Estimating Raindrop Size Distributions and Vertical Motions using S-band & KAZR Vertically Pointing Radars

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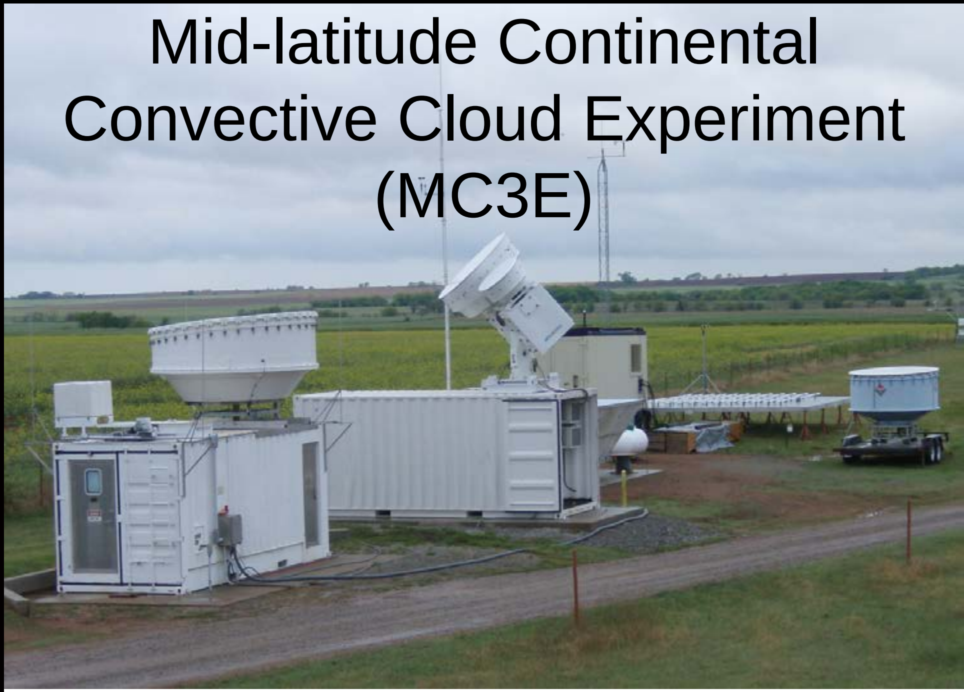
In partnership with

NOAA Earth System Research Laboratory (ESRL)

University of Colorado Boulder

Mid-latitude Continental Convective Cloud Experiment (MC3E)



Support for this work:
DOE ASR Grant: DE-SC0007080
NASA PMM Grant: NNX13AF89G

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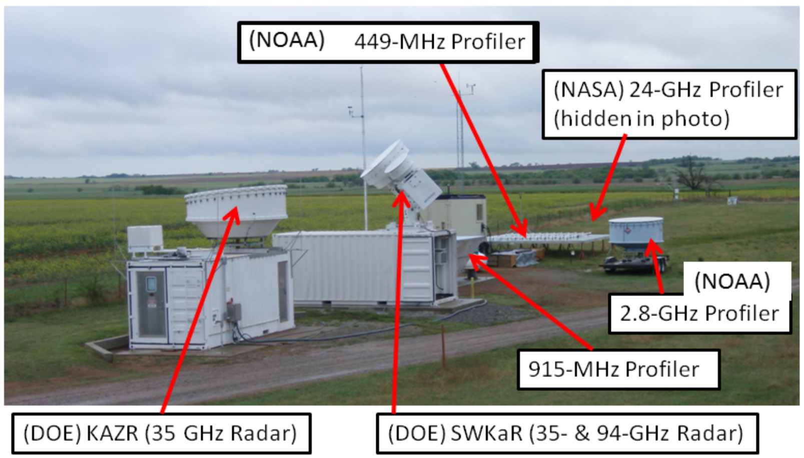
Research Objectives

- Goal
  - Estimate profiles of vertical air motion and raindrop size distributions (DSDs) using two non-synchronous and non-beam matched vertically pointing profilers
- Approach
  - Exploit the different backscattering signatures at Ka-band (KAZR) and S-band
    - ***KAZR – non-Rayleigh (also, non-Bragg)***
    - ***S-band – Rayleigh***
- Key Results
  - Air motion & DSD retrievals in rain
  - Retrievals independent of radar calibration
  - N_w and rain rate dependent on S-band calibration

MC3E Profiling Radar Deployment

Radars deployed in Mid-latitude Continental Convective Cloud Experiment (MC3E)
22 April – 6 June 2011



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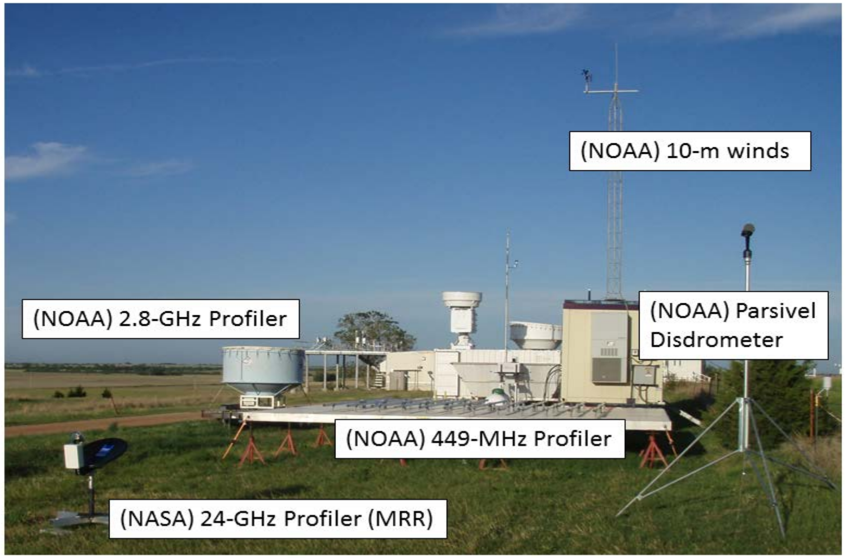
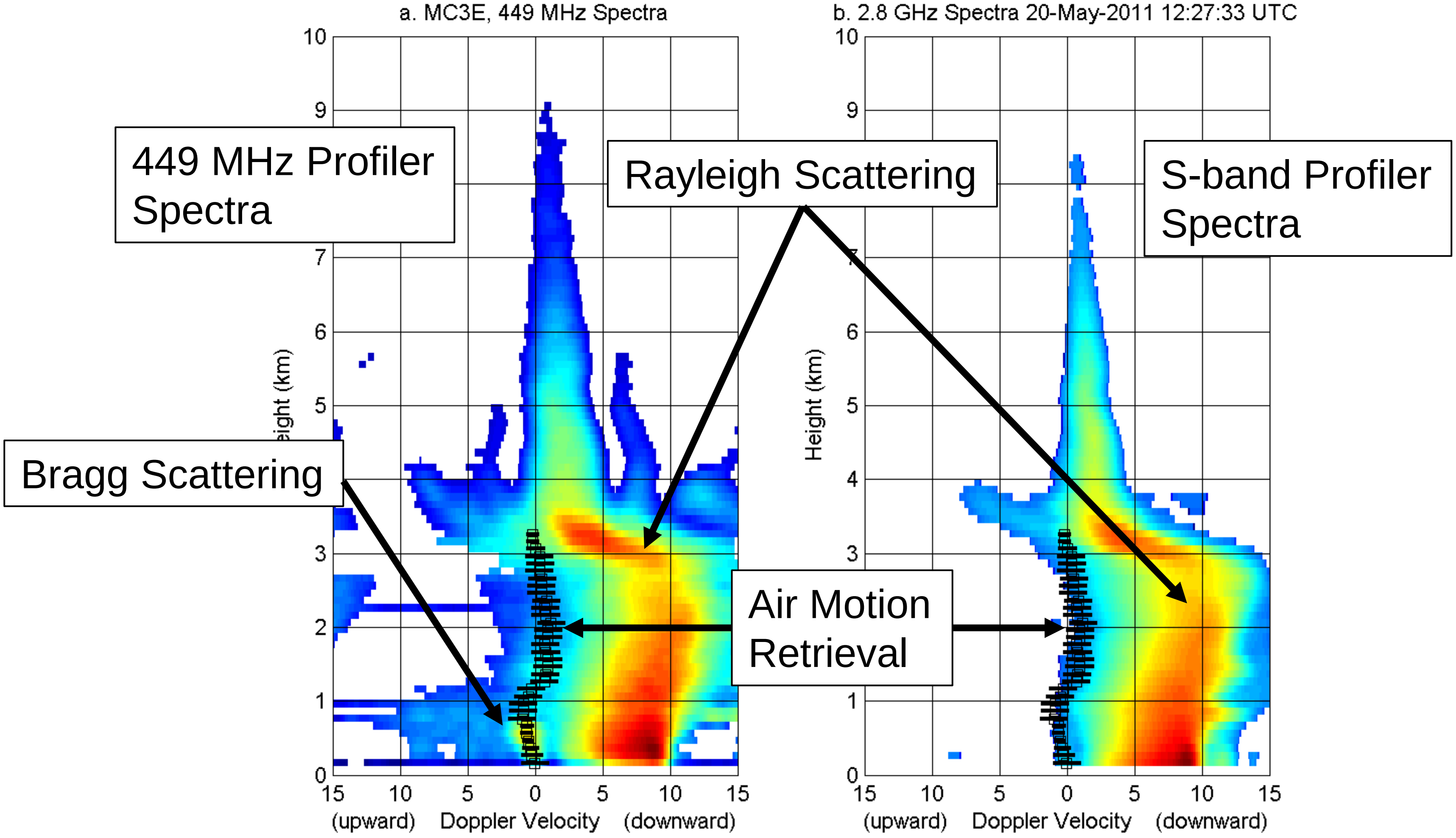


