Comparison of seawater CO_2 system in summer between the East China Sea shelf and the Peter the Great Bay of the Japan (East) Sea

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Abstract

Continental shelves are active sites of air-sea CO_2 exchange and represent an important component of the global carbon budget (Table 1). In this study, we investigated the CO_2 system and pertinent hydrographic parameters in two distinct continental shelf systems in the Northwest Pacific in summer 2014: the East China Sea shelf (ECSS) and the Peter the Great Bay (PGB) of the Japan/East Sea (Fig. 1). The results show that the average temperature, pH, chlorophyll a and nutrients in the ECSS are higher, but salinity, dissolved inorganic carbon (DIC), and fugacity of CO_2 (fCO_2) are lower than those in the PGB (Table 2). Meanwhile, the ECSS acted as a sink of atmospheric CO_2 but the PGB was a source (Fig. 2g). We suggest that the observed divergent behaviors in terms of CO_2 absorption between the ECSS and the PGB may be associated with their difference in riverine runoff (Yangtze River: 30000 m^3/s; Razdolnaya River: 80 m^3/s). Under the influence of the Yangtze River, the nutrient discharge into the ECSS is much higher than that into the PGB, where only a few small rivers empty into. The high nutrient discharge into the ECSS may stimulate high biological production, which may drawdown CO_2 and thereby driving the ECSS to act as a CO_2 sink despite high temperature in summer (Fig. 4c). On the contrary, the temperature effect may dominate over the effect of biological production in the PGB due to the limited nutrient discharge, and thus turn the PGB to be a source of atmospheric CO_2 (Fig. 4a). The results of this study imply that riverine nutrient discharge may exert a large control on net ecosystem productivity in shelf areas, which may subsequently play a critical role on determining whether a shelf system acts as a source or a sink of atmospheric CO_2.

Region	Air-sea CO_2 flux (Pg C y^{-1})	Area (10^{12} m^2)	CO_2 absorption capacity per unit (g C m^{-2} y^{-1})
Open ocean	- 1.5	335	4
Continental shelf	- 0.4	26	15

(Cai, 2011)

Table 1 Comparison of CO_2 uptake capability between open ocean and continental shelf. Although continental shelf area is only 1/10 of open ocean, its CO_2 uptake capacity is about four times higher than that of the open ocean.

