First International Symposium on

Carbon in Peatlands

15-18 April 2007, Wageningen, the Netherlands

Citation
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Preface

Welcome to the first International Symposium on Carbon in Peatlands. The symposium has been organized to bring together starting and established scientists to discuss the state-of-the–art and to identify challenging gaps in our knowledge for further research.

The initial idea was birthed by the offer of PEATNET at the ESA conference in Montreal, 2005, to co-sponsor peatland events. After volunteering to hold such a workshop in Europe, we saw ourselves taken up on our offer. Since then, many things have happened, one of them being the evolution of what started out as a small retreat for a few peat scientists, into a fully-fledged conference with 170 participants from all over the world, 44 oral contributions and over 100 posters covering virtually all topics dealing with carbon sequestration, efflux, and composition in peatlands at different spatial (centimeters to global) and temporal scales (hours to centuries), including results from measurements and modelling. This great success in terms of number of high quality contributions reflects the current large interest in this topic.

Even though the submitted contributions would have allowed us to organize parallel sessions, we intentionally kept the original idea of integrating different disciplines through single sessions. We therefore encourage everybody to pay ample attention to the very rich poster session and we hope that the diverse programme will spark interdisciplinary discussions and lead to interesting new collaborations between participants from the different disciplines and geographical regions. Furthermore we hope that the informal discussions during the social part of the programme will foster the global peat network.

We are sure that with this symposium we all will contribute to a more global understanding of the importance of carbon in peatlands, being of special relevance in the current discussion on climate change.

We thank you all for making this possible, and wish you a highly scientific, successful, and social time in Wageningen!

Juul Limpens
Gabriela Schaepman-Strub
Bjorn Robroek
Angela Breeuwer
Frank Berendse

Symposium convenors

Organisation

Scientific Committee

Local organizers

Juul Limpens, NL
Gabriela Schaepman-Strub, NL
Bjorn Robroek, NL
Angela Breeuwer, NL
Frank Berendse, NL

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Jill Bubier, USA
Jennifer Harden, USA
Merritt Turetsky, USA
Melanie Vile, USA
Dale Vitt, USA
Kelman Wieder, USA

General Information

Venue

The first International Symposium on Carbon in Peatlands will take place at the WICC conference center in Wageningen, the Netherlands.

Hotel and Congress Center WICC
Lawickse Allee 9
6701 AN Wageningen
+31 317 490 133
http://www.wicc-wir.nl/

A route description can be found at http://www.wicc-wir.nl/index.php?cat=contact&pageid=15 or go the symposium homepage containing more detailed visiting information http://www.peatnet.siu.edu/CC07VisitorInfo.htm .

Information for Oral Presenters

We kindly ask presenter to provide their oral presentations as MS PowerPoint or Adobe PDF file prior to the session to the chairperson listed in the programme.

Information for Poster Presenters

Posters will be on display during the whole day of the corresponding poster session. Please hang up your poster in the morning, preferably before the first oral session. Please make sure that your poster is hanging on the indicated poster board. Posters of the size A0 portrait are supported. It is the responsibility of the presenters to take their poster down after the last oral session in the evening of the corresponding day.

Symposium Dinner

The symposium dinner (**only for participants who registered and payed for this special event**) will be on Monday evening, April 16, 2007, in Hotel de Wereld, Wageningen, the Netherlands. In this historical building, first named in 1669, the capitulation was signed in 1945 by German and Canadian representatives.

Hotel de Wereld
5 Mei Plein 1
6703 CD Wageningen
+31 317 460 444
http://www.hoteldewereld.nl/eng/index.html

Saturday, 14 April 2007

20.00 - 22.00 Welcome drink at the bar in the symposium venue (WICC)

Sunday, 15 April 2007

08.00 - 09.00 Registration and coffee

Welcome presentations

09.00 - 09.10 Berendse F. Welcome by Wageningen University, Centre for Ecosystem Studies
09.10 - 09.30 Limpens J. Opening of symposium and introductionary lecture

Biogeochemistry chaired by Luca Bragazza

09.30 - 09.55 Blodau C. Biogeochemistry and the carbon cycle in peatlands invited speaker
09.55 - 10.15 Lamers L. Nitrogen, sulfur and carbonate fluxes control carbon loss in peatlands; consequences for land subsidence
10.15 - 10.35 Eriksson T. Decadal addition of nitrogen deposition to a boreal mire decreases the emission of methane

10.35 - 10.55 Coffee break

10.55 - 11.15 Glaser P. Free-phase gas in large peat basins: storage, transport and ebulation
11.15 - 11.35 Adema A. Occurrence and distribution of buoyancy driven water flow: a mechanism for nutrient recycling in peat bogs
11.35 - 11.55 Novak M. Vertical isotope trends of seven different carbon compounds in 210Pb-dated Sphagnum peat cores
11.55 - 12.15 Hornibrook E. Flux strength and stable isotope composition of methane emissions from peatlands of different trophic status

12.15 - 15.00 Lunch and interactive poster session I

Microbial Ecology chaired by Leon Lamers

15.00 - 15.25 Freeman C. The role of phenol oxidase in regulating peatland carbon cycling invited speaker
15.25 - 15.45 Jaatinen K. (presented by Laiho R.) Microbial communities and soil respiration along a water-level gradient in a northern boreal fen
15.45 - 16.05 Hines. Connections between the pathway and rate of methanogenesis and vegetation in peatlands
16.05 - 16.25 Smolders A.J.P. Substrate derived methane as a carbon source for Sphagnum

16.25 - 16.45 Coffee break

Plant Ecology chaired by Kelman Wieder

16.45 - 17.10 Rydin H. The role of Sphagnum in peatland dynamics invited speaker
17.10 - 17.30 Zona D. The carbon fluxes in a drained lake in Barrow, Alaska
17.30 - 17.50 Wiederman M. How *Sphagnum* physiology reponds to enhanced nitrogen: experimental data and a transect study in Sweden

18.00 - 19.00 Icebreaker (reception) in the WICC

Monday 16 April 2007

08.00 - 08.30 Registration and coffee

Ecohydrology chaired by Harri Vasander

08.30 - 08.55 Holden J. Peatland hydrology and secret carbon flux invited speaker
08.55 - 09.15 Fiedler S. Particulate organic carbon in the pore water of peatlands
09.15 - 09.35 Evans C. Drivers of DOC export from the UK uplands: peats versus organo-mineral soils
09.35 - 09.55 Waldron S. Compositional changes in peatland dissolved organic matter transport: event flow and disturbance

09.55 - 10.15 Coffee break

10.15 - 10.35 Buffam I. Spatial and temporal dynamics of fluvial C export from Swedish boreal peatlands
10.35 - 10.55 Evans M. Geomorphological controls on the carbon balance of eroding peatlands
10.55 - 11.15 Waddington J. The effects of water table draw-down on peatland hydrology, vegetation and carbon dynamics
11.15 - 11.35 Glatzel S. Drought control of methane and nitrous oxide dynamics in a restored peat bog in NW Germany
11.35 - 11.55 Chojnicki B. Impact of reflooding on greenhouse gas exchange of degraded fen peatlands

11.55 - 14.30 Lunch break and interactive poster session II

Ecosystem and Landscape Ecology I chaired by Frank Berendse

14.30 - 14.55 Roulet N. Ecosystem level carbon dynamics of northern peatlands: what do the measurements and models tell us? invited speaker
14.55 - 15.15 Lindroth A. Biophysical controls on CO_2 exchange of boreal mires in northern Europe
15.15 - 15.35 Drosler M. EU peatlands: an overview of current trace gas fluxes
15.35 - 15.55 Moore T. Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog

15.55 - 16.15 Coffee break

16.15 - 16.35 Veenendaal E. Carbon balance and greenhouse gas fluxes in intensive and extensive managed grasslands on peat
16.35 - 16.55 Hooijer A. (presented by Silvius M.). PEAT-CO_2: Assessment of CO_2 emissions from drained peatlands in SE Asia
16.55 - 17.15 Wohland P. Ecosystem fluxes in a papyrus swamp of the Okavango delta, Botswana

19.00 - 22.00 Congress diner at Hotel de Wereld (Registration required!)

Tuesday 17 April 2007

08.00 - 08.30 Registration and coffee

Ecosystem and Landscape Ecology II chaired by David McGuire

08.30 - 08.50 Wieder K. Burning bogs and changing climate: will peatland carbon sinks become sources
08.50 - 09.10 Page S. Are tropical peatlands contributing to climate change? The impact of fire
09.10 - 09.30 Van Bellen S. Fire history and carbon accumulation in peat bogs during the Holocene in the boreal region of Quebec, Canada
09.30 - 09.50 Frolking S. Northern peatland carbon accumulation through the holocene and its impact on climate: a framework for analysis

09.50 - 10.10 Coffee break

Paleoecology chaired by Dale Vitt

10.10 - 10.35 Van Geel B. Raised bogs as archives of climate change invited speaker
10.35 - 10.55 Donner N. Development and carbon accumulation of a polygon mire over the last millennium
10.55 - 11.15 Heijmans M.M.P.D. The effects of vegetation changes in peat bogs on long-term carbon sequestration rates

11.15 - 13.30 Interactive poster session III and lunch

Peatlands and Climate
- Modelling and Larger Spatial Scale Assessments chaired by Gabriela Schaepman-Strub

13.30 - 13.50 Wania R. Sensitivity of northern peatland greenhouse gas emissions to climate change
13.50 - 14.10 Borren W. Effects of drainage and 21st century warming on the greenhouse impact of western Siberian mires
14.10 - 14.30 Lawrence D. Towards modelling high-latitude carbon dynamics in a GCM: Incorporating the physical properties of organic soil

14.30 - 14.40 Poster price
14.40 - 15.00 coffee break

15.00 - 15.20 Connolly J. Using satellite and flux tower data to derive the light use efficiency for two Canadian peatlands
15.20 - 15.40 Krankina O. The challenge of mapping peatlands and the potential of remotely sensed data
15.40 - 16.05 Canadell P. Vulnerability of the carbon cycle, the role of peatlands, and impacts on climate change invited speaker

16.05 - 16.25 Conference conclusion

ORAL PRESENTATION
-ABSTRACTS-

Biogeochemistry and the carbon cycle in peatlands

Christian Blodau

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Biogeochemistry focuses on the dynamic interaction of geologic, biologic, and chemical processes in the cycling of elements across the environmental compartments. The scope of biogeochemical research on carbon cycling in peatlands is thus very broad and ranges from the microscale to watersheds and from process interactions at population level to complex ecosystem adaptions, for example as a result of nitrogen deposition. As all of the mentioned processes interact in the subsurface of peatlands, the biogeochemical approach is most useful to analyze the below-ground remobilization of carbon fixed by photosynthesis, which this presentation will focus on. Looking at below-ground carbon cycling in peatlands and reflecting on our current state of understanding, one quickly recognizes the truth of the biogeochemist's motto: "Biogeochemical cycle work in practice but if the will ever work in theory we don't know". Current theory would, for example, predict CO_2 production in ombrotrophic peatlands to decrease with depth but not to approach zero; it would further predict CO_2 to be produced mainly by methanogenesis because oxidants are diminished or absent, and it would suggest that after environmental perturbations these patterns quickly re-establish. All of these predictions are important with respect to the carbon balance and methane emissions on different time scales. None of these predictions seem to be met in many cases although much uncertainty is added because of the lack of suitable and accurate methods to determine process rates and controls *in situ*. The presentation will thus outline novel concepts that could potentially overcome some of these problems and reconcile theory with reality. First, it will be shown how transport limitations in peatlands may lead to a thermodynamic inhibition of further anaerobic decomposition and result in very low decomposition rates. Second, the role of humic substances as an alternative electron acceptor that may maintain sulfate reduction, divert substrate from methanogenesis and potentially explains anaerobic CO_2 production will be adressed. Third, the interplay of these processes during perturbations, such as dessication and reflooding events, will be illustrated. Based on this analysis, the current shortcomings of these novel approaches are identified and future research avenues to overcome these shortcomings are illustrated.

Nitrogen, sulfur and carbonate fluxes control carbon loss in peatlands; consequences for land subsidence

Leon P.M. Lamers, Jeroen J.M. Geurts, Esther C.H.E.T. Lucassen, Alfons J.P. Smolders and Jan G.M. Roelofs

Radboud University, Toernooiveld 1 6525 ED Nijmegen, Netherlands

Decomposition and concomitant loss of CO_2 and CH_4 in peatlands are determined by a wide range of physicochemical variables including temperature, humidity, pO_2, peat structure, alkalinity, pH, SO_4^{2-}, NH_4^+, NO_3^-, and HPO_4^{2-}. Research on decomposition, mineralization of N and P, and land subsidence in wetlands has strongly focused on oxygen availability (water table fluctuation, desiccation versus waterlogging or flooding) rather than water and air quality.

Anthropogenic changes of nitrogen, sulfur and carbonate fluxes have, however, significantly affected both aerobic and anaerobic decomposition in peatlands at three levels: 1. stimulation of decomposition and altered carbon pathways by increased availability of electron acceptors (including the recently discovered anaerobic CH_4 oxidation by NO_3^-), by pH buffering, or by desalinization; 2. stimulation by N-eutrophication or S-induced P-eutrophication; 3. indirect stimulation through major changes in the vegetation and litter composition as a result of eutrophication or phytotoxicity (NH_4^+, sulfide).

This has far-reaching consequences for carbon loss and land subsidence in coastal lowlands, especially in combination with the rising sea level. Although it is generally believed that high water tables will prevent carbon losses and land subsidence, we show that water and air quality may be just as important for the regulation of decomposition in peatlands.

Decadal addition of nitrogen to a boreal mire decreases the emission of methane

Tobias Eriksson and Mats Nilsson

Swedish University of Agricultural Sciences (SLU), Skogsmarksgränd, 1 901 83 Umeå, Sweden

Methane emission from a peatland is the net of the methane produced by methanogenes and the oxidation of methane by methanotrophs. Deposition of nitrogen, which is increasing in many areas, onto mires, can affect these two processes at different scales; e.g. by NH_4^+ inhibition of methane oxidation (biochemical scale), by a shift in vegetation composition or effects on bacterial communities (community scale), and by increased photosynthetic CO_2 fixation and changed allocation pattern of carbon to roots (ecosystem scale). In order to study the effects of nitrogen on these scales, long-term field experiments are needed, since the process scales have different time constants. The effects of nitrogen additions (30 kg ha^{-1} yr^{-1}), sulfur additions (20 kg ha^{-1} yr^{-1}) and greenhouse treatment, on methane emission were studied in a lawn plant community at an oligotrophic boreal minerogenic mire in northern Sweden. Methane emissions were measured 5-10 times each snow-free season during 1995-1997 and 2005-2006. The treatment effects were analyzed with mean water table and sedge cover included as covariates in the models. The first years of measurements revealed that nitrogen additions decreased the methane emission when sedge cover was high and were close to zero when sedge cover was low. The greenhouse treatment, which increase air and soil temperature, positively effected methane emission when sedge cover was high, but showed no effect when sedge cover was low. Another 8 years of nitrogen additions have significantly increased sedge cover and drastically decreased Sphagnum cover. Methane emission was, despite the change in vegetation cover, still negatively affected by nitrogen additions, even though sedge cover has a positive effect on methane emission. Possible controls on the decreased methane emission will be discussed. Further, the results indicate reduced methane emission by the greenhouse treatment.

Free-phase gas in large peat basins: storage, transport, and ebullition

Paul Glaser, Donald Siegel, Jeff Chanton and Andrew Reeve

University of Minnesota, Pillsbury Hall Minneapolis, Minnesota 55455 Minneapolis, United States

Recent studies indicate that ebullition (i.e. gas emissions via bubbling) may be an important and previously underrepresented mechanism for methane emissions from peatlands. Our studies in the large peat basins of the Glacial Lake Agassiz region of northern Minnesota (USA) and the Hudson Bay Lowland northern Ontario (Canada) indicate that free-phase gas accumulates in the deeper peat under semi-elastic confining layers and is episodically released to the atmosphere by ebullition. Gas bubbles tend to become trapped under confining layers in the deep peat creating zones of abnormal overpressure that may be transient or persist for several years. Periodic ruptures in these confining layers are marked by rapid depressuring cylcles at depth and vertical oscillations of the peat surface, which indicate as much as 35 g CH are released per event. Analysis of bubble shapes in large diameter peat cores by Magentic Resonance Imaging indicate that the observed values for overpressures provide the driving force for the bubbles to create failures in the peat fabric that force their escape to the atmosphere.. This mechanical process for bubble movement may be common to most peat deposits that contain wood layers suggesting that ebullition is more widespread than formerly thought.

Occurrence and Distribution of Buoyancy driven water flow; a mechanism for nutrient recycling in peat bogs

Erwin B. Adema, Ab P. Grootjans, Nancy V.J. De Bakker and Rodolfo Iturraspe

Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, Netherlands

Buoyancy driven water flow may act as transport mechanism for nutrients in the acrotelm of a peat bog. Due to temperature differences between day and night density driven water movement may help to reallocate nutrients from the bottom of the acrotelm of the top. There nutrients become available for growing Sphagnum. This may enhance the carbon accumulation rate of these bogs trough an efficient re-use of limiting nutrients. To explore the possible impact of this phenomenon we focused on two major parameters that determine the occurrence of buoyancy driven water flow in peat lands worldwide. First, we evaluated the potential dispersion of buoyancy driven water flow by analyzing global weather data of the past 10 years. Secondly, we determined the hydraulic conductivity of the acrotelm in different Sphagnum bogs. Both analyses revealed that buoyancy driven water flow may occur regularly in Sphagnum bogs in a large parts of the world. Even in the subartic climate zones, where large peat complexes are situated in the northern hemisphere, it can take place. But also in the southern hemisphere Sphagnum dominated ecosystems occur often in the cooler temperate climate zones. Measurements in Tierra del Fuego, Argentina showed buoyancy driven water flow in the field. We also measured that the oxygen gradient in the acrotelm is affected by this flow. This is a strong indication that buoyancy driven water flow indeed acts as transport mechanism for nutrients.

Vertical isotope trends of seven different carbon compounds in ^{210}Pb-dated *Sphagnum* peat cores

Martin Novak, Iva Jackova, Eva Prechova, Petra Pacherova

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We compared vertical trends in $\delta^{13}C$ of bulk peat in 8 different upland peat bogs located in Central Europe. In the topmost 30 cm, we found that at 4 sites $\delta^{13}C$ increased with an increasing depth. In contrast, at the remaining 4 sites, $\delta^{13}C$ decreased with an increasing depth. Peat in all subsequent 2-cm thick vertical segments was almost purely *Sphagnum* derived. Since $\delta^{13}C$ of *Sphagnum* is not dependent on the species, the question arose which processes control such contrasting vertical $\delta^{13}C$ patterns at nearby sites. To answer this question, we sequentially extracted and quantified the following organic C forms in peat: soluble fats, oils and waxes; soluble carbohydrates; soluble phenolics; total hot-water solubles; holocellulose; δ -cellulose; hemicellulose; lignin; and acid-soluble carbohydrates. Seven most abundant C forms were analysed also isotopically. At Velke Darko, a site with a positive downcore $\delta^{13}C$ shift in bulk peat, three types of vertical $\delta^{13}C$ trends were observed when C forms were analyzed separately: throughout the profile, $\delta^{13}C$ of lipids was the lowest in the system, fluctuating around –30 per mil. At a depth of 30 cm, $\delta^{13}C$ of lipids was 8 per mil lower than that of cellulose. $\delta^{13}C$ of all forms of cellulose, carbohydrates and phenolics overlapped, increasing smothly downcore from –27 to –22 per mil. $\delta^{13}C$ of lignin, also increasing downcore, was off-set relative to cellulose by 2 per mil to more negative values, but never became as low as $\delta^{13}C$ of lipids. Analysis of peat from a contrasting site (decreasing $\delta^{13}C$ of bulk substrate downcore) is under way.

Flux strength and stable C-isotope composition of methane emissions from peatlands of different tropic status

Edward Hornibrook and Helen Bowes

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Peatland trophic status is known to influence rates of methane production and flux through differences in net ecosystem productivity and the types of flora present. Preliminary studies have suggested also that the stable carbon isotope composition of methane in peat soils may vary in a systematic manner with wetland type and productivity. We investigated relationships between soil chemistry and nutrient supply, and the amount and stable carbon isotope composition of methane in peat soils and emissions from four peatlands situated in Wales, UK: Crymlyn Bog (intermediate fen), Cors Lywd (valley mire), Blaen Fign (blanket mire), and Cors Caron (raised bog). Methane abundance in pore water and methane flux rates were highest at the minerotrophic sites, although areas of the rainfed blanket mire that were rich in vascular flora also exhibited significant methane emission rates. Methane in pore water and emissions was notably ^{13}C-depleted in the ombrogenous peatlands compared to the minerotrophic sites. The highly negative delta^{13}C values of methane correlated positively with low pH and low total base cation abundance. Potential rates of methane production were determined in peat every 10 cm to a depth of 1 m at all sites via anaerobic incubations of material from peat monoliths. Low rates of methanogenesis correlated positively with production of highly ^{13}C-depleted methane. Incubation of peat from the monoliths injected with radiocarbon-labelled acetate and bicarbonate demonstrated that methanogenesis in the ombrogeneous sites was occurring predominantly via oxidation of molecular hydrogen coupled to reduction of carbon dioxide. Pore water analysis of volatile fatty acid abundances showed that acetate accumulated in the ombrogeneous sites during summer months, consistent with a lack of acetate turnover indicated by the radiocarbon-labelling experiments. Low pH likely limits dissociation of acetate which precludes utilisation by soil methanogens in the ombrogeneous peatlands. Vascular flora exerted a significant influence on both the amount and stable carbon isotope composition of methane emitted to the atmosphere from each site. A greater abundance of vascular flora typically resulted in higher rates of methane flux. Moreover, a negative carbon isotope fractionation of approximately 20 permil occurred during transport of methane to the atmosphere through vascular flora, producing some of the most negative delta13C values reported to date for methane flux from wetlands (e.g., -95 permil at Cors Caron). The extreme 13C-depletion appears to result from a combination of carbon dioxide/hydrogen-based methanogenesis in low pH soils and preferential transport of ^{12}C-bearing methane during gaseous diffusion through aerenchymatous tissue of vascular flora. In summary, these results suggest that trophic status and peatland type can be used as indicators of flux strength and the stable carbon isotope composition of methane emissions to the troposphere.

Flux strength and stable C-isotope composition of methane emissions from peatlands of different tropic status

The role of phenol oxidase in regulating peatland carbon cycling

Freeman Chris

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Microorganisms play a pivotal role in regulating carbon cycling in peatlands. The disproportionate significance of peatlands in the global carbon cycle, ensures that peat microbes influence our planet at the very highest levels. Microbial carbon cycle functions are greatly influenced by hydrology, warming and nutrient availability, and thus in an era of changing land use and climate, the ecology of microbes warrants intensive study.

Compared to other ecosystems, studies of general community composition and mycorrhizal fungi are relatively sparse. Instead, to date most of the research into peatland microbial ecology has focussed on the processes and specific microorganisms involved in methanogenesis and methanotrophy. These studies show a distinct regulatory role for hydrology, temperature, soil nutrient status and plant species composition. Thus, we are in a strong position to understand the likely impacts of climate change on methane fluxes.

While there are sound reasons for this emphasis on methane, we should not forget that peatlands are also globally significant stores of carbon, with typical estimates suggesting that approximately a third of the worlds soil carbon lies in peatlands, despite these ecosystems occupying less than 5% of our planet. The stability of that carbon store is now under threat not only from direct human impacts, but from global climatic change. There is an urgent need for greater understanding of the ecology of the microbes present in these peatlands for they hold the key to the fate of that carbon store.

The concept of the enzymic latch mechanism offers an opening to understanding the role of microbes in carbon cycling. It suggests that the key factor determining the fate of that carbon store lies in the ability of the phenol oxidase enzymes to eliminate inhibitors of microbial decomposition in the form of phenolic compounds.

New molecular approaches to microbial ecology are opening a door that will allow dramatic advances in our understanding of peatland ecosystems. We are beginning to appreciate the richness of the diversity of microbes present in our peatlands. However, in the future the greatest challenge may lie not just in our ability to recognise which microbes are present, but in determining how those microbes are influencing key ecosystem processes such as enzymic latch suppression of decomposition.

Microbial communities and soil respiration along a water-level gradient in a northern boreal fen

Krista Jaatinen, Raija Laiho, Kari Minkkinen, Taina Pennanen, Timo Penttilä and Hannu Fritze

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We studied the patterns of microbial communities and soil respiration along a water-level gradient, and the resultant vegetation gradient, in a boreal fen located in northern Finland. Microbial community structure was studied by PLFA analyses from peat samples, and two important decomposer groups, fungi and actinobacteria, by PCR-DGGE methods. Basal respiration from the peat samples was measured in the laboratory. Soil respiration was measured in the field from two sets of collars, from one of which roots had been excluded so that only peat decomposition was captured. Overall, the microbial communities diverged from each other in the hydrologically different locations. Both fungal and bacterial biomasses increased towards the drier locations. While fungi together with Gram-negative bacteria seemed to benefit from lowered water-levels, Gram-positive bacteria, including actinobacteria, suffered. At species level the DNA-analyses showed that the fungal community changed, but actinobacteria seemed not to response to changing hydrology. Ectomycorrhizal (ECM) sequences dominated over typical saprotrophes both in the dry and the wet locations.

Of the variation in basal respiration, 71% could be explained with bulk density (BD), sampling depth, mol% of fungal PLFA, and the occurrence of a certain fungal band; otherwise the species composition of the fungal and actinobacterial communities had no discernible effect. Soil respiration (excluding root respiration) was correlated with the water-level and the mass of organic matter above it, being highest at the driest locations. Fungal species composition seemed to have some effect on soil respiration rates as well. On the basis or our results we suggest that ECM fungi may act as important facultative decomposers in northern fens. In nutrient-rich northern fens lowered water-levels result in clearly increased decomposition of the peat brought into aerobic conditions. Unless C inputs via litterfall increase correspondingly, the hydrological change will cause a net loss of C to the atmosphere.

Connections Between the Pathway and Rate of Methanogenesis and Vegetation in Peatlands

Mark Hines, Khrys Duddleston, Juliette Rooney-Varga and Jeff Chanton

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Methanogenic pathways usually include intermediates that turn over rapidly, but incubation and field experiments demonstrated that intermediates accumulate in northern peats due to the lack of consumption by methanogenic bacteria. Acetate is the major organic end product of decomposition rather than CH_4 and acetate formation can exceed methanogenesis by >500-fold. The ratio of CO_2:acetate:CH_4 production rates during anaerobic decomposition varied with vegetation cover. For example, habitats dominated by non-vascular plants produced acetate-C >100 times more rapidly than CH_4, whereas sites with even a small biomass of vascular plants like sedges exhibited a acetate:CH_4 production ratio that was ~15-fold lower. This ratio correlated well with stable C isotope alpha values used to delineate the path of methanogenesis. Methanogenesis appears to be largely inhibited in many oligotrophic wetlands, but the conversion of acetate to CH_4 is more sensitive to this inhibition so the proportion of CH_4 derived from H_2/CO_2 increases despite the low CH_4 production rates. Competition for H_2 by homoacetogenic bacteria can explain the formation of acetate to some degree, but cannot explain the finding that acetate is not used by methanogens and that H_2/CO_2 conversion dominates methanogenesis. The decoupling of methanogenesis from C flow also affects other CH_4 precursors such as methylated S and N compounds, methanol, and even methylmercury. Acetate normally destined to be CH_4 is bypassed to CO_2 and does not contribute to atmospheric CH_4. Vegetation shifts occurring during warming may lead to drastic changes in the path of methanogenesis, which could greatly increase CH_4 production beyond that expected from temperature increases. These changes may influence the biogeochemistry of other important compounds as well.

Substrate derived methane as a carbon source for *Sphagnum*

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Peat bogs in the Northern hemisphere store up to one third of the carbon sequestered in soils globally. Ombrotrophic bogs may counteract climate change by forming a net carbon sink. This is caused by the facts that *Sphagnum* species sequester atmospheric carbon and at the same time show resistance towards decomposition. However, anaerobic decomposition processes in the peat can still be substantial and will result in the production of both methane (CH_4) and carbon dioxide (CO_2), both being important greenhouse gasses. Recent research has demonstrated that substrate-derived methane is recycled by Sphagnum and may even form a highly significant carbon source for *Sphagnum* species. Recently acidophylic CH_4 oxidizing bacteria (MOB) have been isolated from acidic *Sphagnum* bogs. MOB are able to use CH_4 as a sole carbon and energy source releasing part of the oxidized methane carbon as carbon dioxide. Methane oxidation rates have been studied at many locations, however, mainly in peat profiles from bog hollows and hummocks. The highest methane oxidation rates are normally measured close to the water table (boundary between aerobic and anaerobic conditions), in top of the peat profile. Obviously methane oxidation greatly decreases the methane emission rates to the atmosphere so diminishing the greenhouse effect. However, methane oxidation will also increase the availability of carbon dioxide and might thus benefit *Sphagnum* photosynthesis. Molecular and microscopic techniques were applied to reveal the possible presence of symbiotic MOB in *Sphagnum* tissues. In *S. cuspidatum* stems, clusters of a new methanotroph were present in the hyaline cells of the outer cortex. Occasionally, sarcina-like clusters also appeared in the hyaline cells of the stems. The presence of clusters indicated that this bacterium was actively growing inside the hyaline cells. The bacterial clusters consisted of 5-25 individual coccoid cells lying closely together in a random arrangement. On the stem leaves, the same probes hybridised with bacteria occurring as dense, geometric clusters tightly bound to the living plant cells. Incubation experiments with ^{13}C-methane showed rapid in situ oxidation by these bacteria to carbon dioxide which was subsequently fixed by Sphagnum as shown by incorporation of ^{13}C-methane into plant sterols. As *Sphagnum* growth under water is highly limited by carbon availability the oxidation of substrate derived methane by methanotrophic bacteria, growing on *Sphagnum* tissue, may contribute importantly to the carbon nutrition of submerged *Sphagnum* species. Observations with FISH-techniques, revealed that submerged growing *S. cuspidatum* possesses high numbers of symbiotic MOB, which explains the observed high methane oxidation rates.

The role of *Sphagnum* in peatland dynamics

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In this talk I will summarize the morphological, physiological and life history characteristics of *Sphagnum*, and how these affect the dynamics of temperate and boreal peatlands. Ombrotrophic bogs are formed as *Sphagnum* invades and alters the environment by the formation of decay resistant litter, increased wetness, formation of reducing conditions, acidification, and withdrawal of nutrients into peat storage. Because of a series of positive feedback loops, most of these changes appear to be irreversible. Stratigraphic records indicate that the shift from fen with high pH to acid bog is rapid, but one of the enigmas is how Sphagnum can invade fens with high pH and Ca content in the first place. Current experiments to elucidate this process of invasion will be described with some preliminary results. Future changes in peatlands include the effects of climate change, drainage, acidification and nitrogen deposition. The biological attributes of *Sphagnum* are used to discuss the mechanisms of expected changes. Also in this case, positive feedbacks are expected, and changes in peatlands may therefore be irreversible.

The carbon fluxes in a drained lake in Barrow, Alaska

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The Arctic Coastal Plain, the north part of Alaska is characterized by low gradient of slope and the accumulation of water in innumerable lakes and ponds due to the poor drainage. Large portion (50 to 75%) of this terrestrial surface is scarred by elliptical depressions formerly occupied by thaw-lakes basins (Hinkel et al., 2003). Mosses represent a massive population of these ecosystems. Regardless of the fact that bryophytes constitute large part of the vegetation there are big uncertainties on their contribution on the CO_2 fluxes of the Alaskan Arctic tundra. In particular, very little is known about the environmental controls and climate change sensitivities of Arctic mosses. Several authors have reported midday depression of moss photosynthesis due to high irradiance, exacerbated by a low temperature and nitrogen limitation, both factors that reduce the mechanisms leading to photo-acclimatation. The purpose of this study is to understand the role of *Sphagnum ssp.*, the dominant moss in the wet sedge tundra, on the total ecosystem carbon exchange throughout the season. Our hypothesis is that the ecosystem carbon source activity during the period after the snow melt may be a result of sensitivity of mosses to light and photoinhibition in the absence of the protective canopy layer of vascular plants. In this study we measured daily courses of photosynthesis and fluorescence in the moss layer and we compare it to the total ecosystem carbon fluxes determined by the eddy covariance technique. The measurements were conducted in wet coastal tundra from June 2006, to August 2006 in the Biological Experimental Observatory (BEO) in Barrow, Alaska. The photosynthesis in the moss layer was found to be strongly inhibited when the radiation exceeded 800 μmol m^{-2} s^{-1}. Mosses remained fully hydrated throughout the season, precluding drying as a cause of decreased photosynthesis. Dark-adapted fluorescence measurements (Fv/Fm) showed a relatively low value (0.6) right after the snow melt, and remained fairly stable throughout the season. This low value was previously reported as characteristic of photoinhibited *Sphagnum ssp.* in the Arctic.

Literature: Hinkel K.M., Eisner W.R., Bockheim J.G., Nelson F.E. Peterson K.M. and Dai X. Spatial Extend, Age, and Carbon Stocks in Drained Thaw Lake Basins on the Barrow Peninsula, Alaska Arctic, Antarctic, and Alpine Research, Vol.35, No.3, 2003, pp. 291-300

How *Sphagnum* physiology responds to enhanced nitrogen: experimental data and a transect study in Sweden

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The aim of this study was to detect vegetation change, and to examine plant chemistry in a *Sphagnum* dominated oligotrophic mire, in response to raised temperature and N addition. A long-term global change experiment was established in 1995, with monthly additions of N as NH_4NO_3 (30 kg-N ha^{-1} yr^{-1}) and sulfur as Na_2SO_4 (20 kg-S ha^{-1} yr^{-1}) during the vegetation period. Mean air temperature was raised by 3.6 ºC with warming chambers. After eight years of continuous treatments, the closed Sphagnum carpet was drastically reduced from 100% in 1995 down to 41%, averaged over all N treated plots. To elucidate the negative effect of continuously enhanced nitrogen supply on Sphagnum species, we analyzed plant chemistry of the three dominating Sphagnum species (*Sphagnum balticum*, *S. lindbergii* and *S. majus*). Analyses of the C/N ratio were followed by analysis of nitrogen-containing compounds such as free amino acids and chlorophyll. Soluble sugars and complex carbohydrates were additionally investigated. Furthermore we tested for differences in phosphorous concentrations, as phosphorus limitation is often claimed to follow nitrogen saturation. We found that all investigated nitrogen-containing compounds increased in concentration, investigated carbohydrates were not responsive to treatments, whereas N/P ratios were comparatively high. To evaluate experimental data and to test for N uptake regulation, data from *Sphagnum* specimens sampled along a transect of increasing nitrogen deposition from Northern Sweden (2 kg ha^{-1} y^{r-1}) to Southern Sweden (13 kg ha^{-1} yr^{-1}) were analyzed. Intraspecific differences along the deposition gradient and interspecific differences in plant chemistry and nitrogen uptake between two *Sphagnum* species, *S. balticum* a lawn species and *S. fuscum* a strictly oligotrophic hummock species were studied. The uptake of 15N labelled nitrogen applied in mixed solutions of ammonium and nitrate as well as glutamine and alanine was tested. Results from the combined studies were used to help to achieve a better understanding of causes of *Sphagnum* decline associated with enhanced nitrogen deposition and to reveal potential physiological adaptation.

Peatland hydrology and secret carbon flux

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It is the movement of water in peatlands that drives carbon storage and flux. Changing climate or management can alter peatland hydrological processes and pathways for water movement across and below the peat surface. This paper will describe advances in understanding hydrological processes operating in peatlands and the impacts of disturbance on these processes. Peatland overland flow and matrix flow processes are now fairly well understood and this paper will show how recent advances in high resolution topographic modelling provide an insight into the spatial impacts of land management and climate change. However, relatively little is known about macropore and soil pipe processes in peatlands. This paper shows that natural subsurface soil pipes can be very important hydrological components of peatland systems. Understanding these components of peatland hydrology requires us to think beyond the simple acrotelm-catotelm model. The prevalence of piping is controlled by a number of physiographic and human-induced factors (e.g. topographic position, drainage, vegetation cover). Under particular types of land management or climate, soil pipes occur more frequently. These pipes not only transport water, but sediment and dissolved organic carbon sourced from throughout the peat profile. This paper will demonstrate that while the role of pipes in peatland carbon flux remains uncertain, the evidence is pointing towards them being important ecohydrological components of the peatland carbon budget.

