Macquarie Island Clouds and Radiation Experiment (MICRE) Overview

(Roj Marchand, Simon Alexander and Alain Protat)

ARM in coordination with the Australian Bureau of Meteorology (BoM) and the Australian Antarctic Division (AAD) collected obs. from **Macquarie Island** between April 2016 and March 2018

McFarquhar et al. (BAMS 2020): Overview of CAPRICORN, MARCUS, MICRE and SOCRATES, DOI: 10.1175/BAMS-D-20-0132.1

Instrument & Retreival Products

- ARM Instrument data: (ARM archive, sitename mcq)
  - Broadband fluxes (gndrad, skyrad, soon qcrad).
  - Microwave Radiometer (mwrlos and mwrret)
  - Parsivel Disdrometer (pars2)
  - Ceilometer (ceil)
  - Cimel sunphotometer (csphot)
- BoM/AAD Instrumentation data:
  - Radiosondes, Surface Met
  - W-band cloud radar (BASTA) – first year only
  - AAD Depolarizaiton Lidar
  - Sky camera

PI Instrumentation data

- Paul DeMott (CSU) INP from Aerosol Filter Samples – second year
- Ruhi Humphries (CSIRO): CPC, CCN
- Adrian McDonald (U. of Canterbury): Ceilometer

- Retrieval Products (https://atmos.uw.edu/~roj/MARCUS_and_MICRE/)
  - Radar-Lidar Boundaries (merged BASTA radar w/AAD Lidar, ARM and UC Ceilometer)
  - Physical-Iterative MWR retrieval for LWP & PWV
  - Radar-MWR (Z-LWP) retrieval for non-precipitating cloud microphysics (Re and Nd)
  - Precipitation Retrievals:
    - Radar Reflectivity–Velocity (ZV) Light Precipitation (below cloud)
    - PARSIVEL Improved Rate And Type (PIRAT)
    - Blended Precipitation (ZV+PIRAT+Tipping Bucket)
  - Environmental Parameters (Ding and McFarquhar)
    - Lower tropospheric stability (LTS), Boundary layer coupling metrics, Cyclone Distance/Quadrant, Air mass origin (back trajectory), and SS
  - Cloud and Precipitation Phase (Depolarization Lidar) … coming soon.
  - Radar+Lidar Precipitation Microphysics (O'Connor et al. 2005).

rojmarch@u.washington.edu

Macquarie Island Clouds and Radiation Experiment (MICRE) Overview

MY RESEARCH FOCUS

- Documenting seasonal, synoptic and diurnal variations in clouds and radiation and evaluating satellite datasets
  - ➔ Surface SW and LW downwelling fluxes and comparing these with CERES SYN and EBAF surface fluxes
  - ➔ Surface Precipitation and comparing these with CloudSat precipitation characteristics.
  - ➔ Now working on cloud macro- and microphysical properties … and modeling studies …

ARM in coordination with the Australian Bureau of Meteorology (BoM) and the Australian Antarctic Division (AAD) collected obs. from **Macquarie Island** between April 2016 and March 2018

McFarquhar et al. (BAMS 2020): Overview of CAPRICORN, MARCUS, MICRE and SOCRATES, DOI: 10.1175/BAMS-D-20-0132.1

- Radiosondes, Surface Met
- W-band cloud radar (BASTA) – first year only
- AAD Depolarizaiton Lidar
- Sky camera

- Paul DeMott (CSU) INP from Aerosol Filter Samples – second year
- Ruhi Humphries (CSIRO): CPC, CCN
- Adrian McDonald (U. of Canterbury): Ceilometer

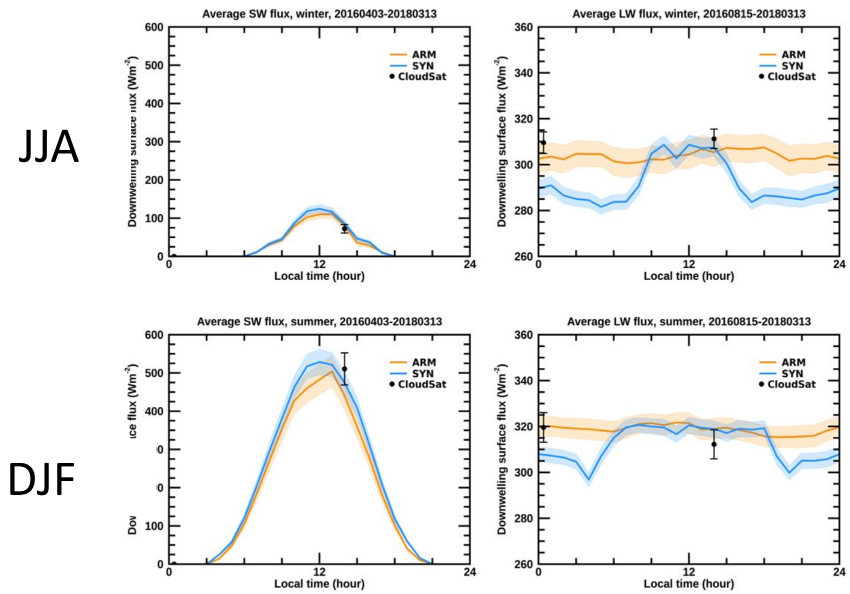
- Retrieval Products (https://atmos.uw.edu/~roj/MARCUS_and_MICRE/)
  - Radar-Lidar Boundaries (merged BASTA radar w/AAD Lidar, ARM and UC Ceilometer)
  - Physical-Iterative MWR retrieval for LWP & PWV
  - Radar-MWR (Z-LWP) retrieval for non-precipitating cloud microphysics (Re and Nd)
  - Precipitation Retrievals:
    - Radar Reflectivity–Velocity (ZV) Light Precipitation (below cloud)
    - PARSIVEL Improved Rate And Type (PIRAT)
    - Blended Precipitation (ZV+PIRAT+Tipping Bucket)
  - Environmental Parameters (Ding and McFarquhar)
    - Lower tropospheric stability (LTS), Boundary layer coupling metrics, Cyclone Distance/Quadrant, Air mass origin (back trajectory), and SS
  - Cloud and Precipitation Phase (Depolarization Lidar) … coming soon.
  - Radar+Lidar Precipitation Microphysics (O'Connor et al. 2005).

