Mesoscale Convective Systems

Pacific Northwest NATIONAL LABORATORY

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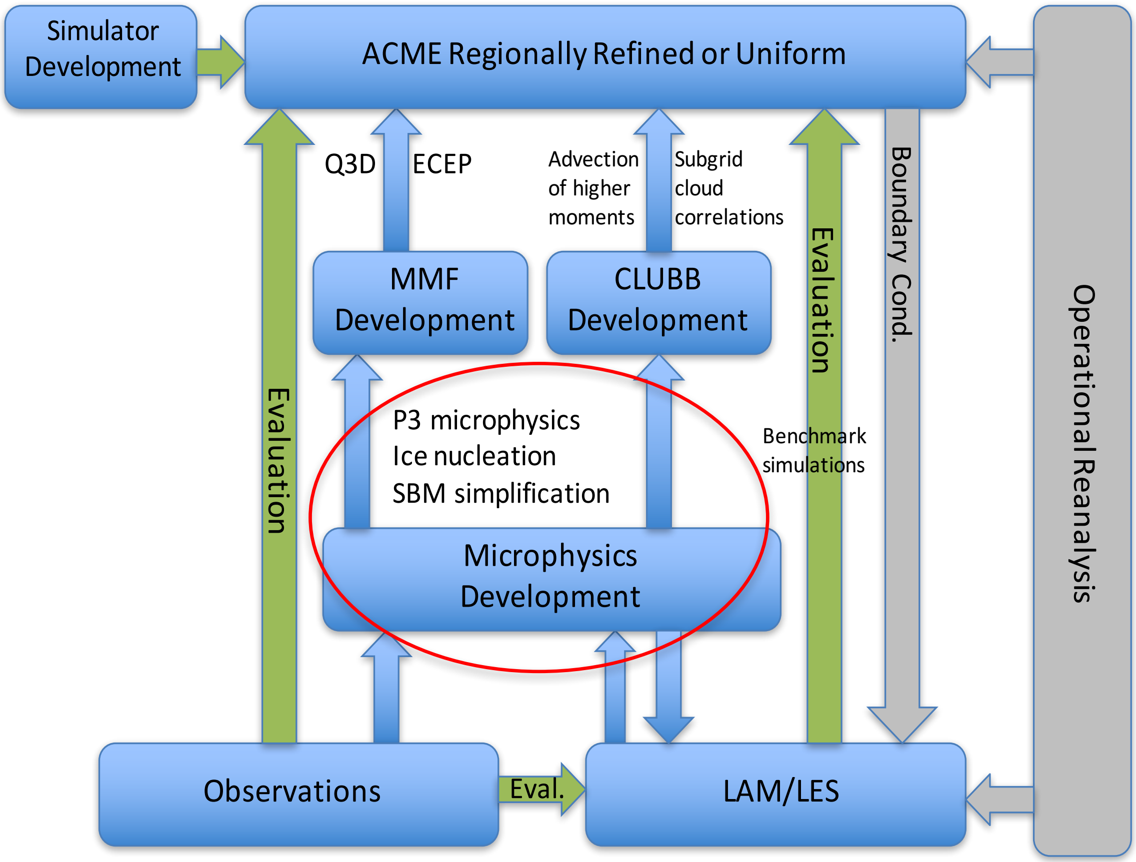
Cloud Microphysics Developments in CMDV-MCS

KEY TEAM MEMBERS: JIWEN FAN, XIAOHONG LIU, MARCO PAUKERT, PHIL RASCH, AND KAI ZHANG

COLLABORATORS: ALEX KHAIN, JASON MILBRANDT, HUGH MORRISON, AND KOBBY SHPUND,

U.S. DEPARTMENT OF ENERGY

CMDV-MCS Strategy



- Use various observations and LAM/LES for development and evaluation of parameterizations in cloud dynamics, macrophysics, and **microphysics**.
- Evaluation of parameterizations is mainly through ACME regionally-refined grid centered over the ARM SGP site.
- Additional global observational data will be used to evaluate the performances of ACME simulations with a uniform grid at selected resolutions

