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Modeling Earth's atmosphere before, during and after the rise in Oxygen

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Abstract

O_2 concentrations have risen from their pre-biotic abundance of about 10^{-12} Present Atmospheric Level (PAL) (Karecha et al. 2005) during the Archean era, up to about 1% by about 2.3 Gyrs ago and may have exceeded 15% PAL by about 2.1 Gyrs (Knoll & Holland, 1995). Understanding the nature of this rise is central to shedding light on the development of life on Earth and is also relevant to the search for atmospheric biomarkers (life-indicating species) on Earth-like exoplanets.

Introduction

Our goal is to simulate the evolution of an Earth-like planetary atmosphere considering the effect of biogeochemical cycles for periods before, during and after the great rise in oxygen. We adapt a 1D radiative-convective photochemical model (after e.g. Kasting et al. 1984; Segura et al. 2003; Grenfell et al. 2007) to calculate O_2, N_2, and CO_2 variable over the whole atmosphere. This includes the proper treatment of their photochemical sources and sinks, and the setting of boundary fluxes at the surface (e.g. for O_2, due to life on Earth, for N_2, due to the nitrogen cycle, and for CO_2 due to the carbon cycle). We calculate the atmosphere before, during and after the great rise in oxygen and show the corresponding surface fluxes needed to maintain surface mixing ratios. In order to understand the resulting fluxes a new tool - the Pathway Analysis Program (PAP) (Lehmann, 2004) - is used to shed light on the complex chemistry producing and destroying oxygen in the atmosphere.

Conclusions

Results suggest that the rise in O_2 could have occurred in response to photochemical changes in the atmosphere induced by a gradual increase in the Sun's luminosity coupled with a gradual decrease in the surface emissions of reducing species such as methane.

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