Dual Frequency Air Motion Retrieval



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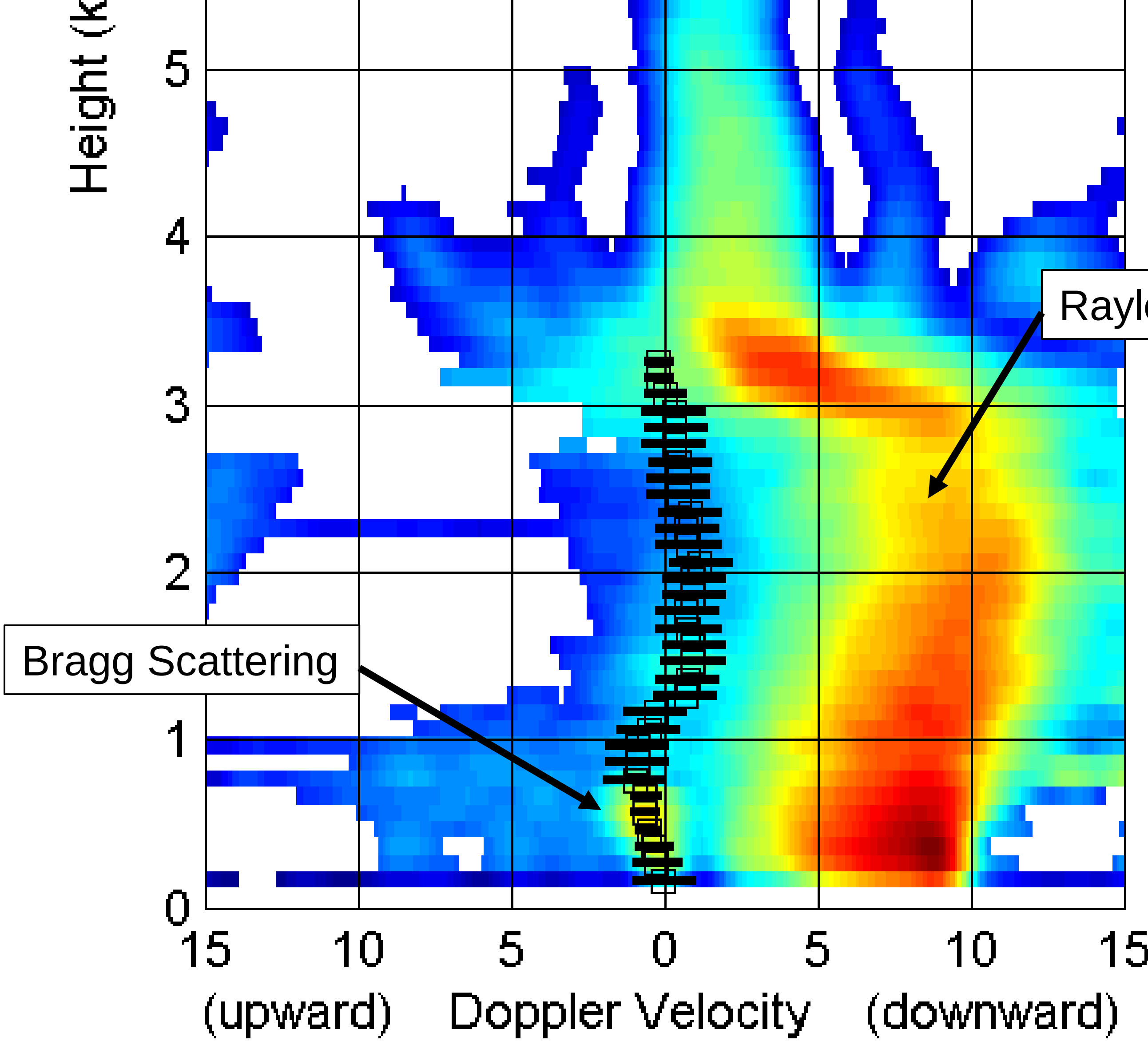


449 MHz
20 May 2011
12:27:33 UTC

1-Minute Dwell – Pros & Cons

Profiles from KAZR and S-band radars are:

- *not simultaneous*
- *not matched beams*

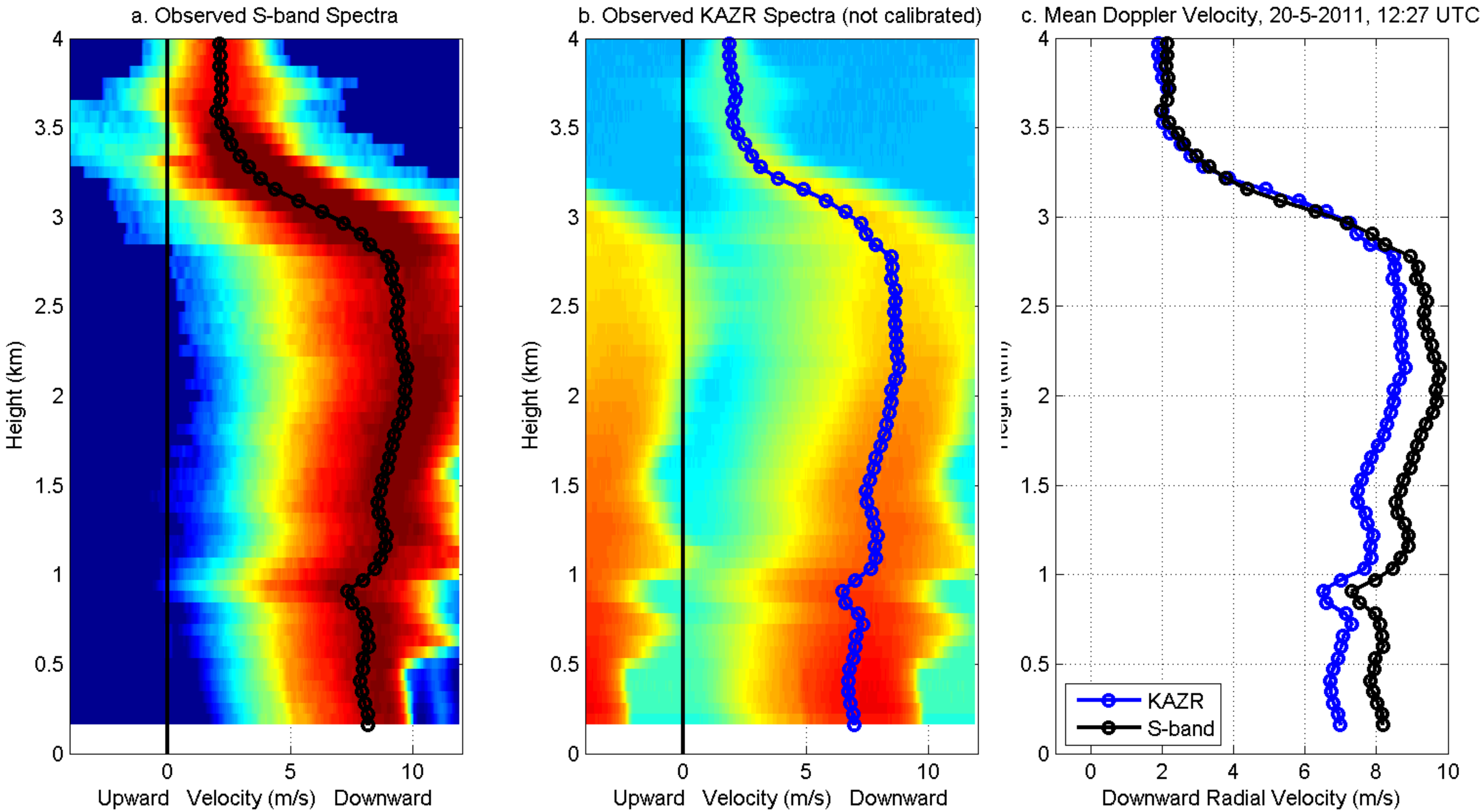
Average spectra for 1-minute

- *Represent larger spatial domain*
- *Cannot represent the turbulence within pulse volume*

Number of profiles per 1-minute dwell:

- *KAZR – 17 profiles per minute*
- *S-band – 7 profiles per minute*

Observed Doppler Velocity Spectra



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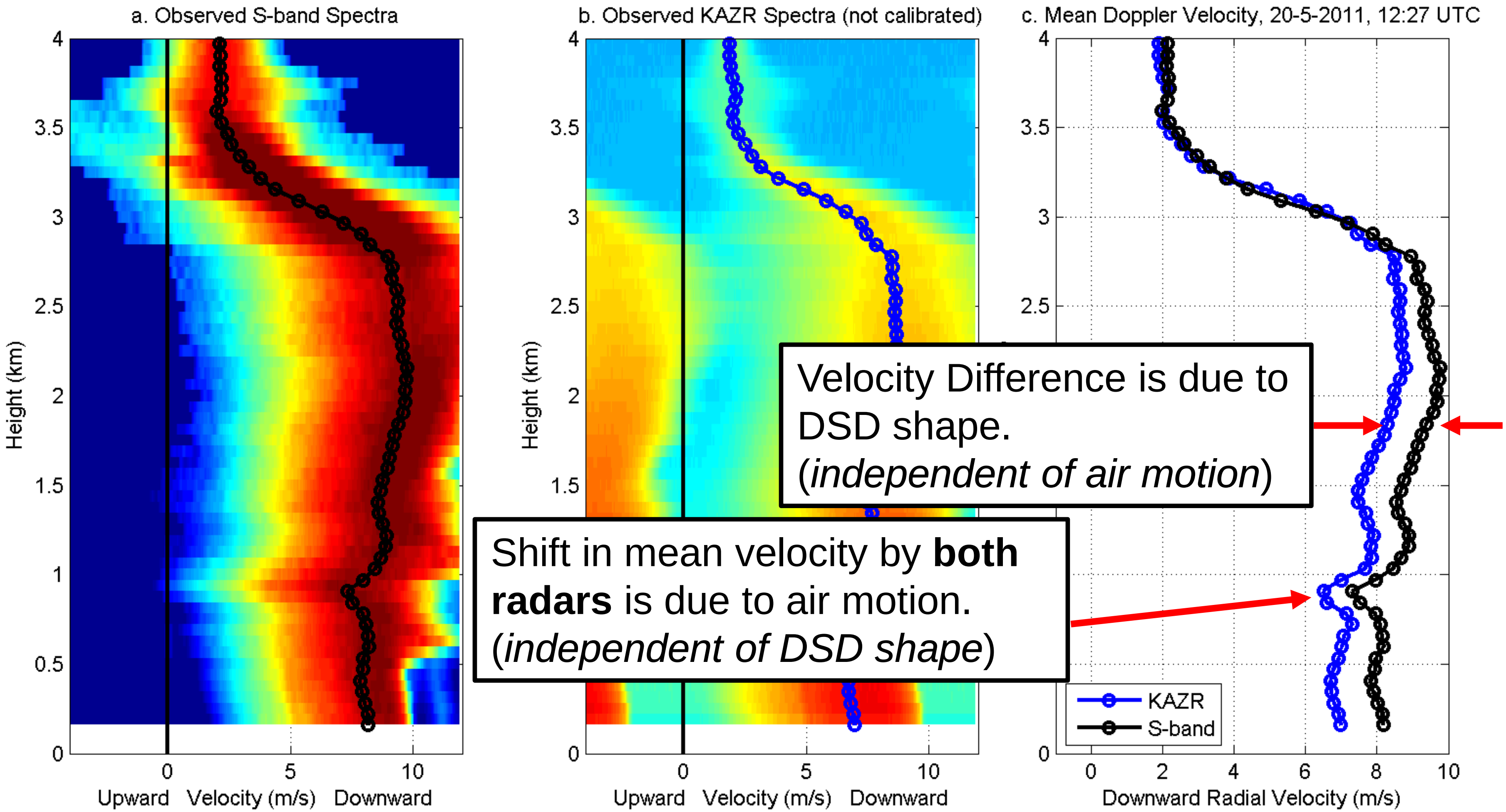


