Increased Gross Primary Productivity in Energy-Limited Ecosystems during Spring Droughts

David L. Miller (UC Berkeley, Department of ESPM, Keenan Group, www.davidlmilleretal.com)

Gross primary productivity (GPP) is a key component in the global carbon cycle and is controlled by many meteorological factors. During meteorological droughts, precipitation declines while temperature and solar radiation often increase, leading to potentially divergent GPP responses between water and energy-limited ecosystems. Since water and energy limitations can vary across seasons and years, long-term eddy covariance (EC) observations form a necessary baseline in estimating GPP sensitivity to meteorological droughts when evaluating land surface model outputs and satellite remote sensing GPP products. Here, we examine how the water energy limitation spectrum affects the sensitivity of GPP to meteorological drought using a network of long-term EC sites in the Northern Hemisphere (>30° N). We relied on the newly combined availability of many flux site datasets with 10+ years of observations, including FLUXNET2015, the AmeriFlux ONEFlux beta product, and recent releases for European sites from ICOS. We find that during spring the sensitivity of GPP to precipitation is a strong function of aridity (R^2 = 0.47), and persists even when air temperature and solar radiation are accounted for (R^2 = 0.29). Spring GPP primarily increases during meteorological droughts for energy-limited ecosystems. We compare the springtime EC results to GPP outputs from an ensemble of terrestrial biosphere models (TRENDY) and satellite remote sensing GPP and SIF products (e.g., MODIS GPP, FLUXCOM, CSIF, GOSIF), and map estimated GPP sensitivities using gridded climate data. We find that the negative sensitivity of spring GPP to precipitation is underestimated for energy-limited sites from TRENDY carbon model outputs compared with eddy covariance observations ($p < 0.001$). Our results demonstrate the variability of GPP sensitivity to meteorological droughts, helping to describe some of the seemingly contradictory impacts of drought on GPP across different ecosystems.