Hydrol. Earth Syst. Sci. Discuss., 10, C2592–C2595, 2013
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Hydrology and Earth System Sciences Discussions
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Interactive comment on "Investigating the spatio-temporal variability in groundwater and surface water interactions: a multi-technical approach" *by* N. P. Unland et al.

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Received and published: 17 June 2013

Response to comments, anonymous reviewer #1

We thank this reviewer for their comments and outline our responses below:

Major comments

1. The reasons for combining the use of chemical tracers with river gauging are:

- To investigate groundwater – surface water exchange at a finer spatial scale than is possible using gauging stations alone (which were located > 20km apart). The

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approach used here with chemical tracers allows examination of the variability of groundwater-surface water interaction on a 2-3 km scale. This is noted on pg 3797 lines 11 and 24-25 and we will emphasize this in the revised manuscript.

- Runoff between the gauging stations under high flow conditions is hard to quantify using gauging alone which will lead to overestimates in groundwater flux calculations by differential flow gauging. These overestimates can be identified by use of chemical tracers as discussed on pg. 3819 line 17.

The McCallum et al. (2012) paper uses high-frequency gauging data to calculate net groundwater fluxes over extended periods of time. This requires a degree of modelling to account for both the time shift and attenuation of flood peaks between gauging stations. While this topic is interesting and worthy of further work, it is beyond the scope of this paper. The use of gauging data in this study was more to analyze and compare it against chemical and physical tracers under specific hydrological conditions.

2. The authors concede that the paper (specifically the results section) is more lengthy than required. In the revised version, we will add a table or figure to help summarize data and condense some of the descriptive text.

3. The results presented in Fig. 13 can be further emphasized in the text. With regard to discrepancies between Cl and 222Rn, it was mentioned that bank infiltration will dilute the Cl concentrations in groundwater for a greater period of time than 222Rn, due to the equilibration of 222Rn with 226Ra in the aquifer over a period of $\sim$ 3 weeks. As such, Cl mass balance will reflect the volume of regional groundwater discharge, while 222Rn mass balance the total volume of groundwater discharge (pg 3818 line 24 to pg 3819 line 5). If bank infiltration has diluted the concentration of Cl in groundwater to a greater degree than at the locations where groundwater was sampled, current calculations will underestimate groundwater discharge by Cl mass balance. This was alluded to on pg 3818 lines 15 to 24 and will be clarified. It has also been shown that the variability of Cl in groundwater is commonly greater than that of 222Rn in groundwater

(Cook, 2012), resulting in discrepancies between Cl and 222Rn mass balance. This point will also be mentioned.

Minor Comments

1. See response to major comment 3.

2. The paper by Burnett et al. (2010) is appropriate and can be included.

3. 222Rn is produced from decay of 226Ra that is present in minerals which occur as both suspended sediments in the river and within the aquifers. As is summarised by Cook (2012), rates of 222Rn production in aquifers is commonly several orders of magnitude higher than the in-river production (due to the relative abundances of water and rock). This point will be clarified in the revised manuscript.

4. The term “Qf” can be changed to “I” for simplification.

5. Cr stands for the concentration of the tracer in river water as defined on pg 3803 line 18.

6. Evasion of 222Rn from water is driven by the turbulence and entrainment of atmospheric gas into a water body. For lakes, estuaries and oceans turbulence is driven mainly by wind or rainfall, but for non-estuarine rivers the turbulence is driven mainly by the velocity, depth and width of a river (Genereux and Hemond, 1992). All 222Rn degassing studies in rivers have concluded the rate of degassing is related to flow rather than wind speed. This will be explained in the revised version of the paper.

7. See response to major comment 2.

8. The range and average 222Rn activities from ingrowth experiments have been listed (pg 3806 lines 24-26, but the specific results can be tabulated if required.

9. As we discussed above, the results section can be abbreviated, reducing replication between the results and discussion sections.

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10. Fig. 5 shows the longitudinal correlations between the different tracer methods and is hard to alter. However it could be combined with Fig. 10 to provide spatial clarity to the distribution of gaining and losing reaches of the Tambo River.

References

Burnett, W.C., Peterson, R.N., Santos, I.R., Hicks, R.W., 2010. Use of automated radon measurements for rapid assessment of groundwater flow into Florida streams. Journal of Hydrology, 380(3–4): 298-304.

Cook, P. G., 2012. Estimating groundwater discharge to rivers from river chemistry surveys. Hydrol. Process., online first, doi:10.1002/hyp.9493.

Genereux, D.P., Hemond, H.F., 1992. Determination of gas exchange rate constants for a small stream on Walker Branch Watershed, Tennessee. Water Resources Research, 28(9): 2365-2374.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 3795, 2013.