Reconstructing the spatial redox structure of anoxic oceans using a 3D ocean-based Earth system model

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Today, oxygen depleted marine environments are limited to oxygen minimum zones, restricted basins and sedimentary pore waters. Before the Phanerozoic Eon (more than 542 million years ago, Ma) however, the global ocean was characterised by extensive anoxic regions. In the absence of oxygen, seawater should become either rich in dissolved ferrous iron (ferruginous) or rich in dissolved sulphide (euxinic). The development of so-called 'redox proxies' in the 1980s allowed, based on the geological record, to infer whether a water column was oxic or euxinic. Further refinements of these redox-proxies in the early 2000s extended this to ferruginous water-column conditions. Today, decades of research has generated a complex picture of spatial and temporal patterns in ancient ocean redox conditions.

Unfortunately, none of the current suite of ocean models explicitely describes anoxic water-column iron cycling. Consequently, there is no numerical model available that is capable of reproducing (and thus falsifying or confirming) the spatial and temporal redox patterns proposed in the literature. Here, we have updated a 3 dimensional ocean-based Earth system model (cGEnIE) with a water-column Fe-S cycle. This model is capable of reproducing complex spatial patterns of oxic, ferruginous and euxinic conditions. We illustrate the applicability and versatility of the cGEnIE model using example model runs of a hypothetical Proterozoic 'shelf-world' and for the end-Permian mass extinction (~251 Ma). We believe that our model description of the anoxic Fe-S cycle in cGEnIE presents a valuable tool to explore spatial patterns in Precambrian redox chemistry, but also during ocean anoxic event in the Phanerozoic, and on hypothetical (extra-terrestrial) worlds.