High-Latitude Processes Working Group Updates

Greg McFarquhar[1] and Gijs de Boer[2]

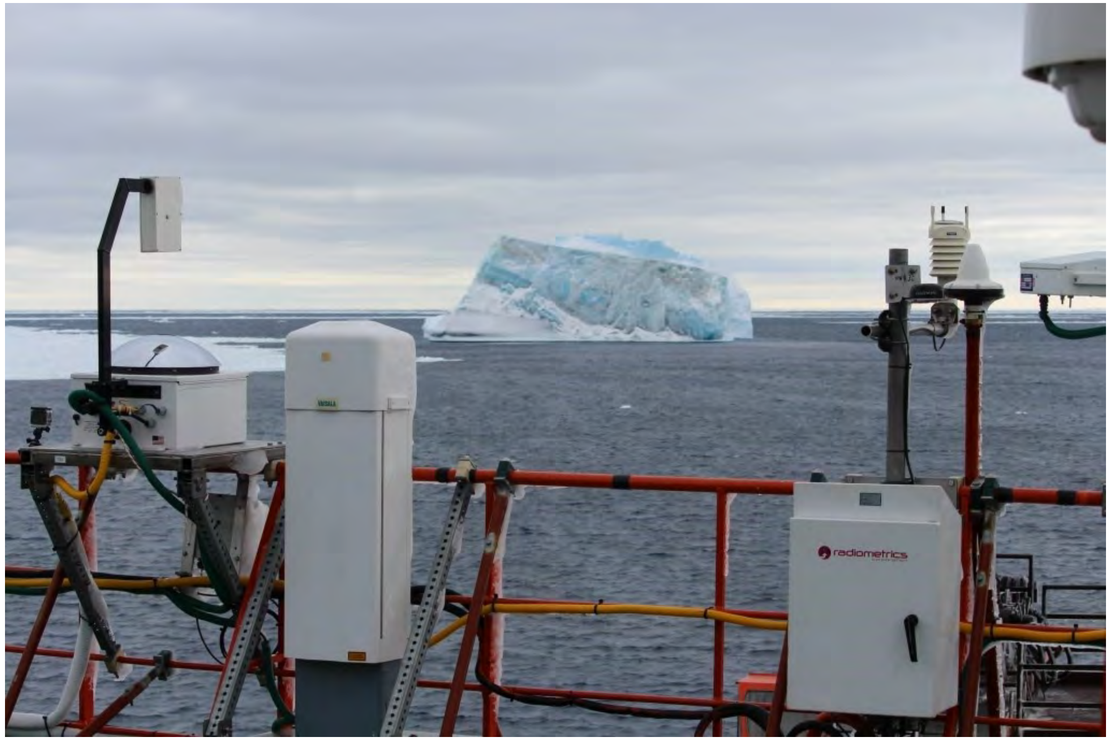
[1]CIMMS & School of Meteorology, University of Oklahoma, Norman, OK
[2]CIRES, University of Colorado, Boulder, CO

Acknowledgments

Alessandro Battaglia, Leicester University
Jessie Creamean, Colorado State University
Paul DeMott, Colorado State University
Minghui Diao, San Jose State University
Saisai Ding, Ocean University of China
Bart Geerts, University of Wyoming
Andrew Gettelman, NCAR
Thomas Hill, Colorado State University
Xiao Ming Hu, University of Oklahoma
Pavlos Kollias, Stony Brook University
Xiaohong Liu, Texas A&M University
Edward Luke, Brookhaven National Lab
Zakary Mages, Stony Brook University
Christina McCluskey, NCAR
Qing Niu, University of Oklahoma
Mikhail Ovchinnikov, PNNL
Kerri Pratt, University of Michigan
Matt Shupe, CIRES
Israel Silber, Penn State University

All those who collected data during AWARE, MARCUS, MICRE, COMBLE and MOSAIC

High-Latitude Processes Working Group Foci



Objective– To understand and improve model representation of physical processes controlling surface energy budget in northern and southern high-latitude regions.

Specific Goals- To understand:

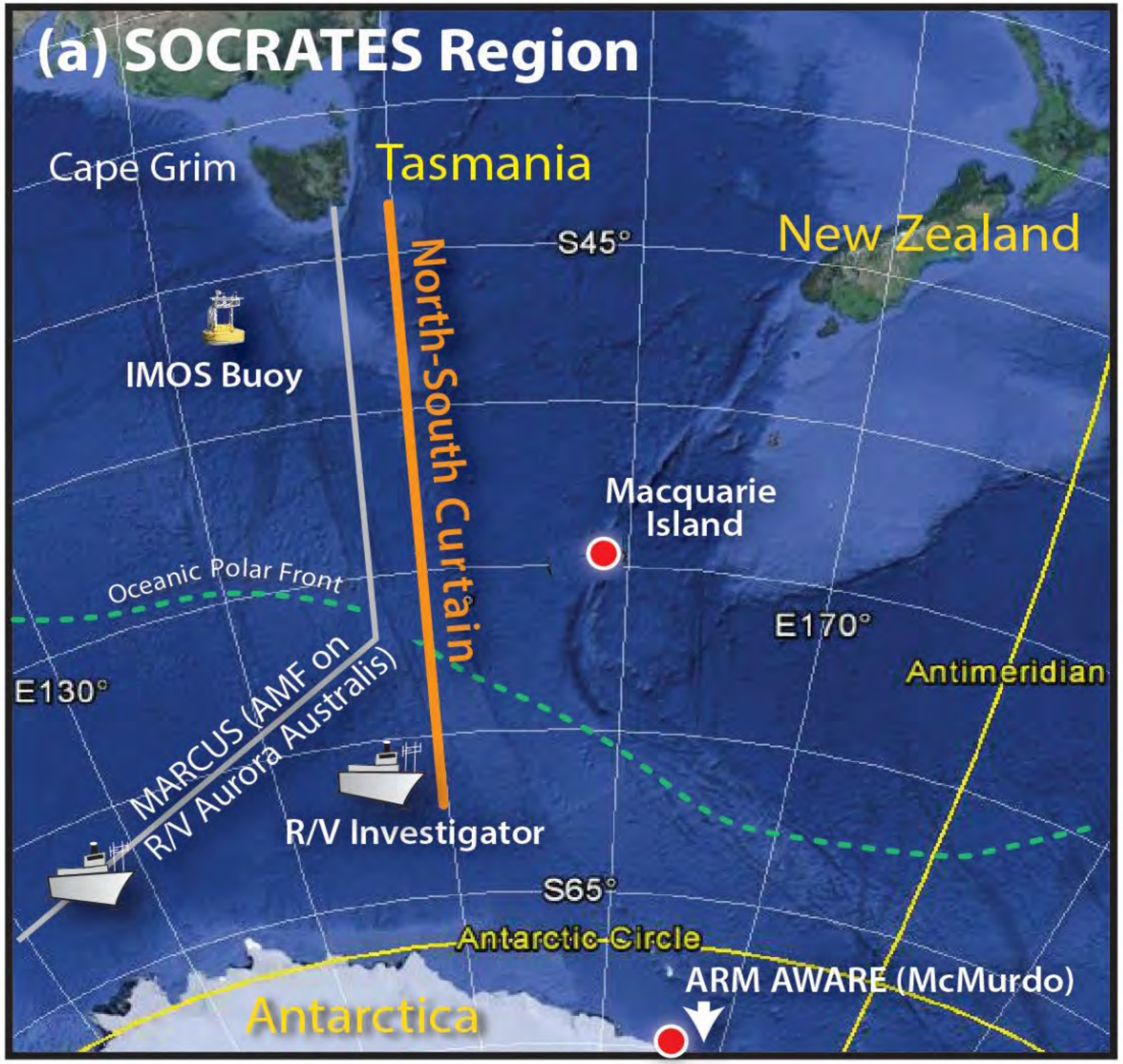
1) cloud microphysical and macrophysical properties, with emphasis on hydrometeor (rain, snow, etc.) phase division and ice crystal properties;

2) aerosol particle properties, including sources and transport, chemical and optical properties, and role of particles in cloud structure;

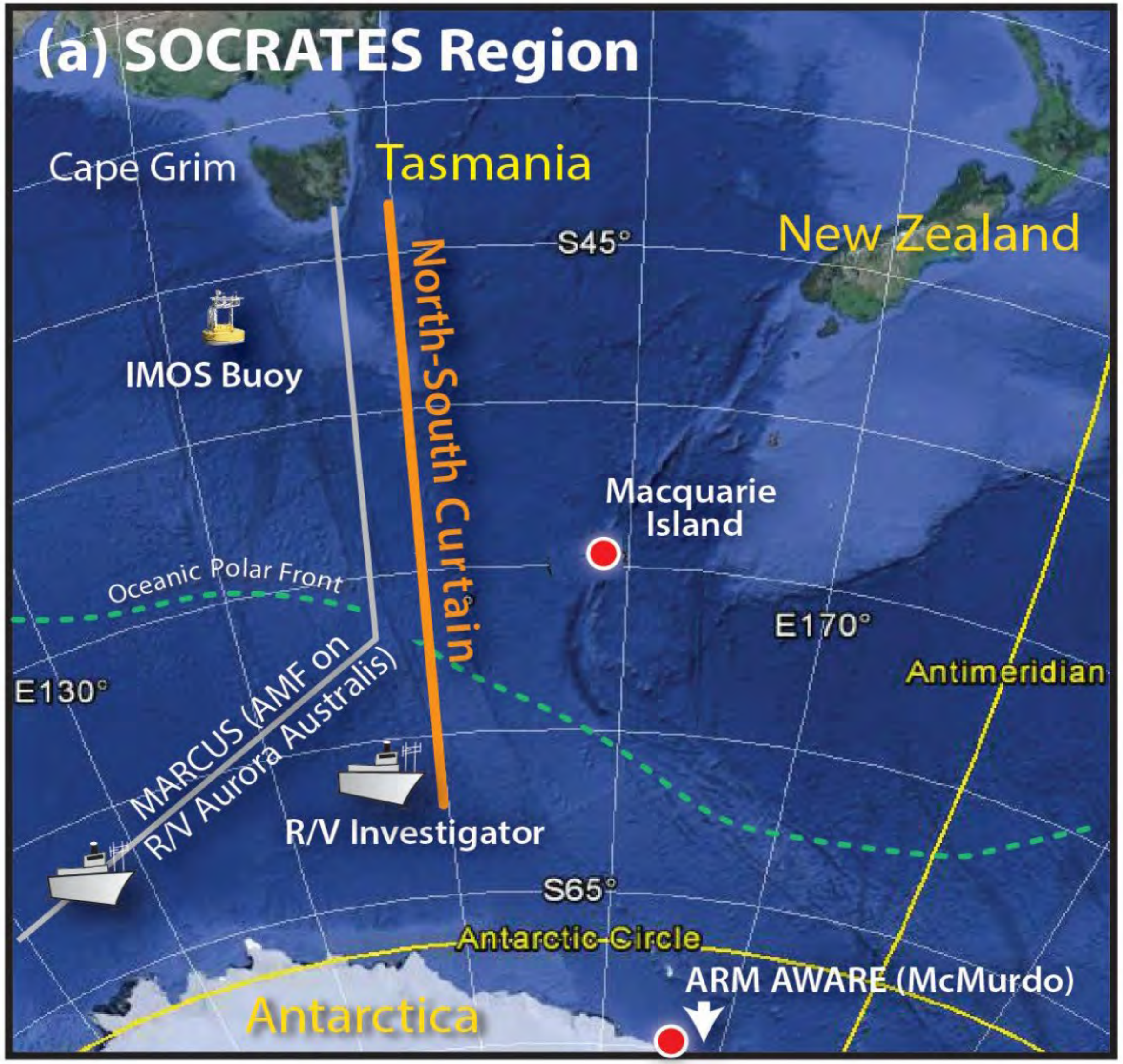
3) tropospheric states (pertaining to lowest atmospheric layer,), including role of clouds in atmospheric mixing, development of convective boundary layers in regions with diverse surface conditions, and role of micro and mesoscale circulation patterns on thermodynamic evolution;

4) surface-atmosphere interactions, including elements affecting radiative and turbulent surface energy exchange.

Southern Ocean Experiments, 2017-2018

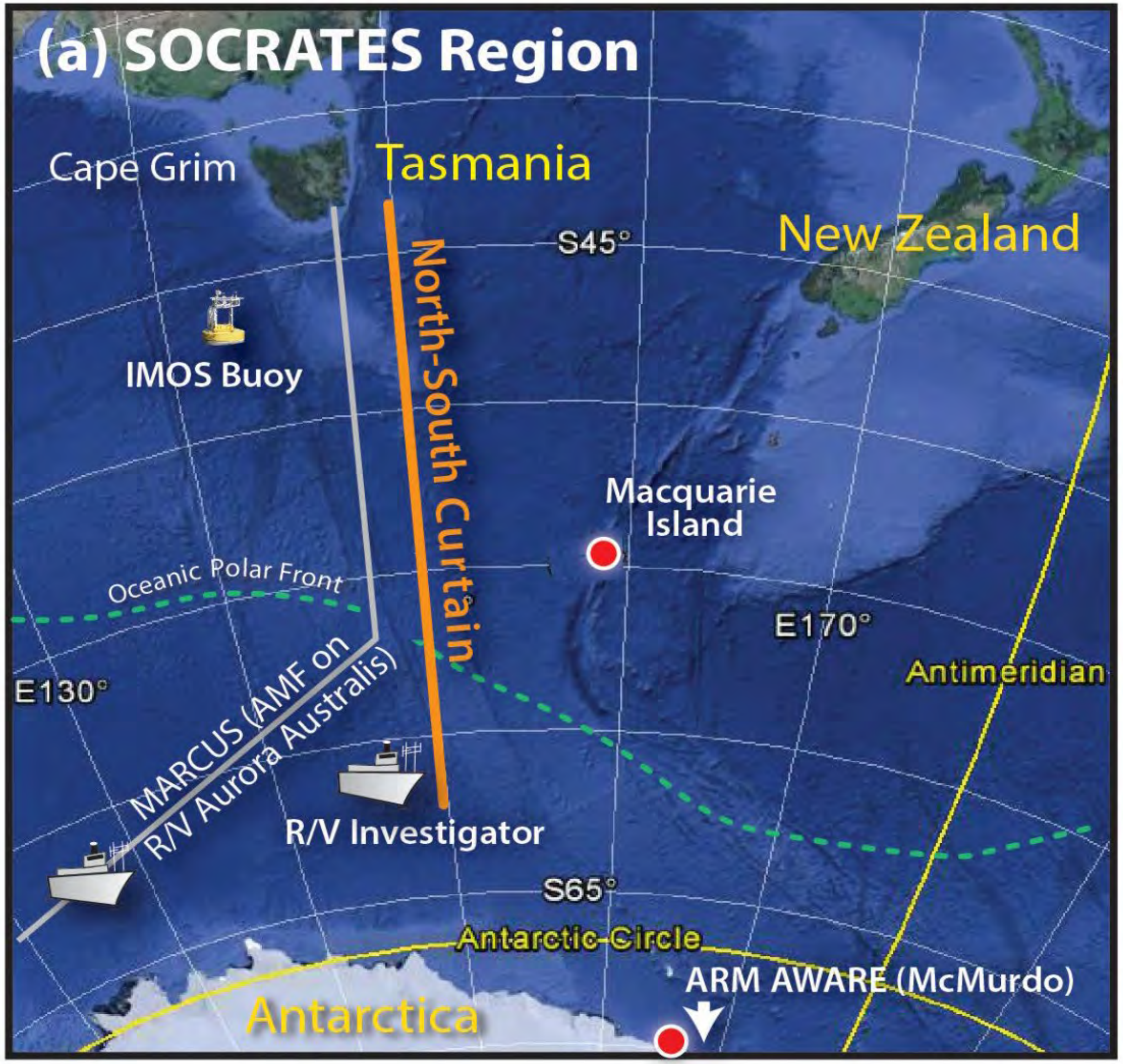


Southern Ocean Experiments, 2017-2018



SOCRATES (Jan 15-Feb 26 2018):
NSF G-V deployment

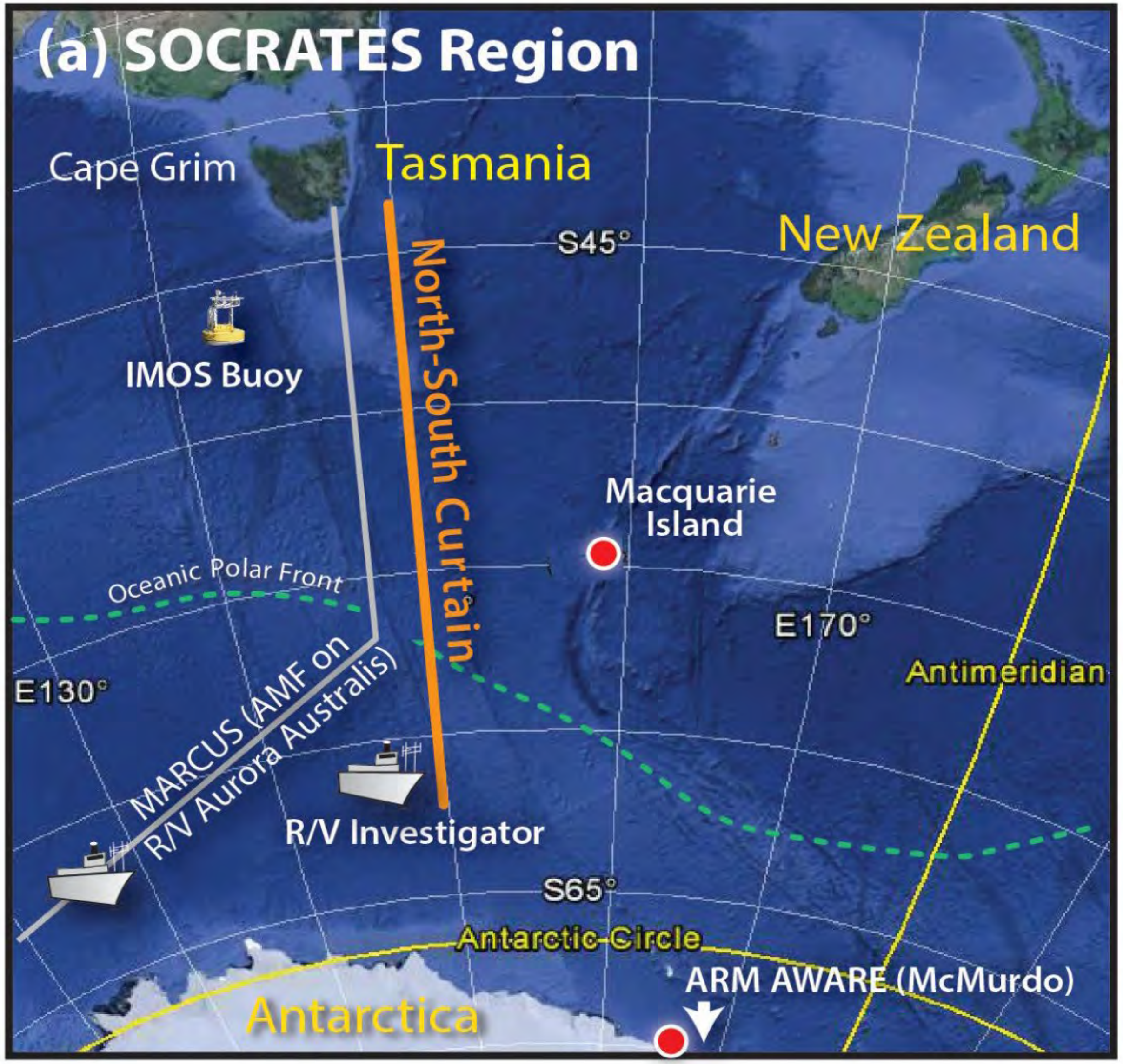
Southern Ocean Experiments, 2017-2018



CAPRICORN (2016-2018):

