Analysis of NASA GPM Ground Validation Multi-frequency Radar Observations

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NASA
POSTDOCTORAL PROGRAM
Administered by USRA

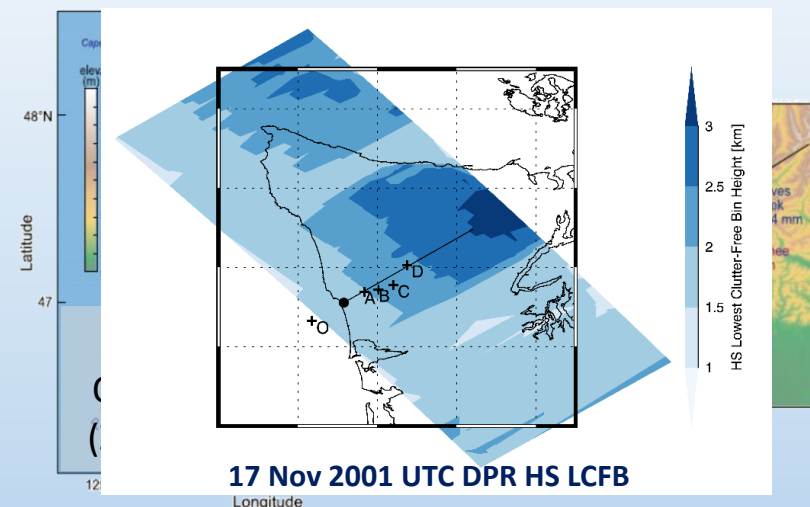Image: Stacy Brodzik

GPM
全球降水観測計画
GLOBAL PRECIPITATION MEASUREMENT

Motivation

- GPM GV Observation Diversity
  - Core Observatory
  - Constellation Partners
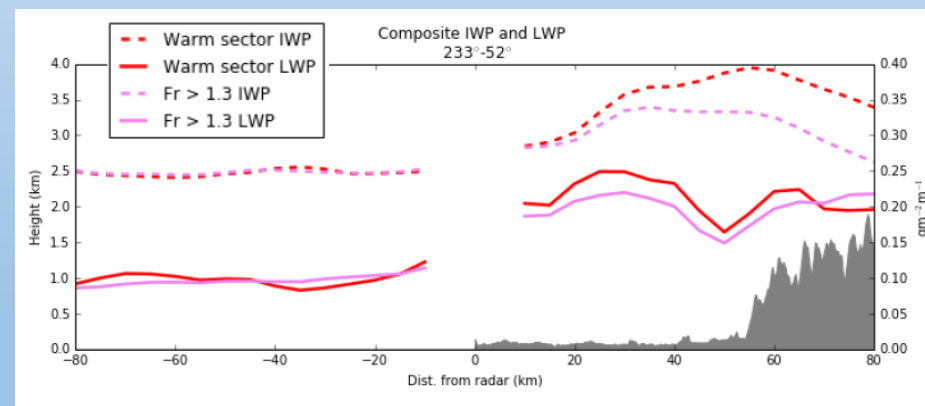 - Field Campaigns

Goals:

Focus on OLYMPEX Atmospheric River (AR) Events:
- Integrative approach/building atmospheric column
  - DPR LCFB often above 0°C in high terrain
- Compositing vertical slices
- Multi-frequency analysis via ground-based radars

17 Nov 2001 UTC DPR HS LCFB

Land/topo **impact ice/liquid** precipitation processes – **unblocked (large Froude) & warm sector** flow regimes
(Hunzinger 2018/Petersen et al. 2018)

Methodology

Case Criteria

- ARs with unblocked terrain-normal component flow: WS, Fr > 1.3
  (Hunzinger 2018/Petersen et al. 2018)
- 6 AR cases, 8 GPM OPs
  - 13 Nov 03-00 UTC (20%)
  - **17 Nov 10-21UTC (10%)**
  - **3 Dec 14-00 UTC (10%)**
  - 6-7 Dec 00-02 UTC (25%)
 - 8-9 Dec 13-10 UTC (20%)
  - 17 Dec 08-00 UTC (15%)

Analysis:

- Vertical slice composites:
  - Z, D_m, RR
- Dual-frequency ratios:
  - NPOL (S-band) & D3R (Ku/Ka-band)
  - 150 x 200 m range-height grid spacing
- Parse results by:
  - NPOL-derived HID (Dolan et al. 2013)
    - LIQ: drizzle, rain, big drops
    - ICE: crystals, aggregates, hail
    - MIX: wet snow, graupel
  - Sea vs. terrain
  - Individual HID type classes

Composites over all ARs
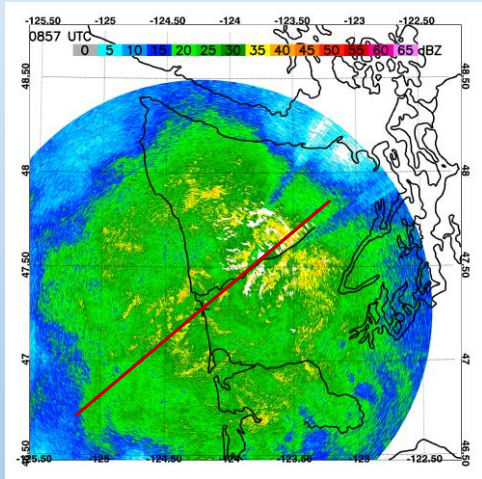
- Along NPOL RHI approaching, through Quinault River Valley

- Terrain, orographic enhancements
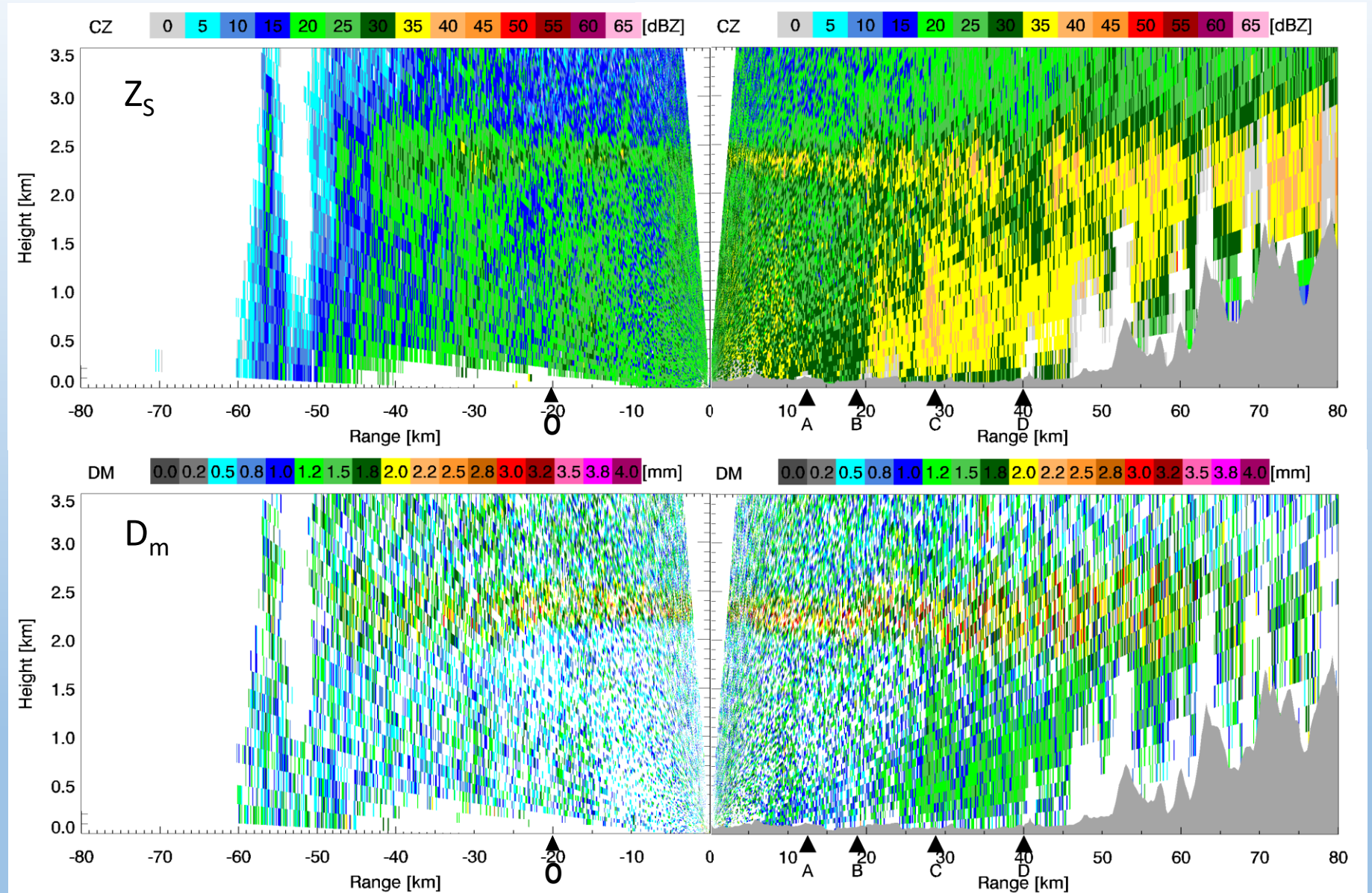
Z$_S$ – NPOL Composites

17 November 2015   10-21 UTC
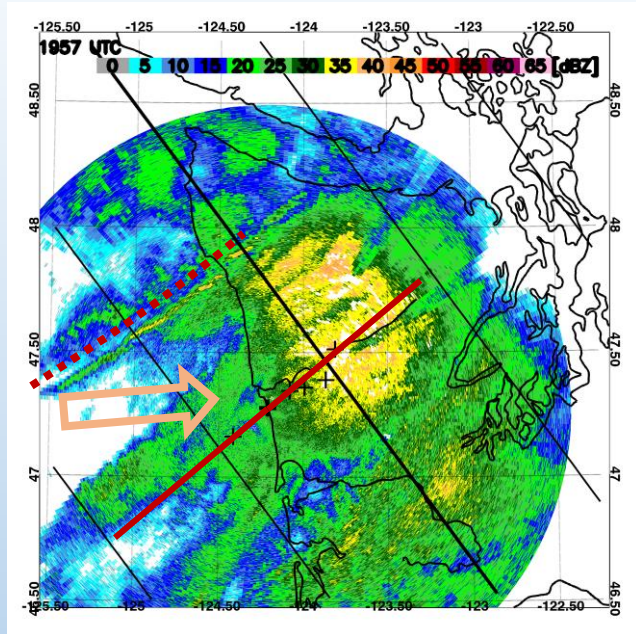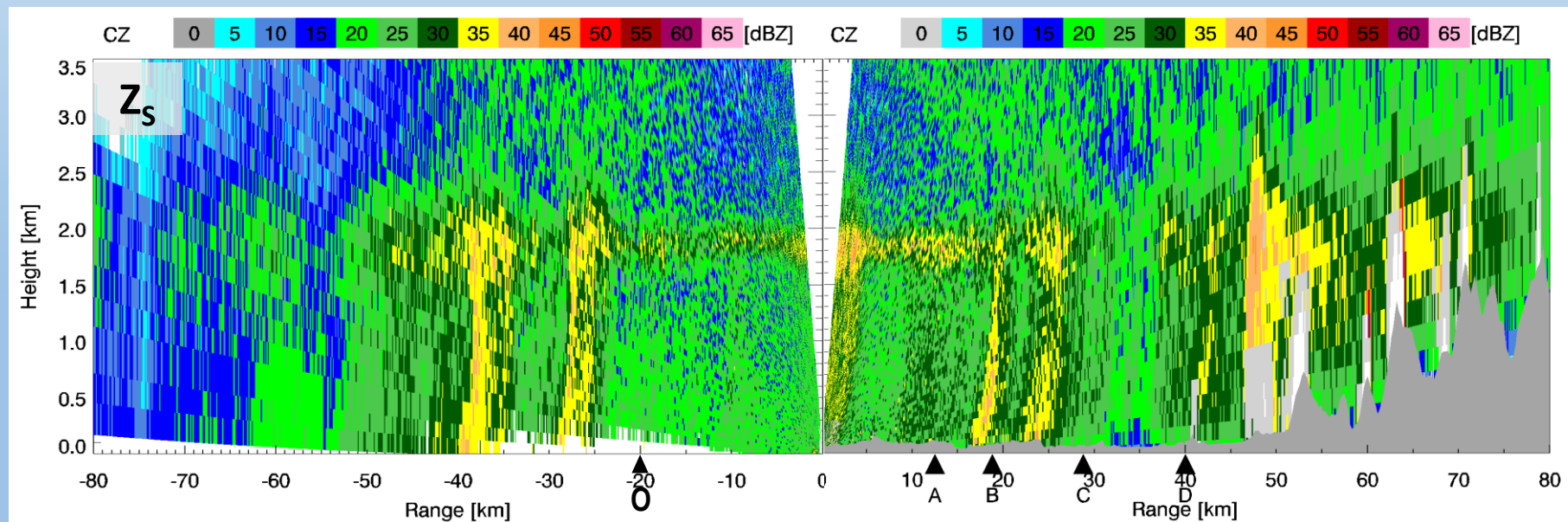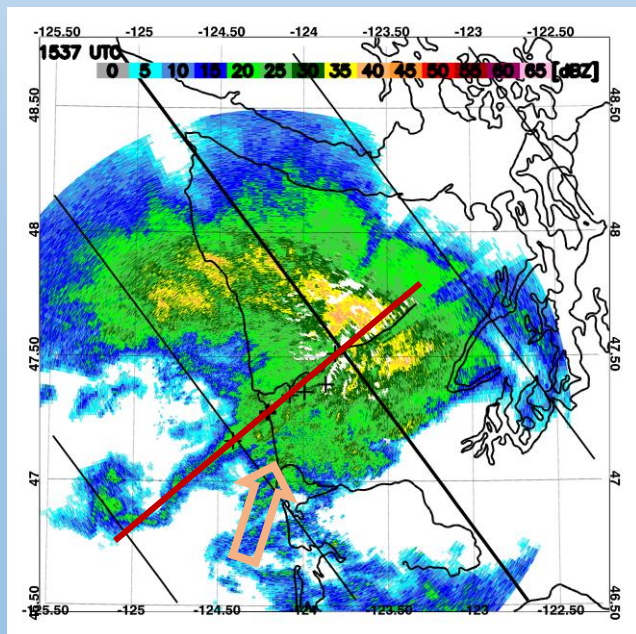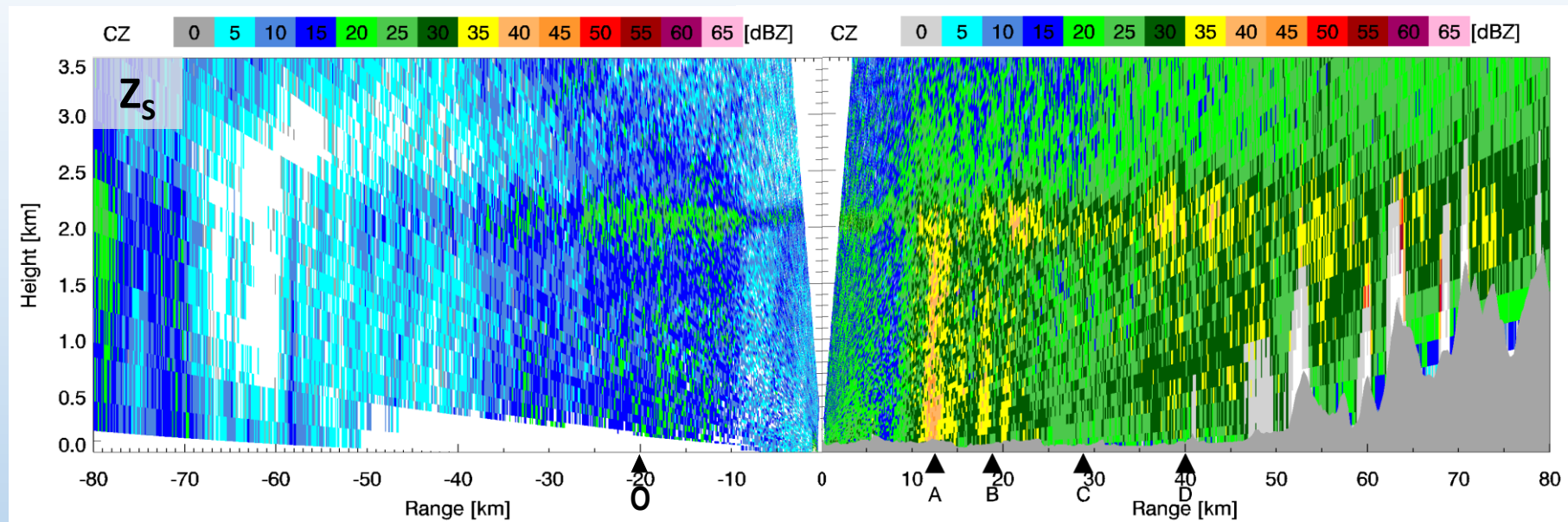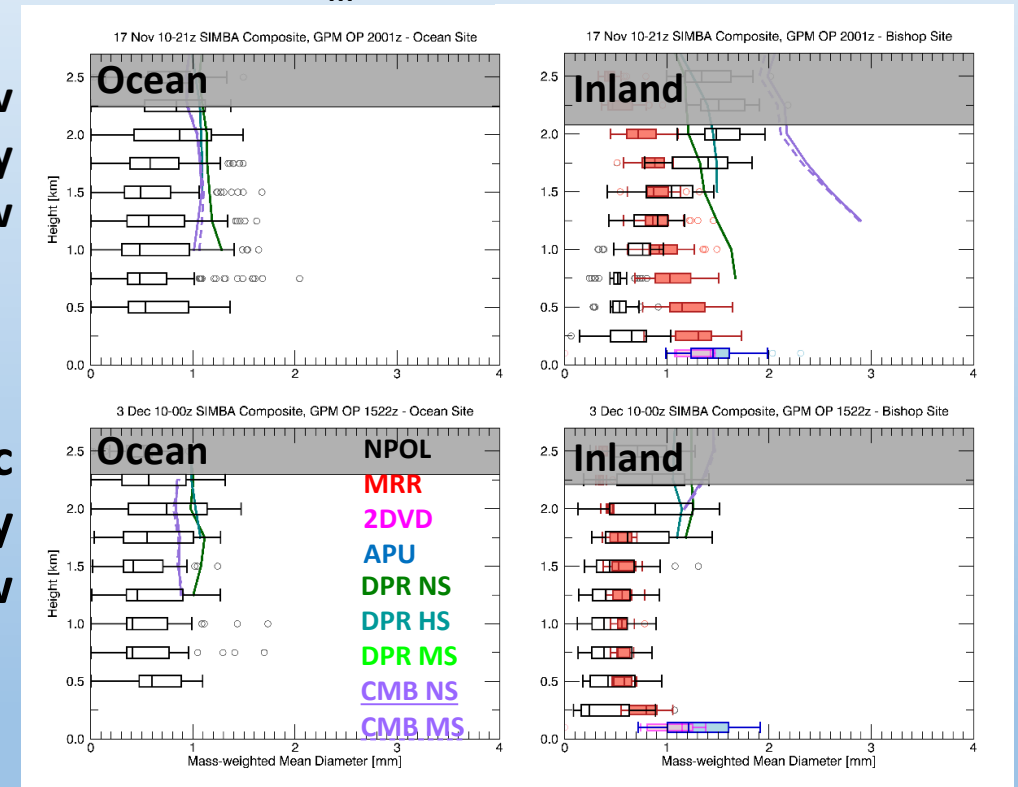
3 December 2015 14-00 UTC

Why Dual-Frequency Ratios for the ARs?

