Comparison of Antarctic and Arctic Stratiform Mixed-phase Cloud Properties Using Ground-based Remote Sensing Measurements

Damao Zhang
Brookhaven National Laboratory (BNL)
Upton, New York

Contributions from: Andrew Vogelmann (BNL), Pavlos Kollias (BNL/Stony Brook University), Dan Lubin (Scripps), Zhien Wang (University of Colorado, Boulder), Ed Luke (BNL), Fan Yang (BNL)

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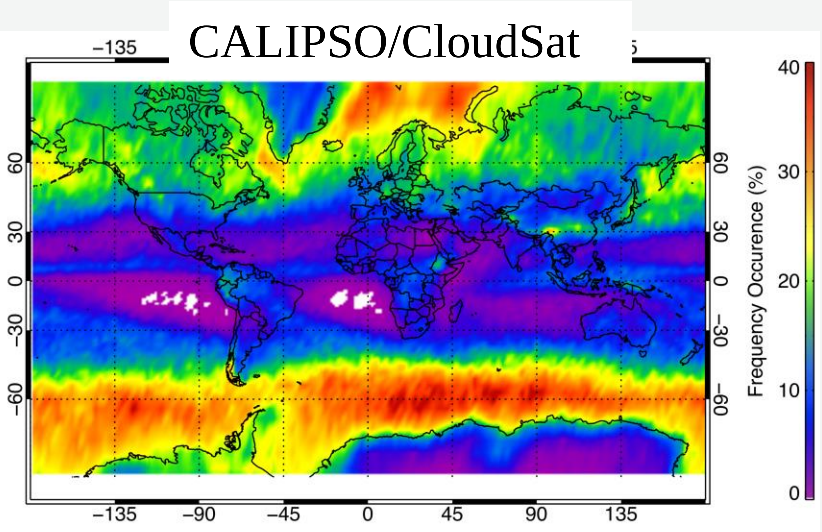
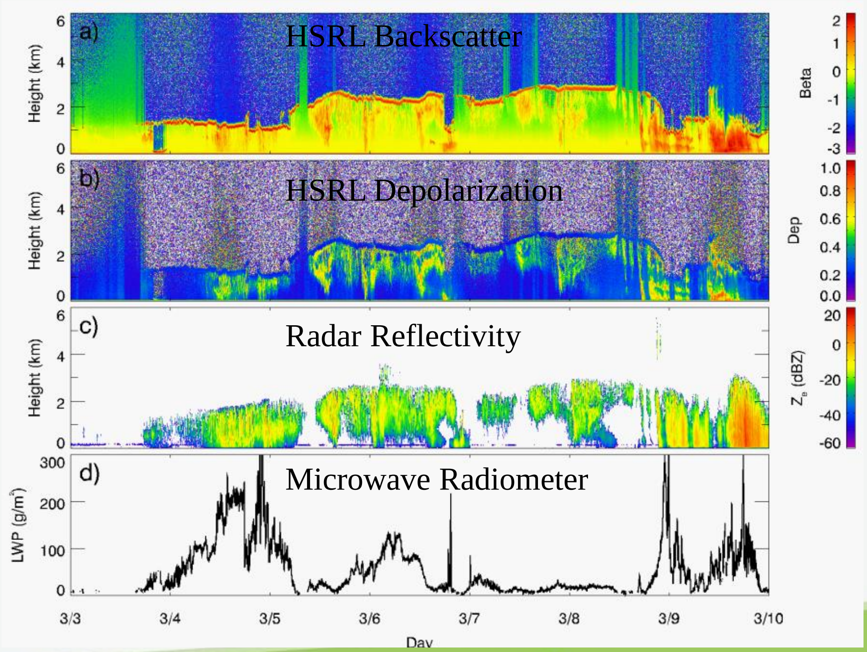
Importance of Mixed-phase Clouds

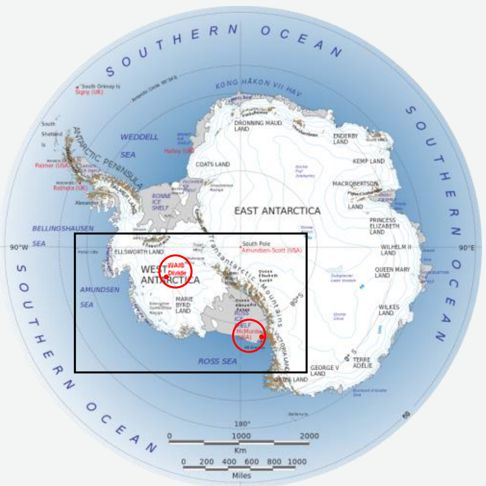
- Large global coverage
- High occurrence, stratiform, and long persistence over polar regions
- Strong radiative impacts
- Climate change is sensitive to mixed-phase clouds
- Challenge to model mixed-phase clouds
- Requires observational constraints





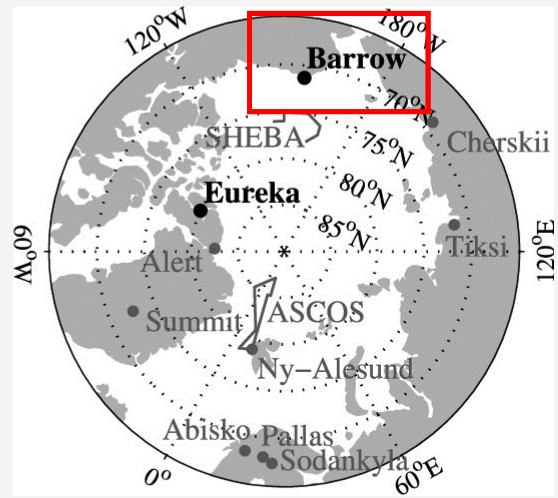
Atmospheric Radiation Measurements (ARM) Datasets

