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i-φ-MaLe: a novel AI-phasor based method for a fast and accurate retrieval of multiple Solar-Induced Fluorescence metrics and biophysical parameters

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The accurate retrieval of Solar-Induced chlorophyll Fluorescence (SIF) is a pivotal target for Earth Observation since SIF can be easily monitored through optical remote sensing and provides unique information concerning the vegetation health status. Here, we propose i-φ-MaLe (metti il nome per esteso), a novel algorithm, which couples the Fourier analysis with a supervised machine learning-based procedure trained with the atmosphere-canopy radiative transfer (RT) SCOPE model. i-φ-MaLe is the first method able to simultaneously retrieve, from the vegetation reflectance spectra, the Top Of Canopy SIF spectrum, the SIF spectrum corrected for leaf/canopy reabsorption (i.e. at photosystem level), the quantum efficiency (Fqe) and three canopy-related biophysical parameters (Leaf Area Index - LAI, Chlorophyll content - Cab and APAR) in few milliseconds. Validation procedures, based on the analysis of RT simulations, demonstrated that i-φ-MaLe, in experimental conditions (signal to noise ratio – SNR >= 500), estimates each biophysical parameter and SIF spectrum with a relative root mean square error (RRMSE) lower than 5%. In order to investigate the seasonal and daily dynamics of SIF, LAI, Cab, Fqe and APAR, the method has been also applied to field experimental data collected in the context of the AtmoFLEX and FLEXSense ESA campaigns, both at top-of-canopy (TOC) and tower (~100 meters) levels. Concerning the TOC scenario, the retrieved annual dynamic for SIF spectra has been compared with the results obtained by inversion-based methods, showing a good consistency amongthe different approaches (RRMSE ~ 10%). Moreover, SIF daily and annual dynamics, retrieved by excluding the oxygen spectral bands affected by the atmospheric reabsorption, have been investigated for high tower measurements. . In this context, i-φ-MaLe provided promising results that can integrate and possibly overcome complex and computationally expensive atmospheric compensation techniques actually needed to retrieve fluorescence from oxygen absorptions bands. This study demonstrates a promising potential to exploit ground and tower spectral

measurements with advanced processing algorithms, for improving our understanding on the link between canopy structure and physiological functioning of plants. Moreover, i-φ-MaLe can be straightforwardly employed to process reflectance spectra and open new perspectives in fluorescence retrieval at different scales.