Using GPM-GV Data for Improved Ice and Mixed Phase Precipitation Retrievals from GPM DPR

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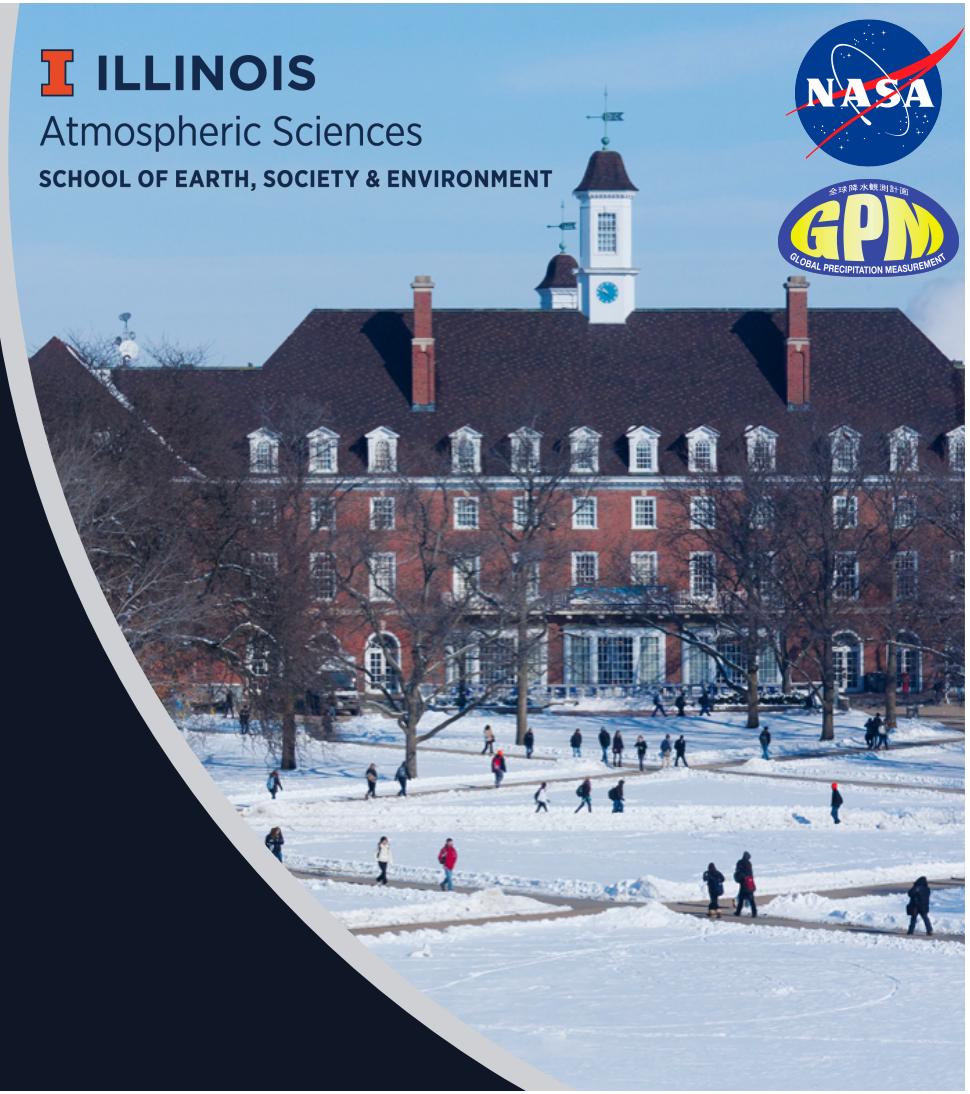
PMM Science Team Meeting

Indianapolis, Indiana

4-8 November 2019



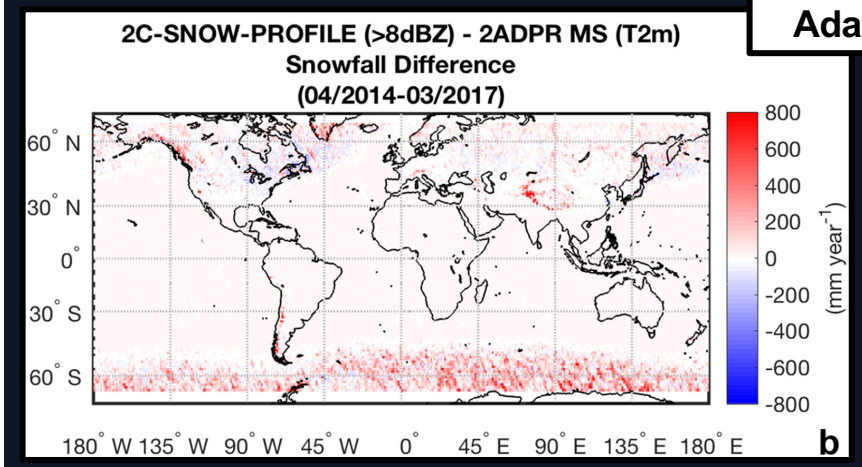
Motivation

- Ice cloud retrievals from GPM have many applications
- GV data reveal that multi-frequency retrievals have the potential to retrieve the microphysical properties of ice clouds [IWC, D_m, N_w, ρ_e]

Q: When GPM DPR + combined algorithm can detect ice and mixed-phase clouds, how is the algorithm performing in retrieving ice cloud properties?

Deep convective system in Sierras de Córdoba, Argentina during RELAMPAGO-CACTI

Adapted from Skofronick-Jackson et al. 2019

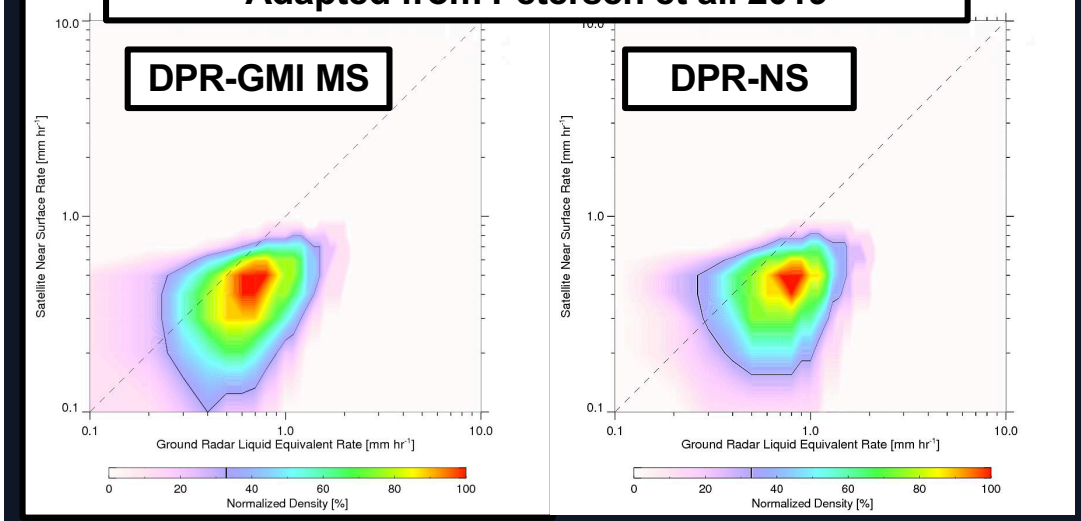


CloudSat – GPM-DPR

Global Mean Difference:

GPM DPR low 43%

Adapted from Petersen et al. 2019



Compared to Hyytiälä

Bias:

GPM DPR low 55%

Also
Heymsfield et al. (2016)
Mroz et al. (2019, AMS Radar)

Taking a closer look at DPR retrievals

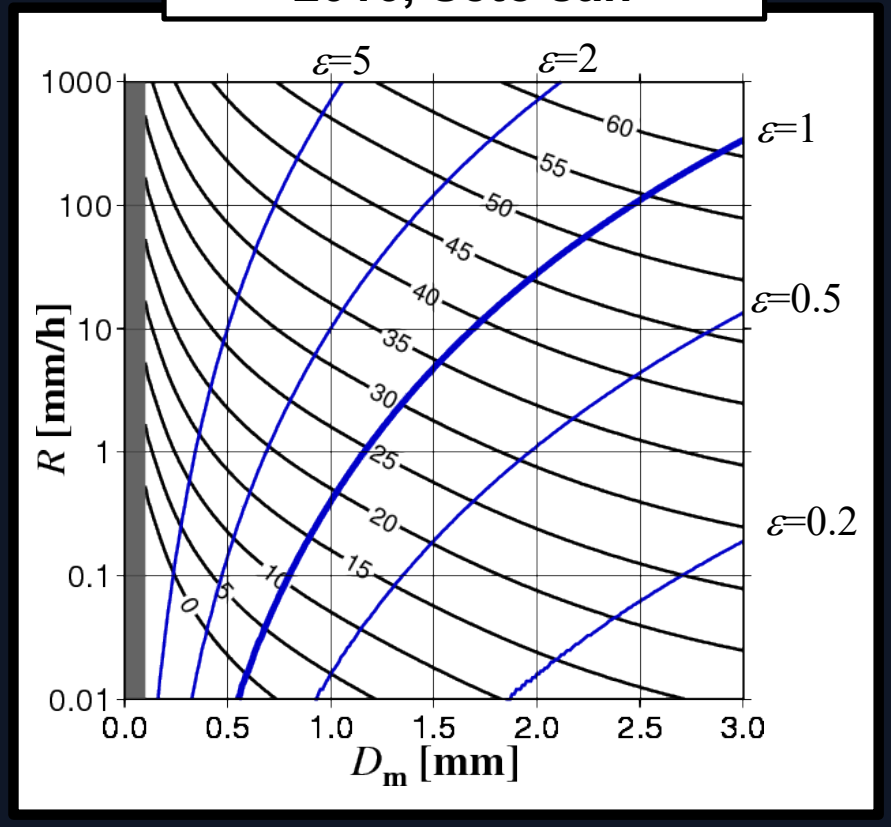
- DPR provides raw and corrected products
- DPR correction algorithm considers column measurements in making corrections (*column by column epsilon estimate* derived from consistency amongst attenuation and DSD), impacting mass and DSD retrievals

$$R = 0.401\epsilon^{4.609} D_m^{6.131}$$ (stratiform)

$$R = 1.370\epsilon^{4.258} D_m^{5.420}$$ (convective)

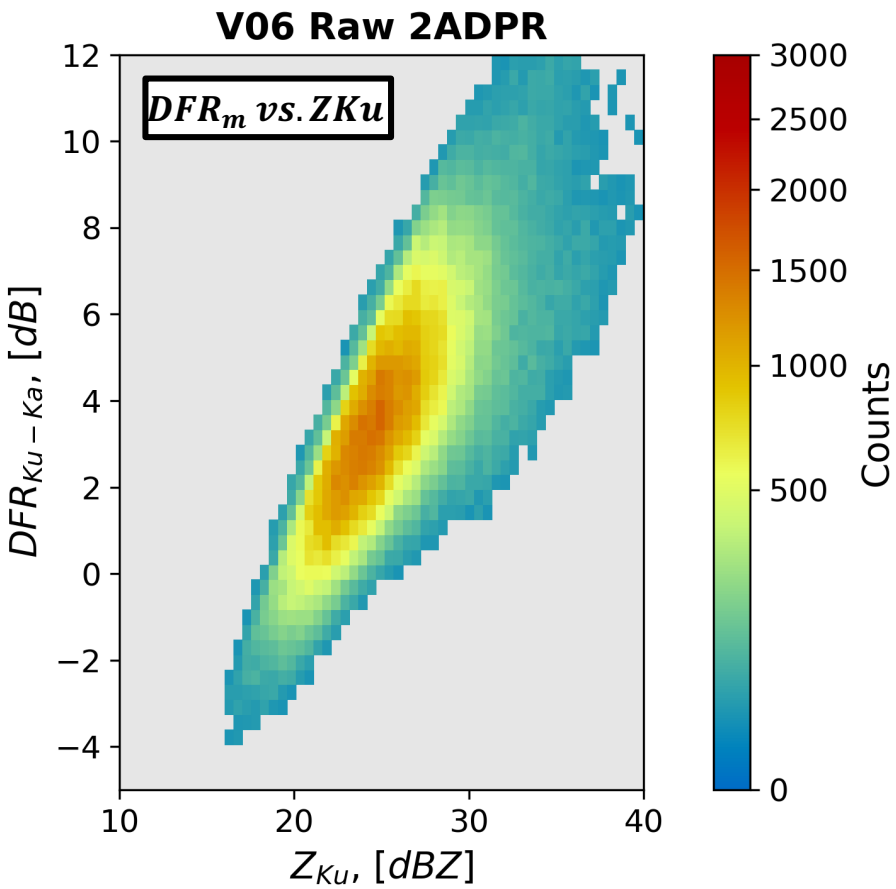
- Is this approach reasonable in ice clouds? ice over rain?
  - Look at products [IWC, N_w, D_m]
  - Compare with scattering models
  - Compare with NASA GPM GV data

