Program and Abstracts

Peat Carbon Accumulation on Earth: An Integrated and Global Perspective

— C-PEAT Launch and Integration Workshop

Compiled and Edited by

Zicheng Yu (Lehigh University, USA)

Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York, USA

11-13 October 2015

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C-PEAT Workshop: Peats On Earth Through Time

Overarching Questions and Focuses:

1. Controls on the formation, persistence and disappearance of peats under different climate and environmental conditions;
2. Changes in peat accumulation rates and C stocks during Earth history; and
3. Future trajectories of peat extent and C stocks, including fate of existing peats.

Agenda and Program

Participants arrival and check-in on Saturday (10 October)

Day 1 (Sunday, 11 October 2015)

8:30-8:40	Jon Nichols	Welcome and logistics
8:40-9:00	Zicheng Yu	Introduction and workshop objectives
	Session I. Peatland processes (Chair: Zicheng Yu)	
9:00-9:15	Nigel Roulet	Peatlands as complex system
9:15-9:30	Tim Moore	Stoichiometry of peat formation
9:30-9:45	Charlie Harvey	Geomorphology, hydrology & dynamics of tropical peatlands
9:45-10:00	René Dommain	Peat accumulation in tropical swamp forests
10:00-10:15	Juan Benavides	Peat initiation following glacier retreat in Colombia Andes
10:15-10:30	Thomas Kleinen	Simulating global peatlands since the LGM
10:30-10:45	Discussion	
10:45-11:10	Break	
	Session II. Peats through Earth's history (Chair: Jon Nichols)	
11:10-11:25	Stephen Greb	Peatlands through time
11:25-11:40	Chris Williams	High-latitude Paleogene and Neogene peat forming forests
11:40-11:55	N. Rybczynski (Yu)	Pliocene peats of Canadian High Arctic
11:55-12:10	Sarah Finkelstein	Pleistocene peatlands of the Hudson Bay Lowlands
12:10-12:25	David Large	Implications of applying modern C rates to pre-Holocene systems
12:25-12:40	Victor Brovkin	Modelling peat contribution to glacial CO_2 cycles
12:40-13:00	Discussion	
13:00-14:00	**Lunch**	
	Session III. Peats from around the world (Chair: Dave Beilman)	
14:00-14:15	Atte Korhola	Circum-Arctic peat initiation and expansion
14:15-14:30	Ian Lawson	Long-term development of western Amazonian peatlands
14:30-14:40	Geoffrey Hope	Peats of New Guinea
14:40-14:50	John Hribljan	Peatland C stocks & accumulation rates in the tropical Andes
14:50-15:00	Karsten Schittek	High-altitude peatlands in the central Andes
15:00-15:10	Tom Roland	*Sphagnum* peatlands in southern South America
15:10-15:20	Kate Dwire	Controls on peat accumulation in western US mountain fens
15:20-15:30	Judith Drexler	Tidal peatlands of the Sacramento-San Joaquin Delta, CA
15:30-15:40	Discussion	
15:40-16:00	Break	

	Session IV. Topical and regional syntheses (Chair: Dan Charman)	
16:00-16:20	Julie Loisel & James Holmquist	Fen-to-bog transition across the northern peatland domain
16:20-16:35	Claire Treat	Pan-arctic synthesis of peatland permafrost aggradation
16:35-16:45	Len Martin	Peat-forming environments in eastern Australia
16:45-16:55	David Large	Deep-time/pre-Holocene peats (C-PEAT Subgroup)
16:55-17:05	Claire Treat & Jon Stelling	Buried peats: data compilation/synthesis (C-PEAT SG)
17:05-17:15	Dave Beilman	Tropical peats synthesis (C-PEAT SG)
17:15-17:25	Julie Loisel	Peatland lateral expansion: data and process (C-PEAT SG)
17:25-17:30	Discussion	
18:00	**BBQ Dinner**	

<u>Day 2 (Monday, 12 October)</u>

	Session V. Issues related to future trajectories (Chair: Nigel Roulet)	
8:30-8:45	Jeffrey Chanton	The stability of the peatland carbon stores
8:45-9:00	Miriam Jones	Carbon dynamics in boreal peat plateaus following permafrost thaw
9:00-9:10	Lydia Cole	Long-term disturbance & resilience of tropical peat swamp forests
9:10-9:20	Elaine Matthews	Natural wetlands and the global methane cycle
9:20-9:30	Tim Daley	Carbon-climate feedbacks and implications for geo-engineering
9:30-9:40	Steve Frolking	Tropical peat C stocks in the 21st century: mitigation implications
9:40-10:00	Discussion	

10:00-11:30 **Poster Session and Break**

11:30-12:00 **Plenary discussion of plan and agenda for Day 2 and Day 3**

12:00-13:00 **Breakout groups discussion & analysis**

4 C-PEAT Topical Subgroups as breakout groups:

(1) Deep-time/pre-Holocene peats
(2) Buried peats: data compilation/synthesis
(3) Tropical peats synthesis
(4) Peatland lateral expansion: data and process

13:00-14:00 **Lunch**

14:00-14:30 Breakout group reports to plenary session

14:30-15:00 **Plenary discussion on how to address overarching questions**

- critical controls/limiting factors of peat accumulation
- estimates of peat C stocks in Earth history: order of magnitude accuracy?
- future fate and trajectory of peat C stocks

15:00-16:30 **4-5 Breakout groups to discuss these same questions/Break**

16:30-17:00 Reports of breakout groups to plenary session

17:00-17:30 Plenary discussion on progress/consensus and plan for Day 3

17:30? **Dinner**

<u>Day 3 (Tuesday, 13 October) morning - detail TBD</u>

Discussions on products & deliverable and post-workshop plan
Participant departure after lunch

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Abstracts for Oral Presentations

Session I. Peatland Processes

Peatlands as complex system: challenge to interpreting the past and projecting the future

Nigel Roulet
McGill University, Montreal, Quebec, Canada

Peatlands exist because of unique set of circumstances at their initiation that change as they develop - in many cases a set of negative feedbacks emerge between the production and decomposition of organic matter and the physical, biogeochemical and ecological processes. The existence of weaker to stronger self-regulation via negative feedbacks has implications for interpreting the past and projecting the future. The extent of self-regulation will filter a signal recorded in a peat profile making the long-term record a combination of the direct response to the forcing (allogenic) and the system's readjustment (autogenic) over an unknown time scale (e.g. Frolking et al. 2010). Projecting how peatlands have responded to climate variability, or might respond to future climate change requires understanding the extent of the range of control over which autogenesis operates (e.g. Hilbert et al., 2000) relative to the magnitude and rate of climate change. Theoretical approaches of peatland structure and function are developing (e.g. Belyea et al. 2006, Eppinga et al. 2009, Morris et al. 2011) and they provide some insight on how and why self-regulation emerges. However, while interpreting empirical evidence is not divorced from the theory of development an investigator adopts, empirical observations suggest certain characteristics of possible emergent properties that some peatlands show in their carbon balances (Roulet et al. 2007, Nilsson et al. 2008), the relationships between water storage – microtopographic features (Wilson et al., in review), and how peatlands respond to catastrophic shifts (Malhotra et al, in prep). To be able to interpret the past and project the future (e.g. Wu and Roulet, 2014) the complexity of peatlands has be incorporated into our thinking to interpret the past and project the future.

References:

Belyea, L. R. and A. J. Baird (2006). *Ecological Monographs* **76**: 299-322.
Eppinga, M. B., et al. (2009). *American Naturalist* **173**(6): 803-818.
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Morris, P. J., et al. (2011). *Journal of Ecology* **99**(5): 1190-1201.
Nilsson, M., J. et al. (2008). *Global Change Biology* **14**: 2317-2332.
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Wilson, P., et al. (in review). *Ecohydrology*
Wu, J. and N. T. Roulet (2014). *Global Biogeochemical Cycles* **28**(10): 1005-1024.

Stoichiometry of peat formation

Tim Moore
McGill University, Montreal, Quebec, Canada

I examine patterns of nutrient stoichiometry (C:N:P:Ca:Mg:K) from vegetation through to peat, based on data from the Mer Bleue peatland and an extensive data base of Ontario peatlands. At Mer Bleue, stoichiometries in plant tissues vary, but generally follow plant functional types. During senescence, there is a fairly consistent decrease in nutrient concentration, and thus increase in C:nutrient ratios during the production of litter. At Mer Bleue, average C:N:P ratios changed from 794:17:1 in the foliar tissues to 911:10:1 in litter and 1285:32:1 in acrotelm peat. The resulting long-term apparent rates of C, N and P accumulation were 29:5 g C, 0:87 g N and 0:017 g P m^{-2} yr^{-1}, respectively, with a significant correlation among the accumulation rates of C, N and P.

The data from 400 Ontario peat profiles (and 1600 individual peat samples) represent bogs, fens, and swamps. Although initial C:N ratios vary (e.g. 35:1 in fens and 50:1 in bogs) the overall pattern is a loss of N, relative to C, resulting in a convergence to 22:1 and 29:1 in peat deeper than 50 cm. In contrast, in all peat types, the C:P ratio rises from vegetation and litter (500:1 to 1300:1) to 1500:1 to 2000:1 in the middle part of the peat profile. Ratios of C to Ca, Mg, and K vary with peatland type (generally bogs > fens and swamps). Most of these stoichiometric changes occur in the early stages of organic matter decomposition (Von Post < 4). We estimate that ~18 Pg of N has been stored in northern peatlands since deglaciation, reflecting high N accumulation rates (~0.8 g m^{-2} yr^{-1}), whereas P accumulation is small (~0.3 Pg, ~0.016 g m^{-2} yr^{-1}), with P being quickly recycled in the surface layers.

Issues that arise include:

- The mechanisms whereby P is ‘mined’ from the upper layer of peats;
- Whether the stoichiometric patterns observed in these northern peatlands are repeated elsewhere and in older, warmer peatlands;
- The effect of increased nutrient availability on plant production and on nutrient stoichiometry: the strength of homeostasis in peatland plants;
- Evidence of changes in peat accumulation and stoichiometry derived from changes in nutrient input: I briefly examine the Florida Everglades example of Glaser et al. (2013) in which a decrease in aeolian P deposition appears to have changed peat accumulation and stoichiometry.

References:

Glaser P.H., B.C.S. Hansen, J.J. Donovan, T.J. Givnish, C.A. Stricker and J.C. Voline 2013. Holocene dynamics of the Florida Everglades with respect to climate, dustfall, and tropical storms. *PNAS* **110**: 17211–17216.

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Wang, M., T.R. Moore, J. Talbot and P.J.H. Richard 2014. The cascade of C:N:P stoichiometry in an ombrotrophic peatland: from plants to peat. *Environmental Research Letters* **9**:024003.

Wang, M., M.T. Murphy and T.R. Moore 2014. Nutrient resorption of two evergreen shrubs in response to long-term fertilization in an ombrotrophic peatland. *Oecologia* **174**: 365–377.

Geomorphology, hydrology and dynamics of tropical peatlands

Charlie Harvey
Massachusetts Institute of Technology, Cambridge, MA, USA

The growth of tropical peatlands over the last 10,000 years has sequestered over 320 gigatonnes of carbon dioxide and their subsidence is now re-emitting that carbon at rates of hundreds of megatonnes per year because of human disturbance. Because peat is mostly organic carbon, a description of the growth and subsidence of tropical peat domes also quantifies fluxes of carbon dioxide. Here we show that tropical peatlands evolve towards a stable geomorphology defined by a single shape parameter that is calculable from the local climate and peat properties. We verified our theory against a comprehensive data set of peat elevation maps, radiocarbon dates, and time series of throughfall and water table elevation. The data and the theory agree that conformance of peatlands to their ultimate shape starts from the edges of peat domes where they are bounded by rivers, and that the carbon flux accompanying their growth is proportionate to the area of the growing interior of the dome. With this new model, we predict how tropical peatland carbon storage and fluxes are controlled by changes in climate, sea level, and drainage networks. Simulations of peatland dynamics show that projected increases in seasonal rainfall fluctuations may increase carbon dioxide emissions from tropical peatlands, but increased net rainfall may compete to drive peat accumulation. Where peatlands are artificially drained, aerobic degradation dominates other processes. The link between hydrologic and geomorphic processes developed here fills a gap in models that attempt to couple carbon fluxes and climate by providing the necessary quantitative framework for studying past and future climates in tropical peatlands.

