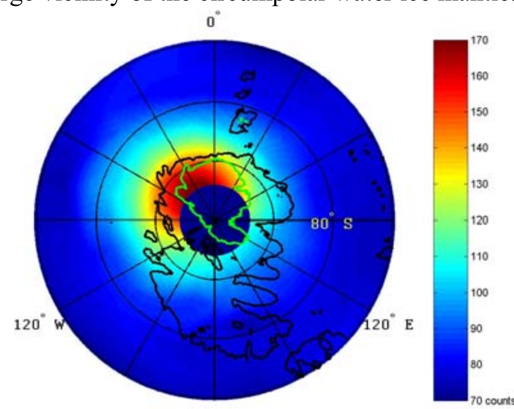
Mars Odyssey Neutron Sensing of the South Residual Polar Cap. R.L.Tokar, K.R.Moore, R.C.Elphic, R.C.Wiens and H.O.Funsten, Space and Atmospheric Sciences, Los Alamos National Laboratory, Los Alamos, NM 87545, rlt@lanl.gov

Introduction

The Viking orbiter infrared thermal mapper indicated that the Mars residual south polar cap is perennially covered in predominantly CO_2 [Kieffer, 1979]. This is in contrast to the North Pole, where the residual cap cover is predominantly water ice, [Kieffer et al., 1976]. There are indications that the CO_2 cover is thin in spots and variable over seasonal time scales. See James et al. [1992] for a review of the early work on both the seasonal and permanent CO_2 and James et al. [2001] for recent observations of the south polar cap. In analogy with the north residual polar cap and supported by recent observations of exposed solid ice near the south pole [Titus et al. 2002], it appears likely that the south residual CO_2 covers dirty water ice. However, the thickness and density of the residual CO_2 cover is not well known. This study extends the analysis in Tokar et al., 2002, concentrating not on the water ice circumpolar region but instead on the south residual cap. It turns out that the Odyssey GRS neutron observations near the cap are ideally suited to provide estimates of the residual cap CO_2 thickness density product. This is because the neutron counts measured in this region are dominated by the cap and are a calculable function of the amount of CO_2 on the cap.

GRS Data

The time period analyzed in this study is March 20 to April 18,2002. The south season is late summer, with the solar areocentric longitude L_s between about 340 and 360 degrees, therefore the seasonal CO_2 frost is mostly absent in the south and the residual polar cap is exposed to Odyssey. On GRS, there are four independent neutron detectors that view nominally in: 1-the nadir direction, 2-the spacecraft velocity direction, 3-the zenith direction, which is toward the spacecraft and 4-opposite the spacecraft velocity. The primary data analyzed in this study are obtained by the forward looking detector 2 that is sensitive to neutrons in the thermal (E < ~0.3 eV) and epithermal (~0.3 eV < E < ~600 keV) energy bands. For this time period, there are a total of 61067 neutron spectra for southbound Odyssey orbit segments and 5317 of these are measured between 87S and 75S. This subset of spectra is used to produce a map of the detector 2 average signal near the residual cap, as shown in the following figure. Mapped are average counts above background measured in 19.6 s. Also shown for reference are two MOLA contours at 2.6 km (black) and at 3.6 km (green) elevation about the cap. The strong neutron signal in the vicinity of the residual cap and attributed to the cap is clear. The signal peaks at about 170 counts directly over the cap, and is about 70 counts in the large vicinity of the circumpolar water ice mantle.