Particulate organic carbon in the pore water of peatlands

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Total organic carbon (TOC) in water is divided into dissolved organic carbon (DOC) and particulate organic carbon (POC) by particle size (>0.45µm). Different ratios of DOC/POC are presented, but generally DOC is considered to be more important. Most studies present concentrations of < 10 mg POC l^{-1} representing about 5% of TOC. However for turbulent water flow (flood water, estuaries) POC may be up to 90% of TOC (concentrations up to 134 mg POC l^{-1}). Peatlands usually are sources of organic carbon for adjacent aquatic systems, but hardly anything is known about the relevance of POC for this exchange. No studies were found determining the role of POC in pore water of (peaty) soils. We conducted a study in the fen area of the Donauried (South Germany) on the influence of peatland restoration on POC in pore water.

Pore water was collected biweekly (April 2005 to April 2006) using slotted PVC-pipes in different depth (10 to 80 cm) of a re-wetted as well as strongly and moderately drained fen site. POC-concentrations were as high as DOC-concentrations as POC represented between 39% and 67% of TOC in the pore water. For the drained fen sites POC-concentrations tended to be lower as DOC-concentrations (averages 34 to 73 mg POC l^{-1} vs. 65 to 100 mg DOC l^{-1}) In contrast, POC-concentrations were up to two-fold higher than DOC-concentrations at the restored site. POC is a mixture of living cells, biogenic aggregates and colloidal material and may play a significant role in peatlands. Due to the high amounts of POC measured in pore water it is highly likely that it has a considerable relevance for carbon dislocation within peatlands. As DOC, it even has to be considered for the total C-Export of peatlandecosystem since, unlike to most miner soil ecosystems, the pore system (usually larger macropores) may allow considerable transport and export.

Drivers of DOC export from the UK uplands: Peats versus organo-mineral soils

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Increasing dissolved organic carbon (DOC) concentrations in upland drainage waters have been recorded during the last two decades in the UK, Scandinavia, parts of central Europe and northeast North America (e.g. Evans et al., 2006). DOC concentrations are generally highest in streams draining peat catchments, and these streams have typically also shown the greatest rates of DOC increase (e.g. Freeman et al., 2001). Over a similar period, evidence has been presented suggesting that UK surface soils are losing carbon (Bellamy et al., 2005), again with the greatest rates of change in peats. Taken together, these data would seem to suggest that 1) riverine DOC may be an important pathway by which carbon is being lost from upland soils; 2) drivers of change may be qualitatively similar for peat and organo-mineral soils; and 3) in quantitative terms, carbon fluxes from peats have the greatest sensitivity to the environmental drivers in operation. Here, using a combination of monitoring, experimental and carbon isotope data, we examine the extent to which a range of proposed drivers of rising DOC (temperature increase, flowpath change, drought, recovery from acidification, elevated productivity due to rising atmospheric CO_2 and/or nitrogen deposition) might be applicable to peats and organo-mineral soils. We find that, while the general consistency of DOC trends across different soil types is suggestive of a single driver, most of the possible drivers of change might be expected to operate differently in peats compared to other soils. In addition, ^{14}C isotope data suggest that much of the DOC lost from peats is derived from relatively recent plant and litter material, whereas DOC from less organic catchments contains a higher proportion of older, soil-derived carbon. The implications of results for understanding of DOC trends, and of the overall carbon balance of peats and other organic soils, is discussed. In general, it is concluded that caution is required in extrapolating process understanding from one soil or ecosystem type to another.

Literature:
- Bellamy PH, Loveland PJ, Bradley RI, Lark RM, Kirk GJD (2005). Carbon losses from all soils across England and Wales 1978-2003. Nature, 437, 245-248
- Evans CD, Chapman PJ, Clark JM, Monteith DT, Cresser MS (2006). Alternative explanations for rising dissolved organic carbon export from organic soils. Global Change Biology, 12, 2044-2053.
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Delineating and quantifying dissolved inorganic carbon loss from peatlands

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For modelling accurately whether peatlands are sequestering or losing carbon, export of aquatic carbon losses (to catchment drainage) must also be included. Publication focus suggests the community has invested more effort in quantifying other components of peatland carbon balance, for example net ecosystem exchange, than in quantifying aquatic losses of carbon.

Carbon can be lost from peatland soils to the drainage system as dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic carbon (POC). Study of the dissolved inorganic carbon pool presents a challenge: how to separate the inorganic carbon contribution from groundwater or minerogenic soils from that from the peatland. We have overcome this by using stable carbon isotope measurements as a tracer of each end-member.

Our study area is a small order river system draining a relatively pristine peatland in NE Scotland. In our preliminary characterisation of DIC systematics we sampled diurnally, using a nested catchment sampling matrix (1, 42 and 90 sq. km) over a 14 month period. From this we observed how the riverine DIC pool reflects differing hydrological and productivity conditions, and could therefore characterise the isotopic composition of the peatland and the groundwater component. Subsequent observation that concentration, [DIC], and isotopic composition can be described well by the continuously-logged parameters, discharge and pH respectively, allows reconstruction of [DIC] and isotopic profiles from this catchment since our study began in June 2003.

Here we will show field carbon stable isotopic profiles to demonstrate how this can be used as a tracer. Additionally we will quantify peatland-derived DIC export for this catchment, consider how this is affected by increasing catchment scale and contextualise these estimates of carbon loss through comparison with other components more commonly studied in models of peatland carbon balance.

Spatial and temporal dynamics of fluvial C export from Swedish boreal peatlands

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Fifteen stream sites within the 67 km^2 Krycklan catchment in Northern Sweden were monitored from 2003-2005 to examine spatial and temporal variations in fluxes of DOC and DIC, and their relationship to subcatchment characteristics (e.g., peatland ranging from 0-50% of catchment). Also included in the study was a headwater stream exiting Degerö Stormyr, a 6.5 km^2 minerotrophic mire (peatland 61%).

DOC flux ranged from 2-10 g C m^{-2} yr^{-1}, while DIC export ranged from 0.2-2 g C m^{-2} yr^{-1}. Peatland dominated catchments had higher overall DOC and DIC fluxes than did forested catchments, although this difference was minimal during the spring flood period, when most sites had similar concentrations of DOC regardless of peatland percentage. Interannual variation in stream C flux at a given site was primarily driven by variation in water discharge.

DIC export was on the order of 10% of DOC export for most streams, but was much higher (40%) for the headwater mire case study, where we sampled directly at an upwelling point before degassing of CO_2 had occurred. This suggests that outgassing of CO_2 may represent a substantial C flux often missed in stream chemistry measurements, particularly in headwater streams and at the soil-stream interface. Using measurements of stream CO_2 supersaturation, CO_2 outgassing averaged over the entire Krycklan stream network was estimated at 2-13 g C m^{-2} yr^{-1}. Measurements of CH4 at the mire upwelling site suggested that fluvially advected CH_4, although not contributing substantially to the C balance, could be important to consider in studies of greenhouse gas emissions.

For headwater boreal catchments with some peatlands, a situation which describes much of the boreal zone, total C export via streams is calculated to be on the order of 4-20 g C m^{-2} yr^{-1}. Stream C export varies substantially from year to year and as a function of catchment characteristics, thus catchment-specific measurements of stream C flux are recommended.

Geomorphological controls on the carbon balance of eroding peatlands

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Upland peatlands are the largest terrestrial carbon store in the UK. Many of these blanket bogs are severely affected by peat erosion although there is evidence of recent re-vegetation of some eroding systems possibly due to reduced atmospheric pollutant levels. This paper uses LiDAR mapping of gully extent and carbon sequestration data to examine the effects of erosion and re-vegetation on the carbon balance of eroding peatlands in the Peak District National Park, England. Net particulate carbon losses exceed 100 gC m^{-2} a^{-1} but making the assumption that only circa 30% of particulate carbon is climatically active the largest effect on the carbon balance is loss of primary productivity on the bare gullied areas. The effect of gully induced drainage in reducing water tables and reducing carbon fixation is relatively small. Overall it the data suggest that the effect of gullying is to shift the peatland from a net carbon store to a position that is carbon neutral. High rates of peat formation are observed in re-vegetated gullies and indicate that restoration of gullied systems has positive effects on carbon storage

The effects of water table draw-down on peatland hydrology, vegetation and carbon dynamics

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The hydrological response to climate change may alter the biogeochemical role that peatlands play in the global climate system, so an understanding of the nature and magnitude of this response is important. In 2002, the water table in a fen peatland near Quebec City was lowered by 20 cm (Experimental site), and the response of vegetation, hydrology and carbon exchange was measured at different microforms and compared to Control (no manipulation) and Drained (previously drained c. 1994) sites.). Microforms of hummocks, lawns or hollows were classified based on microtopography

Because of the draw-down, the surface in the Experimental pool decreased 5, 15 and 20 cm in the ridge, lawn and mat, respectively, increasing bulk density by and decreasing hydraulic conductivity (K) with K trending Control > Experimental > Drained. Water table fluctuations in the Drained site averaged twice those of the Control site. At the drained site at hummocks, the coverage of *Sphagnum* moss declined and Ericaceous shrubs became more prevalent relative to the natural site. Drained lawns were invaded by sedges, particularly *Carex oligosperma*. Hollows shifted from open water plots at the natural site to *Sphagnum* dominated plots with sparse vascular plant cover at the drained site.

Immediately following water table drawdown DOC concentrations were elevated in pore water and open water pools. In subsequent seasons DOC concentration in the pool declined, but remained higher than the control site even 11 years post water table drawdown. This suggests continued elevated DOC production under lower water table conditions likely related to the increase in vegetation biomass and larger water table fluctuations at the experimental and drained sites. Ecosystem respiration was also significantly greater at the drained site at all microforms., likely due to the shift in water table position and vegetation community, When photosynthetically active radiation was greater than 1000µmol m^{-2} s^{-1}, gross ecosystem production was greater at natural hummocks than drained hummocks, GEP was greater at drained lawns and hollows than at similar natural microforms and drained hollows were larger CO_2 sinks than natural hollows. Overall, drained hummocks have become larger sources of atmospheric CO_2, lawns have switched from sinks to sources and hollows have remained unchanged or become slightly larger CO_2 sinks. Methane emissions and storage were lower in the drained fen. Growing season CH_4 emissions at the drained site were 55% lower than the control site, primarily due to significantly reduced fluxes from hummocks (up to 97% reduction), while the flux from hollows/pools remained high.

These results suggest that predictions about the response of northern peatland carbon exchange to climate change must consider the interaction between ecology and hydrology in terms of the potential for ecological succession and the differential responses of microforms related to their initial ecohydrological conditions.

Drought control of methane and nitrous oxide dynamics in a restored peat bog in NW Germany

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As summertime droughts become more common, carbon and nitrogen transformations in peat bogs undergo profound changes. Peat bogs at the edge of their natural occurrence might become significant sources of nitrous oxide (N2O) in case nitrogen (N) is not in short supply due to elevated atmospheric nitrogen (N) deposition.
Examinations were conducted in the Pietzmoor bog, located at the eastern edge of the closed occurrence of rainfed bogs in NW Germany at 53°06`N; 9°50`E. We determined the N_2O and methane (CH_4) exchange during the summer of 2004 in 10 locations throughout the bog using permanently installed collars and closed chambers, syringe sampling and analysis by gas chromatography. Also, we incubated undisturbed peat cores and fertilized them with the equivalent of 20 kg N ha^{-1} y^{r-1}. Some cores were also fertilized with phosphorus (P) in order to detect P limitation of N_2O or CH_4 release. We manipulated the water table in the cores in order to simulate a drought and determined their N_2O and CH_4 exchange as well as the total organic carbon and total nitrogen content of the percolate.
Locations within the peat bog covered by *Sphagnum* fallax were sources of up to 3.9 mg CH_4 m^{-2} h^{-1} and most other microsites released 0 to 1.5 mg CH_4 m^{-2} h^{-1}. The edge of the peat bog released up to 600 µg N_2O m^{-2} h^{-1}. N2O release from the cores during the simulated drought was 0 and rose to 1500 µg N_2O m^{-2} h^{-1} following rewetting. Cores that had been fertilized with P initially released more CH_4 than unfertilized cores. During the dry phase, nitrate concentration of the percolate was elevated. This suggests that during rewetting phase following a drought, peat bogs in NW Germany may release N_2O. P does not seem to profoundly affect N_2O and CH_4 release.

Impact of reflooding on greenhouse gas exchange of degraded fen peatlands

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Fen peatlands in Germany and Northeast Europe contains extremely high amounts of carbon (C) and nitrogen (N). Therefore they can play an important role in the global circulation of greenhouse gases (GHG). Recently more than 95% of these areas are drained and they are sources for CO_2 and N_2O. The reflooding is commonly applied as a method for peatland restoration however its long term impact on GHG exchange is not clear.

The main goal of this study was to assess the short and long term effect of reflooding on GHG budget of fen peatland. This experiment is carried out within the framework of peatland restoration program of the federal state Mecklenburg-Vorpormmern in Germany. It is planned to be conducted in the period from 2004 to 2008.

Two measurement stations were located in the Peene River valley in 2004 on drained fen grassland. Part of this polder was reflooded in 2005 and one of these station started to operate under these conditions while the second one remained on the drained area.

The measurements of greenhouses gases fluxes were carried out using both automated and static chamber techniques. There are two (four replications each) sets of automated chambers applied for net CO_2 exchange measurements (FCO_2). Additionally two sets (five replications each) of static chambers are used for CH_4 (FCH_4) and N_2O (FN_2O) fluxes measurements. The flux measurements are augmented by recording of standard meteorological characteristics: solar radiation (Rs), soil (Ts) and air (Ta) temperatures.

The Michealis-Menten kinetics formula was applied for description of relationship between Rs and FCO_2. The obtained formulas were used for the estimation of seasonal net values of FCO_2. Measured values of FCH_4 and FN_2O were used for calculation of its seasonal values.

The initial analysis of obtained data brings some general conclusions. The drained area is a source N_2O and a weak sink of CO_2 and CH_4. Immediately after reflooding CO_2 absorption was dropped down through reduction of vegetation mass. Simultaneously emission of carbon dioxide was drastically limited. Finally the rewetted area became relatively strong sink of CO_2. This site became also extremely strong source of CH_4 since remarkable increase of organic mass deposition. Lab studies indicates that both newly formed plant biomass and upper substrate layer are the main sources of methane in these ecosystems.

Ecosystem level carbon dynamics of Northern peatlands: what do the measurements and models tell us?

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Northern wetlands contain (200 - 450 Gt C) 30% of the world's terrestrial carbon store and are believed to be a contemporary sink of CO_2 (0.1 to 0.5 Pg C yr^{-1}) and a source of CH_4 (10 - 30 Tg C yr^{-1}). Until recently, most of the studies on the atmosphere-biosphere exchange of greenhouse gases from northern peatlands were short-term and seasonal, and there were few models of peatland carbon cycling that could be used in climate simulations. However, in the past few years more comprehensive, multi-year carbon balances and greenhouse gas exchange are being published. While the results vary considerably from one study to another, they show some commonalities: (1) while northern peatlands are generally a carbon sink, in any one year they may be a source, and one or two years of observations are insufficient to determine the mean sink/source strength; (2) the seasonal and interannual variability is largely controlled by deviations in the moisture conditions from the long-term average; and (3) a C balance without the inclusion of the losses of C via the export of dissolved organic carbon (DOC) and/or CH_4, is too incomplete and uncertain to be useful in climate-greenhouse gas exchange assessments.

Development, evaluation and sensitivity analysis of process-based and less complicated phenomenological models, show the critical interaction of climate, hydrology and peatland ecosystem structure and function needed to simulate peatland carbon dynamics and greenhouse gas exchanges. A reasonable representation of system level hydrology presents a significant challenge in simulating peatlands. Persistent changes in water table of as little as ± 0.1 m can alter significantly the dominant biogeochemical pathways for carbon processes and plant community structure. The latter's direct influence on climate, through changes in energy fluxes, has to date been largely ignored by the peatland community. How to model peatlands that receive some water inputs from the adjacent landscape and how to scale local models to the region and globe remain elusive.

Unlike many other terrestrial ecosystems, peatland carbon balances display a secular transience. To assess the contemporary impact of peatlands on atmospheric CO_2 and CH_4 and by extension climate, this background transience presents some unique challenges. Long-term paleo-ecological models for northern peatlands and simple carbon cycle and radiative forcing models can be used to examine how the sink/source function of northern peatlands changes over their development and provides an approach to determine a baseline condition against which their contemporary variability and change can be assessed.

Biophysical controls on CO_2 exchange of boreal mires in Northern Europe

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Half-hourly data on net ecosystem CO_2 exchange (NEE) from four different peatlands in Scandinavia, measured by eddy covariance, were analysed with respect to responses to different environmental variables. The investigated sites were: Fäje myr in southern Sweden, an ombrotrophic, eccentric bog; Degerö Stormyr in northern Sweden, a boreal, oligotrophic minerotrophic mire; Siikaneva, an oligotrophic fen located on the border of southern and middle boreal vegetation zones in southern Finland and; Kaamanen, a subarctic, mesotrophic fen in sub-arctic Finland. Light response parameters (dark respiration, light use efficiency and light saturation) and ecosystem respiration were estimated for 2-week periods for one typical (no extremes) year from each site. Light use response functions were used to estimate gross photosynthesis (GPP) during daytime. Ecosystem respiration was estimated as the difference between measured NEE and GPP during daytime and from measured nighttime rates during well mixed conditions during nighttime. All parameters of the light response function showed a strong seasonal variation with similar shape for all sites. Both ecosystem respiration and GPP was best explained by temperature. The GPP was two times more sensitive to variations in temperature as was ecosystem respiration. When GPP was normalized for its temperature dependence, it was only one site, Fäje myr, which showed a weak dependency on water table depth. Similarly, ecosystem respiration normalized for its temperature dependency showed no dependency on water table depth for any of the sites. Considering climate change, the conclusion is that wetlands in this part of Europe will probably increase in sink strength at least for moderate changes in water balance.

EU peatlands: An overview of current trace gas fluxes

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The CARBOEUROPE-GHG initiative aimed at compiling the present knowledge base on GHG-exchange of major EU-ecosystems. This presentation on the most up-to-date overview on GHG-exchange of EU-peatlands has three chapters: 1) a compilation of the state of the art up to 2004 (see Byrne et al. 2004), 2) the addition of recent studies to fill the research and knowledge gaps 3) an outlook to potential indicators for explaining the differences of the peatland GHG fluxes over the EU.

1) Major findings of Byrne-study were, that the GHG studies are unevenly distributed in terms of (i) representation of different land-use types of peatland ecosystems and (ii) inclusion of all three gases (CO_2, CH_4, N_2O). Mean emission factors were calculated for natural peatlands and a set of different land-use types, further differentiated in boreal and temperate climate zones. Mean emissions factors (calculated as GWP 100 CO_2-C equivalents) were multiplied with the areas of the different land-use types in the countries (EU-25 plus European Russia). The status of actual inventories of land cover types on peatlands within the member states is very different. This provokes, together with uncertainties in the mean emission factors, that the global warming effect of EU-peatlands (52 Tg CO_2-C equivalents) should be seen as best estimate. Apart from identified major knowledge gaps, some consistent findings are, e.g. that no EU-country is acting as GWP-sink concerning the peatland fluxes, and that NEE of restored fens is totally missing in the database.

2) With the inclusion of the recent studies, the database is more comprehensive. The bog related fluxes were widely confirmed. However, in the fens new studies especially from the temperate region (Netherlands: Dolman et al. and Veenendaal et al.; Southern Germany: Drösler, Freibauer et al., North-eastern Germany: Augustin et al., and Poland: Olejnik et al.) change the picture in terms of significant CO2 uptake (more than 100 g CO_2-C) and extremely high CH_4 fluxes (up to 200 g CH_4-C m^{-2} a^{-1}) from recently restored peatlands, as well as the record for the first GWP-sink from the Rzecin-site (Poland) with 100 g C-equiv m^{-2} a^{-1} uptake.

3) A concept and first results for the use of simple indicators (e.g. peatland type, latitudinal position, climate parameters, mean water table, pH, electric conductivity, peat degradation, aerenchyma a.s.o) to explain the gradient of the different fluxes over the EU via multivariate analysis will be presented.

Effects of nutrient addition on vegetation and carbon cycling in an ombrotrophic bog

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We measured net ecosystem carbon dioxide (CO_2) exchange (NEE), plant biomass and growth, species composition, peat microclimate, and litter decomposition in a fertilization experiment at Mer Bleue Bog, Ottawa, Ontario. The bog is located in the zone with the highest atmospheric nitrogen deposition for Canada, estimated at 0.8 - 1.2 g N m^{-2} yr^{-1} (wet deposition as NH_4 and NO_3). To establish the effect of nutrient addition on this ecosystem, we fertilized the bog with 6 treatments involving the application of 1.6 - 6 g N m^{-2} y^{r-1} (as NH_4NO_3), with and without P and K, in triplicate 3 x 3 m plots. The initial 5-6 years have shown a loss of first *Sphagnum*, then *Polytrichum* mosses, and an increase in vascular plant biomass and leaf area index (LAI). Analyses of NEE, measured in situ with climate-controlled chambers, indicate that contrary to expectations, the treatments with the highest levels of nutrient addition showed lower rates of maximum NEE and gross photosynthesis, but little change in ecosystem respiration after 5 years. Although shrub biomass and leaf area increased in the high nutrient plots, loss of moss photosynthesis owing to nutrient toxicity, increased vascular plant shading and greater litter accumulation contributed to the lower levels of CO_2 uptake. Our study highlights the importance of long-term experiments as we did not observe lower NEE until the 5th year of the experiment. However, this may be a transient response as the ecosystem continues to change. Higher levels of nutrients may cause changes in plant composition and productivity and decrease the ability of peatlands to sequester CO_2 from the atmosphere resulting in a positive feedback to global warming.

Carbon balance Greenhouse gas fluxes in intensive and extensive managed grasslands on peat

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Eutrophic drained peat meadow areas under agricultural exploitation constitute a significant source of CO_2 and water level manipulation is being considered to counteract this. This however may have a major effect on the emission of other GHG's such as CH_4 In this paper we synthesize current findings of a number of research groups from a landscape scale water manipulation experiment involving eddy covariance (EC) measurements and photo-acoustic chamber measurements of CO_2, CH_4, and N_2O. Measurements were made in three areas on peat soils differing in land management in the western part of the Netherlands. One site (Oukoop) is an intensively managed dairy farm; the second (Stein) has recently become a meadow bird reserve and is managed predominantly through mowing in June and August. Since September 2005 a water level increase to near the land surface is periodically being implemented. The third site, (Horstermeer) is a restoration site where the water level was increased 13 years ago, All sites were a source of carbon in winter and a sink during summer, with net ecosystem exchange varying between 10 - 60 mmol CO_2 m^2 d^{-1} in winter to below - 400 mmol CO_2 m^{-2} d^{-1} in summer. NEE was closely correlated with LAI management. Annual Net Ecosystem Exchange showed Oukoop, to be a source for carbon with a net release of 112 g C m^{-2} $a^{-1}$and Stein Carbon neutral Oukoop +0 g C m^{-2} while Horstermeer was a sink at -300 g C m^{-2} a^{-1}However the emission of CH_4 was highest in Horstemeer We explore the consequences of the different management regimes and the water level manipulation for the GHG balance and global warming potential of the three sites.

PEAT-CO_2: Assessment of CO_2 emissions from drained peatlands in SE Asia

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Forested tropical peatlands in SE Asia store at least 42,000 Megatonnes of soil carbon. This carbon is increasingly released to the atmosphere due to drainage and fires associated with plantation development and logging. Peatlands make up 12% of the SE Asian land area but account for 25% of current deforestation. Out of 27 million hectares of peatland, 12 million hectares (45%) are currently deforested and mostly drained. One important crop in drained peatlands is palm oil, which is increasingly used as a biofuel in Europe.

In the PEAT-CO_2 project, present and future emissions from drained peatlands were quantified using the latest data on peat extent and depth, present and projected land use and water management practice, decomposition rates and fire emissions. It was found that current likely CO_2 emissions caused by decomposition of drained peatlands amounts to 632 Mt y^{-1} (between 355 and 874 Mt y^{-1}). This emission will increase in coming decades unless land management practices and peatland development plans are changed, and will continue well beyond the 21st century. In addition, over 1997-2006 an estimated average of 1400 Mt y^{-1} in CO_2 emissions was caused by peatland fires that are also associated with drainage and degradation. The current total peatland CO_2 emission of 2000 Mt/y equals almost 8% of global emissions from fossil fuel burning. These emissions have been rapidly increasing since 1985 and will further increase unless action is taken. Over 90% of this emission originates from Indonesia, which puts the country in 3rd place (after the USA and China) in the global CO_2 emission ranking. It is concluded that deforested and drained peatlands in SE Asia are a globally significant source of CO_2 emissions and a major obstacle to meeting the aim of stabilizing greenhouse gas emissions, as expressed by the international community.

Ecosystem Fluxes in a Papyrus Swamp of the Okavango Delta, Botswana

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Half of the earth's wetlands are located in the tropics and subtropics. These 2 million km^2 of tropical wetlands store about 250 Gt of carbon (Neue, 1997). Especially swamps store carbon due to slow decomposition of organic material. Nevertheless, so far, reliable ecosystem carbon and energy flux data are still sparse, especially for Africa. Most of Africa's permanent swamps are situated in the equatorial belt, where two annual wet seasons occur. This is a more favourable climate for swamps or peatlands to develop, compared to the rest of the rather dry continent. Surprisingly, the Okavango Delta, situated at the edge of the Kalahari Desert zone, which rarely receives more than 400 mm of rain per year, sustains permanent swamps of an area of about 4000 km^2. The advantage of the Delta is the bi-modal hydrological regime, local rains and the annual flood do not occur at the same time. We present final results from a study employing the eddy covariance method in papyrus swamp in the Okavango delta, including energy flux measurements. The study investigated environmental factors controlling seasonal differences in net ecosystem exchange and aimed at identifying those environmental factors that control diurnal net ecosystem exchange during different times of the year.

Burning Bogs and Changing Climate: Will Peatland Carbon Sinks become Sources?

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Peatlands of continental western Canada represent 10% of the global boreal peatland area and contain 17% of the boreal peatland C stock. When peatlands burn they release C to the atmosphere. Because of diminished net primary production after fire, burned peatlands are sources of atmospheric C, recovering their C sink function over time. Using static flux chambers, we measured net ecosystem exchange of CO_2 (NEE) in 10 bogs in the Wabasca area of central Alberta, Canada, representing a time-since-fire chronosequence spanning 1-102 years. Net ecosystem exchange at each site was related to photosynthetically active radiation and near-surface air temperature, and these relationships were used to estimate annual NEE at each site. Immediately after fire, bogs function as net C sources of 7 kmol m^{-2} yr^{-1}, switching to net C sinks at about 21 years after fire, and reaching an asymptotic maximum C sink strength of 14 kmol m^{-2} yr^{-1}. Bogs cover 19% of a 12,000 km^2 region near Wabasca, and experience a fire return interval of about 123 years. Considering both direct C losses during fire and changing C balances during post-fire successional development, Wabasca bogs represent a regional net C sink of about 71 Gg yr^{-1}. However, if the fire return interval decreases to below 80 years or if non-winter air temperatures increase by more than 1.7 oC, Wabasca bogs will switch from C sinks to C sources. Less severe, but concurrent, changes in fire return interval and temperature (e.g., decrease in fire return interval to 100 yr, increase in temperature of 1 oC) also will switch Wabasca bogs from C sinks to C sources. Decreasing fire return intervals and warmer temperatures are likely for continental western Canada as climate change progresses into the 21st century, such that the function of continental western Canadian bogs as C sinks is in jeopardy.

Are tropical peatlands contributing to climate change? The impact of fire

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The status of the world's peatlands is a matter of considerable concern since their degradation can lead to carbon emissions to the atmosphere and loss of carbon sink function. Tropical peatlands, located mostly in SE Asia, make a significant contribution to global terrestrial carbon storage, both in terms of their above-ground biomass (peat swamp forest) and thick deposits of peat. They account for only 10-12% of the global peatland resource by area but may contain up to 70 Gt (21%) of the peat soil carbon store. Tropical peatlands are, however, being impacted by rapid land-use changes that increase their susceptibility to degradation and severely compromise their role as a carbon sink. A recent report by Hooijer et al. (2006) estimates that carbon emissions arising from the drainage of tropical peatlands are currently within the range 100-240 Mt C yr^{-1}, and are rising rapidly. Drainage, however, is not the only cause of atmospheric carbon emissions from tropical peatlands and over the past decade widespread fires have also had a major impact. Page et al. (2002) calculated that 810-2570 Mt C were released into the atmosphere as a result of the ENSO-related 1997/98 Indonesian forest and peatland fires; subsequent studies using atmospheric measurements have also demonstrated Indonesian burning activity makes a significant contribution to atmospheric carbon levels. Using a rapid assessment approach based on annual fire hotspot counts and known fire emission ranges, Hooijer et al (2006) estimate emissions from SE Asian peatland fires to be around 380 Mt C yr^{-1}. In order to provide more accurate spatial and temporal values for these emissions it is necessary to study the impact of peatland fires at a landscape scale and to acquire detailed information on fire history (location and return period), fire severity and the dynamics of post-fire vegetation succession and fire susceptibility. To facilitate this, we have employed a multi-temporal remote sensing approach for a study area of 450,000 ha of peatland in Central Kalimantan (Indonesian Borneo) in order to investigate the impacts of deforestation and drainage on peatland fires and vegetation dynamics. This paper will present results on the mapping and validation of land cover and burnt area, fire frequency and fire severity using a time series of satellite observations, and will discuss how these data are being used to model post-fire vegetation dynamics, to assess fire risk and the scale of fire-related carbon emissions. Initial results show that once disturbed, peat swamp forest, in common with other tropical forests, becomes more susceptible to degradation and fire as a result of the modification and fragmentation of the naturally closed structure of the forest, with repeated fires producing a heavily modified secondary ecosystem dominated by ferns, grasses and sedges, in which both fire-risk and fire return period increase and, hence, a return to pre-fire vegetation becomes almost impossible. Over a 16 year period we show that more than 93% of the study area has been burnt on at least one occasion, and that fires are now a regular feature of every dry season, not just those of ENSO-years. By scaling up the emissions data for the study area, we are able to demonstrate that fires, alongside drainage and degradation, are resulting in globally significant carbon emissions from SE Asian peatlands and a rapid loss of their carbon sink function. The paper concludes with brief recommendations on how to reduce the contribution that the mismanagement of tropical peatlands is making to global climate change.

Fire history and carbon accumulation in peat bogs during the Holocene in the boreal region of Quebec, Canada

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The accumulation of carbon and local fire history during the Holocene are being investigated in four ombrotrophic peat bogs (between 200 and 350 ha in surface) located in the boreal forest region of Quebec. The aim of the project is to improve the comprehension of fire occurrence and its influence on peatland carbon dynamics. In order to quantify stored carbon the total volume of organic material in each peat bog was obtained. High-resolution basin geometry measurements were performed using manual probing and ground penetrating radar (GPR). Surface topography has been measured using a differential GPS on a 200 x 200 m grid. To quantify the total amount of peat and related accumulated carbon, three-dimensional models were created for each basin. Coring sites were chosen based on topographic measurements. In each bog, material was collected by sampling in the deepest section and at four lateral sites. C/N and bulk density analyses are realised to quantify the relative amount of carbon in the peat. Fire horizons recorded along the margins of each peat bog will be identified by digging perpendicular ditches in order to investigate depth, thickness and divergence of the charcoal layers. Fire history will be reconstructed by analysing charcoal layers (particles >150 m) using a binocular microscope and will be associated to local peat wetness derived from testate amoebae identification. Macrofossil analysis is used to reconstruct past vegetation succession linked to climate conditions (hydrology) and fire events. Previous research in eastern Canada shows low boreal forest fire frequencies for the period of 7 to 2.5 ka BP. After 2.5 ka BP, an increase in fire frequency was found. It is expected that accumulation rates of carbon decrease with increasing fire frequency.

Northern peatland carbon accumulation through the Holocene and its impact on climate: a framework for analysis

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Throughout the Holocene, northern peatlands have both accumulated carbon and emitted methane. Their impact on climate radiative forcing has been the net of cooling (persistent CO_2 uptake) and warming (persistent CH_4 emission). We evaluated this by developing very simple scenarios of Holocene peatland carbon fluxes, and using these as inputs to a simple atmospheric perturbation model. Flux scenarios are based on estimates of contemporary CH_4 flux (15-50 Tg y^{-1}), total accumulated peat C (250-450 Pg C), and peatland initiation dates. The contemporary perturbations to the atmosphere due to northern peatlands are an increase of ~100 ppbv CH_4 and a decrease of about 35 ppmv CO_2. The net radiative forcing impact northern peatlands is currently about -0.2 to -0.5 W m^{-2} (a cooling). It is likely that peatlands initially caused a net warming of up to +0.1 W m^{-2}, but have been causing an increasing net cooling for the past 8000-11,000 years. A series of sensitivity simulations indicate that the current radiative forcing impact is determined primarily by the magnitude of the contemporary methane flux and the magnitude of the total C accumulated as peat, and that radiative forcing during the Holocene depends on flux history, but followed a fairly predictable general trajectory.

Raised bogs as archives of climate change

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Without a full knowledge of past climates, it is impossible to distinguish between natural and human-induced components of recent climate change, and erroneous future climate scenarios may be produced. Raised bogs provide excellent multi-proxy data on past climates with decadal resolution. Studies in northwest Europe revealed episodes of abrupt climate change. Diverse proxy-climate sources imply that some Holocene climate changes had significant effects on human societies in Europe and elsewhere. Further south in Europe, climate shifts can also be defined by lake-level changes, linked to changes in solar activity. The records based on peat deposits can be compared with fluctuations of solar activity as reflected in the Holocene radiocarbon and sunspot record. Apart from the 'climate archive value' raised bogs are also sinks of carbon dioxide. Possible relations between climate, species composition and carbon sequestration can be studied. The strategy of ^{14}C AMS wiggle-match dating (WMD) appeared to be very useful in peat research. The deposits can be dated with high precision, but WMD also revealed relationships between ^{14}C variations and short-term climatic fluctuations caused by variations in solar activity. The classical transition from the dry and warm Sub-Boreal to the cool, moist Sub-Atlantic around 850 calendar years BC - often clearly visible in raised bog profiles - appeared to be linked to a temporary decline of solar activity. The effects of this climate shift for Late Bronze Age people living in moist conditions in the Netherlands and for the expansion of the Scythian culture in dry southern Siberian areas will be discussed. The role of the sun - in relation to the effects of greenhouse gasses - might still be underestimated in climate models.

Development and carbon accumulation of a polygon mire over the last millennium

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Polygon mires cover extensive areas in the continuous permafrost zone of arctic lowlands and coastal plains in Russia, Canada and Alaska and are the most important carbon stores in the Arctic. Polygon mires are characterized by wet centres and drier ridges. Their developmental differentiation and its effect on carbon accumulation are, however, hardly studied.

We studied ecosystem functioning of polygon mires in the Lower Indigirka Region (NE Siberia, Russia). Detailed mapping of vegetation and abiotic site parameters revealed the spatial diversity and interrelations, whereas high resolution micro- and macrofossil analyses of four peat cores enabled a hitherto unequalled detailed reconstruction of the development of the polygon centre and ridges. The long term carbon accumulation rates (LORCA) of two cores were assessed by determining dry bulk density and C content and by AMS radiocarbon dating. LORCA of the polygon centre ranges from 10.2 to 11.7 g C m^{-2} yr^{-1} and that of the ridge from 8.3 to 9.5 g C m^{-2} yr^{-1}. These values are similar to the mean carbon accumulation rate of 12.0 g C m^{-2} yr^{-1} for polygon mires of the former Soviet Union as estimated by Botch et al. (1995). The latter overview, however, did not include data of the NE Siberian Peatland Province.