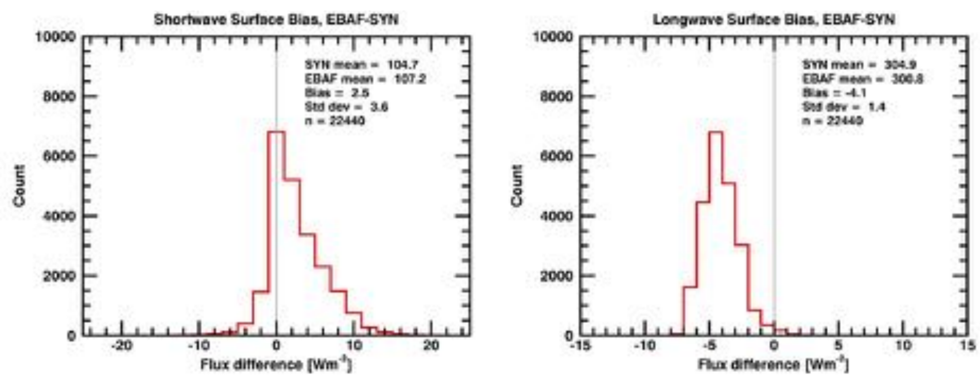
rojmarch@u.washington.edu

Macquarie Island Clouds and Radiation Experiment (MICRE) Overview

MY RESEARCH FOCUS

- Documenting seasonal, synoptic and diurnal variations in clouds and radiation and evaluating satellite datasets
  - ➔ Surface SW and LW downwelling fluxes and comparing these with CERES SYN and EBAF surface fluxes





Hinkelman and Marchand (ESS 2020): CERES and CloudSat Surface Radiative Fluxes over the SO,
DOI: 10.1029/2020EA001224

Key Points:

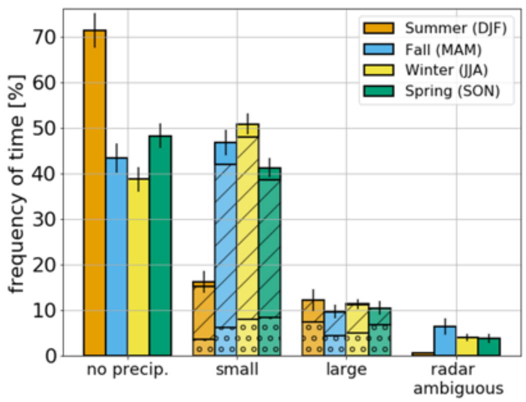
- CERES and CloudSat-CALIPSO surface shortwave (SW) and longwave (LW) fluxes compare well with observations with **annual mean** fluxes differences smaller than ~ 10 W/m^2.
- There are, however, larger and significant seasonal and diurnal differences.
- CERES SYN LW surface fluxes are smaller at night (−16 W m−2), which explains most of the seasonally varying bias.
- And is due to incorrect cloud base for low clouds.

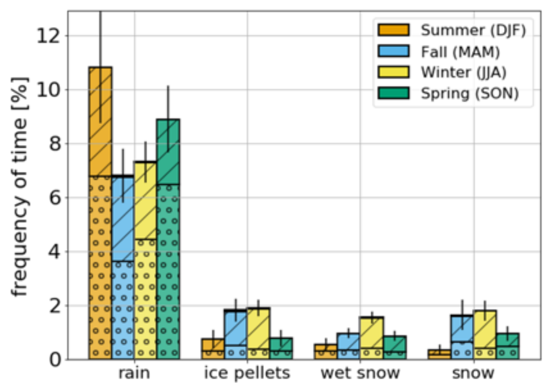
Macquarie Island Clouds and Radiation Experiment (MICRE) Overview

MY RESEARCH FOCUS

POSTER Section 5: Thursday, 2 – 3 pm

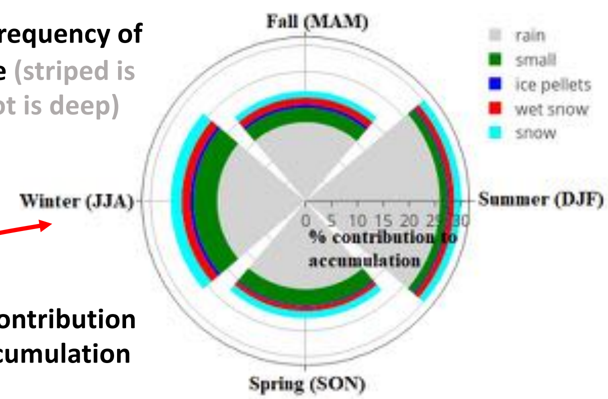
Based on Blend of Parsivel Laser Disdrometer/Tipping Bucketer/Radar data





Seasonal Frequency of Occurrence (striped is shallow, dot is deep)

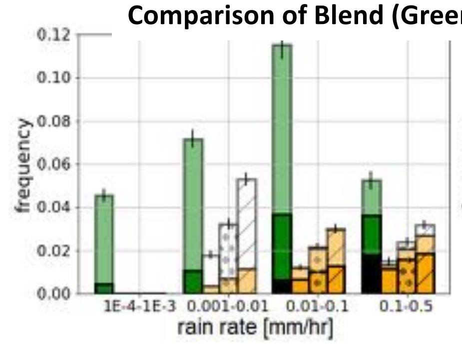
Seasonal contribution to total accumulation by type.

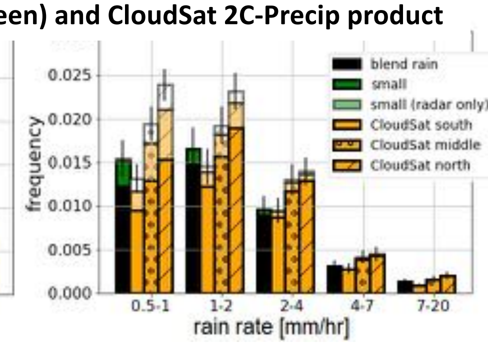


Key Points:

- Surface or near-surface precipitation occurs very frequently
  - → 46% of the time annually / 35% of the time small drops (D< 1 mm).
- Rain, ice and mixed phase precip. occur in all seasons.
  - → Rain = 75%, ice/mixed phase = 12%, and small particle precip. = 13% of the total annual accumulation.
- The CloudSat 2C-Precip-Column product
  - → Total accumulation is slightly overestimated.
  - → Misses much of the lightest precipitation.
  - → Overestimates the occurrence of mixed phase precipitation.
  - → Distribution of rain rates compare well with surface data for rates >0.5mm/hr.

Comparison of Blend (Green) and CloudSat 2C-Precip product





Tansey et al. (JGR 2021): SO surface precipitation observed from satellite and ground instrumentation at Macquarie Island, *submitted*

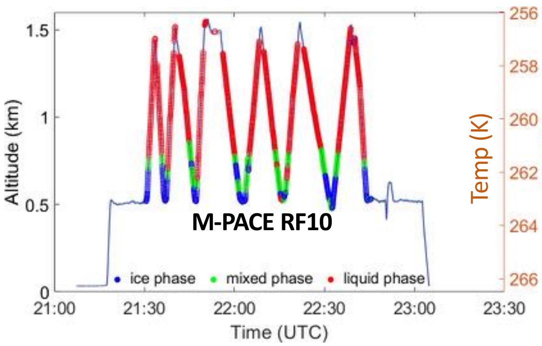
Mixed-Phase Cloud Processes over High Latitudes

Minghui Diao[1], **Neel Desai**[1], Ching AnYang[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