Mean Doppler Velocity

DSD (scaled PDF): $N(D; N_w, D_m, \mu) = N_w \quad f(D; D_m, \mu)$

'Intensity' 'quasi PDF'

Radar Weighted Fall Velocity:

$$S_{hydro}(v; N_w, D_m, \mu) = N_w f(D; D_m, \mu)\sigma_{backscatter}(D)g(D, v)$$

Diameter-to-fall conversion

Mean Hydrometer Fall Velocity:

$$V_{hydro}(D_m, \mu) = \frac{\int S_{hydro}(v; D_m, \mu)vdv}{\int S_{hydro}(v; D_m, \mu)dv}$$

Measured Velocity (Doppler Velocity):

$$V_{measured} = \frac{\int_{v_{min}}^{v_{max}} S(v)vdv}{\int_{v_{min}}^{v_{max}} S(v)dv} = V_{hydro}(D_m, \mu) - W$$

Difference in Doppler Velocity (DDV)

Mean Doppler Velocities:

$$V_{measured}^{Sband} = V_{hydro}^{Sband}(D_m, \mu\ ) - W$$

$$V_{measured}^{KAZR} = V_{hydro}^{KAZR}(D_m, \mu\ ) - W$$

Difference in Doppler Velocities (DDV):

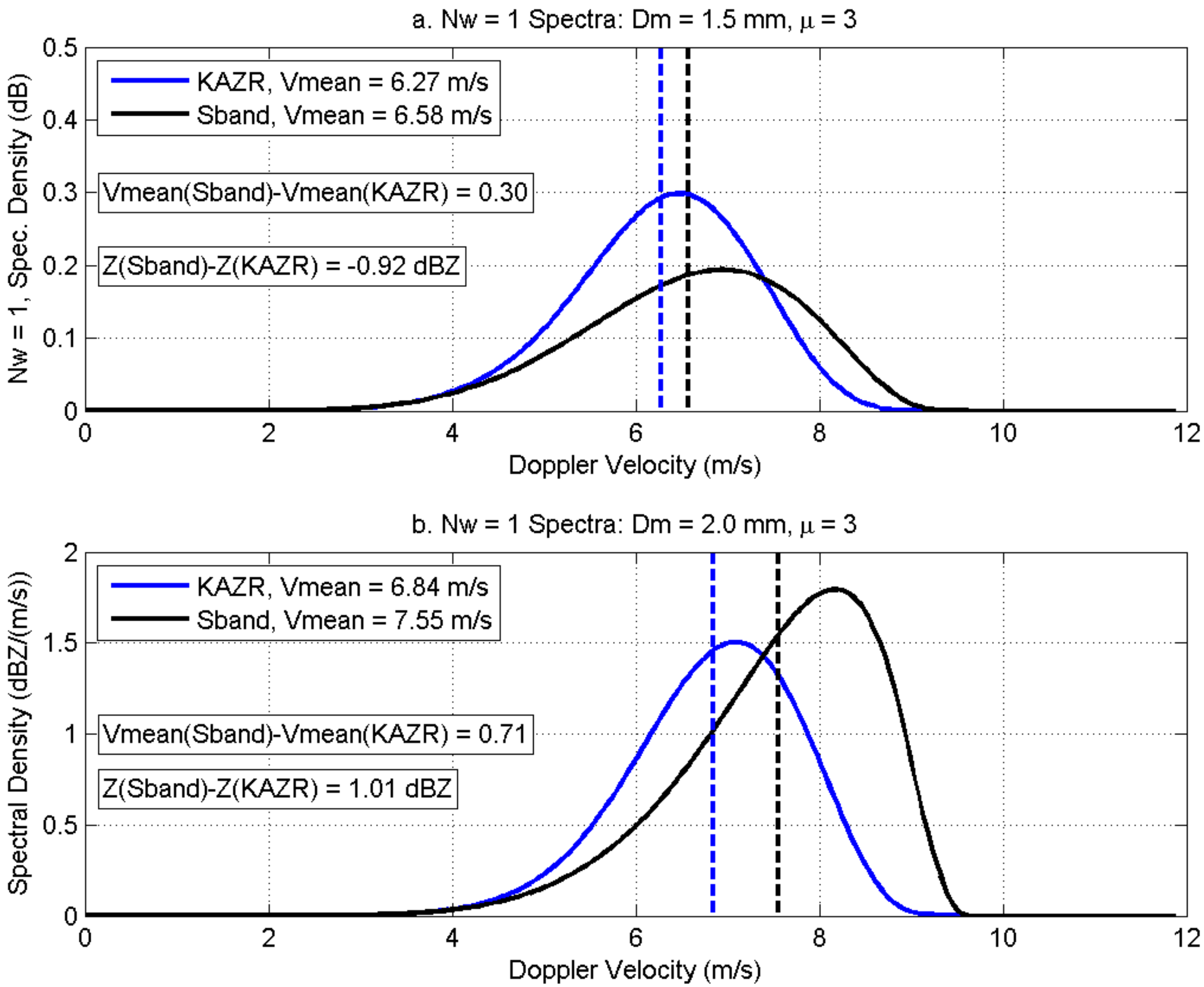
$$DDV\ = V_{measured}^{Sband} - V_{measured}^{KAZR}$$

$$DDV\ = V_{Hydro}^{Sband}(D_m, \mu\ ) - V_{Hydro}^{KAZR}(D_m, \mu)$$

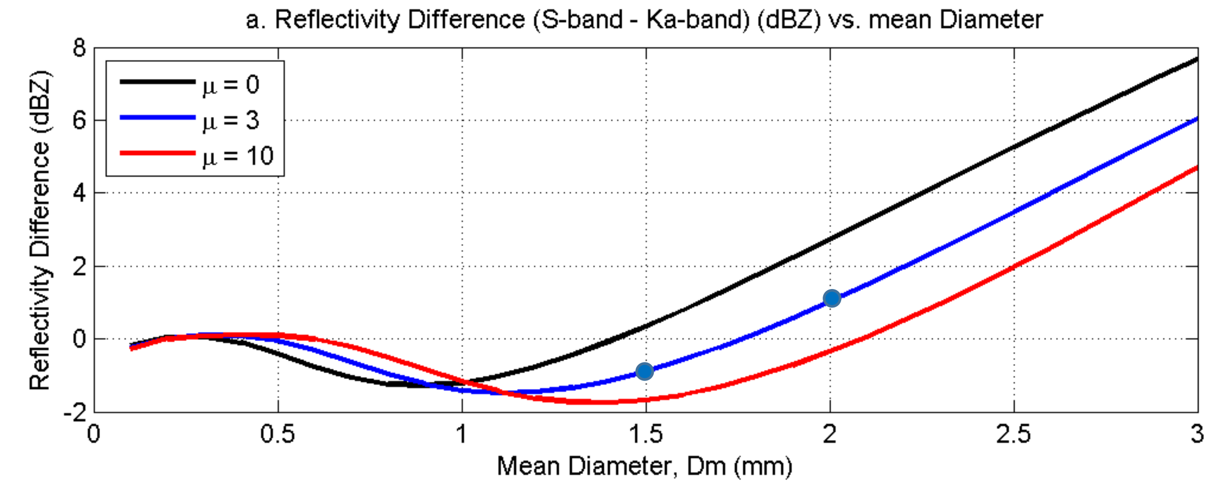
Bottom line:

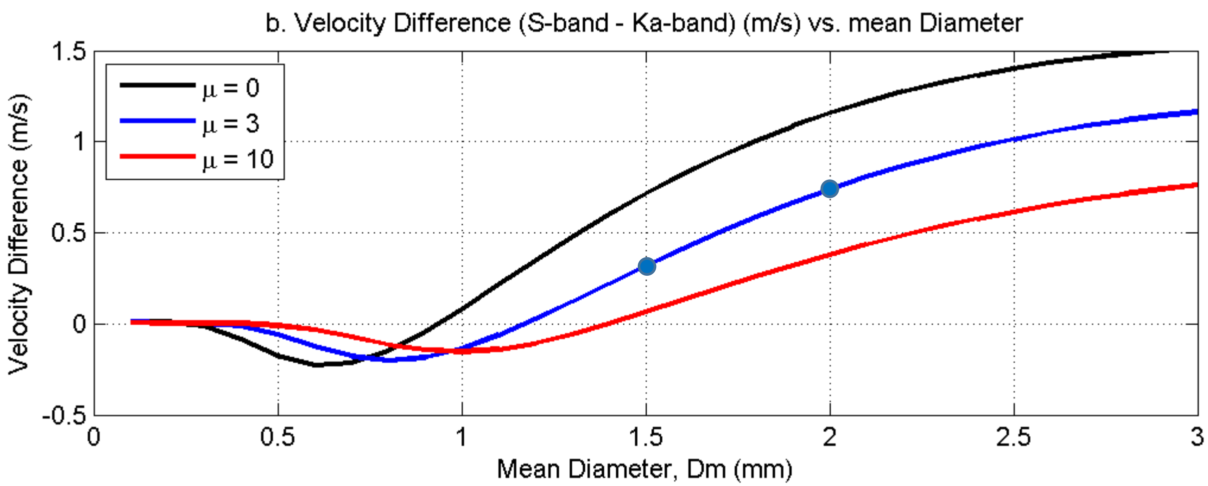
Difference in Doppler velocity (DDV) is independent of air motion and only dependent on the shape of the DSD.

