MER Spirit Albedo Observations: Insights to Surface Processes and Atmospheric Phenomena at Gusev Crater, Mars. M. J. Reynolds II[1], M. S. Rice[1], J. R. Johnson[2], J. F. Bell III[3], G. Studer-Ellis[1]. [1]Western Washington University, [2]Johns Hopkins University, [3]Arizona State University.

Introduction: The Mars Exploration Rover Spirit systematically acquired quantitative albedo observations of the terrain along its traverse in Gusev Crater. These measurements, recorded by the Panoramic Camera (Pancam) instrument, are important to understanding the interactions between the Martian surface and atmosphere. Pancam surface albedo measurements can also be used to "ground truth" measurements from orbit and validate radiometric calibations. Temporal comparisons between the data give insights to further parameterizing climate models, as albedo is linked with temperature changes on the surface, which can affect winds and radiative energy balance, along with creating a proxy used to further understand the mechanisms of surface dust transport.

Of the 20 albedo observations acquired by Spirit during its mission, only 11 have been analyzed in previous studies [1,2]. Here we examine the entire set of PDS-released observations from Spirit and correlate the fluctuations in albedo of whole scenes and specific features with atmospheric events and traverse distance.

Methods: In order to take a complete 360° panorama of a scene, Pancam acquires 27 broad-spectrum images from the L1 filter. The individual images are stitched together to create cylindrical projection (CP) mosaics (Figure 1). For albedo observations taken on a relatively flat regions, a vertical projection (VP) mosaics can represent each pixel with approximately the same surface area.

Pancam images are radiometrically calibrated using near-simultaneous observations of the calibration target [3,4]. Observations are converted to R* ("reflectance factor" [5]) by dividing by the cosine of the solar incidence angle, which allows for direct comparison between images taken at different times of day, and which we use as an estimate of the Lambert albedo. Previous studies of Pancam R* albedo data have shown that they agree with radiometrically calibrated observations from the Mars Global Surveyor (MGS) Mars Orbital Camera (MOC) and Mars Reconnaissance Orbiter (MRO) Context Camera (CTX) instruments to within ± 10-20% [1, 2].

Once the mosaics are compiled and corrected, regions are selected to extract albedo averages. We make two kinds of general selections of the CP scenes: the first includes the entire scene excluding the horizon and regions with substantial suspended dust in the atmosphere; the second includes methodical selections of features in each scene such as boulders, dusty terrain, rock outcrops, and specific formations such as the El Dorado dunes and Home Plate. The selections are completed manually, then albedo averages and standard deviations are calculated. Standard deviations are 1 σ uncertainties computed from the variances in pixel values within each selection. When analyzing the VP scenes, an average is taken over the entire VP out to ~80 m, excluding a 5-meter radius region in the center to avoid pixels containing rover parts.

The Spirit mission ended after the rover had been stuck in loose sand at the location Troy, along the western rim of Home Plate, for approximately 317 sols. Seven albedo observations were made during this time, which provide a unique opportunity to analyze temporal changes in albedo at a single location.

Results: Over the course of the Spirit mission, 20 observations were completed using the L1 filter, all consisting of a 360° view of the landscape, except observations on sols 46, 356, and 799, which were less

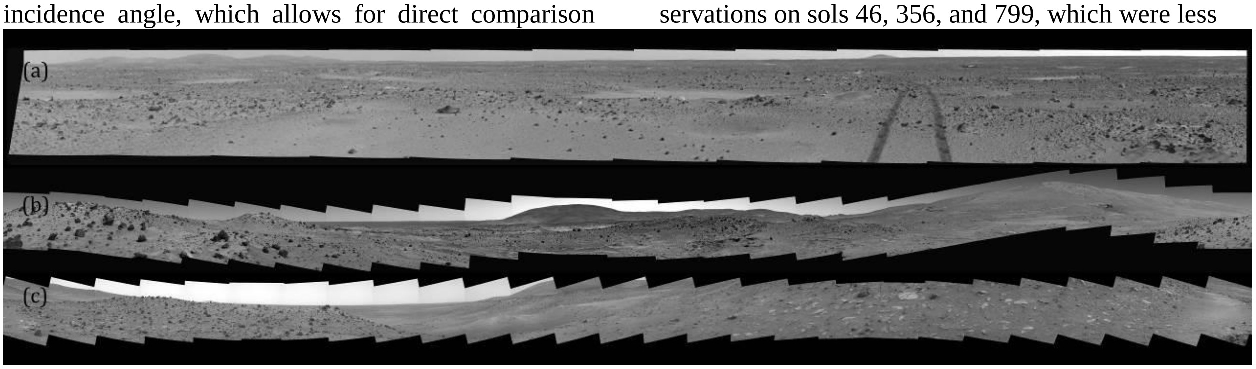

Figure 1. Example Pancam albedo panoramas from Spirit's traverse. (a) 180° mosaic from sol 46, sequence ID P2416, representative of the plains of Gusev Crater. For scale, the distance between Spirit's wheel tracks is about 1 meter. (b) 360° mosaic from sol 969, sequence ID P2269, representative of the Columbia Hills. (c) 360° mosaic from sol 1914, sequence ID P2278, illustrating the Troy scene (where the Spirit mission ended). North is the center in mosaics (b) and (c).

than 360° views. Average scene albedos range from 0.14 ±0.03 to 0.24 ±0.09. Differences in the scenes are largely attributed to changes in surface morphology along the traverse. Scenes dominated by dusty terrain tend to have higher albedo averages, whereas scenes covered by many rocks and boulders tend to have lower albedo averages. From the feature selections, we can confirm these trends by isolating a single feature type, and observing how the presence of this feature across many mosaics influences the scene averages.

