

## *Supplementary Material*

### 1 Supplementary Tables

**Supplementary Table 1.** Initial pigment ratios used for the CHEMTAX software in this study (Lee et al. 2011). Perid, Peridinin; But, 19'-butanoyloxy-fucoxanthin; Fuco, Fucoxanthin; Hex, 19'-hexanoyloxy-fucoxanthin; Neo, Neoxanthin; Pras, Prasinoxanthin; Viola, Violaxanthin; Allo, Alloxanthin; Lut, Lutein; Zea, Zeaxanthin; Chl *b*, Chlorophyll *b*.

Taxa	Perid	But	Fuco	Hex	Neo	Pras	Viola	Allo	Lut	Zea	Chl <i>b</i>
Prasinophytes	0	0	0	0	0.3768	0.1413	0.2165	0	0.0843	0	0.2807
Dinophytes	0.7527	0	0	0	0	0	0	0	0	0	0
Cryptophytes	0	0	0	0	0	0	0	0.1927	0	0	0
Prymnesiophytes	0	0	0	1.7139	0	0	0	0	0	0	0
Pelagophytes	0	0.5076	0.8354	0.2225	0	0	0	0	0	0	0
Chlorophytes	0	0	0	0	0.0756	0	0.0457	0	0.2253	0.0063	0.4255
Cyanophytes	0	0	0	0	0	0	0	0	0	0.1418	0
Bacillariophyceae	0	0	0.5464	0	0	0	0	0	0	0	0

### Supplementary Reference

Lee, Y. -W., M. O. Park, Y. -S. Kim, S. -S. Kim, and C. K. Kang. 2011. Application of photosynthetic pigment analysis using a HPLC and CHEMTAX program to studies of phytoplankton community composition. *J. Korean Soc. Oceanogr.* **16**: 117–124. (in Korean with English abstract)

**Supplementary Table 2.** Summary of the results of Canonical Correspondence Analysis (CCA) for March (upper panel) and June (lower panel) 2016 and 2017.

	Axes 1	Axes 2	Axes 3	Axes 4	Total inertia
Eigenvalues	0.144	0.022	0.012	0.004	0.332
Species-environment correlations	0.875	0.808	0.537	0.410	
Cumulative percentage variance of species data	43.5	50.1	53.8	55.1	
Cumulative percentage variance of species-environmental relation	77.4	89.0	95.7	98.0	
Sum of all unconstrained eigenvalues					0.332
Sum of all canonical eigenvalues					0.187

	Canonical coefficients		Inter set correlations	
	Axes 1	Axes 2	Axes 1	Axes 2
Temperature	0.2795	-0.2748	0.3196	-0.3400
Salinity	0.2249	-0.2344	0.2572	-0.2901
Density	-0.3849	0.2594	-0.4401	0.3210
NO <sub>3</sub>	0.6665	0.0124	-0.3491	-0.1318
PO <sub>4</sub>	0.6413	0.0798	0.7333	0.0988
SiO <sub>2</sub>	0.7796	-0.0963	0.8914	-0.1191
N:P	0.2076	-0.1848	0.2374	-0.2287
Chl <i>a</i>	-0.5574	-0.2781	-0.6373	-0.3442

