Early Earth may have been prone to deep freezes: study

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Two University of Colorado Boulder researchers who have adapted a three-dimensional, general circulation model of Earth's climate to a time some 2.8 billion years ago when the sun was significantly fainter than present think the planet may have been more prone to catastrophic glaciation than previously believed.

The new 3-D model of the Archean Eon on Earth that lasted from about 3.8 billion years to 2.5 billion years ago, incorporates interactions between the atmosphere, ocean, land, ice and hydrological cycles, said CU-Boulder doctoral student Eric Wolf of the atmospheric and oceanic sciences department. Wolf has been using the new climate model -- which is based on the Community Earth System Model maintained by the National Center for Atmospheric Research in Boulder -- in part to solve the "faint young sun paradox" that occurred several billion years ago when the sun's output was only 70 to 80 percent of that today but when geologic evidence shows the climate was as warm or warmer than now.

In the past, scientists have used several types of one-dimensional climate models -- none of which included clouds or dynamic sea ice -- in an attempt to understand the conditions on early Earth that kept it warm and hospitable for primitive life forms. But the 1-D model most commonly used by scientists fixes Earth's sea ice extent at one specific level through time despite periodic temperature fluctuations on the planet, said Wolf.

"The inclusion of dynamic sea ice makes it harder to keep the early Earth warm in our 3-D model," Wolf said. "Stable, global mean temperatures below 55 degrees Fahrenheit are not possible, as the system will slowly succumb to expanding sea ice and cooling temperatures. As sea ice expands, the planet surface becomes highly reflective and less solar energy is absorbed, temperatures cool, and sea ice continues to expand."

Wolf and CU-Boulder Professor Brian Toon are continuing to search for the heating mechanism that apparently kept Earth warm and habitable back then, as evidenced by liquid oceans and primordial life forms. While their calculations show an atmosphere containing 6 percent carbon dioxide could have done the trick by keeping the mean temperatures at 57 degrees F, geological evidence from ancient soils on early Earth indicate such high concentrations of CO_2 were not present at the time.

The CU-Boulder researchers are now looking at cloud composition and formation, the hydrological cycle, movements of continental masses over time and heat transport through Earth's system as other possible modes of keeping early Earth warm enough for liquid water to exist. Wolf gave a presentation on the subject at the annual American Geophysical Union meeting held Dec. 5-9 in San Francisco.

Toon said 1-D models essentially balance the amount of sunshine reaching the atmosphere, clouds, and Earth's terrestrial and aquatic surfaces with the amount of "earthshine" being emitted back into the atmosphere, clouds, and space, primarily in the infrared portion of the electromagnetic spectrum. "The advantage of a 3-D model is that the transport of energy across the planet and changes in all the components of the climate system can be considered in addition to the basic planetary energy balance."

In the new 3-D model, preventing a planet-wide glaciation requires about three times more CO2 than predicted by the 1-D models, said Wolf. For all warm climate scenarios generated by the 3-D model, Earth's mean temperature about 2.8 billion years ago was 5 to 10 degrees F warmer than the 1-D model, given the same abundance of greenhouse gases. "Nonetheless, the 3-D model indicates a roughly 55 degrees F mean temperature was still low enough to trigger a slide by early Earth into a runaway glacial event, causing what some scientists call a 'Snowball Earth,'" said Wolf.

"The ultimate point of this study is to determine what Earth was like around the time that life arose and during the first half of the planet's history," said Toon. "It would have been shrouded by a reddish haze that would have been difficult to see through, and the ocean probably was a greenish color caused by dissolved iron in the oceans. It wasn't a blue planet by any means." By the end of the Archean Eon some 2.5 billion year ago, oxygen levels rose quickly, creating an explosion of new life on the planet, he said.

Testing the new 3-D model has required huge amounts of supercomputer computation time, said Toon, who also is affiliated with CU-Boulder's Laboratory for Atmospheric and Space Physics. A single calculation for the study run on CU-Boulder's powerful new Janus supercomputer can take up to three months.

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