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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 interactions effects emanating from activated aerosols as CCN and/or IN.

Fountoukis and Nenes (2005)
Aerosol activation for liquid clouds

Khovorstynov and Curry (1999)
Cloud particle size distribution

Liu and Penner (2005)
Aerosol activation for ice clouds

Sud and Lee (2007)
Precipitation microphysics

+ McRAS =McRAS-AC

Ice and mixed phase clouds

Homogeneous ice nucleation by sulfate

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

Bergeron-Findeisen process and direct deposition of water vapor for mixed phase clouds

- 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.

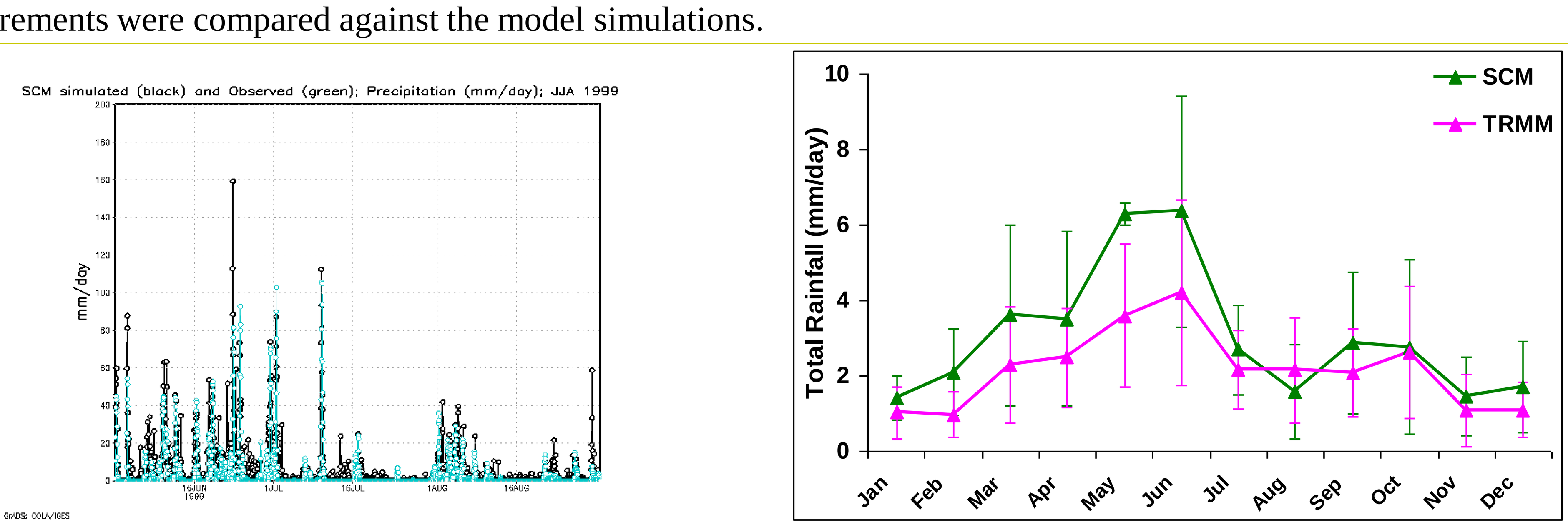


Figure 1. Total precipitation (mm/day) in summer (JJA) months (1999) are compared against ARM in-situ observations (*left*) and rainfall climatology compared against TRMM (3B43 V6) long-term (1998-2010) monthly dataset (*right*)

