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Supplement of

Sonar gas flux estimation by bubble insonification: application to methane bubble flux from seep areas in the outer Laptev Sea

I. Leifer et al.

Correspondence to: Ira Leifer (ira.leifer@bubbleology.com)

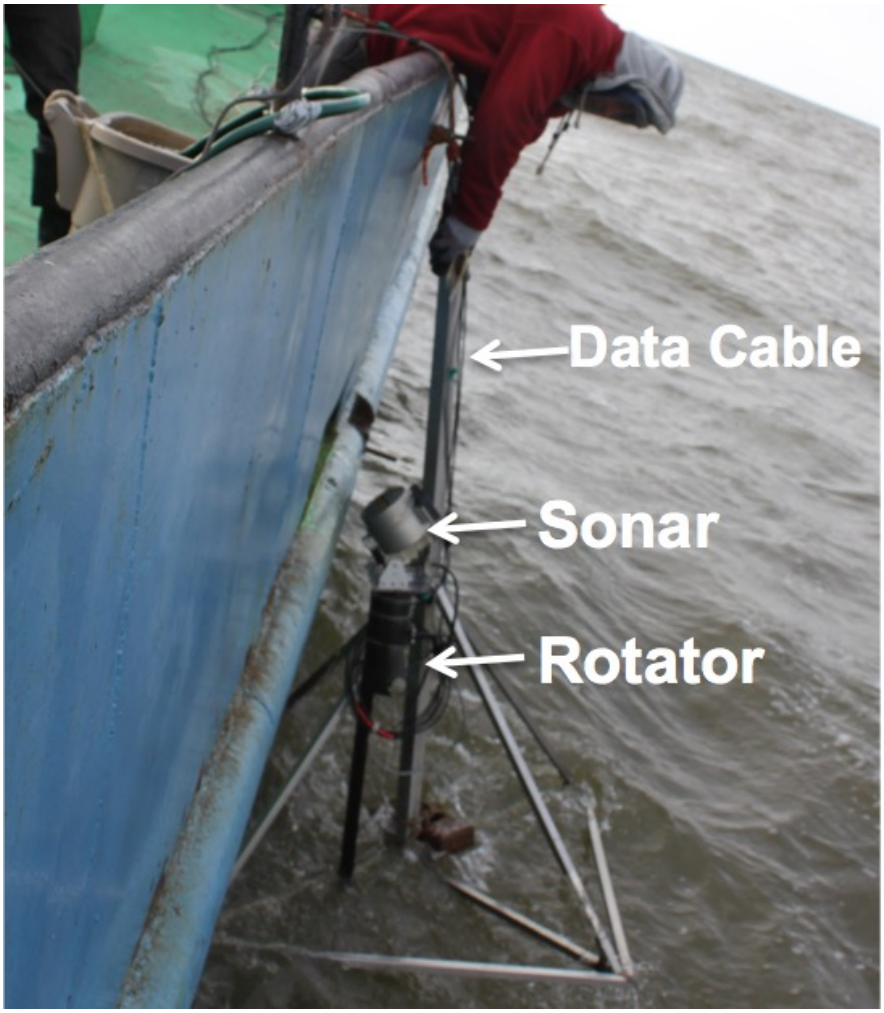

Figure S1. Photo of sonar rotator lander during a deployment in the East Siberian Arctic Sea.

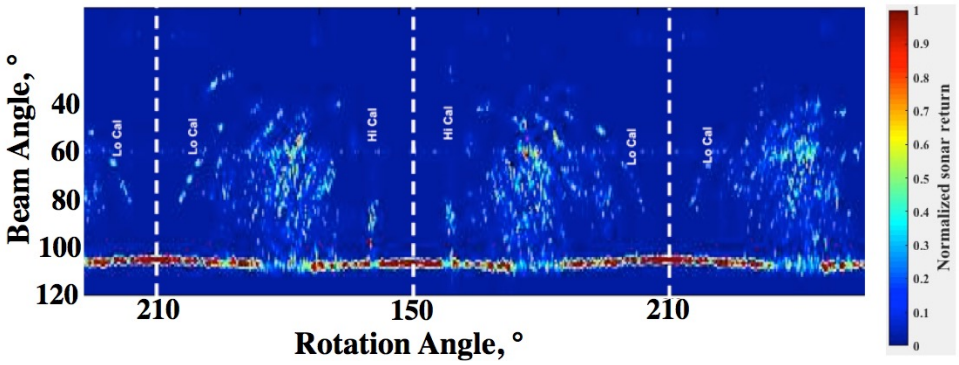

Figure S2. Spherical time slices by the sonar rotator (**Fig. S1**) showing Shane Seep and two calibration airflows in the Coal Oil Point seep field (**Fig. 1**) from a 2008 deployment. Sonar was deployed ~8 m southeast from the main seep bubble plume (see **Fig. 1b**) for location relative to origin). Data key on figure. Calibration flow labeled on figure.

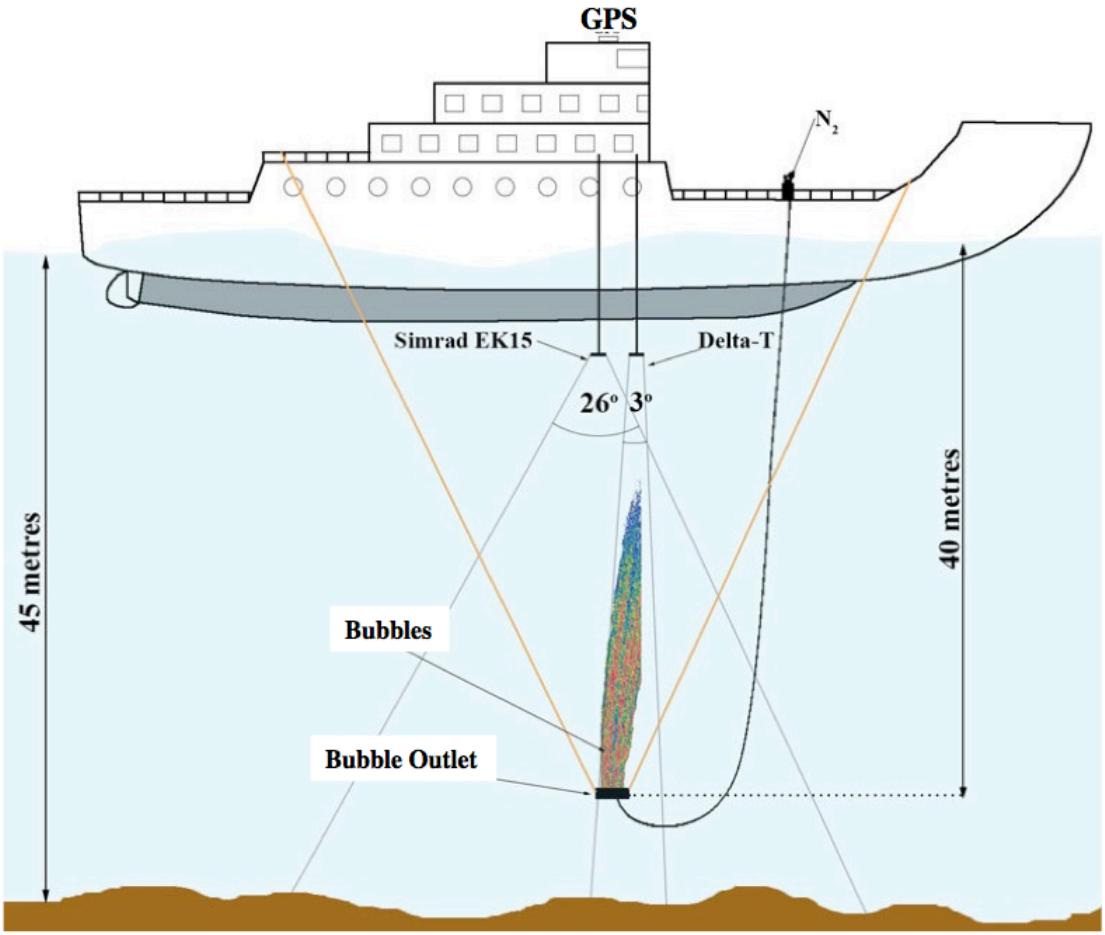

Figure S3. *In situ* calibration experiment set-up schematic as deployed in the ESAS.

