Cloud phase in convective systems

Ann Fridlind • NASA/GISS

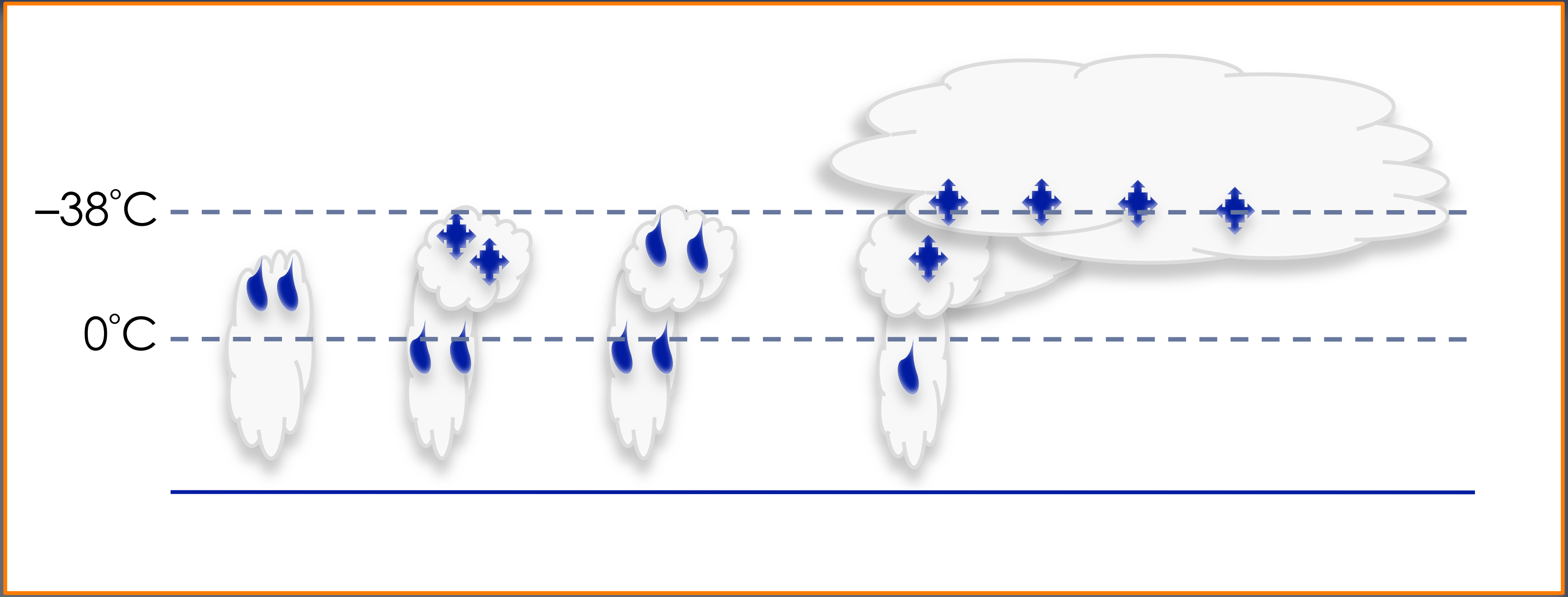
many thanks to

CRYSTAL-FACE, TWP-ICE, MC3E science teams

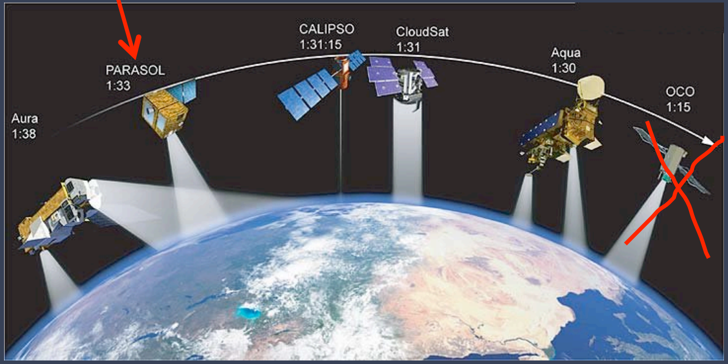
Andy Ackerman, Bastiaan van Diedenhoven, Brian Cairns • GISS
Andy Heymsfield, Hugh Morrison • NCAR
S. Collis • ANL
W. Peterson • NASA
X. Dong • UND

Ice formation in mixed-phase clouds

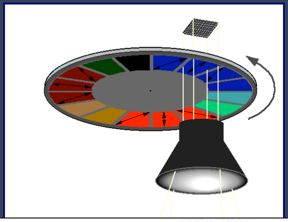
- $0 > T > -38°C$
  - primary ice formation requires ice nuclei (IN)
  - expect < 10s/L
  - secondary ice formation via multiplication?
- $T < -38°C$
  - primary ice formation doesn't require IN
  - droplets freeze sponteously
  - expect < 100s/cm^3



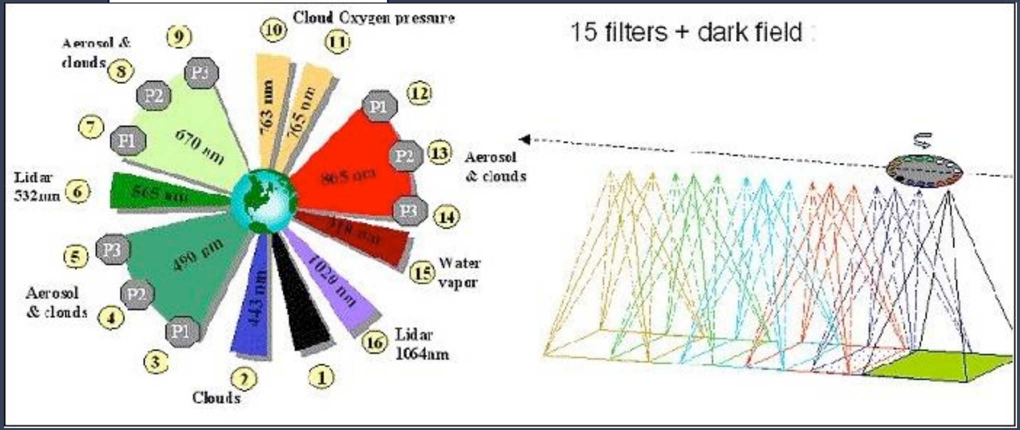
Cloud phase information from POLDER-PARASOL



- Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar

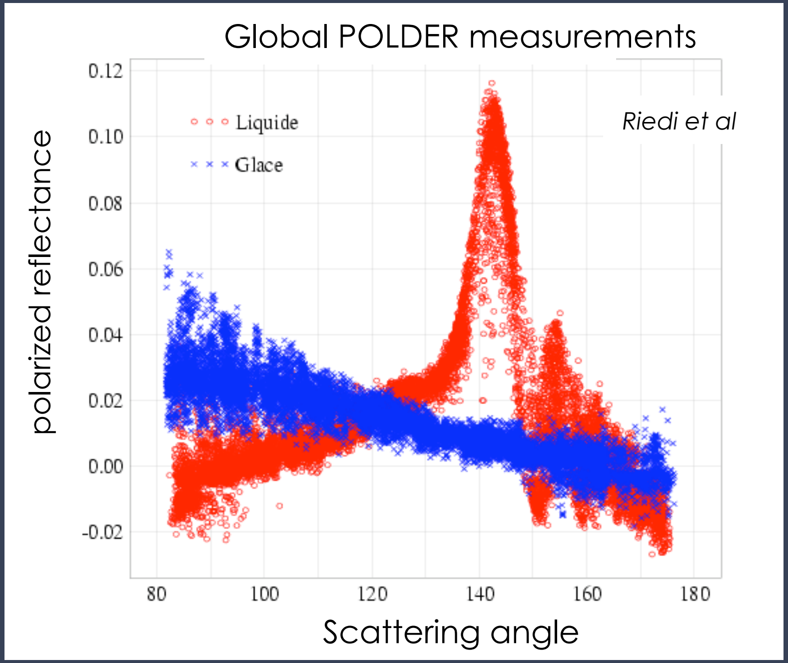


- Polarized reflectance at 490, 670 & 865 nm
- 13-15 viewing angles
- 10 x 10 km^2 resolution



Liquid index

- Fit straight line through 120°–160° measurements
- Liquid index = mean(| fit-measurement |)



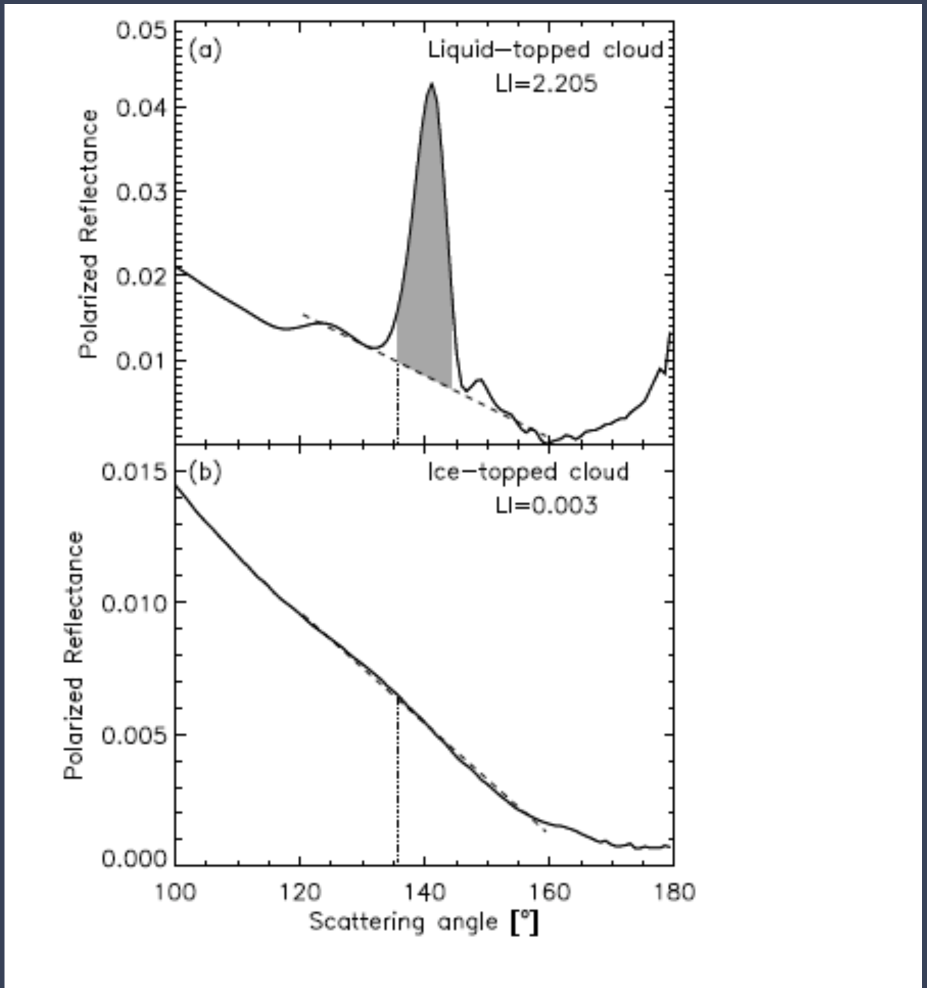
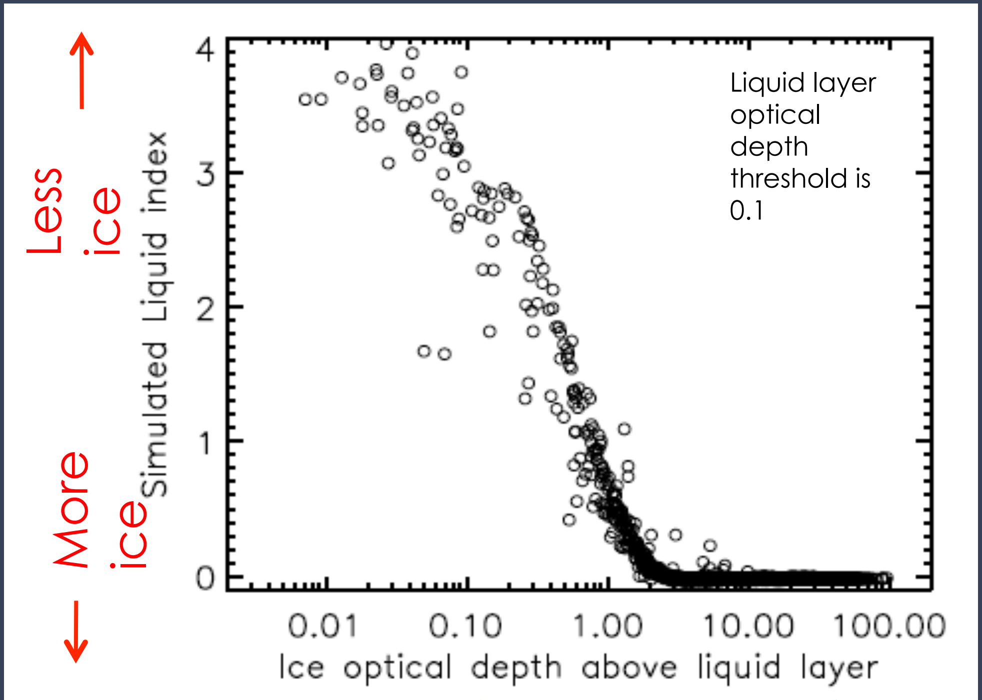


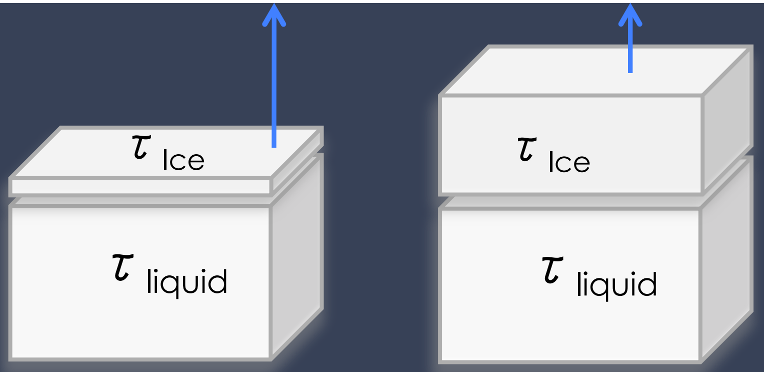
FIG. 2. Illustration of the definition of the liquid index (LI) for an liquid-topped cloud (a) and ice-topped cloud (b). See text for explanation.

