Analysis and Retrievals of Ice Clouds from CoSSIR, CRS, and S-HIS Data

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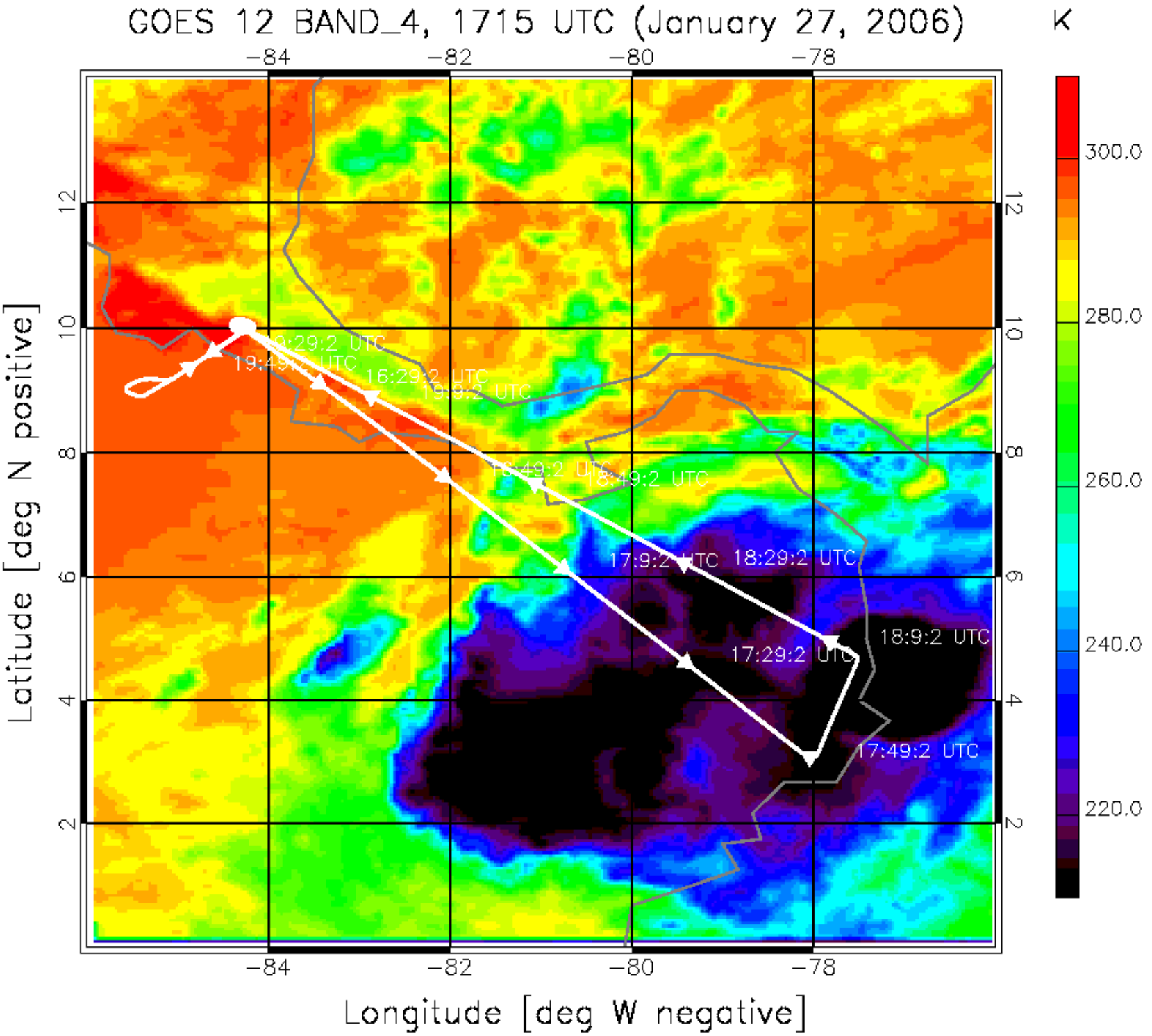
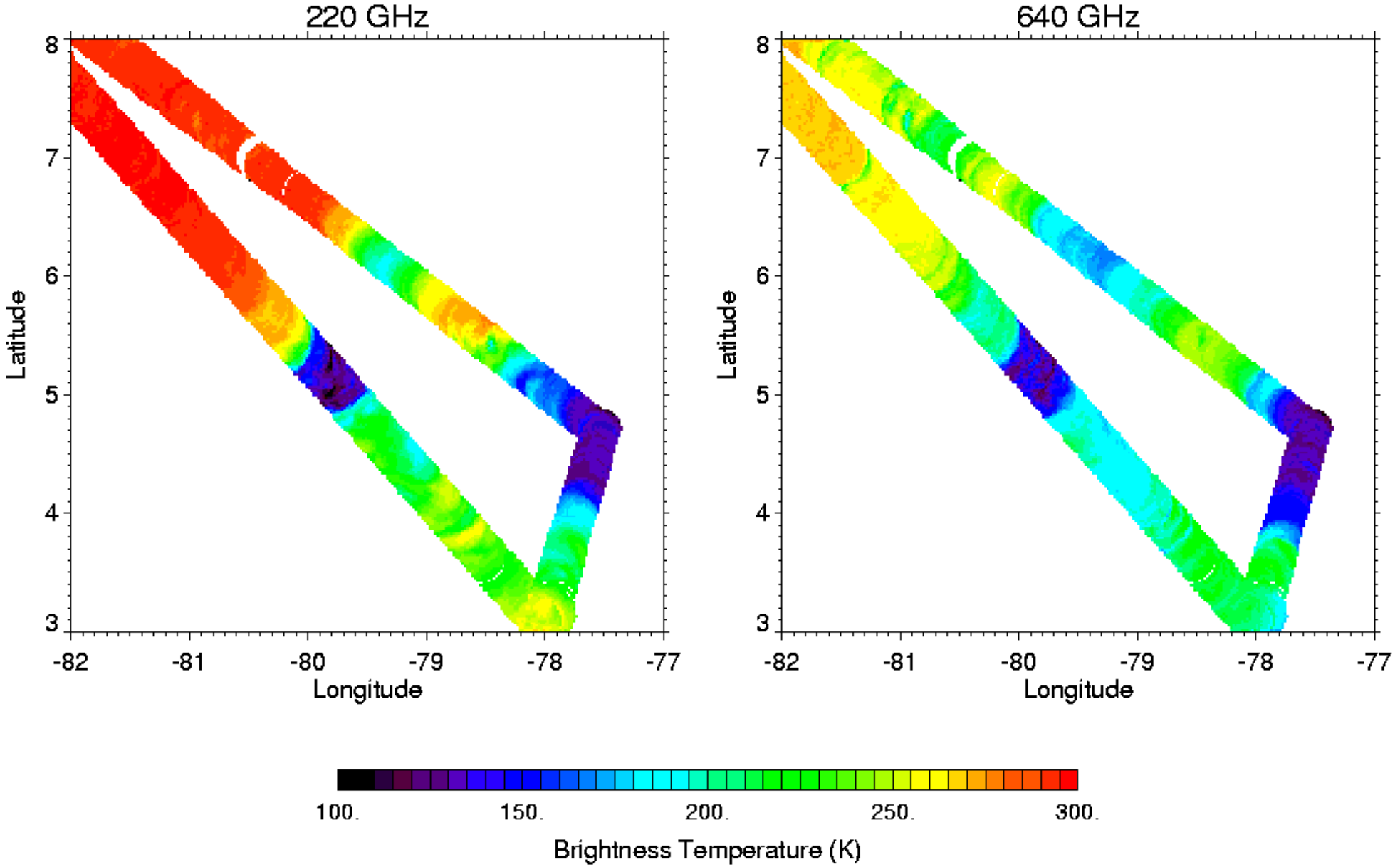
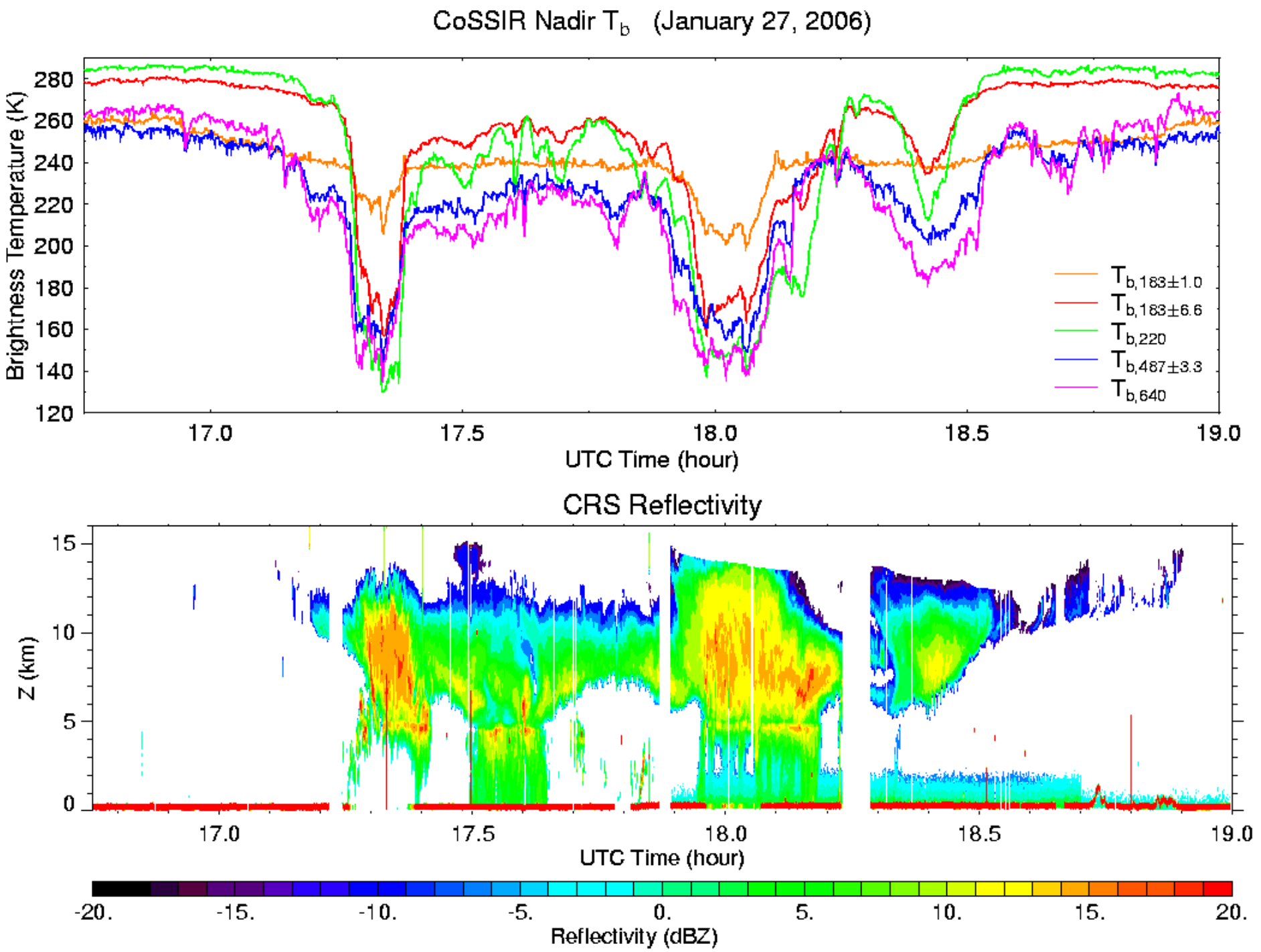
Compact Scanning Submillimeter-wave Imaging Radiometer (CoSSIR) Configuration during CR-AVE