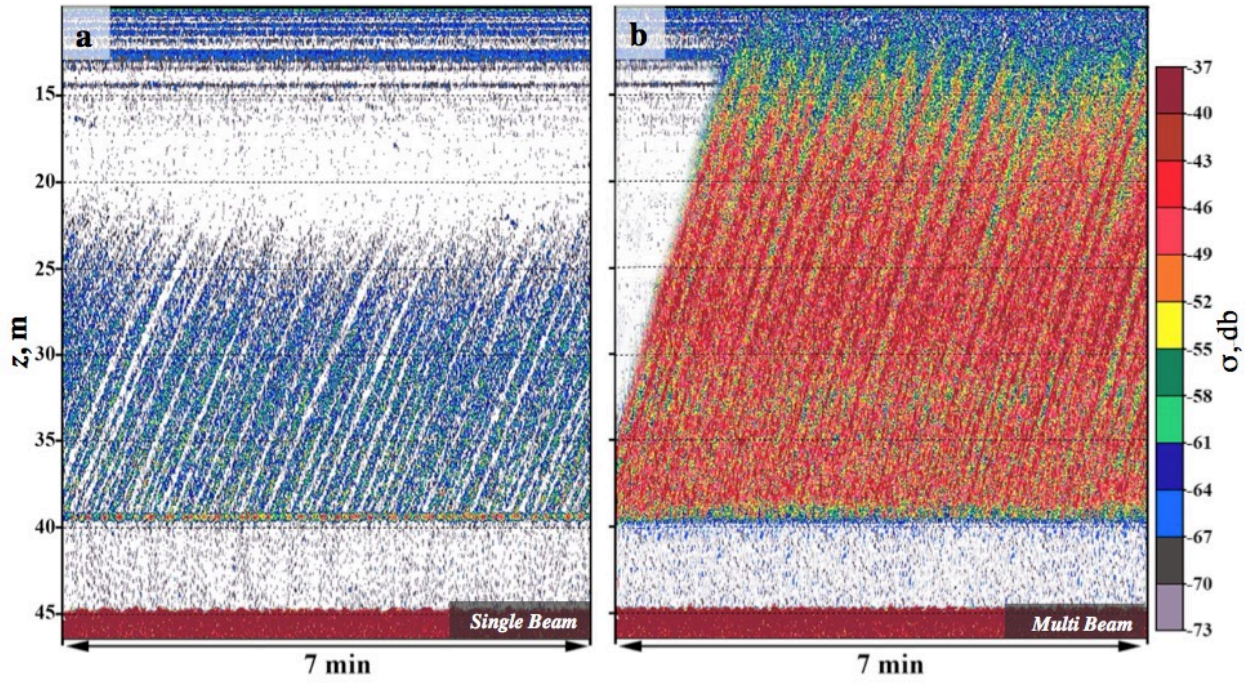

Figure S4. Plume-integrated sonar return (σ) of calibration bubble plume from 40-m depth (*z*) experiment conducted for **a.** 0.042 L/min and **b.** 1.1 L/min at 5.5 bar for the single beam sonar.

13 **Table S1.** Fit parameters for the calibration sonar occurrence distributions.

