

Was Venus ever habitable?

Venus's past is enigmatic. We applied a fully coupled model of Venus's atmosphere, interior, and climate evolution from post-accretion magma ocean to present, incorporating atmospheric escape, mantle convection, melt production, outgassing, deep water cycling, and carbon cycling.

Both never-habitable (left column) and transiently habitable (right column) histories are geochemically self-consistent. Either scenario can reproduce modern bulk atmospheric composition, inferred surface heat flow, and observed ^{40}Ar and ^4He . Moreover, the model suggests that Venus could have been habitable with a ~ 100 m deep global ocean as late as 1 Ga without violating any known constraints.

In fact, if diffusion-limited water loss is throttled by a cool, CO_2 -dominated upper atmosphere, then a habitable past is tentatively favored by our model. This escape throttling makes it difficult to simultaneously recover negligible water vapor and ~ 90 bar CO_2 in the modern atmosphere without temporarily sequestering carbon in the interior via silicate weathering to enhance H escape.

Understanding why Venus's atmosphere is oxygen-free will be important for the interpretation of exoplanet atmospheres, including potential oxygen biosignatures.

