Title

Methane Distribution in the East (Japan) Sea: Baseline for Donghae Gas Field Carbon Storage Project

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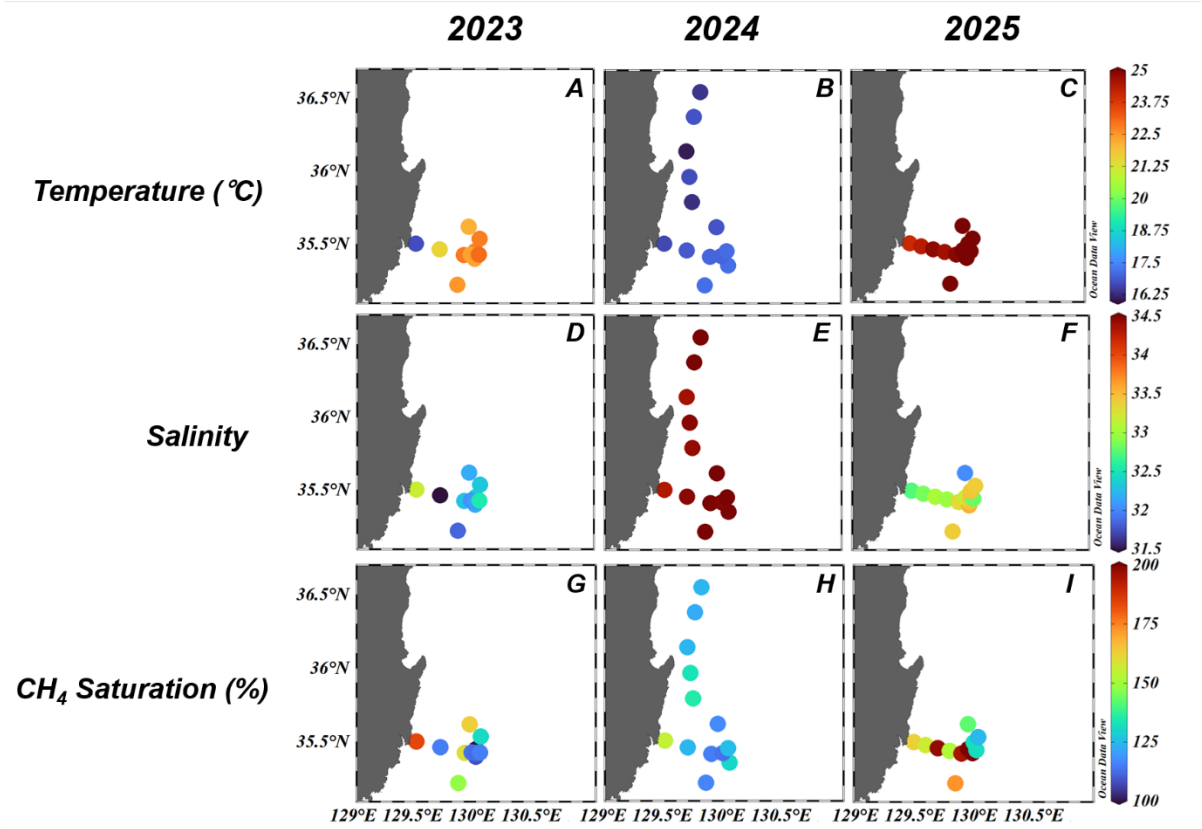


Figure S1. Spatial distributions of surface water parameters in the southwestern East (Japan) Sea observed in July 2023, April 2024, and October 2025: (A–C) temperature (°C), (D–F) salinity, and (G–I) CH_4 saturation (%). Left, middle, and right columns correspond to July 2023 (A, D, G), April 2024 (B, E, H), and October 2025 (C, F, I), respectively.

