ESTIMATION OF TEMPORAL CHANGES IN THE MEAN GLOBAL ATMOSPHERIC PRESSURE ON MARS FROM MARS GLOBAL SURVEYOR DOPPLER TRACKING

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Introduction: The yearly cycle of CO_2 exchange on Mars is reflected in variability in atmospheric pressure. Pressure variations were measured at both Viking lander sites [1-4] over a seasonal cycle. Pressure variations were also observed at the Pathfinder landing site over a fraction of a Mars year [5]. While the lander-derived measurements have been very useful in estimating the seasonally-exchanged mass of carbon dioxide between the atmosphere and surface of Mars, they represent local measurements that are also influenced by mesoscale processes. Measurements of global mean pressure would enable a more realistic estimate of the globally exchanged mass of CO_2 and in addition would permit a quantitative assessment of the role of global and local processes in contributing to landing site-scale pressure variations. We will show that it is now becoming possible to estimate global mean pressure by measuring small changes in the Martian gravity field.

Gravity and the Volatile Cycle: The movement of CO_2 between Mars' atmosphere and surface represents a global re-distribution of a miniscule fraction of the planetary mass that should be manifest by changes in the gravity field. Gravity field changes will arise due to motions in the atmosphere and the deposition of the carbon dioxide on the polar icecaps during the fall and winter seasons. The magnitudes of the expected effects can be estimated from a general circulation model simulation of the CO_2 cycle for a "typical" Mars year [6].

Figure 1 shows the square-root of the degree variance for the predicted time-varying gravity field as calculated from the Ames GCM [7], together with the observed square-root power in the static gravity field [8] and the coefficient sigmas. The figure shows that the relative power in the predicted time-variable gravity field is only about 10^{-5} to 10^{-6} compared to the static gravity field. However, the expected power in low-degree temporal coefficients is nearly an order of magnitude above the estimated standard deviation for these low-degree coefficients [9]. Thus, in principle, these small signals are above the noise level in the tracking data. But in practice they are challenging to detect, due to various factors such as the small amplitudes of the signals, the short time series of the observations compared to periods of global-scale atmospheric variability, and separability issues associated with tracking a single orbiting spacecraft.

Also note that the polar ice component of the time-varying field is approximately an order of magnitude larger than the signal associated with atmosphere transport.

Seasonal Mass: From MGS tracking data between Feb.1999 and the Summer of 2002 we have estimated the changes in the low degree gravity coefficients that have enabled us to derive the total mass deposited on the surface of the planet as a result of the seasonal exchange of CO_2 between the atmosphere and the regolith [9, 10, 11]. Figure 2 shows our preliminary results for the seasonal surface mass derived from the changes in Mars gravity field. The individual 5-day values are shown together with a 4-frequency fit to the data where the arguments are L_s, $2L_s$, $3L_s$ and $4L_s$.

The annual period is clearly evident in Figure 2 and shows a minimum for the mass in late southern hemisphere spring, which is largely consistent with the expectation that the southern hemisphere receives the most precipitation [12]. The quality of our observations is not presently understood but the variations about the 4-frequency fit are at present our best indication.

Global Mean Pressure: From our estimates of the mass deposited on the surface we can derive a "mean global pressure" estimate by subtracting the mass on the surface from the total atmospheric mass. Although this is an unverifiable number without full global surface pressure coverage, our values can be compared with the lander results and with the GCM. Figure 3 shows our estimate of the mean global pressure since February 1999 compared with the pressure measured by VL-2 [2]. In this comparison we have corrected the landing site pressure to the mean elevation of the planet [13] using a scale height of 8 km. To first order the two measurements follow similar trends, but at some L_s values (*e.g.* L_s~170^o) there are notable differences. Because the pressure estimations were made for different Mars years, we have no way of knowing the extent to which any disagreement is due to measurement error or real variability. In addition, the Viking measurement represents the pressure at a specific location while the gravity measures the average pressure at the same mean elevation of the VL-2 landing site, rather than that at the site itself.

Summary: Although the results are preliminary there is sufficiently good agreement between the lander pressure and the global estimate to warrant further efforts to improve recoverability. Our orbital estimates can be compared to future site-specific surface measurements from landers. Global mean pressure measurements would have great value in "tuning" general circulation models that would simulate the dynamics of the Martian atmosphere. Since Mars orbiters are routinely tracked and these pressure estimates derive directly (albeit with some effort) from the tracking data, there is the promise of routine monitoring of global mean pressure on Mars.

References:
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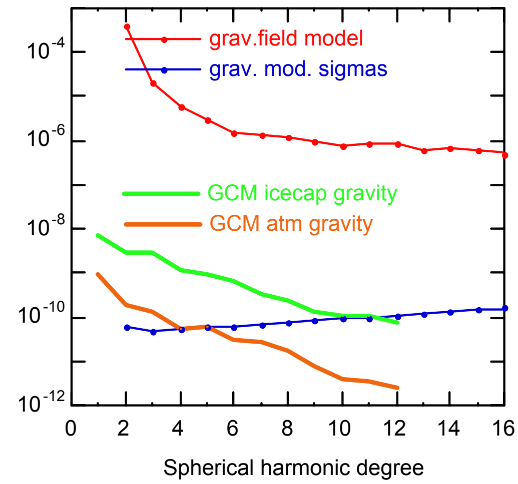

Figure 1. Square root of predicted power in static and temporally-varying gravity field coefficent along with gravity model sigmas. The temporally-varying gravity coefficients represent seasonal changes in the mass of the atmosphere and condensed mass based on a GCM simulation [6]. From [9].

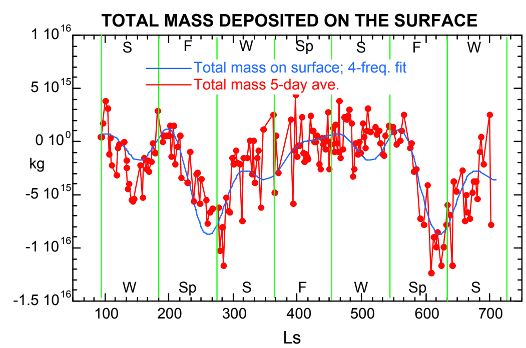

Figure 2. Preliminary estimates of the variation in total ice mass on the surface of Mars.

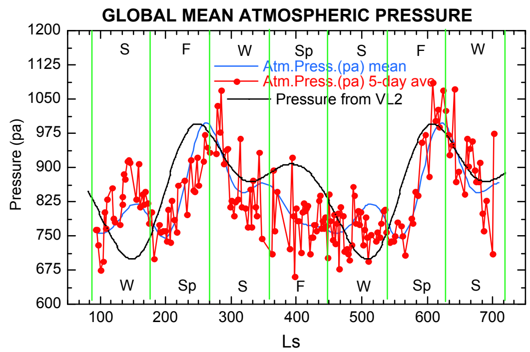

Figure 3. Preliminary estimate of variation of global mean atmospheric pressure from MGS Doppler tracking.