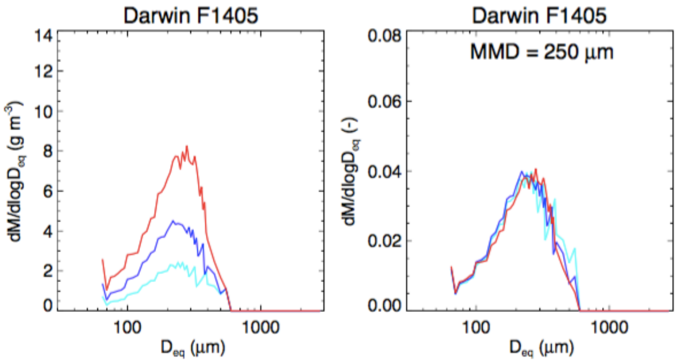
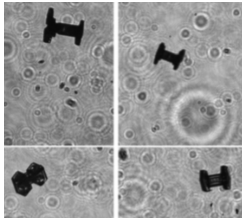
Advancing observational constraints on high-latitude cloud processes

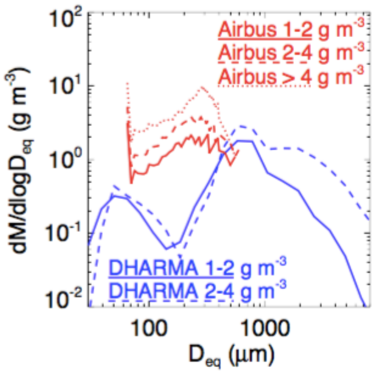
Ann Fridlind, NASA GISS
giss.nasa.gov/staff/afridlind.html

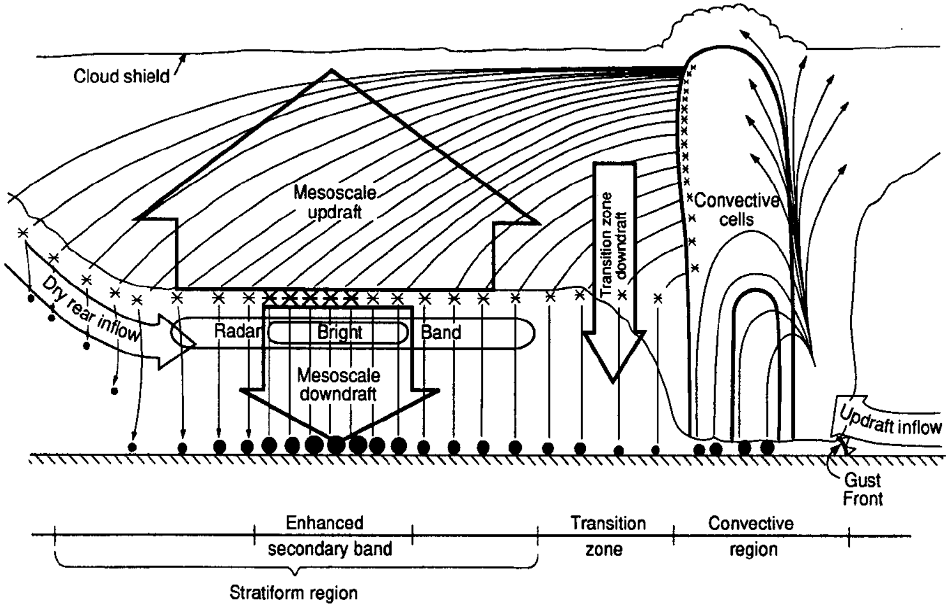


Fridlind et al. [ACP, 2016]
at –43°C near Cayenne (Airbus)

Ackerman et al. [ACP, 2016]





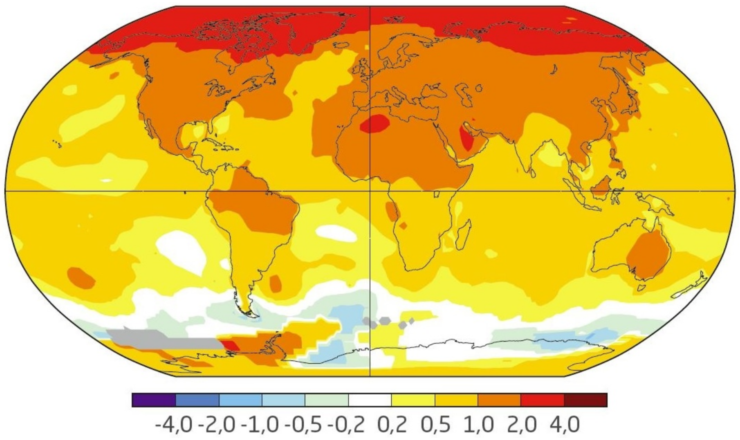


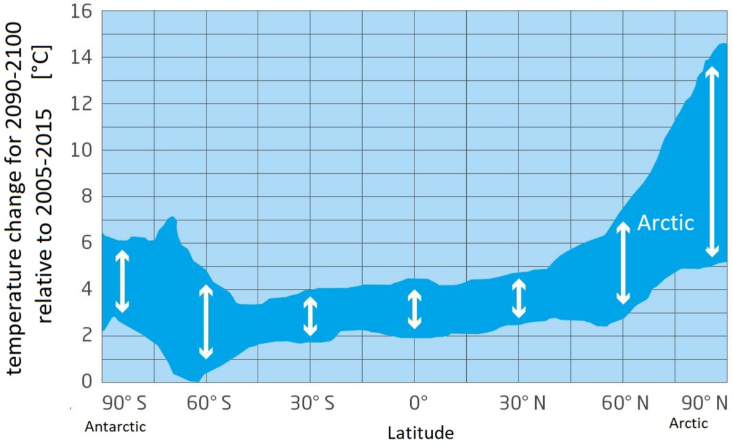
Biggerstaff and Houze [1993]

