

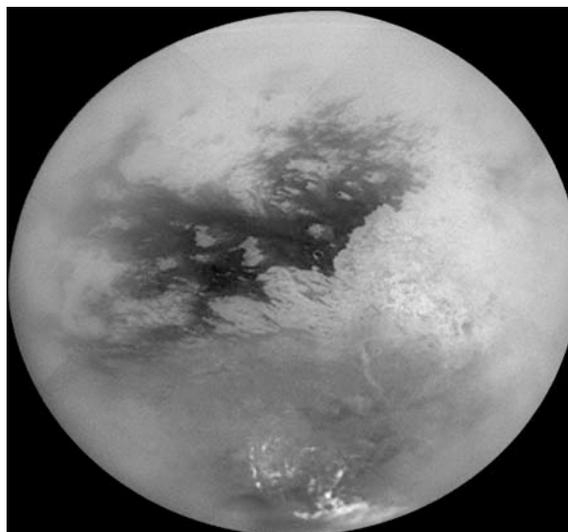
**DEPENDENCE OF SURFACE CONTRAST ON EMISSION ANGLE IN CASSINI ISS 938-NM IMAGES OF TITAN.** S. Fussner<sup>1</sup>, A. McEwen<sup>1</sup>, J. Perry<sup>1</sup>, E. Turtle<sup>1</sup>, D. Dawson<sup>1</sup>, C. Porco<sup>2</sup>, R. West<sup>3</sup>, and the Cassini ISS Team. <sup>1</sup>Lunar and Planetary Laboratory, University of Arizona, Tucson AZ 85721 (campbell@lpl.arizona.edu), <sup>2</sup>Space Science Inst., 4750 Walnut St., Boulder CO 80301, <sup>3</sup>JPL.

**Introduction:** Titan, the largest of Saturn's moons, is one of the most difficult solid surfaces in the Solar System to study. It is shrouded in a thick atmosphere with fine haze particles extending up to 500 km. [1] The atmosphere itself is rich in methane, which allows clear viewing of the surface only through narrow "windows" in the methane spectrum. Even in these methane windows, the haze absorbs and scatters light, blurring surface features and reducing the contrast of images. The haze optical depth is high at visible wavelengths, and decreases at longer (infrared) wavelengths. [2]

**Effects of Haze:** For this project, images at 938 nm were examined. This wavelength corresponds to one of the methane windows, and is the best wavelength the Imaging Science Subsystem (ISS) on the Cassini orbiter can use to image the surface of Titan. The ISS has been described by Porco, et al. [3]. In the 938nm band, methane absorption is quite weak. However, the effect of the haze on the images is significant and not well constrained. There have been many attempts to model the haze on Titan, and estimates of the optical properties vary widely depending on the exact model used. [4-8]

One property of the haze that is immediately obvious upon examining the 938nm Cassini ISS images is that the surface contrast is a strong function of emission angle. At high emission angles, where light from the surface must pass through much more haze to reach the camera, the contrast is greatly reduced. The scale of resolvable surface features also increases, limited by signal/noise from the surface; smaller features can be seen at lower emission angles. It is the dependence of contrast on emission angle that is explored here.

**Method:** Images from the CB3 (938nm) filter on the ISS narrow angle camera were used for this analysis. These particular images are from a full-disk mosaic taken during the October 26, 2004 TA Titan flyby (Figure 1). The mosaic covers the western edge of Xanadu Regio and the dark region nearby, and has a sharp light-dark boundary extending across much of the image, making it a good candidate for investigating changes in contrast as a function of emission angle.

