CHARACTERIZATION OF MARS' POLAR CAPS OVER 8 MARTIAN YEARS: NEW AND EXTENDED ANALYSIS OF MARS ODYSSEY NEUTRON SPECTROMETER DATA

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Introduction: The polar caps on Mars are dynamic regions that affect the global Martian climate through the condensation each Fall/Winter of ∼25% of the atmosphere as CO_2 frost. Insolation in the Spring causes the nothern seasonal CO_2 polar cap to recess completely, leaving behind a water-ice perennial cap, while in the south a small perennial CO_2-ice cap remains throughout the southern Summer. One method of observing the seasonal cap extent, growth and recession rates, and the overall CO_2 column-integrated mass, is using neutron spectroscopy from orbiting spacecraft. Galactic cosmic rays (GCRs) bombard the surface of Mars producing spallation neutrons, which through scattering and nuclear excitation in the top meter of the Marian surface lead to neutrons and gamma-rays that escape and can be detected.

The Mars Odyssey Neutron Spectrometer (MONS) [1] has been in polar orbit around Mars since early 2002, measuring the neutron leakage signal from GCR bombardment on the Martian surface. Through these measurements, one can infer the water content and layering on the surface [2, 3] and characterize the seasonal CO_2 polar caps [4]. The most recent processing and analysis of MONS data covered February 2002 – July 2009, corresponding to nearly 4-Mars Years of data [5]. With Mars Odyssey still in operation, there are now 8 full Mars Years of data available to study seasonal variations in the Martian polar caps. However, to fully utilize the MONS dataset, a new analysis code to process the raw data had to be developed.

Details of the new processing code and preliminary results will be presented.

MONS Instrument: The MONS instrument, shown schematically in Fig. 1, consists of a $11 \times 11 \times 10$ cm^3 boron-loaded plastic scintillator segmented into four optically isolated prisms that provide neutron spectral information in three distinct energy bands – thermal, epithermal, and fast. Thermal and epithermal neutrons are detected through the neutron capture reaction ^{10}B(n,α)^{7}Li*, while fast neutrons (E>0.7 MeV) are detected through the coincidence of a fast scatter followed by a thermal capture within 25.6 μs. The nadir-facing scintillator prism (P1) is covered by a cadmium sheet and therefore mainly sensitive to epithermal neutrons above the Cadmium cutoff (E>0.4 eV to E<0.7 MeV). The Doppler filter technique is used to measure thermal neutrons; Prism 2 (P2) faces the direction of the spacecraft velocity while Prism 4 (P4) faces opposite. P2 records thermal and epithermal neutrons, while P4 records only epithermal neutrons that can "catch up" to the spacecraft velocity of 3.4 km/s, corresponding to an energy cutoff of 0.019 eV. The thermal neutron counting rate comes from a subtraction of P2-P4. The last prism (P3) faces upward from Mars and is mostly sensitive to background.

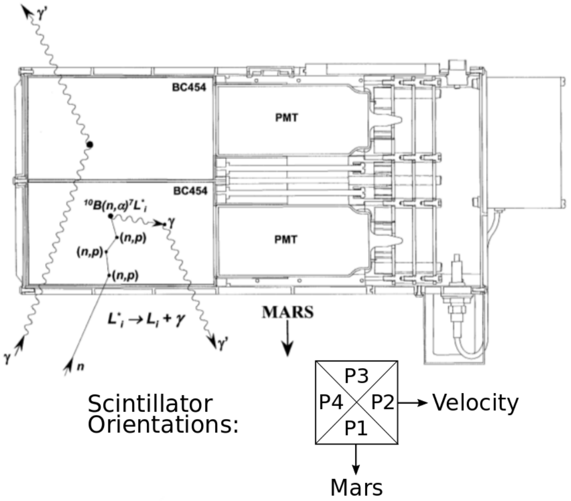

Figure 1: Schematic of the Mars Odyssey Neutron Spectrometer (MONS). Adapted from [5].

New Data Processing: A new data processing effort was undertaken to convert the raw binary MONS data, located in the Planetary Data System, to processed counting rates with appropriately labeled ephemeris data. At this time, only Category 1 data (thermal and epithermal) were processed. The MONS raw data is registered every 19.75 seconds (approximately 1° latitude at the equator) and includes several scalar counters (GCR, deadtime) and 64-channel ADC Category 1 histograms for each Prism. Some ephemeris data is packaged with the MONS data, including a UTC time stamp, a unique clock identifier, sub-satellite latitude and longitude, and satellite position and velocity information.