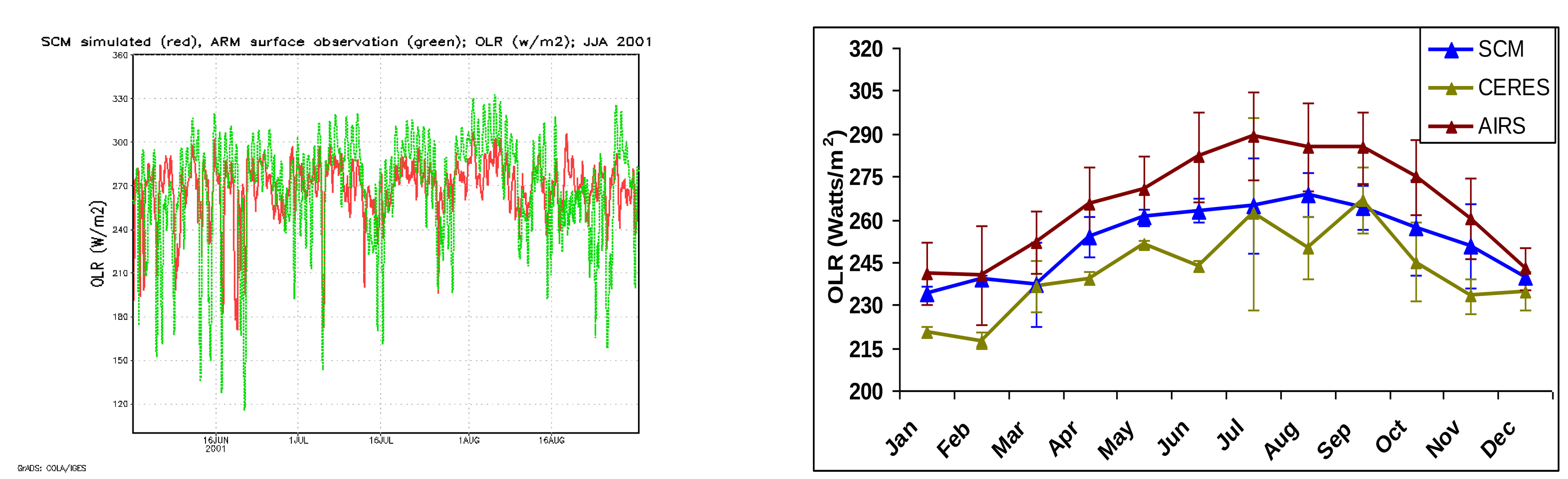


Figure 2. Outgoing Longwave Radiation (all-sky) (OLR) in Wm^{-2} for summer (JJA) months (2001) are compared against ARM in-situ observations (*left*) and climatology compared against CERES (2002-2005) and AIRS dataset (2002-2010) (*right*)

