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

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11th ISTP, Toulouse, France
May 22, 2019
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 Utqiagvik 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 °C
- SLFs at McMURDO tend to be larger than at Utqiagvik for a given CTT warmer than -25 °C
SMC Microphysical Properties

Liquid layer microphysical properties

- Generally McMurdo has greater $N_{\text{liq}}$ and smaller $R_{\text{eff}}$.
SMC Microphysical Properties

Ice layer microphysical properties

- Generally McMurdo has smaller IWC and $N_{\text{ice}}$
Polar Aerosol Profiles

• Aerosol profiles show clear seasonal variations and generally have largest backscatter in summer at McMurdo and in spring and early summer at Utqiagvik
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 Utqiagvik 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 $N_{\text{liq}}$ retrieval with ACE-ENA data

Adi: $35 \pm 15$ (cm$^{-3}$)
MWR: $84 \pm 47$ (cm$^{-3}$)
Radar: $57 \pm 44$ (cm$^{-3}$)
FCDP: $57 \pm 18$ (cm$^{-3}$)
II. Cloud Microphysical Property Retrievals

Evaluating Retrieved $N_{\text{ice}}$ with *In Situ* Measurements

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