van Diedenhoven et al., 2011

Physical interpretation of liquid index

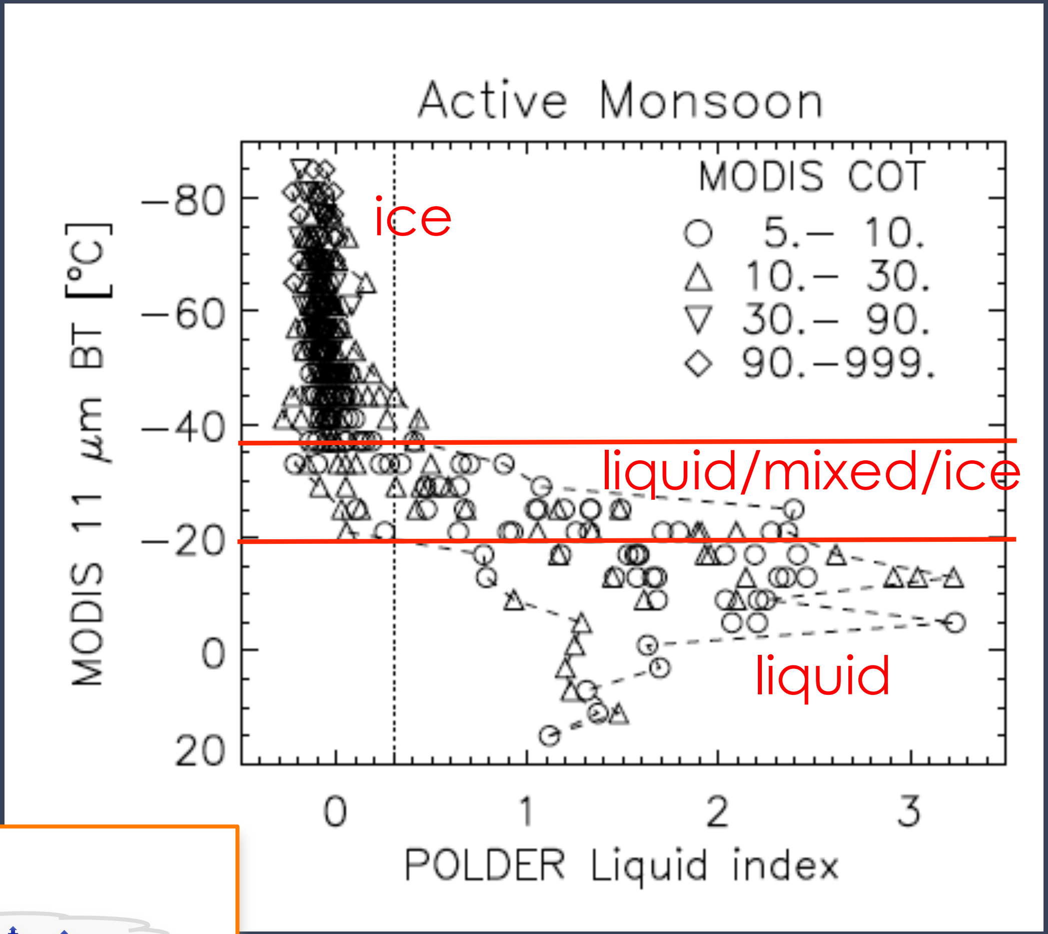
- Liquid index
  - Indicates to what degree liquid is *obscured* by ice above
  - ~3 for pure water clouds
  - ~0 for pure ice clouds or ice *topped* clouds

