Distribution of Cirrus Cloud Ice in the Tropical Tropopause Layer as Indicator of Regional Cloud Formation Processes and Climate Cycles

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High altitude cirrus clouds in the tropical tropopause layer (TTL) indicate where relatively cold temperatures and supersaturated air occur together. The focus of the research presented here is to characterize regional and seasonal changes in the tropical uppermost troposphere, using measurements of thin cirrus clouds as indicators of convection and gravity wave activity. The Cloud and Aerosol LIdar with Orthogonal Polarization (CALIOP) instrument on the CALIPSO satellite has captured more than nine years of elastic backscatter measurements (at 532 and 1064 nm) and depolarization (at 532 nm). CALIOP measures backscatter and depolarization from TTL cirrus of all particle sizes, enabling the lidar to detect very thin TTL cirrus clouds. A critical factor in the newest CALIOP climate data record is the increased stability of the recent Version 4 CALIOP calibration, due to a higher calibration reference altitude that is not impacted significantly by volcanic aerosols. We also take advantage of the recent Airborne Tropical TRopopause EXperiment (ATTREX) aircraft remote and in situ measurements of extinction and semi-direct measurements of condensed (ice) water in the TTL to evaluate our thin cirrus extinction retrievals and cirrus ice water parameterization. Preliminary comparison of the CALIOP Version 4 and NOAA water instrument measurement of ice water content (IWC) during ATTREX show good agreement (within a factor of 2) at temperatures between 188 and 203 K. Having gained confidence in the satellite data from ATTREX, we map regional distributions of TTL cirrus and IWC to highlight the difference in cloud ice amount above tropical marine and continental convection, and to show seasonal cycling in TTL condensed water amount. Finally, we examine nine years of CALIOP Version 4 Level 1 and adjusted Version 3 Level data to correlate variations in TTL ice water content with ENSO, the QBO and other climate cycles.