The Small Particles In Cirrus (SPartICus) ARM Aerial Facility Mission

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- Motivation: Understanding of cirrus has been hampered by uncertainty in measurements primarily due to shattering of large ice crystals on aircraft and probe surfaces—SPartICus will address this uncertainty.

- Using a Lear Jet operated by the Stratton Park Engineering Corp (SPEC), >150 hours of cirrus measurements will be collected between October 2009 and March 2010.

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SPartICus Science Questions

1. To what degree do small particles (i.e., < 50 μm diameter) contribute to the mass and radiative properties of midlatitude cirrus?

2. How do cloud-scale dynamical processes control the evolution of cirrus properties through nucleation, particle growth, and sublimation?

3. What degree of complexity is required in cloud property retrieval algorithms, and what minimal set of algorithms can be used to rigorously describe cirrus microphysical properties using ground-based ACRF data?

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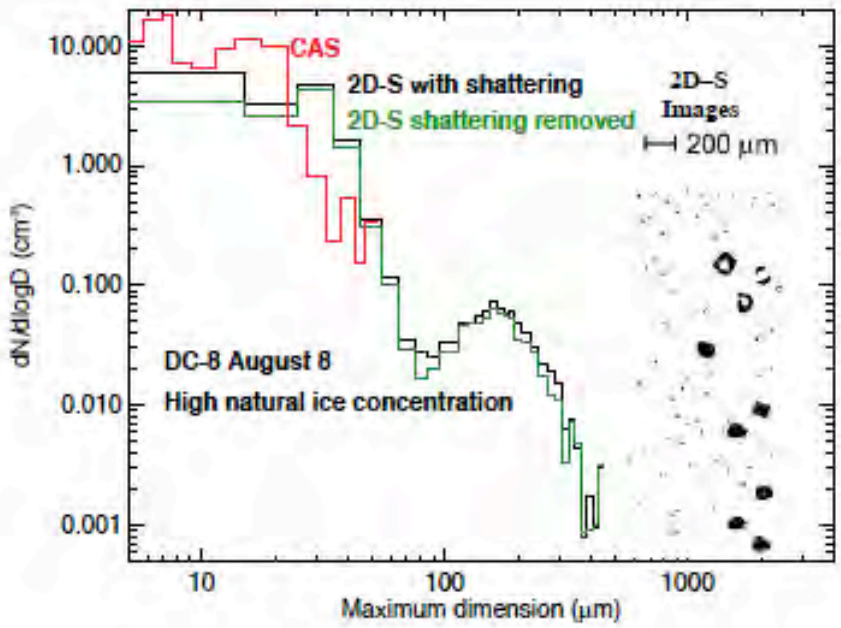

