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Constraining future tropical land carbon-climate feedbacks by water

Laibao Liu and Sonia Seneviratne
ETH Zurich, Atmospheric and Climate Science, Zurich, Switzerland (laibao.liu@env.ethz.ch)

Tropical land carbon-climate feedback is a key determinant of uncertainties in climate change projections. Temperature has been proposed as a primary driver for the land carbon sink and it has been widely used to characterize carbon-climate feedback metrics in the latest reports of the Intergovernmental Panel on Climate Change (IPCC). The historical interannual sensitivity of CO2 growth rate (CGR) to tropical temperature was further identified as an observational constraint that can significantly lower uncertainties in projected changes in tropical land carbon storage. Here, we utilize 1pctCO2 ensemble experiments from the 6th Coupled Model Intercomparison Project (CMIP6) and show that previous emergent constraints (ECs) on tropical land carbon-climate feedback relying on temperature derived from the previous set of CMIP experiments (C4MIP) do not perform well for CMIP6. Long-term climate-driven tropical land carbon uptake is more directly coupled with water availability (soil moisture as the proxy in models) than temperature at both regional and local scale in CMIP6, suggesting that water has a stronger role than temperature in directly determining tropical land carbon-climate feedbacks. We further find that there is a significant emergent relationship between long-term sensitivity of tropical land carbon uptake to drying and its interannual sensitivity to water in CMIP6 (R=0.91, n=16). Combining with observations of interannual sensitivity of CGR to terrestrial water storage during 2002-2018, the resulting EC shows that, compared with an unconstrained ensemble of ESMs in CMIP6 (-1.9±1.4 PgC/yr/ Tt H2O), tropical land carbon losses by drying per Tt H2O are much lower (-0.9±0.7 PgC/yr/Tt H2O). Nonetheless, this does not ensure a less actual carbon loss per degree of global warming, because it also depends on the sensitivity of tropical land drying to global warming. This study suggests a strong potential for constraining future climate-driven terrestrial carbon sink from the perspective of water-carbon limitations.