TITAN SURFACE-ATMOSPHERIC SEPARATION MODELS FOR CASSINI VIMS: SPHERICAL-SHELL RADIATIVE TRANSFER MODELS.

K. M. Pitman[1] , B. J. Buratti[1], R. A. West[1], P. J. Dumont[1], K. H. Baines[1], M. J. Wolff[2], R. H. Brown[3] and the Cassini VIMS Team, [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena, CA 91109 USA <Karly.M.Pitman@jpl.nasa.gov>, [2]Space Science Institute, 4750 Walnut Street Suite 205, Boulder, CO 80301 USA, [3]Lunar and Planetary Lab, University of Arizona, 1629 E. University Blvd., Tucson, AZ USA

Introduction: The Cassini orbiter's Visual and Infrared Mapping Spectrometer (VIMS, [1]) measures the combined surface-atmospheric spectral signature of Saturn's largest moon, Titan, over two detector ranges: visible and near-IR wavelengths (λ = 0.350540-1.045980, 0.884210-5.1125 μm). At these wavelengths, Titan's methane-rich atmosphere is highly absorbing and light scatters strongly off of aerosol particles in Titan's stratified haze. Therefore, most analyses of Titan's surface that require use of the VIMS dataset (e.g., photoclinometry, geologic interpretation, spectral identification of surface materials, photometry) are impeded until a method to separate the atmospheric from the surface spectral signature of Titan is fully developed. Whereas theoretical studies have generally focused on coupling chemistry, microphysics, and dynamics to explain the current state of Titan's atmosphere [2], development of rigorous radiative transfer approaches to approximate the complex properties of Titan's atmosphere and separate those effects from VIMS I/F spectra to derive information on Titan's surface is under active investigation [3-6]. In previous works [7-9], we presented a plane-parallel radiative transfer (RT) correction method with core components extended from Mars surface-atmospheric separation models that can be used for modeling and removing Titan's atmosphere for VIMS observations which are far from the limb. While a large fraction of the VIMS database can be modeled with plane-parallel methods, as observations approach closer to the limb, plane-parallel RT codes are no longer advisable for Titan [10]. Monte Carlo codes have been tested for other applications on Titan [11], and spherical-shell radiative transfer codes have been developed by Cassini engineers to model radiation flow through Titan's atmosphere and are already being run on supercomputing resources at JPL for modeling Titan's atmospheric haze in Cassini ISS and UVIS data [12]. In this work, we explore the utility of JPL's spherical-shell radiative transfer codes for VIMS data that cover a wide range of latitude and longitude coordinates and incorporate recently released Titan atmospheric structure data from the Huygens DISR team [13-14].

Spherical-Shell RT Model: We begin by constructing a 52-layer Titan atmosphere (after ISS/UVIS specifications) from altitude z = 0 to 530 km above Titan's surface. Layers thicknesses are allowed to vary with altitude; the thickest layers are located closest to the surface. To incorporate vertical variation in aerosol properties as given in [13], we break this atmosphere into 3 regimes for single-scattering albedo and optical depth ($z < 30$ km, $30 \leq z \leq 80$ km, and $z > 80$ km) and 2 regimes for single-scattering phase function (z above and below 80 km). In [13], single-scattering phase function values for z above and below 80 km are supplied for 14 DISR wavelengths from 355 nm to 5166 nm, and single-scattering albedo values in the 3 altitude regimes are provided for 15 DISR wavelengths from 430 nm to 1583 nm. Optical depth power laws from [13] also vary depending on wavelength. Therefore, we have focused our preliminary modeling on 3 VIMS wavelengths that best overlap with the DISR wavelengths (934 nm, 1078 nm, 1288 nm). At the time of abstract submission, we are combining the methane coefficients from [14] with our aerosol profiles. In most radiative transfer models, the surface layer is usually assumed to be Lambertian (diffusely reflecting) for simplicity. For Titan (an icy body), this assumption is incorrect; therefore, we also include a lunar-Lambert law option as a subroutine in the spherical-shell RT codes. Using these assumptions and inputs, a model of $I/\pi F$ can be generated for a user's choice of wavelength and rendered as an image of the entire "moon" (Fig. 1). 1024 x 1024 pixel images are shown in color and grayscale here; such images can be scaled down to sizes that better correspond to VIMS images (e.g., 64 x 64 pixel images) and masked to show certain latitudes only.

