N₂O as a possible solution for the Proterozoic Faint Young Sun paradox

- N₂O photodissociation is rapid at low atmospheric O₂, but could slow after the Great Oxidation Event
- The anoxic and iron-rich (ferruginous) Proterozoic ocean would allow NO to be abiotically reduced to N₂O
- Abiotic and biotic sources of NO, such as microbial nitrite reduction, could have been relevant at this time
- Fe²⁺ was enriched in the Proterozoic ocean, possibly greater than 3 mM

We set out to document the rate of N₂O production from the interaction of NO and Fe²⁺, and the amount of N₂O that could be sustained in the Proterozoic atmosphere due to this reaction.

A new model for the Proterozoic nitrogen cycle

Integrating N₂O kinetics into photochemical and climate models

25-100 pM NO is required for an N₂O flux of ~9 x 10⁴ mol/yr

This is similar to modern OMZs: [NO] = 1-60 pM (Ward & Zafirou 1888; Deep Sea Res.)

Chemodenitrification could produce 0.4-10 ppm N₂O according to our photochemical model, possibly generating up to 5°C warming according to climate modeling

Climate model: Proterozoic temperatures as a function of greenhouse gases

Conclusions

Our results show that N₂O could be an important constituent of early greenhouse atmospheres. Chemodenitrification could have helped alleviate the Faint Young Sun paradox and contribute to sustained habitability during the Proterozoic.

Acknowledgements

This material is based upon work supported by the National Aeronautics and Space Administration through the NASA Astrobiology Institute under Cooperative Agreement No. NNA15BA01A issued through the Science Mission Directorate. Additional support provided by NASA Exobiology Grant No. NNH14AD77. Thanks to Dr. Jen Glass, Dr. Chris Reinhard, Dr. James Kasting, and Dr. Tim Lyons for all the support and encouragement.

References