Processing ISS images of Titan's Surface. Jason Perry[1], Alfred McEwen[1], Stephanie Fussner[1], Elizabeth Turtle[1], Robert West[2], Carolyn Porco[3], Ben Knowles[3], Doug Dawson[1], and the Cassini ISS Team. [1]Planetary Image Research Laboratory, University of Arizona, 1541 E. University Blvd, Tucson, AZ 85721, [2]Jet Propulsion Laboratory, Pasadena, CA, [3]Cassini Imaging Central Laboratory for Operations (CICLOPS), Boulder, CO.

Introduction: One of the primary goals of the Cassini-Huygens mission, in orbit around Saturn since July 2004, is to understand the surface and atmosphere of Titan. Surface investigations are primarily accomplished with RADAR, the Visual and Infrared Mapping Spectrometer (VIMS), and the Imaging Science Subsystem (ISS) [1]. The latter two use methane "windows", regions in Titan's reflectance spectrum where its atmosphere is most transparent, to observe the surface. For VIMS, this produces clear views of the surface near 2 and 5 microns [2]. ISS uses a narrow continuum band filter (CB3) at 938 nanometers.

While these methane windows provide our best views of the surface, the images produced are not as crisp as ISS images of satellites like Dione and Iapetus [3] due to the atmosphere. Given a reasonable estimate of contrast (~30%), the apparent resolution of features is approximately 5 pixels due to the effects of the atmosphere and the Modulation Transfer Function of the camera [1,4]. The atmospheric haze also reduces contrast, especially with increasing emission angles [5].

Procedure: Due to the complexities of Titan's photometry, more extensive data processing is needed to obtain the best detail from ISS images of Titan than is the case for most other targets. The first and perhaps the most important is calibration using CISSCAL. This software package includes a flat-fielding procedure to remove features on the raw images (Figures 1a and 2a) produced by imperfections in the camera. One such imperfection is dust motes, which are manifested in the images as dark rings. These become more apparent in regional-scale and high-resolution views (Figure 2) due to lower signal. Some dust specks moved, probably during the Saturn orbit insertion main-engine burn, so not all of the rings are currently removed by CISSCAL, and must be removed later in processing. The image is also radiometrically calibrated to units of I/F, where I is observed intensity and πF is intensity of solar illumination.

The calibrated images are converted to run in ISIS, a USGS-produced software package for geometrically and radiometrically manipulating spacecraft images [6]. In ISIS, Titan images are noise filtered to remove cosmic ray hits and other noise produced during the exposure. Lingering dust rings are removed from the images using a residual flat field created from averaging many bland CB3 images of Titan. Following CISSCAL and these initial ISIS steps, Figures 1b and 2b are produced.

Part of the observing strategy for Titan CB3 imaging is to take multiple images at the same footprint, to be summed on the ground to increase the signal to noise ratio (SNR). During Ta and Tb, this meant taking 3 images at each position with ~12-32 second exposures, to prevent range-to-target smear. However, these images are strongly limited by SNR, so longer exposure times are planned for future orbits. The images in Figures 1c and 2c are the result of removal of the residual dust rings and noise hits and summation.

For some images, particularly those with lower resolution, an image at 619 nm (MT1) that shows only atmospheric haze was acquired at the same time so that its photometric function is similar to that of CB3 images. By dividing each CB3 image by a corresponding MT1 image, the image brightness as a function of emission and illumination angle is normalized or flattened, enabling an image histogram "stretch" to increase apparent contrast (Figure 1c). The MT1 frame also serves to unambiguously identify upper tropospheric clouds, as this weak methane band does not detect the surface.

While Figures 1c and 2c are clearly better than the raw images, they can be improved still further. An unsharp mask procedure is run on the images to dramatically improve the contrast in the images. This is achieved by subtracting ~85% of a low-pass filtered image that simulates atmospheric scattering of surface-reflected photons. The results of this step are seen in Figures 1d and 2d.

