Appendix for: Photochemical modeling of the climate-redox evolution of the Great Oxidation Event: from a Snowball Earth to a Hot-Moist Greenhouse

Daniel Garduno Ruiz[a,*], Colin Goldblatt[a], Anne-Sofie Ahm[a]

[a]*School of Earth and Ocean Sciences, University of Victoria, Victoria, British Columbia, Canada*

1. Sensitivity of results to colder stratosphere

We assume a 215k isothermal stratosphere in our simulations. However, stratospheric temperatures likely varied across the GOE, reaching values as low as 175k (Chen et al., 2019). We performed a simulation using a 175K fixed stratospheric temperature to investigate the effects of a colder stratosphere in our results (figure 1). We found that a colder stratosphere leads to a lower concentration of H_2O vapor in the stratosphere, resulting in higher stratospheric O2 and O3 concentrations before the GOE. However, after the GOE, we found only slight differences of less than one order of magnitude (figure 2). Consequently, we conclude that a colder stratosphere does not significantly affect our results.

2. Eddy diffusivity sensitivity test

We performed a sensitivity test changing our eddy diffusivity profiles to two orders of magnitude above and one below our base case (figure 3). We found that a higher eddy diffusivity enhances water transport to the stratosphere, resulting in slightly lower O2 and O3 mixing ratios (figure 4). However, changing eddy diffusivity leads to similar results to the ones we show in the main manuscript (figure 5). Consequently, changing eddy diffusivity by up to two orders of magnitude does not affect our conclusions.

*Corresponding author
Email address: danielgardunoruiz@uvic.ca (Daniel Garduno Ruiz)

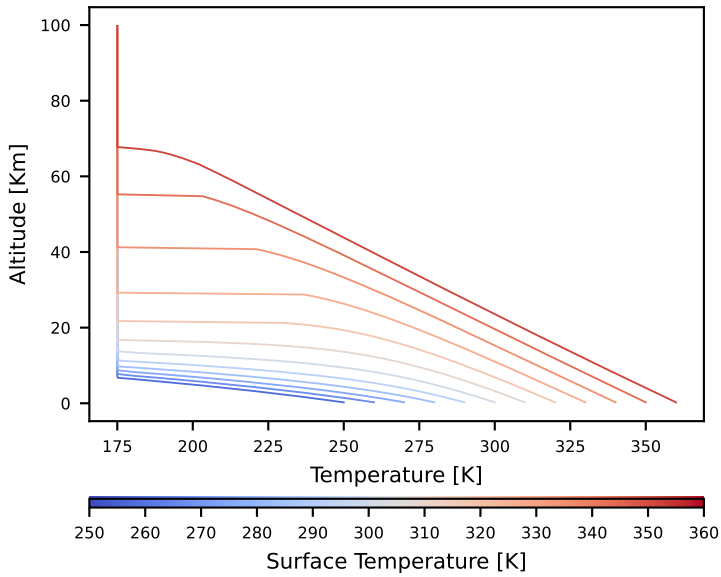

Figure 1: Temperature profiles with 175k isothermal stratosphere.

References

Chen, H., Wolf, E.T., Zhan, Z., Horton, D.E., 2019. Habitability and Spectroscopic Observability of Warm M-dwarf Exoplanets Evaluated with a 3D Chemistry-Climate Model. The Astrophysical Journal 886. doi:10.3847/1538-4357/ab4f7e, arXiv:1907.10048.

