1-D photochemical model predicts oxygen isotope anomalies in early Earth atmospheres

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Atmospheric oxygen and ozone over geological time have been constrained using various geochemical proxies and modelling studies, but ambiguity remains. Triple oxygen isotope measurements from Phanerozoic and Proterozoic rocks (e.g. Crockford et al., 2019) provide a direct record of ancient atmospheric composition, and as such are an exciting novel proxy. The only known source of mass-independent fractionation of oxygen isotopes (O-MIF) on Earth is in the formation of stratospheric ozone. A large positive O-MIF signal is imparted to ozone, while the larger reservoir of oxygen gains a much smaller negative O-MIF signal. These species interact with other gases in the atmosphere, and oxidised end products including nitrate, sulphate and perchlorate can persist in various geological archives such as ice, arid desert soil, and marine evaporites. As a result, the magnitude of the O-MIF signature detected in the geological record could be used to quantify levels of atmospheric ozone (and closely-related molecular oxygen) over certain time intervals. Here we develop a one-dimensional photochemical model to incorporate the three isotopes of oxygen, in order to trace oxygen isotope anomalies from stratospheric ozone through other atmospheric species, and into the geological record. This model, ‘Atmos,’ has been calibrated over 40 years to provide credible estimates of atmospheric composition deviating from the modern. We use the model to show the lowest oxygen levels at which the anomaly can be produced and transferred, putting a potential lower limit on oxygen levels for parts of the Phanerozoic and mid-Proterozoic.

Reference:
