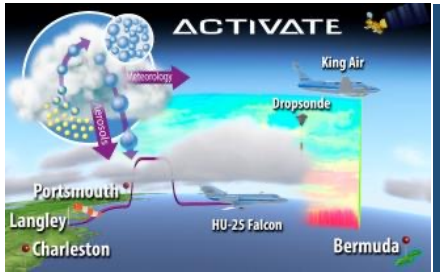

Cloud macro- and microphysics characterized from ASTER underflights during ACTIVATE

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13 November 2023 ■ STM Meeting ■ Tucson AZ

Introduction/Objectives

- ACTIVATE measurements provide opportunity to examine long-standing remote sensing retrieval issues for clouds smaller than conventional satellite imagery retrieval resolution (1km or bigger).

- ACTIVATE sampled six specifically chosen flights along the ASTER track (12 March 2020, 11 September 2020, 29 March 2021, 17 June 2021, 8 June 2022, and 10 June 2022). The cloud types encountered varied from sparse, optically thin and thick cumulus clouds to stratiform clouds.

- To characterize clouds, use high resolution ASTER (15m pixel resolution) data, ACTIVATE in-situ N_d as ground truth, RSP N_d , and MODIS cloud retrievals.

- Examine cloud mixing processes at cloud edges. How well can remote sensing do?

Data Used

- The Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) radiances

  - Cloud mask computation Werner et al (2016) & Meislinger et al (2019) https://github.com/atmtools/typhon/blob/master/typhon/cloudmask/ uses visible bands 1,2, 3N (15m) 0.52 - 0.86 μm range and 11 micron (90m) to discriminate surface.

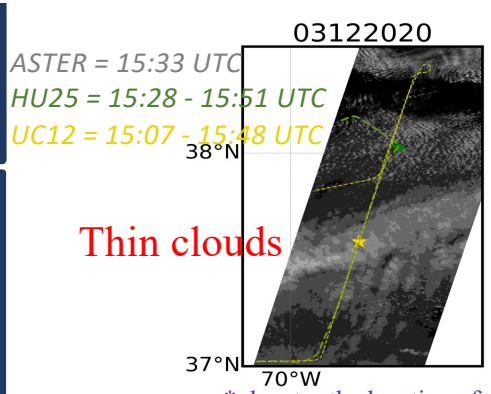
  - cloud sizes from cloud mask

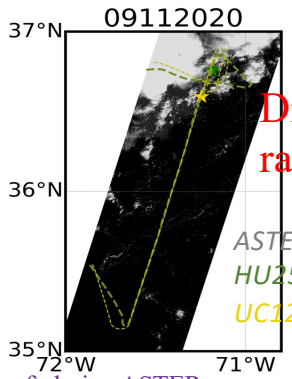
  - No ASTER microphysical retrievals (loss of SW-IR bands)

- MODIS 1km cloud properties and $Nd \propto \tau^{1/2}/r_e^{5/2}$ *(Painemal et al., 2012)*
- Research Scanning Polarimeter (RSP) cloud optical depth, and droplet effective radius data based on polarized cloud bow retrieval at 0.863 micron=> calculated Nd
- Fast Cloud Droplet Probe (FCDP) re, Nd [3-50 μm];
- CDP [2-50 μm]; FCDP+2DS [3um – 1460um]
- Large DMT – CCN and LAS Aerosol – $N_{a(100\text{-}1000nm)}$
- HSRL-2 Cloud top height

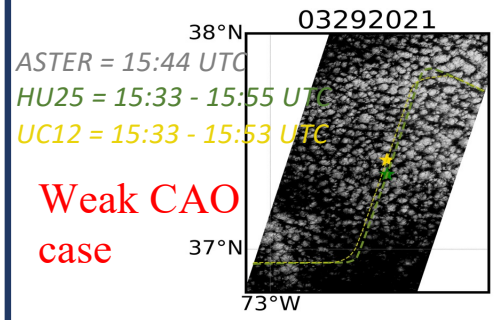
All Six cases: ASTER radiances + ACTIVATE flight tracks

