Investigating Raindrop Evaporation, Breakup, and Coalescence in GoAmazon Observations

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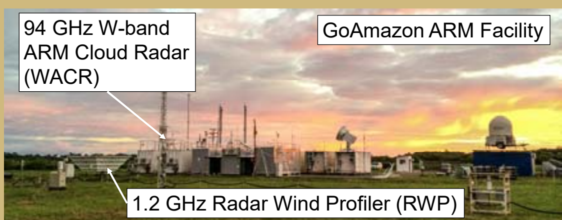
Williams, C.R., R.M. Beauchamp, and V. Chandrasekar, 2016: Vertical air motions and raindrop size distributions estimated using mean Doppler velocity difference from 3- and 35-GHz vertically pointing radars. *IEEE Trans. on Geoscience and Remote Sensing*, **54**, October 2016.

1. Motivation

Microphysical processes modify the distribution of falling raindrops. Evaporation and accretion modify the total liquid mass. While breakup and coalescence modify how that liquid is distributed between different sized raindrops.

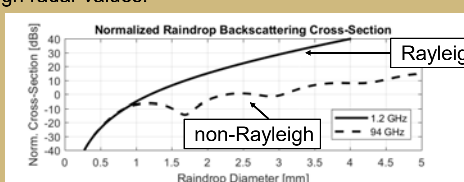
This study uses GoAmazon field campaign vertically pointing radar (VPR) observations to:
(1) Retrieve profile of raindrop size distributions (DSDs).
(2) Investigate raindrop evaporation, breakup, and coalescence.



2. DSD and Air Motion Retrieval

Retrieval methodology exploits the differences in Rayleigh (1.2 GHz) and non-Rayleigh (94-GHz) scattering signatures observed by two VPRs observing the same raindrops.

When raindrops larger than 2 mm diameter are present, the Rayleigh radar reflectivity and velocity are larger than the non-Rayleigh radar values.



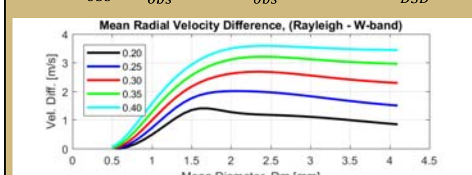
The velocity difference between the two observed radar velocities is independent of air motion ω:

Rayleigh radar velocity: $\bar{V}_{obs}^{Rayleigh} = \bar{V}_{DSD}^{Rayleigh} - \omega$

Non-Rayleigh radar velocity: $\bar{V}_{obs}^{non-Rayleigh} = \bar{V}_{DSD}^{non-Rayleigh} - \omega$

Velocity Difference:

$$\Delta\bar{V}_{obs} = \bar{V}_{obs}^{Rayleigh} - \bar{V}_{obs}^{non-Rayleigh} = \bar{V}_{DSD}^{Rayleigh} - \bar{V}_{DSD}^{non-Rayleigh}$$



Generate lookup table (LUT) for each $\Delta\bar{V}_{obs}$, tabulate all possible D_m and γ_m values.

3. Retrieval Framework

Desire: Estimate 4 unknowns:

3 DSD parameters: N_t - Total number concentration
D_m - mass-spectrum mean diameter
γ_m - mass-spectrum effective variance $\left(\frac{\sigma_m^2}{D_m^2}\right)$

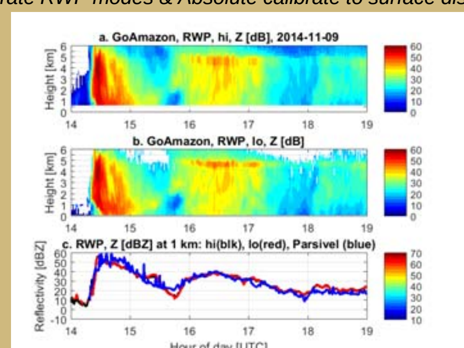
1 vertical air motion - ω

Input Observations:

