

Supplementary Information

Article title:

Long-term changes in water quality in the Seto Inland Sea, Japan: 53-year observations (1973–2025)

Journal name:

Journal of Oceanography

Author names:

Goh Onitsuka^{1,*} • Satoshi Akiyama² • Shota Higo³ • Toyoho Goshō⁴ • Genki Inui⁵ • Masayuki Kagawa⁶ • Toshiteru Watanabe⁷ • Masahiro Kayano⁷ • Youko Ishikawa⁸ • Makoto Yoshida⁹ • Hirotaka Kiyasu¹⁰ • Hiroki Maki¹⁰ • Osamu Ezaki¹¹ • Masato Okada¹² • Ayaka Mouri¹³

Affiliation and e-mail address of the corresponding author:

¹Hatsukaichi Field Station, Fisheries Technology Institute, Japan Fisheries Research and Education Agency, Hatsukaichi, Hiroshima 739-0452, Japan

²Marine Fisheries Research Center, Research Institute of Environment, Agriculture and Fisheries, Osaka Prefecture, Misaki, Osaka 599-0311, Japan

³Fisheries Technology Institute, Hyogo Prefectural Technology Center for Agriculture, Forestry and Fisheries, Akashi, Hyogo 674-0093, Japan

⁴Fisheries Experimental Station Wakayama Research Center of Agriculture, Forestry and Fisheries, Kushimoto, Wakayama 649-3503, Japan

⁵Research Institute for Fisheries Science, Okayama Prefectural Technology Centre for Agriculture, Forestry, and Fisheries, Setouchi, Okayama 701-4303, Japan

⁶Fisheries and Marine Technology Center, Hiroshima Prefectural Technology Research Institute,

Kure, Hiroshima 737-1207, Japan

⁷Yamaguchi Prefectural Fisheries Research Center, Yamaguchi, Yamaguchi 754-0893, Japan

⁸Fisheries Research Division, Tokushima Agriculture, Forestry, and Fisheries Technology Support Center, Kaifu, Tokushima 779-2304, Japan

⁹Kagawa Prefectural Fisheries Experimental Station, Takamatsu, Kagawa 761-0111, Japan

¹⁰Fisheries Research Center, Research Institute of Cultivation Resources, Ehime Research Institute of Agriculture, Forestry and Fisheries, Iyo, Ehime 799-3125, Japan

¹¹Buzenkai Laboratory, Fukuoka Fisheries and Marine Technology Research Center, Buzen, Fukuoka 828-0022, Japan

¹²Northern Fisheries Group, Fisheries Research Division, Oita Prefectural Agriculture, Forestry and Fisheries Research Center, Bungotakada, Oita 879-0608, Japan

¹³Fisheries Research Division, Oita Prefectural Agriculture, Forestry and Fisheries Research Center, Saiki, Oita 879-2602, Japan

*Corresponding author: onitsuka_go81@fra.go.jp

Table S1 Instruments and analytical methodologies for each parameter.

