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Supplement of

Marine biogeochemical cycling and oceanic CO_2 uptake simulated by the NUIST Earth System Model version 3 (NESM v3)

Yifei Dai et al.

Correspondence to: Long Cao (longcao@zju.edu.cn)

S1. Latitude-dependent vertical diffusivity (VD) parameterization scheme

If latitude is among 5 °S and 5 °N, the VD is computed as follow:

$$\mathrm{VD} = \mathrm{abs(latitude)} \times 0.022 + 0.01$$

Where VD represents the vertical diffusivity, the unit of VD is cm^2/s. abs(latitude) represents the absolute value of latitude.

If latitude is among 23.9 °N and 33.9 °N, the VD is computed as follow:

$$\mathrm{VD} = -\mathrm{abs}(28.9 - \mathrm{latitude}) \times 0.066 + 0.5$$

If latitude is among 23.9 °S and 33.9 °S, the VD is computed as follow:

$$\mathrm{VD} = -\mathrm{abs}(28.9 + \mathrm{latitude}) \times 0.036 + 0.3$$

In the north of 33.9 °N, the VD is constant value of 0.17 cm^2/s.

In the rest oceans, the VD is constant value of 0.12 cm^2/s

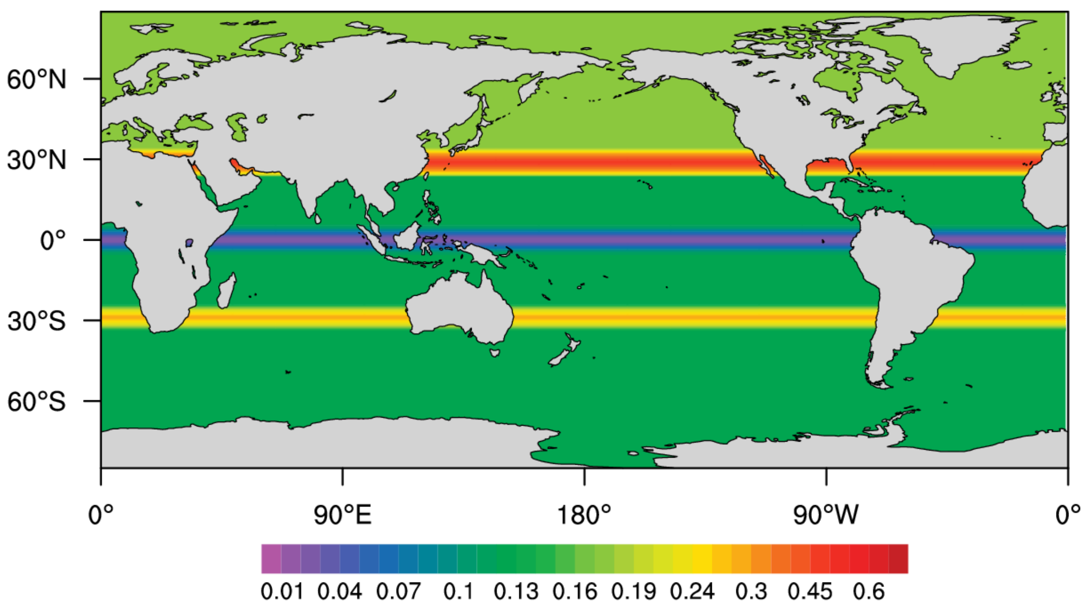

Figure S1. Latitude-dependent vertical diffusivity distribution (in unit of $cm^2\ s^{-1}$).

S2. Comparisons of nutrients, alkalinity, DIC, and chlorophyll in the NESM v3 and IPSL-CM5A-LR

Data

The data in this supplementary for both IPSL-CM5A-LR and NESM v3 is derived from the PI experiment. The data of IPSL-CM5A-LR can be accessed at: https://esgf-node.llnl.gov/search/cmip5.

Results

In this supplementary material, we present some preliminary results of comparisons between the NESM v3 and IPSL-CM5A-LR simulated biogeochemical fields.

