ISDAC Session

8:30 - 8:45: Greg McFarquhar, Understanding cloud measurements from ISDAC

8:45 – 9:00: Alexei Korolev, Effect of ice bouncing and shattering on performance of airborne cloud microphysical instrumentation

9:00 – 9:15: Sara Lance: Cloud microphysical data from the NOAA aircraft

9:15 – 9:30: David Mitchell, Mixed-phase clouds in the -20 to -35^{o}C range: remote sensing results

9:30 – 9:45: Alla Zelenyuk, Characterizing the size and composition of CCN and IN over the North Pole of Alaska

9:45 – 10:00 Sarah Brooks, Heterogeneity of ice nuclei in the Arctic

10:00 – 10:15 M. Dubey, Airborne photoacoustic observations of aerosol optical properties aloft Alaska connected to chemical composition measurements during ISDAC

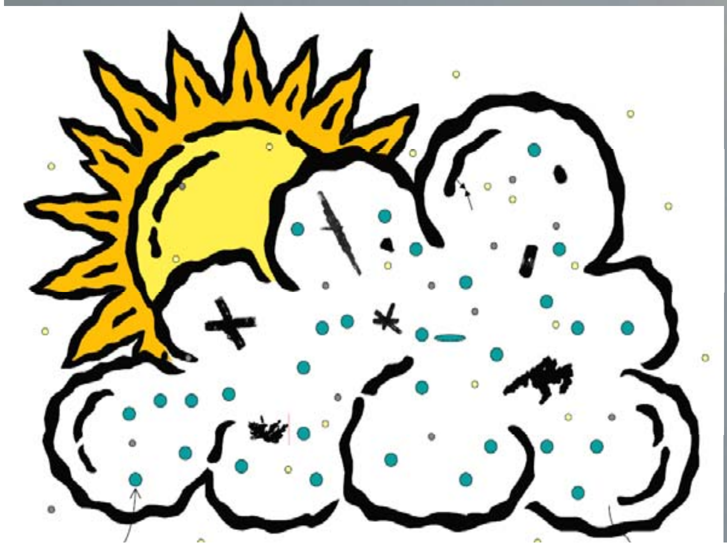
Understanding Cloud Measurements from ISDAC

Greg McFarquhar[1], Robert Jackson[1], Kenny Bae[1], Junshik Um[1], Alexei Korolev[2], Walter Strapp[2], Paul Lawson[3] and Brad Baker[3]

[1]University of Illinois, Urbana, IL

[2]Meteorological Service of Canada, Downsview, Ont.

[3]SPEC Inc., Boulder, CO



1 October 2009

Overview

1. ISDAC Observations
   - What measurements were made during ISDAC
2. Derived Products
   - What do we need to know about clouds
3. Uncertainties
   - What are uncertainties with in-situ observations
   - Impact of ice crystal shattering
4. Preliminary Results
   - Differences between golden days & polluted days
5. Steps forward
   - Can we ultimately consider integrated cloud product?

ISDAC conducted at North Slope Alaska where big changes in arctic climate are occurring (e.g., melting of sea ice), & subsequent changes induced in clouds not well understood

Key ISDAC Issues

1. How do properties of the Arctic aerosol during April differ from those measured by M-PACE during October?

2. To what extent do different properties of arctic aerosol during April produce differences in microphysical and macrophysical properties of clouds and the surface energy balance?

3. How well can cloud models and parameterizations used in climate models simulate the sensitivity of Arctic clouds and the surface energy budget to the differences in aerosol between April and October?

4. How well can long-term surface-based measurements at the ACRF Barrow site provide retrievals of aerosol, cloud, precipitation and radiative heating in the Arctic?

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ISDAC Experiment

- **Convair-580 aircraft from the National Research Council of Canada**

- **Equipped by Environment Canada and others with more than 40 instruments to measure aerosol and cloud particles ranging in size from one-millionth mm to over 10 mm in size**
- **Measurements over Barrow to determine how aerosols impact clouds and to evaluate how well ground instruments retrieve cloud/aerosol properties**

What data did we get for ISDAC?

- Got 27 project sorties representing 103.6 hours of data on 12 different flight days
- Golden days with single-layer strato-cumulus on 8 and 26 April when 3 sorties flown; heavily polluted data on 19 April

