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Towards improved quantification of vegetation photosynthetic activity at global scale: the FLuorescence EXplorer (FLEX) mission

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The fluorescence signal, originated from the core complexes of the photosynthetic machinery, is a sensitive indicator of the actual photosynthesis in both healthy and physiologically stressed vegetation, which can be used as a powerful non-invasive marker to track the status, resilience, and recovery of photochemical processes. This is of particular interest for the improvements in the predictive capability of global carbon cycle models through new parameterizations for canopy photosynthesis and the corresponding exchange processes of energy, water and carbon between the surface and the atmosphere. The shape of the fluorescence emission spectrum consists of two peaks having broad bands with maxima around 685 nm and 740 nm. The variations in amplitude and shape of the emission reflect the efficiency of photosynthetic electron transport. The integral of the overall fluorescence emission provides information about actual photosynthetic light conversion. The shape of the emission spectrum provides additional information about the vegetation health status.

While most of the information that has been acquired by remote sensing of the Earth's surface about vegetation conditions and photosynthetic activity has come from "reflected" light in the solar domain, the ESA's Earth Explorer candidate FLEX (Fluorescence EXplorer) mission is the first space mission focused on the estimation of fluorescence emission by terrestrial vegetation on a global scale with high spatial resolution and resolving the spectral shape of fluorescence emission. The FLEX mission also includes explicit measurement of photochemical changes in reflectance (i.e. PRI), canopy temperature measurements and all the relevant variables (chlorophyll content, Leaf Area Index, etc.) needed to asses the actual physiological status of vegetation and to provide quantitative estimates of photosynthetic rates and gross primary production. FLEX is one of two candidate Earth Explorer-8 missions currently under Phase A/B1 assessment. The FLEX mission concept consist in a single platform that carries a Fluorescence Imaging Spectrometer (FLORIS), which has been designed and optimised for discrimination of the fluorescence signal in terrestrial vegetation, providing images with a 150 km swath and 300 m pixel size. FLORIS will measure the radiance between 500 and 780 nm with a bandwidth between 0.1 nm and 2 nm, with high spectral resolution of 0.3 nm in particular at the Oxygen-A (755-780 nm) and -B bands (677-697 nm). It will also cover the photochemical reflectance features between 500 and 600 nm, the chlorophyll absorption region and the red-edge, which allow a highly accurate measurement of the spectral distribution of vegetation fluorescence in absolute terms as needed by physically-based retrieval methods. FLEX will fly in formation with Sentinel-3 in order to further enhance the spectral coverage from measurements made by the Sentinel-3 instruments OLCI and SLSTR, exploiting the synergy between their data and helping in the proper characterization of the atmospheric state and cloud screening, essential for a reliable retrieval of fluorescence emission.

In this paper, we provide the relevant scientific background and an overview of the FLEX mission concept, measurement methods and scientific challenges, describing current status and perspectives in assimilation of the fluorescence information in Dynamical Vegetation Models.