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Biogeosciences Discussions

Interactive comment on "Submarine groundwater discharge to a small estuary estimated from radon and salinity measurements and a box model" *by* J. Crusius et al.

J. Crusius et al.

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Response to Anonymous Reviewer #1.

(1) In the introduction the authors indicate that hydrological models are problematic as they extrapolate over a large spatial scale while the seepage meters provide measures on short time scale and local spatial scale. Thus the advantage of using Rn is that it integrates over more appropriate space and time scales. After arguing this the authors compare the Rn-salinity model results to the seepage meters and hydrological models and use the general agreement to support their conclusions. I find this a bit circular. Response: We now interpret the SGD discharge based on first principles at the start of the paper. We still try to reconcile all of the different estimates, but the box model interpretations now can be compared to (and agree well with) simple calculations based on radon. Not so much hangs on the box model in this version.

(2) More information about the hydrology should be given (recharge rate, seasonality in recharge and discharge, head etc.). Response: More information was provided about the background hydrology, as also requested by another reviewer.

(3) The box model and related assumptions should be included in the methods as this is an important and central part of the paper. The authors do a good job identifying the assumptions but should also discuss the errors that may arise from these assumptions. Response. The box model is incorporated into the main text and there's an error analysis for the box model now.

(4) I highly recommend reporting the Rn activity in units of dpm/L this is what is used in practically all other SGD papers and it would be nice to be consistent. I know this is a trivial conversion but it is useful. Response: I provide both units of Bq/m3 and dpm/L at most stages when discussing these.

(5) If the conclusion is that only freshwater is being discharged why is there a need to define SGD in this paper as including re-circulated seawater? Response: I stick with the definition of SGD as defined by Burnett because of the possibility/likelihood that Rn partly reflects recirculation of seawater here, or in other places.

(6) Explain why salinity min and Rn max are lagging by almost 1 hour the low tide. Response: There's lots of discussion now about why the Rn max and S min might lag low tide. This is because this discharge is occurring either in the channel or in nearby Nauset Marsh, and takes a while to flush into the N end of the channel.

(7) Discuss Ra results mentioned but not discussed was Ra measured in the pond (particularly short lived)? If so do flux calculations agree? Is the Ra in the GW consistent with only a fresh water component? Response: Only a single Ra sample was collected from the pond, so we chose not to discuss short-lived Ra isotope results. This one result was pretty consistent with our interpretation of pond residence time, for what it's worth.

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(8) How representative is the Rn-nitrogen relation in GW? I would expect the Rn/N in GW to be quite variable? Response: The Rn/N relation in these groundwaters is not that variable because neither Rn nor N was that variable. We don't discuss this in the paper due to lack of space (it's too long as it is).

(9) Is it possible to explain why the results for the model using salinity and Rn do not fully agree and if not this should be discussed in the text. Response: We now point out, in this model version with 5 channel boxes, that decreasing salinity during falling tides is consistent with discharge to the channel. We still don't know why salinity behaves inconsistently during the falling tides (sometimes staying constant, sometimes decreasing, one time increasing). It is ok not to understand everything at this point, in our opinion.

(10) What do the authors mean by Rn lost from saline GW by advection? This is not clear, how is would the Rn get lost and why? Response: The low radon in saline gw could be due to recent recharge from seawater, together with incomplete equilibration with surrounding solids. This is now better phrased in the text.

(11) Why are the results from August not reported here (these are mentioned)? It may strengthen the paper to include these data rather then write yet another paper representing 2 more days in the summer at the same site. Response: The salinity results from August are now presented in Fig. 2. There were no radon data collected at that time.

(12) Was the salinity of the GW end member ever higher than a few units? Were Ra levels high in the GW sampled with the pizometers compared to the pond? Response: Salinity of gw reached values above 25, as shown in Figure 10 of the first draft and figure 3 of this revision. Ra levels were higher in saline gw compared to pondĚ.due to space considerations and sparse data we don't discuss this.

(13) What is the assumption that GW is only discharging at low tide based on? Just the model fit? Can this be justified from the hydrology? Can a different combination of

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fluxes and Rn/salinity or a variable set of such parameters yield a fit to the model that can accommodate discharge at all times? This is particularly important to justify since the seepage meters recorded flux at all times. Response: This model version assumes discharge at all tidal heights. The channel is now treated using 5 boxes. As discussed in the text, this eliminates the model requirement that discharge to the channel occur only at low tide. In a nutshell, with 5 boxes the advection of pond and Nauset water through each channel box remains the same but the gw inputs to each box are 20% of what they were in the original version. This means that flow has to get REALLY low in order for the gw discharge to manifest itself in the channel box near the pond. Thus, even with discharge occuring at all tidal heights, the really low S is only seen at low tide. You do see a gradually decreasing S during outflow in the model, as is often observed.

(14) Is the Rn in the incoming water from the marsh really constant? Response: We still assume Rn in Nauset waters far from the pond are constant. But we create a box for marsh waters waters near the channel. This allows high-tide S and Rn in the channel to vary, as observed. This is discussed more in the text.

(15) Are fluctuations of 50% in GW Rn common? Could this variability be explained? Response: Fluctuations of $>$50% in gw Rn are common, in my limited experience. With additional work, this variability could be explained, I suspect.

16) How good are the water exchange estimates through the channel based only on water level? This assumes the same flow rates in and out of the channel at high and low tide respectively. To get a good representation of the net Rn loss through the channel (which may be equated to the SGD Rn input) ADCPs or ADVs or some other current meters should been deployed in the channel along with the CTD. Response: Current meter measurements would have been good to have. I suspect you'd need at least three integrating ADCPs to begin to do this right. That was beyond our budget. I'm not sure we would have reduced the uncertainty in the inflow and outflow esimates much, even if we had had this instrumentation, because of uncertainties in these mea-

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surements and in the interpolations among the instruments.

Most of the specific comments at the end of Rev.#1's comments were also addressed.

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