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Interactive comment on "Peatlands and the carbon cycle: from local processes to global implications – a synthesis" *by* J. Limpens et al.

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Interactive comment on Biogeosciences Discuss., 5, 1379, 2008. S347

Interactive comment on “Peatlands and the carbon cycle: from local processes to global implications – a synthesis” by J. Limpens et al. T. Moore (Referee) tim.moore@mcgill.ca Received and published: 14 May 2008

This paper provides an overview of some issues around the carbon cycle of peatlands, which provides an introduction to the papers arising from a conference held in April 2007. It is divided into major sections dealing with small-scale processes and plantsoil feedbacks, carbon fluxes at the landscape scale, climate and peatlands before ending in some conclusions and suggestions for further research.

It contains almost 150 references, with a large proportion being authored or co-

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authored by the authorsof the Biogeosciences article: there may be a degree of over-self-citation and in some cases some citations are not strictly correct. I have not checked to see whether all references are cited in the text and vice versa.

Response: we checked the references regarding their correctness and presence in text & reference list and tried to reduce the number of citations, particularly the amount of self-citations. However, the broad scope of the paper does not allow any major reductions in reference numbers and the authorship of the paper is such that it includes many of the people who have published heavily in peatland carbon dynamics over the past 20 years and so self-citation in such a paper is inevitably going to be common.

Covering such a broad field is a large task and the paper does a good job of identifying the main issues in this topic, even though the transit from microbial enzymes to global models is VERY broad. It also illustrates, quite nicely, that some of the things at the small scale cannot be included at the global modelling scale and thus one has to be realistic about what the objectives are. Both the understanding at the microbial and micro-pore scale and the global earth system models incorporating realistic peatlands are valid, though the challenge in this (and other fields) is to ensure that there are not two solitudes. Some of the writing is a bit contorted and I think some changes could be made to improve the utility of the paper, as follows.

The Abstract provides an overview of what is included in the paper, but contains few specific components, such as what the REAL issues are.

Response: We adapted the abstract, particularly including the main uncertainties.

P 1381 I think it would be useful to start out with what we know in specific terms ; for example, the areal coverage of boreal/subarctic and tropical peatlands (one is given as percentage, the other as ha) in km2 and the probable overall storage of C in these two groups. Also, I think we know enough to be able to estimate the contemporary emission of methane to the atmosphere from these two types of peatlands. We also know enough to estimate the contribution of DOC from these peatlands to water bodies

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(assuming 10 g DOC m2/yr). This situates the peatlands in the global C and methane cycle and sets the stage on what we really know in controlling these processes and how they might change under various disturbances.

Response: We added a number of lines to the introduction, giving the areal coverage and estimated stocks in order to give the reader a better background/ to set the stage for the rest of the paper as suggested. We left out estimations on methane and DOC however, as 1) they are covered later on in the text & figure 4. and 2) there is still a lot of uncertainty considering the emission rates for all peatland types. For example methane emissions from Russian peatlands seem to be much higher than values for Canadian peatlands.

1382 line 18 Whilst it is fair to exclude arctic tundra ecosystems, I think the authors have neglected the evidence for changing C cycling in peatlands in permafrost terrain that are undergoing warming. There is now a substantial literature from Alaska, central Canada, Fenno-Scandinavia and Russia/Siberia to suggest that the thawing of permafrost in northern wetlands can lead to increased C fixation and increased methane emission. This seems to be lacking in this paper. The following paragraph mentions across climatic zones though the permafrost zone seems to have been excluded (and is probably the most difficult to model).

Response: We re-arranged the perturbation section under the captions land use change, climate change and restoration. Under the caption Climate change, we now deal with both increases in fire frequency and a few lines on permafrost degradation.

1383 line 9 dissolved organic carbon (DOC) line 14 delete dissolved organic carbon
Response: Changed as suggested

1384 Fig. 1 is illegible to my eyes: too small. It is not clear to me how the different parts of this figure are linked together

Response: We added in-text references to the different parts of the figure and clarified

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the figure caption. To improve overall legibility, we will enlarge the way the figure is presented by reproducing it across the full page width.

