Evaluation of GPM algorithm assumptions using GPM-GV data

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This Talk:

Evaluation of Triple-Frequency Radar Retrieval of Snowfall Properties using Coincident Airborne In-Situ Observations during OLYMPEx (Chase et al., to be submitted)

Poster this afternoon (2-for-1 special):

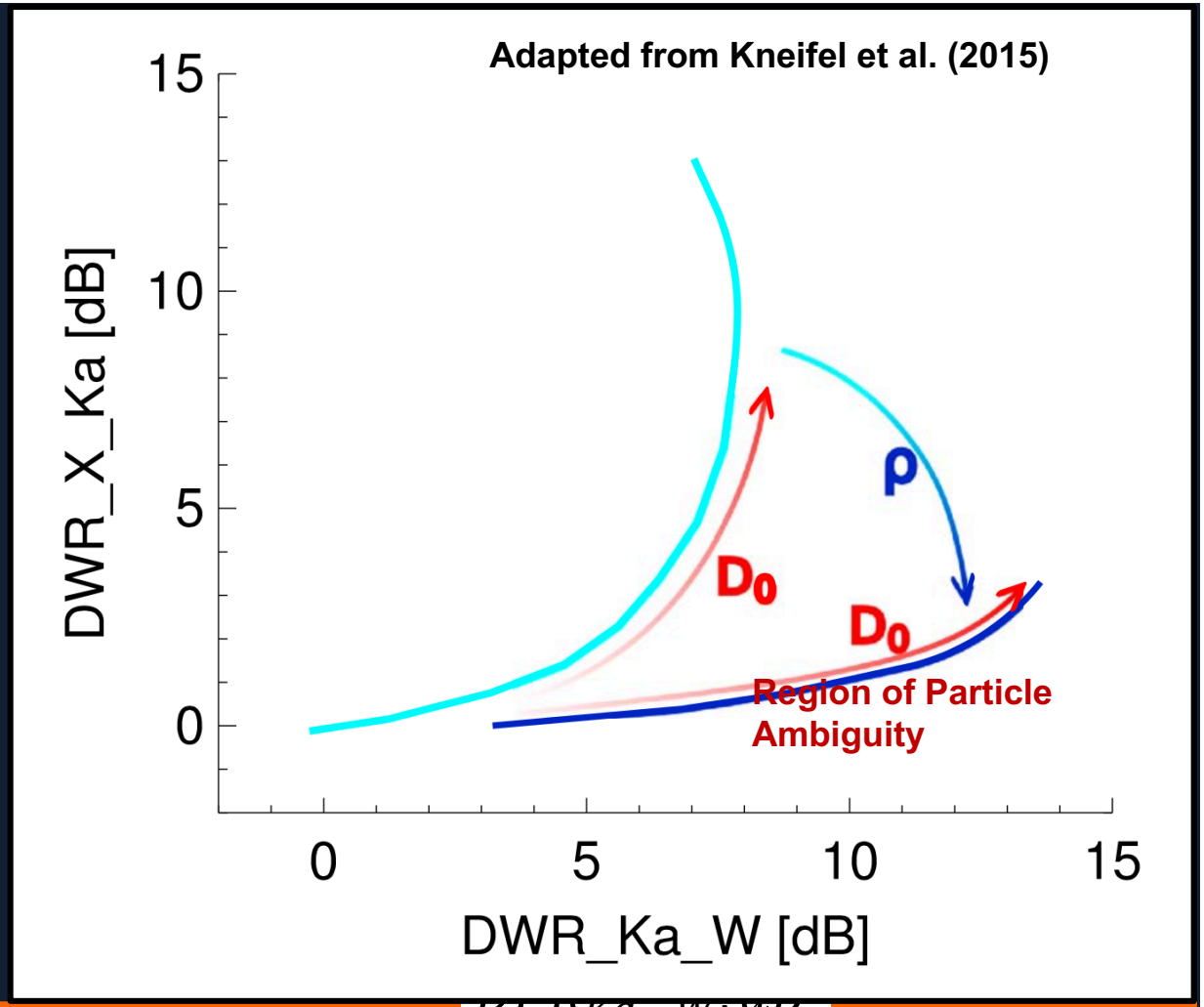
Improved parameterization of particle size distribution in snow using σ_m – D_m approach during GCPEx (Borque et al., to be submitted)

Constraining mass in ice clouds using aircraft-radar matching during MC3E and OLYMPEx (Finlon et al., in prep)

Models show variations in intrinsic dual-frequency ratio (DFR)

Aggregate and Dendrite Models

Sphere and Spheroid Models



Intrinsic DFR:

$$\mathrm{DFR}_{\lambda_1 - \lambda_2} = 10 \log \frac{z_{\lambda_1}}{z_{\lambda_2}}$$

$$z_\lambda \propto \text{Number concentration and Particle size}$$

$$\mathrm{DFR}_{\lambda_1 - \lambda_2} \propto \text{Particle size}$$

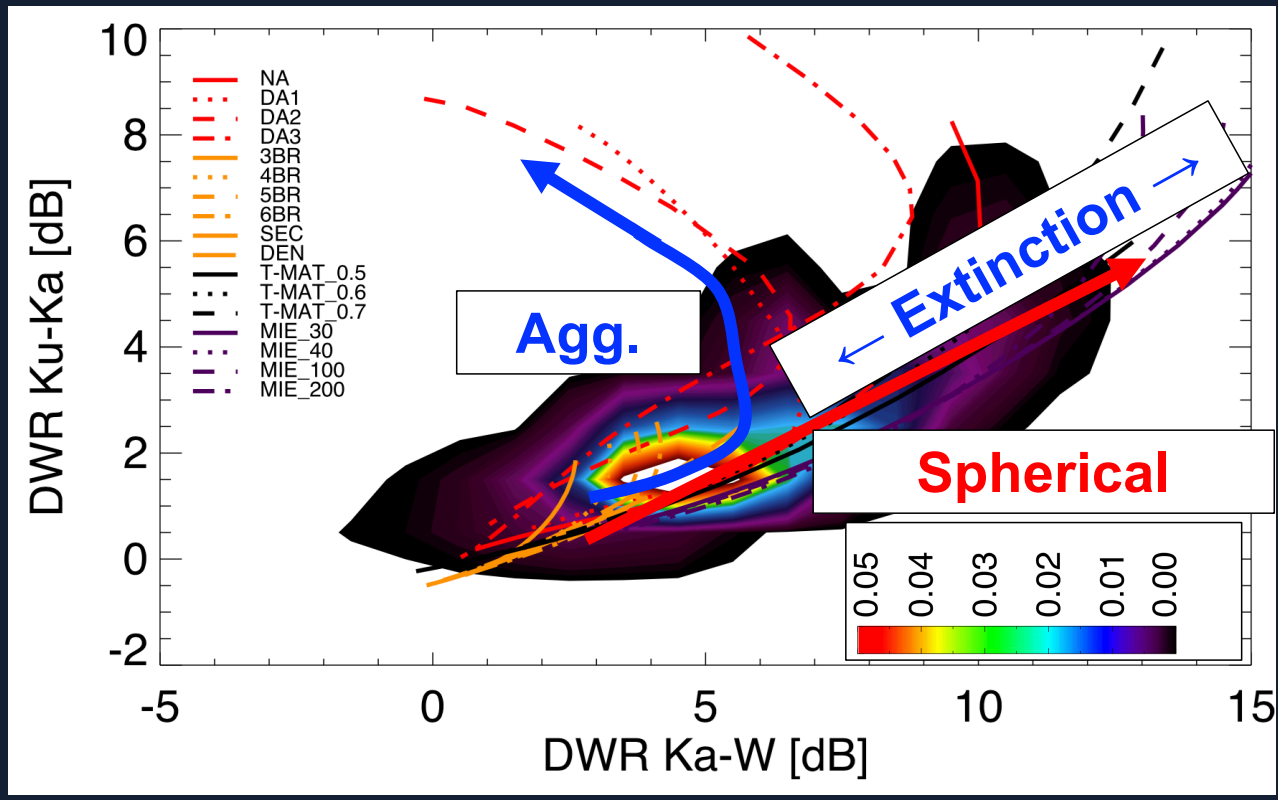
Practically, DFR depends on path-integrated attenuation and measurement error:

$$\mathrm{DFR}_{\lambda_1 - \lambda_2} = 10 \log \frac{Z_{\lambda_1} + PIA_{1\,(0 \to r)} + \varepsilon}{Z_{\lambda_2} + PIA_{2\,(0 \to r)} + \varepsilon}$$

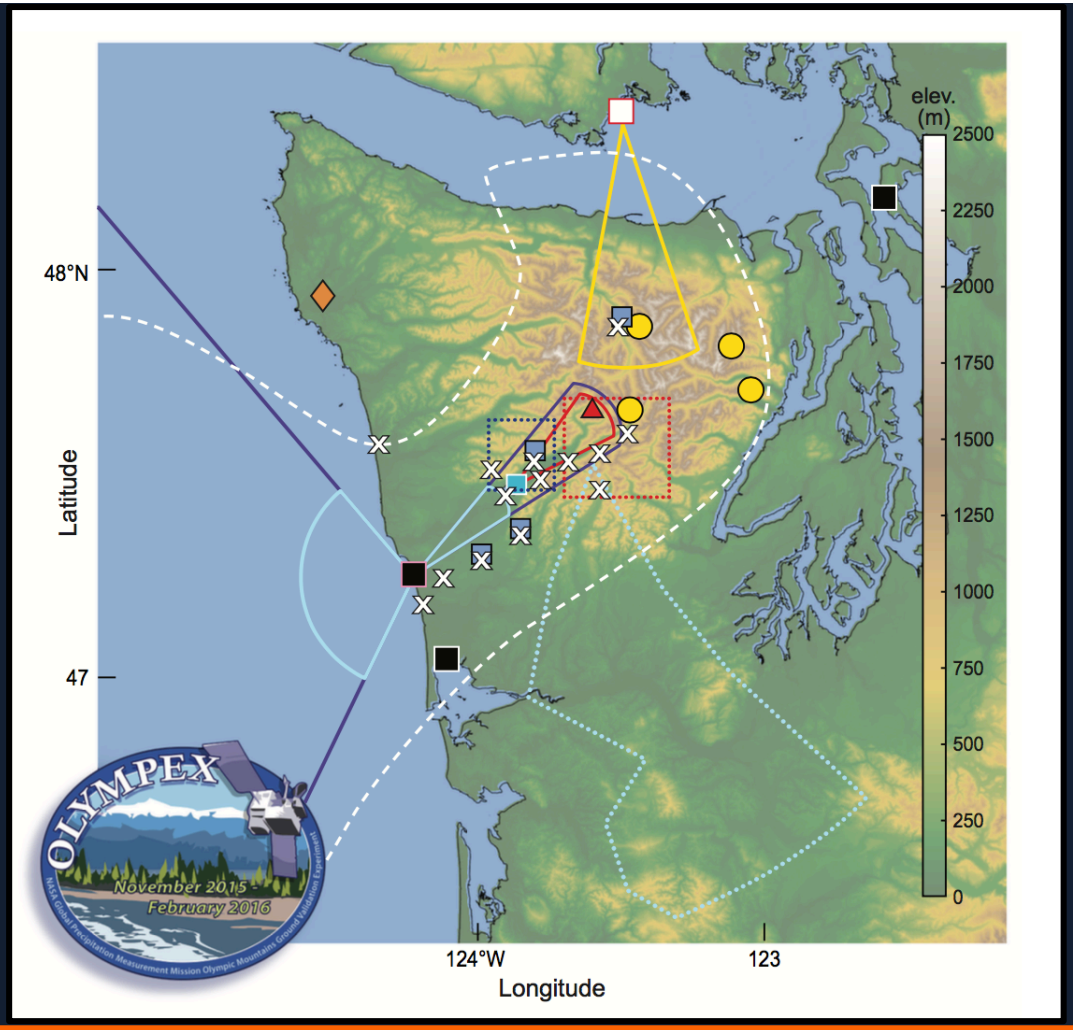
Observations from Wakasa Bay

Kulie et al. 2014:

- **Airborne triple-frequency observations over Wakasa Bay, Japan**
- **No in-situ evaluation**



Adapted from Kulie et al. (2014)



WSR-88D
NPOL/D3R
DOW
EC X-Band

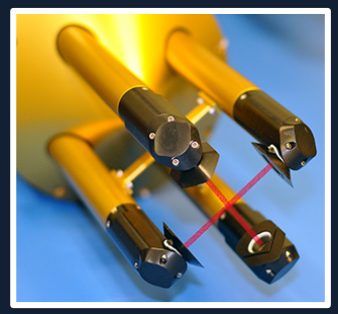
MRR
SNOTEL
Mt. Seattle
Quillayute rawinsonde
Ground obs sites

Chehalis rain gauge network
Snow camera network
UW tipping bucket network
Aircraft sampling
RHI sector: NPOL
RHI sector: D3R
RHI sector: DOW
RHI sector: EC X-Band

Adapted from Houze et al. 2017

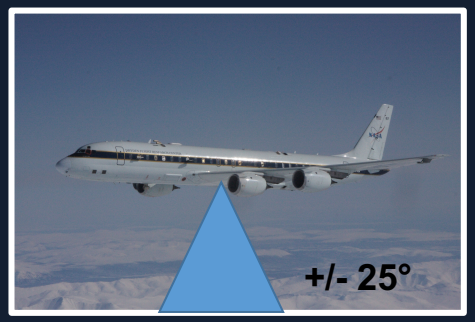
Particle size distributions at D > 225 µm calculated by UIOOPS software

(Jackson et al. 2012)



2DS

HVPS3



DC-8

JPL APR-3

3 Frequencies:
Ku- (13.4 GHz), Ka- (35.6 GHz) and W- (95 GHz) band

Vertical resolution: 30 m

Effective Bulk Density (ρ_e): Mass of ice divided by the volume of ice

Mass of ice from a 2D image is determined using a mass-dimension (m-D) relation (Brown and Francis 1995)

Volume is approximated from the 2D images by assuming a ellipsoidal fit around the particle ($\alpha = 0.6$, Hogan et al. 2012)

$$Mass = \int_{225}^{27500} N(D)\, aD^b\, dD \qquad Vol. = \frac{\pi}{6}\int_{225}^{27500} N(D)\, \alpha^2\, D^3\, dD$$

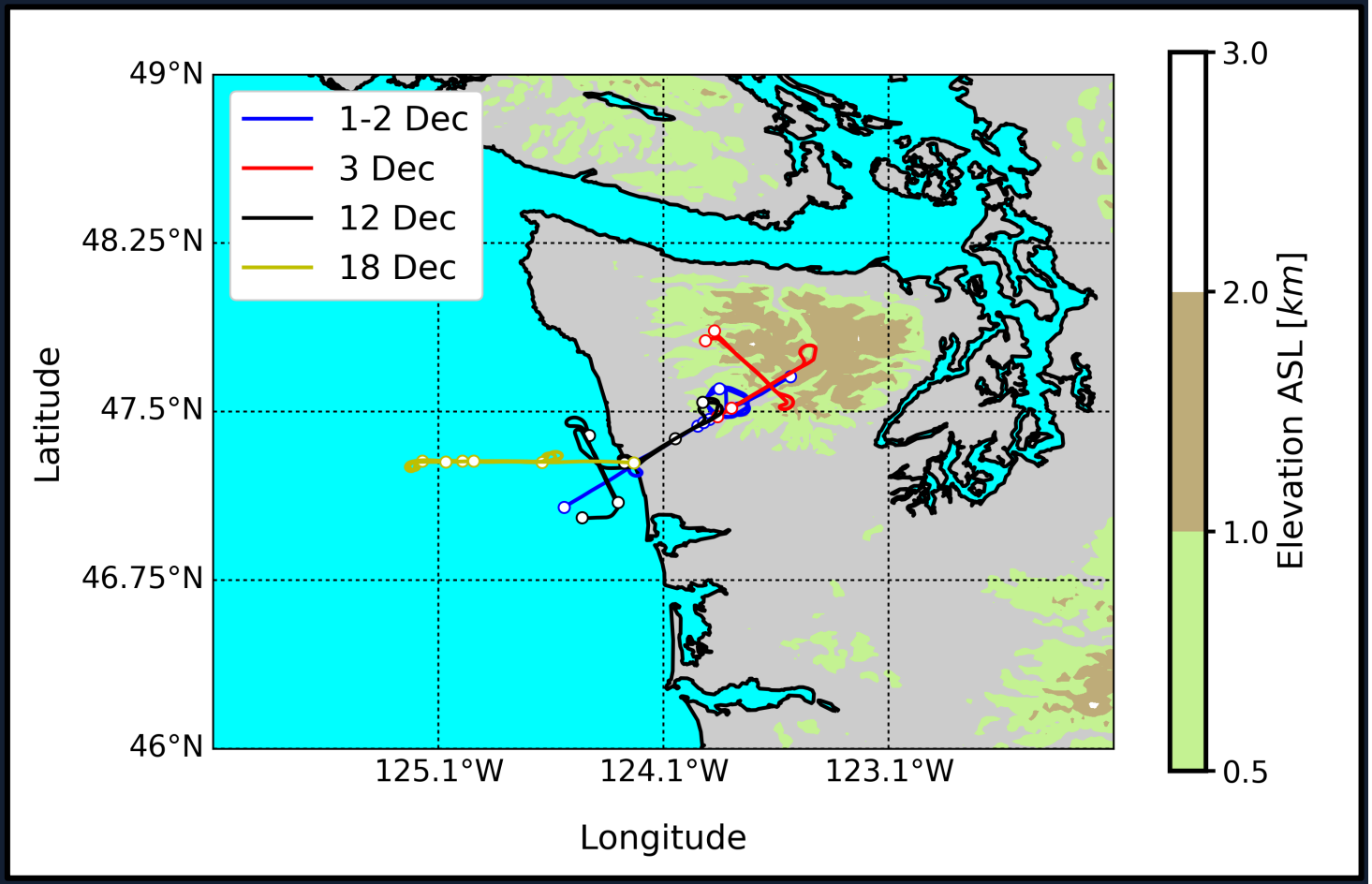
APR-3–Citation Matching

1) Observation time between the radar gate and the Citation must be no greater than 5 minutes
2) Radar data and Citation data that are coincident are then found using a searching algorithm (KdTree) and a Barnes average of the radar data over 30 of the closest gates (Radius of influence 1 km)
3) Skin paints and spurious measurements removed using a standard outlier approach (± 1.5 IQR)