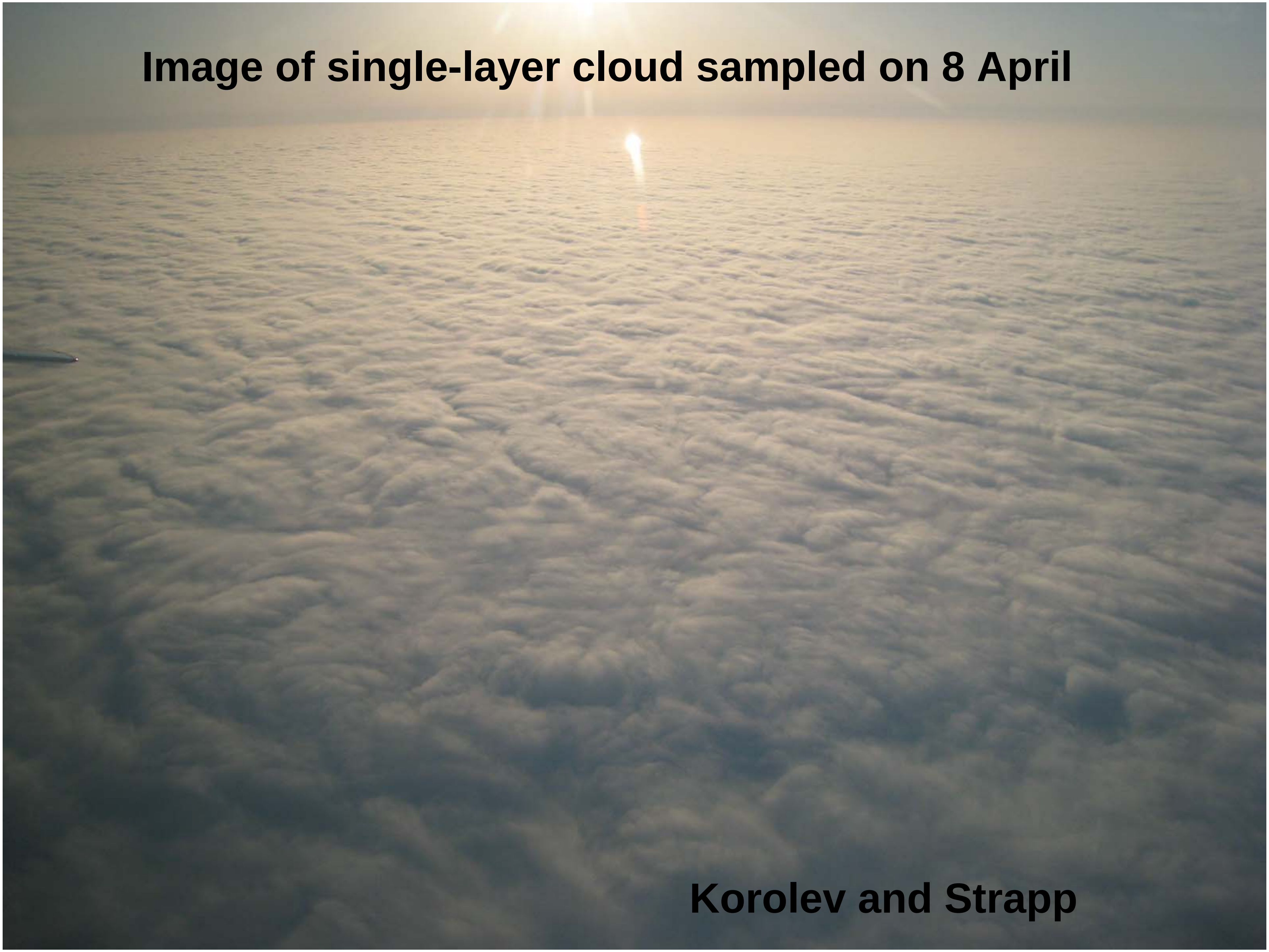


Image of single-layer cloud sampled on 8 April
Korolev and Strapp

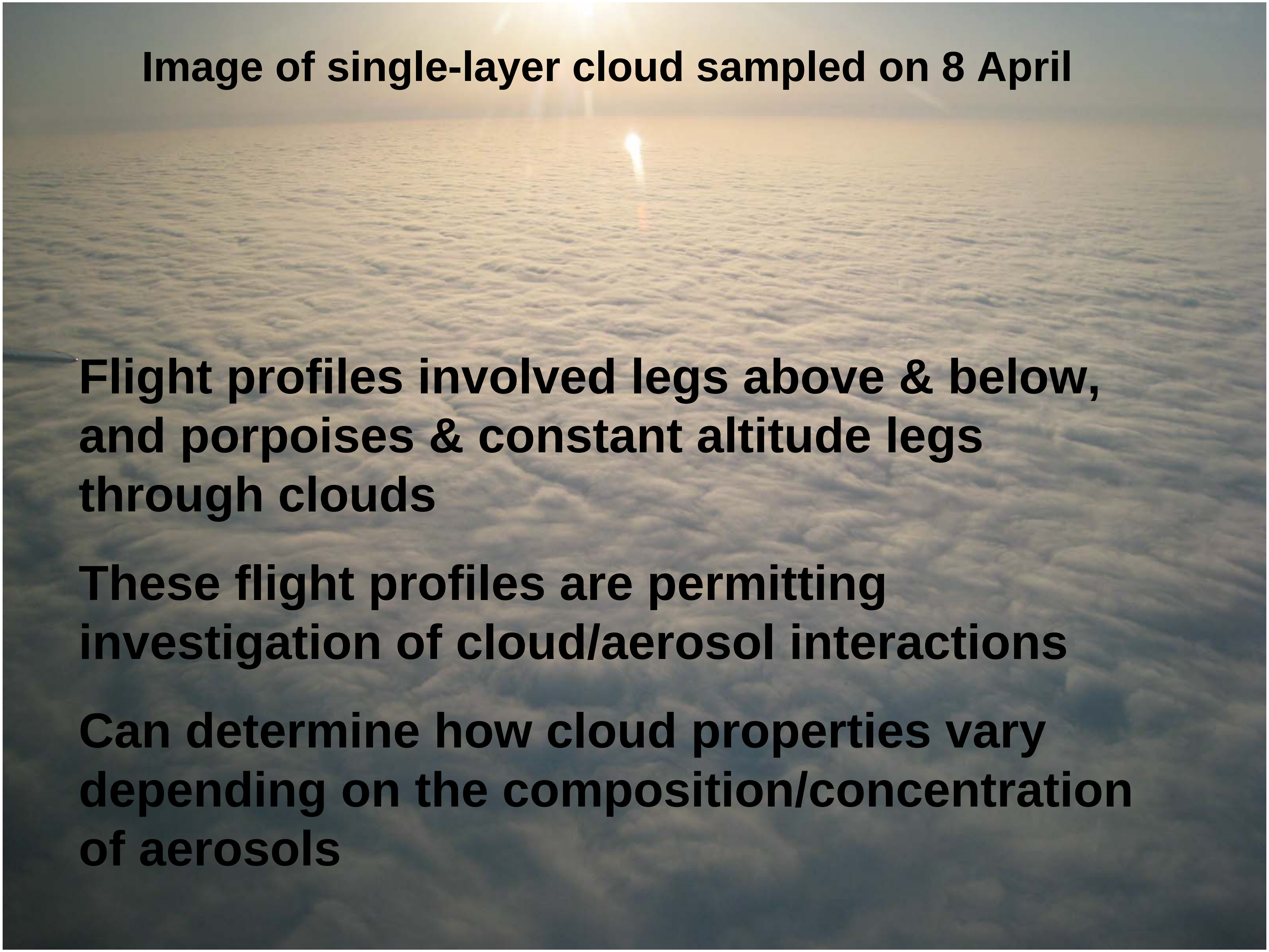
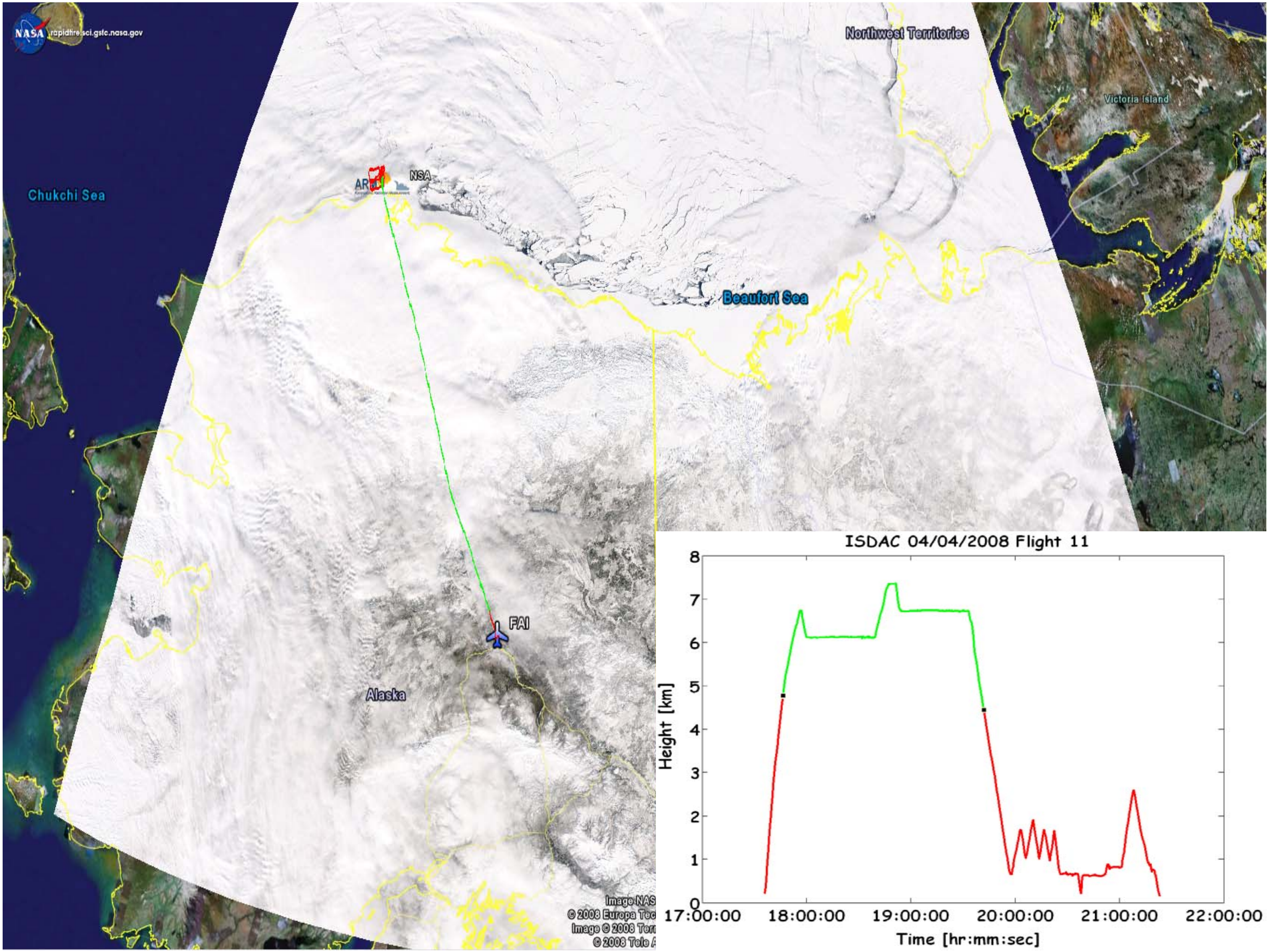
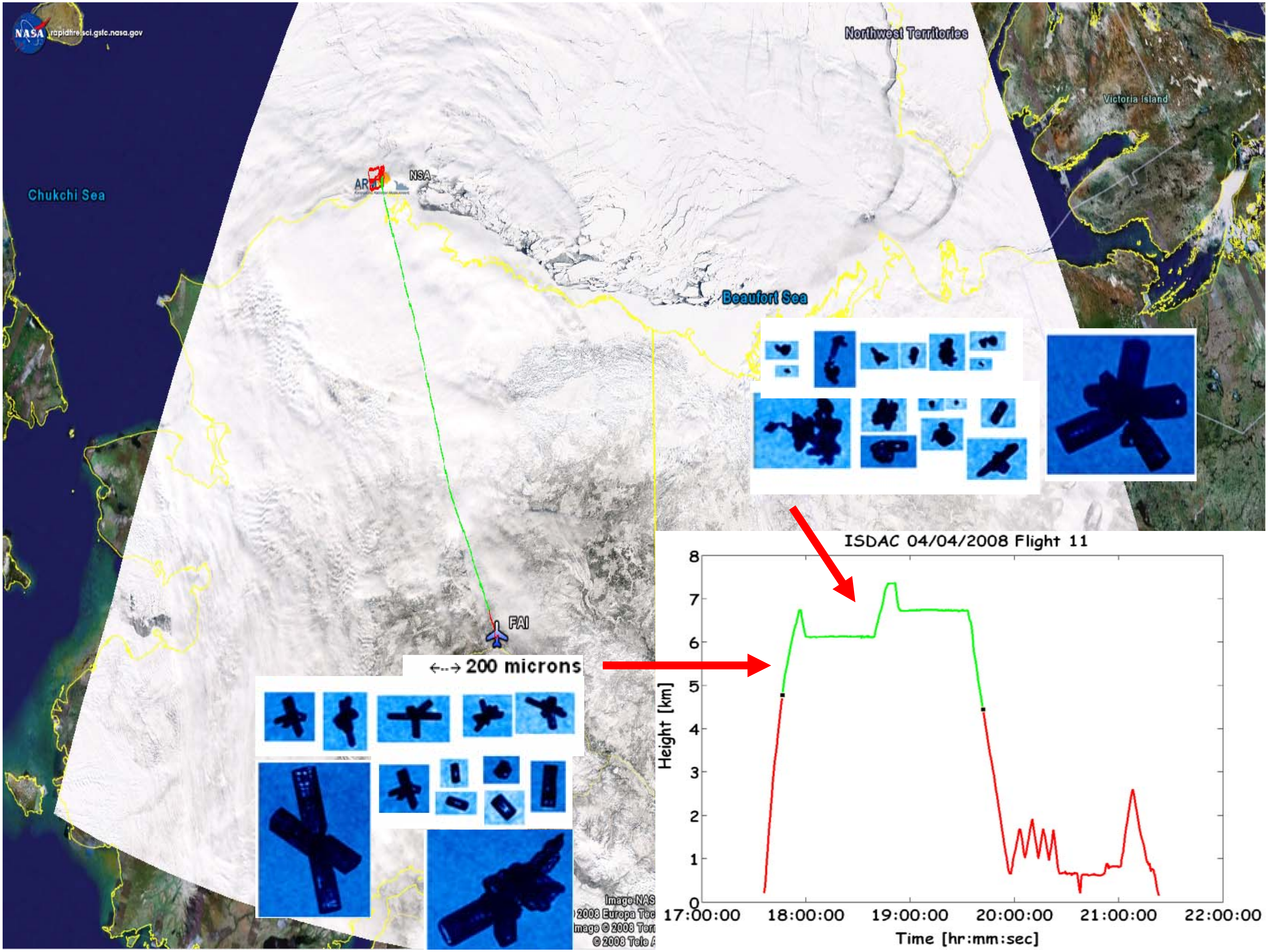
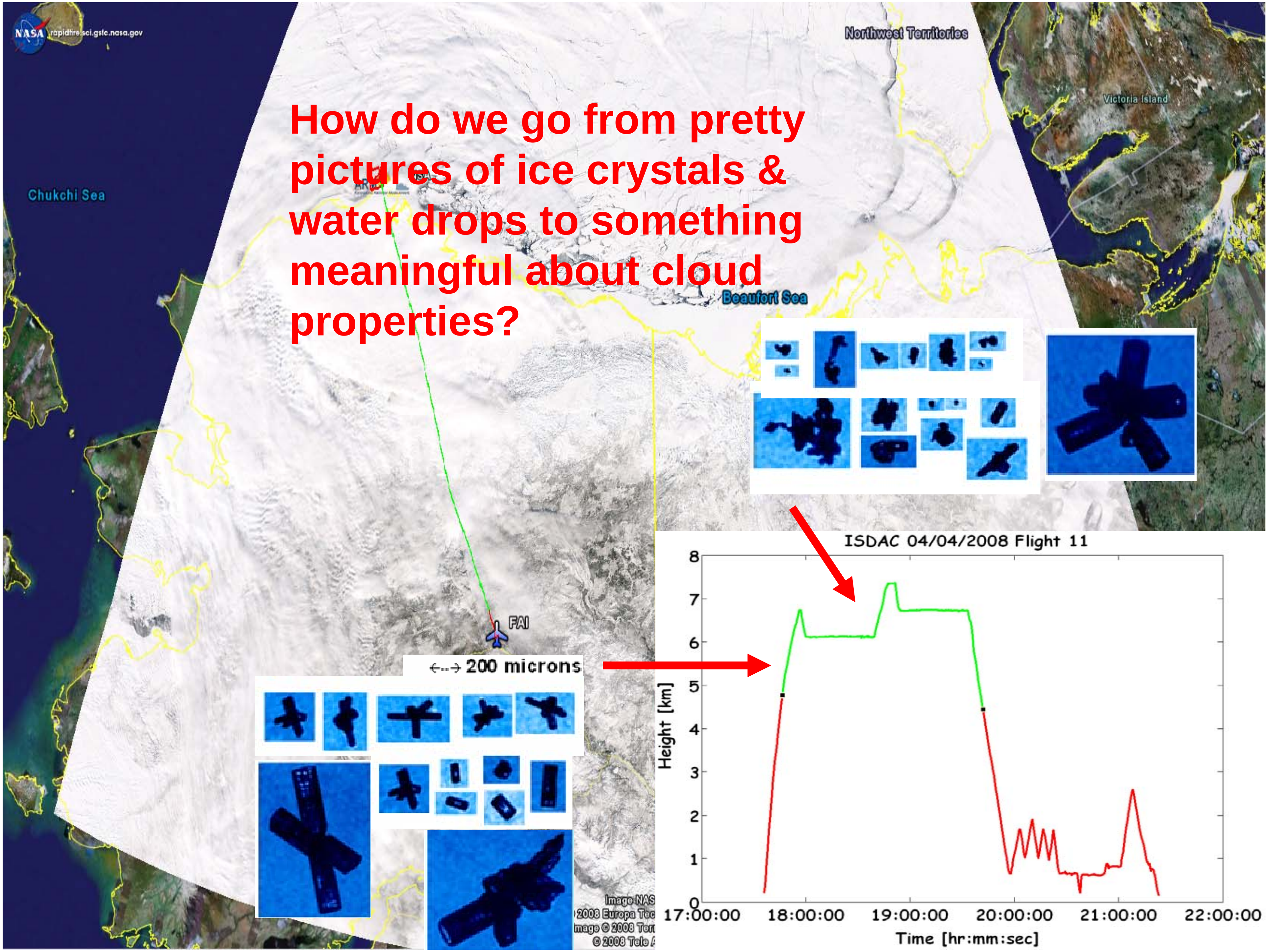


