

Venus: The first Habitable world of our Solar System?

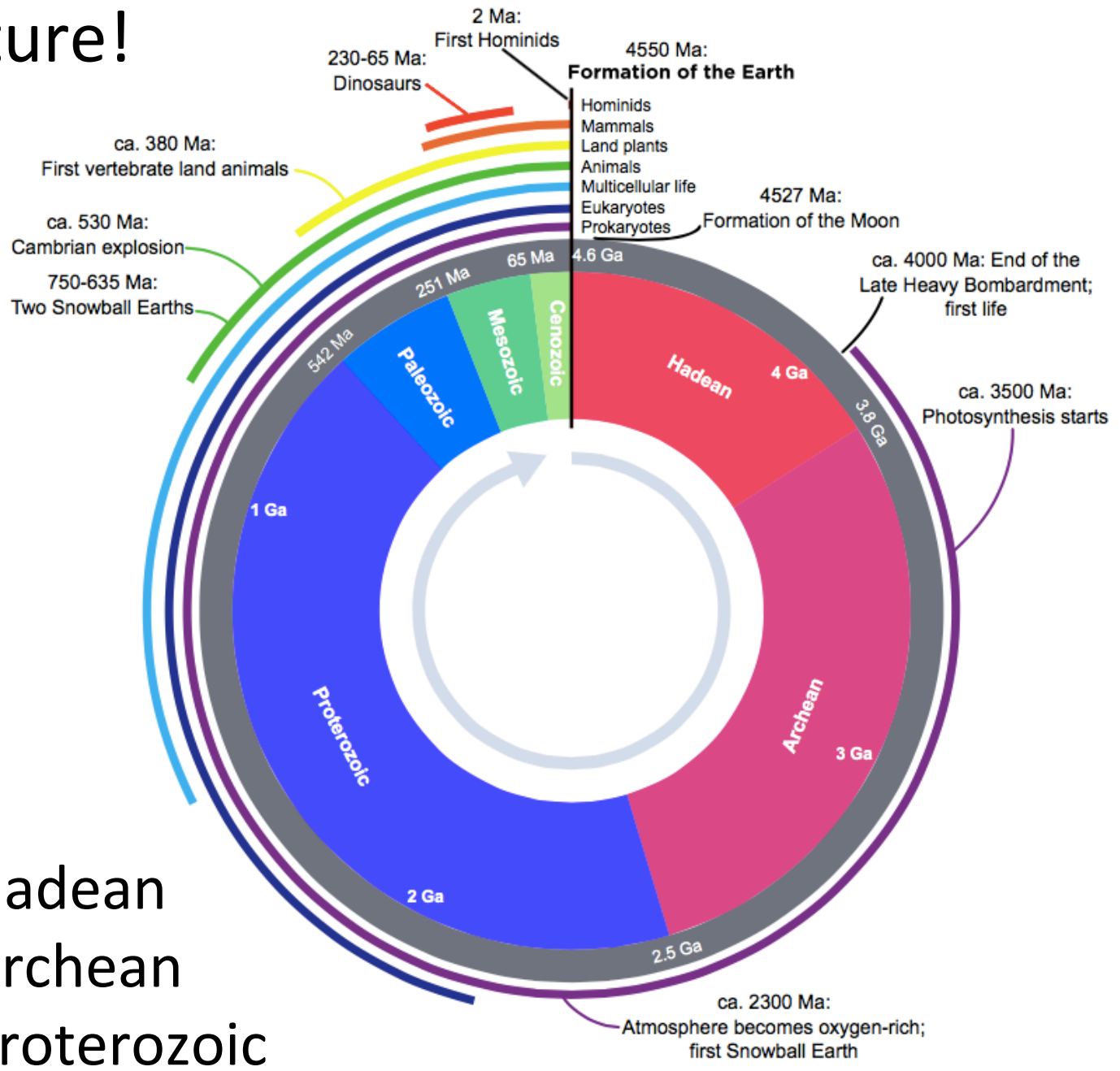
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Tony Del Genio, Nancy Kiang, Linda Sohl,
Tom Clune, Igor Aleinov, Maxwell Kelley

[NeXSS-ROCKE3D]

2015/10/23

Nomenclature!

