The relationship of cirrus ice microphysical properties to meteorological parameters observed during SPARTICUS.

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Atmospheric System Research

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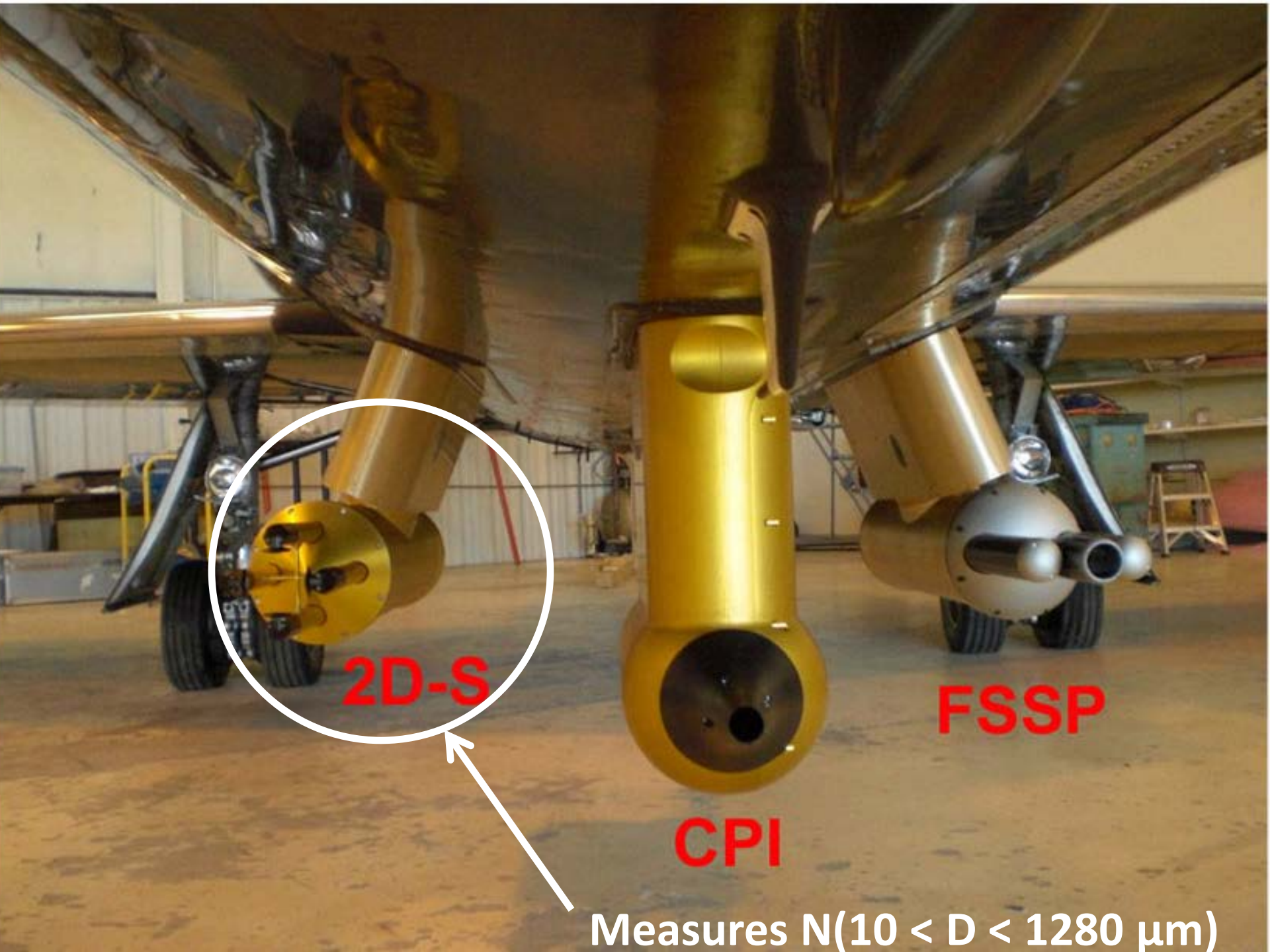
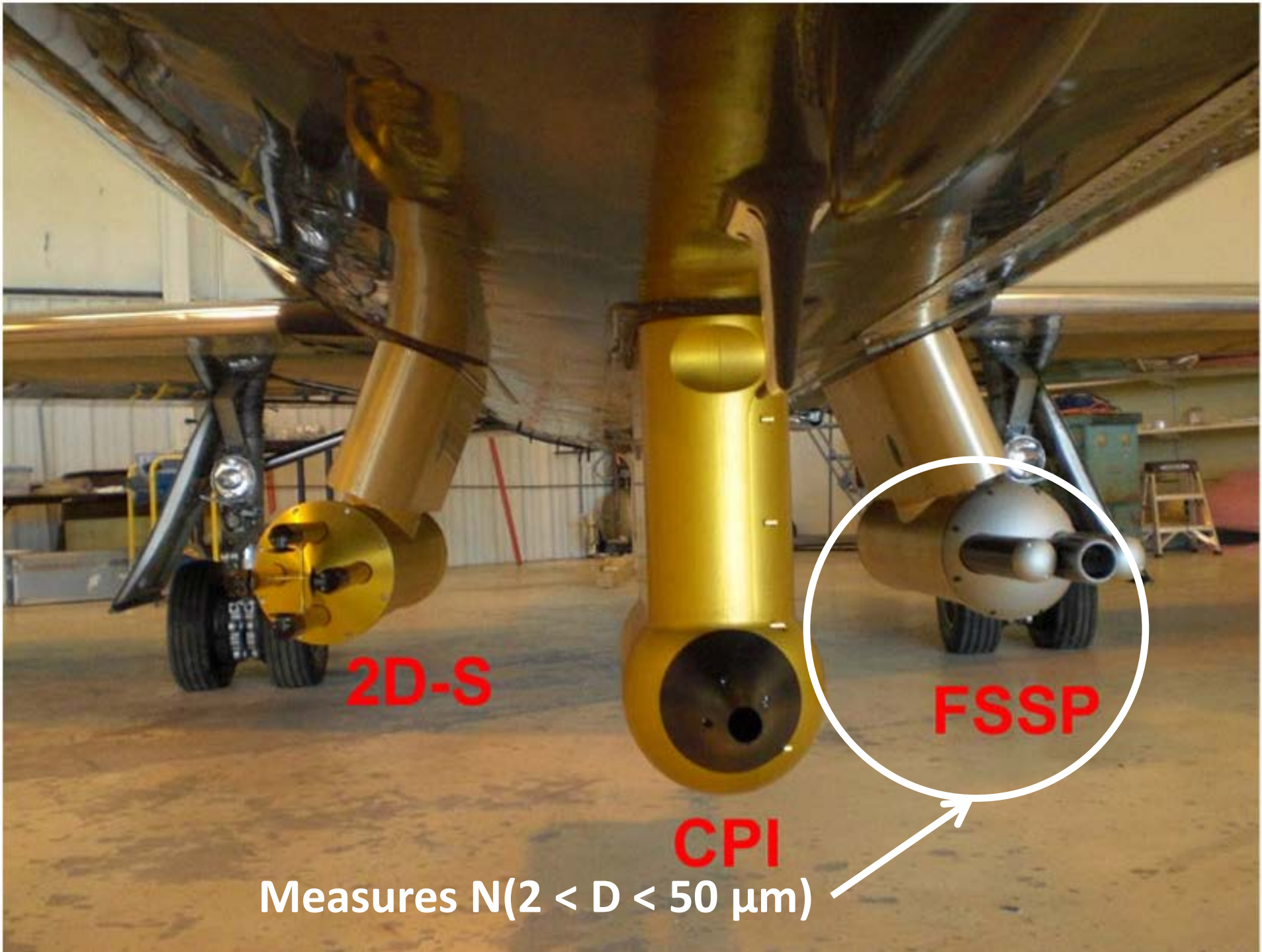
Motivation

