Preliminary Simulations of Thin Cirrus in the TTL Using CAM4/CARMA

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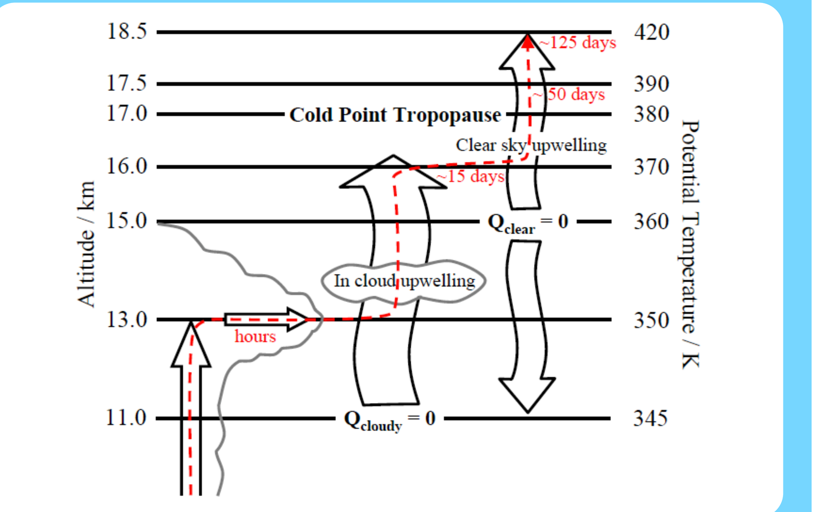
Abstract

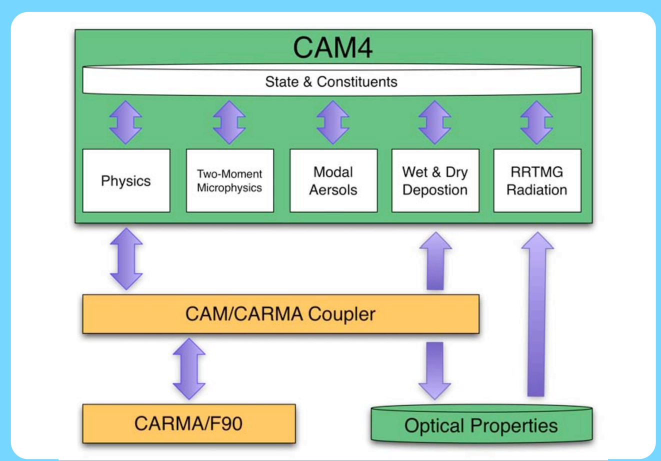
We plan to use CAM4/CARMA, an Eulerian three-dimensional microphysical model to study transport, cloud formation, and dehydration in the tropical tropopause layer. This model is based upon the Community Atmosphere Model (CAM4) with a sectional microphysical model from the Community Aerosol and Radiation Model for Atmospheres (CARMA). CAM4 allows supersaturation with respect to ice, and has a new extensible radiation package. These changes allow for a better treatment of sectional microphysics than was possible with CAM3. CARMA has improved substepping logic and a new Fortran 90 interface to make it easier to embed in other modeling frameworks. Here we present some preliminary results from a TTL cirrus model using CAM4/CARMA as well as results from some diagnostic tests of ascent in the TTL in CAM4.

Motivation

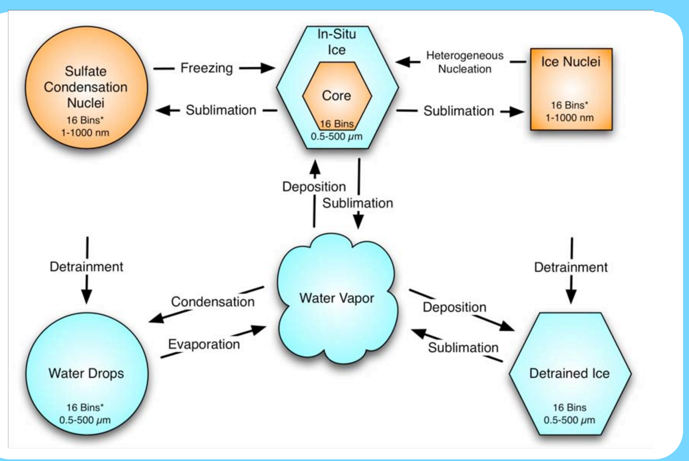


Troposphere-to-Stratosphere transport rates may be influenced by thin cirrus in the TTL [Corti et al. 2006]. These clouds also help regulate stratospheric water vapor and have a radiative impact in the TTL.