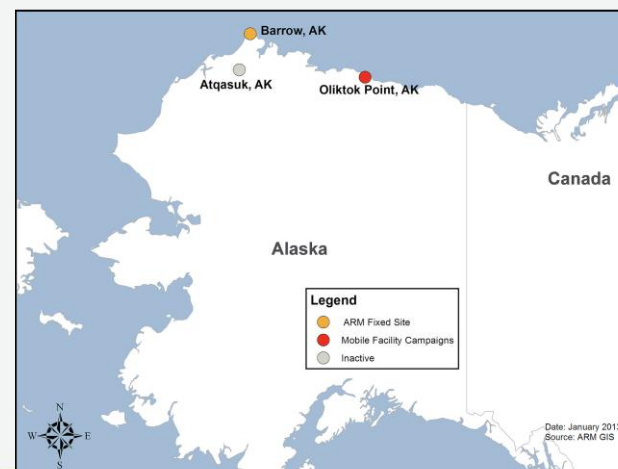
ARM West Antarctic Radiation Experiment-AWARE (Dec 2015 – Jan 2017)



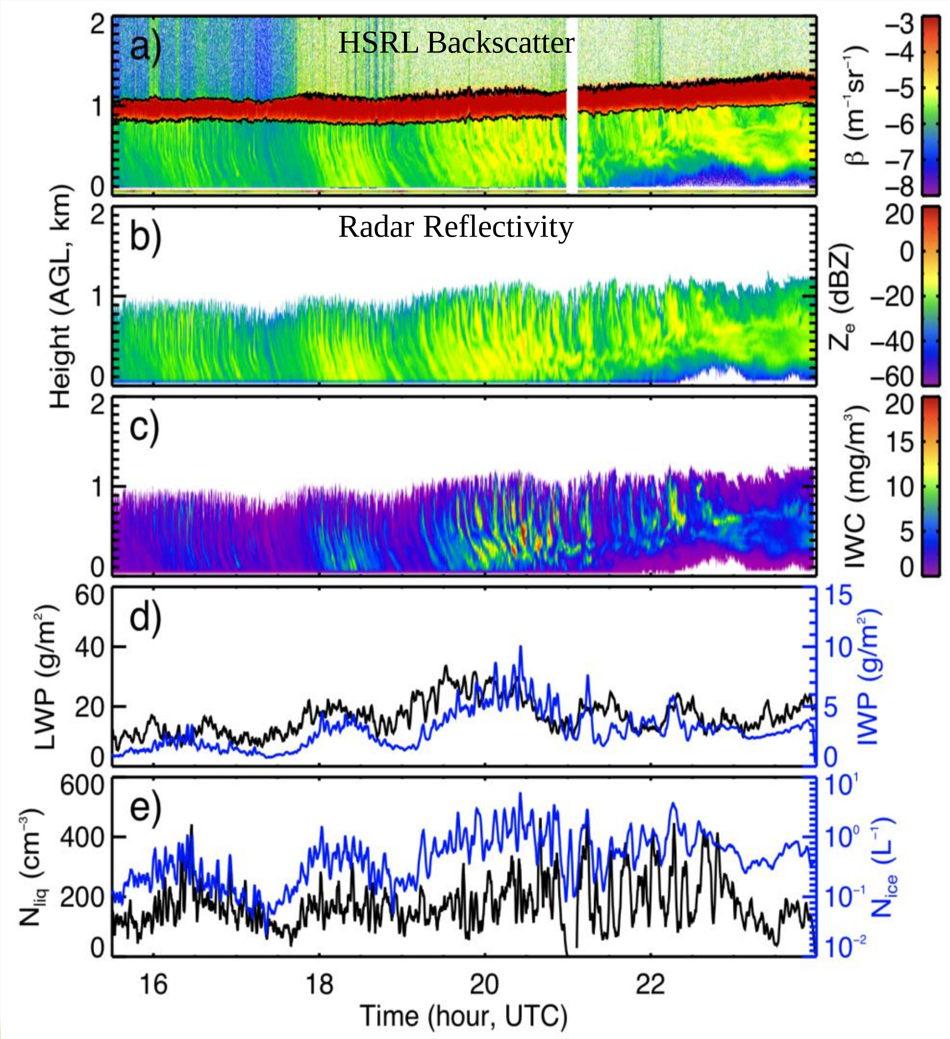
- Micro pulse lidar (MPL) and High Spectral Resolution Lidar (HSRL)
- Ka-Band (35 GHz) ARM Zenith Radar (KAZR)
- Microwave Radiometer (MWR)
- Balloon-Borne Sounding System

NSA Utqiaġvik (formerly known as 'Barrow')