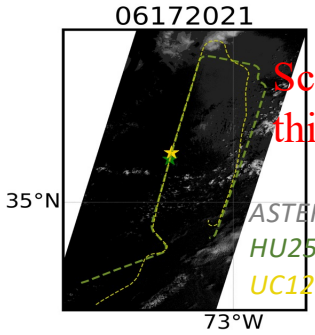
- 12 March 2020: Thin clouds with LWP < 20 gm^{-2}
- 11 September 2020: Thicker clouds over North with LWP > 100 gm^{-2}
- 29 March 2021: Stratiform clouds associated with weak CAO event.
- 17 June 2021: Scattered thin clouds with LWP < 20 gm^{-2}
- 8 June 2022: Thicker clouds over North with LWP > 400 gm^{-2}
- 10 June 2022: Scattered clouds which are also optically thicker.

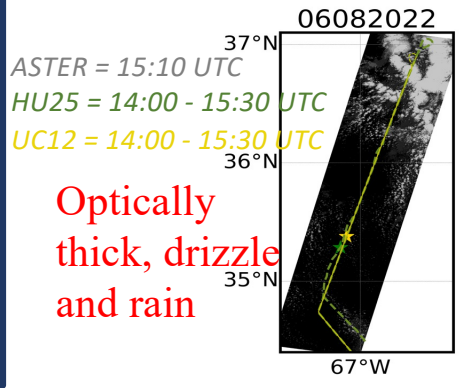


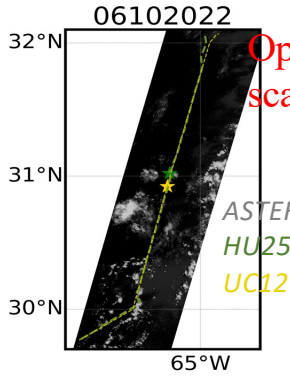


* denotes the location of aircraft during ASTER overpass







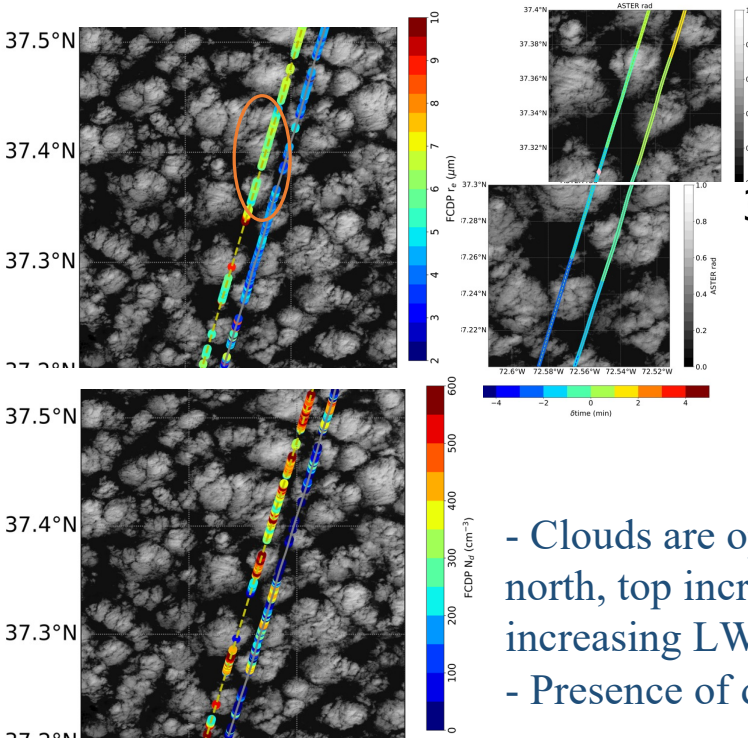


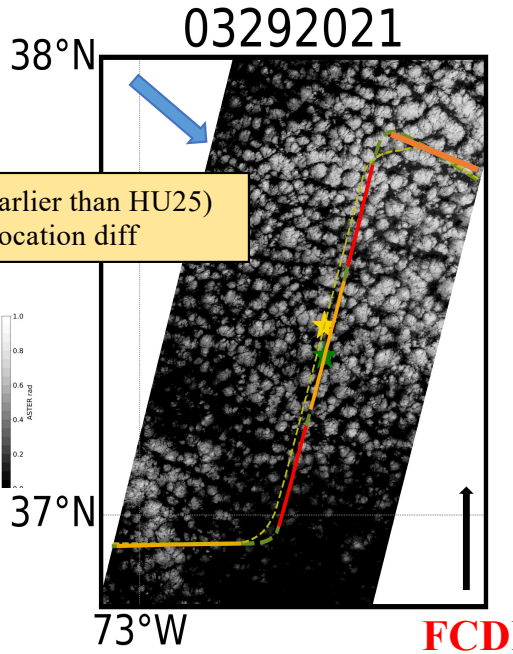
An overview of clouds on 03-29-2021 over ACTIVATE domain

