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The Faint Young Sun Paradox: Coupled 3D Simulations of the Archean Climate

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In the Archean eon (3.8 to 2.5 billion years ago), the Earth received about 30% less solar energy than today, yet the existence of liquid water is confirmed by numerous independent pieces of evidence. Relatively high greenhouse gas concentrations and/or other factors must therefore have compensated for the reduced solar radiation flux, but the solution to the faint young Sun paradox remains elusive.

Even though controversy remains, the last decades have seen a lot of progress in our understanding of the Earth's early climate state. In addition to the solar energy input and the chemical composition of the atmosphere, however, other factors like oceanic and atmospheric heat-transport and feedbacks like the ice-albedo feedback certainly play an important role in the Archean climate system.

To assess which configurations of climate parameters are consistent with the available geochemical evidence, spatially resolved computer simulations of the climate system with all relevant feedback processes are therefore required. So far, however, almost all efforts in this direction have employed strongly simplified or one-dimensional models.

In order to improve our understanding of the Archean climate system, we have carried out simulations with the fully coupled climate model of intermediate complexity CLIMBER-3alpha. It is based on the ocean general circulation model MOM3, and the ocean component is coupled to a statistical-dynamical atmosphere as well as a sea-ice model. The fast integration time enables us to perform parameter studies of equilibrium simulations and examine the influence of changes in the incoming solar energy flux, the continental configuration, rotation of the Earth and other aspects. With this approach, we hope to not only gain a better understanding of the processes governing the Archean climate, but to finally provide tangible ranges of greenhouse gas concentrations and surface configurations that are compatible with observations and resolve the faint young Sun problem.