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Discussions

Interactive comment on "Carbon Stocks and Accumulation Rates in Salt Marshes of the Pacific Coast of Canada" *by* Stephen G. Chastain et al.

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SHORT RESPONSE TO ANONYMOUS REVIEWER #2 ON "Carbon stocks and accumulation rates in salt marshes of the Pacific Coast of Canada" by Chastain et al.

We thank anonymous reviewer #2 for constructive comments which we think will greatly clarify the paper. We have gone through these suggestions, agree with them, and believe that they can be addressed during the revision process. Here we provide a brief response detailing how we intend to address them.

REVIEWER 2: "While the data compilation on organic carbon stocks presented in this manuscript is commendable, insufficient data on carbon accumulation rates (CAR) is provided for the purpose of estimating carbon accumulation rates in the Pacific Coast

of Canada. I found major flaws in information regarding the estimation of sediment accumulation rates (SAR), hence CAR. Also, there are a series of miss-points in the methodology used for the estimation of C stocks and accumulation rates (detailed in the comments below) that the authors should take into consideration to achieve the publication of this work."

#1. REVIEWER 2: "I have major concerns about how carbon accumulation rates (CAR) are estimated. First, authors only estimate CAR in a total of five cores collected at 4 marshes, although they sampled a total of 34 sediment cores for C stock determination. The authors do not explain why only these cores were dated, or whether other cores were also analyzed by 210Pb but could not be dated. Mixing, erosion or changes in sedimentation are common processes in coastal sediments, and could lead to the alteration of sediment records, hence 210Pb concentration profiles (Ruiz-Fernández and Hillaire-Marcel, 2009). However, altered 210Pb profiles, although not datable, are results themselves."

RESPONSE: Reviewer #2's concern is similar to concerns of Reviewer 1, regarding the number of cores for which 210Pb dates were provided. We dated as many cores as we could, given our project funding limitations. We examined stratigraphies to choose cores that were representative of all cores/sediments from a given marsh. We will do the following in our revision to address this concern: (1) modify Figures 2 and 3 to indicate which cores were dated (2) add a discussion of stratigraphic comparison, and how this uncertainty influences our result (3) point out in our text that we saw no visible or measurable indication of sediment alteration via mixing or erosion in our cores. (4) clarify in the text that we have presented all 210Pb profiles for our cores in the appendix, and none exhibits such alteration.

#2. REVIEWER 2: "The authors do not report data on total or excess 210Pb specific activities and no explanations are given regarding the determination of supported 210Pb, which might vary between marshes but also along the depth of their sediment profiles, especially if soils consist of three marked layers, topsoil, peat, and sand/clay

(section 3.1, line16-17)."

RESPONSE: As mentioned for Reviewer 1, we will expand our description of methods and provide all data as an appendix.

#3. REVIEWER 2: "The application of the CRS dating model to estimate SAR is unclear and some arguments should be provided regarding the election and application of this model. To apply this model certain assumptions must be met, for instance, this model is based in excess 210Pb inventories, which implies that the excess 210Pb horizon should have been reached in all dated cores. Without 210Pb data, this is impossible to evaluate. In addition, the CRS model provides estimates of SAR at each sediment layer rather than average sedimentation rates for the last century. In the main text Chastain et al. report average SARs at each core but do not explain how this average is estimated or if they have normalized SARs to a certain age-depth."

RESPONSE: As mentioned for Reviewer 1, we will expand our description of methods and provide all data as an appendix.

#4. REVIEWER 2: "A results section showing 210Pb concentration profiles, 210Pb inventories and estimated fluxes should be included in the paper, this is important to evaluate whether the dating model applied is valid and to discuss the uncertainties associated to the estimation of ages and SAR. This will be included in the revised manuscript."

RESPONSE: (1) The 210Pb concentration profiles will be included and 210Pb data provided in the paper appendix; (2) SARs based on the CRS model were already provided in appendix files but will be moved to the paper). (3) A more complete discussion of uncertainties of ages and SAR will be included.

