Small Ice Particles in Upper Tropospheric Clouds

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McFarquhar et al. (GRL, 2007)

ARM-UAV
PROTEUS

OUTLINE

- ✓ Shattering effect
- ✓ CAS and CDP
- ✓ N_{CAS} and N_{CDP}
- ✓ Theoretical calculation
- ✓ Case study
- ✓ Impacts of small ice crystals
- ✓ Summary

Shattering Effect ?

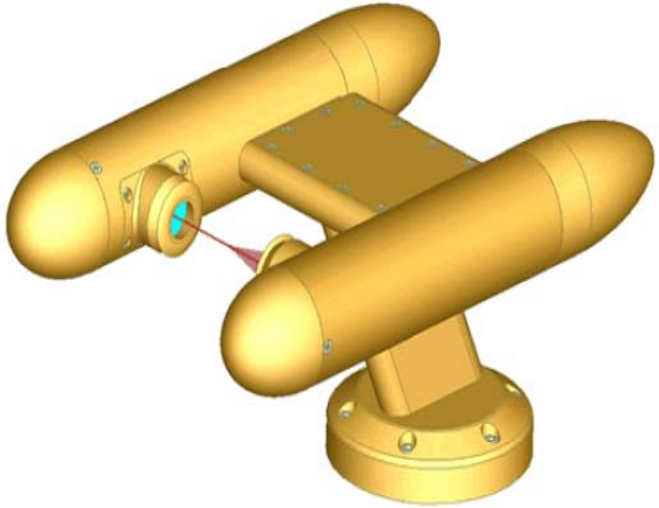
Do ice crystals shatter on the protruding tips of a probe giving high concentrations of small ice crystals