CAM4/CARMA Model

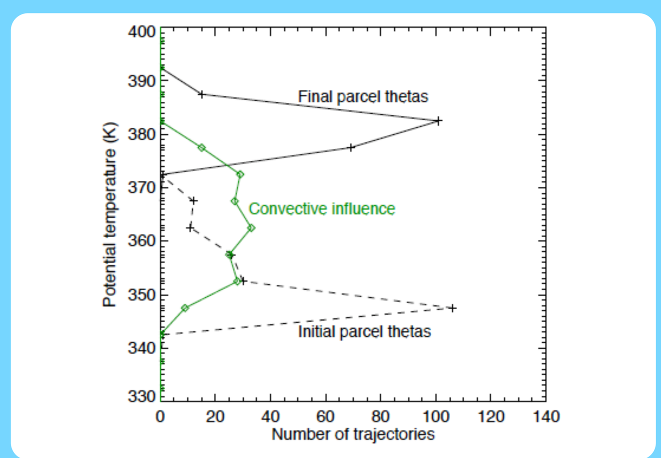


CAM4/CARMA Block Diagram

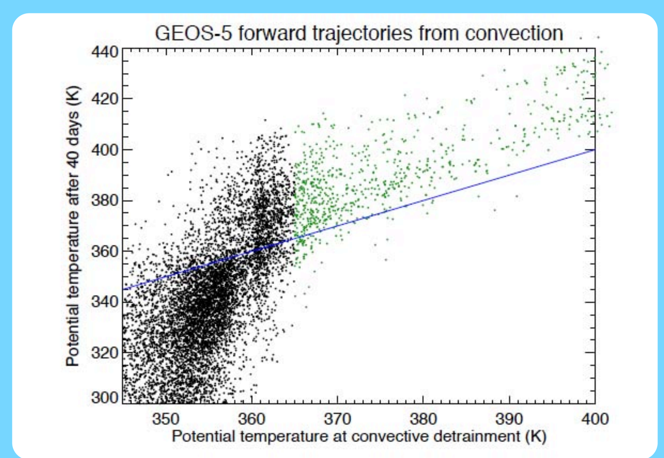


Currently, the sulfate nuclei are prescribed and the ice nuclei and water drops are not implemented .

Ascent in the TTL



Back trajectories from the TTL to the location of last convective influence (Jensen), showing ascent above ~350K.



Forward trajectories in the TLL from points of convective influence in GEOS-5 (Schoeberl) showing ascent above ~360 K.

Conclusion

These tests are performed with an untuned prerelease version of CAM4, so the results may not be representative of the final model. However, it is interesting that the ascent rates, particularly in convective areas seem to depend on the model's horizontal and vertical resolution, with vigorous ascent at 1.9˚x2.5˚ in convective regions. The CARMA cirrus model is currently being run in parallel with the two-moment ice microphysics, with the two-moment scheme controlling the model's climate. The supersaturations generated are sufficient to create some ice clouds in CARMA, but detrained ice predominates. This suggests that when the CARMA microphysics is fully implemented and CAM4 is fully tuned that the CAM4/CARMA cirrus model will be capable of generating realistic TTL cirrus clouds; however, there may be issues with the amount of detrained ice and the amount of mid level cirrus clouds.

Future Work

The next steps are to complete the implementation of the CARMA microphysical model and have it fully replace the CAM4 two-moment ice microphysics. A tuned version of CAM4 should be available shortly, and simulations with ~300 m resolution near the tropopause will be performed with CAM4/CARMA.