In the NESM v3 and IPSL-CM5A-LR, the spatial patterns of nutrients, alkalinity, DIC, and chlorophyll is basically consistent. The PCCs of these fields are very high and the SDRs are close to 1.0. However, the global average concentrations of nutrients, alkalinity, and DIC in the two models vary widely (Table S1).

In the NESM v3 simulation, the nutrient concentration is about 20% higher, and the alkalinity and DIC are about 15% lower (Fig. S2 and Fig. S4). More nutrients in favor of phytoplankton growth, especially in the middle low latitude where the growth rate of phytoplankton is mainly limited by nutrients concentration (Fig. S6). Higher nutrient concentrations may be caused by either strong upper-ocean mixing or weak biological activities. To understand this problem, further research is needed.

The alkalinity and DIC concentration have an effect on both biology activities and chemical conditions. Low alkalinity concentration can reduce the pCO_2, while low DIC can increase the oceanic pCO_2. Their effects on oceanic carbon uptake may be neutralized to some extent.

The NESM v3 and IPSL-CM5A-LR show the same problem in simulating deep-ocean nutrients and DIC in the Northern Pacific, i.e., too higher concentrations. The deep-sea alkalinity in the North Pacific is also overestimated in the NESM v3, while the IPSL-CM5A-LR produce an illogical vertical pattern of alkalinity (Fig. S5).

We are not trying to identify the major cause of the difference between the two models or to tell which model is better, so we don’t give an in-depth analysis in this supplement. We hope that this supplement can give us a basic understanding of the simulation performance of the two models, i.e., disagreements and agreements between the two models.

How does the biogeochemical cycle respond to different physical components and parameterizations in the two models? This question is very interesting but beyond the scope of this study and deserve for a further investigation in future.

Table S1. Pattern correlation coefficients (PCC) and standardized deviation ratio (SDR: NESM / IPSL) of the upper ocean mean nutrients, alkalinity, dissolved inorganic carbon, and chlorophyll between NESM v3 and IPSL-CM5A-LR. The table also shows the upper ocean mean value of these biogeochemical fields.

	Phosphate	Nitrate	Silicate	Alkalinity	DIC	Chlorophyll
PCC	0.94	0.95	0.92	0.82	0.92	0.82
SDR	1.07	1.16	1.09	0.85	1.16	0.96
Global mean (NESM; IPSL)	0.59;0.45	8.6;5.8	13.01;11.50	2159;2404	1905;2111	0.25;0.23