Rayleigh radar reflectivity	(1.2 GHz RWP)
Rayleigh radar mean velocity	(1.2 GHz RWP)
Non-Rayleigh radar mean velocity	(94 GHz WACR)
Non-Rayleigh velocity spectra	(94 GHz WACR)

Retrieval Steps:
(1) Calibrate 1.2 GHz RWP to surface disdrometer.
(2) Given an observed velocity difference $\Delta\bar{V}_{obs}$, there is a family of possible solutions, $\boldsymbol{D_m^{possible}}$, $\boldsymbol{\gamma_m^{possible}}$ (from lookup table).
(3) Estimate possible air motions: $\boldsymbol{\omega^{possible}} = \bar{\boldsymbol{V}}_{DSD}^{Rayleigh} - \bar{V}_{obs}^{Rayleigh}$.
(4) Choose best fit between model and observed W-band spectra.
(5) Estimate N_t from observed Rayleigh reflectivity and $\left(D_m^{best}, \gamma_m^{best}\right)$.

Inter-calibrate RWP modes & Absolute calibrate to surface disdrometer



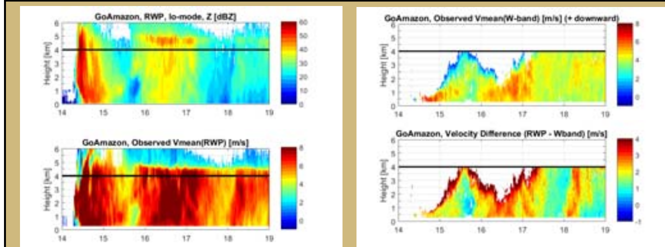
Solution is best fit between model and observed W-band spectra.

W-band spectra for all possible solutions are simulated and compared with observed spectrum.

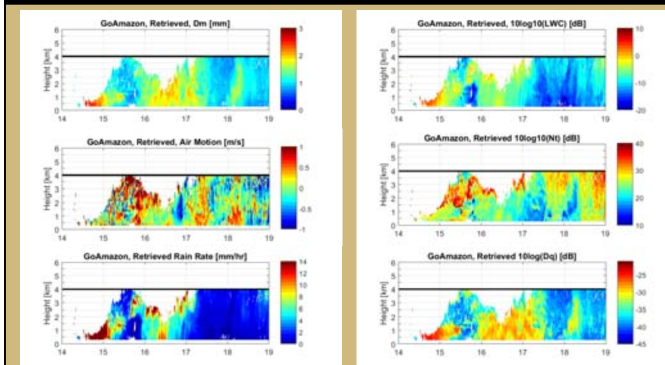
Best solution yields $\hat{D}_m$, $\hat{\gamma}_m$, and $\hat{\omega}$

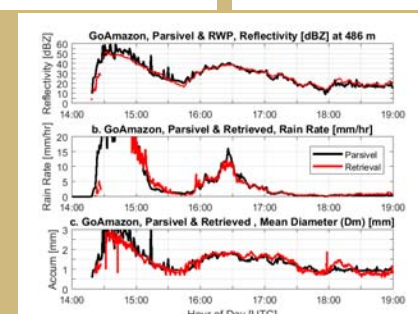
$\hat{N}_t$ is estimated from $Z_{obs}^{Rayleigh}$, $\hat{D}_m$ & $\hat{\gamma}_m$

4. Radar Input Observations



5. Retrievals





6. Concluding Remarks

- Can retrieve raindrop size distribution and vertical air motion by exploiting differences in Rayleigh and non-Rayleigh scattering from radar wind profiler (1.2 GHz) and W-band ARM Cloud Radar (WACR).
- Expressing rain parameters in logarithm units enables diagnosing processes in the vertical column:
  Changes in q^{dB} indicate: **evaporation** or **accretion**
  Changes in N_t^{dB} & D_q^{dB} indicate: **breakup** or **coalescence**