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Constraining Ethane Concentration in Titan's Lakes and Seas.

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Abstract

Contrary to model predictions, Cassini RADAR observations indicate Titan's lakes and seas contain only a small quantity of ethane. Even though Cassini Visual and Mapping Spectrometer (VIMS) has detected ethane in these liquids, using VIMS alone to precisely determine ethane quantity is likely not possible. Instead, we aim to couple laboratory measurements, radiative transfer modeling, and Cassini VIMS observations to determine the minimum ethane concentration detectable by Cassini VIMS in Titan lake observations.

1. Introduction

Besides Earth, Titan is the only known planetary body with a thick nitrogen atmosphere, and stable liquids on its surface [1]. The primary composition of these lakes is likely methane and ethane with dissolved atmospheric nitrogen [2-4]. However, little is known about the exact ratio of these hydrocarbons. Previous studies have used Cassini RADAR to estimate the composition of four Titan lakes (Ligeia Mare, Punga Sinus, Baffin Sinus, and Ontario Lacus), and find varying methane/ethane/nitrogen ratios (12-38/51-80/11-20 mol%, respectively) [5-7]. Furthermore, Cassini VIMS has detected ethane in Ontario Lacus lake/shore ratios, although the exact composition is not possible using this method [8,9]. Another study predicted an ethane concentration of >20% for Cassini VIMS detection, by calculating absorption coefficients [10]. This study aims to take a closer look at the 20% ethane detection limit and couple experiments and Cassini VIMS observations to further constrain a lower limit on ethane detection by Cassini VIMS in Titan's lakes and seas.

2. Methods

1.1 Laboratory Experiments

Laboratory experiments were conducted in the University of Arkansas' Titan surface simulation chamber (TSSC) [11], in which mixtures of liquid hydrocarbons (methane and ethane) are analyzed under Titan surface conditions (89–94K and 1.5 bar nitrogen atmosphere). The sample is cooled, and temperature is maintained via liquid and gaseous nitrogen, respectively. Liquid methane was introduced to the sample dish first, followed by periodic addition of ethane (1-2g every ~10 minutes). After each new ethane addition, a spectrum was obtained using a Fourier-Transform InfraRed (FTIR) spectrometer.

1.2 Comparison/Calibration

In this study we used a north polar lake specular reflection for an imperial atmospheric correction [12]). Additionally, we convolved our experimental spectra to Cassini VIMS wavelengths and used the appropriate wavelength shift [13] to compare our laboratory results to Cassini VIMS observations. The relative ethane band depth was calculated using wavelengths 2.018-µm (channel 70) and 2.034-µm (channel 71) as the top of the window, and 2.002-µm (channel 69) and 2.051-µm (channel 72) as the continuum: [1-(70+71)/(69+72)]. The Cassini VIMS observations (i.e. cubes) were corrected using the latest calibrations.

3. Results/Discussion

We begin by characterizing the 2-µm ethane absorption feature by varying the ethane (relative to methane) concentration over multiple methane path lengths in the laboratory (Fig. 1). We find the 2-µm absorption increases with increasing ethane concentration and increasing methane path length. Band depth analysis shows a stronger correlation with the quantity of ethane than the methane to ethane mole-fraction. In both our experimental convolved spectra and Cassini VIMS observations, we observe that two of the ethane absorption features form a single absorption near the peak of the 2-µm window (also observed by [8]). Thus, the ethane absorption feature is detected similarly in both our Cassini VIMS observations and laboratory spectra.

Additionally, the apparent depth of the ethane absorption feature is strongly dependent on the Cassini VIMS channel aligning and misaligning with the 2-µm triplet feature associated with ethane (Fig. 2). Thus, correction for the wavelength shift is extremely important when examining the 2-µm ethane absorption feature over time.

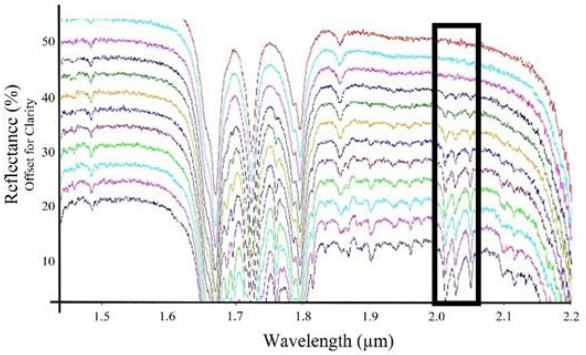

Figure 1: Laboratory spectra with a constant methane path length and increasing ethane concentration (off-set for clarity). The liquid ethane concentration increases as the spectra moves from top to bottom (0-17 mol%). The black box highlights the 2-µm ethane absorption feature, which is the focus of our study.

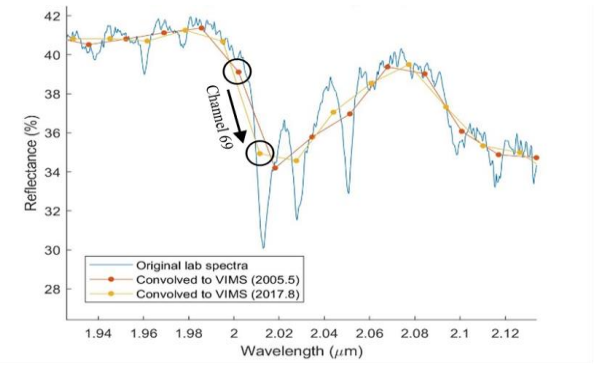

Figure 2**:** Comparison of laboratory ethane spectrum (blue) to the same spectrum convolved to Cassini VIMS sampling. This figure highlights channel 69 as the wavelength shifts between the beginning of the Cassini mission (red) and the end of mission (yellow).

4. Summary and Conclusions

We find that the 2-µm ethane absorption feature appears with similar ethane concentration (weight), not hydrocarbon ratio. In observations, the ethane absorption feature present in the northern lakes are consistent with previous observations of Ontario Lacus [8]. Thus, liquid ethane is likely present in the northern lakes, as well. Initial comparison of the band depths finds stronger absorption features in Cassini VIMS observations than experiments. Further atmospheric correction and radiative transfer modeling [13] will enable us to further compare our experimental results to Cassini VIMS observations and identify a lower limit on ethane detection.

Acknowledgements

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