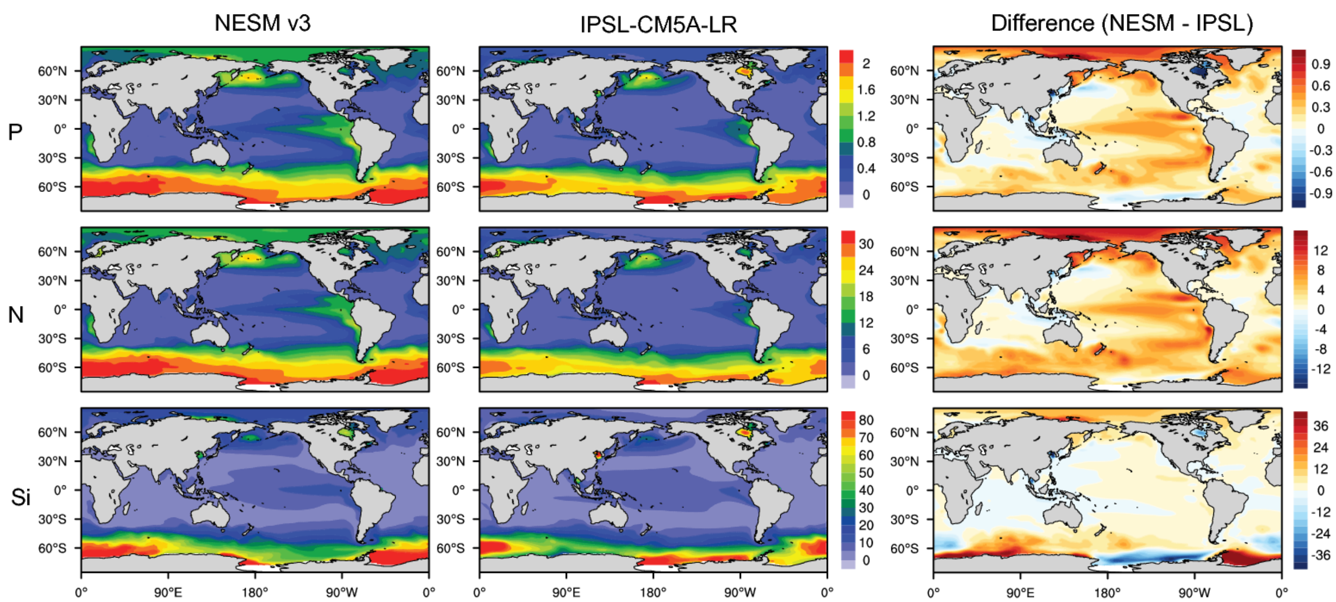

Figure S2. Annual mean upper ocean (averaged in the upper 100m) distribution of phosphate (PO_4^{3-}), nitrate (NO_3^-), and silicate (SiO_4^{2-}) from the PI-experiment of NESM v3 and IPSL-CM5A-LR.

