EPSC Abstracts
Vol. 13, EPSC-DPS2019-906-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

Volatiles in Titan's lower atmosphere: Reinterpretation of Huygens-GCMS data

Thomas Gautier (1), Joseph Serigano (2), Sarah M. Hörst (2) and Melissa G. Trainer (3)
(1) LATMOS-IPSL, CNRS – Sorbonne Université – UVSQ, France (2) Johns Hopkins University, Maryland, USA (3) NASA GSFC, Maryland, USA (thomas.gautier@latmos.ipsl.fr)

Abstract

Using a novel approach, we reanalyzed data acquired by the GCMS instrument aboard Huygens during its descent to Titan. We were able to retrieve concentration of several key volatile species in Titan's troposphere and their vertical profiles.

1. Introduction

Cassini-Huygens employed an array of observational methods at Titan including remote sensing techniques, upper atmosphere in situ sampling, and the descent of the Huygens probe directly through the atmosphere to the surface [1]. More than a decade later, the data acquired by the instruments on the Huygens Probe remain the only in situ measurements in Titan's deep atmosphere. In particular, the Gas Chromatograph Mass Spectrometer (GCMS) experiment on Huygens performed hundreds of mass spectra analyses below 150 km [2]. However, there has not yet been a comprehensive attempt to extract the identity and abundances of many minor components of the GCMS spectra, and at least 60% of the signal in the GCMS spectra has not been identified yet. For example, ethane, the most abundant hydro-carbon produced by methane photolysis and retrieved by both remote observations of the lower stratosphere by CIRS [3,4] and by numerical models (e.g., [5]), is strikingly absent from GCMS measurements during its descent. The absence of ethane in data near the surface can be explained by ethane condensation, but its non-detection in the first measurements above 100 km remains one of the major discrepancies in our understanding of Titan. In addition to ethane, many organics predicted both by models and measurements at higher altitude remain unquantified in GCMS.

We present a re-analysis of the GCMS data collected during Huygens' descent, leveraging recent advances in both knowledge of Titan's atmosphere and mass spectral deconvolution for organic species, to identify and quantify the trace species in Titan's troposphere.

2. Methods

2.1 Flight and calibration data retrieval

More than 13,000 stage 2 mass spectra acquired by the instrument during its descent toward Titan were retrieved from the Huygens GCMS Descent Package on the NASA PDS. Out of these thousands of mass spectra, ~600 were found of sufficient quality for our study. The selected data were mass spectra acquired at a 70 eV ionization energy, and for which Titan's atmosphere was sampled directly through two controlled leaks to the instruments. These data cover the entire descent of Huygens starting at 146 km of altitude above Titan's surface, and an additional 72 minutes of operation at the surface. Unfortunately, calibration data for the GCMS instrument have been scarcely acquired and/or archived and only very few of these calibration data were retrieved.

2.2 Mass spectra decomposition

We use the fragmentation pattern of the molecules detected by the mass spectrometer of the GCMS instrument to decompose the mass spectra acquired by GCMS below 146 km at Huygens landing site. This method has been applied successfully to INMS data of Titan's higher atmosphere during Cassini flybys [6], which required knowledge of the INMS calibration data.

Such calibration data was unfortunately unavailable for the GCMS instrument. Using a novel Monte-Carlo approach to handle molecule fragmentation in the mass spectrometer ionization chamber, we were able to overcome the lack of calibration data for the GCMS instrument.

3. Results and conclusion

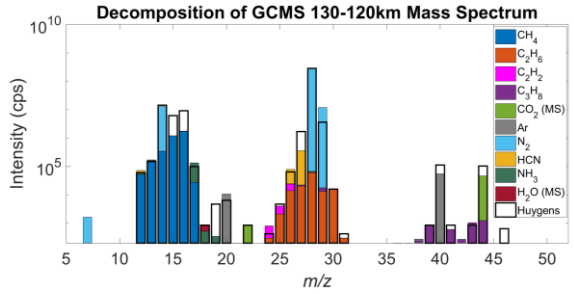

Figure 1: Decomposition result between 130 and 120 km above Titan. The black line corresponds to the measured signal, while the color bar corresponds to the relative contribution and fragmentation patterns of each species retrieved by our decomposition.

