

Table S1. Ions concentrations in the ice samples.

Site	n	Statistical parameters	Na ⁺	NH ₄ ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻	TI
mg/l												
SZ.G	4	min	0.21	0.01	0.07	0.21	0.03	0.27	0.10	0.00	0.07	1.18
		max	0.81	0.07	0.67	0.73	0.09	2.66	0.18	0.00	0.17	4.50
		average	0.44	0.04	0.29	0.40	0.06	0.92	0.12	0.00	0.11	2.38
		median	0.36	0.03	0.22	0.34	0.06	0.37	0.11	0.00	0.11	1.93
		SD	0.26	0.03	0.26	0.24	0.02	1.16	0.04	0.00	0.04	1.52
		CV, %	60.17	67.40	89.40	60.10	40.30	126.92	29.11	29.46	38.96	63.65
AM.TGI/p	9	min	4.90	0.14	0.62	0.72	0.33	6.41	0.00	0.00	1.42	17.42
		max	23.34	0.42	2.62	3.61	1.22	16.56	0.11	0.12	2.94	46.27
		average	12.30	0.27	1.54	1.62	0.67	10.78	0.03	0.06	2.37	29.65
		median	10.37	0.25	1.31	1.35	0.60	8.88	0.03	0.04	2.61	27.76
		SD	6.81	0.10	0.64	0.98	0.33	3.84	0.03	0.04	0.57	9.91
		CV, %	55.35	36.42	41.49	60.47	49.73	35.64	94.33	66.34	23.96	33.41
VD.TGI/p	2	min	1.18	0.14	0.22	0.35	0.06	2.76	0.02	0.00	0.14	5.05
		max	11.07	0.23	1.19	0.65	0.48	8.95	0.10	0.07	1.68	24.29
		average	6.13	0.18	0.71	0.50	0.27	5.85	0.06	0.04	0.91	14.67
		median	6.13	0.18	0.71	0.50	0.27	5.85	0.06	0.04	0.91	14.67
		SD	6.99	0.06	0.68	0.22	0.30	4.38	0.06	0.05	1.10	13.60
		CV, %	114.12	33.52	96.92	43.09	109.99	74.81	100.67	133.45	120.43	92.76
MS.TGI/p	3	min	1.35	0.04	0.10	0.47	0.12	2.04	0.02	0.00	0.18	6.08
		max	3.69	0.11	0.78	0.78	0.18	3.64	0.05	0.09	0.22	7.71
		average	2.65	0.08	0.54	0.66	0.16	2.67	0.03	0.03	0.20	7.05
		median	2.91	0.08	0.74	0.73	0.18	2.35	0.02	0.01	0.20	7.36
		SD	1.19	0.04	0.38	0.17	0.03	0.85	0.02	0.05	0.02	0.86
		CV, %	44.95	47.64	70.39	24.98	20.04	31.76	57.83	154.65	10.50	12.18
F.TGI/p	4	min	5.02	0.70	0.31	1.73	0.54	15.58	0.03	0.00	5.18	32.06
		max	20.56	2.66	1.05	9.06	2.07	22.58	0.19	0.04	34.31	84.46
		average	11.89	1.79	0.70	4.00	1.54	19.72	0.09	0.02	18.06	57.85
		median	11.00	1.89	0.72	2.60	1.77	20.36	0.08	0.02	16.37	57.45
		SD	6.65	0.81	0.37	3.41	0.69	3.38	0.07	0.02	12.72	21.57
		CV, %	55.90	45.47	52.68	85.20	45.01	17.13	79.16	80.58	70.44	37.29
VD.TGI/imp	13	min	8.34	0.27	0.96	0.79	1.00	15.52	0.02	0.19	0.85	32.78
		max	189.04	1.95	5.19	4.47	5.35	262.49	0.58	1.48	11.69	469.54
		average	104.85	1.20	3.28	1.93	2.64	129.90	0.20	0.73	2.57	247.71
		median	106.31	1.08	3.33	2.06	2.60	124.47	0.17	0.69	1.58	238.67
		SD	50.83	0.56	1.17	1.02	1.22	73.13	0.16	0.38	2.88	124.16
		CV, %	48.48	46.51	35.79	52.93	46.09	56.30	81.42	51.86	112.18	50.12
VD.HW	4	min	0.79	0.32	0.41	0.47	0.28	1.60	0.13	0.03	0.30	5.77

