Simulating marine ecosystem dynamics and biogeochemical cycling with multiple plankton functional types

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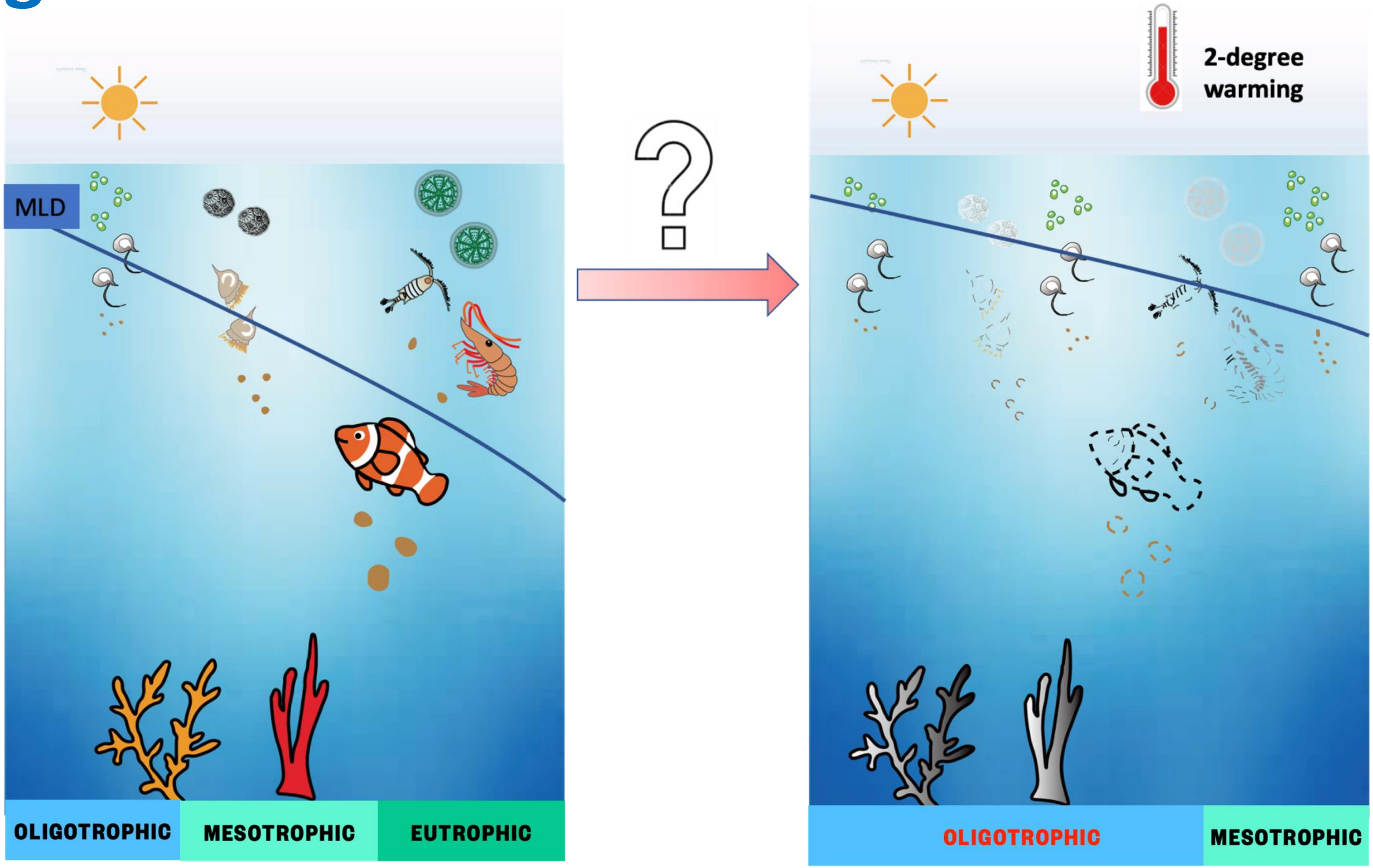
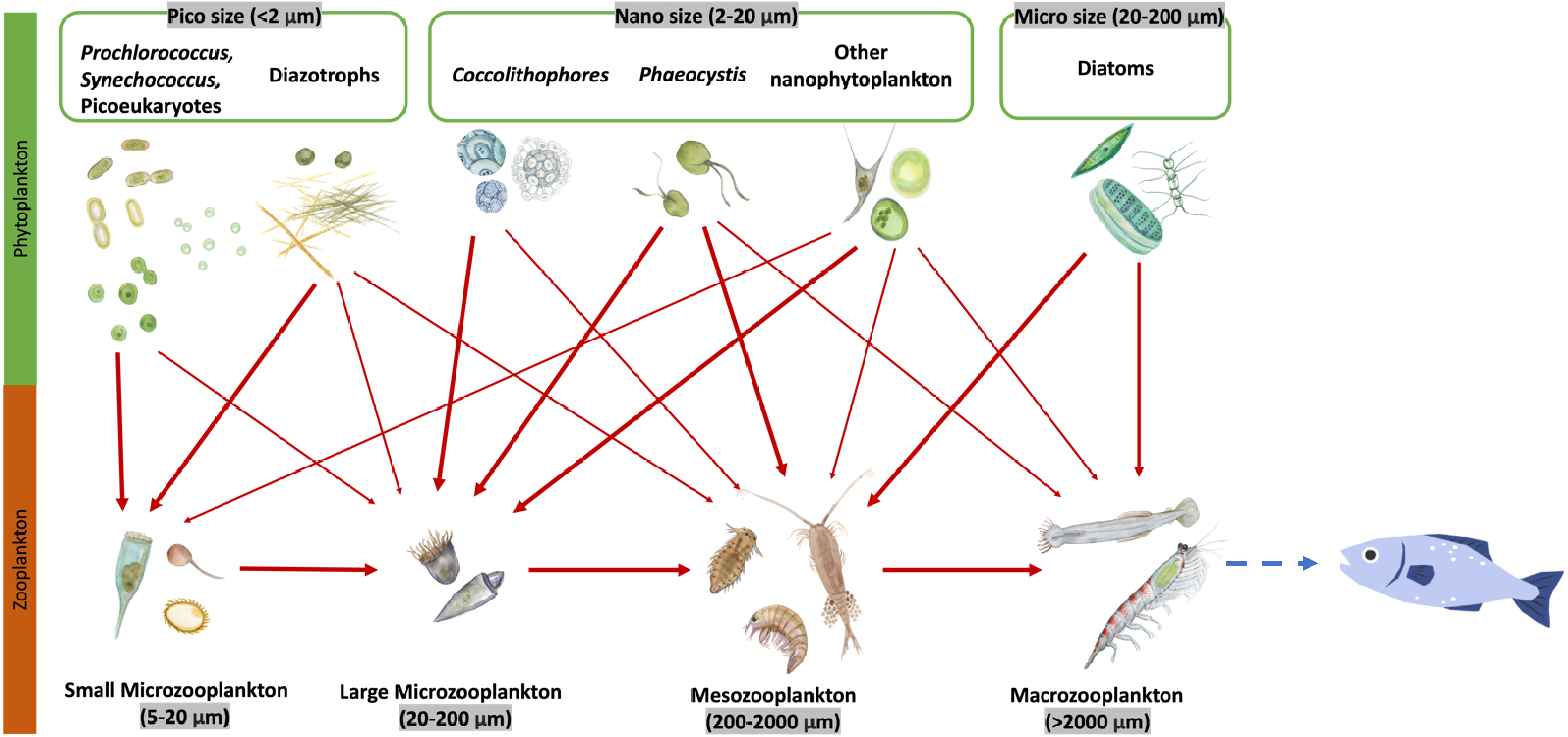
Background