Depth, m	Q, L/s	σ_1, db	σ_2, db	a, db	b	R^2
40-35	0.019	-70	-53	-0.1328	-6.964	0.971
40-35	0.019	-53	-50	-0.5411	-29.01	0.8465
35-30	0.019	-70	-51	-0.151	-8.059	0.9738
35-30	0.019	-51	-50	-0.9285	-48.83	0.7025
30-25	0.019	-70	-50	-0.2119	-12.51	0.9235
40-35	0.028	-70	-57	-0.1358	-7.068	0.9571
40-35	0.028	-57	-50	-0.0354	-1.165	0.36
40-35	0.028	-50	-48	-0.8069	-40.22	0.921
35-30	0.028	70	-50	-0.1151	-5.623	0.978
35-30	0.028	-50	-48	-0.674	-33.85	0.9081
30-25	0.028	-70	-60	-0.2914	-17.88	0.9035
40-35	0.033	-70	-55	-0.128	-6.558	0.954
40-35	0.033	-55	-49	-0.01679	-0.3017	0.1049
40-35	0.033	-49	-47	-0.8539	-41.77	0.9515
35-30	0.033	-70	-48	-0.1151	-5.599	0.9716
35-30	0.033	-48	-46	-0.7112	-34.86	0.768
30-25	0.033	-70	-59	-0.3163	-19.39	0.9329
40-35	0.042	-70	-55	-0.1402	-7.251	0.9634
40-35	0.042	-55	-48	0.001935	0.548	0.001343
40-35	0.042	-48	-46	-1.067	-51.06	0.9517
35-30	0.042	-70	-54	-0.1359	-6.848	0.9507
35-30	0.042	-54	-48	-0.0866	-3.888	0.7971
35-30	0.042	-48	-46	-0.8484	-40.71	0.9565
30-25	0.042	-70	-52	-0.2636	-15.32	0.9799
40-35	0.6	-70	-55	-0.1854	-9.26	0.9535
40-35	0.6	-55	-43	-0.04924	-2.207	0.8892
40-35	0.6	-43	-40	-0.812	-34.75	0.9471
35-30	0.6	-70	-50	-0.1703	-8.186	0.9407
35-30	0.6	-50	-41	0.01915	0.7462	0.1745

35-30	0.6	-41	-39	-1.595	-65.43	0.9313
30-25	0.6	-70	-52	-0.1612	-8.014	0.9867
30-25	0.6	-52	-46	-0.1074	-4.965	0.9399
30-25	0.6	-46	-43	-0.6686	-30.89	0.9109
40-35	0.8	-70	-55	-0.2031	-10.69	0.9754
40-35	0.8	-55	-42	-0.05728	-2.643	0.9443
40-35	0.8	-42	-41	-1.121	-47.8	0.8962
35-30	0.8	-70	-54	-0.1571	-7.398	0.9494
35-30	0.8	-54	-42	-0.04081	-1.87	0.7363
35-30	0.8	-42	-40	-1.046	-43.93	0.9304
30-25	0.8	-70	-50	-0.1732	-8.38	0.9613
30-25	0.8	-50	-42	-0.002552	-0.08721	0.00269
30-25	0.8	-42	-40	-1.156	-48.47	0.9448
40-35	1.1	-70	-53	-0.1881	-9.428	0.954
40-35	1.1	-53	-42	-0.04272	-1.915	0.8601
40-35	1.1	-42	-40	-1.267	-53.37	0.9665
35-30	1.1	-70	-50	-0.1683	-8.042	0.9404
35-30	1.1	-50	-41	0.006602	0.1891	0.09718
35-30	1.1	-41	-39	-1.231	-50.15	0.9191
30-25	1.1	-70	-54	-0.1738	-8.598	0.9821
30-25	1.1	-54	-44	-0.07673	-3.425	0.9659
30-25	1.1	-44	-42	-0.8385	-36.97	0.9269

*Q is flow, σ is sonar return, a and b are fit parameters to $Q = a\ \sigma^{b}$.

