Using Differential Doppler Velocity (DDV) to Estimate Vertical Air Motion & DSD Parameters

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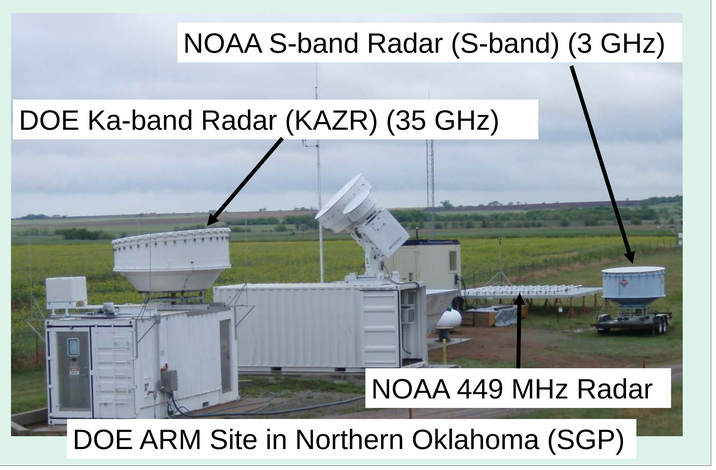
1. Motivation

The Doppler motion measured by vertically pointing precipitation radars is the summation of falling hydrometers and vertical air motion.

A single precipitation radar cannot separate these two vertical motions.

Analyzing Doppler motions from two precipitation radars operating at different frequencies can separate hydrometeor motion and vertical air motion (Meneghini et al. 2003; Tian et al. 2007).

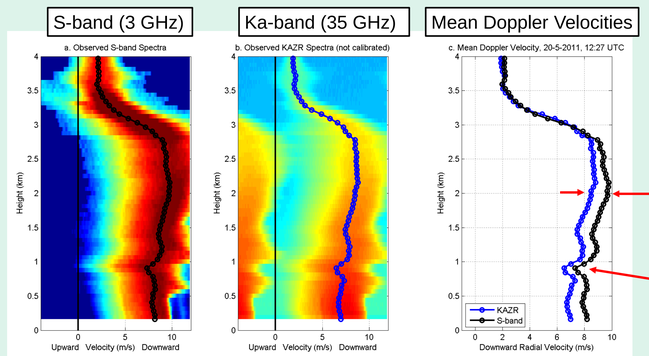
This study uses observations from NOAA's 3 GHz (S-band) radar and DOE's 35 GHz (Ka-band, KAZR) radar deployed during MC3E.



2. Mean Doppler Velocity (MDV)

Mean radar Doppler velocity (MDV) is:

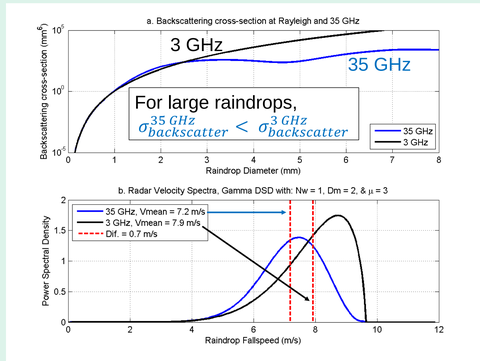
* Independent of radar calibration
* Independent of attenuation
* Dependent of raindrop size distribution (DSD) shape
* Dependent on vertical air motion
* Dependent on radar operating frequency



Observed Spectra and Mean Doppler Velocity (MDV)

Velocity Difference is due to DSD shape. (*independent of air motion*)

Shift in mean velocity by **both radars** is due to air motion. (*independent of DSD shape*)



Backscattering cross-sections at 3 and 35 GHz vs. Diameter

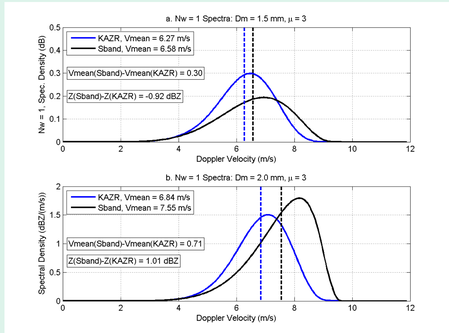
Simulated Doppler velocity spectra vs. Doppler Velocity

Simulated spectra assuming gamma DSD
N_w = 1 (Normalized spectra)
D_m = 2.0 mm
μ = 3