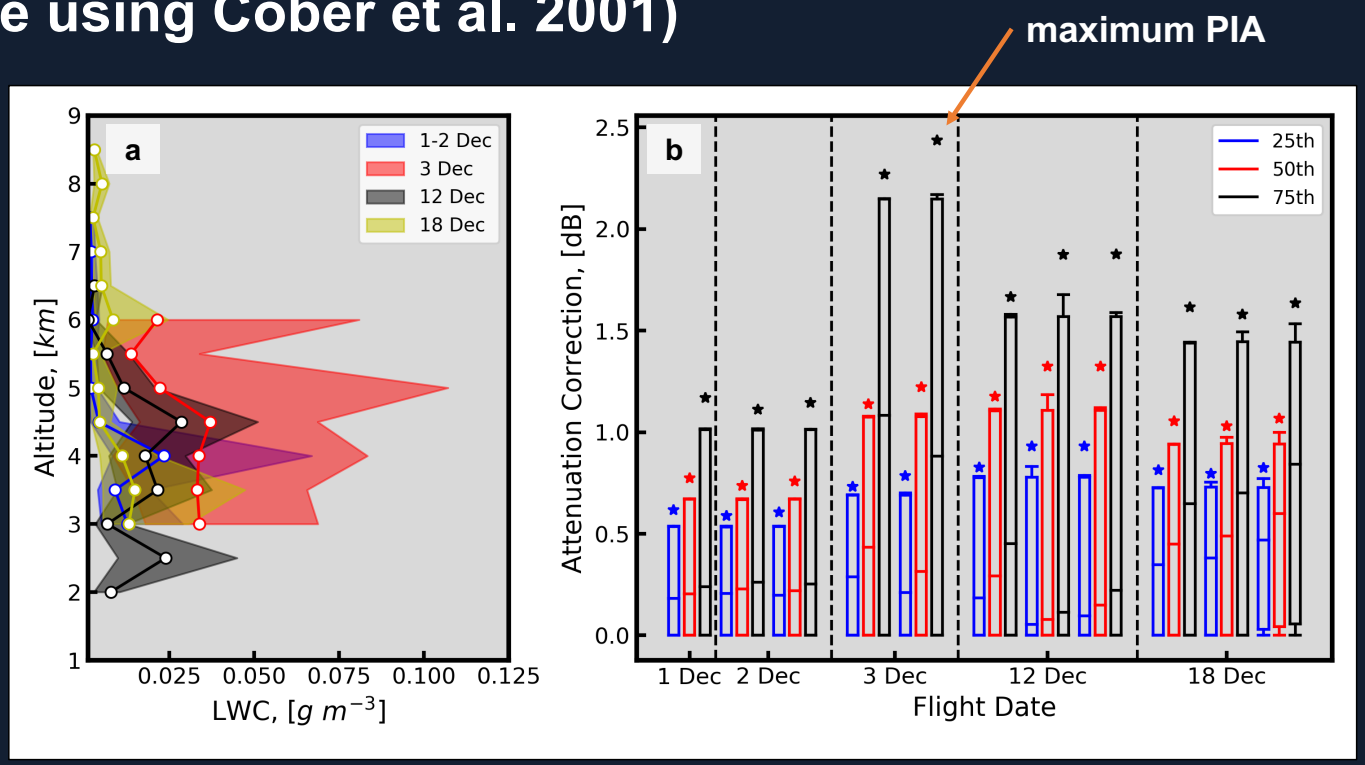
4275 coincident points

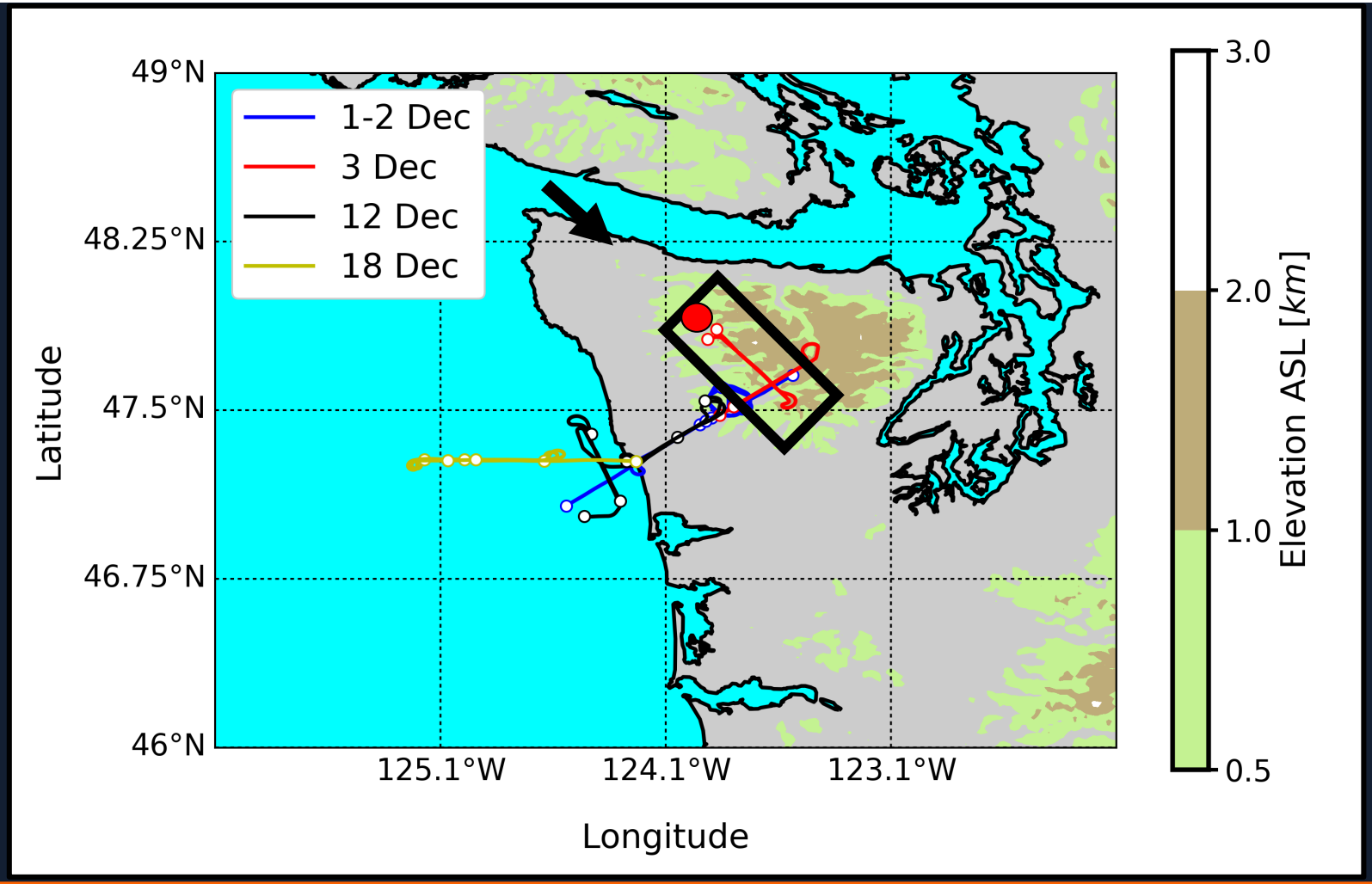
10 flight legs

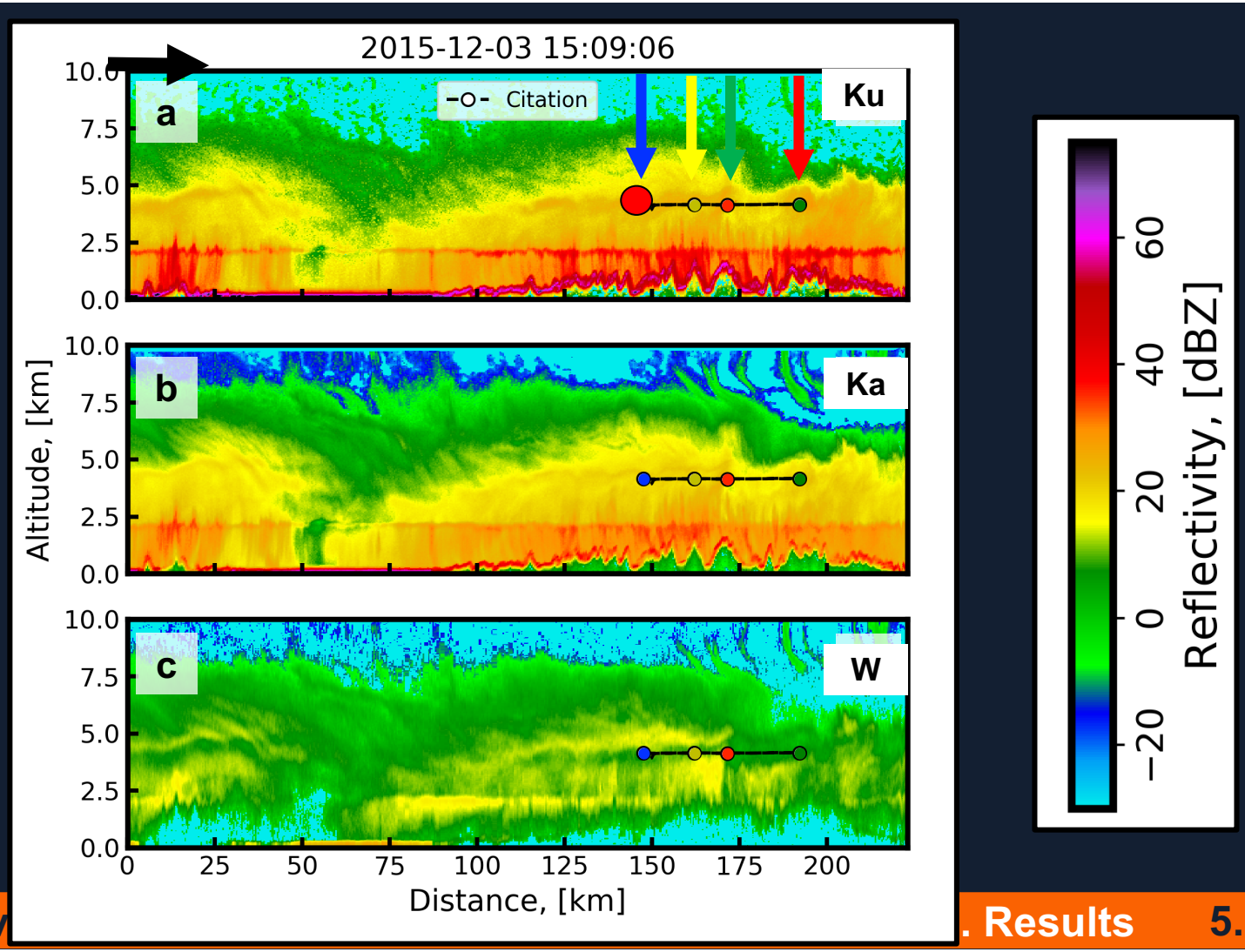
$-30°C \leq T \leq 0°C$

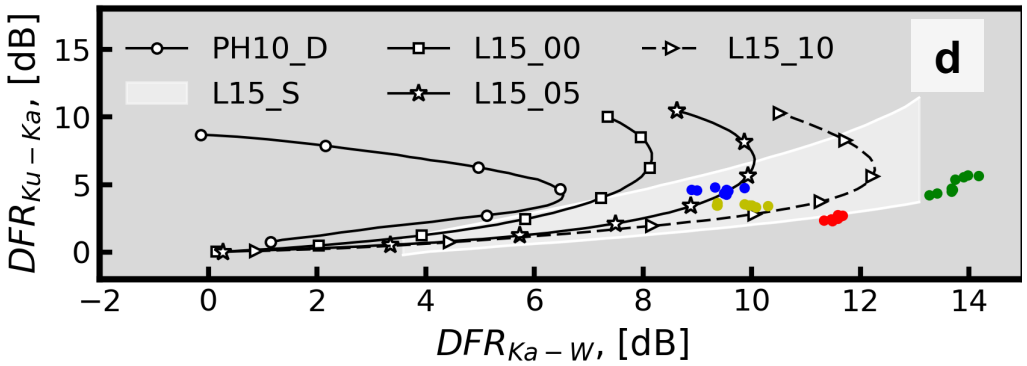


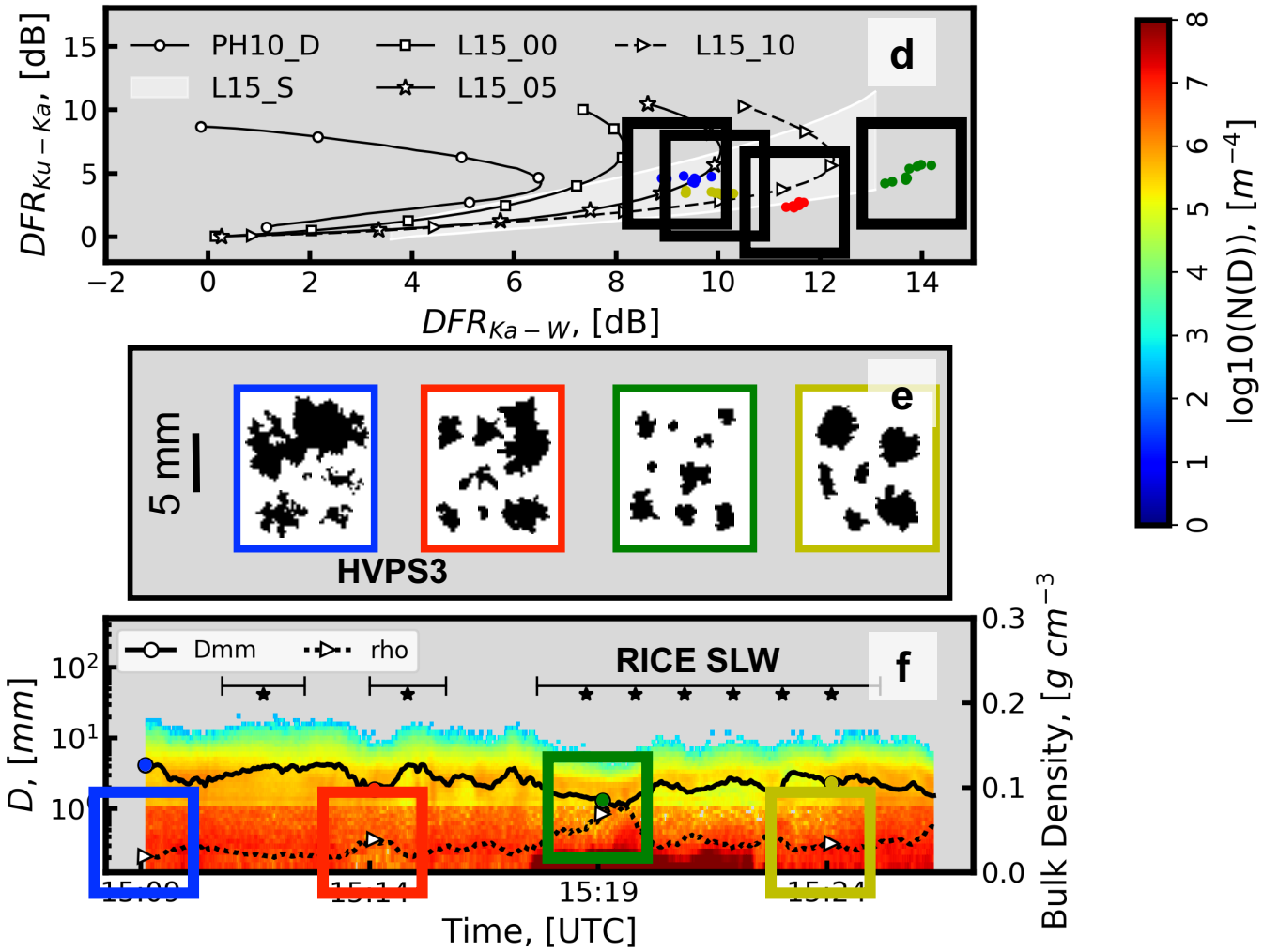
Attenuation correction: CSU soundings launched near the coast ($H2O_{vapor}$, O_2) + observed King Probe supercooled liquid water within the cloud on the respective days (accounting for ice response using Cober et al. 2001)




