Abstract Volume
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15. Greenhouse Gases: Linkages between Biosphere and Climate

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& Werner Eugster, Christoph Ammann, Christoph Ritz (session 15)

ACP – Commission on Atmospheric Chemistry and Physics,
ProClim – Forum for Climate and Global Change,
IGBP- Swiss Committee

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10.1

Importance of evapotranspiration and rainfall reevaporation for the $\delta^2$H and $\delta^{18}$O signature of precipitation and boundary layer water vapour: a case study

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Atmospheric circulation patterns and precipitation determine local meteorological conditions and water availability and thus have a strong impact on plant ecosystems. In turn, local ecohydrology feeds back on the regional atmospheric water cycle through evapotranspiration. Studying evapotranspiration and its link to atmospheric circulation is thus central for a better understanding of the coupling between the land surface vegetation and the atmosphere. In this context, stable water isotopes, which are naturally available tracers of water phase changes, serve as a powerful and instructive research tool.

Here we present a case study, which aims at gaining a better understanding of the respective role of plant transpiration, soil evaporation and below-cloud rainfall reevaporation for the isotope signature of rain and boundary layer water vapour. We performed collocated rain and vapour isotope measurements in Zürich during a week in July 2011 with frequent but moderate rainfall intensities. Precipitation samples were collected hourly for isotope analysis with IRMS and the water vapour isotope signature was measured continuously at a 5 s temporal resolution using a commercial laser spectrometer (Aemisegger, et al. 2012).

An isotope-enabled, limited-area weather prediction model (Pfahl, et al. 2012) has been used to simulate the measurement period and perform sensitivity experiments. The isotope fractionation effects during plant transpiration, soil evaporation and rainfall reevaporation have been alternately suppressed during these experiments to investigate the relative importance of these processes for the isotope signature of low-level water vapour and precipitation. We found that the precipitation isotope signal is controlled to a large extent by cloud and below cloud interaction processes between the rain drops and ambient water vapour. The low-level water vapour isotope signal, however, is strongly influenced by evapotranspiration. By combining our isotope measurements with the results from numerical model simulations we illustrate the used of water isotopes in atmospheric moisture as a constraint for validation of the model representation of processes like evapotranspiration and below-cloud interaction of rain with low-level water vapour.

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The Ca biogeochemical cycle in soils during a tropical tree lifetime

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The study of calcium (Ca) biogeochemical cycle has always been neglected compared to those of other elements, such as carbon or nitrogen. Nevertheless, Ca supply is a key question in the context of the oxalate carbonate pathway (OCP). OCP is a process leading to the conversion of atmospheric CO₂ into pedogenic carbonate through the formation of plant oxalate (Cailleau et al, 2011). Ca is involved all along the OCP. This pathway comprises an oxalogenic tree, i.e an iroko (Milicia excelsa), which leads to the formation of an oxalate-rich forest ground. When accessible in the soil, oxalate is consumed by soil oxalotrophic bacteria. Oxalotrophy induces the release of carbonate ions in the soil solution and thus, allows a local soil pH increase. When stability pH of calcite is reached, in presence of Ca, Ca-carbonate precipitates (Verrecchia et al, 2006). As tropical ferralitic soils are known to be very poor in alkaline elements (Leneuf, 1959), understanding the Ca cycle, and its dynamics, is instrumental in the context of oxalogenic-oxalotrophic ecosystems.

The aim of this study is to provide a snapshot of an OCP system in order to propose a dynamical model focused on Ca during an oxalogenic tree lifetime. A quantification of the Ca cycle in an iroko tree ecosystem is presented and compared to those of a secondary tropical forest (OCP-free ecosystem). This Ca balance between the two systems shows that the Ca amount in the iroko soil is at least one order of magnitude higher than the one in an OCP-free setting. The massive amount of Ca, required to support carbonate accumulation, raises the question of substantial Ca supply in such tropical soils. Thus, figure 1 proposes a sketch of OCP emphasizing the Ca cycle.

In these tropical ecosystems, the Ca reservoir is the vegetation and the high turnover of the organic matter allows Ca recycling (Jordan, 1985) to support phytomass production. During the seedling stage, oxalotrophy starts to influence the initial soil acidic pH, but this process might still be weak. At the juvenile stage, the pH increase is sufficient enough to allow Ca²⁺ storage into soil. In addition, increasing Ca concentration starts to catalyze oxalogenesis (Franceschi and Nakata, 2005), leading to a positive feedback. At the mature stage, the stability pH for calcite is reached and pedogenic carbonate accumulates. Finally, the initial positive feedback is generalized to the entire OCP ecosystem. In conclusion, OCP ecosystems are able to trigger the formation of a long-term pedogenic carbonate reservoir in tropical settings.