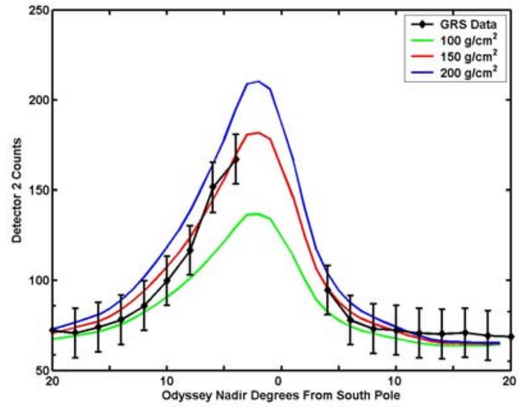


Simulations and Discussion

In order to use these data to estimate the CO_2 thickness-density product on the residual cap, this study employs the simulation model described in Tokar et al. [2002]. The simplest neutron source model possible is employed, and it does a remarkably good job of reproducing many features in the GRS neutron data. The model has three material components near the South Pole, a residual cap with variable CO_2 depth on solid water ice, the hydrogen rich circumpolar region found in previous studies and a uniform Martian atmosphere of 11 g /cm^2 thickness appropriate to the southern highlands. The residual cap radius is assumed to be 175 km and centered at 87S and 45W. In the model, the primary free parameter to reproduce the neutron counts is the thickness-density product of the CO_2 on the cap. A relatively dry equatorial region also exists in the simulations, but it has little effect on the results as the data are studied only within about 20 degrees of the South Pole. Neutron flux spectra for leakage out of the model components are calculated with the code MCNPX [Waters et al., 2002], including gravitational boundary conditions.

The following figure illustrates the primary result of the simulations. The GRS data averaged over 30-60W as the cap is approached (southbound orbits) and 90-180 E as the region is exited (northbound orbits), are shown as the black diamonds in the figure. There are no data within 3 degrees of the pole due to the Odyssey orbit inclination and the data shown are plotted at the center of 2 degree latitude bins. All other curves in the figure are from the simulation model. The blue, red, and green curves are for a uniform 100, 150 and 200 g/cm^2 CO_2 cover on the residual cap, respectively. The results indicate the ~150 g/cm^2 CO_2 cover with an uncertainty of about 25 g/cm^2 provides a reasonable fit to the GRS data. If the density of the CO_2 is taken arbitrarily to be the average density of the seasonal CO_2 deposits found by Smith et al. [2001], ~0.91 g/cm^3, the value 150 g/cm^2 corresponds to a thickness of about 1.6 m. This is not particularly thick and may bear on the long-term stability issues of the residual cap discussed by James et al. [1992]. The assumed cap area is ~9.6x10^{14} cm^2 so the thickness-density product of 150 g/cm^2 represents ~1.5x10^{17} g of CO_2. For reference, this is approximately 5% of the total CO_2 seasonally cycled in and out of the atmosphere.

It is desirable to discuss the sensitivity of these results to the uncertainty in the area of the cap covered by CO_2. A uniformly covered 175 km radius is a reasonable upper bound to the covered area. It follows that because the gradient in thermal neutron counts with CO_2 depth at 150 g/cm^2 is positive, the 150 g/cm^2 is a lower bound for the thickness-density product. It is likely that a "Swiss cheese" model for the cap applies, where the cheese is the CO_2 and the holes are dirty water ice. Under these circumstances, assume the area of the cap covered by CO_2 is reduced by an amount ΔA. For example, if $\Delta A/A = 0.80$ it is found that the average thickness-density product in the CO_2 region must increase to about 210 g/cm^2 to match the GRS observations. It is in this sense that the 150 g/cm^2 is a lower bound. For 210 g/cm^2 and an area decrease of 20%, the total amount of CO_2 is ~1.68x10^{17} g. In addition, an upper bound to ΔA can be found consistent with the GRS data. From the simulations it is known that the relative contribution to the detector 2 counts for pure ice divided by the result for 150 g/cm^2 of CO_2 on ice, R_1, is ~0.04. For uniform CO_2, as the depth of CO_2 increases the detector 2 simulated counts also increase but eventually saturate near 300 g/cm^2 (Drake et al., 1988). The ratio of the saturated value to that for 150 g/cm^2 of CO_2, R_s, sets an upper bound on the amount of exposed ice via $\Delta A/A = (R_s-1)/(R_s-R_1)$. For a typical $R_s = 1.75$, the maximum $\Delta A/A$ is ~0.44, or 44% of the cap could be exposed ice consistent with the neutron data. In this case, the thickness-density product of CO_2 on the covered regions is at least the value at saturation, ~300 g/cm^2, and there is at least ~1.7 x 10^{17} g of CO_2 on the residual cap.



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