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

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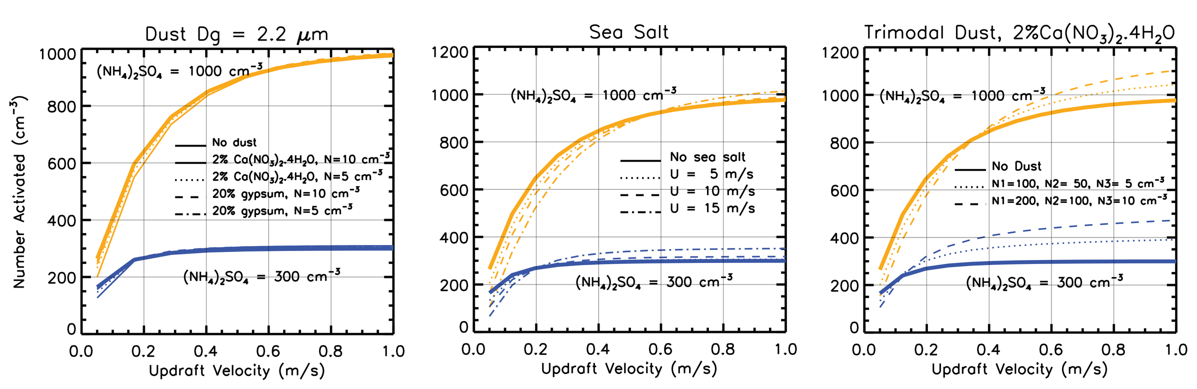
The Issues

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

(1) Micro-Scale Aspects

a. Influence of dust and sea salt on clouds

Adiabatic parcel simulations indicate that only under very specialized conditions does the addition of a coarse dust distribution into a rising parcel containing fine $(NH_4)_2SO_4$ particles significantly reduce the total number of activated particles. Effects of coarse dust particles on cloud saturation are generally smaller than those from sea salt. However, large numbers of fine dust CCN can significantly enhance the number of activated particles under certain conditions. (Kelly *et al.*, 2007)



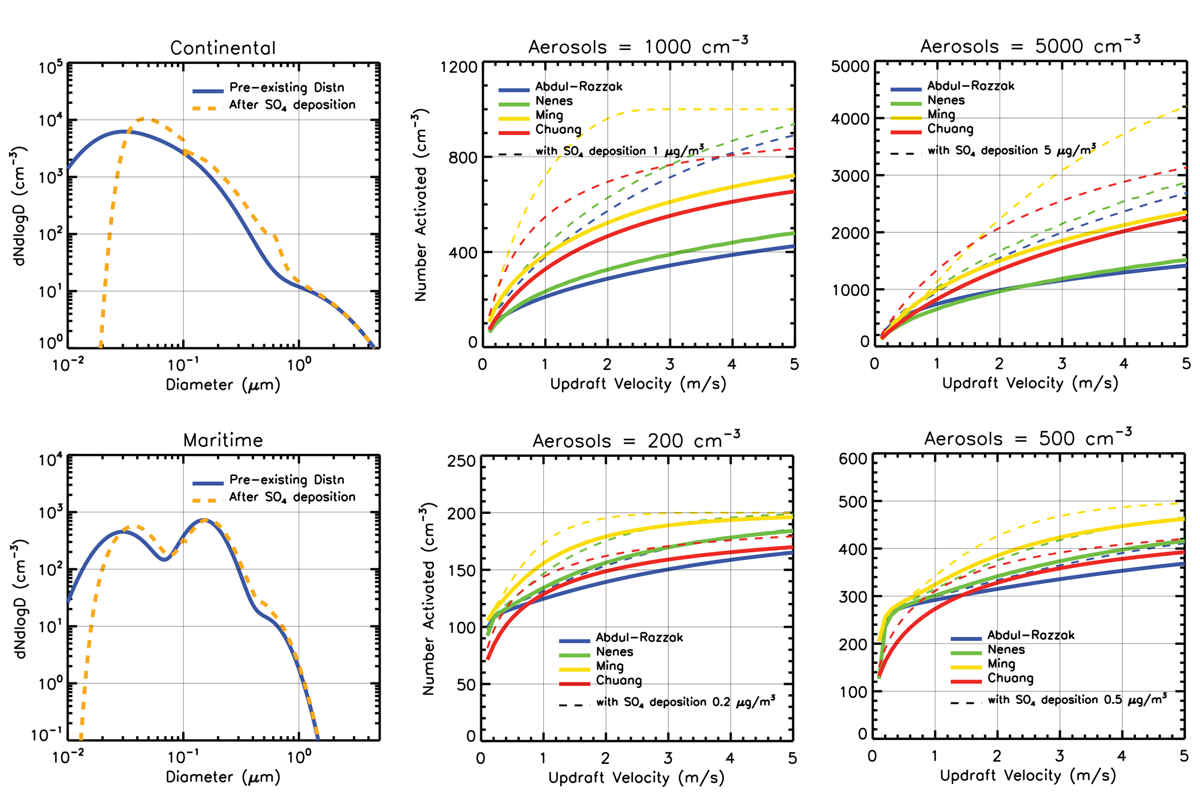
Total number of particles activated. $(NH_4)_2SO_4$ distribution (D_g=0.16 μm, σ_g=1.4)

