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Investigating impacts of drought and disturbance on evapotranspiration over a forested landscape in North Carolina, USA using high spatiotemporal resolution remotely sensed data

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ABSTRACT

Forest ecosystem services such as clean water, wildlife habitat, and timber supplies are increasingly threatened by drought and disturbances (e.g., harvesting, fires and conversion to other uses), which can have great impacts on stand development and water balance. Improved understanding of the hydrologic response of forested systems to drought and disturbance at spatiotemporal resolutions commensurate with these impacts is important for effective forest management. Evapotranspiration (ET) is a key hydrologic variable in assessing forest functioning and health, but it remains a challenge to accurately quantify ET at landscape scales with the spatial and temporal detail required for effective decision-making. In this study, we apply a multi-sensor satellite data fusion approach to study the response of forest ET to drought and disturbance over a 7-year period. This approach combines Landsat and Moderate Resolution Imaging Spectroradiometer (MODIS) ET product time series retrieved using a surface energy balance model to generate a multi-year ET datacube at 30-m resolution and daily timesteps. The study area (~900 km^2) contains natural and managed forest as well as croplands in the humid lower coastal plains in North Carolina, USA, and the simulation period from 2006 to 2012 includes both normal and severe drought conditions. The model results were evaluated at two AmeriFlux sites (US-NC2 and US-NC1) dominated by a mature and a recently clearcut pine plantation, respectively, and showed good agreement with observed fluxes, with 8–13% relative errors at monthly timesteps. Changes in water use patterns in response to drought and disturbance as well as forest stand aging were assessed using the remotely sensed time series describing total evapotranspiration, the transpiration (T) component of ET, and a moisture stress metric given by the actual-to-reference ET ratio (f_{RET}). Analyses demonstrate differential response to drought by land cover type and stand age, with larger impacts on total ET observed in young pine stands than in mature stands which have substantially deeper rooting systems. Transpiration flux shows a clear ascending trend with the growth of young pine plantations, while stand thinning within the plantation leads to decreases in both remotely sensed leaf area index and T, as expected. Time series maps of f_{RET} anomalies at 30-m resolution capture signals of drought, disturbance and the subsequent recovery after clearcut at the stand scale and may be an effective indicator for water use change detection and monitoring in forested landscapes.

1. Introduction

Forests provide many important ecosystem service functions, including wildlife habitat, timber production and watershed water regulation (Sun et al., 2017b). Decline in forests can be caused by many factors, generally relating to human or nature-induced disturbance and changing climate. In this context, disturbance includes forest harvesting, thinning, wind throw, fire, ice storm, landslide, flooding, avalanche, insect outbreaks, and land conversion. Changes in climate, including air temperature, humidity and precipitation regime, also

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