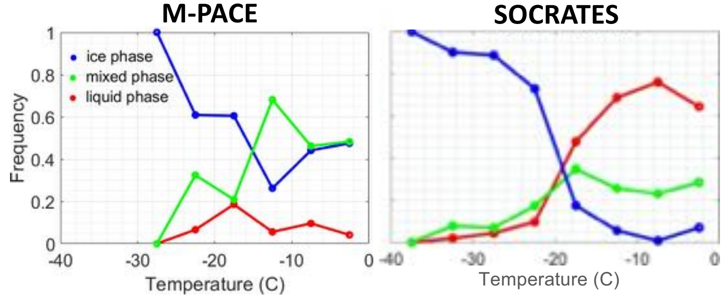
Aircraft Measurements

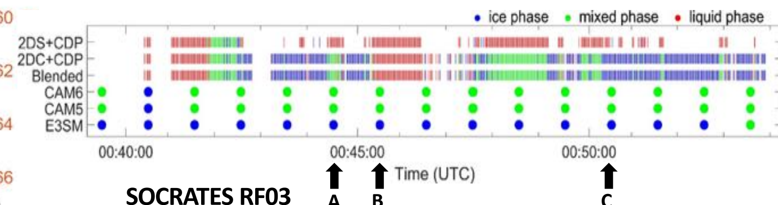
1. DOE M-PACE 2004 (Alaska, 70 – 72 °N)
2. NSF SOCRATES 2018 (Tasmania, 40 – 65 °S)

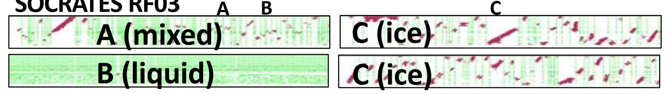
Model Simulations

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

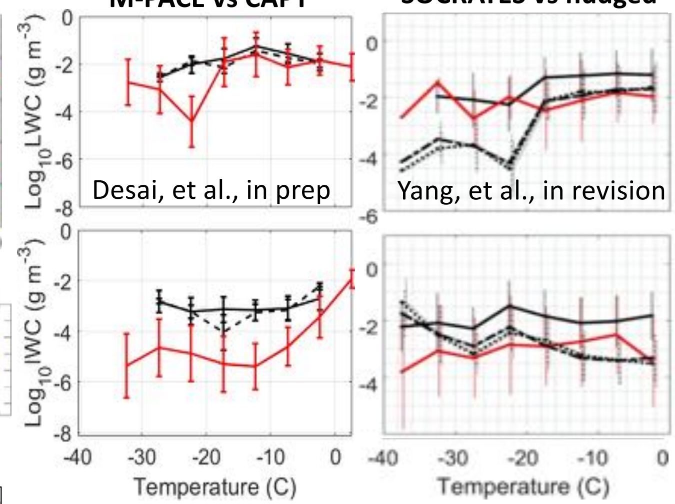
Observations







Comparison with E3SM



Key Findings and Planned Work

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.
4. Planned work: Secondary ice production (SIP) and ice nucleating particles (INP) in high latitudes

Minghui Diao – Thursday June 24 Poster 2-3 pm ET (minghui.diao@sjsu.edu)

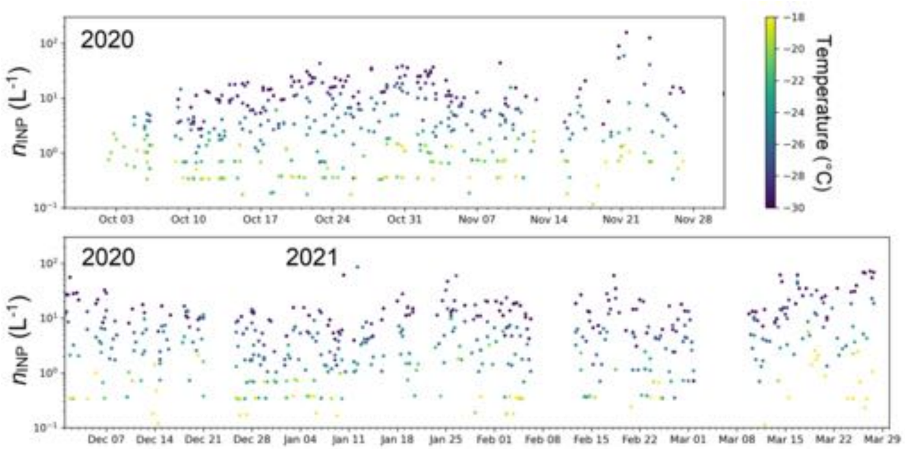
Mixed phase cloud processes and Aerosol Indirect Effect over Southern Ocean and Antarctica

Ice-nucleating particle concentration measurements from the ARM Eastern North Atlantic (ENA) and Southern Great Plains (SGP) sites

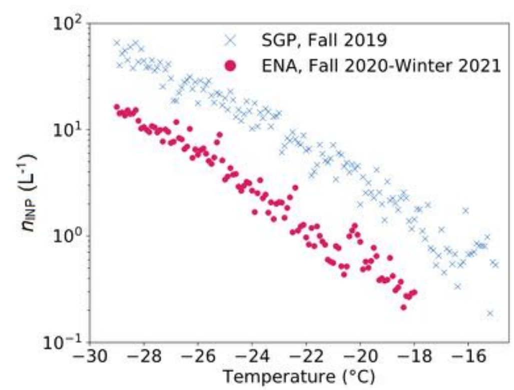
Objective: Generating new ambient INP data from the ARM mega-sites

PI: Naruki Hiranuma
nhiranuma@wtamu.edu

Key Findings: The terrestrial SGP site has higher nINP across the range of examined temperatures than nINP from the marine predominant ENA[1]. A moderate correlation between nINP and cloud condensation nuclei concentration (-20 °C, 0.1% super saturation) was observed at ENA ($\rho = 0.47$, $p<0.001$), and the correlation was higher in Fall ($\rho = 0.81$).



The time series plot of the ice crystal concentration (n_{ice}, L^{-1} air) for temperatures below -18 °C during the ENA campaign. The portable ice nucleation experiment chamber[2] measured n_{ice} for ~200 days from October 2020 to March 2021. Time averaged data (6 hour) of n_{ice} at the end of individual expansion are shown.



Temperature-binned average n_{ice} spectra during SGP campaign (blue Xs) and ENA campaign (pink dots) at each 0.1 °C. The data uncertainties are discussed and presented in the PI's poster.

1) Wilbourn, E. K. et al.: Remote ice-nucleating particle measurements from the Eastern North Atlantic during autumn and winter, https://doi.org/10.5194/egusphere-egu21-6314, EGU General Assembly, Online, April 27, 2021.
2) Möhler, O. et al.: The Portable Ice Nucleation Experiment (PINE): a new online instrument for laboratory studies and automated long-term field observations of ice-nucleating particles, Atmos. Meas. Tech., 14, 1143–1166, https://doi.org/10.5194/amt-14-1143-2021, 2021.

