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What regulates the annual cycle of stratospheric water vapor?

Martin Jucker and Edwin Gerber
New York University, United States (mjucker@nyu.edu)

Stratospheric water vapor is a potent greenhouse gas and active chemical tracer. Most of the stratosphere is well below saturation due to freeze drying at the tropical cold point — the coldest region of the lower stratosphere where most air enters the middle atmosphere. The leading mode of variability of the tropical cold point is an annual cycle, despite the semi-annual cycle of radiative forcing in the tropics. This causes the stratospheric water vapor mixing ratio to follow a similar annual cycle, even remotely from the entry point, the so-called tape recorder. We develop an idealized GCM to investigate the origin of the annual cycle in the tropical cold point, with a particular focus on the interaction between dynamics and radiation.
By varying the surface conditions of the model, we first show that planetary scale asymmetries in the midlatitude troposphere drive the annual cycle in the cold point. Both large scale topography and land sea contrast are important, influencing synoptic and planetary scale wave forcing. We then probe the impact of water vapor on the stratospheric circulation by comparing fully interactive integrations of the model to companion integrations where the coupling between the circulation and water vapor is disconnected. Our findings have implications in estimating the impacts of stratospheric water vapor feedbacks on decadal time scales and sensitivities to climate change.