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15. Biogeochemical cycles in a changing environment

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ACP – Commission on Atmospheric Chemistry and Physics

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15.1

Tracing carbon through grassland: the impact of drought on the short-term carbon flow from photosynthesis to soil respiration

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Mean summer precipitation in Switzerland is projected to decrease by the end of the 21st century and there is a tendency towards more frequent dry spells during summer (CH2011, 2011). However, large uncertainties exist in terms of how extreme events like heat waves or drought periods influence the carbon cycle. Ostle et al. (2009) stated that plant-soil interactions need to be further integrated into global carbon models in order to improve climate change predictions. However, plant-soil interactions themselves have a high level of complexity and many processes are subject to current research.

Here, we present results from a project where we investigated the effect of drought on the short-term carbon transport within the plant-soil system of an intensively managed lowland grassland in Switzerland (ETH research station Chamau) using rainout shelters. A pulse labeling experiment with $^{13}CO_2$, performed in June 2011, allowed tracing the flow of freshly assimilated carbon from above-ground biomass to the roots and finally to soil respiration. Our key method were continuous measurements of soil respiration and its isotopic composition with a laser spectrometer (QCLAS-ISO, Aerodyne Research Inc., MA, USA) coupled to a custom-built chambers. These measurements were complemented by sampling community above- and below-ground biomass and subsequent stable isotope analysis.

Soil respiration showed a diurnal cycle with highest fluxes during the late evening/night, lagging 5-6 hours behind soil temperature under both control and drought treatments. The labeling experiment clearly identified the high nocturnal fluxes as autotrophic. While photosynthesis and soil respiration were reduced under the drought treatment, the appearance of ^{13}C- label in soil respiration was not delayed. Thus, there was no sign of any influence of drought on allocation speed. Our results suggest that during a dry spell, less carbon is entering the system while allocation belowground seems to be maintained, although less carbon is released to the atmosphere by soil respiration. If these results can be generalized is currently investigated. Since grasslands are widespread agroecosystems in Switzerland and beyond, such results are important for carbon sequestration considerations or for the modeling of the future carbon cycle.

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15.2

Photosynthetic ^{13}C discrimination of *Fagus sylvatica* branches: Insights from continuous, high-frequency field measurements and a Bayesian modelling approach

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Isotopic discrimination against $^{13}CO_2$ during photosynthesis ($^{13}\Delta$) causes the overall ^{13}C depletion of the terrestrial biosphere compared to the atmosphere. $^{13}\Delta$ varies in response to environmental variables that influence photosynthetic gas exchange. For C_3 plants, $^{13}\Delta$ mainly reflects the balance between the CO_2 supply to and the CO_2 demand by the carboxylation sites, but it is, to a smaller extent, also influenced by carbon isotope fractionations occurring during mitochondrial and photo-respiration. Understanding and predicting $^{13}\Delta$ variability has gained relevance for CO_2 flux partitioning on the global and the ecosystem scale, for tree ring analysis or for insights into plant/soil dynamics. Estimates of $^{13}\Delta$ are commonly obtained by combining carbon isotope measurements of plant-derived organic matter or air profiles with $^{13}\Delta$-models. In contrast, direct, gas exchange-based measurements of $^{13}\Delta$ under field conditions are sparse, due to the technical deployment involved. Hence, we have little experimental verification of diurnal and seasonal variabilities of $^{13}\Delta$ and their relation to environmental drivers. We further lack a thorough field-based evaluation of the Farquhar et al. (1982) $^{13}\Delta$-model.

