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Retrieval of Titan's haze and mist vertical profile and surface albedo at high latitude with a radiative transfer model

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Abstract

Titan, the largest satellite of Saturn, is surrounded by a very dense atmosphere. The pressure and temperatures allow liquid methane and ethane at the surface. Indeed, the Cassini/Huygens mission discovered lakes and seas in the polar regions. The Visual and Infrared Mapping Spectrometer (VIMS) from the Cassini spacecraft took hyperspectral images of Titan. Due to the strong absorption of the methane in the atmosphere, the surface can only be seen in 7 spectral windows centered at 0.93, 1.08, 1.27, 1.59, 2.01, 2.7-2.8 and 5 µm. In this work, we use a radiative transfer (RT) model to retrieve the haze vertical profile of Titan's north pole, and the surface albedo.

1. Introduction

Titan's atmosphere is composed of gases, clouds, and a thick layer of haze. Titan possesses a methane cycle. Like on Earth, there is rain, evaporation, and liquid at the surface. However, the haze surrounding Titan scatters most of the visible light, and the strong absorptions of methane block most of the reflected light on VIMS infrared spectral range. However the surface geology can be studied in some of VIMS spectral windows. Lakes and seas have been detected on Titan's polar regions by RADAR images. An uncertainty exists about their chemistry : the lakes are estimated to be a mixture of liquid CH_4, C_2H_6 and other minor species, with dissolved N_2 , and sedimented aerosols. Thermodynamic and experimental constraints have been established for the composition of Titan's lakes, but the ratio is still uncertain [3]. The landing site of the Huygens probe is located in the equator region of Titan. The Descent Imager/Spectral Radiometer (DISR) instrument onboard measured the haze extinction coefficient [1][5]. We can infer that the haze vertical profile is separated into two distinct layers. From the surface to the stratosphere, we have an indefinable mixture of aerosols and droplets of liquids that we call mist. From the stratosphere to the top of the atmosphere we have a haze made of aerosols. However, we don't have any indications at high latitude of the vertical and spectral profile of the aerosols extinction in the first hundred of km from the surface.

2. Objectives of the work

To study Titan's poles surface and lakes with a RT model, we need a valid haze vertical profile and optical properties. The only stratospheric data we have is at Huygens landing site near the equator. However, the haze's extinction profile may not be the same between the equator and the poles. We use a RT model to roughly retrieve the haze and mist extinction coefficients. Once they are obtained, the surface albedo can be retrieved as well. Once it's done, we can use the aerosols extinction profile in a RT model that takes into account the marine surface reflective properties to study the observed glints and constrain the existence of waves [4].

3. Radiative Transfer Model

The model uses the existing solver SHDOMPP developed by K. Evans [2] to solve the RT equations in a plane-parallel approximation. We use the HASI data for the CH_4 mixing ratio and temperature and pressure profile. CIRS data are used to reproduce the CO, HCN and C_2H_2 vertical profile. We use a correlated-k approximation to calculate the optical depth of the different gases. The spectral rays of the gases (HITRAN database) are used to calculate their absorption coefficients. We used a model of scattering by fractal aggregates to model the haze spectral properties (single scattering albedo and extinction cross-section) and we used Tomasko's phase functions [5], adapted according to reference [1] suggestions.

4. Method

We selected a VIMS cube with incident and emergent angles near 45° maximum at high latitude to be in adequacy with the plane-parallel approximation (fig. 1). The haze extinction profile $k_h(z)$ from the top of the atmosphere to the altitude of transition z_t is determined by the equation :

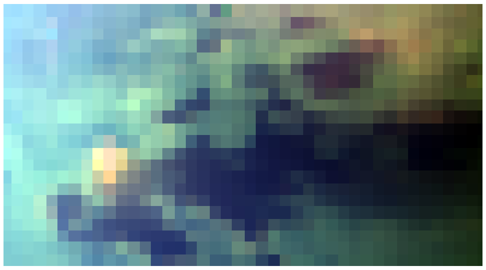

Figure 1: VIMS cube v1883865715

$$k(z) = e^{\frac{-z-z_t}{H}} \quad (1)$$

with z the altitude (km), z_t the transition altitude between the haze and the mist, and H is the scale height of the haze (km). The haze extinction is null after z_t. In our study, we consider the mist extinction profile $k_m(z)$ to be constant from z_t to the surface, and null beyond z_t. We normalize the profile in order to have a coefficient of reference with regard to Doose's extinction profile values. In the present state of our knowledge, we use the same spectral profile for the haze and the mist, among other things our investigations aim at improve this description

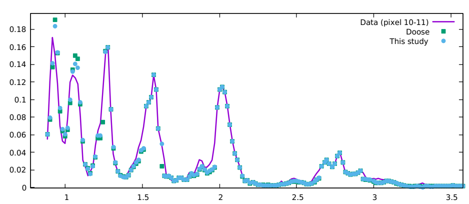

Figure 2: Comparison between the fit with Doose's normalized haze extinction profile (green squares)with z_t at 55 km, and the fit using equation 1 (blue dots), with a scale height H = 60 km, and z_t = 20 km

5. Results

In figure 2 we can see in blue dots an improvement compared to the fit in green squares, where we use the normalized haze extinction profile of Doose, that overestimate in fine the I/F in the first and second atmospheric windows. The resulting surface albedo is lower in consequences. Changing the spectral profile of the mist will improve the retrieval of the surface albedo.

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