A new model of the Earth System nitrogen cycle through time: how biology, plate tectonics, and the atmosphere interact to influence planetary habitability and nutrient cycles. Benjamin W. Johnson[1] and Colin Goldblatt[2], [1]University of Victoria, (School of Earth and Ocean Sciences, Bob Wright Centre A405, PO Box 1700 STN CSC,
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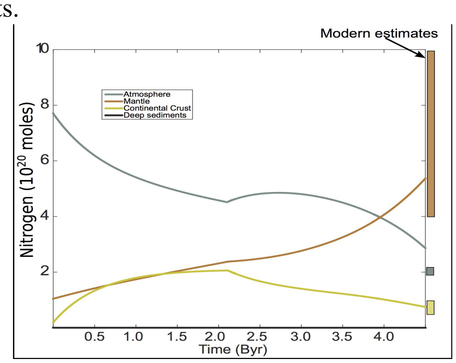
Introduction: Nitrogen is the main component of Earth's atmosphere and is a major component of other planets and moons, including Venus and Titan. On Earth, N plays a key role in the evolution of the biosphere and surface of Earth. It is a crucial nutrient that can be energetically expensive for organisms to obtain, and its abundance and speciation in the atmosphere have a direct effect on climate [1]. Thus, the amount of N on the surface of the Earth, either in the atmosphere, ocean, or easily weathered rocks, has important ramifications on climate and habitability. There are contrasting views, however, on how N has evolved on the surface of the Earth over time.

Some modeling efforts [e.g., 2] indicate a steady-state level of N in the atmosphere over geologic time, while geochemical [e.g., 3], other proxies [e.g., 4], and more recent models [5] indicate the mass of N in the atmosphere can change dramatically over Earth history. We are presented with a clear conundrum: N in the Earth system has been in steady-state for Earth history or it has evolved dynamically over time. This conundrum, and potential solutions to it, present distinct interpretations of the history of Earth, and teleconnections between the surface and interior of the planet have applications to other terrestrial bodies as well.

To help investigate this conundrum, we have constructed an Earth-system N cycle box model. To our knowledge, this is the most capable model for addressing evolution of the N reservoirs of Earth through time. The model combines biologic and geologic processes to more fully describe the N cycle through geologic history. We include the ocean, atmosphere, sediments, ocean and continental crust, and the mantle as reservoirs. The model is driven by a mantle cooling history, which informs estimates of crust production, plate speeds, and volatile recycling at subduction zones over time. In addition to a full biologic N cycle (fixing, nitrification, denitrification), we also dynamically solve for PO4 through time and we have a prescribed O2 history. Inorganic tracers (K and Ar) are also incorporated to act as model performance assessment tools for geologic processes.

Initial model results indicate that the atmosphere of Earth could have experienced major changes in mass over geologic time. Given a high initial atmospheric mass, suggested as a solution to the Faint Young Sun Paradox [1] and also as a potential explanation to the N-isotopic character of the planet [6], the atmosphere of Earth is gradually drawn into the mantle over time, supporting work that indicates the mantle has significantly more N than the atmosphere does today [7]. Transport of N into the mantle is efficient at subduction zones, especially when mantle temperatures cool. A different mantle cooling history would have direct implications for biologically-mediated N movement between the atmosphere and solid planet. In addition, the presence or absence of nutrients such as PO4 exert a strong control on N evolution through time, indicating that N itself is not a limiting nutrient on geologic time scales.

Further applications of this model will be to simulate a variety of different planetary evolution pathways. The construction of this model allows for processes such as plate tectonics, rate of sedimentation, mixing within the ocean, hydrothermal activity in the oceanic crust, and behavior of continental crust to all be varied. The interaction between biologic and geologic forces has shaped the history of N on Earth, and would have important implications for its behavior on other terrestrial planets.



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