Small Particles In Cirrus

(SPartICus)

An ARM Aerial Vehicle Program to Study the Properties of Midlatitude Cirrus Clouds

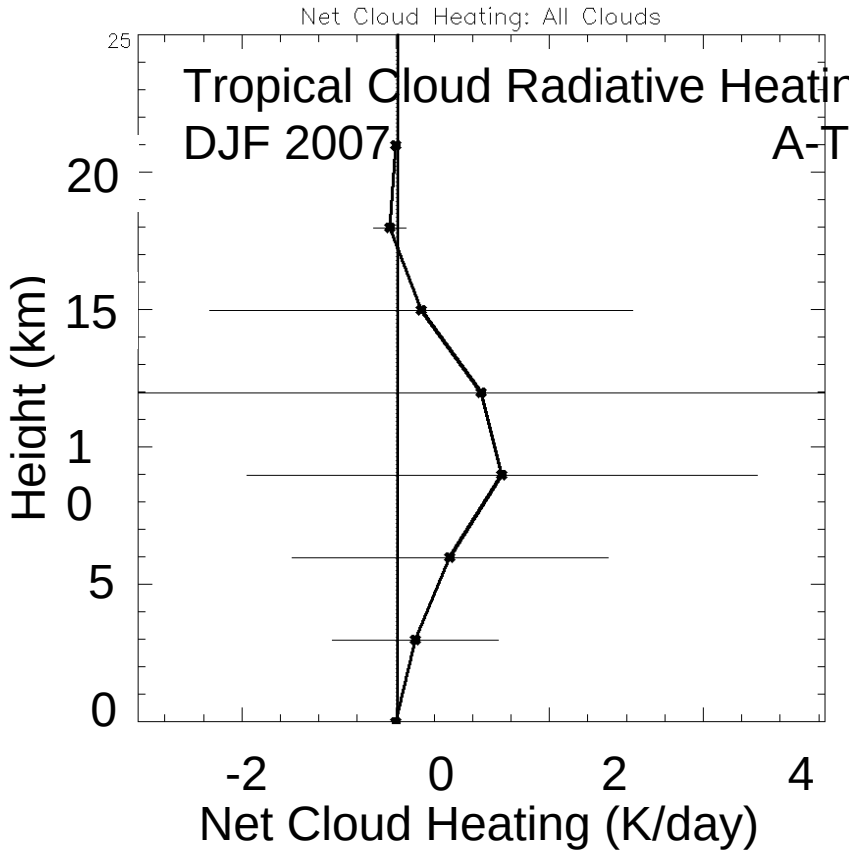
Science Team:

Jay Mace, University of Utah (PI), **Eric Jensen,** NASA Ames, **Jennifer Comstock,** PNNL,
Greg McFarquhar, Univ. of Illinois, **Tom Ackerman,** Univ. of Washington,
David Mitchell, DRI, **Tim Garrett,** Univ. of Utah, **Xiaohong Liu**, PNNL

SPartICus Motivation

Cloud radiative heating of the troposphere is dominated by Cirrus.

The magnitude of this heating depends on
1)cloud occurrence,
2)cloud macrophysical properties,
3)Details of the microphysical profile (PSD as a function of height).

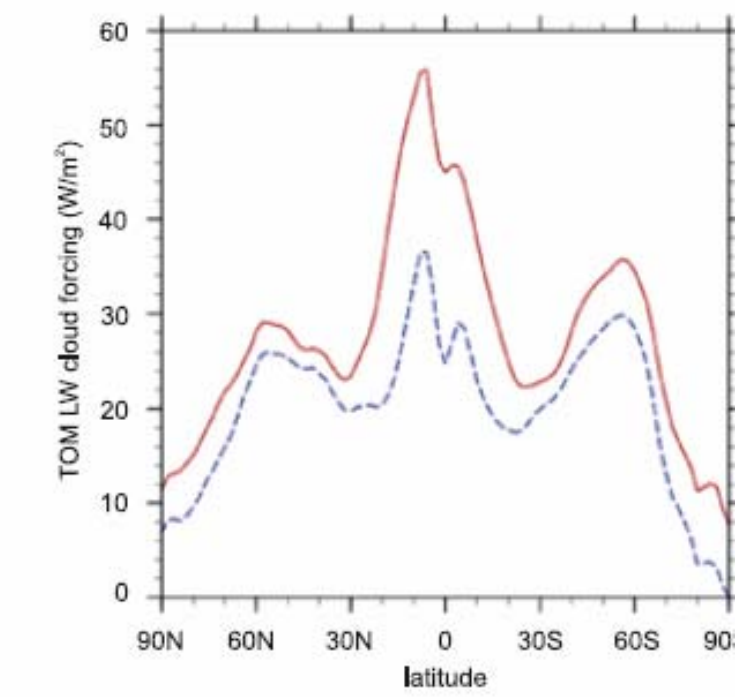


Process Understanding and Climate Model Improvement

Goals:

