RADIATIVE TRANSFER PHOTOMETRIC ANALYSES AT THE MARS EXPLORATION ROVER LANDING SITES. F. P. Seelos[1], R. E. Arvidson[1], E. A. Guinness[1], M. J. Wolff[2], and the Athena Science Team, [1]Washington University, Department of Earth and Planetary Sciences, Campus Box 1169, One Brookings Drive, St. Louis, MO 63130, seelos@wunder.wustl.edu, [2]Space Science Institute, 4750 Walnut Street, Suite 205, Boulder, CO 80301.

Introduction: Mars Exploration Rover (MER) Panoramic Camera (Pancam) [1] observations include multispectral data sets designed specifically to support the photometric analysis of Martian surface materials [2]. We report on the numerical inversion of observed Pancam radiance on sensor data to determine the best-fit surface bidirectional reflectance parameters as defined by Hapke theory [3]. The model bidirectional reflectance parameters for the Martian surface provide constraints on physical and material properties and allow for the direct comparison of Pancam and orbital data sets.

Observation Strategy: The Pancam data sets used in this investigation were acquired during dedicated multi-sol photometric experiments conducted by both rovers. The MER-A data set was acquired on sols 102-103 LST-A and the MER-B data set was acquired on sols 089-091 LST-B. Five filter (L2: 754 nm; L4: 601 nm; L7: 432 nm; R1: 436 nm; R7: 1009 nm), three tier mosaics extending from the rover deck to the horizon were acquired at four azimuth directions at multiple times of day. The mosaic azimuths included the anti-sunrise and anti-sunset directions (the photometric equator) as well as due north and south (**Figure 1**). The multi-sol observation strategy resulted in extensive sampling of the photometric delta azimuth (**Figure 2**) and phase space (**Figure 3**).

Observation Geometry: The observation geometry (incidence, emission, and phase angle) for every pixel of each Pancam frame in the photometric data set is calculated using a combination of the CAHVOR camera model [4] and rover telemetry data that provides the rover and camera orientation at the time of image acquisition. For this study the surface surrounding the rover is modeled as a single photometric unit and treated as a flat plane, consistent with the spatial resolution of orbital observations.

Radiance Forward Models: The radiance on sensor forward models are calculated using a customized implementation of the Discrete Ordinate Radiative Transfer (DISORT) package [5]. The DISORT implementation includes a plane-parallel model of the Martian atmosphere derived from a combination of Thermal Emission Spectrometer and Pancam atmospheric data acquired near in time to the surface observations [6,7,8]. This model accounts for bidirectional illumination from the attenuated solar beam and hemispherical-directional diffuse skylight illumination. The reflectance of the lower boundary in the DISORT model is specified by the four parameter Hapke bidirectional reflectance function in conjunction with a two parameter Henyey-Greenstein phase function.

For each Pancam image in the data set, the six-dimensional bidirectional reflectance parameter space is discretely populated with model radiance on sensor values. This results in an eight-dimensional radiance lookup table with axes that sample the bidirectional reflectance parameters to be optimized and two spatial coordinates (azimuth and emission angle).

Parameter Optimization: The observed radiance data and calculated geometry bands are spatially resampled to reduce data volume and high frequency spatial variability. Parameter optimization is performed with a Levenberg-Marquardt nonlinear least squares optimization engine. The Jacobian matrix partial derivatives are determined by finite-difference approximation. Iterative radiance forward models for each resampled data point are calculated by multilinear interpolation of the appropriate radiance lookup table.

Results and Future Work: Four of the six bidirectional reflectance parameters have been incorporated into the radiance inversion. The current best-fit bidirectional reflectance parameters for Meridiani Planum at 754 nm are – single scattering albedo: 0.596; roughness parameter: 15.4 degrees; phase function asymmetry: 0.243; and phase function forward fraction: 0.376. The optimized single particle phase function is shown in **Figure 4**.

The single scattering albedo derived for the Meridiani Planum surface is slightly higher than the value for dark soil at the Mars Pathfinder site at a comparable wavelength. The inferred roughness parameter is significantly higher than the modeled roughness for any of the Pathfinder soils [9]. Examination of Pancam and Microscopic Imager data suggest that the inferred roughness parameter is largely controlled by millimeter to centimeter scale roughness.

Following the incorporation of the opposition effect parameters (opposition angular width and amplitude) into the radiance inversion, the six-parameter optimization will be completed for the five filter photometric data sets acquired by both rovers. The complete parameterization of the surface bidirectional reflectance will be used to define the lower boundary in future radiative transfer analyses of orbital data acquired over the MER landing sites.