- Only one flight over convective anvils: January 27, 2006
- Channels: 183.3±1.0, 3.0, 6.6; 220; 487.2±0.7,1.2,3.3; 640 GHz at H pol and 487.2±0.7,1.2,3.3 GHz at V pol (380 GHz not operating). 4^o beamwidth for all channels.
- Scanning: Conical scan forward and aft at 53^o plus two quick cross- track scans through nadir per 10 second cycle.
- Lab measured noise levels (LN2 target, 10 ms samples):

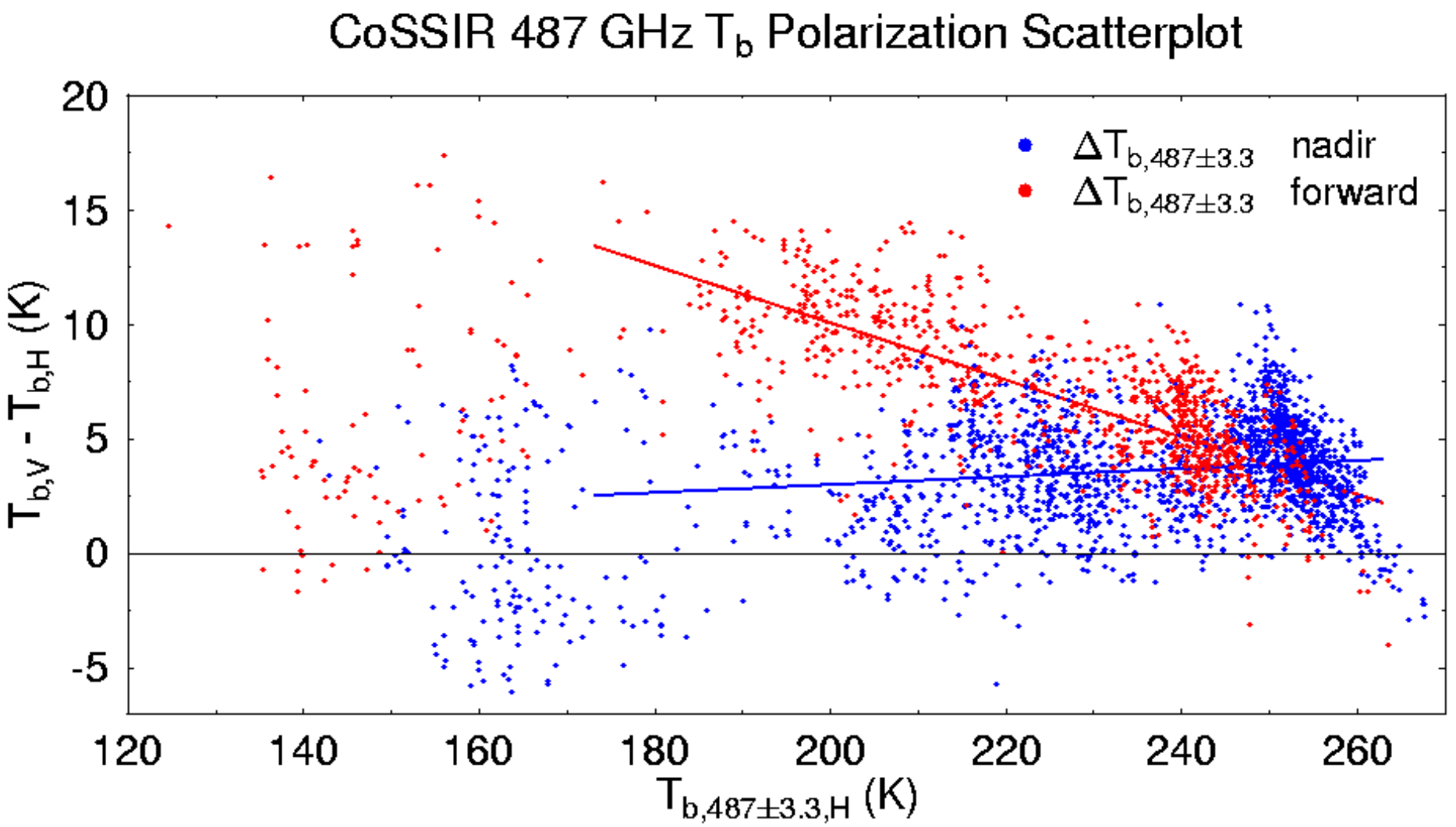
Freq (GHz)	183.3	220	487	640
δT (K)	0.4-0.6	0.6	1.1-1.6	1.2