Improving the understanding of cold-air outbreak cloud regime using COMBLE observations and numerical simulations

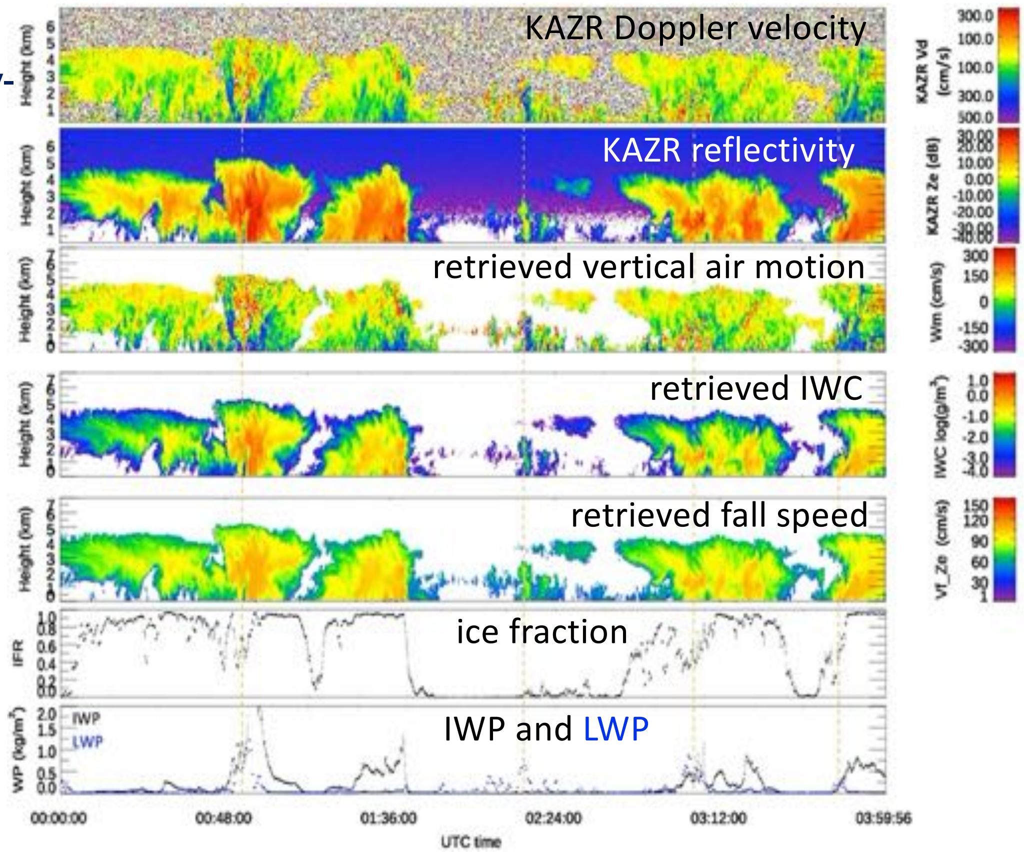
Yonggang Wang (yonggang.wang@oswego.edu) / SUNY Oswego
In collaboration with Bart Geerts and Min Deng from University of Wyoming

Objective

- to explore the role of clouds and precipitation on the boundary-layer circulations that control the CAO cloud macrostructure

Planned works

- Numerical simulations of selected COMBLE CAO events (an KAZR-based case study shown on the right)
- COMBLE datasets for model validation
  - vertical thermodynamic and wind structure, at Andenes and Bear Island
    - ✓ INTERPSONDE
  - vertical cloud and precipitation structure, at Andenes
    - ✓ KAZR, WSACR, and KASACR (*reflectivity, Doppler velocity and spectral width*); MWR (*liquid water path*); MPL (*backscatter power and depolarization ratio*)
    - ✓ retrieved variables: *cloud top height* (KAZR), *vertical air motion* (KAZR), *ice water content* (KAZR), *ice fraction ratio* (KAZR, MWR), and *ice particle effective diameter* (KAZR and MPL)
- Sensitivity runs to test hypotheses of cloud and precipitation processes in mixed-phase CAO clouds



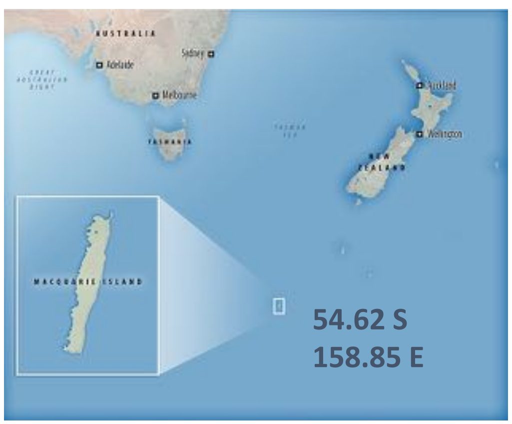
Case study of an intense CAO event over Andenes on 03/29/2020

Precipitation Occurrence Frequency over the Mid-Latitude Southern Ocean

McKenna Stanford, Israel Silber, Ann Fridlind, and Alain Protat, Contact: mws2175@columbia.edu

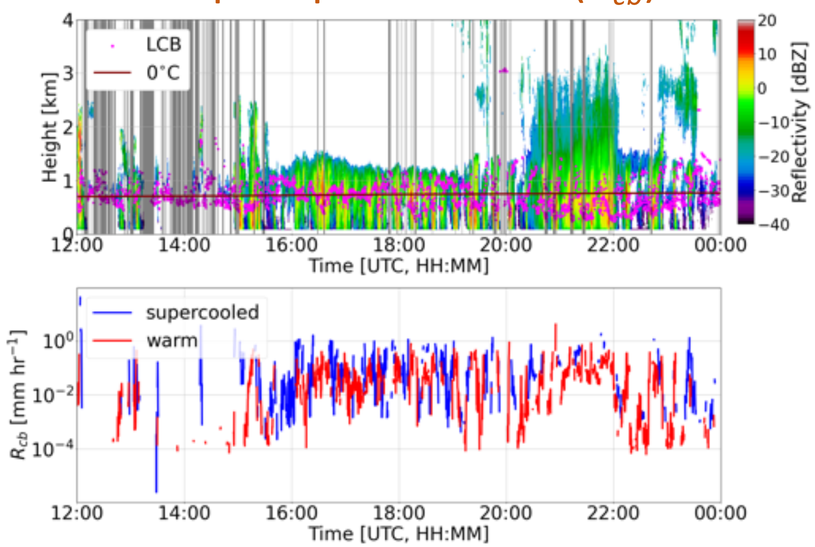
Goal

Establish precipitation occurrence frequency and intensity rate distribution from liquid cloud base (LCB) over a year of MICRE



Approach

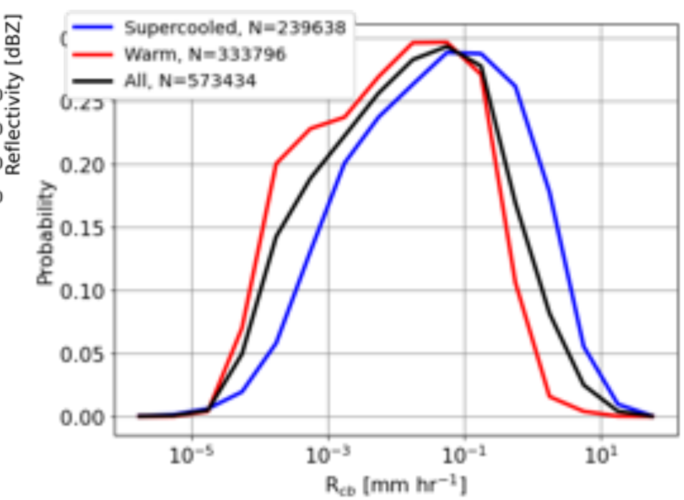
Merge 95 GHz radar, ceilometer, & 12-hourly soundings to calculate instantaneous liquid cloud-base precipitation rate (R_{cb})