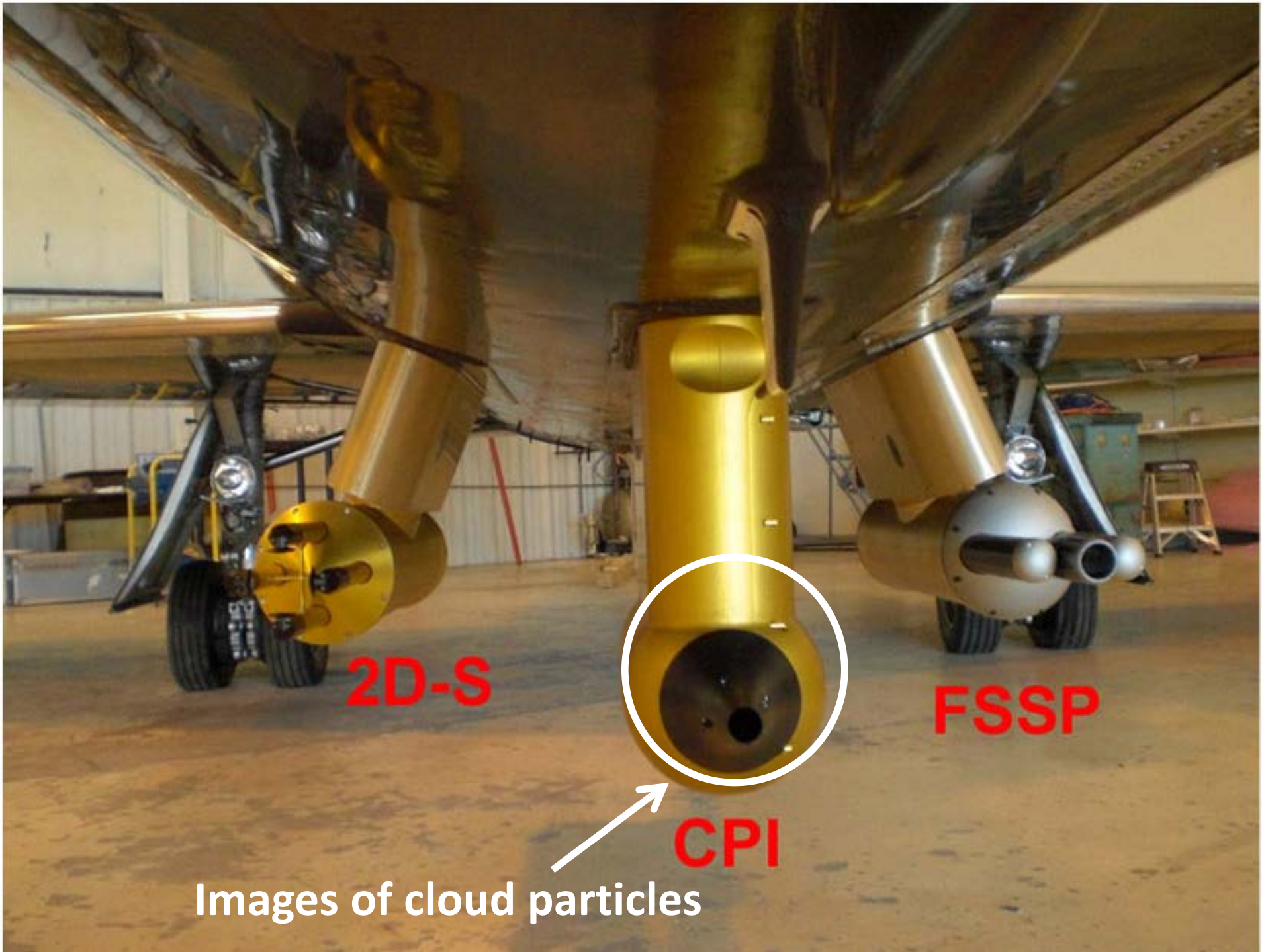
- **Impact of cirrus on the Earth's radiation budget depends on their microphysical + radiative properties.**
- **Sedimentation + single-scattering properties depend on number distribution function *N(D)*, bulk extinction *β*, median mass diameter D_{mm}, effective radius r_e, and ice water content *IWC*.**
- **To evaluate simulations and develop parameterizations for models, dependence of cirrus properties on environmental conditions (temperature, humidity, vertical velocity, formation mechanism) needed.**

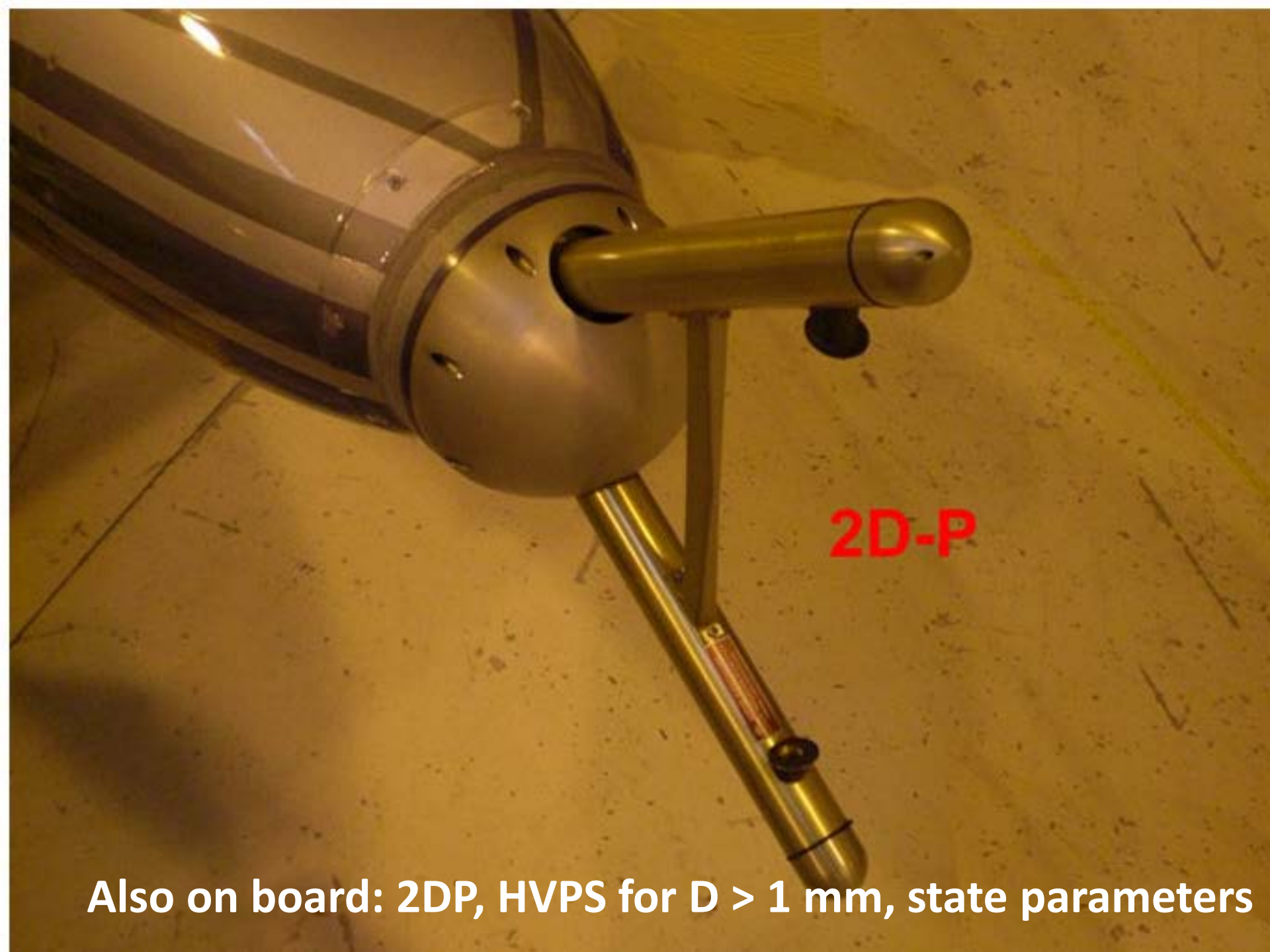
Small PARTicles in CirrUS (SPARTICUS)

Motivated by the need for a large representative dataset of mid-latitude cirrus, SPEC Learjet conducted routine flights in cirrus collecting 190 hr of data from Jan to June 2010 in the vicinity of the Southern Great Plains (SGP) site.


2D-S
FSSP
CPI
Measures N(10 < D < 1280 µm)


2D-S
CPI
FSSP
Measures N(2 < D < 50 µm)