Our study shows that the ridges and centres of polygon mires differ in carbon accumulation rates and that they over time change substantially with respect to their morphology, hydrology and soil properties. We designed a conceptual model describing the development of polygon mires as controlled by feedback processes between vegetation, peat, water and ice that illustrates how ridges and centres influence each other in a dynamic equilibrium. These temporal dynamics and spatial differences have to be considered when carbon accumulation rates of single cores are extrapolated.

Literature: Botch, M.S., Kobak, K.I., Vinson, T.S., Kolchugina, T.P. (1995) Carbon pools and accumulation in peatlands of the former Soviet Union. Global Biochemical Cycles, 9, 37-46.

The effects of vegetation changes in peat bogs on long-term carbon sequestration rates

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The analysis of long-term effects of climate change on the vegetation composition and carbon sequestration in peat bogs requires a model that includes competition between plant species and feedbacks between vegetation, soil and hydrology. We developed a bog ecosystem model that includes vegetation, carbon, nitrogen and water dynamics. Two groups of vascular plant species and three groups of *Sphagnum* species compete with each other for light and nitrogen. This first bog ecosystem model that includes vegetation dynamics was tested by comparing the outcome with long-term historic vegetation changes reconstructed from peat cores from Denmark and England. Currently, the model is also validated against palaeo-ecological data from more northern bog sites in Sweden. The model was used for an analysis of the effects of vegetation changes and *Sphagnum* species on carbon sequestration rates.

The model simulated the main changes in the species composition since mid 18th century in several peat cores. Analysis of the effects of temperature showed that simulated carbon sequestration is negatively related to vascular plant expansion. Model results show that rising temperatures may still increase carbon accumulation at cool, low N deposition sites, but decrease carbon accumulation at high N deposition sites. A comparison of carbon sequestration rates among the *Sphagnum* species groups revealed that hollow Sphagna accumulated most carbon in an oceanic climate, while in a more continental climate hummock Sphagna had the highest carbon sequestration rates.

In conclusion, it is important to take vegetation changes into account when analysing long-term effects of global change in peatlands.

Sensitivity of northern peatland greenhouse gas emissions to climate change

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High latitude peatlands may face summer temperature increases of six degrees C or more by the end of this century. Northern peatlands have been accumulating carbon over the last several millenia, but increasing temperatures now threaten to release this carbon back to the atmosphere in the form of carbon dioxide (CO_2) or methane (CH_4), providing a positive feedback to climate change. The key factors in the carbon balance are soil temperature, water table position, net primary production and decomposition rates. These parameters affect CO_2 and CH_4 emissions directly through microbial activity rates, carbon substrate availability and anaerobic conditions, while possible indirect effects include the enhancement of plant growth by elevated atmospheric CO_2 concentrations and deepening of rooting depths or alteration of water table levels by a shift in the ratio of precipitation to evapotranspiration. We use a modelling approach to study the interaction between the key factors in the peatland carbon cycle and test the sensitivity of these factors to changes in temperature, precipitation and atmospheric CO_2. The Lund-Potsdam-Jena dynamic global vegetation model (LPJ-WHy v.1.0) was extended by including two wetland plant functional types, a wetland hydrology module and a more detailed soil temperature treatment that allows us to simulate permafrost. LPJ-WHy indicates that temperature increases have a negative effect on the water table, but that this effect could be offset by a 20 percent increase in precipitation. Under warmer conditions, the same water table depth could lead to higher CH_4 emissions. Vegetation changes from tree-dominated to grass-dominated biomes lead to a rise in the water table even under very warm conditions. Sites in the discontinuous permafrost area need as little as a 2 degree warming and a 30 percent precipitation increase to change the active layer depth from one to two metres.

Effects of drainage and 21st century warming on the greenhouse impact of Western Siberian mires

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The vast undisturbed mires in Western Siberia form a significant sink of atmospheric carbon. However, besides the sequestration of carbon dioxide by plant growth and peat formation, emission of methane occurs as a result of anaerobic peat decomposition. Furthermore, by drainage the carbon dioxide uptake will turn into emission due to aerobic decay of peat. Although carbon dioxide uptake exceeds methane release in undisturbed conditions, the net contribution to the greenhouse effect might be positive or negative, because methane is a stronger greenhouse gas. We have developed a new approach of quantifying the greenhouse contribution of mire ecosystems. This approach differs from the widely accepted IPCC approach, using Global Warming Potentials, in that it does not treat the two carbon fluxes as impulse fluxes, but as gradually changing fluxes. Besides, we take the past evolution of the mires into account, which sets the initial conditions for our calculations of the near-future greenhouse contribution. This approach has been applied in two cases: (1) the northward shift of bioclimatic zones in Western Siberia under 21st century warming and (2) the Holocene and future carbon exchange in a Western Siberian mire resulting from a 3-D dynamic peat accumulation model. Our results show that Western Siberian mires form a sink of greenhouse gases and have therefore a negative contribution to the greenhouse effect, meaning that they counteract the greenhouse effect. However, under drainage conditions or 21st century warming the mires will turn into a source of greenhouse gases, thus enhancing the greenhouse effect. In the case of warming the dominance of carbon dioxide over methane on the long term will eventually lead to a negative contribution again. Towards modelling high-latitude carbon dynamics in a GCM: Incorporating the physical properties of organic soil

Towards modeling high-latitude carbon dynamics in a GCM: Incorporating the physical properties of organic soil

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In recent decades, the Arctic has witnessed startling environmental change prompting concern that feedbacks in the Arctic climate system could amplify global climate change. Perhaps of greatest concern, at least from a global perspective, is the fate of the carbon balance as the Arctic warms. We will describe ongoing efforts and future plans at the National Center for Atmospheric Research to augment the Community Climate System Model (CCSM) to permit improved simulation, understanding, and prediction of high-latitude terrestrial climate feedbacks. The particular goal of this project is to develop a version of CCSM that can address the critical carbon issues in the Arctic tundra. These issues include, but are not limited to, the accumulation and loss of carbon in organic or peatland type soil profiles, the partitioning of carbon emission between methane and carbon dioxide, hydrologic cycle change related to permafrost degradation, and the interaction between temperature, nitrogen cycling and the transition between herbaceous tundra and woody arctic shrubland.

In particular we will show results from an initial effort to incorporate the physical properties of organic matter into the CCSM land-surface scheme, the Community Land Model (CLM). Organic matter significantly alters a soils thermal and hydraulic properties but is not typically included in land-surface schemes used in global climate models. This omission has consequences for ground thermal and moisture regimes, particularly in the high-latitudes where soil carbon content is generally high. Global soil carbon data is used to build a geographically distributed, profiled soil carbon density dataset for CLM. CLM parameterizations for soil thermal and hydraulic properties are modified to accommodate both mineral and organic soil matter. Offline simulations including organic soil are characterized by cooler annual mean soil temperatures (up to ~2.5°C cooler for regions of high soil carbon content). Cooling is strong in summer due to modulation of early and mid-summer soil heat flux. Winter temperatures are slightly warmer as organic soils do not cool as efficiently during fall and winter. High porosity and hydraulic conductivity of organic soil leads to a wetter soil column but with comparatively low surface layer saturation levels and correspondingly low soil evaporation. When CLM is coupled to the Community Atmosphere Model, the reduced latent heat flux drives deeper boundary layers, associated reductions in low cloud fraction, and warmer summer air temperatures in the Arctic. Lastly, the insulative properties of organic soil reduce interannual soil temperature variability, but only marginally. This result suggests that organic matter may not strongly damp soil temperature response to climate warming although the mean soil temperature cooling will delay the simulated date at which frozen soil begins to thaw.

Using satellite and flux tower data to derive the light use efficiency for two Canadian peatlands

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Northern peatlands contain approximately one third of global soil carbon. Climate simulations have indicated that higher latitudes may experience warming and changes in available moisture. Many peatlands are located in remote boreal and sub arctic climatic zones, therefore developing methods that utilise remotely sensed data to infer changes in ecosystem productivity and net carbon exchange would be very useful. While there has been considerable effort to develop these types of tools for forests and croplands, peatlands have received little attention. In this paper we used satellite data from the Moderate Resolution Imaging Spectroradiometer (MODIS); fraction of Photosynthetically Active Radiation Absorbed (fPAR), in conjunction with Net Ecosystem Exchange (NEE), Ecosystem Respiration (ER) and Incident Photosynthetically Active Radiation (PAR) from tower eddy covariance and meteorological measurements, to characterise the Light Use Efficiency (e) variability for two contrasting Canadian peatlands. Four years of data from the Mer Bleue bog and one and a half years of data from the Western Peatland were examined. The maximum e value for each of the four years (2000 to 2003) at the Mer Bleue bog ranged from 0.58 g C MJ^{-1} to 0.78 g C MJ^{-1} and at the Western Peatland was 0.91g C MJ^{-1} in 2004. The average growing season e was 0.35 g C MJ^{-1} for the Mer Bleue bog (over four years) and was 0.57 g C MJ^{-1} for the Western Peatland was in 2004. The average snow free period e for the Mer Bleue bog over the four year period was 0.27 g C MJ^{-1} and for the Western Peatland in 2004 was 0.39 g C MJ^{-1}.

The Challenge of Mapping Peatlands and the Potential of Remotely Sensed Data

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The difficulty of globally consistent mapping of peatlands is a major source of uncertainty in assessing the current role of peatlands in carbon cycling and projecting its future change. The response of peatlands to climate change is strongly influenced by properties of vegetation and its disturbance. Monitoring change in peatland vegetation is especially important in boreal permafrost peatlands which are expected to produce a strong positive feedback to global warming. Evidence of permafrost melting is abound and associated successional patterns on land surface are well established (i.e. lake formation and draining, characteristic shifts in plant species composition), however the global assessment of these patterns is lacking.

Regional maps of peatlands use different classifications making global compilations problematic; furthermore, the data on peatland distribution in permafrost regions tends to be sparse and for some regions peatland maps are not available. While peatland classifications rely heavily on surface characteristics, modern classifications of landcover (e.g. LCCS) shift to greater reliance on physiognomic features of surface vegetation causing the omission of peatlands from many global vegetation maps and inconsistent representation on some. Approaches to improved mapping of peatlands in ongoing studies include (1) incorporating peatlands in classifications of land cover as a distinct sub-class, (2) evaluation of spectral signatures of peatlands with vegetation cover dominated by different physiognomic types (trees, shrubs, herbaceous, mosses, lichens) and potential for separating peatlands from similar vegetation types on mineral soil, (3) use of microwave sensors for mapping and monitoring spatio-temporal dynamics of peatlands. Future research needs include the development of methods for using remotely sensed data to estimate vegetation biomass and productivity on the surface of peatlands and to monitor patterns of successional change associated with permafrost development and degradation.

This work was carried out at the Oregon State University, Boston University, and at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration.

Vulnerability of the carbon cycle, the role of peatlands, and impacts on climate change

Pep Canadell

Global Carbon Project, CSIRO, Australia, www.globalcarbonproject.or

I'll present an update of the global carbon budget and point out the current trends on C emissions from fossil fuel and land use change, the evolution of the terrestrial and oceans sinks, and their combined effects on the atmospheric CO_2 growth. Exceptional results are the almost tripling of the growth in fossil fuel emissions over the last six years and the impacts on global droughts on the re-distribution of the sinks on land.

A more detailed analysis will be presented on the future evolution of the carbon cycle and feedbacks to the climate system. Particular attention will be placed on carbon pools on land which are vulnerable to climate and land use change capable to emit millions of tones of carbon to the atmosphere. Recent analyses show that potential emissions from vulnerable carbon pools could add up to 200 ppm by the end of this century so rivalling the expected emissions from the combustion of fossil fuels. Examples will be given on the role of peatlands to atmospheric CO_2 growth, including both cold and tropical peatlands.

I'll finalize by discussing some of the key process understanding and observations that are required to better constrained the possible future impact of peatlands in the global carbon cycle as it relates to biogeochemical and earth system modelling of the climate system.

Program Excursion 18 April 2007

9.00	assembly in front of WICC
9.15 -10.45	Bus drive to Nieuwkoop
10.45-12.45	Nieuwkoopse Plassen, coffee and boat tour
12.45-13.45	Lunch at Nieuwkoopse Plassen
13.45-14.30	Bus drive to Lisse
14.30-17.15	Keukenhof, Lisse; including guided walk 1.5 hour
17.30-20.00	Bus drive to Wageningen via Schiphol airport (ETA 18:00)[1]

Nieuwkoopse Plassen

The Nieuwkoopse Plassen are a complex of shallow lakes formed after peat harvesting in the 16th century. The area is now designated as a natural monument and is owned by the largest nature conservation foundation of the Netherlands, “Natuurmonumenten”. Apart from open water, about half of the reserve is composed of narrow strips of land where the peat was left to dry after extraction (Dutch: legakkers). At present the vegetation of the legakkers is either composed of peat and hay meadows or overgrown with reeds and swamp forests, depending on management. Many characteristic bird and plant species can be found here, such as Black-tailed Godwit, Lapwing, Grasshopper warbler and Great Cormorant and Common Cottongrass, Marsh Pea and Snake’s Head.

Keukenhof

Keukenhof, situated in Lisse, also known as the Garden of Europe, is the world’s largest flower garden and has been running throughout spring for 58 years. In 1949, the then-mayor of Lisse had the idea to start a flower exhibit where growers from all over the Netherlands and Europe could show off their hybrids. This year the main theme is “300 years Linnaeus, the King of Flowers” to commemorate the birth of the famous Swedish botanist and physician Carolus Linnaeus 300 years ago.Keukenhof is open from the last week of March to mid-May, but the best time to view the tulips is around mid-April, depending on the weather. Last autumn no less than seven million bulb flowers were planted by hand in the park, which now makes a very nice and colorful picture together with the flowering shrubs and centuries-old trees.

[1] Please inform local organizers (Angela Breeuwer) before the start of the excursion if you would like to make use of this possibility

POSTER PRESENTATION
-ABSTRACTS-

Poster Session Programme

Interactive Poster Session I --- Sunday 15 April, 12:30 - 15:00

Interactive Poster Session II --- Monday 16 April, 12:10 - 14:30

Interactive Poster Session III --- Tuesday 17 April, 11:30 - 13:45

Poster Session I

24 Artz R.R.E., Campbell C.D., Anderson I.C. and Chapman S.J. Does the regeneration of cut-over peatlands restore below-ground functions and diversity?

14 Beer J. and Blodau C. Geochemical controls on organic matter decomposition in deep peat deposits.

29 Benscoter B. and Vitt D. Evaluating feathermoss growth and production: A challenge to traditional methods and implications for boreal C.

1 Brader A. Hydrogen isotope ratios in fossil and actuo Spagnum leaves: a first inventory.

6 Bragazza L., Siffi C. and Gerdol R. Decomposability, nutrient release and isotopic changes in vascular plant and *Sphagnum*.

34 Burke-Scoll M.J., Wieder K. and Scott K.D. Does Surface Bog Peat Reveal Enhanced N Deposition from Oil Sands Mining near Fort McMurray, Alberta, Canada?

37 Caporn S., Carroll J., Field C., Edmondson J., Pilkington M. and Lee J. The influence of air pollution on carbon cycling in British upland heath.

4 Chanton J., Glaser P., Chasar L. and Hines M. Radiocarbon Partitioning in Wetland DOC, DIC, CH_4 and Peat.

12 Clark J. and Chapman P. Temperature sensitivity of DOC release from ombrotrophic peat with respect to water table draw-down.

32 Conlin M., Turetsky M., Harden J. and McGuire D. Soil climate controls on C cycling in an Alaskan fen: responses to water table mediated by vegetation.

35 Crowe S. Beyond Restoration: Developing Community-Centred Microsite Carbon Budgets for Restored Blanket Bog, Northern Schotland.

26 Cwiklinska P. *Sphagnum* biomass production at early successional stages in minerotrophic fens.

10 Diamond J. and Middleton J. The effect of moisture on the decomposition processes in a peat-extracted bog in Southern Ontario, Canada.

30 Dorrepaal E., Van Logtestijn R. and Aerts R. CO_2-emissions in warming, northern peatlands: where does the increase come from?

36 Field C., Caporn S., Sheppard L., Evans C., Carroll J. and Dise N. Carbon and Nitrogen cycling in ericaceous peatlands.

16 Gallego-Sala A.V. and Hornibrook E.R.C. A new method for real-time monitoring of diurnal temperature effects on methanogenesis in acrotelm peat.

9 Goldhammer T. and Blodau C. Thresholds of carbon mineralization under a simulated dry-wet cycle in peat microcore incubations.

22 Harrison K., Waddington J.M., Baird A.J. and Kellner E. Effect of atmospheric pressure and temperature on the storage and episodic release of gas in peat.

21 Hornibrook E.R.C., Bowes H., Culbert A. and Gallego-Sala A. Methanotrophy in northern peatlands: limits to methane flux via pore water diffusion.

23 Jaatinen K., Laiho R., Laine J. and Fritze H. Effects of short- and long-term water-level drawdown on aerobic microbial populations in a boreal peatland.

15 Karofeld E., Frenzel P., Kasemets M., Szava-Kovats R. and Hahn A. The role of increasing temperature on bog pool bottom uplifting: topographic changes and peat decomposition.

27 Kelzer S., Turetsky M. and Shaw J. Ecological and evolutionary controls on Sphagnum traits and their effects on peatland carbon cycling.

5 Knorr K.-H., Glaser B. and Blodau C. CO_2 and CH_4 dynamics in an acidic fen soil under different vegetation cover: insights from delta^{13}C analysis.

8 Laiho R., Karsisto M., Kitunen V. and Penttilä T. Moss litter decomposition in pristine and drained peatland forests.

11 Leifeld J., Fenner S. and Müller M. Indicators for organic matter degradation of agriculturally-used peatlands after decades of drainage.

25 Loisel J., Garneau M. and Helie J.-F. Carbon accumulation in boreal peatlands estimated by Sphagnum carbon isotopic composition and proxy indicators.

18 Lupascu M., Hornibrook E.R.C., Wadham J., Pancost R. and Christensen T. Temperature response of methanogenesis in active permafrost layers at Stordalen, Abisko, Sweden.

7 Moore T., Bubier J. and Bledzki L. Litter decomposition in temperate peatland ecosystems: the effect of substrate and site.

33 Novak M. and Buzek F. Behaviour of carbon isotopes in an 18-month peat transplant experiment between a polluted and unpolluted wetland.

17 Putkinen A., Juottonen H., Juutinen S., Tuittila E.-S., Fritze H. and Yrjälä K. Active Archaea and methane production in southern and northern boreal mire sediments.

28 Robroek B.J.M., Breeuwer A., Crushell P., Kimmel K., Gleichman M., Berendse F. , Schouten M.C.G. and Limpens J. How species patch size, water table and climatic conditions affect performance of Sphagnum.

20 Saarnio S., Alm J. and Silvola J. Effects of roots on methane efflux and concentration in peat in a boreal mire.

13 Sirin A.A., Kravchenko I.K., Bazhin N.M. and Polyakov V.A. Carbon cycling in deep peats: studying key gaps and complex analysis.

19 Strack M. and Waddington J.M. Spatio-temporal variability of dissolved methane at peatland hollows.

31 Talbot J., Roulet N.T. and Moore T.R. Vegetation succession and changes in carbon sequestration following drainage in a bog.

2 Toberman H., Freeman C., Evans C., Artz R., White M. and Fenner N. Summer drought, phenol oxidase activity and soluble phenolic carbon release in an upland Welsh heathland.

3 Vávrová P., Freeman C., Anttila J. and Laiho R. Hydrological influences on enzyme activities in a boreal peatland.

Poster Session II

44 Armstrong A., Holden J. , Kay P., Chapman P. , Clements S. , Foulger M, McDonald A. and Walker A. Impacts of drain-blocking on water colour flux and water table depth.

45 Armstrong A., Holden J. , Kay P., Chapman P. , Clements S. , Foulger M, McDonald A. and Walker A. The effect of drain-blocking on water colour and vegetation type: a UK-wide perspective.

67 Barthelmes A. and Prager A. Carbon accumulation in Alder carrs (case studies from NE-Germany) .

40 Cohen Y., Freeman C. and Cannon J. A temporal study of DOC characteristics and mobilisation at a Welsh fen peatland

48 Freibauer A., Hoell B.S., Droesler M. , Jungkunst H., Fiedler S and Stahr K. Decoupling of in-situ CH_4 and N_2O concentrations and surface fluxes in managed and restored calcaric fens.

68 Fritz C. and Campbell D. What drives water table fluctuations in peatlands?

50 Hendriks D., Schrier A. and Kroon P. The effects of vegetation and soil on methane emissions in a natural fen meadow in the Netherlands.

57 Herbichowa M. Carbon sink versus development dynamics of two Baltic raised bogs at the southern edge of geographical range .

63 Humphreys E., Lafleur P., Moore T., Roulet N., Strachan I. and Bubier J. Research at the Mer Bleue peatland, eastern Canada.

60 Huttunen J.T., Shurpali N.J., Hyvönen N., Pekkarinen N., Biasi C., Repo M.E., Nykänen H., Martikainen P.J. Ecosystem respiration in a bioenergy crop on a boreal cutover peatland during contrasting growing seasons.

59 Jauhiainen J., Silvennoinen H., Limin S.H. and Vasander H. Carbon emissions from degraded tropical peat – does hydrological restoration cut down gaseous C-losses?

51 Kroon P., Hendriks D., Schrier A., Hensen A. and Van 't Veen H. Micrometeorological observations of CH_4 and N_2O at a managed fen meadow in the Netherlands.

47 Laine A., Byrne K.A., Wilson D. , Kiely G. and Tuittila E.-S. CO_2 and CH_4 flux dynamics in an Irish lowland blanket bog.

69 Lode E. Dynamics of groundwater levels in acrotelm layer of the bog landscape .

64 Minkkinen K., Lohila A., Laurila T., Aurela M. and Penttilä T. A drained peatland forest sequesters carbon in southern Finland.

70 Murphy M., McKinley A. and Moore T. Getting to the root of the matter: relating root biomass to hydrology in an ombrotrophic bog.

41 Pawson R Spatial patterns of fluvial carbon flux and quality in upland peat dominated systems.

56 Pelletier L., Garneau M., Moore T. and Roulet N. Carbon fluxes between mid and high boreal peatlands using static chamber, James Bay, Quebec, Canada.

43 Porteous B., Worrall F. and Burt T.P. Using tracers to understand the role of the catotelm in DOC export.

46 Riutta T., Laine J. and Tuittila E.-S. Temporal variability in CO_2 and CH_4 dynamics in a boreal fen - ecosystem components show contrasting patterns.

49 Rowson J., Worrall F. and Ostle N. A prediction of drained upland peats gaseous carbon response to climate change.

53 Saari P., Saarnio S., Kukkonen J.V.K., Akkanen J., Saari V., Luotonen H., Lyytikäinen V., Heikkinen S.M. and Alm J. CH_4, DOC and BOD describe the C cycle in peat of a flooded buffer wetland.

55 Sagerfors J., Lindroth A., Grelle A., Klemedtsson L. and Nilsson M. CO_2 Dynamics at a Boreal Oligotrophic Fen During Spring and Autumn.

42 Sallantaus T. Peatland restoration -induced changes in the DOC of recipient waters.

65 Samaritani E., Siegenthaler A., Yli-Petäys M., Buttler A., Christin P.-A., Mitchell E.A.D. Are *Sphagnum*-dominated regenerating cutover bogs carbon sinks or not? A study in the Swiss Jura Mountains with predictions of climate change impacts on the C balance.

54 Schreiber P., Forbrich I., Wilmking M. and Kutzbach L. CH_4 fluxes during the spring thaw period in a boreal peatland in North Karelia, Finland.

66 Schrier A., Kroon P., Hendriks D., Veenendaal E. and Berendse F. Greenhouse gas fluxes in managed fen meadows in the Netherlands.

61 Shurpali N.J., Huttunen J.T., Hyvönen N., Hassinen A., Lemettinen M., Clement R.J., Launiainen S., Vesala T. and Martikainen P.J. Net ecosystem CO_2 exchange (NEE) from reed canary grass cultivation on a cutover peatland in eastern Finland.

62 Tiiva P., Rinnan R. , Faubert P., Räsänen J., Holopainen T., Kyrö E., Holopainen J. Long-term exposure to enhanced UV-B radiation increases the emissions of isoprene from a sub-arctic fen.

52 Van den Akker J.J.H., Hendriks R., Pleijter M., Wolleswinkel R., Beuving J., Hoving I. and Van Houwelingen K. Empirical relations between subsidence, CO_2 emissions and water management.

58 Vile M., Scott K., Wieder K. and Vitt D. Parched Peatlands and Changing Climate: Will Prolonged Drought Convert Fen C Sinks to Sources?

39 Waldron S., Scott M. and Soulsby C. Delineating and quantifying dissolved inorganic carbon loss from peatlands.

38 Worrall F. Current tends in DOC concentration and flux in UK rivers, lakes and reservoirs.

Poster session III

74 Aurela M., Laurila T., Riutta T., Vesala T., Tuovinen J.-P., Hatakka J., Lohila A., Rinne J., Haapanala S., Tuittila E.-S. and Laine J. Carbon dioxide exchange on three open wetlands in Finland.

97 Becker T., Forbrich I., Jager D., Schneider J., Kutzbach L., Thees B. and Wilmking M. High resolution imagery improves quantification of carbon fluxes in peatlands.

98 Belyea L. and Baird A. The implications of fine-scale heterogeneity in peatlands for models of land-atmosphere carbon exchange.

89 Benscoter B. and Vitt D. Post-Fire Compositional and Functional Recovery of Canadian Bogs.

83 Bergmann L., Drösler M., Schultz R.,Freibauer A., Jungkunst H. and Höll B. Long term effects of fen restoration on Net Ecosystem Exchange: Determining the driving factors of $C0_2$ fluxes.

78 Bleuten W., Naumov A., Huttunen J., Repo M., Lapshina E., Kosykh N., Mironicheva-Tokareva N and Borren W. Methane fluxes by Western Siberian wetlands are overestimated substantially.

94 Boehm H.-D.V. and Sulistiyanto Y. Carbon Storage in the Northern Sebangau Area between Tangkiling and Kasongan, Central Kalimantan and Peatland DEM-measurements with an Airborne Laser Scanner .

90 Breeuwer A., Heijmans M., Robroek B.J.M. and Berendse F. Effects of climate change on vegetation and decomposition: a North-South transplantation of bog monoliths.

88 Clay G. The effect of burning and grazing on soils and water quality.

102 Dimitrov D., Grant R., Lafleur P., Roulet N. and Humphreys E. Modelling of subsurface hydrology, soil temperatures, and hydrological effects on NEP of a northern bog.

82 Drösler M., Augustin J., Bergmann L., Dehnhardt A., Förster C., Freibauer A., Höper H., Kantelhardt J., Minke M., Petschow U., Schaller L., Sommer M. and Zinnecker F. GHG-exchange and economic effects of climate friendly peatland management in Germany.

81 Drösler M., Freibauer A., Bergmann L., Jungkunst H., Höll B., Schultz R. and Fiedler S. C-balance and GWP-balance of degraded and restored fens in the Donauried, southern Germany.

95 Garneau M., Bernier M., Grenier M., Moore T., Roulet N., Richard P.J.H., Asnong H., Beaulieu-Audy V., Collins M., Demers A.-M., Laterreur N., Loisel J., Pelletier L. and Quillet A. An integrated multiscale (spatial and temporal) approach for carbon dynamics comprehension of boreal peatlands.

91 Gunnarsson U., Boresjö Bronge L. and Rydin H. Peat productivity of an open peatlands in southwest Sweden.

86 Harden J., Jorgenson M.T., Wilmking M., Myers-Smith I. and Fuller C. The role of thaw regime in fate of terrestrial carbon in landscapes vulnerable to permafrost degradation.

84 Hendriks R.F.A., Wollewinkel R. and Van den Akker J.J.H. Predicting soil subsidence and greenhouse gas emission in peat soils depending on water management with the SWAP-ANIMO model.

71 Lafleur P., Aurela M., Humphreys E. and Laurila T. The World's Longest Continuous Measurements of CO_2 Exchange at Peatlands - What have we learned?

79 Laurila T., Aurela M., Lohila A., Hatakka J., Tuovinen J.-P., Thum T., Rinne J., Pihlatie M., Vesala T., Aro J., Laine J., Penttilä T., Riutta T. and Minkkinen K. Greenhouse gas balances of natural and drained peatlands in Finland based on the micrometeorological measurements.

77 Leppälä M., Kukko-oja K., Laine J and Tuittila E.-S. CO_2 exchange and vegetation dynamics along a mire chronosequence.

72 Lund M., Lindroth A., Christensen T.R. and Ström L. A temperate bog balance on the edge.

85 Meyers-Smith I., Harden J., Wilmking M., Fuller C., McGuire A.D. and Chapin III, F.S. The influence of disturbance on wetland succession in a permafrost collapse, Fairbanks, Alaska.

99 Morris P., Baird A. and Belyea L. A 'complex adaptive systems' approach to modelling peatland dynamics.

76 Nilsson M., Sagerfors J., Buffam I., Eriksson T., Grelle A., Klemedtsson L., Weslien P., Laudon H. and Lindroth A. Two Years of Complete Carbon Budgets for a Boreal Oligotrophic Minerogenic Mire.

93 Oksanen P. Searching for wetlands since the Last Glacial Maximum.

87 Rowson J., Worrall F. and Evans M. Carbon release from different restoration techniques on wildfire sites.

96 Sagerfors J., Lindroth A., Buffam I., Grelle A., Klemedtsson L., Laudon H. and Nilsson M. Water Budget and Energy Partitioning of a Boreal, Minerogenic Mire .

101 Sonnentag O., Chen J. and Van der Kamp G. Spatially explicit simulation of fen hydrology and carbon fluxes as influenced by topographical setting.

73 Sottocornola M. and Kiely G. Four years Eddy-Covariance CO_2 fluxes from an Irish Atlantic blanket bog.

80 Turetsky M., Flannigan M., Harden J., Kasischke E., McGuire D., Vitt D. and Wieder K. Peatland C responses to changing hydrology and disturbance regimes: perspectives from boreal North America.

92 Van der Linden M. and Van Geel B. Late-Holocene climate change; effects on carbon accumulation in bog ecosystems in Sweden and Germany.

75 Worrall F. Towards a complete carbon budget for a peat catchment.

103 Wosten H., Hooijer A., Siderius C., Satriadi Rais D., Idris A. and Rieley J. Tropical peatland water management modelling of the Air Hitam Laut catchment in Indonesia.

100 Wu J., Roulet N., Moore T. and St-Hilaire F. Does microtopography really matter in modelling ecosystem level carbon cycling of an ombrotrophic bog? .

Does the regeneration of cut-over peatlands restore below-ground functions and diversity?

Artz R.R.E., Campbell C.D., Anderson I.C. and Chapman S.J.

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RECIPE (Reconciling commercial exploitation of peat with biodiversity in peatland ecosystems)
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Abandoned and restored peatlands can sustain re-colonisation by typical peatland vegetation and are able to regain functioning as net carbon sinks. An important part of the carbon balance equation is the level of soil respiration, which is the sum of the metabolic turnover of labile plant-derived carbon and the decomposition of structural plant material (e.g. litter and root turnover). Within the RECIPE project (a three year EU funded initiative) we investigated both the below-ground community level physiological profiles (CLPP) using multiple substrate respiration assays with typical peat labile carbon sources, and the composition of the fungal community (by denaturing gradient gel electrophoresis of fragments of the ribosomal internal transcribed spacer) in peatlands at various stages of restoration within five European sites. CLPP were strongly dependent on the peat horizon used, suggesting both a microbial biomass effect and adaptation of the microbial communities in these horizons to the prevailing substrate composition. We showed, using redundancy analyses (RDA), that a significant proportion of the horizon effect can be explained by a simple proxy measurement of the level of decomposition of the sample using Fourier-transform infrared spectroscopy. In addition, we found a significant influence of vascular plant species in RDA, suggesting that the quality and quantity of rhizoexudate are important in determining the catabolic potential of the soil microbial community. Molecular analysis of the composition of the fungal communities showed significant differences between the stages of vegetational succession. Sequence analysis of selected clones from one of the European sites identified a number of fungal functional types involved in the cycling of carbon such as species known to form mycorrhiza with ericoid hosts and fungi involved in the decomposition of plant litter in permanently waterlogged environments. All analyses of biological diversity showed an encouraging return to the composition observed in intact systems, or at least significant shifts towards the characteristics of sites in advanced stages of regeneration, suggesting that the below-ground functioning and microbial diversity of regenerating peatlands is also being restored.

Geochemical controls on organic matter decomposition in deep peat deposits

Beer J. and Blodau C.

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Peatlands are a major sink in the global carbon cycle. For the long-term sequestration of carbon, the rates of anaerobic decomposition of organic matter are of critical importance. However, in situ decomposition rates and the factors controlling them in deep peat deposits are largely unknown to date.

We hypothesized that an accumulation of decomposition products in deep layers as a result of slow, diffusive transport diminishes the free energy available for decomposition of peat and ultimately thermodynamically constrains decomposition rates. To test this hypothesis, we determined detailed concentration depth profiles of relevant decomposition products using multilevel piezometers and pore-water peepers at an ombrotrophic peat bog. The magnitude of CO_2 and CH_4 production was estimated by inverse pore-water modeling, and Gibbs free energy of key processes was calculated.

Highest production rates occurred close to the water table (decomposition constant kd ~10-3 to 10-4 a^{-1}) or in

some distinct zones at depth (kd ~10-4 a^{-1}). Deeper into the peat, production proceeded slowly at only about kd = 10-7 a^{-1}. This pattern could be related to thermodynamic constraints. The metabolic decomposition end-products CO_2 and CH_4 accumulated at depth (ca. 5500 µmol L^{-1} CO2 and 500 µmol L^{-1} CH_4). As a consequence, Gibbs free energy for acetoclastic methanogenesis decreased (20 to 25 kJ mol^{-1} CH_4) and approached the thermodynamic limit for microbially mediated processes reported earlier. This decrease could not be compensated by an accumulation of the methanogenic precursor acetate (up to 150 µmol L^{-1}). Moreover, as indicated by isotopic fractionation ($\Delta CO2\text{-}CH_4$ of 1.069 to 1.079), CH4 formation was dominated by hydrogenotrophic methanogenesis which occurred at slightly more favorable energy levels than acetoclastic methanogenesis. Gibbs free energy of hydrogenotrophic methanogenesis reached still only 35 to 40 kJ mol^{-1} CH_4 in larger depths. Furthermore, several fermentative decomposition pathways attained energy levels close to 0 kJ mol^{-1}. Based on theoretical consideration, these conditions likely constrained the methanogenic decay and thus explain the overall strong slow-down of anaerobic peat decomposition in the deep peat deposits.

Evaluating feathermoss growth and production: A challenge to traditional methods and implications for boreal C

Benscoter B. and Vitt D.

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Feathermosses dominate the ground layer of boreal ecosystems and play a vital role in soil carbon (C) accumulation. Growth in these pleurocarpous mosses is both apical and lateral, with branches of determinate length at maturity produced at consistent frequencies along the stem. Current methods of estimating annual production of feathermosses measure the annual stem growth increment and multiply it by a species-specific bulk density (plant mass per length), which is determined by destructive sampling of the top portion of the plant. However, these methods underestimate total plant production because they do not account for lateral growth of the previous years immature branches. We present a conceptual model of feathermoss growth using *Pleurozium schreberi* that includes apical and lateral annual growth. From this model, we provide a modified method to more accurately measure *P. schreberi* production that can be calibrated for any monopodial feathermoss. The top 3-cm of ten *P. schreberi* plants from each of five bog peatlands in Alberta, Canada were collected and used to define the parameters of the proposed model. An additional 20 plants were collected from a sixth site for testing the accuracy of our modified method. Stem mass was found to be constant, as was branch frequency and branch mass per length and a logarithmic relationship between branch length and distance from stem apex was found. These parameters were used redefine the mass per stem growth increment constant that, due to lack of significant variability among the sites in the parameters, can be applied regionally and possibly globally. Assessment of our method showed an insignificant mean difference between observed and calculated production values. Furthermore, comparison of our method with classic methods showed a ca. 25% underestimate of annual production by the latter, significantly increasing the importance of feathermosses in the boreal carbon cycle.

