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Sun-induced chlorophyll fluorescence to understand the responses of terrestrial ecosystem functioning to climate, environmental changes and extreme events

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Understanding the responses of ecosystem functioning to climate extremes and environmental changes is an imperative question in global change ecology. Therefore, the development of tools for monitoring the effects of increasing temperature, water stress, increasing atmospheric CO_2 concentration, and nutrient availability on ecosystem functioning (e.g. photosynthesis and water use efficiency) is pivotal. Reflectance based spectroscopy can be used to directly infer variations in biochemical and partially structural changes of vegetation under different meteorological and environmental conditions. Besides, novel measurements of sun-induced chlorophyll fluorescence (SIF) both in the red and far-red regions open new pathways to non-invasively quantify dynamic changes in ecosystem functioning. However, the mechanistic link between photosynthesis, water use efficiency and SIF under different environmental conditions is not completely understood yet.

In this contribution we will synthesize the information coming from a series of campaigns at different eddy covariance sites as well as climate and nutrient manipulation experiments. We collected data from 1) a nitrogen (N) and phosphorous (P) manipulation in a Mediterranean grassland; 2) and a climate manipulation experiment, with elevated CO_2 (+0, +300 ppm), temperature (+0, + 3 °C) and water stress (rain manipulation with shelters), and the combination of the three factors; 3) and various sites where eddy covariance data and SIF were measured simultaneously.

Results show that elevated CO_2 causes an increase of both GPP and SIF. SCOPE simulations show that the increase in SIF emission can be explained by the reduction of Non Photochemical Quenching (NPQ) associated with the higher observed Vcmax and intercellular CO_2 concentration (Ci), which ultimately leads to higher SIF than under ambient CO_2. The N fertilization induced changes in canopy structure and functional traits, which lead to an increase of SIF and GPP, but with a functional relationship between the two variables and modulated mainly by community structure (e.g. fraction of graminoids) and secondarily Vcmax. Surprisingly, we observed a statistical significant effect of P on SIF emission that we demonstrated to be related to the enhancement of the electron transport rate associate with higher P content in leaves. GPP and SIF under water stress treatments and combined CO_2, temperature stress, and water stress showed the expected reduction, associated with an increase in water use efficiency. This comprehensive dataset shows that changes in species and therefore structure and leaf contents induced by treatments can enhance SIF sensitivity to vegetation responses, but have also a confounding effect on the connection between SIF and functioning. Integrated approaches capable of characterize plant structure, composition and function together are necessary to truly understand the different strategies of vegetation to face environmental change. Less clear is the effect of heat waves and temperature stress: while we overall observed reduction of GPP, the response of SIF and water use efficiency is very different across vegetation types. We hypothesize that this response might be related to different stomatal behavior and strategies to cope with heat stress.