Intermediate atmospheric oxygen levels, ocean ventilation, and global biospheric productivity

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The pervasive ventilation of the oceans marks a critical transition in Earth's history, ushering in the widespread marine environments, fauna, and ecosystem structures that begin to resemble those of the modern day. However, basic patterns and drivers of ocean ventilation and downstream biogeochemical impacts during the late Proterozoic and early Paleozoic remain somewhat obscure. Using an Earth system model of ocean biogeochemistry and climate (CANOPS), we explore the combined levels of atmospheric oxygen and primary productivity that are consistent with stable Earth system states relevant to the Neoproterozoic and early Phanerozoic.

The aims of our analysis are to: (1) place better constraints on the Earth system scaling between rates of biospheric productivity and atmospheric O_2 abundance, and quantify their uncertainty; (2) evaluate allowable benthic redox landscapes in the context of an internally consistent open-system model of marine biogeochemistry; (3) quantify marine nutrient abundance, vertical carbon fluxes, and energy flow to the benthic realm in the late Proterozoic and early Phanerozoic; and (4) generate a suite of geochemical predictions that can be tested against observations from Earth's rock record. To this end, we investigate a range of atmospheric oxygen concentrations consistent with current proxy estimates from the mid-Neoproterozoic to the onset of the charcoal record in the Paleozoic (i.e., 1 – 40% of the present atmospheric level), employing a stochastic approach to invert atmospheric O_2 for levels of biospheric productivity, patterns of ocean ventilation, and large-scale marine biogeochemistry.