Australian R/V Investigator

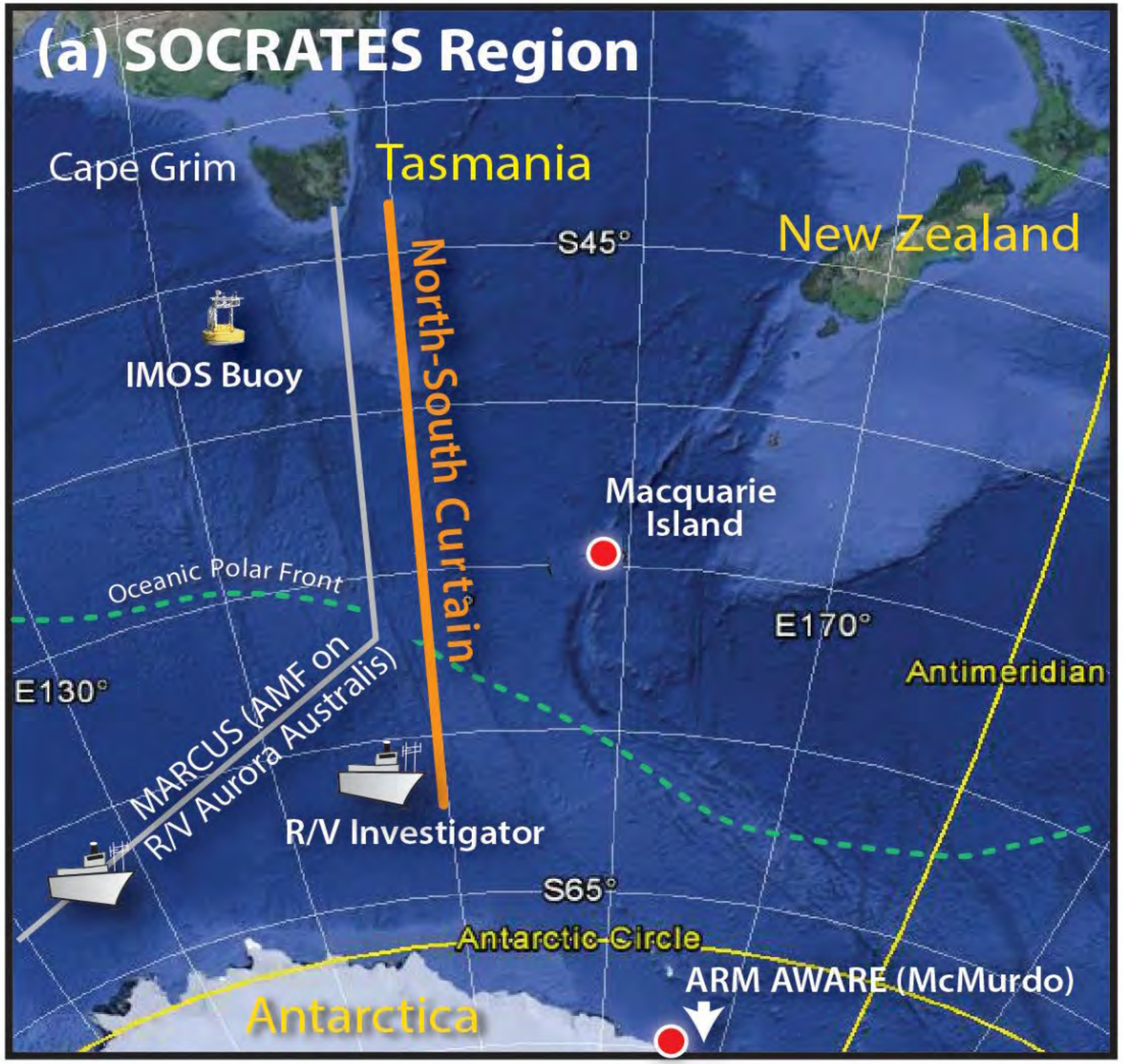
Southern Ocean Experiments, 2017-2018



MICRE (2017-2018):

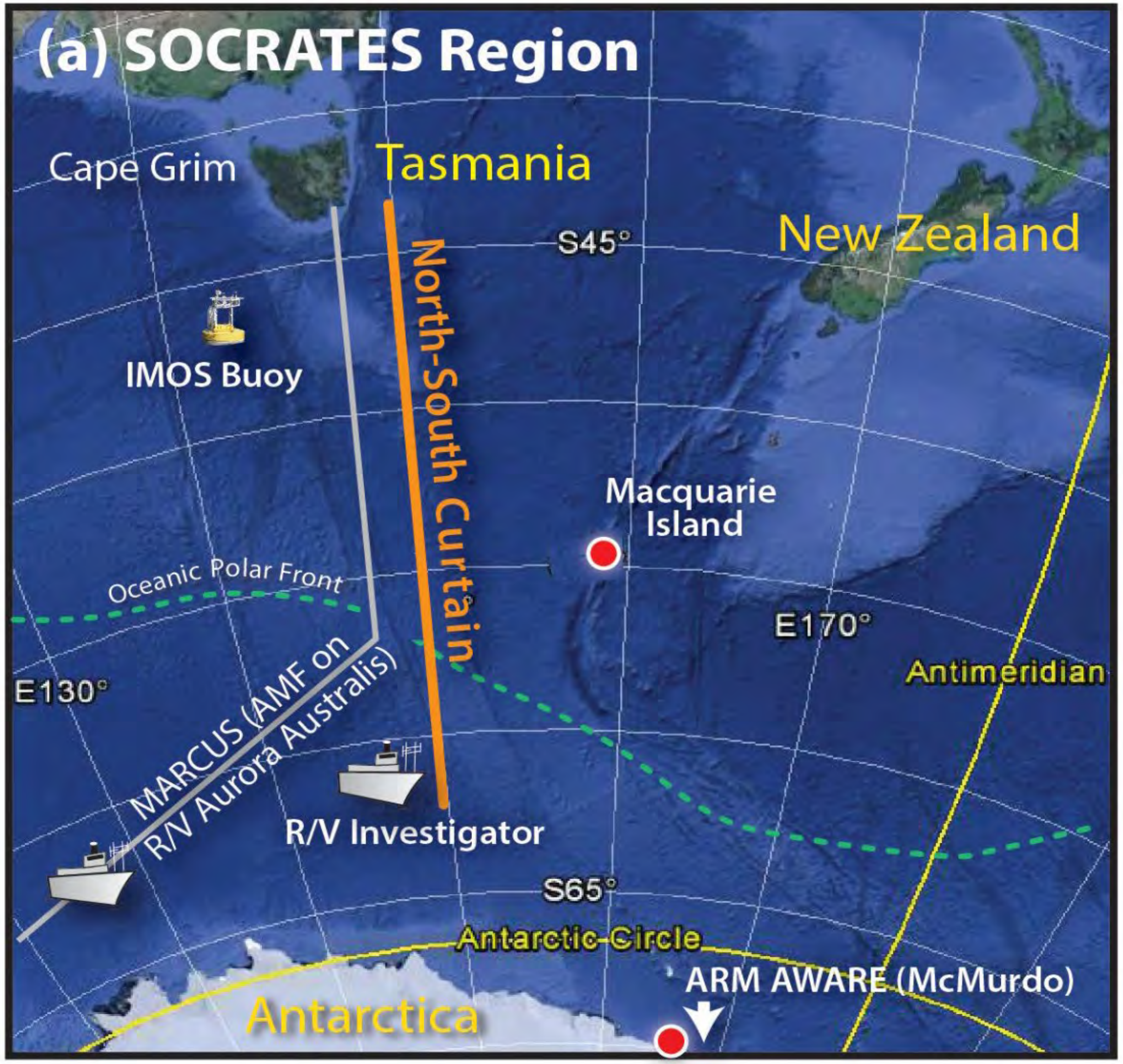
DOE, AUS instruments on Macquarie Island

Southern Ocean Experiments, 2017-2018

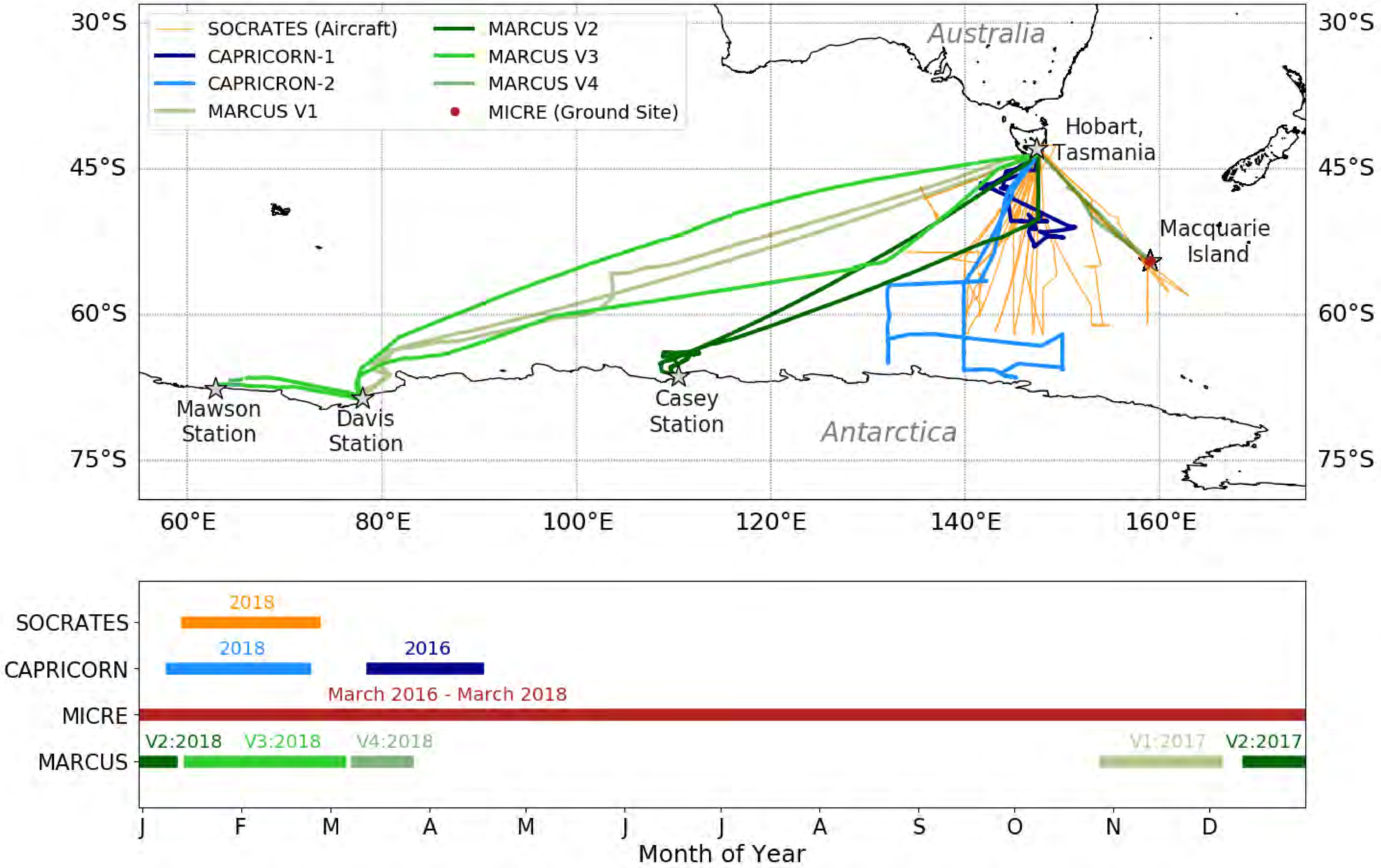


MARCUS (2017-2018):
AMF-2 on Aurora Australis

Southern Ocean Experiments, 2017-2018



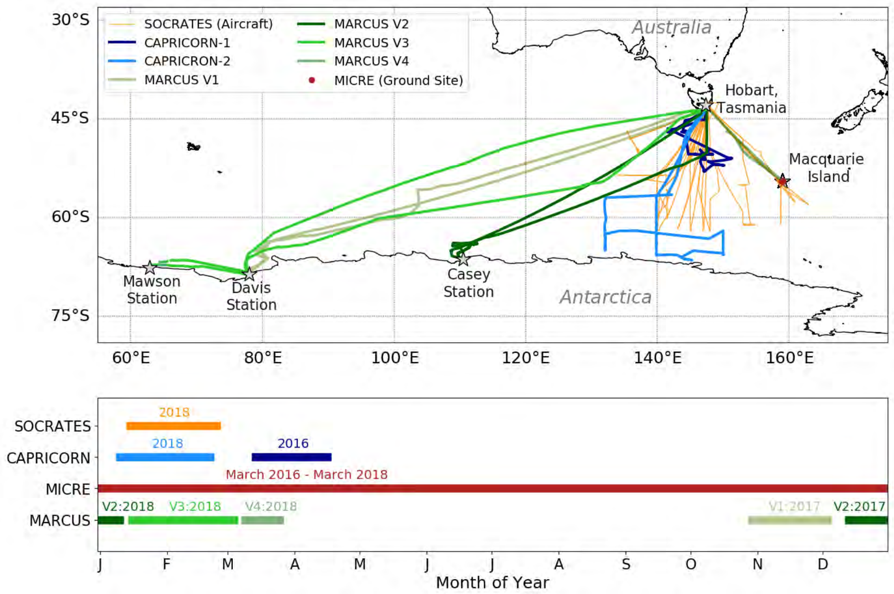
AWARE (2015-2017):
AMF-2 in West Antarctic

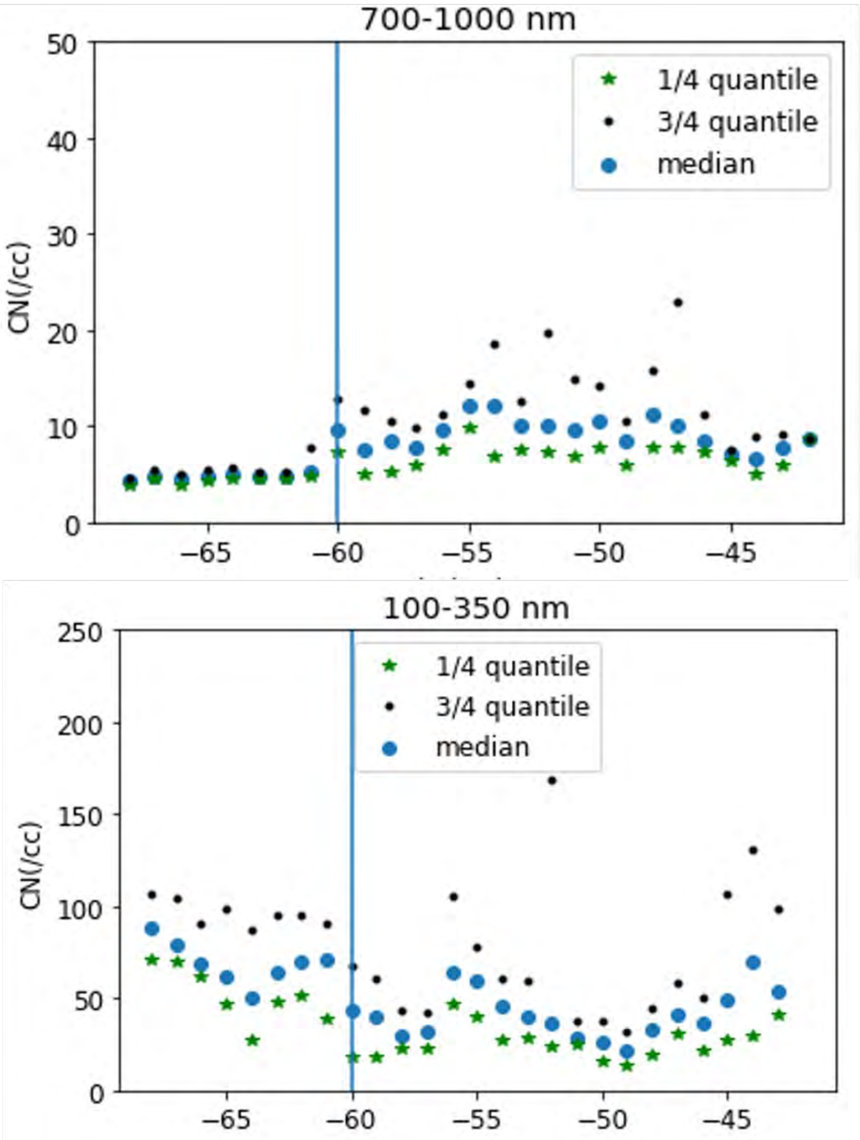

SOCRATES (Aircraft)
CAPRICORN-1
CAPRICRON-2
MARCUS V1
MARCUS V2
MARCUS V3
MARCUS V4
MICRE (Ground Site)
Australia
Hobart, Tasmania
Macquarie Island
Mawson Station
Davis Station
Casey Station
Antarctica
30°S
45°S
60°S
75°S
60°E
80°E
100°E
120°E
140°E
160°E
SOCRATES
CAPRICORN
MICRE
MARCUS
2018
2018
2016
March 2016 - March 2018
V2:2018
V3:2018
V4:2018
V1:2017
V2:2017
J F M A M J J A S O N D
Month of Year

ASR Atmospheric System Research

Controls of Aerosols over SO

Poster Session 5 (Thurs, 2-3 pm)





- UHSAS data from MARCUS cruises used to examine how concentrations of varying sized aerosols vary with latitude

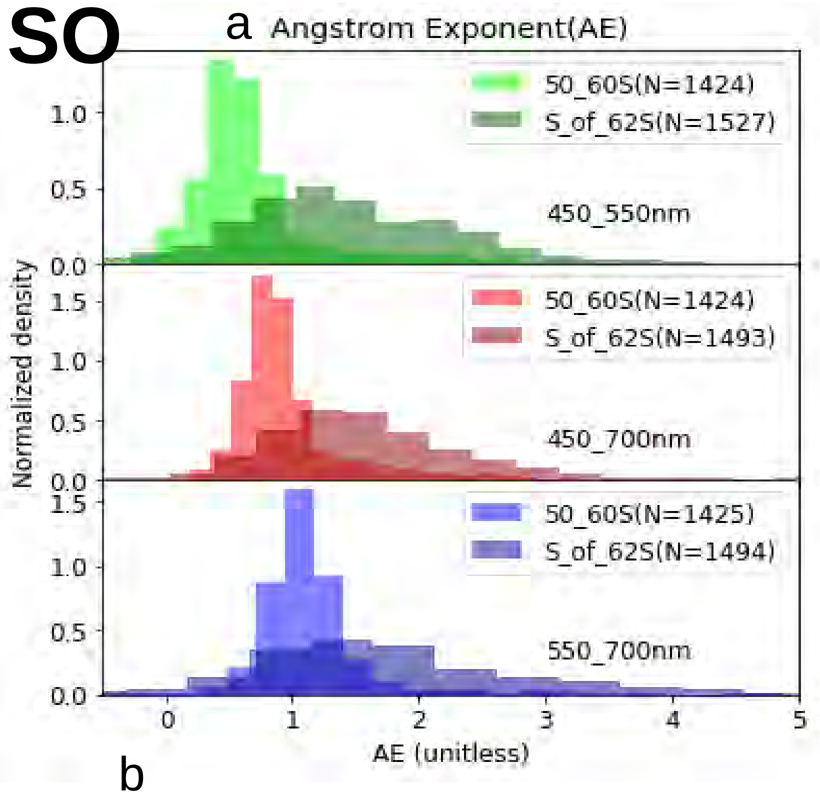
- Transition in accumulation mode aerosols occurred at 60-62°S with more (less) 700-1000 (100-350) nm north compared to south of this threshold

