The workings of a radar *spectrum* simulator and its use to evaluate LES (part 2)

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Outline

- What is a radar Doppler spectrum?
- What do we need to model it?
- How do we model it?

Max

- Applications
- Examples

Jasmine

Applications

- LES (e.g. DHARMA)
  - Backtracking spurious behaviors
  - Evaluate turbulence treatments

- Evaluate sensitivity to parameters and characteristics

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Model description

- LES framework (*Stevens and Bretherton* 1997) with dynamic SGS model (*Kirkpatrick et al.* 2006)
- Parameterized GCSS-style Beer's law longwave cooling
- No large-scale forcings other than subsidence
- Interactive surface fluxes
- Microphysics follow either a size-resolved (bin) or two-moment (bulk) scheme

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Microphysics

BULK MICROPHYSICS

WRF v3.2 *Morrison et al.* (2005) 2-moment with *Morrison & Grabowski* (2007) droplet activation using fixed droplet dispersion of 0.3 from *Geoffroy et al.* (2010), and either exponential or gamma distribution for rain ($\mu = 3$) [a.k.a. drizzle]

BIN MICROPHYSICS

Ackerman et al. (2004) with substepped activation, condensation, and sedimentation

- Mass doubling grid with 25 bins (aerosol, drops, solute)
- Diagnostic aerosol with size distribution and composition fixed

Setup of simulations

BULK MICROPHYSICS

Idealized from CAP-MBL 2009-11-22

- $\Delta x = \Delta y = 100$ m, $\Delta z = 5$–20 m
- $L_x = L_y = 4.8$ km, $L_z = 2.5$ km
- aerosol conc. = 100 cm^{-3}

BIN MICROPHYSICS

FIRE-I (*Duynkerke et al.* 2004)

- $\Delta x = \Delta y = 50$ m, $\Delta z = 5$–20 m
- $L_x = L_y = 3.4$ km, $L_z = 1.2$ km
- aerosol conc. = 75, 150, 600 cm^{-3}
- 8-h simulation, slices at 4th and 8th hours
- 24-h simulation, hourly slices

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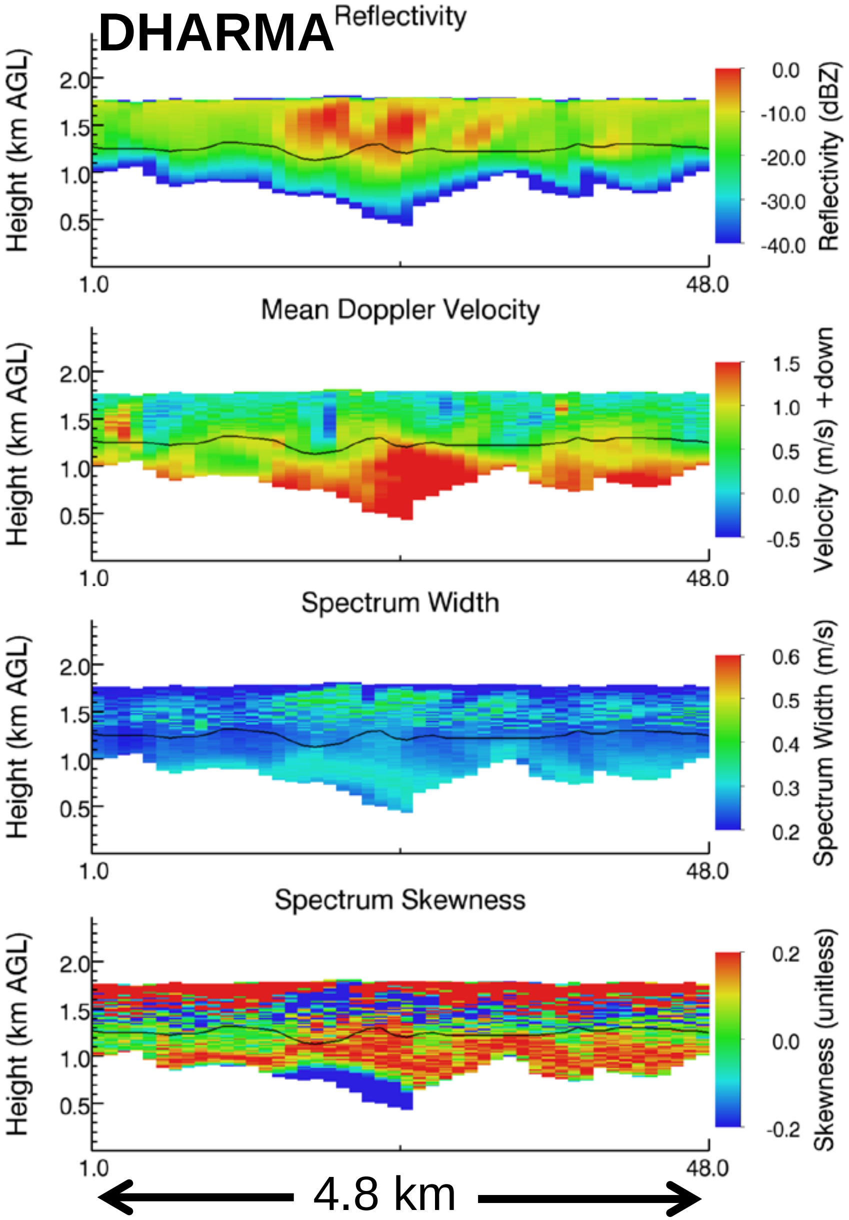
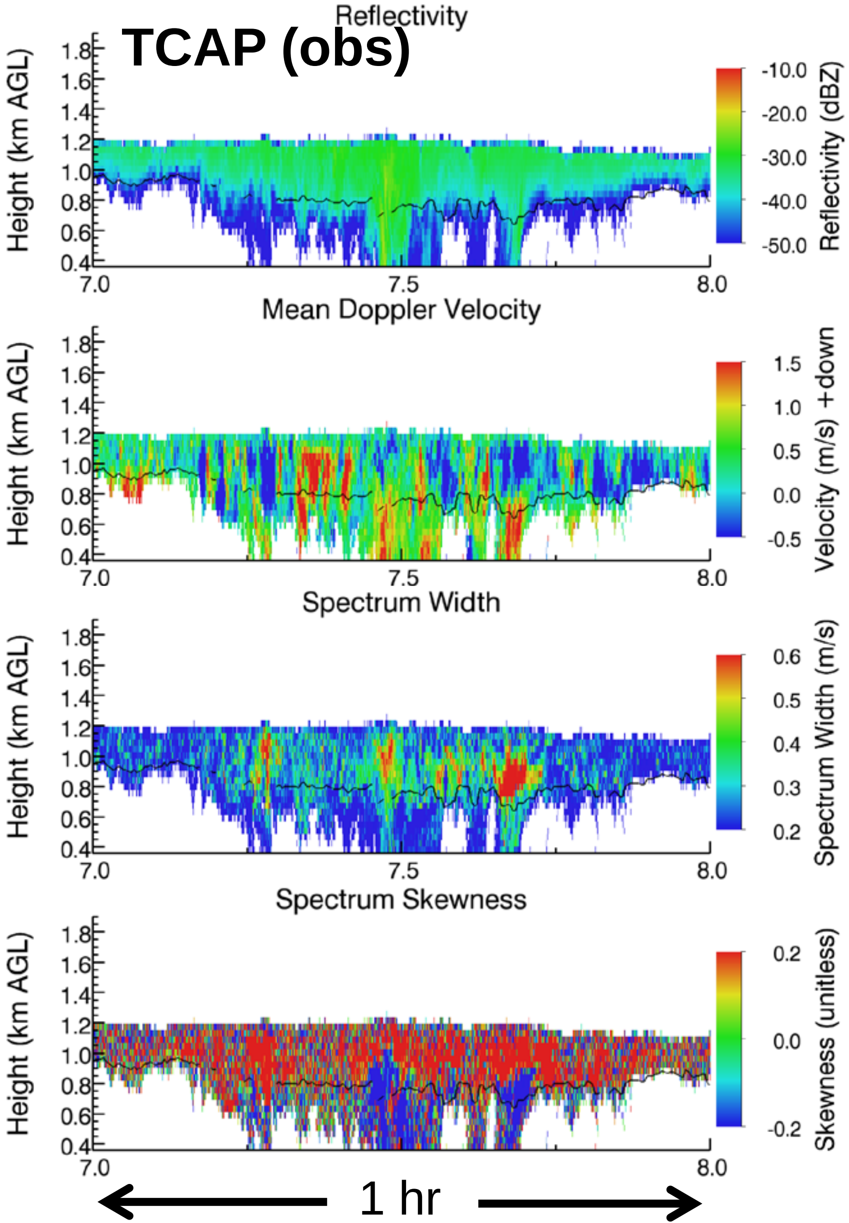
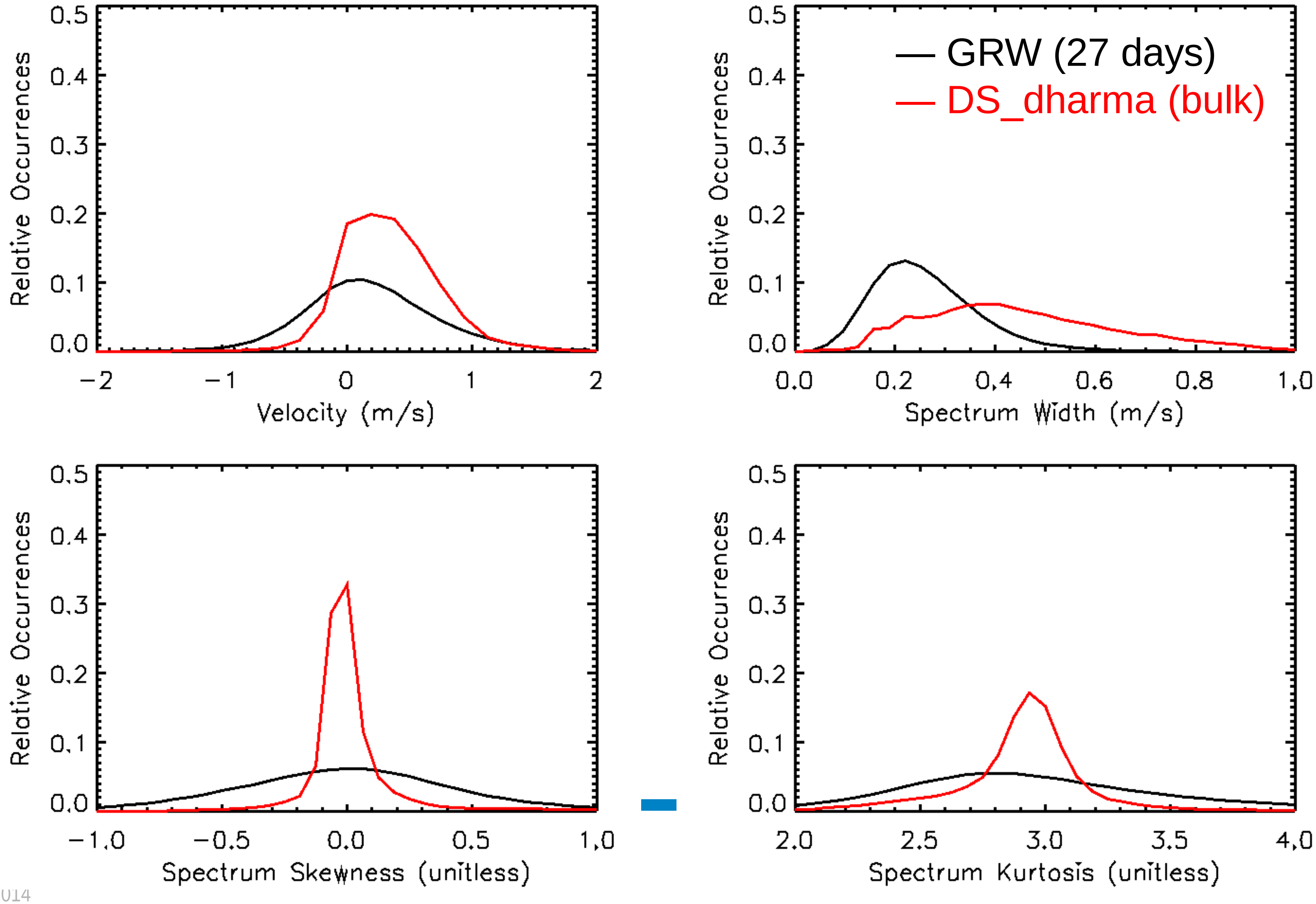
Early example (bulk)