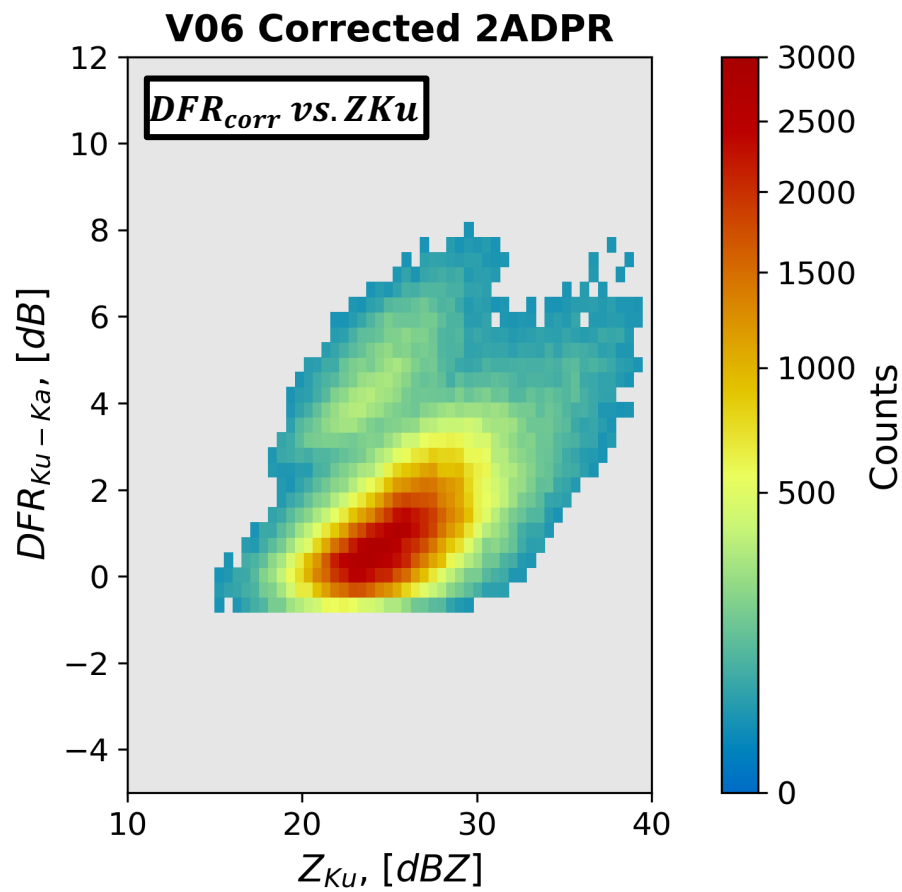
Adapted from PMM 2016, Seto san



ε is constant in the profile in V06

21 Cyclone Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)





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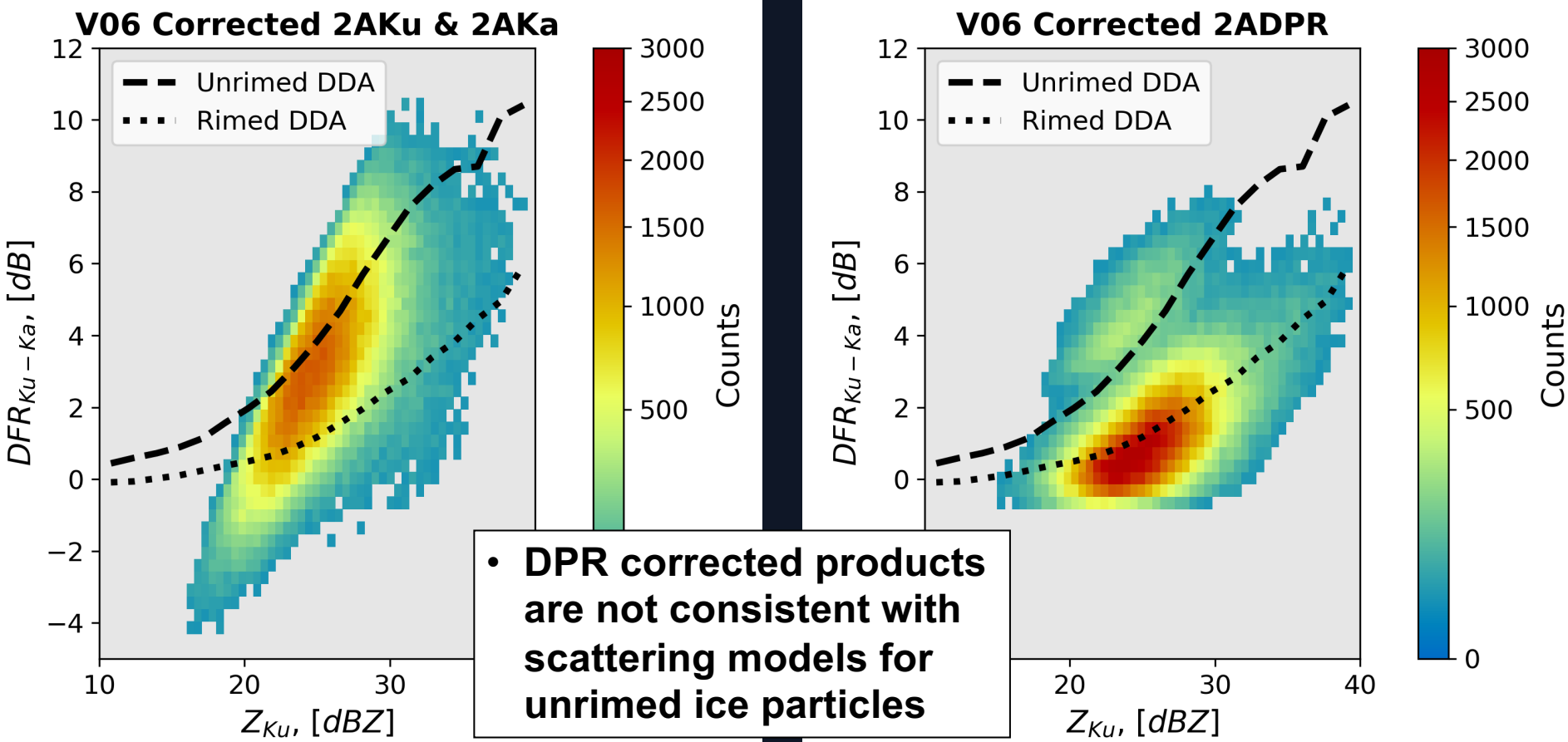
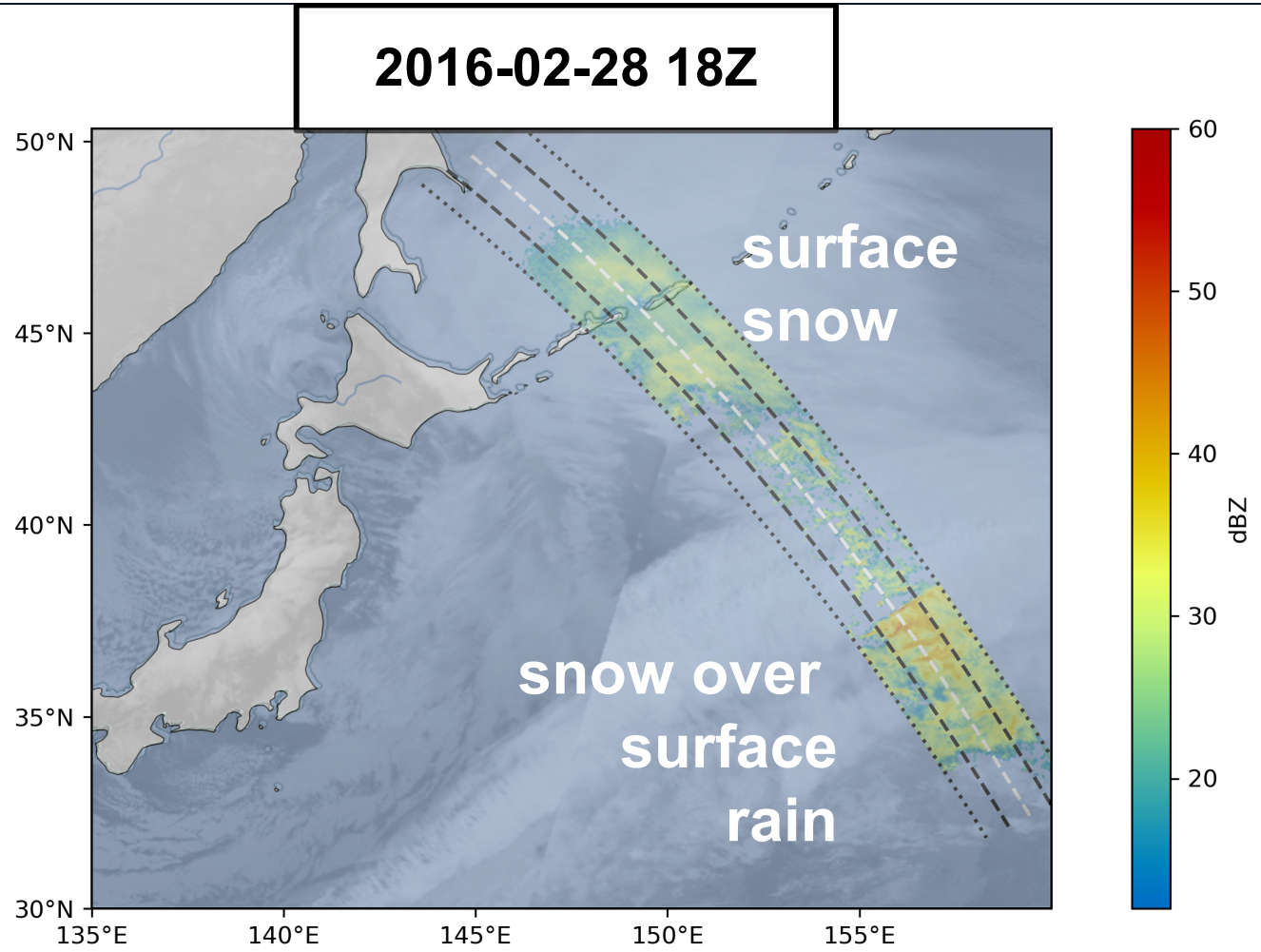
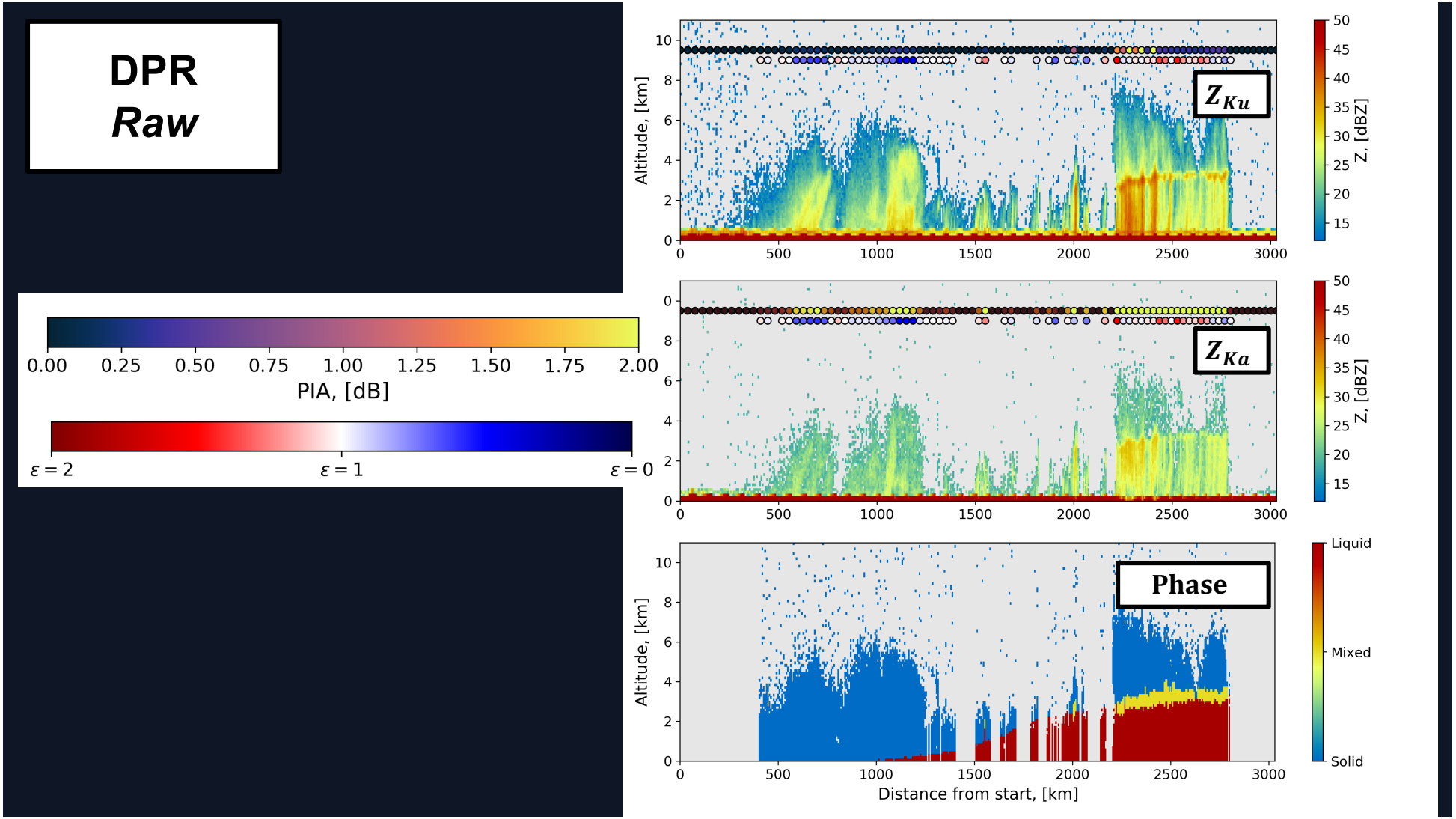
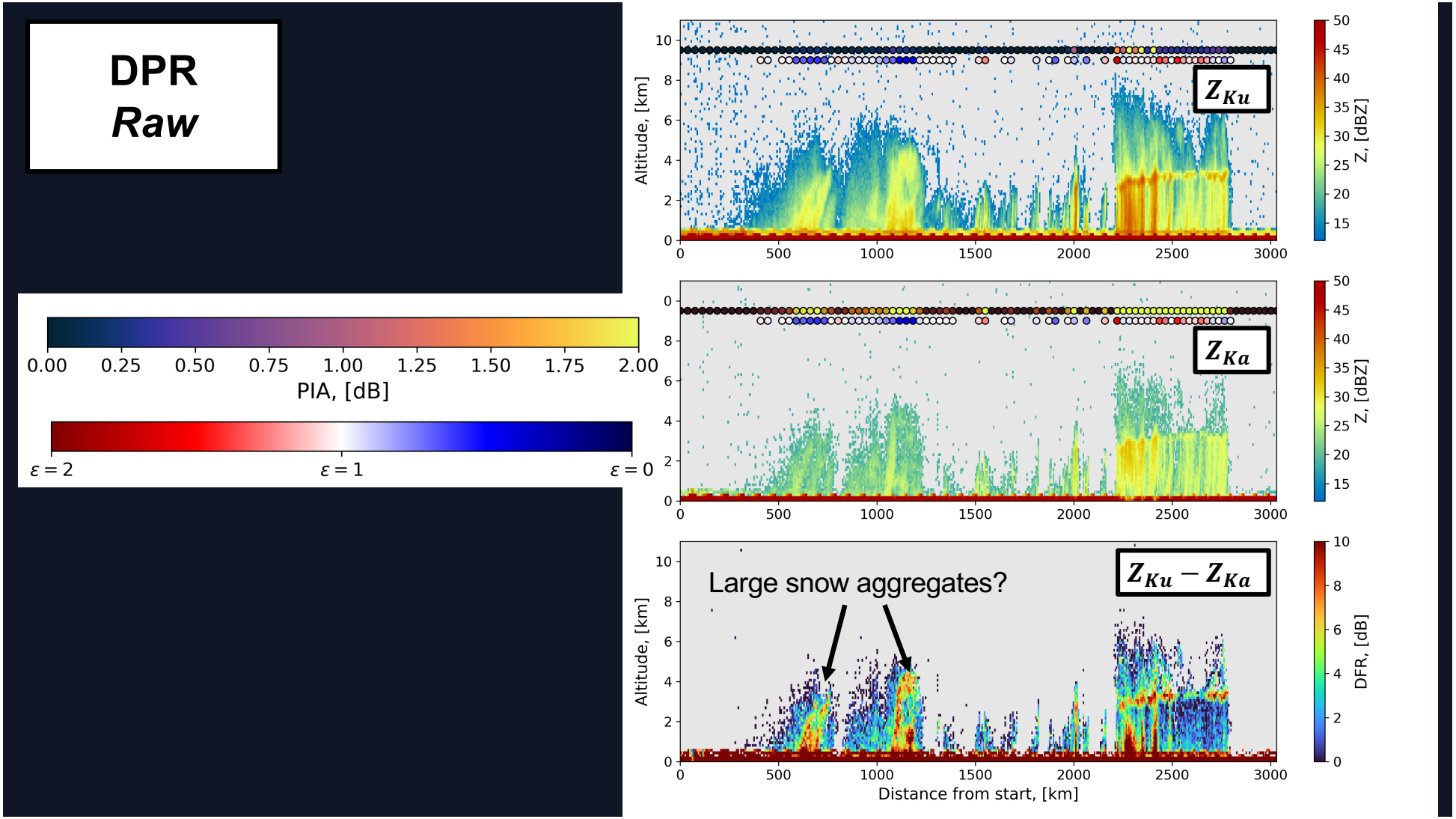
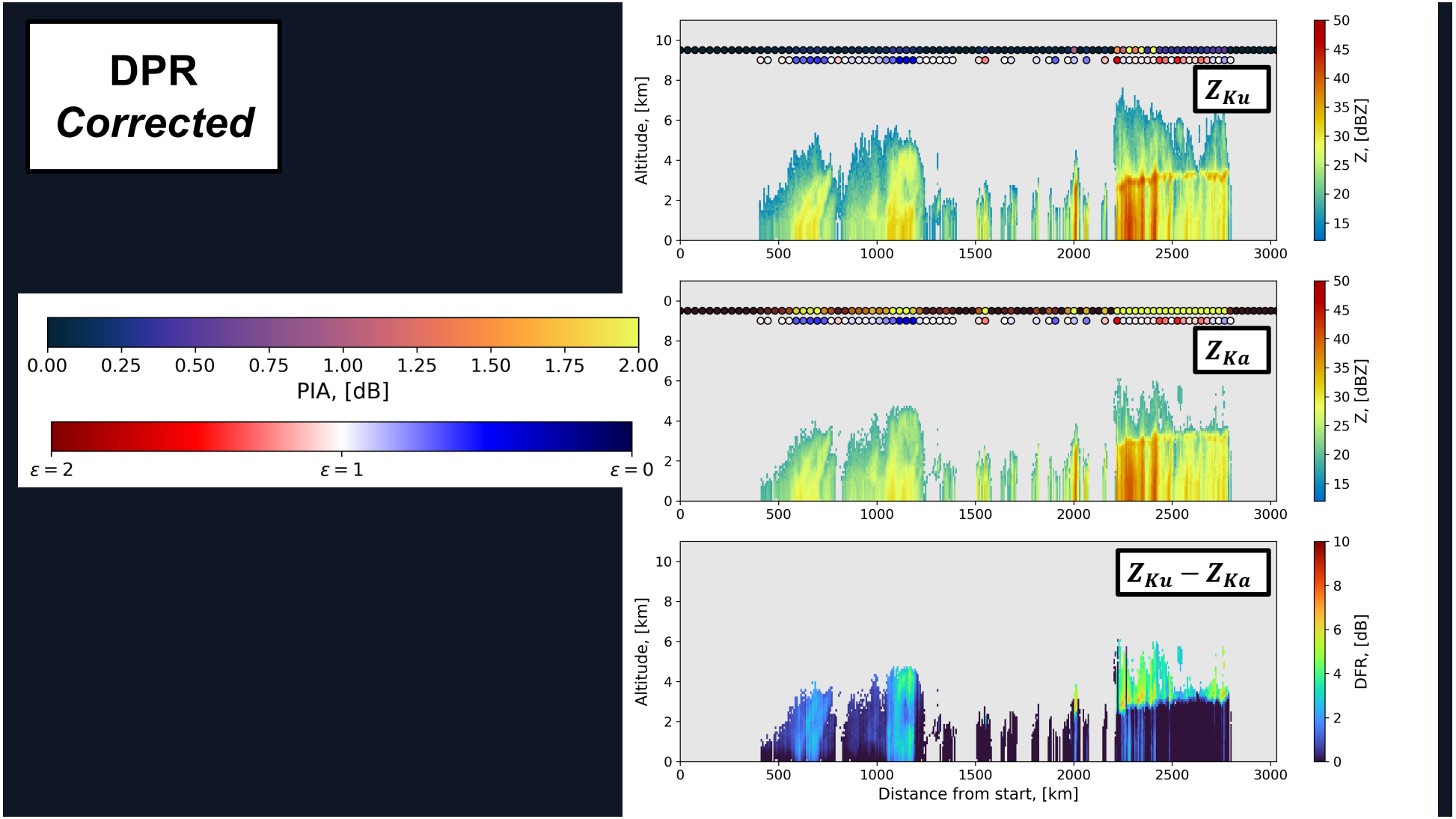


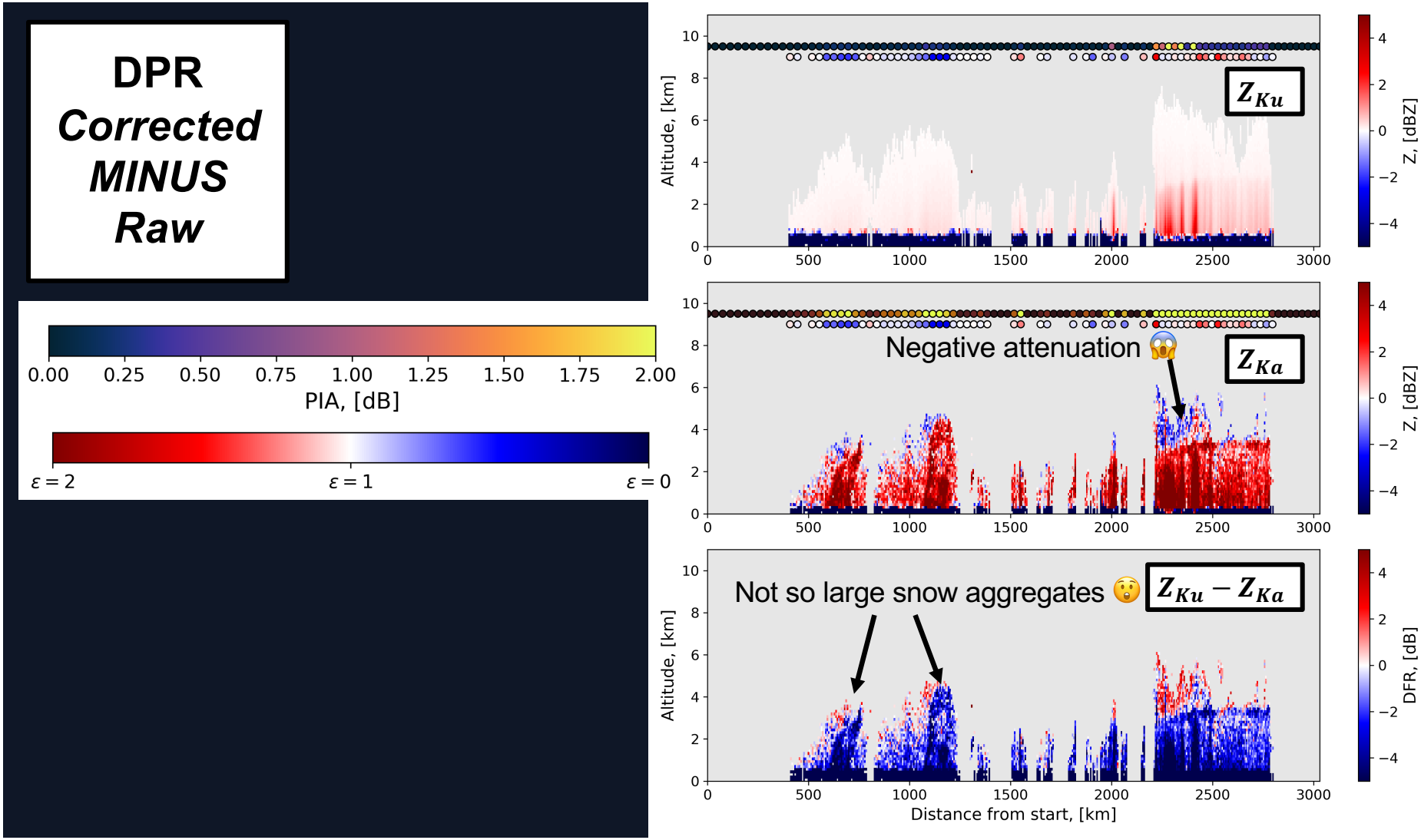
- **DPR corrected products are not consistent with scattering models for unrimed ice particles**


2016-02-28 18Z
surface
snow
snow over
surface
rain
50°N
45°N
40°N
35°N
30°N
135°E
140°E
145°E
150°E
155°E
60
50
40
30
20
dBZ

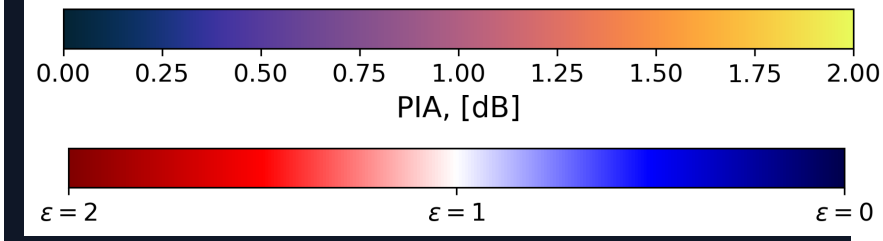

DPR
Raw
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
PIA, [dB]
$\varepsilon = 2$
$\varepsilon = 1$
$\varepsilon = 0$
Z_{Ku}
Z_{Ka}
Phase
Altitude, [km]
Z, [dBZ]
Liquid
Mixed
Solid
Distance from start, [km]