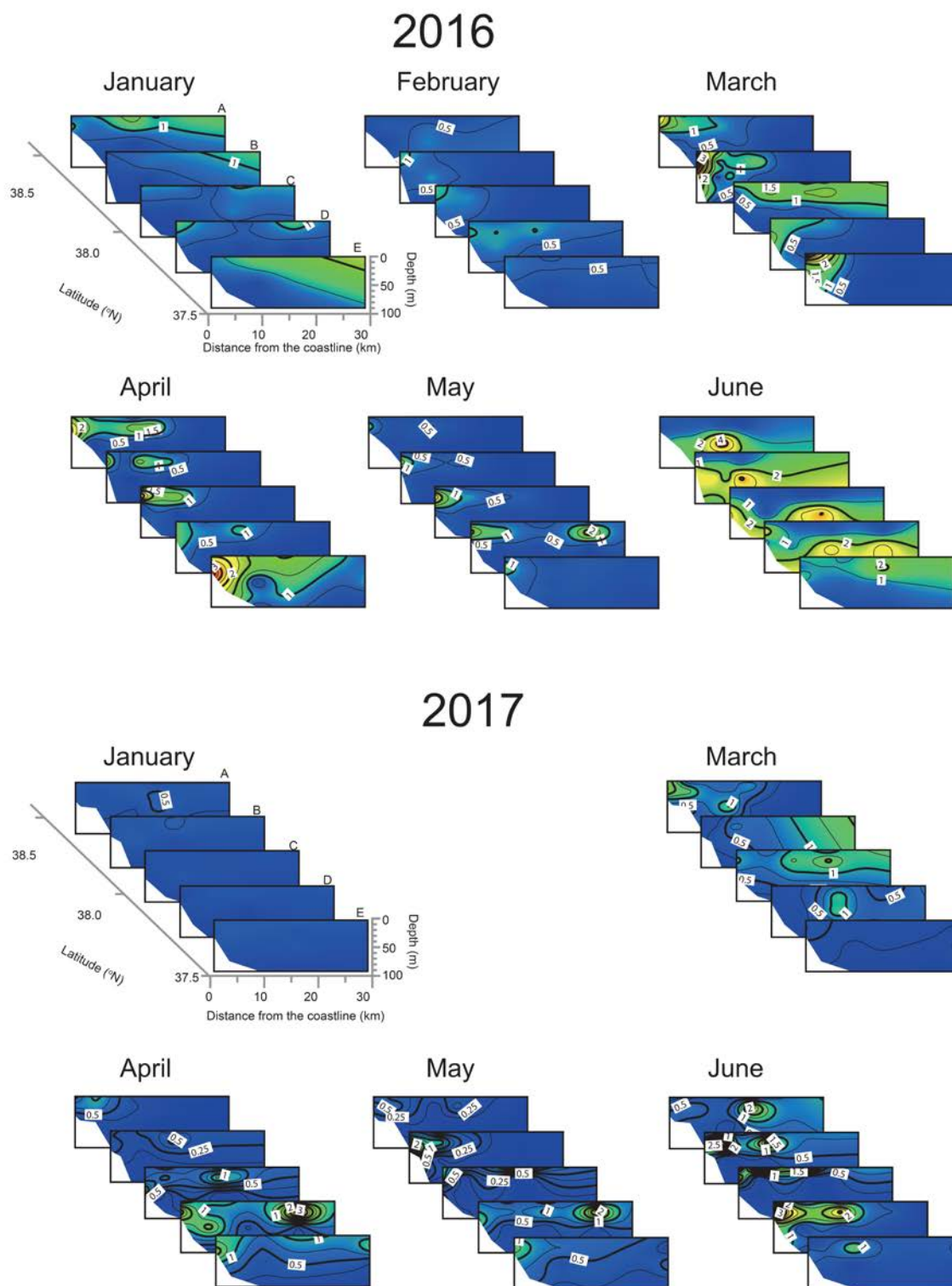
  

	Axes 1	Axes 2	Axes 3	Axes 4	Total inertia
Eigenvalues	0.062	0.038	0.026	0.009	0.626
Species-environment correlations	0.682	0.486	0.540	0.319	
Cumulative percentage variance of species data	9.9	16.1	20.2	21.6	
Cumulative percentage variance of species-environmental relation	43.2	69.8	87.7	93.1	
Sum of all unconstrained eigenvalues					0.626
Sum of all canonical eigenvalues					0.144