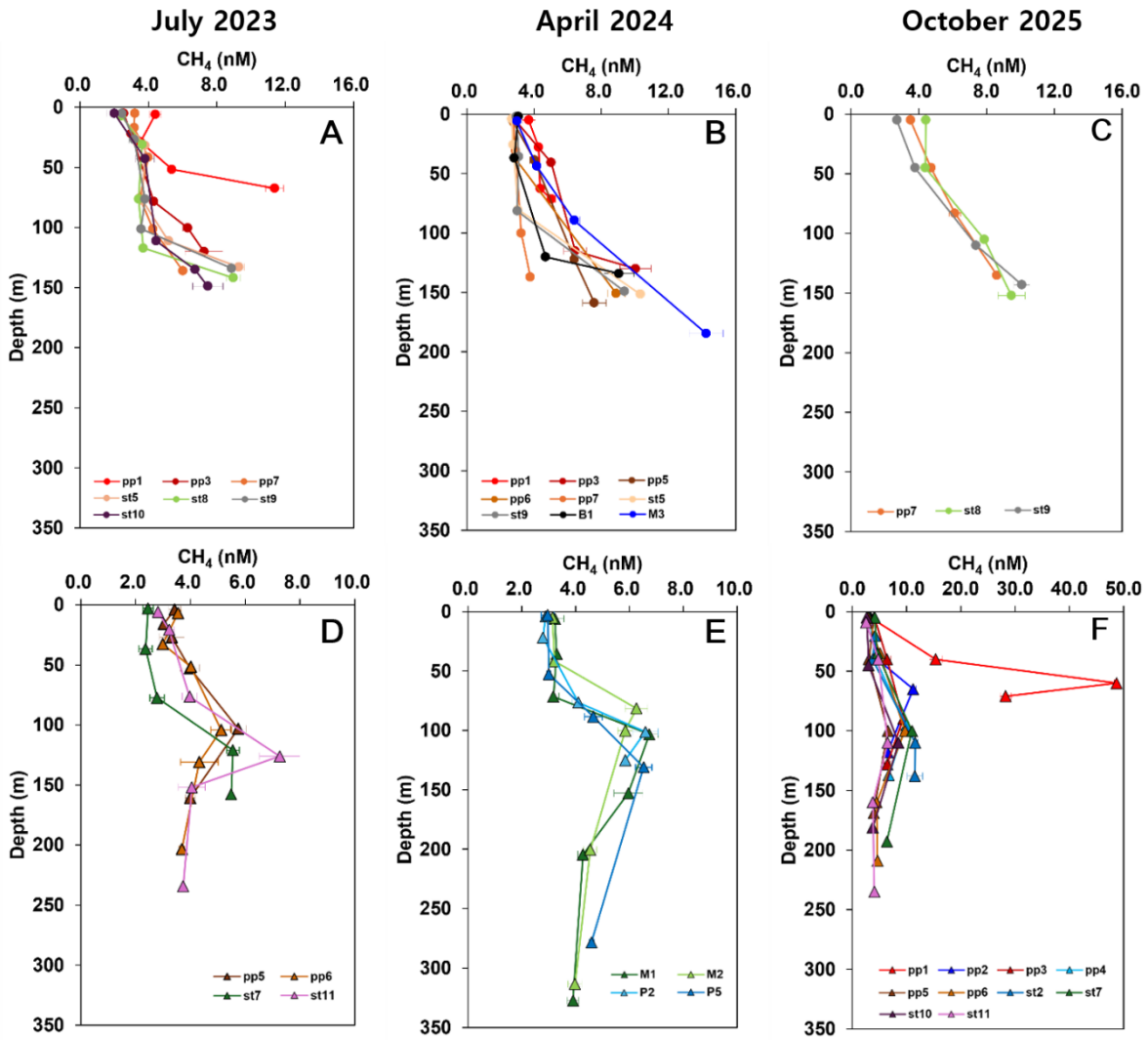


Figure S2. Vertical profiles of dissolved methane (CH_4) concentrations in the southwestern East (Japan) Sea during July 2023 (A, D), April 2024 (B, E), and October 2025 (C, F). The upper panels (A–C) represent stations exhibiting maximum CH_4 concentrations near the bottom water, whereas the lower panels (D–F) represent stations showing subsurface CH_4 concentration maxima.

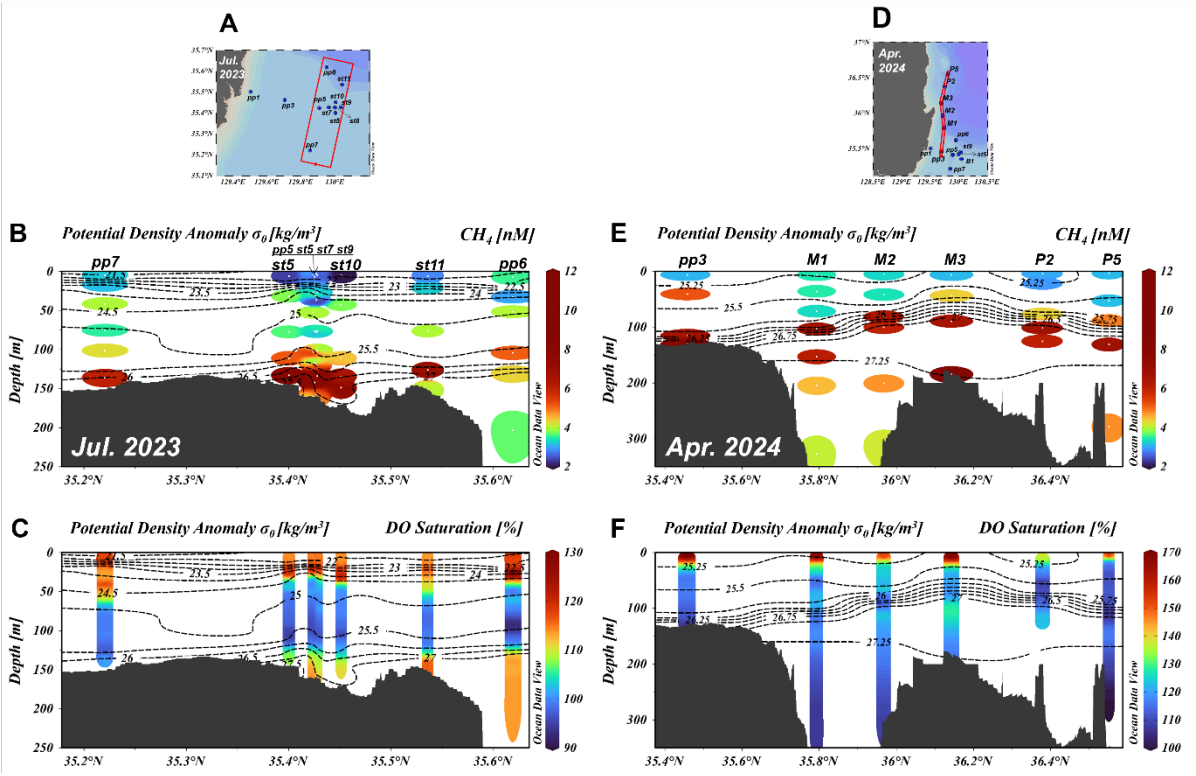


Figure S3. Vertical sections of dissolved methane (CH_4) concentration and dissolved oxygen (DO) saturation along the transects in the southwestern East (Japan) Sea. Panels (A, D) show maps indicating the section locations for July 2023 and April 2024, respectively. Panels (B, C) show the vertical sections of CH_4 concentration and DO saturation (%) for July 2023, while panels (E, F) present the corresponding vertical sections for April 2024. Black dashed contour lines represent potential density anomalies (σ_o, kg/m^3).

