Supplemental material submitted for the paper

# The importance of ocean transport in the fate of anthropogenic $CO_2$

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## Introduction:

This supplemental material includes one table and two figures. Table S1 compares parameter values used in three versions of the GENIE-1 model. Figure S1 shows the effect of vertical diffusivity, vertical resolution, and seasonality on modeled oceanic uptake of anthropogenic $CO_2$. Figure S2 shows the effect of marine biology on modeled oceanic uptake of anthropogenic $CO_2$.

**Table S1**. Controlling parameters in different versions of the GENIE-1 model.

| Parameter Name | GENIE8 | GENIE16 | MESMO | Parameter description and units |
|---|---|---|---|---|
| Ocean physics [a] | | | | |
| $W$ | 1.93 | 1.531 | 2.208 | Wind-scale |
| $\kappa_h$ | 4489 | 1494 | 4467 | Isopycnal diffusion ($m^2$ $s^{-1}$) |
| $\kappa_v$ | 0.27 | 0.25 | 0.1 to1.2 | Diapycnal diffusion ($cm^2$ $s^{-1}$) |
| $\lambda$ | 2.94 | 2.71 | 2.21 | 1/friction (days) |
| Atmosphere physics [a] | | | | |
| $k_T$ | $4.67\times10^6$ | $5.20\times10^6$ | $3.27\times10^6$ | T diffusion amplitude ($m^2$ $s^{-1}$) |
| $l_d$ | 1.08 | 1.41 | 0.979 | T diffusion width (Radians) |
| $s_d$ | 0.06 | 0.09 | 0.1700 | T diffusion slope |
| $\kappa_q$ | $1.10\times10^6$ | $1.17\times10^6$ | $1.70\times10^6$ | Q diffusion ($m^2$ $s^{-1}$) |
| $\beta_T$ | 0.11 | 0.0010 | 0.0023 | T advection coefficient |
| $\beta_q$ | 0.23 | 0.165 | 0.23 | Q diffusion coefficient |
| $F_a$ | 0.23 | 0.73 | 0.36 | FW flux factor (Sv) |
| Sea-ice physics [a] | | | | |
| $\kappa_{hi}$ | 6200 | 3574 | 5579 | Sea-ice diffusion ($m^2$ $s^{-1}$) |
| Ocean biogeochemistry [b] | | | | |
| $u_0^{PO_4}$ | 1.96 | 8.99 | 1.91 | maximum $PO_4$ uptake rate ($\mu$mol kg-1 $yr^{-1}$) |
| $K^{PO_4}$ | 0.22 | 0.89 | 0.21 | $PO_4$ half-saturation concentration ($\mu$mol $kg^{-1}$) |
| $r^{POC}$ | 0.065 | 0.056 | 0.055 | partitioning of POC export into fraction #2 |
| $l^{POC}$ | 550 | 590 | *variable* | *e*-folding depth of POC fraction #1 (m) |
| $l_2^{POC}$ | ∞ | ∞ | ∞ | *e*-folding depth of POC fraction #2 (m) |
| $r_0^{CaCO_3:POC}$ | 0.044 | 0.048 | 0.046 | $CaCO_3$:POC export 'rain ratio' scalar [c] |
| $\eta$ | 0.81 | 0.77 | 1.28 | calcification rate power |
| $r^{CaCO_3}$ | 0. 4325 [d] | 0.45 [d] | 0.49 | partitioning of $CaCO_3$ export into fraction #2 |
| $l^{CaCO_3}$ | 1083 | 1890 | *variable* | *e*-folding depth of $CaCO_3$ fraction #1 (m) |
| $l_2^{CaCO_3}$ | ∞ | ∞ | ∞ | *e*-folding depth of $CaCO_3$ fraction #2 (m) |

[a] See: Edwards and Marsh (2005); Hargreaves et al. (2004); Ridgwell et al. (2007a); Singarayer et al. (2008), Matsumoto (2008)

[b] See: Ridgwell et al. (2007a,b); Ridgwell and Hargreaves (2007).

[c] Note that the rain ratio scalar parameter is not the same as the actual $CaCO_3$:POC export rain ratio because it is multiplied by $(\Omega - 1)^\eta$ where $\Omega$ is the surface ocean saturation state (with respect to calcite), as described in Ridgwell et al. (2007a,b). Pre-industrial mean ocean surface $\Omega$ is ~5.2 in the GENIE-1 model, so that the global $CaCO_3$:POC export rain ratio can be estimated using the 8-parameter assimilation [d] as being equal to $(5.2 - 1)^{0.81} \times 0.044 = 0.14$.