1-2 Dec
3 Dec
12 Dec
18 Dec
49°N
48.25°N
47.5°N
46.75°N
46°N
Latitude
125.1°W
124.1°W
123.1°W
Longitude
3.0
2.0
1.0
0.5
Elevation ASL [km]

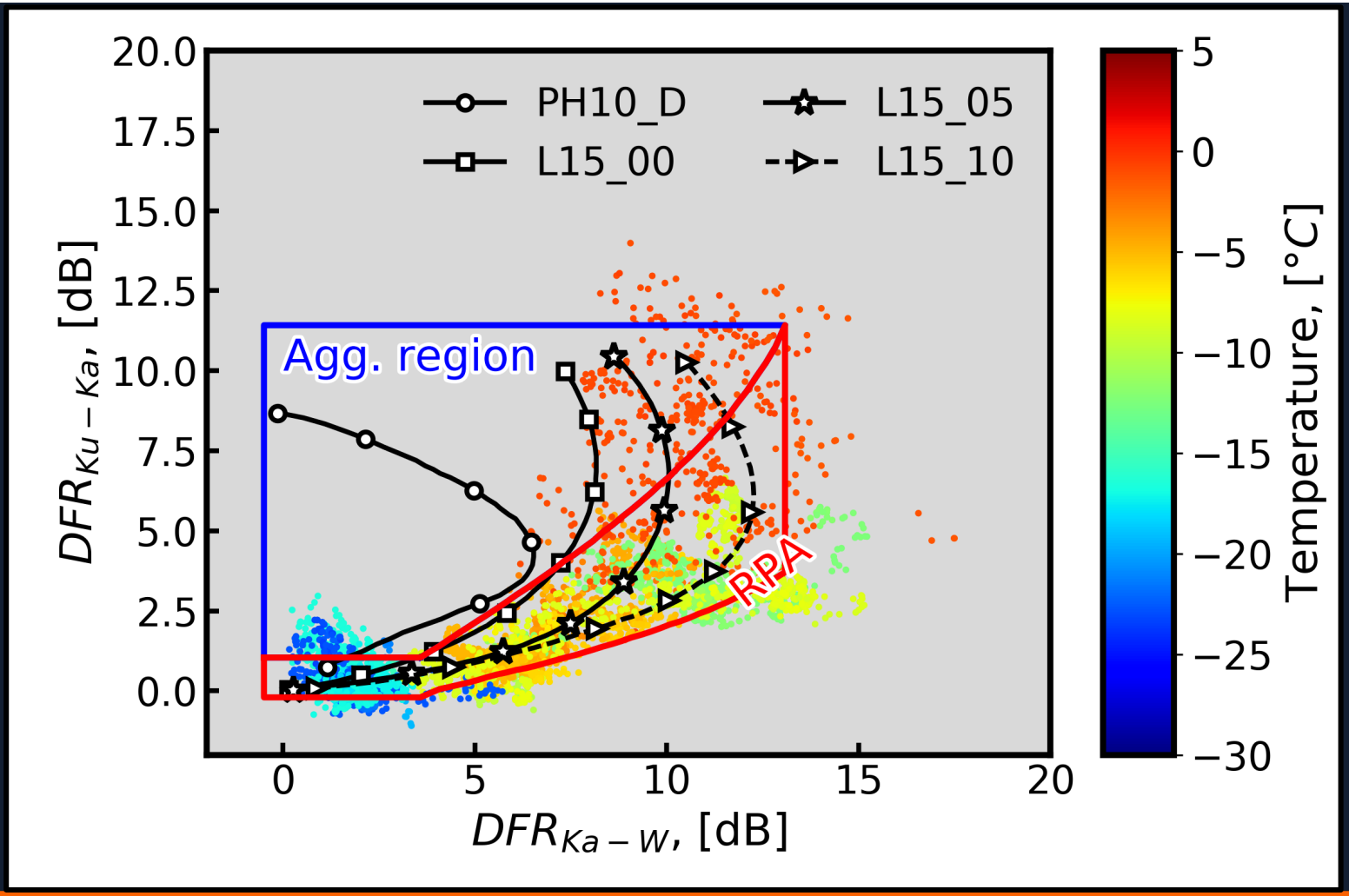

2015-12-03 15:09:06
a
Citation
Ku
b
Ka
c
W
Altitude, [km]
10.0
7.5
5.0
2.5
0.0
0
25
50
75
100
125
150
175
200
Distance, [km]
Reflectivity, [dBZ]
−20
0
20
40
60

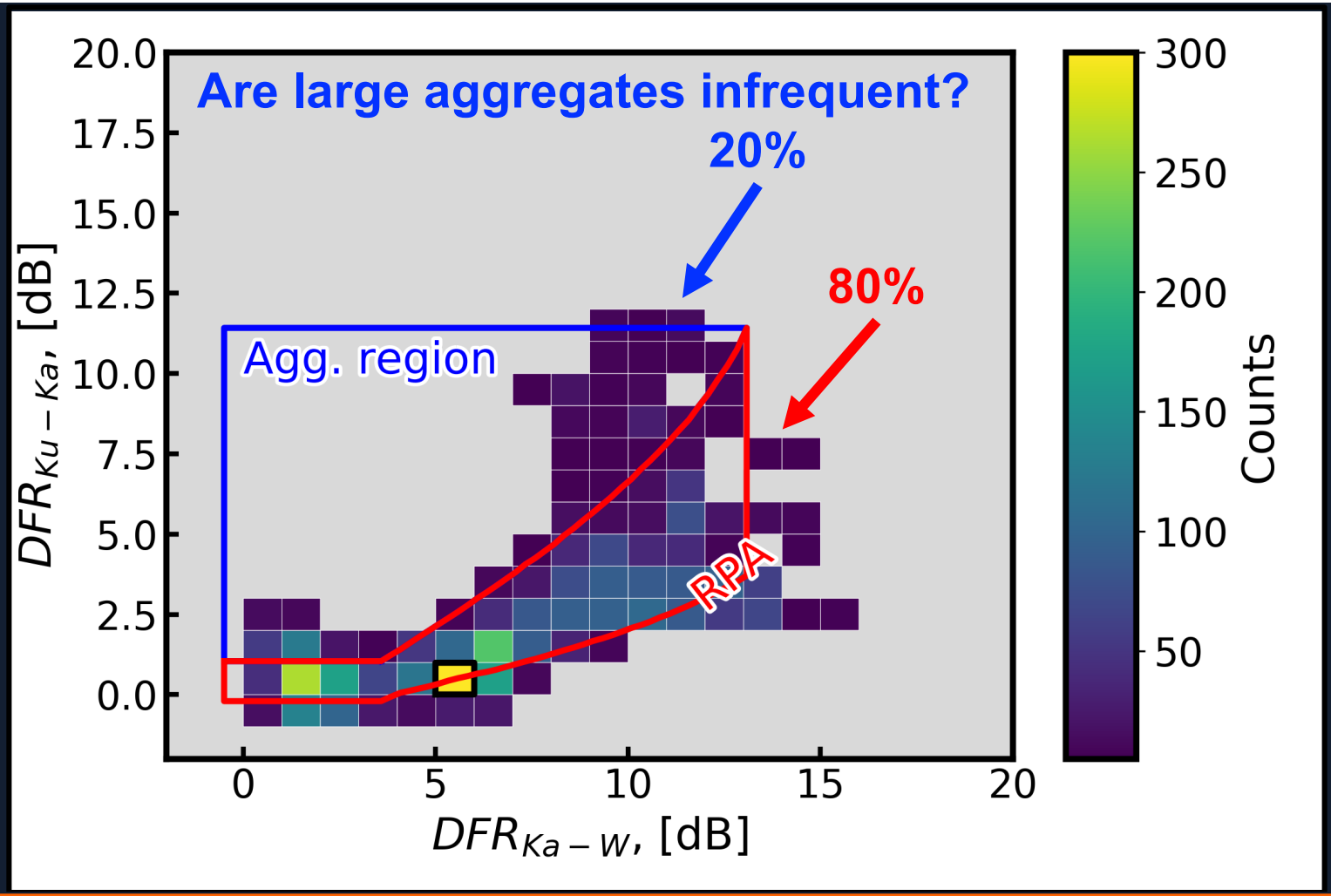

PH10_D
L15_00
L15_10
L15_S
L15_05
d
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]
15
10
5
0
−2
0
2
4
6
8
10
12
14

