Extreme tropical lower stratospheric water vapor and ice amounts during 2015-2016 and their relation to ENSO, QBO, and convective overshooting

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In this presentation, we investigate the relative roles of tropical tropopause layer (TTL, ~14 –19 km) temperatures and overshooting on the tropical lower stratospheric water vapor budget using satellite observations, reanalyses, and dehydration trajectory modeling applied to the highly unusual El Niño-Southern Oscillation (ENSO) and stratospheric quasi-biennial oscillation (QBO) events of 2015-2016.

To first order, the TTL temperature field regulates the amount of water vapor entering the stratosphere by controlling the amount of dehydration in the rising air. Thus, modes of climate variability such as the stratospheric QBO, variations in tropical upwelling, ENSO have the potential to impact the stratospheric entry value of water vapor via their impact on TTL temperatures. Additionally, vigorous convection that overshoots the local tropopause might also have a direct impact on stratospheric water vapor in a manner that circumvents the TTL cold trap mechanism.

The El Niño and subsequent La Niña of 2015-2016 coincided with a remarkable perturbation to the concentration of water vapor entering the stratosphere in the tropics. At the end of 2015 during the El Niño, a decadal record amount of lower stratospheric water vapor was observed in the Western Pacific, followed by a record dry anomaly that occurred after the 2016 QBO "interruption" and during the La Niña.

Coincident with the record setting amount of water vapor at the end of 2015, the TTL Western Pacific cold pool was shifted eastward from its climatological position and aligned with the center of convection over the Central Pacific. Over this region, there was an extreme decadal record amount of convective cloud ice in the lower stratosphere observed by the CALIOP satellite lidar. A trajectory-based analysis that models hydration based solely on reanalysis temperature and wind fields can account for only about half of the observed tropical lower stratospheric moistening during this event. This suggests that unresolved dynamical processes associated with convection and/or sublimation of lofted ice particles also contributed to lower stratospheric moistening. These processes could contribute to climate change-induced stratospheric water vapor increases.

Keywords: stratospheric water vapor, tropical tropopause layer, convective overshooting, ENSO, QBO

