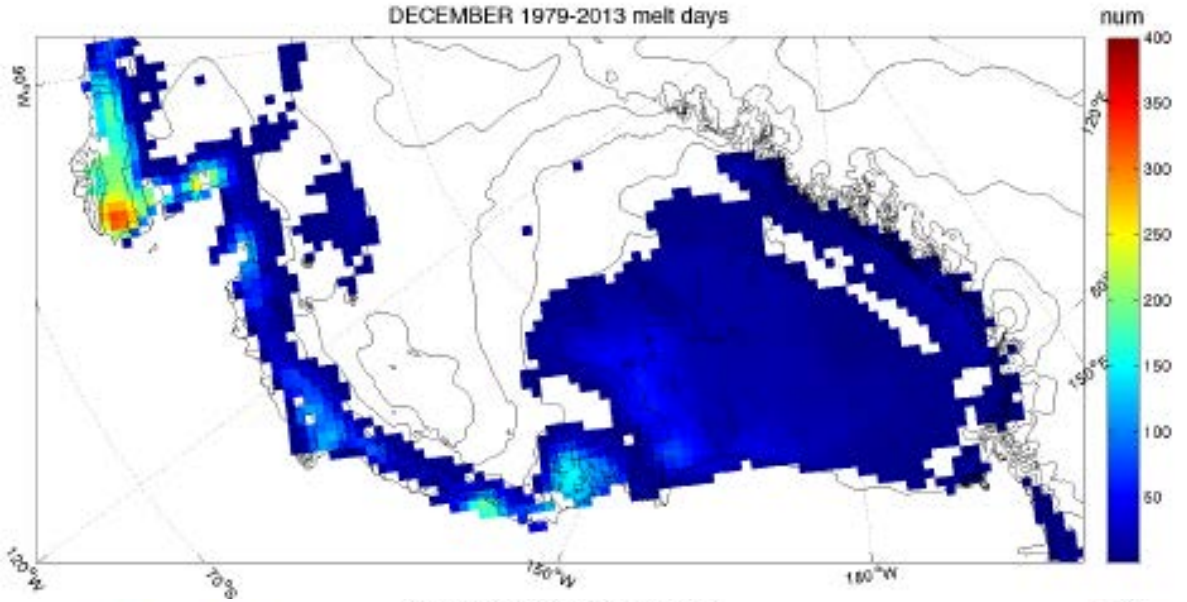
Marine Ice Sheet and Ice Cliff Instabilties

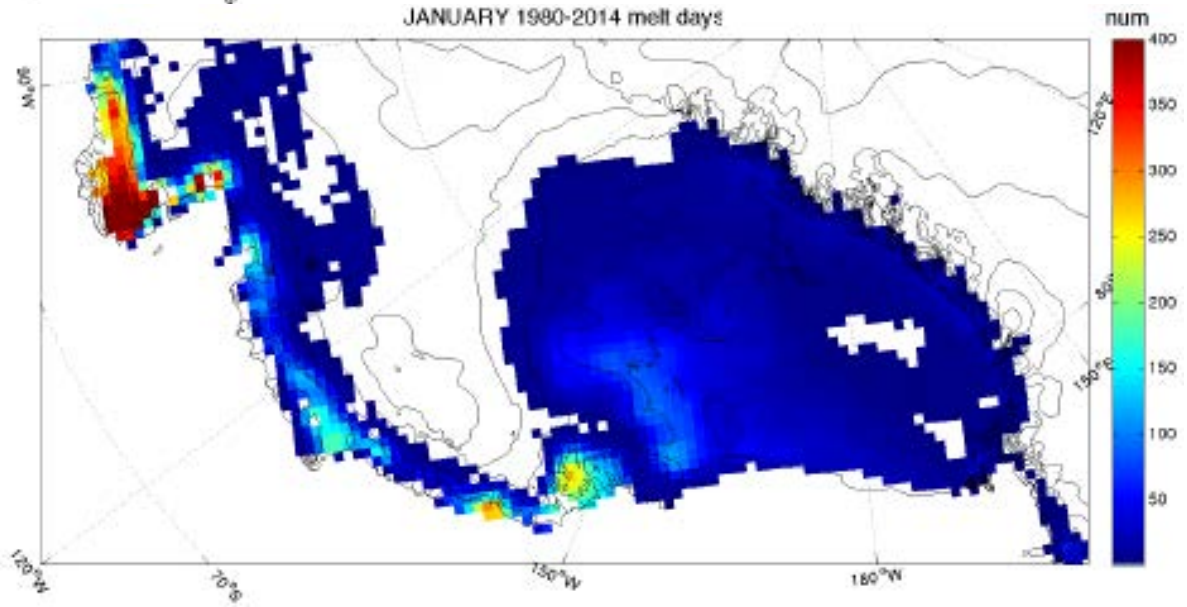
DeConto and Pollard 2016



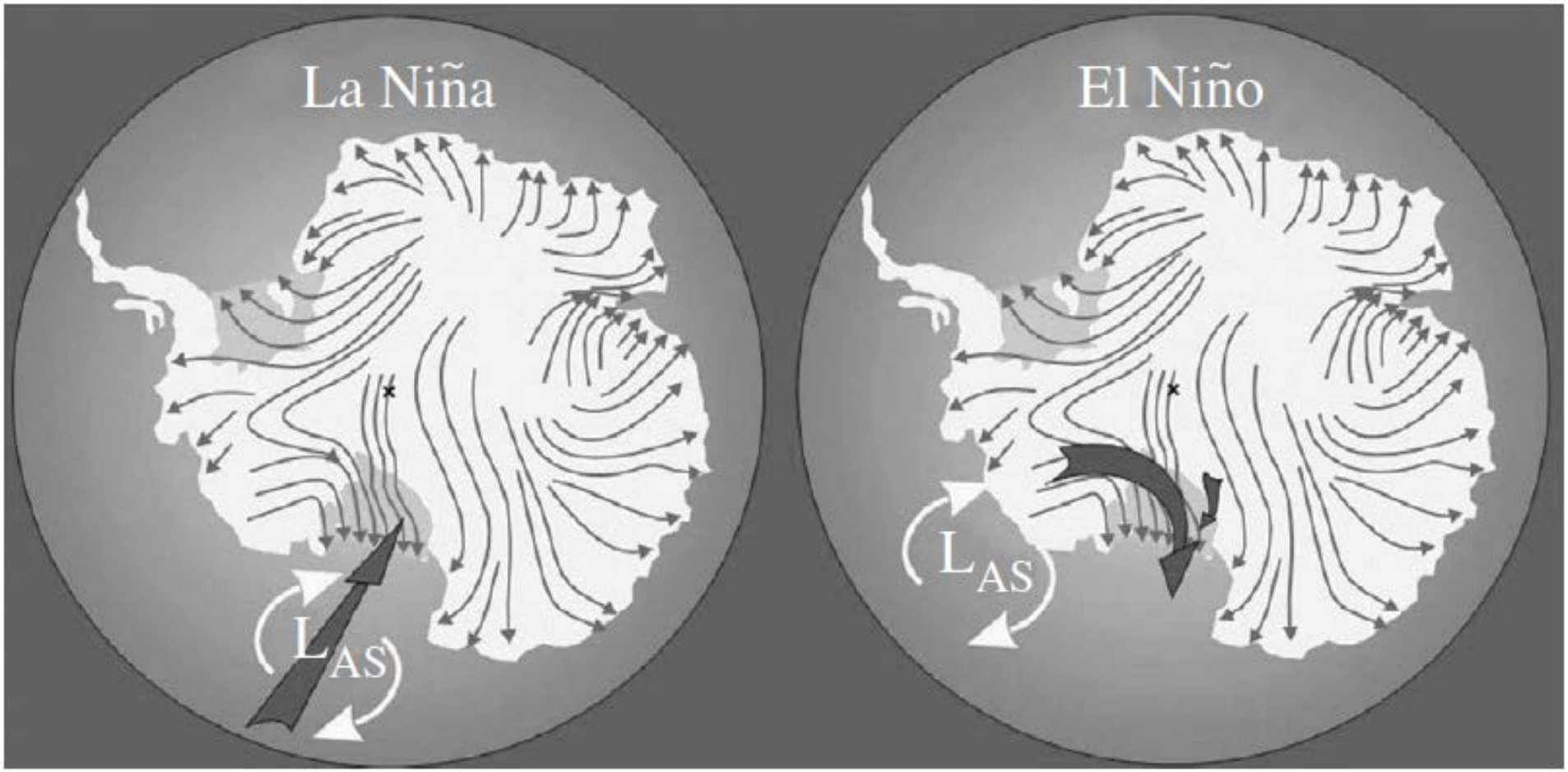
Total Melt Days in West Antarctica

Since Start of Satellite Era (Passive MW)





