Exploring the Multi-Scale Aerosol/Cloud Interactions From ARM Measurements to Global Modeling

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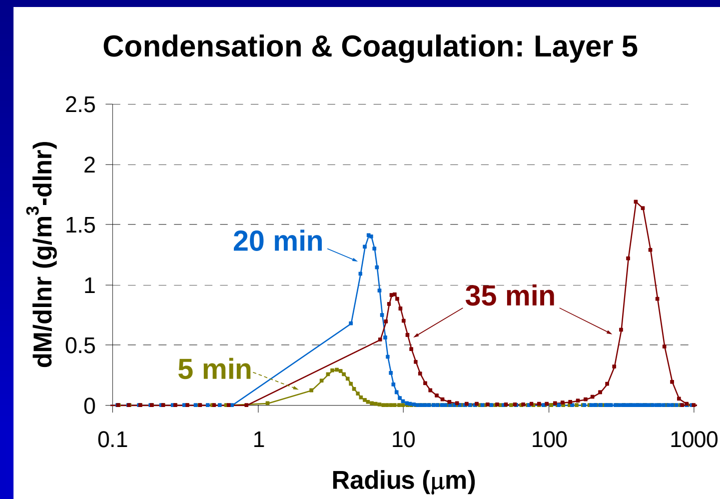
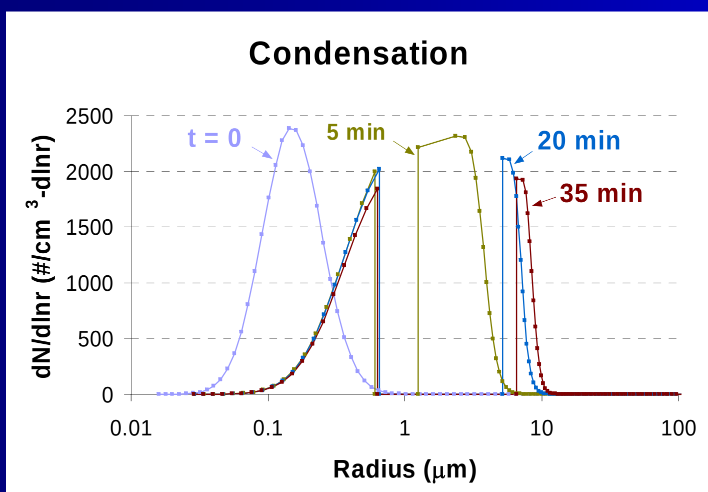
Objectives

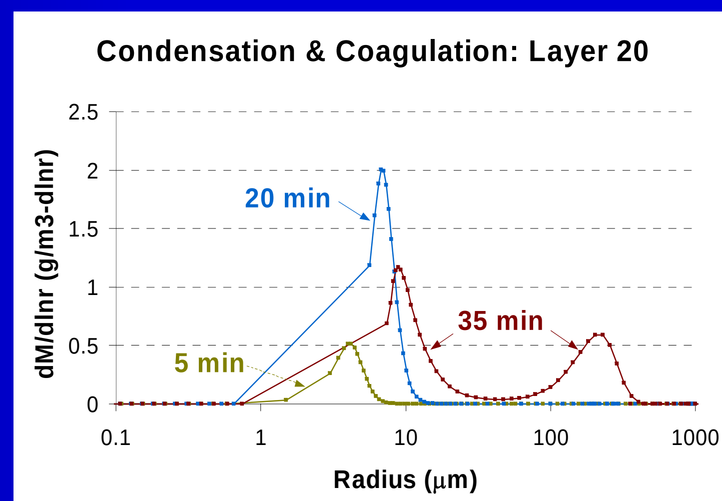
- Examine the influence of aerosol compositions on droplet formation and review different cloud nucleation parameterizations.– Micro Scale
- Investigate impacts of aerosols and autoconversion schemes on cloud properties over SGP with 2-D/3-D cloud resolving models. – Cloud Scale
- Explore the sensitivity of aerosol/cloud interactions to different nucleation parameterizations during TWPICE with NCAR CAM3. – Global Scale

Micro Scale: Examine the linkage between aerosols and clouds using a 1-D sectional cloud microphysical model

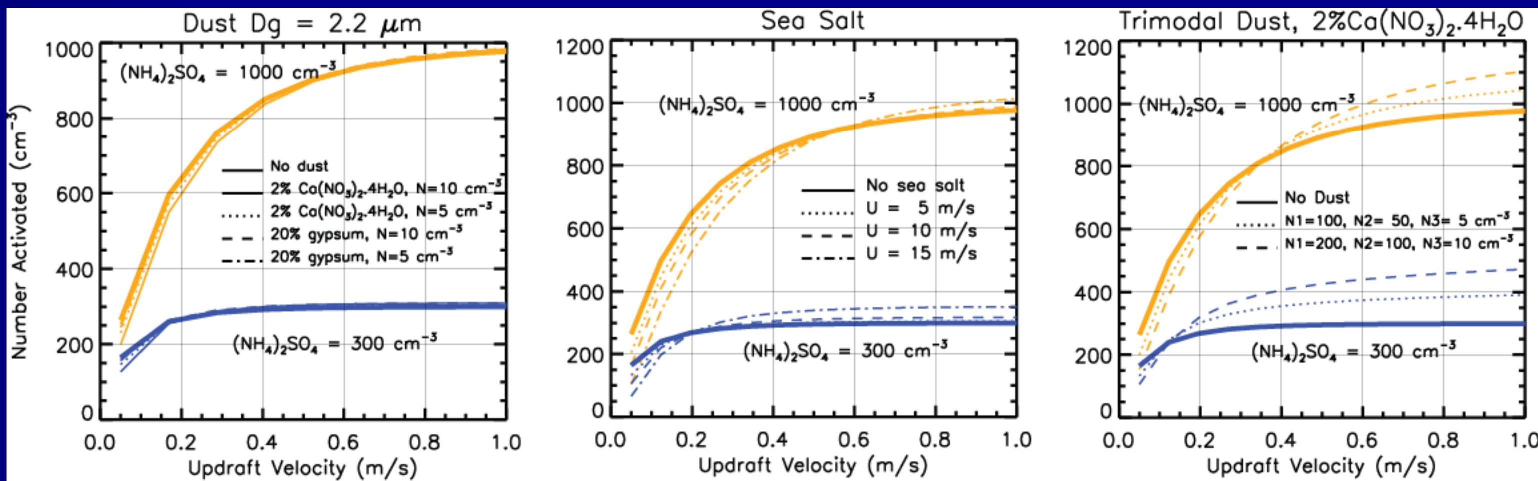
- **Processes**
  Condensation, Coagulation, Sedimentation, Turbulent transport
- **Features**
  Multiple vertical cells allow large drops to sediment