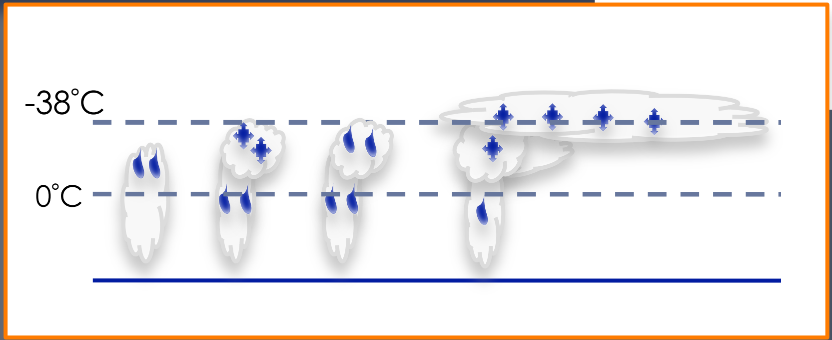




van Diedenhoven et al., 2011

Liquid index for TWP-ICE active monsoon

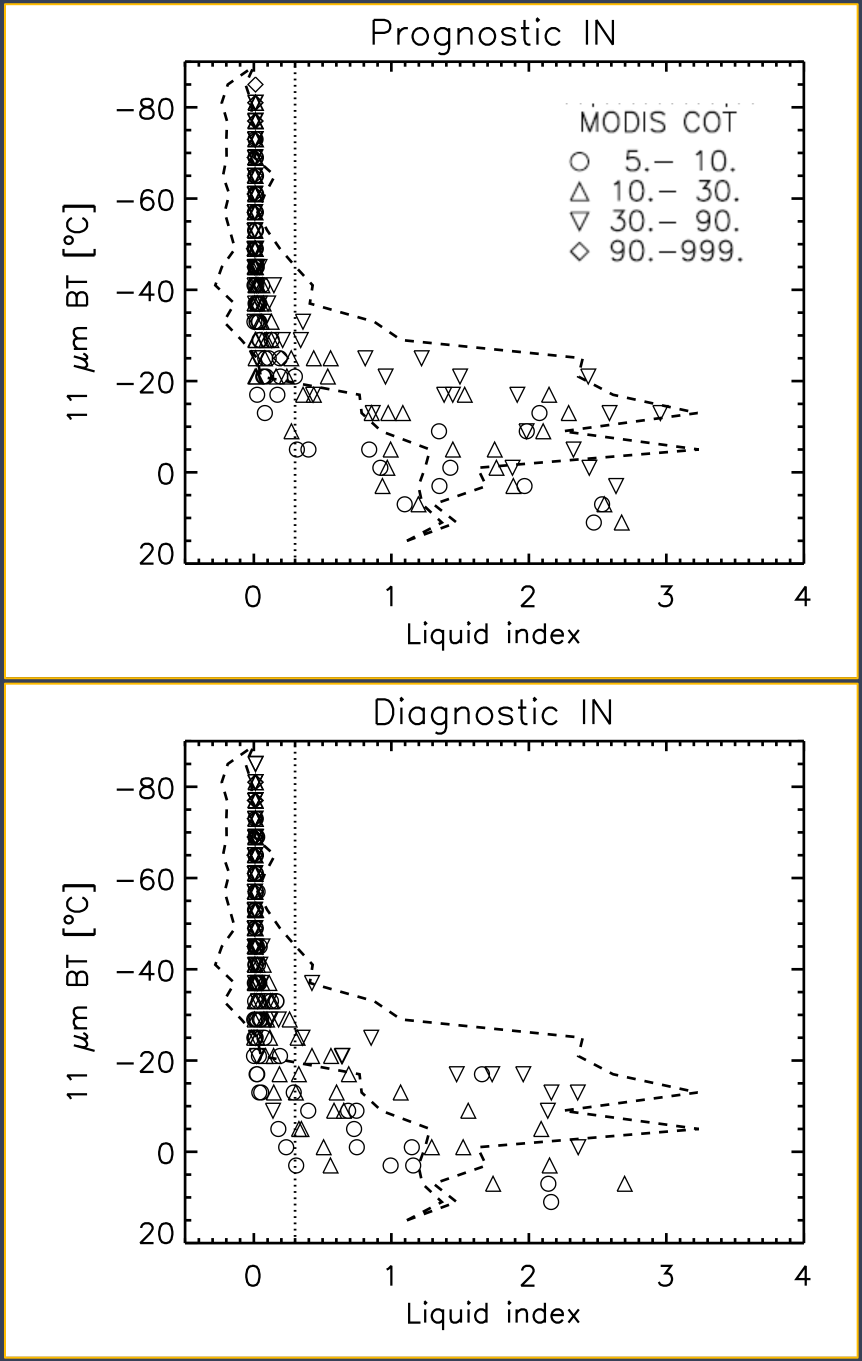




van Diedenhoven et al., 2011

Liquid index

- Simulated from CRM using forward calculations of 0.86-µm polarized reflectance
