# SEASONAL CHANGES IN THE MASSES OF THE POLAR ICECAPS OF MARS DERIVED FROM MARS GLOBAL SURVEYOR GRAVITY

**David E. Smith[1] and Maria T. Zuber[2,3]**,
[1]NASA Goddard Space Flight Center, Code 920, Greenbelt, MD20771 USA; dsmith@tharsis.gsfc.nasa.gov, [2]Department of Earth Atmospheric & Planetary Sciences, MIT, Cambridge, MA 02139 USA; [3]currently at: Department of Earth and Planetary Sciences, Harvard University, Cambridge, MA 02138 USA; zuber@eps.harvard.edu.

**Introduction:** Over the course of a Martian year, approximately 18% of the atmosphere of Mars is deposited on the surface as part of the seasonal cycle of $CO_2$ exchange [1]. This amounts to approximately $10^{-8}$ of the mass of the planet being re-distributed each season, and causes changes in the longest-wavelength components of the gravity field of the planet. From precise tracking of the Mars Global Surveyor spacecraft, these subtle changes in the long wavelength gravity field are now observable [2, 3]. Gravity changes are detectable as very small perturbations of the orbit of the Mars Global Surveyor (MGS) that can be derived from X-band Doppler measurements [4]. Using the MGS X-band tracking data, we have recovered the time variability of some very low-degree coefficients in the Mars gravity field. Based upon a simple model for the seasonal polar icecaps, we have estimated the changes in mass of each of the caps as a function of time, and have compared the results to changes expected from general circulation model (GCM) simulations of the Mars $CO_2$ cycle.

**Measuring Gravity Field Changes:** The form and magnitude of the changes in the gravity field expected from the surface-atmosphere exchange of $CO_2$ can be estimated from general circulation models [*e.g.* 5], and the results form a basis of comparison with the pattern of volatile mass exchange that we estimate from gravity. To determine the predicted effect of volatile cycling on the gravity field, we convert to mass, on a regular time interval, the condensed $CO_2$ precipitation and atmospheric pressure changes associated with the seasonal cycle of $CO_2$ exchange as simulated by the Ames GCM [6]. We then solve for a gravity field using the simulated mass distribution during each time interval, and compute, from the changes in the mass distribution, the associated changes in the low degree terms of the gravity field [7]. The low-degree coefficients, which represent the longest wavelength signals in the global gravity field, have the greatest power and represent the planet-scale redistribution of mass.

**Estimating Mass Variations:** Using Deep Space Network (DSN) tracking of the MGS spacecraft [8] in orbit about Mars over a 3+ Earth-year period, we have monitored changes in the MGS orbit that we associate with the seasonal atmospheric cycle [3]. These changes have been identified as variations in the first 3 low-degree zonal coefficients of the Mars gravity field. Using the simplest geometric form of the polar icecaps (point mass model), we can show that the seasonal masses at each pole can be expressed:

$$m(north) = (1/2).(C_{1,0} + C_{2,0}).M$$
$$m(south) = -(1/2).(C_{1,0} - C_{2,0}).M$$

where the *C's* are spherical harmonic coefficients that represent the seasonal changes in the degree 1 and 2 zonal coefficients and *M* is the mass of Mars.

**Icecaps:** Applying the equations given above to the estimated changes in the gravity field, we obtain (Figure 1) a comparison of the mass computed from our simple model with that predicted by the Ames GCM for a typical Mars year [7].

The general agreement between the GCM and the observations is clear for both poles, but for the north the gravity data suggest a temporary increase in the early fall in two consecutive years. This feature has previously been reported in observations of the temporal change of the flattening of Mars [2]. In the south there is a clear phase difference between the observations and model that suggests the gravity sees the rise in polar accumulation occurring much sooner that the GCM would predict.

**Conclusions:** We describe a new method for estimating how and when the seasonal deposition at the poles occurs based upon observed changes in the gravity field. The approach allows regular estimation of global-scale mass variations attributable to volatile exchange. At present these initial results are very preliminary and our representation of the polar icecaps is very simple, but the observed pattern does reproduce the major features of the predicted signal. We believe this approach could be further developed as a method of monitoring inter-annual changes in Martian icecaps.

**References:**

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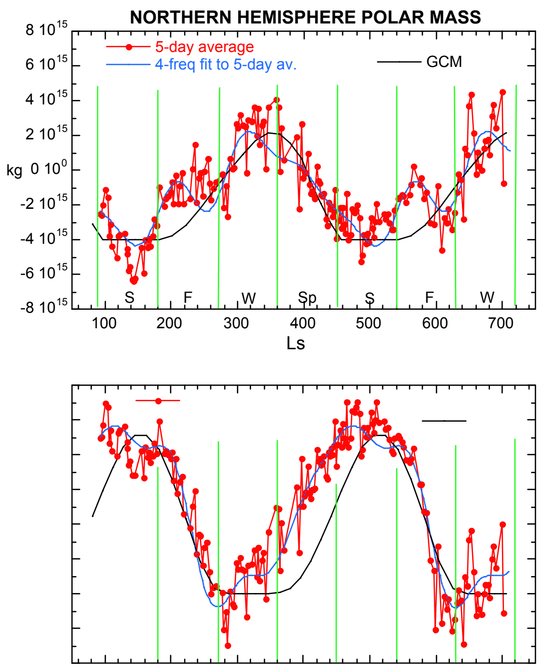


Figure 1. Preliminary results for the seasonal changes in the masses of the north (top) and south (bottom) icecaps derived from changes in the gravity field and compared with predictions from the Ames GCM [7].