Peat accumulation in tropical swamp forests: the influence of forest dynamics, disturbance, and tip-up pools

René Dommain[1,2], Alexander R. Cobb[3], Hans Joosten[2], Paul H. Glaser[4], Amy F. L. Chua[3,5], Laure Gandois[3,6,7], Fuu-Ming Kai[3], Anders Noren[8], Kamariah A. Salim[9], N. Salihah H. Su'ut[10], Charles F. Harvey[3,11]

[1]National Museum of Natural History, Smithsonian Institution, Washington, USA, [2]Institute of Botany and Landscape Ecology, University of Greifswald, Germany, [3]Singapore-MIT Alliance for Research and Technology, Singapore, [4]Department of Earth Sciences, University of Minnesota, Minneapolis, USA, [5]Vale Malaysia Minerals Sdn Bhd, Perak, Malaysia, [6]Université de Toulouse: UPS, INP, EcoLab, ENSAT, Castanet-Tolosan, France, [7]CNRS, EcoLab, Castanet-Tolosan, France, [8]National Lacustrine Core Facility, University of Minnesota, Minneapolis, USA, [9]Biology Programme, Universiti Brunei Darussalam, Bandar Seri Begawan, Brunei Darussalam, [10]Brunei Darussalam Heart of Borneo Centre, Bandar Seri Begawan, Brunei Darussalam, [11] Massachusetts Institute of Technology, Parsons Laboratory, Cambridge, USA

Peat accumulation in the warm and wet tropical lowlands is largely restricted to forested ecosystems. However, the mechanisms of peat accumulation in these tropical lowland forests are poorly understood and systematic paleoecological studies of Late Quaternary tropical peat deposits are still rare. In Southeast Asia peat swamp forests are dominated by trees of the family Dipterocarpaceae. In northwest Borneo the up to 70 m tall dipterocarp *Shorea albida* was until very recently covering large tracts of peatland in monodominant stands. We studied the vegetation dynamics, peat deposits and peat accumulation rates of an intact *Shorea albida* peat swamp forest in Brunei by means of field surveys, peat coring, paleobotanical analyses, radiocarbon dating, aerial photographs, and an analytical peat dome growth model. The tall *Shorea albida* forests experience regular disturbance by wind throw and lightning, which causes the trees to fall and up-root. Uprooting leads to the excavation of over one meter deep and around 8 m wide holes, called tip-up pools. These flooded tip-up pools provide accommodation space for the burial of above-ground litterfall (leaves, twigs, branches). In addition, tip-up pools are invaded by semi-aquatic herbaceous plants (Pandanaceae, Araceae, Hanguanaceae), which allocate belowground biomass to the pool sediments. Tip-up pools completely fill with organic sediments within 100-200 years as a result of a combination of these two processes. The pool deposits can therefore be dominated by herbaceous plant litter in contrast to adjacent wood-rich peat, which formed under a forest floor. Simulating peat dome growth over thousands of years with modern rates of tip-up pool formation indicates that more than 50% of the peat deposits under *Shorea albida* forests could be derived from infilled pools. Importantly, tip-up pools create local discontinuities in the peat strata and thus complicate traditional paleoecological and chronostratigraphic approaches.

Peat initiation following glacier retreat in Colombia Andes

Juan C. Benavides
Department of Forestry Sciences, National University of Colombia-Medellin, Colombia

The rates of glacier retreat in the Tropical Andes has increased steadily during the last 25 years and currently stands at 20 meters in elevation each year. Glacier erosion favors the development of topographical depressions that allow the development of wetlands at high elevations. Cushion plants are ecological engineers able to accumulate peat at the upper limit of any vegetation and can invade rapidly recent deglaciated terrain. Our study focuses on understanding the process of peat initiation after glacier retreat and the lag between glacier retreat, moraine formation and peat initiation. The study site we have sampled is the Nevados National Park (6°N, 75°W) in Colombia (South America) at elevations between 4200 and 4700 m. We have dates (3He) of the exposure time of 10 moraines on the North side of the Santa Isabel peak and have total depths of 40 peatlands located between the moraines. We measured peat accumulated and used the moraine date as the maximum age the peat could have. We found that peat has accumulated at a rate of 0.08 cm*yr^{-1} during the last 1200 years. However the rate of peat accumulation is approximately of 1.1 cm*yr^{-1} for peat initiated at least 400 ybp. The intercept of the line indicates a lag of approximately 21 years between moraine exposure and the onset of peat accumulation. Bulk densities from cushion plants are relatively constant with depth with values between 0.09 and 0.12 g cm $^{-3}$. However a trend of relatively higher values of bulk density were observed at older peatlands. Organic matter accumulation on the visited peatlands follows a clear linear trend with a rate of 0.01 kg m^{-2} yr^{-1}. The northern Andes is a relatively young mountain system with steep slopes and deep valleys. Peatlands are usually small and range from 0.5 to 2 ha rarely larger; however, peatlands are frequent and they develop in almost every site with some topographic concavity. Basal dates of the peat and detailed bulk density analysis are pending for the collected samples to have a more detailed picture of the processes given origin and the recent dynamics of cushion dominated peatlands in tropical high elevations.

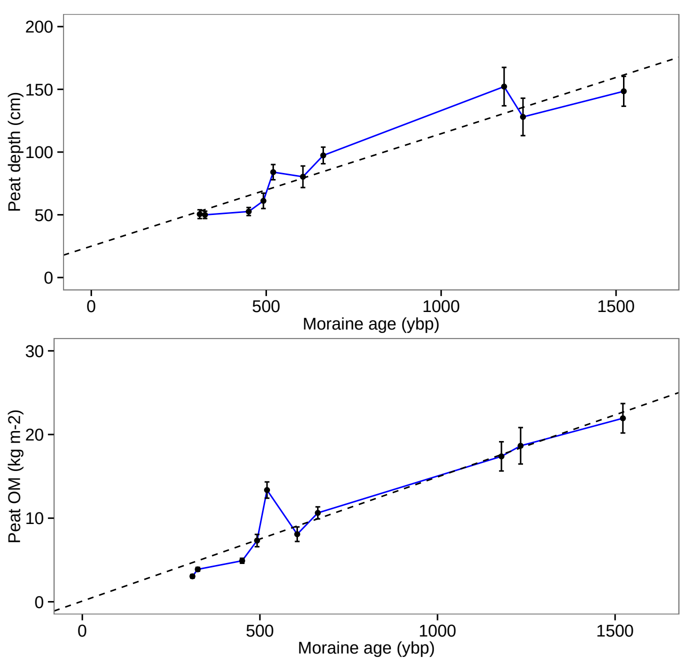

Figure 1. (top) linear accumulation of peat compared to the age of the moraine blocking the outlet of the peat system (regression line adj-rsq=0.77). (bottom) organic matter accumulated in the sampled peatlands compared to the age of the moraine blocking the outlet of the peat system (regression line adj-rsq=0.80).

Global peatlands since the LGM: Model results and needs for improvement

Thomas Kleinen
Max Planck Institute for Meteorology, Hamburg, Germany

The evolution of peatlands since the last glacial is relatively well known, especially for the boreal latitudes of the northern hemisphere, though slightly less for the tropics. What is substantially less clear are the mechanisms that led to this evolution, and therefore representing this evolution in global models remains challenging. I will discuss the approaches taken in global peat modelling, highlighting some simplifications and assumptions that are made in the representation of peatlands in models to obtain a reasonable distribution and extent of peatlands. In both versions of LPJ that determine peatland extent and peat accumulation, peatlands are represented as a "peat-fog", i.e. a mixture of fen and bog. In order to improve on this, we need to develop a better understanding peat-bog dynamics, especially the drivers of changes in horizontal extent. I will discuss needs for improvements, both in theoretical understanding of peatland dynamics and in measurements needed to constrain peatland models.

Session II. Peats Through Earth's History

Peatlands through time

Stephen F. Greb
Kentucky Geological Survey, University of Kentucky, USA

Coal is the geologic record of deep-time peats. Not all peats that have ever accumulated are preserved, but each coal bed is a record of an ancient peat. The global position, distribution, extent, and many characteristics of coals, and therefore ancient peatlands, have changed significantly through time in response to changes in botany, climate, sea level (often in Milankovitch bands) and tectonics. The oldest coal beds from the Middle Devonian of China and Russia represent thin, patchy psilopsid (primitive vascular plant) peats. Later Devonian and Mississippian peats remain relatively thin and spatially restricted but become dominated by proto-ferns, ferns and lycopods. Widespread peatlands were established by the Pennsylvanian Period. Eur-American, Pennsylvanian-age peatlands were tropical and dominated by lycopods, ferns, and tree ferns. Some may have rivaled modern high-latitude peatlands in their extent. In the Permian, peatlands became more common and extensive at higher latitudes than tropical latitudes. Permian Gondwana peatlands were cool-temperate to cold-climate mires, dominated by *Glossopteris* flora, which included ferns, gymnosperms, and bryophytes. Late Permian coals of Australia and Antarctica provide evidence of the oldest permafrost peats. End-Permian perturbations led to a "coal gap" in the early Triassic, with no recorded peatlands globally. Peatlands recovered through the Late Triassic into the Jurassic. Cretaceous coal beds are widely distributed and ranged from tropical-equatorial to high-latitude cooler climates. Although angiosperms evolved in the Cretaceous Period, Cretaceous peatlands remained dominated by gymnosperms with subsidiary ferns. Cenozoic Era peatlands are also globally distributed, and include the thickest coals known; several exceeding 50 m in thickness. From the Paleogene Period to the present, peatlands have increased in diversity; especially relative to angiosperm floral partitioning, although bulk biomass in many Cenozoic peatlands remained dominated by gymnosperms and bryophytes.

High-latitude Paleogene and Neogene peat forming forests

Chris Williams
Department of Earth & Environment, Franklin and Marshall College, Lancaster, PA, USA

This presentation will outline the nature of Paleogene and Neogene peat forming ecosystems that thrived at polar latitudes during the most recent hothouse period of Earth history. At the highest latitudes, seasonally deciduous conifer forests figured prominently in the peat forming wetlands of the Paleogene. In contrast, by the late Miocene and early Pliocene, evergreen conifers became important in these swamps. The role that both types of forested wetlands played in regulating the carbon balance of this unique peat forming will be explored.

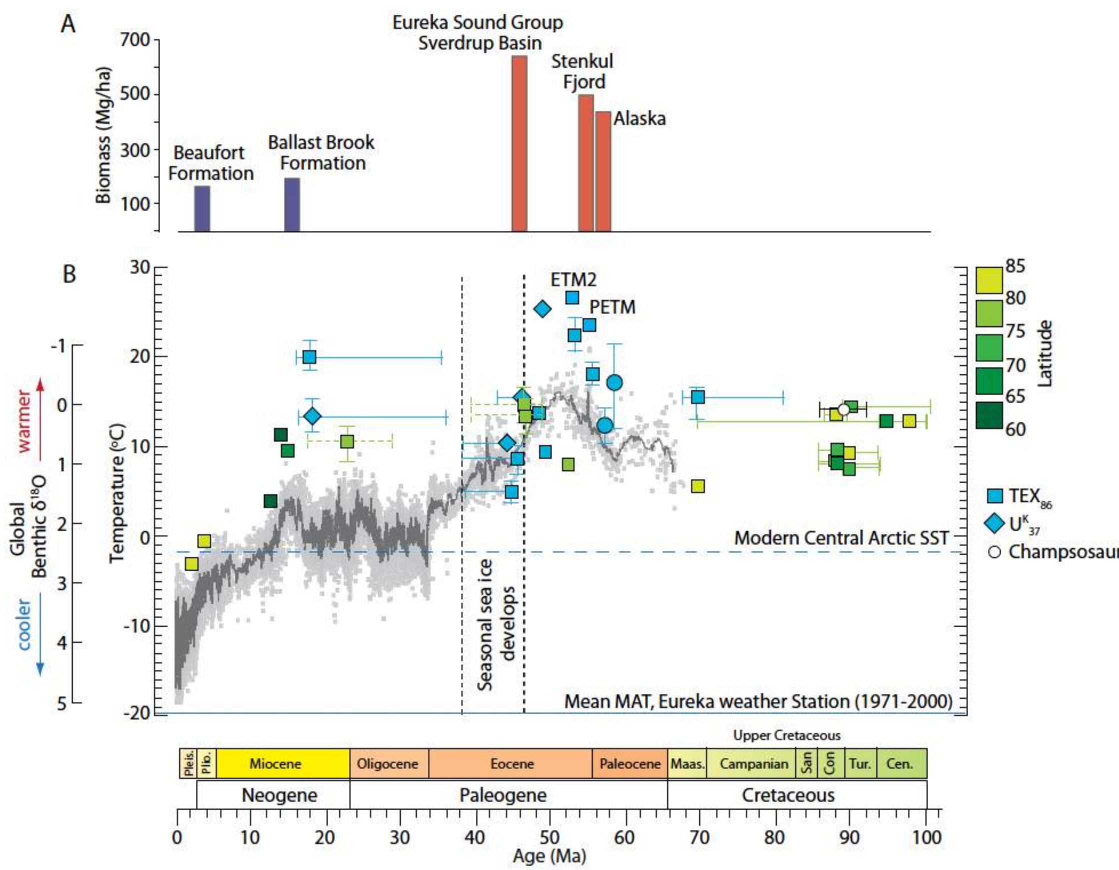

Figure Caption:
Summary paleoclimate data from the Arctic. (A) Biomass estimates of fossilized forests from well-studied formations in the Canadian Arctic Archipelago and Alaska. (B) Compiled air and sea surface temperatures from published studies of terrestrial (green) and marine (blue) records. Terrestrial data are color coded by paleolatitude. Temperatures are overlain on the global benthic δ18O curve of Zachos et al., (2008), illustrating global climate trends from the warmer Paleogene greenhouse world, to the cooler Neogene icehouse world.
Figure modified from: O'Regan, M., C.J. Williams, K.E. Frey, and M. Jakobsson. 2011. A synthesis of the long-term paleoclimatic evolution of the Arctic. *Oceanography*, **24**(3):66–80.

Pliocene peats of Canadian High Arctic

Natalia Rybczynski
Canadian Museum of Nature, Ottawa, Ontario, Canada

Pliocene-aged peats are known from sites located across the Canadian Arctic Archipelago (CAA). Research on these peats began in the 1960s as part of the field efforts of the Geological Survey of Canada. Interest in these deposits has intensified and is greatly aided by emerging techniques and integrative and collaborative approaches (paleoclimatology, paleobiology, geochronology, etc.). Field work planning is in the works for a 2016 field season in the eastern CAA.

