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Towards Coupled Modelling of the Biosphere and Atmosphere for the Archean Climate: the Importance of Methane

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Life has played a key role in shaping the atmosphere since its origin on Earth, but modelling the biosphere's impact on climate is complicated by the range of temporal and spatial scales involved. 3D climate models have been used to spatially resolve key processes, but on relatively short time scales compared to those at which the biosphere interacts with the climate system. Whereas, biogeochemical modelling allows us to estimate biotic gas fluxes in and out of the atmosphere over longer time scales [1], but lacks a sophisticated treatment of a spatially resolved atmosphere. Here, we look to bridge these two modelling approaches to better understand the biosphere's impact on the climate.

We use a biogeochemical model [2] to understand the limits on the potential evolution of the atmosphere, as well as a state-of-the-art 3D climate model [3] to explore potential atmospheric compositions produced by early biospheres. The biogeochemical model, coupled to a 1D atmosphere, has been developed to explore the effects of early biospheres primarily focusing on methane production. We use the 3D climate model to extend a 1D exploration of methane's diminished greenhouse potential during the Archean [4] by looking at how methane concentrations affect the cloud distribution, atmospheric dynamics and surface temperature.

We find that global surface temperature peaks for pCH_4 between 300-1000ppmv, with the peak shifting to higher pCH_4 as pCO_2 is increased. Equator-to-pole temperature differences also have a peaked response driven by changes in the radiative balance. These changes come about from the balance between the effect of methane and carbon dioxide on atmospheric dynamics due to changes in the vertical and meridional heating rates, which also affects cloud formation. This work begins to explore how models of the early biosphere can be coupled to 3D climate models, to understand the biosphere's impact on the climate of Earth following the origin of life.

References

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