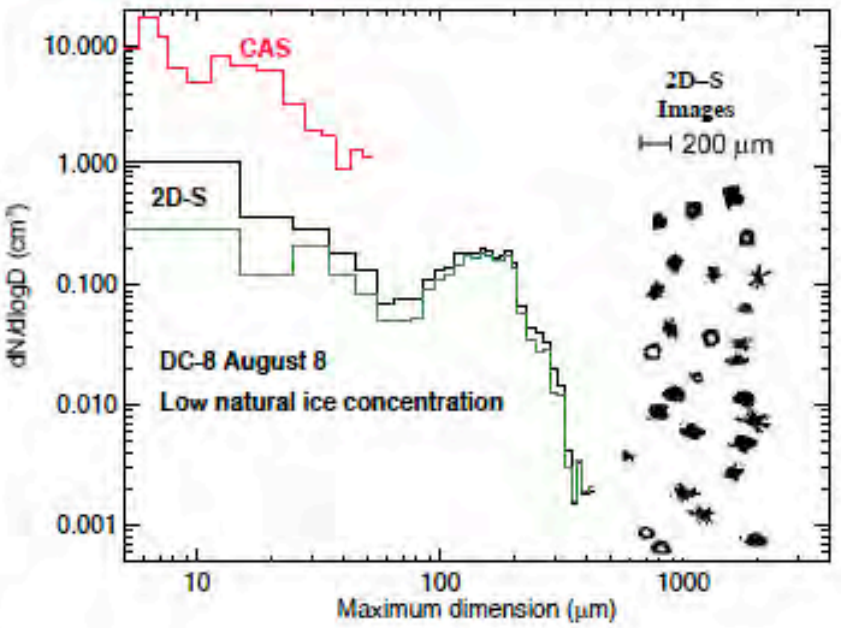

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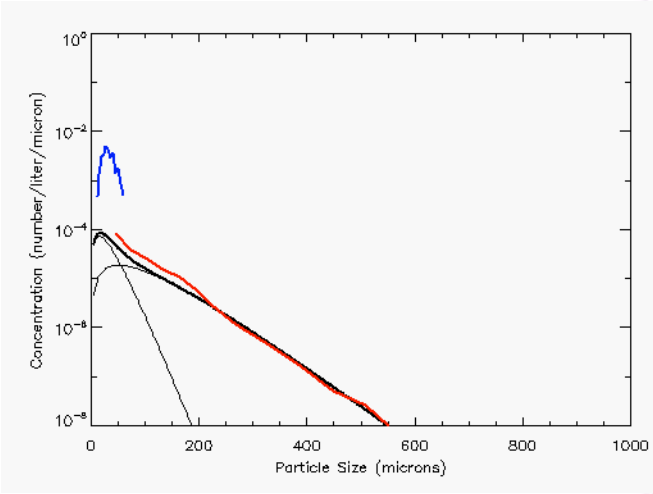
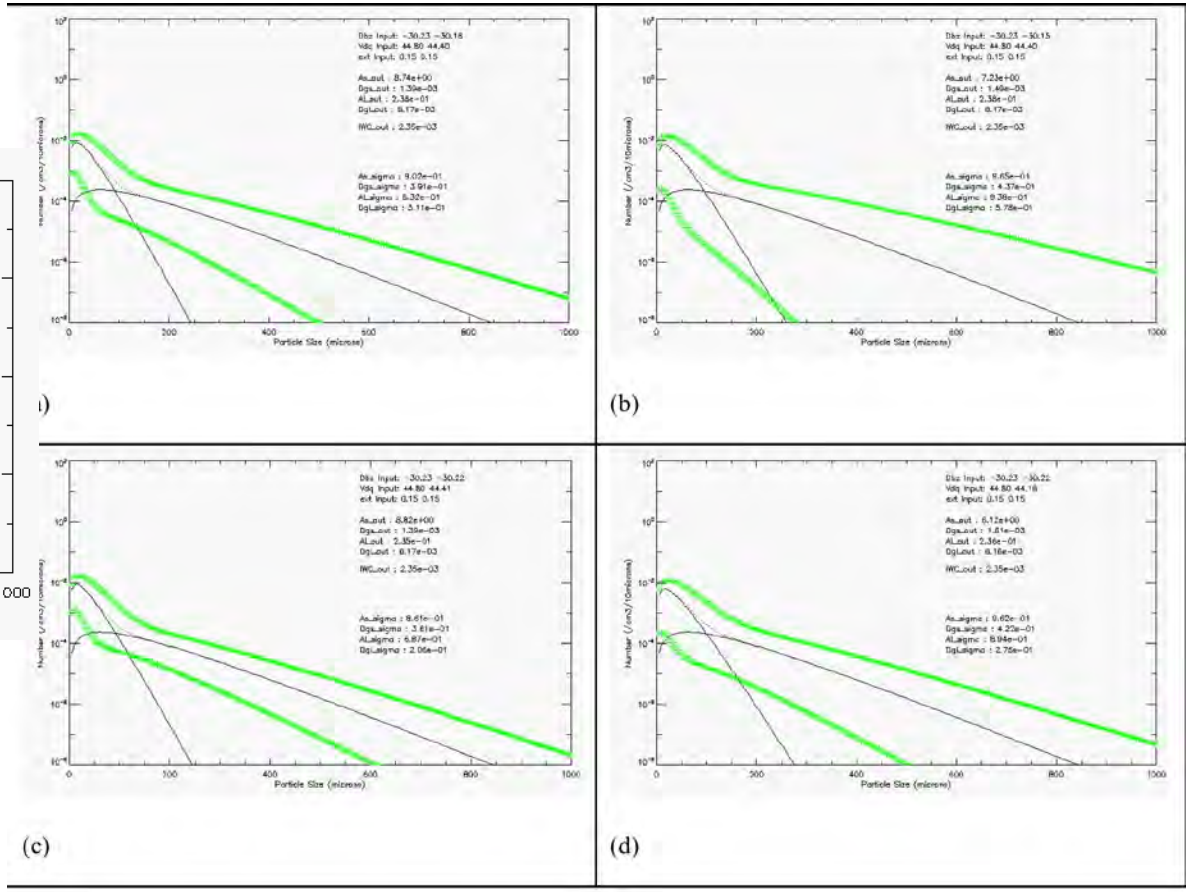
1. Retrievals of particle size distribution from radar Doppler moments and Raman Lidar (solid curves) are very uncertain (envelope created by green curves) when determined rigorously.

2. Quantifying the error in cloud property retrievals is a critical aspect of creating operational products to compare to models.





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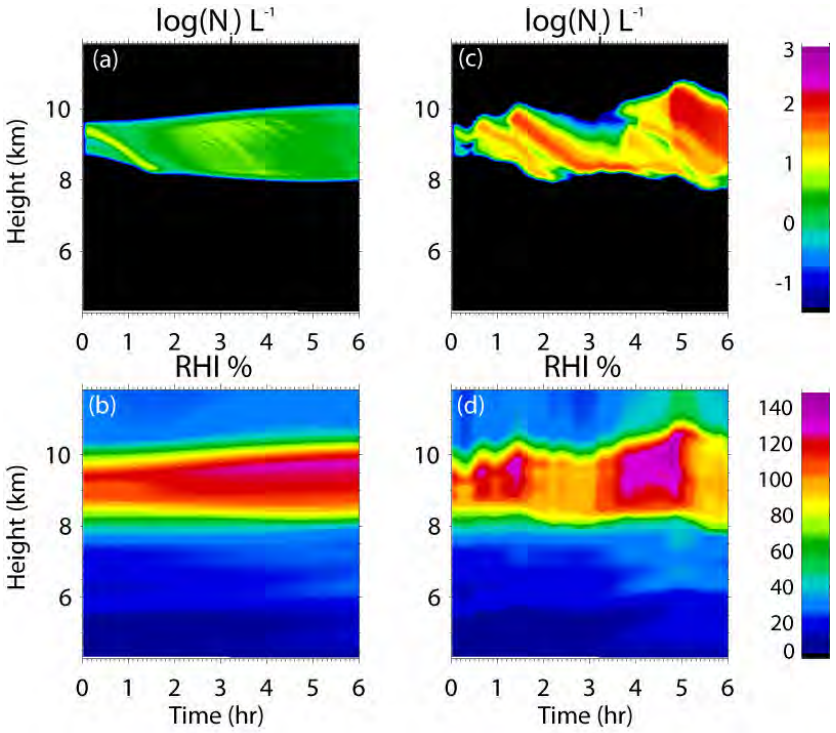
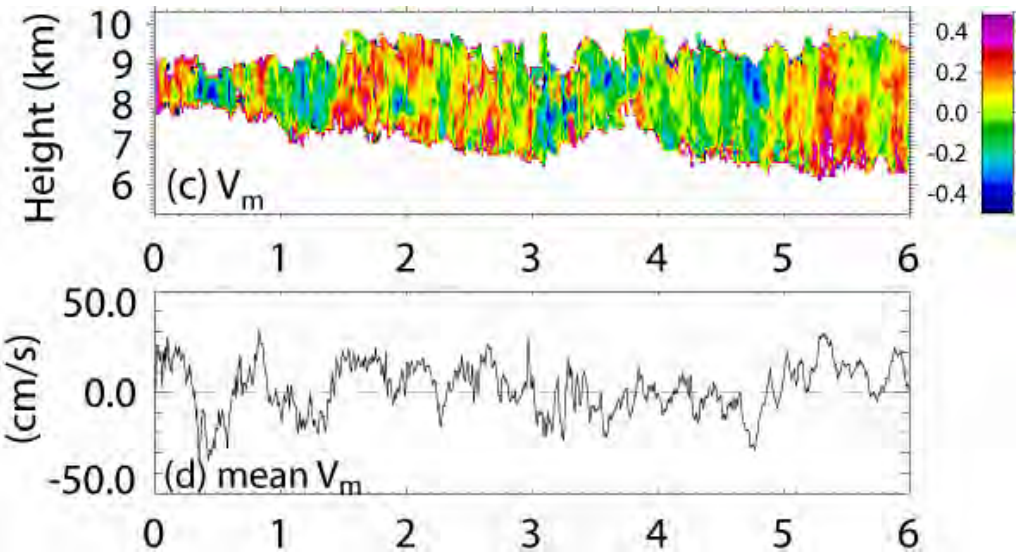
• Cloud scale vertical motions are the primary mechanism controlling the variability of cirrus microphysical properties over a GCM grid box (Comstock et al. JGR, 2008).

