USING SILICON AND HYDROGEN GAMMA RAYS FOR THE SIMULTANEOUS DETERMINATION OF DRY-LAYER THICKNESS AND SUB-SURFACE ICE CONTENT IN THE POLAR REGIONS OF MARS. W. V. Boynton, D. M. Janes, M. Finch, and R. M. S. Williams, Department of Planetary Sciences, University of Arizona, Tucson AZ 85721 (wboynton@LPL.Arizona.edu)

Introduction: The 2001 Mars Odyssey Gamma-Ray Spectrometer (GRS) [1] has been a very useful instrument for estimating the amount of sub-surface ice in the polar regions. In our first preliminary look at ice content in these regions [2], we modeled the surface with two layers: a dry layer containing small amounts of H_2O over an ice-rich layer with a variable ice content. We used a plot of the fluxes of epithermal neutrons *vs.* thermal neutrons and a plot of H gamma-rays *vs.* thermal neutrons to estimate both the ice content in the sub-surface layer as well as the thickness of the dry layer in the south polar region. This analysis gave a result consitent with an ice content around 35% by mass, and a dry-layer thickness (DLT) of about 40 g/cm^2. This interpretation was based on some assumptions concerning a "ground truth" H_2O content in the lower latitudes, and we have since shown our assummed H_2O content was lower than the "true" value found by the GRS after a proper calibration. We recognized this potential problem at the time, and stated that the assumption, if incorrect, would yield a lower-limit to the ice content.

With a better calibration, we have been able to revise our estimates of ice content and depth, and indeed the ice content did go up from our original estimates. Currently we feel we have a solid calibration of the gamma-ray data and have limited our analyses to these data. We have previously shown, based on the flux of H gamma rays, that the DLT cannot be more than about 25 g/cm^2 over most of both polar regions [3]. (The GRS data reduction returns thickness expressed in terms of g/cm^2. It is a measure of column density which is the parameter to which the measurement is sensitive. Linear depth can be estimated by dividing by an assumed density for this upper surface of the regolith.)

This limit was set by assuming the buried ice was 100% H_2O. Similarly, we showed that the H_2O content of the ice-rich soil cannot be any less than about 30% H_2O by assuming the DLT = 0, i.e. the ice-rich soil is not buried at all. If we use only the H gamma-ray flux, we have only one equation for the two unknowns of ice-content and DLT. We have shown that the flux of Si capture gamma rays provides another equation to address the issue [4] (see figure 1).

Approach: In this work we extend the previous work to take into account another important variable. This variable is the total macroscopic thermal-neutron cross section of the H-free model soil. The data in figure 1 show the relationship between H and Si fluxes and the DLT and the H_2O content of the sub-surface layer. These calculations are only valid for a particular composition of the dry (H_2O-free) soil. Different amounts of Fe and Cl, both of which are strong absorbers of thermal neutrons (the excitation source of these gamma rays), can change the locations of the points. Higher amounts of these elements will lower the Si flux for otherwise identical H_2O contents and DLT values.

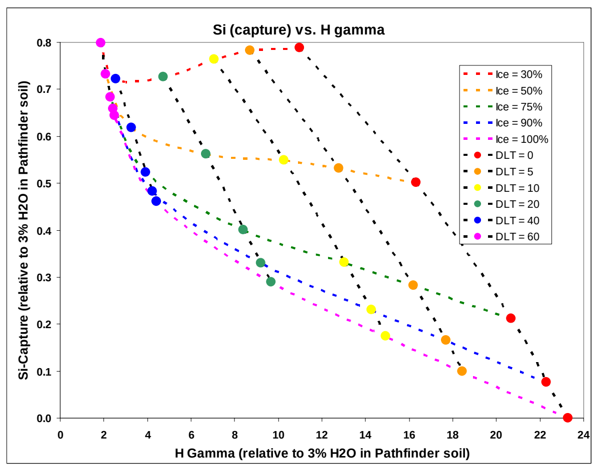

Figure 1. Plot of calculated values of Si and H flux (relative to our standard soil containging 3% H_2O. DLT is the dry layer thickness in g/cm^2 and the ice content refers to the total H_2O content of the sub-surface ice-rich layer. This array is calculated for a soil which is relatively low in Fe and Cl, two elements which significantly absorb thermal neutrons. A similar array for a high-Fe high-Cl soil plots with Si fluxes significantly lower. To use these calculated model results, one plots the observed flux of the H gamma ray and the Si gamma ray at any given location in the polar region and determines both the thickness of dry layer and the H_2O content of the lower layer by interpolation.

Results: We have now extended the calculations to allow for differences in observed Fe and Cl content in the polar regions. We have calculated many different examples of layered model soils with DLT and H_2O contents similar to those shown in figure 1 but with a range of different Fe and Cl contents. In each of these models, we assume the composition of the soil in each of the two layers is identical except for the H_2O content. The different H_2O-free compositions can be characterized by a parameter proportional to the total macroscopic thermal neutron capture cross section, and we then plot our results as a 3-dimensional volume relating the total cross section, the H gamma flux, and the Si gamma flux.

