CONSIDERATIONS ON THE TITAN TOPOGRAPHY BASED ON THE CASSINI-VIMS MEASUREMENTS IN THE NIR RANGE. M. Moriconi[1,2], A. Adriani[1], A. Gardini[1], A. Coradini[1], G. Filacchione[3], R. Orosei[3], E. D'Aversa[1], F. Capaccioni[3], P. Cerroni[3], G. Bellucci[1], R. H. Brown[4], K. H. Baines[5], J. P. Bibring[6], B. J. Buratti[5], R. N. Clark[7], M. Combes[8], D. P. Cruikshank[9], P. Drossart[8], V. Formisano[1], R. Jaumann[10], Y. Langevin[6], D. L. Matson[5], T. B.McCord[11], V. Mennella[12], R. M. Nelson[5], P. D. Nicholson[13], B. Sicardy[8], C. Sotin[14], [1]INAF-IFSI, via del Fosso del Cavaliere, 100, Rome, Italy, alberto.adriani@ifsi.rm.cnr.it, [2]ISAC-CNR, via del Fosso del Cavaliere, 100, Rome, Italy, [3]INAF-IASF, via del Fosso del Cavaliere, 100, 00133, Rome, Italy, [4]Lunar and Planetary Lab, University of Arizona, Tucson, AZ, USA, [5]Jet Propulsion Laboratory, Pasadena, CA, USA, [6]Institut d'Astrophisique Spatiale, Orsay, France, [7]US Geological Survey, Denver, CO, USA, [8]Observatoire de Paris, Meudon, France, [9]NASA Ames Research Center, Moffett Field, CA, USA, [10]Institute for Planetary Exploration, DLR, Berlin, Germany, [11]HIGP/SOEST, University of Hawaii, 22 Fiddler's Rd. Winthrop, WA, USA, [12]INAF-OAC, Napoli, Italy, [13]Cornell University, Astronomy Department, Ithaca, NY, USA, [14]Laboratorie de Planetologie et Geodynamique, Universitè de Nantes, Nantes, France.

Introduction: A technique to estimate surface topography of a celestial object with an atmosphere has been set by using: (a) a radiative transfer code to simulate the radiation field in any point of the atmosphere and in a range of suitable boundary conditions, (b) models to simulate microphysical characteristics of the atmosphere surrounding the object and (c) an algorithm for the atmospheric corrections of hyperspectral images in the visible-NIR domain [1] to apply to VIMS images. This technique bases on the band ratio method for in-band and out-bands reflectances, on a small wavelength range to assure the surface reflectivity invariance. We applied this technique to the Titan image V1490952268_2, taken by VIMS during the March 31st, 2005 flyby, calibrated in the IR range 884.21 – 5108.00 nm. This image has a surface pixel resolution of about 52 x 104 km which is low due to the Cassini spacecraft distance at the moment of the measurement (208000 km). The spectral resolution was about 16 nm.

Methodology: The VIMS bands selected for the band ratio method are centered at 2034.24 nm (n.167) and at 2100.34 nm (n.171), out-band and in-band respectively. The choice of wavelengths in this part of the spectral range minimizes (even if not totally eliminates) the weight of the scattering respect to the absorption optical depth (the scattering get more and more important moving to shorter wavelengths) and makes negligible thermal contributions. The proximity of the two bands assures surface reflectivity invariance for each pixel. Then we can express the reflectance ratio, for a non scattering, plane parallel and horizontally stratified atmosphere as:

$$\frac{R_{171}}{R_{167}} = \exp(-\tau_{171} * \frac{\mu_0 + \mu}{\mu_0 \mu}) \qquad (1)$$

where μ_0 is the cosine of the sun zenith angle, μ is the cosine of the observation angle, τ_{171} is the absorption optical depth of the air column for the in-band reflectance and R_{171} and R_{167} are the in-band and out-band measured reflectances respectively.

As the absorber profile (CH_4 for Titan) is derived from the literature [2], reviewed on the basis of the last Huygens mission [3], we can retrieve the elevation of the reflecting surface by solving the equation (1) knowing all the layer optical depths and applying the k-correlated method to any air column growing from the TOA to the surface. However, the Titan atmosphere is so loaded of aerosol that an algorithm to correct the blurring effects of the haze on the VIMS hyperspectral images was necessary also in the IR range.

