Supporting of

Incorporating Recalcitrant Dissolved Organic Carbon and Microbial Carbon Pump Processes into the cGENIE Earth System Model (cGENIEv0.9.35-MCP)

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Table S1. Comparison of biogeochemical configuration between cGENIE-MCP and previous cGENIE models

Configurations	cGENIE-MCP (This study)	cGENIE (Crichton et al., 2021)
CO_2-climate feedback	YES	YES
Iron cycle	Dust source: (Mahowald et al., 1999)	Dust source: (Mahowald et al., 1999)
	TDFe and TL	TDFe and TL
	F_{esol}= 0.5	F_{esol}= 0.5
	K_{scav}= 0.1	K_{scav}= 0.1
Temperature-dependent	$E_a(POC1)$ =54000	$E_a(POC1)$ =54000
	$E_a(POC2)$ =80000	$E_a(POC2)$ =80000
	$E_a(LDOC)$=54000	$E_a(LDOC)$=54000
	β_{LDOC}=1.32×10^{13}	β_{LDOC}=1.32×10^{13}
MCP process	τ_{SL} = 5	N/A

$\tau_R = 16000$
a=0.015
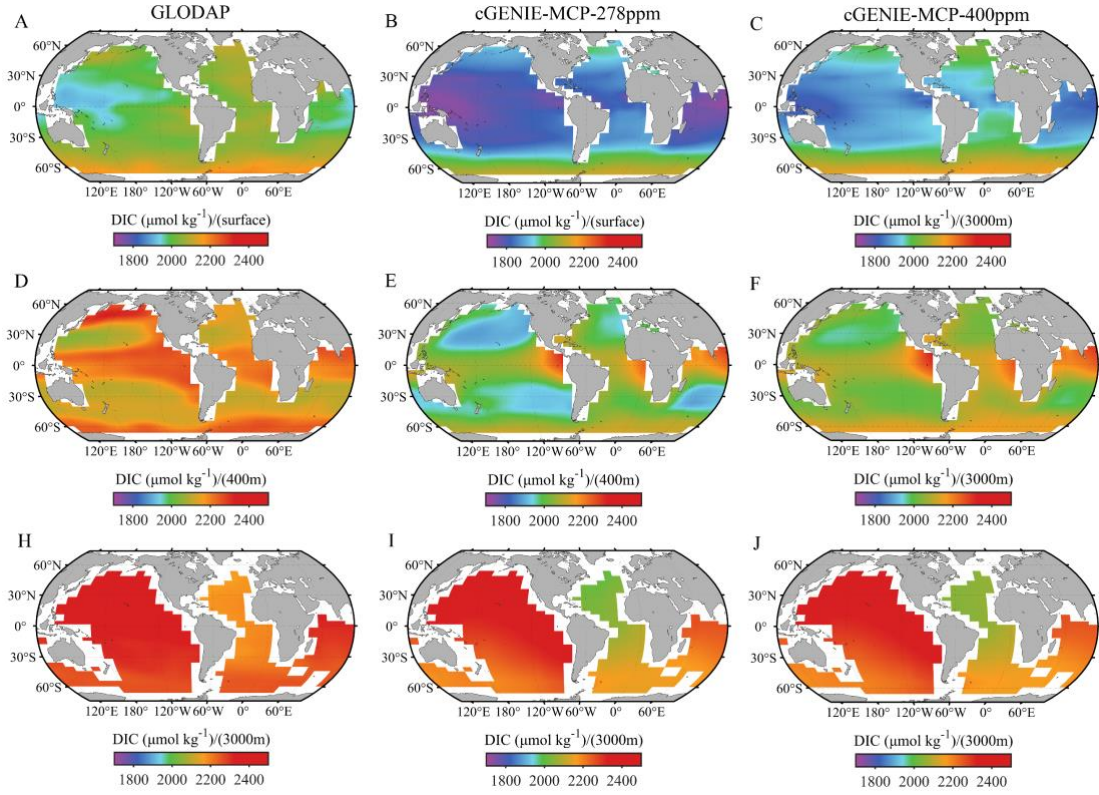
Figure S1. Ocean DIC distributions (μmol kg⁻¹) at three depth levels: (A-C) the surface, (D-F) 400 m, and (H-J) 3000 m. Panels show: (A, D, H) observational data from GLODAP; (B, E, I) simulated results from the cGENIE-MCP model at 278 ppm; and (C, F, J) outputs from the cGENIE-MCP model at 400 ppm.