Micro Scale: Evaluate the Influence of dust and sea salt on clouds



Total number of particles activated. $(NH_4)_2SO_4$ distribution (D_g=0.16 μm, σ_g=1.4)

U-values correspond to wind speeds that result in the trimodal distributions described by Ghan *et al.* (1998) (D_{g1}= 0.2 μm, D_{g2}=2 μm, D_{g3}=12 μm). Initial RH = 97%.

The trimodal dust distribution contains 2% $Ca(NO_3)_2 \cdot 4H_2O$ and 98% SiO_2 (mass percentages) with D_{g1}= 0.2 μm, D_{g2}=0.8 μm, D_{g3}=2 μm, and $\sigma_{g1}=\sigma_{g2}=\sigma_{g3}$= 2.

- Effects of coarse dust particles on cloud nucleation are generally smaller than those from sea salt. The addition of coarse dust particles, in general, would not significantly reduce the number of activated particles.
- Large numbers of fine dust particles can significantly enhance the number of activated particles under certain conditions.

(Kelly, Chuang, and Wexler, 2007)

Cloud Scale: Examine the impacts of aerosols and auto-conversion schemes on cloud properties

Cloud Scale Experiments with/without anthropogenic aerosols and different autoconversion schemes.

Table 1. List of physics processes used in sensitivity experiments.

Physics \ Experiment	Control	1	2	3	4	5	6
Autoconversion	Kessler	Berry	Berry	Beheng	Beheng	Chen & Cotton	Chen & Cotton
Aerosols	*	Natural	N + A	Natural	N + A	Natural	N + A
Cloud Drops	Fixed	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted

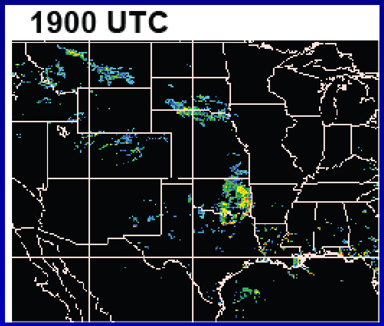
N + A: Natural + Anthropogenic

Cloud resolving model:

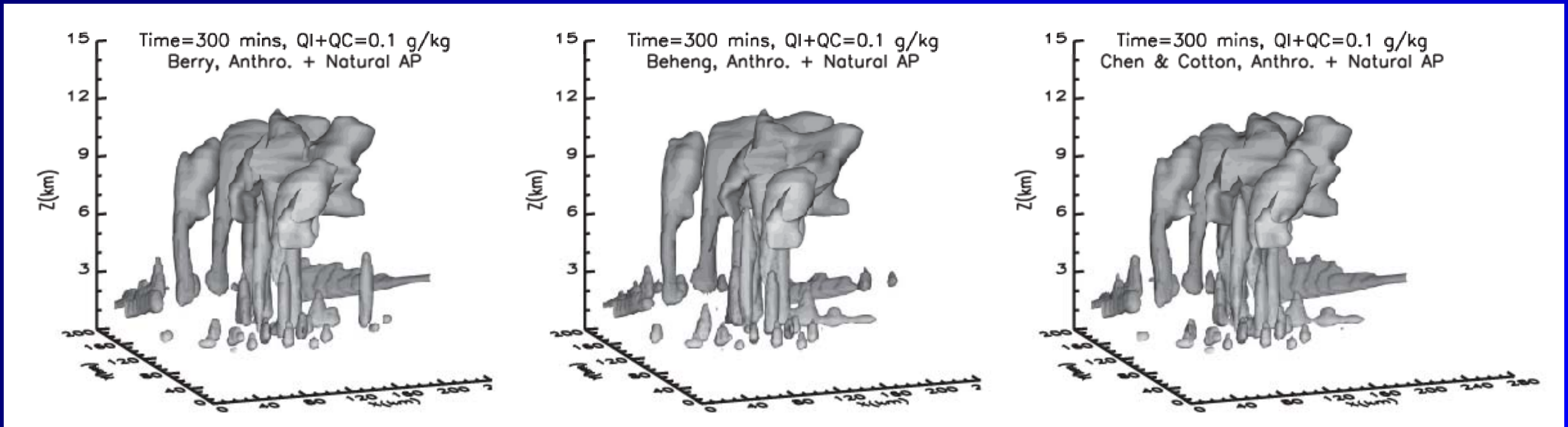
Chin and Wilhelmson (1998) with addition of aerosol radiative impacts through the parameterization of cloud nucleation (Chuang et al., 2002a). The aerosol concentrations and compositions are from LLNL global chemistry/aerosol model (Chuang et al., 2002b).

