Key Unknowns for Venus Atmospheric Evolution 2: Consequences of a Venus-like Magnetosphere for Hydrodynamic Xenon (heavy) Ion Escape. C. M. Fowler[1], M. Chaffin[2], R. Ramstad[2], G. Hanley[3], G. Collinson[4], S. Curry[3], R. Lillis[3], J. Luhmann[3], S. W. Stone[4], S. Xu[3] [1](christopher.fowler@mail.wvu.edu) Department of Physics and Astronomy, West Virginia University, WV; [2]Laboratory for Atmosphere and Space Physics, Colorado University, CO; [3] Space Sciences Laboratory, University of California, CA; [4]NASA Goddard Space Flight Center, MD.

Introduction: The fractionation of atmospheric gases provides us with important constraints on the loss of planetary atmospheres to space over geologic timescales. Under various assumptions, the relative abundances of isotopes can inform us as to how much of each isotope has been lost to space and provide constraints on the mechanisms that drove that escape. At Earth, xenon is strongly mass fractionated, suggesting that it has undergone significant loss to space over time. However, lighter noble gases (in particular argon and krypton) are fractionated by lesser amounts, inconsistent with a single period of hydrodynamic escape.

Xenon ion escape at Earth: A recent study by [1] shows that the loss of xenon as an ion may explain this mystery. A photo-ionized hydrogen wind can flow to space along open polar magnetic fields, 'pushing' xenon ions with it via Coulomb collisions. The 1D model presented in [1] requires several assumptions and parameterizations of particular importance here, including (1) the level of solar EUV irradiation that photo-ionizes the atmosphere; (2) the total hydrogen mixing ratio in the atmosphere; (3) the transport rate of heavy xenon ions from the lower atmosphere upward to the base of the outflowing hydrogen wind region; (4) the percentage area of the upper atmosphere connected to open magnetic field lines that can thus act as a conduit for the ionized hydrogen wind to escape to space (assumed 10% in [1]) and push xenon out with it.

Application to Venus: Despite the fact that Venus does not possess a global dipole magnetic field, the processes described in [1] are still applicable. The solar wind drapes around Venus, leading to open magnetic field lines that can intersect almost the entire nightside atmosphere of the planet. These conditions can lead to the generation of a hydrogen wind at Venus equivalent to that discussed in [1] (and in fact driven by the same underlying physical mechanisms), but intersecting up to ~50% of the planet, as opposed to just 10% as assumed at Earth. Observations made by previous orbiters at Venus have observed these 'hydrogen wind equivalents', which include the outflow of both light and heavy ions to space [e.g. 2, 3, 4, 5]. The nightside ionosphere of Venus can thus act in a similar manner to Earth's open polar magnetic field regions, and may facilitate similar loss processes for heavy ions.

This presentation will describe the Venus analogy in light of the picture depicted in [1], highlighting key similarities and differences between Earth and Venus. In addition, the presentation will discuss existing datasets and their limitations with regard to understanding H^+ wind driven heavy ion escape at Venus, and constraining assumptions 1-4 noted previously. The upcoming DaVINCI, VERITAS and ENVISION missions are likely to revolutionize our understanding of surface processes and volatile exchange with the lower atmosphere; such understanding must be paired with an equally refined understanding of loss processes to fully understand Venus evolution. We will discuss novel measurements that could be made by an orbiter to constrain this loss. Finally, the presentation will discuss means of parameterizing these processes so that they could be incorporated into evolutionary models of Venus' atmosphere.

References:

[1] Zahnle, K. J. et al. (2019) *Geochimica et Cosmochimica Acta*, *244*, 56-85. [2] Brace, L. H. et al. (1987) *Journal of Geophysical Research: Space Physics*, *92*(A1), 15-26. [3] Lundin, R. (2011) *The plasma environment of Venus, Mars, and Titan*, 309-334. [4] Fedorov, A. et al. (2011) *Journal of Geophysical Research: Space Physics*, *116*(A7). [5] Collinson, G. A. et al. (2016) *Geophysical Research Letters*, *43*(12), 5926-5934.