Atmospheric River Precipitation Characteristics Revealed by NASA GPM Ground Validation Observations in Complex Terrain

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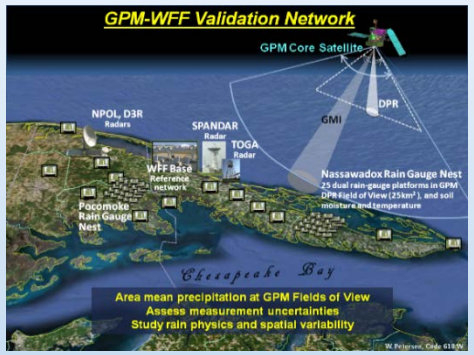
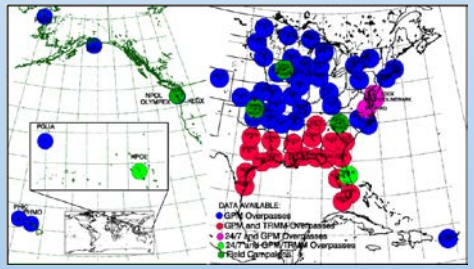
Image: Stacy Brodzik

Motivation

- GPM GV Observation Diversity
  - Core Observatory
  - Constellation Partners
  - Field Campaigns
    - Ground-based
    - Airborne





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

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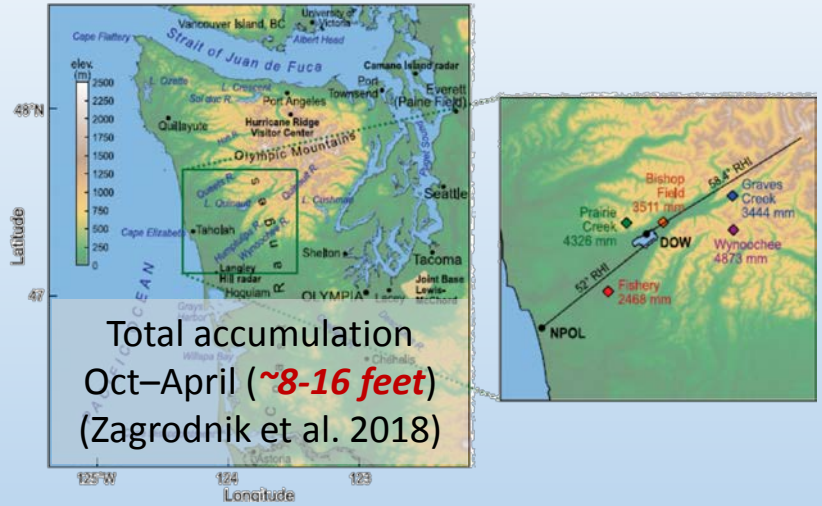

Total accumulation Oct–April (***~8-16 feet***) (Zagrodnik et al. 2018)

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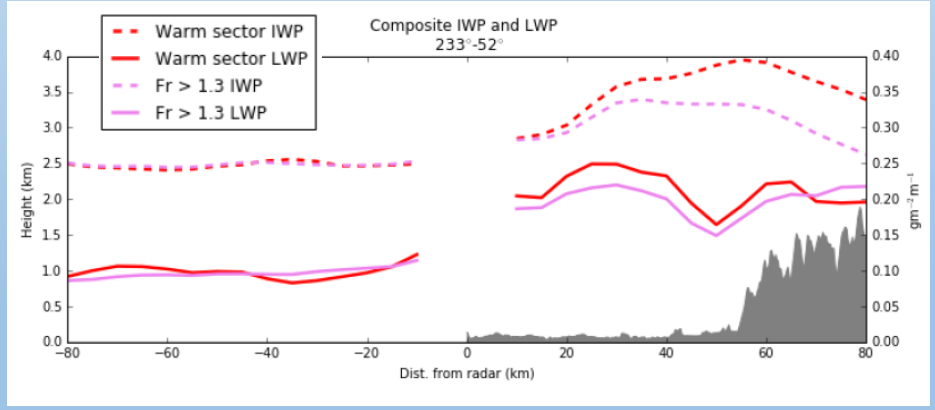


Land/topo **impact ice/liquid** precipitation processes – **unblocked/large Froude and warm sector** flow regimes (Hunzinger 2018/Petersen et al. 2018)

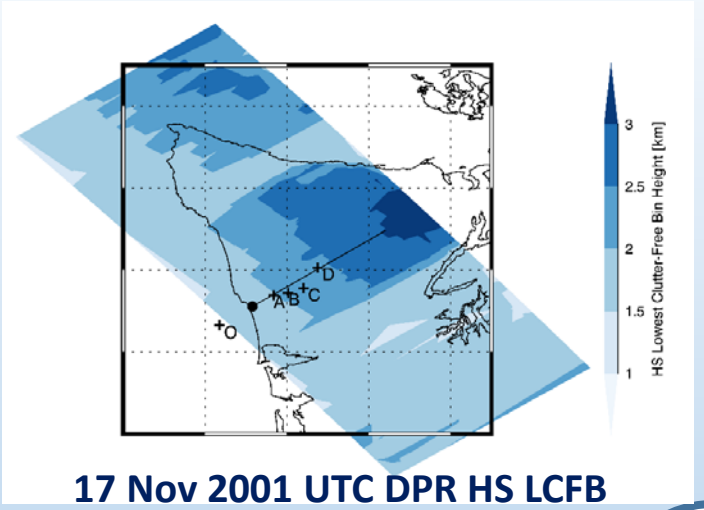
Methodology

Case Criteria

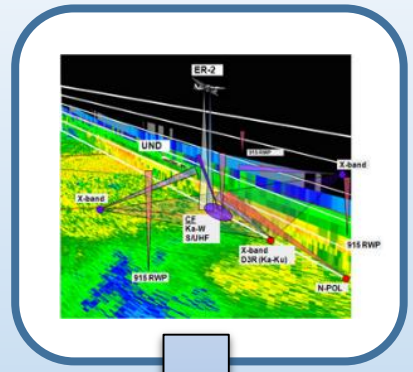
- ARs with unblocked terrain-normal component flow: WS, Fr > 1.3
  (Hunzinger 2018/Petersen et al. 2018)
- 6 AR cases, 8 GPM OPs
  - 13 Nov 03-00 UTC (20%)
  - **17 Nov 10-21UTC (10%)**
  - **3 Dec 14-00 UTC (10%)**
  - 6-7 Dec 00-02 UTC (25%)
  - 8-9 Dec 13-10 UTC (20%)
  - 17 Dec 08-00 UTC (15%)

SIMBA Column Analysis

- 6 locations: sea and up terrain gradient; at key field sites along valley RHI azimuth
- 500 x 500 x 250m spacing, 10 min



17 Nov 2001 UTC DPR HS LCFB



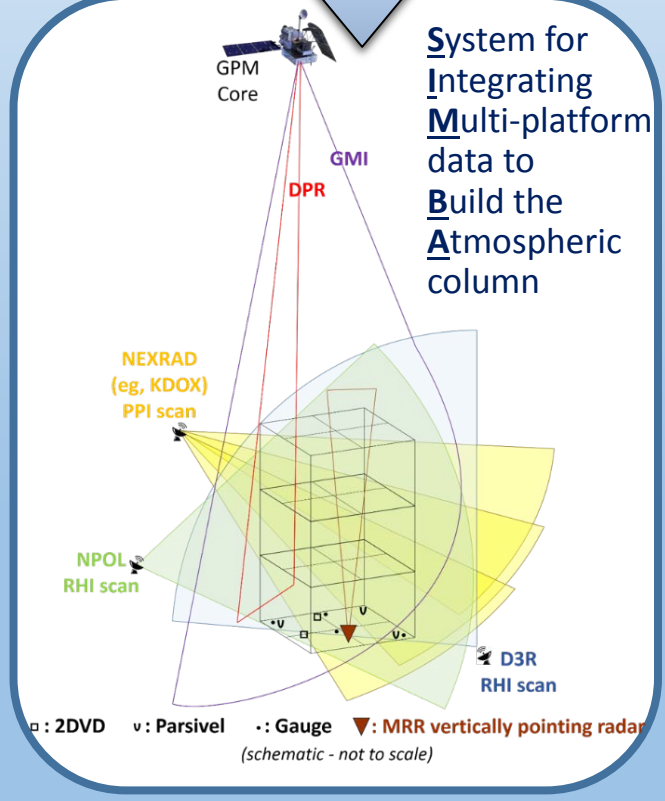
Define Column: grid center location, horizontal and vertical extent, spacing

Platform-specific Modules: read in native data formats, process gridding and/or interpolation as needed to set coincident observations into single, 3D column grid

SIMBA Column Data File: Write all available observations to a **common 3D grid in NetCDF** format. Attributes maintain key properties of original data (exact locations, operation modes, algorithm versions, etc.)

(Wingo et al. 2018)

System for **I**ntegrating **M**ulti-platform data to **B**uild the **A**tmospheric column



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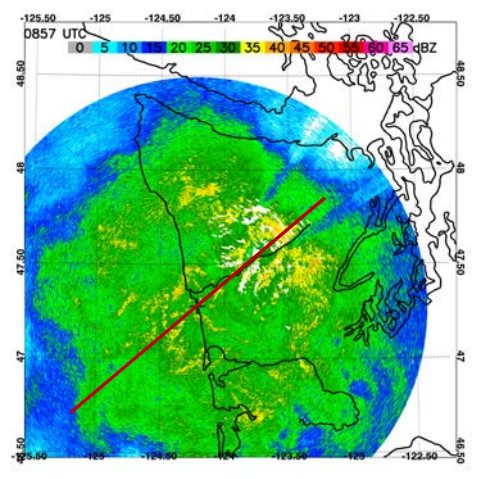
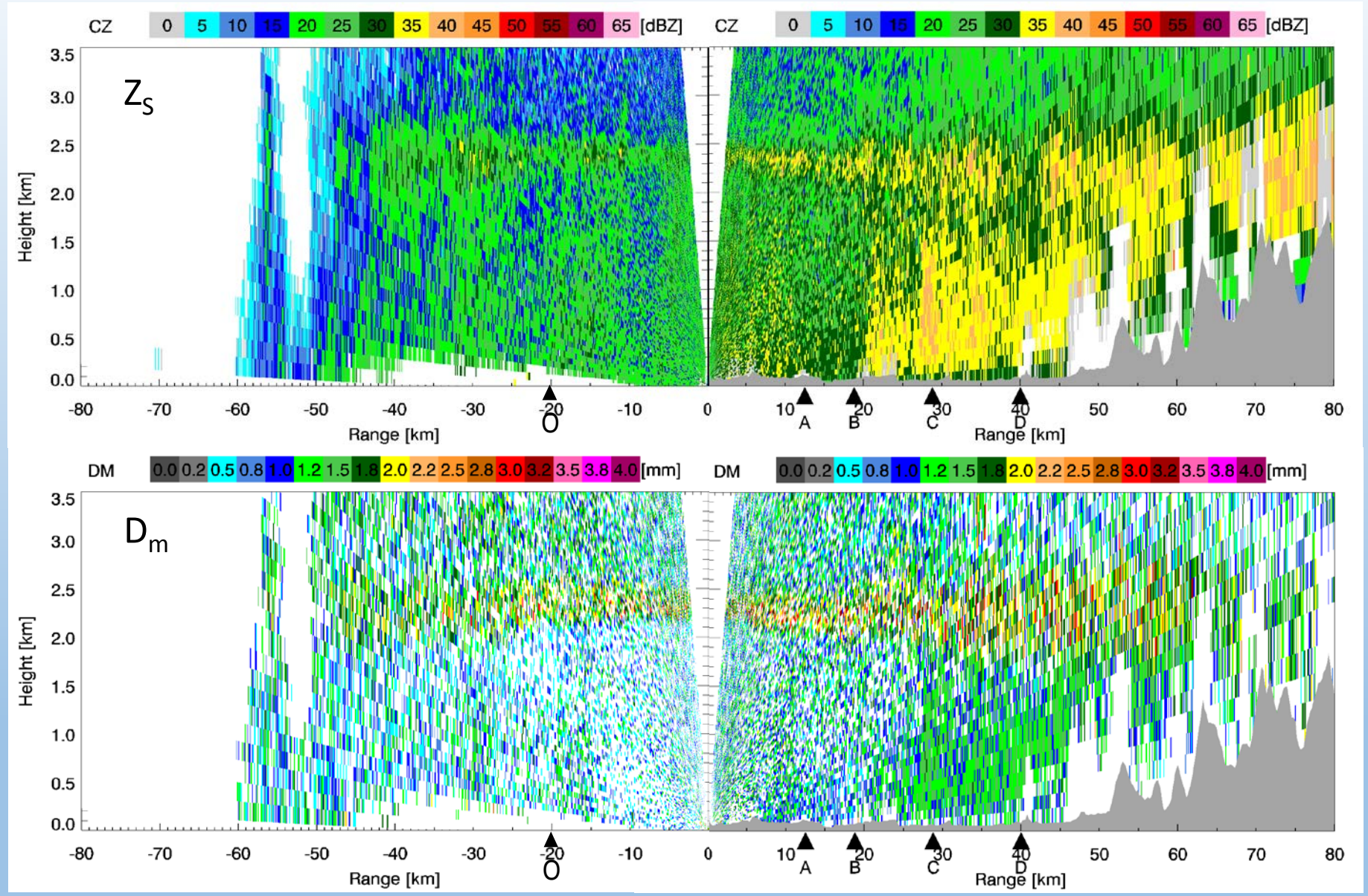
Vertical Slice Composites

- NPOL (S-band)
  - Z, D_m, RR
- **Dual-frequency ratios:**
  - NPOL with 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

