Improving Cloud Water Inhomogeneity Parameterization in CAM

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q = mixing ratio
N = number concentration

(MG 2008, From Morisson, 2011)
Three types of subgrid scale cloud variability

1. Cloud and precipitation particle sizes are represented by the Palmer distributions:

\[ \phi(D) = N_0 D^\mu e^{-\lambda D} \]

For cloud ice, snow, and rain, \( \mu = 0 \).
For cloud droplets, \( \mu = 1/\eta^2 - 1 \), \( \eta = 0.0005714N + 0.2714 \)

2. Subgrid scale distribution of cloud water and ice by gamma functions:

\[ P(x) = \frac{1}{\Gamma(v)} \frac{1}{\theta^v} x^{v-1} \exp\left(-\frac{x}{\theta}\right) \]

\( v \) shape parameter \( \theta \) scale parameter

3. How clouds are vertical stacked.
Bulk microphysics processes

\[ M_p = x q_c^y \]

\[ \overline{M}_p = x \frac{\Gamma(\nu + y)}{\Gamma(\nu) \nu^y} q_c^y \]
ARM MICROBASE Cloud Water Data:

- High temporal and high vertical resolution (10s, 45 meters)
- Different locations Barrow (NSA), Lamont (SGP), and Darwin (TWP3)
- Long term record (2007-2010)
ARM CMBE hourly wind data are used to do time-space conversion

MLM Gamma fitting for different lengths (L)

$L=5 \text{ km}$

$v = 5.2$

$L=100 \text{ km}$

$v = 2.2$

$v = \frac{1}{\sigma^2} = \frac{\bar{q}l^2}{\text{VAR}(q_l)}$
\( \nu \) as a function of height and length scale

Three ARM sites in different seasons, DJF and JJA

\( L = 200 \text{ km} \quad L = 5 \text{ km} \)
Parameterization using grid size and vertical stability as independent variables

\[ \nu = \nu(L, \text{Static Stability}) \]

\[ \nu = 0.44 + 8.3(0.60 - S)(0.05 + L^{-2/3}) \]

\[ S: \frac{h_{950\text{mb}} - h_{500\text{mb}}}{450\text{mb}}, \ (J/\text{Pa}) \]

\[ L: \ (\text{km}) \]
\[ \nu = \nu(L, \text{Stability\_CAPE}) \]
Comparison at individual stations

Parameterization

NSAC1

Observations

Derived Gamma Shape from fitting method

Estimated Gamma Shape

SGPC1

TWPC3
Implementation in CAM5

- Bulk scheme, instead of using fixed $\nu = 2$ or $\nu = 1$, use the parameterized $\nu$ in

$$\bar{M}_p = x \frac{\Gamma(\nu + y)}{\Gamma(\nu) \nu^y} q_c^{y}$$

- Sub column calculations
Sub column microphysics calculations

- Gamma distribution of liquid water content with parameterized *shape parameter*.
- Combination of maximum-random and random cloud overlapping assumption using decorrelation depth assumption.
- Cloud water mass conservation.

Single Column Model Run
SGP 19950719
Use 30 sub columns
Snapshot at 36 timestep

Large Scale LWC Feature
QC

LWC sub column
QC

![Image of LWC sub column QC chart]
Test results

CAM5-SC

Camrun (yrs 1-3)

Precipitation rate

Mean = 2.67 mm/day

ANN

Min = 0.00 Max = 18.59

GPCP

Precipitation rate

Mean = 2.67 mm/day

Min = 0.02 Max = 12.22

camrun - GPCP

Mean = 0.20

Rmse = 1.04 mm/day

Min = -5.25 Max = 9.57

Camrun (yrs 1-3)

Precipitation rate

Mean = 2.94 mm/day

ANN

Min = 0.00 Max = 16.73

GPCP

Precipitation rate

Mean = 2.67 mm/day

Min = 0.02 Max = 12.22

camrun - GPCP

Mean = 0.27

Rmse = 1.11 mm/day

Min = -5.27 Max = 9.42
Summary

1. A simple parameterization of the shape parameter of the subgrid scale distribution of cloud liquid water is proposed as a function of model resolution and vertical stability.

2. Sub-column method by sampling the parameterized pdf of cloud water was used in cloud microphysics and radiation calculations.

3. At 2-degree resolution, the sub-columns do not change the simulated climate much from the default CAM5, but they gave the subgrid scale distribution of stratiform precipitation that can be valuable for land surface processes.