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The breathing of the tropical troposphere

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The dynamics of the tropical tropopause layer are controlled by the complex interplay of (sub-)seasonal, year-to-year and multi-annual variations, driven by, i.e. the Brewer Dobson circulation (BDC), Quasi-biennial oscillation, and equatorial heating responses. Seasonally, both the solar energy input as well as the BDC have been attributed as drivers of seasonal variability. The notion that the net radiative flux at the TOA and the height of the tropopause vary in concert, albeit lagged, is supported by current observational datasets of GPS-derived temperature and CERES radiative fluxes. The story is very different for inter-annually variations. Over the observational period (2006-2015), we find a strong relationship of inverse nature: the tropical tropopause rises when the tropical energy budget (TEB) decreases and vice versa.

The inter-annual variability in both tropopause height and TEB is largely driven by ENSO, resulting in upper level wave response to the equatorial heating that lifts the tropopause uniformly, and cloud and water vapor driven long-wave and short-wave radiative effects that result in a reduction of TBA with respect to its mean variability.

While the tropical troposphere appears to breath uniformly throughout the deep tropics (10S-10N), the response in clouds and radiative effects is spatially more complex and largely confined to the deep convective center in the western central Pacific and surrounding dry areas. Tropics-wide, we find long-wave cloud effects to play a minor role in modulating the inter-annual variability of TEB and to be positive (at the top-of-atmosphere) in response to higher and colder cloud tops during the positive phase of ENSO. The combined increase in clear-sky long-wave emission and reflection of short-wave radiation compensate for the positive long-wave cloud effect and reduce the TEB during the positive ENSO phase when the tropopause is lifted by up to about 300 meters.

The curious relationship between the depth of the tropical troposphere and TEB raises the question of self-regulating feedbacks through the ability of the tropics to remove excess heat by radiative emission through changes in cloud properties and upper tropospheric humidity.