CAS Vs CDP

Cloud and Aerosol Spectrometer

Shroud **Inlet**

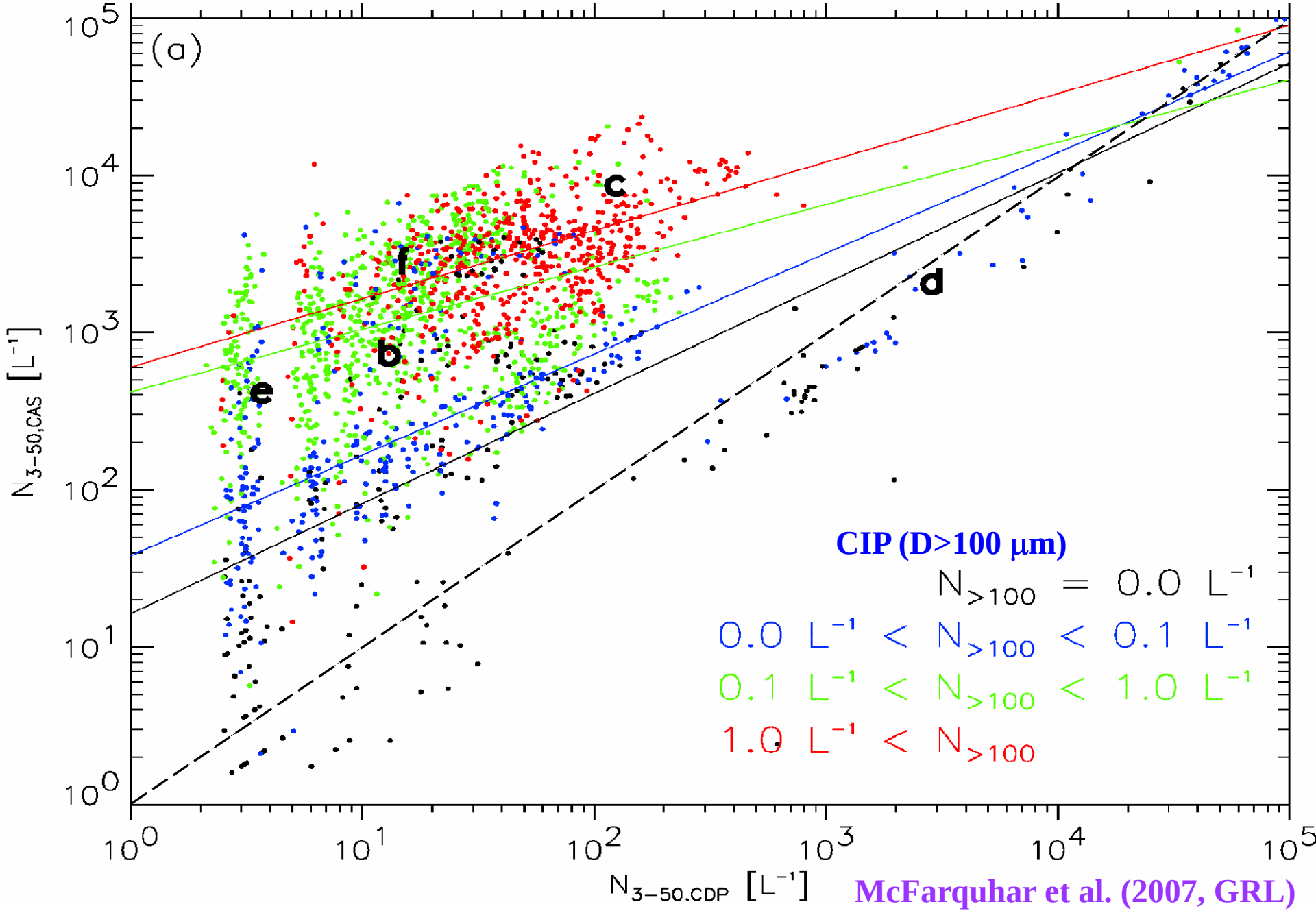
Cloud Droplet Probe

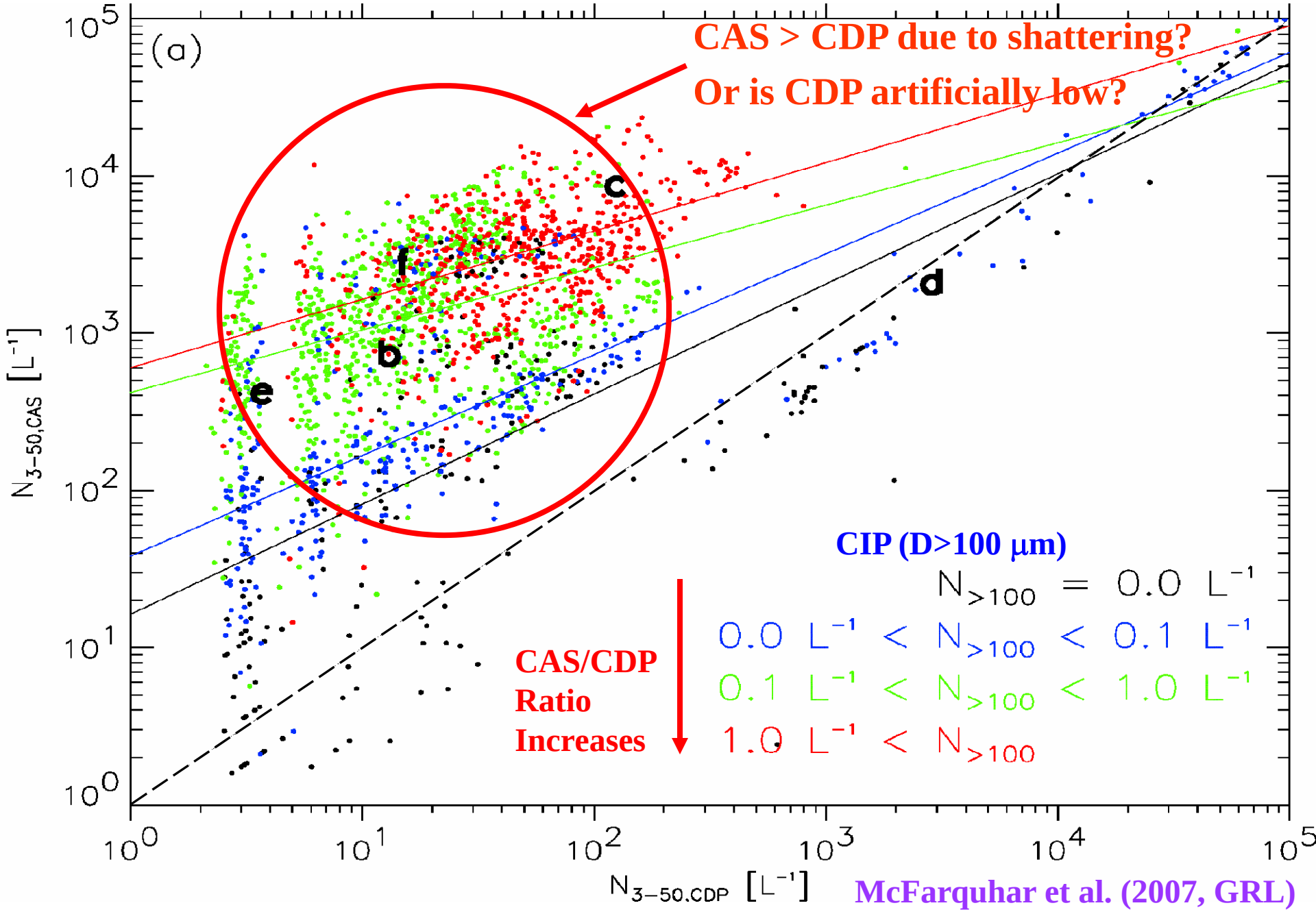


- **Open path**
- **Neither inlet nor shroud**

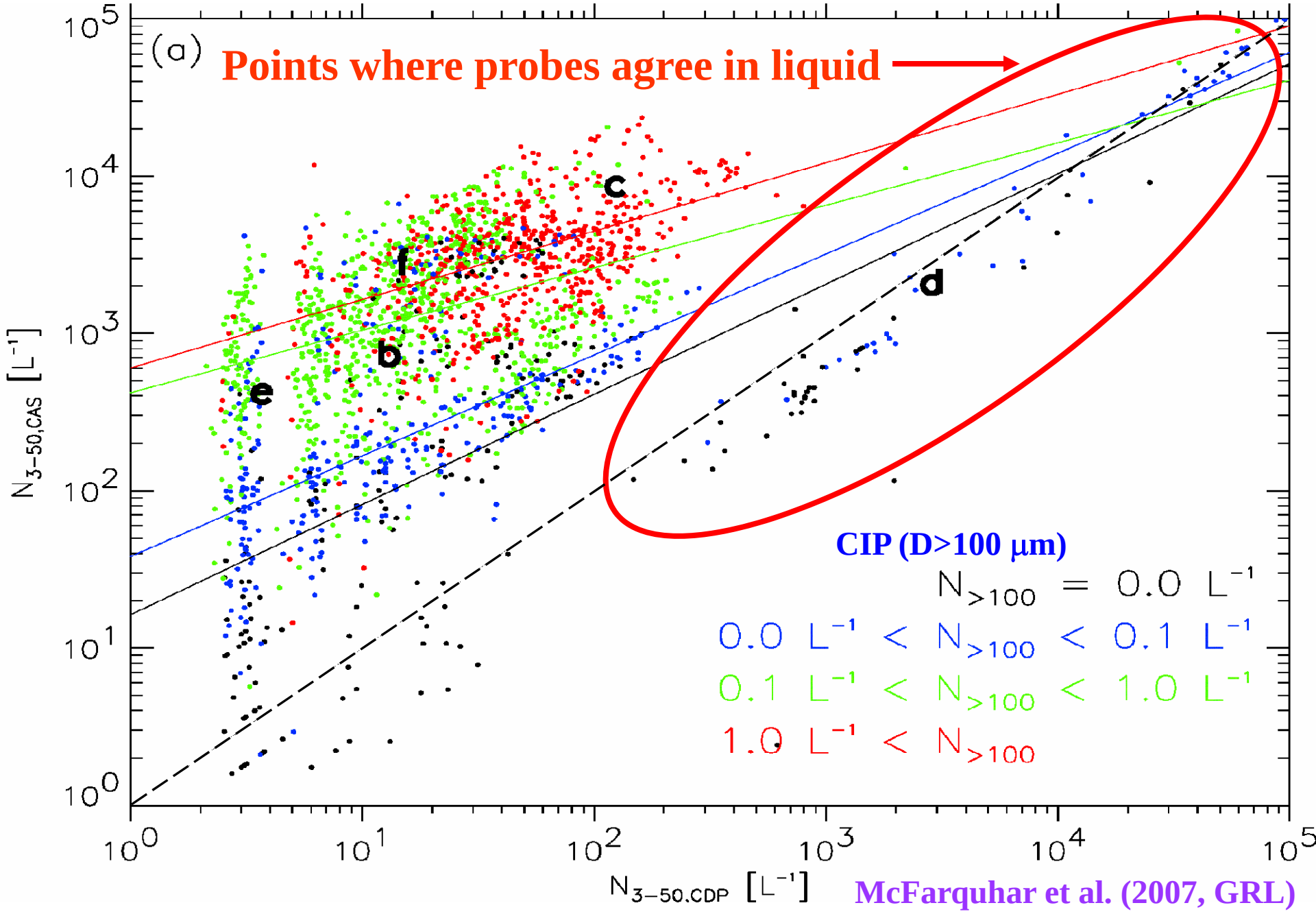
✓ **The same working principle and look-up table**

✓ **Shattering due to an inlet or shroud?**


(a)
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
N3−50,CAS [L⁻¹]
N3−50,CDP [L⁻¹]
McFarquhar et al. (2007, GRL)



McFarquhar et al. (2007, GRL)