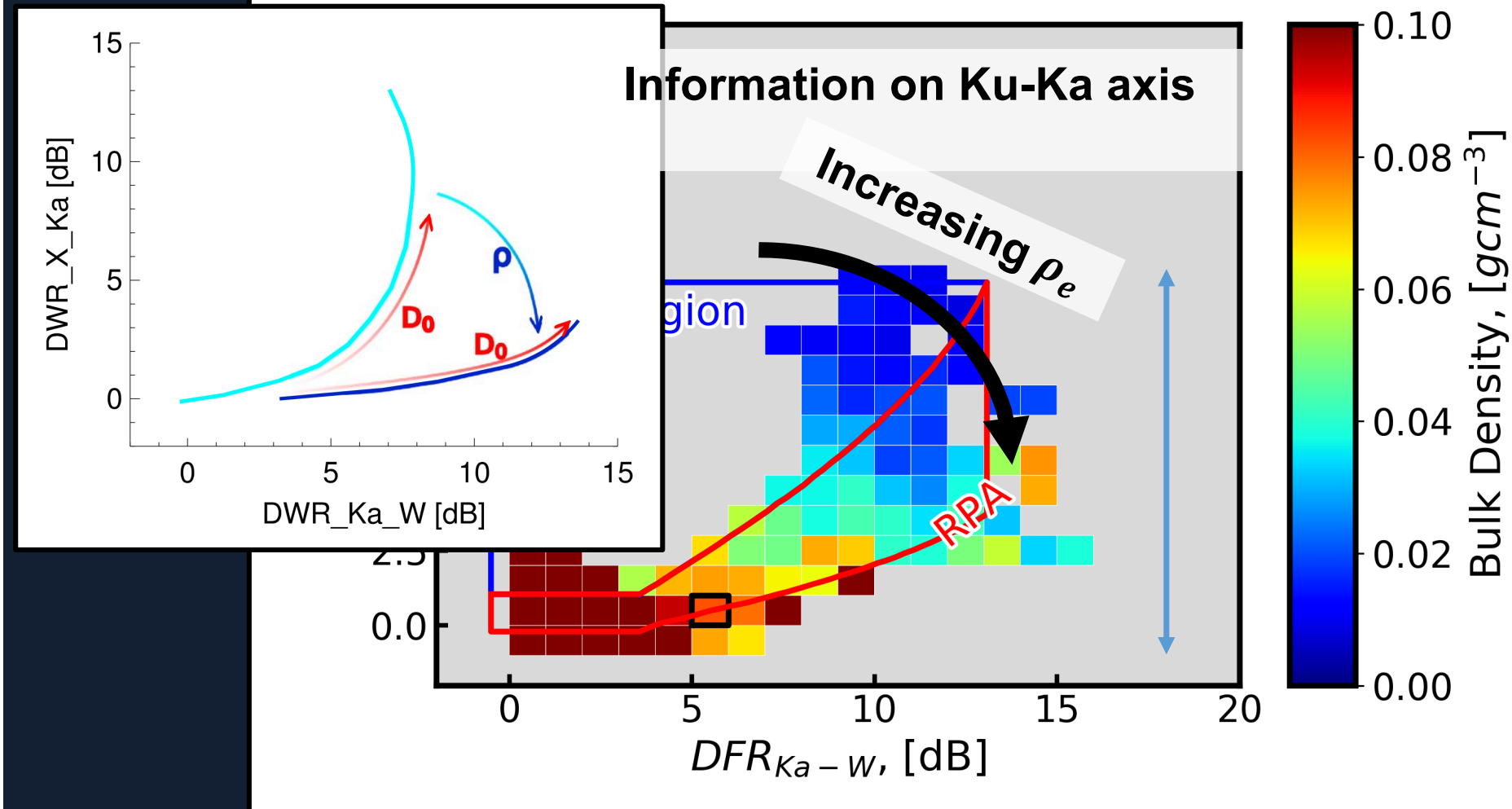


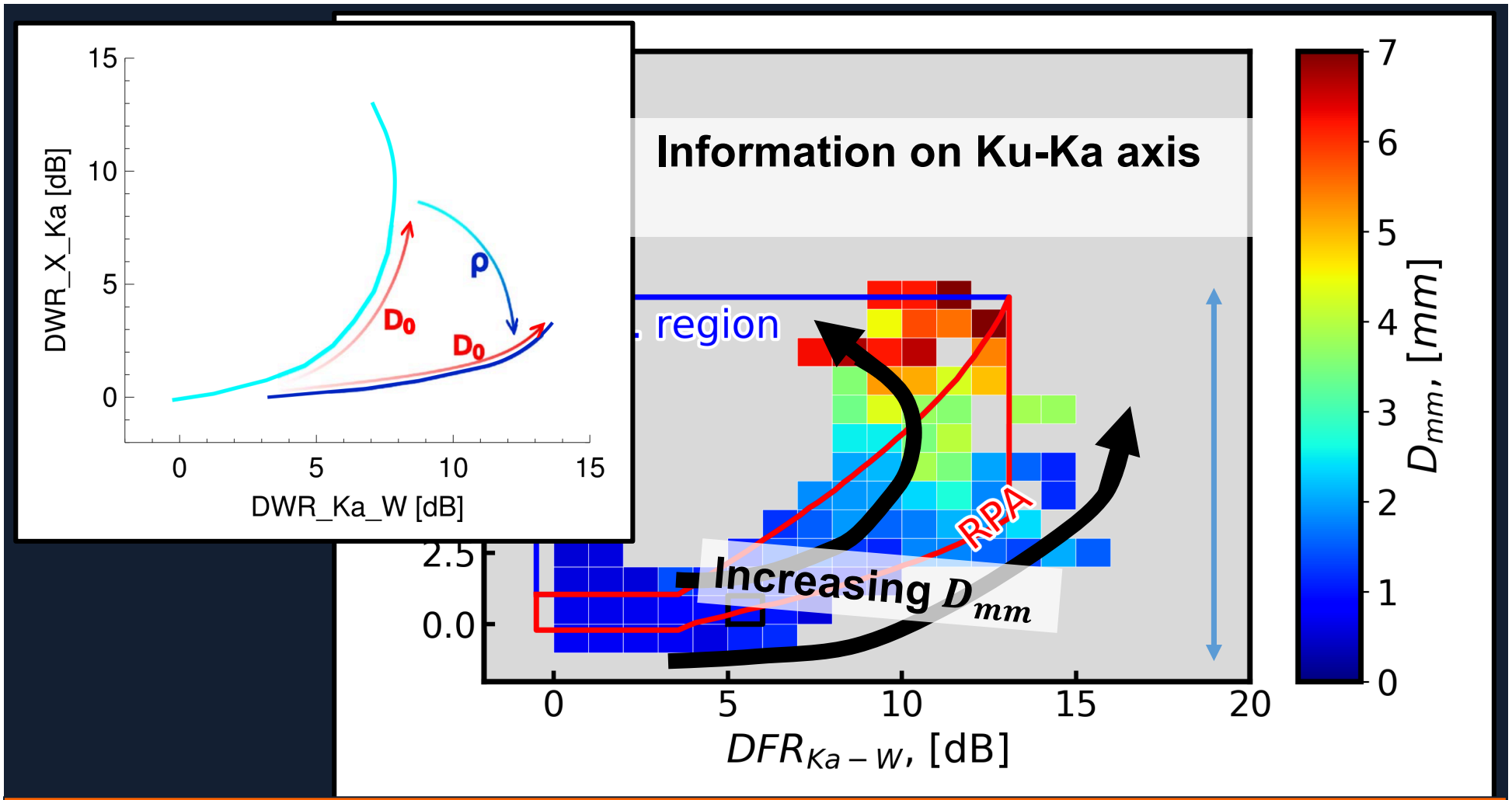
1. Motivatio

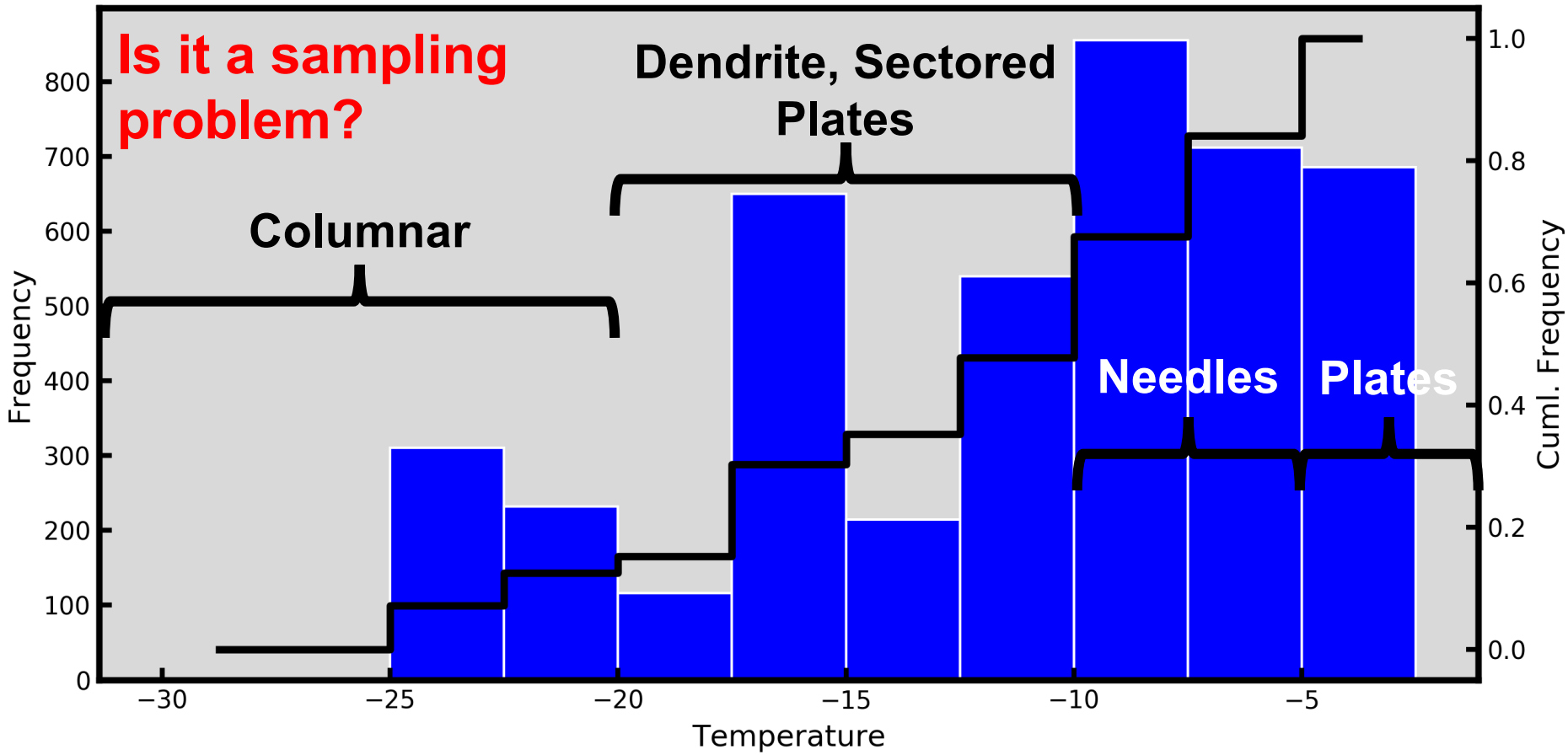
onclusions

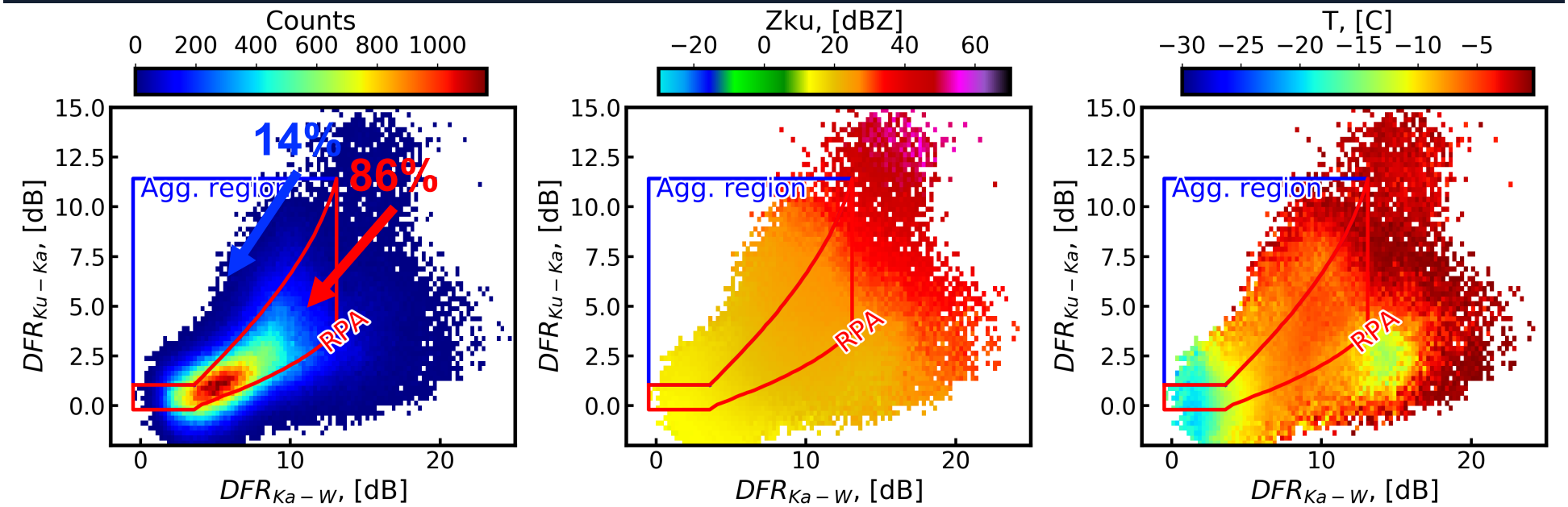

PH10_D
L15_05
L15_00
L15_10
Agg. region
RPA
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]
Temperature, [°C]
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
5
10
15
20
5
0
−5
−10
−15
−20
−25
−30


Are large aggregates infrequent?
20%
80%
Agg. region
RPA
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]
Counts
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
5
10
15
20
300
250
200
150
100
50


Information on Ku-Ka axis
Increasing ρ_e
RPA
gion
DFR_{Ka-W}, [dB]
Bulk Density, $[gcm^{-3}]$
0.10
0.08
0.06
0.04
0.02
0.00
0.0
0
5
10
15
20
DWR_X_Ka [dB]
DWR_Ka_W [dB]
D_0
D_0
ρ

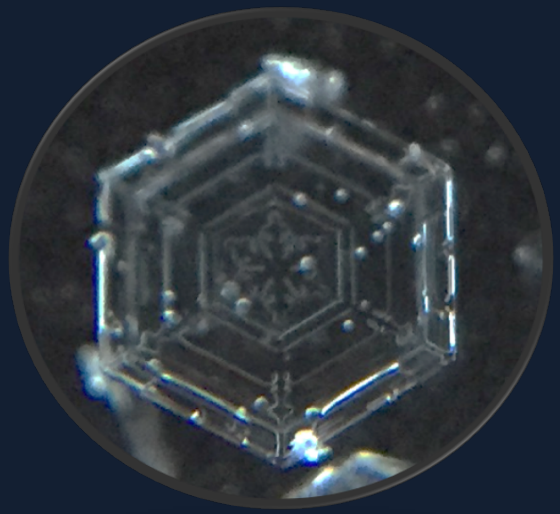

Information on Ku-Ka axis
DWR_X_Ka [dB]
DWR_Ka_W [dB]
ρ
D0
D0
region
RPA
Increasing D_{mm}
DFR_{Ka-W}, [dB]
