HABITAT SUITABILITY INDEX MODEL FOR BRINE ENVIRONMENTS ON MARS. E. G. Rivera-Valentín[1], A. Méndez[2], A. Soto[3], K. L. Lynch[1], V. F. Chevrier[4]; [1]Lunar and Planetary Institute (USRA), [2]Planetary Habitability Laboratory, University of Puerto Rico at Arecibo, [3]Southwest Research Institute, [4]Arkansas Center for Space and Planetary Sciences, University of Arkansas.

Introduction: In ecology, habitat suitability index (HSI) models are quantitative ways of representing the potential for an environment to support a selected species or model organism. These indices apply known environment-species relationships, such as temperature tolerances, to predict survival, reproduction, and development, as well as the environment's potential for species recruitment. Additionally, HSIs allow for a consistent way of comparing environments and to examine their suitability over time. Recently, [1] suggested applying such ecological models to planetary science in order to resolve the habitability of extraterrestrial environments in a consistent manner. Because the question of habitability does not fundamentally have a binary answer but is rather a spectrum – what is habitable to one species is not to another and organisms can adapt to changing conditions - habitat suitability indices provide an excellent resource to compare extraterrestrial environments and understand their potential to support life.

Given the level of environmental data available from both orbiters, landers, and general circulation models (GCMs), HSIs can now be used to assess the present-day habitability of the Martian surface and shallow subsurface. Furthermore, Mars may presently support (meta)stable liquids, specifically brines [2,3]. Such brines may provide the liquid water environment necessary for life, as well as shielding from the martian radiation environment [4]. Two environmental parameters that control brine stability, ambient temperature (T) and water activity (a_w), also strongly control the biologic potential of such liquid environments. When a brine is in equilibrium with the ambient atmosphere (i.e., not freezing, boiling, or evaporating), its water activity is related to the ambient relative humidity with respect to liquid (RH_l) by $a_w = (RH_l/100)$ because at this point the concentration gradient between the brine and the ambient atmosphere is zero. As such, these two environmental measurements available from landers, orbiters, and as outputs from GCMs, can be used to help resolve martian habitability and brine stability.

Here we develop an HSI model based on species-environment relationships dependent on temperature and water activity. The developed quantitative metrics are aimed at finding where and when Mars would be, relatively speaking, the most habitable. Because liquid water is important for life as we know it, the models are particularly applied to potential brine environments. We have also applied the metric to two often used terrestrial analogs for Mars, the Atacama Desert and the Antarctic Dry Valleys, and validated the model against recorded biologic activity as a function of season [5].

HSI Model: Recent work has shown that present-day surface conditions on Mars may lead to (meta)stable brines that can only experience temperatures of up to 225 K [2]; however, the lowest known temperature suitable for life is between 233 K and 253 K [6,7]. On the other hand, (meta)stable martian brines can experience water activities from 0.24 to 0.8 [2]. Thus, at some points, a brine may be habitable relative to water activity because the lower limit for biologically suitable water activity is between 0.565 – 0.605 [8,9]. Here, we adopt a threshold temperature of 245 K (i.e., in between the known temperature limits) and $a_w = 0.55$, $RH_l = 55\%$ (i.e., at the lower limit for water activity) for our HSI. These limits agree well with those suggested by the National Academies' Committee on Planetary Protection [10].

Typically, an HSI varies between zero, for a fully unsuitable environment, to one, for a fully suitable environment [1]; however, given the low temperature and hyperarid conditions experienced on Mars, our developed suitability index ranges between +1 and -1 to increase its dynamic range. The +1 boundary is defined by the maximum possible temperature and brine water activity while the -1 boundary is defined by the minimum possible temperature and brine water activity. The zero boundary represents the mortality conditions in temperature and water activity/relative humidity. In Figure 1, we plot the developed HSI model over the range of Mars-relevant temperatures and relative humidity.

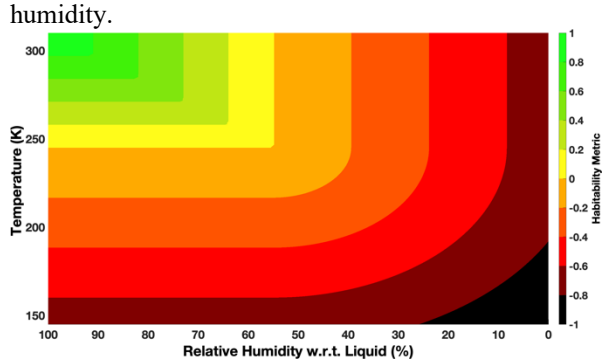

Figure 1: The proposed habitat suitability index model based on species-environment relationships dependent on temperature and relative humidity (water activity) applied to Mars. The colormap (shown on the left) is binned in steps of 0.1.