We chose an analytical formulation similar to that of the 6S code [4] to separate the atmospheric parameters from the ground parameters in the formulation of upwelling radiance reaching the sensor entrance pupil:

$$L_{SAT}(\lambda) = L_{ATM}(\lambda) + t_{dir}(\lambda) * L^{p}{}_{0}(\lambda) + t_{dif}(\lambda) * L^{ENV}{}_{0}(\lambda) \quad (2)$$

where $L_{SAT}(\lambda)$ is the measured radiance, $L_{ATM}(\lambda)$ models the atmospheric contribution, $t_{dir}(\lambda)* L^{p}{}_{0}(\lambda)$ models the direct transmission by the upwelling radiance of the pixel at the ground level and $t_{dif}(\lambda)* L^{ENV}{}_{0}(\lambda)$ models the environment effects. The terms on the right of the equation (2) has been calculated by using the package libRadtran [5] with the radiative solver DISORT2 applied to the microphysical model of the Titan atmosphere by Rannou [6,7] and using the absorption k-coefficient database by Baines [8].

Equation (2), together with some libRadtran suitable applications, permits us to calculate a first approximation of the surface reflectivity by the relationships:

$$L^{p}{}_{0}(\lambda) = \frac{E_0(\lambda) * \rho(\lambda)}{\pi * (1 - \rho_G(\lambda) * S(\lambda))}$$

$$L^{ENV}{}_{0}(\lambda) = \frac{E_0(\lambda) * \rho_F(\lambda)}{\pi * (1 - \rho_G(\lambda) * S(\lambda))}$$

where $E_0(\lambda)$ is the downwelling irradiance at the surface, ρ_G is an average albedo taking into account the adjacency effects due to the ground reflections, ρ_F is the average albedo due to the scattering towards the sensor of the light reflected by the environment and *S(λ)* is the atmospheric spherical albedo.

Results: Assuming, as first guess, that the adjacency and the environmental surface albedo, ρ_G and ρ_F respectively, to be equal to ρ, the first estimate of the pixel albedo has been derived consequently. From equation (2), we can then derive the upwelling radiance contributions for the two VIMS bands 167 and 171, purged by the atmospheric and environmental terms. In figure 1 the original and the purged band ratio images are reported. We solved the equation (1) applied to purged band ratio for each pixel of the y-profile relative to sample 25 of the image in figure 1. Our vertical grid for the layer optical depth calculation has been fixed to 0.5 km (10% of the smaller horizontal dimension), then we cannot retrieve any surface elevations below this level. Really, though in figure 1 differences in surface elevations across the sample 25 would be probable, the first calculation results don't reveal any difference of depth among pixels. Considering the possibility of an elevation difference profile within 0.5 km, we solved again the equation (1) for the purged band ratio magnified by a factor 2.2, to enhance a possible elevation difference profiles. The results of these two calculations are reported in Table 1. As the spatial

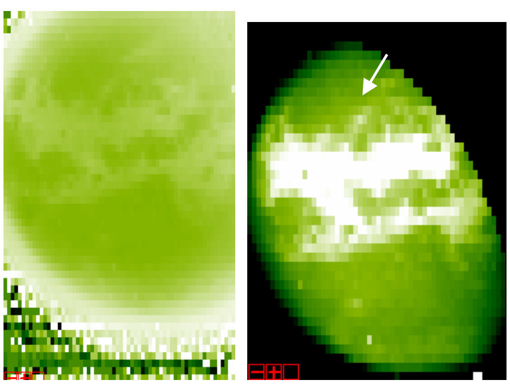

Figure 1: left panel: original band ratio; right panel: purged band ratio. Sample 25 is indicated by a white arrow.

resolution of the image is considerably low it can be stated that the averaged differences in altitude are contained within 0.5 km. On the other hand, the magnified band ratio (second and fifth columns of Table1) give elevation differences up to 5 km. We plan to apply this retrieving technique to different images with significantly higher spatial resolutions.

Table 1

line	Magnified band ratio	No magnified band ratio	line	Magnified band ratio	No magnified band ratio
3	0	0	21	5	0
4	0	0	22	2.5	0
5	0	0	23	0	0
6	0	0	24	0	0
7	0	0	25	0	0
8	0	0	26	0	0
9	0	0	27	0	0
10	0	0	28	0	0
11	0	0	29	0	0
12	0	0	30	0	0
13	0	0	31	0	0
14	0	0	32	0	0
15	0.5	0	33	0	0
16	2	0	34	0	0
17	0.5	0	35	0	0
18	1.5	0	36	0	0
19	0	0	37	0	0
20	2.5	0			

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