Cloud Scale: Convective case (3D study)

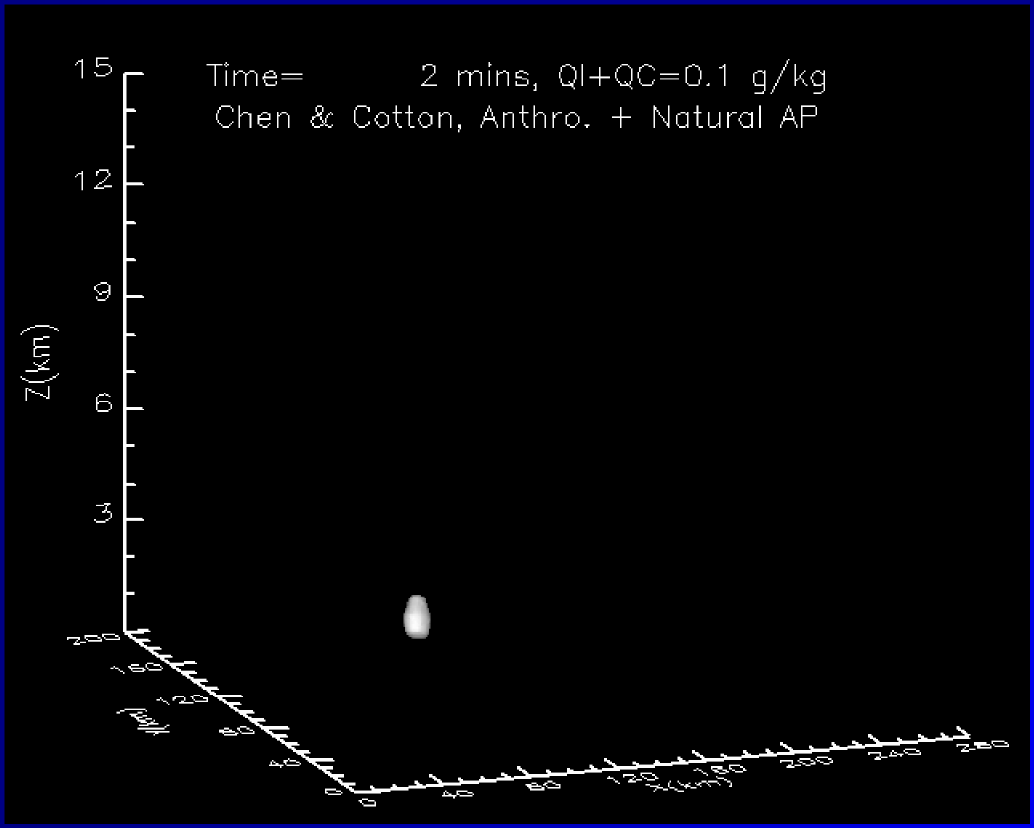
Radar reflectivity of the selected convective system passing through SGP site on June 19, 2004. The initial condition of CRM at 1400 UTC (i.e., 9 AM) is modified from the 1130 UTC sounding at the central facility. Model is running for 5 hours.



Simulated cloud structure at 1900UTC



Cloud Scale: Evolution of clouds



Domain size:
- 280 km x 200 km

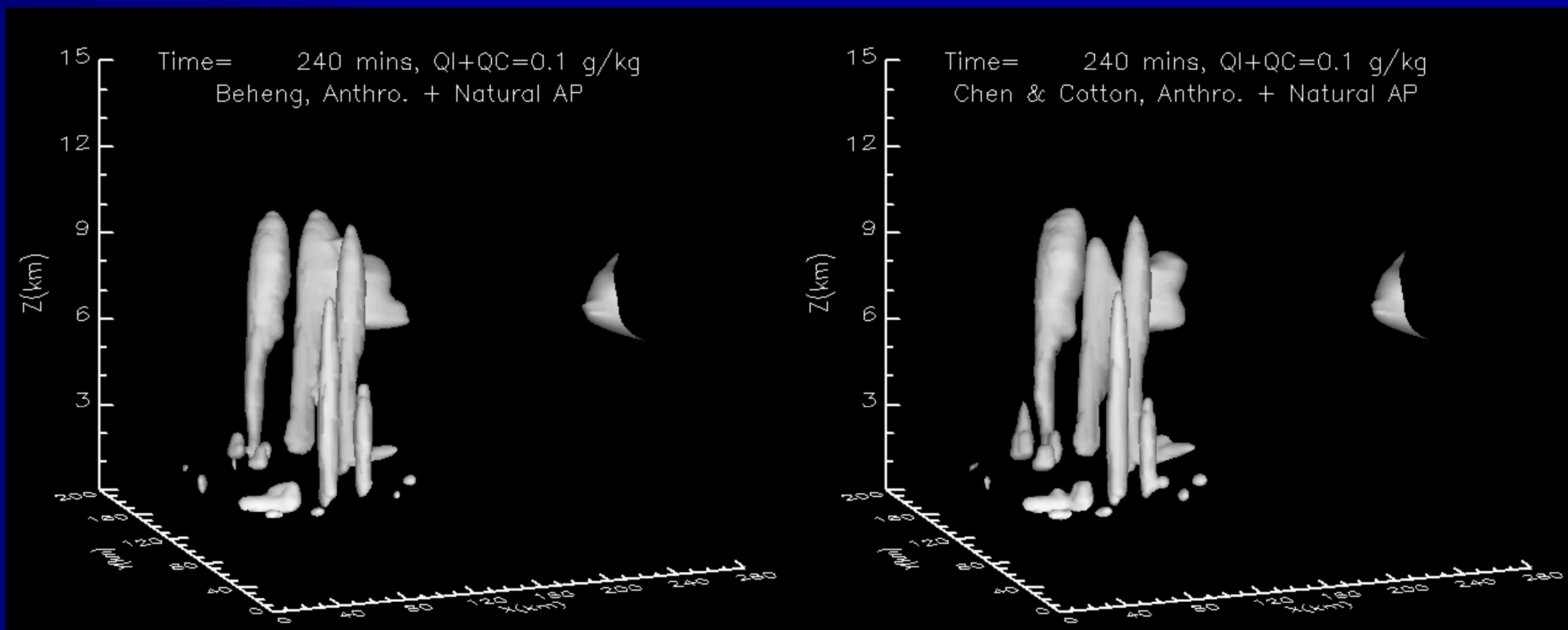
Resolution:
- 2 km in horizontal
- Varied in vertical

