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Aerosols seasonal variations in Titan's upper atmosphere

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Abstract

Cassini repetitive flybys over Titan provide a unique opportunity to monitor the evolution of the aerosol content in its upper atmosphere. Here we will present a complete analysis of the aerosol vertical extinction profiles between 600 to 300 km retrieved by a limb multiple scattering model covering the entire UV3 dataset from the beginning of the mission in 2004 (after the winter solstice in the northern hemisphere) to the end of the mission in 2017 (after the summer solstice). The complexity of these seasonal variations will provide further constrains for GCM and aerosol microphysics models.

1. Introduction

First noticed in 1981 [1] during the Voyager 1 flyby of Saturn, Titan haze layers were analyzed in detail in 1983 by Rages and Pollack [2] after the Voyager 2 flyby. The ISS images showed the presence of an aerosol opaque thick layer around 350 km above the surface and detached from the main haze. Since 2005, the new ISS (wide and narrow) cameras onboard Cassini image Titan at irregular intervals with mean time between intervals of 45 days. In 2011, West et al. [3] confirm the persistence in time of the detached haze layer at the equator but with an important altitude variability. Observed at the equator around 500 km in 2007, the detached haze layer collapsed to 380 km in 2010 and disappeared in 2011 after the equinox. As predicted by 2D and 3D Global Circulation Models (GCM) [4, 5, 6], the detached haze layer reappeared in 2016, but we will see that its behavior did not follow the model predictions.

2. Model description

To get accurate navigation of Cassini ISS images, we search for bright visible stars in the field of view (Fig. 1). With at least two stars we can perform a pointing correction by comparing the star locations with the GAIA catalogue. Otherwise, we fit a circle of Titan's main haze. Both methods provide high precision navigation of the images.

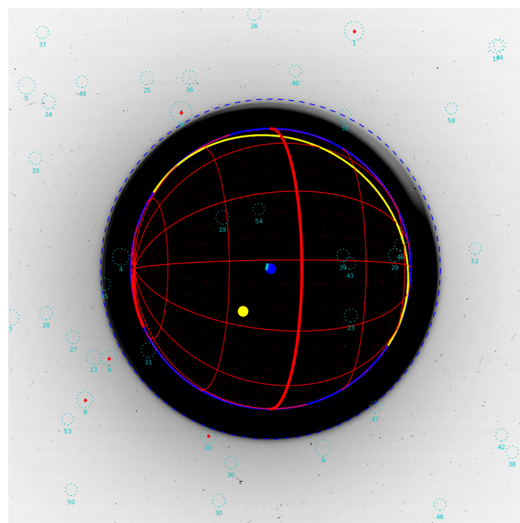

Figure 1: Star locations (red dots) in CL1-UV3 ISS NAC image N1521213736_1 (I/F inverted) compare with the GAIA catalogue (cyan dashed cercles). The red, blue and yellow sketch the solar limb and latitude/longitude grid for the solid body. The blue and yellow dots are the sub-Cassini and sub-solar points.

Based on previous scattering analyses [7, 8], we considered that Titan's detached haze layer is composed of large fractal aggregates with hundreds of monomers of 60 nm [9]. Then, we compute for each altitude between 300 to 600 km a synthetic I_n/F with a spherical limb radiative transfer model inspired from Rages and Pollack 1983 [2]:

$$\frac{I_n}{F} = \sum_{i=1}^{2n} \int_{z_{i-1}}^{z_i} \frac{\langle \omega_0 P(\theta) \rangle_j}{4} \exp\left(-\tau_{0i}(z) - \tau_i(z)\right) \beta_j R_m^j \mathrm{d}z \quad (1)$$

where I is the scattered intensity and $\pi \cdot F$ is the incident solar flux. $\langle \omega_0 P(\theta) \rangle_j$ corresponds to the product of the single scattering albedo and the phase function for a scattering angle θ = 180° - phase. τ_{0i} and τ_i represent the local incoming and outgoing optical depth. β_j is the extinction coefficient in the layer that we want to invert (Fig. 2). We modeled the local multiple scattering input by R_m^j. This correction factor is an estimation of the ratio between the total and the single single scattered intensity calculated in each layer with a local plane-parallel solver (*SHDOMPP*).

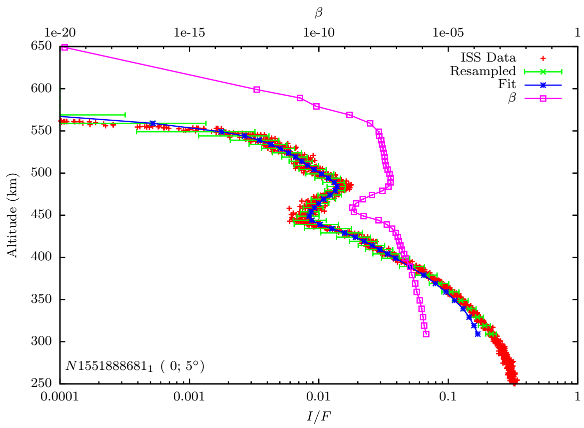

Figure 2: Inverted extinction profile (β) around the photometric equator in N1551888681_1.

3. Results

We carried out a systematic survey of all the illuminated latitudes between 2004 to 2017 (Fig. 3). Between 2004 and 2007 the detached haze layer appears as a continuous layer at 500 km from the south pole to the north polar hood. Around the equinox in 2009, the depletion below the detached layer dropped down to 300 km. We noticed that this drop was quicker in the southern hemisphere. Between 2011 and 2015, the detached haze disappeared but some sporadic depletions are locally observed. In early 2016, the detached haze reappeared as a continuous layer in the northern hemisphere down to the south pole. However, in the most recent images of 2017, we found that the detached layer no longer exists at the equator but is split into two different layers at 525 km in the southern hemisphere and 475 km in the northern hemisphere. All these seasonal variations will be presented in detail to provide further constraints for GCM and aerosol microphysics models.

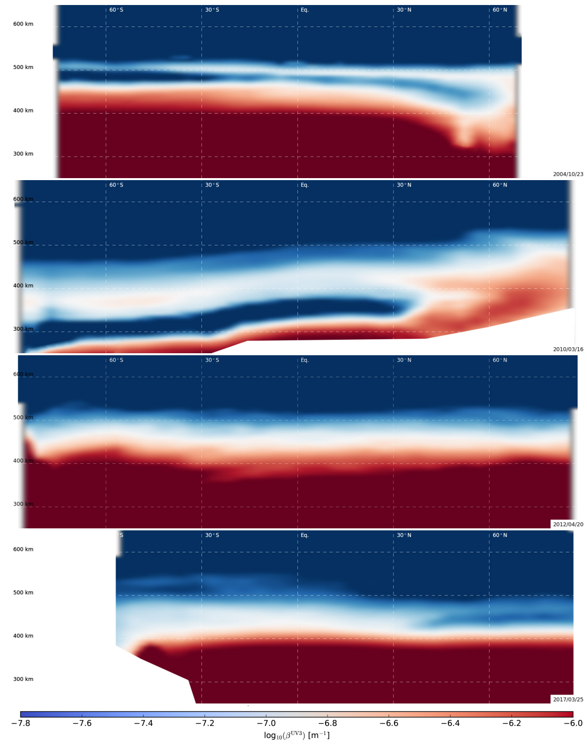

Figure 3: Top to bottom, example of aerosol haze extinction profiles of N1521213736_1 (2004), N1647460435_1 (2010), N1713617586_2 (2013), N1869102271_1 (2017).

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