(a)
Points where probes agree in liquid
c
f
b
e
d
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
N3−50,CAS [L⁻¹]
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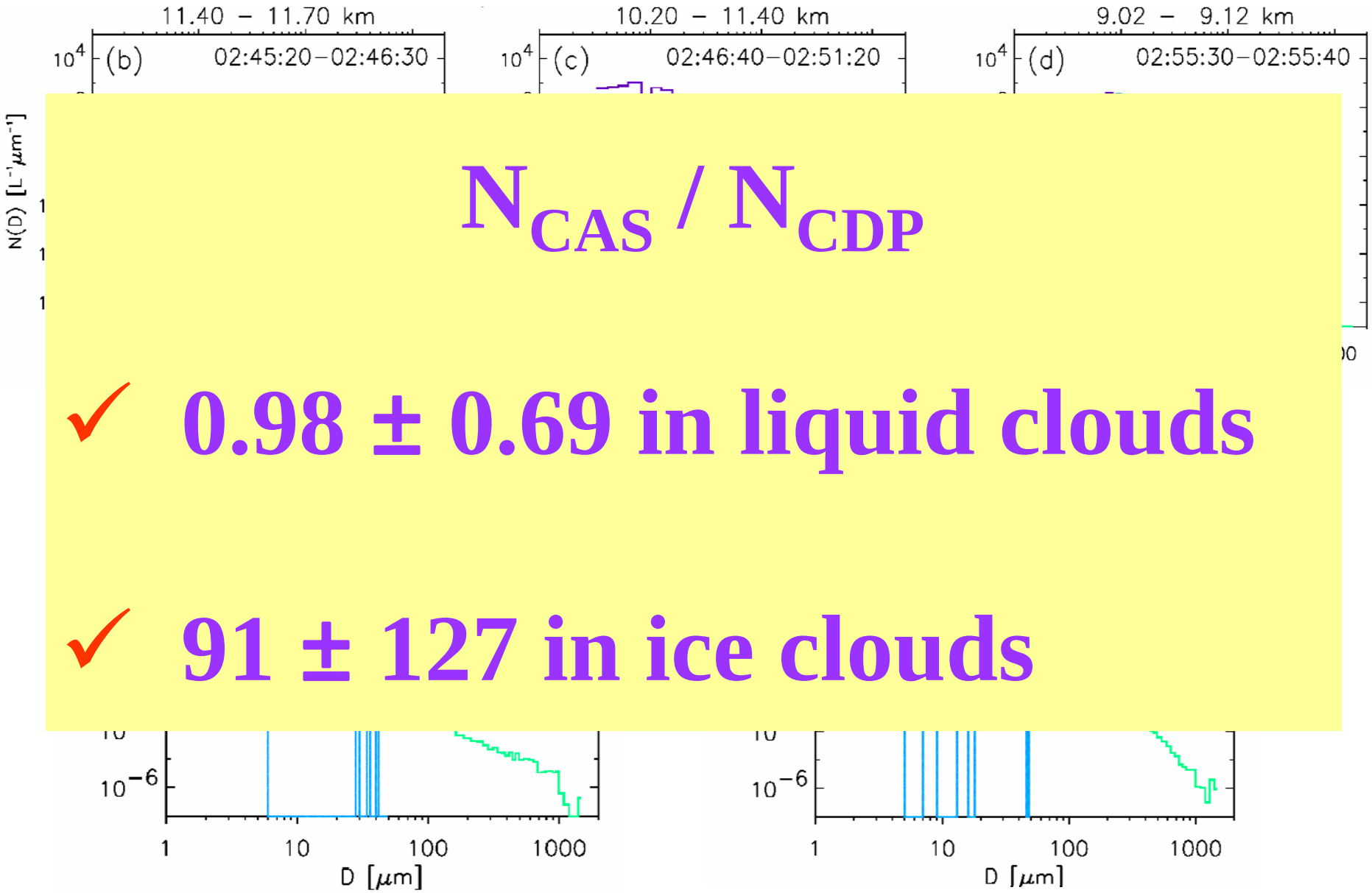
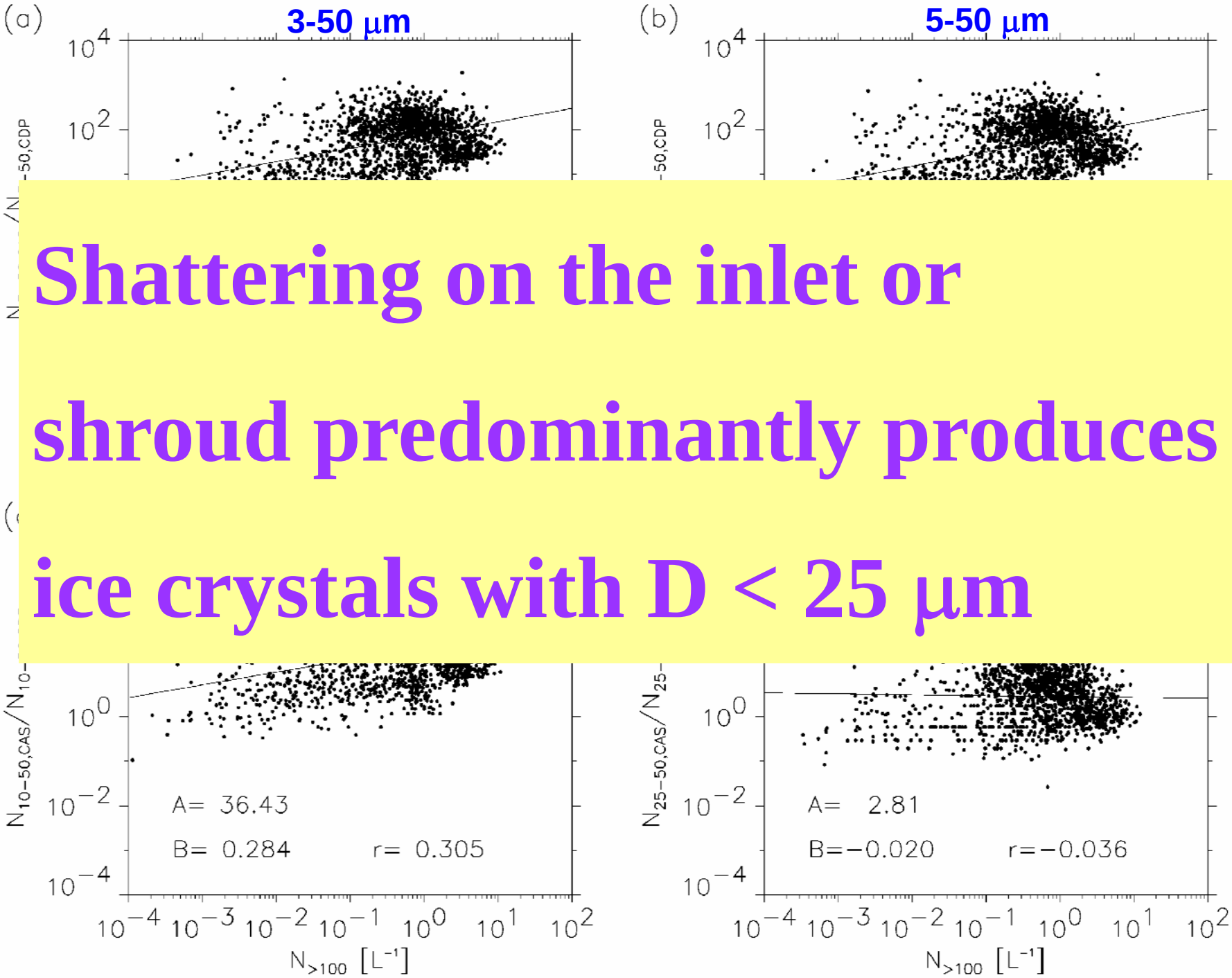
Liquid



N_{CAS} / N_{CDP}

- ✓ **0.98 ± 0.69 in liquid clouds**
- ✓ **91 ± 127 in ice clouds**

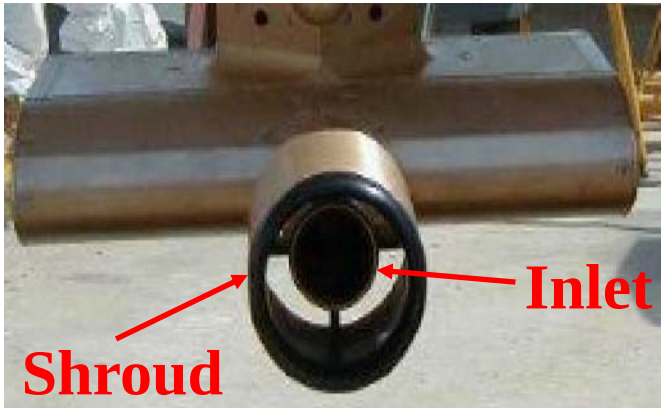
McFarquhar et al. (2007, GRL)