Table S2 – Power law coefficients to echosounder calibration curve

Depth, m	Sonar model	Flow	*a*	*b*	*c*	R^2
25-30	Simrad EK15	*Lo*	-53.22	-0.2188	45.03	0.9402
25-30	Simrad EK15	*Hi*	-2.322e-10	-43.82	-24.83	0.9079
25-30	Simrad EK15	*Total*	-12.32	-0.4396	-11.71	0.9951
27.5-32.5	Simrad EK15	*Lo*	-3.405	-0.6378	-27.91	0.9698
27.5-32.5	Simrad EK15	*Hi*	-0.5079	-2.285	-23.16	1
27.5-32.5	Simrad EK15	*Total*	-8.921	-0.4652	-14.26	0.9975
30-35	Simrad EK15	*Lo*	-0.07429	-1.467	-42.07	0.9945
30-35	Simrad EK15	*Hi*	3.026	0.7402	-26.65	1
30-35	Simrad EK15	*Total*	-4.865	-0.5782	-18.5	0.9985
32.5-37.5	Simrad EK15	*Lo*	-0.003329	-2.215	-44.61	0.9993
32.5-37.5	Simrad EK15	*Hi*	1.866	1.314	-26.04	1
32.5-37.5	Simrad EK15	*Total*	-2.865	-0.6914	-21.23	0.9971
35-40	Simrad EK15	*Lo*	-0.001277	-2.425	-43.74	1
35-40	Simrad EK15	*Hi*	-0.6316	-2.211	-23.15	1
35-40	Simrad EK15	*Total*	-2.811	-0.6764	-21.06	0.9966
25-30	Imagenex Delta-T	*Lo*	3.906e+15	10,88	-52.94	0.9124
25-30	Imagenex Delta-T	*Hi*	-1.171e-11	-51.72	-29.09	0.6868
25-30	Imagenex Delta-T	*Total*	108.4	0.06706	-137.3	0.9708
27.5-32.5	Imagenex Delta-T	*Lo*	3114	1.703	-52.12	0.9989
27.5-32.5	Imagenex Delta-T	*Hi*	-2.02e-08	-33.7	-26.01	0.9994
27.5-32.5	Imagenex Delta-T	*Total*	-2.481	-0.5907	-23.35	0.9914
30-35	Imagenex Delta-T	*Lo*	-1.876	-0.6577	-20.92	0.9992
30-35	Imagenex Delta-T	*Hi*	0.01162	46.11	-26.94	0.3469
30-35	Imagenex Delta-T	*Total*	-0.6475	-0.8726	-25.83	0.9952
32.5-37.5	Imagenex Delta-T	*Lo*	-3.25e-05	-3.208	-35.13	1
32.5-37.5	Imagenex Delta-T	*Hi*	0.01064	50.66	-29.38	0.2465
32.5-37.5	Imagenex Delta-T	*Total*	-0.1123	-1.264	-28.84	0.9732
35-40	Imagenex Delta-T	*Lo*	-2.804e-05	-3.242	-35.74	1
35-40	Imagenex Delta-T	*Hi*	0.008287	47.42	-29.37	0.3025
35-40	Imagenex Delta-T	*Total*	-0.1461	-1.202	-28.96	0.9871

Lo is low flow (from 0.019 to 0.042 L/s), *Hi* is high flow (from 0.6 to 11 L/s), *Total* is total flow (from 0.019 to 1.1 L/s)

