THE MASSES OF MARS/SEASONAL POLAR ICECAPS. David E. Smith[1] and Maria T. Zuber[2], [1]Laboratory for Terrestrial Physics, NASA Goddard Space Flight Center, Greenbelt, MD 20771, e-mail: David.E.Smith@nasa.gov, [2]Dept of Earth Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, 77 Massachusetts Ave., 54-918, Cambridge, MA 02139-4307, e-mail: zuber@mit.edu.

Introduction. Radio tracking of the Mars Global Surveyor spacecraft has revealed temporal changes in the long-wavelength gravity field of Mars that correlate, to first order, with the pattern expected for the seasonal redistribution of carbon dioxide between the atmosphere and surface. Detecting these gravity field changes requires isolating very small perturbations in the velocity of the spacecraft and estimating the very low degree zonal coefficients of the field. A comparison of these coefficients determined every 5 days for a period over 2 Mars years shows annual and semi-annual variations that are similar to those predicted by a General Circulation Model simulation [1]. These changes result from the redistribution of the mass of the planet by the exchange of carbon dioxide between the surface and the atmosphere through deposition and sublimation of CO_2 in the polar regions. A simple time-dependent model for the icecaps enables an estimate to be made of the mass of carbon dioxide at each pole as a function of the seasonal parameter, L_s.

Temporal Variations in Gravity. The gravity field of Mars is typically represented by a series of spherical harmonics [2] of which the largest are the low degree zonal terms. These terms represent the basic gravitational shape of Mars and, in combination with the rotational potential, largely define the long wavelength areoid. The redistribution of atmospheric material, particularly the pole-to-pole transport of carbon dioxide on the surface, causes these low degree terms in the description of the gravity field to change with time. In addition, when the CO_2 is deposited on the surface, the rest of the planet (mantle, core, etc. that is not changing in mass) moves slightly in position in order to maintain the center of mass of the whole planet in the same position in inertial space. This motion, and its gravitational effect, is a $C_{1,0}$ term in the gravity potential of the solid part of the planet. In addition, motion of material in the atmosphere that is deposited at the poles causes a change in the flattening of Mars that is manifest as a change in the $C_{2,0}$ gravitational coefficient. Similarly, there are changes in $C_{3,0}$ and all the higher degree and order terms, although the largest changes are in the first few low degree coefficients.

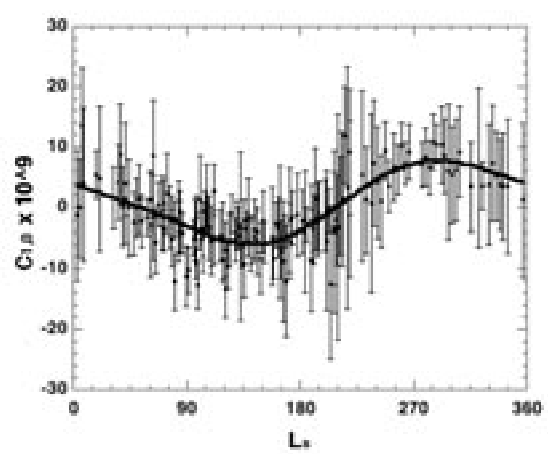

Fig. 1 *The variation in the degree 1 term of the solid part of the planet (core, mantle,* $C_{1,0}$*, e, crust) that arises because the deposition of carbon dioxide at the poles is balanced by a small motion of the rest of the planet.*

We have estimated the changes in the first 3 gravity coefficients by analyzing the small changes in the orbit of the MGS spacecraft [3]. Figure 1 shows the variation in the degree 1 coefficient of the gravity field of the solid part of the planet.

Note that the magnitude of the variation of the $C_{1,0}$ term is of order 10^{-9}, equivalent to a few centimeter movement of the solid component of the planet from its mean position.

Estimating the Seasonal Mass. If we make the assumption that the seasonal polar icecaps can, to first order, be represented as point masses at each of the poles, then it can be shown [4] that the mass of the north seasonal polar cap, *m(n),* can be written

$$m(n) = (1/2)(C_{1,0} + C_{2,0}) \times M,$$

and the mass of the south seasonal polar cap, *m(s),* as

$$m(s) = (1/2)(- C_{1,0} + C_{2,0}) \times M,$$

where $C_{1,0}$ and $C_{2,0}$ are the un-normalized first and second degree zonal coefficients in the expansion of the gravity field, and M ($=6.42 \times 10^{23}$ kg) is the mass of Mars.

The results for each pole for approximately two Earth years (one Mars year) are shown in Figure 2 where the mass in kg is plotted vs. L_s. Both datasets have been fit with annual (L_s), semi-annual ($2L_s$), and tri-annual ($3L_s$) periods. The annual period dominates for each pole as a result of the $C_{1,0}$ variation (Fig. 1) being much larger than the variation in the planetary flattening, $C_{2,0}$. Evident in Figure 2 is the suggestion of slow sublimation ($L_s \sim 270^o$ -140^o) and rapid deposition ($L_s \sim 180^o$ -260^o) in the northern hemisphere. In the south the accumulation and sublimation appear to be of equal length when measured against L_s. The pattern of mass exchange shows differences in comparison to the temporal pattern of latitudinal brightening due to the seasonal changes in frost deposition [5], suggesting that at least some aspects of reflectivity change are not associated with significant mass exchange.

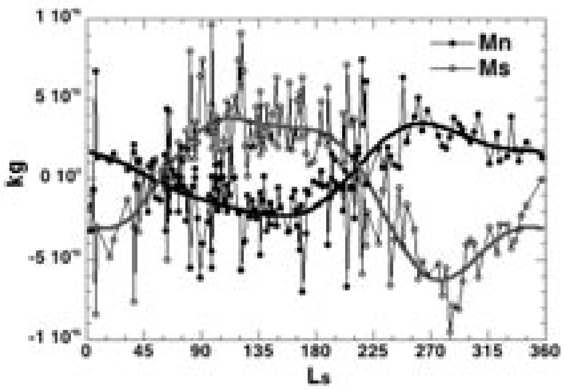

Fig. 2. *Estimated seasonal mass at each of the Martian poles based on a point mass model for the seasonal icecaps. Note that (1) sublimation begins in the southern hemisphere as soon as the sun reaches its maximum northerly latitude (L_s=270^o), and (2) the rapid rise and slow fall of deposition in the north.*

References. [1] Smith D. E. et al. (1999) *JGR, 104,* 1885-1899. [2] Lemoine F. G. et al. (2001) *JGR, 106*, 23,359-23,376. [3] Smith D. E. and Zuber M. T. (2003), submitted to *JGR*. [4] Zuber M. T. and Smith D.E. (2003) in prep. [5] Zuber M.T. and Smith D.E. (2003) this volume.