

## ***Interactive comment on “Northern peatland carbon stocks and dynamics: a review” by Z. Yu***

**Anonymous Referee #1**

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### General comments

The manuscript is a well written and succinct review of the state of current knowledge on carbon stocks and carbon dynamics in northern peatlands, with a particular focus on reconciling concepts and results from both contemporary and historical peatland carbon accumulation studies. It has a good discussion on how carbon stocks are estimated for the circum-boreal region, with the discussion leading up to the author's best estimate of total carbon stock and why it is similar or different from earlier estimates. The manuscript also discusses how historical carbon accumulation can be assessed by the use of inferred net carbon balance (NCB) – an estimate that is argued to give a more representative carbon accumulation history than the often used concept of long-term apparent rates of carbon accumulation (LORCA). NCB is also the only estimate of historical carbon accumulation that can be readily compared to contemporary carbon accumulation – and a comparison shows that the few studies that report contemporary

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net ecosystem carbon balances (NECB) report estimates that are substantially higher than the average inferred NCB for the last few millennia. Lastly the review discusses gaps in knowledge and ways to further research on the topic.

I have a few general comments that should be considered when revising the manuscript along with several specific comments that follow below.

In sections 3 and 4, the author often refers to results and methods from his own previous publications. While this is acceptable, care should be taken so that this review does not read like an extension of the discussions in the cited references. I.e. this review should stand on its own, and not be relying on the reader to have access to earlier publications for method descriptions and figures.

The comparison of contemporary and reconstructed historical carbon accumulation rates is admittedly hampered by the low number of sites with complete contemporary carbon budgets. However, since the review is analysing means of carbon accumulation rates, it seems to me that partial carbon budgets could be used to assess differences between contemporary and historical carbon accumulation rates – i.e. by using a larger dataset of NEE, CH<sub>4</sub> and DOC fluxes from peatlands, even if only one or two of the fluxes are measured. I recognize that compiling a database with carbon fluxes from peatlands would be outside the scope of this review, but there are good reviews available with estimates of average carbon fluxes for boreal peatlands that could be discussed in the context of this review, e.g. Frohking et al., 2011 Environmental review for NEE and CH<sub>4</sub> fluxes and Fraser et al., 2001 Hydrological Processes.

I would like to see an improved discussion on the importance of fire for long-term carbon accumulation. Recent studies in boreal peatlands show that several hundred years of carbon accumulation can be lost in wildfire (Turetsky et al., 2011, Nature). Particularly this is of importance when discussing the apparent discrepancy between contemporary and historical carbon accumulation rates.

Overall, I think that this manuscript addresses a relevant scientific question and

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presents new perspectives that improve our understanding of peatland carbon accumulation.

#### Specific comments

P5074 L2. The abstract would benefit from a short sentence at the start, with the rationale for the review and the importance of improved knowledge in the field.

P5074 L6. "Several ways to improve estimates were discussed..." Omit this sentence or work in a way to briefly describe in what ways estimates can be improved.

P5074 L7. The difference in carbon accumulation history between NCB and Sphagnum spores is discussed in the review and it is clear that the author believes that NCB gives a better estimate (this is what is described in the following sentence) – which should be made clear in the abstract.

P5081, L6. This sentence starting "In their review..." is somewhat confusing; a review of north American wetlands had a global estimate of peatland C storage, which in turn is given two new citations. Are those two the citations that Bridgeham et al. used in their review? Clarify.

P5081, L15. How should the uncertainty range be interpreted? As it stands, I interpret the uncertainty range as a best guess by the author, based on the review of the literature (which I agree with) – rather than based on a numerical exercise (i.e. a formal 95% confidence interval of some sort). If so, this should be stated even clearer than it is at the moment – both in the main text and in the abstract.

P5081, L24. The reference to Yu et al. (2010) is irrelevant for this article since it does not deal with northern peatlands, and could be removed.

P5082, L2. If the analysis of calculating peatland area change over time from peat basal dates was done in Yu et al. (2010), rather than done for this manuscript, then I would recommend re-writing the sentence "The basal ages in Mac-Donald et al. (2006) have been used to derive a first approximation of peatland area changes over time and

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is shown in Fig. 2b (Yu et al., 2010)." As it stands now, the reader gets the impression that this manuscript is an extension of an earlier analysis, and not a review of published data.

P5082, L4. Add a short sentence with the main result from the analysis and figure described in the previous sentence – i.e. rapid initiation followed by reduced rate of peatland area increase.

P5082, L5. The paragraph that starts on L5 could benefit from being restructured. I would start the paragraph by introducing the concept and definition of LORCA, followed by estimates of LORCA and finish the paragraph with critique of LORCA and associated acronyms. The rationale for the apparent increase in LORCA with time should also be expanded.

P5082, L22. Stating the sentence with a statement that a nice review was done, but not providing any examples from that review is not useful. Expand or remove.

P5082, L23. I do not think that a direct citation of Tarnocai is necessary – but the importance and influence of fire and erosion for LORCA results should still be discussed.

P5082, L28. Would you have any suggestions on how large datasets of basal dates could be made of further use? Leaving it as it currently stands is very open ended.

