Path Integrated Attenuation as a Function of Precipitation Variability Across Satellite Field-of-Views

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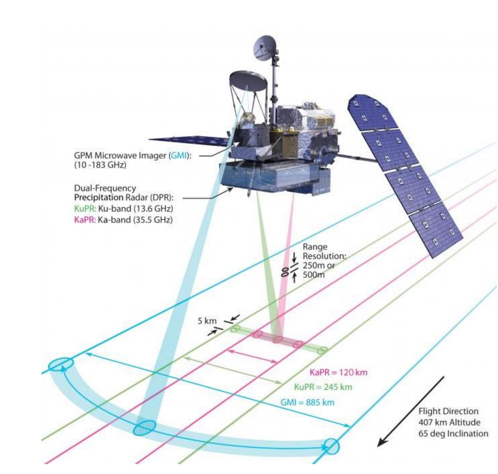
1. Motivation

The radar pulse volume is usually *assumed* to be uniformly filled with hydrometeors. This assumption is not valid as the radar pulse volume increases.

As precipitation variability increases across the radar Field-of-View (FOV), the radar derived areal-averaged rain rate is under estimated. This is primarily due to over estimating the path integrated attenuation (PIA) which causes the near-surface reflectivity to be underestimated, and thus, leads to under estimating rain rate.

Research Question:
Using high-resolution surface scanning radar observations, how does the PIA change as a function of horizontal precipitation variability at the 5 km horizontal footprint of the GPM Dual-Frequency Precipitation Radar (DPR)?

NASA/JAXA Global Precipitation Measuring Mission (GPM) Core Observatory



2. Methodology

This study assumes precipitation is vertically homogenous (e.g., vertical rain shafts), but horizontally variable (Kozu and Iguchi 1999).

For each 1x1 km rain column, calculate the following:

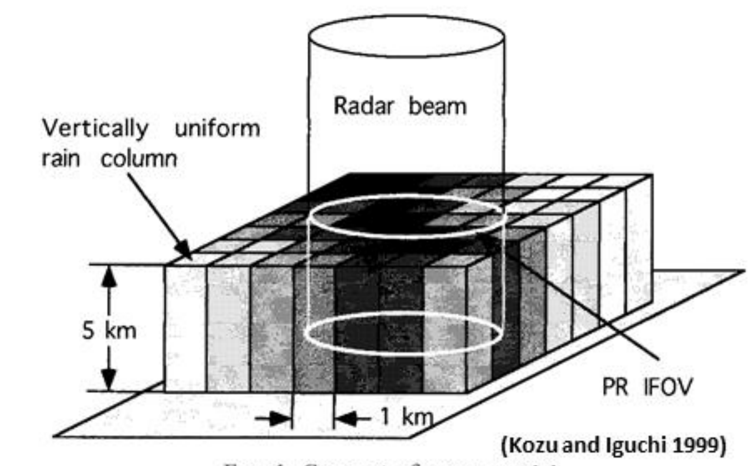


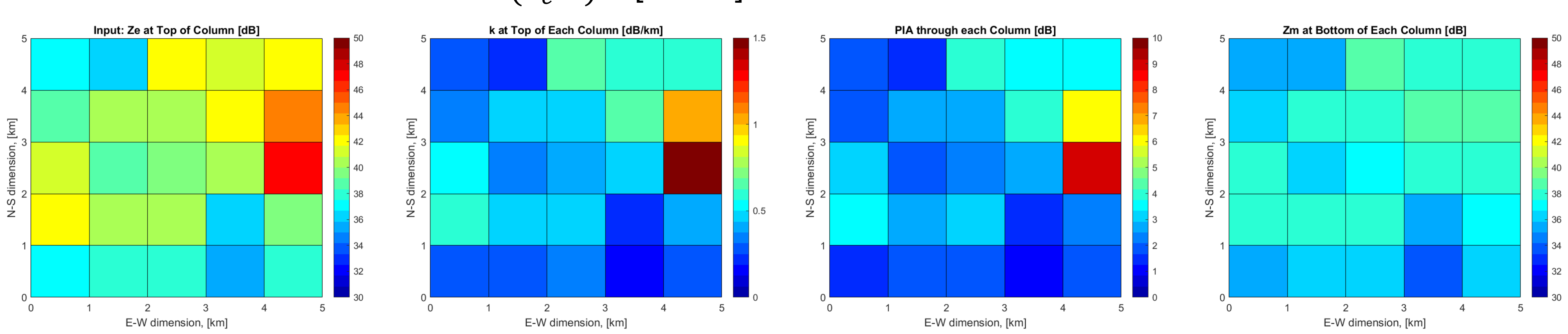
FIG. 1. Concept of storm model.

