What Controls the Low Ice Number Concentration in the Upper Tropical Troposphere?

Cheng Zhou[1], Joyce E. Penner[1], Guangxing Lin[1], Xiaohong Liu[2] and Minghuai Wang[3]

[1]*Department of Atmospheric, Oceanic, and Space Sciences, Space Research Building, University of Michigan, 2455 Hayward Street, Ann Arbor, MI 48109-2143, USA*

[2]*Department of Atmospheric Science, University of Wyoming, Laramie, WY, USA*

[3]*Nanjing University, Nanjing, China*

Cirrus clouds in the tropical tropopause play a key role in regulating the moisture entering the stratosphere through their dehydrating effect. Low ice number concentrations and high supersaturations were frequently were observed in these clouds. However, low ice number concentrations are inconsistent with cirrus cloud formation based on homogeneous freezing. Different mechanisms have been proposed to explain this discrepancy, including the inhibition of homogeneous freezing by pre-existing ice crystals and/or glassy organic aerosol heterogeneous ice nuclei (IN) and limiting the formation of ice number from high frequency gravity waves. In this study, we examined the effect from three different parameterizations of in-cloud updraft velocities, the effect from pre-existing ice crystals, the effect from different water vapor deposition coefficients (α=0.1 or 1), and the effect from 0.1% of secondary organic aerosol (SOA) acting as glassy heterogeneous ice nuclei (IN). Model simulated ice crystal numbers are compared against an aircraft observational dataset. Using grid resolved large-scale updraft velocity in the ice nucleation parameterization generates ice number concentrations in better agreement with observations for temperatures below 205K while using updraft velocities based on the model-generated turbulence kinetic energy generates ice number concentrations in better agreement with observations for temperatures above 205K. A larger water vapor deposition coefficient (α=1) can efficiently reduce the ice number at temperatures below 205K but less so at higher temperatures. Glassy SOA IN are most effective at reducing the ice number concentrations when the effective in-cloud updraft velocities are moderate (~0.05–0.2 m s-1). Including the removal of water vapor on pre-existing ice can also effectively reduce the ice number and diminish the effects from the additional glassy SOA heterogeneous IN.