Motivation

- uncertainty in GCM predictions of polar amplification
- supercooled cloud water plays an outsize 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

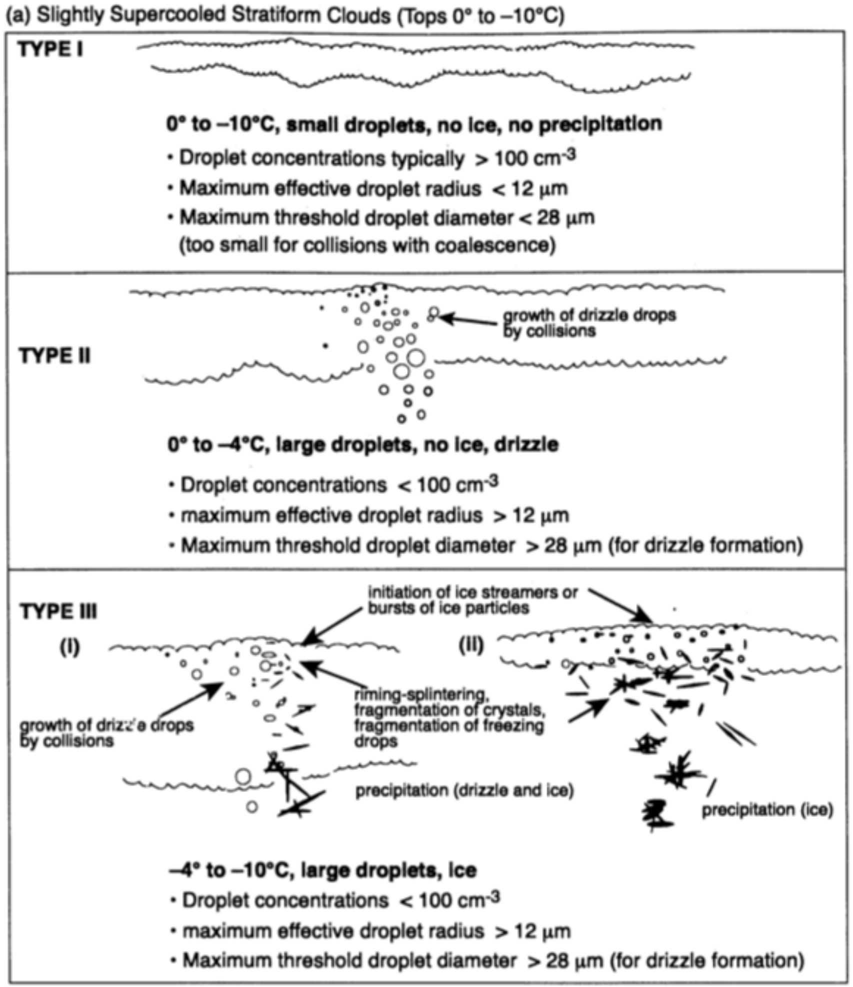
GISSTEMP 1970–2017 near-surface warming (K)