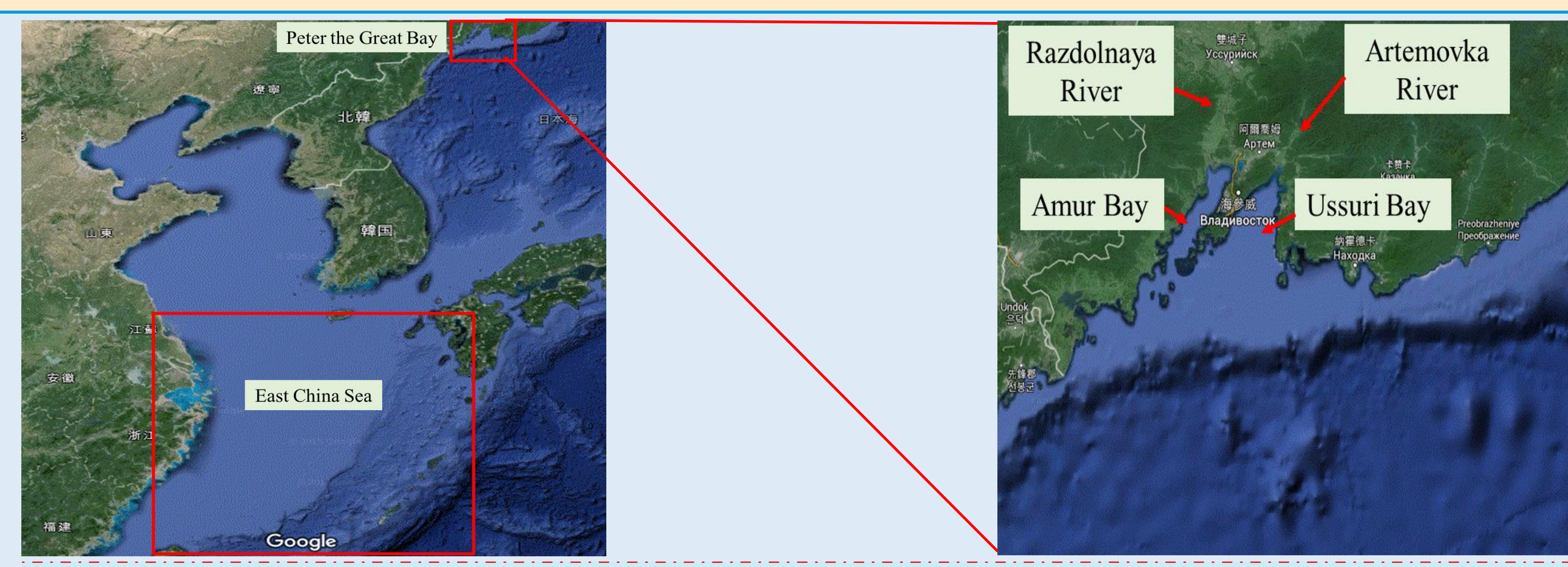

Fig. 1 Location of the East China Sea (ECS) and the Peter the Great Bay (PGB). The right panel is the enlarged view of the PGB, which consists of Amur Bay and Ussuri Bay. Artemovka River and Razdolnaya River are the two major rivers emptying into the PGB.