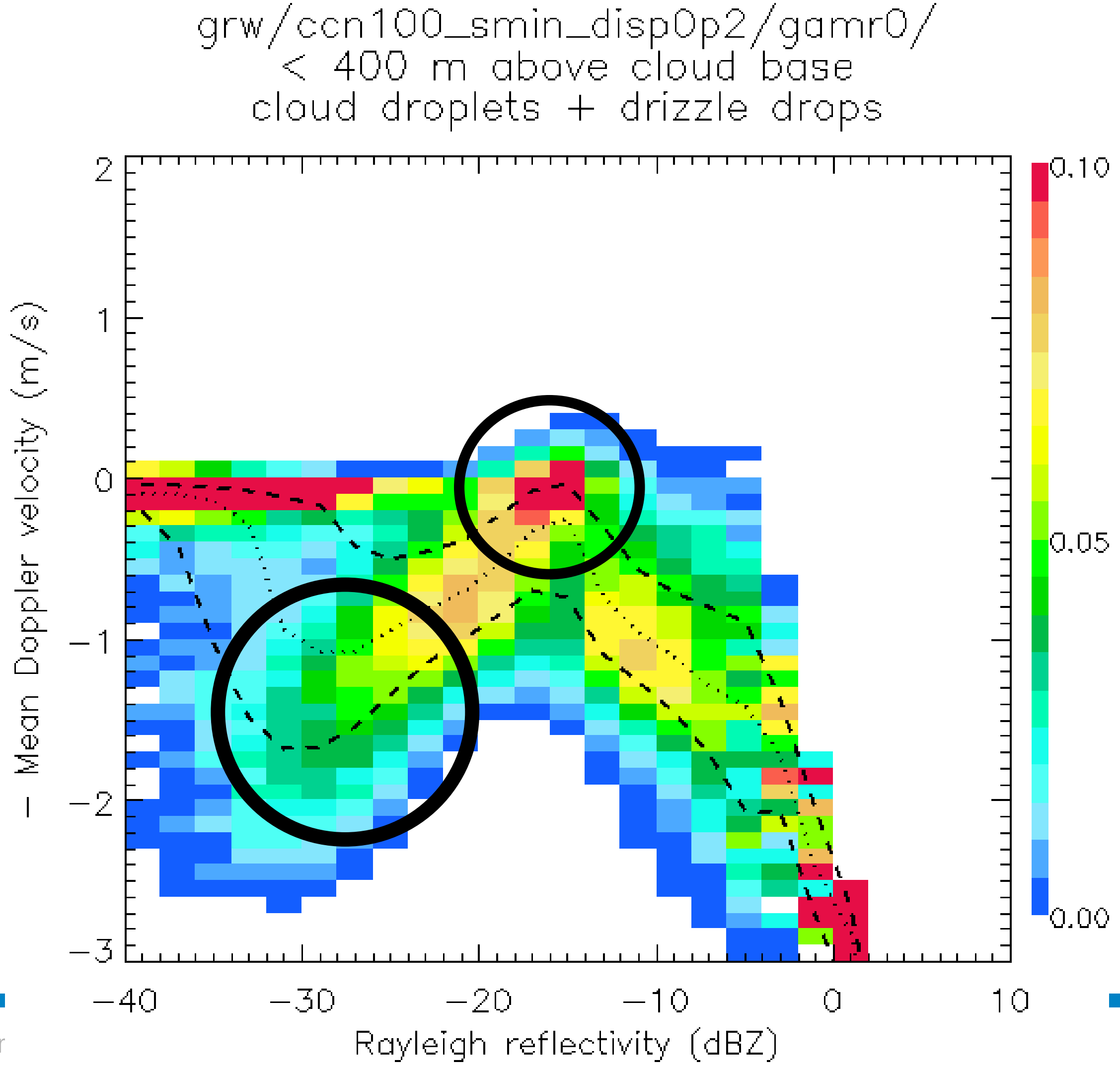




Moments PDF inside Sc clouds



Bulk microphysics, exponential rain

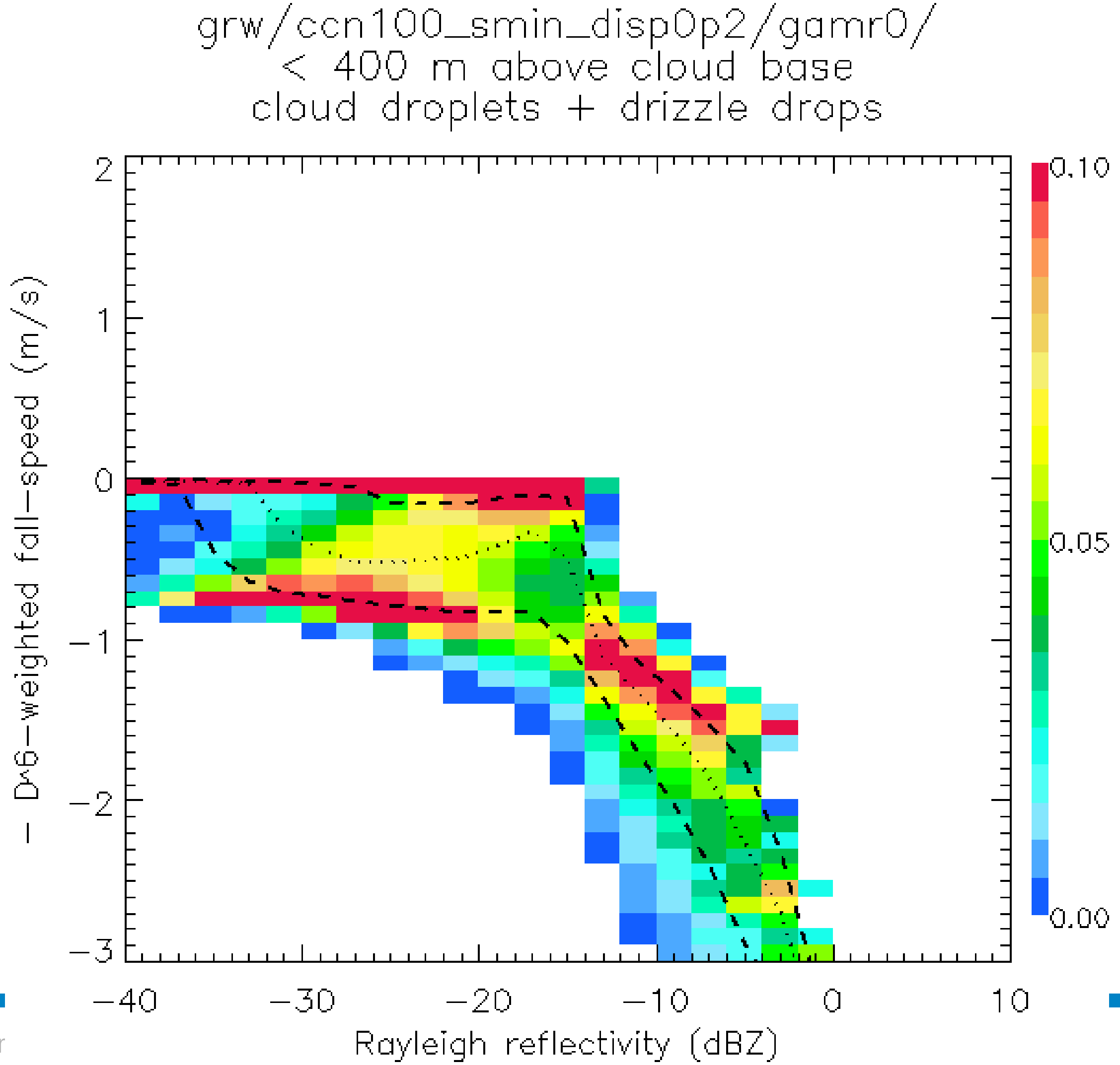


Two wiggles in MDV:

-**upper right** evidently attributable to discontinuous fall-speeds between cloud droplets and raindrops

-**lower left** from light drizzle in downdrafts

Bulk microphysics, exponential rain

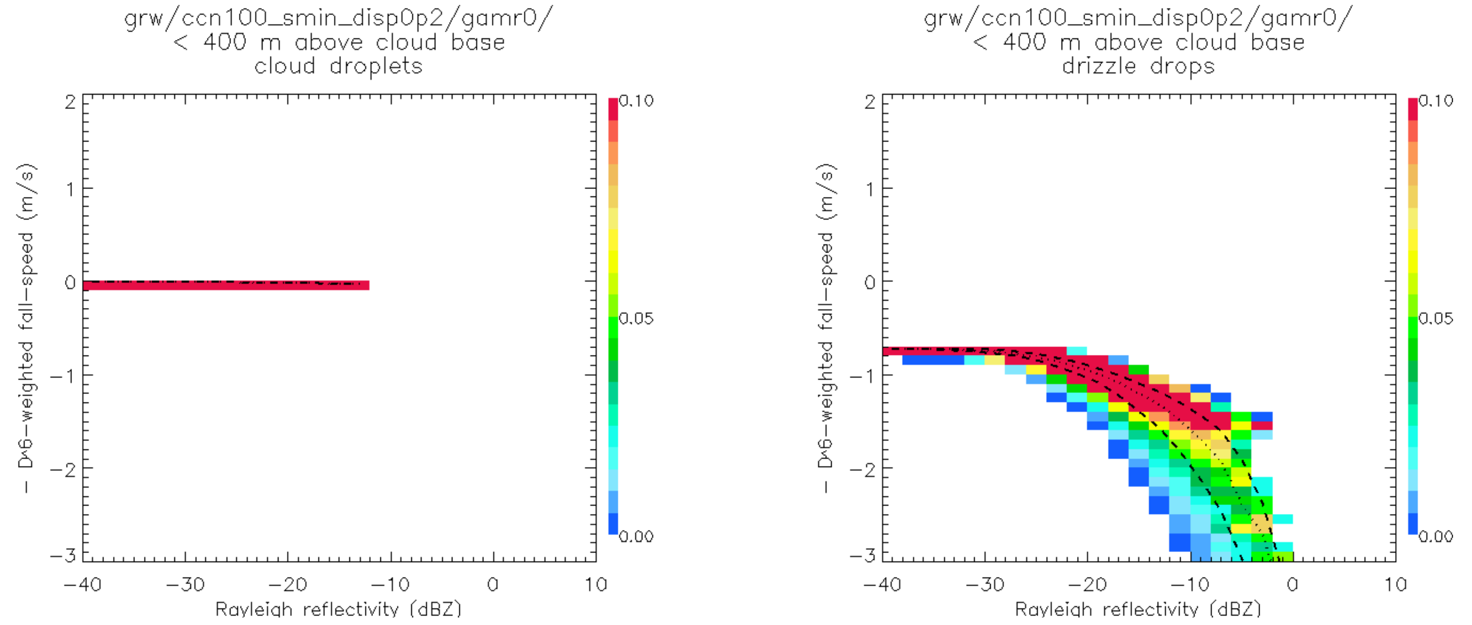


Two branches in VD6 distribution:

-**upper** (flat) from cloud droplets

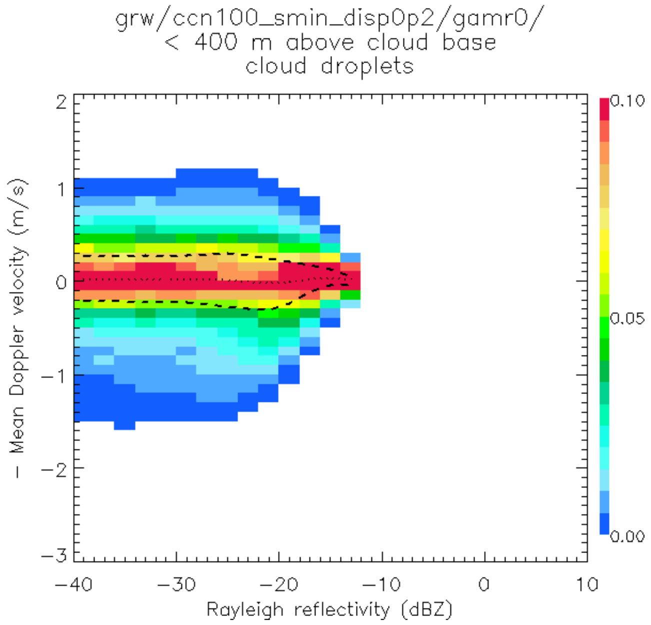
-**lower** from raindrops

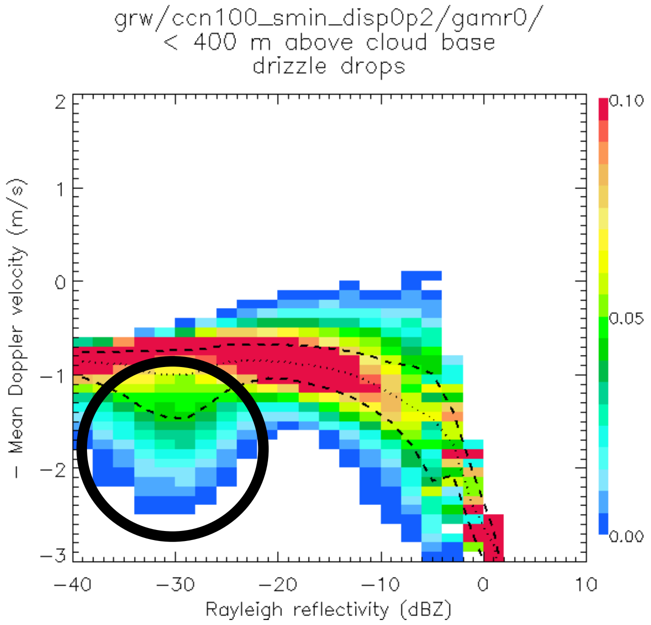
Bulk microphysics, exponential rain



- For 25-µm radius droplet (produced by autoconversion), fall speeds of cloud droplets and raindrops are respectively 7.5 and 30.5 cm/s, but should be the same, in principle
- Swapping in more accurate fall speed relation for raindrops (*Seifert* 2008) reduces gap at 25-µm radius (with fall speed for raindrops of 14 cm/s), but VD6 distribution still has two branches

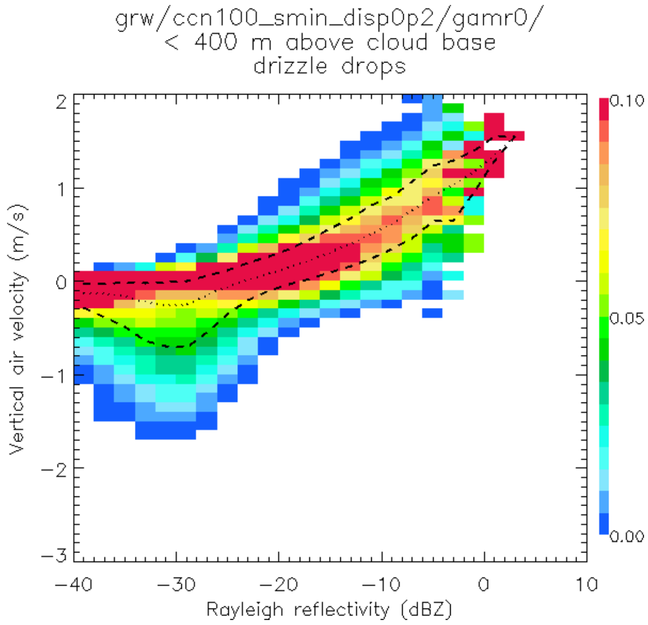
Bulk microphysics, exponential rain

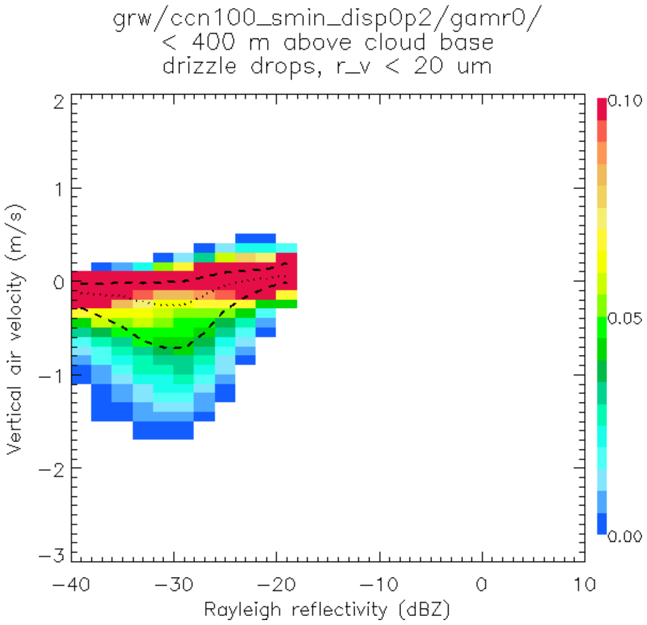




- Second wiggle seen in distribution of raindrops alone
- We have just seen that VD6 distribution for raindrops is not wiggly, leaving only the other component of MDV: vertical wind…

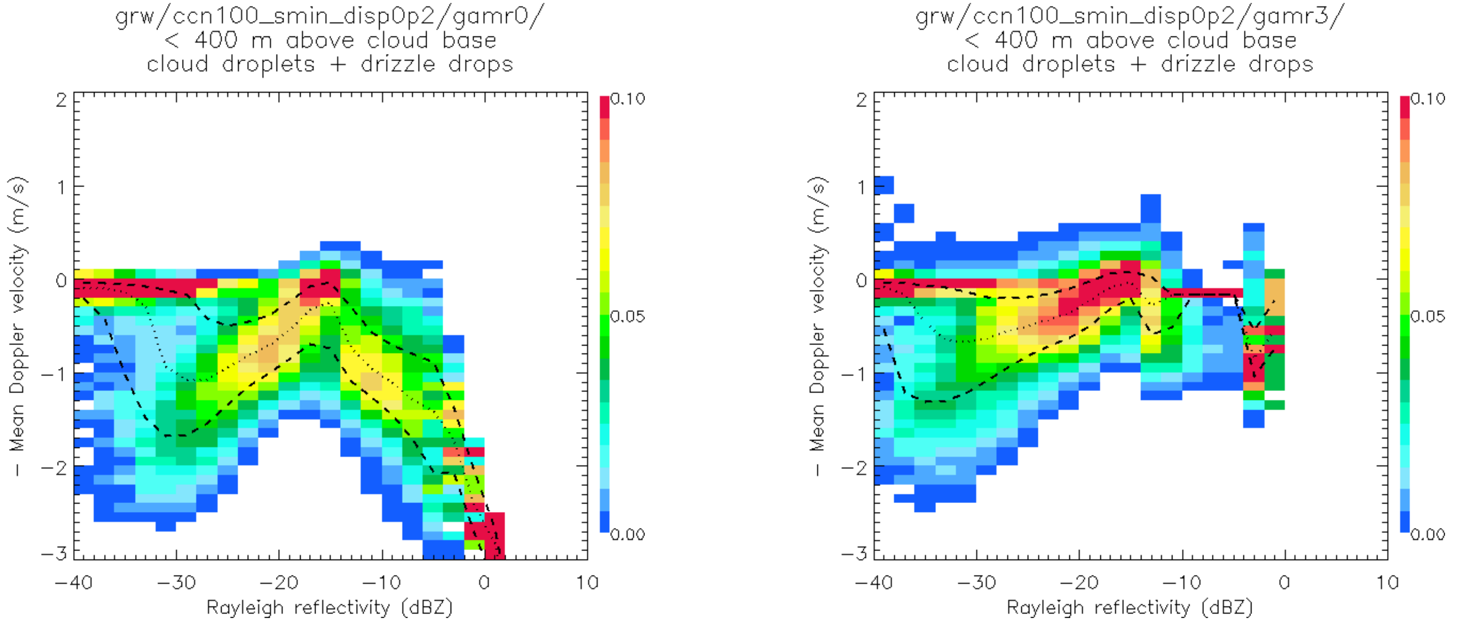
Bulk microphysics, exponential rain





- Wiggle associated with light drizzle in downdrafts, seen in right panel to be attributable to smallest raindrops: r < 20 µm (smallest allowed in scheme is 18.2 µm)
- Not entirely clear what the problem is here
- Perhaps one-way asymmetry between clouds and rain: no reverse autoconversion when raindrops evaporate to sizes smaller than 25 µm radius

