MLS-Scientific Publication

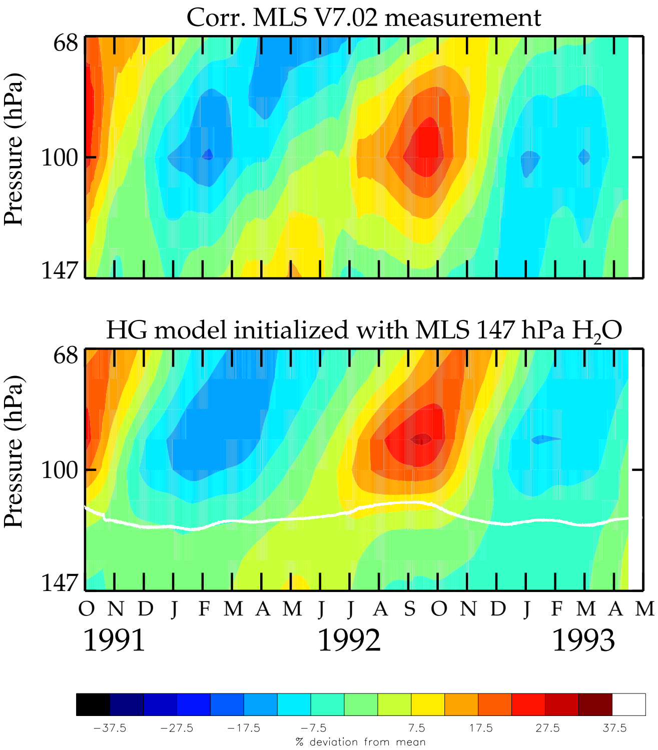
Scientific Themes: Tropospheric-stratospheric exchange, stratospheric water vapor

Dehydration in the Tropical Tropopause Layer: Implications from UARS MLS,
W. G. Read, D. L. Wu, J. W. Waters, and H. C. Pumphrey, *J. Geophys. Res.*, **109**, D06110,doi:10.1029/2003JD004056, 2004

MLS contact: W. G. Read, bill@mls.jpl.nasa.gov, 818-354-6773.

Summary

Understanding the mechanisms that dehydrate the water vapor as it enters the stratosphere is an important research topic. Water vapor enters the stratosphere in the tropics. Rising air is freeze-dried to a tiny fraction of the surface humidity. Although freeze-drying is the dominant process, measurements indicate that the stratosphere is less humid than 100% relative humidity based on the globally-averaged tropical tropopause temperature, the coldest altitude between the troposphere and the stratosphere which resides at 16.5 km high. Two hypotheses have been developed that can explain the additional dehydration. One hypothesis promoted by Drs. S. Sherwood and A. Dessler says that overshooting convection can provide the additional dehydration. The overshooting convective turret rising to the tropopause is much colder than its surroundings and condenses ice that falls out. Turret air being less humid than neighboring air mixes with it and lowers the humidity of its surroundings. The second hypothesis presented by Drs. J. Holton and A. Gettelman says that horizontal transport with in situ freeze-drying can account for the observations. Winds near the tropopause can transport air several thousands of kilometers over the tropics before the air rises into the stratosphere and therefore, the pool of colder-than-average tropopause residing over the Western Pacific can freeze-dry much of the tropospheric air entering the stratosphere. Discriminating between these hypotheses has been difficult because there is very little observational data of H_2O at 14–17 km high where the final dehydration takes place. Special analysis of the UARS MLS water vapor radiometer data have provided humidity profiles in the critical 14–17 km altitude range. The figure shows the good comparison between the MLS measurements and the Holton and Gettelman “cold-trap” model. The data and model show that a maximum amplitude in the seasonal cycle of the H_2O anomaly occurs near the tropopause, consistent with a freeze-drying process driven by lowest temperatures. A representative calculation of the convective dehydration hypothesis published elsewhere predicts that the seasonal cycle maximum in the H_2O anomaly occurs near 140 hPa. This is the height that the overshoot relaxes to and detrains its ice which can evaporate. As this air rises, it mixes with dry air from the overshoot reducing its humidity and the amplitude in the seasonal cycle of the H_2O anomaly. The MLS observations are not consistent with this mechanism. Thus, the MLS observations support the “cold-trap” dehydration hypothesis.



A time-height H_2O anomaly contour plot for the tropics (12°S–12°N). The top panel shows the MLS measured H_2O. The bottom plot shows a simulation using the *Holton and Gettelman* ‘horizontal transport through a cold trap’ model. The white line shown in the bottom panel is ice concentration formed in the model is maximum.

This work benefits society by helping us understand mechanisms that regulate the concentration and trends of water vapor in the stratosphere which has implications for the ozone layer and possibly climate change.