GOES 12 BAND_4, 1715 UTC (January 27, 2006)
K
300.0
280.0
260.0
240.0
220.0
−84
−82
−80
−78
12
10
8
6
4
2
Latitude [deg N positive]
Longitude [deg W negative]
16:29:2 UTC
18:49:2 UTC
17:9:2 UTC
18:29:2 UTC
18:9:2 UTC
17:29:2 UTC
17:49:2 UTC


CR-AVE CoSSIR Forward Scan Brightness Temperatures
220 GHz
640 GHz
Latitude
Longitude
8
7
6
5
4
3
-82
-81
-80
-79
-78
-77
100.
150.
200.
250.
300.
Brightness Temperature (K)



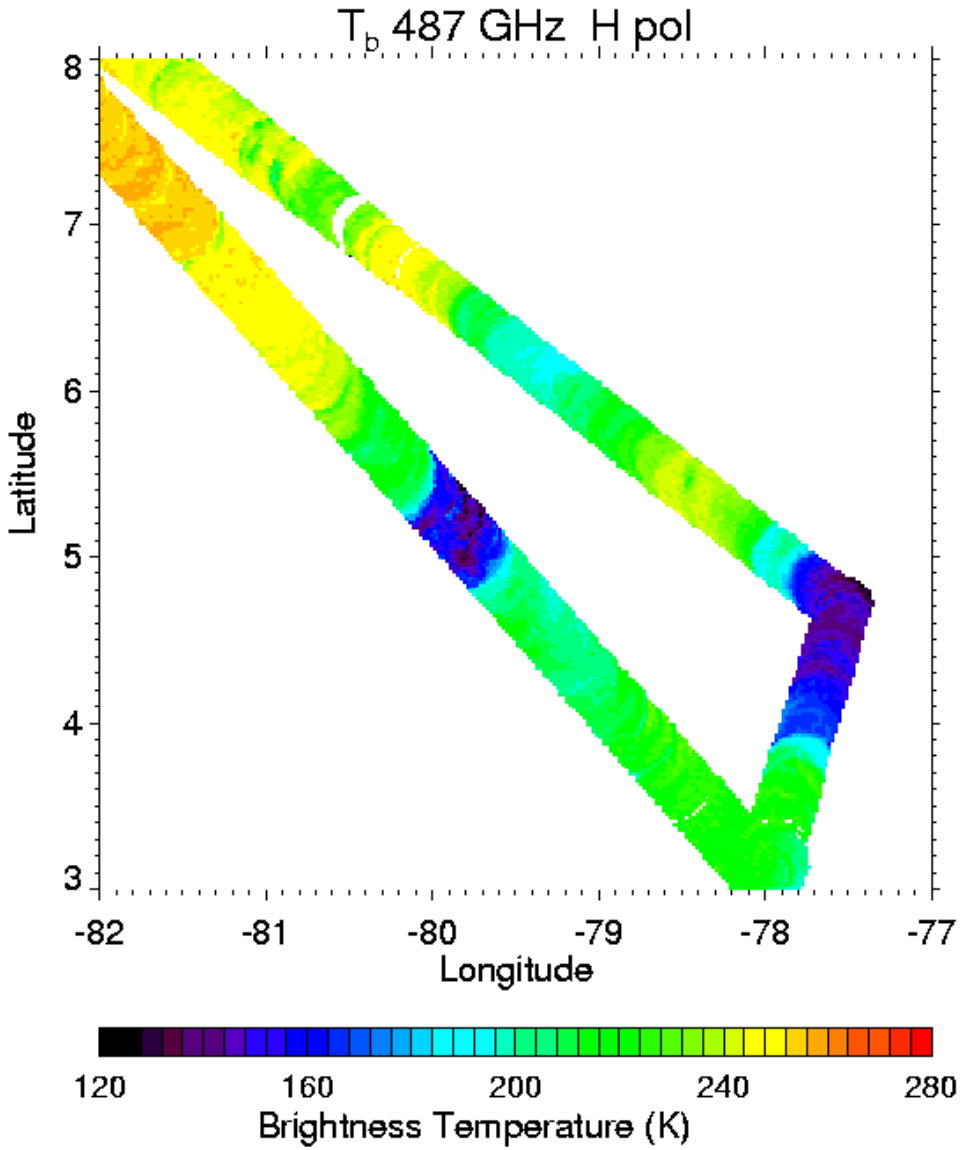
- 640 GHz is sensitive to thin anvil that 220 GHz doesn't see.