• Goal: Characterization and parameterization of this variability using ground-based instruments, cloud resolving modeling, and SPartiCus data



Radar Derived Vertical Velocity



Process Understanding and Climate Model Improvement

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

Approaches

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

McFarquhar research goals for SPARTICUS

Motivation: what do I want?

- **Large data set describing cirrus μphysics**
  - **Determine what controls small ice crystal #s and contributions to mass/radiative properties using state-of-the-art probes (i.e., under what conditions are they present)**
  - **Determine what controls habit/size distributions from large data set**
  - **Determine how parameters used in model & remote sensing parameterizations vary with T, cirrus type & meteorology (e.g,. $M=\alpha D^{\beta}$, $V=aD^{b}$, g, ω_0, P_{11}, $N=N_0D^{\mu}e^{-\lambda D}$, etc.)**

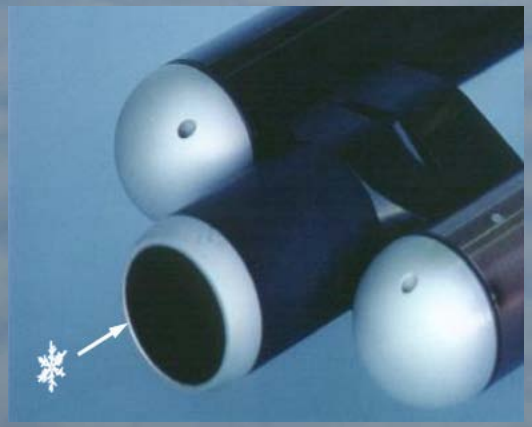
Shattering Effect: CAS vs CDP vs FSSP

Cloud and Aerosol Spectrometer

Shroud

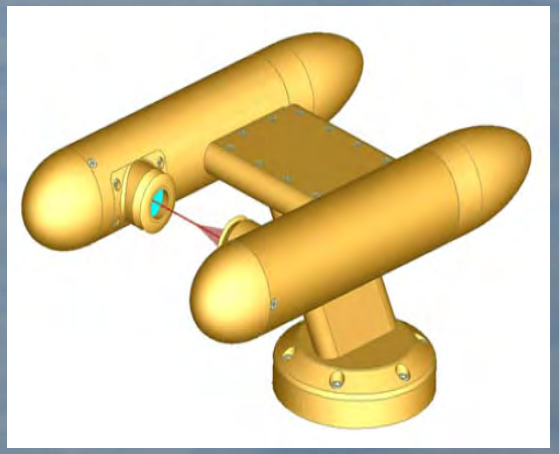
Inlet

Forward Scattering Spectrometer Probe



-Surfaces for shattering

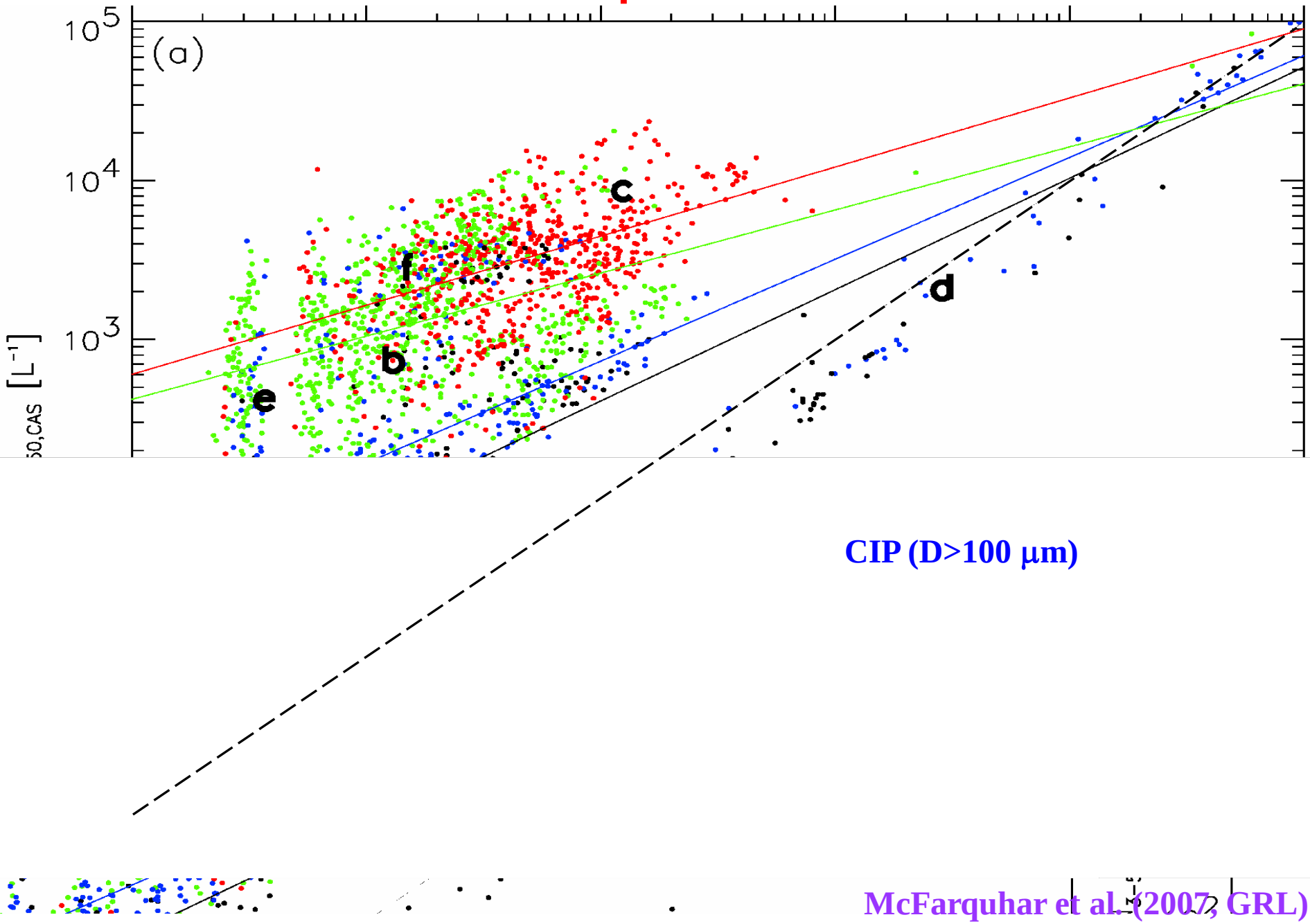
Cloud Droplet Probe



- Open path
- No inlet or shroud

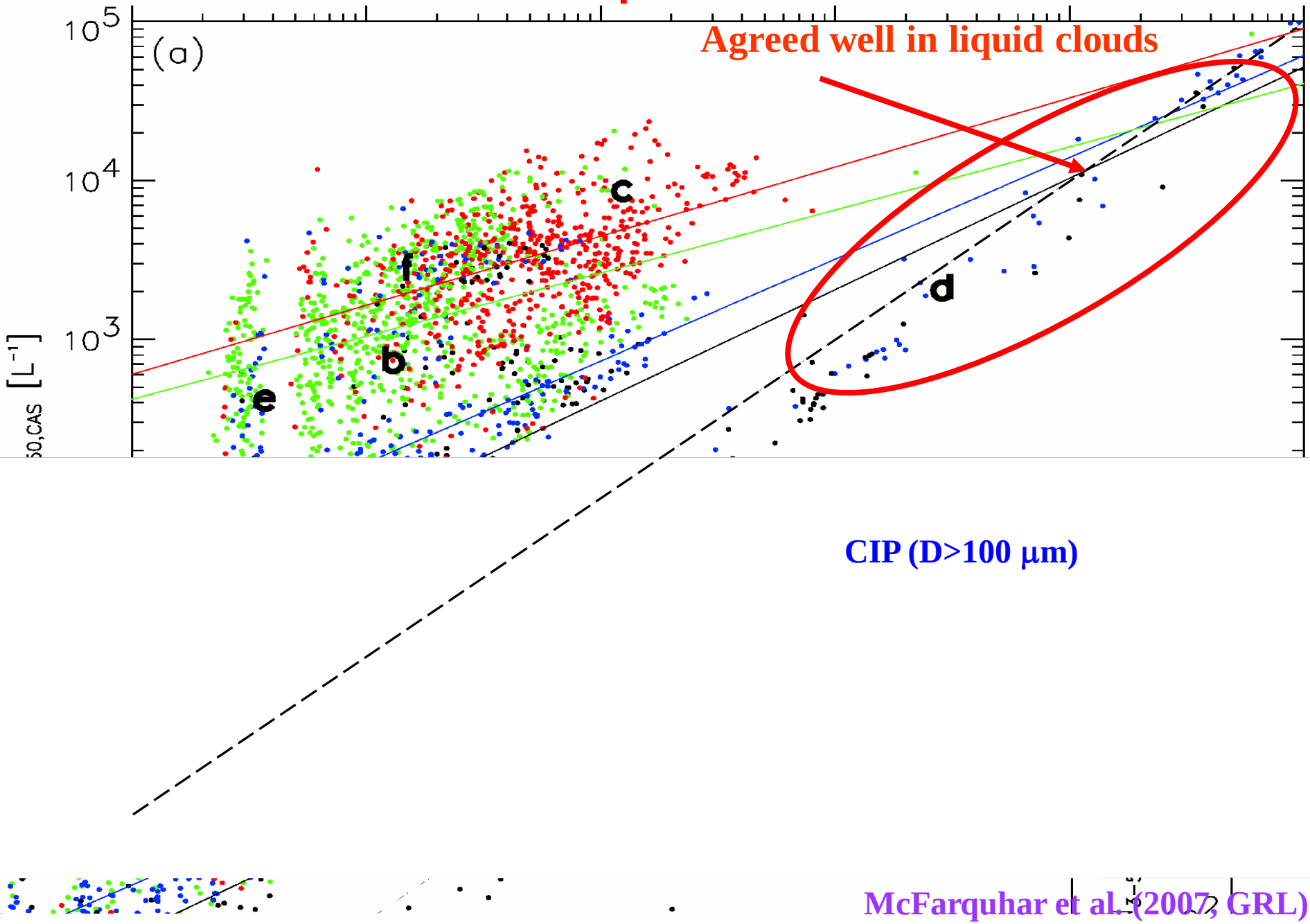
- ✓ The same working principle and look-up table
- ✓ Can we see shattering on FSSP or CAS?

