Sulfate imbalance, climate change and mass extinctions

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Given the widespread acceptance that Earth's long-term surface temperature is regulated by the mutual dependence of silicate weathering and climate on atmospheric CO_2, the root causes of climate change remain unresolved. We show here that some global climate (and oxygenation) events of $>10^5$-yr to $\sim10^7$-yr duration could relate to sulfate cycle imbalance, which can exert a strong control on the long-term carbon cycle through carbonate sedimentation (and pyrite burial). Above steady-state calcium sulfate deposition represents a net transfer of Ca^{2+} ions away from the carbonate carbon sink, which might enhance (or moderate) greenhouse forcing, depending on the precise nature of coincident effects on carbonate speciation in the oceans. Conversely, rapid dissolution of evaporite minerals floods the ocean with Ca^{2+} ions and could drive (or moderate) climate change through excess $CaCO_3$ burial. Depending on the extent of imbalance and nature of background forcings, non-steady state sulfate dynamics could potentially contribute to global climate change by destabilizing the silicate weathering feedback. Sulfate imbalance and emergent feedbacks have largely been overlooked in palaeoclimate studies. However, the approximate coincidence in timing between basin-scale evaporite deposition, mass extinctions and hyperthermal events implies that sulfate imbalance may have helped to determine the timing and severity of mass extinctions by modifying biosphere resilience at vulnerable times in Earth history. This presentation makes a preliminary attempt to consider the complex relationship between sulfate imbalance and climate.