

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

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Image: Stacy Brodzik



Motivation

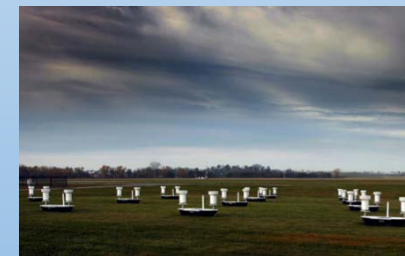
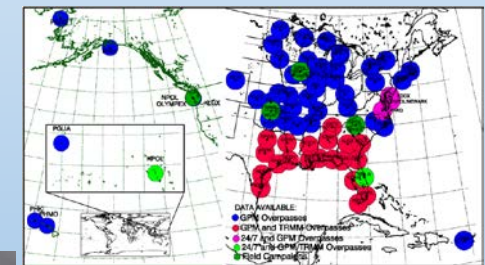
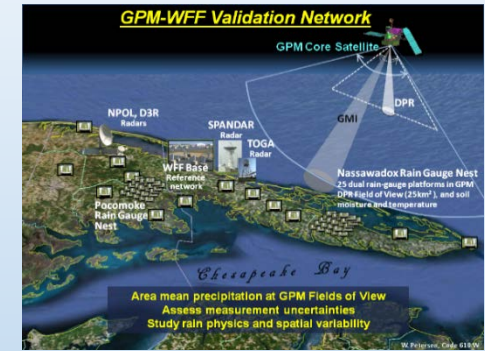
- GPM GV Observation Diversity
 - Core Observatory
 - Constellation Partners
 - Field Campaigns
 - Ground-based
 - Airborne

Goals:

Focus on OLYMPEX Atmospheric River (AR)

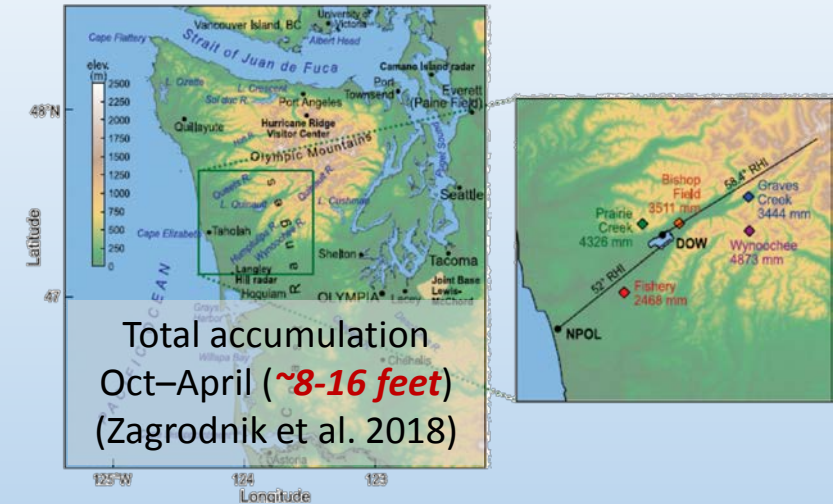
Events:

- 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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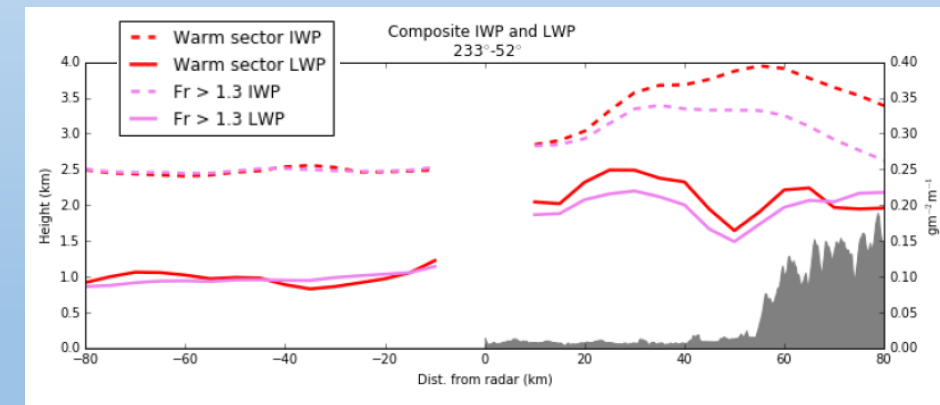


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Land/topo **impact ice/liquid** precipitation processes –
unblocked/large Froude and warm sector flow regimes
(Hunzinger 2018/Petersen et al. 2018)

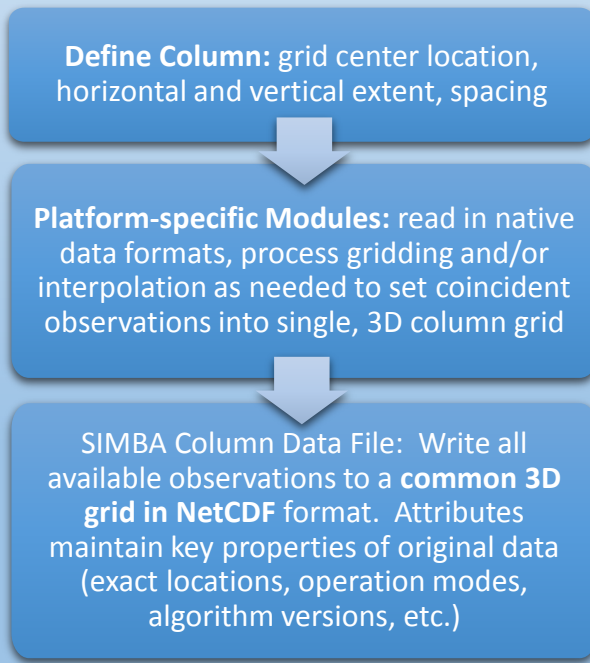
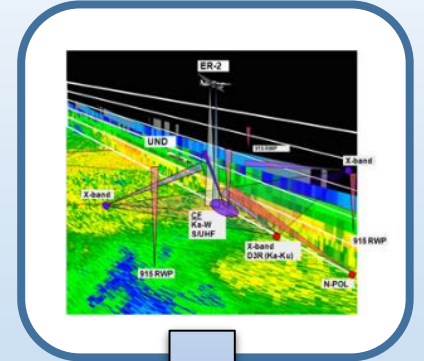
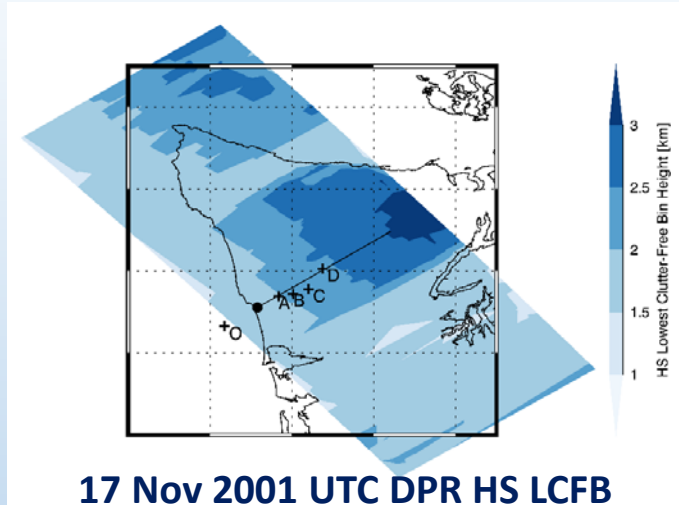
Methodology

Case Criteria

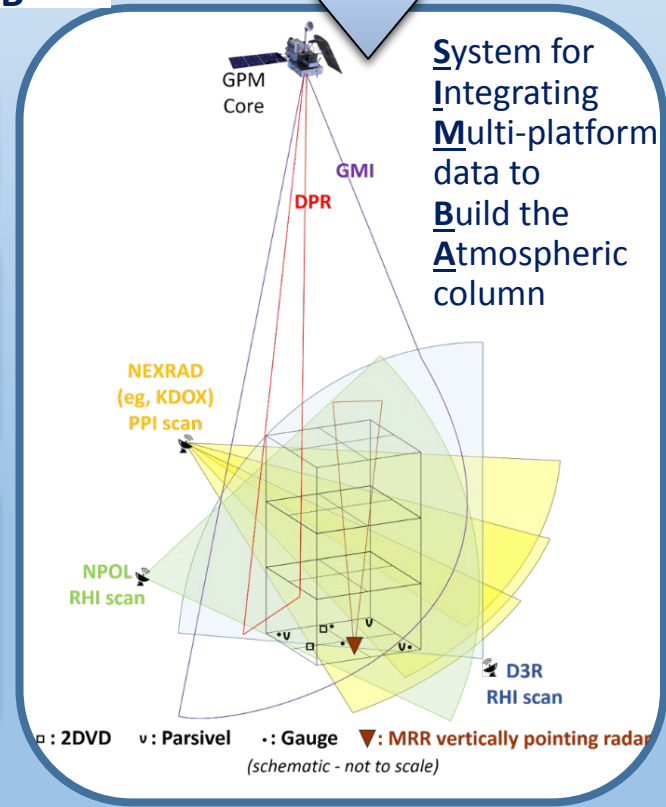
- ARs with unblocked terrain-normal component flow: $WS, Fr > 1.3$ (Hunzinger 2018/Petersen et al. 2018)
- 6 AR cases, 8 GPM OPs
 - 13 Nov 03-00 UTC (20%)
 - **17 Nov 10-21UTC (10%)**
 - **3 Dec 14-00 UTC (10%)**
 - 6-7 Dec 00-02 UTC (25%)
 - 8-9 Dec 13-10 UTC (20%)
 - 17 Dec 08-00 UTC (15%)

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



(Wingo et al. 2018)



Methodology

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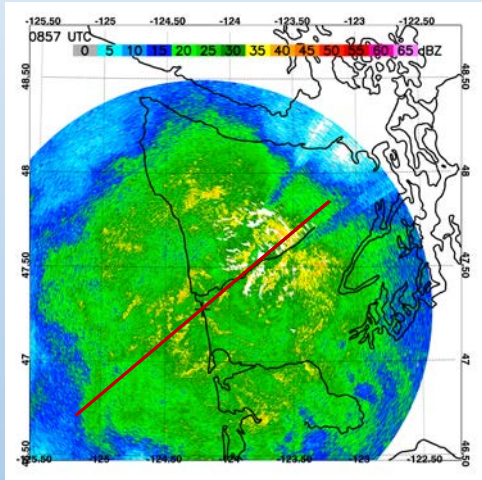
SIMBA Column Analysis

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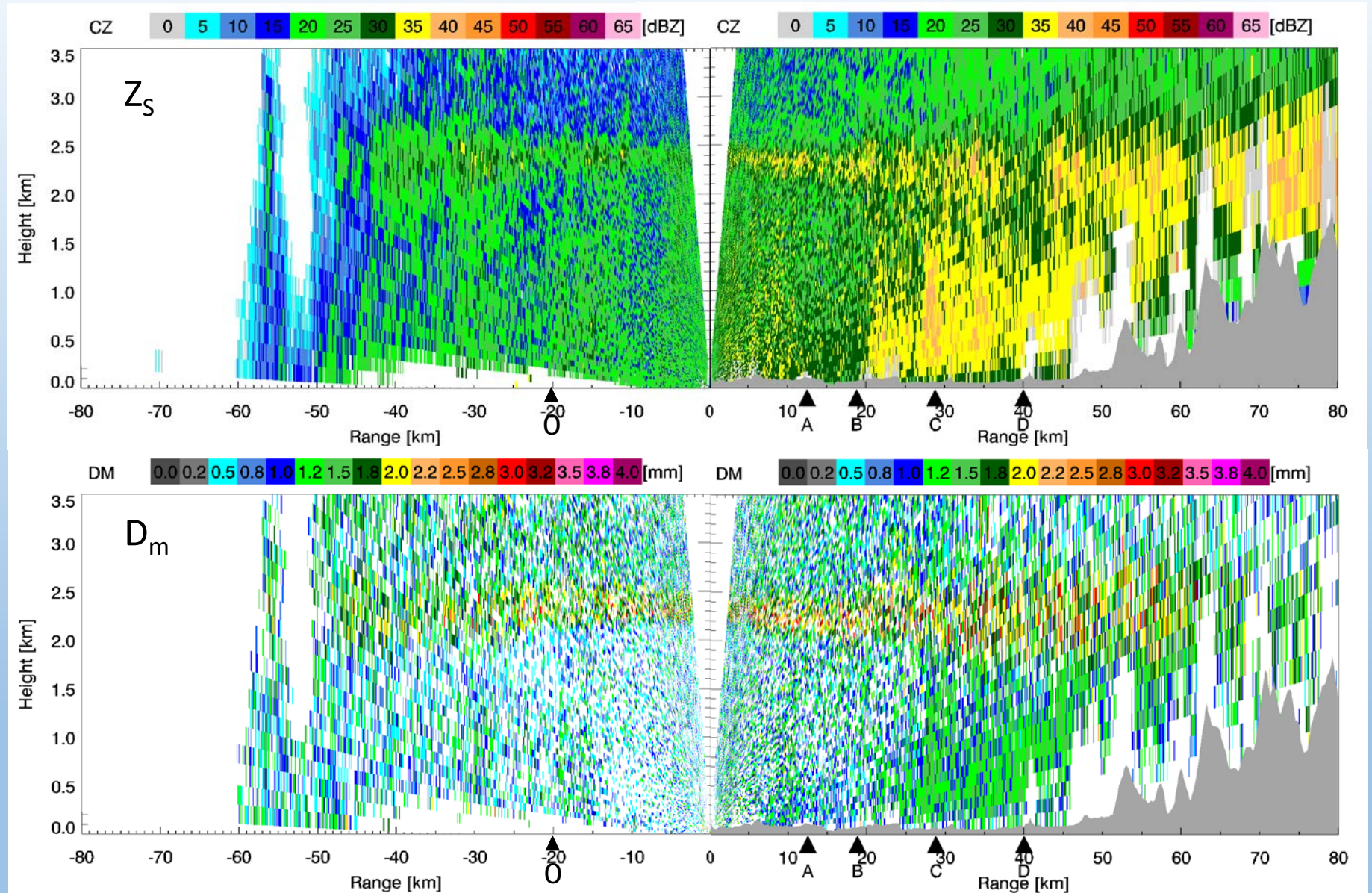
Vertical Slice Composites