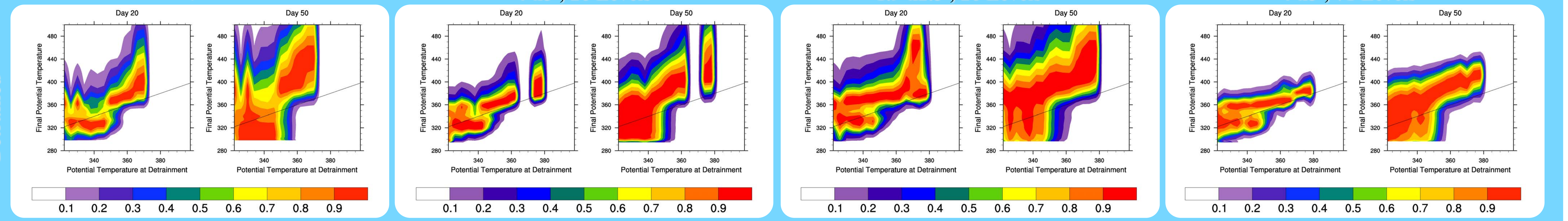
These results will be compared to a number of remote sensing observations to validate the model's performance in the TTL, including temperatures from COSMIC, water vapor from MLS and clouds from CALIPSO, HIRDLS and CloudSat. In-situ data from radiosondes and aircraft campaigns will also be used to validate the atmospheric state and cloud properties.

Several different choices for the cloud microphysics will be evaluated including the effect of different nucleation mechanisms, particle shapes, and detrainment sizes. Sensitivity tests will be performed to look at the impact of the cirrus clouds on transport, temperature and water vapor in the UT/LS in both present day and future climate scenarios.