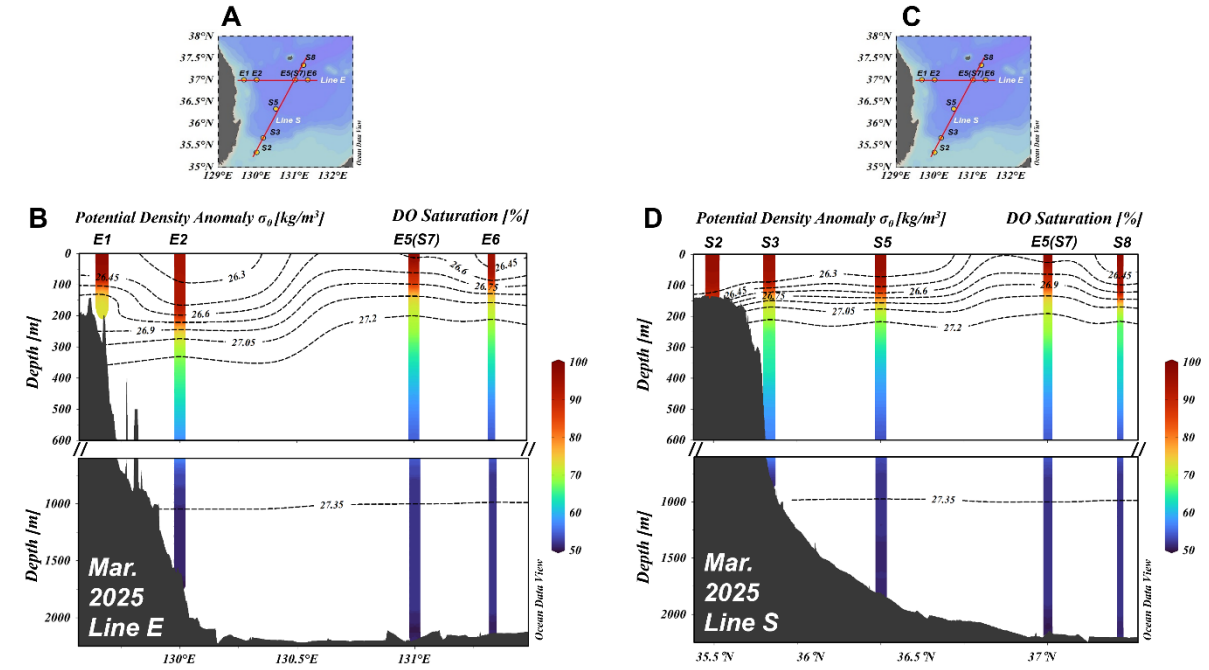


Figure S4. Vertical distributions of dissolved oxygen (DO) saturation along the transects in the Ulleung Basin during March 2025: (A, B) Line E and (C, D) Line S. Panels (A, C) show the sampling station locations along each transect, and panels (B, D) present the vertical sections of DO saturation (%). Black dashed contours indicate potential density anomalies (σ_o, kg/m^3). Note that the vertical axis is broken to separate upper (0–600 m) and deep (600–2,250 m) water columns.

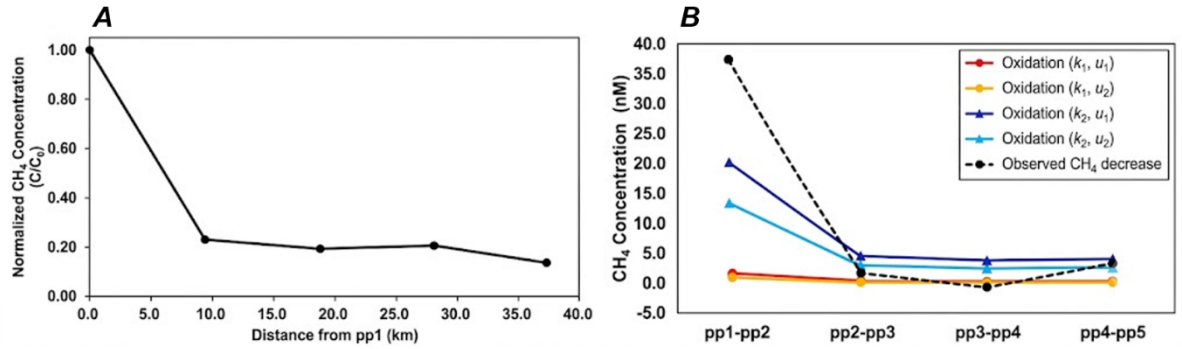


Figure S5. Changes in dissolved methane (CH_4) concentration along the coastal-to-offshore transect in the southwestern East (Japan) Sea during October 2025. (A) Normalized CH_4 concentration (C/C_0) as a function of distance from station pp1, where C_0 is the CH_4 concentration at pp1. (B) Station-to-station decreases in CH_4 concentration between adjacent stations (pp1–pp2, pp2–pp3, pp3–pp4, and pp4–pp5), comparing the observed decrease with that expected from aerobic methane oxidation alone, calculated using oxidation rate constants (k_1 = 0.01 day^{-1}; Steinle et al., 2017 and k_2 = 0.15 day^{-1}; Reeburgh, 2007) and horizontal current speeds (u_1 = 3 cm s^{-1} and u_2 = 5 cm s^{-1}; Park et al., 2016).

