

LIQUID HYDROCARBONS ON TITAN'S SURFACE? HOW CASSINI ISS OBSERVATIONS FIT INTO THE STORY (SO FAR). E.P. Turtle¹, D.D. Dawson¹, S. Fussner¹, E. Hardegree-Ullman¹, A.S. McEwen¹, J. Perry¹, C.C. Porco², R.A. West³, and the *Cassini* ISS Team, ¹Lunar and Planetary Lab., Univ. of Arizona, Tucson, AZ 85721; turtle@lpl.arizona.edu, ²Space Sci. Inst., Boulder, CO 80301, ³Jet Propulsion Lab., Pasadena, CA 91109.

Introduction: Titan is the only satellite in our Solar System with a substantial atmosphere, the origins and evolution of which are still not well understood. Its primary (>90%) component is nitrogen, with a few percent methane and lesser amounts of other species [e.g., 1,2]. Methane and ethane are stable in the liquid state under the temperature and pressure conditions in Titan's lower atmosphere and at the surface [e.g., 3-5]; indeed, clouds, likely composed of methane, have been detected [e.g., 6-8]. Photochemical processes acting in the atmosphere convert methane into more complex hydrocarbons, creating Titan's haze and destroying methane over relatively short timescales [e.g., 9,10]. Therefore, it has been hypothesized that Titan's surface has reservoirs of liquid methane which serve to resupply the atmosphere [e.g., 11,12].

Early observations of Titan's surface revealed albedo patterns [e.g., 13] which have been interpreted as dark hydrocarbon liquids occupying topographically low regions between higher-standing exposures of bright, water-ice bedrock [e.g., 14,15], although this is far from being the only explanation for the observed albedo contrast [e.g., 8,16]. Observations made by the Imaging Science Subsystem [ISS; 17] during *Cassini's* approach to Saturn and its first encounters with Titan show the bright and dark regions in greater detail (Fig. 1) [e.g., 8,18,19], but have yet to resolve the question of whether there are liquids on the surface.

Observational constraints: Earth-based and *Cassini* observations have provided important, although seemingly contradictory, constraints on the distribution, or even the presence, of liquids on Titan's surface. Radar measurements performed using Arecibo revealed specular components in 75% of the returns received from globally distributed sub-Earth longitudes at ~26° S [20; Fig. 1]. Campbell *et al.* [20] interpreted these data to indicate the presence of liquid hydrocarbons on Titan's surface based on the cross-sections and RMS (root mean square) slopes of the specular component in the radar echoes and the derived values for Fresnel reflectivities and dielectric constants. There is no obvious correlation between the locations of specular signals detected at 13 cm and albedo features observed by ISS at 938 nm (Fig. 1), although the radar scattering areas are generally ~100 km, which is comparable to the lowest ISS resolution (for areas imaged only early during Saturn approach) and is well resolved over much of Titan.

There have been no reports of specular reflections at visible or IR wavelengths in almost a decade of Earth-based observations or in *Cassini* observations targeting the specular point [e.g., Figs. 1, 2; 7,8,21]. To date, ISS has observed Titan during Saturn approach, April-June 2004, and three encounters: one distant (T0, 339000 km, 2 July 2004) and two quite close (TA and TB, both 1200 km, on 26 Oct. and 13 Dec. 2004) [8].

During T0, sufficient time elapsed between observations that the location of the specular point traversed a significant distance (Figs. 1, 2). If the regions covered contained liquid, the signal would be expected to be enhanced by $\geq 10\%$ [22] over an area the size of which depends on surface roughness: narrow for a calm liquid, broader for a surface disturbed by waves. To distinguish between inherent albedo and specular enhancement, we created ratio images using two images, well separated in time. The change in the location of the specular point would cause any signal due to specular reflections to appear as a bright area neighbored by a dark area in the ratio images. Brightness variations can be seen here at small scales, due to slight image misregistration, and very large-scales, due to imperfect calibration, but there is no evidence for specular reflections (Fig. 2).

The geometries of *Cassini's* Titan encounters to date have not allowed observations of the specular point directly over dark areas. However, the specular-point locations during TA and TB both fell near enough to bright-dark boundaries (Fig. 1) that if either unit were a liquid, we would expect to see an enhanced return in these observations [22]. None was detected.

