Precipitation Variability Across Satellite Footprints Derived from Ground-based radar observations

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1. Motivation

Without prior parameterization, satellite retrieval algorithms often assume uniform precipitation across the satellite sensor's field-of-view (FOV). Deviations from uniform is called: Non-Uniform Beam Filling (NUBF). The NASA / JAXA Global Precipitation Mission (GPM) Dual-frequency Precipitation Radar (DPR) rainfall algorithm uses statistical relationships to infer sub-FOV variability given DPR mean FOV measurements. Coefficient of variation, $\mathrm{COV} = \text{Standard deviation}/\text{mean}$, is a parameterization that relates sub-FOV variation with FOV mean.

Science Question: Using high spatial resolution ground-based scanning radar observations, can statistical relationships be determined that relate sub-FOV variability with the FOV mean and with the variability from neighboring mean FOVs?

Research Goal: Due to the complexities of satellite retrieval algorithms, this research does not aim to define NUBF algorithm parameterizations, but aims to quantify sub-FOV variability in order to help algorithm developers parameterize NUBF effects in retrieval algorithms.

2. Methodology

Surface Scanning Radar:
This study uses NASA S-band Polarimetric scanning radar (NPOL) observations from the Integrated Precipitation and Hydrology Experiment (IPHEx) held in the southern Appalachian Mountains in the eastern United States in May-June 2014.

Grid to 1x1 km resolution, then grid to 5x5 and 10x10 km:
Reflectivity from constant 2 degree elevation PPI scans with 125 m range resolution are gridded into a uniform 1x1 km grid. This 1x1 km gridded dataset is used to develop 5x5 and 10x10 km satellite pixels which correspond approximately to the DPR footprint at nadir and at maximum off-nadir. (Note: a "pixel" represents a domain larger than an instrument's FOV so that sub-pixel statistics can be calculated.)

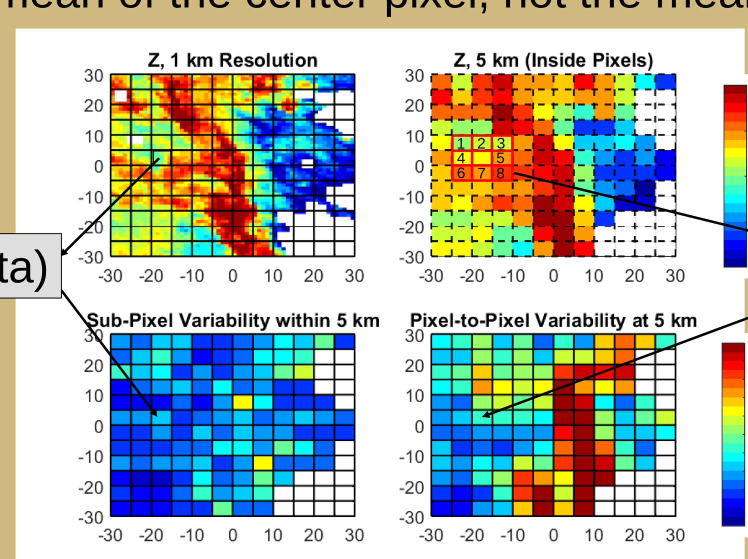
Sub-Pixel Statistics:
Using 1x1 km input data, calculate for each 5x5 and 10x10 km pixel:
- **mean μ**,
- **standard deviation σ_{inner}**,
- **coefficient of variation $COV_{inner} = \sigma_{inner}/\mu$**

Pixel-to-Pixel Statistics:
At 5x5 and 10x10 km pixel resolution, calculate:
- **standard deviation of eight (8) neighboring pixels σ_{outer}**,
- **coefficient of variation $COV_{outer} = \sigma_{outer}/\mu$**.

