MODELING THE ATMOSPHERE OF VENUS AS A POTENTIAL MICROBIAL HABITAT T. M. Fisher[1] and D. Schulze-Makuch[1,2], [1] School of the Environment, Washington State University, Pullman, WA, 99164, thomson.fisher@email.wsu.edu, [2]Center for Astronomy and Astrophysics, Technical University Berlin, Berlin, Germany, dirksm@wsu.edu

Introduction: While the surface of Venus is hostile to life as we know it, at an altitude of 47-51 km the conditions are remarkably Earth-like in terms of temperature and pressure [1]. Nitrogen (in the form of N_2 and an unknown but potentially large amount of lightning-generated NO_x compounds [2] as well as phosphorus (in the form of phosphoric acid [3] are also present in detectable quantities. Energy is available both in the form sunlight, and likely in complex cycling of carbon and sulfur driven by photochemisty in the upper atmosphere and abiotic redox reactions in the lower atmosphere [4].

Venus is thought to have had an ocean early in its history[5], providing an environment potentially friendly to the evolution of life, which could have then adapted to an atmospheric existence; alternatively, lithopanspermia could have "seeded" microbes on Venus from Earth [6]. Consequently, the atmosphere of Venus has been suggested as a target for astrobiological investigation [7,8]

Water, while scarce, is not entirely absent in the atmosphere, and it is possible that if the lower Venusian atmosphere is an inhabited habitat, any putative Venusian organisms may have evolved the ability to "fix" water [9]. Furthermore, the lack of a physical substrate may not present a significant obstacle, due to the relatively long residency time (months or greater) of individual particles in the atmosphere[9]. Additionally, the microbial activity in terrestrial clouds has been shown to be much higher than previously assumed [10][11]. Possible metabolic pathways include the photoxidation of sulfur coupled to the fixation of carbon dioxide into carbohydrates [9].

Model description: To better understand the potential habitability of the Venusian atmosphere, a compartmental stoichiometric model was constructed using XPP and Berkeley Madonna, designed around the flow of nutrients and energy. The model is designed around of a series of various "stocks" or quantities of nutrients and metabolites,represented by differential equations relative to time, in the general
form of

$$dx/dt = (\text{inflow}_x - \text{outflow}_x)$$

Two populations of microbes were incorporated, a phototrophic sulfur oxidizer, and a chemotrophic sulfur reducer; the dynamics of these populations was based on Monod kinetics[12], where the growth of the population is represented as

$$\mu = \mu_{max} (S/K_s + S)[12]$$

where μ is the specific growth rate, μ_{max} is the maximum growth rate per unit time, S is the amount of substrate (in this case, nutrients or metabolites), and Ks is the half-saturation constant of the organism.

Initial parameters for the Venusian environment were derived from remote sensing primarily from Venera and Pioneer Venus missions, and the Monod terms and parameters for the microbes were based off of terrestrial thermoacidophiles that live under analogous conditions. Atmospheric residence for the microbes was assumed to be ~3.5 months.

The model was then subjected to sensitivity testing, to evaluate the stability and resilience of the population under disturbance regimes.

Results: Preliminary results suggest that the modeled environment could support >6000 $\mu mol/m^3$ of biomass carbon, and that a stable equilibrium existed for the populations that would be relatively resilient to disturbance such as sudden population reduction and fluctuations in nutrient and energy availability. Primary productivity was 6.9×10^{-5} g carbon/year and phosphorus was found to be the most limiting nutrient. These results can then be integrated into a wider atmospheric chemistry model to evaluate the plausibility of this ecosystem in the context of the many abiotic processes occurring in the Venusian atmosphere.

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