RETRIEVAL OF ATMOSPHERICALLY CORRECTED CRISM SPECTRA USING RADIATIVE TRANSFER MODELING. S. M. Wiseman[1], R. E. Arvidson[2], M. J. Wolff[3], R. V. Morris[4], F. P. Seelos[5], M. D. Smith[6], D. Humm[5], S. L. Murchie[5], J. F. Mustard[1], [1]Brown University (sandra_wiseman@brown.edu), [2]Washington University in St. Louis, [3]Space Science Institute, [4]NASA Johnson Space Center, [5]Applied Physics Laboratory, [6]NASA Goddard Space Flight Center.

Introduction: Atmospheric correction of visible/near infrared (VNIR) reflectance spectra of the Martian surface is necessary for interpretation of surface spectral properties because of the presence of scattering and absorbing gases and aerosols in the Martian atmosphere (Figure 1). The majority of published CRISM surface spectral analyses are qualitative and rely on an empirical correction for gas absorption that utilizes a scaled empirical transmission spectrum that is commonly referred to as the 'volcano scan' correction [1,2,3]. The volcano scan correction induces prominent artifacts [4] in regions of the spectrum with intense gas absorptions and does not correct for aerosol contributions or variable amounts of atmospheric water vapor. Given the importance of atmospheric correction to the interpretation of surface spectral properties, we developed a radiative transfer-based procedure for retrieving atmospherically corrected CRISM surface Lambert albedo spectra that uses Discrete Ordinate Radiative Transfer (DISORT) model results in conjunction with a constrained iterative retrieval algorithm. The iterative procedure overcomes some of the difficulties to atmospheric correction presented by the CRISM dataset, including small uncertainties in CRISM instrument response functions and noise in regions of strong CO_2 absorption.

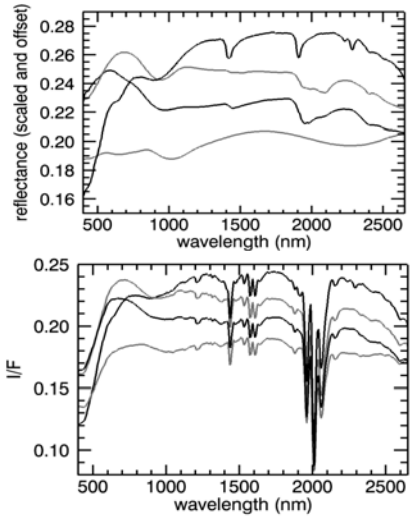

Figure 1. VNIR spectra (nontronite, szomolnokite, rozenite, pyroxene) without (upper) and with (lower) atmospheric contributions.

Dataset: The CRISM spectrometer [5] operates between 360 and 3960nm and is capable of acquiring targeted hyperspectral images at 20 m/pixel. CRISM I/F (radiance (I) at sensor divided by the solar irradiance (F) divided by π) data and ancillary data products are available through the PDS.

The CRISM spectrometer uses 2-D detector arrays and acquires data over 640 across track pixels for each channel (central wavelengths vary across columns, up to ± 7 nm). A relatively small (< 1.5 nm) temperature dependent wavelength shift also occurs [6].

DISORT Model: Discrete Ordinate Radiative Transfer (DISORT) [6] modeling was used to model the Martian atmosphere in which the atmosphere is treated as a plane-parallel medium in which individual layers are homogenous but interlayer properties can be varied. We utilized 'front-end' routines optimized for study of the Martian atmosphere, DISORT_multi [7].

Modeled I/F spectra were calculated that would be observed at the top of the atmosphere (e.g., similar to CRISM) for user defined viewing geometry (*i*, *e*, and *g*) and surface Lambert albedo. Dust aerosol single scattering albedos for 1.5 μm particles and wavelength dependent phase functions defined in [8] were used.

Atmospheric temperature profiles relevant to atmospheric conditions at the latitude, longitude, and Ls of a CRISM observation of interest were derived from spatially binned MGS Thermal Emission Spectrometer (TES) observations of Mars acquired between 1998 and 2000 [9].

Constrained Iterative Method: We developed a constrained iterative retrieval procedure for application to regions of strong gas absorption that leverages the observation that small uncertainties in measured and/or modeled I/F result in large artifacts in retrieved Lambert albedo surface spectra and that spectra of geologically plausible surface materials are smooth at the 10s of nm scale. Mismatches between measured and modeled I/F can result from uncertainty or noise in measured CRISM I/F, imprecise instrument response functions used to convolve modeled I/F to CRISM spectral resolution, and/or inaccurate model inputs. Detailed knowledge of the CRISM instrument response function is important to properly model regions of strong gas absorption because the shape of gas features measured by CRISM is a convolution of very narrow gas

absorptions, or lines, and the CRISM instrument response function (Figure 2).

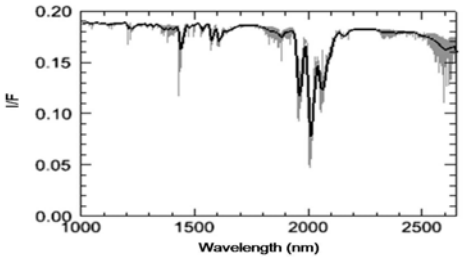

Figure 2. Gray line: DISORT generated I/F spectrum with I/F values calculated every 0.4 nm. Black line: High spectral resolution gray spectrum resampled to CRISM spectral resolution (~12nm FWHM).