Qing Niu

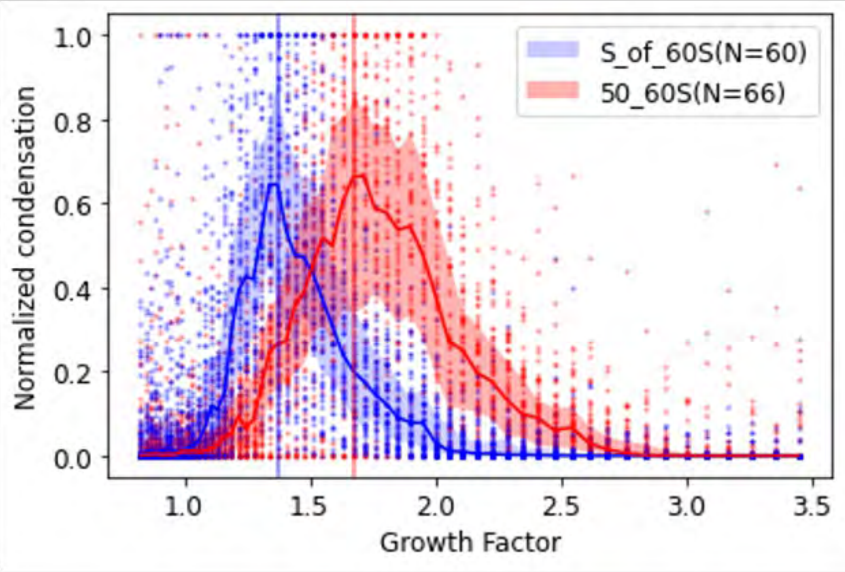
Controls of Aerosols over SO

- a) Angstrom exponent (AE, upper right) and b) growth factor (lower right) also vary north/south of 60-62°S
- HYSPLIT back trajectory analysis (c below)suggest aerosols 50-60°S originate from westerly flow near boundary layer, whereas those 62-65°S originate from higher in free troposphere over Antarctic continent

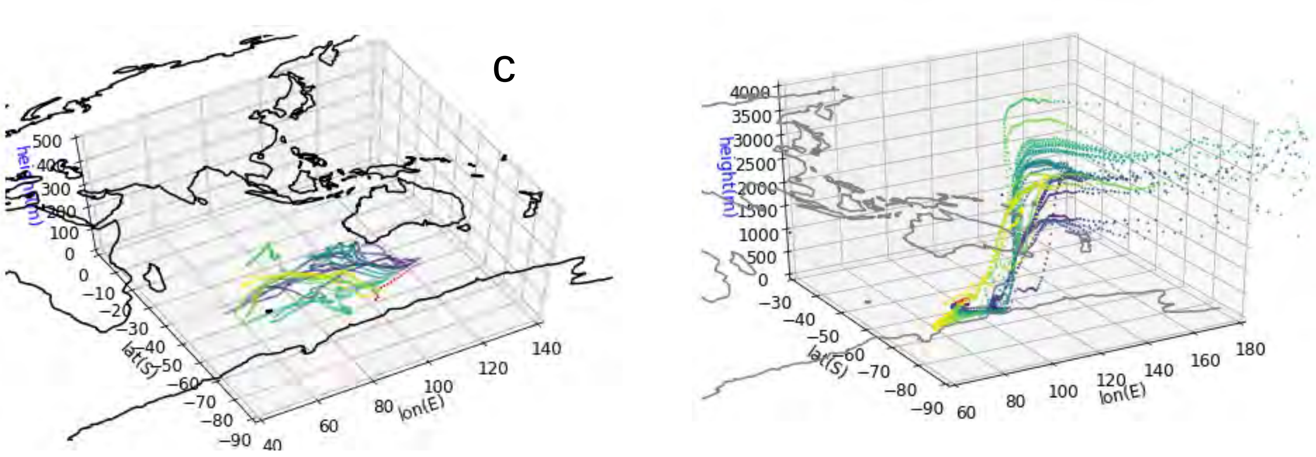
a



b



c



Qing Niu

Simulated Southern Ocean Aerosol and Ice Nucleating Particles

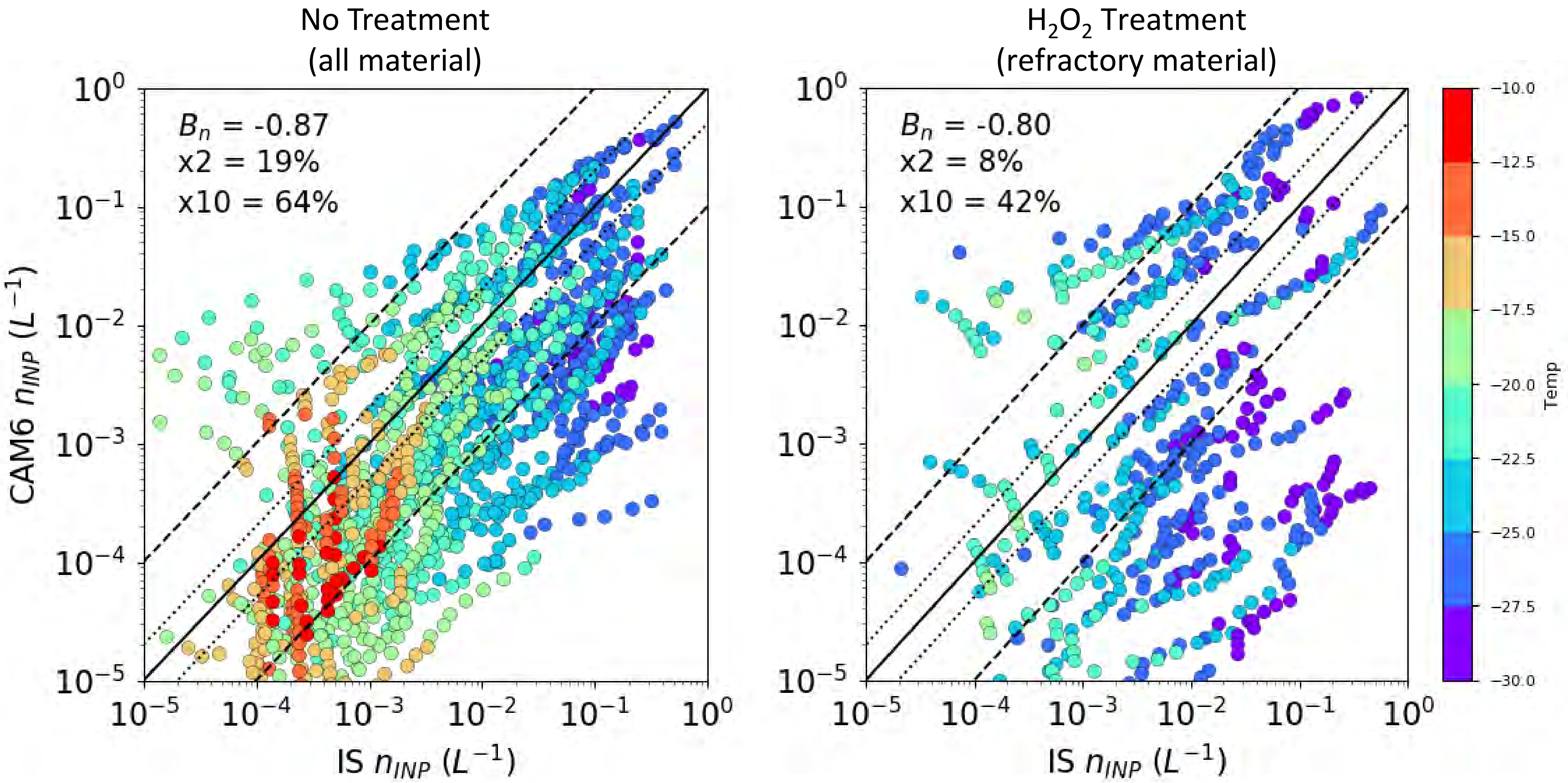
Poster Session 5 (Thurs, 2-3 pm)

Objective

To assess simulated aerosol and parameterizations that inform simulated ice nucleation

Key Result

While simulated land-derived aerosol concentrations are very low, the high ice nucleation efficiency and large variability in dust amount results in large biases in model—predicted INP number concentrations compared to observations.



Ice nucleating particle (INP) number concentrations predicted in CAM6 based on the simulated abundance of dust aerosol (following DeMott et al., 2015) and marine aerosol (following McCluskey et al., 2018) compared to the MARCUS observed INP number concentration for all particles (left) and for refractory particles remaining after a H_2O_2 treatment that removes non-refractory material

McCluskey, C. S., A. Gettelman, C. G. Bardeen, P. J. DeMott, K. A. Moore, S. M. Kreidenweis, T. C. J. Hill, C. H. Twohy, D. W. Toohey, B. Rainwater, J. B. Jensen, and J. M. Reeves, Southern Ocean Aerosol and Ice Nucleating Particles in the Community Earth System Model Version 2, *in prep for JGR Atmos.*

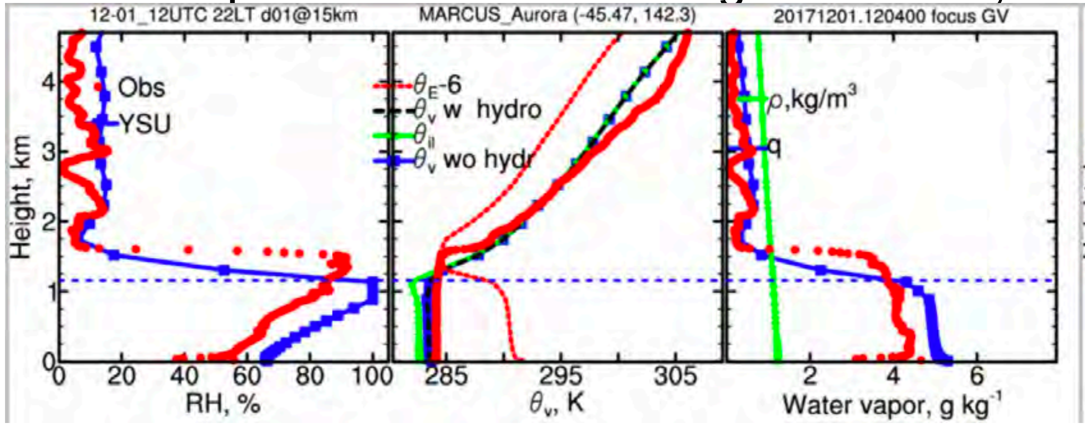
ASR Atmospheric System Research

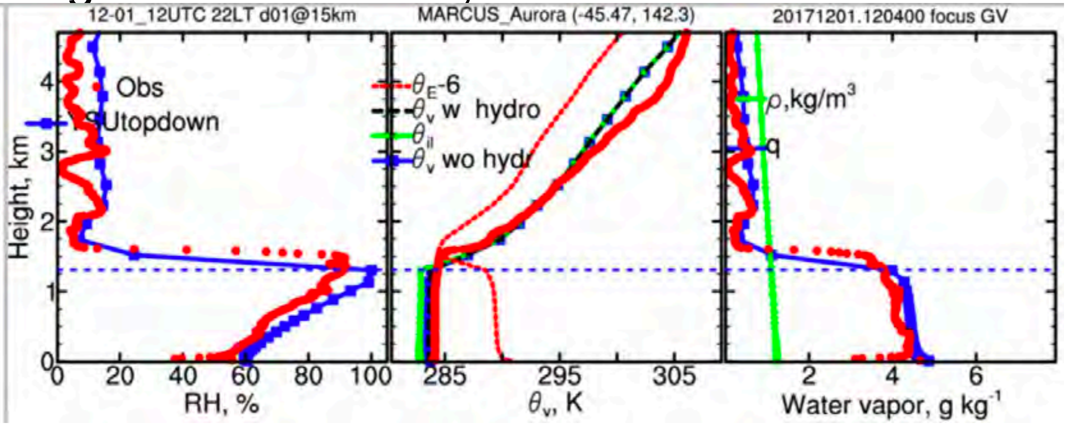
3 Modes of cloud-BL coupling over SO

Poster Session 5 (Thurs, 2-3 pm)

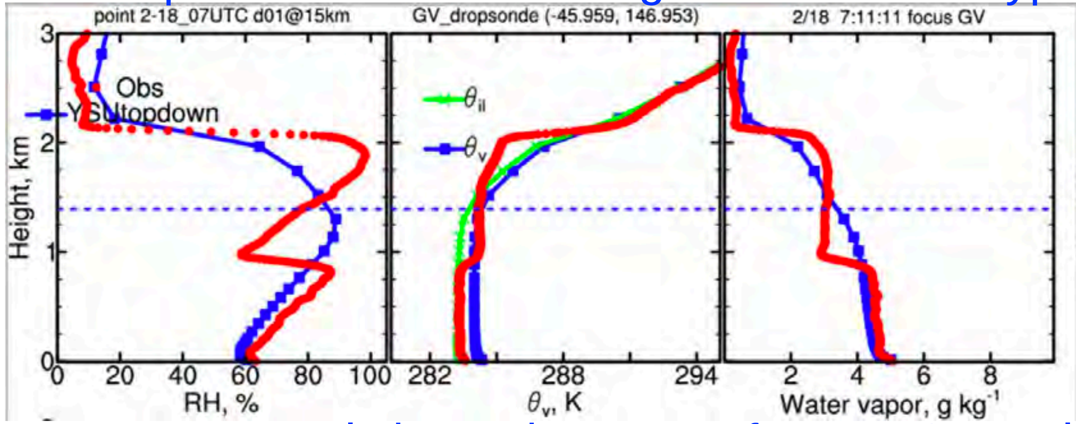
Xiao Ming Hu

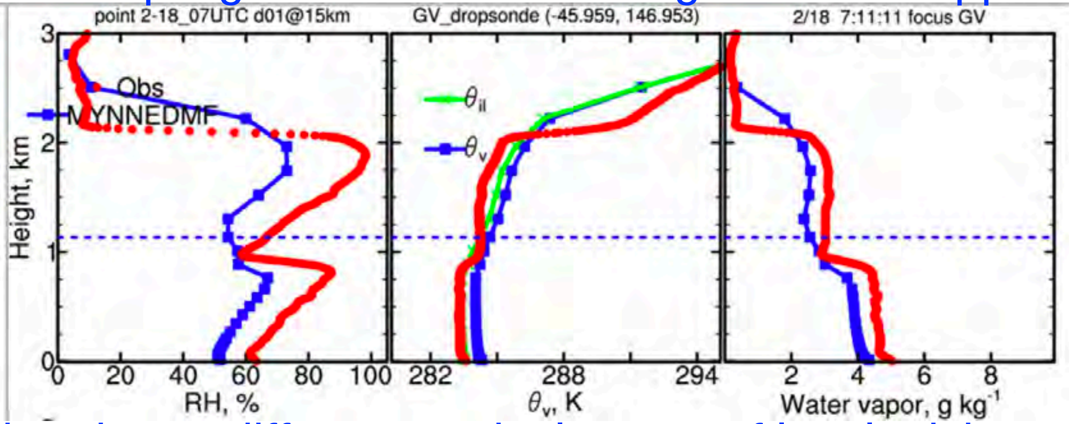
- Coupled cloud-BL in presence of weak surface + flux
- Decoupled cloud-BL in presence of surface - flux, with shallow surface-based BL
- Decoupled cloud-BL with higher clouds, stronger surface +flux, & thicker surface-based BL





YSUtopdown shows advantage over YSU for type 1 coupling mode to simulate higher cloud-topped BL.





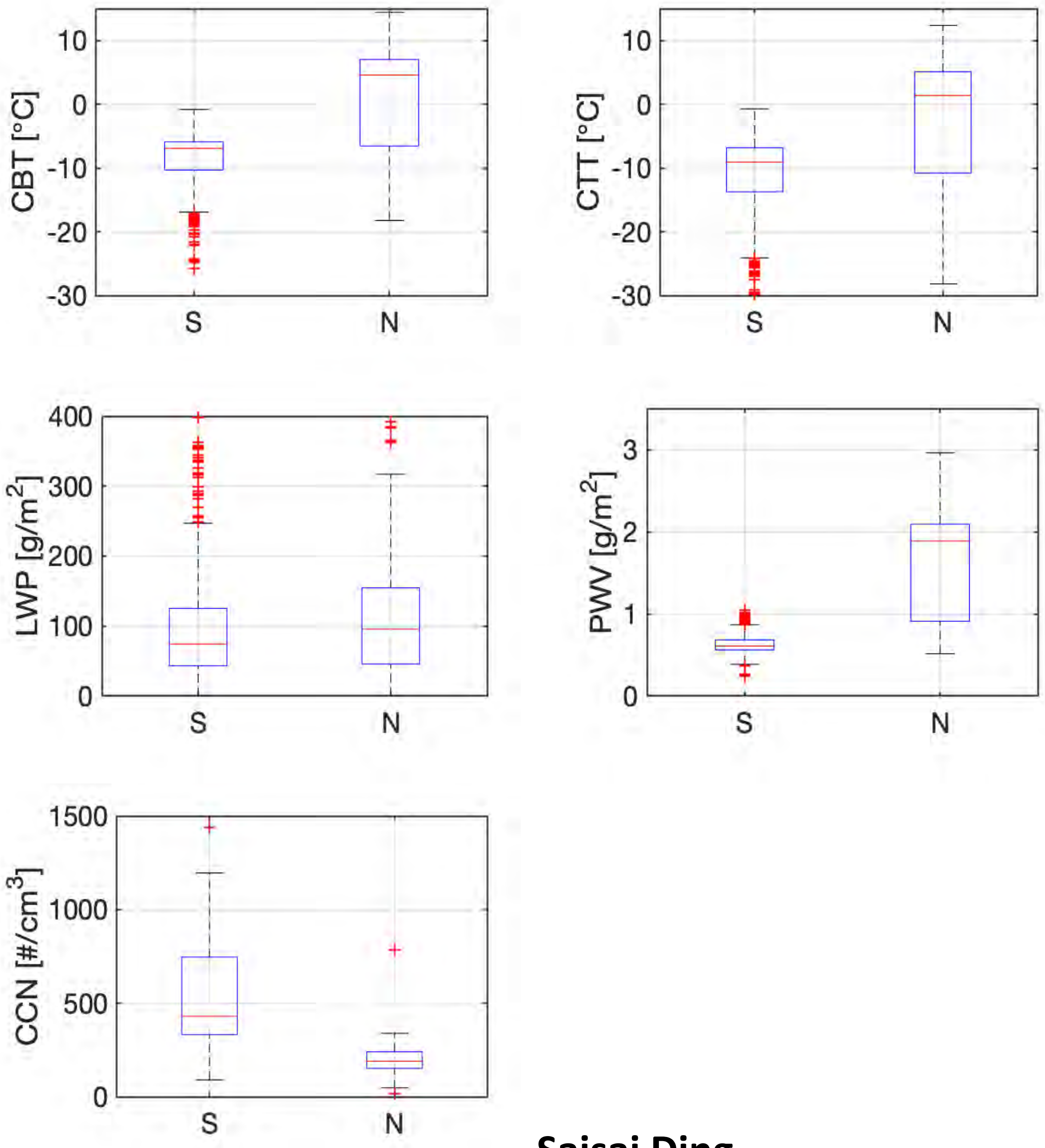
MYNN-EDMF only has advantages for type 3 coupling due to different vertical extent of local mixing & nonlocal mass flux in presence of sufficient enough surface flux.

