DECONVOLUTION OF CASSINI VIMS TITAN CUBES INTO ATMOSPHERIC SPECTRAL SCATTERING, SURFACE TOPOGRAPHIC, AND SURFACE SPECTROSCOPIC COMPONENTS.

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Introduction: The Cassini Visual Infrared Mapping Spectrometer (VIMS) collects spectral imaging cubes at 352 wavelengths from 0.3 to 5.2 µm [1]. The VIMS data discussed here were acquired during the Ta flyby of Titan on October 26, 2004. This study focuses on analysis of the 256 near-infrared spectra (0.88 to 5.2 µm) of a particularly high resolution VIMS cube (CM1477496141_1 also released as Cassini PIA06982). The cube covers an unusual bright feature located near 8° N, 144° W and has a resolution of ~2.5 km/pixel (fig 1.). Sotin and colleagues [2] suggest this may be a cryovolcanic center. They also note an exceedingly important aspect of this cube: surface topography is quite apparent as E-W linear ridges and valleys, most clearly in the darker regions south of the bright spiral feature in fig. 1.

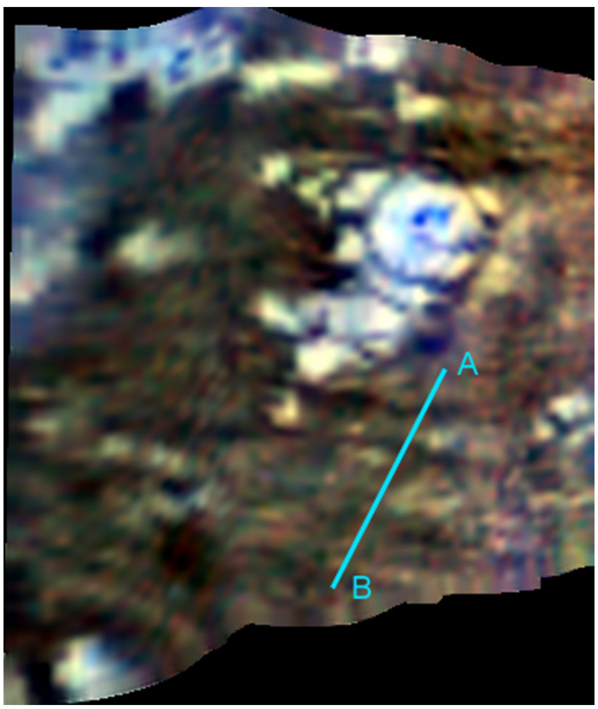

Figure 1. Color composite (RGB averages in the 2.74 µm, 2.03 µm, 1.29 µm windows, see fig. 3). The modeled diffuse component was subtracted and images filtered to enhance fine detail. The area shown is approximately 150 km across.

In fig. 1, the A-B transect is aligned with the direction to the Sun. The illumination is roughly from the lower left; i ~34°. We interpret the E-W linear features of order 50 km in length and 10 km in separation, to be ridges and valleys. The interpretation of topography rests on 1) highest contrast being in the cross-sun direction and 2) characteristic bilateral symmetry with bright-dark oscillations in the down-sun direction. We use the topographic modulation to estimate the atmospheric scattering that dilutes the contrast in the topography differently in each of the spectral windows [2]. This diffuse component includes radiation scattered directly to the observer and that scattered downward and reflected by the surface. Note that the because part of the diffuse component is a function of albedo, the simple solution developed here is strictly valid only for the darker uniform region of ridges and valleys. We assume: 1) the photometric function is roughly independent of wavelength and 2) scattering at 5.0 µm is negligible. Scattering dilutes topographic modulation. If there were no scattering haze, the topographic modulation observed at 5.0 µm would be the same for all wavelengths. We solve for the diffuse component vs wavelength that when subtracted yields uniform topographic modulation. The three shortest-wavelength solutions are very noisy (fig. 2, bottom) as the topographic modulation is only 4-to-6% of the signal.