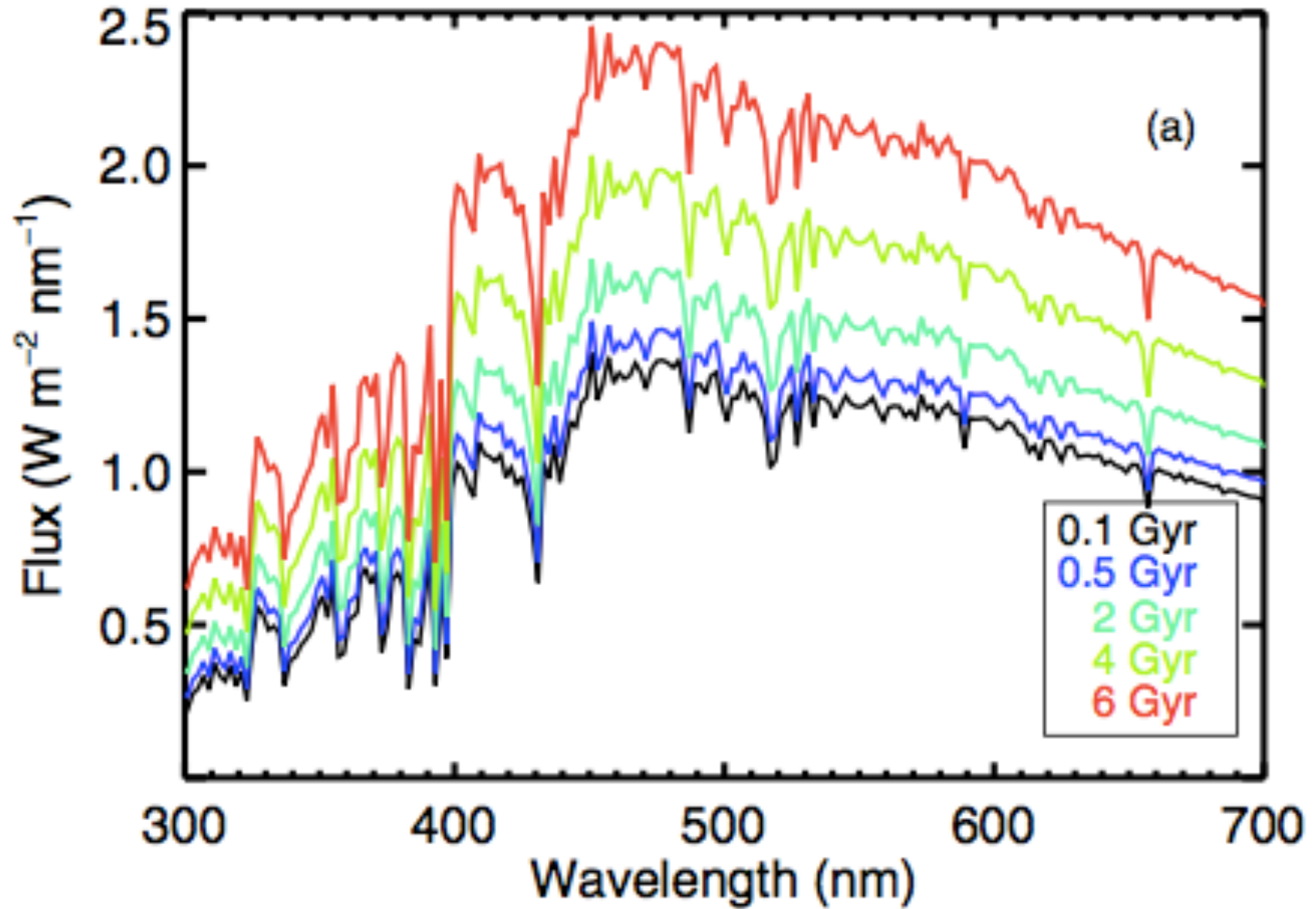


4.6-3.8 Gya Hadean
3.8-2.5 Gya Archean
2.5-0.5 Gya Proterozoic

Faint Young Sun Paradox & Habitability Through Time

- Hard to get Earth warm enough to have liquid water during early Archean = 3.8-2.5 [2.9] Gya
- Hard to get Mars warm enough for global scale oceans to persist in same period
- For Venus' early history we may be in luck
 - Low solar flux & slower rotation rate => liquid H₂O

M. Claire 2012 (Fluxes at 1 AU)



Paleo-Venus: Water?

- Water abundance?
 - High D/H ~ 150 x terrestrial
 - Via history of escape & re-supply in last $\sim 10^9$ years, not a history of primordial escape (Grinspoon 1993,97,98)?
 - Likely received approx. the same amount of H₂O as Earth in early solar system history
 - Timescale of H₂O loss $< \sim 100$ s My (Kasting 1984,88) to 2By (Grinspoon & Bullock 2003)
 - Current estimates are **4-530m** of liquid water
- Early Dry or Wet alternatives impossible with present knowledge - arguments for & against both (Lewis & Prinn, 1984; Yung & DeMore 1999).

Venus slow Rotation a recent phenomenon?

1. Result of thick atmosphere (thermal tides):
 - A. R. Dobrovolskis, A. P. Ingersoll, Atmospheric tides and the rotation of Venus. I - Tidal theory and the balance of torques. *Icarus* 41, 1–17 (1980).
2. Perhaps thick atmosphere is not necessary:
 - J. Leconte et al. 2015

The logo for ScienceExpress, featuring the word "Science" in a bold, sans-serif font and "Express" in a stylized, italicized font with a motion blur effect, all in white on a black background.

Asynchronous rotation of Earth-mass planets in the habitable zone of lower-mass stars

Jérémy Leconte,^{1,2,3*} Hanbo Wu,^{1,4} Kristen Menou,^{3,5} Norman Murray^{1,4}