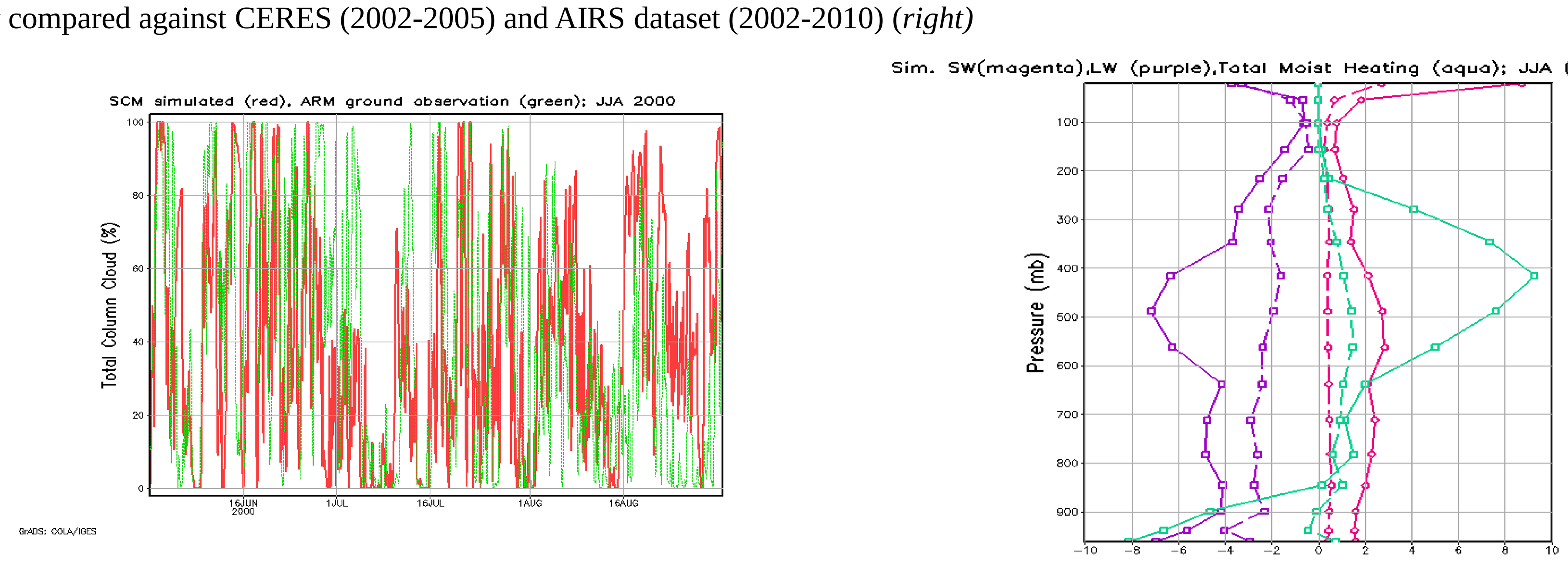
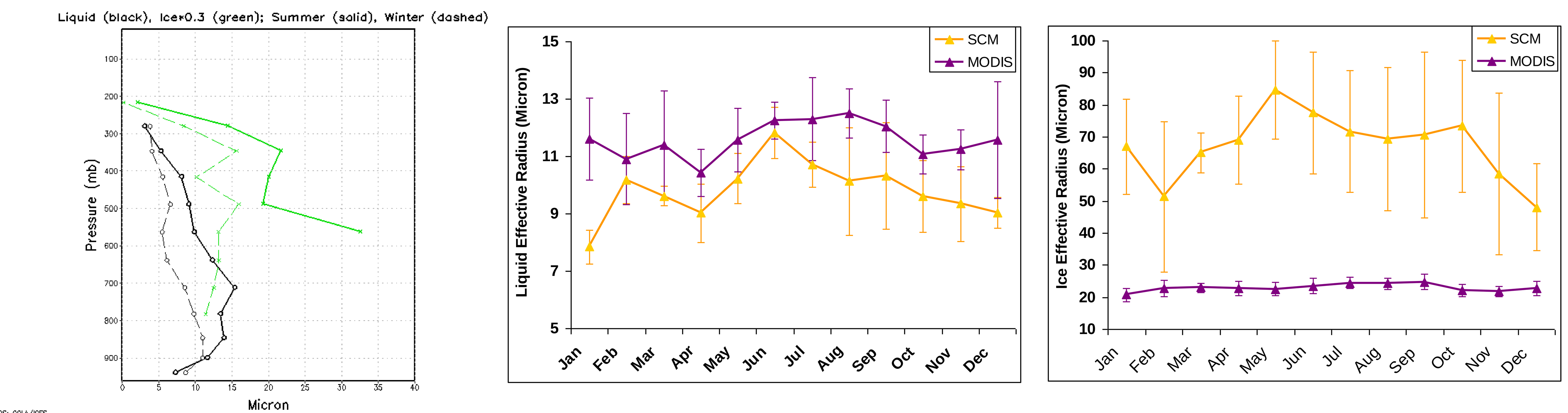


Figure 3. Integrated cloud fraction simulated by SCM compared against GEOS measurement for (JJA) months (2000) (*left*) and LW, SW and moist heating rates (K/day) are averaged for 3 year summer (JJA) and winter (DJF) months. Summer months in solid lines, while winter months are dashed