- 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

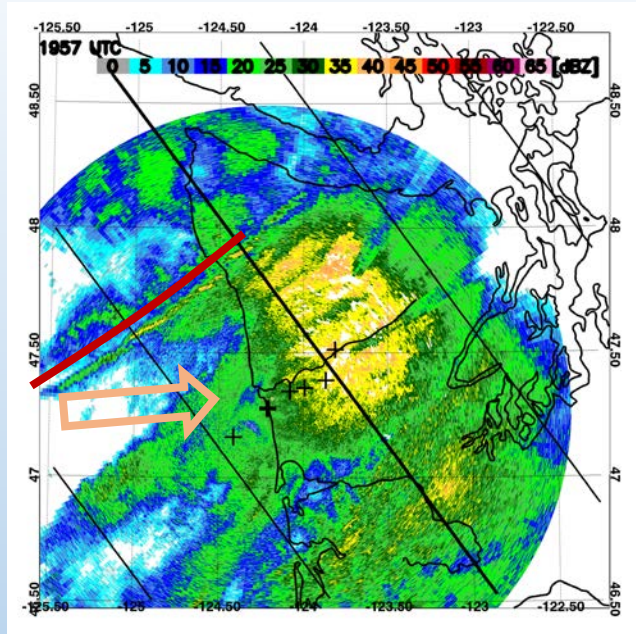
Composites over all ARs



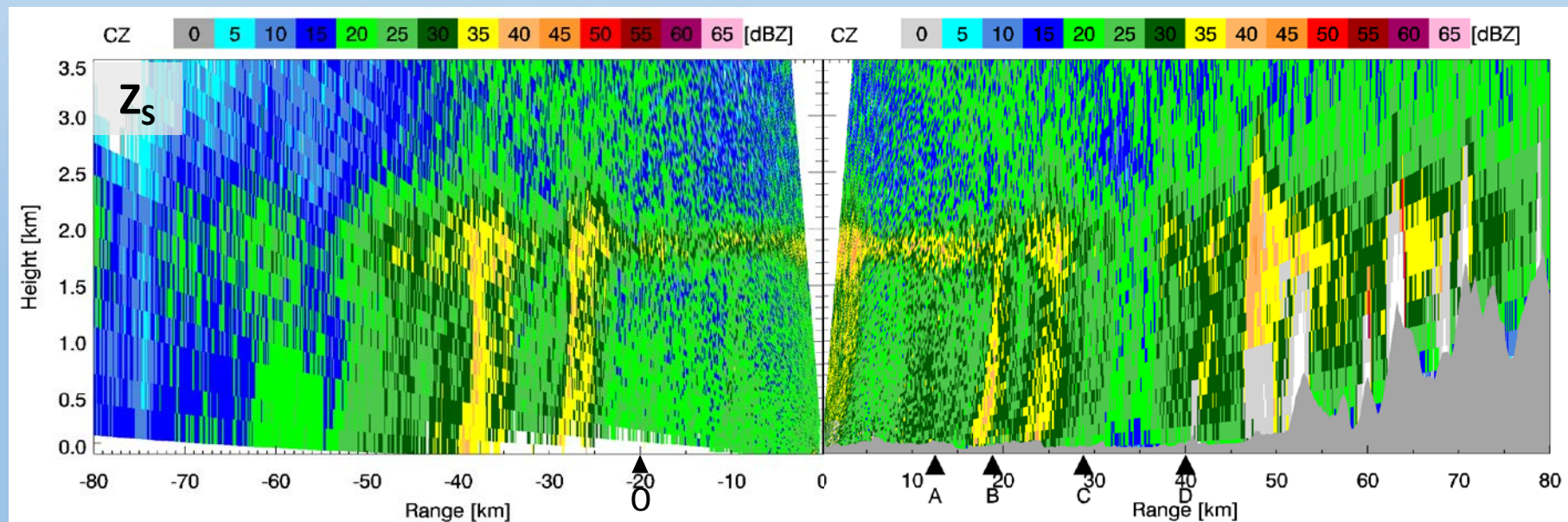
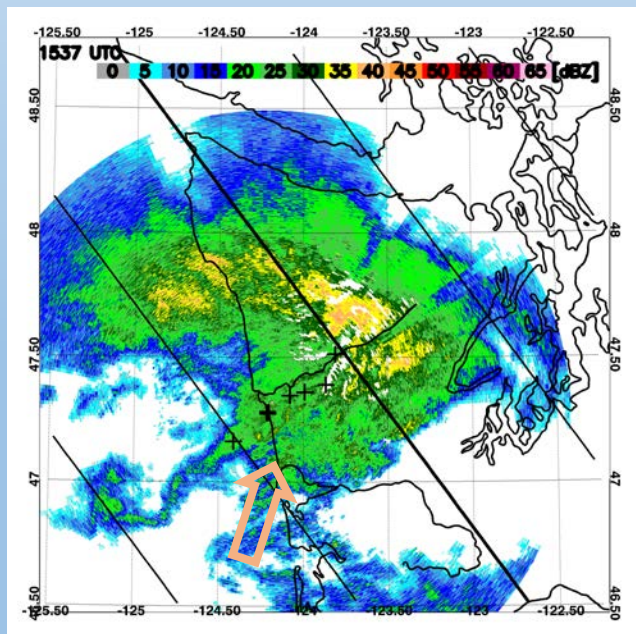
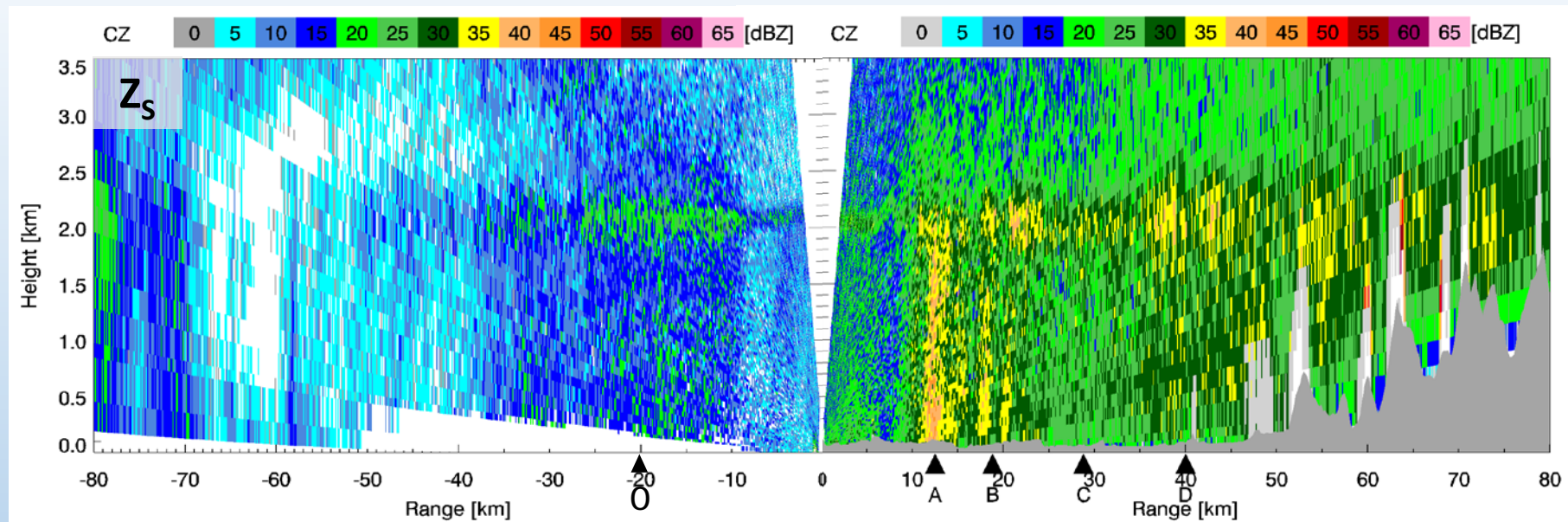
- Along NPOL RHI approaching, through Quinault River Valley
- Terrain, orographic enhancements



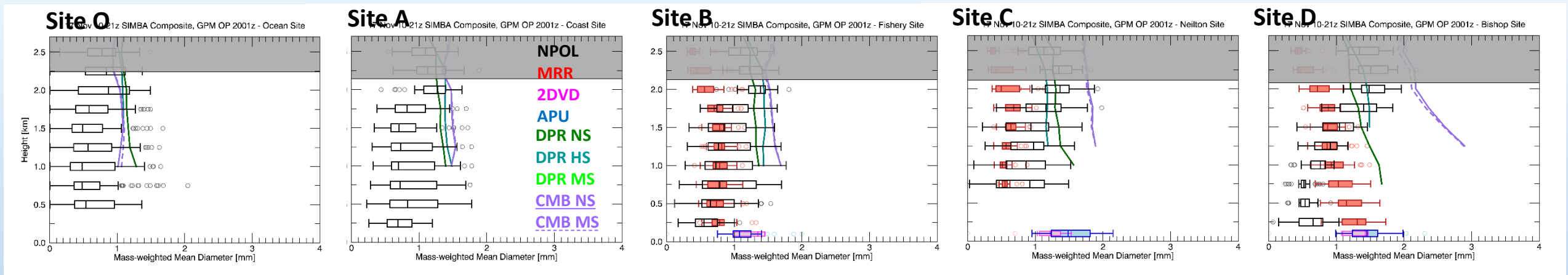
17 November 2015 10-21 UTC



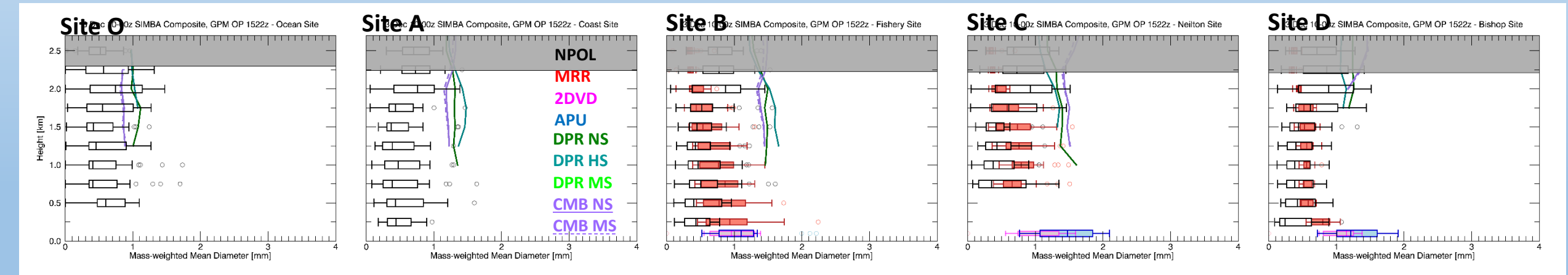
Z_s – NPOL Composites



3 December 2015 14-00 UTC



- **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...