Composites over all ARs

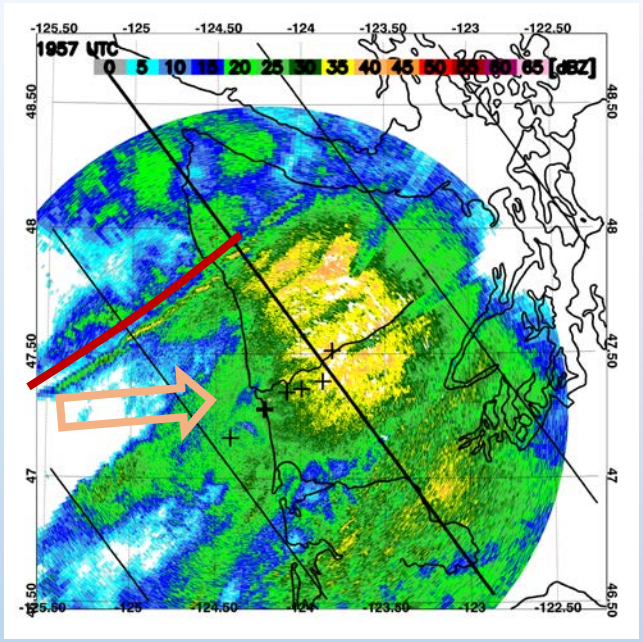


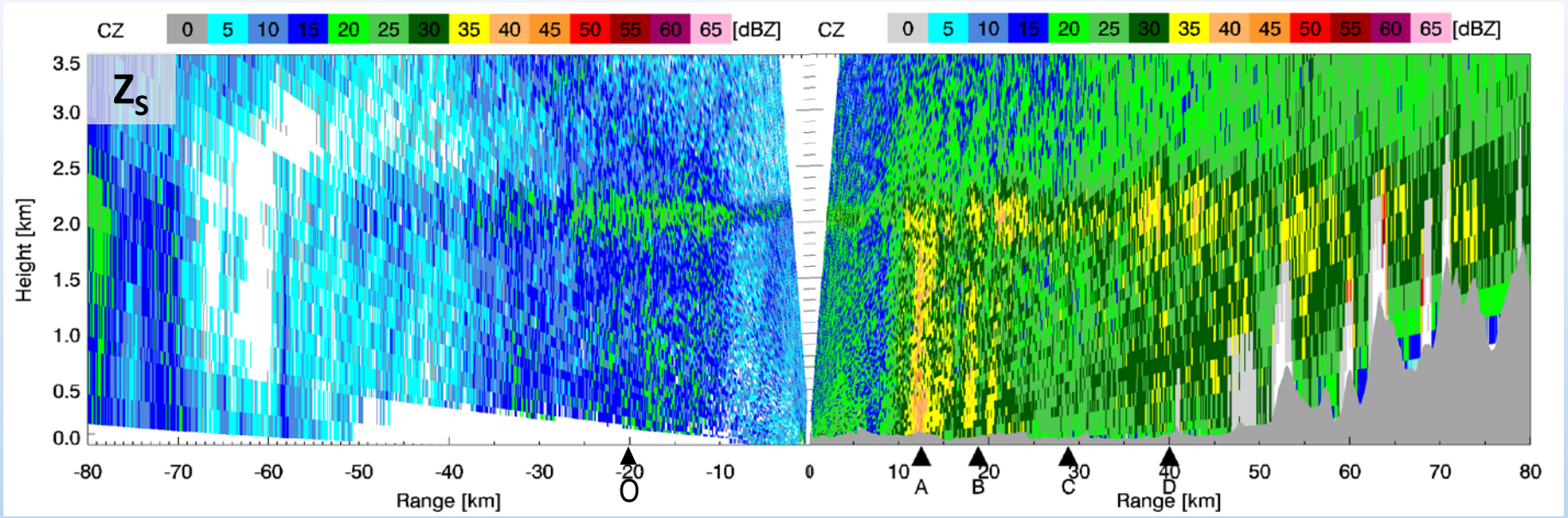
- Along NPOL RHI approaching, through Quinault River Valley
- Terrain, orographic enhancements

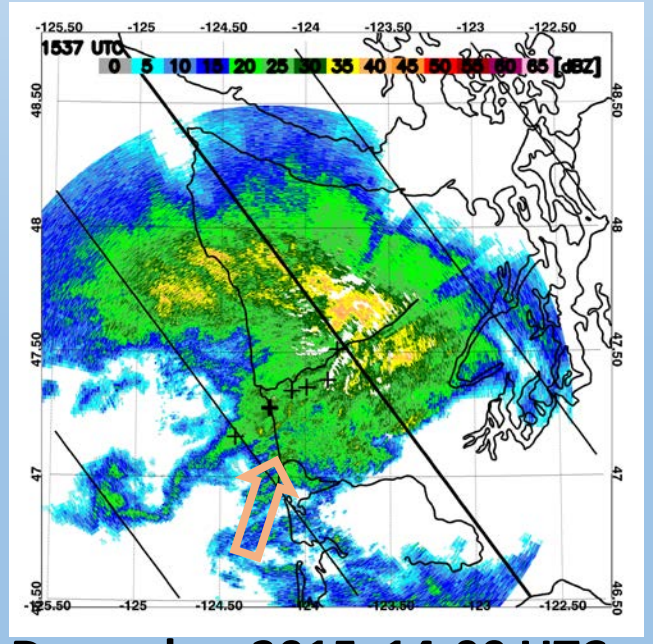


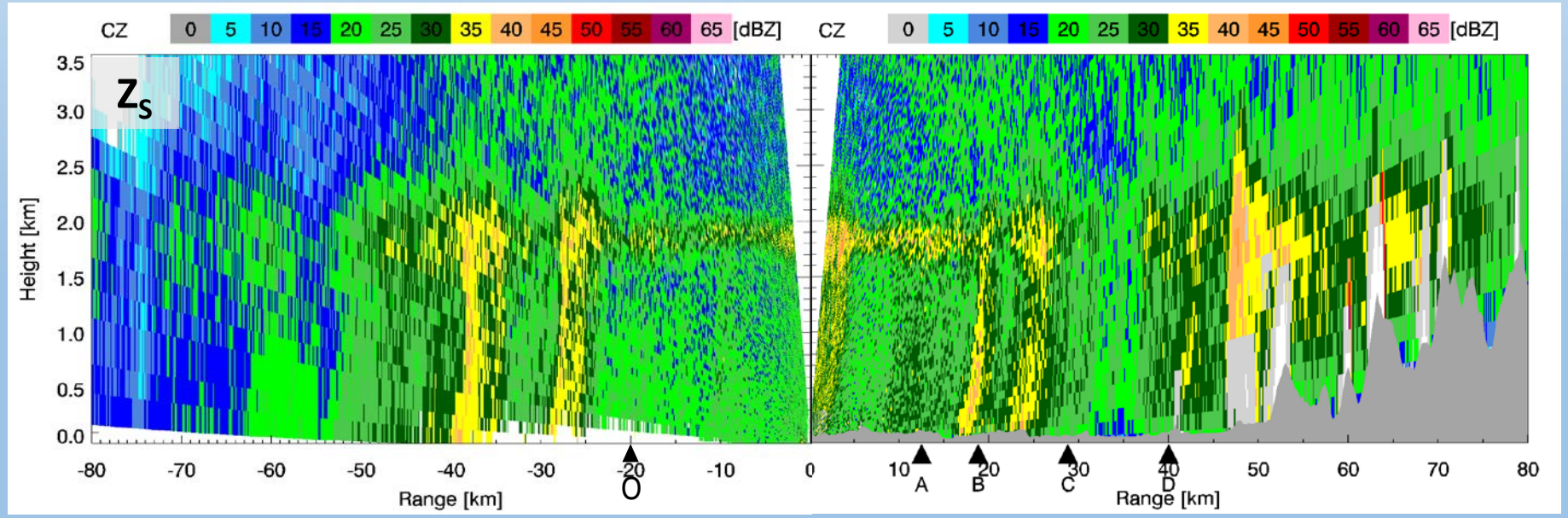
17 November 2015 10-21 UTC

Z_S – NPOL Composites





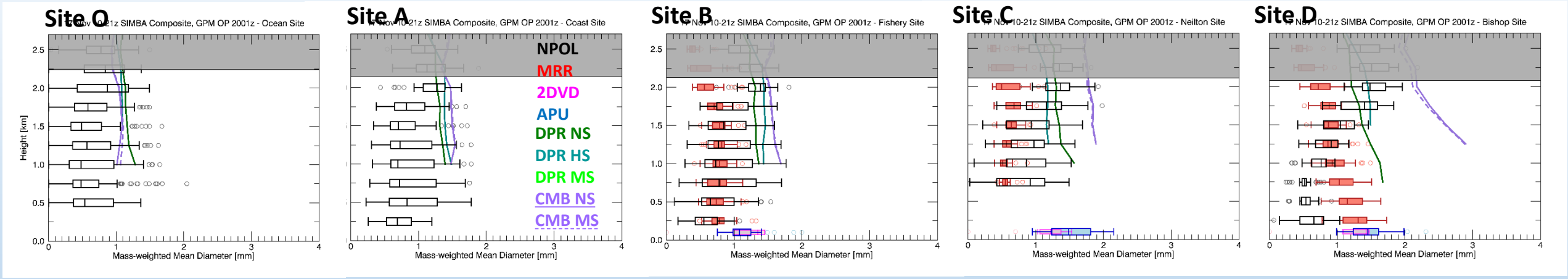




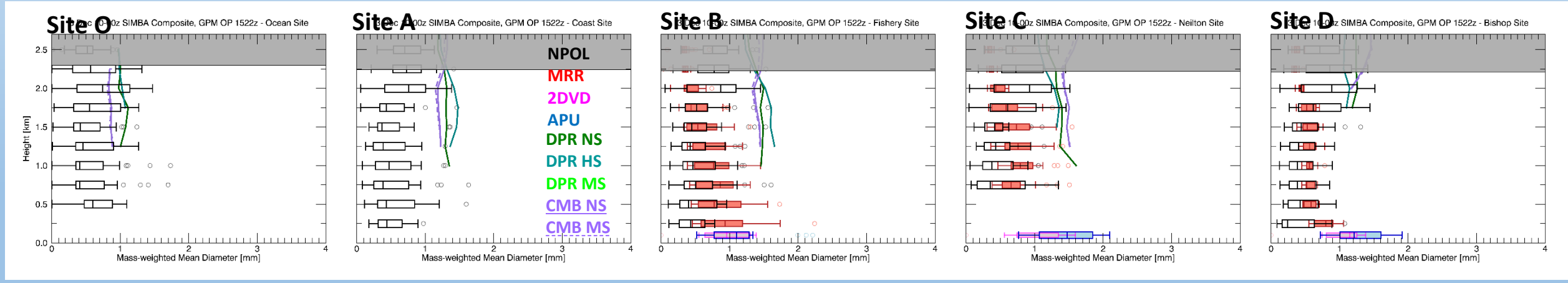
3 December 2015 14-00 UTC

17 November 2015 10-21 UTC Westerly flow

D_m – SIMBA Composites



- **MRR** - drop size enhancement
- **DPR** vs. **CMB** as approach terrain
- **MRR** vs. **NPOL** opposite trend at inland sites



- **DPR** & **CMB** exceed ground-based IQR at all sites
- **MRR** vs. **NPOL** less discrepancy – flow orientation…

3 December 2015 14-00 UTC Southerly flow

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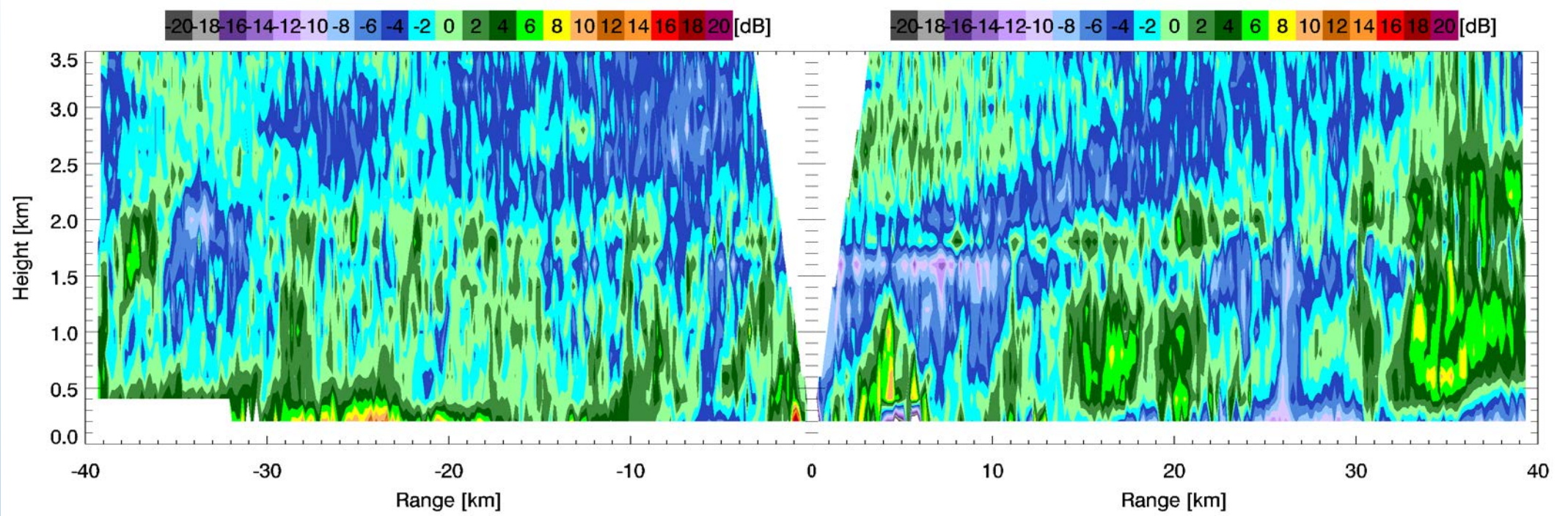
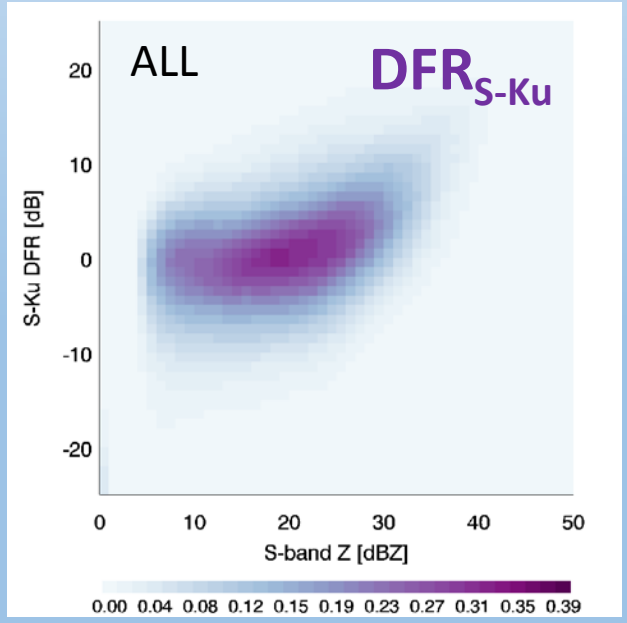
- OLYMPEX Atmospheric Rivers: GPM overpasses, Warm Sector / Fr > 1.3
  - 6 events, over 100+h of obs, 8 GMI/2DPR Ops, 5 SIMBA sites
- *All Cases:*
  - Large variation of precipitation parameters
  - Enhancement at coast & as approach terrain barrier clear, but somewhat gradual
  - **DPR aligns best with ground-based observations over ocean**
- *17 Nov - Westerly flow case:*
  - Larger **MRR vs NPOL, DPR vs CMB** discrepancies
  - More intense precipitation rates
  - Enhancement regions most prominent over land
- *3 Dec - Southerly component case*:
  - MRR & NPOL means better align
  - Generally lower precipitation rates
  - Enhancement regions initiate offshore

