

## **Z.C. Yu: Northern peatland carbon stocks and dynamics: a review**

### **Author's Response to Referee #1's comments:**

I think the referee for his/her constructive, thoughtful, and detailed comments. I have carefully considered and responded to all comments in the responses below and in the proposed revisions of the manuscript. As a result, I believe the revised manuscript will be much improved. I wish I could acknowledge the referee by name for the generous and knowledgeable contributions to this manuscript.

Below my responses are in the same order as reviewer's comments (**comments are in bold/italic**, while my responses in plain text). I have tried to indicate the focus/topic for each of reviewer's comments, so hopefully these comments/responses will be more useful and user-friendly to readers of these public and interactive exchanges of ideas.

### **General Comments**

#### **1. Previous papers and this review paper**

I fully agree with the reviewer that the present review paper should stand on its own, with regards to the descriptions of methodologies and conclusions. As a result, in the revised manuscript, I will and have taken additional care to clarify any statements. Also, I have provided some extension of ideas and discussions in this paper beyond the previous publications. These revisions include the ones as specifically suggested by this reviewer (see below specific comments).

#### **2. Expanded discussion of partial C budget results**

In response to this constructive comment, I plan and have made the following changes.

- (1) I have included additional information in Table 3 (now revised table 4) to include the mean values of NEE, CH<sub>4</sub> and DOC flux results from 5 NECB sites, in addition to NECB results. Also, I include the proportions of NECB, CH<sub>4</sub> and DOC as percentages of NEE. I believe that the addition of these data in this paper will help us evaluate the partial C budget results in the literature (see (2) below).
- (2) In addition, I have discussed, mostly in a new paragraph (second from the last in Section 4), some of partial C budget data in the literature by citing 4 new references, in addition to the two references suggested by the reviewer (Fraser et al. 2001; and Frohking et al. 2011 – the latter paper was cited in the original manuscript, but in the revised version their summary of NEE and CH<sub>4</sub> data is also discussed). The 4 new references are Aurela et al. (2004), Syed et al. (2006), Alm et al. (1999) and Schneider et al. (2012).

The extension provides a relevant and useful addition to the paper.

#### **3. Additional discussion on the importance of fires**

I have added two new references following the suggestion by the reviewer (Turetsky et al. 2011a, 2011b). Also, I provided additional discussion on the C losses

from fires. I believe that this addition provides a balanced treatment of the importance of fires, along with other disturbance (e.g., flooding), which aids the discussion of discrepancy between contemporary NECB and historical NCB.

### **Specific Comments**

All specific comments and suggestions below have been carefully considered and in most case acted on to improve the manuscript.

#### ***P5074 L2 (adding rationale for the review in the abstract)***

I have responded to this constructive suggestion by adding two new sentences at the beginning of the abstract.

They are:

“Peatlands contain a large belowground carbon (C) stock in the biosphere, and their dynamics has important implication for the global carbon cycle. However, there are still large uncertainties in C stock estimates and poor understanding of C dynamics across timescales.”

#### ***P5074 L6 (providing more informative specifics)***

I have taken the suggestion to add additional information, rather than deleting the sentence (I agree that either would work better than the general mention “were discussed” in the original manuscript).

The sentence now reads:

“Several ways to improve estimates of peat carbon stocks were also discussed in this paper, including the estimates of C stocks by regions and further utilizations of widely available basal peat ages.”

#### ***P5074 L7 (clear statement of difference between spore and NCB approaches)***

I have added a phrase “... and I argue that spore-based approach underestimates the abundance of peatlands in their early histories.” in the abstract, as suggested by the reviewer.

#### ***P5081 L6 (clarifying the Bridgham et al. citation)***

I reword the sentence and now it reads:

“Bridgham et al. (2006) estimated that global peatlands contain from 234 to 679 Gt C by summing regional data, which includes 178 Gt C in North America, with about 150 Gt C in Canada (Roulet, 2000; Tarnocai et al., 2005).”