(Note: μ is the mean of the center pixel, not the mean of 8 neighbors)

1x1 km Data

5x5 km Mean μ



std(1x1 km data)

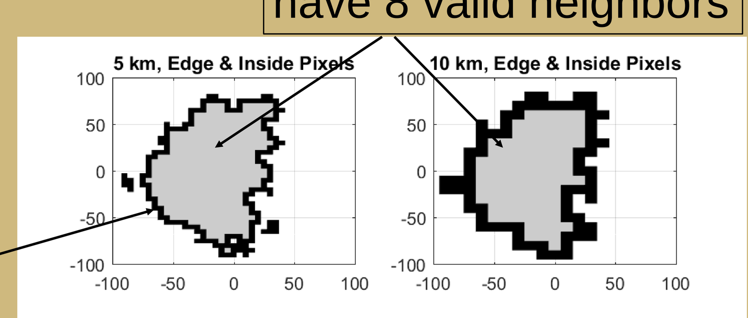
std(8 neighbors)

5x5 km Sub-Pixel Variability, σ_{inner}

5x5 km Pixel-to-Pixel Variability, σ_{outer}

Rain Filled Pixels:
To avoid complications due to partially illuminated pixels, only **Inside Pixels** are analyzed.

Inside Pixels have 8 valid neighbors



Edge Pixels are missing an neighbor

3. Statistics from One PPI Scan

1x1 km | 5x5 km | 10x10 km

Pixel mean μ

Sub-Pixel Variability σ_{inner}

Pixel-to-Pixel Variability σ_{outer}

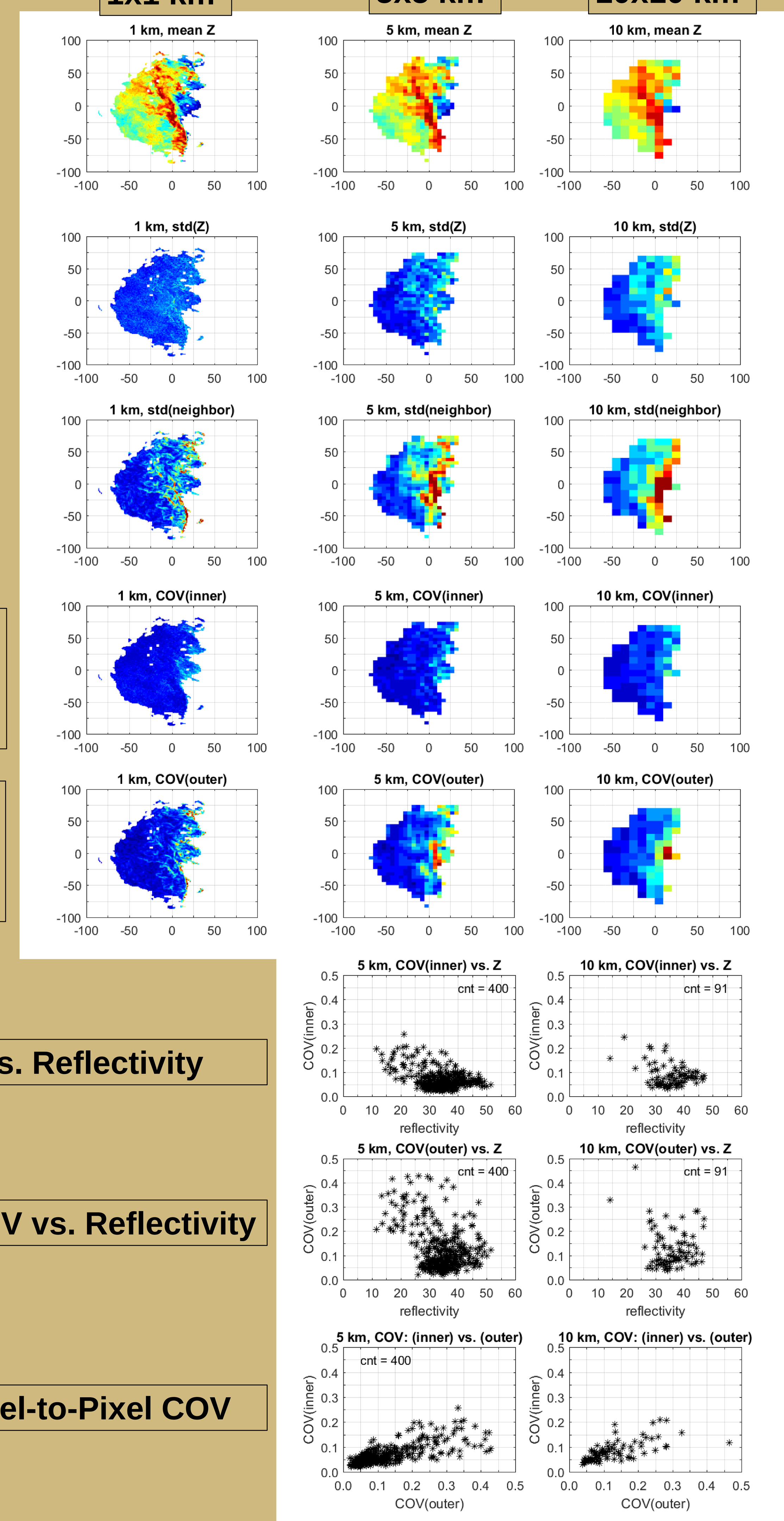
Sub-Pixel COV $COV_{inner} = \frac{\sigma_{inner}}{\mu}$