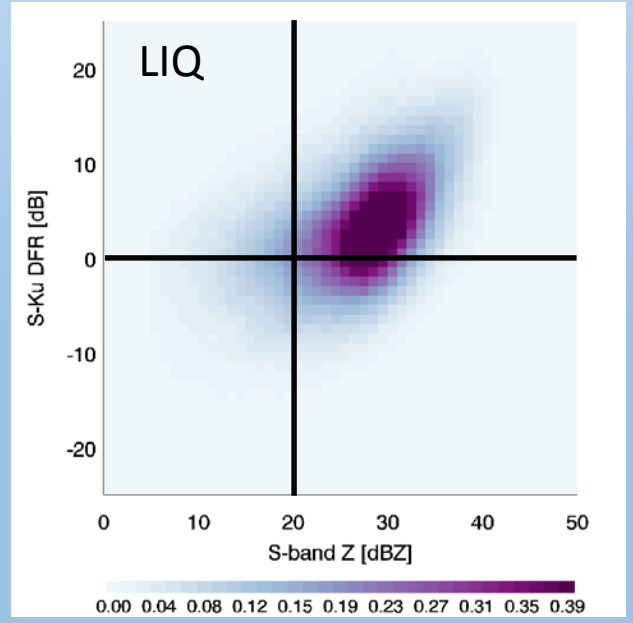
- Precipitation processes and satellite observations involve more than below 0°C level
  - **Importance of identifying and quantifying ICE vs LIQUID vs MIX phases**
  - Incorporating airborne data will improve analysis
  - Compositing with "analog" instruments
  - PMW & CMB algorithm products – impacts of ice and transition to higher terrain

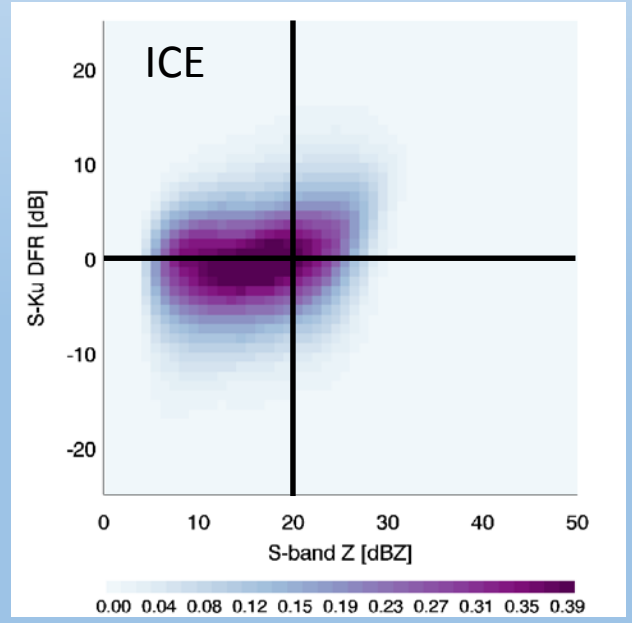
$DFR_{S\text{-}Ku}$ All ARs

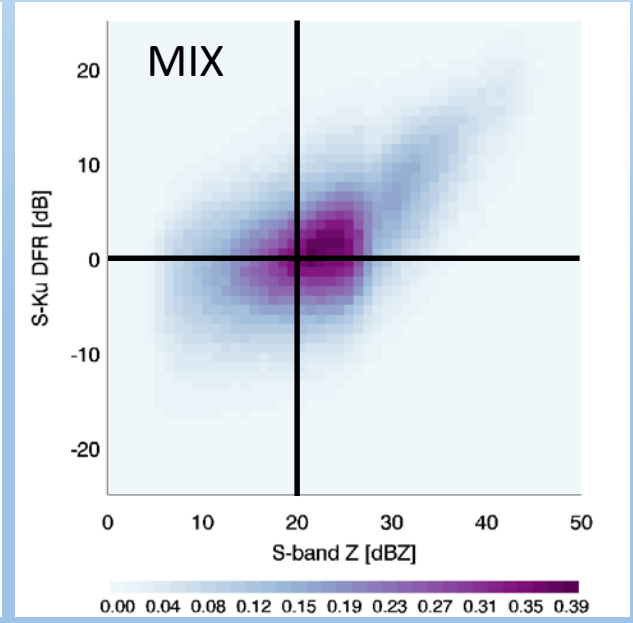
- S-Ku DFR composite, includes all NPOL HID types
- DF2Hs: **BOTH** land & ocean





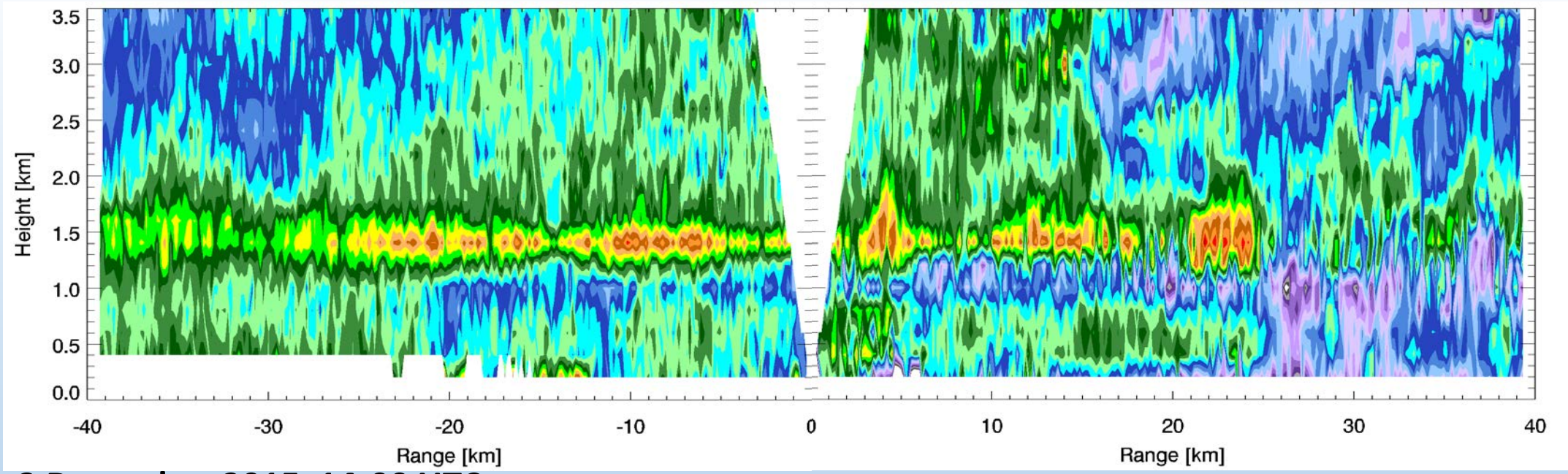






$DFR_{S\text{-}Ku}$ 2 Events

- S-Ku DFR composite, includes all NPOL HID types
- More ocean-side variation in westerly flow case
- DFR layering complexity increases as approach terrain



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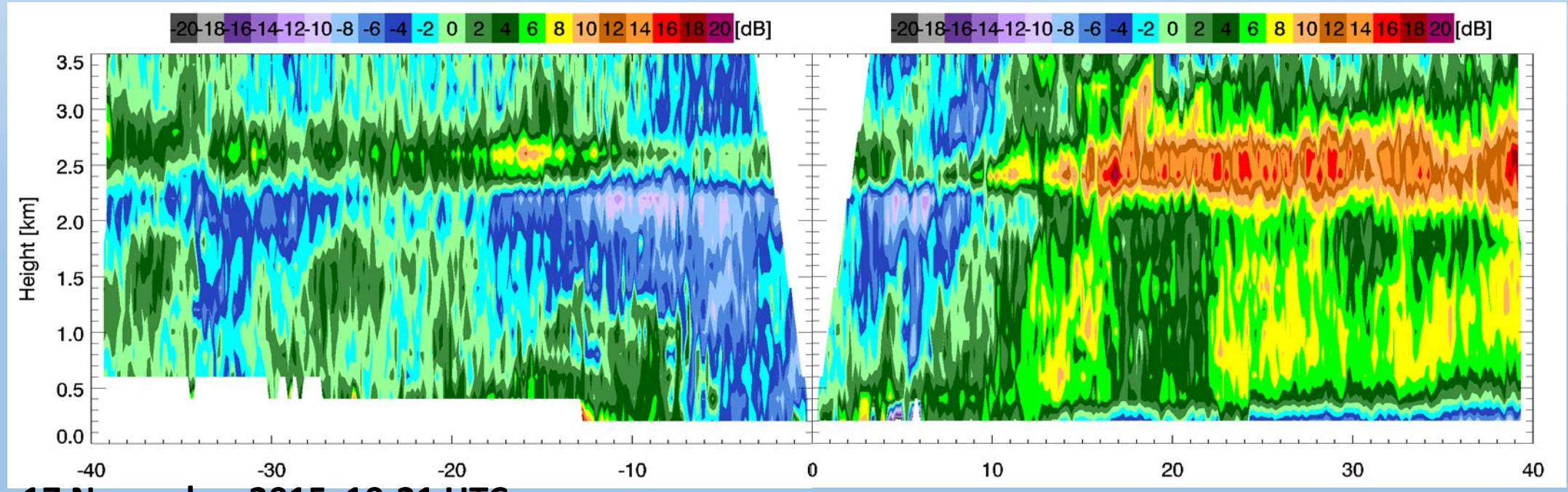
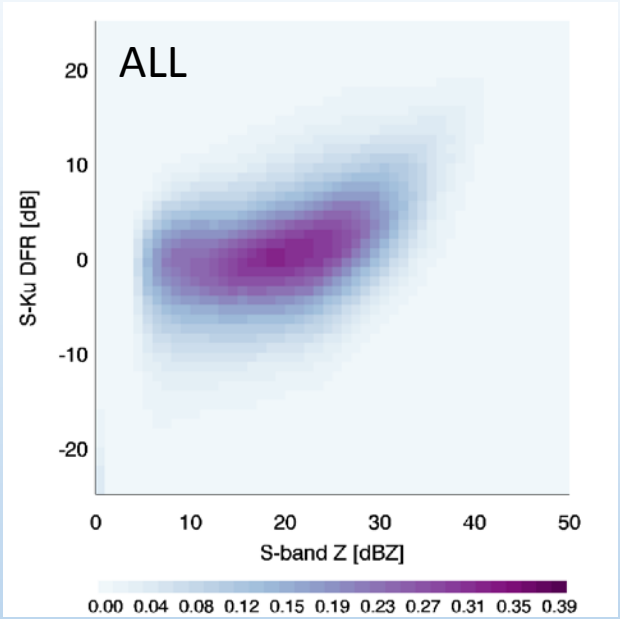
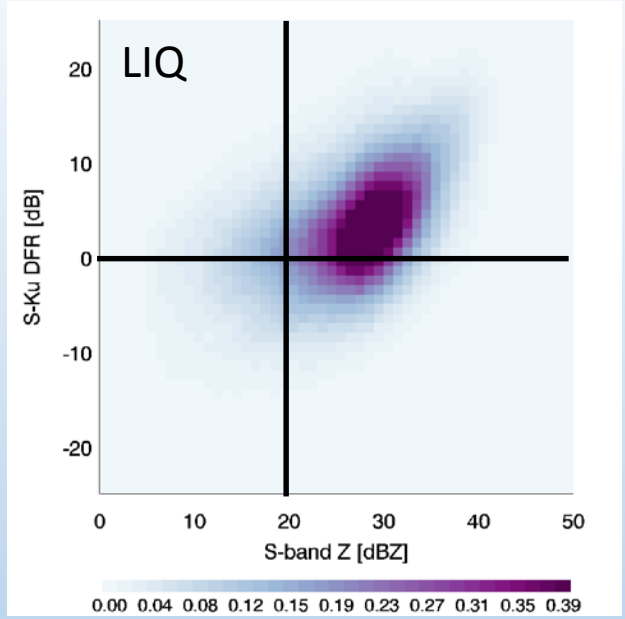
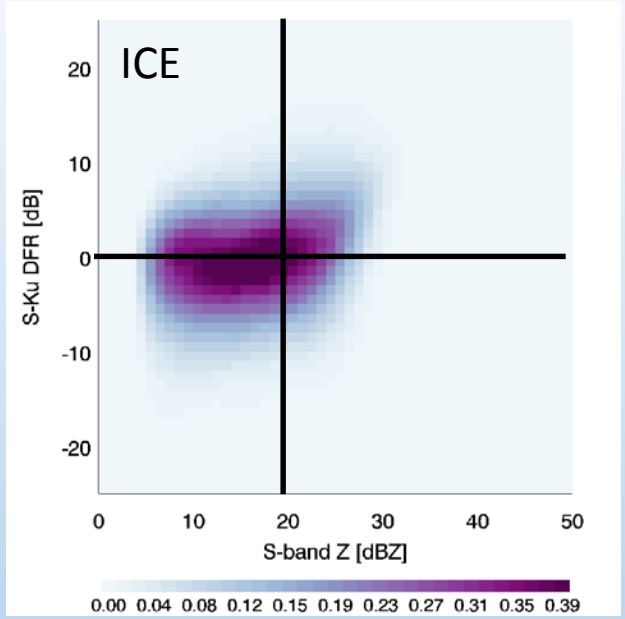


