POTSDAM
GHG FLUX WORKSHOP

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Potsdam Greenhouse Gas Workshop
From Photosystems to Ecosystems
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Abstracts

PDF documents of provided posters are in this abstract book accessible via a download link above respective poster abstract.

Contents

Keynote Presentations

Keynote 02: Understanding Carbon Export from the Calvin-Benson Cycle Using Gas Exchange and Fluorescence

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Carbon assimilation in the Calvin-Benson cycle is the first step toward plant growth and primary productivity. It is convenient to study this metabolism at the leaf level, which allows connections to biochemical reactions and photosynthetic electron transport on the one hand and can be scaled up on the other hand. The response of leaf photosynthetic carbon assimilation (A) to CO_2 gives significant information about the underlying metabolism. Stomatal effects can be accounted for by using the stomatal conductance to estimate the CO_2 concentration in the intercellular air spaces inside the leaf. Additional diffusional constraints can also be accounted for in a parameter called mesophyll conductance. For historical reasons, even when the CO_2 concentration at Rubisco is used in modeling the curves are called A/C_i curves. By adding information from fluorescence yield data, it is possible to map conditions where carbon input into the cycle determines the rate of photosynthesis and electron transport. A second condition is where carbon processing or light input determines the rate of photosynthesis. Less often accounted for is when carbon output from the Calvin-Benson cycle sets the rate of photosynthesis. Optimal photosynthesis occurs when each of these rate-determining steps are fully utilized. However, each is affected by environmental variables in different ways and so there is no single mix of capacities that is optimal for all conditions. This is well-illustrated by CO_2-inhibition of photosynthesis. Regulatory processes that optimize photosynthesis under some conditions can result in reverse CO_2 sensitivity, especially at high CO_2 and low temperature. This results from an inhibition of the capacity for starch synthesis at very high rates of photosynthesis. In some cases, this can be overcome by a bypass of the inhibited enzyme. This cytosolic bypass for starch synthesis increases the flexibility of carbon metabolism, in some cases allowing plants to survive even when they lack an enzyme that should be essential for photosynthesis. However, in some cases the cytosolic bypass can lead to a glucose-6-phosphate shunt that uses up ATP without net CO_2 fixation. The cytosolic bypass and the glucose-6-phosphate shunt provide mechanisms that help plants optimize carbon metabolism so that light use efficiency can remain high under widely varying conditions.

Keynote 06: Addressing the problem of scale.

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As we move up in scale from the chloroplast to the leaf, canopy, region, and ultimately, to the globe, our ability to accurately predict photosynthesis (or gross primary production (GPP)) diminishes. Similarly, our understanding is better at the scale of minutes to hours than at interannual or decadal time frames. Yet the significance for understanding climate and environmental change increases as we ascend this ladder of scale. This challenge of scale is central to our effort to understand what is happening to our planet. The goal of this presentation is to initiate a discussion of this problem. I will draw on two recent studies to get this started. The first is a historical reconstruction and modeling of the concentration of carbonyl sulfide to address the response of global photosynthesis to CO_2 fertilization. The second concerns the emergence of solar induced fluorescence as a proxy for GPP at large scale. In these examples, new measurement technologies have opened new windows on the carbon cycle, but at the same time we find ourselves challenged by mechanistic considerations that were not previously (or even now) thought to be significant by physiologists. The flow of information and challenges up and down these ladders of scale is critical for speeding progress.

Keynote 09: Recent advances in global monitoring of terrestrial sun-induced chlorophyll fluorescence

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Global retrievals of sun-induced chlorophyll fluorescence (SIF) from space have been available since late 2011 from a number of spaceborne spectrometers originally intended for atmospheric research. The first global measurements of SIF were achieved from high spectral resolution spectra acquired by the Japanese GOSAT mission. Global measurements of SIF from ENVISAT/SCIAMACHY and MetOp-A/B GOME-2 followed those from GOSAT. This observational scenario has been completed by the first SIF data from the NASA-JPL OCO-2 mission launched in July 2014, and great expectations are put on the upcoming TROPOMI instrument onboard the Copernicus' Sentinel 5-Precursor mission launched on 13 October 2017. OCO-2 and TROPOMI offer the possibility of monitoring SIF globally with a 100-fold improvement in spatial and temporal resolution with respect to GOSAT, GOME-2 and SCIAMACHY. In particular, TROPOMI will provide daily global coverage with ~3-km spatial resolution and continuous spectral coverage of the visible and near-infrared part of the spectrum. The recent selection of FLEX as the ESA Earth Explorer 8 to be launched around 2022 and several upcoming geostationary mission with potential for SIF retrievals complete an exciting near-future scenario for the monitoring of SIF from space.

This talk will provide an overview of global SIF monitoring and will illustrate the potential of SIF data to improve our knowledge of vegetation photosynthesis at the synoptic scale. We will show examples of ongoing research exploiting SIF data for an improved monitoring of photosynthetic activity at different ecosystems, and will discuss existing issues for the interpretation of the top-of-canopy SIF signal retrieved from space measurements, such as canopy structure and physiological aspects.

Keynote 10: Light Use Efficiency in C3 and C4 Crops

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Vegetation productivity metrics such as gross primary production (GPP) at the canopy scale are affected by the efficiency of using absorbed radiation for photosynthesis, or light use efficiency (LUE). Thus, close investigation of the relationships between canopy GPP and photosynthetically active radiation absorbed by vegetation is the basis for quantification of LUE. Multiyear observations over irrigated and rainfed contrasting C3 (soybean) and C4 (maize) crops having different photosynthetic pathway, physiology, leaf structure, and canopy architecture were used to establish the relationships between canopy GPP and radiation absorbed by vegetation and quantify LUE. Although multiple LUE definitions are reported in the literature, a definition of LUE_{green} based on radiation absorbed by "green" photosynthetically active vegetation on a daily basis has been used. We quantified, irreversible slowly changing seasonal (constitutive) and rapidly day-to-day changing (facultative) LUE_{green}, as well as sensitivity of LUE_{green} to the magnitude of incident radiation and drought events. The quantitative framework of LUE_{green} estimation presented offers a way of characterizing LUE_{green} in plants that can be used to assess their phenological and physiological status and vulnerability to drought under current and future climatic conditions as well as is essential for calibration and validation of globally applied LUE algorithms.

Keynote 13: Cost Action "Innovative Optical Tools for Proximal Sensing of Ecophysiological Processes"

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OPTIMISE COST Action ES1309 builds on the work done in previous international initiatives (SPECNET, BIOSPEC and COST Action ES0903), which explored the use of proximal optical sensing of ecosystems, where carbon and water vapour fluxes are estimated by eddy covariance techniques. The recent advances in Unmanned Aerial Vehicle (UAV) platforms and optical sensors provide unprecedented opportunities for high spatial, spectral and multi-angular near-ground Earth observations. Important progress is also being made in remote sensing of steady-state fluorescence, the most direct proxy for photosynthesis

The aim of the presented COST Action is to optimise reflectance and fluorescence measurements for ground validation of Earth system models and global satellite observations. The specific objectives are:

i. To promote the use of a common 'smart' on-line **spectral information system** to share and standardize proximal sensing data and products.
ii. To bridge the scaling gap between tower measurements and satellite data by integrating **UAV-based proximal sensing** and modelling at differing spatial and temporal scales.
iii. To support and **enlarge the global spectral sampling network** and enhance the understanding of reflectance and fluorescence.
iv. To harmonize instruments and measurement **protocols** to be adopted across flux sites in different ecosystems.

The OPTIMISE COST Action brings together scientists working within the 3 areas: i) Spectral Information Systems, ii) UAV technologies and iii) Reflectance & Fluorescence. OPTIMISE objectives are being reached through a wide range of networking tools supported by COST, such as conferences, workshops, training schools, individual Short-Term Scientific Missions, publications and conference grants. More information may be found on http://optimise.dcs.aber.ac.uk/.

Keynote 15: Eddy Covariance technique as a tool to quantify water use efficiencies at the ecosystem level

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The eddy covariance technique is used worldwide to provide direct and continuous ecosystem-scale measurement of CO_2 and water vapor exchanges between the atmosphere and the surface. This technique requires fast-response (ca. 10 Hz) measurements of densities of CO_2 and water vapor and wind speed near the surface, providing direct information about turbulent fluxes on timescales from half-hours to years. Despite the difficulties of instrument maintenance, long-term integrations of CO_2 and water vapor exchange are feasible. Therefore, the eddy covariance technique is considered an indispensable tool for monitoring the global carbon and water vapor exchange. Water use efficiency (WUE) can be define as the amount of carbon gained per unit of water loss. However, its formulation depends on the technique utilized to measure its components as well as the operating spatial scales. In this regard, the eddy covariance technique can be used for calculating the WUE at the ecosystem level. In a global context, ecosystem WUE is crucial for characterizing the relationships between plant structural and chemical–physiological traits and ecosystem functional properties related to carbon and water fluxes. The objective of this presentation was divided in three main parts: (1) to provide a general overview about the eddy covariance technique, main basis, limitations and uncertainties; (2) to present different definitions and types of WUE; (3) to show examples and main result from bibliography about the use of the eddy covariance technique to calculate the WUE at the ecosystem level, focused in different definitions of WUE and different spatial scales.

Keynote 16: The surface renewal method and its application for GHG measurements over irrigated crops

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During the last 20 years, the surface renewal analysis (SR) method for estimating the surface flux of a scalar (pioneered by Paw U et al., 1995), has been mostly used to estimate the sensible heat flux (H). This focus derives from the relative affordability of measuring air temperature at high frequencies. For field applications the latent heat flux (LE) can be then determined as a residual of the simplified surface energy-balance equation. To extend the use of surface renewal analysis to estimate the flux of other scalars, such as carbon dioxide, H and LE are required to correct for the effects of fluctuating air density. Starting from 1995, an historical overview is given to better understand key research carried out on the SR method and advancements towards its independent application (Castellví, 2004; Castellví et al., 2008).

Recent applications of the SR method were extended to different scalars for estimating H, LE, CO2 and CH4 flux for irrigated crops. The high frequency data (20 Hz) was collected by the eddy covariance (EC) equipment deployed over rice and cotton crops in Arkansas (USA). EC fluxes were computed using EddyPro (advanced settings) after the correction for transducer shadowing in the sonic anemometer wind measurements following Horst et al. (2015). The linear regression results showed the good agreement for H, LE and CO2 fluxes when compared to EC as a reference method. The slopes were close to 1 and the offsets were small regardless of the crop, measurement height and stability conditions. Very small scatter was noticed for H and LE for both crops (R2 from 0.88 to 0.93), while more scatter for CO2 flux (R2 from 0.65 to 0.85). The SR application in CH4 measurements is still uncertain due to poorer linear regression comparison outcome. More research is required to address the possibility of capturing all of the transport mechanisms for CH4 in the rice paddies.