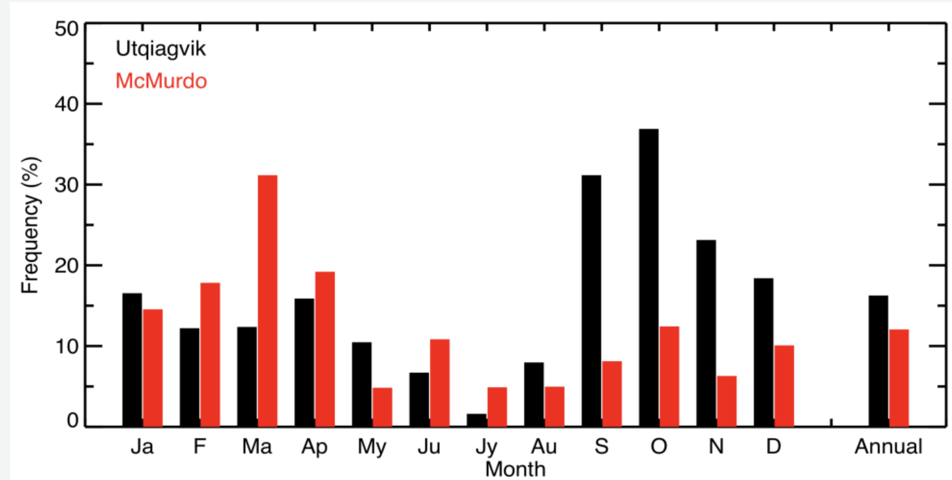
Multi-sensor Retrievals of Stratiform Mixed-phase Cloud (SMC) Microphysical Properties



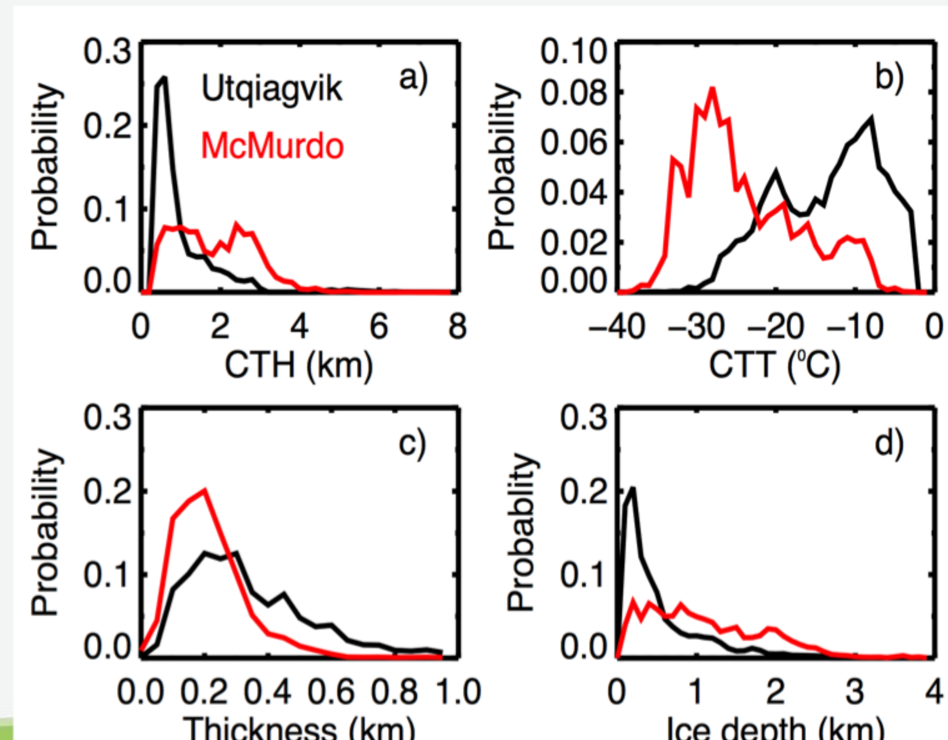
- **LWP:** MWRRet product
- **IWC**: IWC-Z-T relationships (Hogan et al., 2006) .
- **IWP**: integrating IWC from the KAZR-detected cloud base to top.
- **N_{ice}**: Retrieved from Z_e and 1-D ice growth model (Zhang et al., 2014)
- **N_{liq}**: Retrieved from Lidar extinction coefficients (Snider et al., 2017)

