PROBING TITAN'S SURFACE VIA ATMOSPHERIC RADIATIVE TRANSFER CORRECTION METHODS. K. M. Pitman[1], B. J. Buratti[1], K. H. Baines[1], R. A. West[1], and M. J. Wolff[2]. [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

Introduction: Knowledge of Titan's surface geology has been obtained primarily from Cassini radar and imaging data, supported by local surface geology observations from the Huygens probe. As evidenced by the success of the T20 flyby, Cassini's VIMS instrument (Visible and Infrared Mapping Spectrometer) has strong potential for returning global coverage, high-resolution information on Titan's surface geology. VIMS spectra of Titan's surface, however, are strongly affected by contributions from Titan's robust atmosphere [1]; light is scattered by atmospheric haze and absorbed by methane. As opacity changes in the spectrum between the 1 and 2 micron atmospheric methane windows (Fig. 1), it is apparent that the atmosphere is sufficiently transparent to support comparative analyses of surface roughness; while the haze does clear enough to view the surface, its scattering effects are not negligible. To get VIMS surface spectral quality on par with that returned by the Huygens probe, it is clear that atmospheric haze within these infrared windows to Titan's surface must be corrected for. Whereas theoretical studies have focused on coupling chemistry, microphysics, and dynamics to explain the current state of Titan's atmosphere [2], development of rigorous RT approaches to separate the complex properties of Titan's atmosphere from visible/infrared surface information is just beginning [3]. In this work, we review and explore methods to probe Titan's surface by removing optically translucent atmospheric haze and detached layers of high altitude haze in selected methane windows from Cassini VIMS infrared spectra via radiative transfer codes. Specifically, we investigate the utility of adapting surface-atmospheric separation techniques from the Mars program to Titan.

Radiative Transfer Approaches: For Titan, radiative transfer (RT) approaches have been traditionally used to model atmospheric light scattering as part of global climate models used to predict dynamics and feedback mechanisms in Titan's atmosphere. These RT approaches typically involve Mie theory, or the assumption of spherical aerosol particles which scatter light, coupled to a two-stream RT solution for vertically inhomogeneous atmospheres, in which the "two-streams" are upward and downward fluxes of radiation [4, 5]. It has been recognized since the Voyager and Pioneer missions that Titan's haze particles are nonspherical in nature, and thus, recent updates to the RT approaches used as subsets of Titan global climate models have concentrated on developing aggregate particle models to represent Titan's aerosols [6, 7]. In the Mars Global Surveyor Thermal Emission Spectrometer (MGS-TES) dataset, however, there exists a methodology to separate atmospheric from surface contributions. [8] and [9] describe a rigorous RT approach used to model the Mars atmospheric haze as multiple vertical layers with varying optical depths and nonspherical, axisymmetric particle shapes. While the Mars atmosphere is less robust than Titan's, with these techniques, [8] and [9] were able to successfully separate and characterize the relative contributions of ice and dust hazes. For multiple scattering, their RT approach utilized a discrete-ordinates n-stream (i.e., multiple numbers of upwelling and downwelling radiance fluxes) code. In general atmospheric radiative transfer applications, 16 or more streams are typically necessary for accurate determinations of intensities, particularly given the scattering properties of geometrically complex particles such as Titan's aerosols [10]. Using 64-streams [8] over the 2- or recent 8-streams solutions used for modeling Titan's atmosphere (cf. [11]) could constitute a significant model improvement.

Methodology: VIMS spectral profiles plot total signal received I/F as a function of incident light wavelength, where I is radiance and πF is solar irradiance. Total signal I/F includes both surface and atmospheric contributions. For Titan, the VIMS team currently applies an *ad hoc* atmospheric radiative transfer correction by inserting observationally derived optical depths τ (cf., [12]) into Beer's law, which effectively assumes that I is proportional to $e^{-\tau}$. Huygens/DISR spectral measurements to constrain the single scattering albedos and phase function of Titan's aerosols suggest different physical properties for aerosols in three distinct altitude regimes (> 80 km, 80 > x > 30 km, < 30 km above Titan's surface) [13]. Given the complexity of Titan's atmosphere, the *ad hoc* Beer's law application is formally incorrect. We intend to synthesize the nonspherical and fractal aerosol shapes single scattering solutions developed as part of Titan's global climate models with the multiple scattering 64-streams RT solution employed by [8] and [9] which have proved successful for separating atmospheric and surface components for the Mars program data. In particular, we will focus on the 2.01-micron band, which has the lowest opacity for methane but requires substantive haze modeling, and the 5-micron window, which has lesser haze.

In this work, we will describe the first steps in modifying the Mars codes for application to Titan, beginning with adjusting for the necessary model inputs. Primary inputs for the model are, among other quantities, absorption properties of the methane atmosphere, composition and particle size of the aerosols. Recently, improvements have been published for correlated k absorption coefficients of methane in the near infrared [14]; these have been tested in MODTRAN5 models with application to VIMS observations [15] and, with slight modification, incorporated into fractal aggregate aerosol models of Huygens/DISR ULIS (Upward-Looking Infrared Spectrometer) I/F spectra [13]. Relevant molecular species for Titan's aerosols include CH_4, inert nitrogen, organics, and trace amounts of other materials; for aerosol composition, we will adopt optical constant values adapted from laboratory measurements of Titan tholins [cf., 16]. Particle sizes for the Titan atmospheric aerosols will be tested for ranges on the order of 0.1-0.6 up to 10 microns in radius, as guided by [13]. Progress toward achieving the final model will be reported in stages. When the radiative transfer correction methods are complete and we are able to correctly examine how Titan's surface scatters radiation, we will ultimately be able to understand its texture (liquid vs. solid regions and overall roughness) and interpret its fundamental morphological features.

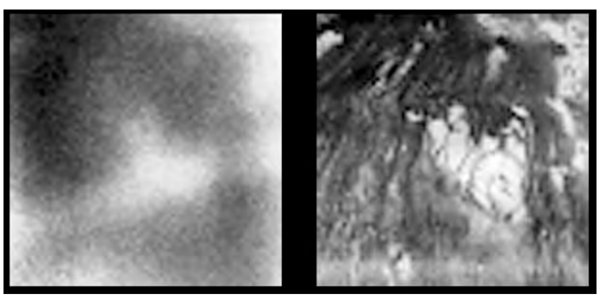

Fig. 1: Cassini VIMS instrument close approach (1200 km altitude) views of Titan's surface taken at 1 micron (left panel) and 2 micron (right panel) infrared wavelengths (10/2004 – NASA/JPL/University of Arizona). Atmospheric opacity clears enough between 1 and 2 microns to provide strong potential to view complex landforms on Titan's surface if proper atmospheric haze correction can be applied.

Acknowledgments: This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract to the National Aeronautics and Space Administration. The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency. KMP is supported by an appointment to the NASA Postdoctoral Program, administered by Oak Ridge Associated Universities.

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