Earth system dynamics and the snowball Earth phenomena

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Evidence for low-latitude glaciations during the Proterozoic have been interpreted as global glaciations. It is interesting to note that all the glaciations during the Proterozoic seems to have been snowball Earth although such an extreme state has never been experienced during the Phanerozoic.

I investigated the possibility that this difference may come from difference in the solar luminosity between the Proterozoic and the Phanerozoic by using a simple climate model combined with a carbon cycle model.

According to the results, a net CO2 flux into the atmosphere-ocean system is shown to be always nearly zero at the critical point. Therefore, the most likely reason for the difference is difference in CO2 flux in the carbon cycle system, rather than difference in the solar luminosity.

Evidence for low-latitude glaciations during the Proterozoic have been interpreted as global glaciations. This is called a snowball Earth hypothesis. It is interesting to note that all three major glaciations during the Proterozoic seems to have been snowball Earth, although such an extreme state has never been experienced during the Phanerozoic. What is the reason for this difference?

I investigated the possibility that this difference may come from difference in the solar luminosity between the Proterozoic and the Phanerozoic by using a one-dimensional energy balance climate model combined with a carbon geochemical cycle model.

According to the results, pCO2 level during the Paleoproterozoic required for maintaining a warm climate similar to the present one is 100 PAL (= present atmospheric level), although pCO2 level at the critical point is 50 PAL. It may have been therefore easy to fall into the snowball Earth state during the Proterozoic owing to the variation of pCO2 level with an amplitude of 1/2 of the standard level.

However, a net CO2 flux into the atmosphere-ocean system at the critical point is estimated to be nearly zero both for the Paleoproterozoic and today. Therefore, the most likely reason for the difference between the Paleoproterozoic and today is difference in CO2 flux within the carbon cycle system, rather than difference in the solar luminosity. Although the fundamental reason has still been unclear, difference in tectonic environment may have played an important role in the behavior of the carbon cycle.