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Possible Climate Histories of Venus Type Worlds

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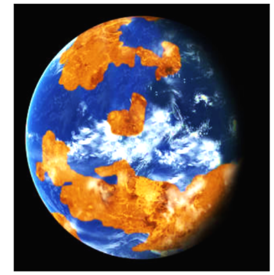
http://www.giss.nasa.gov/projects/astrobio



Abstract

There are two well-known scenarios for Venus' climate evolution. In one Venus had a long-lived magma ocean phase in its first 100Myr with a steam and CO_2 dominated atmosphere [1]. The faint young sun with its high XUV flux would cause photodissociation of the steam atmosphere and hydrodynamic escape would cause most of the hydrogen to escape & left-over oxygen would be absorbed by the magma ocean. Hence Venus would have started out hot and dry and the high D/H ratio measured by Pioneer Venus [2] would be from this period of water loss. The other scenario is that Venus' magma ocean lifetime would have been roughly the same length of time as Earth's (~1Myr) and water would have condensed on its surface in its early history and had a short period of habitability before increasing solar insolation through time drove it into a runaway greenhouse [3]. However, results from 2016 [4] showed that if Venus remains in the slowly rotating climate dynamics regime (as seen in exoplanet related climate studies[5]) its cloud albedo feedback would have kept it temperate for possibly billions of years. The only way to confirm which one of these scenarios occurred for Venus is to visit it and make the necessary measurements of noble and volatile gases [6]. But exoplanet observations of young exo-Venus type worlds around young F,G,K dwarf stars may constrain which scenario is more probable for a population of such planets. We present a vision of Venus' climate history that places it and its exoVenus cousins in an 'Optimistic Venus Zone' for ~3 billion years within the conventionally named 'Venus Zone' [7] and hence encourage the exoplanet community to seek out these worlds as possible habitable environments.

References:

[1] Hamano et al. 2013 Nature 497, 607
[2] Donahue et al. (1982) Science, 216 , 630.
[3] Bullock & Grinspoon (1999) Sci. Amer., 280 (3), 34-41.
[4] Way et al. (2016) GRL 43, 8376
[5] Yang et al. (2014). ApJ, 787 , L2
[6] Baines et al. (2013) CCTP2, 137.
[7] Kane et al. (2014) ApJL, 794, L5.
[8] Way, M.J. et al. (2017) Astroph Journ Suppl, 231, 1

Diagram to right includes 1 bar CO_2 (red point) & N_2 dominated atmospheres (light blue & dark blue points) thru time. **Each point represents the mean of 5 simulations**: Arid-Venus, 10m-Venus, 310m-Venus, 158m-Aqua & 310m-Earth described in the upper right of this poster. For full suite of simulations & more detail see JGR Planets preprint: **"Venusian Habitable Climate Scenarios: Modeling Venus through time and applications to slowly rotating Venus-Like Exoplanets"**