The preservation of materials from the Pliocene high Arctic deposits is remarkable. For example recent research has shown that fossil bone preserves collagen. The preservation of collagen allowed for the recent identification of a giant high Arctic camel from fragmentary remains (Rybczynski et al., 2013). Similarly the fossil plant material is equally well preserved, with wood and leaves appearing essentially mummified.

The most well studied Pliocene peat deposit is from the Beaver Pond site on west central Ellesmere Island. The fossil evidence suggests that the peat is the result of a rich fen deposit that was surrounded by a larch-dominated boreal type forest. Paleoclimate estimates using a multi proxy approach suggests that the mean annual temperature at the Beaver Pond site in the Pliocene was roughly 0°, about 19°C warmer than today (Ballantyne et al., 2010). This paleoclimate reconstruction is consistent with evidence indicating that in the Neogene fossil forests extended to the Arctic Ocean. Such evidence of a warm Arctic has drawn the attention of paleoclimate researchers who are interested in using Neogene fossil records for developing and testing models of a warm earth (i.e. "historical analogues" for future warming).
In an attempt to begin to further characterize the beaver pond site peat deposit we used estimates of carbon accumulation rates from modern fens (Makila, 2001; Makila & Moisanen, 2007; Yu et al. 2006) to infer the duration for the fossil peat deposit. From these modern data and assuming that the rates of carbon accumulation are similar in the Holocene and Pliocene, we estimate that the thickness of the beaver pond site peat (~2.4 m) may represent roughly 49,000 ± 12,000 years of growth. If this estimation is correct it suggests a protracted episode of peatland formation during the Pliocene, with implications for High Arctic carbon cycling and climate processes.

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Yu, Z.C. 2006. Holocene carbon accumulation of fen peatlands in boreal western Canada: A complex ecosystem response to climate variation and disturbance. *Ecosystems,* **9**(8): 1278-1288.

Pleistocene peatlands of the Hudson Bay Lowlands, Northern Canada

Finkelstein SA[1], Dalton ASR[1], Forman SL[2], Barnett PJ[3]
[1] University of Toronto, Toronto, ON, Canada; [2] Baylor University, Waco, TX, USA; [3] Laurentian University, Sudbury, ON. Canada

The Hudson Bay Lowland (HBL) is a low relief plane extending ~372,000 km^2 from the southern and western shores of James and Hudson Bays to the margins of the Canadian Shield in Northern Quebec, Ontario and Manitoba, Canada (latitude: ~ 50-60°N). An extensive peatland has developed in this region during the Holocene, storing ~30 Pg C in a mosaic of bogs, fens and coastal marshes (Packalen *et al*., 2014). The region is also proximal to the centre of growth of the Laurentide Ice Sheet (LIS) (Kleman *et al*., 2010). Given its physiography and latitudinal position, it is likely that similarly extensive peatlands existed in this region during earlier ice-free periods of the Pleistocene, giving the opportunity to analyze peatland-carbon-climate relations for the pre-Holocene Quaternary. Evidence for pre-Holocene ice-free periods is preserved in locations protected from glacial scour, and consists of organic-bearing strata underlying tills or other glacial materials. These are exposed in the deeply incised valleys of the major rivers draining the Lowlands (Terasmae and Hughes, 1960), and have also been accessed through exploration drill cores (Gao *et al*., 2012). Radiocarbon, OSL/TL, U-Th and amino acid methods have been used to correlate the deposits to particular marine isotope stages (MIS) (Allard *et al.*, 2012; Dalton *et al*., in prep). The available geochronological data suggest Eemian (MIS 5e) ages at some sites. Other sites are apparently more recent (MIS3 interstadial; 70-35 ka BP) although given that any ages more recent than MIS5e would require substantial revision of LIS palaeogeography, these ages may be erroneous. Palynology and macrofossils complement the geochronological analyses and have been used to distinguish Quaternary from Pliocene strata (Galloway et al., 2012). Quaternary assemblages indicate a variety of wetland environments including salt marshes, forested peatlands, fens and bogs and yield paleo-temperature reconstructions through modern pollen analogs.

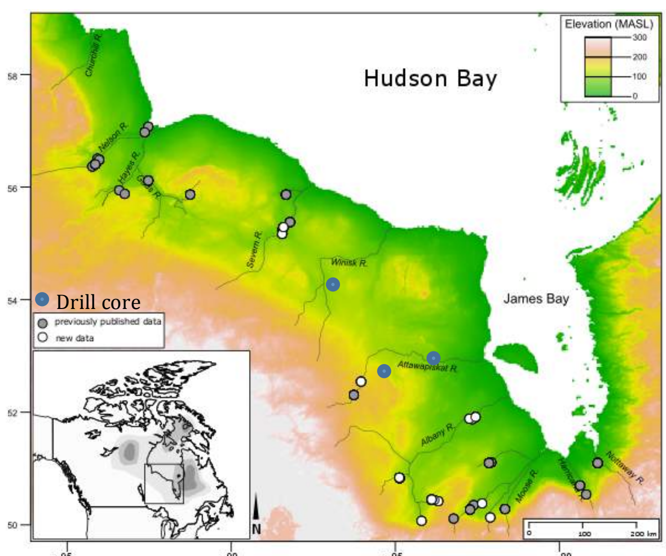

Figure 1. Map of the Hudson Bay Lowland (HBL), showing the locations of “Missinaibi Formation” sub-till organic-bearing sites with geochronological data. Inset map shows present-day isostatic rebound (Peltier *et al*., 2015), where dark values reflect the highest rates of uplift.

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Implications of applying Holocene carbon accumulation rates to pre-Holocene systems

David Large
Department of Chemical and Environmental Engineering, University of Nottingham, UK

The most appropriate approach for estimating the time contained within a coal seam is to use carbon accumulation rates. The application of long-term Holocene carbon accumulation rates, accounting for carbon loss during coalification enables the prediction of coal composition and the interpretation of rates of atmospheric dust accumulation. This approach can be used to understand global climate and atmospheric transport and the processes influencing the composition of pre-Holocene peat. The success of this approach raises many questions regarding Holocene processes for example: What is the relationship between timescale of observation and variability of carbon accumulation rate? Does vegetation type significantly influence rates of carbon accumulation? Can long term carbon accumulation rates lie significantly outside the present day Holocene range? Over long timescales does the decay pathway matter?

Modelling peat contribution to glacial CO_2 cycles

Victor Brovkin (MPI-M, Germany) and Andrey Ganopolski (PIK)

In pre-industrial climate, vegetation biomass and mineral soils contained about 2,000 Gt of carbon, about 4-5 times more than the atmosphere at that time. During last glacial maximum (LGM), effects of climate and CO_2 on terrestrial vegetation should have led to a strong reduction in terrestrial carbon storage. Model-based studies suggest a decrease in land carbon in the range from 300 to 800 GtC, with a largest uncertainty coming from the changes in distribution in vegetation cover. Such strong variability in land carbon does not help to explain changes in atmospheric CO_2 during glacial cycles as changes in land carbon counteract the atmospheric CO_2 drawdown during glaciation inception and CO_2 increase during deglaciation. A possible solution to this problem was recently suggested by an involvement of terrestrial carbon storage in cold and anaerobic environments (eg, Ciais et al., 2012).

To address this hypothesis, we updated the Earth System model of intermediate complexity CLIMBER-2 (Petoukhov et al., 2000; Brovkin et al., 2012) with a module for carbon in permafrost, peat, and carbon buried under ice sheet. A simplified model of the peat growth assumes that under conditions favorable conditions for the peat growth, a small fraction of litter is accumulated in the peat pool. This is occurring during the warm periods such as interglacials. In the course of the four last glacial cycles, total terrestrial carbon storages are changing in the range of 2700 to 3100 GtC. The boreal peat storages grow up to 500 PgC at the end of interglacials or during warm interstadials, but decline to almost zero during glacial maxima. During glacial inception, while biomass and mineral soil carbon decrease, terrestrial carbon storage increases due to an increase in buried and permafrost carbon with peat storages remain high (see comparison of 125 to 115 ka BP on the Figure 1). At the Last Glacial Maximum, the land total storage is slightly less than at pre-industrial. The fast decrease in permafrost and buried carbon during deglaciation contributes to the rapid CO_2 growth as the land carbon storages decrease by about 200 GtC between 20 and 10 ka BP despite of strong increase in the biomass and mineral soil carbon. At the end of the Holocene, the land carbon storage grows due to peat accumulation, and the permafrost carbon starts to increase in response to the cooling in the high northern latitudes. In summary, the growth of boreal peat storage stabilizes atmospheric CO_2 growth during interglacials, and thus controls the maximum of CO_2 interglacial levels during the last 4 glacial cycles.

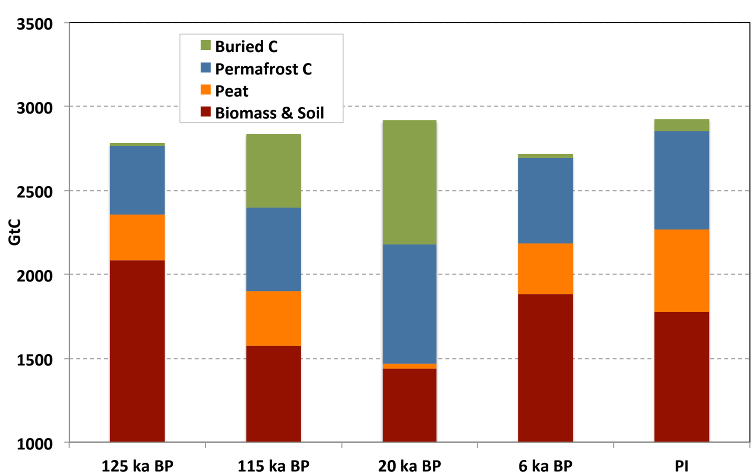

Figure 1. Simulated land carbon storages at the last interglacial (125 ka BP), glacial inception (115 ka BP), last glacial maximum (20 ka BP), mid-Holocene (6 ka BP), and pre-industrial (Brovkin & Ganopolski, 2015).

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Session III. Peats from Around the World

Circum-Arctic peat initiation and expansion

Atte Korhola
Environmental Change Research Unit (ECRU), University of Helsinki, Finland
(with contributions from Meri Ruppel, Minna Väliranta & Tarmo Virtanen)

Peatlands are major ecosystems of the Northern Hemisphere and have a significant role in global biogeochemical processes. Consequently, there is growing interest in understanding past, present and future peatland dynamics. However, chronological and geographical data on peatland initiation are scattered, impeding the reliable establishment of postglacial spatiotemporal peatland formation patterns and their possible connection to climate. In order to present a comprehensive account of postglacial peatland formation histories in North America and northern Europe, we collected a data set of 1400 basal peat ages accompanied by below-peat sediment-type interpretations from literature. Our data indicate that all peatland initiation processes (i.e. primary mire formation, terrestrialization and paludification) co-occurred throughout North America and northern Europe during the Holocene, and almost equal amounts of peatlands formed via these three processes. Furthermore, the data suggest that the processes exhibited some spatiotemporal patterns. On both continents, primary mire formation seems to occur first, soon followed by terrestrialization and later paludification. Primary mire formation appears mostly restricted to coastal areas, whereas terrestrialization and paludification were more evenly distributed across the continents. Primary mire formation seems mainly connected with physical processes, such as ice sheet retreat. Terrestrialization probably reflected progressive infilling of water bodies on longer timescales but was presumably drought driven on shorter timescales. Paludification seems affected by climate as it slowed down in Europe during the driest phase of the Holocene between 6 and 5 ka. Lateral expansion of existing peatlands accelerated c. 5000 years ago on both continents, which was likely connected to an increase in relative moisture. This paper discusses also the role of mire formation type to further development of mire, with particular attention to ombrotrophication and carbon balance. With raised bogs, the time point of ombrotrophication does not automatically mean that a mire turns from carbon source to carbon sink. The peatland unit will remain predominantly a carbon source even thousands years after ombrotrophication of its central part. The term “ombrotrophication” is also discussed as there seems to be misunderstanding about its proper meaning.

Long-term development of western Amazonian peatlands: patterns and processes

Ian Lawson
University of St Andrews, UK
(with Katherine Roucoux, Timothy Jones, Thomas Kelly, Frederick Draper, Timothy Baker, Euridice Honorio Coronado)

Extensive peatlands occur in western Amazonia, but their developmental history, vegetational characteristics, and carbon storage dynamics remain essentially unknown. Recently our group published a re-evaluation of the area and carbon stocks of peatlands in the Pastaza-Marañón basin, lowland Peru (Draper et al. 2014, Env. Res. Lett. 124017). Here we present some of our other recent findings on the present ecology, palaeoecology, geochemistry, and hydrology of these peatlands. Our ecological survey data include the first quantitative description of ‘dwarf pole forest’ occurring on ombrotrophic peat. Using pollen analysis, we documented the developmental history of one palm swamp, Quistococha, which has accumulated up to 4 m of peat since 2200 cal BP in an abandoned channel of the Amazon river. In outline, initial sedge fen and/or floating mat vegetation gave way to seasonally-flooded mixed woodland after 1900 cal BP; palms became more abundant after 1000 cal BP but vegetation similar to the present-day palm swamp forest has only been in place since 400 cal BP. However, in detail the vegetational succession was complex, with reversals, repetitions, and abrupt transitions. Changing flooding regimes probably drove some of this complexity, suggesting that the peatland was sensitive to external (possibly climatic) environmental variations. This sensitivity may be explained by hydraulic conductivity measurements, which indicate that the woody peats at this and other sites in the region are very free-draining, and hence likely prone to dessication during droughts. Geochemical analyses alongside the pollen data demonstrate that variations in peat properties relevant to carbon storage, including lignin content (linked to peat recalcitrance) and base cation abundances, depend partly on the initial botanical composition of the peat and partly on subsequent alteration. Palaeoecology, as a component of multidisciplinary research projects, is critical to our understanding of the past and future dynamics of these important carbon stores.