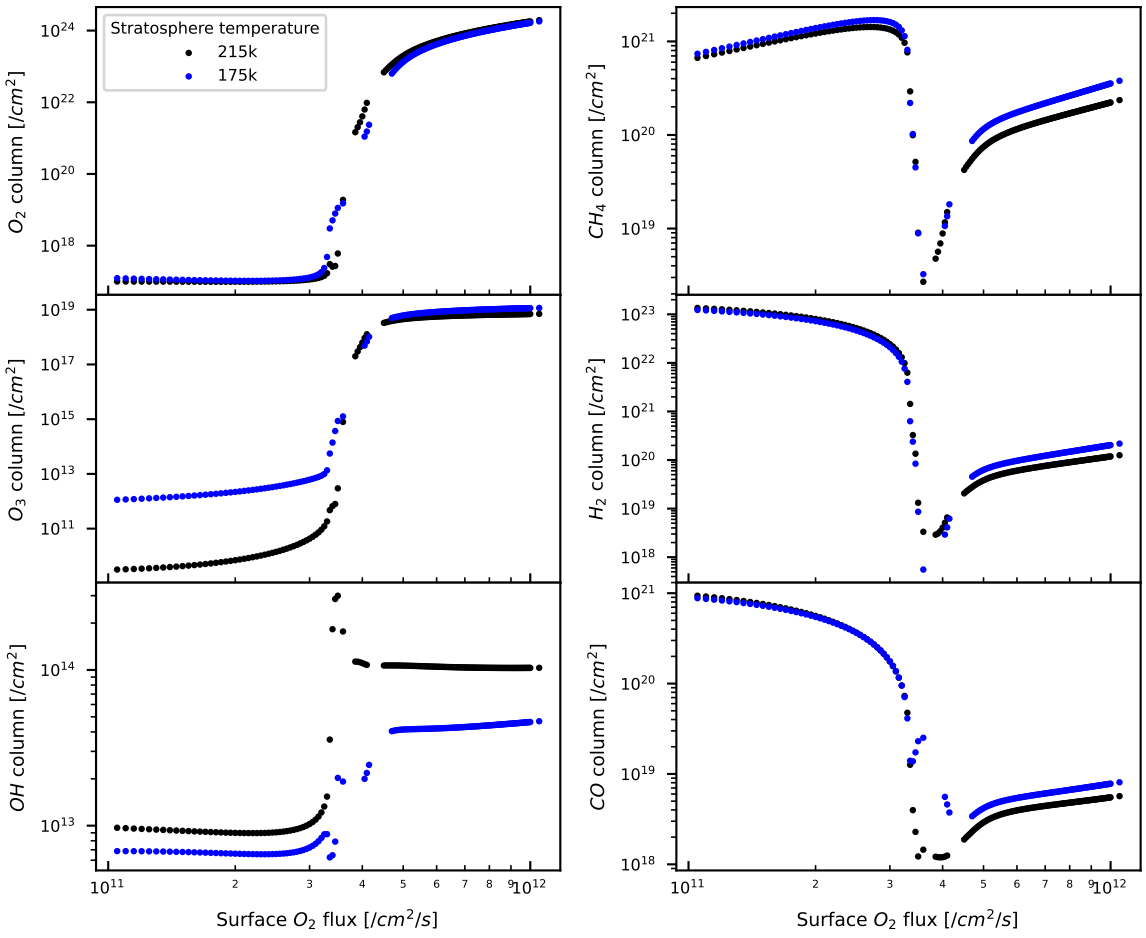

Figure 2: Comparison of atmospheric columns between results with a 215k and a 175k isothermal stratosphere. A colder stratosphere does not have a big effect on our results. These plots are for a constant CH_4 to O_2 flux ratio of 0.3, a relative humidity of 0.6 in the troposphere, and a surface temperature of 290k. We show only a subset of surface O_2 fluxes to focus on the transition.