- Previous work:
  - Column-based ARs analyses show best agreement among DPR, GMI, GV observations over ocean
  - Discrepancies increase:
    - As move **up valley/into more complex terrain**
    - **Terrain-normal flow magnitude**
- Precipitation processes & satellite observations involve more than below 0°C level

D$_m$ Composite Profiles

17 Nov Westerly flow

3 Dec Southerly flow

→ Importance of identifying & quantifying **ICE, LIQUID, and MIX** phase hydrometers to better discern processes, improve observing

DFR$_{S-Ku}$
2 Events
___

- S-Ku DFR composite, includes all NPOL HID types

- More ocean-side variation in westerly flow case

- DFR layering complexity increases as approach terrain
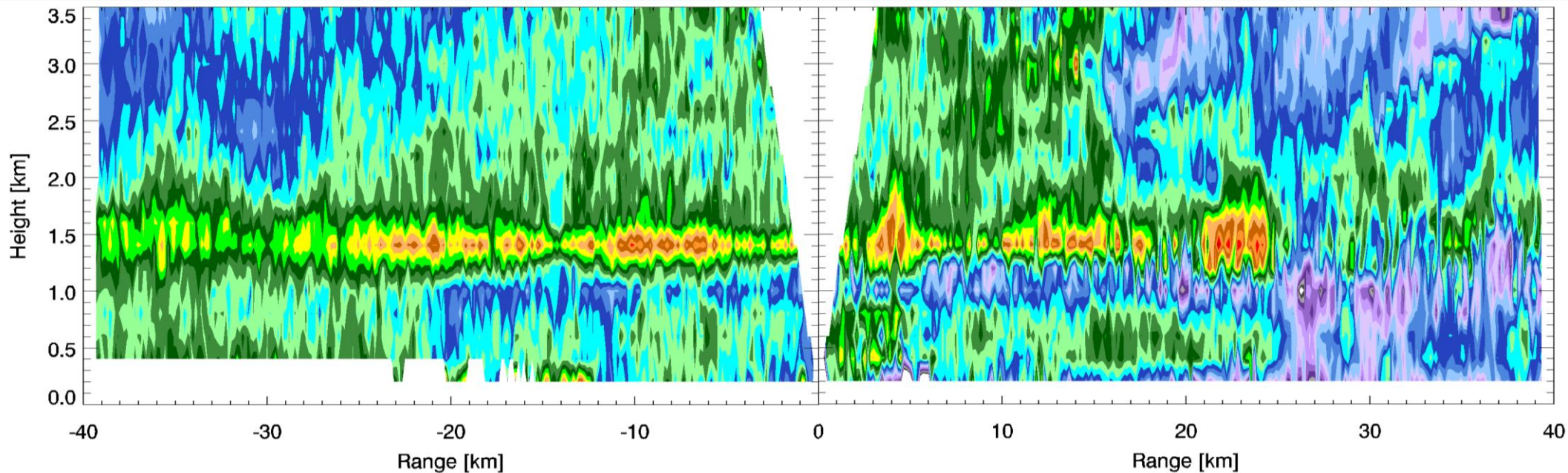
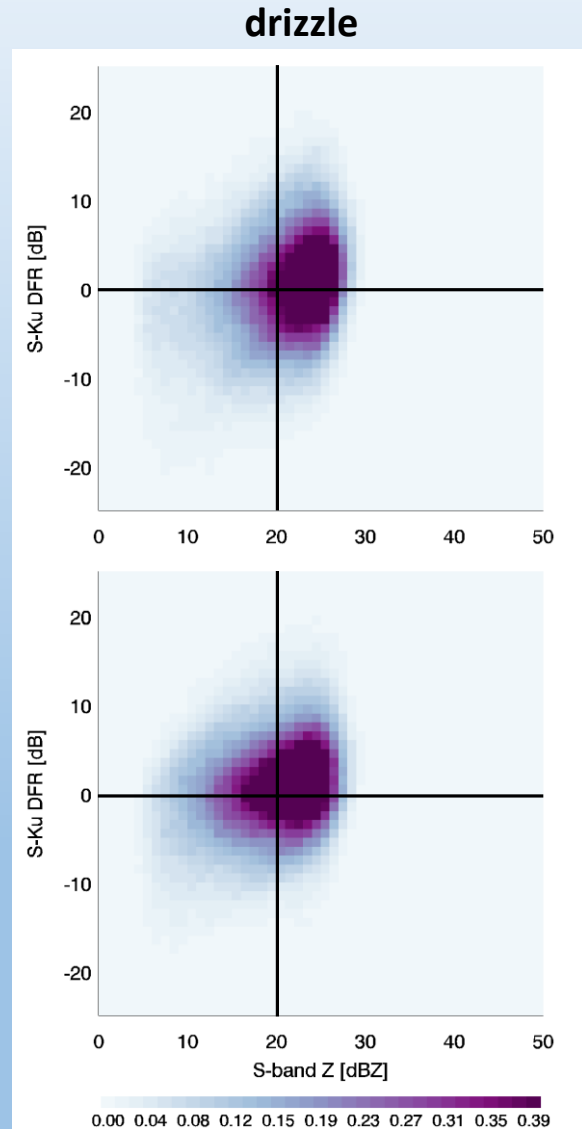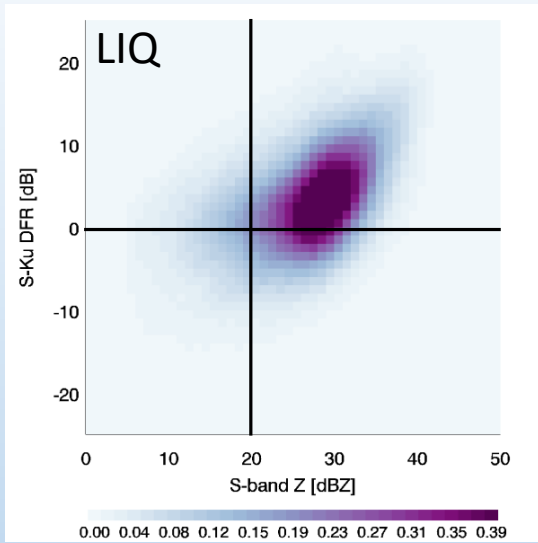**3 December 2015 14-00 UTC – southerly flow**
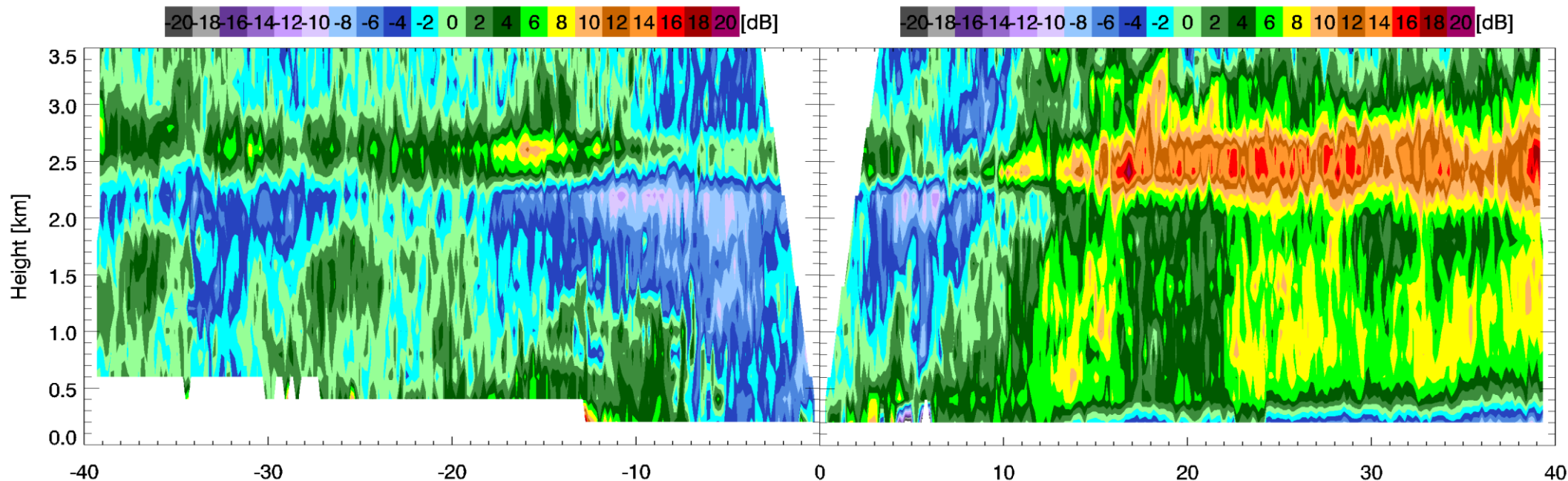
17 November 2015 10-21 UTC – westerly flow

DFR$_{S-Ku}$ ALL ARs Land Side Scans
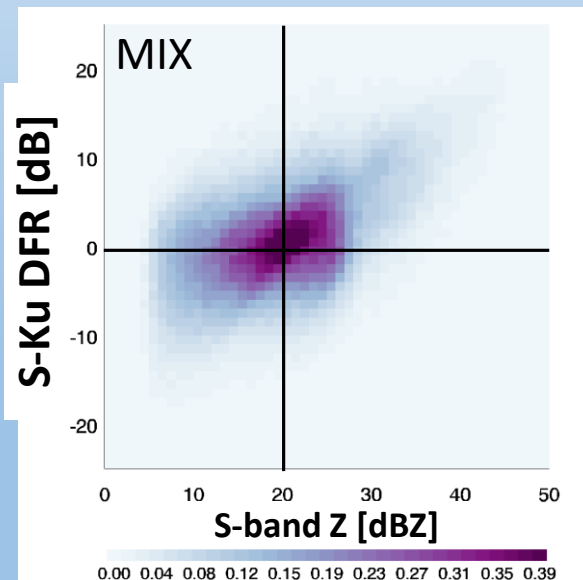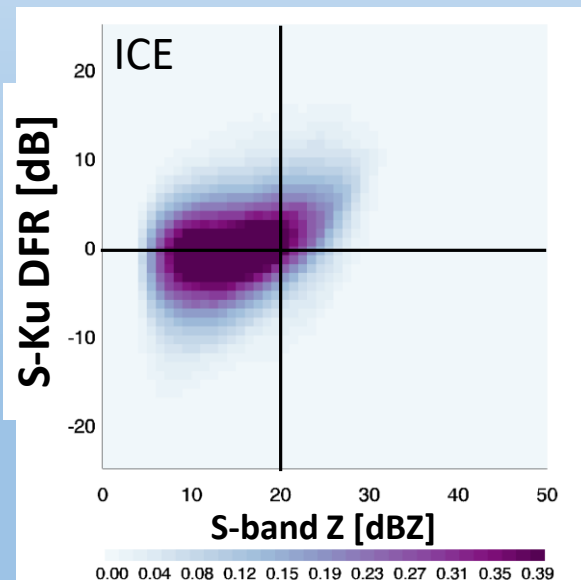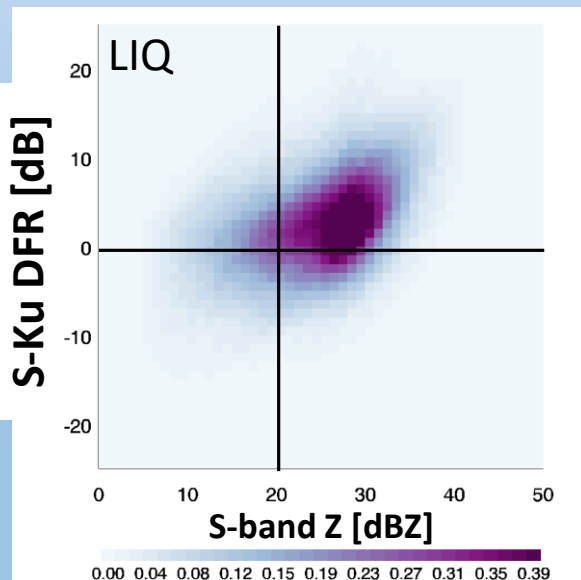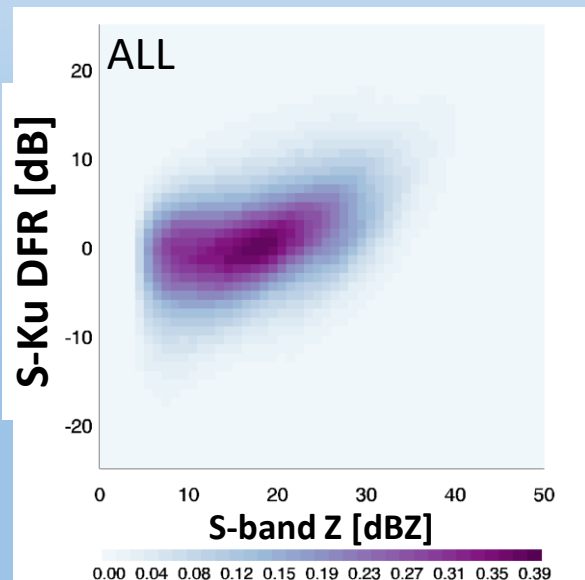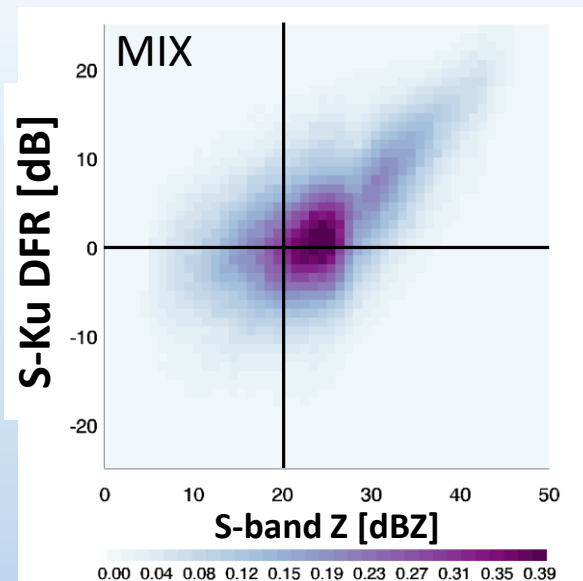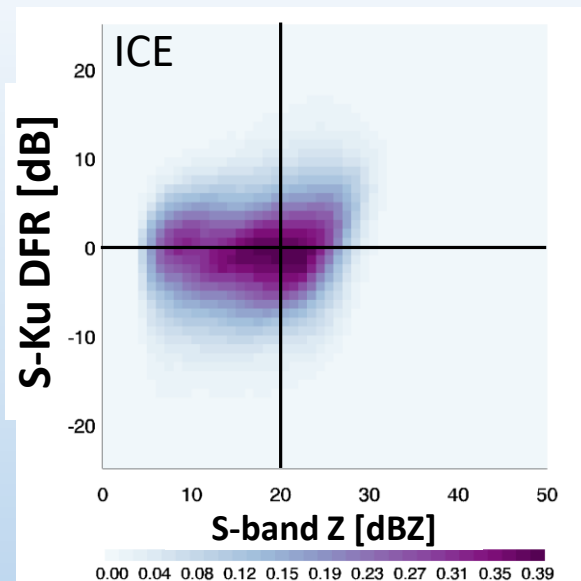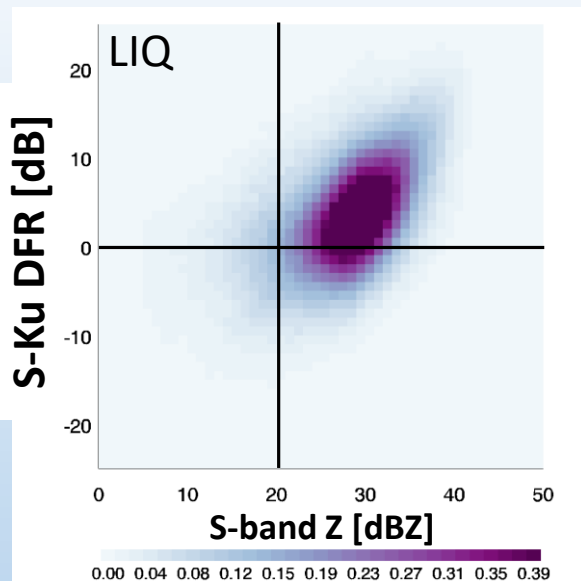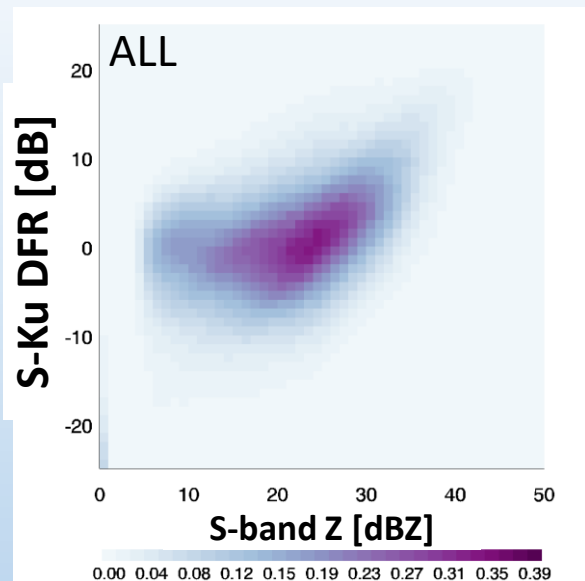
DFR$_{S-Ku}$ ALL ARs Ocean Side Scans
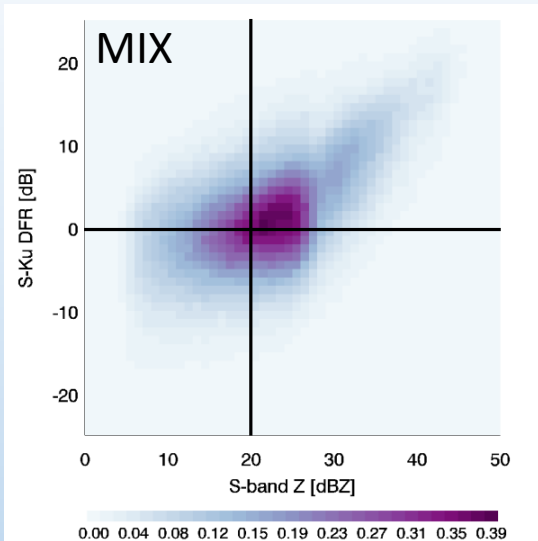
S-Ku: Liquid phase HID type classes
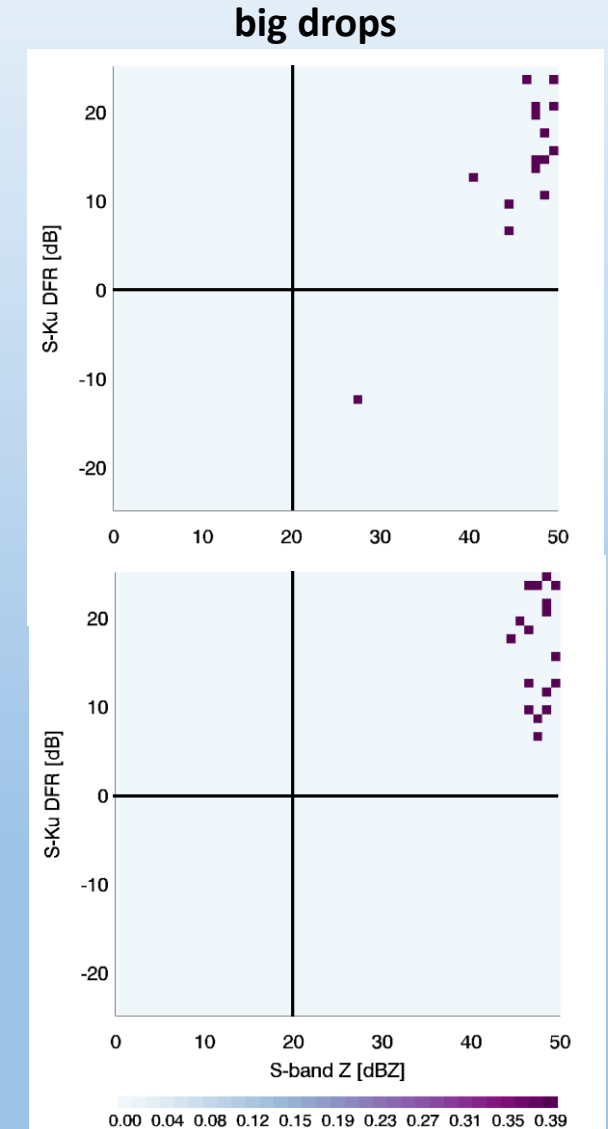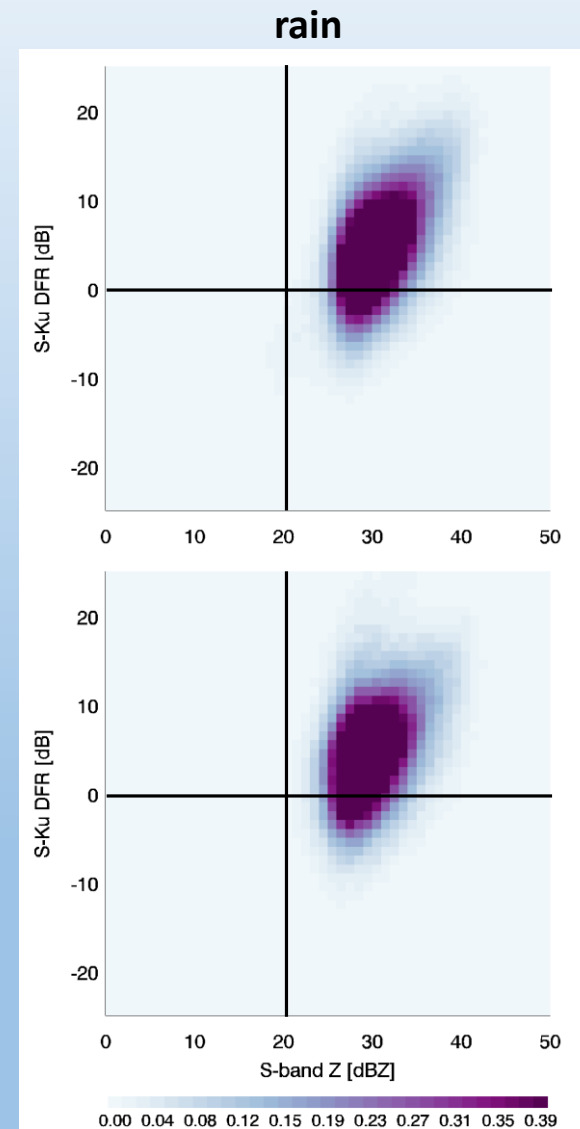
- S-band Z / Rayleigh regime dependence on hydrometeor size evident
- DFR_{S-Ku} values positive & negative
- OLYMPEX region well known for copious numbers of small drops