• 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

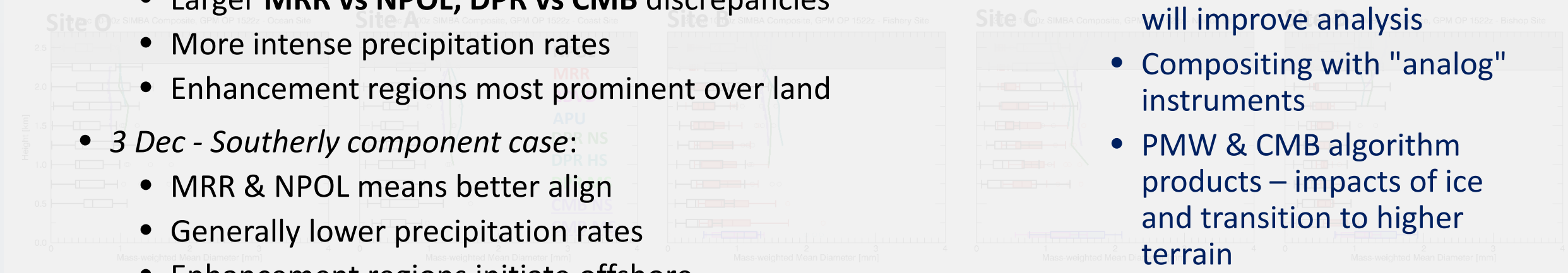
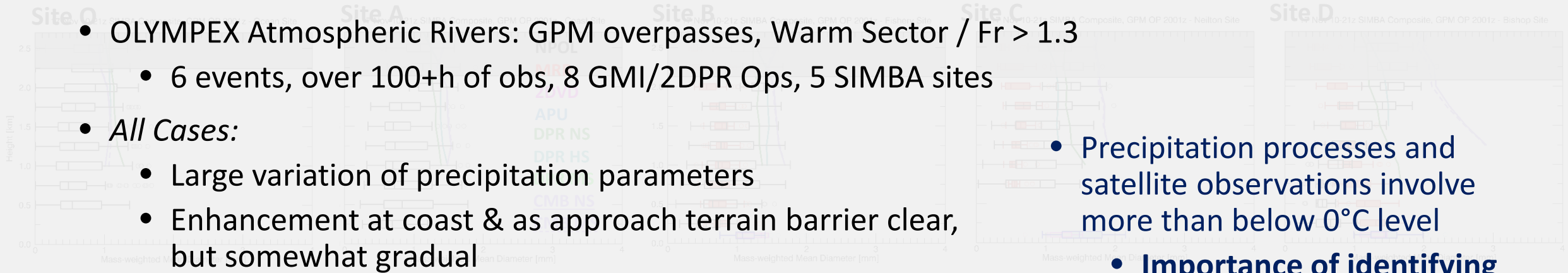
- Precipitation processes and satellite observations involve more than below 0°C level

- **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

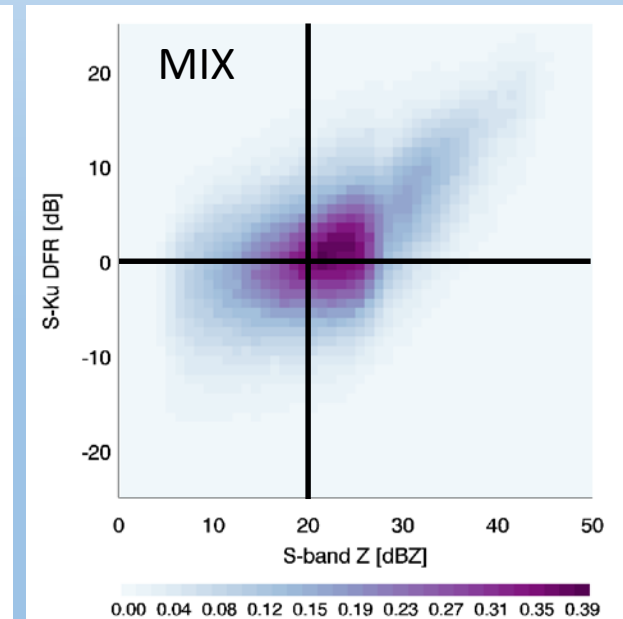
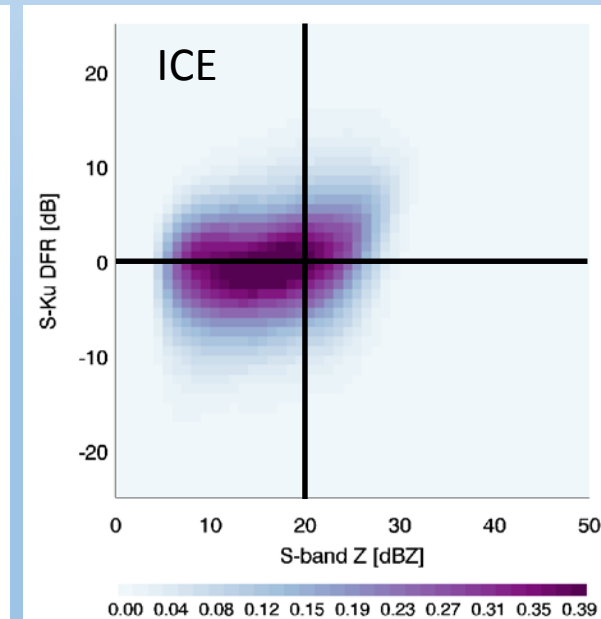
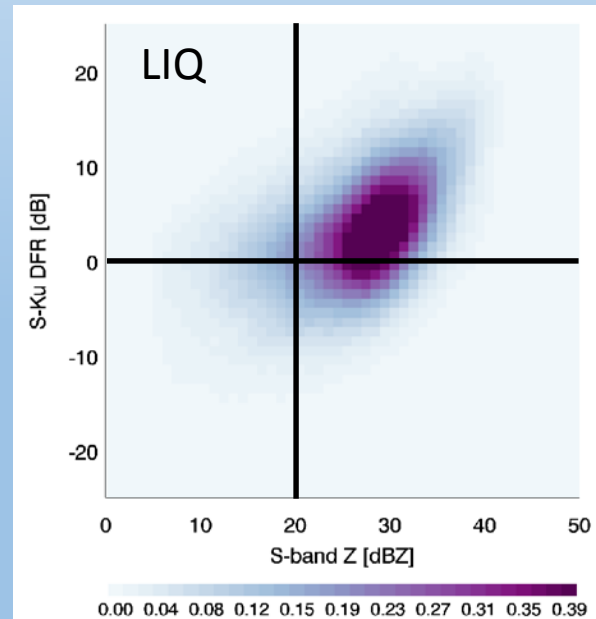
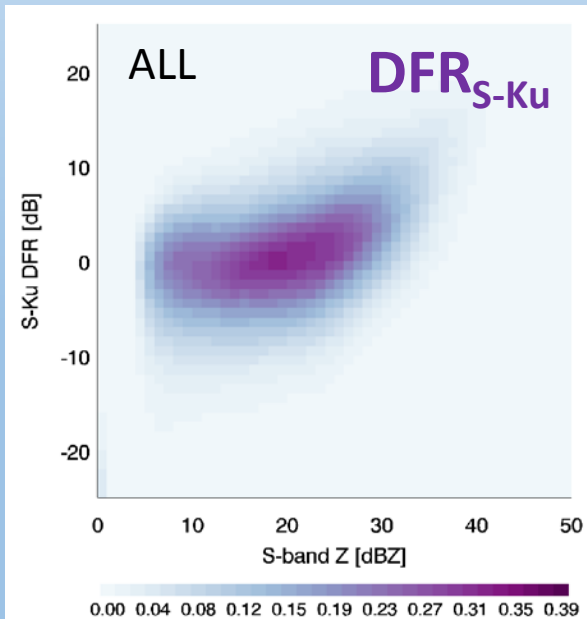
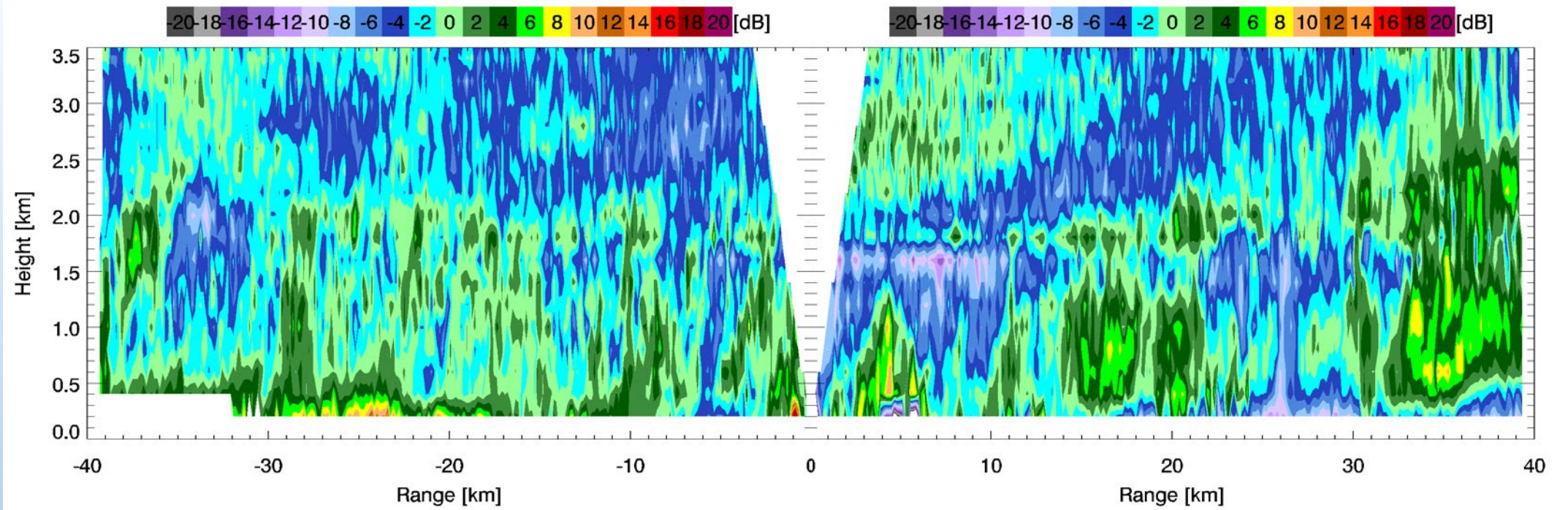


• DPR & CMB exceed ground-based IQR at all sites

• MRR vs. NPOL less discrepancy – flow orientation...