Clouds: Ship- and Ground-based Remote Sensing

- **Ding/McFarquhar VAP segregate data by environmental, geographic & meteorological conditions observed during MARCUS to identify controls of SLW**

Variable	Source
Sea surface temperature (SST)	Infrared Thermometer
Cloud base temperature (CBT)	Cloud base height (CBH) from Ceilometer merged with T profiles from 6hourly sounding
Precipitating /non-precipitating clouds (PC/NPC)	Maximum column radar reflectivity dBZ_{max}>-15 dBZ is PC, -30<dBZ_{max} <-15dBZ is NPC (Huang et al., 2016)
Coupled /decoupled	$\triangle c_b$ = CBH – LCL, $\triangle c_b$ >300m is decoupled & $\triangle c_b$ <300m is coupled (Comstock et al., 2005)
North/ South of the ocean polar front (NPF/SPF)	Daily SST from AVHRR (Dong et al., 2006)
Air mass origin westerly/ easterly (W/E)	48hrs HYSPLIT back trajectory simulation
Location relative to cyclone	Sea level pressure (SLP)

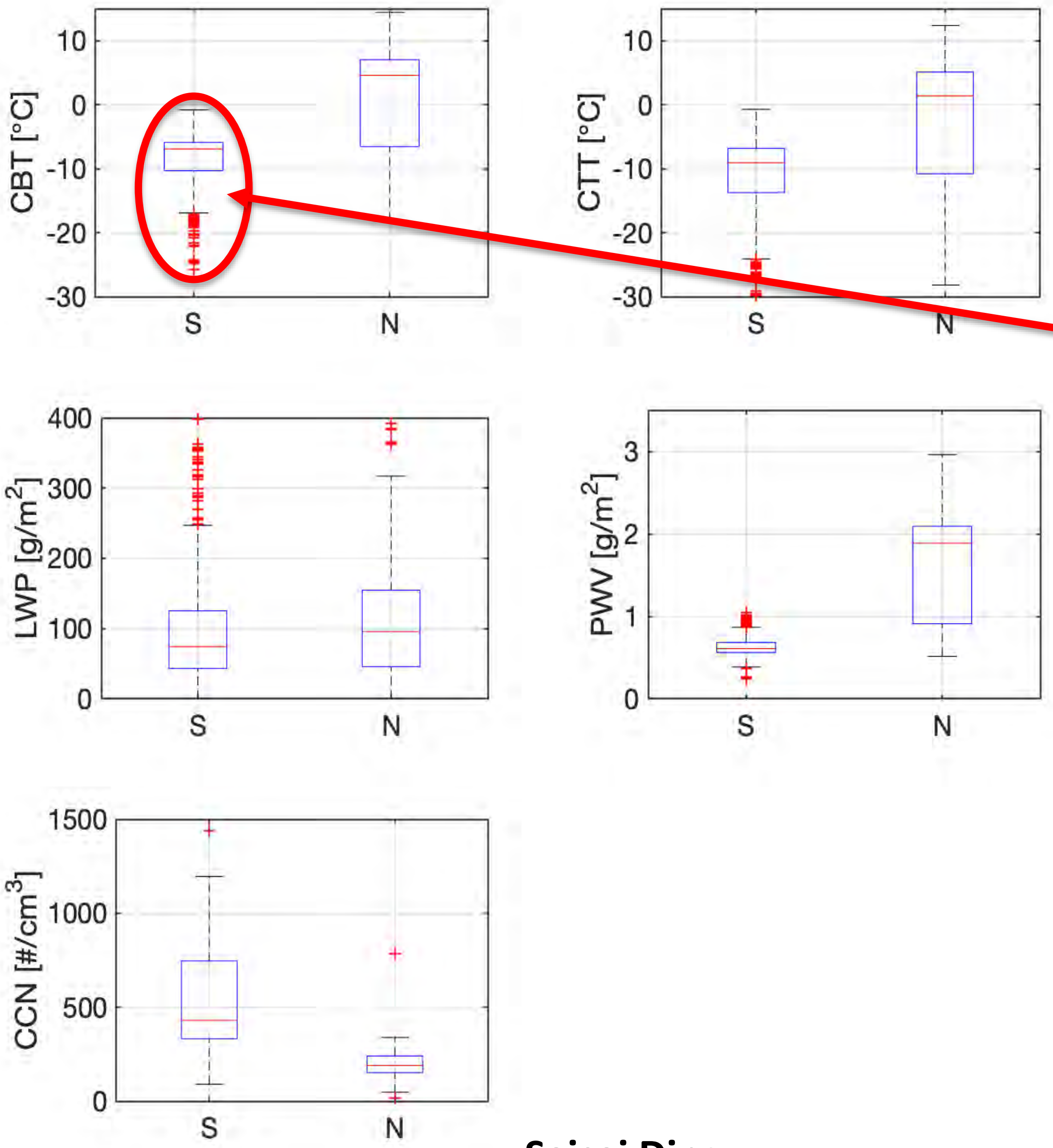
Clouds: Ship- and Ground-based Remote Sensing



- How properties of single-layer, non-precipitating clouds with z_b < 3 km & > 500 km from nearest cyclone center varied whether north or south of 60˚S.

Saisai Ding

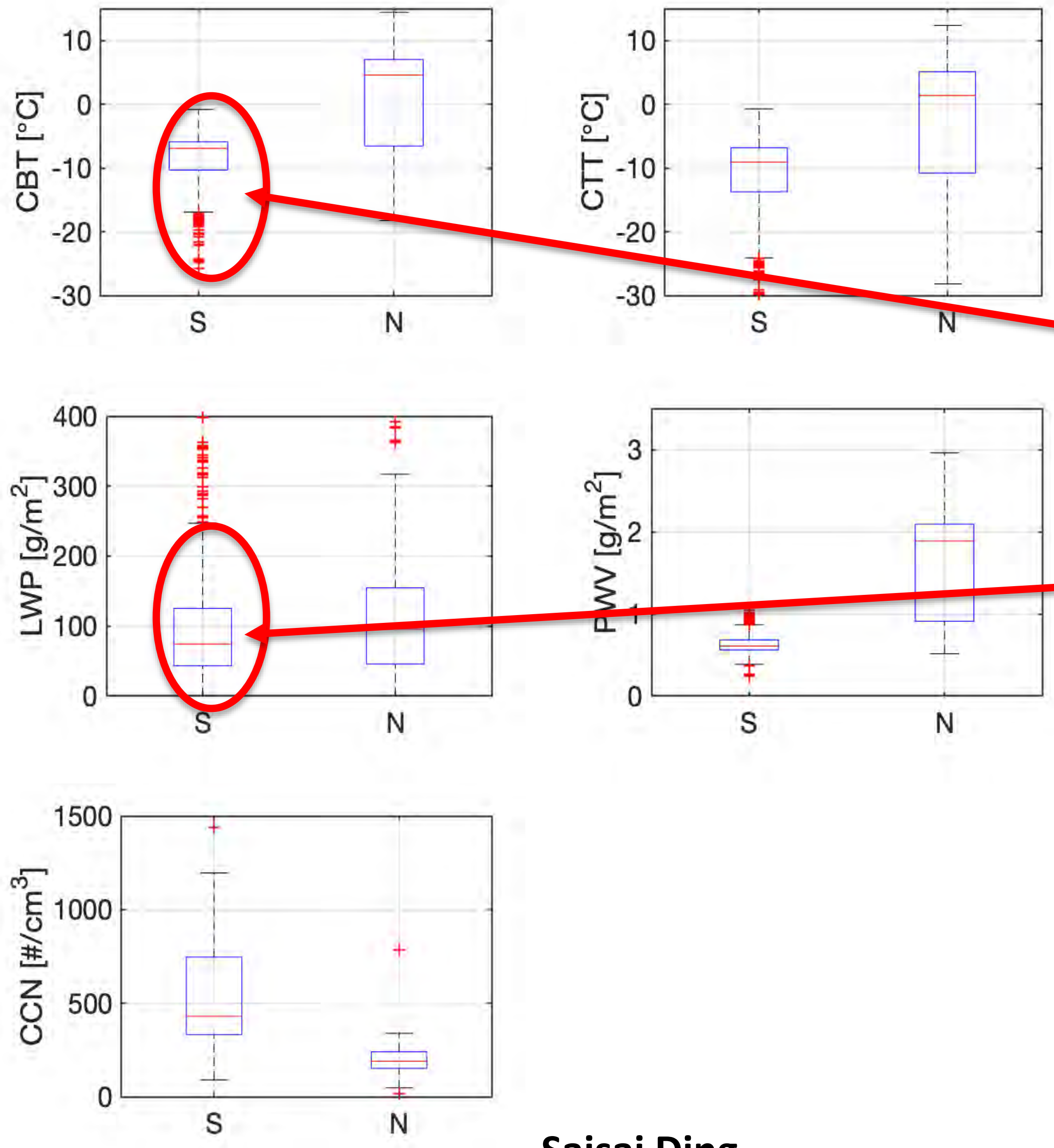
Clouds: Ship- and Ground-based Remote Sensing



- How properties of single-layer, non-precipitating clouds with z_b < 3 km & > 500 km from nearest cyclone center varied whether north or south of 60˚S.
- Average cloud base T ~ -10˚C S of 60˚S

Saisai Ding

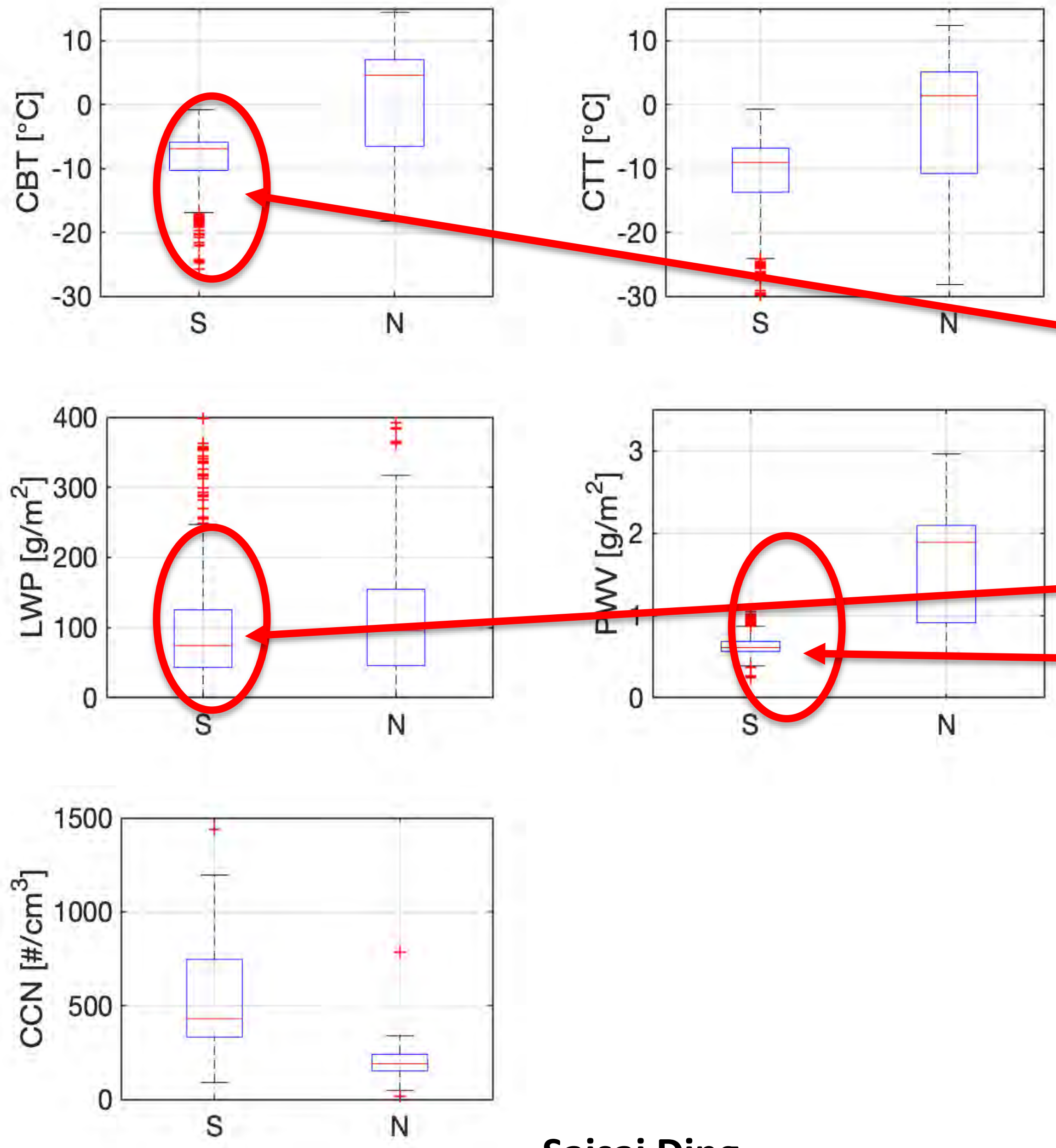
Clouds: Ship- and Ground-based Remote Sensing



- How properties of single-layer, non-precipitating clouds with z_b < 3 km & > 500 km from nearest cyclone center varied whether north or south of 60S.
- Average cloud base T ~ -10C S of 60S → SLW extensive south of polar front

Saisai Ding

Clouds: Ship- and Ground-based Remote Sensing

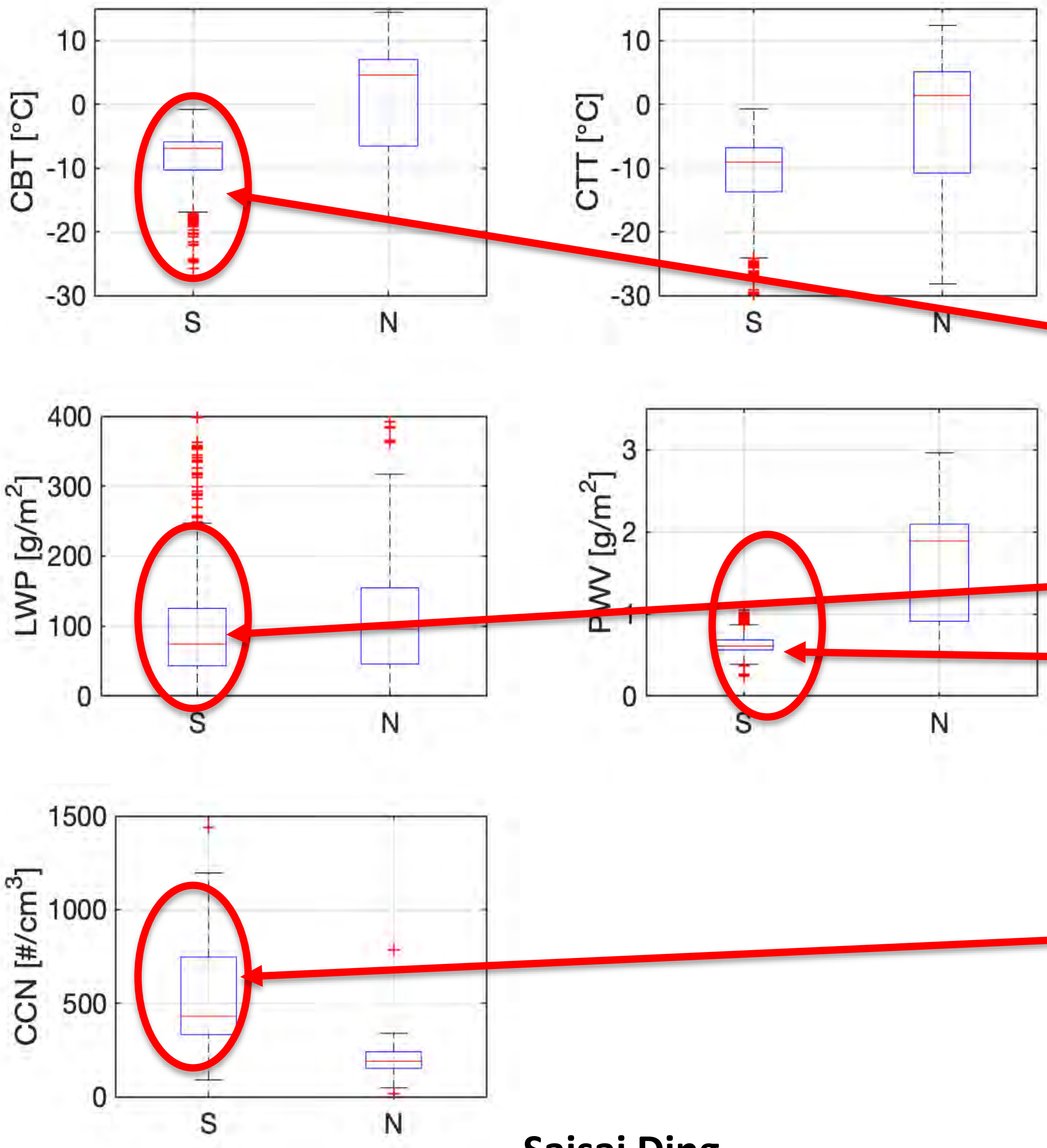


- How properties of single-layer, non-precipitating clouds with z_b < 3 km & > 500 km from nearest cyclone center varied whether north or south of 60˚S.

