Decadal variability of tropical tropopause temperatures and lower stratospheric water vapour

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Tropopause temperatures (TPTs) control the amount of stratospheric water vapour, which influences chemistry, radiation and circulation in the stratosphere, and is also an important driver of surface climate. Decadal variability and long-term trends in tropical TPTs as well as stratospheric water vapour are largely unknown. Here, we investigate the decadal variability of tropical TPTs and lower stratospheric water vapour (LSWV), from observations, atmospheric and oceanic reanalysis and state-of-the-art coupled chemistry-climate model simulations.

Tropical TPTs and LSWV show significant decadal variability in both observations and model simulations, which are closely related to the 11-year solar cycle and the Pacific Decadal Oscillation (PDO). The negative phase of the PDO, associated with cold sea surface temperature (SST) anomalies in the tropical east and central Pacific and positive sea level pressure anomalies over the North Pacific, leads to less convection in the tropics, a less disturbed polar vortex and a slower Brewer-Dobson circulation in the stratosphere. The shallower convection and slower upward motion hence warms the tropical tropopause, enabling more water vapour to enter the stratosphere.

The 11-year solar cycle is associated with ENSO-Modoki-like SST anomalies, i.e. positive SST anomalies in the central Pacific and cold SST anomalies in the western and eastern Pacific. Such anomalous temperatures persist from the surface to about 150 m depth in the central Pacific, which develop and peak approximately 2 years after the solar maximum due to a potential positive feedback through air-sea interactions. The ENSO-Modoki-like SST anomalies in turn enhances vertical motion and deep convection over the central Pacific leading to enhanced tropopause heights and therefore reduced tropopause temperatures as well as stratospheric water vapour. Consistent and opposite effects occur in adjacent regions (subtropics) and indicate zonally asymmetric solar impacts in the tropical atmosphere in agreement with a time evolving solar-induced ENSO Modoki-like SST pattern.

Key words: tropopause temperatures, lower stratospheric water vapour, decadal variability, Pacific Decadal Oscillation, 11-year solar cycle