Image of single-layer cloud sampled on 8 April
Flight profiles involved legs above & below, and porpoises & constant altitude legs through clouds
These flight profiles are permitting investigation of cloud/aerosol interactions
Can determine how cloud properties vary depending on the composition/concentration of aerosols


rapidfire.sci.gsfc.nasa.gov
Northwest Territories
Victoria Island
Chukchi Sea
NSA
Beaufort Sea
FAI
Alaska
ISDAC 04/04/2008 Flight 11
Height [km]
Time [hr:mm:sec]
0
1
2
3
4
5
6
7
8
17:00:00
18:00:00
19:00:00
20:00:00
21:00:00
22:00:00


rapidfire.sci.gsfc.nasa.gov
Northwest Territories
Victoria Island
Chukchi Sea
NSA
Beaufort Sea
FAI
←--→ 200 microns
ISDAC 04/04/2008 Flight 11
Height [km]
Time [hr:mm:sec]
17:00:00
18:00:00
19:00:00
20:00:00
21:00:00
22:00:00

How do we go from pretty pictures of ice crystals & water drops to something meaningful about cloud properties?



What do we need from in-situ data?

- $N_i(D)$ & $N_w(D)$: Size distributions of ice/water for all D
- IWC, LWC, β_i, β_w: Mass content & extinction
- N_i & N_w: Total # concentration of water & ice
- r_{ei} & r_{ew}: effective radius of ice/water
- Shape distribution of ice crystals

- Fits to size distributions $N(D) = N_0 D^{\mu} e^{-\lambda D}$
- Fall speed of ice crystals, $V=aD^b$
- Mass/diameter relations, $m = \alpha D^{\beta}$
- Single-scattering properties (g, ω_0, P_{11})
- Collision/collection efficiencies

Big Question

- How do microphysical data vary with T, aerosol composition/number, surface characteristics & meteorological conditions?
  - In-situ analysis can help answer this
  - Satellite/ground data also required

- First, must quantify uncertainties & determine quality of in-situ data

Uncertainties

- Impact of ice crystal shattering on probe tips/inlets on N(D)
- Determining IWC from two-dimensional images of ice crystals

Evaluating Uncertainty

- **Redundancy key to ISDAC observations**
  - **1- 50 μm: 3 FSSPs, CDP, fast FSSP, CAS**
  - **125-800 μm: 2DC, CIP1, CIP2, 2DC w/o tips, 2DS, CPI**
  - **50 – 125 μm: 2DS, CPI (previous no data)**

- **Closure tests:**
  - **Bulk IWC should match that integrated from size distributions**
  - **Bulk Extinction should match that integrated from size distributions**