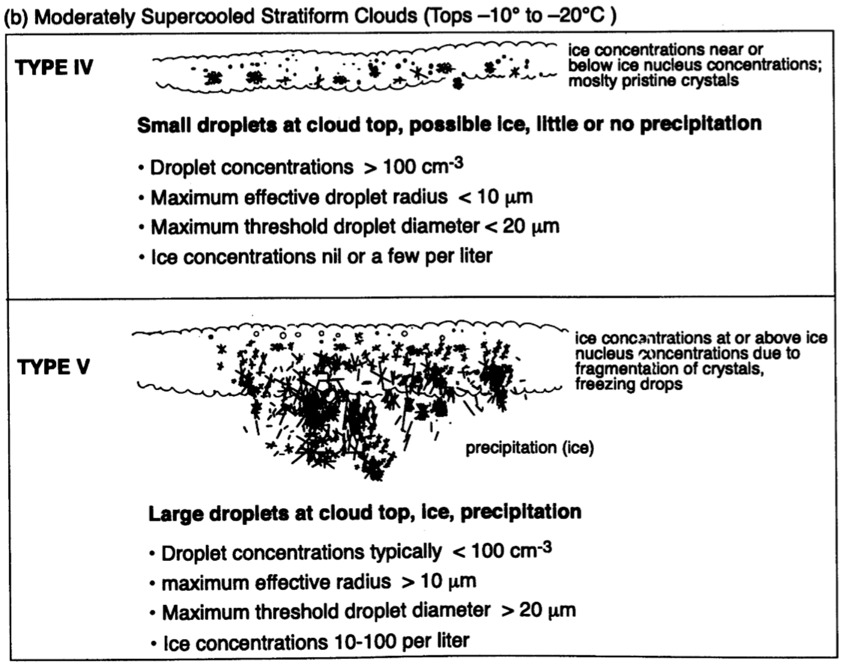




https://www.mosaic-expedition.org/

SHEBA Arctic survey

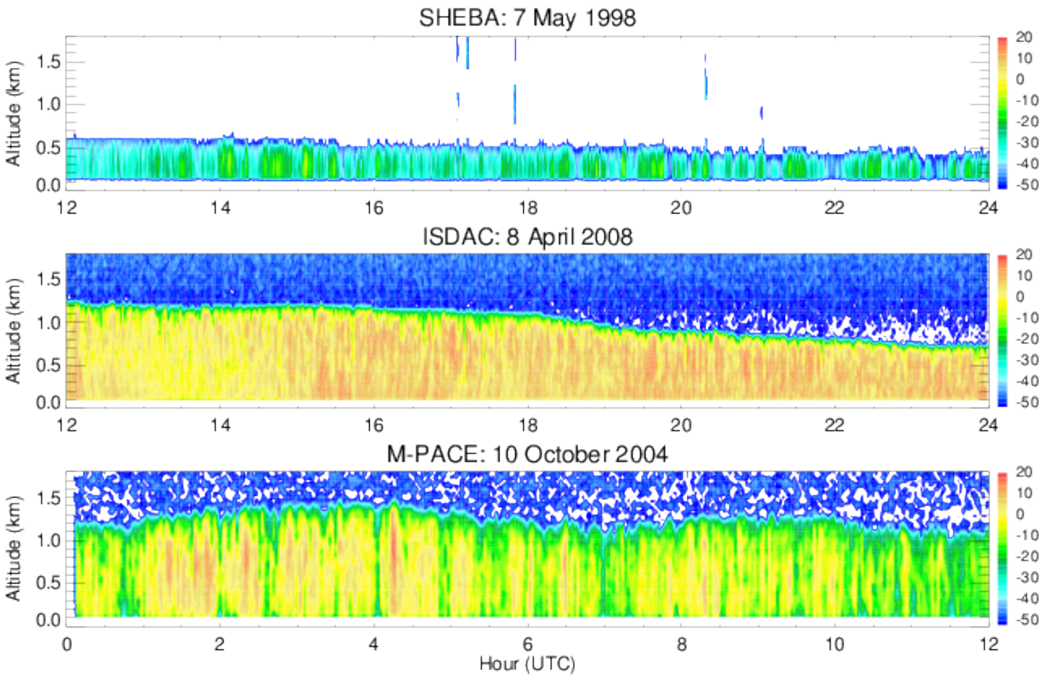




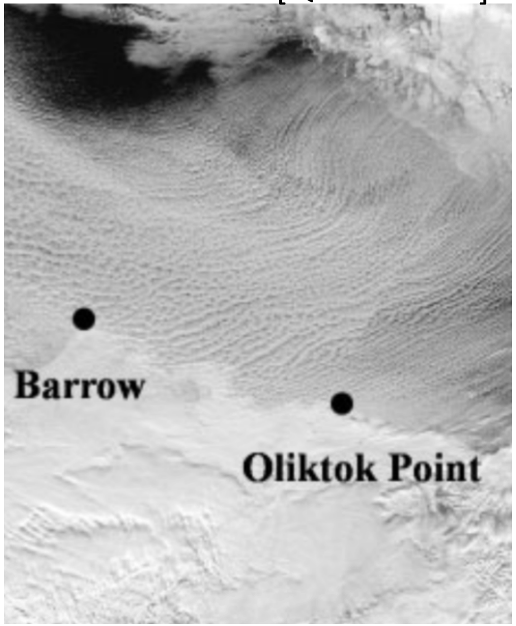
Rangno and Hobbs [JGR 2001]
following Hobbs and Rangno [1998]

Continuous ice precipitation

Vertically pointing mm-wavelength radar



Klein et al. [QJRMS 2009]

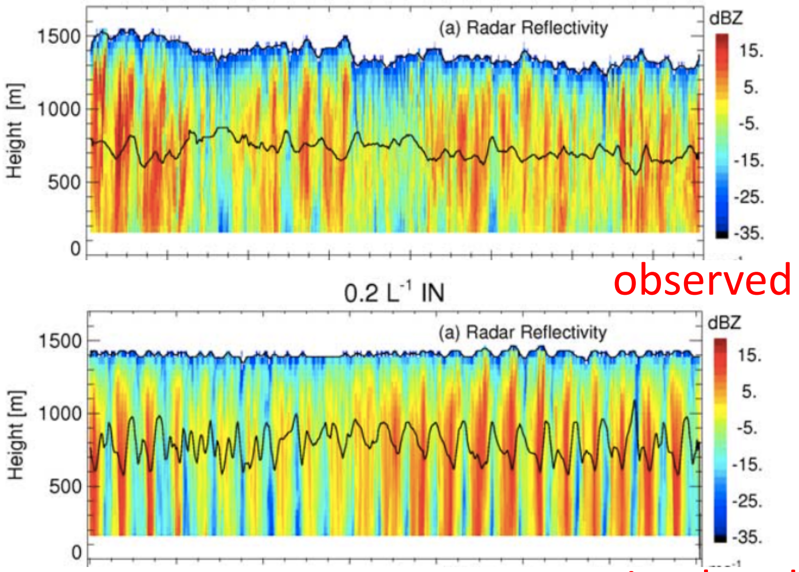


Fridlind and Ackerman [Simulations of Arctic mixed-phase boundary layer clouds: Advances in understanding and outstanding questions, Ch. 7 in *Mixed-Phase Clouds: Observations and Modeling*, Ed. C. Andronache, 2018]