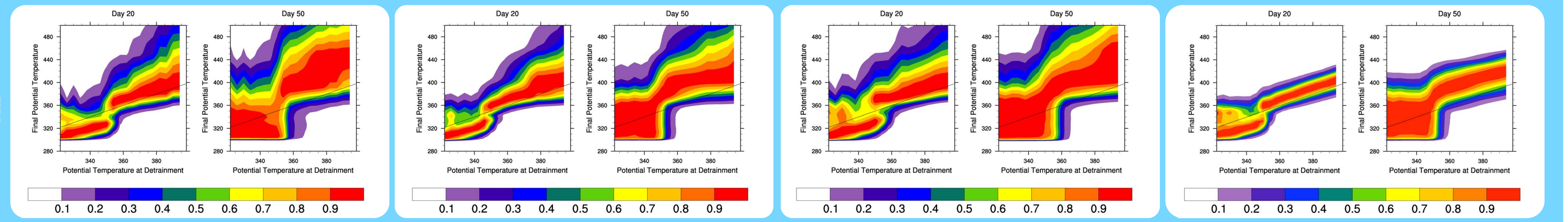
Results : CAM4 Ascent Rates

10˚x15˚, 26 Levels | 4˚x5˚, 26 Levels | 1.9˚x2.5˚, 26 Levels | 4˚x5˚, 71 Levels

Detrained



All

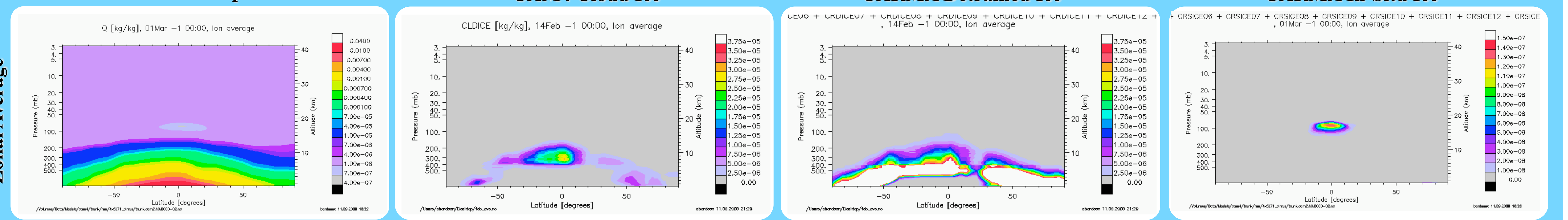


In these tests, a set of passive tracers is added to the model from days 0 to 10, with different bins corresponding to the potential temperature of the source level. Plots are daily averages from 10˚N to 10˚S. In the "detrained" case, the tracer mass is proportional to the mass detrained by convection at that level, and in the "all" case the tracer is added uniformly to each theta level. The plots in the "detrained" case are normalized per bin (source theta level). The "all" cases looks somewhat similar to the Jensen and Schoeberl results with ascent above ~350 K; however, there is more ascent at low thetas in the "detrained" cases when just considering the convective regions. In the 1.9x2.5 and 4˚x5˚ 71 level "detrained" cases, ascent occurs at all theta levels and at 1.9˚x2.5˚ is very rapid for some source thetas. Adding additional vertical resolution results in less diffusive and more uniform ascent at all theta levels.

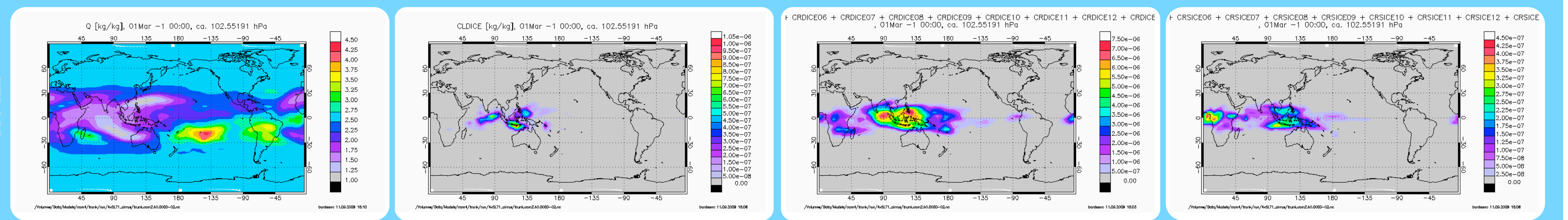
Results : CAM4/CARMA Cirrus Clouds, February, 4˚x5˚, 71 Levels

Water Vapor | CAM4 Cloud Ice | CARMA Detrained Ice | CARMA In-Situ Ice

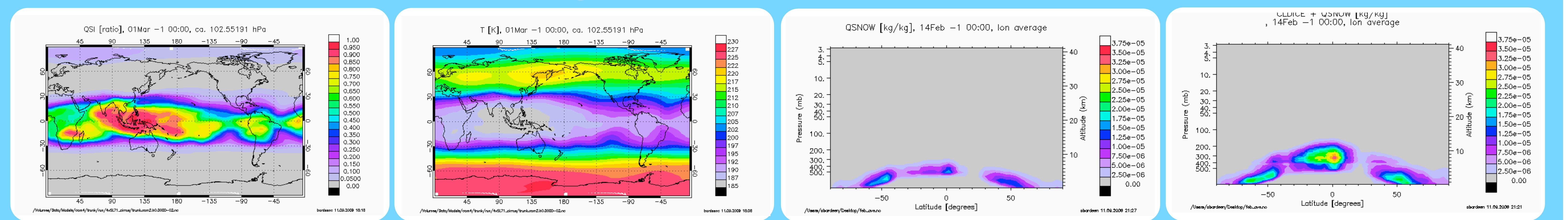
Zonal Average



~100 mb



Ice Saturation | Temperature | Snow | Cloud Ice & Snow



Supersaturation with respect to ice that is allowed in the CAM4 model is sufficient to allow some in-situ ice formation in the TTL via homogenous nucleation of sulfate aerosols. Detrained ice dominates the CARMA cloud ice, and is larger than the CAM4 cloud ice, particularly at pressures higher than ~400 mb. Part of this difference is because CAM4 tracks snow separately. The spatial distribution of cloud ice at ~100 mb formed by CAM4 and CARMA are in general agreement; although, there is broader coverage with the CARMA clouds. In this simulation, the CAM4 two-moment microphysics is controlling the climate and the ice particles formed in CARMA do not deplete the vapor and are not radiatively active. This could lead to higher CARMA ice mass than if CARMA did deplete the vapor. This version of CAM4 has not been tuned, so there are errors in the atmospheric state.