Peatlands of New Guinea

Geoffrey Hope
Australian National University Canberra, Australia

Peatlands in the large (0.8 M km^2) equatorial island of New Guinea are very extensive but poorly understood. In the lowlands, estimates of peatland area range from 4.1-12.8 M ha while the uplands (>850 m) may contain 1.5 M ha or more of peat covered landscapes. In addition there are large areas of seasonally flooded swamps and mangrove areas underlain by organic-rich silts and clays. The lowland peatlands include grass-sedge swamps and swamp forest and occur as back swamps of large river systems and estuarine infills. The occurrence of large peat domes, similar to those in Kalimantan, is likely but has not been demonstrated. Some lowland peatlands are at, or slightly above, modern sea level and they may post-date the Holocene rise in sea level. However there are also higher altitude peatlands of considerable depth that may be older.

Upland peatlands are topogenous and infill river valleys and tectonic basins. They include swamp forests of *Dacridium* and *Castanopsis* as well as sedgelands. Stratigraphic work demonstrates that some of these peatlands span more than 30-50 ka BP. Above around 2800 m cool, everwet conditions have resulted in a greater diversity of grass, herb, fern and shrub covered communities and blanket bog is extensive. The total area of these subalpine peatlands is probably around 1 M ha and most form at the end of the last glaciation.

The peatlands of Papua New Guinea (the better-known eastern half of New Guinea) may store around 5 Gt of carbon or about 20% of South East Asian peat stores. Until the peatlands of Papua Province have been mapped and their depth established no realistic estimate of carbon stores is possible. The Papuan peatlands lack the tephra layers found in PNG so may have different preservation processes as ash in PNG seems to help preserve old organic deposits. A major research question is whether peat forest in New Guinea shares the characteristics of the biogeographically distinct western Indonesian domed peatlands. In the SE Asian lowland tropics, ombrotrophic peat formation under forest cover may depend on mycorrhizal activity that maintains dramatically low pH. The presence of such fungi have still to be established in New Guinea although low pH litter with mycorrhiza are known in the Pacific.

Peatland carbon stocks and accumulation rates in the tropical Andes

John Hribljan
Michigan Technological University/ US Forest Service, Houghton, USA

Carbon storage and current carbon flux rates remains poorly understood for tropical peatlands. My research in the South American Andes includes ecosystem carbon stock and flux measurements to gain a better understanding of the carbon balance in tropical mountain peatlands and determine potential impacts of climate and land-use change on these systems. Soil cores were collected throughout the tropical Andes to quantify carbon pools and ^{14}C accumulation rates. In addition, chamber based fluxes measurements (CO_2 and CH_4) have been initiated in Peru and Ecuador, and next in Colombia. The peatlands contain dense, carbon rich peats with large amounts of interbedded mineral material. Most peatlands sampled were small; however, they were numerous across the landscape and potentially represent a substantial, underreported regional carbon sink. Carbon accumulation rates are among the fastest reported for mountain ecosystems. These data provide insights into the long and short-term controls on South American mountain peatland carbon dynamics.

High-altitude peatlands in the central Andes

Karsten Schittek
Seminar für Geographie und ihre Didaktik, Universität zu Köln, D-50931 Köln, Germany
Markus Forbriger (University of Cologne, Germany)
Sebastian T. Kock (Research Center Juelich, Germany)
Liliana C. Lupo (National University of Jujuy, Argentina)
Frank Schaebitz (University of Cologne, Germany)

The high-altitude cushion peatlands of the Central Andes are a typical element of the high-Andean vegetational belt at altitudes of 4000-5000 m a.s.l. The main peat-accumulating species of these soligenous peatlands are the Juncaceae *Distichia muscoides* and *Oxychloe andina*, which are adapted to the harsh environmental conditions at these altitudes.

High-Andean peats are effective collectors of organic and inorganic components, which can be used for the reconstruction of their development and of paleoclimate. They have the quality to be very sensitive towards environmental changes and are well-suited for the application of a variety of methods that can be used for the reconstruction of palaeoclimates. The strengths of these geoarchives are their comparability over climatic gradients, their high accumulation rates and the high quality of their peat deposits to be precisely 14C-dated.

In the past, the peatlands used to recover from climatic oscillations. Nowadays, most Andean peatlands are heavily degraded by human interventions. The loss of the protective vegetation cover within the water catchment areas due to dry periods and/or overgrazing, leads to an increased input of sediment and the expansion of alluvial fans upon the peat deposits. In the past, sediment layers were rapidly accumulated by the peat-forming vegetation. Only if there is heavy degradation of the vegetation cover, coupled with increased discharge,
the peat deposits become susceptible to erosion and incision. If these processes continue in the future, the high-mountainous ecosystems will lose their unique water storing and regulating capacity.

Carbon and nitrogen dynamics of *Sphagnum* peatlands in southern South America: some initial results

Thomas Roland[1,2], Simon van Bellen[3,4], Dmitri Mauquoy[4], Paul Hughes[2], Tim Daley[5], Neil Loader[6], Alayne Street-Perrott[6], Liz Cressey[1], Lisa Orme[1], Nicole Sanderson[1], Angela Gallego-Sala[1], Dan Charman[1].

[1] University of Exeter, UK; [2] University of Southampton, UK; [3] Université du Québec à Montréal, Canada; [4] University of Aberdeen, UK; [5] Plymouth University, UK; [6] Swansea University, UK.

In contrast to their equivalents in the Northern Hemisphere, the peatlands of the Southern Hemisphere have been subject to relatively little scientific investigation. The PATAGON project seeks to reconstruct the palaeohydrology of ombrotrophic peatlands in southern South America in order to infer changes in the precipitation regime across the region during the late-Holocene (~2000 years), which is driven in large part by changes in the strength and position of the southern westerly wind belt. The project employs a regionally novel multi-proxy approach consisting of plant macrofossil, stable isotope ($\delta^{18}O$, $\delta^{13}C$, D) and testate amoebae analyses using a network of sites across the region's W-E climate gradient (Daley et al., 2012). Quantitative reconstructions of changes in water table depth are produced using a newly developed regional testate amoebae transfer function (van Bellen et al., 2014).

In addition to these data, high-resolution records of carbon and nitrogen content over the last 2000 years are now being developed in an effort to test the relative importance of climate as a driver of carbon accumulation in the region, compared with other environmental variables such as hydrological change, nitrogen content and vegetation type. An understanding of these processes may improve our ability to predict the likely response of these southern peatlands to future climate change scenarios. Here we present and explore some recently developed initial results.

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Peat accumulation in mountain fens of the western USA

Kathleen A. Dwire[1], Allison Aldous[2], Gay Austin[3], Rodney Chimner[4], David J. Cooper[5], David D'Amore[6], Katharine Haynes[7], Barry C. Johnston[8], George Jones[9], Joanna Lemly[10], David Millar[11], David Weixelman[12]

Over the last decade, wetland inventories and assessments have been conducted throughout mountainous regions of the western USA to determine the distribution and characteristics of fens on public lands administered by the Forest Service, Bureau of Land Management, and National Park Service. Preliminary examination of multiple datasets from fen studies and inventories show that mountain fens are numerous, small in size, and exhibit a wide range of peat thickness, organic and mineral content of peat profiles, and relative occurrence of fibric, hemic, and sapric peats, as well as other fen characteristics. Although slope, elevation, fen catchment area, underlying lithology, geomorphic landforms (basin or hillslope location), and fen size exert some influence on peat-bed thickness in mountain fens, other site-level factors, such as persistent, high volume flow of supporting groundwater may be as important for peat accumulation. Peat thickness is important for understanding the origin and development of these valued wetlands, designing restoration efforts, and assigning conservation priorities for fens on public lands in mountainous terrain.

References:

[1] USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO
[2] The Nature Conservancy, Portland, OR
[3] Bureau of Land Management, Gunnison, CO
[4] Michigan Technological University, Houghton, MI
[5] Colorado State University, Fort Collins, CO
[6] USDA Forest Service, Pacific Northwest Research Station, Juneau, AK
[7] USDA Forest Service, Medicine Bow National Forest, Laramie, WY
[8] (retired) USDA Forest Service, Grand Mesa, Uncompahgre, and Gunnison National Forests, Delta, CO
[9] Wyoming Natural Diversity Database, Laramie, WY
[10] Colorado Natural Heritage Program, Fort Collins, CO
[11] University of Wyoming, Laramie, WY
[12] USDA Forest Service, Region 5, Nevada City, CA

Micro-tidal Peatlands of the Sacramento-San Joaquin Delta, California, USA

Judith Z. Drexler
US Geological Survey, California Water Science Center, Sacramento, CA, USA

The Sacramento-San Joaquin Delta is a 1,400 km^2 area bounded by the Sacramento and San Joaquin Rivers and situated at the landward end of the San Francisco Estuary. The historic Delta began forming approximately 6,800 years ago, creating an extensive micro-tidal marsh region containing peat ranging from 2 - 15 m thick. Between the 1880s and 1930s most of the Delta was drained for agriculture, leading to extensive land-surface subsidence. During the past ten years, I along with several collaborators have studied Delta peat and learned that it is unusual in several ways. It consists largely of the roots and rhizomes of the emergent macrophyte, *Schoenoplectus acutus* (common or hardstem bulrush), which is very productive under the climate regime of the Delta, forming a solid peat matrix highly recalcitrant to decay. Secondly, Delta peat can contain up to ~50% inorganic sediment originating from the greater watershed, depending on the hydrogeomorphic position of the marsh in which it forms. Finally, Delta peat reflects variations in salinity (between fresh and oligohaline), which have occurred over the millennia as a result of changing climate and can be identified in the peat using strontium and uranium isotopes ($^{234}U/^{238}U$ and $\delta^{87}S$) as tracers. Currently, there is great interest by managers and stakeholders to restore the micro-tidal peatlands of the Delta for the purpose of mitigating land-surface subsidence, increasing biological carbon sequestration (thereby mitigating carbon pollution), and improving habitat for endangered fish and other sensitive species. Future restoration in the Delta may need to be focused on the northern and eastern reaches of this region, which are likely to be less impacted by future sea-level rise and saltwater intrusion.

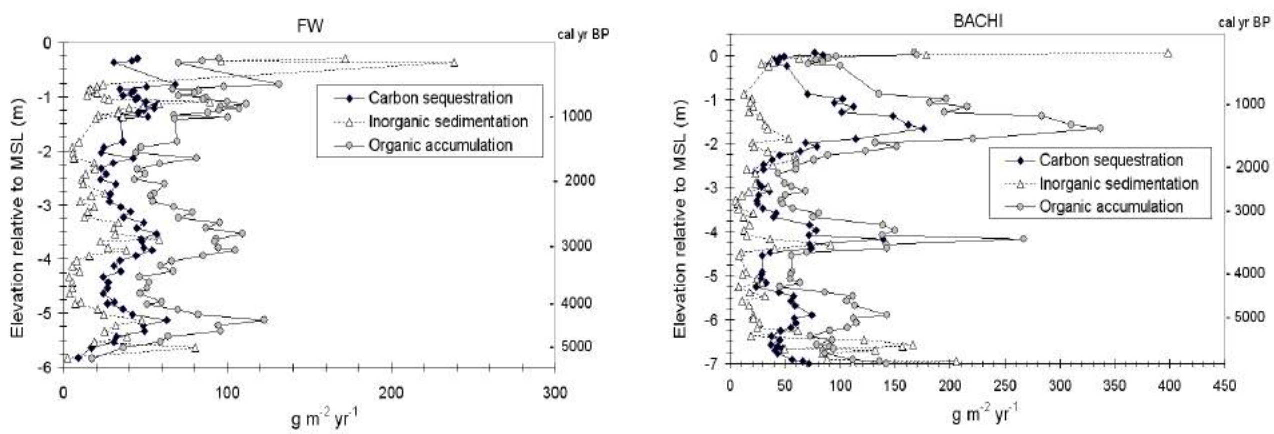


Figure 1. Estimates for rates of carbon sequestration (g organic carbon m^{-2} $year^{-1}$), organic accumulation (g organic matter m^{-2} $year^{-1}$) and inorganic sedimentation (g sediment m^{-2} $year^{-1}$) through the lifetimes of two tidal freshwater marshes in the Delta: (a) Franks Wetland (FW) and (c) Bacon Channel Island (BACHI).