Well-defined liquid cloud base

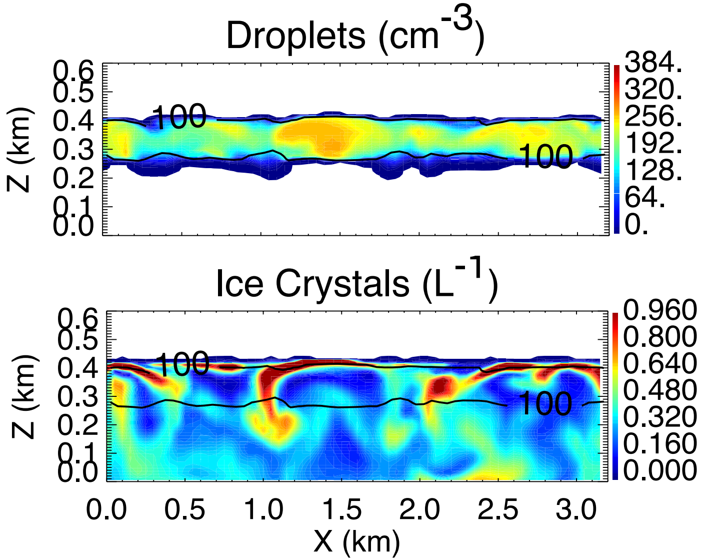
~~*glaciated patches?*~~

M-PACE radar reflectivity and lidar cloud base



van Diedenhoven et al. [JGR 2009]

SHEBA simulation

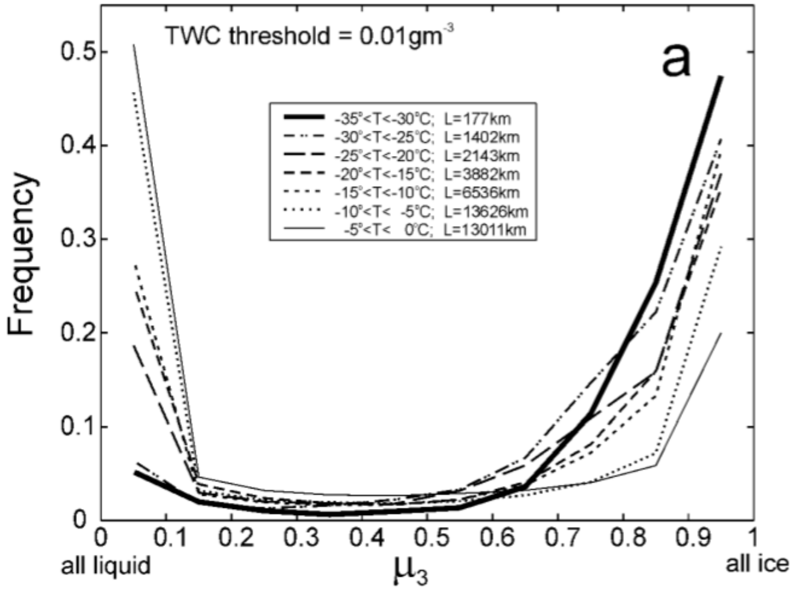


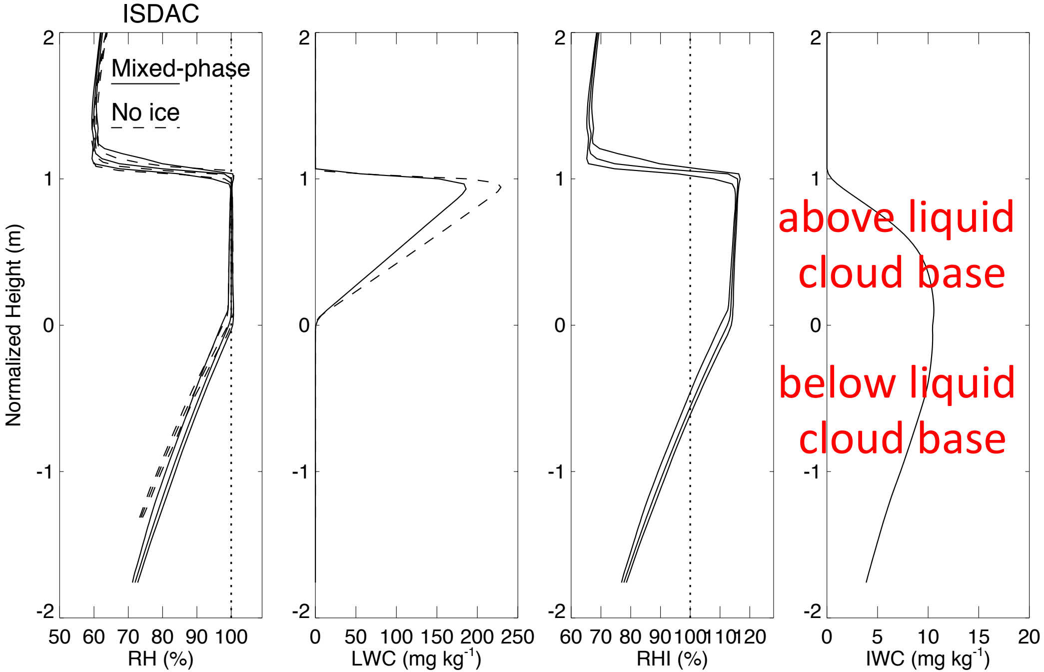
Fridlind et al. [JAS 2012]

Big data

Avramov et al. [JGR 2011]