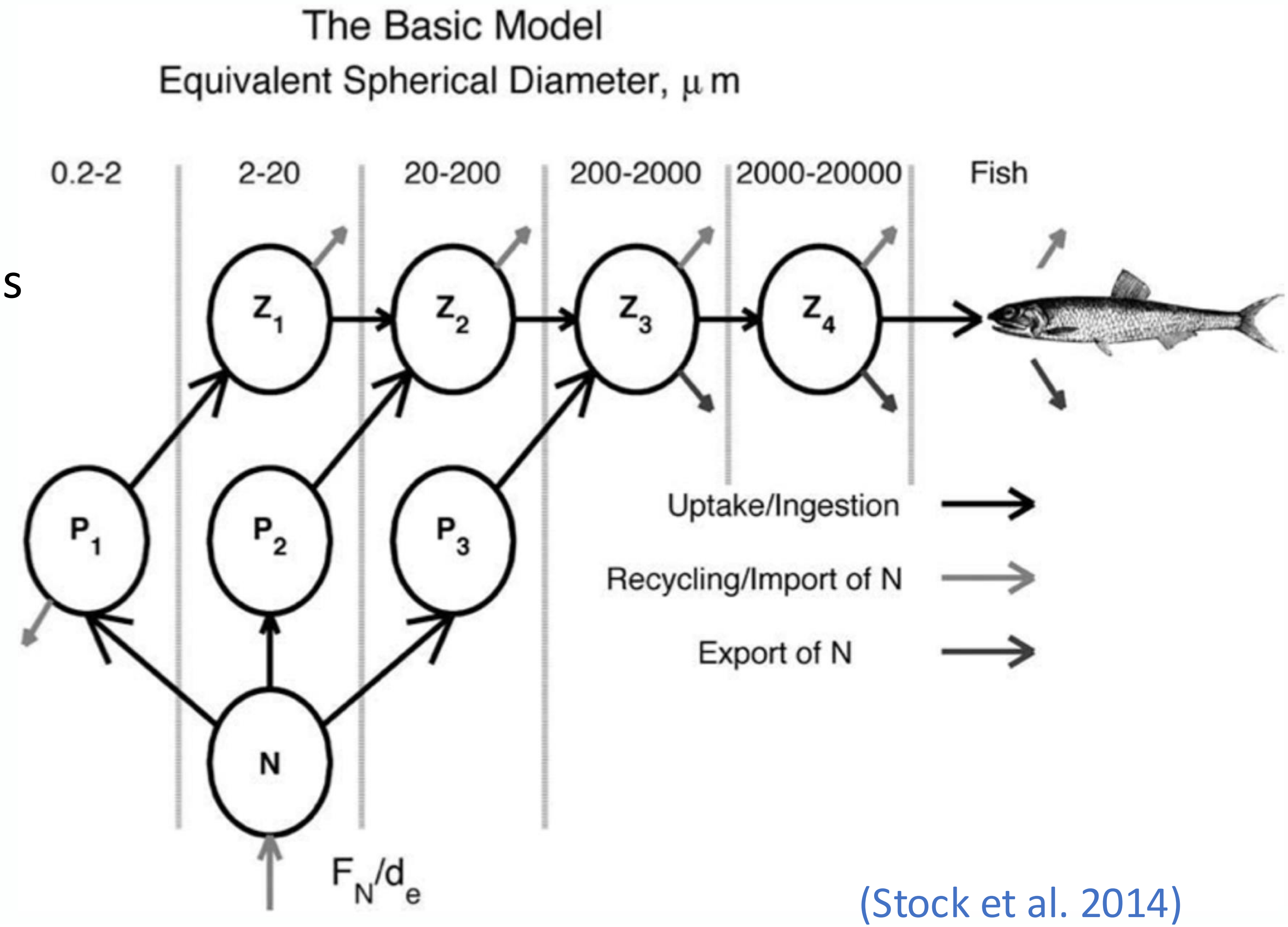

MLD
OLIGOTROPHIC
MESOTROPHIC
EUTROPHIC
2-degree
warming
OLIGOTROPHIC
MESOTROPHIC

The new ecosystem model (CESM2-8P4Z)



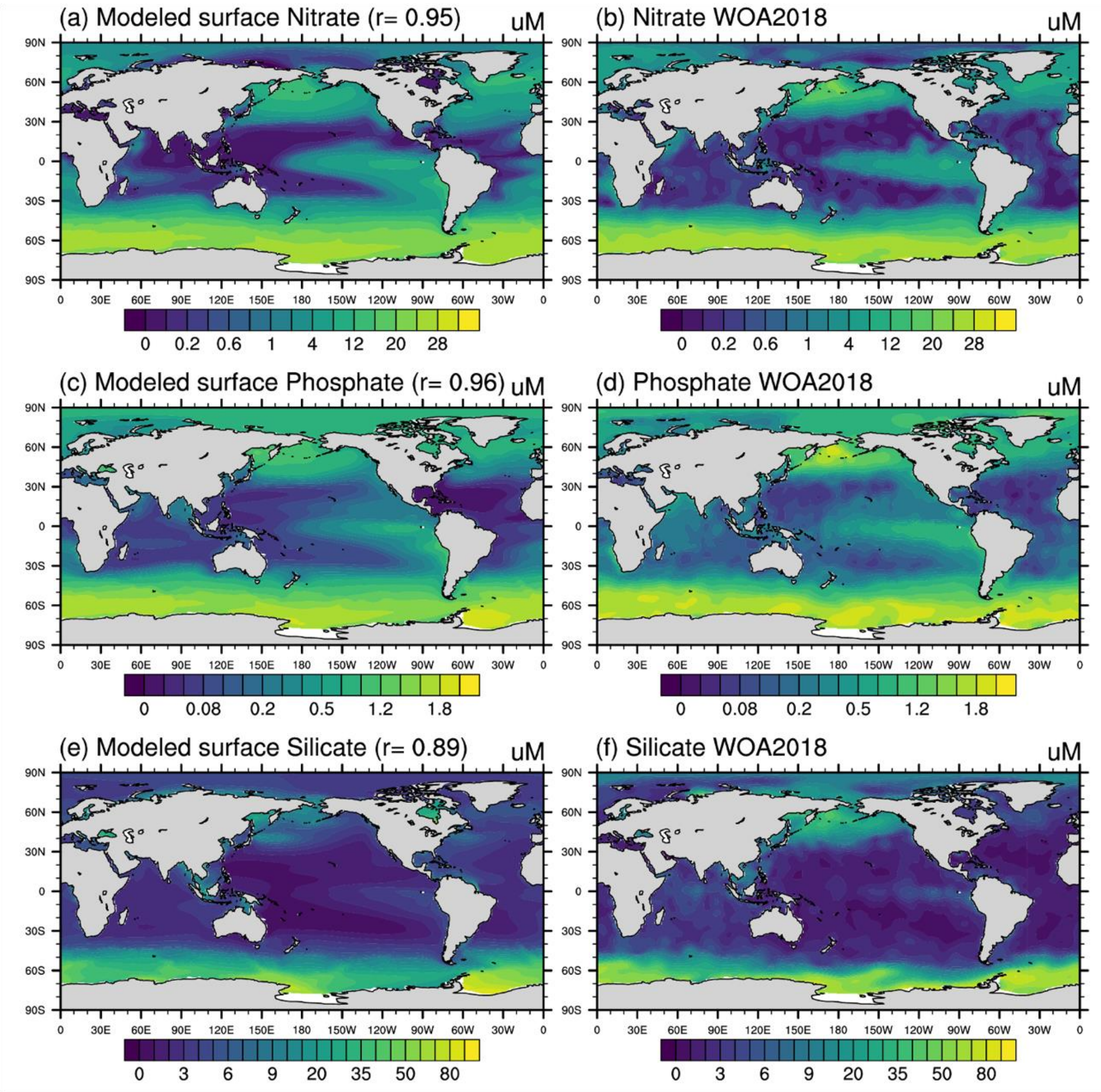
The grazing relationship

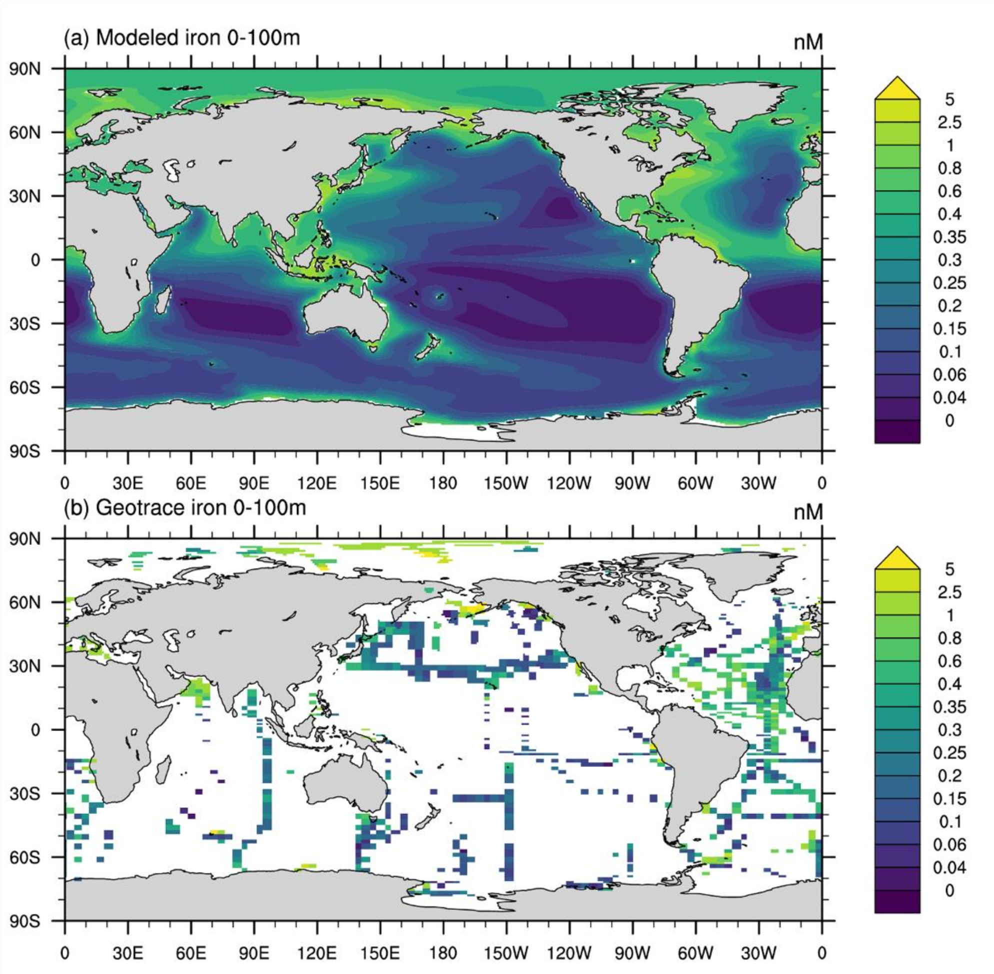
- The food web grazing relationships initially follow the optimum predator-prey size ratio (Stock et al. 2014)



