

CASSINI IMAGING RESULTS AT TITAN A. McEwen¹, E. Turtle¹, J. Perry¹, S. Fussner¹, C. Porco², R. West³, T. Johnson³, G. Collins⁴, T. Del Genio⁵, J. Barbara⁵, and the Cassini ISS Team. ¹LPL, University of Arizona, Tucson AZ 85721, mcewen@pirl.lpl.arizona.edu, ²Space Science Inst., ³JPL, ⁴Wheaton College, ⁵NASA GISS.

Introduction: The Cassini Imaging Science Subsystem (ISS) images show striking albedo markings on the surface of Titan. In equatorial regions the albedo patterns have high contrast and exhibit prominent lineaments and linear/angular boundaries suggestive of tectonic influences or fracturing of brittle surficial materials. There are intriguing dark curving lines near the south pole. Here we present several working hypotheses to explain these patterns. We also briefly summarize atmospheric science results.

Observations: ISS began making systematic observations of Titan in April 2004 with a three-month-long approach sequence, during which the pixel scale improved from ~200 km to 35 km [1]. On July 2, 2004, shortly after Saturn orbit insertion, Cassini had a distant (339,000 km) encounter with Titan (referred to as "T0") during which images of the southern part of the sub-saturnian hemisphere and south-polar region were acquired at pixel scales of 2-3 km. The first close (1200 km) targeted flyby of Titan ("TA") occurred on 26 October 2004, followed by another close pass with similar geometry ("TB") on 13 December 2004. The best ISS filter to peer through Titan's photochemical haze to its surface is a narrow "continuum band" filter (CB3, 938 nm) centered in the best "methane window" available to ISS [2].

The smallest surface features we have been able to detect are ~5 pixels wide, as expected [2]. Most of the photons detected by the ISS through the CB3 filter have been scattered by the atmospheric haze before ever reaching the surface, and at least 70-90% (depending on phase angle and haze properties) of the light that is reflected off the surface from the nadir point is widely scattered by atmospheric haze, spreading the signal over regions up to ~100 km. The ~10-30% surface reflection that passes through the atmosphere without scattering (or perhaps via strong forward scattering and relatively little smearing) returns a weak signal, and the Modulation Transfer Function of the Cassini ISS at the Nyquist frequency reduces the contrast over ~2 pixels by an additional factor of 0.15. As a result, with reasonable estimates of surface contrast, a single medium resolution (0.5 to 3 km/pixel) image with an overall signal-to-noise ratio of ~200:1 cannot reveal surface features on scales smaller than ~5 pixels. The effects of the haze on surface visibility can also be seen by comparison of images showing the same region viewed at

different emission angles. The contrast is reduced approximately linearly with increasing emission angle, e , in degrees, although the path length is proportional to $\cos(e)$ [3].

A near-global mosaic of Titan (2-83 km/pixel) is shown (at reduced scale) in Figure 1, which reveals distinct patterns of relatively bright and dark areas. We summed multiple images to increase signal:noise and subtracted filtered images that approximate the surface signal scattered through the haze [4].

Interpretations: We interpret the surface brightness variations as being due to the presence of different surface materials (with variable albedo) rather than topographic shading, because (1) the phase angle is low in some images (14-16°), (2) such a large icy satellite probably has relatively low topographic relief [5], so any shadows or shading might not be detectable at resolutions of ≥ 1 km, and (3) the atmospheric scattering must reduce the contrast from topographic shading.

The albedo variations reveal only a few distinctly circular or concentric patterns that could indicate the presence of large impact structures, perhaps by trapping dark materials in relatively low areas [6]. Impacts from comets should produce a few hundred structures larger than 20 km in diameter per billion years [7]. We have identified only five prominent circular or concentric albedo features larger than 20 km in diameter over the ~30% of Titan imaged at better than 2 km/pixel. This means either that Titan's surface layer (up to a few km deep) is much younger than 1 Ga on average in these regions, or that the great majority of impact structures are not associated with albedo patterns that have been detected by ISS.

Titan is expected to have a surface rich in organic materials from atmospheric precipitation, of order 0.5 km deep [8]. Although ethane and methane should be liquids at Titan's surface, there are processes that could harden the precipitates [9]. The ISS images suggest that most of the surface is solid because probable wind streaks appear to be common and no specular reflections have been seen at optical wavelengths [1, 10]. In addition, VIMS has detected a grooved morphology on the dark materials [11].

Tectonic or brittle-fracture processes of some form are likely, as straight and angular lineaments and albedo boundaries are pervasive. Wind may account for east-west streaks over the equatorial region of the anti-Saturn hemisphere.