Influence of Southern Ocean Lows on WAIS

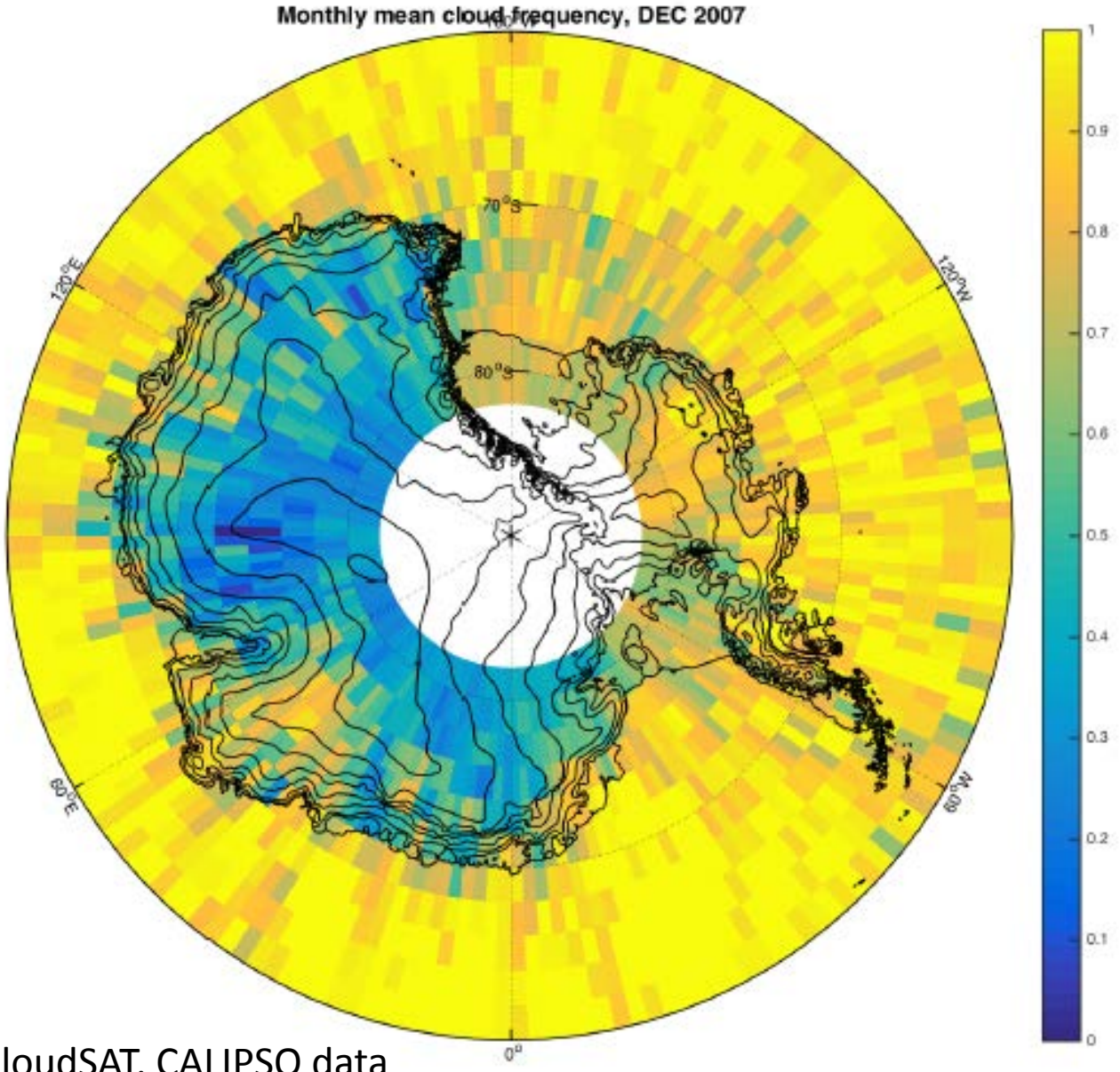


Low located in Ross Sea ➔
Low moisture and colder air over WAIS

Low located in
Amundsen/Bellingshausen Seas ➔
Warm & moist air driven up onto WAIS

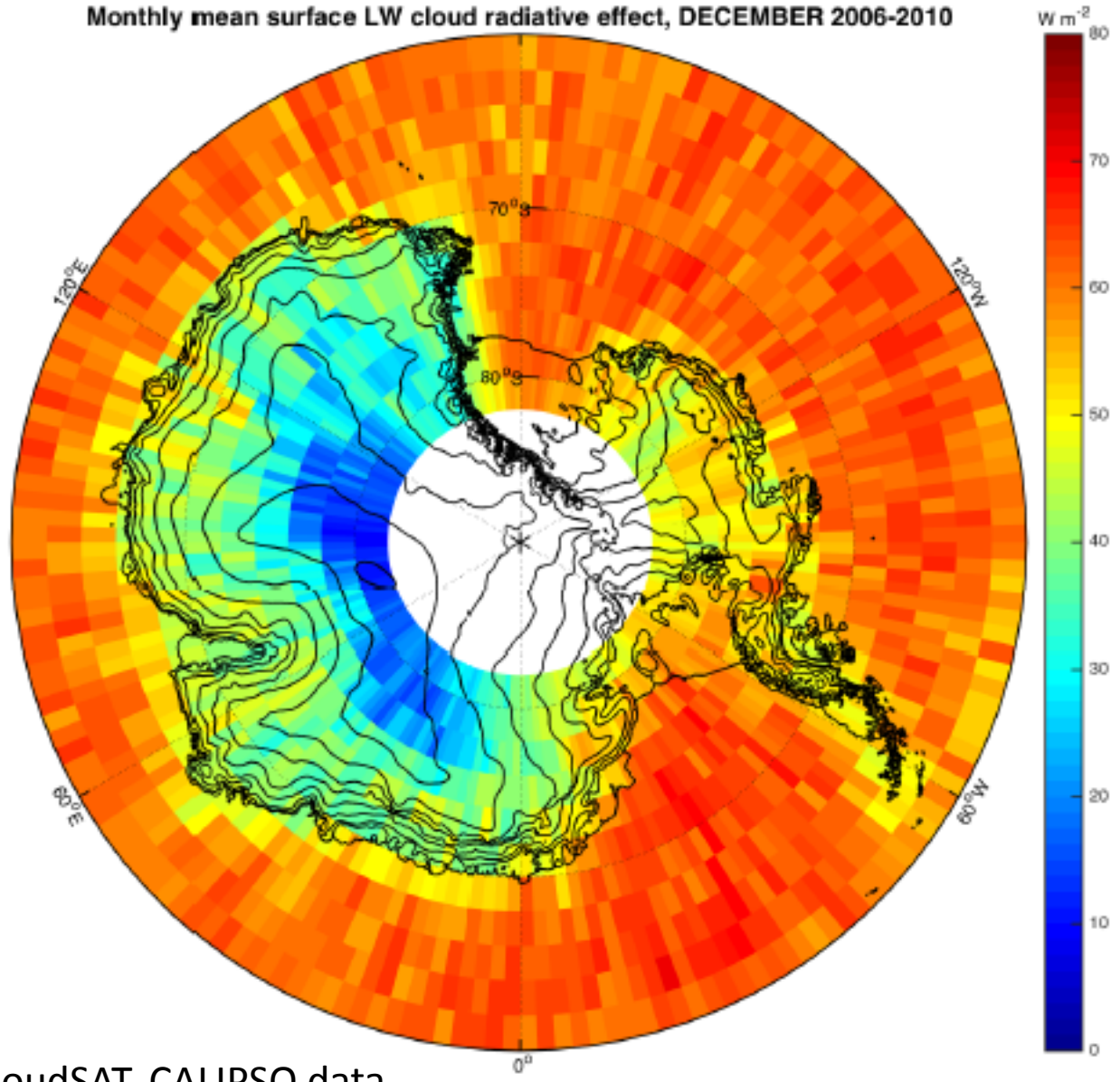
Figure from Bindschadler, *Phil. Trans. R. Soc. A*, 2006

