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Insights into Multi-Sensor UAV Parameterization of TSEB Across Crops

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Very-high-resolution unmanned aerial vehicle (UAV) observations provide new opportunities to better constrain surface temperature and canopy properties for improved model parameterization. Here, we integrate thermal infrared (TIR), multispectral (MS), and light detection and ranging (LiDAR) UAV observations within the Priestley–Taylor two source energy balance (TSEB-PT) [1] model to evaluate how structural and functional canopy information influence evapotranspiration (ET) estimates across multiple crops and growing seasons. TSEB-PT was applied using pyTSEB [2] and UAV observations over a 10-ha field across three seasons: sugar beet (2021), potato (2022), and winter wheat (2023). Key inputs included TIR data for land surface temperature (LST), MS and LiDAR observations for canopy characterization, and a fusion of MS-derived green area index (GAI) and LiDAR-derived plant area index (PAI) to estimate the fraction of green LAI (f_g). Model outputs were evaluated against eddy covariance fluxes using footprint modeling. Results demonstrate robust TSEB-PT performance using UAV inputs with minimal ground calibration while highlighting strong sensitivity to LST accuracy, emphasizing the importance of precise TIR calibration. Structural LiDAR-derived metrics presents the possibility of stable LAI estimates during peak growth and under shadowing conditions, whereas MS information better captured functional decline during stress and senescence. Divergence between structural (PAI) and functional (GAI) representations was most evident in winter wheat, where dense canopy structure produced cooling effects unrelated to transpiration. A LiDAR–MS fusion approach to estimate dynamic f_g improved ET estimates across crops and physiological states by better scaling transpiration. High-resolution thermal observations further enabled detection of early spatial reductions in transpiration prior to structural or spectral canopy changes, demonstrating potential for early stress detection and targeted irrigation management. These findings highlight how multi-sensor UAV observations improve TSEB parameterization and provide insight into model behavior across crops and phenological stages, supporting future development, scaling, and structural integration of UAV LiDAR in high-resolution ET applications.

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