Bulk microphysics, rain shape factor varied



- Assuming a gamma distribution (μ=3) for rain (right panel) does not solve any problems seen for exponential rain (left panel)

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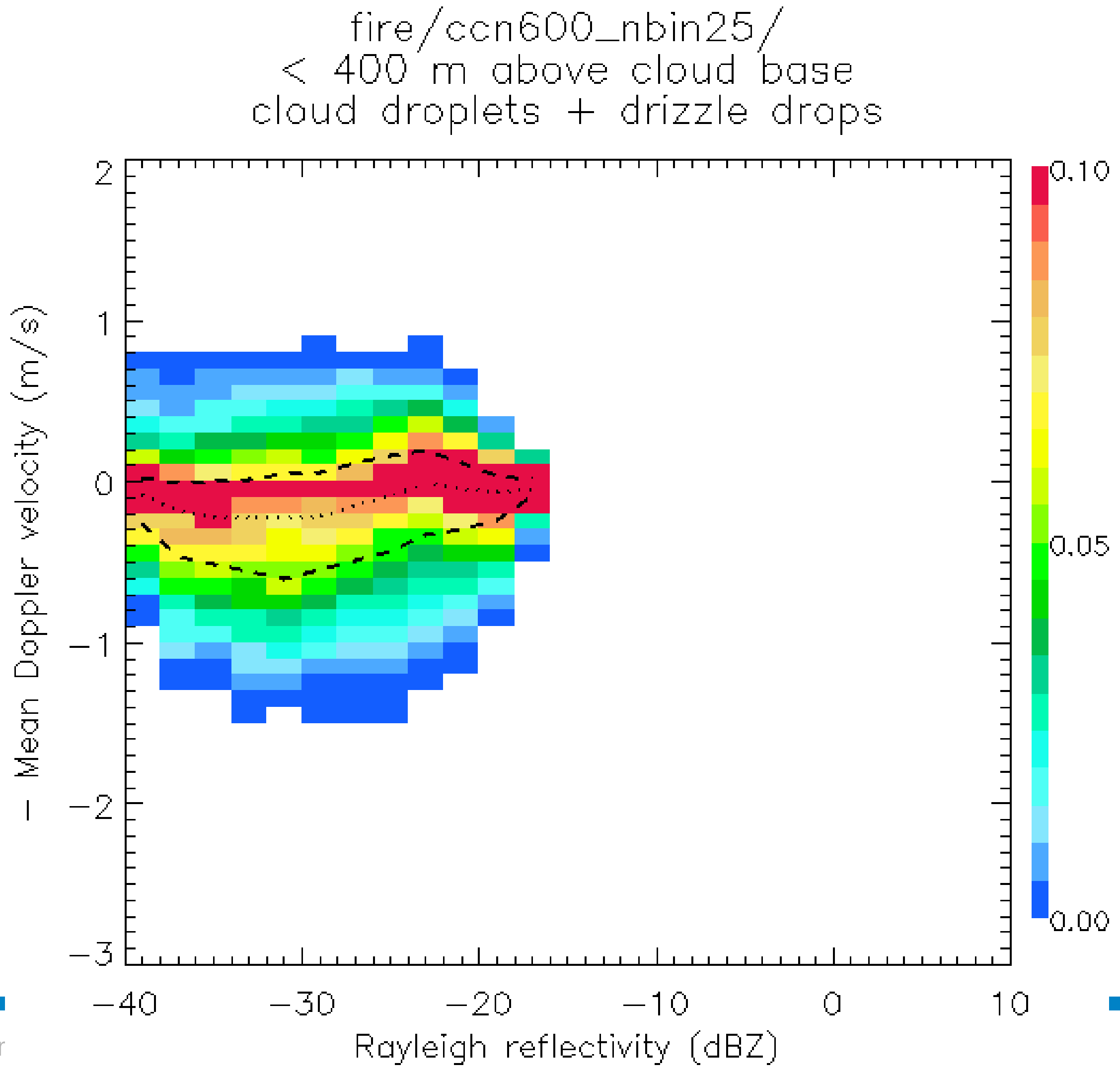
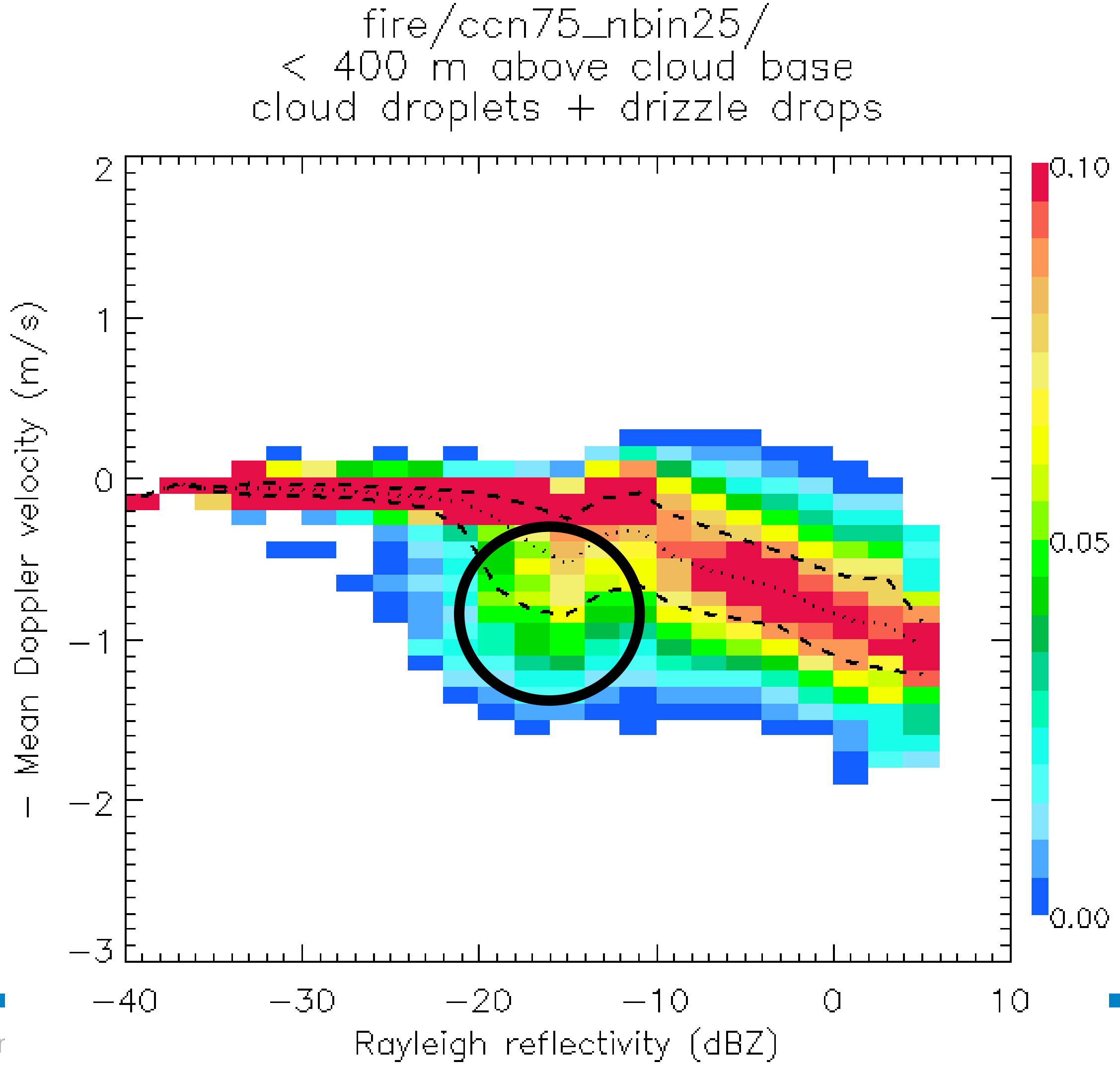
Bin microphysics, $N_{aerosol}$ = 600 cm^{-3}



