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SCION 2.0: A new biogeochemical model for investigating atmosphere and ocean oxygenation across the Phanerozoic

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The chemical composition of Earth's atmosphere and oceans has changed significantly throughout its 4.5-billion-year history, in the process affecting its capability to host complex life [1]. However, the main drivers behind the various chemical changes and their relative importance to eliciting fluctuations in, for example, oxygen concentrations and climate, are still widely contested.

Numerical model simulations have enhanced our understanding of the evolution of the Earth system, but because of their computational expense trade-offs between spatial and temporal resolution must be made. While 0D box models can explore changes to the Earth over multi-million-year timescales, typically their atmosphere and oceans are combined into a single reservoir [2]. Furthermore, spatially heterogeneous processes (e.g., silicate weathering [3]) are denoted as global averages, thus the extent of their impact on the evolution of Earth's environment and life remains inconclusive. At the other end of the scale, 3D models can explore fine scale Earth system processes, but the computing power and wall time required to run such models means that they are limited to investigating geologically shorter timescales (~ <= 10 million years) [4,5].

Here, we present a spatially-resolved model capable of exploring the various hypothesized mechanisms behind Earth system changes and consequently planetary habitability over multi-million-year timeframes. The work here substantially updates the SCION model [6] by adding a new biogeochemistry framework [7], with terrestrial reservoirs, an atmosphere reservoir and a separate ocean split into five reservoirs, allowing us to explore: abiotic and biotic influences on nutrient cycling in the ocean; the consequent impact on Earth's climate; and both atmosphere and ocean oxygenation during the Phanerozoic.

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