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Supporting Information for

Effects of snow and remineralization processes on nutrient distributions in multi-year Antarctic landfast sea ice

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Contents of this file

Introduction

The supporting information file describes biogeochemical data in the landfast sea ice, snow and under-ice water in Lützow-Holm Bay, East Antarctica collected during the 56–60th JAREs (2015–2019).

Sea ice observations of multi-year fast ice were performed during the summers of 2015–2019 as part of the 56–60th JAREs. Sea-ice cores were collected near Syowa Station. Ice cores were sampled using an ice corer (Geo Tecs Co., Ltd., Chiba, Japan) with an internal diameter of 0.09 m. Cores were immediately placed in tubular polyethylene bags and kept horizontal in a cooler box along with refrigerants to maintain below-freezing temperatures and minimize brine drainage from the core. Fresh snow samples were collected with an acid-washed polycarbonate shovel and placed into polyethylene zipper storage bags.

Sea ice cores were stored in a freezer at −30°C during their transport to the Institute of Low Temperature Science (ILTS), Hokkaido University, Sapporo, Japan. In the ILTS cold room (−15°C), cores were split lengthwise into two halves with an electric band saw: the first half for ice textural analysis and the second half for measurements of bulk ice salinity, $\delta^{18}O$ composition, nutrient and chl.a concentrations, and cell counting for ice algae community assemblage.

Under-ice water was collected through the coring holes with a Teflon water sampler (GL Science Inc., Japan) from 1 m below the bottom of the sea ice during JARE60 (2019). Water samples were collected approximately 30 minutes after the ice core was drilled at JARE60_KU_2 to avoid potential artifacts associated with the disturbance of drilling. All collected water samples were subsampled into (1) a 120-mL glass vial (Maruemu Co., Ltd., Osaka, Japan) for salinity measurement, (2) a 15-mL glass screw-cap vial (Nichiden-Rika Glass Co. Ltd, Kobe, Japan) for $\delta^{18}O$ analysis, (3) a 10-mL polyethylene screw-cap vial (Eiken Chemical Co. Ltd, Tokyo, Japan) for measurement of major inorganic nutrient concentrations (NO_3^- + NO_2^-, NH_4^+, PO_4^{3-}, and $Si(OH)_4$), and (4) a 500-mL Nalgene polycarbonate bottle (Thermo Fisher Scientific Inc., Waltham, MA, USA) for measurement of chlorophyll a (chl.a) concentrations. All samples were returned to the laboratory of the Japan Maritime Self-Defense Force icebreaker *Shirase* immediately after sampling.

Table S1. Dataset. "–" indicates no data.

