CONSTRAINTS ON EARLY VENUS HABITABILITY FROM ATMOSPHERIC O_2. A. O. Warren[1] and E. S. Kite[1], [1]Department of Geophysical Sciences, University of Chicago (aowarren@uchicago.edu).

Introduction: A major outstanding question is whether Venus could ever have had habitable surface conditions. Recent climate models suggest conditions suitable for surface liquid water on Venus may have been possible as recently as the planet's last resurfacing[1], but whether a habitable is consistent with Venus' atmospheric composition has not yet been investigated. We present a new mass-balance model of Venus' atmospheric evolution to determine areas of parameter space that are consistent with an early habitable era on Venus and present day H_2O and O_2 concentrations in the Venus atmosphere.

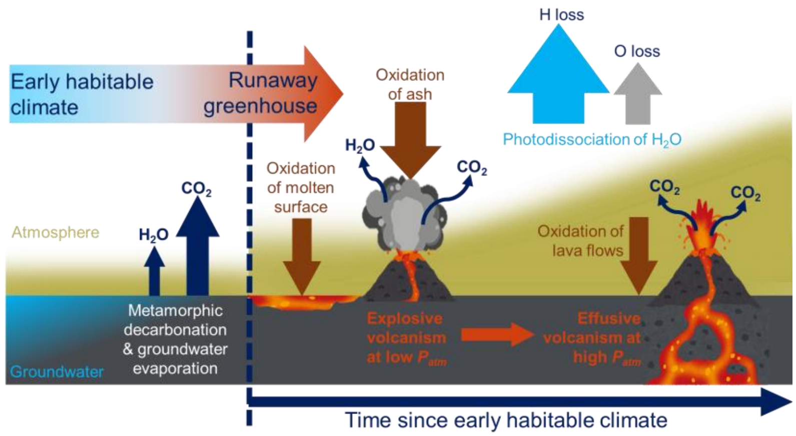

Figure 1. Schematic illustration of our Venus atmospheric evolution model. We vary 5 free parameters (habitable era end time, initial water inventory, melt H_2O and CO_2 concentrations, extrusive volume fraction, and fraction of Venus' atmospheric CO_2 contributed by volcanism) to identify areas of parameter space that maximize the likelihood of a habitable era on Venus.

Venus' present day atmosphere is CO_2-dominated, with <100ppm H_2O[2] and <50ppm O_2.[3] This observation can constrain the sources and sinks of atmospheric H_2O and O_2 on Venus over time. Any early habitable climate on early Venus would have required liquid water.[1] As water is lost to space through photolysis and H escape, O_2 can accumulate in the atmosphere.[4] Climate models suggest that the atmosphere on an early habitable Venus would have been thinner than 93 bar atmosphere. This, combined with the observation of volcanic features on Venus' surface,[5] suggests some atmospheric CO_2 must have been sourced from volcanic degassing. Unless Venus' mantle is dessicated,[e.g. 6] volcanic degassing of CO_2 would also be accompanied by H_2O degassing, introducing more of O to the atmosphere. O can be removed though non-thermal escape to space,[7] and through the oxidation of basaltic material.[8]

Methods: Our model (Fig. 1) considers initial water inventory on Venus (comprising a surface water reservoir and the groundwater needed to prevent draining into the subsurface), fraction of volcanically derived CO_2 in Venus' present day atmosphere, loss of O and H to space, volcanic degassing of CO_2 and H_2O, and O loss by oxidation of basaltic material, including lava flows and pyroclastics (if volatile concentrations are high enough to produce explosive volcanism[9,10]). We have also built a model that investigates the effect of oxidation of a basaltic surface melt layer produced during the high surface temperatures reached in runaway greenhouse climates.[11]

Results: When oxidation of a surface melt layer is not considered, the only early habitable Venus scenarios that can match the present-day atmosphere have <300m global equivalent layer (GEL) initial water, a higher extrusive volcanism fraction than the modern Earth, and ended before 1.5 Ga. The H_2O concentration in average Venusian melts must also be <0.7 wt%. Higher H_2O concentrations produce pyroclastic material, which is an effective O_2 sink, but also add H_2O – and therefore O_2 – to the atmosphere faster than the loss of H & O to space and the available oxidation sinks for O can remove them.

Future work: Oxidation of a surface melt layer after the early habitable era adds an O sink to the model and could enable early habitable eras on Venus with more initial water to be consistent with the present day atmospheric composition. We will quantify the oxygen sink effects of surface melting during a runaway greenhouse by running a suite of models with the same input parameters as our simulations without melting.

References:

[1] Way M. & Del Genio A. D. (2020) *JGR: Planets.*, *125(5)*, e2019JE006276. [2] Von Zahn U. et al. (1983) *Composition of the Venus Atmosphere*, *Univ. Arizona Press*, 299-431. [3] Moroz V. I. (1981) *Space Sci. Rev.*, *29(1)*, 3-127. [4] Tian F. (2015) *EPSL*, *432*, 126-132 [5] Masursky H. et al. (1980) *JGR: Space Phys.*, *85(A13)*, 8232-8260. [6] Hamano K. et al. (2013) *Nature*, *497(7451)*, 607-610. [7] Kulikov Y. N. et al. (2006) *Planetary & Space Sci*, *54*, 1425-1444. [8] Fegley B. (1995) *Icarus*, *118*, 373-383. [9] Airey M. W. et al. (2015) *Planet. & Space Sci.*, *113-114*, 33-48. [10] Sparks R. S. J. (1978) *Journal of Volcanology & Geothermal Res.*, *3*, 1-37.