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Model validation of the polar clouds at Saturn as inferred by Cassini/VIMS data in the visual range

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Abstract

In this study the microphysical, optical and geometrical parameters obtained by Colosimo et al [5] to represent the clouds observed in the South Pole atmosphere of Saturn are used in a radiative transfer model to simulate the corresponding observations from Cassini/VIMS VIS-channel data in the wavelength range 0.84-1 µm. The disagreement between simulated and observed spectra has been interpreted taking into account the different nature of the measurements. Taking into account possible sources of discrepancies, an adjustment of the model parameters is suggested. The proposed values, reduce the difference between the simulations and the measurements from ~ 63% down to ~ 17%.

1. Introduction

Saturn clouds are the object of several studies pointing to define the morphology, composition and vertical structure of the planet's decks and upper haze layer. Like similar studies, also the model of Colosimo et al. [5] (that we call hereafter the IR-model) does not cover the wavelengths below 1 micron. However a study of this wavelength range would be anyhow important since it would provide useful information regarding the scattering properties of the clouds and the haze layer particles in order to constrain the modelled vertical structure of the atmosphere.

The IR-model is based on the Equilibrium Cloud Condensation Model (ECCM) by Atreya [1] with three cloud layers: a stratospheric haze layer, putatively made of "tholin"-like particles [8]; a tropospheric cloud of ammonia ice [9]; a deep thick cloud of ammonium hydrosulphide ice [6]. All the molecular absorption coefficients for the atmosphere have been estimated from the HITRAN 2008 database [11]. The model parameters have been set up by a best-fit application to the Cassini/VIMS-IR data.

VIMS is a multi-channel imaging spectrometer on board of the Cassini spacecraft. It consists of an IR-channel ranging from 0.85 to 5.1 µm and a VIS-channel operating in the wavelength range 0.3 – 1.05 µm. The VIS-channel has a nominal spectral resolution of 7.3 nm and a nominal angular resolution of 500 µrad. Thanks to the Cassini mission, a very large number of observations of the Saturn atmosphere has been taken, with different illumination and observation configurations. Here we present the extending of the IR-model to lower wavelengths and its results for a limited region of Saturn's South Pole atmosphere.

2. Analysis

In order to extend the IR-model to the VIMS-VIS wavelengths (hereafter the VIS-model) the LibRadtran radiative transfer tool [10] has been used. The total molecular optical depth calculation was modified to take into account the different part of the spectrum. The CIA (Collision Induced Absorption) for the H_2-H_2 [2] and H_2-He [3,4] interactions has been adapted to account for the new spectral range. For the CH_4 absorption, though the same gas concentration of the IR-model has been used, coefficients by Karkoschka [7] have been applied, as the HITRAN database does not cover the wavelength range under study. On the other hand the cloud structure, namely effective radii, clouds base pressures and clouds optical depths, has been retained as inferred by the IR-model. Both ammonia and ammonium hydrosulphide ices (NH_3 and NH_4SH respectively) indices of refraction have been got from Howett [6] because the Martonchik dataset [9], used by Colosimo et al. [5] for the NH_3 ice, has a very coarse spectral resolution in the range under investigation. In both models, the bottoms of the haze layer and the NH_3 cloud have been set at 30 mbar pressure (~ 85 K) and 400 mbar pressure (~ 100 K) respectively. The particle size has been considered lognormal distributed for each cloud deck, with effective sigma fixed to 0.1 µm and effective radii 0.1 µm and 0.7 µm, for the haze layer and the ammonia ice cloud respectively.

In spite of our cautions, the LibRadtran simulations in the 0.84 - 1 μm range do not acceptably reproduce the VIS-channel measured spectra corresponding to the same geographical regions considered in the IR-model, but result in spectra with radiance levels lower than expected for all wavelengths (~63% between the simulations and the measurements).

In order to reduce the discrepancies, the nominal concentration should be multiplied by a factor of 0.3 in the NH_3 ice cloud case, and by a factor of 10 in the haze layer case, resulting in values of optical depth significantly higher than those obtained in the IR-model. No NH_4SH cloud was necessary in the VIS-model, because at those wavelengths solar radiation extinguishes before reaching their level. They are only essential to model the thermal part of the spectrum. With the described exceptions, all the other parameters were the same for both the VIS-model and the IR-model. This fact suggests that the discrepancies between the VIS- and the IR- models' results could be related to the different parameter sets used. A preliminary analysis shows a tendency for Karkoschka's coefficients to have marked minima less than those calculated from the HITRAN dataset. On the other hand, the imaginary part of the ammonia ice refractive index differs up to two orders of magnitude, between 0.84 and 1 μm, according to whether Howett [6] or Martonchik [9] dataset are used.

3. Conclusions

The different datasets used for methane absorption coefficients and ammonia ice indices of refraction could be responsible for the discrepancies between the simulations and the measurements, so several tests are planned to check their limits of applicability, and possibly to estimate the confidence interval within which the simulations can be considered equivalent. Also, due to the fact that the parameters connected to Rayleigh and particle scattering play an important role in the visible wavelengths range, in the future the model sensitivity to their influence will be checked.

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