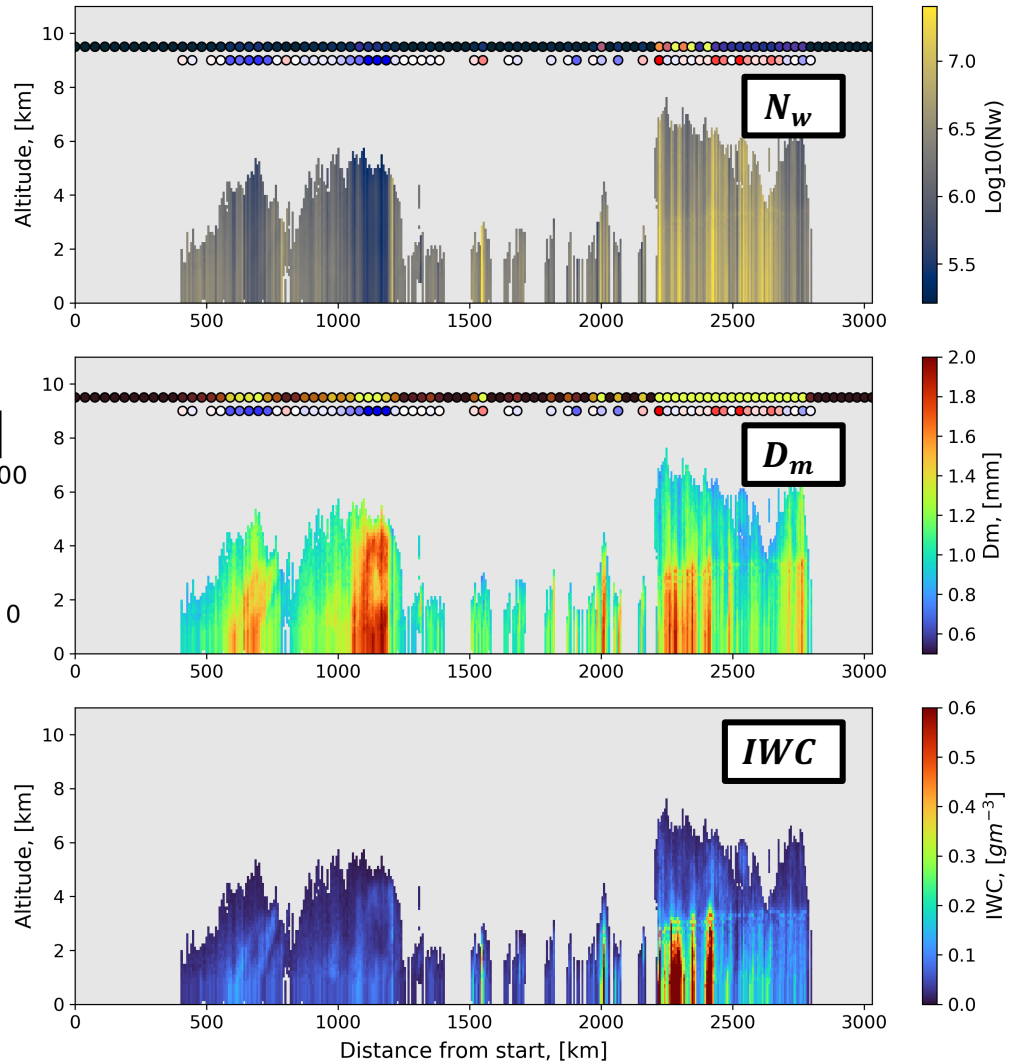

DPR
Raw
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
PIA, [dB]
$\varepsilon = 2$
$\varepsilon = 1$
$\varepsilon = 0$
Z_{Ku}
Z_{Ka}
$Z_{Ku} - Z_{Ka}$
Large snow aggregates?
Altitude, [km]
Distance from start, [km]
Z, [dBZ]
DFR, [dB]


DPR
Corrected
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
PIA, [dB]
$\varepsilon = 2$
$\varepsilon = 1$
$\varepsilon = 0$
Z_{Ku}
Z_{Ka}
$Z_{Ku} - Z_{Ka}$
Altitude, [km]
Distance from start, [km]
Z, [dBZ]
DFR, [dB]

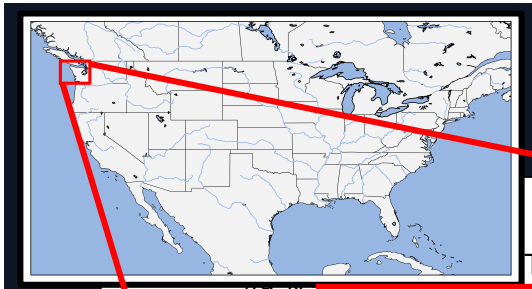

DPR
Corrected
MINUS
Raw
0.00 0.25 0.50 0.75 1.00 1.25 1.50 1.75 2.00
PIA, [dB]
ε = 2
ε = 1
ε = 0
Altitude, [km]
Z_{Ku}
Z, [dBZ]
Negative attenuation
Z_{Ka}
Z, [dBZ]
Not so large snow aggregates
$Z_{Ku} - Z_{Ka}$
DFR, [dB]
Distance from start, [km]

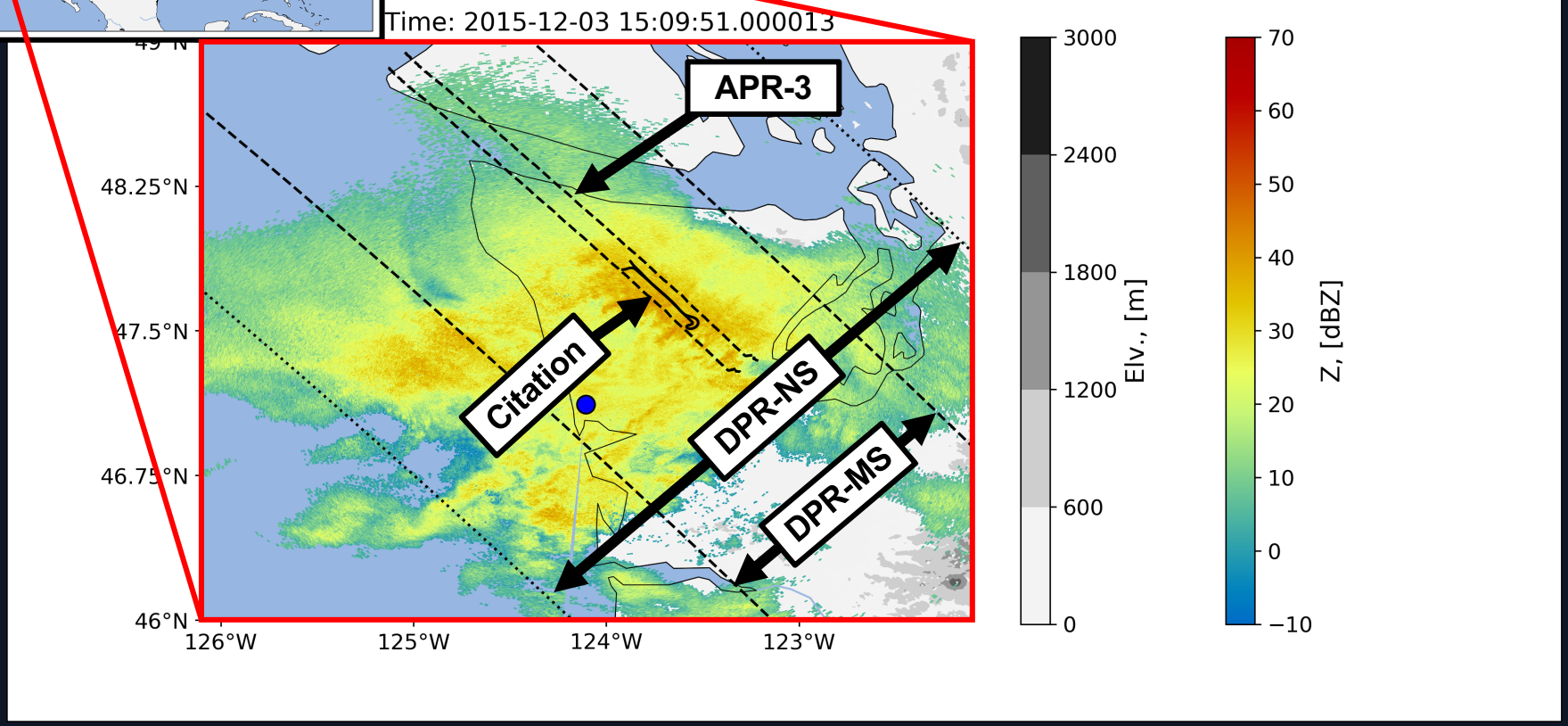
DPR Microphysical retrievals



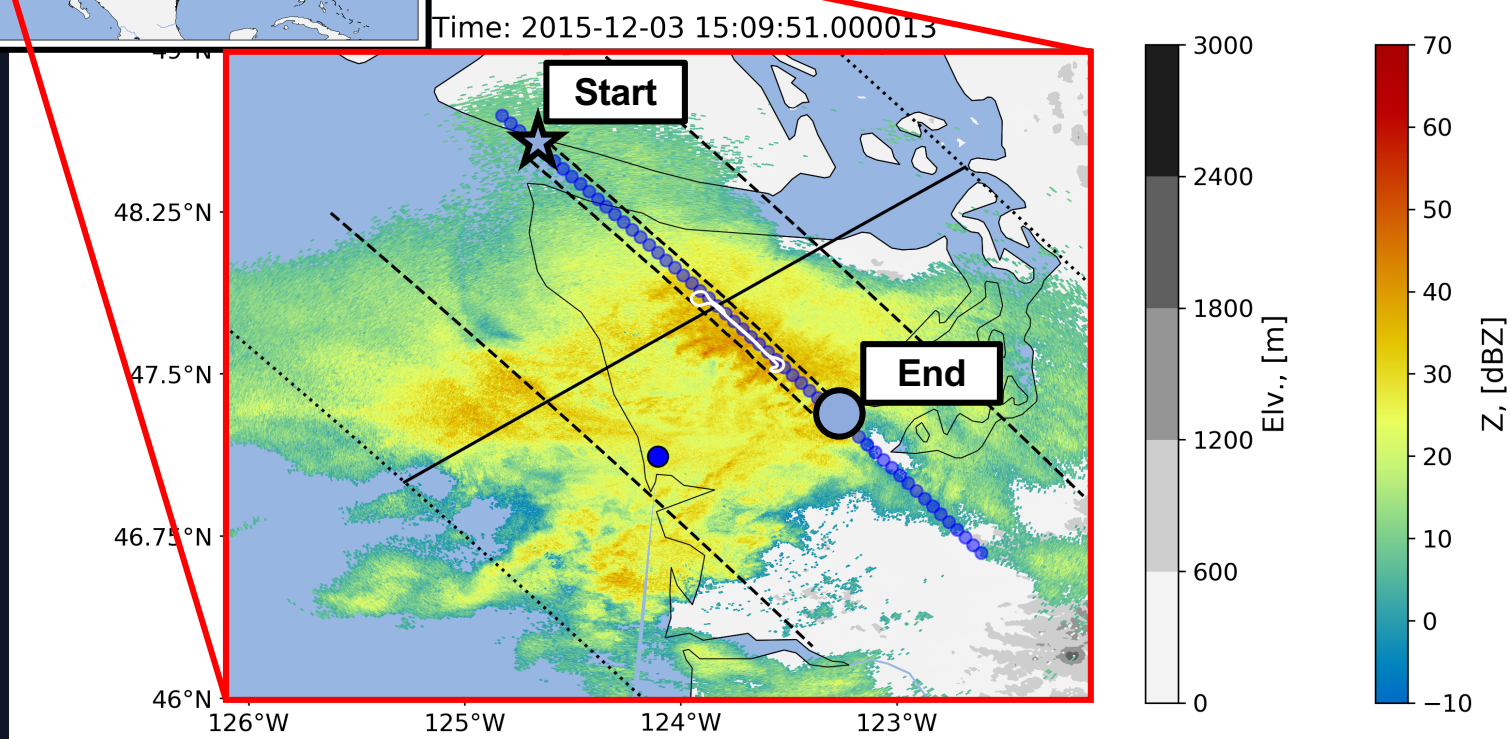


3 December 2015

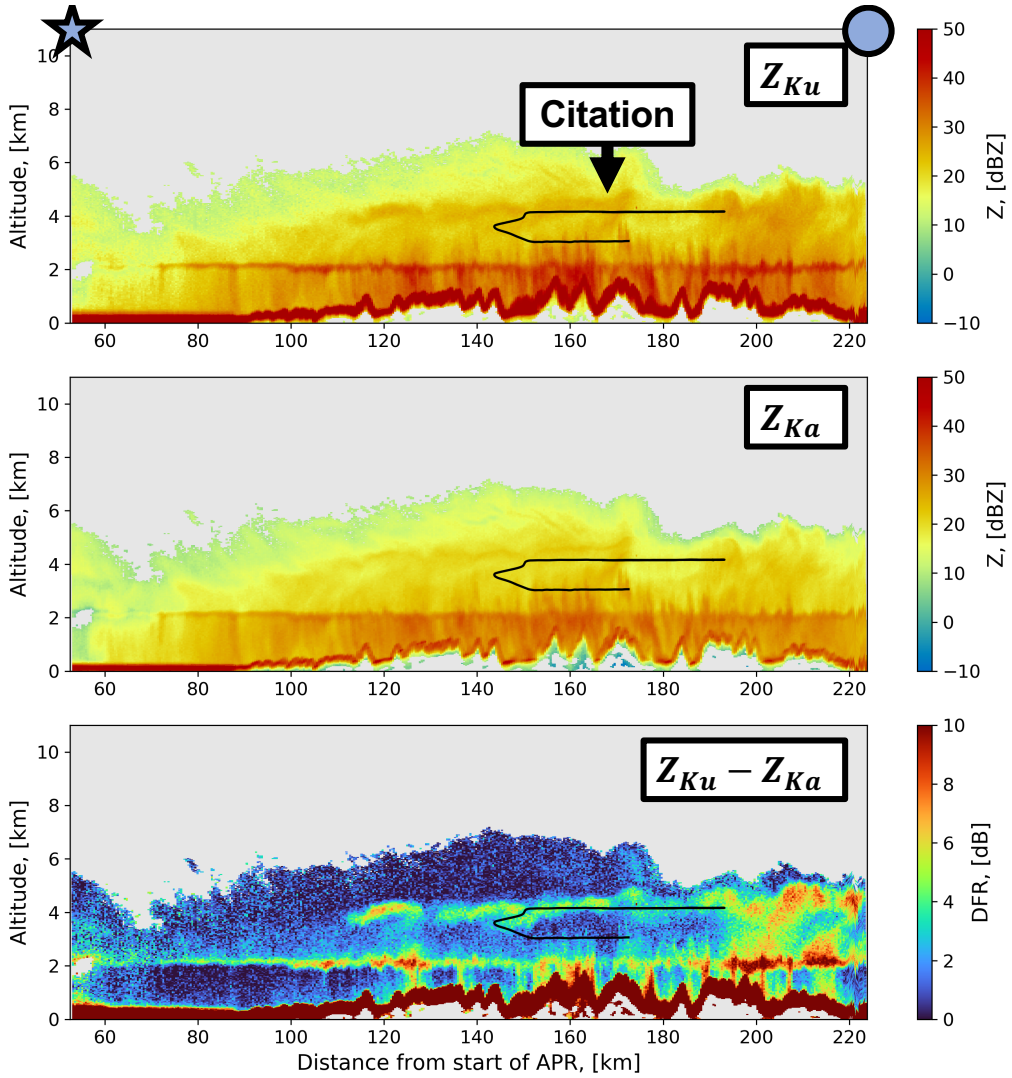




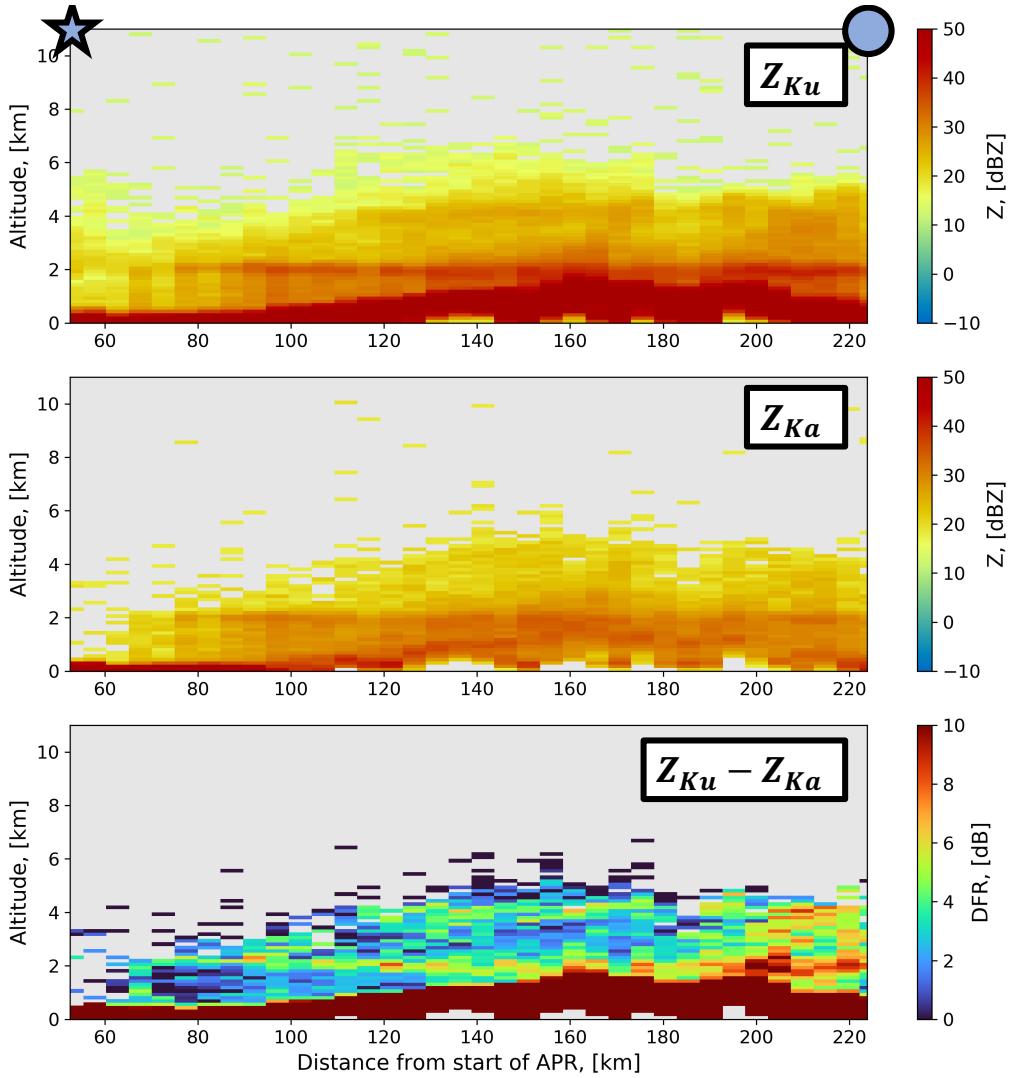
3 December 2015



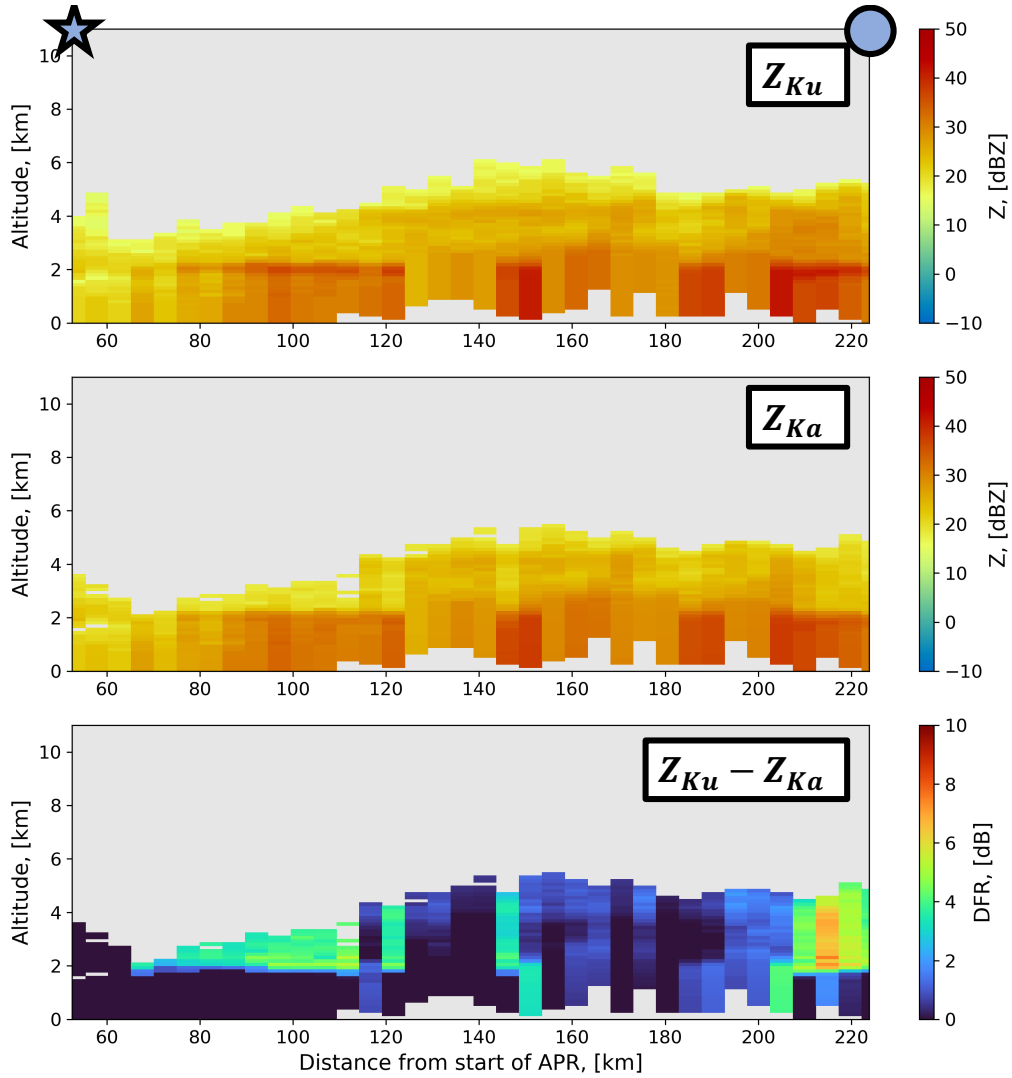
APR-3


Citation
Z_{Ku}
Z_{Ka}
$Z_{Ku} - Z_{Ka}$
Altitude, [km]
Z, [dBZ]
DFR, [dB]
Distance from start of APR, [km]

