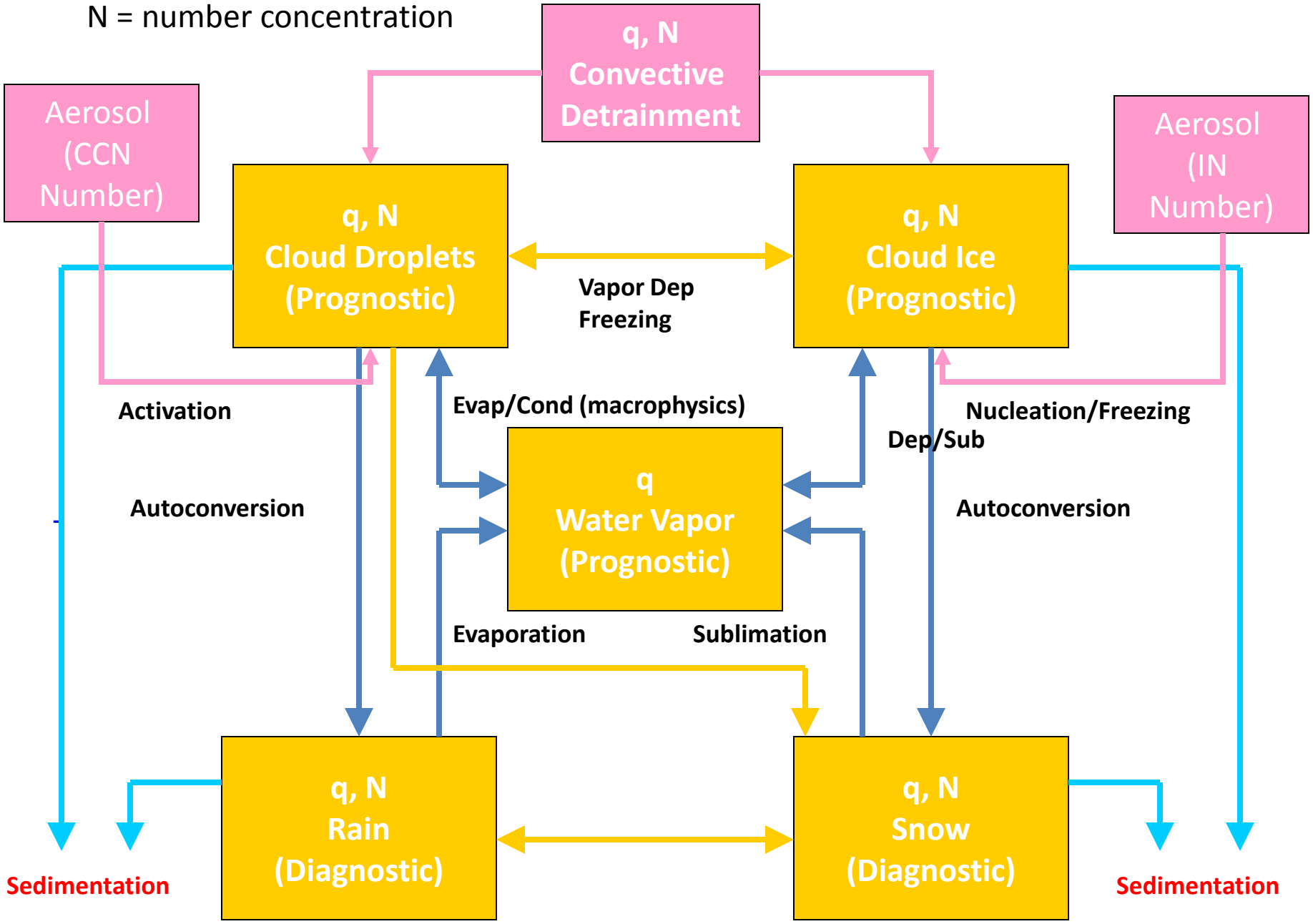
Improving Cloud Water Inhomogeneity Parameterization in CAM

Xin Xie and Minghua Zhang

Stony Brook University, SUNY

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:

$$P(x) = \frac{1}{\Gamma(v)} \frac{1}{\theta^v} x^{v-1} \exp(-\frac{x}{\theta})$$