#### ***P5081 L15 (clarify the meaning of uncertainty range)***

“Best guess” is the meaning of the mean value and uncertainty range. I have made this clearer as suggested in the abstract and the main text.

#### ***P5081 L24 (removing mention of tropical and southern peatlands by Yu et al. 2010)***

I do not agree, and think it is useful to provide readers a broader background that similar data have been compiled for other regions, in addition to northern peatlands. I don't have strong opinion on that, though.

***P5082 L2 (extension or review of published work on peatland area over time)***

I fully agreed and reworded as suggested. This is one of the examples to clearly distinguish between reviewing published results and new extension in this review paper (see general comments above by the reviewer).

***P5082 L4 (a new sentence spelling out results on initiation pattern)***

I have added a new sentence as suggested: "The results show that the area of northern peatlands increased monotonically, but with reduced rate over time during the Holocene (Fig. 1b). " This is a useful addition.

***P5082 L5 (reorganizing the paragraph)***

Done as suggested. Now it reads better, and the flow of ideas is clearer.

***P5082 L22 (Expand or remove a general statement on LORCA)***

The sentence is removed as suggested.

***P5082 L23 (the need for direct citation of Tarnocai et al. 2012)***

I have reworded the sentence by removing direct quotes and citation from this reference. The discussion on fires and flood is retained as suggested.

***P5082 L28 (suggestions for using basal ages for C study)***

I have provided a few sentences to describe a possible way to use the basal age database, as encouraged by the reviewer.

They are:

"However, it may be possible to make more meaningful use of these large and valuable basal age datasets, if a new approach and methodology can be developed in analyzing the data. For example, if we assume that all the basal ages for a region or for the entire northern peatlands were from a Super Peatland (see Yu, 2011), then we might be able to derive C accumulation history by binning these basal ages and deriving C accumulation rates for individual bins. Of course, this possible approach would require C measurements (bulk density, and C content) from these peat profiles with basal ages; however, most of these profiles lack such data."

***P5083 L1 (LORCA or an alternative approach)***

I meant to indicate that some workers mistakenly expanded the initial definition of LORCA, perhaps unintentionally, by including C accumulation rates from multiple data. So the goal here is to point out such a concept and associated terminology may not help understanding and communication of our science. I used the wording "alternative way" by referring LORCA as originally defined.

***P5083 L16 (droughts causing C losses)***

I have changed the statement by adding “climate-related losses”, and it now reads: “any disturbance-related and climate-related loss of carbon”.

***P5083 L20 (sensitivity of decay model used)***

The decay constant (fractional loss rate due to decomposition) used is 0.0000855 yr<sup>-1</sup>, so the loss rate is <0.01% per year. It is a very slow rate under anaerobic and cold conditions in deep peat, but it is significant over thousands of years acting on a large peat C pool. As there is no data available to evaluate conclusively the goodness of particular decay models/rules (Clymo et al. 1998; Yu 2011), we cannot yet generate uncertainties associated with assumptions of decay models. So as correctly pointed out by the reviewer, the uncertainties shown were derived from inter-site variations of 33 historical C accumulation sites.

I have added the following new sentences to state the impact of different decay rules on the results, as partly suggested by the reviewer.

“Modeling analysis following different decay rules in Clymo et al. (1998) showed no significant differences or improvement in results (Yu, 2011). In any case, even if different decay rules affect the magnitude of NCB estimates, the pattern of NCB over time will likely remain the same. “

***P5083 L25 (rephrase and clarify the sentence)***

Done as suggested.

***P5084 L9 (paragraph reorganization and conclusions of different approaches)***

I have followed the reviewer’s suggestion to add the following two sentences, one as opening topical sentence, and another as closing sentence of the paragraph.

First sentence: “How does the peatland C sequestration history from the NCB approach compare with other studies? “

Last sentence: “I argue that methods other than the NCB method tend to overestimate late Holocene C sequestration in peatlands since they do not account for peat decomposition during the period from their deposition until the present.”

***P5084 L21 (additional references to support the statement about Sphagnum spore approach)***

I added “MacDonald et al. 2006” that also concluded that fens tend to dominate early on in peatland histories.