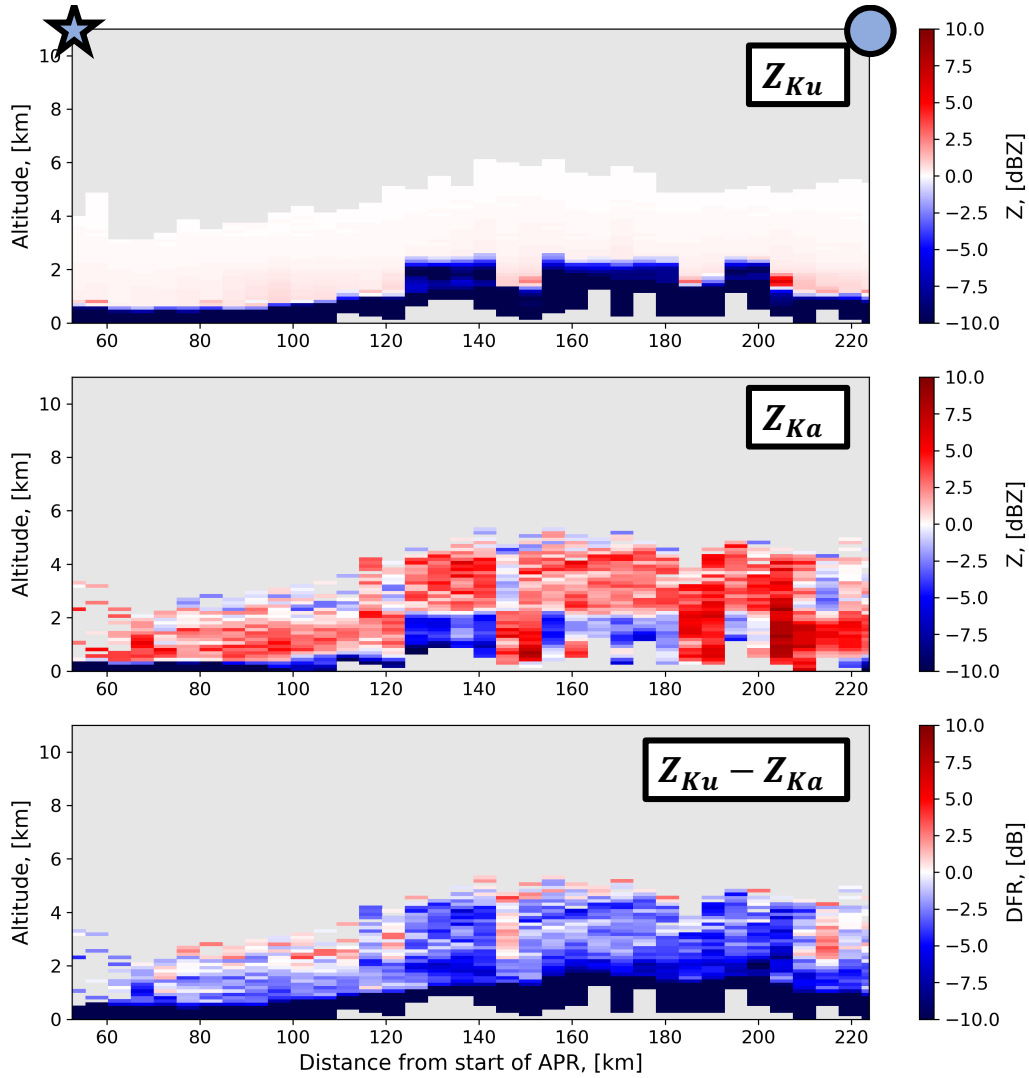
DPR
Raw


Z_{Ku}
Z_{Ka}
$Z_{Ku} - Z_{Ka}$
Altitude, [km]
Z, [dBZ]
DFR, [dB]
Distance from start of APR, [km]

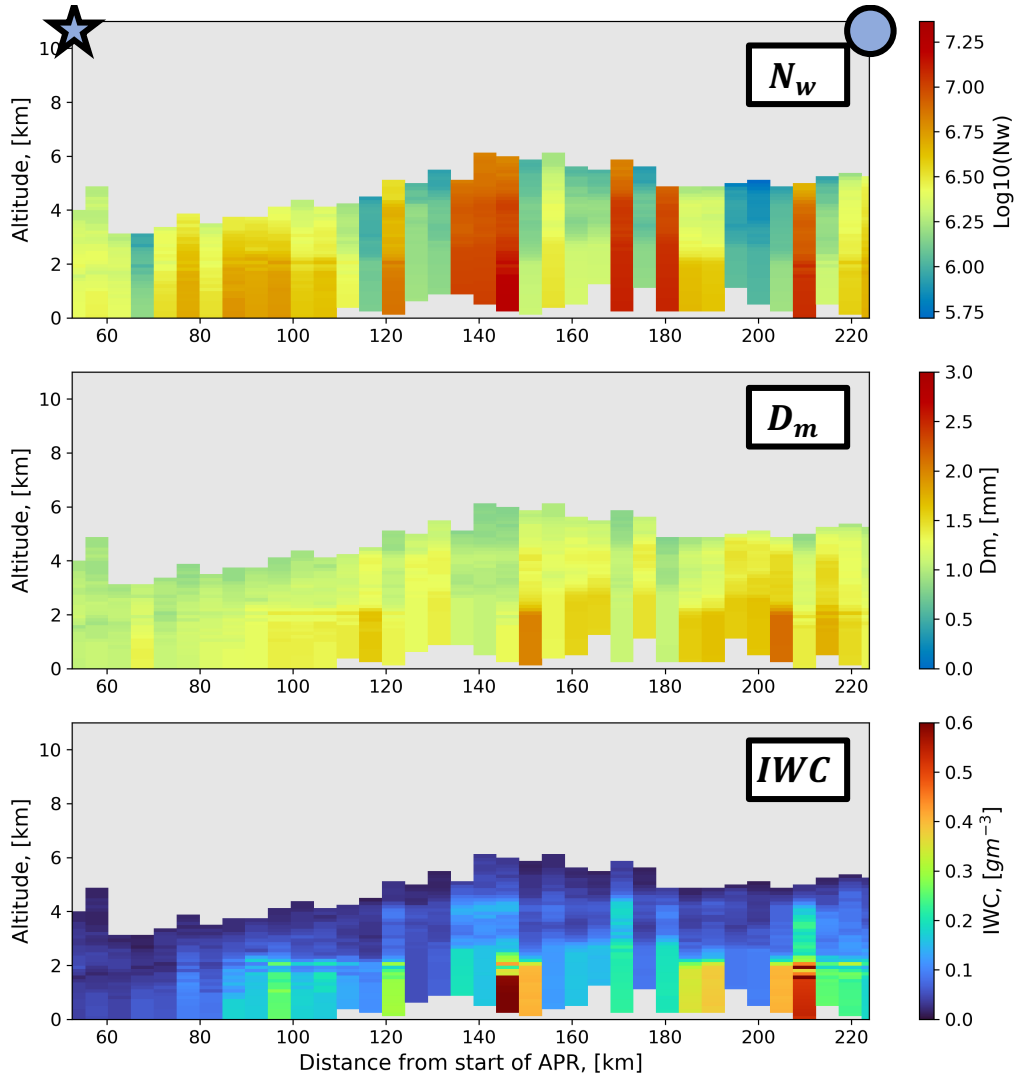
DPR
Corrected



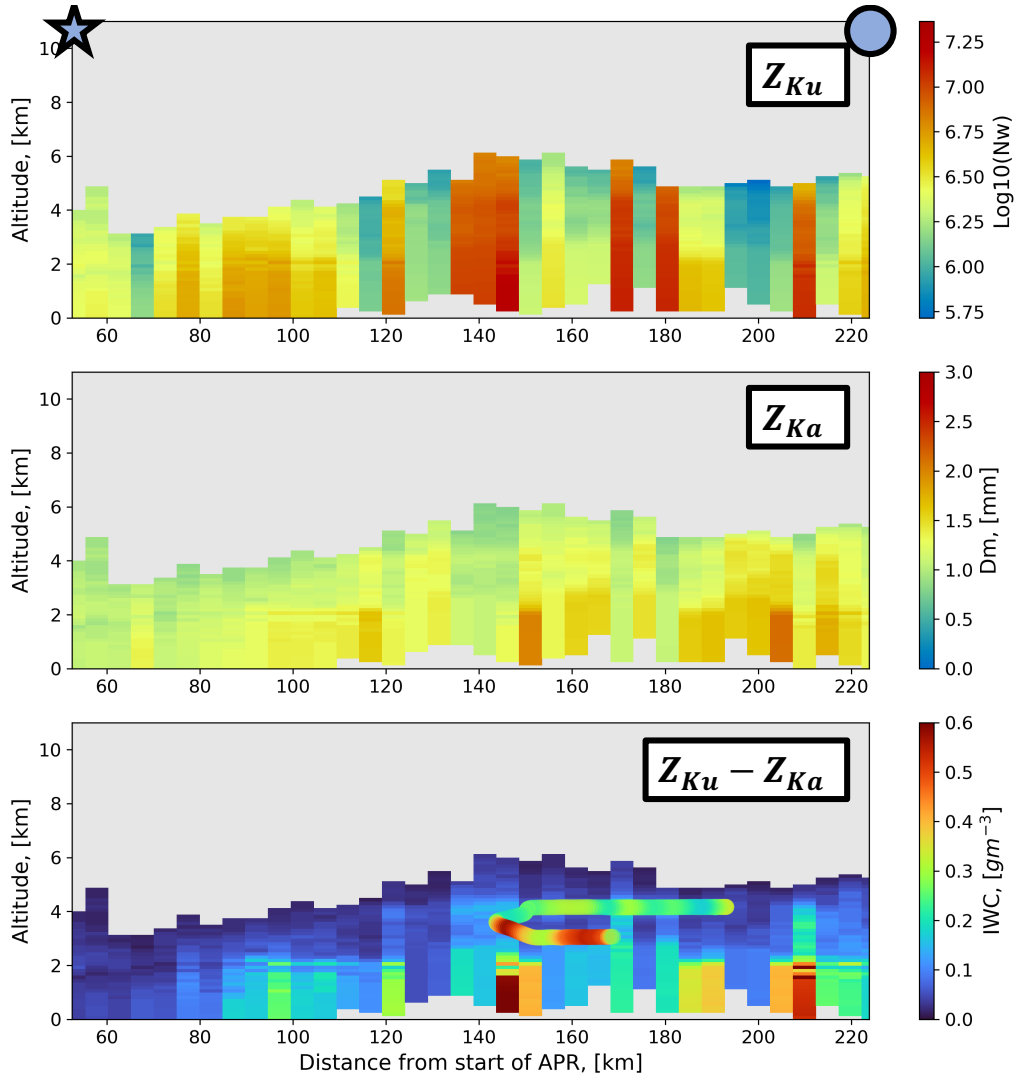
DPR
Corrected
MINUS
Raw



DPR *Retrieval*

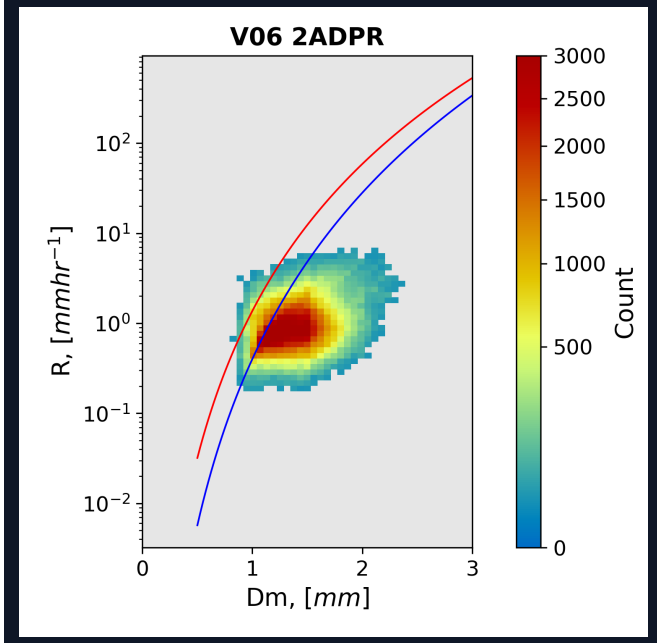


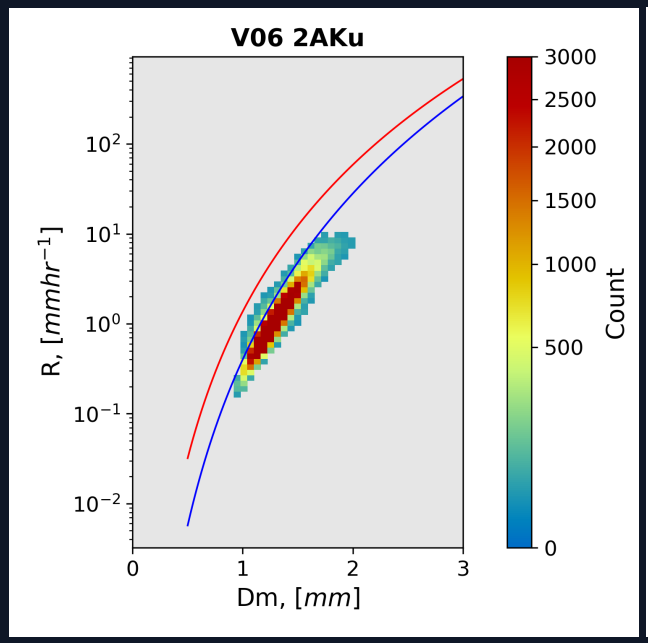
DPR *Retrieved with in-situ* IWC

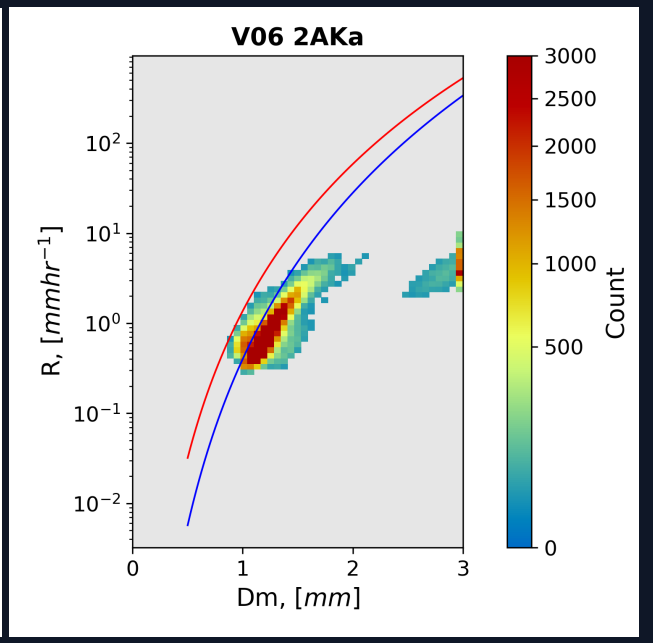


Underestimation of DFR leads to lower IWC (S) for a given Z

21 Cyclone Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)







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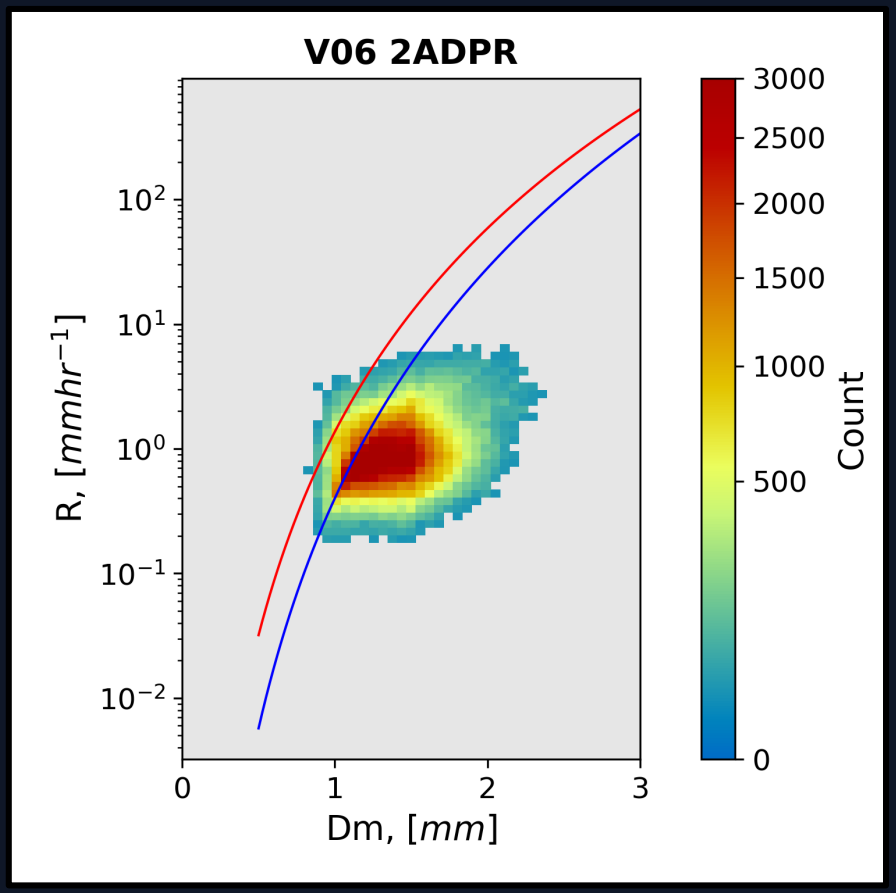
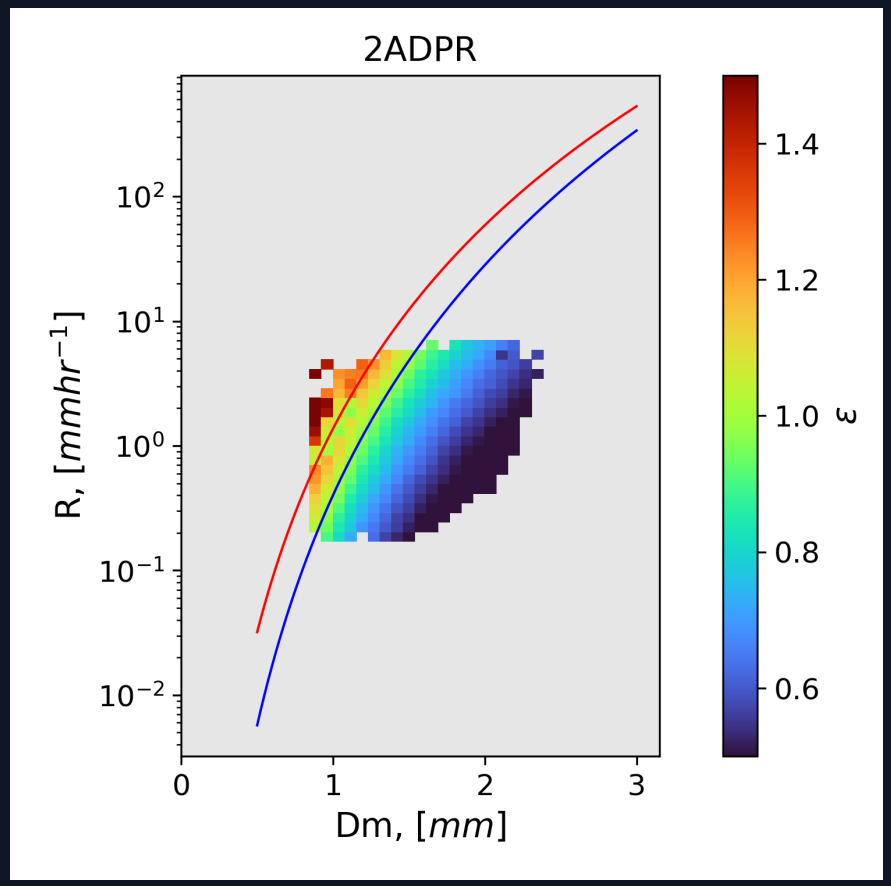
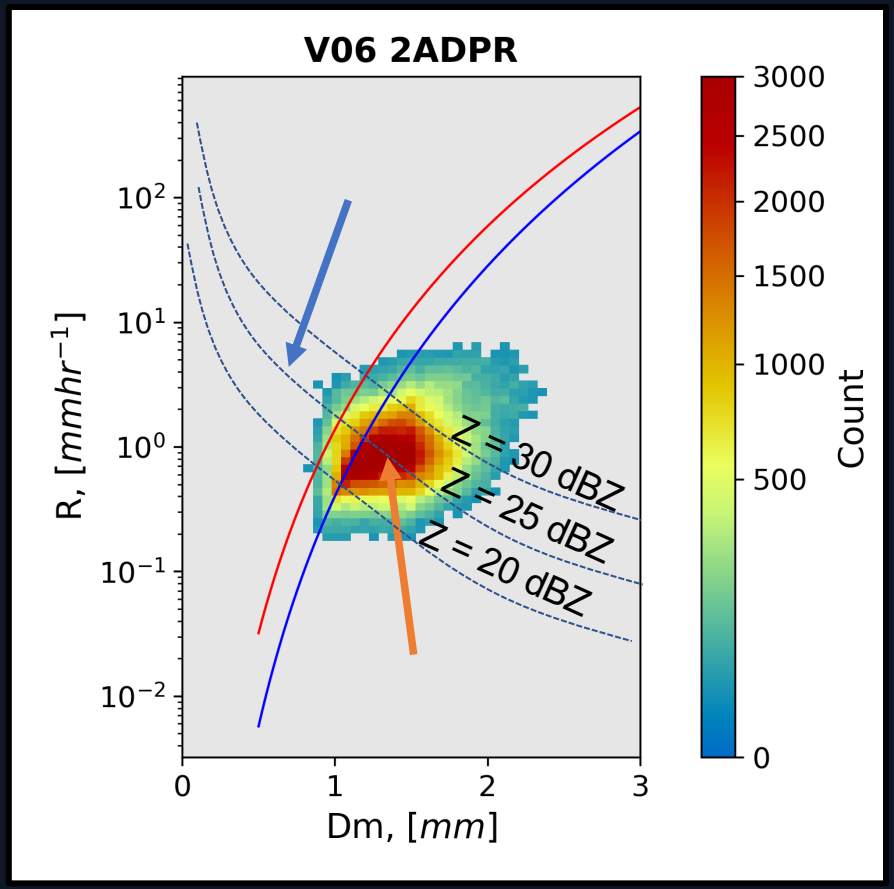