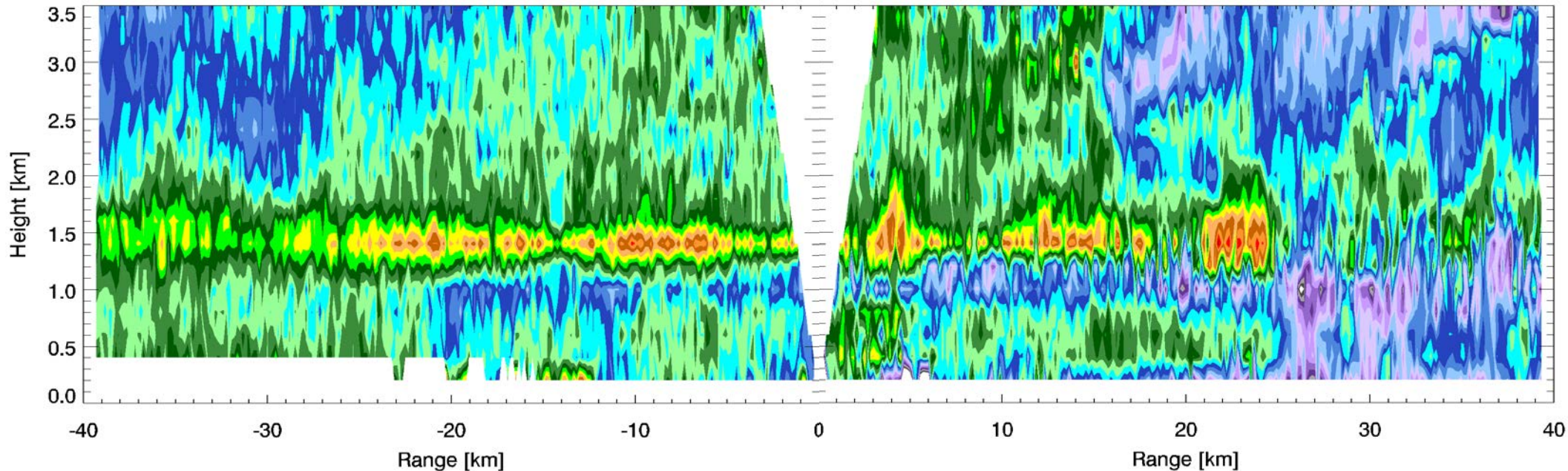
DFR_{S-Ku} All ARs

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



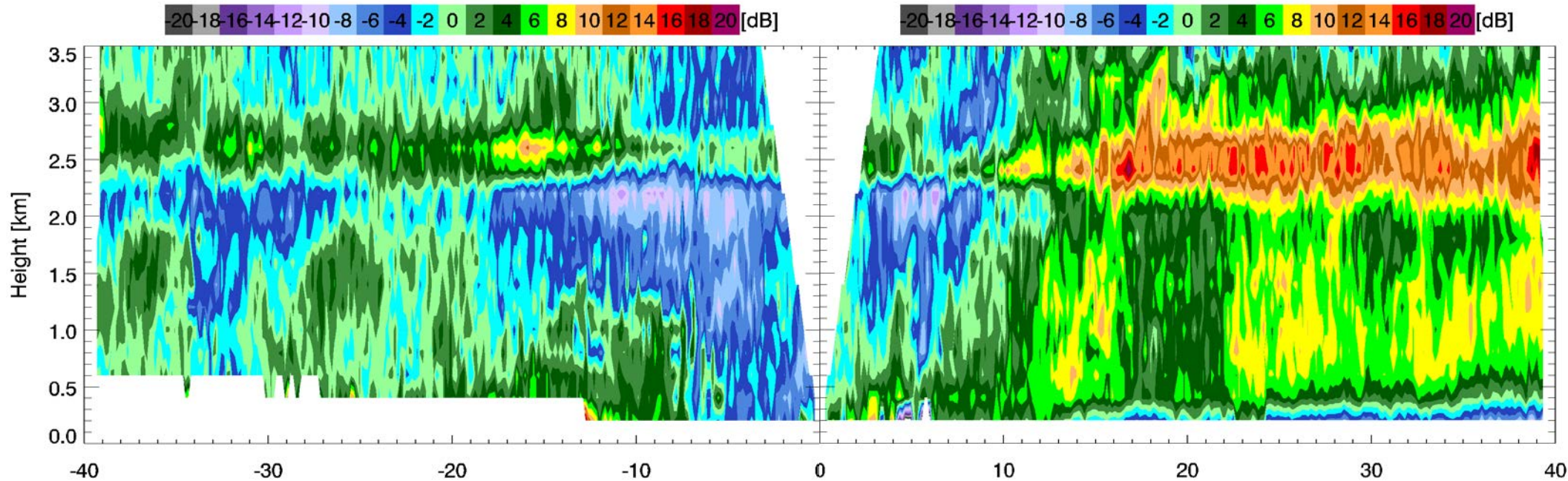
DFR_{S-Ku} 2 Events

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



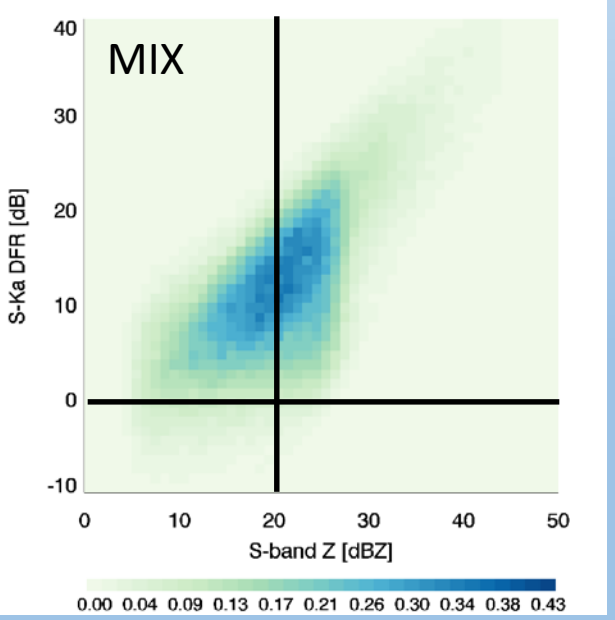
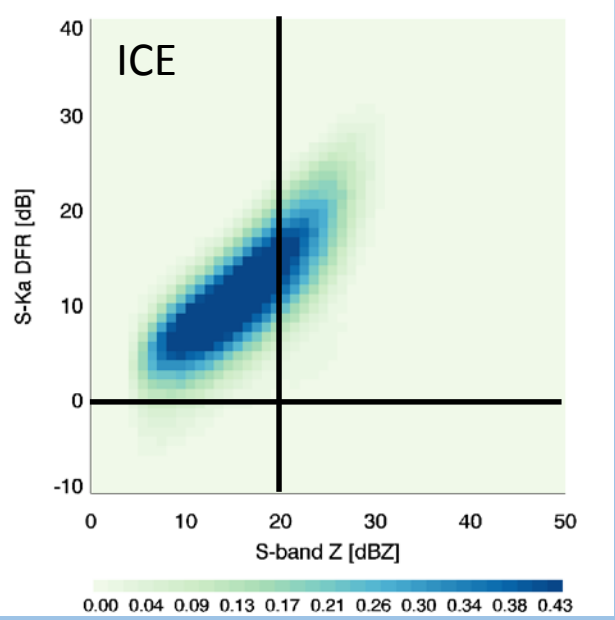
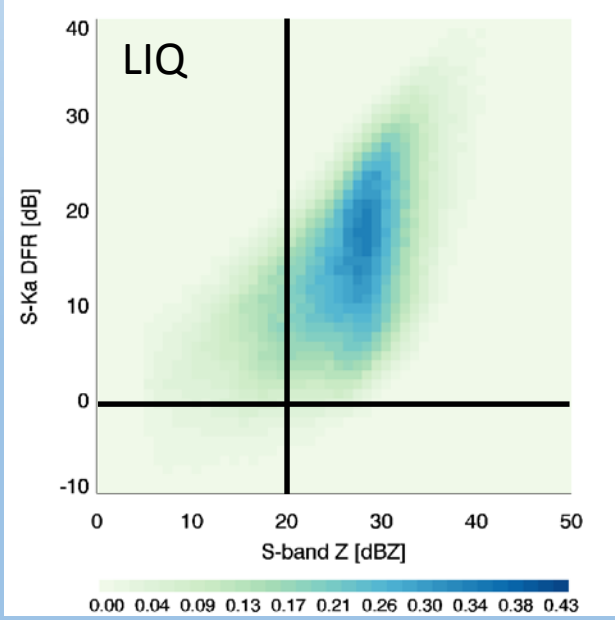
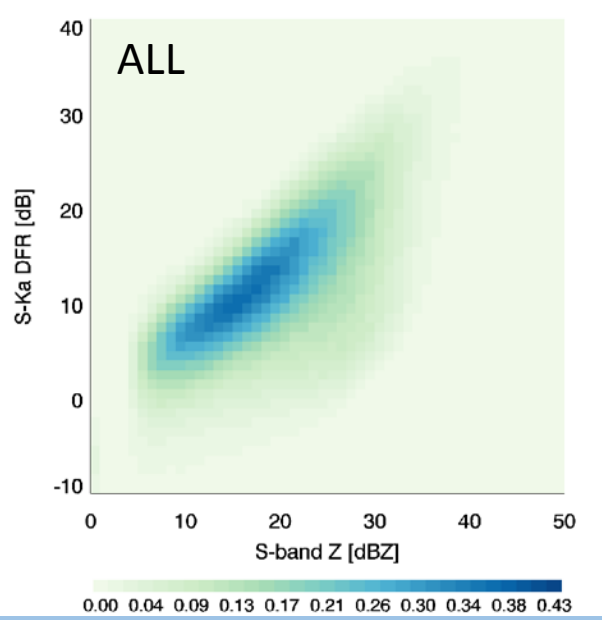
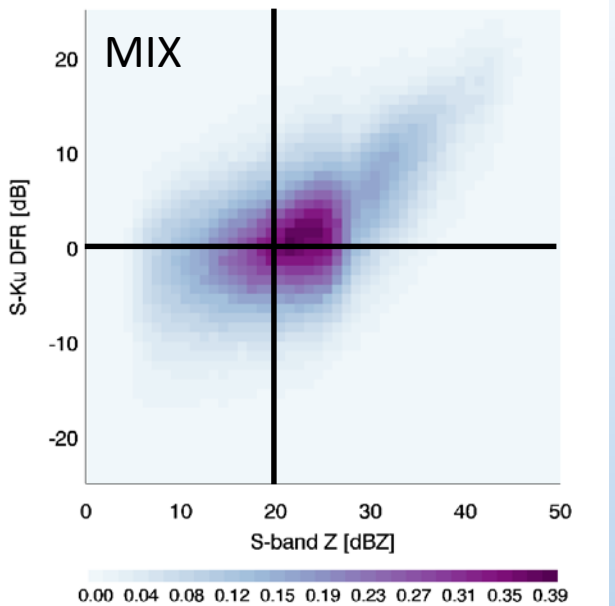
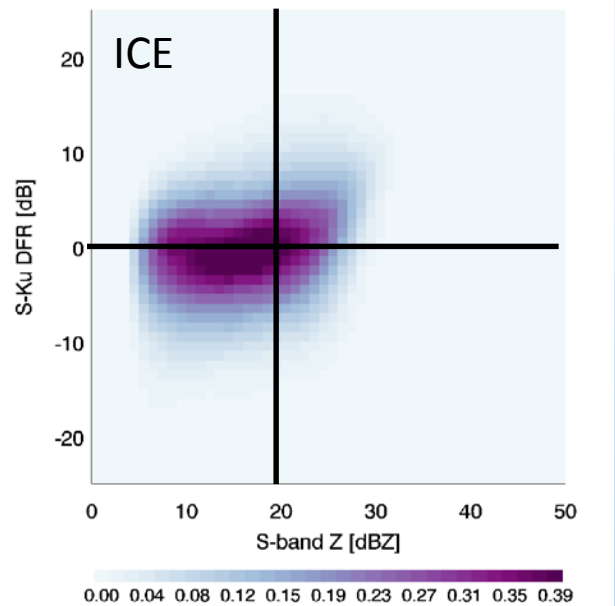
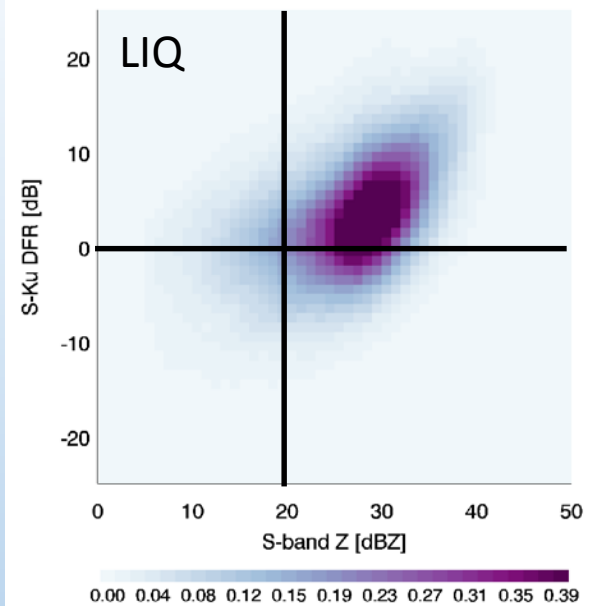
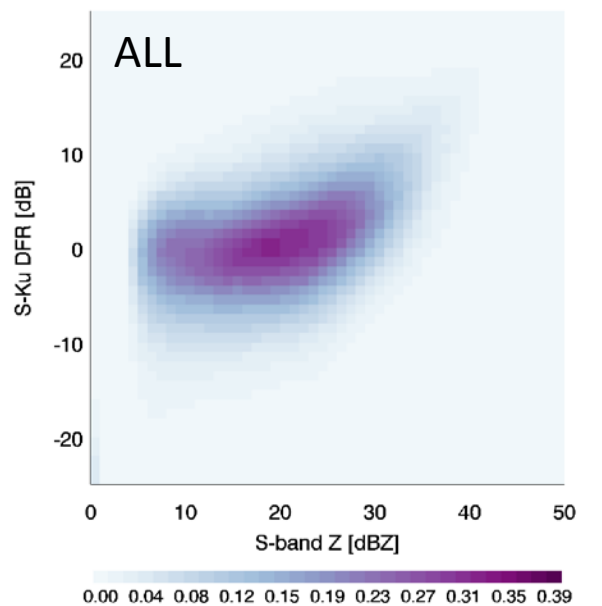
3 December 2015 14-00 UTC