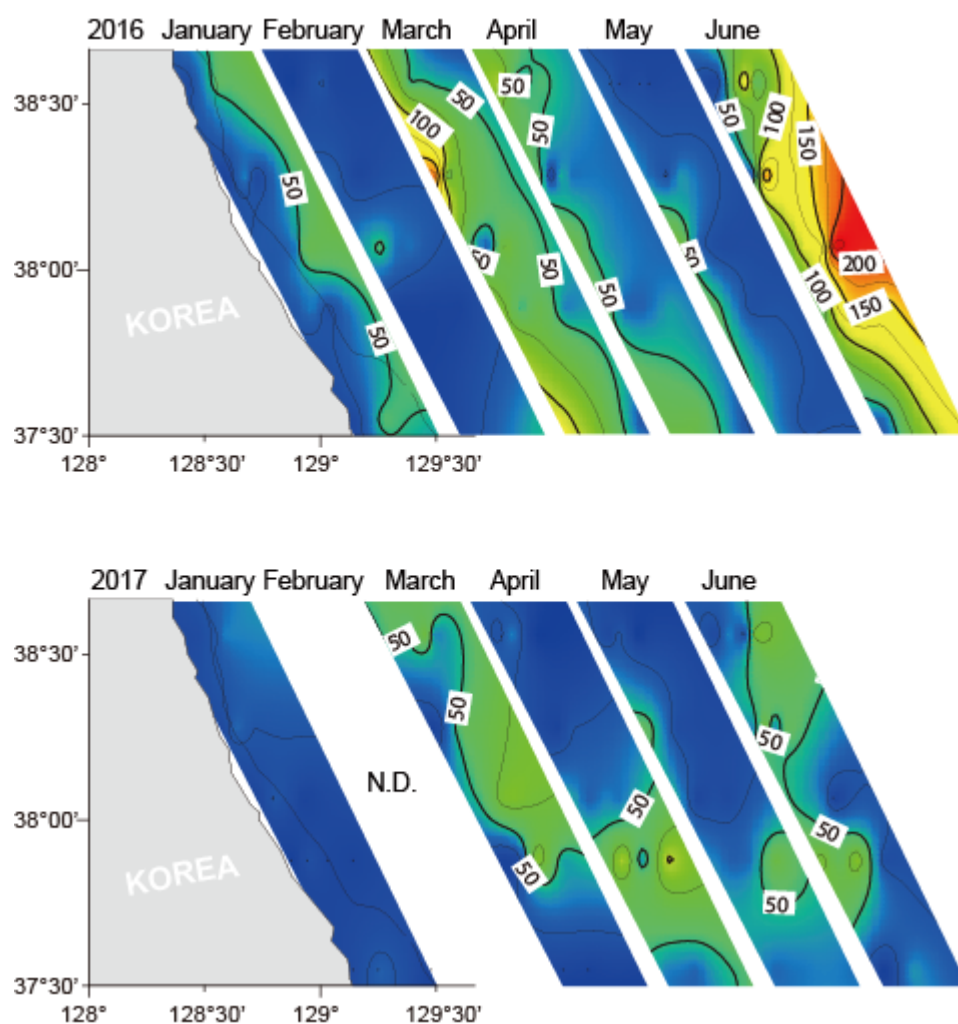
  

	Canonical coefficients		Inter set correlations	
	Axes 1	Axes 2	Axes 1	Axes 2
Temperature	0.1572	0.1806	0.2304	0.3719
Salinity	-0.0846	-0.0829	-0.1240	0.1708
Density	-0.1749	-0.1498	-0.2563	-0.3085
NO <sub>3</sub>	-0.2418	0.0254	-0.3544	0.0523
PO <sub>4</sub>	-0.3919	-0.0266	-0.5744	-0.0548
SiO <sub>2</sub>	-0.2410	-0.1543	-0.3533	-0.3176
N:P	-0.1727	0.1891	-0.2531	0.3893
Chl <i>a</i>	-0.2917	-0.3123	-0.4276	-0.6430