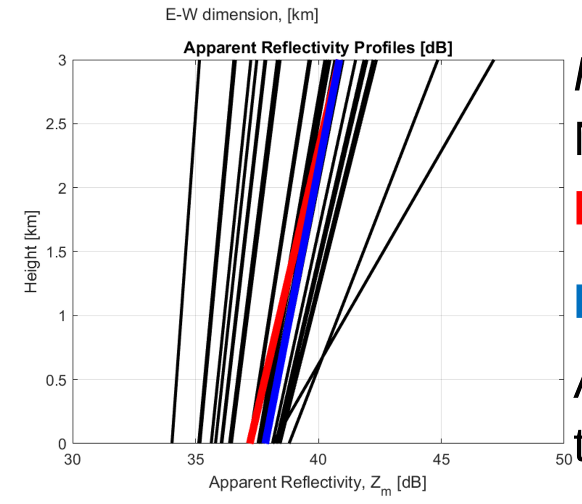
(1) Define effective reflectivity at top of column: Z_e^{top} [dBZ]

(2) Estimate Specific Attenuation: $k = \alpha\left(Z_e^{top}\right)^{\beta}$ [dB/km]

(3) Calculate PIA: $PIA = 2(\Delta ht)k$ [dB]

(4) Calculate apparent reflectivity at bottom: $Z_m^{bot} = Z_e^{top} - PIA$ [dBZ]



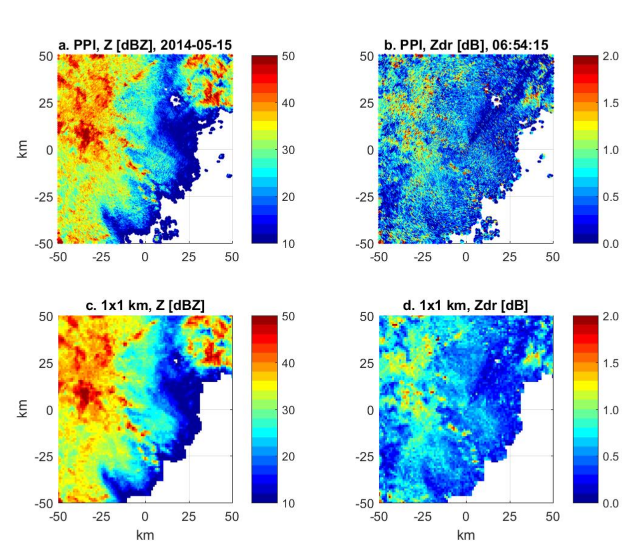


Profiles of apparent reflectivity for each column.
Note: Columns with larger Z_e^{top} have larger PIA through column.
Red line is areal-average apparent reflectivity $\langle Z_m \rangle_{apparent} = \frac{1}{n}\sum_{i=1}^{n} Z_m(i)$
Blue line is areal-average uniform reflectivity $\langle Z_m \rangle_{uniform} = Z_e^{top} - 2(\Delta ht)\left(\alpha\left\langle Z_e^{top}\right\rangle^{\beta}\right)$
At bottom, difference between $\langle Z_m \rangle_{apparent}$ and $\langle Z_m \rangle_{uniform}$ is due to precipitation variability.

If rain were uniform across 5x5 km domain, then $\langle Z_m \rangle_{apparent} = \langle Z_m \rangle_{uniform}$.

3. Scanning Radar Input Observations

- NASA S-band Polarimetric radar (NPOL) was deployed during NASA GPM Ground Validation (GV) field campaign *Integrated Precipitation and Hydrology Experiment (IPHEx)* in Southern Appalachian Mountains in North & South Carolina, USA, May-June 2014.
- Polarimetric measurements were converted to raindrop size distribution (DSD) parameters (N_w, D_m, μ) at each 1x1 km.
- DSD parameters were used to estimate Z_e^{top} in the Ku-band (13 GHz).