Timing of Fen-Bog Transition Across the Northern Peatland Domain

Julie Loisel[1,2*], Glen MacDonald[1,2], Konstantine Kremenetski[1], James Holmquist[1,2]

[1]Department of Geography and [2]UCLA Institute of the Environment and Sustainability
University of California – Los Angeles, Los Angeles CA 90049 USA

*juloisel@hotmail.com

UCLA Geography

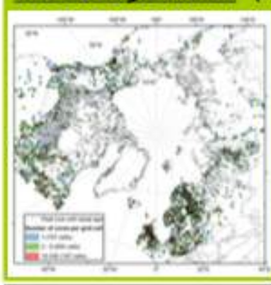
UCLA Institute of the Environment and Sustainability

INQUA

Significance Statement

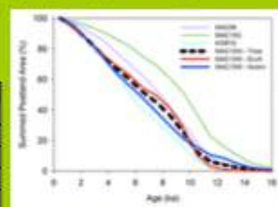
Causes for the rapid increase in atmospheric CH_4 concentration ($[CH_4]_{atm}$) during the last glacial termination are uncertain. Top-down inferences from ice-core CH_4 concentration and isotope measurements suggest a dominant contribution from northern high-latitude wetlands, but gathering the bottom-up data needed to support this hypothesis remains challenging. **Here we combine modern peatland area and modern wetland CH_4 fluxes with new global databases of peatland initiation, lateral expansion, and fen-bog transition (FBT) to address this question.** We show that (1) lateral expansion peaked from 10 to 8 ka in Eurasia (EurA) while it remained steady from 8 ka to present in North America (NoAm); (2) the FBT occurred during the late Holocene at about half of our sites, with NoAm lagging EurA by about 1 kyr, (3) CH_4 fluxes from peatlands plateaued from 8 to 4 ka and could have been is high as 30 Tg CH_4 yr^{-1}, and (4) northern peatlands were probably not the main player in the late-Holocene increase in $[CH_4]_{atm}$.

The MAC15 Dataset *(MacDonald et al. In Prep)*



Total modern peat area: 1,320,000 km²

North America	1,395,333 km²	Eurasia	1,792,333 km²
W Canada	701,000	Russia	1,420,000
N Canada	284,000	Fennoscandia + Iceland	215,000
E Canada	187,000	E Europe	88,000
Alaska USA	132,000	W Europe	38,000
Conterminous USA	111,000	British Isles + Ireland	31,000



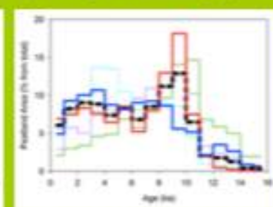
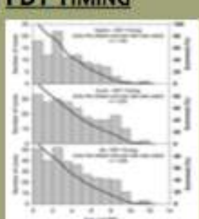


FIG 1. 7571 ^{14}C-dated peat basal ages from 4420 sites (map) were combined into 1x1° grid cells (MAC15G, n=1807, in green). Cells with 10+ basal ages (map) were intersected with modern peatland areas (table) to reconstruct Holocene peatland lateral expansion for North America (NoAm, in blue) and Eurasia (EurA, in red). The final result, (in black) is compared to data from MacDonald et al. 2006 (MAC06, n=1516 cores) and Korhola et al. 2010 (KOR10, n=1190 cores from sites with 2+ cores). This dataset constitutes the basis for the FBT analysis presented below.

(1) FBT Timing



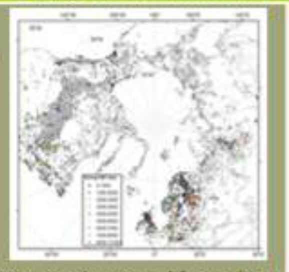


FIG 2. The FBT in NoAm and EurA mostly occurred from 5 ka to the present, with more sites switching to bogs during the mid-Holocene in EurA than in NoAm. The 50% mark was passed at 4 ka in EurA and at 3 ka in NoAm.

(2) Scaling Up the FBT Core Data

Assumptions: (1) modern fen area is ~1.1 Mkm² (34% of total area) of which 460,000 km² is found in NoAm and 658,000 km² in EurA*, (2) modern bog area is ~2.1 Mkm² (66% of total area), of which 935,000 km² is distributed in NoAm and 1,125,000 km² in EurA*, (3) all peatlands start as fens and 66% become bogs following the NoAm and EurA distributions as shown in Fig 2, and (4) a bog cannot become a fen.

*Peatland area values were obtained from several published sources.

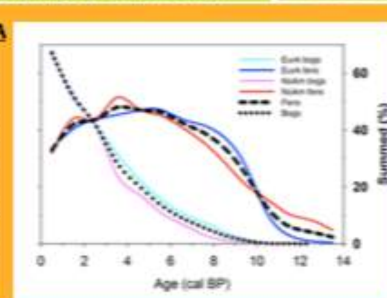
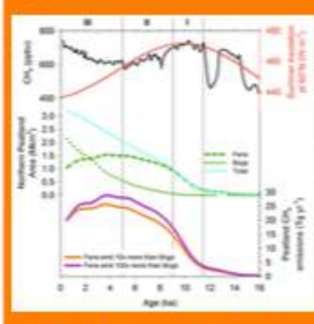


FIG 3. Explosive expansion of fens from 11 to 8 ka that levels off from 6 to 4 ka. Bog expansion follows an exponential curve; bogs abundance surpass that of fens at 3 ka.

(3) Towards Estimating CH_4 Emissions from Northern Peatlands Since the Last Glacial Termination



Assumptions: (1) modern-day CH_4 emissions from northern peatlands = 20 Tg yr^{-1}, (2) CH_4 flux rates per unit area have remained constant throughout the Holocene such that total fluxes scale linearly with peatland area, from 0 Tg at 16 ka to 20 Tg at 0 ka, (3) brown-moss dominated fens emit 10x or 100x more CH_4 than *Sphagnum*-dominated bogs and poor fens, and (4) CH_4 lifetime and radiative efficiency have remained constant over time.

Results and Implications: (1) rapid increase in peat-CH_4 fluxes during the early Holocene due to widespread expansion of fens coincides with peak $[CH_4]_{atm}$ and warmer/longer growing season → suggests a potential increase in CH_4 emissions from peats in a warmer future, particularly if permafrost peatlands and wet tundras switch to fens; (2) high plateau in peat-CH_4 emissions from ~8 to 4 ka coincides with a decrease in $[CH_4]_{atm}$ and cooling → these opposite trend could be reconciled if we allow our peat-CH_4 model to be sensitive to temperature (less emissions during this time due to cooler conditions), and (3) decrease in peat-CH_4 emissions from 4 to 0 ka coincides with rapid bog expansion and increase in $[CH_4]_{atm}$ → suggests a non-peatland source to the atmosphere (e.g., Ruddiman 2003).

FIG 4. $[CH_4]_{atm}$ curve (Brook et al. 2000), summer insolation in the northern high latitudes, fen vs. bog area, and peat-CH_4 emission estimates.

The authors acknowledge the contribution of every dataset that was provided by our collaborators from the peatland and quaternary geology communities, and INQUA conference support to JL. References: MacDonald et al. '06 Science; Korhola et al. '10 Quat Sci Rev; XYZ; Brook et al. '00 GBC; Ruddiman '03 Clim Ch.

Effects of permafrost aggradation on peat properties as determined from a pan-arctic synthesis of plant macrofossils

Claire Treat*, Miriam Jones, and the Permafrost Peat Properties Working Group
*University of Alaska Fairbanks, ctreat@usgs.gov

Permafrost dynamics play an important role in high-latitude peatland carbon balance and are key to understanding the future response of soil carbon stocks under climate warming. Permafrost aggradation can control the magnitude of the carbon feedback in peatlands through effects on peat properties. We compiled peatland plant macrofossil records for the northern permafrost zone (515 cores from 280 sites) and classified samples by vegetation type and environmental class (fen, bog, tundra and boreal permafrost, thawed permafrost). We examined differences in peat properties (bulk density, carbon (C), nitrogen and organic matter content, C/N ratio) and C accumulation rates among vegetation types and environmental classes. The vegetation composition of tundra permafrost peatlands was similar to permafrost-free fens, while boreal permafrost peatlands more closely resembled permafrost-free bogs. Nitrogen content in boreal permafrost and thawed permafrost peatlands was significantly lower than in permafrost-free bogs despite similar vegetation types (0.9% versus 1.5% N). Median long-term C accumulation rates were higher in fens (23 g C m^{-2} y^{-1}) than in permafrost-free bogs (18 g C m^{-2} y^{-1}), and were lowest in boreal permafrost peatlands (14 g C m^{-2} y^{-1}). The plant macrofossil record demonstrated transitions not just from fen to bog to permafrost peatlands, but also bog to fen transitions, permafrost aggradation within fens, and permafrost thaw and re-aggradation. Using data synthesis from across the permafrost zone, we've identified predominant peatland successional pathways, changes in vegetation type, peat properties, and C accumulation rates associated with permafrost aggradation. We then use this dataset to examine the regional trends in permafrost aggradation. The first occurrences of permafrost aggradation varied across the high latitudes, ranging from > 8000 yr BP in tundra regions to the Little Ice Age in areas with discontinuous permafrost. Regional trends in permafrost development may be indicative of regional climate patterns.

Emergent questions:

- What mechanisms control the observed differences in peat nitrogen content in peat deposited before and after permafrost aggradation?
- What are good indicators of permafrost aggradation? How can new types of analyses help pinpoint permafrost aggradation?

Long moisture records from sensitive peat-forming environments in eastern Australia – from the LGM to present

Len Martin
UNSW, Sydney, Australia

Sediment accumulation rates, organic content and basal ages from 44 depositional environments from around the Sydney Region with 131 ^{14}C age control points are synthesised. This record indicates stable, low accumulation rates between 21 ka and 11.7 ka, at which point accumulation rates double, subsequently remaining high with an increasing trend throughout the Holocene to present. A subset of sites with reported organic content were also collated to reveal a much more gradual increase in from ~14 ka to present. This synthesis forms the first step in an improved understanding of the paleoenvironmental significance of the peat-forming environments of eastern Australia, which are inherently sensitive archives due to the narrow range of environmental conditions in which they form. Also presented is a long (LGM-present), high resolution humification, geochemical and sedimentary record from the peatland environments of the Sydney region. This record is informed by a robust chronology of >30 AMS ^{14}C dates which aimed to determine the optimal organic fraction for ^{14}C dating. The outcome of this review and new research provides insights into the dynamic climate of eastern Australia. Results suggest long-term moisture availability in the Sydney region does not follow established or accepted trends for SE Australia during the Holocene.

Session V. Issues Related to Future Trajectories

The stability of the peatland carbon stores (or the stability of deep buried peat)

Jeffrey Chanton
Department of Earth, Ocean & Atmospheric Science, Florida State University, Tallahassee, USA
(with Paul Hanson, Joel Kostka, Karis McFarlane, Tom Guilderson, Rachel Wilson, William Cooper, Scott Bridgham, Jason Keller, Cassandra Medredeff, Mort Barlaz, Tino De La Cruz, Malak Tfaily, Randy Kolka, Steve Sebestyen)

In response to warming climate, to what extent will peatland organic matter be activated to form additional CH_4 and CO_2 relative to current production rates? To predict the answer to this question the SPRUCE (Spruce and Peatland Responses Under Climatic and Environmental Change) project is being conducted in a bog ecosystem in northern Minnesota. The manipulation is being conducted in a staged approach, and deep warming through the entire ~2 m peat profile was initiated in June of 2014 at +0, +2.2, +4.5, +6.8 and +9C. Following one year of temperature enhancement there is no evidence of an effect on catotelm peat. In bog pre-treatment, control and treatment plots, microbial respiration and CO2 and CH4 production in the deep peat is driven primarily by recent plant production and to date, this trend continues in the catolem following treatment. Methane $\delta^{13}C$ and fractionation factors are invariant across the treatments, as are gas concentrations at depth

Carbon dynamics in boreal peat plateaus following permafrost thaw

Miriam C. Jones
Eastern Geology and Paleoclimate Science Center, U.S. Geological Survey, Reston, VA, USA

Permafrost peatlands are becoming increasingly vulnerable to thaw, as high latitude temperatures increase at a faster rate than the rest of the planet and as disturbances such as wildfires become more frequent and more intense. Peatlands account for nearly 30% of the soil organic carbon (C) within the northern permafrost region, storing roughly 275 Pg of organic C, equivalent to over one-third of the C currently in the atmosphere. The loss of carbon following permafrost thaw remains uncertain, as the biogeochemical processes remain largely unknown. Here, I use a chronosequence and mass-balance modeling approach, as well as paleoecological reconstructions to determine the quantities of post-thaw C losses and rates of new peatland C inputs. Results show that C from the formerly frozen permafrost plateau is released to the atmosphere upon permafrost thaw on the order of years to decades, and long-term accumulation of post-thaw bog peat leads to carbon uptake over centuries to millennia, but whether a site can regain the pre-thaw C losses depends on the age of the peatland and the rate of post-thaw peat accumulation, which is controlled by local hydrological and biogeophysical factors, as well as local climate. We also hypothesize that permafrost formation processes (i.e., syngenetic or epigenetic) are important in predicting the amount of post-thaw C losses. In order to more accurately predict C dynamics in permafrost peatland environments in Earth System models, it is necessary to understand the depositional environment, as well as age and thicknesses of peat.