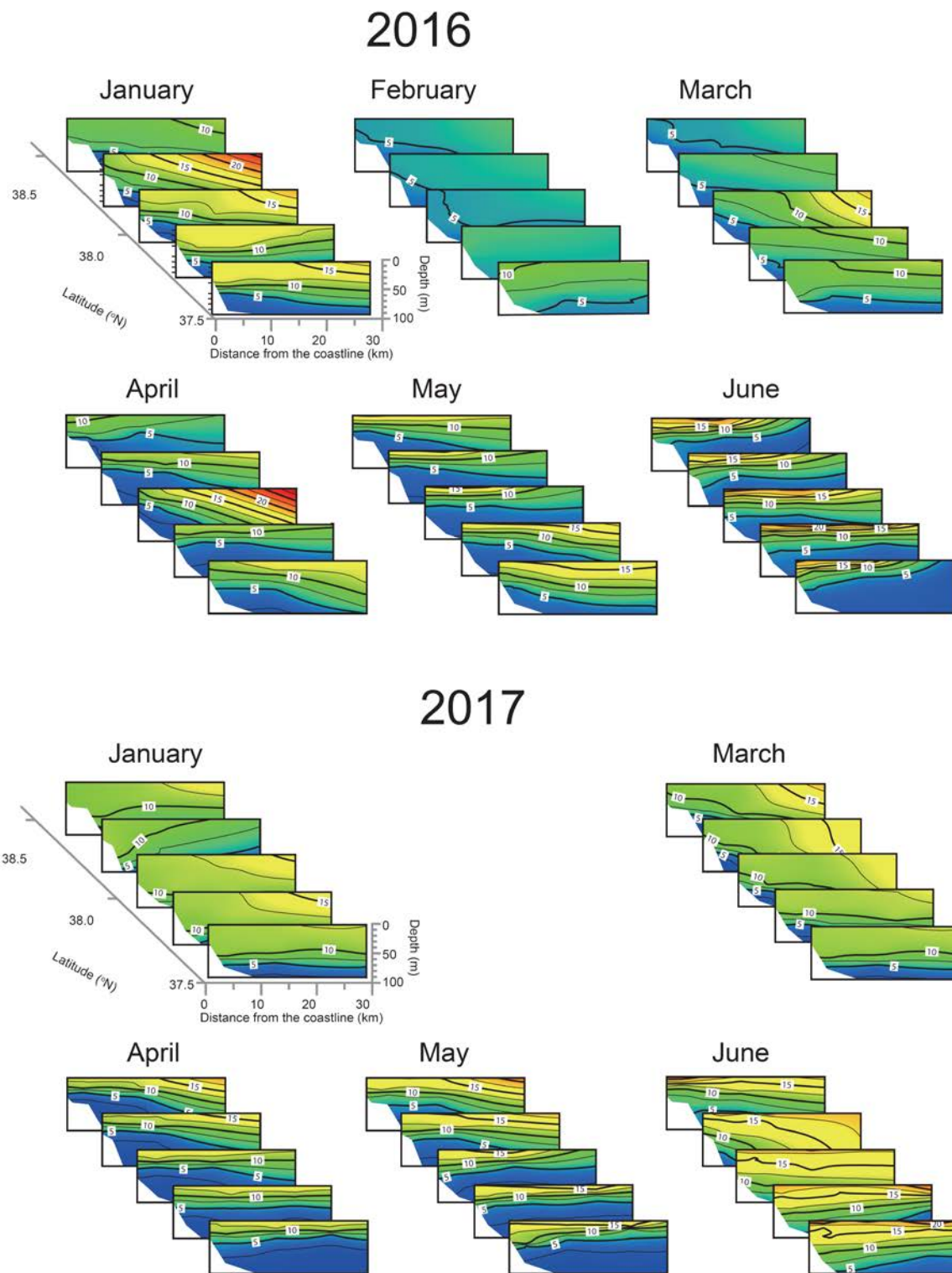
## 2 Supplementary Figures



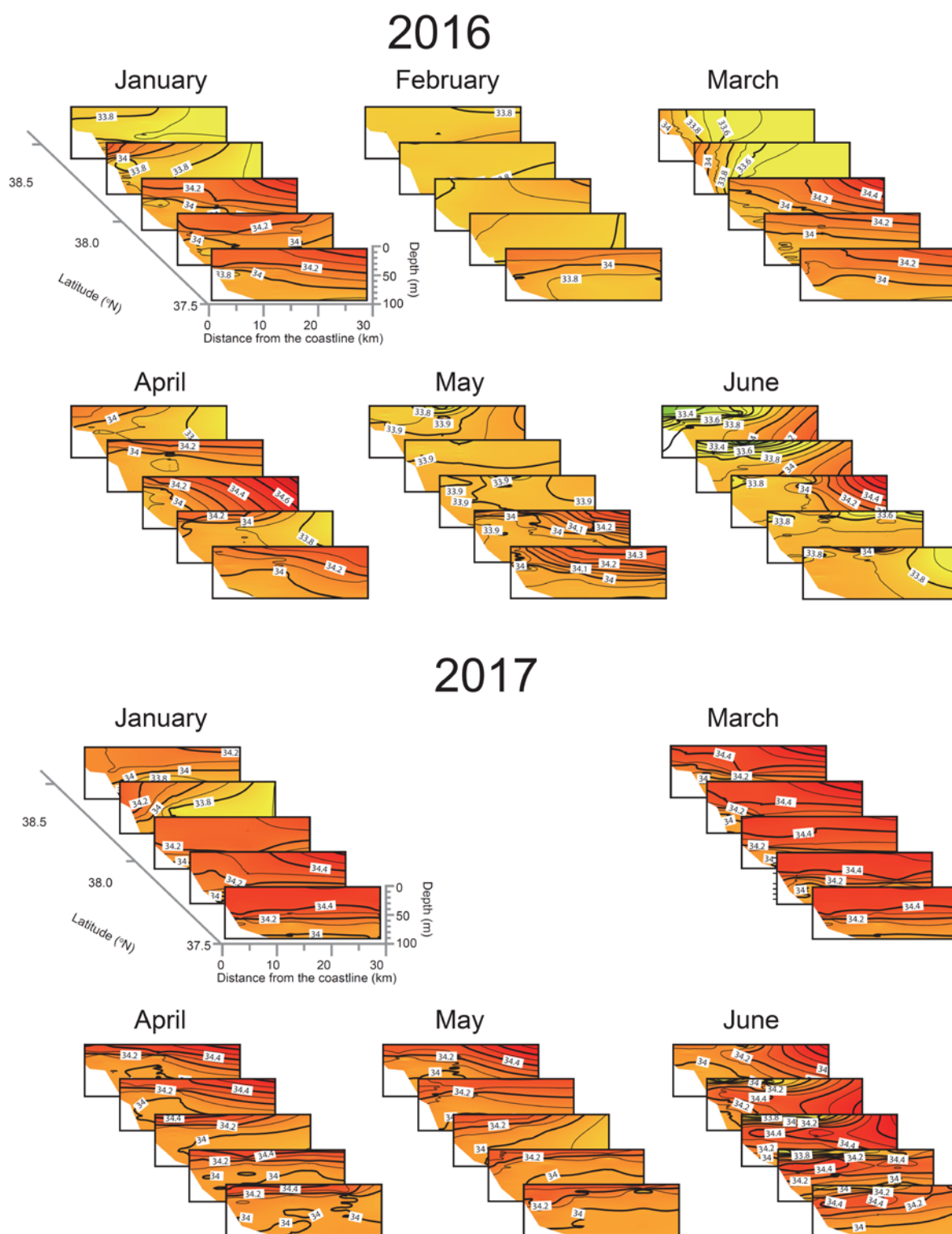
**Supplementary Figure S1A.** Three-dimensional structures of chlorophyll *a* concentrations ( $\mu\text{g l}^{-1}$ ) in the study area in 2016 and 2017.



**Supplementary Figure S1B.** Depth-integrated chlorophyll *a* concentration (mg m<sup>-2</sup>) in the study area in 2016 and 2017.