- Improved understanding of ice nucleation and ice growth in cirrus clouds
- Improved understanding of microphysics of ice crystals from convective detrainment
- Improved representation of ice microphysics (ice nucleation and growth, and ice terminal velocity) in cirrus clouds in climate models
- Improved representation of ice clouds detrained from convection (microphysics and macrophysics) in climate models

SPartICus Motivation



Mitchell et al 2008

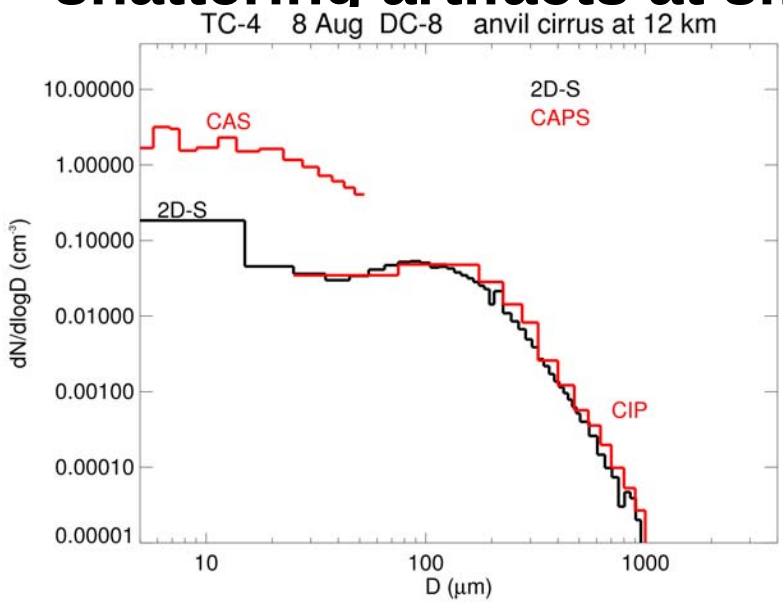
Sensitivity of the Earth's energy budget to the presence (red line) of high concentrations of small ice crystals in cirrus.

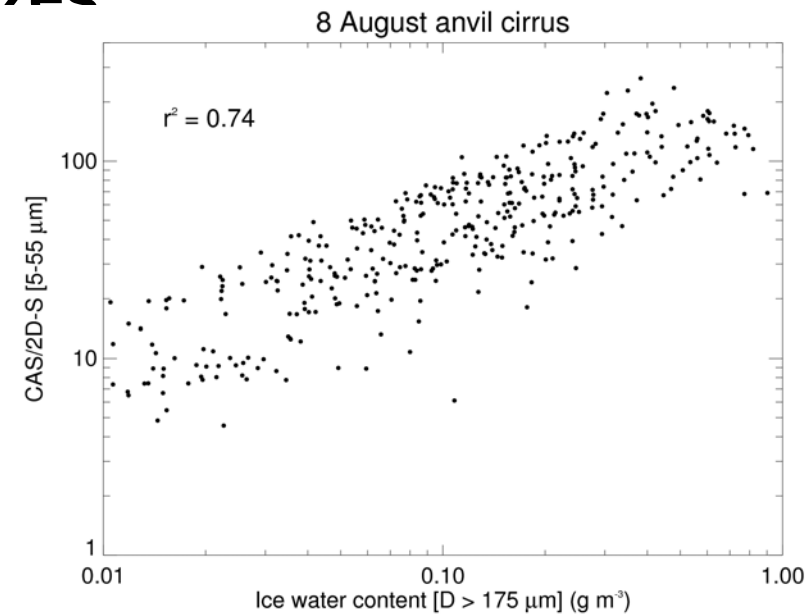
SPartICus Motivation

- **The details of the microphysical properties of cirrus are not well known.**

- **Significant uncertainties have persisted regarding the relative importance of small (D<50μm) ice crystals**