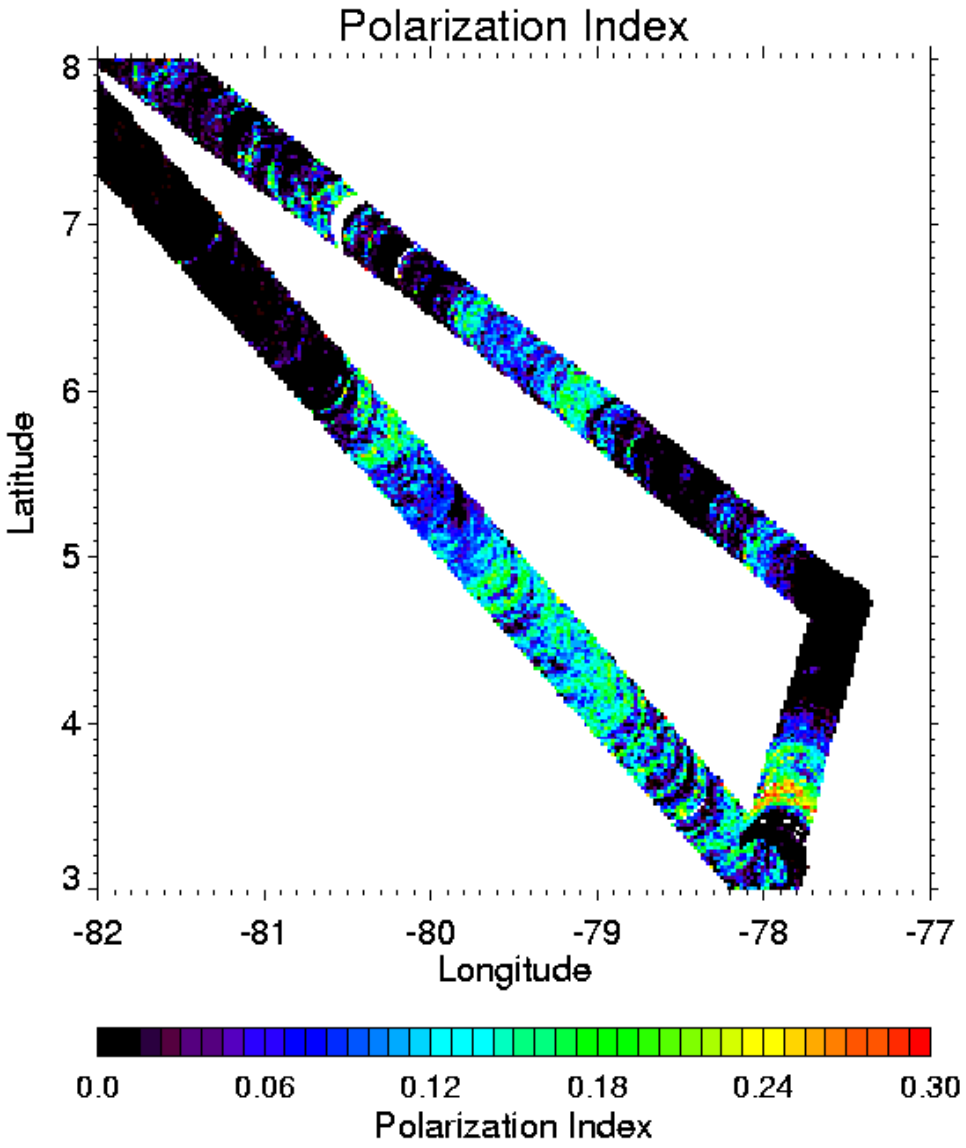


- Nadir view should have no polarization diff., but does from bandpass mismatch.
- Along track forward view has significant polarization where T_b < 220 K.

CoSSIR 487 GHz Polarization Index

- $PI = (T_V - T_H) / (T_{clr} - T_H)$
- Retrieval of PI from observed $T_V - T_H$ and $T_{clr} - T_H$ is done to deal with noise.
- Polarization in anvils indicates oriented ice crystals; note low PI in cores.

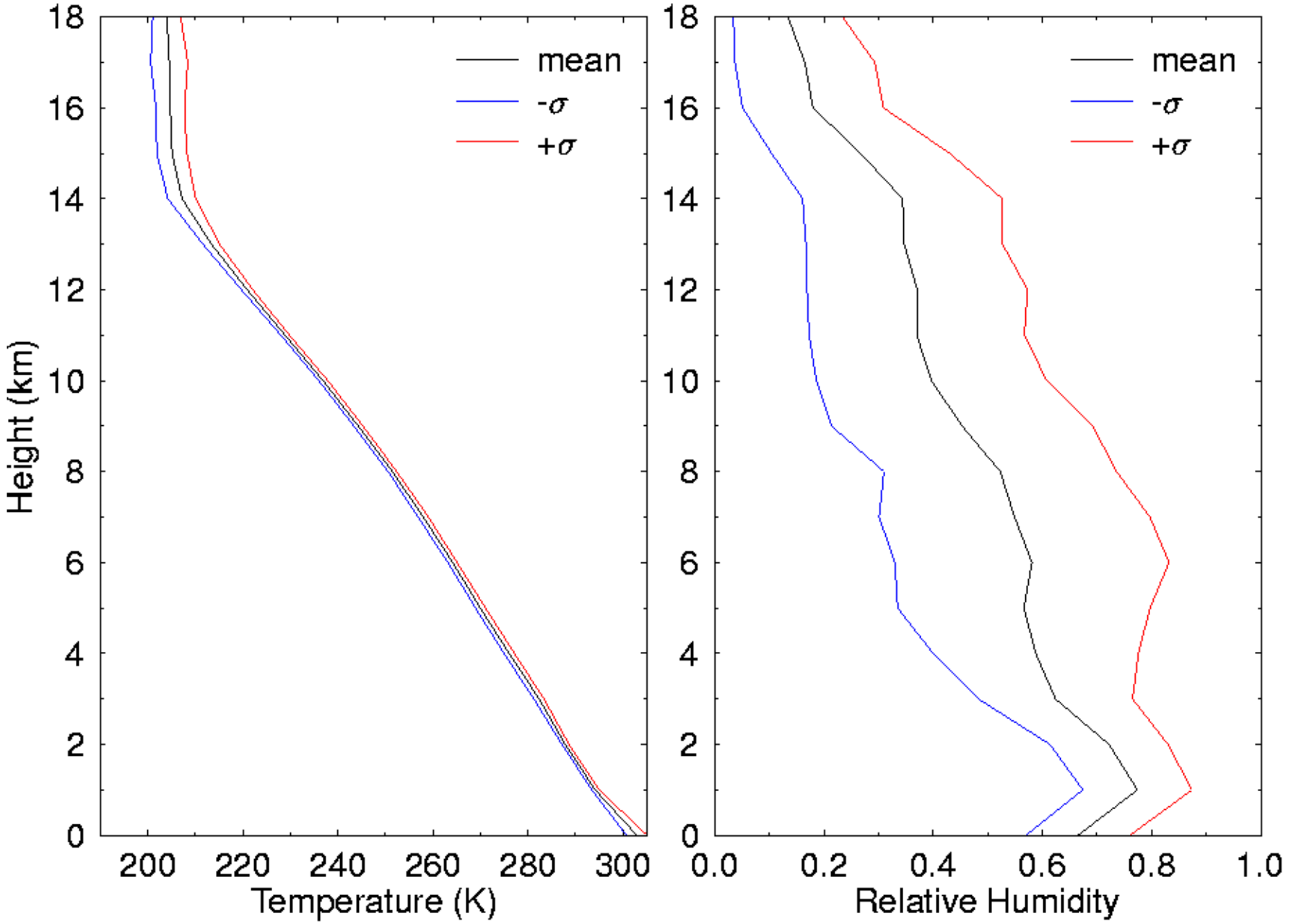




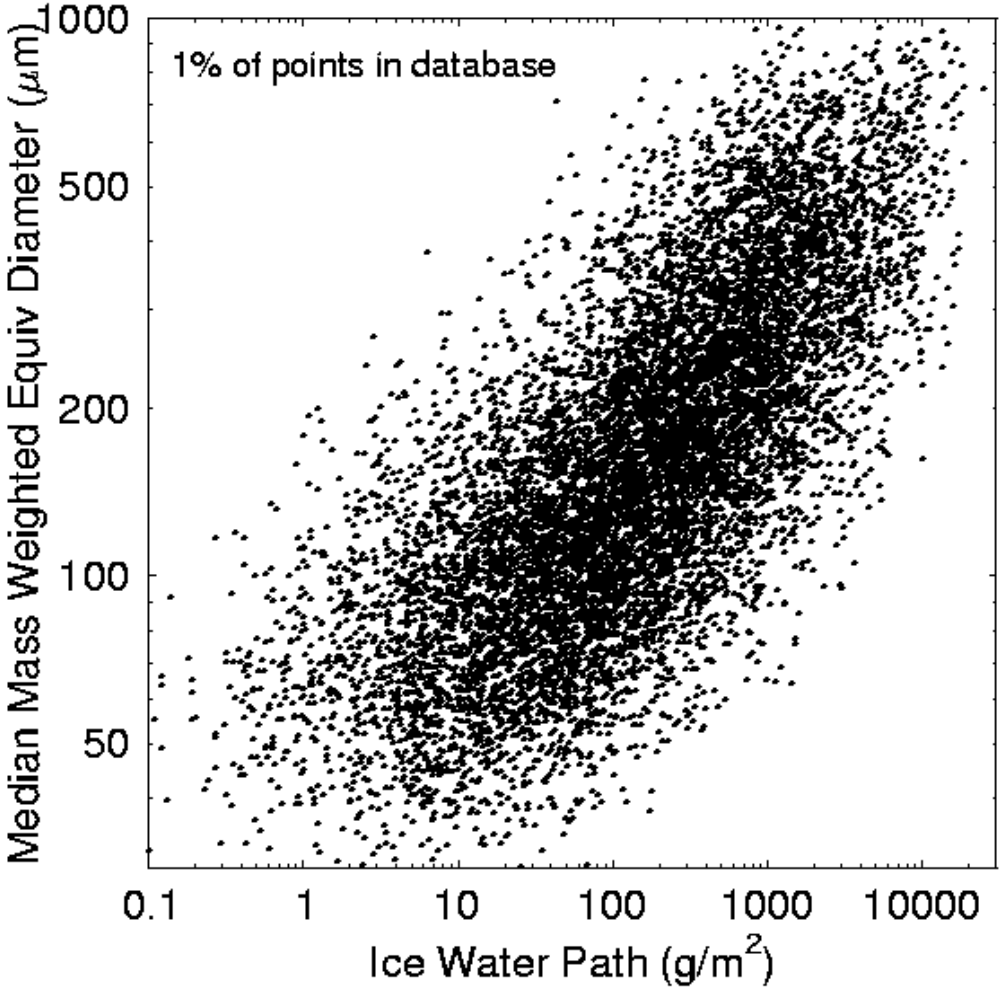
Bayesian Monte Carlo Integration Ice Cloud Retrieval Method