Shattering on the inlet or shroud predominantly produces ice crystals with D < 25 μm

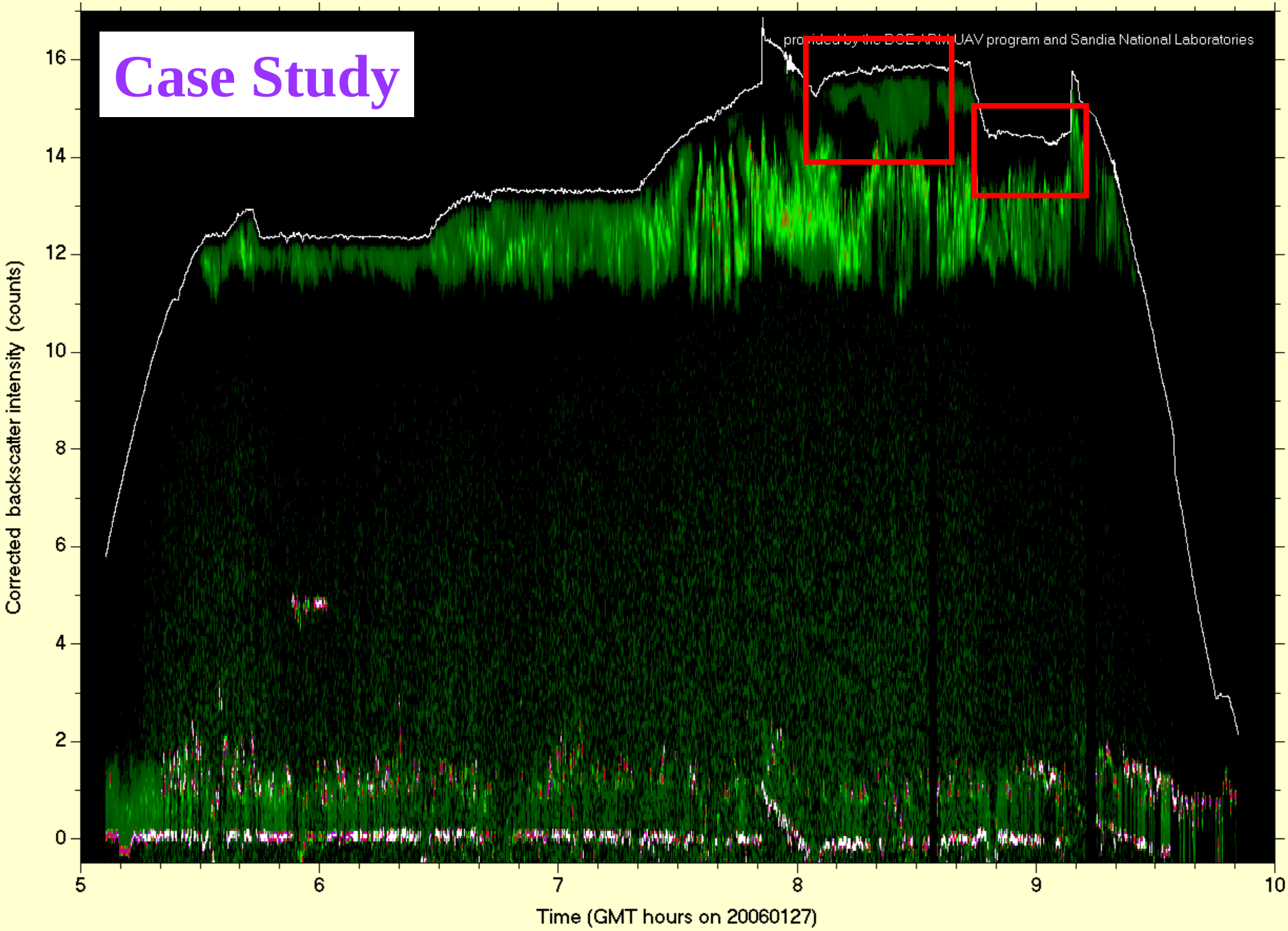
Theoretical Calculation of Shattering

- **TAS = 130 ms^{-1}**
- **IWC= 0.1 gm^{-3}**

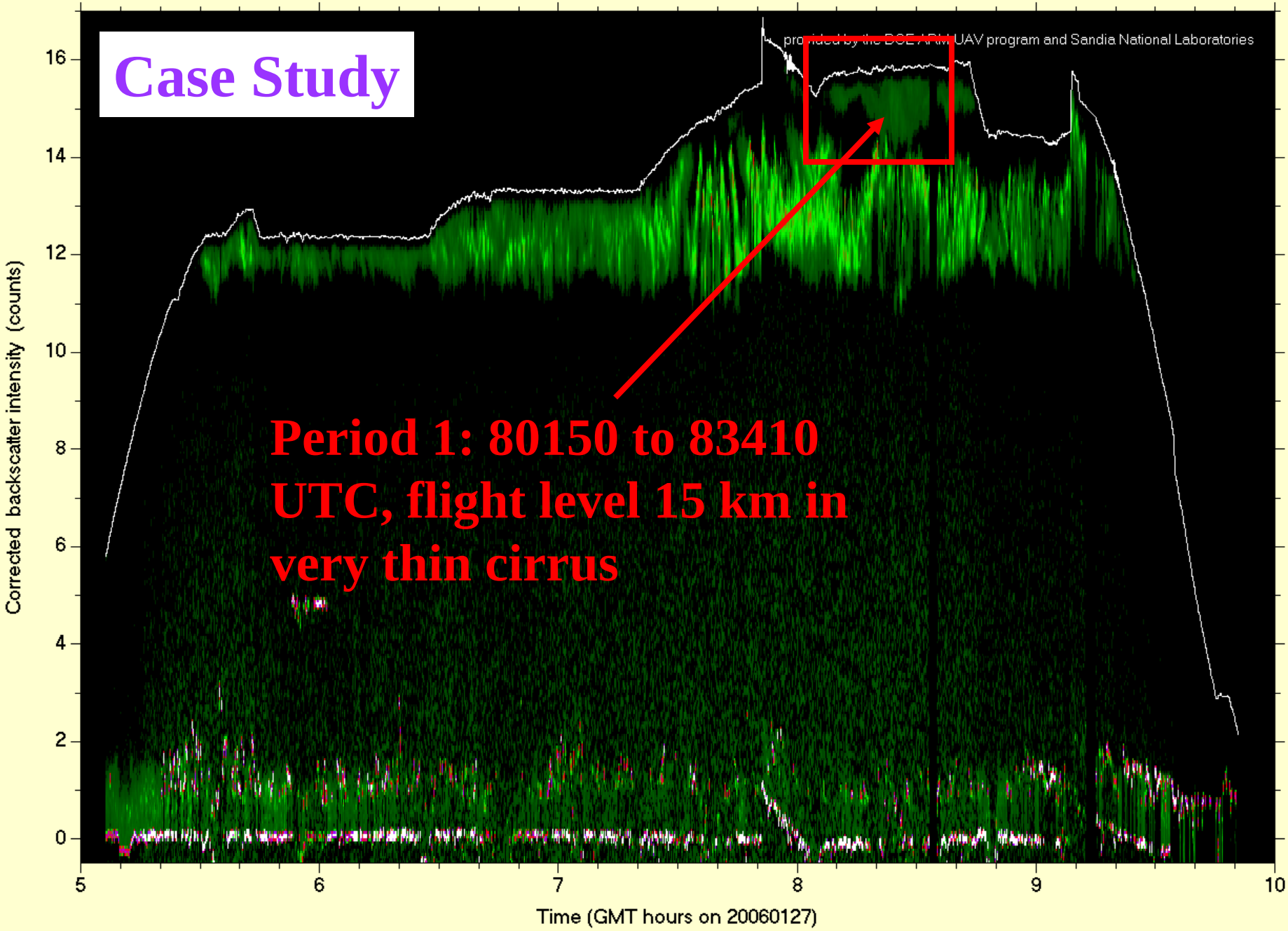


(s^{-1})	Inlet	Shroud
10 μm	1.4×10^{7}	4.0×10^{8}
25 μm	8.8×10^{5}	2.5×10^{7}