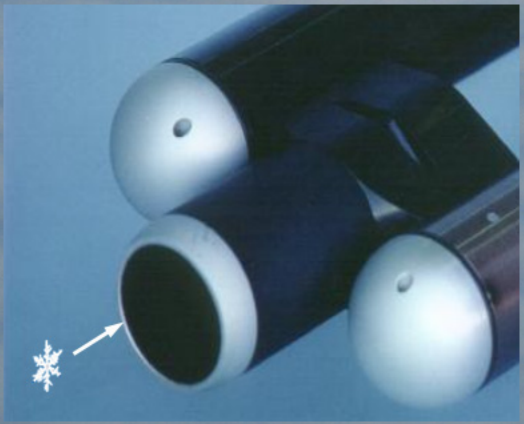
Shattering Effect: CAS vs CDP vs FSSP

Cloud and Aerosol Spectrometer

Shroud

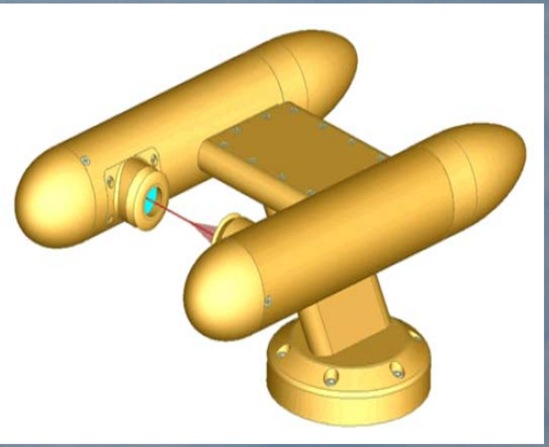
Inlet

Forward Scattering Spectrometer Probe



-Surfaces for shattering

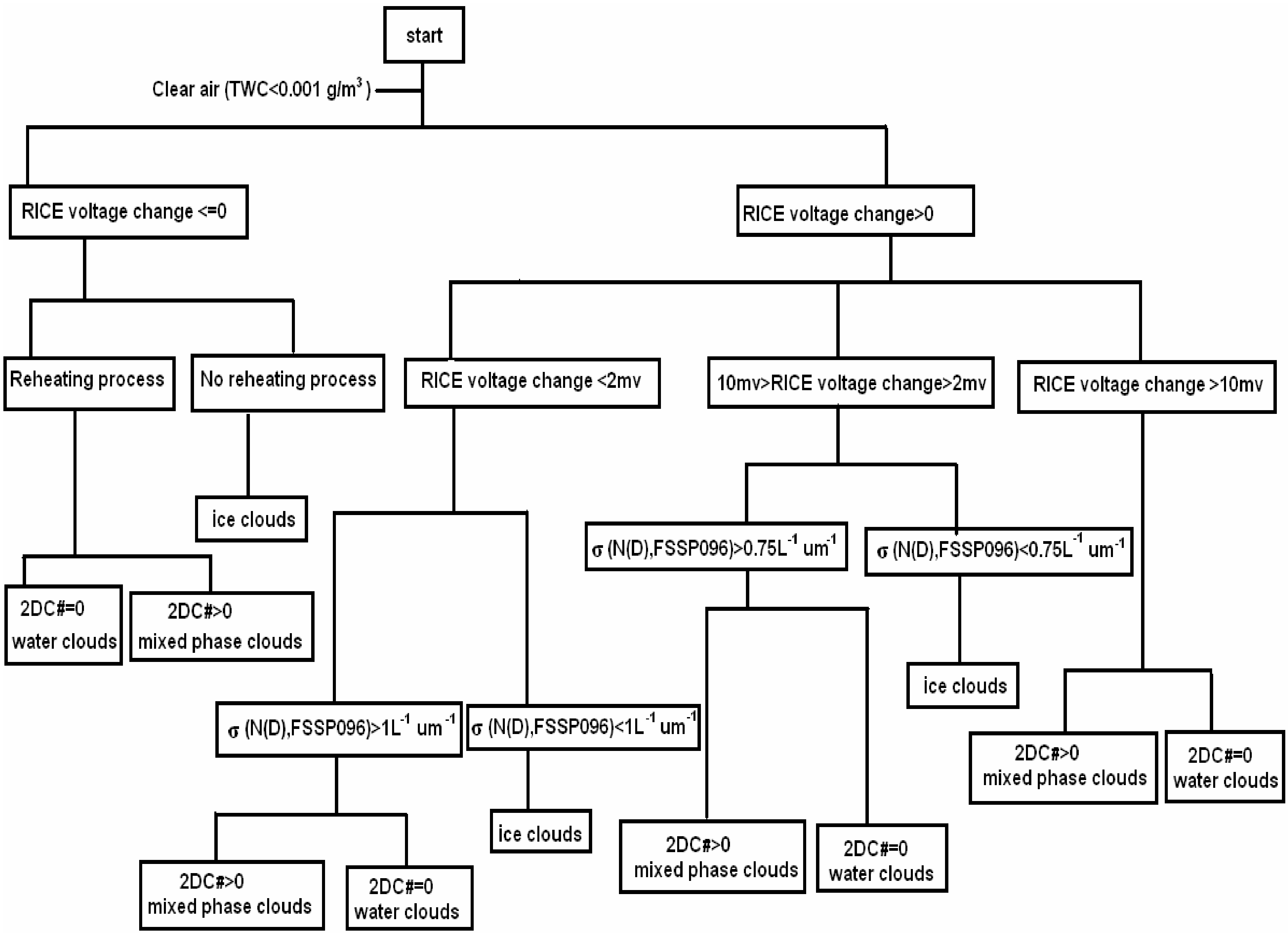
Cloud Droplet Probe



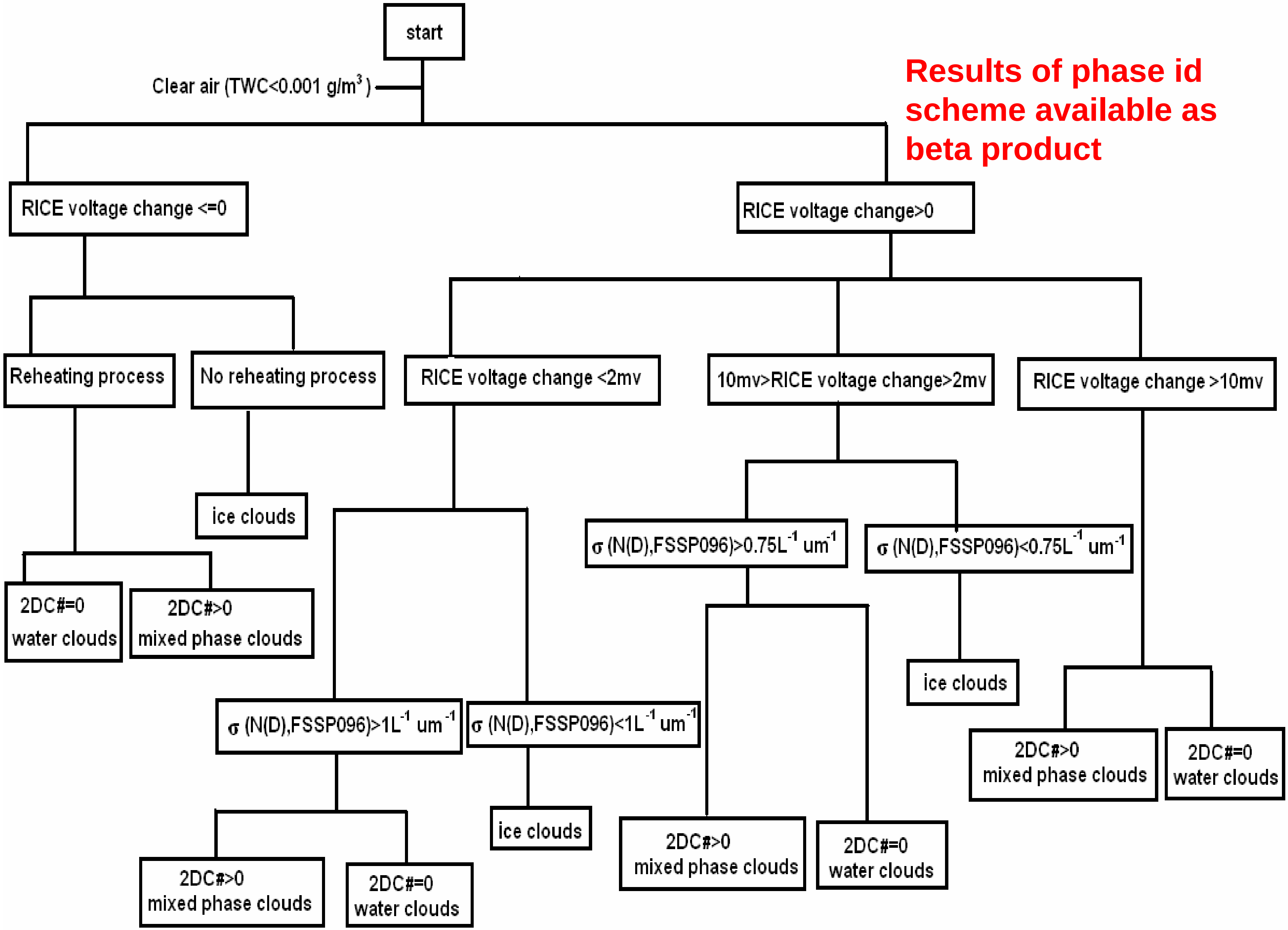
- No inlet or shroud

✓ The same working principle and look-up table

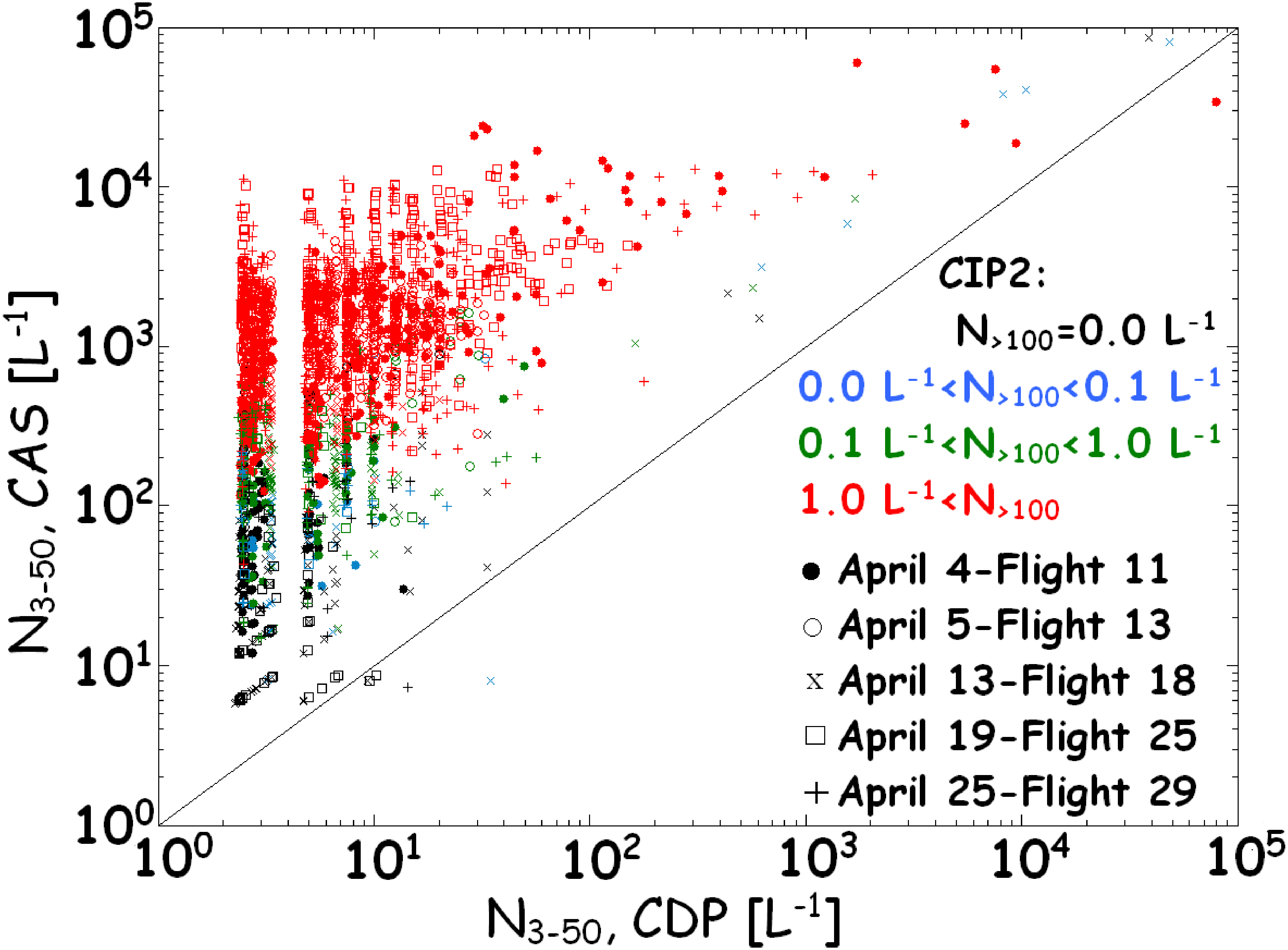
✓ Can we see evidence that shattering on FSSP or CAS amplifies small crystal concentrations?



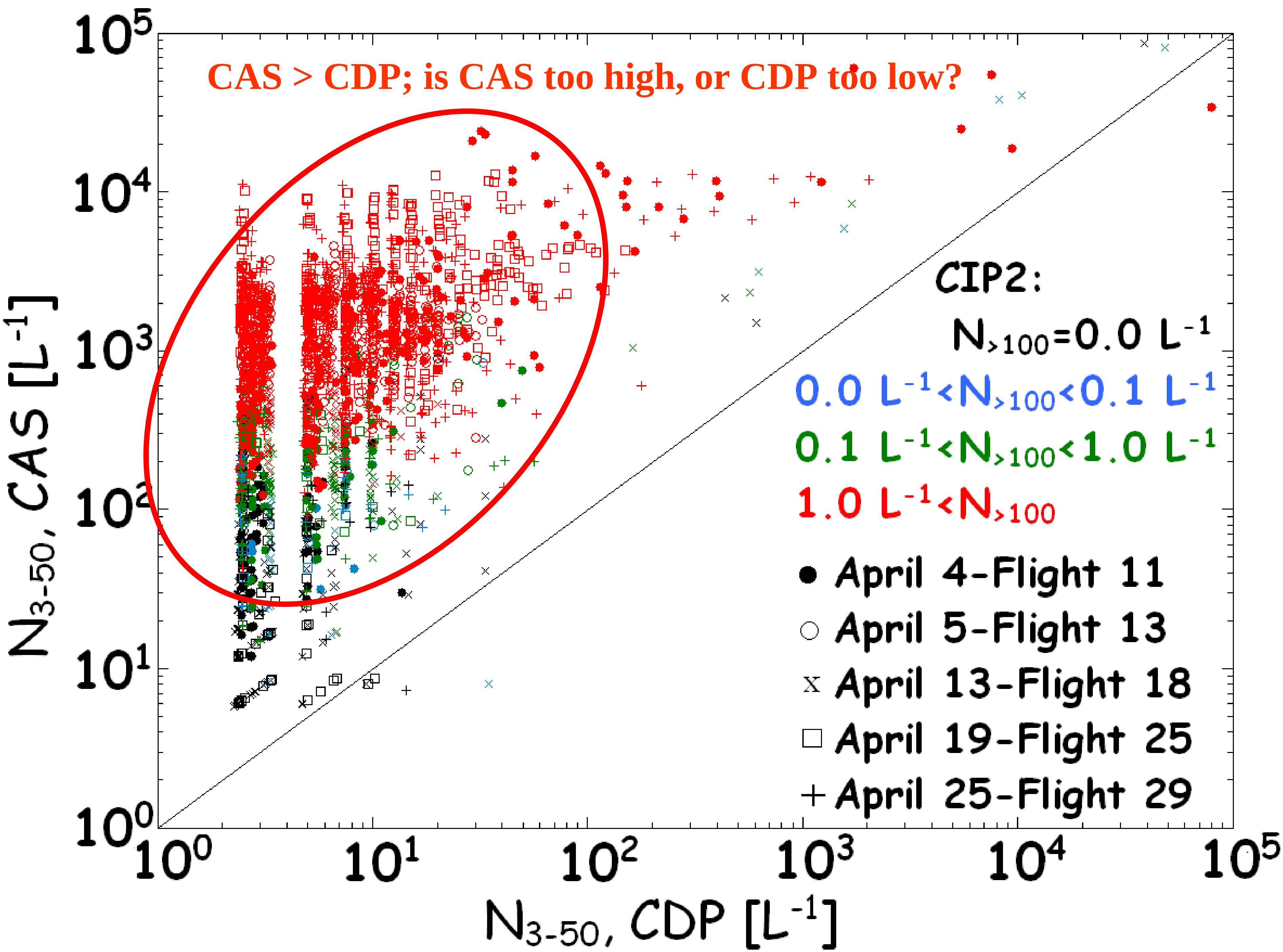
start
Clear air (TWC<0.001 g/m³)
RICE voltage change <=0
RICE voltage change>0
Reheating process
No reheating process
RICE voltage change <2mv
10mv>RICE voltage change>2mv
RICE voltage change >10mv
ice clouds
σ (N(D),FSSP096)>0.75L⁻¹ um⁻¹
σ (N(D),FSSP096)<0.75L⁻¹ um⁻¹
2DC#=0 water clouds
2DC#>0 mixed phase clouds
ice clouds
σ (N(D),FSSP096)>1L⁻¹ um⁻¹
σ (N(D),FSSP096)<1L⁻¹ um⁻¹
2DC#>0 mixed phase clouds
2DC#=0 water clouds
ice clouds
2DC#>0 mixed phase clouds
2DC#=0 water clouds
2DC#>0 mixed phase clouds
2DC#=0 water clouds