SMC Macrophysical Properties

- Frequency occurrences have maxima in Fall at both Utqiaġvik and McMurdo

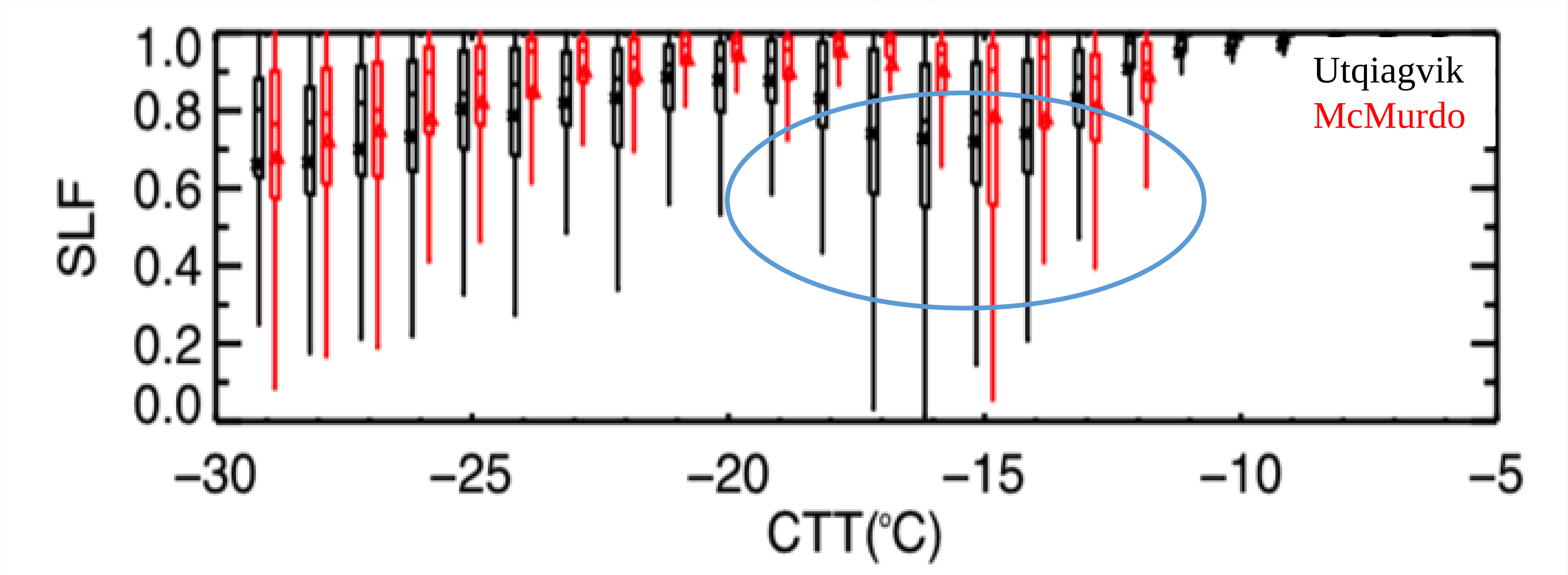


- SMCs at McMurdo are higher and much colder
- Liquid-dominated layers are thinner at McMurdo but ice layer depths are greater.



SMC Microphysical Properties

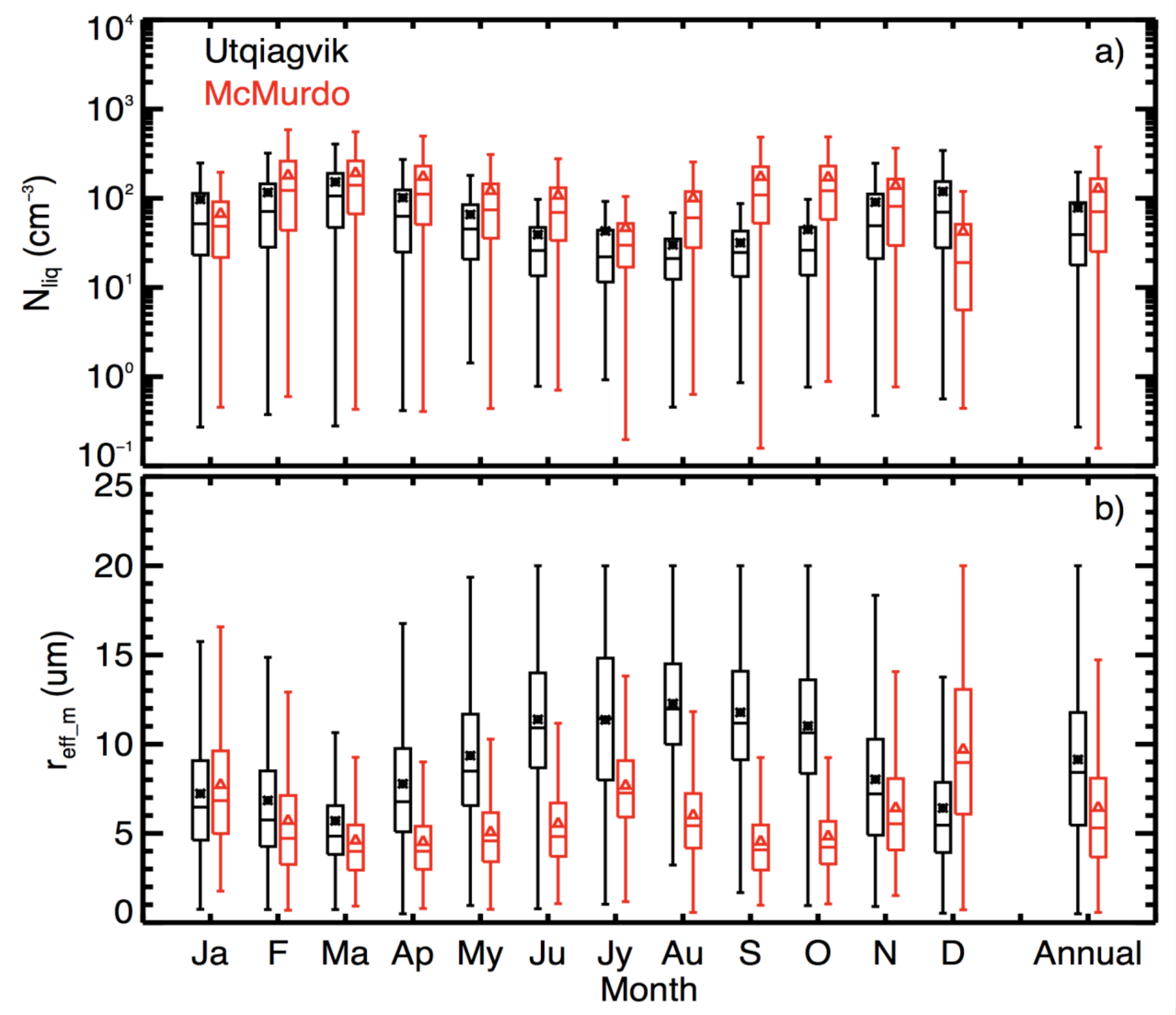
Supercooled liquid fraction



- SLF = LWP/(LWP + IWP)
- SLF decreases with decreasing temperature
- SLFs are dramatically lower at CTTs close to -15 ºC
- SLFs at McMurdo tend to be larger than at Utqiaġvik for a given CTT warmer than -25 ºC