	Parameter	Salinity	Transparency	DO	DIN	DIP
	Water temperature					
	1971-1977: Bathythermograph (Wilder & Trama, Inc.) 1978-1982: CTD (InterOcean Systems, Inc.) 1983: Pooled Reversing Thermometer 1984-1999: CTD (OKSB, Neel Brown Instrument Systems, Inc.) 2000-2025: CTD (Salomus Scientific, Inc.)	1973-2006: Salinometer 2006-2025: CTD (Taimon Scientific, Inc.)	Secchi disk	Winkler titration method	1973-1976: Manual analysis 1977-1993: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1994-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2025: Autoanalyzer (swAA, BL TEC K.K.)	1973-1976: Manual analysis 1977-1993: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1994-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2025: Autoanalyzer (swAA, BL TEC K.K.)
	1973-1980s: Reversing Thermometer 1980s-2016: CTD (AST-1000 ec., Aise Electronics Co., Ltd., Model unknown, Falmoud Scientific, Inc.) 2016-2025: CTD (SBE-phius, Sea-Bird Scientific)	1973-1980s: Salinometer 1980s-2016: CTD (AST-1000 ec., Aise Electronics Co., Ltd., Model unknown, Falmoud Scientific, Inc.) 2016-2025: CTD (SBE-phius, Sea-Bird Scientific)	Secchi disk	Winkler titration method	1991-2010: Manual analysis 2011-2017: Autoanalyzer (swAA, BL TEC K.K.) 2018-2025: Autoanalyzer (QuAAro, BL TEC K.K.)	1991-2010: Manual analysis 2011-2017: Autoanalyzer (swAA, BL TEC K.K.) 2018-2025: Autoanalyzer (QuAAro, BL TEC K.K.)
	1973-1991: Stem thermometer* *Surface layer until 2025 1991-1998: CTD (AST-1000M, Aise Electronics Co., Ltd.) 1998-2011: CTD (ALC215-DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1991: Salinometer* *Surface layer until 2025 1991-1998: CTD (AST-1000M, Aise Electronics Co., Ltd.) 1998-2011: CTD (ALC215-DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-2010: Winkler titration method 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1976-1991: Manual analysis 1992-1999: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 2001-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2025: Autoanalyzer (swAA, BL TEC K.K.)	1973-1976: Manual analysis 1977-1993: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1999-2001: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2001-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2025: Autoanalyzer (swAA, BL TEC K.K.)
	1973-1994: Thermistor thermometer 1994-2002: CTD (AST-1000S or AST230, Aise Electronics Co., Ltd.) 2002-2011: CTD (AC1215-9DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1994: Salinometer 1994-2002: CTD (AST-1000S or AST230, Aise Electronics Co., Ltd.) 2002-2011: CTD (AC1215-9DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-2011: Membrane electrode dissolved oxygen meter 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-2005: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 2005-2009: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2009-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1973-2005: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 2005-2009: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2009-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1988: Stem thermometer 1989-2005: CTD (AST-1000S, Aise Electronics Co., Ltd.) 2005-2011: CTD (AC1-180, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD687, Aise Electronics Co., Ltd.) 2012-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1988: Salinometer (DIGI-AUTO, Taimon Seiki Co., Ltd.) 1989-2005: CTD (AST-1000S, Aise Electronics Co., Ltd.) 2005-2011: CTD (AC1-180, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD687, Aise Electronics Co., Ltd.) 2012-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-2011: Winkler titration method 2012-2025: CTD (ASTD102, JFE Advantech Co., Ltd.) combined by Winkler titration	1974-1992: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2010: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2011-2025: Autoanalyzer (QuAAro, BL TEC K.K.)	1974-1992: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2010: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2011-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1987: Thermistor thermometer 1988-2002: CTD (AST1000M, AS000M, Aise Electronics Co., Ltd.) 2003-2010: CTD (AC1208-DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1987: Salinometer (DIGI-AUTO, Taimon Seiki Co., Ltd.) 1988-2002: CTD (AST1000M, AS000M, Aise Electronics Co., Ltd.) 2003-2010: CTD (AC1208-DK, Aise Electronics Co., Ltd.) 2011-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-2021: Winkler titration method 2022-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1982-1993: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2007-2017: Autoanalyzer (swAA, BL TEC K.K.) 2018-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1982-1993: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2007-2017: Autoanalyzer (swAA, BL TEC K.K.) 2018-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1982: Reversing Thermometer 1983-1990: Mechanical Bathythermograph 1991-2019: CTD (AST-1000M, Aise Electronics Co., Ltd.) 2019-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1982: Salinometer 1991-2019: CTD (AST-1000M, Aise Electronics Co., Ltd.) 2019-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	Winkler titration method	1973-1980: Manual analysis 1980-1991: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1991-2002: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2021-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1973-1980: Manual analysis 1980-1991: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1991-2002: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2021-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1982: Reversing Thermometer 1983-1991: Stem thermometer (Digital Water Thermometer) 1992-2016: CTD (AC1215-DK, Aise Electronics Co., Ltd.) 2016-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1991: Salinometer 1992-1998: CTD (AST250-PK, AC1208-DK, Aise Electronics Co., Ltd.) 1999-2016: CTD (AC1215-DK, Aise Electronics Co., Ltd.) 2016-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-1994: Winkler titration method 1995-2016: DFG-AUTO MODELS-6, Taimon Seiki Co., Ltd.) 2016-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1980: Manual analysis 1980-1991: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1991-2005: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1992-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2016-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1973-1991: Manual analysis 1992-2021: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2021-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1988: Stem thermometer* *Surface layer until 2025 1988-2014: CTD (AST500, Aise Electronics Co., Ltd.) 2014-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1988: Salinometer (MODELS-6, Taimon Seiki Co., Ltd.) * *Surface layer until 2025 (MODELS-6, DIGI-AUTO MODELS-6, Taimon Seiki Co., Ltd.) 1988-2014: CTD (AST500, Aise Electronics Co., Ltd.) 2014-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	Winkler titration method	1973-1978: Manual analysis 1979-1994: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1995-2015: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2015-2025: Autoanalyzer (QuAAro-HR, BL TEC K.K.)	1973-1978: Manual analysis 1979-1994: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1995-2015: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2015-2025: Autoanalyzer (QuAAro-HR, BL TEC K.K.)
	1973-1981: Stem thermometer 1982-1985: Electrical Thermometer (ET-5D, Toho Denso Co., Ltd.) 1985-1988: CTD (ADM-300, Aise Electronics Co., Ltd.) 1989-2003: CTD (AST-1000M, Aise Electronics Co., Ltd.) 2003-2025: CTD (ASTD102, JFE Advantech Co., Ltd.) 2015-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1975: Electrical Salinometer (Danki Kagaku Keshi Co., Ltd.) 1976-1981: Stem thermometer 1982-1985: Electrical Thermometer (ET-5D, Toho Denso Co., Ltd.) 1985-1988: CTD (ADM-300, Aise Electronics Co., Ltd.) 1989-2003: CTD (AST-1000M, Aise Electronics Co., Ltd.) 2003-2025: CTD (ASTD102, JFE Advantech Co., Ltd.) 2015-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	1973-1983: Dissolved oxygen meter (1.5N, Electronics Instrument Ltd.) 1984-1994: Dissolved oxygen meter (3N, YSI Inc.) 1995-2009: Dissolved oxygen meter (550A, YSI Inc.) 2010-2015: Dissolved oxygen meter (HQ304, Hach Company) 2015-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1982: Manual analysis 1983-1992: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2002: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2002-2025: Oursourcing	1973-1982: Manual analysis 1983-1992: Autoanalyzer (Technicon Autoanalyzer II, Technicon Corporation) 1993-2002: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2002-2025: Oursourcing
	1973-1988: Stem thermometer 1989-2005: CTD (Model and manufacturer unknown) 2006-2020: CTD (AST-687, Aise Electronics Co., Ltd.) 2021-2025: CTD (AAQ-175, JFE Advantech Co., Ltd.)	1973-1988: Salinometer 1989-2005: CTD (Model and manufacturer unknown) 2006-2020: CTD (ASTD-687, Aise Electronics Co., Ltd.) 2021-2025: CTD (AAQ-175, JFE Advantech Co., Ltd.)	Secchi disk	Winkler titration method	1973-2004: Manual analysis 2005-2020: Autoanalyzer (Model and manufacturer unknown, swAA, BL TEC K.K.) 2020-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1973-2004: Manual analysis 2005-2020: Autoanalyzer (Model and manufacturer unknown, swAA, BL TEC K.K.) 2020-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)
	1973-1988: Stem thermometer* *Surface layer until 2025 1989-1999: CTD (AST-1000 ec., Aise Electronics Co., Ltd.) 2000-2018: CTD (Model unknown, Sea-Bird Scientific, Aise Electronics Co., Ltd.) 2019-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	1973-1988: Salinometer* *Surface layer during 2015-2025 (DIGI-AUTO MODELS-6, Taimon Seiki Co., Ltd.) 1989-2005: CTD (AST-1000 ec., Aise Electronics Co., Ltd.) 2000-2018: CTD (Model unknown, Sea-Bird Scientific, Aise Electronics Co., Ltd.) 2019-2025: CTD (ASTD102, JFE Advantech Co., Ltd.)	Secchi disk	Winkler titration method	1973-1991: Manual analysis 1992-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2020: Autoanalyzer (swAA, BL TEC K.K.) 2020-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)	1973-1991: Manual analysis 1992-2006: Autoanalyzer (TRACS800, Bran+Luebbe GmbH) 2006-2020: Autoanalyzer (swAA, BL TEC K.K.) 2020-2025: Autoanalyzer (QuAAro39, BL TEC K.K.)

