# Venus habitability?

- Morowitz, H. & Sagan, C. *Life in the clouds of Venus?* Nature 215, 1259–1260 (1967).
- New: Venus $PH_3$ phosphine detection at cloud layer, speculation and controversy:
  - In September 2020, an international team of astronomers made headlines when it reported finding phosphine — a potential (?) marker of life — in the planet's atmosphere. Greaves, J. S. *et al. Nature Astron*. https://doi.org/10.1038/s41550-020-1174-4 (2020).
  - The Joint ALMA Observatory then issued a revised calibration of the data.
  - Multiple articles claimed that the data were wrongly interpreted (polynomial fitting can identify instrumental features similar to absorption lines).
  - Villanueva, G.L., Cordiner, M., Irwin, P.G.J. *et al. No evidence of phosphine in the atmosphere of Venus from independent analyses*. *Nat Astron* **5,** 631–635 (2021). https://doi.org/10.1038/s41550-021-01422-z
  - Greaves, J.S., Richards, A.M.S., Bains, W. *et al. Reply to: No evidence of phosphine in the atmosphere of Venus from independent analyses*. *Nat Astron* **5,** 636–639 (2021). https://doi.org/10.1038/s41550-021-01424-x

Astrobiology, Vol. 21, No. 10 |



# Introducing the Venus Collection—Papers from the First Workshop on Habitability of the Cloud Layer

Multiple workshops on Habitability of the Cloud Layer

Sanjay S. Limaye, Lev Zelenyi, and Ludmilla Zasova

**Published Online:** 7 Oct 2021 | https://doi.org/10.1089/ast.2021.0142



## Abstract

We introduce the collection of papers from the first workshop on the habitability of the venusian cloud layer organized by the Roscosmos/IKI-NASA Joint Science Definition Team (JSDT) for Russia's Venera-D mission and hosted by the Space Research Institute in Moscow, Russia, during October 2–5, 2019. The collection also includes three papers that were developed independently of the workshop but are relevant to venusian cloud habitability.

New!! 3 NASA & ESA missions to Venus


### Meeting Location and Dates

We are happy to announce the Venera-D: Venus Cloud Habitability System Workshop scheduled for November 29–December 3, 2021, 14:00–17:00 GMT.

# Special Regions (SR): water and temperature as habitability requirement

https://www.nature.com/articles/s41550-021-01391-3

- **SR Requirements:**

**T> 255 K and**

**RH (water activity) > 0.6**

Rummel, J.D. et al 2014. *A New Analysis of Mars Special Regions: Findings of the Second MEPAG Special Regions Science Analysis Group (SR-SAG2).* Astrobiology 14, 887-968.

