Spatial and Temporal Variation of Water in Titan's Atmosphere.

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Introduction: Although water has been detected and quantified in Titan's atmosphere by previous modeling efforts, its temporal and spatial variability has yet to be investigated over the entirety of Cassini's operational lifetime.[1][2] Contrasting stratospheric mixing ratios of 0.023 ppb at 12.1 mbar and 0.14 ppb at 10.7 mbar have been retrieved by previous atmospheric modeling efforts.[3-4] Similarly, no conclusive evidence has yet been gathered to identify systematic latitudinal variation of water vapor abundances—which is a behavior observed with other trace gas species.

Water is one of three main oxygen-bearing compounds in Titan's atmosphere, and its presence plays an important role in Titan's complex photochemistry.[5] It is thought that the bulk of water vapor is deposited in Titan's upper atmosphere through either micrometeorite ablation or infalling oxygen compounds.[6] Through further investigation of Titan's spatial and temporal dispersion of water vapor, we aim to provide insight into important questions regarding water's seasonal behavior and dominant sources and sinks.

Methodology: We have focused our search for latitudinal and temporal variation of water vapor in the 120-260 cm^{-1} range, using Cassini's Composite Infrared Spectrometer (CIRS) instrument.[7] CIRS Focal Plane 1 (FP1, 10-600 cm^{-1}) has high spectral resolution (0.5 cm^{-1}), which is required for the detection of weak water lines. Nadir spectra were chosen to cover all latitudes over Titan's disk during the operational lifetime of Cassini. We split the 12.5 year data set (2005-2017) into five Titan months (2.5 Earth years) to allow for high temporal resolution of spectra around seasonal changes. Each Titan month was split again and into six latitude bins corresponding to 30 degrees latitude each, for a total of 30 bins over the entire temporal range.

We modeled the data set using the **N**on-linear Optimal **E**stimator for **M**ultivariat**E** Spectral Analy**SIS** (**NEMESIS**) planetary atmosphere radiative transfer and retrieval tool.[8] We began by retrieving temperature profiles through modeling a series of methane lines between 125 and 155 cm^{-1}. Aerosol, trace gas, and water vapor scaling factors were also retrieved from a set of modeled *a priori* estimates. The models targeted the entire 120-260 cm^{-1} range, which allowed for the robust detection and modeling of rotational water lines. In these models, contribution functions, which denote our retrieval's water sensitivity, peaked in the lower stratosphere (90-180km). We subsequently derived stratospheric mixing ratios for water in each of the modeled bins.

Results: Here, we are able to provide new stratospheric water vapor mixing ratios. Initial results are in agreement with previous retrievals, such as Cottini et al. (2012), who found an abundance of 0.14 ppb at 97 km.[3] At an altitude of 107 km, we retrieved water vapor mixing ratios of 0.11 ppb, and the retrieved water profile is depicted in Figure 1.

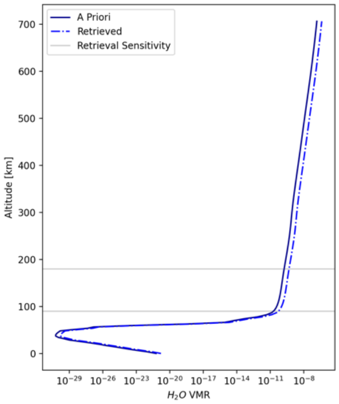

Figure 1: Water retrieval of southern summer equatorial latitudes (30-0º S, 2005 to 2007)

Determining where, when, and to what extent external sources contribute to water vapor abundances will better constrain current photochemical models and help identify if the dominant source of water on Titan is interplanetary dust particles, Saturn's rings, or Enceladus.

References: [1] Coustenis et al. *Icarus* 207 (1998): 461-476. [2] Bauduin et al. *Icarus* 311 (2018): 288–305. [3] Moreno et al. *Icarus* 221 (2012): 753–767. [4] Cottini et al. *Icarus* 220 (2012): 855–862. [5] Teanby et al. *The Astronomical Journal* 155:251 8pp (2018): 1-8. [6] Dobrijevic et al. *Icarus* 228 (2014): 324–346. [7] Jennings et al. *Applied Optics* 56 (2017): 5897-5897. [8] Irwin et al. *Journal of Quantitative Spectroscopy & Radiative Transfer* 109 (2008): 1136–1150.