- **These uncertainties are due to the high likelihood that all cirrus PSD measurements are contaminated by shattering artifacts at small sizes**





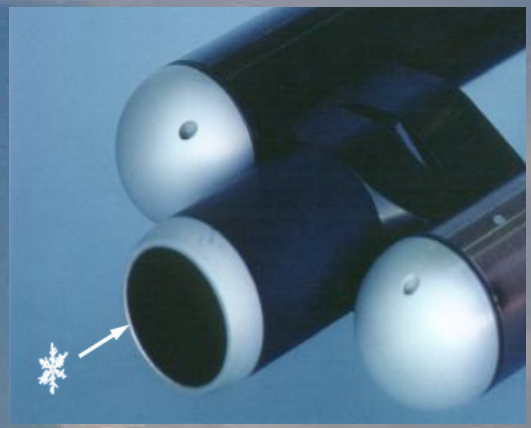
Shattering Effect: CAS vs CDP vs FSSP

Cloud and Aerosol Spectrometer

Shroud

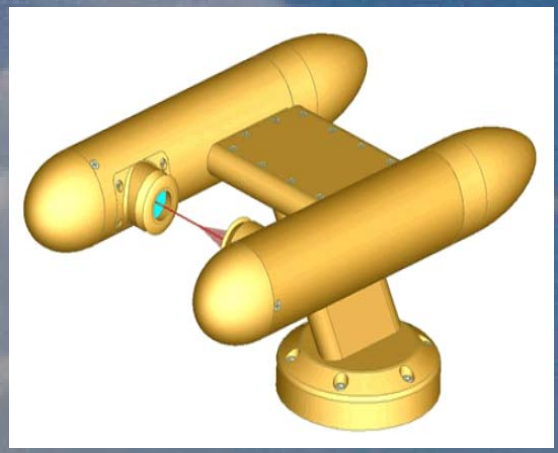