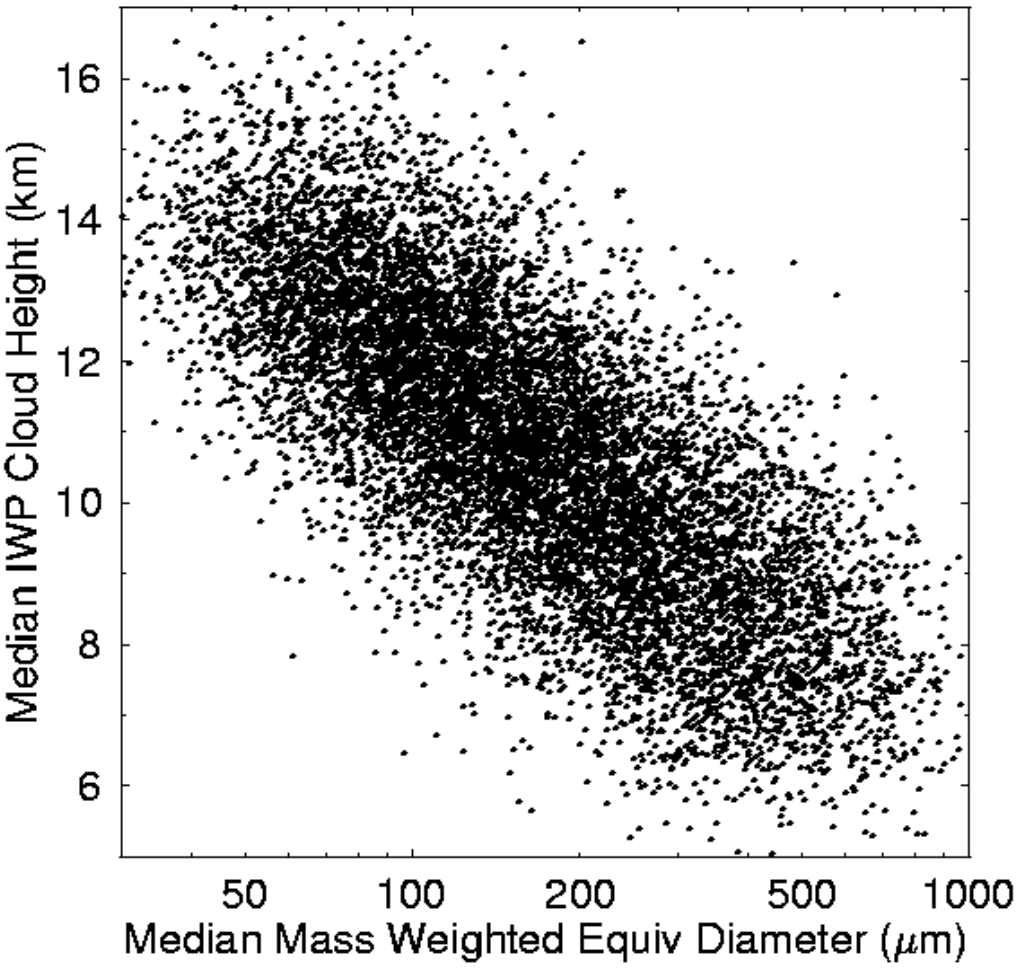
- Monte Carlo integration of the posterior pdf to retrieve, with error bars, the ice water path (IWP) and median mass weighted equivalent sphere particle diameter (D_{me}).
- Prior information represented by distribution of 10^6 cases of atmosphere and cloud properties in retrieval database. Prior for microphysics [Gaussian in T, ln(IWC), ln(D_{me})] from Citation cloud probes during CRYSTAL-FACE. Temperature and RH profile stats from C-F radiosondes. Cloud height and thickness stats from CRS. Mixed phase and BL clouds are included.
- Brightness temperatures [183(x3), 220, 487±3.3, 640 GHz (H pol)] computed with unpolarized Eddington radiative transfer. Database cases are weighted by likelihood function, thus cases with T_b's close to observations are selected.

Statistics of Atmospheric Profiles in Retrieval Database



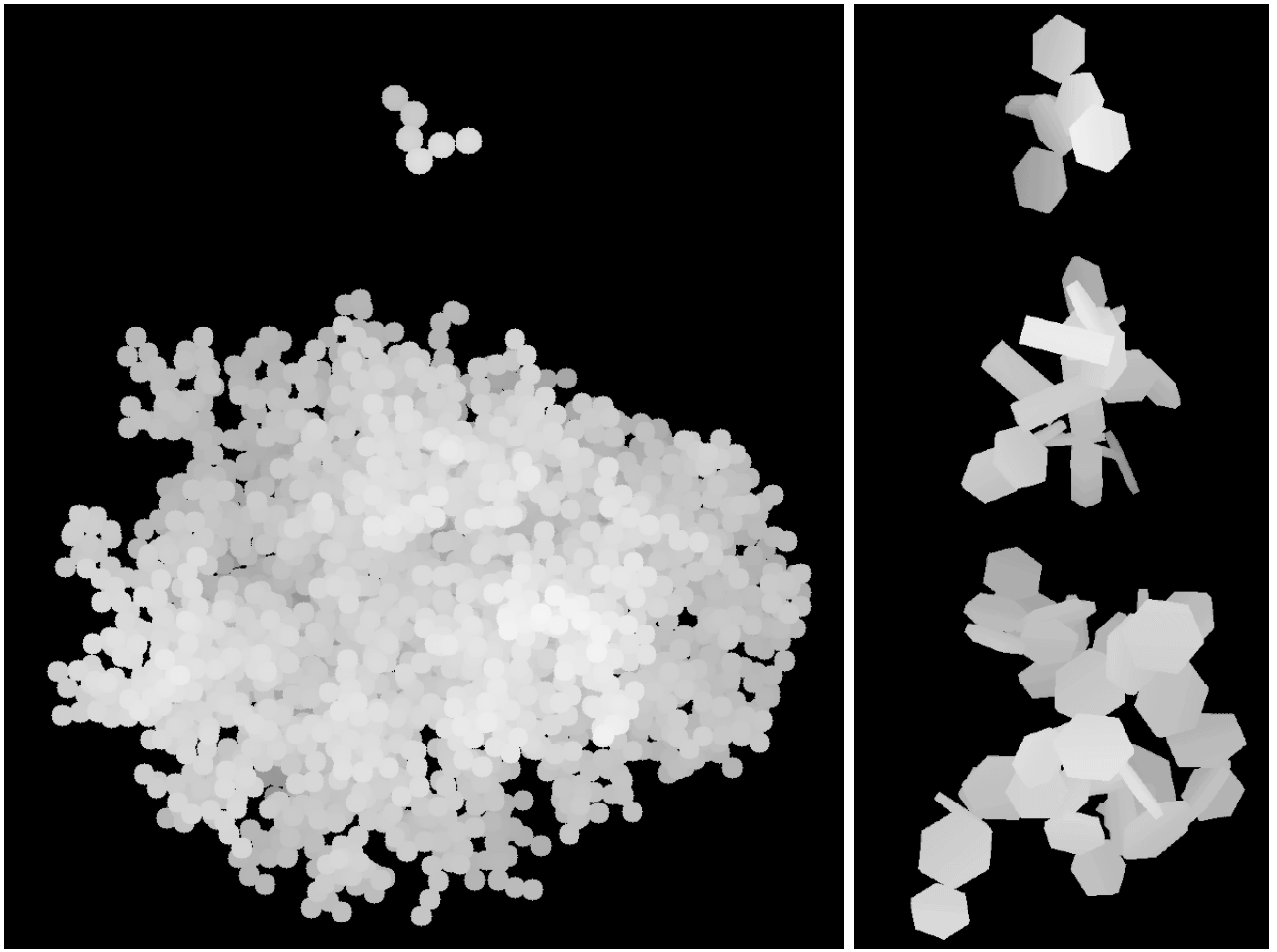
Ice Cloud Properties in Retrieval Database