Sample type	Station	Upper Limit of Depth range (cm)	Lower Limit of Depth range (cm)	Salinity	$\delta^{18}O$ (‰)	NO_3^- (μmol L^{-1})	NO_2^- (μmol L^{-1})	PO_4^{3-} (μmol L^{-1})	$Si(OH)_4$ (μmol L^{-1})	Chl.a (μg L^{-1})
Snow	JARE58_KU3	168	112	0.0	−21.8	0.0	0.0	0.0	0.0	0.0
Snow	JARE58_KU3	112	56	0.0	−22.6	0.1	0.0	0.0	0.0	0.0
Snow	JARE58_KU3	56	0	0.0	−22.2	0.1	0.0	0.0	0.0	0.0
Snow	JARE59_2	78	52	0.0	−22.3	0.1	0.0	0.0	0.1	0.0
Snow	JARE59_2	52	26	0.0	−19.8	0.1	0.0	0.0	0.1	0.0
Snow	JARE59_2	26	0	0.0	−21.0	0.0	0.0	0.0	0.1	0.0
Snow	JARE59_POPs	8	0	0.0	−16.1	0.4	0.0	0.0	0.0	0.0
Snow	JARE59_POPs	20	8	0.0	−17.4	0.3	0.0	0.0	0.0	0.3
Snow	JARE60_KU1	20	0.0	0.0	−21.2	0.3	0.0	0.0	0.0	0.0
Snow	JARE60_KU2	8	0	0.0	−18.9	0.3	0.0	0.0	0.0	0.0
Sea ice	JARE56_NMS	0	−13	0.0	−18.9	0.1	0.0	0.0	0.1	0.0
Sea ice	JARE56_NMS	−13	−25	0.0	−18.9	0.4	0.0	0.0	0.1	0.0
Sea ice	JARE56_NMS	−25	−38	0.0	−18.9	0.1	0.0	0.0	0.1	0.0
Sea ice	JARE56_NMS	−38	−50	0.0	−18.7	0.2	0.0	0.0	0.1	0.0
Sea ice	JARE56_NMS	−50	−63	0.0	−18.9	0.1	0.0	0.0	0.2	0.0
Sea ice	JARE56_NMS	−63	−76	0.0	−18.8	0.1	0.0	0.1	0.2	0.0
Sea ice	JARE56_NMS	−76	−88	0.0	−22.8	0.0	0.0	0.0	0.2	0.0
Sea ice	JARE56_NMS	−88	−101	0.2	−20.2	0.1	0.0	0.0	0.4	0.0
Sea ice	JARE56_NMS	−101	−113	0.0	−16.5	0.1	0.0	0.0	0.1	0.0
Sea ice	JARE56_NMS	−113	−126	0.0	−16.2	0.1	0.0	0.0	0.2	0.0
Sea ice	JARE56_NMS	−126	−139	0.2	−15.6	0.1	0.0	0.0	0.3	0.0
Sea ice	JARE56_NMS	−139	−151	0.5	−15.5	0.2	0.0	0.1	0.6	0.1
Sea ice	JARE56_NMS	−151	−164	0.6	−15.6	0.1	0.0	0.1	0.8	0.2
Sea ice	JARE56_NMS	−164	−176	0.2	−16.6	0.0	0.0	0.2	0.5	0.3
Sea ice	JARE56_NMS	−176	−189	0.4	−21.2	0.0	0.0	0.1	0.6	0.5

Sea ice	JARE56_NMS	−189	−201	1.8	−14.7	0.0	0.0	0.5	2.1	1.2
Sea ice	JARE56_NMS	−201	−214	1.5	−12.6	0.0	0.1	0.4	1.5	1.2
Sea ice	JARE56_NMS	−214	−227	0.6	−9.9	0.0	0.0	0.2	0.7	0.6
Sea ice	JARE56_NMS	−227	−239	0.5	−7.8	0.0	0.0	0.2	0.7	0.4
Sea ice	JARE56_NMS	−239	−252	1.0	−6.7	0.0	0.0	0.4	1.4	1.5
Sea ice	JARE56_NMS	−252	−264	0.9	−6.1	0.0	0.0	0.3	1.3	1.9
Sea ice	JARE56_NMS	−264	−277	1.0	−5.2	0.1	0.0	0.4	0.9	5.0
Sea ice	JARE56_NMS	−277	−290	1.9	−3.1	0.3	0.1	0.9	1.4	15.3
Sea ice	JARE56_NMS	−290	−302	2.3	−2.3	1.1	0.1	0.9	1.7	18.0
Sea ice	JARE56_NMS	−302	−315	1.4	−0.6	1.1	0.0	0.2	0.9	4.1
Sea ice	JARE56_NMS	−315	−327	1.2	0.8	1.0	0.0	0.2	1.0	4.8
Sea ice	JARE56_NMS	−327	−340	2.7	1.5	2.4	0.0	0.2	2.8	2.2
Sea ice	JARE57_P.31.5	0	−12	0.0	−19.8	0.1	0.0	0.0	0.0	0.0
Sea ice	JARE57_P.31.5	−12	−25	0.0	−19.9	0.0	0.0	0.0	0.0	0.0
Sea ice	JARE57_P.31.5	−25	−37	0.0	−20.6	−	0.0	0.0	0.1	0.0
Sea ice	JARE57_P.31.5	−37	−49	0.0	−20.7	0.2	0.0	0.0	0.0	0.0
Sea ice	JARE57_P.31.5	−49	−62	0.0	−20.7	0.2	0.0	0.0	0.0	0.0
Sea ice	JARE57_P.31.5	−62	−74	0.0	−22.4	0.0	0.0	0.0	0.1	0.0
Sea ice	JARE57_P.31.5	−74	−86	0.0	−22.2	0.0	0.0	0.0	0.0	0.0
Sea ice	JARE57_P.31.5	−86	−98	0.0	−21.1	0.0	0.0	0.0	0.1	0.0
Sea ice	JARE57_P.31.5	−98	−111	0.0	−22.6	0.0	0.0	0.0	0.1	0.0
Sea ice	JARE57_P.31.5	−111	−123	0.0	−23.8	0.0	0.0	0.0	0.2	0.0
Sea ice	JARE57_P.31.5	−123	−135	1.9	−20.1	0.0	0.0	0.1	1.7	0.1
Sea ice	JARE57_P.31.5	−135	−148	0.4	−17.5	0.0	0.0	0.1	0.5	0.1
Sea ice	JARE57_P.31.5	−148	−160	0.3	−13.5	0.0	0.0	0.2	0.8	0.3
Sea ice	JARE57_P.31.5	−160	−172	1.2	−14.9	0.0	0.0	0.4	1.6	0.6
Sea ice	JARE57_P.31.5	−172	−185	1.9	−15.5	0.0	0.0	0.4	3.0	0.9
Sea ice	JARE57_P.31.5	−185	−197	1.2	−19.8	0.0	0.0	0.3	1.4	0.6
Sea ice	JARE57_P.31.5	−197	−209	0.8	−18.2	0.0	0.0	0.1	1.1	0.5
Sea ice	JARE57_P.31.5	−209	−221	1.8	−16.8	0.0	0.0	0.3	2.9	1.7
Sea ice	JARE57_P.31.5	−221	−234	2.6	−15.3	0.0	0.0	0.4	4.8	1.9
Sea ice	JARE57_P.31.5	−234	−246	2.3	−15.8	0.0	0.0	0.3	4.5	1.5
Sea ice	JARE57_P.31.5	−246	−258	2.2	−15.7	0.0	0.0	0.4	4.9	1.8
Sea ice	JARE57_P.31.5	−258	−271	1.9	−15.3	0.0	0.0	0.5	4.1	3.7

