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A System for Long-Term Continuous Solar-Induced Chlorophyll Fluorescence Measurements for Synergy with Eddy Covariance Flux Networks

Lianhong Gu[1], Jeffrey D. Wood[2], Christine Yao-Yun Chang[3], and Ying Sun[3]

[1]Environmental Sciences Division and Climate Change Science Institute, Oak Ridge National Laboratory, Oak Ridge, TN
[2]School of Natural Resources, University of Missouri, Columbia, MO
[3]School of Integrative Plant Science, Cornell University, Ithaca, NY

Contact: lianhong-gu@ornl.gov

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Solar-induced chlorophyll fluorescence (SIF) is a direct probe of canopy photosynthesis that provides critical information on the dynamics of terrestrial gross primary production—a unique role that cannot be achieved using any other method. Therefore, long-term continuous SIF observations have the potential to greatly advance terrestrial ecosystem science and applications. Realizing and exploiting this potential requires synergistic implementation of SIF measurements within eddy covariance (EC) flux networks—the backbone of contemporary ecosystem research—because the two measurements provide independent, but complementary information. We currently lack a robust SIF measurement system that can withstand harsh environmental conditions and integrate seamlessly with instrumentation at flux tower sites. Here, we introduce the Fluorescence Auto-Measurement Equipment (FAME) and protocol that fulfill such a purpose. FAME's innovative hardware and software designs aim at versatility, extensibility, autonomous operation, and ease of maintenance for the acquisition of SIF data of unprecedented quality and quantity. FAME has the unique feature that the same system measures ancillary environmental variables at the precise time of spectral irradiance sampling, allowing for the proper interpretation of SIF signal. The FAME prototype has been deployed since September 2016 at the top of a 32 m walkup tower in an oak-hickory forest at the Missouri Ozark AmeriFlux site, and has provided stable measurements even when air temperatures approached 40 °C. Preliminary results reveal that canopy SIF saturates at high light, similar to leaf-level photosynthesis. Furthermore, clear patterns of diurnal hysteresis were observed whereby for the same light level, morning SIF was higher than in the afternoon. We hypothesize that the dynamics of non-photochemical quenching and movements of chloroplasts and leaves may explain the observed pattern. The technology and measurement protocol introduced here advances the coordinated observation of SIF and EC fluxes, and thus represents a step-change in observational ecosystem and carbon-cycle science.