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Photochemical modelling of the climate-redox evolution of the Great Oxidation Event: from a Snowball Earth to a Hot-Moist Greenhouse

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We use an atmospheric one-dimensional photochemical model to investigate the effect of temperature and humidity on the evolution of oxygen and ozone across the Great Oxidation Event (GOE). We model the GOE using fixed surface flux boundary conditions with two scenarios: increasing the oxygen and decreasing the carbon monoxide surface input flux. We find that cold temperatures (<280K) result in oxygen-depleted atmospheres, whereas temperate (280K-310K) and hot (>310K) temperatures result in oxygen-enriched atmospheres after the GOE. Warm and wet climates lead to an increased atmospheric oxidation power through the production of hydrogen oxide radicals, catalyzing the oxidation and depletion of the principal reduced species (methane, carbon monoxide and hydrogen). Consequently, warmer temperatures lead to less oxygen lost through the oxidation of reduced species, resulting in higher oxygen and ozone levels relative to colder temperatures. Therefore, oxygen and ozone can accumulate in the atmosphere faster at warmer temperatures, and the GOE tends to occur at lower oxygen, and higher carbon monoxide, surface input fluxes compared to colder temperatures. However, at temperatures >320K, the abundant water and hydrogen oxide radicals catalyze the depletion of ozone.

The GOE occurred around the same period as the onset of the Snowball Earth Huronian glaciations. Cold climates during the glaciations were probably ended by the build-up of volcanic greenhouse gases in the atmosphere, leading to Hot-Moist Greenhouse climates. Temperature and humidity likely varied extensively from Snowball Earth climates during the glaciations to Hot-Moist Greenhouse climates. Our results show that temperature and humidity exert a strong control on atmospheric chemistry through oxygen, ozone, and hydrogen oxide feedbacks, which has important implications for our understanding of the climate-redox evolution of the GOE.