P5083, L1. The expanded definition of LORCA, with multiple age determinations along the peat profile is the same method described in the following paragraph? Starting the next paragraph then with the statement 'An alternative way' becomes confusing. Clarify.

P5083, L16. Although a decreased carbon accumulation rate could be due to factors other than abrupt disturbances (fire) – e.g. drier conditions that promote decomposition.

P5083, L20. How sensitive are results of the back-calculations of NCB to assumptions of the decay model? What per-cent of the peat carbon is assumed to be respired each

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year in the model? Figure 2d only shows the uncertainty based on the 33 replicates, but not uncertainties associated with assumptions of the decay model if I understand it correctly. If assumptions of the decay model have a large influence on magnitude of NCB estimates, but not the pattern of NCB over time (or both) I would like this to be stated.

P5083, L25. The word 'inevitable' implies that all carbon is lost. I would re-phrase it 'NCB represents the carbon sequestration at different times in the past (including abrupt losses, e.g. through fire), after taking into account partial subsequent losses through decomposition.'

P5084, L9. This paragraph really needs a first sentence that signals the direction and purpose of the arguments in the paragraph. As it stands now, I did not catch on to the direction of the paragraph until L.26. A version of the sentence 'These Holocene histories of carbon sequestration...' should thus be moved to the beginning of the paragraph. The argument in this paragraph is really that methods other than the described NCB method will overestimate late Holocene C accumulation since they do not account for decomposition of peat stocks during the period from their accumulation until today. This is an important and interesting point, and should be emphasized.

P5084 L21. The statement on why the pollen record underestimates carbon accumulation needs further evidence in order to convince the reader that carbon accumulation based on NCB gives an improved history of carbon accumulation. Use additional references to strengthen your argument.

P5085, L20. There are additional discrepancies between NCB and NECB that are not related to the time-frames discussed, and that is the possible importance of additional C fluxes. For example; emissions of volatile organic carbon (see Holst, Arneeth, Hayward et al. 2010, Atmos.Chem.Phys) are seldom included in NECB estimates, and neither is waterborne export of dissolved inorganic carbon. While these fluxes are small (probably  $\sim 0.1-5$  g C yr<sup>-1</sup>), they represent continuous losses from peatlands and

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thus have the potential to have minor but detectable influences on long term C accumulation. This is another reason why NCB and NECB might not be identical estimates of carbon accumulation, and a short discussion on this topic should be included.

P5086, L7. The sentence 'When plotted...' should be moved (or removed) down into the next paragraph where you discuss the possible reasons why observed NECB is greater than observed NCB – i.e. towards the argument that these sites are potentially not representative for northern peatlands, since they are likely warmer than the average site of equal precipitation.

P5086 L9. The large inter-annual variability at individual sites and the maximum and minimum NECB among sites are two separate issues and should not be included in the same sentence.

P5086 L19. The number 32.3 needs not to be repeated, since it was mentioned only 2 sentences prior. "The carbon accumulation rate as estimated by NECB studies is about threefold...".

P5086 L24. Nearest in temperature/precipitation space or in physical space?

P5087 L3. How about: '...if derived Holocene NCB represents true carbon accumulation robustly and accurately, and if...'

P5087 L9. The sentence 'I added...' is unnecessary and can be removed. You have already pointed out the large inter-site and inter-annual variation, and the fact that the mean increased from an earlier estimate is irrelevant.

P5087 L16. I would like to see an expanded discussion on the influence of fire on the comparison of NECB and NCB – see recent publications by Turetsky, Donahue & Benscoter, 2011, Nature and Turetsky Kane et al., 2010, Nature Geoscience. Several hundred years of NECB accumulation can be erased by fire, and there are important connections between fire and drought. Also, I don't think that fire is actively suppressed in the studied sites, it is just an unlikely event that did not happen to occur (most

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researchers would probably be delighted if a site burned after a few years of NECB measurements – it would make for a very nice comparison of NECBs before and after fire –as long as equipment can be replaced).

P5087 L18. References should be included for both the impact of fire and flooding on C accumulation.

P5089 L26. Any suggestions on how NCB can be estimated from basal dates? Fig. 1 I think this figure can be omitted, the data is presented in table 2. I would like to see a table with regional estimates of C stocks. Several studies and estimates are mentioned in the text. Showing this in a table could explicitly show for what regions specific estimates are missing.

Technical comments

P5080 L4. Reference should be Kuhry, not Khury, I believe. Again on P5082, L22.

P5081 L23. Double specification of the characteristics of the MacDonald reference – was it the first comprehensive compilation, or the most comprehensive compilation? Remove either the word first or most, but consider expanding the explanation, e.g. note if MacDonald et al. used basal cores from the full circum-boreal region.

P5083 L11. This is a long sentence that starts with ‘Using this approach.’ – consider splitting into two sentences.

P5083 L13. ‘... in climate space’ is more appropriate than ‘... on climate space’.

P5087 L29. The Lund study included peatland sites, not wet tundra sites, I believe.

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Interactive comment on Biogeosciences Discuss., 9, 5073, 2012.