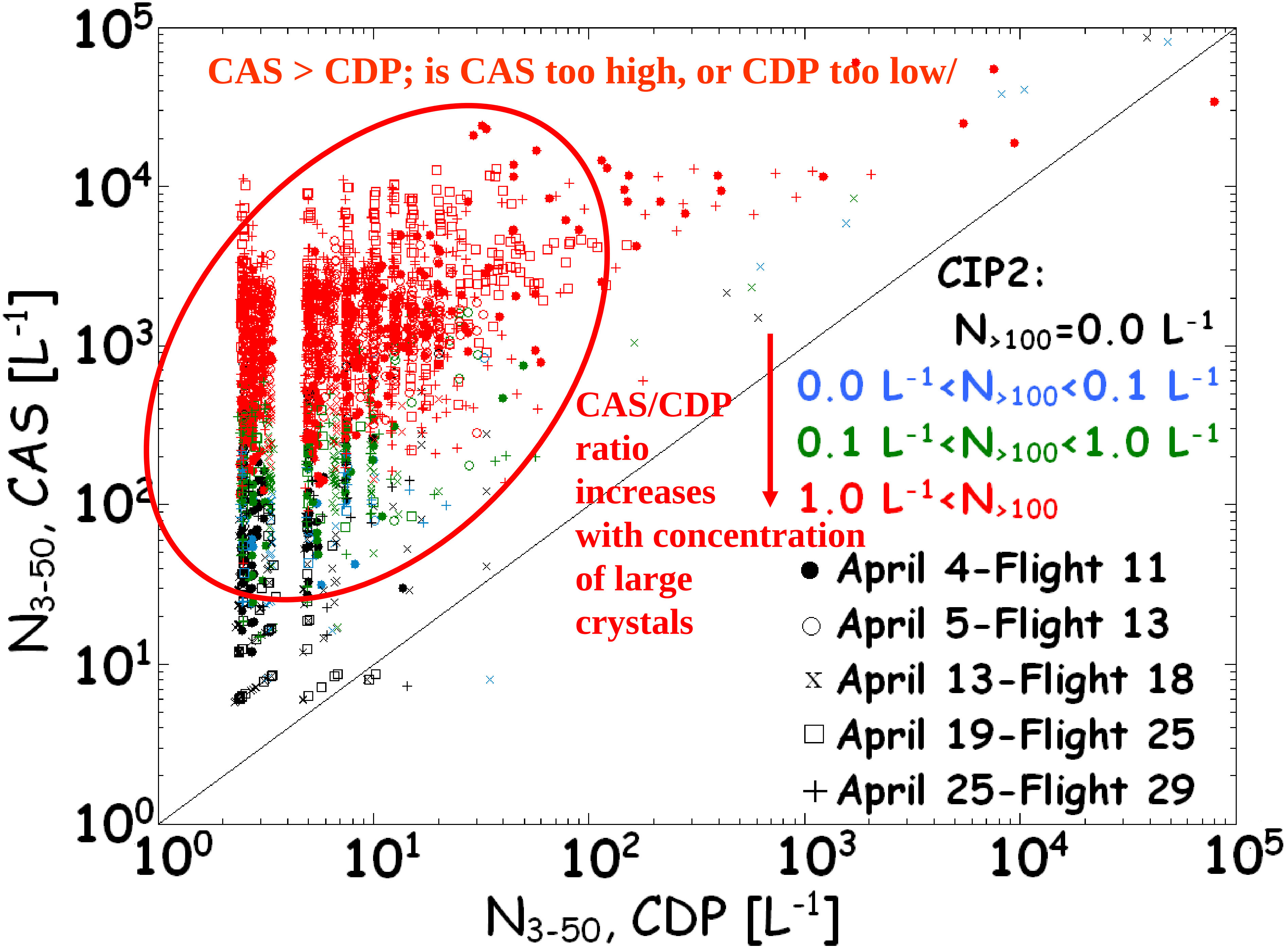
Results of phase id scheme available as beta product

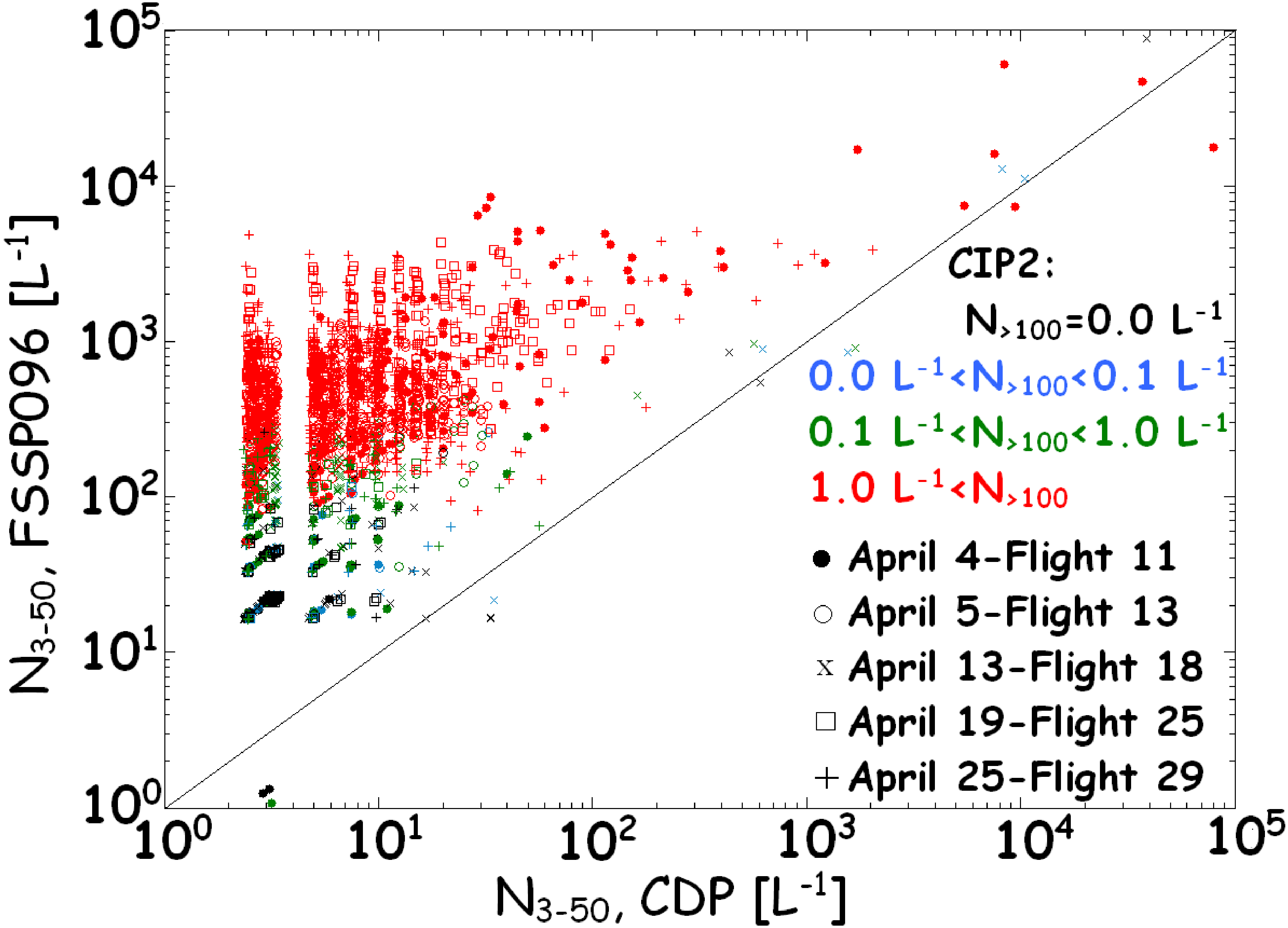


N3-50, CAS [L-1]
N3-50, CDP [L-1]
10^0
10^1
10^2
10^3
10^4
10^5
CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29