4. Results from 15-May-2014

For each 5x5 km footprint, calculate areal-averaged quantities:

At top of column: $\left\langle Z_e^{top}\right\rangle = \frac{1}{n}\sum_{i=1}^{n} Z_e^{top}(i)$

At bottom of column: $\left\langle Z_m^{bot}\right\rangle = \frac{1}{n}\sum_{i=1}^{n} Z_m^{bot}(i)$

Specific Attenuation: $\langle k \rangle = \alpha\left\langle Z_e^{top}\right\rangle^{\beta}$

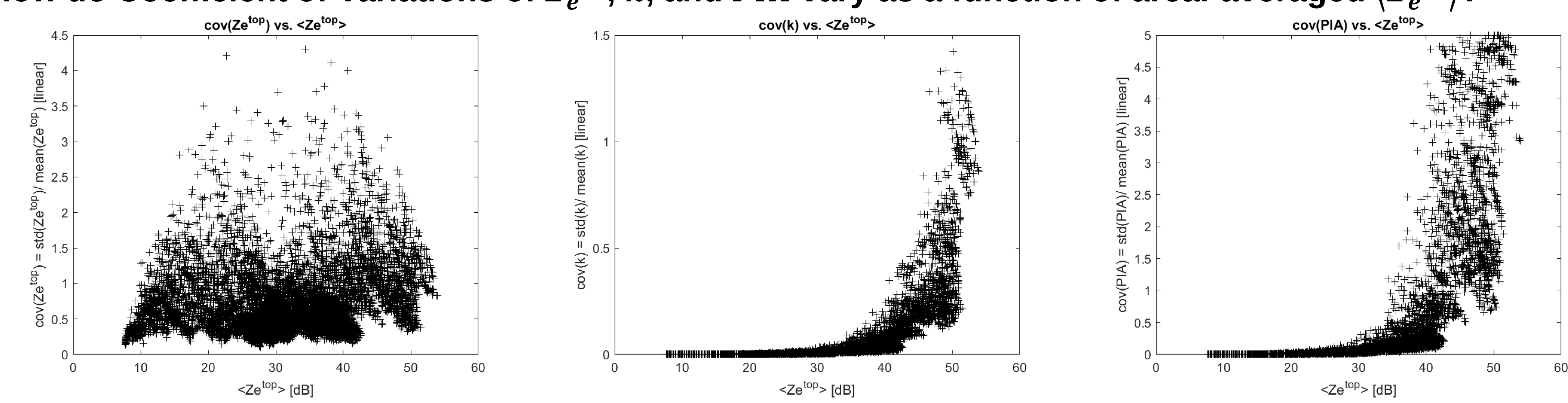
Apparent PIA: $\langle PIA \rangle_{apparent} = \left\langle Z_e^{top}\right\rangle - \left\langle Z_m^{bot}\right\rangle$

Uniform PIA: $\langle PIA \rangle_{uniform} = 2(\Delta ht)\langle k \rangle$

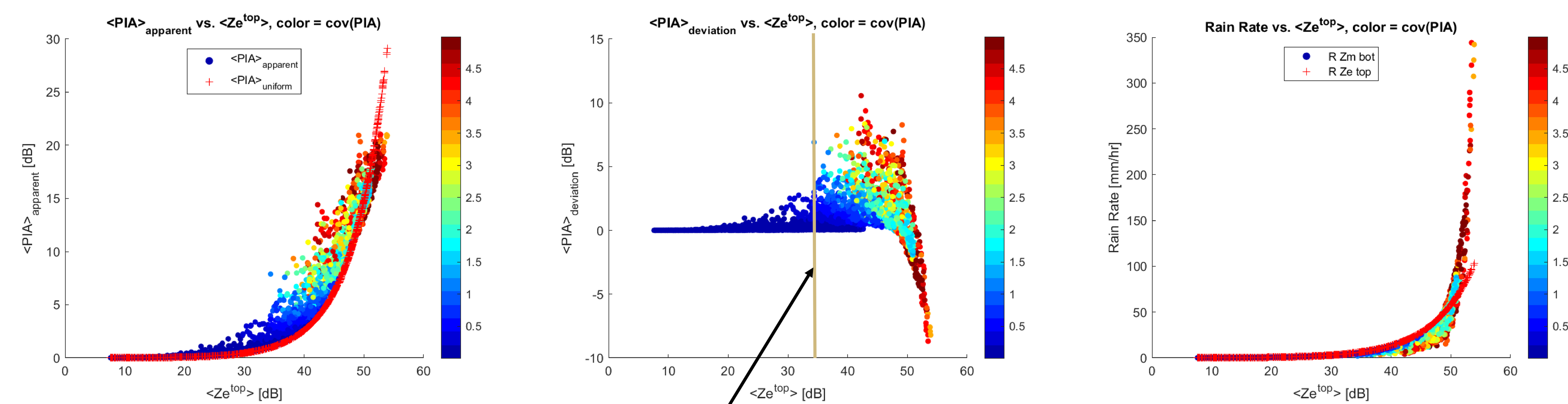
Deviation in PIA: $\langle PIA \rangle_{deviation} = \langle PIA \rangle_{apparent} - \langle PIA \rangle_{uniform}$