v shape parameter

θ scale parameter

3. How clouds are vertical stacked.

Bulk microphysics processes

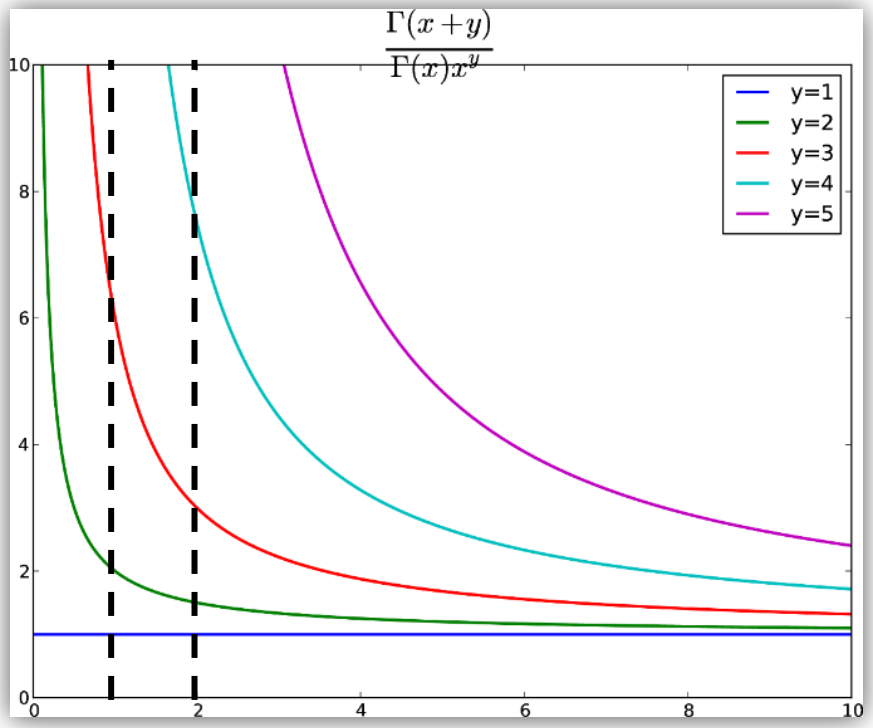
$$M_p = x q_c{}^y$$

$$\overline{M_p} = x \frac{\Gamma(\nu + y)}{\Gamma(\nu)\nu^y} \overline{q_c}{}^y$$

$\frac{\Gamma(\nu + y)}{\Gamma(\nu)\nu^y}$

4

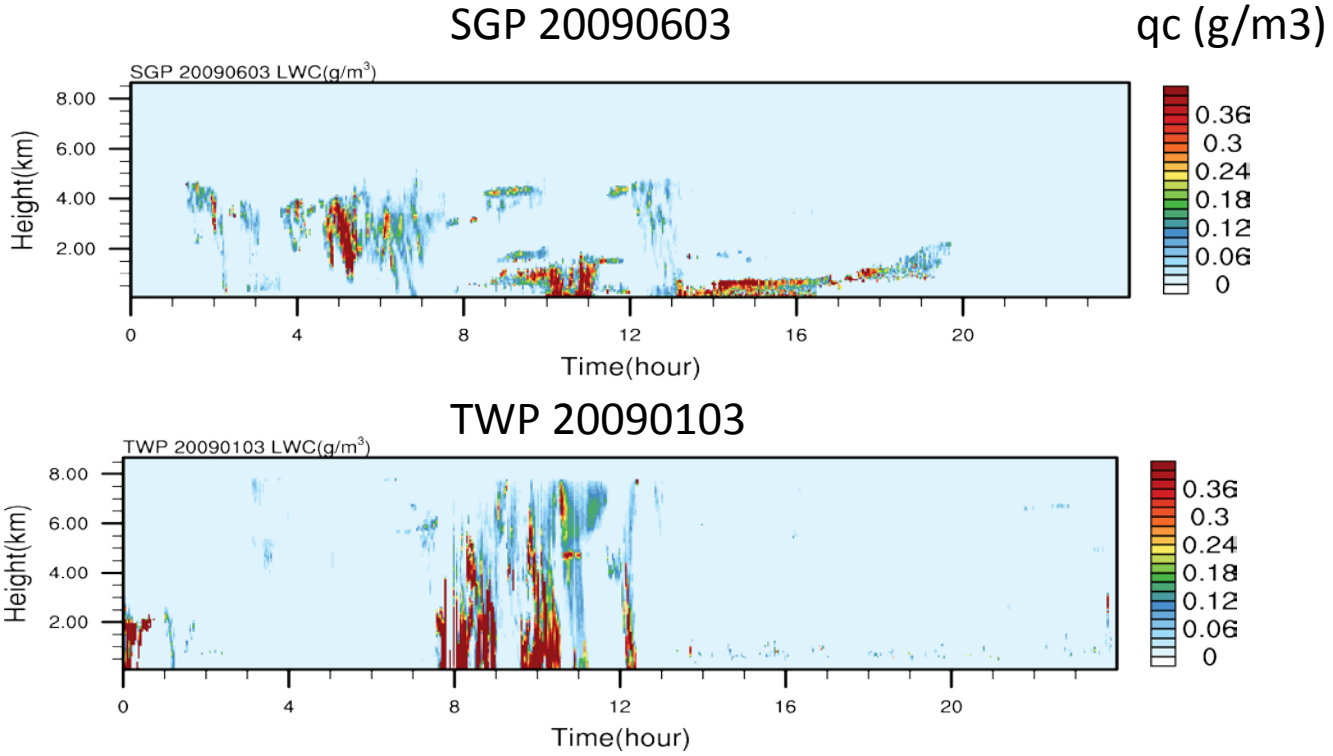
1



$\nu = 1$, $\nu = 2$ ν

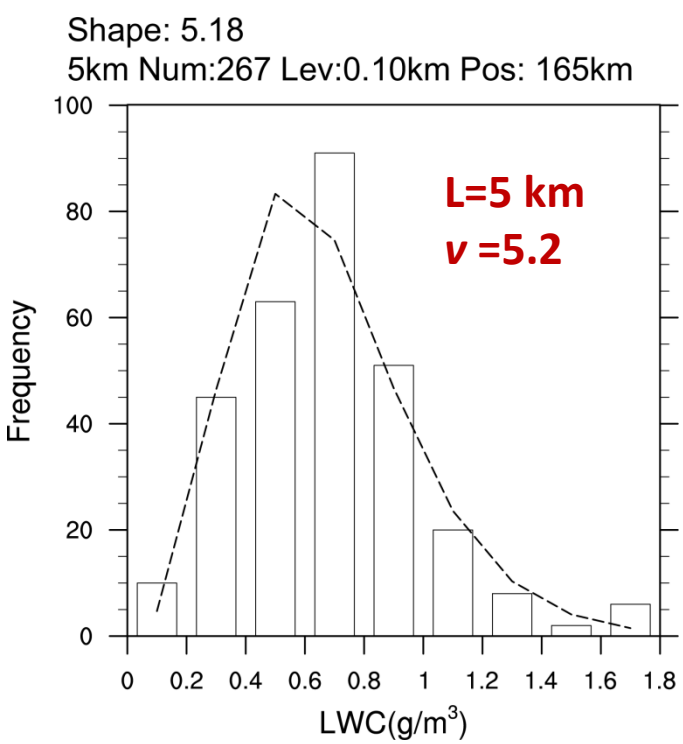
ARM MICROBASE Cloud Water Data:

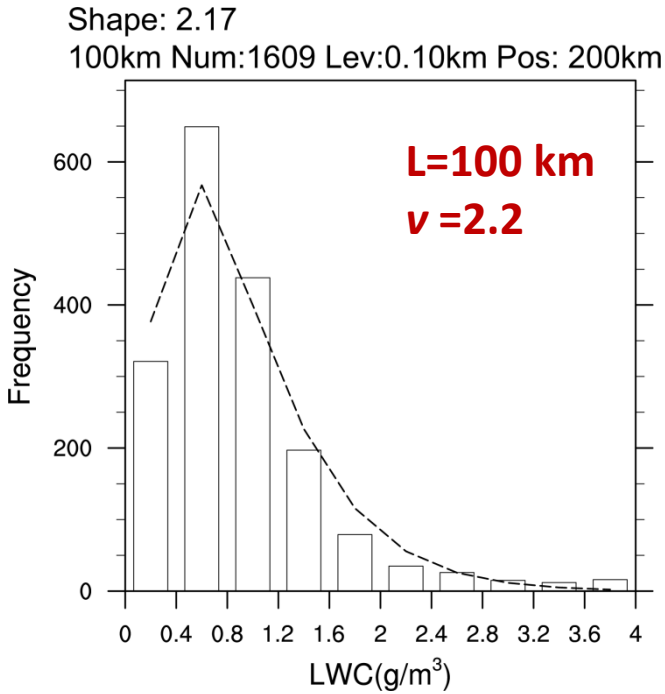
- High temporal and high vertical resolution (10s, 45 meters)
- Different locations Barrow (NSA), Lamont (SGP), and Darwin (TWP3)
- Long term record (2007-2010)



ARM CMBE hourly wind data are used to do time-space conversion

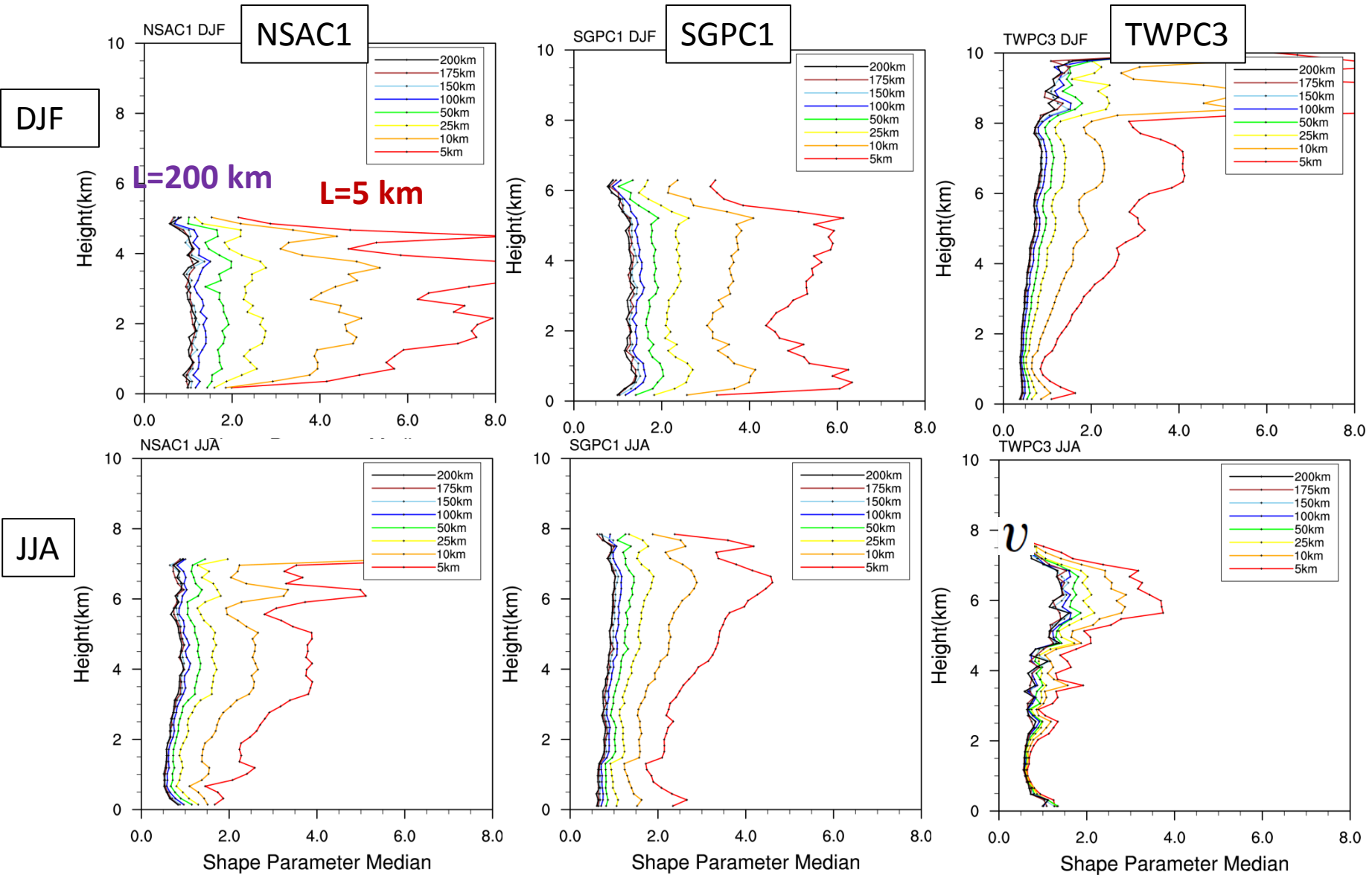
MLM Gamma fitting for different lengths (L)





