HABITABILITY OF NEAR-SURFACE ENVIRONMENTS ON MARS. A. Mendez, Department of Physics and Chemistry, University of Puerto Rico at Arecibo (a_mendez@cuta.upr.clu.edu).

Introduction: Liquid water on Mars may be available at the surface in recent times [1,2] and preliminary observations of Mars Odyssey suggest ice at shallow levels [3]. An ice-rich near-surface environment may provide temporary habitats for microbial life where daily thermal gradients, due to insolation, exchange water between the atmosphere and regolith. Here habitat refers to a physical environment that supports microbial growth provided the other ingredients of life, water, an energy source, and biogenic elements are present.

In this work the problem of habitability of the near-surface of Mars is studied in more detail than previous research [4,5]. First, a model of the martian near-surface microenvironment is constructed to describe the habitat at microbial relevant space and time scales. Second, the theory of environmental biophysics is used to quantify rates of mass and energy transfer between potential microorganisms and the martian environment. Finally, an extensive biodiversity database of physical, chemical and biological requirements of prokaryotes is used to suggest possible interactions of indigenous or exogenous microorganisms with the martian environment.

Mars Microenvironment: Mars surface layer is very dry with a mean global environment of 213 K at 6.1 mbars [6]. In general, these physical conditions make water available only as vapor and ice. However, daily and seasonal variations in combination with the topography may allow liquid water in transient states [7]. This work focus in the near-surface environment above and below two meters from the surface during a sol (martian day). These spatial and temporal scales where selected because they represent, due to insolation, the largest changes in the physical environment in the shortest time. They are important for the temporal stability of liquid water, atmosphere-regolith water exchanges, and thus microbial processes.

A model of the vertical profile of the near-surface physical environment of Mars was constructed from Viking Landers and Mars Pathfinder meteorological data [8]. The model describes the temperature, T, pressure, P, and different scenarios of water density or concentration, w, as function of the vertical, z, and time of day, t. It can be applied to different topography, latitude or seasons. For simplicity, other important factors, wind, dust, and UV exposure were excluded. Therefore, the model describes the near-surface physical microenvironment with no wind and protected from solar UV for a typical sol.

Habitability: Microorganisms are adapted to a wide variety of environments on our planet. Usually, their natural environment does not provide optimum growth conditions because nutrients may be limited, temperature is to low or to high, or unfavorable biological interactions. Life requires not only the right chemistry and biology of the environment but the right physics as well. Less attention has been given to the physical environment state where the necessary ingredients for life are mixed.

Most known microorganisms require an environmental temperature for optimum growth of 310 K at standard atmospheric pressure (1.013 bars), but prokaryotes can growth between 263 and 386 K [9]. Steady hydrostatic pressure changes have little or no effect on the growth rate of most microorganisms but pressures over 300 bars reduce the growth rate of most terrestrial microorganism [10]. Lower pressure limits for some microorganisms have been measured at 10 mbars [11]. In general, lower temperatures accentuated the growth-retarding and sterilizing effects of pressure. Although much has been studied about the effects of temperature, little is known about the combined effects of low pressures and low temperatures on microbial growth.

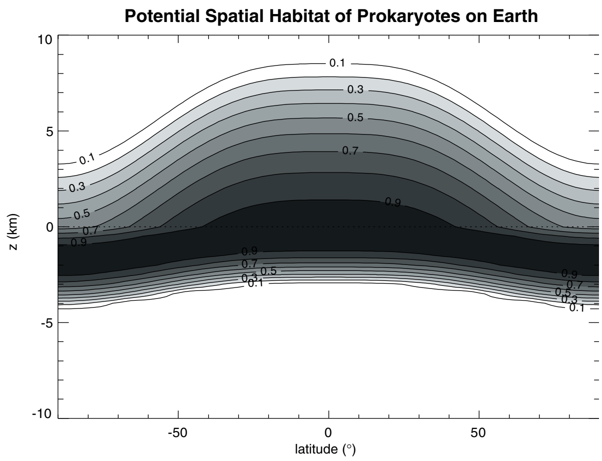

Figure 1. Mean habitability, H, for prokaryotes on Earth as function of the vertical with respect to mean sea level and latitude. The diagram shows values of H close to one in the equatorial regions and subsurface.

In this work the biological relevant physical state of the environment is described in terms of temperature, T, pressure, P, and water density or concentration, w. Therefore, this work introduces a quantitative description of the concept of habitability (see figure 1) to describe the suitability of a physical environment to microbial growth.

For practical purposes, the concept of habitability for microorganisms is quantified and defined in this work as:

$$H(T,P,w) = \frac{k(T,P,w)}{k_{opt}(T_{opt},P_{opt},w_{opt})}$$

where k is the specific growth rate at the natural environment physical state, k_{opt} the optimum growth rate (usually measured in the laboratory), and H the habitability. This unitless quantity provides a measure of how suitable is a physical environment for a particular microorganism under the same chemical and biological conditions. The mean terrestrial physical environment at surface level provides habitabilities well below one ($H < 1$) for most prokaryotes.

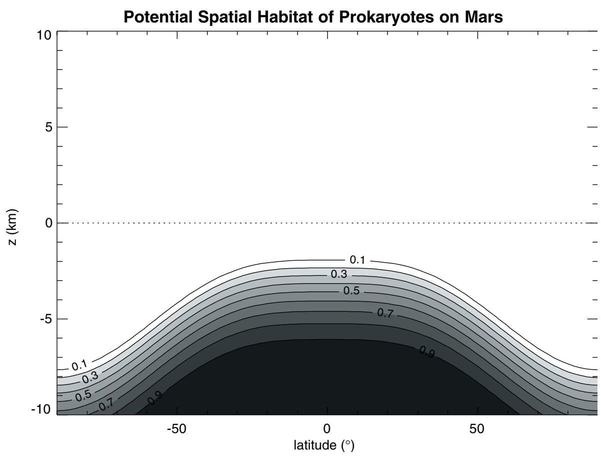

Figure 2. Mean habitability, H, for prokaryotes on Mars as function of the vertical with respect to the areoid and latitude. The diagram shows that, on average, any potential habitat on Mars is well below the surface. However, daily and seasonal changes shift this zone to shallow depths at low latitudes.

In a global sense, the concept of habitability was applied to the Mars environment (see figure 2). It is only at shorter space and time scales that Mars s near-surface environments provide a suitable habitat. Still, more theoretical and experimental work is needed to understand not only viability, but also microbial growth in the Mars environment.

Conclusion: The studied data and models suggest that some near-surface equatorial regions on Mars may have the physical environment to support microbial growth provided the other requirements of life are present. An ice-rich regolith might provide a protective layer and habitat for any indigenous or exogenous microorganisms. Growth will be limited to a few hours during the day at very low growth rates. This suggests that the potential to contaminate the planet from Earth s biota is not negligible. Also, growth of indigenous microbial forms under the present Mars environment is an open possibility.

Experimental work is being done to quantify some of the issues discussed in this work.

References:

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