Here, we present continuous, hourly field measurements of $^{13}\Delta$ of *Fagus sylvatica* L. branches, conducted with three custom-made open branch bags and a laser spectrometer for CO_2 isotopologue measurements (QCLAS-ISO, Aerodyne Research Inc.). Data from two field campaigns (in total 38 and 60 days) in a mature, temperate mixed-deciduous forest in Switzerland during August / September 2009 and 2010 are shown. We observed a high diurnal variability of $^{13}\Delta$, with average diurnal amplitudes of ≈ 10‰ and maximum diurnal amplitudes of ≈ 20‰. Highest $^{13}\Delta$ were generally observed during dawn and dusk, and lowest $^{13}\Delta$ during midday. Morning and afternoon $^{13}\Delta$ commonly displayed intermediate values. Day-to-day variations were summarized with flux-weighted daily means of $^{13}\Delta$, which ranged from 15‰ to 23‰ in 2009 and from 18‰ to 29‰ in 2010. Regression analysis suggested that CO_2 assimilation (and hence CO_2 demand) played the dominant role in driving $^{13}\Delta$ variability at the branch level, as long as trees were not water-limited. For the environmental drivers, changes in incident *PAR* appeared to strongly determine changes in the branch gas exchange, and hence $^{13}\Delta$.

Using data from the 2010 field campaign only, we explored the applicability of three versions of the commonly used Farquhar *et al.* (1982)-model (comprehensive: $^{13}\Delta_{comp}$, simplified: $^{13}\Delta_{simple}$ and revised: $^{13}\Delta_{revised}$ versions) for predicting observed diurnal and day-to-day $^{13}\Delta$ variabilities. $^{13}\Delta_{comp}$ predicted the mean diurnal variability of $^{13}\Delta$ much better than $^{13}\Delta_{simple}$ ($RMSE_{simple}$ ≈ 3.4‰; $RMSE_{comp}$ ≈ 2.5‰). Furthermore, $^{13}\Delta_{comp}$ was more suitable than $^{13}\Delta_{simple}$ for predicting flux-weighted daily means of observed $^{13}\Delta$. For model calibrations, a Bayesian inference approach was used. This approach allowed us to reliably quantify uncertainties in the model parameter estimation and to reveal the amount of model-relevant information present in our field dataset.

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15.3

$\delta^{13}C$ (DIC) profiles of Lake Geneva, Switzerland/France

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There is a growing awareness that lakes may represent significant sinks and sources for atmospheric CO_2 (e.g. Cole et al. 2007). And while the carbon cycling of the oceans is incorporated into climate change models, further understanding is needed to involve carbon fluxes of lakes in the global carbon balance.

A tool to constrain carbon sources are studies of the variations of the stable isotopes (^{12}C and ^{13}C) of dissolved inorganic carbon (DIC). In general, most studies of $\delta^{13}C_{DIC}$ in lakes show the same patterns: variations in the isotope composition of DIC are closely coupled to the biologic cycle in the lake, as aquatic photosynthesis in the epilimnion preferentially consumes $^{12}CO_2$ (e.g. Baird et al. 2001). Respiration in the hypolimnion consumes the ^{13}C depleted organic matter and produces CO_2 with a similar ^{13}C depleted composition (e.g. Herczeg 1987). However, recent studies (e.g. Karim et al. 2011) concluded that it does not necessarily imply that the effects of GPP (gross primary productivity) and R (respiration) are reflected in carbon dioxide concentrations and isotopes in lakes. Especially, studies on large lakes are underrepresented in the literature, and therefore the research aim of this study is to evaluate the isotope composition of DIC in Lake Geneva.

Depth profiles were taken between 2009 and 2011 and the results show that even within the same lake, parameters which are indicating photosynthesis, are not necessarily linked to $\delta^{13}C_{DIC}$ values. Moreover, it can be concluded that $\delta^{13}C_{DIC}$ values in summer do not only reflect the amount of PP. This is based on the fact, that the amount of PP in summer shows a strong discrepancy between 2009 and 2010 (CIPEL 2011), but annual $\delta^{13}C_{DIC}$ values of the epilimnion and metalimnion do not indicate variations. However, in shallow bay regions the $\delta^{13}C_{DIC}$ variation correlates with the seasonal cycle of PP. Furthermore, results indicate that the progressive depletion of $^{13}C_{DIC}$, observed in the metalimnion, is dependent on the local variation of temperature and conductivity, thus density stratification. This suggests that the vertical variation of $\delta^{13}C_{DIC}$ may also be induced by turbulent mixing.