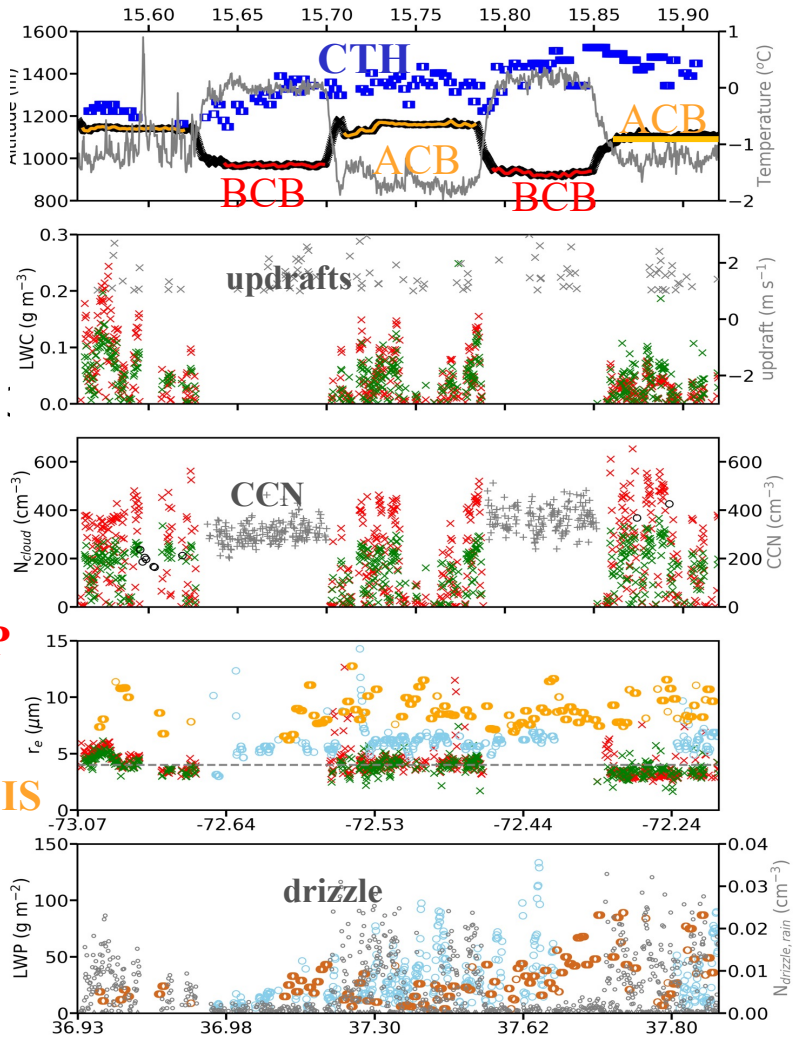
- ASTER pass at 15:44:16 (18sec)
- South to North aircraft sampling
HU25_tme = [15:33:36 - 15:55:12];
UC12_tme = [15:33:18 - 15:53:24]

