SPATIAL DECONVOLUTION OF MARS ODYSSEY NEUTRON SPECTROSCOPY DATA: ANALYSIS OF MARS SOUTHERN SEASONAL CAP.

T. H. Prettyman,[1] R. C. Elphic,[1] W. C. Feldman[1], J. R. Murphy,[2] S. Nelli,[2] T. N. Titus,[3] and R. L. Tokar,[1] [1]Los Alamos National Laboratory, Los Alamos, New Mexico, [2]New Mexico State University (NMSU), Las Cruces, NM, [3]U.S. Geological Survey, Flagstaff, AZ.

Introduction: During autumn and winter, CO_2 gas condenses in the polar night forming an ice cap that extends from the pole to roughly 45° latitude. In the spring and summer, the ice sublimes, replenishing the atmosphere with CO_2. Approximately 25% of the martian atmosphere is cycled into and out of the northern and southern seasonal caps. Consequently, the seasonal caps play a dominant role in atmospheric circulation. The main questions about the seasonal caps that remain unanswered concern the local energy balance, polar atmospheric dynamics, and CO_2 condensation mechanisms.

Mars general circulation models (GCM) can be calibrated by adjusting the emissivity and albedo of the seasonal caps to fit the model results to Viking pressure measurements [1,2]. The albedo and emissivity of the seasonal ice are generally assumed to be spatially uniform and constant with time. This calibration method enables accurate determination of the total amount of CO_2 cycled through the northern and southern caps; however, the adjusted emissivity and albedo values are inconsistent with those observed by the Mars Global Surveyor Thermal Emission Spectrometer (TES). TES observations reveal a cap that is spatially heterogenous with time varying emissivity and albedo [3-5].

Neutron spectroscopy data provide additional information needed to more accurately determine local properties of the atmosphere, seasonal cap, and regolith. Data have been acquired by Mars Odyssey for a full martian year, enabling a complete picture of the CO_2 cycle to be constructed. An important test of the accuracy of the neutron data analysis procedure is whether the total mass of CO_2 in the seasonal caps determined from the neutron data is consistent with the mass determined by GCM calculations calibrated using Viking pressure data. In this abstract, we will compare results of the analysis of neutron data to a calculation by the Ames Research Center Mars GCM carried out by NMSU. We will show that spatial deconvolution of the neutron data is needed in order to accurately analyze the recession of the southern seasonal cap.

Data analysis: The leakage flux of neutrons from Mars depends on a number of parameters, including the concentration of absorbers such as (N_2 and Ar) in the atmosphere, the atmospheric column abundance, the column abundance of CO_2 ice on the surface, and the composition and stratigraphy of the underlying regolith to depths <200 g/cm^2. Epithermal neutrons have the advantage of being relatively insensitive to

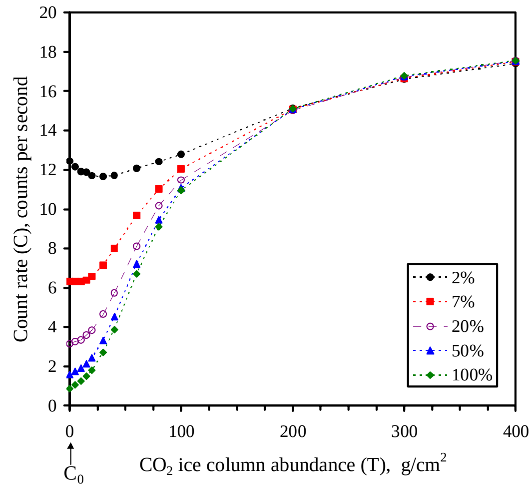

Fig. 1. Modeled epithermal count rate as a function of CO_2 ice column abundance for surfaces with different WEH abundances (see legend).

each of the aforementioned parameters except for CO_2 ice column abundance and the abundance and stratigraphy of water equivalent hydrogen (WEH) within the surface. Fig. 1 shows that for surfaces with WEH concentration greater than about 7%, epithermal neutrons provide a unique mapping between CO_2 ice column abundance and count rate. Based on modeling, we found that the epithermal count rate (C) can be accurately predicted given the column abundance of CO_2 ice (T) and the count rate (C_0) observed during summer when seasonal frost is not present: $C = f(T, C_0)$. This relationship can be inverted to determine T from observations of C and C_0.

In order to test the accuracy of our analysis method, we simulated zonally averaged epithermal neutron count rates for the southern high latitudes as a function of time. CO_2 column abundances calculated by the Ames GCM were used in the simulation along with a realistic model of the underlying regolith [6]. The simulation included a detailed model of the neutron exosphere and an accurate treatment of the spatial response of the spectrometer. The results of the analysis are shown in Fig. 2 for L_S=90° during the advance of the seasonal frost, and L_S=220° during the recession.

The apparent blurring of the spatial distribution of CO_2 ice determined from the simulated epithermal data is caused by the broad spatial response of the spectrometer. The error introduced by the spatial response is larger during the recession when gradient of the CO_2 column abundance with latitude is highest. Because low latitude zones cover larger areas than high latitude zones of equal angle, the erroneous placement of ice at low latitudes results in biased estimates of the total amount of CO_2 in the seasonal cap.