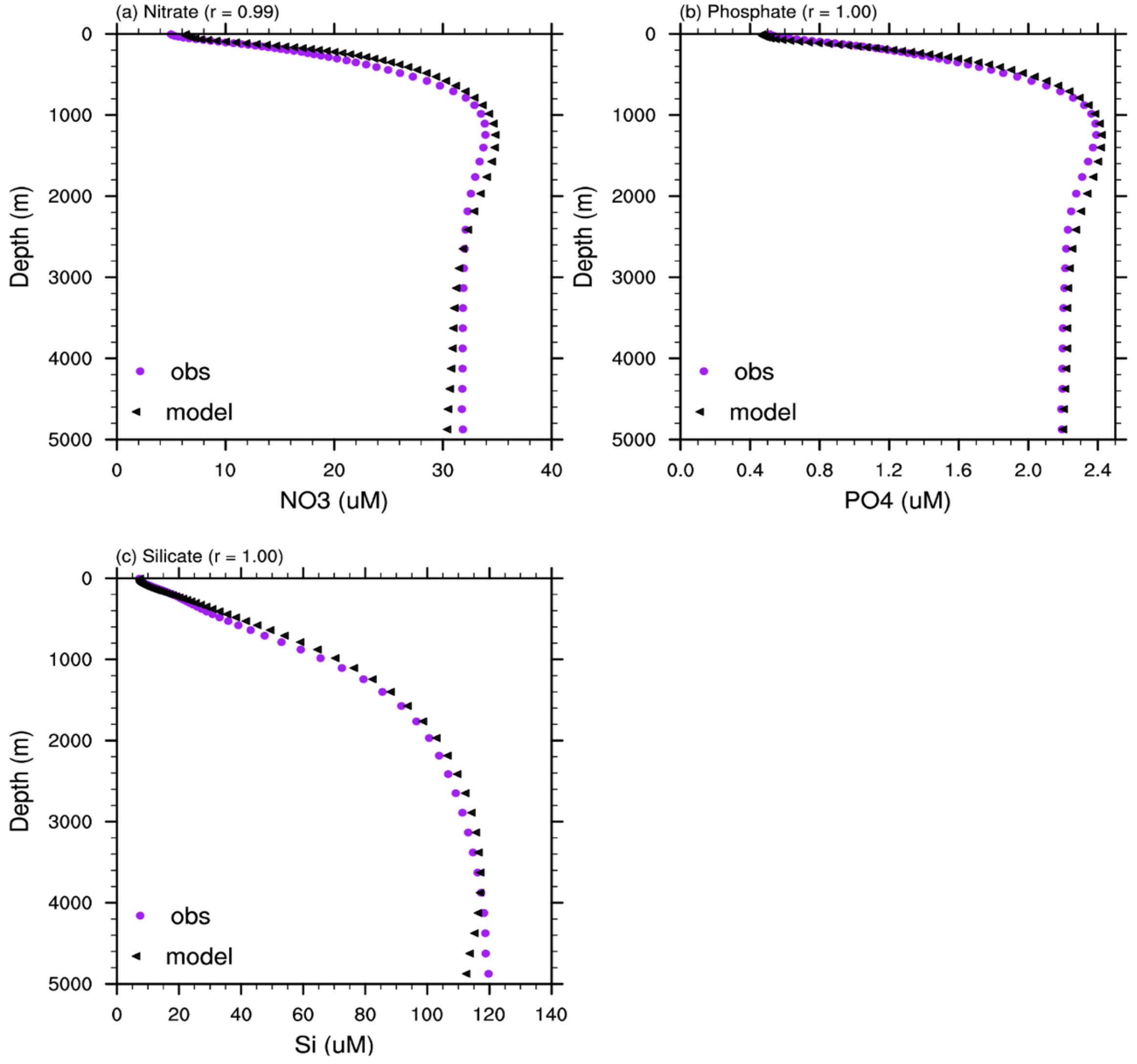
(Stock et al. 2014)

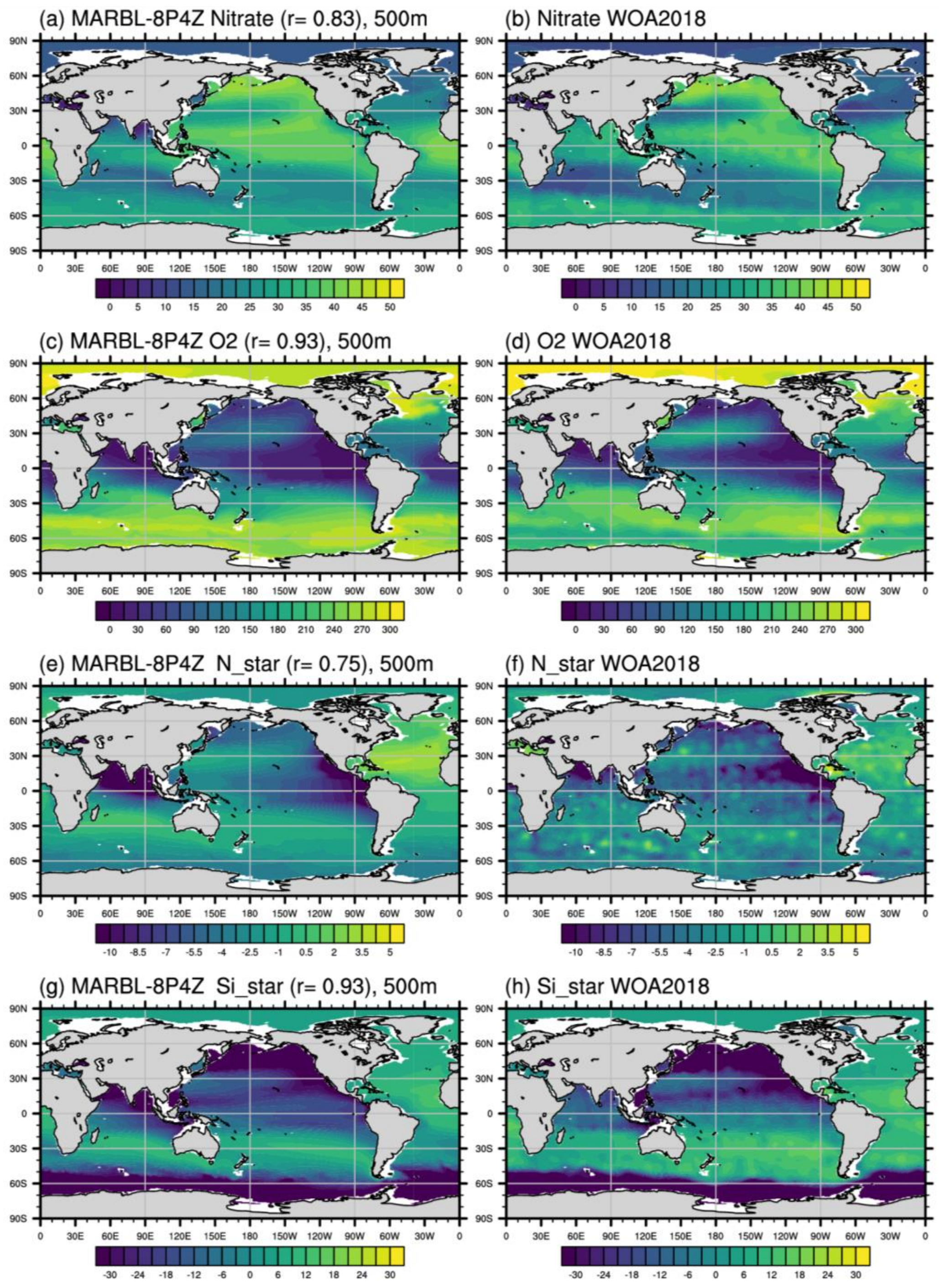
Model performance: basic biogeochemical aspects