Development of cloud microphysics parameterizations

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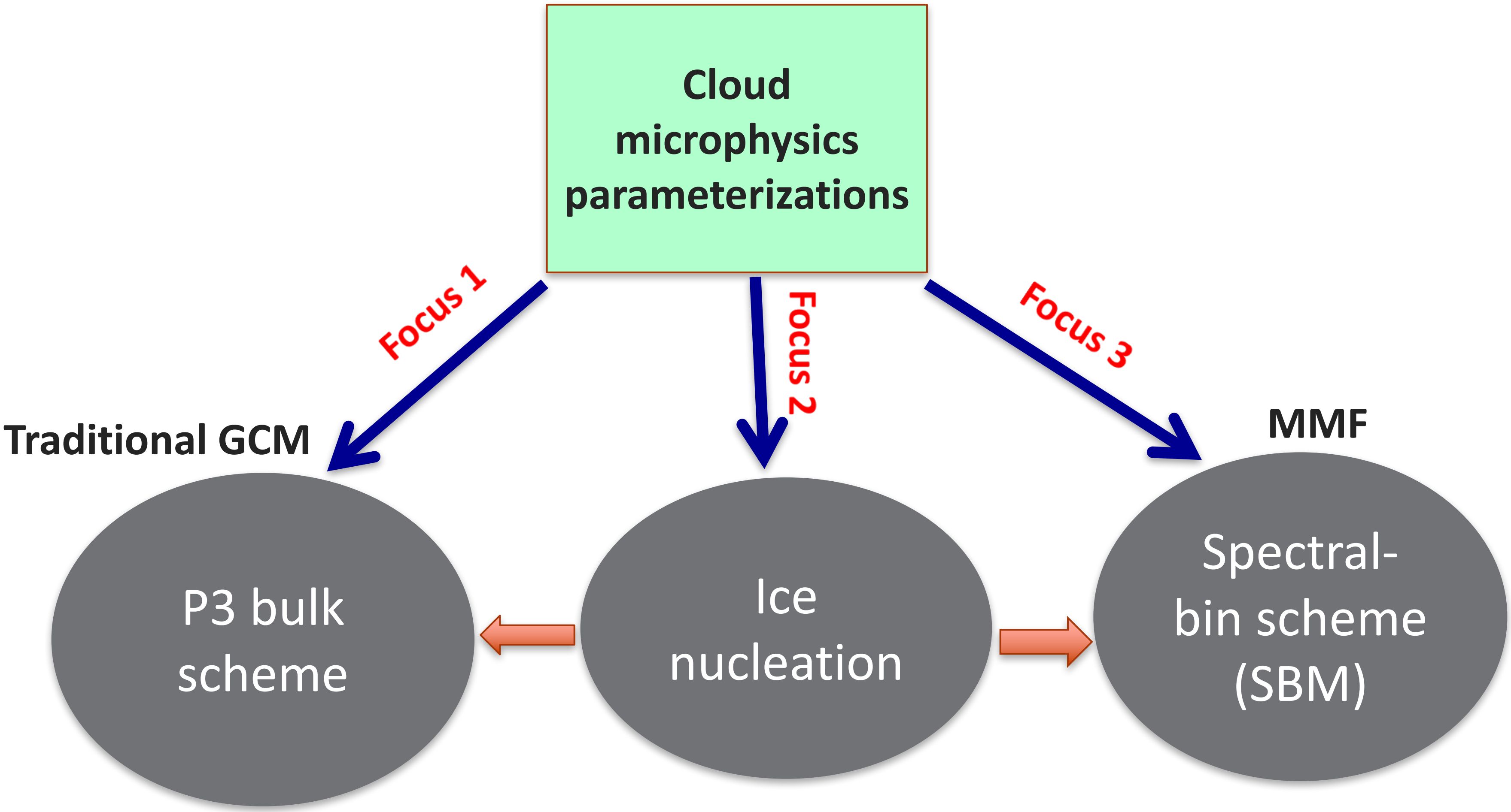


CMDV Mesoscale Convective Systems

1. Development of 3-moment P3 bulk scheme

P3 (Predicted Particle Properties)