Korolev et al. [QJRMS 2003]





above liquid cloud base

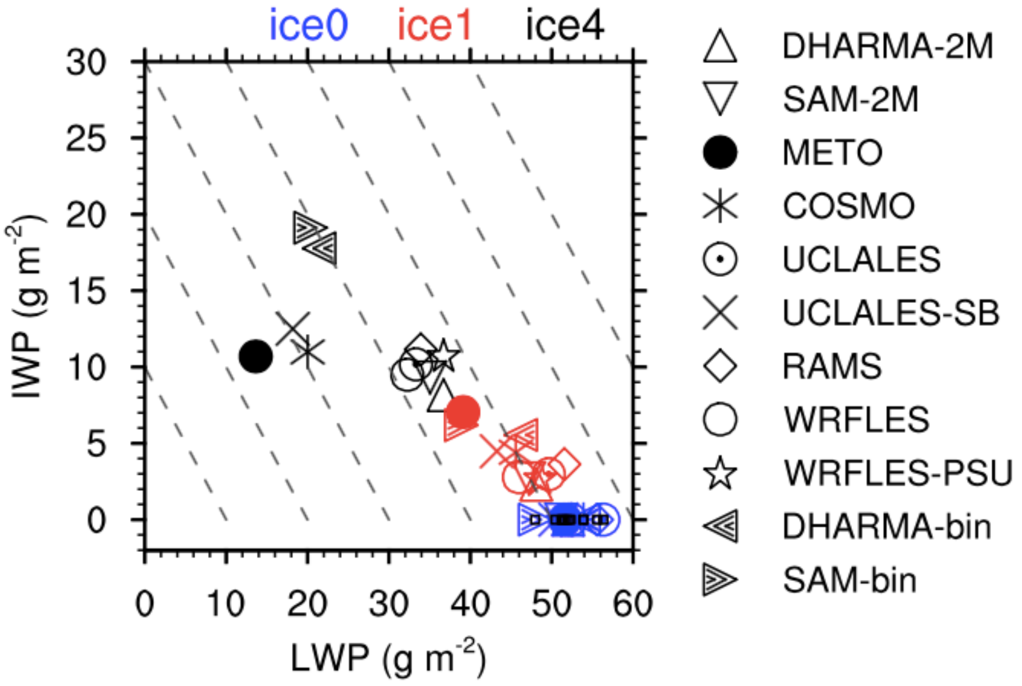
below liquid cloud base

~ 100 m (1 s) averaging

N ~ 0.5 million

see also e.g. McFarquhar et al. [JGR 2004], Jackson et al. [JGR 2012]

ISDAC intercomparison



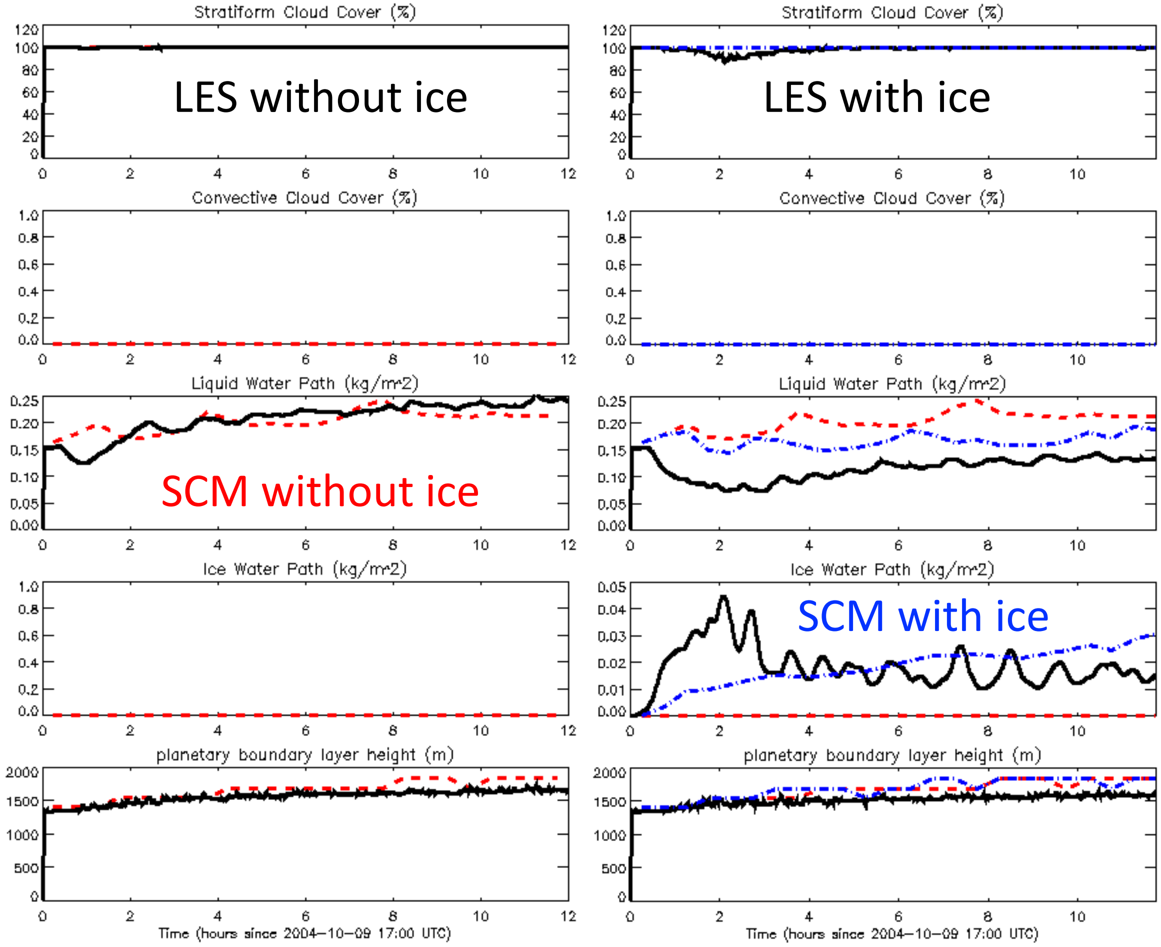
persistence remarkable?