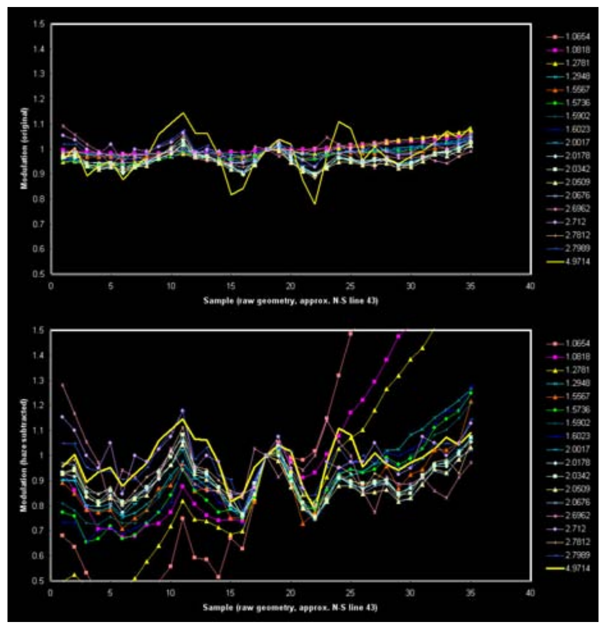

Figure 2. Use of topographic modulation along A-B profile to estimate diffuse components. Top: Original brightness profiles for each wavelength (in µm); 5µm profile shown in heavy yellow. Bottom: Brightness profiles after estimation/subtraction of diffuse component at each wavelength.

Figure 3 shows the derived wavelength-dependent diffuse component; solutions are valid only near the centers of the atmospheric windows where sufficient surface modulation is detectable. As stated the scattering was assumed negligible at 5 µm. The estimated diffuse component increases toward shorter wavelength constituting about 96%, 94%, 86%, 74%, 51% of the total signal (I/F) in the 0.93 µm, 1.07 µm, 1.29 µm, 1.59 µm, and 2.03 µm windows, respectively. Having approximated the diffuse component, the topographic modulation can then used to roughly estimate slopes and, by integration, the topographic relief across the ridge and valley complex (a Lambertian surface was assumed here) [4,5].

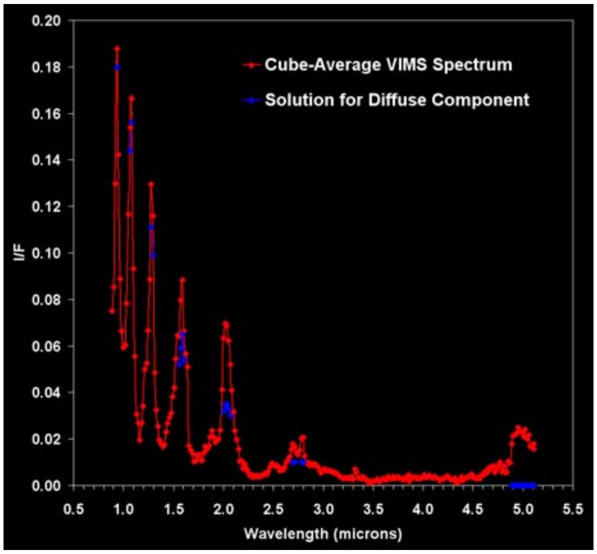

Figure 3. Estimated diffuse component from the topographic normalization procedure depicted in fig. 2, compared to total signal, I/F, where I is irradiance and πF is solar flux.

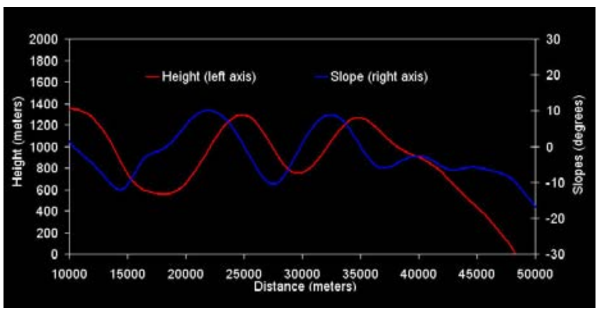

Figure 4. Estimation of slope and integration of topographic relief along profile A-B. Vertical exaggeration is about 10:1.

