Advancing observational constraints on high-latitude cloud processes

Fridlind et al. [ACP, 2016] at −43°C near Cayenne (Airbus)

Ackerman et al. [ACP, 2016]

Biggerstaff and Houze [1993]
Motivation

• uncertainty in GCM predictions of polar amplification
• supercooled cloud water plays an outsized role in polar surface energy budgets, GCM predictions
  – Zuidema, Intrieri, Curry et al. papers using SHEBA ice camp observations
  – Tan, Storelvmo, Kay et al. papers using climate models and CALIPSO observations

GISSTEMP 1970–2017 near-surface warming (K)

https://www.mosaic-expedition.org/
SHEBA Arctic survey

Rangno and Hobbs [JGR 2001]
following Hobbs and Rangno [1998]
Continuous ice precipitation

Vertically pointing mm-wavelength radar

Fridlind and Ackerman [Simulations of Arctic mixed-phase boundary layer clouds: Advances in understanding and outstanding questions, Ch. 7 in Mixed-Phase Clouds: Observations and Modeling, Ed. C. Andronache, 2018]
Well-defined liquid cloud base

M-PACE radar reflectivity and lidar cloud base

van Diedenhoven et al. [JGR 2009]

SHEBA simulation

Fridlind et al. [JAS 2012]
Big data

Korolev et al. [QJRMS 2003]

TWC threshold = 0.01 gm⁻³

-35°C<T<-30°C: L=177 km
-30°C<T<-25°C: L=1403 km
-25°C<T<-20°C: L=2143 km
-20°C<T<-15°C: L=3883 km
-15°C<T<-10°C: L=6938 km
-10°C<T<-5°C: L=13626 km
-5°C<T<0°C: L=13011 km

~ 100 m (1 s) averaging
N ~ 0.5 million
see also e.g. McFarquhar et al. [JGR 2004], Jackson et al. [JGR 2012]

Avramov et al. [JGR 2011]

above liquid cloud base
below liquid cloud base
ISDAC intercomparison

Ovchinnikov et al. [2014]
GCM in SCM mode

- M-PACE intercomparison case [Klein et al. QJRMS 2009]
- GISS ModelE3 single-column model (Andy Ackerman)
  - moist turbulence scheme [Bretherton and Park 2009]
  - two-moment microphysics with prognostic precipitation [Gettelman and Morrison 2015]

GCM $\Delta z \sim 100$ m
LES $\Delta z \sim 30$ m
Mixed-phase Sc LES case studies

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<tr>
<th>Field Campaign</th>
<th>Observation Period (UTC)</th>
<th>Cloud Top Height (m)</th>
<th>Cloud Temp. (C)</th>
<th>Path (g m(^{-2}))</th>
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Fridlind and Ackerman [Elsevier 2018]
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![Diagram showing LWP and Droplet Number Concentration with SHEBA, ISDAC, and M-PACE regions]
Reflectivity-weighted aspect ratio

- Matrosov et al. [JAOT 2017]
  - SACR Ka-band
  - circulation depolarization ratio (CDR) proxy

VIPS in situ
0.2–0.5 km

MASC period 1
stereo images

period 1
period 5
Reflectivity-weighted aspect ratio

- Matrosov et al. [JAOT 2017]
  - 40° CDR proxy or Zdr-based
  - characteristic size from dual-frequency reflectivity ratio (DFR) or dual Doppler velocity (for smaller particles)
  - uncertainty of 0.1–0.15
  - RHI scans averaged over 2° around 40° and 140°
Cloud structure, too

- cloud structure deconvolution from vertically pointing or QVP: is it even robustly possible?
- if there is not a very substantial gain from QVP, RHI is preferable

Lamer [2017] NSA KAZR and ceilometer
Matrosov et al. [2017]