

Climatic effects of primitive biosphere and reductants supply from the mantle in the Archean Earth system

*Kazumi Ozaki¹

1. Georgia Institute of Technology

Understanding the factors regulating the stability of Earth's early climate in the face of 'faint young Sun' is a central problem in the geosciences and planetary science, with important implications for the long-term maintenance of habitability on Earth and Earth-like planets. This 'Faint Young Sun Paradox', which remains somewhat enigmatic, is further exacerbated by the potential for severely restricted primary productivity by the primitive photosynthetic biosphere. Here, we focus on a novel mechanism for stabilizing the climate system before the advent of oxygenic photosynthesis via a hybrid ecosystem of primitive photosynthetic metabolisms. Our global redox balance model demonstrates that for H₂-based or Fe-based photosynthetic biospheres the electron donor (H₂ and Fe²⁺) fluxes from the solid Earth required to attain warm climate states are extremely high, and may require geophysical conditions that deviate beyond those of the modern or even ancient Earth-such as elevated heat flow and volcanic degassing, lower mantle oxygen fugacity or pervasively ultramafic crustal compositions. However, we also found that the hybrid ecosystem of H₂-based and Fe²⁺-based anoxygenic photoautotrophs yield warm climate solutions at relatively modest H₂/Fe²⁺ fluxes well within those attainable on the Archean Earth system because of a strong nonlinear amplification of Earth's methane cycle. Our results imply an intriguing series of unexplored climate feedbacks within the coupled H-C-Fe cycles, opening entirely new vistas for future work to better understand the evolution of Earth's early climate system and the evolution of habitable planets more broadly.

Keywords: Archean, Faint Young Sun Paradox, Anoxygenic photosynthesis