Hydrogen isotope ratios in fossil and actuo *Sphagnum* leaves: a first inventory

Brader A.

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Raised bogs are frequently used as Holocene palaeoclimate archives. They form a continuous record through time from which many proxies for palaeoclimate reconstruction can be deduced, e.g. stable isotopes, pollen, macro remains, testate amoebae. Precipitation in the Holocene has only been described in general and solely qualitative terms, and bog plant stable isotopes have mainly been used for reconstruction of palaeotemperature. Climatic factors affect the stable isotope ratio in precipitation. Raised bogs are purely rain water fed, and *Sphagnum* mosses in particular have a very direct link with the precipitation, reflecting the stable isotope ratio in their tissue. Apart from the isotope ratio in precipitation, the isotope ratio in bog plants can also be affected by enrichment through evaporation and biochemical fractionation in the plant.I will try to make a sharper and more quantitative reconstruction of precipitation, temperature and evaporation in the late-Holocene. For that purpose, I am studying a peat core from the Hautes Fagnes, picking samples at the *Sphagnum* species level for stable isotope analysis of oxygen and hydrogen. Calibration of the palaeo *Sphagnum* samples will be based on greenhouse experiments and a European training set of *Sphagnum* samples with a large geographical spread. Furthermore, I shall use a new and very accurate method for D/H ratio measurement, based on the lipid fraction in the Sphagna. The advantage of lipids over cellulose is their stable conservation through time.

At this meeting, I shall present my first results, coming from a greenhouse experiment investigating differences in fractionation of stable isotopes between different *Sphagnum* species, and from the European training set for calibration. Besides, some preliminary data from a rough survey through the Hautes Fagnes core will be presented. On top of that I can tell something about on the lipid extraction method applied to *Sphagnum* samples.

Decomposability, nutrient release and isotopic changes in vascular plant and *Sphagnum* litter

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Plant litter decomposition controls nutrient availability in natural ecosystems and, ultimately, the amount of carbon (C) released to the atmosphere. Because organic matter stored in peatlands significantly contributes to the global soil C pool, a better knowledge of plant litter decomposition in peatlands is crucial to understand potential feedbacks to global warming. This study aims at evaluating the rate of mass loss, nitrogen (N) and phosphorus (P) release, as well as changes in N and C isotopic composition during litter decomposition of the most representative plant species (two *Sphagnum* species and four vascular plant species) in a bog on the south-eastern Alps of Italy. After 1 and 2 years, mass loss was greatest for *Potentilla erecta* (84% and 87% of initial mass, respectively) and lowest for *Sphagnum* fuscum (13% and 14% of initial mass, respectively). An inter-specific comparison of decomposition rate and initial litter chemistry resulted in a negative correlation between mass loss after 1 year and C:N, C:P and N:P ratio. For all species, we observed net mineralization of N and P, with greatest values for *Potentilla erecta* (75% and 81%, respectively) and lowest values for *Sphagnum fuscum* (13% and 32%, respectively). Nitrogen mineralization was negatively correlated with N:P ratio suggesting a primary limiting role of P availability, whereas P mineralization was negatively correlated with C:P and N:P ratio. Increasing mass loss was accompanied by a significant decrease of ^{13}C content, but no correlation was found between decomposition rate and ^{15}N content.

Does Surface Bog Peat Reveal Enhanced N Deposition from Oil Sands Mining near Fort McMurray, Alberta, Canada?

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Peatlands cover 31% of the land area of northeastern Alberta where background atmospheric N deposition is 1 kg ha^{-1} yr^{-1}. A CALPUFF dispersion model predicted that the oil sands mining industry in the Fort McMurray (56°39' N, 111°13' W) area has increased N deposition by up to 4.0 kg ha^{-1} yr^{-1} in areas downwind of the mines. Ombrotrophic bogs are N-sensitive, and when N input is low, *Sphagnum* uses atmospherically deposited N to support net primary production. As N deposition increases beyond the N demands of net primary production, *Sphagnum* tissue N concentrations increase. If there is enhanced N deposition in the Fort McMurray area, N concentrations in near-surface bog peat should be higher downwind of the mining operation than upwind. To test this prediction, 2 replicate peat cores (10-cm diameter) were collected from each of 10 sites distributed among four regions: two (Birch Mountains, BM, 3 sites; west of Fort McMurray,WF, 1 site) are located upwind of oil sands mining; two (Stony Mountains, SM, 3 sites; northeast of Fort McMurray, NE, 3 sites) are located downwind of oil sands mining. Mean N (± SE) concentrations (mg/g) for the 0-2, 2-4, and 4-6 cm depths are: 10.4 ± 0.5, 7.8 ± 0.4, 7.6 ± 0.4, respectively, for BM; 10.3 ± 0.6, 7.9 ± 0.4, 7.6 ± 0.1, respectively, for WF; 10.8 ± 0.9, 8.8 ± 0.3, 8.6 ± 0.3, respectively, for SM; and 10.7 ± 0.9, 8.3 ± 0.6, 7.9 ± 0.7, respectively, for NE. Data show no difference in N concentrations based on region (upwind vs. downwind from the oil sands mining). If there is an N deposition gradient within the oil sands region, it is likely that increased N input is low enough that the plant community is incorporating additional N directly into new growth.

The influence of air pollution on carbon cycling in British upland heath

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In the UK, upland heath and related dwarf shrub communities are habitats of high conservation value and provide vital ecosystem services including carbon storage. Although generally located in remote regions of the country these areas are frequently the most affected by air pollution. Exposure of the UK upland areas to acid rain, nitrogen pollution and, in some areas, heavy metals has been considerable since the industrial revolution. At the same time upland soils are usually poorly buffered and therefore are vulnerable to changes caused by deposited acidity. Upland moorland vegetation is dominant on soils of low nutrient status, and nitrogen eutrophication threatens the most sensitive elements of the plant communities, such as the bryophytes, limiting their production and diversity. In recent years the rapid change in climate, probably resulting from air pollution, has brought new threats to the uplands which now face relatively sudden physical and biological transition.

This presentation examines the effect of air pollution on carbon cycling by reference to two case studies. The first is a long term experiment on the effect of atmospheric nitrogen deposition on the carbon cycling in upland heath. Since 1989 we have made regular, monthly additions of nitrogen (between 0-120 kg N ha^{-1} y^{-1}) to *Calluna vulgaris* dominated moorland in the hills of north Wales. Nitrogen accelerated the growth rate and the development of the vegetation despite the incidence of winter injury in *Calluna* which was worst in the higher nitrogen treatments. Nitrogen advanced the plant's development which, under typical management, could mean that the vegetation

would require more frequent burning. This has implications for carbon and nitrogen release since burning causes large losses to the air and groundwater. Nitrogen treatment increased leaching losses of C and N, particularly following the burn. Nevertheless, eleven years after starting the experiment the net carbon storage in the soil as well as in above ground vegetation was increased by the nitrogen treatment.

Below the canopy of the healthy dominant shrub vegetation, the bryophyte and lichen layers responded very differently and were severely damaged by the extra nitrogen supply. The abundance and species diversity of the bryophytes were strongly affected by nitrogen and while this vegetation is a relatively small part of the primary production in *Calluna* moorland, it is of much greater importance in nearby mire communities. Such ecosystems are found in the uplands of northern England and the second case study examines the sustained changes to these peatlands under the influence of air pollution since the Industrial revolution. Large areas of the southern Pennines in northern England are bare peat surfaces due to a complex combination of natural and anthropogenic stress conditions, including air pollution. Despite improvements in air pollution, much of this area is still exposed to rates of atmospheric nitrogen deposition of around 30 kg ha^{-1} y^{-1} and in addition residual, stored pollution (nitrogen, sulphur, metals) in the soils and sediments from at least the past 200 years is likely to play a role in limiting plant production and carbon sequestration. The prospects for improving carbon storage in the eroding southern Pennine peatlands are very uncertain given the pollution constraints and future climate scenarios.

Radiocarbon Partitioning in Wetland DOC, DIC, CH_4 and Peat

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In this presentation, we will report on some interesting observations of radiocarbon distributions between porewater constituents DOC, DIC, CH_4 and bulk solid phase peat. We will contrast differences between hummocks/bogs (*Sphagnum* dominated, Carex absent) and lawns and/or fens (*Sphagnum* present or not, *Carex* present or dominant). We have previously observed in sampling a raised bog and fen in the Glacial Lake Agassiz Peatland in northern Minnesota that DOC was ^{14}C enriched relative to peat from the surface to 3m depth in both wetlands. Also, the radiocarbon content of DIC and CH_4 was not different. However, the wetlands differed in that the products of respiration, DIC and CH_4, were similar to DOC in the fen, but in the bog, they were more similar to the peat. We can report that we have confirmed those observations in a 2nd round of sampling at those wetlands. We have further examined a *Sphagnum* lawn (dominated by *Sphagnum* but with *Carex* present in Minnesota and two other bogs, Turnagain Bog in Alaska and Bleak Lake Bog in Alberta. In these wetlands the pattern has held, in that the lawn containing *Carex* has displayed a pattern similar to the *Carex* dominated fen, while the bogs have patterns similar to the Minnesota bog. We cautiously interpret these results as being due to a fundamental difference in dissolved organic matter reactivity between bogs and fens, with fen DOC being more reactive than bog DOC. We speculate that these differences are related to vegetation type, and the presence or absence of *Carex*.

Temperature sensitivity of DOC release from ombrotrophic peat with respect to water table draw-down

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The release of dissolved organic carbon (DOC) from peat soils is thought to be sensitive to changes in climate, specifically changes in temperature and rainfall. There is a wide body of evidence showing that increased temperatures cause an increase in DOC release during organic matter decomposition, however the role of changes in rainfall is less clear. Water table draw-down caused by reduced rainfall has been associated with both an increase and decrease in DOC release, with some studies reporting no change in DOC release at all. Our controlled laboratory experiments that were integrated with analysis of monitoring data from an ombrotrophic peat in northern England, showed that soil water acidification, driven by sulphur redox reactions, caused an episodic reduction in DOC concentrations during periods of water table draw-down. However, our experiments also showed that once the effect of episodic soil water acidification had been reversed, following water table recovery, DOC concentrations in peat soil waters increased substantially and were higher than concentrations in the control cores where the water table had not been drawn-down. The increase in post-drought DOC concentrations was more pronounced at higher temperatures, such that the estimated Q_{10} for DOC release increased from 2.13 under anaerobic conditions to 3.66 under aerobic conditions. These results imply that water table draw-down during drought events can increase DOC release from peat soils, although increased DOC may not be seen until after the drought event as other drought-induced changes in soil water chemistry can obscure detection of DOC release by temporarily altering its solubility. These findings highlight both the sensitivity of DOC release from ombrotrophic peat to episodic changes in water table draw-down, and the need to disentangle complex and interacting controls on DOC dynamics to fully understand the impact of environmental change on this system.

Soil climate controls on C cycling in an Alaskan fen: responses to water table mediated by vegetation

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To better understand soil climate (temperature, moisture) controls on carbon cycling in Alaskan peatland and permafrost soils, we are using an integrated approach that relies on measurements of C fluxes across a 1) full factorial design of water table and soil warming manipulations, and 2) natural moisture and vegetation gradient that ranges from water tables flush with the moss surface in an open fen (~100 cm of peat) to an active layer > 60 cm in a forested permafrost site (~50 cm of soil organic matter). Our sites are situated at the Bonanza Creek Long Term Ecological Research (LTER) site in interior Alaska, approximately 20 km south of Fairbanks. In 2005, we established three water table treatments within a moderately rich fen. We are using trenches to lower water table levels in the lowered plot by 10 cm on average in 2005 and 37 cm on average in 2006 (relative to our control plot). We are using solar powered pumps to inundate soils in a raised water table treatment 5 cm and 12 cm higher than the control plot in 2005 and 2006, respectively. Within each of the three water table treatments, we are using open top chambers to passively warm air and surface soil temperatures by 1ºC on average. CO_2 (dark respiration and NEE) fluxes are analyzed within static chamber techniques biweekly through the growing

season (2005 and 2006). Similar C flux measurements are performed across our natural moisture gradient, which includes our experimental fen. We hypothesized that short-term responses to warming or moisture variations would be dominated by heterotrophic respiration due to decomposition of organic matter previously protected by cold and/or wet soils. Along the gradient, we expected greater C fixation with moisture due to differences in plant productivity and community structure.

Across our experimental plots (control, raised, lowered treatments), ecosystem respiration (ER) and net ecosystem exchange of C (NEE) varied by a water table x year interaction ($p=0.0144$, $F_{2,8}=7.54$; $p=0.0729$, $F_{2,8}=3.70$). NEE was greater in 2006 than in 2005 ($p=0.0164$, $F_{1,5}=12.60$) due to inter-annual variability in precipitation (drier in 2006). Net ecosystem exchange was lower in our lowered water table plot compared to the other two treatments ($p=0.006$, $F_{2,8}=21.2$). Our data suggest that this is due to low rates of C uptake by vegetation under lowered water tables rather than greater rates of ecosystem respiration. Light response curves indicate that the raised plot has a higher GP_{max} (limit to productivity at high light, 9.83+/-0.93) than the lowered plot (GP_{max}=4.51+/-0.57), indicating that vegetation in the lowered plot may be exhibiting reduced photosynthesis due to drought or temperature stress. Our vegetation analyses show a reduction in moss cover in the lowered water table plot and an increase in *Sphagnum* cover in the raised water table plot. Light response curves agree with mean NEE estimates at PAR values exceeding 1000 µmol photon m^{-2} s^{-1}, which were greater in the raised water table treatment than the lowered or control plots (raised: 3.49 +/- 0.27, control: 1.48 +/- 0.29, lowered: -0.025 +/- 0.22).

Across the gradient, both ER and NEE increased with moisture availability at each of our monitoring stations, which is most likely driven by differences in plant productivity. NEE varied by a water table x year interaction ($p=0.0386$, $F_{2,8}=3.70$). NEE values overall were greater in 2006 due to differences in precipitation among our sampling years. Results from these two approaches show that soil moisture and temperature are strong controls on boreal wetland CO_2 fluxes via direct controls on plant and microbial activity.

Sphagnum biomass production at early successional stages in minerotrophic fens.

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The amount of carbon sequestered in peatlands acrotelm and the rate of sequestration depends on the type of vegetation, plants production and the rate of decomposition. Changes in species composition may affect the process of carbon sequestration because species differ strongly in both productivity and decomposability.

Contemporary in fens of northern Poland the replacement of brown mosses by *Sphagnum* species is commonly observed. It concerns even rich fens originated on lake chalk deposits and fens fed by calcium-rich waters. This process leads to the development of a new type of mire vegetation, but may also lead to changes in carbon accumulation. Carbon sequestration in peatlands is likely to increase when *Sphagnum* gains a competitive advantage over other plants.

The aim of the research was to evaluate the biomass production of three *Sphagnum* species at early stages of peat mosses establishment in fens. The study area was Kashubian Lakeland (N Poland), conspicuous by fen diversity. The shoot density, shoot biomass and annual biomass production per area unit were estimated for *Sphagnum teres*, *S. fimbriatum* and *S. fuscum* in gradient from rich to poor fens. Additionally the comparative samples of *S. fuscum* biomass were taken in bogs. The influence of vascular plant cover, height above the water level, peatland water pH, conductivity (K_{corr}), Ca, Mg and total N concentration on analyzed *Sphagnum* traits was estimated using RDA analysis. The results show that:

(i) *S. teres* shoot biomass depends mostly on the distance to the water level, whereas shoot density and annual biomass per area unit increases with decrease of pH and Ca content in fen water. High cover of vascular plants negatively affects *S. teres* growth and biomass production. *Sphagnum teres* from rich fens is characterized

by the lowest values of analyzed traits. (ii) Shoot biomass of *S. fimbriatum* does not depend on considered environmental factors. Shoot density increases with increasing Ca concentration. Annual production depends positively on Kcorr, distance to the water level and Mg concentration and is negatively affected by increasing Ntot concentration. Analyzed traits of S. fimbriatum does not depend on vascular plants cover. (iii) The biomass of *S. fuscum* shoots is positively related to water conductivity, pH and Ca concentration. Shoot density increases with the distance to the water level. Annual production depends mostly on the height above water level and is slightly positively related to pH as well as to Ca and Mg concentration. The shoot density and biomass production are negatively affected by increasing vascular plants cover. *S. fuscum* in rich fens produces higher amount of biomass than *S. teres* and *S. fimbriatum* in the same habitats. *S. fuscum* annual production in rich fens is nearly the same as in comparatively studied bogs. This species has not been reported from intermediate, moderately acid fens (pH 4.8 - 6.4).

Taking into account the total spectrum of fen habitats within the study area, the most wide-spread and frequent species is *Sphagnum* teres, thus it seems to be a key-species in the process of *Sphagnum* establishment in fens. The role of *S. fimbriatum* is significant in fens with relatively low water level and in places overshadowed by vascular plants. *Sphagnum fuscum* plays an important role during peat mosses succession in rich, subneutral fens because of its high biomass production and the ability to strong acidification of the occupied habitats. In order to estimate the effect of *Sphagnum* establishment on fen carbon balance more detailed studies, concerning both production and decomposition of different plant groups and competitive relations among them are required.

The effect of moisture on the decomposition processes in a peat-extracted bog in Southern Ontario, Canada

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The Wainfleet Bog is the largest protected wetland (1500 ha) in southern Ontario, Canada. This ecosystem sustains many taxa that are considered threatened in Ontario. Prior to its protection, this peatland was highly impacted by drainage and peat mining. Research into peatland restoration is a relatively new science, but evidence from the scientific literature suggests the first step to restoring a disturbed peatland, such as the Wainfleet Bog, is to remediate soil moisture levels. The purpose of this study was to determine the effect of increased soil moisture levels on decomposition in the peat-extracted areas of the bog. Field experiments were conducted in microcosms consisting of a section of peat soil with a 35 cm length, 25 cm width and 20 cm depth. The soil moisture levels within these microcosms were manipulated from May 2002 to November 2004. To measure decomposition, litter bags containing wooden toothpicks, filter paper and leaves were buried in the soil and removed at regular time intervals up to one year. The results of the litter bag studies demonstrated a significant reduction of the decomposition of toothpicks ($p<0.001$), filter paper ($p<0.001$), and *Betula pendula* leaves ($p<0.001$) when soil moisture levels were increased to levels approaching those of natural conditions. These conditions significantly reduced the mean mass loss of toothpicks by 30 %, filter paper by 20 % and *Betula pendula* leaves by 18 % over one year when compared to the existing bog conditions. The conclusions of this study indicate that the greatest reductions in the decomposition of litter in a peat-extracted bog can be obtained by restoring the soil moisture levels to near those of undisturbed conditions.

CO_2-emissions in warming, northern peatlands: where does the increase come from?

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While considerable increases in temperature have been recorded at high latitudes over the past decades, and continued warming is projected for the coming century, net effects of climate change on the carbon balance of northern peatlands remain uncertain. At the same time these peatlands store about one-third of the world soil carbon pool, and the release thereof, through temperature-enhanced decay rates, may form a major, positive feedback to our global climate.
To investigate the responses of the carbon balance to climate change, we have used open-top chambers (OTCs) to subject a sub-arctic peatland (Abisko, north Sweden) to six different climate change scenarios, using combinations of summer warming, spring warming, and increased winter snow cover. Measurements of the CO_2 emission after 6 years showed strong increases of ecosystem respiration in response to the warming treatments. We now aim to identify and quantify the sources of this extra CO_2, in order to find out whether climate warming only enhances the fast turn-over of recently fixated carbon, or whether the decay of old peat layers also responds. We tackle this question using both field and laboratory experiments, manipulating and monitoring several environmental factors and the vegetation, and examining their effects on CO_2 fluxes and isotopic signatures at different depths in the soil. Our approach and first promising results will be shown.

Carbon and Nitrogen cycling in ericaceous peatlands.

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Anthropogenic activity has increased the concentration of atmospheric CO_2 to levels not seen for at least the last 200,000 years (Petit et al, 1999), predominantly through fossil fuel burning but also through accelerated deforestation and industrial activities like cement manufacture. These activities have led to significant increases in atmospheric CO2 from pre-industrial levels of around 280ppm (around year 1800) to current day levels of around 370ppm, this increase in atmospheric CO_2 is considered to be the main driver behind climate change. The world¿s oceans provide a considerable long-term sink for much CO_2 however, smaller, but still significant, terrestrial sinks exist in vegetation and soil. The exact size and nature of these sinks is unknown though it is thought that the terrestrial biosphere sequesters up to 30% of all fossil fuel emissions (Byrne et al, 2004). The quantification of the size of the terrestrial sinks of carbon (C) represents one of the most important tasks facing scientists today.
Potential terrestrial sinks for C include heathland and bog ecosystems. In these systems decomposition and C loss through microbial respiration and Dissolved Organic Carbon (DOC) in leachate is often limited by temperature, soil moisture content and acidity. Losses of C through turnover of soil organic matter (SOM) may therefore be lower than C sequestered during plant growth. Furthermore, most terrestrial ecosystems (including heathlands and bogs) are limited by nutrient nitrogen (N), therefore the amount of C sequestered into biomass by photosynthesis may also be strongly coupled to N availability. Indeed, N addition has been shown to increase plant growth and litter production on heathlands (Caporn et al , 1995; Carroll et al, 1999) and also to influence soil processes by both positively and negatively affecting decomposition of SOM and increasing or reducing soil and litter respiration depending on plant species (Berg and Laskowski, 2005).
The study compares the interactions of the N and C cycles at three contrasting N addition experiments established on peatlands subject to different climatic regimes; lowland heath (Budworth, England), upland heath (Ruabon,

Wales) and a raised bog (Whim, Scotland). The objective of the study is to understand the effects of increased N on C sequestration at each location. At each sites N treatments have been added for between 5-10 years in a randomised block design. Measurements are made of key components of the N and C cycles.
N treatments have not conclusively affected soil respiration at a field level though laboratory experiments suggest that N may increase soil respiration in the short term. Soil respiration rates have responded strongly to temperature and seasonal change with greater levels witnessed during the warm summer season. At one site nitrate and ammonium treatments are applied separately, this has led to increasing soil and soil water pH and a subsequent increase in soil respiration under the nitrate treatments. Soil leachate has also been monitored and this too has been responsive to increasing pH with greater levels of DOC as nitrate application is increased.
Initial rate of decomposition is being estimated by the litter bag method. Three bags were placed out in each plot in July 2006 and the results from the first litter bag collection will be presented in the poster.
An open-chamber system to monitor net ecosystem exchange is currently under construction, it is hoped that differences in photosynthesis and respiration at the different treatment levels of N application will be identified; in the past a stimulation of growth by N has been recorded at two of the field sites used. Current biomass has been estimated.

A new method for real-time monitoring of diurnal temperature effects on methanogenesis in acrotelm peat

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One of the current gaps in knowledge about carbon cycling in peatlands is how diurnal temperature fluctuations influence rates and pathways of methanogenesis. A recent advance in incubator technology (the Metz Syn10 Reaction System, Radleys Discovery Technologies) enables peat samples to be incubated in gas tight vessels under a smoothly cyclical temperature regimes or using actual in situ soil temperature records. By coupling vessels held in the incubator to automated gas sampling valves in a reduction gas analyzer (H_2 analysis) and a gas chromatography equipped with a thermal conductivity detector (CO_2 analysis) and a flame ionisation detector (CH_4 analysis) the concentrations of key reactants and products in the terminal steps of anaerobic carbon mineralization can be measured at a high temporal resolution (every 3 minutes) in real-time. Furthermore, by precisely controlling the rate at which an incubation vessel is flushed with carrier gas, rates of H_2, CO_2 and CH_4 turnover can be characterised during diurnal temperature cycles in different types of peatlands at different depths. Our findings demonstrate that the Gibbs free energy of methane formation in peat soils from the acrotelm is maintained at or near the theoretical minimum 'biological energy quantum' (i.e., -30 to -20 kJ mol^{-1} H_2) for the formation of ATP. Our results suggest that methanogens in shallow peat individually or collectively have the metabolic capacity to adapt rapidly to short-term cyclical changes in temperature to optimise rates of substrate utilisation. An additional goal being pursed in this work is to use solid phase microextraction techniques to monitor changes in the abundance of short chain volatile fatty acids and simple alcohols in concert with the gas measurements to investigate the influence of diurnal temperature variations on carbon flow pathways higher in the anaerobic chain of decay.

Thresholds of carbon mineralization under a simulated dry-wet cycle in peat microcore incubations

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To gain insight into how drying and rewetting events affect the interplay between carbon mineralization, methane production, and sulfate reduction in ombrotrophic peat soils we investigated sulfate (SO_4) reduction and methane (CH_4) production in anaerobic incubations of intact peat microcores (ca. 400 mL) from different depth levels of Mer Bleue bog, Ontario/Canada. Concentration trends of dissolved SO_4, carbon dioxide (CO_2), CH_4, acetate, and hydrogen (H_2) were recorded during a 87 + 30 d incubation phase and net production rates calculated from regression. Water table fluctuations were simulated by controlled drying and rewetting of peat cores between two phases of incubation, and the contribution of prevailing pathways to total CO_2 production was determined. Peat was subjected to molybdate (MoO4) treatment to suppress sulfate reduction, controlled drainage and rewetting, or both. Sulfate reduction was additionally quantified using a ^{35}S radiotracer technique.
CO_2 production was initially rapid (up to > 400 nmol cm^{-3} d^{-1}) and slowed towards a depth-dependent threshold value of 2-4 mmol L^{-1}, which was unrelated to Gibbs free energies of the involved processes. Acetate rapidly accumulated to levels of 600-800 µmol L^{-1} and remained constant thereafter. CH_4 production (0-7.7 nmol cm^{-3} d^{-1}) was small and delayed, even after SO_4 was depleted, by about 30-40 d. Hydrogenotrophic methanogenesis was endergonic and the process thus likely followed an acetotrophic pathway. Drying and rewetting replenished the SO_4 pool, enhanced sulfate reduction rates and suppressed methanogenesis. The overall contribution of SO_4 reduction and methanogenesis to the CO_2 production rate was small (0.5-22 % of CO_2 equivalent turnover) and only enhanced in replicates subjected to drainage (35-62 %). We therefore conclude that with terminal electron transfers playing a minor role the major portion of CO_2 production in the enclosed incubation systems might have been caused by fermentation processes.

Effect of atmospheric pressure and temperature on the storage and episodic release of gas in peat

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Recent research suggests that entrapped gas in peatlands may act as a significant storage mechanism for CH_4; however, the episodic release of these gases via ebullition has also been identified as a major pathway for CH_4 transfer to the atmosphere. As such, it is necessary to understand and better describe the dynamic relationship between the processes of gas storage and episodic release in peat. Two simple models were developed to examine ebullition and fluctuations in entrapped gas (Vg) volumes. The ebullition model initiates Vg fluctuations through production and variations in pressure and temperature; gas fluctuations that exceed an applied gas storage threshold are released via ebullition. The Vg model similarly uses production, temperature and pressure to generate fluctuations in Vg, however uses measured ebullition events to test the influence of pressure and temperature on Vg volumes. Peat cores were incubated for 190 days in the laboratory and volumetric gas content, ebullition, atmospheric pressure and temperature were measured. Laboratory results agreed with the application of a threshold value for modelling ebullition, and given the simplicity of the model, good agreement was found between measured and modelled values with an r^2 of 0.66 in the final 120 days. More realistic production and

bubble retention values would improve model fit. The Vg model also generated good agreement with measured data with an average r^2 value of 0.56 with a maximum r^2 of 0.97. Increased measurement frequency, an improved representation of the relationship between temperature and solubility and a more realistic production term would improve model fit. Results from these models indicate that peat temperature and atmospheric pressure are dominant controls on Vg fluctuation and that there is a strong relationship between Vg fluctuation and the episodic release of gas from peat.

Methanotrophy in northern peatlands: limits to methane flux via pore water diffusion

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Methane oxidation by low affinity methanotrophs at the oxic-anoxic interface in peatland soils significantly attenuates the quantity of methane that reaches the troposphere by molecular diffusion through pore water. Most estimates of the efficiency of the methanotrophy barrier in peatlands range from 60 to 90%. Detailed pore water profiles of methane abundance (1 cm resolution to a depth of 0.75 m) in four peatlands (Blaen Fign, Cors Caron, Crymlyn Bog & Gors Lwyd) situated in Wales, UK collected in 2003 suggest that the barrier to diffusive flux of methane through pore water is ~100% effective during summer months. In situ methane oxidation rates based upon maximum rates of pore diffusion of methane into the methanotrophic zone ranged from 0.9 to 7.7 mg m^{-2} d^{-1} and generally, were higher in the minerotrophic than ombrogenous peatlands. However, net rates of methane flux to the atmosphere were consistently higher from the minerotrophic sites, in particular, from areas rich in vascular flora, indicating the importance of such plants in mediating methane transport across the oxic-anoxic interface. Anaerobic incubations of peat from different depths from the four peatlands confirmed that the potential for methane production was lowest in the ombrogenous mires; however, all peatlands had similar production potential distributions with depth in that each exhibited a maximum potential for methane generation at approximately 10 cm depth below the ambient water-table level. Determination of methane oxidation kinetic parameters for Cors Caron (raised bog) and Crymlyn Bog (intermediated fen) from aerobic incubation of peat with different starting quantities of dissolved methane yielded a maximum for both Km and Vmax at the oxic-anoxic interface in each peatland. The maximum Km and Vmax values were greater for Crymlyn Bog than Cors Caron consistent with adaptation of methanotroph populations in the minerotrophic peatland to higher rates of methane production and flux.

Effects of short- and long-term water-level drawdown on aerobic microbial populations in a boreal peatland

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We analyzed the responses of microbial communities, characterized by phospholipid fatty acids (PLFAs), to changing hydrological conditions at sites representing different nutrient levels in a southern boreal peatland. Overall, PLFA from gram-negative bacteria characterized the peatland complex. Anyhow, the microbial communities differed among sites (ombrotrophic bog, oligotrophic fen, mesotrophic fen) and sampling depths (0-5, 5-10, 10-20, 20-30 cm). Further, the microbial communities in each site changed significantly following water-

level drawdown. The patterns of change varied among sites and sampling depths. Fungi benefited from water-level drawdown in the top 5 cm of the mesotrophic fen, but suffered in the drier surfaces of the bog, especially in the 5-10 cm layer. In contrast, actinobacteria suffered from water-level drawdown in the mesotrophic fen, and benefited in the wet surfaces of the bog. The proportion of gram-negative bacteria decreased in the top 10 cm but increased in deeper layers of the fen sites. Basal respiration rate correlated positively with pH and fungal PLFA, and negatively with depth. We suggest that the changes in microbial community structure after persistent water-level drawdown follow not only the hydrological conditions as such, but also the patterns of vegetation change. Our results imply that the patterns of change in the microbial community structure and activity in response to climate change will be strongly dependent on the type of peatland.

The role of increasing temperature on bog pool bottom uplifting: topographic changes and peat decomposition

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Peat in Nordic mires acts as a store for a large portion of terrestrial carbon. Therefore, it is important to know how predicted increases in temperature will influence peat decomposition, accumulation and greenhouse gas emission. During the latter half of warm summers, increased temperatures enhance peat decomposition at pool bottoms to produce CO2 and CH4, which are partly trapped in the peat pores. Upon achieving sufficient buoyancy, the pool bottom will either rise to or near the pool surface or junks of peat will be cast from the pool bottom to form floating islets. During the warm summer of 2006, this phenomenon, resulting in significant disturbances to pool depth and bottom topography, was observed in more than 70% of the ca 120 bog pools in Männikjärve Bog in Central Estonia.

In order to determine the effects of pool bottom uplift on peat decomposition, a series of *Sphagnum* peat samples originating from the pool bottom were exposed at the pool bottom (depth ca 2 m) and ca 0.2 m below the pool surface for the period when most uplifted peat islets were afloat (July 7 - Oct. 16, 2006). Samples exposed near the pool surface featured a dry mass loss ca 60% greater than the bottom exposed samples (1.3% and 0.8%, respectively). We also recorded temperatures in situ, and measured mineralization rates with respect to temperature. Methane production increased on average 1.6- to 2.6-fold by transferring peat from the colder bottom to the warmer surface.

However, despite the increased temperatures at the pool surface, further peat decomposition was likely limited by its age and quality. Continued rising temperatures will likely increase disturbances to pool bottom topography, which could affect further uplift of peat to the pool surface. This, in turn, would accelerate peat decomposition and carbon gas release from bog pools.

Ecological and evolutionary controls on *Sphagnum* traits and their effects on peatland carbon cycling

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Peatlands in the boreal North American region (NABR) already are experiencing rapid climate changes that have resulted in permafrost collapse and increased growing season length. Future climate change is expected to cause widespread warming and drying of peatland soils in the NABR, which could cause peatlands to begin releasing stored C back to the atmosphere. However, dominant peatland mosses such as *Sphagnum* species are recognized as having strong controls on peatland C sequestration largely through the formation of recalcitrant litter that decomposes slowly. The mechanisms underlying litter recalcitrance in mosses are not been well understood. Our research suggests that dominant *Sphagnum* species in Canadian peatlands vary widely in litter decomposition rates, and that the abundance of metabolic and structural carbohydrates serves as a strong control on decomposition rates across a variety of peatland types. We hypothesize that moss species interactions with their environments contribute to tissue quality. We predict that species dominating peatland hollows will have fast rates of stem elongation and net primary production in response to their high resource environments (water, nutrients), and that their growth patterns will correspond to the production of large amounts of metabolic carbohydrates that will decompose quickly in litter and soils. Alternatively, we expect that species dominating hummocks will have slower stem elongation rates, and will produce more recalcitrant tissue that decomposes slowly. Phylogenetic analyses will be used as a tool for understanding species variation. *Sphagnum* traits relevant to C sequestration in NABR will be investigated across species and regions to provide insight into trait variation. These traits include: cation exchange capacity, key biochemical compounds (i.e. amino acids, phenolics and carbohydrates), C:N ratios and water wicking ability. Linking traits to a history of trait evolution, as well as understanding environmental variability can provide insight into the stability of NABR peatlands under changing climatic regimes.

CO_2 and CH_4 dynamics in an acid fen soil under different vegetation cover: insights from delta^{13}C analysis

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As clearly evaluated during the last years, peatlands play an important role in the global carbon cycle. Particularly in the context of climate change and greenhouse gas emissions, peatlands have gained increasing attention. Future climate scenarios not only predict higher temperatures but also an increasing frequency of extreme weather events. Thus, studies addressing the effect of these changes are needed. More frequent drying/rewetting cycles in usually waterlogged peat soils can be expected to have substantial effects on C-turnover and vegetation cover of fen and bog ecosystems.