SMC Microphysical Properties

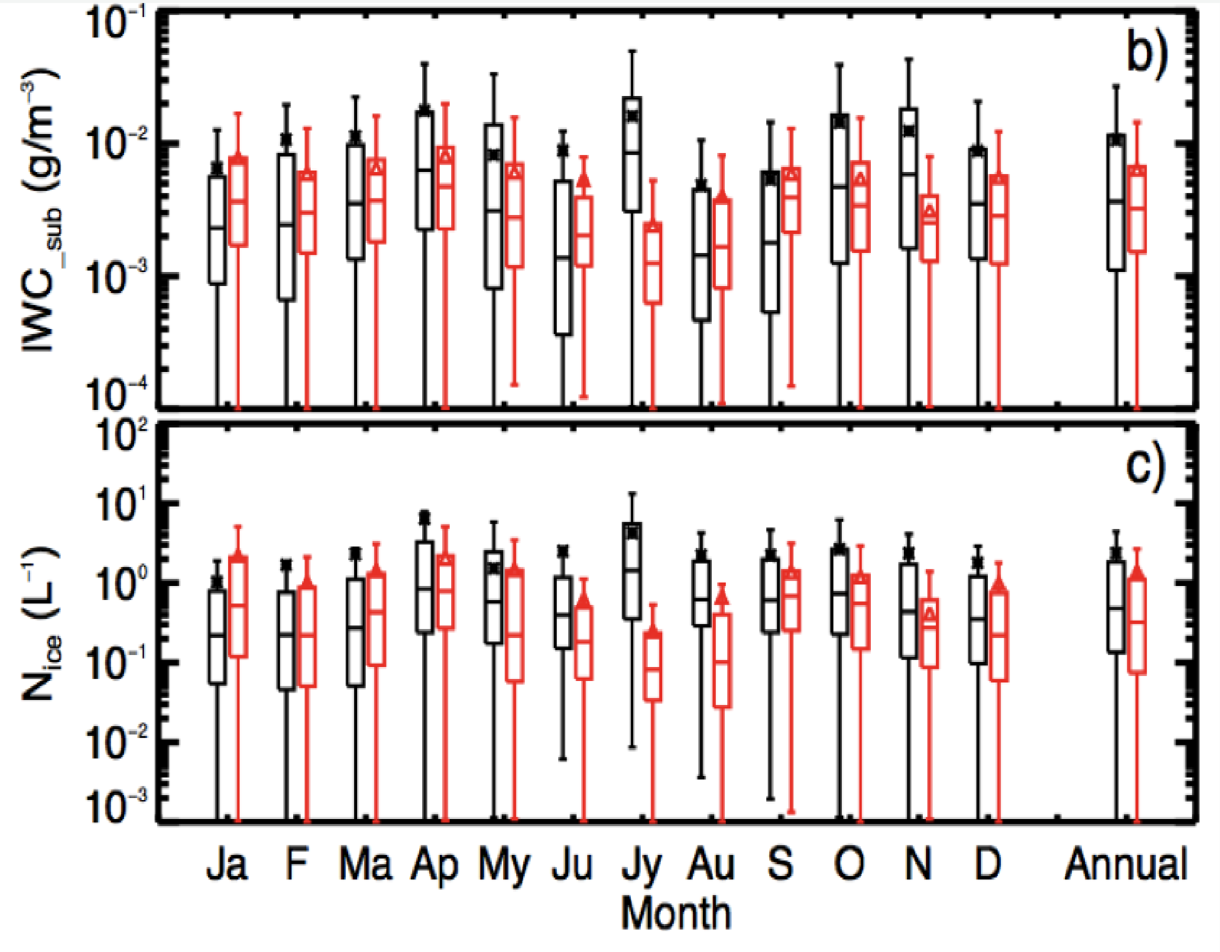
Liquid layer microphysical properties



- Generally McMurdo has greater N_{liq} and smaller R_{eff}

SMC Microphysical Properties

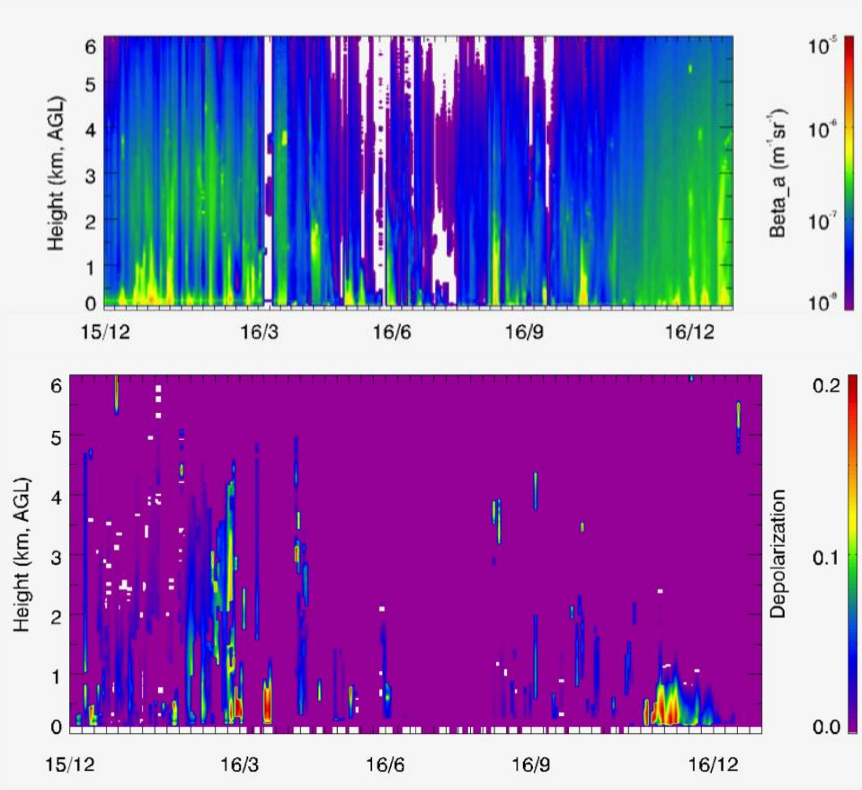
Ice layer microphysical properties



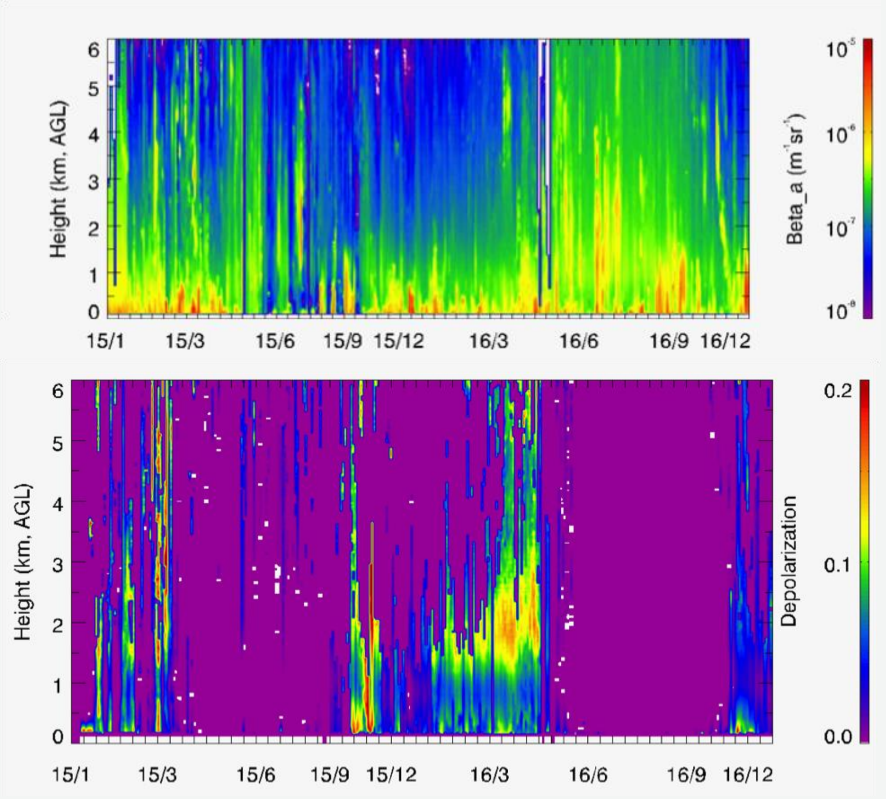
- Generally McMurdo has smaller IWC and N_{ice}

Polar Aerosol Profiles

McMurdo