REFERENCES
Figure 1. Sketch showing the model for the positive feedback of Ca on the OCP ecosystems.
10.3

Winter climate extremes and their role in biogeochemical processes under the snow

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The central research question of this project is how soil respiration and soil microbial community composition and activity of subalpine grasslands are affected by extreme winter climate events, such as advanced snowmelt date. Continuous winter season data on source and fate of CO₂ produced in soil under ambient and reduced snowpack will be presented, testing hypotheses on the underlying mechanisms.

In the scope of this talk, focus will be laid on the assumptions that (1) under ambient snow regime with a consistent snow cover, temporal variations in soil respiration rates are independent from fluctuations in soil temperature and moisture, but are determined by DOC concentration in the soil solution. In contrast, (2) reduced snow cover due to advanced snowmelt leads to intensive freeze-thaw cycles in the soil with larger amplitudes of microbial biomass, DOC and soil CO₂ production and efflux over the course of winter. Expected (3) shift in microbial community composition towards decreased fungal / bacterial ratios due to snow removal will further result in (4) a stronger incorporation of labile C in microbial biomass and more pronounced priming effects of soil organic matter turnover.

As a perspective, adequate carbon budgets for temperate mountain ecosystems could be constructed, relating snow insulation capacities to soil carbon availability, to microbial diversity and activity, and ultimately to the production and efflux of CO₂ from soils under various snow conditions. We hope to contribute some further understanding on the process of temperature decoupling of soil respiration in winter, which should feed into the development of more accurate global carbon circulation models.
10.4

Carbon isotopic signatures in leaf dark-respired CO₂ under different environments in potato

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Plants permanently respire various carbon sources to gain energy and intermediates for many essential plants processes. Thereby, CO₂ is produced during the Krebs cycle and connected anabolic reactions. Typically, the carbon isotope ratio of leaf dark-respired CO₂ (δ¹³Cₐ) shows a diel cycle with a ¹³C-enrichment during illumination and a ¹³C-depletion during darkness. δ¹³Cₐ can be enriched by 10‰ relative to the isotopic composition of the respiratory compounds (δ¹³Cₑ) such as sugars or organic acids. The reasons for this isotopic offset between δ¹³Cₐ and δ¹³Cₑ are not fully understood, since we lack knowledge about the δ¹³C values of single respiratory compounds. Moreover, the diel cycle of δ¹³Cₑ and δ¹³Cₐ can also vary due to species and environmental factors such as temperature and water status. For example, δ¹³Cₑ and δ¹³Cₐ were shown to be more positive under drought, but less is known about the influence of higher temperature.

We carried out climate chamber experiments with potato plants grown under two different temperature and two water regimes. Using the in-tube incubation technique, we assessed the diel cycle of δ¹³Cₑ. In parallel, we measured δ¹³C and concentrations of several carbohydrates (soluble mono- and disaccharides; starch) as well as organic acids (malate and citrate) using EA- and HPLC-IRMS.

At higher temperatures, δ¹³Cₑ and δ¹³Cₐ values were significantly more negative, whereas under drought δ¹³Cₑ and δ¹³Cₐ values were significantly more positive. The combined treatment of higher temperature and drought showed intermediate δ¹³Cₑ and δ¹³Cₐ, seeming that both impacts partially compensate each other. The diel course of δ¹³Cₑ cannot be explained by δ¹³C of soluble sugars and starch, but we suggest malate as a key carbon source of δ¹³Cₑ.
10.5

Altitude effects on soil function in forest and grassland systems of the Swiss Jura.

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We investigated the role of altitude as a proxy for climate along a ~800m transect in the Swiss Jura, as a driver of soil function in forest and grassland systems. We used radiocarbon-labelled substrates to mimic soil solution concentrations of low molecular weight compounds and measured potential enzymatic activity as two broad measures of soil function. Functional measures are variably sensitive to altitude, with strong response in mineralisation kinetics of sugars, amino acids and organic acids, but not all enzyme activities showed a response. Grasslands showed a much greater altitude response than forests, suggesting a decoupling of decomposition processes with climate under forests, and a role for ground-cover vegetation. Our results also highlighted the exceptional soil functional capacity of dry grassland systems, which in the current study had metrics of function twice that of other grassland systems. These findings suggest a disconnect between some metrics of soil function, but reinforce the strong link between function and organic matter content in soils. This underpins the need to elucidate ecosystem effects on soil function, and encourages further safeguarding of SOM as a significant reservoir of functional capacity.
10.6

Constraining future climate-land carbon cycle projections using observationally-based carbon flux estimates

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The increase in atmospheric CO₂ concentration as a result of the human perturbation of the carbon cycle is mainly driven by fossil fuel and cement emissions, and land-use associated emissions and partially compensated by ocean and land carbon uptake. It is well known that the terrestrial biosphere response to climate change is not well understood. The need to better understand the behaviour of the land biosphere has been driving the development of terrestrial biogeochemistry models (Prentice et al., 1989). The ability of these models to reproduce the observed features of the terrestrial carbon cycle increases the confidence in future projections but the sensitivity of carbon cycle models to different environmental factors is possibly just a result of the particular parameterization chosen by the model developer.