We studied the effect of pronounced drying/rewetting by incubating three intact cores (60 cm diameter, 60 cm depth) from a northern temperate fen were in a climate chamber (15° C; 12h/12h day/night cycle) for 9 months. As many previous studies left out the effect of vegetation, two of the cores were kept with the original vegetation, while all plants had been removed from the third core. The water level below surface (b.s.) was manipulated by artificial precipitation as follows: 10 cm b.s. 70 days, drying out 50 days (water level ~50 cm b.s.), rewetting to

10 cm b.s. within 2 days, kept for 100 days.
The effect of pronounced drying and rewetting was substantially affected by the plant cover. Maximum CO_2/CO_3^{2-} concentrations were closely below the water table (2-5 mmol L^{-1} below, 1-2 mmol L^{-1} above the water table) but always higher under vegetation. Methane was mainly produced in the deeper profile after thermodynamically preferred electron acceptors (nitrate, iron, sulphate) had been consumed, but also in the densely rooted zones of the cores with vegetation cover. The reestablishment of maximum DIC concentrations (~30 days vs ~50 days) and methanogenic conditions (~50 vs. ~70 days) was also faster under vegetation. In the presence of increasing CH4 concentrations, $d^{13}C(CO_2)$ was within the range of -21 to -15 per mil (PDB), while in zones with low or decreasing CH_4 concentrations, $d^{13}C(CO_2)$ adjusted to values of -23 to -21 per mil. High increases in CH_4 concentrations in the deeper profile were accompanied by a $d^{13}C$ in CH_4 of around -80 to -100 per mil. This suggests a methane formation via the CO_2-reduction pathway, dominating before and after rewetting. CH_4 oxidation zones around the capillary fringe and in densely rooted zones lead to values of -60 to -50 per mil. A plant cover dominated by sedges allowed methane oxidation throughout the 60 cm profile as indicated by $d^{13}C(CH_4)$ of around -60 per mil.
This study demonstrates the impact of a changing climate on carbon turnover in peatland ecosystems. A constantly high water table allowed little renewal of electron acceptors and promoted permanent methanogenesis, while a recycling of electron acceptors during drying and rewetting retarded methanogenesis. The study further illustrates the importance of the plant cover for the internal turnover and response to external forces.

Moss litter decomposition in pristine and drained peatland forests

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Mosses generally have a major role in the organic matter and element cycles in pristine peatlands. Decomposition rates of *Sphagnum* mosses in pristine peatlands vary with species, but are generally low. This is one of the reasons for peatlands acting as C sinks. Early research on vegetation changes following drainage of peatlands for forestry indicated that *Sphagnum* mosses rapidly decline (e.g., Sarasto 1952). Consequently, it was suggested that in the forest succession following drainage, Sphagna would eventually be more or less completely replaced by typical (upland) forest mosses, if the drainage system is and remains successfully functional. This may be one of the reasons for peatlands turning into sources of C to the atmosphere. More recent studies show that in some cases Sphagna may remain as an important component in the moss layer even in old drainage areas (Laine et al. 1995). Further, the moss layer may also remain a significant source of litter inputs (Laiho et al. 2003). It has also been shown that the forest mosses typically colonising drainage areas may also have low decomposition rates. Thus, the moss layer as a whole may have a significant role in the C balance of not only pristine, but also drained peatlands. Moss-related processes in drained peatlands have, however, received little attention.
Our aim was to 1) measure the litter decomposition (mass loss) rates for dominant moss species growing on pristine and/or drained peatlands in their native environment, and 2) relate the decomposition rates to litter quality and environmental parameters. Our sites were clustered in northern (1+1) and southern (1+2) Finland.
After 3 years of decomposition, cumulative mass losses varied between 5% and 53%. The greatest losses were observed for *P. schreberi* in a drained site and *S. fallax* in a pristine site in the South. The smallest losses occurred in S. magellanicum and S. russowii in a drained site in the North. Mass loss of *P. schreberi* was rather linear over the years in the drained sites, whereas the mass losses of all Sphagna, and *P. schreberi* in the pristine site in the North, seemed to cease after 2 years. The chemical parameters measured (C fractions, total nutrients) did not unambiguously explain the differences in decomposition rates among species. In a preliminary analysis, Ca:P ratio and Mg concentration explained 21% of the variation in the mass loss data, while adding

a binary variable for *P. schreber*i increased this figure to 39%. Our results suggest that *S. magellanicum* and *S. russowii* when abundant in drained peatland forests may contribute significantly to the soil C pool as their productivity may be quite high (Laiho et al. unpublished data) and their litter decomposes extremely slowly.

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Indicators for organic matter degradation of agriculturally-used peatlands after decades of drainage

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Peatland drainage is globally one of the major contributors to CO_2 from land-use change. In Switzerland, degraded peatlands account for approximately 18000 ha and thus for about half of the former peatland area. Major drainage activities took place between 1870 and 1970, leaving strongly decomposed organic soils behind, most of which are under agricultural use today. Preliminary estimates indicated annual fluxes of between 7 and 16 t CO_2-C ha^{-1}, suggesting that the remaining peat body must be chemically degraded to a large extent. We analysed samples from several locations of the largest Swiss fen area Witzwil in the temperate Central Plateau and from Seebodenalp, a peatland located at 1000 m above sea level. At both sites, drainage can be tracked back several decades. Our main goal was to identify chemical properties of the remaining peat that are indicative for the degree of microbial decay and to derive the depth to which peat degradation has proceeded until today. The combination of spectroscopic measurements (DRIFT, NMR), differential scanning calorimetry DSC, elemental analysis (C, N, H, O), and soil physical attributes of samples taken at different depth indicated that the frontier of strong degradation goes down to approximately 0.5 m, but that also horizons below are affected by oxidation. Organic matter at Seebodenalp showed up typical attributes of degraded peat, e.g. a relatively high aromaticity probably deriving from a selective enrichment of phenolic compounds such as lignin. Soils at Witzwil were in addition characterized by external organic contamination stemming from residues of burned domestic fuels, mainly coal and wood, from the city of Bern that were deposited in the first half of the 20th century. This black carbon emerged as a thermally stable peak in the DSC thermograms and was relatively enriched in the upper horizons, suggesting that its decomposition rate is much smaller than that of the pristine peat material and that its rate of dislocation downwards the profile is negligible. Because of the different chemical composition of black carbon relative to peat (H/C, O/C), indicators for peat degradation based on elemental analysis alone are potentially biased when such a contamination has been part of the overall management history. The evaluation of the various methods applied here provides valuable information for identifying proper indicators of peat degradation.

Carbon accumulation in boreal peatlands estimated by *Sphagnum* carbon isotopic composition and proxy indicators

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Since organic material stored in ombrotrophic peatlands constitute a continuous high-resolution record of Holocene climatic changes, a combined analysis of proxy climate indicators that respond to different climate signals can potentially improve palaeoclimate reconstructions. To enhance comprehension of the environmental factors that control recent carbon accumulation in boreal peatlands, we examined surface peatland patterns, organic carbon isotopic composition and C/N ratio of four *Sphagnum* mosses species (*S. fuscum, S. capillifolium, S. magellanicum* and *S. pulchrum*), and testate amoebae relative abundance in two boreal peat bogs of the James Bay region, Northern Quebec. In order to interpret these palaeoindicators as a record of environmental parameters, we attempted to calibrate *Sphagnum*-climate relationships by 24 sets of surface mosses species from dry hummocks, lawns and submerged hollows, since the hypothesis of a relationship between isotopic composition of the *Sphagnum* mosses and water table depth was suggested. A total of twelve cores (1 m long) were collected in the three different biotopes. Chronology of peat accumulation was obtained by 210Pb and AMS radiocarbon dating. The carbon isotopic composition and C/N ratios were performed on bulk material of the *Sphagnum* species.

Temperature response of methanogenesis in active permafrost layers at Stordalen, Abisko, Sweden

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The aim of this study was to determine how changes in temperature might influence rates of methane production in the active layer of permafrost areas at Stordalen, Abisko, northern Sweden. Field work was conducted during the thaw period in the summer of 2006 at three contrasting sites: minerotrophic, mesotrophic and ombrotrophic mires. Temperature, moisture, pH, dissolved organic carbon, methane and carbon dioxide concentrations were measured in situ in the active layer at each site during June, August and September. Peat samples from 0 to 45 cm depth were incubated in triplicate in the laboratory at 4, 14, 24°C under anaerobic conditions. Rates of methane and carbon dioxide production were determined by measuring the concentration increase with time of both gases in the headspace of incubation vials. Soils at the ombrotrophic site contained no methane in situ and did not produce methane when incubated under anoxic conditions. Minor amounts of methane were present in the active layer of the mesotrophic peatland and correspondingly small amounts of methane were generated in incubation vials from the shallowest depths. The greatest abundance of pore water methane occurred in the minerotrophic peatland and methane was produced in anoxic peat incubations from all depths and at all temperatures for this site. The Q_{10} values ranged from 2.4 to 3.5 in the active layer of the site and extrapolation of the Q_{10} equation to 0°C yielded methane production rates ranging from 4.9 to 6.0 ng CH_4 d^{-1} g^{-1}. Rates of methane production consistently decreased with depth at all incubation temperatures for the minerotrophic peatland. Carbon dioxide was produced in peat incubations from all sites and the Q_{10} values were notably lower than for methanogenesis, ranging from 1.0 to 2.5.

Litter decomposition in temperate peatland ecosystems: the effect of substrate and site

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The large accumulation of organic matter in peatlands is primarily caused by slow rates of litter decomposition. We determined rates of decomposition of major peat-forming litters of vascular plants and mosses at five sites: a poor fen in New Hampshire and a bog hummock, a poor fen, a beaver pond margin and a beaver pond in Ontario. We used the litterbag technique, retrieving triplicate litterbags 6 or 7 times over 3 to 5 years, and found that a simple exponential decay model could adequately characterize the decomposition in most cases. Within each site, the rate of decomposition at the surface was generally Typha latifolia leaves = *Chamaedaphne calyculata* leaves = *Carex* leaves > *Chamaedaphne calyculata* stems > hummock *Sphagnum* > lawn/hollow *Sphagnum*, with exponential decay constant (k) values generally ranging from 0.05 to 0.37. In general, surface decay rates were slowest at the bog hummock site, which had the lowest water table, and in the beaver pond, which was inundated, and fastest at the fens. Analysis of original litter samples for C, N and proximate fractions revealed a relatively poor explanation of decomposition rates, compared to most well-drained ecosystems. Three litters, roots of a sedge and a shrub and *Typha* leaves, were placed at depths of 10, 30 and 60 cm at the sites. Decomposition rates decreased with depth at each site, with k means of 0.15, 0.08 and 0.05 yr^{-1} at 10, 30 and 60 cm, respectively. These differences are primarily related to the position of the water table at each site and to a lesser extent the cooler temperatures in the lower layers of the peat. The distinction between bog and fen was less important than the position of the water table. These results show that we can characterize decomposition rates of surface litter in northern peatlands, but given the large primary productivity below-ground in these ecosystems, and the differential rates of decomposition with depth, subsurface input and decomposition of organic matter is an important and relatively uncertain attribute.

Behaviour of carbon isotopes in an 18-month peat transplant experiment between a polluted and unpolluted wetland

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Before stable isotopes can be used to constrain the magnitude of global sources and sinks of greenhouse gases, it is necessary to quantify possible isotope fractionations at the ecosystem level. Manipulations of environmental and chemical parameters of peat monoliths represent one possible approach. We transplanted replicated *Sphagnum* peat cores, 10-cm in diameter, 35-cm deep, between two sites in the Czech Republic (VJJ, CB) differing in temperature (ΔT = 3 °C; VJJ colder) and N and S supply (VJJ 4 times more polluted). Five replicate cores were taken at each site at the beginning of the experiment and analyzed, another five cores were transplanted to the host site. The experiment was terminated after 18 months, peat cores were sectioned to 2-cm subsamples, and analyzed for $\delta^{13}C$ and C concentrations. After the transplant experiment was terminated, headspace gases (CO_2, CH_4) were taken 5 times during 24 hours from closed PE cylinders containing the peat colums. Anaerobic conditions were maintained in the headspace by purging with N_2, the incubation temperature was 20 °C. CO_2 and CH_4 were analyzed for concentrations and $\delta^{13}C$. At the end of the transplant experiment, accumulation of methane in the headspace stopped after 8 hours, while CO_2 kept accumulating thoughout the 24-hour incubation. Control local peat cores from VJJ had the highest emissions of CO_2 and CH_4, followed by the CB-to-VJJ transplants. All $\delta^{13}C$ values of CO_2 and CH_4 were lower than –20 and –25 per mil, respectively.

The site with higher S input from the atmosphere (VJJ) emitted more methane, which was surprising in light of the known competition between bacterial sulfate reduction and methanogenesis.

Active Archaea and methane production in southern and northern boreal mire sediments

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The deepest layers of mires contain old, highly decomposed organic material that is microbiologically uncharacterized. An extensive amount of carbon is stored in these sediments, and due to their large volume even low rates of methane (CH_4) production could have a considerable environmental effect when the methane is released into the atmosphere. We investigated methanogenic activity and microbial community composition in sediments of two divergent mires located in southern and northern Finland.

Mire sediment was sampled below the main vegetative root zone, and at the bottom of the mires. The samples were incubated anoxically, and potential CH_4 production was measured by gas chromatography. Active archaeal communities were studied by analysis of marker genes: RNA was extracted from sediment samples and reverse-transcribed into DNA, and archaeal ^{16}S ribosomal RNA (rRNA) gene fragments were amplified by polymerase chain reaction (PCR). The PCR products were analyzed by terminal restriction fragment length polymorphism (T-RFLP) fingerprinting to display the archaeal community structure. Archaea were identified by DNA sequencing and subsequent phylogenetic analysis.

The mire sediment samples showed, as expected, very low but still detectable CH_4 production rates, typically at least ten times lower than those of surface peat. Methanogenic activity in the sediments was most likely restricted by low substrate availability and small methanogenic biomass. RNA could, however, be obtained for generating community fingerprints, clearly showing active Archaea in the sediments. Archaeal communities differed between the southern and northern sediments, possibly reflecting differences in vegetation history of sediments. Preliminary phylogenetic analysis of Archaea in the mire sediments indicated that although methane-producing Archaea could be detected, the active communities mainly consist of non-methanogenic Crenarchaeota. Similar Crenarchaeota have previously been found in lakes, sediments and wetlands but their function remains unknown.

How species patch size, water table and climatic conditions affect performance of *Sphagnum*

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Sphagnum mosses play a crucial role in the ecology of raised bogs; they regulate the hydrological conditions to a high degree and are largely responsible for the sequestration of atmospheric carbon into peat. The extent to which these bryophytes influence their environment, however, differs among species. Effects of climate change, such as changing rates of precipitation and water table depths, may affect the species composition in raised

bogs, and ultimately the functioning of the whole ecosystem.
To examine the role of species, patch size, water table and climatic conditions on the performance of *Sphagnum* mosses, we performed a large-scale field transplantation experiment at two sites in continental Estonia (Männikjärve and Linnusaare) and one site in oceanic Ireland (Clara bog). We transplanted small and large patches of 4-6 *Sphagnum* species into existing *Sphagnum* vegetation at 5 cm, 15 cm and 25 cm above the water table, and followed height increment and cover change for three years.
Preliminary results indicate that patch size rather than water table affected cover change and biomass production of the transplants. Contrary to our expectations all species decreased in cover when transplanted, irrespective of patch size. For all species, however, larger patches seemed more productive and showed less decrease in cover than smaller patches. Interestingly, decrease in cover was largest for those species that are thought to be the more productive *Sphagnum* mosses (hollow species), irrespective of the water table, and was highest at the Irish site, possibly as a result of the wetter and extended growing season.
Our results indicate that patch size effects exceeded the effects of water table, illustrating the importance of spatial patterns/ sociability when considering the response of *Sphagnum* to changing environmental conditions.

Effects of roots on methane efflux and concentration in peat in a boreal mire

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Connection between methane (CH_4) efflux and vascular plants is evident but not yet fully understood. Vascular plants can affect CH_4 release in three ways: 1) vascular plants with aerenchyma transfer oxygen into the anoxic soil and thus can enhance CH_4 oxidation in the rhizosphere, 2) aerenchyma provides a free route for CH_4 from anoxic soil to the atmosphere and 3) plants provide fresh litter and root exudates, which are important substrates for decomposers. Effects of living roots on CH_4 concentration in peat and diffusive CH4 release were studied on two mire site types in Finland. The above-ground vascular vegetation was regularly cut from all 32 study plots. Half of the study plots (rootless) were isolated from the surrounding vegetation with a plastic sheeting down to a depth of 50 cm. In other plots (roots-growing), the surrounding vegetation was allowed to grow roots normally into the peat under the study plots. Methane release from study plots were monitored during growing seasons 1997, 1998, 2000 and 2001. In 2000 and 2001, the concentration of CH_4 and CO_2 in pore water at 5, 15 and 25 cm depths below the peat surface was determined several times during the season. Results indicate that the presence of living vascular plant roots stimulated CH_4 efflux and even species-specific differences were seen. Diffusive CH_4 release was higher from root-growing plots in both mire site types. Methane release and bubbling activity seemed to be higher on tall-sedge fen dominated by *Carex rostrat*a compared to low-sedge *Sphagnum papillosum* pine fen dominated by *Eriophorum vaginatum*. The fading of CH_4 release during the experiment indicates that the quantity of litter regulates the rate of methanogenesis instead of quantitatively more easily usable but tiny amounts of exudates provided by the living rhizosphere.

Carbon cycling in deep peats: studying key gaps and complex analysis

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We tried to understand linkages between the microbiological, hydrological, geochemical and hydrophysical processes in anaerobic deep peat layers – *catotelm* (traditionally treated to be biogeochemically inert) and to update their possible position in the carbon cycling of boreal mires. The study was based on peat profiles of different boreal mires (raised bogs, fens and swamps) being part of a long-term observation network in central European part of Russia within the "mire belt" of Northern Hemisphere. Different techniques were combined to study the processes involved in C-gas formation, transfer, storage, transport and consumption processes in relation to peat layer parameters, as a complex solid/liquid/gas media. By several years monitoring data we revealed seasonal dynamics of C-gases concentrations in deep peat layers and relation of their vertical distribution with physical processes of mass exchange defined by the hydrologic origin of mire. Exchange of peat pore water was evaluated using ^{3}H, ^{18}O and ^{2}H isotopic data. The detected evidence of temperature inversion was suggested as additional driving force for convective exchange of gaseous and dissolved products in the deep peat layers. ^{222}Rn data directly supported the possibility of gas exchange in deep peats. The rates of microbial activity in deep peat soils seemed to be sufficiently high to explain temporal fluctuations of carbon dioxide and methane concentrations: decrease CH_4 and CO_2 values during warm period of a year and their rebuilt in winter under frozen peat layer. The results supported the hypothesis that anaerobic decomposition in deep peat layers is weekly connected with material of peat matrix and likely to be related to "fresh" organic matter transported from the surface strata by water movement driven by hydrological and thermal processes. The same processes could strongly support the upward movement of C-gases produced there and their final release to the atmosphere.

Spatio-temporal variability of dissolved methane at peatland hollows

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We measured pore water methane (CH_4) concentrations from 2-90 cm depth at several hollows in a poor fen between May and August in 2003 and 2004. All sampling sites had a water table within 5 cm of the surface during this time and thus were near saturation throughout the study period. The objectives of this study were to 1) describe spatial and temporal patterns of pore water CH4 concentrations at peatland hollows and 2) investigate potential controls on concentration such as temperature, water table, depth, pH, electrical conductivity (EC), and entrapped gas dynamics.

Concentrations were 1-450 μM during both study seasons. Depth profiles were generally consistent at one location throughout the sampling period; however, profiles varied between locations. At some sites concentration increased with depth, while at others concentration decreased or had no clear relationship with depth. Also, depth profiles taken at 2-5 cm intervals revealed discrete concentration 'spikes' which were often maintained throughout the season. This small scale variability may be related to localized differences in CH_4 production

potential and/or capacity for gas entrapment. Temporal variability in CH_4 concentration in the upper 30 cm were related to temperature and water table at some locations suggesting links to redox potential near the surface. At depth, shifts in concentration did not occur simultaneously between sampling sites except later in the growing season. These appear to be related to atmospheric pressure suggesting a link to the release of entrapped gaseous CH_4. The observed spatio-temporal variability in dissolved CH_4 concentrations indicate a need to improve our understanding of the spatial variability and controls on peat CH_4 production rates and entrapped gas behaviour in order to improve our description of subsurface CH_4 dynamics. This information is necessary for a processed based description of concentration gradients, linked to diffusive CH_4 fluxes, and CH_4 efflux via ebullition which can be used to improve models of CH_4 emissions from peatlands.

Vegetation succession and changes in carbon sequestration following drainage in a bog

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There is much uncertainty about the role of peatlands as either sinks or sources of carbon and other greenhouse gases in warmer and drier or wetter conditions. Drainage of pristine peatlands has been used in the past to assess the impact of climate warming and lowered water tables on the carbon balance of different types of peatlands. We studied the long-term impact of artificial drainage on vegetation succession and carbon sequestration at Mer Bleue bog, Ontario, Canada. The drained portion of the peatland, left untouched for the 80 years following drainage, was invaded by birch trees and deciduous shrubs. This part of the bog sequesters more carbon as living biomass than the undrained portion, but sequesters less carbon as peat. A mix of model simulations and field investigations, including carbon and methane fluxes, gives insights into the possible ecological, physiological and biogeochemical explanations of these results.

Summer drought, phenol oxidase activity and soluble phenolic carbon release in an upland Welsh heathland

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The Intergovernmental Panel on Climate Change has predicted that global warming may result in a greater frequency of summer droughts at higher latitudes. Studies in deep peatlands have found drought conditions to stimulate soil phenol oxidase activity. Retractable transparent roofs have been used to simulate repeated summer drought in a natural stand of upland Calluna heathland in north-west Wales, characterised by a shallow peat horizon (~ 10 cm deep). This study looks at the effects of these summer drought events upon litter and peat phenol oxidase activity, the dynamics of soluble phenolics and soil fungal diversity at the site. The summer drought 2005 reduced soil moisture levels by 52% and significantly reduced peat phenol oxidase activity ($P = < 0.001$). Thus it appears that in shallow peats with high sensitivity to substantial drying over short periods of restricted rainfall drought may in fact inhibit soil phenol oxidase activity as a result of water limitations. Litter phenol oxidase activity was not significantly affected by the drought ($P = 0.41$), the litter tending to rapidly re-wet in the short periods of incoming rainfall received as the roofs close in response to rain events. The 2005 drought

resulted in lower phenolic concentrations in the peat (P = 0.004) and water draining from the peat horizon (P = 0.07). It remains to be investigated whether this resulted from lower leaching of phenolics from the litter in the drought plots or is related to the changes in peat phenol oxidase activity. Results for litter phenolic levels were not conclusive. Phenolic concentrations in the water draining from the peat horizon of the summer droughted plots throughout the non-droughted months of the year from were consistently higher than the controls (P = 0.001). This being in contrast to a large spike in phenolic washout that may be expected from the drought plots upon re-wetting if phenolic outputs in the plots were being affected by leaching dynamics alone, and suggests that the summer drought events may indeed be having an effect on key soil biological processes involved in the processing of polyphenolic material. Soil fungal diversity was found to be altered by summer drought.

Hydrological influences on enzyme activities in a boreal peatland

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Boreal peatlands store ca. 1/3 of the world´s soil organic carbon and this is attributed to low decomposition rates of plant litters as a result of waterlogged, anaerobic conditions. Changing climate, or land-use, may lead to persistently lowered water-levels in peatlands. Information on the effects of water-level drawdown on litter production, litter quality and decomposition rates is still too sparse to facilitate accurate estimation of changes in the C balance of peatlands. Decomposition is largely mediated by extracellular enzymes excreted by certain fungi, actinomyces and bacteria to decompose high molecular weight complex compounds. We study the effects of short-term and long-term water-level drawdown in peatlands on activities of four enzymes during decomposition process: beta-glucosidase (involved in C mineralisation), chitinase (N mineralisation), phosphatase (P mineralisation) and oxidative phenol oxidase (phenolic degradation), an enzyme suggested to be a key regulator of peatland C balance (Freeman et al. 2004). The litters studied represent typical peatland litters: sedges (*Carex lasiocarpa* leaf litter), shrubs (*Betula nan*a leaf litter), mosses (*Sphagnum* fallax, *Sphagnum* angustifolium, *Sphagnum* balticum and *Sphagnum* fuscum litter) and tree litter (*Pinus sylvestris* needle litter). The overall aim of our study is to determine how changes in the quantity and quality of the litter inputs, together with changes in soil conditions critical for decomposition and changes in microbial populations and their extracellular enzyme activities affect the C balance of peatlands.
We will analyze the impacts of both short-term and long-term water-level drawdown that may be caused by the predicted climate change, and/or land-use change of pristine peatlands to forestry. The research is done at two nutrient regime levels: ombrotrophic (nutrient-poor) and mesotrophic (nutrient-rich). The variation in enzyme activities is linked to changes in the peatland soil conditions, litter production and initial litter chemistry (amount of soluble compounds, holocellulose, acid insoluble and acid soluble lignin) following the water-level drawdown. Results from the first and the second year of decomposition will be discussed in this poster.

Impacts of drain-blocking on water colour flux and water table depth.

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Discolouration of water from peat catchments is of concern to water companies because the colour is variable, difficult to forecast, and expensive and complex to remove. Treatment may leave undesirable end products and if untreated will be a cause of water quality failures. Much of the UK peatlands have been drained using open ditches and drained catchments produce more discoloured water than undrained catchments. Therefore, blocking peatland drains has been advocated to improve water quality and decrease water discolouration. However, there is limited knowledge of the short-term impacts on water colour and whether these are different to longer-term impacts. This paper examines colour loads from four instrumented drains. Two sites in West Yorkshire, UK, were chosen: Upper Wharfedale and Winscar. Wharfedale had some drains that were blocked in 1999 and Winscar has more recently blocked drains. At each site a blocked and unblocked drain were monitored using automated water samplers, dip wells, and stage loggers. The automated samplers were programmed to take water samples during storm events and at base flow. All the samples were analysed for absorbance at 254 nm and 400 nm and selected storms were analysed for dissolved organic carbon. The variation in colour export and the different colour components are examined at storm time-scales in all four drains. The impact of drain-blocking on water colour in Wharfedale in 1999 is examined and the impacts on water treatability and hydrological flow pathways elucidated. The effect of drain-blocking on water table depth, in close proximity and mid-way between drains, is assessed.

The effect of drain-blocking on water colour and vegetation type: a UK-wide perspective.

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Peatland drainage has influenced runoff production, water quality (e.g. colour), sediment transfer and upland vegetation. The damming (blocking) of open peat drains (ditches) has been advocated to rehabilitate peatlands, but this is costly, as yet unproven and there are many different damming techniques. This project evaluates drain-blocking as a rehabilitation strategy, the techniques used, and the impacts on water colour/dissolved organic carbon concentrations and vegetation. Approximately 30 sites throughout the UK where peatland drain-blocking has occurred, encompassing a range of dam types, dam ages and physiographic settings, were identified and sampled. Blocked and unblocked drains were surveyed at each site for: location; orientation; slope angle; drain dimensions; peat depth; soil type; ground wetness; erosive state of the drain; apparent block effectiveness, including notes on type, spacing and style; and vegetation. Water samples were analysed from each drain for absorbance at 254 and 400 nm and dissolved organic carbon concentration. This information was then combined into a database with variables obtained from a GIS including catchment area, drain length and aspect. The database allows us to identify generic trends/patterns in these data which can be used to maximise the positive impacts of future drain-blocking. For example, it was found that, in some settings, expensive drain-blocking strategies, such as plastic piling, were no better than using peat to create dams. Also, drain catchments dominated by heather were characterised by more discoloured water than those dominated by grasses. Insight into the changing effect of drain-blocking over time was gained by examining drains which were blocked at different dates in the past. Analysis of water colour at different wavelengths and dissolved organic carbon concentrations provides information on the potential impacts of peatland rehabilitation on potable water quality and treatment costs and changing hydrological flow pathways.

Carbon accumulation in Alder carrs (case studies from NE-Germany).

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At the University of Greifswald various projects explore the possibilities of alternative, non-destructive use of the extended wetland areas in NE-Germany. The project ALNUS (www.uni-greifswald.de/~alnus) studied environment-friendly production of Alder wood in rewetted fens. One subtask was to determine peat forming Alder carr types by using a retrospective approach. Although Alder (*Alnus*) carrs are widespread, they have rarely been subject of palaeoecological research. Alder carr peat is generally highly decomposed and macro- and microfossils are usually badly preserved. Long term Carbon accumulation rates (LORCA's in t C ha^{-1} a^{-1}) of *Alnus glutinosa* dominated peatlands are not available and research into carbon fluxes in recent Alder forests has not been successful until now.

One important aspect is the carbon balance of alder carrs compared to drained and rewetted fens. To determine whether and how much peat is accumulated in alder carrs under different site conditions, we used pollen- and macrofossil-analyses in four Alder wood profiles from NE-Germany. These showed there are distinct wooded and open phases. Poor pollen preservation, however, prevents the detailed reconstruction of former floristic composition and hence site conditions (e.g. water level).

For sharper reconstructions the occurrence of additional microfossils (non-pollen palynomorphs = NPPs, also known as extrafossils or Types sensu van Geel 1972): wood, fungal, algal and invertebratal remains was studied. Such microfossils are abundant in Alder carr peat, but they are usually of unknown origin and as such their indicative value is unclear. Surface samples from 10 different Alder carr types in NE-Germany were analysed to correlate the occurrence of NPPs with known site conditions. Approximately 500 previously undescribed NPP types were found. Ten percent of NPPs were present both in surface and fossil peat samples. NPPs indicative for e.g. presence of Alder or Birch, specific water levels and trophic states were found.

To determine long term accumulation rates of Alder carrs bulk density measurements were combined with radiocarbon datings. We found LORCA's of 0.1 to 1.1 t C ha^{-1} a^{-1} in *very wet* Alder carrs with a mean water level of 15-0 cm above surface. Surprisingly, accumulation rates of the *wet* Alder carrs with a mean water level of 0-15 cm below surface were quite similar, in some cases even somewhat higher. This may be related to the much higher production of highly decomposition resistant wood (lignin) in wet Alder carrs without long-term floodings.

A temporal study of DOC characteristics and mobilisation at a Welsh fen peatland

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Dissolved organic carbon (DOC) release from peatlands plays an important role in the recent rise in DOC in freshwater systems throughout the UK, Europe and North America, as some of the largest increases occur in areas containing peat soils. The increase of DOC release from peatlands can be attributed to processes such as enhanced microbial and enzyme activity within the soil matrix, changes in rainfall, drought periods and water-table levels due to climate change, elevated atmospheric carbon dioxide levels and hydrochemical changes, such as a reduction of acidity and increased nitrates.

To gain an insight into the characteristics of DOC released from peat soil, a 12 month study was carried out at a calcareous fen in North Wales, UK. Peat pore water and stream water were collected monthly from

locations less than 20m apart within the fen. DOC concentration (mgl^{-1}) reduced significantly from peat to stream (87.1% average, P=0.000) and apparent molecular weight (mol.wt.) characteristics of the carbon were also analysed to investigate different fractions. Significant differences in high and intermediate mol.wt. proportions of carbon (100,000-10,000, 10,000-1,000 daltons respectively) were found between pore and stream water (P=0.000), whilst there was no significant difference in the proportion of low molecular weight carbon (1,000-100 daltons). The high mol.wt. proportion of carbon reduced by 79% from peat to stream, whilst the intermediate proportion increased 127% in stream water. Processes responsible for the breakdown of the carbon from higher to intermediate, such as UV attenuation and microbial degradation, can now be analysed further, along with isotopic characterisation of different carbon fractions.

The study indicates that peatland carbon exports vary greatly, not just in terms of quantity, but also in terms of quality, over an annual cycle. These changes will have profound implications for recipient aquatic ecosystems, and for the water industry.

Decoupling of in-situ CH_4 and N_2O concentrations and surface fluxes in managed and restored calcaric fens.

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To what extent are CH_4 fluxes in fens driven by gas concentration gradients in soil or by vegetation activity? We will present results of greenhouse gas measurements from a study in a fen complex at Donauried, South Germany. Surface fluxes (closed chamber method) and gas concentrations (soil air probes in 5, 10, 20, 40 and 60 cm) of CH_4 in the soil profile were measured under two adjacent land uses: 1) long-term drained cultivated fen, and 2) wet fen with a mosaic of reeds and sedges restored by flooding for 22 years for nature protection purposes. Soil CH_4 concentrations and water level were good predictors whether the ecosystems acted as a sink or source of CH_4. Concentrations up to 4.5% CH_4 and CH_4 emissions of up to almost 80 g CH_4-C m^{-2} yr^{-1} were measured in the flooded site (mean water table 0±6 cm below surface) in contrast to the drained site. Solely in the flooded fen CH_4 surface fluxes and gas concentrations were highly correlated with temperature. The gas concentrations correlated well between all depth of the flooded site but less in the drained site (5 to 10 cm). The surface flux of the flooded fen was regulated by CH_4 concentrations in particular depth of 5 cm, 20 cm and 40 cm, except for summer time. In this period with the highest CH_4 emissions the temporal dynamics of CH_4 soil concentrations and surface fluxes were decoupled like most of the time in the drained fen. The findings suggest a dominance of plant mediated CH_4 emissions in the flooded site rather than diffusion and ebullition. N_2O emissions occurred episodically in drained sites only and were not correlated with management activities and were below 170 mg N_2O-N m^{-2} yr^{-1}. Belowground data will be processed until the conference.

What drives water table fluctuations in peatlands?

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The position of the water table below the surface (relative water level, RWL) is an important control on peatland carbon fluxes because it substantially influences the moisture and redox state of the soil. As the absolute surface level (ASL) of a peatland oscillates, RWL differs from the absolute water level (AWL - water table above an absolute elevation datum eg. sea level).
We measured ASL and AWL monthly at 23 sites over one year in a restiad peatland in New Zealand by using stable benchmarks.
AWL fluctuations were uniform over all sites and averaged 40 cm (sd ±2.8 cm). ASL fluctuated up to 28 cm (mean 15 cm) and reduced RWL fluctuations by 30-50% for 19 of 23 sites. This reduction of RWL fluctuations is high compared to literature values. Three sites at the peatland margin with shallow and dense peat showed little ASL changes. One site showed floating like behaviour resulting in little RWL fluctuation.
A continuous record of AWL and RWL at one site revealed hysteresis of ASL oscillation: the ASL followed the change in AWL with a delay. The delay reversed the positive ASL-AWL relationship because the surface continued rising for more than 24 hrs when AWL was already falling. This effect was more pronounced during the dry season than during the wet season.
We recommend to consider differences between RWL and AWL due to surface level oscillation in water level monitoring: RWL controls the transformation of carbon but AWL gradients determine the export of carbon via water.

The effects of vegetation and soil on methane emissions in a natural fen meadow in the Netherlands.

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Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 (30%, 150% and 17% respectively). The global increases in carbon dioxide concentration are primarily due to fossil fuel and land-use change, while those of methane and nitrous oxide are primarily due to agriculture (IPCC, 2007). Our research is part of the BSIK ME1 project that has its main focus on fen meadow ecosystems in the western part of the Netherlands. Since the 19th century these areas have been a strong net source of carbon dioxide as a result of increased peat oxidation caused by drainage. To understand the effect of natural changes and management on the green house gas emission and uptake in the areas an integral assessment of the greenhouse gases balance in these areas is required. Three experimental sites have been selected for this purpose: a restored nature reserve with relatively high ground water level and no agricultural activities (Horstermeer) a site under extensive agricultural exploitation where the ground water level will be raised in the coming years (Stein) and a site under intensive agricultural exploitation with low a ground water level (Oukoop).
Former research on CH_4 fluxes in the fen meadow areas pointed out that temperature and water level alone do not satisfactory explain the variations in emission of CH_4. In this subproject the effects of vegetation and soil parameters with CH_4 emissions are assessed in detail by performing a variety of field- and lab-experiments at the Horstermeer site. The research site could be divided in seven different vegetation zones by analysis of areal photographs and vegetation mapping in the field. The vegetation zones are named after the most abundant or

marking vegetation species occurring in the zone and consist of the *Glyceria maxima* Holmberg zone, the *Holcus lanatus* L. zone, the Juncus effusus zone, the *Phalaris arundinacea* L. zone, the *Phragmites australis* Steudel zone, the Typha latifolia zone and the *Urtica dioica* zone. All measurements and analyses were carried out at least monthly at all seven vegetation types over the growing season of 2006. Statistical analyses of all data pointed out that some parameters are stronger correlated to CH4 emission than others. Electrical conductivity, nitrate- and nitrite-concentration and C:N-ratio appeared to be the most important soil characteristics in this perspective, while root mass, biomass, C:N-ratio of the leaves and the amount of vascular plants are the most important vegetation parameters.

