STANDARD PLANETARY HABITABILITY (SPH) OF GLOBAL LAND AREAS. Abel Méndez, Department of Physics and Chemistry, University of Puerto Rico at Arecibo, Arecibo, PR 00614 (abel.mendez@upr.edu).

Introduction: Habitability is a qualitative concept, generally defined as the suitability of an environment to support life, which depends on many environmental physical, chemical and biological factors. Planetary habitability is an essential astrobiology concept that needs a practical and universal definition if we want to measure, assess and compare the distribution of life on Earth and beyond. Although there are many works related to planetary habitability (about 300 currently cited in Google Scholar), there is no agreement in a quantitative definition to measure habitability. Just recently, a few works are starting to propose quantitative definitions of habitability, mostly in terms of available energy [1, 2, 3].

In a global scale, Earth is a very habitable planet. However, the biosphere is not equally distributed in our planet. In general, tropical regions are more abundant in species and diversity than higher latitudes [4]. Global latitudinal gradients are present for all species, from microorganisms [5, 6] to macroorganisms [7]. This is a long-standing problem in the field of biogeography and many mechanisms have been suggested to explain the global biodistribution [8, 9]. Most models explain the global distribution of life based in a complex interaction of many environmental variables including temperature, precipitation, photosynthetic active radiation (PAR) and soil properties.

One way to evaluate the distribution of life in our planet is by measuring the distribution of primary producers. The Normalized Difference Vegetation Index (NDVI) or the Fraction of Absorbed Photosynthetically Active Radiation (faPAR) can be used to quantify vegetation density on land. A more important biophysical quantity is the Net Primary Productivity (NPP), a measure of the fixed carbon flux mostly by primary producers. The NPP is more difficult to measure because it requires *in situ* observations, something hard to do at global scales. However, many computer models can estimate terrestrial NPP from climatology data from surface or satellites measurements [10]. One recent simpler model estimates global land NPP from just three variables: temperature, precipitation and vegetation class [11].

This works presents a quantitative habitability model applied to study the habitability of our global biosphere [12]. The Standard Planetary Habitability (SPH) was constructed as a quantity that measures and compares the potential for life of global land areas for primary producers. The SPH provides a simpler and complimentary method to NDVI, faPAR, and NPP to assess the biosphere.

Quantitative Habitability: Habitability, H, is defined here as the suitability of an environment for life processes as measure by their normalized metabolic rate (NMR) as function of one or more environmental variables. The habitability describes the effect of the environment in the metabolic rate for any species or community of prokaryotes (bacteria and archaea) or eukaryotes (i.e., plants). This is a practical quantitative formulation with a normalized unitless number between zero (no metabolic activity) and one (highest metabolic activity). This relative scale is especially convenient to study planetary habitability because it can be related to other biological quantities such as growth and productivity. In practice, direct measurement of metabolic rates might be difficult. Changes in biomass can be used as an indirect measurement of metabolic rate during growth.

One important postulate of the presented definition is that complex habitability functions for many environmental variables can be constructed from simple ones. For example, the simultaneous effects of temperature, pH and water activity has been used to model microbial growth [13]. The habitability of a complex system can be expressed as a product of the individual habitabilities, where each habitability function is usually dependent on one environmental variable. The main problem is finding appropriate habitability functions for the environmental variables and species of interest.

Temperature is one of the most important environmental variables for life. A modified model of Raich et al. [14] was used to model a thermal habitability function, H_T, for both plants and prokaryotes. Precipitation is usually used as a measure of water available for plants and water activity in prokaryotes. Relative humidity was used as a rough estimate of both the water activity of the air and potential precipitation in natural environments. This is only true for life exposed to the air (i.e., plants) not considering the subsurface components. A relative humidity habitability, H_{RH}, was constructed with a similar function as the thermal habitability.

