ADSORPTION DRIVEN REGOLITH-ATMOSPHERIC WATER VAPOR TRANSFER ON MARS: ANALYSIS OF PHOENIX TECP AND MSL REMS DATA. H. N. Farris[1], M. B. Conner[2], V. F. Chevrier[1], E. G. Rivera-Valentin[3], [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas, Fayetteville, AR 72701, (*hnfarris@uark.edu*), [2]Department of Physics, Reed College, Portland, OR 97202, [3]Arecibo Observatory (USRA), Arecibo, PR, 00612.

Introduction: NASA Phoenix landed in the Martian northern hemisphere spring of May 2008. The landing site, Vastitias Borealis (68.2 °N, 234.3 °E), is a polar region characterized by near-surface ice. Some of the more insightful measurements from the Phoenix mission were of atmospheric temperature and humidity using the Thermal and Electrical Conductivity Probe (TECP) instrument [1, 2], which has allowed for the study of water vapor content and transfer over diurnal timescales [3]. More recently, Mars Science Laboratory (MSL) landed at Gale Crater (4.5 °S, 137.4 °E) with the Rover Environmental Monitoring Station (REMS) on board. A proposed evaporation-adsorption cycle, where water alternates between thin layers on the surface of porous regolith and as water vapor in the atmosphere, suggests regolith parameters, such as specific surface area, may control atmospheric humidity through adsorption and desorption [4-7]. Adsorption, the process by which gas molecules adhere to and create a film upon a substrate, can be expressed through two layer-based theories built upon these regolith parameters: Langmuir theory, which assumes a monolayer (one molecular thickness, $l \approx 3\times10^{-10}$ m) of adsorbed water and a more rigorous BET theory, which allows for a multilayer construct. These theories may be implemented to explain sol-to-sol dependencies of temperature and humidity at the Phoenix landing site and along the MSL traverse and thus, the implications for transient, adsorbed, liquid water at the surface.

Phoenix TECP data: Phoenix TECP relative humidity, R_H, data was determined from the PDS for sols 0–150. Saturation vapor pressure, P_{sat}, calculated using the board temperature, T. Computing the vapor pressure at the frost point temperature allowed for the calculation of the water vapor pressure, P_{H2O}. Using these two calculations, R_H could then be found and plotted as a logarithmic function against the temperature. The frost line and theoretical Langmuir and BET lines are plotted atop the Phoenix TECP temperature and relative humidity data (Fig 1). Both seem to fit the data well, however, there is a strong divergence between the data and Langmuir, especially at high relative humidities and low temperatures (martian night). Over these same values, BET fits all the data points. Since Langmuir only accounts for a monolayer, once saturation is reached, BET becomes the favored, multilayer model of adsorption, despite the low water pressure on Mars.

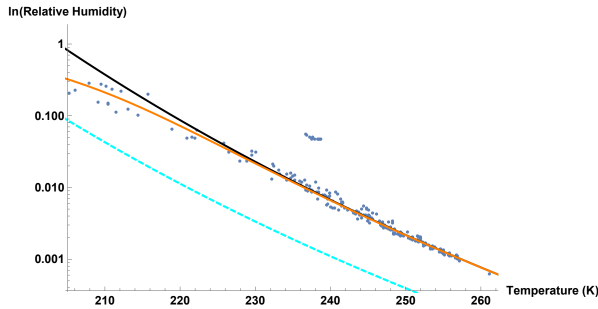

Figure 1. *Phoenix TECP temperature and relative humidity data plotted with the frost line (cyan, dashed), Langmuir (black), and BET (orange).*

Rearranging the BET equation and solving for R_H:

$$R_H = \frac{-C - 2\theta + C\theta + \frac{\sqrt{C}\sqrt{C + 4\theta - 2C\theta + C\theta^2}}{\theta}}{2\theta(C-1)}$$

where θ is the volumetric coverage, and C is a constant that is defined as α times the saturation pressure. C can also be expressed as:

$$C = C_o exp\left[-\frac{\Delta H}{R}\left(\frac{1}{T} - \frac{1}{T_o}\right)\right]$$

Origin 9.1's advanced curve-fitting function, which fits a complex data set, employing a user-defined function, was used. The BET adsorption function was fit to the Phoenix TECP data, keeping θ = 0.336 and ΔH = 52.78 kJ/mol as fixed values (averaged from the literature). The value for C which yielded the smallest error was C = 89.4. We will call this our ideal coefficient of adsorption, near the average of the range of reported values in the literature (86.3), but does not correspond to any one compound.

An average surface coverage, $\theta \approx 0.336$, suggests that liquid water can adsorb onto the surface at Phoenix conditions, but in very small amounts, 2.96 x 10^{-7} kg of H_2O/m^2. Small changes in the surface coverage weakens the fit of BET to the data, while small changes in enthalpy does not (Fig 2), suggesting a mostly constant surface coverage and adsorption that is only dependent on the specific surface area of the regolith, a result of the regolith's composition. Specific surface areas consistent with findings from Mars point to adsorption preferentially occurring on mixtures of compounds, as opposed to expanses of homogeneous regoliths (Table 1).