(UC12 is ~70 secs earlier than HU25)
- distance of ~1km location diff

Wind speed ~ 12 – 16 m/s
Wind direction ~ 300 – 310°



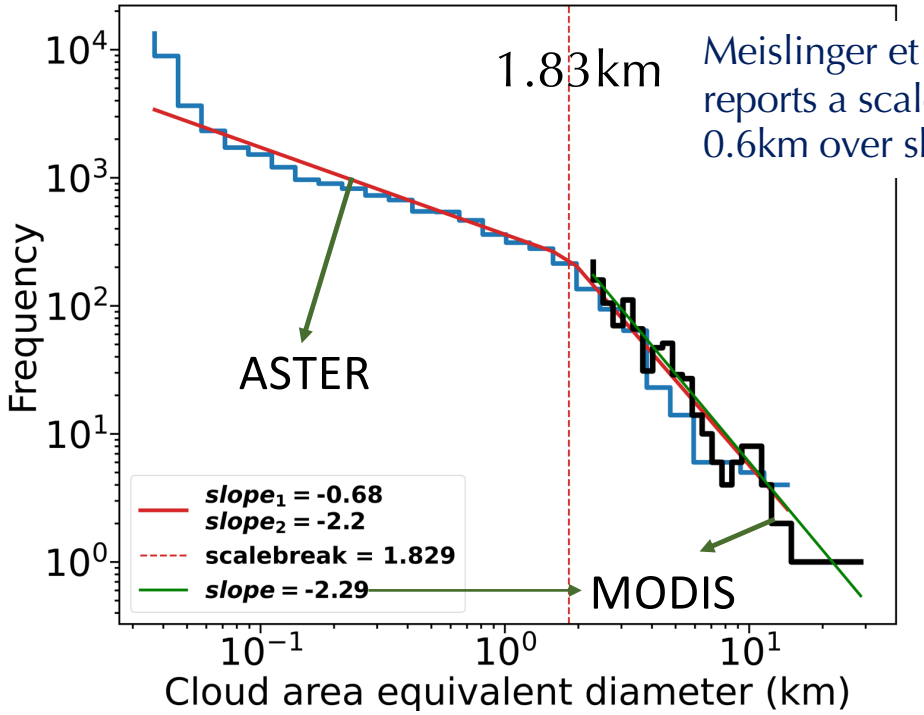




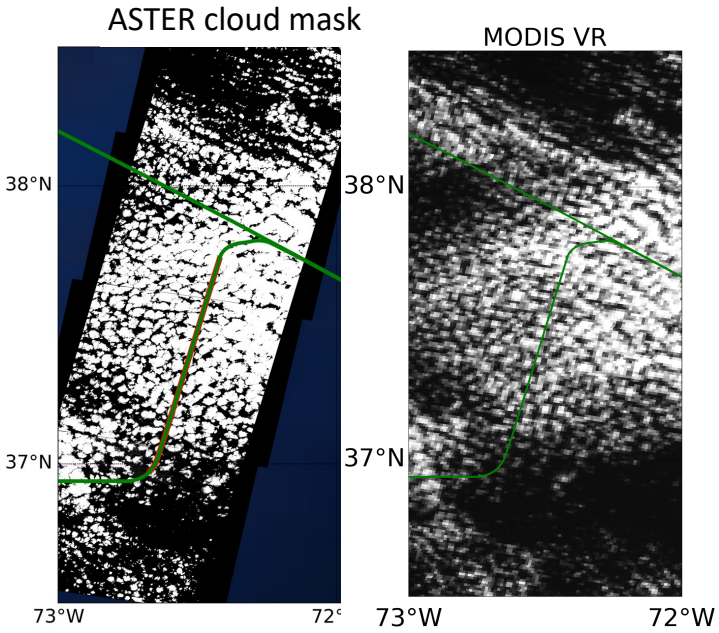
FCDP
CDP
RSP
MODIS

- Clouds are optically thicker towards north, top increased from 1.2 to 1.5km, increasing LWP.
- Presence of drizzle drops

Cloud size distribution: ASTER 15mx15m *vs.* MODIS 1kmx1km



March 29, 2021

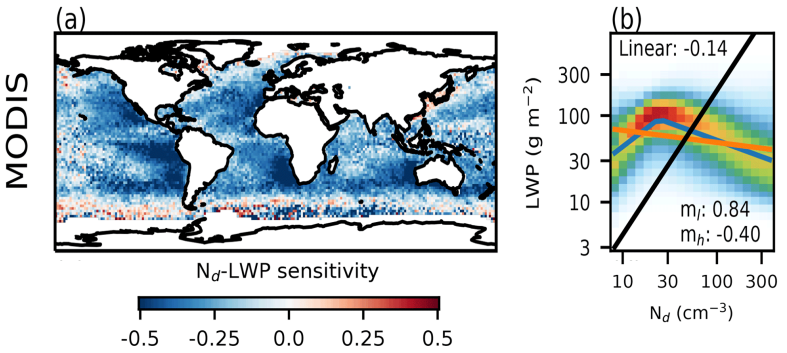


- Most clouds are < MODIS 1 km pixel resolution
- Clouds>1km represented similarly by ASTER/MODIS
- Cloud size follows a double power-law fit to logarithmic $n(D) \propto D^b$ (b = slope -1)
- ASTER cloud size shows a scale break at 1.83 km.