Utqiagvik



- Aerosol profiles show clear seasonal variations and generally have largest backscatter in summer at McMurdo and in spring and early summer at Utqiaġvik

Summary

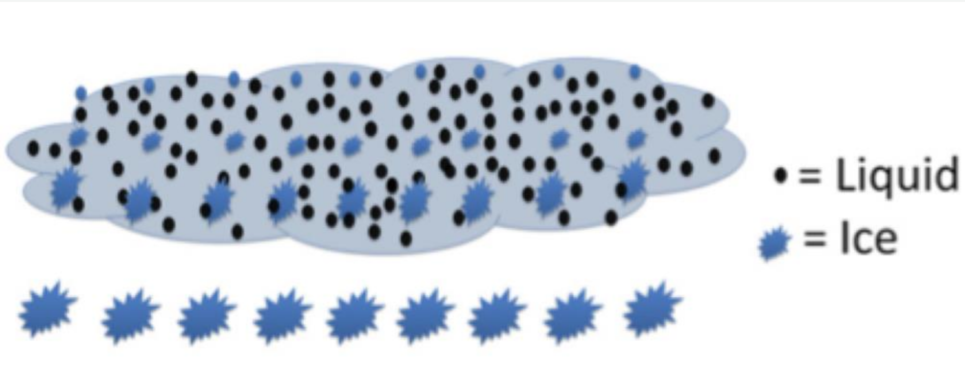
- Polar stratiform mixed-phase cloud microphysical properties are retrieved using recently developed advanced multi-sensor retrieval algorithms (Zhang et al., submitted to JGR-Atmosphere)