2D-S
FSSP
CPI
Images of cloud particles



Also on board: 2DP, HVPS for D > 1 mm, state parameters

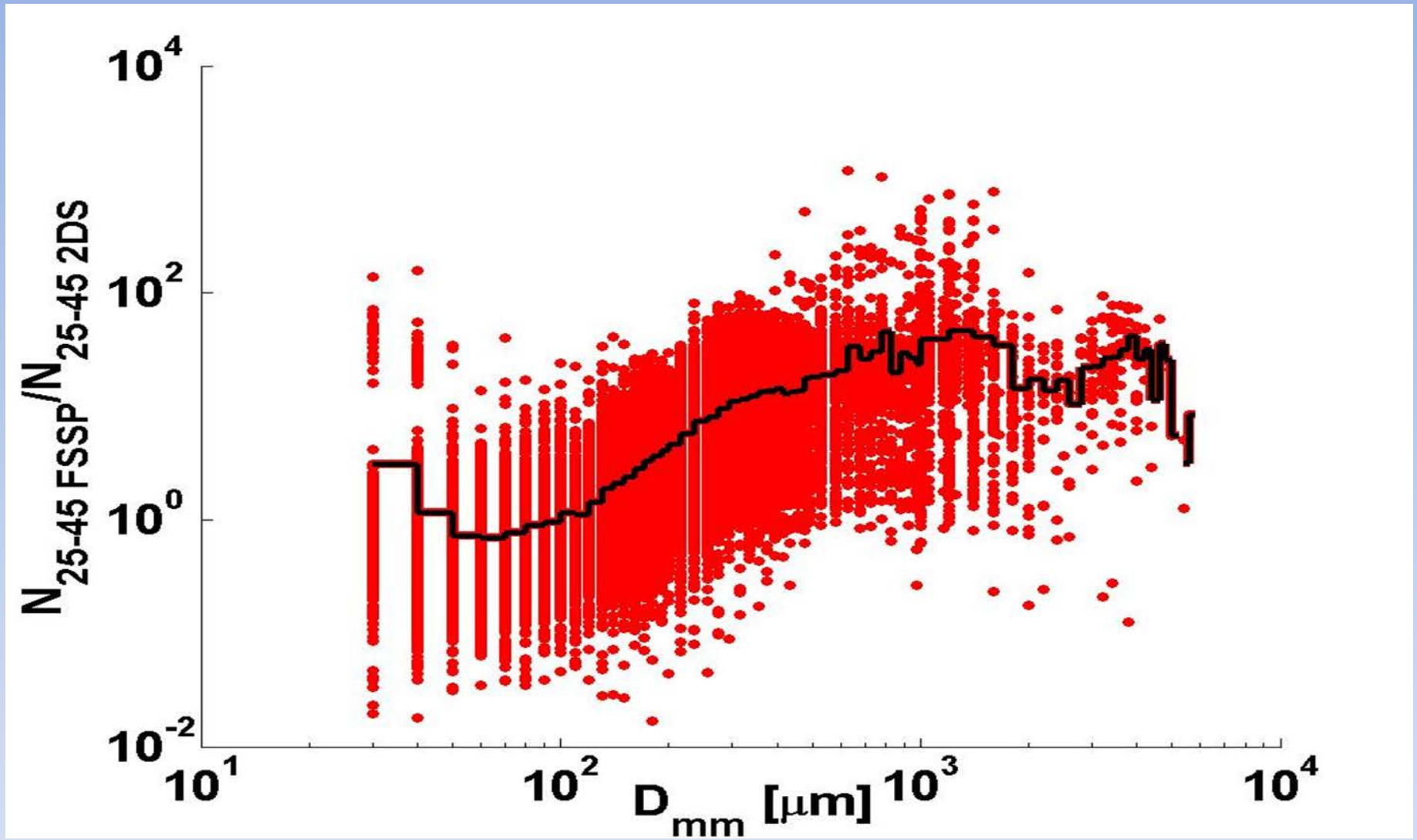
Methodology

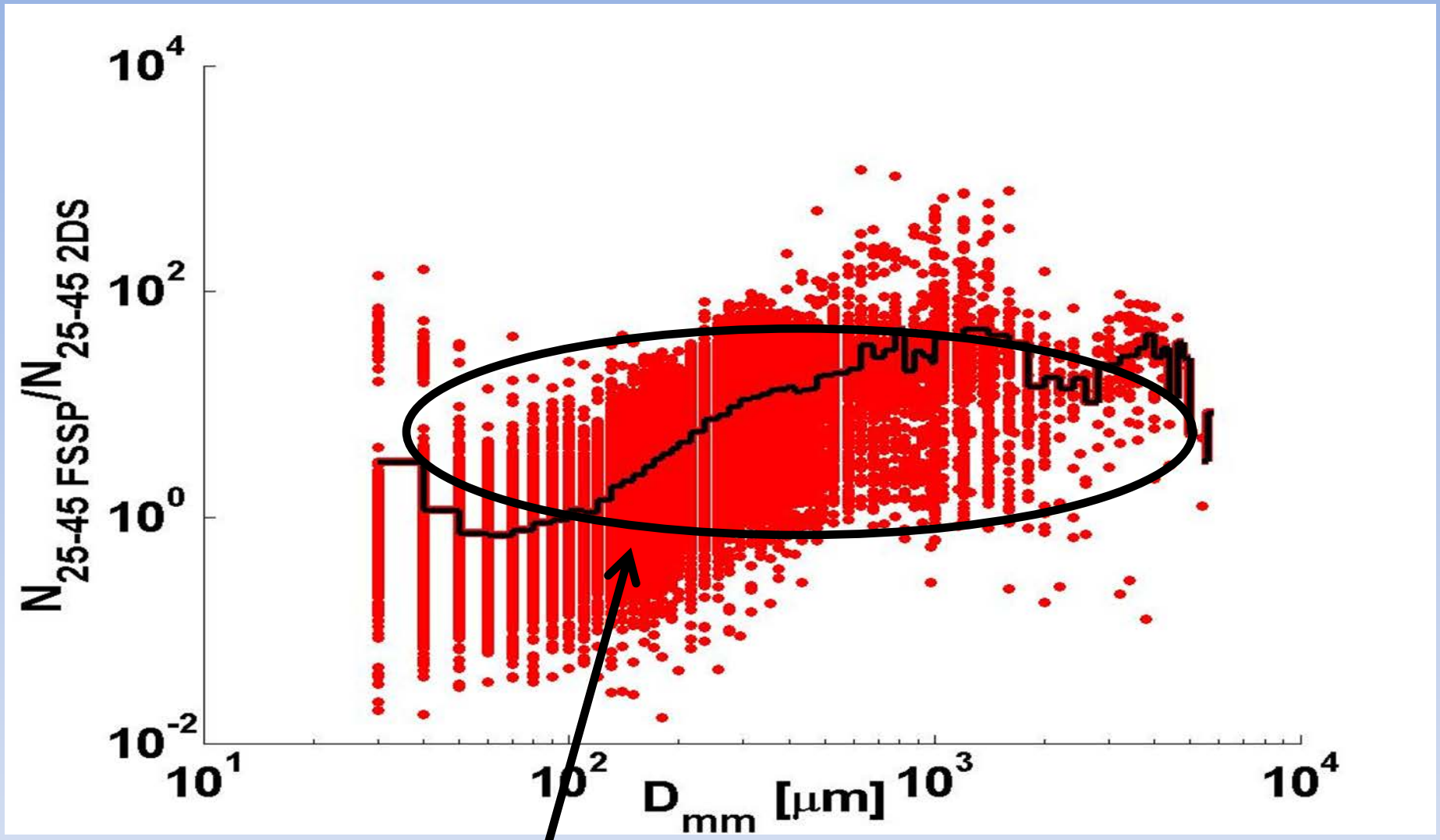
- Using flight notes, satellite imagery, and radar observations at SGP, SPARTICUS cases sorted into 3 broad categories:

Formation Mechanism	Mission
Synoptic	Jan 12, 14, 15, 19, 20, 26, 27, 31 Feb 1, 3, 4, 10, 11, 17, 19, 22 Mar 10, 14, 15, 17, 19, 23, 26, 27, 30 Apr 1, 2, 5, 6, 11a, 11c, 12, 14a, 16, 17, 19, 28, 29 Jun 7, 12b, 17, 24b
Anvil	Jan 21 Apr 14b, 22, 23, 24 Jun 4,11, 12a, 14, 15, 24a
Orographic	Mar 22, Apr 11b, June 2