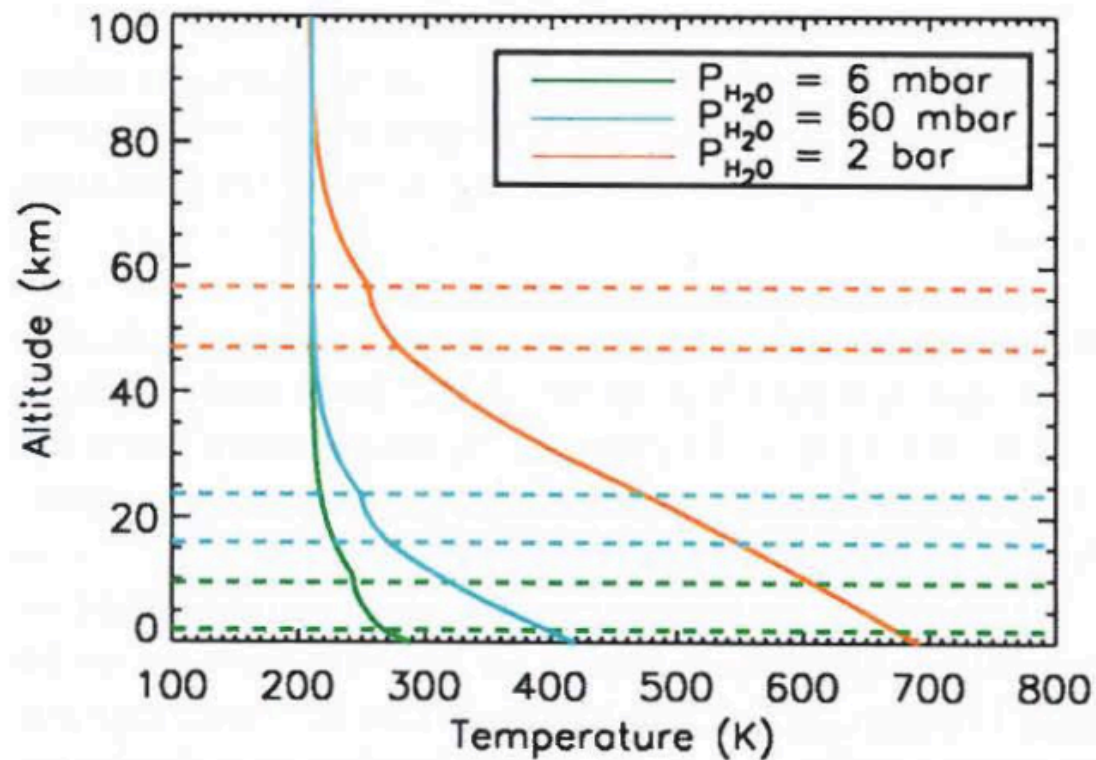
¹Canadian Institute for Theoretical Astrophysics, 60 St George Street, University of Toronto, Toronto, ON, M5S3H8,

Venus Geology

- Cosmochemical/geochemical **models** imply Venus' bulk composition \approx Earth (Lodders & Fegley 1998)
- Complete resurfacing of Venus in past 750My-1By
- Minimal magnetic field (today)
- No present day evidence of plate tectonics
 - But: present day evidence of volcanism (Mars Express)
- Need in-situ measurements of Xe, Kr, Ar & isotopes to provide accessible record of ancient events pertinent to planetary formation & early evolutionary processes

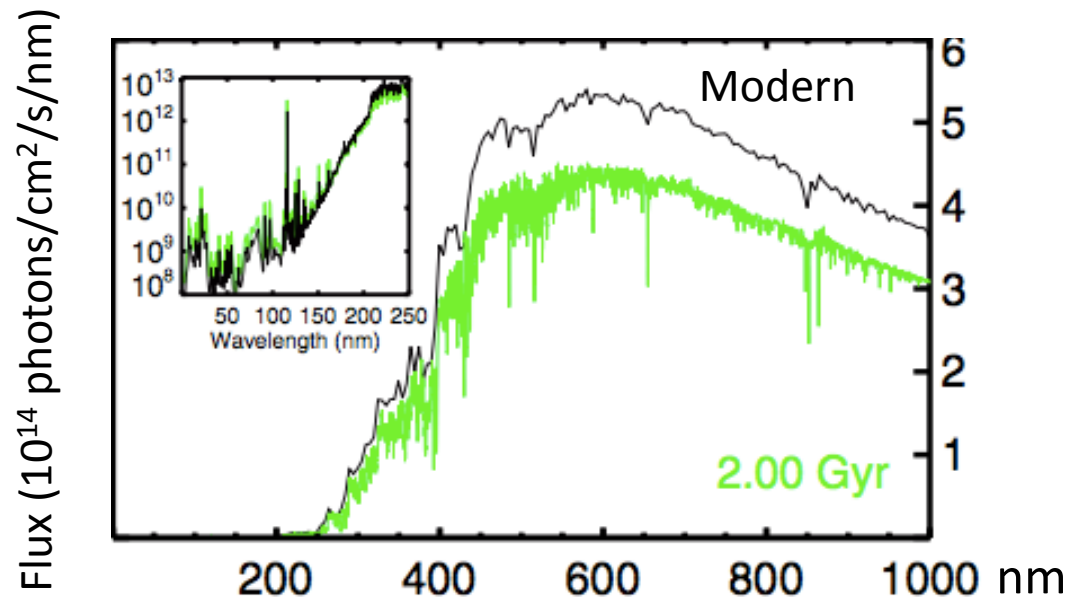
1-D Simulations: Grinspoon & Bullock 2003

- 1 bar N₂, CO₂=.35mb, H₂O=6mb
- 100% cloud cover
- Yields mean global surface temp ~300K



