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Parallel Earths: the Role of Orbital Parameters in Atmospheric Biosignature Expression

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One of the longstanding goals of the astrobiology community has been the discovery and characterization of an Earth twin orbiting a Sun-like star. Given the incredible diversity of exoplanets seen by Kepler, it seems likely that there exists a wide range of planets that may be very nearly Earth-like, but might differ in substantial ways. Recently, more sophisticated models have demonstrated increasingly nuanced atmospheric and climatic responses to distinctly non-terrestrial orbital parameters [e.g., 1,2]. Missing from these studies, however, has been a thorough analysis of the response of atmospheric photochemistry, in particular relevant biosignature gases like ozone, to the primary and secondary drivers associated with these changes. Here, we present some of the first fully interactive atmospheric chemistry-climate simulations for planets that differ from the modern Earth only in terms of their eccentricity, obliquity, and rotation rate using ROCKE-3D, a planetary general circulation model (GCM) [3]. ROCKE-3D has been developed out of (and continues to develop in parallel with) a modern Earth GCM [4]. Leveraging Earth science to tackle this problem affords us new insights into what we might expect to see for a nearly Earth-twin exoplanet. By generating synthetic spectra of these simulations, we demonstrate that the effect of climate on photochemistry (and vice versa) is both observable, and an important effect that should be included in future climate-only modelling efforts.

References: [1] Dressing et al 2010 ApJ 721 1295. [2] Haqq-Misra et al 2018 ApJ 852 67. [3] Way et al 2017 ApJS 231 12. [4] Schmidt et al 2014 JAMES 6 141.