The effects of climate, forest age, and disturbance history on carbon and water processes at AmeriFlux sites across gradients in Pacific Northwest forests

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We investigated climatic and hydrologic effects on terrestrial ecosystem carbon and water processes across a climatic gradient and age class gradient in important forests (i.e., mature ponderosa pine, US-Me2, young ponderosa pine, US-Me3, and mature Douglas-fir, US-MRf) in the Pacific Northwest, USA. US-Me2 and US-Me3 are semi-arid forests with seasonal drought, whereas US-MRf is a mesic forest with high winter precipitation. We conducted eddy covariance measurements to measure carbon and water balances over 20 site-years and used hydrological year to define seasons and explain annual variation. Annual net ecosystem CO_2 exchange (NEE) at US-Me2 (2003-2012), US-Me3 (2005-2009), and US-MRf (2007-2011) varied from -571 to -248, from -160 to -19, and from -601 to -313 g C m-2 yr-1, respectively. Annual evapotranspiration (ET) ranged from 410 to 687, from 342 to 418, and from 369 to 521 mm yr-1 for the same period. On average (2005-2009), US-Me2 had 5.0 times larger NEE and 1.4 times larger ET than US-Me3 due to higher leaf area index (LAI) and more available soil water from precipitation. Despite lower LAI and precipitation at US-Me2, difference in climatic gradient (e.g., higher radiation and evaporative demand) at US-Me2 resulted in a similar NEE and 1.4 times larger ET than US-MRf for the 5-year period (2007-2011). The annual average inherent water use efficiency (IWUE) at US-Me2, US-Me3, and US-MRf varied from 2.0 to 3.7, from 2.0 to 3.6, and from 2.4 to 3.9 g C kPa per kg H2O, respectively. The variation in the annual IWUE at the drought-affected US-Me2 and US-Me3 was correlated with precipitation and vapor pressure deficit (VPD), whereas IWUE at US-MRf was constrained by VPD and had no correlation with precipitation. The trend of the anomaly of the annual IWUE (ΔIWUE) at US-Me2 and US-Me3 was a decreasing slope of -0.13 and -0.10 gC kPa per kg H2O yr-1, respectively. In contrast to the two ponderosa pine sites, ΔIWUE at US-MRf showed an increasing trend of 0.35 g C kPa per kg H2O yr-1. The trends of ΔIWUE at the three sites were primarily associated with the changes in ET rather than gross primary production. The increased ET at US-Me2 and US-Me3 resulted in decreased ΔIWUE, whereas the decreased ET at US-MRf resulted in increased ΔIWUE. Our study suggests that climate projection with higher temperature and evaporative demand in the Pacific Northwest will shift carbon and water balance of the forests by altering ET.