Inlet

Forward Scattering Spectrometer Probe



-Surfaces for shattering

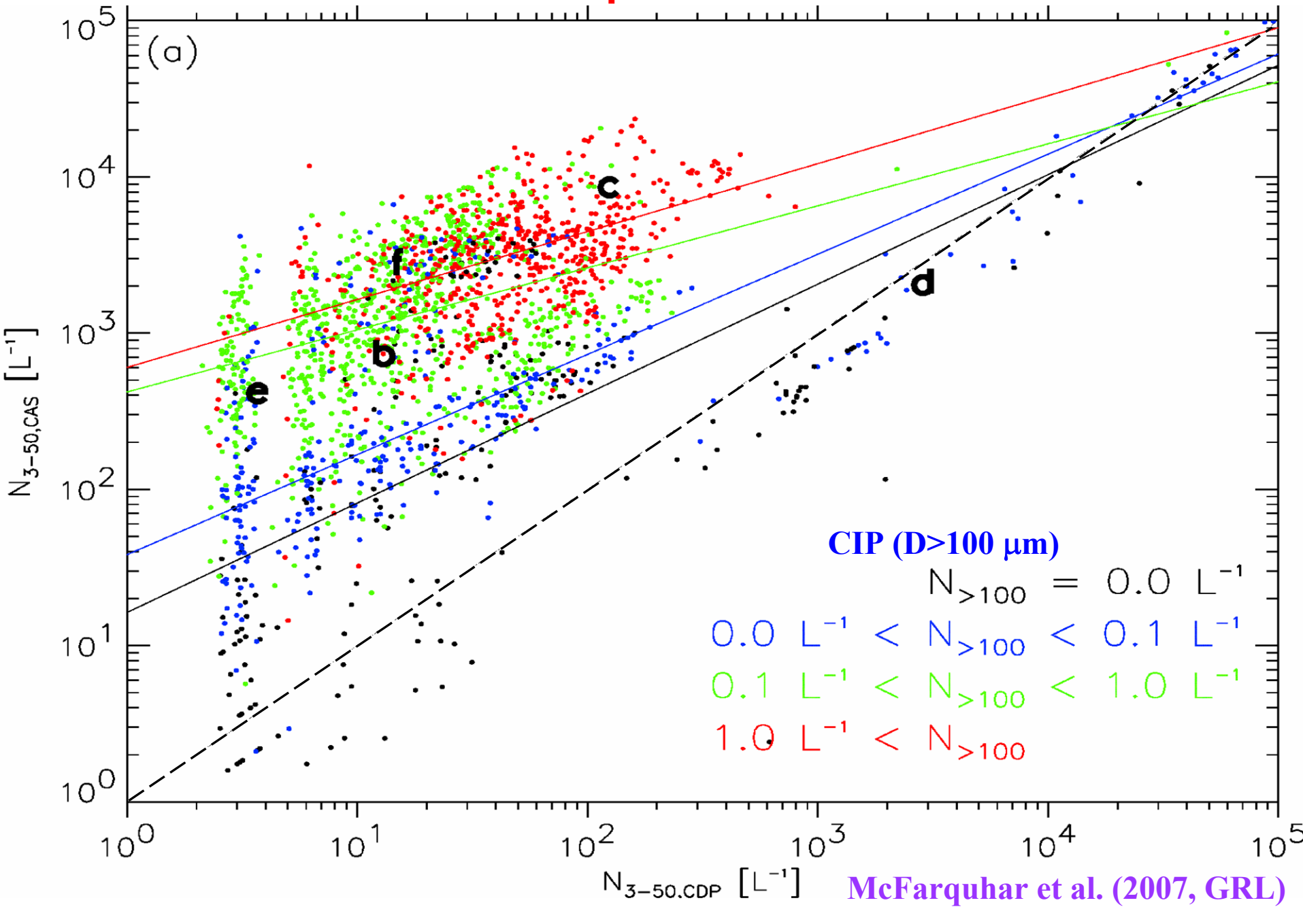
Cloud Droplet Probe



- Open path
- No inlet or shroud

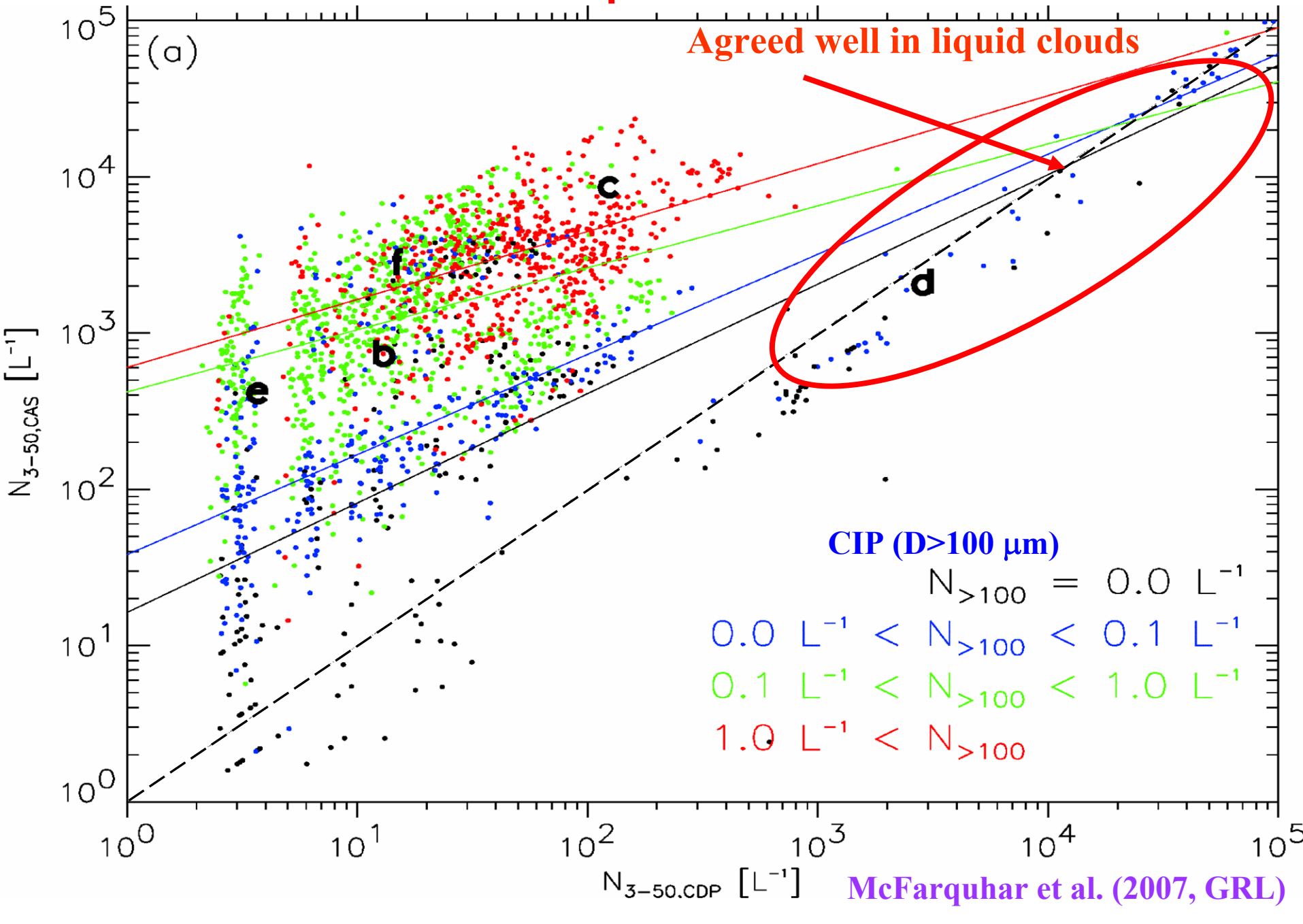
- ✓ The same working principle and look-up table
- ✓ Can we see shattering on FSSP or CAS?

