MONITORING EVAPORATION RATES OF LIQUID METHANE UNDER TITAN SIMULATED CONDITIONS. T. Cornet[1], A. Luspay-Kuti[2], F.C. Wasiak[2], W.D.D.P. Welivitiya[2], V. Chevrier[2], L. Roe[2], [1]*Laboratoire de Planétologie et Géodynamique, Université de Nantes, Nantes, France.* [2]*Arkansas Center for Space and Planetary Sciences, Fayetteville, Arkansas, USA. (thomas.cornet@univ-nantes.fr).*

Introduction

Since the arrival of the Cassini-Huygens mission in the Saturn system in 2004, strong evidences of the presence of liquid bodies have been found on Titan's surface near the poles [1, 2]. Titan possesses a thick atmosphere mainly composed of nitrogen (N_2) and methane (CH_4), and experiences an active methane cycle due to surface pressure (1.5 bar) and temperature (90 - 94 K) conditions. This cycle is in many ways similar to the water cycle on Earth [1, 3] and allows the potential presence of liquid hydrocarbons (methane and ethane) on Titan's surface [4, 5].

These liquid hydrocarbons would experience evaporation processes, potentially allowing shorelines changes detection from the Cassini orbiter over the time, as previously mentioned for Ontario Lacus on Titan [6, 7]. In this study we investigate the evaporation rate of methane using the Titan Module designed in the Keck Laboratory for Space and Planetary Simulation, University of Arkansas, to give new experimental constraints that can be compared to theoretical computations, and will be checked against evaporation rates potentially recorded by Cassini's orbiter from the shoreline retreat observations in future works.

Description of the Titan Module

The Titan Module (TM) is an experimental chamber used to simulate Titan's temperature and pressure conditions [8, 9]. It consists of a stainless steel structure containing a Temperature Control Box (TCB) surrounded by cooling coils. Liquid nitrogen (LN_2) flows in these coils to keep Titan's temperature. These temperatures are continuously recorded by thermocouples located inside the chamber. The TCB is also set to keep an atmospheric pressure equal to 1.5 bar of N_2 in order to simulate Titan's atmosphere.

A condenser is located inside of the TCB and allows the formation of liquids. As shown on Fig. 1, once Titan's temperature is reached, the liquids are poured in a Petri dish that is continuously weighted by a balance. We thus deduce the evaporation rate of the liquids by the recorded loss of mass over the time at steady Titan's pressure and temperature conditions. We also use a Nicolet 6700 FTIR Spectrometer to monitor the evaporation of liquid methane using the analysis of infrared spectra.

Mass onitoring of the evaporation

Figure 1 shows the mass and temperature evolution with time. The decrease of mass occurs at steady Titan's temperatures (between 90 and 94 K), with a mean temperature during the evaporation of 93 K. The pressure is equal to 1.5 bar.

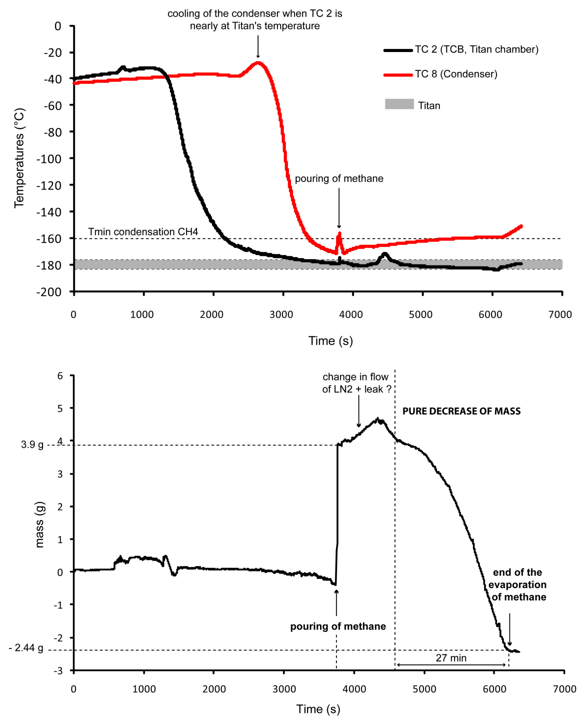

Figure 1: Temperature and mass recordings versus time. The condenser is cooled to synthesize liquid methane from gas once Titan's temperatures are almost reached in the TCB under Titan's pressure. The mass sharply increases when the liquids are poured in the Petri dish and then decreases.