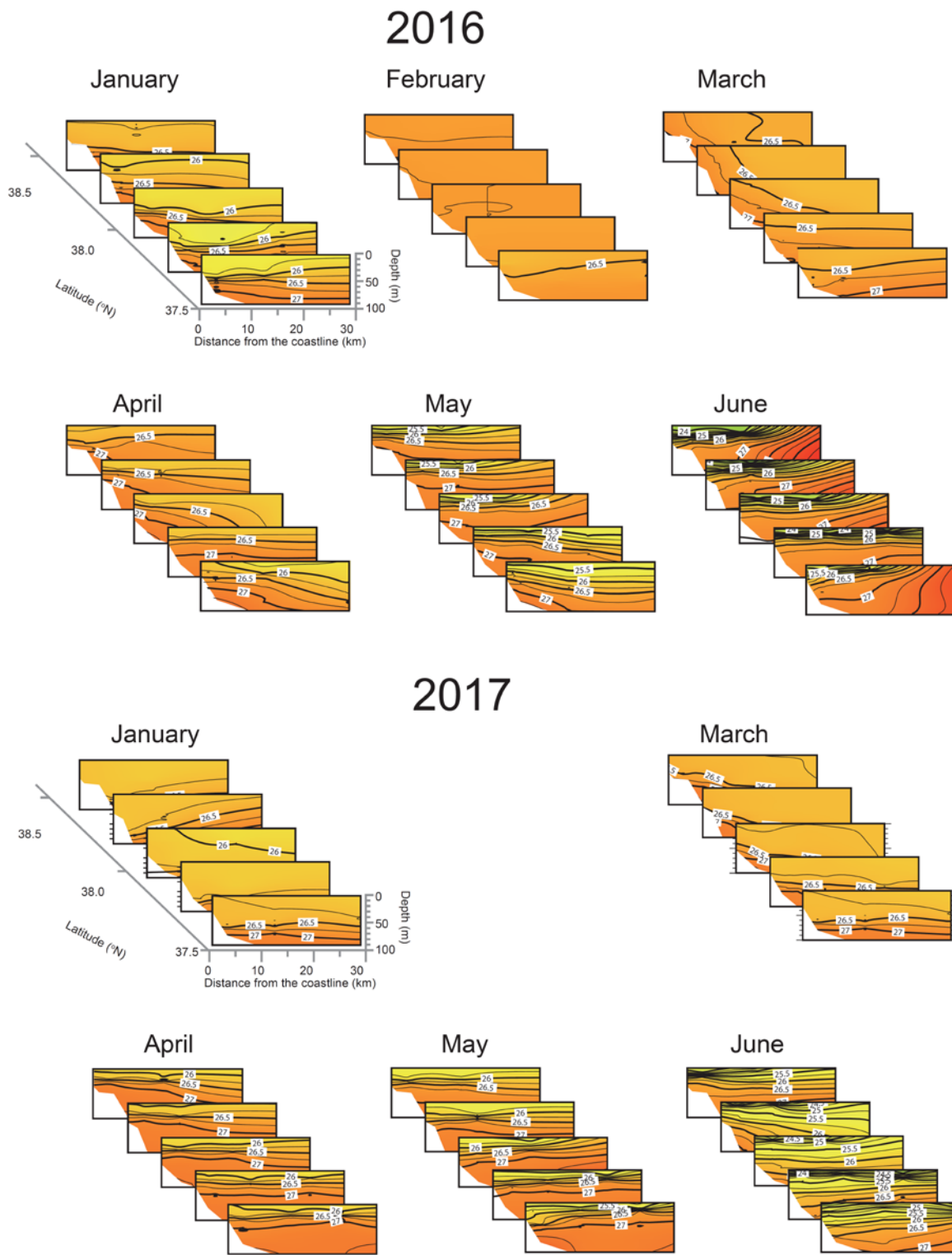


**Supplementary Figure S2.** Three-dimensional structures of water temperature (°C) in the study area in 2016 and 2017.

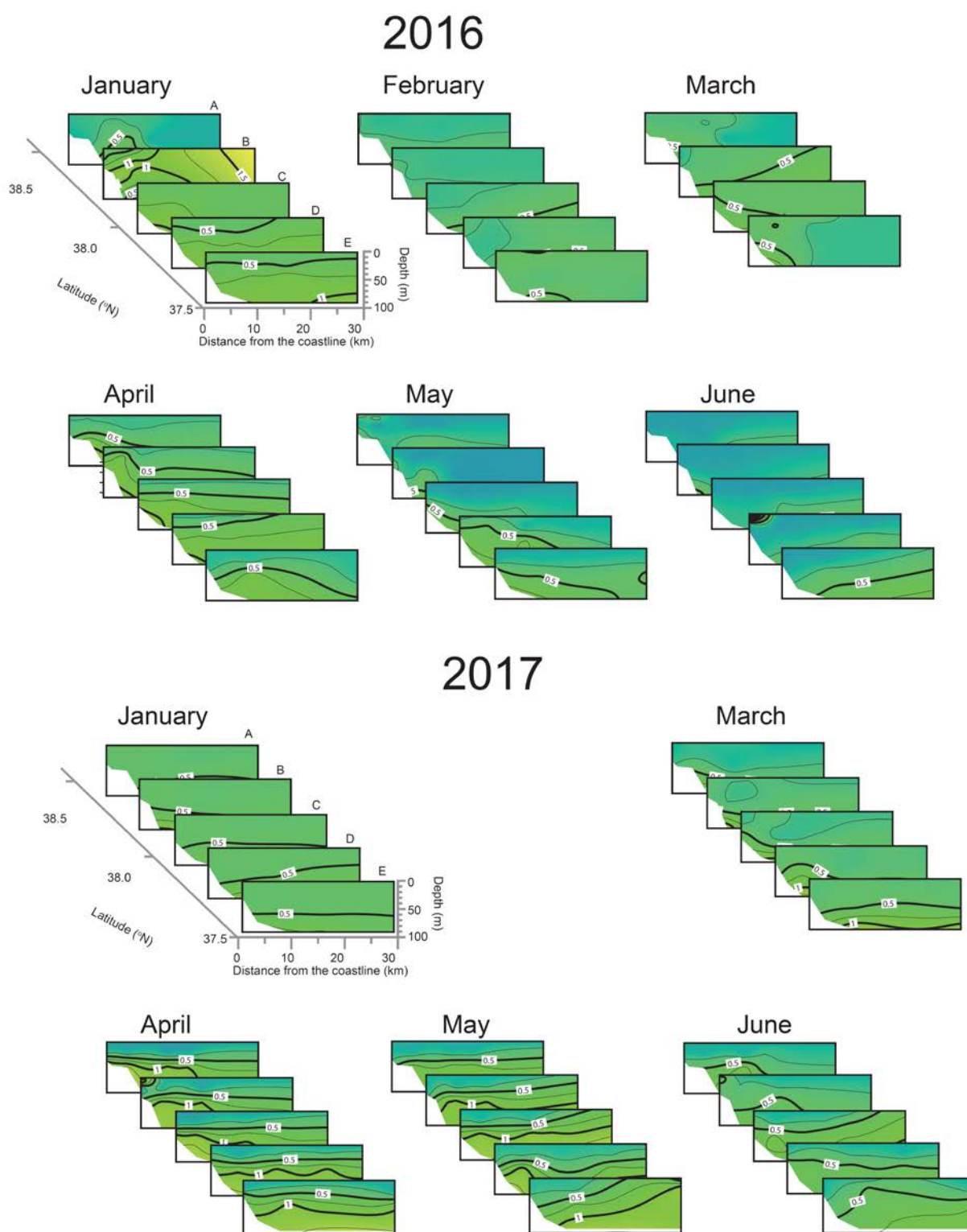


