CORRELATION BETWEEN AVERAGE LOCAL RELIEF AND PASSIVE THERMAL NEUTRON COUNT RATES MEASURED BY THE CURIOSITY ROVER DYNAMIC ALBEDO OF NEUTRONS (DAN) INSTRUMENT. S. D. Dibb[1] and C. Hardgrove[2], [1]Bay Area Environmental Research Institute, NASA Ames Research Center, Moffett Field, CA (dibb@baeri.org), [2]School of Earth and Space Exploration, Arizona State University, Tempe, AZ.

Introduction: The Mars Science Laboratory (MSL) rover is currently exploring Gale Crater, Mars and is ascending the northern slope of Aeolis Mons [1]. The Dynamic Albedo of Neutrons (DAN) instrument on MSL measures thermal (E < 0.4 eV) and epithermal (0.4 eV < E < ~100 keV) neutrons generated in the martian atmosphere and subsurface [2]. Variation in neutron count rates is typically interpreted as variation in the subsurface geochemistry [2].

However, as the rover ascends Aeolis Mons, it continues to encounter higher relief local topography. We document five locations of the rover's traverse where DAN measured increases in thermal neutron count rates that are correlated with increased average local relief. These locations are Hidden Valley, Jocko Butte, the Glen Torridon Benches, Mont Mercou, and the Maria Gordon Notch.

We show that this correlation is consistent with radiation transport models of the instrument's performance when near topography compared to a flat plane geometry. Most importantly, this work demonstrates that additional neutron measurements with DAN made near topography could be used to confirm this correlation and may constrain geochemical properties of both the topographic feature and materials below the rover.

Data Sources: Reduced data records of DAN data are published on NASA's Planetary Data System (PDS) and contain total neutron counts for each DAN measurement, the duration of the measurement, the spacecraft clock time (SCLK), and the latitude and longitude of each measurement. We excluded off-nominal measurements from our analysis (e.g., those with abnormal durations or erroneous spatial information). The count rates for each measurement are computed as the total counts divided by the measurement duration.

We used the 1m/px MSL Orbital DEM [3] in the MSL PLACES database on the PDS to compute a parameter we call "average local relief" for each DAN measurement. We define this parameter as the average difference in elevation (in meters) between the pixel that a DAN measurement was taken in and an 11x11 pixel (i.e., 11x11 m) grid centered on the rover. The vast majority (>98%) of DAN measurements were taken where the average local relief was <0.25 m.

Table 1. Spearman R correlation coefficients between thermal neutron count rates and average local relief.

Location	Sols	Spearman's R
Hidden Valley	696-731	0.804
Jocko Butte	981-987	0.402
Glen Torridon Benches	2938-2951	0.396
Mont Mercou	3049-3109	0.758
Maria Gordon Notch	3313-3329	0.555

Spearman's R: We use Spearman's R to quantify the correlation between the thermal neutron count rates and the average local relief. This correlation coefficient can be used to determine the monotonicity of the relationship between two variables. Spearman's R ranges between -1 and +1. Negative values indicate that as one value increases, the other decreases. Positive values indicate that as one variable increases, the other also increases. Table 1 contains Spearman's R coefficients for thermal neutron count rates and average local relief at each location.

MCNP Models: Interpretation of subsurface geochemistry from DAN data is typically done using radiation transport models [e.g., 4]. These models track interactions of particles through a 3D geometry defined by the user. This has traditionally been done using a flat-plane geometry beneath the rover and detector. In this work, we use modified versions of MCNP models from [4] to examine the influence of idealized versions of local topography (i.e. vertical walls of variable height) around the rover and detectors on simulated count rates. We used a typical lacustrine mudstone ('Sebina', [5]) representative of the bulk compositions observed by the rover throughout most of its traverse with varying hydrogen content to represent the martian regolith. In our models, this material was used in both the 'floor' beneath the rover and the 'walls' representing topography.

Results: The five locations described here all have significant correlations between thermal neutron count rates measured during the sol ranges in Table 1 and average local relief (Table 1). These positive Spearman's R values indicate that as the average local relief increases, the thermal neutron count rates tend to increase. The strongest correlations are seen at Hidden Valley and Mont Mercou, where the rover was within a few meters of large (>1 m) outcrops.

Figure 1 shows the average local relief of our models versus the relative change in modeled thermal neutron flux for models with varying hydrogen content (reported as wt.% water-equivalent hydrogen, WEH). For all values of WEH, there is a significant positive correlation between average local relief and modeled neutron flux. The gray box in Fig 1 represents the range of average local relief and variation in measured count rate during the Hidden Valley encounter. This change in count rate has been interpreted as a ~4.0 wt.% WEH variation [6], but our models suggest a more modest change in WEH (~1.5 wt.% WEH) is also possible if the topography is included in the analysis.

