Title: A Closed Model of Light Reactions of Photosynthesis for General Applications

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Project Abstract: Plants have evolved sophisticated mechanisms to balance the light and carbon reactions of photosynthesis as this match is vital to the normal functioning of the photosynthetic apparatus and long-term species survival. In theory, photosynthesis could be modeled from either the light or carbon reactions with a convergence expected. Historically, mechanistic modeling efforts have focused on the carbon reactions. This traditional focus is challenged in the era of growing interest in engineering crops for better photosynthetic efficiency and stress resilience and in using sun-induced chlorophyll fluorescence (SIF) to monitor photosynthesis at different scales; both efforts depend on our predictive capability on not just the carbon but also the light reactions. We have developed a closed system of light reactions that models photosynthesis, SIF and the balance between the light and carbon reactions with internal consistency. The closed system is formed by modeling the regulatory mechanisms of photosynthetic electron transport as a function of excess energy (the absorbed energy that cannot be dissipated photochemically) conditioned with the feedback effects of carbon reactions as influenced by temperature and CO_2 concentration. This solution embodies our understanding of the light reactions and is successfully tested against large datasets of fluorometry and gas exchange measured on a broadleaf deciduous and a needleleaf evergreen species across a wide range of environmental conditions. The closed system of light reactions eliminates circularity in photosynthesis estimation with SIF. It complements carbon reaction models to provide a framework for quantifying the light-carbon reaction balance to assist engineering crops with desired properties.