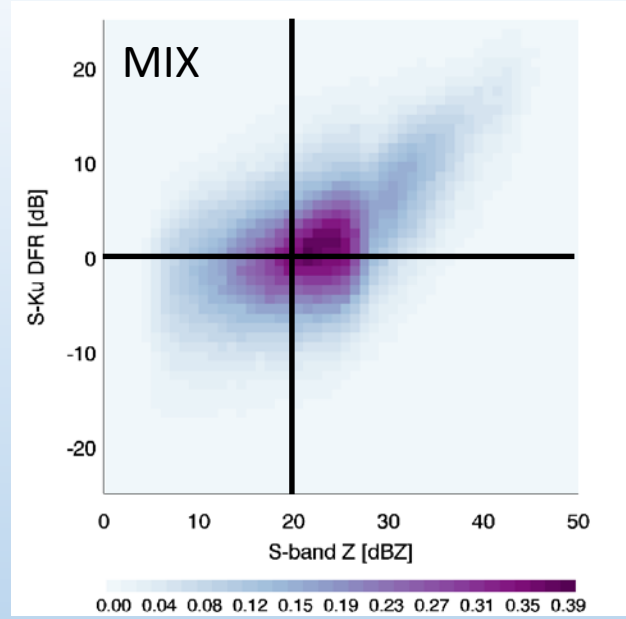
17 November 2015 10-21 UTC

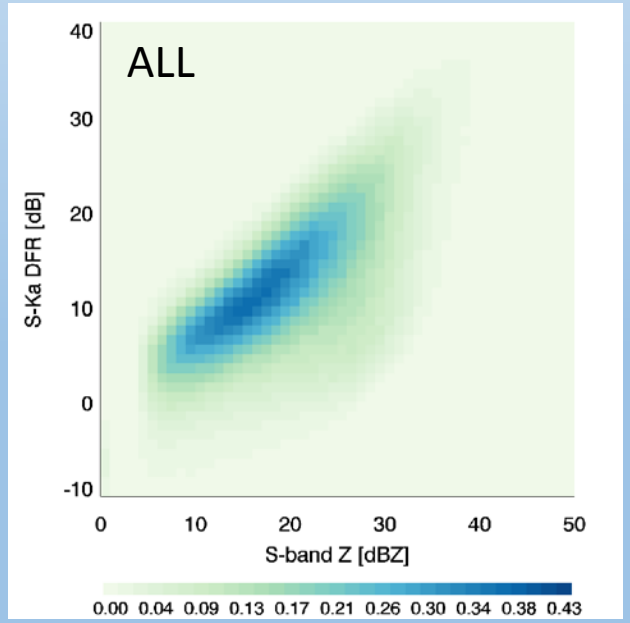
DFR_{S-Ku} ALL ARs Land + Ocean

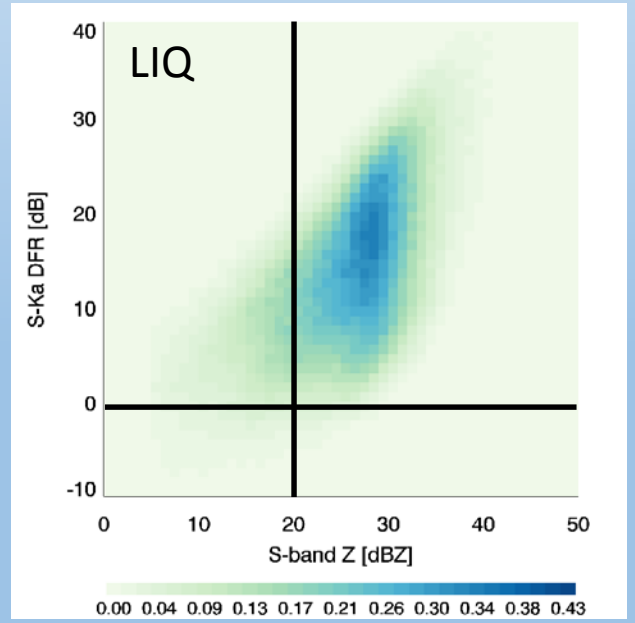


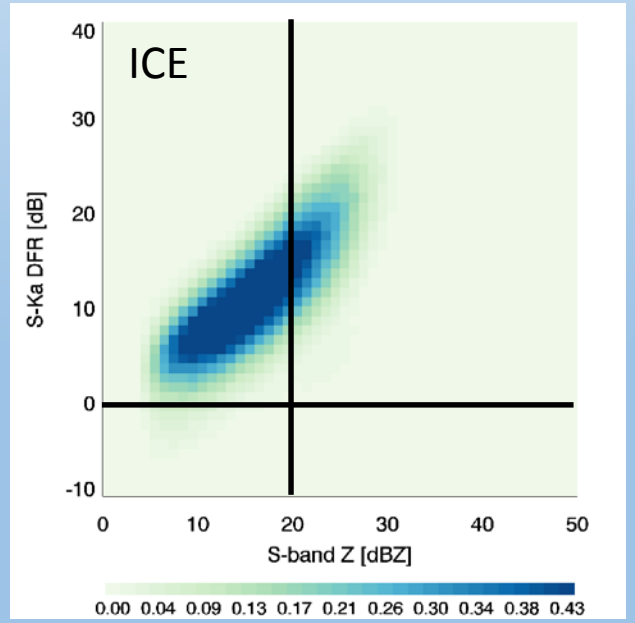


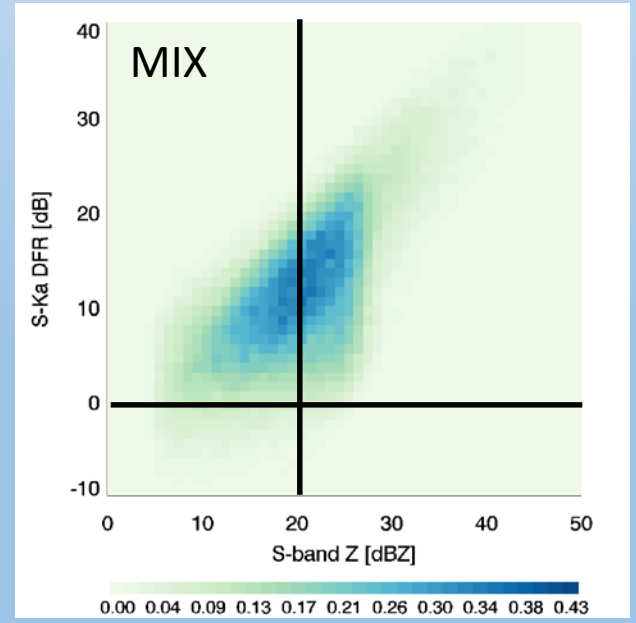






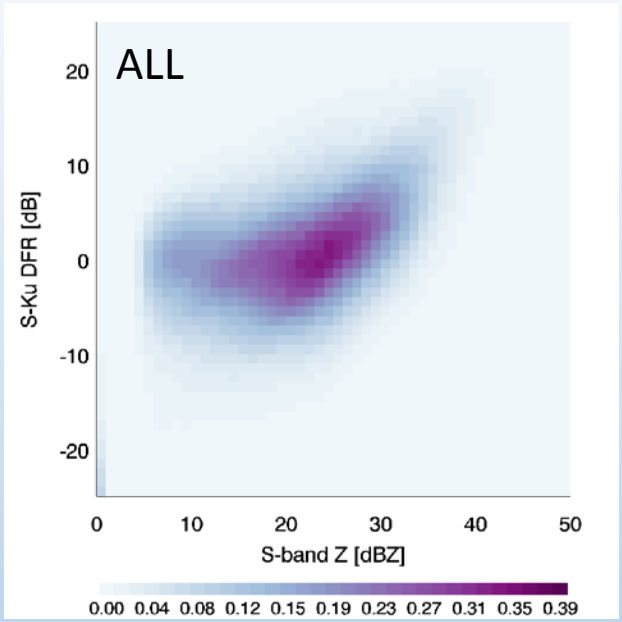


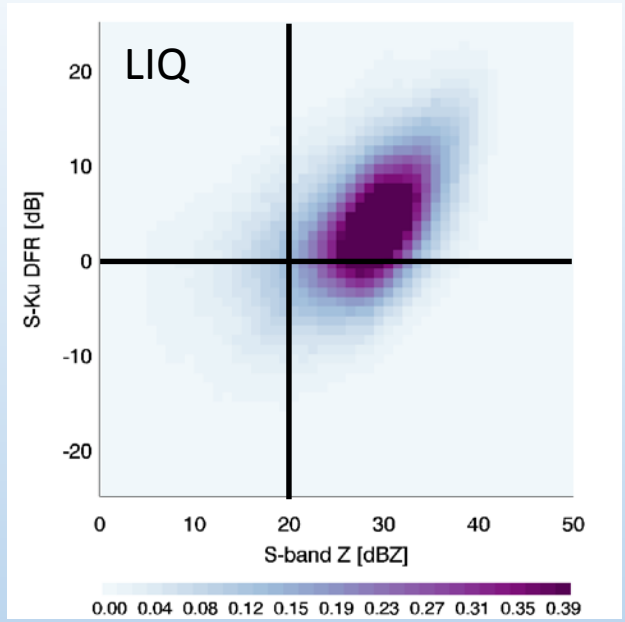


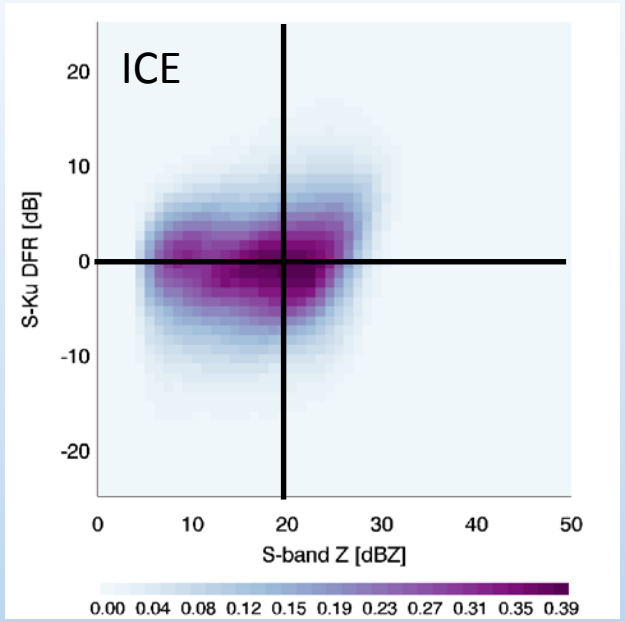


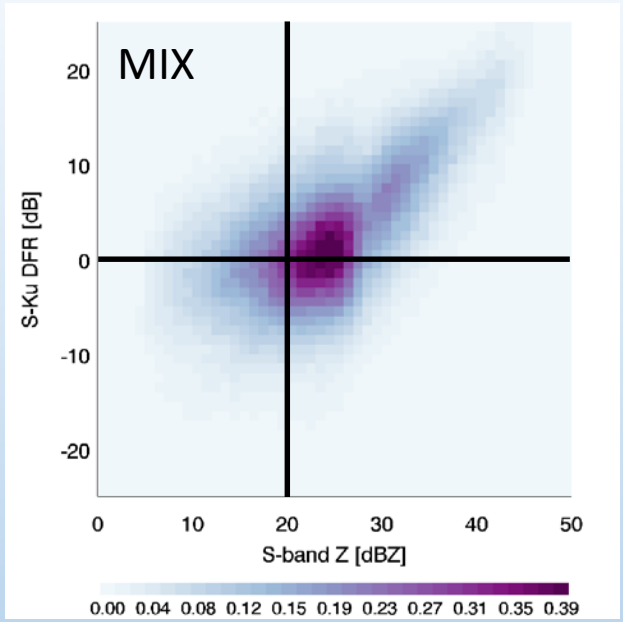
DFR_{S-Ka} ALL ARs Land + Ocean

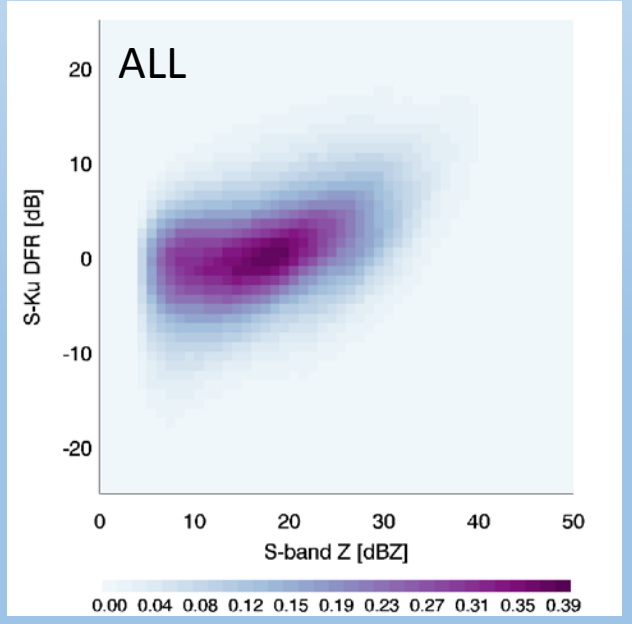
$DFR_{S\text{-}Ku}$ ALL ARs Land Side Scans

