DISTRIBUTION AND ABUNDANCE OF MARS' ATMOSPHERIC ARGON: A.L. Sprague[1], W.V. Boynton[1], K. E. Kerry[1], Steven Nelli[2], and Jim Murphy[2], R.C. Reedy[3], A.E. Metzger[4], D.M. Hunten[1], K. D. Janes[1] and M. K. Crombie[1]. [1]Lunar and Planetary Laboratory, 1629 E. University Blvd., University of Arizona, Tucson, AZ 85721-0092, [2]New Mexico State University, Las Cruces, NM, [3] Institute of Meteoritics, MSC03-2050, University of New Mexico, Albuquerque, NM, 87131-0001, [4]Jet Propulsion Laboratory, Pasadena, CA 91109.

Background: One and one half Mars years (MY 26 and 27) of atmospheric Argon measurements are described and studied in the context of understanding how Argon, a minor constituent of Mars atmosphere that does not condense at Mars temperatures, can be used to study martian circulation and dynamics. Argon data are from the 2001 Mars Odyssey Gamma Subsystem (GS) of the suite of three instruments comprising the Gamma Ray Spectrometer (GRS). A comprehensive data analysis including gamma-ray production and attenuation by the atmosphere is included. Of particular interest is the enhanced abundance of Ar over the observed Ar abundance at lower latitudes at south (up to a factor of 10) and north (up to a factor of 4) polar regions during winter. Calibration of the measurements to actual Ar abundance is possible because GS measurements cover the same latitude and season as measurements made by the gas chromatograph mass spectrometer (GCMS) on Viking Landers 1 and 2 (VL1 and VL2).

These new analyses augment those already published for the southern polar region [2] where estimates of the horizontal eddy mixing efficiencies (Fig. 1) in and out of the south polar region for the autumn and winter of MY 26 (April 2002 to March 2004) were made based on the enhanced mass of Ar observed over the south polar region and a comparison to an advection only model derived from the amount of CO_2 accumulated on the southern polar region (Fig. 2).

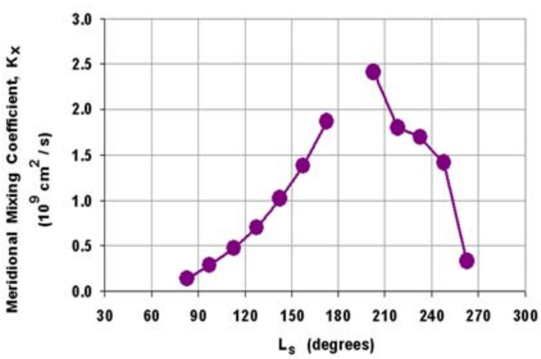

Fig. 1. *Meridional mixing coefficients calculated using the time rate of change of atmospheric Argon measured over the southern polar region and modeling [2].*

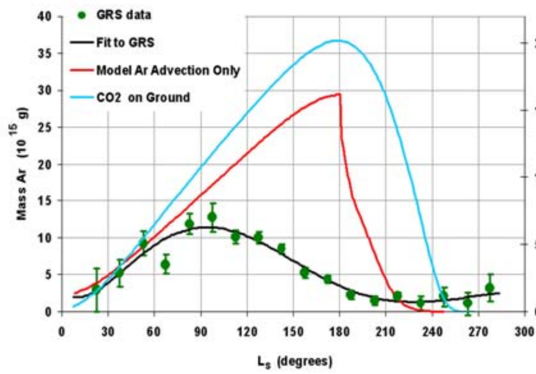

Fig. 2. *Argon measurements (data points with 1 σ) error bars are compared to a model of the amount of Argon expected over the south polar region computed from an advection only model and the estimated accumulation rate and amount of CO_2 frost on the south polar region (reproduced from [2]).*

Data and Analysis: Measurements are made by the Gamma Ray Spectrometer (GRS) on Mars Odyssey [1]. The Gamma Subsystem (GS) of the GRS integrates the energy from 1294 keV gamma rays resulting from the decay of atmospheric ^{41}Ar while in its mapping orbit about Mars. The 1294 keV gamma ray results from the decay of ^{41}Ar made by the capture of thermal neutrons by atmospheric ^{40}Ar. These measurements permit computation of Argon abundances for 15^O latitude zonal bins and 15^O seasonal increments in L_s from the start of the mapping orbit (April 2002) to the present.

The gamma ray flux at 1294 keV measured at the spacecraft depends upon the abundance and distribution of Ar and thermal neutrons. In addition there is a small component from spallation of ^{48}Ti in the GS container. By using measurements made in cruise and during the mapping orbit of several lines produced similarly we have estimated a background peak area for removal from the ^{41}Ar peak area used in the computation of Ar abundance. Variations in gamma-ray flux caused by changes in the thermal neutron flux produced in the CO_2 frost cap are removed by taking a simple ratio of Ar gamma flux at 1294 keV to that from the 1382 keV gamma-ray made by thermal neutron capture in the ^{48}Ti structure of the GRS. Because the Ti content in the GRS is constant, the ^{41}Ar flux can be normalized to that from ^{48}Ti as a way of eliminating the effects of seasonal changes in thermal neutron flux above the polar cap as the CO_2 frost thickens. Production of neutrons and attenuation of gamma rays within the column of atmosphere itself are also accounted for in our modeling by using a linear relationship found for the ratio of gamma rays to thermals at the top of the atmosphere. This relationship was determined by Monte Carlo modeling with MCNPX of surface and atmospheric models appropriate for conditions of Mars during the mapping orbit.

