Implementation of spectral bin microphysics within GFDL's cloud-resolving regional and global models

N. BenMoshe[1], S.J. Lin[2]

[1]The program of Atmospheric and Oceanic Sciences/CICS, Princeton University, Princeton, NJ, USA , [2] GFDL/NOAA, Princeton, NJ, USA

Abstract

Microphysics-->latent heat release-->TC intensity.
The Microphysics is a dominating factor for TC and other Cloud resolving models. There are two main methods to describe microphysics in cloud resolving models.
1. Bulk-schemes assume gamma-distributions as master functions and use many other simplifications. However, any microphysical process leads to deviation from Gamma.
2. Spectral Bin Microphysics (SBM) is more accurate. So, our first goal was to implement SBM into a GFDL model and to compare the results and optimize the SBM to use less CPU.

BULK vs BIN

Properties	BULK –parameterization	Spectral bin microphysics
Main principle	The shape of size distributions is prescribed *a priori*	Model solves system of kinetic equations for size distributions
Aerosols	No aerosol budget, No aerosol transport, no distribution of aerosols with size	Aerosol budget, size distribution of CCN, transport of aerosols, cloud-aerosol interaction
Condensation/evaporation of drops:	No equation for condensational growth ; All supersaturation immediately transfers to cloud water	$r\frac{dr}{dt}=\frac{1}{F}(S-\frac{A}{r}+\frac{Br_N^3}{r^3-r_N^3})$ In maritime clouds S>10%
Collisions	Simplified equations like: $\frac{dq_{rain}}{dt}=k(q_{cloud}-q_{thresh})$	Stochastic collision equation $\frac{\partial f(m,t)}{\partial t}=\int_0^{m/2} f(m',t)K(m',m-m')f(m-m',t)dm'-\int_0^{\infty} f(m,t)K(m,m')f(m',t)dm',$
Sedimentation	The same fall velocity for particles belonging to the same class	Differential fall velocity depending on particle size , form and air density
Melting , freezing	Wrong assumption that the shape of size distributions remains during these higly non-linear processes	the shape of size distributions changes during these non-linear processes

Golaz et al. 2013 checked the model sensitivity to rainout effective radius, according to measurements (Rosenfeld et al. 2002), it should be 12-15 microns.

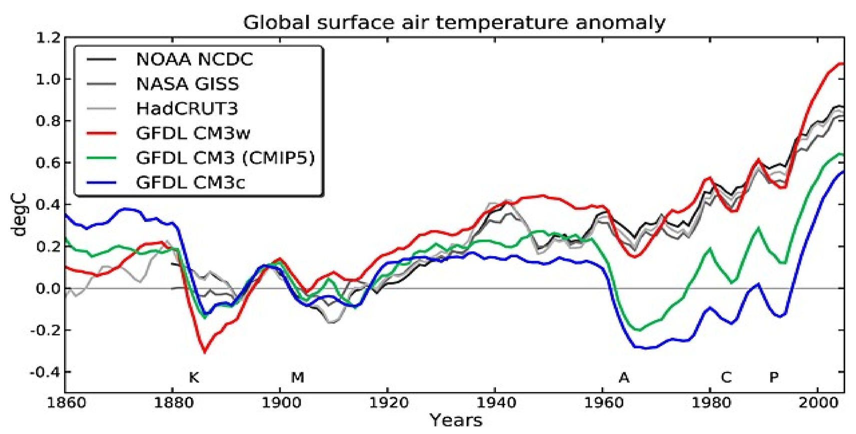
The changes in this free parameter connect to latent heat release

Red line (CM3w) – rainout radius 6um

Green line (CM3) – default rainout radius 8.2um

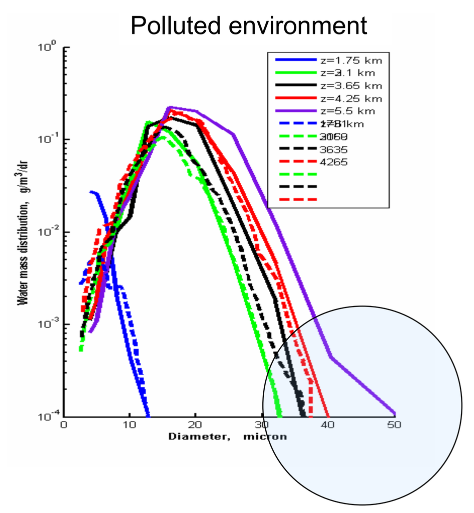
Blue line (CM3c) – rainout radius 10.6um