CAS & CDP were compared for TWP-ICE

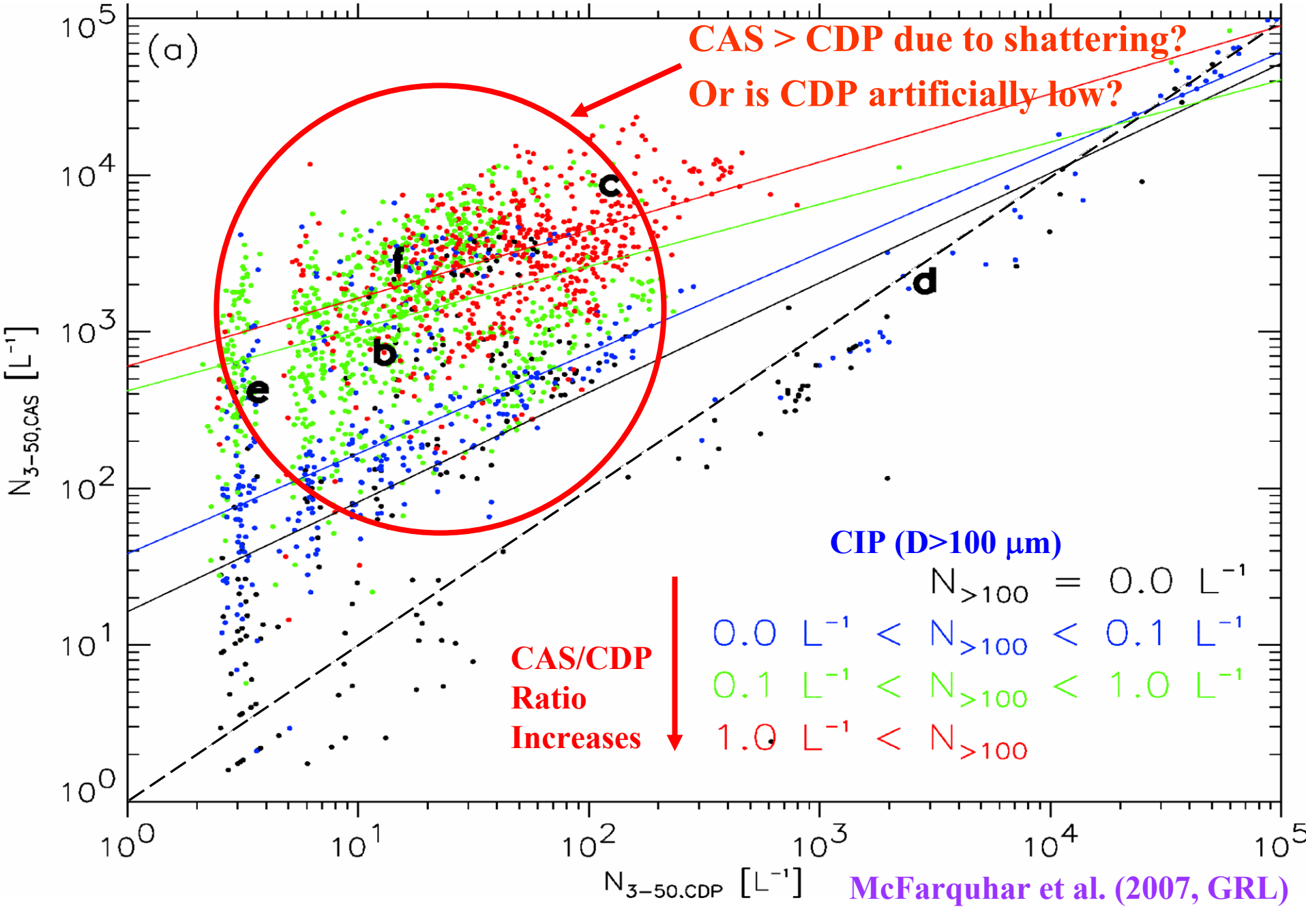


McFarquhar et al. (2007, GRL)

CAS & CDP were compared for TWP-ICE



McFarquhar et al. (2007, GRL)


(a)
CAS > CDP due to shattering?
Or is CDP artificially low?
a
b
c
d
e
f
CIP (D>100 μm)
$N_{>100} = 0.0\ L^{-1}$
$0.0\ L^{-1} < N_{>100} < 0.1\ L^{-1}$
$0.1\ L^{-1} < N_{>100} < 1.0\ L^{-1}$
$1.0\ L^{-1} < N_{>100}$
CAS/CDP Ratio Increases
$N_{3-50,CAS}$ [L^{-1}]
$N_{3-50,CDP}$ [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
McFarquhar et al. (2007, GRL)

Impacts of Small Ice Crystals

3 μm < D < 50 μm	CAS	CDP
Total Number Concentration (N_T)	98 %	64 %
Projected Area (A_c)	85 %	44 %
IWC	67 %	33 %

0127, 0129, and 0202

Goal: Collect a cirrus data set that is specifically designed to a shattering artifacts

SPartICus Science Questions

1. **Cirrus Particle Size Distributions**: Do small particles (i.e., < 50 μm diameter) contribute to the mass and radiative properties of midlatitude cirrus?

2. **Cirrus Processes**: How do cloud-scale dynamics and thermodynamics control the evolution of cirrus properties through nucleation, particle growth, and sublimation?

3. **Cloud Property Retrieval**: What degree of complexity is required in cloud property retrieval algorithms? What minimal set of algorithms can be used to rigorously describe cirrus microphysical properties using ground-based ACRF data?

Experimental Approach:

1.Long term measurements by ARM Aerial Vehicle Program (AVP)

