EGU24-14707, updated on 08 Apr 2024
https://doi.org/10.5194/egusphere-egu24-14707
EGU General Assembly 2024

Do local-scale climate tipping points exist in Amazon forests, and can they warn of impending basin-scale tipping point vulnerability?

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The risk of a tipping point for Amazon forests — a perturbation threshold beyond which abrupt, irreversible (or difficult to reverse) changes in forest function and large-scale tree die-off occur — motivates much recent Amazon forest science and policy work to understand and reduce the risk. However, virtually all the science to date focuses on tipping points as *a basin-wide* phenomenon. To understand how large-scale tipping points may be triggered, **we urgently need to study mechanisms of tipping point onsets *at local-scales*** in pivotal forests.

Here, we used 12+ years of observations (spread over two decades from 2001-2020) of water and energy fluxes from eddy covariance measurements, and associated ecological and meteorological observations in the eastern Amazon basin, to investigate the potential for hydrological extremes to induce a "local scale" tipping point. We focused on forest transpiration capacity (the capacity of vegetation to convert available energy into latent heat, quantified as the ratio of transpiration to incoming radiation, T/R) because transpiration in eastern Amazon forests is the basis for precipitation recycling on which forests to the west depend.

Our observations encompassed two strong El Niño droughts, in 2002-2003 and in 2015-2016. Both events were characterized by similarly reduced rainfall; however, the 2015 El Nino was further amplified by an ongoing warming trend, which made for a hotter drought with higher atmospheric vapor demand, exacerbating the drought effects on the forest.

This amplification of drought by warming was apparently sufficient to cause widely divergent responses to the two droughts. The forest responded positively to the 2002 drought, with increases in canopy conductance (Gs) and in evapotranspiration, consistent with a stable forest transpiration capacity (T/R) that saw proportional increases in T in response to higher R. By

contrast, the transpiration capacity (sustained through two decades of previous dry seasons and the 2002 El Nino drought) collapsed during the 2015 drought. Notably, the forest's ability to transpire did not return with the rain as the drought ended, but remained low for several years. Thus, we concluded that the difference between the 2002 and 2015 El Nino's was sufficient to push the forest past a "tipping point" threshold in forest transpiration function, into an alternate state of reduced function in which it remained trapped until the forest could regenerate the canopy with new leaves.

This discovery of the phenomenon of local-scale short-term tipping point dynamics in forest canopy function opens the door to investigating and understanding how basin-scale tipping points may emerge from local phenomena, and how careful local observations may provide early warnings of impending larger-scale forest vulnerability.