Building the Precipitation Column using Multiple Looks from HIWRAP Airborne Radar Observations

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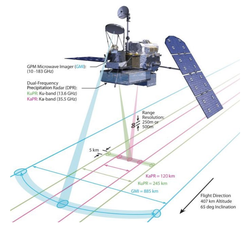
1. Motivation

The radar pulse volume is usually *assumed* to be uniformly filled with hydrometeors. This assumption is not valid as the radar pulse volume increases which changes the coefficients in *k-Z* and *Z-R* relationships needed to make accurate rainfall retrievals. Statistically methods are being developed to correct for the affects of non-uniform beam filling (NUBF) [Iguchi et al. 2000].

The long-term objective of this work is to estimate precipitation variability over the GPM radar Field-of-View (FOV) using HIWRAP Ku- and Ka-band radar observations over open ocean conditions. These precipitation statistics will be used in a radar forward simulator to understand the impact of NUBF on rainfall retrievals.

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

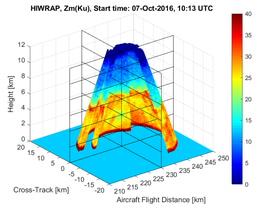


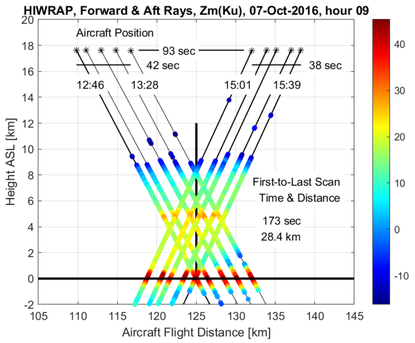
The deliverables presented in this poster are four HIWRAP data sets. Two slant path data sets contain Hitschfeld-Bordan with PIA_{srt} constraint *Ze* estimates. Two other data sets contain gridded vertical column *Ze* estimates aggregated for either forward or backward view scans.

2. Forward and Backward Scans

This study uses observations from the conical scanning High Altitude Wind and Rain Profiler (HIWRAP) when mounted on the Global Hawk. All observations are over open ocean.

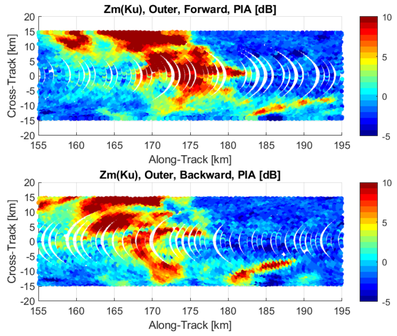
The precipitation column can be built either as slanted columns at the native conical scanning angle, or can be built as vertical columns.
The vertical column representation is preferred so that different shaped convective cores can be simulated in the radar forward simulator.
The vertical column is constructed from conical observations observing the same voxel first with a forward facing scan and then with a backward view.





Example of Time of Observation:
Looking at rays directly in front and behind the aircraft (along-track)

- First forward ray intersects surface at 125 km
- It takes about 40 seconds for the forward and backward rays to build the column
- There is a gap of about 90 seconds between the forward and backward views
- **It takes about 180 sec (3 min) to build the column with forward & backward rays**



Path Integrated Attenuation from Surface Reference Technique

$$PIA_{srt}[dB] = \sigma^0(clear) - \sigma^0\,(precip)$$

$\sigma^0(clear)$ estimated outside of precipitation

- Forward & backward rays observe different PIA patterns
- Slant paths are through different convective cells
- Also, there is about 3 minutes between forward and backward views

3. Slant Path Column: Retrieval of *Ze*

Measured reflectivity (*Zm*) within the same voxel will be different for the forward and backward views because the rays will propagate through different precipitation columns. Therefore, *need to estimate effective radar reflectivity factor (Ze) along each ray and then build Ze in the vertical column.*

Hitschfeld-Bordan (HB) with PIA_{srt} Constraint Retrieval Method

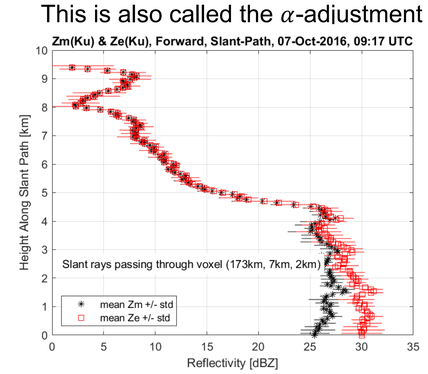
The HB method assumes a k-Z_e relationship: $k(r) = \alpha(r)Z_e(r)^\beta$, where r is the range from the radar. The effective radar reflectivity factor Z_e is derived analytically from the measured radar reflectivity Z_m by $Z_e = \frac{Z_m(r)}{[1-\zeta(r)]^{1/\beta}}$, where ζ is defined as $\zeta(r) \equiv 0.2(ln10)\beta\int_0^r \alpha(s)Z_m(s)^\beta ds$.

The path integrated attenuation (PIA) through the reflectivity column is: $PIA = -\frac{10}{\beta}log_{10}\left[1-\zeta(r_{surface})\right]$.

Using PIA_{srt} as a constraint, ε is introduced and the HB equations become:

$$PIA_{srt} = -\frac{10}{\beta}log_{10}\left[1-\varepsilon\zeta(r_{surface})\right] \qquad Z_e = \frac{Z_m(r)}{[1-\varepsilon\zeta(r)]^{1/\beta}} \qquad \text{and} \qquad \varepsilon = \frac{1-10^{\frac{-\beta(PIA_{srt})}{10}}}{\zeta(r_{surface})}$$

This is also called the α-adjustment method because α in the k-Z_e relationship becomes $\alpha' = \varepsilon\alpha$.

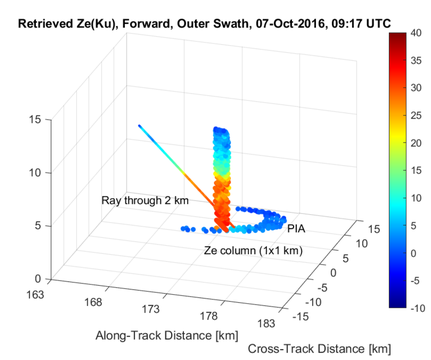


Slant Path Column Data Sets

Two data sets are produced for Ku- and Ka-band observations

1. **Individual Profiles**
   a. Effective *Ze* is estimate along each slant profile
   b. PIA_{srt} and ε saved for every slant profile
2. **Gridded Slant Profiles**
   a. Aggregate profiles passing through 1x1 km pixel at 2 km height
   b. Estimate mean and STD at each slant range gate

4. Construction of *Ze* Vertical Columns



Using slant path retrievals, *Ze* vertical columns are constructed by identifying all range gates within 1x1 km horizontal grid boxes.

Figure shows:
constructed *Ze* vertical column
Retrieved *Ze* along slant path passing through 2 km
PIA_{srt} on surface (indicating surface swath)

Ze Vertical Column Data Sets

Two data sets are produced for Ku- and Ka-band observations:

a. Forward view scans
b. Backward view scans

5. References

Iguchi, T., T. Kozu, R. Meneghini, J. Awaka, and K. Okamoto, 2000: Rain-profiling algorithm for the TRMM Precipitation Radar. *J. Appl.* Meteor., 39, 2038-2052.

Acknowledgments

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