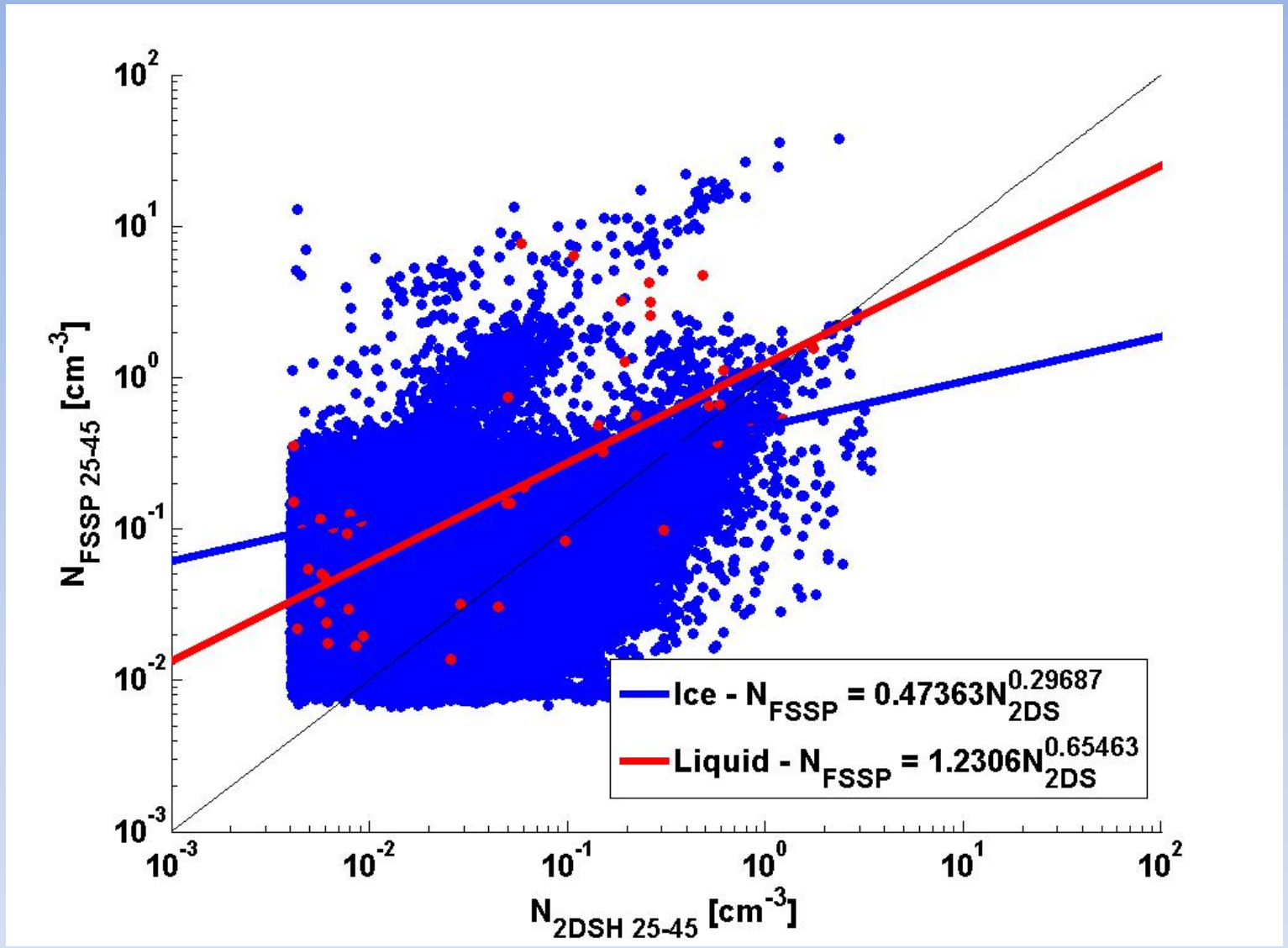
Methodology

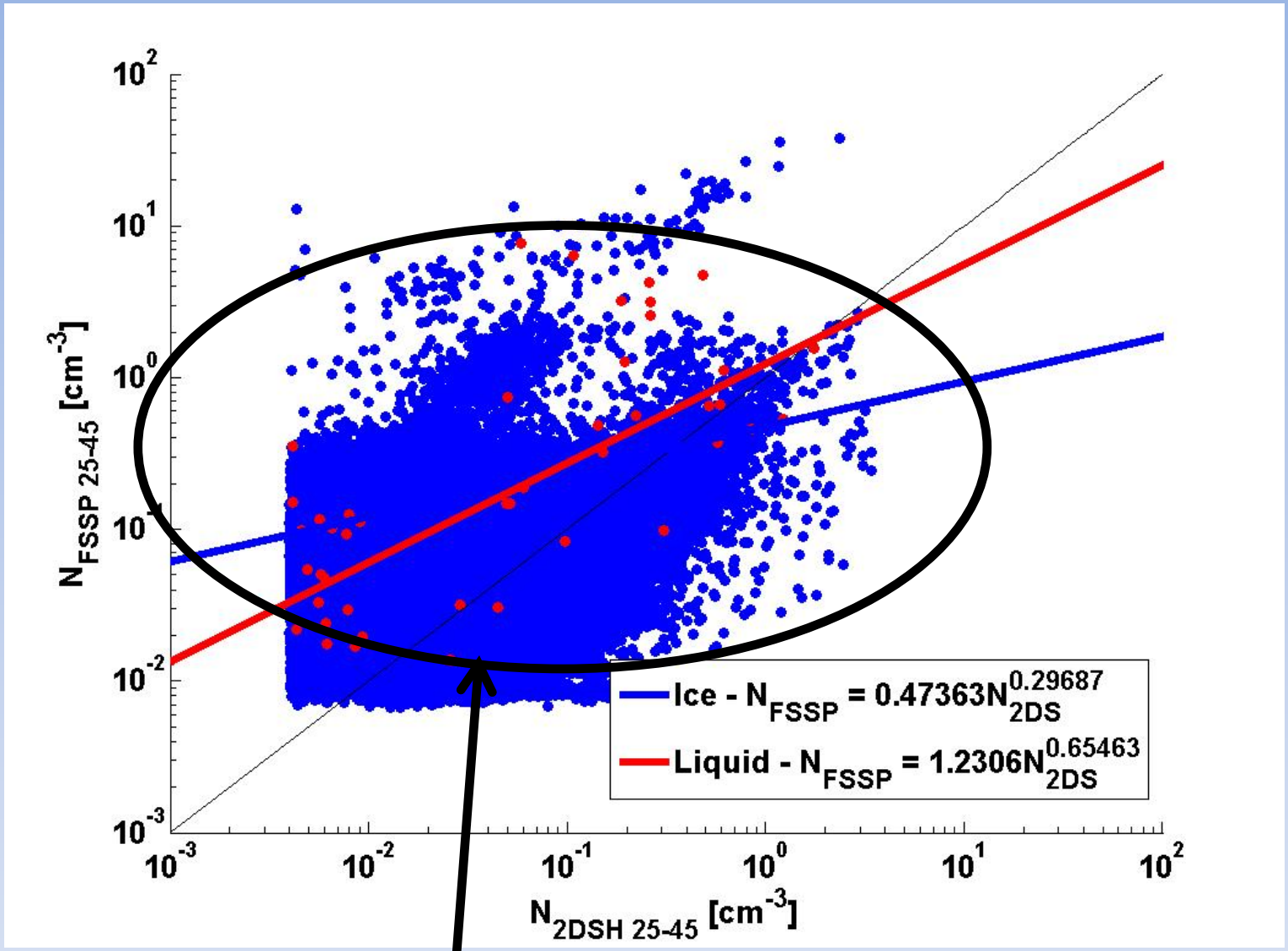
- Shattered artifact removal algorithms applied to Fast FSSP + 2DS data (Field et al. 2003; 2006).
- 2DS data processed using UIUC software.
- ***β*** from 2DS/2DP/HVPS cross sectional area
- **IWC** from 2DS/HVPS/2DP using m-D relationships determined from CPI size-habit distributions.


10^4
10^2
10^0
10^{-2}
$N_{25\text{-}45\ FSSP}/N_{25\text{-}45\ 2DS}$
10^1
10^2
D_{mm} [μm]
10^3
10^4

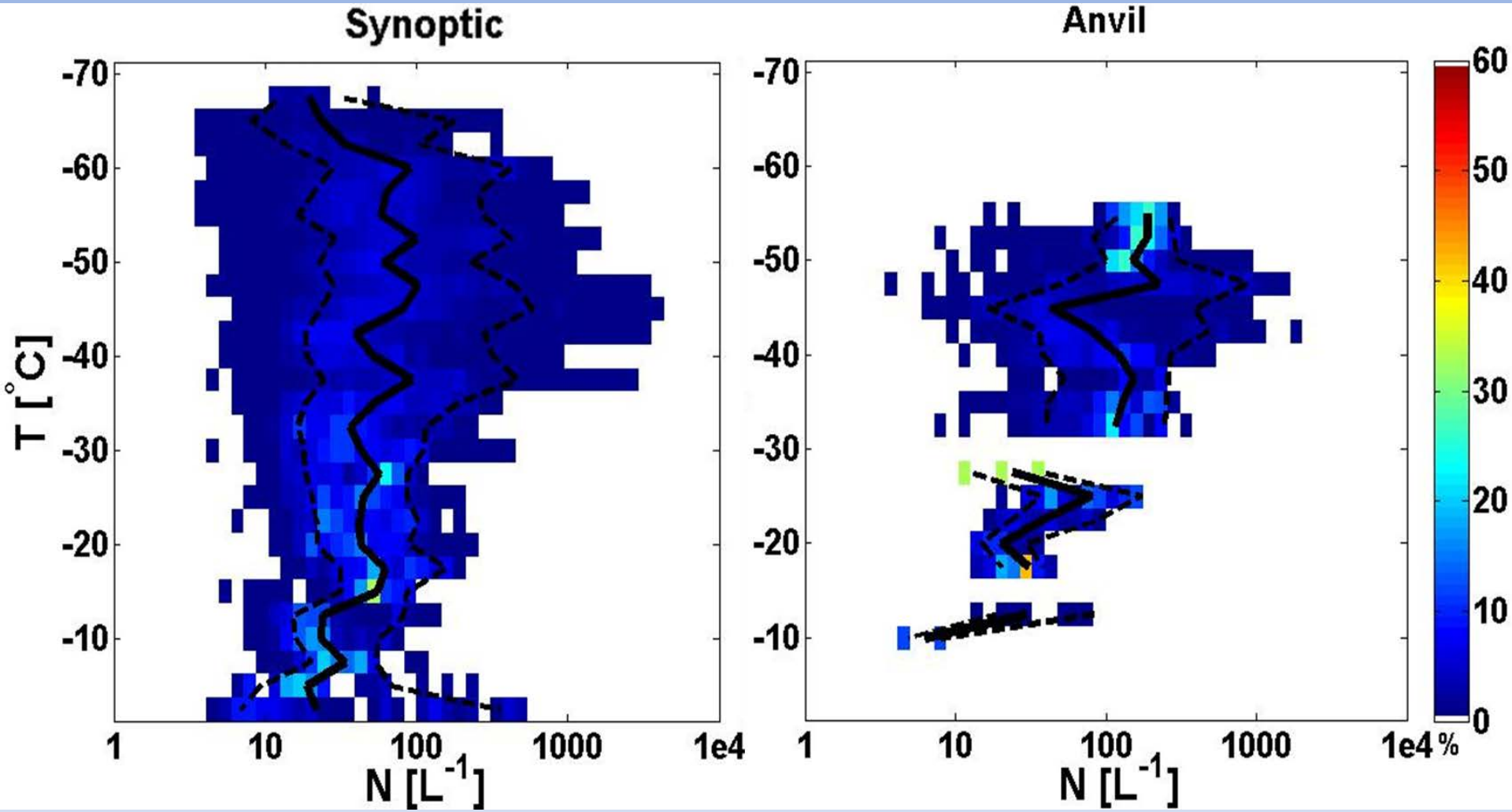


Ratio of Fast FSSP concentration/2DS concentration increases with Dmm → Fast FSSP may overestimate concentrations due to shattering even after algorithm applied.


