EPSC Abstracts
Vol. 5, EPSC2010-721, 2010
European Planetary Science Congress 2010

Titan's aerosol distribution in the middle atmosphere and constraints on its spectral properties from Cassini/CIRS data

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Abstract

Observations of the Composite Infrared Spectrometer (CIRS) during the entire nominal Cassini mission (2004-2008) provide us with an accurate global view of composition (molecules and aerosols) and temperature in the middle atmosphere of Titan between 100 and 500 km. We will present here the spatial distribution of aerosol extinction and mass mixing ratio in the 150 - 350 km altitude range, as well as the spectral dependence of the aerosol opacity retrieved in the 600 - 1420 cm^{-1} spectral range and the corresponding imaginary refractive index.

1. Introduction

Titan's atmosphere displays complex interactions between chemistry, aerosols, radiative transfer and dynamics. The spatial distribution of aerosols, which are the result of a complex atmospheric chemistry, affects the radiative balance and therefore the global dynamics. The study of the spatial distributions of molecular gas and aerosol can help us to better understand mechanisms that are involved in Titan's atmosphere. These spatial distributions can be deduced from the thermal emission of Titan's atmosphere observed by CIRS.

2. Observations

We used spectra acquired by CIRS in a limb viewing geometry with a 0.5- cm^{-1} spectral resolution. The gas emission bands are well separated with this resolution, which allow us to better constrain the molecular abundances. We focused on the spectral range 600-1420 cm^{-1}, which is probed by two of the three focal planes of CIRS (FP3 spans 600-1100 cm^{-1} and FP4 spans 1000-1500 cm^{-1}) [1]. FP3 and FP4 are each composed of a linear array of 10 detectors (0.273 square mrad field of view). During a limb observation, each of the 10 detectors of the FP3 and FP4 probe a different altitude for a given latitude. By fitting individual spectra simultaneously, it is possible to derive vertically-resolved information on physical parameters in Titan's middle atmosphere. We focused on spectra recorded at nine latitudes ranging between 56 S and 80 N.

3. Retrieval of aerosol extinction vertical profiles

CIRS spectra display emission bands from roughly fifteen gases. Outside these bands, continuum emission results from aerosols opacity and the N_2-N_2, N_2-CH_4, N_2-H_2 and CH_4-CH_4 collision-induced absorption. We modeled CIRS spectra by means of a line-by-line radiative transfer code, which solves the radiative transfer equation. At a given wavenumber, the spectral emission intensity depends on the temperature, the gas and the aerosol abundances. The knowledge of the temperature profile is crucial to correctly reproduce the observed emission. Temperature is deduced from the emission of CH_4 whose abundance is known independently (1.41 %, [2]). The temperature profile is retrieved by means of an inversion algorithm. The thermal profile is then used to retrieve the mixing ratio vertical profiles by fitting the molecular emission bands and using an inversion algorithm similar to the temperature retrieval algorithm. Aerosol extinction profiles were retrieved using the same inversion algorithm by fitting 20- cm^{-1} spectral ranges generally outside the

gas emission bands. By focusing on seventeen 20-cm^{-1} wide spectral ranges, we were able to constrain the spectral dependence of the aerosol vertical optical depth.

4. Results

At a given latitude, all extinction vertical profiles retrieved from various spectral intervals between 600 and 1120 cm^{-1} display similar vertical variations; this implies similar spectral characteristics of the material at all altitudes. We calculated a mean vertical extinction profile for each latitude and derived the ratio of the haze scale height to the pressure scale height as a function of altitude. The aerosol scale height varies with altitude and also with latitude. The spectral dependence of the haze vertical optical depth is uniform with latitude and displays three main features centered at 630 cm^{-1}, 745 cm^{-1} and 1390 cm^{-1} with a wide tail extending down to ~1000 cm^{-1}. From 600 to 750 cm^{-1}, the optical depth increases by a factor of 3 in contrast with the absorbance of laboratory tholins, which is generally constant. We constrained the corresponding refractive imaginary index. We derived the mass mixing ratio profiles of haze at the nine latitudes. The global increase with height of the haze mixing ratio profiles suggest a source at high altitudes and a sink at low altitudes.

Acknowledgements

This research was founded by the Centre National d'Etudes Spatiales, the Programme National de Planetologie (INSU) and the NASA Postdoctoral Program.

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