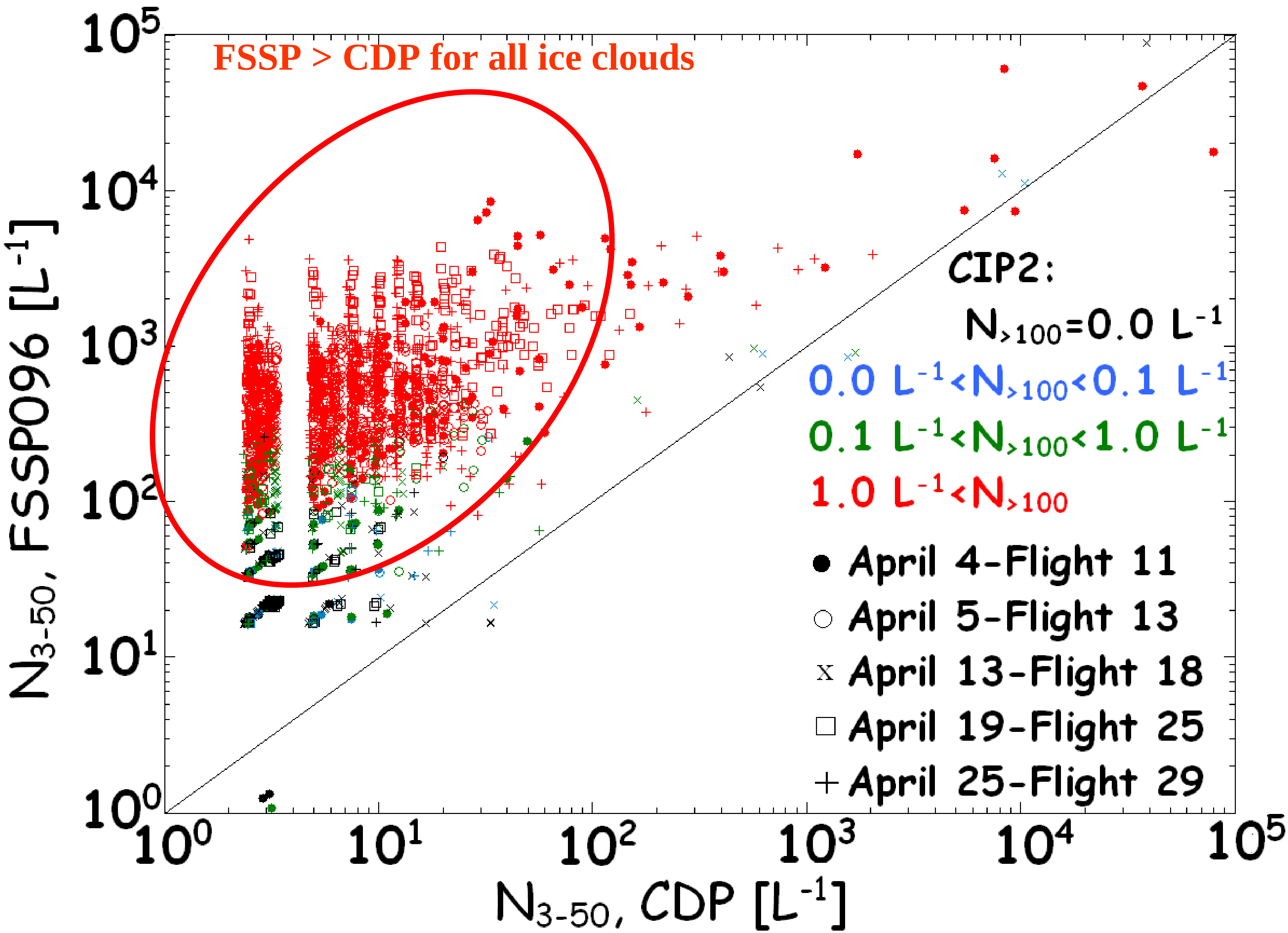


CAS > CDP; is CAS too high, or CDP too low?
CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N3-50, CAS [L-1]
N3-50, CDP [L-1]


CAS > CDP; is CAS too high, or CDP too low/
CAS/CDP ratio increases with concentration of large crystals
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, CAS [L-1]
N3-50, CDP [L-1]
10^0
10^1
10^2
10^3
10^4
10^5



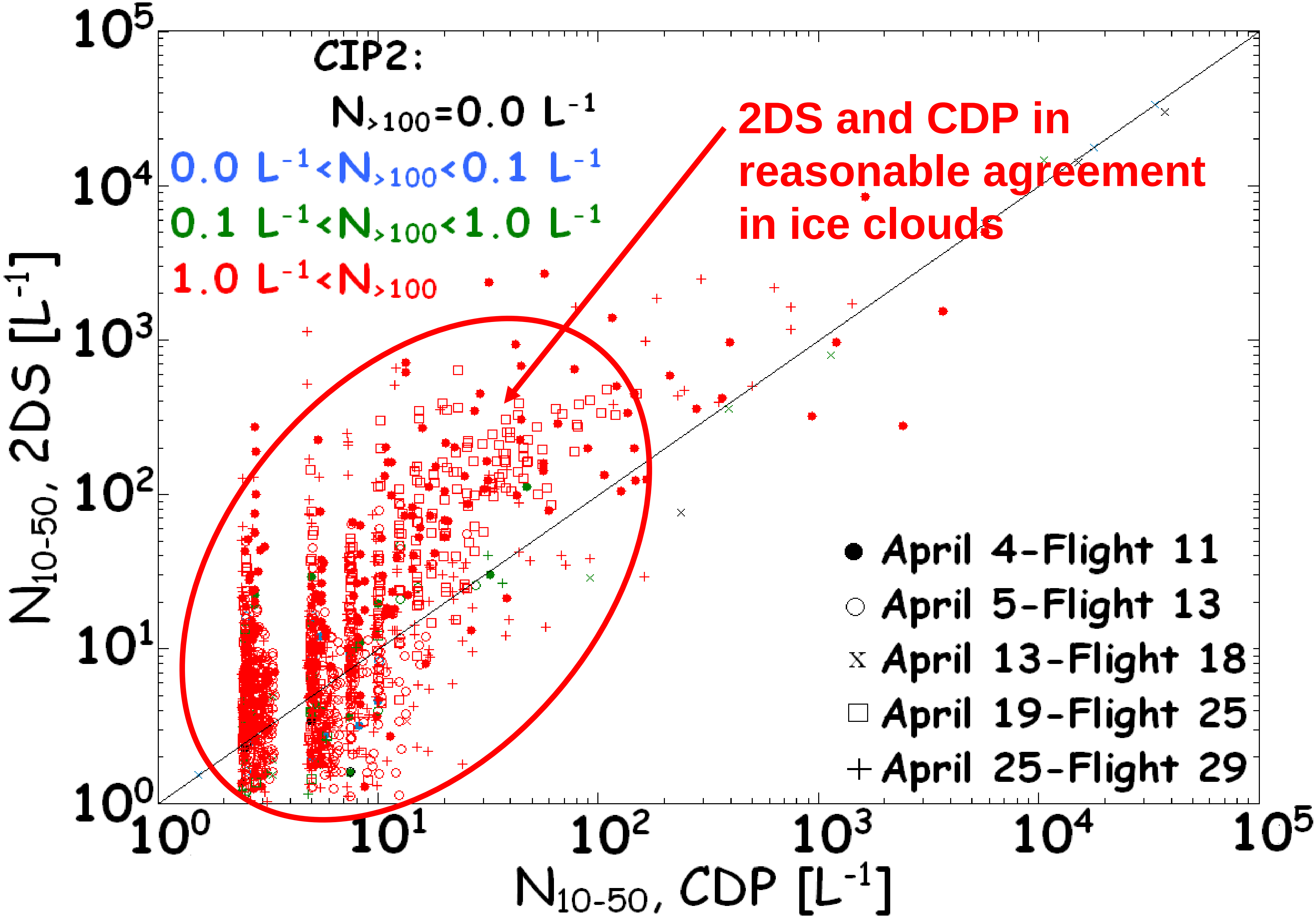
10^5
10^4
10^3
10^2
10^1
10^0
N_{3-50}, FSSP096 [L^{-1}]
10^0
10^1
10^2
10^3
10^4
10^5
N_{3-50}, CDP [L^{-1}]
CIP2:
$N_{>100}$=0.0 L^{-1}
0.0 L^{-1}<$N_{>100}$<0.1 L^{-1}
0.1 L^{-1}<$N_{>100}$<1.0 L^{-1}
1.0 L^{-1}<$N_{>100}$
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April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