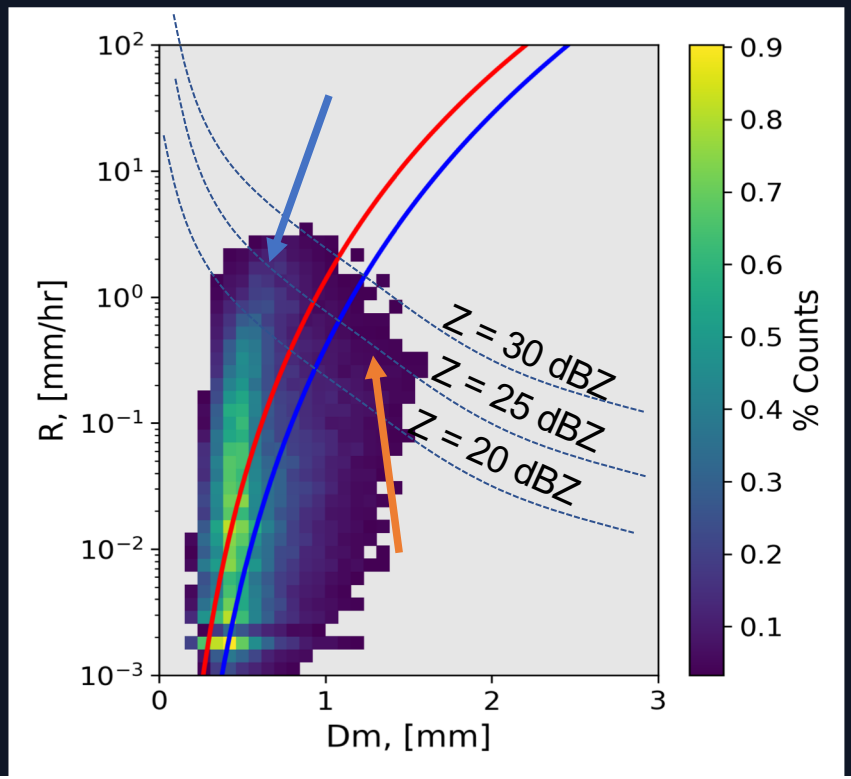


21 Cyclone Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)



$$R = 0.401\epsilon^{4.609} D_m^{6.131}$$

MQT; Pettersen and Kulie; Chase et al. (2019, in prep)



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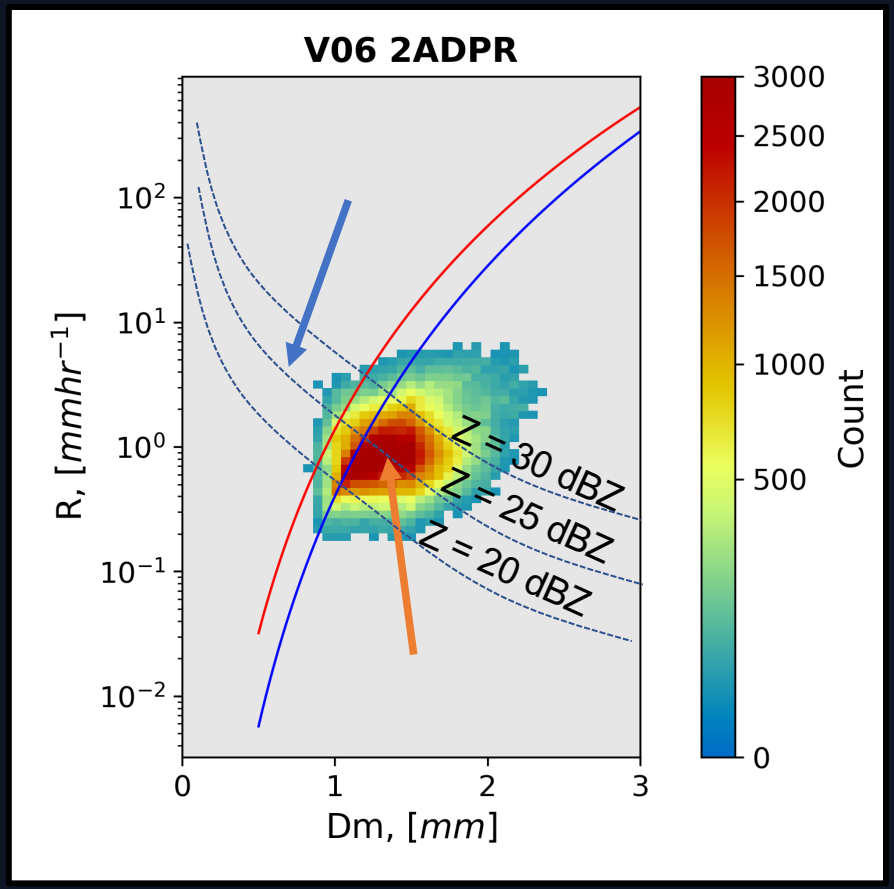
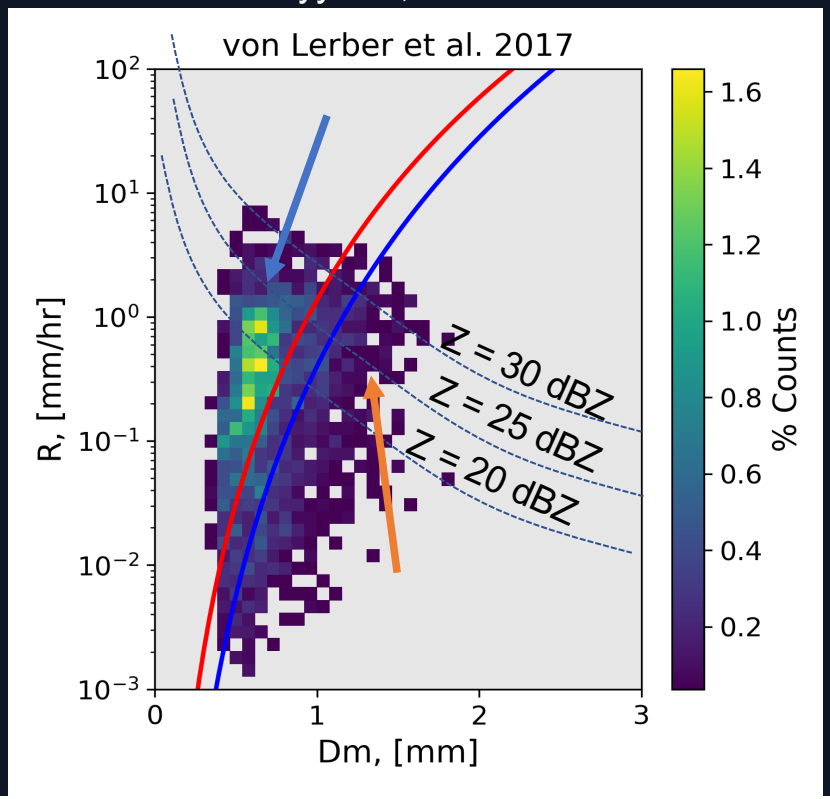
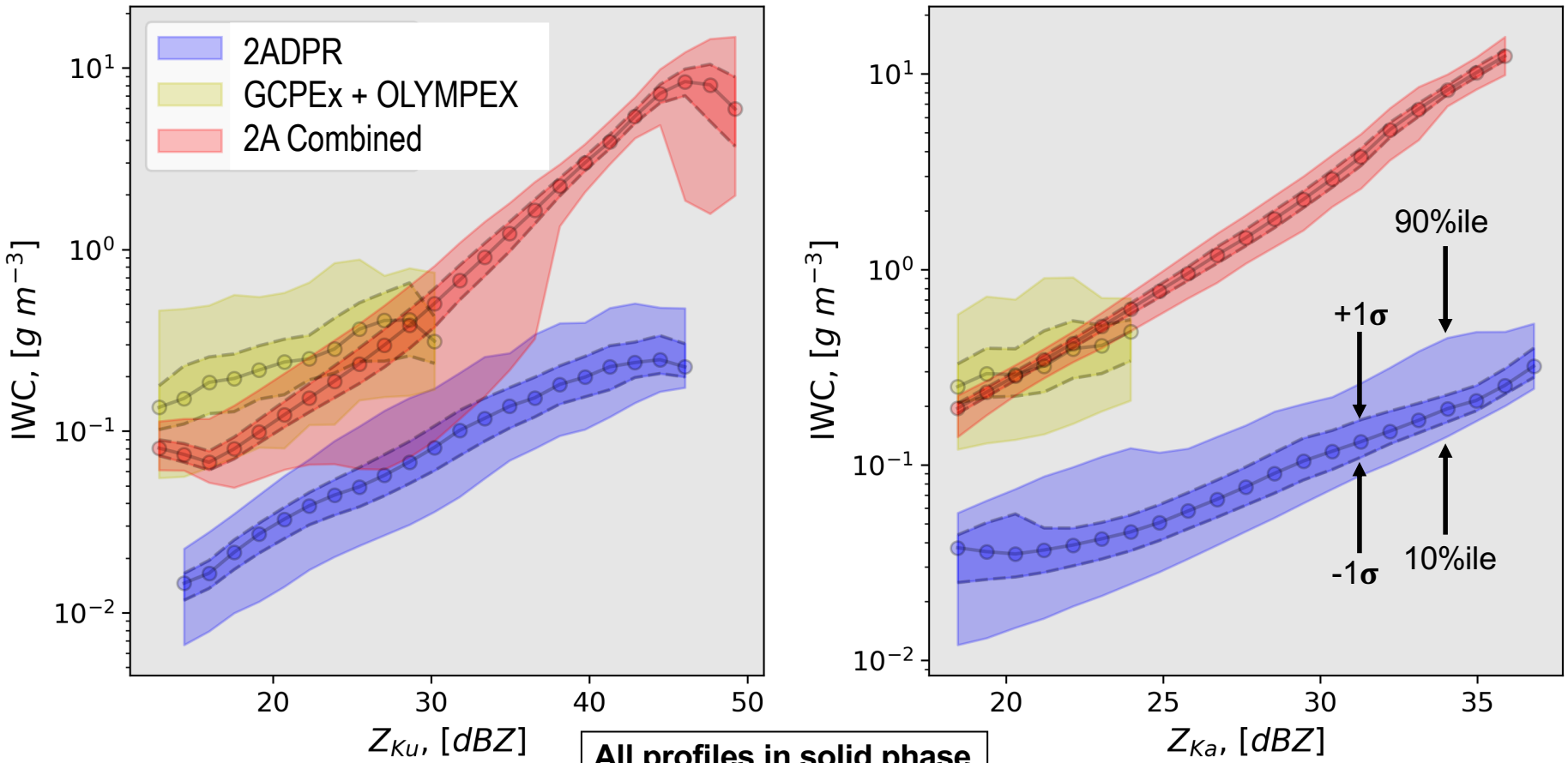


$$R = 0.401\epsilon^{4.609} D_m^{6.131}$$

Hyytiälä, Finland

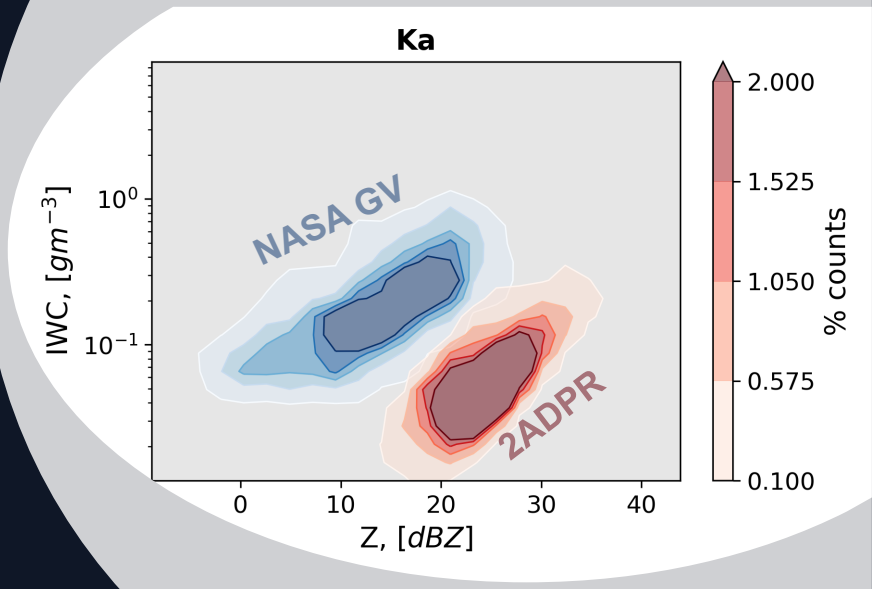




All profiles in solid phase (convective + stratiform)

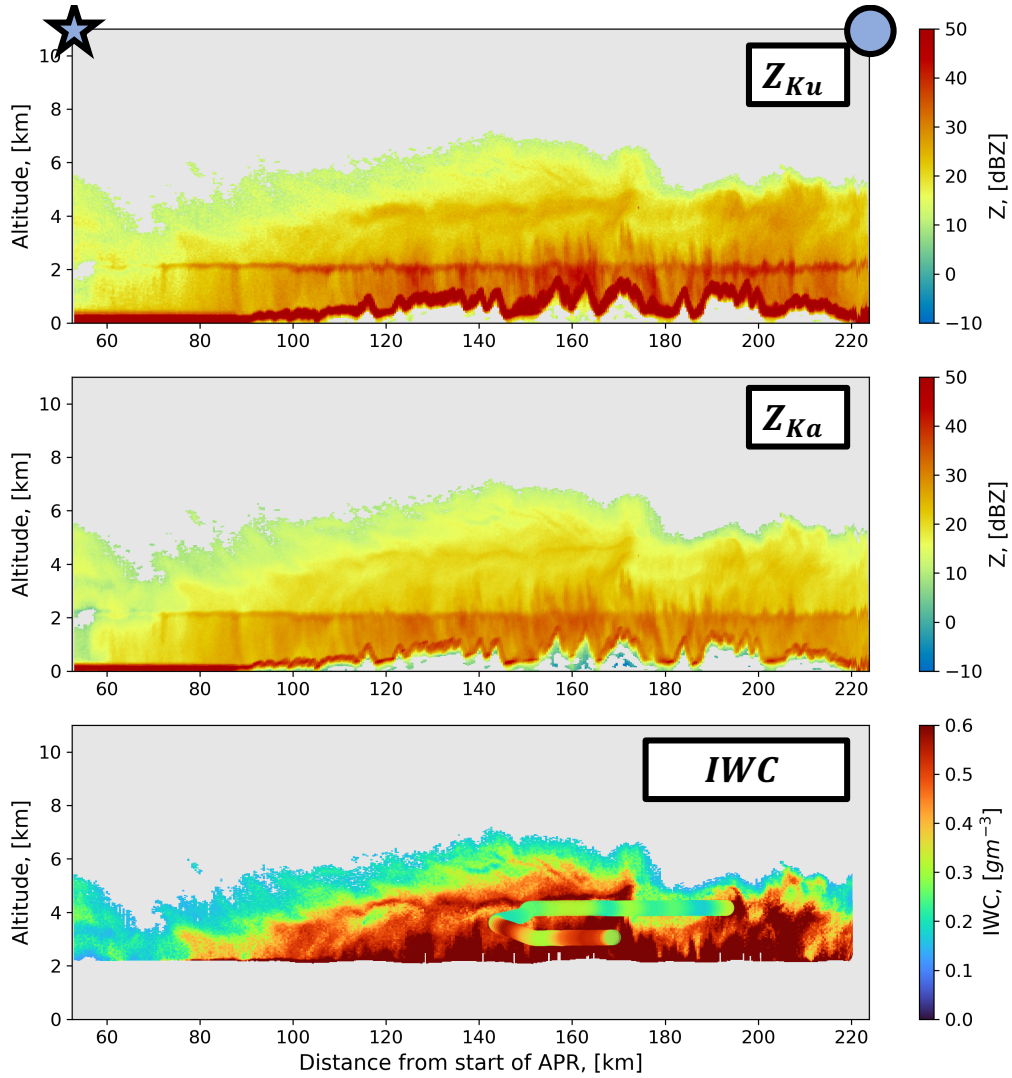
Summary

- Corrected DPR products underestimate IWC by a factor of 6-10 (aside from detection issues)
  - Epsilon too low, which leads to low R (IWC)
  - Ice DSD parameter estimates in corrected products have artifacts, not meaningful in V06
- DFR corrections unreliable at Ka-band, impacts potential retrievals of Dm
- The way forward (short term): Use uncorrected products (e.g., Iguchi et al. 2017)
- Our project: Implement more physically-consistent products constrained by GV-observed PSDs (aircraft+ground), DDA scattering tables, and retrievals using Bayesian and Neural Network retrievals