- Average cloud base T ~ -10˚C S of 60˚S → SLW extensive south of polar front even though less precipitable water

Saisai Ding

Clouds: Ship- and Ground-based Remote Sensing



- How properties of single-layer, non-precipitating clouds with $z_b < 3$ km & > 500 km from nearest cyclone center varied whether north or south of 60°S.
- Average cloud base T ~ -10°C S of 60°S → SLW extensive south of polar front even though less precipitable water
- CCN and retrieved N_c peaked in December and appear less south of 60°S

Saisai Ding

Evaluating Earth System Models with MICRE Data

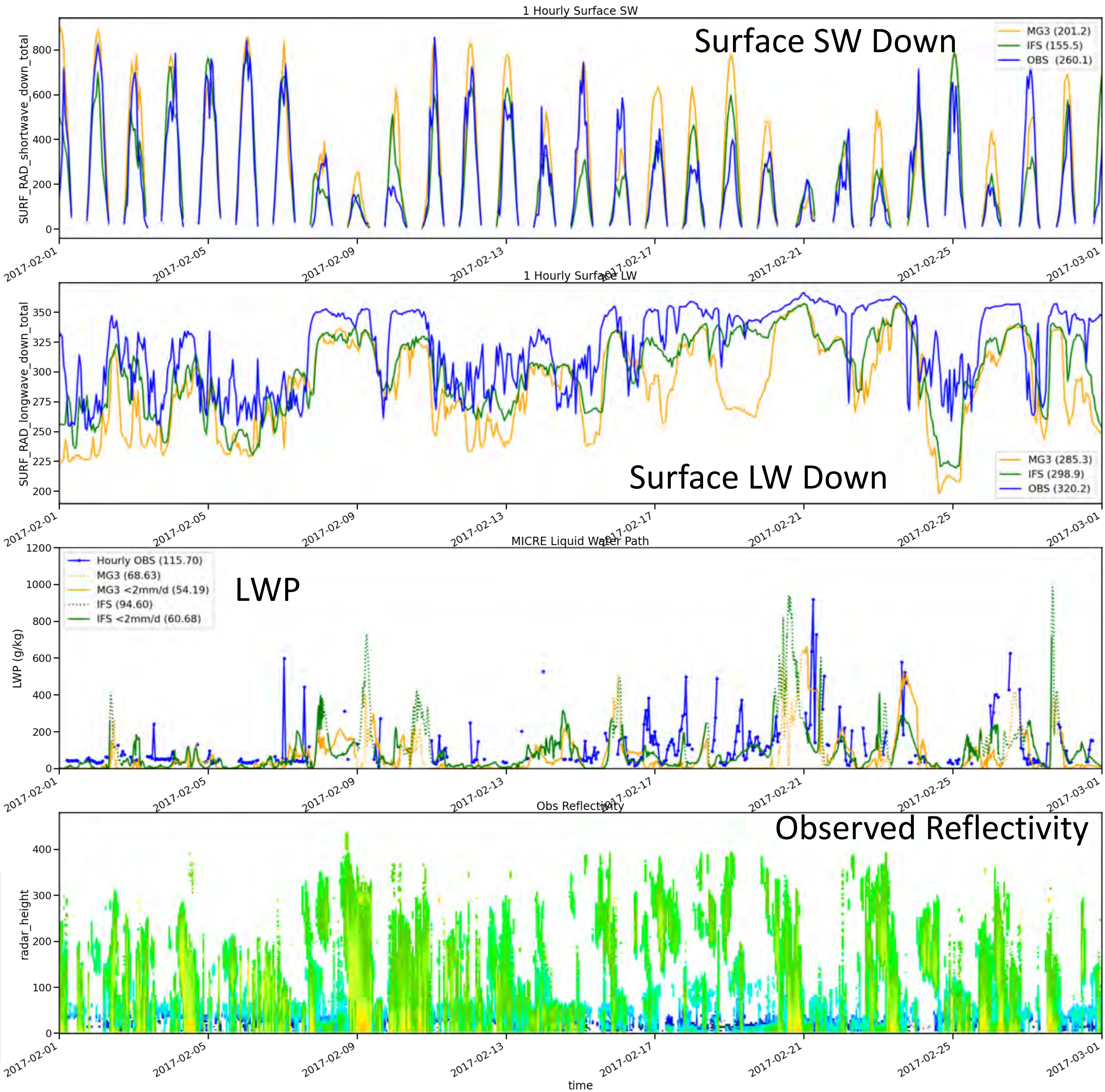
A. Gettelman (NCAR), R. Forbes (ECMWF), R. Marchand (UW-Seattle)

- MICRE :Macquarie Island, S. Ocean, Jan-Mar 2017
- Single Column forced by observed meteorology
- Perform detailed comparisons to in-situ data

- Focus on cloud microphysics
- Evaluate statistics over 90 days & individual events
- Goal: understand model biases from process level to statistical biases in radiation

- SCM methods will be made available (moving into standard CESM SCM case suite)

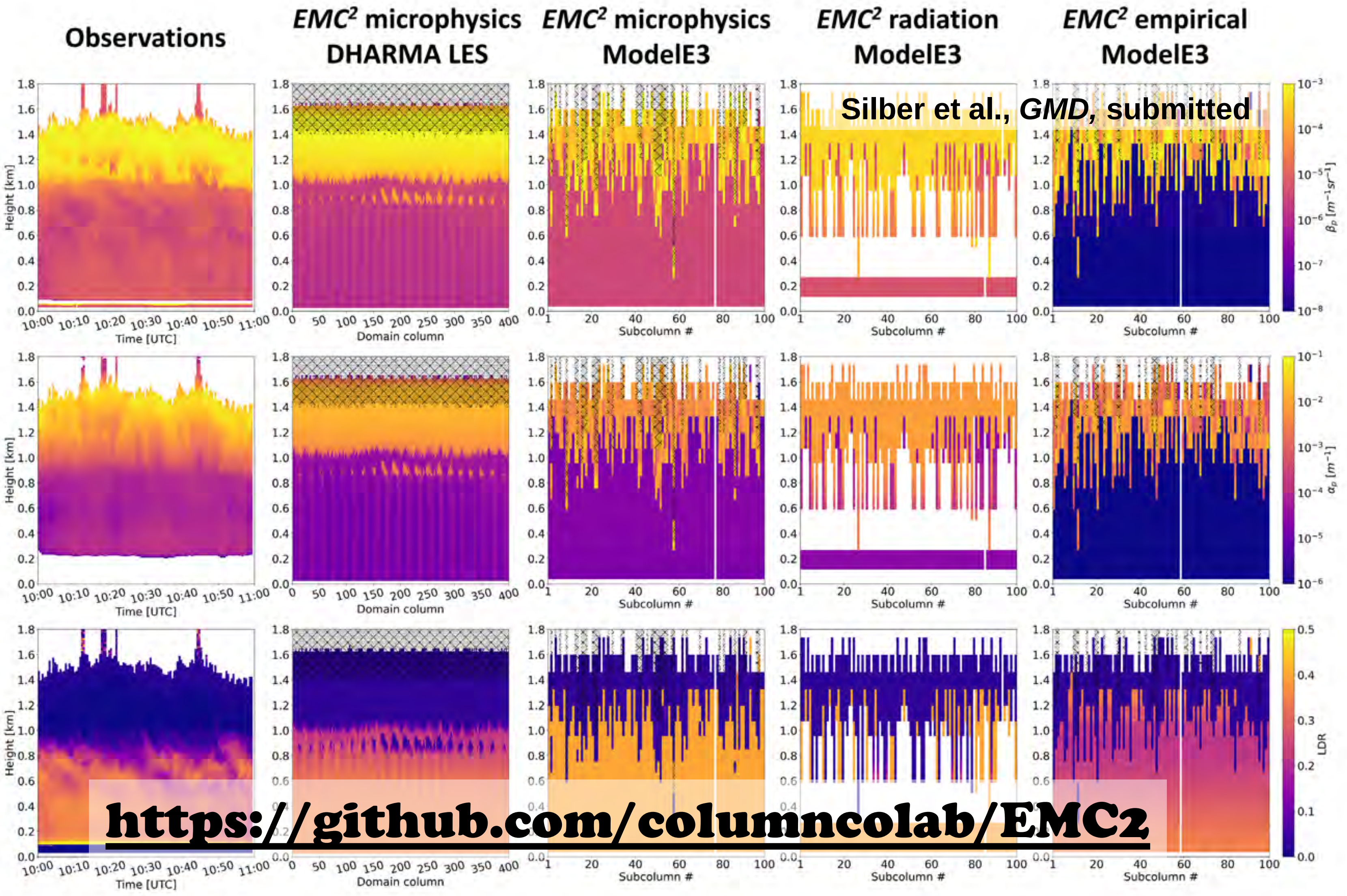
February 2017
MG3 2-moment micro
IFS Microphysics
MICRE Observations



The Earth Model Column Collaboratory (*EMC²*) Ground-Based Lidar and Radar Simulator and Subcolumn Generator for Global Climate Model

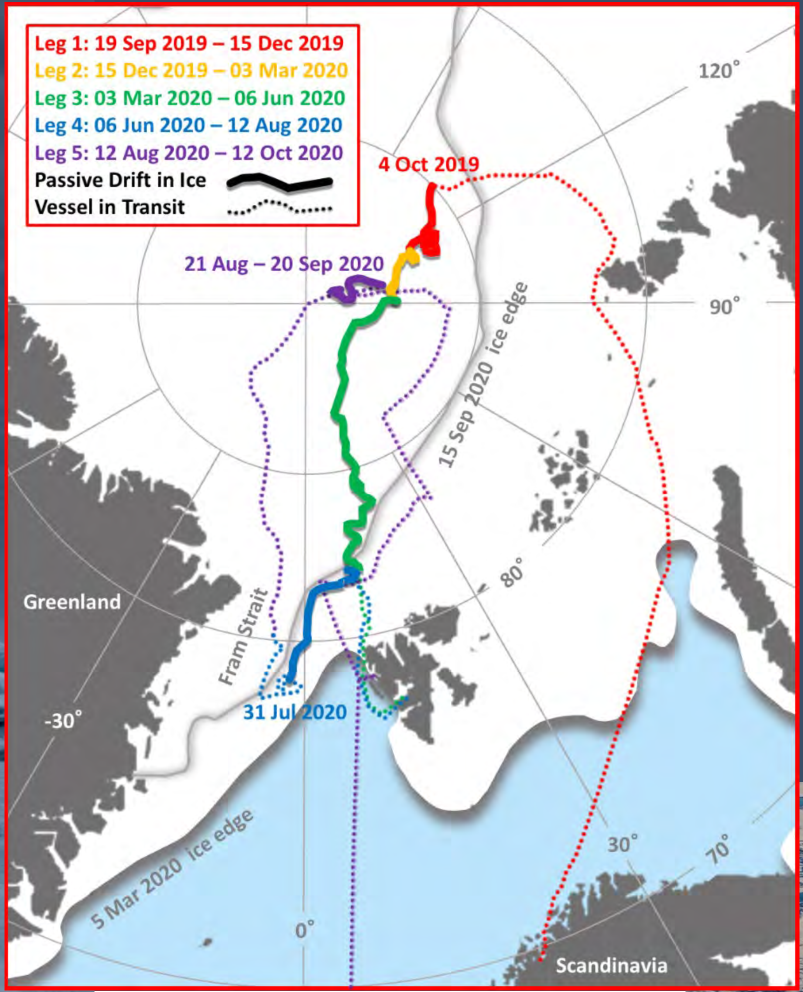
Israel Silber, Robert C. Jackson, Ann M. Fridlind, Andrew S. Ackerman, Scott Collis, Johannes Verlinde, and Jiachen Ding

- *EMC²* is an open-source ground-based lidar and radar simulator and subcolumn generator, specifically designed for climate models but also applicable to high-resolution model output.
- *EMC²* provides a flexible framework enabling direct comparison of model output with ground-based radar and lidar observations.
- *EMC²* enables the emulation of ground-based (and air- or space-borne) measurements while remaining faithful to models' physical assumptions implemented in their microphysics or radiation schemes.
- The *EMC²* software is written in Python, allowing fast orientation, and can be straightforwardly customized for different models, radars, and lidars.
- **See more at our poster!**



Caption: Use of EMC² to compare the AWARE highly supercooled precipitating cloud LES case study lidar observations (Silber et al., *JGR*, 2019) with the NASA GISS ModelE3 climate model SCM. SCM initialization files required to run this case are accessible at: http://dx.doi.org/10.17632/gz4gdn3jvz.1

MOSAiC – Multidisciplinary drifting Observatory for the Study of Arctic Climate



- *AMF2 for 1 year in the Arctic sea ice*
- *Most comprehensive Central Arctic observations ever*
- *Covered all seasons, including cold-dark winter*
- *Lots of data available at the ARM archive (!Please use it!)*
- *New Scientific Insights (among many others):*
  - ➢ *aerosol processes, annual cycle, and sources*
  - ➢ *cloud impacts on surface energy budget*
  - ➢ *atmospheric stratification*
  - ➢ *cyclone structure and impacts*
  - ➢ *snowfall and snow on sea ice*
  - ➢ *atmosphere-ice-ocean coupling*
- *MOSAiC Breakout Session: Tuesday, 22 June, 11am EDT*

The Expedition:
Sept 2019 – Oct 2020

ARM

ASR Atmospheric System Research

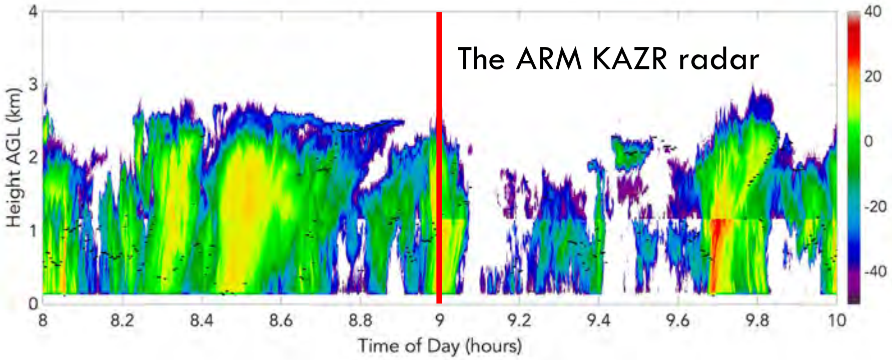
Contact: Matthew.Shupe@noaa.gov

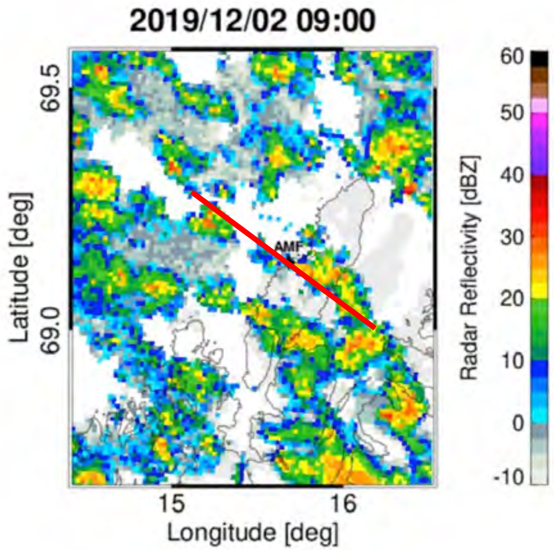
Dynamics of high-latitude boundary layer clouds during Cold-Air Outbreaks

Pavlos Kollias[1,2], Zeen Zhu[1], Zackary Mages[1], Edward Luke[2], Fan Yang[2], Alessandro Battaglia[3] and Bernat Puigdomenech[4]

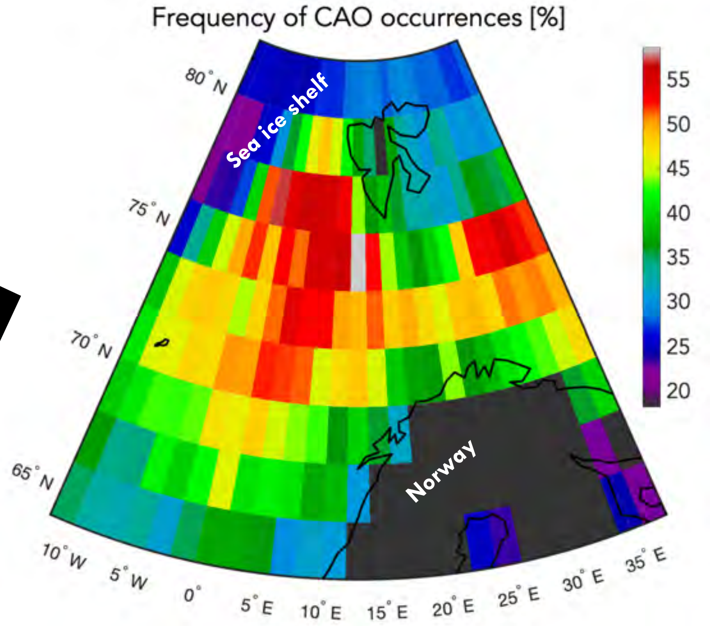
1. Division of Atmospheric Sciences, Stony Brook University, NY USA
2. Environmental and Climate Sciences Dept., Brookhaven National Laboratory, NY USA
3. Dept. of Environment, Land and Infrastructure Engineering, Polytechnic University of Turin, Italy
4. Atmospheric and Oceanic Sciences, McGill University, Canada

Objective: (1) Describe the mesoscale organization of CAO clouds and precipitation and (2) describe the profiles of vertical velocity, cloud properties, and boundary layer precipitation and radiation





The Met Norway weather radar network



A 4-year CloudSat climatology 2007-2011 Dec 1st to May 31st

RADAR SCIENCE

Stony Brook University

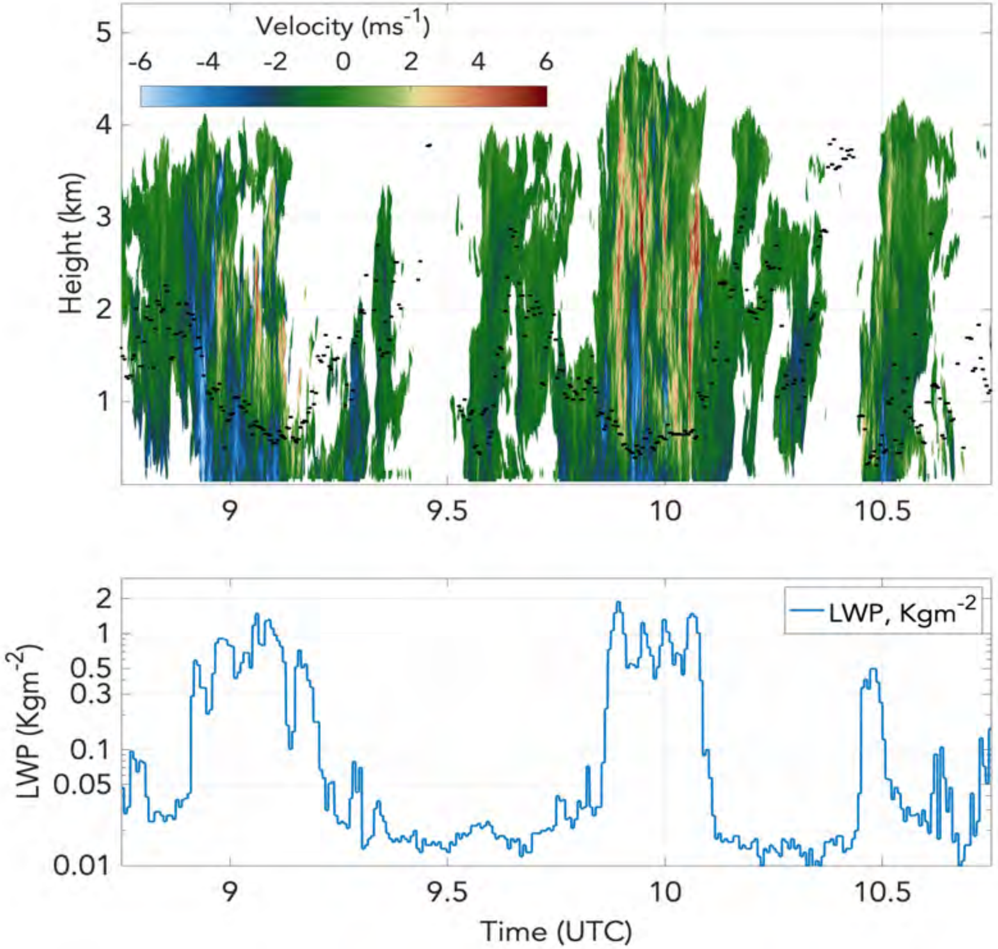
Brookhaven National Laboratory

Ongoing and future work

Develop high resolution (KAZR resolution) product with TKE, vertical air motion and supercooled liquid mask

Investigate ice particle growth in CAO's and the role of supercooled liquid

Apply radar simulators (CR-SIM, GO^2-SIM etc.,) to model output (i.e., E3SM, UK Met Office) for MODEX studies



For info contact: zeen.zhu@stonybrook.edu & zackary.mages@stonybrook.edu

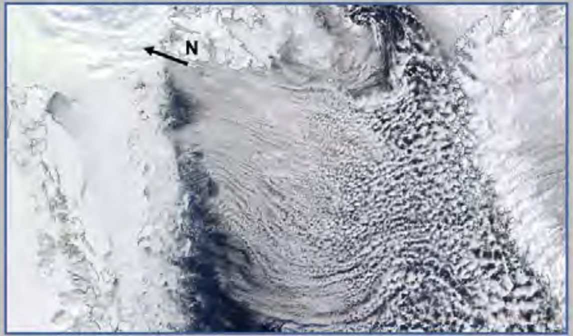
Follow our progress: http://doppler.somas.stonybrook.edu/comble/index.html