WAIS is a cloudier region than most of Antarctica



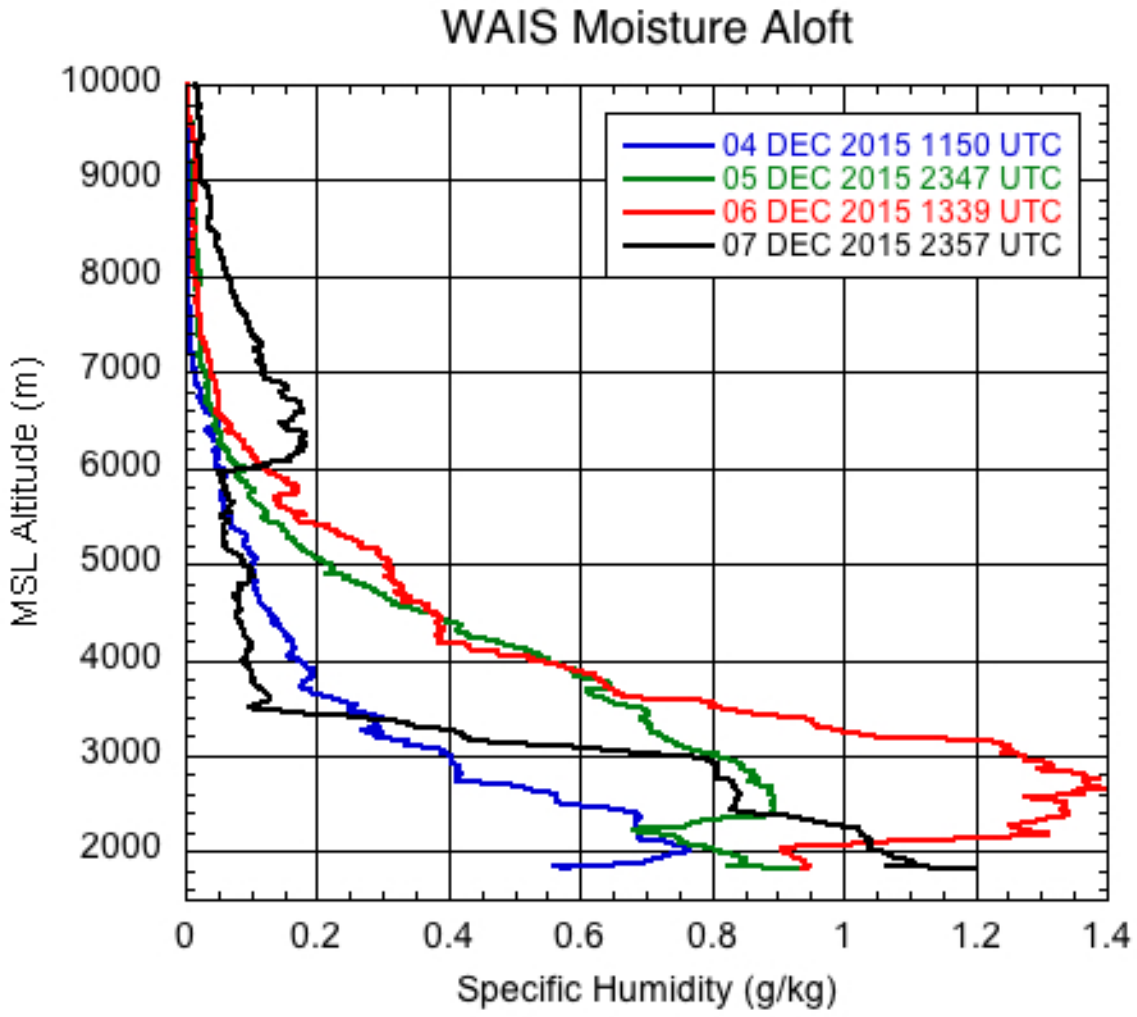
NASA CERES, CloudSAT, CALIPSO data

Clouds Provide a Thermal Blanket for WAIS



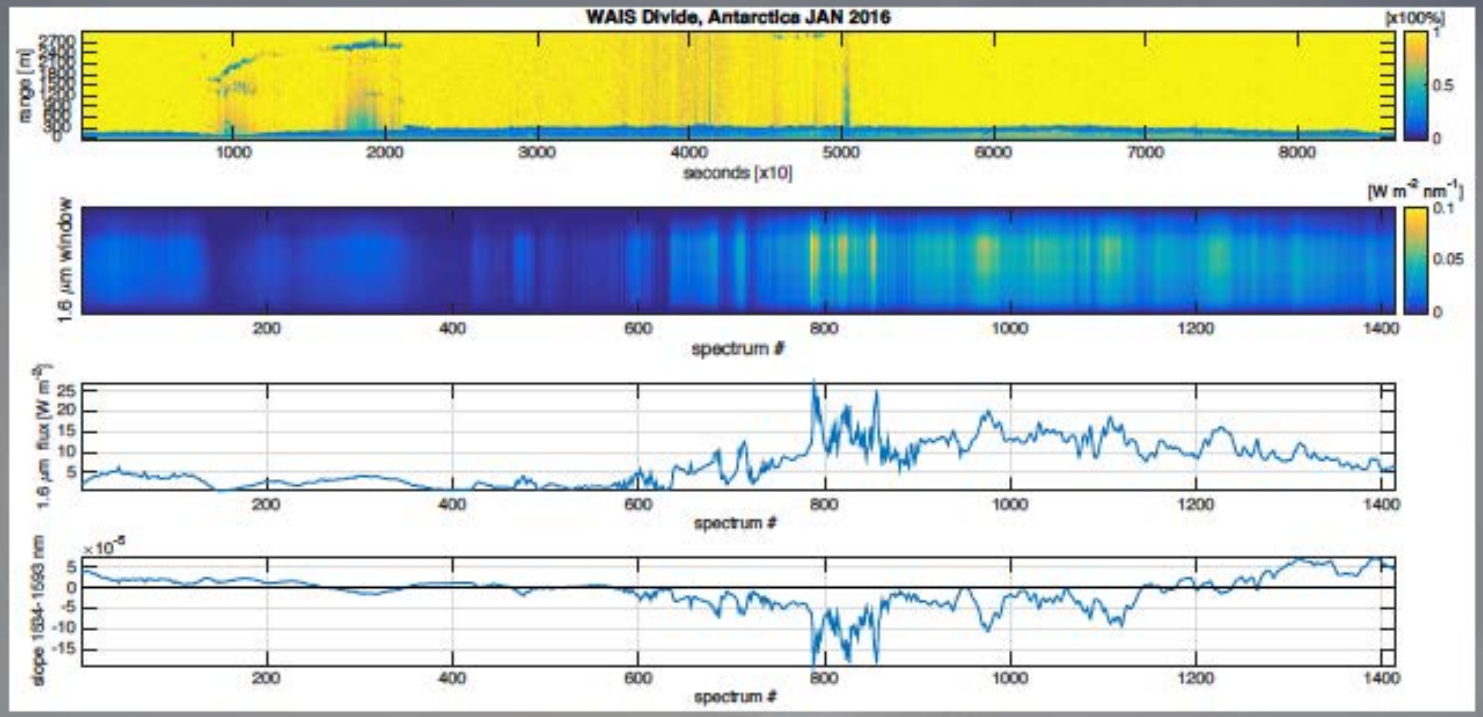
NASA CERES, CloudSAT, CALIPSO data

WAIS – First Sonde Data Since 1967