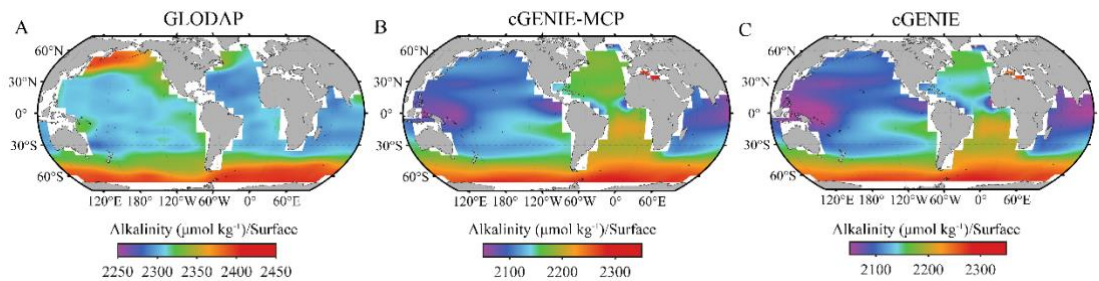
Figure S2. Ocean alkalinity distributions (μmol kg⁻¹) at surface: (A) observational data from GLODAP; (B) simulated results from the cGENIE-MCP; and (C) outputs from the cGENIE model.
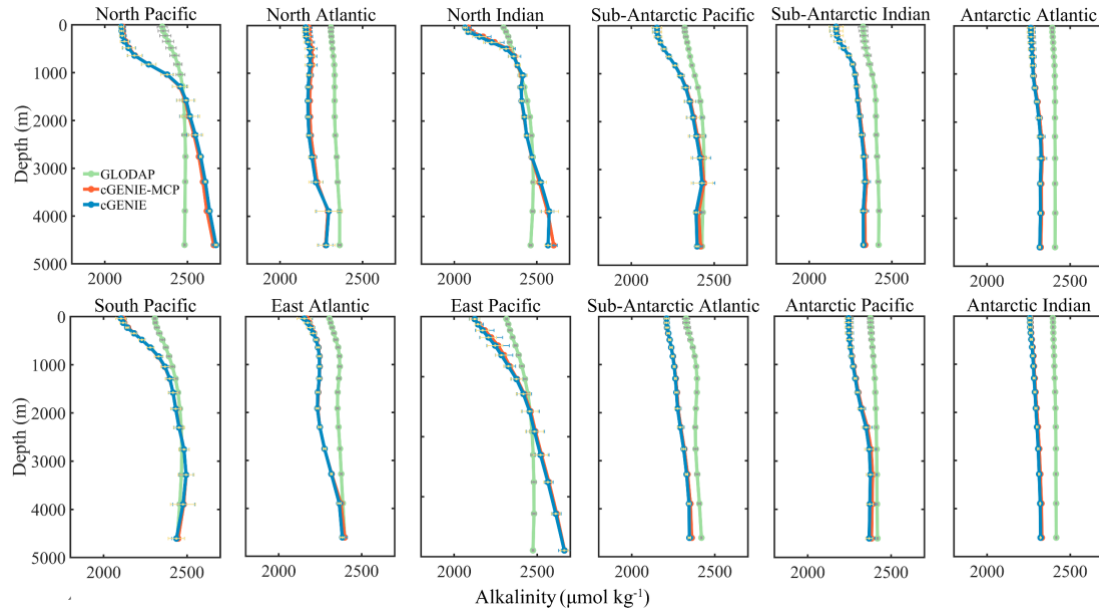
Figure S3. Vertical profiles of alkalinity (µmol kg^{-1}) in selected ocean regions, comparing among GLODAP data, cGENIE-MCP and standard cGENIE model outputs. Regions include the Atlantic Ocean, low-latitude tropics, South Pacific, and Northern Indian Ocean, as defined in the model evaluation.
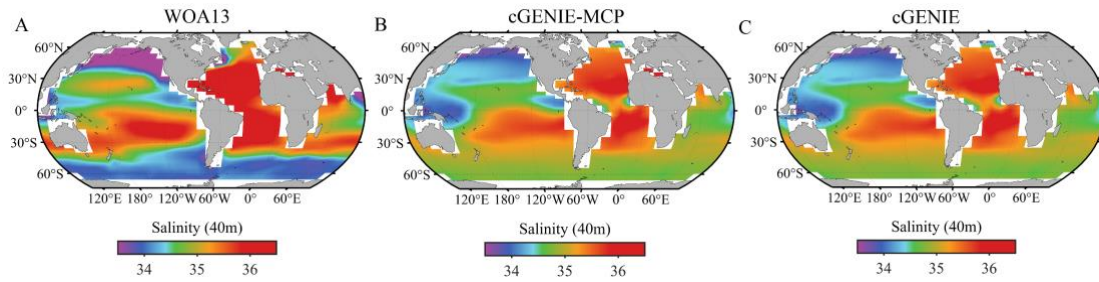
Figure S4. Ocean salinity distributions at surface: (A) observational data from WOA23; (B) simulated results from the cGENIE-MCP; and (C) outputs from the cGENIE model.
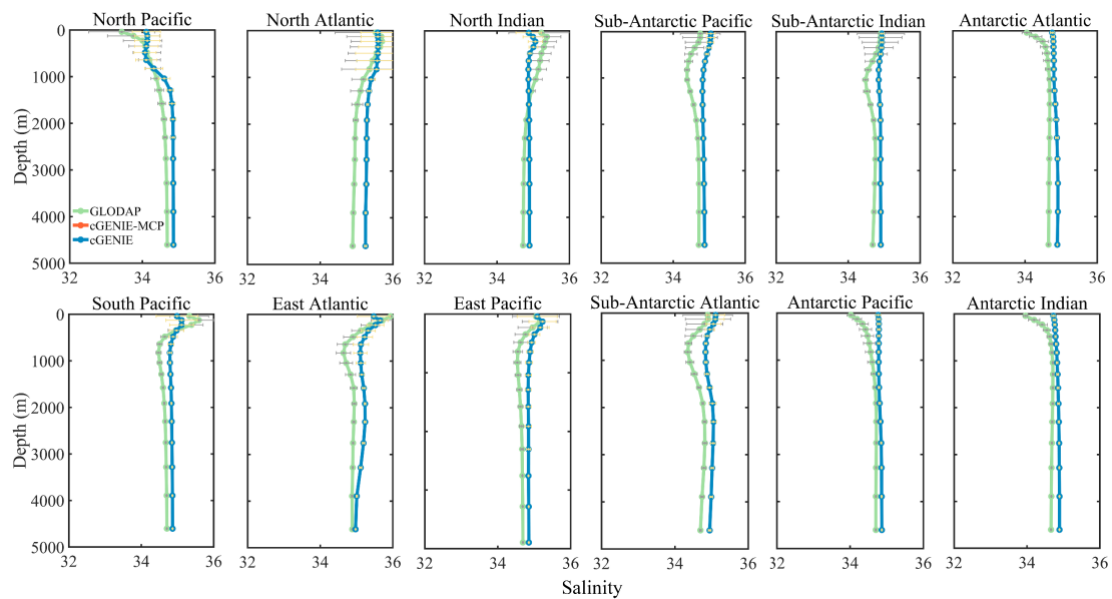