RADAR SCIENCE

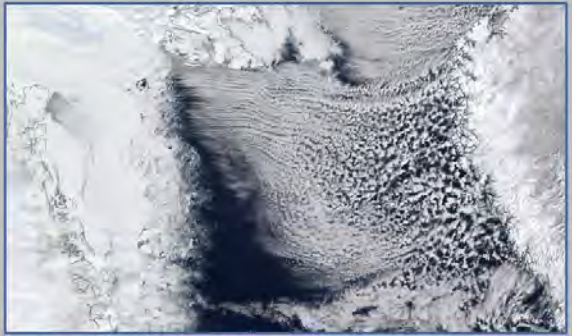
Stony Brook University

Brookhaven National Laboratory

28-29 March 2020 COMBLE event: Satellite imagery

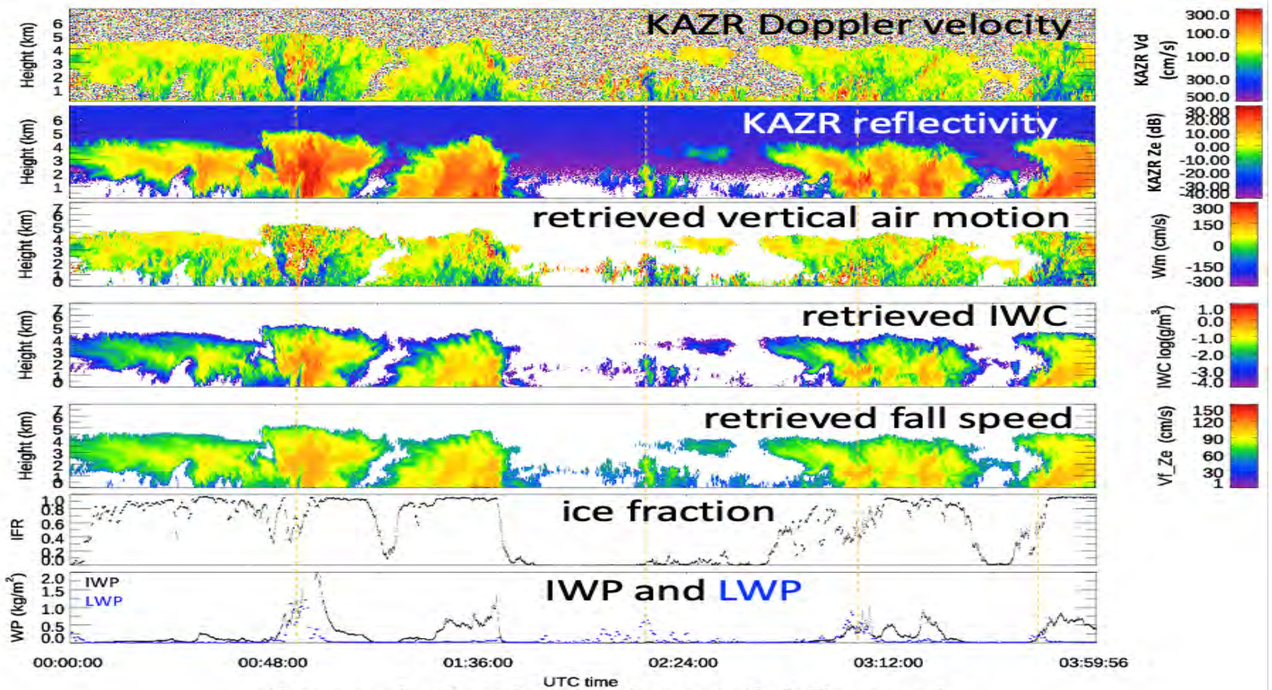


MODIS visible image from 28 March 2020 at ~11 UTC



MODIS visible image from 29 March 2020 at ~12 UTC

- Mostly northerly flow near ice edge where we observe roll structures
- Cloud transitions are very apparent
- Cloud-free zone develops near ice edge, followed by cloud boundary
- More numerous & larger open cell structures

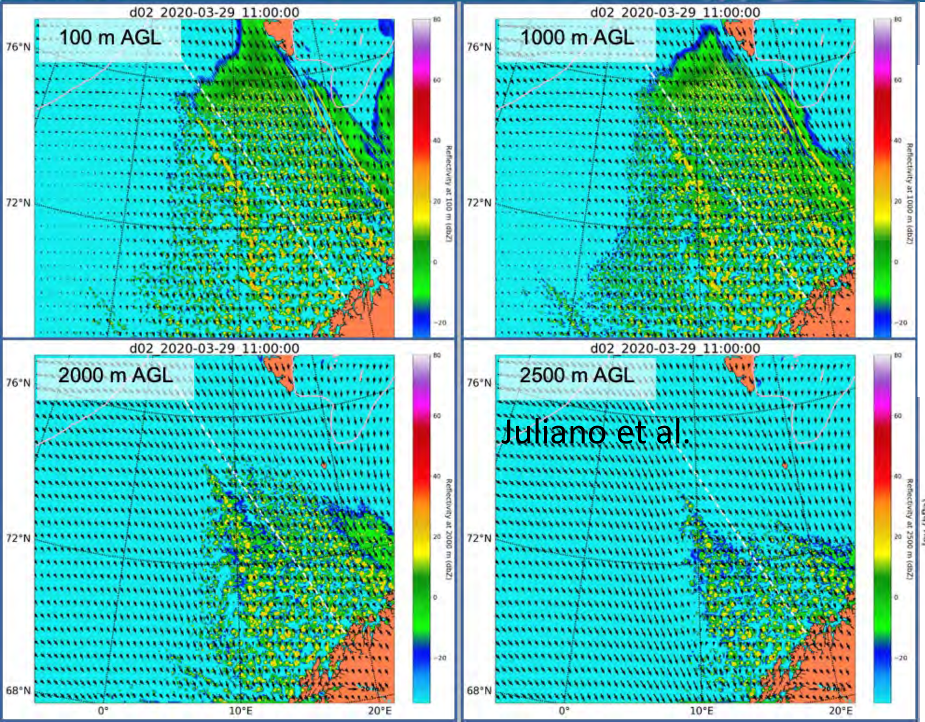


Case study of an intense CAO event over Andenes on 03/29/2020

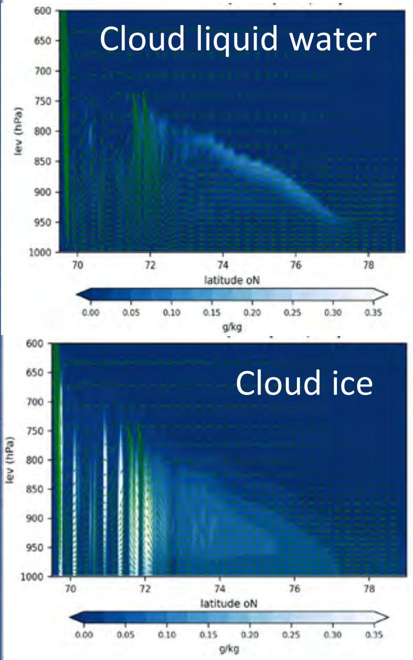
Geerts et al.

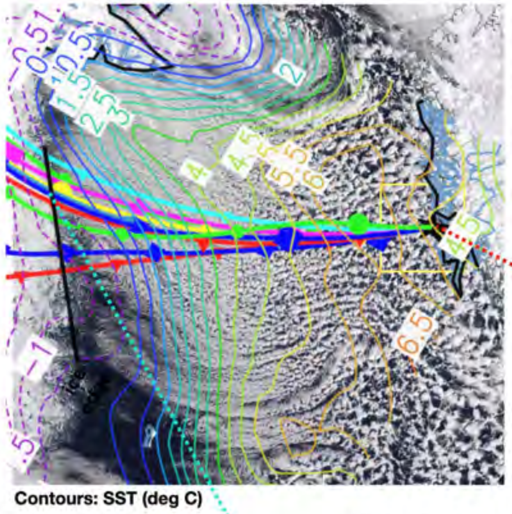
NCAR UCAR | Modeled boundary layer and cloud properties during the 28-29 March COMBLE case

Juliano et al.



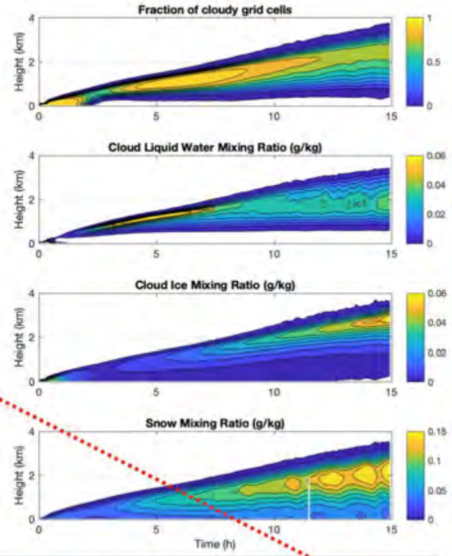
Zheng et al.





It is computationally economical to simulate the evolution of the boundary layer in a Lagrangian frame of reference.

In this approach, the model domain translates with the boundary layer air column, and the lower boundary condition (i.e., SST) changes in time.



Krueger et al.

Radar Reflectivity from CloudSat CPR

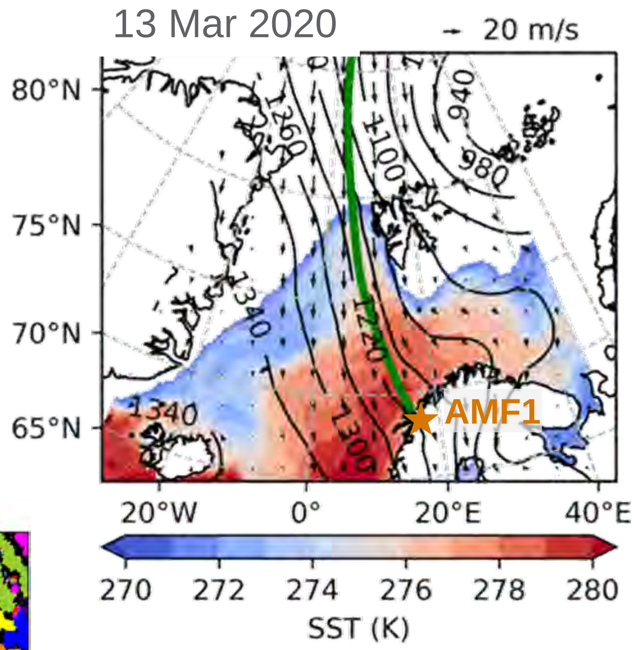
Observations and modeling of cloud morphology in cold air outbreak cases from COMBLE

Mikhail Ovchinnikov and Peng Wu (PNNL)

Questions:

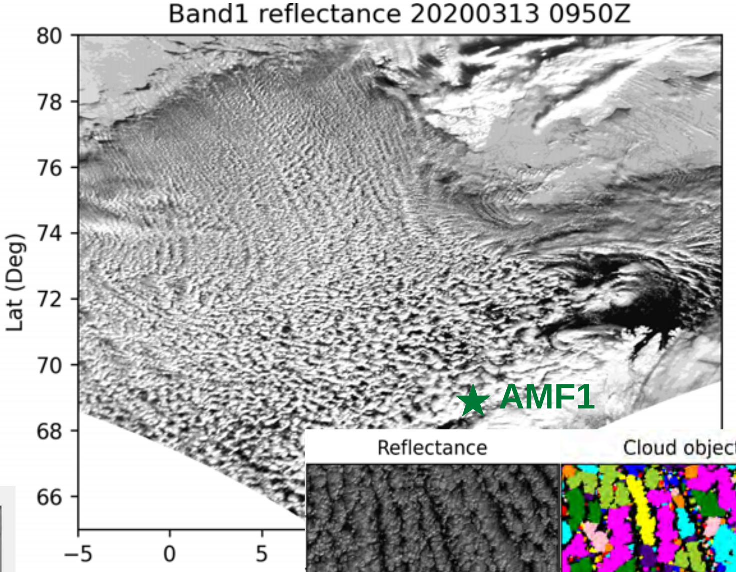
- How does mesoscale organization depend on dynamical and microphysical processes and their interactions?
- What are the relationships between external forcing, mean state, and internal cloud field structure (rolls & cells)?

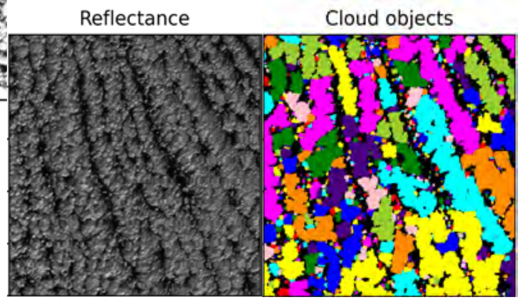
Modeling approach: Lagrangian LES along HYSPLIT trajectories for March 13 & 29, 2020

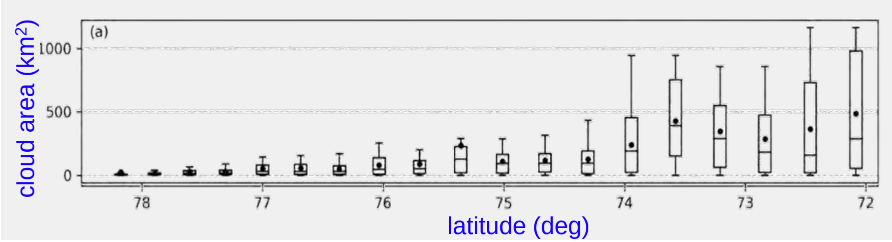


Observational analysis:

- Satellite data for areal coverage
- AMF1 for atmosphere and cloud profiling
- ERA5 for large-scale environment
- Cloud object identification from MODIS and radar observations



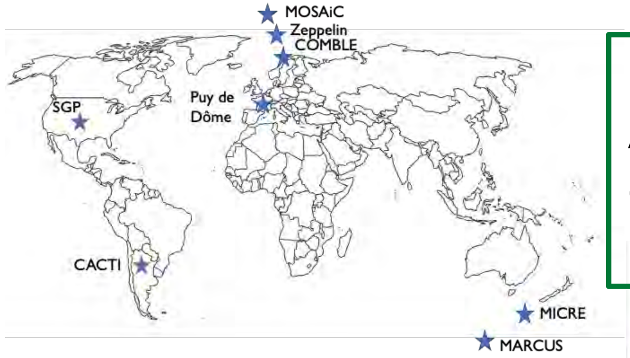




Poster, Wu & Ovchinnikov @ Thurs, 2-3 pm

Understanding the natural sources of aerosols and their impacts on cloud formation and climate across hemispheres (Poster Session 5, 2-3p Thursday; **DeMott** et al., given by **Ben Swanson**)

ASR Atmospheric System Research



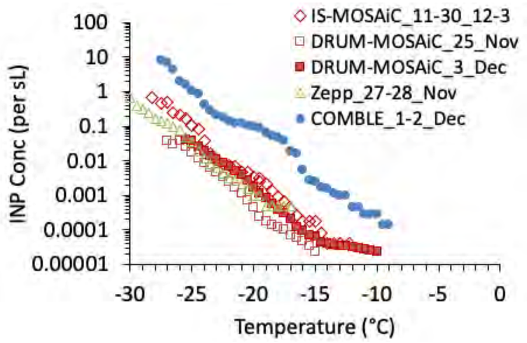
Focus here on Arctic INP data in cold air outbreaks (CAOs)

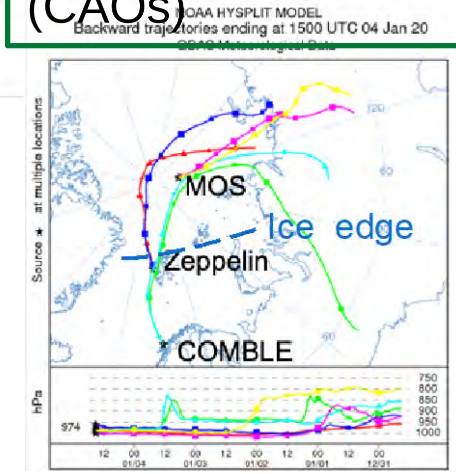
Objective

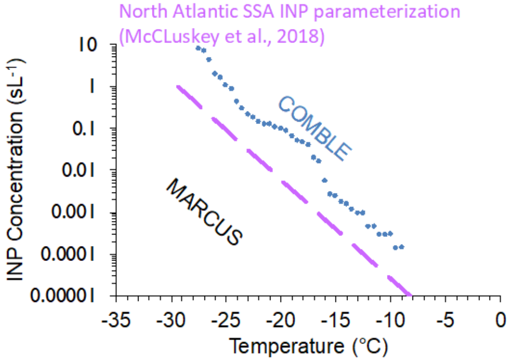
- Quantify the factors driving the makeup and temporal variability of CCN and ice nucleating particles (INPs) in continental versus marine regions (map) through direct measurements, ARM aerosol and meteorological data.

Findings

- CAOs identified transiting N→S from MOSAiC to COMBLE, through collaborator site (Zeppelin) during winter overlap period (2019-2020)
- INP concentrations typically lowest over ice at MOSAiC, with small changes at around ice edge in Svalbard, and large changes by the time air moves to Norway.
- INP differences align with aerosol differences (here, surface area in supermicron regime), all indicating sea spray INPs, albeit uniquely enhanced for this type.







Station	>1 µm Sfc Area ($\mu m^2\ cm^{-3}$)
MOSAiC	2.3
Zeppelin	1.3
COMBLE	26

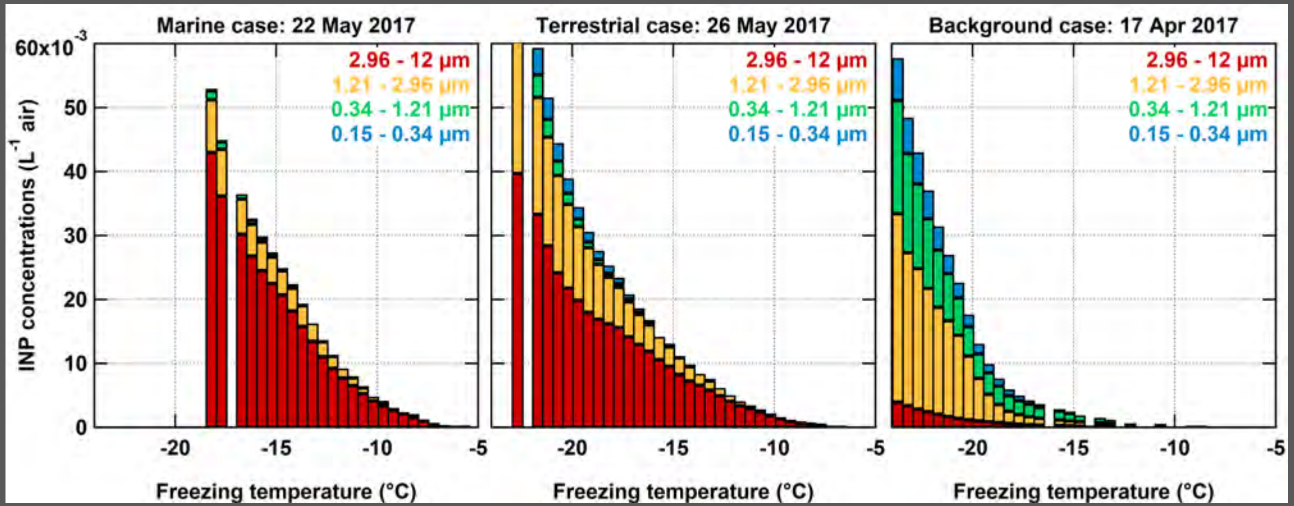
Acknowledgment: DE- SC0021116

DeMott, P. J., J. C. Creamean, B. E. Swanson et al., 2021: Tracking modification of ice nucleating particles in transition from the central Arctic to Norway during cold air outbreaks, in preparation for *Frontiers in Environmental Sciences*.