  - too much ice at T > –20 C
  - worse with diagnostic IN
- Not sensitive to ice properties (actual or assumed)



van Diedenhoven et al., 2011

Mixed phase in mature deep convection

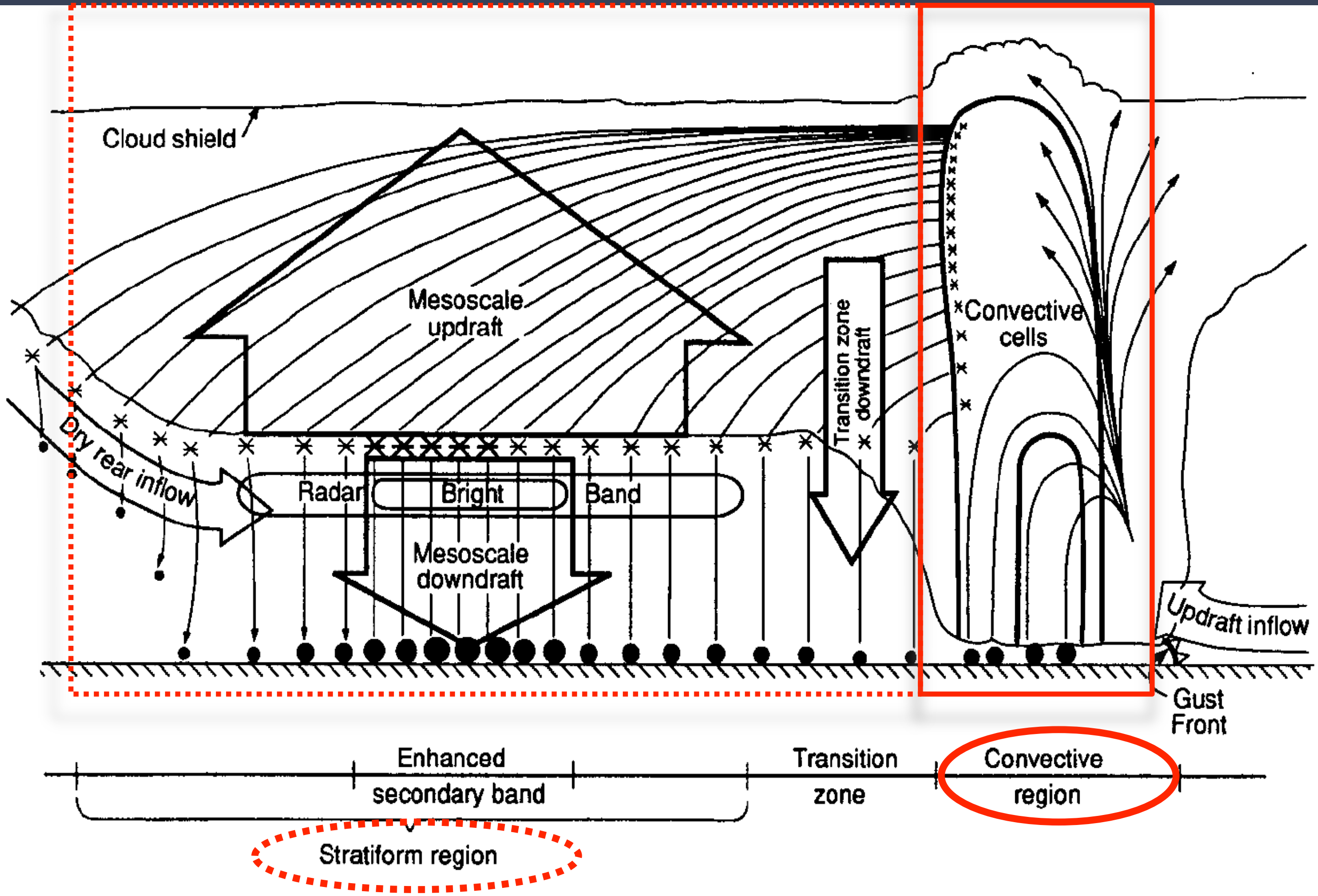
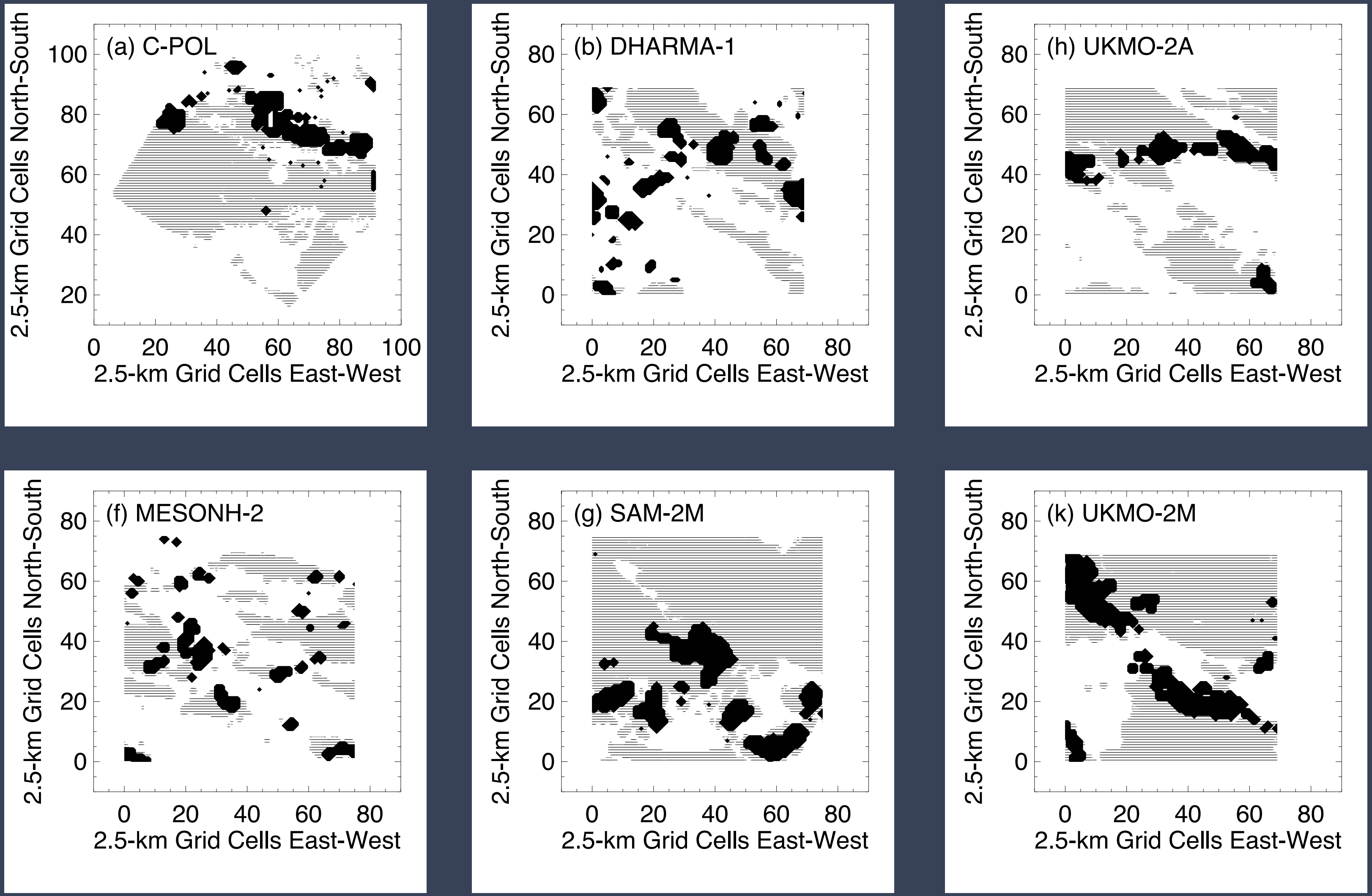


