EPSC Abstracts
Vol. 7 EPSC2012-677-1 2012
European Planetary Science Congress 2012

Water vapor in Titan's stratosphere from Cassini/CIRS Far-infrared spectra

V. Cottini (1), C. A. Nixon (1,2), D. E. Jennings (1), C. M. Anderson (1), N. Gorius (1,3), G. L. Bjoraker (1), A. Coustenis (4), N. A. Teanby (5), R. K. Achterberg (1,2), B. Bézard (4), R. de Kok (6), E. Lellouch (4), P. G. J. Irwin (7), F. M. Flasar (1), G. Bampasidis (4,8)
(1) Planetary Systems Laboratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA, (2) Department of Astronomy, University of Maryland at College Park, College Park, MD 20742, USA, (3) Department of Physics, The Catholic University of America, Washington, DC 20064, USA, (4) LESIA-Observatoire de Paris, CNRS, UPMC Univ. Paris 06, Univ. Paris-Diderot, France, (5) School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol BS8 1RJ, United Kingdom, (6) SRON, Sorbonnelaan 2, 3584 CA Utrecht, Netherlands, (7) Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, OX1 3PU, UK, (8) Faculty of Physics, National and Kapodistrian University of Athens, Athens, Greece.

Abstract

We report here the detection of stratospheric water vapor [1] using the Cassini Composite Infrared Spectrometer (CIRS, [2]). CIRS senses water emissions in the far infrared spectral region near 50 microns, which we have modeled using a radiative transfer computation code (NEMESIS, [3]). From the analysis of nadir spectra we have derived a mixing ratio of 0.14 ± 0.05 ppb at an altitude of 97 km, which corresponds to an integrated (from 0 to 600 km) surface normalized column abundance of 3.7 ± 1.3 × 10^{14} molecules/cm^2. Using limb observations, we obtained mixing ratios of 0.13 ± 0.04 ppb at an altitude of 115 km and 0.45 ± 0.15 ppb at an altitude of 230 km, confirming that the water abundance has a positive vertical gradient as predicted by photochemical models (e.g. [4], [5] and [6]); retrieved scaling factors (from ~ 0.1 to ~ 0.6) to the water profile suggested by these models show that water vapor is present in Titan's stratosphere with less abundance than predicted.

1. Introduction

Titan's known oxygen compounds to date are carbon monoxide (CO, ~47 ppm), carbon dioxide (CO_2, ~15 ppb) and water vapor (H_2O), where the abundances are quoted for the low-latitude stratosphere [7]. Water was detected at a mixing ratio of 0.4 ppb, assumed to be uniform above the condensation level, using Short Wavelength Spectrometer (SWS) spectra acquired by the Infrared Space Observatory (ISO) in 1997 [8]. Only an upper limit of 0.9 ppb could be retrieved with Cassini CIRS data [7]. Since then, water emission in CIRS data have been definitely observed, albeit without deriving any further information on its abundance and distribution [9] untill now with this study [1].

2. Data and method

CIRS [2] has three Focal Planes observing in the range 10 - 1400 cm^{-1} with spectral resolutions from 0.5 to 15.5 cm^{-1}. Focal Plane 1 detector (FP1) is characterized by a circular field of view of 3.9 mrad. It records data in the far infrared spectral range (10 – 600 cm^{-1}) with a spectral resolution of 0.5 cm^{-1}, allowing us to observe the water vapor signature, and by modeling, to retrieve its abundance. Water presents its rotational lines in the CIRS FP1 spectral region up to 400 cm^{-1}, with the strongest and most visible lines between 90 and 260 cm^{-1}. We use the range from 150 to 260 cm^{-1} for the water detection, as this is the range of maximum responsivity of FP1. We use data from two different types of observations: the far infrared on-disk integrations and the far infrared limb integrations observing two altitudes in the limb in order to derive constraints on water vapor vertical profile. We average the data to reach sufficient signal-to-noise ratio and we model them using a code (NEMESIS, [3]) which solves the radiative transfer equation using as source function the thermal emission of the surface and that of the atmospheric layers (example of data and model in Figure 1). We include in the model also the collision induced absorption opacities between the main atmospheric gases - nitrogen, methane and hydrogen- due to Titan's dense lower atmosphere, the photochemical aerosol plus stratospheric condensates, and the ro-vibrational emission lines of other atmospheric species present in the atmosphere.