Table S2 Sen’s slope (change per 50 years) and change-point years for annual and seasonal values in the eight regions and the entire Seto Inland Sea. Numerical values indicate statistically significant results ($p < 0.05$) in Mann-Kendall and Pettitt tests. ”n.s.” = not significant ($p \geq 0.05$). Arrows located at the right of the change-point year indicate upward or downward shifts.

			IB	SN	AH	HB	BS	HN	OB	KC	SIS
Water temperature (Surface)	Sen’s slope ($^{\circ}\text{C } 50\text{-yr}^{-1}$)	Annual	1.02	1.22	1.30	1.15	1.41	1.48	1.24	1.11	1.25
		Winter	0.82	0.98	1.21	1.28	0.97	0.89	n.s.	0.82	0.93
		Spring	0.94	1.06	0.92	0.53	1.31	1.40	1.22	n.s.	0.99
		Summer	1.04	n.s.	1.32	1.04	1.30	1.51	1.35	1.06	1.13
		Autumn	1.13	1.45	1.73	1.98	1.93	1.61	1.36	1.43	1.57
	Change point (year)	Annual	1993↑	1997↑	1997↑	1997↑	1997↑	1997↑	1996↑	1993↑	1996↑
		Winter	1986↑	1987↑	1987↑	1988↑	1986↑	n.s.	n.s.	1988↑	1987↑
		Spring	1996↑	1996↑	1996↑	n.s.	1996↑	1996↑	1993↑	1993↑	1996↑
		Summer	1993↑	n.s.	1997↑	n.s.	1997↑	1997↑	1993↑	1993↑	1993↑
		Autumn	1993↑	1997↑	1997↑	1997↑	1997↑	1997↑	1997↑	1997↑	1997↑
Water temperature (Bottom)	Sen’s slope ($^{\circ}\text{C } 50\text{-yr}^{-1}$)	Annual	0.71	0.97	0.85	1.15	1.35	1.10	1.12	0.70	1.03
		Winter	0.98	1.04	1.10	1.20	1.06	0.86	0.99	0.83	0.96
		Spring	0.72	1.03	0.80	1.06	1.23	1.03	1.10	0.95	1.00
		Summer	n.s.	n.s.	n.s.	0.93	1.04	0.70	n.s.	n.s.	n.s.
		Autumn	1.17	1.40	1.52	1.70	1.89	1.65	1.48	1.26	1.46
	Change point (year)	Annual	1996↑	1996↑	1996↑	1997↑	1997↑	1997↑	1997↑	1991↑	1997↑
		Winter	1986↑	1987↑	1987↑	1987↑	1986↑	n.s.	n.s.	n.s.	1987↑
		Spring	1996↑	1996↑	1996↑	1996↑	1996↑	1997↑	2001↑	1993↑	1996↑
		Summer	n.s.	n.s.	n.s.	2015↑	1993↑	1996↑	n.s.	n.s.	1993↑
		Autumn	1997↑	1997↑	1997↑	1997↑	1997↑	1997↑	1997↑	1990↑	1997↑
Salinity (Surface)	Sen’s slope (50-yr^{-1})	Annual	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	−0.86	n.s.	n.s.
		Winter	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Summer	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	−1.91	n.s.	n.s.
		Autumn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Change point (year)	Annual	n.s.	n.s.	2009↓	n.s.	2011↓	n.s.	2008↓	n.s.	2009↓
		Winter	n.s.	n.s.	2011↓	2011↓	2011↓	n.s.	n.s.	n.s.	2011↓
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Summer	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	2005↓	n.s.	n.s.
		Autumn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Salinity (Bottom)	Sen’s slope (50-yr^{-1})	Annual	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Winter	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Summer	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Autumn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Change point (year)	Annual	2011↓	n.s.	2011↓	2011↓	2011↓	n.s.	n.s.	n.s.	n.s.
		Winter	n.s.	n.s.	n.s.	2011↓	n.s.	n.s.	n.s.	n.s.	n.s.
		Spring	2011↓	n.s.	n.s.	2011↓	n.s.	n.s.	n.s.	n.s.	n.s.
		Summer	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
		Autumn	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Transparency	Sen’s slope ($\text{m } 50\text{-yr}^{-1}$)	Annual	1.21	0.52	0.97	1.13	1.53	1.59	1.59	1.15	1.11
		Winter	n.s.	0.69	1.67	1.72	2.26	0.90	2.00	1.36	1.19
		Spring	2.18	n.s.	n.s.	n.s.	0.92	2.51	1.39	1.06	1.21
		Summer	n.s.	n.s.	0.47	n.s.	1.18	1.85	1.50	1.39	1.08
		Autumn	1.45	0.75	1.30	0.86	1.61	1.05	1.05	n.s.	0.88
	Change point (year)	Annual	1989↑	2015↑	1997↑	1987↑	2006↑	2006↑	1997↑	1994↑	1993↑
		Winter	n.s.	n.s.	1990↑	2004↑	2006↑	2008↑	2002↑	1994↑	2003↑
		Spring	1989↑	n.s.	n.s.	n.s.	1999↑	1994↑	1997↑	1994↑	1993↑
		Summer	n.s.	n.s.	n.s.	n.s.	2004↑	2011↑	1997↑	n.s.	1989↑
		Autumn	2002↑	2001↑	2000↑	n.s.	2006↑	2007↑	2006↑	n.s.	2006↑

