Dual frequency Radar Retrievals of Ice Water Content

George Duffy
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA

Motivation

The Dual Frequency Radar (DFR) is the only advanced radar technique currently provided by spaceborne radar

So far, DFR has only been used to identify the characteristic hydrometeor size of PSDs

Here, I present and evaluate a method to use Dual Frequency Radar to retrieve Ice Water Content

Key Takeaways

A monotonic Z-DWR sensitivity to IWC is visible from simulations (Figure 1).

Collocated observations radar and *in-situ* confirm a sensitivity of IWC to Z-DWR in real clouds (Figure 2a)

The Z-DWR method can be used to retrieve IWC from DPR observations and provides results that agree with observations from experiments (Figures 2b, 3)

Theory

Assuming a gamma distribution and a power-law mass-diameter relationship, Rayleigh reflectivity of falling snow is influenced by 5 parameters

$$Z = \int N_0 D^{\mu} e^{-\Lambda D} \, a^2 D^{2b} dD$$

The coefficient terms N_0 and a will not be influential to a dual frequency ratio

$$DWR = \frac{Z_1}{Z_2} = f(\mu, \Lambda, b, \dots)$$

N_0 and a both provide information that is relevant to the ice water content of a cloud. **Therefore, a Z/DWR plot could isolate and retrieve the information relevant for changes in IWC**

Data

- Data comes from GPM Cold-season Precipitation Experiment (**GCPEX**), Midlatitudes Continental Convective Clouds Experiment (**MC3E**) and Olympic Mountains Experiment (**OLYMPEX**)
- *In-situ* and radar data are collocated from nearest neighbors to vertically pointing radar gates within 12 km and 3.5 minutes [1].
- Reflectivity is simulated PSDs using **SnowScatt** [2]. Mass was estimated using parameters from [3]. PSDs are rejected if they have a simulated Ku reflectivity < 10 dBZ.

Simulated relationships

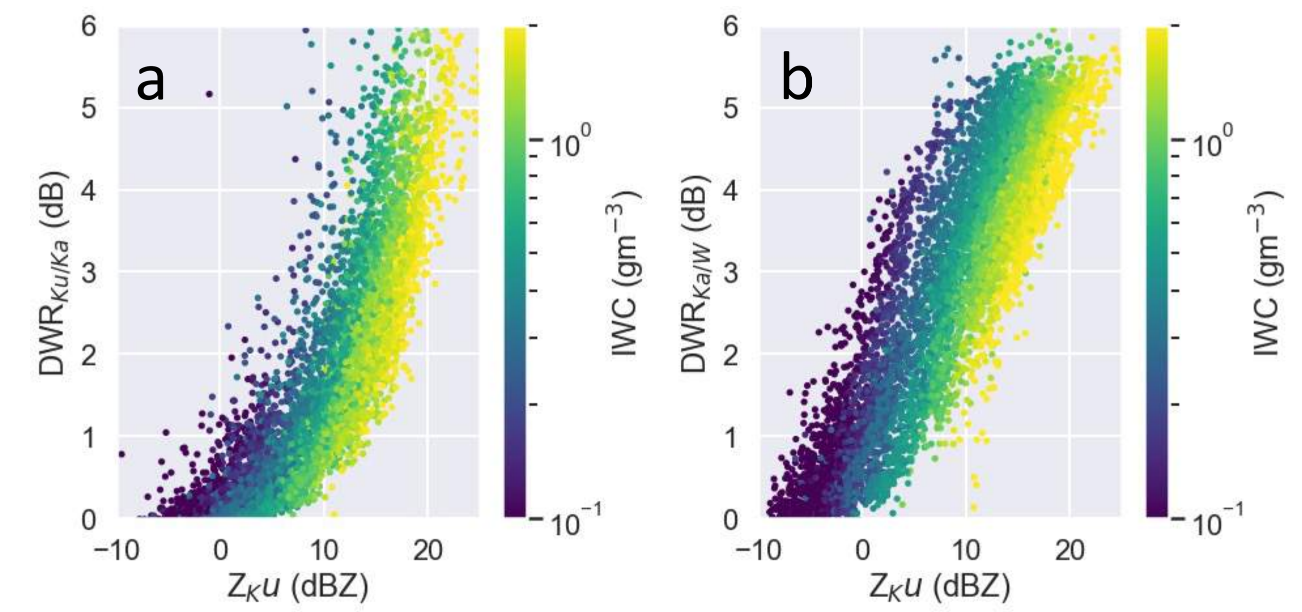

Figure 1

Simulated Z-DWR IWC retrievals using Ku/Ka DWR (a) and Ka/W DWR (b). Ka/W DWR provides a more sensitive retrieval, but at DPR sensitivity the difference is minimal.

Maximum simulated DWR is below expected values. There may be an error in simulated reflectivity, but observations suggest such extreme values may also be rare and indicative of special conditions.

