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A radiative model for Titan's atmosphere in the IR

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Abstract

The aim of this work is the development of a model of Titan atmosphere between 1 and 5 micron, using data from Cassini-Huygens mission. The simulations will be useful to remove the atmospheric features from the measured spectrum, to study the surface. The radiative transfer model is performed with ARS (Atmosphere Radiation Spectrum), a a group of Fortran 77 routines, able to calculate absorption coefficients, radiance and other parameters about gas and aerosols at LTE (Local Thermal Equilibrium) [5] and considering multiple scattering in nadir geometry. Our study covers the IR spectral range but it would be extended also to the visible spectrum.

1. Introduction

1.1 Physical and chemical characteristics

With a mean density of 1.8 g/cm^3, Titan is likely formed by rocks and ice , like Dione and Enceladus but with an higher density for the gravitational compression probably due to a salty ocean present under the surface [7]. The pression and the temperature at the surface are 1500 hPa (1.5 times Earth pression)and 95 K, respectively.
The atmosphere is mainly composed by nitrogen but also by methane that is 5% at the surface and decreases to 2% in the upper layers. [9]
Methane plays an important role in atmosphere dynamics and structure, since photoionization forms different organic compounds. It was demonstrated by the Huygens probe that provided precious information about atmosphere dynamics and the interactions between surface and atmosphere.
Also complex hydrocarbons (ethane, acetylene), PAHs (benzene) and nitriles are present and form haze of reddish-brown organic compounds (tholin).
Hydrocarbons and compounds are formed by the photodissociation and ionization of molecular nitrogen and methane. They are carried by precipitation to the surface, so methane and ethane condense. [12]

1.2 VIMS and HASI instruments

In this work we compare the spectrum obtained by VIMS (Visible and Near-Infrared Mapping Spectrometer) with the simulated spectrum. VIMS is a spectrometer aboard the Cassini spacecraft, aimed at the study of Saturn system. It acquires images in 352 channels with a angular resolution of 0.25 x 0.25 mrad between 0.85 and 5.2 μm for the IR channel. Its spectral resolution is 16 nm [1].
HASI (Huygens Atmospheric Structure Instrument) was part of the probe Huygens a multi-sensor package designed to measure the physical properties of Titan's atmosphere. [3]

2. Proceedings and data

The ARS code uses the main equation of the radiative transfer to produce the synthetic spectrum. It takes into account also Mie scattering, valid when a particle is bigger than an incident wave, as for the haze layers in our case. We extracted the molecular information from the HITRAN 2012 and Sromovsky et al. 2012. [10,11] databases. [2]
Despite methane is considerably less than nitrogen, it characterizes the main features in the IR spectrum. All other molecules (N_2, HCN, C_2H_2, C_2H_4, C_2H_6, CO_2, CO) can be neglected for the aim of this work.
We use the temperature-pressure profiles taken from HASI (data on PDS nodes) and observation geometries of a specific observed spectrum as input for the simulations. . The surface albedo is difficult to interpret for the optically thick and complex atmosphere. Therefore, we used an approximated constant albedo and then we tried with Negrao's profile [8]. The atmosphere has been split in 101 layers, with a constant layering step of 10 Km. Moreover, we assumed constant all the calculated physical parameters in each single layer. Measured spectra used for our comparison are average over 7 point, taken by the different flybys of Cassini. [2]

2.1 Aerosols

Titan's aerosol spreads in a main haze under 300 km and in other separated layers at 520 km and at 1000 km. These particles have a fractal–aggregate and also spherical nature. The spectrum at different wavelength is strongly dependent by them. For the model we used the particle size distribution by Lavvas [6], that is unimodal in the upper atmosphere, then it become bimodal. We calculated the MIE scattering properties of assumed spherical particles using the refractive index data by Khare. [4] [2]

3. Results

We are producing the radiative transfer model of Titan atmosphere in the infrared range. At first we tested the compatibility of ARS with Titan atmosphere changing different parameters. During the testing we added other methan bands by Sromovsky improving the comparison with the measured spectrum. We introduced collision-induced absorption of the N_2 and CH_4 molecules. Lavvas distribution improved a lot the quality of our model. The synthetic spectrum is in good agreement with the measured one, but the fit must be still improved at certain wavelength. Our work will continue changing values of albedo in each wavelength and also using different measured spectra. [2]

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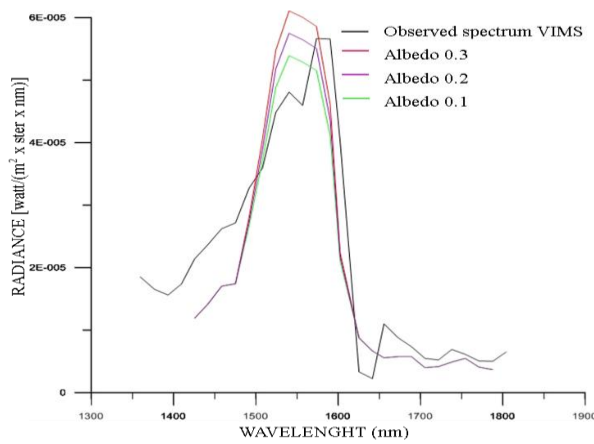

Figure 1: Simulated (only CH_4) and observed radiance spectrum of Titan at different albedo, range 1350-1800 nm.