Carbon sink versus development dynamics of two Baltic raised bogs at the southern edge of geographical range.

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Raised bogs are believed to be relatively efficient ecosystems in the process of carbon accumulation. The amount of sequestrated carbon in such mires depends among others on the plant composition of peatforming vegetation and the water balance of a bog, shaped first of all by climatological conditions. This last factor is the most important, limiting the distribution of raised bogs, their dimension and height, moreover influencing to some degree the species composition of plant communities. The southern border of raised bogs distribution in Europe runs across the northern Poland where medium size, domed Baltic type bogs are concentrated in a narrow coastal zone.

The relative differences in carbon sequestration during the growth of cupolas of two raised bogs - Sowiskie raised bog and Janiewickie raised bog- were estimated. Investigated bogs are located nearby the Baltic Sea shore, each close to the other. They are around 150 ha and their cupolas are elevated about 1,5 m. The main peatforming vegetation during formation of cupolas was a treeless community with a predominance of *Sphagnum fuscum*. Today both bogs still have partly opened plateaus with remnants of bog vegetation, their slopes are covered by pine bog forest. They differ in topographical situation (Sowiskie bog is located in shallow depression in ground moraine, Janiewickie - in a river valley), time of beginning of peat accumulation (5030 ± 70 years BP and 7010 ± years BP) and duration of drainage (ca 100 years and ca 200 years respectively).

The estimation of carbon sink was carried through indirect way, using C/N ratio and N total concentration, supported by macrofossil analysis, few radiocarbon data and additional geochemical data. Samples were taken from consecutive layers of 5 cm thickness. Total length each of profiles is ca 3 m and includes the whole raised bog peat layer and at least a part of underlaying deposits.

It was found that: 1. C/N and N curves of compared bogs are very similar on the depth scale. It concerns especially sections including transition and raised bog peat, excluding the uppermost layers. 2. The crucial changes in shape of C/N and N curves are almost in the same depth and are correlated with almost the same sequence of peatforming vegetation. 3. Within *Sphagnum fuscum* peat sections three depressions in C/N are distinguishable, all correlated with an admixture of Eriophorum vaginatum and Calluna vulgaris macrofossils as well with changes in Fe/Mn ratio. 4. Ca/Mg ratio in both profiles generally indicates changes toward increase of ombrotrophy, but Ca concentration on each of bogs differs significantly. 5. On the time scale all mentioned features started around 3000 years BP, but the beginning of raised bog peat accumulation started simultaneously on both bogs at 1850 ± 70 years BP. 6. The most intensive accumulation of organic matter, expressed by C/N ratio higher than 50, was between around 1600 and 700 (500) years BP in case of Sowiskie raised bog and between 1700 and 500 years BP in Janiewickie bog (data calculated by extrapolation). It includes the period of *Sphagnum fuscum* community establisment, during of which distinct decrease in accumulation of peat in both

bogs was around 1400 years BP. 7. The highest rate of peat accumulation was about 1 mm/year. 8. Since around 700 years BP the *Sphagnum fuscum* community was gradually replaced by vegetation with big share of *Eriophorum vaginatum*, producing more decomposed peat.

Research at the Mer Bleue peatland, eastern Canada.

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We present the results of recent research activities at the temperate Mer Bleue bog located 10 km east of Ottawa, which is part of Fluxnet Canada. These include: methane fluxes from the bog, carbon dioxide and methane evasion from surrounding beaver ponds and streams, eddy covariance measurements of carbon dioxide exchange at different sites within the bog and controls on ecosystem carbon exchange.

Ecosystem respiration in a bioenergy crop on a boreal cutover peatland during contrasting growing seasons.

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More than 50% of the natural wetlands in Finland are drained for forestry, agriculture and peat extraction. Due to drainage, organic soils have been found to be persistent sources of CO_2. With a view to mitigate the high CO_2 emissions and to increase the proportion of bionergy in the total energy consumption, cultivation of bioenergy crops such as reed canary grass (RCG) ((Phalaris arundinacea L.) on agricultural organic soils and cutover peatlands abandoned after peat extraction is gaining importance. With this background, we have started since 2004 measurements of CO_2 exchange from RCG cultivation on a cutover peatland in eastern Finland. As a part of this larger study, we have monitored RCG ecosystem respiration during three growing seasons (2004-2006).

The 2004 summer was wet, while those of 2005 and 2006 were drier. The total amount of rain received during May through September in 2004 was 554 mm, while the total amounts during a similar period in 2005 and 2006 were less than 50% of the 2004 total. The CO_2 release from the ecosystem was measured using closed static chambers combined with a portable infrared gas analyzer. Supporting measurements included air and soil temperatures, soil moisture, precipitation and radiation balance. We present in this paper results on seasonal variation in RCG ecosystem respiration during three contrasting summers and examine the important environmental factors governing the total respiration in this ecosystem.

Carbon emissions from degraded tropical peat – does hydrological restoration cut down gaseous C-losses?

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Tropical peat swamp forest forms one of the most efficient carbon-sequestering ecosystems and important carbon stores. Some peatlands, even in a natural condition, are in a steady-state and no longer accumulating peat. Others, especially drained peatlands, are undergoing degradation and form a marked C-source. One most important abiotic factors influencing on peatland C-balance is hydrology. Rainfall in excess of evaporation forms predominant peat hydrology-regulating parameter because evaporation and (groundwater) outflow are fairly constant in tropical peat. Peat drainage decreases water holding capacity, and thus speeds up creation of oxic condition and surface peat stored carbon oxidation.

Temporal and cumulative CO_2 and CH_4 fluxes were studied in selectively logged and clear felled tropical peatland sites affected by drainage. The work included, in fact one of the very first, practical hydrological restoration efforts in tropical peat. Large drainage canals, excavated in mid 1990's, were blocked by dams in 2005in an area outlining ~13 km^2. Construction of dams was done in order to see; i.) how water flow retarding attempt influences peat hydrology, and ii.) what is the potential effect on peat CO_2 and CH_4 emissions. Gas flux regression models were tested by applying *in situ* collected water level (WL) data in periods before and after the establishment of dams, and by applying hypothetical peat WL data.

Higher annual minimum water levels prevailed on both sites, open site WL prevailed considerably longer near the peat surface, and forest WL was a longer period in the topmost 30 cm peat profile after dam establishment. Carbon dioxide flux rates and cumulative emissions were clearly higher in comparison to CH_4, and were clearly higher in the forest floor in comparison to open site. Soil in both sites could reverse from CH_4-sink to -source depending on the WL in peat. Actual and conceivable raise of WL was noted to have a minor effect on cumulative CO_2 emissions in the forest floor but cause decreasing trend in emissions of the clear felled site.

Micrometeorological observations of CH_4 and N_2O at a managed fen meadow in the Netherlands.

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Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 (30%, 150% and 17% respectively). The global increases in carbon dioxide concentration are primarily due to fossil fuel and land-use change, while those of methane and nitrous oxide are primarily due to agriculture (IPCC, 2007). Our research is part of the BSIK ME1 project that has its main focus on fen meadow ecosystems in the western part of the Netherlands. Since the 19th century these areas have been a strong net source of carbon dioxide as a result of increased peat oxidation caused by drainage. To understand the effect of natural changes and management on the green house gas emission and uptake in the areas an integral

assessment of the greenhouse gases balance in these areas is required. Three experimental sites have been selected for this purpose: a restored nature reserve with relatively high ground water level and no agricultural activities (Horstermeer) a site under extensive agricultural exploitation where the ground water level will be raised in the coming years (Stein) and a site under intensive agricultural exploitation with low a ground water level (Oukoop).
However, there are significant uncertainties in the estimated CH_4 and N_2O fluxes, mainly due to a combination of complexity of the source (i.e. spatial and temporal variation) and instrument limitations. High-frequency micrometeorological methods are an option to obtain integrated emission estimates on a hectare scale that also has continuous coverage in time. In this study, a quantum cascade laser spectrometer (Aerodyne Research Inc.) is used for eddy covariance measurements of CH_4 and N_2O. The system has been running continuously in Oukoop since August 2006. An automatic liquid nitrogen filling system is employed for unattended operation of the system. A sampling frequency of 10 Hz is obtained using a 1.0 GHz PC system. A precision of 2.6 and 0.3 ppb $Hz^{-1/2}$ is obtained for CH_4 and N_2O, respectively. However, it proved to be important to calibrate the equipment frequently using a low and a high standard. Drift in the system is removed using a 120 s running mean filter. Average fluxes and standard deviations in these averages of 461 ± 485 ngC $m^{-2}s^{-1}$ (2.21 ± 2.33 mg $m^{-2}hr^{-1}$) and 38 ± 64 ngN $m^{-2}s^{-1}$ (0.22 ± 0.36 mg $m^{-2}hr^{-1}$) were observed over the period August 17th to November 6th 2006. About 40% of this total N_2O emission was due to a fertilizing event. Besides these observed emissions, uptake of CH_4 and N_2O occurred in short events lasting at most a few hours.

CO_2 and CH_4 flux dynamics in an Irish lowland blanket bog.

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Pristine peatlands affect the atmospheric concentration of greenhouse gases by acting as a small sink for carbon dioxide (CO_2) and a source of methane (CH_4). Large spatial variation has been observed in the flux rates within and between peatlands, which is linked to water level and vegetation characteristics. Strong temporal variation has also been observed, with the annual C balance oscillating from positive to negative according to weather conditions. While a number of C exchange studies have been carried out in boreal and continental peatlands, maritime blanket bogs have received less attention. In this study, CO_2 and CH_4 exchange were studied in an Irish lowland blanket bog from July 2003 to September 2005. The study area was characterized by temperate maritime climate (precipitation > 2000 mm yr^{-1}, average temperature in July 14.6 ºC and in February 6.1ºC) and a patterned surface structure. Chamber methods were used to measure fluxes and non-linear regression models combined with environmental data were used to integrate the fluxes over the study period. Fluxes were measured in four different vegetation communities along a water level gradient, namely hummocks, high lawns, low lawns and hollows. Gas exchange followed the water level gradient, with gross photosynthesis, ecosystem respiration and net ecosystem exchange (NEE) being highest in hummocks and lowest in hollows. Contrastingly, CH_4 fluxes were highest in hollows and lowest in hummock. The spatial variation in fluxes was primarily controlled by the water level. The seasonal dynamics in the gas fluxes followed the changes in temperature and vegetation cover. Flux rates were lowest, but still noteworthy, during winter and highest during the second half of the summer. The bog acted as a moderate C sink for the duration of the study. Annual NEE was 65 g CO_2 -C m^{-2} y^{r-1} and CH_4 efflux 4.7 g CH_4-C m^{-2} yr^{-1}.

Dynamics of groundwater levels in acrotelm layer of the bog landscape.

Lode E.

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Functional importance of the peat bog acrotelm layer is related to decomposition of the biomass material, sequestration of the carbon (C) in the peat and releasing of the trace gaseous (CO_2 and CH_4) to the atmosphere. In some few year schedule the dynamics of eco-hydrological processes of the acrotelm layer is the main force for development of microtopographic variations on the bog surface whereas the long-term integration of those to the surrounding conditions, resulted in hydro-topographical specifics of the bog landscape incl. eco-hydrological specifics on the microtopes. Presentation topics will be related to the analysis results of the 50 year hydrometeorological data range monitored at the Männikjärve and Linnussaare bogs (centre of Estonia). It was found that in the bog acrotelm layer there is a three important groundwater level (GWL) depth layers which might have an important role in described above processes: a) the GWL "standing" layer with the quartile sequence range between 100% & 75% i.e. with prevailing aerobic conditions; b) - between 75% & 25% i.e. with proxy equalled anaerobic and aerobic conditions, and c) between 25% & 0% i.e. with prevailing anaerobic conditions. Also it was obtained that statistically significant warming trend of the hydrological year (HY) winter and spring seasons, and HY precipitatiotion increment for the winter and decrement for the spring seasons reflected on almost no GWL changing trends for the hummock microforms of the ridge-hollow microtopes but an arising GWL trends of +11cm ... +13cm for the ridge-pool microtope. The quartile range of 25%-75% for the long-term GWL-s of those microtopes were about 30-20 cm below the bog surface while the daily GWL extremes were from 7cm down to 68cm below the surface. The bog pine forest microtope and drained lagg area favoured the lower and deeper ranges for all three layers.

A drained peatland forest sequesters carbon in southern Finland.

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During the last two decades there has been debate whether the drainage of peatlands for foresty turns them into C sources into the atmosphere, whether they remain sinks or become even stronger sinks. Until now, however, few direct NEE measurements over whole peatland forest ecosystems have been reported, and none from forestry-drained peatlands. We measured net C exchange by eddy covariance method simultaneously with soil C gas fluxes by chambers on a drained peatland forest in southern Finland in 2004 - 2005. The flow of organic carbon (above ground litter) onto the soil and C sequestration in the tree stand were also measured and their contributions to the total C balance were estimated. The Scots pine dominated forest ecosystem was a strong sink of C, sequestering ca. 1000 g CO_2 m^{-2} a^{-1}. Simultaneously, tree stand biomass increased by ca. 600 g CO_2 m^{-2} a^{-1}, leaving ca. 400 g CO_2 to be sequestered in ground vegetation and peat soil. Ground vegetation biomass is usually quite stable if no changes in environment (light, space) take place. In the absence of recent disturbances, the most probable C sink is the soil through above and below ground litterfall, which exceeds the measured gaseous C loss from decomposing litter. Comparison to a similar pine stand on a drained peatland, but with agricultural history, reveals big differences between C fluxes in the seemingly similar stands. The relatively high water table, poor nutrient status and vigorous moss layer at the forestry-drained site may explain the high C sink at the site, compared to the C source of the former agricultural site, where the moss layer is less vivid

and decomposition processes are much faster. The study confirms the earlier findings that C sequestration in nutrient-poor peatlands may continue after drainage for forestry, as well as the nutrient-rich sites may turn into C sources.

Getting to the root of the matter: relating root biomass to hydrology in an ombrotrophic bog.

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Root biomass pools and production were studied in an ombrotrophic bog, near Ottawa, ON, Canada in summer 2006. 62 cores were harvested between May and September from hummocks and hollows in an undrained site and from hummocks at a drained site. Roots were removed in 10 cm depth increments to a depth of 40 cm and separated by species. Root production was estimated for undrained hummocks using ingrowth cores. Root biomass was highest in drained hummocks followed by undrained hummocks and lawns, with values of 2.3, 2.1, and 1.3 kg/m^2, respectively. Drained sites had significantly higher root biomass from 0 to 30 cm depth than undrained sites. Above: belowground biomass ratios decreased in the order undrained hummocks (.48), drained hummocks (0.31), and undrained hollows (0.27). Above- and belowground biomass was strongly correlated to watertable.

Spatial patterns of fluvial carbon flux and quality in upland peat dominated systems.

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Research into fluvial losses of carbon has overwhelmingly focussed on dissolved organic carbon (DOC). Particulate organic carbon (POC) has the potential to be the dominant component of fluvial carbon flux in unstable peatlands (Evans et al., 2006) and limited evidence suggests that significant in-stream POC - DOC transitions may be an important source of POC (Pawson et al., 2006).

This paper presents data from current research investigating the relative roles of DOC and POC flux from a range of catchments in the Peak District, UK. Annual data for DOC and POC fluxes have been obtained from routine and storm sampling. This allows the comparison of the overall fluxes of both DOC and POC from catchments with varied characteristics and at various points along a 7 km reach. POC and DOC quality have been assessed via optical absorbance scans (DOC) and particle size analysis using a video image analyser (POC).

Preliminary results from this study suggest that there is a measurable change in nature of both POC and DOC with distance downstream from a small headland catchment, noted as a shift in particle size and optical properties of dissolved acids. These data support the hypothesis of in-stream POC - DOC transformation. The importance of understanding these interactions between solid and dissolved carbon phases extends beyond carbon budget work to ecological studies and economic water extraction.

Carbon fluxes between mid and high boreal peatlands using static chamber, James Bay, Quebec, Canada.

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This project is part of a multidisciplinary research that has for aim to evaluate carbon exchanges (CO_2 and $CH_{4)}$ in boreal peatland ecosystems of Quebec (Canada) and to understand the local and regional fluxes variability in order to estimate near-future natural (climate change) and anthropogenic (flooding) impacts on their dynamics. Carbon fluxes have been measured since 2003 in 9 distinct peatlands from mid to high boreal latitudes using static chamber method. In 2003 and 2004, measurements were made in 3 peatlands of the La Grande river watershed (55°N) while in 2005 and 2006, measurements were realized on 6 peatlands in the Eastmain river region (52°N). Peatlands were chosen to be representative of their respective region and sampling was made on preinstalled collars. In 2003, in the La Grande region in 2003, 20 sampling collars were installed in each peatland for surface measurements while 2004, 15 sites were chosen for pool flux measurements. During 2005 and 2006 summers in the EM region, 8 collars were installed on surface and 2 pool sites in each peatland for flux measurements. Sampling sites were chosen to cover all the vegetation type present. Preliminary results show that mean CH4 fluxes from the LG peatlands vegetated surface in 2003 are lower than the EM peatlands mean fluxes for 2005 with value range of 39 ±4.9 to 72 ±16 mg CH_4 m^{-2} d^{-1} for LG and 66 ±10 to 124 ±14 mg CH_4 m^{-2} d^{-1}. Results will be used to model C dynamics from low to high boreal on the James Bay east coast.

Using tracers to understand the role of the catotelm in DOC export.

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Concentrations of dissolved organic carbon (DOC) in rivers draining peatlands have increased dramatically - doubling over the past 30 years. These areas are important catchments in the UK, and the issue has significant consequences for water quality, aquatic nutrition, maintenance of peatland ecosystems, and the overall carbon cycle. One emerging hypothesis suggests severe drought as a cause. But there are several problems with this explanation, in particular: i) there should be a change in the composition of DOC following a severe drought as new production mechanisms operate; but no such compositional change has yet been observed (though only two measures have been examined) ii) the source of the additional DOC would be at or near the acrotelm-catotelm boundary; but most current evidence suggests that DOC in runoff is sourced high in the peat profile and above the catotelm.

A much better understanding of the problem would be possible, particularly in relation to the drought hypothesis, if we knew to what extent deep peat layers may in fact contribute to the chemistry of runoff, and whether DOC can be transferred from below the water table. This study therefore used arrange of tracers on both the DOC and the water, to examine this. Natural and applied tracer abundance has been studied in both laboratory columns and field studies.

Temporal variability in CO_2 and CH_4 dynamics in a boreal fen -ecosystem components show contrasting patterns.

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Our study site was an oligotrophic sedge-dominated fen in Central Finland. CO_2 and CH_4 fluxes were measured weekly or biweekly during four growing seasons with static chamber technique in plots with unmanipulated vegetation and in plots with different vegetation removal treatments.
Although the ecosystem was a net CO_2 sink and CH_4 source to the atmosphere every year, the magnitude of the fluxes varied more than three-fold between the years. Cumulative (growing season) CH_4 emissions had a strong positive correlation with the cumulative net ecosystem exchange (NEE). NEE, nevertheless, could not be explained solely by one single factor, such as the mean water level, temperature or leaf area. Both the variability in gross photosynthesis (PG) and respiration (R) contributed to the variability in NEE. Furthermore, PG, R and NEE of the individual ecosystem components showed contrasting interannual patterns, adding to the complexity of the carbon balance of the ecosystem.
In addition to interannual variation, the ecosystem carbon gas dynamics had a clear within-season pattern related to the pattern in leaf area and temperature. Similar to the interannual variation, the seasonal pattern differed between the ecosystem components. The activity of sedges was connected to their leaf area development while the activity of the *Sphagnum* mosses was strongly controlled by moisture conditions. Dwarf shrubs were rather insensitive to environmental variation.

A prediction of drained upland peats gaseous carbon response to climate change.

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There are a number of approaches to the prediction of CO_2 flux from peats for either CO_2 respiration or CO_2 uptake due to primary productivity, however, these approaches are often drawn up over a limited range of conditions and compared to a small range of assumed driving variables. From a drained upland peat in Northern England a year's time course of closed chamber flux readings of CO_2 were measured along with a series of environmental variables including; water table depth, soil temperature and PAR. In addition, a series of deep peat cores was then extracted from the same site and moved to a lower altitude with a lower rainfall and higher temperatures. These peat cores were sealed at the base and a siphon tube fitted so that the depth to the water table could be fixed and controlled. Thus these columns allowed CO_2 release and uptake from peat to be measured over a greater range of driving variables than would be possible on an upland peat bog. This study compares the comparability of peat core fluxes with peat surface flux measurements, and the affects of increased temperature and decreased water table depth on carbon fluxes, and the implications for the future of UK upland peat.

CH_4, DOC and BOD describe the C cycle in peat of a flooded buffer wetland.

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About 5 million ha of peatlands have been ditched for forestry in Finland. These forests are approaching maturity and harvesting. Regeneration assumes soil amelioration and ditch cleaning, which would release nutrients, solids and dissolved organic matter (DOM) from the catchment. Watercourses below the forest management areas are protected with buffer zones. The raising water level and increasing nutrient load in the flooded buffers may affect both primary producers and decomposers of organic matter. We followed the changes in carbon cycle in peatland buffer ecosystem by means of methane (CH_4) fluxes, content of DOC and it's character in soil water, depth of water table, and related these changes with those in the composition of ground vegetation.
In a spruce swamp buffer area, the CH_4 fluxes are nearly similar to those in undrained spruce swamp peatlands. The gas formation is related to oxic/anoxic conditions in organic soils. DOC concentrations are higher in the wet parts of the buffer than in the dry reference. At a drained reference area the peat layer was thinner and water table often close to the boundary of mineral soil and peat. The highest CH_4 fluxes and DOC concentrations were measured in spring and summer time. A higher water level favors methanogenesis over methanotrophy increasing the CH_4 fluxes. The molecular size of DOC does not differ in different parts of the peatland buffer. Organic material has more aromatic characteristics within the buffer area than in the reference. Different characteristics may indicate variations in capacity of DOC to sorb dissolved molecules. The changes in water table are reflected in the changes of ground vegetation communities. Some grasses and herbs indicating mesotrophy have increased, trees died, and the abundance of dwarf shrubs and forest mosses has decreased. These changes may indicate changes in decomposition and retention of nutrients.

CO_2 Dynamics at a Boreal Oligotrophic Fen During Spring and Autumn.

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A five-year dataset of CO_2 exchange measurements, acquired by the Eddy Covariance technique, was used to evaluate spring and autumn CO_2 dynamics at a boreal oligotrophic fen in northern Sweden (64°11N, 19°33E), focusing on the transitions from positive to negative CO_2 fluxes (daily sums) in spring and the reverse transition in autumn. The 30-year (1961-1990) mean annual precipitation is 523 mm at the study site and the mean annual, July and January temperatures are +1.2°C, +14.7°C and -12.4°C, respectively. The length of the growing season is approximately five months. The snow cover normally reaches a depth of 0.6 m and lasts for six months on average. The dates of snowmelt or soil thaw (when the soil becomes water permeable) together with the beginning of soil heating in spring were highly correlated to the spring transition ($r^2 = 0.99$, $p<0.01$) in both models. This also reflects the close correlation between snowmelt and soil thaw ($r^2 = 0.99$). Data also suggests that the mechanism controlling the spring transition from source to sink was the degree of water saturation in the moss surface. A high water level during spring delayed the fen's transition to a CO_2 sink ($r^2 = 0.99$, $p<0.01$) and an aerated zone of 3 cm or more seemed to be required for the transition to a sink to occur. Data suggests that the spring transition is controlled by the transport rate of CO_2 to the mosses, which is severely hampered by a high water content. No correlation with air or soil temperatures where found. In contrast, the autumn transition was most strongly correlated to the mean soil temperature at 18 cm depth during the 30 days preceding it ($r^2 = 0.99$, $p<0.01$).

Peatland restoration -induced changes in the DOC of recipient waters.

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About 12 % of the original mire area in Finland is protected by law. However, about 40 000 ha of peatlands in the present Finnish nature conservation network had been drained by landowners be-fore inclusion to nature reserves. The greater part of the ditchings took place in the 60ies and in the 70ies, mainly for forestry purposes. The current practice is that inside nature reserves these areas are restored, to recreate a functional mire ecosystem and a hydrological entity. Restoration, in the short term, is, however, a severe disturbance to the ecosystem occupying the drained site. Hydrological monitoring in sites to be restored was initiated in 1997 in the Seitseminen National Park. The aims of the monitoring included quantification of the water quality impacts of restoration in the downstream watercourses. The short term impacts proved to be problematic in some respects, and at the moment we have long term water quality monitoring results from more than 10 catchments in Finland. One of the potential problems is the increase in the leaching of organic carbon as a consequence of rewetting. The mires of Seitseminen are ombrotrophic or nearly so, and fed by small catchments. About half of the land area is covered by peat, and the watercourses are naturally very rich in DOC. Restoration caused a relatively small increase in the originally high concentrations. In minerotrophic mires the changes in peatland ecosystem are much greater due to ditching than in bogs: tree stand develops much faster, vegetation changes are substantial, and the peat properties change much more thoroughly. In these kind of peatlands the impacts of restoration cause much greater increases in the leaching of organic carbon. One of the reasons is the fact that in minerotrophic mires there may be a large catchment surrounding the mire, and the export of organic matter is aided by these waters from the catchment, passing through the altered surface peat after filling in the ditches and causing a very effective rewetting. The vegetation developed in the drained state cannot stand the anoxia caused by the increase in the ground water level, and a lot of fresh organic matter is released from the dying plants and soil microbes. Temporal anoxia may develop in the runoff waters and recipient watercourses as well. The potential shock effects caused by these phenomena to the downstream aquatic or telmatic life should be carefully considered in restoration schemes. The results give also perspective to the factors controlling DOC leaching and to the general behaviour of peat ecosystems in the case of disturbances.

Are *Sphagnum*-dominated regenerating cutover bogs carbon sinks or not? A study in the Swiss Jura Mountains with predictions of climate change impacts on the C balance.

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Growing peatlands are an important long-term carbon (C) sink and thus play a key role in the global C cycle. Vast surfaces of northern peatlands have been mined for peat and are currently abandoned. In these surfaces,

secondary vegetation succession takes place, leading to *Sphagnum*-dominated communities. It is unclear if these regenerating cutover bogs accumulate C, and in particular if the successful re-establishment of *Sphagnum* mosses suffices to infer that the C sequestration function has been restored.

We studied the vegetation and C dynamics in a cutover bog in the Swiss Jura Mountains at three stages of regeneration and estimated the Net Ecosystem Exchange (NEE) under several climate change scenarios.

Sphagnum cover increased from the younger to the older stage. In the early stage the vegetation was heterogeneous and contained many fen species. In the intermediate stage diversity and heterogeneity decreased as several fen species disappeared. In the later stage, heterogeneity increased and bog species appeared.

According to our modelled NEE estimations the youngest regeneration stage was a net CO_2 source while the oldest site was accumulating CO_2 over the vegetation period.

Climate change simulations suggest that the younger stage was more sensitive to climatic change, emitting ten times more CO_2-carbon with an increase of 1.5°C air and peat temperatures. The intermediate site was less sensitive, but yet an increase of 1.5°C air and peat temperature converts it into a net source of atmospheric C. The older site was only slightly influenced by an increase of temperature and water table variations, suggesting a higher resilience of the C cycling towards environmental change.

Synthesis and applications: Our results show that the CO_2 balance of regenerating cutover bogs is more strongly influenced by the plant community response than by the abiotic conditions. After ca. 30 years of regeneration a *Sphagnum*-dominated vegetation is present but not the CO_2-sequestrating function. After ca. 40 years the system accumulates CO_2, but is converted to a CO_2 source in the climate change scenario. In our study site, over 50 years of regeneration were necessary to create a stable CO_2-sequestrating system, more resilient to the climate change scenarios.

CH_4 fluxes during the spring thaw period in a boreal peatland in North Karelia, Finland.

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High-latitude peatlands (87 % of total peatland area) are globally important sources of the atmospheric trace gas CH_4. CH_4 emissions from boreal peatlands are characterised by a strong small-scale spatial heterogeneity and a pronounced seasonal variability due to extreme climatic contrasts between seasons. Although winter is the predominant season in boreal climates, most CH_4 studies were conducted during the vegetation period whereas wintertime data are sparse. Here, we present the results of an intense field campaign during April and May 2006 in the boreal peatland Salmisuo, Finland (64.46°N, 30.58°E), focussing on the CH_4 fluxes during the very dynamic spring thaw period.

CH_4 fluxes were determined by closed-chamber and snow concentration gradient approaches. Additionally, profiles of snow density and temperature were measured. Snow structure and texture were described. Meteorological conditions were recorded by a climate station. During spring thaw period, CH_4 fluxes were highly dynamic due to rapidly changing snow and ice properties. Before start of snowmelt, fluxes from hummocks and lawns were between 0.19 and 0.46 mg CH_4 m^{-2} h^{-1}. During snowmelt, CH_4 diffusion decreased due to dense layers within the snow pack. Below these layers, concentrations increased up to 47 ppm CH_4. This stored gas amount is probably suddenly released during the final phase of snow thaw at the end of April. On ice-covered flarks, fluxes were practically zero. The massive ice layers melted only after snow ablation period coinciding with a peak in CH_4 release.

The presented study demonstrates that snow and ice dynamics have a strong impact on the winter CH_4 fluxes in boreal peatlands. Considering that climate change in high-latitudes is expected to be most extreme during

the cold seasons, the influence of the cryospheric processes on the carbon cycle is particularly important for the assessment of future carbon balance changes.

Greenhouse gas fluxes in managed fen meadows in the Netherlands.

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Global atmospheric concentrations of CO_2, CH_4 and N_2O have increased markedly as a result of human activities since 1750 (30%, 150% and 17% respectively). The global increases in carbon dioxide concentration are primarily due to fossil fuel and land-use change, while those of methane and nitrous oxide are primarily due to agriculture (IPCC, 2007). Our research is part of the BSIK ME1 project that has its main focus on fen meadow ecosystems in the western part of the Netherlands. Since the 19th century these areas have been a strong net source of carbon dioxide as a result of increased peat oxidation caused by drainage. To understand the effect of natural changes and management on the green house gas emission and uptake in the areas an integral assessment of the greenhouse gases balance in these areas is required. Three experimental sites have been selected for this purpose: a restored nature reserve with relatively high ground water level and no agricultural activities (Horstermeer) a site under extensive agricultural exploitation where the ground water level will be raised in the coming years (Stein) and a site under intensive agricultural exploitation with low a ground water level (Oukoop).

Our research focuses on the production, transport and spatial/temporal variability of GHG in managed fen meadow ecosystems. We like to determine the effect of management and ground water level manipulation on GHG production and to see what the possibilities are for emission reduction in fen meadow areas.

The sites 'Stein and Oukoop' have peaty soils with clay in the upper part. About 20% of the area is open water, and the remaining part is grassland. Incoming solar radiation ranged between a minimum of 300 W m^{-2} in December and January to a maximum of 850 W m^{-2} in June and July. Leaf nutrient concentrations of N and P were for most of the time around 2500 mmol N kg^{-1} dry weight and 150 mmol P kg^{-1} respectively. Grass height was found to correlate well with biomass and leaf area index.

Gas flux measurements are done at both sites with (1) and eddy correlation system for CO_2 since January 2005 and (2) the closed chamber method (using an Innova photo-acoustic gas monitor) for CO_2, CH_4 and N_2O since January 2006, about every month. Open water measurements are carried out using a floating chamber, since February 2006.

. The landscape is divided in 4 landform elements: ditches, ditch edges, low and high parts in the peat meadows and trenches. We found significant differences in CO2 and CH4 fluxes between open water and fields. For CO2 we found good correlations with parameters such as soil temperature and WFPS. We discuss the relations between soil parameters and emissions of CO2, CH4 and N2O and the uncertainties. We also discuss the importance of taking into account the spatial variability.

Net ecosystem CO_2 exchange (NEE) from reed canary grass cultivation on a cutover peatland in eastern Finland.

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Drainage of natural peatlands and subsequent land use change alter their biogeochemistry. Peatlands drained for peat extraction have been known to be persistent sources of CO_2. Attempts are being made in Finland and elsewhere to offset the atmospheric CO_2 load from organic soils through the cultivation of bioenergy crops such as reed canary grass (RCG) (*Phalaris arundinacea* L). However, to our knowledge, there is hardly any information available on the impact of the RCG cultivation on the ecosystem behaviour. With this in view, we are measuring net ecosystem CO_2 exchange from a cutover peatland in eastern Finland since April 2004 using micrometeorological eddy covariance technique. The eddy covariance system consists of an open path infrared CO_2/H_2O gas analyser and a three dimensional sonic anemometer. Supporting micrometeorological measurements include air temperature and humidity, radiation balance, soil temperatures and moisture, precipitation, snow depth, etc. We report in this paper our observations on seasonal and diurnal patterns of NEE from RCG cultivation on a cutover peatland, and examine the important variables governing the carbon exchange in this ecosystem. In addition, we discuss in brief our experience on using an open path IRGA for eddy covariance measurements under boreal winter conditions.

Long-term exposure to enhanced UV-B radiation increases the emissions of isoprene from a sub-arctic fen.

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Isoprene is the most abundant non-methane volatile organic compound (VOC) emitted to the atmosphere by vegetation. Due to its high reactivity, isoprene affects the composition of atmosphere by contributing to the formation of ozone and fine particles, and by changing the oxidative capacity of the atmosphere. *Sphagnum* peatlands release considerable amounts of assimilated carbon back to the atmosphere as isoprene, but emissions from other peatlands are largely unknown. In general, isoprene emissions are affected by various stresses. We assessed isoprene emissions from a natural sub-arctic flark fen dominated by the moss *Warnstorfia exannulata* and the sedges *Eriophorum russeolum* and *Carex limosa* under a long-term enhancement of UV-B radiation corresponding to a 20 % loss in the ozone layer. During a warm period in the third growing season, isoprene emissions were approx. 1100 μg m^{-2} h^{-1}, and enhanced UV-B had no effects on the emissions. However, during the fourth growing season under the exposure, the emissions were significantly increased by enhanced UV-B radiation. The mean emission was 66 μg m^{-2} h^{-1} in the UV-B treatment, while it was 41 and 51 μg m^{-2} h^{-1} in the ambient control and the UV-A control, respectively. The isoprene emissions correlated with the density of the sedges E. russeolum and C. limosa. The dominant moss, *W. exannulata*, proved to emit isoprene at a rate of 155.9 ng g^{-1} d.w. h^{-1} in our laboratory trial. We conclude that sub-arctic fens are a significant source of isoprene to the atmosphere, especially under periods of warm weather. If the recovery of the ozone layer above the Arctic is delayed and the fluxes of UV-B radiation continue increasing, this has the potential to further increase the isoprene emissions.

Empirical relations between subsidence, CO_2 emissions and water management.

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During more 30 years the subsidence of Dutch peat soils is monitored in relation to ditch water and ground water levels. This monitoring, additional measurements and collected data from other monitoring are the basis for developed empirical relations between ditch water and ground water levels and subsidence of peat soils. The most important driver of subsidence of peat soils is oxidation. One mm subsidence by oxidation equals a CO_2 emission of about 2.3 tons of CO_2 per year per hectare. We calculated that about 3% of the annual anthropological CO_2 emission in the Netherlands can be accounted to the oxidation of peat soils. In the last 40 years more than 70 000 ha of peat soils degraded according soil classification to mineral soils. This is about 25% of the peat soil area in the Netherlands. Water management to create higher ground water levels in summer is an effective way to diminish oxidation and so degradation of peat soils. However, just raising ditch water levels proves to be not as effective as thought to raise groundwater levels. A promising option to raise ground water levels to preserve peat soils is the use of subsurface irrigation by submerged drains with a spacing from drain to drain of 4 to 6 meters. Results of experiments with subsurface irrigation with submerged drains versus the classical situation with high and low ditch water levels will be presented. In these experiments the soil temperature and the complete hydrological situation of fields with and without submerged drains is monitored during several years. Also peat soil properties such as decomposition rate, saturated and unsaturated soil water conductivity and shrinkage characteristics are determined. All these measurements are the basis for modelling and scenario studies on the effect of water management and climatic change, which will be presented by Hendriks et al in an other contribution at this conference.