3. Differential Doppler Velocity

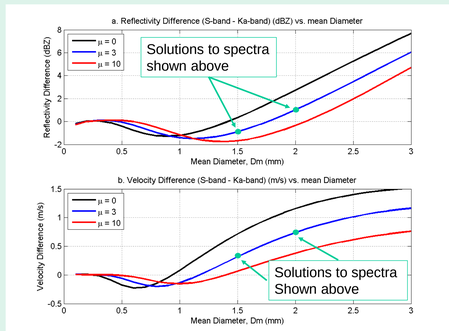
Differential Doppler velocity (DDV) is:

* Independent of radar calibration
* Independent of attenuation
* Dependent of raindrop size distribution (DSD) shape
* Independent on vertical air motion
* Dependent on radar operating frequency



Simulated gamma DSD spectra
N_w = 1 (Normalized spectra)
D_m = 2.0 mm
μ = 3

Simulated gamma DSD spectra
N_w = 1 (Normalized spectra)
D_m = 1.5 mm
μ = 3



Lookup Tables

Dual Frequency Reflectivity Ratio (DFR)

Differential Doppler Velocity (DDV)

4. Retrieval Methodology

Mean Doppler Velocities (MDV):

$$V^{3GHz}_{measured} = V^{3GHz}_{Hydro}(D_m,\mu) - W$$

$$V^{35GHz}_{measured} = V^{35GHz}_{Hydro}(D_m,\mu) - W$$

Dependent of air motion (W)

Differential Doppler Velocity (DDV):

$$DDV = V^{3GHz}_{measured} - V^{35GHz}_{measured}$$

$$DDV = V^{3GHz}_{Hydro}(D_m,\mu) - V^{35GHz}_{Hydro}(D_m,\mu)$$

Independent of air motion (W)

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4 Measurements

Doppler Velocity: $V^{3\,GHz}_{Doppler}$

Doppler Velocity: $V^{35\,GHz}_{Doppler}$

Reflectivity: $Z^{3\,GHz}_{m}$

Reflectivity: $Z^{35\,GHz}_{m}$

→

4 Unknowns

Mean Diameter: D_m

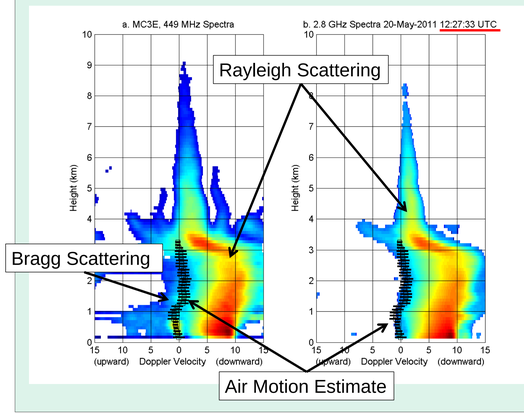
Air Motion: W

Number concentration: N_w

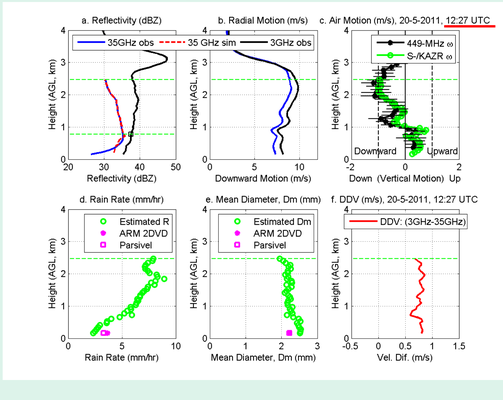
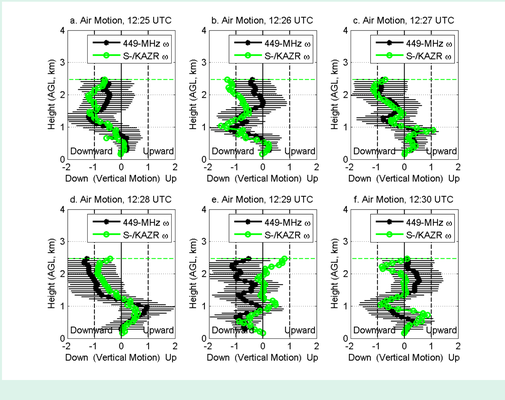
DSD breath parameter: μ

5. Verification using 449-MHz Profiler Retrievals

Air Motion Reference: 449 MHz & S-band Profiler Retrievals



DSD and Air Motion Estimates 20-May-2011, 12:27 UTC



1-minute Sequence of Air Motions 20-May-2011, 12:25-to-12:30 UTC