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Characterization of Saturn's polar haze in the thermal infrared

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Abstract

We report on the first detection of stratospheric aerosol signatures in Cassini/CIRS infrared spectra acquired in Saturn's polar region. Vertical opacity profiles of these polar aerosols are retrieved in different spectral regions. The hazes' spectral properties present similarities with those of Titan's, suggesting similarities in their composition (chains or aromatic hydrocarbons). Finally, preliminary results suggests that this polar haze contributes to a net stratospheric heating of 3–5K in summer, and a cooling of 2–7K in winter.

1. Introduction

Saturn's polar regions are characterized by dark polar caps in the UV light, which are nearly coincident with auroral emissions. These dark regions are generally explained by the presence of a stratospheric haze layer [9, 4], possibly produced by the precipitation of energetic electrons combined to high auroral temperatures [7, 10]. Saturn's polar haze is of particular interest as it could significantly impact the stratospheric radiative heat budget and chemistry. The size and optical properties (in the UV and visible light) of these aerosols have been derived from HST observations [5, 6], but little is known about their infrared properties, vertical profile, composition or radiative impact.

2. Cassini/CIRS data analysis

2.1. Dataset and retrieval method

CIRS is a thermal infrared Fourier transform spectrometer onboard the Cassini spacecraft. It acquires spectra in nadir and limb viewing geometry, in the range 10–1400 cm^{-1} (7–1000 μm). Limb data acquired in 2005-2010 have been used to retrieve vertical profiles of the stratospheric temperature and of the abundance of several photochemical products [2]. Those profiles were obtained by coupling a forward radiative transfer model to a retrieval algorithm. In those studies, thermal emission by aerosols was neglected, as they were not needed in order to get satisfactory fits to the data.

Our study is focused on the analysis of a dataset acquired in limb viewing geometry in June 2007, within the polar cap (at 80S). In this particular case, in contrast to mid- and low-latitude limb data, several spectral features could not be reproduced by our baseline radiative transfer model. We interpret these features as aerosol signatures, and we implemented the additional retrieval of an aerosol opacity profile in our algorithm. These opacity profiles were retrieved in small spectral regions independently (10–20 cm^{-1} wide) in order to constrain the spectral dependancy of the haze opacity. An example of a fit to the data, with and without haze opacity, is shown in Fig. 1 for the spectral range 685–755 cm^{-1}.

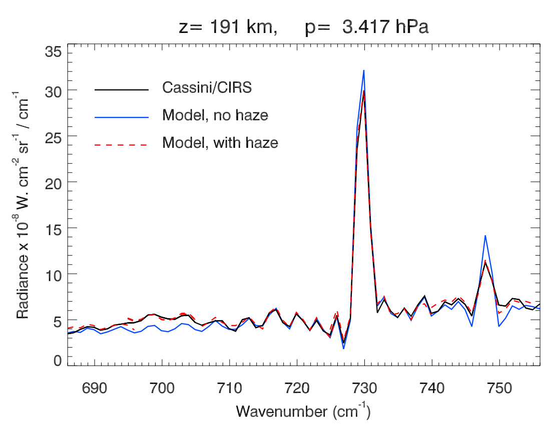

Figure 1: Example of a CIRS spectra acquired in limb geometry at 80S. Emission from acetylene and propane are prominent at 730 cm^{-1} and 748 cm^{-1}, respectively. Best fits are shown in red and blue, with or without the retrieval of a haze layer. Data at four different tangent heights z are combined to get the haze opacity profile.

2.2. Results: opacity profiles and spectral features

From the analysis of the CIRS data, we constrain the haze opacity profile between $\sim$ 5 mbar and 0.1 mbar. We find that the aerosol scale height is about twice the pressure scale height. This suggests that these aerosols are produced at high altitudes and are lost in the lower stratosphere, possibly through sedimentation. The haze integrated opacity varies significantly with wavelength, and exhibits four distinct spectral bands at 700, 750, 1380 and 1450 cm^{-1}. Interestingly, these spectral features are also observed in Titan's stratosphere, and have been assigned to vibration modes of aliphatic and aromatic hydrocarbons [8].

3. Modelling of the haze's radiative impact

To evaluate the radiative impact of this stratospheric haze layer, we employ the seasonal, 1-D radiative-convective model of Saturn's atmosphere described in [3]. First, assuming spherical particles, the haze's single scattering albedo and extinction coefficients are derived using a Mie code. Real and imaginary refraction indexes are taken from [5, 6] for the UV and visible part, and from [8] for the thermal infrared, given the similarities between Saturn's and Titan's aerosol spectra at these wavenumbers. The particle size is set to 0.08 μm and the integrated optical depth at 300 nm to 0.6 [5, 6]. An opacity vertical profile is then constructed given the aerosol scale height and the bottom pressure level of the haze layer. The latter is not well constrained by observations and was set to 50, 20 or 10 mbar to evaluate different scenarios.

We note that using the infrared optical constants of [8] (derived from Titan's spectra) yields infrared opacities that are consistent with the ones derived from Saturn's spectra, which validates this hypothesis.

Finally, we estimate that these aerosols are responsible for a net heating of the stratosphere during summer, reaching +5K at the bottom of the haze layer, and a net stratospheric cooling during winter, reaching -7K at the 0.1-mbar pressure level.

4. Summary and Conclusions

This study represents the first characterization of Saturn's polar stratospheric aerosols in the thermal infrared. Their spectral properties present striking similarities with Titan's stratospheric aerosols. Saturn's polar aerosols have a significant impact on the stratospheric radiative balance and could be partly responsible for the warm polar hood observed in the lower stratosphere during summer, at latitudes polewards of 70S [1].

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