10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
$N_{FSSP\ 25\text{-}45}$ [cm^{-3}]
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
$N_{2DSH\ 25\text{-}45}$ [cm^{-3}]
Ice - $N_{FSSP} = 0.47363N_{2DS}^{0.29687}$
Liquid - $N_{FSSP} = 1.2306N_{2DS}^{0.65463}$



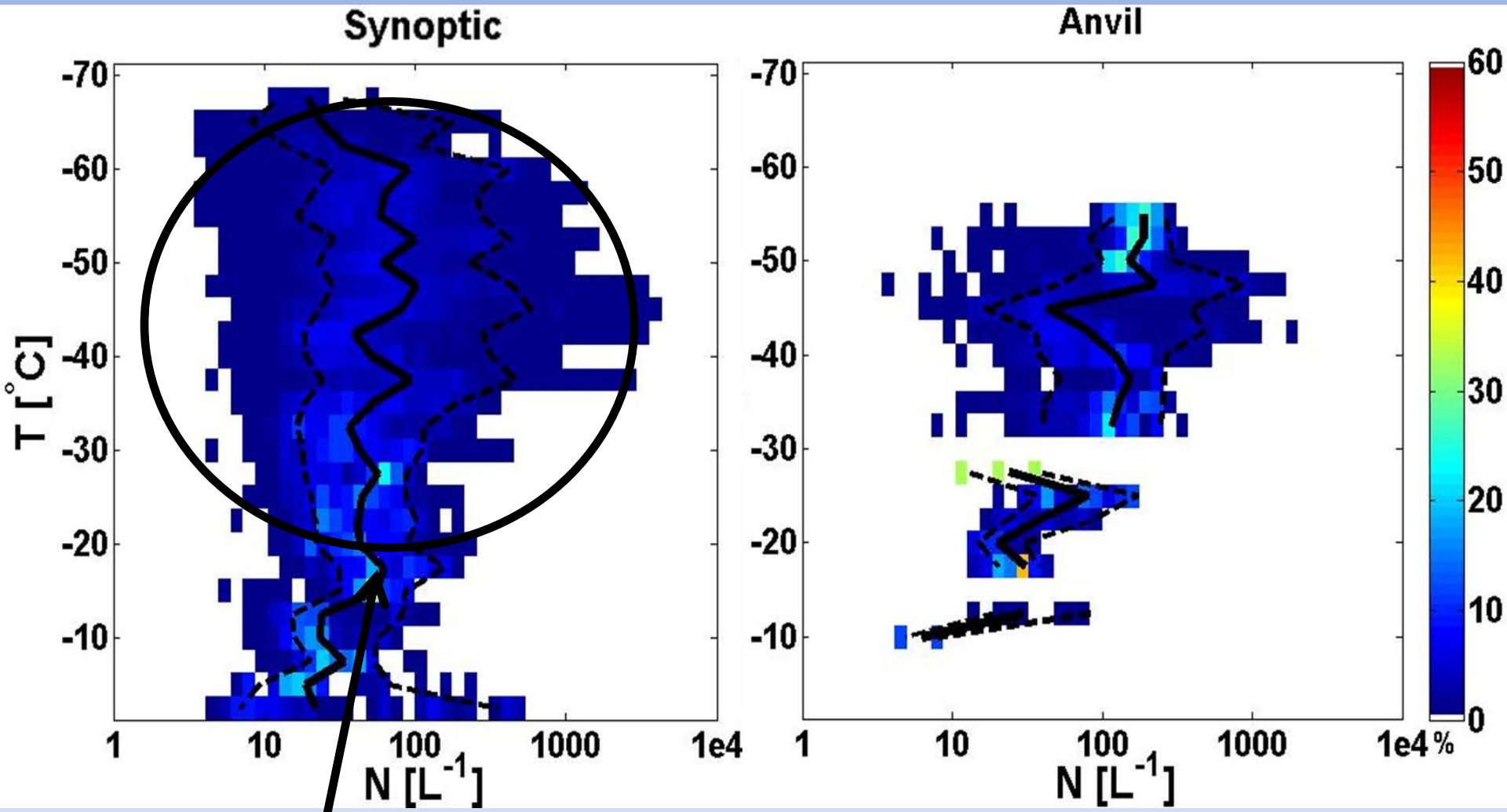
Fast FSSP concentration >> 2DS concentration in liquid clouds→ 2DS may not count all small particles. Further investigations are being conducted.



Shading = Frequency normalized by temperature.

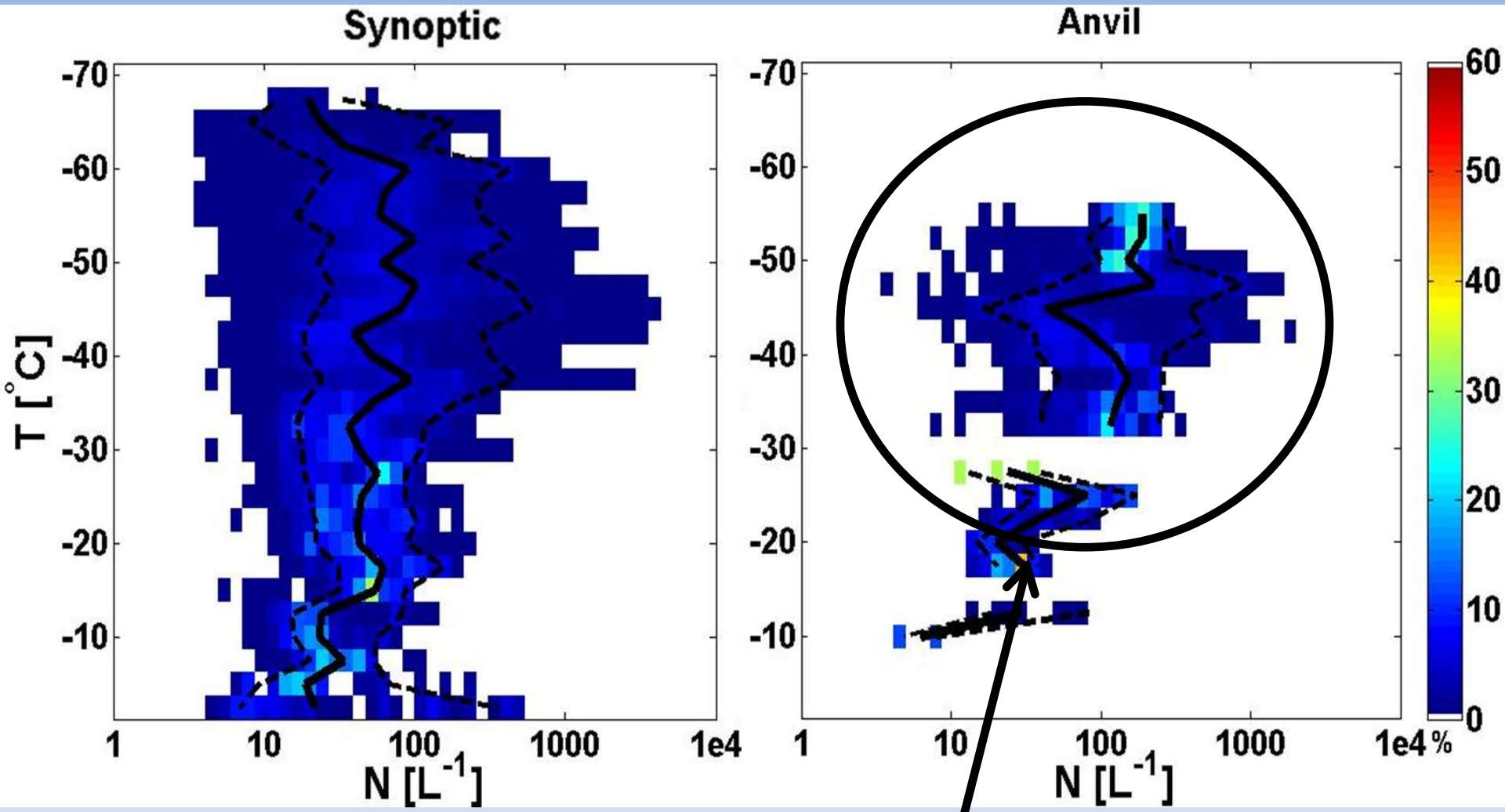
Solid line = median

Dashed lines = 10th/90th percentile.

