

be fully incorporated later into the Lambert albedo retrieval system for CRISM multispectral data. Enhancements to the spatial resolution of the surface temperature data will include as follows: 1) an empirical approach to estimate the albedos between 3.8 and 3.92 μm based upon an observed correlation between albedos at 2.5 μm and albedos at 3.8–3.92 μm ¹¹ (purple lines in Fig. 1), and 2) a physical approach to estimate the surface temperature for each pixel based upon using the ADR-TE¹² LUT which was computed from a physical thermal model of the martian surface (red and green lines in Fig. 1). The empirical thermal-correction approach [23] will allow the thermal emission to be estimated at 3.8–3.92 μm , which will facilitate the estimation of temperature for each CRISM spatial pixel, allowing thermal correction for shorter thermal wavelengths, i.e., between 3.0 and 3.8 μm . The physical thermal-correction approach [24], [28] has input parameters that include surface albedo, solar incidence angle, surface slope, surface slope azimuth, altitude, and aerosol optical depths. Both of these more advanced thermal-correction techniques will allow better identification of H₂O and CO₂ ices on the surface in minor quantities, for example.

III. DISORT-BASED RADIATIVE TRANSFER RETRIEVAL OF LAMBERT ALBEDOS

In order to estimate the Lambert albedo for a given CRISM spectel,¹³ we employ a LUT named the “Ancillary Data Record—Atmospheric Correction,” or ADR AC for short. This ADR-AC LUT was computed by using a DISORT-based¹⁴ radiative-transfer forward-model software package [54] to model how I/F will change as a function of 6–8 input parameters (see Fig. 2). For a given spectel at a given wavelength λ , the subroutine for accessing the ADR-AC LUT is called multiple times in order to “invert” the LUT and to estimate the Lambert albedo from I/F . These multiple different values of Lambert albedo are then used for populating the values of the grid-point corners of a multidimensional cube. Multidimensional interpolation is then employed to estimate the value of Lambert albedo for interior points that are not grid points. In this way, Lambert albedos can be calculated for all spectels in a multispectral map tile or image.

The use of these ADR-AC LUTs allows a substantial acceleration in the retrieval of the Lambert albedos than would be allowed by direct forward calls to DISORT, reducing the computation time per MSP¹⁵ TRDR strip (2700 rows, 60 columns, 72 spectral channels)¹⁶ on a fast Linux or

¹¹Therefore, this empirical approach will need to wait until the CRISM data calibration is improved for wavelengths $> 3.7 \mu\text{m}$.

¹²Ancillary data record—thermal emission.

¹³We use the definition of spectel as the contents of a spectral channel for a particular pixel. For example, I/F spectel #1 is the value of I/F for spectral channel #1; spectral channel #1 is the channel of the L detector of CRISM which is at $\lambda = 3.92 \mu\text{m}$.

¹⁴DIScrete-Ordinates-method Radiative Transfer.

¹⁵Multispectral.

¹⁶This image size roughly corresponds to 548 km \times 13 km of surface area on Mars. The image width depends greatly on range to target. For the northern plains, the image width is about 13 km, but the MSP strips in the southern hemisphere are much closer to 10-km wide.

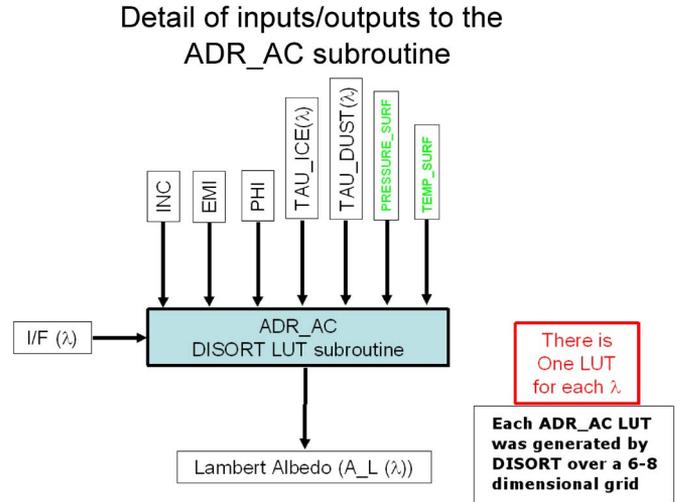


Fig. 2. Detail of how the ADR AC is queried. This LUT is shown in context in Fig. 1. The ADR AC consists of $I/F(\lambda)$ values computed with forward calls for each grid point at several input values of the photometric angles (INC, EMI, PHI), several input values of the aerosol opacities ($\tau_{\text{dust}}(\lambda)$, $\tau_{\text{ice}}(\lambda)$), and several input values of Lambert albedo $A_L(\lambda)$. The surface pressure and surface temperature inputs are only included as input values to the grid forward-call computation for particular wavelength bands. For use in the CRISM multispectral retrieval of Lambert albedos, the ADR-AC LUT is used in the inverse direction together with multidimensional interpolation, in order to use the $I/F(\lambda)$ value to estimate the Lambert albedo value $A_L(\lambda)$.

MSWindows workstation from about 3000 h¹⁷ to about 1 h. This is much slower than the calibration software that converts from the raw data to I/F . It is also much slower than a simpler alternative Lambert albedo retrieval software that corrects the I/F data for photometric effects by dividing by $\cos(\text{INC})$ and for atmospheric effects using the “Volcano-Scan” technique, without correcting for aerosol effects (for a discussion of some aspects of the Volcano-Scan technique, see Section V-B of this paper as well as the works of Langevin *et al.* [25] and Murchie *et al.* [32]). Nonetheless, the benefits of quantitative accuracy for this technique, which is based upon radiative transfer and utilizes a physical model for the correction of effects due to aerosols and for absorption in the CO₂ gas bands, can be worth the extra computation time when compared to the Volcano-Scan technique.

After the application of the atmospheric correction software to each TRDR, the TRDRs are mosaicked into map tiles (Fig. 1). At the equator, the tiles are on the order of 300 km \times 300 km in size, corresponding to $5^\circ \times 5^\circ$ in latitude and longitude. There will sometimes be more than 30 TRDR strips per map tile. With 1964 map tiles to span the planet and with about 61% CRISM coverage of the planet¹⁸ to date (as of March 1, 2008, with complete coverage expected), we need to make this Lambert albedo retrieval software as fast as possible, without sacrificing accuracy. Table I shows details on the grid parameters, whereas Table II provides detail of the atmospheric layers

¹⁷By using 1 s for computing the Lambert albedo via forward calls for each spectel, this gives $(2700 * 60 * 72 \text{ spectels}) * (1 \text{ s/spectel}) / (3600 \text{ s/h}) = 3240 \text{ h}$.

¹⁸The coverage depends on latitude: For the equatorial region, the coverage is 47%; the poles are nearly complete. Furthermore, this coverage does not account for periods of low data quality, most notably during periods of high dust optical depths in the atmosphere.