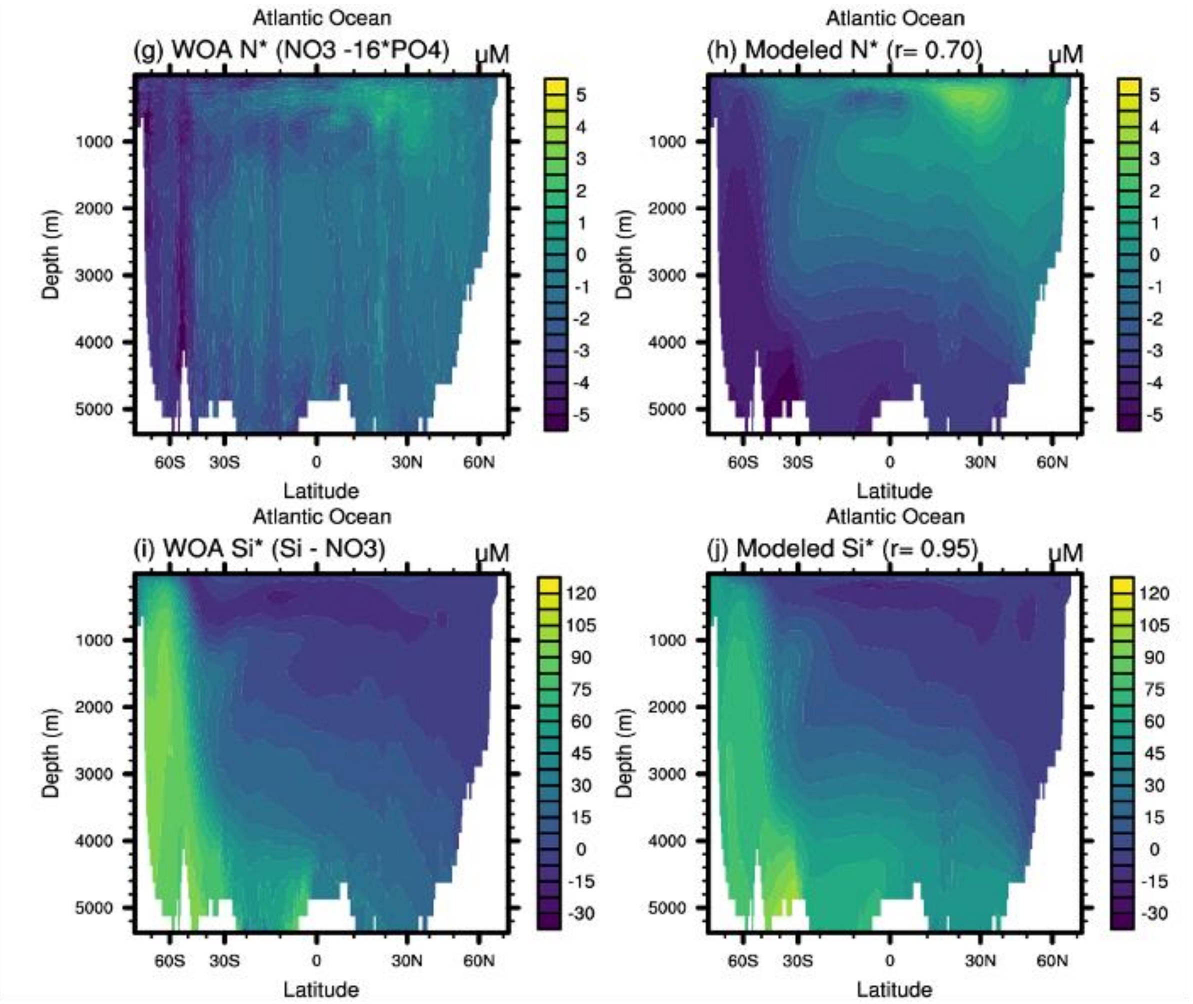


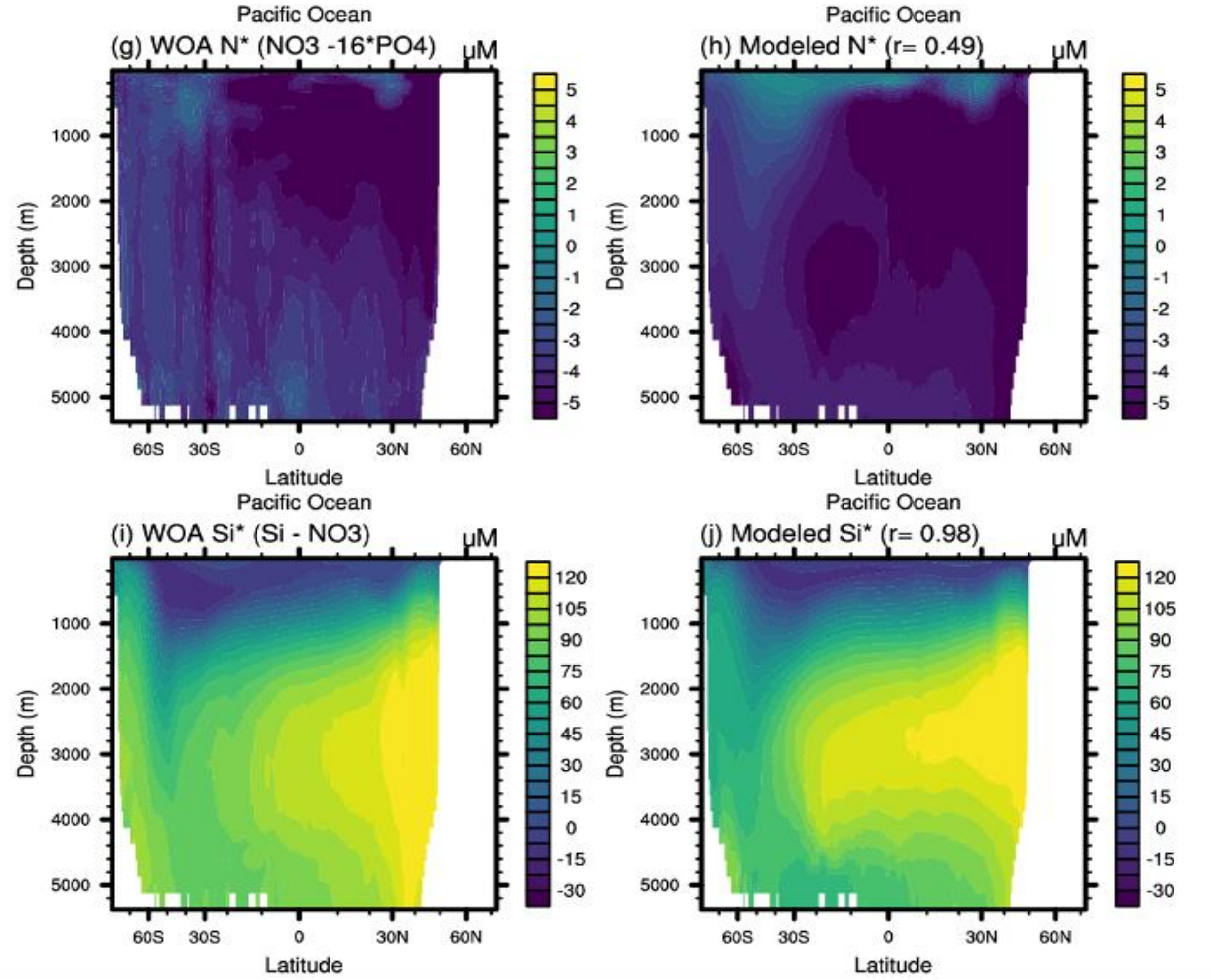
Obs vs. model, nutrients vertical distribution



