# On the relationship between sun-induced fluorescence and gross primary productivity during a heat wave

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**Background:**

- Plants use the absorbed photons for three processes: photochemistry, chlorophyll fluorescence and heat dissipation – a change in the yield of one process entails compensating changes in the others.
- Sun-induced chlorophyll fluorescence (SIF) is one option to address the efficiency of photosynthesis
- By now, SIF was successfully used to monitor gross primary productivity (GPP) under conditions were it changed due to variations in absorbed photosynthetically active radiation (aPAR) over a) seasonal cycles and/or b) latitudinal gradients in productivity – but there are unanswered questions on how SIF reacts to short-term changing environmental conditions, in e.g. temperature, when aPAR is stable

Our **study aim** was to examine how SIF and photosynthesis change during a short-term temperature induced stress situation (i.e. heat wave).

**Study site:** The Yatir forest (ISR) is a ca. 60 years old forest, planted at the northern edge of the Negev desert. Summers are characterized by enduring drought periods and winters by moderate temperatures and precipitation. Additionally, the forest experiences frequently occurring heat waves (termed hamsin), mainly during springtime. These heat waves build up over a period of 1-7 days and can hold changes in daily temperature of over 10 °C.

(I) Yatir forest is an open forest with sparse understory, dominated by Aleppo pine (*Pinus halepensis* Miller); trees reach a height of ca. 10 m.



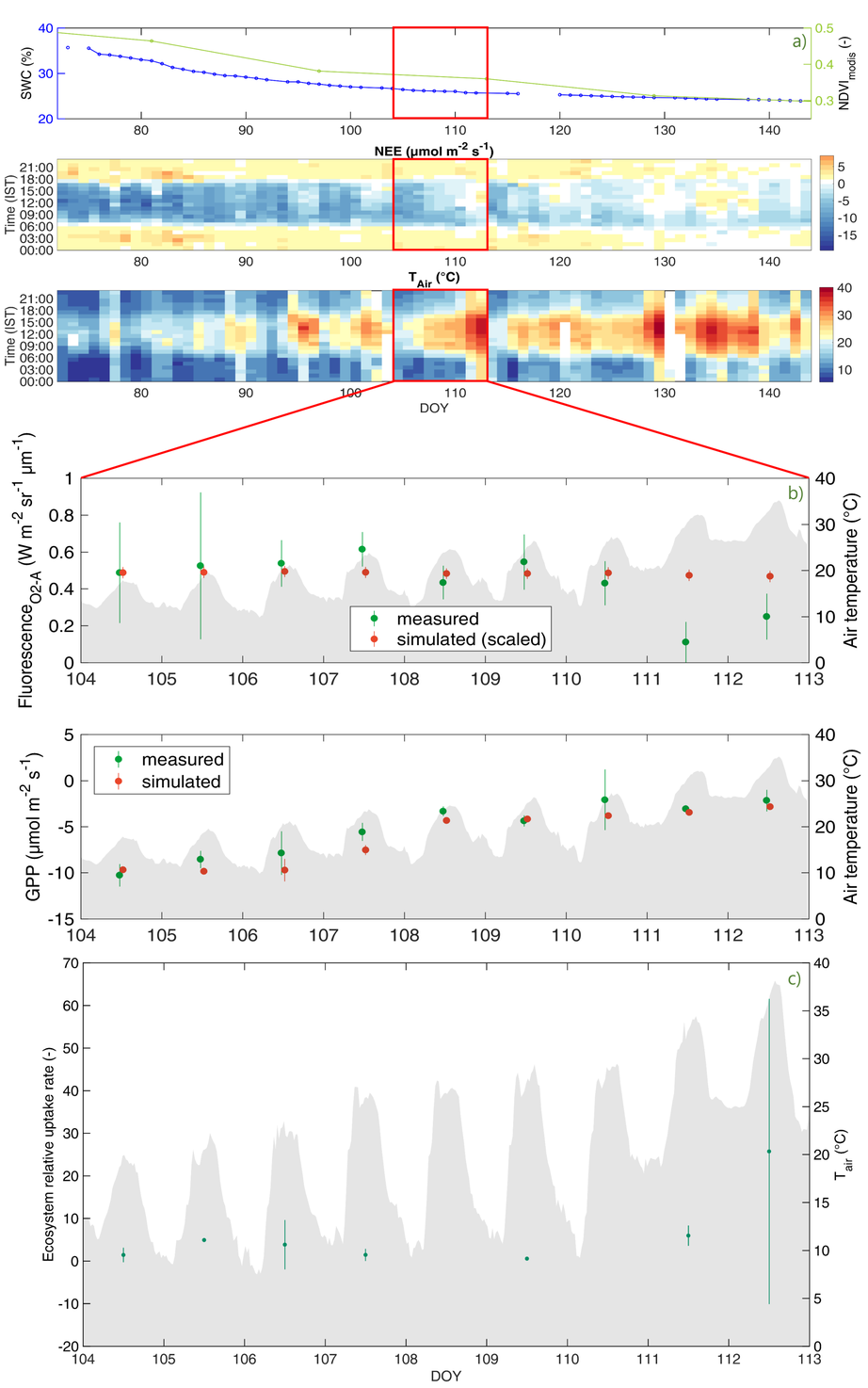
(II) Set up (19 m a.g.l.) of the FLOX (SIF measurement device), NNW-facing. Up-welling radiance was measured at a zenith angle of ca. 30°.