Time interval:
- 10 secs for dynamics
- 10 mins for radiation

Simulation time:
- 5 hours

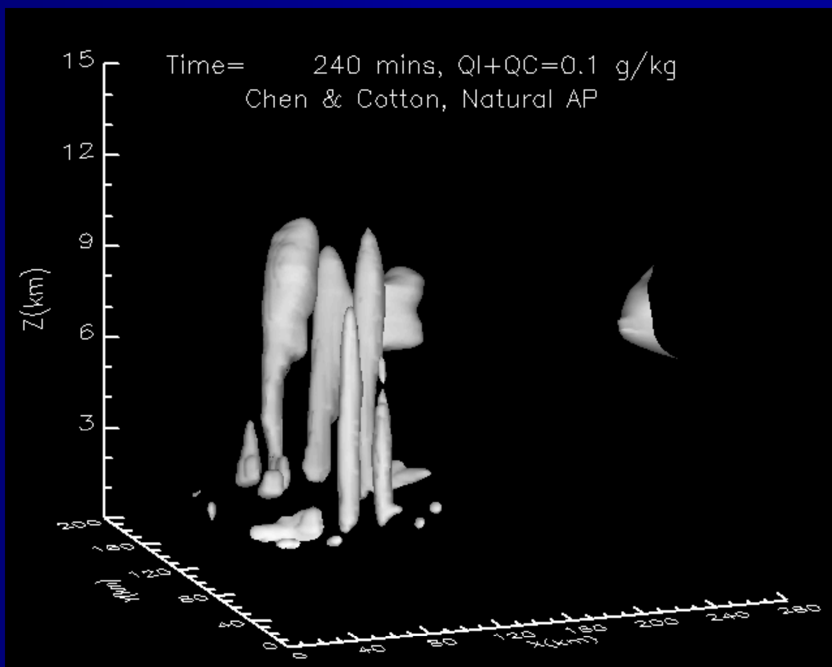
Cloud Scale: Evolution of clouds
Comparison between different schemes

Beheng — Chen & Cotton

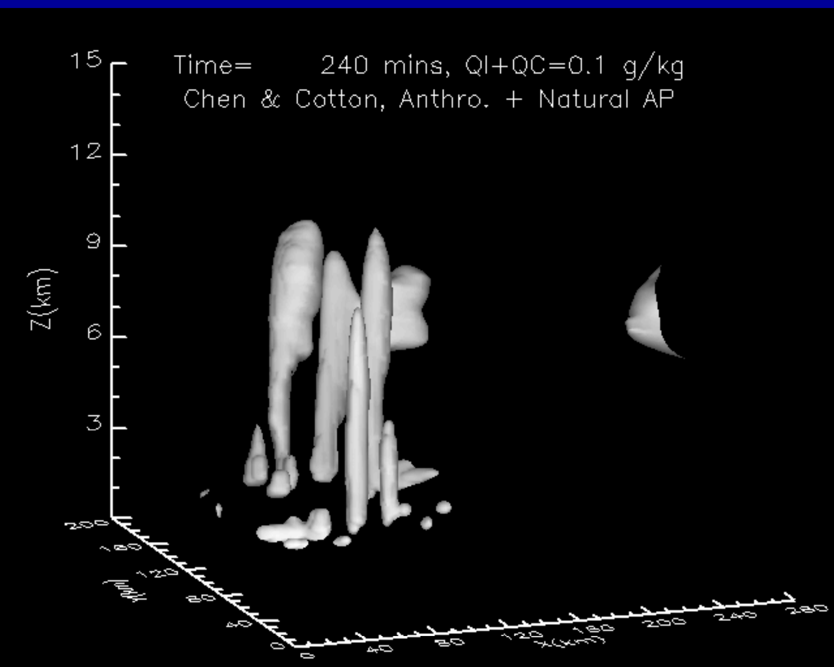


Cloud Scale: Evolution of clouds
Comparison between with/without anthropogenic aerosols

