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Remote sensing to track differential responses of forests and grasses to variations in soil water content

Sophia Walther (1,2,3), Gregory Duveiller (2), Martin Jung (3), Luis Guanter (1,4), Alessandro Cescatti (2), and Gustau Camps-Valls (5)

(1) GFZ German Research Centre for Geosciences, Helmholtz-Centre Potsdam, Section 1.4 Remote Sensing, Germany, (2) European Commission, Joint Research Centre, Ispra, Italy, (3) Max-Planck-Institute for Biogeochemistry, Jena, Germany, (4) Institute of Earth and Environmental Science, Potsdam University, Potsdam, Germany, (5) Universitat de València, Image Processing Laboratory (IPL), València, Spain

Increasing evidence points towards soil moisture availability as the single most important factor
for variations of vegetation productivity between years [1,2] with substantial effects on fluctuations in the atmospheric CO 2 growth rate [3]. Forests sequester about half of the global annual biospheric carbon uptake, yet, there are still gaps in our understanding of how short-term environmental fluctuations affect their metabolism and photosynthetic activity. Current observational capabilities are limited as the trees do not show immediate visible signs of stress or health.

In our study, we re-evaluate how plant productivity varies globally with changing soil moisture along a tree cover gradient. For that, we use three different types of remote sensing proxies for vegetation productivity (16 day temporal and 1degree spatial resolution) : 1) traditional vegetation indices sensitive to greenness (EVI, NDVI, NIRv based on MODIS surface reflectances MCD43C4), 2) sun-induced chlorophyll fluorescence as a proxy for photosynthesis (based on GOME2), and 3) data-driven estimates of gross primary productivity based on machine learning upscaling of flux-tower data (FLUXCOM,http://www.fluxcom.org/). We find that, when soil water content is reduced, both fluorescence and the modelled gross photosynthesis reflect a consistent pattern of enhanced photosynthesis for high tree cover and reduced photosynthesis in regions with low tree cover. In contrast, the traditional satellite-based greenness indices do barely show this pattern of increased forest productivity during below average soil moisture. Our work therefore represents an important incentive to reconsider the differential responses of ecosystems along a tree cover gradient and it illustrates the importance of differentiating indicators of plant greenness from those of photosynthesis for the monitoring and understanding of ecosystems. Moreover, by evaluating the variability in proxies of absorbed light energy and of the efficiency of using it in C-fixation or reemission as fluorescence we can explain that the effects of higher illumination (and temperature) concurrently to and despite of reduced soil water content on photosynthesis actually overcompensate opposed changes in light-use-efficiency in forests on average (and vice versa for wetter than normal conditions).

[1] Ahlström et al. 2015, Science, doi: 10.1126/science.aaa1668;
[2] Jung et al. 2017, Nature, doi:10.1038/nature20780)
[3] Poulter et al. 2014, Nature, doi:10.1038/nature13376