CAS & CDP were compared for TWP-ICE

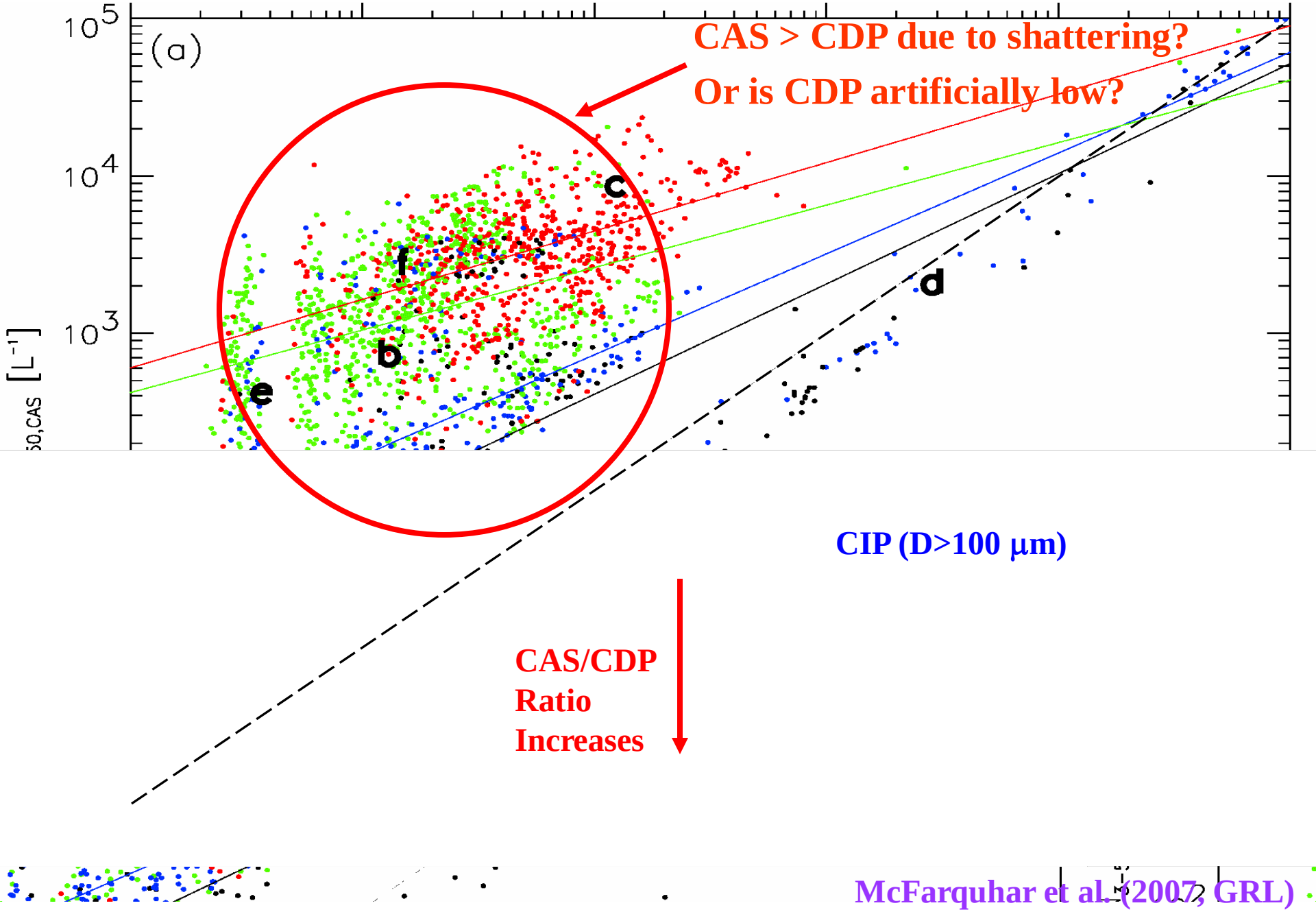


McFarquhar et al. (2007, GRL)