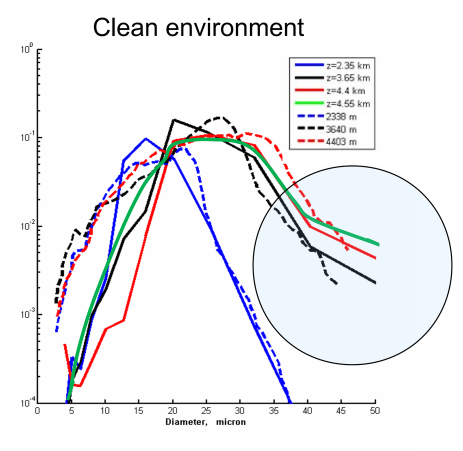
Gray lines - observations



Observed (local) size distributions are often not gamma. In case averaging is over many clouds the averaged DSD tends to gamma, but not always.

I would give as an example (attached fig-bimodal DSD)





Benmoshe et al. 2012

The SBM (HUCM) module calculate

Diffusional growth,

collisions,

Freezing / melting,

Breakup (drops/ice),

shedding (Khain et al. 2013)

43 spectral double mass bins

8 different hydrometeor types (+LWF)

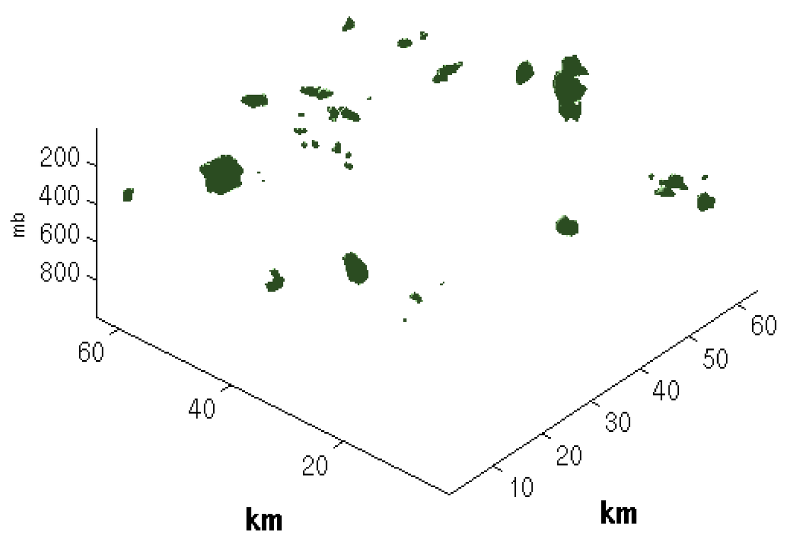
Aerosols

Cloud ensemble

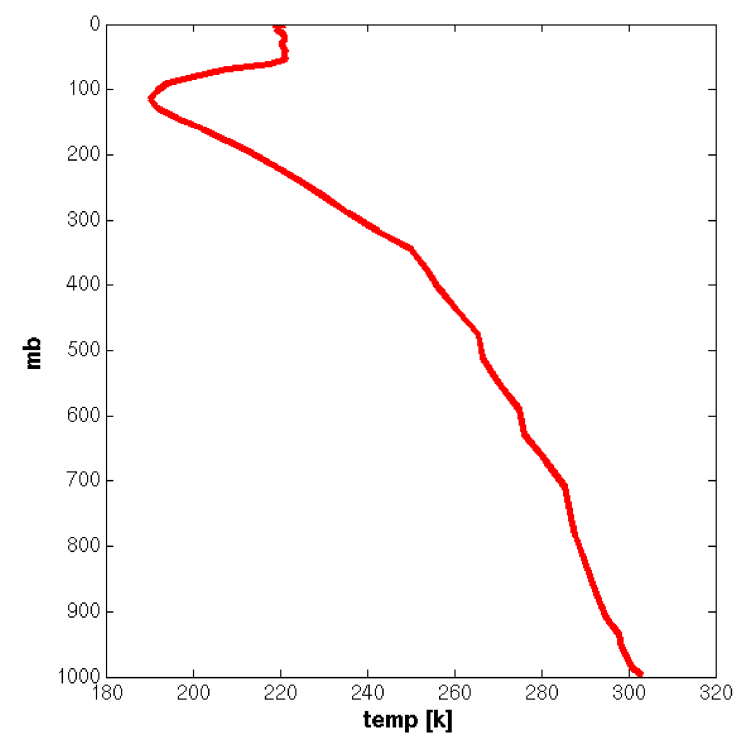
64km*64km

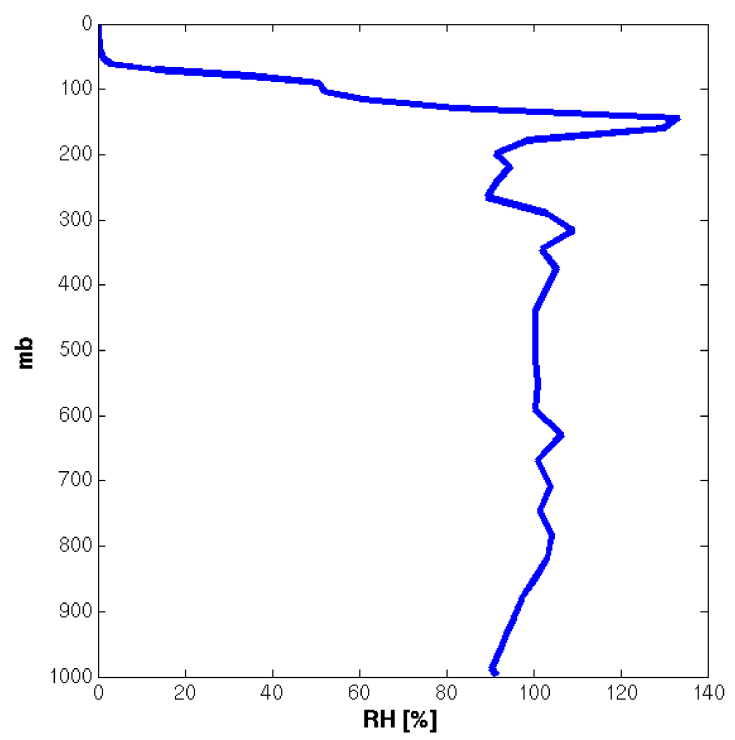
51 levels

1km horizontal resolution

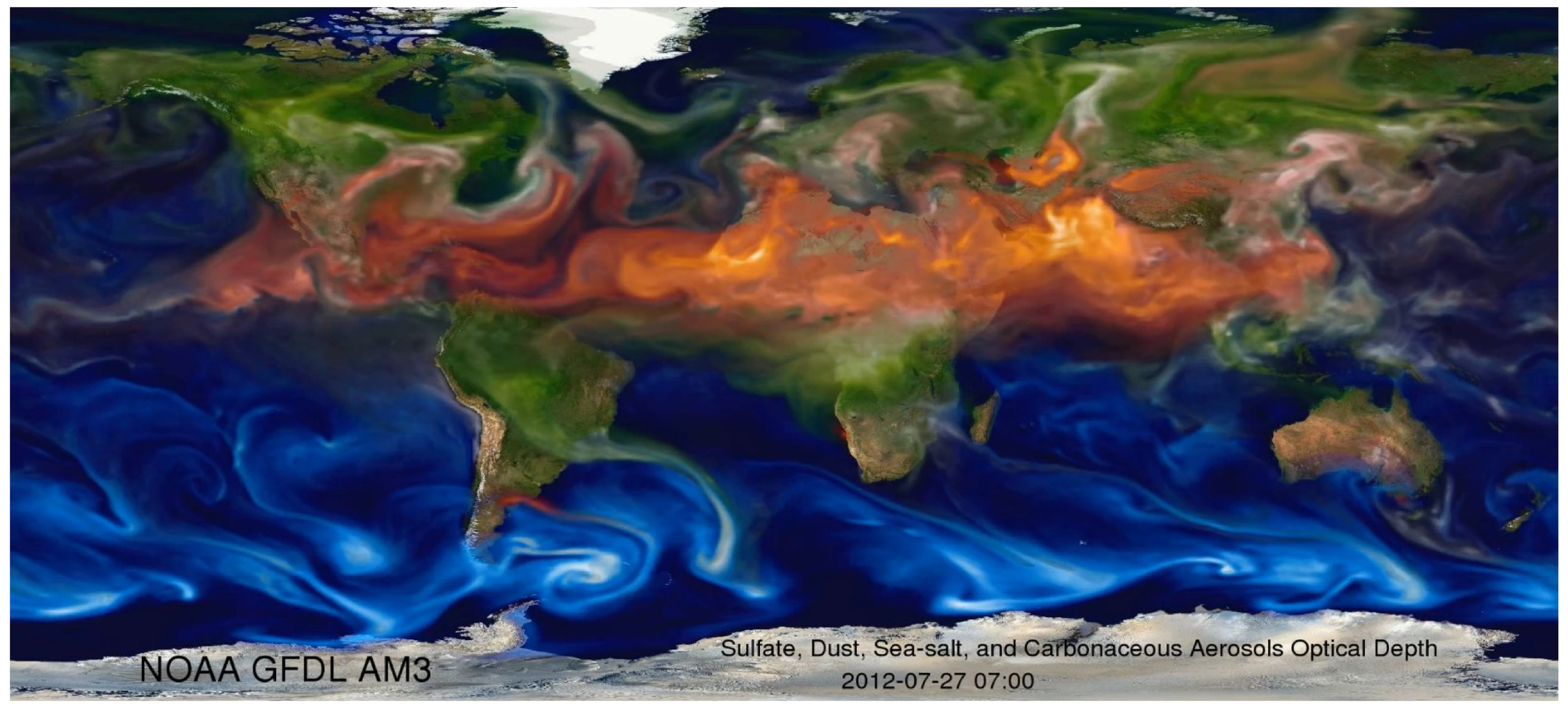


Initial conditions