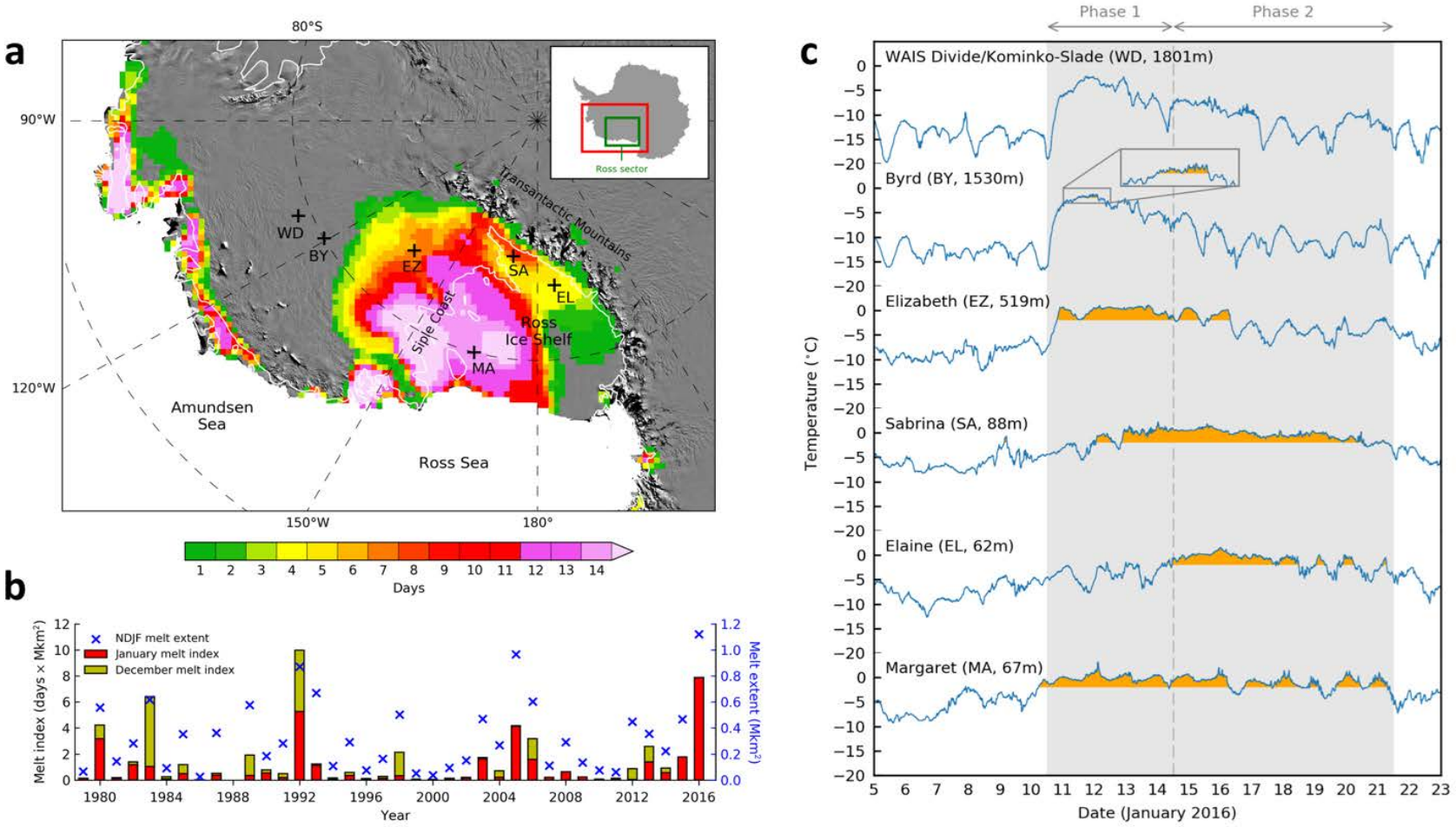
Storms in Amundsen-Bellingshausen Seas bring deep layers of warm air and moisture over West Antarctica – measured here during AWARE.

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

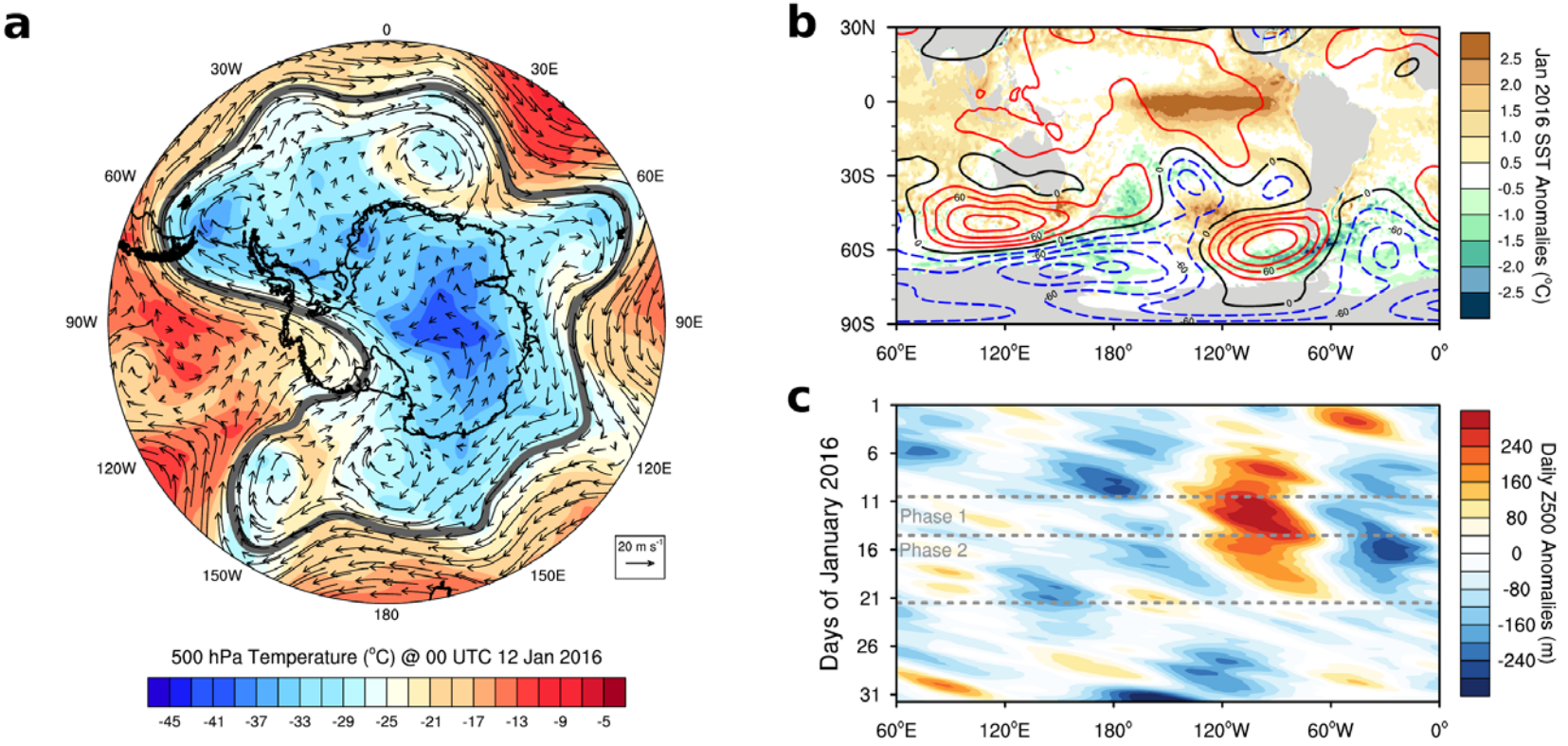
Melt Event in Satellite and Surface Observations