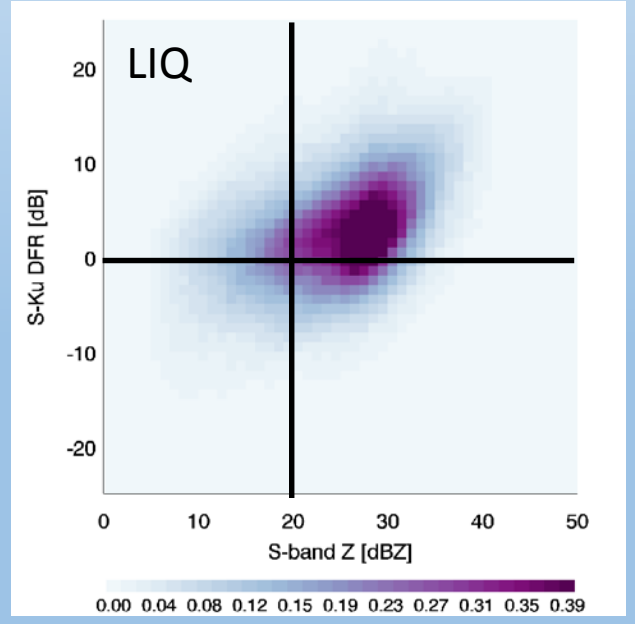


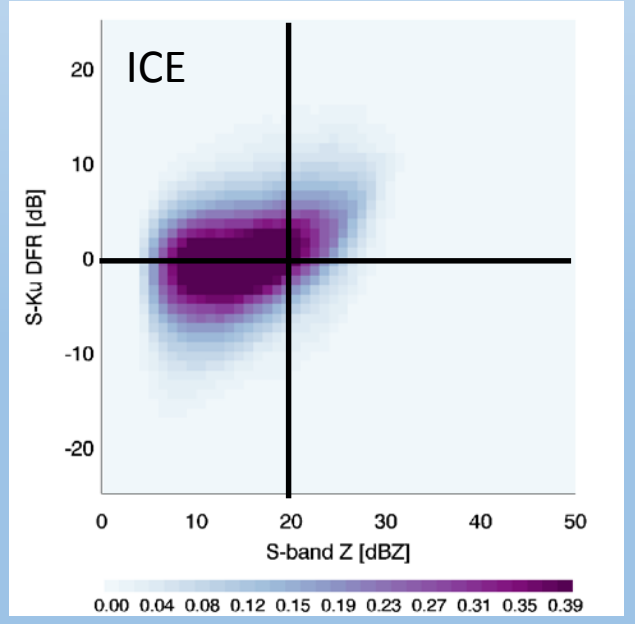


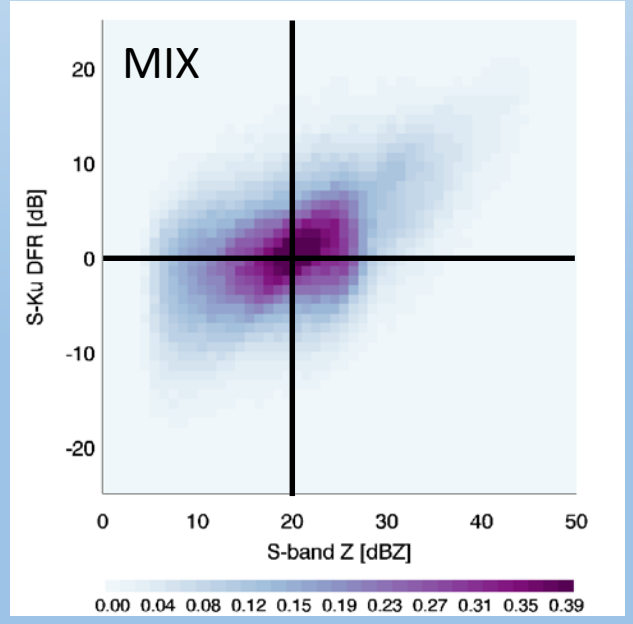






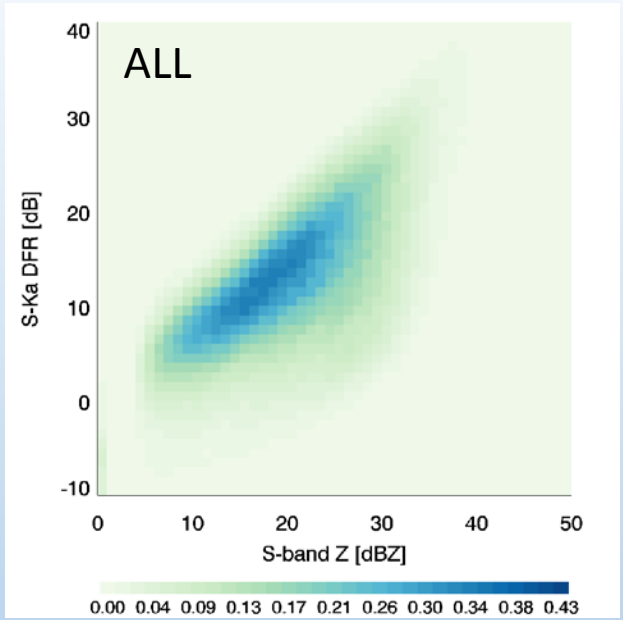


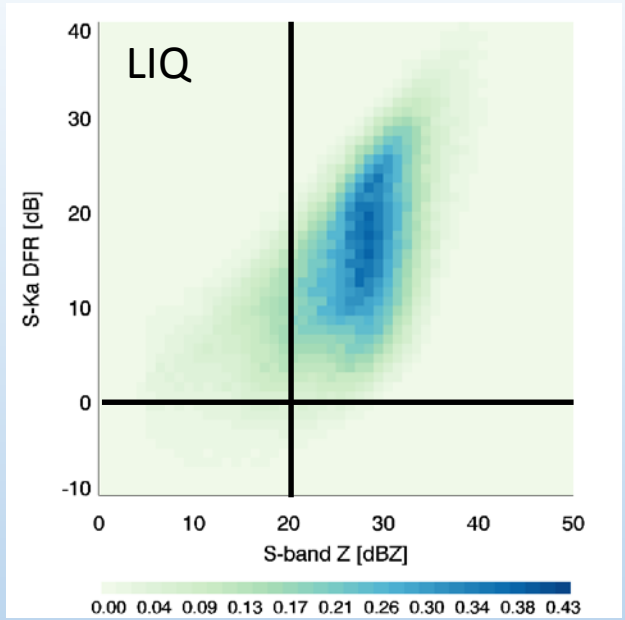


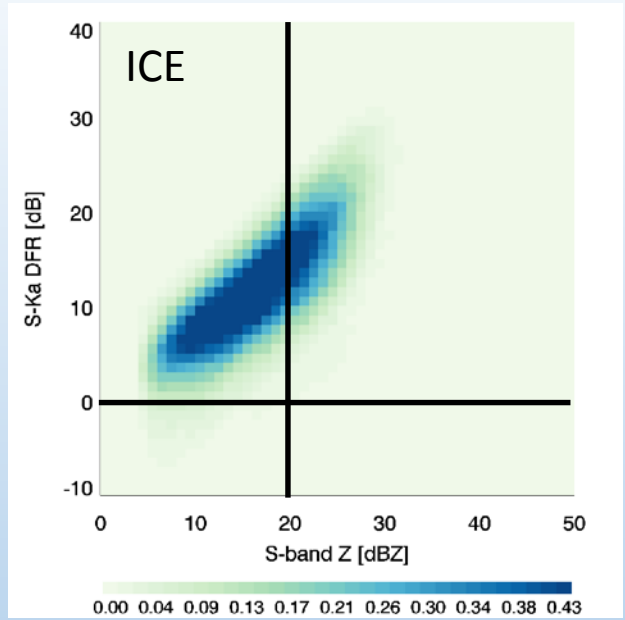


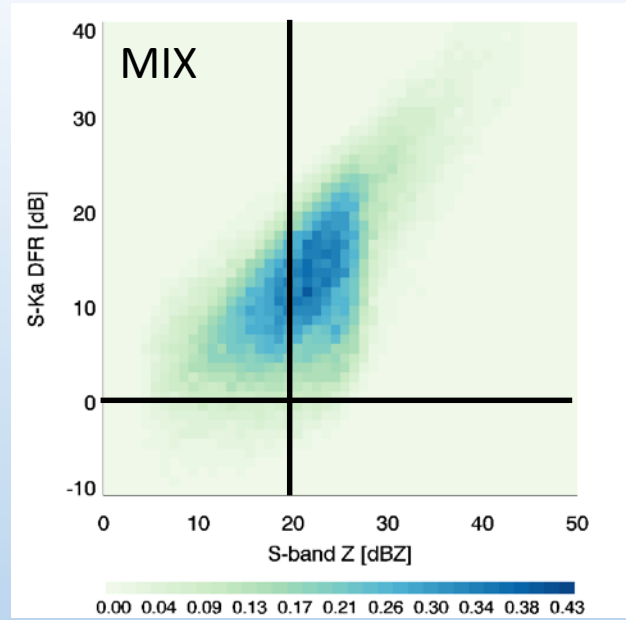
$DFR_{S\text{-}Ku}$ ALL ARs Ocean Side Scans

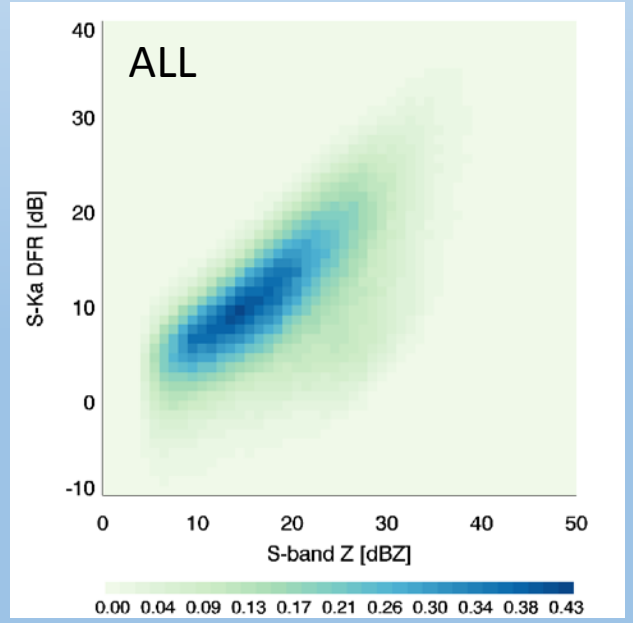
$DFR_{S\text{-}Ka}$ ALL ARs Land Side Scans