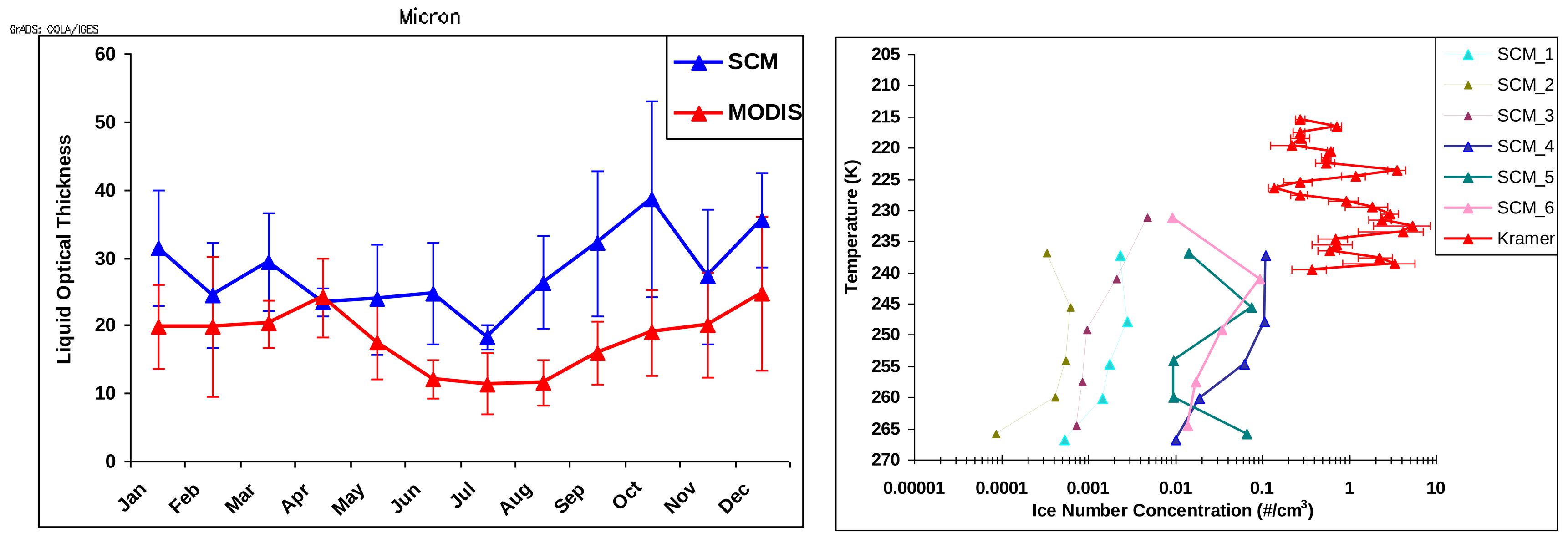


Figure 4. Cloud effective radius & optical thickness simulated by SCM and compared against long-term MODIS measurement (2000-2009) over ARM-SGP. Liquid effective radius and optical thickness agrees reasonably well with the satellite observations. Left figure shows yearly averaged ice concentration simulated 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.