nature astronomy

ARTICLES

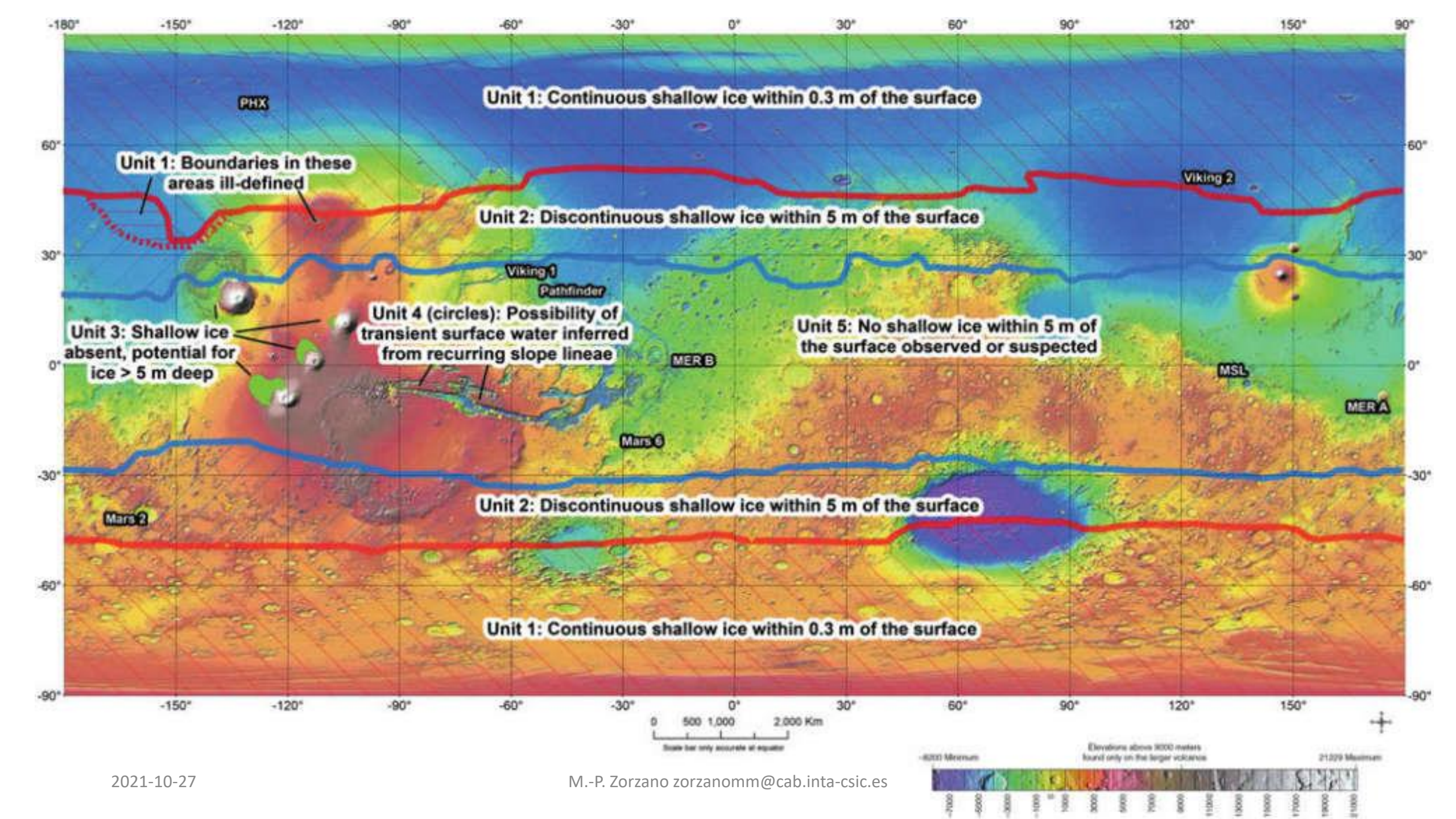
https://doi.org/10.1038/s41550-021-01391-3

Check for updates

## Water activity in Venus's uninhabitable clouds and other planetary atmospheres

John E. Hallsworth[1]✉, Thomas Koop[2], Tiffany D. Dallas[1], María-Paz Zorzano[3,4], Juergen Burkhardt[5], Olga V. Golyshina[6], Javier Martín-Torres[4,7], Marcus K. Dymond[8], Philip Ball[9] and Christopher P. McKay[10]

**The recent suggestion of phosphine in Venus's atmosphere has regenerated interest in the idea of life in clouds. However, such analyses usually neglect the role of water activity, which is a measure of the relative availability of water, in habitability. Here we compute the water activity within the clouds of Venus and other Solar System planets from observations of temperature and water-vapour abundance. We find water-activity values of sulfuric acid droplets, which constitute the bulk of Venus's clouds, of ≤0.004, two orders of magnitude below the 0.585 limit for known extremophiles. Considering other planets, ice formation on Mars imposes a water activity of ≤0.537, slightly below the habitable range, whereas conditions are biologically permissive (>0.585) at Jupiter's clouds (although other factors such as their composition may play a role in limiting their habitability). By way of comparison, Earth's troposphere conditions are, in general, biologically permissive, whereas the atmosphere becomes too dry for active life above the middle stratosphere. The approach used in the current study can also be applied to extrasolar planets.**






M.-P. Zorzano zorzanomm@cab.inta-csic.es

- Venus's surface is too hot for organic life forms.
- It has been argued, that the lower cloud layer (at 40 to 70 km) has a temperature range that makes it potentially habitable. The clouds of Venus consist mostly of sulfuric acid droplets but there are indications of water vapour too.
- Most of the previous discussions about the potential challenges of habitability of Venus clouds has only considered the extreme acidity of sulfuric acid clouds. Some extreme acidophiles are capable of metabolism close to pH 0. Record growth: *Pierophilus torridus* (pH -0,06 at 60°C, which is equivalent to only 11,5% w/w sulfuric acid).
- Water activity is a potent determinant of functionality for microbial cells. It varies between 0 and 1. The present "record" for water activity tolerance is 0.537 (fungal halophile/xerophile *Aspergillus penicillioides*).
- We compute the water activity (Relative Humidity) within the clouds of Venus from OBSERVATIONS of Temperature and water-vapour abundance and find $a_w$<0.004 for the sulfuric acid droplets which constitute the bulk of Venus clouds.
- **Pressure and temperature** is taken from **Venus entry probes measurements**. The **water-vapour mixing ratio** is taken from the parametrization of Gao et al, which is based on observations from Bertaux et al. using **SPICAV on Venus Express (2007)** and the **Venera 11, 13 and 14 missions (1983)**.
- We derive then the sulfuric acid concentration that corresponds to this water activity according to models of $H_2SO_4$-$H_2O$ mixtures. This is consistent with published observations and models of acid content on the clouds of Venus.


