Evaluating a model of mixed-phase cloud processes using radar Doppler spectra

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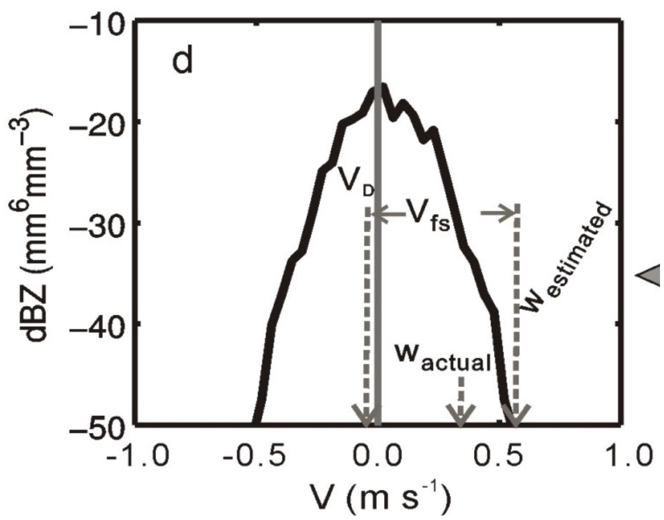
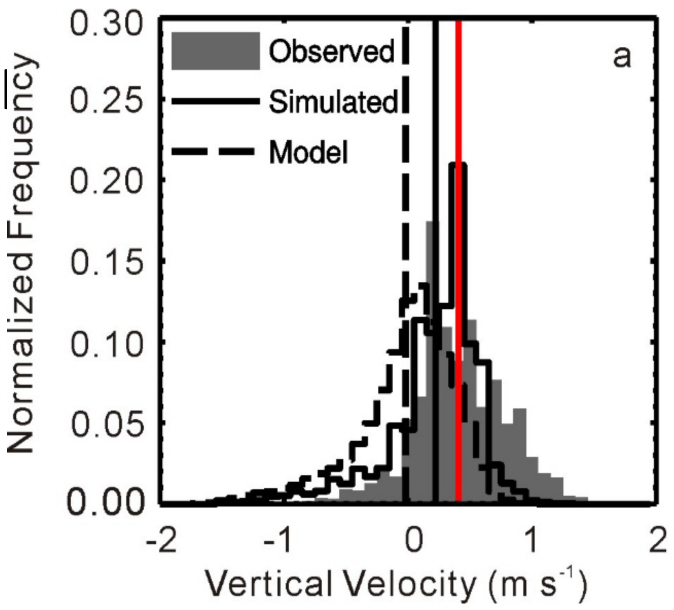
Methodology

- Data (ISDAC - 8 April 2008 Golden case)
  - KAZR spectra
  - Model: DHARMA
    - Size resolved bin microphysics (drops, dendrites, aggregates): mass and fall speeds
    - Vertical velocity: mean and variance
  - Doppler spectrum simulator
    - Liquid/dendrites: small particle scattering theory
    - Aggregates: Generalize Multi-particle Mie (Botta et al.)
    - Adjusted for model/radar volume differences
  - Processing
    - Reflectivity (dBZ)
    - Volume-mean air velocity (w_{est})
    - Volume-mean Doppler velocity (V_D)
    - Hydrometeor fall speed (V_{fs})
  - Compare in-cloud histograms
    - One slice through model
    - One hour of KAZR data