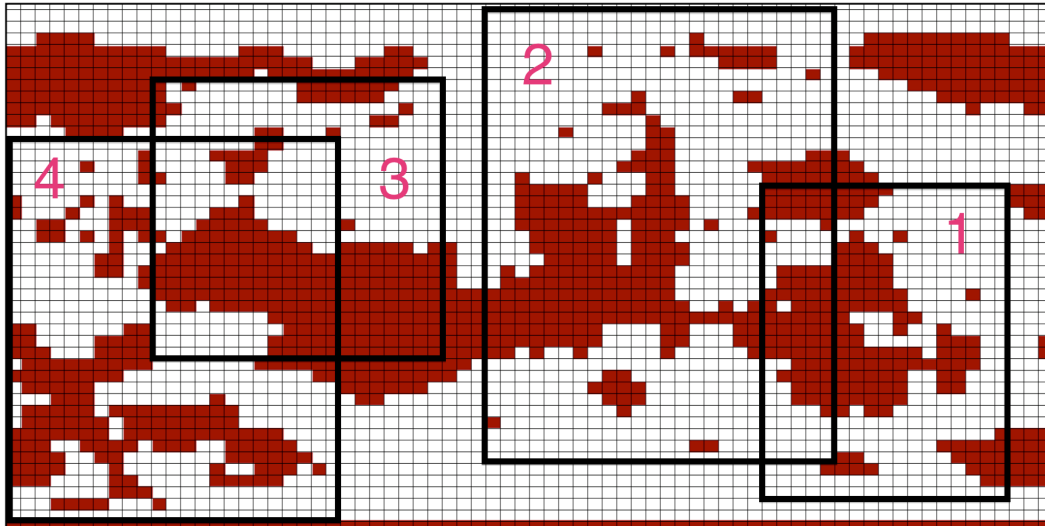
GISS: 3-D General Circulation Model

- Modern Venus topography, radius, mass, spin
- N₂=1bar, CO₂=0.4mb, CH₄=0.001mb
- 2.9Gya solar spectrum from M. Claire 2012
 - ~0.820 x present day solar luminosity

