Characterizing N_2O as an Exoplanet Biosignature: Early Earth as a Template

E.W. SCHWIETERMAN[1], S.L. OLSON[1], C.T. REINHARD[2], V.S. MEADOWS[3], T.W. LYONS[1]

[1]Department of Earth Sciences, University of California, Riverside, CA, 92521, USA (eschwiet@ucr.edu)
[2]School of Earth and Atmospheric Sciences, Georgia Institute of Technology, GA, 30332, USA
[3]Department of Astronomy, University of Washington, Seattle, WA, 98115, USA

Recent work has illuminated both potential 'false positives' for biotic O_2 in terrestrial atmospheres [e.g., 1] and 'false negatives', scenarios where analogs to early (mid-Proterozoic) Earth may maintain undetectably low abundances of O_2 and CH_4 despite the presence of a productive photosynthetic biosphere [2]. To enhance the chance for success in the search for life outside the solar system, it is important to assess alternative biosignature gases. N_2O is often referenced as an exoplanet biosignature gas because its abiotic sources on Earth are small, and it has potentially detectable spectral features in the near- and mid-infrared [3]. It also has been suggested that N_2O concentrations may have been higher in early Earth's history with notable climatic implications [4]. However, the spectral signatures of N_2O are weak at the levels of modern Earth, and no study has thus far explored the self-consistent biogeochemical-photochemical limits of N_2O production with the aim of quantifying N_2O's spectral detectability.

Here we use a global biogeochemical model calibrated for early Earth studies [5] coupled with photochemical and spectral models to quantify the limits of N_2O spectral detectability for exoEarth analogs. We find that denitrification fluxes (a proxy for N_2O) are maximized at pO_2 between 10-75% PAL but supressed at modern or Archean levels. Higher phosphate concentrations, perhaps from robust weathering, would increase productivity and enhance N_2O production above modern levels. Elevated pO_2 boosts N_2O photochemical lifetimes due to UV shielding, ultimately favoring N_2O at intermediate oxygenation conditions. We suggest that the combination of N_2O and O_3 is a promising biosignature pair for intermediately oxic terrestrial exoplanets but would require spectroscopic data at $\lambda > 3.7$ μm.

[1] Harman et al. (2015) *ApJ,* 812:137. [2] Reinhard et al. (2017) *Astrobiology,* in press. [3] Sagan, et al. (1993) Nature 365:715–21. [4] Buick (2007) Geobiology 5:97–100. [5] Olson et al. (2016) *PNAS*, 113:11447–11452.