Pixel-to-Pixel COV $COV_{outer} = \frac{\sigma_{outer}}{\mu}$

Sub-Pixel COV vs. Reflectivity

Pixel-to-Pixel COV vs. Reflectivity

Sub-Pixel vs. Pixel-to-Pixel COV



4. Statistics from 736 PPI Scans

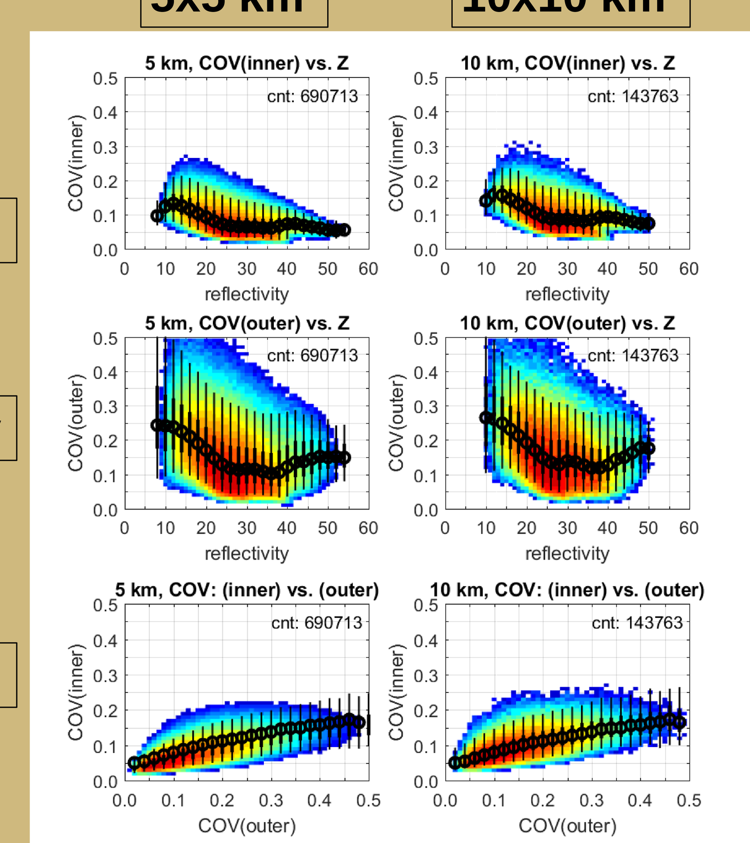
7 days of PPI scans (May 9, 10, 15, 18, 23, 30 and June 11)