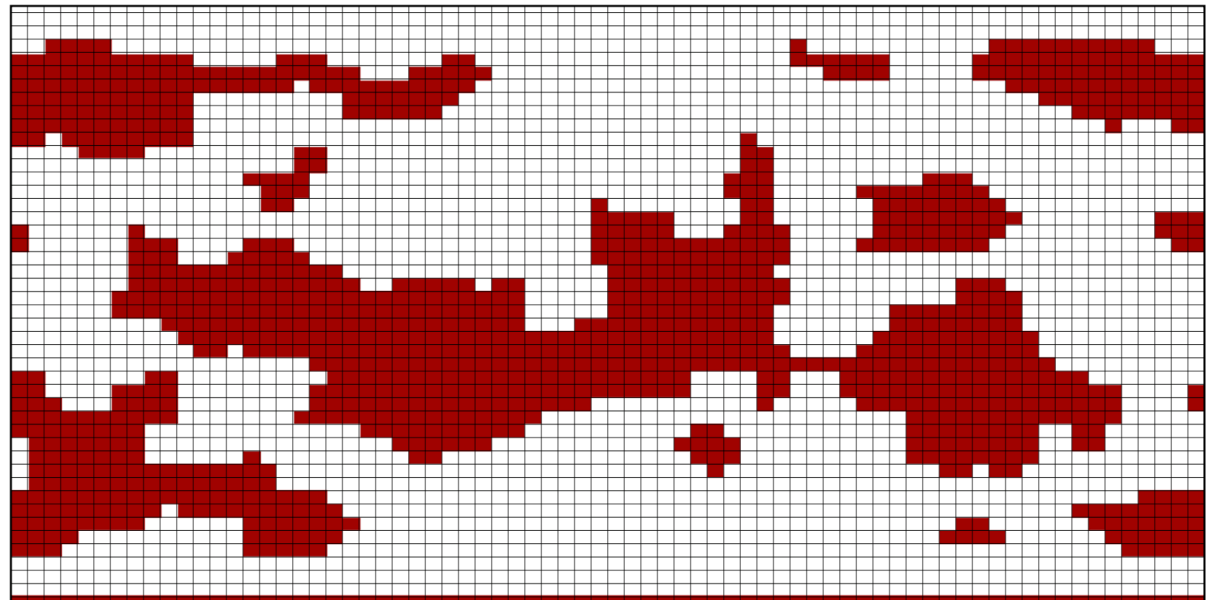


3-D Model Setup: Venus topography changes

fgrnd in Z72X46N_venus001

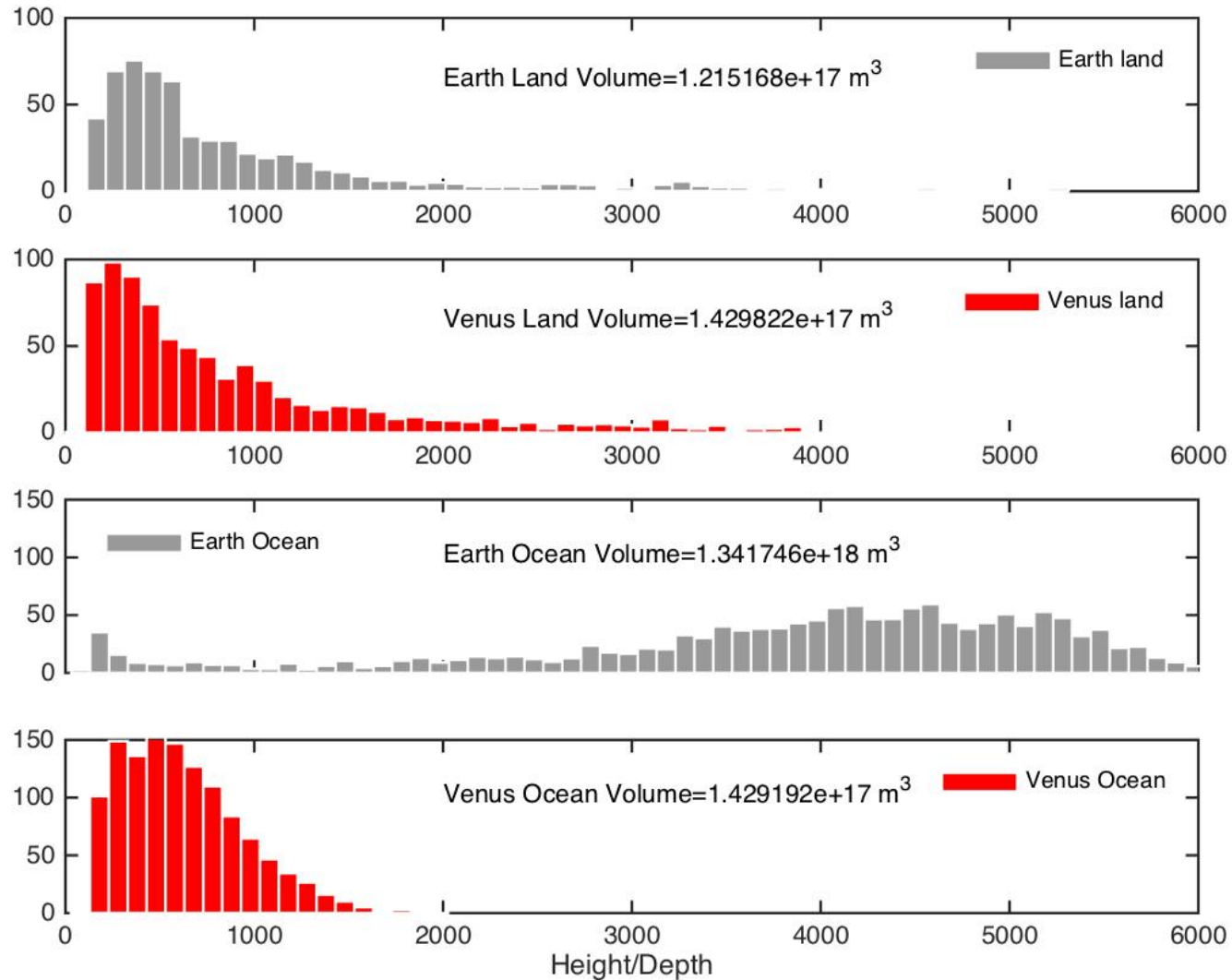


fgrnd in Z72X46N_venus002



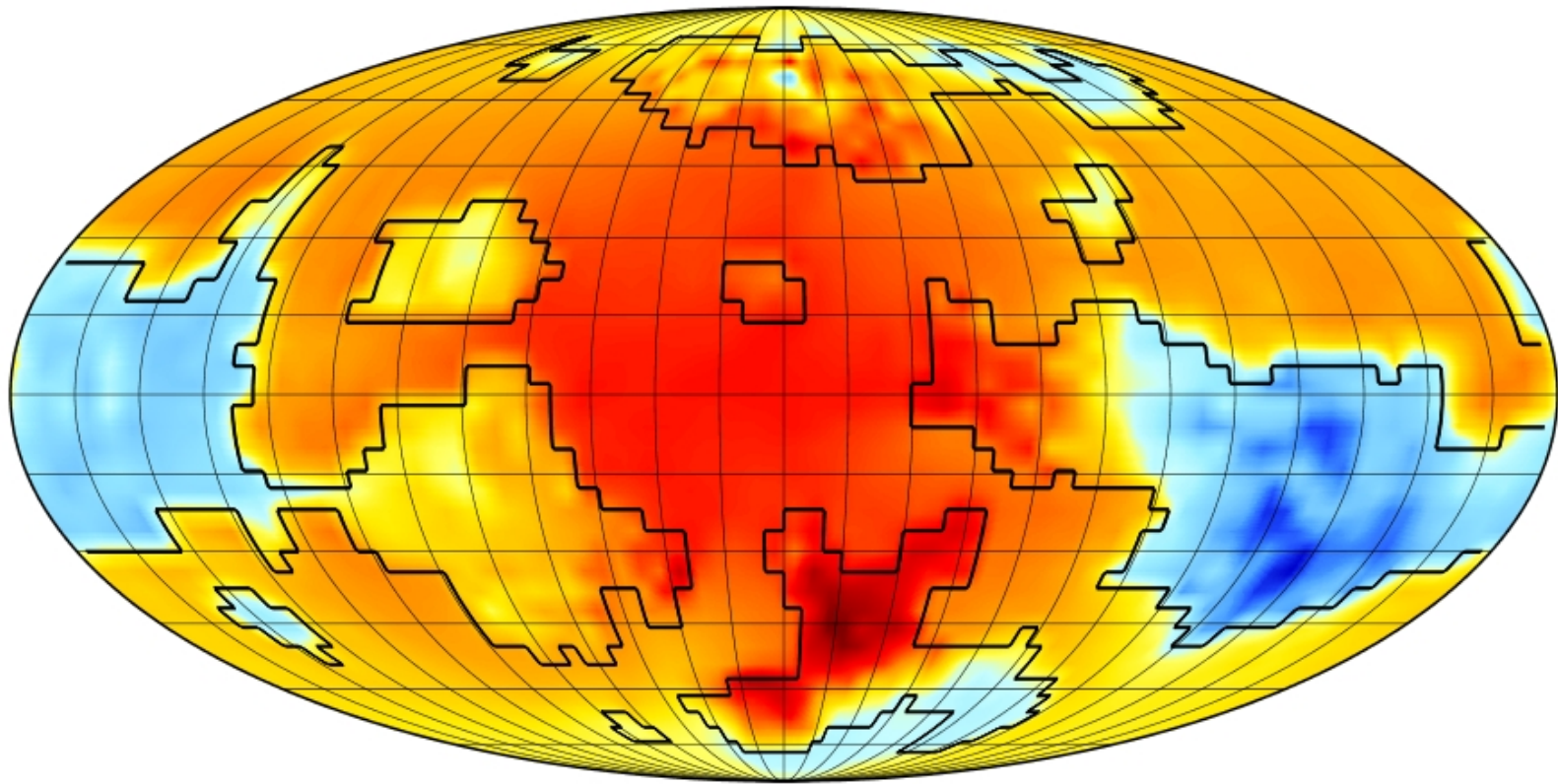
