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# Ocean biogeochemistry amplifies cooling caused by increase in cloud condensation nuclei from algae prior to Cryogenian Snowball Earth events

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The shift from the climate of the “boring billion” without evidence for major glaciations to the globally ice-covered “Snowball Earth” events of the Cryogenian (720–635 million years ago, Ma) remains enigmatic. Various factors have been suggested to drive the cooling in the early Neoproterozoic (1000–539 Ma), most prominently decreasing carbon-dioxide levels due to enhanced weathering of tropical continents or fresh volcanic material. However, these processes should have operated during the boring billion as well, triggering the quest for alternative explanations. It has been suggested, for example, that the increase in both the diversity and the biomass of eukaryotic algae around 800 Ma could have contributed to the cooling via the emission of dimethyl sulfide (DMS), a source of cloud condensation nuclei instrumental in forming bright clouds over dark ocean surfaces. Here, we investigate this hypothesis with a coupled climate–ocean biogeochemistry model, allowing for the first time the quantification of the relevant marine carbon cycle feedbacks. We confirm that the increase in cloud condensation nuclei cools the Neoproterozoic climate and can lead to global glaciation at low atmospheric carbon-dioxide concentrations. Our analysis sheds light on the positive and negative feedback loops associated with the rise of algae and demonstrates that changes in cloud cover remain a plausible contribution to Neoproterozoic cooling.