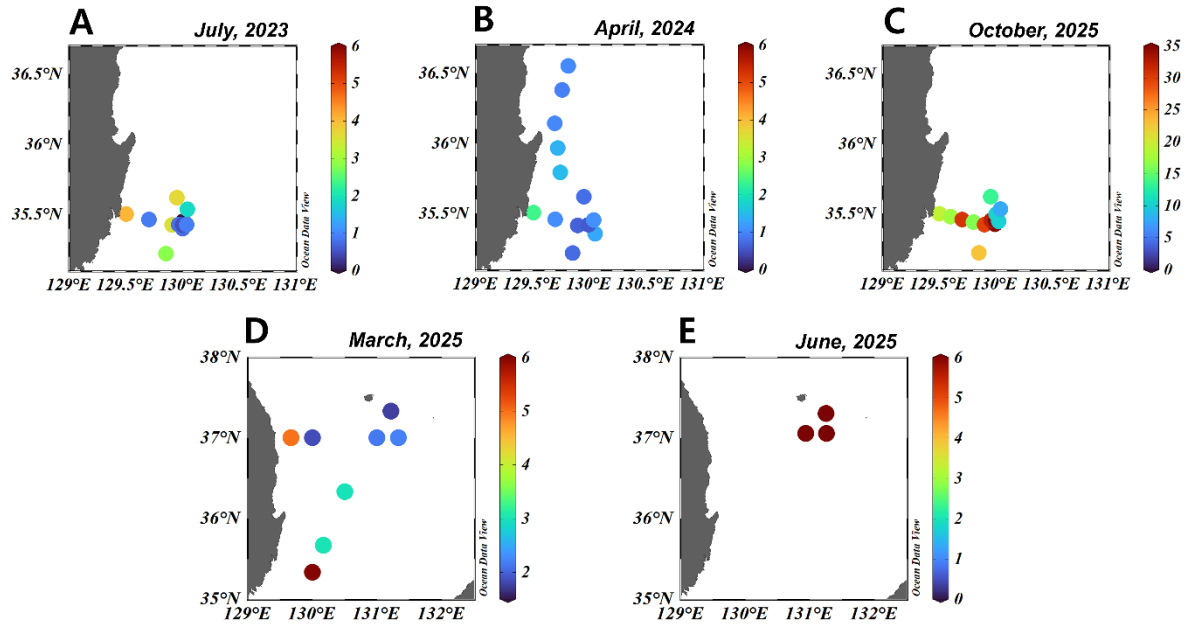


Figure S6. Sea-to-air methane (CH_4) fluxes (μmol $m^{-2}d^{-1}$) in the southwestern East (Japan) Sea and the Ulleung Basin. Panels (A–C) show fluxes in the southwestern East Sea in July 2023, April 2024, and October 2025, respectively. Panels (D–E) present fluxes in the Ulleung Basin in March 2025 and June 2025.

Table S1. Summary of station names, minimum distance from the coast, water depth, and measurements values of temperature, salinity, dissolved oxygen (DO), DO saturation, dissolved methane (CH_4) concentration, and CH_4 saturation in 2023.

Station	Distance to coast (km)	Depth (m)	Temperature (°C)	Salinity	DO (μmol kg^{-1})	DO Sat. ratio (%)	CH_4 (nM)	CH_4 Sat. ratio (%)
pp1	5.3	Surface	16.7	33.2	203.0	101	4.4 ± 0.3	175
pp1		30	12.8	34.3	183.49	92	3.5 ± 0.1	130
pp1		50	9.0	34.2	197.4	97	5.4 ± 0.0	181
pp1		71	6.2	34.2	214.5	103	11.4 ± 0.5	359
pp3	24.1	Surface	21.6	31.4	233.7	117	2.5 ± 0.2	110
pp3		20	17.2	33.6	239.0	121	3.0 ± 0.0	120
pp3		80	14.8	34.4	180.7	92	4.3 ± 0.2	166
pp3		100	8.0	34.2	213.0	104	6.3 ± 0.3	208
pp3		125	4.7	34.1	234.0	112	7.2 ± 1.0	220
pp5	48.0	Surface	22.9	32.3	224.4	115	3.4 ± 0.2	152
pp5		15	21.8	33.3	228.0	118	3.0 ± 0.0	133
pp5		25	18.1	34.1	233.4	120	3.3 ± 0.5	137
pp5		50	16.1	34.0	202.2	103	4.0 ± 0.3	157
pp5		100	13.3	34.4	191.7	96	5.8 ± 0.3	215
pp5		160	1.7	34.1	242.8	114	4.0 ± 0.2	112
pp6	42.6	Surface	22.2	32.2	230.4	117	3.5 ± 0.1	155
pp6		30	18.4	34.1	231.7	119	3.0 ± 0.1	123
pp6		50	16.3	34.0	194.1	99	4.0 ± 0.0	159
pp6		100	14.0	34.4	189.7	96	5.1 ± 0.4	194
pp6		130	4.7	34.2	235.1	112.5	4.3 ± 0.7	131
pp6		200	1.6	34.0	241.8	114	3.7 ± 0.1	103
pp7	55.4	Surface	22.5	31.8	231.5	117	3.2 ± 0.0	141
pp7		15	21.4	33.4	231.2	120	3.2 ± 0.1	136
pp7		40	18.9	34.0	230.2	119	4.0 ± 0.4	166
pp7		75	16.3	34.2	197.3	101	3.5 ± 0.2	139
pp7		100	16.0	34.2	195.3	99	4.3 ± 0.2	168
pp7		135	12.1	34.3	203.8	102	6.0 ± 0.1	218
st5	56.9	Surface	22.3	32.2	224.0	114	2.3 ± 0.0	103

st5		30	19.1	34.2	219.5	113	3.8 ± 0.1	160
st5		75	16.0	34.2	192.2	98	3.6 ± 0.0	143
st5		110	15.0	34.0	187.9	95	5.2 ± 0.3	200
st5		130	8.0	34.2	221.3	108	9.3 ± 0.3	307
st7	46.6	Surface	22.3	32.0	227.2	116	2.5 ± 0.2	108
st7		35	17.1	34.1	195.4	100	2.4 ± 0.3	95
st7		75	15.9	34.2	193.2	98	2.8 ± 0.3	110
st7		120	12.4	34.3	202.8	101	5.6 ± 0.2	203
st7		160	2.8	34.1	239.1	113	5.5 ± 0.0	163
st8	50.9	Surface	22.4	32.1	226.6	115	2.4 ± 0.1	107
st8		30	18.8	34.2	205.1	106	3.6 ± 0.2	151
st8		75	16.2	34.2	192.9	98	3.4 ± 0.1	136
st8		120	13.0	34.3	195.5	98	3.7 ± 0.1	137
st8		140	7.6	34.2	223.5	109	9.0 ± 0.4	292
st9	60.3	Surface	23.0	32.5	222.2	114	2.5 ± 0.0	109
st9		25	19.5	33.8	223.1	115	3.2 ± 0.3	133
st9		75	16.0	34.2	198.6	101	3.8 ± 0.3	150
st9		100	15.6	34.3	192.3	98	3.6± 0.0	139
st9		130	9.0	34.3	220.8	108	8.9 ± 0.2	299
st10	49.7	Surface	22.8	32.4	222.6	114	2.0 ± 0.5	89
st10		40	17.0	34.0	205.4	105	3.8 ± 0.5	153
st10		110	13.6	34.4	196.3	99	4.5 ± 0.0	167
st10		135	9.0	34.3	213.7	105	6.7 ± 0.2	227
st10		145	6.3	34.2	229.6	111	7.5 ± 0.9	236
st11	52.5	Surface	22.8	32.3	222.3	114	2.8 ± 0.0	125
st11		20	21.1	33.5	227.7	118	3.2 ± 0.2	140
st11		75	16.9	34.4	192.5	99	4.0 ± 0.3	160
st11		125	11.3	34.3	210.2	104	7.3 ± 0.7	259
st11		150	1.9	34.1	246.6	116	4.1 ± 0.5	114
st11		235	1.3	34.0	242.9	114	3.7 ± N/A	103

N/A: Not applicable due to single sample measurement.