Venus land/ocean

Venus Ocean volume equivalent to 310m depth average

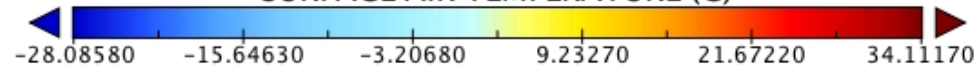


Paleo-Venus Surface Temperature

SURFACE AIR TEMPERATURE

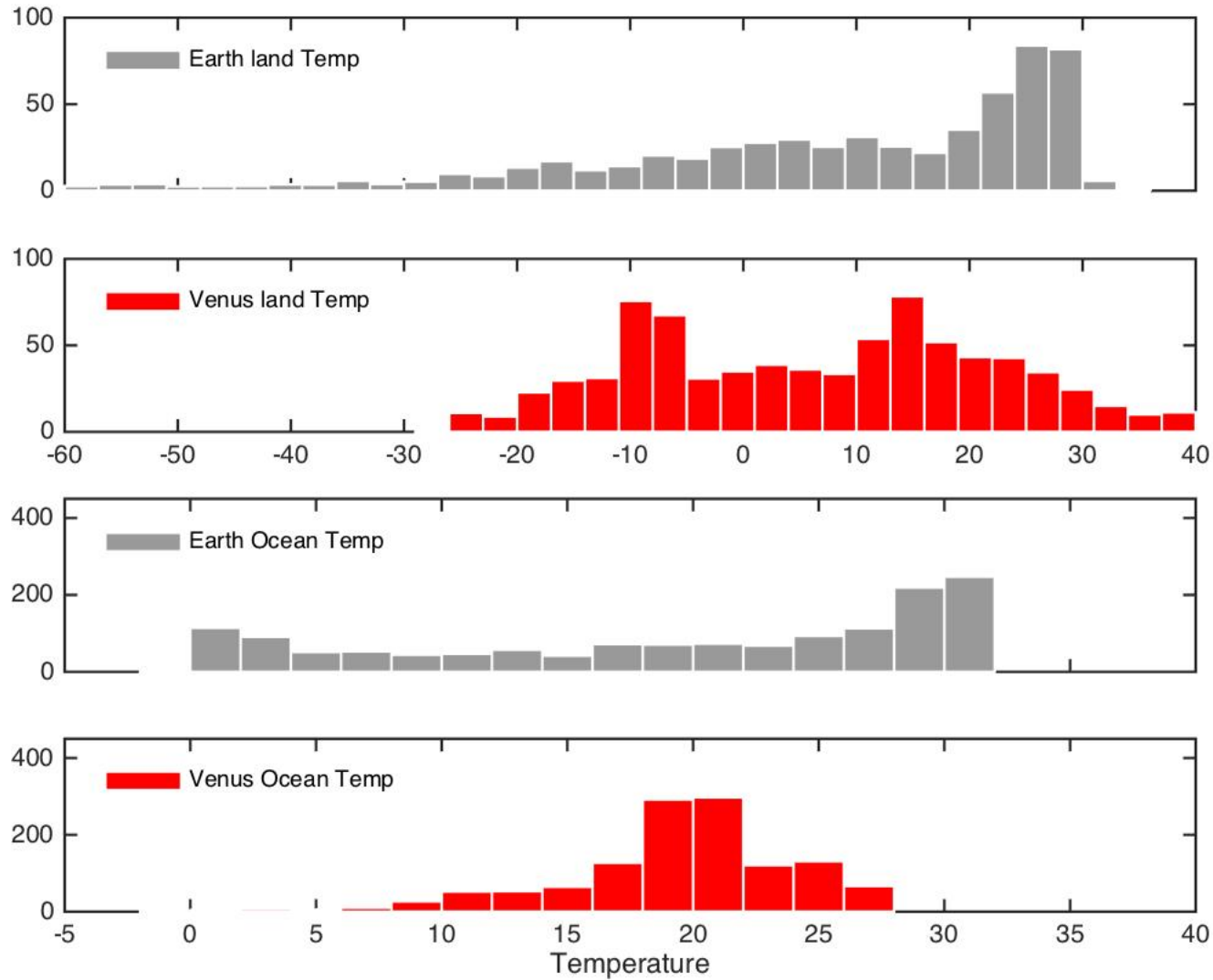


SURFACE AIR TEMPERATURE (C)

