Supplementary Material

S1 Water probe response time

During the 2011 and 2012 field seasons, several factors related to the water probe setup may have influenced the response time of the water probe. First, in order to keep the RAD7 a safe distance from the unstable riverbank, the length of tubing between the detector and water probe had to be increased (from 8 to 12.5 m) effectively changing the system air volume from 1650 to 1750 cm^3. Furthermore, the interface area of the membrane coil changed as two Accruel® membrane coils of slightly different lengths (a 2.1 m coil and the 2.2 m coil within the Durridge Inc. 'water probe') were used interchangeably across the two field seasons. The effect of these changes was quantified using the empirical relationships developed by Shubert et al., (2012), which suggest that our minor changes in air volume and membrane interface area likely only caused a 12-minute difference in equilibration time. This is a negligible difference when considering that the minimum time-scale over which significant changes in observed river ^{222}Rn were diurnal. Furthermore, a field test was conducted in which both membrane coils were simultaneously deployed in the proglacial river for 12 hours. During this test, both systems recorded ^{222}Rn activities well within the statistical counting errors. Consequently, the continuous ^{222}Rn record reported here is a compilation of results obtained using both water probes. During deployment, the membrane coil was checked daily for wear and sediment buildup on its surface. Throughout either field seasons, no algae or sediment buildup was observed. To test the effectiveness of long term deployment of the membrane coil over the course of a melt season, two probes were deployed simultaneously, one that had been in continual use for ~30 days and a second unit with a new membrane coil. Following an initial equilibration period, both units measured identical ^{222}Rn activities (within the method's uncertainty) for several days.

To assess the water probe's response to changes in ^{222}Rn activity, we conducted several laboratory experiments. First, the water probe was deployed simultaneously with the more conventional air-water equilibrating spray chamber (Burnett and Dulaiova, 2003) in a 200 L tank of circulating 10˚C seawater for 70 hours. Seawater was continuously pumped into the tank from Vineyard Sound, ~50 m offshore of Woods Hole (MA). The air-water equilibrator spray chamber provided a baseline from which to compare the water probe, because with an optimum setup, its equilibration time is less than 30 minutes (Schubert et al., 2012). The residence time of seawater in the tank was <1 hour and water was kept in constant motion using six submersible bilge pumps, each capable of pumping ~30 L min^{-1}. Slow but significant changes in ^{222}Rn were observed by both the spay chamber and water probe likely caused by the changing tide and submarine groundwater discharge (Burnett and Dulaiova, 2003). The equilibration time was defined as the length of time at which the recorded ^{222}Rn activities reached an activity plateau within the statistical counting errors. With this experimental setup, the water probe required an initial six-hour equilibration time while the spray chamber reached equilibrium in <30 min. Subsequent changes in ^{222}Rn activity measured by the water probe lagged 1-2 hours behind the spray chamber. In a separate experiment, the water probe and spray chamber were allowed to equilibrate with ^{222}Rn-free water before being moved quickly into a tank containing ^{222}Rn-enriched groundwater. In this case, both water probe and spray chamber systems responded to the activity change in <30 minutes though the water probe required much longer to reach the new equilibrium plateau.

To determine the equilibration time of the water probe system in the proglacial river, we examined the first six hours of data recorded after the water probe was freshly deployed (see Figure S2 for one example). Our analysis included 14 separate deployments in 2011 and 2012 in river flows ranging from 1 to 750 m^3 s^{-1}. In each case, an equilibration plateau was reached within two hours of deployment regardless of river flow rate or system configuration (as described above). The equilibration time was therefore three times faster than the laboratory experiments. This was likely because water in the proglacial river was flowing much faster than in laboratory experiments keeping the ^{222}Rn activity gradient at the water/air interface of the membrane coil closer to 100%. These results support the findings of Hofmann et al. (2011) and Schubert et al. (2012) showing that the water flow rate over the membrane coil is the most important factor for passive ^{222}Rn extraction. Because of the much faster equilibration time in the proglacial river, we expect the water probe's response time to changing ^{222}Rn activities was also faster in the field than the one to two hours suggested by laboratory experiments.

In summary, when interpreting results from continuous ^{222}Rn measurements, we assume changes in ^{222}Rn activity recorded by our methods occurred within one hour of actual ^{222}Rn activity changes in the proglacial river. Also, we have excluded ^{222}Rn results from the first two hours from each fresh deployment while the water probe was equilibrating.