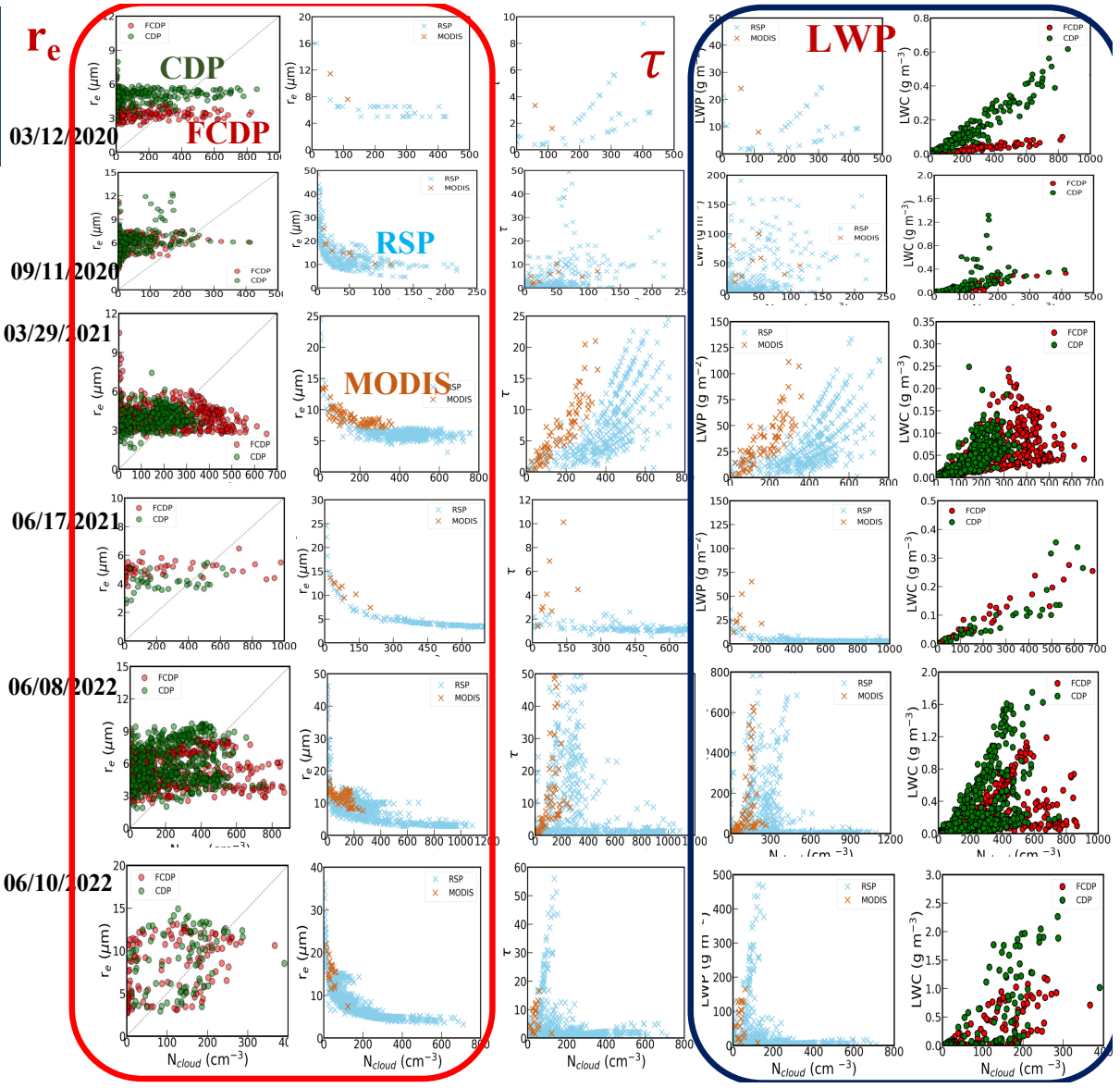
How do cloud properties vary with Nd?