Nicolas et al. 2017



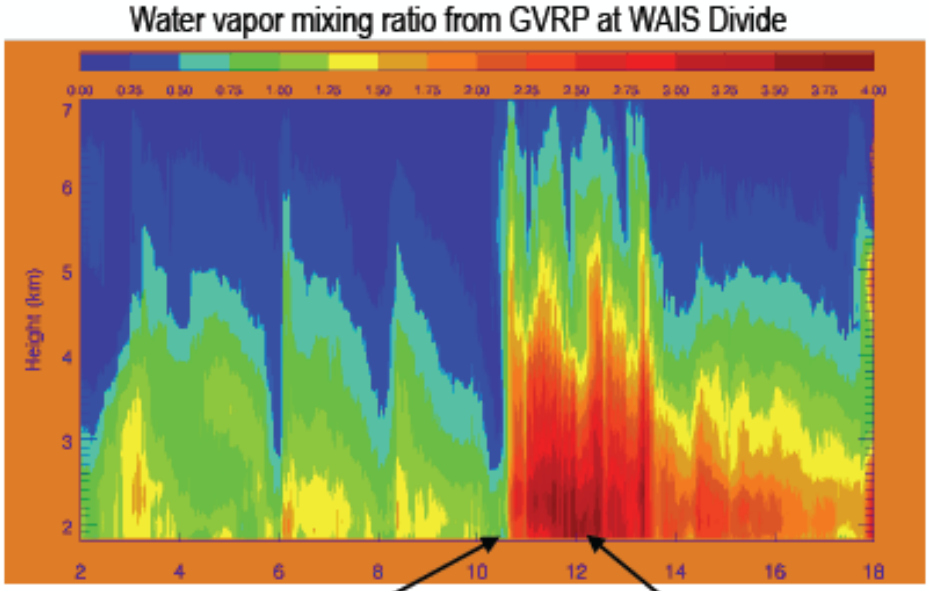
Melt Event Atmospheric Circulation

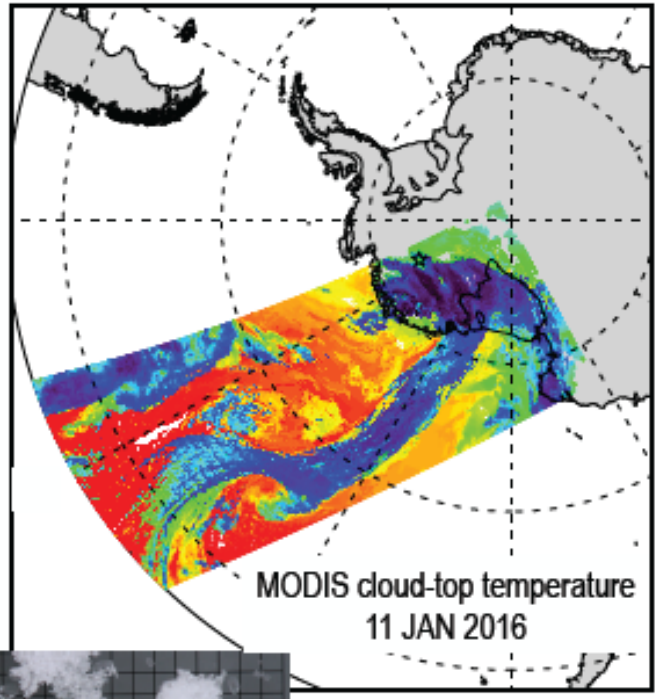
Nicolas et al. 2017

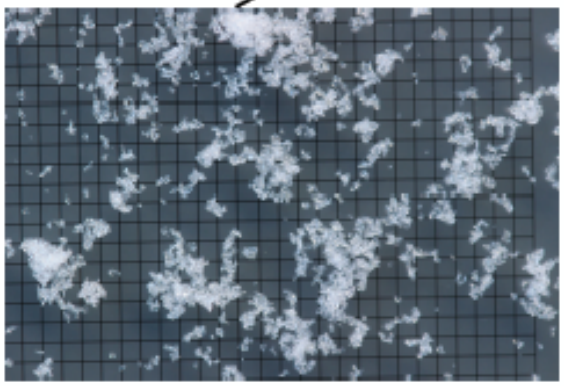


- Blocking ridge directs moist air over SST anomaly and onto WAIS and Ross Ice Shelf.
- High pressure in SE Pacific sector of Southern Ocean a feature of El Niño teleconnection.

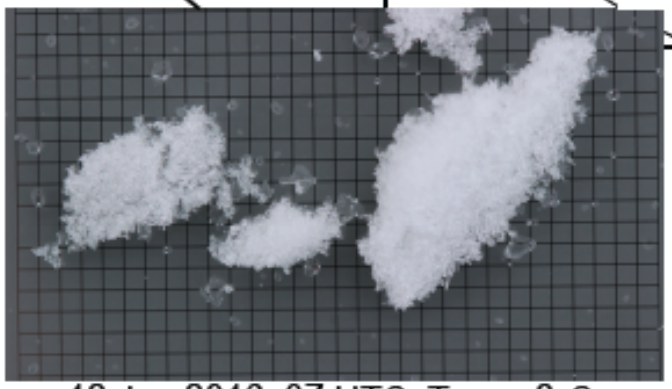
January 2016 surface melt driven by atmospheric river