Simulated Doppler Spectra

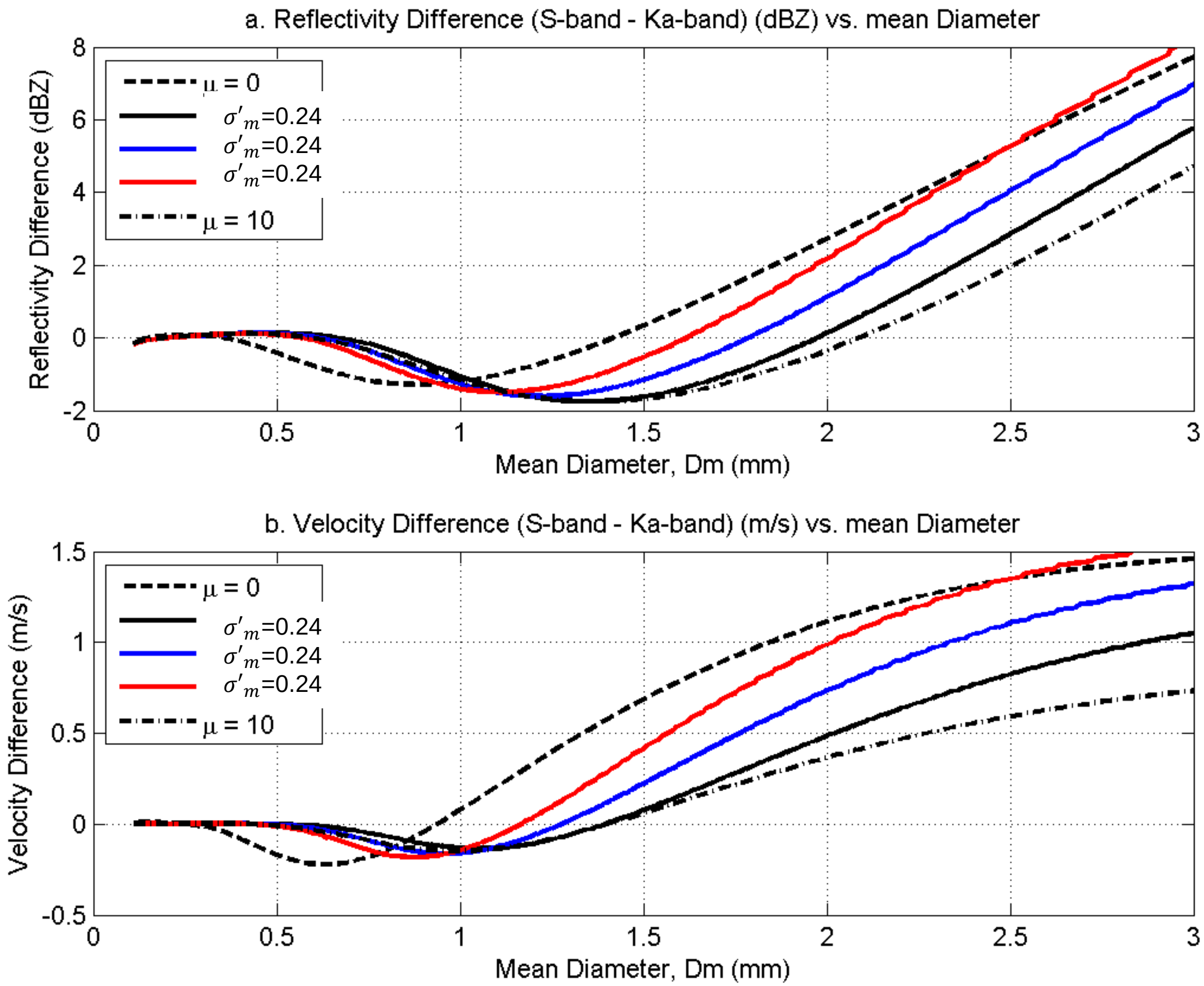


DFR and DDV vs. Mean Diameter





DFR & DDV with Norm. Breadth



Retrieval Sequence

Two Measurements:

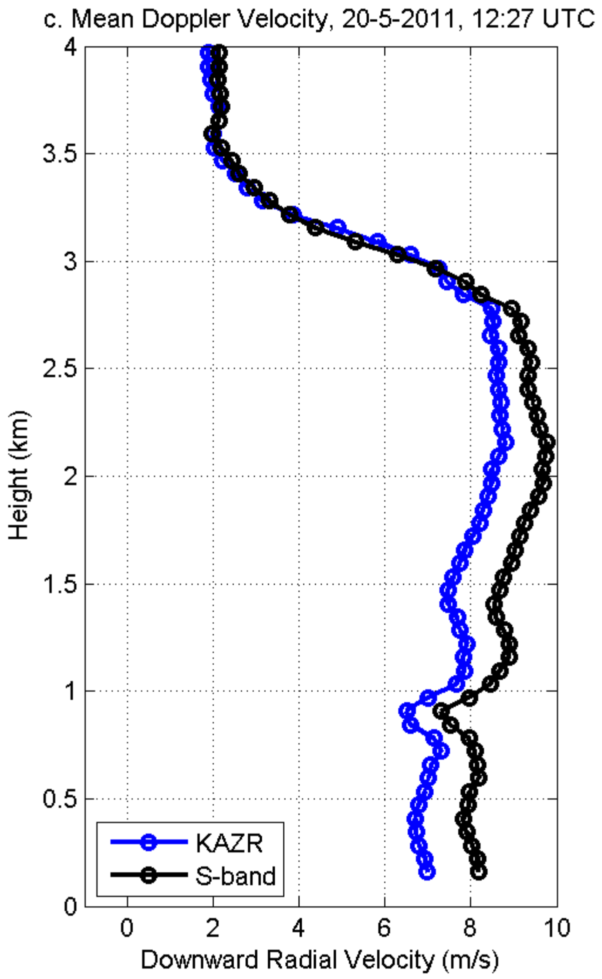
- KAZR Doppler Velocity
- Sband Doppler Velocity

Three Unknowns:

- Air motion (W)
- Mean Diameter (D_m)
- Breadth Parameter (σ'_m)

Assumptions:

- Zero air motion at lowest range gate
- Breadth Parameter constant with ht



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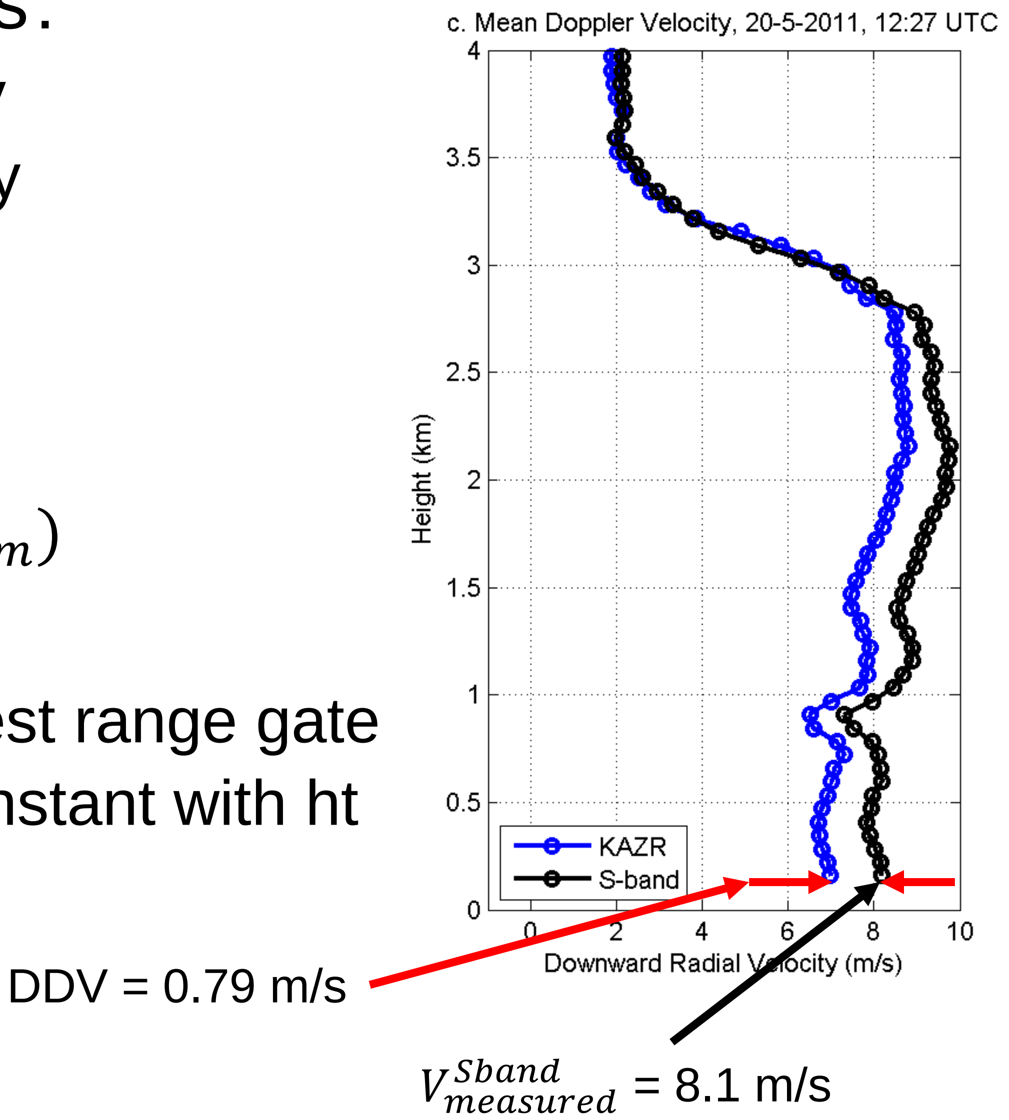
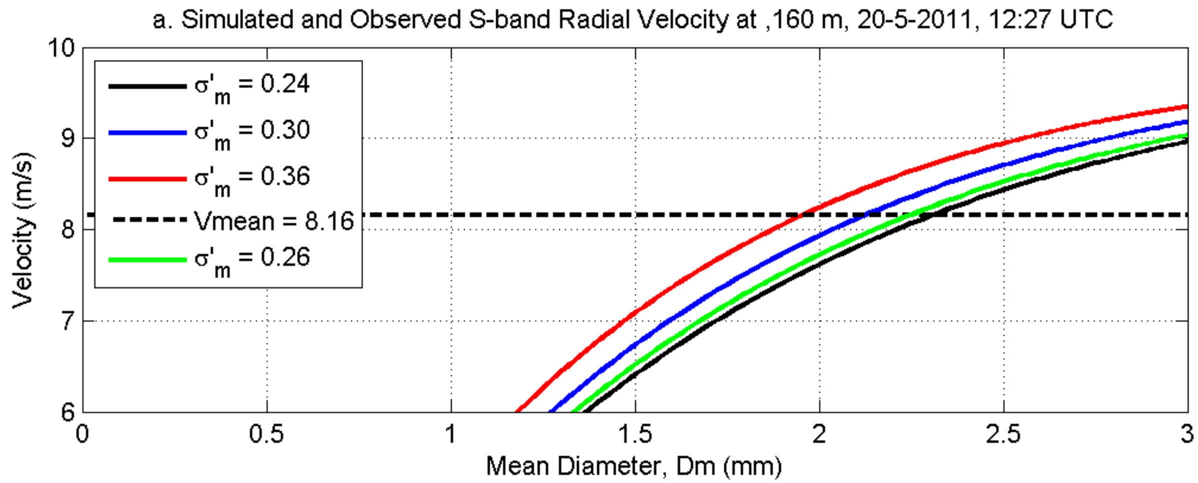
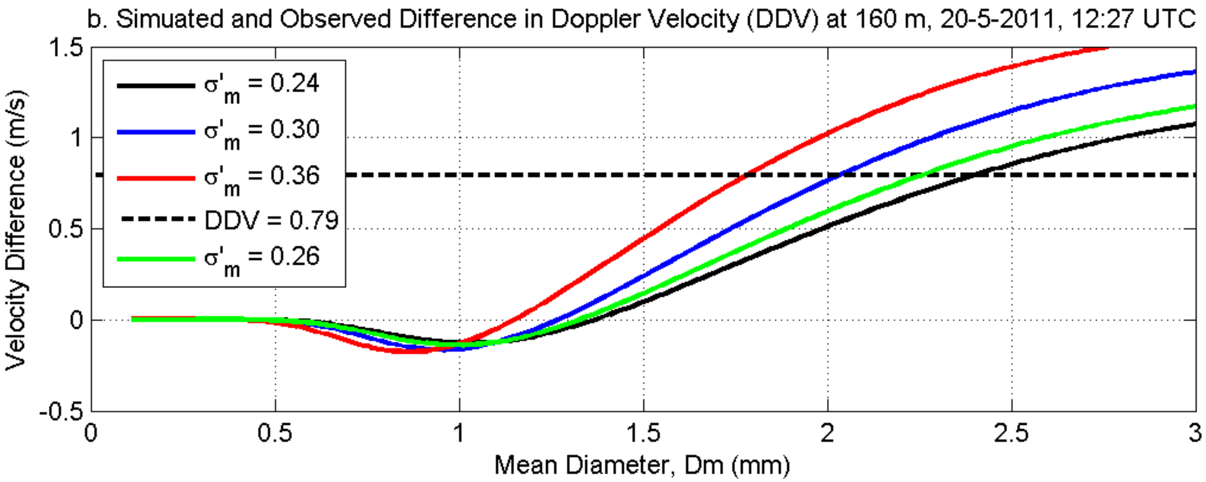