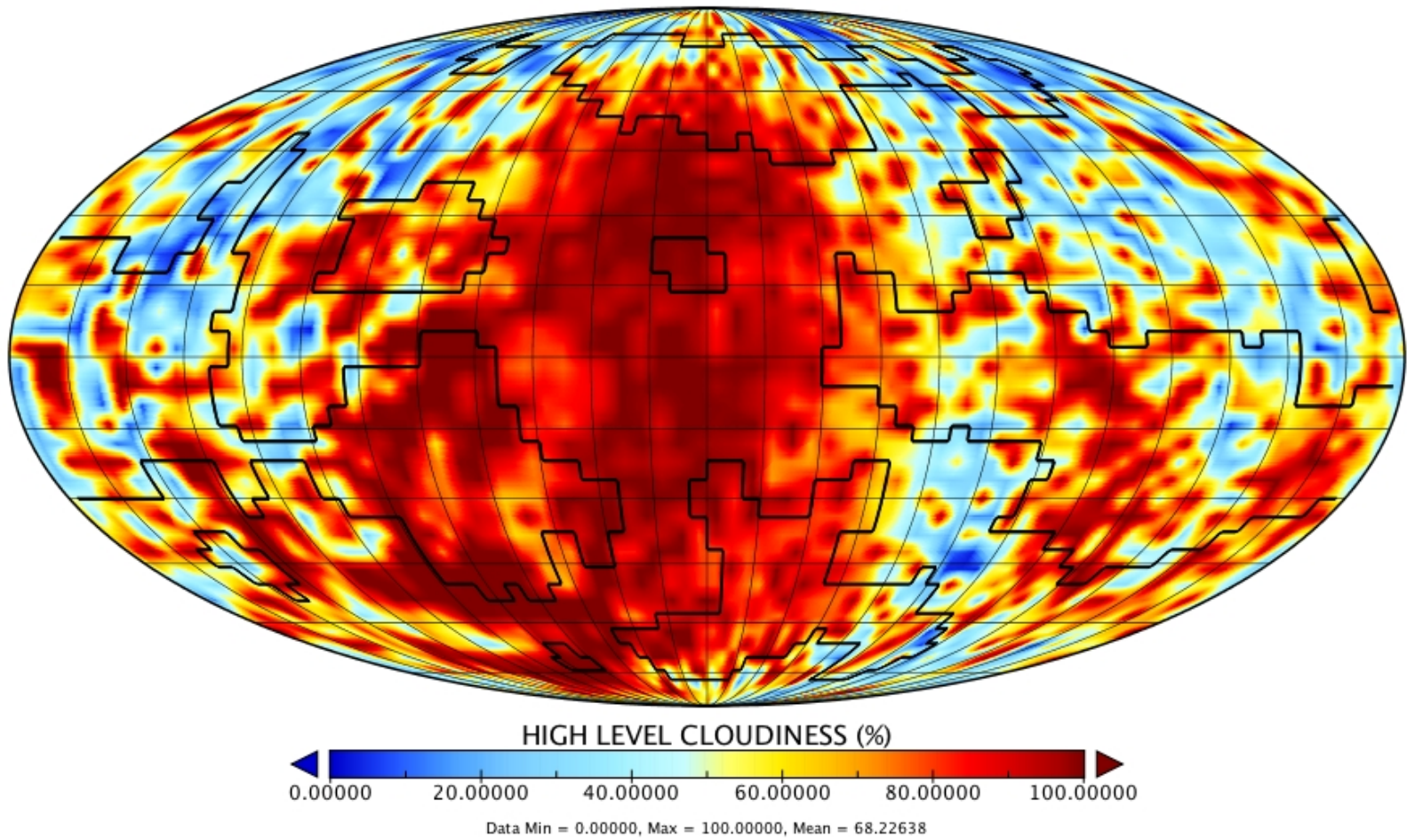


Data Min = -28.08580, Max = 34.11170, Mean = 11.01060

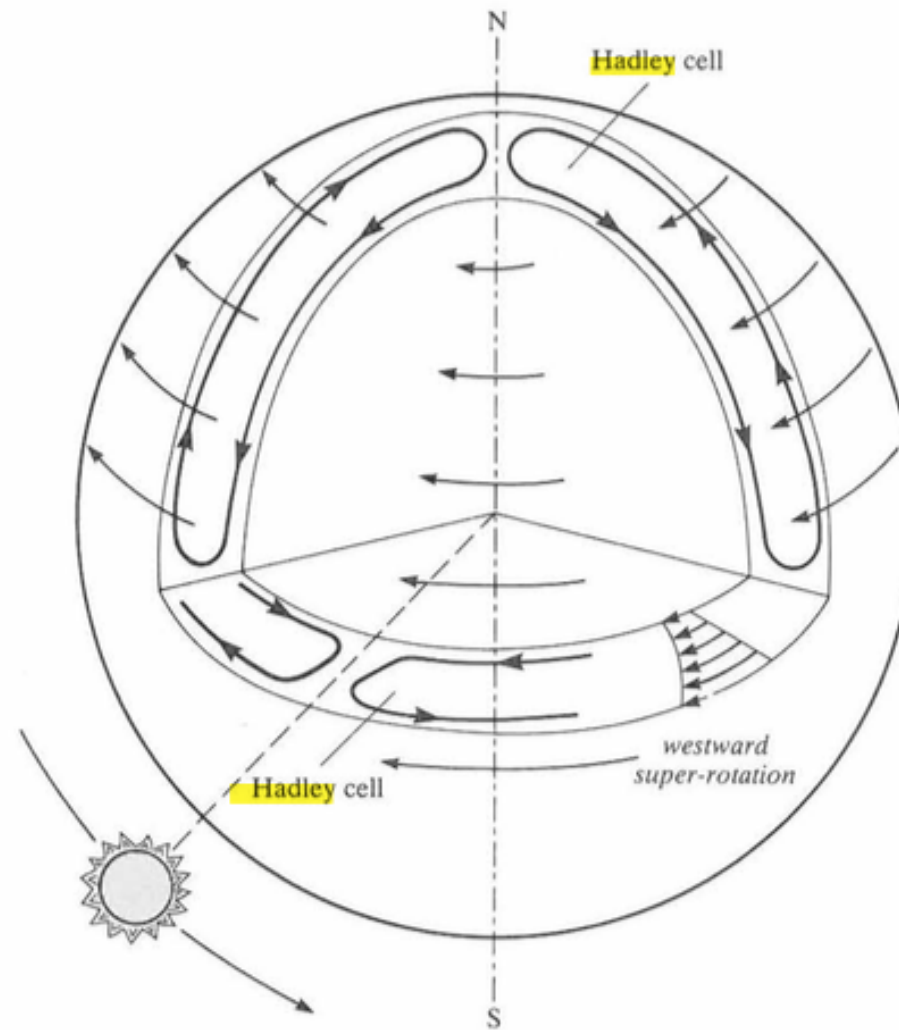
Venus preliminary results?