1385 line 8 relatively small is redundant: small is relative though here we are not sure what small and large are compared with: what is the comparison group to allow the statement that sulphate deposition reduced methane emission rates in these zones?

Response: we omitted small. It is a bit difficult to talk about comparison groups when dealing with regression analysis across deposition gradients. We reworded the sentence to avoid confusion. It now reads The potential effect of S deposition as a control on CH4 emission from nutrient poor peatlands is illustrated by studies across S deposition gradients in eastern North America and Europe (Nedwell and Watson, 1995; Gauci et al., 2002; Vile et al., 2003). The authors showed that CH4 production rates increased and SO4 reduction rates decreased with increasing S deposition

Line 27 Fig. 1D 1386 line 23 I am not sure what this sentence means: what is an active unsaturated layer (arent all unsaturated layers active?) Response: we removed active I am not sure what the aerobic decomposition is

Response: we meant k under aerobic conditions and I am not sure what role photosynthetically driven root respiration plays here: surely it is part of autotrophic respiration, unless there is a priming effect associated with the rhizosphere.

Response: with photosynthetically driven root respiration we meant the root exudation rate. The latter is directly related to photosynthetic activity. So yes, we meant a kind of priming effect. To accommodate above comments, we reworded the sentence. It now reads: If such findings could be generalized, C fluxes from heterotrophic respiration could be modeled by the depth of the unsaturated layer, the distribution of the decomposition constant, the soil temperature, and the photosynthetically driven root exudation rate in the unsaturated zone. 1388 line 19 what sort of modeling approach is required?

Response: We adapted the sentence. It now reads: This research field, requiring dynamic vegetation models that allow for continual feedbacks between vegetation and environment, is just starting to emerge (Heijmans et al., 2008; St- Hilaire et al. 2008 this issue).

1389 line 18 minerotrophic Response: changed as suggested

1389 From the perspective of plant ecology, knowledge of (let alone understanding of) the belowground activities of plants (roots) lags well behind aboveground activities (biomass, photosynthesis), yet there is a clear regulation on the root mass and distribution by the water table. The belowground weakness of knowledge appears in most ecosystems, but I think is particularly profound in peatlands, where the effect of global change may be through belowground activities

Response: we agree. Effects of global change may be felt first in belowground activity, when no response in aboveground processes is observed yet. Nevertheless, we decided against adding this to the plant-feedback paragraph, since it is implicitly mentioned in 2.2 –effects on litter degradability, peat physical properties, root exudates & roots with aerenchymetic tissue all imply below-ground activity.

1390 Here we have some nice quantified DOC export from peatlands, which might be used in the initial paragraph to situate peatlands within the global C cycle.

Response: we decided not to include this information in the introduction. For reasons see response co earlier comment on P 1381 (same referee) concerning the introduction.

1391 The photo of the peatland pipe is impressive, but I wonder how common this is. Most peatlands have very low topographic gradients and thus low-energy aquatic systems, the exception being blanket bogs in hilly terrain, which is where this is from, I guess. This must be a rare phenomenon in the global peatland picture (or not, if we have not looked for it).

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Response: it seems that the latter is true – these phenomena may be more common than we have thought, even in peatlands with relatively low topographic gradients. We have expanded the text with a few lines describing the peatland types where pipes have been reported from. See response to referee 3.

1392 line 10 I think these were for Swedish peatland streams. Response: true, we inserted peatland

Line 21 I assume that these measurements were made by eddy covariance systems (the alternative being chambers extrapolated to the annual scale). I think it is worth mentioning that eddy covariance towers do provide year-round measurements though one should not enquire too closely at gap-filling) and observe patterns with a foot-print of several hundred square meters. Of course, one does not know where in the footprint the gas exchanges are occurring and given the high spatial/topographic variability in most peatlands, thee is a need to determine processes within that variability: again the issue of scale.

Response: the measurements were made by eddy covariance systems. We added this information to the text. We stressed the issue of scale-dependency more in the rewritten conclusion section as well as in the abstract

1393 Given the rather narrow range of observed rates of C accumulation in peatlands, it is interesting to speculate whether there are feedbacks in peatlands which, over sites and years/seasons, effectively work to reduce the variability in C accumulation rates. Comparison of multi-year and multi-site results (such as started by Humphreys and Lindroth etc.) of NEE, CH4 and DOC may identify some interesting and perhaps generalizable patterns, which eddy covariance towers (plus CH4 and DOC measurements) can capture. Here we might be able to generate some hypotheses, based on plant ecology and physiology and testable by towers.