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]

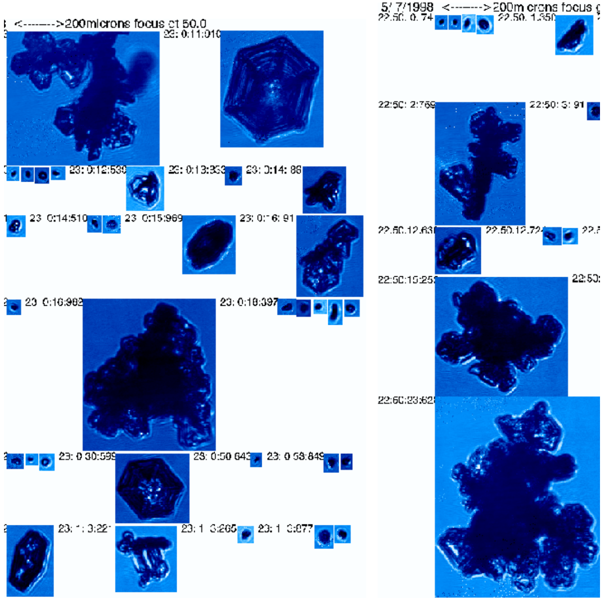
GCM Δz ~ 100 m
LES Δz ~ 30 m

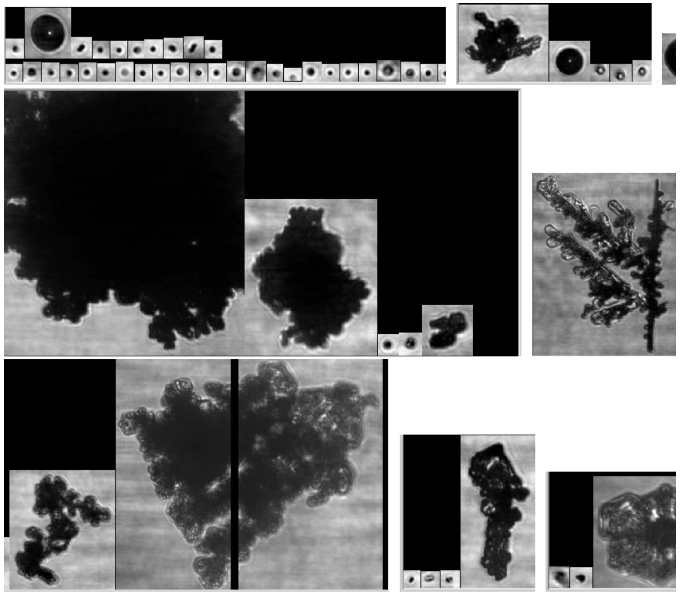


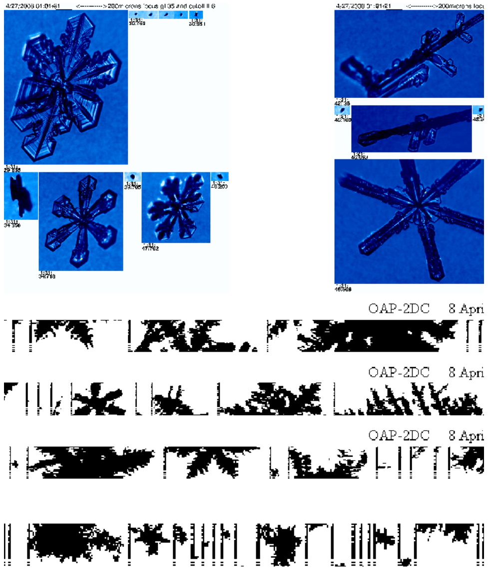
Mixed-phase Sc LES case studies

Fridlind and Ackerman [Elsevier 2018]

Field Campaign	Observation Period (UTC)	Cloud Top Height (m)	Cloud Temp. (C) Top	Cloud Temp. (C) Base	Path ($g\ m^{-2}$) Liquid	Path ($g\ m^{-2}$) Ice	Conc. (cm^{-3}) Drops	Conc. (cm^{-3}) Ice
SHEBA	7 May 1998	500	−20°	−18°	5–20	0.2–1	200	∼0.0005
M-PACE	9–10 Oct. 2004	1000	−16°	−9°	110–210	8–30	40	∼0.01
ISDAC	26 April 2008	800	−15°	−11°	10–40	2–6	200	∼0.001