Table S2. Summary of station names, minimum distance from the coast, water depth, and measurements values of temperature, salinity, dissolved oxygen (DO), DO saturation, dissolved methane (CH_4) concentration, and CH_4 saturation in April 2024.

Station	Distance to coast (km)	Depth (m)	Temperature (°C)	Salinity	DO ($\mu mol\ kg^{-1}$)	DO Sat. ratio (%)	CH_4 (nM)	CH_4 Sat. ratio (%)
pp1	5.3	Surface	16.6	34.3			3.7 ± 0.4	147
pp1		25	14.3	34.3	236.5	119	4.3 ± 0.1	163
pp1		60	11.0	34.3	216.4	107	4.4 ± 0.1	154
pp1		71	5.3	34.2	234.3	113	5.0 ± 0.2	155
pp3	24.1	Surface	16.8	34.5			2.9 ± 0.2	118
pp3		40	15.8	34.5	229.4	117	5.0 ± 0.2	197
pp3		115	14.4	34.5	220.9	112	6.4 ± 0.7	246
pp3		130	7.0	34.3	219.7	107	10.0 ± 0.9	323
pp5	48.0	Surface	17.0	34.5			2.7 ± 0.2	109
pp5		40	16.3	34.5	239.4	123	4.0 ± 0.3	160
pp5		120	13.8	34.4	228.2	115	6.4 ± 0.2	241
pp5		158	1.9	34.1	227.1	107	7.6 ± 0.7	213
pp6	42.6	Surface	16.8	34.5			2.8 ± 0.2	112
pp6		35	15.5	34.5	250.3	128	2.9 ± 0.1	112
pp6		150	1.9	34.1	257.9	121	8.9 ± 0.5	250
pp7	55.4	Surface	17.1	34.5			2.7 ± 0.2	111
pp7		30	17.0	34.5	247.9	127	2.9 ± 0.1	117
pp7		100	14.8	34.4	201.7	102	3.2 ± 0.0	125
pp7		137	12.8	34.4	227.1	114	3.8 ± 0.0	139
B1	62.4	Surface	17.1	34.5			3.1 ± 0.1	123
B1		35	16.1	34.5	251.4	129	2.8 ± 0.2	112
B1		120	14.4	34.5	236.8	120	4.7 ± 0.1	179
B1		130	11.0	34.4	228.9	114	9.1 ± 0.9	321
st5	56.9	Surface	17.0	34.5			2.7 ± 0.2	107
st5		25	17.0	34.5	252.5	130	2.7 ± 0.1	111
st5		80	15.4	34.5	227.6	116	3.0 ± 0.1	119
st5		151	8.7	34.3	226.5	111	10.3 ± 0.0	347
st9	60.3	Surface	17.1	34.5			2.9 ± 0.3	119

st9		35	16.4	34.5	242.2	124	3.1 ± 0.1	123
st9		80	15.5	34.5	237.8	121	3.0 ± 0.2	117
st9		149	7.1	34.3	230.4	112	9.4 ± 0.5	303
M1	21.7	Surface	16.3	34.4			3.2 ± 0.3	128
M1		35	15.5	34.4	251.3	128	3.3 ± 0.2	129
M1		70	14.5	34.3	240.6	122	3.2 ± 0.2	121
M1		100	12.3	34.4	243.1	122	6.7 ± 0.3	246
M1		150	2.0	34.1	249.9	118	6.0 ± 0.5	168
M1		200	0.9	34.1	240.1	112	4.3 ± 0.2	117
M1		327	0.9	34.0	228.7	107	3.9 ± 0.2	107
M2	15.1	Surface	16.7	34.5			3.1 ± 0.0	126
M2		40	16.3	34.5	243.7	125	3.2 ± 0.2	128
M2		80	11.3	34.4	231.8	115	6.3 ± 0.4	223
M2		100	3.7	34.1	247.6	118	5.8 ± 0.3	173
M2		200	1.1	34.0	247.2	116	4.5 ± 0.2	125
M2		313	0.9	34.0	229.9	108	4.0 ± 0.3	109
M3	26.9	Surface	16.0	34.4			3.0 ± 0.0	117
M3		40	13.7	34.3	240.2	121	4.2 ± 0.1	159
M3		90	3.1	34.1	266.3	126	6.4 ± 0.3	186
M3		185	1.4	34.0	247.0	116	14.2 ± 1.0	395
P2	31.5	Surface	16.8	34.5			2.9 ± 0.2	116
P2		20	16.4	34.5	242.1	124	2.8 ± 0.1	111
P2		75	13.6	34.4	219.5	111	4.1 ± 0.2	154
P2		100	4.1	34.1	248.5	118	6.6 ± 0.5	197
P2		125	1.8	34.0	260.8	123	5.8 ± 0.1	164
P5	33.0	Surface	16.4	34.5			3.0 ± 0.2	118
P5		50	15.2	34.5	217.6	111	3.0 ± 0.1	117
P5		90	14.5	34.5	217.9	110	4.7 ± 0.3	178
P5		130	2.2	34.1	241.7	144	6.5 ± 0.3	185
P5		278	0.9	34.0	206.3	97	4.6 ± 0.1	126

Table S3. Summary of station names, minimum distance from the coast, water depth, and measurements values of temperature, salinity, dissolved oxygen (DO), DO saturation, dissolved methane (CH_4) concentration, and CH_4 saturation in October 2025.