D_{mm}, [mm]


Is it a sampling problem?
Columnar
Dendrite, Sectored Plates
Needles
Plates
Frequency
Cuml. Frequency
Temperature
0
100
200
300
400
500
600
700
800
−30
−25
−20
−15
−10
−5
0.0
0.2
0.4
0.6
0.8
1.0


Counts
0 200 400 600 800 1000
Zku, [dBZ]
−20 0 20 40 60
T, [C]
−30 −25 −20 −15 −10 −5
Agg. region
14%
86%
RPA
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]

Based on our investigation of OLYMPEX airborne triple-frequency radar observations coincident with microphysical measurements

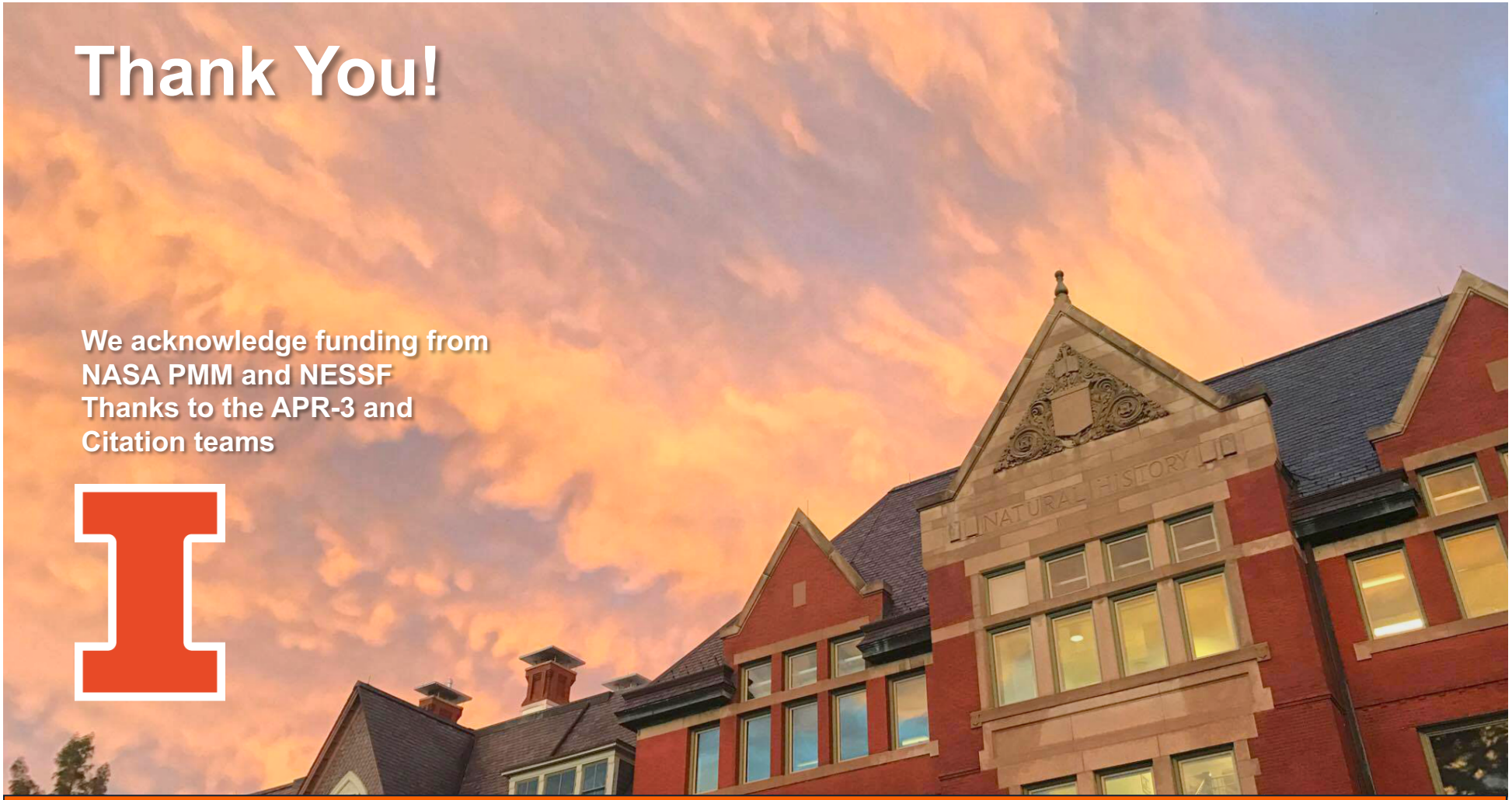
Conclusions:



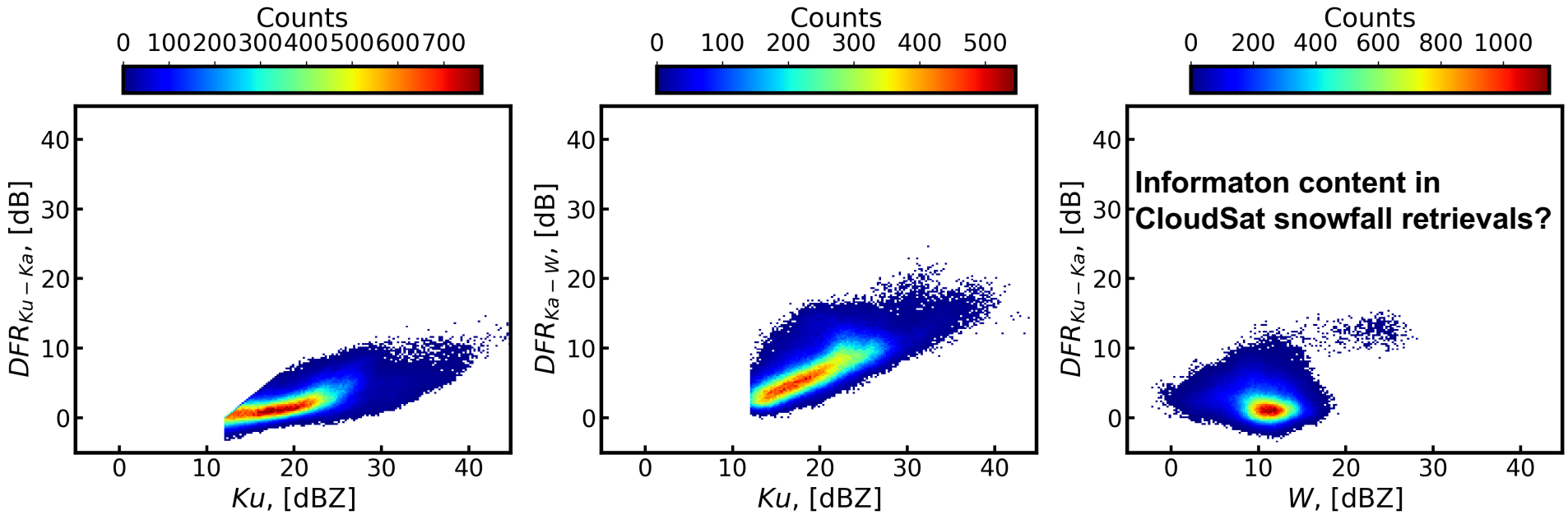
1) The 3-frequency DFR, as well as Ku-Ka DFR plane exhibits information about ρ_e and D_{mm}
2) Most matched points are found within the DFR retrieval region termed here as the RPA due to overlapping scattering models of different particle shapes
3) Information in Ku-Ka DFR in retrieving effective density and D_m

Thank You!