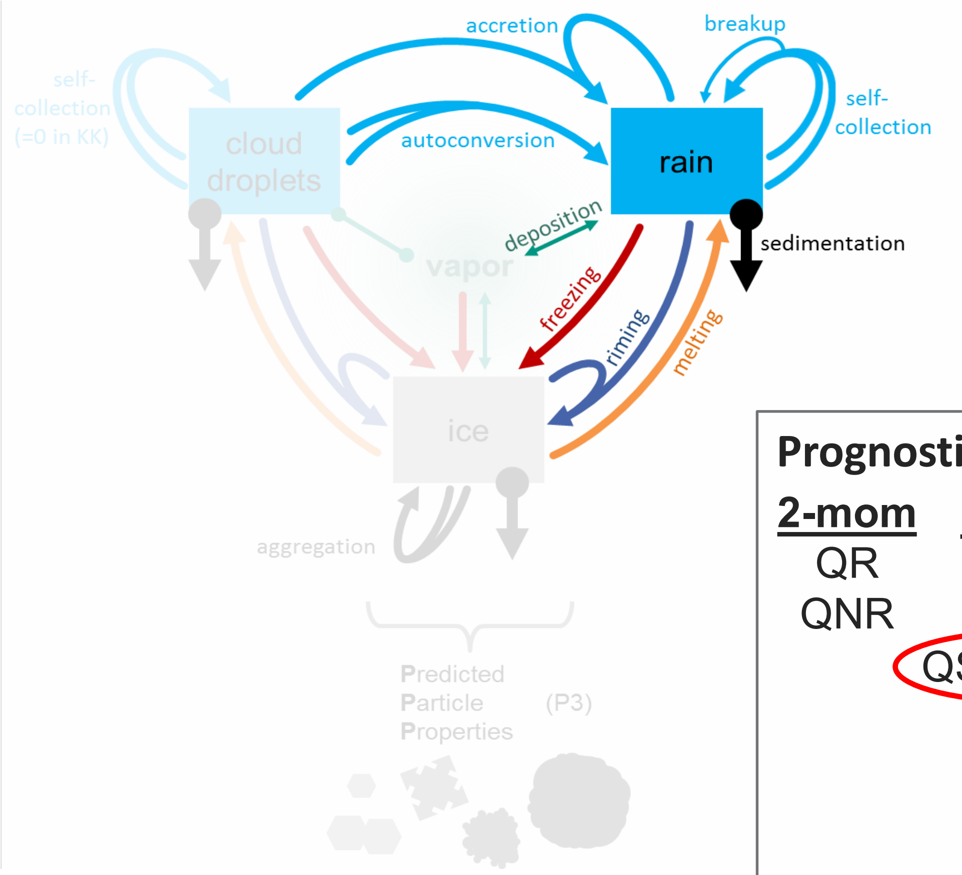
Morrison and Milbrandt (2015)
Milbrandt and Morrison (2016)

- Two-moment Gamma distribution. No predefined ice particle category so no artificial “conversions”.
- For a single ice-phase category, four prognostic mixing ratio variables: the total ice mass q_i, ice number N_i, the rime mass q_{rim}, and the bulk rime volume B_{rim}.
- Based on the four prognostic variables, ice properties are predicted, including the rime mass fraction, bulk density, and mean particle size.

Main work

- Couple P3 with ACME (conventional GCM)
- Develop 3-moment P3:
  - PNNL: 3-moment warm cloud
  - Hugh/Jason: 3-moment ice cloud

3-moment rain development



Prognostic variables / microphysical sources and sinks

2-mom	3-mom
QR	QR
QNR	QNR
	QSR / QZR

Finished
- Sedimentation

Other processes:
- Drop-drop collisions including breakup
- Condensation / evaporation
- Riming
- Freezing
- Melting
- Shedding

2. Simplified SBM for MMF

SBM: Spectral –bin Microphysics

Khain et al., 2004

- Fast version of SBM (FSBM): four size distributions with each of 33 bin at least (aerosol, liquid drops, ice/snow, graupel or hail)
- The advection of the 132 tracers is the major cost source in computation time

Advection in bin approach

$$\frac{\partial n_r}{\partial t} = -\nabla \cdot V n_r, r = 1, \ldots R$$

Assume $n(r,x,y,z,t) = \sum_{i}^{I} c_i(t,x,y,z) P_i(r)$

$$\frac{\partial c_i}{\partial t} = -\nabla \cdot V c_i, i = 1, \ldots I$$

I << R

Advection in coefficient approach

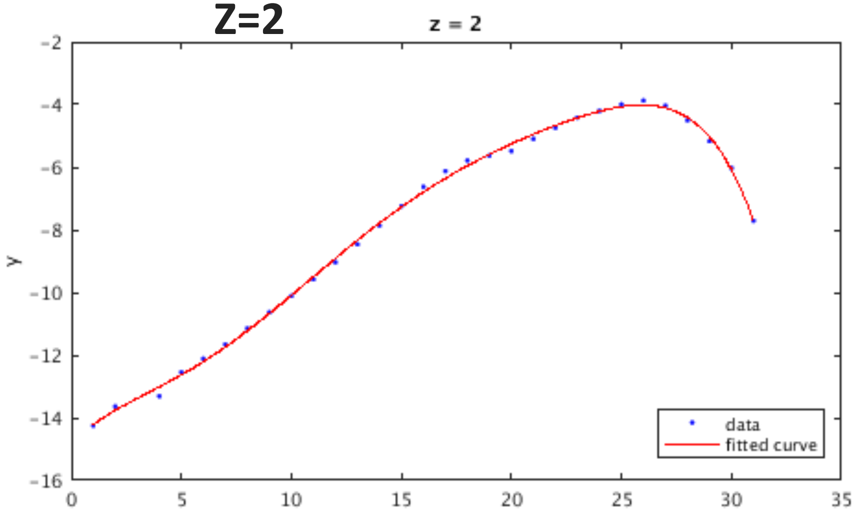
Main work

- For advection, decompose each size spectrum with small number of coefficients of orthogonal polynomials
- Simplify and reduce computational costs for the microphysical calculations inside SBM