S-Ku: Mix-phase HID type classes

- Wet snow shows most variation, and **more dispersed over ocean**
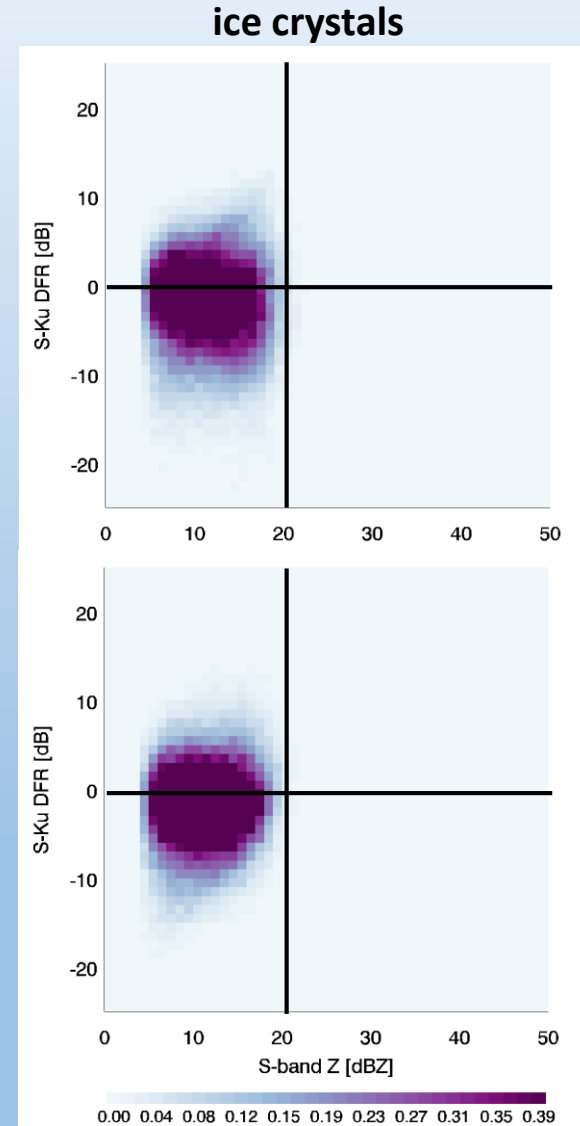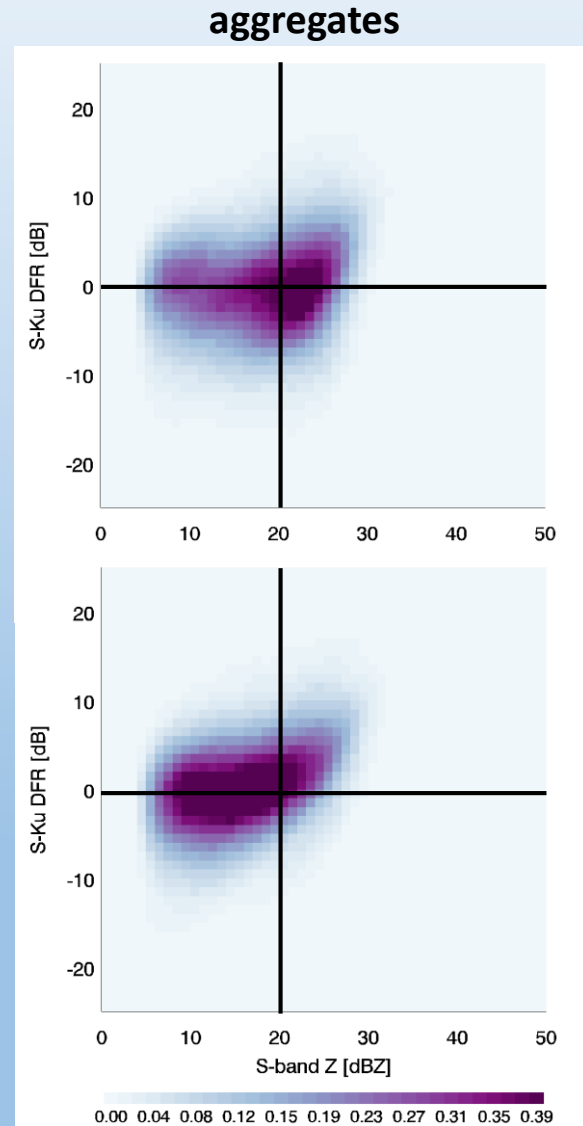- Graupel classes more similar to rain, hail; **more dispersed over land**
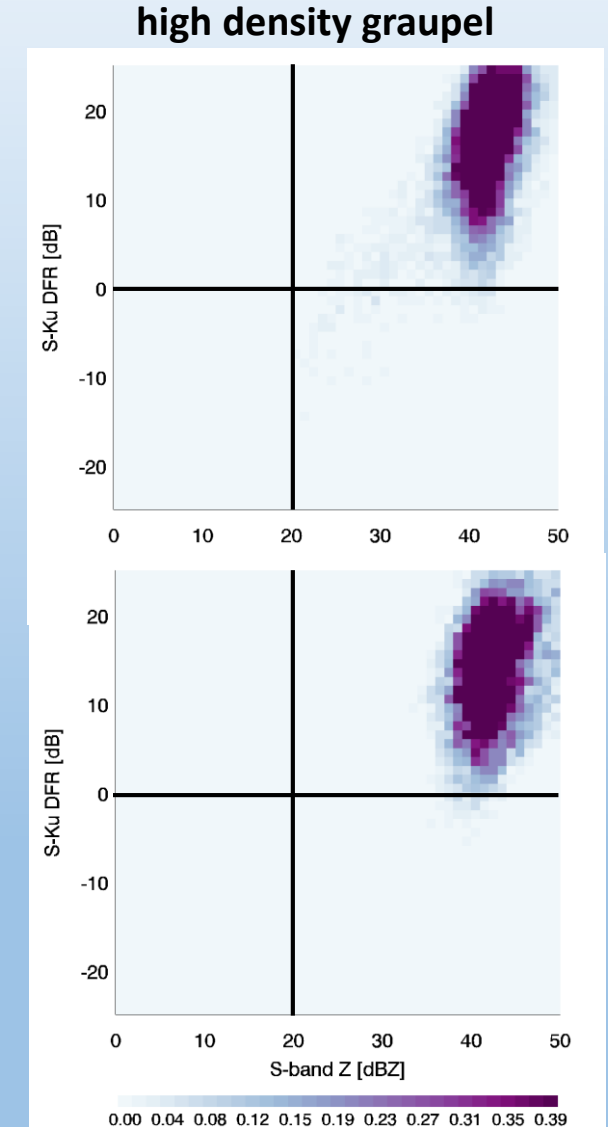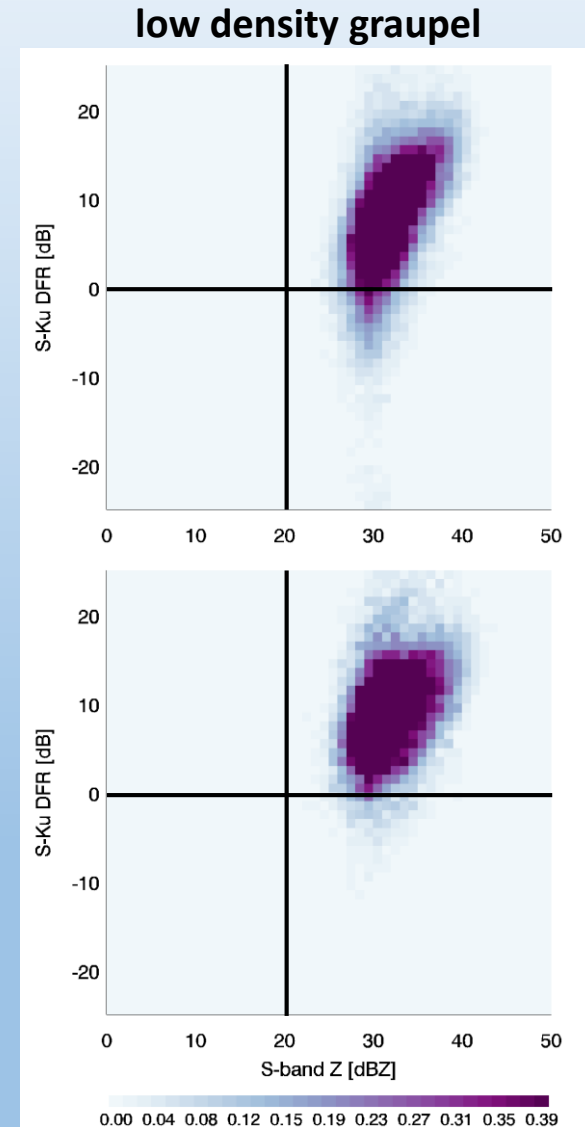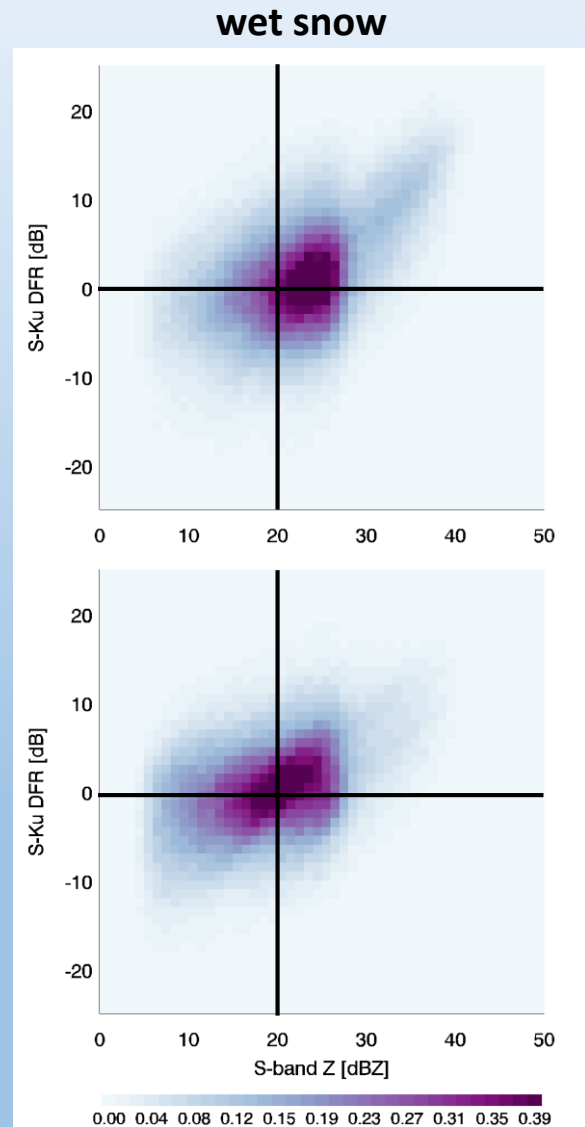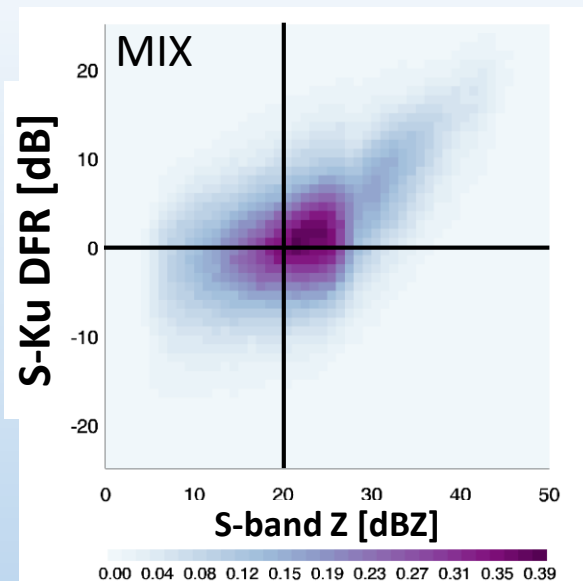
S-Ku: Ice phase HID type classes
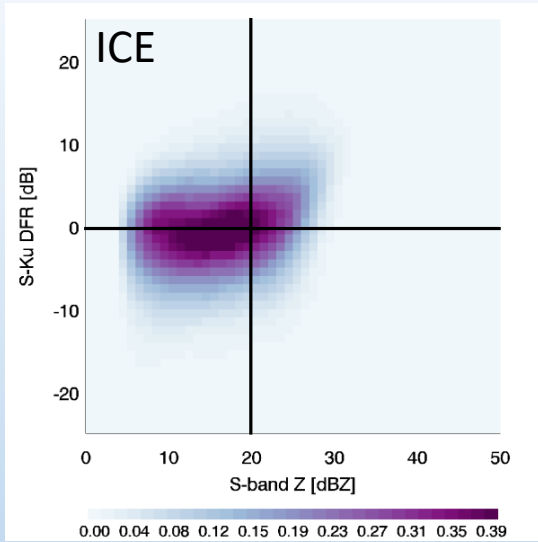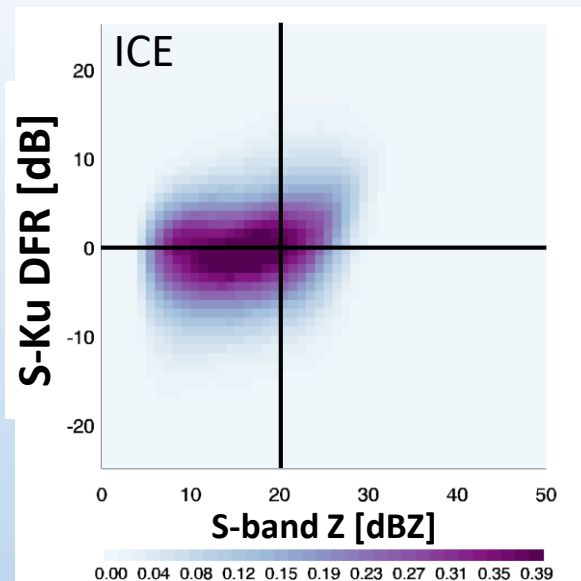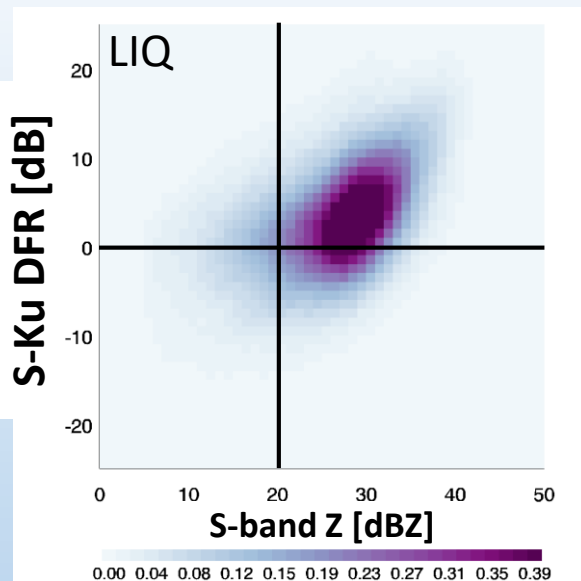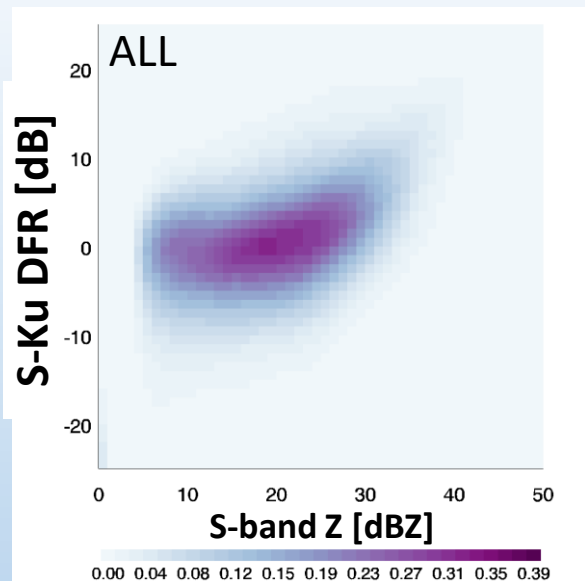