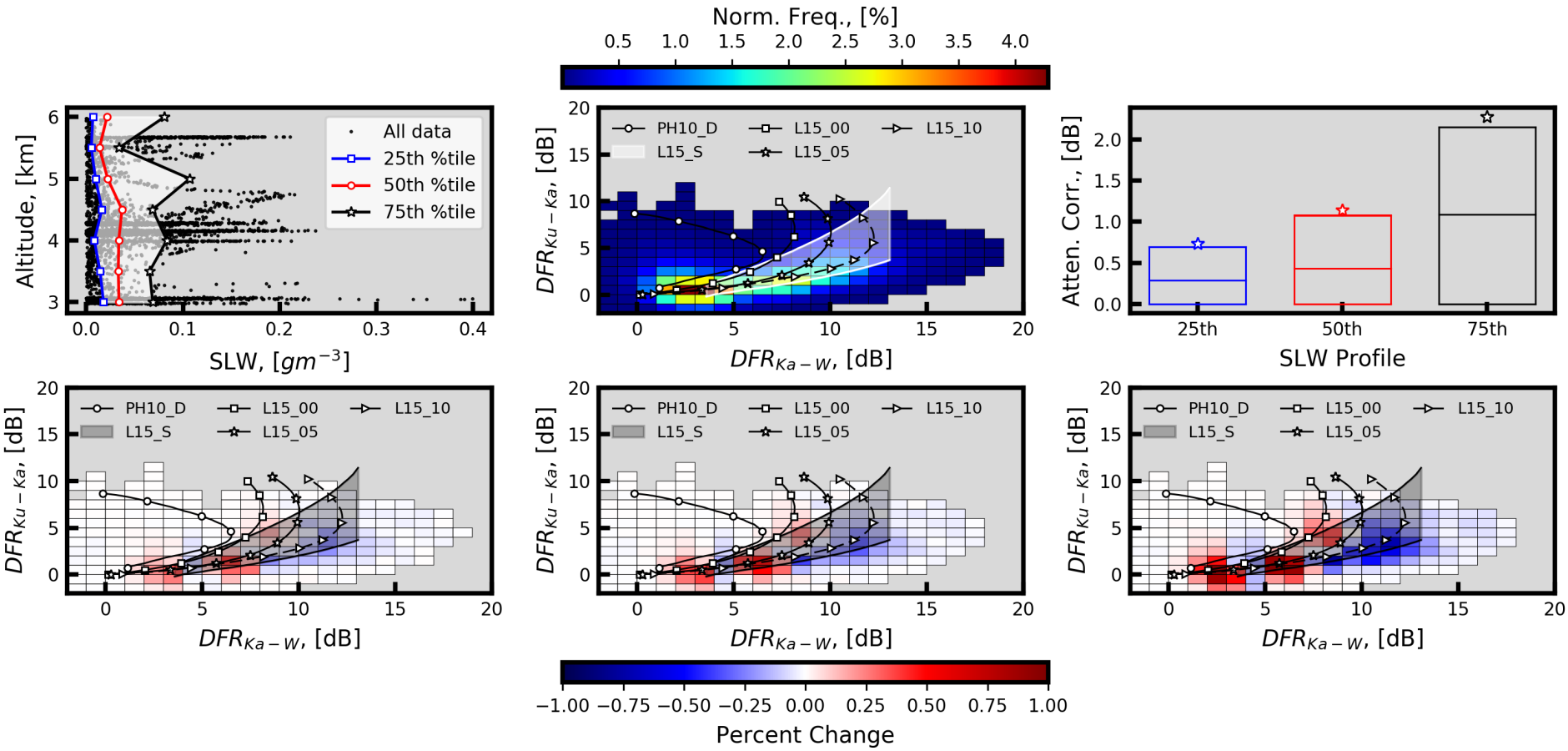
We acknowledge funding from
NASA PMM and NESSF
Thanks to the APR-3 and
Citation teams



All points at Ku Z > 12 dBZ

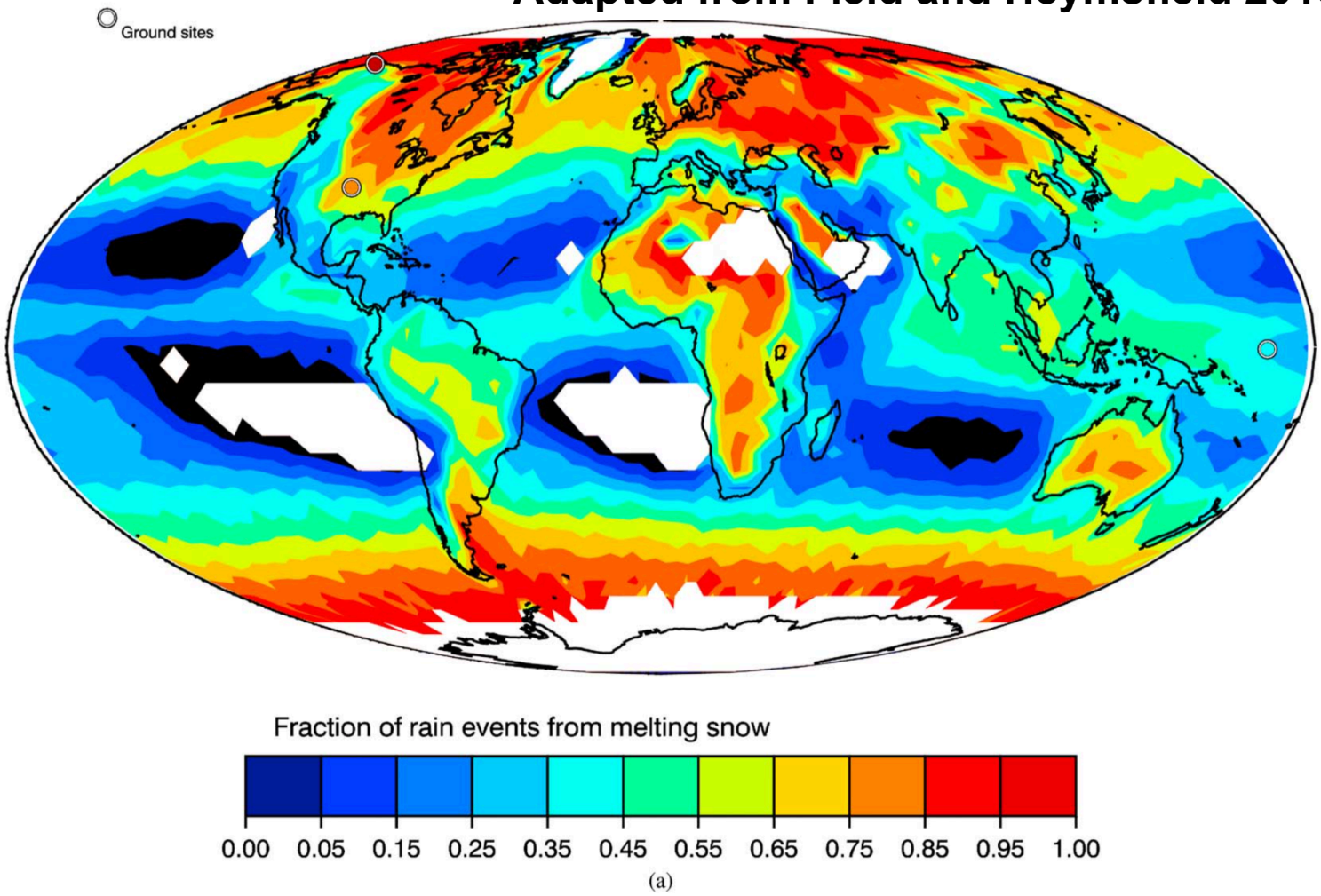


Corrected for attenuation


Norm. Freq., [%]
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0
Altitude, [km]
SLW, [gm^{-3}]
All data
25th %tile
50th %tile
75th %tile
PH10_D
L15_00
L15_10
L15_S
L15_05
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]
Atten. Corr., [dB]
25th
50th
75th
SLW Profile
−1.00 −0.75 −0.50 −0.25 0.00 0.25 0.50 0.75 1.00
Percent Change

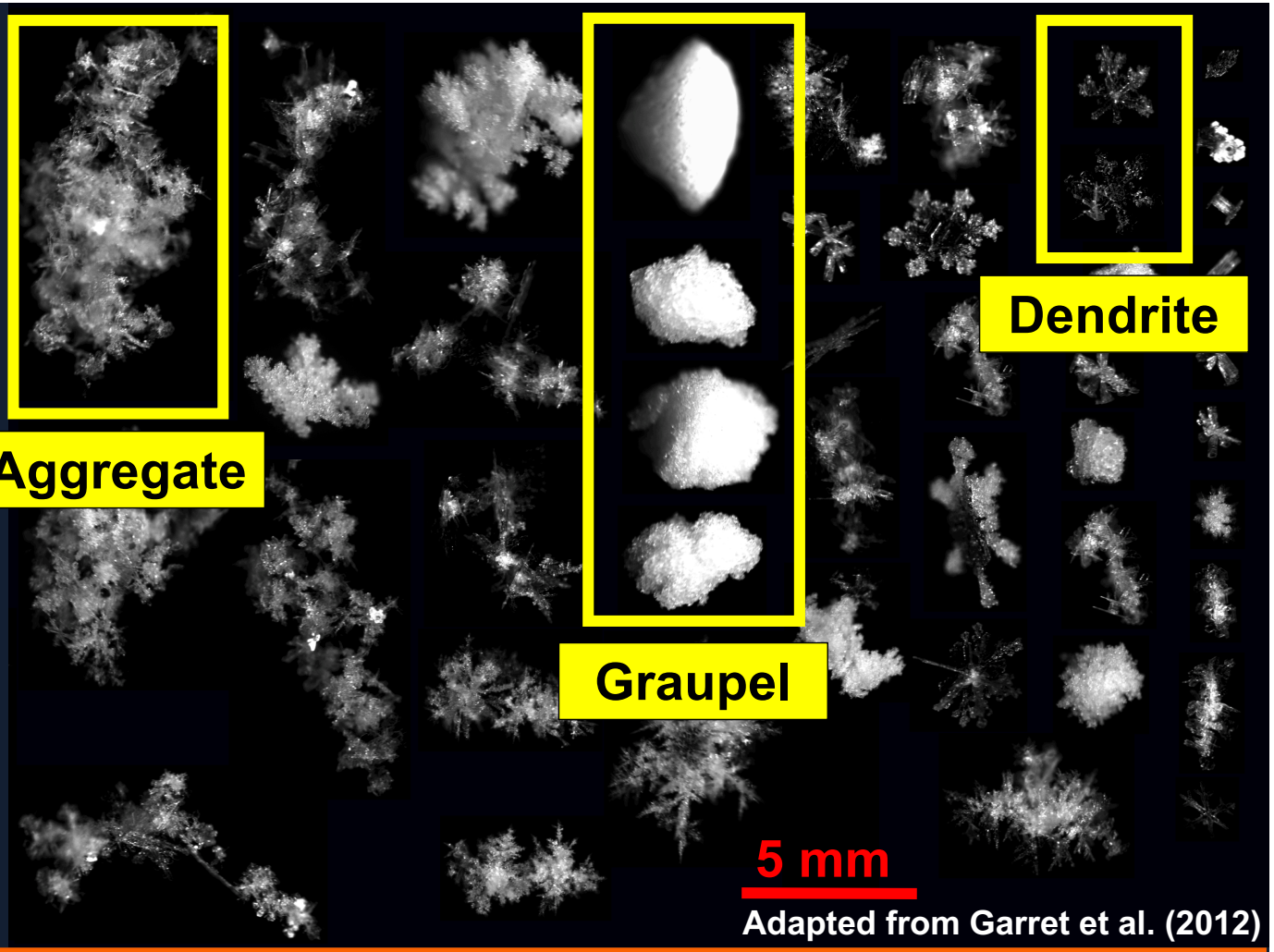
Why is ice important?