**Supplementary Figure S3.** Three-dimensional structures of salinity in the study area in 2016 and 2017.





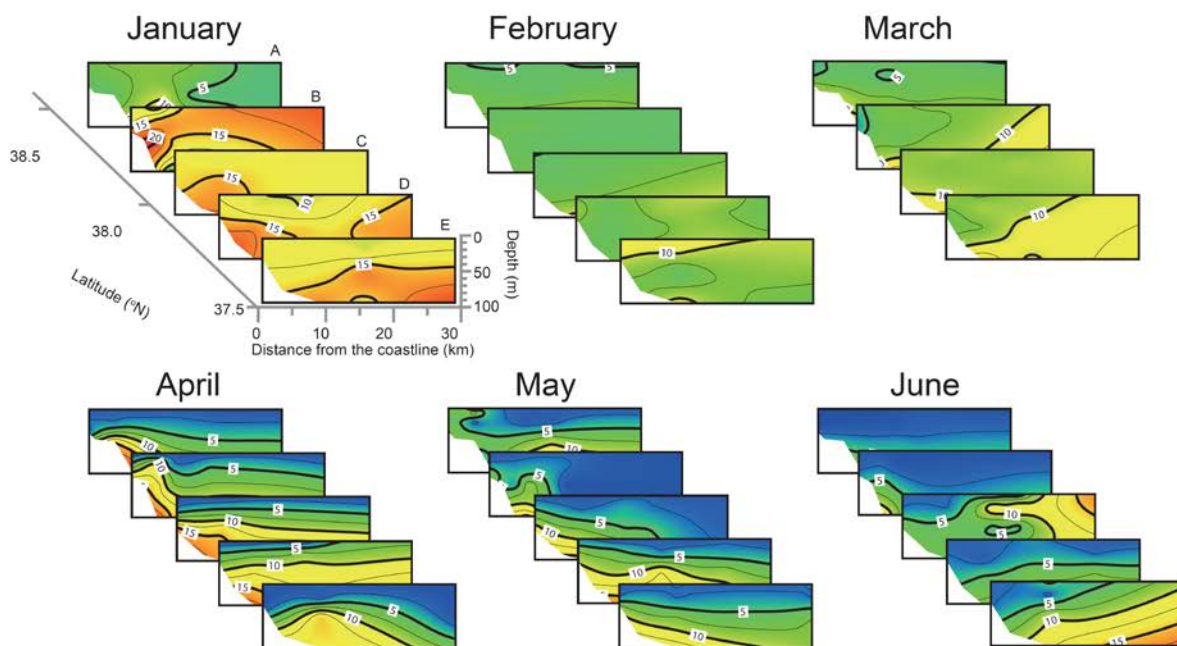
**Supplementary Figure S4.** Three-dimensional structures of density ( $\sigma_t$ ) in the study area in 2016 and 2017.