Long-term disturbance dynamics and resilience of tropical peat swamp forests

Lydia Cole
University of Oxford, UK

The coastal peat swamp forests of Southeast Asia are rapidly undergoing logging and conversion into oil palm plantations. These ecosystems are assumed to have experienced little significant natural or anthropogenic disturbance in the past, persisting under a single ecologically-stable regime. However, their long-term disturbance history has been poorly assessed, and little is known of their resilience to internal and external stresses. Have peat swamp forests been disturbed in the past? What were the drivers? How did the vegetation respond? In order to answer these questions, three peat cores were extracted from coastal peatlands in Sarawak, Malaysian Borneo. Fossil pollen grains and charcoal particles were surveyed at regular depths in all cores, and inferred past vegetation change plotted. Results suggest that the peat swamp forest community has been the dominant vegetation type in these ecosystems throughout the last 4000 years, demonstrating resilience to episodes of burning and climatic change, such as short-term ENSO events. Only within the last 200 years, coincident with increasing indicators of human presence and elevated burning, does the peat swamp forest vegetation show a decline. Thus, it appears that recent anthropogenic disturbances are challenging the resilience of these ecosystems. This research highlights the ecological functioning and requirements of this unique ecosystem, and provides information on what levels of disturbance they can tolerate.

(Based on the publication: Cole, L.E.S., S.A. Bhagwat. and Willis, K.J. (2015) Long-term disturbance dynamics and resilience of tropical peat swamp forests. *Journal of Ecology* – Special Issue on Forest Resilience. DOI: 10.1111/1365-2745.12329.)

Natural wetlands and the global methane cycle

Elaine Matthews
NASA GISS, NY; currently at NASA ARC, Mountain View, CA, USA
(with J. Romanski, Columbia University at NASA GISS, NY, USA)

Natural wetlands are the world's largest source of methane now and under past climates. Their distribution and CH_4 fluxes are sensitive to inter-annual and longer-term climate variations. However, the sign and magnitude of the response of wetlands and their methane emissions to changing climate is highly uncertain despite the typical assumption that emissions will rise.

Wetland distributions used in wetland-CH_4 models diverge widely, and strongly reflect the methodology used to develop them. These areal differences contribute substantially to variations in magnitude, seasonality and distribution of modeled methane fluxes under current conditions. Modeling wetland type and distribution—inherently tied to simulating CH_4 and CO_2 dynamics—is a crucial capability in studies of the role of wetlands in carbon dynamics under past and future climates, but wetland models perform poorly, often for predictable reasons.

Methane-wetland models either prescribe or simulate methane-producing areas (aka wetlands) and both approaches result in predictable over- and under-estimates. 1) Monthly satellite-derived inundation data used to prescribe methane-producing areas includes flooded areas that are not wetlands (e.g., irrigated rice, lakes, reservoirs, rivers) and cannot identify non-flooded ecosystems typical of Arctic regions (Prigent/Papa (PP)). 2) Models simulating methane-producing areas employ no information on wetlands themselves, relying instead on modeled soil moisture which over-estimates global area, and regionally over- and under-estimates area.

We summarize the current state of wetland/methane modeling; compare several wetland data sets used in methane studies; diagnose methodological biases; illustrate sensitivity of methane emission to wetland representations; and introduce a new framework for modeling wetlands and their emissions. The approach is anchored in an existing global wetland data set (Matthews/Fung (MF)) and a comprehensive compilation of data on wetland characteristics including climate, soil type, and carbon, inundation dynamics, permafrost state, etc. to produce a wetland model (or suite of models).

- observation-based wetland models provide the capability to simulate wetland distributions under multiple climates thus addressing the indirect impact of climate change on methane emissions via changing wetland distribution
- coupling wetland models with methane models makes a critical contribution to explaining atmospheric methane concentrations under past and future climates
- coupling wetland models with peat models provides the means to globalize peat models and to improve simulations of peat composition and dynamics

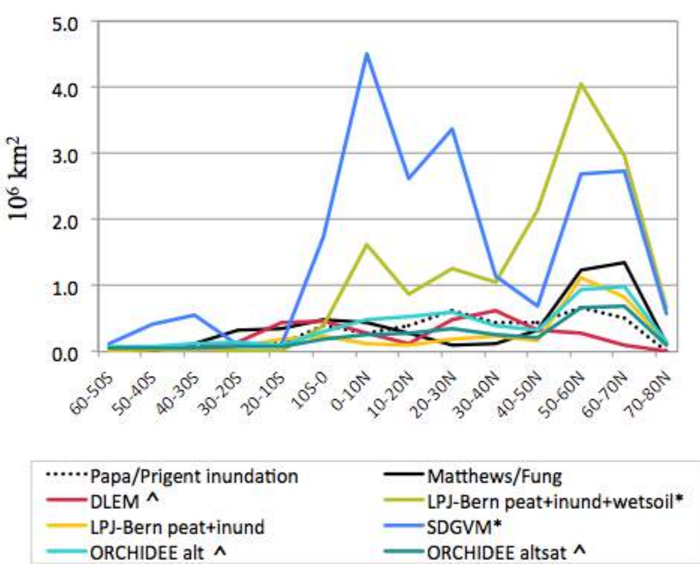


Fig. 1. Latitudinal wetland areas from observations (PP and MF), simulations (*) and inundation-prescription (^). All but PP and MF are models from the Wetchimp model comparison (Melton et al. 2013, *Biogeosciences* **10**: 753-788)

To wet or not to wet? Carbon-climate feedbacks and implications for geoengineering

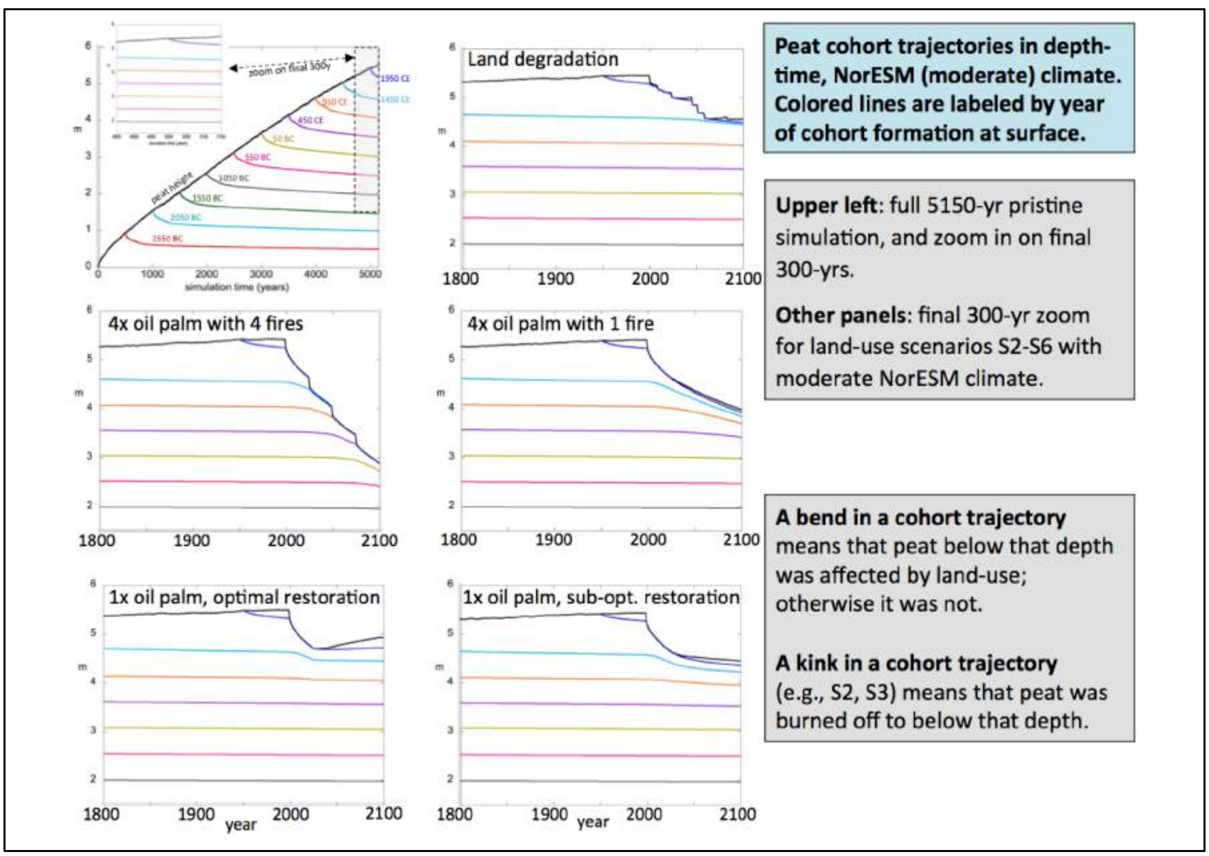
Daley, T.J. [1], Garcia-Meneses, P. [2], Rowland, S.J. [1], Sutton, P.A. [1], Fyfe, R. [1]
[1]Sustainable Earth Institute, Plymouth University, Plymouth, PL4 8AA, UK
[2]Instituto Nacional de Ecologia, Mexico City, Mexico

Sphagnum moss peatlands sequester carbon (Yu et al 2010; Turunen et al., 2002), providing a vital climate regulation service, but it is unclear how much of this carbon is drawn-down from the atmosphere and how much is recycled from methane released from anoxic decay in the sub-surface layers (Kip et al., 2010). Submerged mosses may source at least some of their CO_2 for photosynthesis from that respired by partly endophytic methanotrophic bacteria (Raghoebarsing et al., 2005; Kip et al, 2010). Peatland re-wetting has become a multi-million pound, globally-endorsed (FAO, 2012) land management practice, in response, in part, to the potential for carbon sequestration and as an important tool for mitigating GHG emissions. A major assumption of that practice is that plant species, such as *Sphagnum* mosses that thrive through rewetting, enhance carbon accumulation through photosynthesis of atmospheric CO_2 (FAO, 2012). Past climatic changes naturally alter the hydrology of raised bog peatlands and provide an ideal record for estimating the scale of variability in the source of carbon over time. Here we estimate changes in the proportion of atmospheric carbon sourcing over time through the combined application of high temperature GCMS, EA-IRMS and micropalaeoecology on samples from a peat core from northern England. The data reveal episodes of methane-recycling that challenge the standard rationale for geoengineering interventions.

Impacts of land use, restoration, and climate change on tropical peat carbon stocks in the 21st century: Implications for climate mitigation

S. Frolking (UNH), M. Warren (USFS), Z. Dai (UNH), S. Kurnianto (OSU), S. Hagen (AGS)

Southeast Asian peatlands are being deforested, drained and burned at very high rates, mostly for conversion to industrial oil palm or pulp and paper plantations. Climate impact inventory guidelines and methodologies have only recently become available, and are based on few data from a limited number of sites. Few heuristic tools are available to evaluate the impact of management practices on carbon dynamics in tropical peatlands, and the potential climate mitigation benefits of peatland restoration. We used a tropical peatland model to explore peat C dynamics of several peatland management scenarios, within the context of 21st century climate change. Simulations of all scenarios with land use, including those with optimal restoration, indicated net C loss over the 21st century, with C losses ranging from 10% to essentially 100% of pre-disturbance 5-m of peat. Fire, either prescribed as part of a crop rotation cycle, or stochastic wildfire in sub-optimally managed or degraded land can be a dominant C-loss pathway, particularly in the drier climate scenario we tested, so peat fire suppression is the most effective management tool to maintain peatland carbon stocks, and should be a high priority for climate mitigation efforts on peatlands. A single 25-year oil palm rotation, with a prescribed initial burn, lost ~500 Mg C ha^{-1} of peat, equivalent to accumulation during the previous 500 years. About 10-30% of that peat loss was regained after 75 years of optimal restoration. Land use/disturbance impacts are an immediate risk for near-surface peat, while peat deeper than ~2m is likely only at risk in cases of extreme burning/ditching, or persistent land-use impacts over many decades. This implies that restricting land-use activities to shallow peats will not reduce near-term impacts, and that accurate mapping of peatland distribution and the extent of peatland disturbance are more important for accurate carbon impact accounting than accurate mapping of peat depths.



Abstracts for Posters

Peatland response to nutrient additions

Jill Bubier
Mount Holyoke College, South Hadley, MA, USA

Atmospheric nitrogen (N) deposition has led to nutrient enrichment in wetlands globally, affecting plant community composition, carbon (C) cycling, and microbial dynamics. Nutrient-limited boreal bogs are long-term sinks of carbon dioxide (CO_2), but sources of methane (CH_4), an important greenhouse gas. We fertilized Mer Bleue Bog, a *Sphagnum* moss and evergreen shrub-dominated ombrotrophic bog near Ottawa, Ontario, for 10-15 years with N as NO_3 and NH_4 at 5, 10 and 20 times ambient N deposition (0.6-0.8 g N m^{-2} y^{-1}), with and without phosphorus (P) and potassium (K). Treatments were applied to triplicate plots (3 x 3 m) from May – August 2000-2015 and control plots received distilled water. We measured net ecosystem CO_2 exchange (NEE), ecosystem photosynthesis and respiration, and CH_4 flux with climate-controlled chambers; leaf-level CO_2 exchange and biochemistry; substrate-induced respiration, CH_4 production and consumption potentials with laboratory incubations; plant species composition and abundance; and microclimate (peat temperature, moisture, light interception). After 15 years, we have found that NEE has decreased, and CH_4 emissions have increased, in the highest nutrient treatments owing to changes in vegetation, microtopography, and peat characteristics. Vegetation changes include a loss of *Sphagnum* moss and introduction of new deciduous species. Simulated atmospheric N deposition has not benefitted the photosynthetic apparatus of the dominant evergreen shrubs, but resulted in higher foliar respiration, contributing to a weaker ecosystem CO_2 sink. Loss of moss has led to wetter near-surface substrate, higher rates of decomposition and CH_4 emission, and a shift in microbial communities. Thus, elevated atmospheric deposition of nutrients may endanger C storage in peatlands through a complex suite of feedbacks and interactions among vegetation, microclimate, and microbial communities.