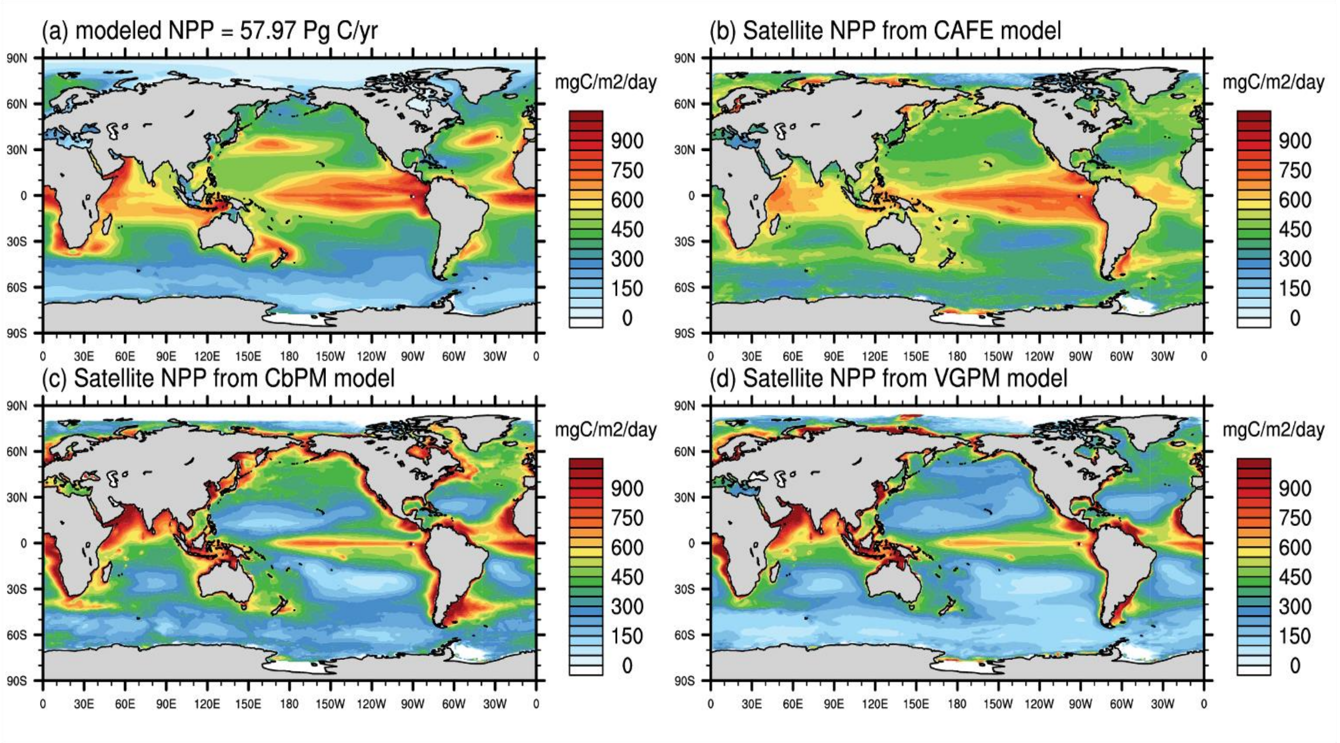


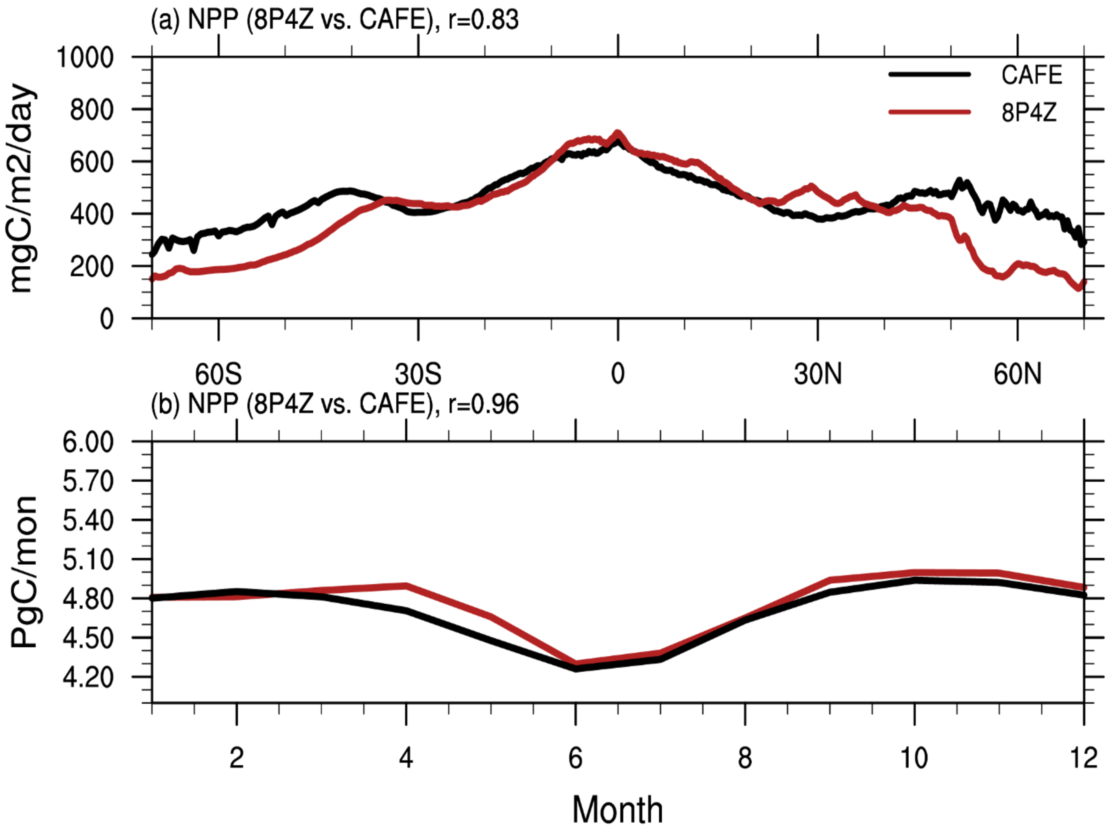
Obs vs. model, nutrients vertical distribution



