Geophysical Research Abstracts
Vol. 20, EGU2018-13094, 2018
EGU General Assembly 2018

Gross primary productivity during a heat wave – putting sun-induced fluorescence to the test

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Gross primary productivity (GPP) is the proximal driver of the terrestrial land sink, which presently removes around one quarter of the anthropogenic carbon dioxide (CO_2) emissions from the atmosphere each year and thus contributes towards slowing down anthropogenic climate change. Beyond the scale of single leaves, however, GPP cannot be measured directly, but instead must be inferred by means of some model from a related variable. During the past decade, measurements of sun-induced fluorescence (SIF) have been proposed to hold great promise for remote sensing of GPP, based on the fact that fluorescence and photosynthesis compete for the same energy. So far, the potential of SIF for estimating GPP has been demonstrated mostly for situations where/when variability in GPP was largely driven by underlying changes in the fraction of absorbed photosynthetically active radiation (fAPAR). In this study we investigated the potential of SIF as a proxy for GPP during a short-term heat wave, during which fAPAR remains constant and changes in pigment pools can be considered negligible, but a significant down-regulation of photosynthesis is expected. To this end, flux measurements of CO_2 and carbonyl sulfide (COS), together with SIF were made during April 2017 at Yatir forest (Israel).
During the eight days long heat wave, maximum daily air temperature increased from 20°C to over 35°C, which went along with a steady decline in GPP. The ecosystem relative uptake of COS compared to CO_2 remained relatively stable, except for the last days of the heatwave, when an increase indicated a progressive shift from a diffusional to a biochemical limitation of photosynthesis. SIF decreased slowly initially and then rapidly during the peak of the heat wave. Using the SCOPE model, this decrease could be shown to result from a concomitant temperature-driven decrease in the maximum light-adapted fluorescence, which counteracted the decline in photochemical yield. SIF thus explained just 35 % of the variability in GPP and we conclude that SIF has limited potential for monitoring GPP in the absence of large changes in fAPAR.