RECONCILING THE MOLA, TES, AND NEUTRON OBSERVATIONS OF THE NORTH POLAR CO_2 MASS BUDGET ON MARS.

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Introduction: There are now three independent observations of the CO_2 polar cap mass budget of Mars' north polar cap. The first is based elevation changes detected by the Mars Orbiter Laser Altimeter (MOLA) on the Mars Global Surveyor (MGS) [1]. The second is based on MGS Thermal Emission Spectrometer (TES) broadband observations of the solar and infrared radiation fields at the top of the atmosphere [2,3]. The third is based on neutron counts measured by the neutron spectrometer (NS) on Odyssey [4]. If one assumes a cap density of 910 kg/m^3 [1], then the peak mass loading poleward of 85°N inferred from the MOLA data is ~1090 kg/m^2, which compares to ~1150 kg/m^2 inferred from TES for the same region, and ~700 kg/m^2 from the NS data. TES and MOLA are in good agreement, but are about 60% higher than the NS data. Is there a way to reconcile these discrepancies?

Role of surface heat storage: The TES data are based on an energy balance. The net radiative loss (gain) in a column is balanced by latent heating due condensation (sublimation) of CO_2. In calculating the mass budget, the other main energy sources, atmospheric heat transport and subsurface conduction, were neglected [2,3]. At the pole, atmospheric heat transport is indeed a small term. However, subsurface heat conduction can be significant because at the North Pole water ice, which has a high thermal conductivity compared to bare soil, is a dominant component of the subsurface. Thus, heat conducted down into the ice during summer will slowly bleed back out during fall and winter reducing the amount of CO_2 that condenses on the pole.

We have taken a first cut at quantifying this effect by fitting a curve to Paige's [5] estimates of the conducted energy flux in his analysis of Viking IRTM data. For a thermal inertia of ~2100 (SI units) this curve shows a peak upward conducted heat flux of about 30 W/m^2 at L_s=180°, which is just after the time CO_2 begins condensing. This then gradually tapers off to less than several W/m^2 near the end of spring just before the CO_2 ice completely sublimes. We then added this term to the TES radiation fields and recalculated the CO_2 mass budget. We find that subsurface heat conduction at the North Pole can reduce the amount of CO_2 that condenses by about 400 kg/m^2, which brings the TES data in close agreement with the NS data.

CO_2 ice density: That leaves the MOLA data much higher the both TES and NS. However, the MOLA data are based on elevation changes and are not direct measurements of the mass loading. To relate the elevation changes to a mass loading requires knowledge of the ice density. The MOLA data can be reconciled with TES and NS if the CO_2 ice density is ~600 kg/m^3. Feldman et al. [4] suggested that low ice densities could be a way to explain the difference between MOLA and NS.

The MOLA combined gravity/elevation measurements infer a mean cap density of 910 ± 230 kg/m^2 [1]. Thus, 600 kg/m^3 is below the lower limit of the MOLA measurements. However, the MOLA-derived density is an average for the entire seasonal cap. It is possible that the density of the north polar deposits is less than the average of the entire seasonal cap. A good physical basis for this is the much more frequent occurrence of "cold spots" at the North Pole compared to lower latitudes [6]. Snowfall is a strong candidate for the origin of these cold spots. If true, it means that a much greater fraction of the north polar deposits originate from the atmosphere as snowfall rather than direct condensation onto the surface. Surface accumulations resulting from snowfall have lower densities than those originating from direct deposition.

Conclusion: Of the three measurements that bear on the north polar CO_2 mass budget, the NS provides the most direct measurement of the mass loading. Yet it shows much less CO_2 accumulating on the pole than initially predicted by either MOLA or TES. These differences can be reconciled by (a) including subsurface heat conduction in the TES calculations, and (b) using a lower ice density to convert MOLA elevation data to a mass loading.

References: [1] Smith D.E., Zuber M.T. and Neumann G.A. (2001) *Science, 294*, 2141-2148. [2] Kieffer, H.H. and Titus, T.N. (2001) *Icarus*, *154*, 162-180. [3] Titus, T.N. (2003) *International workshop: Mars atmosphere modelling and observatiions,* Granada, Spain. [4] Feldman W.C., et al. (2003) *JGR*, submitted. [5] Paige, D.A. (1985) *Ph.D. Thesis*, UCLA, 206p. [6] Titus T.N. and Kieffer, H.H. (2003) *6th International Mars Conference*, Pasadena Ca.