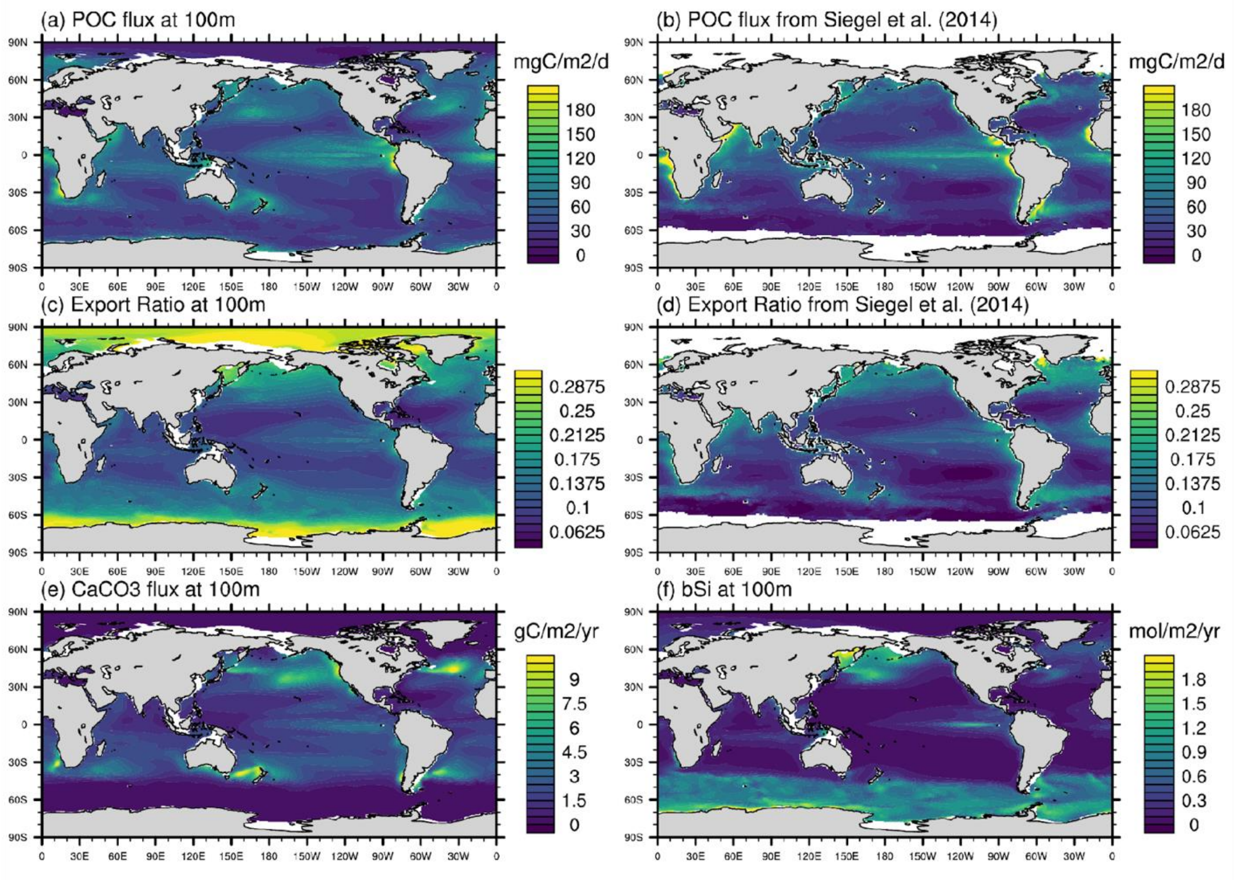


Model performance: key fluxes



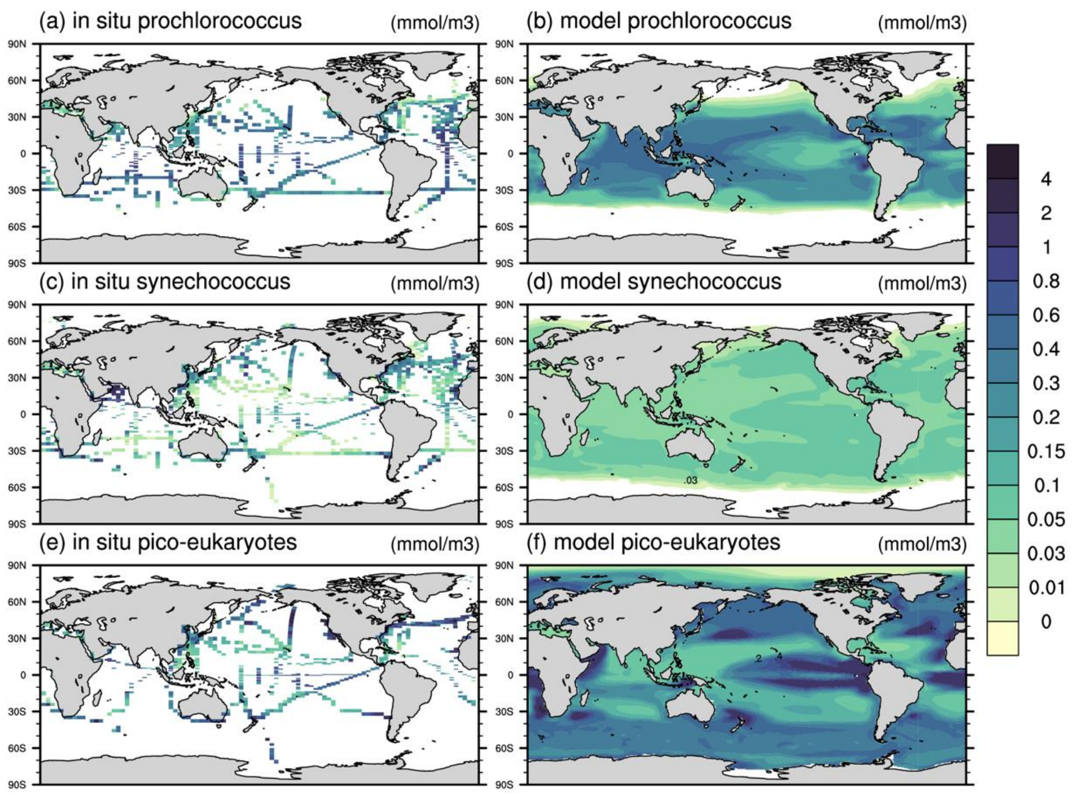


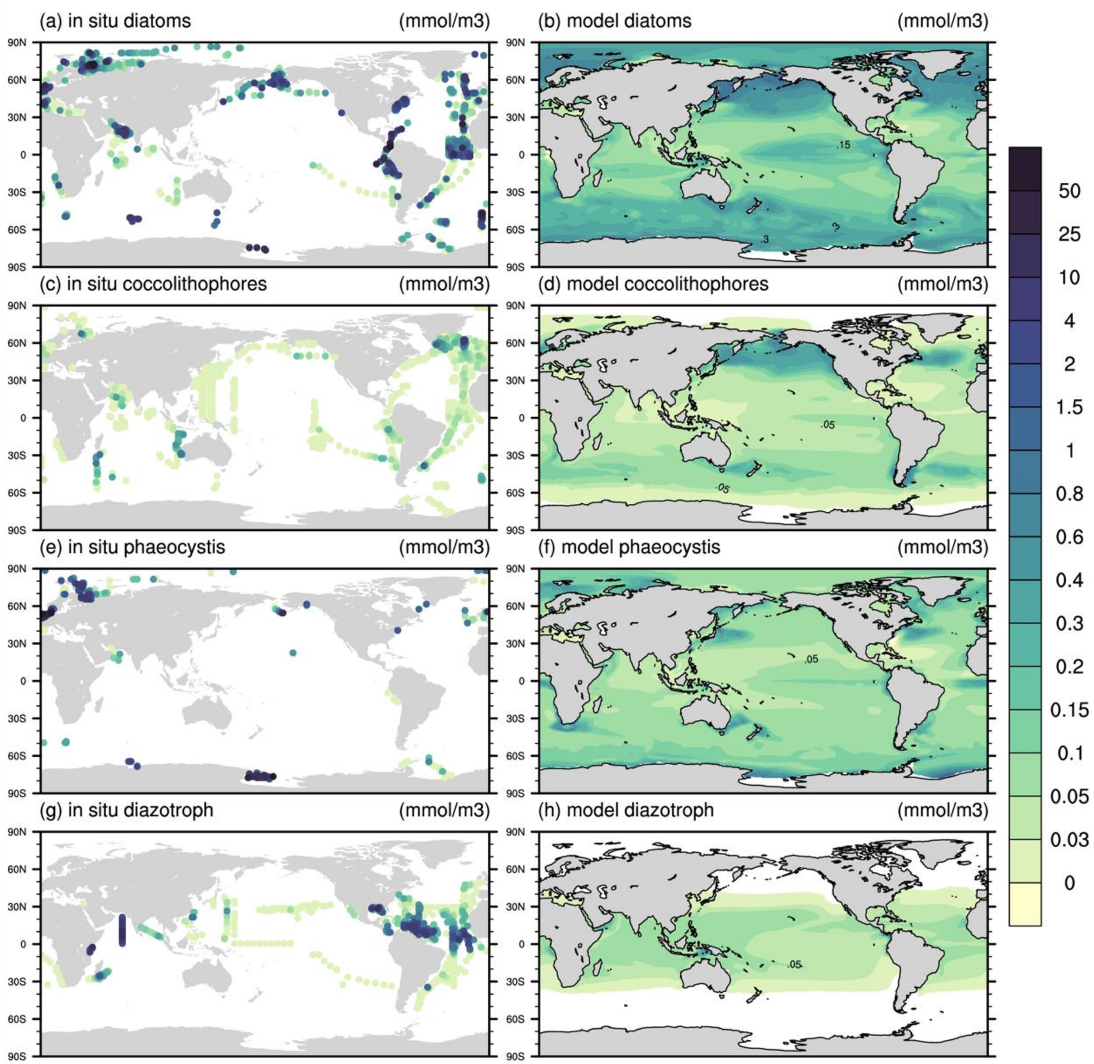
Model performance: key fluxes



Key fluxes	Unit	8P4Z	Observations	Reference
NPP	PgC/year	58.0	52.9 ± 9.1	Doney et al. (2024)
N-fixation	TgN/year	218	223±30 126-223	Shao et al. (2023) Wang et al. (2019)
POC flux at 100m	PgC/year	6.86	8.2 ± 2.78 5-12 7.28 ± 0.06	Doney et al. (2024) Emerson (2014) Wang et al. (2023)
Global mean E-ratio at 100m		0.147	0.196 ± 0.106	Doney et al. (2024)
$CaCO_3$ flux at 100m	PgC/year	0.64	0.7-4.7	Liang et al. (2023) and Ziveri et al. (2023) and refs therein
Si flux at 100m	Tmol Si/year	109	88-122	Tréguer and De La Rocha (2013)