#5. REVIEWER 2: "In the current version of the manuscript the authors include a section comparing 210Pb and 137Cs dating, which I believe is unnecessary; the authors did not analyze 137Cs in their cores and 137Cs is most commonly used to validate

210Pb chronologies. There are many aspects that can bias SAR and CAR high, for instance the presence of sediment mixing in 210Pb concentration profiles. My recommendation to the authors is to look critically at their 210Pb data and discuss the uncertainties related to their age-depth models, SAR and CAR estimates."

RESPONSE: Reviewer #1 had a similar concern with this section of our manuscript. We will revise for clarity and generalize to describe the "many aspects" that can bias SAR and CAR rather than an exclusive focus on 137Cs. For example, we could include a more detailed explanation of the effect of spatial variability, which can affect carbon measurement even on small scales within a single marsh.

#6. REVIEWER 2: "Second, to estimate CAR authors use sediment accumulation rates (SAR) which they multiply by the soil carbon density (SCD). While they acknowledge that sediment compaction occurred during coring and so they correct SAR for potential compaction, they do not correct SCD for such. This might lead to an overestimation of CAR. The authors estimate SCD multiplying the percent carbon content (%C) by the soil dry bulk density (DBD). While the rationale behind this is correct, soil DBD should be corrected for core compaction prior to the estimation of SCD. The mass contained in one cc volume of soil after coring occupies a greater volume in the field (before compaction occurs). Related to core compaction, I disagree with the statement in equation 8 used to estimate the uncompacted depth of a given subsample. Let's assume the recovered core length is 50 cm and the core penetration is 100 cm. This would result in a correction factor of 0.5 following equation 7. Then, if the correction factor is applied in equation 8 and is multiplied by the subsample depth (i.e., 1 cm-thick slice) this do not result in an uncompacted depth, please revise. In addition, compaction would unlikely have been linear throughout the soil column due to the presence of different soil layers (topsoil, peat, and sand/clay), which may show different degrees of compaction. For this reason, any variable that is sensitive to soil compaction such as DBD, SCD and SAR should not be used for the determination of CAR or C stocks. Variables such as the mass depth (m) (or mass per unit of area; g cm-2) and

mass accumulation rate (MAR; g cm-2 yr-1) are not affected by soil compaction, then should be used instead of DBD and SAR to avoid the propagation of errors in the determination of CAR or C stocks (see below). My recommendation to the authors is to recalculate CAR as:

CAR (g C m-2 yr-1) = MAR (g cm-2 yr-1) x %C

Where the % C is not the average percentage of C along the sediment column but the fraction of the accumulated mass of C (gC cm-2/ g soil cm-2), estimated from the sum of the sediment layers accumulated over a period t = 100 yr, which should be approximately where the excess 210Pb horizon is reached."

RESPONSE: We thank the reviewer for pointing out this error in our assumptions regarding the compaction factor. In our revision we will redo the CAR and Stock estimates without the compaction factor, following the suggestion above.

#7 REVIEWER 2: "To finish with concerns about CAR estimates, I think differentiation between low and high marsh CAR is not possible with only one CAR estimate for a low marsh. The authors indeed acknowledge this at the end of the manuscript in section 4.4, line 3-4. I believe this should be said upfront. Accordingly, comparisons of Clayoquot Sound CAR with other salt marshes should be based only on high marsh CAR estimates reported at the other study sites. Final recommendation to the authors would be to avoid estimating total CAR for a marsh with only a dated core as the high marsh core CAR times the total marsh area (this is represented as a crosshatched column in figure 4). The latter is probably unlikely according to the results presented: lower C stocks in low marsh cores and low CAR in the single low marsh core."

RESPONSE: We agree and will eliminate discussion of comparison between high and low marsh cores. Figure 4 will be altered to remove the high marsh CAR * total marsh area column.