[d] Adjusted compared to formal calibration in order to achieve an improved prediction of mean sediment surface wt% $CaCO_3$ compared to observations (Ridgwell and Hargreaves, 2007).

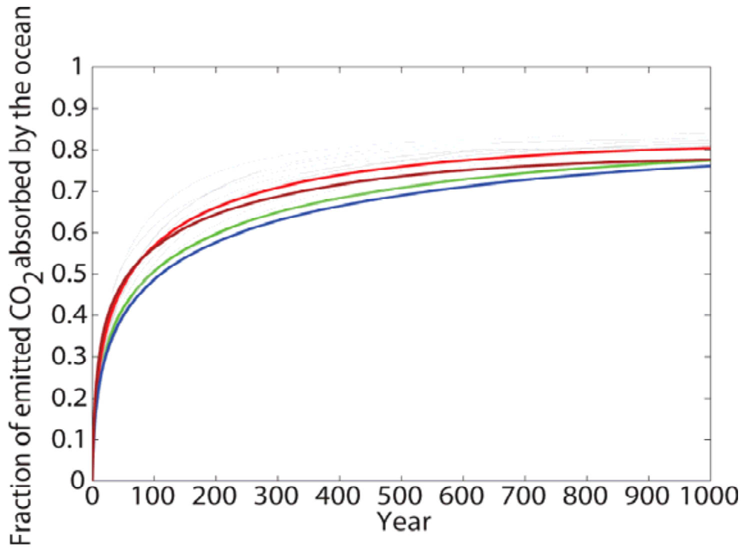


**Fig. S1.** Model-simulated oceanic uptake of $CO_2$ in response to a $CO_2$ pulse emission of 590.2 PgC (corresponding to an instantaneous doubling of atmospheric $CO_2$ from 278 to 556 ppm). Results from different runs using the GENIE16 model are shown: GENIE16 base run as shown in Fig. 1 (green), GENIE16 run with vertical diffusivity doubled from 0.25 to 0.5 $cm^{-2}\ s^{-1}$ (red), GENIE16 run with vertical resolution reduced from 16 to 8 levels (brown), GENIE16 run with the seasonal cycle removed (blue). Other model results as shown in Fig. 1 are presented here by grey lines.

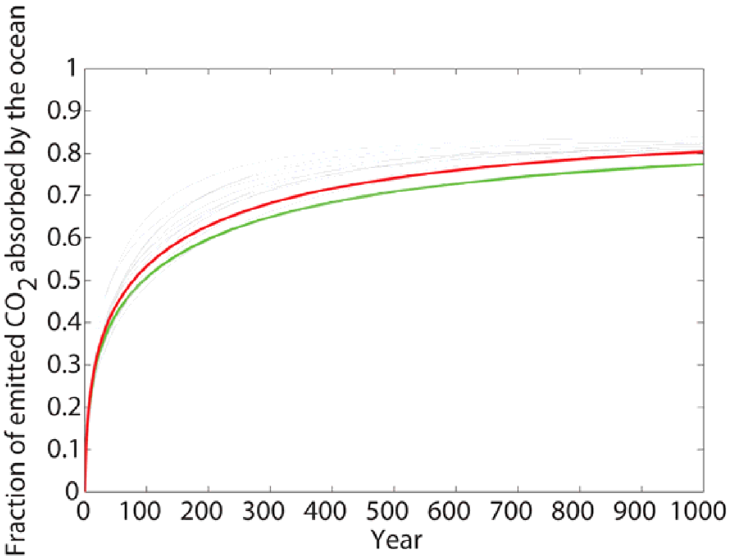


**Fig. S2.** Model-simulated oceanic uptake of $CO_2$ in response to a $CO_2$ pulse emission of 590.2 PgC (corresponding to an instantaneous doubling of atmospheric $CO_2$ from 278 to 556 ppm). Results from two different runs using the GENIE16 model are shown: GENIE16 base run as shown in Fig. 1 (green), GENIE16 run without the inclusion of marine biology (red). Other model results as shown in Fig. 1 are presented here by grey lines. The abiotic run absorbs more excess $CO_2$ than the biotic run because during model spinup the removal of marine biology leads to higher surface alkalinity (a global mean value of 2361.9 µmole/kg in abiotic run compared with 2271.5 µmole/kg in biotic run). Higher surface alkalinity leads to greater buffering capacity of the ocean to absorb excess $CO_2$.

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