Findings

Precipitation occurrence frequency from LCB:

96%



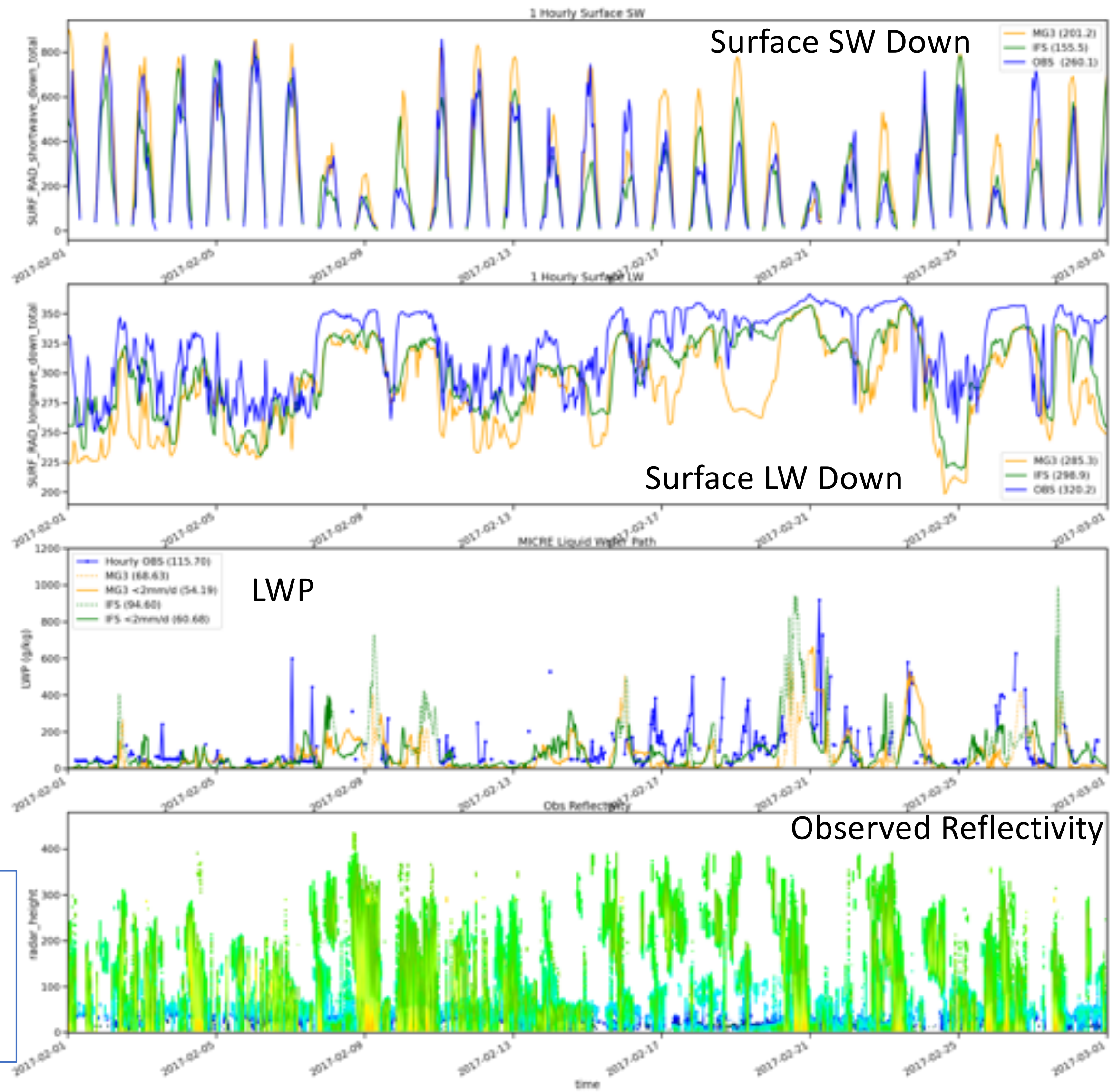
Evaluating Earth System Models with MICRE Data

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

Concentrations and Characteristics of Ice Nucleating Particles (INPs) at Macquarie Island during MICRE

T.C.J. Hill, P. J. DeMott and MICRE team

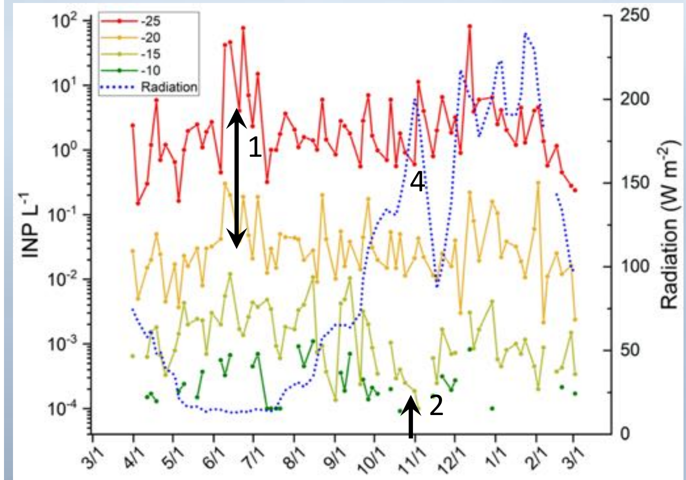
Objective

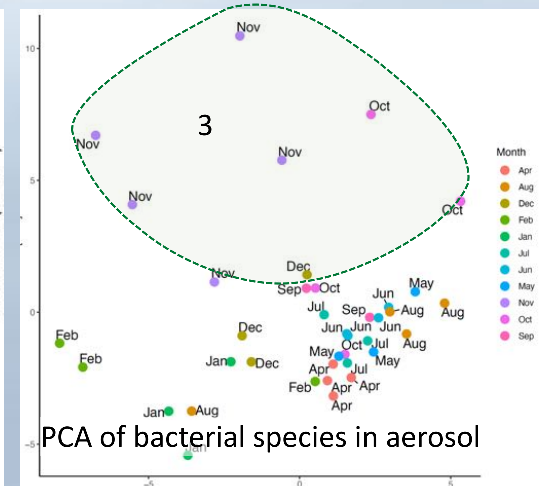
- Over an annual cycle during MICRE (Macquarie Island Cloud and Radiation Experiment), characterize boundary layer INPs: concentrations, seasonal trends, likely sources.