A linear fit is applied to the decreasing part of the mass curve as a first approximation to evaluate the methane evaporation rate. We thus found a loss of mass of 0.006 g/s, corresponding to a liquid methane evaporation rate of 2.79 mm/hr. We then compared this to theoretical evaporation calculations for an open system using Ingersoll's equation (Eq. 1) [10].

$$E_{CH_4} = 0.17\, D_{CH_4/N_2} \frac{\rho_{sat}}{\rho_{sol}} \left[\frac{\frac{\Delta\rho}{\rho} g}{\nu^2} \right]^{\frac{1}{3}}, \qquad (1)$$

with E_{CH_4}: the evaporation rate of liquid methane (g/s), D_{CH_4/N_2}: the interdiffusion coefficient of methane and nitrogen vapors (m/s), ρ_{sat} and ρ_{sol}: respectively the saturation density of methane vapor and the density of liquid methane (kg/m^3), g: the gravitational acceleration (m/s^2), $\Delta\rho/\rho$: the density difference of the gas mixture of methane and nitrogen between the surface and the atmosphere, and ν: the kinematic viscosity of nitrogen (m/s). Using this equation, we find a theoretical evaporation rate equal to 2.92 mm/hr.

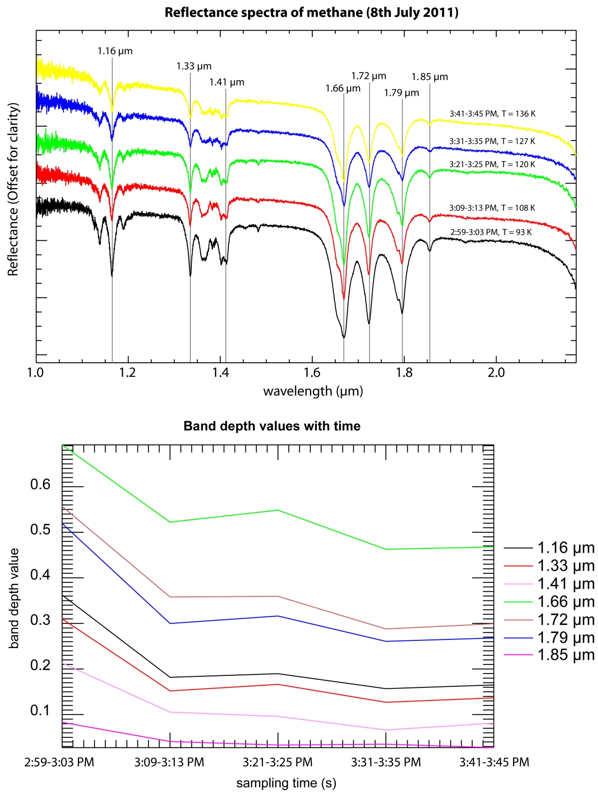

Figure 2: Top: example of FTIR spectra of liquid methane acquired during a run at Titan's pressure. Bottom: computed band depths values from the liquid methane spectra.

An additional experiment under Titan's conditions led to a measured evaporation rate of liquid methane equal to 2.09 mm/hr at a mean temperature of 91 K. At such a temperature, theoretical calculations with Eq. 1 predict an evaporation rate equal to 2.10 mm/hr. First measurements are therefore in close agreement with theoretical computations.

Spectroscopic monitoring of the evaporation

We also aim at monitoring the evaporation of liquid methane using infrared spectra acquired between 1.0 and 2.6 μm with a spectral sampling of about 1 cm^{-1}. The first results of spectra acquisition at Titan's pressure are shown on Fig. 2. Unfortunately, temperatures were higher than Titan's ones during the acquisition of almost any spectra (ranging from 93 K up to 137 K).

Methane possesses absorption bands in the infrared part of the electromagnetic spectrum, centered at 1.16, 1.33, 1.41, 1.66, 1.72, 1.79 and 1.85 μm [11]. Each of these bands can be characterized by its depth. The deeper is an absorption band, the more abundant is liquid methane in the dish. We therefore computed these band depths over the time using the formula of Massé et al. [12] (see Fig. 2).

During the evaporation, the absorption bands are shortening. The increase of the band depths during the 3rd record can be attributed to an additional pouring of liquid methane remaining in the condenser. Further work is needed to better understand the evaporation recording via the infrared monitoring, in order to potentially derive an empirical evaporation law from the spectra. This law would confirm the mass loss rate evaluated both from the experimental measurements and theoretical calculations.

Conclusion

Experiments on evaporation rates of liquid hydrocarbons are great of interest to understand the behavior of such liquids on Titan's surface. This can be responsible of shorelines moving over the time and therefore allows a better comprehension of geologic/ "hydrologic" processes acting on Titan.

First measurements of methane evaporation rates realized under simulated Titan pressure and temperature conditions with the Titan Module seem to be in good agreement with theoretical evaporation rates computed using empirical equations. Future work will include the measurement of the evaporation of liquid methane, ethane (the first photochemical product of methane photodissociation) and methane-ethane mixtures. The influence of other hydrocarbons, such as acetylene (C_2H_2), detected by the Huygens probe after landing on Titan's surface [13] and predicted to be involved in Titan's lakes chemistry as a dissolved compound like "salts" [14], will also be investigated during crystallisation of soluble crusts experiments. These experiments will be useful for the study of dissolution processes that can occur on Titan's surface, as observed lake morphologies seem to suggest [15, 16].

Acknowledgments

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