Result

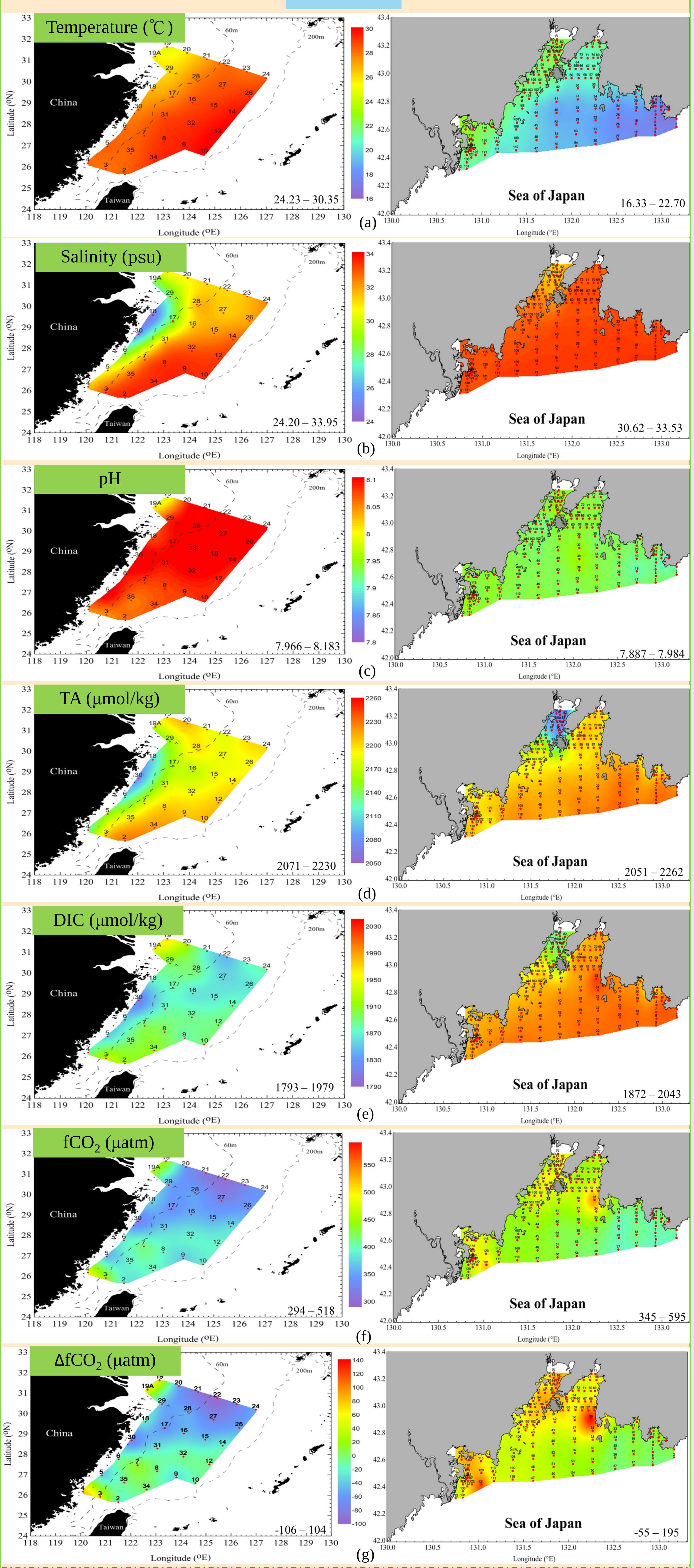

Fig. 2 The surface distributions of (a) temperature, (b) salinity, (c) pH, (d) TA, (e) DIC, (f) fCO_2 and (g) ΔfCO_2 in the ECSS and the PGB. Fig. 2g shows that the ECSS generally acts as a sink of atmospheric CO_2, while the PGB tends to be a source of atmospheric CO_2 in the summer 2014. This result is different from the general latitudinal trend for the global pattern of CO_2 fluxes in coastal oceans, i.e. high latitude continental shelves are sinks for atmospheric CO_2, while the low latitude continental shelves are sources for CO_2.

Discussion

Parameters	ECS (n = 34)	PGB (n = 155)	P value (α = 0.05)
*Temperature (℃)	28.20±1.39	20.49±1.51	p = 10^{-31}
*Salinity (psu)	31.30±2.47	32.78±0.63	p = 0.002
*pH	8.092±0.047	7.934±0.017	p = 10^{-18}
TA (μmol/kg)	2181±40	2178±53	p = 0.79
*DIC (μmol/kg)	1885±37	1969±44	p = 10^{-17}
*fCO_2 (μatm)	374±51	452±39	p = 10^{-9}
*Chlorophyll a (mg/m^3)	1.73±2.01	0.87±0.87	p = 0.03
*NO_3^- (μM)	3.6±2.2	0.2±0.1	p = 0.02

Table 2 Comparison of the average temperature, salinity, pH, TA, DIC, fCO_2, chlorophyll a and NO_3^- between the ECSS and the PGB. The average temperature, pH, Chl a and NO_3^- in the ECSS are higher, but salinity, DIC, and fCO_2 are lower than those in the PGB. Astral symbols (*) represent that the difference between the ECSS and the PGB is statistically significant (p–value < 0.05).