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			Top	Base	Liquid	Ice	Drops	Ice
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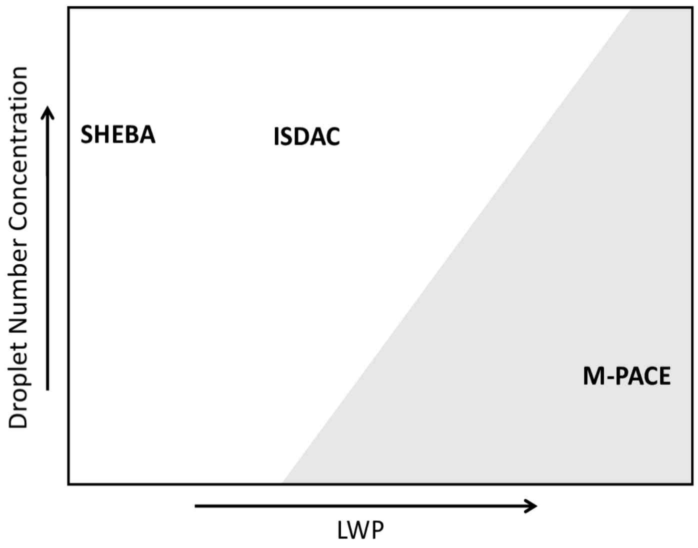
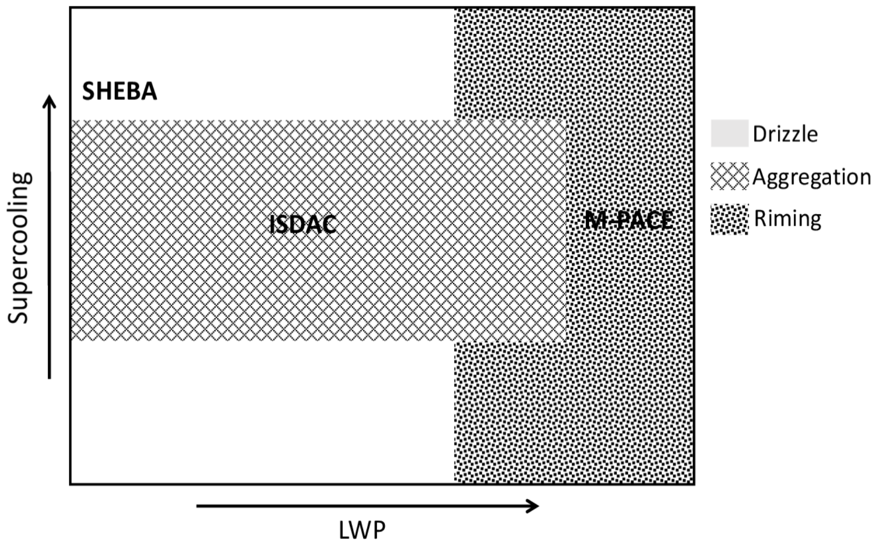
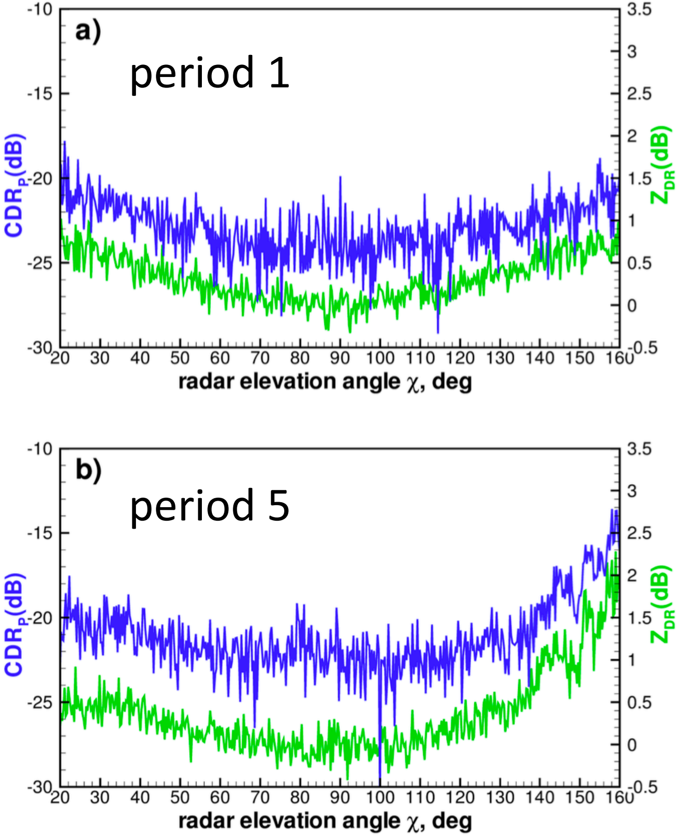


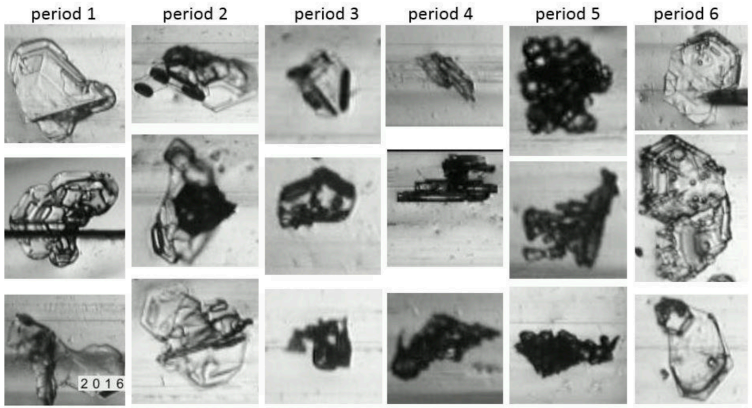


Reflectivity-weighted aspect ratio

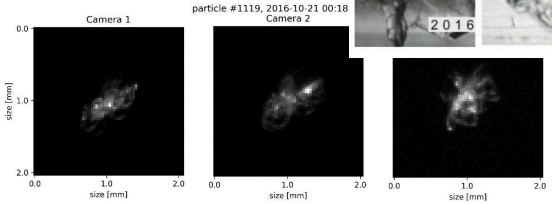
- Matrosov et al. [JAOT 2017]
  - SACR Ka-band
  - circulation depolarization ratio (CDR) proxy