FIG. 1. Conceptual model of precipitation particle trajectories and mean vertical motions through the trailing stratiform region of a squall-line system.

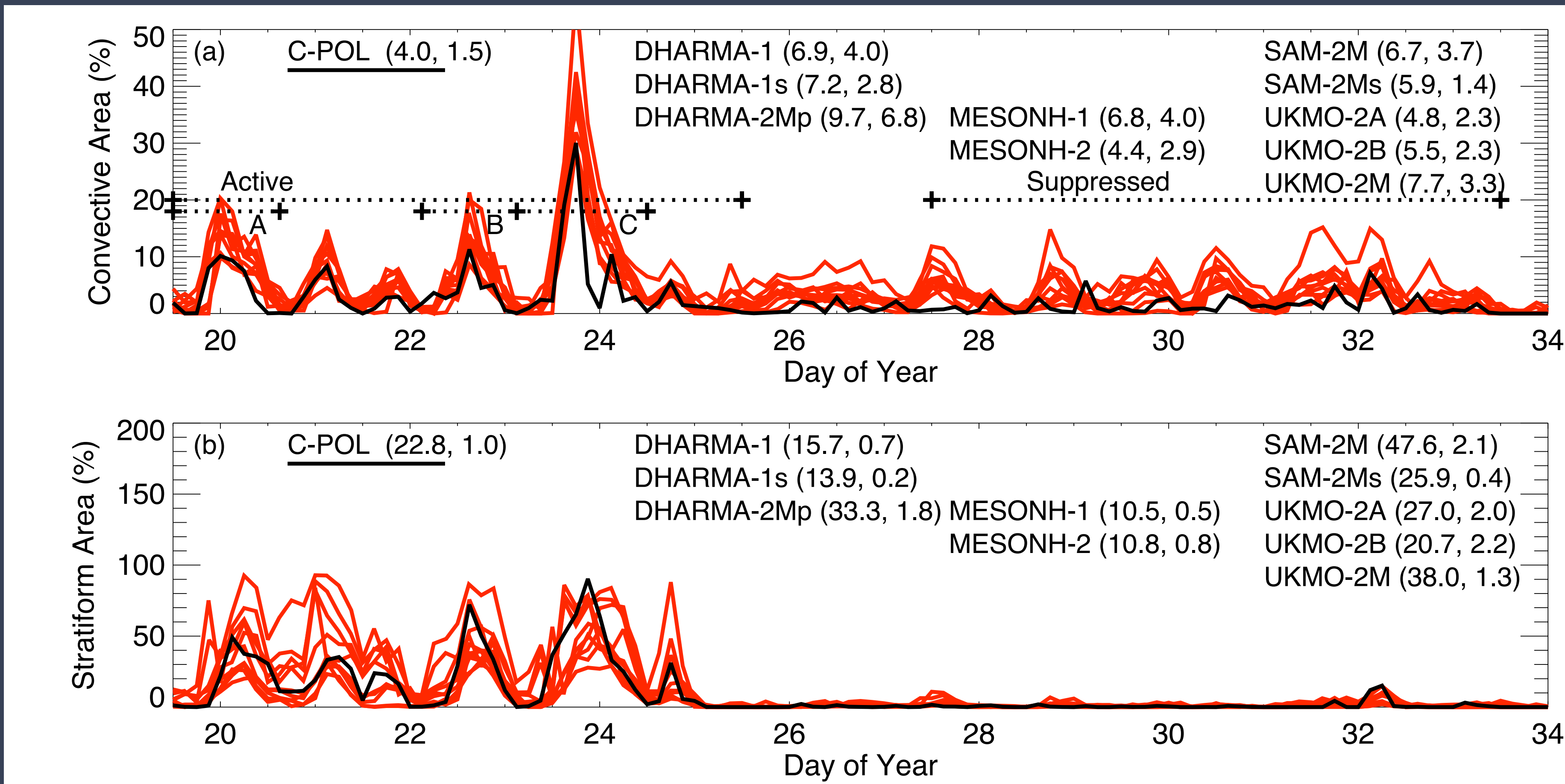
Biggerstaff and Houze, 1993

Locations of convective, stratiform area



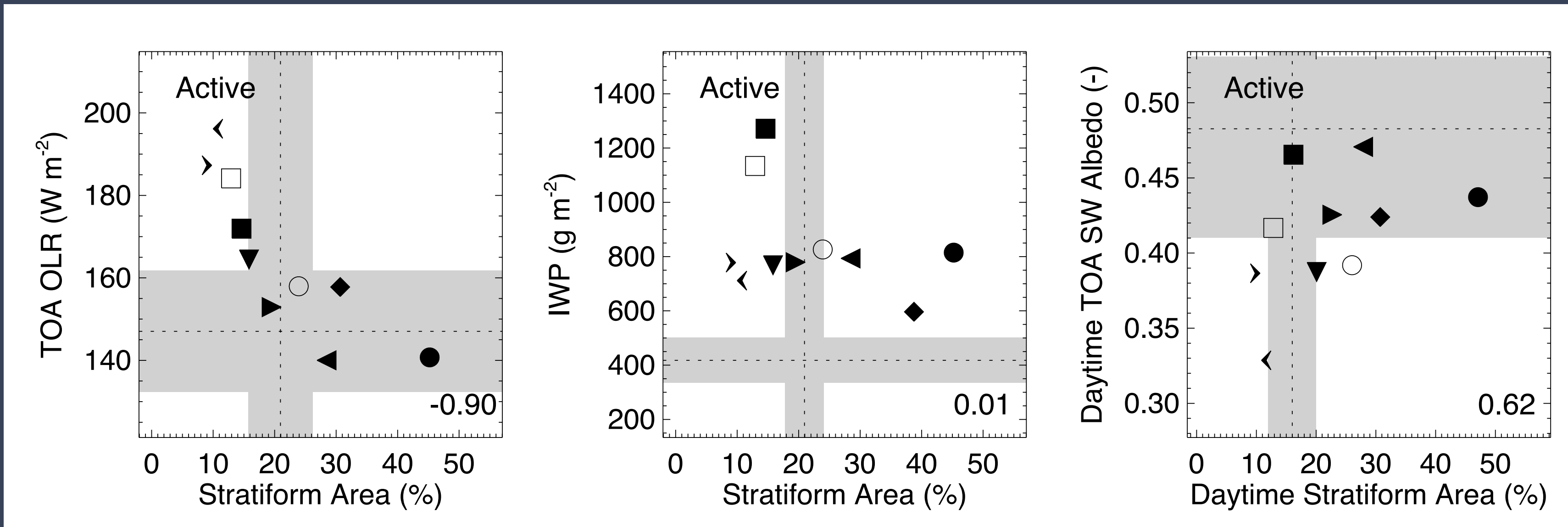
Fridlind et al., 2012

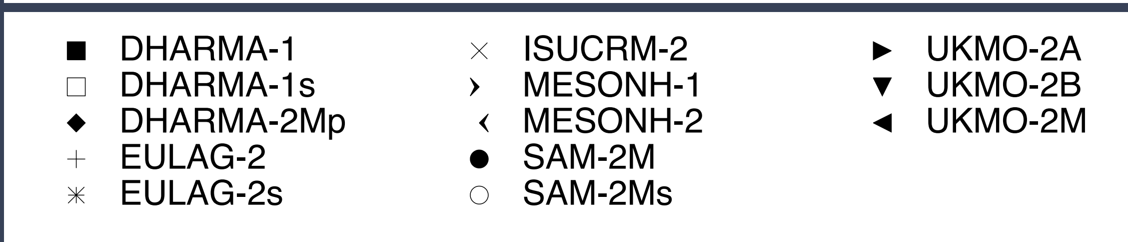
Convective, stratiform area coverage

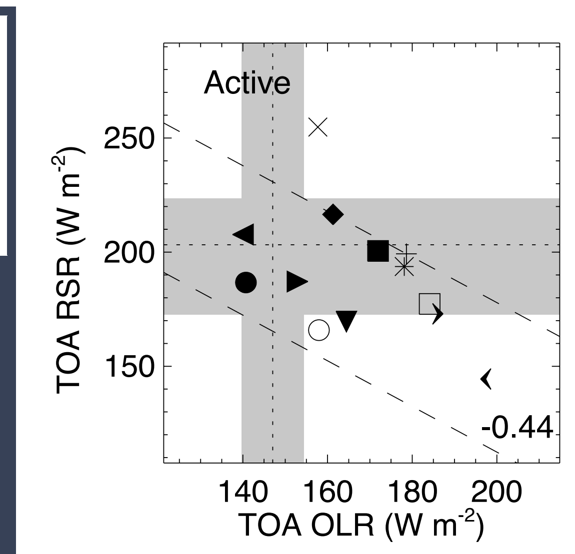


