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Photochemistry of the early Earth and co-evolution of life and atmosphere

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Abstract

1. Introduction

Earth's history reveals the co-evolution of life and environment. The best example is the Great Oxidation Event (GOE), triggered by the appearance of oxygenic photosynthesis, which drastically changed the atmospheric and oceanic chemistry, the mineralogy, life and the climate, with potentially the trigerring of the Huronian glaciations. It has been proposed that the early atmosphere before the GOE was methane-rich. This biological methane would have produced a strong greenhouse effect, compensating the weaker early Sun. However, no global and accurate modelling of the Earth system has been done to test this hypothesis.

2. Methods

In order to study the feedbacks between the ecosystems and the environment of the early Earth, we coupled:

1) a 3D climate model (Charnay et al., 2017) including the photochemistry (Lefèvre et al. 2003, Charnay et al., in prep). This model simulates the methane chemistry with a pathway for the formation of organic hazes. Organic haze growth is computed with a microphysics model (Burgalat & Rannou 2017). Radiative effects of haze are taken into account.

2) a carbon-cycle model (Krissansen-Totton et al. 2018) simulating the evolution of atmospheric CO_2, dissolved carbon, oceanic pH and temperature.

3) a new dynamic ecosystem model (Sauterey et al. in prep), accounting for the dynamics of cell populations by scaling-up from the intracellular processes of energy acquisition (i.e., catabolism), cell maintenance, and biomass production (i.e., anabolism) to ecosystem dynamics.

3. Results and conclusions

During this talk, I will present the results of the photochemical model, with the first 3D simulation of photochemistry and organic haze for the early Earth.

I will after show the results obtained by coupling the atmospheric model to the carbon-cycle model and the ecosystem model. This approach allows to quantify the amount of biological methane during the Archean/Hadean and the climatic feedbacks produced by methanogens. Our results show that methanogens could have played a major role for maintaining a temperate climate during the Archean, but their presence would have surprisingly favored the triggering of glaciations. Finally, I will also briefly discuss the perspectives of this global planetary model for studying the GOE and for simulating biospheres on early Mars and exoplanets.

References

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