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A novel surface energy balance algorithm for estimating evapotranspiration from UAV-acquired data

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Evapotranspiration (ET) is the largest loss term in the terrestrial water balance and plays a key role in the energy and carbon cycles. Accurate and timely measurements of ET are critical for understanding the ecosystem responses to climate change and managing water resources. Traditional methods for measuring ET are either highly individualistic leaf- or stem-scale approaches or large-scale tools that aggregate across entire landscapes. Unmanned aerial vehicles (UAVs) constitute a new frontier in measurement of ET that bridges the gap between *in situ* measurements and remotely sensed observations of water and energy fluxes. With advances in sensor technology and data processing algorithms, UAV-based remote sensing of ET provides both an avenue to refine satellite-based algorithms for retrieving water use and an improved understanding of the fundamental exchange processes between vegetation and the atmosphere.

We present an approach for estimating ET at leaf to landscape scales using thermal imagery, structural data, and a suite of environmental sensors mounted on a UAV platform. Our approach derives ET solely from UAV-acquired data using a combined atmospheric profiling and surface energy balance algorithm. Centimeter-scale leaf position and orientation information derived from Structure-from-Motion (SfM) are integrated with the functional data to constrain available energy, allowing for multi-scale estimation of plant water use within and across canopies.

Using thermal imagery and a suite of environmental sensors mounted on a UAV platform, we calculated ET of a Mediterranean grassland in Southern California at <1-m spatial resolution for 16 flights across the 2021 and 2022 growing seasons. We compare UAV-derived fluxes using four different formulations of aerodynamic resistance to measurements from an eddy covariance tower at the site. We then discuss the relative importance of surface temperature, aerodynamic terms, and meteorological variables for calculating ET from surface energy balance, highlighting the limitations of current approaches and the potential opportunities for future studies.