- More ocean-side variation in westerly flow case
- DFR layering complexity increases as approach terrain



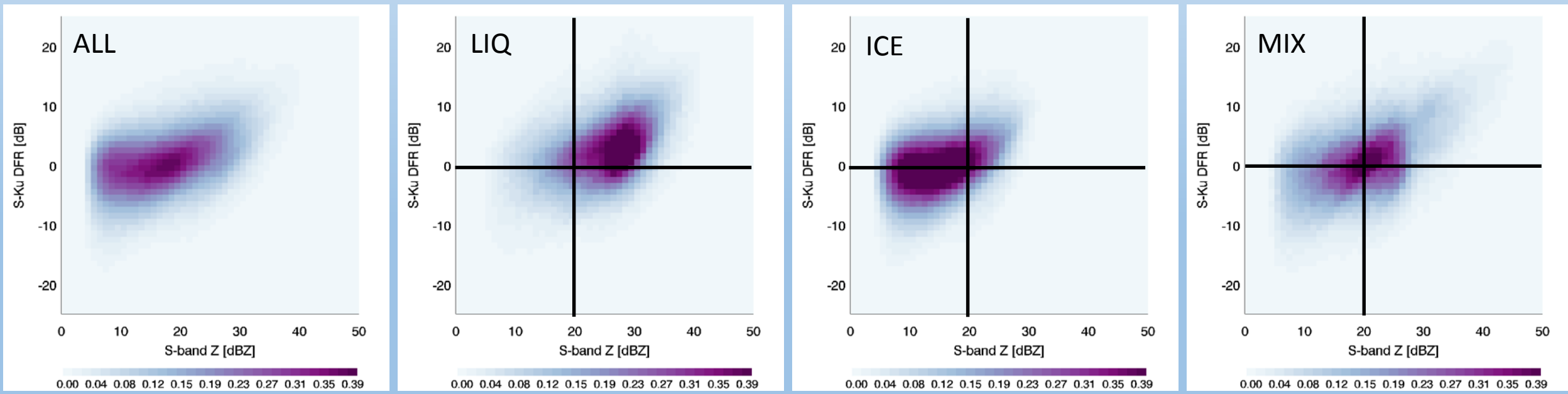
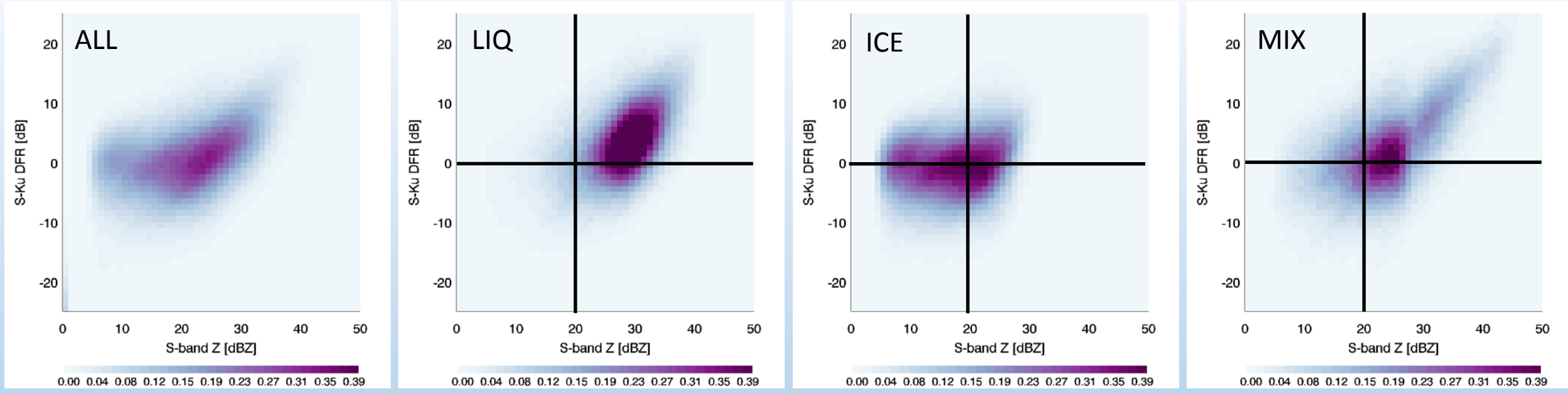
17 November 2015 10-21 UTC

DFR_{S-Ku} ALL ARs Land + Ocean



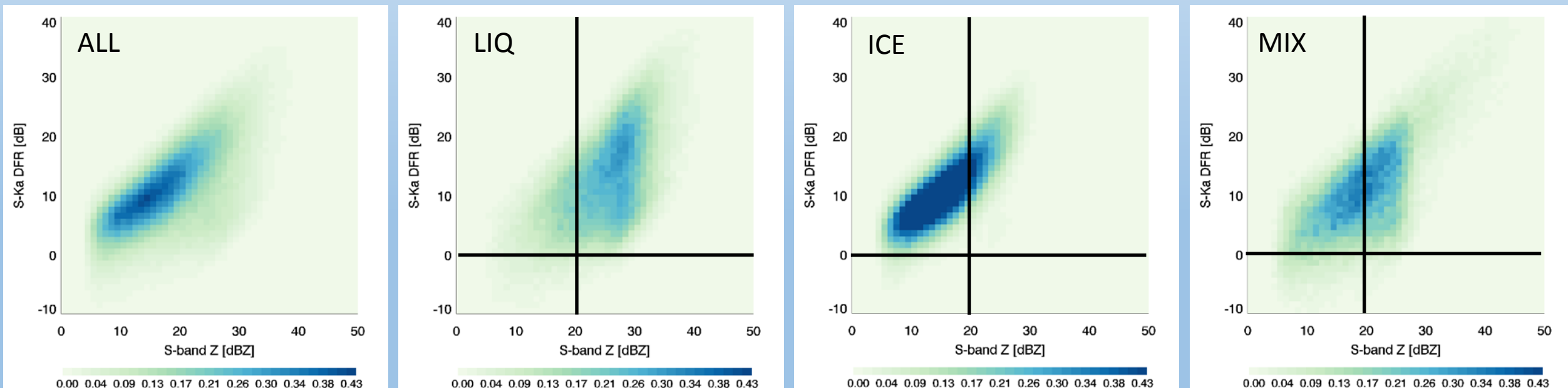
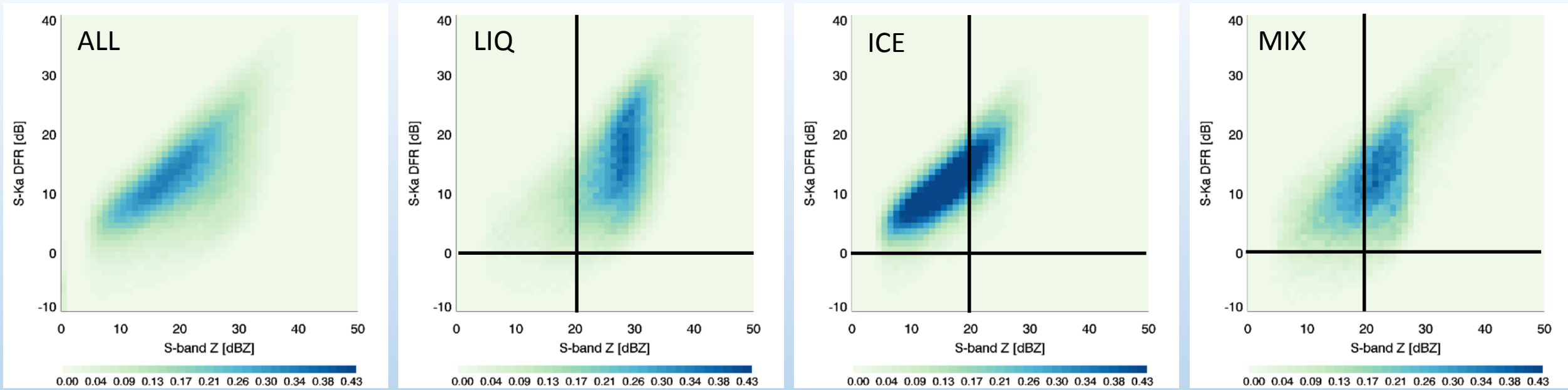
DFR_{S-Ka} ALL ARs Land + Ocean

DFR_{S-Ku} ALL ARs Land Side Scans



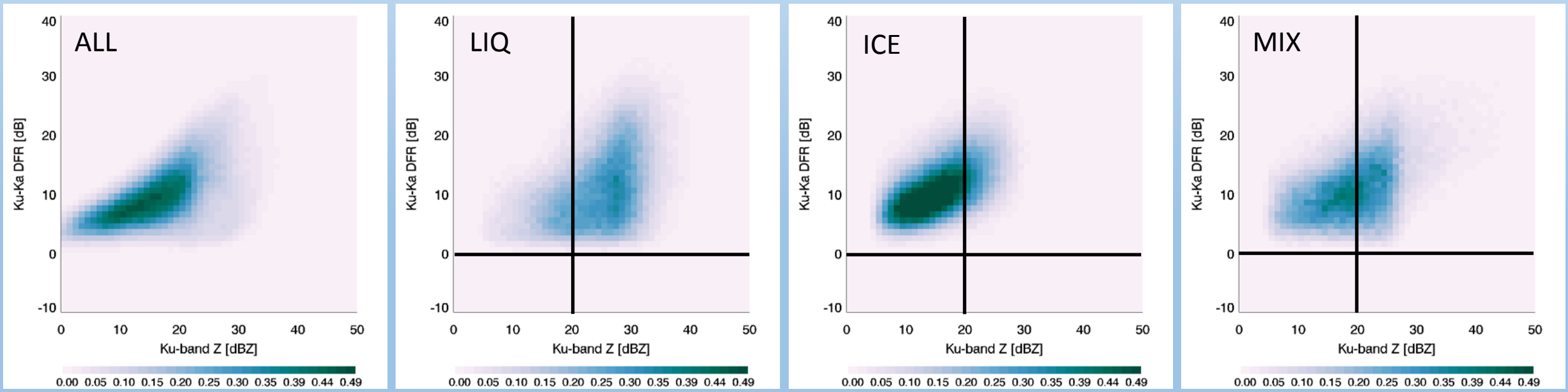
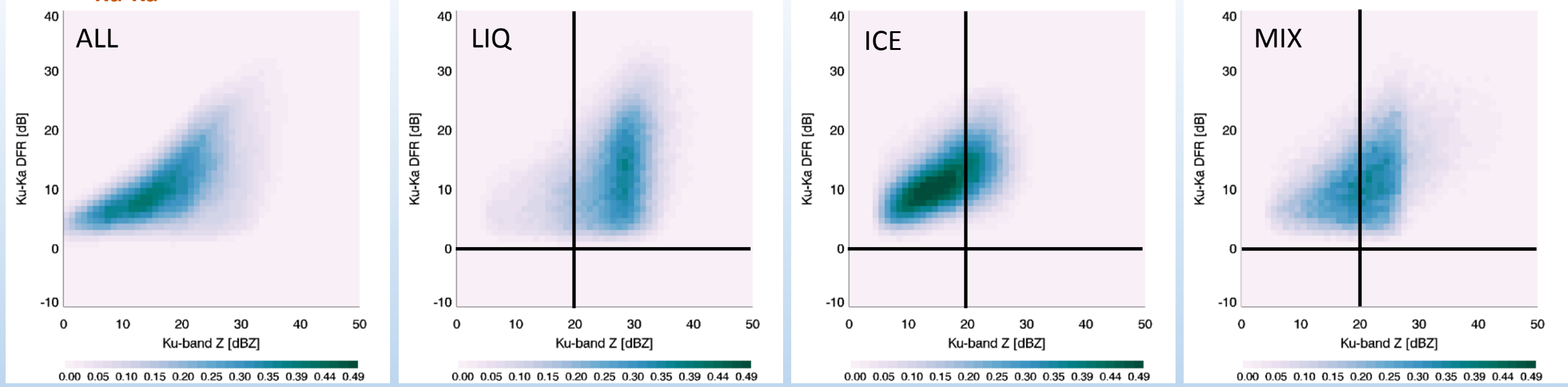
DFR_{S-Ku} ALL ARs Ocean Side Scans

