



Supporting Online Material for

Carbon Emissions and Acidification

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Figs. S1 and S2

References

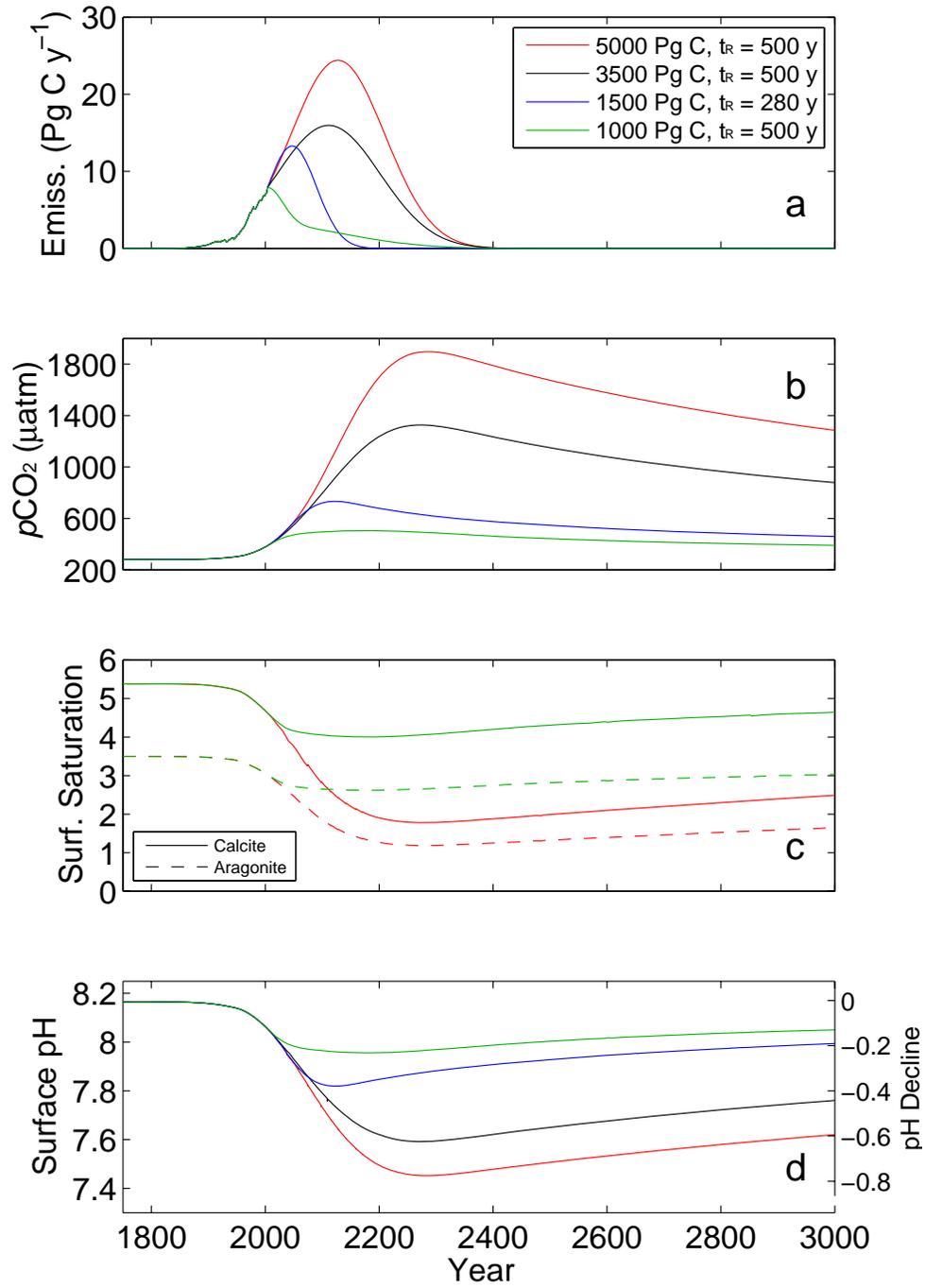


Fig. S1

Fig. S1: (a) Anthropogenic CO₂ emission scenarios (t_R = release time) and response of (b) atmospheric CO₂ (c) surface ocean saturation state of CaCO₃ mineral phases (d) surface ocean pH and pH decline. The projections were obtained using a carbon-cycle reservoir model coupled to a sediment module (1–3) and agree well with the results of other types of carbon-cycle models over the next few centuries (4–6). The estimated maximum pH decline displayed here is slightly smaller (more conservative) than in previous studies (4–6) because buffering by CaCO₃ sediment dissolution and weathering feedbacks have been taken into account (3). All scenarios are based on historic emission data with total emissions of 315 Pg C until year 2004 (7) and projected future emissions that match the prescribed total emissions and release time. Future emission curves in (a) are based on a single (or the sum of two) Gaussian function(s).