Site	n	Statistical parameters	Na ⁺	NH ₄ ⁺	K ⁺	Ca ²⁺	Mg ²⁺	Cl ⁻	NO ₃ ⁻	PO ₄ ³⁻	SO ₄ ²⁻	TI
mg/l												
		max	7.19	5.17	1.33	2.70	1.80	3.89	0.57	0.05	0.82	15.20
		average	3.17	1.82	0.74	1.22	0.76	2.68	0.31	0.04	0.56	11.31
		median	2.35	0.89	0.60	0.86	0.48	2.61	0.26	0.04	0.57	12.13
		SD	2.79	2.27	0.40	1.01	0.71	1.05	0.19	0.01	0.23	4.68
		CV, %	87.86	124.94	54.61	82.34	93.49	39.40	61.02	26.69	41.58	41.37
VD.LPW	15	min	2.28	0.24	0.35	0.32	0.19	1.10	0.00	0.00	0.95	5.85
		max	18.85	0.67	1.33	2.00	0.85	17.31	0.54	0.09	14.04	47.87
		average	10.74	0.41	0.89	0.85	0.50	8.80	0.17	0.03	6.74	29.16
		median	11.12	0.35	0.93	0.67	0.58	9.91	0.13	0.02	6.66	32.37
		SD	4.80	0.16	0.30	0.41	0.22	4.70	0.16	0.03	4.17	13.08
		CV, %	44.69	38.24	33.66	48.05	42.93	53.35	94.23	104.67	61.80	44.86
F.HW	16	min	3.50	0.06	0.37	1.07	0.80	6.12	0.05	0.00	1.24	17.10
		max	51.31	1.06	3.38	3.82	5.23	100.50	0.52	0.69	22.25	188.04
		average	11.09	0.41	1.33	2.33	1.91	26.10	0.20	0.13	4.24	47.91
		median	6.94	0.35	1.12	2.32	1.62	16.61	0.16	0.02	2.44	32.45
		SD	11.88	0.30	0.78	0.88	1.13	23.56	0.14	0.21	5.13	42.71
		CV, %	107.15	74.93	58.48	37.80	59.38	90.25	71.00	157.22	121.04	89.15
F.LPW	8	min	4.02	0.52	0.98	2.03	1.33	6.73	0.07	0.00	4.18	22.50
		max	47.03	2.34	2.57	6.34	8.75	76.66	0.22	0.66	131.65	246.71
		average	19.69	1.14	1.77	3.90	4.26	35.14	0.13	0.22	39.84	106.27
		median	15.44	1.08	1.80	3.78	4.04	29.41	0.11	0.13	28.55	81.26
		SD	13.95	0.58	0.47	1.58	2.36	21.38	0.05	0.28	40.84	74.27
		CV, %	70.85	50.88	26.31	40.46	55.38	60.85	42.90	124.62	102.50	69.89

Table S2. Gases and bulk biogeochemical components in ice samples.

Site	n	Statistical parameters	Fraction	CO ₂	CH ₄	DOC	DIC	DIN
			%	ppmV		mg/l		
SZ.G	4	min	0.01	45.07	0.11	1.05	0.49	0.03
		max	0.01	63.26	1.10	1.75	1.71	0.06
		average	0.01	53.73	0.40	1.39	0.92	0.04
		median	0.01	53.30	0.19	1.38	0.74	0.03
		SD	0.00	9.22	0.47	0.31	0.54	0.01
		CV, %	0.00	17.16	117.76	21.95	58.83	38.10
AM.TGI/p	9	min	0.33	43.12	3.16	0.84	3.87	0.10