Cloud Detection Lidar (CDL) corrected data for flight 20060127.033000



Cloud Detection Lidar (CDL) corrected data for flight 20060127.033000



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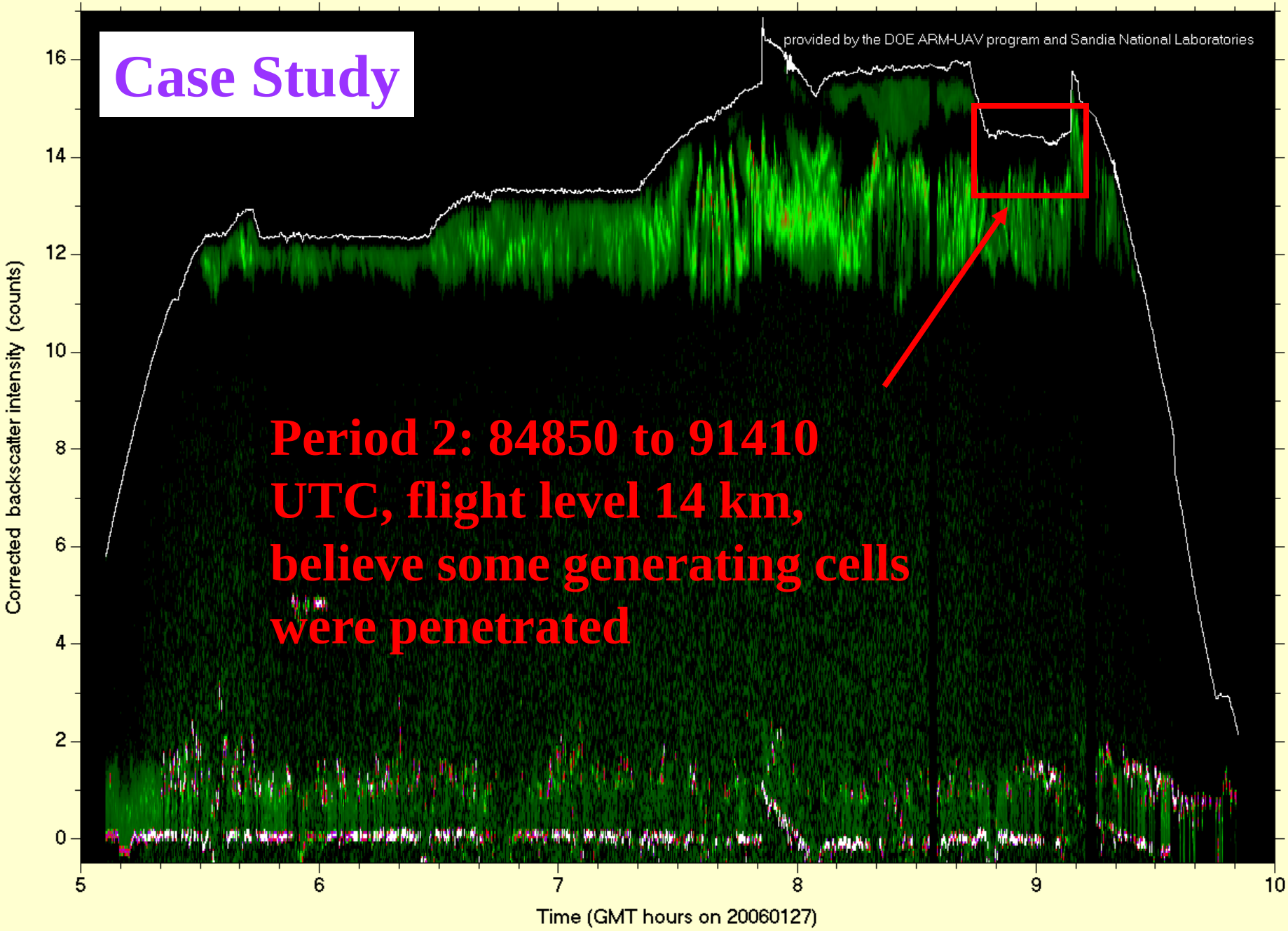
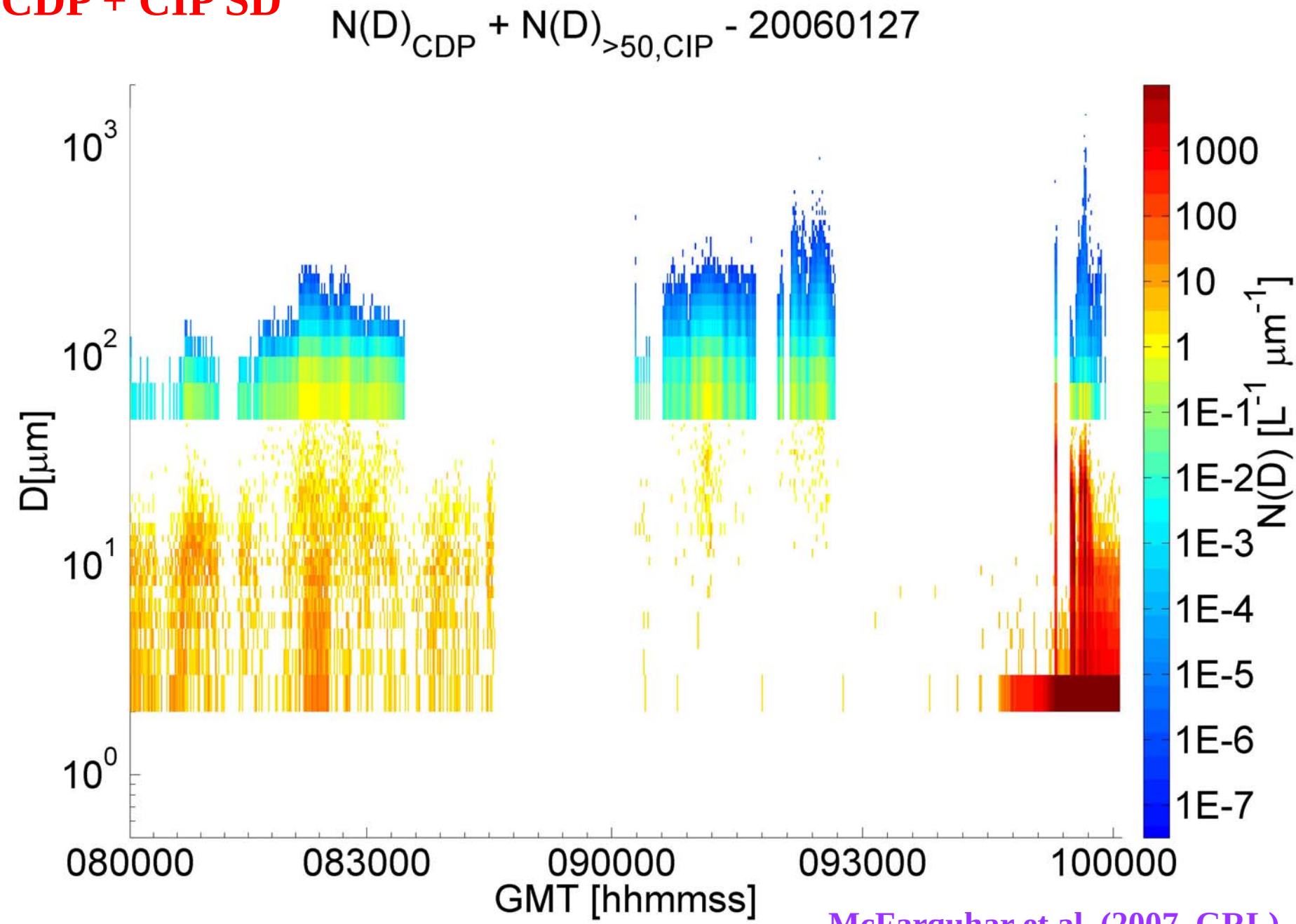
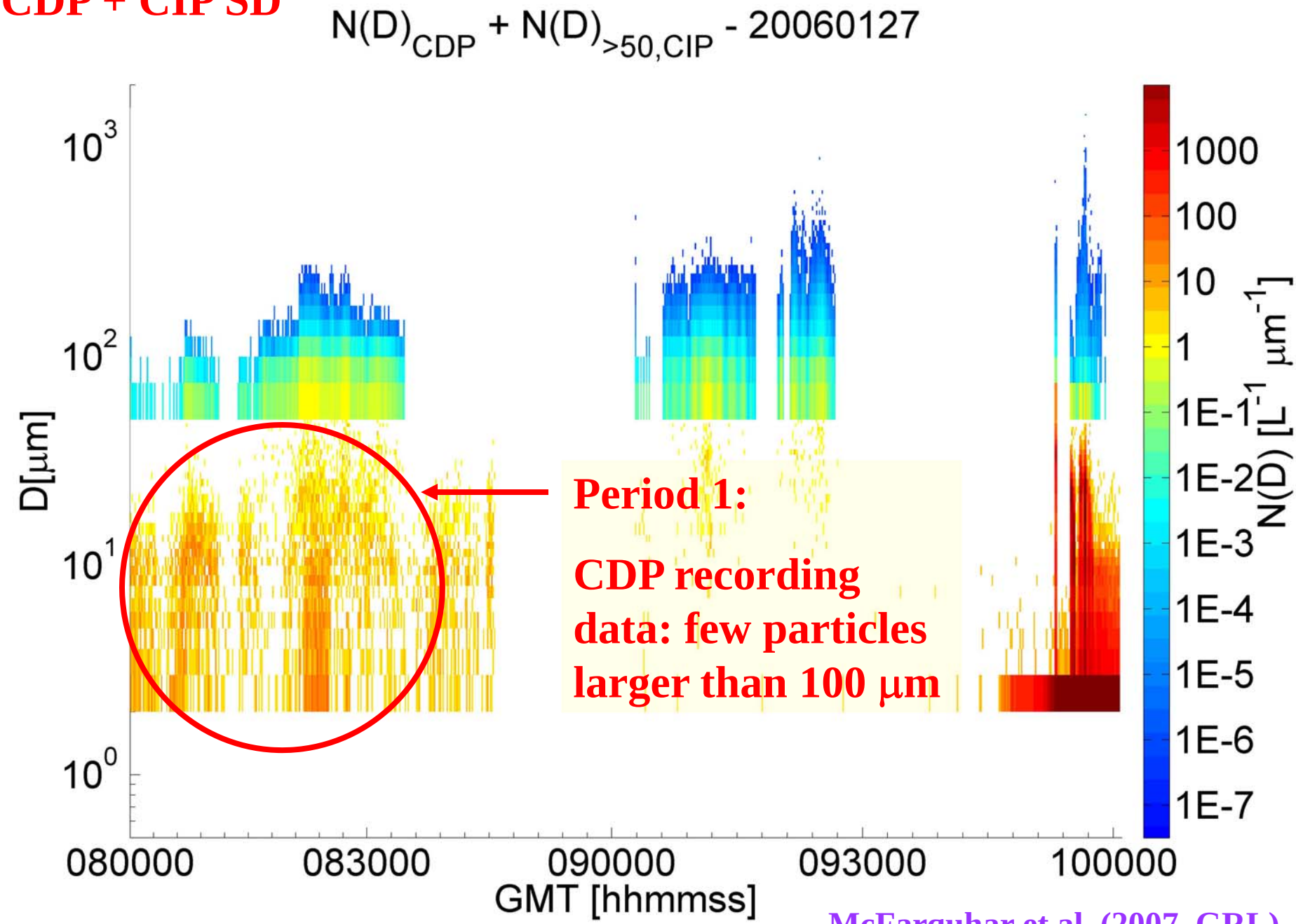


