

Responses to reviewer #2

I have some concerns about the use of the ^{210}Pb dating method to determine short term accumulation rates. It seems to me that this approach hinges on the assumption that the effects of organic matter decomposition and vertical transport on the ^{210}Pb profile are negligible. For both processes this may not be true. Decomposition is likely relevant, particularly for the dryer ecosystems. In fact, the authors acknowledge in the discussion that the accumulation rates are the result of the balance between input and decomposition. Significant loss of organic matter by decomposition would cause ^{210}Pb to become more concentrated, resulting in underestimation of the age. In two cases the ^{210}Pb age is significantly lower than the ^{14}C age (Figure 1)—it seems to me that this could be explained by the effects of decomposition. With regard to vertical transport, the authors indicate that this may be relevant for the Tussock grass site (section 3.1) because of the occurrence of ^{210}Pb in the mineral soil. However, the fact that ^{210}Pb is not found in the mineral soil for the other sites is no assurance that vertical transport is not relevant there. It is good that the authors include ^{14}C measurements for validation of the ^{210}Pb ages. However, I think some more justification of the approach is appropriate. For example, based on previously published decomposition rates for similar soils the authors could estimate the effects of decomposition on the ^{210}Pb concentration.

The reviewer is correct that decomposition can influence ^{210}Pb ages if you are modeling them on the basis of ^{210}Pb activity per gram (dpm/g) vs depth (cm) since loss of mass by degradation will increase the ^{210}Pb activity per gram. However, we have accounted for the influence of decomposition as well as compaction over time by modeling our ^{210}Pb profiles on a drymass basis (e.g. vs cumulative dry mass, g/cm^2) instead of depth. This approach derives accumulation rates from the activity of unsupported ^{210}Pb within the entire volume of interval based on the bulk density, which also increases in response to compaction and organic matter degradation, thus accounting for both effects. We have made this point clear in the text (line 138) by adding: “To account for compaction and loss of mass due to organic matter decomposition, both methods modelled unsupported ^{210}Pb as a function of cumulative dry mass (g/cm^2), not depth (Appleby and Oldfield, 1992). Cumulative dry mass is the product of bulk density of the horizon (g/cm^3) and the horizon thickness (cm)” Although the effects of decomposition and/or compaction are addressed with our methodology, we still need to consider the effect of movement of ^{210}Pb down the soil profile on age estimates. For this reason we submitted surface samples for ^{14}C data, hoping to corroborate all ^{210}Pb dates with ^{14}C dates. This possibility is now explicitly addressed within the results section. As previously mentioned in the manuscript, adjusting the dates of the shrub ecosystem to the ^{14}C ages does not impact our results. Therefore, we feel comfortable moving forward using the ^{210}Pb dates. The new text (line 198) is as follows: “The younger ^{210}Pb date for the 8.5 – 12.5 cm Shrub-1 horizon could indicate that there has been some movement of ^{210}Pb within the soil profile, which has been known to occur with this dating technique (Turetsky et al., 2004). However, the ^{14}C and ^{210}Pb ages for the 4.5 – 8.5 cm horizon match well, which we would not expect if downward transport was a significant issue. In addition, adjusting our analyses to the ^{14}C dates does not change our results. Therefore, we feel comfortable moving forward using the ^{210}Pb age values.”

I think a honest discussion of the limitations and uncertainties in Section 4 should be added. We have added a paragraph (line 329) discussing both the limitation and uncertainties of our data. It reads “It is

