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Characterization of the vertical composition of Titan atmosphere by Cassini/VIMS data

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Abstract

Limb measurements by Cassini/VIMS allow the characterization of the vertical structure of the Titan atmosphere. Spectra acquired pointing to the middle-low atmosphere are affected by strong scattering by aerosols. Their analysis requires a radiative transfer code that takes into account the multiple scattering by particles in a spherical-shell atmosphere. The use of an innovative method, based on the Monte-Carlo approach, provides important constraints on the vertical composition of the Titan atmosphere.

1. Introduction

Since 2004, the VIMS (Visual and Infrared Mapping Spectrometer) instrument aboard the Cassini spacecraft has provided new insights on Jupiter, Saturn and Titan atmospheres through remote sensing observations. In particular, the Titan atmosphere was widely studied using Cassini CIRS (Composite Infrared Spectrometer) and VIMS data. In previous works, all the information about its vertical composition were retrieved under conditions where the scattering can be neglected [1,3]. So far, the lack of robust radiative transfer codes able to simulate limb measurements of extraterrestrial environments prevented a direct retrieval of the vertical properties of a scattering atmosphere. The difficulty in modeling the radiative transfer for limb geometries, in the wavelength range covered by VIMS, is caused by the treatment of multiple scattering, which becomes very important in the infrared and visible ranges when the atmosphere contains aerosol particles.
In this work we present the first attempt to characterize the Titan atmosphere by limb measurements in spectral and atmospheric regions where the scattering by particles becomes important.

2. Instrument and Atmospheric Model

The VIMS instrument on board the Cassini spacecraft is a multi-channel hyperspectral imaging spectrometer spanning visible and infrared wavelengths from 0. 3 to 5. 1 μm [2]. The instrument IFOV is 0.5x0.5 mrad, whereas the spectral resolutions of the VIS and IR channels are about 6-7.5 nm and 13-20 nm, respectively [2]. VIMS is able to acquire both nadir and limb measurements.
In this work, the Titan atmosphere is modeled using spherical shells having the thermal profile suggested by [5]. The composition of the gaseous atmosphere is the one by [8], whereas the aerosol component is represented by equivalent spherical particles (following the Mie theory) characterized by the optical properties described in [6].

3. Method

The first step in the analysis of VIMS measurements is the characterization of the mean parameters in modeling the Titan atmosphere by few test cases acquired close to the region of interest (e. g. Huygens landing site) in nadir geometry. The gaseous concentrations and the particles vertical and size distributions are retrieved using the DISORT code [10] for the radiative transfer treatment. The optical properties of the equivalent spherical particles are computed using the algorithm by [11]. As the mean and approximated structure of the atmosphere is retrieved, a new fitting loop is performed on limb spectra using a radiative transfer code which takes into account the multiple scattering in spherical geometry. The code calculates spectral monochromatic intensities for an atmosphere that is defined as homogeneous spherical-shells using the statistical Monte-Carlo approach [9]. The Monte-

Carlo solver is the one developed by [7,4]. The radiative transfer code, included into a fitting routine, provides as final result the vertical profiles of the atmospheric quantities of interest.

4. Conclusions and Future Work

The developed code for the analysis of limb measurements with a Monte Carlo (MCRT) approach allows the characterization of the vertical structure of the Titan atmosphere. The innovative treatment of the multiple scattering provides, for the first time, important constraints about the scattering properties of the particles in Titan's atmosphere.

In future, we plan to add in our MCRT code the air refraction of the line of sight and the polarization effects. Moreover, we plan to improve the scattering treatment by the computation of optical properties for non-spherical particles.

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