Other *Cassini* observations are difficult to reconcile with the hypothesis that Titan's dark features represent liquids. ISS images have revealed what appear to be streaks of bright material that overlie dark regions and have been interpreted to be eolian in nature [8]. Also, a high-resolution image taken by *Cassini's* Visual and Infrared Mapping Spectrometer (VIMS) during TA appears to show considerable structure in a dark region [7,21]. Alternatively, *Cassini* RADAR SAR data from TA include some small, very dark features that could be consistent with small patches of liquid [23].

Although there are some indications of liquids on Titan's surface, *Cassini* observations have yet to provide conclusive evidence for or against this hypothesis. Further *Cassini* exploration, at various wavelengths, is planned. Of course, imminent *Huygens* observations may well provide the answer even sooner!

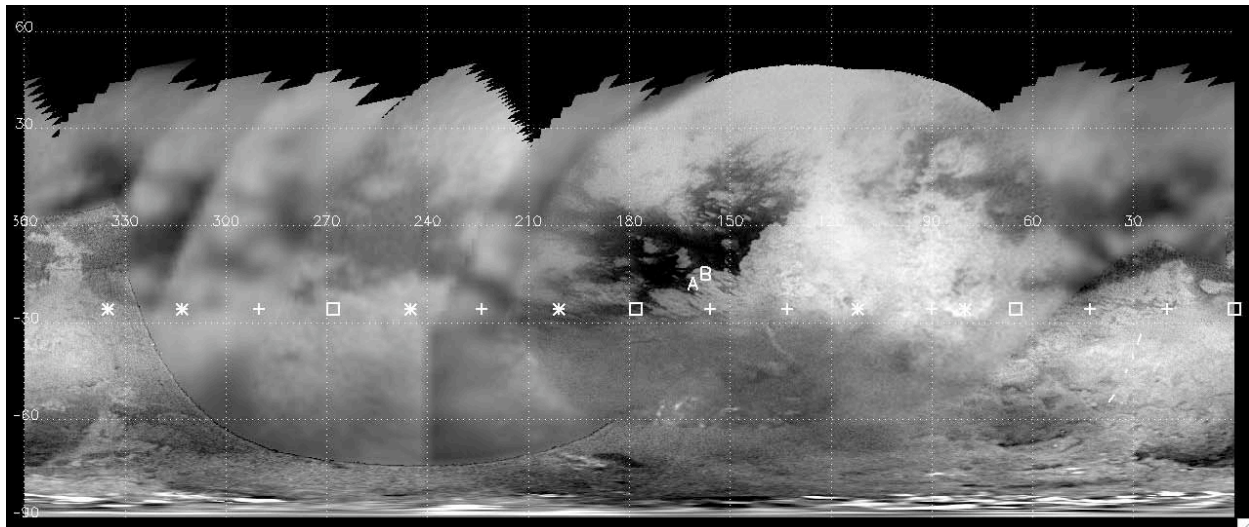


Fig. 1: 938-nm, albedo map of Titan from *Cassini* ISS [8]. The resolution varies from 10 to 176 km. The broken curve between $\sim 30^\circ$ and 60° S around 30° W indicates the track of the specular point during ISS observations made during T0 (Fig. 2). The points labeled “A” and “B” are the locations of the specular point in higher-resolution ISS observations acquired during TA and TB. Points at $\sim 26^\circ$ S latitude are the locations of Arecibo radar measurements: *s indicate a specular return and RMS slope $< 1.2^\circ$; squares indicate no specular component; and +s indicate intermediate RMS slopes [20 and Campbell, Black, Carter, and Ostro, unpublished data]. (Very bright patches near the South Pole are tropospheric clouds. Unilluminated northern (winter) regions are not illustrated here.)