CDP + CIP SD



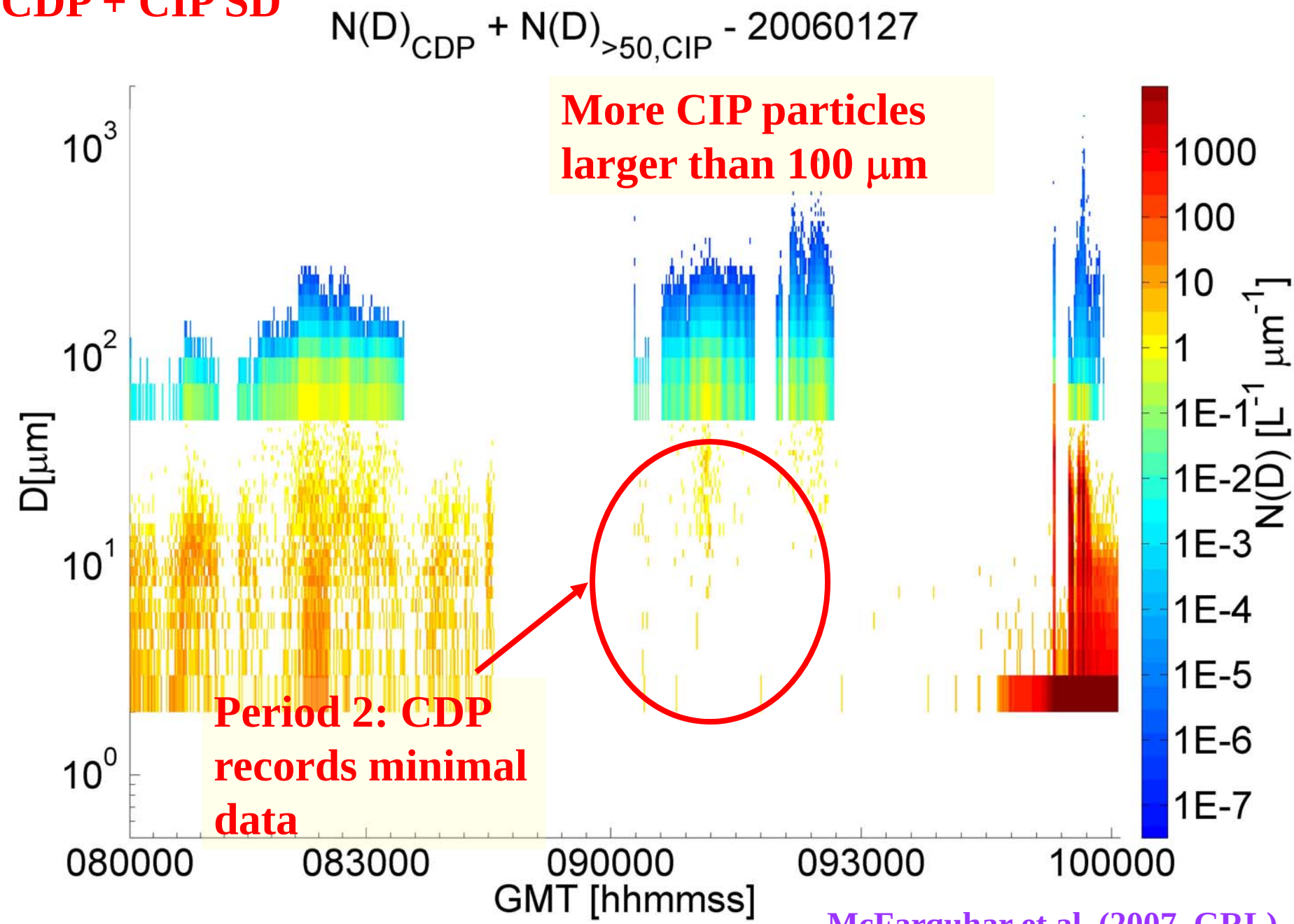
McFarquhar et al. (2007, GRL)