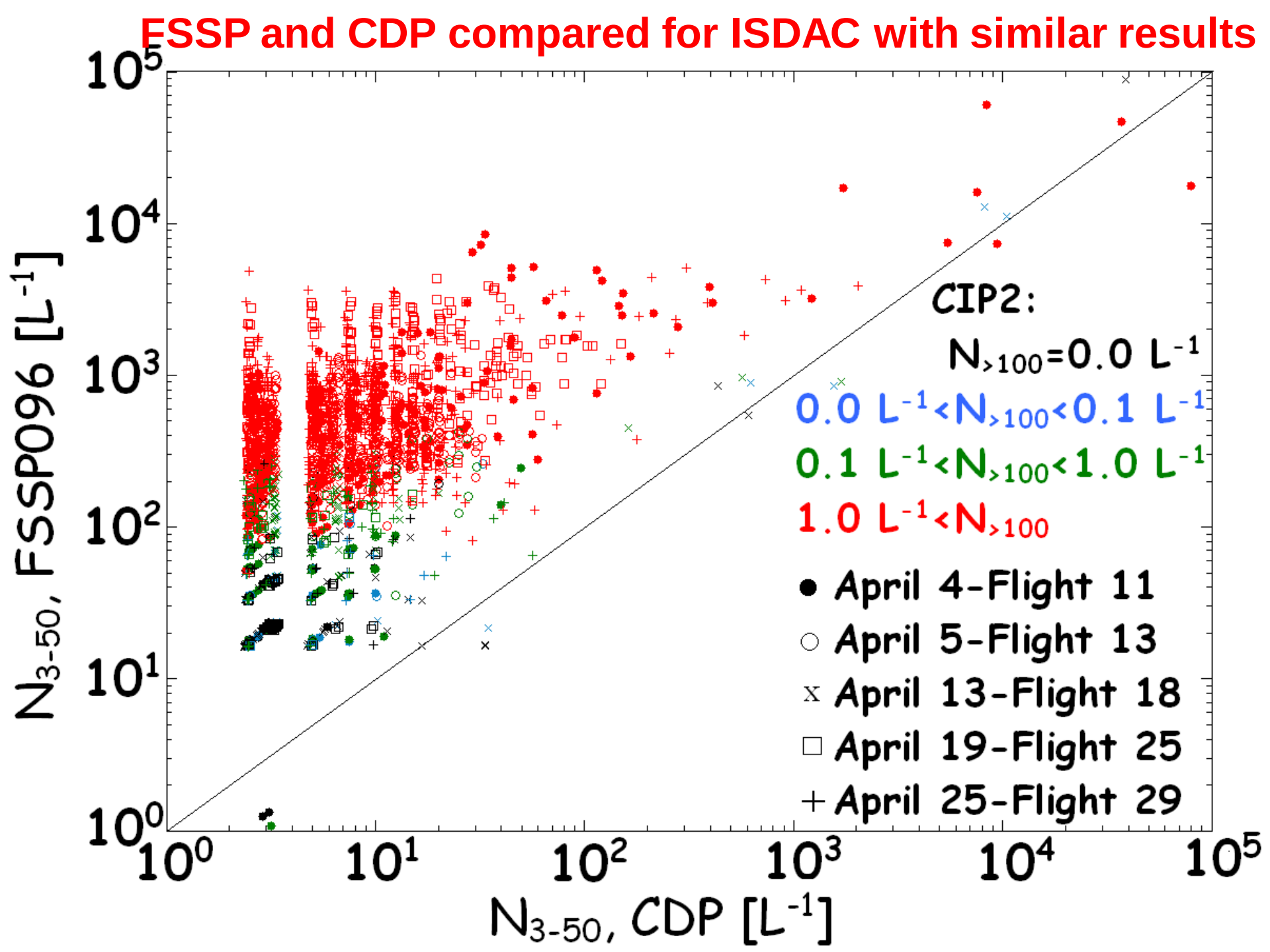
CAS & CDP were compared for TWP-ICE