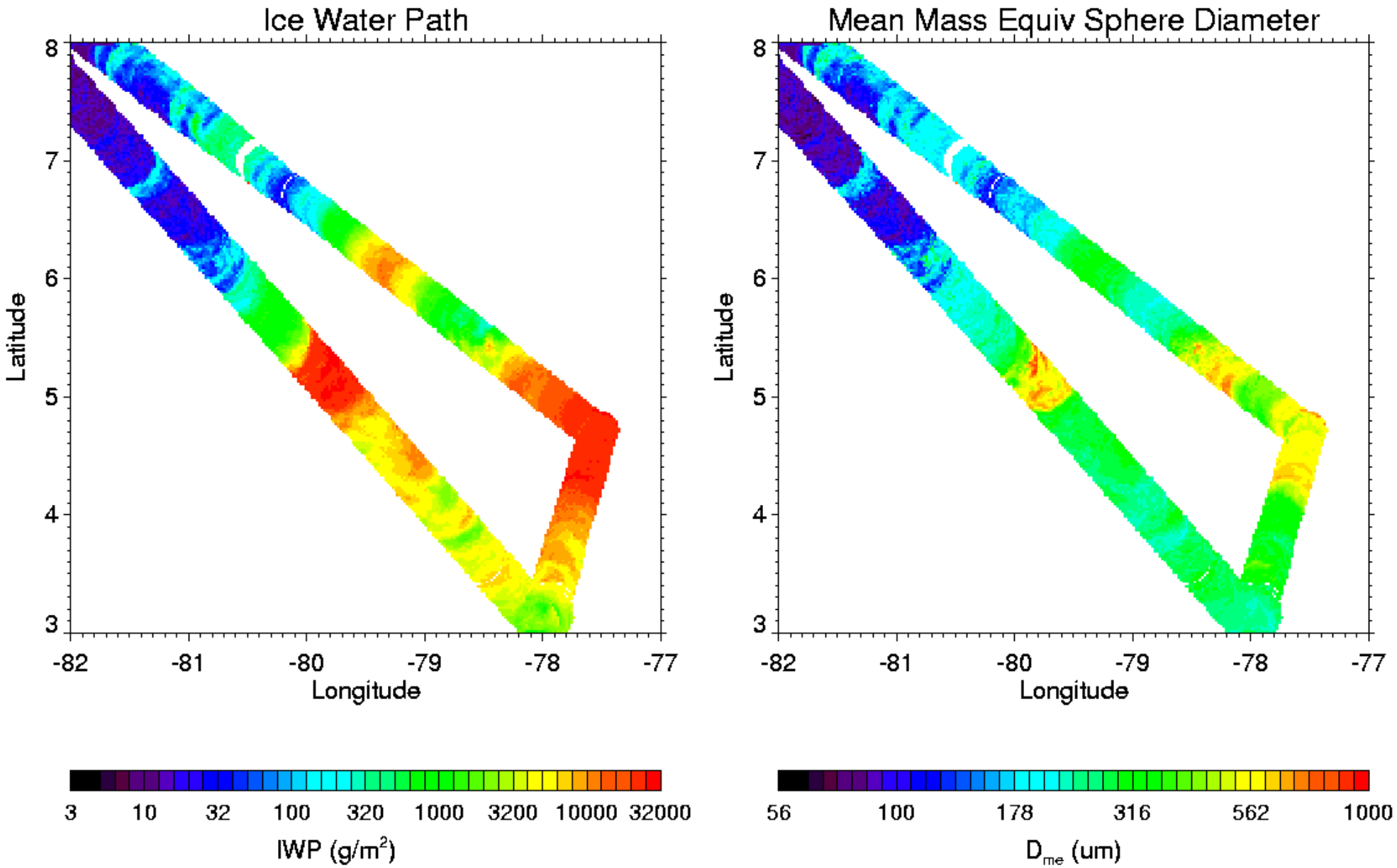


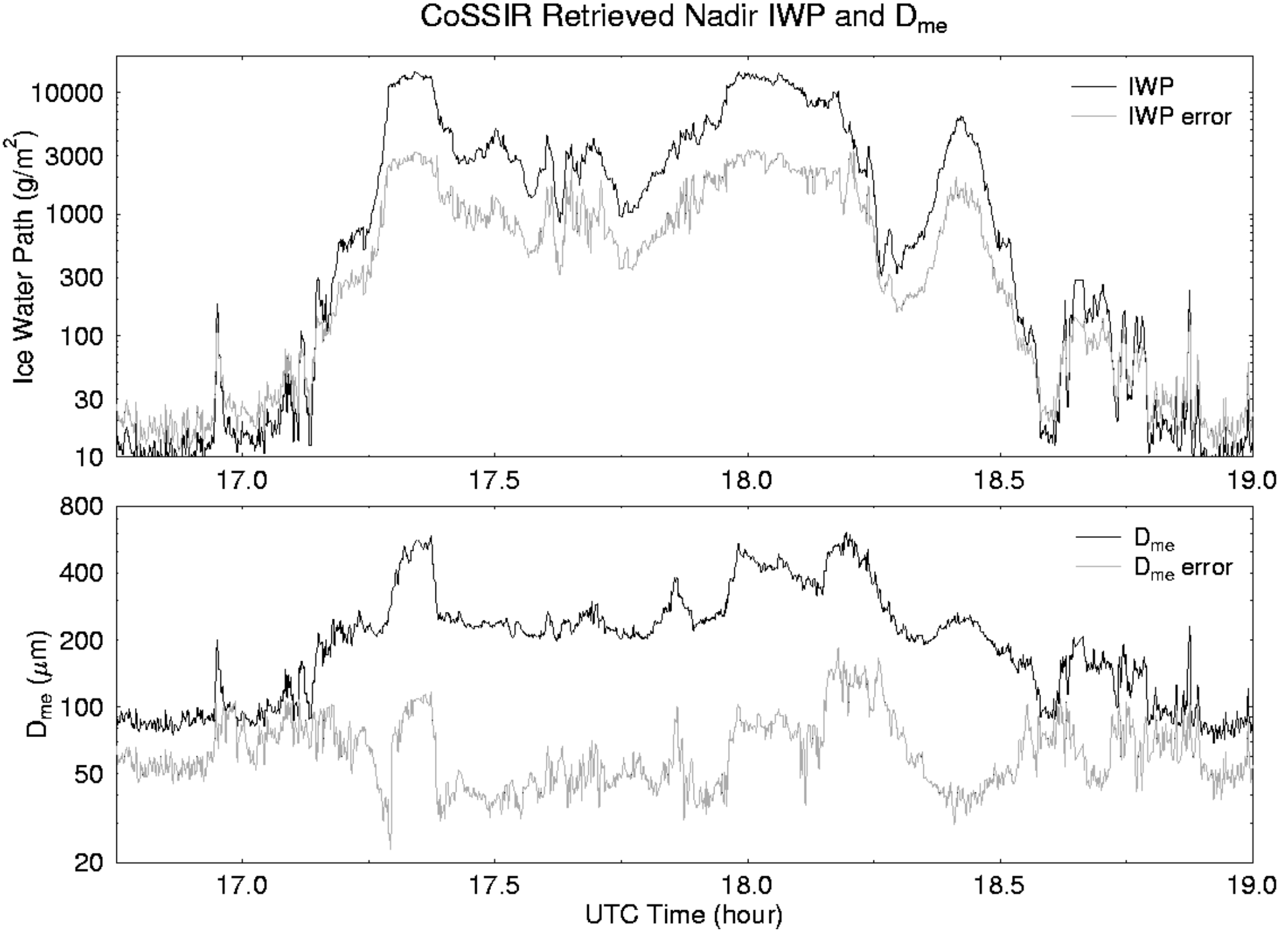
- Random cloud top and bottom IWC and D_{me} depend on temperature.
- Prior has correlation between IWP and D_{me} and between D_{me} and cloud height.