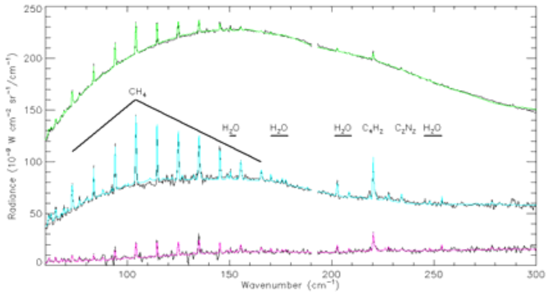

Figure 1: average of CIRS far-IR on-disk observations (from Dec. 2004 to Dec. 2008) in the lat. range of 0˚–30˚N, limb observations centered around 115 and 230 km (from Dec. 2004 to Sep. 2009 in the latitudinal range of 90˚S– 20˚S) and their fit (in green, blue, red respectively) assuming a constant water mole fraction above the condensation altitude.

6. Results

To measure the water abundance from the on-disk average (0˚ – 30˚N) data we first use a constant water profile and a temperature profile for 15˚S previously retrieved from CIRS [10]. We retrieve a volume mixing ratio of 0.14 ± 0.05 ppb for altitudes ranging between ~ 93 and 130 km, where the contribution function of the water vapor peaks at around 97 km. This value corresponds to a surface-normalized H_2O total column density on the order of $3.7 \pm 1.3 \times 10^{14}$ molecules/cm^2.

The measurement of water vapor obtained by modeling the first limb spectrum under the assumption of a constant mixing ratio profile is equal to 0.13 ± 0.04 ppb. This value is relative to an altitude around 115 km according to the position of the peak of the corresponding contribution function. We retrieve a water mixing ratio of 0.45 ± 0.15 ppb using a constant water profile at an altitude centered around 230 km. These values indicate an increase of the water mole fraction with altitude in the stratosphere from 115 km to 230 km of about 3 times.

We also fit the water lines for three other water vertical distribution profiles ([4], [5] and [6]) and obtained the necessary scale factors to fit the data. These values, between 0.11 and 0.63, show the retrieved water mole fraction to be less than predicted from these previous models.

References

[1] Cottini V., Jennings, D. E., Nixon C. A., Anderson, C. M., Gorius, N., Bjoraker, G. L., Coustenis A., Achterberg, R. K., Teanby, N. A., de Kok, R., Irwin, P. G. J., Bézard, B., Lellouch, E., Flasar, F. M., Bampasidis, G. Detection of water vapor in Titan’s atmosphere from Cassini/CIRS infrared spectra. Submitted to Icarus

[2] Flasar, F. M., and 44 colleagues: Exploring the Saturn system in the thermal infrared: The Composite Infrared Spectrometer. Space Sci. Rev., 115, 169 – 297, 2004.

[3] Irwin, P.G.J., Teanby, N.A., de Kok, R., Fletcher, L.N., Howett, C.J.A., Tsang, C.C., Wilson, C.F., Calcutt, S.B., Nixon, C.A., Parrish, P.D.: The NEMESIS planetary atmosphere radiative transfer and retrieval tool. J. Quant. Spectrosc. Radiat. Trans., 109, 1136-1150, 2008.

[4] Lara, L. M., Lellouch, F., Lopez-Moreno, J. J., & Rodrigo, R.: J. Geophys. Res., 101, 23,261, 1996.

[5] Wilson, E. H.; Atreya, S. K.: Current state of modeling the photochemistry of Titan's mutually dependent atmosphere and ionosphere. J. Geophys. Res., 109, E6, 2004.

[6] Hörst, S. M.; Vuitton, V.; Yelle, R. V.: Origin of oxygen species in Titan's atmosphere. J. Geophys. Res., 113, E10, 2008.

[7] de Kok, R. et al.: Oxygen compounds in Titan's stratosphere as observed by Cassini CIRS. Icarus, 186, 354-363, 2007a.

[8] Coustenis, A.; Salama, A.; Lellouch, E.; Encrenaz, Th.; Bjoraker, G. L.; Samuelson, R. E.; de Graauw, Th.; Feuchtgruber, H.; Kessler, M. F.: Evidence for water vapor in Titan's atmosphere from ISO/SWS data. A&A, 336, L85-L89, 1998.

[9] Bjoraker, G., Achterberg, R., Anderson, C., Samuelson, R.; Carlson, R.; Jennings, D.: American Astronomical Society, DPS meeting #40, #31.12; Bulletin of the AAS, 40, 448, 2008.

[10] Anderson, C. M., Samuelson, R. E.: Titan’s aerosol and stratospheric ice opacities between 18 and 500 µm: Vertical and spectral characteristics from Cassini CIRS. Icarus, 212, 762-778, 2011.