Formation of Large (100 μm) Ice Crystals Near the Tropical Tropopause

During the recent NASA Costa Rica Aura Validation Experiment (CRAVE) imaging instruments onboard the WB-57F aircraft indicated the presence of surprisingly large crystals near the tropical tropopause (see Figure 1). The CRAVE mission also identified significant discrepancies between water vapor measurements made by various instruments, with the Harvard Lyman-α and ICOS instruments reporting water vapor concentrations nearly a factor of two larger than the JLH, frostpoint balloon, and satellite remote-sensing instruments. Resolving these discrepancies is important for understanding dehydration of air entering the stratosphere (see Figure 2). In this study, we investigate the formation of the large ice crystals and possible implications for water vapor concentrations.

Since the large crystals did not originate from deep convection, they must have nucleated and grown by deposition of water vapor in the narrow supersaturated layer near the cold tropopause. We have conducted simple growth-sedimentation calculations as well as full simulations of the clouds with a detailed cloud model. We start at the time and location of the observed large crystals and integrate backwards in time, running simulations for a range of assumed water vapor concentrations. As shown in Figure 3, if the water vapor concentration is less than about 3.1 ppmv, then the ice crystals do not reach zero radius before they ascend into the subsaturated stratosphere, and hence the H_2O concentration must have been at least 3.1 ppmv in order to grow the large crystals. Detailed simulations of ice nucleation, transport, and interaction with water vapor suggest that the large crystals probably nucleated on very effective ice nuclei and most aerosols present did not nucleate ice in spite of very large supersaturations.

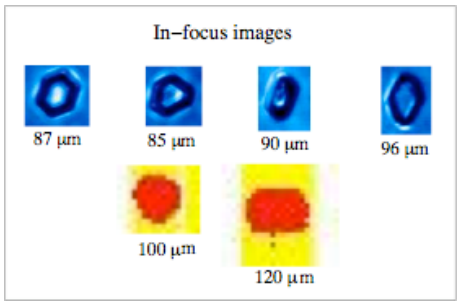

Figure 1.

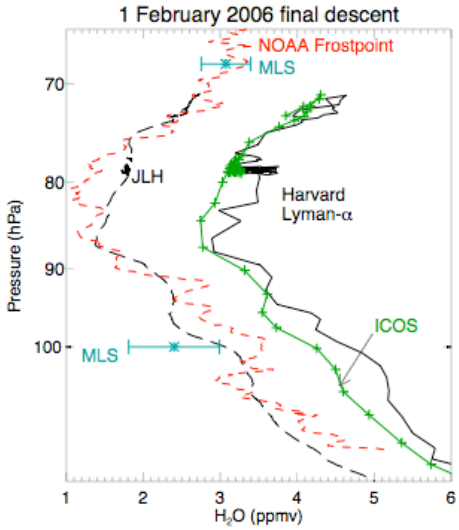

Figure 2.

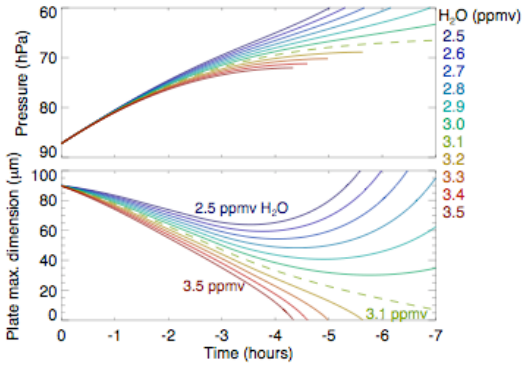

Figure 3.

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