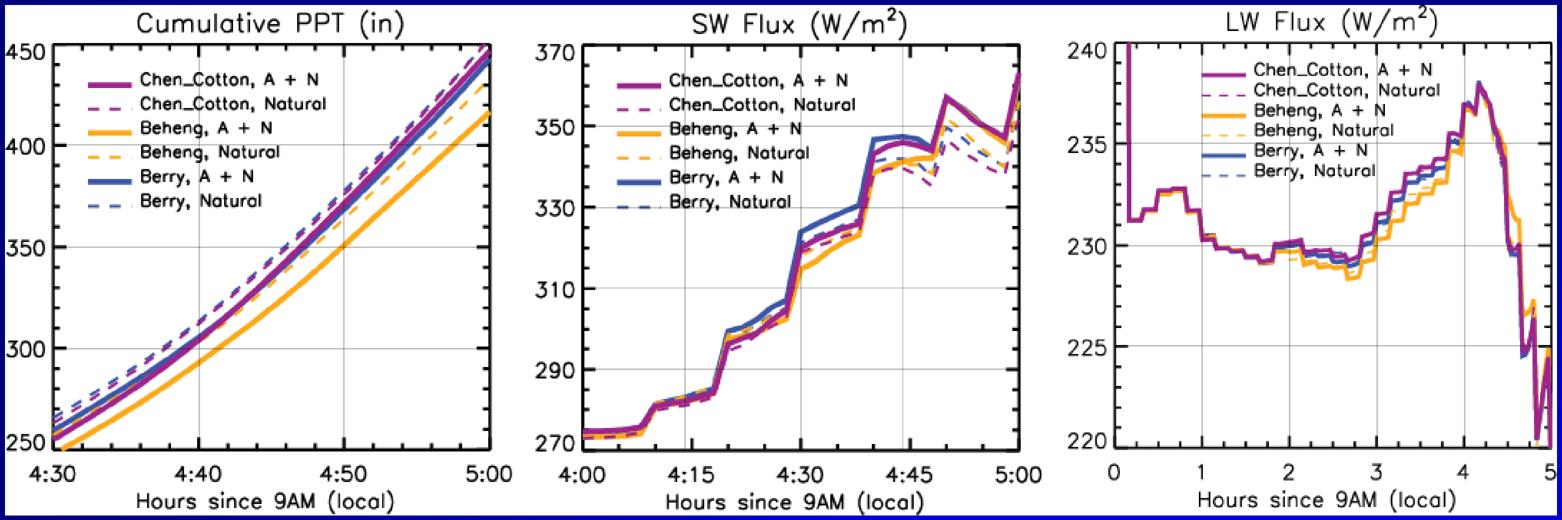
Natural



Anthropogenic + Natural



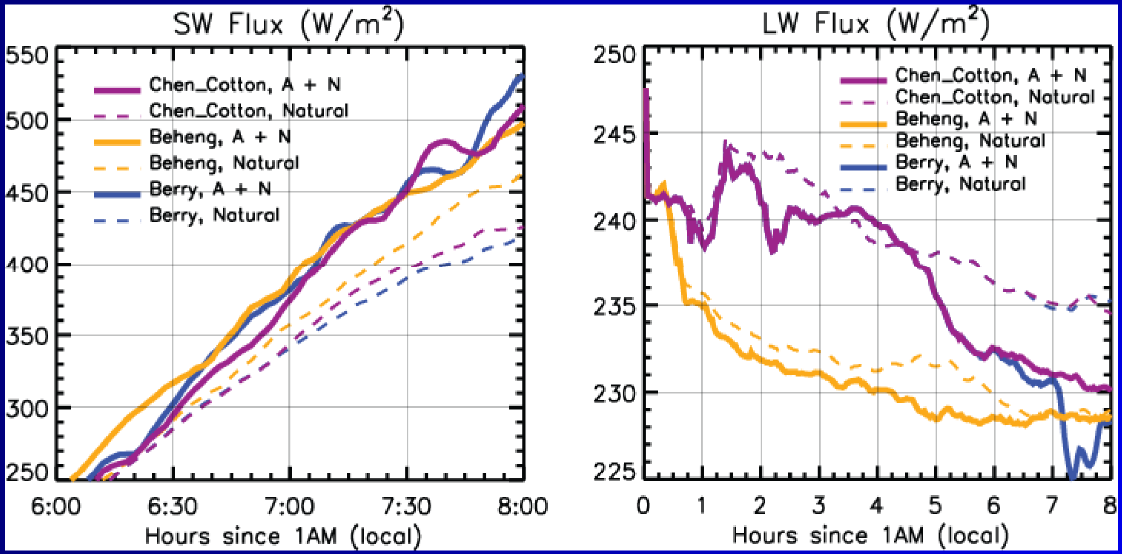
Cloud Scale: Precipitation and Radiative fluxes



- Anthropogenic aerosols reduce the total precipitation (2nd indirect effect) and increase the reflected SW radiation (1st indirect effect).
- The outgoing LW flux is mainly determined by the altitude of clouds. Since cloud structures are similar with or without anthropogenic aerosols, there is little difference in outgoing LW radiation for this selective convective system.
- Considerable difference in surface ppt is noticed for Beheng scheme.

Cloud Scale: Stratiform case (2D study)

The 2D version of CRM was used to simulate the light precipitating stratiform cloud system occurring over SGP on April 9, 1997. Contrary to the convective case, anthropogenic aerosols significantly reduce the outgoing LW radiation as the result of a higher cloud top .



Domain size:

30 km

Resolution:

100 m in horizontal

Varied in vertical

Time interval:

0.03 sec for dynamics

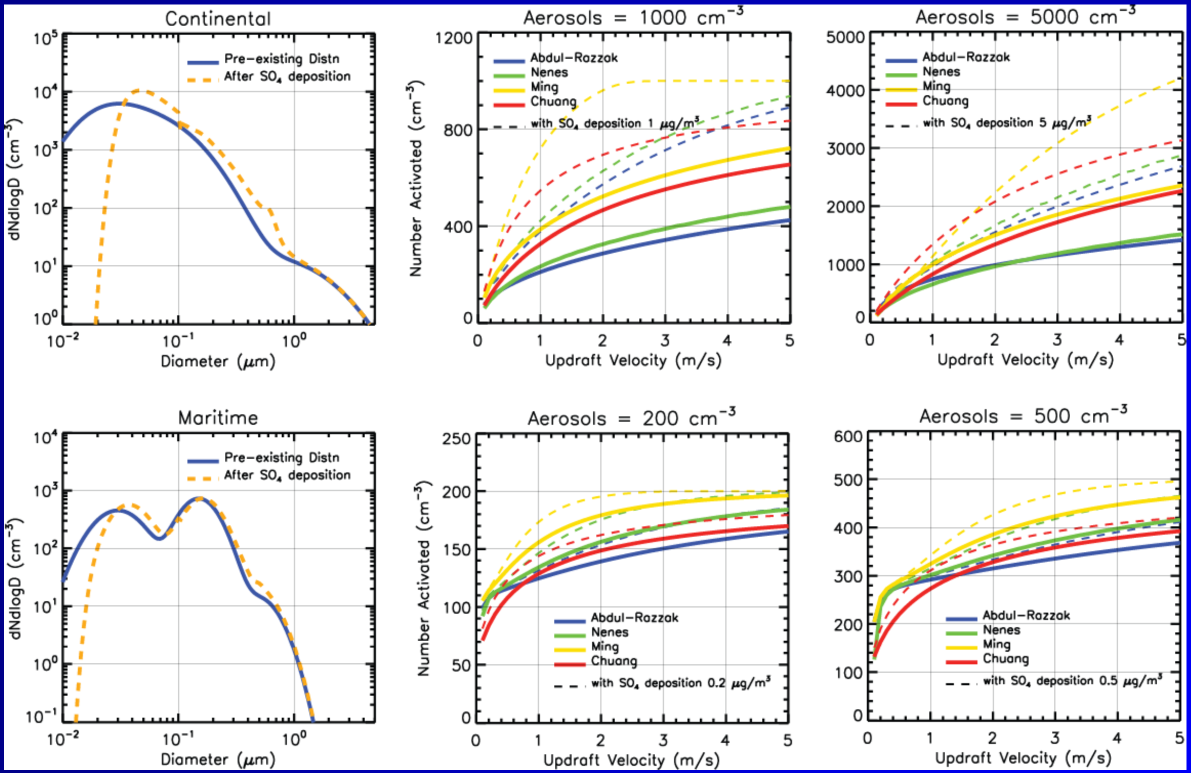
2 mins for radiation

Simulation time:

9 hours

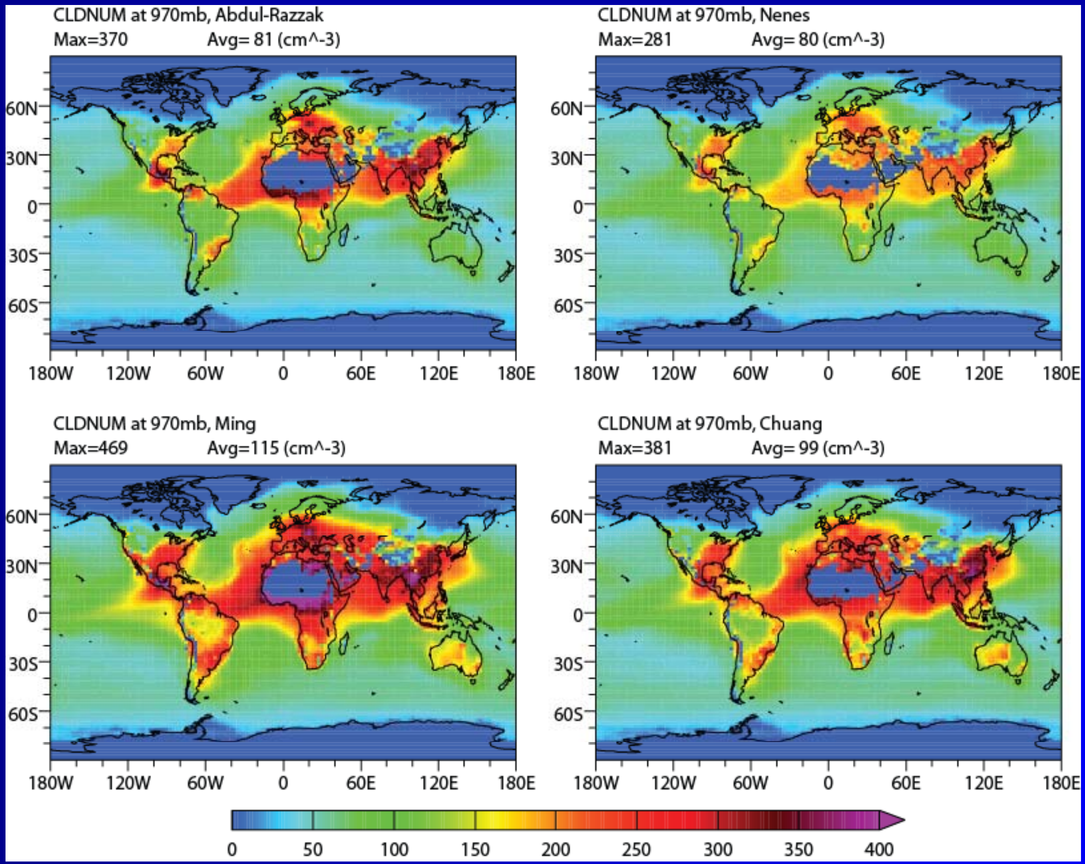
Global Scale: Examine the sensitivity of climate system to aerosol/cloud interactions

- Apply 4 different parameterizations of drop nucleation into NCAR CAM3
  (1) Abdul-Razzak and Ghan, 2002 (2) Nenes and Seinfeld, 2003 (3) Ming et al., 2006 (4) Chuang et al., 2002
- The predicted drop concentrations could differ by up to a factor of 2 among different schemes.