$$v = \frac{1}{\sigma^2} = \frac{\bar{q_l}^2}{VAR(q_l)}$$

v as a function of height and length scale
Three ARM sites in different seasons, DJF and JJA



Parameterization using grid size and vertical stability as independent variables

$$v = v(\text{L, Static Stability})$$

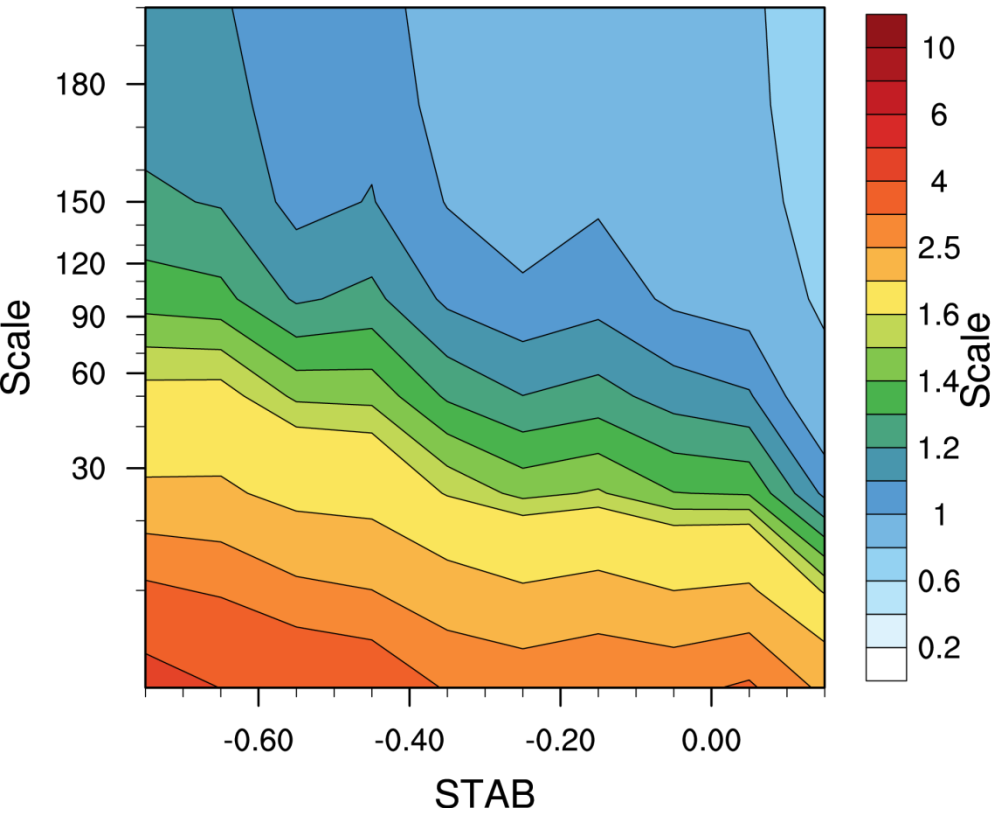
$$v = 0.44 + 8.3(0.60 - S)(0.05 + L^{-2/3})$$

