Ferrier Microphysics Scheme

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Introduction

- Double moment, 4 class, ice-phase microphysics scheme
- Consists of 90 microphysical processes
- Improves parameterization of several cloud and precipitation processes
- Combines features from Lin et al. 1983, Rutledge and Hobbs 1984, and others

Continuity Equations

- Calculate mixing ratios of:
  - Water vapor
  - Cloud water
  - Small ice crystals
  - Low-density snow
  - Moderate-density graupel
  - High density frozen drops/hail

Continuity Equations

- Includes prognostic variables for:
  - Number concentrations of 4 ice types
  - Mixing ratios of liquid water during growth and melting
- Also calculates the thermodynamic equation

Size Distributions

- Volume of cloud droplets assumed to have exponential distribution
  - Modeled after Williams and Wojtowicz (1982) and Ziegler (1985)
- Size distribution of rain represented by gamma functions
- Shape parameters are specified for each hydrometeor

Size Assumptions

- Precipitation ice is assumed to be spherical
- Cloud ice is assumed to be bullet rosettes, following Heymsfield (1972) and Starr and Cox (1985)
- Willis (1984) gamma distributions of rain are assumed

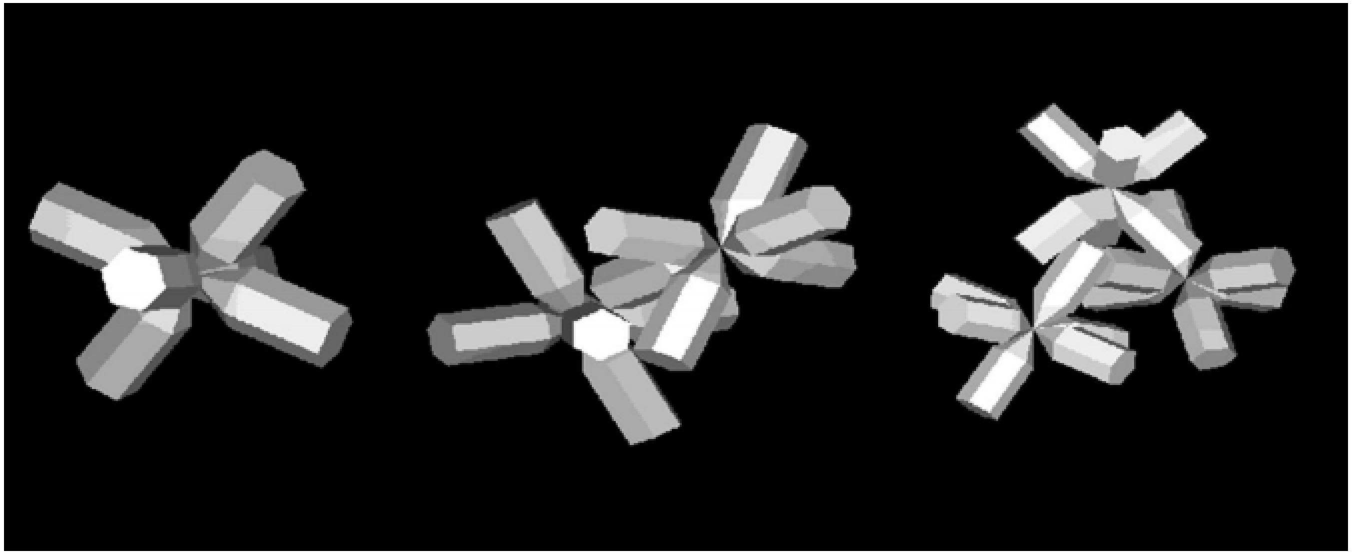

Figure 3. Idealized geometry of bullet rosette (1_br), 2_br, and 3_br.

Terminal Fall Speeds

- Terminal fall speeds for each hydrometeor represented by same equation
- Small cloud ice allowed to have non-zero fall speed

Densities of Wet Ice

- Assumes constant density for dry snow, graupel, and frozen drops
- Density of wet precipitation is allowed to change

Densities of Wet Ice

- Porous snow and graupel
  - Liquid water uniformly distributed
  - Volumes of wet and dry particles of equal mass are the same
- Frozen drops/hail
  - Liquid water uniformly covered
  - Liquid water content proportional to difference in volume between frozen drops and ice centers

Collection of Precipitation

- Three methods
  - Binary accretion
  - Three-component accretion
  - Rapid accretion

Binary Accretion

- No straightforward analytical solution
- Solve equations numerically and store solutions in lookup tables
- Modified for collection of snow by graupel and frozen drops in supercooled water

Three-component Accretion

- Collisional freezing of rain produces multiple precipitation types
- Microphysics scheme assumes the liquid water from the rain drop is evenly distributed through the volume of the collided particle before freezing
- Effects of ice crystal fall speeds are neglected

Three-component Accretion

- Assume rain drops collect ice crystals larger than critical size
- Creates collection efficiency less than one

Rapid Accretion

- Collisional freezing of super-cooled raindrops in convective cells can cause very large changes in hydrometeor mixing ratio
- Revise mixing ratio calculation for intermediate values of raindrop freezing by collection of small ice