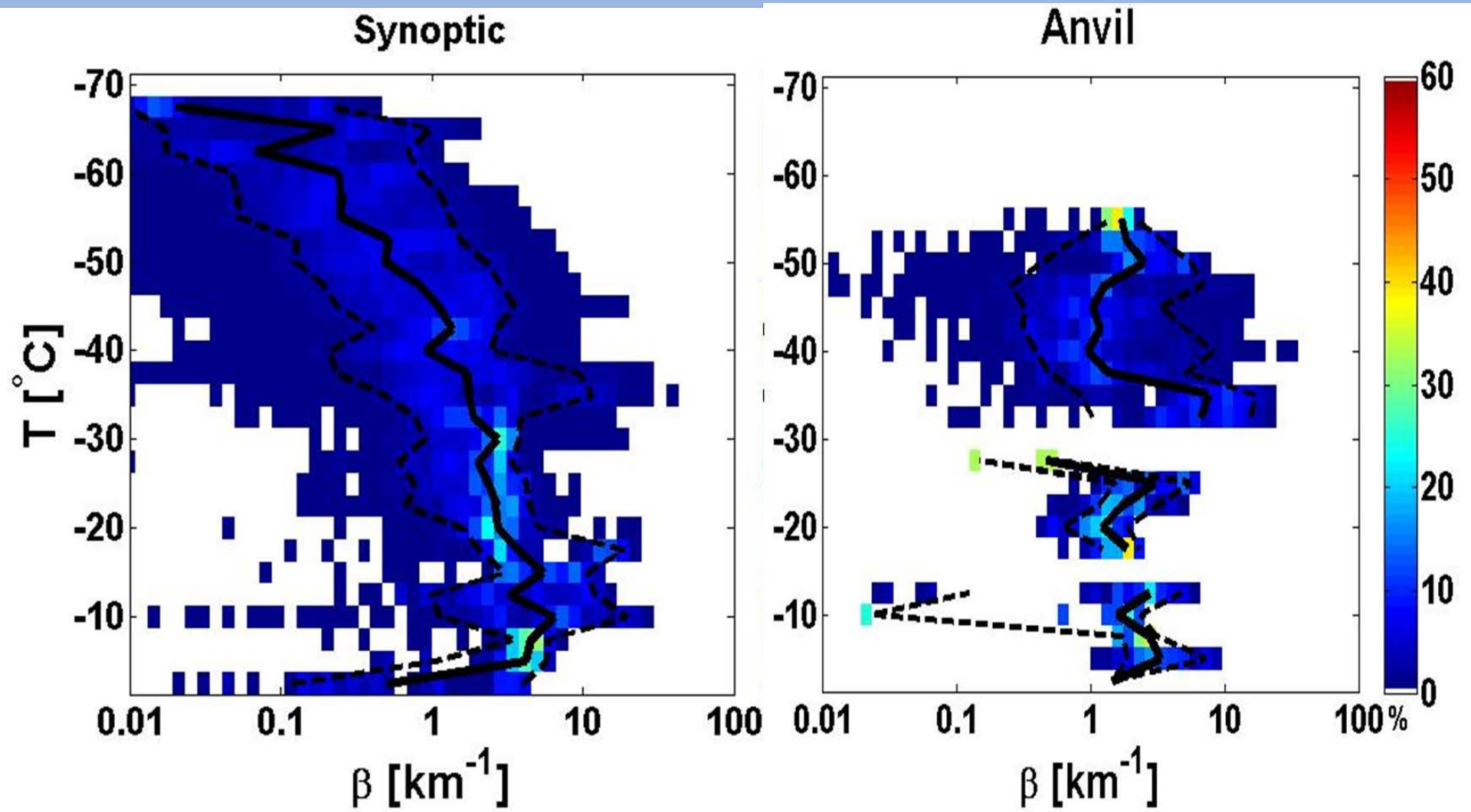


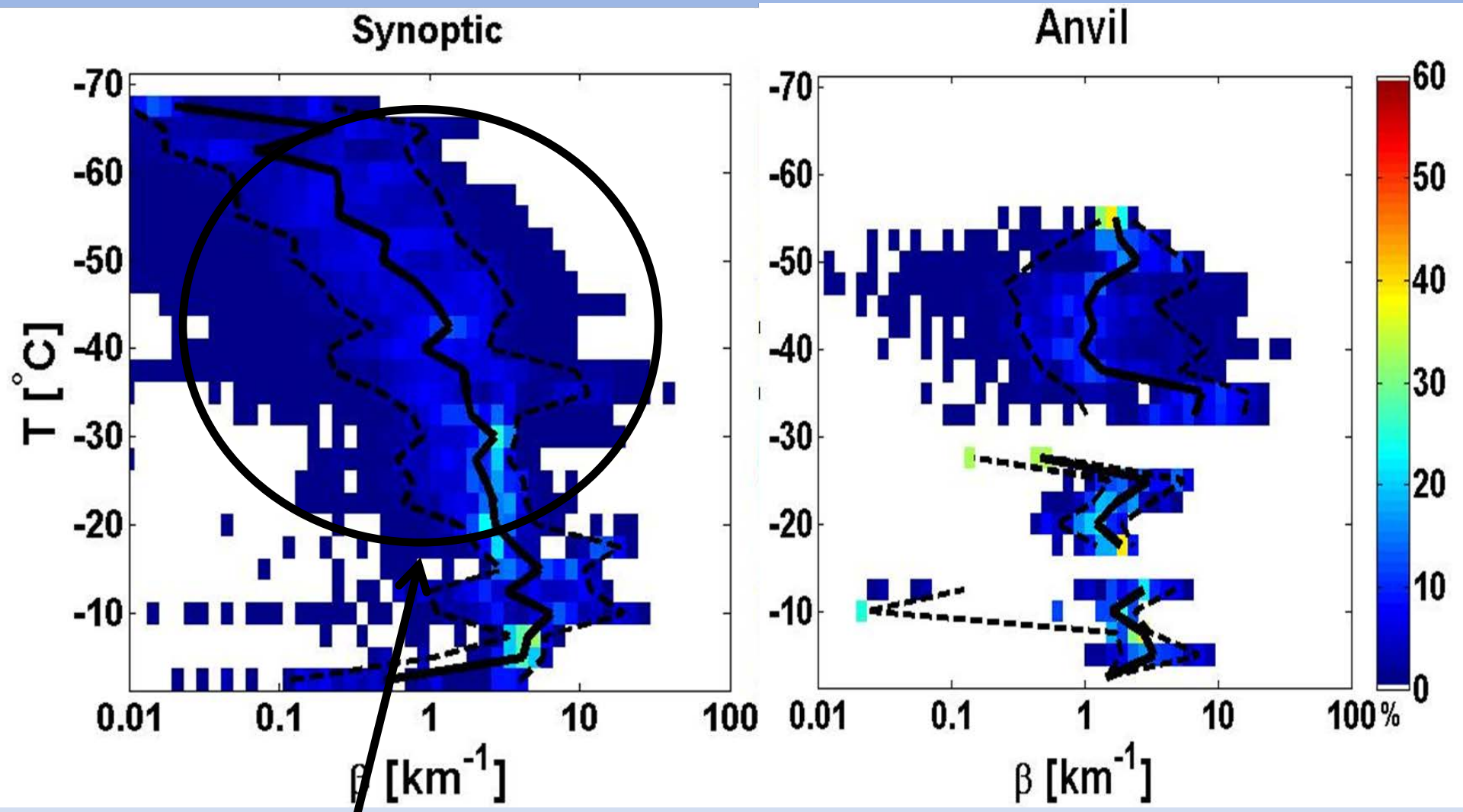
N constant with height for Synoptic cases

More regenerating cells in Synoptic cases.

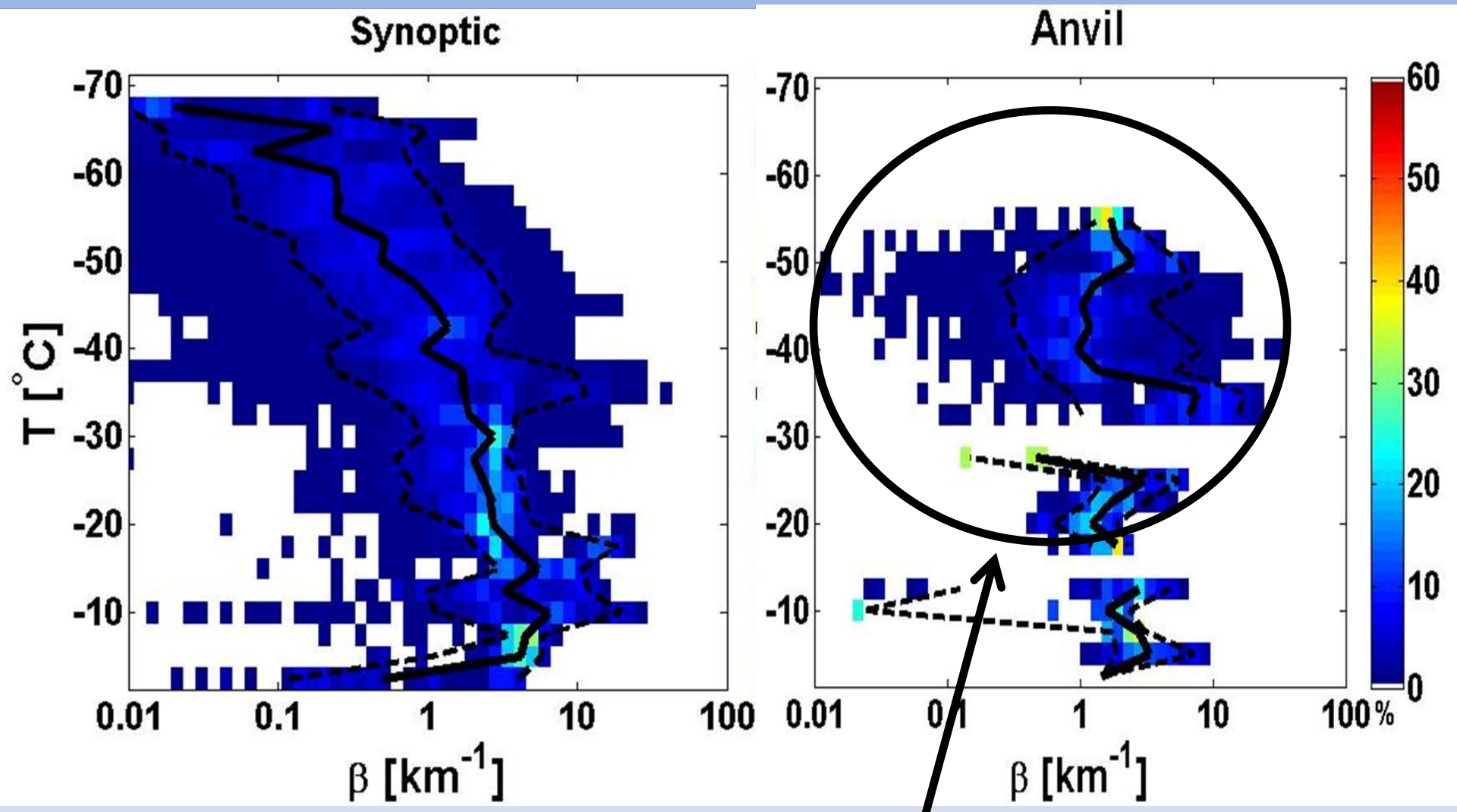


N decreases with height for Anvil cases. Higher Concentrations at lower T. Transport of ice up to colder temperatures via convection.