- High conc. of cloud droplets produces little drizzle
- Analysis of slight dip in distribution does not turn up any obvious artifacts

Bin microphysics, $N_{aerosol} = 75\ cm^{-3}$



- With heavy drizzle, wiggle appears, attributable to population of strong MDV for modest reflectivities

- Amplification and shift to higher reflectivities of dip seen in previous slide

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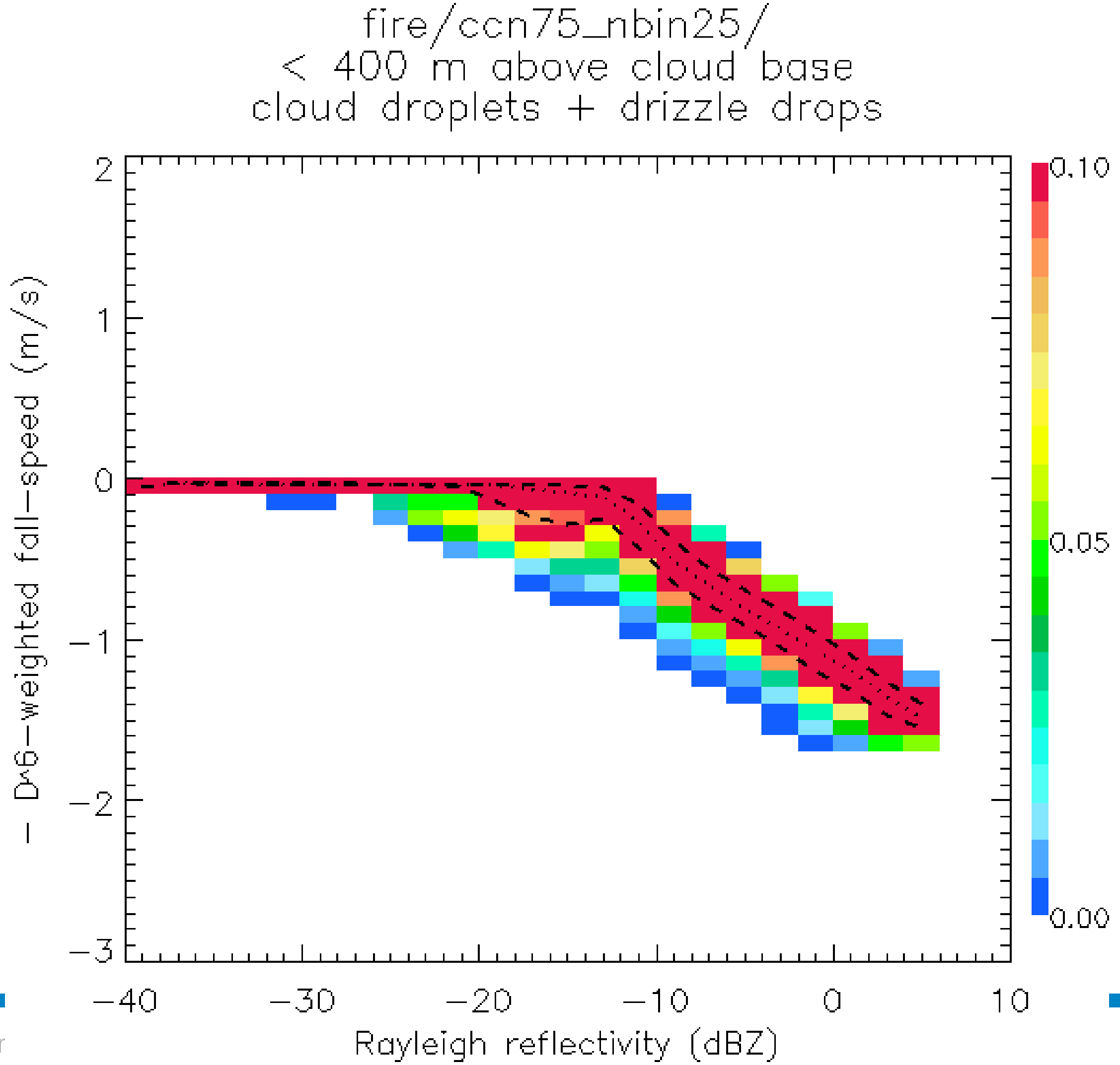
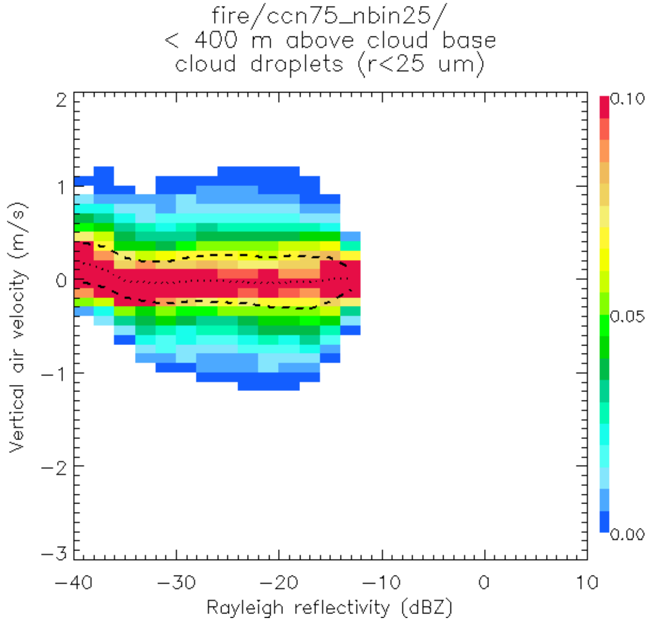
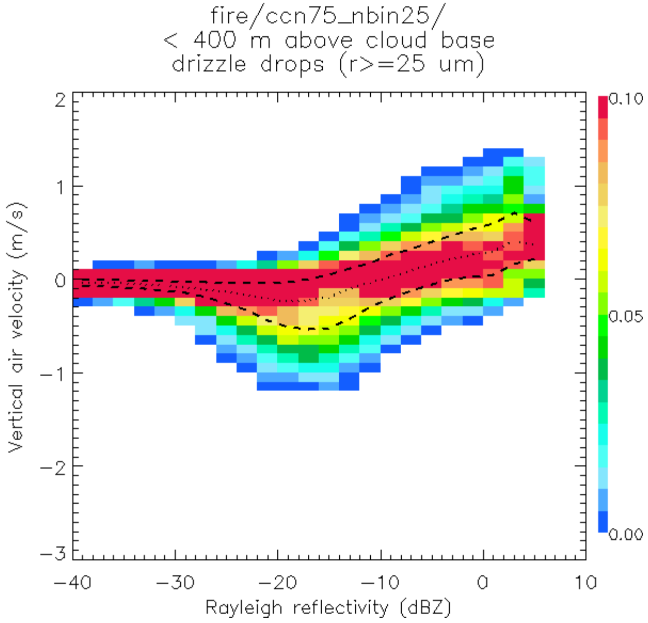
Bin microphysics, $N_{aerosol}$ = 75 cm^{-3}