#8 REVIEWER 2: "Specific comments on the estimation of C stocks: Similarly, esti-

mation of C stocks should be done using soil mass depth (g cm-2) rather than SCD multiplied by the thickness of soil slices, i.e., 1 cm, which is affected by soil compaction. My recommendation to the authors is to recalculate C stocks using the soil mass per unit area (m) rather than the sum of all sections DBD x %C x 1 cm. The soil mass per unit area at each layer is not affected by compaction or by inaccurate slicing. It is estimated by dividing the dry sample mass by the area sampled by the core tube, which is the cross-sectional area of its inner diameter (D), _(D/2)ËĘ2: Cstock_core=P (DW=(_rËĘ2)) x %C" RESPONSE: This is a very helpful suggestion and we will apply this modification in the revised version of the manuscript.

#9. REVIEWER 2: "The second problem here is the computation of overall averages when the averaged values are computed over a number of estimates that are different at each site or when the area each marsh represents is not the same. - The mean C stock at a marsh (Cstockmarsh) should be calculated as the weighted average of the mean Cstockscore estimated in the low marsh area and the mean of those estimated in the high marsh area, being the weights, the area made by low and high marsh at each individual marsh. - Then, the average C stock of low marshes at Clayoquot Sound (Cstock-LowCS) also should be a weighted average, with weights being the low marsh area of each individual marsh. Same for CstockHighCS."

RESPONSE: We agree with this assessment of how to calculate the mean C stocks, and have done this in the manuscript. We will clarify this description, as we separately calculated both the average stock per hectare and the total C stock of the marshes.

#10. REVIEWER 2: "The authors use the depth of refusal (DoR) as a measure of the maximum depth of organic accumulation. C stocks are then estimated down to this depth (average 27.6 cm) and compared with those of global estimates (which some are estimated down to 1 m and others extrapolated to the same depth, 1 m). The authors conclude the C stocks at Clayoquot Sound are lower than those globally, but this is not a fair comparison. DoR is relative to the equipment being used and to the type of soils, therefore I feel that any comparisons made without standardizing

all sites to a certain depth/mass depth (preferably) can be misleading. Rather than extrapolating their measurements to 1 m, the authors could normalize global estimates to 30 cm or perhaps to a certain mass depth, which would be the most consistent to establish comparisons (see Wendt and Hauser, 2013). As well, authors could discuss differences on C stocks based on %C, DBD and CAR rates found globally and at other regions such as eastern Canada, the Pacific Coast of the United States and Mexico. "

RESPONSE: (1) We agree in principle that it is not appropriate to compare marsh accumulation to a depth of 27.6 cm with a depth of 1m. However, we should be clear that our depth of refusal was based on substrate at the base of the core (gravel), not that we could not core any deeper due to mechanical issues. We will make this point clearer in our Methods and in our Discussion of comparisons with global sites. (2) We can extend our comparison between %C, DBD, SCD, and CAR, although we believe stock comparisons between marshes can be challenging because of an incomplete understanding of the total soil volume, differing methods to estimate this volume, and small-scale variability in soil strata. As the stratigraphies in Clayoquot Sound are relatively simple, we could compare marsh carbon stocks with other studies to a depth of 30 cm, with appropriate caveats added to clarify these uncertainties.

#11.REVIEWER 2: "Authors should take action on the points listed above and revisit their calculations to provide more consistent estimates of C stocks and CAR. As well, they should discuss their results, perhaps, with more emphasis on C stocks and intra marsh variability (for which they have a good dataset), while presenting CAR results in a more local scale, avoiding upscaling to the Pacific coast of Canada. Instead, I encourage the authors to discuss temporal trends in C accumulation at the dated marshes if 210Pb profiles allow so. "

RESPONSE: We thank Reviewer 2 for these very helpful comments. In our revision we intend to revisit these calculations and document how changing them affects our conclusions. Although we will continue to place our results within the context of global estimates, we will also emphasize the role of local intra-marsh variability and how stock

characteristics (DBD, %C, SCD) compare locally and regionally. As stated for our short response to reviewer 1, we will discuss temporal trends in C accumulation.

#12. Minor Comments RESPONSE: We have reviewed these minor requests and will implement them in our revised version.

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