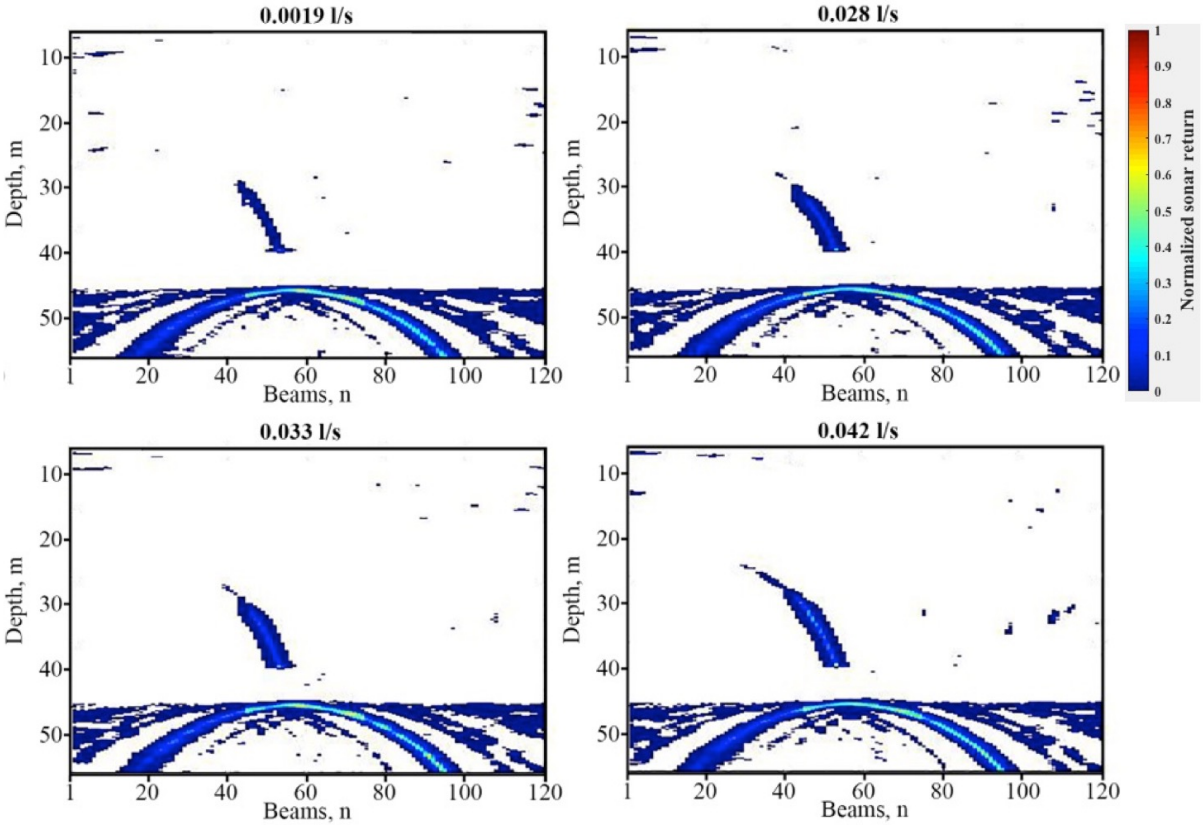

Figure S5. Example multibeam echosounder sonar data for calibration plume flux rates from 0.019 L/s to 0.042 L/s. Flux labeled on figure.

