2012 FLEX/Sentinel-3 Tandem Mission Photosynthesis Study

ABSTRACT

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Abstract

Within the context of ESA's Phase A/B1 assessments of the FLuorescence EXplorer (FLEX) Earth Explorer 8 candidate mission, the Photosynthesis Study developed and tested a mechanistically-based model to link steady-state chlorophyll fluorescence with photosynthesis. The photosynthesis model developed was an advancement of the SCOPE (Soil Canopy Observation of Photochemistry and Energy fluxes) canopy model and comprises state-of-the-art modules connecting leaf fundamental physiology to top-of-canopy outputs of fluorescence and photosynthesis. Tests of the model show successful simulation of canopy primary productivity comparable to that obtained by eddy flux towers, and sensitivity tests revealed the essential parameters needed to optimize computational speed and efficiency. For convenience of usage, a Graphic User Interface called *A-SCOPE* was created and customized for the new SCOPE v1.53 model, with full user documentation and manuals.

Development of simplified algorithms linking fluorescence to photosynthesis was accomplished based on the model. Relatively simple regression models based on Gaussian processes regression and polynomial & rational functions were able to predict photosynthetic products (e.g., net photosynthesis of the canopy, gross primary productivity, light use efficiency, absorbed photosynthetically active radiation by chlorophyll) in unstressed C3 and C4 species. Noteworthy was the finding that in regression models for C3 and C4 plants, the F685 fluorescence emission peak was more informative than the far-red fluorescence. Nonetheless, relationships were stronger when both bands were included and, for C4 plants, the full fluorescence emission profile was essential to meet an error threshold of 10%.

A second component of the research identified steady-state or solar-induced fluorescence features useful as indicators of stress effects from water deficit, temperature extremes, and nitrogen insufficiency. Red and far-red fluorescence peaks and their ratios were found responsive for the detection of physiological strain from these stresses. Novel stress indices were introduced here as well and require further testing. These included the Stress Intensity Fluorescence Index (SIFI), the Temperature Stress Fluorescence Index (TSFI), the Water Stress Fluorescence Index (WSFI), and the Nitrogen Stress Fluorescence Index (NSFI). In addition, the photosynthesis model and its simplified formats and related algorithms also could provide stress indices based on ratios of actual to potential photosynthesis.

Analysis of knowledge gaps with respect to stress applications indicated the topics of vegetation canopy structural effects, environmental heterogeneity, combined stresses, and sources of variability or error as among the highest priority for study. A conceptual framework was then developed to provide strategic guidance in applying space-based fluorescence to stress detection and in planning future research.

Overall, the findings of this study revealed the inherent value of having a minimum of both the red and far-red fluorescence emission peaks, and in C4 plants the full fluorescence profile. This underscores the unique advantages of FLEX, since its FLORIS sensor would be optimized to extract these spectral features with appropriate spatial and spectral detail.

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