- Aggregates: different land/ ocean modes

- Ice crystals: land/ocean similar

- Vertical ice: slightly lower DFR
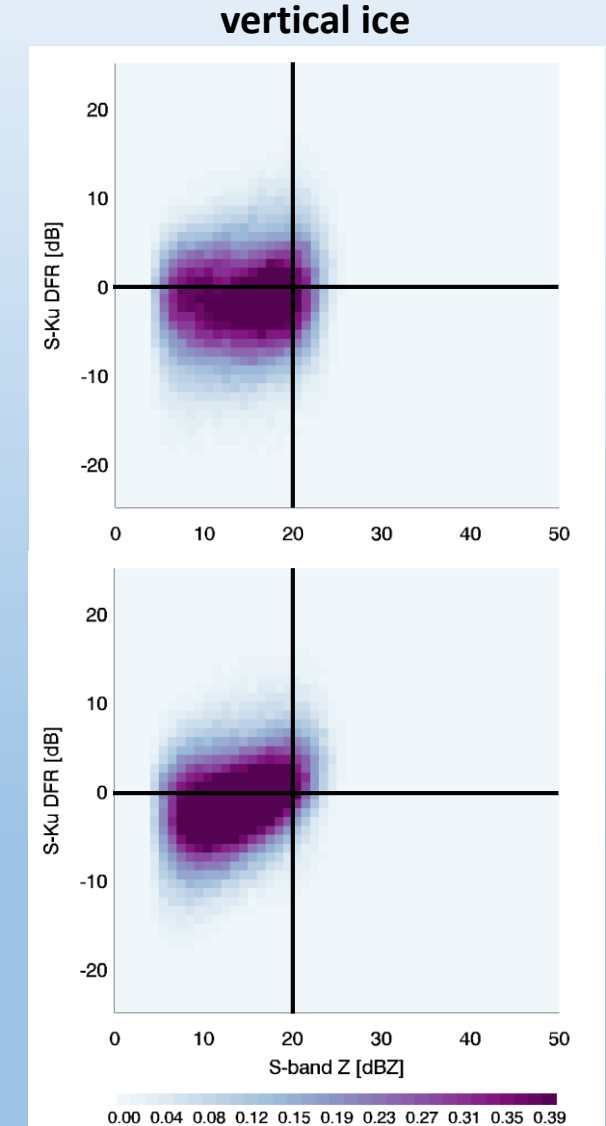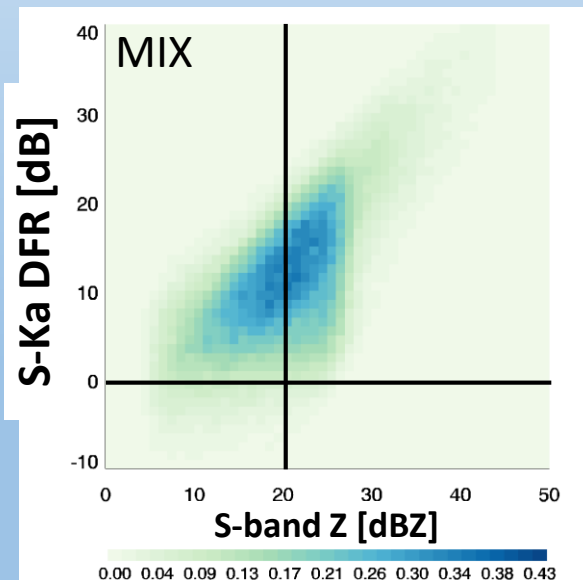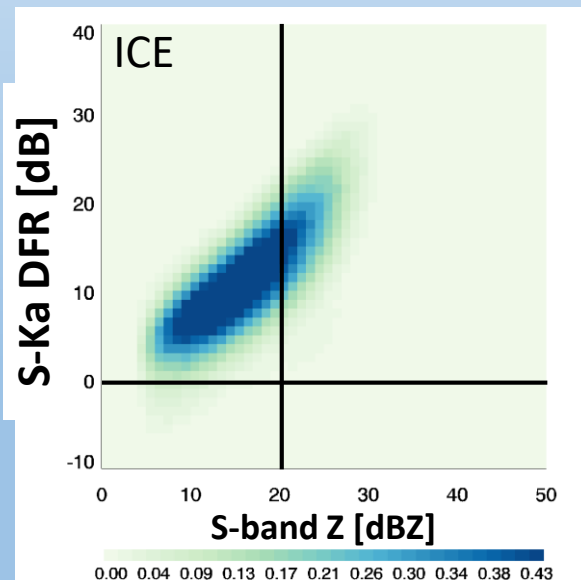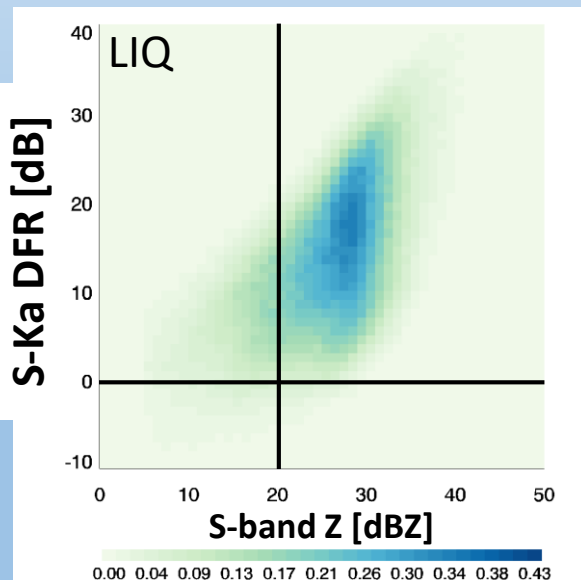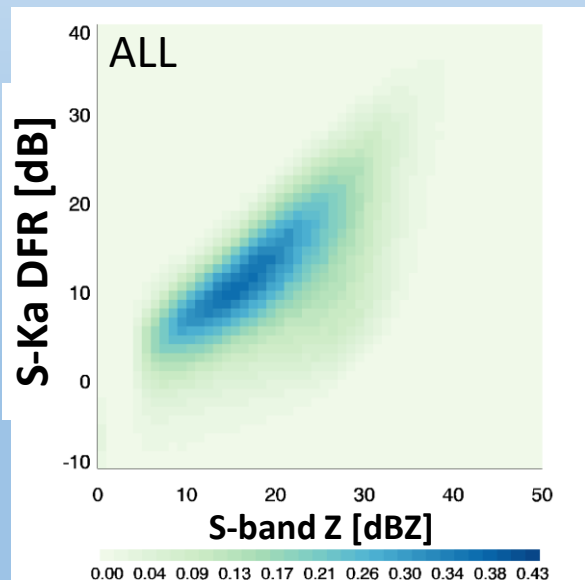
DFR$_{S-Ka}$ ALL ARs Land + Ocean
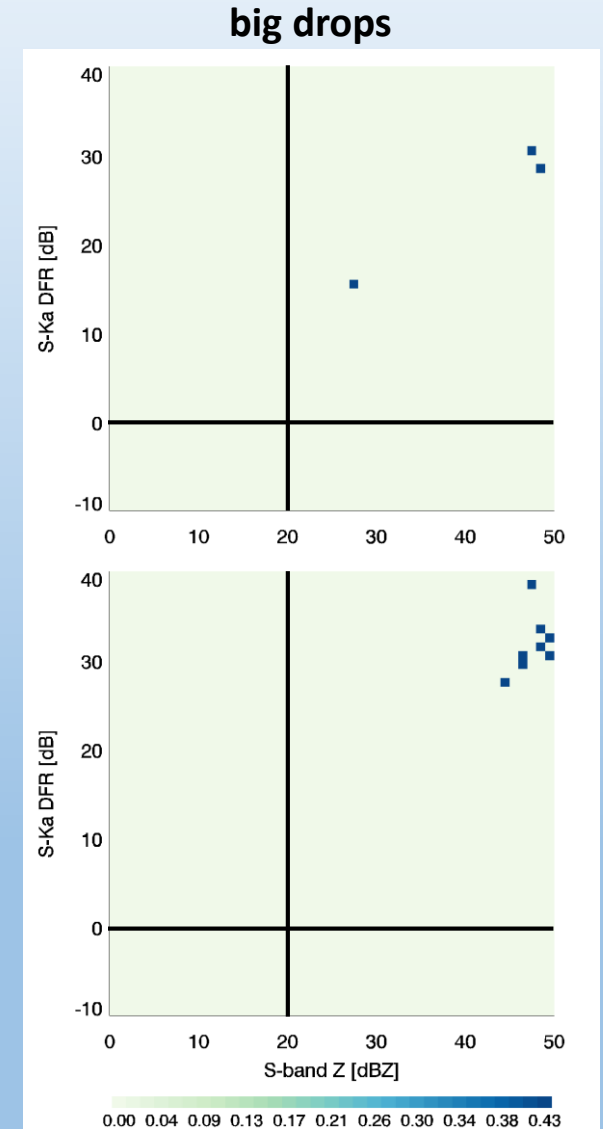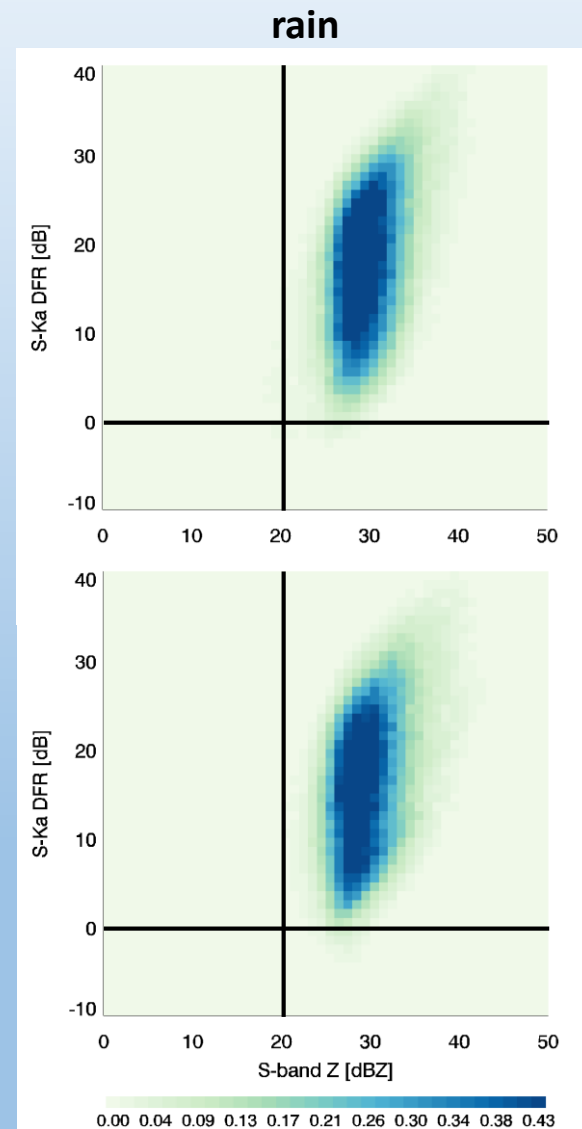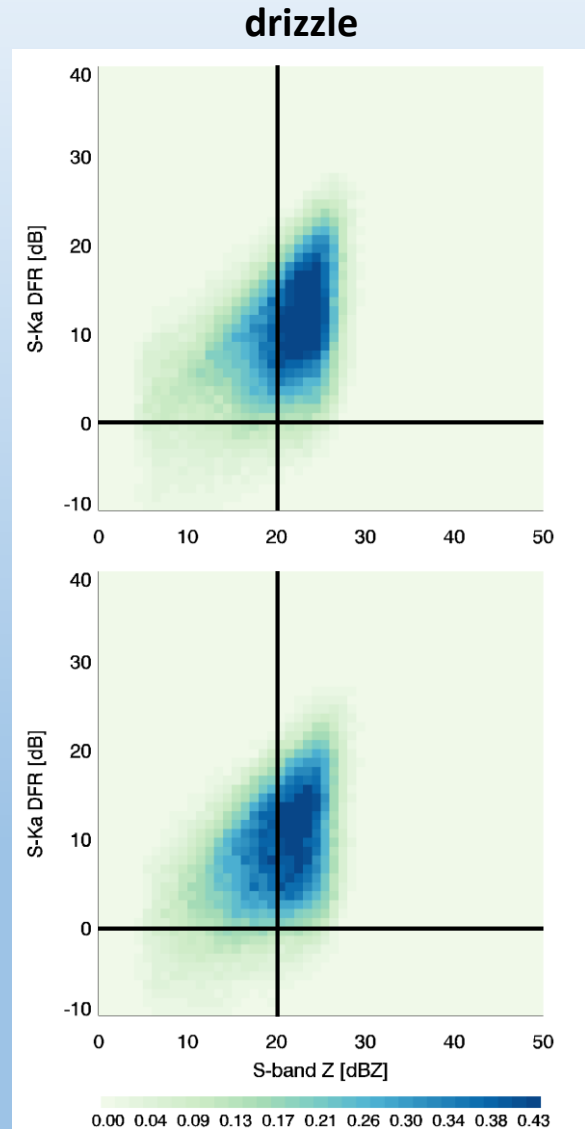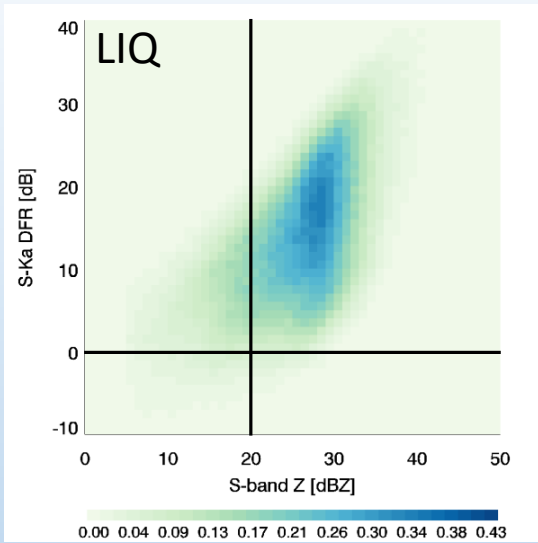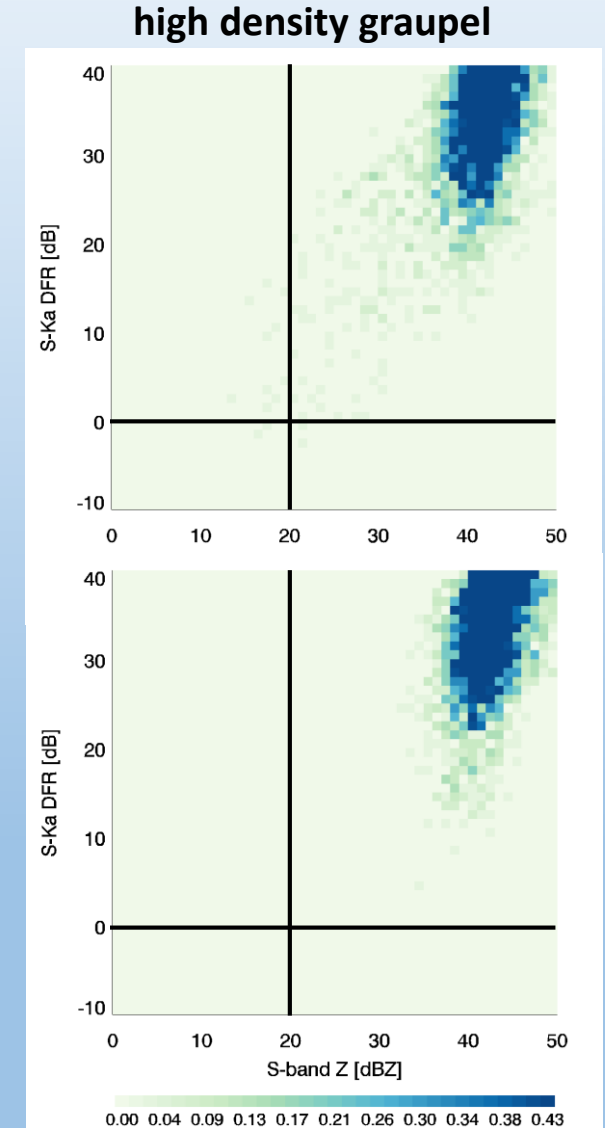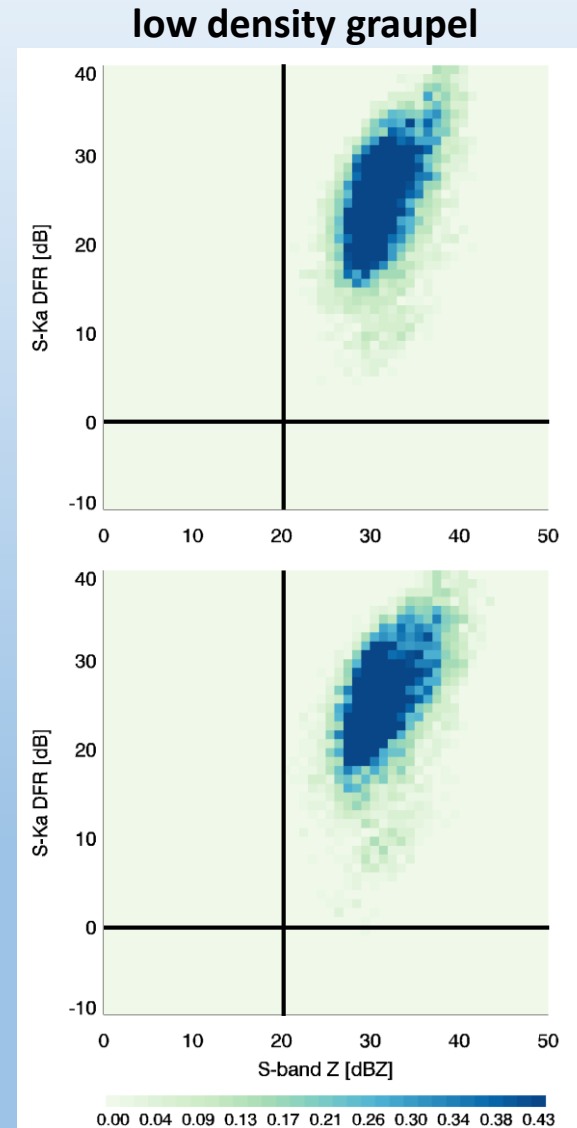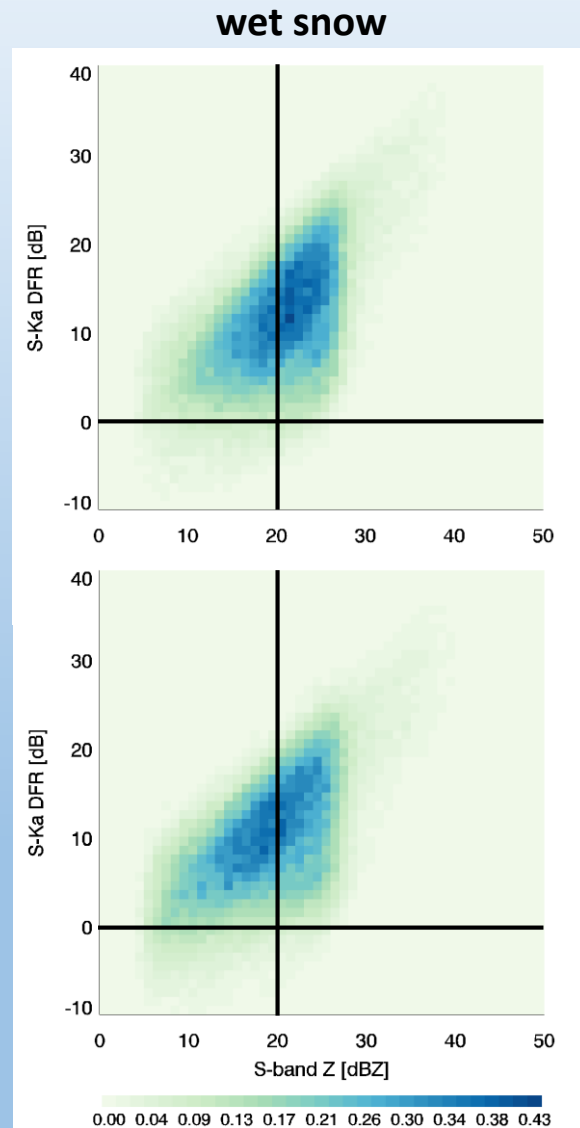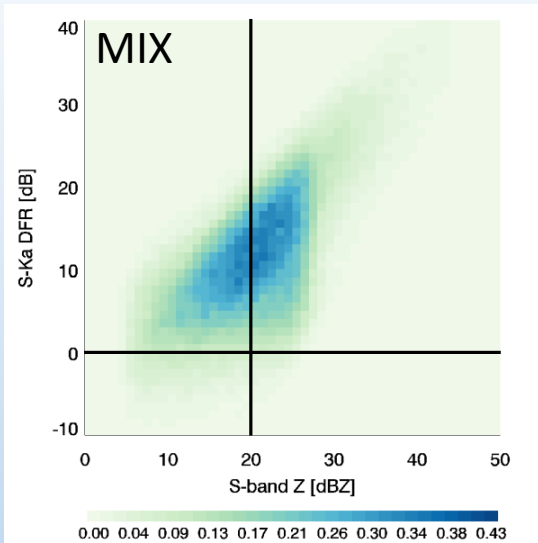
S-Ka: Liquid phase HID type classes