While our models are consistent with the actual DAN measurements, Spearman's R values for our models are stronger than the real measurements. This is likely due to the fact that galactic cosmic ray flux (the source of neutrons measured by DAN) and subsurface geochemistry are not, in reality, as uniform and fixed as they are in our models. Variation in these properties as the rover drove through our study areas induces variation in the thermal neutron count rate measured by DAN, which is convolved with any variation induced by local topography.

Finally, Fig 1 suggests a method for using DAN to constrain the WEH in both the subsurface and a nearby topographic feature by collecting a series of DAN measurements at increasing proximity to the feature. The slope of a linear fit to these measurements as a function of average local relief could be used to constrain the WEH in both the subsurface and topographic features. Deviation in the measured flux from a linear fit would imply a difference in the WEH between the subsurface and the feature.

Future missions carrying neutron spectrometers on landed spacecraft (e.g., VIPER [7]), particularly those with mobility, should include local topography in their analyses of passive neutron data to better constrain local hydrogen content.

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References: [1] Vasavada, A.R. (2022) Space Sci. Rev., 218(3), 1-65. [2] Mitrofanov, I.G. et al. (2012) Space Sci. Rev., 170(1), 559-582. [3] Calef, F.J. et al. (2013) LPSC 44, Abstract #1719. [4] Jun, I. et al. (2013) JGR: Planets, 118(11), 2400-2412. [5] Jackson, R.S. et al. (2018). LPSC 49, Abstract # 2314. [6] Tate, C.G. et al. (2018) Icarus, 299, 513-537. [7] Colaprete, A. et al. (2019) AGU Fall Meeting, P34B-03.

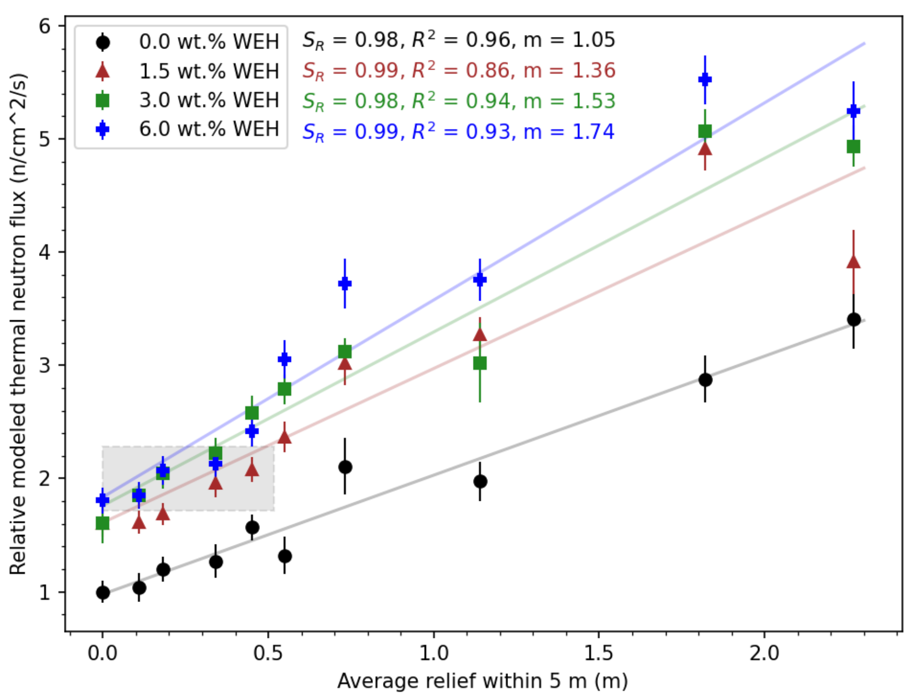

Figure 1. Average local relief versus relative thermal neutron flux from our MCNP models. Variations in the hydrogen abundance in the models (reported as wt. % water-equivalent hydrogen, WEH) are shown as different colors and symbols. The Spearman R values (S_R), coefficients of determination (R^2), and slopes (m) of first-degree polynomials fit to the model sets at each value of WEH are shown. Upper and lower bounds of the gray box indicate the variation in count rate observered during the Hidden Valley encounter (sols 696-731), while left and right bounds indicate the range of average local relief experienced during the Hidden Valley encounter.