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Titan's upper atmosphere revealed by Cassini/UVIS stellar occultations

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Abstract

Stellar occultations observed by the Cassini/UVIS instrument probe Titan's mesosphere and lower thermosphere at altitudes between 400–1400 km. This region is believed to be the site of complex photochemistry, and the production and growth of aerosols that form the detached and main haze layers. Despite its importance, the region is poorly characterized by previous measurements. We analyzed several stellar occultations in detail, particularly the stable occultations obtained during flybys T21, T41 and T53. Based on this analysis, we present density profiles for CH_4, C_2H_2, C_2H_4, C_4H_2, HCN, HC_3N and C_6H_6, and extinction profiles for aerosols. The data reveals the presence of distinct extinction layers that are associated with large perturbations in the density profiles of the gaseous species and aerosol extinction profiles. These features vary slowly over time but overall they are relatively stable. In particular, we identify a sharp extinction layer between 450–550 km as the detached haze layer and show that the altitude of this layer changes consistently with recent images obtained by Cassini/ISS.

1. Introduction

Titan's atmosphere between the altitudes of 400–1000 km is poorly characterized because it falls between the thermosphere that is probed directly by Cassini/INMS [9] and Cassini/CAPS [2] instruments, and the stratosphere that is probed primarily by thermal infrared emissions measured by Cassini/CIRS [3]. Previous measurements characterizing this region consist of density profiles derived from solar occultations observed by Voyager/UVS [8], the density profiles obtained by the HASI instrument [4] and analysis of airglow spectra obtained by the Cassini/UVIS instrument [1]. Column density profiles for the key minor species and aerosol extinction coefficients were also derived from the first UVIS stellar occultations obtained during flyby Tb [6, 5].

We present light curves for UVIS stellar occultations obtained between flyby Tb in December 2004 and flyby T58 in July 2009. We also present density profiles for CH_4, C_2H_2, C_2H_4, C_4H_2, HCN, HC_3N, and C_6H_6 and extinction coefficients for the aerosols at altitudes between ∼400–1000 km based on the stable occultations obtained during flybys T41 and T53. We use the density profile of CH_4 to derive a temperature profile for Titan's upper atmosphere at altitudes below 1000 km.

2. Results

The light curves derived from the data contain distinct extinction layers. The appearance of these features depends on the location but overall they are relatively stable and change only slowly over time. Figures 1 and 2 show the density profiles of the minor species and the optical depth profile of the aerosols, respectively, obtained from the T41 data. The data indicates that the profiles contain large perturbations that give rise to the extinction layers observed in the light curves. The temperature profile derived from the CH_4 profile reveals the presence of perturbations with an amplitude of 10–20 K and a vertical wavelength of 100–200 km. These characteristics agree with the HASI measurements and are consistent with gravitational tidal waves [7]. In fact both the temperature measurements and the density perturbations can be caused by large-scale, low frequency waves and thus the data provides evidence for the presence of such waves in Titan's mesosphere.

Figure 2 shows a distinct peak in the optical depth of the aerosols near 500 km that coincides with the detached haze layer. We determined the altitude of this layer from all of the occultations between 2004 and 2009. Our results show that the altitude of the detached haze layer decreases rapidly with time near the equinox of 2009. This is in line with images obtained recently by Cassini/ISS [10].

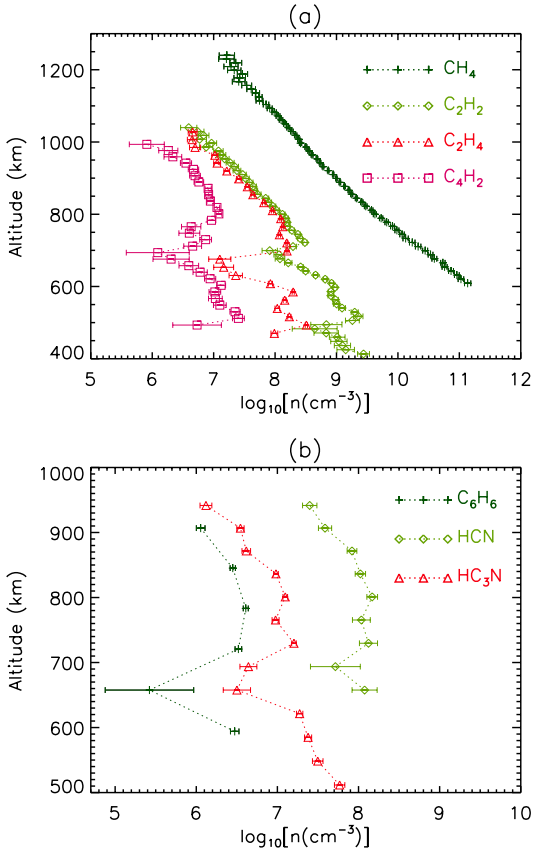

Figure 1: Density profiles of the minor species based on an occultation obtained during flyby T41.

3. Summary and Conclusions

We analyzed Cassini/UVIS stellar occultations obtained during flybys between December 2004 and July 2009. The data reveals the presence of large perturbations in the density profiles of the minor species and aerosols that provide evidence for the presence of large-scale, low-frequency waves in the upper atmosphere of Titan. If confirmed, the presence of these waves has significant implications for the dynamics and physical processes affecting the atmosphere.

Acknowledgements

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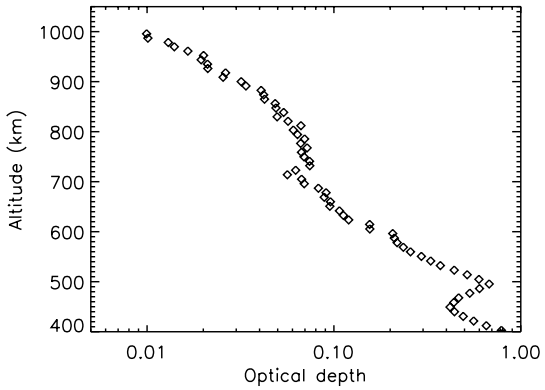

Figure 2: Optical depth due to aerosol extinction obtained from the T41 data.

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