Here, we first evaluate the land carbon fluxes from coupled carbon-climate models used in the framework the CMIP5 project (Coupled Model Intercomparison Project-phase 5, Taylor et al., 2011) for the historical period and then use the fit of the different models to better constrain the modeled sensitivity of the land carbon cycle in these models to future climate change. The overall aim of the study is to find an emergent constrain linking the future change in the land carbon sink to observationally-based carbon flux estimates. To this end, we compare monthly mean Gross Primary Production (GPP) estimates for the period 1989–2005 from the CMIP5 models with the MPI FLUXNET-based upscaled GPP (Jung et al., 2009, 2011) for 26 different regions in the world based on the definition of the IPCC’s SREX Report (Seneviratne et al., 2012) by means of quantile-quantile (q-q) diagrams showing model against observations. We find that the CMIP5 models tend to underestimate (overestimate) the low (high) quantiles of GPP. Depending on the regions these biases in GPP can be related to biases in other variables such as evapotranspiration, temperature and precipitation.

The identified biases in present-day GPP are then used to constrain future change in climate-carbon cycle projections. A strong relationship (r>0.8) is found between the future changes in the land carbon sink (NEE) and GPP biases in CMIP5 models. Preliminary results suggest that the use of this emergent constraint decreases the future land carbon uptake by photosynthesis and the net land carbon sink by more than 30% in the Tropics (30°N-30°S). The use of a second constraint based on atmospheric CO₂ inversions of the Transcom 3 project (Baker et al., 2006, Gurney et al., 2004) will also be discussed.

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Aluminum toxicity in tropical montane forest soils

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Aluminum is a major cation in the tropical element cycle on acid soils. In the literature, it is therefore frequently stated that Al phytotoxicity might inhibit plant growth on acid tropical soils (Alleoni et al. 2010; Delhaize and Ryan 1995; Schaedle et al. 1989). Possible Al toxicity is indicated by a wide distribution of Al-accumulating plant species (> 1000 mg kg⁻¹ in leaves), mostly appertaining to the families Rubiaceae and Melastomataceae which is usually interpreted as adaptation to Al toxicity (Jansen et al. 2002). A further adaptation is a shallow rooting mainly in the organic horizons, where Al toxicity can be avoided, because of low Al concentrations and organo-complexation of Al (Wullaert et al. 2013).

Environmental changes, such as elevated H and N deposition because of Amazonian forest fires acidify the ecosystem and could result in increased Al availability and thus, increased phytotoxicity to Al-sensitive plants.

To explore the role of Al in a tropical montane rain forest in south Ecuador, we determined Al fluxes through the forest canopy (Boy et al. 2008) and conducted an hydroponic experiment for selected tropical montane forest trees – which were no Al accumulators. To determine dose-response functions of Al, seedlings of Cedrela odorata Moritz ex Turcz., Heliocarpus americanus L., and Tabebuia chrysantha (Jacq.) G. Nicholson were incubated with a Hoagland nutrient solution containing 0, 300, 600, 1200, and 2400 µM Al. In an additional treatment, we grew the same tree species in native litter leachate from the study area. Nutrient solutions were sampled and replaced weekly. After six weeks, plants were harvested. Roots and leaves were scanned and parameters like root length and diameter and leaf area were determined with the software WinRhizo™. Furthermore, we determined macro and micro nutrient concentrations in nutrient solutions before and after incubation and in plant tissue with AAS, ICP-MS, and TOC and CNS analyzer.

Total Al deposition (bulk and dry) from the atmosphere was low (2 kg ha⁻¹ yr⁻¹) and increased strongly in throughfall (10) and litterfall (7.5) indicating substantial Al uptake into the plant. Increasing Al concentrations reduced biomass production, healthy leaf area, and number of root tips. Root diameter, root-to-shoot biomass ratio, and diseased leaf area increased (Figure 1). Yet, Al toxicity occurred at Al concentrations between 300 and 600 µM, which is far above usual total Al concentrations (< 60 µM, even mostly as non-toxic organo-Al complex) in native litter leachate which can be considered as the plant-available Al pool. Biomass production was lowest if plants grew in litter leachate indicating limitation of plant growth by other factors than Al toxicity. We conclude that Al toxicity in the studied ecosystem is unlikely and that considerable Al is cycled through the plants without damage.