Coastal and central Arctic INPs: AMF3 & MOSAiC

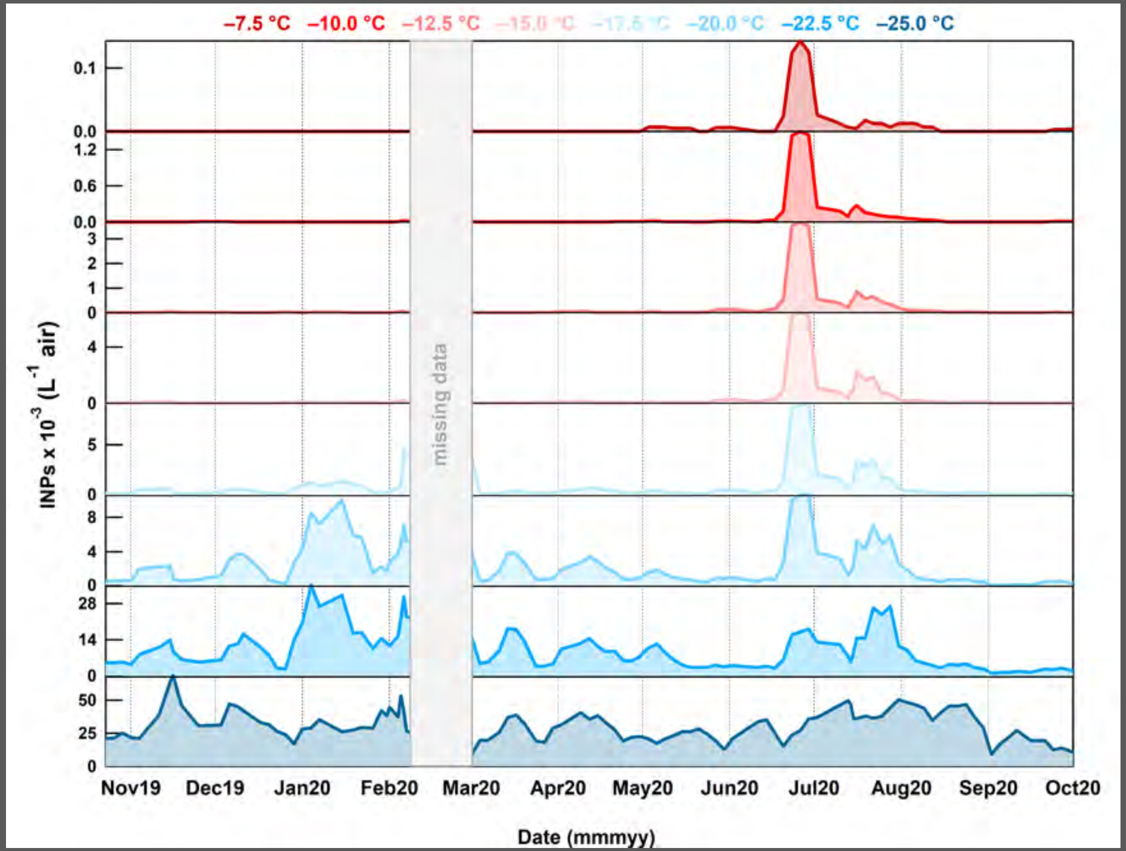
AMF3: Testing sensitivity of clouds in WRF to INPs

- Using cloud & atmospheric state data to set up WRF with prognostic aerosol
- Using size-resolved INP data from marine & terrestrial cases during INPOP (Creamean et al., 2018)



MOSAiC: A full year of total and size-resolved INPs

- Highest INPs in the summer during the melt season
- Data will be available on the DOE Archive by end of summer
- New ASR project to continue MOSAiC INP & aerosol analysis



Questions? Contact: jessie.creamean@colostate.edu

Find out more at my 2 posters! – Session 1 on Tues, 2-3 pm

A new ARM initiative: the measurement of ice nucleating particles (INPs)

- INP mentors: Jessie Creamean and Tom Hill
- Started in 2020 for INP concentrations from 24-h filters collected ~ every 6 days at ARM sites
- FY21 locations included AMF3 (and SGP)
- Data will be available on the ARM Data Archive starting summer 2021
    - Total aerosol INP concentrations for all samples
    - Heat-labile and organic INPs on 1/3 of all samples
- Duplicate filters preserved for users
- PI requests can be made for INP measurements!

U.S. DEPARTMENT OF ENERGY ARM Colorado State University

Questions? Contact:
jessie.creamean@colostate.edu and thomas.hill@colostate.edu
Find out more at Tom's poster! – Session 5 on Thurs, 2-3 pm

Research & ARM Field Campaign Highlights from Kerri A. Pratt, Univ. of Michigan

Research Highlight:

Gunsch & Liu et al. 2020, *Environ. Sci. Technol.* doi:10.1021/acs.est.9b04825.

- **Aug. – Sep. 2016, Oliktok Point**, AK (AMF3)
- PM_1 number dominated by diesel soot and oil field organic-sulfate particles both in background air & plumes; PM_1 sea spray aerosol was ~20% of the mass both in background air & plumes

See Poster for more results – Session 1 (Tues 2-3 pm)!

Recent ARM Field Campaigns:

APUN (Aerosols in the Polar Utqiaġvik Night): Nov. – Dec. 2018, NSA (Utqiaġvik, AK)

- Single-particle mass spectrometry (real-time aerosol mixing state, source identification)

Arctic CLOROX (Chlorine Oxidation): Mar. 2020, Oliktok Point, AK (AMF3)

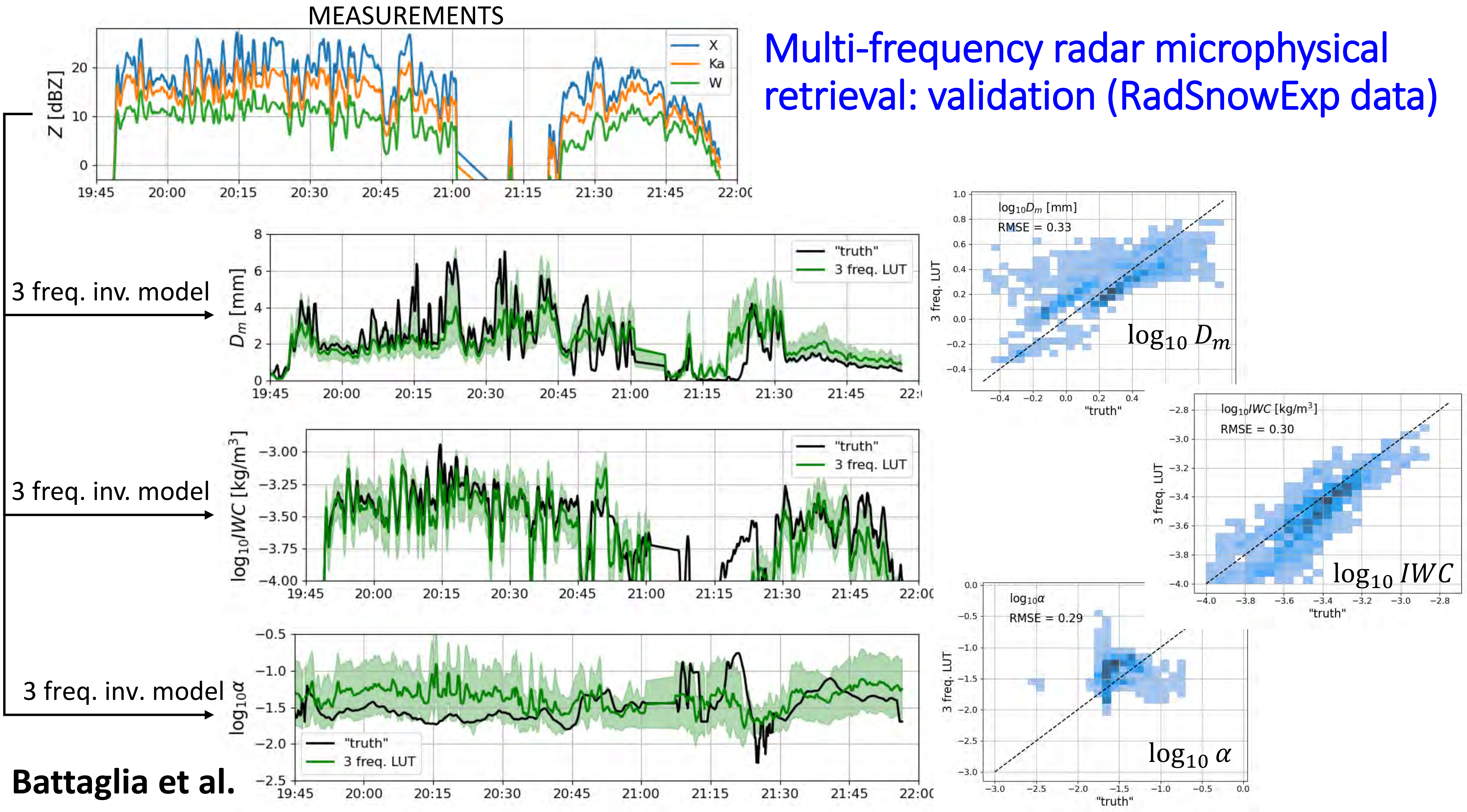
- Real-time mass spectrometry measuring VOCs, OVOCs, and halogens (secondary organic aerosol precursors), aerosol size distributions, particle collection for microscopy
- Collaboration with Andy Lambe (Aerodyne)

MOSAiC: Oct. 2019 – Sep. 2020, High Arctic – Polarstern Icebreaker

- Collected aerosol particles for individual particle microscopy to determine elemental composition and morphology (aerosol mixing state, source identification)

Stay tuned for research results! Collaborations welcome. prattka@umich.edu

Multi-frequency radar microphysical retrieval: validation (RadSnowExp data)

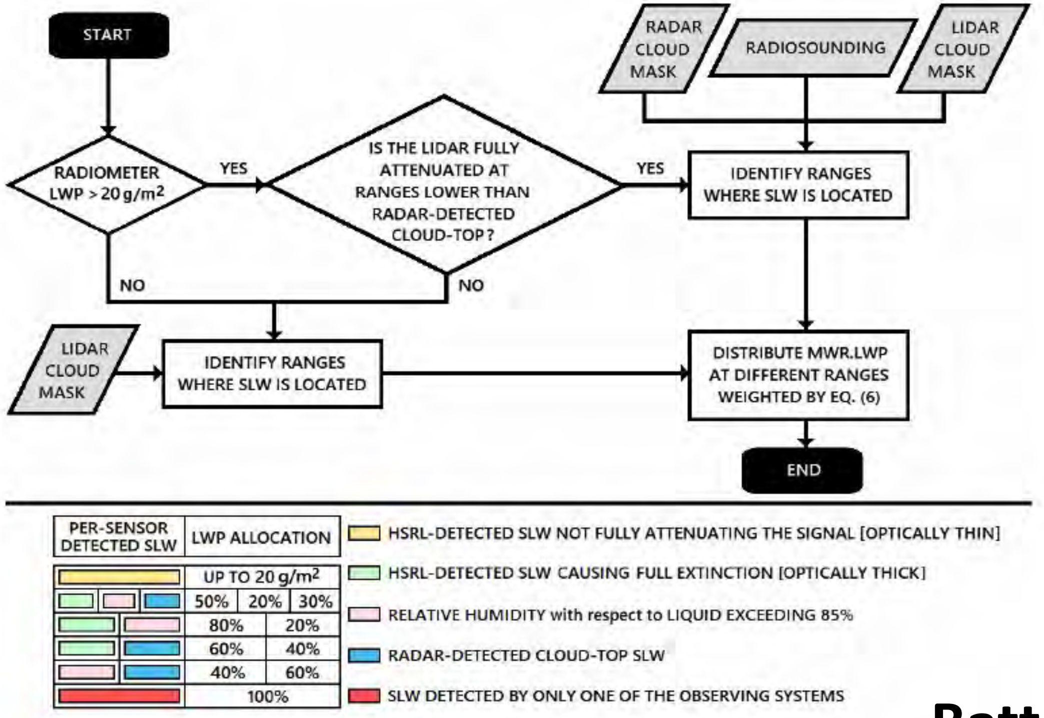


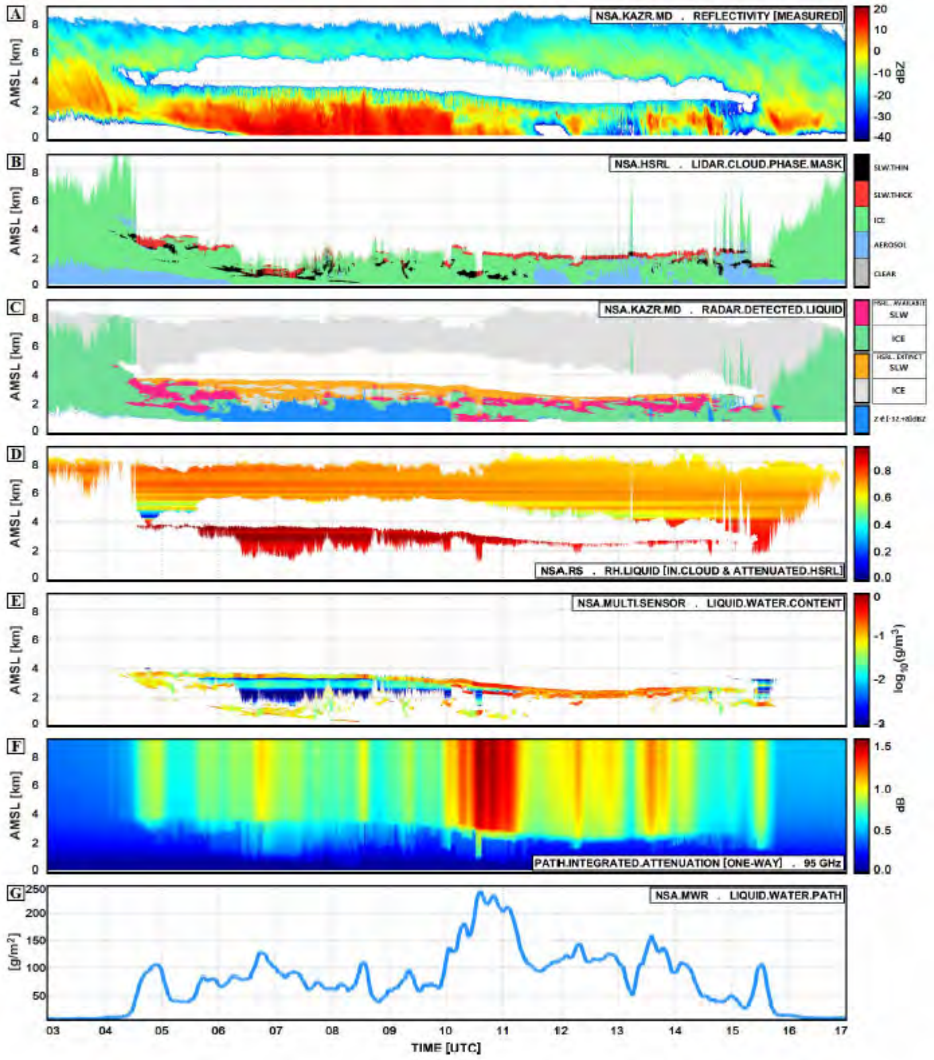
Battaglia et al.

W-band SLWC attenuation correction

Millimeter radars attenuation correction is imperative before performing multi-frequency DWR-based retrievals in mixed-phase clouds.

By integrating radiometer LWP, lidar cloud mask, balloon soundings and radar SLWC detection at cloud top we have optimized the cloud attenuation correction





Case study for NSA, 28/2/2015

Battaglia et al.

New insights into ice multiplication using remote-sensing observations in the Arctic

Objective

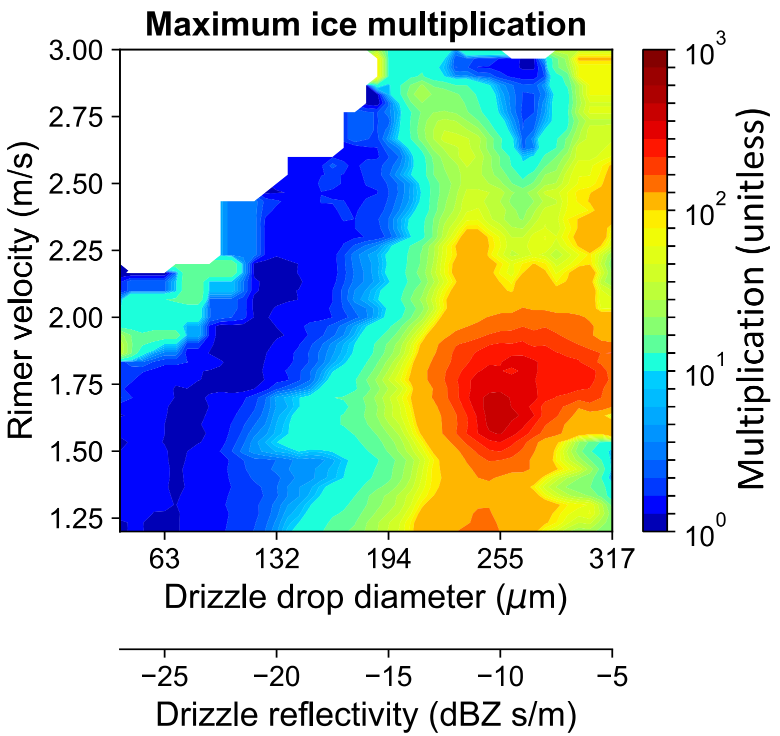
- Determine the conditions under which secondary ice production occurs in slightly supercooled clouds in the Arctic and quantify the extent to which ice number concentration is enhanced.

Findings

- Secondary ice events are found to occur preferentially in the presence of drizzle versus rimers.
- Secondary ice number concentrations depend primarily on drizzle drop size, with some additional enhancement dependent on the speed of rimer when present.
- Secondary ice events are relatively infrequent but can significantly enhance local ice number concentration when they occur by to 1,000x.

Impact

- Our results provide critical insights for model parameterizations and guidance for future laboratory experiments of secondary ice production.



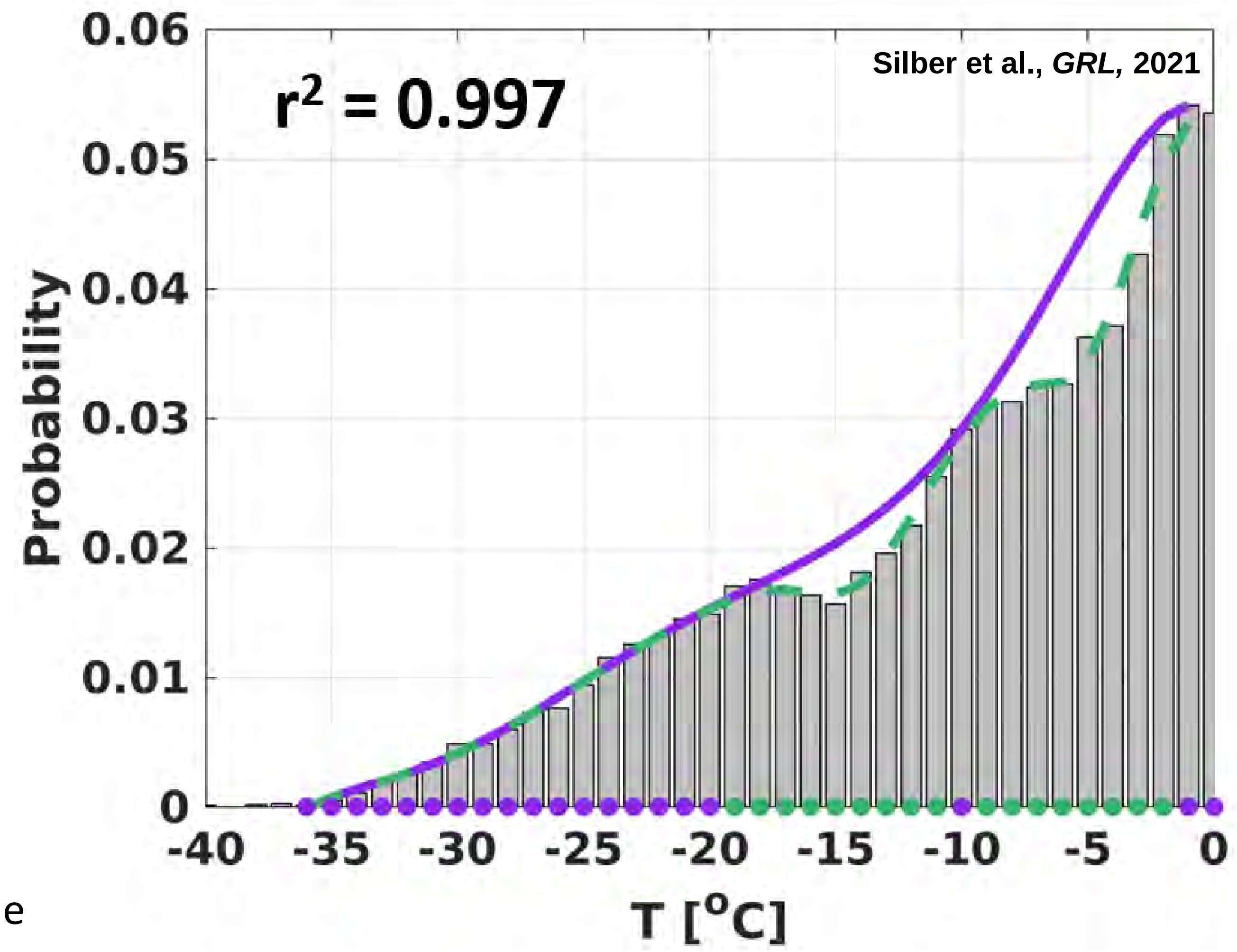
Maximum ice multiplication as a joint function of rimer velocity and drizzle drop diameter. The color bar represents maximum ice multiplication over the full six-year dataset, which is a unitless quantity. Drizzle drop diameter is associated with drizzle spectral reflectivity (second x axis). The results indicate a greater dependence of ice multiplication on drizzle drop diameter via freezing fragmentation than on the rimer velocity associated with the well-known rime-splintering or Hallett-Mossop process.