The iterative procedure calculates a surface Lambert albedo spectrum that minimizes the error between the measured CRISM I/F spectrum and the modeled I/F spectrum by iteratively adjusting the Lambert albedo spectrum used to calculate the modeled I/F spectrum. The iteratively fit Lambert albedo spectrum is constrained to be relatively smooth at the 3 CRISM channel scale (~21 nm) in order to minimize gas band artifacts while minimally impacting real spectral features. The quality of Lambert albedo spectra can be accessed via analysis of residuals in the I/F domain (Figure 3e).

In order to confirm that our simple constrained iterative procedure produces reasonable results, we tested the method on a set of simulated CRISM spectra. Spectra were chosen that exhibit a variety of spectral features that overlap with the CO_2 triplet (Figure 3a). Simulated CRISM I/F spectra were generated using a reverse lookup table approach in which input surface Lambert albedo spectra were converted to I/F that would be measured at the top of the Martian atmosphere. Noise was added and I/F spectra were convolved using slightly different bandpasses between the lookup table and the modeled I/F spectrum to simulate uncertainties when modeling CRISM data.

As anticipated, the Lambert albedo spectra retrieved using the constrained iterative approach exhibit fewer high frequency artifacts in the wavelength region of the CO_2 triplet than the spectra retrieved using just the lookup table approach (Figure 3b-c). The modeled I/F spectra match closely with the input I/F spectra. Residuals between input and modeled I/F are relatively small and appear random (Figure 3e). The Lambert albedo spectra retrieved for the arbitrary linear spectrum (Figure 3a-b, column 1) lack the bowl shaped artifact induced by the volcano scan correction (Figure 3f, column 1). Because both gases and aerosols are modeled, the long frequency shape of the retrieved Lambert albedo spectrum overlaps with the actual Lambert albedo spectrum, unlike volcano scan corrected spectra (Figure 3f).

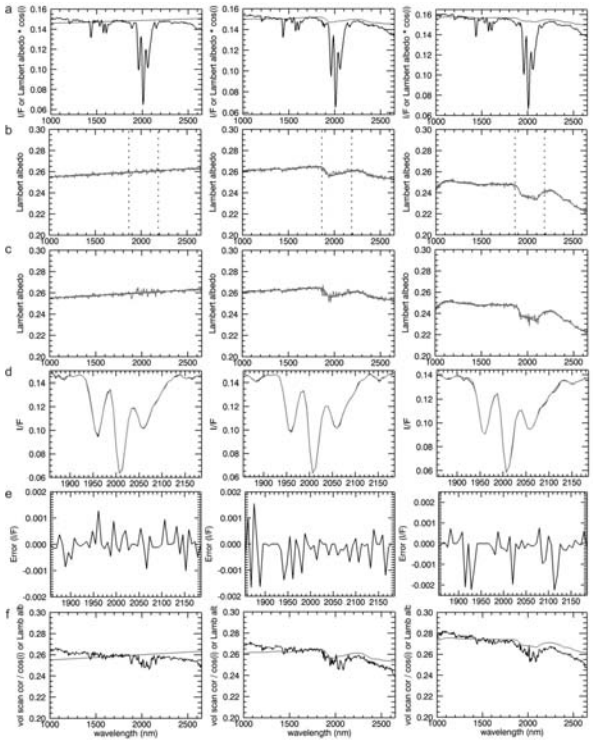

Figure 3. Columns 1-3 show modeled results related to surfaces represented by an arbitrary linear spectrum, a polyhydrated sulfate spectrum, and a monohydrated sulfate spectrum, respectively. a) Lambert albedo spectra (black) and corresponding I/F spectra (gray) with noise added. b) Lambert albedo spectra retrieved using the constrained iterative procedure (black) over plotted on the actual Lambert albedo spectrum (gray) for comparison. The iterative technique was applied only to wavelengths within the dashed vertical lines in these examples. c) Lambert albedo spectra retrieved using the lookup table approach (black) over plotted on the actual Lambert albedo spectrum (gray) for comparison. d) Modeled I/F spectrum (gray) generated for wavelengths in the CO_2 triplet using the constrained iterative method over plotted on the input I/F spectrum (black). e) Error between the actual I/F spectrum and the modeled I/F spectrum shown in part (d). f) Simulated volcano scan corrected spectrum (black) over plotted on the actual Lambert albedo spectrum (gray) for comparison.

References: [1] J.-P. Bibring et al. (1989), *Nature*, 341, [2] Y. Langevin et al. (2005) *Science*, 307, [3] P. McGuire et al. (2009) *Planet. Spac. Sci.*, 57 [4] S. M. Wiseman, 2010, LPSC 41, #2461, [5] Murchie S. M. et al. (2007) *JGR*, 112, [6] Smith M. D. et al. (2009) *JGR*, 114. [7] Stamnes K. et al. (1998) *Appl. Opt.*, 27. [8] Wolff M. J. et al. (2009) *JGR*, 114, [9] M. D. Smith (2004) *Icarus*, 167.