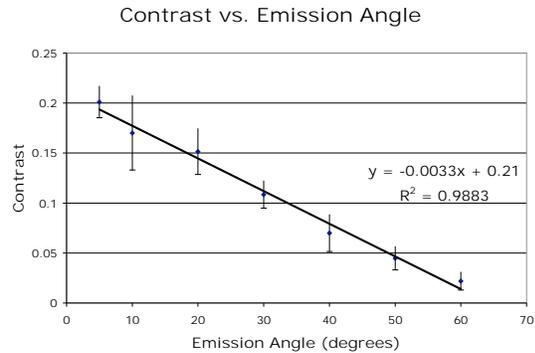


**Figure 1: Full-disk 938nm mosaic from the October 26, 2004 TA Titan flyby**

We collected data on contrast from these images (Figure 2). For each value of emission angle, we collected data at between 3 and 6 different locations, depending on how many appropriate light-dark boundaries could be found. Each data point consists of information from dark and light terrain separated by a few degrees of latitude or longitude at most. For each pair, we measured  $I_{\text{bright}}$  and  $I_{\text{dark}}$ , the I/F value for bright and dark terrain, respectively. Top-of-the-atmosphere contrast was calculated using the following formula:

$$C = 2 * (I_{\text{bright}} - I_{\text{dark}}) / (I_{\text{bright}} + I_{\text{dark}}).$$

Since this contrast is measured at the top of the atmosphere, after the light has passed through the atmosphere and haze, and also includes a haze contribution that does not interact with the surface, the actual surface contrast must be significantly greater than these values. The errors given in Figure 2 are the standard deviation of the contrast at each emission angle. At angles greater than 60°, the contrast was too low to reliably determine.



**Figure 2: Contrast (top of atmosphere) as a function of emission angle**

**Discussion:** From Figure 2, it can be seen that contrast does indeed decrease with increasing emission angle, confirming what is suspected with a brief glance at the image (Figure 1). The decrease seems to be approximately linear with emission angle, not cosine of emission angle (path length). One possible explanation is that, since haze is a major portion of the image brightness, it varies with emission angle in a different manner than the surface brightness. This causes the contrast to decrease more rapidly than the cosine of the emission angle. From 0° to 60° emission angle, the optical depth of haze changes by a factor of two; light leaving the planet from 60° emission angle must pass through twice as much haze as light leaving at 0°. Over this same range, the contrast changes by an order of magnitude, from 0.20 to 0.02. These results depend on the inherent contrast at various locations being constant. From looking at multiple images of the same location at different emission angles, it appears that contrast in the equatorial region of Titan varies primarily with emission angle, rather than changes in surface contrast.

These results could have an impact on our understanding of the Titan haze. With a better understanding of the true surface contrast of Titan and the scattering and absorbing properties of the haze, the optical depth of the haze could be determined. Alternatively, by subtracting the haze contribution to the flux, it should be possible to normalize the contrast to that at 0° emission angle. It would be necessary to know the optical depth of haze at 0° emission angle in order to normalize to the true surface contrast. These results also show that we must image at very low emission angles to achieve the highest effective spatial resolutions.

**Future Work:** For this work, we examined a bright-dark boundary across the disk of Titan, which could be affected by inherent contrast variations. It would be useful to examine the same features in

several different images, at different emission angles, to avoid any inherent contrast variations. The phase angle could also affect the contrast, so we need to examine the contrast function at a range of phase angles.

The haze scattering also blurs boundaries on the surface. Investigating this effect would yield information on the scattering properties of the haze. This could be done by identifying the smallest features visible at various emission angles. We also plan to run radiative transfer models of atmospheric scattering.

**References:** [1] Porco, C. C. et al. (2005) *Nature*, submitted. [2] Griffith, C. A. et al. (1991) *Icarus* 93, 362-378. [3] Porco, C. C. et al. (2004) *Space Sci. Rev.*, 115, 363-497. [4] Courtin, R. et al. (1991) *Icarus*, 90, 43-56. [5] West, R. A. and Smith, P. H. (1991) *Icarus* 90, 330-333. [6] Tomasko, M. G. et al. (1997) *ESA SP-1177*, 345-358 [7] McKay et al. (2000) *Planet Spac Sci.* 49, 79-99. [8] Rannou, P. et al. (2003) *Planet. Space Sci.*, 51, 963-976.