This allowed us to decompose the mass spectra acquired by Huygens during its descent, from 135km altitude down to the surface. We thus retrieved the relative abundances of volatiles species in Titan's lower atmosphere. Figure 1 presents the decomposition result for the mass spectra acquired by GCMS between 130 and 120 km above Titan's surface between *m/z* 5 and 50. We were able to clearly identify and relatively quantify not only CH_4, N_2 and Ar as in the original GCMS paper [2], but we also identify 5 new species in this mass spectrum, including ethane. By decomposing the mass spectra at every altitude during Huygens descent, we obtained the vertical profile of major volatile species in Titan's lower atmosphere. Figure 2 presents the preliminary methane signal vertical profile.

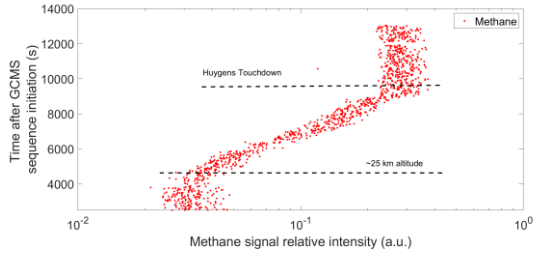

Figure 2: Preliminary retrieved vertical profile of methane as a function of time during Huygens descent. Bottom and top dashed lines correspond to Huygens crossing the ~25 km barrier and touchdown respectively.

In summary, by applying a novel data decomposition approach we were able to retrieve the composition in volatiles in Titan's lower atmosphere from GCMS data. These data are of prime importance for the study of Titan's troposphere as being the only available measurements for volatiles in this complex region.

Acknowledgements

This work was financially supported by the NASA Cassini Data Analysis Program.

References

[1] Owen, T., Planetary science: Huygens rediscovers Titan, Nature 438(7069), pp. 756-757, 2005

[2] Niemann, H. B., S. K. Atreya, S. J. Bauer, G. R. Carignan, J. E. Demick, R. L. Frost, D. Gautier, J. A. Haberman, D. N. Harpold, D. M. Hunten, G. Israel, J. I. Lunine, W. T. Kasprzak, T. C. Owen, M. Paulkovich, F. Raulin, E. Raaen and S. H. Way: The abundances of constituents of Titan's atmosphere from the GCMS instrument on the Huygens probe, Nature 438(7069), pp. 779-784, 2005

[3] Bézard, B.; Yelle, R.; Nixon, C. A.: The Composition Of Titan's Atmosphere, In Titan: Surface, Atmosphere and Magnetosphere, Eds: I. Muller-Wodarg, C. Griffith, E. Lellouch and T. Cravens, Chap. 6, Cambridge University Press, 2014.

[4] Vinatier S., B. Bézard, T. Fouchet, N. A. Teanby, R. de Kok, P.G.J. Irwin, B. J. Conrath, C. A. Nixon, P. N. Romani, F. M. Flasar, A. Coustenis: Vertical abundance profiles of hydrocarbons in Titan's atmosphere at 15° S and 80° N retrieved from Cassini/CIRS spectra, Icarus 188 (1), pp. 120-138, 2007

[5] Lavvas, P., C. A. Griffith and R. V. Yelle: Condensation in Titan's atmosphere at the Huygens landing site, Icarus 215(2), pp. 732-750, 2011

[6] Cui, J., R.V. Yelle, V. Vuitton, J.H. Waite, W.T. Kasprzak, D.A. Gell, H.B. Niemann, I.C.F. Muller-Wodarg, N. Borggren, G.G. Fletcher, E. L. Patrick, E. Raaen, B.A. Magee: Analysis of Titan's neutral upper atmosphere from Cassini Ion Neutral Mass Spectrometer Measurements, Icarus 200, pp. 581-615, 2009