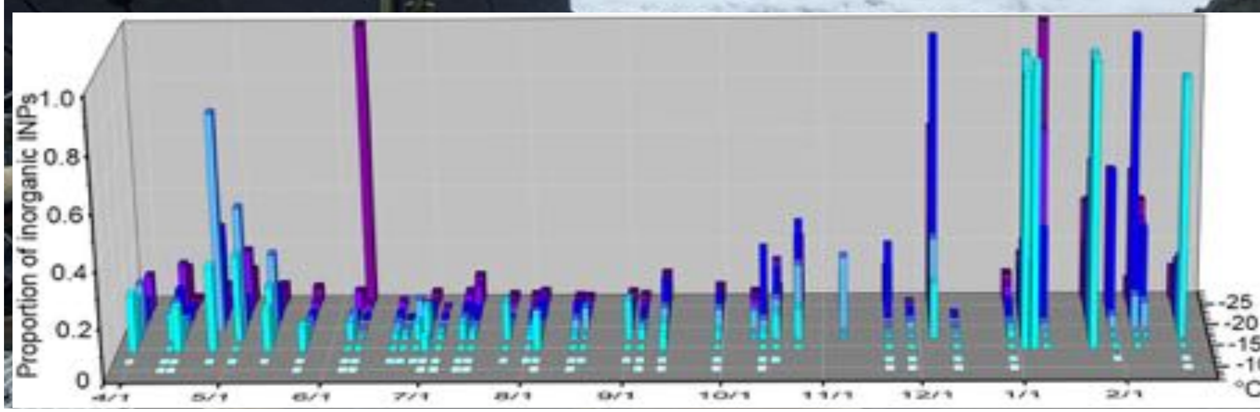
Findings

- Seasonal INP variation limited to a peak in mid winter (1) and a decrease at -15°C in spring (2).
- The decrease of INPs at -15°C in spring coincided with a change in bacteria in the aerosol (3), and an increase in solar radiation (4).
- Organic INPs predominated. Inorganic INP relative abundance increased mid summer and fall.

Acknowledgment: DE-SC0018929



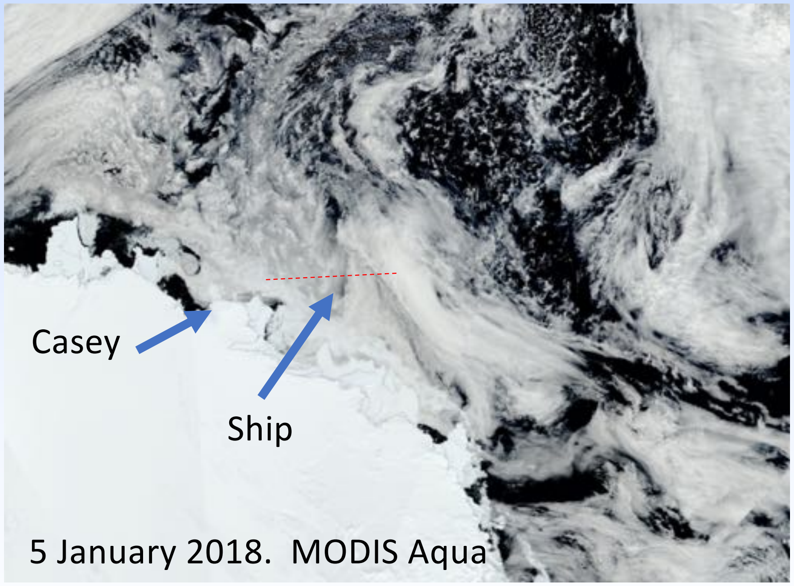




High Latitude Aerosol-Cloud Interaction during MARCUS: The role of CCN variability and links to Precipitation

Jay Mace, R. Humphries, Alain Protat, Peter Gombert, Sally Benson

- The Southern Ocean (SO) is a pristine region removed from anthropogenic influence .
- Over the broader SO, aerosol and CCN demonstrate large seasonal oscillations thought to be associated with marine biology .
- Over the broader SO, marine Boundary Layer (MBL) Clouds also demonstrate seasonal oscillations in droplet number (N_d) .
- **In the Marginal Ice Zone of East Antarctica (MIZ), aerosol numbers and chemistry vary substantially based on air mass history**



THE UNIVERSITY OF UTAH

NASA

ASR Atmospheric System Research

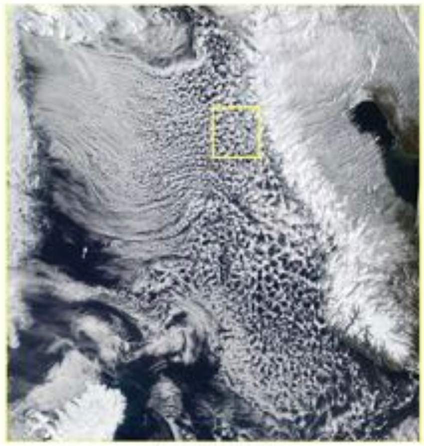
ARM CLIMATE RESEARCH FACILITY

Lagrangian Simulations of Arctic Cold Air Outbreak Cloud Systems over the Greenland and Norwegian Seas

Steven K. Krueger
Emina Maric, Xia Li, and Gerald G. Mace
University of Utah

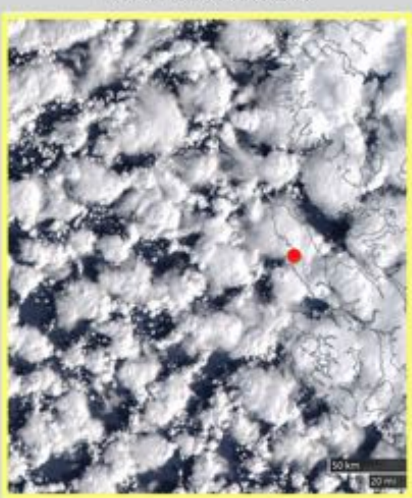
Our scientific objectives are to:

- Increase our understanding of how microphysical processes determine macrophysical cloud properties of marine cold-air outbreaks (CAOs).
- Document and understand the life cycle of the large and long-lived mesoscale cells observed in CAOs which may be the result of a new type of convection aggregation.

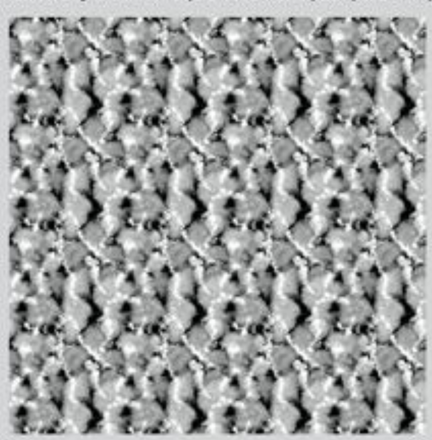


28 March 2020

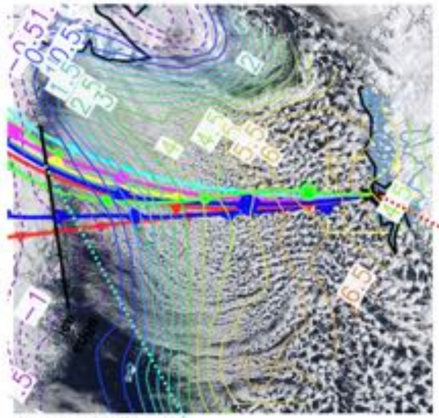
MODIS Visible Reflectance



Numericaly simulated liquid + ice water path (tiled 4 x 4)



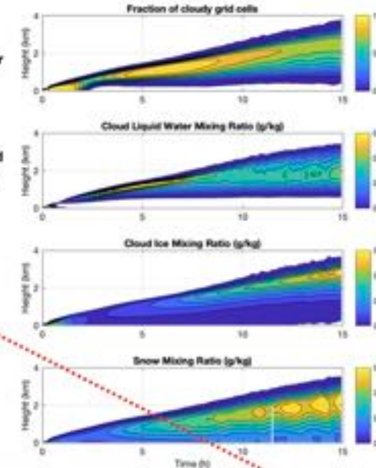
256 km



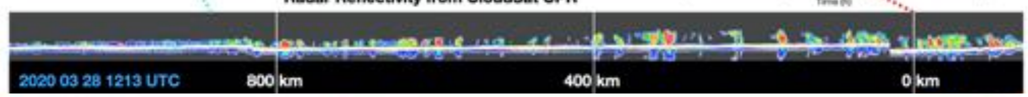
Contours: SST (deg C)

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.