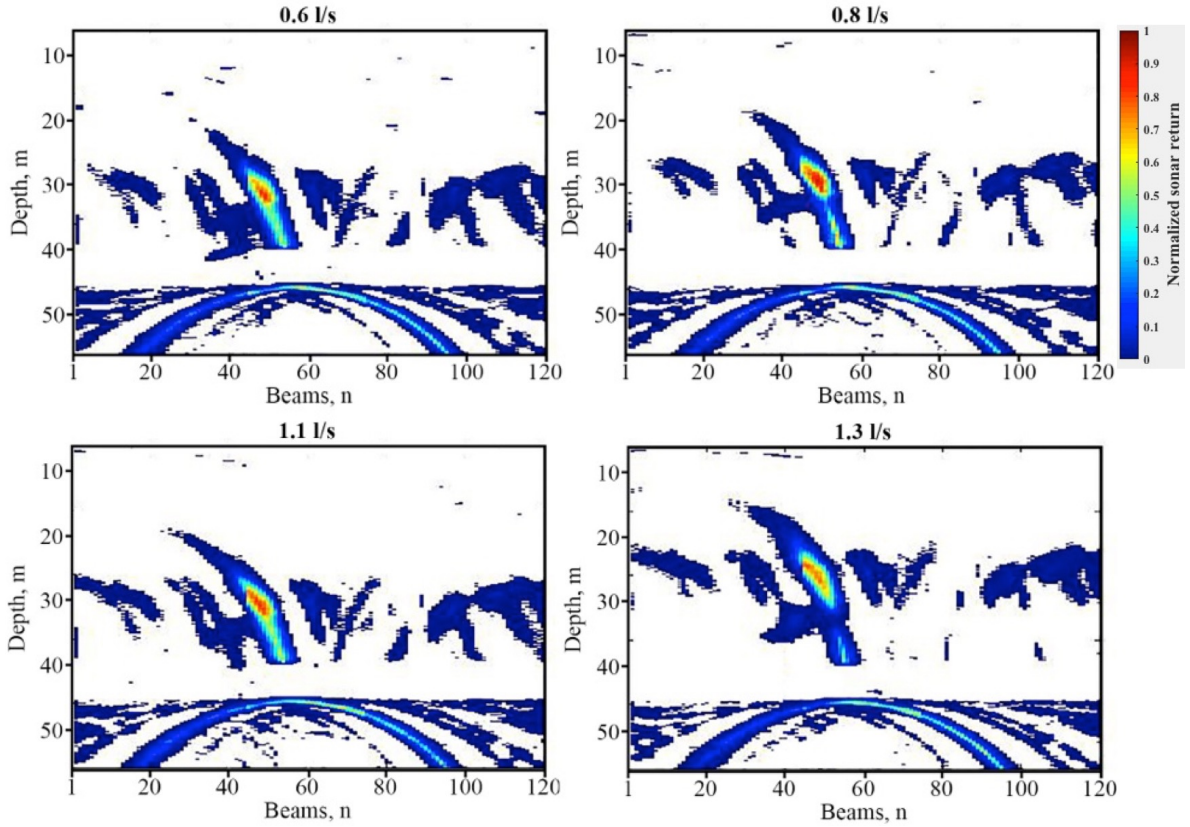

Figure S6. Example multibeam echosounder sonar data for calibration plume flux rate from 0.6 L/s to 1.3 L/s. Flux rate labeled on figure.

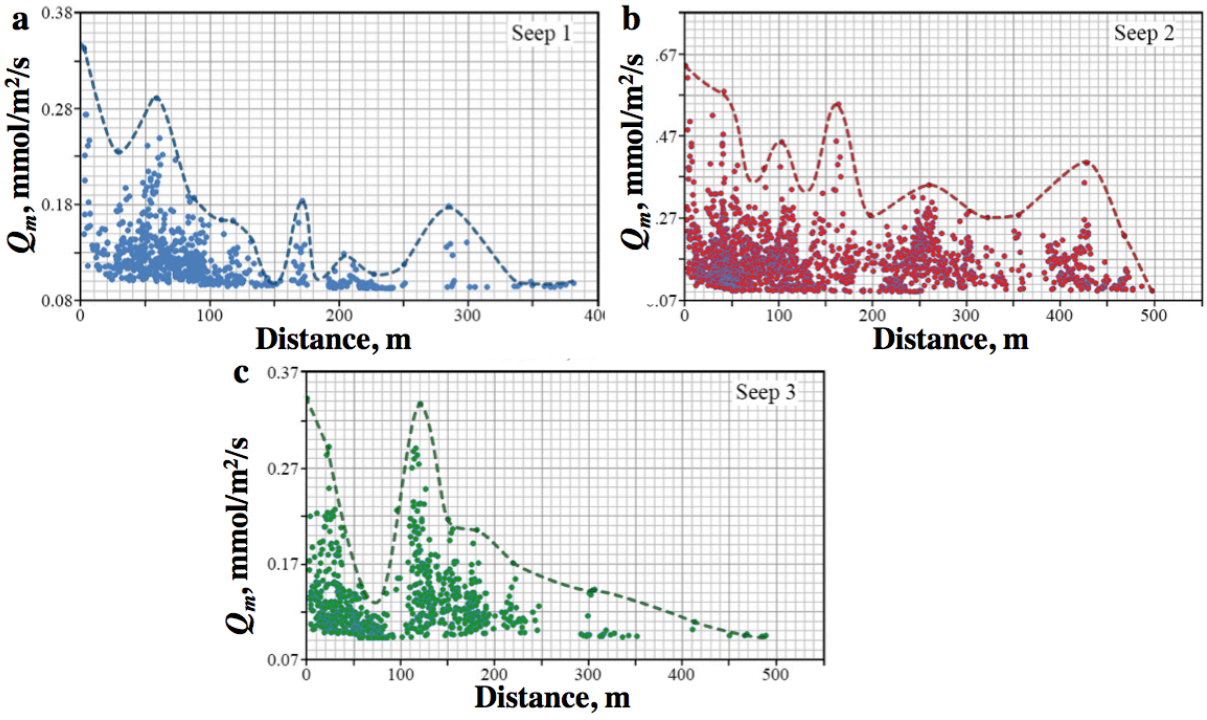

Figure S7. Radial distance, plots of mass flux (Q_m) for three seep areas. Radius origin shown in **Fig. 12**.