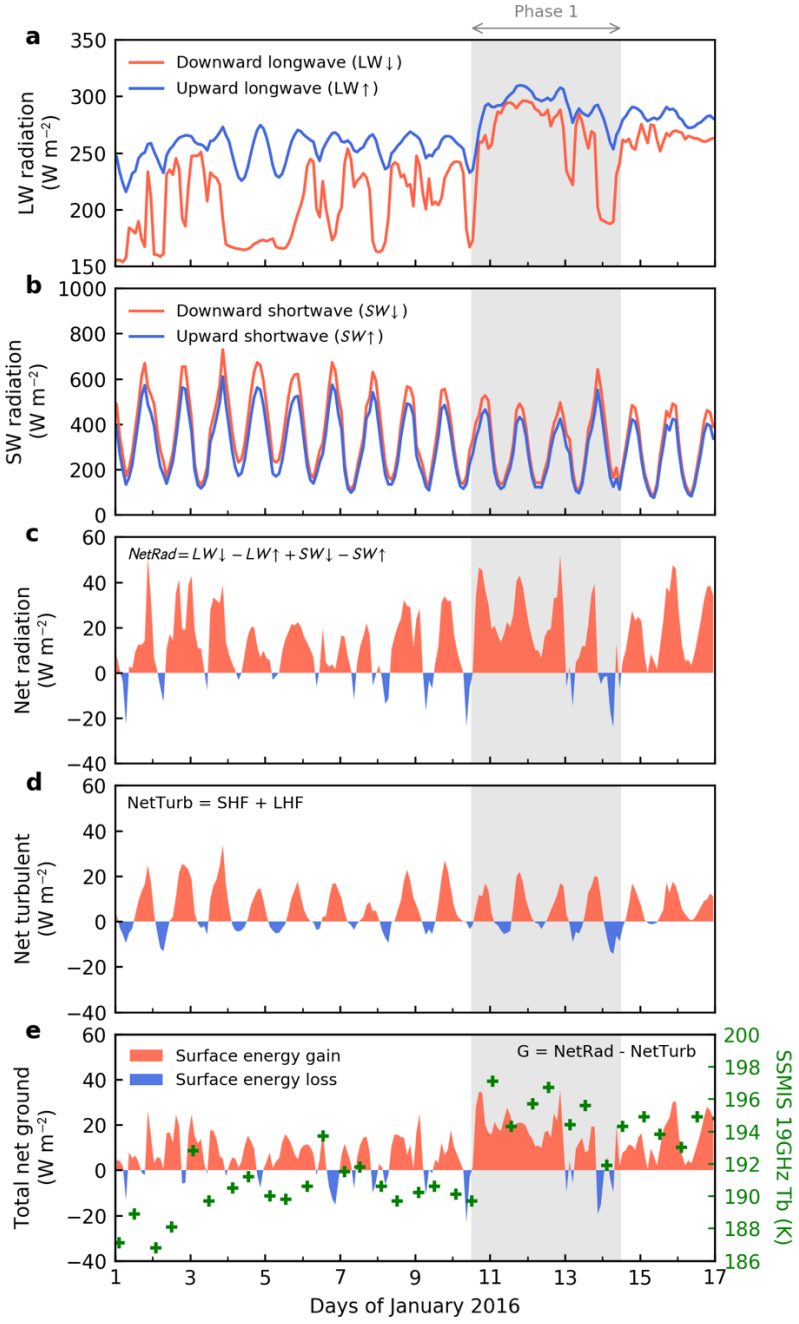


10 Jan 2016, 08 UTC, T_{2m} = -18°C



12 Jan 2016, 07 UTC, T_{2m} = -3°C

Daily snow grain macrophotographs



Melt Event AWARE Observations

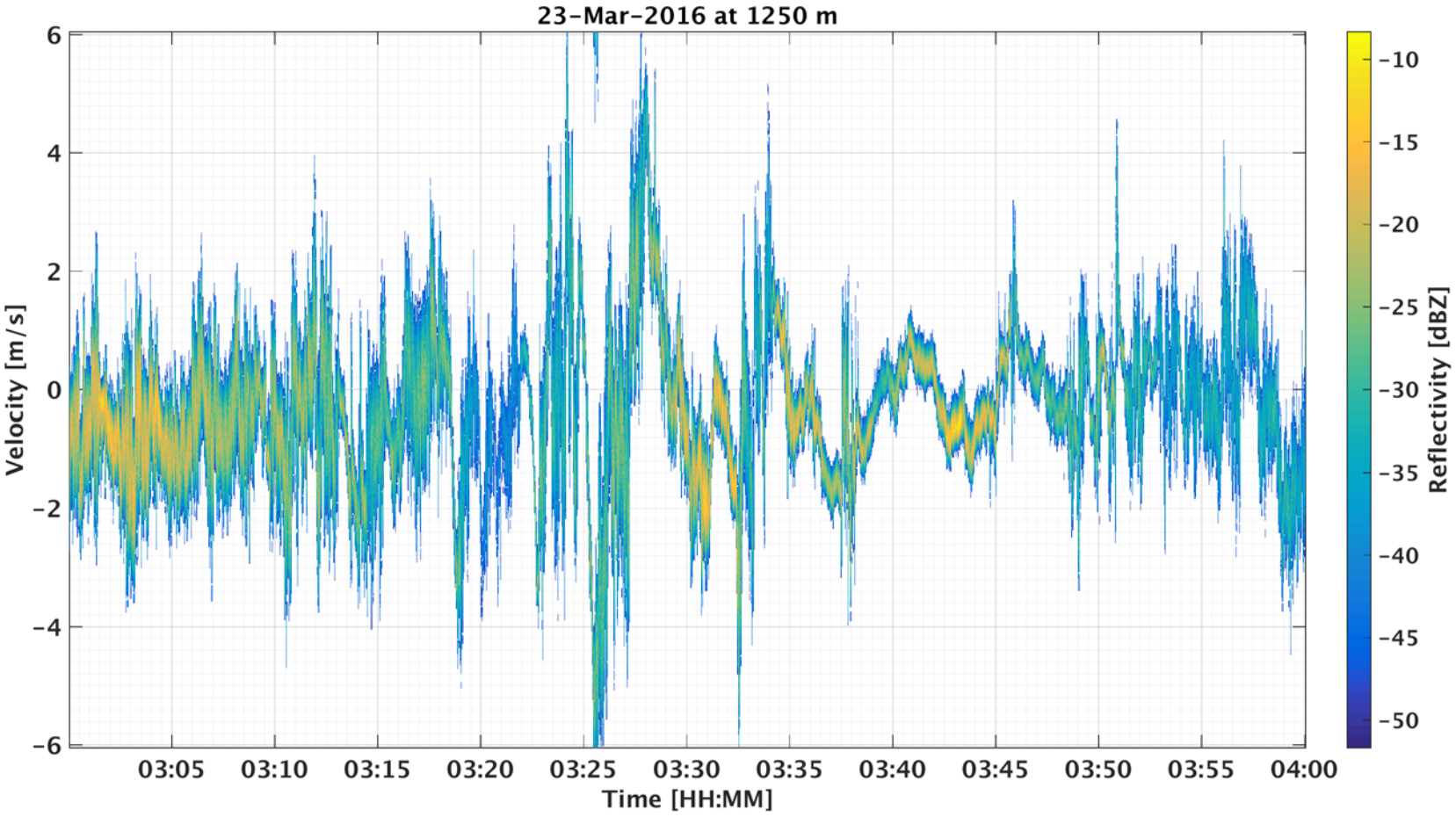
Nicolas et al. 2017

Very rapid response from ARM Archive and instrument mentors.

Andy Vogelmann (BNL) worked up the surface energy balance.

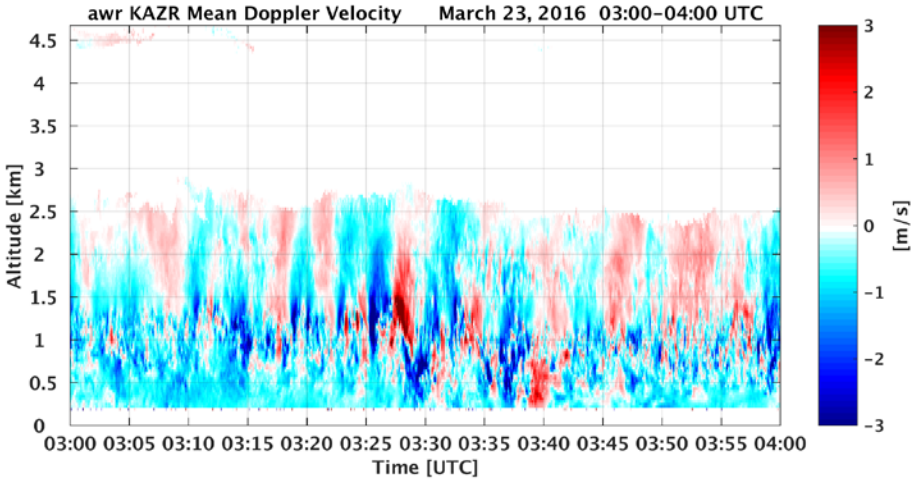
This work represents most of Byrd Polar's effort during the first year of AWARE.

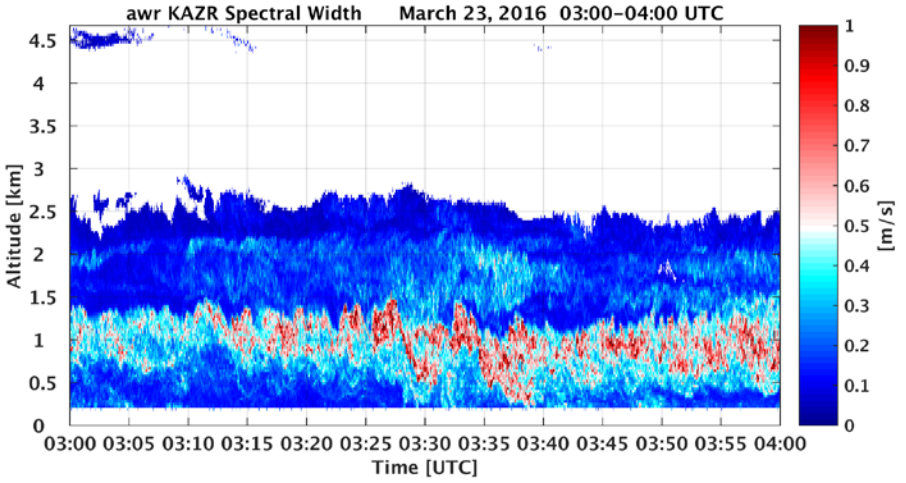
Alien World:
Penn State Preliminary Wave Activity Cases

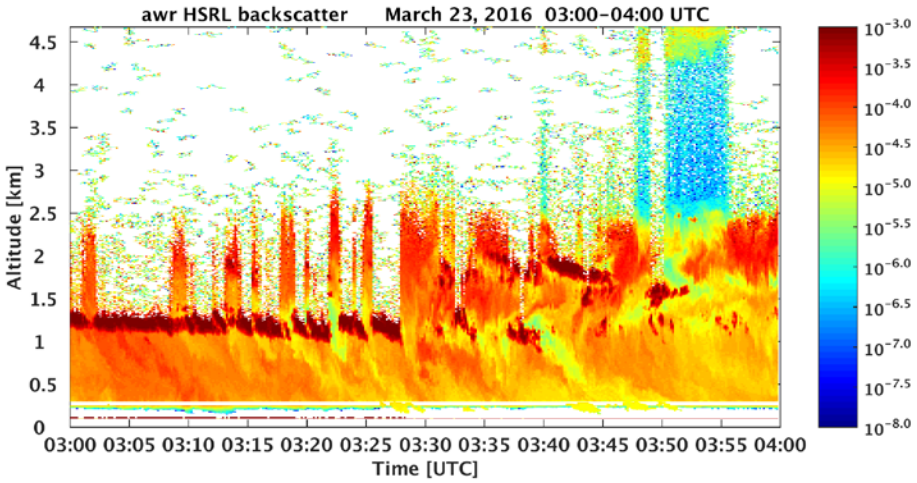


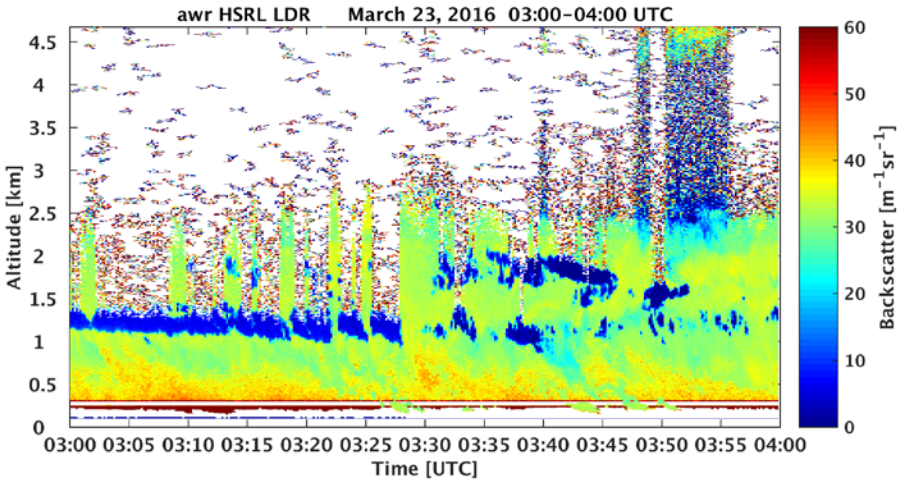
Ross Island is not Barrow!