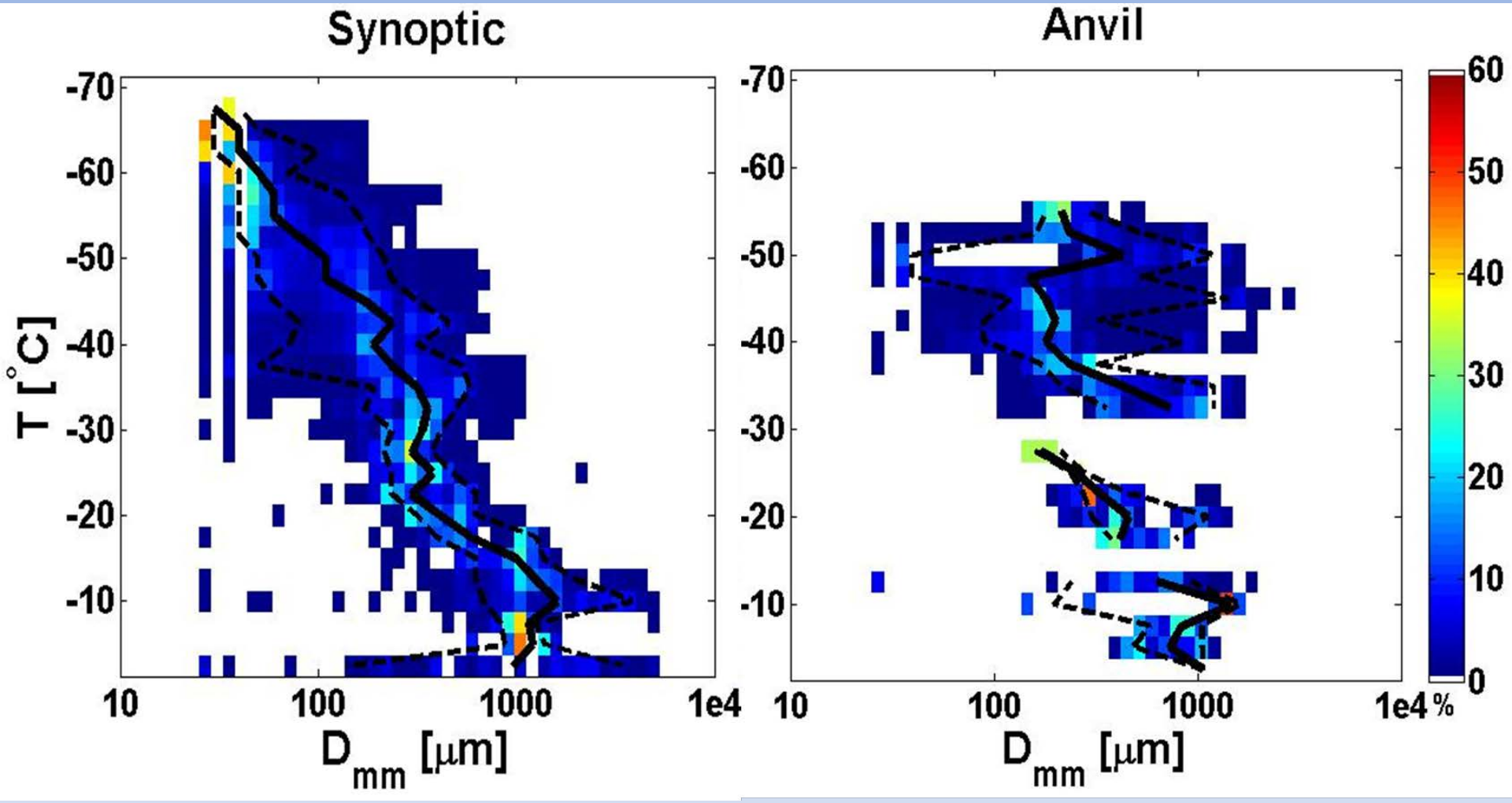

Synoptic
Anvil
T [°C]
-70
-60
-50
-40
-30
-20
-10
0.01
0.1
1
10
100
β [km-1]
60
50
40
30
20
10
0
%