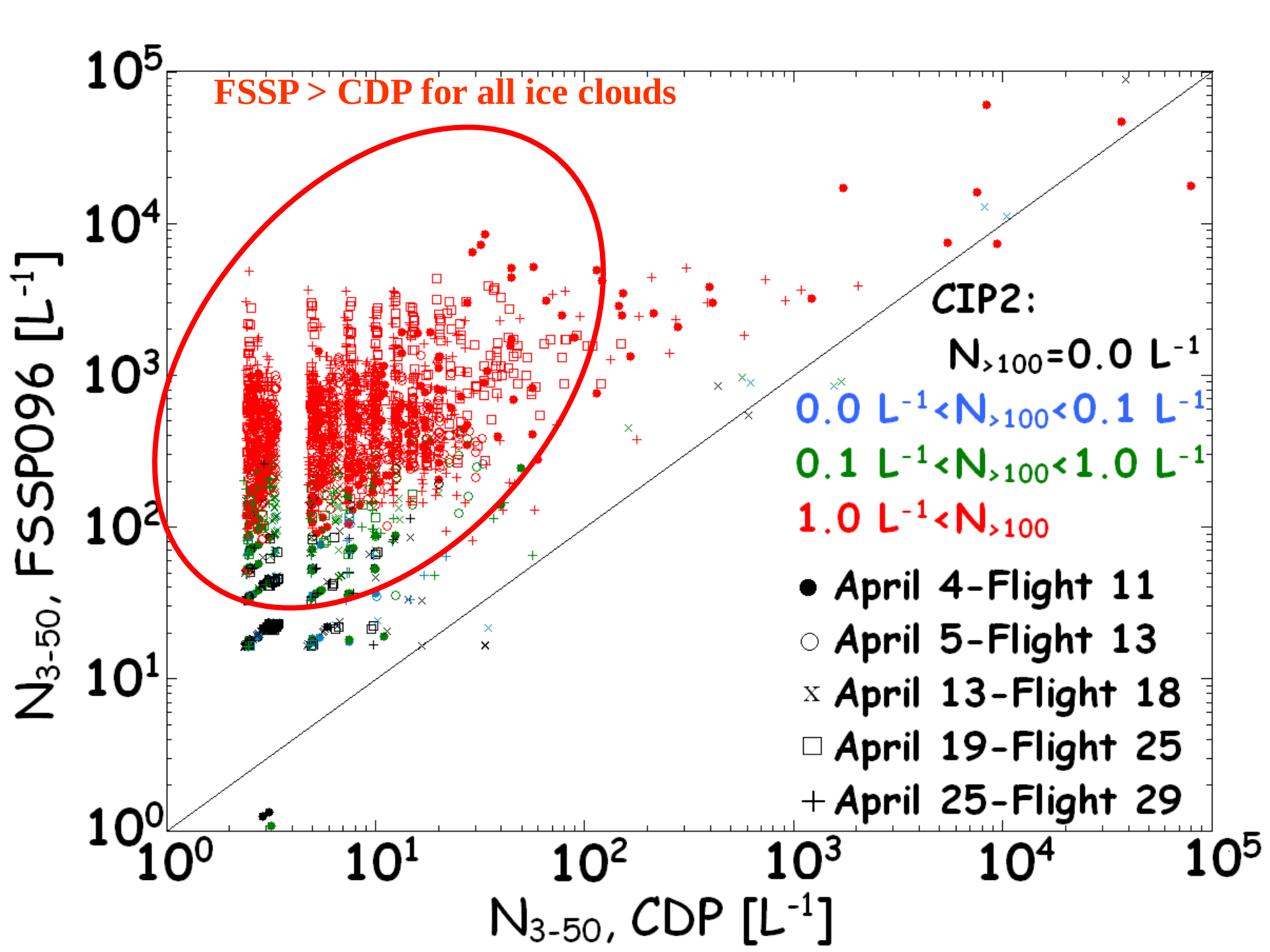


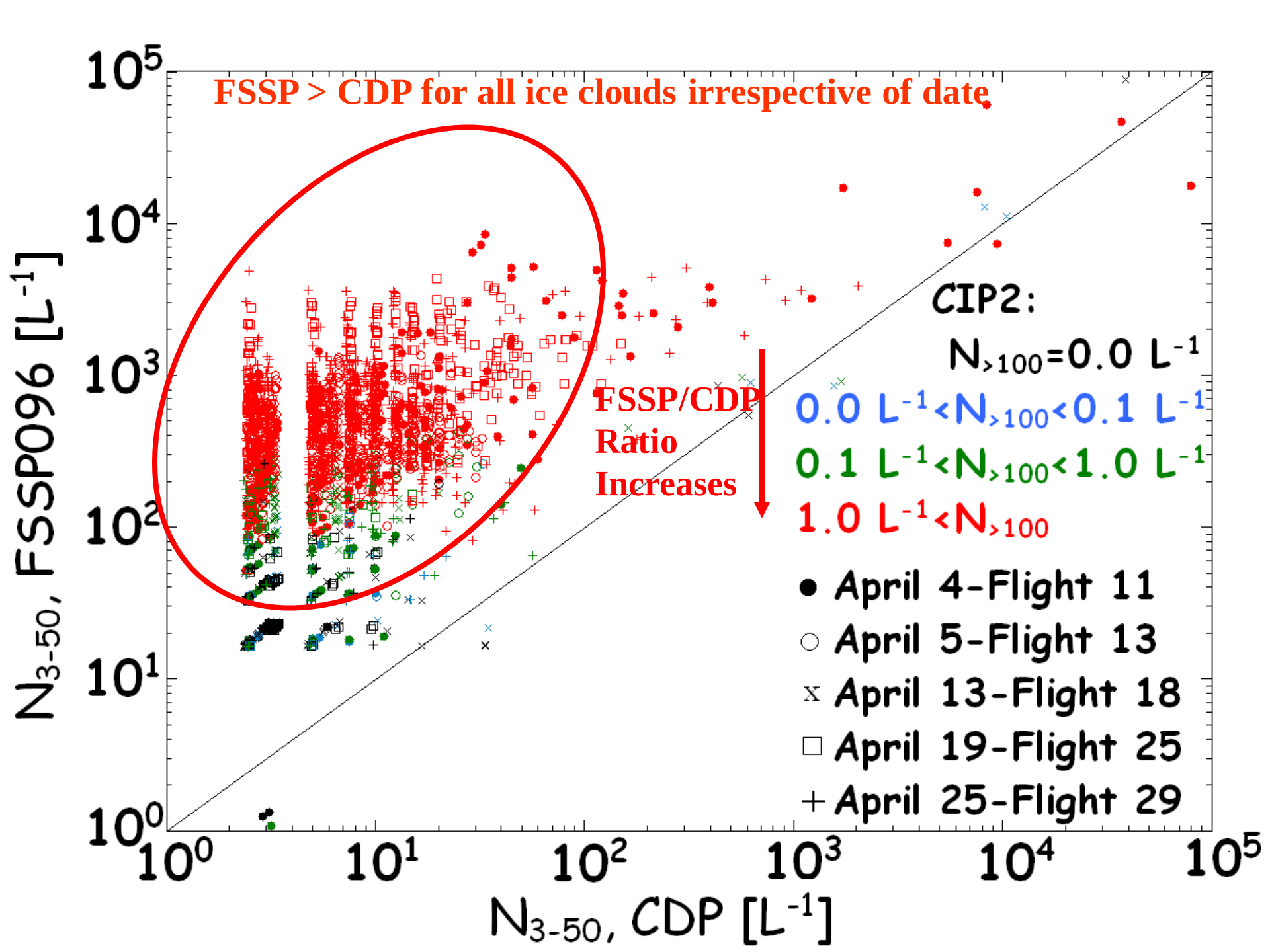
McFarquhar et al. (2007, GRL)