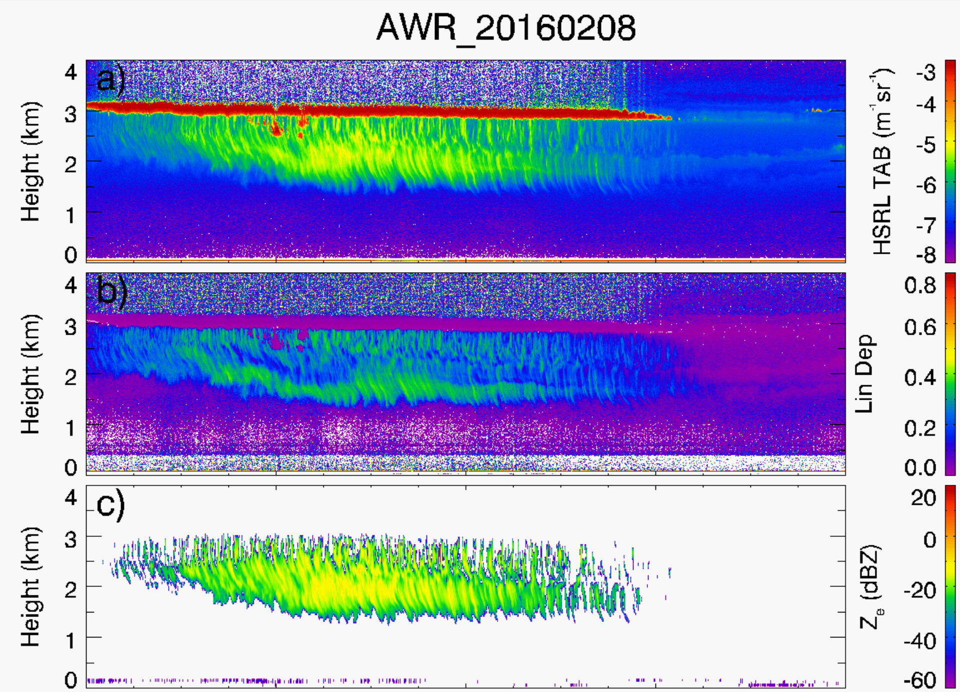
- Stratiform mixed-phase clouds at McMurdo are often well above the boundary layer while those at Utqiaġvik are usually within the boundary layer.

- For a given CTT stratiform mixed-phase clouds at McMurdo have larger SLF, N_{liq}, but a smaller $r_{eff,}$ IWC, and N_{ice}.

- A strong seasonal variation in aerosol loading is fund at both sites that likely affects cloud properties, along with aerosol chemical composition.