The pCO_2 (partial pressure of CO_2) lies below atmospheric equilibrium from April to October and based on this results it can be concluded that Lake Geneva is taking up CO_2 from the atmosphere between spring and fall and is emitting CO_2 from the lake to the atmosphere in winter. A good correlation between pCO_2 and $\delta^{13}C_{DIC}$ values indicates that pCO_2 has a primary control on the isotopic composition of DIC.

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15.4

Snow-cover effects on substrate-induced respiration and SOM density fractions in transplanted pasture soils.

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Sub-alpine pasture soils were transplanted from 1400m to three locations along an altitudinal gradient (600-1400m a.s.l) in the Swiss Jura mountains as a climate simulation. Following observations of potential snow-pack effects on in-situ soil respiration along our hill-slope gradient, we collected topsoils from three transplant sites with variable snow cover to investigate variations in microbial biomass stoichiometry, soil organic matter (SOM) characteristics and substrate induced respiration. We hypothesised that addition of an artificial root-exudate cocktail would simulate the spring input of low molecular weight substrate and stimulate respiration in a pattern according to the snow cover regime. Response to substrate addition was highly variable among sites, with persistent snow-cover dampening the substrate response compared to sites which typically experienced lower snow cover and higher incidence of freeze-thaw cycles. We also present edaphic an microbial biomass data along with density fractionated SOM and explore function-driver relations among the transplanted soils. Our results have implications for the seasonal dynamics of C turnover in soils which will, under future climate scenarios, experience a much reduced snow cover, and more frequent freeze-thaw episodes.

15.5

The water sourcing strategy of drought affected temperate grasslands

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In Central Europe, temperate grasslands are agroecosystems of high agricultural, ecological and economic importance. Growth, distribution and yield of this vegetation type depend strongly on the sufficiency of water supply in late spring/early summer. Until now, water has never been considered as a limiting factor. However, climate models project a change in the future precipitation patterns: until 2070, a reduction in summer precipitation of about 20% (compared to 1961-1990) is projected for northeastern Switzerland. In addition, the frequency of extreme drought periods is likely to increase. The aim of this study was to investigate if herbaceous grassland species adapt their water sourcing to (simulated) drought by exploring deeper soil layers to compensate the decreasing soil moisture. Summer drought was simulated by using transparent shelters (3 m x 3.5 m) at three different Swiss sites along an altitudinal gradient (400 m to 2000 m). Water of soil and plant root crown (xylem) samples was cryogenically extracted. Soil, plant and precipitation waters were analyzed for $\delta^{18}O$ using isotope ratio mass spectrometry. Standing belowground biomass was sampled regularly to determine possible shifts in the root mass distribution.

The $\delta^{18}O$ values of drought affected plants differed significantly from those of control plants, and often were similar to those of upper soil layers, although upper soil layers were very dry. This pattern occurred at the three sites and during three years in different intensity. Particularly, in the recovery periods, i.e., about 4 weeks after removing the shelters, a very strong relationship with the $\delta^{18}O$ value of precipitation could be found. Our results were confirmed by an additional evaluation with a Bayesian calibrated mixing model. Belowground biomass distribution supported the results based on the stable isotopes approach: Under drought stress, a highly dynamic and strong increase of root mass was observed in the top soil. Thus, in contrast to the hypothesized drought adaption to deeper rooting patterns, temperate grassland species shifted root growth and water uptake to the top soil, supposedly towards the next most likely water source: the next precipitation event.

15.6

Temporal trends of organic carbon in Swiss rivers, 1974-2010

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Until recently, continental waters have been neglected as significant components of the global carbon cycle. Nowadays, the important role played by lakes and rivers in organic carbon processing, and not merely in transport, is widely acknowledged (Cole et al 2007). Moreover, organic carbon concentrations in rivers and lakes have been reported to have increased in the last decades in many places of the Northern hemisphere. This increase is not without exceptions and its causes are multiple (Evans et al 2005). Most studies have focused on small rivers and lakes of boreal and/or peat-rich ecosystems. We want to expand the scope of studied systems by analyzing the temporal series of organic carbon concentrations in temperate rivers. Switzerland offers a good opportunity for such studies, as extensive long-term temporal series of hydrological data are available through the NADUF program (NADUF).