S: $\frac{h_{950mb} - h_{*500\,mb}}{450mb}$, *(J/Pa)*

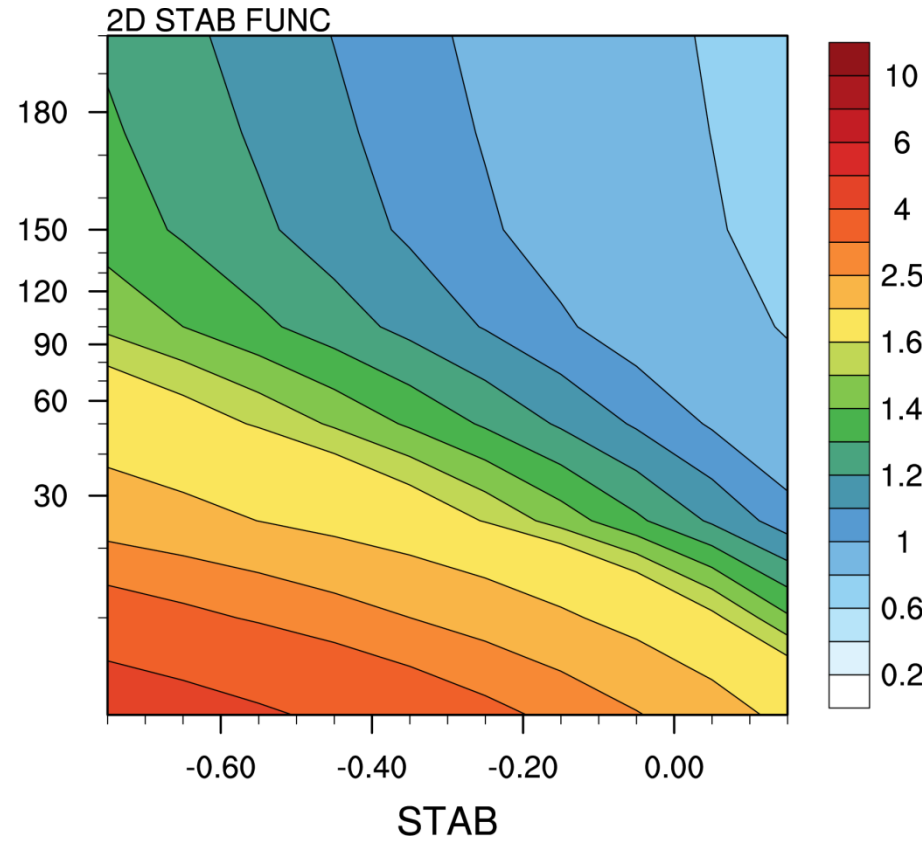
L: (km)