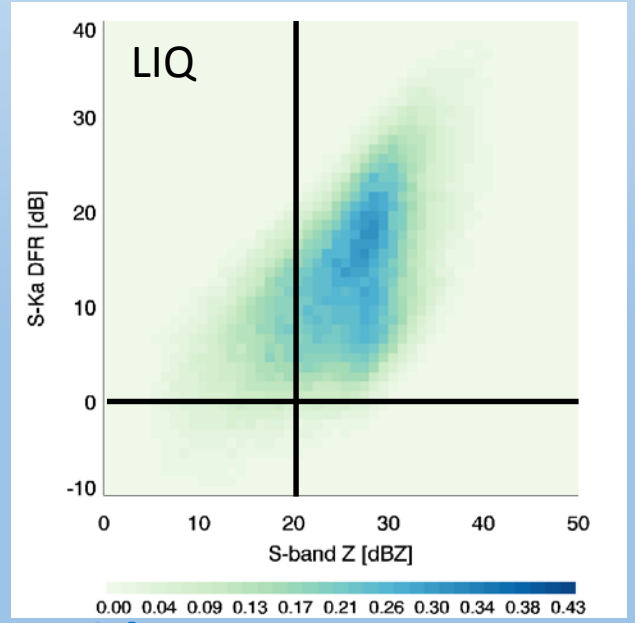


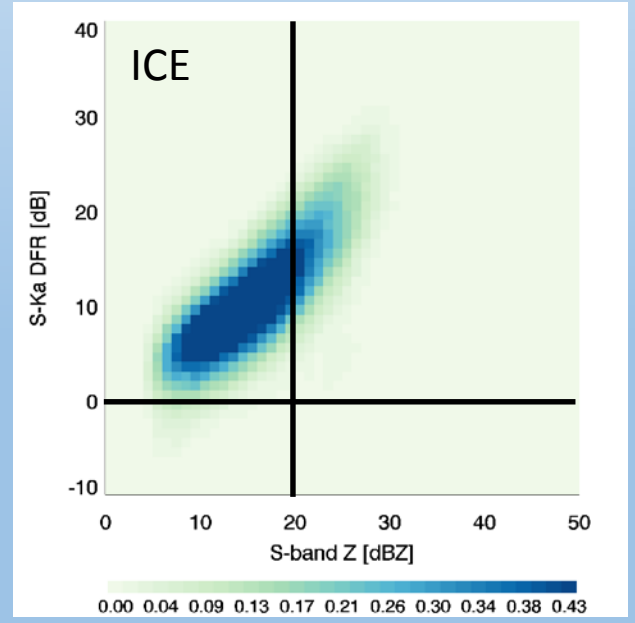


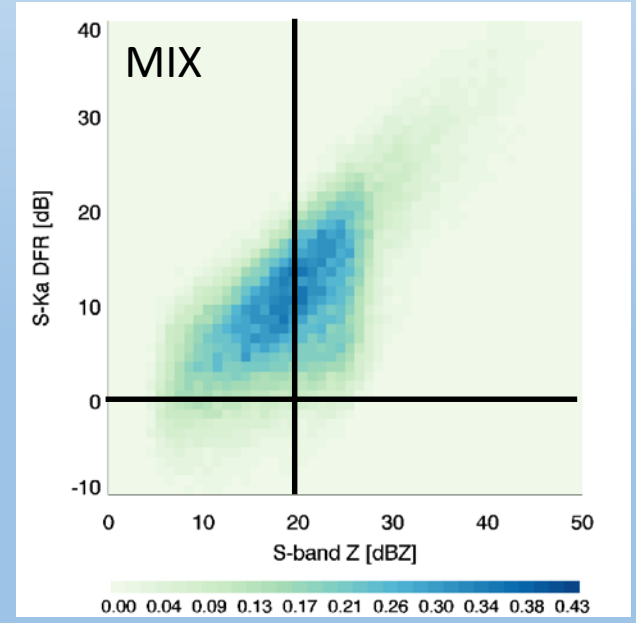






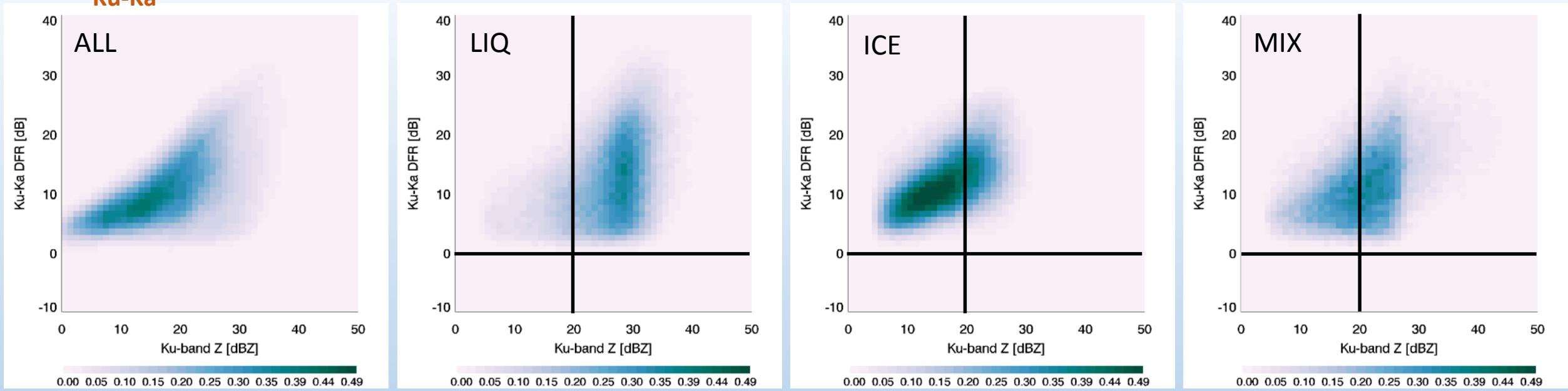


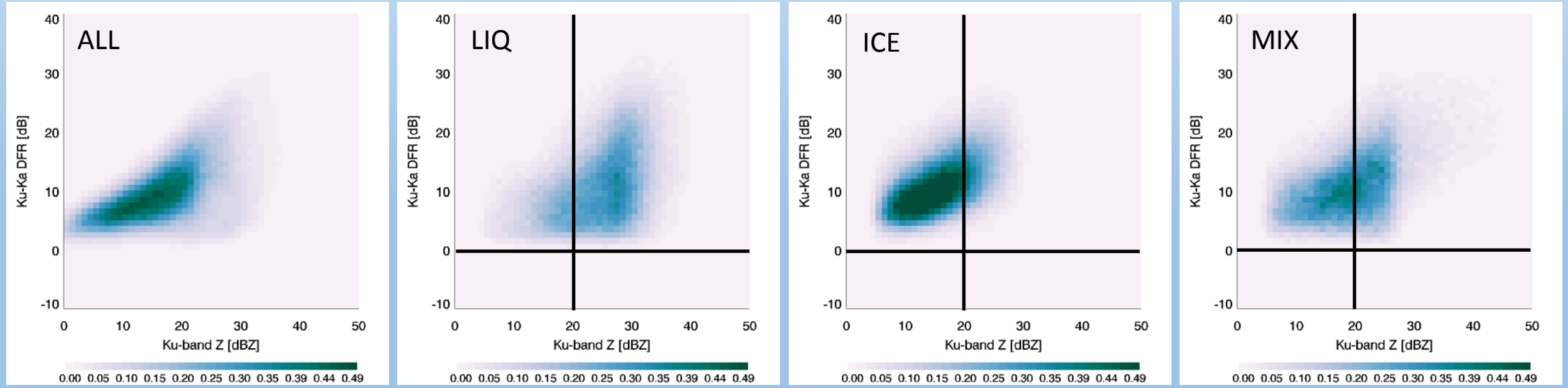




$DFR_{S\text{-}Ka}$ ALL ARs Ocean Side Scans

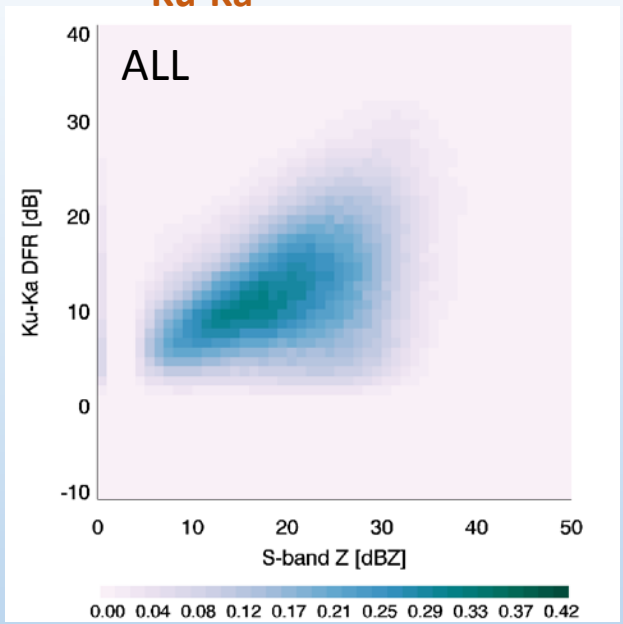
DFR_{Ku-Ka} ALL ARs Land Side Scans

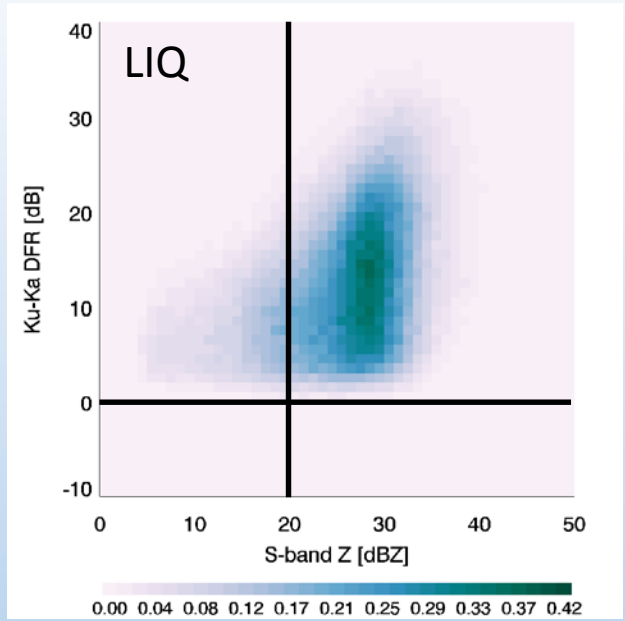


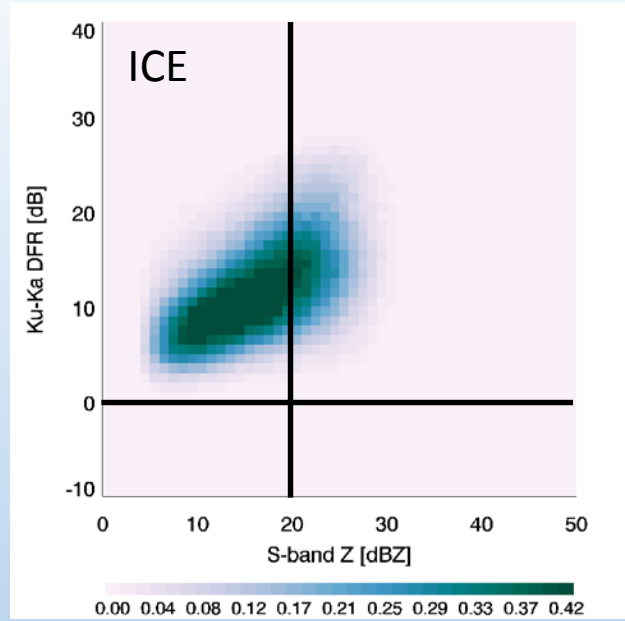


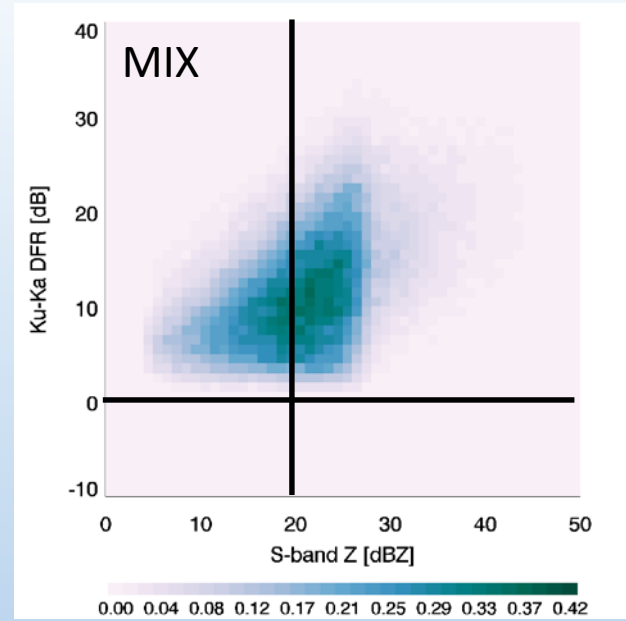
DFR_{Ku-Ka} ALL ARs Ocean Side Scans

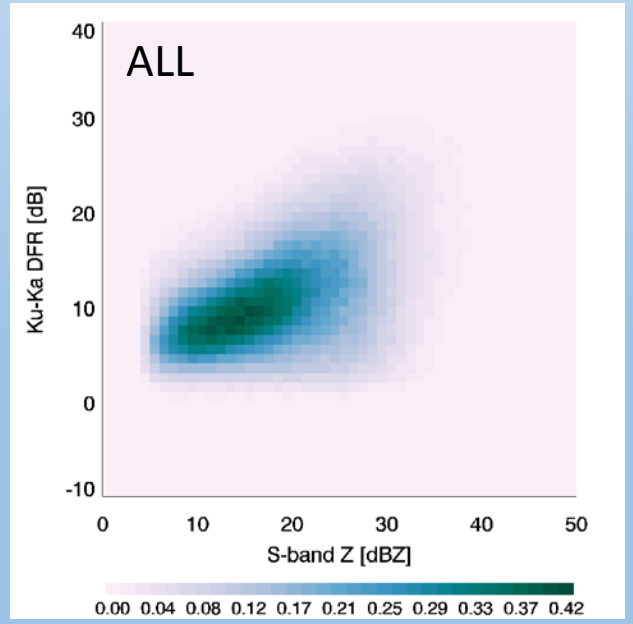
DFR_{Ku-Ka} ALL ARs Land Side Scans

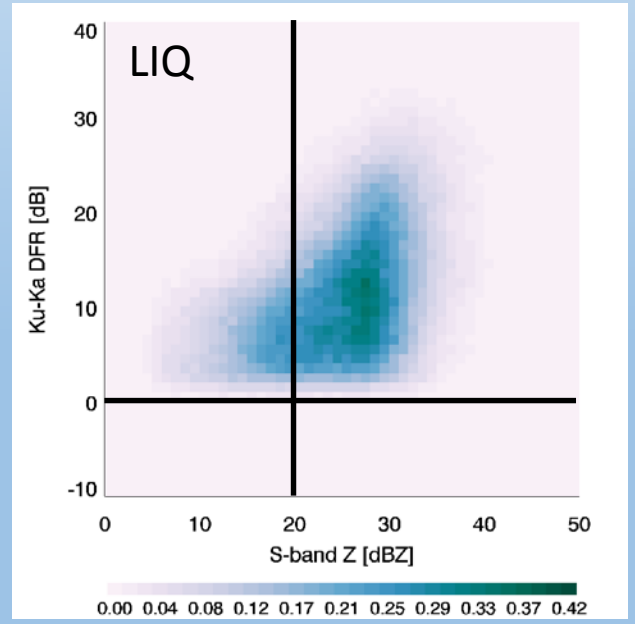


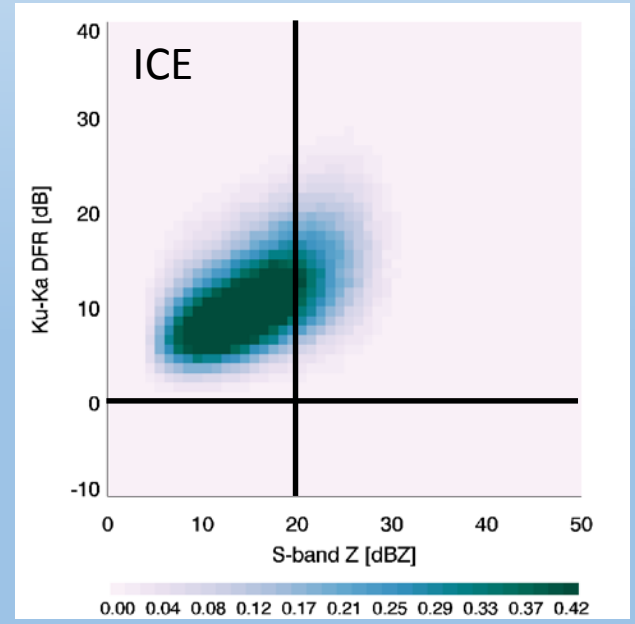


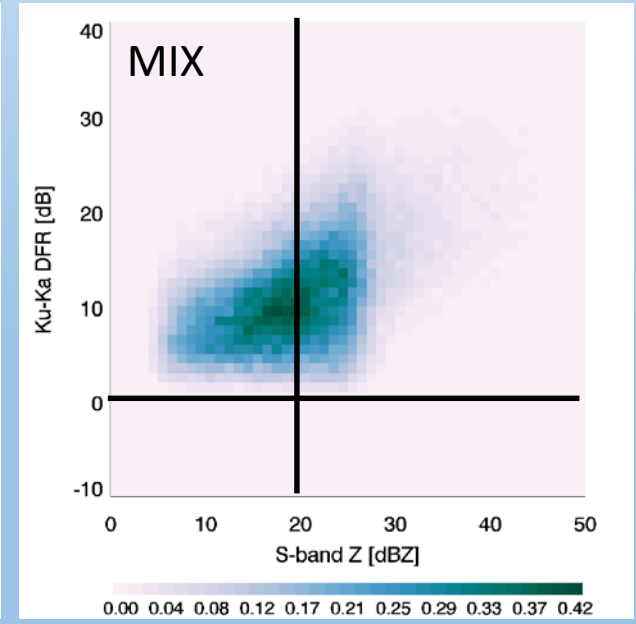






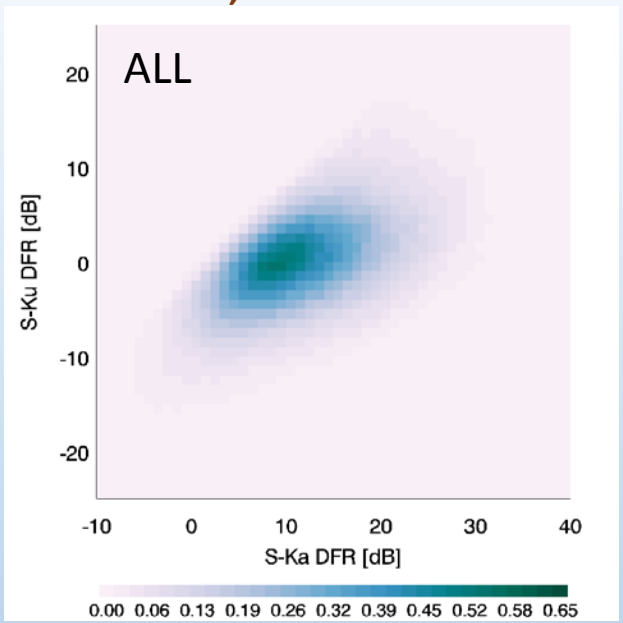


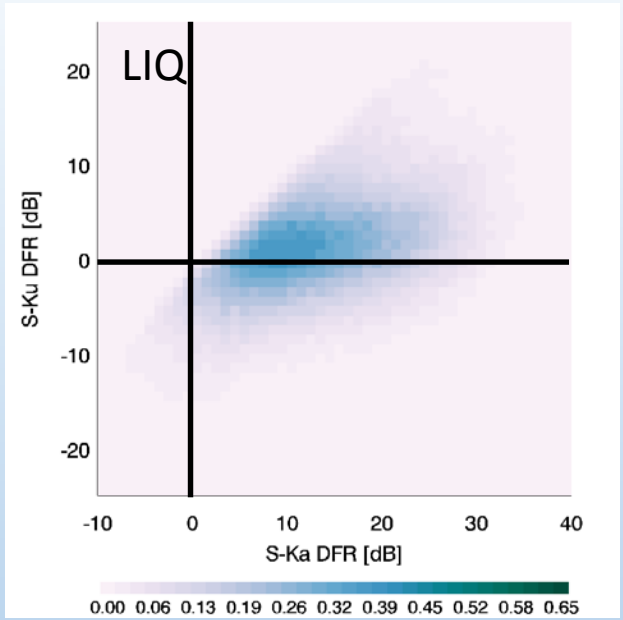


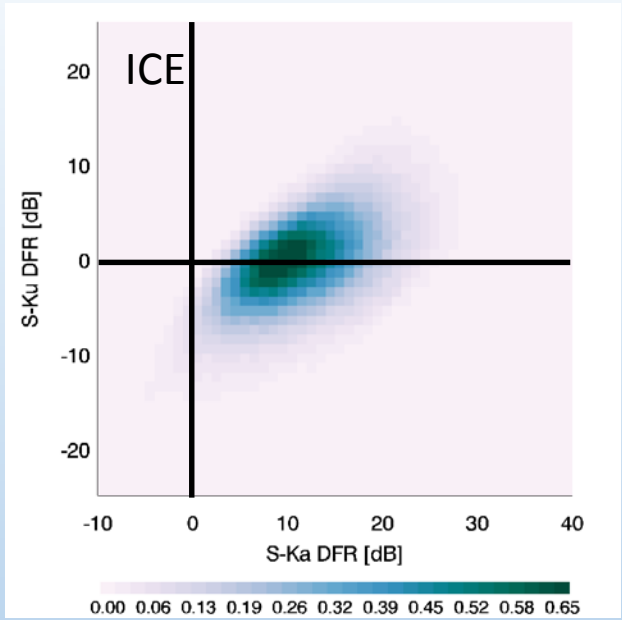


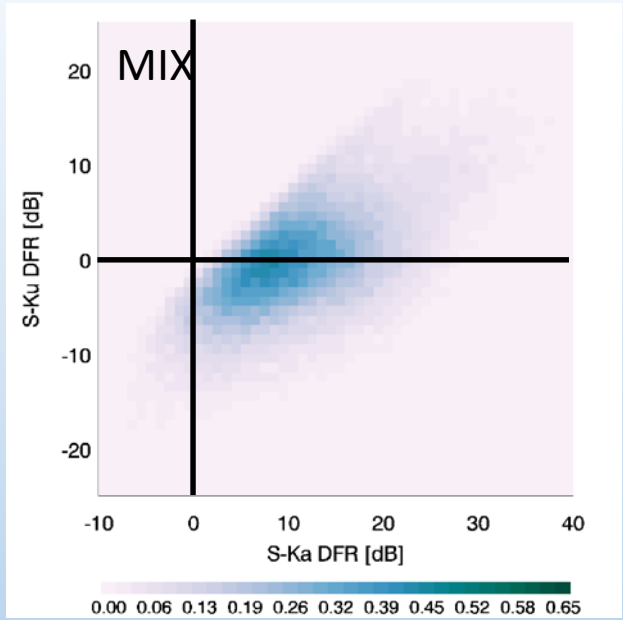
DFR_{Ku-Ka} ALL ARs Ocean Side Scans

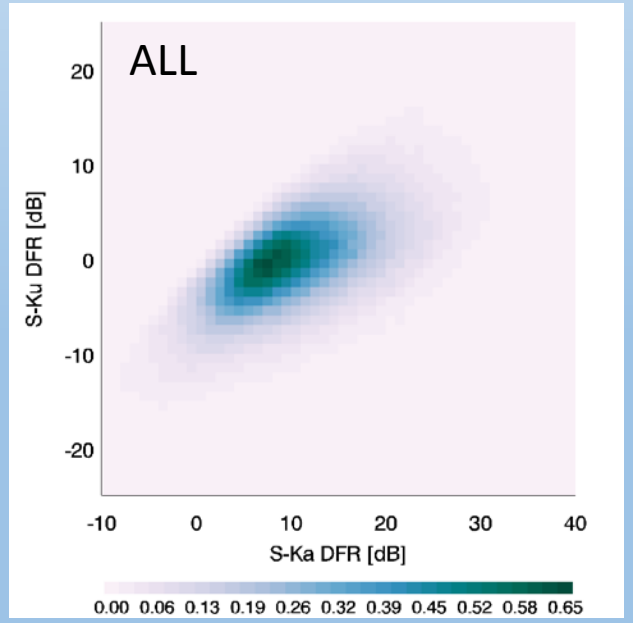
$DFR_{S\text{-}Ku,S\text{-}Ka}$ ALL ARs Land Side Scans