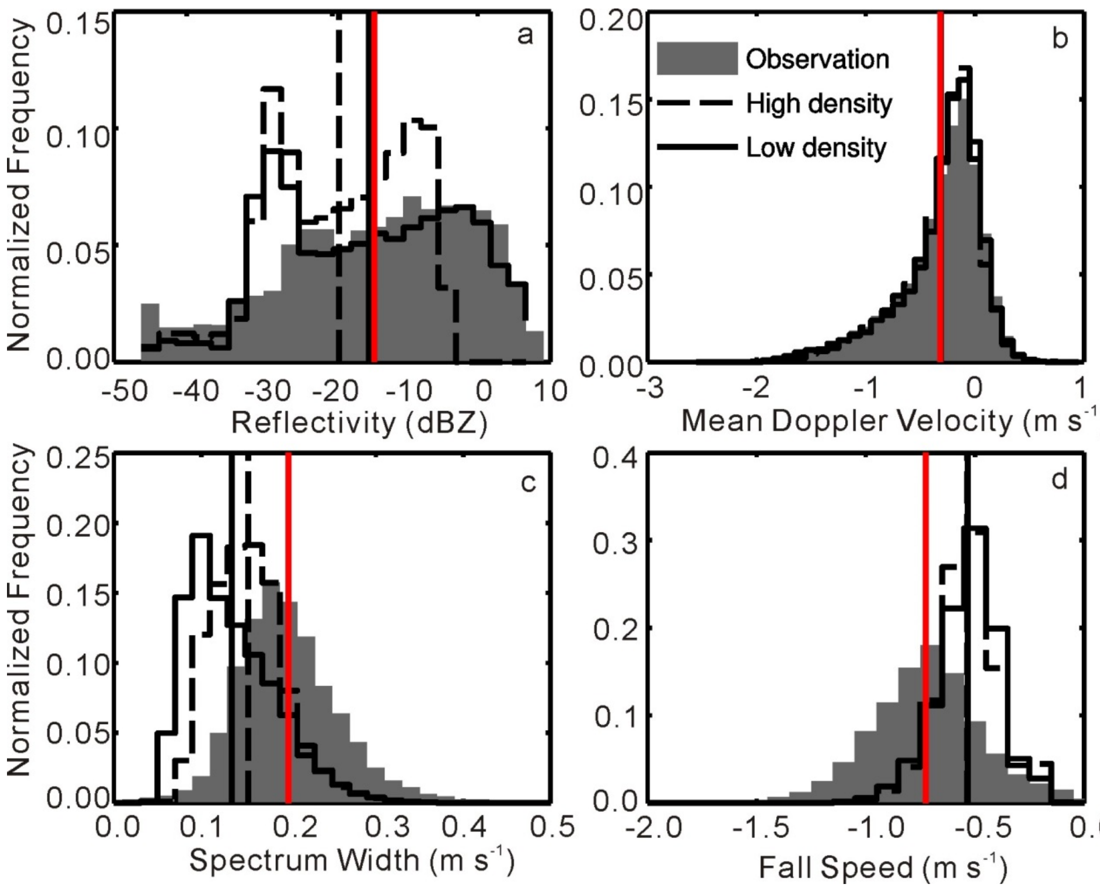
Vertical velocity comparisons

- Velocity offset (a) depends on sub-volume turbulence and LWC
  - Model resolved -0.02 m s^{-1}
  - Model retrieved 0.17 m s^{-1} (bias expected)
  - Radar retrieved 0.40 m s^{-1}
- Model underestimation may be caused b
  - Underestimation of broadening (model)
  - Underestimation of LWC (model)
  - Shear across volume
  - Radar processor artifact



Radar moment comparisons

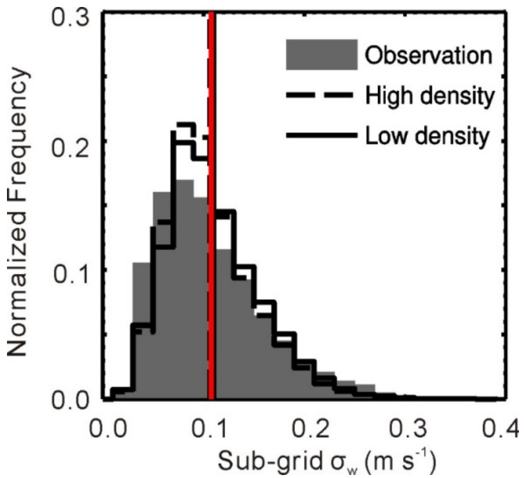
- Two simulations: high- and low density ice (dendrite & aggregates)
- Low density:
  - Match precipitation dBZ
  - Cloud top dBZ high
  - Match V_D
  - Spectrum width too small
  - V_{fs} too small
- High density:
  - Precipitation dBZ low
  - Cloud top dBZ high
  - Match V_D
  - Spectrum width too small
  - V_{fs} too small
- Broadening?
- Reflectivity weighting?