Keynote 17: Dynamics of photoprotection mechanisms through passive measurement of SIF, reflectance and transmittance at a leaf scale

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When experiments to develop and test remote sensing of Sun-induced fluorescence (SIF) started to take place, it became evident that we also needed some direct measurement at field level in order to validate the indirect results. The result was the design of a device that was capable of providing such measurement.

It allows measuring at leaf level, by means of a short-pass cut-off filter the fluorescence emission spectrum. It was rapidly found the versatility of the clip to provide more information than just SIF for validation purposes. Since, it also measures leaf reflectance and transmittance, that allows an accurate estimate of absorbance; hence of APAR, as well as PRI. Thus, suitable to monitor different quenching mechanisms of plants under stress.

Some examples of experiments are provided, such as urban trees under different air pollution levels, corn crops with a gradient of water availability and the adaptation of sugar beet during a heat wave.

Keynote 19: HyScreen: Hyperspectral Ground Imaging System for reflectance and fluorescence

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As part of the German Plant Phenotyping Network (DPPN) the Forschungszentrum Jülich is building a new automated positioning system for high throughput plant phenotyping. To support the mobile platforms initiative as well as the European Space Agency's Flex-satellite mission, HyScreen, a new hyperspectral imaging system for ground-based measurements of Sun Induced Fluorescence (SIF) and hyperspectral reflectance was developed. By using HyScreen, which mimick Hyplant characterisctics, we aim to improve our understanting of SIF signal (i.e spatial variability, contribution of shaded/sunlit components). In this study we present the technical requirements and acquisition protocols needed for reliable and accurate reflectance and fluorescence ground measurements (i.e. signal to noise ratio, flat flied, point spread function). Fuerthemore the first HyScreen fluorescence images obtained from representative samples (i.e. vegetation, non-fluorescence targets, and active reference) will be shown.

Keynote 21: SPECCHIO Spectral Information System

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Spectral data recorded by spectroradiometers are a versatile source of information, enabling e.g. to infer biophysical properties of vegetation. The interpretation of such data relies on detailed metadata that describes the sampling setup and the conditions under which the measurement was conducted. These metadata are indispensable when sharing data and making the spectral data accessible by other tools, e.g. to relate the spectral signals to flux data.

The SPECCHIO Spectral Information System is a purpose built software system that can handle spectral point data and metadata generically. A flexible metadata storage implementation supports the easy update of the available metadata attributes. Spectral data selections are performed by defining constraints on the metadata space, allowing the detailed selection of spectral subsets.

SPECCHIO offers a graphical user interface and a rich Java API to support access to the system from any programming language providing a Java bridging solution, such as Matlab, R or Python. This allows the development of automated data ingestion, metadata augmentation and spectral data analysis. SPECCHIO is open source and supported by the Australian National Data Service, Geosciences Australia, EMPIR MetEOC-3, APEX Airborne Prism Experiment, COST OPTIMISE ES0903 and the Swiss Commission on Remote Sensing.

More information may be found on www.specchio.ch

Keynote 24: Retrieving photosynthetic parameters and essential biodiversity variables from SCOPE inversion. A multiple-constrain approach.

Javier Pacheco-Labrador (1), Mirco Migliavacca (1), Micol Rossini (2), Oscar Perez-Priego (1), Tommaso Julitta (2), Tarek S. El-Madany (1), Gerardo Moreno (3), Arnaud Carrara (4), Rosario González-Cascón (5), M. Pilar Martín (6), Francesco Fava (7), Jin-Hong Guan (1), Tiana W. Hammer (1), Kathrin Henkel (1), Enrique Juarez-Alcalde (5), Olaf Kolle (3), Andrea Pérez-Burgueño (3), Thomas Wutzler (1) and Markus Reichstein (1).

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Upcoming Remote Sensing products are funded on coupled physiological models describing leave photosynthetic processes and radiative transfer models. The state-of-the-art in this approach is the model SCOPE (Soil Canopy Observation, Photochemistry and Energy fluxes). The upcoming Fluorescence Explorer (FLEX, ESA) mission will make use of Sun Induced Fluorescence (*SIF*) and hyperspectral data to provide photosynthesis and related variables products. Oher imminent hyperspectral sensors such as the Environmental Mapping and Analysis Program (EnMAP, DLR), are not designed to retrieve *SIF*. In this work, we explore the potential of hyperspectral information to retrieve essential biodiversity variables related to photosynthesis, structure and biochemistry.

Proximal hyperspectral and gas exchange chamber measurements were acquired between 2014-2016 in the Small-scale MANIpulation Experiment (SMANIE), in Majadas del Tiétar, Spain. We inverted SCOPE testing different combinations of Hyperspectral Hemispherical-Conical Reflectance Factors (*HCRF*), *SIF*@760 nm and Gross Primary Production (*GPP*). Also, priors based in measured relationships between biophysical variables used to stabilize solutions. Results show that together with *HCRF*, *GPP* improves estimations of Leaf Area Index (*LAI*) and values of maximum carboxylation capacity (*V*cmax). This suggests that hyperspectral sensors such as EnMAP could provide products of photosynthetic parameters such as *V*cmax in combination with *GPP* data.

Posters

P2017-1 Poster download (PDF)

Recovery of net ecosystem exchange two years after clear-felling of an upland conifer lantation on organo-mineral soil

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Forests are one of the biggest land cover globally and a significant carbon pool is stored within both trees and forest soils. The quantity of carbon stored is highly dependent on climatic and edaphic conditions as well natural and human-induced disturbances. Forest management can result in disturbance impacts which affect the carbon stocks in trees and soils. In particular, during clear-felling, commercial timber (logs) is removed and leaves, root systems and small branches are left on site to decay. The site is then left fallow for up to three years prior to replanting. This is expected to have an impact on the emissions of carbon dioxide. In this study we quantified CO2 fluxes from an upland mature Sitka spruce (*Picea sitchensis* (Bong.) Carr.) even-aged commercial plantation on organo-mineral (peaty gley) soil with eddy covariance, and compared fluxes in a mature stand and those from a clearfell site. Two eddy covariance towers, one 6 and one 32 meters height, were established with infra-red gas analysers, sonic anemometers and met stations. Net ecosystem exchange (NEE) was measured during 2015 and 2016, 1-2 and 2-3 years after clearfell. We found that clear-felling reduced the overall mean NEE by 11.3 gC m-2 d-1 turning a mature stand from a strong sink (-9.2 gC m-2 d-1) to a source of 2.1 gC m-2 d-1. Clear-felling removed the photosynthetic uptake, but also reduced night-time respiration by 1.4 gC m-2 d-1. In the second year, although the clear-fell remained overall a weak source with an average NEE of 0.5 gC m-2 d-1 the site was a small sink in the daytime with a mean of -0.7 gC m-2 d-1. A significant asymptotic relationship found at the clear-fell site between day-time NEE and photosynthetic photon flux density on the first year ($R^2=0.28$ $P<0.05$) and an even stronger relationship on the second year ($R^2=0.61$, $P<0.01$), suggesting that as early as six months after felling ecosystem exchange starts recovering due to immediate growth of ground vegetation. Tree planting is currently underway which is expected to turn the site to a stronger sink within the next year.

P2017-2

Wavelength-dependent performance of sun induced chlorophyll fluorescence to estimate GPP

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Recent studies have demonstrated that solar-induced chlorophyll fluorescence (SIF) can offer a new way for directly estimating the terrestrial gross primary production (GPP). In this paper, the wavelength-dependent ability of SIF to estimate GPP was investigated using both simulations by SCOPE model (Soil Canopy Observation, Photochemistry and Energy fluxes) and observations at the canopy level.

Understanding the response of the remotely sensed SIF at the canopy level (SIF_{canopy}) to the absorbed photosynthetically active radiation (APAR) is a key step in estimating GPP. Both the simulations and observations confirm that the relationship between SIF_{canopy} and APAR is species-specific and affected by biochemical components and canopy structure, especially at the O_2-B band.

The statistical relations between SIF_{canopy} and GPP also showed that the diurnal GPP could be robustly estimated from the SIF spectra for winter wheat at each growth stage, while the correlation weakened greatly at red band if all the observations made at different growth stages and different years or all simulations with different LAI values were pooled together — a situation which did not occur at the far-red band. The far-red SIF may be more reliable to map GPP for remote sensing applications with heterogeneous and diverse vegetation growth conditions

Remotely sensed SIF is only a part of the total SIF emission at the photosystem level. The relationship between SIF and GPP would be weaken greatly for canopies with different biochemical components and canopy structures. Therefore, it is very important to correct for reabsorption and scattering of the SIF radiative transfer from the photosystem to the canopy level before the remotely sensed SIF is linked to the GPP, especially at red band.

P2017-3

Camera-derived phenology indices for the prediction of CO_2 and CH_4 exchange in peatlands - First results and methodological developments derived from the PhenoPeatCam Network

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Phenology has multiple implications for the atmospheric exchange of CO_2 and CH_4 in ecosystems. Greenness indices extracted from digital repeat photography present continuous measures for the seasonal vegetation change on a spatial level that fits to the coverage of tower-based GHG measurements. Mostly deployed in forests and grasslands, greenness indices have proven to be suitable predictors for the seasonal variation in ecosystem CO_2 exchange.

Here, we present first results and methodological developments from the PhenoPeatCam Network, a European network of 10 peatland sites that couple measurements of ecosystem CO_2 and CH_4 exchange with the green chromatic coordinate (gcc) derived from RGB photography. This setup allows to address the effect of phenology on peatland CO_2 and CH_4 exchange across a large spatial extent. More specifically, we will investigate how the timing of key phenological events, the growing season length and the rate of gcc change affect CO_2 and CH_4 fluxes in peatlands. Based on our experience with a variety of different peatland sites, we will also report on the processing routines required to minimize the effect of scene illumination and day length on the final gcc time series. We will further introduce approaches to reduce the computational effort of gcc processing and provide a higher level of data transparency. These techniques could complement existing tools such as the R package PhenoPix and facilitate gcc processing in larger synthesis studies.

P2017-4 Poster download (PDF)

Generality of relationships between leaf pigment contents and spectral vegetation indices

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Vegetation indices are calculated from reflectance data of discrete spectral bands. The reflectance signal in the visible spectral range is dominated by the optical properties of photosynthetic pigments in plant leaves. Numerous spectral indices have been proposed for the estimation of leaf pigment contents.