These methods are referred to as "shape from shading" or photoclinometry. In general they are only reliable under two conditions: a) additive components that dilute topography are estimated, as has been done here and b) the albedo of area of integration is uniform or its variations have been modeled. The 50-km-long ridges and valleys crossed by profile A-B have relief of the order of 600-800 m and maximum slopes of ~10°. These results are probably accurate to only

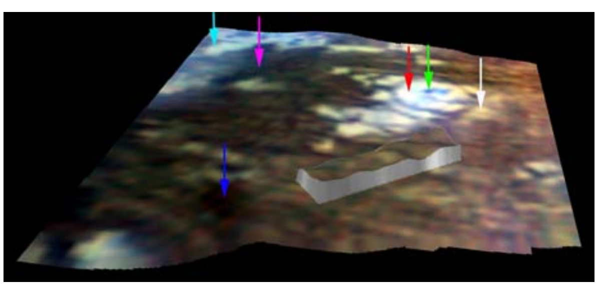

Figure 5. Two dimensional photoclinometric solution for a small region of ridges and valleys containing profile A-B. The vertical exaggeration is 5:1. Arrows denote locations of spectra shown in fig. 6.

within a factor of ~2. Because of strong variations in color and albedo across most of the scence in this VIMS cube, photoclinometry or shape from shading cannot be reliably used to estimate topography in other parts. Figure 5 shows the full 2-D integral solution using Kirk's methods [4] for a small region in which stated necessary conditions are met.

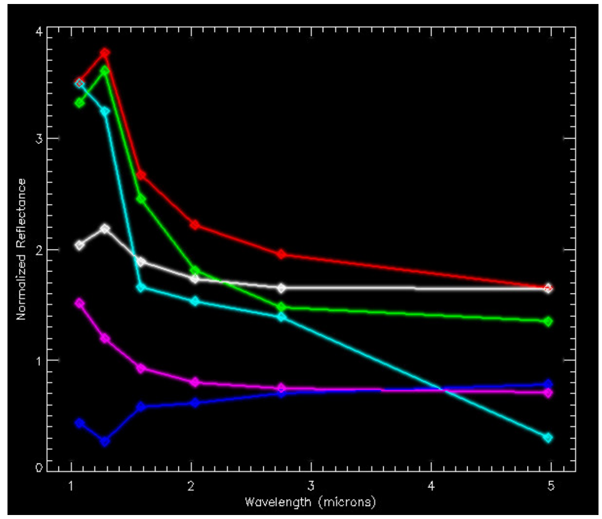

Figure 6. Spectral reflectance of units normalized to average brown plains unit (location of each spectrum in fig. 5).

Having accounted for the additive diffuse component we can now also estimate the unscattered component that directly illuminates and is reflected by the surface to reveal variations in spectral reflectance. The relative reflection spectra of fig. 6 were normalized to that of the overall average brown plains unit in figs. 1 and 5 (characteristic of the area of the A-B profile). The units within the bright spiral feature display strong spectral variations 1-2 µm that could be on the surface or low-lying featues in the atmosphere. These spectra are very preliminary and we offer two caveats: 1) the solution for the diffuse component was derived for the darker plains unit (A-B) and does not strictly apply to the brighter units and 2) low-lying clouds, ground fog, eruptive plumes are not discriminable in the modeling here from surface color and albedo variations. Radiative transfer models can be used to understand and to extend the models of the diffuse component to brighter units. Also repeat coverage at different incidence/emission angles would be invaluable to extending this type of analysis. <u>But it is now clear that the ability of VIMS to provide high resolution images of surface topography is crucial to understanding the Titan's geology</u>.

References:

[1] Brown R. H. et al. (2003) *Icarus* ***164*** *2*, [2] Sotin C. et al. *submitted to Nature*, [3] Gaddis L. R. et al. (1996) *IEEE Trans. Geoscience and Remote Sensing* ***34*** *1,* [4] Soderblom L. et al. (2002) *LPS XXXIII*, Abstract #1254, [5] Kirk R.L. (1984) Ph.D. Thesis, Caltech; Kirk R.L. et al. (2003) online http://astrogeology.usgs.gov/Projects/ISPRS/Meetings/Houston 2003/abstracts/Kirk_isprs_mar03.pdf.