A DYNAMIC PLANT WATER AND CARBON BALANCE MODEL FOR TESTING TREE MORTALITY MECHANISMS UNDER CLIMATE-DRIVEN DISTURBANCES

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Predictions of the feedbacks between the land surface and the atmosphere are becoming more constrained through improved models of the physical interactions. A major limitation of these models is a crude and often non-dynamic representation of the land surface. These limitations are especially poignant given that the land surface exchange of carbon dioxide will not only be directly influenced by changing climate drivers including temperature, humidity, precipitation and carbon dioxide concentrations, but also by disturbances that are driven by climate change. Vegetation mortality is one such feedback that has gained considerable interest in the Earth Sciences community, and yet our und erstanding of the mechanisms controlling plant mortality is still quite limited. Consequently, predicting flux responses to these changes is challenging. Flux data in areas of bark beetle outbreaks in the western U.S.A. show differential declines in water and carbon flux in response to the occlusion of xylem by associated fungi. For example, bark beetle infestation at the GLEES AmeriFlux site manifested in a decline in summer water use efficiency to 60% in the year after peak infestation compared to previous years, and no re covery of c arbon uptake following a period of high vapor pressure deficit.
Theory based on plant hydraulics and extending to include links to carbon storage and exhaustion has potential for explaining these dynamics models. In this spirit we developed a dynamic vegetation model that combines the strengths of a coupled canopy water and carbon flow model [Loranty et al., 2010] with a detailed plant water balance model [Sperry et al., 1998]. The new model simultaneously solves carbon uptake, allocation to structural and non-structural elements, and plant hydraulics. It allows for testing specific hypotheses on feedbacks between xylem dysfunction, stomatal and non-stomatal controls on ph otosynthesis and carbon allocation, respiration, and defense. These are constrained through gas exchange, root vulnerability to cavitation, sap flux, and eddy covariance data in a Bayesian model complexity-testing framework. Our analysis focuses on t wo ecosystem-disturbance settings: piñon pine mortality in New Mexico, and bark beetle infestation in lodgepole pine and spruce/fir forests in Wyoming. Our modeling results support recent hypotheses on feedbacks between hydraulic dysfunction and 1) non-stomatal control on photosynthesis, 2) shifting balance between growth and maintenance respiration, and 3) d eclines in carbon reserves during prolonged disturbances.
References Cited:
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Sperry, J. S., F. R. Adler, G. S. Campbell, and J. P. Comstock (1998), Limitation of plant water use by rhizosphere and xylem conductance: results from a model, Plant Cell Environ., 21(4), 347-359.