Fitting PSD of SBM with the coefficients of orthogonal polynomials

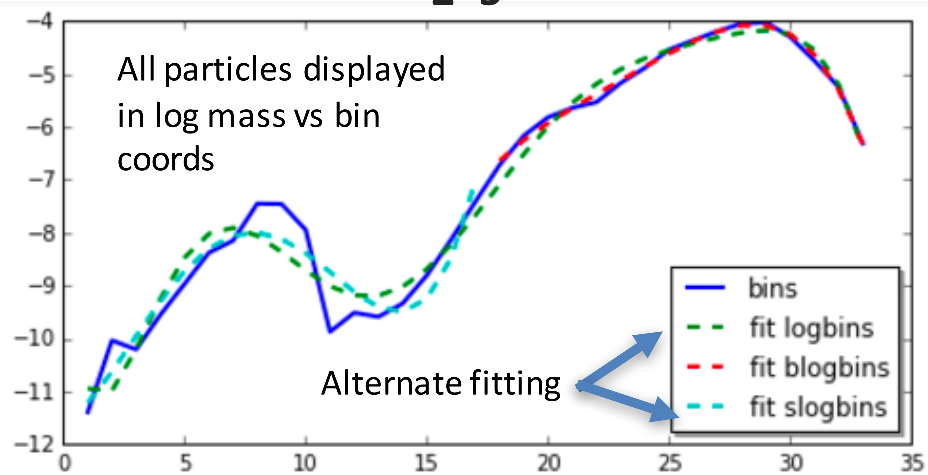
Near the surface, simple mode, PSD is fitted well with **6** polynomial coefficients

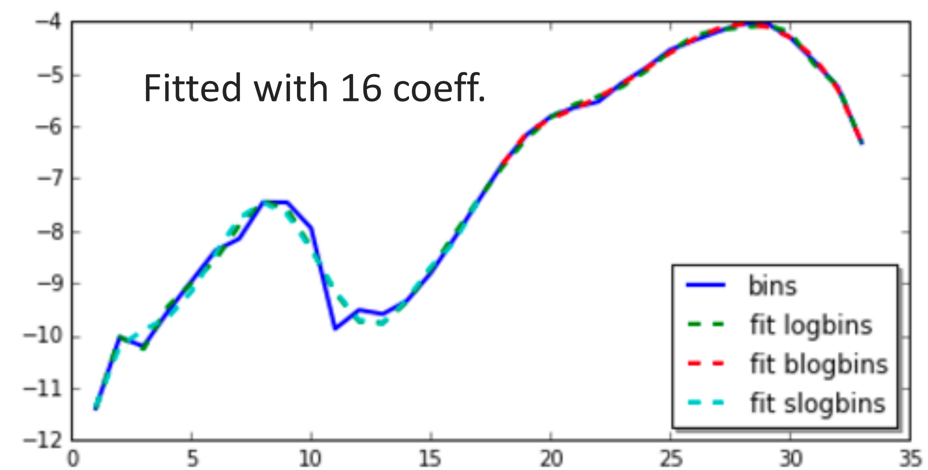
Z=2



At higher altitudes, liquid particles have two modes, PSD is not fitted well with **8** coefficients

Z=5





- For one mode PSD, 6 coefficients fits well
- For two modes, probably 12 coefficients is needed for reasonable fidelity. Then, the speedup is only about a factor of 3.

3. Implement new ice nucleation parameterizations in both P3 and SBM

- Currently, both P3 and SBM uses temperature- and supersaturation-dependent ice nucleation without connecting with aerosol properties.

Main work

- **Implement the recent ice nucleation parameterizations that also depend on aerosol properties.**
- **Improve the treatments of subgrid dynamics and thermodynamics driving the ice nucleation**

Discussion

➢ Seek for collaboration on parameterization evaluation:

- Observational data and analysis for MCSs, particularly cloud microphysics data over SGP and Amazonia.

Our team members in observations: Laura Riihimaki, Xiquan Dong, Scott Giangrande, Nitin Bharadwaj, Zhe Feng, Joseph Hardin, Pavlos Kollias, Mariko Oue, Jingjing Tian, Die Wang.

We will develop many new datasets such as MCS structure, lifecycle, cloud phase, 3-D ice microphysical properties, **especially multi-instrument retrievals**: in-cloud vertical velocity, multi-radar composite precipitation(with disdrometers), joint estimation of hydrometeor classification

- PECAN data and analysis related to MCS initiation and propagation