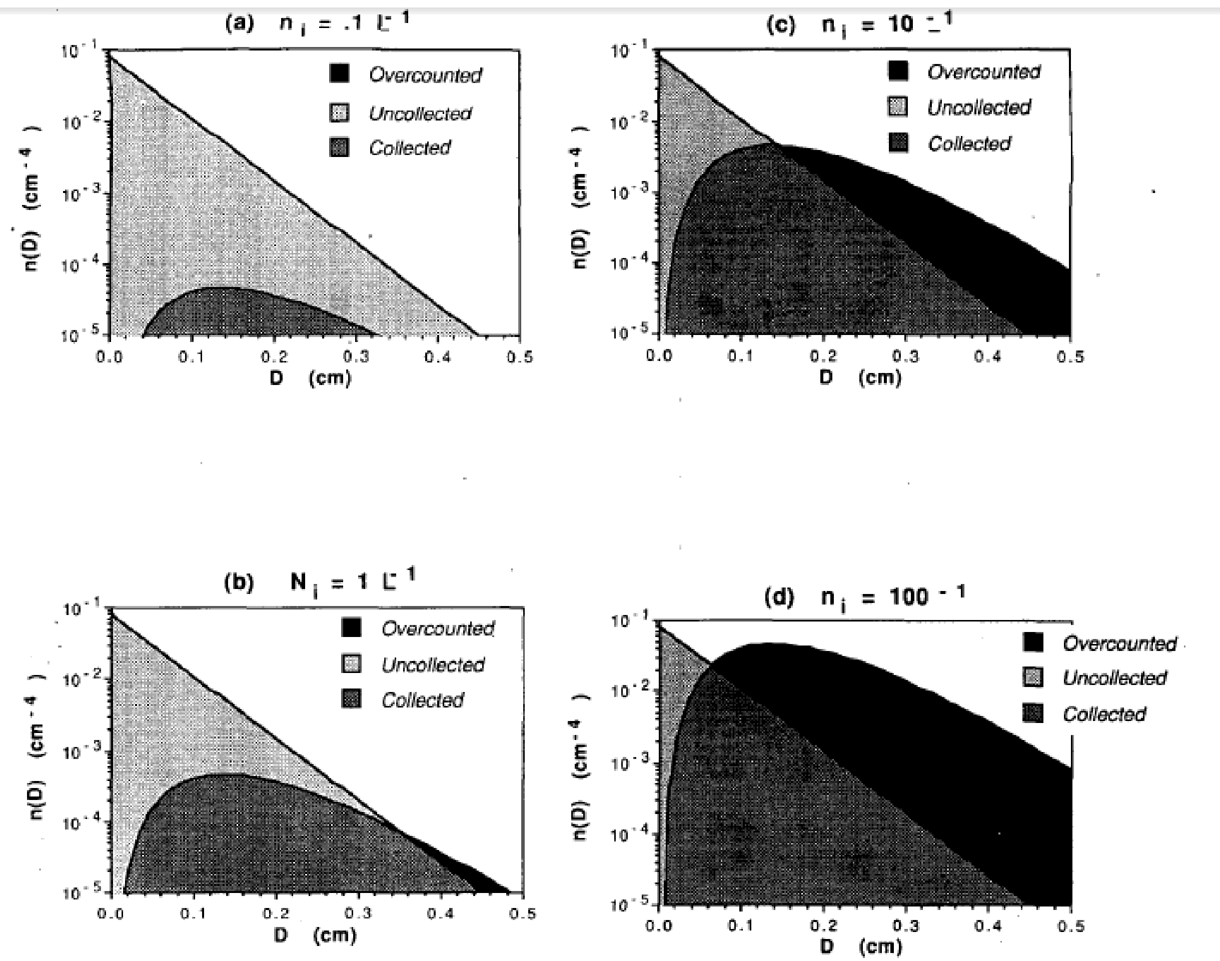

FIG. 1. The freezing of an exponential ($\alpha_r = 0$) raindrop size distribution with $n_{0r} = 0.08$ cm^{-4} and $\lambda_r = 20$ cm^{-1} resulting from the collection of small ice crystals is shown for ice number concentrations of (a) 0.1 L^{-1}, (b) 1 L^{-1}, (c) 10 L^{-1}, and (d) 100 L^{-1}. Light shading denotes those raindrops that do not collect any ice crystals; medium shading indicates those raindrops that do collect ice crystals, as properly represented by (4.19) and (4.23); and dark shading shows the overcounting of the larger raindrops, as represented by the traditional collection equations of (4.16) and (4.17). Calculations assume $E_{ri} = 1$, $\gamma = 1.2$, and $\Delta t = 10$ s. In (a) D_{rp} is not defined because $n_{ri} < 1$ for all drop sizes. Values of D_{rp} in (b)–(d) are 0.36 cm, 0.14 cm, and 0.06 cm, respectively.

Riming Processes

- Assume:
  - Rime density is similar to converted particle
  - Enough rime accumulated to alter the bulk density of the converted particle

Freezing and melting of precipitation ice

- Liquid water removed by complete melting of precipitation which changes the number concentrations
- Assuming intercept of particle distribution is constant during melting produced unrealistic results
- Removing the mass and number concentrations of smallest ice created unrealistic particle diameters

Radar Reflectivity

- Used to determine validity of a microphysical scheme
- Calculations using Rayleigh theory find reflectivity within 0.5 dBZ of Mie calculations on 10 cm radar

Improvements

- Four class scheme
- Look-up tables for computational efficiency
- Allow small ice crystals to have terminal fall speed
- Modified collection equations

References

- Ferrier, B., 1994: A double-moment multiple-phase four-class bulk ice scheme. Part 1: Description. *J. Atmos. Sci.*, **51**(2).
- Um, J. and G. M. McFarquhar, 2004: Single scattering properties of aggregates of bullet rosettes in cirrus cloud. *Proc. Fourteenth ARM Science Team Meeting*, Albuquerque, NM.