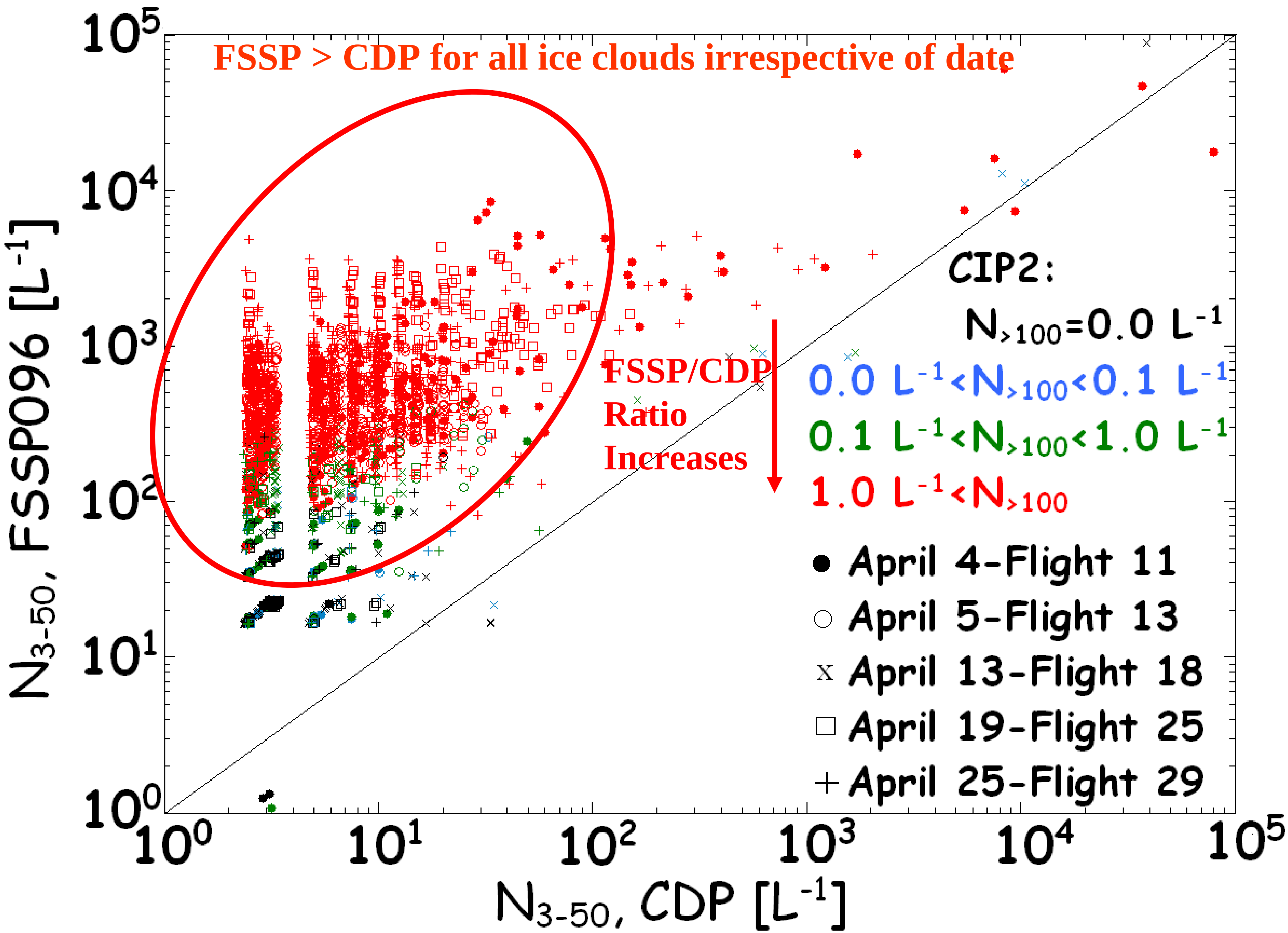


FSSP > CDP for all ice clouds
CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N3-50, FSSP096 [L-1]
N3-50, CDP [L-1]
10^0
10^1
10^2
10^3
10^4
10^5

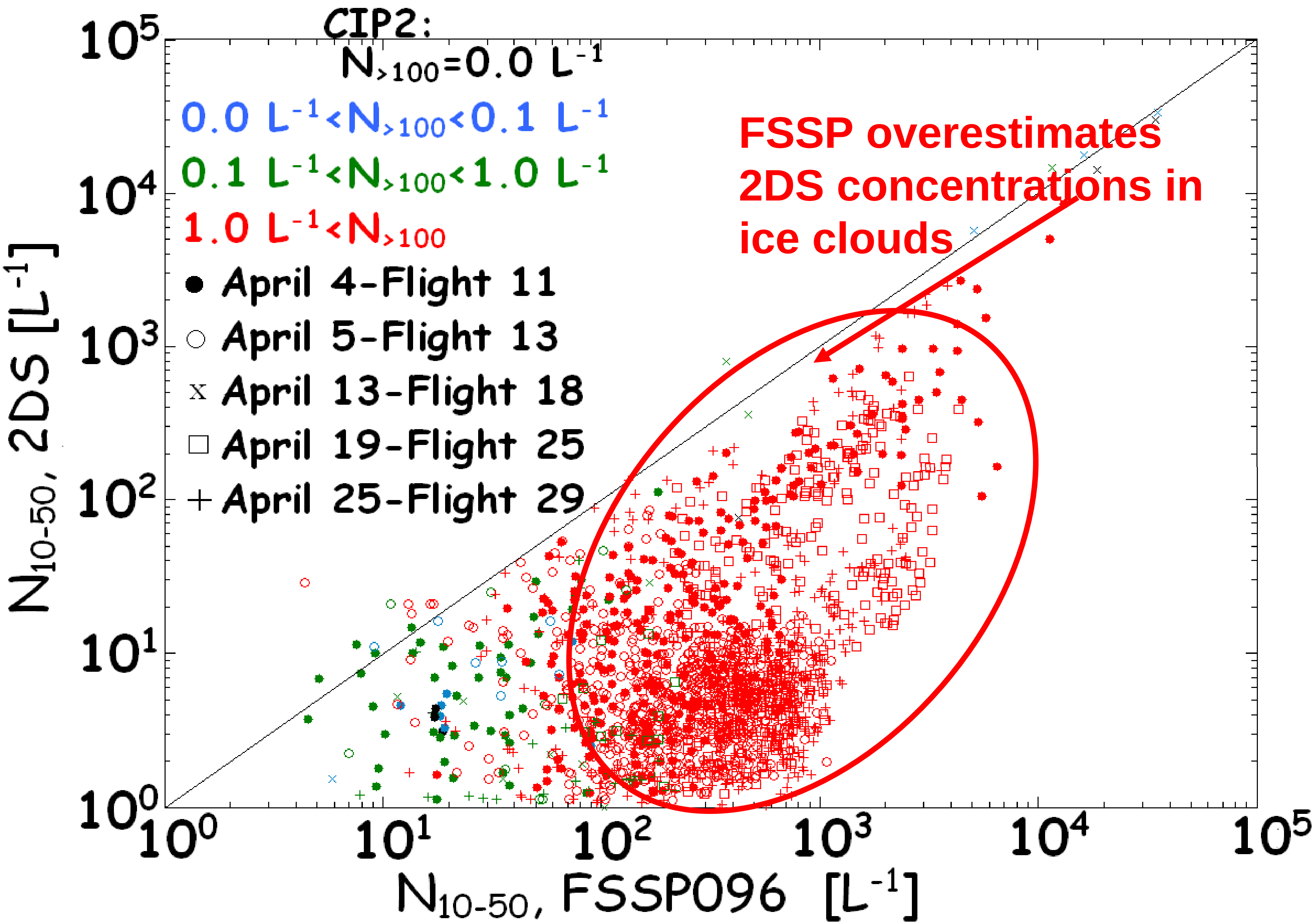
SPEC Inc. 2-D Stereo Probe

- Two photodiode arrays capture 2-d images of ice particles with D > 10 µm
- Data from this probe used to quantify small ice concentrations and helps resolve whether CDP or FSSP/CAS best characterizes small crystals

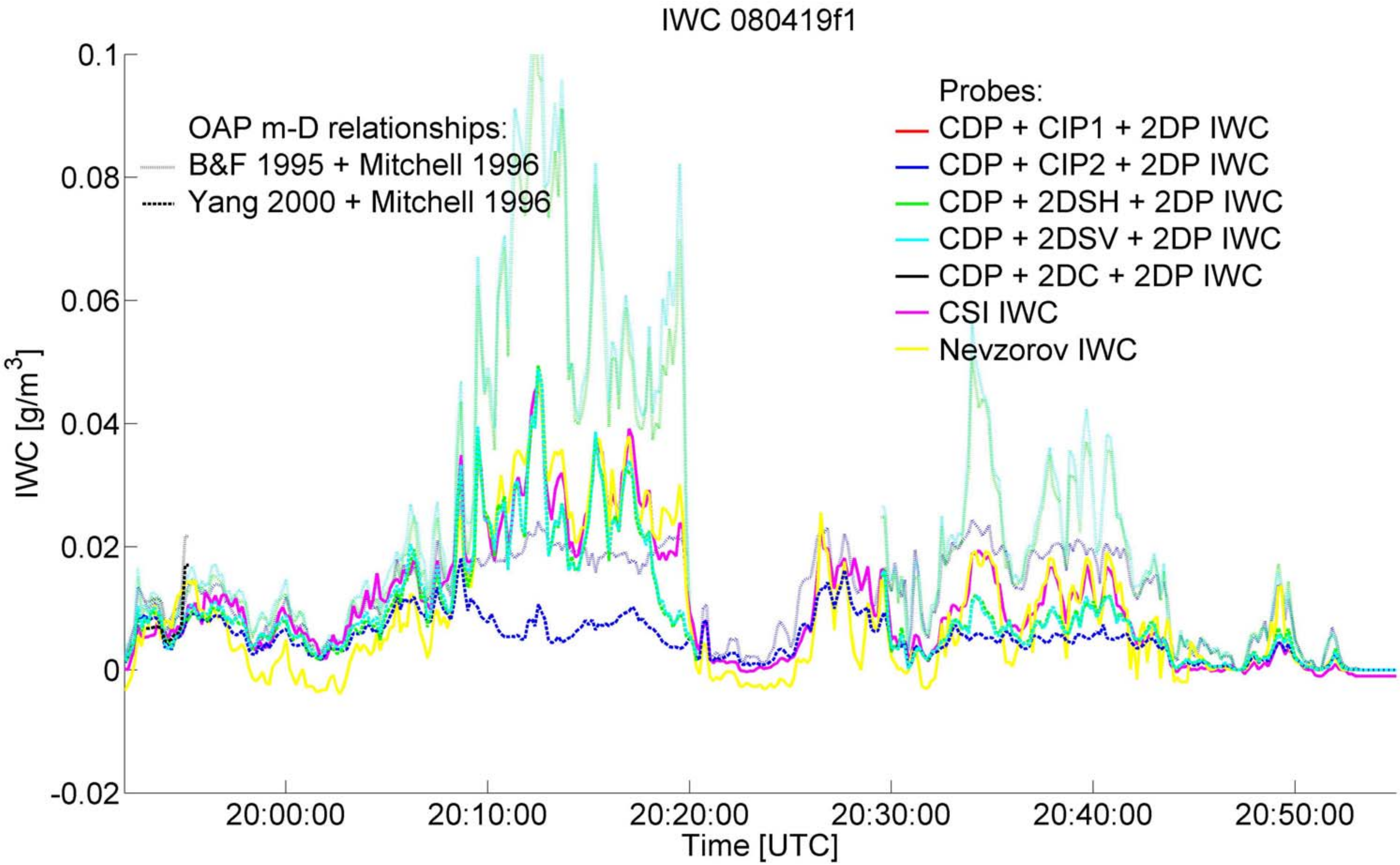

CIP2:
N>100=0.0 L-1
0.0 L-1<N>100<0.1 L-1
0.1 L-1<N>100<1.0 L-1
1.0 L-1<N>100
2DS and CDP in reasonable agreement in ice clouds
April 4-Flight 11
April 5-Flight 13
April 13-Flight 18
April 19-Flight 25
April 25-Flight 29
N10-50, 2DS [L-1]
N10-50, CDP [L-1]
10^0
10^1
10^2
10^3
10^4
10^5



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]



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
FSSP overestimates 2DS concentrations in ice clouds
N10-50, 2DS [L-1]
N10-50, FSSP096 [L-1]
10^0
10^1
10^2
10^3
10^4
10^5

