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Simultaneous mapping of Titan's surface albedo and aerosol opacity from Cassini/VIMS massive inversion

Luca Maltagliati (1), Sébastien Rodriguez (1), Christophe Sotin (2,3), Thomas Cornet (4), Pascal Rannou (5), Stéphane LeMouelic (2), Anezina Solomonidou (3), Athena Coustenis (6) and Robert Brown (7).
(1) Laboratoire AIM, CEA/Saclay, Gif/Yvette, France. (2) LPG, Nantes, France. (3) JPL, Pasadena, CA, USA. (4) ESAC/ESA, Villanueva de la Cañada, Madrid, Spain. (5) GSMA, Reims, France. (6) LESIA, Meudon, France. (7) University of Arizona, Tucson, US.

Abstract

Titan still lacks information on the cartography of its surface albedo, due to the complications linked to the treatment of the atmospheric contributions on surface observations. We present in this paper the results of our massive inversion method that we developed to treat Cassini/VIMS hyperspectral data of Titan. Our minimization procedure is based on look-up tables (LUTs) we create from a state-of-the-art radiative transfer (RT) model [1]. This allows us to decrease the computational time by a factor of several thousands with respect to the standard radiative transfer applications. We will present the improvements on the RT modeling thanks to the acquisition of new information on Titan's aerosol properties and our results for the simultaneous mapping of Titan's surface albedo and aerosol abundance in some regions of interest.

1. Introduction

Knowledge of surface albedo of a body is essential to constrain its composition and, consequently, its geological history. This is particularly true for infrared observations, where a wealth of absorption bands of ices and minerals are located. However, albedo maps of Titan still do not exist. This lack of information, even more striking considering that the Cassini mission has been observing Titan since 2004, is due to the thick atmosphere of the Saturn's satellite. First of all, a series of methane absorption bands make the infrared spectrum opaque at most near-IR wavelengths. Titan's surface is thus only visible around 7 narrow spectral atmospheric windows centered at 0.93, 1.08, 1.27, 1.59, 2.01, 2.7-2.8 and 5 μm (Fig. 1). Moreover, the thick aerosol haze affects the whole spectral range, transparency windows included, in a complex way through absorption and scattering processes.

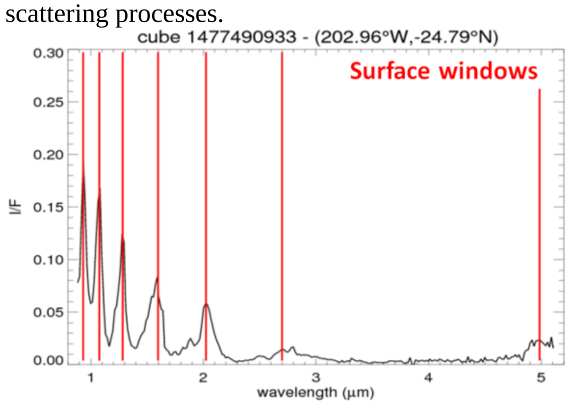

Figure 1: near-IR spectrum of Titan in nadir geometry from a pixel of a VIMS datacube.

The most rigorous way to treat the atmospheric effects on Titan in order to get the surface albedo is through radiative transfer models. They have, however, two main drawbacks. First, they are very demanding in computational time and thus inadequate to treat big datasets. Then, a precise description of aerosol properties is needed. Yet, up to recently we had direct measurements of Titan's aerosol properties only at the moment of the Huygens descent, thus linked to a specific place and time [2], when we know that the aerosol distribution depends on latitude and season [3][4].
In the next two Sections we describe how our method takes into consideration both these issues.

2. Massive inversion of VIMS data

The mapping spectrometer VIMS onboard Cassini is the best-suited instrument to extract maps of Titan's surface albedo with good spatial resolution. In the ~100 flybys of Cassini over Titan, VIMS has recorded ~ 40,000 hyperspectral images of the moon, gathering several millions of spectra. Considering that the classical radiative transfer solvers, as the one employed by our reference RT model [1], process the minimization of a single spectrum on a timescale of the order of ~1-10 minutes, their employment to study the VIMS dataset is unreasonable.

Our approach is to apply our RT model not directly to the inversion, but to create lookup tables (LUTs) for different values of the model's input parameters: the three angles that define the geometry (incidence, emergence, azimuth), and the two physical characteristics (haze total opacity and surface albedo). We performed a thorough analysis in the parameters' space to obtain the optimized LUTs grid for the five parameters. At the end, 8 values are used for incidence and emergence, 6 for the azimuth, 4 for the haze opacity and 3 for the surface albedo, for a total of 4608 spectra in a LUT. Once a LUT is ready, it is fed to ad ad-hoc minimization routine that creates simultaneous maps of haze opacity and surface albedo. For a 64×64 datacube, these maps are obtained in less than a minute, a huge gain with respect to the ~10 days needed with classical minimization procedures with full RT (Fig. 2).

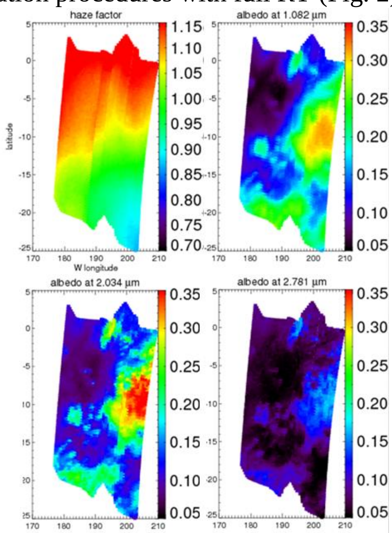

Figure 2: maps of haze opacity (top left) and albedo in different surface windows for a VIMS cube over the Huygens landing site.

3. Improving the aerosols with the T88 "EPF" observation

As mentioned above, in order to consider correctly the atmospheric contribution on the observations, the characteristics of the aerosols must be known as precisely as possible. On Titan the lack of direct observations is a significant drawback and the first results of our massive inversion showed a clear dependence of the output aerosol opacity with the geometry of the observation. In order to improve the aerosol description, we analyzed an "Emergence-Phase Function'' (or EPF) recently acquired by VIMS during the T88 flyby. It consists of 25 cubes targeting the same area at a constant incidence angle of ~51^{o} and with varying emergence and phase angles (from 0 to 60^{o}). We then changed the trend of the integrated aerosol extinction with wavelength and the aerosol phase function, previously fixed in our model [1] by the results of [2]. With this study we have constrained a new description of aerosols' extinction and phase function that improve significantly the reproduction of the EPF data by our model.

4. Conclusions

We apply our massive inversion method, with improved information from aerosol properties, to several datacubes of VIMS. We will study in particular the Huygens landing site, useful also for method validation by comparing our results with Huygens itself, and some regions of interest as for example the vast region (-40°-+40° latitude, -20°-+40° longitude) covered by two flybys (T13/T17) in quick succession.

Acknowledgements

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