Step #1: Lowest range gate (160 m)

$V_{measured}^{Sband}$ = 8.16 m/s



DDV = 0.79 m/s



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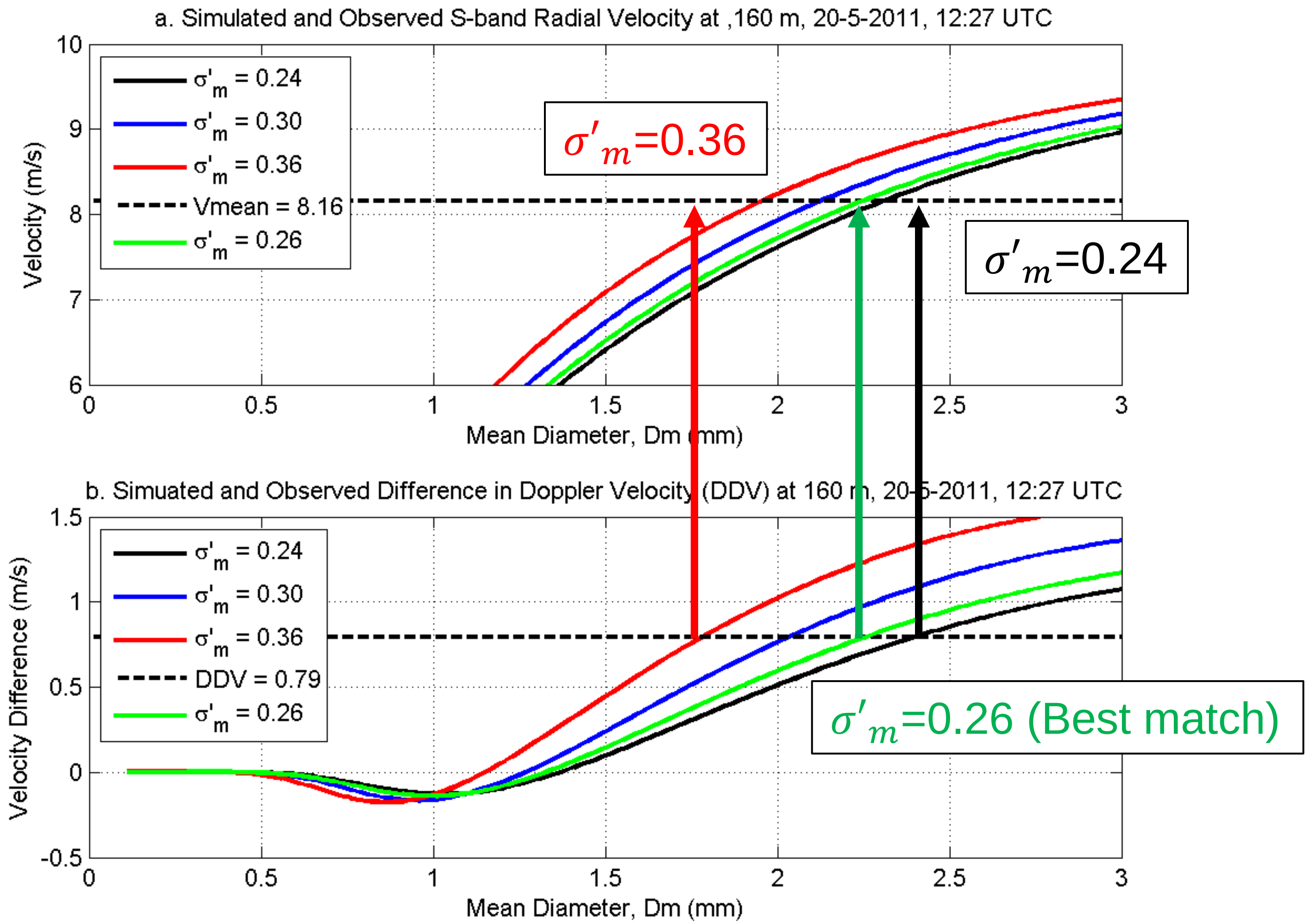

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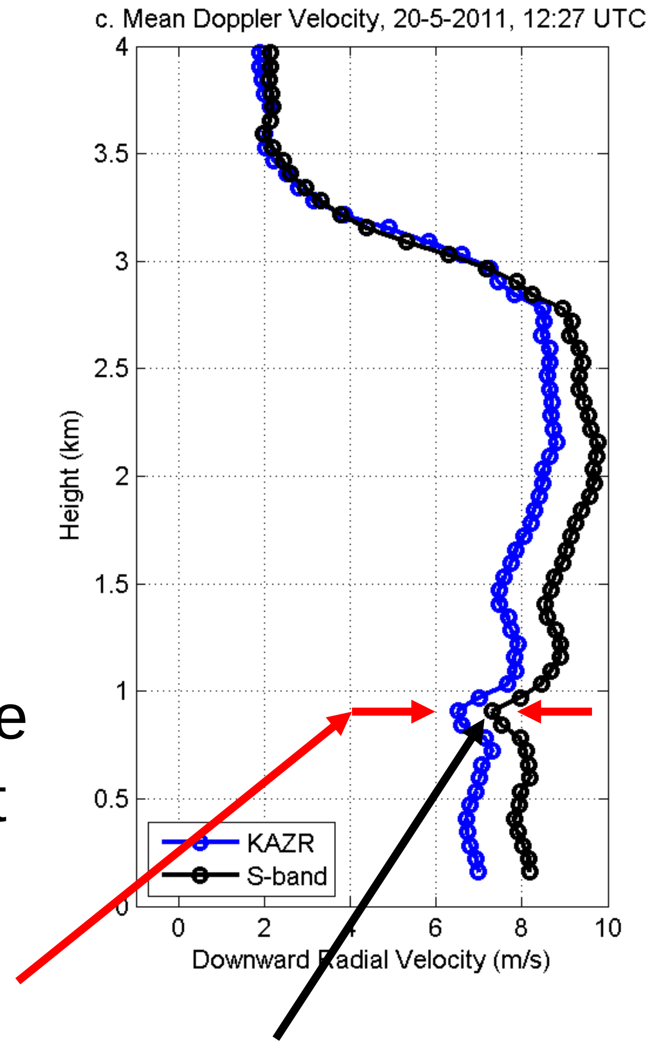


