THE MARTIAN SURFACE BOUNDARY LAYER. G. R. Wilson[1] and M. Joshi[2], [1]Jet Propulsion Laboratory, 4800 Oak Grove Drive, MS 183-501, Pasadena, CA 91109 (Gregory.R. Wilson@jpl.nasa.gov), [2]NASA Ames Research Center, MS 245-3, Moffett Field, CA 94035 (joshi@humbabe.arc.nasa.gov).

Introduction: The acquisition of meteorological data from the surface of Mars by the two Viking Landers and Mars Pathfinder make it possible to estimate atmospheric boundary layer parameters and surface properties at three different locations on the planet. Because the Martian atmosphere is so thin the majority of the solar radiance is converted to heat at the surface. The difference between surface and atmospheric temperature can also constraint surface albedo, thermal inertia, and infrared emissivity.

These boundary layer parameters were first measured by Viking landers by Sutton et al. [1] and later refined by Tillman et al. [2]. The two principal drawbacks of these analyses were the use an IRTM derived ground surface temperature model [3] and "composite sols" due to poor diurnal sampling coverage.

The Mars Pathfinder Atmospheric Structure Instrument/Meteorological package (ASI/MET) was the most capable weather monitoring system ever sent to the surface of another planet to date [4,5]. During the surface operations phase of the mission, the ASI/MET instrument, equipped with a directional wind sensor, three thermocouples at 0.59, 0.84, and 1.34 meter above the surface, and a pressure sensor, returned more than 6.5 million individual weather measurements from the Carl Sagan Memorial Station. One of the prime objectives of the ASI/MET package is to characterize the surface boundary layer parameters, particularly the heat and momentum fluxes, scaling temperature and friction velocity, and estimate surface roughness. Other important boundary layer parameters, such as Richardson Number, Monin-Obukhov length, analysis of turbulence characteristics of wind and temperature, and atmospheric stability class can also be determined from these measurements.

Boundary Layer Parameters: During the Mars Pathfinder prime mission, the surface meteorological experiment collected weather measurements 51 times per sol at 0.25 Hz for 3 minutes. This data set comprised the most complete diurnal weather data set of the entire mission. In addition to these measurements, high rate (better than 1 Hz) boundary layer measurements were taken throughout the day for periods ranging from 15 minutes to 1 hour. In addition to these measurements, the Imager for Mars Pathfinder (IMP) monitored deflections of three windsocks mounted on the ASI/MET mast. These two distinct data sets can be combined to help constrain and calculate important boundary layer parameters such as the heat and momentum fluxes, surface roughness (z_o), friction velocity and scaling temperature, and ultimately, the bulk and flux Richardson Numbers, Monin-Obukhov length, and stability classes.

Surface heat flux can be calculated from this data set by extrapolating the ground surface temperature from the three mast thermocouples. Using boundary layer theory and relationships derived from terrestrial experiments we relate a bulk Richardson number to the more analytically powerful flux Richardson number. From this relationship the heat flux can be determined for a surface with a known z_o (0.01 m). Results are presented in Figure 1.

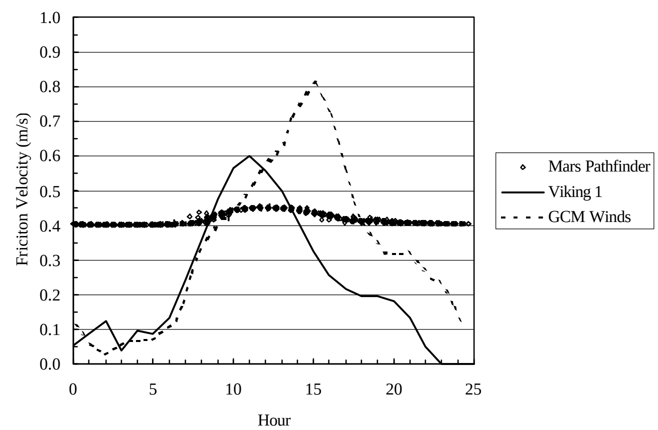

Figure 1.

Friction velocity can be calculated by using log profile and the Richardson number to correct for stability (Figure 2).

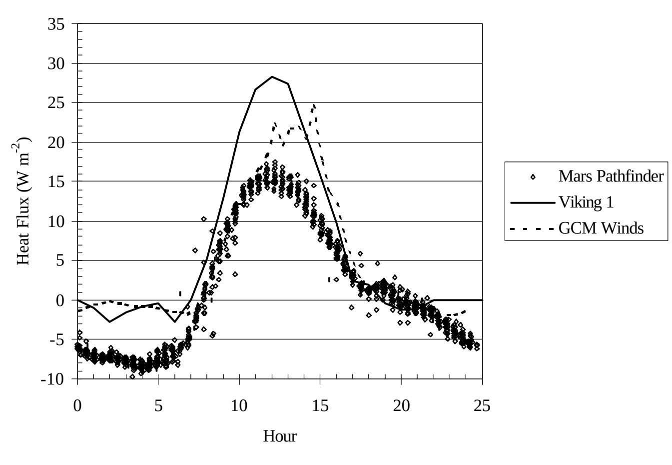

Figure 2.