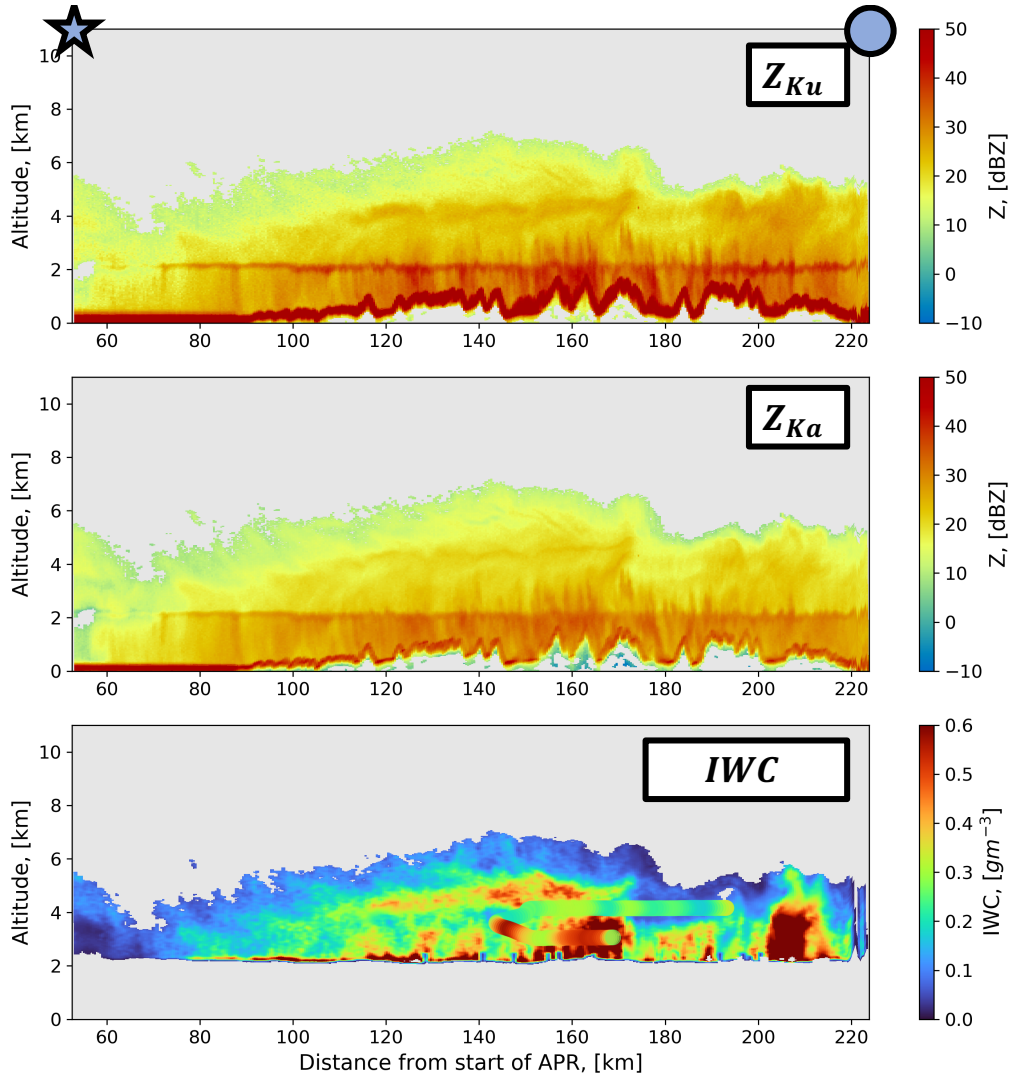


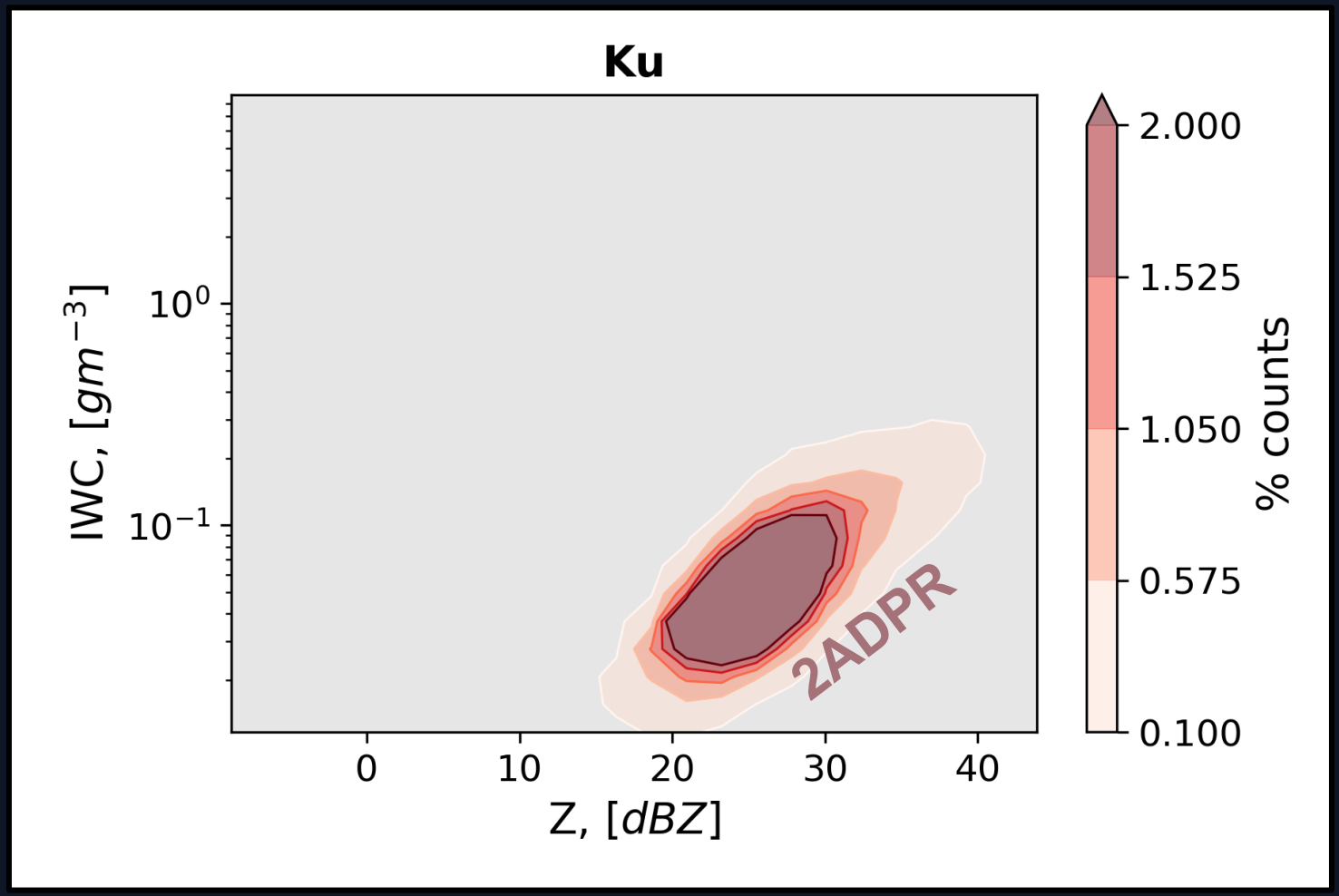
Leionen et al. (AMT)
Tridon et al. (JGR)
Chase et al. (2019, in prep)

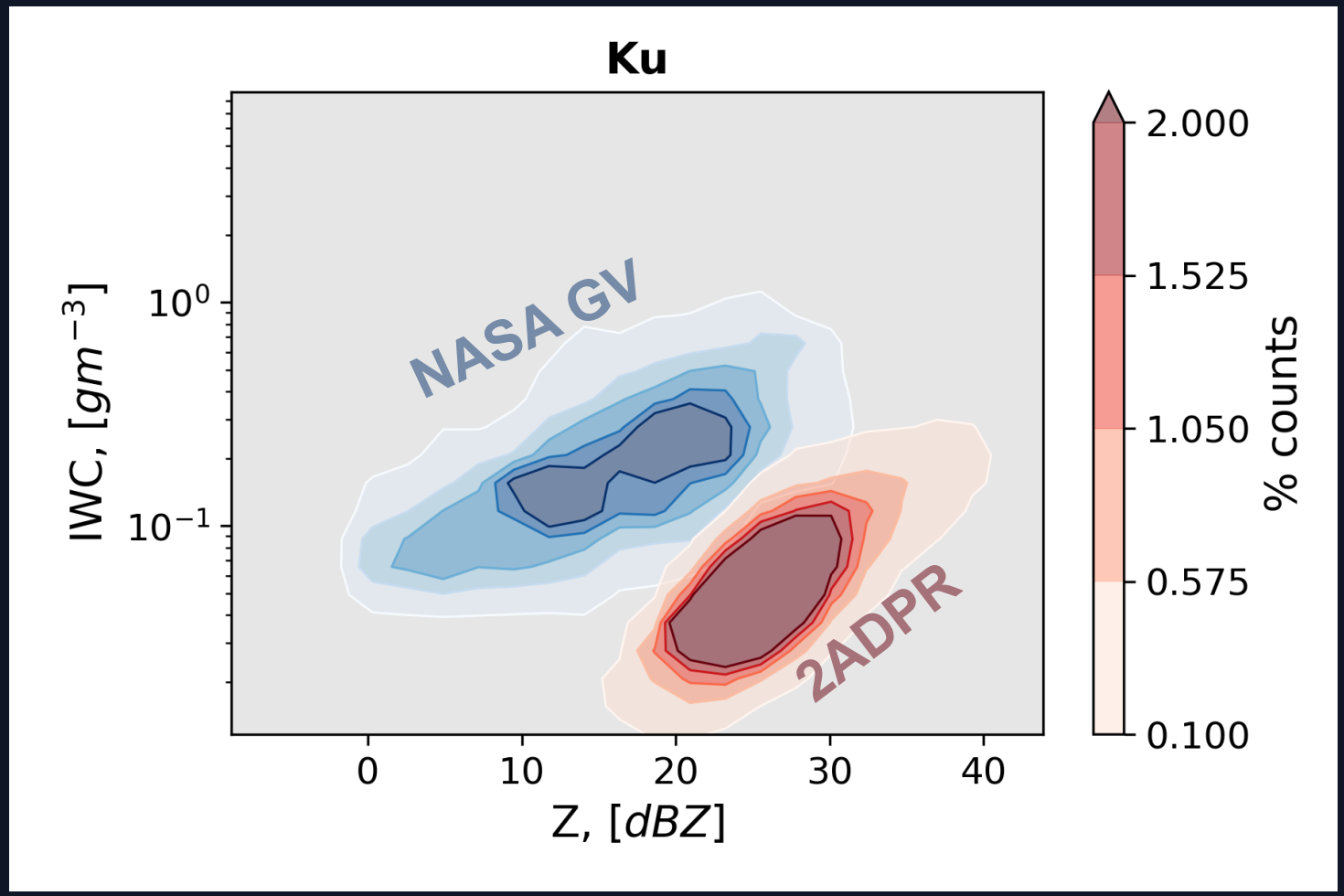
Chase et al. in prep 2-Freq. NN Retrieval

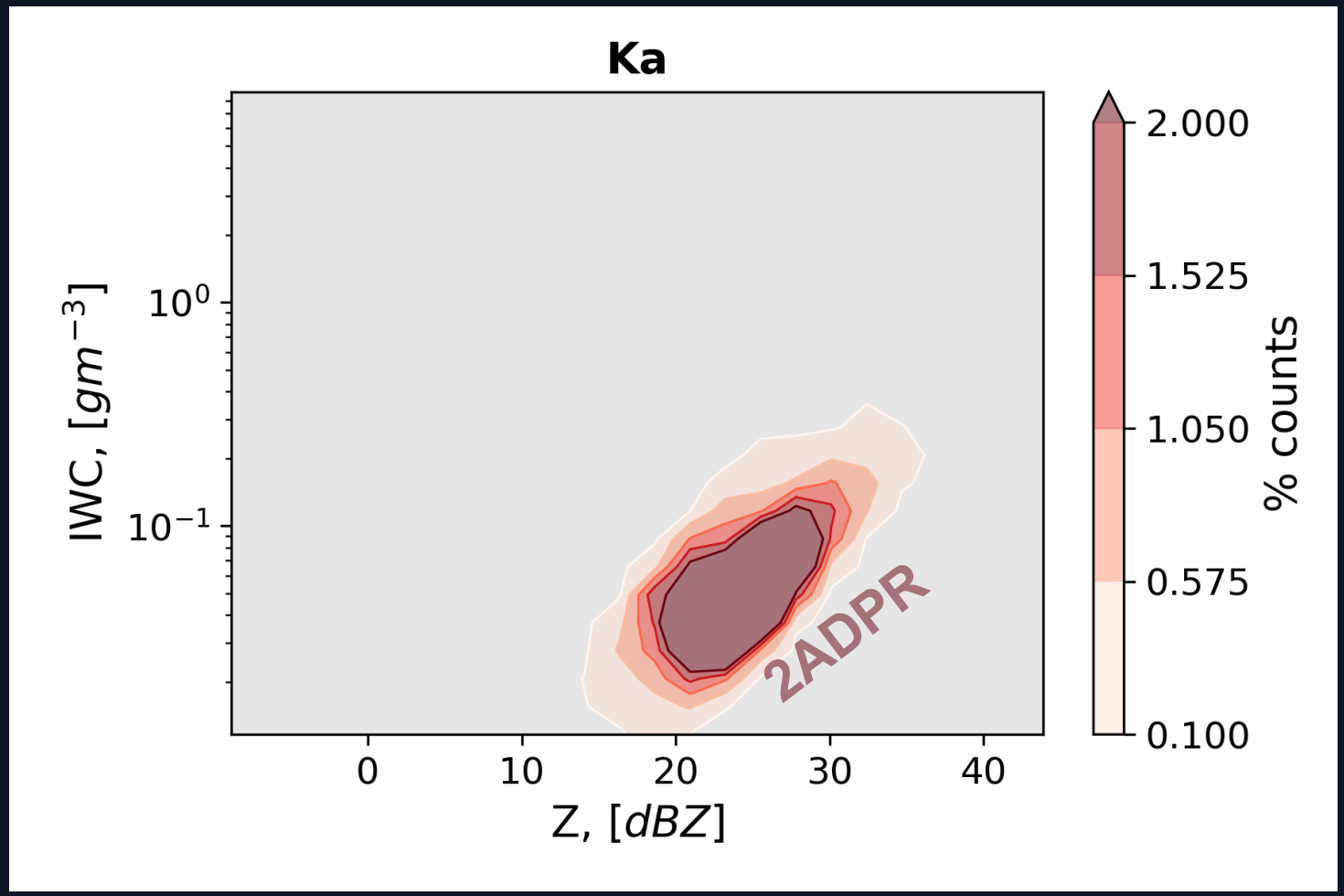


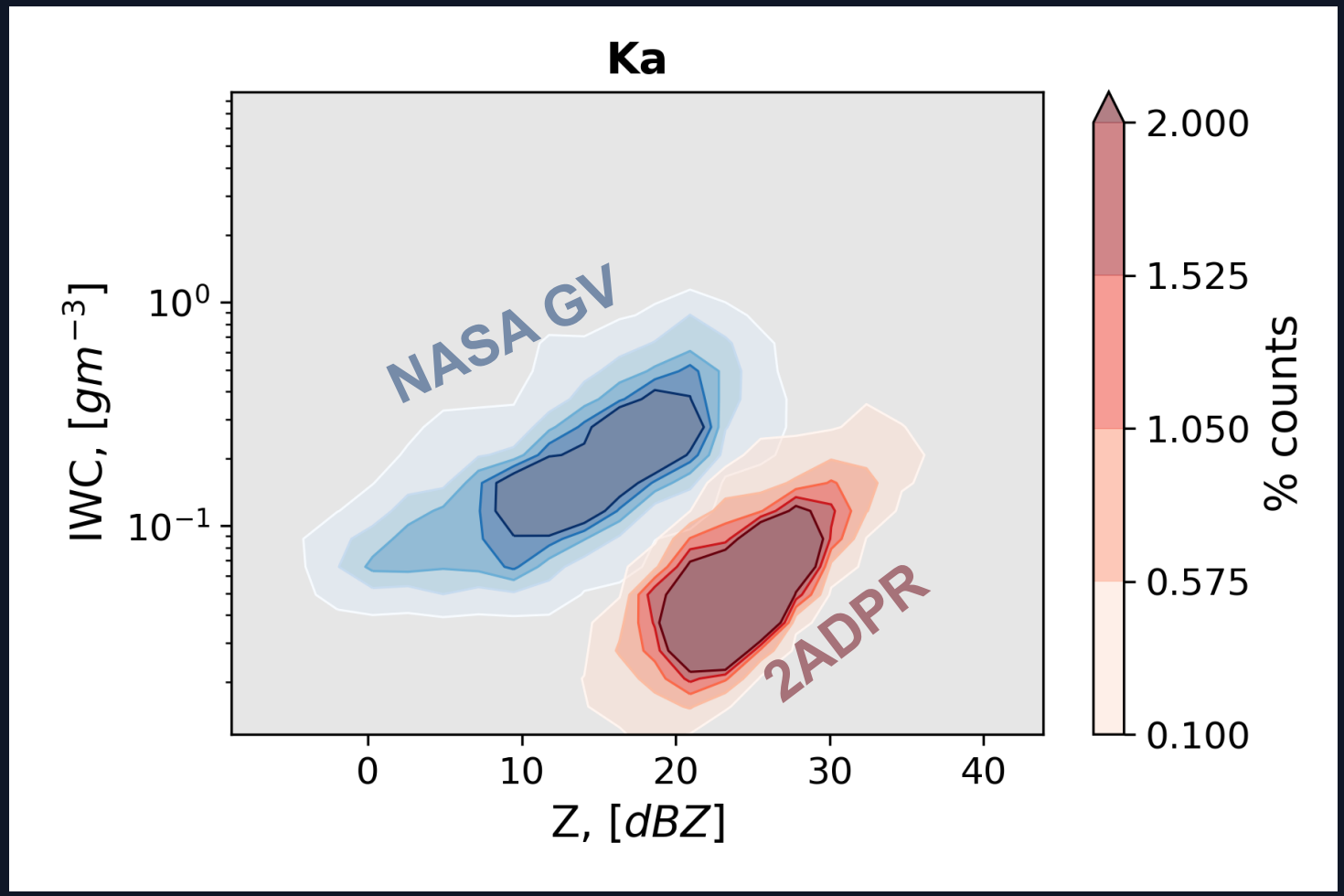
Leinonen et al. 2018 3-Freq. Bayes Retrieval



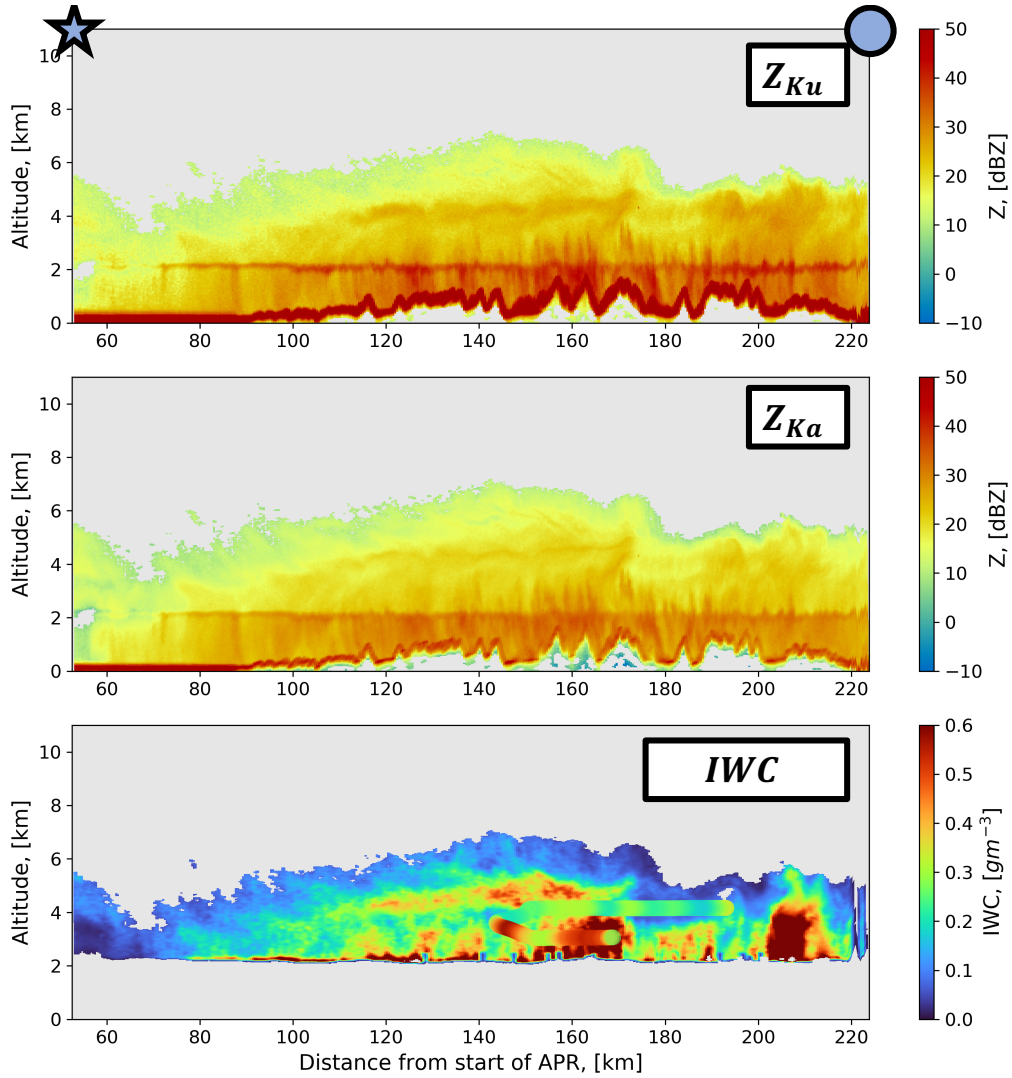

Ku
IWC, [gm^{-3}]
10^0
10^{-1}
0
10
20
30
40
Z, [dBZ]
2ADPR
2.000
1.525
1.050
0.575
0.100
% counts