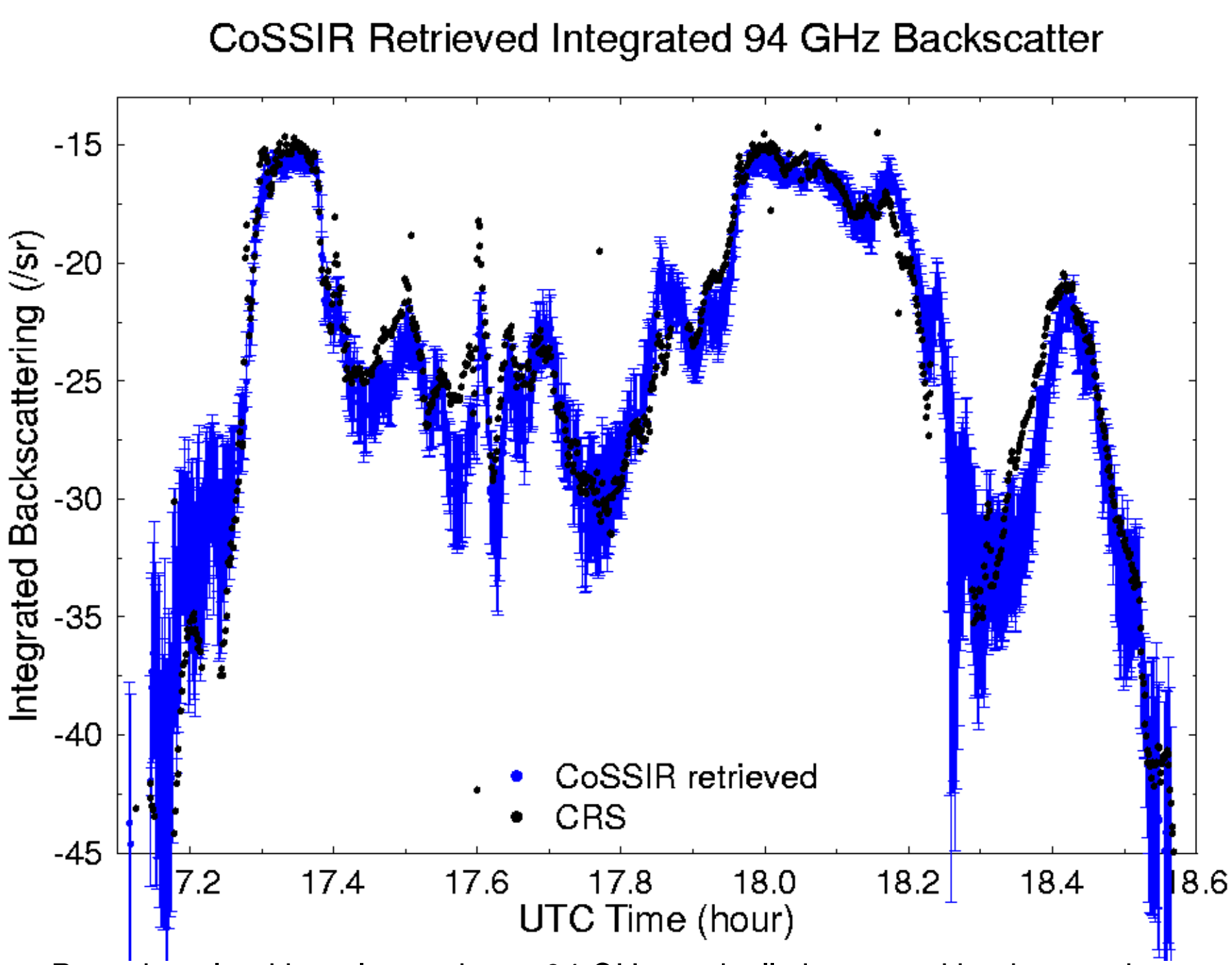
Ice Particle Shapes in Retrieval Database



