FOLLOWING TWO YEARS OF TITAN CLOUD EVENTS WITH CASSINI/VIMS. S. Rodriguez[1], S. Le Mouelic[2], G. Tobie[2], C. Sotin[2], P. Rannou[3], C. Griffith[4], M. Hirtzig[2], J.W. Barnes[4], B.J. Buratti[5], R.H. Brown[4], P.D. Nicholson[6], K.H. Baines[5] and the VIMS Science team, [1] Laboratoire AIM, Centre d'étude de Saclay, DAPNIA/Sap, Centre de l'Orme des Merisiers, bât. 709, 91191 Gif/Yvette Cedex France, (email: sebastien.rodriguez@cea.fr), [2] Laboratoire de Planétologie et de Géodynamique de Nantes, France, [3] Service d'Aéronomie, Université Versailles-St-Quentin, France, [4] Lunar and Planetary Lab and Stewart Observatory, University of Arizona, Tucson, USA, [5] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA, USA, [6] Cornell University, Astronomy Department, USA.

Introduction: The atmosphere of Saturn's largest moon, Titan, contains 2% of methane, and up to 5% on the surface. Methane on Titan may participate to a meteorological cycle in a way similar to the terrestrial hydrological cycle, including methane clouds, rain, surface or sub-surface liquids and evaporation. Transient cloud activity in Titan's was detected as early as 1995 through ground-based observations **[1,2,3,4, 5,6,7,8,9]**, and their latitudinal distribution is interpreted as a natural consequence of the atmospheric global circulation **[10]**.

The Visual and Infrared Mapping Spectrometer (VIMS) acquires hyperspectral images in 352 contiguous spectral channels between 0.3 and 5.2 µm **[11]**. Since its insertion into Saturn orbit in July 2004 and until late 2006 spring, Cassini orbiter has done 15 close flybys of Titan. At these occasions, VIMS accumulated a large amount of hyperspectral images of Titan from global scale at low to medium resolution (400 to 25 km/pixel) to small scale at high resolution (up to 2 km/pixel). Observations by VIMS during some close Titan's flybys already provide crucial information to track the cloud activity and to determine their morphologies and their basic properties **[12,13]**.

Here we present the VIMS observations of Titan's clouds for almost a two years duration, between autumn 2004 and summer 2006, and propose the first high resolution global mapping of Titan's clouds coverage.

Detecting clouds of Titan with VIMS: Clouds systems are clearly visible in some VIMS global scale images at some wavelengths, making the VIMS instrument a powerful tool to detect such Titan's atmospheric events.

Owing to specific spectral signatures, clouds on Titan can be unambiguously distinguished from other atmospheric or surface features (**Figure 1a**). In particular, clouds spectra systematically present in their spectrum two small "peaks" at 4.047 and 4.552 µm and a particularly large and bright methane windows at 2.75 and 5 µm. These spectral features do not show up simultaneously in the case of surface or limb pixels in the images. **Figure 1a** shows an example of spectra taken from three different regions over Titan within the same scene: surface, limb and clouds. This figure illustrates the spectral differences that can be observed between clouds and any other surface or atmospheric features on Titan. We use these particular characteristics of the clouds spectra (see **Figure 1b**) to automatically detect cloudy events in the VIMS images. The detection is limited by the Cassini flybys geometry and frequency and at the present stage of the computations this method only allows us to detect large and thick clouds without any indications about their altitude or nature (ethane or methane clouds?).

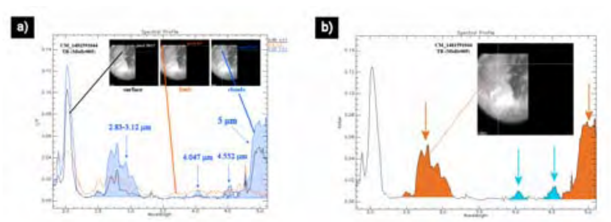

Figure 1. *Left (a):* Example of three very different Titan's spectra extracted from a single VIMS observation. Surface spectrum is in black, limb spectrum in orange and a typical "cloudy" pixel spectrum in blue. The "cloudy" spectrum is the only one to simultaneously present large atmospheric windows (in particular in the 3 and 5 µm spectral regions) and two small peaks at 4 and 4.5 µm, emerging from the noise in some cases. *Right (b):* Typical "cloudy" spectrum (same as the one showed in (a)) with an emphasis in blue and orange on spectral criteria applied by our automated cloud detection method.

Global mapping of Titan's clouds between October 2004 and July 2006: We applied the spectral detection criteria described in the previous section to the whole VIMS dataset between autumn 2004 (corresponding to the first close Titan's flyby in October 2004, tagged TA) and summer 2006 (15th close Titan's flyby in July 2006, tagged T15). We isolate within each VIMS data cube only the pixels that present spectral cloud characteristics and reproject them onto Titan's surface map (ISS basemap).

Figure 2 shows the summary of all the cloud events which have been detected with this method. Large south pole clouds outbursts are clearly visible. Clusters of clouds also show up in the southern hemisphere at higher latitudes of ~40°S, as it was already reported through isolated studies by **[12]**.