Ku
NASA GV
2ADPR
IWC, [gm^{-3}]
10^0
10^{-1}
0
10
20
30
40
Z, [dBZ]
2.000
1.525
1.050
0.575
0.100
% counts

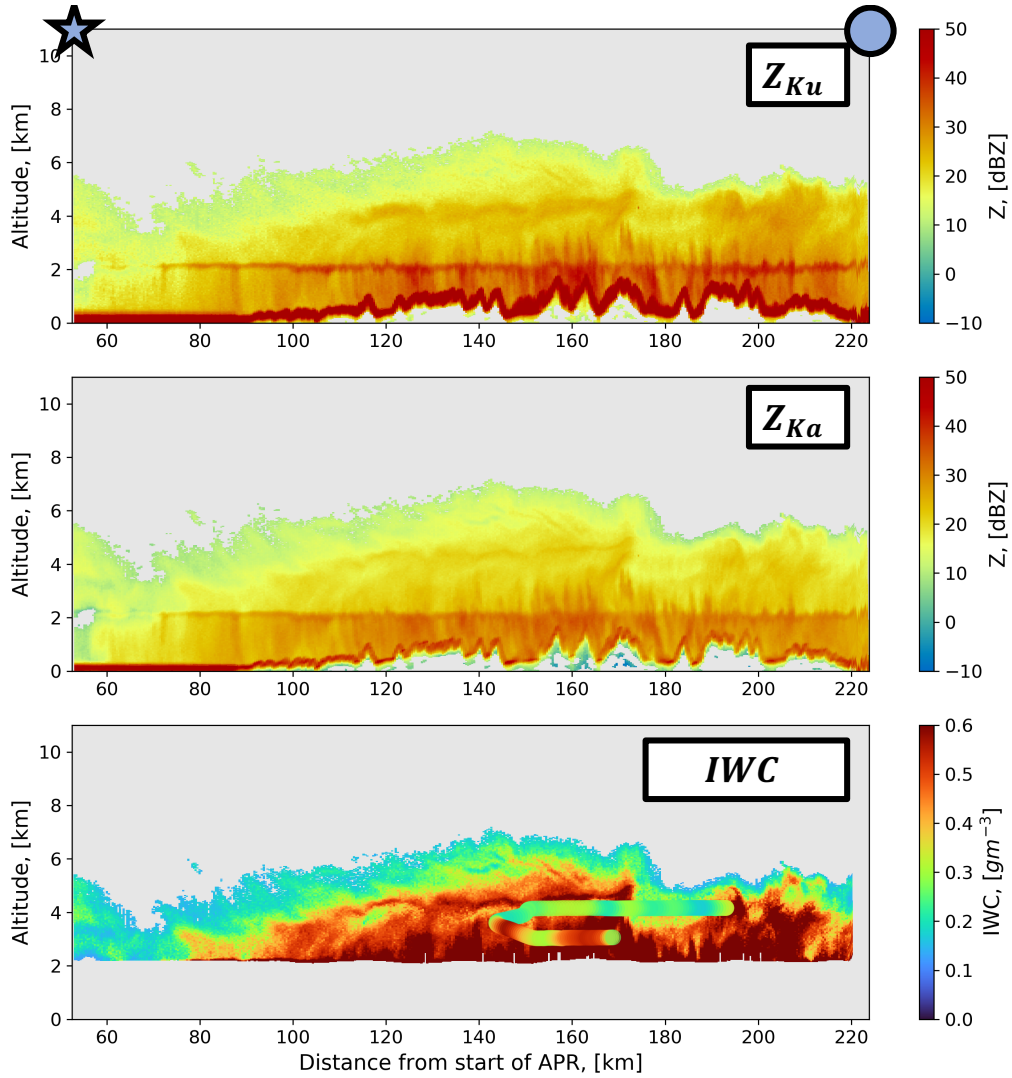

Ka
IWC, [gm^{-3}]
10^0
10^{-1}
0
10
20
30
40
Z, [dBZ]
2ADPR
2.000
1.525
1.050
0.575
0.100
% counts

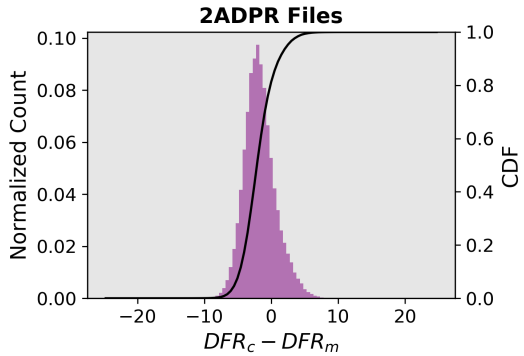
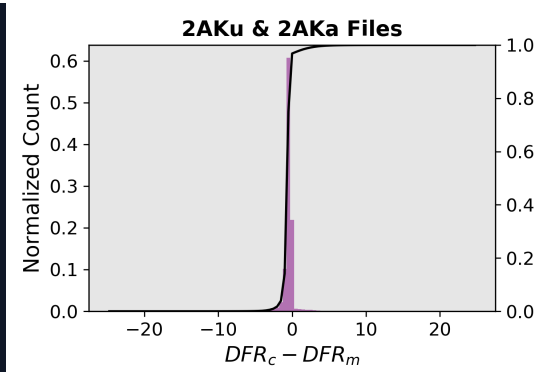
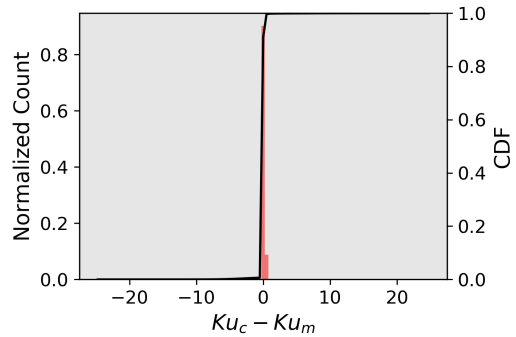
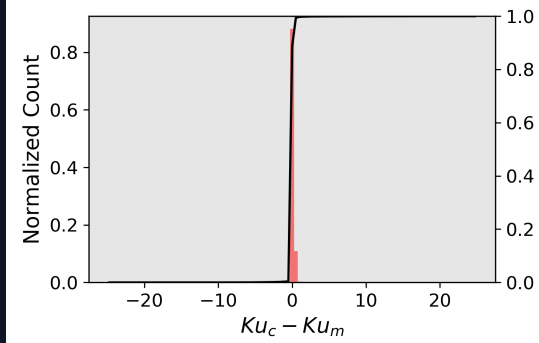
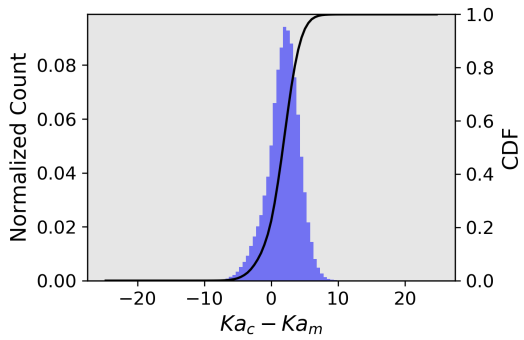
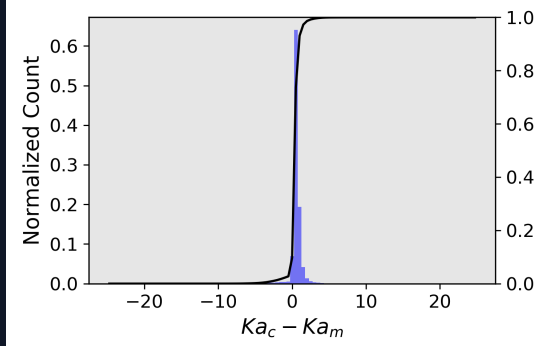

Ka
NASA GV
2ADPR
IWC, [gm^{-3}]
10^0
10^{-1}
0
10
20
30
40
Z, [dBZ]
2.000
1.525
1.050
0.575
0.100
% counts

Leinonen et al. 2018 3-Freq. Bayes Retrieval

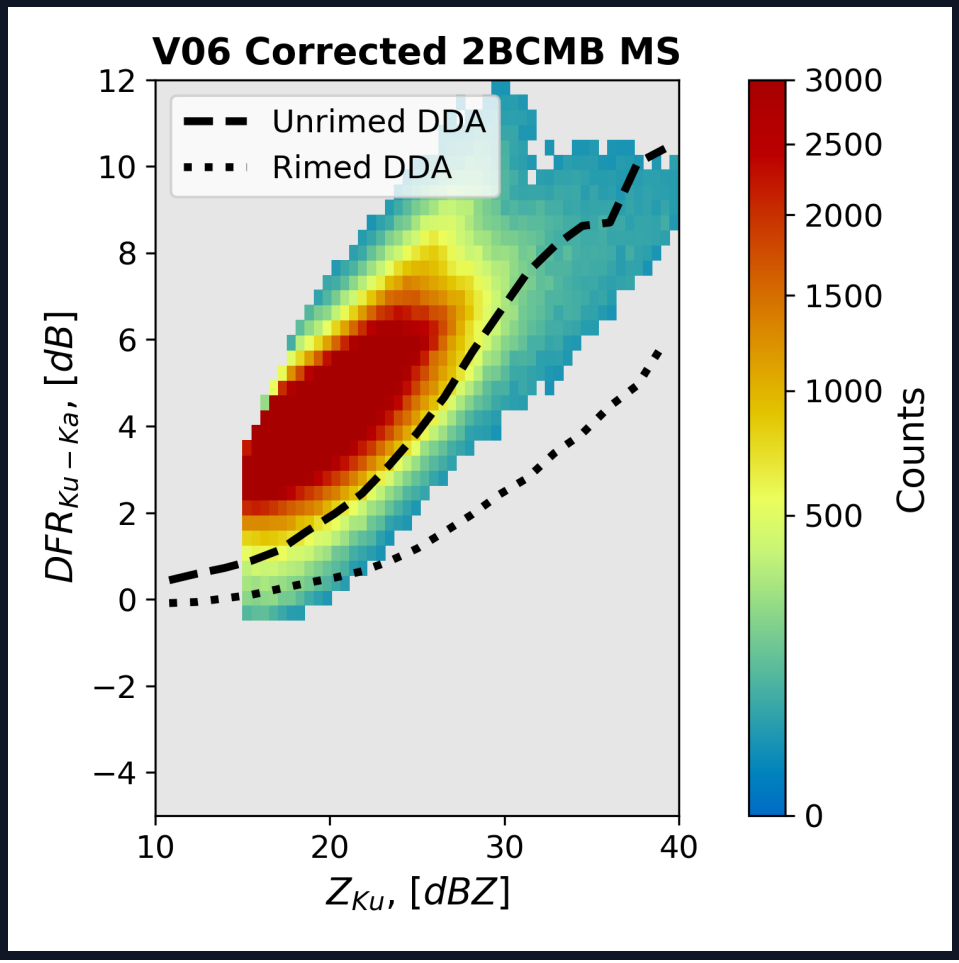


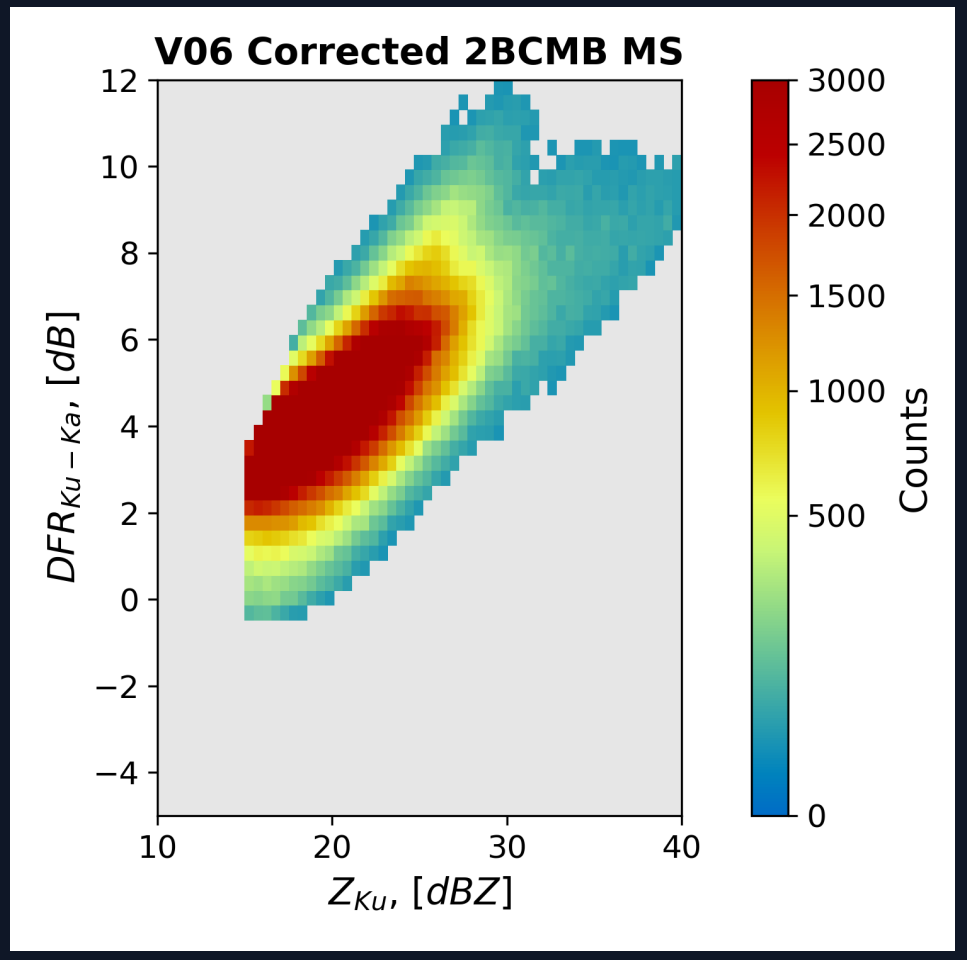
Chase et al. in prep 2-Freq. NN Retrieval



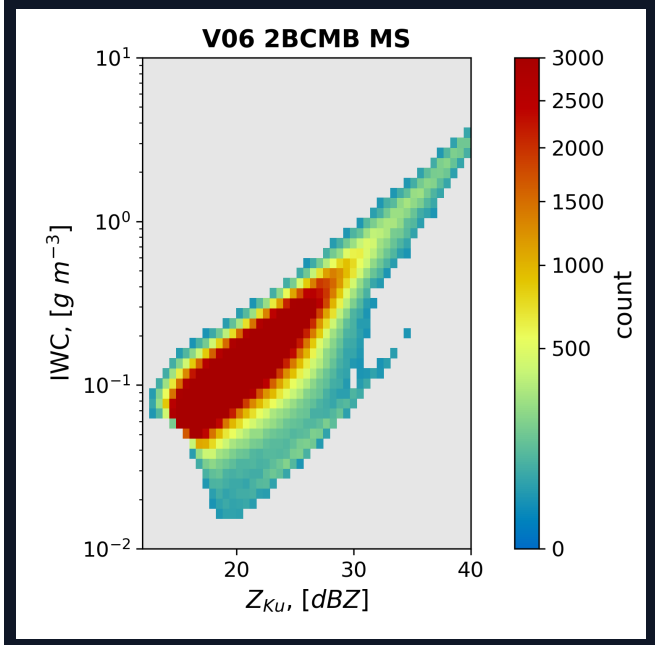
Median	2ADPR Files	Median	2AKu & 2AKa Files
-1.88 dB		-0.38 dB	
0.14 dB		0.15 dB	
2 dB		0.53 dB	

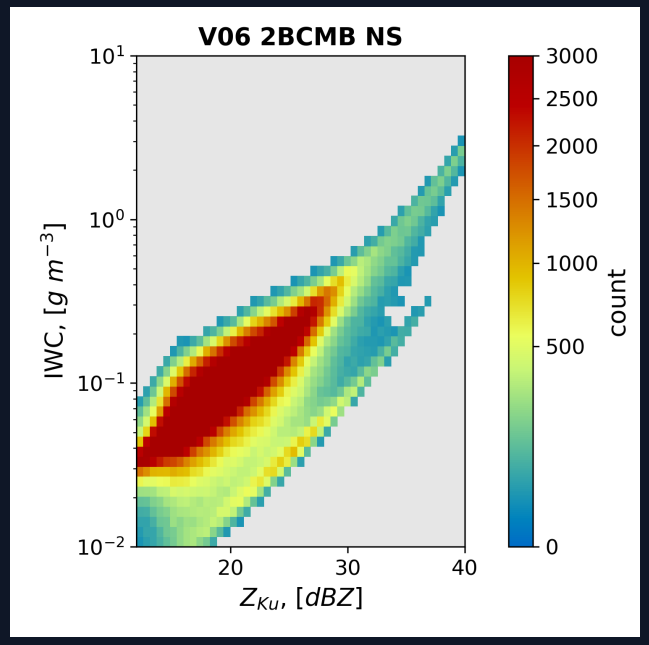
21 Orbitals (2014-2019) Only gates above melting level

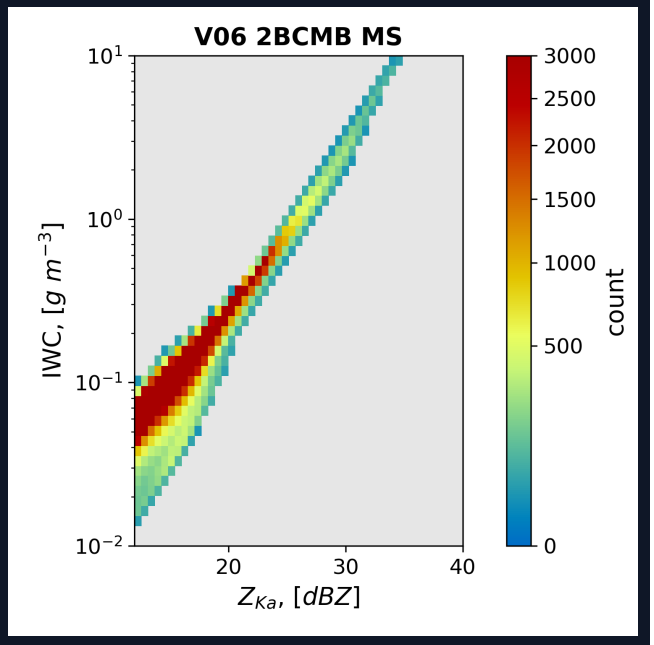


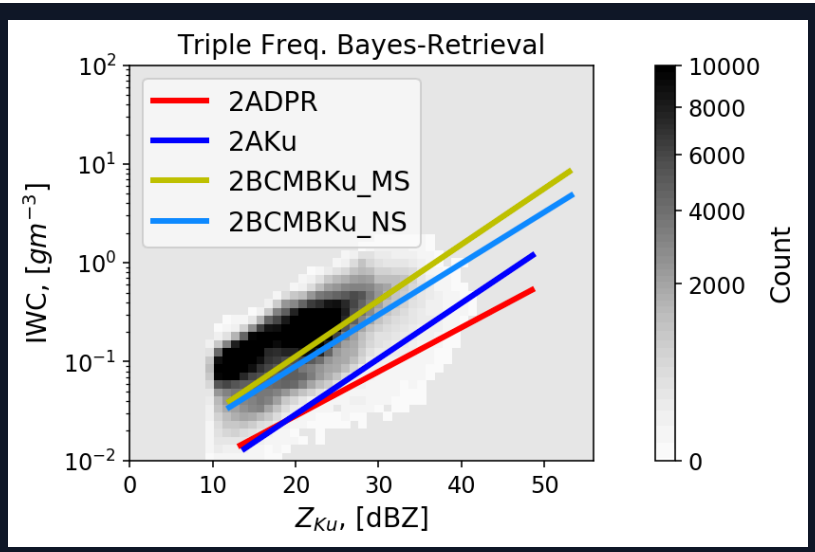


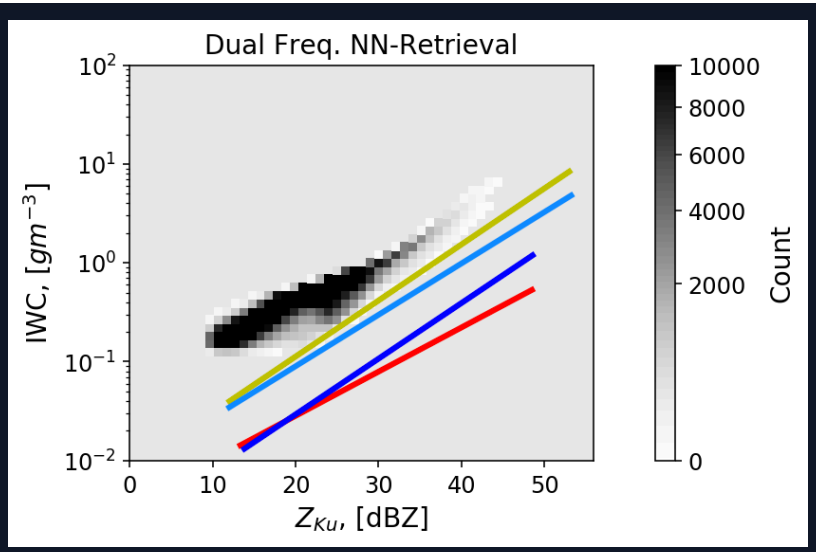
21 Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)