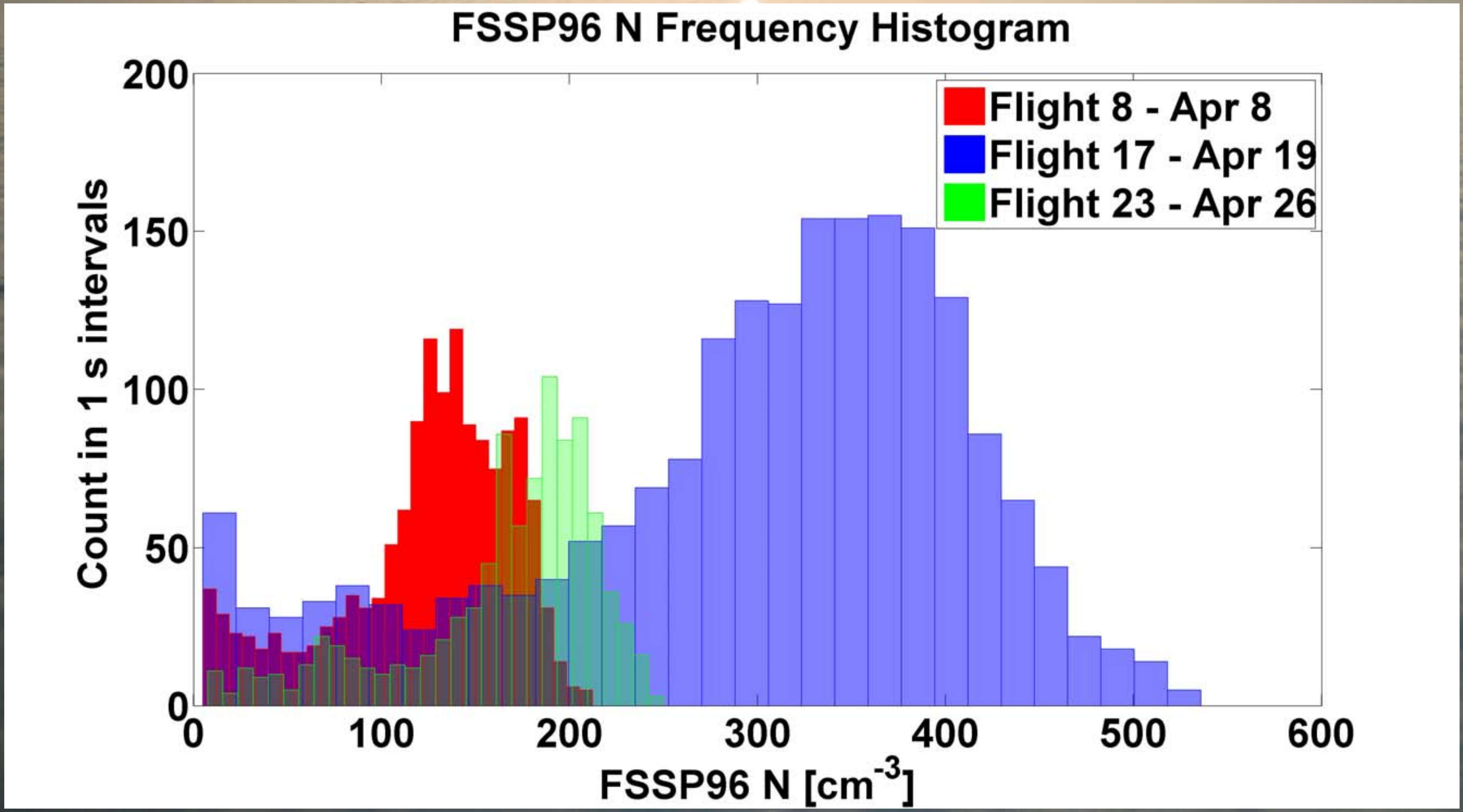


Closure tests complicated by fact are testing different combinations of probes and different techniques for computing mass from size distributions

Use of CPI habits should improve this comparison

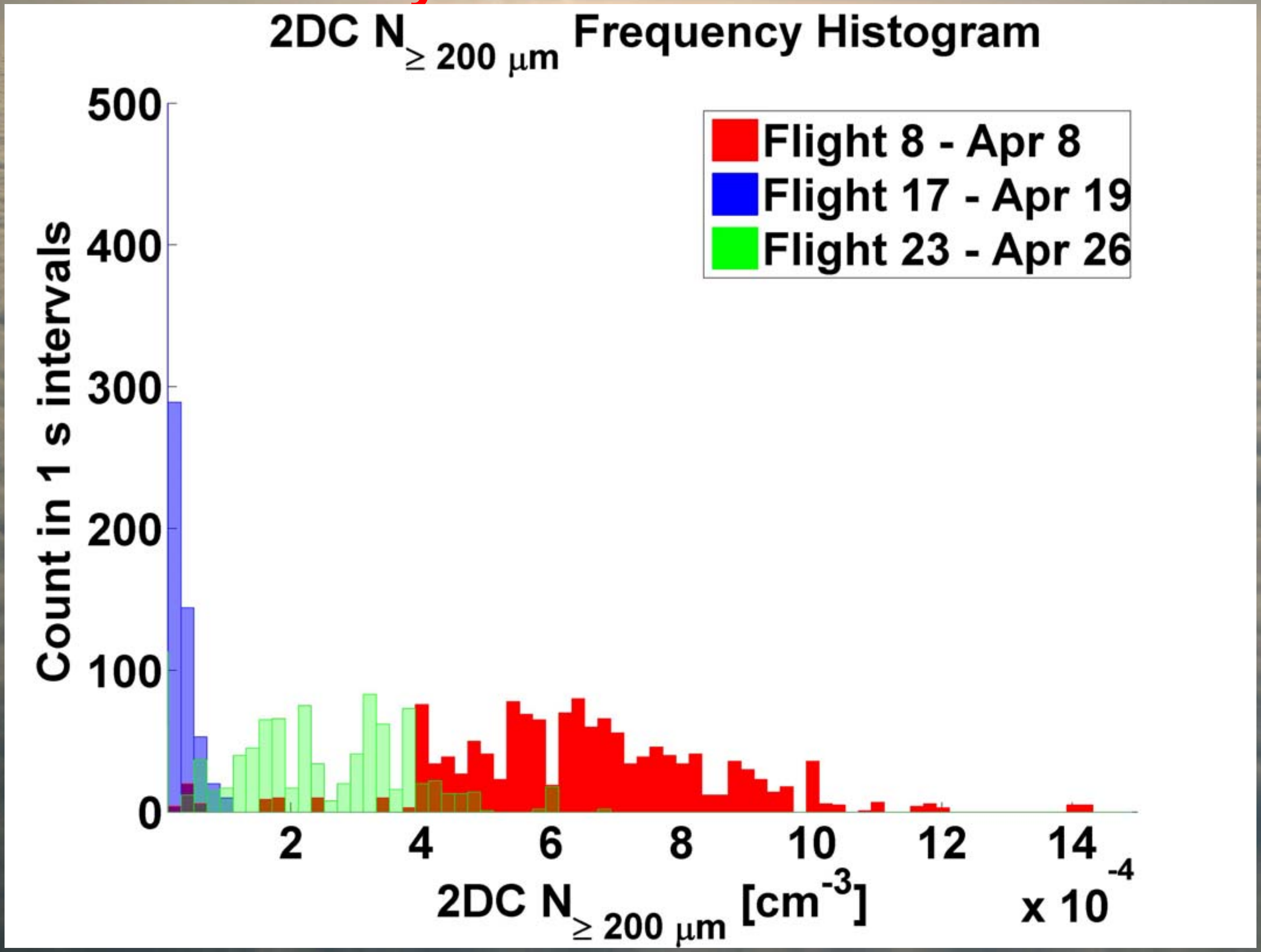
Preliminary Results

Preliminary Results



Cloud droplet number concentrations appear to be larger on polluted day of 19 Apr. compared to more pristine day of 8 Apr.

Preliminary Results



Cloud droplet number concentrations appear to be larger on polluted day of 19 Apr. compared to more pristine day of 8 Apr.

Also see variations in the ice crystal concentrations

Summary

- FSSP/CAS biased by shattering → use CDP for small crystals (we did not have such data for M-PACE)
- 2D-S gives us cloud particles for 50 < D < 125 μm, an important range where we were lacking data from M-PACE
- Have many probes for D > 125 μm: also have enhanced capability for removing shattered artifacts from these data did not have for M-PACE (still some uncertainties)

Available

- Microphysical data available in archive (e.g., N(D) from each probe)
- Beta version phase id scheme available
- Time period of all vertical profiles available
- Illinois working on cloud product (like we did for M-PACE, subject of R. Jackson M.S.)
- Completed calibration of CPI in Manchester in Aug. 2009, will allow us to estimate SDs from CPI

ISDAC Session

10:45 – 11:00: Peter Liu, Droplet closure studies using ISDAC data

11:00 – 11: 15: Mikhail Ovtchinnikov, On modeling ice-liquid partitioning in mixed phase arctic stratus: effects of cloud dynamics and microphysics representation

11:15 – 11:30: Jiwen Fan, ISDAC case studies: model simulations and observations

11:30 – 11:45: Amy Solomon, The radiative and dynamical impact of aerosols on mixed-phase clouds observed during ISDAC & M-PACE

11:45 – 12:00: Alex Avramov, Ice formation closure during ISDAC: Flight 31 as a first modeling case study

12:00 – 12:15: Ismail Gultepe, Surface observations during ISDAC: Light precipitation and ice fog occurrence

ISDAC Session

1:30 – 1:45: Xiaohong Liu, Effects of mixed-phase cloud ice nucleation parameterizations on clouds, radiation and climate

1:45 – 2: 00: Nicole Shantz, Aerosol effects on ice, liquid and mixed-phase clouds during ISDAC flights

2:00 – 2:15: Ismail Gultepe, Microphysical parameterizations based on ISDAC aircraft observations and aerosol-cloud effects on radiative fluxes

2:15 – 2:30: Rich Ferrare, High Spectral Resolution Lidar (HSRL) aerosol/cloud measurements during the ARCTAS/ISDAC campaigns

2:30 – 2:45: Hugh Morrison, Preliminary results from WMO/GCSS SHEBA model intercomparison

2:45 – 3:00: B. van Diedenhoven, Simulating lidar depolarization by aerosols and clouds: Lessons from the SHEBA campaign

Questions for Break-out

- Do we want to attempt to establish integrated cloud product between research groups (Illinois, SPEC, EC)?
- What parameters need to be included on list?
- Do we also want to establish an integrated aerosol product between research groups?
- Interface between models/observations
- BAMS paper contributions!!!
- ISDAC paper list
- How to attribute uncertainties?