Going Forward: The procedures presented here are part of continuing work to improve ISS images of Titan's surface. Improvement is coming from two fronts. First, longer dwell times are being used for each footprint location, meaning more images at the same footprint and longer exposure times. This change will increase the SNR of the images, particularly those with pixel scales less than 1 km. However, this strategy also reduces coverage of the surface. In addition, images taken at higher phase angles (> 45 degrees) utilize a polarizing filter, which can further reduce the contribution from the atmospheric haze and improve contrast [1] [although at the expense of signal]. The polarizing filter was used during T0 (July 2004) and prior to Saturn Orbit

Insertion [4]. Second, the haze-correction procedures discussed above are being improved from a more-or-less trial-and-error process to one that reflects recent measurements and updated models of Titan appearance in CB3 images, as discussed in [5]. We may benefit most from improved image sharpening, particularly from modeling of how the atmosphere scatters photons reflected off the surface (which determines the box sizes used in the low-pass filtered image) and how contrast decreases as emission angle increases (which constrains how much of the fuzzy image to subtract from the original image).

References: [1] C. C. Porco et al. (2004), *Space Science Reviews,* 115, 363-497. [2] C. Sotin et al. *Nature*, submitted. [3] T. Denk et al. (2005) *LPS XXXVI*. This Volume. [4] C.C. Porco et al. *Nature,* submitted. [5] S. Fussner et al. (2005), *LPS XXXVI*, this volume. [6] L. Gaddis et al. (1997), *LPS XXVIII*, pg. 387.

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Figure 1: Processing of a global scale Titan image: (a) shows the raw image; (b) shows the same image once radiometric calibration, flat-fielding, and despiking have been performed; (c) shows the same footprint with three frames summed together (each frame also having been divided by an MT1 frame); and (d) shows the final result once a sharpening procedure had been applied. Image used: N1477439465, 1.975 km/pixel, CB3 filter, target distance=333573 km, phase angle=13.7 degrees. For the MT1 divide filter, image N1477439149 was used. For summation, images N1477439277 and N1477439371 were used.

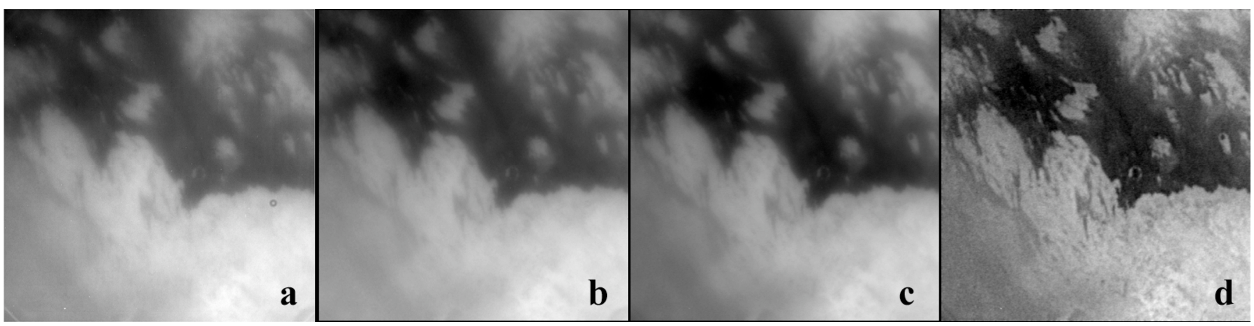

Figure 2: Processing of a regional scale Titan image: (a) shows the raw image; (b) shows the same image once radiometric calibration, flat-fielding, and despiking have been performed; (c) shows the same footprint with three frames summed together; and (d) shows the final result once a sharpening procedure had been applied. Image used: N1481618305, 812 m/pixel, CB3 filter, target distance=70662 km, phase angle=16.4 degrees. For summation, images N1481618211 and N1481618243 were used.