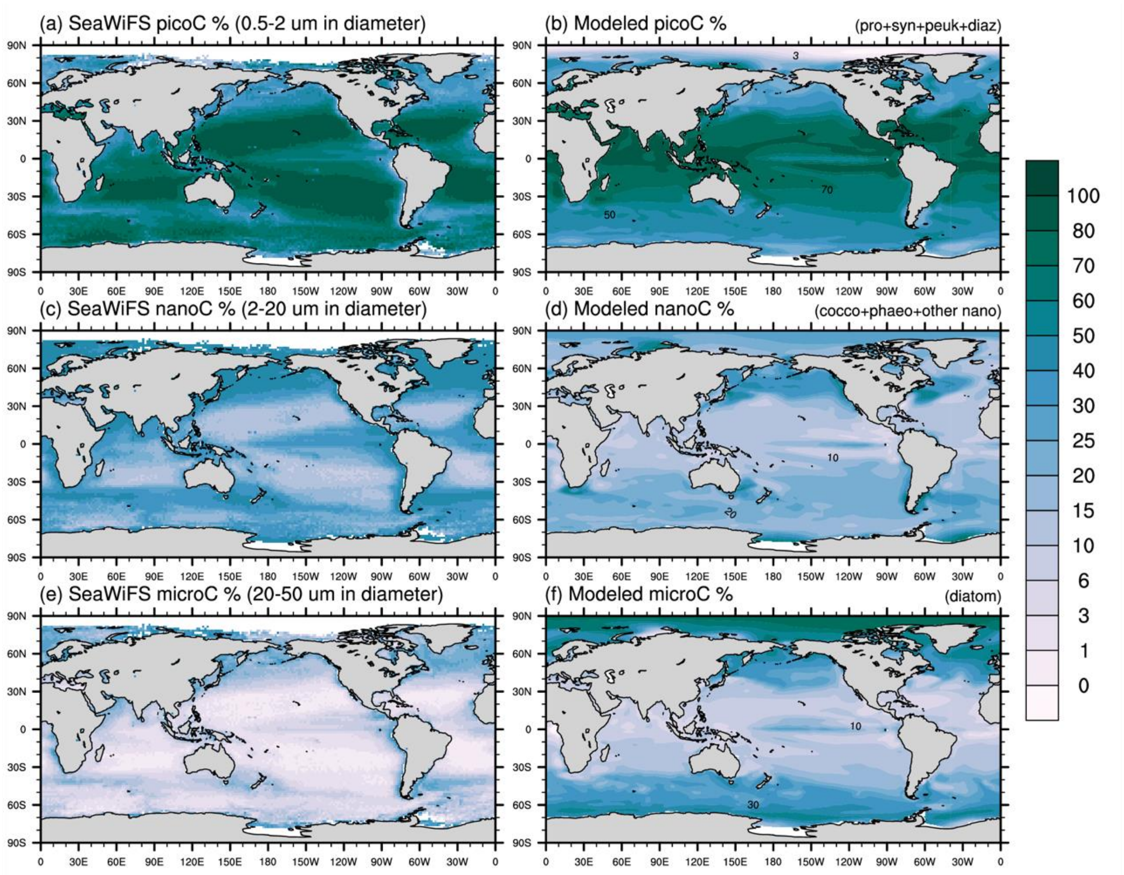
Phytoplankton biomass

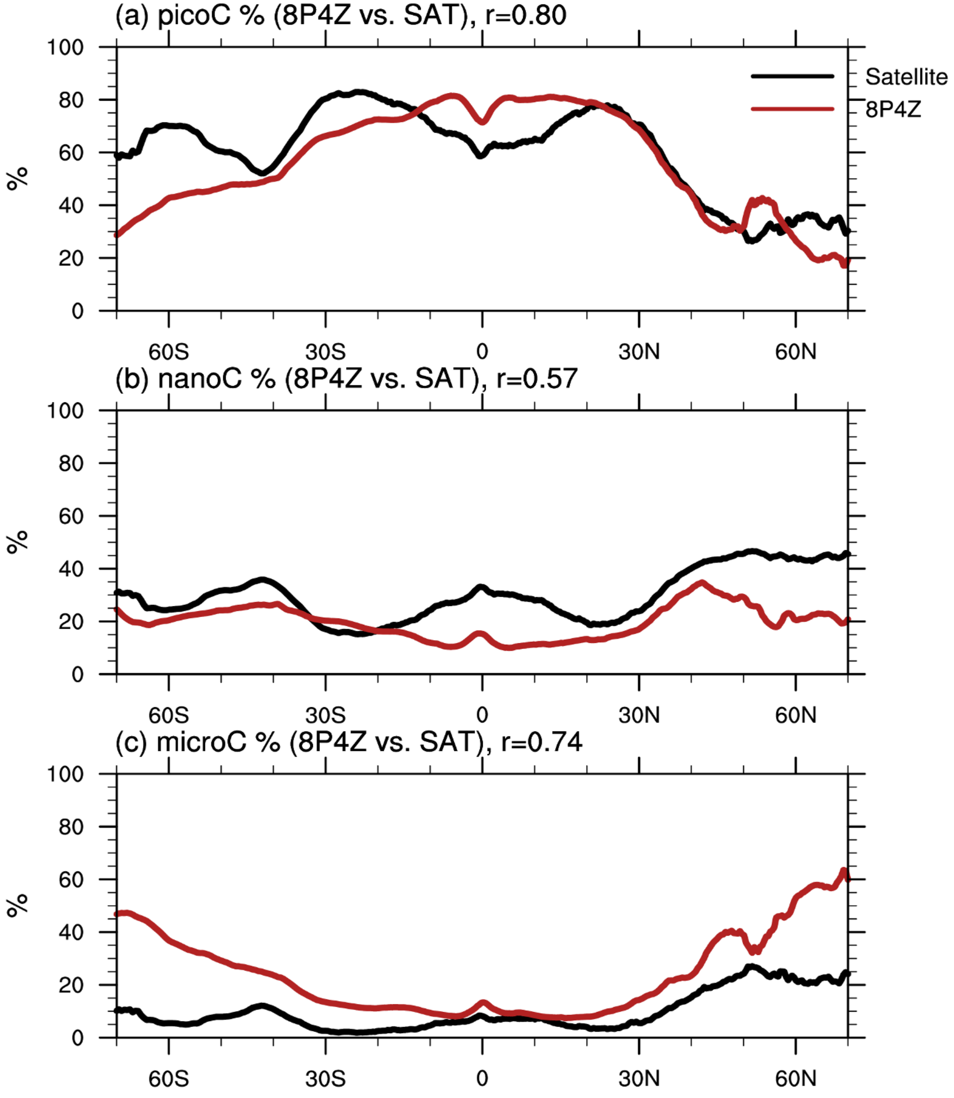




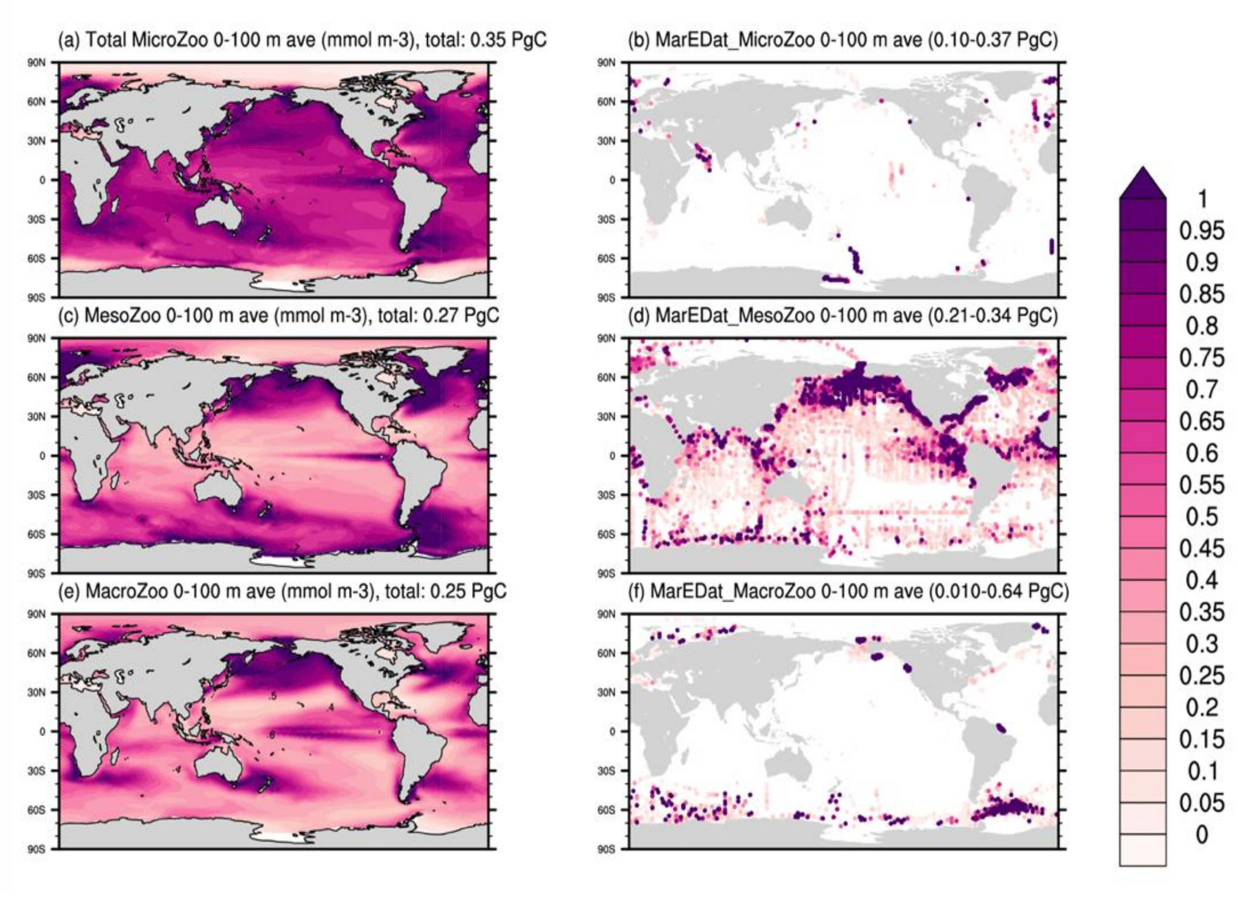
- ❖ MAREDAT dataset faces considerable uncertainties related to cell counts, unidentified species, and conversions of cell abundance to biomass, thus carbon conversion estimates are susceptible to large errors if cell size is not accurately assessed.

