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Saturn's stratospheric hydrocarbons from 2005-2012 Cassini/CIRS limb data analysis

S. Guerlet (1), T. Fouchet (2), M. Sylvestre (1,2), A. Spiga (1), J. Moses (3) and F.M. Flasar (4)
(1) Laboratoire de Météorologie Dynamique/IPSL/UPMC/CNRS, 4 Place Jussieu, 75252 Paris Cedex 05, France (sandrine.guerlet@lmd.jussieu.fr)
(2) Observatoire de Paris-Meudon/UPMC/CNRS, 5 place Jules Janssen, F-92195 Meudon Cedex, France
(3) Space Science Institute, Seabrook, TX 77586, USA
(4) NASA/GSFC, Greenbelt, MD 20771, USA

Abstract

We present an analysis of Cassini/CIRS infrared spectra of Saturn's stratosphere acquired in limb geometry in 2010-2012. We retrieve stratospheric temperature vertical profiles as well as volume mixing ratio profiles of three hydrocarbons (ethane, acetylene and propane) between 5 mbar and 1 μbar, at latitudes between 70°S and 70°N. These results are compared to 1-D seasonal photochemical model predictions [4] and to previous Cassini/CIRS limb observations from 2005-2006 [2]. The observed changes in hydrocarbons' distribution between 2005-2006 and 2010-2012 reflect seasonal changes in photochemistry and atmospheric dynamics, as Saturn's Northern Hemisphere is going from winter to spring. On top of these seasonal variations, we also report on the impact of the Great White Spot on hydrocarbon abundance profiles in the 30-50°N region.

1. Introduction

Saturn's stratosphere is host to a rich hydrocarbon photochemistry initiated by the photolysis of methane (CH_4) near the homopause level that produces various hydrocarbons, from ethane (C_2H_6) to benzene (C_6H_6). Their meridional distribution and their variations with altitude and time (seasons) are governed by coupled photochemical and dynamical processes. Saturn's stratospheric circulation is still poorly known to this day, as direct wind measurements are lacking. However, detailed measurements of hydrocarbons' meridional distribution and their vertical gradients can provide indirect constraints on atmospheric meridional and vertical transport.

The Composite InfraRed Spectrometer (CIRS) onboard Cassini offers a unique opportunity to study Saturn's stratospheric composition fields in detail. In particular, measurements of the thermal emission of the planet acquired in limb geometry allow the retrieval of the vertical profiles of the volume mixing ratios of five hydrocarbons over several decades of pressure (typically in the range 5–0.001 mbar). Using this technique, [2] and [3] presented for the first time 2-D (latitude $\times$ pressure) fields of C_2H_6, C_2H_2, C_3H_8, C_4H_2 and C_3H_4 abundances obtained from 2005-2006 limb data. Their results show evidence of meridional transport in the upper stratosphere, with possible upwelling in the summer hemisphere and downwelling under the ring's shadow, suggesting a seasonal circulation. Since then, [5] have analysed CIRS nadir-viewing datasets to retrieve the meridional distribution of ethane and acetylene at the 2-mbar level and their seasonal variations between 2005 and 2010. Our goal is to complement this existing dataset by constraining the seasonal variations of the 2-D hydrocarbon maps from the analysis of new CIRS limb data from 2010-2012.

2. Methods

CIRS is a Fourier-transform spectrometer comprising three focal planes, two of which (FP3 and FP4) covering the mid-infrared region in the range 7–17 μm. These focal planes consist of two linear arrays of ten detectors, with an individual projected field of view of typically 70km on Saturn, ie. 1 to 1.5 scale height. In limb viewing geometry, each detector probes a different altitude, allowing the retrieval of atmospheric profiles with a good vertical extent and resolution. We use a line-by-line radiative transfer model coupled to a constrained linear inverse method to 1) retrieved temperature vertical profiles from the analysis of the CH_4 emission band at 7.7μm and from the H_2-He collision-induced emission ; then 2) retrieve the volume mixing ratio vertical profiles of five hydrocarbons from their emission bands.

3. Results

We will present the results of the analysis of 30 limb measurements acquired in 2010-2012, at latitudes ranging from 70°S to 70°N. During this period, the Northern Hemisphere was mapped two times, first in September 2010 and then in July-August 2011, which allows us to study separately the response of the atmosphere to seasonal changes and the impact of the December 2010 storm, known as the Great White Spot. The retrieved temperature profiles and the study of seasonal variations of temperature are discussed in *Sylvestre et al.* (this issue). We will present the overall distribution of ethane, acetylene and propane between 70°S and 70°N compared to that in 2005-2006 and compared to the predictions of a 1-D photochemical model [4]. These results will also be discussed in the light of a new Global Climate Model (GCM) of Saturn's stratosphere, currently under development (see *Spiga et al.*, this issue).

An example of retrieved acetylene profiles at 40°N, at five different dates, is shown in Figure 1. We note that the C_2H_2 profiles are very similar in 2005 and 2010, indicating a low seasonal response at this latitude. However, in 2011, about 9 months after the start of the great storm, we report on a significant enhancement of C_2H_2 by a factor of 2 to 4 at pressures lower than 0.5 mbar. The three profiles acquired in 2011 are located at the storm latitude but outside the beacon (more than 90° in longitude away from the center of the storm). Our results indicate that the Great White Spot has not only impacted the temperature and hydrocarbons fields in the low stratosphere (at the 1-2 mbar level, as reported in [1]), but it has also strongly modified the hydrocarbons' distribution high up in the stratosphere, outside the beacon.

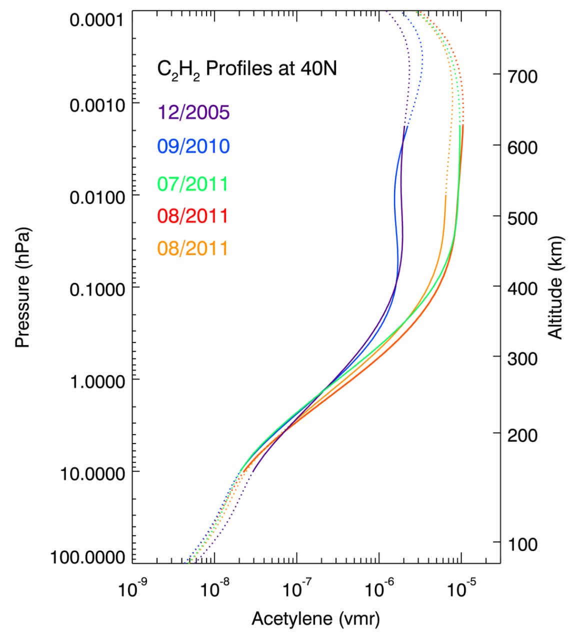

Figure 1: Vertical profiles of C_2H_2 volume mixing ratio at 40°N acquired between December 2005 and August 2011, showing the impact of the December 2010 storm *(limb data in 2011 shown here are located at the storm latitudes, but outside the beacon)*.

Acknowledgements

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