Field-grown high light exposed leaves of over 30 angiosperm species from different plant functional types, covering a wide range of leaf structures and pigment content, were collected from Mallorca (Balearic Islands). Leaf reflectance spectra were measured with an integrating sphere and spectrophotometer SpectraVista HR-1024. Chlorophylls and carotenoids contents were measured with HPLC. Anthocyanins content was assessed spectrophotometrically. Chl a, Chl b and carotenoids contents were very strongly correlated to each other. Most of previous studies have produced the variability in leaf pigments content by collecting leaves from different light conditions or by senescence. Our dataset contains only high-light-grown leaves and the variability in pigment composition originates from species-specific differences not from the acclimation to different light conditions. Such selection of leaves bears a resemblance to the situation in stand-level remote sensing measurements from satellite platforms where the reflectance signal is dominated by the spectral properties of uppermost leaves of the multispecies canopy.

We tested the performance of 152 previously published Vegetation Indices (VI) for estimating leaf pigment contents. The best spectral region for estimation of leaf total chlorophyll content was the beginning of near-infrared (NIR) plateau at larger wavelengths than 700 nm (e.g. R736/R751). The best-performing VIs had stronger correlation with leaf Chl a content than with leaf total chlorophylls content (Chl a+b). The regression slopes to estimate pigment content from reflectance data differed often remarkably between monocots and dicots.

P2017-5

Assessing tree water use in dry environment by branch scale gas exchange, sap flow and dendrometers high resolution continues measurements.

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Projected intensification of droughts and temperature rise impose severe risks for widespread forest mortality. Drought adapted trees in semiarid ecosystems cope with extreme and continues soil water deficit and vapor pressure deficit by regulating their transpiration rate, thus saving internal water content and avoiding irreversible hydraulic failure. Our goal is to characterize how trees manage their water budget in order to increase survival probability under prolonged drought periods. Furthermore, we wish to understand the relative role of soil water deficit and vapor pressure deficit on the tree strategies for maintaining its internal water storage. We approach these objectives by using a unique online branch chamber gas exchange measurements, measuring continuously canopy transpiration and net photosynthesis. This branch chambers measurements are supported by high resolution Sap Flow (SF) and electronic dendrometers sensors, monitoring the water transport via the tree, together with soil moisture sensors. In total we measure 16 trees with gas exchange branch chambers, 25 trees with high resolution dendrometers and 45 trees with SF sensors of irrigated and non-irrigated plots in the semiarid Yatir forest, Israel (mean annual precipitation: 280 mm). The irrigation experiment was established in order to determine: **a.** The role of soil drought vs. atmospheric drought **b.** The usage of tree's internal water storage without a limitation of the external water source (irrigated soil). The preliminary results from this study indicate that the role of soil moisture as the main controller of transpiration is more crucial than the known role of VPD as the main controller on stomatal regulation; transpiration rate is not reducing even extremely high VPD values (>5Kpa) in the irrigated area. in addition, the use of internal water stores in an irrigated trees is becoming negligible at the diurnal water cycle, expressed by minimum time lag between SF and transpiration at the irrigated area vs. large time lag in the non-irrigated area (up to 8hr).

P2017-6 Poster download (PDF)

Line-averaging measurement concept to determine CO_2 advection – possibilities and uncertainties

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A closing gap for energy balance measurements which affects the balance closure of greenhouse gases, e.g., CO_2, is still observed although all necessary corrections and conversions are applied to the raw data. Against this background, advection is discussed as one important process that can have an impact on the CO_2 balance. Thus, there is a crucial need for tailored advection measurements. Ground-based remote sensing techniques for an estimation of CO_2 concentration and wind velocity are ideal tools to provide the spatially representative measurements within the same voxel structure. For this purpose, the SQuAd (Spatially resolved Quantification of the Advection influence on the balance closure of greenhouse gases)-approach applies an integrated method combination of acoustic and optical remote sensing. The innovative combination of acoustic travel-time tomography (A-TOM) and open-path Fourier transform infrared spectroscopy (OP-FTIR) will enable an upscaling and enhancement of eddy covariance measurements. The poster will give an overview about experimental tests at the FLUXNET site Grillenburg in Germany.

Preliminary results of the observations reveal a mean night-time horizontal advection of CO_2 of about 10 µmol m^{-2} s^{-1} estimated by the spatially integrating and representative SQuAd method. Additionally, uncertainties in determining CO_2 concentrations using passive OP-FTIR and wind speed applying A-TOM are systematically quantified. The maximum uncertainty for CO_2 concentration measurements was estimated due to environmental parameters, instrumental characteristics, and retrieval procedure with a total amount of approx. 30 % for a single measurement. Instantaneous wind components can be derived with a maximum uncertainty of 0.3 m s^{-1} depending on sampling, signal analysis, and environmental influences on sound propagation. By averaging over a period of 30 minutes, the standard error of the mean values can be decreased by a factor of at least 0.5 for OP-FTIR and 0.1 for A-TOM. The presented validation of the joint application of the two independent, non-intrusive methods underlines their ability to quantify advective fluxes.

P2017-7

Downscaling of solar-induced chlorophyll fluorescence from canopy level to photosystem level

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In recent years, the solar-induced chlorophyll fluorescence (SIF) has been proved to be an efficient tool for monitoring the vegetation productivity. SIF can be effectively retrieved from ground-based, airborne and satellite measurements. However, remotely sensed SIF at the canopy level is only a part of the total SIF emission at the photosystem level due to the scattering and re-absorption effects inside the leaves and canopy. Therefore, the downscaling of SIF from canopy level to photosystem level is important for better understanding of the relationship between SIF and GPP. In this study, firstly, the canopy scattering effect was physically analyzed based on a simple parameterization with the concept of photon recollision probability. The escaping probability of SIF from photosystem level to canopy level was fond to be related to the bidirectional reflectance, canopy interception of the downwelling solar radiation, and leaf absorption. Secondly, the Random Forest (RF) approach was used for the estimation of the SIF escaping probability with the reflectance at red, red-edge, and far-red band, and vegetation indices as input parameters, and the RF was trained with SCOPE simulation. Finally, the performance of the RF approach was evaluated with simulated datasets, in-situ measurements and airborne image. For SCOPE simulation, the RRMSE of estimated SIF at photosystem level is 5.10% and 7.43% for the far-red band and red band, respectively. For multi-angular observation, the variation of SIF within the solar principal plain is reduced obviously after the downscaling from canopy level to photosystem level. For in-situ measurements on different species, the estimated SIF at photosystem level is more linearly related to the PAR absorbed by chlorophyll than the SIF observed at canopy level, which is obviously influenced by the canopy structure. For the airborne image acquired by HyPlant covering farmland with different LAI levels, the relationship between far-red SIF and APAR becomes stronger after the downscaling, with an R^2 increased from 0.574 to 0.653. Therefore, we can conclude that, the RF approach is efficient for the downscaling of SIF from canopy level to photosystem level, and will be helpful for the application of SIF in the estimation of GPP.

P2017-8

A new method based on Surface Renewal to estimate the eddy flux of a scalar

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In the framework of Surface Renewal (SR) theory, a new sketch is proposed for estimating the eddy flux of a scalar from measurements taken at one height above the canopy. The earlier SR sketch assumed (1) that most eddy flux is carried out by a large coherent structure, and (2) that the main role played by smaller eddies, attached to the macro-parcel of air following the coherent motion, was to uniform the scalar concentration within the macro-parcel of air. From time series of scalar concentration sampled at high frequency, SR approaches require numerical analysis to determine the signature of the coherent structure (ramp-like pattern in the trace of the scalar) responsible of most eddy flux. The ramp-like pattern is characterized by a ramp amplitude and period.

The sketch proposed assumes (1) that any eddy capable to generate 'peaks and valleys' (ramps) in the trace of the scalar account to explain the eddy flux, and (2) that these eddies interact with the mean flow generating friction. The first assumption leads to calculate the eddy flux (i.e, half-hour block averaging) integrating the flux carried out by each single eddy. The latter integration is difficult to solve. However, based on the second assumption, the shape-parameter of the frequency distribution function of the ramp periods and the mean wind speed allow estimating the friction velocity near neutral conditions. The latter was crucial to propose an expression to estimate the eddy flux (half hourly).

To determine greenhouse eddy fluxes (e.g., carbon dioxide), prior determination of the sensible heat flux (H) is required to apply the density correction. The results obtained comparing the H estimates vs the H measured using the eddy covariance method over a short canopy [1] suggested that the proposed SR approach was accurate and free of calibration and canopy parameters. Further research is required.

[1] F. Castellví & R.L. Snyder, 2010. A comparison between latent heat fluxes over grass using a weighing lysimeter and surface renewal analysis. *J. Hydrol*., 381, 213-220.

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P2017-9 Poster download (PDF)

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

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On the ecosystem-scale, gross primary productivity (GPP) describes the amount of fixed carbon dioxide by the terrestrial vegetation. In the light of climate change, an increase of extreme weather phenomena (e.g. heat waves, droughts) is predicted and involves the necessity to understand their impact on terrestrial vegetation. Sun-induced chlorophyll fluorescence (SIF) is one option that can address the efficiency of photosynthesis, however, there are unanswered questions on how SIF reacts to changing environmental conditions (e.g. temperature). During April 2017, we measured SIF in Yatir forest (Israel). These measurements were part of a three month (March-May) eddy covariance (EC) measurement campaign, also involving measurements of carbonyl sulphide (COS) with a quantum cascade laser absorption spectrometer. The forest experiences frequently occurring heat waves (termed hamsin), which build up over a period of 1-7 days and can hold changes in daily temperature of over 10 °C.

EC measurements support findings of previous studies, demonstrating a decline of photosynthesis during the change from well-watered (winter) to dry (spring/summer) conditions. Declining COS fluxes additionally demonstrate a reduction in stomatal conductance. SIF slightly decreased over the course of April and notably during the hamsin events. We used the soil–canopy observation of photosynthesis and energy (SCOPE) model for further explanation and found that a temperature induced decline in the maximum fluorescence of light adapted leaves over-compensated the effect of parallel-reduction in the photochemical yield which led to the observed decline. Simulated data reproduced the field data satisfyingly, but the model showed a less obvious decline in SIF during the heat wave. By now, SIF was successfully used to monitor GPP under conditions were it changed due to variations in absorbed photosynthetically active radiation (aPAR). Our findings by using SCOPE 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.