A common interpretation of Titan's high-contrast albedo patterns is that the bright regions are relatively high-standing and dark areas are liquids that have filled in the lower regions [8]. Titan's crust should be mostly water ice, so the bright regions may consist of the ice "bedrock", probably dirty ice. Several bright circular features could be the rims of impact craters in the ice "bedrock". An alternative interpretation is that some of the bright material is a relatively thin brittle coating or "crust" on top of dark material, and has been pulled apart or destroyed in place to expose dark materials. Perhaps the dark material consists of the expected organic materials precipitated from the atmosphere, although it does not necessarily remain in a liquid state. There are intriguing dark "meandering" lines at about 40-80° S, 0-90° W (Fig. 2); we can speculate that these are river channels. We anticipate that Huygens will provide 'ground truth' (or below-the-haze truth) to better calibrate the orbital data.

Atmospheric Results: In addition to convective clouds in the south-polar region, we detected mid-latitude tropospheric clouds. Tracking of cloud motions consistently yields eastward winds with

speeds as high as 34 m s^{-1} , providing the first direct evidence of super-rotation in Titan's troposphere. Clouds that are elongated east to west are observed to preferentially occur at certain latitudes, and in one case at lower altitude than the polar clouds. Upper-atmospheric banding is also apparent, being especially prominent in Titan's north polar region. A prominent haze layer is seen at 500 km altitude, higher by 150-200 km than one seen during the Voyager 2 flyby (1981), and many more tenuous haze layers have been resolved [1].

References: [1] Porco, C. et al., *Nature*, in press. [2] Porco, C. et al., *Space Science Reviews* **115**, 363-497 (2004). [3] Fussner, S. et al., this conference. [4] Perry, J. et al., this conference. [5] Perron, J.T., & de Pater, I., *Geophys. Res. Letters* **31**, 2004. [6] Lorenz, R.D. *Planet. Space Sci.* **42**, 1-4 (1994). [7] Korycansky, D.G., & Zahnle, K.J., *Planet. Space Sci.*, in press (2005). [8] Lorenz, R.D., & Lunine, J.I., *Planet. Space Sci.*, in press (2005). [9] Dimitrov, V., & Bar-Nun, A., *Icarus* **166**, 440-443 (2003). [10] Turtle, E. et al., this conference. [11] Sotin, C., et al., *Nature*, in press.

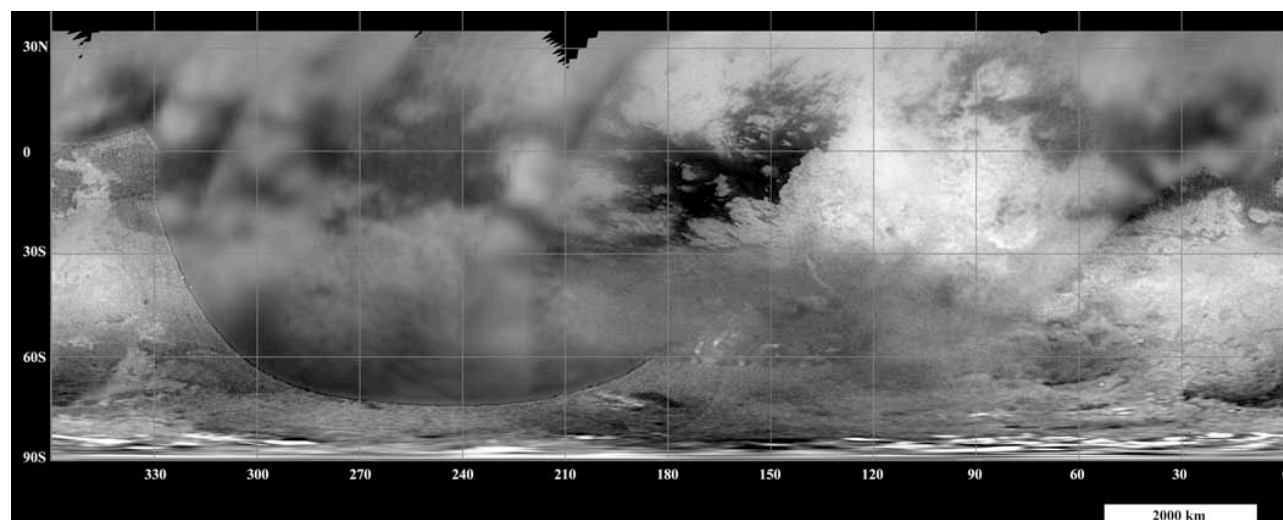


Figure 1. Global (to 35° N) mosaic of ISS images of Titan, in Simple Cylindrical projection. The very bright spots (stretched into streaks in this projection) near the south pole are clouds. The full-resolution mosaic is available at <http://ciclops.lpl.arizona.edu>.



Figure 2. Dark curving lines: river channels in the S. Polar region?