Remote sensors show re anticorrelated with Nd at the lower Nd (inhomogeneous mixing?) but in-situ probes show litte re variation with Nd

- LWP positively correlated with Nd, because of COT
- Insitu LWC also increases with Nd

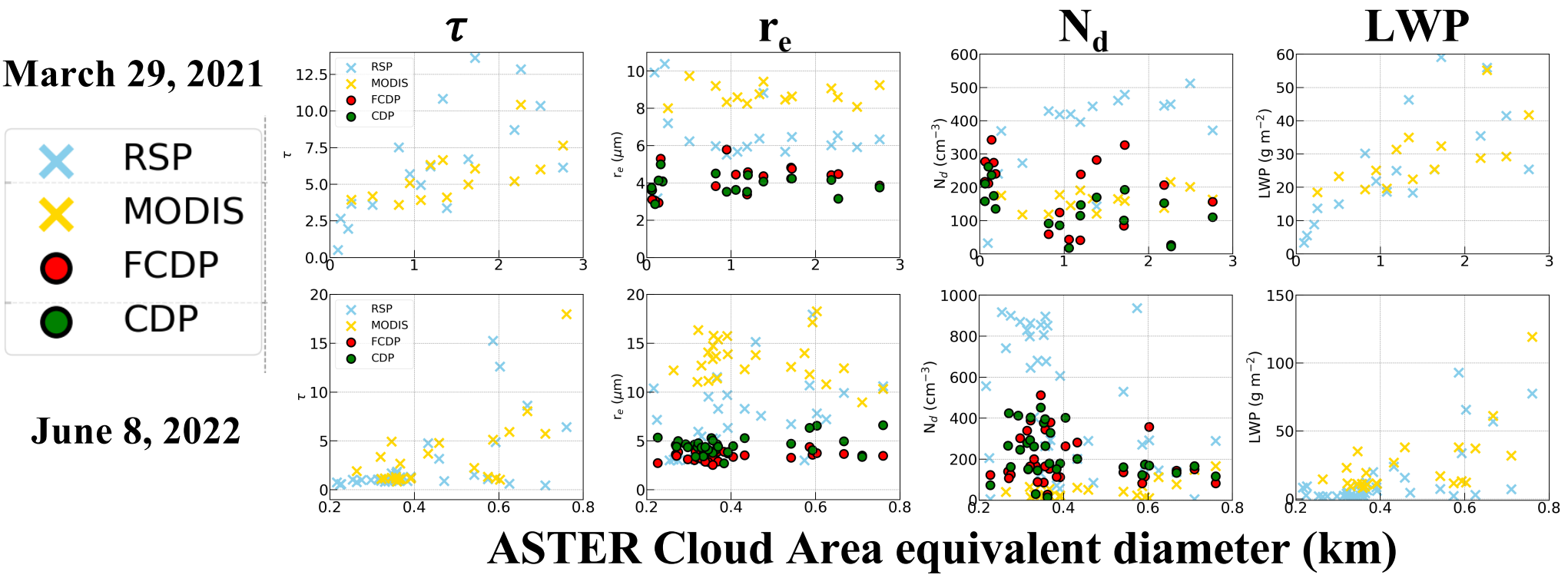


Gryspeerdt et al, 2019



Combining ASTER macrophysics with insitu/RSP/MODIS microphysics

- Cloud optical thickness increases with cloud size in both RSP and MODIS
- Droplet effective radius constant with cloud size in both RSP and MODIS, except for the smallest clouds.



Summary

- ACTIVATE sampled six days along the ASTER tracks – to characterize clouds from high resolution ASTER data.

- The samplings included stratiform clouds as well as optically thin and thick cumulus clouds – providing an opportunity for examining cloud retrievals
- High resolution (15m) ASTER data suggests most clouds are smaller than the 1km MODIS pixel resolution.

- The remote sensing data suggests inhomogeneous mixing at cloud edges, but in-situ data does not signify this feature.