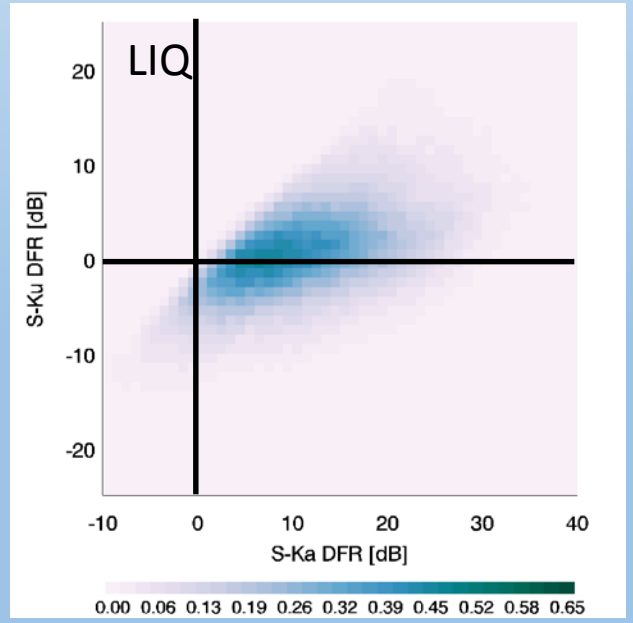


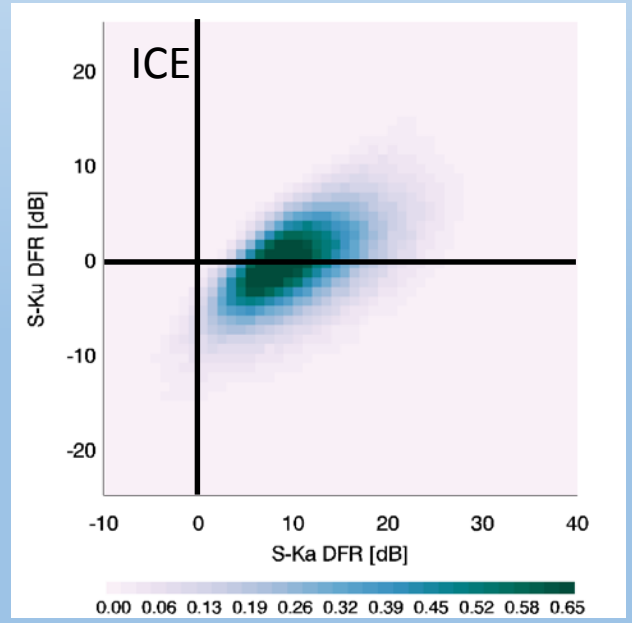


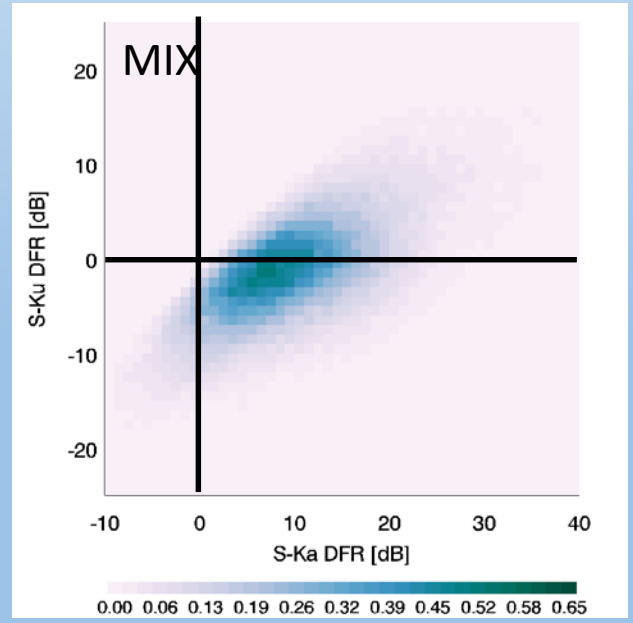






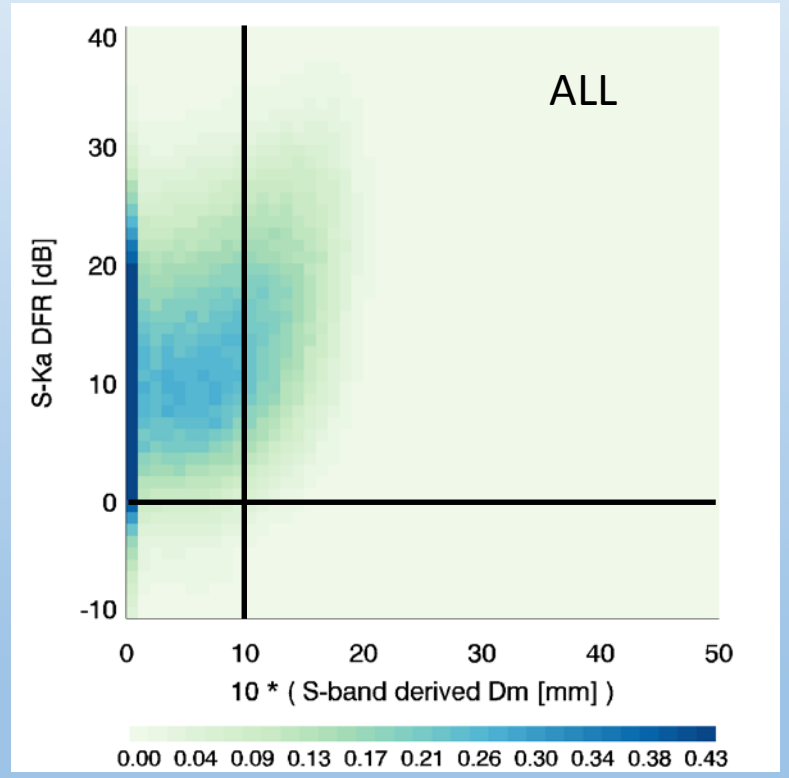


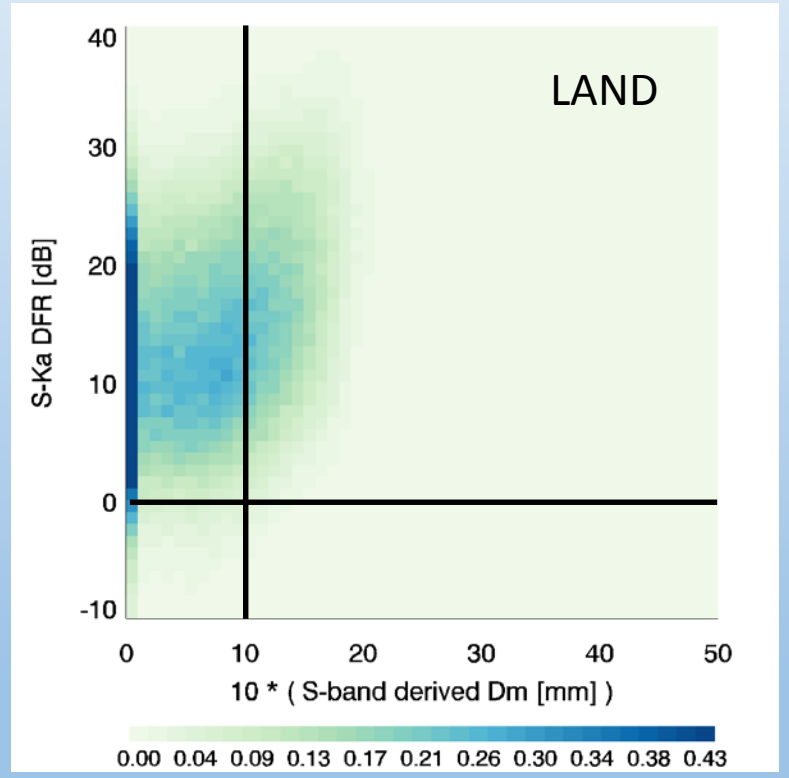


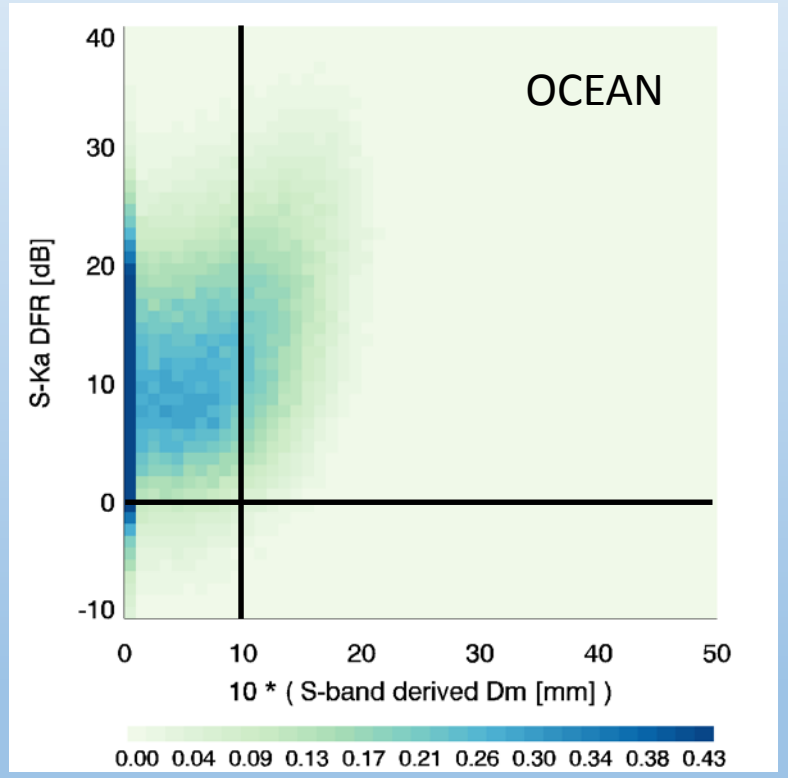


$DFR_{S\text{-}Ku,S\text{-}Ka}$ ALL ARs Ocean Side Scans

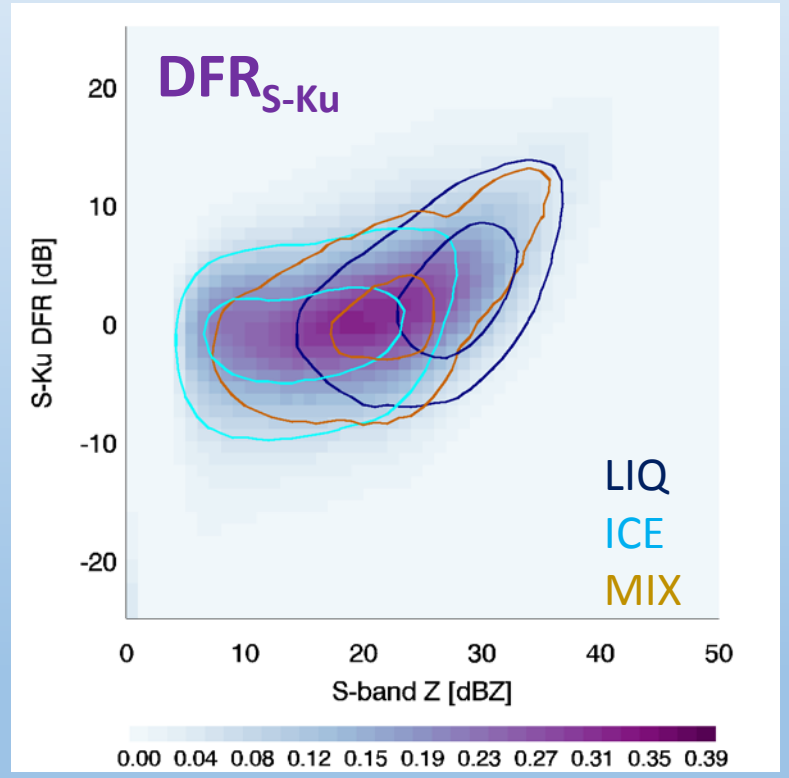
Only LIQ HID Types: $DFR_{S\text{-}Ka}$ vs. $10*D_m$