Issues for discussion:

- What are the long-term trajectories for the C balance? Depends on plant community response; deciduous v. evergreen species; moss re-colonization; microclimate and peat chemistry; microbial communities; plant –soil interactions, e.g. mycorrhizal fungi.
- Meta-analyses of *Sphagnum* response across N deposition gradients and experiments (Limpens et al 2011) indicate climate plays a role in the response.
- Examples from arctic tundra fertilization experiments compared with peatlands.

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Long-term disturbance dynamics and resilience of tropical peat swamp forests

Lydia Cole
University of Oxford, UK

(Abstract as for talk listed above)

Vegetation changes influence carbon storage and greenhouse gas escape in a coastal marsh along the Hudson River Estuary

J. Elizabeth Corbett
Lamont-Doherty Earth Observatory, Columbia University

Methane production and loss estimates in coastal salt marshes are understudied and reported values are highly variable. Three vegetation sites within Piermont Marsh, NY (40°00' N, 73°55'W) were investigated to assess whether differences in vegetation patterns influenced methane escape, dissolved organic carbon quality, and biogeochemical patterns within the marsh porewater. Pore water was taken in 50 cm intervals from 0–3 m. Sites were dominated by either invasive *Phragmites australis*, native *Eleocharis*, or native mixed vegetation (*Spartina patens*, *Scirpus*, and *Typha angustifolia*). Methane chamber studies showed significant CH_4 loss from the *Eleocharis* site and negligible loss from the *Phragmites* site. Higher sulfate, lower methane, and lower dissolved organic carbon (DOC) concentrations, and a higher proportion of labile DOC were found in the site dominated by *Phragmites australis* as compared to both the native *Eleocharis* and native mixed vegetation. These results suggest that carbon storage may be lower in sites dominated by invasive *Phragmites* as these sites may contain more reactive carbon substrates and more efficient respiration pathways.

Bio Sketch. I investigate greenhouse gas emissions and subsurface production from global wetlands. To do this, I look at the quality of the carbon substrates utilized by the microbial community, the quantity of greenhouse gases both produced and emitted, and the isotopic composition of carbon stored and emitted from wetlands. I received my PhD from Florida State University in Chemical Oceanography with Jeffrey Chanton where I investigated northern Minnesota peatlands and permafrost sites. I am currently a NASA postdoc with Dorothy Peteet investigating an urban, coastal wetland containing sites dominated by different types of vegetation including an invasive species, *Phragmites australis*, to assess if changes in vegetation patterns may alter greenhouse gas production and emissions.

Dissolved organic matter (DOM) in peatlands: origin, dynamic and impact of land use change

Laure Gandois
CNRS, Toulouse, France

DOM is a small but important fraction of peatland carbon because it is both reactive and mobile. In addition to being recognized as an important part of peatland carbon budget, DOM plays with numerous ecological roles in peatland and within stream. DOM originates from various compartment of peatlands (living and dead vegetation, microorganism…) and therefore its composition quickly evolves with climatic conditions and land use change.

Two examples of peatlands DOM study in relation to land use change will be presented, in Brunei (tropical peatland) and in France (Pyrenees, temperate peatland).

In a study comparing a pristine and a logged site in Brunei, logging without drainage had a clear impact on DOM isotopic, molecular and optical properties, where no changes could be observed on the solid peat composition, in relation to extra input of litter after logging and vegetation changes.

Optical properties of DOM can also be used in situ to catch high frequency DOM dynamic, in relation to climate and hydrology. In a temperate peatland of the Pyrenees, DOM export is surveyed at high frequency using is situ fluorescence sensor. Logging activity is planned upstream of the peatland with potential impact on the watershed hydrology. This project aims at identifying hydrological constraints on DOM export in order to understand logging impact on peatlands carbon cycle.

Methane fluxes from a tropical peatland

Alison Hoyt
Massachusetts Institute of Technology, Cambridge, MA, USA

Wetlands are the largest source of CH_4 to the atmosphere, but emissions measurements are highly uncertain, particularly in the tropics. We examine CH_4 production and transport in a pristine tropical peatland in Borneo. We use the carbon isotopic (stable and radioactive) composition of dissolved CH_4, DIC and DOC within the peat porewater to identify the source and mechanism of CH_4 production in tropical peat. First, we measure ^{14}C in all carbon phases to identify the source of CH_4. In contrast to the peat, which ages with depth to nearly 3000 cal BP, DOC is modern throughout the peat column, to depths of 4.5 m. The ^{14}C content of CH_4 and DIC are nearly identical, and are intermediate between the DOC and peat ^{14}C content. Thus, despite the presence of modern carbon throughout the peat profile, peat decomposition is an important source of CH_4 production. We find consistent trends with depth across the peatland, attributable to the unique hydrologic behavior of the dome. These trends are similar to those observed in northern peat bogs. Finally, we use information on site hydrology, CH_4 and DIC concentrations, isotopic compositions and fluxes to build a model of CH_4 production and transport.

Chemotaxonomical significance of tropical peat bogs: A case study from the brackish Bolgoda Lake and its watershed area

Amila Ratnayake
Department of Geoscience, Faculty of Science and Engineering, Shimane University, Nishikawatsu-cho 1060, Matsue 690-8504, Japan

The sedimentary organic matter made up of complex mixtures of lipids, carbohydrates, proteins and other biochemical constituents. The compositions of sedimentary organic matter have been used for a variety of purposes including the paleoecology and chemotaxonomy (molecular paleontology). In particular, paleoecological and chemotaxonomical markers have been mainly investigated using hemicellulosic sugars, lignin and isotopic compositions, pollen records, *n*-alkanes and triterpenols/ triterpenoids.

Tropical coastal systems generally have greater rates of primary productivity than the open marine, freshwater lakes, and streams. Also, the contributions of terrestrial organic matters are significantly abundant in tropical continental shelves. Mangroves are highly complex and unique terrestrial ecosystems occupying a significant part of tropical and subtropical coastlines. Moreover, mangrove swamps can be considered as one of the most productive ecosystems on the Earth. The high nutrient demand for their high productivity can be maintained by dissolved nutrient from continental and marine environments as well as internal recycling of mangrove organic matter. Also, tropical mangrove swamps can be recognized as one of the important peat forming environment since the Last Glacial Maximum. Consequently, these systems offer an ideal opportunity to study the peat organic matter exchange at the continental-marine boundary.

The author studied molecular composition in peat-forming sediments. It was compared to mid- to high-latitude peat bogs (literature studies) for understanding similarities in swamp type environments. Interesting, the author would be able to understand unique molecular compositions in these environments. Although molecular compositions of peat forming sedimentary organic matter mainly depend on intra- and inter-species variability, paleoclimate, and geographical region, constructive mixings of various terrestrial organic matters in the sedimentary successions are typically provided unique characteristics for many organic geochemical proxies. Therefore, organic geochemical proxies can be applied as a useful chemosystematic marker to identify post-Quaternary peat bogs elsewhere.

Holocene peatland development, carbon accumulation and permafrost history in Tavvavuoma, northern Sweden

A. Britta K. Sannel[1], Liljen Hempel[1], Alexander Kessler[1], Peter Kuhry[1] and Vilmantas Prėskienis[1,2]

[1] Department of Physical Geography, Stockholm University, Sweden
[2] Centre for Northern Studies (CEN), Québec, Canada

Peatlands in the northern circumpolar permafrost region are important soil organic carbon reservoirs. Throughout the Holocene they have acted as carbon sinks, but under future warmer conditions ground collapse as a result of permafrost thaw may, at least temporarily, turn these peatlands into carbon sources. In this study analyses of plant macrofossils, bulk density, carbon and nitrogen content, and AMS radiocarbon dating have been performed for six profiles collected from peat plateaus and palsas in Tavvavuoma (68°28'N, 20°54'E), located in the sporadic permafrost zone in northernmost Sweden. The preliminary results suggest that peatland development started around 10000 cal yr BP, long-term net carbon accumulation rates are slightly lower than the mean Holocene value for northern peatlands of 23 g C/m^2/yr (Loisel et al., 2014), and that fen-bog transition and permafrost aggradation took place relatively recently, most likely during the Little Ice Age (further radiocarbon dating is needed to confirm this). A better understanding of Holocene carbon and permafrost dynamics can improve our knowledge of permafrost peatland sensitivity to climate change, and help us make predictions of future climate-carbon feedbacks from these ecosystems.

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Simulating Holocene peat carbon accumulation in Alaska using an improved process-based biogeochemistry model

Sirui Wang
Purdue Unievrsity, West Lafayette, Indiana, USA
(with Qianlai Zhuang, and Zicheng Yu)

This study quantifies the long-term peat carbon accumulation during the Holocene in Alaska. The dynamics of hydrology, soil thermal regime, and ecosystem carbon are simulated using a revised global biogeochemistry model, the Terrestrial Ecosystem Model (TEM). The parameters are optimized and verified at observation sites in Canada and Alaska. The dynamics of water table depth and methane production and oxidation are evaluated with observation data of lowland open fen and black spruce forested peatlands in Alaska and Minnesota. The estimated net primary productivity and litter fall carbon along with other ecosystem carbon fluxes are verified for the same type fen ecosystems in Alaska. The model is then applied for a 10000-year (15 ka to 5 ka; 1 ka = 1000 cal yr before present) simulation of four peatlands. The comparison between simulation and observations indicates that the model is able to accurately simulate the peat carbon accumulation rate during the Holocene (R= 0.91, 0.90 and 0.68 for three peatlands). We find that the early Holocene carbon accumulation rates, especially during the Holocene thermal maximum (HTM), are up to four times higher than the rest of the Holocene. Our analysis suggests that the high growing season temperature resulted from maximum summer insolation during the HTM in Alaska might be a major factor causing the rapid carbon accumulation.

Summary of Research Expertise and Interests

Changes in peat carbon accrual rates under rising temperatures in recent times

C. Fissore
Whittier College, Whittier, CA, USA

Peatland ecosystems have been accumulating substantial amounts of carbon (C) over several millennia and currently store about one third of all C worldwide. At northern latitudes alone, the current C stock in peatland ecosystems amounts to 273-547 Pg C. An increase in air and soil temperature has been observed for the past several decades at northern latitudes, where most of the Sphagnum peatland is located. A temperature increase of 0.4°C per decade has been detected during the past 40 years at the Marcell Experimental Forest, in Northern Minnesota. Similarly, a consistent soil temperature increase of 0.045ºC to 0.048ºC year^{-1} has been recorded to a depth up to 12.8 m during the past 37 years at northern latitudes in Minnesota. Recent studies have challenged the widespread notion that northern peatland ecosystems will positively feedback warming due to enhanced decomposers activity, arguing that higher temperatures and lengthening of the growing season will instead favor the expansion of Sphagnum mosses, which could result in greater C sequestration. However, the debate is still open on the future trend in Sphagnum peat C accumulation at northern latitudes. With my work, I investigate decadal C accrual rates at three Sphagnum-rich peatlands located in Northern Minnesota (Marcell Experimental Forests) with the scope to detect whether recent warming has had an effect on peat decomposition and C accumulation rates. I use isotope techniques applied to isolated sphagnum cellulose, quantification of C and N content, infrared spectroscopy, and model fitting to determine C accrual rates at these sites. Delta 14C from Sphagnum cellulose shows clear correlation with atmospheric 14C signal, more so that bulk peat 14C, demonstrating that dating of cellulose can be an effective tool to investigate peat and C accrual at the decadal scale. Carbon accumulation over time differs across peat systems, potentially in relation to differences in vegetation and hydrology, and at these locations Sphagnum bogs appear to have accumulated C consistently during the past 50 years. My work has also highlighted the issue related to using sphagnum mosses to investigate C accumulation due to uptake of old CO2 dissolved in the water in which the sphagnum grows. While refixation of CO_2 derived from decomposition in sphagnum moss is somewhat understood, stable isotopes may help shade lights on this process.

Carbon accumulation and climate reconstructions from peatlands in Alaska and Estonia

Eric Klein
University of Alaska Anchorage, Anchorage, Alaska, USA

Eric Klein has been working with high northern latitude peatlands, primarily in Alaska, for almost 15 years. His research is predominantly associated with both modern and paleo peatland carbon accumulation and hydrology. He has studied modern dynamics of peatland systems using such tools as water isotopes, weather stations, and water table depth and temperature loggers. These data help provide context to changes observed in paleo records collected from peatlands, which are interpreted using proxies such as macrofossils and testate amoebae. For example, he studied wetland (including peatland) drying and succession in southcentral Alaska in one of the first studies to document land cover shifts consistent with climate change in Alaska. Incorporating natural landscape differences, he also demonstrated the importance of hydrogeologic variability on the response of Alaskan peatland carbon accumulation and hydrology to changes in climate. Additionally, he has worked in permafrost peatlands, including studies of how carbon accumulation rates change across ecosystem transitions, such as those from thermokarst lake to peatland.