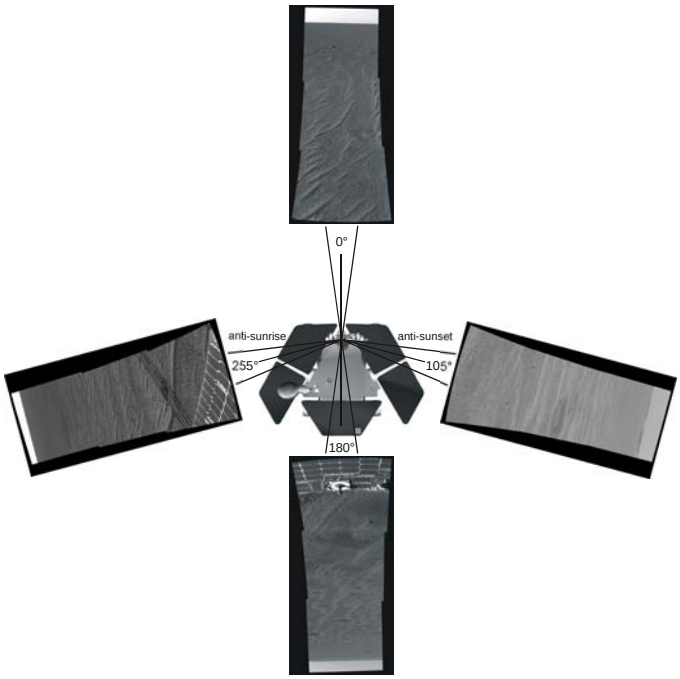

Figure 1. Polar perspective of the MER-B photometric observation strategy. The photometric equator lies along the east and west trending mosaics. The L2 (754 nm) mosaics shown were acquired sequentially with a solar azimuth of approximately 285°. The backscattering nature of the Terra Meridiani surface is readily apparent.

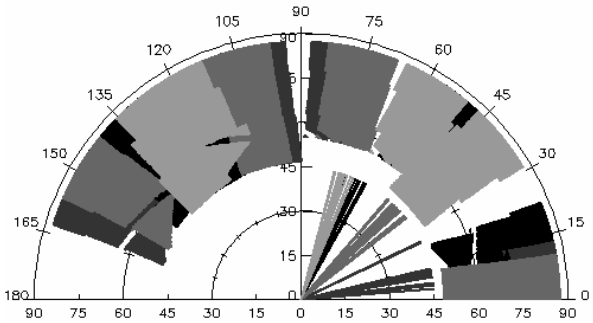

Figure 2. Distribution of MER-B 754 nm Pancam photometric observations in emission - delta azimuth (radius - theta) space. Each of the four greyscale levels correspond to a quartet of constant-azimuth mosaics. The incident plane is at zero azimuth in this view. Radial lines indicate the solar elevation angle.

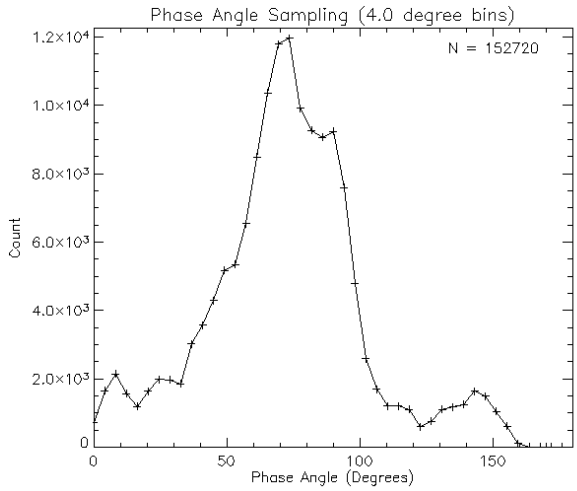

Figure 3. Phase angle sampling achieved by the MER photometric observation strategy. Rover deck obscuration limited the observation of small phase angles. Operational time of day restrictions limited data acquisition at large phase angles. The source images were resampled by a factor of 16 in this example.

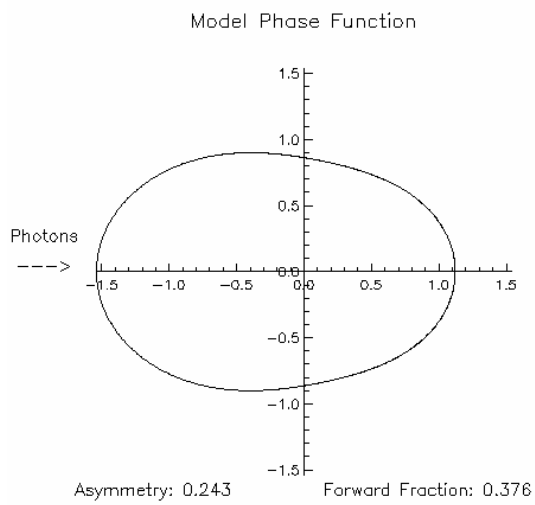

Figure 4. Polar plot of the model two parameter Henyey-Greenstein phase function for the Meridiani Planum surface at 754 nm. The plot is in magnitude – phase angle (radius - theta) space.

References: [1] Bell, J. F. et al. *Science*, 305, 800-806, 2004. [2] Johnson, J. R. et al. *this conference.* [3] Hapke, B. Cambridge University Press, 1993. [4] Gennery, D. B. *XVII Congress of the International Society of Photogrammetry and Remote Sensing*, 1992. [5] Stamnes, K. et al. DISORT Report v1.1, 2000. [6] Conrath, B. J. et al. *J. Geophys. Res.* 105, 9509-9519, 2000. [7] Tomasko, M. G. et al. *J. Geophys. Res.*, 104, 8987-9008, 1999. [8] Lemmon, M. T. et al. *Science*, 306, 1753-1756, 2004. [9] Johnson, J. R. el al. *J. Geophys Res.*, 104, 8809-8830, 1999.