SIMPLIFYING THE MARTIAN CARBON DIOXIDE CYCLE: AN EMPIRICAL METHOD FOR PREDICTING SURFACE PRESSURE. Paul Withers[1] and Silvia Tellmann[2], [1]Center for Space Physics, Boston University, 725 Commonwealth Avenue, Boston MA 02215 (withers@bu.edu), [2]Rheinisches Institut fur Umwelt-forschung, Abteilung Planetenforschung, Universitat zu Koln, D-50931, Cologne, Germany (stellman@uni-koeln.de).

Introduction: Temporal and spatial variations in martian surface pressure are strongly influenced by the exchange of carbon dioxide between solid and gaseous phases at the polar caps. Martian surface pressure is thus a sensitive indicator of polar cap processes. Many studies of martian polar energy balance and the carbon dioxide cycle use a model for surface pressure as a constraint or input. Typically, each of these studies uses a different model for surface pressure, often the output from a general circulation model, and it can be difficult for other scientists to replicate the assumed surface pressures in their studies. Here we report a simple empirical model for martian surface pressure and total atmospheric mass. This can provide a common reference surface pressure, thereby eliminating one possible cause of differences between models. It is also useful for a range of other applications.

Available Data: Surface pressure on Mars has been measured by landers and orbiters. Landed measurements of surface pressure come from Viking Lander 1, Viking Lander 2, Mars Pathfinder and Phoenix. Orbital measurements of surface pressure by radio occultation experiments come from Mariner 9, Viking Orbiter 1, Viking Orbiter 2, Mars Global Surveyor and Mars Express. These datasets are consistent, with the exception that Pathfinder's surface pressures seem 0.1 mbar too small. This is probably due to poor knowledge of the gain of the Pathfinder pressure sensor [1].

We tested different empirical expressions for surface pressure against these datasets to identify the best empirical expression. The most useful datasets are Viking Lander 1 and Viking Lander 2, because of their long durations, and Mars Global Surveyor, because of its extensive spatial coverage, long duration and tens of thousands of measurements.

Empirical Expression: We found that the following empirical expression gave reasonable predictions of diurnal mean surface pressure, p_s:

$$p_s(z,Ls) = p_{0,VL1}(Ls) \exp(-(z-z_{VL1})/H) \times (1 + s1 \sin(Ls) + c1 \cos(Ls) + s2 \sin(2Ls) + c2 \cos(2Ls)) \qquad \text{[Eqn 1]}$$

where z is altitude and Ls is season, $p_{0,VL1}$ = 7.9723740 mbar, z_{VL1} = -3.63 km, H = 11 km, s1 = -0.068622849, c1 = 0.060390972, s2 = 0.044663631, c2 = -0.050183946. All parameters except z_{VL1} and H were found by a fit to Viking Lander 1 surface pressure data. The value of H was found by trial and error using 21243 MGS measurements of surface pressure. The functional form of this expression was selected because variations in surface pressure due to variations in season and altitude are much greater, and much simpler to model, than those due to variations in latitude, longitude, local time, interannual variability and day-to-day variability. The dependence of surface pressure on altitude is represented by a constant and uniform scale height (11 km, equivalent to a reasonable 215 K). The dependence of surface pressure on season is represented by a truncated harmonic series. Additional terms did not significantly improve the accuracy of predictions.

This expression was tested on Viking Lander 2, Pathfinder, Phoenix and Mars Express data with satisfactory results. Figures 1-3 demonstrate the accuracy of this expression. This work has been performed to support the safe landing of Mars Science Laboratory, so validation has focused on latitudes within 45^{o} of the equator and altitudes below +1 km. These contraints, and many others, must be satisfied by candidate landing sites. Analyses to date suggest that, at a 1-σ confidence level, the diurnal mean surface pressure predicted for the MSL landing by Equation 1 will be within 3% of the actual value.

Other Applications: According to this expression, the total atmospheric mass is proportional to p_0R^2/g, where R is the planetary radius and g is the gravitational acceleration, and has the same seasonal dependence as surface pressure. Integration of Equation 1 across the surface of Mars gives a mean total atmospheric mass of approximately 2.4E16 kg, consistent with previous results [2]. Predicted atmospheric masses can be used by geodetic studies of topics such as the martian rotational state and gravitational field.

This expression can be used to support landing site selections, the determination of absolute altitude scales for atmospheric T(p) profiles, and theoretical simulations of topics as diverse as dust lifting and aeolian modification of surface features, the thermodynamic stability of near-surface liquids, and the radiation environment at the surface.

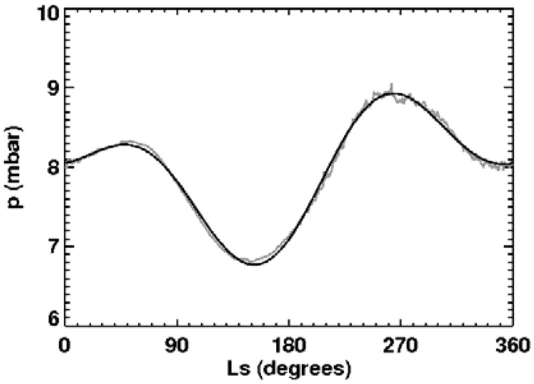

Figure 1: The grey line shows diurnal mean surface pressures observed by Viking Lander 1. The black line shows the corresponding predictions.

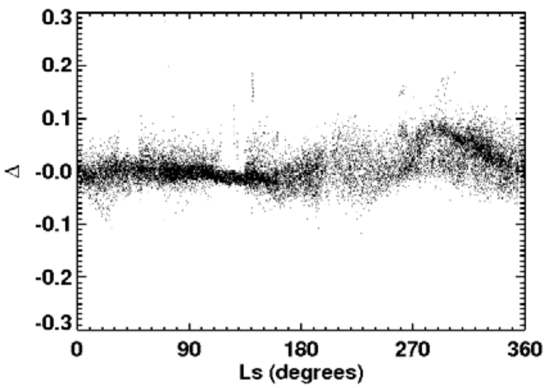

Figure 2: Δ for 21243 MGS surface pressure measurements as a function of season. Δ is defined as $(p_{pred}-p_{meas})/p_{meas}$, where p_{meas} is a measured pressure and p_{pred} is the corresponding prediction.

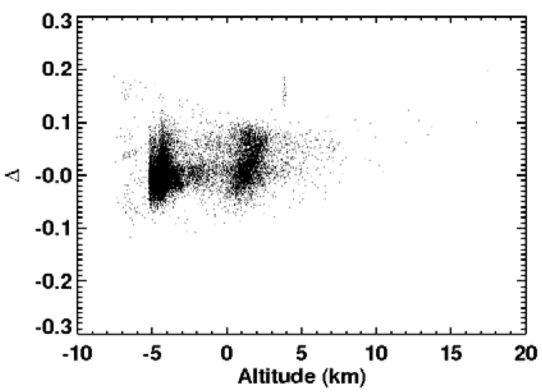

Figure 3: Δ for 21243 MGS surface pressure measurements as a function of altitude. Δ is defined as $(p_{pred}-p_{meas})/p_{meas}$, where p_{meas} is a measured pressure and p_{pred} is the corresponding prediction.

Conclusions: The simple expression reported here can be used to predict martian diurnal mean surface pressures to approximately 3% accuracy (1-σ). Predictions of surface pressure are important for a range of applications.

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References: [1] Haberle et al. (1999) JGR, 104, 8957-8974. [2] James et al. (1992) Mars, University of Arizona Press, 934-968.