Mars as an Exoplanet: Constraining Potential Climate Scenarios Using the ROCKE-3D GCM. D. M. Glaser¹, T. Leboissetier¹, I. Aleinov¹,², K. Tsigaridis¹,², J. Perlwitz¹,³, and M. J. Way¹,⁴ ¹NASA Goddard Institute for Space Studies, ²Center for Climate Systems Research, Columbia University, ³Climate, Aerosol, and Pollution Research, LLC, ⁴Department of Physics and Astronomy, Uppsala University.

Abstract: The extent and distribution of continents (i.e., topography) over time has had profound effects on Earth’s climate, considering the supercontinent cycle, but the effect of topography on climate has not been studied in an idealized and systematic way. Mars is an interesting analog test case in the pursuit to better understand the effect of topography on planetary climates. This is due to the almost 50/50 distribution of highlands and lowlands with a singular ‘continent’. Modern Mars is a cold, arid world; however, there is evidence that early Martian climate was more temperate with extensive liquid water, higher surface temperatures, and higher atmospheric pressures. It is evident that Mars has lost the majority of its water over the last 3 Ga; the causes of loss are up for debate, however, including its low gravity (low mass and radius) and lack of an intrinsic magnetic field. Here, we explore the climate outcomes for an idealized planet with a paleo Mars topography (~3.7 Ga), Earth’s gravity, Earth’s atmospheric pressure, and archean Earth’s atmospheric composition (i.e., no oxygen) using the ROCKE-3D Global Climate Model. We consider a suite of simulations with differing ocean surface water area ranging from 20 to 50%.

Our results show that changes in ocean surface area change the overall extent and distribution of arid regions, as calculated by aridity index (AI; ratio of precipitation to evaporation). The extent of hyperarid land climate (AI ≤ 0.05) is strongly dependent on ocean surface area, where increasing ocean surface area decreases hyperarid land climate. The same is not true with the extent of humid (AI > 0.65) land climate; the global extent of humid climates remains constant at ~12% across all simulations (20 – 50% ocean surface area). Our modeled extent of humid climate in these simulations is only slightly lower than modern Earth (~15%). This suggests that even relatively dry planets (20% ocean surface area) with a single, large continent may be capable of sustaining a similar extent of humid climate as Earth, providing evidence for potential clement conditions under vastly different land-ocean configurations from Earth.

Brief Summary: Here we investigate the climate of land planets. We find that humid conditions have constant extent (~12% global) from 20 – 50% ocean surface area. This provides evidence for potential clement conditions under vastly different topography from Earth.