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Constraints on atmospheric pCO2 during the Great Oxygenation Event inferred from 3-D climate modeling and relevance regarding paleosol studies

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Geologic records suggest that Earth was warm during most of its early history, except for two periods where evidences for regional (2.9 Gyr old; Pongola) and global (2.3 Gyr old; Huronian) glaciations have been identified. In order to constraint the greenhouse CO_2 and CH_4gases concentrations (i.e. pCO_2, pCH_4) required to induce a global glaciation during the Early Proterozoic (2.3 Ga), a set of 3-D simulations accounting for the paleogeography and a reduced solar constant has been performed using the general circulation climate model (GCM) FOAM. Comparison between model outputs and proxies of the 2.4 Ga glaciation allows defining liable climate states as a function of pCO_2 and pCH_4. Our model predicts that Earth can be maintained in an ice-free state while pCO_2 is lower than 4.10^{-2} bar as constrained by paleosol studies (Sheldon, 2006; Rye et al. 1995). Moreover, considering a pCH_4 of 1000 ppmv during the Late Archean (Pavlov, 2001), the required pCO_2 for maintaining ice-free conditions is about $8.4.10^{-3}$ bar, strikingly close to Sheldon (2006) “best guess” estimation ($8.5.10^{-3}$ bar). Assuming that the Great Oxygenation Event is associated with global, we also show that snowball conditions are reached when pCH_4 drops from 1000 to 10 ppmvfor a pCO_2 fixed at $8.4.10^{-3}$bar. Throughout the Paleoproterozoic, maintenance of mild temperate conditions comparable with those observed during the Phanerozoic requires at least 1.6 10^{-2} bar of CO_2 because pCH_4 cannot exceed 100 ppmv in a partially oxidized atmosphere