Figure S5. Vertical profiles of salinity in selected ocean regions, comparing among WOA23 data, cGENIE-MCP and standard cGENIE model outputs. Regions include the Atlantic Ocean, low-latitude tropics, South Pacific, and Northern Indian Ocean, as defined in the model evaluation.
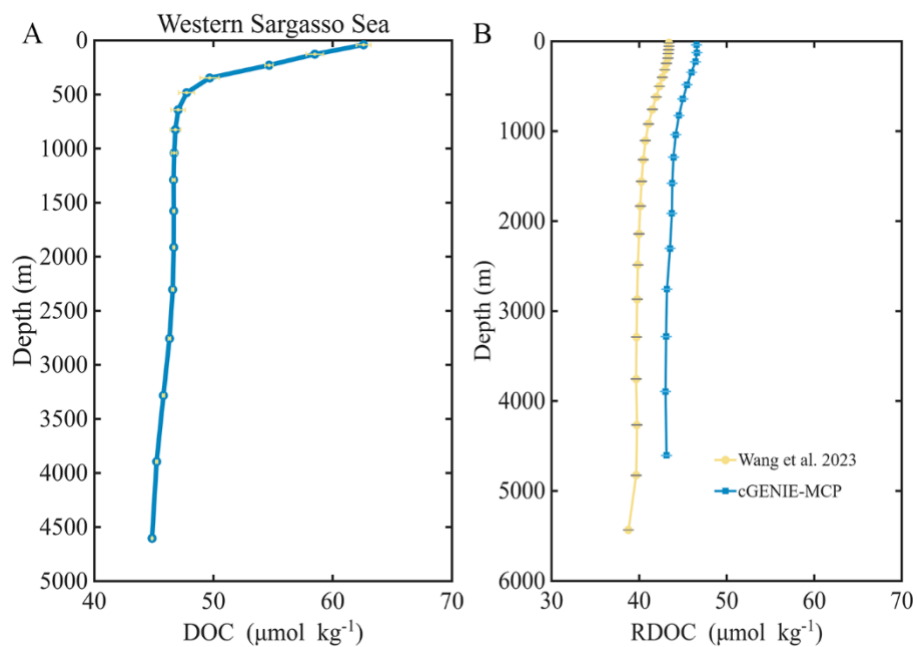
Figure S6. Vertical profiles of DOC and RDOC in selected ocean regions: (A) western Sargasso Sea, (B) the average concentration comparing the results of Wang et al. (2023).

Table S2 The LDOC, SLDOC, and RDOC concentrations from previous studies

Study Region	Water Layer	LDOC	SLDOC	RDOC	Reference
NW Pacific	Surface <200 m	20−40%	15−20%	Deep >1000 m: >90%	Ge et al. (2022)
NW Pacific	Surface <200 m	5-20%	15-30%	Deep >1000 m: >90%	This study

Table S3 The LDOC, SLDOC, and RDOC production rate from previous studies

Study Region	LDOC	SLDOC	RDOC	Reference
Global euphotic zone	25 Pg C yr^{-1}	3.7 Pg C yr^{-1}	0.04 Pg C yr^{-1}	Legendre et al. (2015)
Global euphotic zone	26 Pg C yr^{-1}	3.9 Pg C yr^{-1}	0.06 Pg C yr^{-1}	This study

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