- S-band Z / Rayleigh regime dependence on hydrometeor size evident
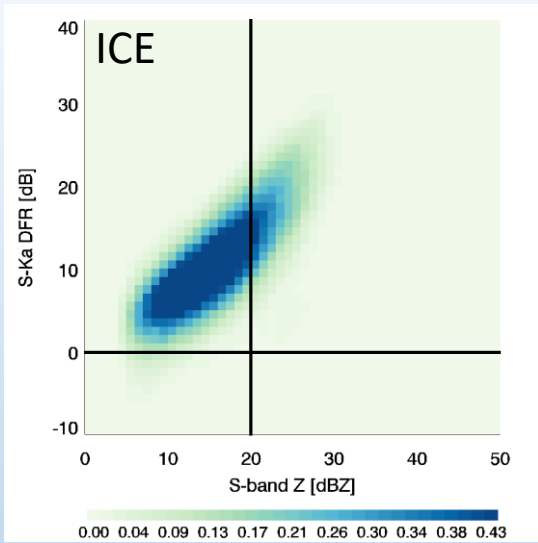
- Almost all DFR$_{S-Ka}$ values **positive**

S-Ka: Mix-phase HID type classes

- Wet snow most varied, **more dispersed over ocean**
- Graupel classes more similar to rain, hail; **more dispersed over land**
- Almost all DFR_{S-Ka} values **positive**

S-Ka: Ice phase HID type classes

ICE

aggregates

ice crystals

vertical ice

LAND

OCEAN

- Aggregates & ice crystals: slightly more compact over ocean

- Vertical ice: similar to other ICE HID type classes

- Modes more consistent (vs. S-Ku)
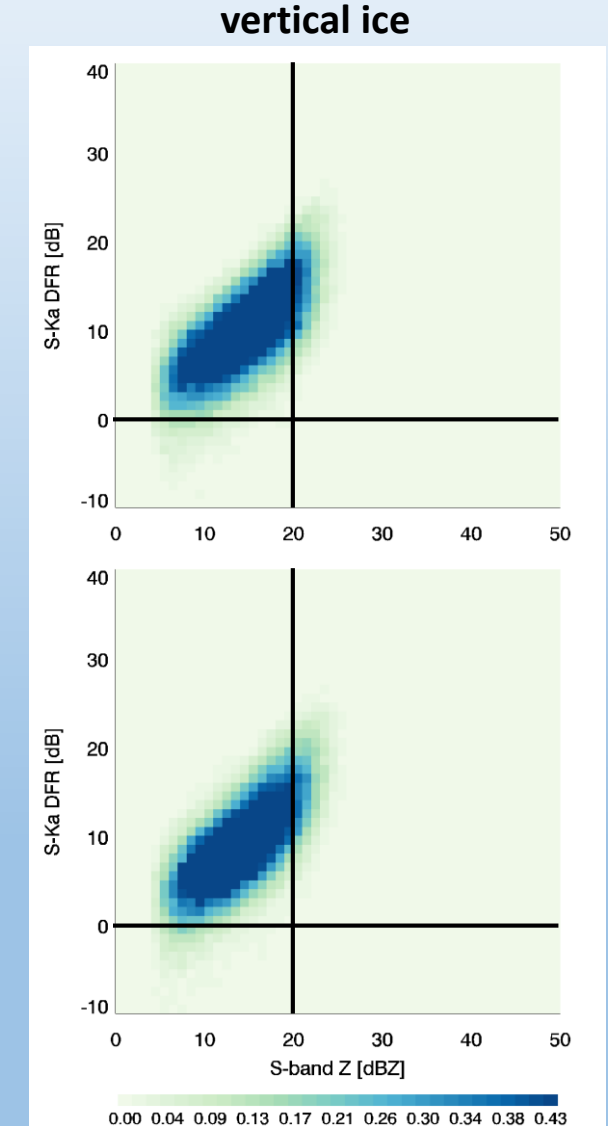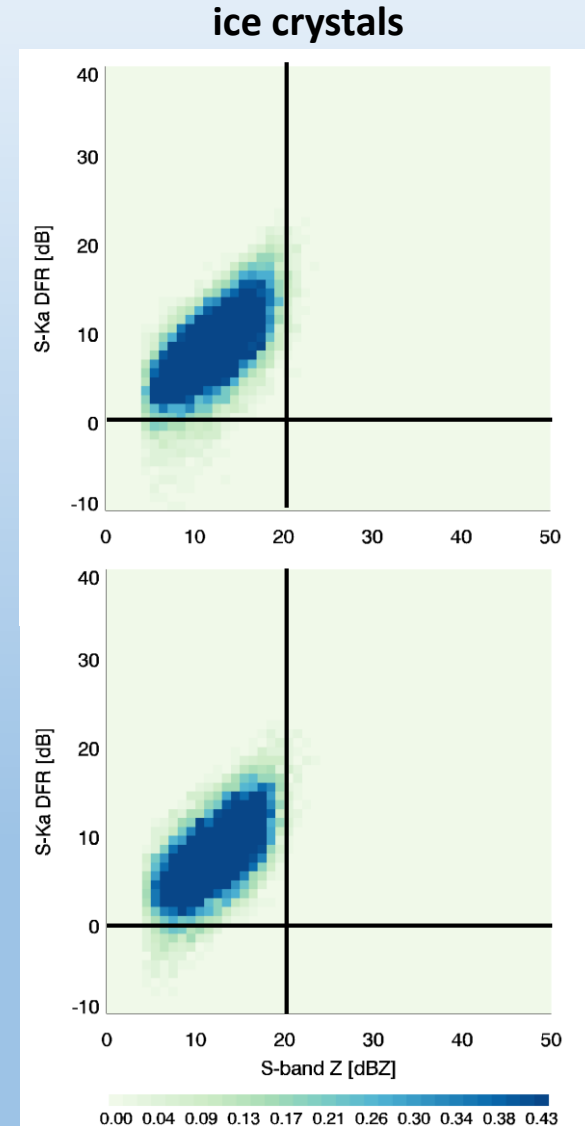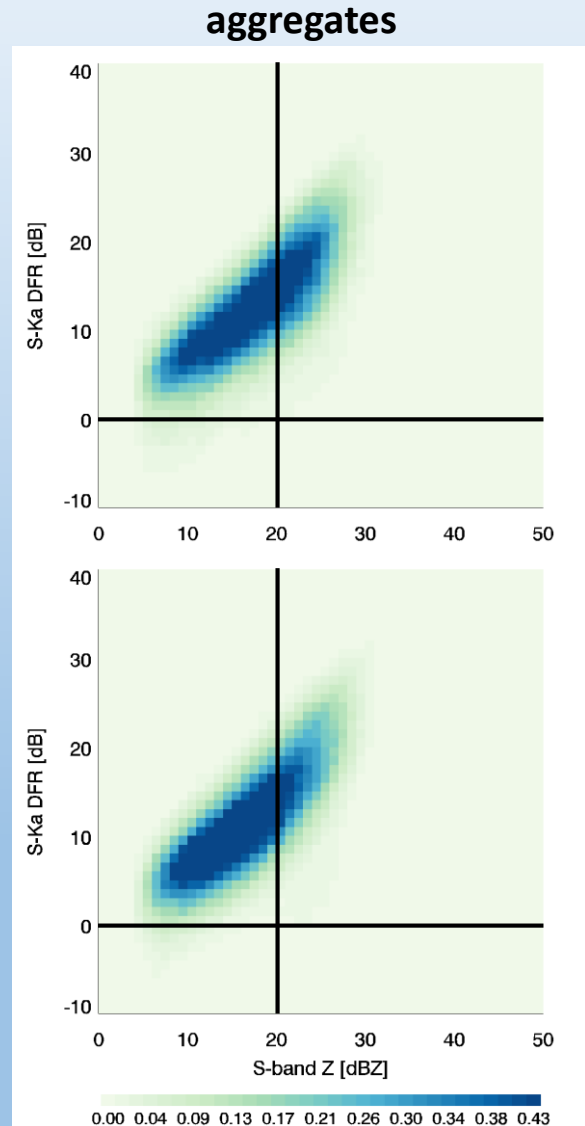
DFR$_{Ku-Ka}$: All HID Types – Distribution Space

DFR$_{Ku-Ka}$ vs Ku-band Z:
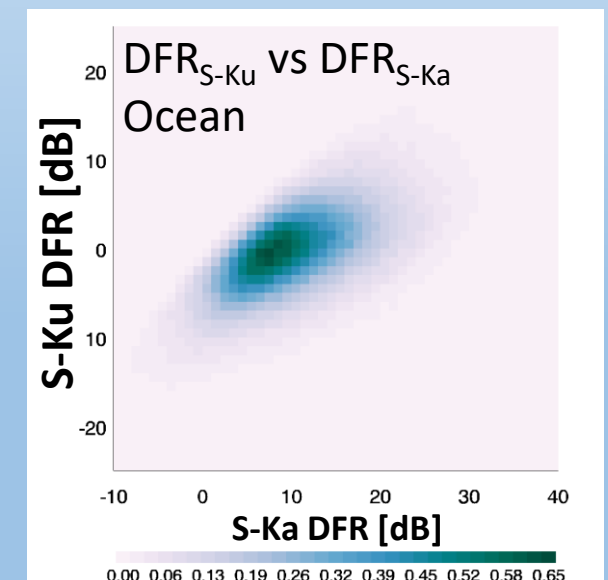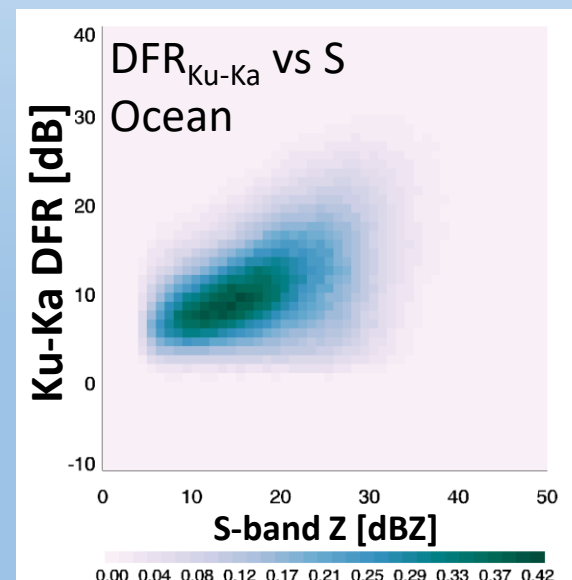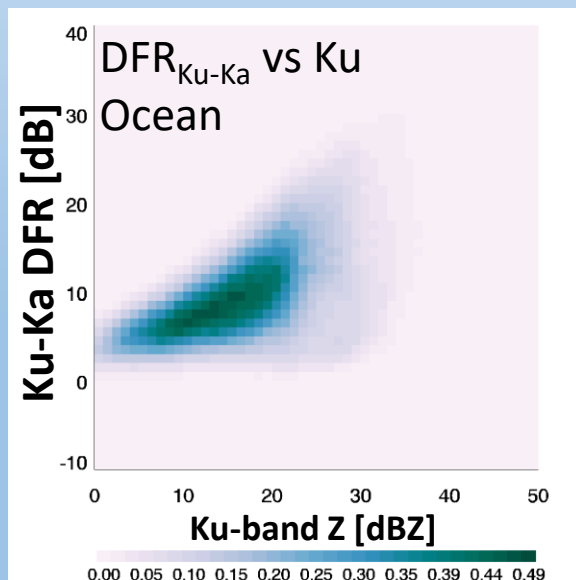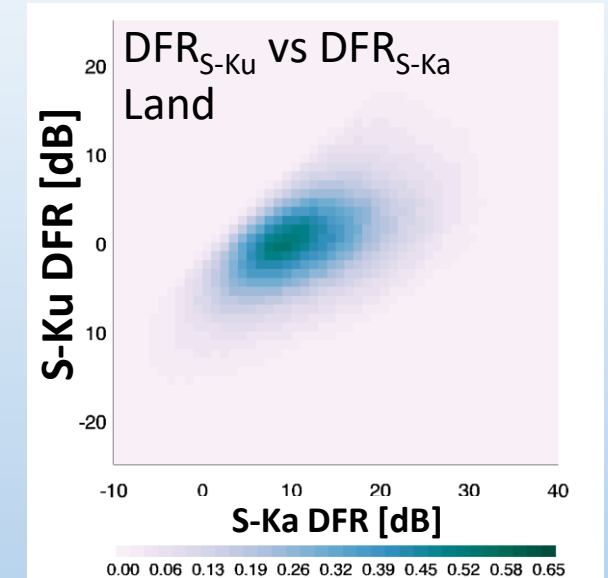- Triangular, almost parabolic shape
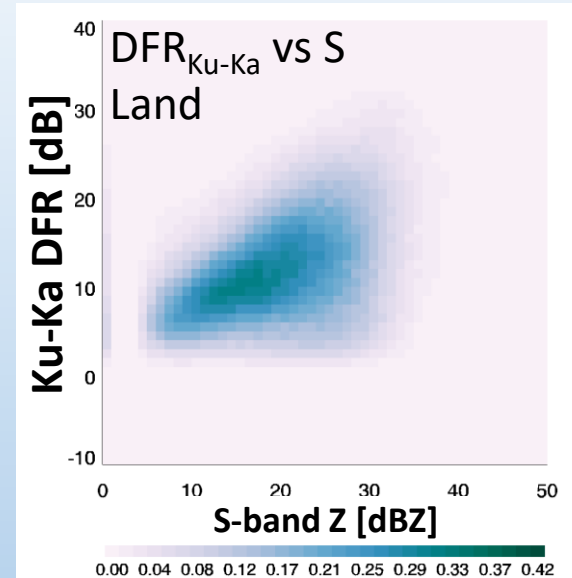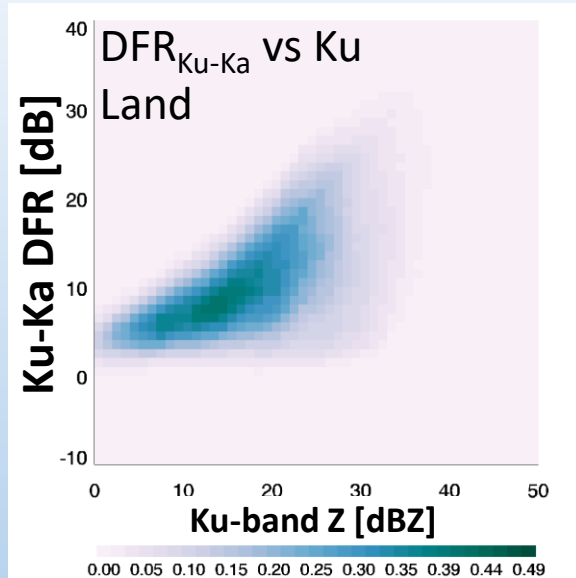
DFR$_{Ku-Ka}$ vs S-band Z:
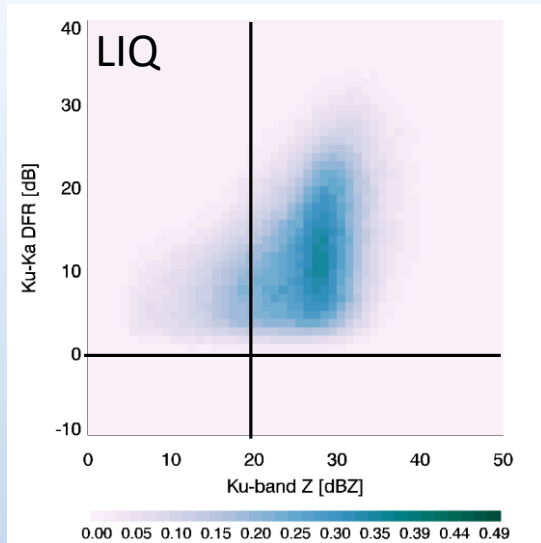- More broad triangular shape