Figure 1. Dose response functions for total biomass (a), healthy leaf area cm² (b), number of root tips (c), root diameter (mm) (d), root-to-shoot biomass ratio (e), and diseased leaf area (% of total) (f), for C. odorata (N=9), H. americanus (N=8), and T. chrysantha (N=8). Error bars represent SE of means. Lines are fitted sigmoid growth functions.
REFERENCES
10.8

SnowMan: peatland carbon and nitrogen cycling under changing snow conditions

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Most of the studies on climate change effects on ecosystem processes have mainly focused on the effects of temperature and precipitation during the plant growing season, but recently awareness of the importance of altered environmental conditions during winter has increased (Groffman et al., 2011). Global warming has caused the snow free period (i.e. earlier spring melt) to advance by 3-5 days per decade (Dye, 2002). As snow has an insulating effect on soil and vegetation, a reduction in depth and duration of the snow cover can alter the structure and function of microbial and plant community (Brooks et al., 2011; Robroek et al., 2013), with cascade effects on biogeochemical cycles (Groffman et al., 2011).

In a Swiss Jura peatland, we performed a snow manipulation experiment to understand the complex interplay between snow cover and soil freezing dynamics on enzymatic activities (roots and mosses), carbon and nitrogen cycling and plant ecophysiology. We studied 15 plots in Sphagnum domintad lawns, equally divided in control (no manipulation), snow removal, and snow addition plots (Fig. 1).

Figure 1. Snow removal plot (left) and control and addition plots (right) in the Swiss Jura peatland.

Soil C fluxes were measured form all plots on a weekly basis from December 2012 to September 2013. All plots were inoculated with 15N four times over the experimental period (under peak snow conditions, just before and after melt-out and during summer period) while making sure not to disturb the physical character of the snow (control and addition plots). Before each inoculation, we collected peat soil samples from which all roots were sorted for background 15N analyses and root enzymatic activity analyses. One week after inoculation, additional peat soil samples were taken and roots were sorted according to the corresponding plant functional type (ericoids and graminoids), whereas all vascular plants and Sphagnum mosses were sorted to species level and analysed for 15N. Enzymatic activities from Sphagnum mosses were measured at above-mentioned periods as well as some ecophysiological parameters (i.e. photosynthesis, chlorophyll content, chlorophyll fluorescence) on a representative graminoid and moss species.

In this presentation we will present the results of this extensive snow manipulation experiment. Initial data exploration shows no discernable trend in a treatment effect regarding C fluxes, indicating resilience of respiration processes under changing snow conditions. Soil respiration peaks in all treatments just after melt-out (Fig. 2). Under the snowpack (control and addition), maximum efficiency of PSII (health indicator for the plant) of the grass and moss species was close to the maximum, while in the removal plot PSII of both species was strongly reduced. After full melt-out, PSII of both species in the removal plots recovered and their photosynthetic performance was higher as compared to the control and addition. Similar patterns were recorded for enzymatic activities in Sphagnum mosses, especially for β-glucosidase activity.
REFERENCES

Figure 2. Soil respiration over the experimental period.
Woody plant diversity drives retention of nitrogen in Central European forest canopies

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Studies in experimental grassland showed that ecosystem processes and services such as nitrogen (N) use are related with plant diversity but evidence is scarce for real-world ecosystems like managed forests. We assessed the effect of shrub and tree diversity (Shannon index based on species cover values) in forests on the retention of bulk (wet and coarse particles) and dry deposited N (fine particles) in a range of forest canopies in three distinct research areas in Germany that are representative for large parts of the Central European landscape and represent the most common cultivated tree species.

Deposited N was retained in 25 out of 27 studied forest canopies. Canopy N retention differed by region (Table 1) which we attributed to differences in soil fertility and nutrient availability in soils. However, N concentrations in soil solution were not directly related with canopy N retention indicating that there were other biogeochemical controls of soil N availability to plants. Total deposition of N differed between deciduous and coniferous forests because of higher dry deposition resulting from higher aerosol scavenging of conifers. Furthermore, canopy N retention increased with total deposition (P<0.001). This pointed at a higher foliar uptake because of the larger canopy surface area. Alternatively, foliar N uptake could be favored by an adaptation of the plant N-use strategies at higher N deposition rates. However, the effect of forest type was not uniform among regions (as indicated by the interaction term in Table 1) suggesting that foliar N uptake was co-determined by regional site conditions.

After accounting for regional and forest type effects, shrub and tree diversity explained 14% of the variance in canopy N retention (Table 1) and increased canopy N retention (Fig. 1). We attributed the biodiversity effect to spatial (resulting from canopy stratification), temporal (resulting from temporal variability in phenological and nutritional N demands), and functional complementarity (resulting from variation in preferential use of various N forms) in complex plant assemblages. However, strength and direction of the biodiversity effect varied by region and forest type highlighting the need for large-scale studies that include variation among regions and habitats within landscapes to test general relationships between biodiversity and ecosystem services and processes.

Our results are the first evidence for complementary N use in real-world forests and also for complementarity in aboveground N acquisition. We therefore conclude that the theory of belowground complementary N use can be extended to aboveground N use.

Table 1: Analysis of (Co-)Variance of the canopy budget of total dissolved nitrogen based on linear modeling.