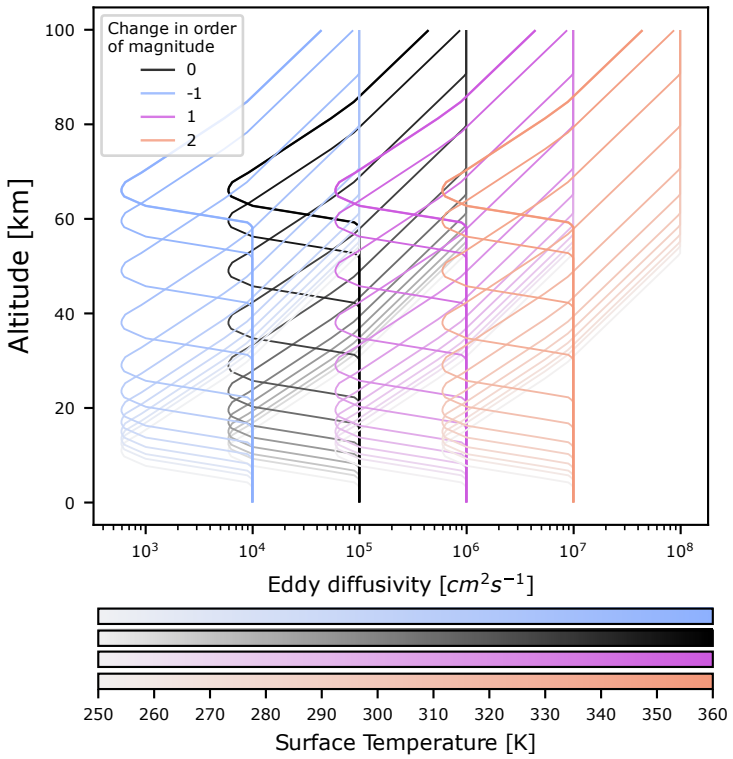

Figure 3: Eddy diffusivity profiles used for sensitivity test. Surface temperature increases as the color becomes more saturated.

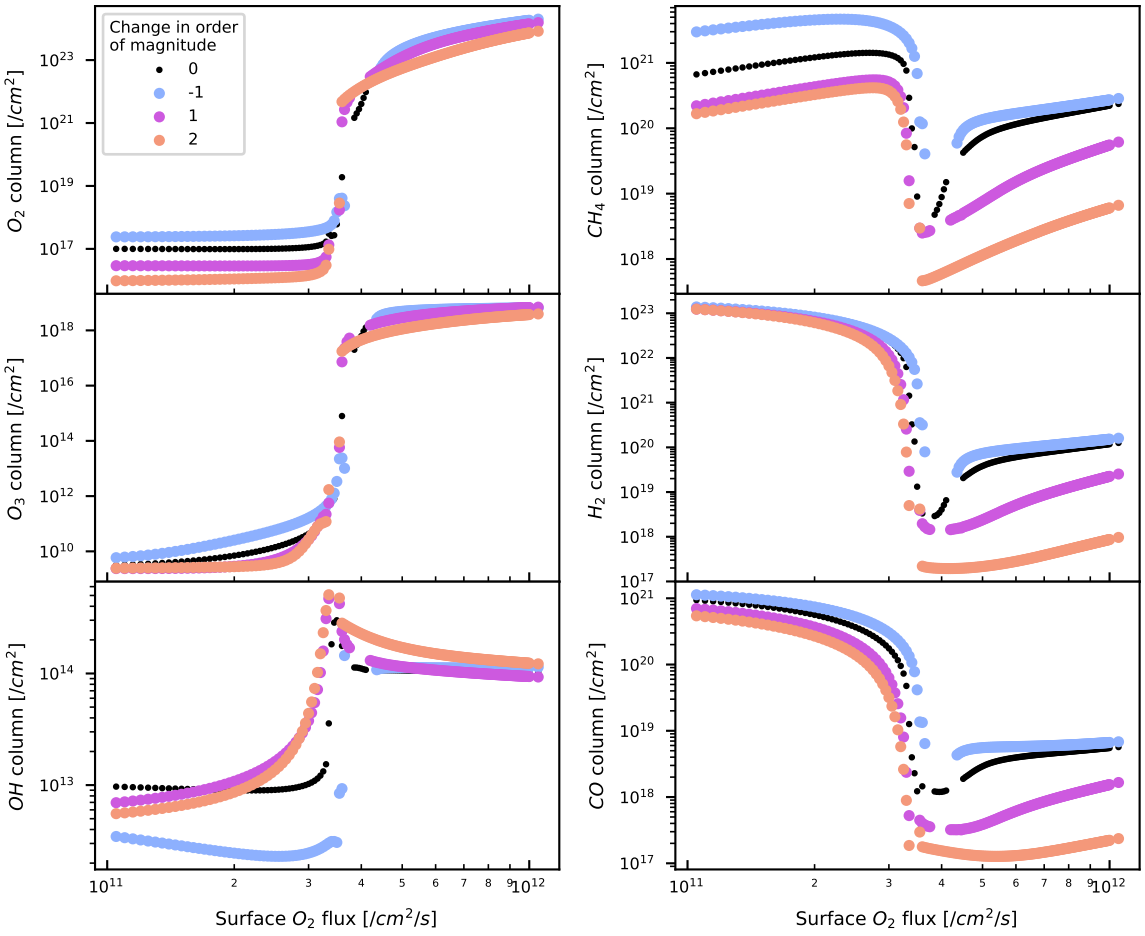

Figure 4: Results of eddy diffusivity sensitivity for the atmospheric columns of key species. The different colors represent the change in the order of magnitude of the eddy diffusivity profiles and correspond to the profiles shown in figure 3. These plots are for a constant CH_4 to O_2 flux ratio of 0.3, a relative humidity of 0.6 in the troposphere, and a surface temperature of 290k. We show only a subset of surface O_2 fluxes to focus on the transition.