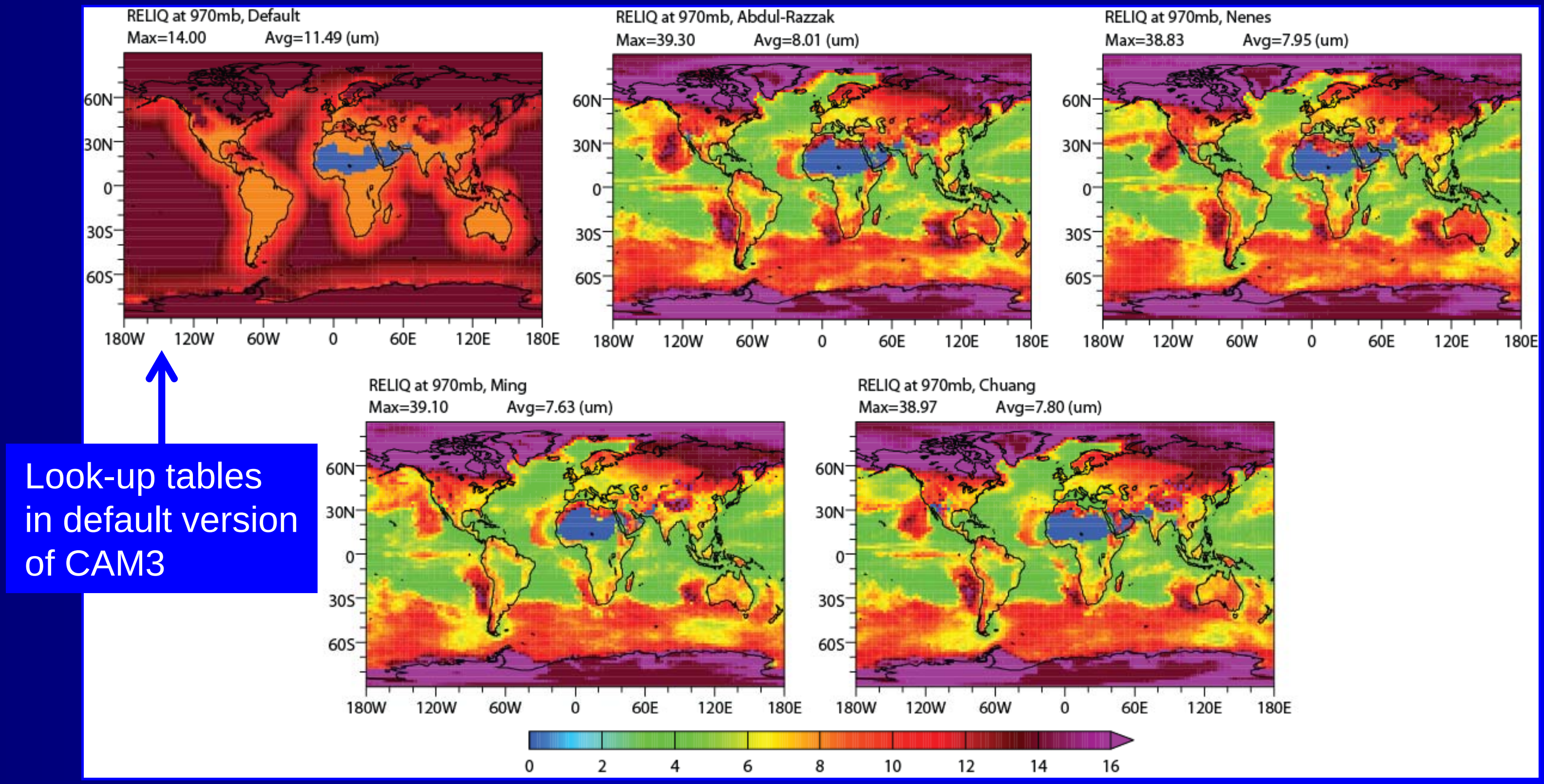


Global Scale: Averaged drop concentrations at cloud bottom during TWPICE

CAM3 was initialized by the ECMWF reanalyses from CAPT and run for two months covering the period of TWPICE (Jan 19 - Feb 28, 2006). Climatology aerosol concentrations were used in this study.

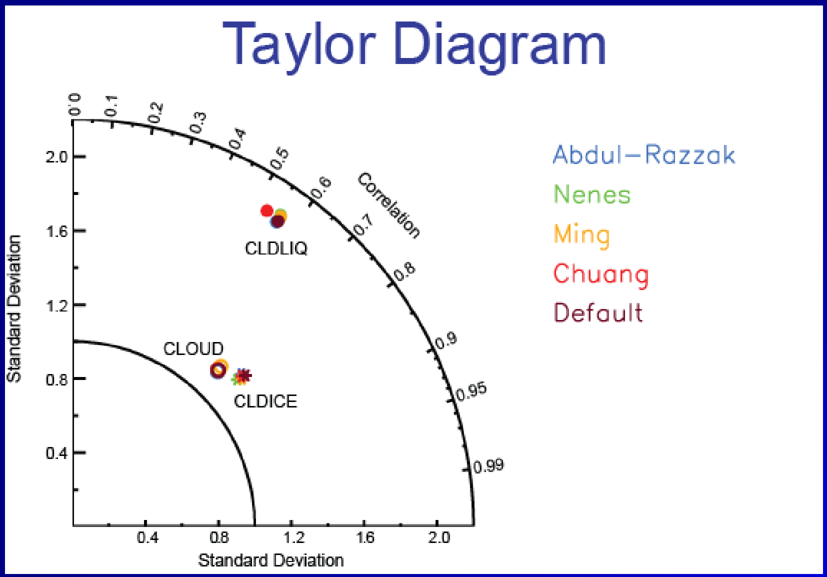


Global Scale: Averaged effective radii of liquid drops at cloud bottom during TWPICE

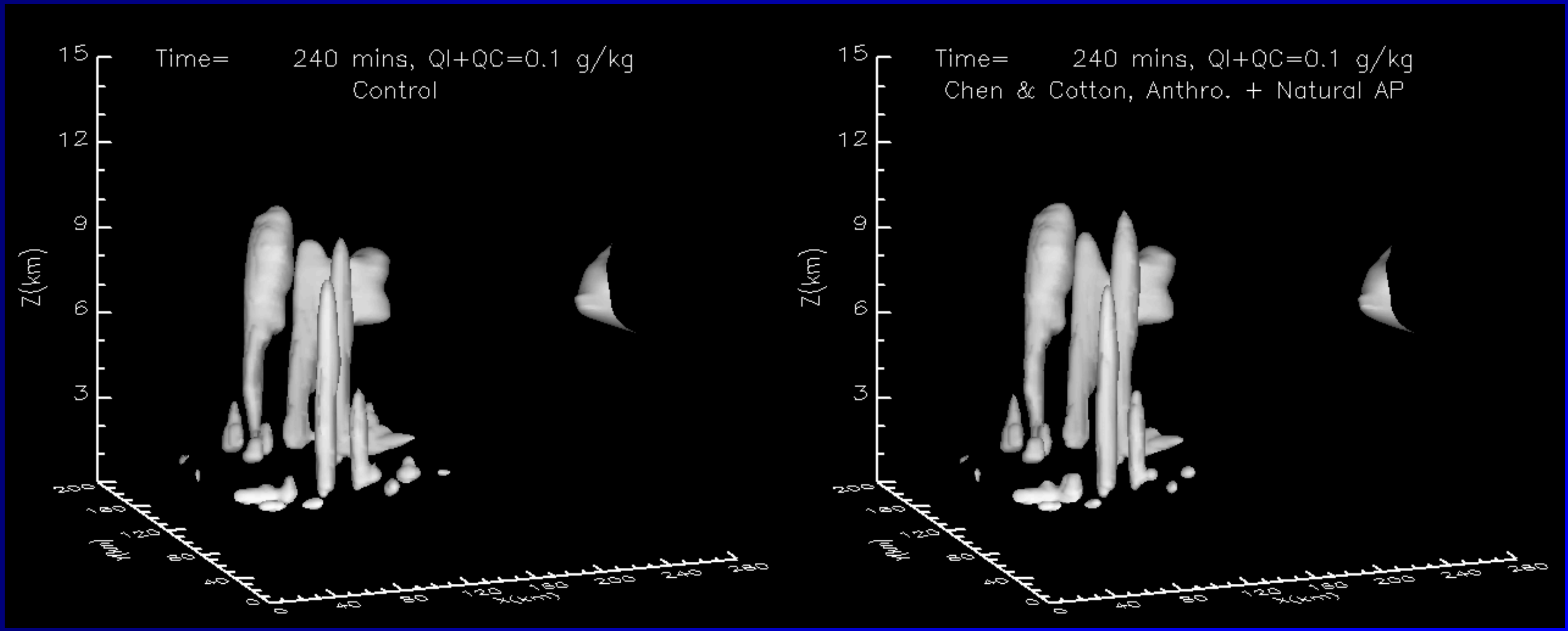


- CAM3 simulations with aerosol/cloud interactions predict more realistic effective radii for liquid clouds

Global Scale: Does including aerosol/cloud interactions reduce bias of climate simulations?