Site	n	Statistical parameters	Fraction %	CO ₂ ppmV	CH ₄	DOC	DIC mg/l	DIN
		max	2.51	270.55	12.14	5.02	7.44	0.29
		average	1.26	84.37	5.44	2.47	5.24	0.18
		median	0.86	55.62	4.55	1.74	4.80	0.17
		SD	0.85	73.18	2.72	1.71	1.23	0.06
		CV, %	67.52	86.75	49.96	67.02	23.48	35.22
VD.TGI/p	2	min	0.13	853.87	476.60	0.92	0.19	0.10
		max	3.49	1019.13	1490.72	5.79	5.47	0.16
		average	1.81	936.50	983.66	3.36	2.83	0.13
		median	1.81	936.50	983.66	3.36	2.83	0.13
		SD	2.38	116.86	717.09	2.435	3.73	0.05
		CV, %	131.38	12.48	72.90	72.58	131.93	35.77
MS.TGI/p	3	min	0.01	200.48	9.83	1.22	0.77	0.03
		max	0.01	633.83	69.13	2.28	0.98	0.73
		average	0.01	360.35	34.23	1.67	0.86	0.27
		median	0.01	246.74	23.72	1.51	0.84	0.06
		SD	0	237.97	31.01	0.55	0.10	0.40
		CV, %	0	66.04	90.60	32.80	12.09	145.79
F.TGI/p	4	min	0.02	49.27	1.51	1.67	0.79	0.49
		max	0.54	191.40	11.21	6.45	2.51	1.79
		average	0.21	85.93	4.08	4.23	1.41	1.21
		median	0.14	51.53	1.79	4.40	1.18	1.27
		SD	0.23	70.32	4.76	2.12	0.76	0.54
		CV, %	112.29	81.84	116.71	50.22	53.86	44.54
VD.TGI/imp	13	min	16.23	391.93	1357.91	33.21	7.29	0.18
		max	68.65	2430.94	32281.65	111.00	35.80	1.33
		average	42.01	1044.57	8960.32	65.41	18.89	0.83
		median	39.96	786.35	5075.57	66.65	16.73	0.73
		SD	13.83	619.06	9841.92	20.01	7.44	0.38
		CV, %	32.91	59.26	109.84	30.60	39.42	46.56
VD.HW	4	min	0.03	1276.51	6.90	5.53	0.67	0.27
		max	7.44	3539.96	418.14	84.39	3.38	3.48
		average	1.92	2162.75	110.59	27.39	1.75	1.22
		median	0.11	1917.27	8.66	9.81	1.21	0.56
		SD	3.68	973.10	205.04	38.06	1.43	1.52
		CV, %	191.38	44.99	185.40	138.98	81.81	124.42
VD.LPW	15	min	2.60	52.63	372.18	3.93	1.00	0.16
		max	6.73	1529.85	14138.08	19.70	5.88	0.50

Site	n	Statistical parameters	Fraction %	CO ₂	CH ₄	DOC	DIC	DIN
				ppmV			mg/l	
		average	4.11	610.95	7241.99	11.91	3.49	0.29
		median	3.74	482.25	3009.33	10.71	3.43	0.24
		SD	1.20	470.00	10851.65	4.88	1.35	0.11
		CV, %	29.08	76.87	149.84	40.96	38.50	38.03
		min	0.21	49.61	0.42	3.50	0.87	0.05
		max	11.38	379.61	50.75	13.59	5.66	0.74
F.HW	16	average	1.73	171.41	14.72	7.82	2.50	0.29
		median	1.15	115.58	5.46	7.61	2.13	0.26
		SD	2.67	131.03	16.19	2.86	1.26	0.21
		CV, %	154.20	76.44	110.00	36.52	50.52	72.64
		min	0.24	445.53	0.39	10.52	1.63	0.37
		max	8.63	1547.98	4.28	17.71	3.02	1.58
F.LPW	8	average	1.61	885.90	1.74	13.58	2.42	0.78
		median	0.35	758.89	1.30	13.01	2.51	0.74
		SD	2.91	383.06	1.50	2.62	0.53	0.39
		CV, %	180.50	43.24	85.90	19.31	21.93	49.84

