

Lessons from Earth Aerobiology for Venus Astrobiology

Ames Aerobiology Laboratory (ABL)

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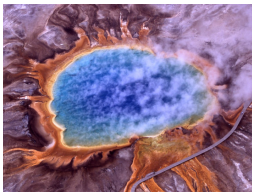
[1]NASA Ames Research Center

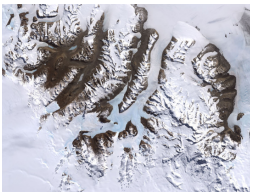
Venus Today Workshop
1 September 2020

A (very) brief introduction to astrobiology

Astrobiology by analogy: where is life (*extremophiles*) on Earth?

- assumes water, carbon, CHNOPS (e.g., no supercritical CO_2)
- flexibility in biochemistry (e.g., no DNA, ATP, lipids...)

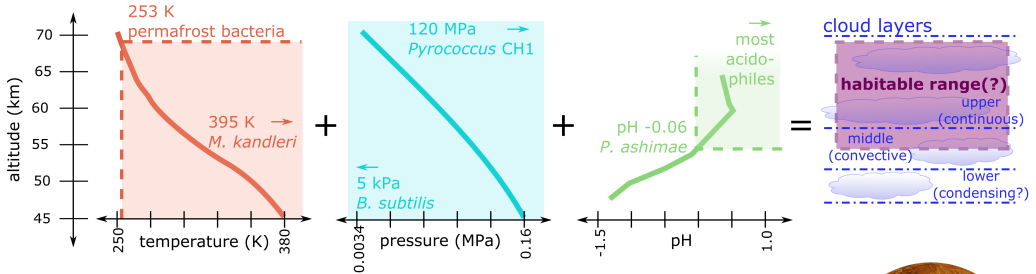





Relevant stressors for airborne life:

- lack of water / desiccation (includes low pressure)
- energy availability (chemical, photonic)
- radiation (UV, cosmic rays)
- temperature (cold)
- particle size & residence time

Venus clouds: why all the interest?



Current state of knowledge has analogues for:

- T, P[9;13], radiation[6;16], particle size, residence time[15]

Less well constrained, but supported in theory:

- energy source (redox, photonic); CHNO(P)S[12;17]

Not well understood:

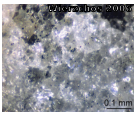
- interactions between stressors, microenvironments

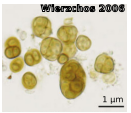


How does this inform the priority of *in situ* measurements?

Venus clouds: the less good news







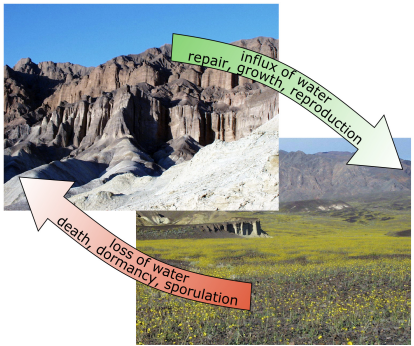
Venus aerosols are akin to Earth's barren deserts in a_w

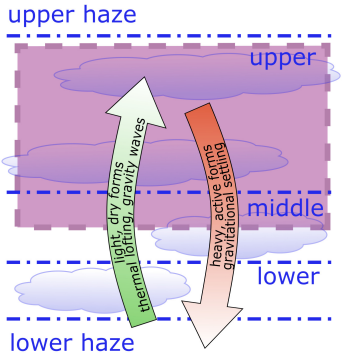
Phenomenon	ψ (Pa)	a_w	Cite
Microbial growth media	$\sim -2\times10^5$	0.996	[8;10]
Non-xerophile growth	-5×10^6		[14]
Bacterial growth(?)	-1.7×10^7		[14]
NaCl solubility	-4.1×10^7	0.74	[5]
Fungal growth(?)		0.61	[8]
Archean growth(?)		0.4–0.7	[3]
Don Juan Pond		0.45	[8]
$MgCl_2$ solubility		0.3	[3]
Atacama desert soils	$< -1.5\times10^8$	0.01–0.52	[5;11]
75% H_2SO_4 solution		0.02	[7]

Not to mention...

- acid activity at ultralow pH
- biomolecular stability
- bioavailability of 'dissolved' nutrients
- stratification

The 'desert bloom' scenario

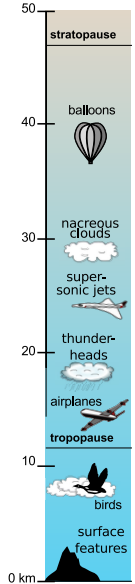




Typical biological characteristics

- Dependent on sporadic influx of distant water/nutrients (*e.g.*, volcanism)
- *Very* low biomass during typical dry stage, and 'tough to crack' (e.g. spores)
- Distribution dominated by 'hot spots' on very small scales (< 1 m)
- To endure, residence time (incl. cycles) must exceed generation time (incl. inactivity)

Lessons from Earth: what's the right analogue?



Troposphere

- Lots of surface influx/mixing
- Clouds (water hot spots) carry 10^3–10^5 cells/mL [2]
- Metabolic activity found in some warm low-altitude samples[1]

Stratosphere

- Relatively isolated and stratified (volcanic exceptions)
- Overall very low water content ($\psi = -1.5 \times 10^9$ Pa)
- Sulfate aerosol layer as an analogue
  - supercooled sulfuric acid and water
  - acid weight fraction is 0.6–0.85[18]
  - size is 0.1–1 µm
- Viable cell concentration can be $< 10^2$–10^5 cells/m^3 if mixed[4]
- Reproduction not yet observed

Implications for ongoing research & sampling

In situ targets

- Differentiate size-specific aerosol composition and residence dynamics
- Compare aerosol regions with upwelling/mixing to isolated regions
- Measure water activity (and/or major factors affecting it)
- Spectral irradiance across altitude to constrain available photochemical energy

Analogue exploration

- Viability, metabolism, and division in high-altitude (especially stratospheric) aerosols
- Better lab analogue environments (e.g. long-term suspension chambers)

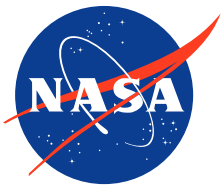
Useful benchtop work

- Water activity in potential aerosol analogue solutions
- Energetics and kinetics of potential metabolic pathways
- Adaptation of electrochemical fluidics/electrodes to Venus environment

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Questions?

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