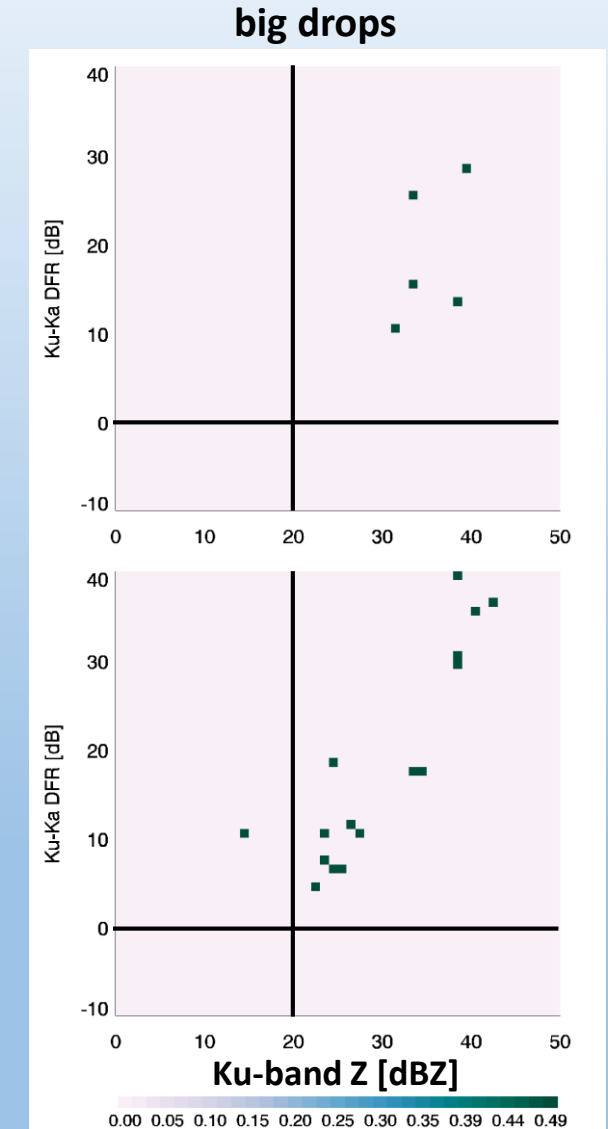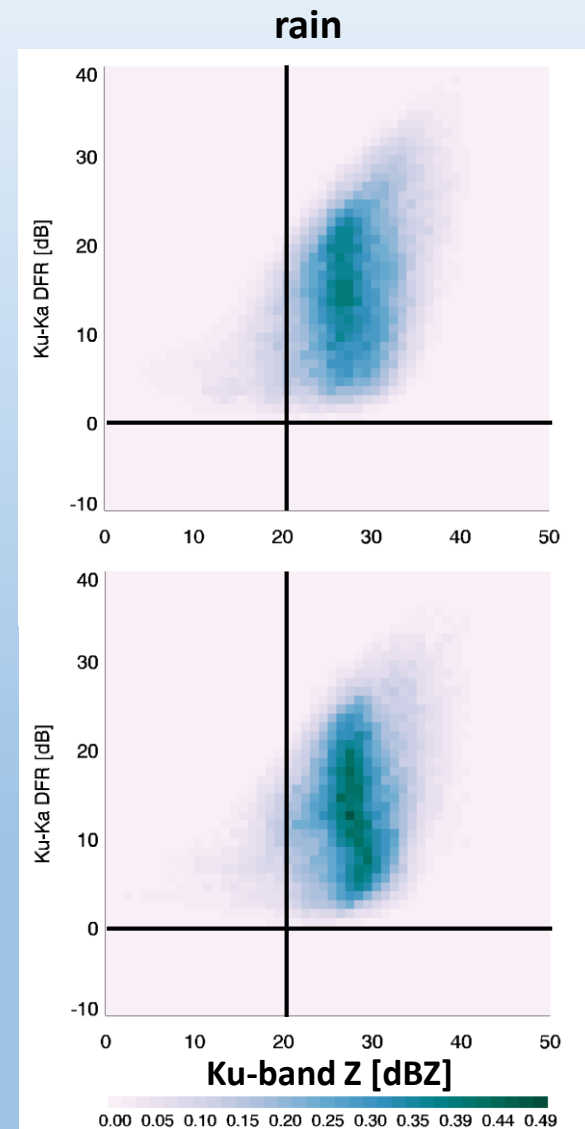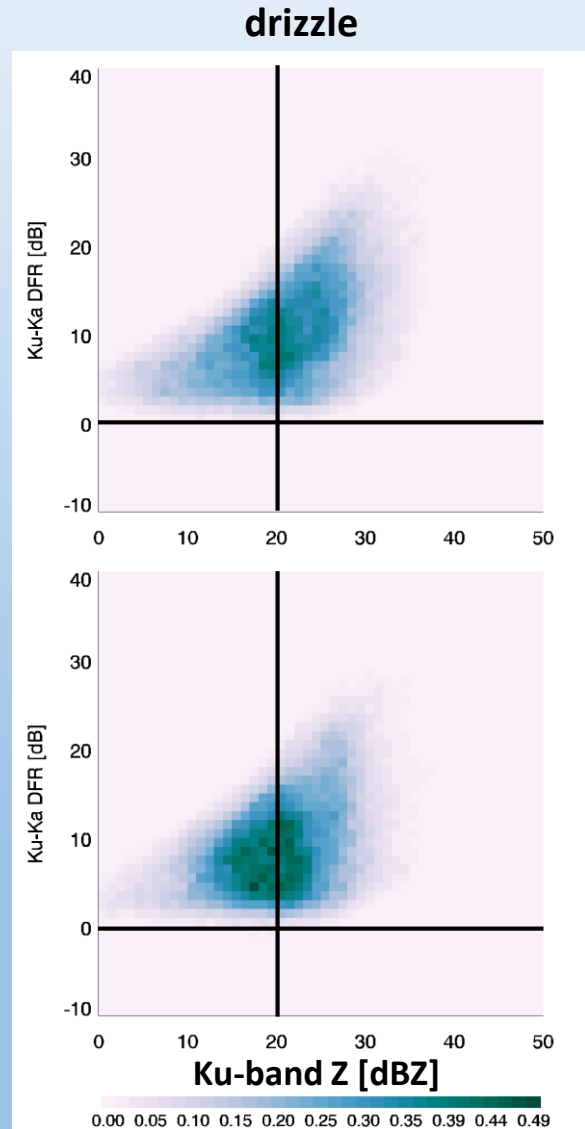DFR$_{S-Ku}$ vs DFR$_{S-Ka}$:
- Most confined distribution

All:
- Ocean distribution more compact than land

Ku-Ka: Liquid phase HID type classes

LIQ

drizzle

rain

big drops

LAND

OCEAN

- No negative DFR$_{Ku-Ka}$ values
- Ocean distributions more compact
- Modes & size separation more pronounced in S-band space

Ku-Ka: Liquid phase HID type classes

LIQ

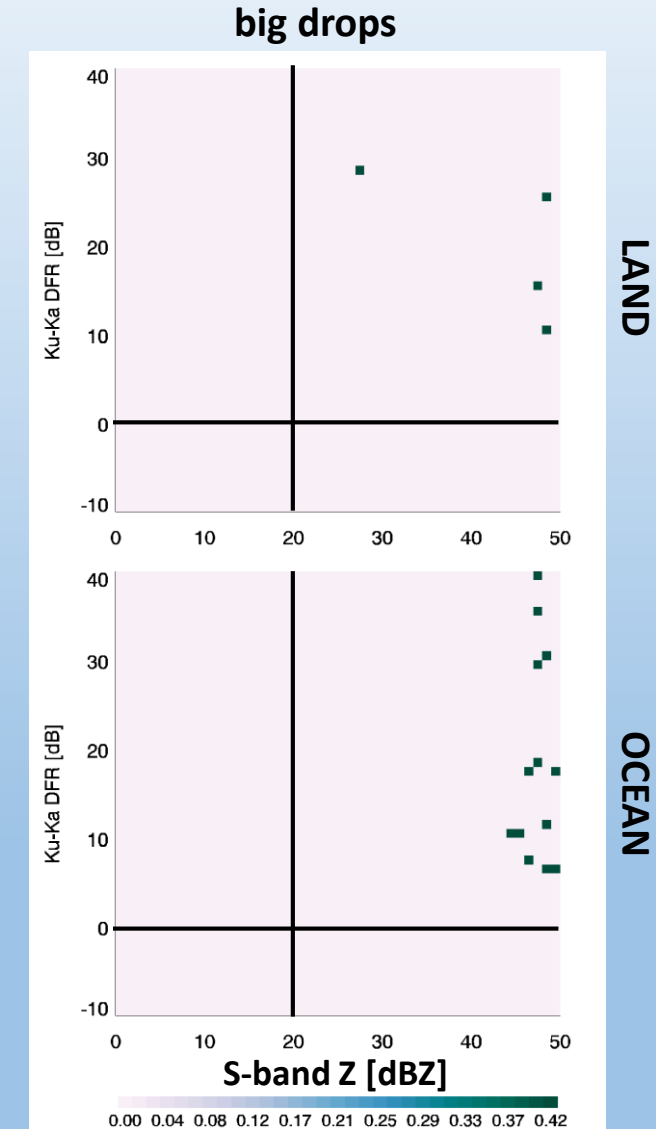**drizzle** **rain** **big drops**

LAND

OCEAN
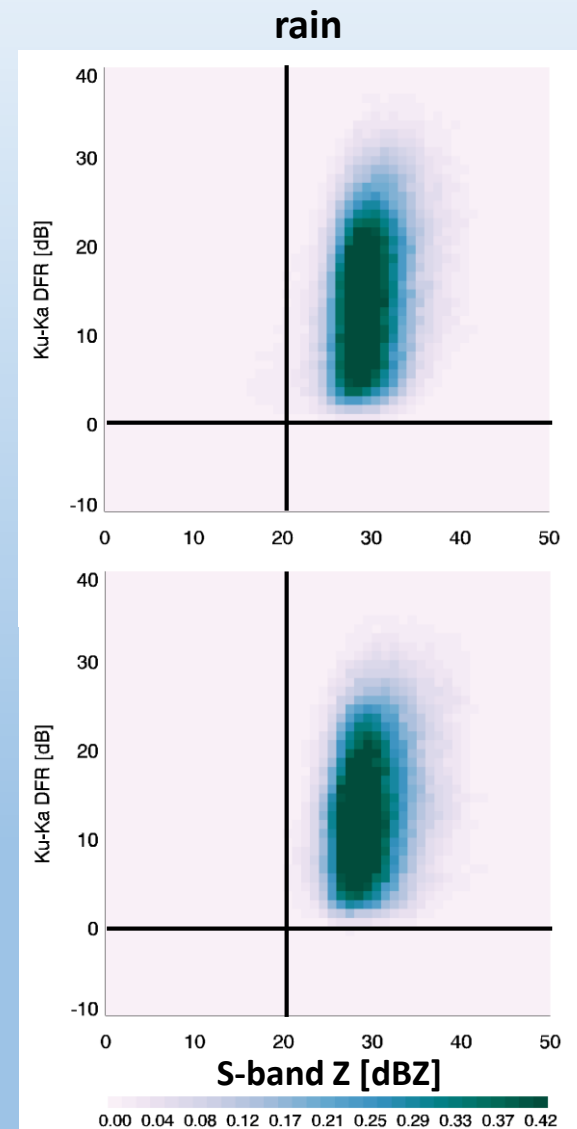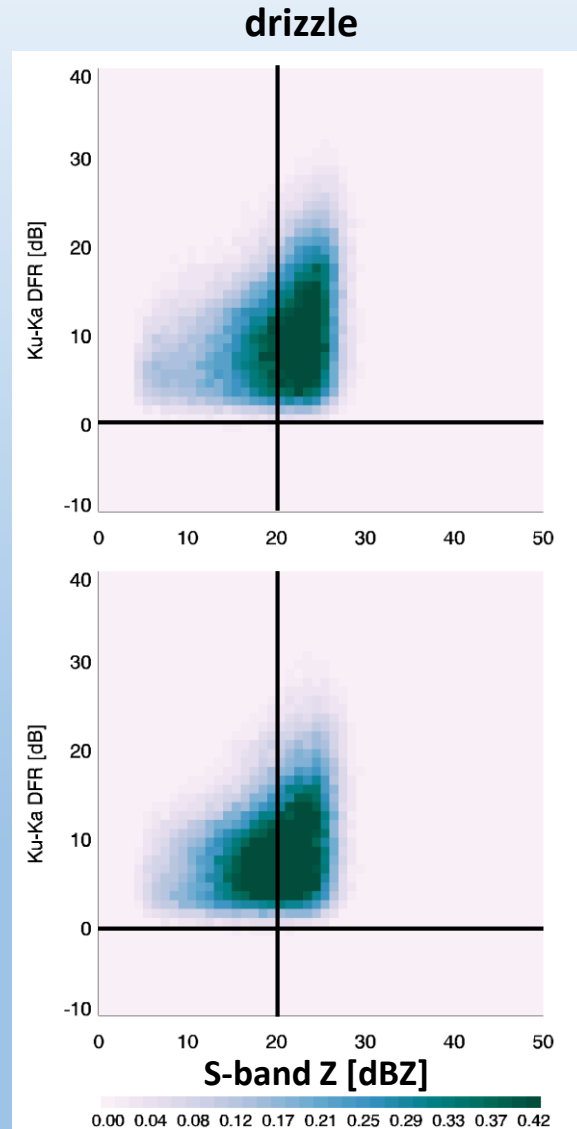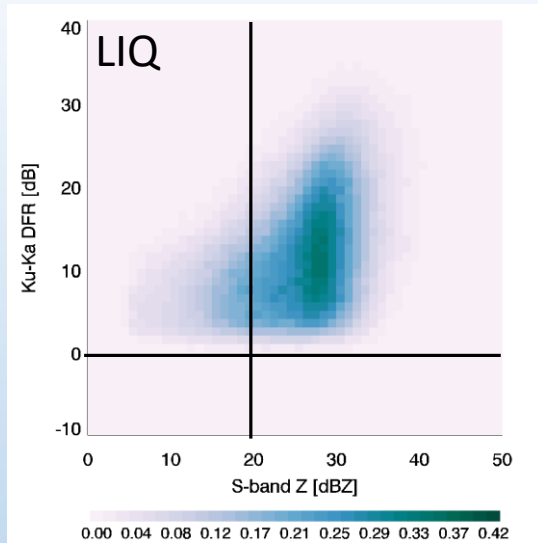
- No negative DFR$_{Ku-Ka}$ values
- Ocean distributions more compact
- Modes & size separation more pronounced in S-band space

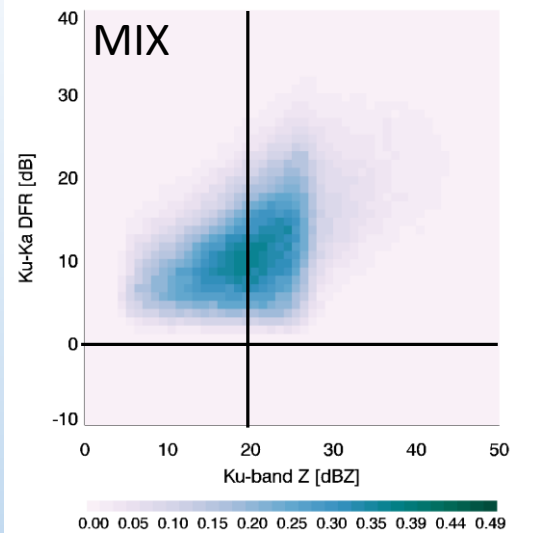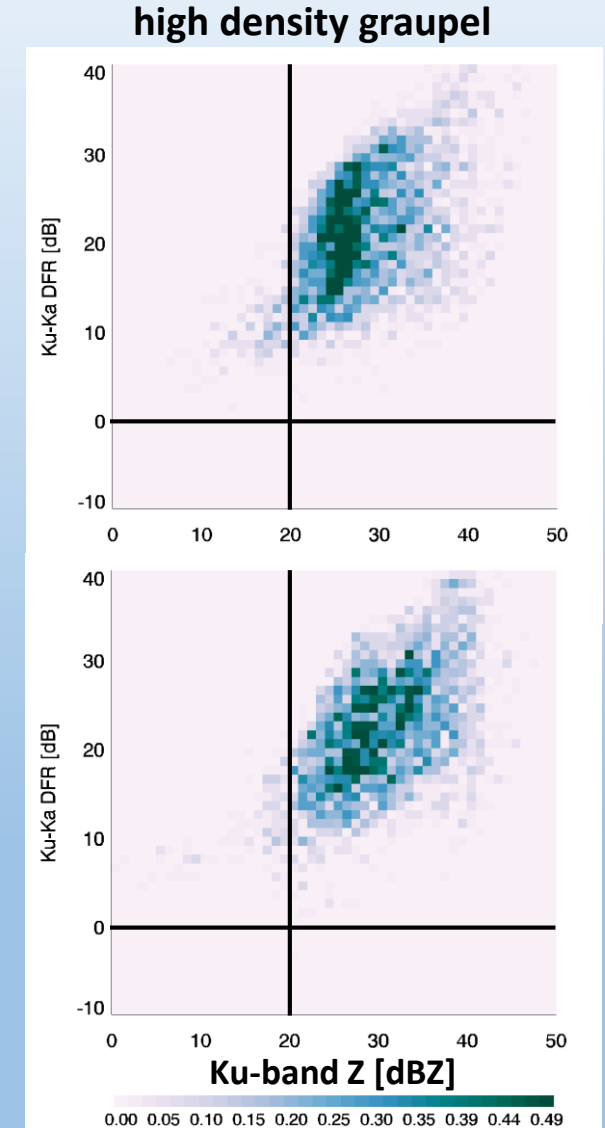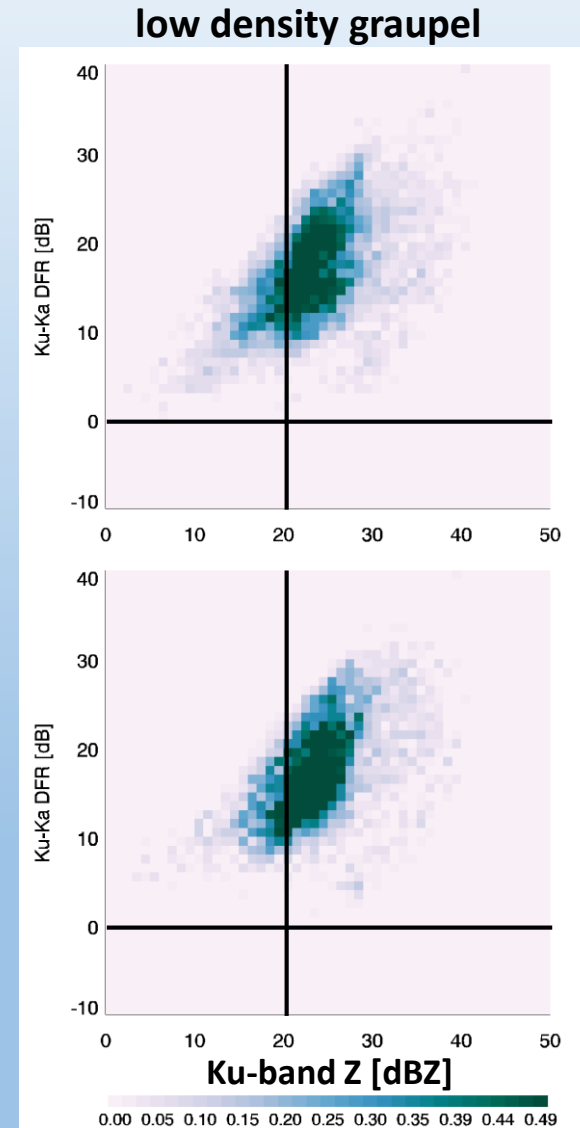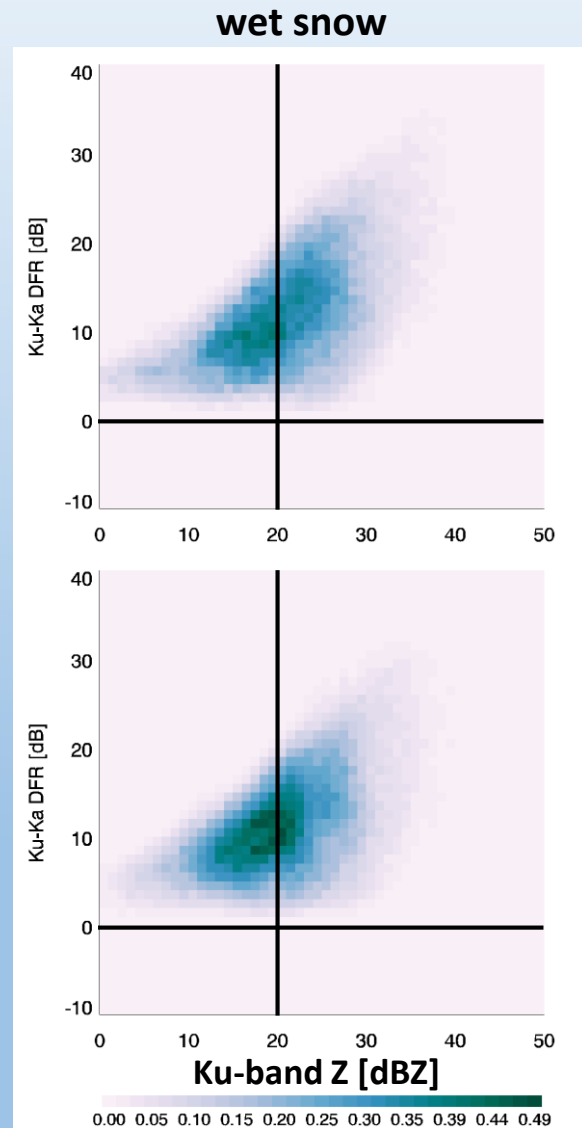# Ku-Ka: Mix-phase HID type classes