Parched Peatlands and Changing Climate: Will Prolonged Drought Convert Fen C Sinks to Sources?

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Boreal regions of the northern hemisphere are expected to undergo some of the most dramatic changes in climate. Boreal peatlands store large quantities of C (455 Pg globally), a testament to their long-term functioning as a sink for atmospheric C. Peatlands of continental western Canada represent 10% of the global boreal peatland area and contain 17% of the boreal peatland C stock. Soil surfaces of boreal peatlands typically have close to 100% cover of mosses. These nonvascular plants, without true stomates and with narrow tolerances to precipitation and temperature, may respond with exceptional sensitivity to changing climate. Boreal, continental, western Canada has been experiencing prolonged drought conditions since 1996, and in 2003 we observed moss decline on southward facing hummocks in our fen sites. With continued drought conditions predicted, understanding the carbon balance of dying and dead fens is timely and important. Our goal was to quantify carbon fluxes from peat deposits in fen microenvironments where mosses have recently died. We established 10 replicate plots per site (two stressed fens with dead and dying mosses and two control sites). Flux measurements were made once or twice monthly throughout the field season in 2004, 2005 and 2006. While drought conditions were predicted to continue in 2005 and 2006, these years were wetter than the previous year. Monthly CO_2 fluxes from dying fens represented either a small net source or small net sink for C, while fluxes from control sites always represented net sinks for atmospheric C, consuming ~ 20 times more C than dying fen sites

(2.539 vs. 0.141 umol m^{-2} sec^{-1}, respectively). Differences between control and drought-stressed sites were driven mainly by changes in *Sphagnum* production (i.e, photosynthesis) rather than changes in respiration. Our observations of dead fens throughout north-central Alberta may indicate fens as harbingers of ecosystem responses to climate change.

Delineating and quantifying dissolved inorganic carbon loss from peatlands.

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For modelling accurately whether peatlands are sequestering or losing carbon, export of aquatic carbon losses (to catchment drainage) must also be included. Publication focus suggests the community has invested more effort in quantifying other components of peatland carbon balance, for example net ecosystem exchange, than in quantifying aquatic losses of carbon. Carbon can be lost from peatland soils to the drainage system as dissolved inorganic carbon (DIC), dissolved organic carbon (DOC) and particulate organic carbon (POC). Study of the dissolved inorganic carbon pool presents a challenge: how to separate the inorganic carbon contribution from groundwater or minerogenic soils from that from the peatland. We have overcome this by using stable carbon isotope measurements as a tracer of each end-member. Our study area is a small order river system draining a relatively pristine peatland in NE Scotland. In our preliminary characterisation of DIC systematics we sampled diurnally, using a nested catchment sampling matrix (1, 42 and 90 sq. km) over a 14 month period. From this we observed how the riverine DIC pool reflects differing hydrological and productivity conditions, and could therefore characterise the isotopic composition of the peatland and the groundwater component. Subsequent observation that concentration, [DIC], and isotopic composition can be described well by the continuously-logged parameters, discharge and pH respectively, allows reconstruction of [DIC] and isotopic profiles from this catchment since our study began in June 2003. Here we will show field carbon stable isotopic profiles to demonstrate how this can be used as a tracer. Additionally we will quantify peatland-derived DIC export for this catchment, consider how this is affected by increasing catchment scale and contextualise these estimates of carbon loss through comparison with other components more commonly studied in models of peatland carbon balance.

Current tends in DOC concentration and flux in UK rivers, lakes and reservoirs.

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The rise in DOC concentrations in the Northern Hemisphere in recent decades has been taken as indicative of increased turnover of terrestrial carbon and in particular in the vital reserve of peat. Hypotheses for this rise have been hotly debated in the literature. Studies have often been based on small spatially restricted datasets. This paper uses data from 315 river, lake and reservoir sites from across Great Britain to document trends in DOC concentration. Records came from the period 1961 - 2003 and were all of at least 10 years in length. In addition, for 208 river sites it was possible to calculate the flux of DOC. Against such a large dataset it possible to test a range of proposed explanations for the upward trend. There is a linear change in flux over the study period which is consistent with explanations based upon other linear drivers, i.e. atmospheric CO_2 and air temperature. There are gradual decreases in flux between these changes which are inconsistent with control by atmospheric deposition. The spatial distribution of trend in flux also discounts changes in land use, and atmospheric deposition. Trends in flux and concentration show significant declines in catchments draining the south west of Britain and no hypothesis is yet adequate to explain this.

Carbon dioxide exchange on three open wetlands in Finland.

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Carbon dioxide exchange between atmosphere and biosphere has been measured by eddy covariance technique on three open wetland ecosystems in Finland: Kaamanen subarctic fen, Lompolojänkkä northern boreal fen and Siikaneva southern boreal fen. The fen at Kaamanen (69° 08' 26.5" N, 27° 17' 42.1" E, 155 m a.s.l) has the longest data set with continuous measurements since 1997. The measurements at Lompolojänkkä (67° 59' 83" N, 24° 14' 51" E, 269 m a.s.l) started in 2005 and those at Siikaneva (61° 48' N, 24° 09' E, 160 m a.s.l) were started in 2004. According to the preliminary results the annual CO_2 balance at Lompolojänkkä was -80 gCO_2 $m^{-2}yr^{-1}$ which is practically the same as the 6-year (1997-2002) average of -79 gCO_2 $m^{-2}yr^{-1}$ obtained at Kaamanen. At Siikaneva the net uptake is somewhat higher with an annual CO_2 balance of -170 gCO_2 $m^{-2}yr^{-1}$. Even though all the sites are net sinks for CO_2 in annual scale they all act as a net source of greenhouse gases when the CH_4 emission is taken into account

High resolution imagery improves quantification of carbon fluxes in peatlands.

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Boreal peatlands play an important role in the global carbon cycle. Aim of our study is the calculation of a complete carbon balance of a boreal peatland (Salmisuo, Finland). Due to it's patchiness we use very high resolution aerial photographs to obtain spatial information about different microsites. On the mesoscale we distinguish between a minerotrophic and ombrotrophic part and on the microscale between flarks, lawns and hummocks. We conducted chamber measurements of CO_2 and CH_4 once a week and eddy covariance for CO_2 continuously in 2005. To model seasonal flux of CO_2 and CH_4 we use e.g. peat temperature, moisture and PAR as parameters. DOC discharge was based on piezometers and outflow measurements. We then used near aerial photography as the basis for extrapolation of the chamber measurements. Platform to obtain photographs was a helium filled zeppelin equipped with a digital camera. Photographs taken in 2005 have been georectified, merged and classified. Result of the classification is an estimation of the spatial distribution for each microsite type. Based on calculated average seasonal carbon fluxes and the area information of each microsite type we are able to present a complete carbon balance of a boreal peatland. As an independent test we used eddy covariance data to verify our extrapolation results.

The implications of fine-scale heterogeneity in peatlands for models of land-atmosphere carbon exchange.

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Peatland landscapes are characterised by fine-scale heterogeneity in vegetation and surface topography (and hence water-table depth) at length scales of 1-10 m (microform scale). Chamber measurements, carried out at the smaller end of this scale range (1 m) across a wide range of peatland types in diverse regions, show that atmospheric gas exchanges of CO_2 and CH_4 also vary greatly in response to the fine-scale heterogeneity in these driving variables. At a much coarser scale, an individual grid cell in land-atmosphere models typically ranges from 1-50 km (mesoscale models) to 100-500 km (global models). In this paper, we argue that fine-scale heterogeneity of driving variables must be accounted for when applying coarse-scale land-atmosphere models to peatlands. Specifically, we consider how the spatial variability of fluxes across different classes of peatland microform are integrated and averaged over larger spatial scales.
Large biases can result if carbon exchanges at a coarse scale are calculated using the spatially-averaged value of a forcing variable. The magnitude of the error increases with (i) the degree of non-linearity of the equation used and (ii) spatial variance in the driving variable. In theory, the error can be corrected with a linearization technique that quantifies the interaction between non-linearity and variance. We explore the interaction between these two effects using linearization solutions to published equations of carbon exchange and empirical estimates of spatial variance in water-table depth. In some cases, the linearization technique fails to correct bias error. Hence, carbon exchanges on peatlands should be aggregated using a distributed approach, in which a value is computed individually for different classes of microform and the area-weighted exchanges for these classes are summed over the total area. We discuss how this approach might be linked to a spatially-distributed model of peatland dynamics.

Post-Fire Compositional and Functional Recovery of Canadian Bogs.

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Fire impacts 1850 km^2 of western Canadian peatland annually, altering the structure of the ground layer and indirectly affecting carbon storage. Peat accumulation is the net result of disproportionate rates of production and decomposition, both of which are species-specific. As the plant community changes during post-fire succession, peat accumulation also changes through autogenic control. To determine the post-fire peatland vegetation recovery and carbon storage trajectory, assessments of current ground layer plant composition and carbon storage were made along a chronosequence of 13 historically burned bogs, ranging from 1-105 years since fire. At five plots within each site, vegetation surveys were conducted to evaluate the present plant community composition. Peat accumulation was assessed by measuring ground layer production using cranked wires and by monitoring decomposition in the upper peat column with stratigraphic in situ decomposition bags. Bogs are triphasic post-fire, shifting dominance from true mosses to *Sphagnum* mosses, followed by feathermoss encroachment with time since fire. Bogs show greater compositional differences among early successional sites (1-11 ysf) than among more mature bogs (>21 ysf), indicating rapid changes in the composition of the ground layer with greater compositional stability over time. A similar relationship for surface carbon storage was also observed, showing a logarithmic recovery trajectory. A simple model based on the projected recovery trajectory

indicates that while bogs may recommence peat accumulation relatively quickly post-fire, a substantially greater period may be required to compensate for cumulative post-fire carbon losses, affecting their carbon sink capacity. Increases in fire severity, frequency, and extent with global warming could extend bog functional recovery times, further compromising peatland carbon storage.

Long term effects of fen restoration on Net Ecosystem Exchange: Determining the driving factors of CO_2 fluxes.

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Trace gas exchange reflects the functioning of peatland ecosystems and can therefore be used to asses the restoration success. Our goal was to determine the long term effects of fen restoration on CO_2 fluxes and to identify the driving parameters causing differential fluxes along a disturbance gradient.
A climate controlled chamber system was used for measuring instantaneous NEE over the entire year in the Donauried (1 grassland site, 1 carrot field, and 1 unmanaged and 2 managed restored sites) in 2005 and in the Loisach-Kochelsee fens in 2006, both in southern Germany. Instantaneous and seasonal parameter (PAR, soil and air temperatures, biomass, water level, LAI and management activities) dynamics were monitored at each site. Modeling seasonal best fits provided a realistic adjustment for seasonal variability. First year results show that management strongly influenced both ecosystem respiration and GPP and thus NEE, where Reco remained a strong determinant of NEE balances.
Although management reduced Reco in the grassland (2070.83 g $C0_2$-C m^{-2} a^{-1}) after each cut (by 42% and 20%), relatively high Reco values may be explained by the constant fresh plant cover which also provides ideal heterotrophic respiration conditions. In the carrot field, GPP was relatively low (-640.67 g $C0_2$-C m^{-2} a^{-1}) due to seasonal crop coverage and could not compensate for the Reco during the growing season. Whereas water table does not play a determining role when comparing degraded sites, it may help explain slight differences in Reco among the three restored sites. The two managed sites showed lower Reco levels (1031.28 and 1161.6 g $C0_2$-C m^{-2} a^{-1}) than the unmanaged site (1441.62 g $C0_2$-C m^{-2}). Lower water levels in the unmanaged site allow for different vegetation with a higher GPP and enable higher respiration rates. Overall, the restored sites proved to be efficient sinks for CO_2-C with NEE ranging from -98.43 to -133.32 $C0_2$-C m^{-2} a^{-1} whereas the carrot and grassland sites were significant sources with NEE balances of 483.41 and 510.14 $C0_2$-C m^{-2} a^{-1}.

Methane fluxes by Western Siberian wetlands are overestimated substantially.

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Western Siberian plain (57-67 ^{o}N) comprises the largest wetland complexes of the Northern hemisphere (10^6 km^2) and because wetlands produce the greenhouse gas methane this area is supposed to form a substantial positive feedback to climate warming. The plain include pristine peatlands (mires) and paludified forests spread over 3 Taiga biomes and the Forest Tundra. Contrary to the general conception (discontinuous) permafrost is present in less than 15% of the plain. Therefore Carbon cycling of the mire ecosystems cannot be compared with data of arctic, permafrost dominated ecosystems.

By recent closed chamber measurements methane fluxes have been established by mire type of sites spread over Western Siberian plain, subsequently extrapolated using satellite images. In this paper we present recent data of the Middle taiga (MT), Northern Taiga (NT) and Forest Tundra (FT) zones. Methane fluxes vary from negative by methane uptake at raised bog sites with dwarf shrubs-*Sphagnum*-pine vegetation to emissions of 1.6 mg CH_4 $m^{-2}h^{-1}$ at sedge-*Sphagnum* FT hollow sites. Large lakes (< 5% of the area) produce 0.05-5 mg CH4$m^{-2}h^{-1}$, though one shallow lakes produced up to 26 mg$CH_4$$m^{-2}h^{-1}$. In general the methane emission measured in Taiga and Forest Tundra are substantial lower then have been measured in Tundra Sites (e.g. Heyer et al 2002: 8 mg CH_4 $m^{-2}h^{-1}$, Van Huissteden et al 2005: 4.3 mg CH_4 $m^{-2}h^{-1}$).
In the Taiga sites low methane fluxes are explained by high primary productivity of *Sphagnum* In the Forest Tundra fluxes from relatively dry palså mires (35%) are low. Highest fluxes have been measured in partly drained thermokarst lakes (3-13%). Because mire vegetation resettle in such former lakes methane emission is expected to decrease over time. Moreover, in most of these former lakes permafrost returns, followed by development of palsås with very low emission rates. It is concluded that methane fluxes from Western Siberian wetlands are overestimated and for climate change modeling need to be revised.

This study was funded by INTAS and was a part of the project: The effect of climate change on the pristine peatland ecosystems and (sub)actual carbon balance of the permafrost boundary zone in subarctic Western Siberia (CASUS).

Carbon Storage in the Northern Sebangau Area between Tangkiling and Kasongan, Central Kalimantan and Peatland DEM-measurements with an Airborne Laser Scanner.

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In 1997, 2002 and 2006 El Niño prolonged the dry season considerably causing additional risk of fire, haze and smoke in Central Kalimantan. The peatland fires during the dry season have greatly increased, caused mainly by the Ex-Mega-Rice Project (MRP).
With the help of Remote Sensing and Geographical Information System (GIS) exact surveys are possible, providing information as to the changes in landscapes and the condition of environments. An integrated planning and management program has been achieved. With a high-resolution Airborne Laser Scanner (ALS) the topography of peatlands will be measured. Also the biomass of Peat Swamp Forest (PSF) will be analysed by this modern technology with an elevation resolution of +/-15cm. Additionally illegal channels in PSF can be monitored and the volume of peat and loss of carbon by peat-fires better estimated.
To understand the situation of this area peat drillings parallel to the Kalimantan highway between Tangkiling and Kasongan have been measured. Results of the peat depth (up to 8.3m) combined with measured minerals below peat and its characteristics will be presented during the symposium. The estimation of carbon storage of that area will be evaluated with the additional help of high-resolution ALS-, Landsat- and SRTM DEM-Satellite images (Shuttle Radar Topography Mission, Digital Elevation Model).

Literature: Page, S., Siegert, F., Rieley, J.O., Boehm, H.-D.V., Jaya, A., Limin, S. (2002) The amount of carbon released from peat and forest fires in Indonesia during 1997. Nature 420

Effects of climate change on vegetation and decomposition: a North-South transplantation of bog monoliths.

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To predict the future role of bogs as carbon sinks, it is necessary to know how its vegetation will respond to global warming and increased nitrogen levels. To examine this, we transplanted large monoliths of peat over a gradient from the Northeast of Sweden to Northeast Germany. This North-South gradient represents rising temperature and nitrogen deposition. Also a decomposition experiment has been set up in which material of *Sphagnum balticum* and *Sphagnum fuscum* from the most northern site and *Eriophorum vaginatum* from all four sites was put in litterbags and these litterbags were buried in the four transplantation sites. During the three years that the experiment lasted, a clear increase in vascular plant cover was observed in the monoliths that were transplanted to the south. *S. balticum* showed a decrease in height increment in the two southern sites. Decomposition rates of both the *Sphagnum* and *E. vaginatum* material increased as litterbags where buried more to the south. *S. balticum* had a higher decomposition rate than *S. fuscum* and also reacted more strongly to increased temperature. From these preliminary results we conclude that an increase in temperature and nitrogen deposition will have a negative effect on the growth of *S. balticum* and a positive effect on the decomposition rate of the peat. The increase in vascular plant cover will probably have a negative effect on *Sphagnum* growth and a positive effect on decomposition of the peat. Therefore we expect that global change will lead to a decrease of the carbon sink function of northern peat bogs.

The effect of burning and grazing on soils and water quality.

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Careful stewardship of the UK uplands is important for several reasons: in the UK they are the largest terrestrial store of carbon; over half the UK receives its water from peat covered catchments, and they are maintained to provide grazing for sheep and ground cover for recreational shooting. However recent trends show that there are widespread increases in loss of sediment, water colour, loss of habitat and may already be a net source of carbon. It is suggested that good land management may return these areas to net carbon sinks. So, is our present land management compatible with long term sustainable use and carbon storage?

Long running experimental plots at Moor House National Nature Reserve in the North Pennines, are being used to investigate the effects of grazing and burning rotation on water quality and carbon storage. Monitoring began in April 2005 and since then samples for water quality have been collected at least once a month and CO2 flux data has been collected since November 2006. Results from the site show that land management controls hydrology and water quality through differential development of vegetation. The data collected so far, examines the effect of burning and grazing at the end of a ten year burning cycle. The plots are due to be burnt in the near future so the project will aim to investigate any effects on the water quality and carbon storage after the burn.

Modelling of subsurface hydrology, soil temperatures, and hydrological effects on NEP of a northern bog.

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This research examines hypotheses for modelling peat hydrology and temperature, and their effects on bog NEP. The complex mathematical model ecosys was applied on a 3D transect, representing detailed hummock-hollow bog microtopography. Volume of the near-surface fibric peat was resolved into macropore and micropore components, the former estimated to be 0.8. Combined use of the Hagen-Poiseuille equation for macropore flow and the Richards equation for micropore flow allowed the model adequately to represent water movement through the peat, as tested against hourly TDR measurements of peat water content at 10, 20, 30, 40 and 50 cm under hummock surface, and at 3 and 15 cm under hollow surface, confirming the importance of macroporosity in peat water dynamics. Modelled water movement was further corroborated by agreement between water table depths in the model and those from the piesometric measurements. Heat transfer was hastened in the model by convection through large air-filled porosities of near-surface fibric peat, determined by bog hummock/hollow microtopography and driven by temperature gradients beneath the peat surface. This convection explained diurnal variation in heat fluxes measured at the peat surface, and peat temperatures measured at 1, 10, 20, 40 cm under the hummock surface, and at 1, 5, 10, 20 cm under the hollow surface. Subsurface hydrology affected NEP through its effects on ecosystem respiration and GPP. Microbial respiration is explained through compensating increased soil O_2 by decreased soil water contents in near-surface peat as it dries, and vice versa. Suppressed GPP of shrubs is partially compensated by increased GPP of mosses during wet years, while dry years stimulate shrub GPP through increased soil O_2.

GHG-exchange and economic effects of climate friendly peatland management in Germany.

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GHG-exchange of managed peatlands amount to 2.3-4.5 % of the anthropogenic emissions in Germany (Byrne et al. 2004). Several federal states of Germany have specific mire conservation programmes, which should be evaluated in terms of their potential climate mitigation effects. Previous studies of the partners give hints to a climate mitigation potential via peatland restoration, depending on the dominating factor: the water table. In face of this we definitely must further span the site conditions and restoration measures for a large scale assessment of peatlands GHG-exchange processes in the temperate region. To fill these gaps, the German Ministry of Education and Research funded an interdisciplinary research project (2006-2009) focusing on the GHG-exchange and economic consequences of climate friendly peatland management. At six sites (2 bogs and 4 fens) spread over Germany´s major peatland areas and an associated natural fen site in Poland gas exchange of CH_4 and N_2O as well as NEE of CO_2 will be measured over the next 2 years. GHG-exchange will be modelled based on whole year field data. Process studies with peat columns in the lab will help to further parameterize the modelling approaches. Up-scaling of the plot measurements to the landscape level will be done with remote sensing technologies using plant communities, which serve as well as indicators for mean annual water table depth. At selected sites, proximal sensing (geophysical approaches) will be used to detect peat-depth. The methodological focus in up-scaling procedures will be on ‘hot spots’ (driving factors) rather than

complete spatial imaging. One novelty is the inclusion of research on the socio-economic consequences of climate friendly peatland management. The focus is to study, if alternative land-use or even complete restoration provoke microeconomic restrictions at the farm level, but may lead to higher economic welfare for the society. At the end of the project, we can offer the decision basis for specific subsidies for climate mitigation via peatland management.
The poster will present the structure of the project, the research aims and methodologies, the sites and the expected outcome of the project.

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C-balance and GWP-balance of degraded and restored fens in the Donauried, southern Germany.

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In their natural function, peatlands are almost continuously sequestering carbon. Drainage and peat-cutting or even global warming can convert peatlands to significant carbon sources. Until recently, restoration in peatlands focussed on the development of typical vegetation types. However, for assessing a functional restoration success, the carbon balance is of major importance. But the carbon balance alone cannot explain the climate effect of peatland sites. Therefore, we studied the exchange of all three biogenic trace gases of restored sites in comparison to grassland and arable land on fens (Donauried, southern Germany). A climate controlled chamber technique was applied to measure CH_4, N_2O and NEE of CO_2. Year balances for entire 2005 were calculated after parameterization of the models with the instant field measurements. Restored sites with dominating sedges showed a significant CO_2-C uptake with up to 133 g C m^{-2} a^{-1}. Agricultural sites were sources of CO_2-C (500 g C m^{-2} a^{-1}). CH_4-C emissions of the restored sites differed widely between 13 g C m^{-2} a^{-1} and 77 g C m^{-2} a^{-1}, whereas at the agricultural sites methane flux was close to zero. N_2O-N emissions were only found at the agricultural sites (78-179 mg N m^{-2} a^{-1}). Restoration was able to re-establish the C-sink function with an uptake of between 21 and 117 g C m^{-2} a^{-1}. However this is partly counteracted by the overall climate effect of the sites (GWP-balance): The two restored sites with the higher methane emissions were climate heaters (400-487 g C-equiv m^{-2} a^{-1}). This is in the same magnitude as the warming effect of the agricultural sites (502-522 g C-equiv m^{-2} a^{-1}). In contrast the restored site, with the lowest water table (around -10 cm) acted as a moderate climate cooler with an uptake of 29 g C-equiv m^{-2} a^{-1} because of the reduced methane emissions. The mean water table of the restored sites explains significantly the difference in the methane-balances. This offers management options for climate-friendly peatland restoration.

An integrated multiscale (spatial and temporal) approach for carbon dynamics comprehension of boreal peatlands.

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In boreal regions of the northern hemisphere, peatlands cover up to 20% of the Canadian territory, and between 9 to 12% of the Quebec province. Considering that peat accumulation is thought to be largely a function of moisture and temperature, we developed a multidisciplinary approach in order to improve the understanding of peatland carbon dynamics in the James Bay Lowlands (51-54°N; 73-78° W). Between 2003 and 2006, we investigated from a local to a regional scale, different peatlands types representative of the ecogeomorphic areas from which they belong. The approach has been defined following three major axis of research and presents data from paleoecology, biogeochemistry, surface vegetation ecology, surface hydrology, geomorphology and remote sensing, integrated into a geographic information system (GIS). Axis 1 of the project focuses on regional characterization and classification of present-day surface peatland types using satellite images and aerial photos. Axis 2 of the project set sights on assessing the local and regional variability of CO_2 and CH_4 exchanges to determine the relative sensitivity of the peatland carbon fluxes in relation with current climate conditions and nutrient context (bogs vs fens). Axis 3 of the project aims to understand and quantify: 1) isotopic fractionation (? C13) of surface and subsurface vegetation, 2) peat and carbon accumulation reconstructed through the last centuries (ca 250 yrs) and dated with 210Pb and 3) holocene paleoenvironmental conditions related with peat and carbon accumulation since the beginning of peat inception in the region (ca 7000 BP). Sequential reconstructions are to be achieved using radiochronology (^{14}C), carbon content (LOI and C/N), microfossils (pollen, spores and rhizopods) and plant macrofossils. Models will be run to determine the relative sensitivity of CO_2 and CH_4 exchanges under past, current and future climate conditions using transfert functions and CGCM2 simulations. The integration of these data will allow a comprehensive spatial and temporal understanding of boreal peatlands dynamics from the time they first began accumulating carbon to their present day patterns and processes.

This research is supported by NSERC (Natural Sciences and Engineering Research Council of Canada), Hydro-Québec (coordinator, Dr. Alain Tremblay) and CFCAS (Canadian Foundation for Climate and Atmospheric Sciences).

Peat productivity of an open peatlands in southwest Sweden.

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Ombrotrophic bogs in southwest Sweden are receiving highest nitrogen deposition levels in the country. Changes in climate and increased N deposition affect the balance between communities with different peat producing capacity. *Sphagnum* species are important peat producers, while most vascular plants contribute less to the productivity. The reduction in *Sphagnum*, caused by high N deposition levels, is additionally linked to an increased shading and litter-fall by expanding vascular plants, which respond positively on higher N supply and on drier climatic conditions. Climatic and deposition driven vegetation shifts may thus be important for changes in the total input of carbon into ombrotrophic ecosystems.

In this study we will estimate the recent rate of peat accumulation and carbon sequestration in a southwest

Swedish bog (Store mosse, Halland). We will do this by using remote sensed satellite images (QuickBird) over the peatland, which give high resolved images. A classification of the images was established by field calibration against the vegetation. The different vegetation classes were sampled for peat productivity using the 'pine method'. This method uses small pines to date peat cores and gives measures of recent accumulation of matter in the acrotelm. These measurements will then be used to scale up to get peatland level peat productivity measurements. We hope this method can be used to monitor future changes in carbon sequestration rates of entire peatlands and to get estimates of regional peat productivity of open peatlands.

The role of thaw regime in fate of terrestrial carbon in landscapes vulnerable to permafrost degradation.

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Central Alaska encompasses a broad range of permafrost-dominated boreal ecosystems. At the landscape scale, there is an abundance of upland terrain with or without permafrost, and lowland terrain with thick peat deposits and ice-rich permafrost. Further nested within these landscapes are highly patchy vegetation and soil conditions that result from frequent fires. In central Alaska, recent results indicate that 7% of the landscape has undergone thermokarst, 47% has permafrost, 27% is unfrozen without a recent permafrost history, and 19% of the area has an uncertain thermal status (Jorgenson et al., 2005). The dominant modes of thermokarst in Interior Alaska are collapse-scar fens (3.1%), thermokarst lakes (1.5%), and collapse-scar bogs (1.0%). The landscape is comprised of 41% lowlands (typically ice-rich), 23% uplands (ice-poor or unfrozen), 26% alpine and subalpine, 9% riverine (lacking permafrost), and 3% lakes. In Interior Alaska, the fate of terrestrial carbon over the next few decades likely will be determined by the mode of thermokarst, or thaw regime. We have begun testing this hypothesis using Cs137 and C inventories to account for net C stocks in frozen and thawed soils. A shift from tussock black spruce to acidic bog resulted in an increase in terrestrial C storage. A shift from Tussock Tundra to woodland and black spruce forest resulted in a decline in terrestrial C storage. We propose a similar approach for other thaw regimes using Cs137 and C inventories.

Predicting soil subsidence and greenhouse gas emission in peat soils depending on water management with the SWAP-ANIMO model.

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A process-based model was developed to simulate for peat land areas subsidence of the soil surface, emission of the greenhouse gasses (GHG) carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and loading of the surface water with the nutrients nitrogen (N) and phosphorus (P). The model consist of two existing models: SWAP for simulating the hydrology and soil temperature, and ANIMO for simulating the processes in the carbon and nutrient cycles, subsidence, GHG emission and N and P loading of the surface water.
The model was calibrated and validated against data from several experimental fields in a Dutch peat land area. With the validated model scenario studies were carried out to quantify the effects of water management, land use and global climate change on soil subsidence, GHG emission and N and P leaching.
Raising groundwater level is an effective measure to diminish subsidence and emission of the GHG CO_2 and

N_2O. The increase of CH_4 emission was negligible in comparison to the decrease of the other two GHG. The most effective scenario was a high ditch water level (30 cm below soil surface) in combination with submerged drains at a spacing of 4 m and at a depth of 15 cm below ditch water level. These drains enhance substantially infiltration from ditch water into the soil. However, drains at such a shallow depth draw off nutrients of fertilization from the root zone, leading to high N and P loading of the surface water. Submerged drains at depths below 70 cm draw off nutrient rich water from by nature nutrient rich peat layers. Besides, they do not add to the decrease of GHG emission. From the point of view of lowering both GHG emission and nutrient loading, the optimal depths of submerged drains is between 50 and 60 cm below soil surface.
Future climatic conditions appear to increase soil subsidence and GHG emission with a factor up to 2.

The World's Longest Continuous Measurements of CO_2 Exchange at Peatlands - What have we learned?

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The world's two longest continuous measurement records of net ecosystem CO2 exchange (NEE) at peatlands are taking place at the Kaamanen fen in northern Finland (69°08'N, 27°17'W) and at the Mer Bleue bog in Ontario, Canada (45°24'N, 75°30'W). Both sites have been in operation for more than 8 years and measurements continue to date. This paper presents a comparison of results from these two extensive records. Despite differences in peatland type (bog vs. fen) and climate (cool temperate vs. subarctic), neither peatland has been a significant annual source of CO_2 to the atmosphere over the length of record. The longterm mean annual NEE is larger at the bog site, mostly due to a longer growing season. However, the daily NEE values during the peak summer are actually somewhat higher at the fen site. Respiratory losses during winter are greater at the bog site, due to less soil freezing and warmer soil temperatures. The most dramatic difference in CO_2 exchange at these sites is the dominant climatic control on annual NEE. At the fen site, springtime temperature and timing of snowmelt strongly influences the annual NEE. In contrast, late summer dryness and growing conditions are the strongest influence on annual NEE at the bog.

Greenhouse gas balances of natural and drained peatlands in Finland based on the micrometeorological measurements.

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During the Holocene, northern mires have accumulated large amounts of carbon, which originates from the atmosphere. Concurrently they have acted as a source of methane produced by the methanogenic bacteria in the anoxic conditions. The emissions of nitrous oxide are relatively low in natural mires. Extensive natural mires exist in uninhabited areas of Eurasia and North America but in populated regions most wetlands have been drained for agriculture, forestry, and energy production. In Finland, 5.7 million ha mire area have been drained

for forestry and 0.7 million ha for agriculture. Draining, liming and addition of nutrients are common practices for making the soil more fertile, but they also change the greenhouse gas (GHG) budgets profoundly. After draining, soil respiration increases but methane emissions cease. When soil is prepared for agriculture, higher nutrient concentrations and soil mineralization produce substantial emissions of nitrous oxide.
Here we present GHG balances of natural mires and managed peatlands in Finland. The study sites include three natural fens, two of them in the northern and one in the central boreal zone. Annual balances have been measured also on an agricultural organic soil cropland, afforested former organic soil cropland and on a drained Scots pine bog. We used the eddy-covariance method at all the study sites for carbon dioxide fluxes and at the fen sites for methane emissions. The other fluxes were measured using manual chambers.
The results show that the agricultural and the afforested cropland sites have high carbon dioxide and nitrous oxide emissions. The other sites are sinks of carbon dioxide, the drained pine bog having the annual carbon balance similar to the upland pine forests. The methane emissions of the natural fens increase towards warmer climate. At all fen sites, the positive global warming potentials of methane emissions exceed the cooling effect of carbon dioxide emissions.

CO_2 exchange and vegetation dynamics along a mire chronosequence.

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Plant community composition changes during the succession leading to plant groups with differing phenologies gradually replacing each other. Thus, succession involves also a change in ecosystem functions and processes. In northern mires a long-term succession is usually seen as a shift from ground water fed fens to solely rainwater fed bogs. During the succession herbs and sedges, typical for fen stage, are gradually replaced by shrubs in the bog stage, with concurrent increase in the *Sphagnum* cover.
Our aim was to study the importance of different functional plant groups with their characteristic phenologies and relative photosynthetical efficiencies to CO_2 exchange along the chronosequence. We measured carbon dioxide exchange and development of assimilating green area of vegetation during one growing season along a mire succession gradient on the land uplift coast of Bothnian bay. We chose five mires differing in age (from appr. 100 to 2520 ± 50 years old), peat depth (between 0.1 to almost two meters) and vegetation. The youngest sites are young fens with meadow vegetation and the oldest site is in transition from fen to bog phase. All the mires are born via primary paludification after emergence under sea. The precipitation and mean temperature during the study season were higher than long-time averages. There was a unimodal relationship between the total green area (GA) of plants and age of the site, which followed the pattern in vascular green area. Unlike in vascular plants, there was an increasing trend in the abundance of mosses along the chronosequence. Although the total number of species did not change along the chronosequence, their frequency did. In the beginning only few species dominated while the proportions of species became more even with the age of the site. Also the dominant plant species in functional plant groups differed along the chronosequence. Sedges were abundant throughout the chronosequence. Graminoids were present only at the youngest sites and evergreen shrubs in the older ones. The herbs, deciduous shrubs and sedges showed a strong pattern in the development of their green area; the growth in spring and senescence in autumn was rapid. Unlike graminoids and evergreen shrubs they formed all or most of their leaves in spring. The seasonal pattern in evergreens was less pronounced with only a slight increase in the green area before mid summer. Similarly to vascular plant development, both photosynthesis (PG) and ecosystem respiration (RE) showed unimodal patterns over the growing season. This pattern was most pronounced at the younger end of chronosequence. The seasonal variation and the level of PG both decreased along chronosequence towards the fen-bog transition stage.
We produced seasonal estimates for CO_2 exchange dynamics by modelling in order to quantify

the importance of different functional plant groups with their characteristic phenologies and the importance of different parameters (air temperature, vegetation and water table level) to the respiration during mire succession. We compared relative photosynthetic efficiency between the studied functional plant groups based on the group specific GA parameters in PG model. Our results showed that plant groups with efficient GA production and photosynthesis (particularly the functional groups of sedges and graminoids) dominate the early stages of succession. High level of PG combined with low RE resulted in high net ecosystem exchange in the young successional stages. Our results indicate that the pattern of high seasonal variation and level in PG, ecosystem respiration and plant phenology decreases during mire succession.

A temperate bog balance on the edge.

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Peatlands are generally small but consistent sinks for atmospheric carbon (C). During the course of thousands of years, this has resulted in an enormous C pool in peatland soils, amounting to almost one-third of the world total soil C pool, or one-half of the atmospheric C pool. However, the sustainability of this sink functioning is threatened in a changing climate. We measured the carbon dioxide (CO_2) exchange in a temperate, ombrotrophic bog between August 2005 and July 2006 using the eddy covariance technique. During this period, the CO_2 balance was 21.5 ± 5.4 g C m^{-2} yr^{-1}, which is a lower uptake than others have reported for comparable ecosystems, but in accordance with average Holocene uptake rates. Average winter emissions were small, but accumulated over the non-growing season, they a represent a larger CO_2 flux than the whole year average. Taking into consideration that wintertime temperatures in the northern hemisphere are expected to increase drastically in the future, wintertime fluxes may become increasingly important. The highest average monthly CO_2 uptake occurred in June, while the drier month of July showed a distinctly smaller sink. This was likely due to lowered water tables and decreased soil moisture that caused gross primary production to decline, while night time respiration increased steadily. Our findings indicate that the effect of future warmer temperatures on the growing season CO_2 exchange in peatlands is dependent on climate wetness. In order to understand how future climate will affect the peatland C sink functioning, it is necessary to obtain multi-year NEE measurements, and establish a mechanistic, process-based knowledge of the C fluxes in different peatland types.