Sea ice	JARE57_P.31.5	−271	−283	2.3	−15.0	0.0	0.1	0.7	6.6	7.0
Sea ice	JARE57_P.31.5	−283	−295	1.5	−14.3	0.0	0.1	0.8	11.5	8.2
Sea ice	JARE57_P.31.5	−295	−308	0.6	−13.8	0.0	0.1	1.1	8.3	13.9
Sea ice	JARE57_P.31.5	−308	−320	1.0	−6.3	0.0	0.0	0.5	9.3	4.8
Sea ice	JARE57_P.31.5	−320	−332	1.4	−3.9	0.4	0.0	0.7	12.3	6.0
Sea ice	JARE57_P.31.5	−332	−344	1.8	−2.0	1.6	0.0	0.6	7.6	5.8
Sea ice	JARE57_P.31.5	−344	−357	2.1	−1.0	2.4	0.0	0.8	9.2	6.0
Sea ice	JARE57_P.31.5	−357	−369	2.3	0.4	1.3	0.1	1.6	16.0	14.8
Sea ice	JARE57_P.31.5	−369	−381	1.6	1.6	0.4	0.1	1.2	8.5	11.5
Sea ice	JARE57_P.31.5	−381	−394	1.2	1.8	0.6	0.0	0.5	1.5	5.2
Sea ice	JARE57_P.31.5	−394	−406	1.4	1.0	1.9	0.0	0.3	1.9	3.3
Sea ice	JARE57_P.31.5	−406	−418	1.3	−0.4	2.1	0.0	0.4	1.6	3.6
Sea ice	JARE57_P.31.5	−418	−431	1.4	1.1	2.2	0.0	0.3	1.8	1.9
Sea ice	JARE57_P.31.5	−431	−443	2.1	1.7	3.5	0.0	0.3	2.9	0.6
Sea ice	JARE57_P.31.5	−443	−455	1.5	2.0	2.4	0.0	0.2	1.9	0.6
Sea ice	JARE57_P.31.5	−455	−467	1.6	2.0	2.5	0.0	0.2	1.9	0.6
Sea ice	JARE57_P.31.5	−467	−480	2.6	1.7	3.0	0.0	0.3	3.6	0.3
Sea ice	JARE57_P.31.5	−480	−492	1.2	−7.1	1.3	0.0	0.7	1.3	0.6
Sea ice	JARE57_EM	0	−15	0.6	−16.6	0.6	0.0	0.0	1.1	0.1
Sea ice	JARE57_EM	−15	−29	2.6	−1.9	0.4	0.0	0.1	1.7	0.2
Sea ice	JARE57_EM	−29	−44	2.3	−0.4	0.5	0.1	0.1	1.7	0.2
Sea ice	JARE57_EM	−44	−59	2.2	0.6	0.2	0.0	0.1	1.4	0.2
Sea ice	JARE57_EM	−59	−73	1.7	1.2	0.1	0.0	0.1	1.4	0.1
Sea ice	JARE57_EM	−73	−88	1.8	1.4	0.2	0.0	0.1	1.2	0.7
Sea ice	JARE57_EM	−88	−103	1.9	1.4	0.5	0.0	0.2	1.6	3.3
Sea ice	JARE57_EM	−103	−117	2.4	1.4	0.5	0.0	1.0	2.2	4.4
Sea ice	JARE57_EM	−117	−132	2.8	1.2	1.3	0.1	2.0	5.0	99.2
Sea ice	JARE58_KU3	0	−15	0.0	−20.6	−	0.0	0.0	0.0	0.1
Sea ice	JARE58_KU3	−15	−29	0.0	−20.6	−	0.0	0.0	0.0	0.1
Sea ice	JARE58_KU3	−29	−44	0.0	−21.7	−	0.0	0.0	0.0	0.0
Sea ice	JARE58_KU3	−44	−59	0.0	−20.6	0.1	0.0	0.0	0.0	0.0
Sea ice	JARE58_KU3	−59	−73	0.0	−19.8	0.1	0.0	0.0	0.0	0.0
Sea ice	JARE58_KU3	−73	−88	0.0	−20.0	0.1	0.0	0.0	0.0	0.1
Sea ice	JARE58_KU3	−88	−102	0.0	−21.6	0.2	0.0	0.0	0.0	0.1