Table S2 Continued

			IB	SN	AH	HB	BS	HN	OB	KC	SIS
DO (Bottom)	Sen's slope (mg L ⁻¹ 50-yr ⁻¹)	Annual	0.57	n.s.	n.s.	n.s.	-0.65	n.s.	0.47	n.s.	n.s.
		Winter	0.80	-0.48	n.s.	n.s.	-0.67	-0.46	0.38	n.s.	n.s.
		Spring	n.s.	n.s.	-0.35	n.s.	-0.35	n.s.	0.47	n.s.	n.s.
		Summer	0.53	n.s.	n.s.	n.s.	-0.66	n.s.	0.92	n.s.	n.s.
		Autumn	0.44	-0.28	n.s.	n.s.	-0.97	n.s.	n.s.	n.s.	-0.28
	Change point (year)	Annual	2000↑	n.s.	n.s.	2011↓	1996↓	n.s.	1998↑	n.s.	n.s.
		Winter	2001↑	1986↓	n.s.	n.s.	1986↓	n.s.	n.s.	n.s.	n.s.
		Spring	1999↑	n.s.	2008↓	2013↓	1987↓	1991↓	1998↑	n.s.	n.s.
		Summer	1990↑	n.s.	n.s.	1983↓	2011↓	n.s.	n.s.	n.s.	1987↓
		Autumn	2000↑	n.s.	n.s.	2011↓	1995↓	n.s.	n.s.	n.s.	1995↓
DIN (Surface)	Sen's slope (μM 50-yr ⁻¹)	Annual	-2.02	-2.23	n.s.	n.s.	-2.93	-5.42	-15.57	-1.84	-4.33
		Winter	-2.00	-2.28	n.s.	n.s.	-3.90	-6.95	-27.51	-3.04	-6.21
		Spring	-0.94	-2.06	n.s.	n.s.	-2.63	-4.38	-14.45	-1.46	-3.89
		Summer	-1.37	n.s.	n.s.	-1.16	-1.63	-1.88	-3.35	n.s.	-1.33
		Autumn	-2.02	-3.23	n.s.	n.s.	-4.33	-7.43	-16.05	n.s.	-5.09
	Change point (year)	Annual	2011↓	2001↓	n.s.	2005↓	2006↓	2001↓	2002↓	2002↓	2001↓
		Winter	2011↓	2001↓	n.s.	n.s.	2002↓	2001↓	2002↓	n.s.	2002↓
		Spring	2010↓	1998↓	n.s.	2006↓	1995↓	2000↓	2001↓	2001↓	2001↓
		Summer	2007↓	1983↓	n.s.	2004↓	n.s.	1997↓	1993↓	n.s.	1993↓
		Autumn	2013↓	2002↓	n.s.	n.s.	n.s.	2005↓	2003↓	n.s.	2002↓
DIN (Bottom)	Sen's slope (μM 50-yr ⁻¹)	Annual	n.s.	-1.81	-2.04	n.s.	-3.11	-4.97	-9.58	n.s.	-3.25
		Winter	-1.63	-2.05	-2.42	n.s.	-4.80	-6.05	-14.36	-2.44	-4.33
		Spring	n.s.	-1.32	-1.77	n.s.	-2.64	-3.37	-9.01	-1.89	-2.70
		Summer	n.s.	-1.15	n.s.	n.s.	-2.12	-4.38	-6.65	n.s.	-2.15
		Autumn	2.01	-2.85	-2.37	n.s.	-3.62	-6.45	-9.03	n.s.	-4.00
	Change point (year)	Annual	n.s.	1993↓	2006↓	n.s.	2006↓	2007↓	1998↓	n.s.	2001↓
		Winter	2011↓	2001↓	2002↓	n.s.	2001↓	2002↓	2001↓	n.s.	2001↓
		Spring	n.s.	1998↓	1991↓	2005↓	1995↓	2002↓	1998↓	n.s.	1998↓
		Summer	n.s.	1993↓	n.s.	n.s.	n.s.	1995↓	2009↓	n.s.	1993↓
		Autumn	n.s.	1987↓	1987↓	n.s.	n.s.	2007↓	2002↓	n.s.	2005↓
DIP (Surface)	Sen's slope (μM 50-yr ⁻¹)	Annual	n.s.	n.s.	n.s.	n.s.	n.s.	-0.09	-0.26	-0.10	n.s.
		Winter	n.s.	0.07	0.14	n.s.	-0.12	n.s.	-0.48	-0.13	n.s.
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	-0.08	n.s.
		Summer	n.s.	n.s.	n.s.	n.s.	0.19	n.s.	n.s.	-0.15	n.s.
		Autumn	0.12	n.s.	0.23	n.s.	0.29	-0.17	-0.44	n.s.	n.s.
	Change point (year)	Annual	n.s.	n.s.	2012↑	2012↑	n.s.	2008↓	1996↓	1982↓	1982↓
		Winter	n.s.	1994↑	n.s.	n.s.	2001↓	2001↓	2003↓	n.s.	n.s.
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	1981↓
		Summer	1980↓	n.s.	n.s.	n.s.	2010↑	n.s.	n.s.	1986↓	1982↓
		Autumn	2004↑	n.s.	1994↑	2013↑	1989↑	n.s.	2003↓	n.s.	n.s.
DIP (Bottom)	Sen's slope (μM 50-yr ⁻¹)	Annual	n.s.	n.s.	0.11	n.s.	0.14	n.s.	-0.36	-0.24	n.s.
		Winter	n.s.	0.06	n.s.	n.s.	-0.11	n.s.	-0.37	-0.24	-0.08
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	0.08	-0.11	-0.30	n.s.
		Summer	n.s.	n.s.	0.19	n.s.	0.32	n.s.	-0.60	-0.28	n.s.
		Autumn	0.40	n.s.	0.17	0.22	0.29	n.s.	-0.29	n.s.	n.s.
	Change point (year)	Annual	2004↑	2004↑	2012↑	2012↑	n.s.	n.s.	2002↓	2001↓	1980↓
		Winter	n.s.	n.s.	n.s.	n.s.	2001↓	2001↓	2001↓	n.s.	2001↓
		Spring	n.s.	n.s.	n.s.	n.s.	n.s.	1990↑	1986↓	1992↓	1980↓
		Summer	n.s.	n.s.	n.s.	2012↑	n.s.	2000↑	n.s.	1988↓	1981↓
		Autumn	n.s.	n.s.	1995↑	2010↑	1989↑	n.s.	2002↓	n.s.	n.s.