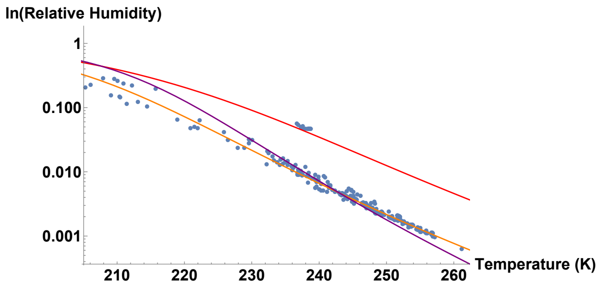

Figure 2. *Phoenix TECP temperature and relative humidity data plotted with "ideal" BET (purple), BET with increased surface coverage (red), and BET with increased enthalpy (yellow).*

	"Ideal" Regolith	Regolith 1
Composition	Viking 1 Landing Site	50% Dunite 50% Ferrihydrite
Surface Coverage (θ)	0.336	0.336
Enthalpy (ΔH)	52.78 kJ/mol	52.78 kJ/mol
Adsorption Constant (C)	89.4	104.7
Specific Surface Area (SSA)	1.7 x 10^4 m^2/kg *	3.56 x 10^4 m^2/kg

Table 1. *Parameters of an "ideal" martian regolith and a hypothetical martian regolith composed of 50% dunite and 50% ferrihydrite.*

MSL REMS data: First, to eliminate instrument error and anomalies, the temperature and relative humidity data acquired from the REMS instrument were averaged every hour across sols 10-602. Unlike Phoenix, the MSL data set is very large and at time cumbersome, so data is plotted by density, for now (Fig 3). Moving forward, focus will be on the portions of the data with the highest density: yellow/orange, until future analyses where the data can be organized in such a way that vastly different terrains and seasons are not grouped together.

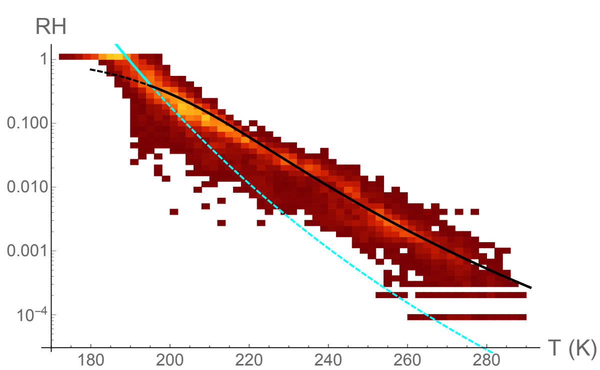

Figure 3. *Density plot of MSL REMS temperature and relative humidity data (yellow = high plot density, red = low plot density) plotted with ice line (blue) and BET (black) for JSC-Mars 1 martian regolith simulant.*

The MSL data follows a very similar trend as Phoenix, where BET adsorption very well explains the data. However, it is interesting to note the ice line playing an important role in the interpretation of the data. It appears that adsorption is only the dominant phase until ice takes over around T ≤ 200 K. This could be indicative of surface frost at the MSL site [8]. In the case of Phoenix, the frost line is of no significance to the data.

Discussion: It is important when comparing the two datasets to keep in mind the opposing geographic and seasonal natures of the missions. Phoenix being a stationary, polar lander that operated only over the summer season and MSL, an equatorial, traversing rover that operates over all seasons. We attribute the spread of the MSL data to the rover's exposure to a variety of terrains as a function of time. Regardless, we do not see surface coverage vary greatly. We explain theta remaining nearly constant, around θ = 0.336, by looking at the water distribution across the planet. Most of the water is locked up in the dominant phase as ice comprising the polar caps. If the atmosphere were condensed onto the surface, it would only result in a water layer about 10-12 μm thick. There is simply not enough water vapor in the atmosphere to large adsorb quantities of water onto the surface, which correspond to higher surface coverage values. Most recently, work done with Laser-Induced Breakdown Spectroscopy (LIBS), part of the ChemCam suite on NASA's Mars Science Laboratory (MSL), agrees with this finding. The instrument preferentially detects light elements, like hydrogen, which may indicate the presence of water. The data shows no diurnal variation of the hydrogen signal, with uniform hydration across dusts, rocks, and soils [9]. In addition, Meslin, et al. [10] cites adsorbed atmospheric water, controlled by the soil specific surface area, as the favored carrier of hydrogen detected by LIBS, especially in the absence of any detected hydrated crystalline minerals in the soil.

Conclusions: BET is more conducive to describing the dynamic nature of adsorption, particularly at low temperatures and high humidities. We see this to be true at the Phoenix landing site, at night. With an average surface coverage of θ = 0.336, water can adsorb onto the surface at both Phoenix and MSL conditions, but in very small quantities. Small changes in surface coverage lead us to believe specific surface area to be the dominant variable on which adsorption is dependent. Specific surface areas consistent with Mars findings suggest adsorption preferentially occurs on regoliths composed of mixtures of compounds.

References: [1] Hecht M. et al. (2008) *JGR, 113*. [2] Zent A. P. et al. (2009) *JGR,* 114. [3] Chevrier V. F. et al. (2008) *Icarus,* 196, 459-479. [4] Jakosky B. M. (2005) *Icarus,* 175, 58-67. [5] Pommerol A. et al. (2009) *Icarus.* [6] Poulet F. et al. (2009) *LPSC XL*, Abstract #1551. [7] Smith M. D. (2002) *JGR*, 120, 1011-1021. [8] Martinez G. M. et al. (2015) *Icarus*. [9] Schroder S. et al. (2014) *EPSC*, 9, EPSC2014-143. [10] Meslin P. Y. et al. (2013) *Science*, 341.