VIPS in situ
0.2–0.5 km

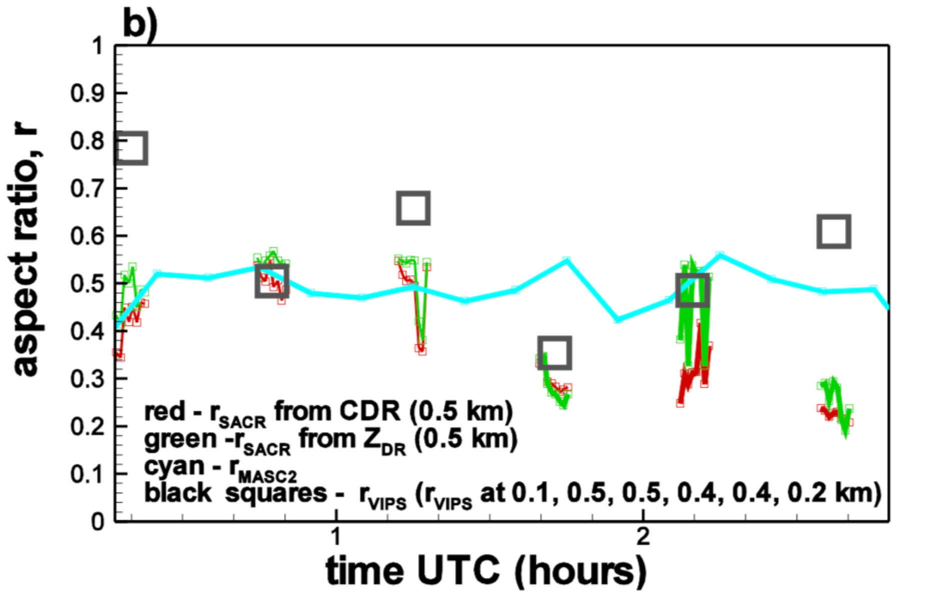


MASC period 1
stereo images



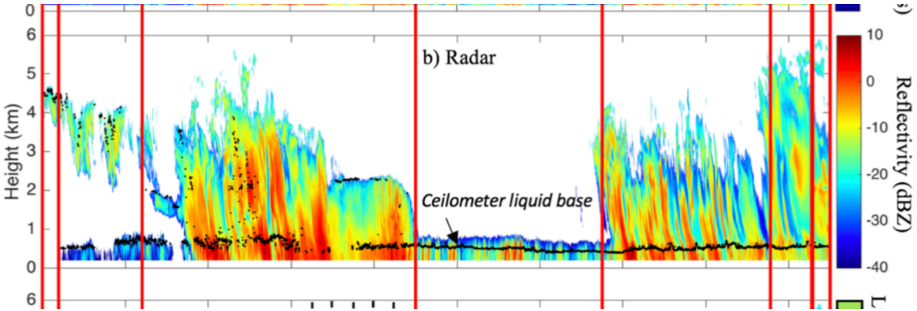
Reflectivity-weighted aspect ratio

- 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°

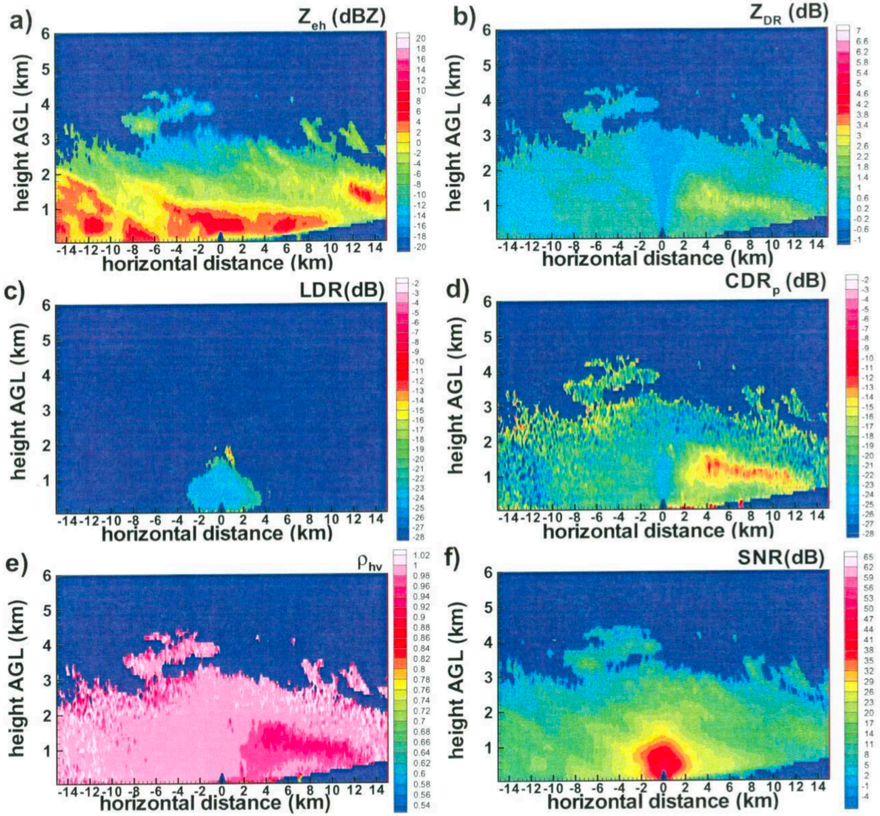


Cloud structure, too

- 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]