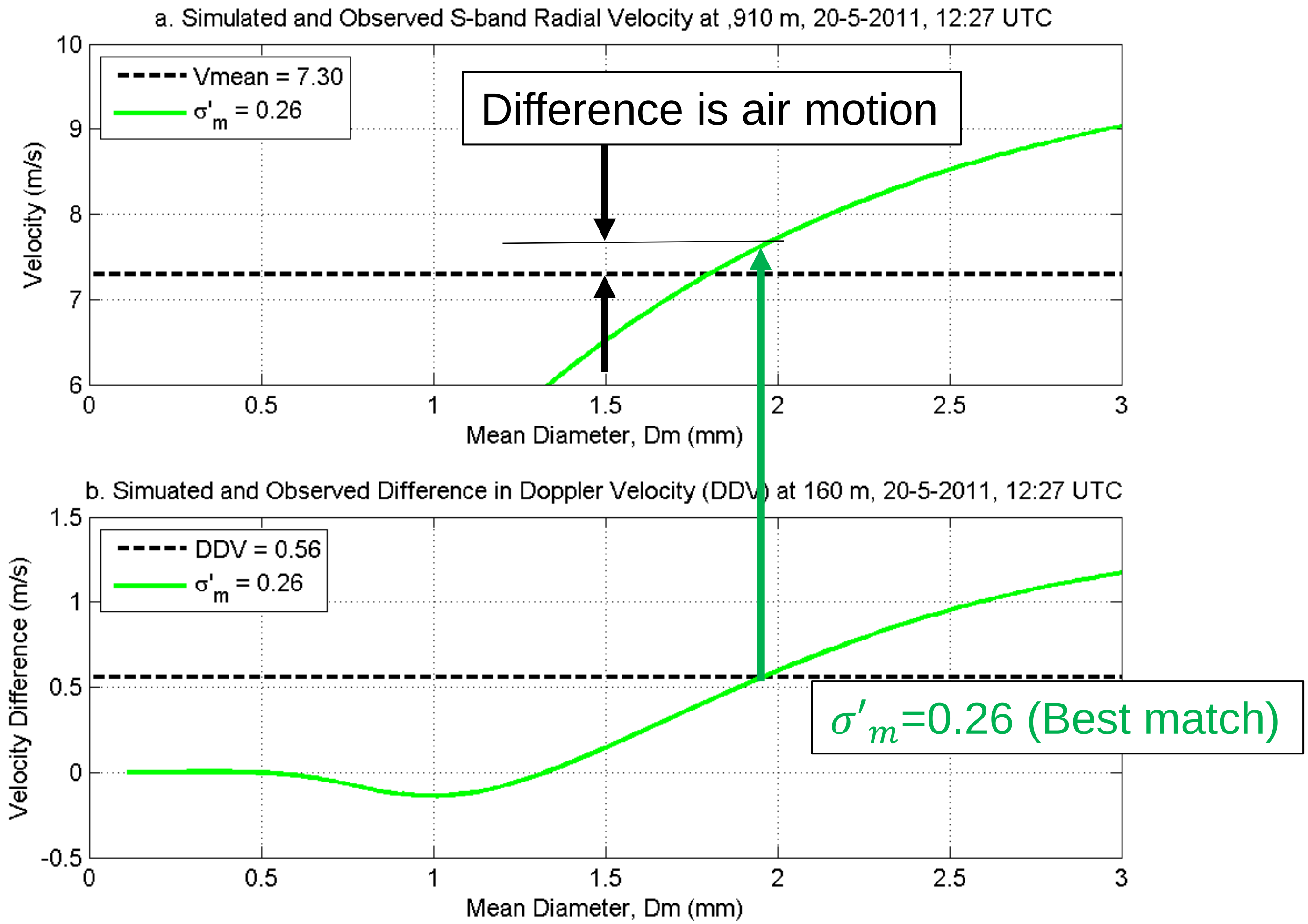
DDV = 0.56 m/s

$V_{measured}^{Sband}$ = 7.3 m/s

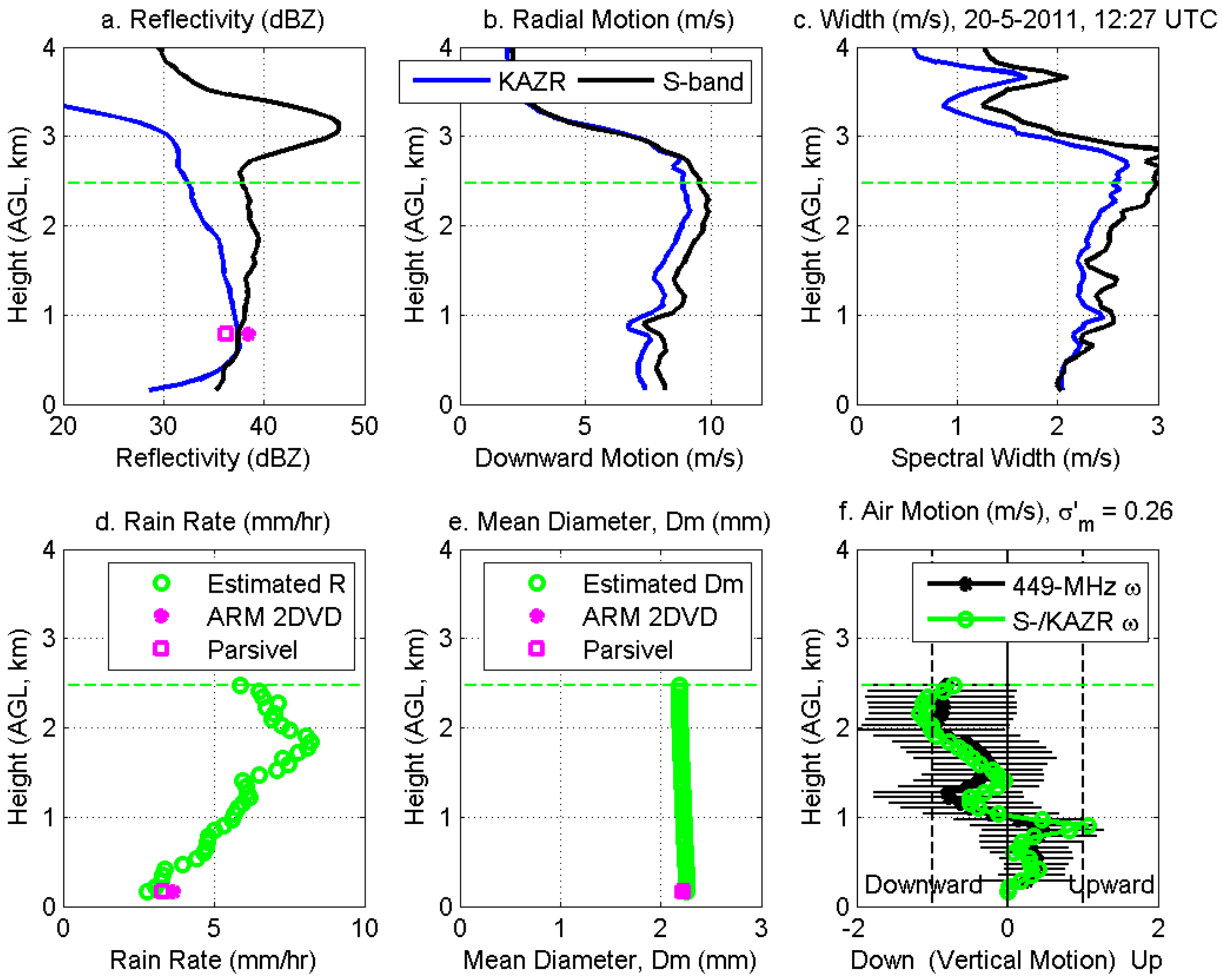
Step #1: Lowest range gate

$V_{measured}^{Sband}$ = 7.30 m/s

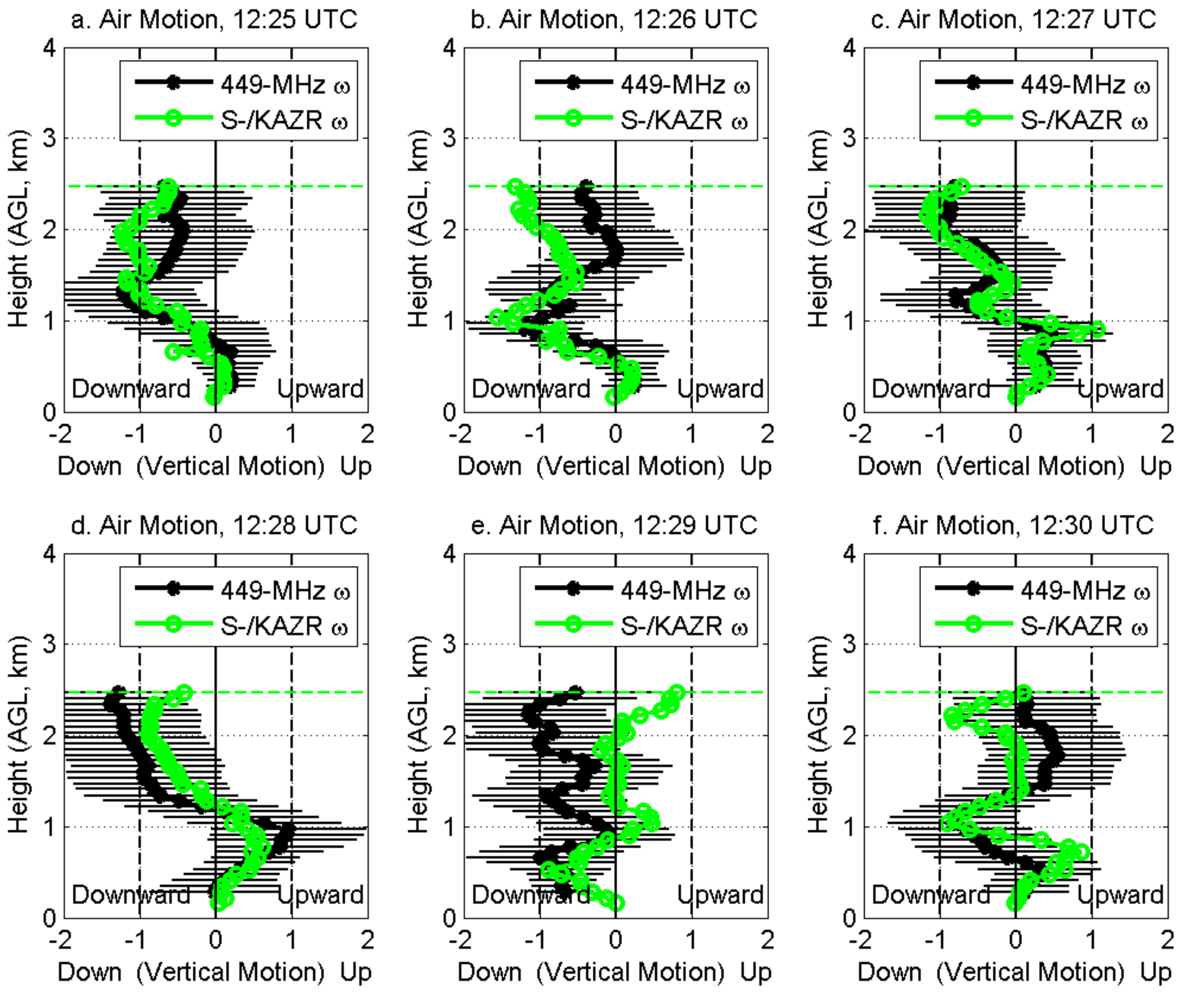
DDV = 0.56 m/s



