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On the Breathing of the Tropical Troposphere and its relation to the Tropical energy balance

Maria Hakuba (1,2), Graeme Stephens (2), Panagiotis Vergados (2), Chi Ao (2), and Anthony Mannucci (2)

(1) Colorado State University, Atmospheric Science, Fort Collins, United States (maria.z.hakuba@jpl.nasa.gov), (2) Jet Propulsion Laboratory/California Institute of Technology, Pasadena, United States

High cloud feedbacks connected to tropical convection are thought to play an essential role in shaping global sensitivities of climate to a doubling of CO_2. There is a large spread across models on the magnitude of positive longwave (LW) and offsetting negative shortwave (SW) high cloud feedbacks with each tending to cancel one another. The so-called FAT (fixed anvil temperature) hypothesis or its derivative PHAT (proportionally higher anvil temperature), suggests a LW positive feedback that is dominant within the tropics. Negative feedbacks have also been hypothesized such as the so-called Iris effect suggesting the area of high clouds detrained from convection reduces with warming, thus reducing the warming effect of these clouds. Yet, other negative or regulatory feedbacks have been proposed including the thermostat hypothesis associated with solar radiation reductions that feedback on tropical sea surface temperature (SST) and the humidistat feedback based on differential heating processes that control convective aggregation. Although these various tropical cloud feedback concepts are of potentially great importance, it is not known whether a decrease or increase in convective detrainment will actually occur in climate change, or how the high clouds will change, nor is it known if associated opposing SW and LW feedbacks cancel or whether one component dominates over the other.

In this study we bring together different multi-annual data records to show how the tropical energy budget (TEB) and cloud radiative effects (CRE) vary on interannual time scales associated with the “breathing” – large-scale expansion and contraction – of the tropical troposphere. There are good reasons to expect that the depth of the tropical troposphere, expressed in terms of the tropopause height (TROH), and the TEB are related and that this relationship involves processes that are central mechanisms to any high cloud feedback hypothesis. The dynamics of the tropical tropopause layer and its cloudiness, are influenced by (sub-)seasonal, interannual and multi-annual variations associated with the Brewer Dobson circulation, the Quasi-biennial oscillation, and equatorial heating/cooling responses to ENSO variability.

In the current study we demonstrate an unexpected pattern of robust interannual co-variability: the troposphere breaths in (positive TROH anomaly) while losing energy to space (negative TEB anomaly), a pattern that is largely a delayed response to ENSO-controlled SST variability. This is in contrast to the seasonal co-variability and suggests an overall negative radiative effect associated with the expansion of the troposphere through convective processes. While we highlight the nature of this observed co-variability in the deep tropics (10°S-10°N) and explore factors that potentially influence this variability, we also dissect the TEB variability in its LW, SW, clear and cloudy components to identify the chief causes for the observed TEB interannual variability. Preliminary results suggest the main cause of TEB interannual variability lies in the SW cloud effect largely driven by variability in the thickness of clouds. This interannual relationship, although modified, holds true beyond the tropical domain, and suggests that tropical convection is associated with overall negative cloud radiative feedback controlled by the SW spectrum and its modulation by cloud thickness variability.