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<th>Source</th>
<th>Df</th>
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Figure 1. Relationship of the Shannon index of shrubs and tree species versus the residuals of the canopy budget of total dissolved N of a linear model using region, forest type, and basal area as explanatory variables.
10.10

The mobility of nitrogen between tree-rings of Norway spruce \textit{(Picea abies L.)} and the effect of extraction on tree-ring $\delta^{15}$N and $\delta^{13}$C

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Studies utilising stable isotopes of nitrogen ($\delta^{15}$N) in tree-rings are rare in comparison to those using carbon ($\delta^{13}$C) and oxygen ($\delta^{18}$O). This is mainly due to the potential distortion of environmental signals by the translocation of mobile N compounds between tree-rings (Hart & Classen, 2003). Thus, pre-treatment extraction procedures have been used to remove these mobile N compounds prior to isotope analysis. Studies in the recent past, however, have begun to question the necessity of this extraction procedure (Doucet et al., 2011).

We studied the magnitude of the mobility of tree-ring nitrogen by comparing five Norway spruce \textit{(Picea abies L.)} trees from a plot labelled with $^{15}$N in 1995/6, and under experimentally elevated N deposition (Schleppi et al. 1999), with five control trees. We also investigated the effect of the extraction of mobile N compounds on the tree-ring $\delta^{15}$N and N concentration, as well as the tree-ring $\delta^{13}$C and C concentration.

The $^{15}$N label was found in all tree-rings between 1951-2009 at the labelling plot, suggesting a high radial redistribution of N within the tree stem sapwood. The extraction procedure had no significant effect on either the $\delta^{28}$N or $\delta^{15}$C in either the labelled or control trees. Similarly the N concentrations from both plots were also unaffected by the extraction procedure. These results imply that the pre-treatment removal of mobile N compounds is not necessary prior of using $\delta^{15}$N and $\delta^{13}$C in dendrological studies. However, the use of Norway spruce tree-ring $\delta^{15}$N to understand tree response to changing environmental conditions must be carried out with extreme care due to the high radial mobility of N within the tree stem.

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15.1

Spatial variability of atmospheric methane: Attributing measured concentrations to emissions

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Regional variations of methane concentrations are poorly understood, although methane is known to be a highly abundant trace gas and very potent greenhouse gas. Atmospheric methane concentrations are typically only measured at sites close to methane emitters or at remote areas to quantify atmospheric background levels. But at the same time, the density of measurement stations is not sufficient to resolve small-scale regional variations in methane concentration levels.

In this study, we measured diurnal and regional variations of methane concentrations in a valley located in the Alpine foreland in Switzerland and compared the data to a spatially explicit emission inventory. Methane measurements were carried out in July 2012 using a Fast Methane Analyzer (Los Gatos Research, USA), installed in the luggage compartment of a car. The measurement tracks extended over 87.5 km alongside the valley floor as well as the eastern and western hillsides. The measurement area is mainly used for agriculture and livestock farming, representing a major source of methane.

Methane concentrations showed high spatio-temporal variability, with concentrations ranging from 1.88 ppm in remote areas to 7.66 ppm close to local sources. Peak concentrations were observed during the night within the valley; average daytime methane concentrations were typically below 2.1 ppm. Nighttime vertical profiles of temperature and methane concentrations showed a clear temperature inversion, suppressing vertical mixing. Thus, methane was trapped at the valley bottom below the nocturnal boundary layer inversion. In contrast, diel patterns of methane concentrations at the hill sides were mainly affected by topography and local transport processes. Although we did not observe strong diurnal patterns at the eastern hillside, we measured elevated methane concentrations in the morning at the western slopes. An autocorrelation analysis of the spatial measurements indicated that point sources had expanded (for areas up to 64 km²) influence on regional patterns of methane concentrations close to the valley bottom during nighttime. In contrast, daytime methane concentrations were only increased very close (< 200 m) to local sources as a consequence of the efficient turbulent mixing. Comparing our measurement data with a spatially explicit, high resolution (500 m x 500 m) methane emission inventory we found a significant positive correlation for the relationship between the lowest flux percentiles and concentrations. Thus the source distribution for the lower methane sources in the emission inventory was reproducible by ambient concentration measurements.
15.2

Understanding and quantifying CO₂ and CH₄ greenhouse gas fluxes on the regional scale: The project CarboCount CH