The relationship between atmosphere opacity (tau [6]) and surface average scene albedo was studied to find what effects wind events have on the albedo of the surface, since surface albedo changes are frequently linked to removal or deposition of sediments. After a spike in the tau value, we would expect a slight rise in albedo value, or a brightening as dust settles onto the surface. Figure 2 shows a slight correlation between tau and average surface albedo, but due to the rover moving between scenes, it is difficult to observe the evolution of a single scene after specific atmospheric events until the rover got stuck at Troy.

A detailed analysis of the observations at Troy demonstrated a general decrease in albedo over the 250 sols that Pancam acquired albedo observations (to the right of the vertical bar in Figure 2). Interestingly, the surface abledo did not increase following a spike in tau around sol 2000. An explanation for this decrease in albedo could include local, discrete wind events transporting high albedo surface dust out of the scene.

Conclusions and Future Work: We have been able to extract surface Lambertian albedo values from images taken from the Pancam broad-wavelength L1 filter across the entire MER Spirit traverse. Average scene albedo values for Gusev Crater range between 0.14-0.24, and when Spirit observed the Troy scene between sol 1900 and sol 2160 we observed a decrease in albedo values possibly due to net dust transport out of the scene foreground. Future work will include comparisons of ground-based albedo observations to cameras on orbiters around Mars including MOC, CTX, HiRISE, THEMIS-VIS, and MARCI in order to validate their radiometric calibrations. Making these comparisons will provide a useful standard when characterizing albedo elsewhere on the martian surface.

References: [1] Bell, J. F. III et al., (2008) JGR, 113, E06S18. [2] Bell et al. (2013) MARS 8, 1-14, 2013; doi:10.1555/mars.2013.0001. [3] Bell, J. F. III et al. (2003) JGR, 108(E12). [4] Bell et al., (2006), JGR, 111, E02S03. [5] Reid, R. J., et al. (1999), Imager for Mars Pathfinder (IMP) image calibration, J. Geophys. Res., 104, 8907. [6] Lemmon et al. (2015), Icarus, 251, doi:10.1016/j.icarus.2014.03.029

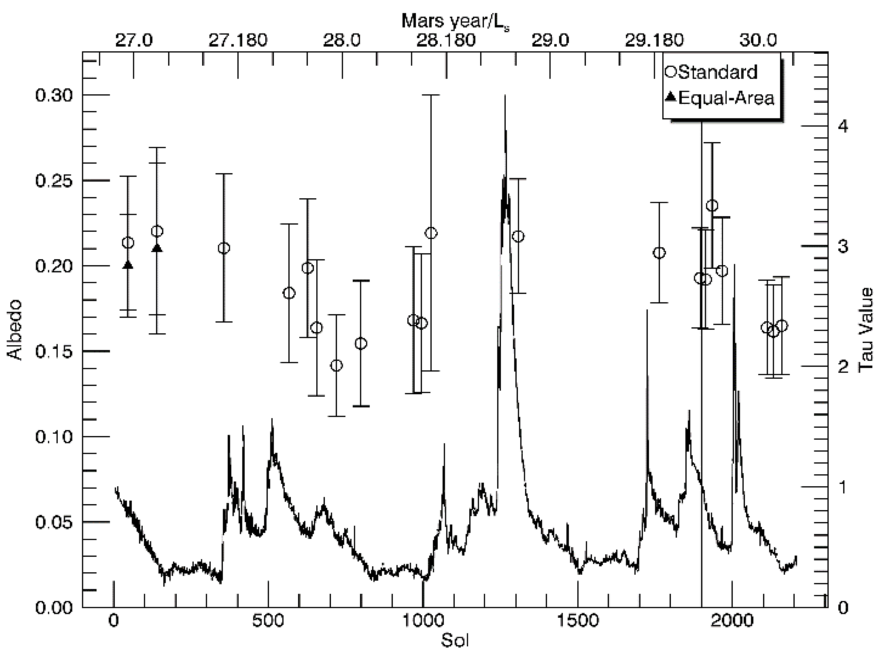

Figure 2. Average albedo values (open circles) measured by Spirit's Pancam at Gusev crater plotted against sol as well as the Mars year and L_s. Error bars indicate the scene's standard deviation. Scenes of little or no foreground topography are subject to equal area averaging (solid triangles) of the Pancam albedo values. Tau measurements from Pancam [6] are plotted representing the atmospheric opacity along Spirit's traverse. The vertical line around sol 1800 indicates when Spirit marooned at Troy; all measurements beyond this sol were acquired from the same position.