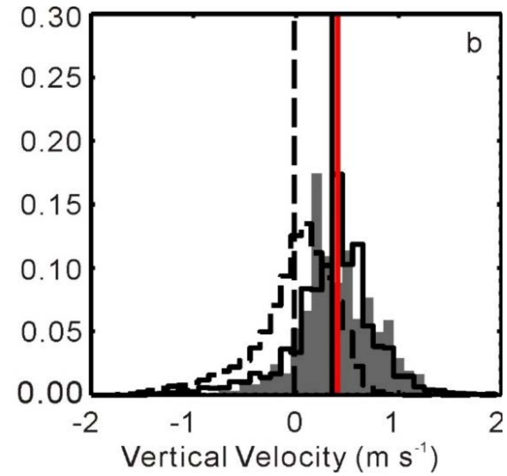


Turbulence:

$$\sigma^2 = \sigma_w^2 + \sigma_s^2 + \sigma_d^2 + \sigma_B^2$$

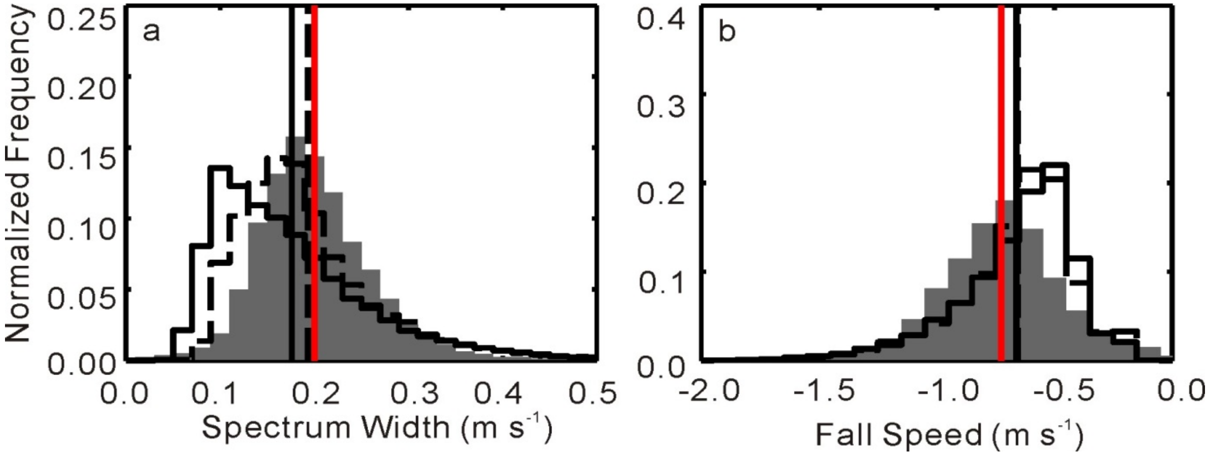
- Beamwidth (σ_B) no issue (narrow beam)
- Sub-volume turbulence width (σ_w) comparison OK (Shupe et al 2008)
- Discrepancy from
  - Shear (σ_s) [dynamical broadening]
  - PSD width (σ_d) [microphysical broadening]
- Microphysical broadening
  - No impact on air motion (also underestimated)
- Dynamical broadening
  - No good observations of vertical air motion
  - Increase (σ_s) by factor of three
  - Much better model/radar match
  - No physical basis: model physically consistent





Final comparisons

- With artificial dynamical broadening
  - Spectrum width comparison better
  - Mean fall speeds closer, but distribution off
  - PSD offsets? Reflectivity weighting offsets?



- What have we learned?
  - Using radars to evaluate models is deceptively easy
  - Must represent model ice characteristics in scattering model consistently (Must treat radar backscatter cross sections with care)
  - Must characterize ice better in observations (size, aspect ratio, mass, ice mass distribution in ice crystal)