Retrieval at 12:27 UTC



Air motions: 12:25 to 12:30 UTC



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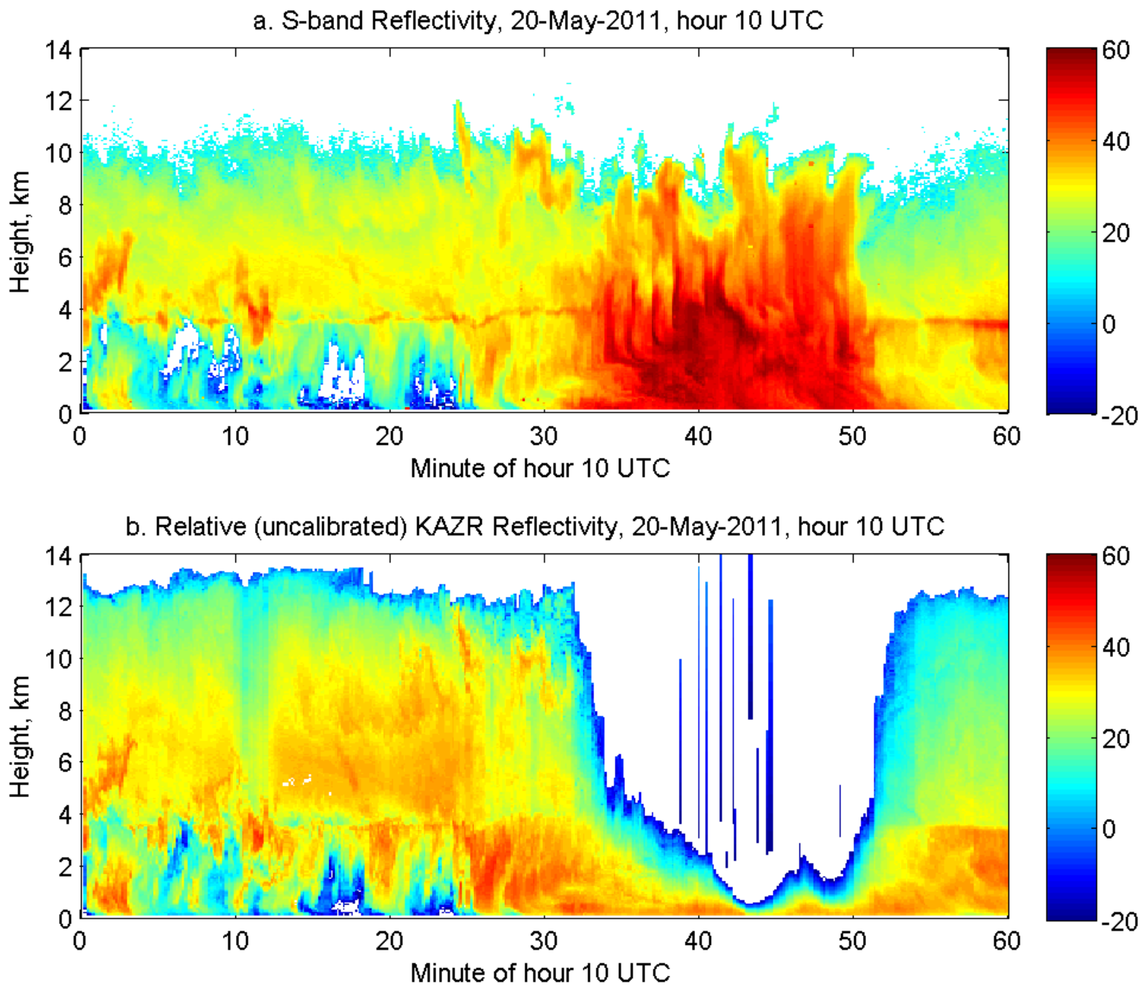
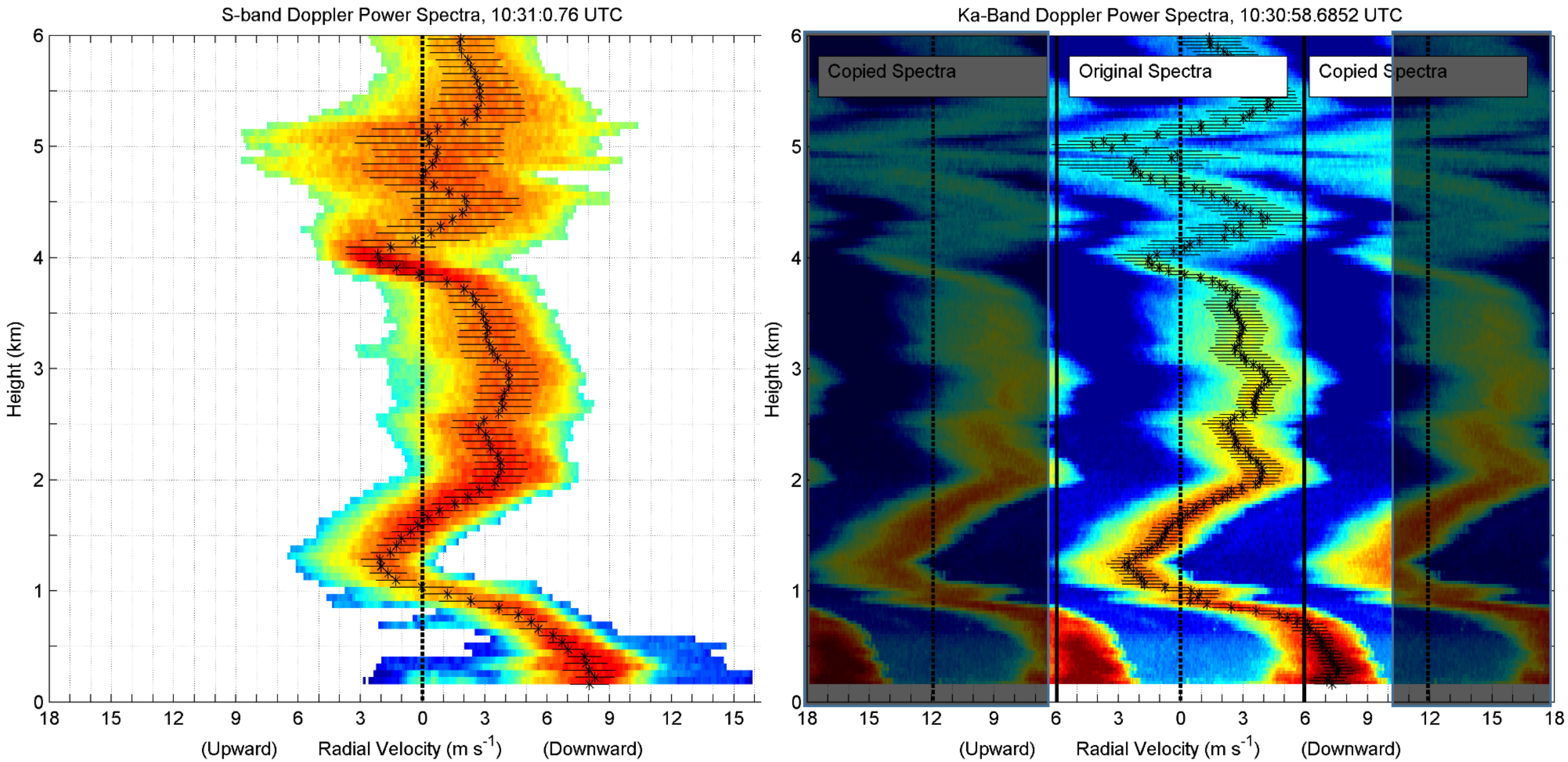
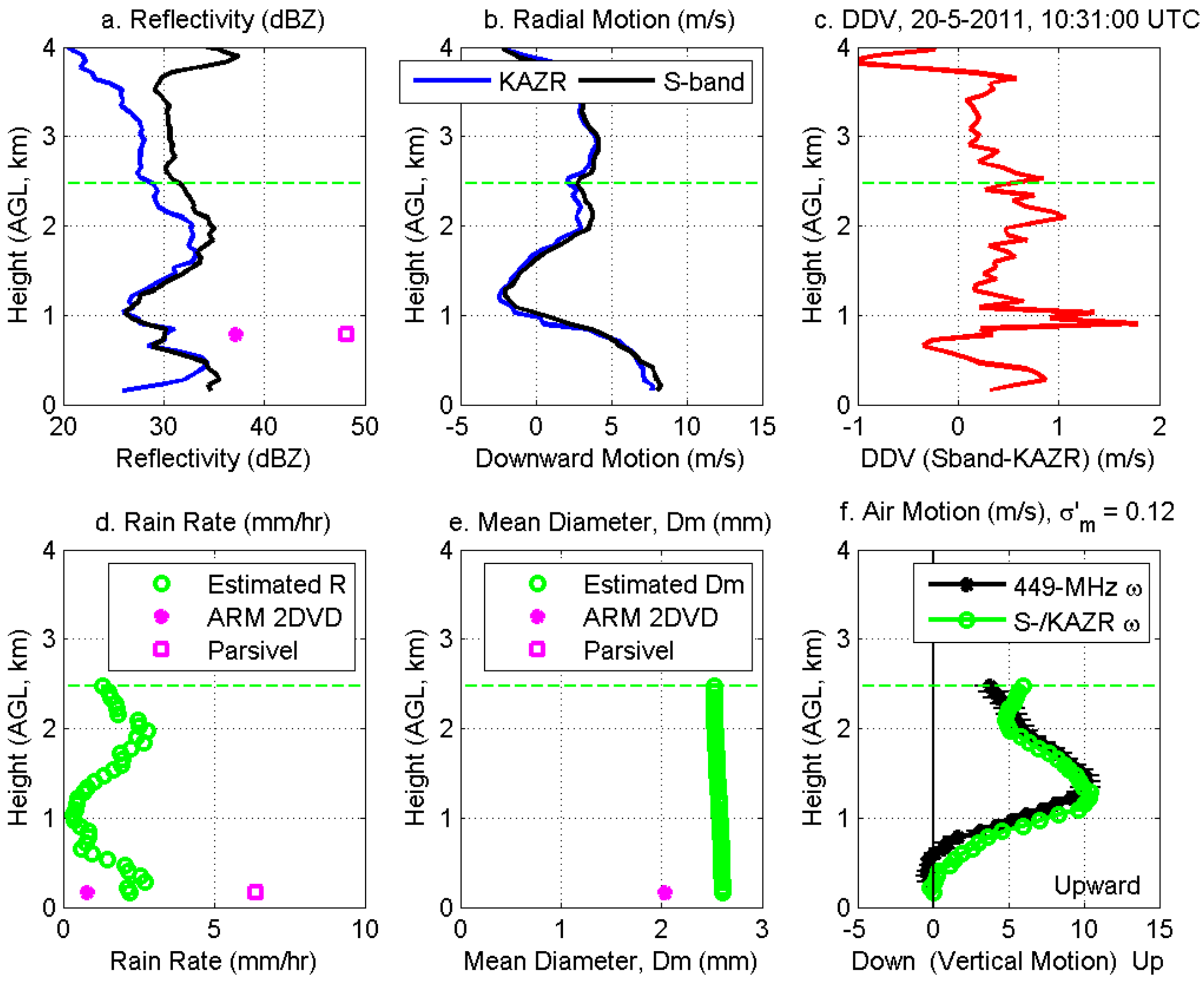
Time-height Cross-Section Z



