Solar Luminosity through time: Does it determine Venus' climate history? M. J. Way[1,2], [1]*NASA/Goddard Institute for Space Studies, 2880 Broadway, New York, New York, USA (michael.way@nasa.gov)* [2]*Theoretical Astrophysics, Department of Physics & Astronomy, Uppsala University, Uppsala, Sweden*

Introduction: In the popular mind the idea of Venus' water past with abundant surface oceans is a compelling concept. In the scientific mind it is equally compelling, if rightly accompanied by deep skepticism. In both minds there is a penchant to believe that Venus reached its current hot greenhouse state because of the gradually increasing luminosity of the sun through time [1]. Yet even 4.2Ga Venus received nearly 40% more luminosity than Earth receives today. It has been shown in a number of 1-D and 3-D modeling studies [2,3,4,5] that the mechanism to maintain habitable conditions on Venus 4.2Ga is via wide area high albedo clouds at the substellar point. In the 1-D case [2] the dense cloud mechanism went unexplained until the work of [3,4,5] showed that slowly rotating worlds have extensive Hadley cells that generate large contiguous cloud decks at the substellar point that reflect much of the incident solar radiation back to space.

Unfortunately what has been overlooked by many is the effectiveness of the cloud mechanism through time. In two different 3-D GCMs [3,5] it was explicitly demonstrated that even today when Venus receives nearly twice as much incident solar radiation as Earth the cloud albedo feedback mechanism would be intact and temperate surface conditions would be still be possible.

We explicitly demonstrate the fact that if the cloud mechanism of [3,4,5] is correct that the increase in solar luminosity through time could not be the primary determining factor in the evolution of Venus' climate history. In other words the evolution from a temperate Earth-like state to the present hot-house state cannot be motivated by increasing solar luminosity through time. We have proposed an alternative mechanism [5] that could have been responsible for Venus' climate catastrophe: large area volcanism similar to the large igneous provinces (LIPs) on Earth. Such LIPs have been tied to multiple mass extinction events through geologic time on Earth. However, the evolutionary scenario we propose is more complicated (planets are complex!) than this. The present day young surface of Venus may be the result of a post-LIP epoch when Venus became a stagnant lid world. This evolutionary hypothesis may be completely incorrect, or it may be fully correct, but either way it may contain important lessons for planetary evolution that we should consider as we look to Venus and Earth-like worlds around other stars.

Acknowledgments: This work was supported by the National Aeronautics and Space Administration (NASA) Astrobiology Program through collaborations arising from our participation in the Nexus for Exoplanet System Science (NExSS) and the NASA Habitable Worlds Program. Resources supporting this work were provided by the NASA High-End Computing (HEC) Program through the NASA Center for Climate Simulation (NCCS) at Goddard Space Flight Center. M. J. W. acknowledges the support from the GSFC Sellers Exoplanet Environments Collaboration (SEEC), which is funded by the NASA Planetary Science Division's Internal Scientist Funding Model.

References:

[1] Gough, D.O. (1981) Solar Phys, 74, 21
[2] Pollack, J. B. (1971) Icarus, 14, 295–306. https://doi.org/10.1016/0019-1035(71)90001-7
[3] Yang, J. et al. (2014). ApJ 787, L2. https://doi.org/10.1088/2041-8205/787/1/L2
[4] Way, M. J., Del Genio A.D., et al. (2016) GRL 43, 8376. https://doi.org/10.1002/2016GL069790
[5] Way, M. J., Del Genio A.D. (2020) JGR-Planets 125. https://doi.org/10.1029/2019JE006276