CCN concentration assumed to be 100 per cm^3, but in realty it is a mixture of clean and polluted parcels, the concentrations can't be simply added due to different size distributions



Courtesy of Paul Ginoux

Simulation design

•The SBM was implemented and a compress options were added:

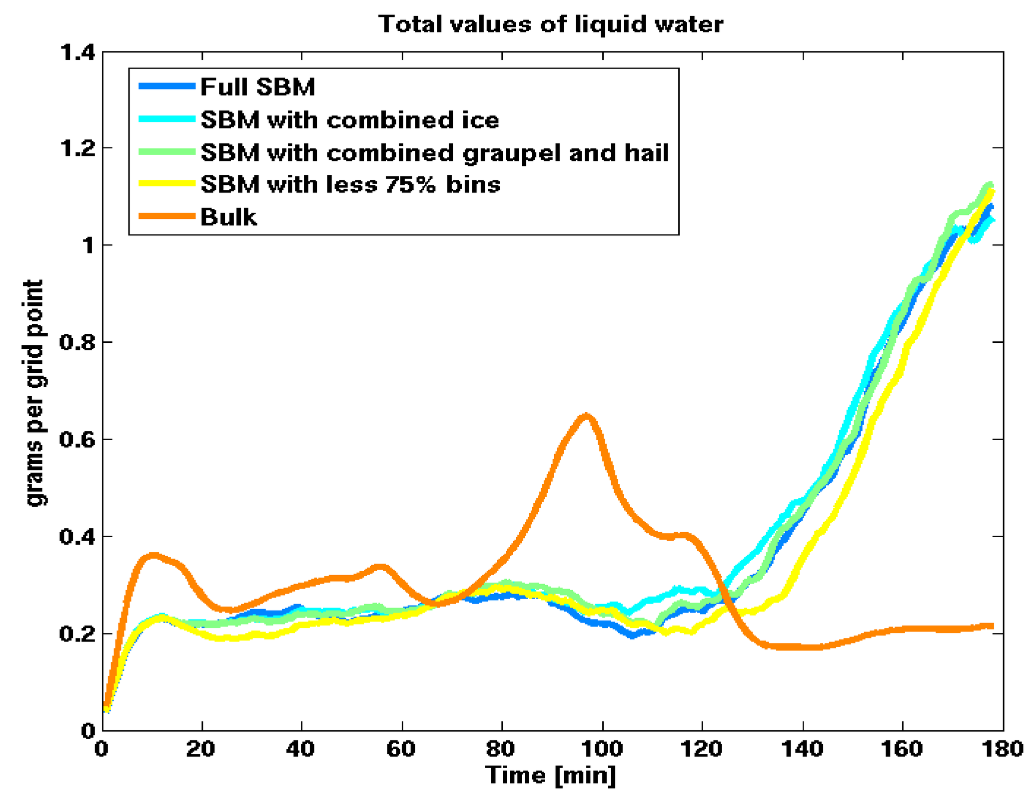
• Full scheme (without freezing drops)