M.-P. Zorzano zorzanomm@cab.inta-csic.es

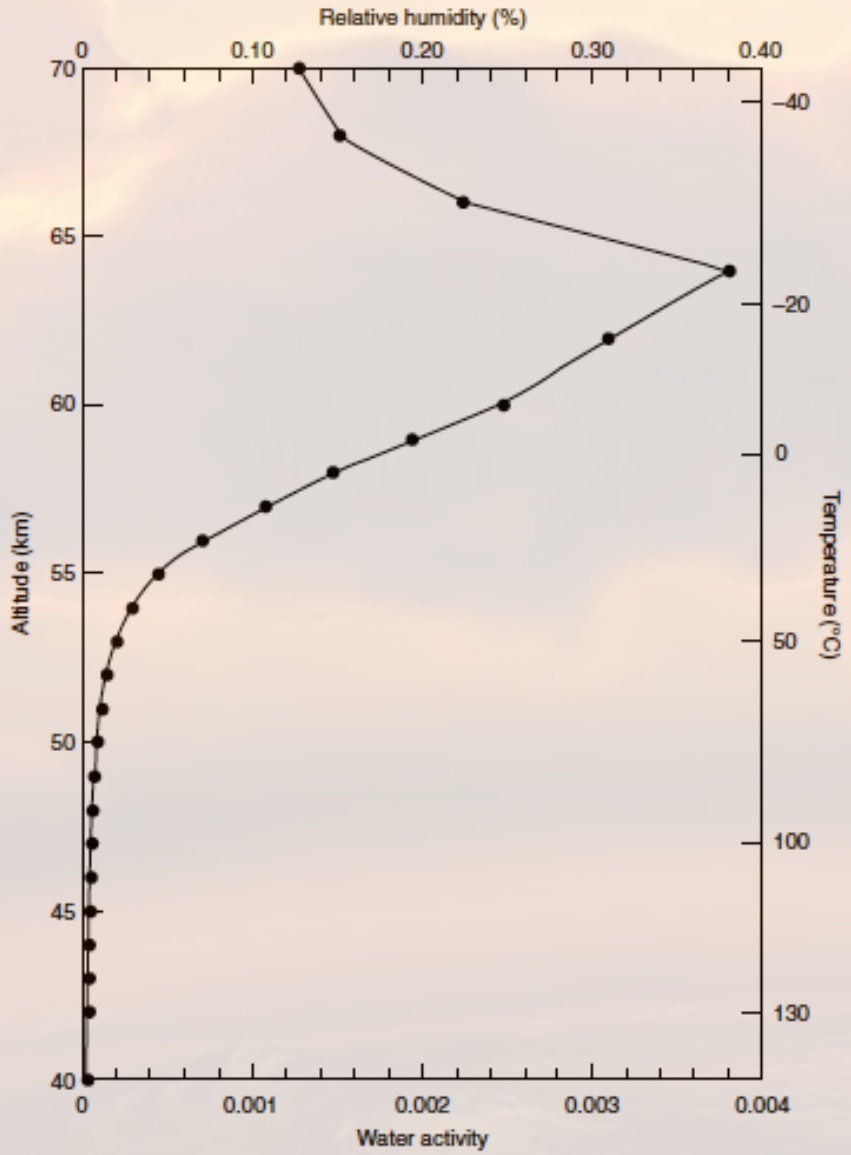



**Fig. 2 | Water activity and relative humidity of the Venusian atmosphere in the region where temperatures are in the range of possible biological interest (between −40 °C and 130 °C).** The uncertainty in altitude is smaller than the size of the data-point markers. The uncertainty in water activity is ±30% of the value, as described in the main text.