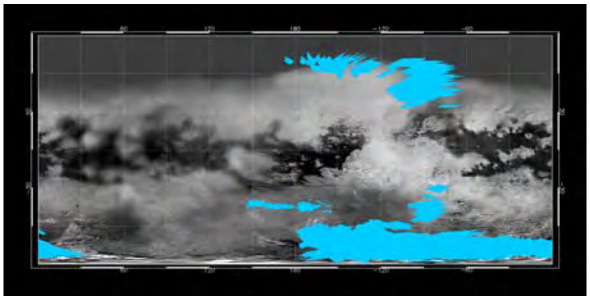

Figure 2. Global spatial distribution of clouds (in blue) in Titan's atmosphere as derived from all VIMS observations between October 2004 and July 2006.

Patches of clouds are detected in the northern hemisphere near 50-60°N, confirming previous reports of **[13]**. Some north polar clouds extend at lower latitude (down to 35-40°N). These observations are consistent with the predictions of the global circulation model (GCM) proposed by **[10]**, indicating that the general patterns of cloud events in Titan's atmosphere, almost symmetric in latitudes, is likely to be latitudinally and seasonally controlled by large cells of airmass uplift generated by a global atmospheric circulation.

Clouds distribution for a two years period: 14 clouds maps, one for each close flyby from October 2004 until July 2006, are presented in **Figure 3**. These maps allow us to identify the individual clouds systems present in the hemisphere imaged by VIMS during each flyby and accurately follow their motion and persistence with time. The large clouds outburst at Titan's south pole, present in October 2004, vanish for almost one year and reappear in December 2005. The same behaviour is observed for the north polar clouds with a one month shift. With a maximum duration of one month, the 2005 south polar outburst was way more transient than previous southern events (seen by Cassini and ground-based telescopes in 2004, and only followed by ground-based telescopes before) that were lasting for at least 6 months for the shortest. Transient middle latitudes cloud events are also visible in both hemispheres and seem to develop thick clouds system at preferential longitudes (every 90° starting from the center of the anti-Saturn hemisphere), but with a periodicity still hard to accurately determine. These clouds may have an orographic origin in addition to the global circulation forcing, and may hint for local reliefs and the presence of surface features releasing methane from the interior, such as cryovolcanos.

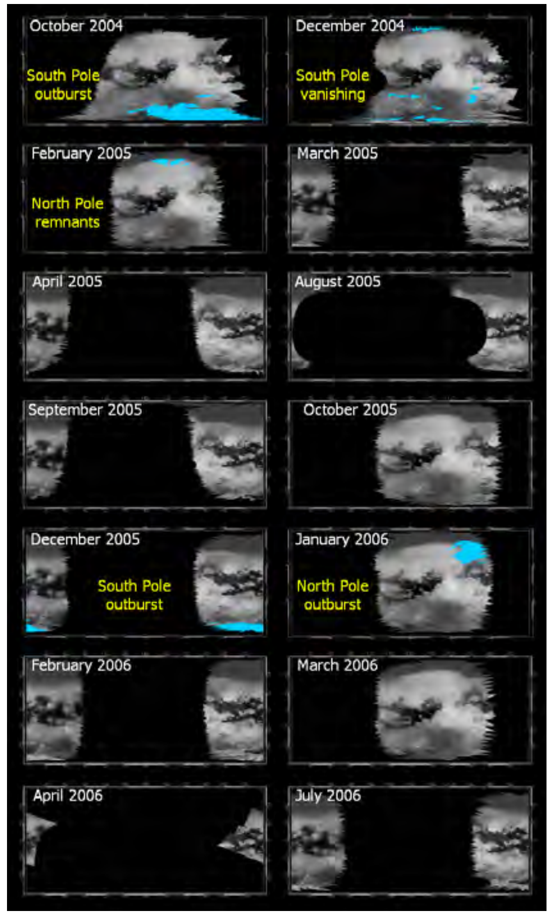

Figure 3. Occurrence maps of clouds (in blue) in Titan's atmosphere as derived from VIMS observations for each Cassini close flyby between October 2004 and July 2006.

Conclusions and perspectives: We present here measurements from VIMS of the occurrence and location of Titan's clouds and propose the first global mapping of Titan's clouds coverage between autumn 2004 and summer 2006. This mapping allows us to identify individual clouds systems and follow their evolution in time. Clouds persistence, latitudes and periodicity can then be compared with GCM predictions. These new constraints, along with ground-based observations, particiipate to a better comprehension of Titan's climate.

References: **[1]** Griffith C.A. et al. (1998), *Nature, 395, 575.* **[2]** Griffith C.A. et al. (2000), *Science, 290, 509*. **[3]** Brown M.E. et al. (2002), *Nature, 420, Issue 6917, 795*. **[4]** Roe H.G. et al. (2002), *ApJ, 581, Issue 2, 1399*. **[5]** Gibbard S.G. et al. (2004), *Icarus, 169, Issue 2, 429*. **[6]** Roe H.G. et al. (2005), *ApJ, 618, Issue 1, L49*. **[7]** Bouchez A.H. et al. (2005), *ApJ, 618, Issue 1, L53*. **[8]** Roe H.G. et al. (2005), *Science, 310, Issue 5747, 477*. **[9]** Schaller E.L. et al. (2006), *Icarus, 182, Issue 1, 224*. **[10]** Rannou P. et al. (2006), *Science, 311, Issue 5758, 201*. **[11]** Brown R.H. et al. (2003), *Icarus, 164, 461*. **[12]** Griffith C.A. et al. (2005), *Science, 310, 474*. **[13]** Griffith C.A. et al. . (2006), *Science, 313, 1620*.