CDP + CIP SD



McFarquhar et al. (2007, GRL)

CDP + CIP SD



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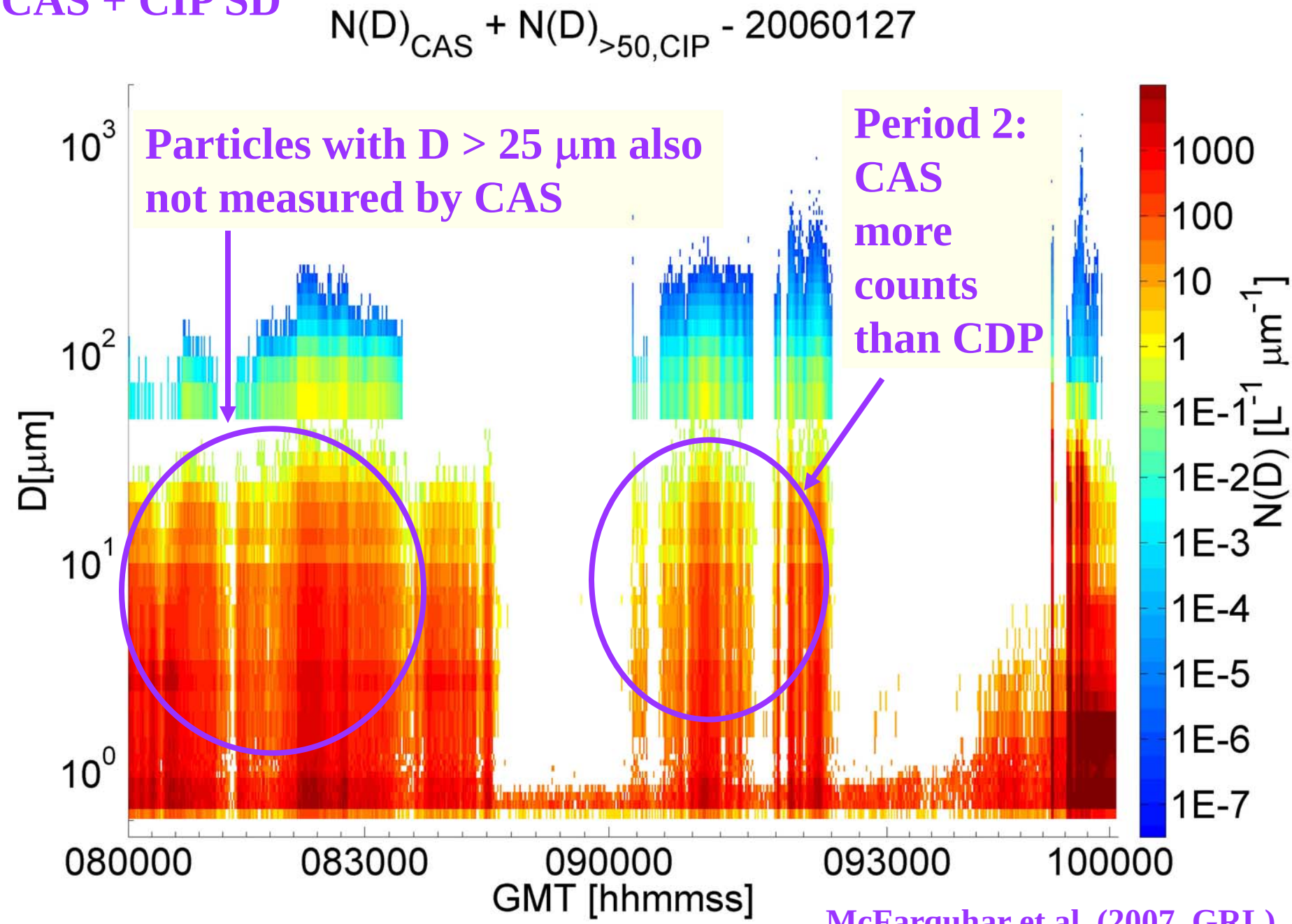
CAS + CIP SD