Data reduction to remove bad data largely followed the steps outlined in [5] and included removing data during solar energetic particle (SEP) events, applying stability cuts to counter data, and removing outliers and transients in spacecraft orbit parameters. Overall, 14.4% of the data were removed, with the majority cut from SEP events (12.3%). Following data reduction, several corrections were applied: The nonlinearity of the ADC his-

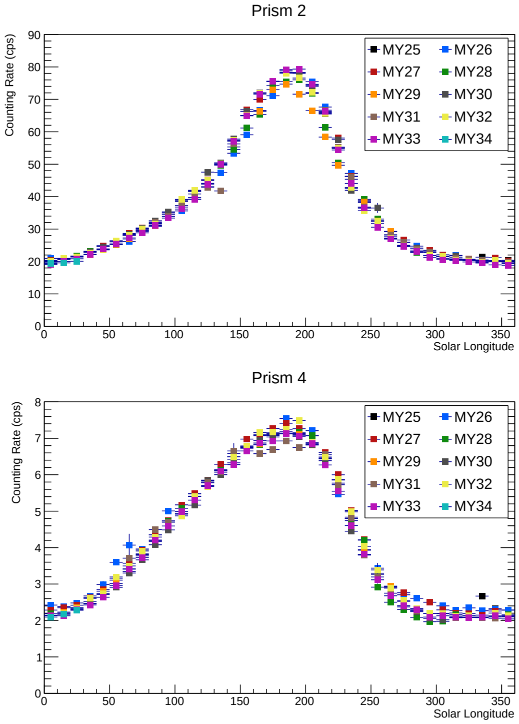

Figure 2: Prism 2 (top) and Prism 4 (bottom) counting rates at the south pole ($< -85°$) as a function of solar longitude for the newly processed MONS data.

tograms was corrected for, a gain correction was applied to remove shifts in the position of the ^{10}B capture peak due to high voltage changes, drifts, and degradation over the duration of the mission, variations in the altitude of the spacecraft and therefore MONS solid angle were corrected, and lastly ground track corrections were applied to determine appropriate latitude and longitude registration for each 19.75 s data entry. The gain-corrected prism histograms were fit with a Gaussian plus quadratic background term in log-log space, resulting in the total prism counts within each 19.75 s window. At this stage, corrections for variations in the GCR flux were applied. The resulting data contains counting rates for each prism and associated latitude, longitude, and time stamp.

Preliminary Results: An example of the counting rates compared for all 8 Mars Years (MY 26–33, plus some data in MY 25 and MY 34) is given in Fig. 2 for Prisms 2 and 4. Differences in the overall normalization of the counting rate in comparison to [5] are due to the reference GCR flux used in the GCR correction. The trends in this data are fit with a double Gaussian and compared year-to-year to look for inter-annual variability in the seasonal CO_2 frost deposition and sublimation processes. An example of such a fit is shown in Fig. 3 for all Prism 1 data.

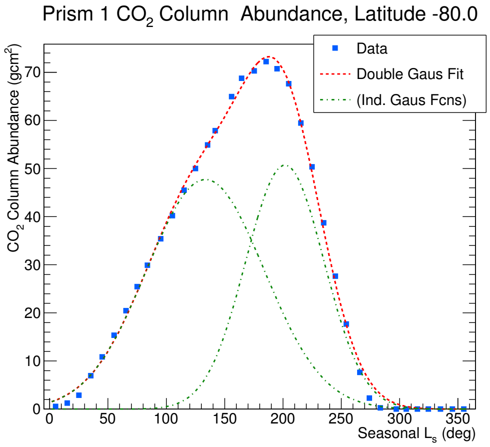

Figure 3: Example of double Gaussian fit to Prism 1 data as a function of L_s, showing the individual Gaussian functions (green) and the combined fit (red).

To convert counting rates to CO_2 frost thickness, radiation transport simulations must be performed. We developed a Geant4-based framework to simulate the production of the leakage neutrons from GCR interactions on the Martian surface and the transport of the neutron leakage signal from the atmosphere to the MONS spacecraft and translation into counting rates based on detector response models. To determine the overall normalization of the simulations, we used the Mars Climate Database global circulation model [6] to predict the maximum thickness of CO_2 in the Northern winter. The simulated neutron counting rate for this thickness in comparison to the measured counting rates at the peak of northern winter provide the simulation normalization constants.

Further work includes development of a pixon reconstruction code which will be applied to the MONS data to improve the spatial resolution of the data in the polar regions. This will allow for the comparison of local seasonal CO_2 cap properties and seasonal trends in column integrated mass to be compared with results from other observational techniques.

References: [1] W.V. Boynton *et al.* (2004), *Space Science Reviews, 110, 37-83.* [2] W.C. Feldman *et al.* (2002), *Science, 297, 75-78.* [3] A.V. Pathare *et al.* (2018), *Icarus, 301, 97-116.* [4] T.H. Prettyman *et al.* (2009), *JGR: Planets, 114.* [5] S. Maurice *et al.* (2011), *JGR, 116, E11008.* [6] F. Forget *et al.* (1999), *JGR: Planets, 104, E10.*

Acknowledgements This research was supported by the Laboratory Directed Research and Development program of Los Alamos National Laboratory under project number 20160672PRD3 and the NASA Mars Data Analysis Program under grant number 80HQTR170004.