- Wet snow: **more compact over ocean**
- Graupel: more compact over land (vs. Ku-band Z)
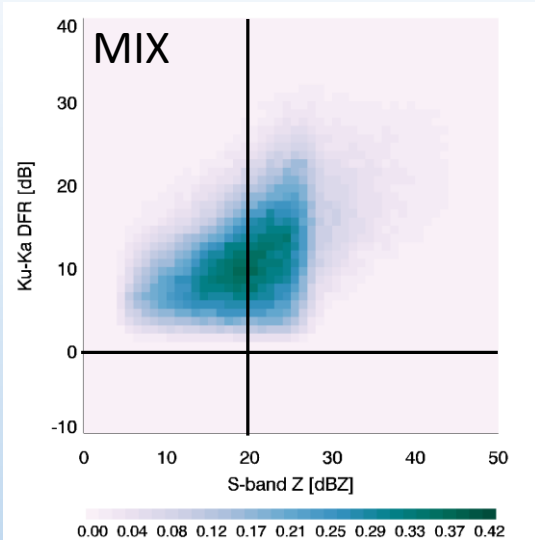- Modes & size separation more pronounced in S-band space

Ku-Ka: Mix-phase HID type classes
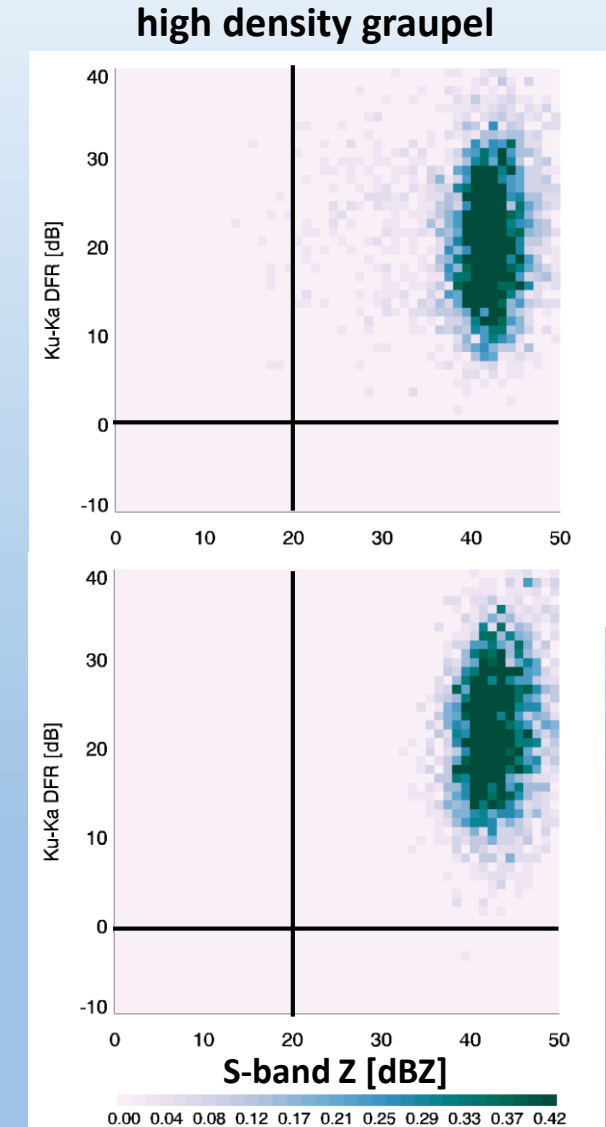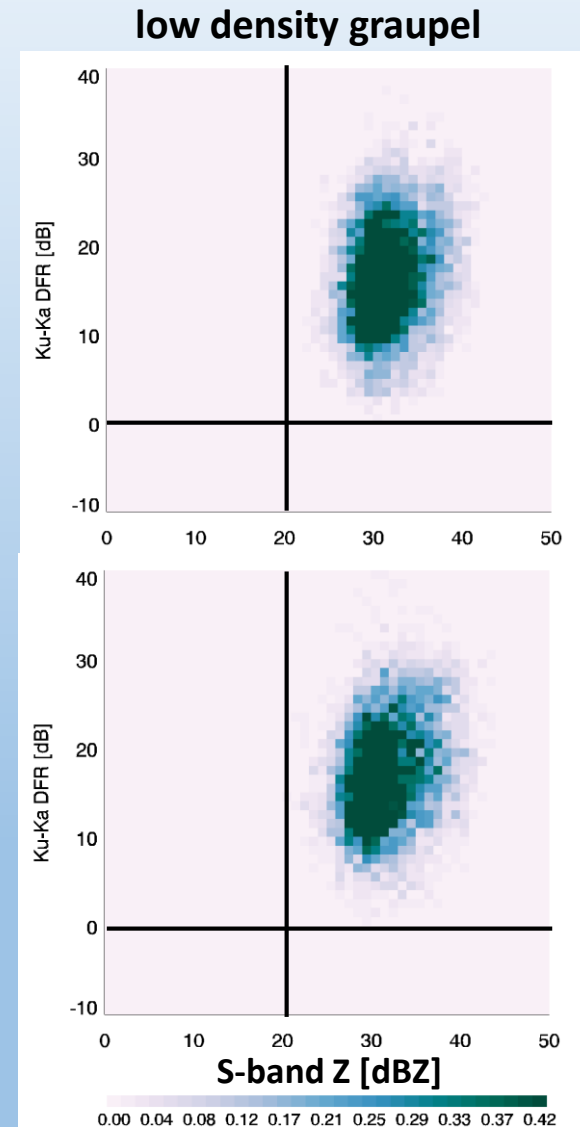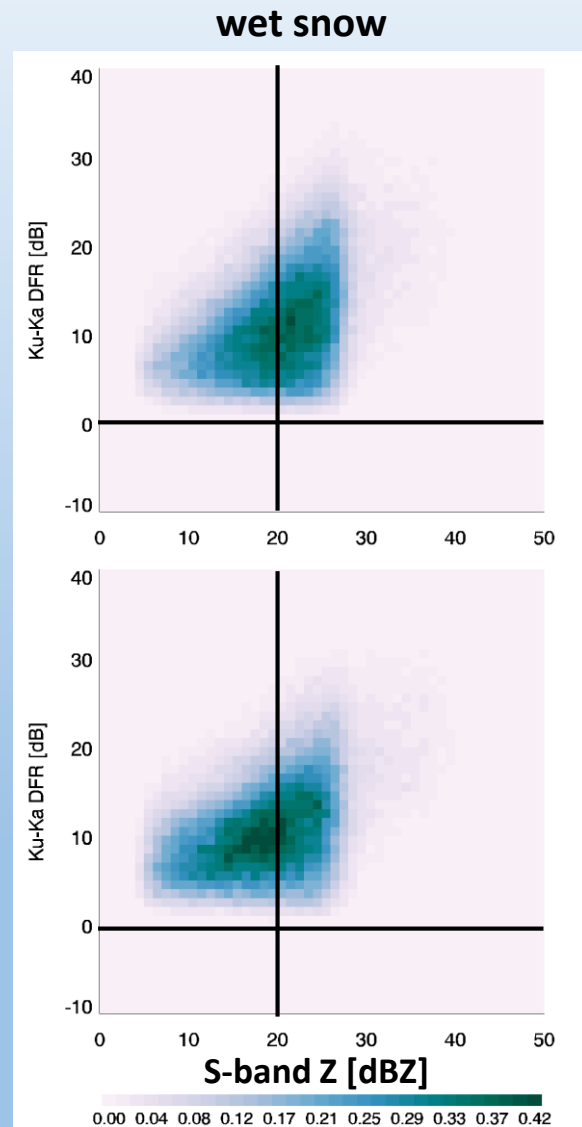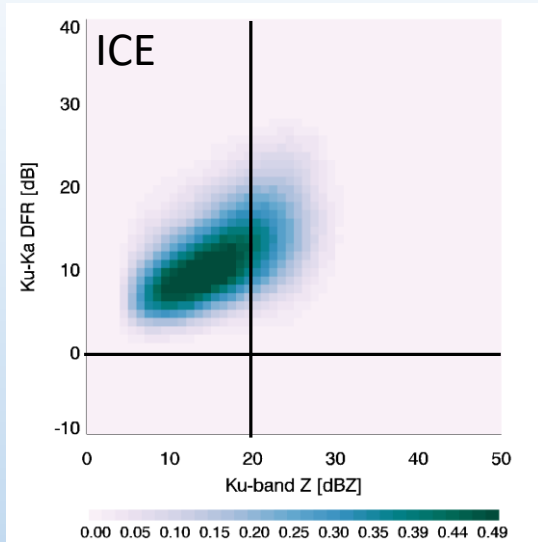

- Wet snow: **more compact over ocean**
- Graupel: more compact over land (vs. Ku-band Z)
- Modes & size separation more pronounced in S-band space

Ku-Ka: Ice phase HID type classes

- Ku-band:
  - more consistent distribution shape among all ice types (but hail – not shown)
- S-band:
  - all ice: slightly broader distributions
  - Size separation more pronounced
  - Less linear

Ku-Ka: Ice phase HID type classes

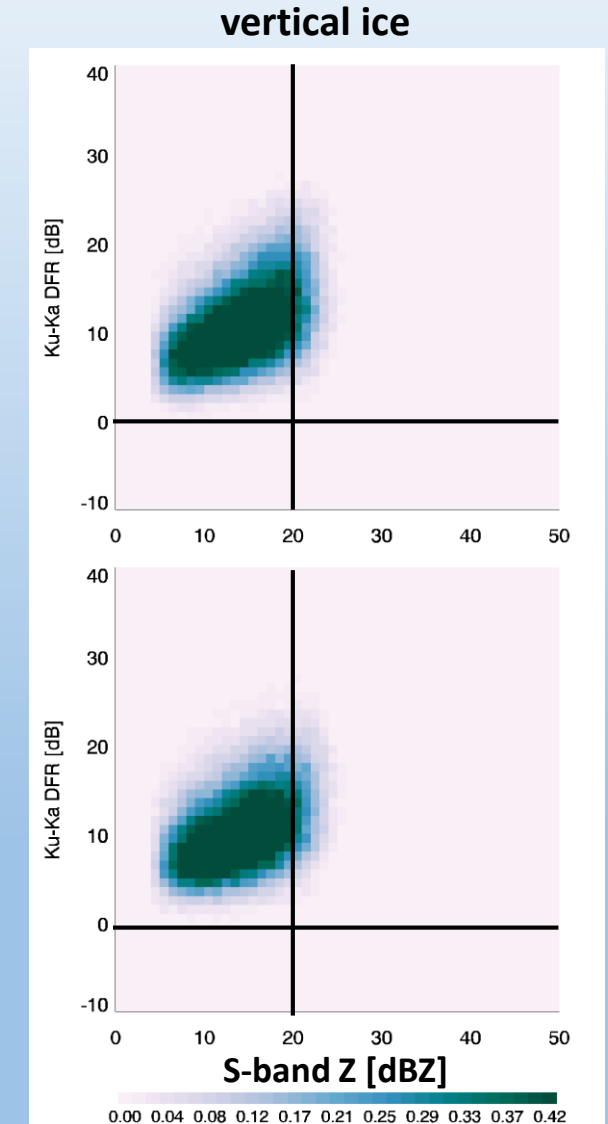**aggregates** — **ice crystals** — **vertical ice**
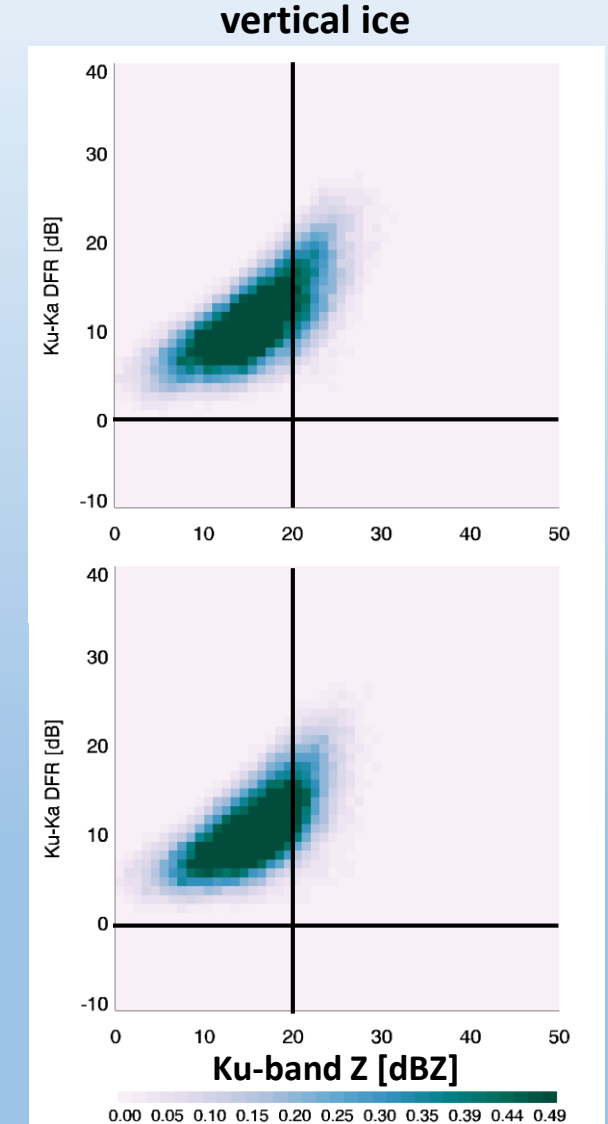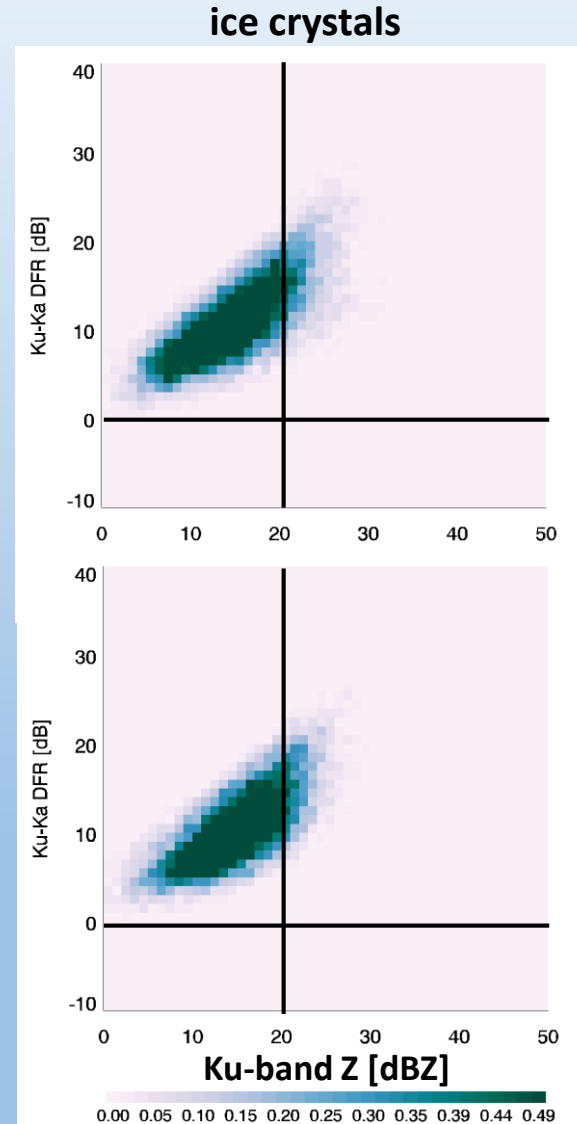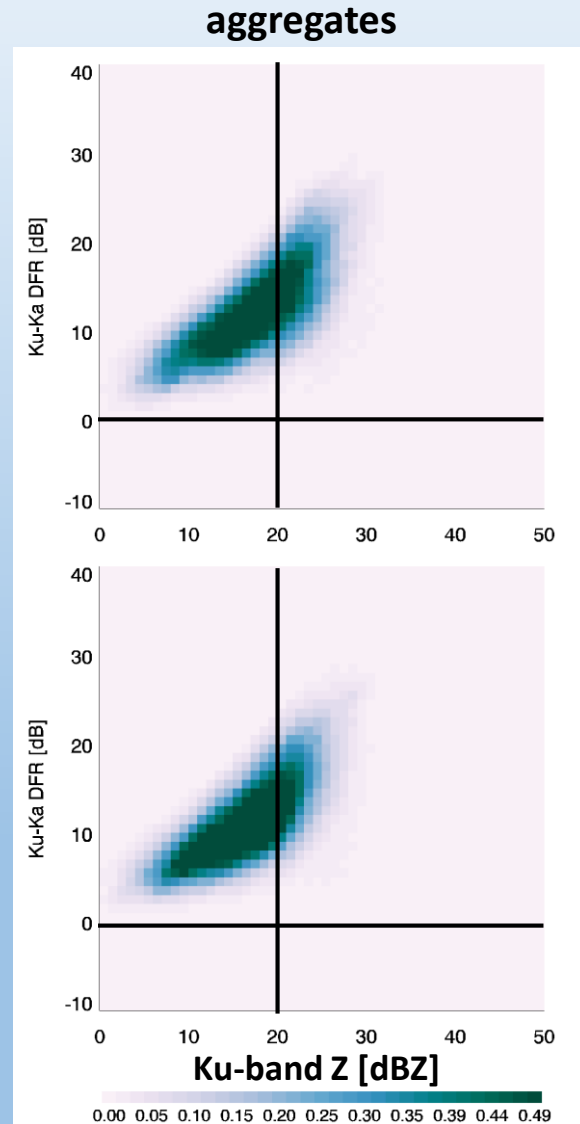
LAND / OCEAN
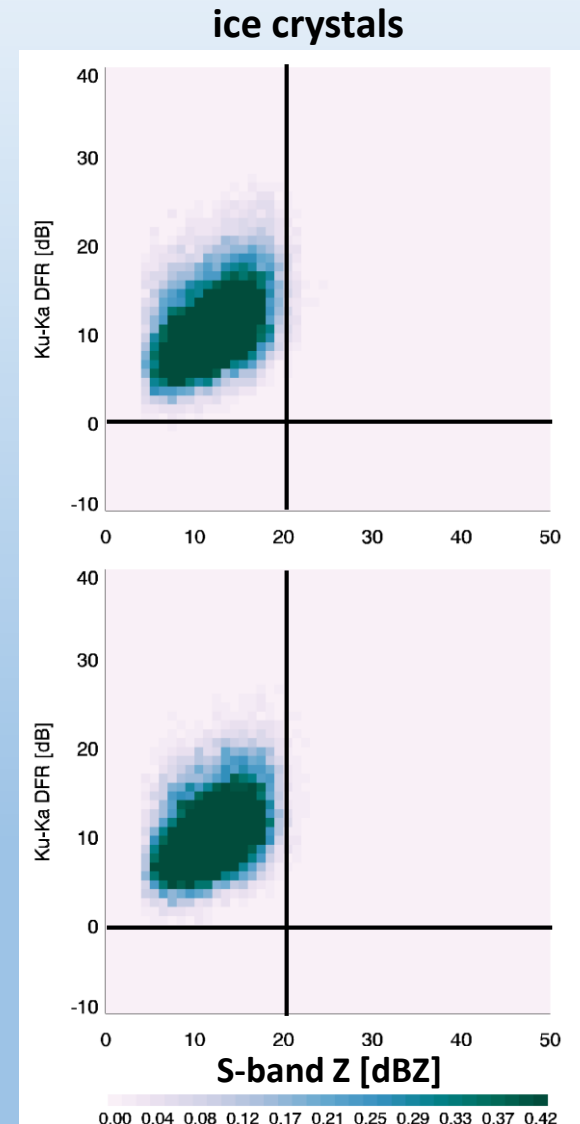
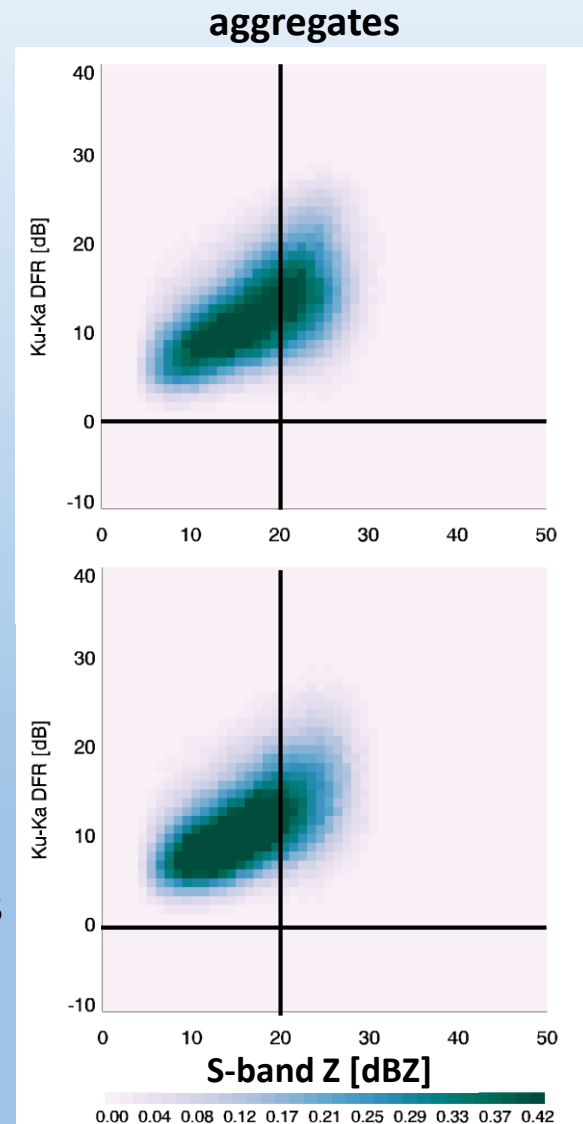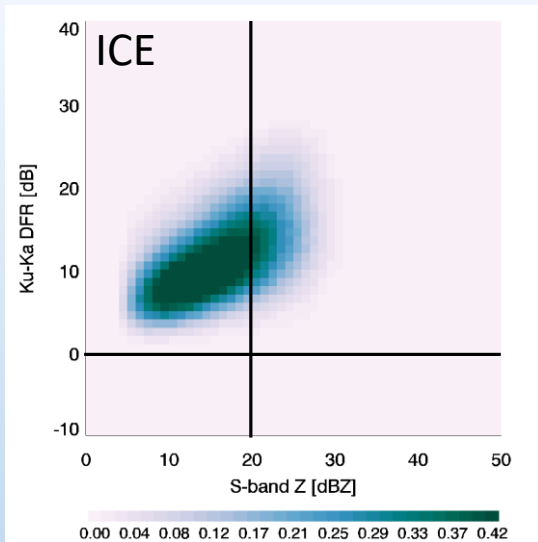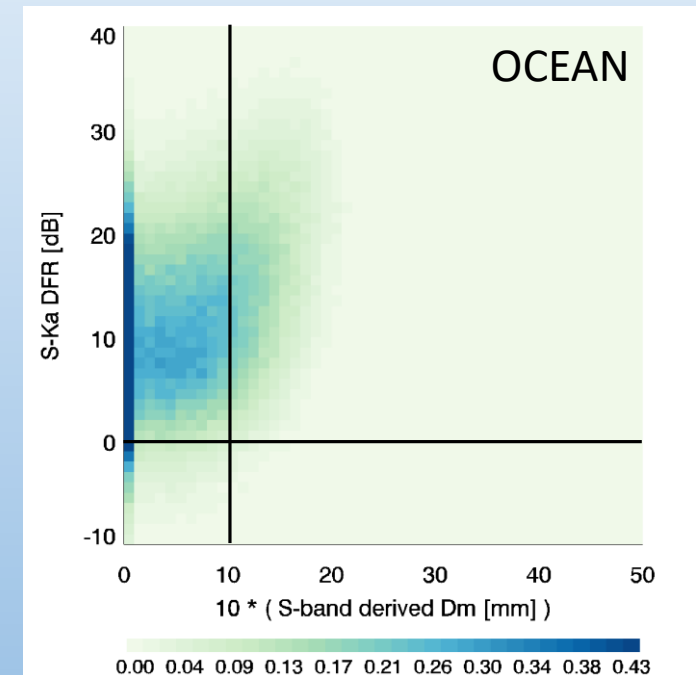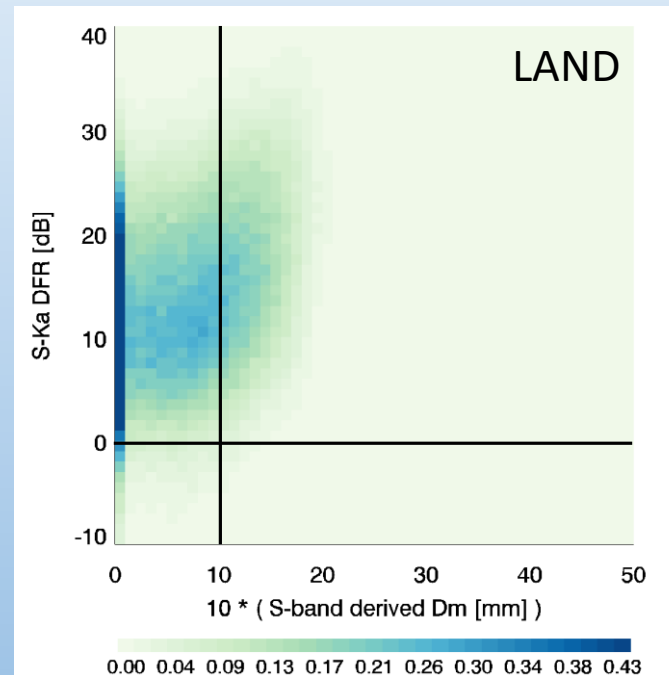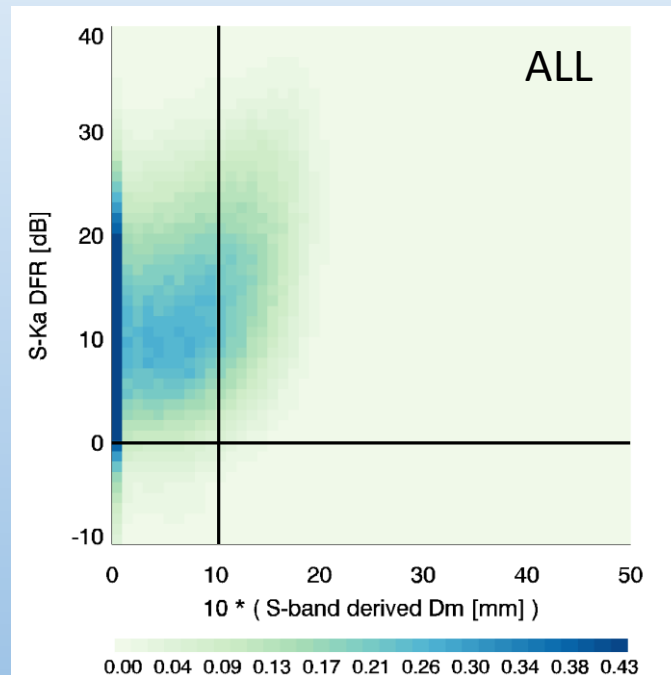- Ku-band:
  - more consistent distribution shape among all ice types (but hail – not shown)
- S-band:
  - all ice: slightly broader distributions
  - Some size separation
  - Less linear