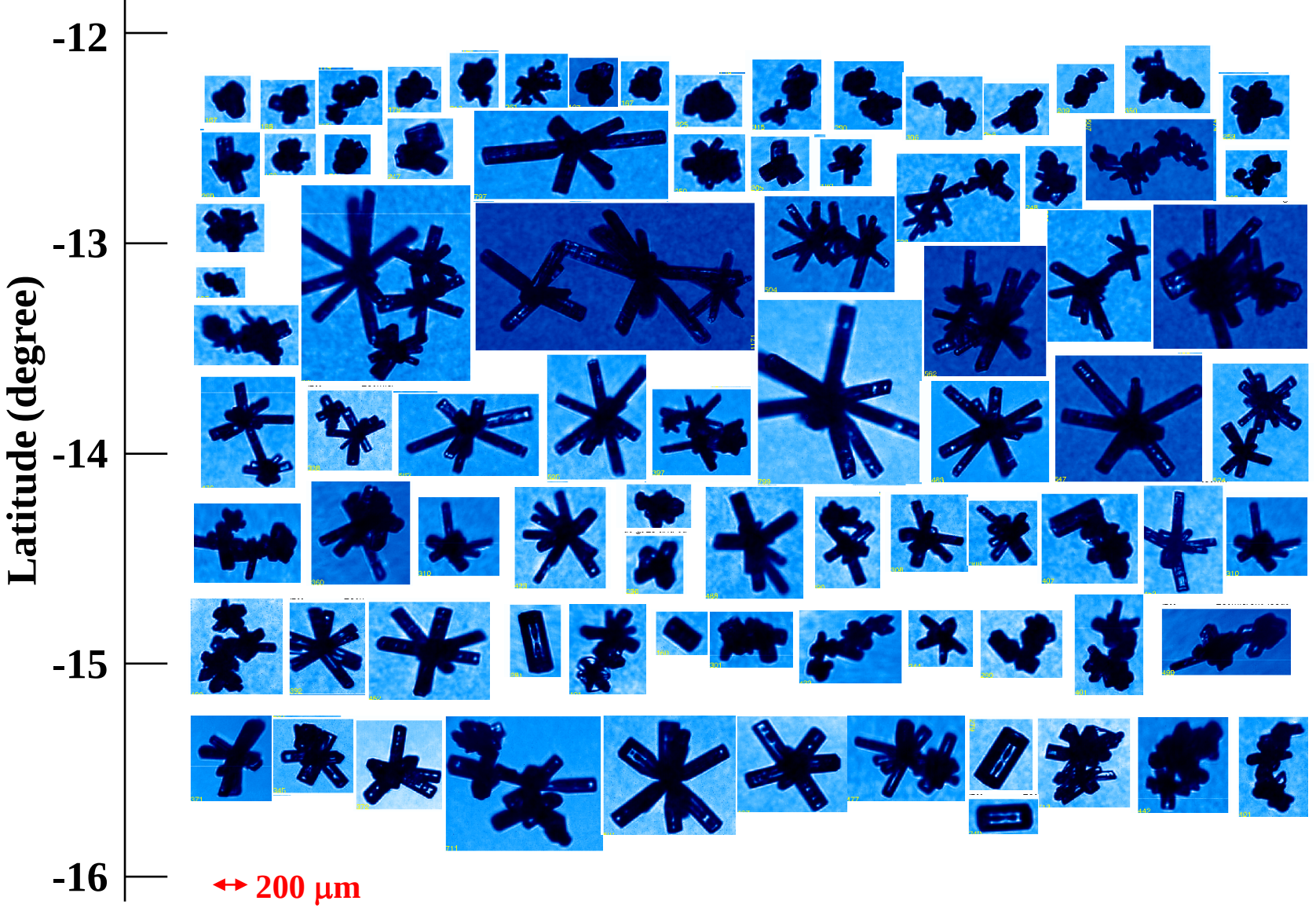

(a)
CAS > CDP due to shattering?
Or is CDP artificially low?
CIP (D>100 μm)
CAS/CDP
Ratio
Increases
McFarquhar et al. (2007, GRL)