Comparison to Ar measurements of VL2: Both VL1 and VL2 made atmospheric measurements with the GCMS. Because soil studies were made prior to the atmospheric measurements during the VL1 experiment, those measurements were superceded by those of VL2 which made its atmospheric abundance and isotopic ratio measurements prior to soil studies [3]. VL2 measured ^{40}Ar to be 1.6% of the Martian atmosphere above the surface at 48^O N latitude at L_s of ~ 135^O, or mid-summer in the northern hemisphere. For our computations we convert this volume % to a mass mixing ratio (0.0145) because our atmospheric models express atmospheric column abundance in terms of g/cm^2.

Results: Mars atmospheric Ar abundances are not homogeneous for all latitudes and seasons. When GRS Ar/Ti ratios are compared to simulated Ar/Ti ratios expected for a homogeneously and globally distributed uniform Ar mass mixing ratio of 0.0145 significant enhancements are found at high latitudes and autumn and winter seasons. Evidence for changes on timescales of tens of days is also observed. .

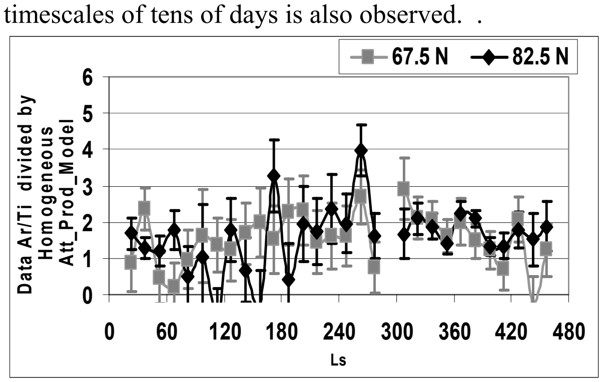

Fig. 3. *Enhancement of Mars atmospheric Ar over a model based on the mid-summerAr abundance at 48^ON latitude found by VL2 is shown as a function of L_s for 60^O to 90^O N latitude. The peak enhancement found for the north polar region was a factor of 4 greater than the VL2 value (Ls 252.5^O).*

For easy visual recognition and quantitative study, we computed the enhancement factor over nominal VL2 Ar mass mixing ratio for each zonal latitude bin and L_s (seasonal) increment Figure 3. displays the results for the two most northern latitude zonal bins from the beginning of the mapping orbit to Nov. 26, 2004 (here denoted L_s 472.5^O). To conveniently keep the continuance of time from one year to the next, and for plotting ease, the L_s scale (abscissa) is numbered from 0^O (the beginning of spring in the northern hemisphere) through 360^O (the beginning of the next spring in the northern hemisphere) and continuing with a scale of numbers larger than 360^O for the second Mars year. Fig. 4 shows the enhancement factors for 60^O S to 90^O S latitude.

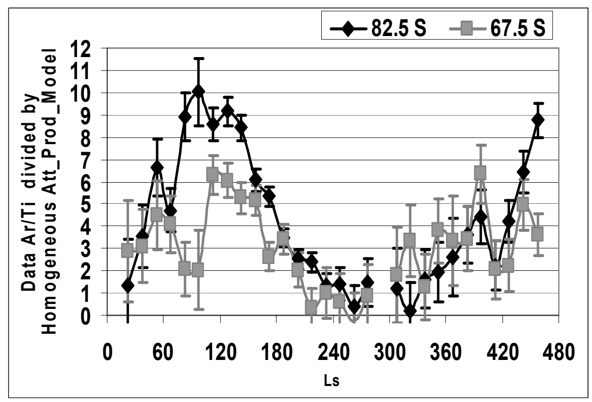

Fig. 4. *The enhancement factors for Mars atmospheric Ar measured by the GRS at 60^OS to 75^OS and 75^OS to 90^OS show even greater accumulation of Ar over the south polar region than in the north (Fig. 3).*

Modeling atmospheric circulation using parameters tuned to these measurements will help in predicting past and future climate at Mars. Observations by the Neutron Spectrometer (NS), another instrument of the GRS suite has measured the accumulation of all non-condensibles in Mars atmosphere [4][5]. Together these data sets provide valuable tracers for understanding circulation and redistribution of Mars atmosphere and minor constituents.

References: [1] Boynton, W.V. and 28 authors (2004) *Space Sci. Revs.,* [2] Sprague et al. *Science* 306, 1364, (2004). [3] Owen et al. *JGR 82, 28-4635 (1977)* [4] Feldman et al. *JGR. 108i*, 7-1.E9,5103,(2003) doi:101029/2003JE002101. [5] Prettyman et al. JGR 109, Eo5001(2004) doi:1029/2003JE002139.

Acknowledgements: We thank the entire GRS team for providing the data that were analyzed in this research. The GRS and the scientists are supported through NASA contract #1228726.