***P5085 L20 (VOC and discrepancies between NECB and NCB)***

I have added a short discussion on these possible factors that cause the difference between NECB and NCB, as suggested.

The new sentences added are:

“Furthermore, other C losses from peatlands, including volatile organic carbon (VOC) (e.g., Holst et al., 2010) and dissolved inorganic carbon (DIC) (e.g., Nilsson et al., 2008; Dinsmore et al., 2010), that are implicitly included in historical NCB

calculations, but are often not included in NECB estimates. While these C fluxes are small (for example,  $\sim 0.4 - 9 \text{ g C m}^{-2} \text{ yr}^{-1}$ ; Dinsmore et al., 2010; Nilsson et al., 2008), they represent continuous C losses from peatlands.”

***P5086 L7 (move the sentence on climate space)***

Done as suggested.

***P5086 L9 (inter-annual variability vs. variations among sites)***

I agree that they are two separate issues and I have separated to 2 sentences.

***P5086 L19 (replication)***

Replication is removed, and the sentence is reworded as suggested.

***P5086 L24 (physical or climate space)***

It refers to climate space and is clarified as such in the revised manuscript.

***P5087 L3 (rewording)***

Done as suggested.

***P5087 L9 (redundancy)***

The sentence has been reworded in response to the reviewer’s comment. However, I feel that the disclosure of previous average as discussed in Yu et al. (2011) is needed in this paper, despite the fact that a bit redundancy still exists. It seems to me that disclosure over-weights slight redundancy. The sentence has been changed to: “The updated mean value of  $32.3 \text{ g C m}^{-2} \text{ yr}^{-1}$  from 5 sites presented here is higher than the mean of  $25 \text{ g C m}^{-2} \text{ yr}^{-1}$  from three sites (Yu et al., 2011), suggesting again the high interannual and between-site variability of contemporary NECB measurements. “

***P5087 L16 (discussion of fires and fire suppression)***

I have added these two references (Turetsky et al. 2011a, 2011b), and expanded discussion of the importance of fires. See my response to general comments on the same issue above. Also, I agree that site PIs may welcome a fire disturbance at their tower sites, so proactive suppression of fires may not be true as I speculated in the original manuscript. As a result, I changed the sentence related to suppression of fires to the following:

“However, these disturbances were likely not encountered during the period of carbon flux measurements at these flux study sites. “

***P5087 L18 (references for fire and flood)***

I have added 4 new references: two on fire, and two on flood. They are: Bhiry et al. (2007), St. Louis et al. (2000), and Turetsky et al. (2011a, 2011b).

***P5089 L26 (estimate NCB from basal ages)***

See my response to specific comment ***P5082 L28*** above.

### **Delete Fig. 1**

Fig. 1 has been removed from the revised manuscript.

### **Adding a new table on regional peat C stocks**

I have added a new table (Table 3) to summarize available regional peatland C stock estimates. That is a great suggestion that increases the usefulness of the paper.

### **Technical Comments**

All suggested editorial changes have been made. For Lund et al. (2010) synthesis study, we indicated “12 wetland sites (peatlands and wet tundra)”, as they indeed include a few wet tundra sites (even in their article title), which are indistinguishable from wetlands/peatlands, though.

### **New references**

**(added to the manuscript and mentioned in the responses above):**

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Fraser, C.J.D., Roulet, N.T., and Moore, T.R.: Hydrology and dissolved organic carbon biogeochemistry in an ombrotrophic bog, *Hydrol. Processes*, 15, 3151–3166, 2001.

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Schneider, J., Kutzbach, L., and Wilmking, M.: Carbon dioxide exchange fluxes of a boreal peatland over a complete growing season, Komi Republic, NW Russia, *Biogeochemistry*, DOI 10.1007/s10533-011-9684-x, 2012.

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Turetsky, M.R., Donahue, W.F., and Benscoter, B.W.: Experimental drying intensifies burning and carbon losses in a northern peatland, *Nature Communications*, 2, Article No. 514, doi:10.1038/ncomms1523, 2011b.