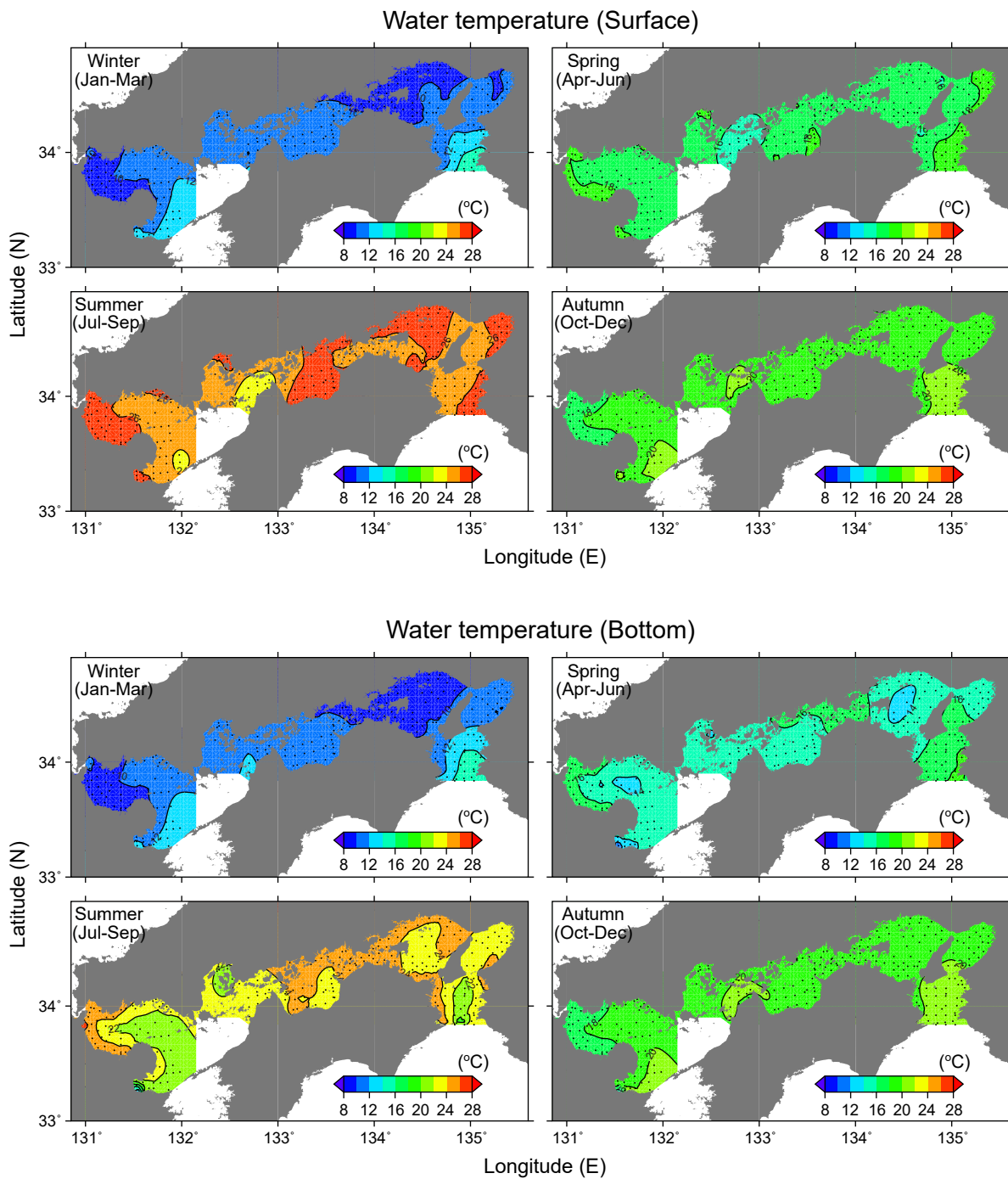


Fig. S1 Climatological mean (1991–2020) distributions of water temperature from winter to autumn in the surface and bottom layers.