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.

b. Parameterization of cloud drop nucleation

Four different parameterizations of cloud drop nucleation have been reviewed (Abdul-Razzak and Ghan, 2002; Nenes and Seinfeld, 2003; Ming *et al.*, 2006; and Chuang et al., 2002). The first three were developed for an arbitrary aerosol size distribution while the last one was based on parcel model results with prescribed size distribution of pre-existing particles. Predicted droplet concentrations corresponding to continental and maritime aerosol size distributions from each parameterization are presented. As shown below, the predicted drop concentrations could differ by up to a factor of 2 .



This work was performed under the auspices of the U. S. Department of Energy at the University of California Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.

(2) Cloud-Scale Experiments

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

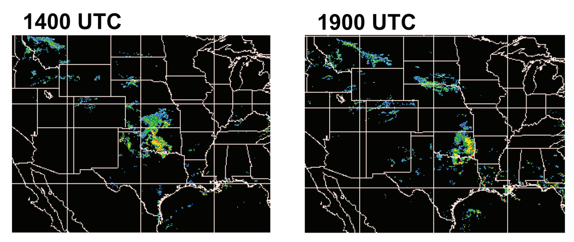
Physics \ Experiment	Control	1	2	3	4	5	6
Autoconversion	Kessler	Berry	Berry	Beheng	Beheng	Chen & Cotton	Chen & Cotton
Aerosols	*	Natural	N + A	Natural	N + A	Natural	N + A
Cloud Drops	Fixed	Predicted	Predicted	Predicted	Predicted	Predicted	Predicted

N + A: Natural + Anthropogenic

a. Convective case

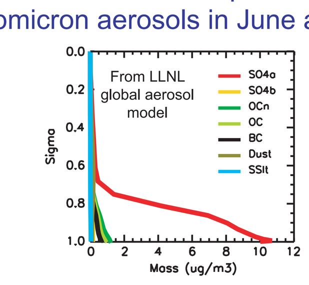
A 3D cloud resolving model (Chin and Wilhelmson 1998) with addition of aerosol radiative impacts was used to investigate the response of convective clouds to anthropogenic aerosols as well as the sensitivity to parameterization of autoconversion.

Radar reflectivity of the selected convective system passing through SGP site on June 19, 2004.

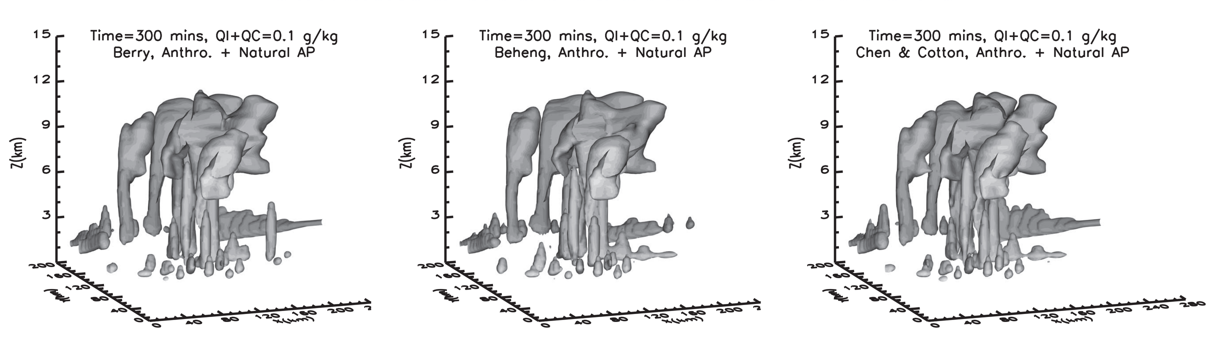


Simulation time: 5 hours from 9 AM local time (1400 - 1900 UTC)