Response: interesting point. We included part of the text above in the conclusion section.

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1395 I do think one might include climate change as a perturbation here: it is not as dramatic and as rapid as fire and drainage, but in permafrost environments, there can be profound changes in thermal regime, leading to hydrologic changes, plant composition and C budgets, as shown in Alaska, Canada, Sweden and Siberia.

Response: We re-arranged the perturbation section under the captions land use change, climate change and restoration. Under the caption Climate change, we now deal with both increases in fire frequency and a few lines on permafrost degradation.

1396 line 19 is this DOC production, or export? Here we have a rather confusing mixture of concentration and production, whereas the interest seems to be on export. Creating anaerobic conditions probably slows the rate at which DOC is produced within a soil.

Response: we reworded the sentences. Many degraded peatlands are the subject of restoration projects. Management practices are varied but include raising the water table through gully and ditch blocking (Evans et al., 2005) and reseeding or planting bare surfaces (Petrone et al., 2004). These management interventions can have an immediate impact on the export of C to streams and rivers. Holden et al. (2007b) for example, demonstrated an almost two orders of magnitude decrease in POC export for a restoration project in northern England while Wallage et al. (2006) and Armstrong et al., (in press) have shown that DOC fluxes are significantly reduced through drain blocking and water table recovery.

Line 25 Experience in eastern Canada in restored peatlands shows that you need to get a vascular plant cover to provide the surface roughness/microclimatic niches in which mosses and shrubs can colonize the peat surface. This (particularly cotton grass) creates new biomass but also primes the peat through fresh organic matter, leading to increased rates of peat decomposition, and to increased methane emission rates, before the normal cover of mosses and shrubs develops.

Response: We included the information. The text now reads: Quick re-vegetation of

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degraded peat is often possible and peat formation can be fast in gullies and drains, even without water table restoration measures, thereby still having positive effects on ecosystem C storage (Evans and Warburton, 2007). Re-vegetation outside gullies is often aimed at restoring a vascular plant cover (often Eriophorum sp.), or applying a layer of straw mulch to provide a suitable microclimate for Sphagnum mosses to re-establish (Grosvernier et al., 1995; Rochefort et al., 2003). This creates new biomass but also primes the peat through input of fresh organic matter, leading to a transient increases in peat decomposition and increased methane emission rates (Chojnicki et al., 2007), before the normal cover of mosses and shrubs develops.

1397 line 25 Thornton 1398 line This sentence is a bit redundant, repeating the Introduction.

Response: Changed as suggested

1399 line 7 and 9; perhaps a left-handed slip. I think these fluxes should be 1012, not 1015 (teragrams not gigatons or petagrams).

Response: true, figures should be expressed in teragrams - changed as suggested

Line 26 I am not sure water balance is the right term. Peatlands can have large inputs and outputs (e,g, tropical) or small (subarctic), and the carbon economy is tied to the exchange of C with the atmosphere (CO2, CH4) and water bodies (DOC and DIC), both of which appear to be related to the water table position, or some similar hydrologic parameter (maybe even residence time of water). I think the community is grappling with water table and water movement as the key connecting elements of peatlands. 1401 I think a way forward (the wish list of things to do) might also include some thought about how to integrate information, and possibly knowledge, at varying scales. The peatland community is rather small (compared to the numbers studying other terrestrial ecosystems) and by nature ranges from those fiddling about with enzymes and biogeochemicals at the scale of a few centimeters, to those dealing with plant communities (a few square meters) to the eddy covariance towers (several

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hundred square meters) and to those at the regional/continental scales who wish to include peatlands in global system models. A challenge (or way forward) is to ensure some dialogue between these disparate groups, and I think that this conference and this overview paper points in some directions whereby the dialogue can be developed.

Response: we rewrote the conclusion section, making use of part of the issues raised in the text above

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