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The project CarboCount CH investigates human-related emissions and natural exchange between atmosphere and biosphere of the two most important long-lived greenhouse gases carbon dioxide (CO₂) and methane (CH₄) in Europe and especially in Switzerland. In addition to performing long-term simulations of CO₂ exchange fluxes and their response to climate variations in Europe during the past 30 years, the project combines measured and simulated concentrations in an inverse modelling framework to better quantify CO₂ and CH₄ fluxes at the regional scale. For this purpose, four new measurement sites have been established in Switzerland including the tall tower (210 m) at Beromünster, all equipped with Picarro instruments for continuous measurements of CO₂, CH₄, and partially CO. Bi-weekly ¹⁴CO₂ samples at the tall tower site will provide valuable insights into the contributions from fossil fuel emissions. Two separate atmospheric transport and inverse modelling frameworks are being developed within the project. The first one uses the new tracer transport module of the regional numerical weather prediction model COSMO together with the CarbonTracker inversion scheme (Peters et al. 2010). The second framework is based on backward simulations with the Lagrangian transport model FLEXPART-COSMO and a Kalman filter (Brunner et al. 2012). Anthropogenic a priori emissions are taken from newly developed high-resolution (500 m x 500 m) inventories of CH₄ emissions in Switzerland. Atmosphere-biosphere exchange fluxes of CO₂ are simulated with the coupled system COSMO-CLM2, i.e. COSMO coupled to the Community Land Model.

Here we will present a general outline of the project, the setup of the measurement network and of the different modelling components and inverse methods. By the time of the meeting, a complete year of measurements will be available for most sites. These data are analysed for their diurnal and seasonal components and for their dependence on meteorology. Correlations between the measured trace gases provide a first indication of their relative emission strengths and for the variation of sources and sinks with season. First simulations and an analysis of model performance in comparison with observations will also be demonstrated.

Figure 1. The CarboCount CH observation network. The filled red circles denote the 4 new sites. Blue and green circles are measurements from complementary networks including Swiss Fluxnet with Eddy covariance sites and further sites with continuous CO2 and CH4 measurements including Jungfraujoch.
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Discerning cows from pasture – Contribution of grazing animals to eddy covariance greenhouse gas fluxes

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Grasslands act as sinks and sources for greenhouse gases (GHG) and are, in conjunction with the animals utilizing these feed resources, responsible for a large share of agricultural GHG emissions. Ecosystem scale flux measurements (by eddy covariance; EC) have been extensively used to investigate CO2, CH4, and N2O exchange over different ecosystems and are becoming state-of-the-art for animal grazing systems, too (e.g. Dengel et al., 2013). Direct GHG emissions from ruminants in agriculture are usually investigated on the scale of individual animals by respiration chambers (Münger & Kreuzer, 2008) or by the SF6 method (Pinares-Patino et al., 2007). The advantage of EC flux measurements is the possibility of emission monitoring under real grazing conditions on the pasture with a high time resolution (about 30 min). However, EC measurements do not provide individual animal data and represent a spatially integrated flux over an upwind area (the so-called footprint) in the order of 1000 m2 containing a variable number of grazing animals. Thus a careful analysis of the location and extension of the flux footprint is necessary. In addition, data on the position of the animals relative to the flux footprint is very important but usually lacking (Baldocchi et al., 2012).

In our experiment we investigate the ability of EC flux measurements to reliably quantify the contribution of the grazing animals to the net exchange of CO2 and CH4 over pasture systems. For this purpose, a field experiment with a herd of twenty dairy cows in a full-day rotational grazing system has been established in Posieux near Fribourg. Net CO2 and CH4 exchange of the grazing system are measured continuously by the eddy covariance technique (Sonic Anemometer HS-50, Gill Instruments Ltd; FGGA, Los Gatos Research Inc. and LI-7500, LI-COR Biosciences). In order to quantify the contribution of the animals to the net flux, the position, movement and grazing/rumination activity of the individual cows is recorded using GPS (5 s time resolution) and mastication sensors on each animal. In combination with a detailed footprint analysis of the eddy covariance fluxes, the animal related CO2 and CH4 emissions are derived and compared to calculated animal emission rates based on animal energy expenditure factors.

First results show, that the accuracy of the GPS derived cow position is better than 4 m and thus clearly sufficient for the localization of grazing animals within the EC flux footprint (see example in Fig. 1). Observed eddy covariance fluxes indicate a good detectability of the grazing animals especially for CH4, which has a very low background flux. For CO2 a partitioning of the net flux is necessary to separate contributions of vegetation and soil (assimilation and respiration) from the animal respiration flux.

Figure 1. Cow distribution (colored pixels in a.u.; 4 x 4 m) and footprint extension (dashed lines) during two 30 minutes measurement intervals. The lines comprising 80%, 60%, 40%, and 20% of the flux footprint. The triangle indicates the measurement tower. According to the animal density in the footprint, a decreasing methane flux of 0.99 and 0.24 µmol m⁻² s⁻¹ was observed for 11:00 and 13:00, respectively.
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15.4
Greenhouse gas fluxes from agricultural soils under organic and non-organic management – a global meta-analysis

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Agricultural soil management induces nitrous oxide and methane emissions that account for around 40% of the sector’s direct greenhouse gas (GHG) emissions globally (Smith et al., 2007). The reduction of these emissions thus constitutes an important part of agriculture’s mitigation potential concerning climate change.

