Simulating Climates and JWST Observations of Two Potential ExoVenuses C. M. Ostberg[1], O. Clarkson[2], E. L. Miles [1], S. R. Kane[1] , and M. J. Way[2] [1]Department of Earth and Planetary Sciences, University of California, Riverside, CA 92521, USA | costb001@ucr.edu, [2]NASA Goddard Institute for Space Studies, 2880 Broadway, New York, NY 10025, USA

The next generation of Venus missions such as the Deep Atmosphere Venus Investigation of Noble gases, Chemistry, and Imaging (DAVINCI), Venus Emissivity, Radio Science, InSAR, Topography, and Spectroscopy (VERITAS), and EnVision missions will be crucial for understanding Venus' history. A complimentary approach to studying possible evolutionary pathways of Venus is through the study of terrestrial exoplanets in the Venus Zone (VZ; 1), hereafter referred to as exoVenuses. Constraining the range of climates that can be found on exoVenuses can provide insight into Venus' history, and improve our understanding of terrestrial planet evolution. In this work we investigate two potential exoVenuses: LHS 1140 c and TOI-1266 c. We simulate the climates of both planets using a three-dimensional (3D) general circulation model (GCM) and use the GCM outputs to model the transmission and emission spectra that could be achieved with the James Webb Space Telescope (JWST).

To model the climates of both LHS 1140 c and TOI-1266 c we used a 3D GCM called ROCKE-3D [2]. ROCKE-3D is an Earth-based model that has been used to model various exoplanet climates, as well as infer if an exoVenus is in a runaway greenhouse state [3]. For our simulations we assumed both planets had modern-Earth atmospheric compositions and were assumed to be tidally locked. The goal of the simulations was to either illustrate that the planet could maintain a stable climate with an Earth-like atmosphere, or infer that the planet may be in a runway greenhouse if excessive heating occurs. Using a fixed atmospheric composition, we ran multiple simulations of each planet with varying topographies and surface ocean sizes.

For both planets, having an ocean of any depth resulted in substantial water evaporation followed by continuous heating until the model crashed. The only scenario where both planets were able to maintain thermal equilibrium was with Venus' topography and no surface ocean. Figure 1 shows the global surface temperature distribution of the LHS 1140 c simulation which reached thermal equilibrium. Due to being tidally locked, the dayside temperature can exceed 270 C, but the nightside temperature gets cold enough to allow snowfall at higher elevations. This demonstrates it may be possible for life to survive on the planet's nightside.

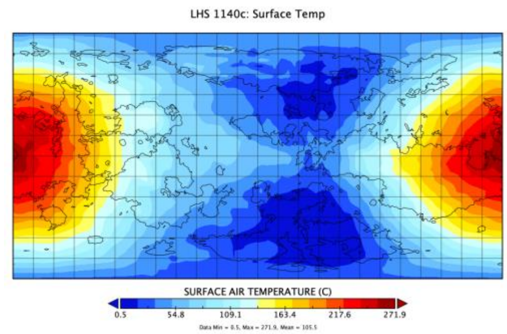

Figure 1: The surface temperature of LHS-1140 c with Venus' topography and no surface ocean.

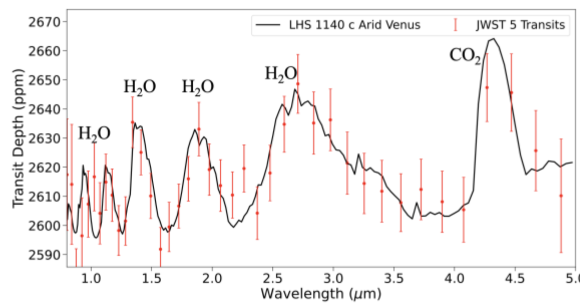

Figure 2: Simulated JWST NIRSpec PRISM data from 5 transit observations of LHS 1140 c.

We used the resulting atmospheres from the ROCKE-3D simulations which reached equilibrium as inputs for the Planetary Spectrum Generator [4] to model the transmission and emission spectrum for both planets. We then used PandExo [5] to simulate the data uncertainties if JWST were to conduct observations of both planets. Figure 2 shows the simulated JWST NIRSpec PRISM data from 5 transit observations of LHS 1140 c. This demonstrates that 5 transit observations would likely be sufficient for JWST to resolve the transmission spectrum of LHS 1140 c. 5 transit observations of TOI-1266 c would likely be sufficient to constrain its atmosphere as well.

References: [1] Kane et al. 2014 The Astrophysical Journal Letters 794.1 L5. [2] Way et al. 2017 The Astrophysical Journal Supplement Series 231.1 12. [3] Kane et al. 2018 Astrophysical Journal 869.1 46. [4] Villanueva et al. 2018 Journal of Quantitative Spectroscopy and Radiative Transfer 217 86-104 [5] Batalha et al. 2017 Publications of the Astronomical Society of the Pacific 129.976 064501.