- Planning approximately **200** hours of cirrus measurements between October 2009 and March/April 2010 over ARM SGP.

- Focus will be on conducting routine flights with an established flight pattern and a set of well-characterized instruments.

2.Intensive measurement campaign.

- NASA supported flight series Spring

Table 1. Measurements and Instruments proposed for the operational phase of SPartICus.

Measurement	Possible Instrument	Status
PSD 1-50 µm	CDP	Critical
PSD 1-50 µm	FSSP	Desirable/Legacy
PSD 20-2000 µm	2DS	Critical
PSD 100-1500 µm	2DC/CIP	Desirable/Legacy
PSD 500-50000 µm	HVPS or 2DP	Critical
Ice Habit, PSD	CPI	Critical
IWC	CSI or Deep Cone Nevzorov	Desirable
Extinction	CIN	Desirable
Turbulence	MMS	Critical
State Parameters	MMS	Critical
Humidity	JPL Laser Hygrometer	Critical
Ice Nuclei	TRAC	Desirable

Table 2. Additional Measurements and Instruments proposed for the Intensive phase of SPartICus.

Measurement	Possible Instrument	Status
Aerosol PSD	FCAS/NMASS	Desirable
Aerosol Composition	PALMS	Desirable
Ice Nuclei	CFDS	Desirable
Additional Water Vapor	Harvard Water Vapor	Desirable
Water Isotopes	ICOS/HOXITOPE	Desirable
Additional IWC	CVI/CLH	Desirable
Additional Extinction	CIN	Desirable

Approaches

- Model tools (WRF, SCAM, CAM) to understand the processes, and to test and improve parameterizations in climate models
- WRF: run as a cloud resolving model with spectral-bin microphysics as model testbed.
- SCAM: single column model to test climate model parameterizations
- CAM: NCAR climate model to explore global impact.