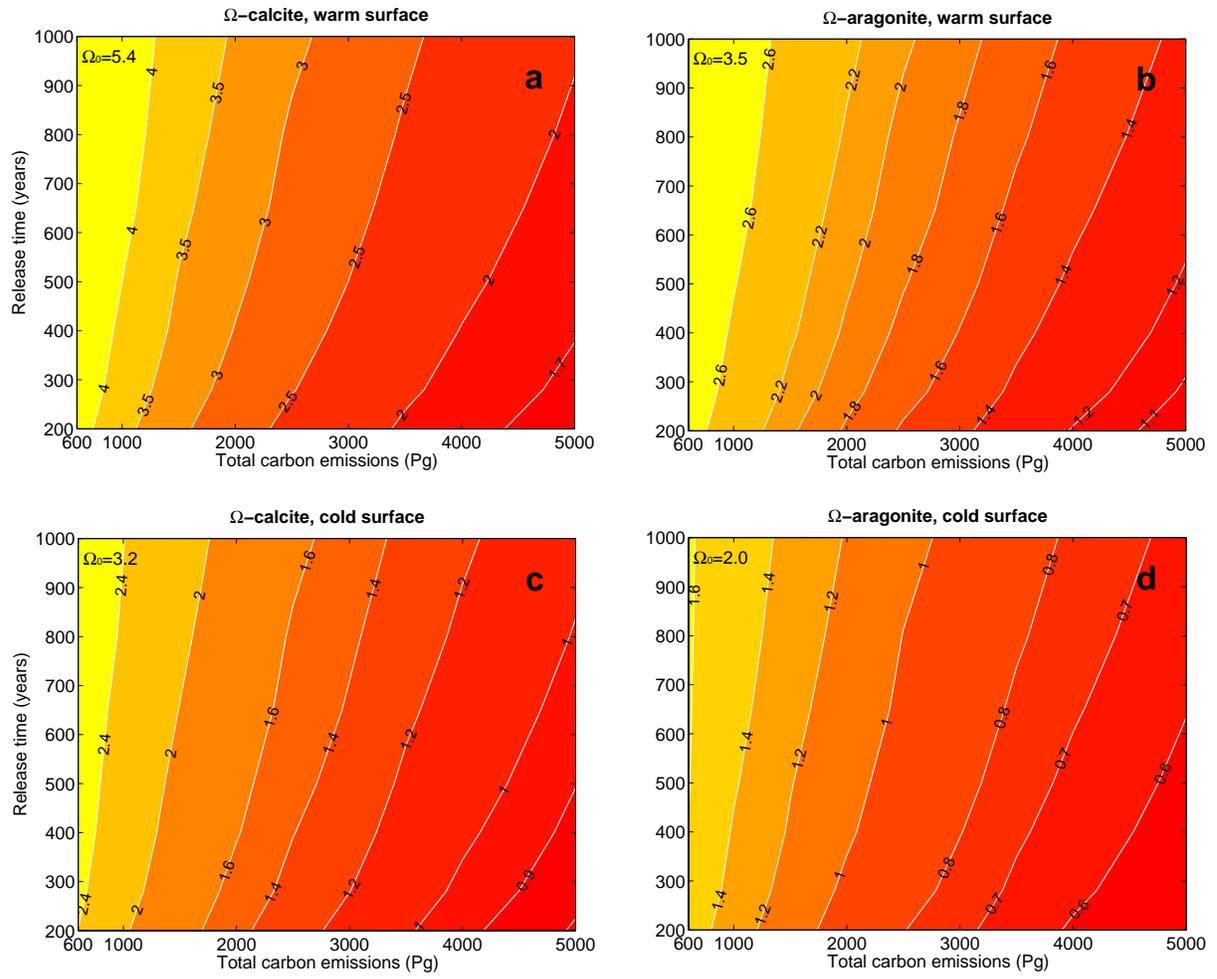


Fig. S2

Fig. S2: Expected maximum decline of calcite and aragonite saturation state (Ω) in the warm (a,b) and cold (c,d) surface ocean corresponding to carbon emissions, release times, and pH changes as illustrated in the primary figure of the article. The saturation state Ω is given by $\Omega = [\text{CO}_3^{2-}]_{\text{sw}} \times [\text{Ca}^{2+}]_{\text{sw}} / K_{\text{sp}}^*$, where 'sw' refers to seawater concentrations and K_{sp}^* is the solubility product of calcite or aragonite at *in situ* conditions of temperature, salinity, and pressure [see (8) and references therein]. Warm and cold surface ocean conditions refer to initial (pre-industrial) seawater temperatures of 20°C and 2°C, respectively. The corresponding initial saturation state values are indicated by Ω_0 (upper left).

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References

1. Walker, J. C. G., and J. F. Kasting, *Palaeogeogr. Palaeoclim. Palaeoecology* **97**, 151 (1992).
2. Zeebe, R. E. and J. C. Zachos, *Paleoceanogr.* **22**, PA3201, doi:10.1029/2006PA001395 (2007).
3. Zachos, J. C., G. R. Dickens, and R. E. Zeebe, *Nature* **451**, 279 (2008).
4. Caldeira, K. and M. E. Wickett, *Nature* **425**, 365 (2003).
5. Orr, J. C. et al., *Nature* **437**, 681 (2005).
6. Montenegro, A., V. Brovkin, M. Eby, D. Archer, and A. J. Weaver, *Geophys. Res. Lett.* **34**, L19707, doi:10.1029/2007GL030905 (2007).
7. Marland, G., T. A. Boden, and R. J. Andres, *Global, regional, and national CO2 emissions*, CDIAC, ORNL, U.S. DOE (2007).
8. Zeebe, R. E. and D. A. Wolf-Gladrow, *CO2 in Seawater: Equilibrium, Kinetics, Isotopes* (Elsevier Oceanography Series, Amsterdam, pp. 346, 2001).