Some of his recent work also uses water isotope geochemistry to help understand northern latitude hydroclimatic processes. This research includes collection and analysis of the first water vapor isotopes from an Arctic cyclone, which provided a novel explanation of changes in sea ice and precipitation during past warm periods recorded in Greenland Ice Sheet cores. He used these relationships and Arctic Alaska mountain glacier ice cores isotope records to reconstruct past precipitation changes associated with fluctuations in sea ice. Similarly, he also studies Arctic Ocean water isotopes to learn more about sea ice and water isotope interactions. Ideas from these water vapor and ice core isotope-based studies of temporal and spatial moisture source variability are being incorporated into peatland paleo reconstructions of precipitation source changes and carbon accumulation rates in northern latitude regions, such as Estonia.

Holocene peat studies on the Pacific Coast of Canada

Terri Lacourse
Department of Biology, University of Victoria, British Columbia (BC), Canada

Peatland research in my lab focuses on multi-proxy studies of Holocene peat from ombrotrophic bogs in coastal BC, Canada, where wetlands are common landscape components but have been infrequently studied. We use pollen, testate amoebae, plant macrofossil, and physicochemical analyses to document changes in vegetation, bog development, and C and N accumulation. On Vancouver Is. (50°N), Lacourse & Davies (2015 *Holocene* 25:1165-1178) showed that mean C accumulation (16 g C/m^2/yr) is significantly lower than rates at most continental sites. C accumulation was highest (31 g C/m^2/yr) in the early Holocene during accumulation of herbaceous peat and when summer temperatures were higher, precipitation was lower, and seasonality was high relative to the present. Long-term changes in C accumulation correspond with changes in plant functional types and hydrological conditions, with the lowest rates during accumulation of *Sphagnum* peat when climate was cooler, wetter, and less seasonal than in the early Holocene. This research shows both the dominant control of climate on bog development and C accumulation as well as the importance of autogenic processes. We are continuing this work at other sites in coastal BC, along climatic gradients, to help clarify the links between climate, vegetation, and C accumulation in this temperate, maritime region.

Coastal bogs generally accumulate less peat and store less C than continental peatlands because the high primary production that results from long growing seasons and abundant precipitation is offset by higher decomposition. Gorham et al (2003 *CJB* 81:429-438) noted a strong negative correlation between precipitation and long-term peat accumulation rates, but their study did not include sites with 1500–3000 mm/yr of precipitation such as those in coastal BC. Our results support Gorham et al's predicted inverse relationship ($r = -0.78$). With this limited dataset, we also note a strong positive correlation ($r = 0.68$) between continentality and peat accumulation. These relationships reflect the important role that the balance between productivity and decomposition plays in accounting for differences in peat accumulation between coastal and continental sites and by extension, on long timescales.

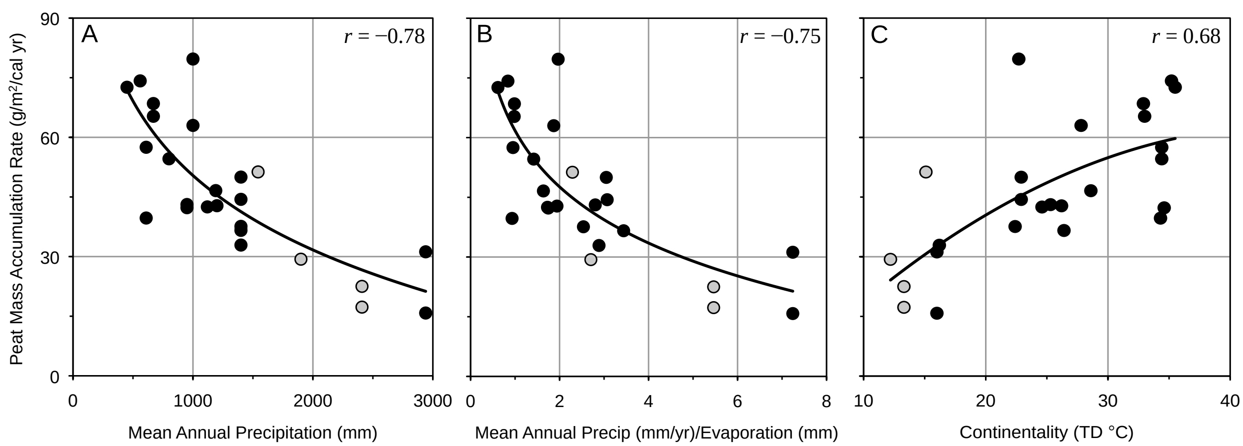

Figure 1. The relationship between peat accumulation and (A) precipitation, (B) precipitation:evaporation ratio, and (C) continentality at 25 North American peatlands. Gorham et al's (2003) sites shown as black circles, sites in coastal BC (Turunen & Turunen 2003; Lacourse & Davies 2015) shown as grey circles.

Carbon dynamics and ecosystem diversity of Amazonian peatlands

Outi Lähteenoja
University of Turku,Turku, Finland

My area of expertise is the carbon dynamics and ecosystem diversity of Amazonian peatlands. The core findings of my PhD thesis and related publications (published in 2009−2013) were: 1) Extensive and up to 7.5 m thick but previously unstudied peatlands exist in the Amazonian lowlands. 2) Peruvian Amazonian peatlands, especially in the Pastaza-Marañón foreland basin, form a significant carbon store, which is 3−6 Gt according to recent estimates. 3) The extensive peatlands in the Pastaza-Marañón foreland basin not only act as a current carbon sink, but also as a long-term biogeological carbon sink, which forms when peat gets buried under minerogenic sediments deposited by dynamically moving rivers. The buried peat deposits subside into the basin owing to geological subsidence. 4) The Peruvian Amazonian peatlands represent a high diversity of ecosystem types from nutrient-rich minerotrophic peat swamps to nutrient-poor ombrotrophic peat bogs. 5) Peatlands also exist in the lowlands of central Amazonia (in the Negro river basin in Brazil), but they are not as thick and as extensive as the Peruvian peatlands.

Peatlands studies: Paleoecology, climate change, pollution and carbon accumulation

Richard Payne
University of York, York, UK

I am a broad-ranging peatland scientist with interests in most things peaty. Some particular areas of interest and current/recent research are:
Peatland Palaeoecology. My background is in peatland palaeoecology where I have particular expertise in testate amoeba analysis, tephrochronology and statistical methods. I have worked on the reconstruction of (late) Holocene climate change in the UK, Alaska and Russia and on the impacts of volcanic eruptions.

Peatlands and forestry. A major current focus is afforested peatlands. I have a new research project looking at the impacts of conifer afforestation on peatland carbon stock in the UK and a PhD student working on the impacts of forest-to-bog peatland restoration on carbon fluxes, and the role of microbial communities in restoration.

Peatlands and climate change. Since 2010 we have operated a climate change simulation experiment on two UK peatlands with warming by open top chambers and summer drought simulation by direct pumping. We have monitored carbon fluxes, plant physiological processes, nutrient pools, microbial communities and much else.

Carbon accumulation. I have worked a little on Holocene carbon accumulation by peatlands. We are currently working on assembling a large dataset of carbon accumulation records for British peatlands to fill what is currently a rather surprising data-gap (only 4 published records).

Peatlands and pollution. I am interested in the impacts of natural and anthropogenic pollution on peatlands. I have worked on the impacts of sulphur and nitrogen deposition on peatland plant and microbial communities using both experiments and spatial gradients.

List of participantsof PAGES C-PEAT Workshop
11-13 October 2015
Lamont-Doherty Earth Observatory, Columbia University, New York, United States

Name	**Affiliation**	**City and Country**	**Email**
Alison Hoyt	MIT	Cambridge, MA, USA	ahoyt@mit.edu
Amila Sandaruwan Ratnayake	Shimane University, Japan	Matsue-shi, Japan	amilageopera@gmail.com
Atte Korhola	University of Helsinki	Helsinki, Finland	atte.korhola@helsinki.fi
Britta Sannel	Stockholm University	Stockholm, Sweden	britta.sannel@natgeo.su.se
Charlie Harvey	MIT	Cambridge, MA, USA	charvey@mit.edu>
Chris Williams	Franklin & Marshall College	Lancaster, PA, USA	chris.williams@fandm.edu
Cinzia Fissore	Whittier College	Whittier, CA, USA	cfissore@whittier.edu
Claire Treat	University of Alaska Fairbanks	Fairbanks, Alaska, USA	ctreat@usgs.gov
Dan Charman	University of Exeter	Exeter, United Kingdom	D.J.Charman@exeter.ac.uk
Dave Beilman	University of Hawaii	Honolulu, Hawaii, USA	beilman@hawaii.edu
David Large	University of Nottingham	Nottingham, UK	david.large@nottingham.ac.uk
Dorothy Peteet	Lamont-Doherty Earth Observatory - Columbia Univ.	New York, USA	peteet@ldeo.columbia.edu
Elaine Matthews	NASA GISS/NASA Ames	New York/Mountain View CA, USA	elaine.matthews@nasa.gov
Elizabeth Corbett	Lamont - Columbia University	New York, USA	jecorbet@gmail.com
Eric Klein	University of Alaska Anchorage	Anchorage, Alaska, USA	esklein@uaa.alaska.edu
Frank Pavia	Lamont-Doherty Earth Observatory - Columbia Univ.	New York, USA	fpavia@ldeo.columbia.edu
Geoffrey Hope	Australian National University	Canberra Australia	geoffrey.hope@anu.edu.au
Ian Lawson	University of St Andrews	St Andrews, UK	itl2@st-andrews.ac.uk
James Holmquist	Smithsonian Environmental Research Center	Edgewater, MD, USA	HolmquistJ@si.edu
Jeff Chanton	Florida State University	Tallahassee, FL USA	jchanton@fsu.edu
John Hribljan	Michigan Technological University/ US Forest Service	Houghton, USA	jahriblj@mtu.edu
Jon Nichols	Lamont-Doherty Earth Observatory - Columbia Univ.	New York, USA	jnichols@ldeo.columbia.edu
Jonathan Stelling	Lehigh University	Bethlehem PA, USA	jmsa14@lehigh.edu
Juan C Benavides	Department of Forest Sciences, National University of Colombia	Medellin, Colombia	jcbenavides@gmail.com
Judith Drexler	US Geological Survey, California Water Science Center	Sacramento, CA, USA	jdrexler@usgs.gov
Julie Loisel	UCLA - Geography	Los Angeles, USA	juloisel@hotmail.com
Julie Talbot	Université de Montréal	Montreal, Canada	j.talbot@umontreal.ca
Karsten Schittek	University of Cologne	Cologne, Germany	schittek@uni-koeln.de
Kate Dwire	USDA Forest Service	Ft. Collins, Colorado, USA	kadwire@fs.fed.us
Laure Gandois	CNRS	Toulouse, France	laure.gandois@ensat.fr
Len Martin	UNSW Australia	Sydney, Australia	lennard@student.unsw.edu.au
Lydia Cole	University of Oxford	London, UK	lydcole@gmail.com
Michelle Garneau	Université du Québec à Montréal	Montréal, Canada	garneau.michelle@uqam.ca
Minna Väliranta	University of Helsinki	Finland	minna.valiranta@helsinki.fi
Miriam Jones	USGS	Reston, VA USA	miriamjones@usgs.gov
Nigel Roulet	McGill University	Montreal, Canada	nigel.roulet@mcgill.ca
Outi Lähteenoja	University of Turku	Turku, Finland	outi.lahteenoja@gmail.com
René Dommain	Smithsonian Institution, National Museum of Natural History	Washington, D.C., USA	rene.dommain@gmx.de
Richard Payne	University of York	York, United Kingdom	richard.payne@york.ac.uk
Sarah Finkelstein	University of Toronto	Toronto, Canada	finkelstein@es.utoronto.ca
Simon van Bellen	Université du Québec à Montréal	Montréal, Canada	simonvanbellen@gmail.com
Sirui Wang	Purdue University	West Lafayette, Indiana, USA	wang2381@purdue.edu
Stephen Greb	Kentucky Geological Survey	Lexington, Kentuky, USA	greb@uky.edu
Steve Frolking	University of New Hampshire	Durham NH USA	steve.frolking@unh.edu
Terri Lacourse	Dept of Biology, University of Victoria	Victoria, Canada	tlacours@uvic.ca
Thomas Kleinen	Max Planck Institute for Meteorology	Hamburg, Germany	thomas.kleinen@mpimet.mpg.de
Thomas Roland	University of Exeter	Exeter, United Kingdom	t.p.roland@exeter.ac.uk
Tim Daley	Plymouth University	Plymouth, UK	Tim.daley@plymouth.ac.uk
Tim Moore	McGill University	Montreal, Canada	tim.moore@mcgill.ca
Victor Brovkin	Max Planck Institute for Meteorology	Hamburg, Germany	victor.brovkin@mpimet.mpg.de
Zhengyu Xia	Lehigh University	Bethlehem, USA	zhx215@lehigh.edu
Zicheng Yu	Lehigh University	Bethlehem, USA	ziy2@lehigh.edu

Other Contributors:

Jill Bubier	Mount Holyoke College	South Hadley, MA USA	jbubier@mtholyoke.edu
Natalia Rybczynski	Canadian Museum of Nature	Ottawa, Canada	NRybczynski@mus-nature.ca