- VD6 not particularly wiggly

Bin microphysics, $N_{aerosol} = 75\ cm^{-3}$





- Population responsible for dip in MDV is evidently small drizzle drops in downdrafts
- Large cloud droplets in downdrafts appear implicated as well
- Cause(s) of the apparent problem = open question at this point

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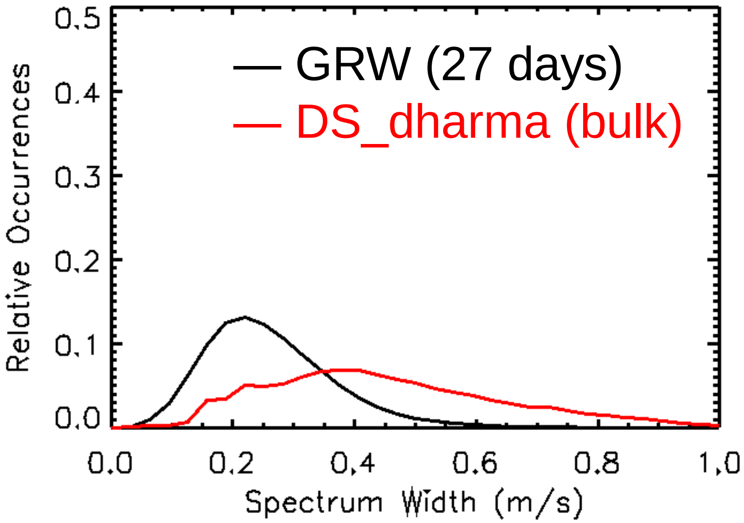
Turbulence treatment

- **The width of a Doppler spectrum has various contributions:**
  - ☑**DSDs**
  - ☐**turbulence**
  - ☑**wind components**



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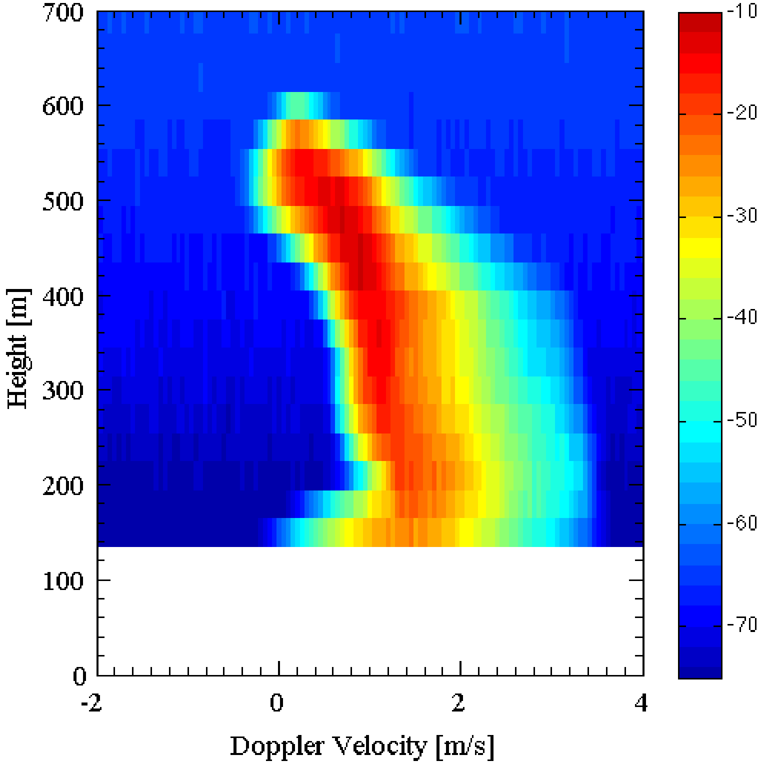
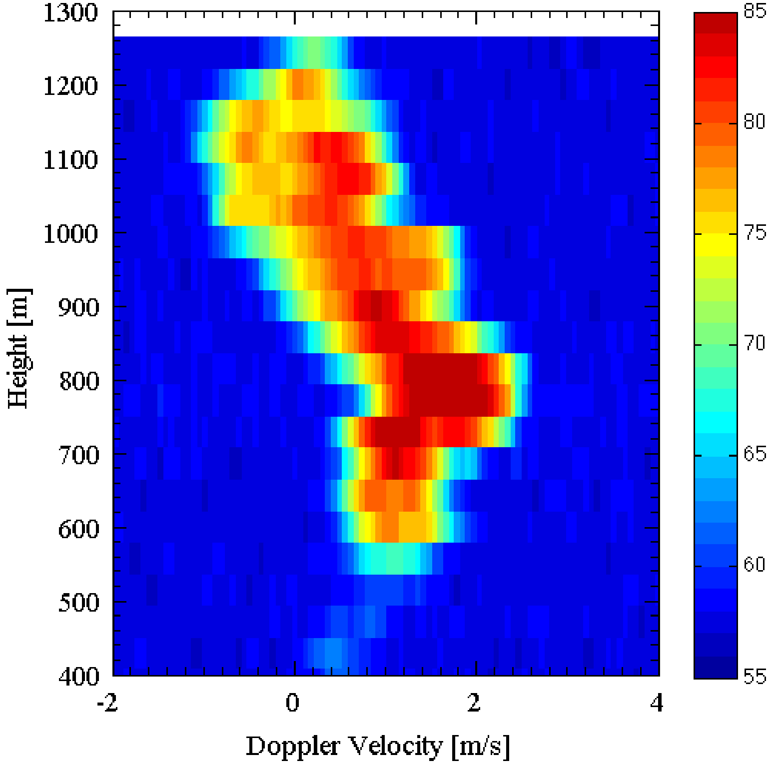
Comparison of two treatments

Equation 1



Observations



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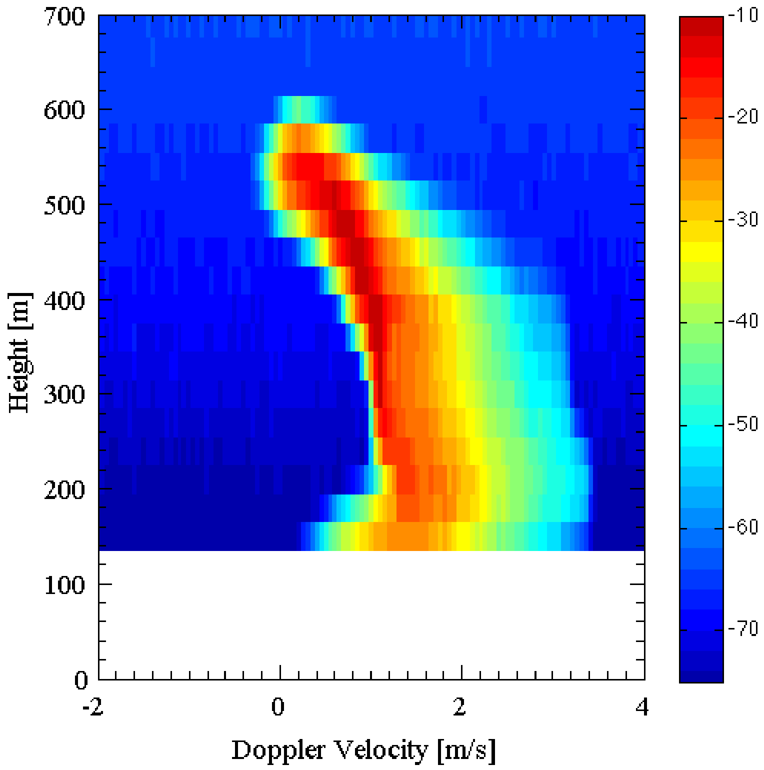
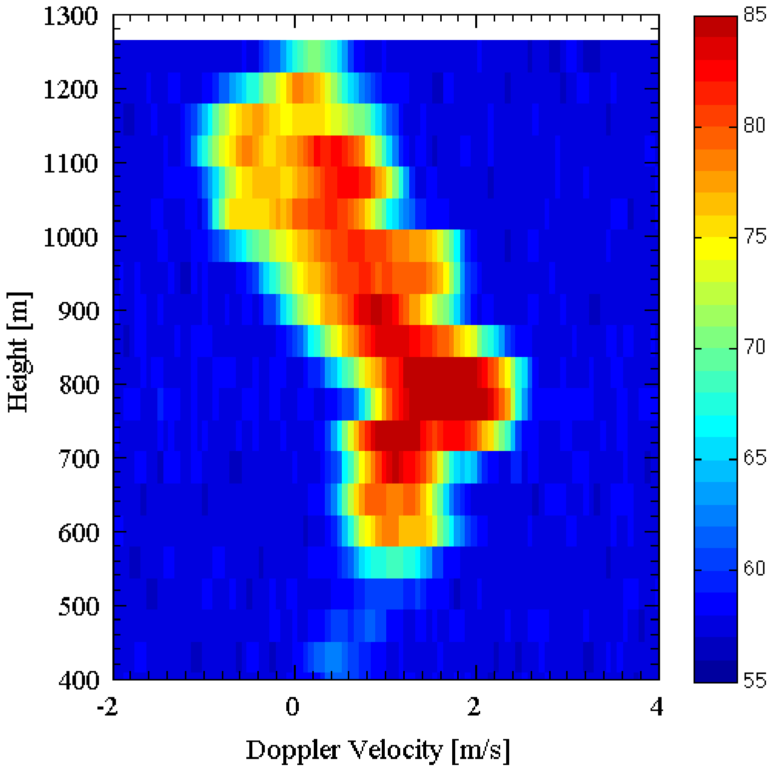
Comparison of two treatments