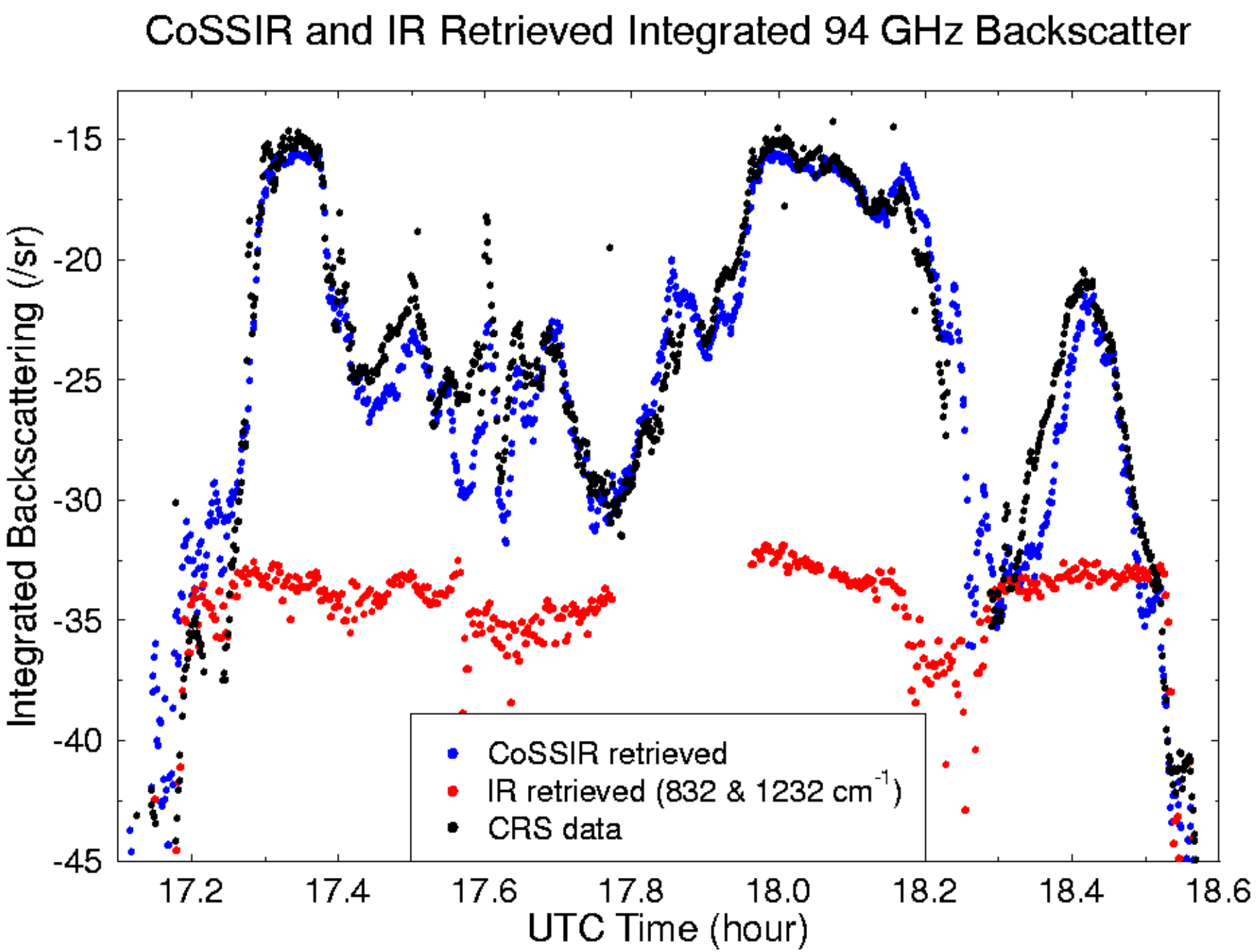
- Five particle shapes: random sphere aggregates, three types of random hex plate and column aggregates, low density spherical “snow”.
- Gamma size distributions with variable width.
- Microwave scattering properties computed with discrete dipole approximation; infrared scattering computed using equivalent volume and area spheres.


CR-AVE CoSSIR Retrievals of IWP and D_{me}
Ice Water Path
Mean Mass Equiv Sphere Diameter
Latitude
Longitude
8
7
6
5
4
3
-82
-81
-80
-79
-78
-77
3
10
32
100
320
1000
3200
10000
32000
IWP (g/m^2)
56
100
178
316
562
1000
D_{me} (um)

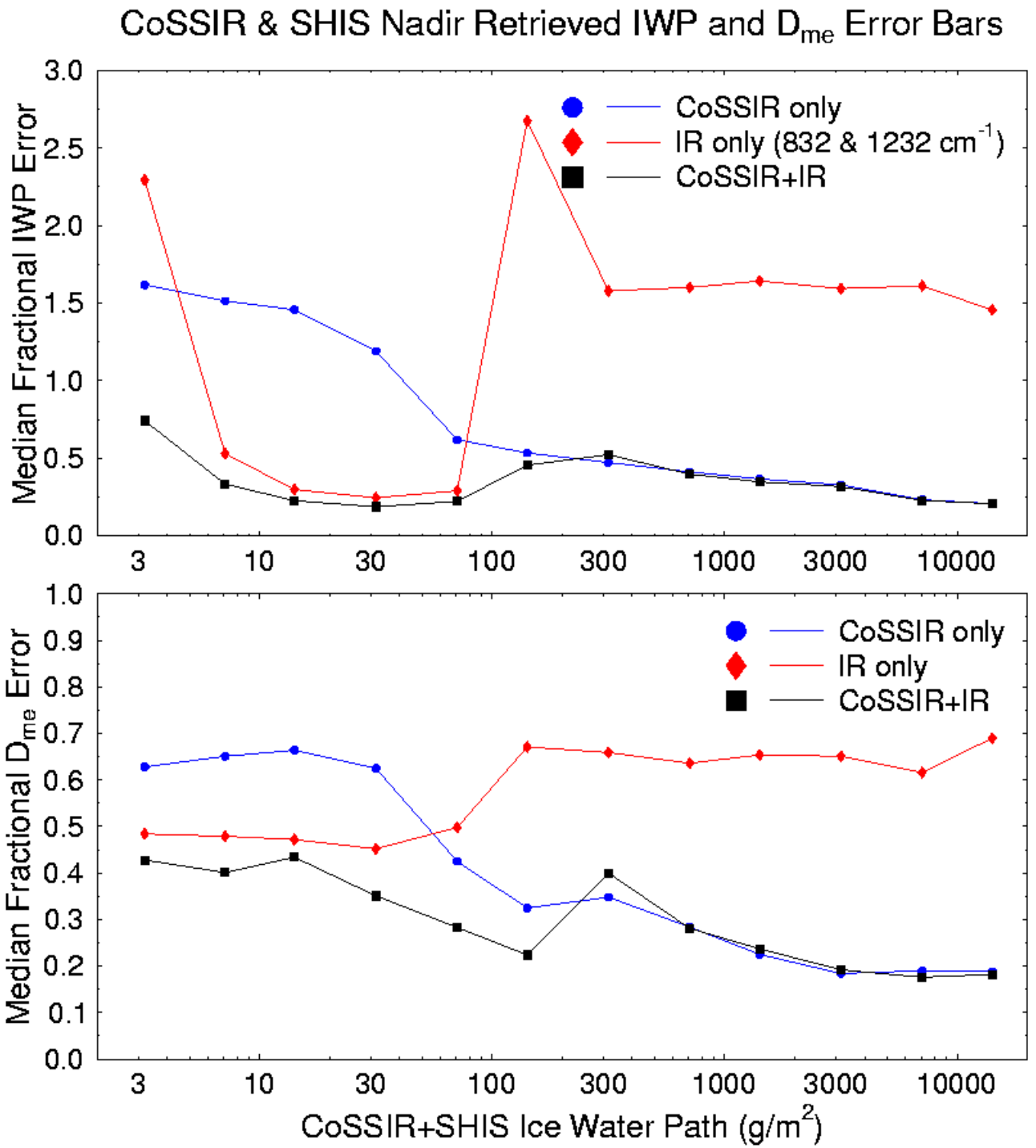

CoSSIR Retrieved Nadir IWP and D_{me}
Ice Water Path (g/m^2)
10000
3000
1000
300
100
30
10
IWP
IWP error
17.0
17.5
18.0
18.5
19.0
D_{me} (μm)
800
400
200
100
50
20
D_{me}
D_{me} error
17.0
17.5
18.0
18.5
19.0
UTC Time (hour)



- Bayesian algorithm also retrieves 94 GHz vertically integrated backscattering from CoSSIR data, which compares well with Cloud Radar System data.



- Retrievals from two IR window channels (from Scanning HIS) are poor for convective cores and most of anvils.



- Bayesian retrieved error bars show complementarity of submillimeter and infrared.

Summary and Future Research

- CoSSIR improvements have resulted in submm channels being much more sensitive than during CRYSTAL-FACE.
- CoSSIR retrievals of IWP and D_{me} were “validated” by good agreement of integrated reflectivity with Cloud Radar System.
- CoSSIR made first measurement of submm polarization in CR-AVE.
- Combining IR with submm improves low IWP retrievals.
- CoSSIR is being upgraded to 183, 220, 380, 640H & 640V, and 874 GHz receivers. 874 GHz will have added sensitivity to small ice particles; dual pol at 640 GHz won't have bandpass matching problems.
- We hope to participate in TC^4 to provide products (IWP, D_{me}, polarization, and water vapor profiles in presence of cirrus), further advance submm technique, and evaluate CloudSat IWP retrievals.