Fitting Model to VIMS Data: We have determined that the best course of action for fitting actual VIMS data to this type of model is to generate a few models and rotate the VIMS data into the frame of these models. The main required inputs that must be extracted from VIMS hyperspectral cubes are the dimensions of the VIMS image, the mid-time at the time the image was acquired, the number of kilometers per pixel, and the subspacecraft latitude and longitude coordinates. The standard VIMS geometric backplane information must be supplied in separate files; XDR format is preferred to conserve on data storage space. The following quantities are also required as a function of time: right ascension (RA) and declination (Dec) of each pixel, RA/Dec of Titan's center, range (i.e., spacecraft distance from center), and the heliocentric RA/Dec of Titan. Whereas ISS and UVIS stored RA and Dec in their geometry information, RA and Dec are not supplied in the VIMS geometry backplanes. However, it is possible to forensically reconstruct the time per pixel from the VIMS data using modified algorithms from VIMS mosaicking software and then invoke SPICE kernels to get the pointing information. Our trial VIMS Titan dataset shown at LPSC will be from the T9 Cassini flyby, corresponding to selected ISS limb-pointing observations.

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References: [1] Brown R. H. et al. (2004) *Space Sci. Rev.*, *115*, 111–168. [2] Rannou P. et al. (2004) *Icarus*, *170*, 443–462. [3] Griffith C. A. et al. (2005) *Science*, *310*, 474-477. [4] Hansen G. B. et al. (2006) American Geophysical Union Fall Meeting 2006, Abstract # P13A-015. [5] Pitman K. M. et al. (2007) *LPSC XXXVIII*, no. 1338, 1164. [6] McCord T. B. et al. (2007) *Icarus*, submitted. [7] Pitman K. M. et al. (2007) American Astronomical Society, DPS meeting #39, #56.03. [8] Pitman K. M. et al. (2007) Workshop on Planetary Atmospheres, held November 6-7, 2007 in Greenbelt, Maryland. LPI Contribution No. 1376, 96-97. [9] Pitman K. M. et al. (2007) American Geophysical Union, Fall Meeting 2007, abstract #P23B-1357. [10] Gibbard S. G. et al. (2004) *Icarus*, *169*, 429–439. [11] Lebonnois S. & Toublanc S. (1999) *J. Geophys. Res.,104*, 22025–22034. [12] West R. A. et al. (2006) American Astronomical Society, DPS meeting # 38, Abstract # 22.02; *BAAS*, *38*, p. 519. [13] Tomasko M. G. et al. (2007a) "A Model of Titan's Aerosols Based on Measurements Made Inside the Atmosphere," *Planet. Space Sci.*, in press. [14] Tomasko M. G. et al. (2007b) "Measurements of Methane Absorption by the Descent Imager/Spectral Radiometer (DISR) During its Descent through Titan's Atmosphere," *Planet. Space Sci.*, in press.

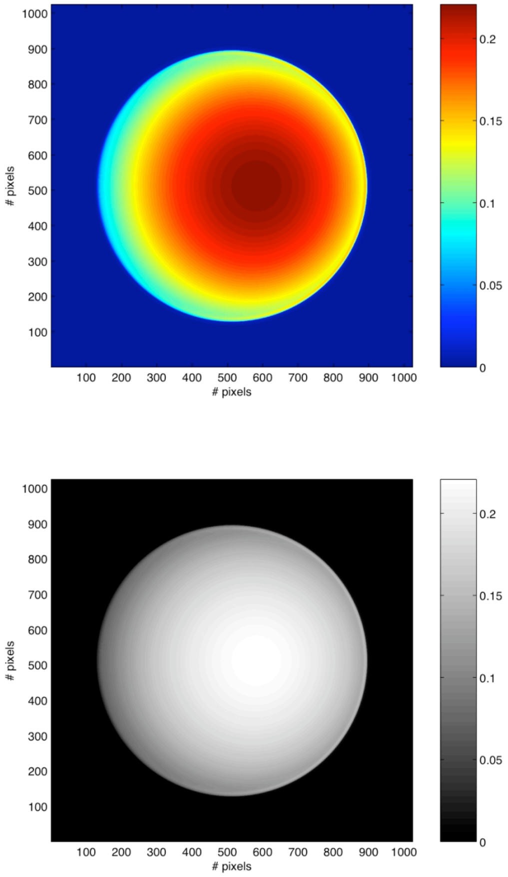

Fig. 1: Preliminary "proof of concept" 2D spherical-shell radiative transfer model of $\lambda = 1.078$ μm (vertically varying aerosol properties only, Lambertian surface assumed). x- and y-axes are # of pixels; sidebar = I/πF. 1024 x 1024 pixel image shown.