P2017-10

Diurnal and seasonal patterns of photosynthesis and its relationship to F_{687}, F_{760} and a revised PRI

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Due to its direct link to the photosynthetic process, sun-induced fluorescence (F) is a promising signal to improve the estimation of photosynthesis in space and time. However, due to the lack of long term measurements the diurnal and seasonal relationship between photosynthesis and its protection mechanisms fluorescence and non-photochemical quenching (NPQ) is still unclear.

We here present results of a two month measurement campaign carried out during the European heatwave of 2015. The used spectrometer system (*SIF-Sys*) measured in a range of 350 to 1100 nm, with a high spectral (FWHM: 1 nm) and a fast sampling frequency of 6 sec. The measurements were carried out in close proximity (3 m) to a micrometeorological station, designed for Eddy Covariance measurements. On the basis of these measurements we analyzed the diurnal and seasonal relationship of the absorbed photosynthetic active radiation (APAR), F and gross primary product (GPP) as well as F_{yield} (F_{yield} = F/APAR), light use efficiency (LUE = GPP/APAR) and the canopy structure and chlorophyll corrected photochemical reflectance index (rPRI) under changing environmental conditions.

We show that under drought conditions the usually linear relationship between F and GPP weakens due to the physiological regulation of photosynthetic efficiency that is non-linearly reflected in F. We also show that far-red fluorescence yield ($F_{760yield}$) can explain 49% of the diurnal and 78% of the seasonal variance in LUE during non-stressed and drought conditions. Red fluorescence yield ($F_{687yield}$) in contrast showed to be a poor LUE predictor under drought conditions. We furthermore found that under non-drought conditions the usually positive relationship between $F_{760yield}$ and LUE inverts, after solar noon, to a negative relationship. Some hours after solar noon the negative relationship changes again to a positive one. We argue that these changes could be explained by a higher degree of photochemical quenching (PQ) after solar noon while the non-photochemical energy dissipation is still high, which would result in a downregulation of $F_{760yield}$.

P2017-11

COS measurements as a tool for flux partitioning: applications and complications

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Flux partitioning, the estimation of photosynthesis and respiration from the measured net CO_2 exchange, is a major uncertainty in modelling the carbon cycle and in times when robust models are needed to assess future global changes a persistent problem. A promising new approach is to derive gross primary production (GPP) from measurements of the carbonyl sulfide (COS) flux. This is possible because COS and CO_2 enter the leaf via a similar pathway and are processed by the same enzyme (carbonic anhydrase). Prerequisites for using COS as a proxy for photosynthesis is a robust estimation of all non-leaf sources and sinks in an ecosystem and a thorough understanding of the variability of the ecosystem relative uptake (ERU; the value linking CO_2 to COS uptake).

We conducted field campaigns in four major biomes – a managed temperate grassland, a Mediterranean savannah, a temperate beech forest and a hemi-boreal forest - across Europe. Ecosystem to atmosphere COS and CO_2 fluxes were measured using the eddy covariance technique, soil to atmosphere fluxes were measured using self-built fused silica soil chambers. The grassland sites were characterized by highly positive soil COS fluxes during daytime and soil COS fluxes around zero during nighttime. In contrast, the soils at the forest sites, characterized by less radiation on the soil surface, acted as a sink for COS. To further investigate the soil contribution we took soil samples at the study sites and used them to measure COS fluxes under controlled conditions in the lab.

After accounting for the soil contribution, GPP was estimated using the COS flux and compared to conventional CO_2 flux partitioning techniques (e.g. nighttime respiration).

P2017-12 Poster download (PDF)

Assessing the effect of atmospheric transmittance on canopy Light Use Efficiency with the use of the eddy covariance technique for a Mediterranean Aleppo pine forest

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Light Use Efficiency (LUE) models have been extensively used for the estimation of ecosystems primary productivity, mainly due to their simplicity and ability to be parameterized by satellite data. Generally, this type of models estimate primary productivity as the product of Absorbed Photosynthetically Active Radiation (APAR) by the canopy and a conversion factor (ε). While APAR depends mostly on architectural characteristics of the canopy, ε is estimated as a constant species-specific value (ε_0) which is scaled by meteorological or developmental factors, such as temperature, water deficit etc.

Although it is documented that during obscured sky conditions canopy tends to appear enhanced Light Use Efficiency, mainly due to the non-linear dependence of photosynthesis to solar radiation and the ability of the canopy to treat diffuse radiation more efficient than direct, this is not well quantified and usually not incorporated into LUE models.

In this study the effect of obscured sky conditions on LUE is quantified and presented for a Mediterranean Aleppo pine forest. A two years period of primary productivity measurements have been performed with the use of the eddy covariance technique and canopy LUE is estimated as the ratio of GPP to APAR on daily basis. Atmospheric transmittance, i.e. the ratio of daily PAR on canopy surface to extraterrestrial PAR, is used as a representative of sky conditions and its effect on LUE is studied by its comparison to canopy LUE under favorable conditions (e.g. at the absence of water and temperature stresses). We found that daily LUE efficiency values are 2.3 times higher during total obscured compared to total clear sky conditions for averaged values, while some extreme values can be as much as 4.5 times higher.

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P2017-13

PhotoSpec: A New Instrument to Measure Spatially Distributed Red and Far-Red Solar Induced Chlorophyll Fluorescence

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Solar-Induced Chlorophyll Fluorescence (SIF) is a powerful proxy for photosynthetic activity. Despite its potential, the relationship between SIF, photosynthetic efficiencies, Gross Primary Productivity (GPP), and the impact of canopy radiative transfer, viewing geometry and stress conditions remain poorly constrained at the canopy scale.

We present a novel ground-based spectrometer system - PhotoSpec - for measuring SIF from an elevated viewpoint above a canopy. The 2D scanning telescope unit enables pointing to any point in a canopy with an identical field of view for three spectrometers. The SIF spectrometers are of a high spectral resolution covering the red and far-red wavelength range. Additionally, a moderate resolution is used to determine vegetation indices (NDVI, EVI), and the photochemical reflectance index (PRI).

Initial measurements of single leaves show that the PhotoSpec instrument is indeed able to sensitively detect SIF under various conditions. Currently, four PhotoSpec instruments are deployed in the field at four different field sites (tropical rain forest of La Selva Biological Station, Costa Rica; corn and soy bean field in Ames, Iowa, USA; alpine forest at Niwot Ridge Long Term Ecological Research Site in the Rocky Mountain Front Range, Colorado, USA).

Results from the first continuous tower-based measurements of the prototype instrument at La Selva Biological Station in Costa Rica show that the instrument can continuously monitor SIF of several tropical species throughout the day. Our initial results demonstrate the potential of the PhotoSpec system to provide high quality spatially resolved SIF observations on the canopy scale.

P2017-14

The surface renewal method independent from calibration and wind measurements: Possibilities for application over irrigated crops for sensible and latent heat flux estimation

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The advanced surface renewal (SR) approach for estimating the eddy flux of a scalar proposed by Shapland et al. (2012a; 2012b) was applied to estimate sensible (H) and latent (LE) heat fluxes. This SR approach is exempt of calibration and does not require measurement of the mean wind speed. The sonic temperature and the water vapor concentration were sampled at 20 Hz over three different irrigated crops (cotton, rice and maize). The advantage of SR approaches vs the eddy covariance method are to allow measurements even in limited fetch conditions and to be able to capture fluxes from the majority of wind directions over the area of interest. SR approaches can operate in both roughness and inertial sublayers (Paw U et al., 1995). The eddy covariance (EC) sensors' placement over cotton and rice crops (Arkansas) were well above the canopy and the estimated roughness sublayer depth indicated that the majority of the measurements were in the constant flux (i.e., inertial) sublayer. The small (1 ha) corn crop plots (NE Spain) required measurements to be taken in the roughness sublayer. EC fluxes were computed using EddyPro (advanced settings) after the correction for transducer shadowing in the sonic anemometer wind measurements following Horst et al. (2015). Linear regression analysis was used to compare the SR and EC fluxes taking the EC method as a reference. Regardless of the crop and atmospheric stability conditions, the agreement between methods was higher for H than for LE. Major shortcomings were that the coefficient of determination (R^2) obtained was smaller than 0.75 and that a significant amount of fluxes were missed (as outliers or spikes in the half-hourly flux time series). The latter shortcoming was reported for a study case taking measurements in the inertial sublayer over a moderately heterogeneous canopy (peach orchard) (Suvočarev et al., 2014). The results obtained suggest that application of this SR approach may not be useful to integrate fluxes, such as on a daily basis, without some additional modeling.

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P2017-15

Four years of eddy-covariance measurements of GHG fluxes at Biebrza mires – the impact of ground water level on the GHG exchange

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We present the results of four-year (2013-2016) continuous eddy-covariance measurements of turbulent fluxes of methane and carbon dioxide and the energy balance components at the mires of Biebrza National Park (BPN) – one of the biggest wetlands in central Europe. The measurement site (53º35'30.8"N, 22º53'32.4"E, 110 m a.s.l.) was located in the central basin of Biebrza valley on the large, flat surface near to the village Kopytkowo. The surroundings are characterized by a relatively homogenous mixture of reeds, sedges and rushes characteristic for the Biebrza wetlands.

The turbulent fluxes were measured with the aid of open-path eddy-covariance system. The fast respond sensors (Li7500 for CO_2/H_2O and Li7700 for CH_4) operating with 10 Hz frequency were mounted at the height of 3.7 m. The eddy-covariance system was complemented by slow-respond measurements including: standard meteorological parameters, components of radiation balance, photosynthetically active photon flux density (up and down), heat flux to the ground, volumetric water content in the ground and ground water level. The fluxes were calculated with the EddyPro software, but 3 additional stationarity test were used to get a high quality data.

In the long-term perspective the year 2013 was relatively wet whereas 2015 was extremely dry. In the measurement period a linear relation between annual CO_2 exchange and ground water level was observed. The Biebrza mires are a significant sink of CO_2 in the wet years (the annual CO_2 uptake reached almost 1000 g_{CO2} m^{-2} y^{-1} in 2013) and turn into a CO_2 source in dry years (the CO_2 release reached about 600 g_{CO2} m^{-2} y^{-1} in 2015). The annual methane release, was on the level of 29 g_{CH4} m^{-2} y^{-1} in 2013, trough 20 g_{CH4} m^{-2} y^{-1} in 2014, and dropped below 5 g_{CH4} m^{-2} y^{-1} in dry years. Moreover, it is worth to mention than only little differences between wet and dry years were recorded in latent heat flux (evapotranspiration).