**Table 1 | Water activity and sulfuric acid concentrations of droplets in the Venusian cloud layer[a]**

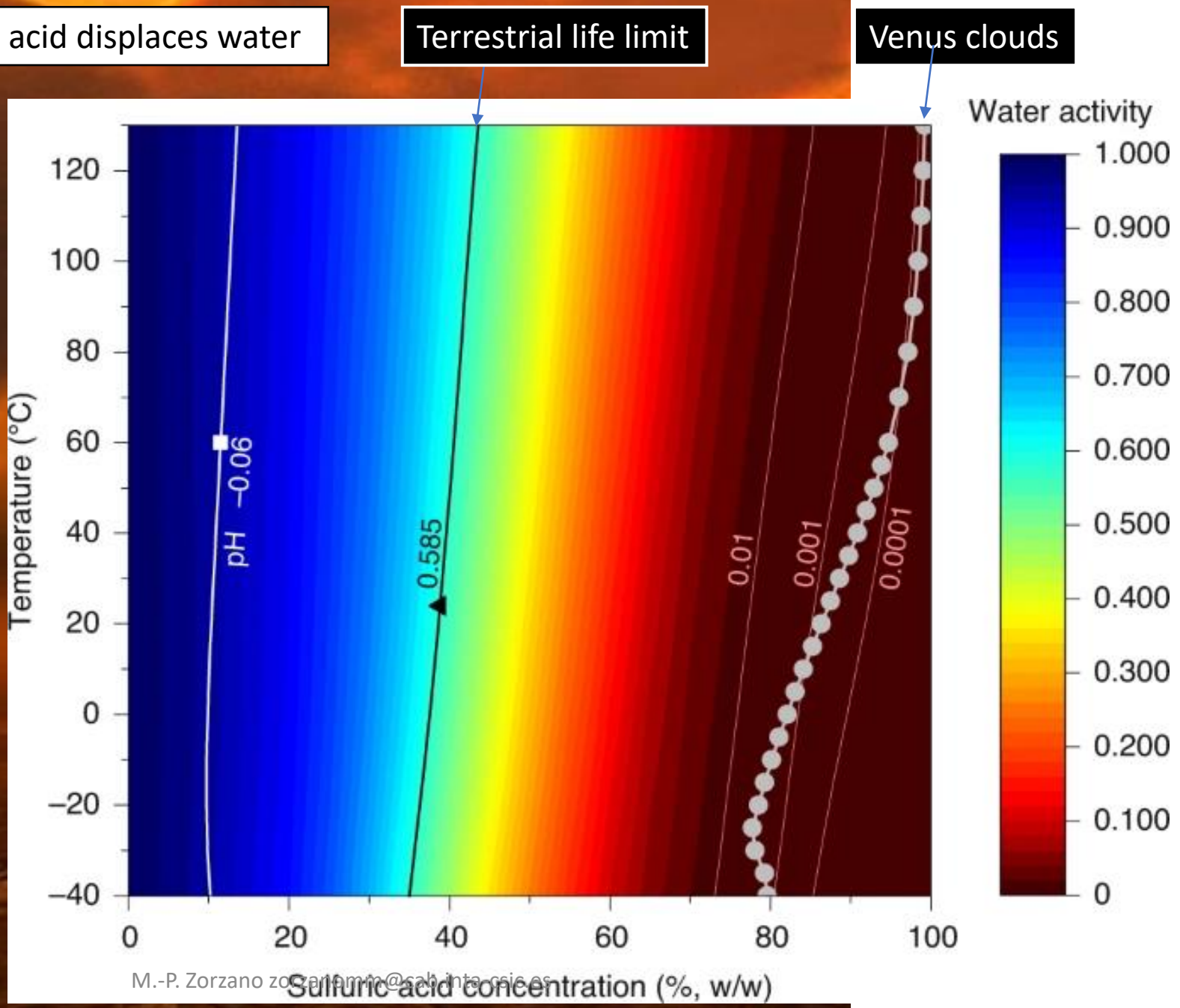
| Temperature (°C)[b] | Altitude above mean ground level (km)[b] | Pressure (bar)[b] | Relative humidity (%)[c] | Water activity[d] of cloud droplets | Sulfuric acid concentration of cloud droplets (%, w/w)[e] |
|---|---|---|---|---|---|
| −40 | 68.80 | 0.047 | 0.1397 | 0.001397 | 79.6 |
| −35 | 67.02 | 0.067 | 0.1803 | 0.001803 | 79.3 |
| −30 | 65.02 | 0.097 | 0.3051 | 0.003051 | 78.1 |
| −25 | 63.40 | 0.131 | 0.3692 | 0.003692 | 77.8 |
| −20 | 62.30 | 0.158 | 0.3235 | 0.003235 | 78.6 |
| −15 | 61.12 | 0.197 | 0.2847 | 0.002847 | 79.3 |
| −10 | 59.94 | 0.238 | 0.2440 | 0.002440 | 80.2 |
| −5 | 59.09 | 0.276 | 0.1982 | 0.001982 | 81.1 |
| 0 | 58.32 | 0.313 | 0.1605 | 0.001605 | 82.1 |
| 5 | 57.60 | 0.354 | 0.1296 | 0.001296 | 83.1 |
| 10 | 56.93 | 0.394 | 0.1043 | 0.001043 | 84.2 |
| 15 | 56.39 | 0.430 | 0.0831 | 0.000831 | 85.2 |
| 20 | 55.87 | 0.466 | 0.0664 | 0.000664 | 86.4 |
| 25 | 55.40 | 0.502 | 0.0533 | 0.000533 | 87.5 |
| 30 | 54.92 | 0.538 | 0.0430 | 0.000430 | 88.7 |
| 35 | 54.44 | 0.579 | 0.0351 | 0.000351 | 89.8 |
| 40 | 53.97 | 0.619 | 0.0288 | 0.000288 | 90.9 |
| 45 | 53.48 | 0.666 | 0.0239 | 0.000239 | 91.9 |
| 50 | 52.99 | 0.712 | 0.0199 | 0.000199 | 92.9 |
| 55 | 52.50 | 0.764 | 0.0167 | 0.000167 | 93.9 |
| 60 | 52.02 | 0.815 | 0.0140 | 0.000140 | 94.7 |
| 70 | 50.87 | 0.952 | 0.0104 | 0.000104 | 96.1 |
| 80 | 49.67 | 1.061 | 0.0075 | 0.000075 | 97.2 |
| 90 | 48.42 | 1.308 | 0.0061 | 0.000061 | 97.9 |
| 100 | 46.99 | 1.558 | 0.0048 | 0.000048 | 98.4 |
| 110 | 45.40 | 1.891 | 0.0040 | 0.000040 | 98.8 |
| 120 | 43.67 | 2.316 | 0.0034 | 0.000034 | 99.1 |
| 130 | 42.06 | 2.285 | 0.0030 | 0.000030 | 99.2 |

