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Evaluating climate model performance in the tropics with retrievals of water isotopic composition from Aura TES

Robert Field (1), Daehyun Kim (2,3), Max Kelley (1), Allegra LeGrande (1), John Worden (4), and Gavin Schmidt (1)

(1) NASA Goddard Institute for Space Studies, United States (rf2426@columbia.edu), (2) Lamont-Doherty Earth Observatory, Columbia University, (3) Dept. Atmospheric Sciences, University of Washington, (4) NASA Jet Propulsion Laboratory

Observational and theoretical arguments suggest that satellite retrievals of the stable isotope composition of water vapor could be useful for climate model evaluation. The isotopic composition of water vapor is controlled by the same processes that control water vapor amount, but the observed distribution of isotopic composition is distinct from amount itself . This is due to the fractionation that occurs between the abundant H216O isotopes (isotopologues) and the rare and heavy H218O and HDO isotopes during evaporation and condensation. The fractionation physics are much simpler than the underlying moist physics; discrepancies between observed and modeled isotopic fields are more likely due to problems in the latter. Isotopic measurements therefore have the potential for identifying problems that might not be apparent from more conventional measurements.

Isotopic tracers have existed in climate models since the 1980s but it is only since the mid 2000s that there have been enough data for meaningful model evaluation in this sense, in the troposphere at least. We have evaluated the NASA GISS ModelE2 general circulation model over the tropics against water isotope (HDO/H_2O) retrievals from the Aura Tropospheric Emission Spectrometer (TES), alongside more conventional measurements. A small ensemble of experiments was performed with physics perturbations to the cumulus and planetary boundary layer schemes, done in the context of the normal model development process. We examined the degree to which model-data agreement could be used to constrain a select group of internal processes in the model, namely condensate evaporation, entrainment strength, and moist convective air mass flux. All are difficult to parameterize, but exert strong influence over model performance.

We found that the water isotope composition was significantly more sensitive to physics changes than precipitation, temperature or relative humidity through the depth of the tropical troposphere. Among the processes considered, this was most closely, and fairly exclusively, related to mid-tropospheric entrainment strength. This demonstrates that water isotope retrievals have considerable potential alongside more conventional measurements for climate model evaluation and development.