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P2017-16 Poster download (PDF) Student Poster Award Winner

High Precision Phenotyping of Field Grown Breeding Populations of White Spruce

Ariana Besik (1), Petra D'Odorico (1), Nathalie Isabel (2) and Ingo Ensminger (1)

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Climate change is expected to cause mismatch between locally adapted white spruce populations and the environment where they naturally occurred, leading to maladaptation. The field of tree genomics has greatly advanced over the past decade providing genomic tools for improved tree breeding and selection, which will help to identify and select genotypes that are better adapted to future warmer and drier climates. However, technological development in phenotyping has lagged behind advances in genomics, causing phenotyping to be the limiting step for high-throughput identification and connection of specific traits with these genomic resources. The long-term objective of this experiment is to develop a precise method for phenotyping white spruce grown in the field for use as ground validation data for high-throughput phenotyping using drone imaging. Another aim is to analyze and compare the contribution of genetics, environment and their interaction to phenotypic performance. One pedigree population (2000 genotypes of white spruce genotyped previously for 9000 single nucleotide polymorphisms) has been clonally replicated and established across four different field sites in Quebec and Ontario. For this study, a subset of genotypes have been selected for data collection across the four sites, with several replicates on each site. The phenotypic response of different genotypes of white spruce to naturally occurring drought stress have been quantified and compared using leaf level measurements of chlorophyll fluorescence, pigment composition, and water potential for later comparison with drone images. Fluorescence data yields information on the photosynthetic performance of the plants and can be used to compare the impact of abiotic and biotic stress on photosynthetic efficiency. Data obtained from the leaf level measurements will eventually be up-scaled to validate proxies of photosynthesis obtained from multispectral imagery acquired with a drone. Preliminary findings show variation among genotypes in response to minor drought stress.

P2017-17

Prospective: land cover change and ecosystem services interactions in dry-land ecosystems under future warmer and drier climate

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About 40% of the land surface is considered dryland (DL) where the aridity index [AI: ratio of annual precipitation (P) to potential evapotranspiration (ET)] is below 0.65, and where about 1/3 of world population lives (Safriel & Adeel, 2005). According to models and the RCP 8.5 scenario, the DL area will expand to cover ~56% of the land surface by the end of this century (Huang, 2017). Dry lands are sparsely forested (FAO, 2000) and the effects of land use and climate changes on the ecosystems services, in particular on water and carbon fluxes, are seldom studied or quantified.

We present results from 16-year study of the effects of afforestation on carbon sequestration and water yield (WY=P-ET; which is water available for consumption) at the edge of the Negev desert, and which was extended over the past 5 years across the precipitation gradient from a semi-arid site (AI=0.18, annual precipitation (P=280 mm) to sub-humid site (AI=0.65, P=750 mm) 200 Km to the north. Measurements were made over pine forests and adjacent non-forested ecosystems, and included fluxes of carbon, water, and energy, supplemented with eco-physiological measurement and modeling.

The results indicated that afforestation can be extended to the desert edge (annual mean P of ~280 mm), and maintain mean annual carbon sequestration of ~2 t C ha^{-1}, while adjacent non-forest ecosystems remain carbon neutral. Considering the extent of DL, this indicates that afforestation about 10% of the semiarid region can potentially capture about 10% of currently anthropogenic carbon emission helping mitigate climate change. However, our results suggest that forestation in this region also reduces ecosystem WY by over 30%, which varies along the climatic gradient. Predicted future rainfall reduction (ΔP), air drying and warming can increase VPD as well and ecosystem ET is not expected to decrease with P. In dry regions, our results suggest WY is likely to decrease mostlyand by ~$\Delta P/WY_{AVG}$ (current conditions average WY). The results also indicate that such effects can be minimized by proper management practices, such as by develop less water demanding spices, optimizing stand density, applying proper grazing intensities, and others to the world dry-land regions.

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P2017-18

Ground network of SIF based on eddy flux and spectral measurement tower in Japan

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Terrestrial ecosystems, forest, grassland and so on, absorbs atmospheric CO_2 as a greenhouse gas by photosynthesis, and are thought to mitigate global warming. Estimation of geographical extent of their photosynthetic activity is very crucial for the understanding of global climate change in future. However, conventional vegetation indices (for ex, NDVI, EVI, etc.) representing the greenness of ecosystem, reduce the accuracy for photosynthesis estimation in the particular situations; e.g., the overestimation in evergreen forest in winter and in drought.

Chlorophyll fluorescence is emitted from chloroplast to release the overflown energy of incident sunlight (so-called as Solar-Induced Fluorescence; SIF). Recently, many studies proved that SIF could be utilized for photosynthesis estimation at the ecosystem spatial scale (Zarco-Tejada et al., 2013, AFM, etc.) as shown by the strong correlationship between SIF and gross primary production (GPP). On the other hand, the availability of SIF is reduced due to small number of ground-based measurement thought highly evaluated potential of them.

Here we introduce the activity in Japan for measuring the SIF at several ecosystems at tower-based flux stations in Japan (all belongs to both Phenological Eyes Network (PEN) and AsiaFlux or Japanflux): paddy field in Mase, grassland in Tsukuba university, deciduous broad-leaf and evergreen coniferous forests in Takayama, deciduous coniferous forest in Fujihokuroku in cooperation with modeling effort.

P2017-19

Water availability may limit photosynthesis and drive resource allocation in the canopy of beech and silver fir trees

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The accurate assessment of terrestrial carbon dynamics requires a better understanding of mechanisms and drivers of within-canopy variation of photosynthesis. Presently, no consensus exists about the vertical distribution of factors driving photosynthesis and resource allocation within tree canopies under natural conditions.

In spring and summer 2017, we assessed vertical gradients of photosynthesis in the canopy of beech and silver fir trees growing in an unmanaged mixed deciduous forest stand in Central Europe. We characterised the morphology, photosynthetic gas exchange, water-use efficiency ($\partial^{13}C$ fractionation), chlorophyll and nitrogen content of individual leaves and needles at four canopy heights, as well as at saplings in the understorey. We related leaf traits to the seasonality and the microclimate along the vertical gradient in the canopy.

Although the light availability increased up to threefold along the vertical gradient in the canopy of beech and silver fir trees, the maximum photosynthetic capacity, as well as chlorophyll and nitrogen concentrations remained relatively constant in both species. In contrast, the light compensation point of photosynthesis increased up to threefold with higher light availability in the upper canopy, revealing a larger potential of leaves from the lower canopy to use low light intensities for net photosynthesis. Water-use efficiency increased along the vertical gradient as well, which corresponds to the measured increase of vapour pressure deficit in the canopy. A higher vapour pressure deficit, as well as lower leaf water potential may thus limit water availability for photosynthesis at higher canopy heights and also drive resource allocation. As a consequence, parameters of plant-atmosphere models may need to be reviewed.

P2017-20

Accurate measurements of fluorescence in the O2A and O2B band using the FloX spectroscopy system – results and prospects

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Measurement of Sun Induced Fluorescence (SIF) is a demanding task, but offers unique insights into vegetation´s photosynthetic activities. Especially comparison of the SIF signal in O2A and O2B over longer time series enables the understanding of the fluorescence as a proxy for modelling the plant activity. Addressing this problem, the Fluorescence box (FloX) was developed by JB Hyperspectral Devices UG in collaboration with Jülich Research Center, the Remote Sensing of Environmental Dynamics Laboratory of the University Milano Bicocca and the Max Planck Institute for biogeochemistry. FloX is an automated field spectroscopy device capable of collecting unattended, continuous, long-term hyperspectral measurements and it is specifically designed to passively measure Chlorophyll fluorescence induced by sun, under natural light conditions. Therefore, the design is optimized in order to achieve maximum efficiency in terms of: Signal to Noise Ratio, Spectral Resolution and quick acquisition time. Upward and downward channels of FloX allow to sequentially measure the solar irradiance and the reflected radiance from the canopy. The optical characteristics of the system fit with the ESA-FLEX mission requirement and can be used to retrieve fluorescence applying the advanced retrieval technique such as Spectral Fitting Methods. The data collected by the FloX are processed by using two open source R packages (FieldSpectrosocpy CC and FieldSpectroscopyDP) specifically developed. The final outputs of the processing are: at surface incoming radiances, top of canopy reflected radiances, apparent reflectances and fluorescence estimates at both atmospheric Oxygen absorption bands retrieved by applying multiple published methods as the Fraunhofer Line Discriminator (in its 3 version FLD, 3FLD and iFLD) and the Spectral Fitting Methods (SFM). Moreover, at each fluorescence estimate a quality flag is associated reporting information related to the illumination stability during the measurement cycle and the internal noise of the instrument at the moment of the data acquisition. FloXes have been largely used in the last year and some application example will be shown: from long terms time series up to small scale experiments.

P2017-21

Estimation of GPP with SIF based on flux tower measurement data using a theoretical model.

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Chlorophyll fluorescence is a kind of release pathway for excess incident light in the photosynthetic process. At ecosystem scale, recently, it has been known that the solar-induced chlorophyll fluorescence (SIF) would be correlated to gross primary production (GPP) from remote sensing studies by both field and satellite measurements, and is expexted that the SIF could be used for GPP estimation.

The theoretical model is one of the tools to analyze the correlation between the GPP and the SIF at leaf scale. Here, we designed the model based on the reaction kinetics by means of the rate coefficients and quantum yields of photosynthesis, fluorescence and heat dissipations, and explains the behavior of the relationship between fluorescence and photosynthesis that has been reported in previous literatures. Most of the previous studies, the quantum yield of SIF is estimated using short-term chlorophyll fluorescence data measured by pulse amplitude-modulated (PAM), and the GPP is estimated using physiological data, such as the concentration of chlorophyll and the photosynthesis rate. However, the acquisition of these data by field observation and satellites is difficult.

Thus, in this study, we estimate the GPP from the SIF data by a theoretical model, and compared with eddy tower GPP in a cool temperate deciduous forest in Takayama (TKY) in central Japan for a single growing season. The preliminary results of seasonal and annual changes in correlation between SIF and GPP at the leaf level would be presented.