In general, the Mar Pathfinder atmosphere-ground temperature differences are greater than those observed by VL-1 but the winds were lighter. Drag coefficients indicate that the surface is roughest in the direction of the rock garden and that surface roughness values vary between 1 and 5 cm.

1-D Model Results and Analysis: In order to understand the differences in the atmosphere-ground temperature seen by ASI/MET, a 1-D boundary simulation model was run to evaluate results.

Model conditions for the simulations are an atmospheric opacity of 0.45, albedo of 0.08, infrared emissivity of 0.9 and thermal inertia value of 300 J m^{-2} $s^{-1/2}$ K^{-1}. Figure 3 shows the diurnal cycle of atmospheric temperature. Note the generally good fit between the model and measured data. Figure 4 shows the diurnal cycle of the ground surface temperature. It was not possible to fit the night time temperatures because it would required such a low thermal inertia that the surface could not warm up enough during the day.

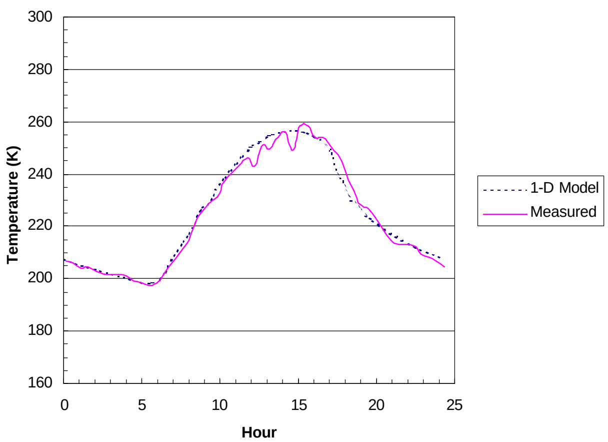

Figure 3.

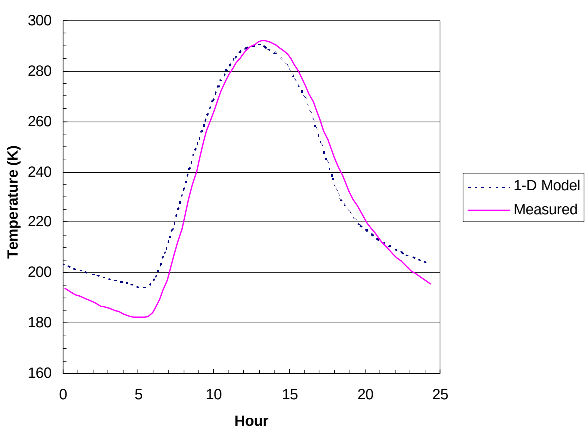

Figure 4.

Very low albedos and emissivities are required to match measured data. This might be considered inconsistent with the fact that albedos as low as these are likely to be bare rock and thus have far higher thermal inertia's.

Christensen [5] observed a strong correlation between thermal emissivity with albedo. In Syrtis Major an albedo of 0.1 is correlated with a thermal emissivity of 0.92.

An albedo of 0.08 is considered unusually low. Golomobek et al. [6] reported an albedo for the MPF landing site at between 0.19 and 0.23. The differences can be accounted for by variations in local and regional albedo patterns or in calculation uncertainties.

Derived thermal inertia's are slightly less than that reported [6].

Conclusion: Mars Pathfinder ASI/MET was used to calculate important boundary layer parameters. These parameters were compared with observations from Viking Lander 1. In general, MPF results are similar to results from VL-1, but ground-atmosphere temperature difference was significantly greater. To resolve the difference a 1-D boundary layer model was used to evaluate the contribution of surface albedo, thermal inertia, and thermal emissivity to the near surface thermal gradient. Results indicated that the MPF site is composed to very dark rocks with a low thermal emissivity.

References: [1] Sutton, J.L. et al. (1978) *J. Atmos. Sci.* 35, 2346-2355. [2] Tillman, J.E. et al. (1994) *J. Atmos. Sci. 51, 1709-1727*. [3] Kieffer, H.H. (1976) *Science*, 194, 1344-1346. [4] Seif, A. et al. (1997) *J. GeoPhys.Res.* 102, 4045-4056. [5] Schofield, T.J. et al. (1997) *Science*, 278, 1752-1758. [6] Christensen, P.R. (1982) *JGR*, 87, 9985-9998. [7] Golombek, M.P. et al. (1997) *JGR*, 102, 3967-3988.