Spectra at 10:31 UTC



Convective profile, 10:31:00 UTC



Next Steps

1. Convective Rain in rain portion only

   Use profiles every 10 seconds

2. UAZR instead of S-band?

   FASTER analysis suggests UAZR & S-band moments are very similar (Scott G. & Tami)

3. Produce a PI Product using 2 years of KAZR / UAZR observations at SGP

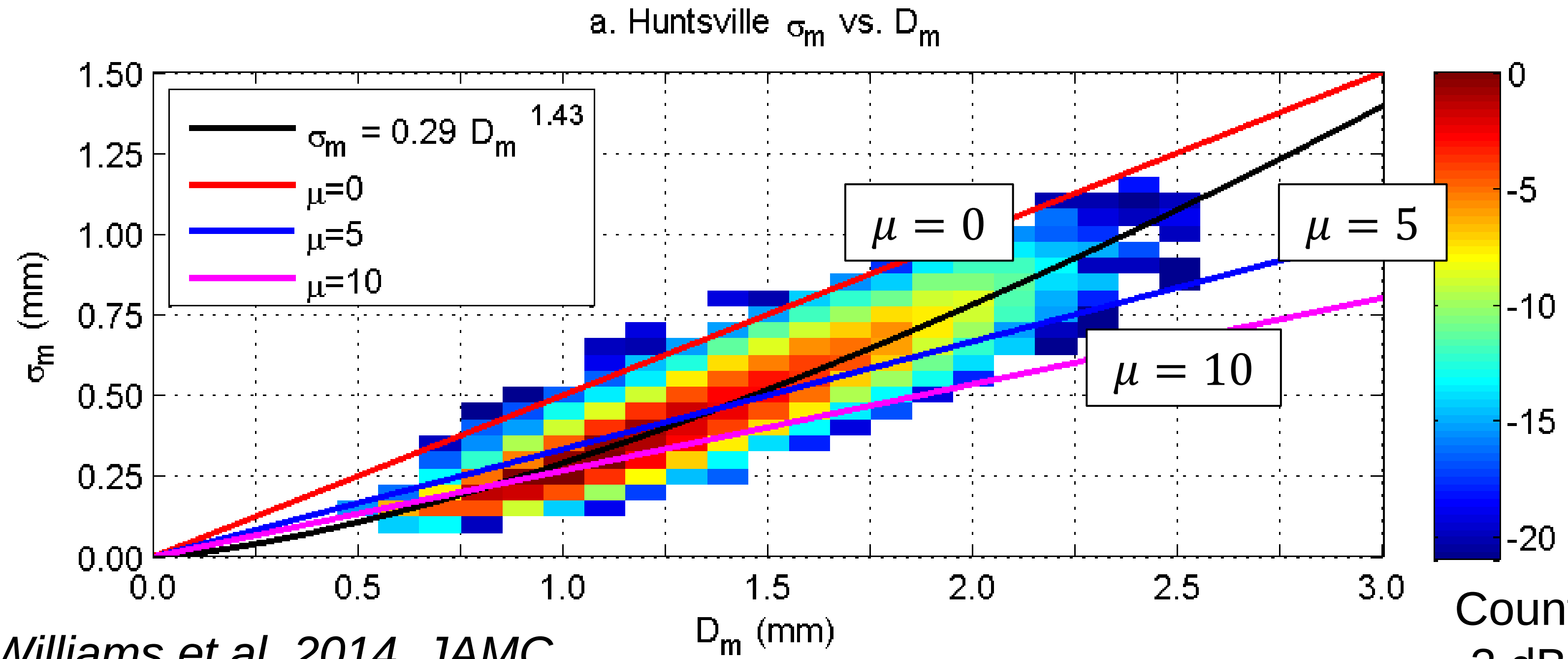
Backup slides

Huntsville, 2DVD: 21,000 minutes

If we assume a gamma shape DSD, there is a relationship between $\sigma_m - D_m - \mu$ (Assume the $D_{max} = \infty$)

1. Can estimate σ_m from D_m and μ $$\sigma_m^2 = \frac{D_m^2}{\mu + 4}$$

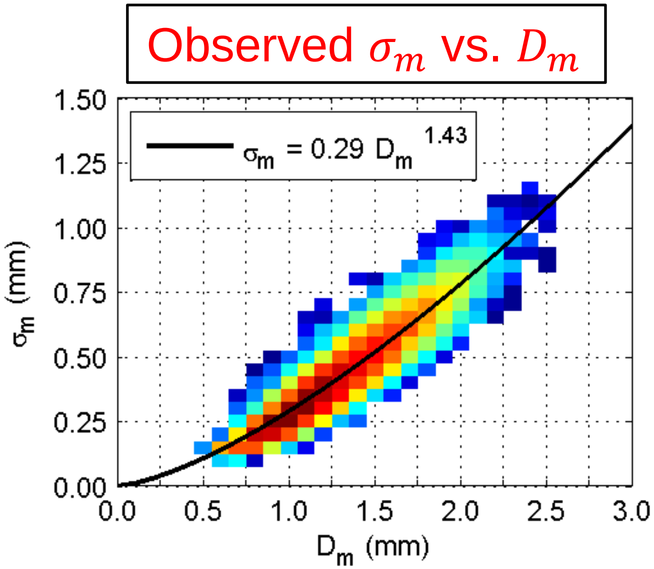
2. Can estimate μ from D_m and σ_m $$\mu = \frac{D_m^2}{\sigma_m^2} - 4$$

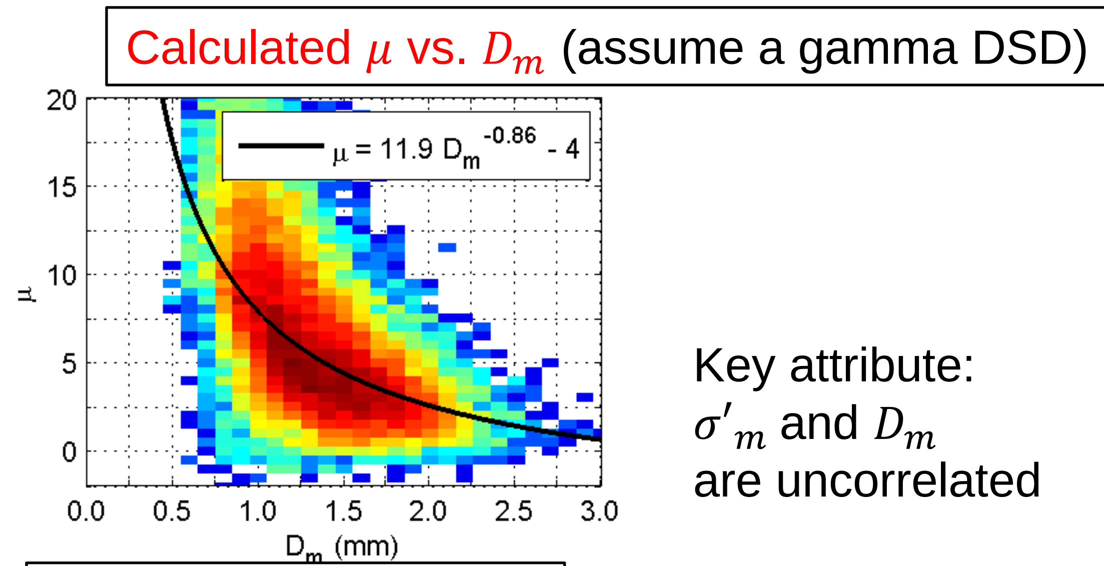


Count in dB
-3 dB = ½ cnt

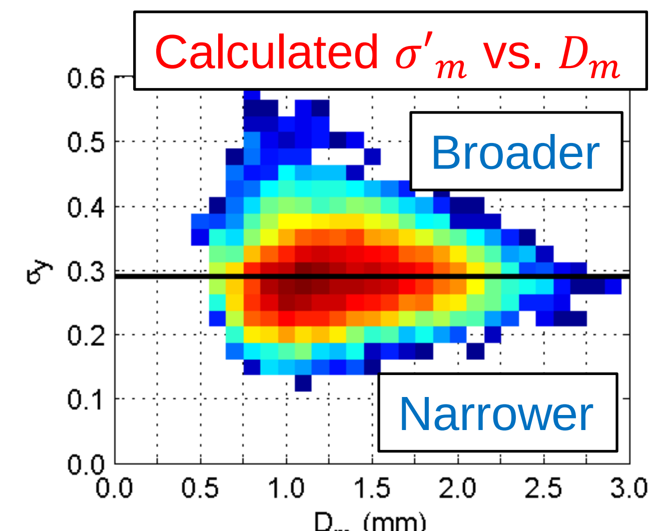
Williams et al. 2014, JAMC

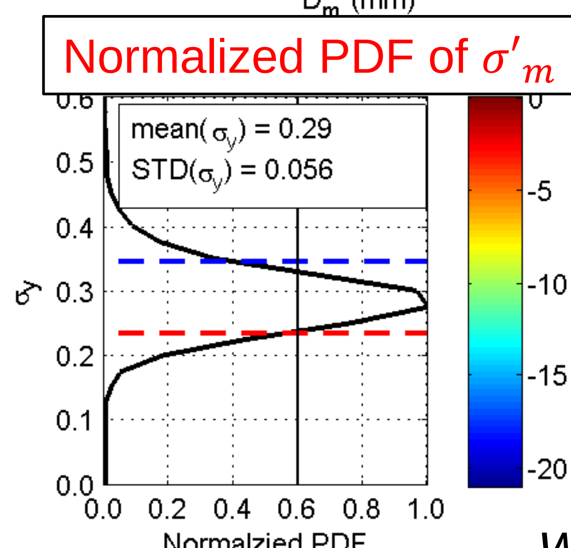
Huntsville 2DVD: 21,000 minutes





Key attribute:
σ'_m and D_m
are uncorrelated





74% of observations
are within +/- 1 STD
(a normal distribution
would have 68%)

Williams et al. 2014, JAMC

Difference in Doppler Velocity (DDV)

Mean Doppler Velocities:

$$V^{Sband}_{measured} = V^{Sband}_{hydro}(D_m, \sigma'_m) - W$$

$$V^{KAZR}_{measured} = V^{KAZR}_{hydro}(D_m, \sigma'_m) - W$$

Difference in Doppler Velocities (DDV):

$$DDV = V^{Sband}_{measured} - V^{KAZR}_{measured}$$

$$DDV = V^{Sband}_{Hydro}(D_m, \sigma'_m) - V^{KAZR}_{Hydro}(D_m, \sigma'_m)$$

Difference in Doppler velocity (DDV) is independent of air motion and only dependent on the shape of the DSD.