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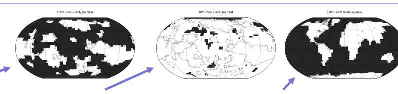
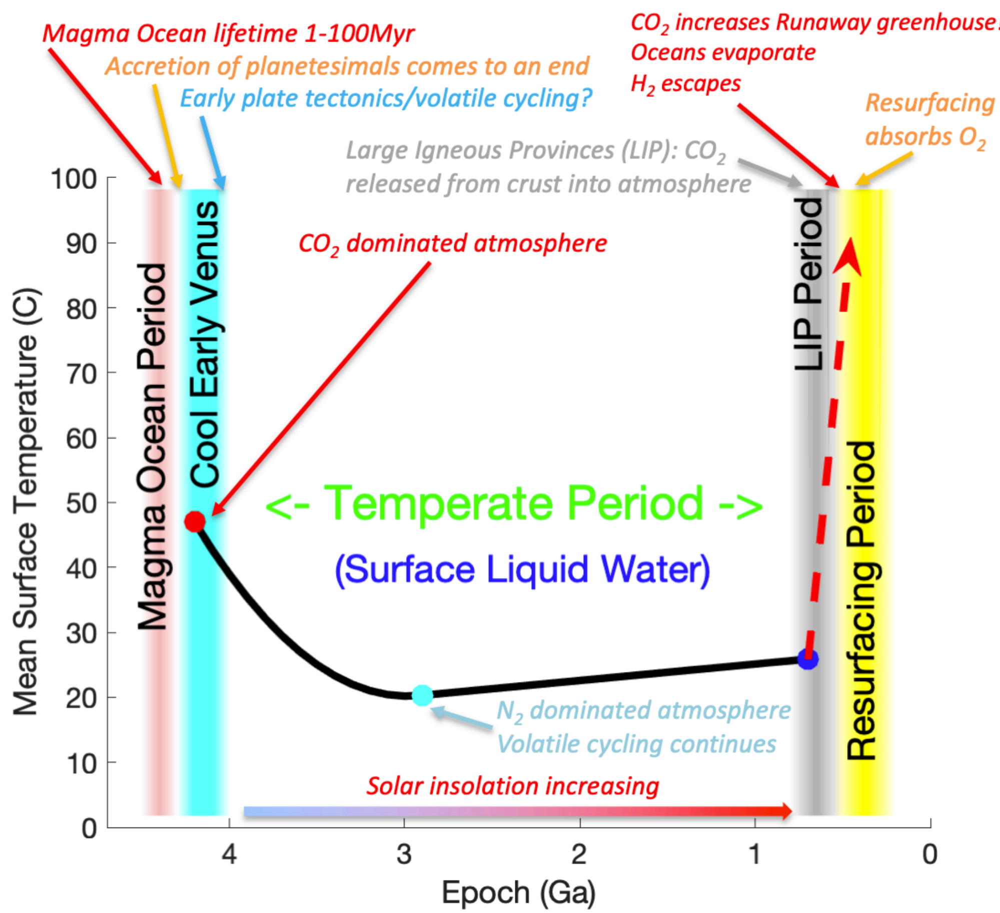
Model Setup



3-D General Circulation Model: ROCKE-3D [8]
Topographies: 1.) Modern Venus shallow ocean, 2.) Modern Venus land planet 3.) Aquaplanet, 4.) Earth topography
Model Resolution: Atmosphere: 4° x 5° x 40 (latitude x longitude x layers), Ocean: 4° x 5° x 13 layers
Land: Albedo=0.2 At Model Start (AMS), No land ice AMS, No vegetation, 50/50=clay/sand soil
Surface Water: Fully coupled 310m GEL, 10m GEL (Land planet), 900m (Aqua planet), 20cm soil (Arid planet)
Orbital Parameters: Modern Venus including modern Venus (retrograde) rotation rate.
Atmospheres (1 bar): 97% CO2 + 3% N2 (4.2 Ga) & N_2 dominated + CO_2=400.0, CH_4=1 ppmv (2.9Ga->0.7Ga)
Insolations: 4.2Ga → 0.7Ga : 1.4 → 1.7 x present day fluxes seen by Earth (1361 W/m^2)

Five simulations w/differing topography/land-mask/surface-water in each epoch (see 3 colored points in main figure)

1.) **Arid-Venus**: 0.2m water in soil at model start using modern Venus topography.
2.) **10m-Venus**: 10m of water Global Equivalent Layer (GEL) distributed as lakes in lowest lying topographic regions in a modern Venus topography.
3.) **310m-Venus**: 310m GEL in lowest topographic regions in a modern Venus topography.
4.) **158m-Aqua**: 158m deep aquaplanet bathtub ocean commonly utilized in exoplanet studies (1 land grid point at south pole).
5.) **310m-Earth**: 310m deep bathtub ocean with modern Earth-like topography



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