5x5 km | 10x10 km

Sub-Pixel COV vs. Reflectivity

Pixel-to-Pixel COV vs. Reflectivity

Sub-Pixel vs. Pixel-to-Pixel COV



5. Rain Rate Statistics, 736 PPI Scans

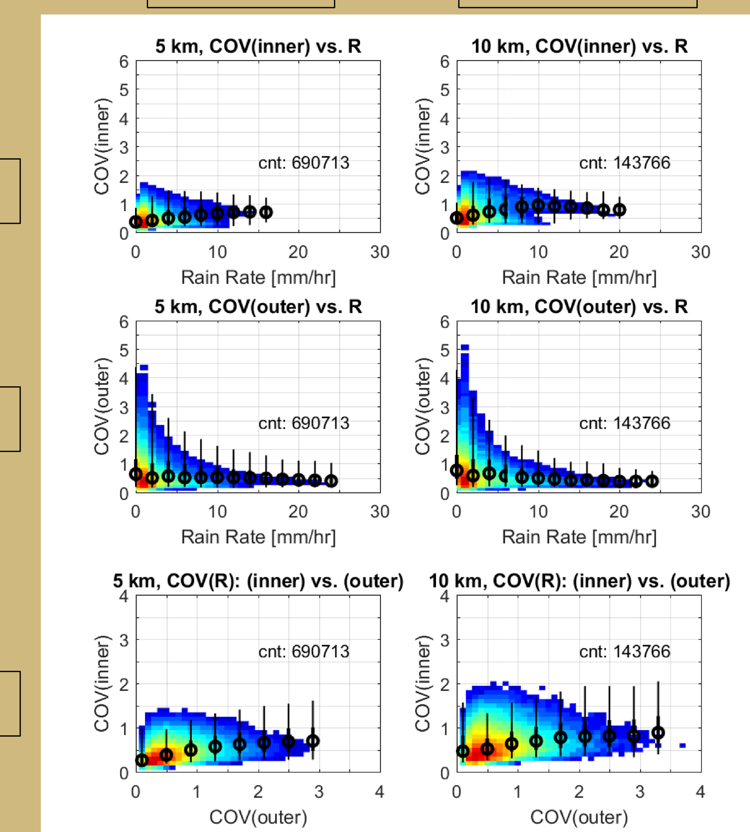
7 days of PPI scans (May 9, 10, 15, 18, 23, 30 and June 11)

5x5 km | 10x10 km

Sub-Pixel COV vs. Rain rate

Pixel-to-Pixel COV vs. Rain rate

Sub-Pixel vs. Pixel-to-Pixel COV



6. Median Diameter, 736 PPI Scans

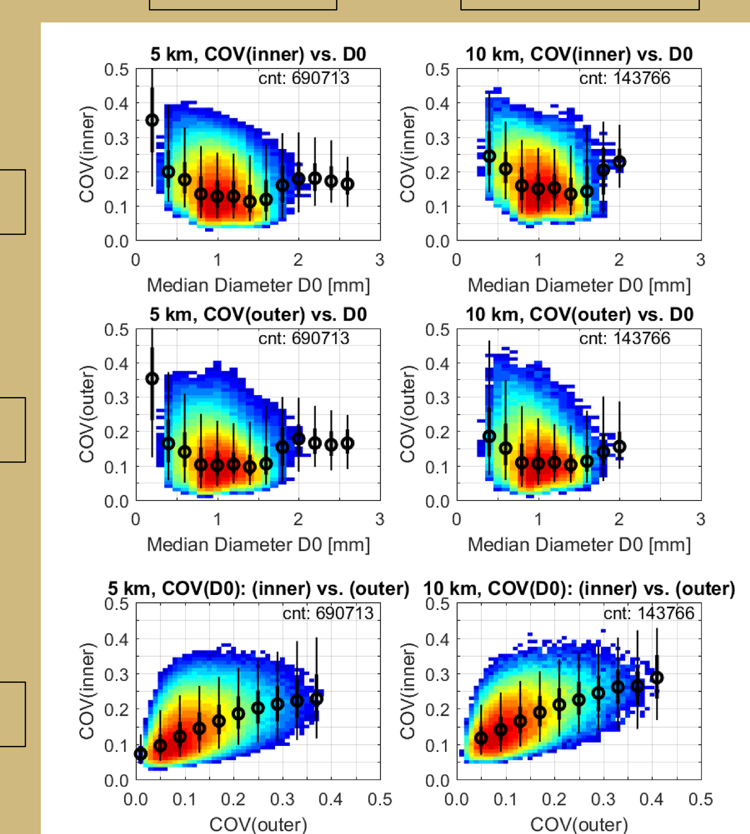
7 days of PPI scans (May 9, 10, 15, 18, 23, 30 and June 11)

5x5 km | 10x10 km

Sub-Pixel COV vs. D_0

Pixel-to-Pixel COV vs. D_0

Sub-Pixel vs. Pixel-to-Pixel COV



7. N_w Statistics, 736 PPI Scans

7 days of PPI scans (May 9, 10, 15, 18, 23, 30 and June 11)

5x5 km | 10x10 km

Sub-Pixel COV vs. N_w

Pixel-to-Pixel COV vs. N_w

Sub-Pixel vs. Pixel-to-Pixel COV