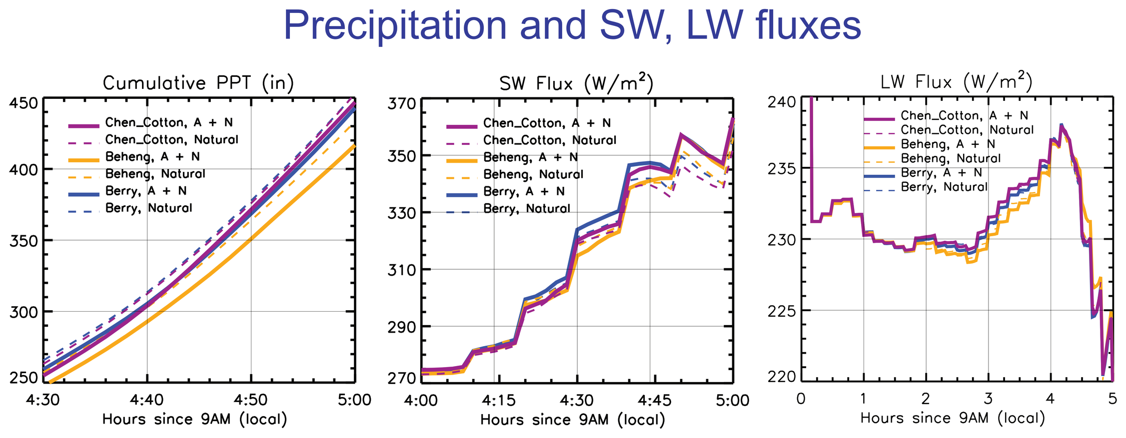
Simulated vertical profiles of submicron aerosols in June at SGP



Simulated cloud structure at 1900UTC

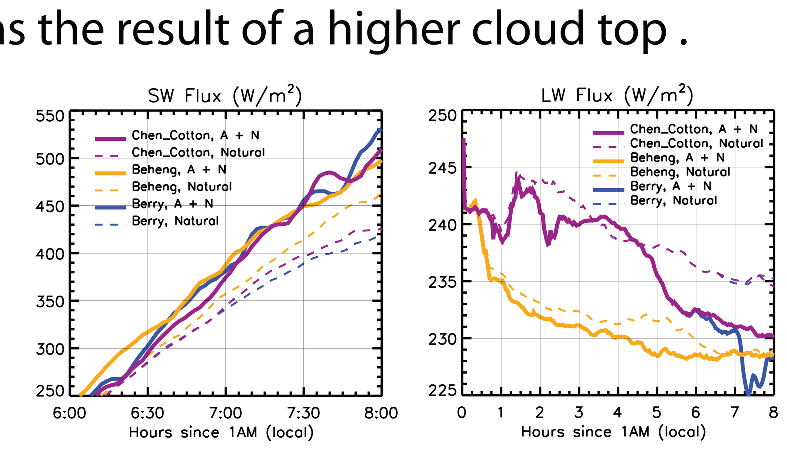


Precipitation and SW, LW fluxes



b. Stratiform case

The 2D version of CRM was used to simulate the light precipitating stratiform cloud system passing 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 .



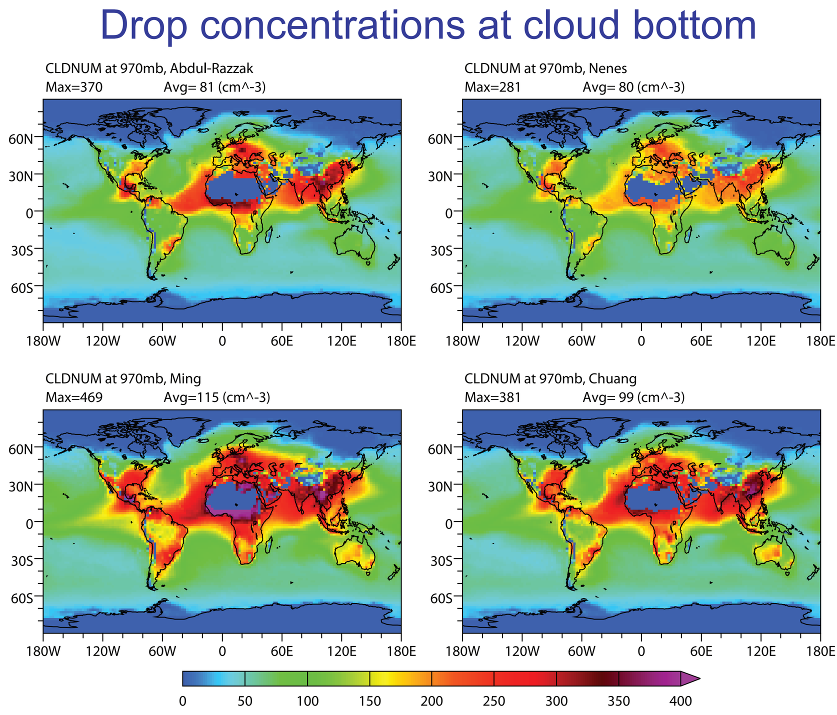
Simulation time: 8 hours from 1 AM local time (0600 - 1400 UTC)