Thirty seven Mio hectares of agricultural land (= 0.9% of total agricultural land) are currently farmed organically. It is anticipated that these systems provide environmental benefits, particularly with regard to soil conservation and climate protection. A literature search, the first of its kind, on measured soil-derived greenhouse gas (GHG) (nitrous oxide and methane) fluxes under organic and non-organic management from farming system comparisons was conducted and followed by a meta-analysis. This review showed that paired field measurement data of soil GHG emissions is scarce. Up to date only 19 studies based on field measurements could be retrieved, all conducted in the Northern hemisphere under temperate climate. Among them is only one comparative study on rice paddies.

Based on 12 studies that cover annual measurements, it appeared with a high significance that area-scaled nitrous oxide emissions from organically managed soils are 492±160 kg CO₂ eq. ha⁻¹ a⁻¹ lower than from non-organically managed soils. For arable soils the difference amounts to 497±162 kg CO₂ eq. ha⁻¹ a⁻¹. Furthermore, a higher methane uptake of 3.2±2.5 kg CO₂ eq. ha⁻¹ a⁻¹ for arable soils under organic management can be observed. However, yield-scaled nitrous oxide emissions are higher by 41±34 kg CO₂ eq. t⁻¹ dry matter (arable land use). This is due to 26% lower crop yields under organic management. To equalize this mean difference in yield-scaled nitrous oxide emissions between both farming systems, the yield gap has to be less than 17%.
Nitrous oxide emissions from conventionally managed soils seemed to be influenced mainly by total N inputs, whereas for organically managed soils other variables such as soil characteristics seemed to be more important. This can be explained by the higher bioavailability of the synthetic N fertilisers in non-organic farming systems while the necessary mineralisation of the N sources under organic management leads to lower and retarded availability. This might also be the reason for the large variation of the corresponding nitrous oxide emission factors ranging from 0.3 to 36% of the applied N (Fig. 1), whereas most of the calculated emission factors for soils under non-organic management were within the uncertainty range of 0.3 – 3% attributed to the 1% standard emission factor for N fertiliser also used in the IPCC Guidelines for National GHG Inventories (De Klein et al., 2006). Thus, it seems quite likely that due to the retarded release of mineral N from organic sources a substantial part of the resulting nitrous oxide emissions will become effective later than the vegetation period under study.

Further GHG flux measurements in farming system comparisons are required to confirm the results and close the existing knowledge gaps.

**Fig.1.** Emission factors for the organic and non-organic farming system of the different land uses. Box plots illustrate the distribution of the emission factors from the treatments of the respective farming systems and land use category. The boxes denote the 25 to 75% quartiles including the median (= 50% quartile). The error bars denote the non-outlier range and black dots are outliers. The dashed grey lines indicate the uncertainty range (0.3% - 3%) of the 2006 IPCC guidelines standard emission factor for N fertiliser that is 1% (De Klein et al., 2006).

**REFERENCES**


P 10.1

Gap-filling Strategies for Annual VOC Flux Data Sets

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Chemical degradations of volatile organic compounds (VOCs) in the atmosphere facilitate tropospheric ozone production and secondary organic aerosol formation and thus VOCs are influencing air quality and climate. Flux data sets which quantify the exchange of volatile organic compounds at the interface between biosphere and atmosphere, however, are sparse and often measurements are performed for several weeks to some months only. To make an important step towards a better understanding of the VOC ecosystem-atmosphere exchange on longer time scales complete annual data sets are required and a gap-filling of missing VOC data is inevitable.

Flux measurements of several VOCs were conducted above a mountain meadow in Austria during the complete snow-free period of the years 2009 and 2011. The performance of four different gap-filling routines, mean diurnal variation (MDV), mean gliding window (MGW), look up tables (LUT) and linear interpolation (LIP), in missing data replacement was tested using the measured VOC flux data set. The MDV routine yielded to the lowest gap-filling errors for both years and all quantified VOCs. The other gap-filling routines, which performed gap-filling on 24h average values, introduced considerably larger uncertainties. The gap-filling error scaled linearly with the number of data gaps for each gap-filling routine. Measured VOC fluxes during times of complete snow cover were close to zero but also highly variable. Consequently the missing data replacement for the winter period introduced considerably higher uncertainties than the gap-filling during the measurement period.

The compound which contributed most to the cumulative non-methane VOC carbon emissions was with annual sums of 381.5 mg C m$^{-2}$ (2009) and 449.9 mg C m$^{-2}$ (2011) methanol during both years. As opposed to the year 2011, when monoterpene cumulative fluxes were quite low, we observed considerable deposition fluxes of monoterpenes to the grassland ($\sim$327.3 mg C m$^{-2}$) in 2009. The monoterpene uptake in 2009 was a consequence of a severe hailstorm in June 2009. The influence of the other quantified VOCs on the annual patterns was considerably lower.
P 10.2

Hydrodynamic controls on the age and composition of sedimentary organic matter on continental shelves: a case study from Chinese marginal seas

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As a crucial interface between the land and the ocean, continental shelves receive organic carbon inputs from both reservoirs. Although these systems account for ~90% of global organic carbon in the modern oceans (Hedges and Keil, 1995), considerable uncertainty remains concerning the source and fate of organic carbon delivered to and produced over continental shelves. In particular, controls on spatial variability in the content and composition of sedimentary organic matter on continental shelves remain the focus of on-going investigations (e.g., Schmidt et al., 2010; Vonk et al., 2012).