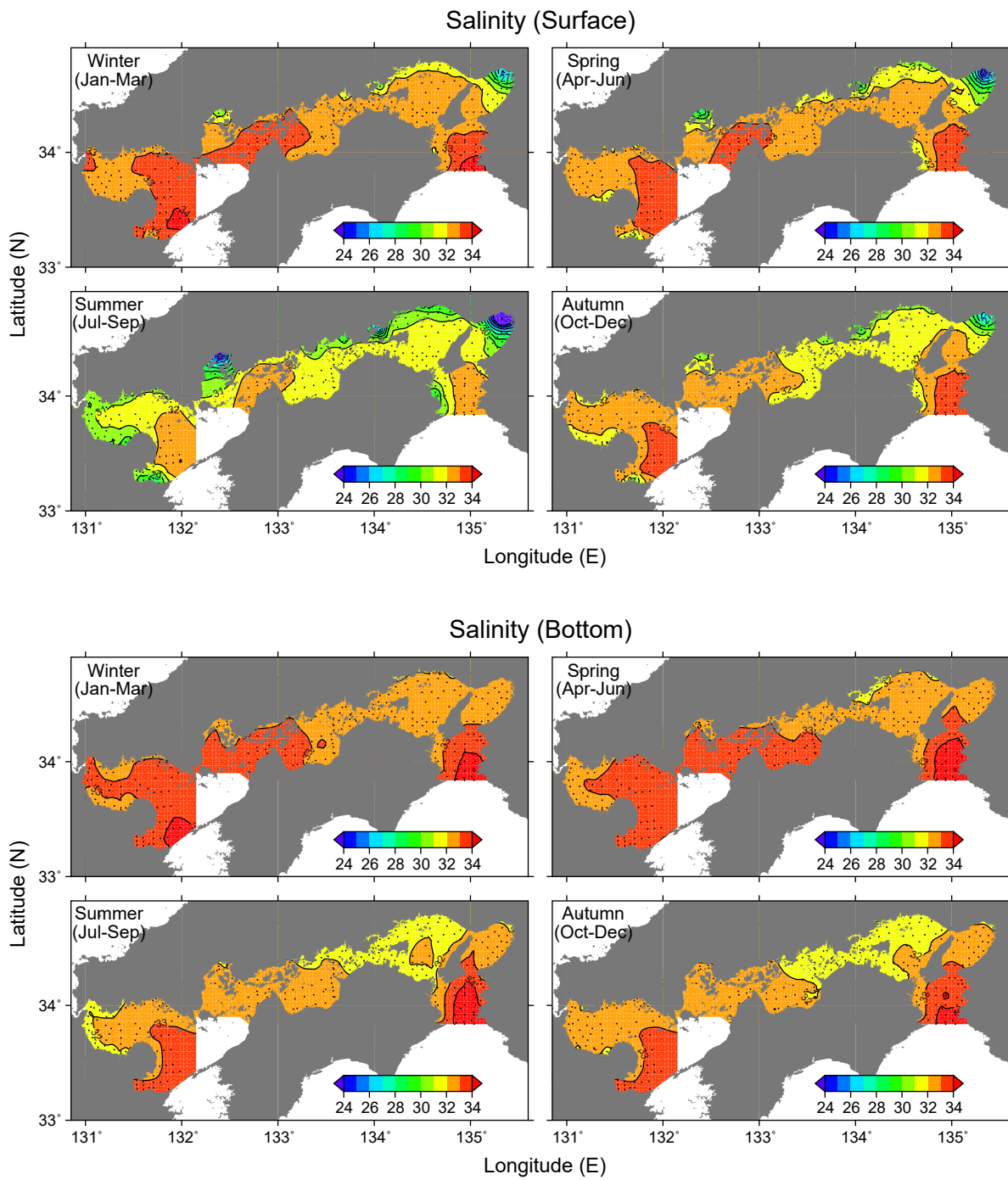


Fig. S2 Climatological mean (1991–2020) distributions of salinity from winter to autumn in the surface and bottom layers.

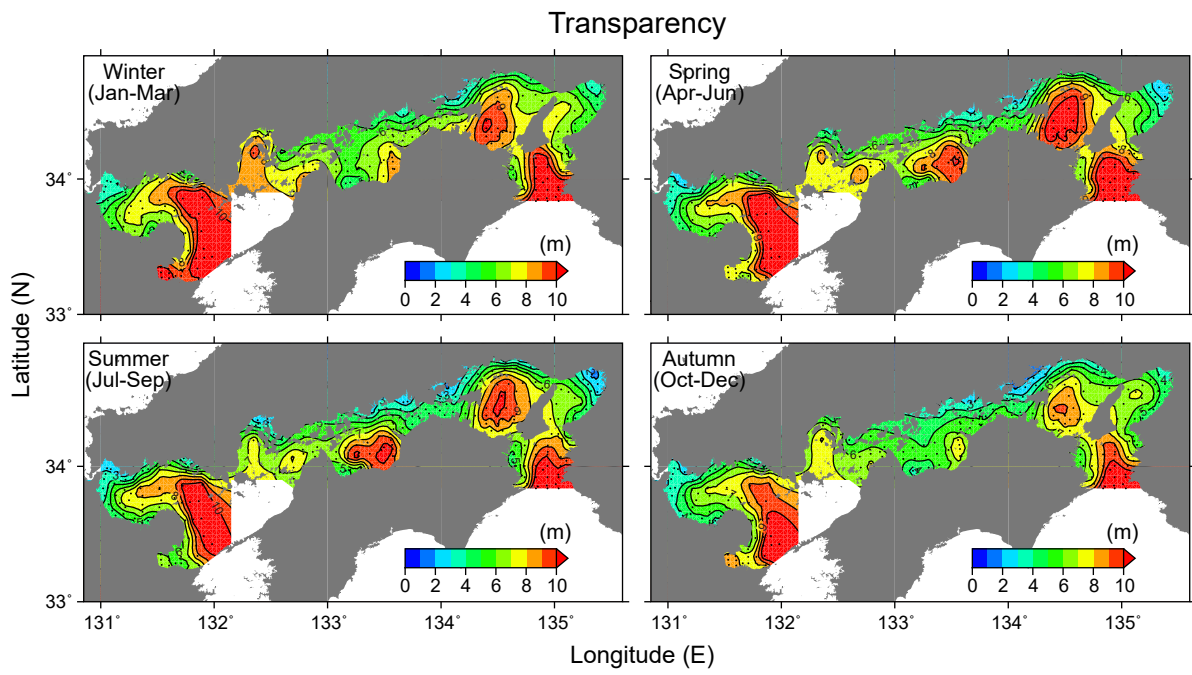


Fig. S3 Climatological mean (1991–2020) distributions of transparency from winter to autumn.