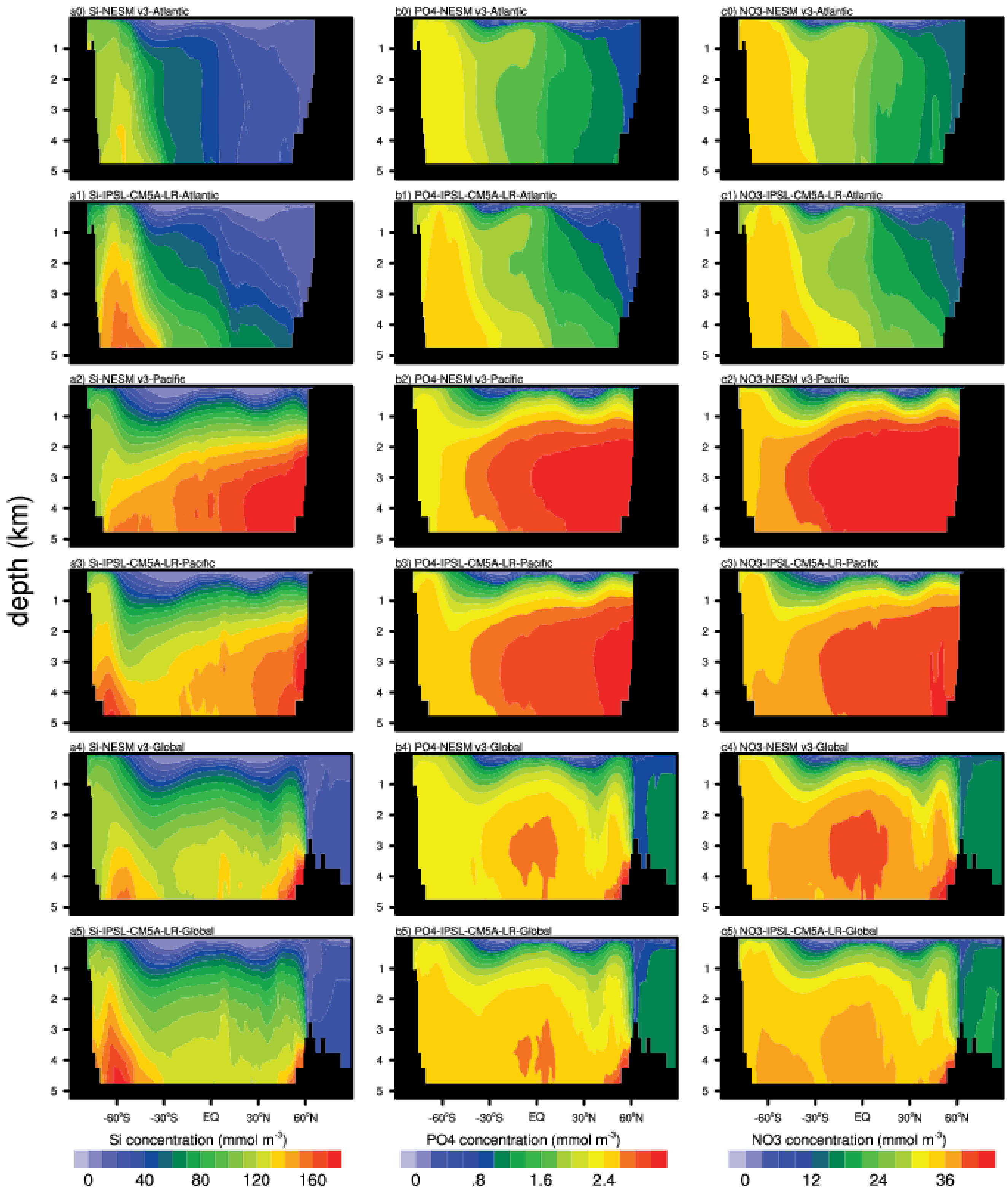

Figure S3. The latitude-depth distribution of silicate (a), phosphate (b), and nitrate (c) from the PI-experiment of NESM v3 and IPSL-CM5A-LR (with a unit of mmol m^{-3}).