S2 Sediment Properties

The porosity and bulk density of glacial flour collected in the proglacial river was determined using the moisture content and particle density measured in the laboratory.

Moisture content (%M) was determined by weighing sediments before and after drying at 100˚C: using Equation S1:

$$\%M = \frac{wet\ wt. - dry\ wt.}{wet\ wt.} \times 100 \tag{S1}$$

Grain density (ρ_s) was determined using the oven dry weight and volume of sediment. The volume of sediment was determined by adding the sediments to a volumetric flask and measuring the weight of water displaced by the sediments.

Bulk density (β_D) was calculated using Equation S2

$$\beta_D = \frac{1}{\left(\left[\frac{1}{100 - \%M}\right] \times 100 + \frac{1}{\rho_z}\right) - 1} \tag{S2}$$

where ρ_s is the average sediment grain density of triplicate analysis. Finally, porosity (ϕ) was estimated from Equation S3.

$$\phi = (\rho_s - \beta_D) / \rho_s \qquad \text{(S3).}$$

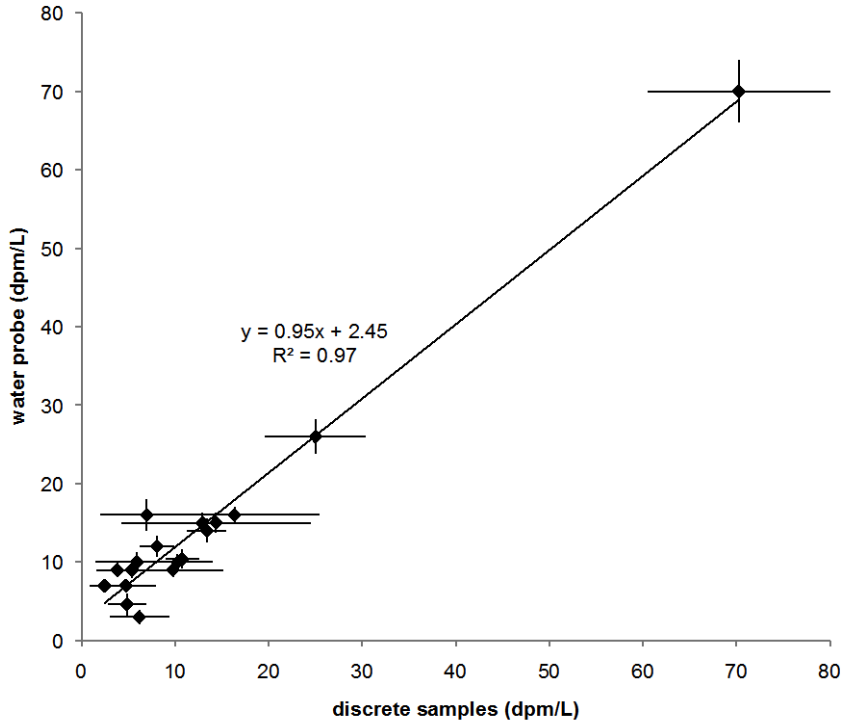

Figure S1: Comparison of discrete ^{222}Rn samples with comparable time-series measurements using the water probe. Error bars represent 1-sigma counting errors on each measurement. Many of these discrete ^{222}Rn samples were taken at the ice terminus while the water probe measured ^{222}Rn downstream. This implies that gas loss in the proglacial river between the ice terminus and the water probe was within the errors of our measurements.

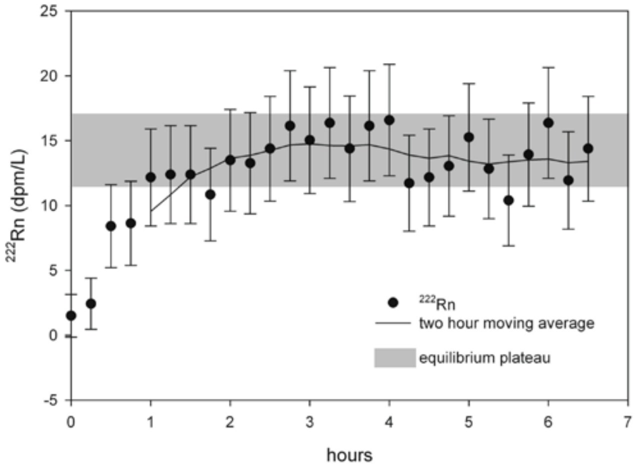

Figure S2: Equilibration time of the ^{222}Rn water probe on 6/2/2011 (day 153) after being deployed in the proglacial river. Throughout the 2011 and 2012 field seasons, the water probed required 1-2 hours to reach an equilibrium plateau, the time at which the recorded radon activities reach an equilibrium activity plateau within the statistical counting errors.

