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Retrieval of H_2O abundance in Titan's stratosphere from CIRS and Herschel disc-averaged observations

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Abstract

Since its first measurement 20 years ago by the Infrared Space Observatory (ISO), the water (H_2O) mole fraction in Titan's stratosphere remains uncertain, due to large differences between the determinations from available measurements. This has notably prevented current models from fully constraining the oxygen flux flowing into Titan's atmosphere. In this work, we aim to understand the differences between the H_2O mole fractions estimated from Herschel and Cassini/CIRS observations. This is done by (re)analysing disc-averaged observations from both instruments using an identical retrieval scheme. Previous differences in modelling/retrieval methods, along with differing viewing geometries between the two datasets are in this way mainly avoided. The whole methodology will be presented and the comparison between the two sets of H_2O mole fractions will be discussed.

1. Introduction and objectives

The discovery of carbon dioxide (CO_2) in Titan's atmosphere by Voyager [6] more than 30 years ago demonstrated the presence of oxygen compounds in its atmosphere. The CO_2 retrieved abundance also suggested the presence of stratospheric H_2O as the required source of oxygen, in the form of hydroxyl (OH) radicals. This presence was confirmed 15 years later with observations from the Infrared Space Observatory (ISO) [2], and is the result of external sources of oxygen, which can take different forms and are difficult to disentangle (e.g., [3]). ISO observations were modeled using an uniform H_2O mixing ratio of 0.4 ppb. This first detection was then followed by measurements from the Herschel Space Telescope [5], taken by the Photodetector Array Camera and Spectrometer (PACS) and the Heterodyne Instrument for the Far-Infrared (HIFI), and by the Composite Infrared Spectrometer (CIRS) onboard the NASA Cassini spacecraft [1]. These observations revealed that the H_2O mole fraction increases with the altitude, which is consistent with a high altitude source and a low-level sink (condensation and photolysis). However, the H_2O mole fraction in Titan's stratosphere remains uncertain. More especially, in the low stratosphere, Herschel and CIRS H_2O measurements differ by around a factor of 4. From Herschel observations, [5] retrieved a H_2O vertical profile and estimated the mole fraction at around 0.03 ppb in the low stratosphere, whereas [1] retrieved H_2O mole fractions of 0.13 ppb from Cassini/CIRS measurements. This discrepancy has limited the ability of current models to constrain the flux of oxygen into Titan's atmosphere [3]. Understanding the difference between the H_2O mole fractions measured from Herschel and CIRS is therefore crucial to better constrain the existing photochemical models, and more largely to improve the knowledge of the source and chemistry of oxygen in Titan's atmosphere.

In this work, we analyse recent disc-averaged observations (2013-2015) of the CIRS/Cassini instrument and retrieve new H_2O mole fractions. The use of disc-averaged observations allows an easier comparison with Herschel measurements, which share the same viewing geometry. Besides a difference in observation geometry, the previous studies have also applied distinct retrieval methods and used different a priori information and radiative transfer modelling codes to retrieve H_2O. This work aims at (re)analyzing the CIRS and Herschel datasets with the same retrieval scheme. This is essential to distinguish the potential contribution of modelling/retrieval differences to the discrepancies in the retrieved H_2O abundances from other possible sources.

2. Observations and method

In this work, we analyse four sets of CIRS disc-averaged observations, recorded in the far-infrared range (FP1, 5-695 cm^{-1}) at a spectral resolution of 0.5 cm^{-1} between February 2013 and July 2015. These sets include around 800 spectra each and span sub-spacecraft latitudes from 40.6°S to 47°N. The disk-averaged observations of Herschel recorded by the PACS and HIFI instruments, which were previously examined, are reanalysed (Tables 1 and 2 in [5]). These were mostly recorded in 2010. PACS measurements include the 66.4 µm, 75.4 µm and 108.1 µm lines, whereas HIFI measured the 557 GHz and 1097 GHz lines.

To retrieve H_2O mole fraction, a similar method is applied to both datasets. This includes 3 steps: 1) the retrieval of temperature profile from methane (CH_4) emission lines (Figure 1), 2) the fitting of the spectral continuum by retrieving aerosols profiles and absorption cross-sections, and 3) the retrieval of the H_2O mole fraction (Figure 1). The whole retrieval scheme is performed using the NEMESIS software [4].

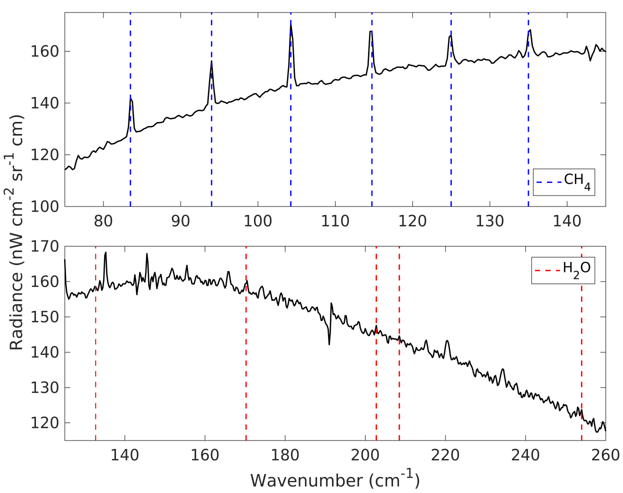

Figure 1: Averaged CIRS spectrum (black) calculated for the set recorded on 21/02/2013. Blue dashed lines are CH_4 emission lines used for the temperature retrieval. Red dashed lines correspond to H_2O lines used for the H_2O mole fraction retrieval.

3. Discussion

In this presentation, we will describe the whole retrieval methodology. A complete error analysis, examining the propagation of different uncertainty sources to the retrieved H_2O mole fraction, has been performed and will be discussed. Thanks to the sub-spacecraft latitudinal spanning of CIRS observations, the possibility of H_2O latitudinal variations will be assessed. Retrievals performed on CIRS and Herschel measurements will be finally compared, and the understanding of potential differences between the two datasets will be particularly targeted.

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