In addition to the magnitude and nature of organic matter supply from terrestrial sources and from surface water productivity, there is strong evidence that hydrodynamic processes and physical protection mechanisms play a critical role in influencing dispersal redistribution and eventual burial of organic matter on the continental shelf (Keil et al., 1994). This study explores these processes in a large marginal sea system: Chinese marginal seas. We are examining spatial variations in grain-size, mineral surface area, bulk elemental, and isotopic compositions of organic matter in surface sediments. Preliminary measurements of organic carbon contents and isotopic compositions coupled with grain size measurements suggest that pre-aged organic matter accumulates on the outer shelf and in low energy regions where clay-rich sediments accumulate. Further geochemical investigations are underway on surface sediment fractions separated by grain size in order to examine variations in organic matter content and isotopic composition between different fractions as well as within the same fractions from different regions within the Chinese marginal seas. Observations are discussed in the context of both hydrodynamic and mineralogical control on sedimentary organic matter distribution and composition.

We discuss the implications of our findings for the application of organic geochemical proxies and for budgets of organic carbon burial in this and other continental shelf sea systems.

REFERENCES
Uplifting of hummocks in palsal peatlands in northern Sweden identified by stable carbon isotope profiles

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The carbon pool of palsal peatlands is an important component in the global carbon cycle and is projected to change in the 21st century. It is predicted that the area suitable for palsal development will be lost until 2100. Uplifting of the hummocks above the surrounding wetter areas is a process which starts at the beginning of palsa formation. The degradation of palsal peatlands with cracks and erosion on the edges can be a natural process after the palsa reached his mature status but is now accelerated by permafrost thawing under climate change regime.

We took samples from uplifted peat material down to the permafrost in three palsal peatlands in the Abisko valley, northern Sweden, and analyzed them for ¹³C, C and N contents. In the profile δ¹³C values change from increasing to decreasing values; the highest values are found at the so-called turning point (Alewell et al. 2011). The turning point indicates a change from anaerobic to aerobic conditions due to the uplifting of the peat material by permafrost and is indicative for the time of uplifting of the palsa. The stable isotope depth pattern is supported by the C/N ratio of the peat material. Above the turning point C/N ratios are high, indicating oligotrophic decomposition, whereas C/N ratios are lower below the turning point, corresponding to minerotrophic conditions. We calculated palsal formation in this peatlands at about 120 to 600 years BP based on ¹⁴C dated peat layers (Alewell et al. 2011). Kokfelt et al. (2010) detected a similar time period of palsal formation and a change from minerotrophic to oligotrophic conditions at a similar depth. Hence, stable carbon isotopes indicators for the depth and thus the time when uplift of hummocks in palsal peatlands by permafrost commenced.

REFERENCES

P 10.4

Soil respiration rates of degrading palsa mires in northern Sweden

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Quantifying carbon decomposition rates in soils is a key approach to estimate potential CO₂ emissions that lead to climate warming and permafrost thawing. High emission rates are predicted especially in northern peatlands storing 280 Pg C. Palsa mires are common peatlands in the discontinuous permafrost region characterized by dry mounds or plateaus, which have been raised up by permafrost out of the wetter parts. In palsa mires, rapid changes in environmental conditions may accelerate peat degradation and alter hydrological and biogeochemical processes. (Bäckstrand et al. 2010; Olefeldt et al. 2012). The magnitude of the resulting shift in CO₂ emission rates has not been well investigated yet. We measured respiration rates from degraded and non-degraded palsa sites under laboratory conditions. Soil samples were taken from the Stordalen and the Storflaket mires in the Abisko region, northern Sweden. The samples were separated in two vertical depth layers (5 – 10 and 15 – 20 cm) and incubated at 4 and 12°C for one month. We sampled the headspace for analysis of CO₂ by gas chromatography. The emission rates ranged between 0 and 7.638 µg CO₂ g⁻² h⁻¹ over the whole experiment. Respiration rates at 12°C were almost twice as large as at 4°C. In the vertical soil profile, the upper peat layer respired in average 34 % more CO₂ than the lower one. CO₂ emissions were 25 % higher on degraded than on non-degraded sites. Higher respiration rates of the upper soil layer are most likely due to stronger microbial activity and less recalcitrant organic compounds. Our results confirm the general assumptions that carbon decomposition rates increase with increasing temperature. Furthermore, the difference between degraded and non-degraded sites indicates that disturbance of peat layers due to thawing also leads to higher CO₂ release.

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