P2017-22 Poster download (PDF)

Ongoing and Future Plan of CO2 Flux Estimation in Global Scale by GOSAT and GOSAT-2 Observation

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Climate changes caused by increase of anthropogenic emission of greenhouse gases (GHG) affect the ecosystem, climatic hazard, agricultural production, etc., and it is necessary to deal with them. The Greenhouse gases Observing SATellite (GOSAT) was launched to contribute environmental administration such as assessment of local carbon balance by more reliable estimation of GHG flux. The spectral data observed by GOSAT TANSO-FTS enable us to estimate column concentration of CO_2 and CH_4. The terrestrial ecosystem model, VISIT (Ito et al., 2012) applies to calculation of terrestrial CO_2 fluxes in Level 4A product of GOSAT (Maksyutov et al., 2013). Frankenberg et al. (2011) and Joiner et al. (2011) demonstrated that GOSAT-observed solar induced fluorescence (SIF) can be estimated from the spectrum data of GOSAT and correlates to the measured gross primary production (GPP). In recent years, many studies reported that SIF observed by satellites strongly correlated to the photosynthesis productivity (e.g., Ito et al., 2017). Therefore, SIF data by GOSAT applicable to improve the accuracy of GPP estimation by VISIT. Previous studies demonstrated parameter adjustment of models using SIF data ,and maximum carboxylation (V_{cmax}), light use efficiency (LUE) and photochemical reflectance index (PRI) were used frequently (e.g. Lee et al., 2015; Damm et al., 2010). In this presentation, we will explain how VISIT is used to produce level 4A product of GOSAT and review the application of SIF to the photosynthetic process of terrestrial models. Moreover, we will discuss the future plan to apply SIF for upgrading the estimation of photosynthetic productivity by VISIT and the accuracy of level 4A product based on the relationship between SIF and LUE.

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P2017-23

Phenology of Leaf-level Optical Properties and Their Consequences with Canopy Spectral Profile in a Deciduous Broadleaf Forest in Japan

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Optical properties, i.e., spectral reflectance and transmittance, of leaves in a canopy, affect the diffuse light environment which can be expressed by radiative transfer models (Verhoef 1984), and the reflected radiation from the canopy surface is utilized for optical remote sensing, includes measurements by spectroradiometers mounted on towers, aircraft and Earth-observation satellite (Field 1995; Ustin et al. 2004). The leaf optical properties vary among species and developmental stages of the leaf (Noda et al. 2013; 2014) because those are determined by leaf biochemical components, such as chlorophylls, carotenes, anthocyanins, nitrogen, cellulose, lignin and water, and anatomical structures. Thus, deep understanding of the optical properties in single-leaf level helps us to interpret remote-sensing data to vegetation characteristics that are responsible for photosynthetic CO_2 absorption.

Deciduous forest shows the remarkable seasonal change in CO_2 flux and also canopy reflectance because of changes in canopy structure (such as leaf expansion in spring and leaf fall in autumn) and growth and senescence of the leaves. In present study, we show seasonal changes in the leaf optical properties in a cool-temperate deciduous broadleaf forest, namely, “Takayama site” on the northwestern slope of Mt. Norikura in central Japan. In this forest, we measured the leaf optical properties of canopy trees, *Quercus crispula* and *Betula ermanii* during the growing season, from budburst in mid-May to senescence at beginning of November in 2004, 2005, 2006 and 2010. The measurement was conducted for both adaxial and abaxial side of the leaves by using integrating sphere and spectral radiometer. Both reflectance and transmittance in visible region decreased during growing period and the change in transmittance is steeper than reflectance. In near infrared region, the reflectance increase and transmittance decrease during the growing season. We examined the consequence between the changes in optical properties and growth and senescence of the leaves by radiative transfer model in single-leaf scale, PROSPECT (Jacquemoud and Baret 1990).

P2017-24 Poster download (PDF)

A New Optical Chamber Method to Quantify the Seasonal Variation in Ambient and 77K Leaf-Level Chlorophyll Fluorescence Spectra

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Chlorophyll fluorescence (ChF) has been widely used as a tool for tracking changes in photosynthetic activity for decades. However, a number of questions still remains open, as to how the shape and intensity of the ChlF spectra is connected to the mechanistic acclimation of photosynthesis. This is particularly critical at the leaf-level - the smallest scale at which spectral fluorescence can be measured in vivo, and especially for conifer needles which are difficult to measure due to their complex geometry.

One of the goal of our recent campaign ("*Fluorescence Across Space and Time"- FAST*, February – July 2017), was to develop a new optical chamber and protocol for measuring ambient and 77K spectral fluorescence in intact leaves. The new protocol was used to quantify the seasonal variation in leaf-level fluorescence properties across boreal species, during the spring recovery of photosynthesis and at different canopy heights. The crucial advantage of the new optical chamber method is an ability to measure reflectance, fluorescence in room temperature and fluorescencein 77K of each sample at the identical footprint. At ambient temperature, ChlF emissions of PSII and PSI are overlapped, thus the interpretation of photosynthesis' acclimation is not straightforward. At 77K, the two main fluorescence peaks can be distinctly attributed to PSI and PSII populations in the leaf providing the supporting information to understand the ChlF dynamics of each of the photosystems and their impact on ambient fluorescence spectra. That co-supplementation of data would be impossible to achieve if the sample footprint was not identical in two measurements.

Here we present examples of species, considering the seasonal variation on ChlF signal at different position within the canopy profile in ambient temperature and 77K.

P2017-25

Exploring the potential of high-resolution CubeSats imagery for evapotranspiration retrievals: a case study in Saudi Arabia

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Water is one of the most important resources for human survival, as it is used for energy production, for consumption and food production. Informed allocation of water resources is particularly important in arid land environments, where the lack of renewable water supplies presents an ever increasing pressure on food and energy supply, and has resulted in increasing aquifer depletion rates. Since agriculture is the largest sectoral user of freshwater globally, it is vital to have accurate estimates of agricultural water requirements. Through remote sensing, it is possible to obtain farm-scale information of water use indirectly through evapotranspiration (ET) estimates. To date, these ET estimates have been constrained by both spatial and temporal limitations: for instance, the widely used Landsat satellite imagery has a 16 day revisit time and a 30 m pixel resolution, although the recently launched Sentinel-2A/B improves this with 10 m pixel resolution and a 5 day revisit time. In contrast, Planet CubeSats aim to relax these constraints by offering daily ultra-high resolution (3 m) imagery. The objective of this study is to explore the capacity of CubeSats, in combination with a modified version of the Priestly-Taylor Jet Propulsion Labs (PT-JPL) model, to retrieve spatial crop water use maps. The PT-JPL model is forced by local meteorological variables and satellite derived normalized difference vegetation index (NDVI) and leaf area index (LAI) estimates. The retrievals are assessed against measured fluxes from an eddy covariance tower.

P2017-26 Poster download (PDF)

Diurnal response of sun-induced fluorescence and photochemical reflectance index in *npq*-deficient mutants of *Arabidopsis thaliana*.

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Photosynthetic light-use efficiency of plants is highly linked with its capacity to dissipate excess energy for photo-protection. To understand this dynamic process remotely in the field, spectrally derived sun-induced fluorescence (SIF) and photochemical reflectance index (PRI) are often used as an index for instantaneous plant photosynthesis and de-epoxidation state of the xanthophylls, respectively. Despite this, the relationship between SIF and PRI with regards to PSII efficiency is not yet well-understood. To fill this gap, we concurrently measured active and passive fluorescence in Arabidopsis mutants using Light-Induced Fluorescence Transients (LIFT) and Fluorescence Box (Flox), respectively. The mutants investigated were either zeaxanthin deficient (*npq1*) or lacking PsbS protein (*npq4*) which consequently diminished the capacity of non-photochemical quenching (NPQ). We retrieved PRI and passive fluorescence at 760 nm and 680 nm diurnally along with Fo', Fm', effective quantum yield of PSII (ΔF/Fm') and NPQ from diurnal LIFT measurements in the field condition.

Diurnal response of SIF_{yield} showed differences between the *npq* mutants and wildtype (WT), demonstrating the effect of NPQ on the SIF intensity. The diurnal responses of SIF were similar in *npq1* and *npq4* mutants. The differences in diurnal PRI were found between the genotypes with (WT and *npq4*) and without (*npq1*) zeaxanthin, confirming the sensitivity of PRI to xanthophyll conversion. In all genotypes, the LIFT-derived Fo', Fm' NPQ and ΔF/Fm' changed dynamically throughout the day. The results from active and passive fluorescence measurements are being compared with each other as well as with PRI to assess the diurnal impact of NPQ on SIF in the field condition.

P2017-27

Photosynthesis, chlorophyll fluorescence and photochemical reflection index under various conditions

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Light energy abosrbed by chlorophyll be utilized as either of photochemistry, heat dissipation and fluorescence. Sun-induced chlorophyll fluorescence can be detected using Fraunhofer line depth method and others. Heat dissipation is known to be correlated with 531 nm reflectance, called as photochemical reflection index (PRI). I established a laboratory system to measure gas exchange rates, chlorophyll fluorescence and reflection spectrum simultaneously and determined them from *Chenopodium album* leaves under different light, temperature, CO_2 concentration and water availability manipulated with cutting the petiole. I also used photoinhibited leaves produced by inhibiting repair of photodamaged photosystem II using lincomysin.

CO_2 assimilation rate, quantum yield of photochemistry ($\Delta F/F_m'$), quantum yield of chlorophyll fluorescence (F) and PRI decreased with decreasing CO_2 concentration and with decreasing water availability. CO_2 assimilation rate, $\Delta F/Fm'$ and PRI exhibited a parabolic curve against leaf temperature whereas F decreased monotonically decreased with increasing leaf temperature. Artificially photoinhibited leaves had lower CO_2 assimilation rate, $\Delta F/Fm'$ and PRI and higher F.

The relationship between gas exchange rates and chlorophyll fluorescence is not a simple function but influenced by various factors. Simultaneous use of fluorescence and PRI may improve accuracy in remote scencing of photosynthesis.

P2017-28

Drought Sensitivity of Rare Native Tree Species in NE-Germany – An Ecophysiological and Dendroecological Approach

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Forestry administration in Germany has adopted a policy to increase tree species diversity in the face of climate change and to convert monospecific into mixed stands in order to minimise the risk of the effects of extreme climatic events and calamities. However, the number of species being used in commercial forestry in Germany as mayor and admixed species is rather small and their resilience to prolonged summer drought as predicted for many areas in Germany is limited.

In Brandenburg in NE Germany, half the forest stands are monospecific and 70 % of the forested area is occupied by *Pinus sylvestris*. Additionally, in Brandenburg the annual precipitation is rather low already and dry spells during the growing season are common, with projections forecasting higher temperatures and less precipitation during the growing season and generally more extreme events. This makes the region a prime area to study the suitability of alternative tree species under changing climate.