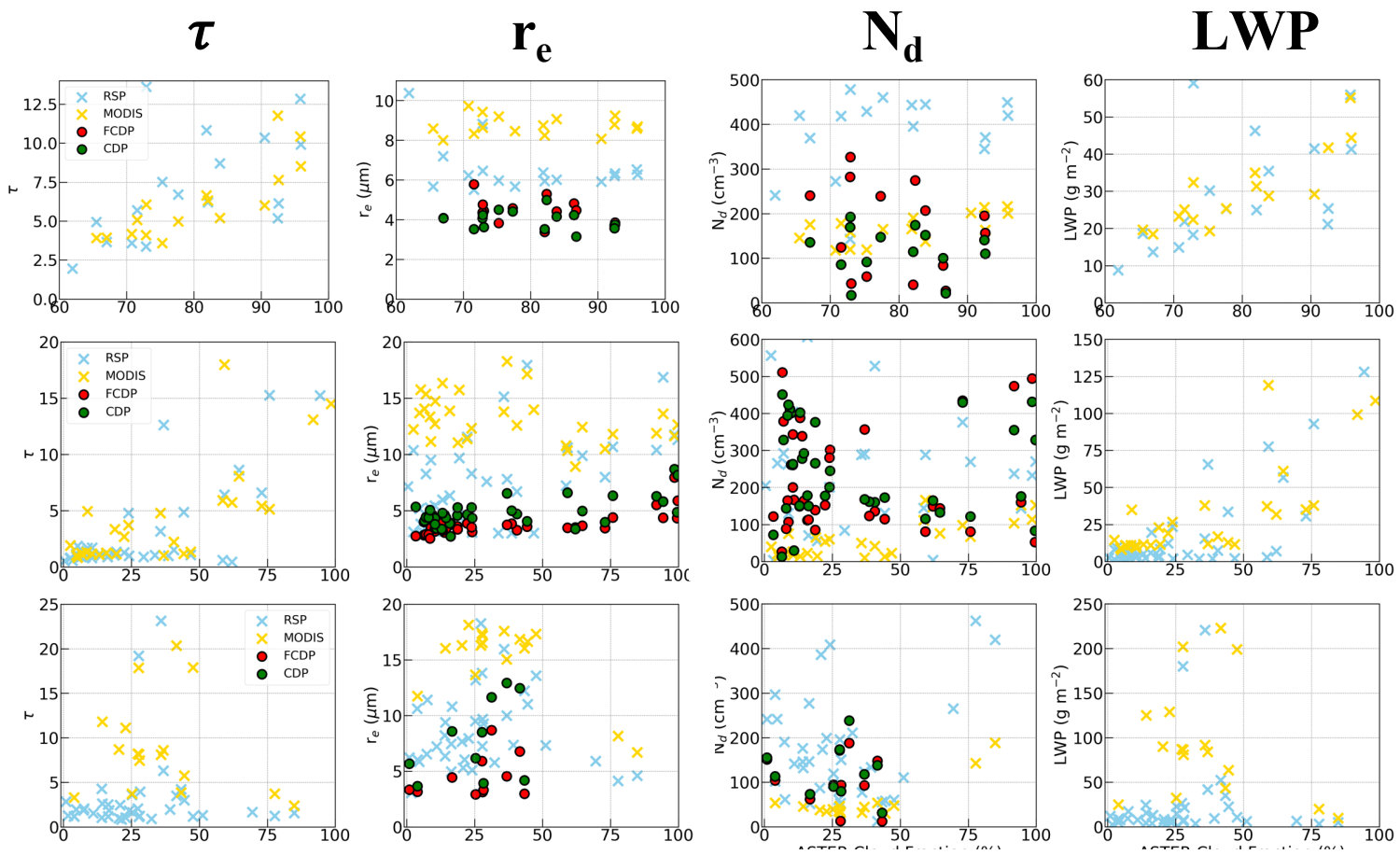
- In-situ data and remote sensors indicate consistent microphysics with cloud size for the stratiform clouds. MODIS Nds are overcompensated by re overestimate (indicating the 3D effect)?
- Why does RSP Nds are high, esp for smaller clouds? Does the 0.8 adiabaticity is impacting?

Combining ASTER macrophysics with insitu/RSP/MODIS microphysics

March 29, 2021

June 8, 2022

June 10, 2022



ASTER Cloud Fraction (%)