

Formation of a tropopause cirrus layer observed over Florida during CRYSTAL-FACE

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Abstract

On 13 July 2002 a widespread, subvisible tropopause cirrus layer occurred over the Florida region. This cloud was observed in great detail with the NASA Cirrus Regional Study of Tropical Anvils and Cirrus Layers–Florida Area Cirrus Experiment (CRYSTAL-FACE) instrumentation, including in situ measurements with the WB-57 aircraft. In this paper, we use the 13 July cloud as a case study to evaluate the physical processes controlling the formation and evolution of tropopause cirrus layers. Microphysics measurements indicate that ice crystal diameters in the cloud layer ranged from about 7 to 50 μm , and the peak number mode was about 10–25 μm . In situ water vapor and temperature measurements in the cloud indicated supersaturation with respect to ice throughout, with ice saturation ratios as large as 1.8. Even when the ice surface area density was as high as about 500 $\mu\text{m}^2 \text{cm}^{-3}$, ice supersaturations of 20–30% were observed. Trajectory analysis shows that the air sampled near the tropopause on this day generally came from the north and cooled considerably during the previous few days. Examination of infrared satellite imagery along air parcel back trajectories from the WB-57 flight track indicates that the tropopause cloud layer formation was, in general, not simply left over ice from recently generated anvil cirrus. Simulations of cloud formation using time-height curtains of temperature along the trajectory paths show that the cloud could have formed in situ near the tropopause as the air was advected into the south Florida region and cooled to unusually low temperatures. If we assume a high threshold for ice nucleation via homogeneous freezing of aqueous sulfate aerosols, the model reproduces the observed cloud structure, ice crystal size distributions, and ice supersaturation statistics. Inclusion of observed gravity wave temperature perturbations in the simulations is essential to reproduce the observed cloud properties. Without waves, crystal number densities are too low, crystal sizes are too large, and the crystals fall out too fast, leaving very little cloud persisting at the end of the simulations. In the cloud simulations, coincidence of high supersaturations and high surface areas can be produced by either recent nucleation or sedimentation of crystals into supersaturated layers. The agreement between model results and observed supersaturations is improved somewhat if we assume that the steady state relative humidity within cirrus at $T < 200 \text{ K}$ is enhanced by about 30%. The WB-57 measurements and the model results suggest that the cloud layer irreversibly dehydrated air near the tropopause.

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