Geophysical Research Abstracts
Vol. 12, EGU2010-12858, 2010
EGU General Assembly 2010

Imaging and imagining the spatio-temporal variations of photosynthesis – remote sensing of sun-induced fluorescence to understand physiological changes of the photosynthetic apparatus

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Light use efficiency of photosynthesis dynamically adapts to environmental factors, which lead to complex spatio-temporal variations of photosynthesis on various scales from the leaf to the canopy level. The need to scale leaf-level physiology to ecosystem responses and climate feedbacks has been emphasized recently in the context of global climate change research.

Recently the FLuorescence EXplorer (FLEX) mission that proposed to launch a satellite for the global monitoring of steady-state chlorophyll fluorescence in terrestrial vegetation was selected for pre-phase A by European Space Agency (ESA). This method aims for mapping photosynthetic efficiency by quantifying steady state fluorescence in the so called Fraunhofer lines. In preparation for this satellite mission an extensive field campaign was conducted. The CEFLES2 campaign during the Carbo Europe Regional Experiment Strategy was designed to provide simultaneous airborne measurements of solar induced fluorescence and CO2 fluxes. It was combined with extensive ground-based quantification of leaf- and canopy-level processes. The aim of this campaign was to test if fluorescence signal detected from an airborne platform can be used to improve estimates of plant mediated exchange on the mesoscale. Canopy fluorescence was quantified from four airborne platforms using a combination of novel sensors including a prototype airborne sensor AirFLEX quantifing fluorescence in the oxygen A and B bands, and the first employment of the high performance imaging spectrometer HYPER delivering spatially explicit and multi-temporal transects across the whole region. During three measurement periods in April, June and September 2007 structural, functional and radiometric characteristics of more than 20 different vegetation types in the Les Landes region, Southwest France, were extensively characterized on the ground focussing especially on quantifying plant mediated exchange processes (photosynthetic electron transport, CO2 uptake, evapotranspiration) and fluorescence emission. On the large scale, airborne and ground-level measurements of fluorescence were compared on several vegetation types supporting the scaling of this novel remote sensing signal. The multi-scale design of the four airborne radiometric measurements along with extensive ground activities fosters a nested approach to quantify photosynthetic efficiency and gross primary productivity (GPP) from passive fluorescence. Linking these results with ecosystem flux measurements and regional carbon modeling shows the way how direct quantification of photosynthesis may reduce uncertainties to predict plant mediated exchange processes.

Selected Publications

[1] Rascher U. & Nedbal L. (2006) Dynamics of plant photosynthesis under fluctuating natural conditions. Current Opinion in Plant Biology, 9, 671-678.

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[3] Soukupová J., Cséfalvay L., Urban O., Košvancová M., Marek M., Rascher U. & Nedbal L. (2008) Annual variation of the steady-state chlorophyll fluorescence emission of evergreen plants in temperate zone. Functional Plant Biology, 35, 63-76.

[4] Rascher U., and 35 others (2009) CEFLES2: The remote sensing component to quantify photosynthetic efficiency from the leaf to the region by measuring sun-induced fluorescence in the oxygen absorption bands, Biogeosciences, 6, 1181-1198.
[5] Damm A., Elbers J., Erler E., Gioli B., Hamdi K., Hutjes R., Kosvancova M., Meroni M., Miglietta F., Moersch A., Moreno J., Schickling A., Sonnenschein R., Udelhoven T., van der Linden S., Hostert P. & Rascher U. (2010) Remote sensing of sun induced fluorescence to improve modeling of diurnal courses of gross primary production (GPP). Global Change Biology, 16, 171-186.