Penn State Preliminary Wave Activity Cases









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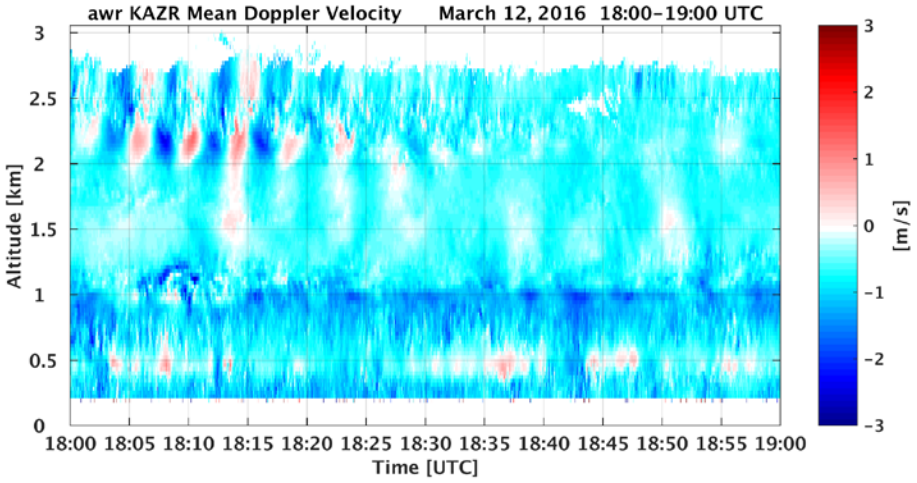
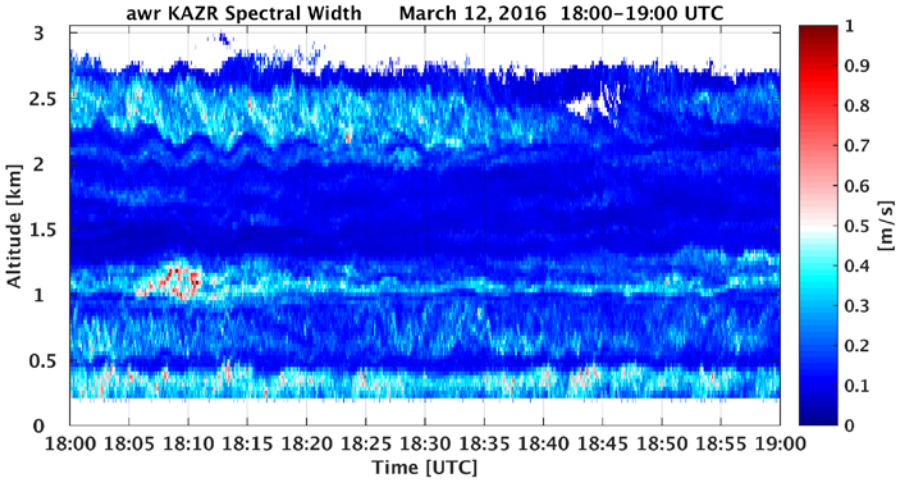
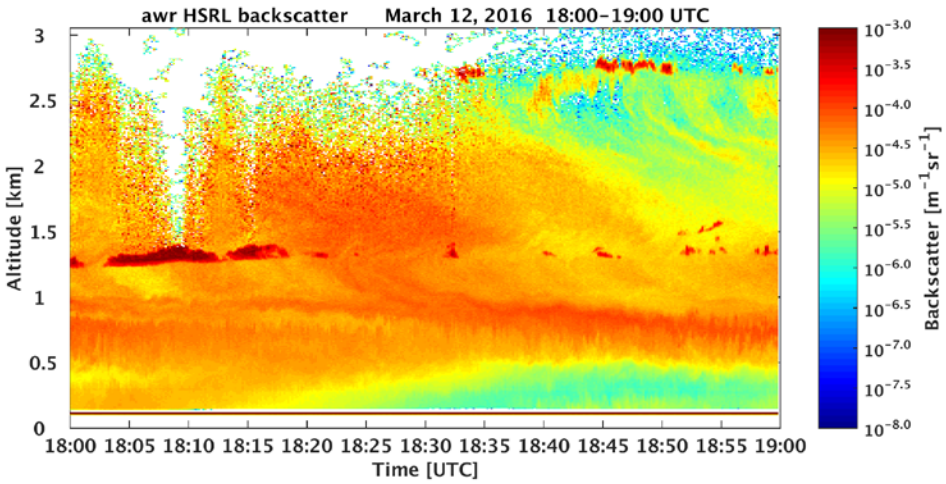
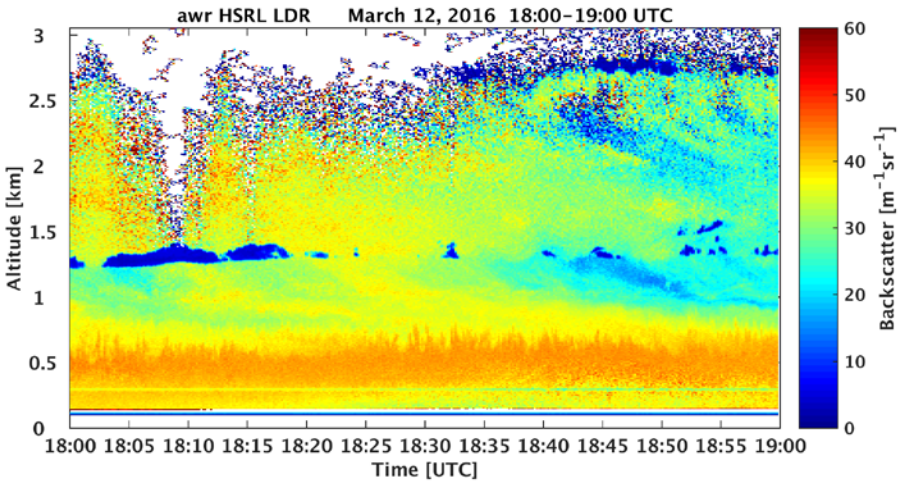
Penn State Preliminary Wave Activity Cases





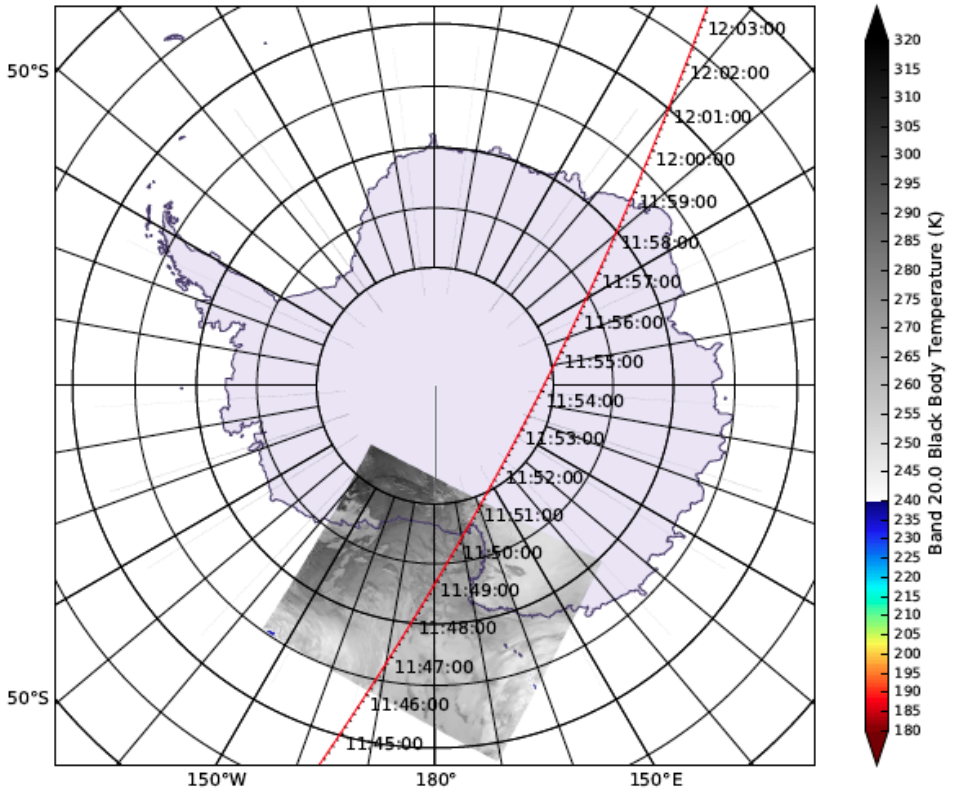




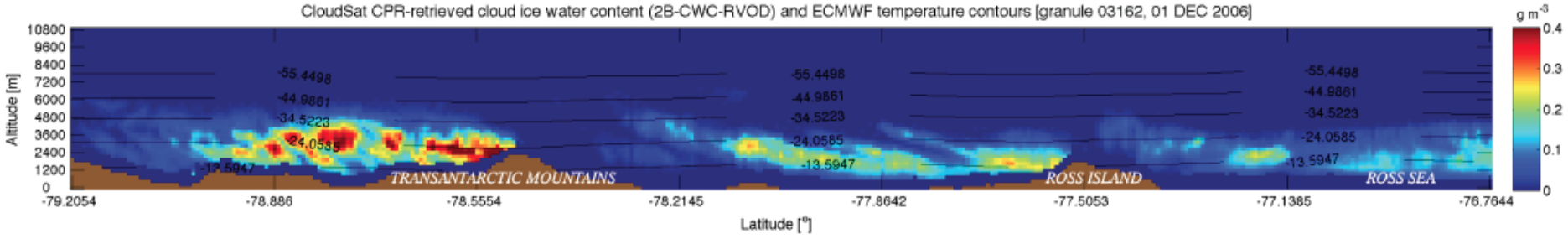
Ross Island is not Barrow!