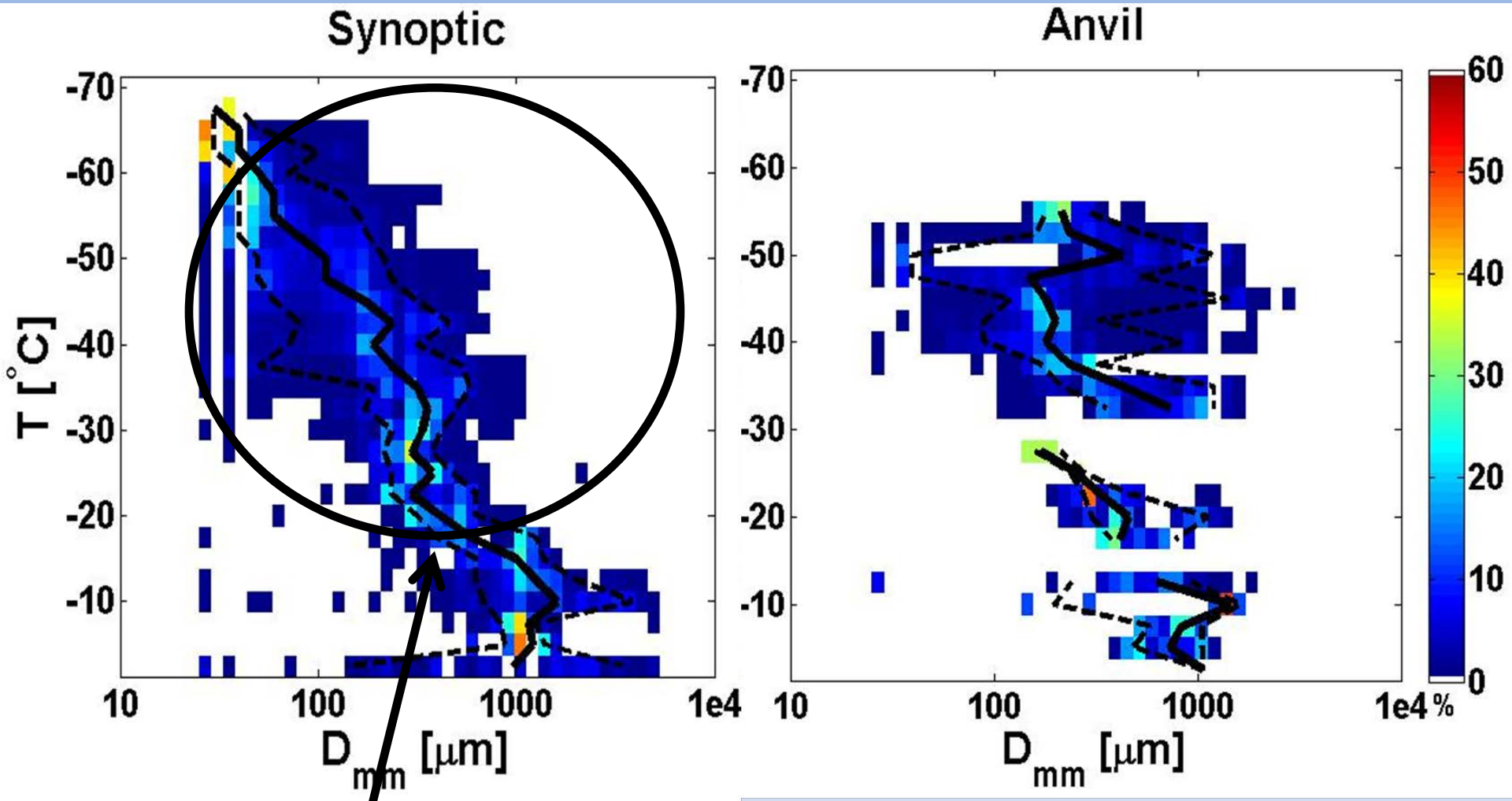


Extinction increases with T for Synoptic cases

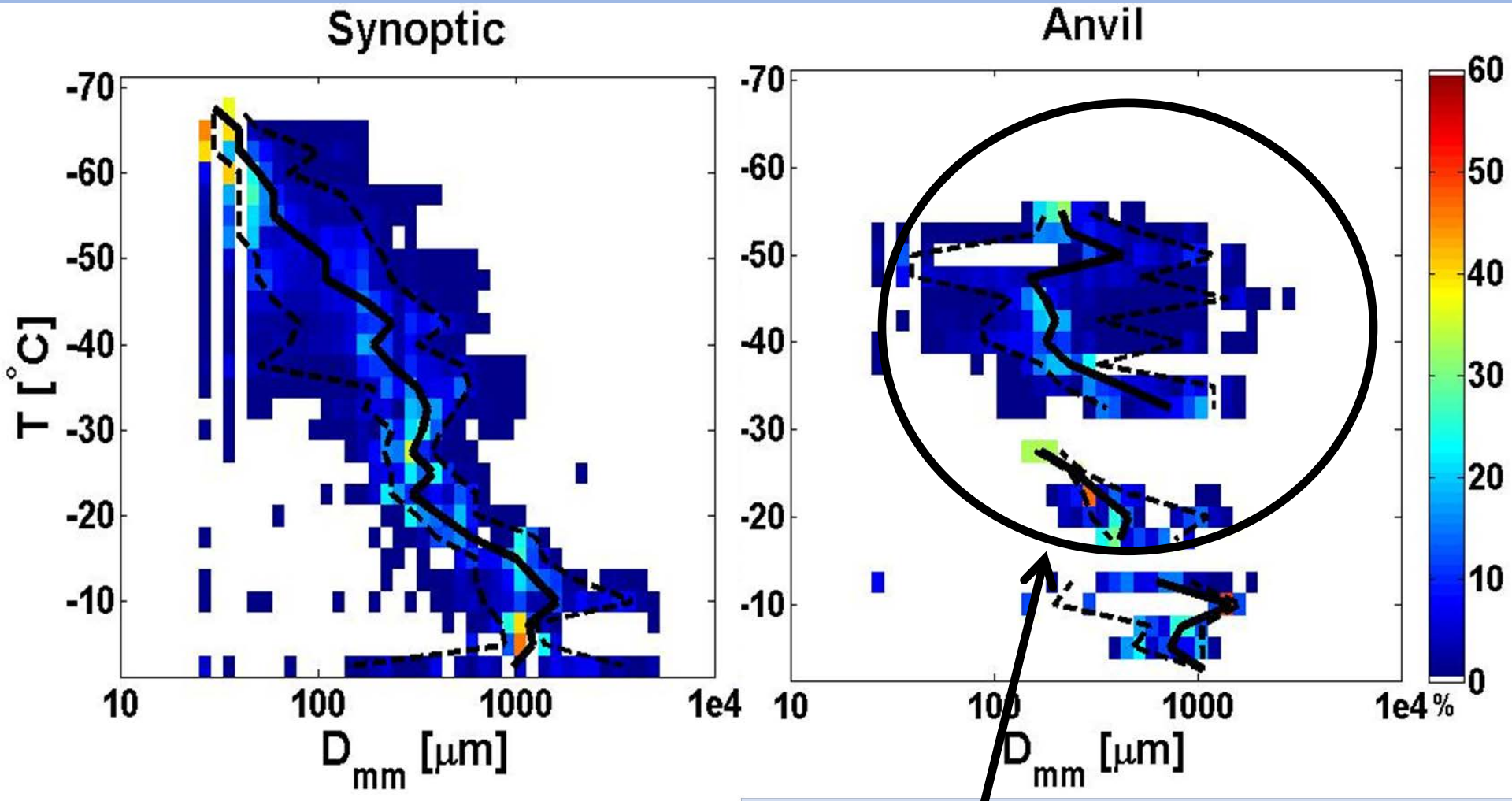


Extinction is constant with height for Anvil cases (and Larger for T ~-50 C)

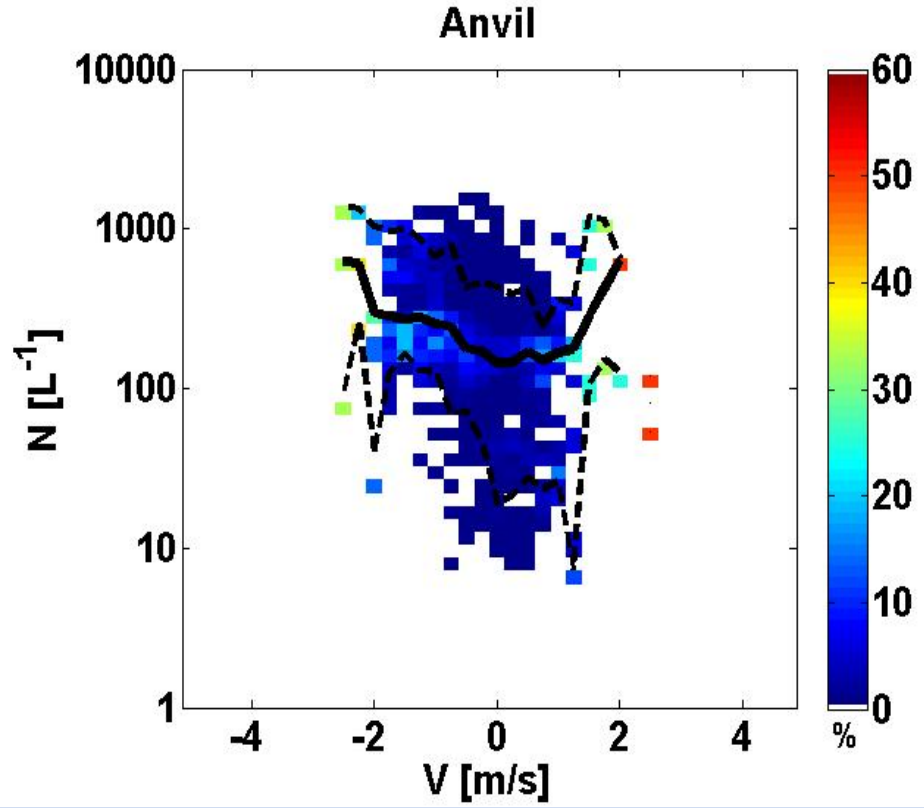

Synoptic
Anvil
T [°C]
-70
-60
-50
-40
-30
-20
-10
10
100
1000
1e4
D mm [μm]
60
50
40
30
20
10
0
%

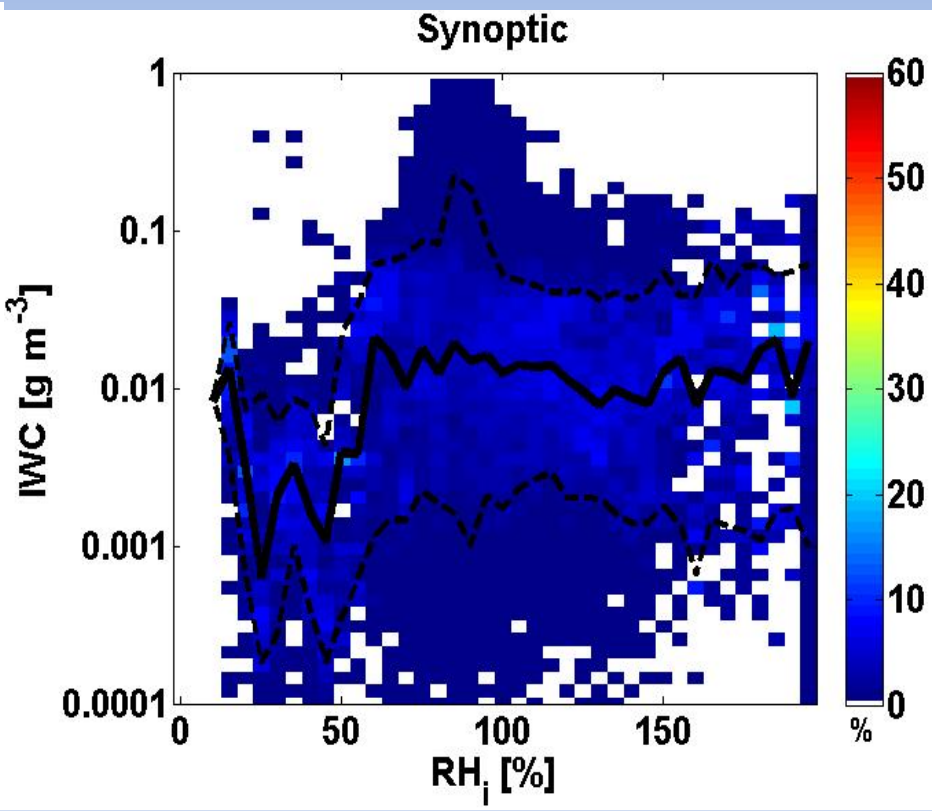


Dmm increases with T for synoptic cases.



Dmm increases with T for Anvil cases, larger Dmm at T ~-50 C





Investigation of relationship of parameters vs. vertical velocity, relative humidity also being conducted

Conclusions + Future Work

- **N(D) from Fast FSSP may be contaminated by shattering even after application of shattered artifact removal algorithm, inconsistencies between 2DS and FSSP in liquid conditions are unresolved.**
- **Future work will focus on further comparison of FSSP and 2DS in liquid in order to determine which probe best estimates N(D).**
- **β, D_{mm} increase with T for synoptic cases -> colder synoptic cirrus dominated by small particles.**
- **N constant with T for synoptic cases -> regenerating cells present at all T**
- **β, D_{mm} larger for T ≈ -50 C in anvil cases than synoptic cases → more regions with large particles in colder regions of anvils. Convection takes ice up to colder temperatures.**
- **Future work will determine how *N(D), β, r_e, IWC,* single scattering properties, gamma fits depend on environmental conditions (i.e. vertical velocity, relative humidity) and how these relationships relate to dynamical and microphysical processes.**
- **Current proposal is out for a "SPARTICUS on steroids" which may help fill in some of the gaps in data presented.**