Projected change in climatic drivers of extreme forest productivity, and the impacts on water availability in the western US

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Forests are integrated into the culture, ecology, and economy of western North America. Changing climate conditions may threaten the health of forests, enhancing vulnerability to mortality. During periods of low productivity, trees are more vulnerable to biotic and abiotic driven mortality. We investigated the climate and landsurface conditions leading to periods of low forest productivity in a large initial condition ensemble of coupled land-atmosphere simulations. We evaluated how the interactions among temperature, water supply, and forest productivity, are projected to change under future conditions, and assessed how these changes feedback onto soil water availability during the summer dry season.

We compared projections of a future period (2046-2075) under ‘business as usual’ greenhouse gas emissions to the contemporary period (1986-2015). A large initial condition ensemble of global climate simulations from HadAM3p was dynamically downscaled using a 25-km resolution regional climate model, HadRM3p, with the land-surface scheme MOSES2. We varied parameters relating to the exchange of carbon, water, and energy between the land surface and atmosphere to account for uncertainty in model parameterization. Utilizing the large ensemble size, we analyzed composites of simulations resulting in extreme low forest productivity. We assessed the climatic drivers of extreme productivity and the feedbacks on summer water availability. In rain-dominated watersheds, CO_2 fertilization enhances forest productivity, and increased water use efficiency preserves summer soil moisture. In regions where spring snowpack is projected to decline, periods of extreme low forest productivity and high vulnerability to mortality are projected to persist; the combination of water limitations and temperature stress counteract the CO_2 fertilization effect. In high elevation regions, the combination or earlier, warmer growing seasons, available soil moisture, and CO_2 fertilization enhance forest productivity. The additional transpiration depletes summer soil moisture despite increased water use efficiency and retained spring snowpack.

Understanding the interactions between vegetation and local hydrology during extreme conditions improves our understanding of the joint risk climate change poses to critical resources. This facilitates an improved framework off which to design management strategies. However, much uncertainty still exists around the physiological response of trees to drought and temperature stress and our findings illustrates key areas for further improvements to model representation of vegetation physiology.