THE MASSES OF MARS' SEASONAL POLAR CAPS AND CHANGES IN THE GRAVITY FIELD.

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Introduction: Tracking of the Mars Global Surveyor spacecraft has continued almost uninterrupted for 7 years since the beginning of mapping in February 1999 and provided detailed information about the motion of the spacecraft around Mars. These data reveal the small perturbations of the orbit due to the changing masses of the icecaps arising from the seasonal exchange of carbon dioxide with the atmosphere. We have analyzed over 3 Mars-years (six Earth-years) of these data to obtain variations in the gravity field and the seasonal masses of each of the icecaps and their variation throughout the Martian year.

Approach: We processed the tracking data in orbital arcs of approximately 5 days and, after editing time-periods of minimal data and poor quality, we analyzed over 340 5-day arcs covering over 3 Mars years. The data consisted of X-band Doppler and range data; the Doppler were accurate to about 0.1 mm/s and the range to about 2 m. We determined the orbit of MGS for each orbital arc and estimated one or more low degree coefficients of the Mars gravity field. We found considerable difficulty in obtaining reliable values for the C2,0 gravity coefficient that we ascribed to the small effect that this parameter has on the orbit of MGS. The estimation of the C3,0 coefficient was remarkably robust and inline with expectations in terms of amplitude of variation and phase from GCM predictions. Further, the recovery of the C3,0 did not change when it was estimated simultaneously with the C2,0 coefficient. We interpret this result as an indication that the C3,0 result is robust and is a reasonable estimate of the lumped effect of the odd zonal coefficients, primarily C3 and C5 but also those of higher degree. However, because we were unable to estimate a reliable value for the C2,0 gravity coefficient we were not able to estimate the hypothetical mass of the seasonable icecaps based upon point masses at each pole.

We also used the tracking data to make direct estimates of the masses of the icecaps. We modeled each icecap as a circular cone centered on the pole where the size of the cone in latitude was derived from observations obtained from MOLA radiometry [1] and the height of the cone from MOLA altimetry [2]. The northern cap extended down to a maximum of 55 degrees and the southern cap extended to latitude 50. The maximum height of both caps was taken as 1 meter and the height decreased linearly with cap size. The theoretical gravity field of each cap was derived for every 5 degrees in cap size and assuming the seasonal material was of nominal density. Subsequently we solved for scale factors from the tracking data for the densities, and obtained the total mass of each icecap. Because the polar deposition is composed of carbon dioxide that is being withdrawn from the atmosphere and returned to the atmosphere during sublimation, there is a (minute) variation in the mass of the atmosphere that also perturbs the spacecraft and needs to be accounted for in the analysis. We used GCM [3]results for the *a priori* mass of the atmosphere and we effectively solved for the variation in mass of the atmosphere simultaneously with the two icecaps and applied a constraint to our solution that requiring the sum of all mass changes at both poles and in the atmosphere to sum to zero, thus maintaining a constant volatile mass of the planet.

Results: Our gravity field coefficient solutions did not really enable us to estimate the masses of the seasonal caps even though the C3,0 variation showed the seasonal affect. This was not only due to our inability to estimate a reliable value for C2,0 but even if we had accomplished our goal it would only have enabled us to estimate the mass of the simplest of cap model – a point mass model, which does not account for the change in size of the cap with season.

The result of the direct estimation of the polar masses indicates variations similar to those predicted by the Ames GCM. Variations are seen from year to year and are revealed as scatter about a mean curve, but it is not clear whether the scatter represents real short-term variability or alternatively is the result of observational error.

For both poles the data suggest that the accumulation of precipitation begins immediately after the end of the sublimation phase, i.e at the time of the summer solstice. This is surprising since it is the beginning of summer. However, it may be associated with the inclusion of the atmospheric mass above the poles in our estimates for the polar masses since it is impossible to separate the mass of the atmosphere over the polar cap from the mass of the cap itself. Ultimately separability may be attempted by comparisons with column density estimations from other sensors. These temporal records of Mars' hemispheric mass distribution are beginning to approach the level required to study interannual variability suggested by changes in polar surface morphology.

Reference: [1] Zuber M.T. and Smith D.E. (2003) Third Mars Polar Conf. Banff. [2] Smith D.E.

et al. (2001) *Science 294*, 2141-2146. [3] Haberle R.M. (2003) Third Mars Polar Conf, Banff.