We have selected data from nine measuring stations in the main Swiss rivers: Rhône (Porte du Scex, Chancy), Rhine (Diepoldsau, Rekingen, Village Neuf-Weil), Inn (S-Chanf, Martina), Aar (Brugg), and Thur (Andelfingen). These stations have at least 10 years (usually more than 25 years), of uninterrupted temporal series of biweekly recorded dissolved (DOC) and total organic carbon (TOC) data. We have analyzed temporal series of DOC and TOC concentrations, discharge, water temperature, conductivity, total suspended solids, phosphate and DOC and TOC loads. Since data are non-normally distributed, with frequent outlying values, and show a pronounced seasonality, robust non-parametric statistical methods have been used, namely Mann-Kendall and Seasonal Mann-Kendall. Temporal tendencies have been described by Sen's slopes of regression lines (Helsel and Hirsch 2002).

We have found a generalized decrease of TOC concentrations in rivers during the time period studied. DOC tendencies are less marked, with DOC concentrations having increased in Rekingen and Chancy. Decreases in TOC and changes in DOC concentrations are small –generally less than 1% of mean TOC or DOC content per year.This is the first time that a different temporal behaviour between DOC and TOC concentrations in continental waters has been reported. It could result in a temporal change of organic carbon quality and processing with the consequence of a higher percentage of DOC and a lower percentage of particulate organic carbon (TOC – DOC) in the rivers.

Loads of organic carbon leaving Switzerland have been calculated. They are a small but significant part of the Swiss forest net ecosystem production. TOC loads experienced a marked decrease in the last decade. This means a small, but probably worth of consideration, potential carbon sink in Switzerland.

Time evolution of DOC and TOC are not monotonic. This has been clearly shown by dividing the time-series in two sub-periods (before 1999 and 1999-2010) and obtaining the corresponding temporal trends. Many time-series in the first period considered show increasing concentrations, whereas all TOC and DOC late series (1999-2010) are decreasing, again with DOC decreasing slower than TOC.

Different temporal behaviour in the two sub-periods suggests a cyclic evolution of TOC and DOC concentrations. This hypothesis is supported by the calculation of moving averages of annual TOC and DOC concentrations, which show the probable existence of two cycles of increasing and decreasing organic carbon in the period studied (1974-2010).

As of yet, we have not been able to ascertain the causes of the observed temporal behaviour of river organic carbon concentrations. Statistical relationships of TOC with river discharge do exist but they are weak (30% of explained TOC variability at most, and usually 10-15%). Relationships with water temperature and phosphate concentrations are even weaker and non-significant in many cases. Discharge only explains a few percent of DOC variation, and water temperature and phosphate do not increase much the fraction of explained DOC variability.

Both the similarity of the recent trends in TOC and DOC concentrations in all the rivers studied and the probable existence of temporal cycles in DOC and TOC, point to a climate-related driving variable of their evolution. We are now trying to relate TOC and DOC data with precipitation data in the river basins to get a better insight in this challenging part of the global carbon cycle.

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15.7

Diffusive flux of methane and other greenhouse gases from lakes has a distinct within-lake spatial distribution

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Lakes are responsible for a significant amount of the natural production of the greenhouse gas methane. Methane can escape lakes through gas bubbles (ebullition) and plant-mediated gas transport. A third pathway, which becomes increasingly important with increasing lake size, is gas exchange on the air-water interface (diffusive flux). Estimates of diffusive methane flux from lakes are obtained through various methods, most of which rely on extrapolations from measurements done in a specific part of the lake (often the deep, central part). It has been suggested that diffusive flux, which depends on the concentration gradient from the water to the atmosphere and turbulence caused primarily by winds, shows a within-lake spatial variability. If true, this variability needs to be investigated to assess the validity of the estimates that are based on extrapolations. Moreover, the process of diffusive flux is not only relevant for methane, but also for other greenhouse gases (e.g. carbon dioxide). Improving our understanding of the greenhouse gas footprint of lakes might allow for lakes to be incorporated in the terrestrial greenhouse gas balance, something that has been called for in various papers.