Station	Distance to coast (km)	Depth (m)	Temperature (°C)	Salinity	DO (μmol kg^{-1})	DO Sat. ratio (%)	CH_4 (nM)	CH_4 Sat. ratio (%)
pp1	5.3	Surface	24.1	32.7	206.5	97	3.4 ± 0.1	154
pp1		40	17.7	33.0	214.2	90	15.4 ± 1.1	624
pp1		60	6.0	34.1	211.6	70	48.7 ± 0.4	1527
pp1		71	4.6	34.1	225.7	72	28.2 ± 1.0	854
pp2	14.7	Surface	24.4	32.8	207.0	98	3.2 ± 0.1	149
pp2		40	23.2	32.8	188.7	87	4.6 ± 0.3	207
pp2		65	8.5	34.2	191.1	67	11.2 ± 0.5	374
pp2		118	2.9	34.0	235.4	72	6.5 ± 0.5	188
pp3	24.1	Surface	24.9	33.0	203.9	97	4.1 ± 0.2	188
pp3		40	20.4	32.7	141.2	62	6.4 ± 0.6	273
pp3		90	6.3	34.2	205.8	69	9.4 ± 0.3	296
pp3		128	3.4	34.1	233.0	72	6.4 ± 0.5	188
pp4	33.4	Surface	24.7	33.0	204.6	97	3.1 ± 0.0	144
pp4		40	24.7	33.2	204.8	97	4.3 ± 0.3	197
pp4		95	6.1	34.1	200.5	67	10.0 ± 0.4	313
pp4		137	3.2	34.1	234.9	73	6.7 ± 0.2	196
pp5	48.0	Surface	24.9	33.3	203.6	97	4.0 ± 0.1	185
pp5		40	24.7	33.5	199.0	95	3.1 ± 0.2	142
pp5		100	7.5	34.2	200.6	69	6.6 ± 0.2	214
pp5		169	2.0	34.0	244.3	73	3.9 ± 0.2	110
pp6	42.6	Surface	25.0	32.0	188.7	90	2.9 ± 0.1	135
pp6		35	22.8	33.7	183.7	85	5.1 ± 0.3	227
pp6		100	8.5	34.2	191.9	67	9.7 ± 0.7	323
pp6		160	1.9	34.0	256.7	77	4.5 ± 0.1	125
pp6		209	1.5	34.0	250.9	74	4.6 ± 0.3	129
pp7	55.4	Surface	25.2	33.4	205.3	99	3.5 ± 0.1	164
pp7		45	25.0	33.6	197.3	95	4.7 ± 0.2	220
pp7		83	16.3	34.5	150.8	62	6.1 ± 0.3	244

pp7		135	3.7	34.1	220.2	69	8.6 ± 0.2	255
st2	56.9	20	25.3	33.6	201.6	97	4.2 ± 0.2	197
st2		40	24.7	33.6	200.5	95	3.7 ± 0.1	172
st2		110	10.1	34.3	183.1	66	11.6 ± 0.5	402
st2		138	5.3	34.1	214.4	70	11.5 ± 1.4	355
st5	56.9	Surface	25.3	33.4	206.1	99	4.3 ± 0.6	199
st5		35	24.4	33.4	204.6	97	5.3 ± 0.3	244
st5		110	7.3	34.1	191.1	65	13.2 ± 0.9	427
st5		147	5.2	34.1	216.3	70	13.3 ± 0.3	411
st7	46.6	Surface	25.2	33.2	206.9	99	4.1 ± 0.2	192
st7		35	25.2	33.5	196.5	94	4.6 ± 0.1	216
st7		100	7.7	34.2	192.1	66	11.0 ± 0.2	359
st7		193	2.1	34.0	242.8	73	6.4 ± 0.1	180
st8	50.9	Surface	25.4	33.4	205.7	99	4.4 ± 0.1	207
st8		45	23.9	33.6	193.8	91	4.4 ± 0.0	200
st8		105	7.7	34.2	199.9	69	7.9 ± 0.1	257
st8		152	5.1	34.1	217.8	71	9.5 ± 0.8	290
st9	60.3	Surface	24.9	32.7			2.7 ± 0.2	125
st9		45	24.0	33.5	202.2	95	3.8 ± 0.2	173
st9		110	7.3	34.2	200.5	68	7.4 ± 0.1	239
st9		143	5.0	34.1	218.4	71	10.1 ± 0.5	308
st10	49.7	Surface	25.3	33.4	204.7	98	2.7 ± 0.0	125
st10		45	23.6	33.6	183.8	86	3.0 ± 0.2	136
st10		110	9.7	34.2	191.2	69	8.5 ± 0.6	293
st10		181	1.9	34.0	245.3	73	3.8 ± 0.1	106
st11	52.5	Surface	25.2	33.4	204.2	98	2.5 ± 0.1	118
st11		40	24.8	33.5	193.8	93	4.8 ± 0.3	222
st11		110	6.5	34.1	207.6	70	6.5 ± 0.3	208
st11		160	1.8	34.0	248.4	74	3.8 ± 0.2	106
st11		235	1.6	34.0	247.4	73	4.0 ± 0.1	113

Table S4. Summary of station names, water depth, and measured values of temperature, salinity, dissolved oxygen (DO), DO saturation, dissolved methane (CH_4) concentration, CH_4 saturation, and total bacterial abundance (TBA) in March 2025 (stations E1 to S8) and June 2025 (stations D1 to D3).