$$\upsilon = \upsilon(\mathrm{L}, \mathrm{Stability\_CAPE})$$

Observation



Parameterization



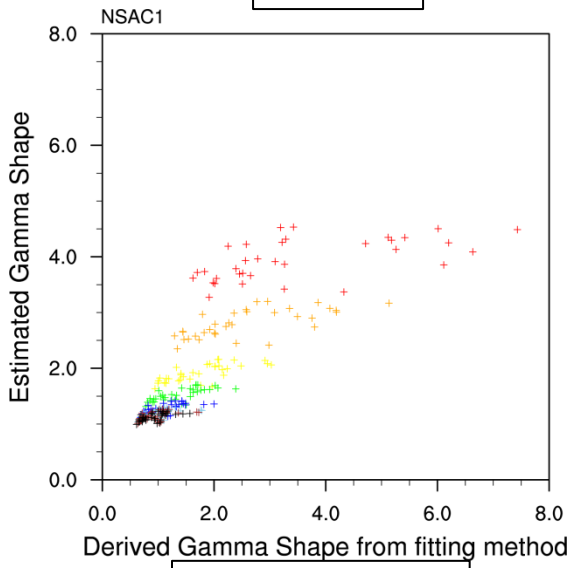
Comparison at individual stations

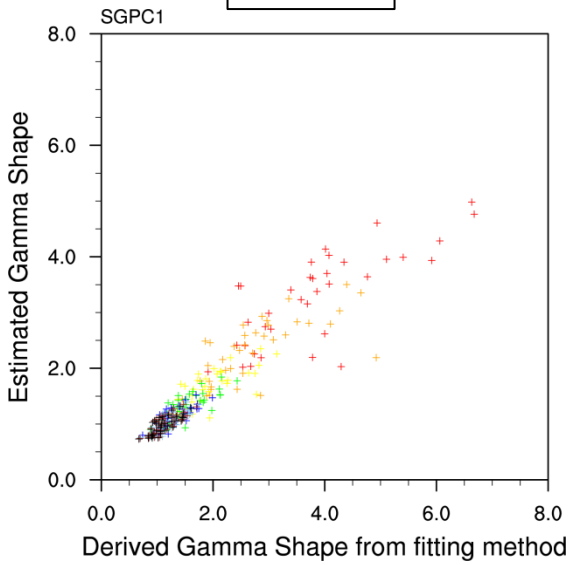
NSAC1

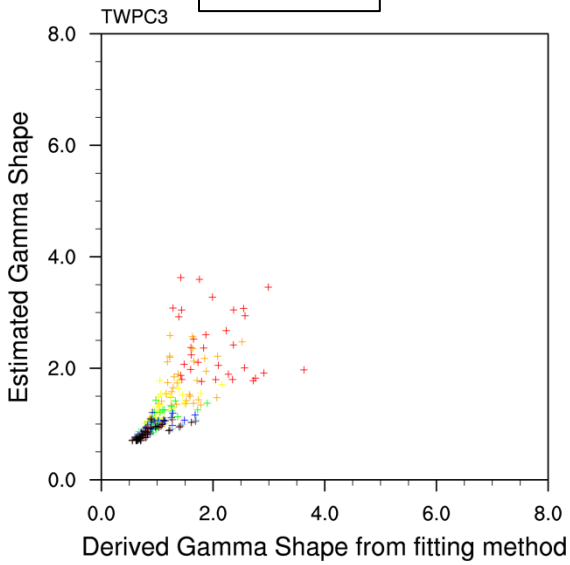
SGPC1

TWPC3

Parameterization







Observations

Implementation in CAM5

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

$$\overline{M_p} = x \frac{\Gamma(\nu + y)}{\Gamma(\nu)\nu^y} \overline{q_c}^y$$

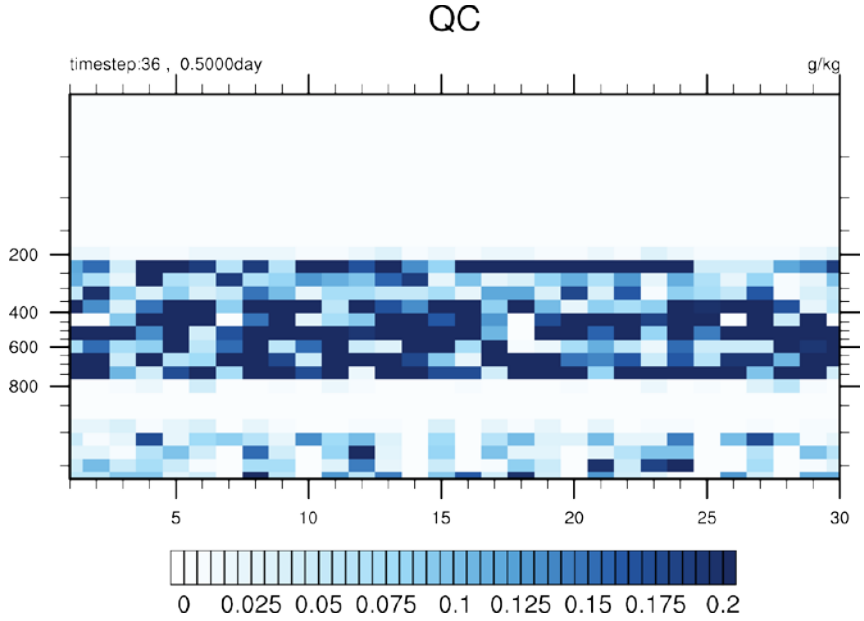
- Sub column calculations

Sub column microphysics calculations

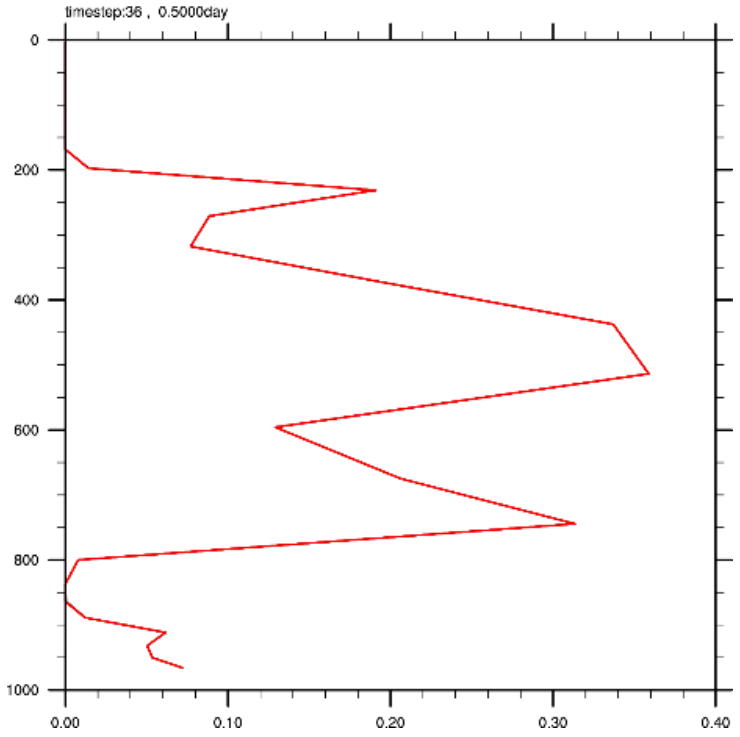
- Gamma distribution of liquid water content with parameterized *shape parameter* .
- Combination of maximum-random and random cloud overlapping assumption using decorrelation depth assumption.
- Cloud water mass conservation.