Sea ice	JARE58_KU3	−102	−117	0.1	−20.6	0.2	0.0	0.0	0.0	0.1
Sea ice	JARE58_KU3	−117	−132	0.1	−20.2	0.2	0.0	0.0	0.0	0.0
Sea ice	JARE58_KU3	−132	−146	0.1	−20.2	0.1	0.0	0.0	0.0	0.1
Sea ice	JARE58_KU3	−146	−161	1.0	−17.9	0.2	0.0	0.1	1.0	1.3
Sea ice	JARE58_KU3	−161	−176	1.4	−16.7	0.2	0.0	0.0	1.3	0.8
Sea ice	JARE58_KU3	−176	−190	2.5	−18.2	0.2	0.0	0.1	2.6	0.5
Sea ice	JARE58_KU3	−190	−205	3.1	−20.9	0.4	0.0	0.1	2.8	1.4
Sea ice	JARE58_KU3	−205	−219	3.8	−21.4	0.7	0.0	0.1	3.9	1.1
Sea ice	JARE58_KU3	−219	−234	3.6	−21.4	0.2	0.0	0.2	2.8	1.4
Sea ice	JARE58_KU3	−234	−249	3.2	−22.6	0.3	0.0	0.1	2.1	1.3
Sea ice	JARE58_KU3	−249	−263	0.9	−23.3	0.3	0.0	0.0	0.3	0.8
Sea ice	JARE58_KU3	−263	−278	0.5	−22.6	0.1	0.0	0.0	0.3	1.0
Sea ice	JARE59_2	0	−18	0.0	−21.6	–	0.0	0.0	0.1	0.0
Sea ice	JARE59_2	−18	−35	0.0	−21.2	–	0.0	0.0	0.1	0.0
Sea ice	JARE59_2	−35	−53	0.0	−21.0	–	–	0.0	0.0	0.0
Sea ice	JARE59_2	−53	−71	0.0	−20.0	–	0.0	0.0	0.0	0.0
Sea ice	JARE59_2	−71	−88	0.0	−20.8	0.2	0.0	0.0	0.0	0.0
Sea ice	JARE59_2	−88	−106	0.0	−20.7	0.2	0.0	0.0	0.1	0.0
Sea ice	JARE59_2	−106	−123	0.0	−21.1	0.2	0.0	0.0	0.2	0.0
Sea ice	JARE59_2	−123	−141	0.0	−21.3	0.2	0.0	0.0	0.1	0.0
Sea ice	JARE59_2	−141	−159	0.0	−19.9	0.3	0.0	0.0	0.0	0.0
Sea ice	JARE59_2	−159	−176	0.0	−19.2	0.3	0.0	0.0	0.1	0.0
Sea ice	JARE59_2	−176	−194	0.3	−20.1	0.3	0.0	0.1	0.2	0.0
Sea ice	JARE59_2	−194	−212	0.6	−18.6	0.3	0.0	0.3	0.7	0.2
Sea ice	JARE59_2	−212	−229	0.4	−14.4	0.6	0.0	0.3	0.6	0.2
Sea ice	JARE59_2	−229	−247	0.5	−17.5	0.7	0.0	0.3	0.7	0.2
Sea ice	JARE59_POPs	0	−16	0.4	−16.4	0.2	0.0	0.1	0.1	0.0
Sea ice	JARE59_POPs	−16	−32	1.8	−4.5	0.3	0.0	0.3	1.2	0.3
Sea ice	JARE59_POPs	−32	−48	1.9	−1.5	0.3	0.0	0.3	0.8	1.2
Sea ice	JARE59_POPs	−48	−64	1.7	−1.1	0.5	0.0	0.3	0.5	1.1
Sea ice	JARE59_POPs	−64	−80	1.9	−0.1	0.2	0.0	0.4	0.5	1.0
Sea ice	JARE59_POPs	−80	−96	2.3	0.3	0.5	0.0	0.2	0.5	1.3
Sea ice	JARE59_POPs	−96	−112	2.9	0.2	0.4	0.0	0.5	1.1	1.8
Sea ice	JARE59_POPs	−112	−128	3.3	0.7	0.5	0.0	0.6	1.5	4.0