NASA CloudSat Comparison: Ross Island with Arctic Sites

(Scott & Lubin 2016, GRL)

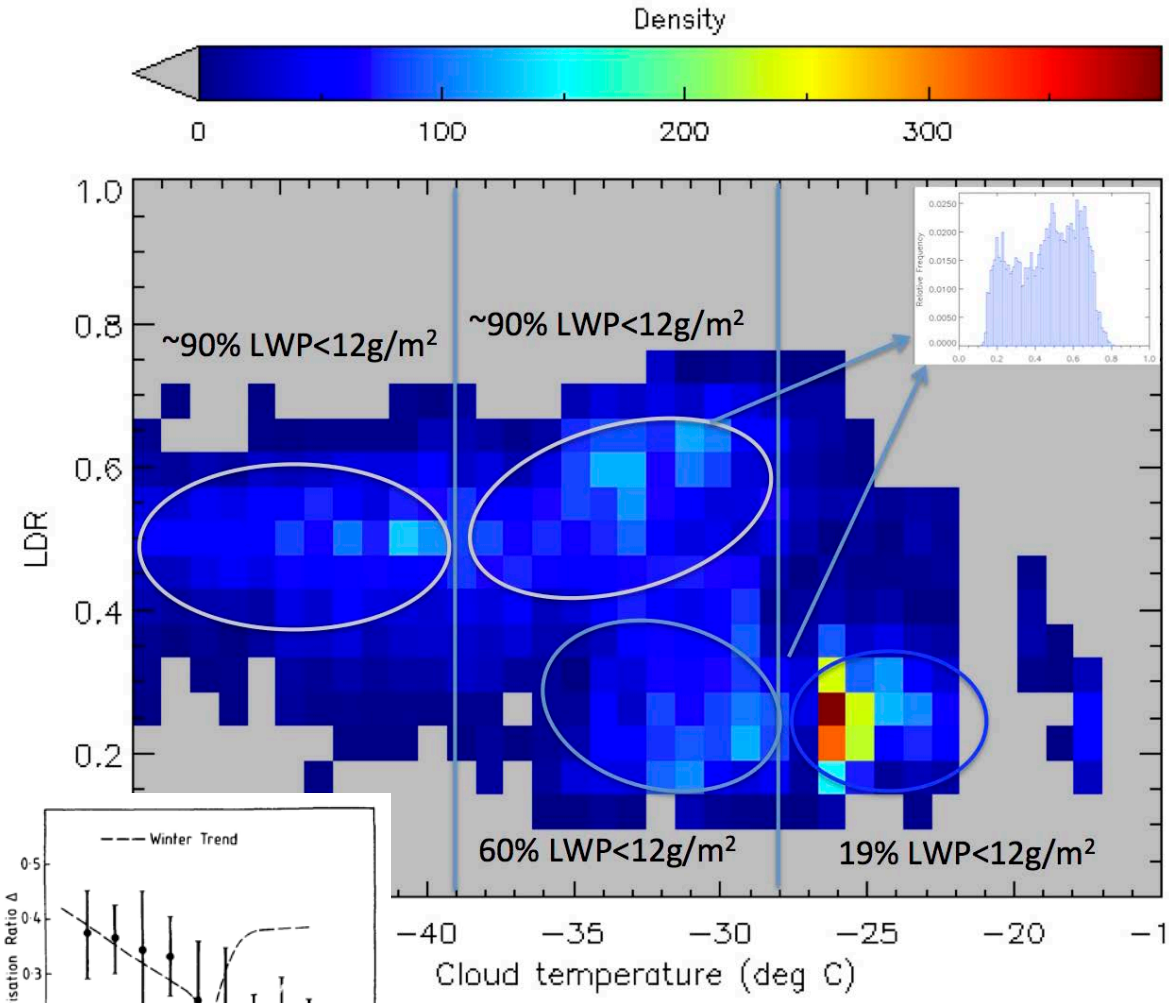


- CloudSat/CALIPSO data reveal that orographic forcing of cloud cover and high IWC is pervasive around the Antarctic coast.
- Ross Island has unique manifestations of polar cloud microphysics, very distinct from the Arctic.
- Studies of these contrasting clouds are very relevant to Antarctic climate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



Cloud Phase from GVRP and MPL

see Maria Cadeddu's poster



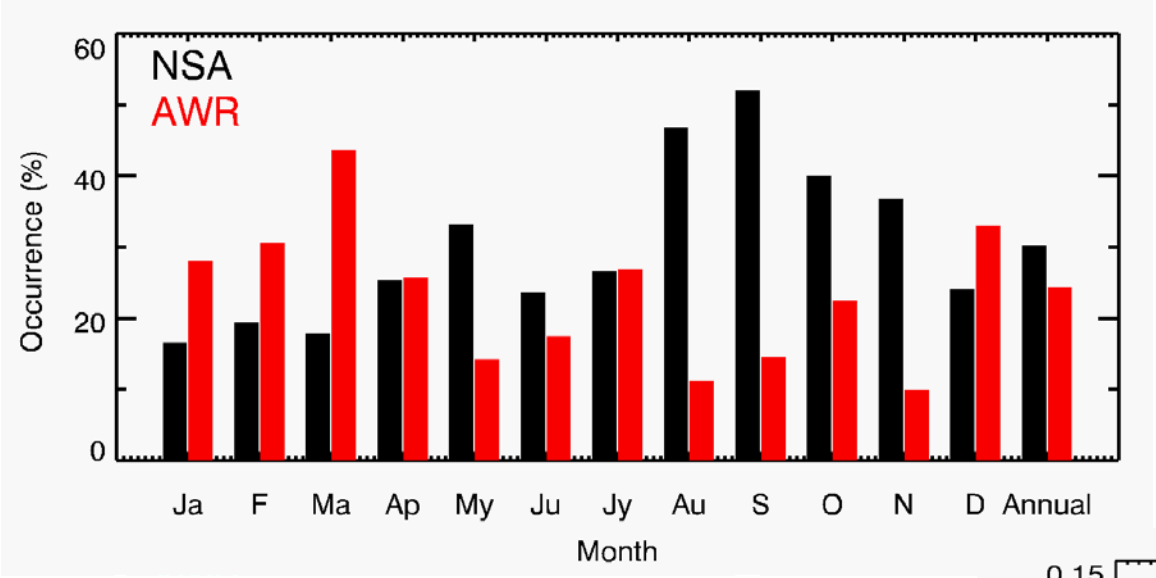
The bimodal distribution is similar to what is reported in Sassen, 1991, but at lower temperatures

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.

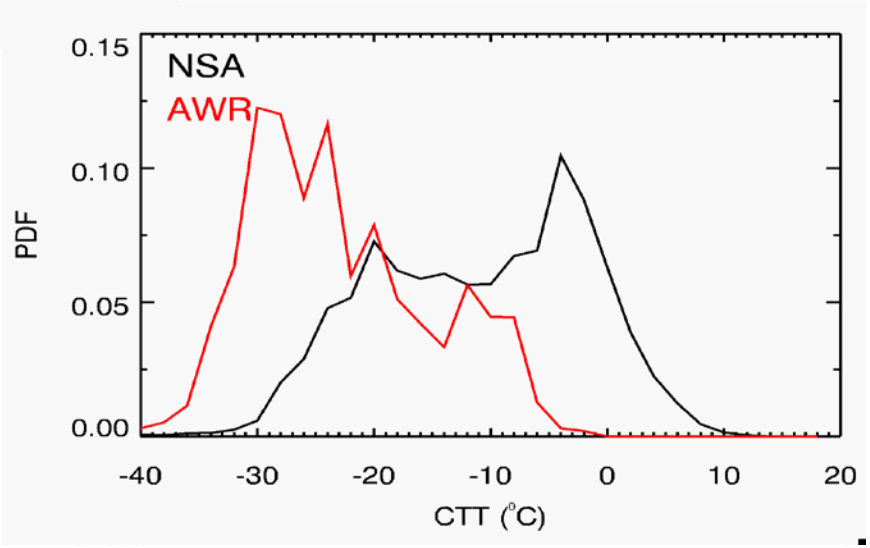
Stratiform Cloud Occurrence

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) and A. Vogelmann (BNL)
  - Surface radiation & energy budget, and cloud optical properties from *some* instruments.
- 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.

AWARE Science Team will only just scratch the surface…

Most Important Slide of All

- ★ AWARE is the most complete and technologically advanced atmospheric and climate science experiment yet fielded in Antarctica.
  - ➢ Should have great relevance for polar process study and model improvement.
- ★ 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