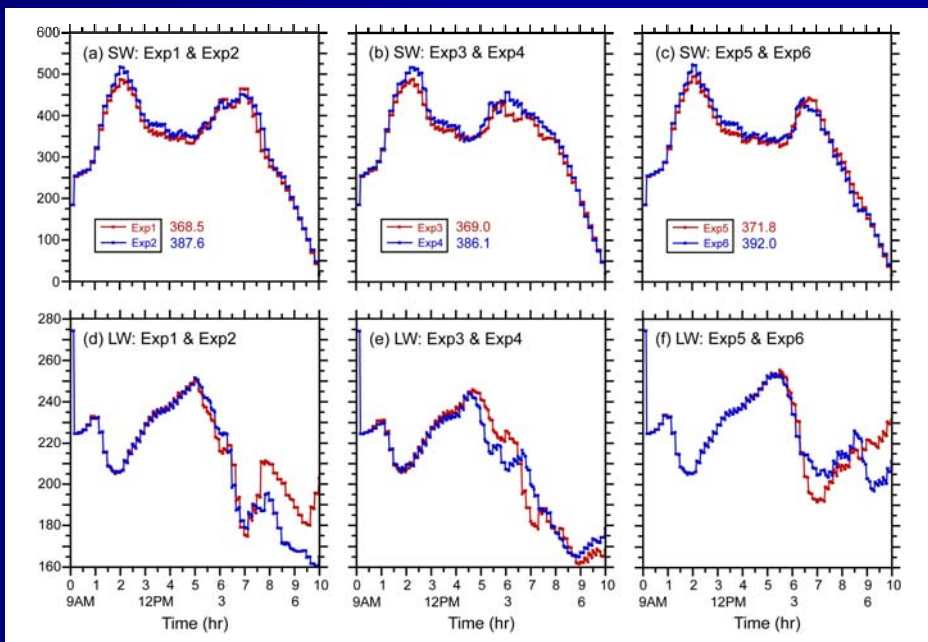


- Current simulations do not show closer agreement with ECMWF reanalyses.
- Data collected during TWPICE will be used to validate and improve our treatments of multi-scale aerosol/cloud interactions.

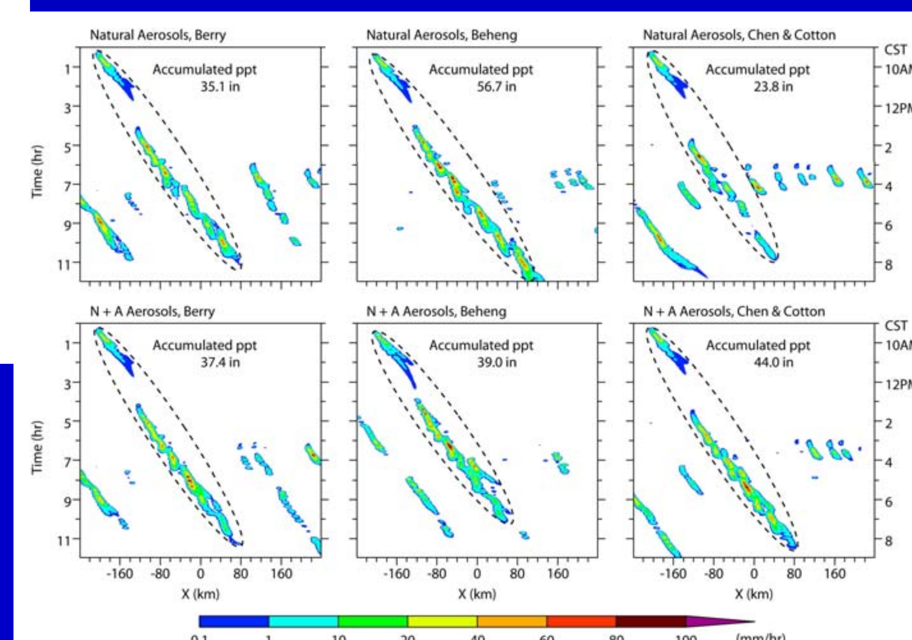

Time= 240 mins, QI+QC=0.1 g/kg
Control
Time= 240 mins, QI+QC=0.1 g/kg
Chen & Cotton, Anthro. + Natural AP
Z(km)
X(km)
Y(km)

Examine aerosol indirect effects using LLNL cloud resolving model

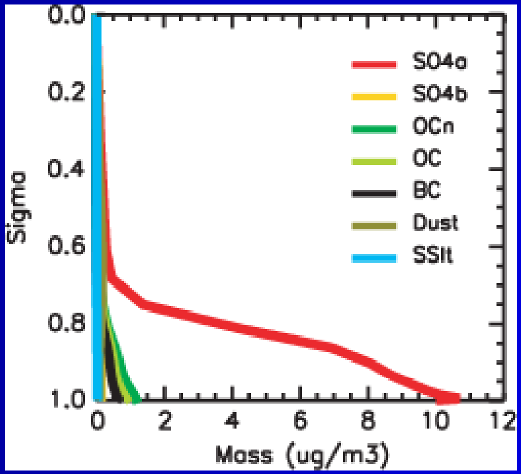
Experiments with/without anthropogenic aerosols and different autoconversion schemes.



- Averaged SW and LW fluxes (Wm^{-2}) at model top layer over a domain of 200 km with the convective core as the center.



- Simulated surface precipitation rate (mm/hr)



S04a
S04b
OCn
OC
BC
Dust
SSlt
Sigma
0.0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
8
10
12
Mass (ug/m3)