VOLUMES OF THE SEASONAL POLAR CAPS OF MARS AND IMPLICATIONS FOR DENSITY.

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Introduction:

A martian year of data from the Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor spacecraft have been analyzed to provide estimates of the depth and volume of seasonal precipitation at the martian poles as a function of season. The data indicate a larger volume of precipitation in the north than the south, and that the accumulation in the north is deepest in the lower elevations at the edge of the permanent cap around latitude 80N. The maximum depth of precipitation approaches 2 meters at both poles and increases with latitude at 5 to 6 cm per degree. The data suggest the accumulation is not uniform and that latitude maxima occur at different times during the fall and winter season. The volumes have been combined with estimates of the mass of the precipitation to provide an estimate of the mass density. The preliminary results indicate a difference in the density of the precipitation material at the north pole from the south pole with the south appearing to reach a density close to solid carbon dioxide (~1600 kg/m^3) and the north a density of ~600kg/m^3.

Altimeter Data:

The altimetry data used in this analysis was the finally corrected data that incorporated all known corrections for the MGS orbit, timing corrections to the MGS clock, attitude corrections, geometric corrections for pulse spreading, and using orbital crossovers. The actual dataset consisted of nearly 700 million measurement residuals to the best-fit global shape model of Mars covering the period March 1999 to June 2001 when the failure of an oscillator in the instrument caused the end of the altimetry component of the MOLA investigation. These residuals contained all the information about the variation in topography as a function of time and position, including the elevation changes due to seasonal deposition and sublimation in the polar regions.

The altimetry data have a nominal precision of approximately 38 cm with an orbital uncertainty of order 70 cm rms making the elevation uncertain at the 80 cm level (1 sigma). The orbital error has a long wavelength character that is predominantly 0.5 revolutions so it can introduce a slope and a bias into the elevations. The orbit of MGS was near circular with an average altitude of approximately 400 km and with an orbital inclination of nearly 92.7 degrees. Altimetry data were obtained up to latitudes of 87.5N and S.

For the analysis, the altimetry data were combined into 50-orbit datasets, of approximately 4 days. The data were averaged over all longitudes into one-degree latitude bands from 50 to 87 north and south and in each band there were of order 15,000 to 20,000 thousand altimetry measurements. The total number of measurements in each of the polar regions was of order 100 million.

The elevations from latitudes 50N & S to the pole show a spread of ±50 cm due largely to orbital error. We normalized the altimetry at 50N and 50S so as to minimize the effect of the radial orbit error. The normalized elevations show a clear variation in depth with latitude at both north and south poles. The maximum accumulation is 1.5 to 2 meters and in the north the range reaches a maximum at approximately 80N then decreases slightly nearer the pole. The zonal topography reaches its lowest value at 80N at the edge of the permanent icecap. This observation suggests that the accumulation is affected by the regional trend in elevation and that the maximum accumulation occurs in the “valley” between the sloping northern planes and the rise of the permanent ice cap.

Volume of precipitation:

The volume of precipitation for each degree of latitude was derived for every ~ 2 degrees of Ls. This dataset enabled the volume to be studied by latitude and also time (Ls). For the northern pole the volume has a clear variation with latitude that increases with latitude, as might be expected, and reaches a maximum just below 80N at the edge of the permanent icecap. The southern pole shows no significant change with latitude but rather a flat pattern suggesting that accumulation is more regular at all latitudes and that the depth increase with latitude is balanced by a decrease in surface area. The difference between the two poles could indicate the form of precipitation is different at the two poles and that the process of compaction may not be a factor in the south as compared to the north, for example if the former were frost or slab ice.

Density:

The seasonal volume estimates were combined with estimates of the seasonal masses of precipitation from (1) gravity observations and (2) from the Ames GCM to provide average densities of the seasonal precipitation. The striking difference between the two poles is the high density in the south compared to the north. In the south the density of CO_2 approaches 1600 kg m-3 and further suggests the density in the south increases with Ls and approaches an average density of slab ice near Ls 180, the beginning of southern Spring.

Conclusions:

Recent re-analysis of the MOLA laser altimeter data has provided an estimate of the volume of seasonal material deposited on the polar caps. The results indicate that the volume of deposited material in the south is much smaller that the north and suggestive of a differing mechanisms of deposition. When compared with the masses of the seasonal material, either from a GCM or from gravity analysis, the implied densities suggest the southern seasonal cap has a significant fraction of solid CO_2 while the north has a much smaller density consistent with CO_2 snow or some less densely packed form.