In this project we therefore investigate the sensitivity of rare and minor, less studied native tree species towards drought. On young potted plants we study the effect of prolonged drought on ecophysiological parameters and growth in a rainout shelter over the course of three years. Dendroecological studies on mature trees in forest stands in Brandenburg and further afar complement the manipulative experiments. Stable isotopes analyses of wood from both potted plants and mature trees will be employed to bridge the scales. The species studied include, among others, *Carpinus betulus*, *Malus sylvestris*, *Prunus avium*, *Pyrus pyraster* and *Sorbus torminalis*. First results from the dry-down experiment will be presented, including net photosynthesis, stomatal conductance and leaf water potential.

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P2017-29

Combining Sentinel-2 observations, SCOPE modeling and machine learning for estimating crop status and gross primary productivity

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Monitoring spatio-temporal changes in gross primary productivity (GPP) of crops is important for estimating, understanding and predicting global carbon fluxes, as well as for securing food and fiber for the increasing world's population. Such efforts have been largely improved due to satellite remote sensing providing consistent and systematic Earth observations. Nowadays, with the increasing amount of freely available data that allow sub-field observations (e.g., Sentinel-2 at 10 and 20 m spatial resolution), also applications in precision agriculture (in addition to large scale flux estimations) can be supported by remote sensing.

Two approaches are typically applied to model GPP with the use of satellite data: process-based models (PBMs), and light use efficiency (LUE) models. In general, PBMs are considered to perform better than LUE models, but because of their high complexity, they result in a large computational cost, and a need to define a large set of input parameters, some of which may not be available.

The integrated radiative transfer and energy balance model SCOPE combines radiative transfer in leaves and canopy, enzyme kinetics of photosynthesis, and micrometeorology of the surface layer, but is still a rare choice to estimate GPP using remote-sensing data. However, it is constantly being extended and improved, especially since SCOPE will be used to analyze chlorophyll *a* fluorescence data from a future Fluorescence Explorer (FLEX) mission.

Here, we discuss the possibility of applying the SCOPE model to the Sentinel-2 data. Our aim is to benefit from the complexity of the model, while making it applicable to a large dataset. We investigate important variables for modeling GPP, along with the possibility of retrieving the canopy, leaf and soil parameters from Sentinel-2 data. We also suggest an approach to calculate GPP by combining machine learning (artificial neural networks) with SCOPE simulations. We show some results of estimating GPP for soybean fields in the USA for Sentinel-2 observations from year 2016.

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P2017-30

Semi-arid ecosystem monitoring with remotely-sensed data

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Dryland ecosystems constitute one of the largest terrestrial biomes, and play a major role in determining the trend and interannual variability of the global gas balance. It has been estimated that biological soil crusts (biocrusts), a combination of communities including mosses, lichens, liverworts, algae and cyanobacteria, play an important role in the carbon and nitrogen fixation from the atmosphere at a global scale. It has been estimated that cryptogamic covers, which include biocrusts, account for 7% of net primary production by terrestrial vegetation, and nearly half of the nitrogen fixation on land (Elbert *et al*., 2012).

We examine the potential of hyperspectral data for characterizing biocrust composition and activity from dry to wet states by means of a spectral index sensitive to changes in biocrust activity and insensitive to changes in soil wetness. Biocrusts with different species compositions (i.e. lichens, mosses and cyanobacteria) were sampled along two altitudinal transects in the Aranjuez Experimental Station, Spain (40°01'57.7"N-3°32'53.7"W). Biocrust optical properties were measured in laboratory by means of a hyperspectral imaging spectrometer (Hyperspec VNIR, HeadWall Photonics) covering the VIS-NIR spectrum. We applied the continuum removal algorithm to the hyperspectral reflectances to quantify the absorption features related to the pigment composition of biocrust contituents (i.e. chlorophyll, carotenoid and phycobilins).

The continuum removal algorithm allowed us to identify the absorption features related to the pigment content from the biocrust spectra, and to monitor the change from dry to wet status. All the lichen species (*Buellia zoharyi*, *Diploschistes diacapsis*, *Fulgensia* spp., *Psora decipiens*, *Squamarina lentigera*) and mosses (*Pleurochaete squarrosa* and *Tortula revolvens*) surveyed show absorption peaks at 500 nm, typical of carotenoid/phycoerythrin, and at 685 nm, typical of chlorophyll *a (Weber and Hill, 2016).* However, they show different absorption depths, probably related to the different pigment composition. Immediately after wetting these absorption features increase, while the overall reflectance decreases due to soil moisture. The change of absorption from dry to wet is related to an increase of light absorption that should be linked to biocrust activation.

The methodology applied shows that pigment absorption depth calculated with the continuum removal algorithm is a robust index to monitor spatial and temporal changes in biocrust activity in semi-arid ecosystems. Further developments are foreseen in linking the absorption depth to pigment compositions and to couple spectral changes with photosynthetic rates.

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P2017-32 Poster download (PDF)

Ten-year period of GOME-2 SIF dynamics relates to seasonal drought and high temperatures at three Brazilian ecoregions.

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Chlorophyll *a* fluorescence provides valuable insights into photosynthesis and relates directly to plant productivity and carbon accumulation. Sun-Induced Fluorescence (SIF) data from the orbital instrument GOME-2 has global coverage spanning a long period (2007 to present) and therefore, allows for substantial study of fluorescence seasonal dynamics despite its relatively low spatial resolution (0.5° x 0.5°). Nevertheless, the interpretation of SIF when measured from natural heterogeneous vegetation is still uncertain and should benefit from more studies testing basic assumptions with meaningful samples of plant communities.

The Brazilian ecoregions called Caatinga (xeric shrublands and forests), Cerrado (savanna forests) and Pantanal (tropical wetland-forests), located in a swath from north-east to south-west of Brazil, present a gradient of seasonal drought and high-temperatures with heterogeneous plant formations developing in conditions ranging from semi-desertic to seasonally inundated. The analysis of plant communities from regions within such a gradient of environmental conditions can, therefore, yield interesting results through the comparison of climate data and photosynthesis-related physiological and phenological data.

Therefore, we have chosen sites of natural vegetation based on preservation areas within those ecoregions, with low contamination by human activities, and sampled monthly means of PAR-normalized SIF from GOME-2 (v2.7) data from the last 10 years (2007 - 2016) at these locations. We have tested this normalized chlorophyll fluorescence with MODIS land surface temperature (MOD11C3) and with TRMM precipitation rate (TMPA 3B43) from the same period in repeated-measures GLMMs. Our results have shown significant effects of seasonal drought and high temperatures on SIF monthly means with the observed effects differing between the three ecoregions. We have also compared PAR-normalized SIF with EVI2 (MEaSUREs, VIP30 v004) measured from 2007 to 2014, and found significant correlation between fluorescence and EVI2 in that period.

P2017-33

Sun-induced chlorophyll fluorescence retrievals using the Chlorophyll Fluorescence Imaging Spectrometer (CFIS)

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Chlorophyll pigments in terrestrial vegetation absorb sunlight to cover the energy demand during the process of photosynthesis. A part of the excess energy dissipates as sun-induced fluorescence (SIF) emitted by chlorophyll a in the red and NIR spectral region (650-800nm). Though the amount of SIF represents only a few percent of the total light energy absorbed, SIF measurements can serve as a valuable tool to assess the photosynthetic performance of vegetation.

First satellite-based SIF retrieval methods have been developed in 2011. Since then, the availability, duration, and quality of global data sets steadily increased. However, there are still large discrepancies among different SIF data sets in terms of absolute values. A possible pathway to calibrate/validate space-borne SIF retrievals consists of using rare airborne SIF measurements. In this contribution we will discuss the retrieval of SIF using simulated and real data from the Chlorophyll Fluorescence Imaging Spectrometer (CFIS).

CFIS was recently developed at JPL (Jet Propulsion Laboratory) for OCO-2 (Orbiting Carbon Observatory-2) validation purposes and provides an airborne capability to help fill the spatial gap between leaf- or canopy-level observations of SIF flux and extensive satellite footprints. Here, we present an overview of the instrument design along with different retrieval methodologies. We also compare SIF retrieval results from airborne and space-borne spectroscopic measurements based on a CFIS - OCO-2 underpass.

P2017-34

Revealing the Relationship Between Solar Induced Chlorophyll Fluorescence (SIF) and Gross Primary Production (GPP) from Diurnal to Seasonal Scales at a Corn Field in Upstate New York

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Recent technological advancements enable the detection of Solar Induced chlorophyll Fluorescence (SIF) via satellite for real-time monitoring of photosynthesis. One current challenge is the validation of satellite-retrieved SIF with ground-based measurements. A key step to this validation process is resolving the relationship between traditional leaf-level active fluorescence and canopy-level passive fluorescence under varying seasonal and diurnal conditions. We present initial retrievals of canopy SIF for corn using paired QE Pro spectrometers controlled by the novel Fluorescence Auto-Measurement Equipment (FAME) system, and discuss in context with leaf-level paired measurements of gas exchange and active fluorescence assessed using Walz GFS-3000, from field corn grown at a farm in upstate New York during August and September of 2017. We will present 1) comparison of SIF retrievals using the O2A band and spectral fitting method, versus Fraunhofer line and singular-value decomposition (SVD) method; 2) comparisons of leaf-level measurements of chlorophyll fluorescence and gas exchange with SIF and gross primary productivity (GPP) measured at the canopy level on diurnal and seasonal scales; 3) comparison of the newly developed FAME software, which optimizes integration time for measurements, versus traditional measurements using commercial OceanView software. Implications of these findings will be discussed.

P2017-35

Estimation of the components of the carbon and water budgets for winter wheat by combining high resolution remote sensing data with a crop model

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Croplands occupy more than one third of Earth's terrestrial surface contributing to climate change and also being impacted by those changes, since their production is conditioned by climatic conditions and water resources. It is thus essential to quantify and analyze the production and the main components of the carbon and water cycles for crop ecosystems. We propose here a regional modeling approach that combines: high spatial and temporal resolutions (HSTR) optical remote sensing data, a simple crop model and an extensive set of *in-situ* measurements for model's calibration and validation.