Table S3. EEM-DOM PARAFAC components loadings

Site	n	Statistical parameters	P1	P2	P3	P4	Psum
				RU*10			
		min	0.02	0.01	0.00	0.23	0.28
		max	0.06	0.01	0.01	0.43	0.51
SZ.G	4	average	0.04	0.01	0.00	0.31	0.36
		median	0.03	0.01	0.00	0.30	0.33
		SD	0.02	0.00	0.00	0.09	0.10
		CV, %	46.56	14.39	167.40	27.15	27.93
		min	0.44	0.48	0.08	0.16	1.29
		max	0.70	3.77	0.34	0.78	5.00
AM.TGI/ p	9	average	0.53	1.43	0.18	0.31	2.44
		median	0.48	0.88	0.14	0.21	1.81
		SD	0.09	1.20	0.10	0.20	1.31
		CV, %	17.05	83.97	54.29	65.65	53.54
		min	0.09	0.05	0.01	0.14	0.29
		max	1.30	1.20	0.09	0.16	2.76
VD.TGI/ p	2	average	0.70	0.63	0.05	0.15	1.53
		median	0.70	0.63	0.05	0.15	1.53
		SD	0.86	0.82	0.06	0.02	1.75

Site	n	Statistical parameters	P1	P2	P3	P4	Psum
			RU*10				
		CV, %	122.36	131.02	109.26	10.32	114.56
MS.TGI/ p	3	min	0.05	0.02	0.00	0.14	0.22
		max	0.06	0.04	0.01	0.52	0.60
		average	0.05	0.03	0.01	0.32	0.41
		median	0.05	0.03	0.01	0.30	0.40
		SD	0.01	0.01	0.01	0.19	0.19
		CV, %	10.89	39.84	76.15	58.55	46.54
F.TGI/p	4	min	0.07	0.03	0.00	0.17	0.51
		max	0.27	0.21	0.06	0.40	0.76
		average	0.19	0.13	0.03	0.26	0.62
		median	0.21	0.14	0.04	0.23	0.60
		SD	0.09	0.07	0.02	0.10	0.11
		CV, %	45.94	55.58	68.08	38.46	18.21
VD.TGI/i mp	13	min	4.05	7.04	0.30	0.07	12.05
		max	15.39	32.40	2.49	0.62	48.56
		average	10.76	18.28	1.46	0.31	30.81
		median	11.63	17.74	1.31	0.27	31.26
		SD	3.59	7.56	0.61	0.18	10.65
		CV, %	33.36	41.36	41.84	56.63	34.55
VD.HW	4	min	1.64	4.60	0.31	0.00	6.91
		max	9.85	28.84	5.00	0.08	43.73
		average	4.31	13.95	1.62	0.04	19.91
		median	2.87	11.17	0.58	0.04	14.51
		SD	3.82	10.92	2.27	0.03	16.86
		CV, %	88.65	78.32	140.07	74.95	84.66
VD.LPW	15	min	0.37	0.43	0.09	0.06	0.95
		max	3.53	7.55	1.41	0.28	12.77
		average	1.43	2.94	0.60	0.16	5.12
		median	1.38	2.62	0.59	0.14	4.69
		SD	0.72	1.59	0.29	0.08	2.63
		CV, %	50.27	54.13	48.38	51.10	51.33
F.HW	16	min	0.59	1.29	0.23	0.11	2.36
		max	1.49	5.98	0.97	0.31	8.45
		average	1.03	3.10	0.53	0.19	4.86
		median	0.95	2.60	0.48	0.20	4.12

Site	n	Statistical parameters	P1	P2	P3	P4	Psum
			RU*10				
		SD	0.28	1.50	0.21	0.06	1.91
		CV, %	27.00	48.25	39.16	30.96	39.29
F.LPW	8	min	0.90	1.52	0.41	0.12	3.14
		max	3.15	13.30	2.46	0.46	18.46
		average	2.17	6.28	1.39	0.26	10.11
		median	2.23	4.55	1.31	0.27	8.37
		SD	0.77	4.04	0.66	0.10	5.05
		CV, %	35.28	64.31	47.37	39.01	49.95

Table S4. Pearson correlation coefficients matrix of the EEM-DOM PARAFAC Components.

	P1	P2	P3
P1			
P2	0.96		
P3	0.85	0.90	
P4	0.34	0.31	0.34