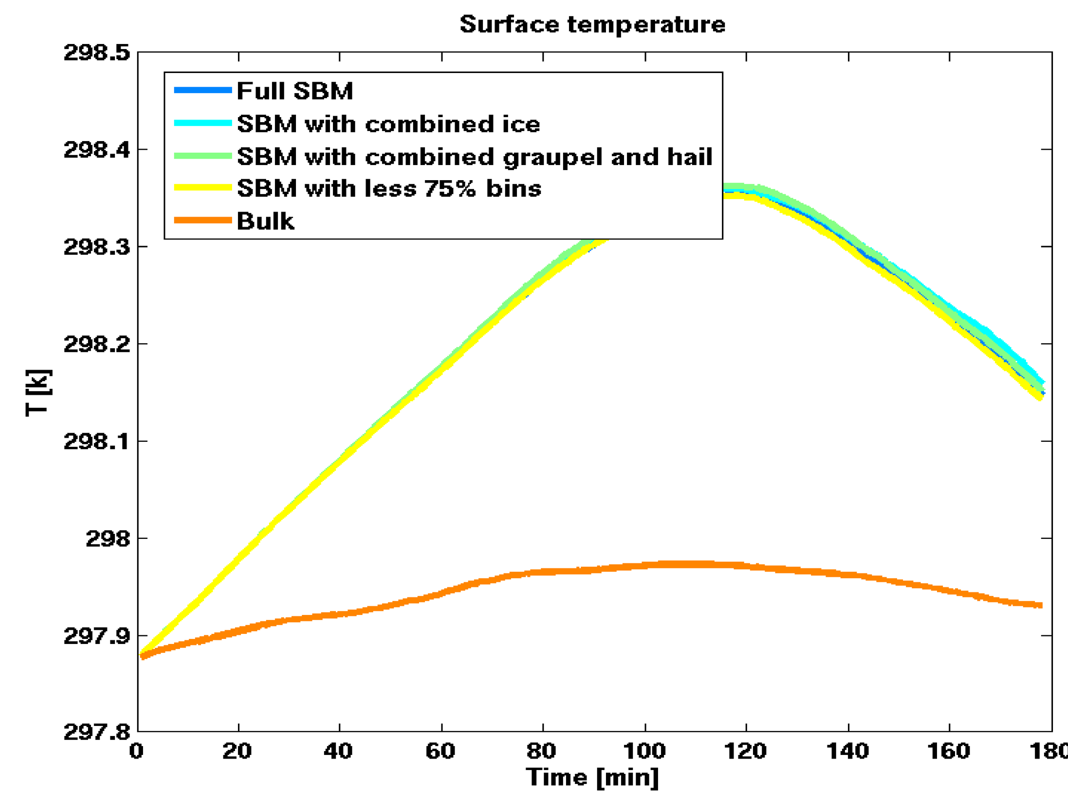
• Using only the 33 bins

• Unified ice size distribution

• Unified graupel and hail size distribution

Results





Summery

• We converted a spectral bin model to a spectral bin microphysical module (we separate the microphysics and the dynamics)
• We implement it in a GFDL model
• We check several methods of optimization
• We checked the surface temperature response to the module.