The Venusian Lower Atmosphere Haze as a Depot for Desiccated Microbial Life: A Proposed Life Cycle for Persistence of the Venusian Aerial Biosphere

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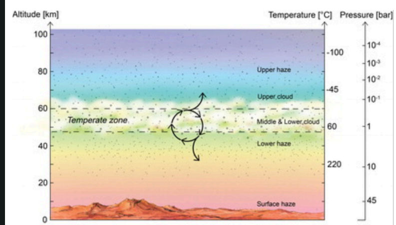
Published Online: 13 Aug 2020 | https://doi.org/10.1089/ast.2020.2244

We revisit the hypothesis that there is life in the Venusian clouds to propose a life cycle that resolves the conundrum of how life can persist aloft for hundreds of millions to billions of years. Most discussions of an aerial biosphere in the Venus atmosphere temperate layers never address whether the life—small microbial-type particles—is free floating or confined to the liquid environment inside cloud droplets. We argue that life must reside inside liquid droplets such that it will be protected from a fatal net loss of liquid to the atmosphere, an unavoidable problem for any free-floating microbial life forms. However, the droplet habitat poses a lifetime limitation: Droplets inexorably grow (over a few months) to large enough sizes that are forced by gravity to settle downward to hotter, uninhabitable layers of the Venusian atmosphere. (Droplet fragmentation—which would reduce particle size—does not occur in Venusian atmosphere conditions.) We propose for the first time that the only way life can survive indefinitely is with a life cycle that involves microbial life drying out as liquid droplets evaporate during settling, with the small desiccated "spores" halting at, and partially populating, the Venus atmosphere stagnant lower haze layer (33–48 km altitude). We, thus, call the Venusian lower haze layer a "depot" for desiccated microbial life. The spores eventually return to the cloud layer by upward diffusion caused by mixing induced by gravity waves, act as cloud condensation nuclei, and rehydrate for a continued life cycle. We also review the challenges for life in the extremely harsh conditions of the Venusian atmosphere, refuting the notion that the "habitable" cloud layer has an analogy in any terrestrial environment.



However, fragmentation of droplets should not occur in Venus' atmosphere. Fragmentation is quantitatively captured by the Weber number, *We*, which represents the ratio of disruptive hydrodynamic forces to the stabilizing surface tension forces (Pilch and Erdman, 1987; Testik and Gebremichael, 2010), $We = \frac{\rho v^2 d}{\sigma}$. Here, ρ is the density of the flow field (*i.e.*, atmosphere), v is the initial relative velocity between the flow field and the drop, d is the initial diameter of the drop, and σ is the surface tension of the drop. There is a critical Weber number below which droplet fragmentation does not occur, $We < 12$, (as long as the droplet's viscous forces are less than the combined inertial and surface tension forces; Pilch and Erdman, 1987). For the Venus atmosphere habitable cloud layer: The atmosphere density is 0.4 to 1.5 kg m^{-3}; most particles are 1 to a few microns in size falling at maximum 1 cm s^{-1} (Figs. 2 and 3); the surface tension for a mixture of 10% water and 90% H_2SO_4 by volume at a range of temperatures (273–323 K) is 55 (mN m^{-1}) (Myhre *et al.*, 1998), resulting in $We \ll 1$, well below the Weber critical number for fragmentation.