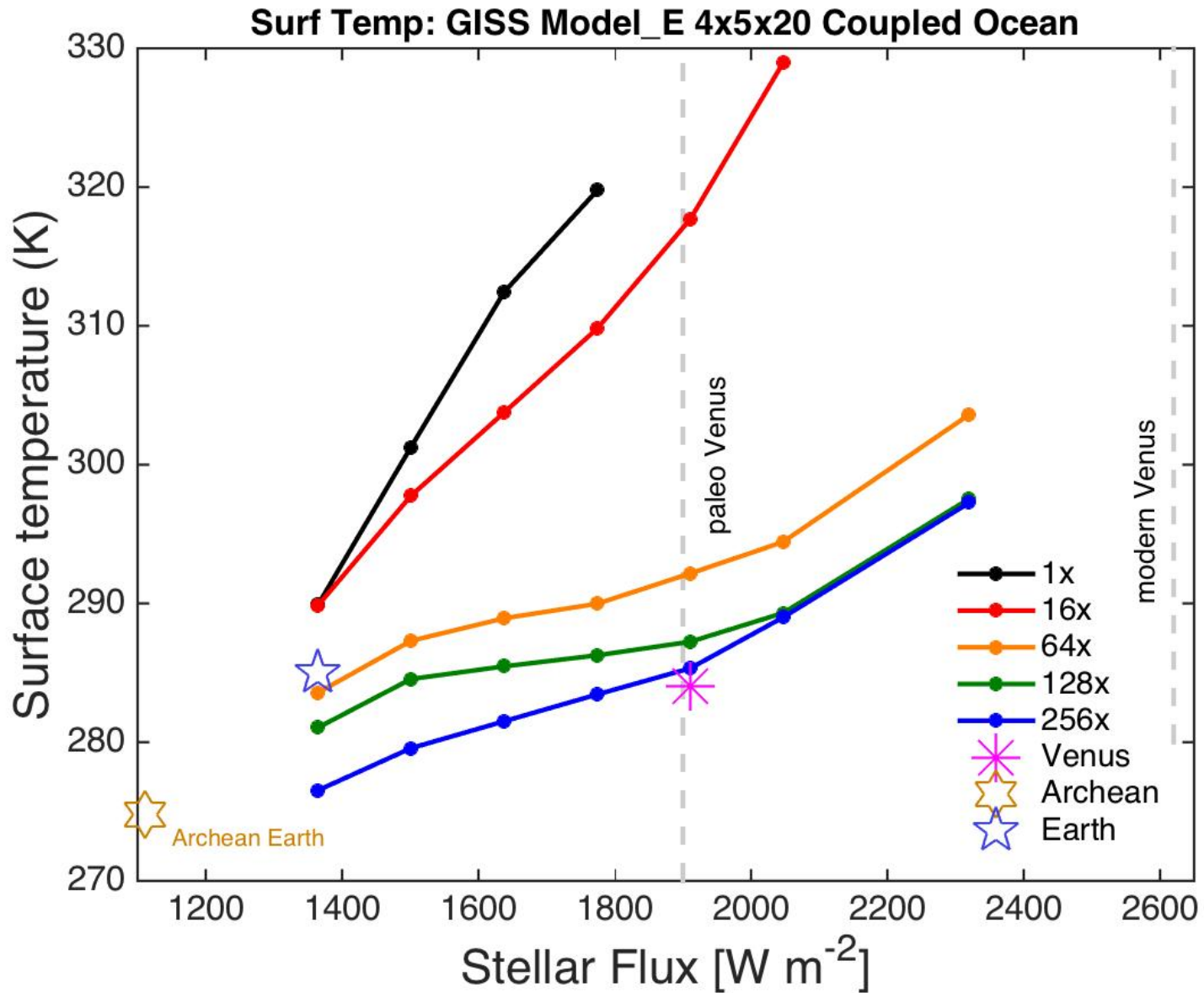
High Level Cloudiness => High Albedo



Hadley Cell is different from Earth's



Other Worlds



Conclusions

- Venus not Earth or Mars may have been the first habitable world of our solar system
- Can fewer assumptions be made for 1 vs another?
- Need for new in-situ observations to confirm Venus' geologic history – and water inventory