Equation 2



Observations



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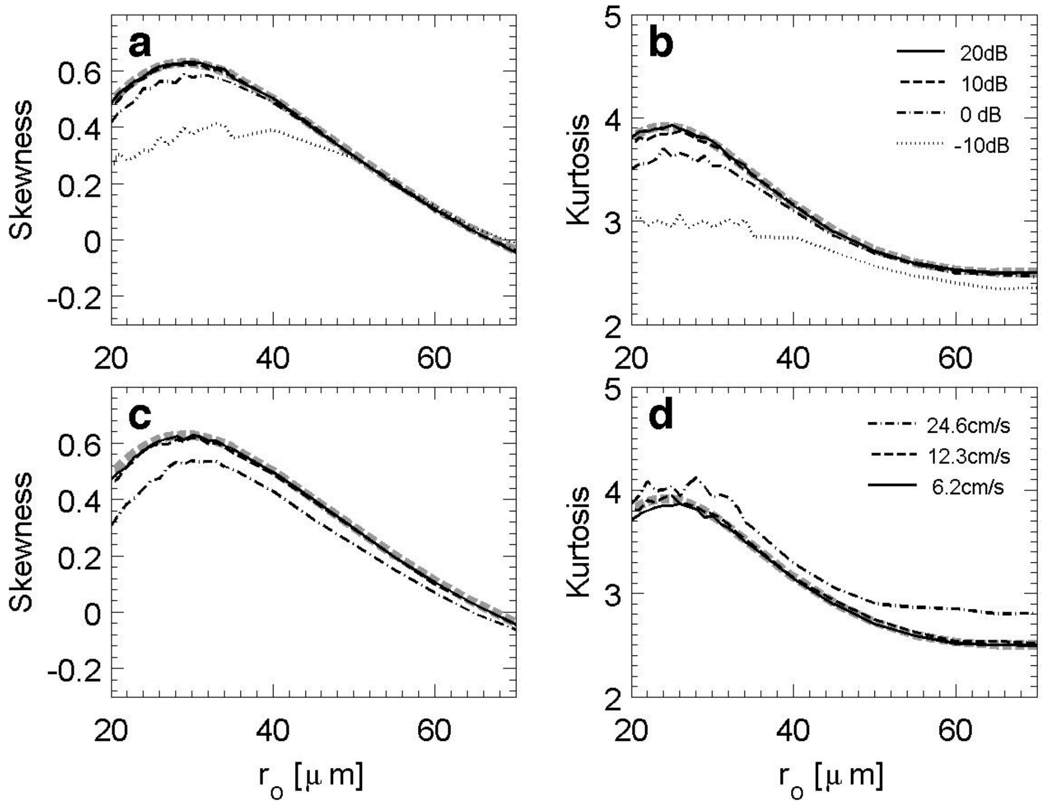
Sensitivity to radar parameters (e.g. N_{FFT}, SNR, etc.)



Kollias et al. 2011

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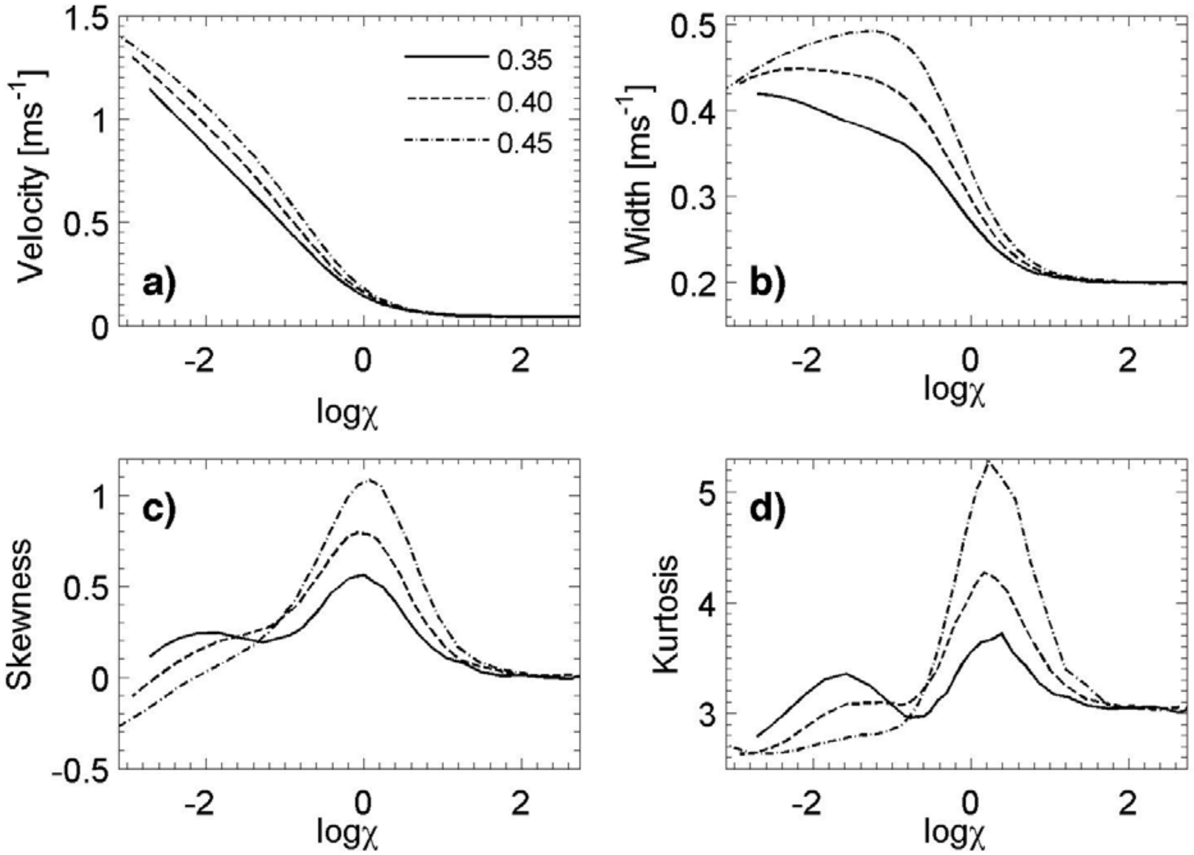
Sensitivity to drizzle parameters (e.g. shape, strength, etc.)



Kollias et al. 2011

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Summary

- Simulator almost ready for release
  - Working to find most (all?) bugs
  - Liquid aspect is more mature
- Need input from the community…
  - How would you use it (e.g. black box?)
  - Typical input you have (i.e. units, levels, etc.)

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