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Continuous monitoring with VIMS/Cassini of cloud activity in Titan's atmosphere from southern summer (2004) to northern spring (2010)

S. Rodriguez (1), S. Le Mouélic (2), P. Rannou (3,4), C. Sotin (2,5), Jason. W. Barnes (6), C. A. Griffith (7), R.H. Brown (7), K.H. Baines (8), B. J. Buratti (5), R.N. Clark (9), P.D. Nicholson (10)

(1) Laboratoire AIM, Université Paris 7/CNRS/CEA-Saclay, DSM/IRFU/SAp, France, (sebastien.rodriguez@cea.fr / Fax: +33 (0)1 69 08 65 77), (2) Laboratoire de Planétologie et Géodynamique, CNRS UMR-6112, Université de Nantes, France, (3) Groupe de Spectrométrie Moléculaire et Atmosphérique, Université de Reims Champagne-Ardenne, France, (4) Service d'Aéronomie, Université Versailles-St-Quentin, France, (5) Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, (6) NASA Ames Research Center M/S 244-30, Moffett Field, CA 94035, (7) Lunar and Planetary Lab and Steward Observatory, University of Arizona, Tucson, AZ, USA, (8) Space Science and Engineering Center, University of Wisconsin - Madison, Madison, Wisconsin 53706, USA, (9) USGS, Denver Federal Center, Denver, CO, USA, (10) Cornell University, Dept. of Astronomy, Ithaca, NY, USA.

Abstract

We report on the monitoring of cloud activity in Titan's atmosphere over a period which includes the equinox. Clouds have been observed by the Visual and Infrared Mapping Spectrometer (VIMS) onboard the Cassini spacecraft since the insertion. A semi-automated method is used to detect cloud events in each VIMS cube acquired since July 2004. Statistics are drawn on the location of the clouds and their evolution. It is shown that the cloud activity has recently decreased at the northern pole. The first clouds at northern mid-latitudes were detected a few terrestrial months after the Titan's equinox. Few clouds have been detected in the equatorial area. Clouds at southern mid-latitudes are still present although the activity in this area seems to decrease, especially around the south pole. Such observations are compared with predictions of Global Circulation Models (GCMs) in order to better constrain such models and to better understand the processes which drive Titan's weather.

1. Introduction

Methane and ethane play a central role in Titan's atmospheric activity and meteorological cycle. Near Titan's surface and in the lower part of its atmosphere, they can experience gaseous, liquid and solid states and thus can form clouds and possibly rains. The search for Titan's clouds location and the monitoring of their long-term activity contribute to the global understanding of Titan's climate and meteorological cycle that are key questions to be addressed by the Cassini-Huygens mission.
Since its insertion into Saturn's orbit in July 2004, the Cassini mission complements ground-based observations and provides new constraints on the seasonal evolution of Titan's meteorology.
Continuing and completing the work of [1], we present here the mapping of all Titan's clouds detected in the full VIMS dataset [2] between the Cassini insertion in July 2004 and April 2010, (i.e. during 67 close flybys of Titan, one every month in average, between Titan's southern summer and early northern spring).

2. Detecting Titan's clouds with VIMS

Between July 2004 (flyby T0) and April 2010 (T67), VIMS acquired more than 20,000 hyperspectral images of Titan in the 0.3-5.1 µm spectral range [11]. By eliminating redundant, night side, limb viewing, very low time exposure and also very small images, we reduced the dataset down to ~2,000 images useful for the purpose of clouds detection. This still represents several millions of spectra, preventing the effective use of a manual detection technique alone. We therefore developed a semi-automated algorithm to detect clouds in VIMS images [1]. We found that the most robust automated detection criterion to separate pixels that contain cloudy spectral

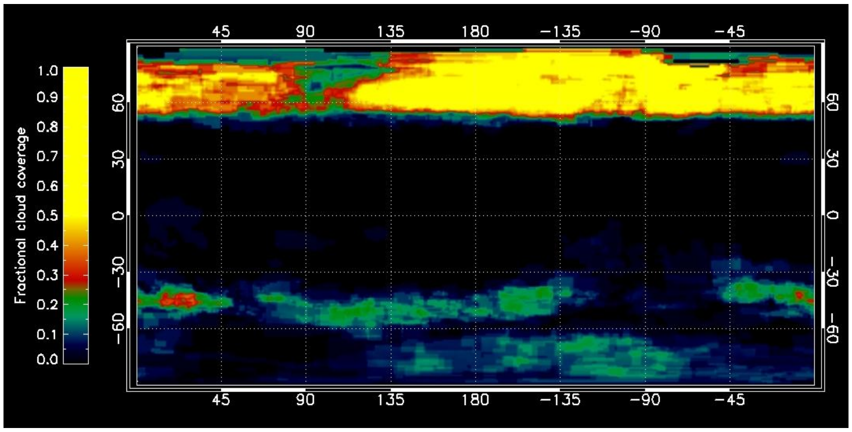

Figure 1: Mean fractional cloud coverage in Titan's atmosphere between July 2004 and April 2010.

component from any other components is to use the simultaneous widening of the 2.75 and 5 µm windows. Automated detections are then systematically visually checked to confirm their relevance. This technique developed by [1] was recently improved by adding the possibility to select regions of interest, to mask Titan's bright limb and to manually check detections with the help of the 2.1 µm reference image, particularly sensitive to tropospheric clouds.

3. VIMS global mapping of Titan's clouds during 6 years, including the equinox

Figure 1 shows the mean fractional cloud coverage between July 2004 and April 2010. This map was obtained by dividing the number of time a cloud was observed by VIMS at each region of Titan by the number of flybys during which each region was imaged by VIMS. We find that clouds appear clustered in three distinct latitude regions of Titan: the south polar region (poleward 60°S), the north polar region (poleward 50°N), and a narrow belt centered around latitude 40°S. South polar clouds are present in 2004, disappear, and reappear in early 2006 to progressively and completely vanish since mid-2008. A north polar cloud is systematically detected during the mission at latitudes higher than 50-60°N, but as observed at the south pole, the cloud activity near the north pole shows evidences of declining activity as equinox is approaching (August 2009) (see also [3]). Temperate clouds are regularly observed between 55°S and 30°S. Only very few occurrences of clouds are found in equatorial regions (blue patches in Figure 1). They appear slightly more frequent around equinox.

4. Comparison with Global Circulation Models

The cloud evolution monitored by VIMS shows that significant atmospheric changes occurred during our observing time period. Since clouds trace atmosphere circulation, Global Climate Models (GCMs) [4] enables the interpretation of the time evolution revealed by our data.

The model from [4] shows that the south pole clouds should be sporadic by nature, as should the mid-latitude clouds, and that the decreasing intensity of the south polar cloud events seen in our data is due to a change in the south polar circulation, which temporarily interrupts the transport of methane to the poles. The north polar clouds appear confined northward of 62°N as predicted. The large temporal stability of this north polar cloud during southern summer and progressive declining as equinox is coming is consistent with GCM predictions [4]. Clouds are produced during the winter, by a constant influx of ethane and aerosols from stratosphere. Mid-latitude clouds essentially appear in 2004 and, with a high frequency between May 2006 and April 2010. The coincident vanishing of cloud's activity at both poles a few months before the equinox clearly indicates evidence of the seasonal circulation turnover on Titan.

References

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