We measured methane fluxes from the surface of 32 lakes in Europe along a transect from the shallowest to the deepest zones. Of 13 lakes we obtained reliable (i.e. not affected by ebullition) measurements of diffusive flux at all sampling locations. We found a distinct within-lake spatial pattern as the deeper zones typically had higher diffusive methane fluxes than the shallower zones. This pattern appears to be caused by large differences in turbulence driven diffusive flux. Moreover, this spatial gradient in turbulence driven diffusive flux was larger in bigger lakes. This means that calculations of whole basin diffusive methane flux based on extrapolations of measurements done in the deep, central zones tend to produce overestimations. To illustrate the implications of our findings, we plotted the overestimation of whole basin diffusive flux had we measured diffusive flux only in the central part of our 13 lakes compared with our spatially resolved measurements (Fig. 1).

Our findings indicate that estimates of whole basin diffusive gas fluxes need to be based on measurements at various sites along a spatial gradient. Also, more research is needed to improve our understanding of the variability in diffusive gas fluxes from lakes in order to incorporate lakes in the terrestrial greenhouse gas balance as accurately as possible. Therefore, future studies will address the spatial variability of diffusive gas fluxes in more detail, as well as explore the temporal (diurnal and seasonal) variability.

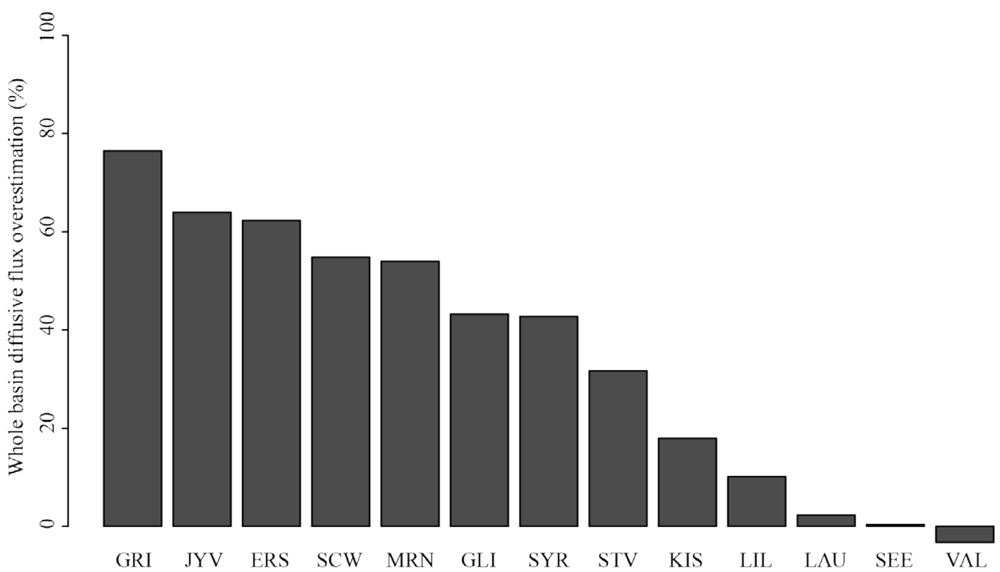

Figure 1. Bar plot showing the amount of overestimation (%) of whole basin diffusive methane flux (mmol m-2 day-1) had we extrapolated based on measurements done in the central, deep zone only. For 10 out of 13 lakes, this overestimation is considerable and it can be up to 77%.

15.8

Response of carbon and nitrogen cycles of a tropical montane forest in Ecuador to environmental change

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Global environmental change reaches even the most remote ecosystems like the east-exposed tropical montane forests in the north Andes on the rim of the Amazon basin. Between 1998 and 2010, we observed increasing N deposition and soil dryness in line with predictions for the study region on the east-exposed slope of the eastern cordillera of the Andes in south Ecuador (Vuille et al., 2003; Galloway et al., 2008). Our objectives were to explore the responses of biogeochemical cycles of C and N to these changes. We equipped a ca. 9-ha large microcatchment at 1850-2150 m a.s.l. (MC2), which is entirely covered by native old-growth lower montane forest with all devices needed to determine the major ecosystem fluxes in 1998 (Beck et al., 2008).