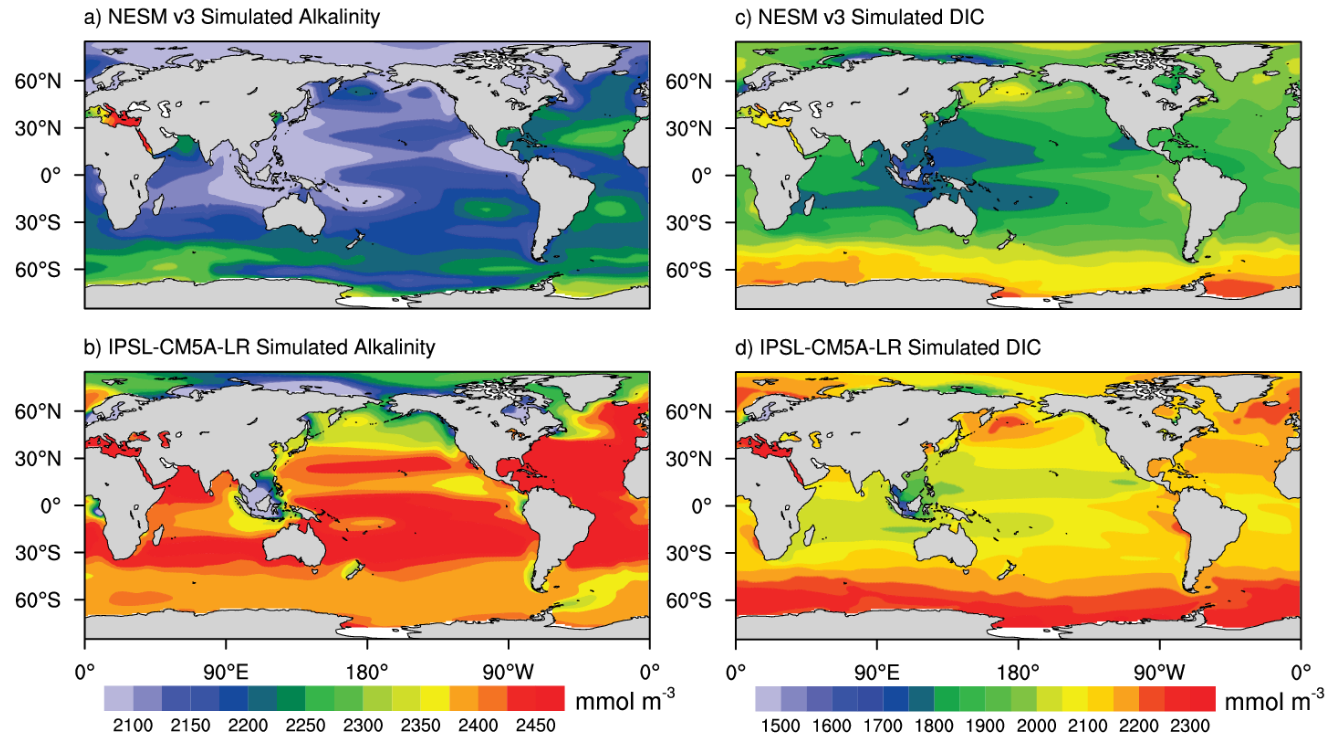

Figure S4. Annual mean distributions of upper ocean mean (0-100m) alkalinity (mmol m^{-3}) (a, b) and DIC (mol m^{-3}) (c, d) from the PI-experiment of NESM v3 (a, c) and IPSL-CM5A-LR (b, d).