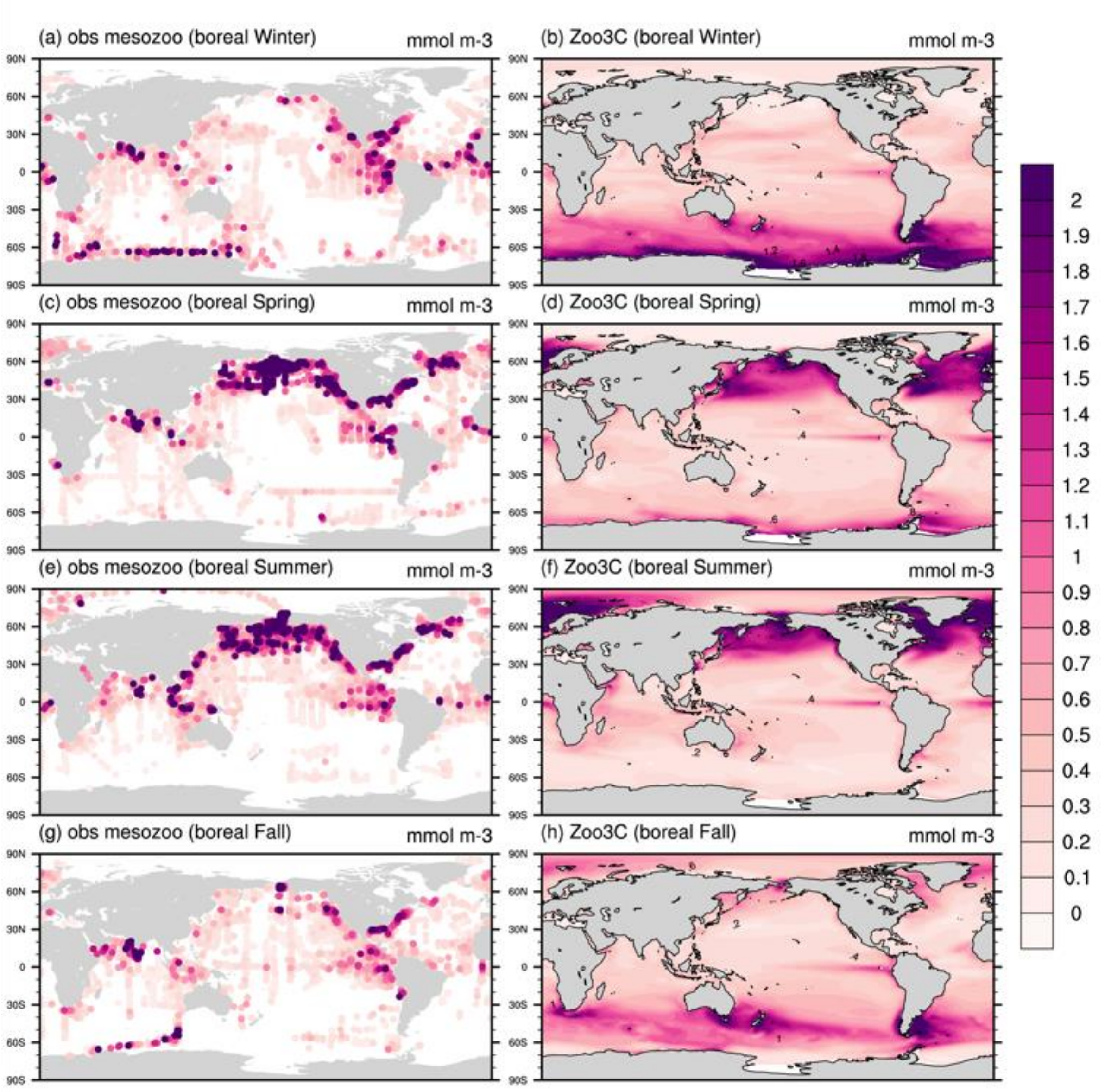
Satellite vs. modeled biomass





Zooplankton biomass





Modeled energy flow

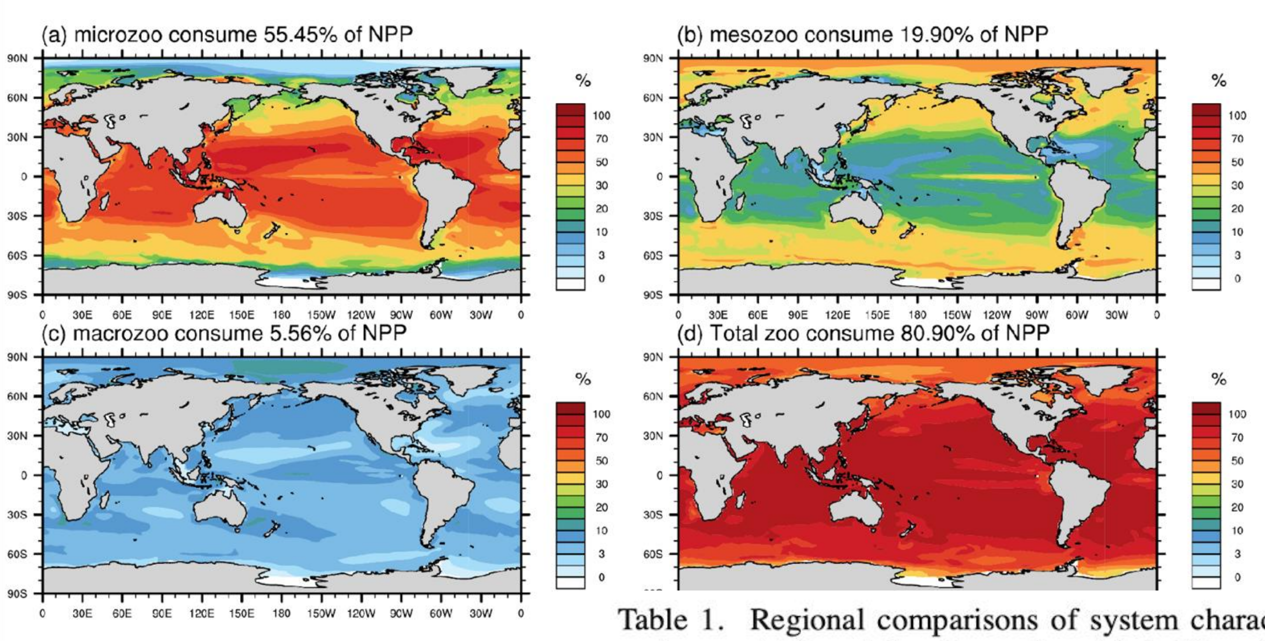
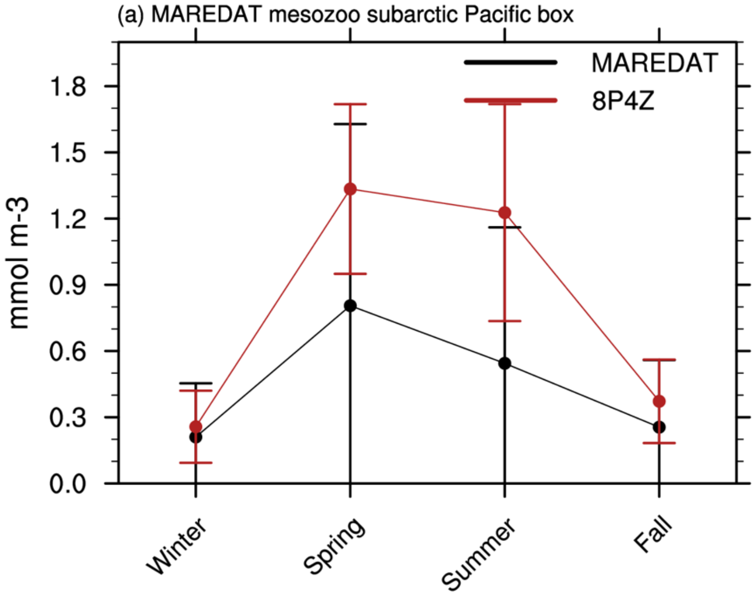


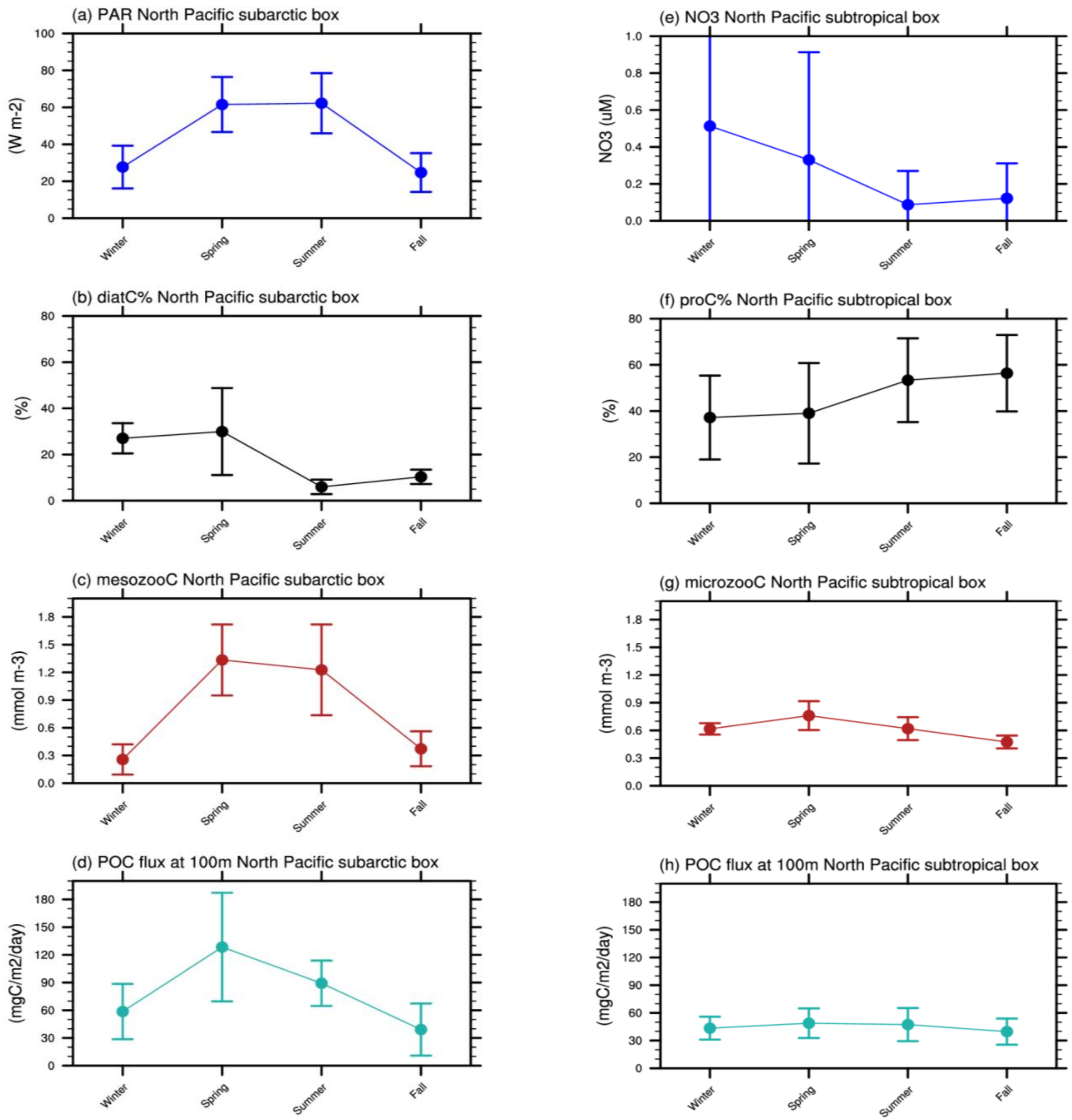
Table 1. Regional comparisons of system characteristics from the full data set of dilution experiments. Data are distinguished among oceanic, coastal (overlying the continental shelf), and estuarine habitats in the upper table and among tropical/subtropical, temperate/subpolar, and polar habitats in the lower table. Mean values (± standard errors) are given for initial Chl *a*, phytoplankton growth rate (μg), grazing mortality (m), % Chl *a* grazed day^{-1}, and % primary production (PP) grazed day^{-1}. Growth and mortality rate averages are significantly different among zones and climates ($p < 0.05$, Tukey–Kramer test), except for oceanic and coastal (μm and m), and for tropical and temperature (μ).

	Chl *a* (μg L^{-1})	μ (day^{-1})	m (day^{-1})	% Chl *a* grazed	% PP grazed
Oceanic	0.58±0.03	0.59±0.02	0.39±0.01	41.5±1.4	69.6±1.5
Coastal	3.06±0.53	0.67±0.05	0.40±0.04	47.3±4.4	59.9±3.3
Estuarine	13.0±1.8	0.97±0.07	0.53±0.04	78.7∓7.3	59.7±2.7
Tropical	1.01±0.21	0.72±0.02	0.50±0.02	55.1±2.3	74.5±2.0
Temperate	5.18±0.66	0.69±0.03	0.41±0.02	51.4±2.9	60.8±1.8
Polar	0.62±0.06	0.44±0.05	0.16±0.01	19.5±2.1	59.2±3.3

(Calbet and Landry, 2004)

Potential for capturing future ecological shift





Conclusions

- We developed a next-generation marine biogeochemical model with an expanded ecosystem in CESM2-MARBL, with the ability to model key species observed in the ocean;

- The 8P4Z model generally reproduces the observed phytoplankton and zooplankton community composition, with a good performance of simulating broad biogeochemical fields;

- The 8P4Z model simulates reasonable energy transfer through the food web, with the potential to capture future ecological shifts that drives the marine biogeochemistry.