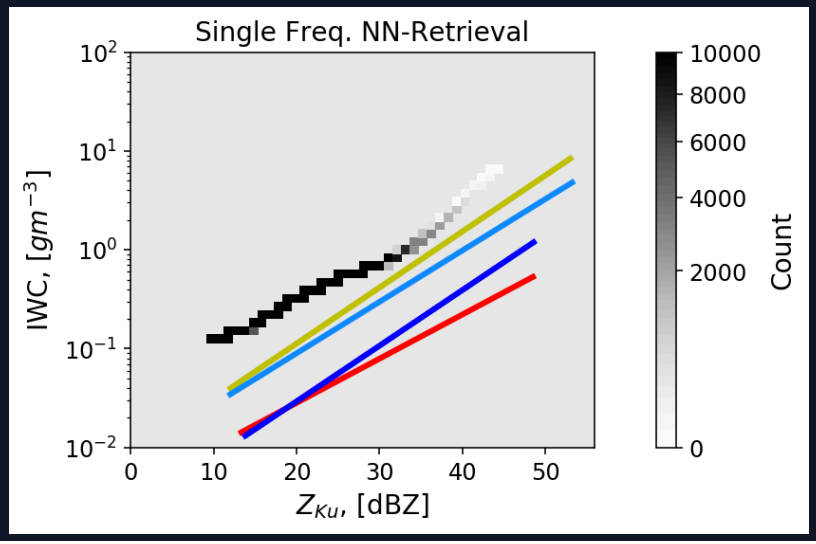




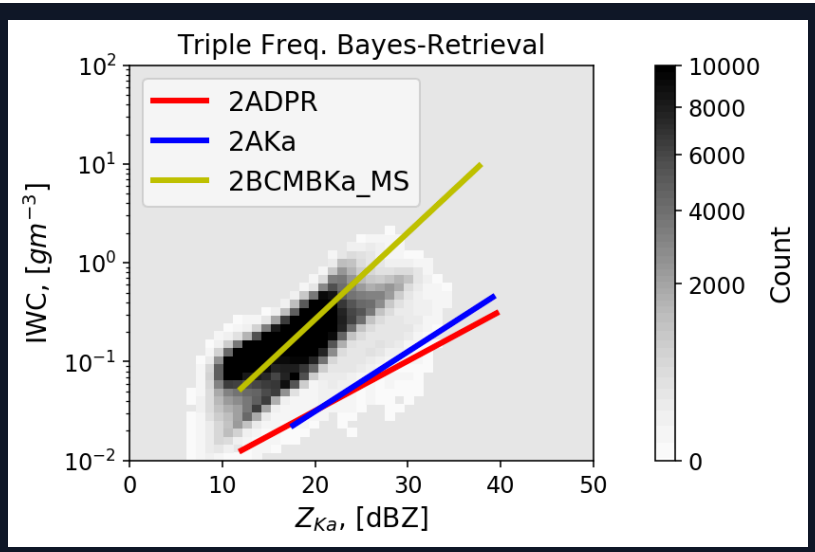


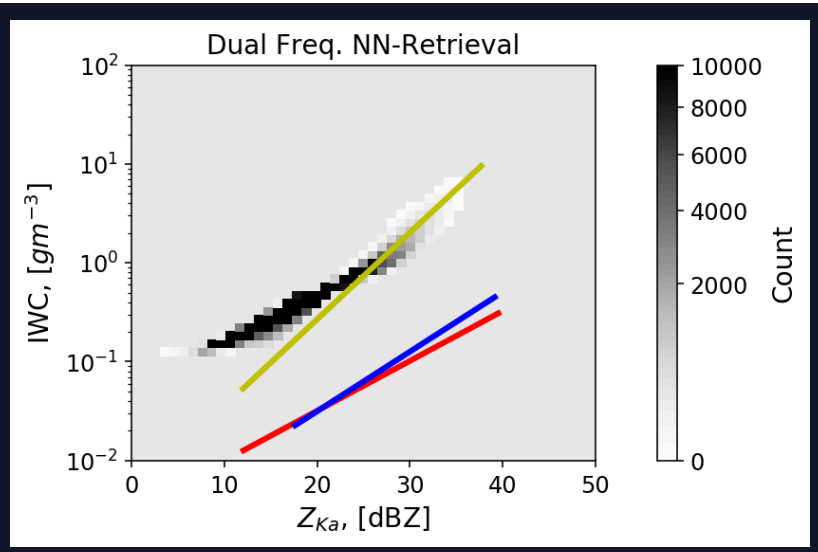

Triple Freq. Bayes-Retrieval
2ADPR
2AKu
2BCMBKu_MS
2BCMBKu_NS
IWC, $[gm^{-3}]$
Z_{Ku}, [dBZ]
Count

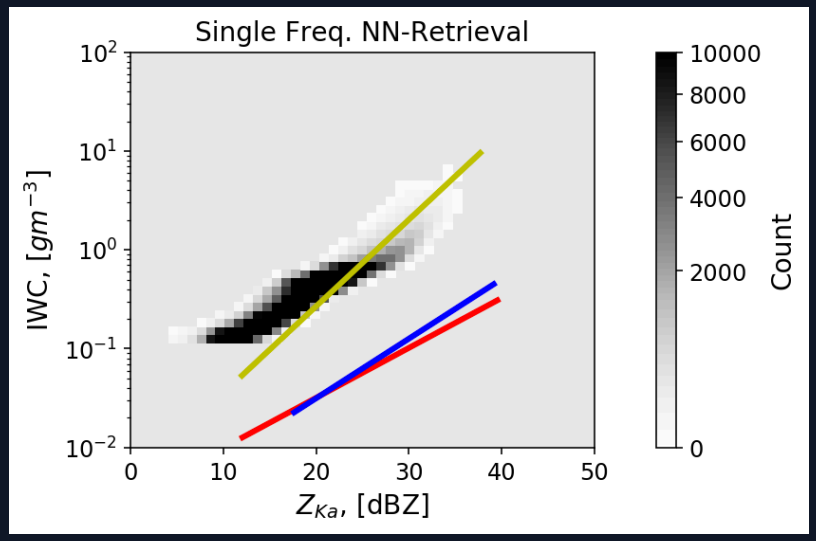

Dual Freq. NN-Retrieval
IWC, $[gm^{-3}]$
Z_{Ku}, [dBZ]
Count


Single Freq. NN-Retrieval
IWC, $[gm^{-3}]$
Z_{Ku}, [dBZ]
Count

Zku - IWC

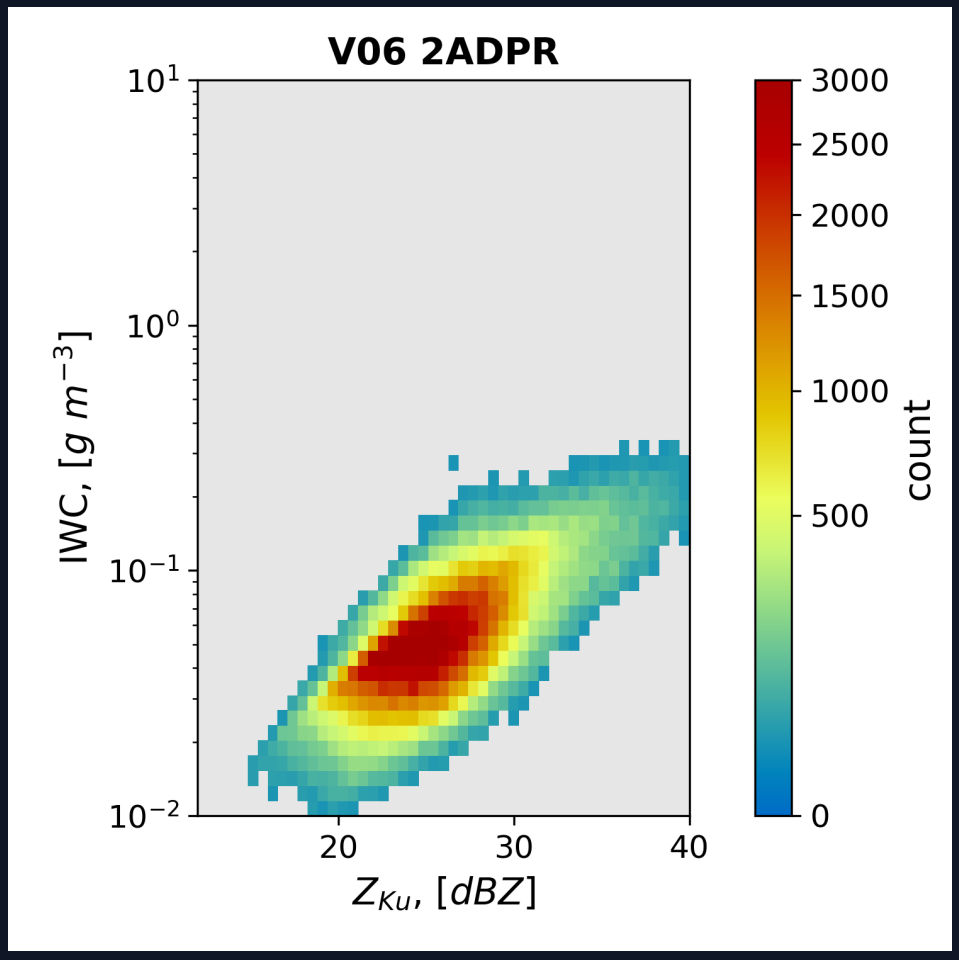

Triple Freq. Bayes-Retrieval
2ADPR
2AKa
2BCMBKa_MS
IWC, $[gm^{-3}]$
Z_{Ka}, [dBZ]
Count

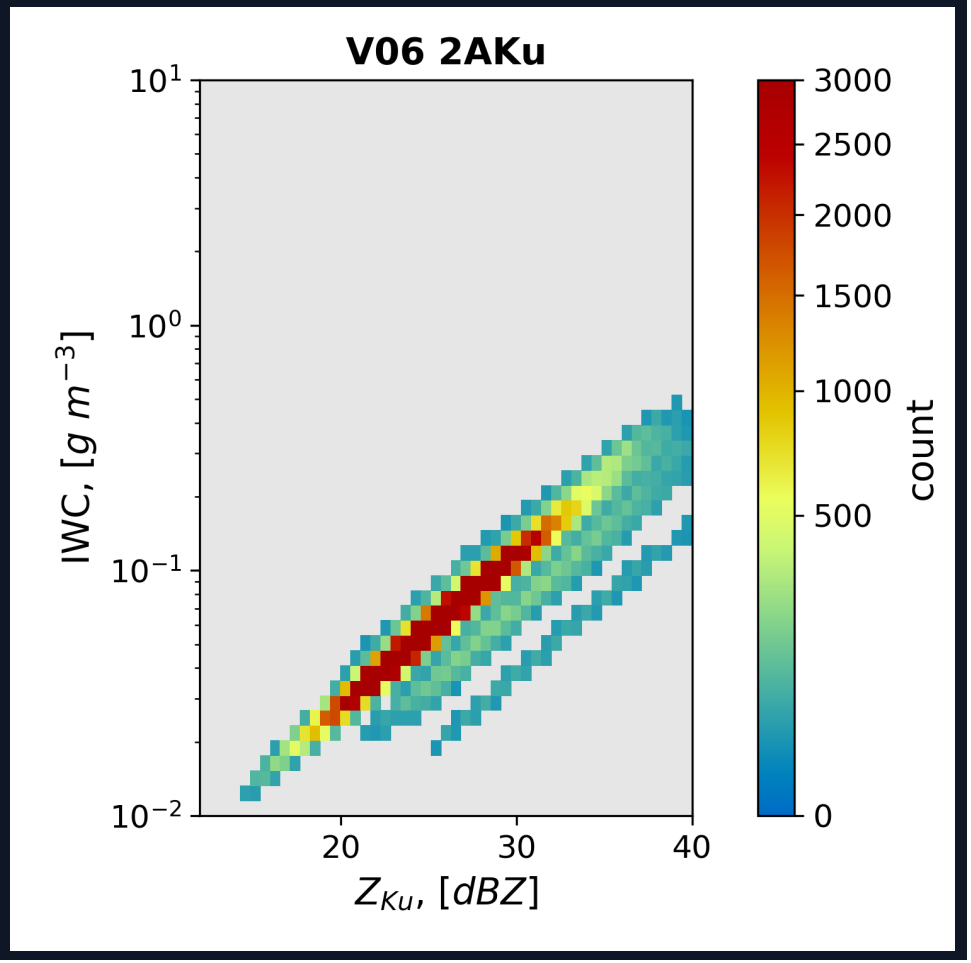
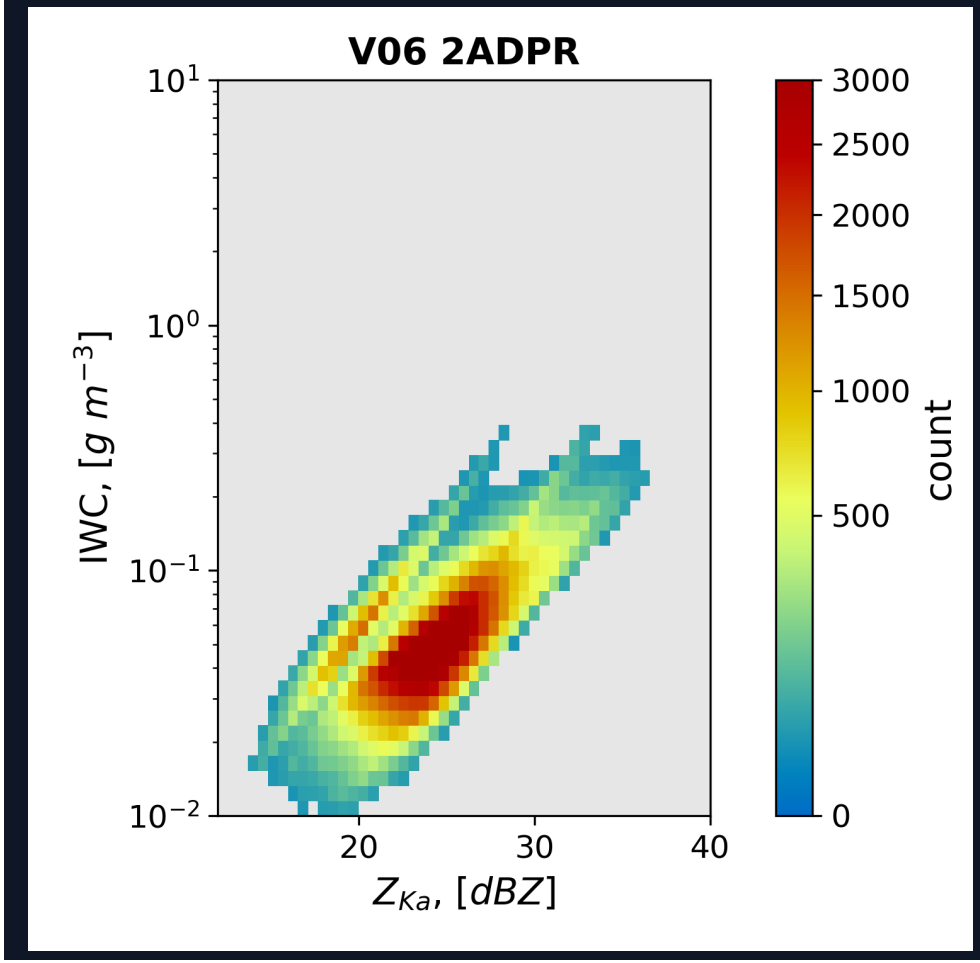
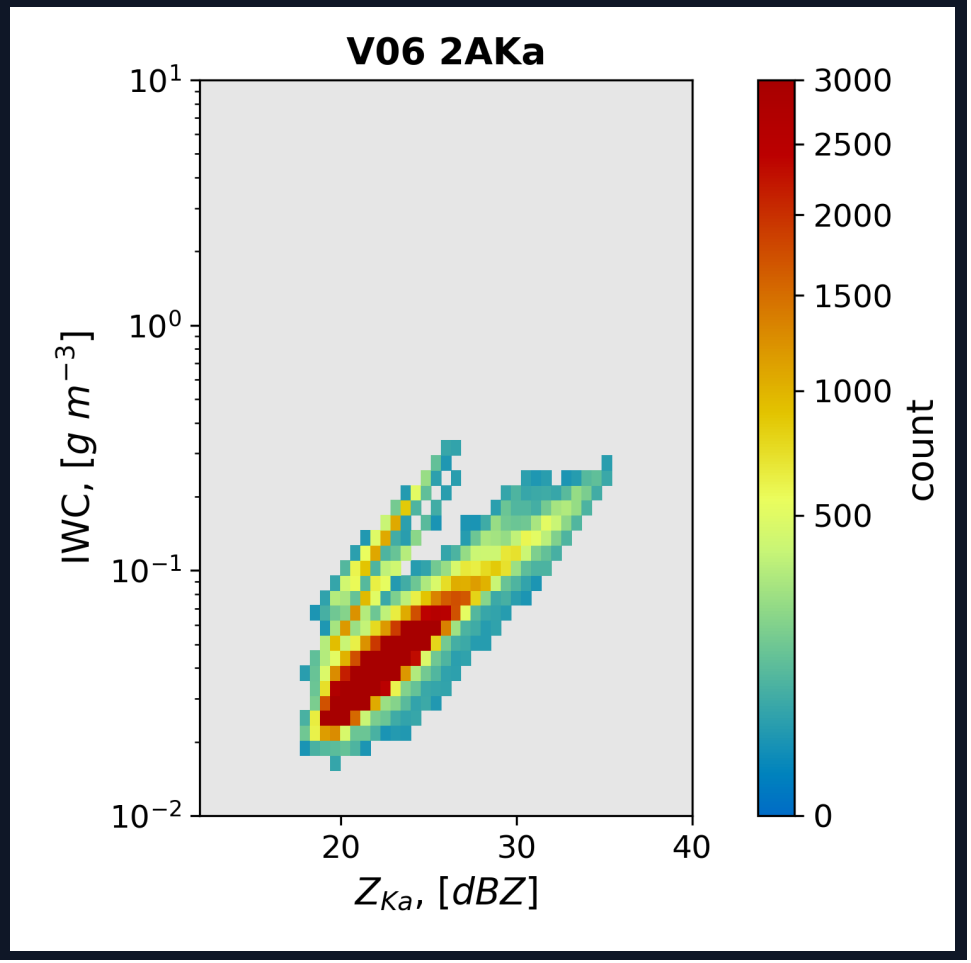

Dual Freq. NN-Retrieval
IWC, $[gm^{-3}]$
Z_{Ka}, [dBZ]
Count


Single Freq. NN-Retrieval
IWC, $[gm^{-3}]$
Z_{Ka}, [dBZ]
Count

Zka - IWC

21 Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)





21 Orbitals (2014-2019) Cold ($T_{surf} \leq 5°C$)