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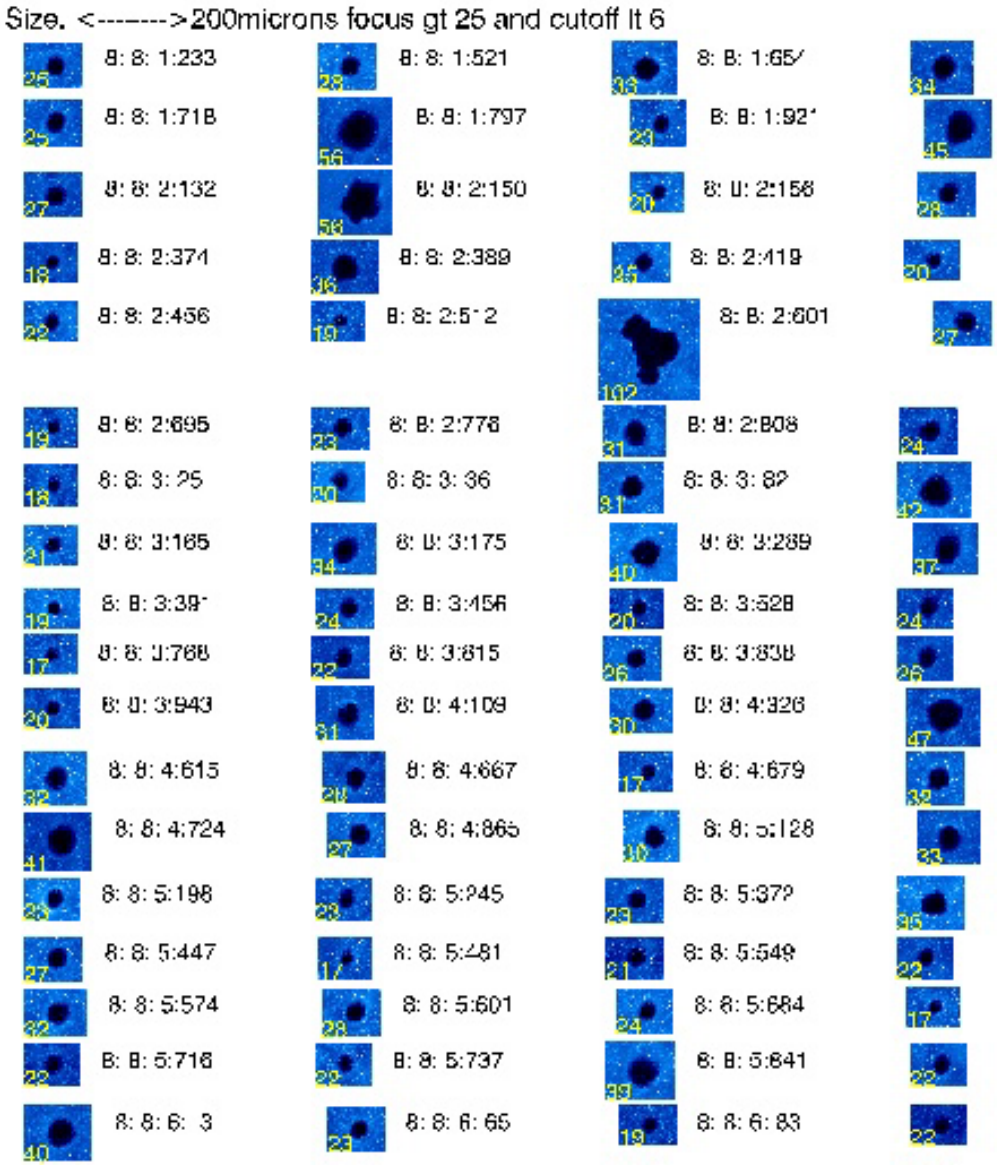


Period 1

- ✓ **Most quasi-spherical & particles have D < 50 μm**
- ✓ **Total number (79 %)**
- ✓ **Total mass (19 %)**
- ✓ **Roundness (0.94)**

Period 2

- ✓ More non-spherical and larger particles present
- ✓ Total number (35 %)
- ✓ Total mass (1.5 %)
- ✓ Roundness (0.86)

Shattered-looking particles

Impacts of Small Ice Crystals

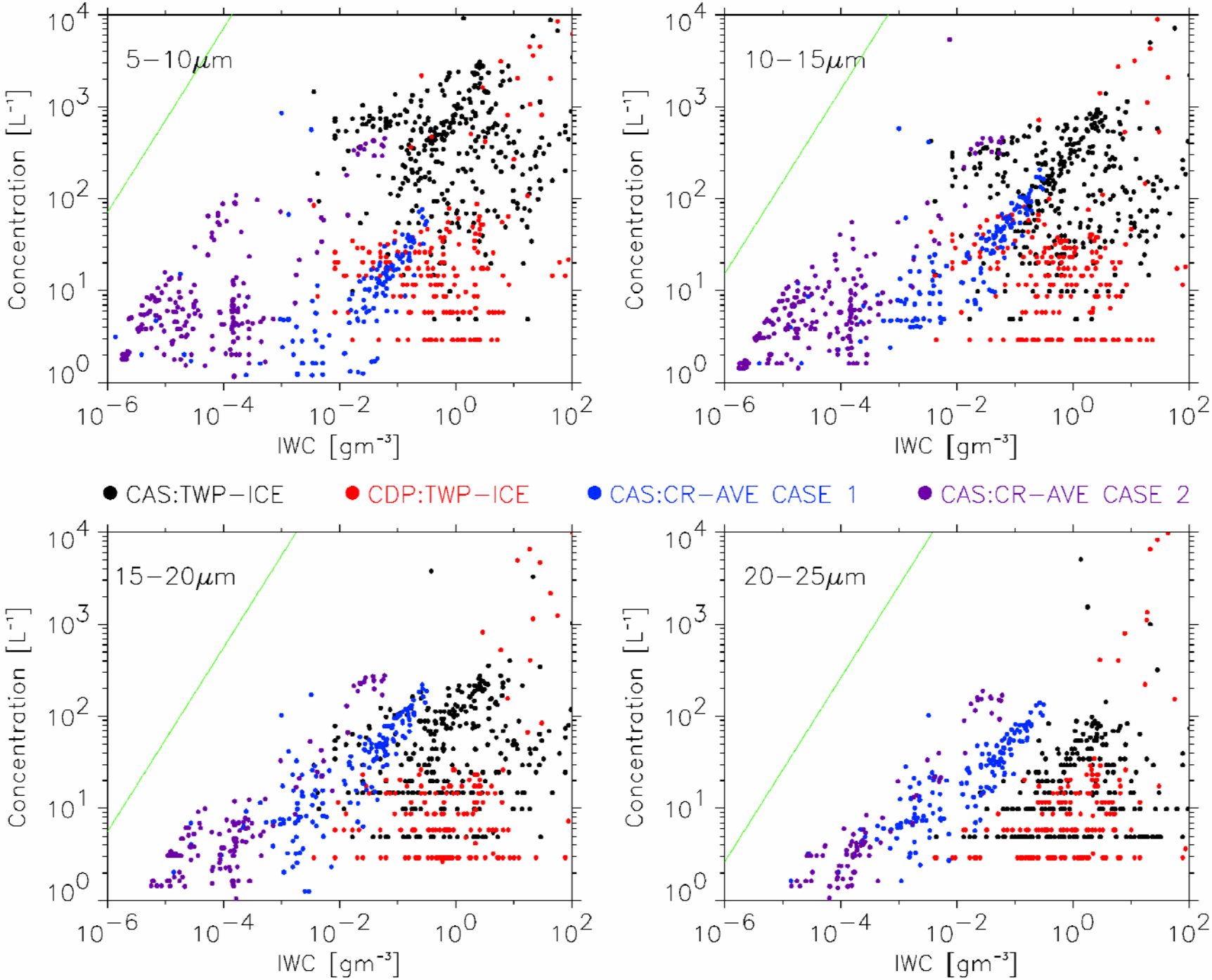
N_T(300%), extinction (106%), and IWC(49%) can be overestimated by the shattering

From 0127, 0129, and 0202 flights

Summary

- ✓ **Ice crystals (D < 25 μm) predominantly produced by the shattering**
- ✓ **CAS & CDP good agree in liquid clouds, while not in ice clouds**
- ✓ **N_T(300%), extinction (106%), and IWC(49%) can be overestimated by the shattering**
- ✓ **Observation with more probes in cloud types and meteorological conditions**

Questions?


5−10μm
10−15μm
15−20μm
20−25μm
Concentration [L⁻¹]
IWC [gm⁻³]
CAS:TWP−ICE
CDP:TWP−ICE
CAS:CR−AVE CASE 1
CAS:CR−AVE CASE 2

- ✓ **Most parameterization schemes depend on in situ FSSP measurements**

- ✓ **Recent experiments with the NCAR GCM (CAM) indicate that it is very sensitive to the formulation of the ice crystal size distribution, especially the concentration assumed for small ice crystal.**

- ✓ **1-year CAM simulations with higher concentration of small ice crystals**

- ✓ **Much higher ice water path (IWP), cirrus coverage, and heating rates**

- ✓ **3 degree higher temperature in the upper tropical troposphere**