DFR_{S-Ka} ALL ARs Land Side Scans



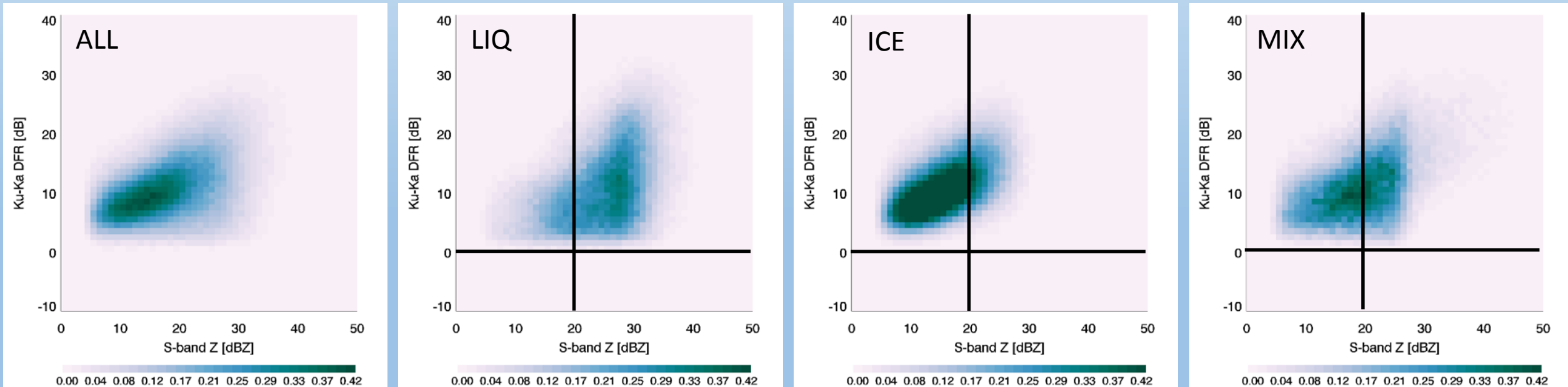
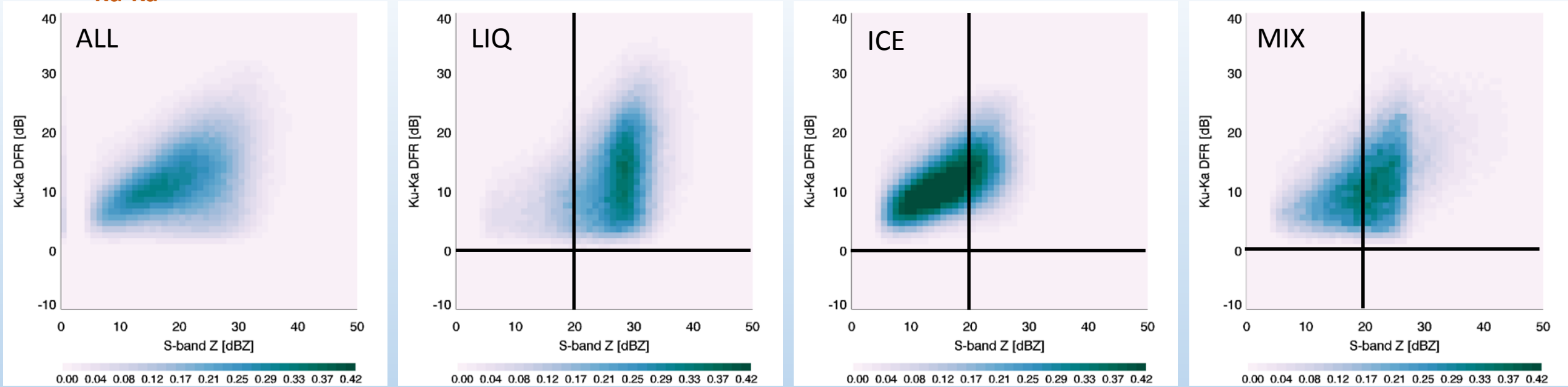
DFR_{S-Ka} ALL ARs Ocean Side Scans

DFR_{Ku-Ka} ALL ARs Land Side Scans



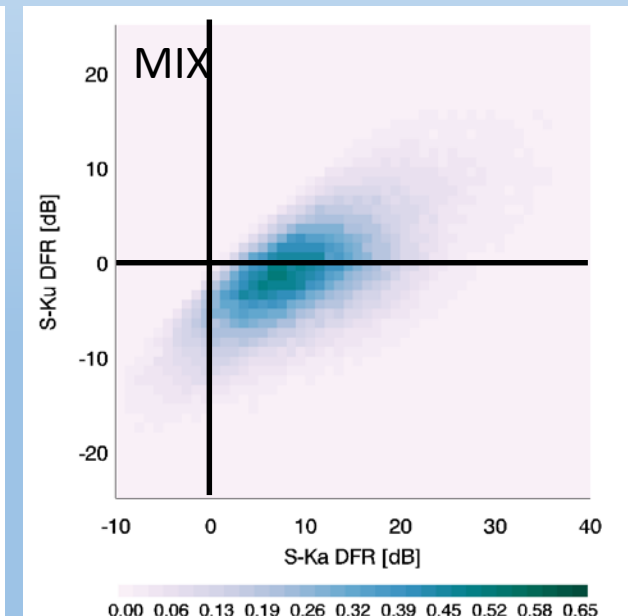
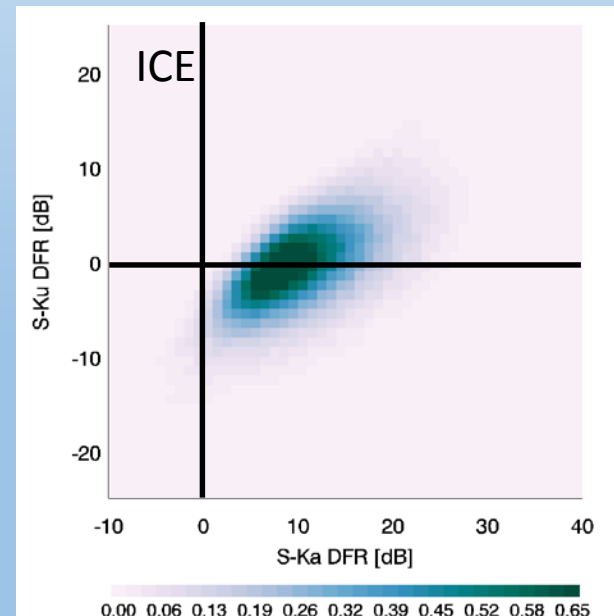
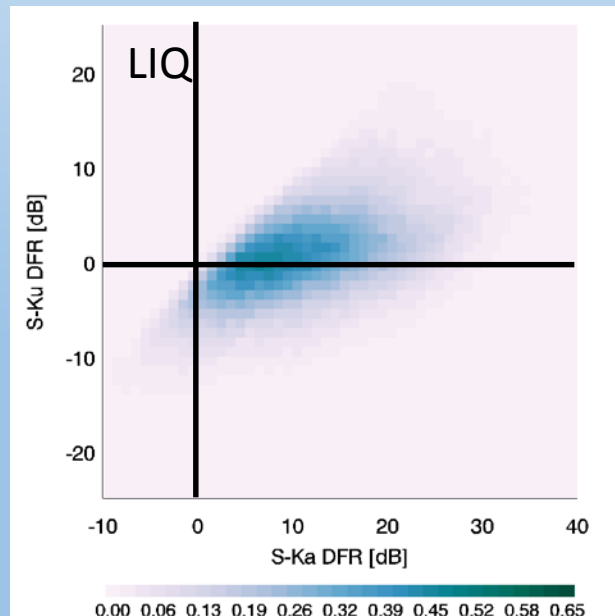
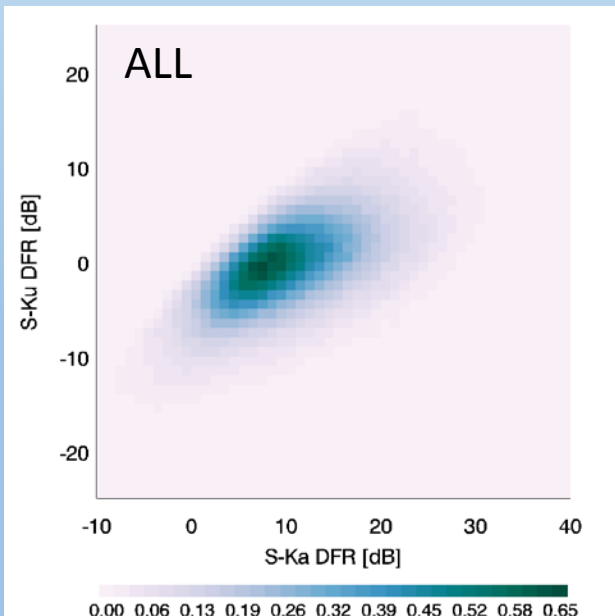
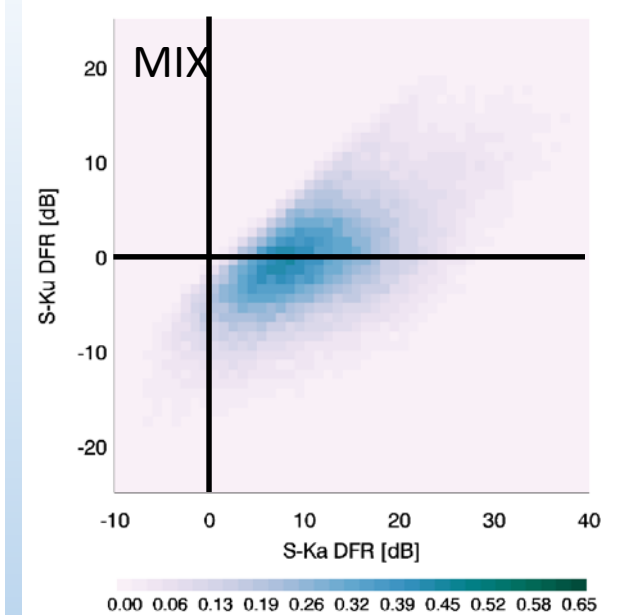
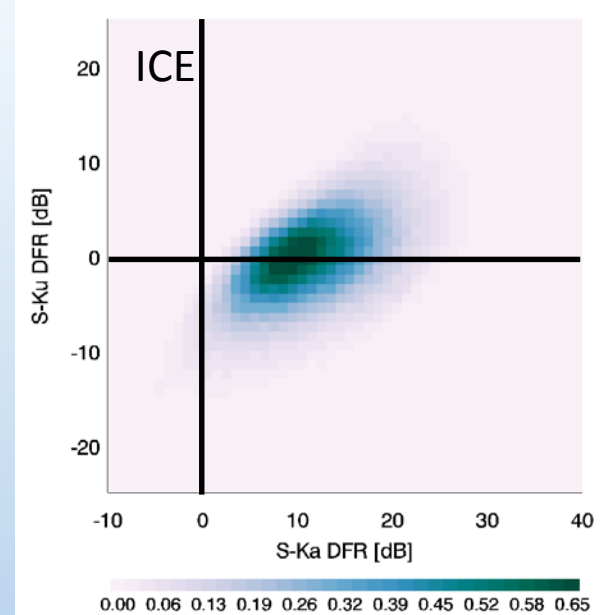
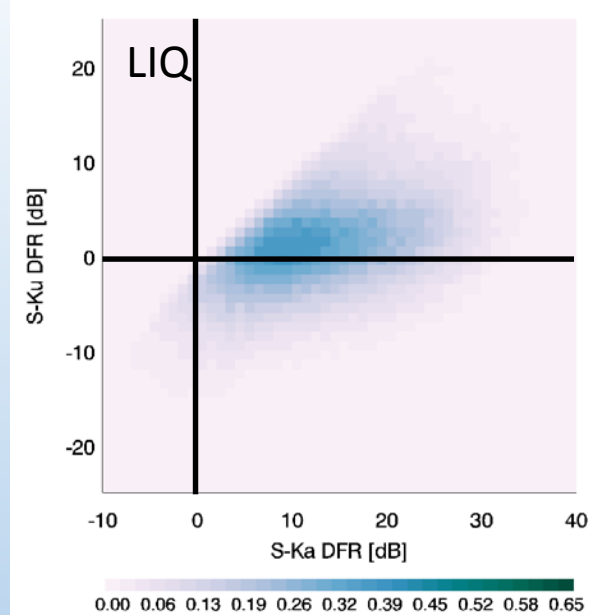
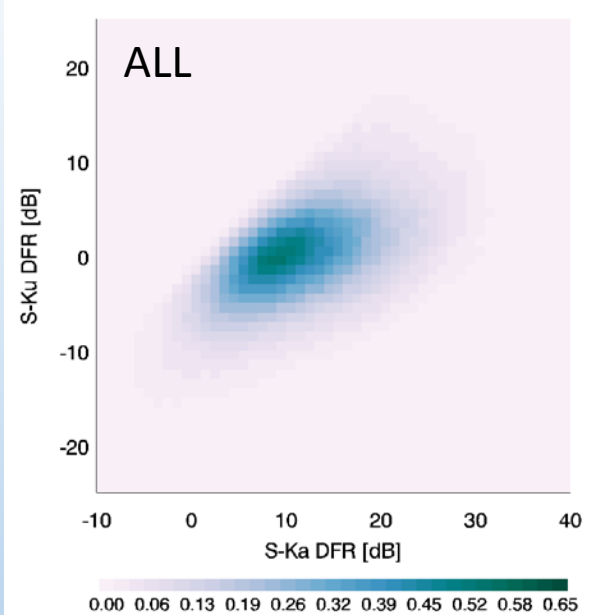
DFR_{Ku-Ka} ALL ARs Ocean Side Scans

