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?
- Applications
- Examples
Applications

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

• Evaluate sensitivity to parameters and characteristics
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
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
Early example (bulk)

DHARMA

TCAP (obs)

- Height (km AGL)
- Reflectivity (dBZ)
- Mean Doppler Velocity
- Spectrum Width
- Spectrum Skewness

4.8 km

1 hr
Moments PDF inside Sc clouds

- GRW (27 days)
- DS_dharma (bulk)
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
• 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…
• Wiggle associated with light drizzle in downdrafts, seen in right panel to be attributable to smallest raindrops: $r < 20 \, \mu m$ (smallest allowed in scheme is $18.2 \, \mu m$)

• 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 $25 \, \mu m$ radius
• Assuming a gamma distribution ($\mu=3$) for rain (right panel) does not solve any problems seen for exponential rain (left panel)
Bin microphysics, $N_{aerosol} = 600 \text{ cm}^{-3}$

- High conc. of cloud droplets produces little drizzle

- Analysis of slight dip in distribution does not turn up any obvious artifacts
Bin microphysics, \( N_{\text{aerosol}} = 75 \text{ cm}^{-3} \)

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

- $\text{fire/ccn75_nbin25/}$
- <400 m above cloud base
- cloud droplets + drizzle drops

- VD6 not particularly wiggly
Bin microphysics, $N_{aerosol} = 75 \text{ cm}^{-3}$

- 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
Turbulence treatment

- The width of a Doppler spectrum has various contributions:
  - DSDs
  - Turbulence
  - Wind components
Comparison of two treatments

Equation 1

Observations
Comparison of two treatments

Equation 2

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

Kollias et al. 2011
Sensitivity to drizzle parameters (e.g. shape, strength, etc.)

Kollias et al. 2011
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.)