Global Habitability: If we assume that NPP is proportional to the metabolic rate per unit area, then NPP can be defined as

$$\mathrm{NPP} = \mathrm{NPP}_{max} \cdot H \qquad (1)$$

where NPP is net primary productivity, NPP_{max} is the maximum potential NPP and H is the habitability. This definition is important because it shows an alternative method to calculate NPP from known habitabilities. A thermal and relative humidity habitability model was constructed as

$$H = H_T(T) \cdot H_{RH}(RH) \quad (2)$$

where T is temperature and RH is relative humidity [12]. Global estimates of NPP for land areas [10], mean monthly surface temperatures, and relative humidities [15] where used to fit equations (1) and (2) to obtain the cardinal habitability parameters for plants (table 1). These values are in agreement with individual studies of plants survival and growth.

Table 1. Global biosphere temperature and relative humidity requirements of plants. Values were obtained from fitting the habitability model to NPP and monthly climatology data.

	Minimum	Optimum	Maximum
Temperature (°C)	-31	21	36
Relative Humidity	0.16	>0.85	—

The habitability model (eq. 2) and the requirements of plants (table 1) were used to define the Standard Planetary Habitability (SPH), a quantity that measures the habitability of the biosphere for primary producers. The SPH can be used to evaluate the habitability of our biosphere as a function of time or space given only two easy to measure environmental variables from ground or remote sensors observations: surface temperature (correlated with light) and relative humidity (correlated with precipitation). The SPH can be used for easy global estimates of NPP (figure 1). The incorporation of some biological feedbacks in ecological modeling or GCM will require less computational time with this formulation.

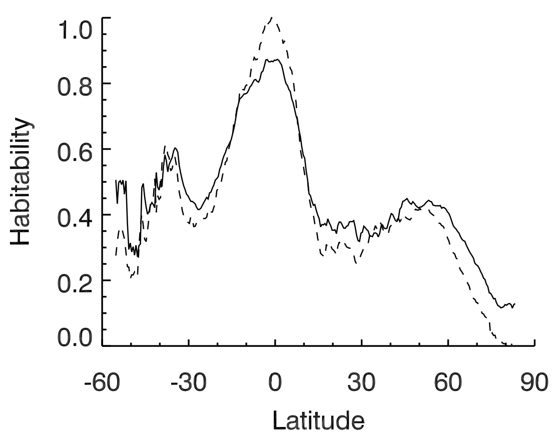

Figure 1. Mean latitudinal SPH (solid line) and normalized NPP (dotted line). SPH and NPP are highly correlated ($r^2 = 0.96$).

The SPH defines and weights the distribution of planetary habitable zones (figure 2). Our biosphere land areas have the higher habitabilities during the months of August (due to larger land areas in the northern hemisphere). The mean global SPH of Earth is about 0.47, which means that the current state of our planet is not in an optimum condition for its primary producers. Probably, past terrestrial environments had higher values, and provided a better habitat to support life (i.e., during the Cambrian Explosion). The potential habitability of any discovered terrestrial-size extrasolar planet might be calculated from estimates of surface temperature and atmospheric water vapor content. Current work includes the use of data from SeaWiFS, Aqua and Terra, the inclusion of the oceans and other environmental variables in the model.

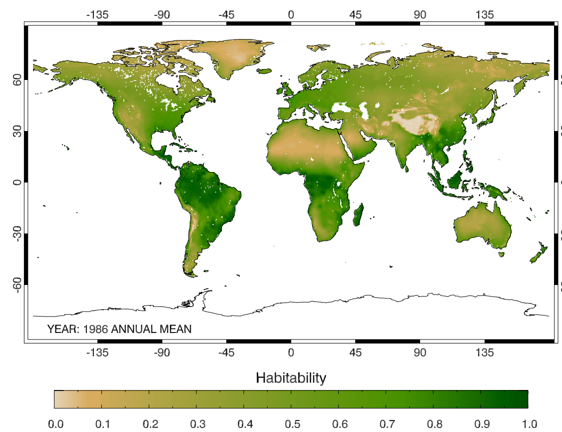

Figure 2. Mean annual SPH for terrestrial land areas on 1986. Greener regions are more habitable for primary producers in terms of temperature and relative humidity. The map correlates well with the actual distribution of vegetation.

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