The influence of disturbance on wetland succession in a permafrost collapse, Fairbanks, Alaska.

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To determine the influence of fire and thermokarst in a boreal landscape, we investigated vegetation succession of a permafrost collapse feature on the Tanana River Floodplain of Interior Alaska. Radioisotope dating and characterization of diatom assemblages and plant macrofossils preserved in the peat profile indicate that succession proceeded from a terrestrial forest to a sedge-dominated wetland over 100 years ago and to a *Sphagnum*-dominated bog in approximately 1970. The shift from *Sphagnum* to sedge was concurrent with a

decrease in the detrended tree ring width index of black spruce trees adjacent to the collapse and an increase in the growing season temperature record from Fairbanks. In 2001, fire initiated additional permafrost collapse and resulted in lateral expansion of the bog. Our results suggest that future warming and increased fire disturbance will promote bog expansion and permafrost degradation; however, the development of drought conditions could reduce the success of black spruce and *Sphagnum*, resulting in decreased long-term carbon storage in this landscape.

A 'complex adaptive systems' approach to modelling peatland dynamics.

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On peatlands, vegetation and water-table depth exhibit fine-scale (1-10 m) heterogeneity. The resultant surface structure has a large effect on peatland-atmosphere exchanges of methane and carbon dioxide, as well as on hydrological processes. Predictions of the response of peatland carbon cycling to changes in climate must account for the dynamics of fine-scale vegetation/topographic features ('microforms'). We present a spatially-distributed model of peatland ecohydrology in which variations in cover of different microform types and their spatial patterns are simulated. The model's structure allows for variation of hydraulic properties in three dimensions, and the hydrological behaviour at any grid location is a function of water-table elevation and the hydraulic properties of a number of older peat layers. The history of past microform types influences contemporary behaviour via the properties of peat layers preserved in the stratigraphic column.

Numerical experiments using the model reveal that microform pattern and temporal stability depend profoundly on the strength of the 'ecological memory' incorporated in the model. Ecological memory reflects the degree to which past microform types at a given location are preserved as distinctive layers of peat with characteristic hydraulic conductivities. We comment on how our model, because it can deal with ecological memory, offers a more realistic representation of the development and stability of microform patterns than previous cellular models. In particular, we show how the temporal stability of microform patterns increases with the strength of ecological memory.

We also show how perturbations (e.g. periods of increased net rainfall) affect microform patterning and stability and how the resistance and resilience of a peatland's microstructure are affected by the strength of the ecological memory.

The model structure is to be further developed to include more sophisticated vegetation micro-succession, productivity and peat decay routines, in order to examine the role of northern peatlands in global carbon cycling.

Two Years of Complete Carbon Budgets for a Boreal Oligotrophic Minerogenic Mire.

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Based on theories on both mire development and their response to a changing climate, the current role of mires as a net carbon sink has been questioned. A rigorous evaluation of the current net C-exchange in mires requires direct measurements of all relevant fluxes. Here we present a total carbon budget over two years from a boreal minerogenic oligotrophic mire (64°11' N, 19°33E). Data on the following fluxes was collected: land-atmosphere CO_2 (continuous Eddy Covariance measurements) and CH_4 (static chambers during the snow free period) exchange; DOC in precipitation; loss of TOC, CO_2 and CH_4 through water runoff (continuous discharge measurement and regular C-content measurements). The mire constituted a net sink of 31 ± 2.7 (SD) gC $m^{-2}yr^{-1}$ during 2004 and 23 ± 2.8 gC $m^{-2}yr^{-1}$ during 2005. This could be partitioned into an annual surface-atmosphere CO_2 net uptake of 55 ± 1.9 gC $m^{-2}yr^{-1}$ during 2004 and 48 ± 1.6 gC $m^{-2}yr^{-1}$ during 2005. The annual NEE was further separated in a growing season uptake of 92 g$Cm^{-2}yr^{-1}$ during 2004 and 86 gC $m^{-2}yr^{-1}$ during 2005 and a winter season loss of 37 gC $m^{-2}yr^{-1}$ during 2004 and 38 g$Cm^{-2}yr^{-1}$ during 2005. The CH_4-C loss during the snow free season was 7 ± 1.4 gC $m^{-2}yr^{-1}$ during 2004 and 11 ± 2.0 gC $m^{-2}yr^{-1}$ during 2005. The annual C-export from the mire through runoff was 15 ± 1.2 gC $m^{-2}yr^{-1}$ during 2004 and 11 ± 1.0 g$Cm^{-2}yr^{-1}$ during 2005. TOC constituted 65% of total runoff C during 2004 and 74% during 2005. Of the annual net CO_2-C uptake 20 % and 27 % was lost through runoff and 16% and 29% through methane emission during 2004 and 2005 respectively. This mire still is a significant C-sink comparable to the long-term Holocene apparent C-accumulation, and higher than the C-accumulation during late Holocene in the same region.

Searching for wetlands since the Last Glacial Maximum.

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QUEST-Deglaciation project aims to improve palaeoenvironmental databases as means of better understanding the causes of changes in climate, atmospheric composition and biogeochemical cycles since the Last Glacial Maximum, and for evaluating and creating Earth system model simulations.
Wetlands play an important role in the terrestrial carbon cycle today, but it is unclear what their part as carbon sinks and e.g. methane sources was during the last Ice Age and deglaciation. Most modern peatlands, now storing some 500 Gt of carbon, are of the Holocene age, but there were large areas suitable for wetlands during the Last Glacial Maximum. The existing Earth system models do not usually include wetlands due to the lack of data. As a part of QUEST-Deglaciation, the compilation of global wetland database is underway. The database includes at the moment in situ stratigraphical and dating information on modern and buried peatlands and other terrestrial wetlands; for a fuller picture of wetland extent, indirect evidence, e.g. pollen data has to considered as well. The existing regional databases only present basal peat dates, or are pollen-based reconstructions of wetland coverage. Based on these, and added sites from world-wide wetland research literature survey, spot maps of the studied sites for peatland initiation and presence since the Last Glacial Maximum can be presented

for selected time-slices. Arctic and boreal regions are best represented. The final goal is to be able to present as maps and time-series the global extent and distribution of different wetlands through time.

Carbon release from different restoration techniques on wildfire sites.

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Restoration of wildfire sites on upland peat is important in preserving carbon stores. On a site located on Bleaklow in the Peak district, a wild fire occurred in April 2003 and devastated large areas of peat by removing the surface vegetation. The bare peat surface was subsequently weathered by rainfall events leading to 2-3 meter gullies forming, which even cut into the underlying bedrock. In order to restore the peat at these sites a number of treatments were prepared, including: re-seeding, gully-blocking, fertilising, liming, geo-jute and use of heather brash cover. These sites have been monitored for their re-vegetation but not for their carbon balance. This study has sort to monitor complete carbon budgets for a range of treated sites. Monitoring includes: soil respiration, primary productivity, CH_4, dissolved CO_2, dissolved organic carbon and particulate organic carbon. In total 7 different treatments are being monitored each in duplicate and including controls of both pristine peat that was not burnt in the events of April 2003 and peat that received restoration but left bare.

Water Budget and Energy Partitioning of a Boreal, Minerogenic Mire.

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Exchanges of energy and water between the atmosphere and a boreal oligotrophic fen in northern Sweden were measured continuously for five years (2001-2005) using the eddy covariance technique. Five year estimates (±SE) were as follows: the Bowen ratio (average daytime, 0800-1800, 1 May to31 August) was 0.36±0.02; the evaporative ratio, LE/Rn (daily averages 1 May to 31 August) was 56±8%; AET/PET (daily averages, full year data) was 75±1%; and the Priestly-Taylor coefficient (daily averages, 1 May to31 August) was 0.90±0.01. Maximum evapotranspiration rates reached 4-5 mmd^{-1}, usually during the month of July. Two of the five years were essentially wetter, with a higher water level (WL) than the other years, and one year was essentially drier (low WL). Annual evapotranspiration ranged from 230 to 337 mm. Stream discharge from the fen was measured during the last three years to determine the full water budget. The closure of the water balance, accumulated over three years, was 92%. The variation in annual discharge was even greater than the evapotranspiration, ranging from 170 mm to 367 mm. Discharge was highly sensitive to temporal variations in precipitation and there was a negative correlation between discharge and evapotranspiration. The diurnal change in surface conductance was dependent on WL. It was fairly constant for a WL within the range 0-10 cm, while it for a WL < 10 cm declined significantly. A diurnal decline from higher levels in the morning during daylight hours was also seen. Incoming solar radiation only affected the surface conductance at vapour pressure deficits (VPD) less than 1 kPa, at higher VPD no significant effect were seen. The surface resistance was larger than the aerodynamic resistance and thus the primary controlling factor of the water transport to the atmosphere. It was found that, in the fen, physiological regulation of the water flux was very limited and that drying of the peat surface was the main factor controlling evapotranspiration.

Spatially explicit simulation of fen hydrology and carbon fluxes as influenced by topographical setting.

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Peatlands have generally been ignored in many carbon cycle and hydrological modeling efforts at the watershed scale, mainly due to the incomplete understanding of peatlands' complex hydrology, which is influenced by their climatic, topographic, and (hydro) geologic settings. An important parameter in peatlands that influences both net primary productivity, and decomposition under aerobic and anaerobic conditions, is the position of the water table. Distributed, process-oriented ecosystem models can be considered as promising tools to further the understanding of peatland carbon dynamics and their hydrological controls as influenced by peatlands' topographical settings within the landscape. Common types of peatlands include fens with peat surfaces topographically lower relative to their surrounding mineral uplands. As a result of the concave shape of the upland-peatland profile, fens receive, in addition to precipitation, hydrological inputs from their surrounding mineral uplands in the form of surface and subsurface flows. From a modelling perspective the hydrological connectivity between peatlands and surrounding mineral uplands requires that process-oriented models that examine the links between peatland hydrology, ecosystem functioning, and climate must incorporate some form of lateral surface and subsurface flow consideration. Our objective is to explicitly simulate the upland-peatland hydrological connectivity and its influence on peatland hydrology and carbon fluxes using the Boreal Ecosystem Productivity Simulator (BEPS) adapted to peatlands in boreal and subarctic ecozones. BEPS is a distributed, process-oriented ecosystem model in a remote sensing framework that takes into account peatlands multi-layer canopy through separately mapped leaf area indices. Model outputs of water table, and water and carbon fluxes are validated against multi-year measurements taken at an eddy-covariance flux tower located within Sandhill fen, an open patterned fen in central Saskatchewan, Canada.

Four years Eddy-Covariance CO_2 fluxes from an Irish Atlantic blanket bog.

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Northern peatlands contain about 30% of the world's soil carbon pool. In Ireland, peatlands cover about 16% of the landscape, of which 240,000 ha are blanket bogs. Blanket bogs are peatlands that occur in maritime regions where precipitation is much greater than evapotranspiration. The role of blanket bogs in C dynamics has not been quantified. We describe an investigation of CO_2 fluxes using an eddy covariance (EC) system in a pristine Atlantic blanket bog in Glencar, Co. Kerry between the 1st October 2002 and the 30th September 2006. This is the first multiyear study using EC techniques in a blanket bog. We found that the bog ecosystem was a CO_2 sink for five months in each year. The annual CO_2 flux had a sink magnitude of about 0.6 ± 0.3 T C-CO_2 ha^{-2}. The CO_2 fluxes measured in the Glencar peatland are similar to those found in boreal raised bogs, despite the occurrence in the Atlantic blanket bog of a perennial high water table, that reduce decomposition. The reason for this similarity may be due to the lower plant cover and the higher litter decomposition rate of the plant species occurring in the blanket bog, both factors reducing the CO_2 uptake compared with the boreal bog.

Peatland C responses to changing hydrology and disturbance regimes: perspectives from boreal North America.

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The North American Boreal region (NABR) is experiencing ongoing climatic changes that have led to longer and drier growing seasons, changing fire regimes, and the degradation of permafrost. Changes in peat environments in response to these climate changes could have significant implications for C emissions to the atmosphere, and thus the radiative forcing of high latitude regions. We predicted that water table drawdown and soil warming would stimulate C mineralization due to microbial respiration of soil organic matter previously protected by cold and/or wet conditions. However, observations at both short-term (several years) and longer-term (>20 years of soil drainage) experiments in Canadian and Alaskan fens show that vegetation structure and function strongly mediates CO_2 fluxes and soil C storage following water table drawdown. In contrast, CH_4 emissions show large increases following experimental flooding and soil warming in an Alaskan fen, with minor decreases in response to water table drawdown.

Increased occurrence of climate-mediated disturbances such as wildfire and permafrost degradation will influence regional C storage and fluxes in boreal peatlands. Annual burn area across the entire NABR has more than doubled since 1950, with more frequent occurrence of large fire years that tend to burn large areas of peatlands. Empirical reconstruction of organic matter consumption during peat fires shows that the extreme fire weather conditions that trigger large fire years increases fire severity in peatlands and exacerbates C emissions to the atmosphere. Together, this research suggests that peatland C stocks in the NABR are vulnerable to ongoing climate change at multiple spatial scales, as soil C losses are being subjected to regional changes in drought and fire weather. However, interactions between changing environmental conditions and peatland vegetation could offer some resilience of peatland C cycling to future climate change.

Late-Holocene climate change; effects on carbon accumulation in bog ecosystems in Sweden and Germany.

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In order to investigate the effects of climate change and human impact on vegetation and carbon accumulation, we took peat cores of c. 1 meter depth from four raised bogs situated on a North-South transect, at intervals of c. 500 km, from northern Sweden to northern Germany. A number of analyses were conducted, and ^{14}C wiggle-match dating was applied to obtain a fine-resolution chronology.
By using the bulk density data, the C concentration and the detailed chronology, we were able to calculate the historic carbon accumulation rates of the four research sites. The calculations show that the North-South gradient is visible in the carbon accumulation rates (CAR). The most northern Swedish site generally showed the lowest CAR, and the most southern site in Germany showed the highest CAR. We conclude that carbon sequestration was less in the northern sites than in the southern sites.

Further, we analysed the correlation of temperature with the carbon accumulation rates over time of the northern and central Swedish site. First results show that the Pearson correlation between carbon accumulation rates and temperature is highly significant ($p<0.01$). A significant ($p<0.05$) negative correlation exists between CAR and delta ^{14}C, a measure of solar activity.

We conclude that temperature is a limiting factor in carbon sequestration process in peat bogs. A higher temperature may result in more plant growth than decomposition and therefore in more carbon sequestration. However, too warm and/or dry local conditions may result in a decrease in carbon sequestration, owing to a higher decomposition rate. To further investigate this balance we will relate the carbon accumulation rates to precipitation measurements of Umeå and Uppsala and to the plant composition in the bog itself to see how this affected carbon sequestration. We will also compare the nitrogen deposition between sites. These palaeo data will be compared with the results of experiments by Angela Breeuwer, Wageningen University, and with model outcome of the NUCOM-BOG model of Monique Heijmans, Wageningen University.

Towards a complete carbon budget for a peat catchment.

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Peat is the largest single terrestrial carbon in the UK and as such it is vital that we understand its carbon budget. Most studies of peat carbon budgets have been based either on carbon accumulation studies or fluxes of greenhouse gases. Neither of these methods takes account of the fluvial flux of carbon peat. This study uses detailed observations from a series of upland peat catchments in order to assess a complete carbon budget that includes: soil respiration of CH_4 and CO_2; primary productivity; excess dissolved CO_2; dissolved organic carbon and particulate organic carbon. The measurement of fluvial fluxes can never occur at the point at which the water leaves the peat profile and once the water enters the stream, both dissolved CO_2 and DOC begin to exsolve and degrade. Therefore, in order to get an accurate fluvial flux, these in-stream processes must be accounted for. This study will detail the methods used to account for in-stream processes and will show that the catchments studied are near neutral with regard to carbon accumulation. Pristine catchments remain a small net sink (11.4 Mg C km^{-2} yr^{-1}) of carbon, but a much smaller sink than proposed in most peat literature; managed catchments are a net source, up to 106 Mg C km^{-2} yr^{-1}.

Tropical peatland water management modelling of the Air Hitam Laut catchment in Indonesia.

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Human induced land use change and associated fire alter profoundly the hydrology of tropical peatlands and thus affect the functioning of entire river catchments. The hydrological model SIMGRO was used to calculate the effects of drainage on peat water levels, peat surface morphology and river flows within the Air Hitam Laut catchment in Jambi Province, Sumatra, Indonesia. Model outcomes were calibrated and validated using groundwater levels monitored at several sites, discharges measured in the Air Hitam Laut River and flooding patterns derived from remotely sensed Radar images. The validated model was used to predict consequences of three possible scenarios: i) expansion of oil palm plantations upstream, ii) expansion of agriculture downstream and iii) continuing fire damage. Oil palm plantation development results in changes to the drainage pattern of the catchment and reduces its natural extent. Lowered river discharge will have a detrimental affect upon the sustainability of Berbak National Park in the centre of the catchment and reduce prospects for agriculture

and fisheries in the coastal zone. Expansion of agriculture downstream causes peat subsidence, resulting in exposure of underlying, acid sulphate soils and intrusion of saline sea water. Continuing fires will increase considerably the area of permanently flooded land and thus constrain peatland restoration options. For peatland restoration to be successful hydrological management must be accompanied by economic measures to improve the livelihoods of local people and by effective law enforcement.

Keywords: peat swamp forest; catchment modelling; scenario analysis; peat subsidence; land use change; fire; restoration.

Does microtopography really matter in modelling ecosystem level carbon cycling of an ombrotrophic bog?

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Peatlands contain approximately 25% of the total soil carbon, despite covering only 3% of earth's land surface. In order to evaluate the role of peatlands in global carbon cycling, it is necessary to understand the ecosystem-level carbon dynamics.. The surface of bogs often comprises hummocks and hollows. The hydrology, struxture and function, can vary considerably in these microforms . The question for whole ecosystem and larger scale modelling is 'does microtography need to be treated explicitly'. To examine this question we used the process-based ecosystem model, the McGill Wetland Model (MWM), configured for a hummock, a hollow, and then a weighted mixure of a hummock and hollow. It is found that moss begins to take up C earlier in the year than shrubs, and continues to photosynthesize later in the season on both hummocks and hollows. However, hummock shrubs account for far more of the overall net C exchange while in the hollows the mosses are more dominant. At both hummocks and hollows, both NEE and NPP is not significantly correlated with air temperature, but was correlated with water table depth. Autotrophic respiration contributed more than 90% to ecosystem respiration in both microforms. While heterotrophic respiration was determined by the water table depth, autotrophic respiration responded more to the air temperature and the temperature of the top layer of peat. Therefore, ecosystem respiration, dominated by autotrophic respiration, responded more to the air temperature as well. In addition, the ecosystem level carbon exchange, simulated from a weighted mixture of hummocks and hollows, was not significantly different from the one, calculated from the separate configuration of hummocks and hollows explicitly. So, it can be concluded that a weighted mixture of a hummock and hollow could be used to represent the spatial structure of hummocks and hollows implicitly.

overview on

Research Projects

compiled by Angela Breeuwer

Overview on Organizations, Networks and Research Projects relating to Carbon in Peatlands

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To improve mutual knowledge of initiatives dealing with carbon and peat research we offer you an overview of organizations involved with carbon and peat and give an overview of the main research programmes dealing with carbon in peat or forest ecosystems, which were executed in the past or are currently still ongoing. On the following pages the main aims and results of the latter research initiatives have been summarized.

Organizations and networks on Carbon

- Carbon Cycle Science Program
  http://www.carboncyclescience.gov
- CAMELS: Carbon Assimilation and Modeling of the European Land Surfaces
  http://camels.metoffice.com
- IGBP: International Geosphere-Biosphere Programme
  http://www.igbp.kva.se
- GCTE: Global Change and Terrestrial Ecosystems
  http://www.gcte.org
- USGCRP: The US Carbon Cycle Science Programme
  http://www.usgcrp.gov

Organizations and networks on Peat

- Peatnet
  http://www.peatnet.siu.edu
- IMCG: International Mire Conservation Group
  http://www.imcg.net
- IPS: International Peat Society
  http://www.peatsociety.org
- Global Peatland Initiative
  http://www.globalpeatlands.net
- Peat Research
  http://www.peatresearch.com

Research Initiatives

1 BOREAS
2 BERI
3 CarboEurope
4 Global Carbon Project
5 Fluxnet – Canada
6 Integrated Management of Peatlands for Biodiversity and Climate Change
7 CASUS
8 CARBOPEAT

Name: BOREAS: Boreal Ecosystem-Atmosphere Study
Period: 1993-1998
Aim: BOREAS was intended to investigate the interactions between the boreal forest biome and the atmosphere, clarifying their roles in global change. More specifically, the objectives were (1) to improve process models that describe the exchanges of radiative energy, water, heat, carbon and trace constituents between the boreal forest and the atmosphere and (2) to develop methods for applying the process models over large spatial scales using remote sensing and other integrative modeling techniques.
Method: Remote-sensing techniques, along with field measurements, were used for developing and testing models and algorithms to transfer the understanding of processes from the local scale to the regional scale.
Main findings:
Physical climate system: BOREAS results had a direct impact on climate modeling and numerical weather prediction. Observations from the mesoscale meteorological network and tower flux sites have provided new insight into the radiation and energy budgets of the forest and how these affect the regional climate.
Carbon and biogeochemistry: The field program provided a comprehensive data set covering almost all components of the plant and soil physiological controls related to the energy, water and carbon cycles in the region.
Ecology: The future course of carbon dynamics in the boreal zone is thought to depend on variations in the physical climate in the near term and on ecological responses in the midterm and long term. The leaf-scale and canopy-scale measurements conducted present a consistent picture of an ecosystem operating at a relatively low level. Tower flux and flux aircraft measurements confirmed tight links between evapotranspiration and photosynthesis during the growing season.
Remote Sensing: Remote sensing and development during BOREAS produced results that are key to investigating the role of the boreal ecosystem in global change. Results should provide more robust global classification and biophysical parameter mapping and should also provide more reliable components in numerical snowmelt models. RS showed that the role of fire in the boreal ecosystem is even more important than previously thought. Finally, RS was used to develop seasonally varying, regional scale parameter maps for all the major driving variables governing carbon/water and energy processes.
Geographic region: Boreal forest of Central Canada
Partners: 85 science teams in USA and Canada, the staff scientists came from
National Aeronautics and Space Administration (NASA); Atmospheric Environment Services (AES), Canada; Canada Centre for Remote Sensing (CCRS); School of Forestry, University of Wisconsin and the Canadian Forest Service
Website: http://www-eosdis.ornl.gov/BOREAS/boreas_home_page.html

Name: BERI: Bog Ecosystem Research Initiative
Website:
Period: 1996-2000
Aim: The primary objective of the BERI project was to study, at five climatically different sites across Europe, (1) the effects of elevated CO_2 and N deposition on the net exchange of CO_2 and CH_4 between bogs and the atmosphere and (2) to study the effects of elevated CO_2 and N deposition on the plant biodiversity of bog communities.
Method: four treatments were replicated five times in five climatically different sites in Europe.
Treatments: 1-Elevated atmospheric CO_2 (560 ppm) in Mini-FACE rings
2- Ambient CO_2 in Mini-FACE rings
3- Elevated N (5 g N /m^2 /yr)
4- Ambient N
Main findings:
Contrary to expectations, elevated CO_2 did not significantly affect *Sphagnum* growth, except for the Dutch site where *Sphagnum* length growth was 33% higher under elevated CO_2. Increased N deposition reduced *Sphagnum* mass growth, because it increased the cover of vascular plants and the tall moss *Polytrichum strictum* in NL and CH. The sites in SE and FIN had lower ambient N deposition and showed no effect of increasing N deposition on the competitive relationships between bog plant species.

CH_4 emissions increased with 4, 15, 20 and 33% in SE, FIN, CH and NL under elevated CO_2. There was no effect of increased N deposition on CH_4 release. In a lab experiment significantly greater CH_4 release was observed from cores with vascular species possessing aerenchyma than from cores dominated by *Sphagnum* spp. The isotopic composition of CH_4 emitted from *Sphagnum* cores was significantly more enriched in ^{13}C than that emitted from cores with vascular plants. When the water table was at the moss surface CH_4 oxidation was minimal or inhibited

The CO_2 treatment had no effect on the C/N ratio of *Sphagnum* and major vascular plants, except for the Swiss site where the C/N ratio of *Sphagnum* significantly increased. Under elevated N deposition the C/N ratio of *Sphagnum* decreased significantly in FI, SW, NL and CH. The elevated N effect on the C/N ratio of vascular plants was not significant, except for one species in FI and one species in NL. Water chemical data collected during the 1997 growing season suggested P limited growing conditions for part of the season.
Geographic region: Bogs in Sweden, Finland, England, The Netherlands, Switzerland
Partners: Dept. of Biology, University of Joensuu, FIN; Dept. of Forest Ecology, University of Helsinki, FIN; Dept. of Plant Ecology, Lund University, SE; Dept. of Ecological Botany, Upsala University, SE; Dept. of Environmental Biology, University of Sheffield, UK; Dept. of Soil Science and Geology, Wageningen Agricultural University, NL; Dept. of Nature conservation and plant ecology, Wageningen Agricultural University, NL; Rijksuniversiteit Groningen, NL; Lab. for Plant Ecology and Phytosociology, University of Neuchâtel, CH
Website: /
main findings in Berendse, F., Breemen, N.v., Rydin, H., Buttler, A., Heijmans, M.M.P.D., Hoosbeek, M.R., Lee, J.A., Mitchell, E., Saarinen, T., Vasander, H. & Wallen, B. 2001. Raised atmospheric CO2 levels and increased N deposition cause shifts in plant species composition and production in Sphagnum bogs. Glob Change Biol 7: 591-598.

Name: CarboEurope-IP
Period: 2000-2008
Aim: CarboEurope-IP aims to understand and quantify the present terrestrial carbon balance of Europe and the associated uncertainty at local, regional and continental scale. This means to (1) determine the European carbon balance with its spatial and temporal patterns, (2) understand the controlling processes and mechanisms of carbon cycling in European ecosystems and how these are affected by climate change and variability and human management, (3) develop an observation system to detect changes in atmospheric CO2 concentrations and ecosystem carbon stocks related to the European commitments under the Kyoto Protocol.
Method: The project is founded on a network of more than 30 European test sites for in situ measurement of carbon and energy fluxes in boreal, temperate and Mediterranean forests. The measurements cover the whole suite of available techniques at all relevant scales. These are soil carbon and biomass studies, continuous measurements of carbon, nitrogen, energy and water fluxes at forest stand scale, as well as an aircraft monitoring programme of CO_2 and atmospheric tracers on regional and European scale in order to determine the interplay of anthropogenic emissions and ecosystem behaviour.

Models are used to integrate individual measurements. Joint efforts are taken to develop techniques for upscaling ecosystem models from stand and ecosystem level to landscape (bottom-up approach) and for downscaling results of inverse atmospheric modeling from the continental and regional level to ecosystems (top-down approach) in order to verify the various approaches and to constrain the CO_2 budget at the local, regional, national and continental level. Furthermore, atmospheric mesoscale models will be coupled to terrestrial ecosystem models to bridge the existing gap at regional level.
Main findings: ongoing, see website
Geographic region: Europe: forest, grasslands, crops
Partners: 61 research centers from 17 European countries, Max-Planck-Institute for Biogeochemistry, Germany, is project co-ordinator
Website: http://www.carboeurope.org

Name: GCP: Global Carbon Project
Period: 2001-2011
Aim: The Global Carbon Project was formed to assist the international science community to establish a common, mutually agreed knowledge base supporting policy debate and action to slow the rate of increase of greenhouse gases in the atmosphere. The scientific goal of the Global Carbon Project is to develop a complete picture of the global carbon cycle, including both its biophysical and human dimensions together with the interactions and feedbacks between them.
Methods and intended results: *Three science themes:*
(1) Patterns and Variability: Quantify current geographical and temporal distributions
of the major carbon pools and fluxes through compiling new sectorial and regional budgets and developing model data fusion.
(2) Processes and Interactions: Promote new research and synthesis to increase understanding of the controls on natural and human-driven sources and sinks of carbon, and the spatially explicit links between causes and effects, with particular emphasis on understanding the interactions among mechanisms and feedbacks among components of the coupled carbon-climate-human system
(3) Management of the carbon cycle: Identify and quantify points for intervention and windows of opportunity in the carbon cycle to steer the evolution of the coupled carbon-climate-human system.
Geographic region: worldwide
Partners: Earth System Science Partnership (ESSP); CSIRO Marine and Atmospheric Research, Australia; National Institute of Environmental Studies
Japan; Institute of Geographic Sciences and Natural Resource Research, China; Max-Planck-Institute for Biogeochemistry, Germany; Carbon Cycle Science Program Office, USA
Website: http://www.globalcarbonproject.org

Name: Fluxnet –Canada
Period: 2002-
Aim: Fluxnet-Canada is a national research network bringing together university and government scientists to study the influence of climate and disturbance on carbon cycling in Canadian forest and peatland ecosystems.
Method: The network currently has 22 sites making continuous measurements of carbon, water, and energy exchanges between ecosystems and the atmosphere using the eddy covariance flux measurement technique. Non-continuous measurements are also being made at 7 additional sites during the growing season. The network maintains a publicly-accessible database, containing flux and associated ecological data, which is updated on a regular basis.
Main findings: Carbon flux data from an open bog in eastern Ontario showed that over a several year period, the bog absorbed an average of 1.5 tonnes of CO_2 per hectare annually. Meanwhile, two sites in Alberta highlighted the importance of nutrient status on carbon accumulation in peatlands. To the surprise of the research community, carbon uptake in a nutrient-poor fen was three times higher than the uptake in nutrient-rich fen during the same six-month growing season.

After six years of continuous measurements, the Mer Bleue bog in eastern Ontario was a C sink in all but the driest years. Inter-annual variation in NEP was mostly due to reduced late summer C uptake during droughts. Early soil freeze and late snowcover were associated with larger C losses during winter. The timing of autumn appears to be a key factor determining the strength of the C sink, as opposed to the timing of spring for forests. Over the six years, the C sink was 253 g m^{-2}. If this value is representative of peatlands across Canada, then it implies that peatlands are important to Canada's national C budget and are sensitive to inter-annual variability in climate. Around 10% of NEE at Mer Bleue is lost as DOC and DIC, while CH_4 represents only a small loss. If loss of C in water is not accounted for, the C sink in peatlands would be overestimated. It is also a large enough component to determine whether a peatland is a sink or source for a given year.

Geographic region: Canada
Partners: Canadian Forest Service; Canada Centre for Remote Sensing; University of British Columbia; University of Victoria; University of Lethbridge; University of Alberta; University of Saskatchewan; McMaster University; University of Toronto; Queen's University; Trent University; McGill University; Université de Montréal; Université Laval;the University of New Brunswick; Alberta Environment; the Ministère des ressources naturelles du Québec; the Ontario Forest Research Institute and the Research Branch of the BC Ministry of Forests.
Website: http://www.fluxnet-canada.ca

Name: Integrated Management of Peatlands for Biodiversity and Climate Change
Period: 2003-2006
Aim: The objective of the project is to assess peatland management practices and the associated impacts on biodiversity and climate change. The project aims to provide recommendations on how peatlands could be managed in the future to maintain the role of peatlands as carbon stores and sinks, while at the same time conserving the biodiversity and mitigating climate change.
Method: The Project has six components. They are (1) Global Technical Component, (2) Country Study in Russia, (3) Country Study in Indonesia
(4) Country Study in China, (5) Regional Component for South East Asia, (6) Global Outreach/ Capacity Building and Linkage to Environmental Conventions
Under each component are activities which will lead to the production of an up-to-date status report of scientific knowledge and improved understanding of management issues affecting peatlands in the selected countries
Main findings: Publication of several leaflets, posters and reports. PEAT-Portal and SEA-Peat Network established (www.peat-portal.net); Indo-Peat incorporated into PEAT-Portal (www.indo-peat.net); Training manual on the PEAT-Portal.
Geographic region: Russia, Indonesia, China, South East Asia
Partners: Wetlands International; Global Environment Centre;
Website: http://www.peat-portal.net

Name: CASUS: Carbon Balance of Subarctic Western Siberia
Period: 2004-2007
Aim: Estimation of the annual carbon balance of Subarctic Western Siberia in relation to changing climate
Method:
(1) Analysis and classification of the peatland ecosystems by vegetation, hydrology, trophic conditions and permafrost appearances;
(2) Analysis of carbon storage by subrecent (last 200 year) peat accumulation in selected key areas;
(3) Measurement of CO_2 and CH_4 fluxes of functionally different terrestrial wetland ecosystems (mires) and aquatic systems (small rivers and lakes);
(4) Measurement of carbon storage by net primary biomass production (NPP) of the main mire types within the selected key areas;
(5) Development of a spatial database (Geographical Information System) – the "Peatland GIS" – which include properties and location of mire types;
(6) Estimation of the area flux (key area) of CO_2 and CH_4 with GIS techniques;
(7) Estimation of atmospheric (troposphere) concentration of CO_2 and CH_4 over the northern part of Western Siberia by remote sensing techniques using hyperspectral satellite images;
(8) Development of a 2D modelling tool based on cellular automates for the prediction of carbon gas transport and gas concentrations in the lower atmosphere using surface flux measurements;
(9) Comparative analysis between area weighted carbon gas concentrations and fluxes measured with surface measurements and the outcome of carbon gas concentrations with remote sensing techniques;
(10) Prediction of carbon balances using IPCC scenarios of climate change.
Main findings: To quantify carbon exchange fluxes in subarctic peatlands, new techniques and software for monitoring of methane using high-resolution emission spectra of atmosphere observed from space have been developed. Neural network technique is promising for instantaneous retrieval of methane content in atmosphere from huge amount of data provided by AIRS/AQUA sensor. IMG/ADEOS data, FIRE-ARMS forward simulations and retrieval of methane profiles from IMG spectra on the base of constrained optimization were used for the purposes of validation of the neural network techniques applied to AIRS/AQUA data. Preliminary maps of methane content in atmosphere of the permafrost boundary zone in Western Siberia are obtained from AIRS/AQUA data.
Geographic region: Western Siberia
Partners: Physical Geography Research Institute, Utrecht University,The Netherlands; University of Kuopio, Finland ; Ural State University, Russia; Tomsk Research Institute of Biology and Biophysics, Russia; Institute of Soil Science and Agrochemistry, Russia; Ugra Research Institute of Information Technology
Website: http://www.geog.uu.nl/fg/casus/Welcome.html

Name: CARBOPEAT

Period: 2007-
Aim: Utilizing and synergizing results from 3 INCO research projects, CARBOPEAT promotes enhanced understanding and awareness of carbon-climate-human interactions in tropical peatlands, focusing on vulnerabilities of and risks to their carbon pools and mitigation to reduce greenhouse gas (GHG) emissions, through 'wise use' of natural resources.
The CARBOPEAT objectives are to:
(1) Integrate data from EU projects with those of other research teams to determine more precisely the magnitude of the tropical peat carbon store;
(2) Establish an international expert network to address global and regional issues of tropical peatland carbon balance;
(3) Share and diffuse expertise on carbon-climate-human interactions of tropical peatlands through working groups and workshops and integrate with information on boreal and temperate peatlands;
(4) Investigate cost effective ways to manage peatland carbon stocks, and explore potential carbon offset and trading mechanisms;
(5) Establish platforms for information dissemination, strategy implementation and policy guidance targeted at International Conventions, industry, EU and DC Governments.
Methods and Main findings: ongoing, see website
Geographic region: tropical peatlands
Partners: University of Leicester, UK; Universiti Gadjah Mada, Indonesia; Universiti Sarawak Malaysia; Wageningen University & Research Centre (Alterra), The Netherlands; University of Helsinki, Finland; University of Nottingham, UK; University of Can Tho, Vietnam
Website: http://www.geog.le.ac.uk/staff/sep5/tropeat/carbopeat/index.html

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