- *Reflected SW is enhanced by anthropogenic aerosols in both convective and stratiform cases.*
- *Considerable difference in surface ppt is noticed for Beheng scheme.*

(3) Global-Scale Modeling

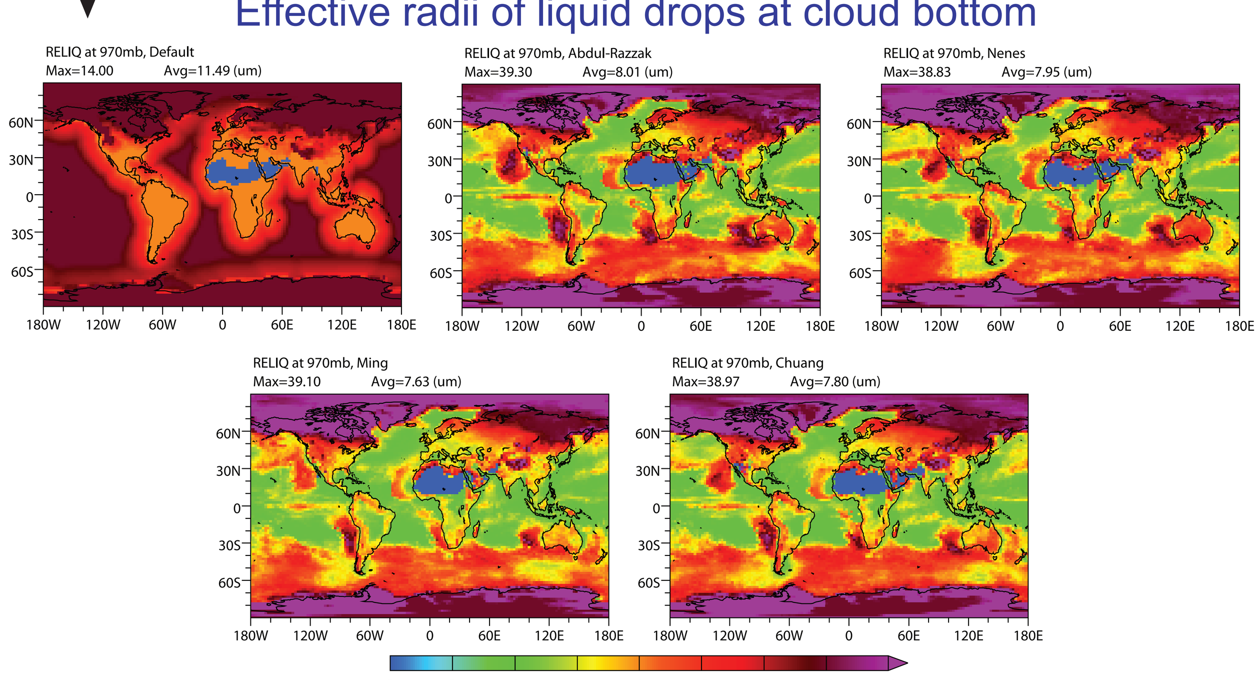
Four droplet nucleation parameterizations were implemented into NCAR CAM3 initialized by the ECMWF reanalyses from CAPT to examine the sensitivity of climate system to aerosol/cloud interactions. CAM3 was run for two months covering the period of TWPICE (Jan 19 - Feb 28, 2006). Climatology aerosol concentrations were used in this study. Applying interactive chemistry/aerosol module with detailed aerosol microphysics (e.g., size distribution, state of mixing) are underway.

Drop concentrations at cloud bottom

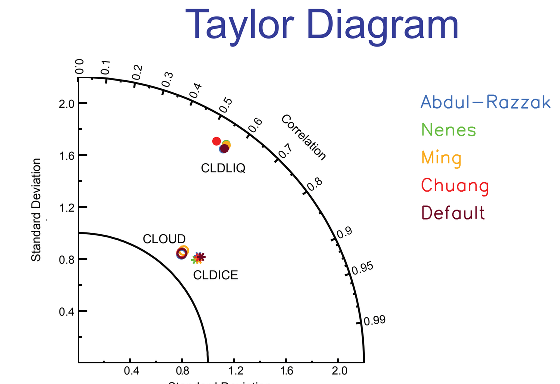


Look-up tables are currently used in default version of CAM3

Effective radii of liquid drops at cloud bottom



Taylor Diagram



- *CAM3 simulations with aerosol/cloud interactions predict more realistic effective radii for liquid clouds.*
- *Current simulations do not show closer agreement with ECMWF reanalyses (see the Taylor Diagram).*
- *Data collected during TWPICE will be used to validate and improve our treatments of multi-scale aerosol/cloud interactions.*