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

Author's Response to Referee #2's Comments

I think the reviewer for offering these thoughtful comments. I have tried to respond these comments below and revise the manuscript accordingly as much as I can. However, I confess that I am unable to address some comments, mostly as I consider they are beyond scope of the paper. In any case, I hope the reviewer's comments and my responses below are of use in general discussions of ecosystem C dynamics.

Reviewer's comments are in bold and italic, and my responses in plain text.

How peat C stocks change with climate and hydrology, including changes in NECB with climate (temperature, precipitation) and hydrology (water table depth) at annual to millennial time scales? What 'process understanding' would be required for such analysis?

I have added a few sentences at the end of the second-from-the-last paragraphs in section 3 about proposed climate controls of historical NCB pattern during the Holocene. They are:
"The greater C sequestration in the early Holocene is likely induced by warmer climates in many high-latitude regions dominated by peatlands (Yu et al., 2009, 2010; Jones and Yu, 2010), corresponding to the Holocene thermal maximum (HTM; Kaufman et al., 2004). The subsequent decline in C sequestration is caused by climate cooling in the late Holocene (neoglacial cooling) after the HTM and the widespread initiation and formation of permafrost (e.g., Zoltai, 1993). "

In terms of climate and, more importantly, hydrology controls on contemporary NECB, I have discussed the role of interannual weather/climate and resultant hydrology change in the original manuscript. In the revised manuscript, I added a phrase to emphasize the role of hydrology by citing the suggested paper by Sulman et al. (2010). The new addition reads:
"Most variability at interannual timescale was caused by weather and resultant changes in temperature and peatland hydrology, *including water-table influence on species composition of different types of peatlands and on gross ecosystem photosynthesis and ecosystem respiration (Sulman et al., 2010).* "

I fully agree with the reviewer that understanding the environmental controls of peatland C dynamics across different timescales is one of the most important goals in all our efforts by researchers working on contemporary C flux and historical paleo studies. Also, in this review paper I specifically highlight the need and potential scientific and practical values of linking C dynamics across different timescales from annual to millennial. However, I don't think we are there yet, so we still have a long way to go to reach that goal, but again I believe that it is an important research direction and that peatlands can potentially serve as a model ecosystem in addressing this important question (see also Yu et al., 2011).

I very much like the question brought up by the reviewer: what do we need in order to carry out such analysis on environmental controls of C dynamics across timescales? I wish I know the answers, but I don't. However, here are some speculations that I hope would be useful to guide our research along this line. I think we'd need additional data for both contemporary NECB measurements and historical NCB reconstructions, preferably at the same study sites. In addition, the coordinated and integrated data sets will inform process model design and experiments to investigate the influences of timescales on peatland C dynamics.

What inferences about variation in NECB with climate might be drawn from the early vs. late Holocene accumulation rates in Sec. 3?
The high accumulation in the early Holocene was likely caused by a warmer climate, and the low C accumulate rates during the late Holocene by climate cooling following the Holocene Thermal maximum. See also response above.

I have added a few sentences at the end of the second-from-last paragraphs in section 3 about proposed climate controls of historical NCB pattern during the Holocene. They are:
"The greater C sequestration in the early Holocene is likely induced by warmer climates in many high-latitude regions dominated by peatlands (Yu et al., 2009, 2010; Jones and Yu, 2010), corresponding to the Holocene thermal maximum (HTM; Kaufman et al., 2004). The subsequent decline in C sequestration is caused by climate cooling in the late Holocene (neoglacial cooling) after the HTM and the widespread aggradation of permafrost (e.g., Zoltai, 1993). "

The paper by Sulman et al. 2010 (Geophys. Res. Lett.)
Cited as suggested (see above).

Sensitivity of NCB to assumptions about decomposition rates
See response to Referee #1's comment. In short, I have added the following new sentences to state the impact of different decay rules on the results.
"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. "

What are the implications of these different rates for global C cycling as mentioned at the end of Section 3?
I have added a new sentence at the end of Section 3 to highlight the different implications of these results for the global C cycle. It is:
"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."

For detail, the readers were referred to other papers that discuss the roles of peatlands in the global C cycle during the Holocene (Ruddiman et al., 2011; Yu, 2011; Yu et al., 2011; Menviel et al., 2012), as I don't think it is appropriate to discuss these in detail in this paper. This review paper focuses on peatland C stock estimate and uncertainties, and their change over time and across timescales.

Is there any way to test these assumptions at an annual time scale under site-specific conditions with estimates of ecosystem respiration from eddy co-variance measurements?

A general pattern and rule emerged from analyzing data at annual timescales under site-specific conditions would be very useful in process understanding, which potentially can be applied to longer timescales. I like this idea, and we should strive to do that, but I cannot offer specific ways forward. One practical difficulty is that NECB data show very large interannnual variability at individual sites and also large difference among sites – that would limit the ability to derive general patterns or rules from these still limited datasets, as discussed in the paper.

The causes of larger NECB vs. NCB in Fig. 4 and gap-filling procedure to derive NECB?

I have discussed possible influence of recent increase in N deposition on high NECB values. However, I cannot comment on the likelihood of overestimates of NECB, due to gap-filling procedures in estimating CO_2 effluxes. I understand that the synthesis data after gap-filling procedures, as in La Thuile Fluxnet dataset (www.fluxdata.org), tend to change the flux values as reported in the original publications (see Lund et al. 2010). I look forward to seeing systematic analysis of this suggested possible bias, if any, in gap-filling procedures under different turbulent conditions, when such an analysis is available, but I think more detailed discussion here is beyond the scope of the paper.

Can the NECB – NCB comparisons in Sec. 4 be more resolved in climate space (i.e. under comparable temperature and precipitation) while removing disturbance effects in NCB?

We don't have information for historical Holocene disturbances at NCB sites to disentangle climate and disturbance influences. Indeed, it would be desirable to carry out more resolved comparisons between NECB and NCB in climate space. However, due to large inter-annual and inter-site variability in NECB data and also due to the incomplete knowledge about C fluxes at NCB sites, it may not be feasible at the moment.

Specific comments

Done.

Fig. 1 seems redundant.

Done as also suggested by Referee #1.

References mentioned above and new to the revised manuscript:

Sulman, B. N., Desai, A.R., Saliendra, N.Z., Lafleur, P.M., Flanagan, L.B., Sonnentag, O., Mackay, D.S., Barr, A.G., and van der Kamp, G.: CO_2 fluxes at northern fens and bogs have opposite responses to inter- annual fluctuations in water table, Geophys. Res. Lett., 37, L19702, doi:10.1029/2010GL044018, 2010.