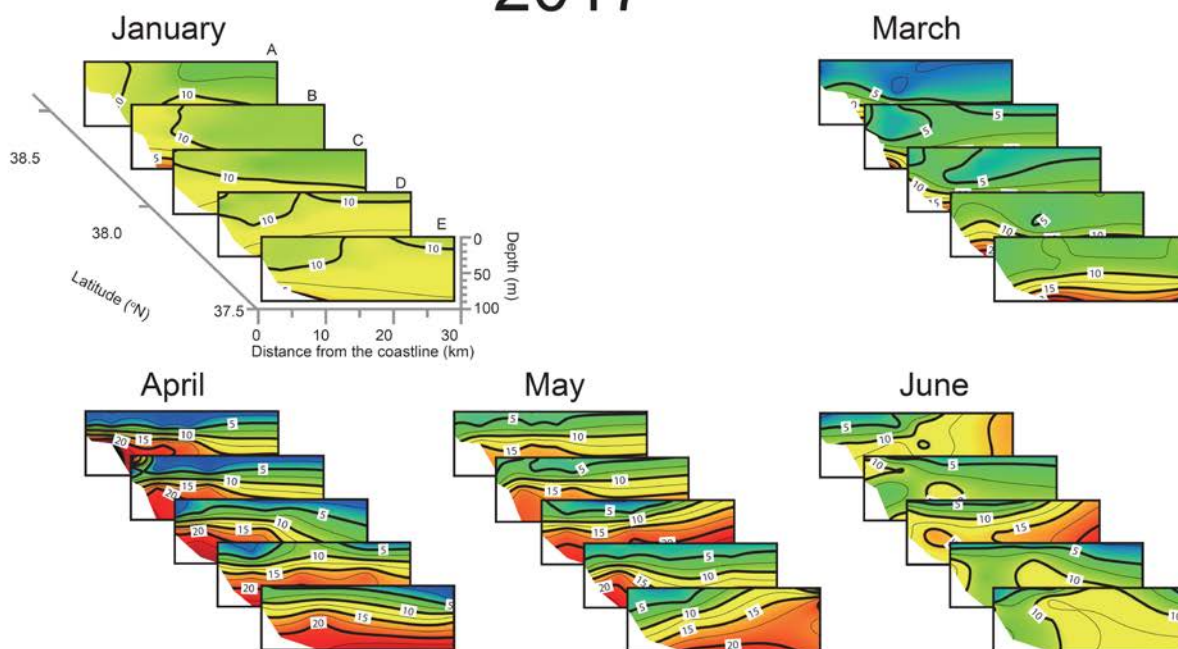
**Supplementary Figure S5.** Three-dimensional structures of dissolved phosphate concentrations ( $\mu\text{M}$ ) in the study area in 2016 and 2017.