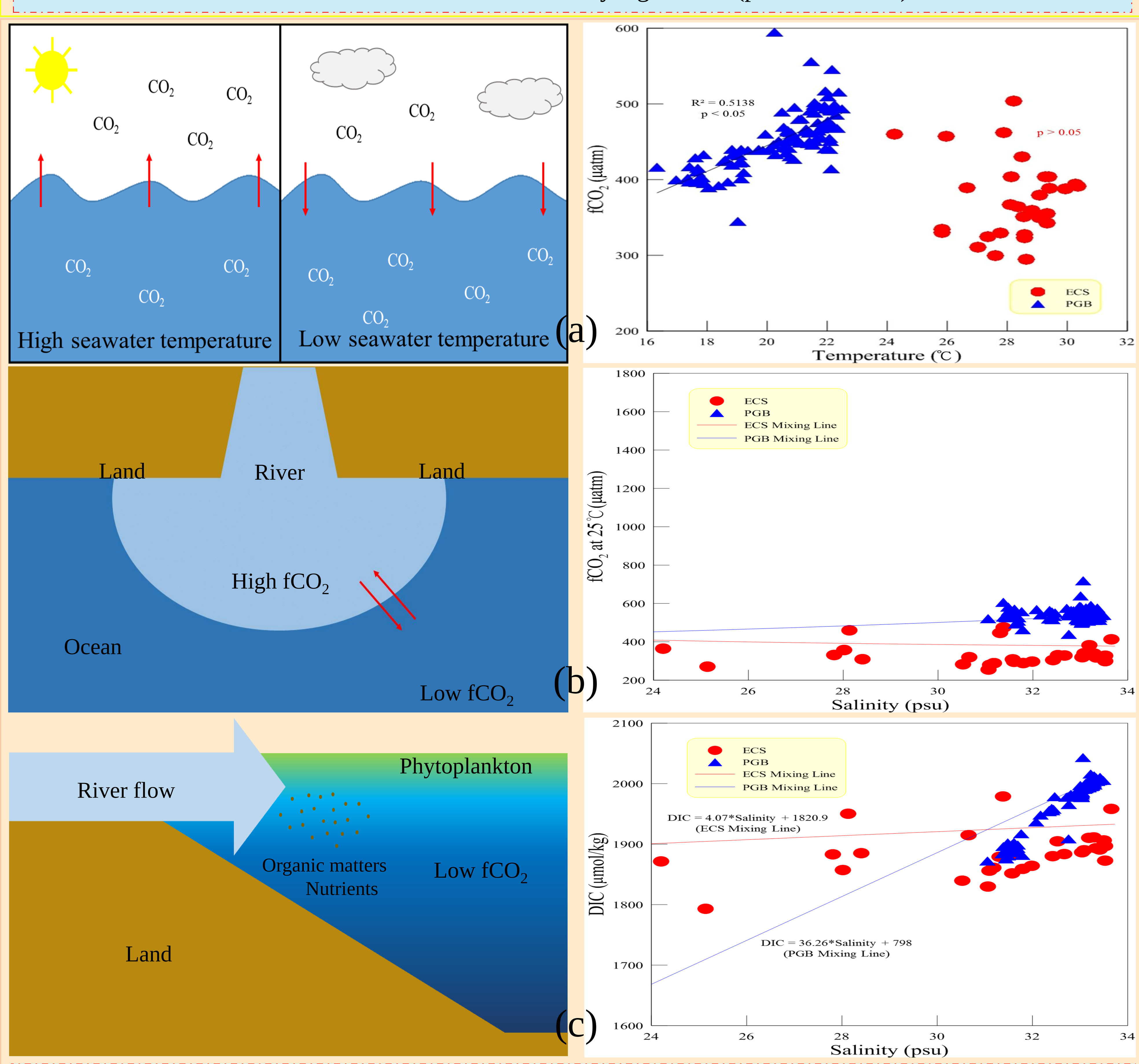

Fig. 4 Factors controlling spatial variation of fCO_2 in the ECSS and the PGB:

(a) Temperature: the significant positive correlation between fCO_2 and temperature indicates that temperature is an important factor controlling spatial variation of fCO_2 in the PGB, whereas the insignificant correlation suggests other factor(s) may overwhelm temperature in controlling spatial variation of fCO_2 in the ECSS.

(b) Mixing: The observed $nfCO_2$ are generally below the hypothetical mixing lines between the fresh and seawater end-members, suggesting some process(s) may largely draw fCO_2 down in the ECSS, while the comparatively fair agreement between fCO_2 and the hypothetical mixing line implying mixing may play a certainty role on regulating spatial variation of fCO_2 in the PGB.

(c) Biological production: The observed DIC are generally below the hypothetical mixing line between the fresh and seawater endmembers in the ECSS and the PGB, suggesting that biological removal of DIC may have taken place in both area. However, the differences between the observed and the hypothetical DIC in the ECSS are apparently larger than those in the PGB, implying the higher biological production in the ECSS, which may be stimulated by high nutrient discharge from the Changjiang River.