Evaluating Aerosol-Cloud and Cloud-Radiation interaction simulations with a Single Column Model (SCM) using McRAS cloud physics with ARM data and satellite retrievals


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We have used cloud physics of McRAS-AC (NASA’s microphysical cloud scheme with Relaxed Arakawa Schubert cloud parameterization upgraded with aerosol-cloud interaction physics) in a single column (SCM) version of GEOS-4 GCM together with following modules to simulate realistic aerosol-cloud-radiation interaction effects emanating from activated aerosols as CCN and/or IN.

- Fountoukis and Nenes (2005) Aerosol activation for liquid clouds
- Liu and Penner (2005) Aerosol activation for ice clouds
- Sud and Lee (2007) Precipitation microphysics

• McRAS = McRAS-AC

We have incorporated mass and number of liquid and ice inside the convective tower for the first time ever to simulate aerosol-cloud-radiation interaction inside the tower and in large-scale clouds.

• With limited observations available to validate SCM, it does reasonable well to simulate cloud optical properties and radiations.

• SCM is evaluated over the ARM-SGP site (using 1999-2001 3 year continuous forcing data) while the in situ ARM-observations and satellite measurements were compared against the model simulations.

![Figure 1](image1.png)
Figure 1. Total precipitation (mm/day) in summer (JJA) months (1999) are compared against ARM in-situ observations (left) and rainfall climatology compared against TRMM (SMS V6) long-term (1998-2010) monthly dataset (right)

![Figure 2](image2.png)
Figure 2. Outgoing Longwave Radiation (all-sky) (OLR) in Wm² for summer (JJA) months (2001) are compared against ARM in-situ observations (left) and climatology compared against CERES (2002-2005) and AIRS dataset (2002-2010) (right)

![Figure 3](image3.png)
Figure 3. Integrated cloud fraction simulated by SCM compared against GEOS measurement for (JJA) months (2000) (left) and LW, SW and moist Heating rates (Kday) are averaged for 3 year summer (JJA) and winter (DJF) months. Summer months in solid lines, while winter months are dashed

- Homogeneous ice nucleation by sulfate
- Heterogeneous ice nucleation including
  - Contact freezing, Immersion freezing,
  - Deposition by dust and black carbon

- Ice and mixed phase clouds

Figure 4. Cloud effective radius & optical thickness simulated by SCM and compared against long-term MODIS measurement (2000-2009) over ARM-SGP. Liquid effective radius and optical thickness agree reasonably well with the satellite observations. Left figure shows yearly averaged ice concentration simulated by the model, with large scale concentration in solid line and convective in dashed line are compared against Kramer (2009) aircraft data (in red). SCM simulates ice number 1/10 of observation with effective radius of ~70 micron.

Figure 5. Time series of SCM simulated convective and large scale liquid and ice number (#/cm³) and mass (g/kg) averaged for 3 year summer months

- Convective Liquid Mass
- Convective Liquid Number
- Large Scale Liquid Mass
- Large Scale Liquid Number
- Convective Ice Mass
- Convective Ice Number
- Large Scale Ice Mass
- Large Scale Ice Number

Figure 6. SCM simulated convective and large Scale liquid and ice number (#/cm³) and mass (g/kg) averaged for 3 year summer (JJA) and winter (DJF) months. In the figure convective is (blue). Large Scale is (red) and solid for summer months and dashed lines for winter months.

- Results show current SCM parameterizations result realistic annual mean and cycles of cloud water, optical and radiational properties that lead to conduct aerosol-cloud-radiation interaction experiments using GEOS-4 GCM over monsoon areas.
- Compare and improve ice activation physics in the model with Barahona and Nenes against current Liu and Penner ice parameterizations

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