C cycling.
From 1998 to 2008, TOC concentrations decreased and C/N ratios of DOM increased in litter leachate (i.e. the soil solution of the thick organic layers harboring almost all plant roots) of three study sites in MC2 (Fig. 1A) and in mineral soil solution at the 0.15 and 0.30 m depths. In litter leachates, simultaneously (i) pH decreased by one unit, (ii) NO_3^- concentrations increased, and (iii) the increasingly drier conditions reduced water flow and TOC input to the mineral soil. We attribute the changes in quantity and quality of DOM to a fertilizer effect of the improved N availability stimulating microbial DOM degradation. In an hierarchical ANOVA, mean TOC concentrations in litter leachates were significantly explained by H^+, dissolved inorganic N (i.e. NO_3^--N^+ NH_4^+ -N), and base metal concentrations of soil solution suggesting a microbial control of TOC concentrations. In mineral soil solutions, in contrast, Na (both depths), EC (0.15 m), and H^+ (0.30 m) contributed significantly to explain TOC concentrations suggesting a physical control of TOC concentrations by ionic strength and dispersion effects. This is corroborated by the observation that TOC concentrations, C/N ratios and $\Delta^{14}C$ values indicating a young age of ca. 1-2 yr of the DOM did not change between 0.15 and 0.3 m in the mineral soil.

N cycling.
In parallel to the decrease in DOM concentrations, the contribution of dissolved organic nitrogen (DON) to total N and DON concentrations decreased significantly in rainfall, throughfall, and soil solutions (Fig. 1B). This inorganic turn of the N cycle was most pronounced in rainfall and became weaker along the flow path of water through the system until it disappeared in stream water. The reason for decreasing organic contributions to the N cycling was not only the increasing inorganic N input – NH_4^+ and NO_3^- deposition increased by a factor of ca. 4 and 2, respectively, in the last decade – but also reduced DON production and/or enhanced DON decomposition. Accelerated DON decomposition can be attributed to improved living conditions for microorganisms (less waterlogging as indicated by significantly decreasing soil water contents and frequency of water saturation, higher nutrient availability). Significantly increasing NO_3-N/NH_4-N concentration ratios in throughfall and litter leachate below the thick organic layers indicated increasing NH_4^+ immobilization and nitrification. In contrast, NO_3-N/NH_4-N concentration ratios in mineral soil solutions decreased significantly, reflecting NO_3^- uptake by increased biomass production as indicated by rising fine litterfall rates.

Our results demonstrate that the C and N cycles of the very remote study ecosystem underwent significant changes in only one decade.