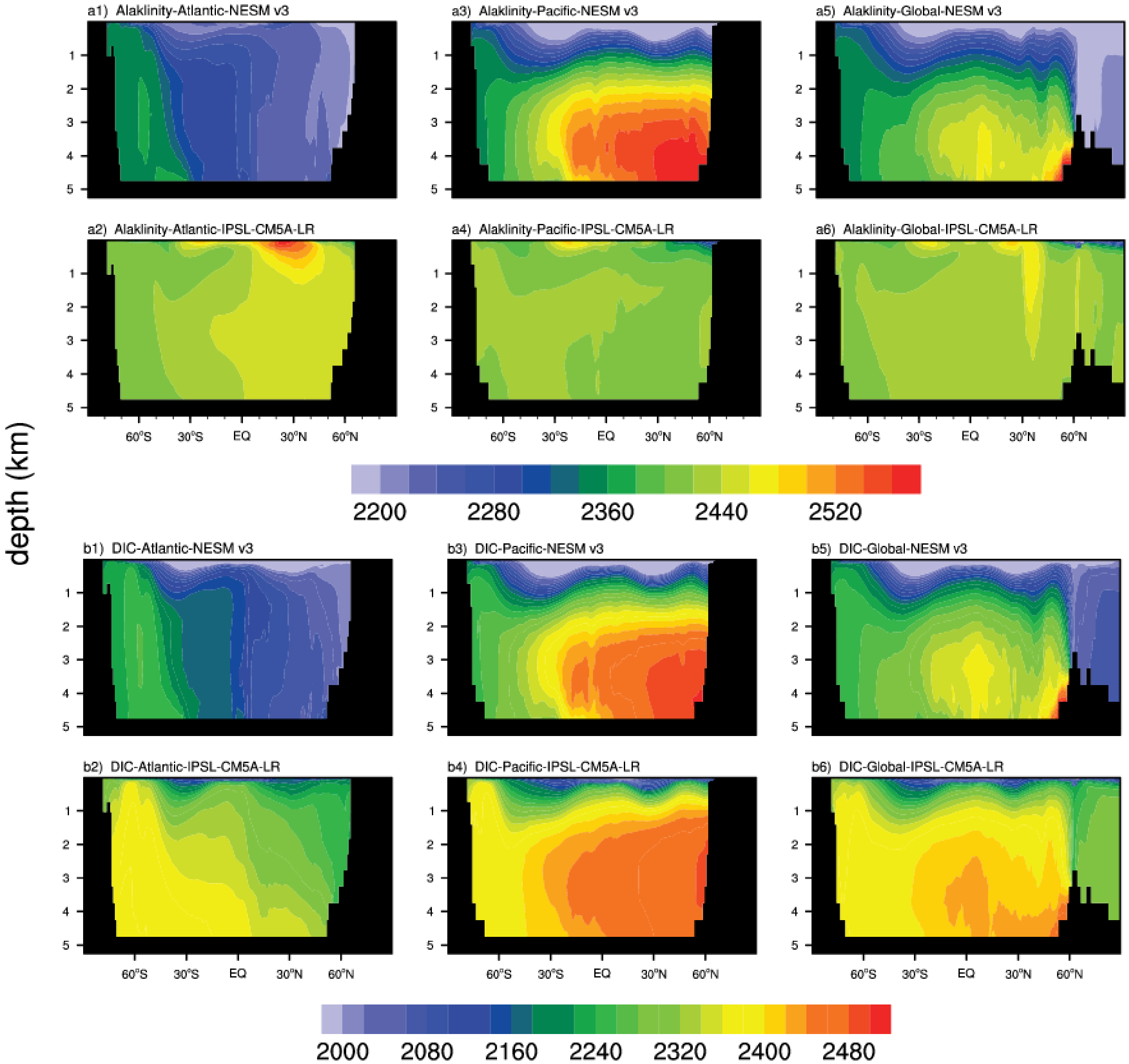

Figure S5. The latitude-depth distribution of alkalinity and DIC from the PI-experiment of NESM v3 and IPSL-CM5A-LR (with a unit of mmol m^{-3}).

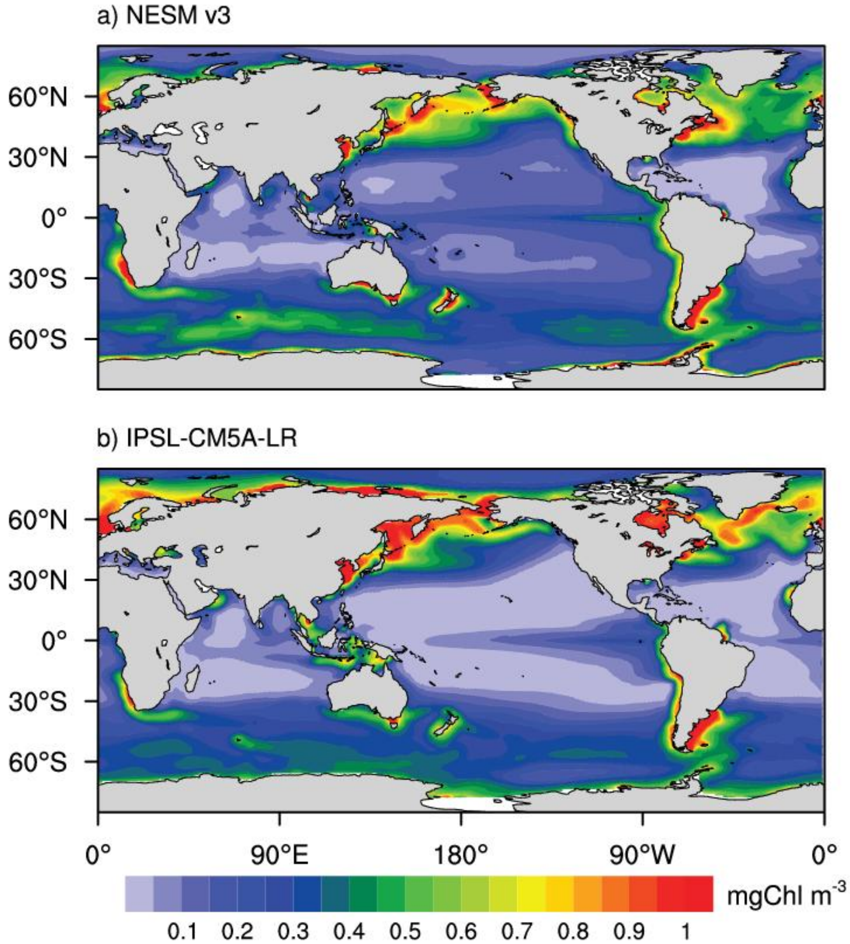

Figure S6. Annual mean upper ocean (0-50m) chlorophyll concentration (mg Chl m^{-3}) climatology from PI-experiment of the NESM v3 (a) and IPSL-CM5A-LR (b).