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

LWC sub column

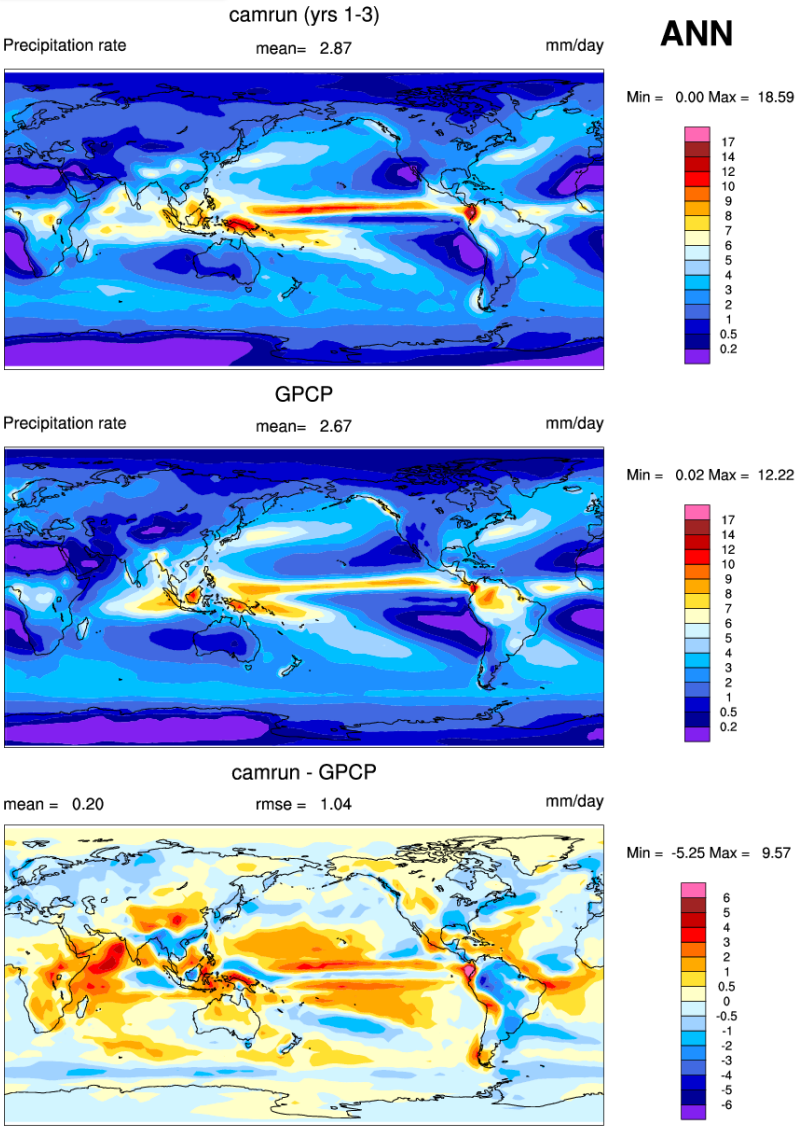


Large Scale LWC Feature

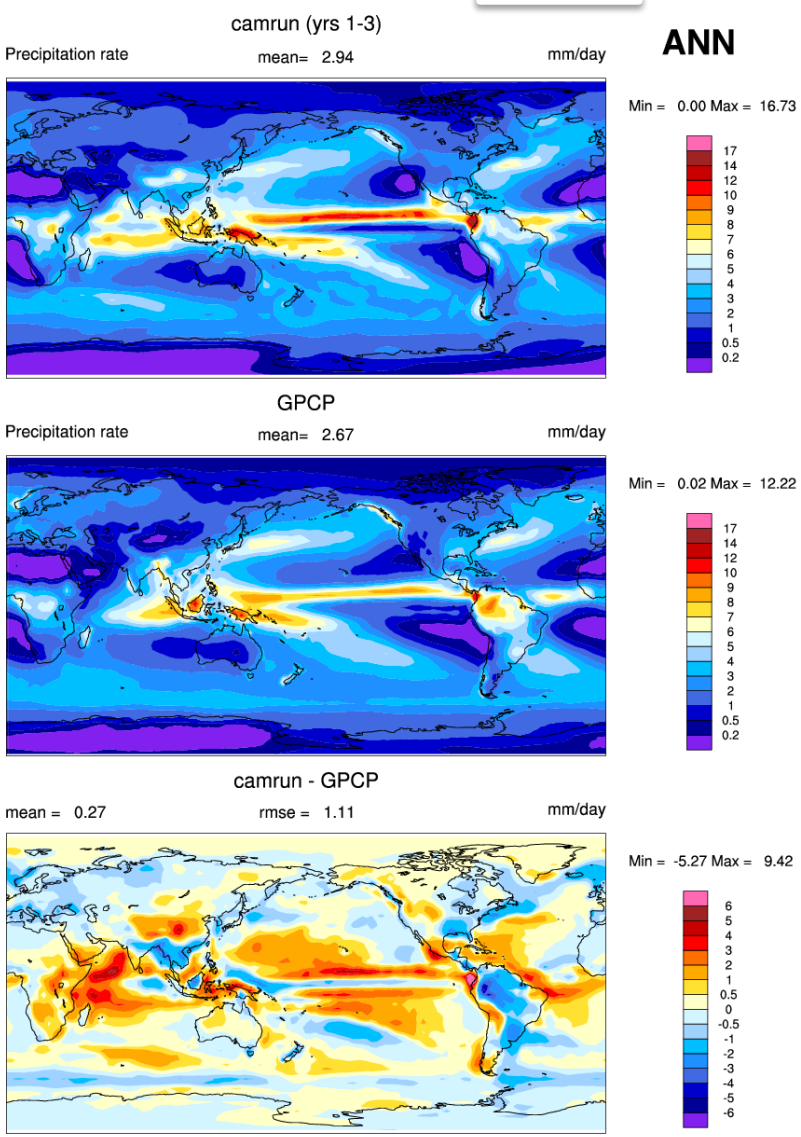


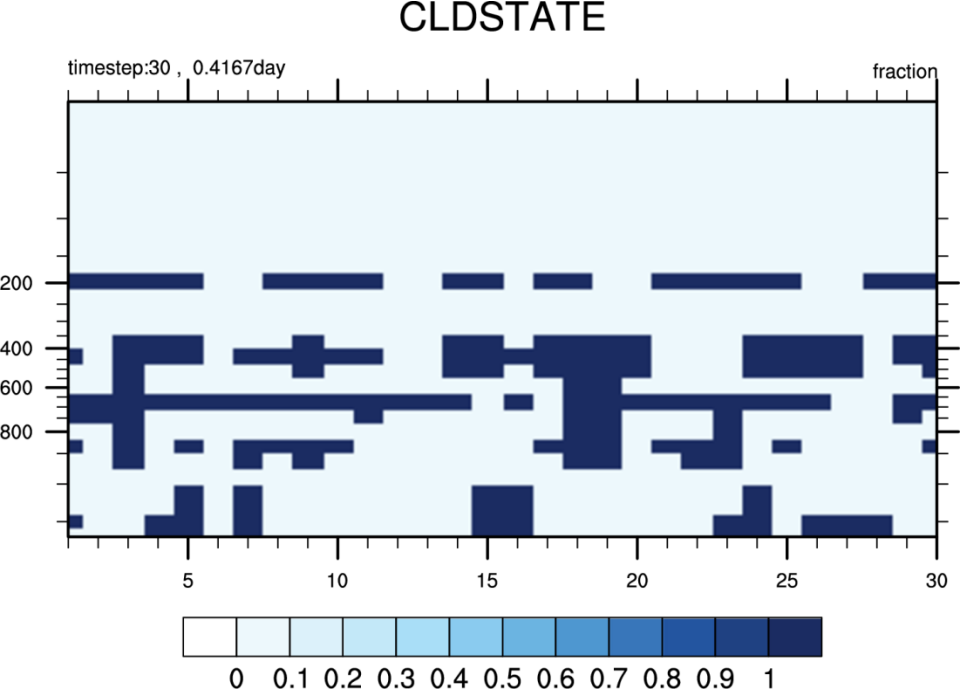
Test results

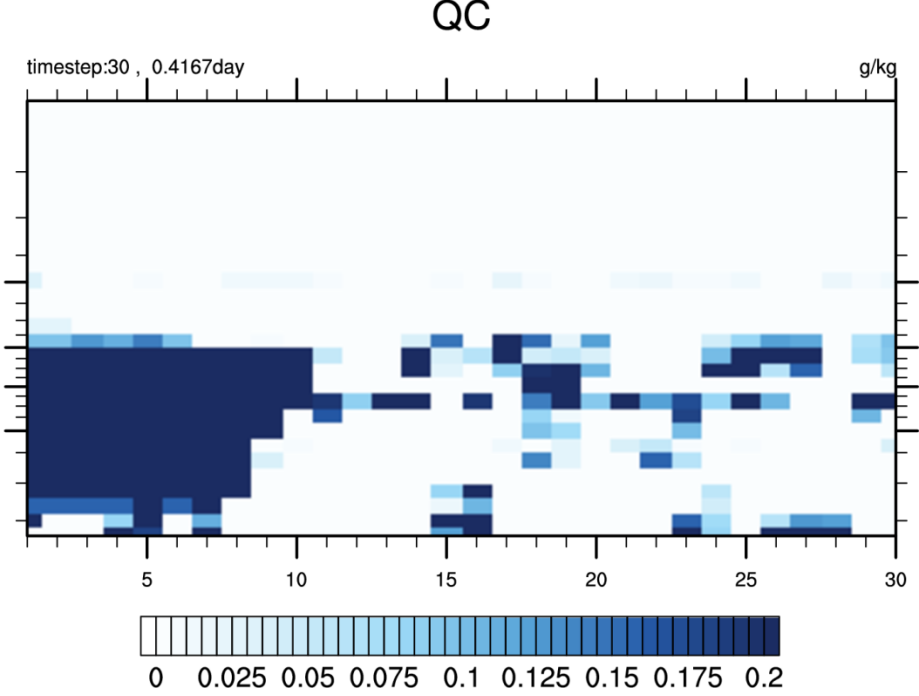
CAM5-SC

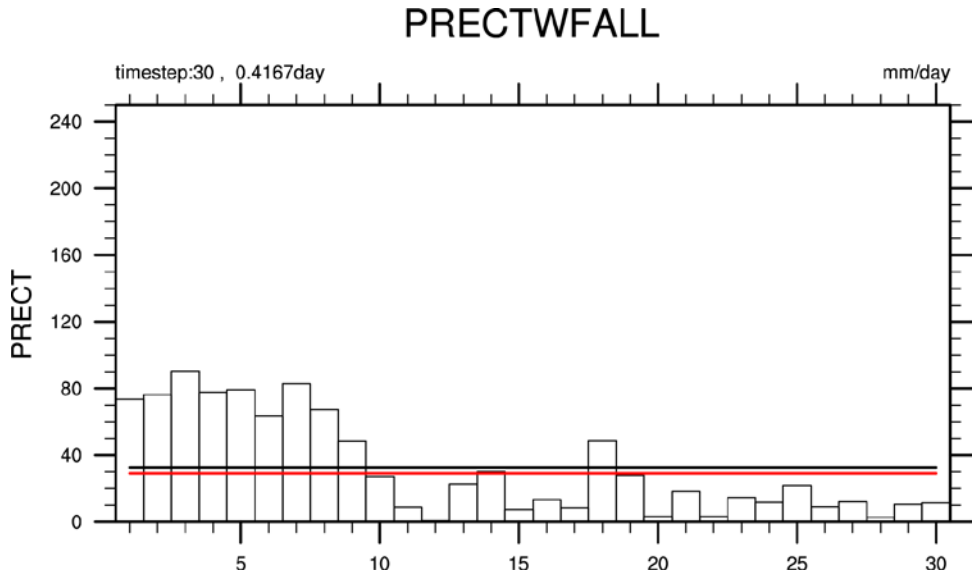


CAM5




CLDSTATE
timestep:30 , 0.4167day
fraction
200
400
600
800
5
10
15
20
25
30
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1


QC
timestep:30 , 0.4167day
g/kg
200
400
600
800
5
10
15
20
25
30
0 0.025 0.05 0.075 0.1 0.125 0.15 0.175 0.2


PRECTWFALL
timestep:30 , 0.4167day
mm/day
PRECT
240
200
160
120
80
40
0
5
10
15
20
25
30

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.