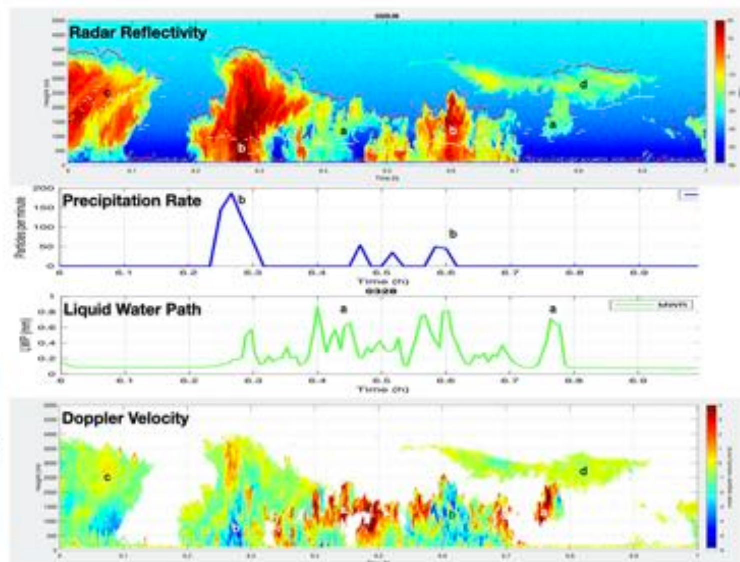
Radar Reflectivity from CloudSat CPR



ARM COMBLE measurements made on the coast of Norway.

- (a): **convective updrafts** are associated with liquid water and low Ze.
- (b): **convective downdrafts** are associated with snowfall at the surface and high Ze.
- (c): moderate Ze, high lidar-detected cloud base, and weak updrafts above downdrafts suggest **elevated convection**.
- (d): an elevated, low Ze cloud layer with a well-defined base, and little air motion, consists of **small hydrometeors**.

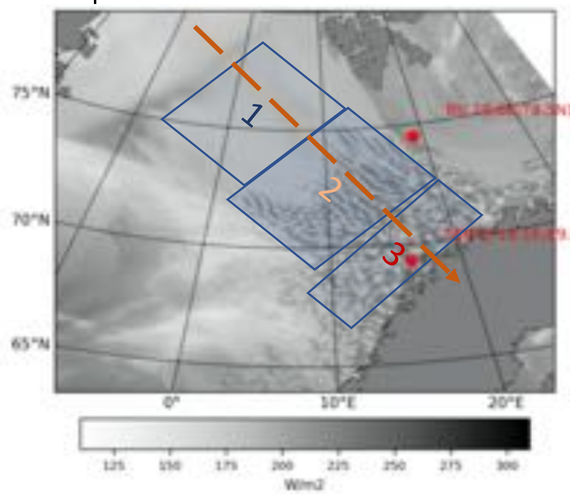
The COMBLE CAO cloud systems are strongly forced, widespread, and long-lasting, with rather simple boundary and initial conditions, and are remarkably repeatable, (but with interesting variations from case to case). In other words, the COMBLE CAO events effectively provide an atmospheric laboratory.



Steve.Krueger@Utah.edu

The cloud field associated with MCAOs in the E3SM SCREAM simulation

Top of model net LW flux

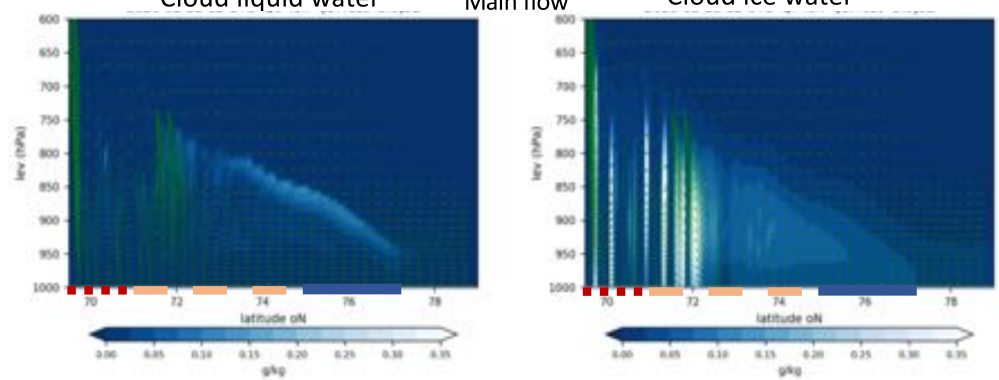


Three cloud phases:
1. solid stratus, 2. cloud streets, 3. open cells

Vertical cross section along the main flow

Main flow

Cloud liquid water | Cloud ice water



The cloud phase is marked as:
3 2 1

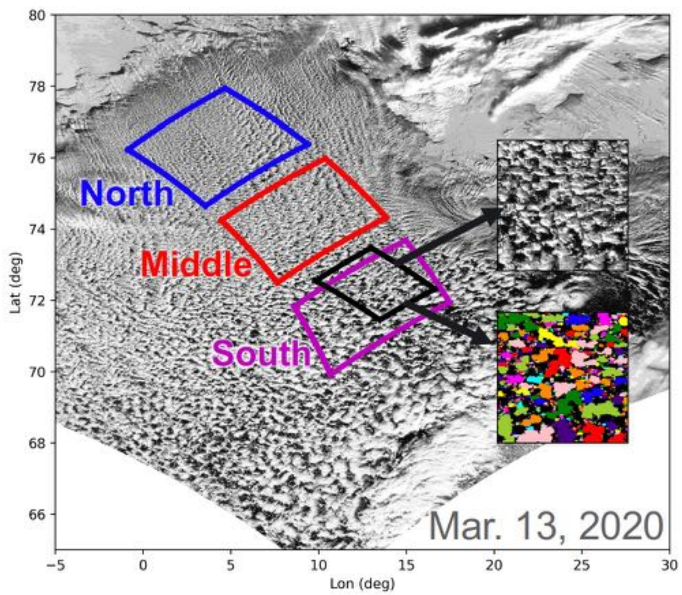
- A new E3SM convection permitting model SCREAM with globally uniform 3.25 km grid spacing.
- We analyzed a MCAO event from a 40-day global SCREAM simulation (Caldwell *et al*, *JAMES,* under review).
- E3SM SCREAM simulates three cloud phases during the MCAO event (top left panel): phase 1 is lack of cloud streets, and during phase 2 the cloud streets have larger wavelength than the observed cloud streets.
- A thin liquid cloud is at the top of the ice cloud during the growth of the PBL (phases 1 & 2), while deeper ice clouds associated with clear small-scale vertical circulations occur at phases 2 & 3 (top right panels).

