Formation of Cirrus Clouds Near the Tropical Tropopause and their Implications for Stratospheric Humidity, Radiation Budgets, and Climate

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Optically-thin cirrus clouds are a nearly ubiquitous feature of the transition layer between the tropical troposphere and stratosphere (known as the Tropical Tropopause Layer). Given their high occurrence frequency, these clouds have significant impacts on the Earth's radiation budget, with a particularly strong influence on the outgoing longwave radiation. Further, ice crystal growth and sedimentation in these clouds dehydrates air in the cold TTL to very low water vapor mixing ratios. Since transport from the troposphere into the stratosphere occurs primarily through the tropical tropopause and the Brewer-Dobson circulation transports air from the TTL throughout the stratosphere, cloud processes in the TTL cold trap essentially regulate the humidity of the entire stratosphere. It has been shown that even small changes in stratospheric humidity can have significant impacts on the Earth's radiation budget and climate, with magnitudes comparable to anthropogenic changes in greenhouse gases. The humidity of air crossing the TTL cold trap depends to first order on tropical tropopause temperatures, but also on deep convection reaching the TTL, large-scale transport (in balance with TTL radiative heating), atmospheric waves, and cloud microphysical processes. Gaps in our understanding of TTL transport and cloud processes motivated the NASA Airborne Tropical TRopopause EXperiment (ATTREX). ATTREX used the long-range (16,000 km), high-altitude (20 km) Global Hawk unmanned aircraft system equipped with twelve instruments measuring clouds, water vapor, meteorological conditions, chemical tracers, chemical radicals, and radiation. I will discuss the physics of TTL cirrus formation and the impact of these clouds on water vapor and radiation budgets, including new results emerging from the ATTREX measurements.