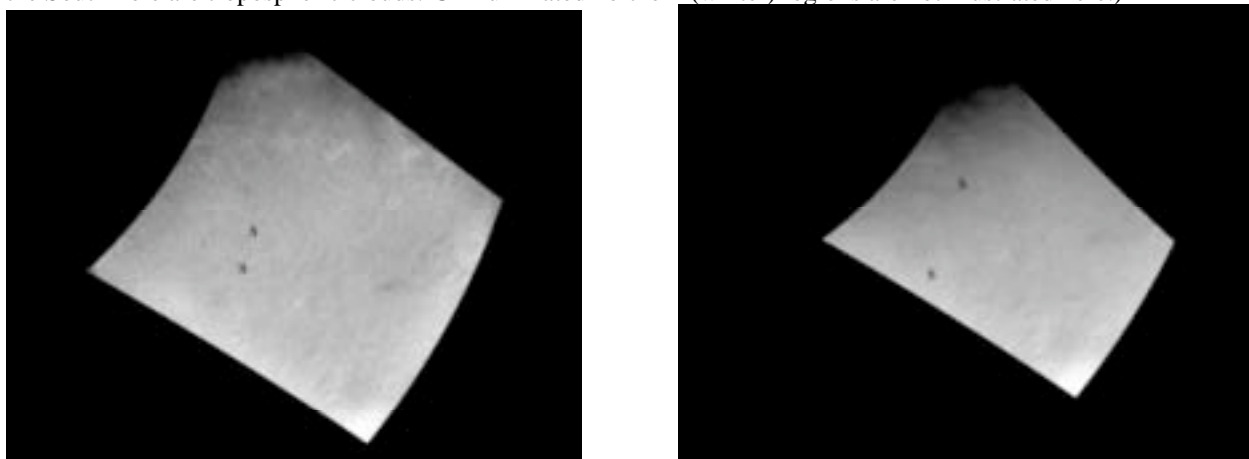


Fig. 2: Ratio images made from pairs of 938-nm images of Titan acquired at different times during *Cassini*'s T0 encounter. Specular point locations (cf. Fig. 1) at the time of each image are indicated by “s”.

References: [1] Broadfoot, A.L. *et al.*, *Science*, 212, 206-211 (1981) [2] Hanel, R. *et al.*, *ibid.* 192-200 (1981) [3] Tyler, G.L. *et al.*, *ibid.* 201-206 [4] McKay, C.P. *et al.*, *Icarus*, 129, 498-505 (1997) [5] Samuelson, R.E. *et al.*, *Space Sci. Rev.*, 104, 191-208 (2002) [6] Griffith, C.A. *et al.*, *Nature*, 395, 575-578 (1998) [7] Sotin, C. *et al.*, *Nature*, submitted (2005) [8] Porco, C.C. *et al.*, *Nature*, submitted (2005) [9] Strobel, D.F., *Planet. Space Sci.*, 30, 839-848 (1982) [10] Yung, Y.L. *et al.*, *Ap. J. Suppl.*, 55, 465-506 (1984) [11] Lunine, J.I. *et al.*, *Science*, 222, 1229-1230 (1983) [12] Lunine, J.I., *Rev. Geophys.* 31, 133-150 (1993) [13] Smith *et al.*, *Icarus*, 119, 336-349 (1996) [14] Lorenz, R.D. and Lunine, J.I., *Planet. Space Sci.*, in press (2005) [15]

Griffith C.A. *et al.*, *Science*, 300, 628-630 (2003) [16] McEwen, A.S. *et al.*, *LPSC XXXVI* #1968 (2005) [17] Porco, C.C. *et al.*, *Space Sci. Rev.*, 115, 363-497 (2004). [18] Perry, J. *et al.*, *LPSC XXXVI* (2005) [19] Fussner, S. *et al.*, *LPSC XXXVI* (2005) [20] Campbell, D.B. *et al.*, *Science*, 302, 431-434 (2003) [21] Sotin, C. *et al.*, *AGU Fall Mtg.*, P53A-1440 (2004) [22] West, R.W., manuscript in prep. [23] Elachi, C. *et al.*, *AGU Fall Mtg.*, P41B-02 (2004)

Acknowledgements: The authors would like to thank S. Ostro for sharing the Arecibo data and for stimulating discussions regarding possible ways to resolve the apparent discrepancy. We are also very grateful to all those who support ISS and *Cassini*.