Xue Zheng (zheng7@llnl.gov) Poster session 5: Thurs, 2-3 pm

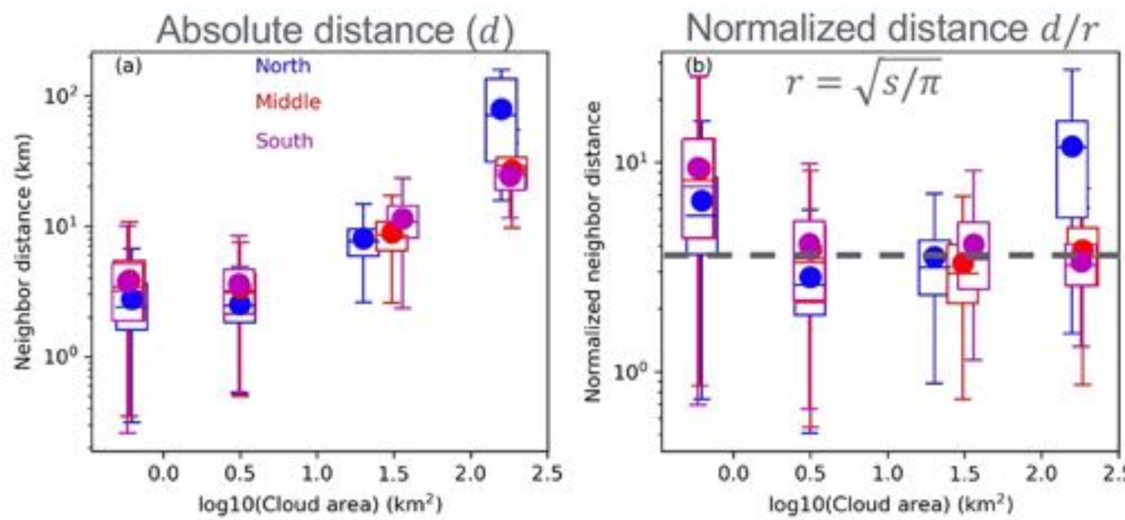
Cloud morphology evolution in Arctic cold-air outbreak: A COMBLE case study

Peng Wu and Mikhail Ovchinnikov, Pacific Northwest National Laboratory

1. Identify individual clouds using an image segmentation procedure on MODIS reflectance field; obtain cloud areas (s)



2. For each cloud, identify nearest neighbors from the same area category



- Absolute neighbor distance increases exponentially with cloud area
- Except for very small clouds ($s < 1$ km^2) and biggest clouds in the north, normalized neighbor distance converges to 3.5
  → comparably sized clouds are separated by a distance of 3.5 r

Next: Apply the same approach to ARM scanning radars and model simulations to study cloud morphology statistics

peng.wu@pnnl.gov

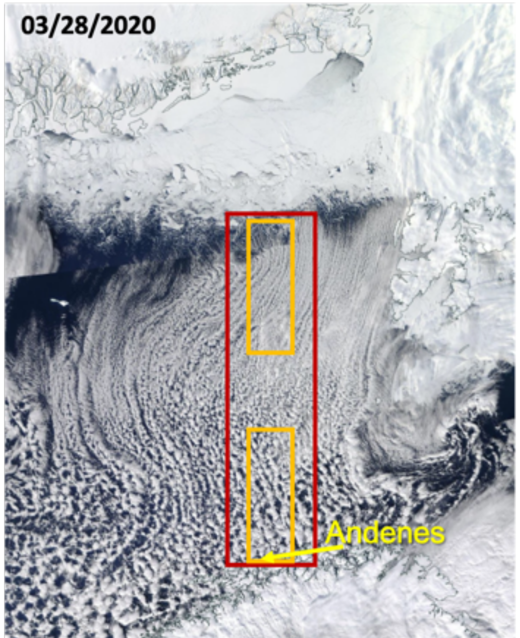
More on poster @ Thurs, 2-3 pm

Acknowledgement

ASR Atmospheric System Research

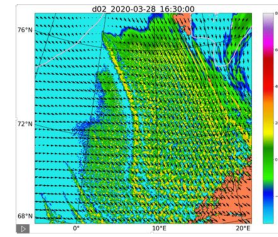
Numerical Simulations of Cold Air Outbreaks Using a Multi-Scale Modeling Framework

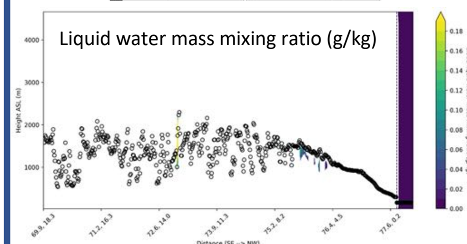
Branko Kosovic, Timothy W. Juliano, Lulin Xue, Bart Geerts, and Christian P. Lackner

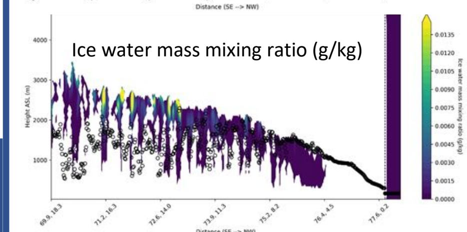


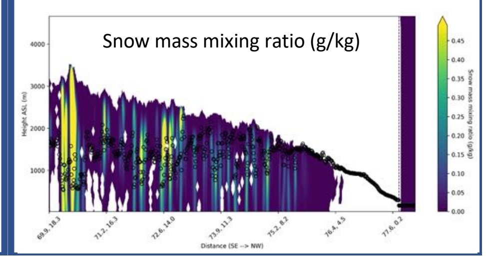
- *How do multi-scale interactions drive the organization of mesoscale convective circulations during CAOs over open water?*
- *What is the role of mixed-phase cloud processes in the context of mesoscale cellular convection structure and evolution*?
- We will conduct multi-scale simulations coupling mesoscale and large-eddy simulations (LES). LES will cover a domain ~ 1000 km x 300 km using 90 m grid cells. Within this domain nested will be two domains ~ 300 km x 100 km with 30 m grid cell.
- Two nested domains will be focused on the transition from helical rolls to cells and the transition from closed cells to open cells.
- Before conducting multi-scale simulations we are performing sensitivity analysis using Lagrangian LES by deriving forcing from ERA5 reanalysis and following Calipso satellite trajectory

Mesoscale simulations









Lagrangian LES

Control and sensitivity simulations:

1. CCN: high (x10) and low (x0.1)
2. INP: high (x10) and low (x0.1)
3. Shut off mixed phase
4. Shut off precipitation
5. No LW radiation
6. SST: warm (+2 K) & cool (-2 K)