Luke, E.P., F. Yang, P. Kollias, A.M. Vogelmann, and M. Maahn, 2021: New insights into ice multiplication using remote-sensing observations of slightly supercooled mixed-phase clouds in the Arctic, *PNAS*, 118(13), e2021387118, DOI: 10.1073/pnas.2021387118

Habit-Dependent Vapor Growth Modulates Arctic Supercooled Water Occurrence

Israel Silber, Paul S. McGlynn, Jerry Y. Harrington, and Johannes Verlinde

- The probability of finding topmost unseeded supercooled water layers given cloud temperature, P(L|T), provides an impartial water occurrence metric.
- P(L|T) using long-term Arctic-site data shows a significant (>20%) ice habit growth impact on liquid occurrence.
- This significant ice habit growth impact is supported by parcel and 1-D model simulations.
- P(L|T) datasets can provide strong observational targets of atmospheric state variables for models; an example parameterization for the NSA site is provided.



Caption: Probability of topmost unseeded liquid given temperature, P(L|T) (bars). The green and purple curves illustrate polynomial fits using the distribution data points representing habit effects and a qualitative distribution estimate for spheres, respectively.

Silber, I., P. S. McGlynn, J. Y. Harrington, and J. Verlinde (2021), Habit-Dependent Vapor Growth Modulates Arctic Supercooled Water Occurrence, *Geophys. Res. Lett.,* doi: 10.1029/2021GL092767.

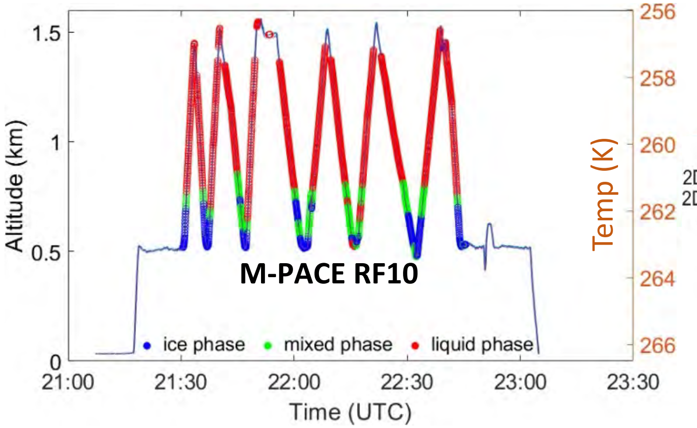
Mixed-Phase Cloud Processes over High Latitudes

Minghui Diao[1], Neel Desai[1], Ching An Yang[1], Meng Zhang[2,3], Xiaohong Liu[2], Shaocheng Xie[3], Damao Zhang[4], Andrew Gettelman[5], Kai Zhang[4], Jian Sun[4], Wei Wu[6] and Greg McFarquhar[6]

[1]San Jose State University, [2]Texas A&M University, [3]Lawrence Livermore National Laboratory, [4]Pacific Northwest National Laboratory, [5]National Center for Atmospheric Research, [6]University of Oklahoma

Objectives

1. Examine mixed phase cloud (MPC) characteristics in high latitudes in the Northern and Southern Hemispheres
2. Evaluate MPC in DOE Energy Exascale Earth System Model (E3SM) model



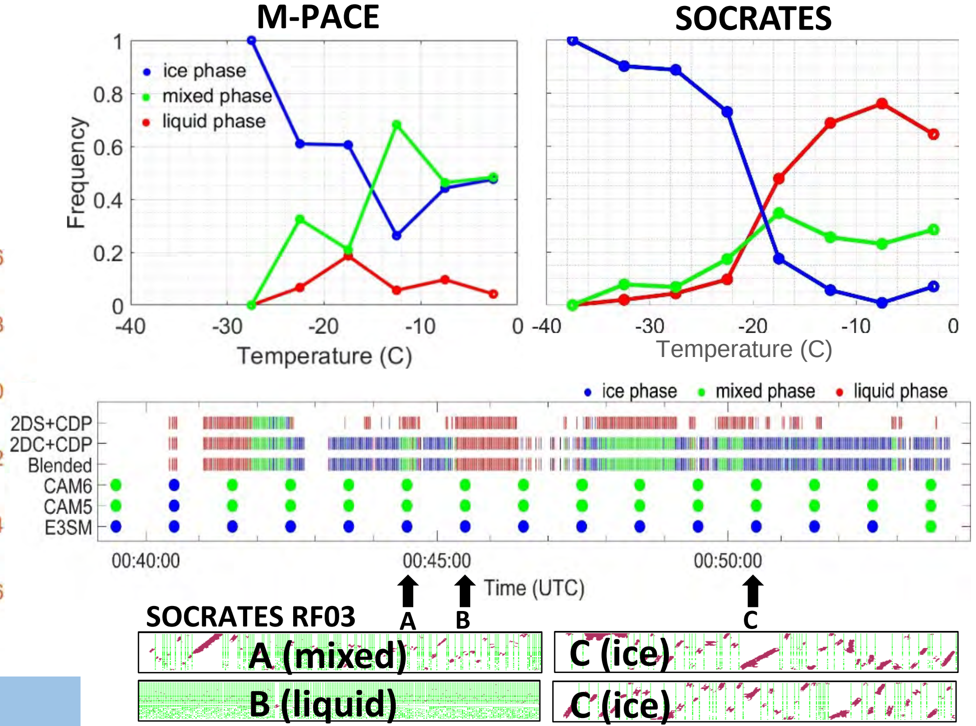
Aircraft Measurements

1. DOE M-PACE 2004 (Alaska, 70 – 72 °N)
2. NSF SOCRATES 2018 (Tasmania, 40 – 65 °S)

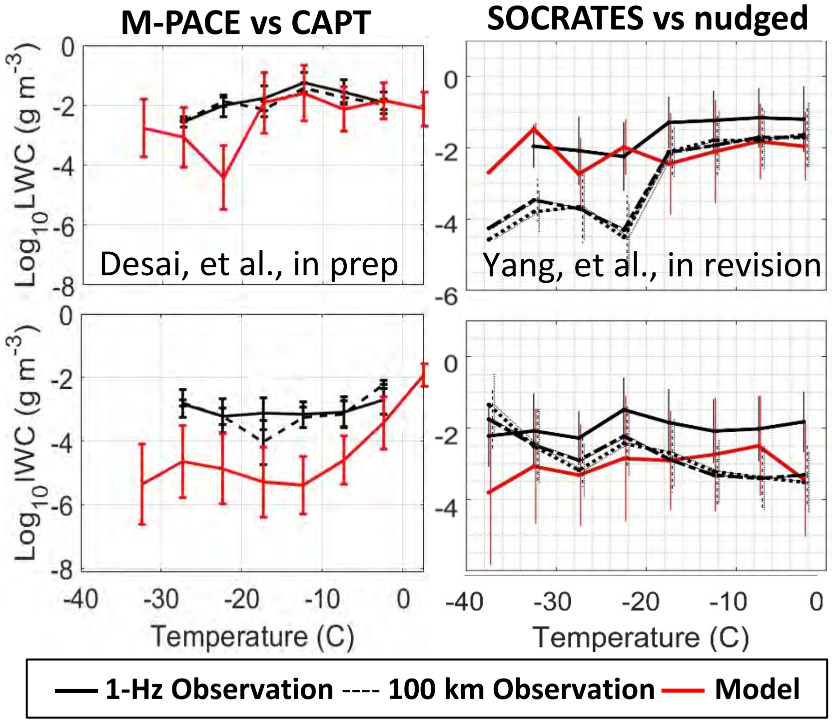
Model Simulations

1. E3SM in CAPT (Cloud-Associated Parameterizations Testbed) mode
2. E3SM in nudged mode

Observations



Comparison with E3SM



Key Findings

1. Observations show vertical stratifications of cloud phase in many cases
2. E3SM shows improvement of allowing more supercooled liquid water than NCAR CAM5
3. E3SM consistently underestimates IWC, but LWC is well represented at -20 to 0°C.

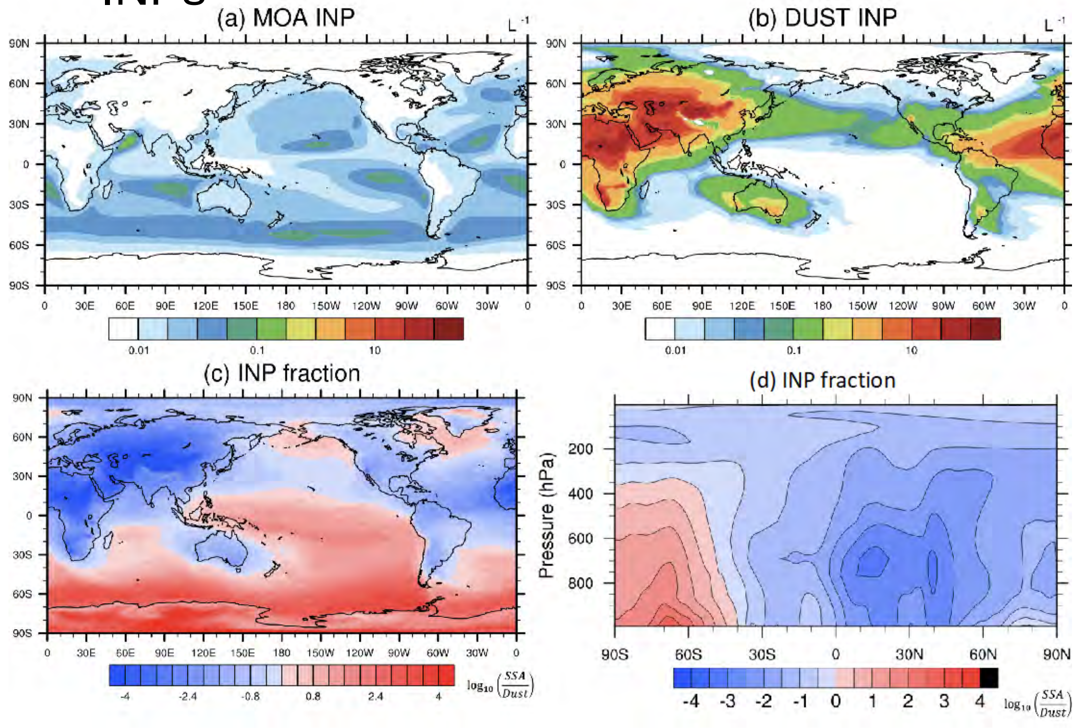
Minghui Diao – Thursday June 24 Poster 2-3 pm ET

Mixed phase cloud processes and Aerosol Indirect Effect over Southern Ocean and Antarctica

Sources of Ice Crystals and Impacts on High-Latitude Mixed-Phase Clouds

Xiaohong Liu[1], Xi Zhao[1], Yang Shi[1], Vaughan Phillips[2], Sachin Patade[2], Minghui Diao[3], Susannah Burrows[4]
[1]TAMU [2]U. Lund [3]SJSU [4]PNNL

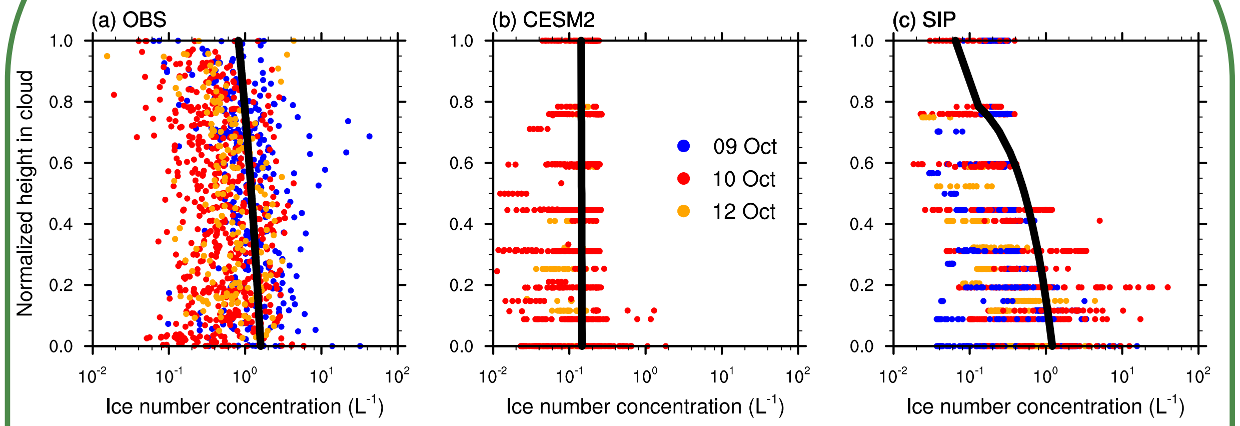
Sea spray aerosol vs. dust to total INPs



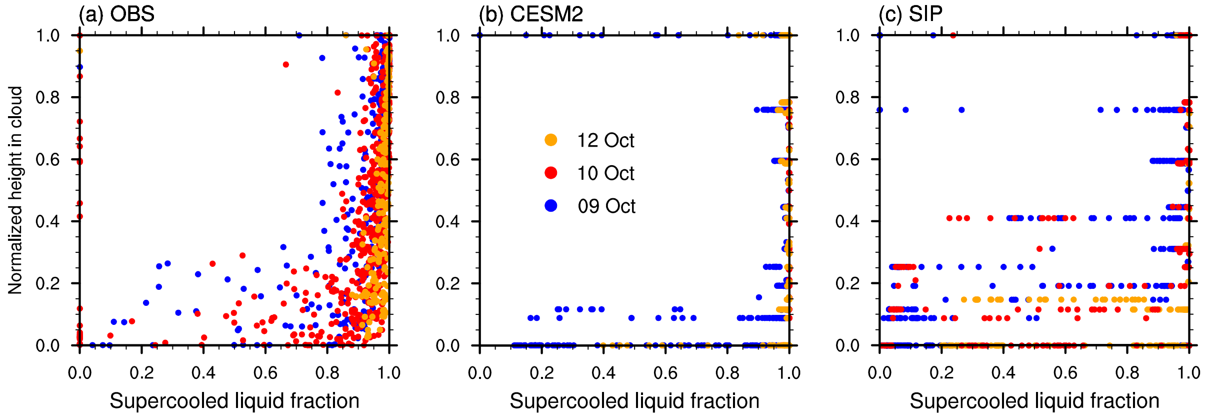
- Sea spray INPs dominate ice nucleation below 400 hPa over Southern Hemisphere high latitudes

Xiaohong Liu – Thursday Poster 2-3 pm
Impacts of Ice Production Processes on High-Latitude Mixed-Phase Clouds

Secondary ice production (SIP) in mixed-phase clouds during M-PACE



- SIP increases ice number at T>-15°C and changes cloud



- SIP initiates a chain of microphysical processes that impact cloud radiative forcing and may have important implications for cloud feedbacks

ARM/ASR PI meeting 2021 Breakout session

Cloud process studies needed to reduce uncertainty in extratropical cloud feedbacks in climate models: a focus on observations and modelling of high-latitude marine post-frontal clouds

Thursday, June 24, 11 a.m. – 1 p.m. EDT

Lead convener: Bart Geerts, Xiaohong Liu

Co-conveners: Greg McFarquhar, Mikhail Ovchinnikov, Branco Kosovic, Roger Marchand, Scott Giangrande, Ann Fridlind, Johannes Mülmenstädt, Susannah Burrows, Paul DeMott, Daniel Knopf, Po-Lun Ma, Nicole Riemer

Agenda

A. Extratropical cloud feedbacks in climate models

11:00 am: Steve Klein, DOE LLNL: *Extratropical cloud feedbacks in climate models*
11:20 am: *Extratropical cloud process studies*
Ann Fridlind, NASA GISS: *Brief overview of relevant processes*
Susannah Burrows, DOE PNNL: *Marine sources of CCN/INPs*
Xiaohong Liu, Texas A&M University: *Secondary ice production*
Johannes Muelmenstaedt, DOE PNNL: *Rain processes*
11:50 am: **Discussion** of extratropical cloud feedbacks in climate models

B. High-latitude marine post-frontal clouds

B.1 **Brief presentations**

12:00 pm: Greg McFarquhar, NOAA CIMMS: *Overview of post-frontal shallow clouds over the Southern Ocean*
12:10 am: Bart Geerts, University of Wyoming: *Post-frontal shallow convection observed in COMBLE: preliminary findings and some promising cases*
12:15 am: Scott Giangrande, DOE BNL: *Recent updates on the COMBLE and MARCUS datasets and products*
12:20 pm: Roger Marchand, University of Washington: *MICRE: overview and findings*

B.2 **Contributed slides**

12:25 pm: *One-slide summaries will be presented in rapid succession:*

- *Branko Kosovic et al: Numerical Simulations of Cold Air Outbreaks Using a Multi-Scale Modeling Framework*
- *Peng Wu et al: Cloud morphology evolution in Arctic cold-air outbreak: A COMBLE case study*
- *Minghui Diao et al: Mixed-Phase Cloud Processes over High Latitudes*
- *Xue Zheng et al: Cloud field associated with MCAOs in the E3SM SCREAM simulation*
- *Steven Krueger et al: Lagrangian simulations of Arctic cold air outbreak cloud systems over Greenland and Norwegian Sea*
- *Yonggang Wang: Improving the understanding of cold-air outbreak cloud regime using COMBLE observations and numerical simulations*
- *Naruki Hiranuma et al: INP concentrations at the ENA and SGP sites*

B.3 **Discussion**

12:35 pm: COMBLE case selection, VAP data interest, plans for collaboration (moderators: Bart Geerts, Greg McFarquhar, Scott Giangrande)
12:45 pm: Model objectives, intercomparisons, collaborations (moderators: Mikhail Ovchinnikov, Branko Kosovic)
1:00 pm: adjourn