**Methods:** During April 2017, we measured SIF (set-up, see *Fig. II*) in Yatir forest as an additional part of a three month (March-May) eddy covariance (EC) measurement campaign, also involving measurements of carbonyl sulphide (COS/OCS) and carbon dioxide ($CO_2$) with a quantum cascade laser absorption spectrometer (QCLAS). We also used the soil–canopy observation of photosynthesis and energy (SCOPE) model for a process analysis of measurements.

**Hypothesis:** A decrease in the photochemical activity during the heat wave will lead to an increase in SIF.

**Findings:**

- EC measurements of COS (not shown) and $CO_2$ (*III-a, middle panel*) demonstrate a decline in stomatal conductance during the change from well-watered (winter) to dry (spring/summer) conditions, supporting previous findings of other studies
- *III-b, lower panel*: GPP (from $CO_2$ flux partitioning) linearly declined over the course of the heat wave in April (DOY: 104-113)
- *III-b, upper panel*: SIF decreased during the course of the heat wave (DOY: 104-113), notably during the hottest two days; simulated SIF, however, showed a less obvious decline. The decline could be explained by using SCOPE: A temperature-induced decrease in the maximum fluorescence yield of light-adapted leaves over-compensated the effect of the parallel reduction in the photochemical yield
- *III-c, lower panel*: An increase in the ERU during the hottest days of the heat wave indicates the down regulation of photosynthesis




(III-a) Soil water content (SWC) and the normalized difference vegetation index (NDVI; from MODIS) declined over the course of the campaign, as well as the net ecosystem exchange (NEE). Air temperatures steadily increased from mid-March untill the end of May; the April-hamsin event between DOY 104-113 can clearly be seen (highlighted by the red rectangle).
Values of NEE (gap-filled)and $T_{air}$ are hourly means of EC measurements; white spaces in $T_{air}$ are due to instrument failures.

(III-b) Fluorescence and GPP during the heat wave. Measurements depict a clear decline of SIF during the hottest two days of the hamsin event, whereas simulated data (using SCOPE) only showed a slight decrease. GPP also decreased and both, measured as well as simulated data, showed the same trend.

(III-c) Ecosystem relative uptake rate (ERU) calculated as $ERU = {}^{(COS_{flux}/COS)}/_{(GPP/CO_2)}$.
The trend of the ERU during the first days of the hamsin event shows that the physiological response of the trees was basically regulated by stomatal conductance, however, during the last two days the ERU increased, indicating a down-regulation of photosynthesis.
Data represents mean values of measurements between 10 am and 2 pm.

**Conclusion:** Plants at Yatir forest reduced their stomatal conductance and down-regulated their photosynthesis during a heat wave, however, SIF was also reduced with increasing temperatures. Our findings suggest that it may be challenging to use SIF for monitoring GPP in situations when aPAR remains unaffected and temperature becomes the main driver for changes in GPP.