FSSP and CDP compared for ISDAC with similar results

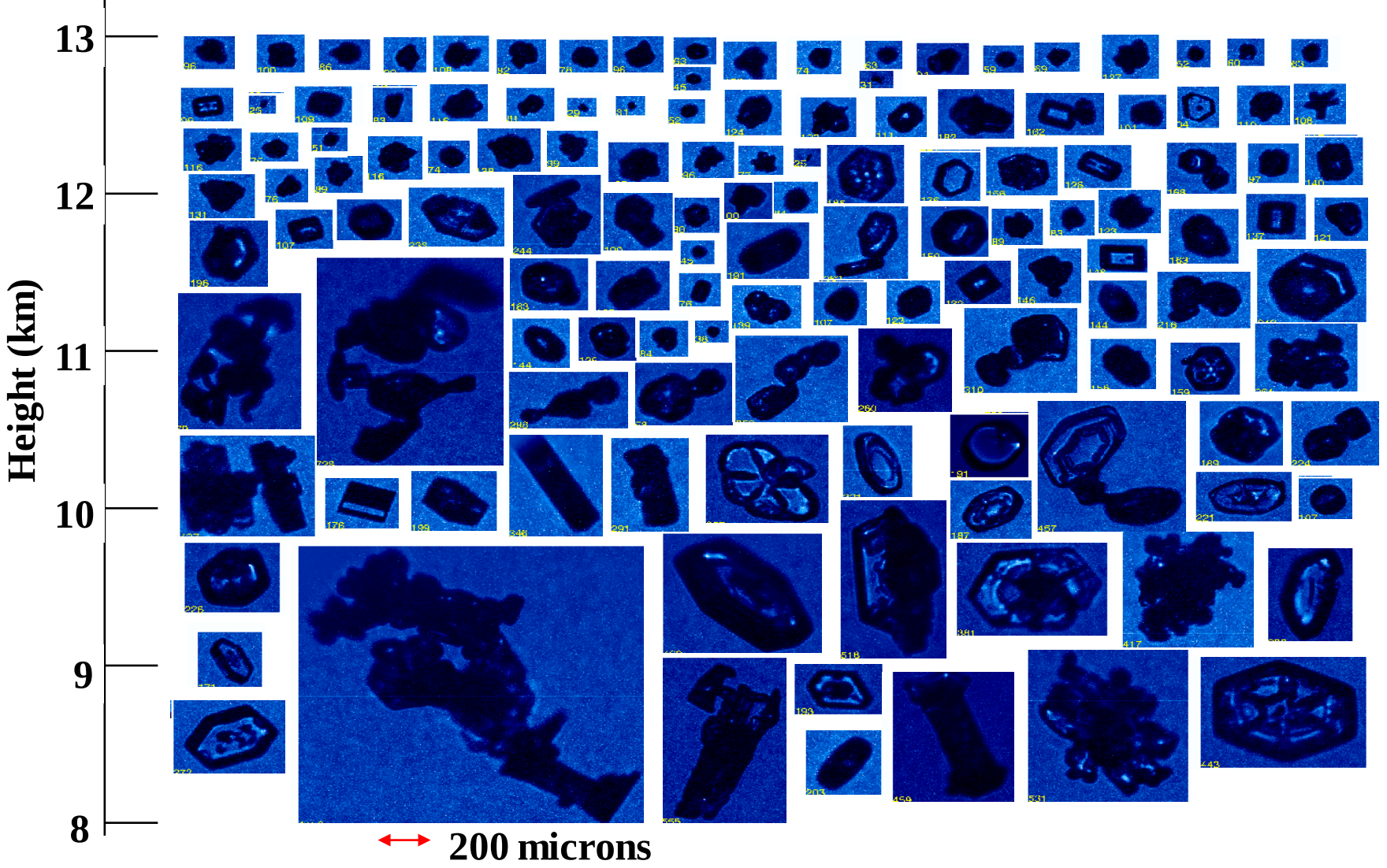



FSSP > CDP for all ice clouds
CIP2:
$N_{>100}$=0.0 L^{-1}
0.0 L^{-1}<$N_{>100}$<0.1 L^{-1}
0.1 L^{-1}<$N_{>100}$<1.0 L^{-1}
1.0 L^{-1}<$N_{>100}$
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
$N_{3\text{-}50}$, FSSP096 [L^{-1}]
$N_{3\text{-}50}$, CDP [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5


FSSP > CDP for all ice clouds irrespective of date
FSSP/CDP Ratio Increases
CIP2:
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
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N3-50, FSSP096 [L-1]
N3-50, CDP [L-1]
10^0
10^1
10^2
10^3
10^4
10^5



Many bullet rosettes & aggregates seen on leg at 12 km through aged cirrus bands during TWP-ICE



- Fresh anvil had very different habits than aged cirrus: fewer bullet rosettes, more plates & irregulars: differences in SDs also noted
- What controls habits & SDs, and how does this affect parameterizations for models & remote sensing?

Aircraft Instruments

Goal: To balance newer measurements that minimize biases with legacy measurements so that past data can be evaluated

Include PSD with bulk measurements

Include parameters that address microphysical processes

Measurement	Instrument	Provider
PSD 1 - 50 mm	CDP	SPEC or DMT Kok
PSD 1 - 50 mm	FSSP	SPEC
PSD 20 - 2000 mm	2DS	SPEC
PSD 100 - 1500 mm	2DC	SPEC
PSD 500 - 50000 mm	PIP or 2DP	EC or WMI
PSD 0.1 - 3.0 μm	PCASP	DOE or WMI
Ice Habit, PSD	CPI	DOE
Ice Water Content	CSI or Deep Cone Nevzorov	DMT or C.Twohy, SPEC
Turbulence	Various	SPEC
Atmospheric and Aircraft State Parameters	Various	SPEC
Humidity	DLH	LaRC/Diskin

Number of Cirrus Hours

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1997	190.33	204.67	112.50	212.00	237.00	248.17	214.17	162.75	130.42	108.25	184.33	139.50
1998	285.17	250.58	118.83	68.75	208.67	94.50	119.08	107.42	31.00	178.42	148.50	154.17
1999	237.58	148.25	177.58	221.00	175.75	233.42	99.25	51.00	97.17	72.33	60.25	176.58
2000	191.42	217.92	200.58	176.08	223.17	248.25	160.17	163.50	21.25	186.67	179.50	188.08
2001	159.08	335.83	287.75	196.50	209.08	189.75	104.08	83.50	128.92	158.50	184.25	112.92
Avg	212.72	231.45	179.45	174.87	210.73	202.82	139.35	113.63	81.75	140.83	151.37	154.25

Data Collection Strategy:

- Primary Mission will be to collect data over ARM SGP in conjunction with ground-based remote sensors
    - Critical Ground-based Instruments: MMCR, MPL, Raman, AERI
    - Balance day and early evening measurements (Raman lidar considerations)
    - Flight Patterns need to be simple and done the same over and over.
        - Along the wind legs (50-100 km long) that are centered on the site with steps up or down (300 m) from base to top or top to base followed by a series of spirals up and down.
- Secondary Objective: Should there be one? I argue yes.
    - Flying in Cirrus under the A-Train. Both spirals (for MODIS) and along-track for Cloudsat and Calipso are desired.
    - Others?

Operations.

Decision making

- Go- no Go
  - Weather forecasting (Dan Hartsock)
  - Rotating Team
    - 3 science team members with rotating chair,
    - SPEC,
    - Project (Beat or Jason?)
    - Weather forecasting
    - ARM SGP
  - Morning conference call to decide on present day plan and plan for following days
- In-Flight Decision Making
  - Is satellite tracking of aircraft necessary?
  - Communication between science and aircraft and ground?

Ongoing Operations Evaluation.

Very critical that aircraft and ground-based data are available and posted so that science team (and others?) can evaluate the success or not of a given flight and the strategy used to plan and execute it.

Plan to have a web page modeled after midcix page for this

Data availability and quicklooks – SPEC and ARM

Science Team must commit to looking at and commenting on data – wicki or some such?

Suggestions?