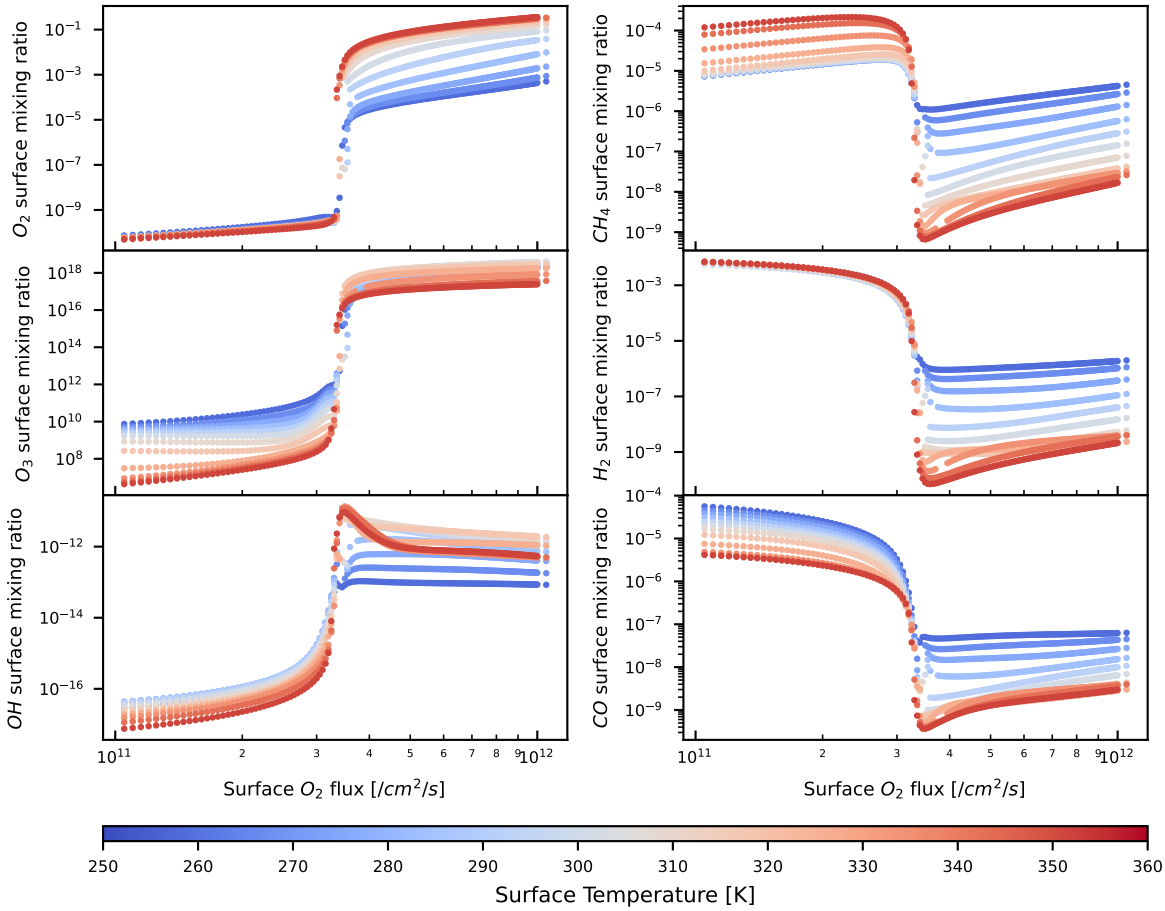

Figure 5: Same as figure 3 of the main manuscript, but with eddy diffusivity increased by two orders of magnitude. The results are very similar to those shown in the main manuscript despite the increase in eddy diffusivity.