Station	Depth (m)	Temperature (°C)	Salinity	DO ($\mu mol\ kg^{-1}$)	DO Sat. ratio (%)	CH_4 (nM)	CH_4 Sat. ratio (%)	TBA (Gene copies $L^{-1} \times 10^7$)
E1	Surface	10.2	34.2	272.3	99	3.6 ± 0.1	124	7.8
E1	50	9.7	34.2	269.3	97	3.8 ± 0.1	131	6.9
E1	90	9.2	34.1	258.3	92	4.3 ± 0.1	146	4.0
E1	120	5.5	34.0	234.3	76	5.0 ± 0.2	156	6.9
E1	130	4.7	34.0	233.1	75	5.2 ± 0.1	158	8.1
E1	167	3.3	34.0	233.2	72	5.0 ± 0.2	146	7.7
E2	Surface	10.3	34.1	261.6	95	2.8 ± 0.3	97	2.3
E2	100	10.0	34.1	259.1	94	2.7 ± 0.1	93	6.6
E2	160	9.7	34.1	255.7	92	2.7 ± 0.1	94	5.8
E2	200	8.6	34.1	251.7	88	2.8 ± 0.2	95	6.3
E2	220	7.0	34.1	240.4	81	3.5 ± 0.1	114	4.4
E2	300	2.0	34.0	236.6	71	3.3 ± 0.1	93	2.0
E2	500	0.8	34.1	210.8	61	3.2 ± 0.2	87	1.5
E2	1000	0.3	34.1	179.4	52	2.1 ± 0.1	57	1.5
E2	1500	0.2	34.1	178.9	51	1.9 ± 0.1	50	1.8
E2	1700	0.2	34.1	175.9	50	1.9 ± 0.1	49	1.6
E5(S7)	Surface	8.4	34.1	280.2	98	2.9 ± 0.1	96	3.3
E5(S7)	30	8.2	34.1	278.4	97	2.9 ± 0.1	96	5.1
E5(S7)	100	5.2	34.0	270.7	88	3.5 ± 0.1	108	13.0
E5(S7)	200	1.7	34.0	239.0	71	3.3 ± 0.0	91	5.8
E5(S7)	300	1.1	34.0	225.1	66	2.8 ± 0.1	77	2.9
E5(S7)	400	0.8	34.1	210.1	61	3.0 ± 0.1	81	7.0
E5(S7)	500	0.7	34.1	198.2	58	2.6 ± 0.2	71	3.2
E5(S7)	700	0.5	34.1	184.0	53	2.5 ± 0.1	66	2.5
E5(S7)	1000	0.3	34.1	180.2	52	2.5 ± 0.2	66	1.6
E5(S7)	1500	0.2	34.1	180.4	52	2.3 ± 0.1	61	2.4
E5(S7)	2000	0.1	34.1	178.6	51	2.3 ± 0.1	62	1.8
E5(S7)	2150	0.1	34.1	176.9	51	2.1 ± 0.2	57	2.6

E6	Surface	9.3	34.1	270.7	96	3.6 ± 0.2	123	1.2
E6	80	9.0	34.1	266.0	94	3.9 ± 0.2	129	4.2
E6	140	4.0	34.0	238.0	75	4.6 ± 0.2	137	1.9
E6	200	1.7	34.0	239.0	71	4.1 ± 0.2	115	1.4
E6	300	1.1	34.0	224.9	66	3.8 ± 0.3	106	0.7
E6	400	0.8	34.1	210.0	62	3.2 ± 0.3	87	1.8
E6	500	0.6	34.1	196.4	57	3.1 ± 0.3	85	1.2
E6	750	0.4	34.1	181.4	52	2.6 ± 0.2	70	0.7
E6	1000	0.3	34.1	180.1	52	2.1 ± 0.0	57	0.3
E6	1500	0.2	34.1	180.2	52	2.0 ± 0.1	53	0.8
E6	2000	0.1	34.1	179.3	51	2.3 ± 0.2	61	0.6
E6	2130	0.1	34.1	178.6	51	2.2 ± 0.1	59	0.6
S2	Surface	12.1	34.4	253.1	96	3.7 ± 0.3	136	3.8
S2	50	12.1	34.4	253.2	96	4.0 ± 0.3	145	2.8
S2	100	12.1	34.4	250.2	95	3.9 ± 0.2	140	2.9
S2	110	12.0	34.4	249.0	94	4.0 ± 0.4	144	29.3
S2	130	11.1	34.4	236.8	88	6.0 ± 0.2	213	16.0
S3	Surface	11.9	34.4	253.3	96	3.2 ± 0.1	114	2.4
S3	100	11.5	34.4	248.6	93	3.1 ± 0.1	110	7.4
S3	120	8.7	34.2	230.9	81	4.3 ± 0.4	145	3.8
S3	180	1.9	34.0	240.9	72	3.0 ± 0.2	84	2.1
S3	500	0.7	34.1	204.0	59	3.2 ± 0.1	86	5.6
S3	820	0.4	34.1	178.0	51	3.0 ± 0.2	81	15.3
S5	Surface	12.1	34.5	254.2	96	2.8 ± 0.1	100	5.6
S5	70	10.6	34.3	254.0	93	3.4 ± 0.2	120	7.9
S5	150	5.3	34.0	237.2	77	4.2 ± 0.4	130	5.4
S5	200	1.9	34.0	233.3	70	3.5 ± 0.1	98	3.0
S5	300	1.1	34.0	219.1	64	4.2 ± 0.2	117	0.4
S5	400	0.8	34.1	204.9	60	6.6 ± 0.2	180	2.3
S5	500	0.6	34.1	196.6	57	2.5 ± 0.3	67	2.5
S5	1000	0.3	34.1	179.8	52	2.6 ± 0.2	69	1.9
S5	1500	0.2	34.1	179.6	51	2.2 ± 0.1	58	5.0
S5	1825	0.1	34.1	176.8	51	3.0 ± 0.1	80	7.6