[a]Based on the assumptions that droplets are in equilibrium with the atmospheric relative humidity and that the primary sulfate species is sulfuric acid. [b]Altitude, temperature and pressure values are from entry-probe data with uncertainties of ±1 km, ±1 K and ±5%, respectively[23]. [c]Values were computed using the mixing ratio of water from observations as parameterized by Gao et al.[26]. Uncertainty, based on reported uncertainties in atmospheric profile, is ±30% of the value. [d]Derived by dividing relative humidity by 100, based on the assumption that droplets are in equilibrium with the atmospheric relative humidity. Each value is pertinent to the stated temperature (column 1). Uncertainty, based on reported uncertainties in atmospheric profile, is ±30% of the value. [e]Values, stated to one decimal place, were derived from interpolations of the data of Gmitro and Vermeulen[20,21] to the water-activity values in column 5, based on the assumption that the primary sulfate species is sulfuric acid (Methods).


M.-P. Zorzano zorzanomm@cab.inta-csic.es

Habitability is defined by Temperature and water activity (=RH/100):

The water level is orders of magnitude lower than any known terrestrial limit for life





M.-P. Zorzano zorzanomp@cab.inta-csic.es

# Venus, poses no concern for planetary protection …because "*life as we know*" from Earth would not proliferate there.

- Finding: **Based on the existing measurements VENUS CLOUDS ARE NOT SPECIAL REGIONS.** Due to the low level of water in the clouds where the temperatures are mild enough, life as we know, would not be able to replicate there even if there were nutrients available (and protection from radiation, sulfuric acid etc).
- Recommendation: **unless there are new measurements that demonstrate water activity > 0.6 (RH> 60%), Venus clouds are not a concern for planetary protection.** They are of course extremely interesting for planetary science, including atmospheric chemistry, P cycle, etc.


M.-P. Zorzano zorzanomm@cab.inta-csic.es