Remote sensing of instantaneous drought stress using sun-induced chlorophyll fluorescence and hyperspectral canopy refelctance

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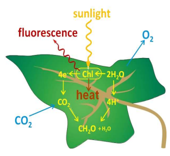
Goal: detect drought onset using remote sensing

Drought is one of the major reasons for global crop yield loss. This research aims at **detecting the drought onset** with remote sensing data. To do so, the **sun-induced chlorophyll fluorescence (SIF)** signal is used. This signal originates from a photon that is re-emitted by a chlorophyll molecule, and it is therefore mechanistically coupled to the photosynthetic apparatus, making **SIF sensitive to small-drought induced changes in photosynthetic activity**. Since SIF only comprises only of 2% of the absorbed radiation, it can only be measured in solar telluric lines or atmospheric absorption lines, in which solar irradiation is absent. This research focusses on SIF in the O_2A absorption band, which is the best-described band. The European Space Agency plans to **launch the Fluorescence Explorer (FLEX) in 2025** to measure SIF at the global scale. In order to maximally benefit from the FLEX observations, it is necessary to precisely describe the link between SIF and increasing drought conditions.



Maxwell & Johnson, 2000

Chlorophyll fluorescence is mechanistically coupled to photosynthesis

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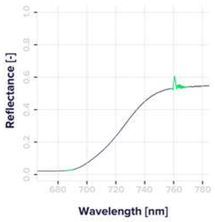

State of the art spectrometers allow measurements in narrow spectral windows

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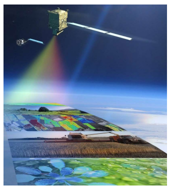
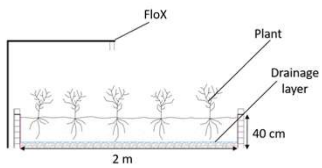


Final goal: FLEX measures ecosystem stress at the global scale

Need for **FIELD EXPERIMENT** to characterize **SIF DROUGHT RESPONSE**

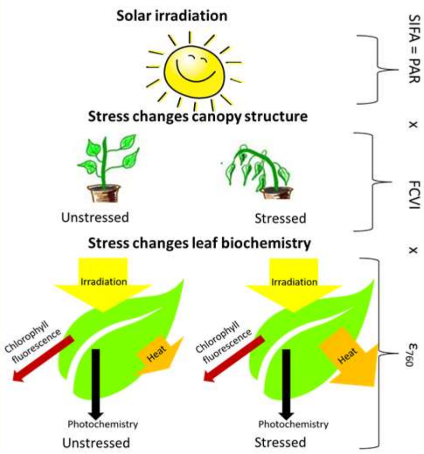
Description of field experiment

By making use of **continuous observations** of SIF and hyperspectral canopy reflectance along with environmental variables during the entire growing season, it is possible to get the behavior of SIF under **different environmental conditions**. The experiment was performed once with mustard and once with lettuce. Lettuce is known for its anisohydric properties.



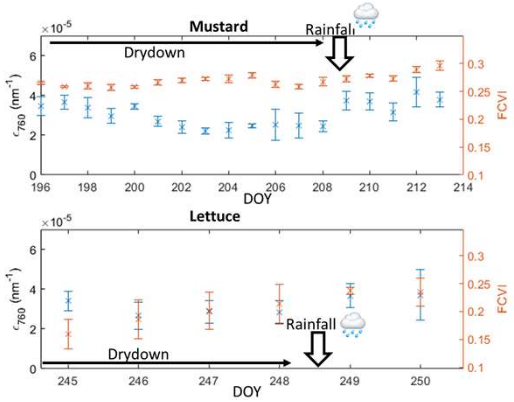
Extracting biochemical information from the SIF signal

As a by-product of photosynthesis, **SIF is mainly impacted by the solar irradiation (PAR).** The SIF is also affected by two plant variables, being the canopy structure and the fluorescence emission efficiency (ε). The canopy structure's contribution to the SIF signal is characterised with the Fluorescence Correction Vegetation Index (FCVI). **The biochemical component of SIF can be isolated by normalizing SIF by PAR and FCVI.** This approach is only valid in the O_2A band, at 760 nm.



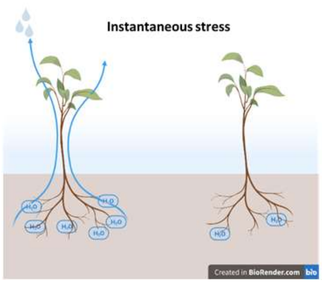
Results

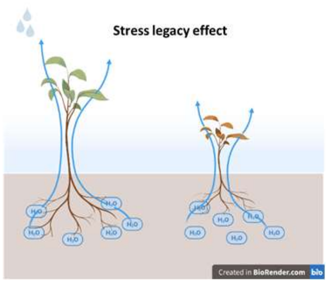
The biochemical component of the SIF decreased during a drydown for both the lettuce and the mustard dataset, albeit more expressed for the mustard dataset. After a rainfall, ε760 promptly jumped up again. In the lettuce dataset, However, the daily standard deviation in the FCVI increased in the lettuce dataset increased during stressed days. This can be linked to leaf hanging, a sign of low turgor in lettuce plants at mid-day. This can be linked to the anisohydric nature of the lettuce plant, causing it to rather drop its turgor pressure than to close its stomata. The mustard FCVI did not show any reactivity to the drought stress.



Conclusion

The **SIF biochemical component reacts instantaneously** to changes in soil moisture during and after a drydown. This way, SIF is an indicator the stress conditions at the very moment of the measurement, this way, SIF, as well as its biochemical component, is affected by both its soil and meteorological conditions. The short-term changes in FCVI is another indicator of the instantaneous stress condition. Since both indicator originate from different parts of the stress reaction; the structural change is the result of turgor loss, the change in ε is the result of a change in the photosynthesis. As a result, ε and FCVI are **complementary stress indicators**. The isohydricity determines whether a plant shows a clearer reaction in its turgor or in its leaf biochemistry. In contrast to FCVI and ε, more classical optical remote sensing metrics, like **NDVI, measure drought legacy effects**, like pigment loss or defoliation, rather than the drought itself.





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