DFR_{Ku-Ka} ALL ARs Land Side Scans



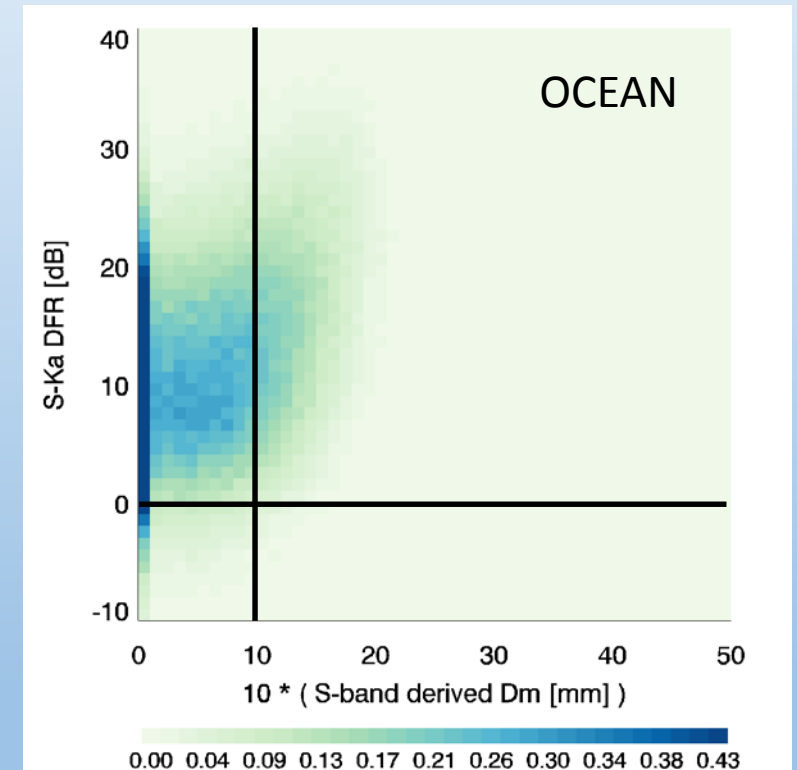
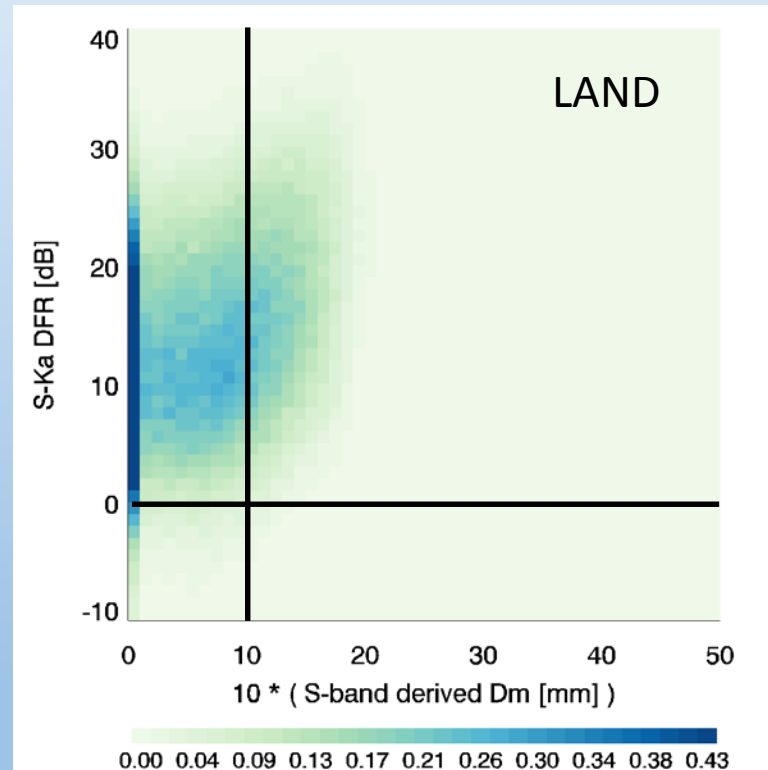
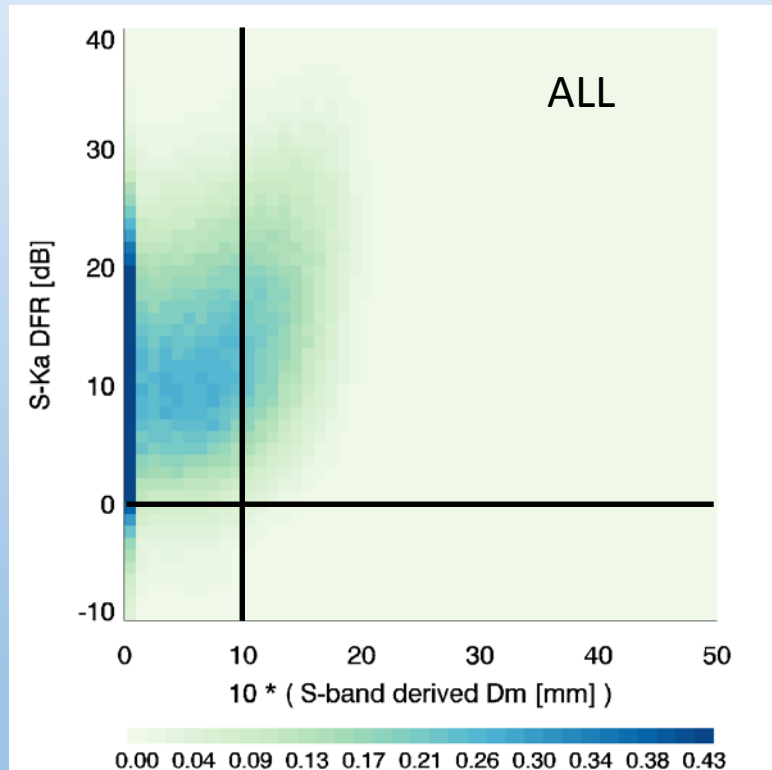
DFR_{Ku-Ka} ALL ARs Ocean Side Scans

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

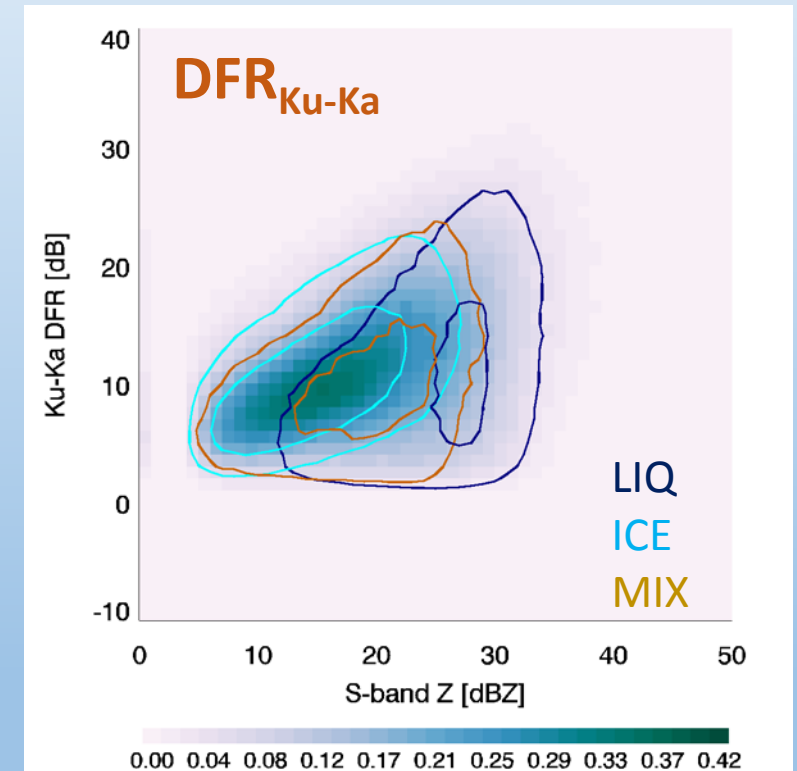
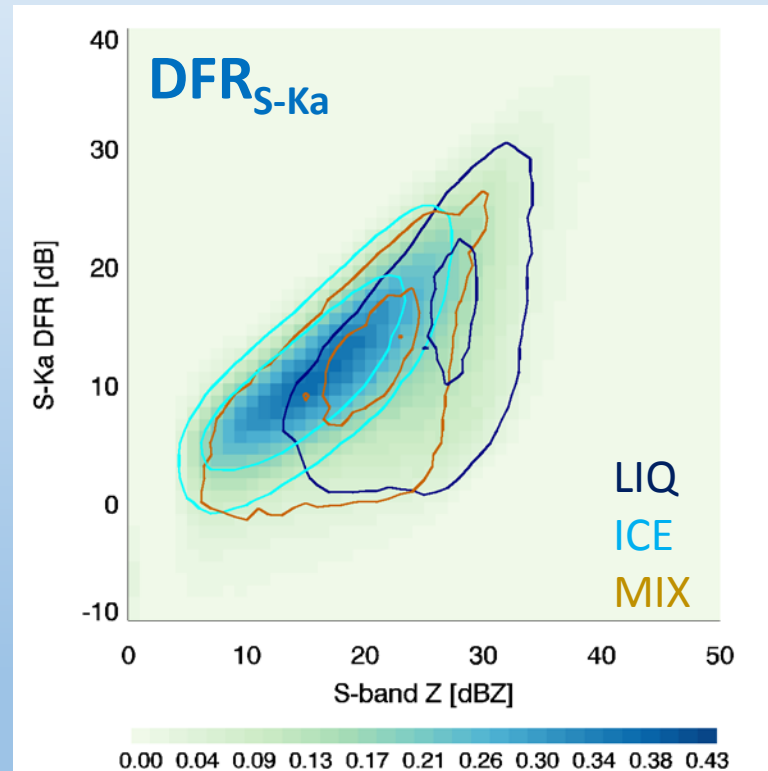
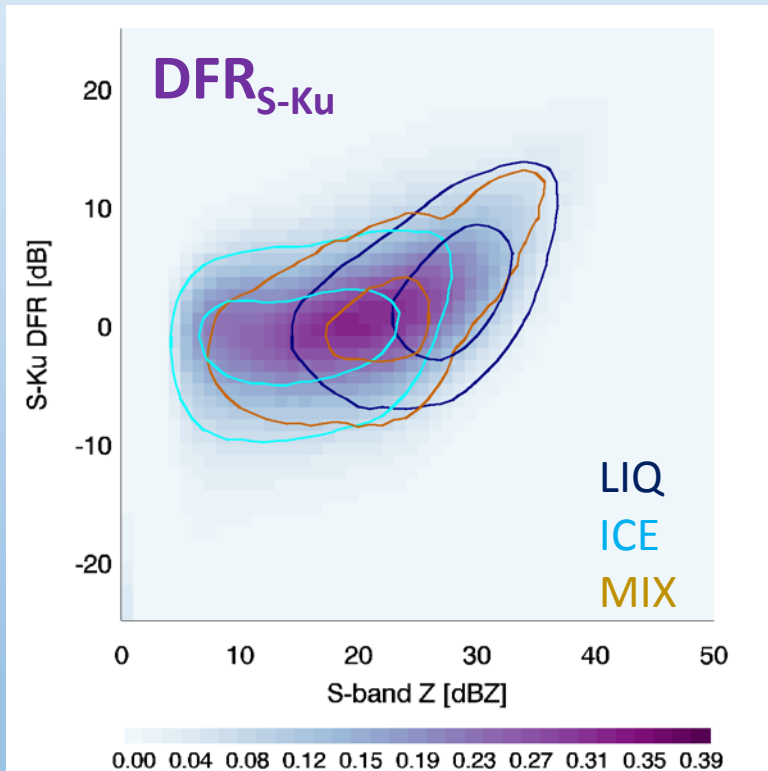