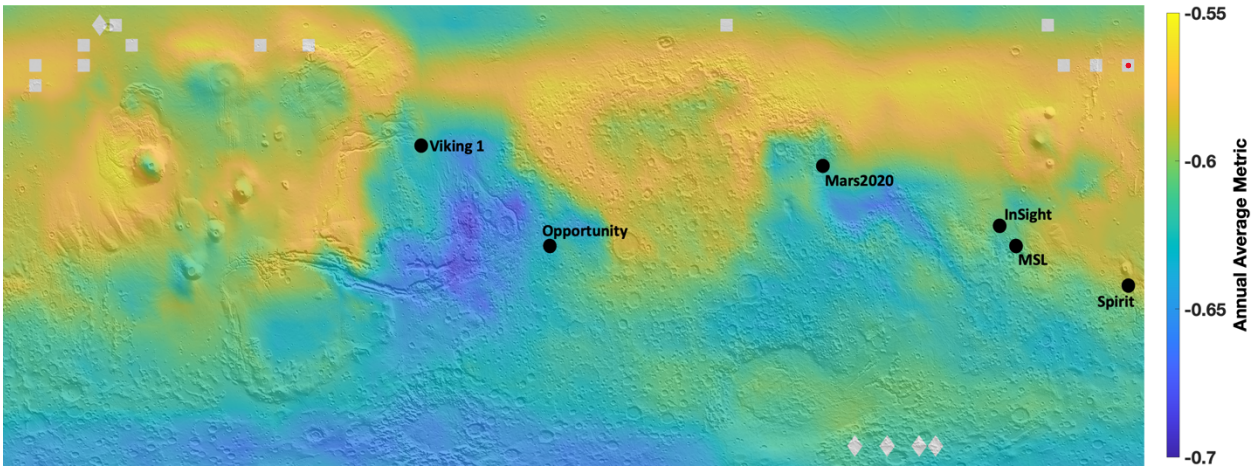

Figure 2: Calculated annual average HSI metric overlain onto a MOLA shaded relief map between ±60° latitude. Gray squares denote recently exposed ice formed by impact craters, diamonds denote exposed ice along cliffs [12], and black circles denote mission landing sites. The square with a red dot denotes the location exampled in Fig. 3.

Results: To conduct global HSI calculations, we used hourly surface temperature and water mixing ratio, which we then translated to RH_l, outputs from the MarsWRF general circulation model [11]. In Fig. 2, we plot the annual average HSI metric, which varies from -0.69 to -0.55, with a global average of -0.61. On an hourly basis, the metric varies globally from about -0.2 down to -0.97. As such, the simultaneous surface temperature and relative humidity on Mars do not surpass the known tolerances for life as we know it. Nevertheless, Fig. 2. shows where Mars is the most habitable on average, relatively speaking.

Here we particularly studied the locations of fresh ice recently exposed by impact cratering or exposed on cliffs [12]. Such ice exposures are of particular interest because experimental work has shown that when temperatures are above the eutectic, ice in contact with salts will readily lead to stable brines on Mars [13]. Furthermore, [2] showed that the conditions at these locations may allow for deliquescence of calcium perchlorate up to 1% of the martian year. We find that these locations are associated with a high annual average HSI value of on average -0.58. As such, these locations may be of astrobiological interest.

For example, in Fig. 3 we plot a diurnal curve for the ice exposure located at (46°N, 176°E) on Ls 152°. During this time, the HSI metric varies from -0.71 to -0.30. Over the year, the metric varies from -0.81 to -0.29 at this location. On this sol, we found that calcium perchlorate could deliquesce to form a brine for up to two consecutive hours; this time coincides with the maximum HSI. As such, when a brine is possible, the conditions are, relatively speaking, the most habitable, warranting further studies of these and other similar locations.

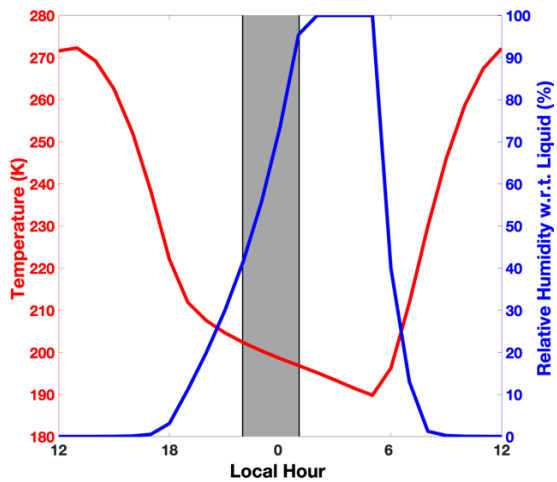

Figure 3: Example diurnal curves from noon to noon for the location of exposed ice noted in Fig. 2. The gray area denotes the time when brine formation is possible.

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