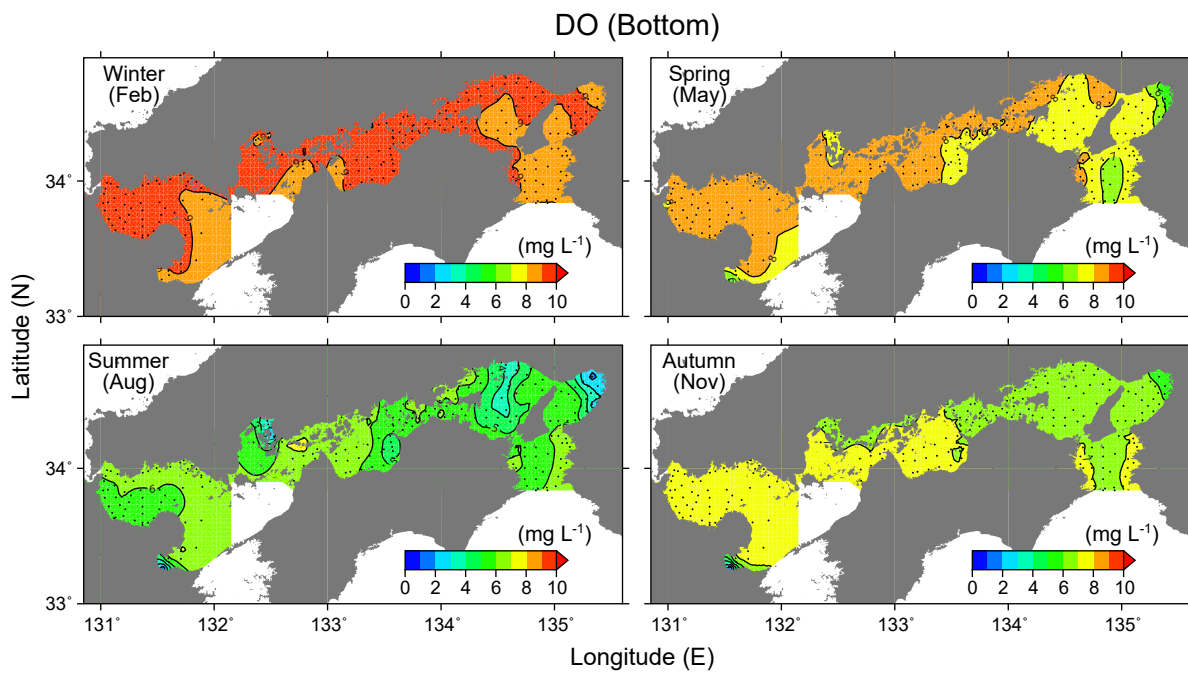


Fig. S4 Climatological mean (1991–2020) distributions of DO concentration in the bottom layer from winter to autumn.