DFR_{S-Ku,S-Ka} ALL ARs Ocean Side Scans

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



ALL HID Types: Land + Ocean Scans

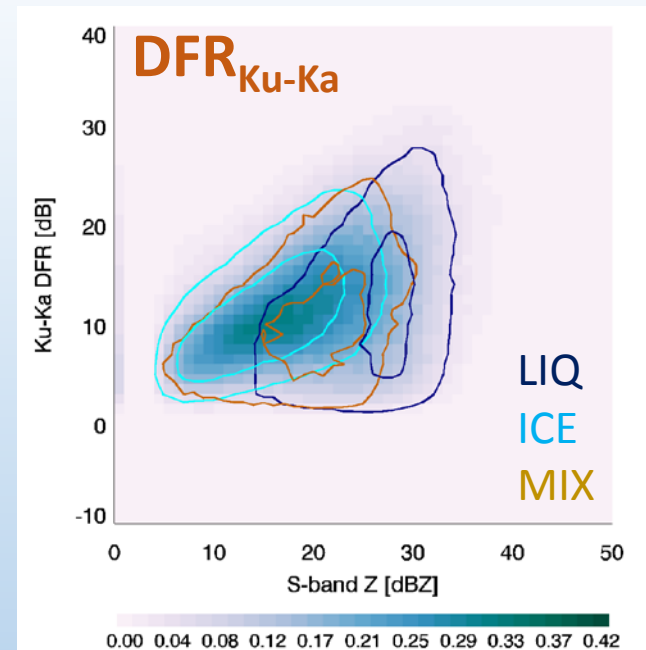
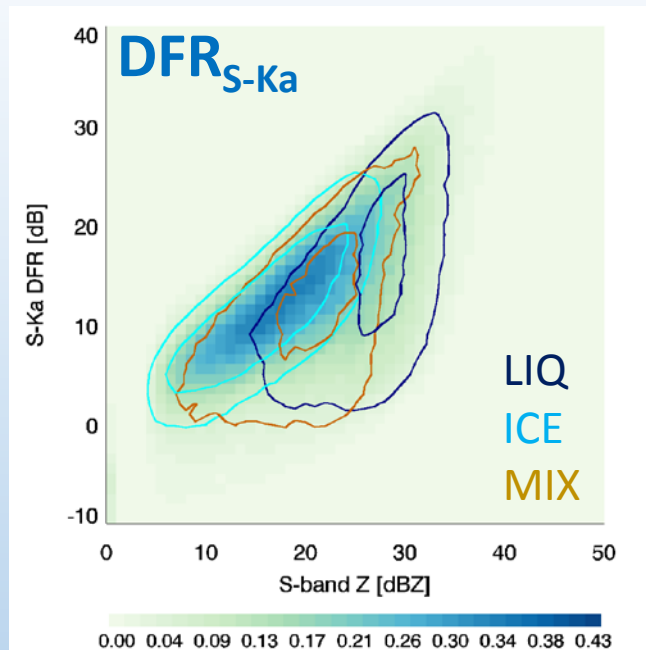
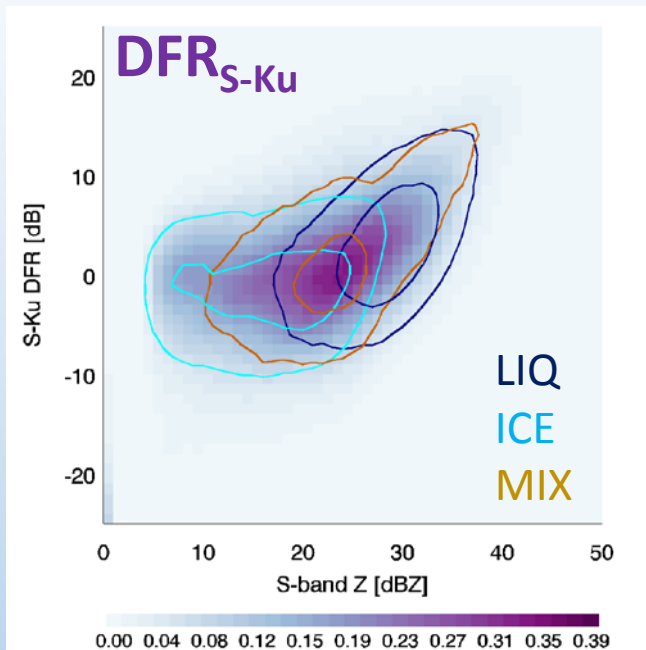


*Histograms include all HID phases

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

DFRs All ARs

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

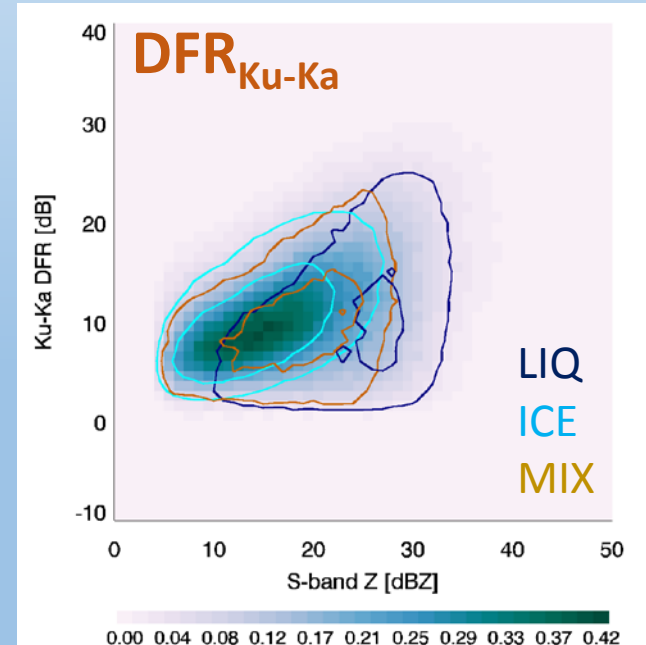
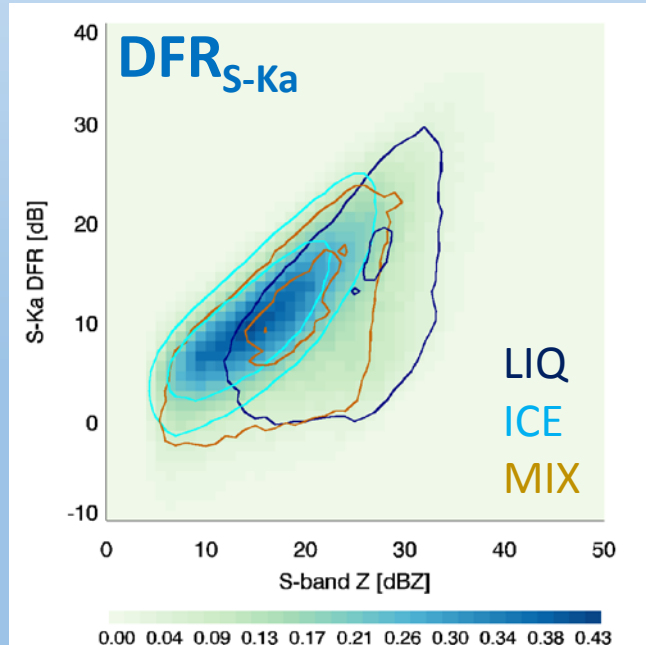
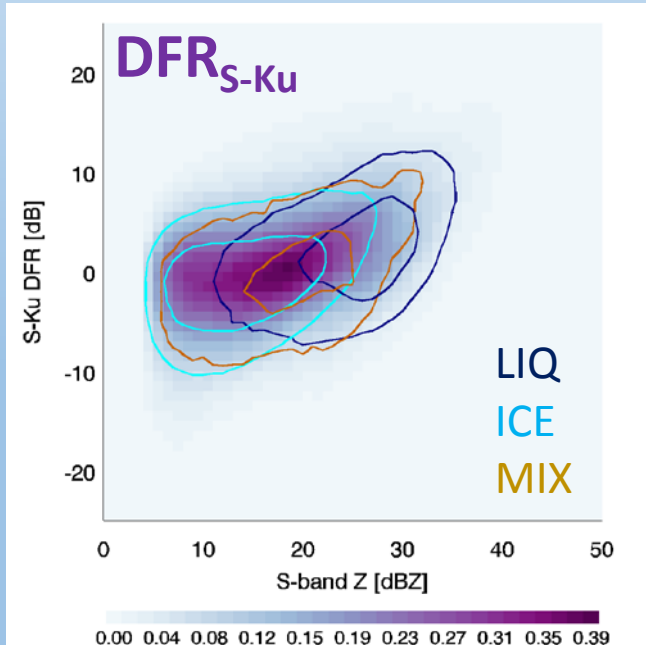


Land Scans

- 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

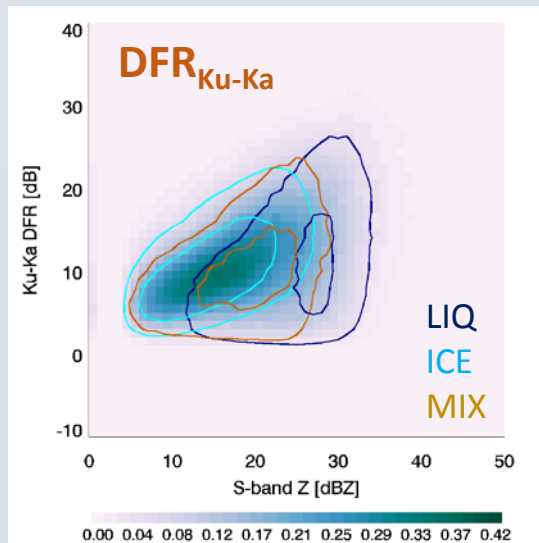
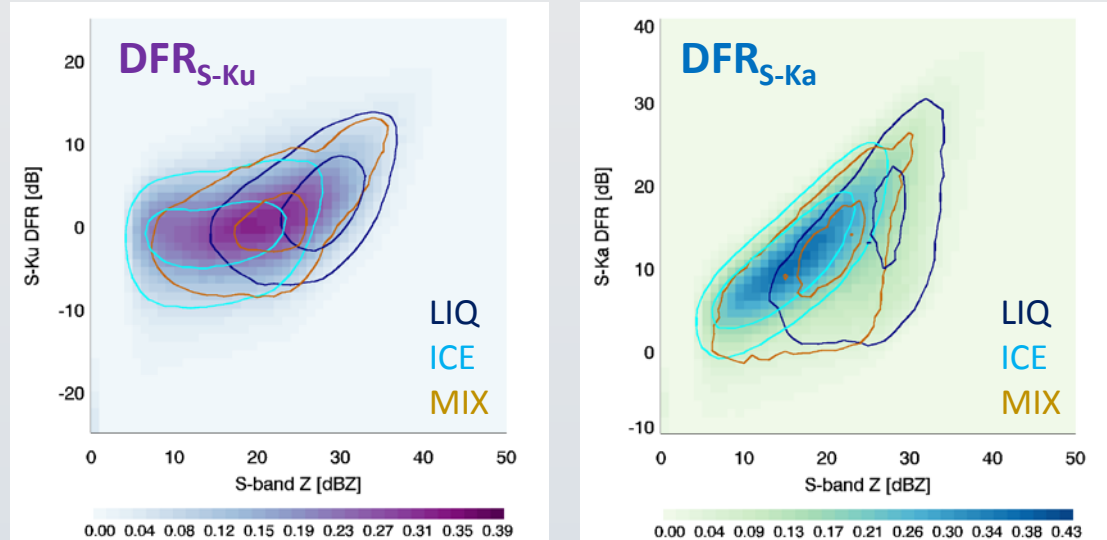


Ocean Scans

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-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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