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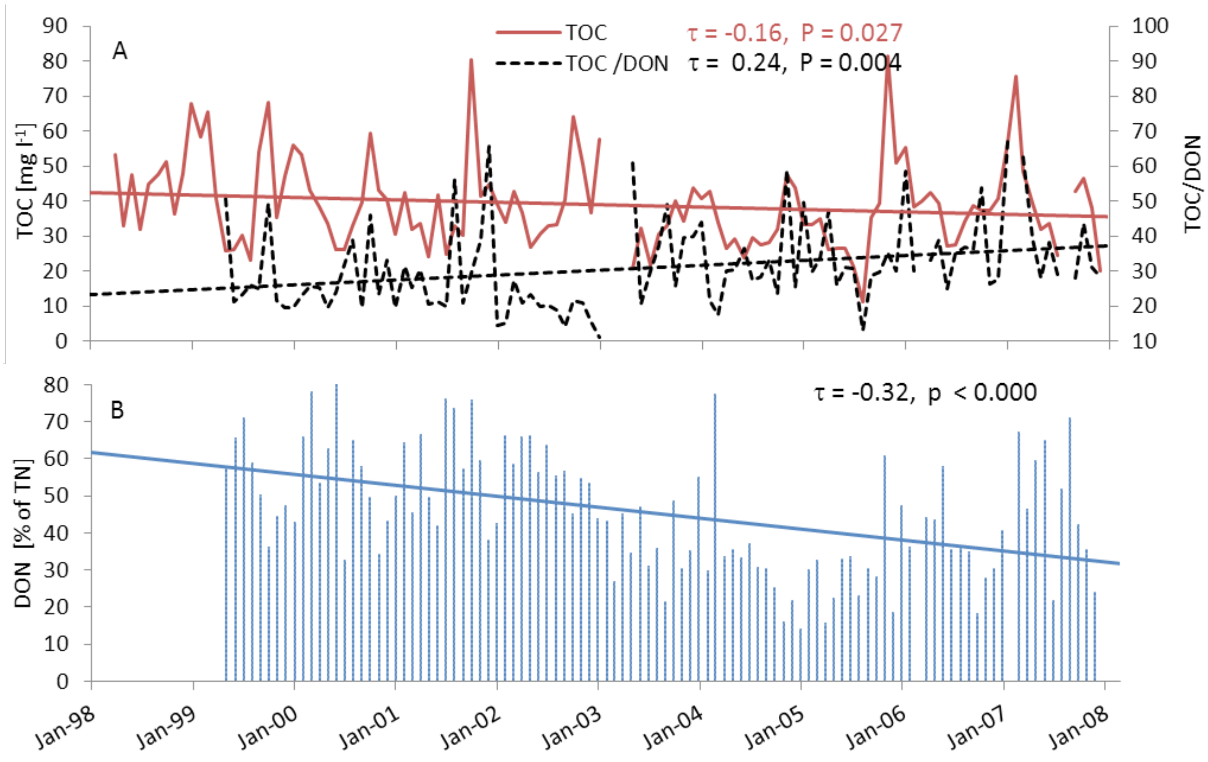

Figure 1. Mean temporal course between 1998 and 2008 of (A) total organic C concentrations (TOC) and C/N ratios of dissolved organic matter and (B) the contribution of dissolved organic N (DON) to total N concentrations (TN) in litter leachates. N = three measurement stations; sampling interval of zero-tension lysimeters was weekly. Trends were tested with the nonparametric Seasonal Mann Kendall test (Hirsch et al., 1982). Significant trends are indicated with straight lines and Kendall's t and error probability are given.

P 15.1

Modeling ^{14}C of Organic Carbon in Marine Surface Sediments

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Mixed-layer ^{14}C content is predicted by assuming a homogeneously mixed surface sediment whose carbon content is dictated by influx of fresh, marine organic carbon, radioactive decay of ^{14}C, degradation of organic carbon, and burial. Organic matter is divided into three pools of reactivity: labile, semi-labile and recalcitrant, which all reflect surface water, marine DI14C. The program requires the input of sedimentation rate, mixed-layer depth and sample collection year to run. Integration from 1950 to the given year allows the anthropogenic ^{14}C perturbation to be projected into the sedimentary organic carbon pool. Modeled fraction modern values are compared with measured fraction modern values of 81 surface sediment samples; discrepancies between the two are used to constrain organic matter sources and sedimentological controls. In particular, tracing inputs of pre-aged (e.g. soil) organic carbon or organic carbon bearing near-atmospheric signatures become real possibilities. The model builds upon previous work by Griffith et al. (2010) and includes experimentations with non-marine input terms, data-fitting and accounting for mixed-layer heterogeneity.