important to note that our sites are located close to the Tanana River and thus our findings are may be more indicative of locations where the groundwater can be influenced by river water. We also found a high level of within-ecosystem variability, with coefficients of variability of up to 60%. This variability is likely due microsite variability in surface vegetation, microtopography, and soil characteristics such as porosity, all influence which C and N cycling, and thus, accumulation rates. This variability limited our ability to make inferences about soil C and N accumulation rates between the four non-fen ecosystems. We also acknowledge that there is uncertainty associated with both dating techniques used in this study. Downward transport of ^{210}Pb could make the ages presented here appear younger than the actual age of the soil horizon. There are also potential uncertainties with ^{14}C ages due to the movement of younger atmospheric C into the soil through roots or fungi and the uptake of C from non-atmospheric sources (Bauer et al., 2009). To minimize these factors, future researchers could improve upon our methods by increasing the number of soil cores, having higher resolution for soil horizons, and studying the possibility of ^{210}Pb downwash using ^7Be (Hansson et al., 2014). Regardless of the high within-ecosystem variability and potential accuracy of ages, we found significant differences in the long-term C and N accumulation rates of the rich fen in comparison to the other four ecosystems studied.

p 3/l 55-56: This sentence is not clear to me. What does "these ecosystems" refer to? Clarified to read "fen ecosystems" (line 57).

p 5/l 116: please indicate the units of the mesh. Added information that 60 mesh is 0.25 mm (line 126).

p 6/l 148: "Bulk peat samples" suggests that these measurements were only performed for the fen/bog soils but later text suggest that these measurements were done for all sites. Please clarify. Sentence rewritten to make it clear that it was soil, not peat, so all sites were included: "Additionally, bulk soil samples, with roots removed, were submitted..." (line 60).

p 6/l 154: "age of that profile": is that the age inferred from the ^{14}C measurement of the "basal soil organic horizon"? The sentences (line 66) have been rewritten to clarify. " Long-term C accumulation rates were calculated as the amount of C within the organic soil profile divided by the ^{14}C age of that ecosystem. Ecosystem age was calculated as the average of the minimum and maximum ^{14}C calibrated ages (Suppl. Table S2)."

p 7/l 174: I found this sentence somewhat confusing. It seems that the sample, including macrofossils, is homogenized, which is not the case, I assume. Unfortunately, when we divided the soil cores into horizons we were not planning on sampling macrofossils. Therefore, the horizons are wider than usual and were homogenized when splitting them for analytical sampling and creating an archive. This means that macrofossils could have come from anywhere within the horizon (surface, middle, base). This fact is now explicitly stated in the methods section in two places: line 122) "Soils horizon samples were processed in several steps: first they were air dried (20-25 °C) and then homogenized. The samples were then split into two parts: an archive split and an analytical split. The analytical split was oven dried and then ground." and line 159) "We also dated macrofossils, obtained from several, homogenized soil horizons, using AMS radiocarbon measurements for comparison to ^{210}Pb ages. (Suppl. Material S2)."

p 10/ l 235: please remove the closing parenthesis ")" at the end of the sentence or insert an opening parenthesis somewhere appropriate. Done.

p 11/ l 266: It is not clear to me how decreasing q_{10} values suggest that oxygen availability is a dominant factor for C preservation. We have rewritten these sentences (line 300) to make them clearer. "Another mechanism for reducing rates of C cycling is oxygen availability. McConnell et al. (2013) found lower Q^{10} values at the rich fen, indicating less temperature sensitivity. Instead, with the shallowest water table (Table 1), it is thought that oxygen availability plays a dominant role in the protection of deep C at the rich fen (McConnell et al., 2013)."

p 12/ l 311: please add "of" after "many". Done

Table 3: The short term accumulation rates were determined horizon-wise in the table single numbers are given. Are these averages over all horizons? We have added the following text to the table caption to clarify how these were calculated. "Accumulation rates were determined by averaging values calculated for each individual soil profile by ecosystem type."

Table 3: Please indicate what the superscript letters a,b,c mean. In the text (section 3.3) it is written that the decadal C accumulation rates are not significantly different between the sites, but this is not clear from the letter "a" in the table. We have clarified what the superscripts mean with the following text: "Different letters indicate significant differences among ecosystems for that accumulation rate, based on Tukey Honest Significant Difference test."

Table S2 (supplement), caption: I assume you mean "younger" than 1950, not "older". Changed.