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Abrupt shifts in ecosystem function and intensification of global biogeochemical cycle driven by hydroclimatic extremes

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Amplification of the hydrologic cycle as a consequence of global warming is increasing the frequency, intensity, and spatial extent of extreme climate events globally. The potential influences resulting from amplification of the hydro-climatic cycle, coupled with an accelerating warming trend, pose great concerns on the sustainability of terrestrial ecosystems to sequester carbon, maintain biodiversity, provide ecosystem services, food security, and support human livelihood. Despite the great implications, the magnitude, direction, and carry-over effect of these extreme climate events on ecosystem function, remain largely uncertain. To address these pressing issues, we conducted an observational, interdisciplinary study using satellite retrievals of atmospheric CO_2 and photosynthesis (chlorophyll fluorescence), and in-situ flux tower measures of ecosystem-atmosphere carbon exchange, to reveal the shifts in ecosystem function across extreme drought and wet periods. We further determine the factors that govern ecosystem sensitivity to hydroclimatic extremes. We focus on Australia but extended our analyses to other global dryland regions due to their significant role in global biogeochemical cycles.

Our results revealed dramatic impacts of drought and wet hydroclimatic extremes on ecosystem function, with abrupt changes in vegetation productivity, carbon uptake, and water-use-efficiency between years. Drought resulted in widespread reductions or collapse in the normal patterns of vegetation growth seasonality such that in many cases there was no detectable phenological cycle during extreme drought years. We further identified a significant increasing trend ($p < 0.001$) in extreme wet year precipitation amounts over Australia and many other global regions, resulting in an increasing trend in magnitude of the episodic carbon sink pulses coupled to each La Niña-induced wet years. This finding is of global biogeochemical significance, with the consequence of amplifying the global carbon cycle. Lastly, we use landscape measurements of carbon and water fluxes from eddy-covariance towers and field sampling of aboveground net primary productivity from long-term ecological networks to verify the patterns observed by top-down approaches. Our results demonstrate the intensification of hydroclimatic extremes due to global warming is exerting important impacts on ecosystem function, which further have significant implications on global biogeochemical cycles as well as local ecosystem processes.