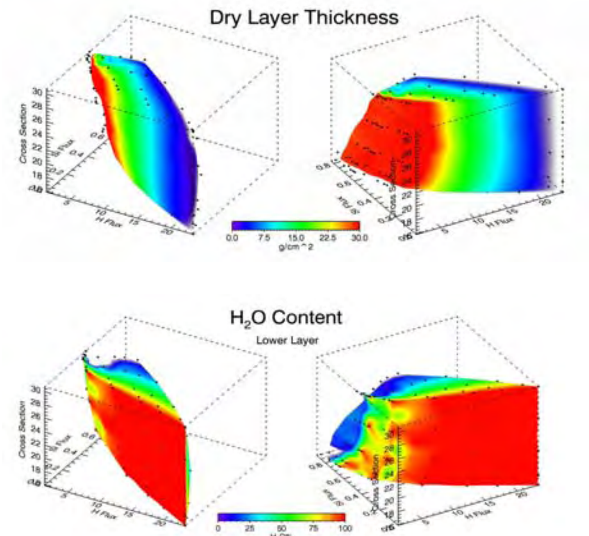

Figure 2. Different views of 3-d plot of calculated fluxes of H and Si gamma rays as a function of different 2-layer models. The models differ in the H_2O content of an ice-rich lower layer, the thickness of the dry layer above it, and a parameter related to the total macroscopic thermal neutron cross section of the dry soil.

In figure 2 we show a graphical representation of the results of these model calculations. The observed Fe and Cl content and the H and Si gamma-ray fluxes of the polar region are used with these model calculations to determine both the H_2O content in the lower layer and the thickness of the dry layer on top. (In these calculations the H_2O content of the upper layer is assumed to be 5%, but the results are not strongly dependent on this value.)

Over most of both the north and south polar regions (Figure 3), the dry-layer thickness is similar, in the range of 0 to 12 g/cm^2 with a 1-sigma uncertainty ranging from 2 to 7 g/cm^2 over most of the region. (The uncertainty is dependent on the statistical uncertainty in the Fe and Cl content and the H and Si fluxes; it does not include model uncertainties.) The H_2O content of the ice-rich layer differs between the two poles with the south having the greater H_2O content. Values in the south range from about 35% to 75% H_2O. In the north, the values range from about 35% to 50%. The uncertainties on these values are larger in the south, ranging from about 10% to 16% H_2O over most of the south and 6% to 10% H_2O over most of the north. (The uncertainties at lower latitudes where the signal is weaker is generally higher than that given above.)

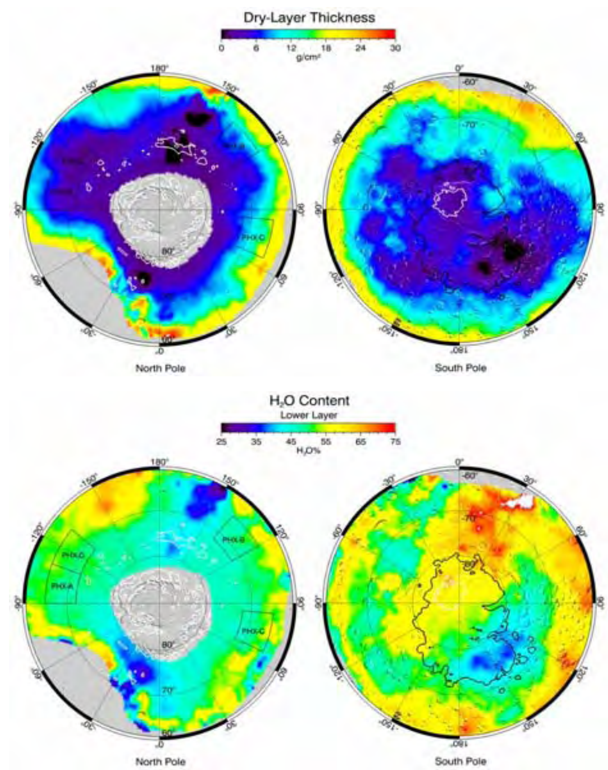

Figure 3. Maps of the polar region showing variations in dry-layer thickness (DLT) and H_2O content of the lower layer. Regions around the north polar residual cap, where the spatial resolution of the GRS does not permit a clear determination of the surrounding areas, has been masked out. Similarly, the areas at lower latitudes where the presumed ice level is deep are also masked out. The residual caps are outlined in white and south polar layered terrain is outlined in black.

Discussion: The differences in H_2O content between the north and south may be an indicator of differences in the accumulation rates of snow and dust in the two hemispheres when the ice-rich layers were deposited. The thickness of the dry layer is probably more indicative of current conditions rather than conditions in the past when the ice was deposited. These points will be discussed at the meeting.

References:

[1] Boynton *et al.* (2004) *Space Sci Rev. 110*, 37-83. [2] Boynton *et al.* (2002) *Science, 297*, 81-85. [3] Boynton *et al.* (2004) *6th Intl. Conf. on Mars*, Abstract #3259. [4] Boynton *et al.* (2005) *LPS XXXVI* Abstract #2154.