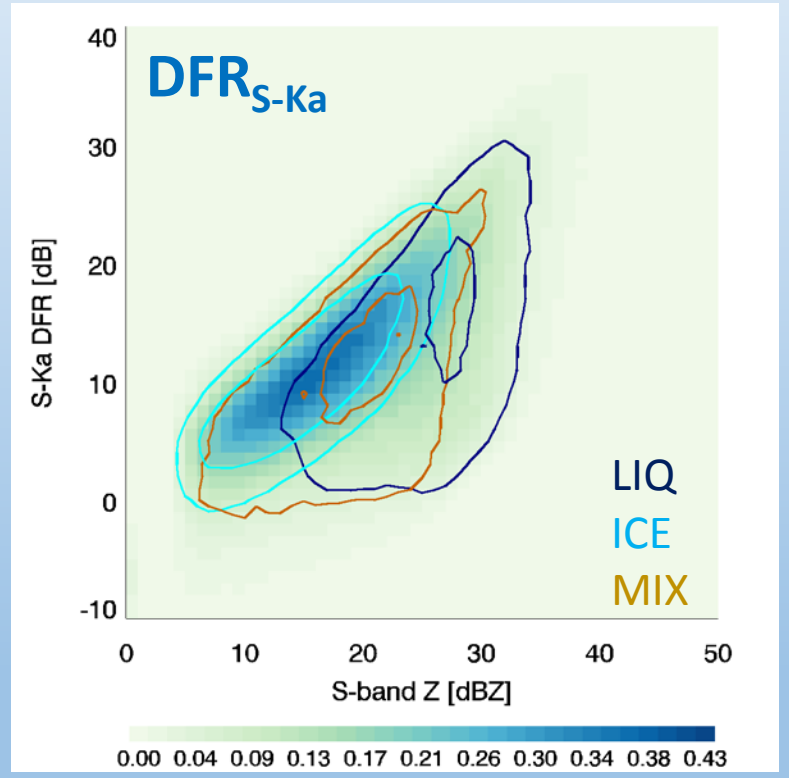


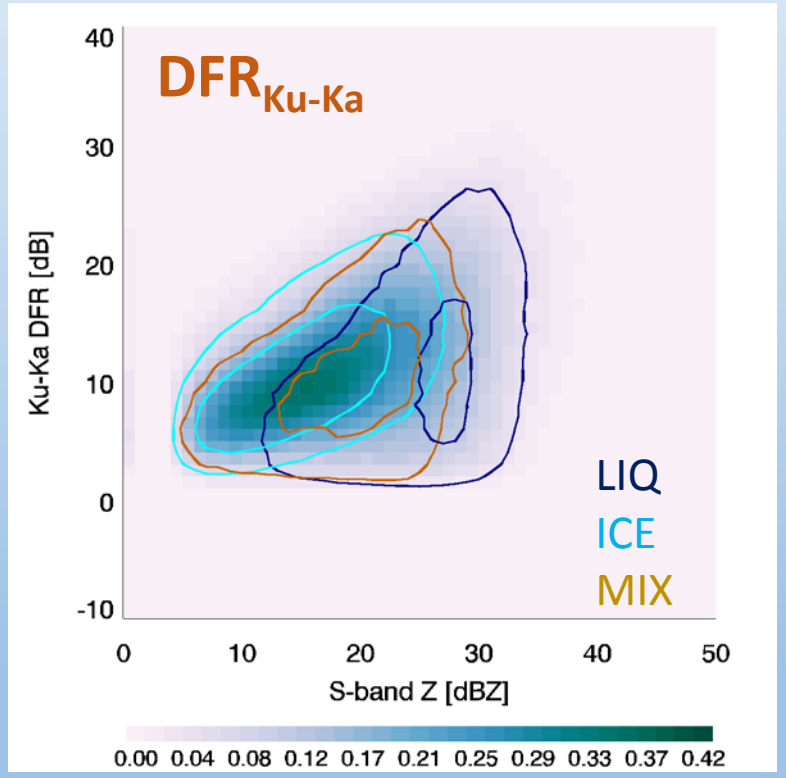




ALL HID Types: Land + Ocean Scans







*Histograms include all HID phases

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

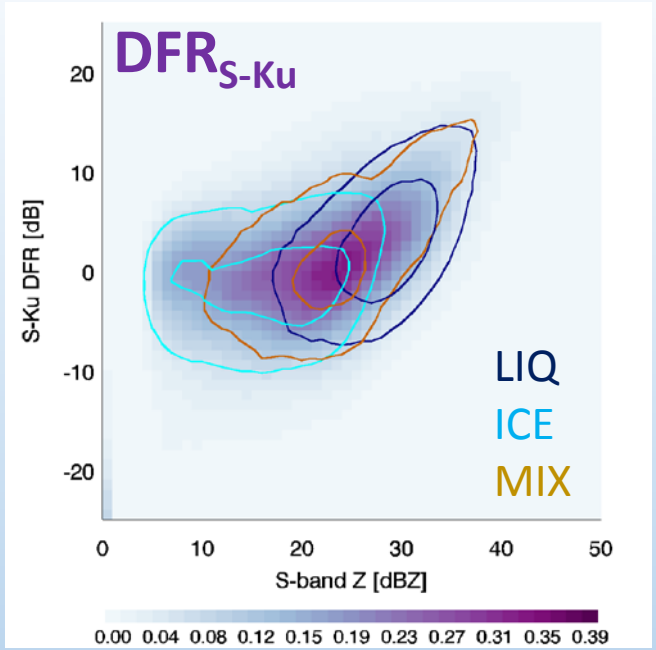
DFRs All ARs

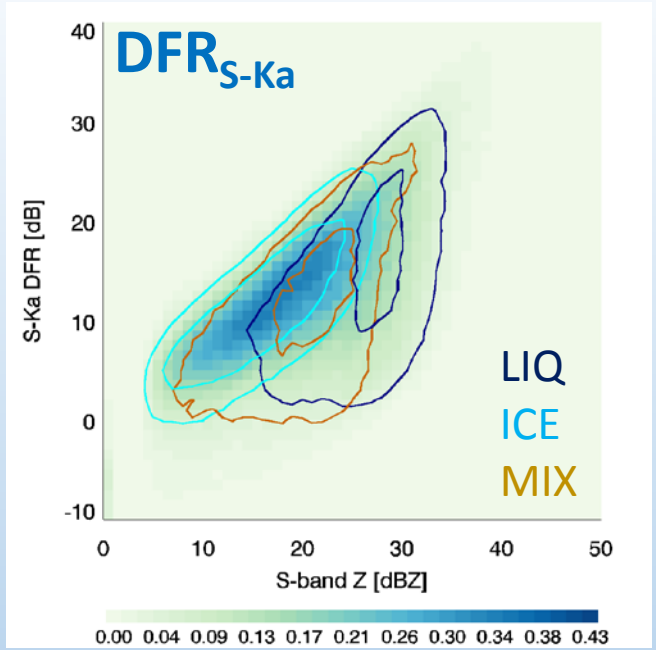
S-Ku
S-Ka
Ku-Ka
(vs. Z_S)

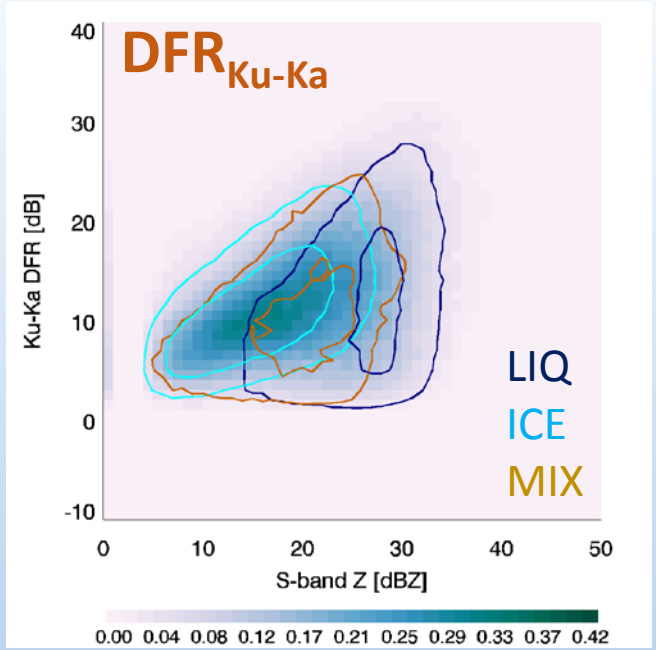
- S-Ku DFR has largest LIQ and ICE overlap
- MIX overlaps in all 3 spaces
- Ocean regime is slightly more compact

*Histograms include all HID phases

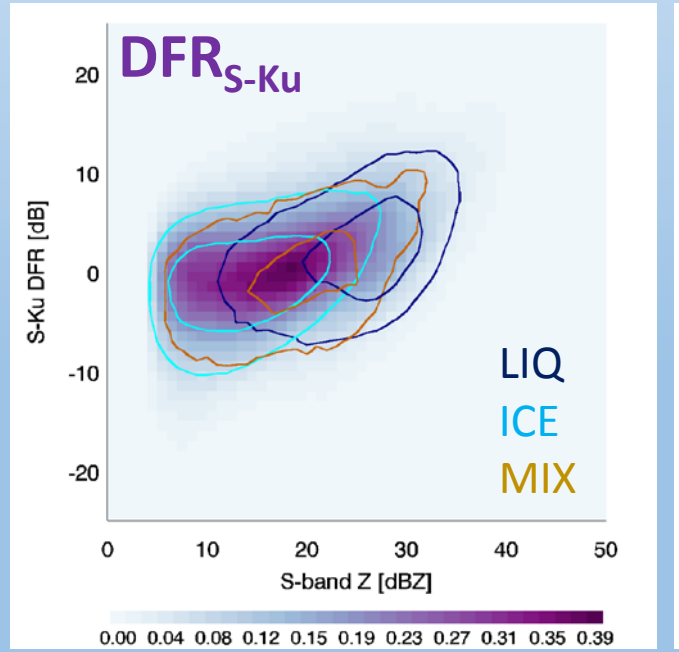
*Contours at densities of 0.1, 0.3 for each HID phase

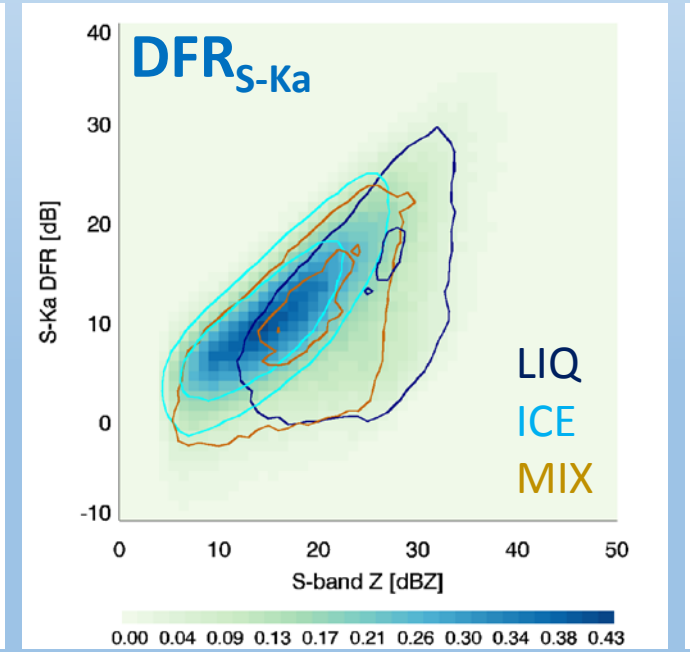


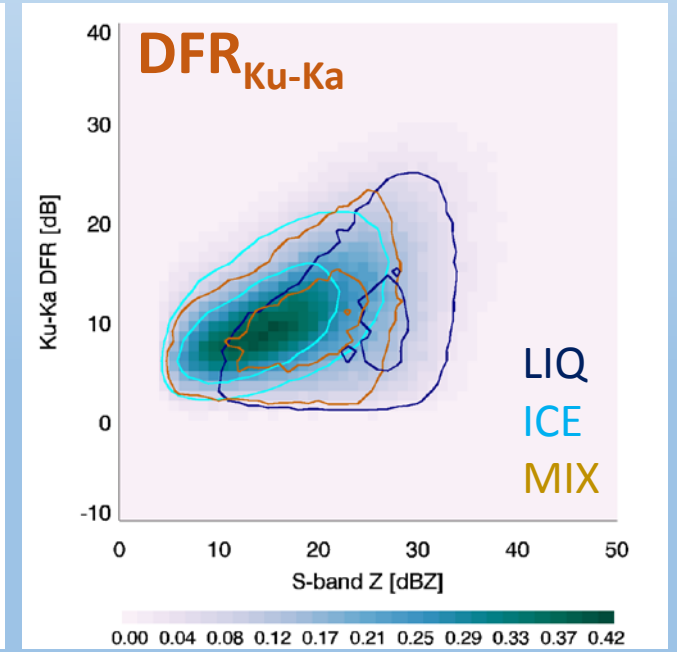




Land Scans





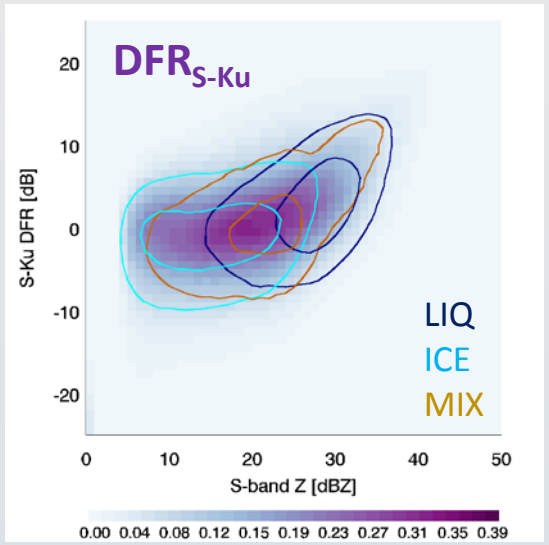


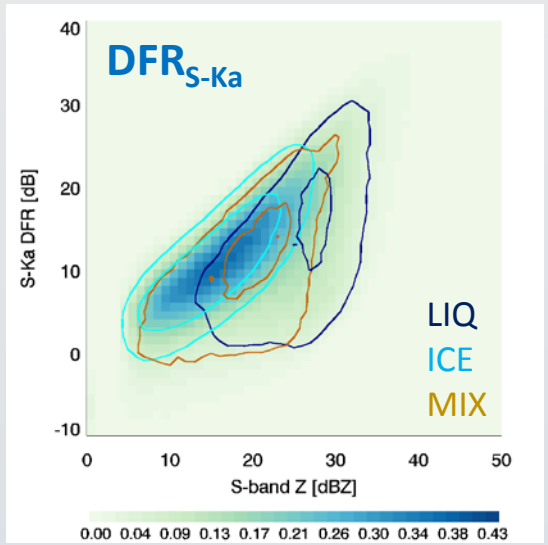
Ocean Scans

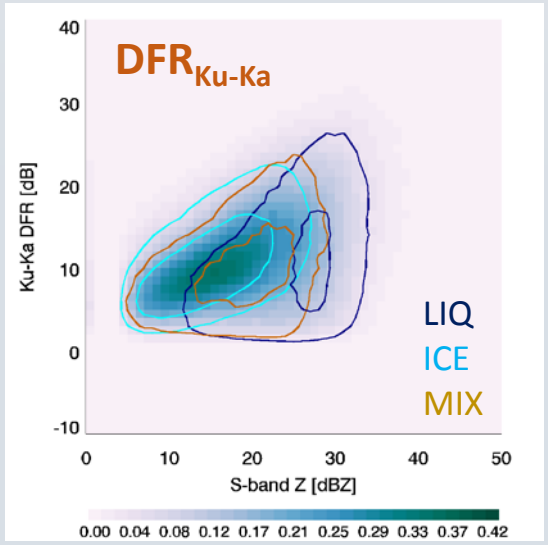
Summary

- OLYMPEX Atmospheric Rivers: Warm Sector / Fr > 1.3
  - 6 events, >100 h of ground-based observations
- Composite RHIs show preferential enhancement regions as approach terrain
  - Offshore vs. inland locations based on mean flow orientation
- DPR aligns best with ground-based observations over ocean
- MRR vs. NPOL trend/discrepancy, variation with flow orientation
- DFR layering consistent with terrain complexity
  - Magnitude of terrain-normal flow influences DFR enhancement location, severity
- $DFR_{S\text{-}Ka}$ shows most difference among LIQ/ICE/MIX HID phase types
- DFR distributions slightly more compact over ocean
  - Indicates more complex processes over land

Summary







Next Steps:

- Further refinements to multi-frequency analyses
  - S-Ka/Ku-Ka
  - Partition by HID type
- DPR Ku/Ka
  - Ground-based/S-band available via GPM GV VN
- Incorporating airborne data to improve analysis, physical interpretation
- Compare to scattering simulations

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