Table S1. Summary of 250 mL discrete ^{222}Rn samples collected in the proglacial river in 2011.

Distance	Day	Date	^{222}Rn	+/-	EC
			dpm L^{-1}		μS cm^{-1}
0.5	128.5	5/8/11	15.9	6.4	
0.5	129.6	5/9/11	3.2	2.1	
0.5	132.5	5/12/11	3.2	2.8	69
0.5	132.5	5/12/11	7.0	5.4	69
0.5	132.8	5/12/11	4.3	3.0	75
0.5	132.8	5/12/11	5.9	4.4	75
0.5	133.4	5/13/11	4.8	2.1	94
0.5	133.4	5/13/11	7.0	6.4	94
0.5	133.7	5/13/11	18.2	10.1	79
0.5	133.7	5/13/11	14.5	7.5	89
0	133.6	5/13/11	4.3	3.9	
0	133.6	5/13/11	13.4	2.1	
0.5	134.5	5/14/11	9.1	2.1	90
0.5	134.5	5/14/11	7.0	4.4	90
0.5	135.5	5/15/11	5.4	2.8	74
0.5	135.5	5/15/11	7.0	6.2	76
0.5	136.0	5/16/11	10.8	1.8	81
0.5	137.5	5/17/11	9.1	6.2	76
0.5	137.5	5/17/11	1.6	2.0	76
0.5	139.6	5/19/11	4.3	1.8	81
0.5	140.8	5/20/11	5.9	1.1	73
0.5	140.8	5/20/11	5.4	2.8	73
0.5	141.6	5/21/11	14.0	4.1	75
0.5	145.8	5/25/11	4.3	4.7	65
0.5	144.6	5/24/11	6.9	3.2	88
0	147.7	5/27/11	67.4	11.6	49
0	147.7	5/27/11	32.2	7.3	45
0.5	147.8	5/27/11	7.5	2.8	45
0.5	147.8	5/27/11	12.9	3.0	45
0	148.5	5/28/11	41.4	8.1	85
0	148.5	5/28/11	54.3	7.3	84
0.5	148.5	5/28/11	70.3	9.7	62
0.5	149.8	5/29/11	24.3	6.2	40
0	149.8	5/29/11	17.8	8.8	40
0	151.9	5/31/11	17.8	3.1	37
0	148.8	5/28/11	6.5	3.5	61
0	150.8	5/30/11	5.4	1.3	40

0.5	150.8	5/30/11	14.7	6.8	40

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Distance	Day	Date	^{222}Rn	+/-	EC
			dpm L^{-1}		µS cm^{-1}
0.5	153.7	6/2/11	22.6	9.5	36
0	153.7	6/2/11	3.2	2.8	36
0	152.7	6/1/11	24.1	7.0	36
0.5	156.6	6/5/11	5.4	3.7	14
0.5	156.6	6/5/11	4.1	4.8	15
0.5	156.7	6/5/11	17.1	3.0	12
0.5	156.7	6/5/11	17.2	5.3	12
0	157.7	6/6/11	4.3	3.0	44
0	157.7	6/6/11	6.5	5.3	45
0.5	158.3	6/7/11	4.8	3.1	21
0.5	159.2	6/8/11	3.8	2.1	37
0.5	159.3	6/8/11	9.7	5.4	36
0.5	153.7	6/2/11	8.2	5.7	42
0.5	153.7	6/2/11	20.5	5.5	50
0.5	162.7	6/11/11	1.6	1.1	16
0.5	162.7	6/11/11	3.3	1.2	16
0.5	165.0	6/14/11	4.9	6.9	35
0.5	165.5	6/14/11	5.4	2.1	27
0	166.7	6/15/11	3.2	2.1	23
0	166.7	6/15/11	10.7	5.8	23
0.5	167.5	6/16/11	2.7	1.1	18
1	167.6	6/16/11	2.7	3.2	18
1	170.0	6/19/11	3.8	1.1	12
1	170.0	6/19/11	4.3	1.8	12
0	172.7	6/21/11	2.7	2.7	14
0	172.7	6/21/11	4.8	4.7	14
0	184.6	7/3/11	2.1	0.9	
1	198.9	7/17/11	1.6	2.0	