Fridlind et al., 2012

Stratiform area: effects on TOA radiative fluxes



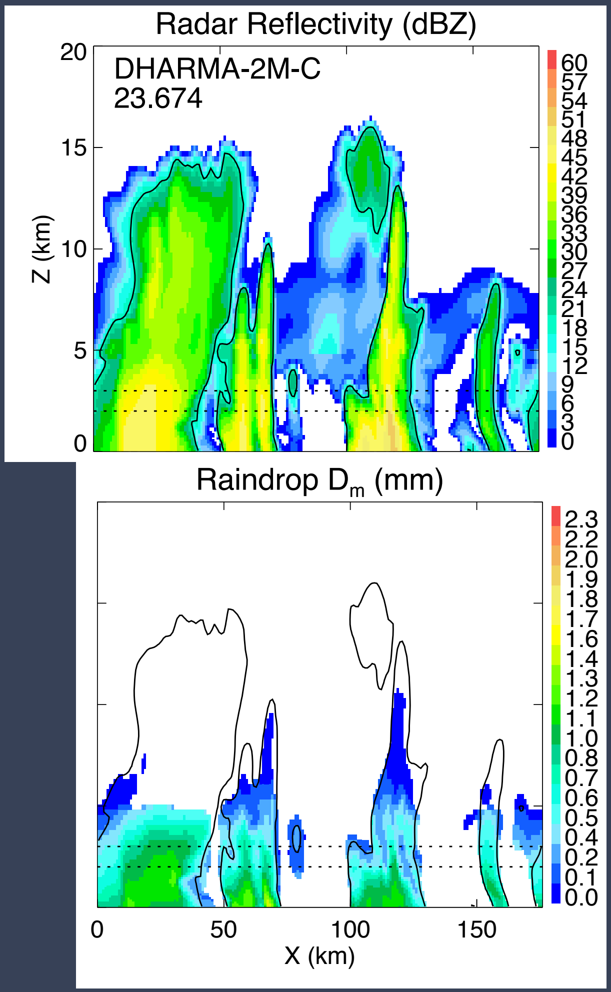




Fridlind et al., 2012

Varble et al., 2011 and in preparation

TWP-ICE polarimetric retrievals

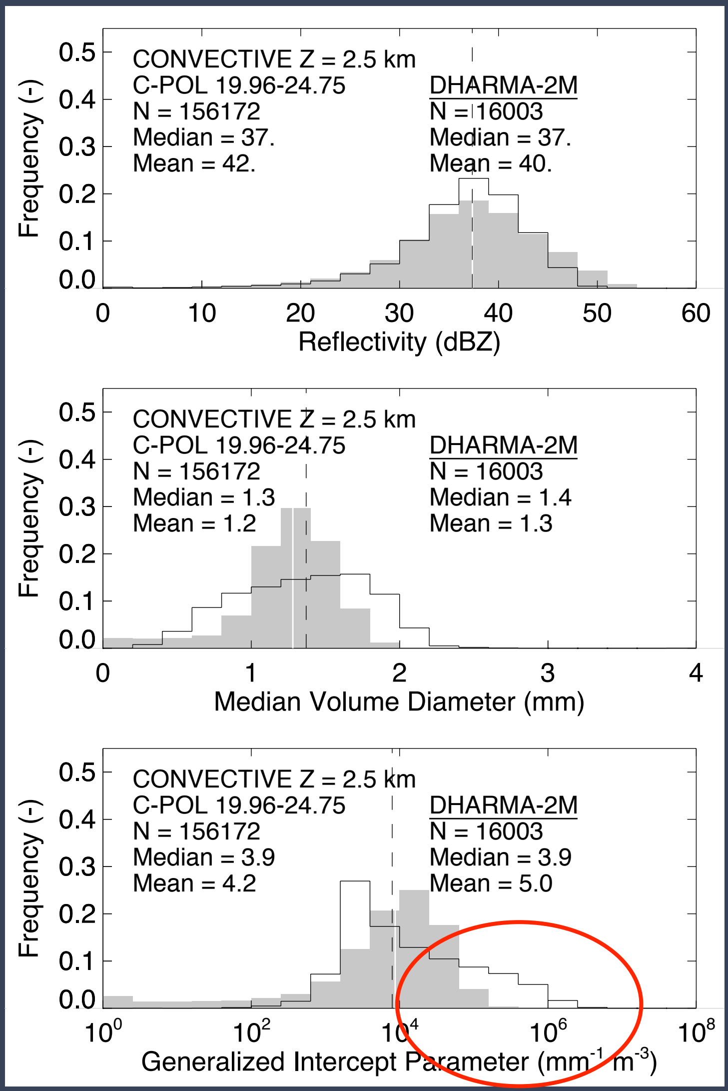


convective

radar reflectivity

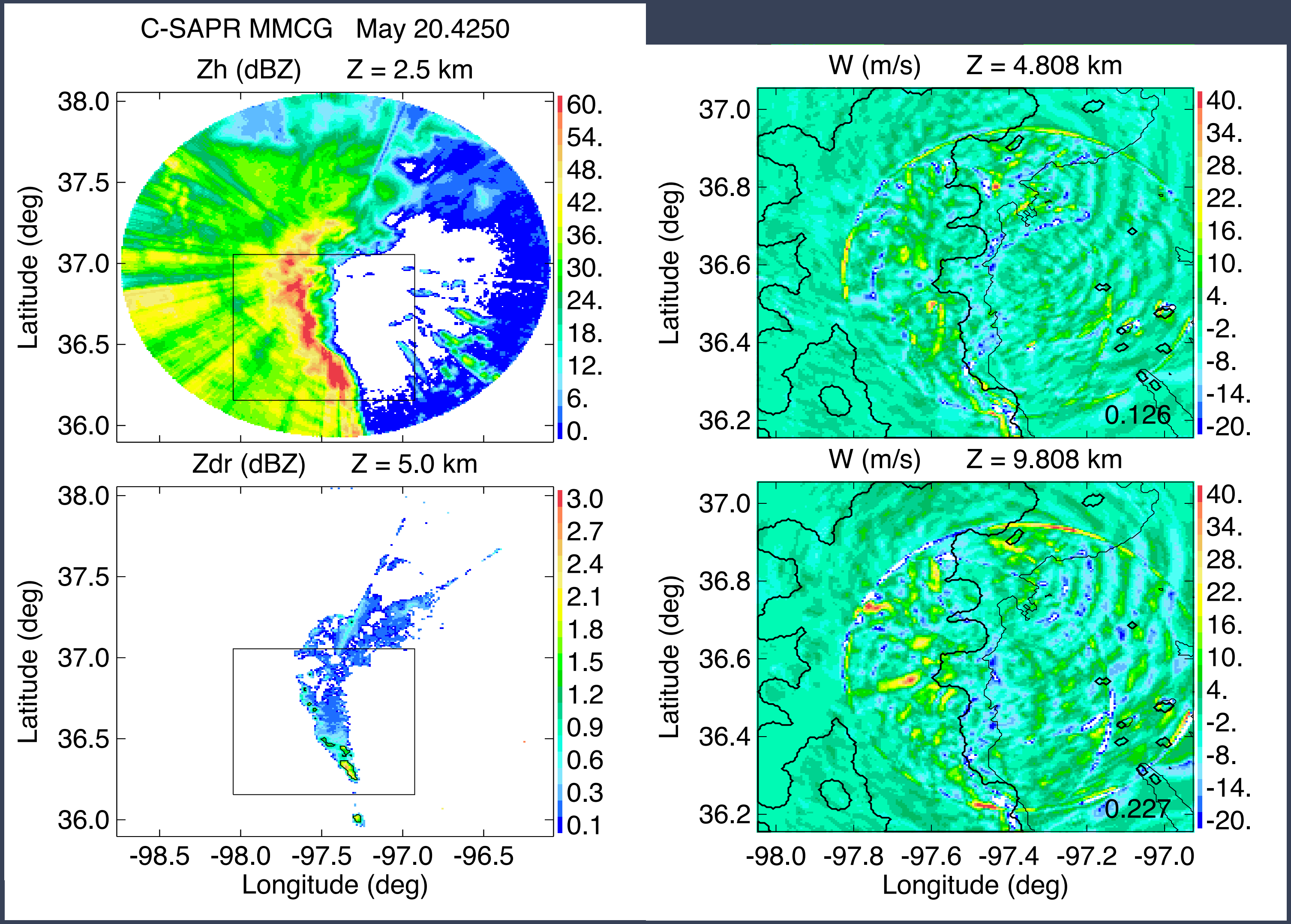
median volume diameter

generalized intercept parameter



manuscript in preparation (C-POL data: P. May)