Measured relationships

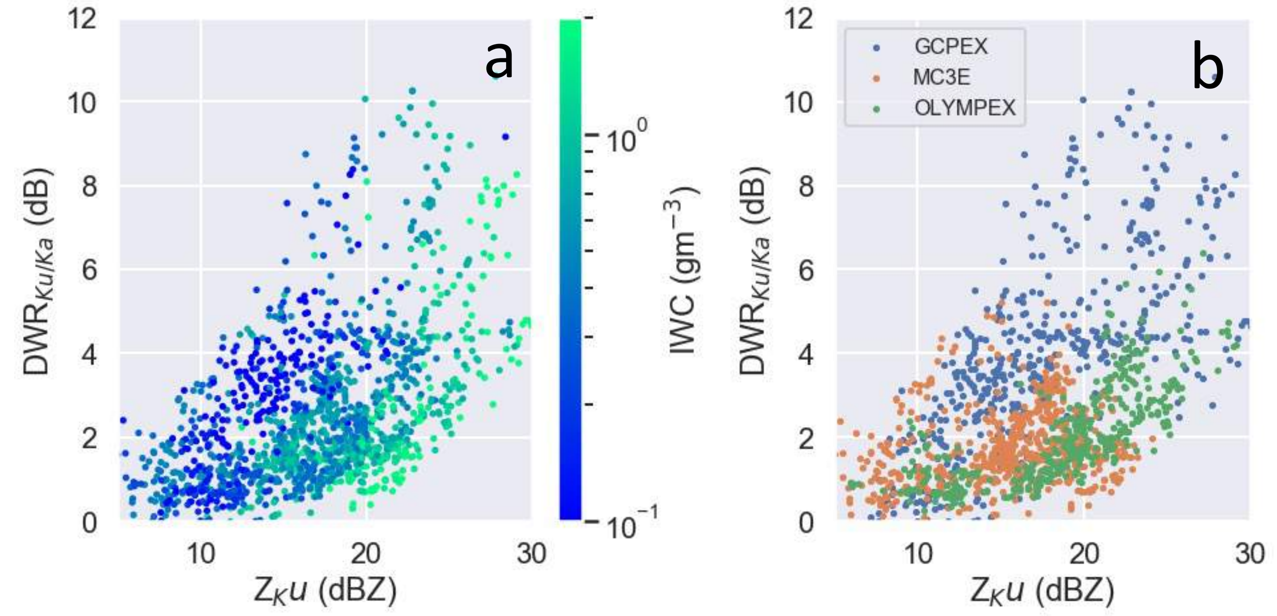

Figure 2

Measurements of Z and DWR collocated with an *in-situ* aircraft. Data are colored by estimated IWC (**a**) and by experiment (**b**) to demonstrate how the sensitivity of Z-DWR-IWC is common across dissimilar cloud environments.

Satellite applications

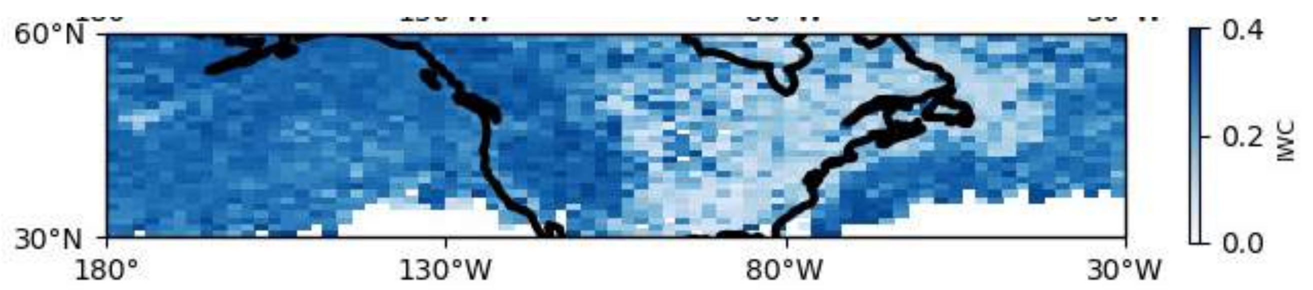

Figure 3

Median IWC for GPM detectable clouds at the 5°C isotherm over stratiform clouds using an empirical retrieval generated from GPM experimental data. Preliminary results reveal a potential difference between western and eastern CONUS precipitation that agrees with GV experiments (High IWC from OLYMPEX-area, low IWC from GCPEX-area.

Next Steps

- Continue working with reflectivity simulation to synchronize predictions and observations of Z-DWR-IWC relationships.
- Incorporate **IMPACTS** data to provide more data on multiple frequency radar/aircraft observations in snow clouds.
- Investigate trends on satellite observed IWC retrievals from GPM.

[1] Duffy et al 2021 https://doi.org/10.1175/JAS-D-20-0174.1
[2] Ori et al.2020 https://doi.org/10.5194/gmd-14-1511-2021
[3] Heymsfield et al https://doi.org/10.1175/2010JAS3507.1