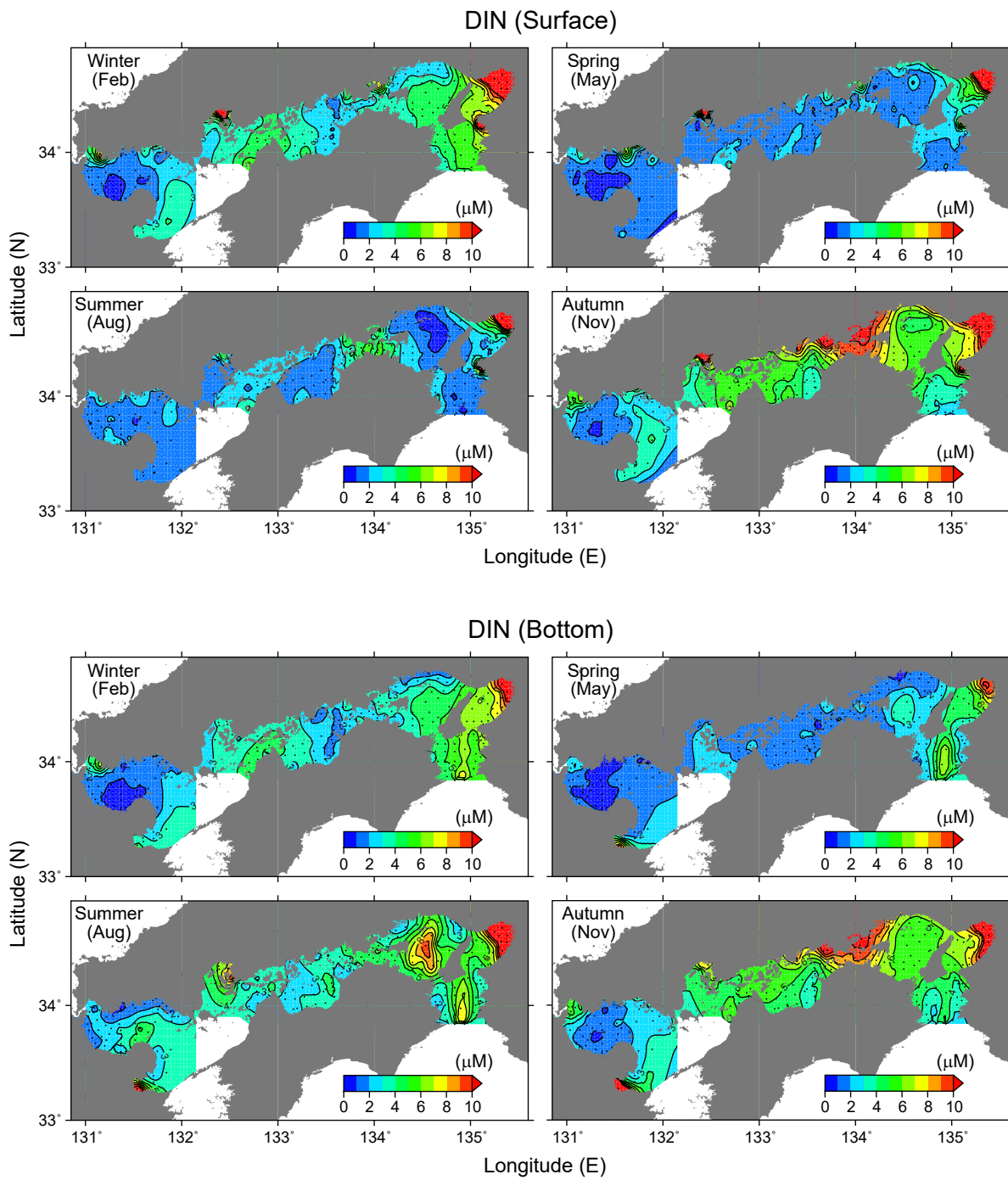


Fig. S5 Climatological mean (1991–2020) distributions of DIN concentration from winter to autumn in the surface and bottom layers.

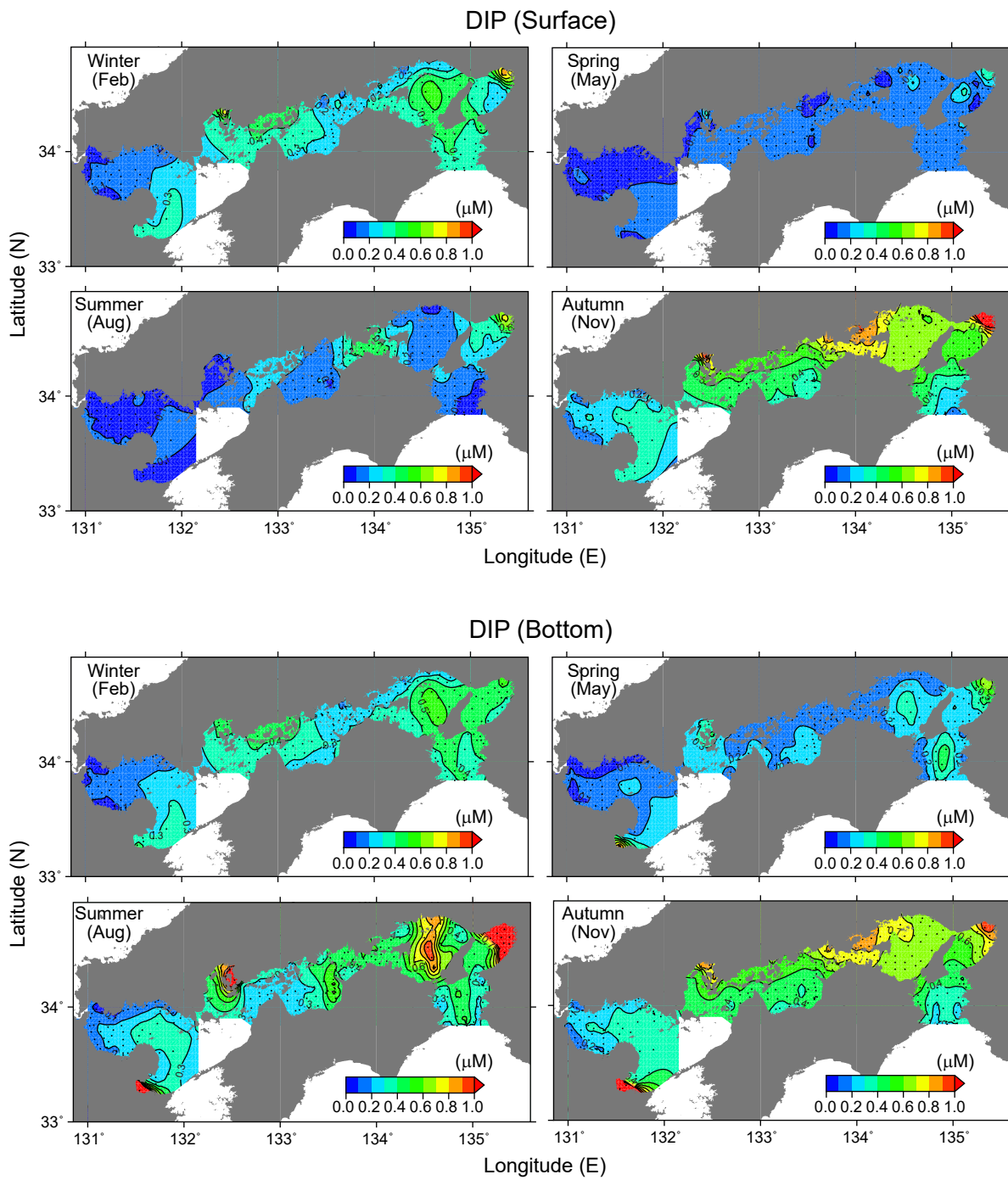


Fig. S6 Climatological mean (1991–2020) distributions of DIP concentration from winter to autumn in the surface and bottom layers.