Stratiform mixed-phase cloud detection

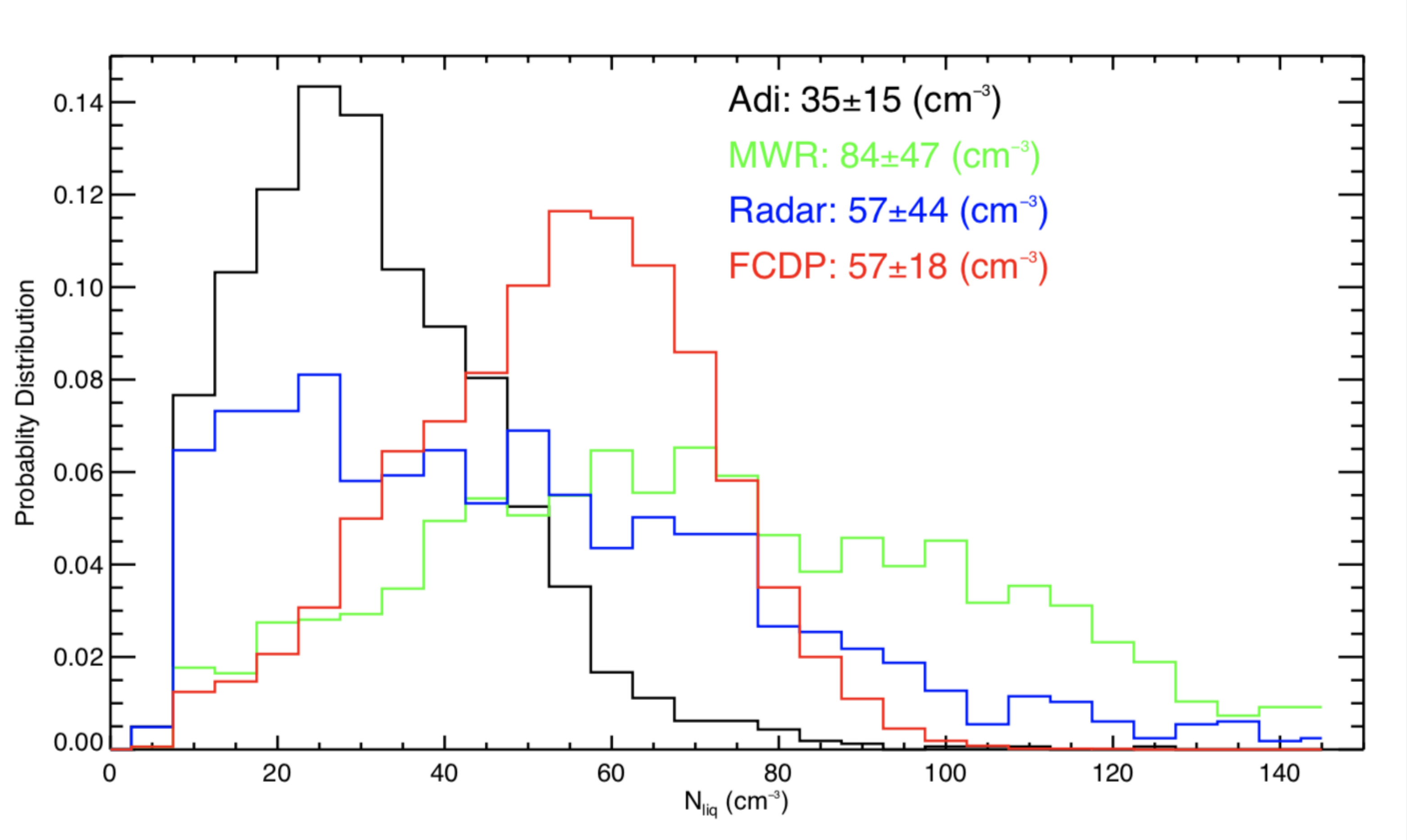




- Large positive and negative slopes of HSRL backscatter coefficients plus small HSRL circular depolarization ratios (e.g., less than 0.3) are used to determine the liquid-dominated layer.
- A radar reflectivity below the liquid-dominated layer indicates the presence of ice particles.
- Cloud top heights have a small standard deviation (e.g., smaller than 300 m) .

II. Cloud Microphysical Property Retrievals

Evaluation of N_{liq} retrieval with ACE-ENA data



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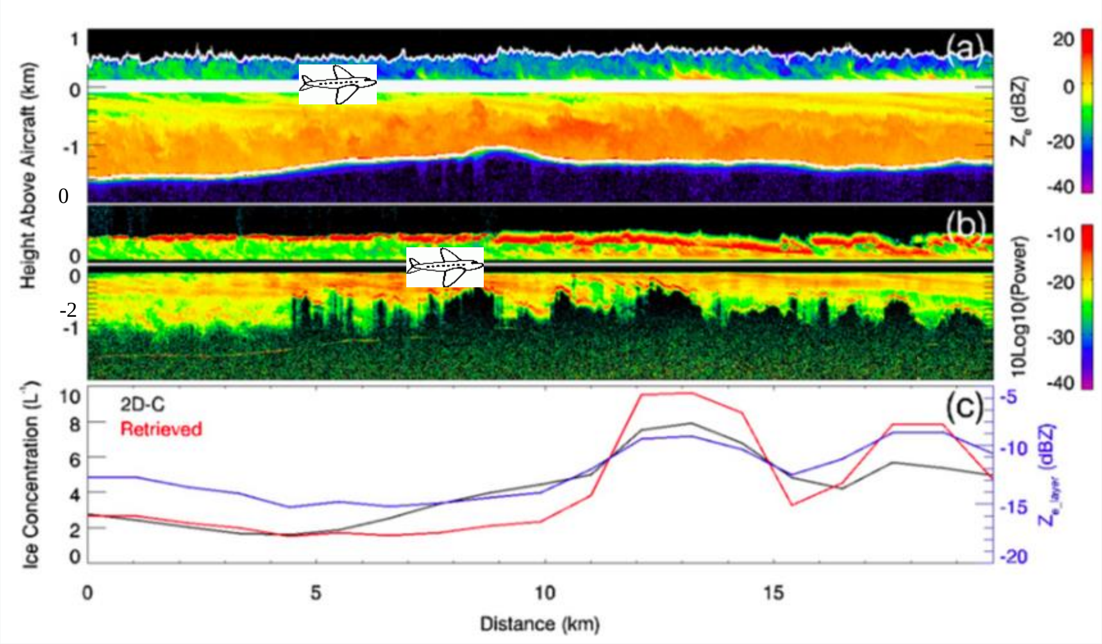
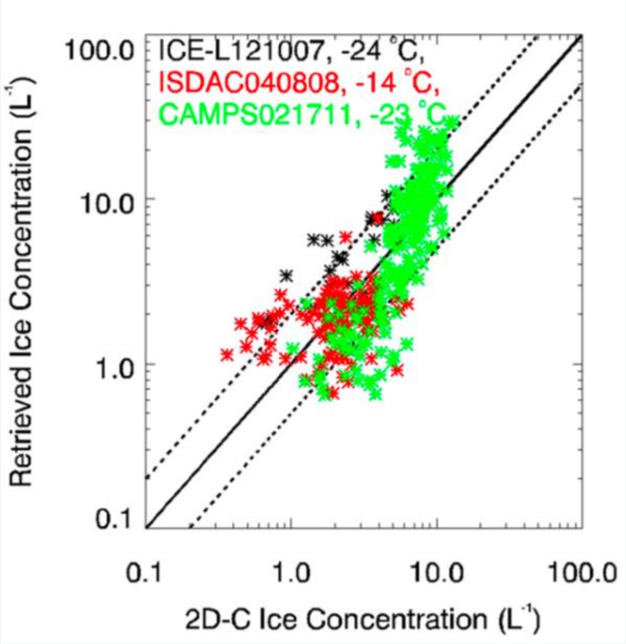
II. Cloud Microphysical Property Retrievals

Evaluating Retrieved N_{ice} with *In Situ* Measurements





(Zhang et al., 2014, *JAS*)