The model, called SAFYE-CO2 (Simple Algorithm for Fluxes and Yield Estimates), is a daily time step model based on Monteith's light-use efficiency theory and coupled with a water budget module (FAO-56 method). SAFYE-CO2 estimates the components of the carbon budget (gross primary production (GPP), ecosystem respiration (Reco), net ecosystem exchange (NEE), …) and of the crop water cycle (evaporation, (E), transpiration (TR), evapotranspiration (ETR) and soil water content) and also time courses of dry aboveground biomass and yield by assimilating Green Area Index (GAI) data obtained from HSTR satellite observations. For this work, we used a unique set of Formosat-2 and SPOT images acquired from 2006 to 2011 in southwest France. Crop and soil model parameters were determined using both in-situ measurements and values found in the literature. Phenological parameters were calibrated by the GAI assimilation. The results indicate that the model is able to correctly reproduce the winter wheat biomass and yield production (relative error about 25%) for years with contrasted climatic conditions. The estimated net carbon flux components were overall in agreement with the flux measurements, presenting very good correlations (R^2 about 0.9 for GPP, 0.77 for Reco and 0.84 for NEE). Regarding the ETR, a good correlation (R2 about 0.73) and satisfactory errors (RMSE about 0.47 mm.d-1) were obtained. Carbon and water budgets, as well as some water use efficiency (WUE) indices were computed, allowing to evaluate the crop ecosystems in terms of environmental and agronomical aspects. Still, the performances of this method could be improved by considering weeds or re-growths events after harvest.

P2017-36

Monitoring photosynthetic phenology in temperate evergreen and mixed deciduous forests using the normalize difference vegetation index (NDVI), photochemical reflectance index (PRI) and chlorophyll/carotenoid index (CCI) at leaf and canopy scales

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Forests in boreal and temperate regions undergo strong seasonal changes in photoperiod and temperatures, which drives their photosynthetic phenology. These forests consist of deciduous and evergreen trees that utilize different overwintering strategies. Annually, evergreens needles are retained and undergo “invisible” changes in the leaf pigments, whereas deciduous leaves grow and abscise. Due to this difference, optically derived vegetation indices behave differently in their ability to track phenology. In this study, we evaluated the normalized difference vegetation index (NDVI), a greenness index, and two carotenoid pigment-sensitive indices, the photochemical reflectance index (PRI) and the chlorophyll/carotenoid index (CCI). To better understand these vegetation indices as proxies of photosynthetic activity across plant functional types, the phenology of NDVI, PRI, CCI and photosynthesis was monitored in a temperate evergreen forest and a mixed deciduous forest at the leaf and canopy scale. We found that NDVI resolved deciduous phenology, while PRI and CCI resolved both deciduous and evergreen phenology. Leaf- and canopy-scale measurements yielded similar results. These findings have implications to improve our use and understanding of remotely sensed vegetation indices as proxies of photosynthetic activity in northern forests for long-term monitoring.

P2017-37 Poster download (PDF)

The response of environmental manipulation on photosynthetic activity of peatland vegetation

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The global warming is an important issue which is leading to changes in world vegetation. The environment biologist is continually assessing how the global warming is going to impact the current population. Peatland is one of the very important part of terrestrial area which makes only 4% of it but contains more than 30% of organic carbon. Therefore, our work is to focused on the behaviour of *Sphagnum* peatland in Poland, subjected to manipulated environment. The experimental set up consisted of four treatments (control, warming, drought and combined drought & warming), three replicates each. Active manipulation with infrared heaters (1.0-1.4^{o}C peat temperature increase) and an automatic curtain for drought (37% reduction in rain) were used from 2015-2017. Net ecosystem exchange (NEE), ecosystem respiration (R_{eco}) and methane (CH_4) fluxes were measured in high frequency by a prototyped automated chamber system equipped with fast response analyzers. Warming increased both R_{eco} and gross primary production (GPP). Combined effect of warming and drought, however, resulted in higher NEE in both years, specifically due to reduced R_{eco}. Along with this a significant variation in photosynthetic activity of four different plant species (*Carex rostrata*, *Menyanthes trifoliate*, *Sphagnum* spp. and *Oxycoccus palustris*) was measured by active fluorescence method. *Menyanthes trifoliate* was observed to be very sensitive to heating and low precipitation, whereas *Oxycoccus palustris* was observed to be better performing under heated condition but low precipitation results into a decrease in photosynthetic efficiency. *Carex rostrata* was observed to slightly impacted by environmental manipulation, whereas in *Sphagnum spp.* the impact was observed to be sever due to drying in heated condition. The observation indicates that the simultaneous heating and reduction of precipitation (a condition depicting global warming) will leads to change in current peatland vegetation physiology.

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P2017-38

Development of a low-cost Arduino based sap flow measurement system.

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Measurements of sap-flow velocity provide one useful means of estimating plant water use at the individual tree level. Such measurements can easily be made with a high temporal resolution on individual trees, but with the scaling up of such data to provide evapotranspiration estimates at the canopy or regional (ecosystem) scale remains problematic due to the need for a large number of trees to be sampled so as to account for variability. Such a widespread deployment of sap-flow sensors on the stand-scale is in most cases not feasible due to the high cost of commercially available sensors (*ca.* $US1000 per unit).

As part of the *Nordeste* Project working in the semi-arid shrub-like *caatinga* vegetation of North Eastern Brazil, we have made some first steps for a widespread deployment of sap-flow technology through the development a more economically accessible tool for measuring sap flow with the Thermal Dissipation Probe (TDP) method (Granier, 1985), with such probes being used in conjunction with low-cost Arduino dataloggers. First results for which the Arduino's based sap flow sensor performance was tested against some commercially available ICT/HMR (Heat Ratio Method) sensors (Burgess et al. 2001) showed remarkably similar conifer tree diurnal water use patterns with a regression of Arduino-based sensor estimates against the commercial sensor giving a slope close to 1.0 and with a r^2 of 0.94. Further work is required, especially in terms of a testing the long term durability and reliability of the Arduino-based system. Nevertheless, these first results do seem promising, and with the cost of these 'home made' sensors being about $1/20^{th}$ that of currently available commercial sensors, this new approach should hopefully in the future allow for a widespread deployment of sapflow technology for estimates of stand-level water use.

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Sun induced fluorescence – GPP and ET dynamics in a tree/grass ecosystem

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Sun induced fluorescence (SIF), the radiation flux emitted by plant chlorophylls molecules in the 650-800 nm spectral window, is considered an indicator of photosynthetic performance. Recently it has been shown that SIF can track changes in light use efficiency (LUE), and therefore it is a good predictor of gross primary production (GPP) at various scales, from leaves and ecosystem to regional and global scale.

As SIF, photochemistry and heat dissipation compete for the same photons, the relationship between SIF and GPP is influenced by stress, canopy structure and functional traits such as leaf N content. Canopy structure is crucial as it affects the fraction of fluorescence that escapes the canopy and the light quality profile in the canopy. For this reason, it is especially interesting to investigate the effects of seasonality and nutrient fertilization on the relation between SIF, CO_2 and water fluxes at the ecosystem scale.

Although the SIF – GPP relationship has been investigated at multiple scales, little is known about SIF dynamics at the ecosystem's level. Consequently, the understanding of the mechanistic relationship between SIF and GPP is limited. Moreover, the understanding of the relationship between SIF and transpiration is also lacking.

As new instruments for proximal remote sensing of SIF are being developed, collecting time series of SIF with high temporal frequencies at flux tower locations has become substantially easier.

In this contribution we will show preliminary results the time series of SIF, GPP and ET collected half-hourly time scales and we evaluated the capability of SIF to track photosynthetis and transpiration. Moreover we analyzed the information content in SIF time series using time causal information quantifiers. The research site is at *Majadas del Tietar*, with its multiple above-canopy and sub-canopy eddy covariance towers and a Fluorescence BOX (FLOX) for SIF retrieval.

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Is near-infrared reflectance of a forest canopy driven by sun elevation and Irradiance?

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Estimates of gross primary production (GPP) are highly uncertain. **NIR_V is** a proxy for the reflectance in the near-infrared (NIR) waveband attributable to vegetation and has recently been promoted as a a new approach for estimating GPP. NIR_V shows high correlations with GPP and sun-induced chlorophyll fluorescence on the monthly and regional scale (Badgley et al., 2017). Badgley et al. (2017) define NIR_V as the product NIR_V = NDVI * $Refl_{NIR}$ of the normalized difference vegetation index (NDVI) and reflectance in the NIR. We think that NIR_V is mainly driven by sun elevation angle, solar irradiation and canopy structure. We used cross correlations, time series analysis and machine learning to test the hypothesis. Our Results show that 1. During vegetation period from May to October measured $Refl_{NIR}$ (and NIR_V) show a slight decrease but actual $Refl_{NIR}$ should be constant, as the main drivers for variations in $Refl_{NIR}$ (leaf area, leaf angles) remain nearly contstant during that period. 2. $Refl_{NIR}$ measured from May to October correlates with the sun elevation angle and solar irradiation. 3. NIR reflectance reaches its minimum at solar noon during the course of a day . For high sun elevation angles more light is reflected by the soil and the reflectance of soil is lower than the reflectance of leafs in the NIR (in the red it is vice versa). In future we want to model radiative transfer within forest canopies and compare simulated and observed relationships of NIR_V, solar irradiance, sun elevation angle and GPP. This may include modelling vertical and angular gap probabilities and multiple scattering by leafs in a multi-layer canopy model.

2017-41

Ecophysiological analysis and study of ecosystem dynamics for a Mediterranean Aleppo pine forest with the use of the eddy covariance technique and modelling approaches.

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The study of ecosystem dynamics and the accurate estimation of their primary productivity are crucial for the assessment of their contribution to the global carbon cycle and their overall performance, especially under the frame of the ongoing climate change. Mediterranean ecosystems in particular are characterized by warm and dry summer periods, thus they are considered among the most sensitive ecosystems to the climate change. Eddy covariance technique is considered as the only method that provides direct measurements of primary productivity on ecosystem level, however due to various reasons it has to be combined with modelling approaches.

In this study we present the seasonal fluctuation of primary productivity, in terms o CO_2 assimilation, for a Mediterranean Aleppo pine (Pinus halepensis) forest, as it was measured with the eddy covariance technique for a two year period, on a natural habitat of the species, in Kassandra Peninsula, Chalkidiki, Greece (40º 06' N, 23º 18' E, el: 0-10 m). An analysis of the main environmental factors influence on primary productivity has also performed, in order to assess their relative significance and the way they affect primary productivity on ecosystem level. From the above analysis, the mathematical dependence on environmental factors of primary productivity has been carried out and a simple model was developed. The latter is used for gap filling purposes and for a potential use to other ecosystems of the same species.

The seasonal fluctuation of primary productivity follows the seasonal fluctuation of environmental factors, while daily GPP values varying from as low as 0.5 g C m^{-2} d^{-1} during wintertime to 8.5 g C m^{-2} d^{-1} at mid-spring. From the studied environmental factors, Photosyntetically Active Radiation implies the greater affection on GPP fluctuation, while temperature has a minimal effect on GPP, but a strong effect on ecosystem respiration. Although the summer periods are warm and dry, the studied species is not subjected on great water stress, keeping relative high GPP values during summer.

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