Coefficient of Variation: $cov(x) = {}^{std(x)}/_{mean(x)}$

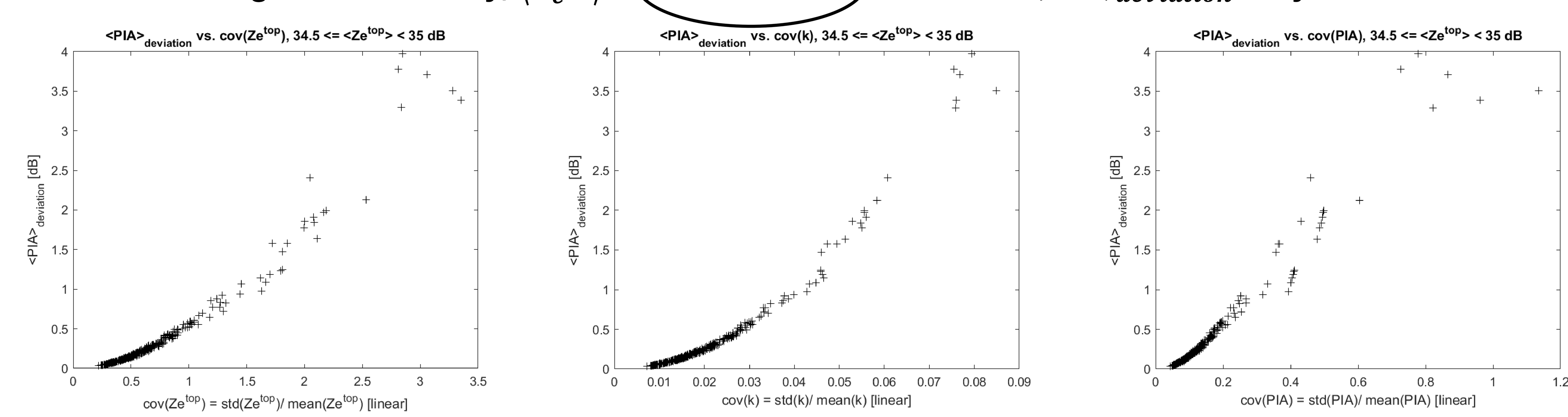
How do Coefficient of Variations of Z_e^{top}, k, and PIA vary as a function of areal-averaged $\left\langle Z_e^{top}\right\rangle$?



How do $\langle PIA \rangle_{apparent}$, $\langle PIA \rangle_{deviation}$, Rain Rate vary as a function of areal-averaged $\left\langle Z_e^{top}\right\rangle$ and $cov(PIA)$?



For a narrow range of reflectivity, $\left\langle Z_e^{top}\right\rangle = 35 \pm 0.5$ dBZ, how does $\langle PIA \rangle_{deviation}$ vary as a function of cov?



5. References

Kozu, T. and T. Iguchi, "Nonuniform beamfilling correction for spaceborne radar rainfall measurement: Implications from TOGA COARE radar data analysis", *J. Atmos. Oceanic Technol.*, **16**, pp. 1722-1735, 1999.

Acknowledgments
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