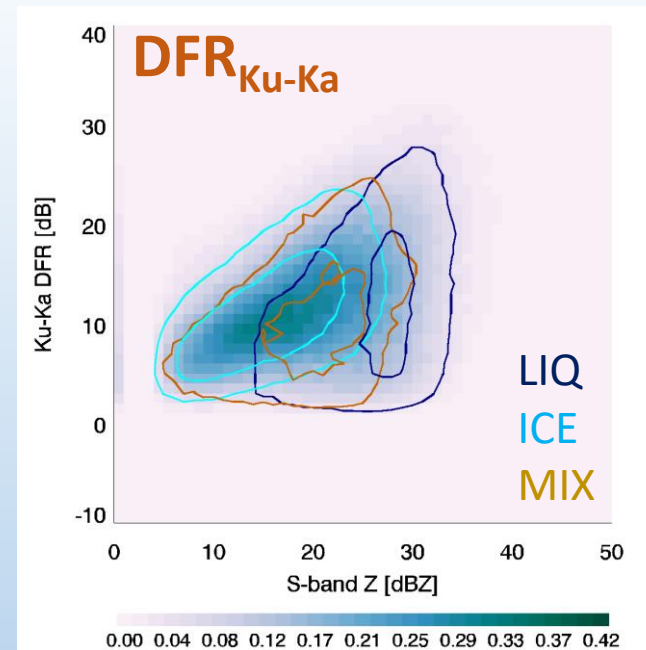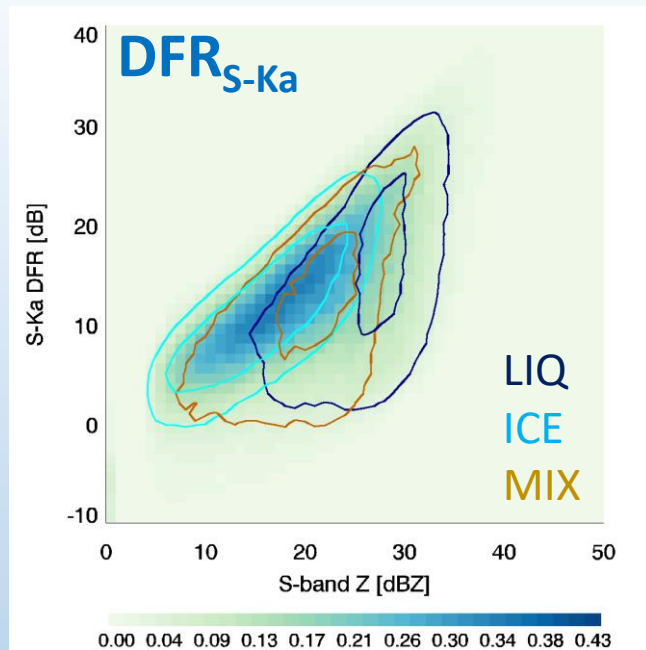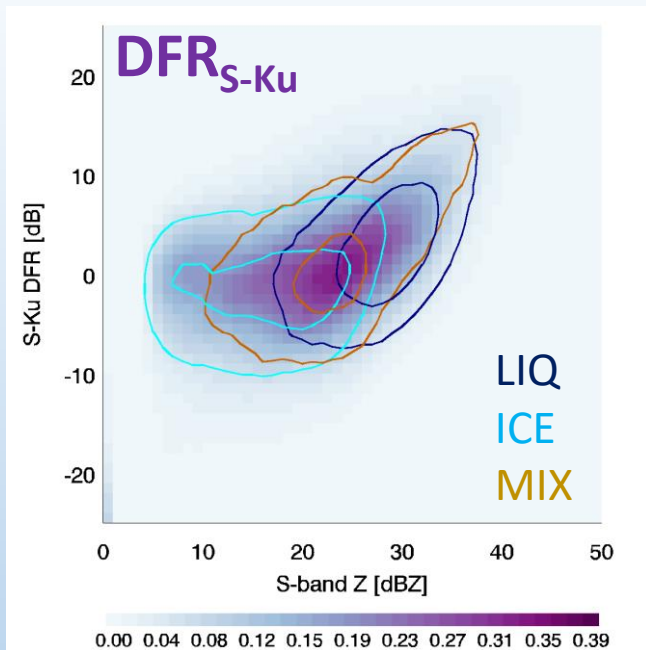# Only LIQ HID Types: DFR_{S-Ka} vs. $10*D_m$

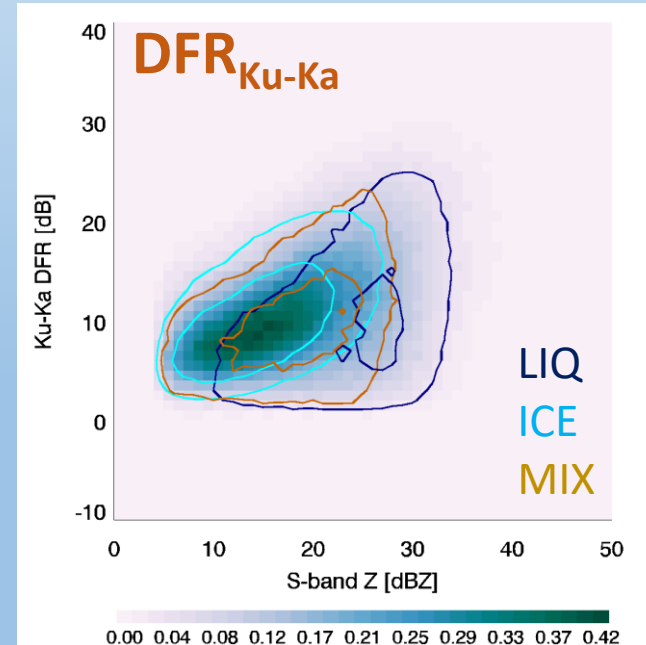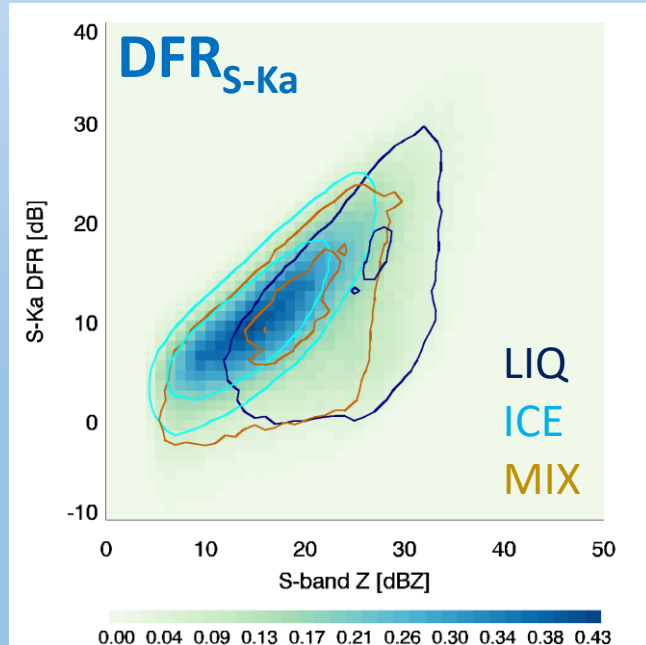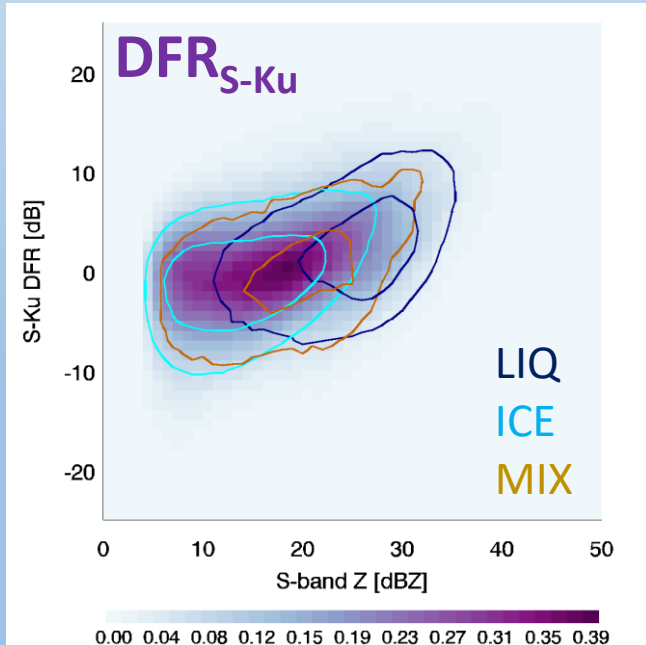- Little trend, somewhat more compact over ocean
- Many very small drops

DFRs All ARs

___

S-Ku
S-Ka
Ku-Ka
(vs. Z_S)

___

- S-Ku DFR has largest LIQ and ICE overlap
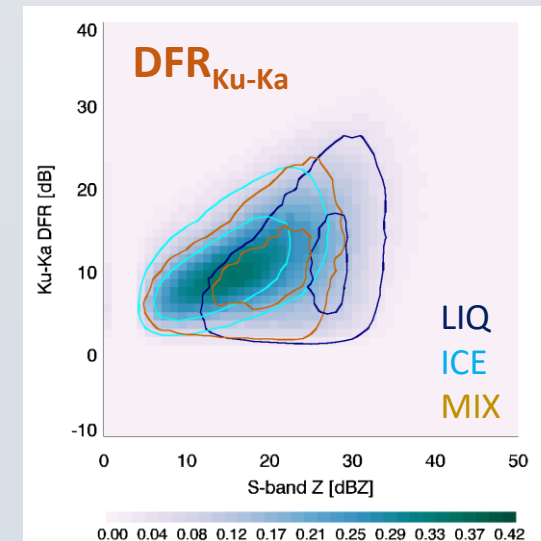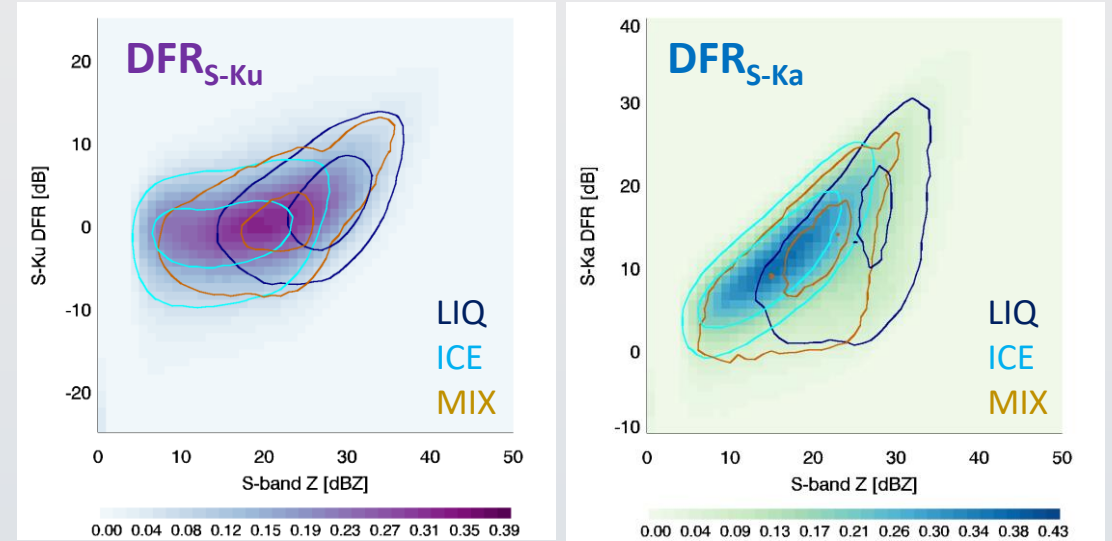- MIX overlaps in all 3 spaces
- Ocean regime is slightly more compact

*Histograms include all HID phases

*Contours at densities of 0.1, 0.3 for each HID phase

Land Scans

Ocean Scans

Summary

- OLYMPEX AR composite RHIs show enhancement as approach terrain, mean flow orientation control

- *DFR layering* consistent with terrain complexity
  - Magnitude of terrain-normal flow influences DFR enhancement location, severity

- DFR_{S-Ka} *shows most difference among HID phases*

- DFR_{Ku-Ka} *vs S-band Z* gives most space for comparing individual HID type classes

- Ocean DFR distributions in general are slightly more compact
  - Indicates more complex processes over land
  - But there are exceptions: wet snow (S-Ku, S-Ka), graupel (Ku-Ka vs. Ku-band Z)

- Inexact beam matching

- *Implications for future spaceborne radar concepts*

*Histograms include all HID phases
*Contours at densities of 0.1, 0.3 for each HID phase

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