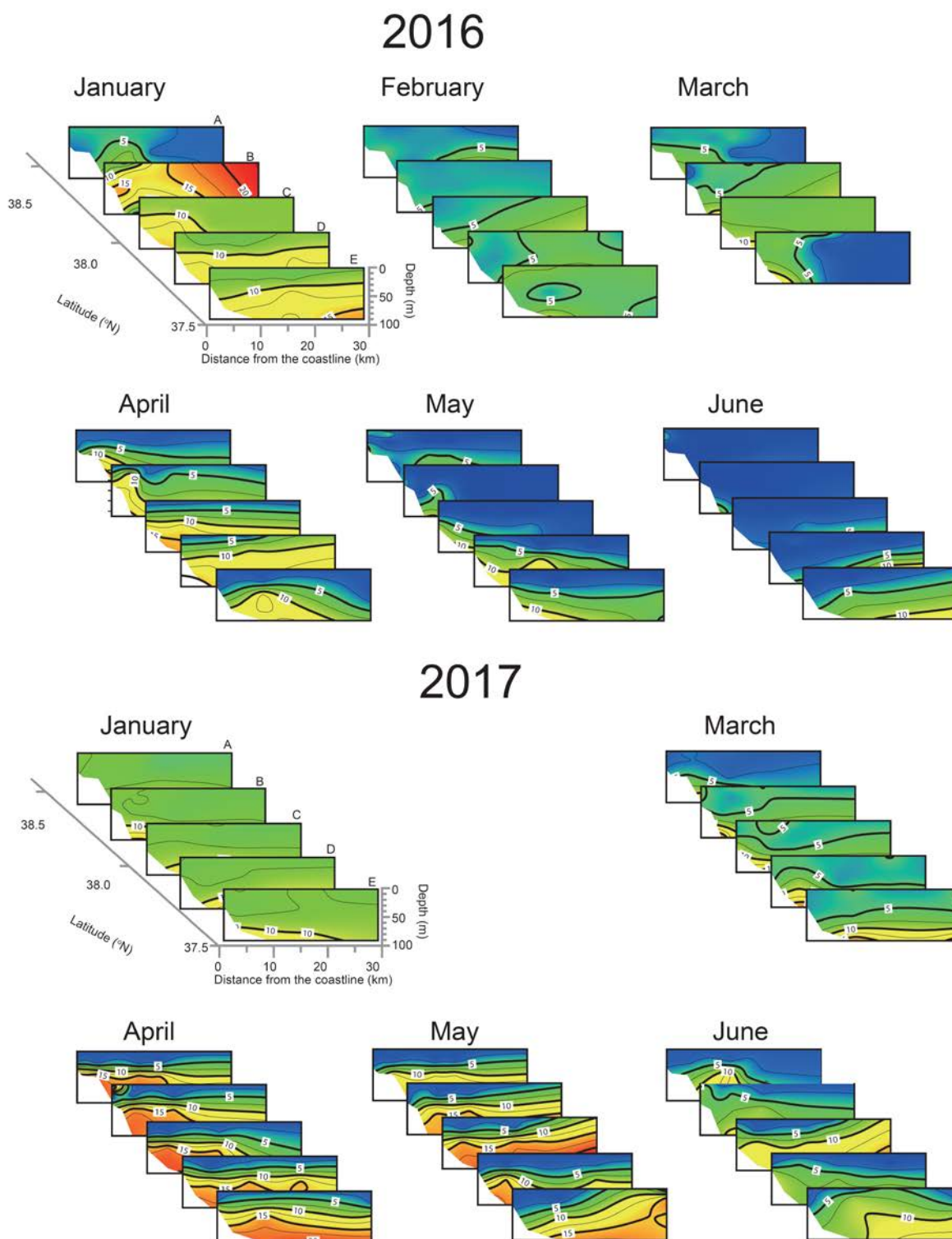
# 2016



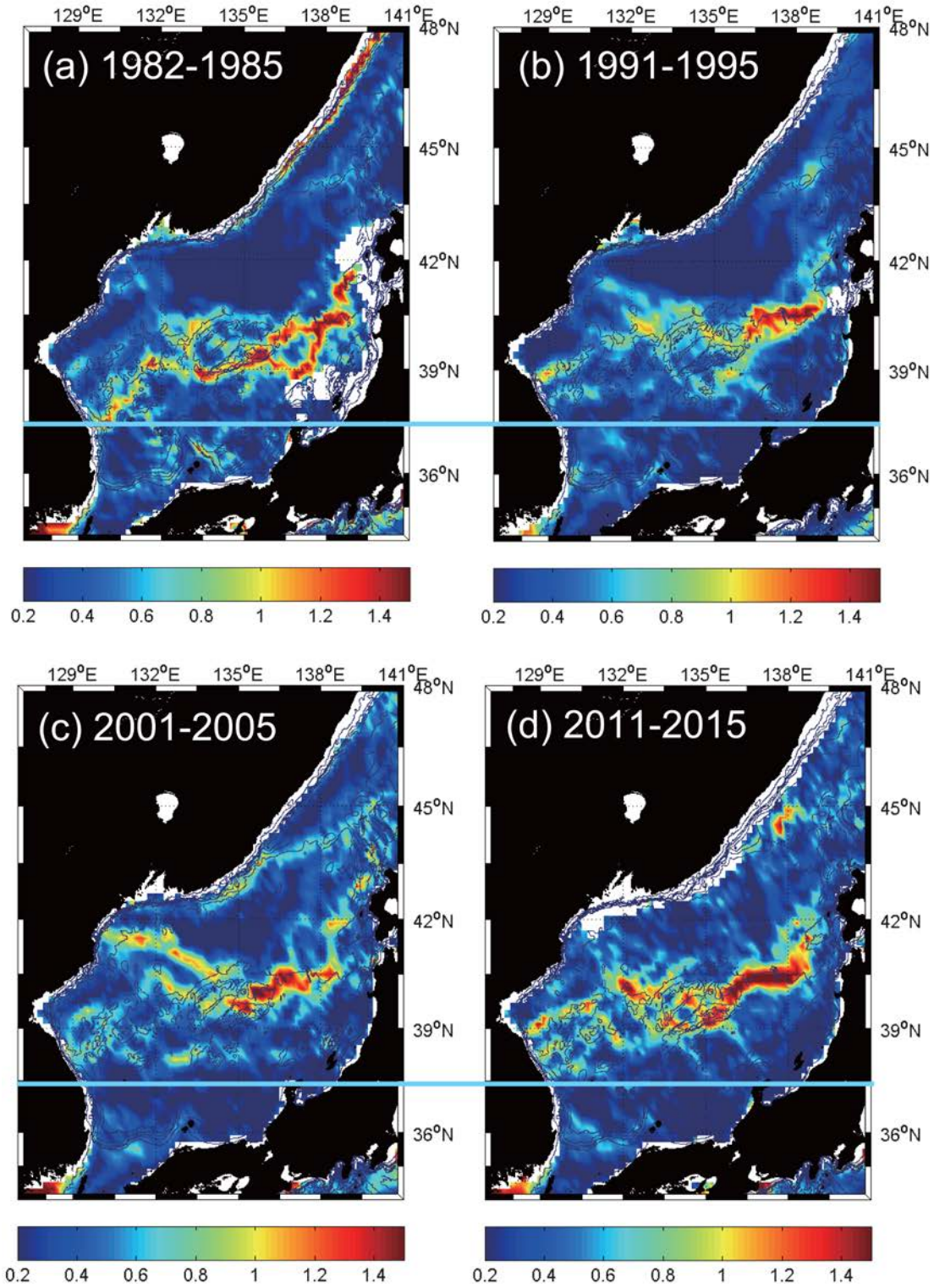
# 2017



**Supplementary Figure S6.** Three-dimensional structures of dissolved silicate concentrations ( $\mu\text{M}$ ) in the study area in 2016 and 2017.



**Supplementary Figure S7.** Three-dimensional structures of dissolved nitrate concentrations ( $\mu\text{M}$ ) in the study area in 2016 and 2017.



**Supplementary Figure S8.** Maps of mean sea surface temperature (SST) frontal gradients ( $^{\circ}\text{C km}^{-1}$ ) in February (a) 1982-1985, (b) 1991-1995, (c) 2001-2005, (d) 2011-2015. Sky blue lines indicate 37.5°N. A gradual northward shift of subpolar front in winter can be detected especially in the western region of the East/Japan Sea.