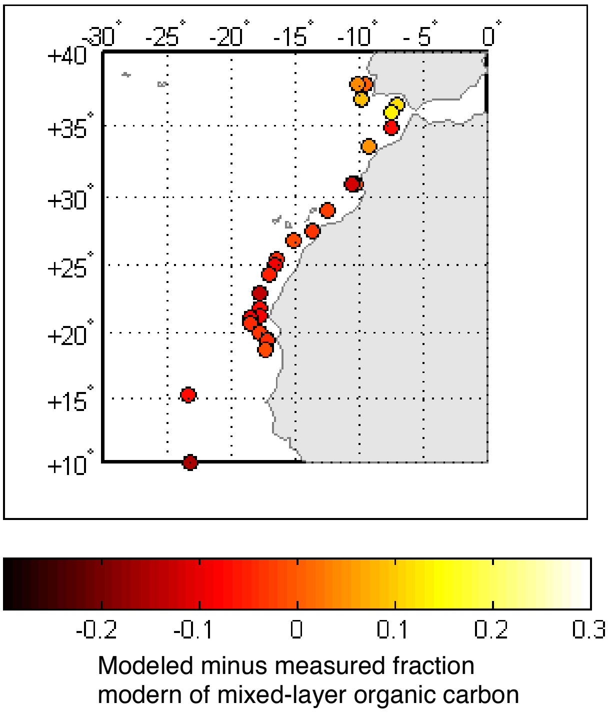

Figure 1. A study by Griffith et al. (2010) along NW African Margin exemplifies the strengths of investigating discrepancies between modeled and measured ^{14}C signatures in organic carbon. In the north, the model overestimates ^{14}C content and vice versa in the south. Speculatively, this could be due to influx of soil runoff (pre-aged organic carbon) in the north and influx of aeolian (near-atmospheric ^{14}C fingerprint) in the south.

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P 15.2

Loess as an environmental archive of atmospheric selenium deposition

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The element selenium (Se) is of key importance to human health but it has a very narrow range between essential and toxic levels. Selenium concentrations in soils and food crops show extreme geographical variations, which have led to serious health problems. In order to prevent future health hazards due to unsafe environmental Se concentrations it is essential to understand what factors control the distribution of Se in the terrestrial environment. Estimates of global Se fluxes indicate that biologic processes in the marine environment play a key role in the global biogeochemical Se cycle. Biogenic Se species produced in marine environments are thought to be volatilized and transported through the atmosphere and could thus be an important source of Se in the terrestrial environment. However, thus far there has been virtually no research that quantifies terrestrial deposition of naturally derived Se and how this has fluctuated through time. This study investigates the relationship between the distribution of Se in the terrestrial environment, wet and dry atmospheric deposition of Se and the influence of climatic factors.

Past climatic variability has been well recorded in the alternating layers of loess and paleosols at the Chinese Loess Plateau (CLP). The CLP is the largest deposit of wind-blown sediment in the world and represents up to 7Myr of continual atmospheric sediment deposition. The CLP can serve as an invaluable record of atmospheric Se deposition and may provide unique insights into how the global Se cycle is influenced by climatic factors and changes in these factors. Presented here are the Se concentrations along with other trace and major elements in the Lingtai loess-palaesol sequence of the CLP, which has been intensively studied in paleoclimatic studies. The data are examined in relation to paleoclimatic proxies (e.g. magnetic susceptibility and grain size) and first interpretations of depth-concentration profiles are presented. Insight in the role that climate plays on atmospheric Se deposition will lead to a better understanding of the global biogeochemical Se cycle and will pave the way for future predictions of terrestrial Se distribution.

P 15.3

Soil respiration and microbial biomass constrained by warmer winter climate and reduced snow cover in transplanted subalpine pasture turfs

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Overwinter degradation of soil organic matter is an important component of carbon and nutrient turnover in cold biomes where soils lying under a thick snowpack remain decoupled from the often times rough atmospheric conditions. Data from our 3-years experiment simulating an in situ year-round climate warming provides clear evidence about the beneficial effects of snow on soil microbial abundance and activity. We report up to 10 times higher heterotrophic soil respiration from plots experiencing an ambient climate and remaining under a stable cover of snow for 5 months compared to those subjected to a milder climate with intermittent frosts and snowpack accumulation. These high rates of CO_2 efflux under the snow could not be explained by any of the classically used soil microclimate parameters (i.e., soil temperature and moisture) and were tentatively attributed to the presence/absence of snow. Such a decoupling of soil respiration from its seasonal temperature dependence in the presence of snow has broad implications for the modelling of global carbon cycling. Our data provide insights on the importance of snow for soil microbial abundance and activity in winter, and hints on possible feedbacks on the turnover of organic matter and the overall functioning of ecosystems in a future warmer climate.