Land Surface Water Variability and Dynamics During a Severe Drought in the Southwest, U.S.A

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The Southwest U.S. is a mountainous region where the topographic relief leads to the confluence of many major biome types with highly diverse vegetation physiognomies that include desert scrub, grasslands, savanna, and riparian zones interspersed with montane forests. These dryland ecosystems are currently undergoing rapid land transformations (e.g. woody plant encroachment, invasive species, phreatophytes) causing significant shifts in the physiognomic makeup of the vegetation with consequences to surface hydrologic processes and water balance. Water is the most limiting resource to biological activity in these dryland zones, however, the degree of coupling between precipitation and biological activity is not simple with differential sensitivities of net primary production (NPP) to inter-annual variability in precipitation existing across land cover types. Our understanding and predictions of vegetation – water interactions and land cover modifications, including drought and degradation, can be significantly improved with consideration of precipitation use efficiencies (PUE = NPP/ mean annual precipitation). The PUE concept can be tied directly to surface hydrology (water content, runoff, deep soil recharge) and provide measures of current vegetation-climate equilibrium states and future vegetation responses to changes in water availability. In this study we coupled an upper boundary condition of maximum biomass accumulation per unit rainfall (PUEmax) with remotely-sensed drought indices, such as the vegetation condition index, to provide a mechanism in which spatiotemporal variability in water availability and/ or precipitation may be retrieved. We investigated the spatial and temporal variations in vegetation biologic activity with carbon and water indices derived from fine resolution AVIRIS data and moderate resolution MODIS observations. Leaf level and canopy level surface moisture indices were computed over the range of ecosystems and drought-induced mortality sites with hyperspectral AVIRIS data in the 1240nm and 2100nm water absorption regions. The coupled water and carbon indices were scaled up to MODIS data for spatial extension and time series analysis over the past 5 years. Land surface moisture and carbon patterns behaved differently across the range of ecosystems and within drought impact sites. Improved estimates of soil moisture and evapotranspiration (ET) were possible with inclusion of the moisture indices and the PUE concept. Drought impacts were observed in all ecosystems, particularly in tree mortality areas and the grassland and desert areas. Our results show that combined water and carbon indices offer improved sensitivity to ecosystem health assessment and drought detection and analysis. Remotely-sensed land surface water indices combined with the carbon products yielded important information useful in the prediction of vegetation health response to climate change and human land cover modifications.