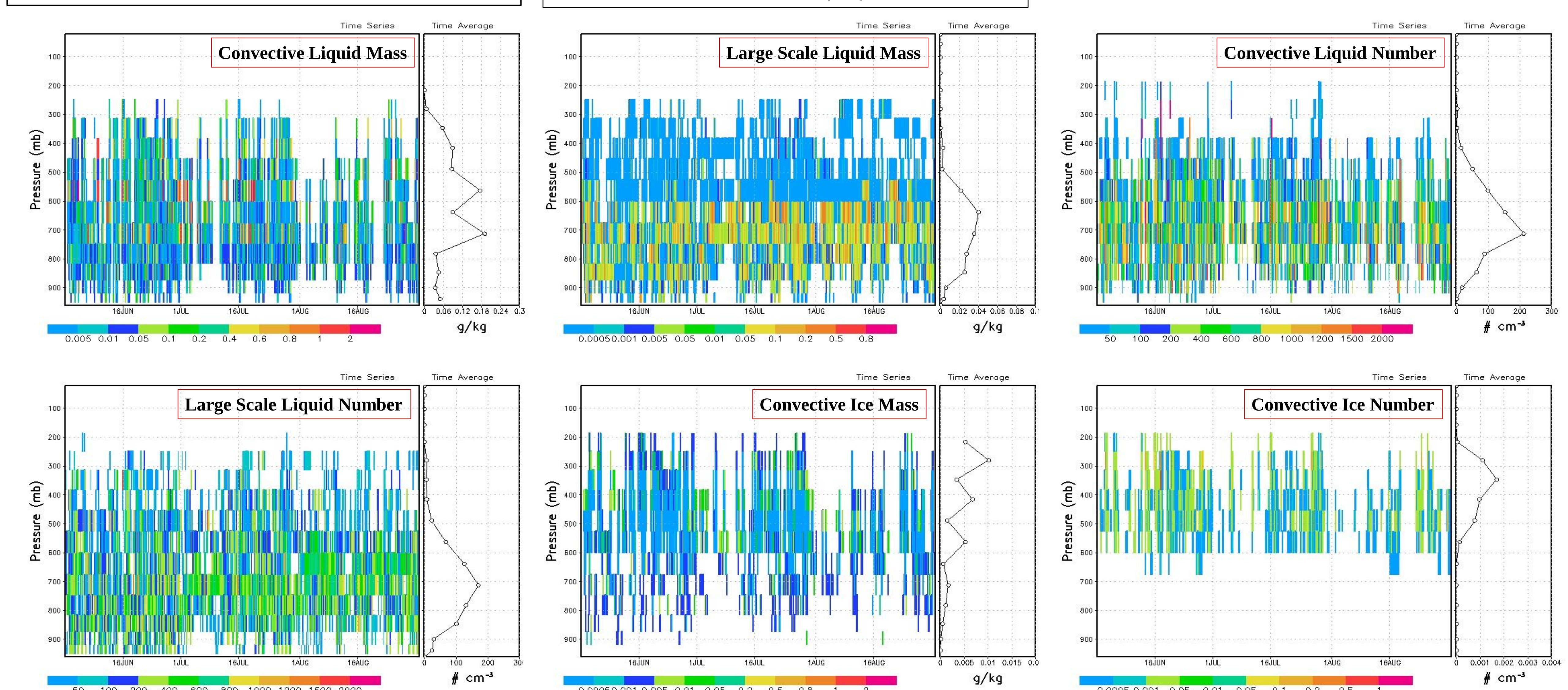


Figure 5. Time series of SCM simulated convective and large Scale liquid and ice number (#/cm^3) and mass (g/kg) averaged for 3 year summer months

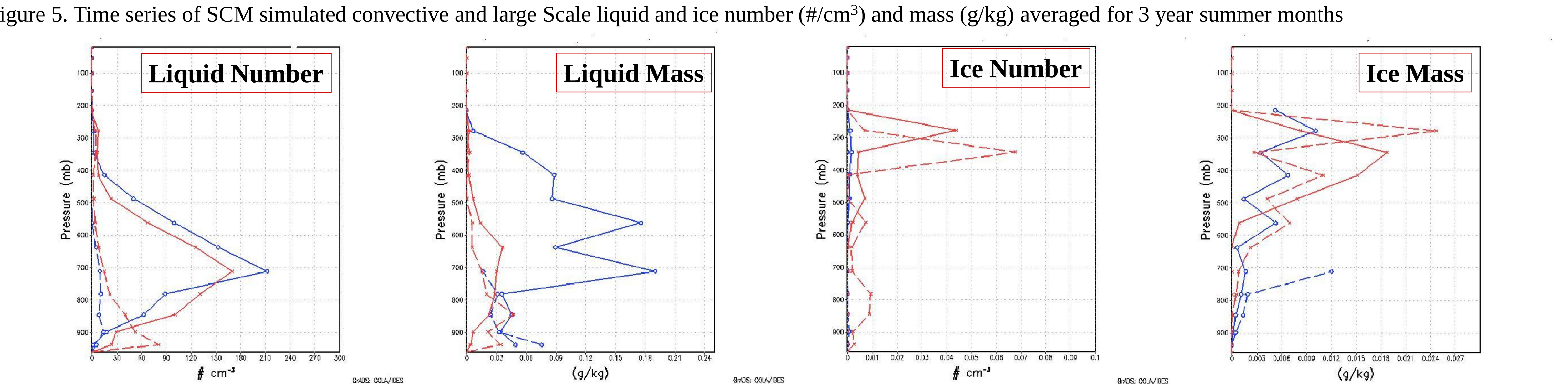


Figure 6. SCM simulated convective and large Scale liquid and ice number (#/cm^3) and mass (g/kg) averaged for 3 year summer (JJA) and winter (DJF) months. In the figure convective is (blue), Large Scale is (red) and solid for summer moths and dashed lines for winter months.

- 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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