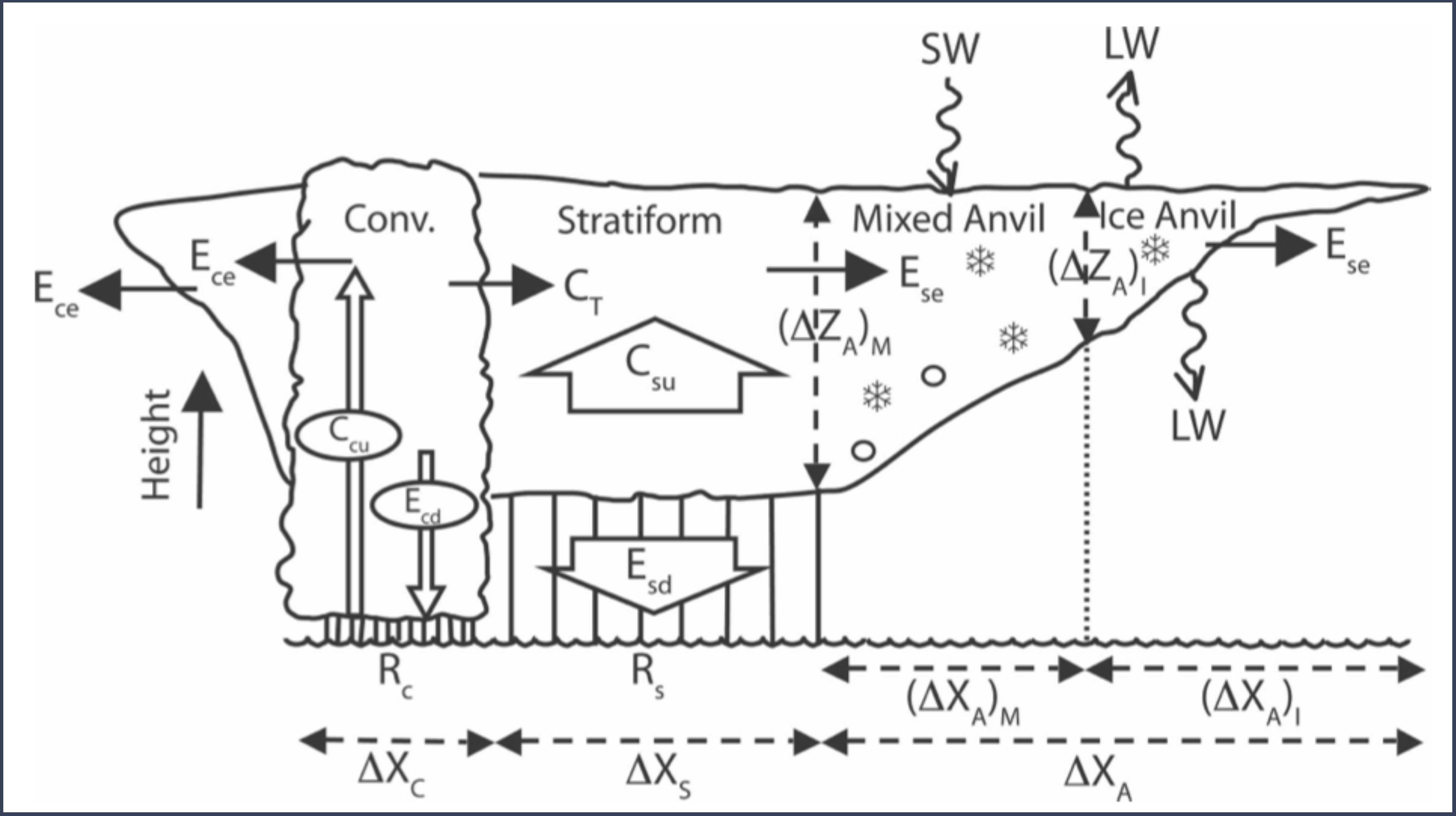
MC3E C-/X-band obs/retrievals



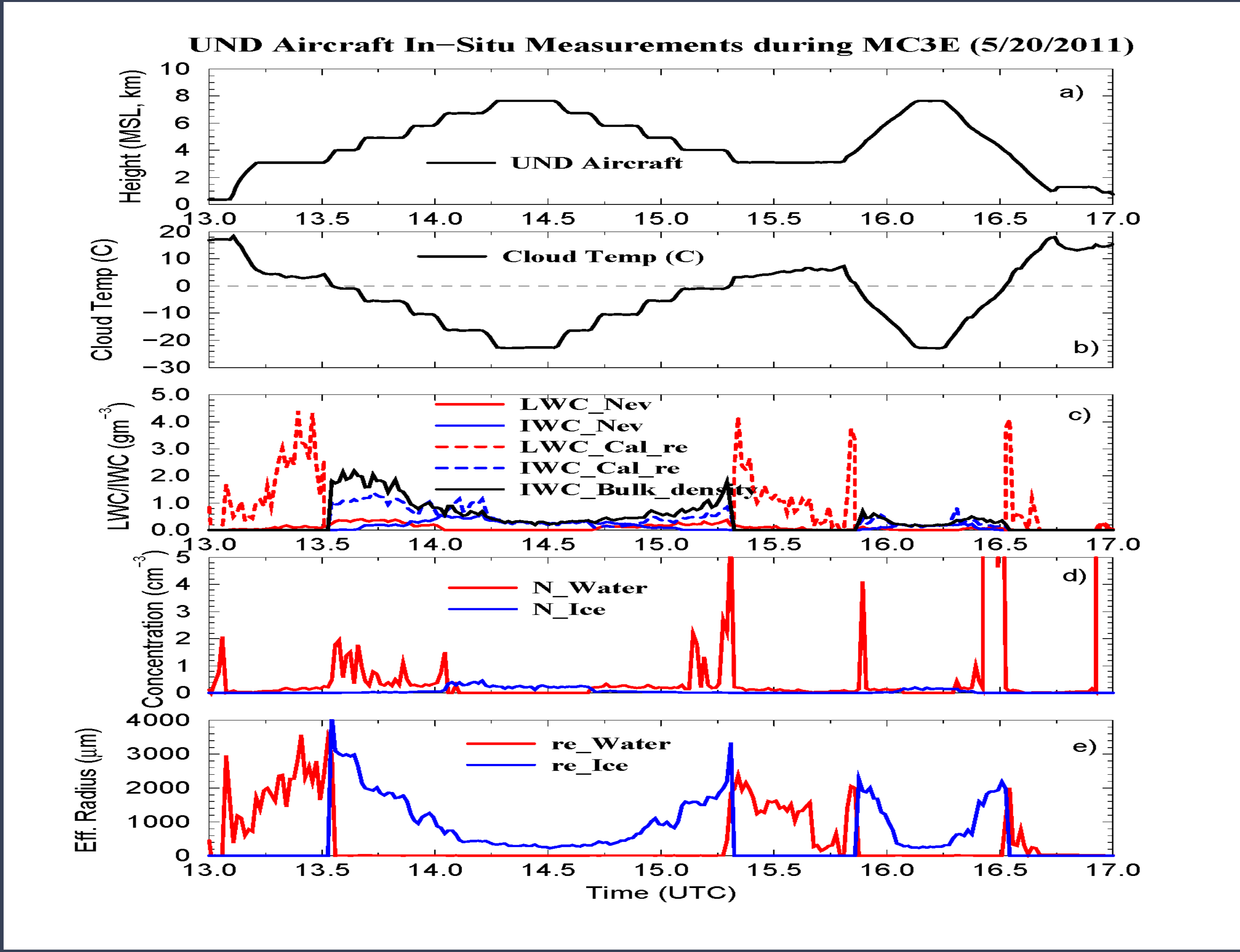
Source: S. Collis, K. North, A. Fridlind (see poster #224)

Mixed phase elsewhere in mature systems

- Frederick and Schumacher (2008)



MC3E UND in situ measurements



Source: X. Dong (see poster #222)

Summary and comments

- Mixed-phase in deep convection
  - what processes control the extent and evolution of mixed-phase in updraft regions and how is it associated with ice nucleation?
  - how are the properties of mixed-phase updraft regions related to the properties of stratiform rain and anvil clouds?
- Support field measurements (short- and long-term)
  - environmental conditions (profiles and surface, BL)
  - aerosol properties (profiles and surface)
  - aerosol CCN and IN activity and chemical composition
  - remote-sensing and in situ measurements of hydrometeor properties (phase, mixing ratios, ice properties) and collocated dynamical fields (updrafts, downdrafts, cold pools)
- Support close model-observation comparisons