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Titan's Stratospheric Water Vapor profile from Cassini CIRS far-infrared Spectra

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Abstract

In this work we present an update of water vapor abundance in Titan's stratosphere through modeling of its emission lines present in the spectral range (100 – 300 cm^{-1}) observed by the Cassini Composite Infrared Spectrometer (CIRS) far-IR Focal Plane 1 (FP1) detector. We model and analyze high spectral resolution (0.5 cm^{-1}) disk and limb observations acquired from December 2004 to December 2016 to determine the water mixing ratio profile. Nadir data and limb data acquired up to 2011 and pointing at two altitudes in Titan's stratosphere (125 and 225 km) have been previously used in [1] to detect water vapor and retrieve its abundance at two limb altitudes. Few years of more data and improved calibrations are now available to further investigate water vapor. In particular, three far-infrared limb integrations were planned and acquired in 2014 and 2016 with CIRS staring at a single altitude (175 km) for longer time. These new data provided us with one more altitude point to derive the water vapor abundance and improve its retrieved vertical profile, increasing significantly the science results. These results will also be compared to previous results and to the latest photochemical models of Titan's oxygen species.

1. Introduction

Oxygen compounds observed in Titan's atmosphere are CO, CO_2 and H_2O, with a volume mixing ratio of ~50 ppm, ~15 ppb and ~1 ppb, respectively. The abundances of these species are determined by the physical and chemical processes occurring in Titan's atmosphere. These processes place fundamental constraints on the origin and evolution of Titan's atmosphere, thus bringing oxygen chemistry and its impact on the chemical composition at the center of a long-standing debate. Determine the abundance distribution and profile of these molecules is therefore a very important step for understanding Titan's history. Information on water vapor profile is needed in photochemical models to constraint the origin on water and the other oxygen compounds on Titan. Water vapor on Titan was first detected using whole-disk observations from the Infrared Space Observatory ([2]). An early attempt to measure H_2O with Cassini CIRS was unsuccessful due to poor signal-to-noise (S/N) ratios in early versions of the calibration pipeline spectra and a limited number of available spectra. Therefore, only an upper limit could be retrieved ([3]). Since then, water emission in the CIRS data has been only qualitatively observed ([4]). The Cassini Ion and Neutral Mass Spectrometer (INMS) detected H_2O in the upper atmosphere ([5]). After that water stratospheric profile was finally inferred by CIRS [1] and HERSHEL [6]. New CIRS data analyzed in this work provided us with one more altitude point to derive water vapor abundance and improve its retrieved vertical profile and few more years of observations allow us better signal to noise averages and also variations of water with time.

2. Data and Method

CIRS has obtained spectra of Titan during most of the 127 flybys that have taken place since Saturn Orbit Insertion in 2004. Water vapor abundance in Titan's stratosphere is retrieved through modeling of its emission lines observed by CIRS far-IR Focal Plane 1 detector. About 30 lines are present in the spectral range 100 – 300 cm^{-1}. Averages of multiple spectra are necessary to improve the signal to noise and observe water. We retrieve the water abundance from zonal averages of high spectral resolution (0.5 cm^{-1}) far infrared on-disk observations (FIRNADCMP) of equatorial latitudes (Fig. 1). We also retrieve the water stratospheric profile analyzing limb far infrared integrations (FIRLMBINT), which are CIRS observations acquired from 75 to 135 minutes from closest approach (25,000 to 45,000 km range) and pointing at two altitudes in Titan's stratosphere (125 and 225 km) for about 30 min for each altitude. In order to obtain an average of homogenous data we include observations of Titan's with stratospheric temperatures at 1 mbar between 165 and 170 K. We also planned a new observational type design, essentially a FIRLMBINT (same distance/time from closest approach), but staring at a single altitude only (175 km) for 1 hr. This new observational mode (FIRLMBWTR) was designed to add a third data point to the water vertical profile and was performed three times, in April 2014 and May and November 2016. The average of these observations at an intermediate altitude, although more noisy than at other levels, allowed us to retrieve water at one more point. Stratospheric temperatures in the 0.5 - 4.0 mbar range were obtained by inverting spectra of CH_4 in the ν_4 band centered at 1304 cm^{-1} and measured by CIRS in the focal plane 4 (FP4) detector.

3. Figures

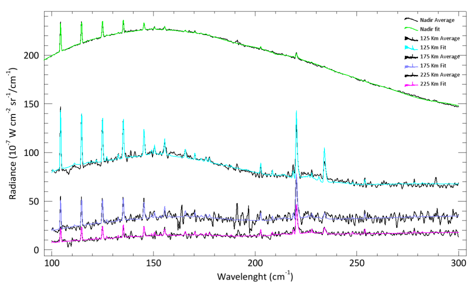

Figure 1: CIRS far-IR observations used to retrieve water from four different averages. From the top are plotted: on-disk observations (21100 spectra acquired from December 2004 to December 2016 in the latitudinal range of 30°S –30°N), limb observations centered around 5590, 175 and 225 km (respectively 693, 175, 687 and 280 spectra acquired from December 2004 to December 2016 for regions with atmospheric temperature at 1 mbar >165K) and their fit (in green, blue, purple and cyan respectively) assuming a constant water mole fraction above the condensation altitude.

4. Summary and Conclusions

Nadir and limb spectra at 125 and 225 km have been used in the past to retrieve water vapor [1]. More data are now available to retrieve the water vapor stratospheric profile. Three far infrared integrations have been replaced in 2014 and 2016 with observations at 175 km only. These new data provided us with one more altitude point to derive water vapor abundance and improve its retrieved vertical profile, increasing the information provided to photochemical models to derive Titan's atmospheric processes. The 175 km observations provide ~175 spectra and despite the average being lower signal-to-noise than at other altitudes, making water retrieval more challenging, the water abundance was retrieved with significance > 3-σ. The retrieved water abundances are consistent within errors to results in [1]. The results are compared to previous work and to the latest photochemical models of Titan's oxygen species.

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