Sea ice	JARE59_POPs	−128	−144	3.2	1.3	0.5	0.0	1.1	1.7	11.2
Sea ice	JARE60_KU1	0	−16	4.9	−1.5	0.1	0.0	0.6	0.9	7.3
Sea ice	JARE60_KU1	−16	−33	5.8	−0.9	0.2	0.0	0.7	1.1	13.9
Sea ice	JARE60_KU1	−33	−49	5.6	0.0	1.6	0.0	0.5	0.4	13.6
Sea ice	JARE60_KU1	−49	−65	4.8	0.6	1.8	0.0	0.8	0.6	17.7
Sea ice	JARE60_KU1	−65	−82	5.1	0.6	0.7	0.0	0.5	0.4	10.7
Sea ice	JARE60_KU1	−82	−98	3.8	1.4	0.8	0.0	0.6	0.6	10.4
Sea ice	JARE60_KU1	−98	−114	4.2	1.6	2.6	0.0	1.1	1.1	56.4
Sea ice	JARE60_KU2	0	−16	3.3	−11.4	0.3	0.1	0.2	0.3	2.9
Sea ice	JARE60_KU2	−16	−31	3.0	−7.5	0.5	0.1	0.3	0.5	1.6
Sea ice	JARE60_KU2	−31	−47	3.8	−6.2	0.3	0.0	0.2	0.5	1.6
Sea ice	JARE60_KU2	−47	−62	4.6	−2.7	0.1	0.0	0.4	1.1	3.5
Sea ice	JARE60_KU2	−62	−78	4.2	−1.3	0.2	0.0	0.6	1.4	6.0
Sea ice	JARE60_KU2	−78	−94	4.1	−0.1	0.3	0.0	0.5	1.2	10.1
Sea ice	JARE60_KU2	−94	−109	3.2	1.1	0.2	0.0	0.2	0.6	7.0
Sea ice	JARE60_KU2	−109	−125	2.9	1.4	0.2	0.0	0.1	0.4	3.0
Sea ice	JARE60_KU2	−125	−140	3.6	1.4	0.5	0.0	0.6	1.3	13.7
Under-ice water (1 m from ice bottom)	JARE60_KU2	−	−	33.9	−0.7	28.0	0.2	1.8	60.6	−