Adapted from Field and Heymsfield 2015



Retrieval of precipitation rate (I) and ice water content (IWC) require assumptions about:

1) Particle shape
2) Particle size
3) Particle mass
4) Terminal fall velocity (only for S)

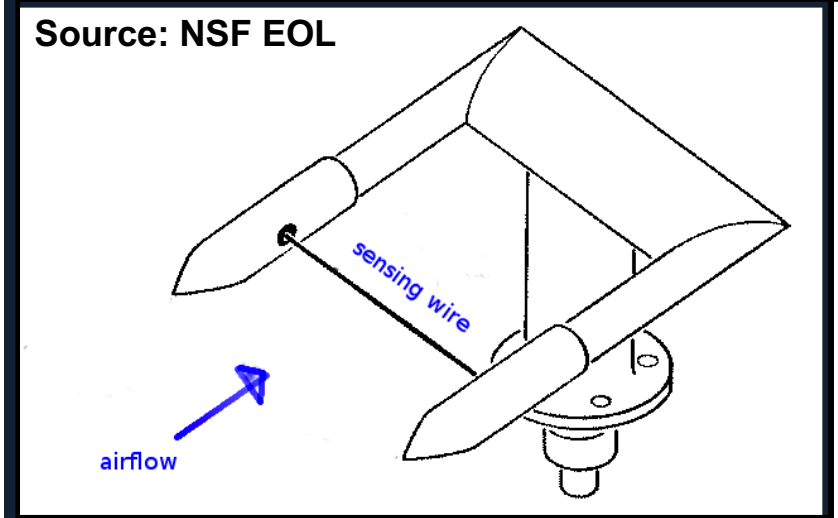


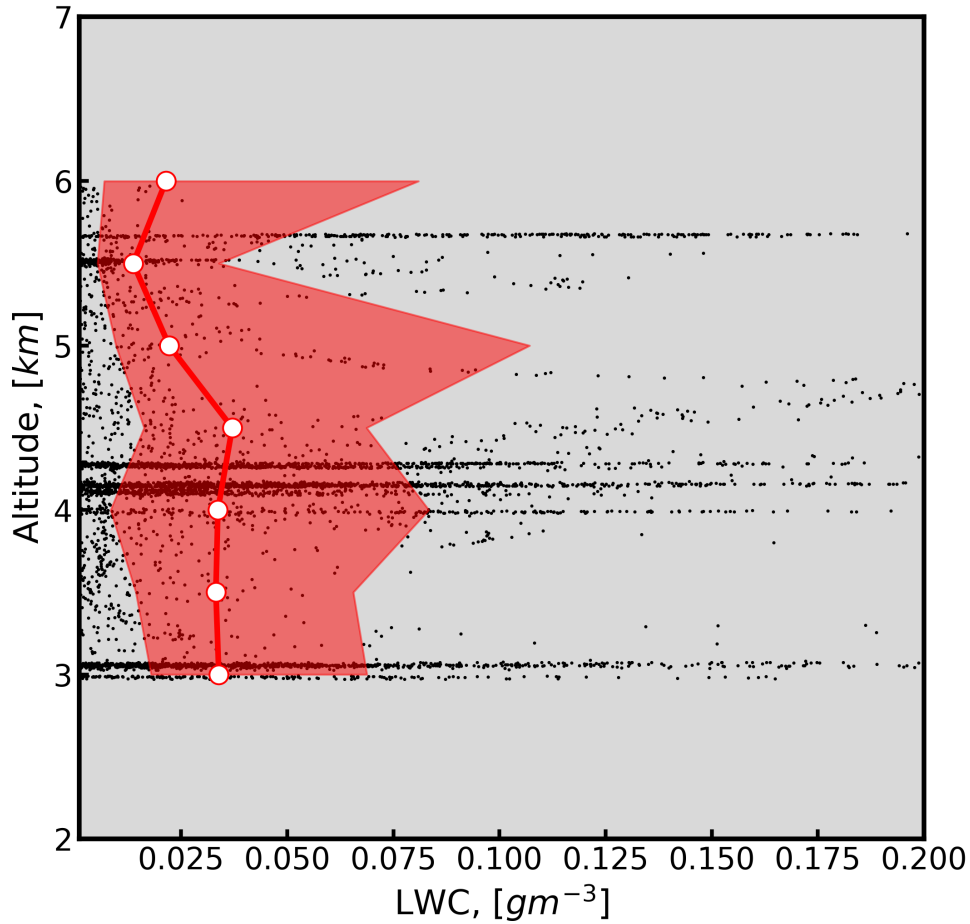
Adapted from Garret et al. (2012)

Before the Olympic Mountain Experiment, no dataset contained airborne triple-frequency radar and airborne microphysical in-situ measurements

OLYMPEx, a NASA/GPM field campaign planned and succeeded to collect such data

Source: NSF EOL





Observed LWC

Line: Median

Dots: Observations

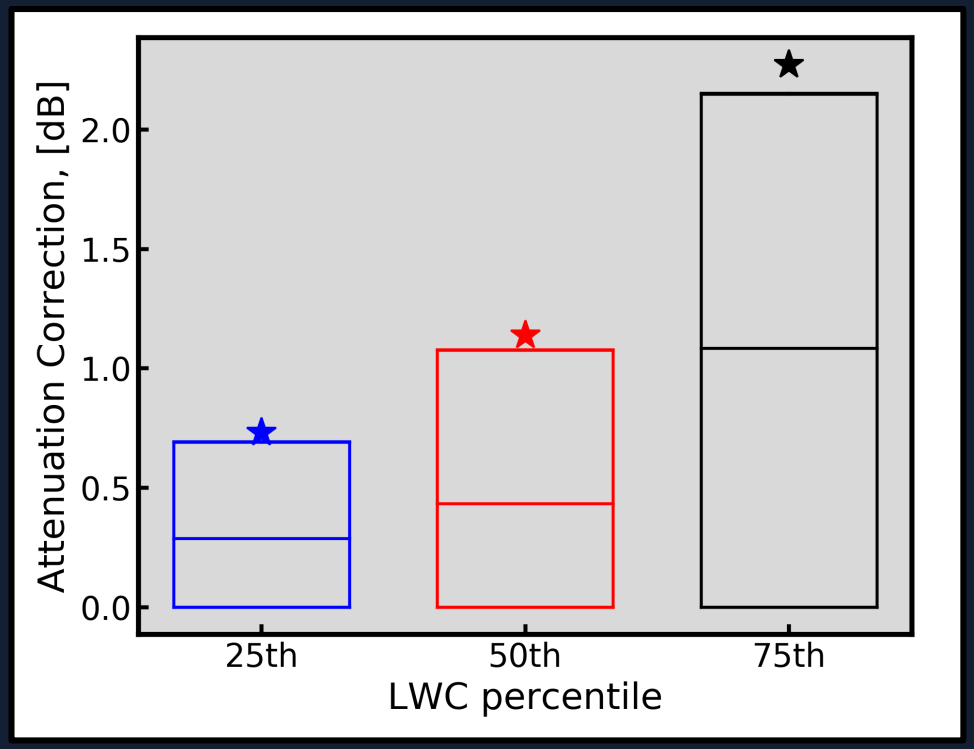
Shaded region: 25th – 75th percentile

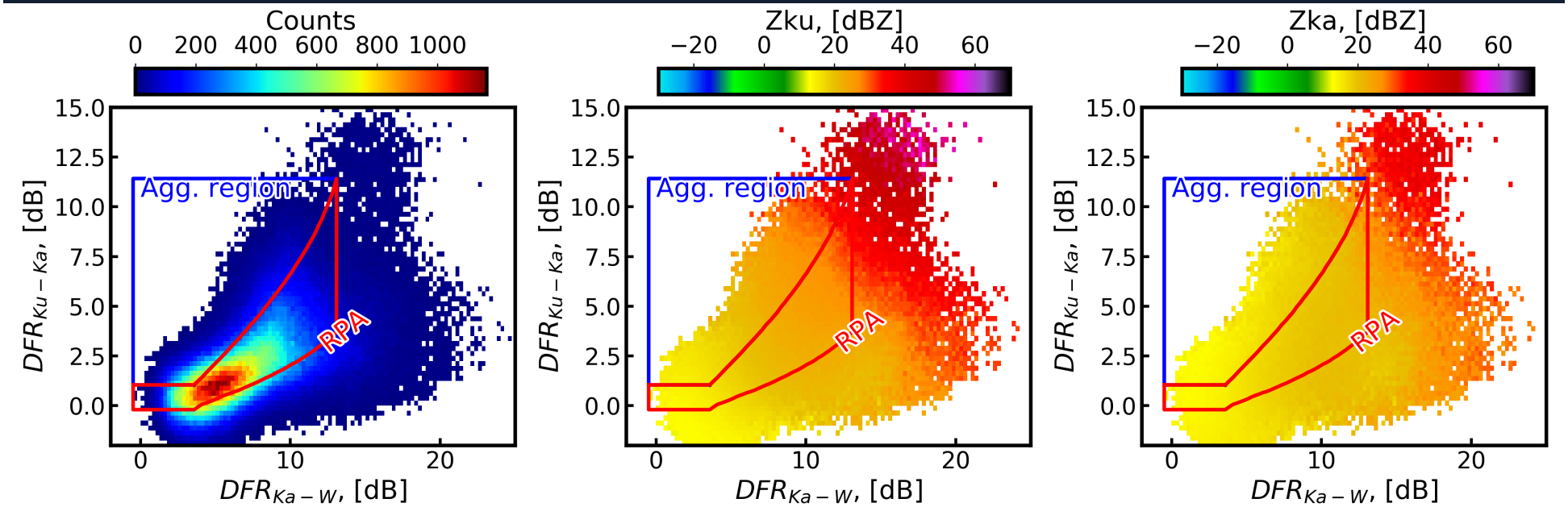
Attenuation Correction statistics:

Considering medians, correction around 0.5 dB

Calibration error 1.5 dB

Choose to use 50th percentile of LWC




Counts
0 200 400 600 800 1000
Zku, [dBZ]
−20 0 20 40 60
Zka, [dBZ]
−20 0 20 40 60
Agg. region
RPA
DFR_{Ku-Ka}, [dB]
DFR_{Ka-W}, [dB]
15.0
12.5
10.0
7.5
5.0
2.5
0.0
0
10
20