S8	Surface	9.4	34.1	273.7	98	3.8 ± 0.1	130	4.1
S8	80	9.1	34.1	268.3	95	3.3 ± 0.3	111	1.1
S8	140	5.5	34.0	257.7	85	4.4 ± 0.1	134	3.1
S8	200	2.1	34.0	231.7	70	3.5 ± 0.1	97	1.3
S8	300	1.1	34.0	223.1	66	3.0 ± 0.2	81	0.8
S8	400	0.9	34.1	214.5	63	2.7 ± 0.2	74	0.9
S8	500	0.7	34.1	203.4	59	2.9 ± 0.2	78	1.2
S8	1000	0.3	34.1	179.9	52	2.4 ± 0.0	63	1.2
S8	1500	0.2	34.1	181.2	52	1.8 ± 0.1	49	0.6
S8	2000	0.1	34.1	180.4	52	2.1 ± 0.1	56	1.3
S8	2200	0.1	34.1	180.3	52	1.8 ± 0.1	47	2.9
D1	Surface	20.5	33.9			3.9 ± 0.2	167	27.9
D1	20	20.0	34.0			3.5 ± 0.3	150	47.6
D1	200	3.7	34.0			4.9 ± 0.3	146	89.1
D1	500	0.7	34.0			3.7 ± 0.4	100	8.6
D2	Surface	18.6	33.5			4.4 ± 0.2	184	9.1
D2	100	14.4	34.5			5.5 ± 0.3	210	50.8
D2	200	2.7	34.0			4.1 ± 0.2	117	30.1
D2	580	0.6	34.0			3.3 ± 0.2	90	38.7
D3	Surface	18.9	33.6			4.2 ± 0.3	176	8.3
D3	100	13.8	34.4			5.4 ± 0.2	204	46.3
D3	200	2.9	34.0			5.2 ± 0.3	151	27.8
D3	500	0.7	34.0			3.1 ± 0.2	86	16.5

Table S5. Comparisons of surface water methane (CH_4) concentrations, CH_4 saturation, and sea to air CH_4 fluxes for various oceanic regions.

Regions	Date	Surface CH_4 (nM)	CH_4 Sat. ratio (%)	CH_4 flux ($\mu mol\ m^{-2}\ d^{-1}$)	Refs.
East Sea (Southwestern region)	Jul. 2023	2.9 ± 0.7	125 ± 26	4.4 ± 4.4	This study
	Apr. 2024	3.0 ± 0.3	119 ± 10	0.8 ± 0.4	
	Oct. 2025	3.5 ± 0.6	161 ± 30	20.0 ± 9.9	
East Sea (Ulleung Basin)	Mar. 2025	3.3 ± 0.4	115 ± 15	1.3 ± 1.2	This study
	Jun. 2025	4.2 ± 0.2	176 ± 6	6.4 ± 0.4	
East Sea (Northwestern region)	Aug. 2010	2.7 ± 0.5	121 ± 25	0.7 ± 1.0	Vereshchagina et al. (2013)
East Sea (Major basins)	Sep., Oct. 2007	2.6–2.8	143 ± 22	2.6	Gamo et al. (2012)
Yellow Sea (Gunsan basin)	Dec. 2013–Oct. 2015	3.4 ± 0.7	163 ± 69	15.6 ± 5.5	Lee et al. (2018)
North Yellow Sea	Apr. 2007	6.4 ± 2.5	200 ± 77	6.9 ± 7.3	Yang et al. (2010)
	Aug. 2006	12.0 ± 5.7	515 ± 232	21.1 ± 16.4	
	Oct. 2007	5.7 ± 3.5	249 ± 152	14.6 ± 22.3	
	Jan. 2007	3.4 ± 0.6	109 ± 17	10.1 ± 16.1	
South China Sea	Aug., Sep. 2003 Jul. 2004 Jul. 2006 Jul. 2007	4.5 ± 3.6	230 ± 184	8.6 ± 6.4	Tseng et al. (2017)
East China Sea Coastal zone	May 2011	10.4 ± 7.7	480 ± 356	21.7 ± 28.0	Sun et al. (2018)
East China Sea Shelf zone	May 2011	5.2 ± 4.4	218 ± 179	13.4 ± 28.6	Sun et al. (2018)
Black Sea North-western Shelf	Jul.–Aug. 1995	13.1 ± 10.6	567	53.0	Amouroux et al. (2002)
Northern Gulf of Mexico	Jul. 2009	4.0	–	7.4	Hu et al. (2012)

Western Svalbard (offshore)	Jul. 2011 Jul., Aug. 2012	–	–	20 (8–45)	Graves et al. (2015)
Open Arctic Ocean North of Alaska	Jan., Nov. 2009 Mar., Apr. 2010	–	–	125 (30–500)	Kort et al. (2012)
East Siberian Arctic Sea	Sep. 2003–2008 Apr. 2007	–	–	230 (190–300)	Shakhova et al. (2010)
Western North Pacific	May–Jun. 2021	2.4 ± 0.3	108 ± 5	0.6 ± 0.9	Wang et al. (2024)
North Pacific Subtropical Gyre	2008−2014 2015–2016	2.3 ± 0.2 2.0 ± 0.1	120 ± 12 99 ± 6	1.5 ± 1.2 −0.2 ± 0.5	Wilson et al. (2017)
Northeastern Subarctic Pacific Open ocean	Feb. 2015 Jun. 2015 Aug. 2015 Feb. 2016 Jun. 2016 Aug. 2016	–	–	−0.7 ± 1.2 1.3 ± 1.7 −0.4 ± 0.5 1.0 ± 1.4 0.4 ± 0.5 1.4 ± 0.8	Fenwick and Tortell (2018)
South Pacific	Dec. 2001 Jan. 2002 Feb. 2002	> 2.0[a]	–	3.4 ± 0.6 2.7 ± 0.8 2.9 ± 1.1	Yoshida et al. (2011)
North Atlantic	Jan.–Mar. 2020	3.0–10.0	110–370	1.9	Kolomijeca et al. (2022)
North Atlantic Subtropical Gyre	Apr.-May 2003 Sep.–Oct. 2003	3.7 ± 0.9[b] 2.2 ± 0.2[b]	185 ± 50[b] 120 ± 11[b]	1.9–3.7 1.2–2.3	Forster et al. (2009)
South Atlantic gyre	Apr.–May 2003 Sep.–Oct. 2003	3.0 ± 0.5[b] 7.4 ± 1.0[b]	162 ± 31[b] 141 ± 19[b]	3.6–5.9 3.3–5.7	Foster et al. (2009)

[a] Converted from the original unit (nmol kg^{-1}) assuming a seawater density of 1.025 kg L^{-1}.

[b] Value represents the average within the mixed layer depth.

–: Data not reported.

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