Spatial deconvolution: In order to correct for this source of bias, we deconvolved (removed the spatial blurring from) the zonal epithermal counting data measured by Mars Odyssey prior to applying the inversion algorithm to determine column abundance. A variant of Van Cittert's iterative algorithm [7] was used, in which the solution was determined for each iteration (k) by $D^k = D^{k-1} + \lambda\left(C - D^{k-1} \otimes R\right)$, where D was the deconvolved count rate, λ was a relaxation parameter, and R was the epithermal spatial response function, which was determined by modeling. The symbol $\otimes$ is the convolution operator. The spatial deconvolution algorithm was applied to zonal data binned on 2.5° latitude intervals for time intervals of roughly 7.5° L_S spanning a martian year. A deconvolved zonal profile for L_S=236.2° is compared, for example, with the raw epithermal counting data along with the epithermal spatial response function in Fig. 3.

The same algorithm used to invert the raw epithermal counting data was applied to determine column abundances from the deconvolved data. A comparison of the mass of CO_2 in the seasonal cap from -60°N to the south pole determined using the raw epithermal data, the deconvolved data, and the GCM calculation is shown in Fig. 4.

Conclusions: Fig. 4 shows that the inversion of raw zonal epithermal count rates to determine CO_2 column abundance causes a bias in the mass of CO_2 in the seasonal cap during the recession relative to the GCM results. Application of the spatial deconvolution algorithm reduces this source of bias by placing more mass closer to the pole. Consequently, the deconvolution algorithm produces results that are more consistent with Viking lander pressure observations. The algorithm does not significantly change results during the advance, for which the ice is distributed more uniformly over a wider range of latitudes. The correction for spatial blurring presented here is needed to analyze local asymmetric features in the southern hemisphere such as the residual cap and the "cryptic region," which appears opposite the cap during the recession. Results of the analysis of these regions based on two dimensional deconvolution of the epithermal counting data will be presented.

References: [1] Hourdin F., et al. (1995), *JGR*, *100(E3)*, 5501-23. [2] Haberle R. M., et al. (1999) *JGR*, *104(E4)*, 8957–74. [3] Kieffer H. H., et al. (2000) *JGR*, *105(E4)*, 9643-52. [4] Kieffer H. H. and Titus T. N. (2001) *Icarus*, *154(1)*, 162-80. [5] Titus T. N., et al. (2001) *JGR*, *106(E10)*, 23181-96. [6] Prettyman T. H., et al. (2004) *JGR*, *109(E5)*, E05001. [7] Jansson P. A. (1970), *J. Opt. Soc. Am.*, *60*, 184-91.

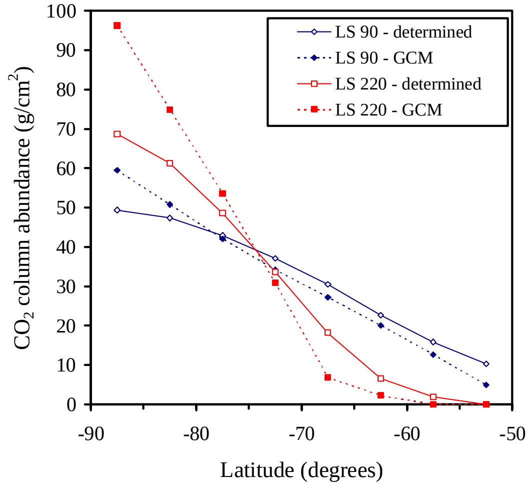

Fig. 2. CO_2 column abundances determined from simulated epithermal counting data compared to GCM column abundances used in the simulation.

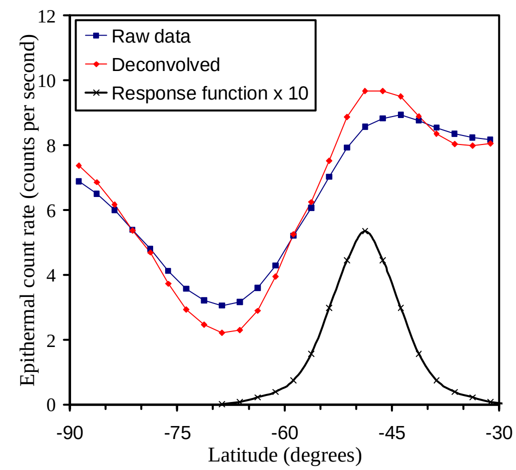

Fig. 3. Zonal epithermal count rates for L_S=236.2° (see text for details).

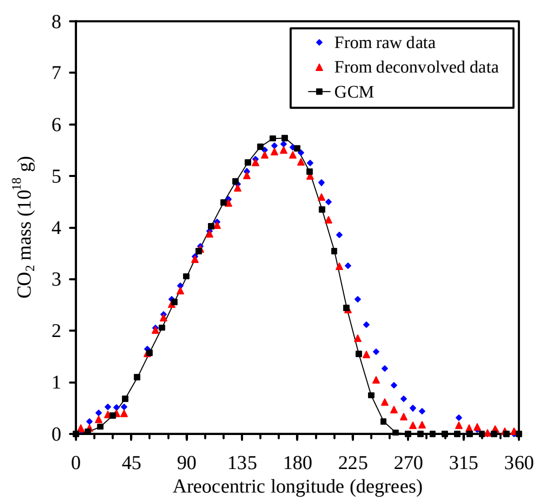

Fig. 4. Mass of CO_2 in the southern seasonal cap, from -60°N to the south pole (see text for details).