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Subtle changes on Titan's surface observed by Cassini ISS

Erich Karkoschka (1), Alfred McEwen (1), Jason Perry (1), and Elizabeth Turtle (2)
(1) University of Arizona, USA, (2) Johns Hopkins Applied Physics Laboratory (erich@lpl.arizona.edu)

Abstract

Cassini's Imaging Science Subsystem (ISS) acquired images of Titan, spanning over 13 years, of which about 16,000 images at 938 nm wavelength show surface features. Analyzing the entire set of images with corrections for illumination and atmospheric effects (Karkoschka *et al.* 2017), provides a powerful tool to look for changes on the surface. By comparing re-processed images in this way, we found changes in surface albedo in many regions up to about ±65° latitude and across all longitudes. Several changes appear to have occurred near September 2010 when a large cloud, and surface changes (interpreted as due to subsequent rainfall) had been observed (Turtle *et al.* 2011; Barnes *et al.* 2013). A few low-contrast regions changed their appearance. We also find evidence for local changes at other periods. Most of the changes reported here are too subtle to be detectable in single images, but stand out in mosaics created with our new method of stacking images to improve the signal-to-noise ratio.

1. Introduction

Changes have previously been observed on Titan's surface by comparing images taken at different times by ISS, as well as by the Visual and Infrared Mapping Spectrometer (VIMS) and RADAR instruments (e.g., Barnes *et al.* 2013; Hofgartner *et al.* 2016). In individual ISS observations, only high-contrast changes, including clouds, can be detected this way since Titan's haze decreases the contrast of small-scale features by a factor of 50 or more. Combining the full ISS dataset allows more subtle surface changes to be revealed.

2. Observations and Results

Recently, we implemented a technique that stacks thousands of ISS images of the same region in order to remove atmospheric and illumination effects and improve signal-to-noise. By combining these re-processed images in groups taken at different times throughout the mission, we can also perform a systematic search for surface changes. Our method shows changes within ±65° latitude, where ISS has good, long-term coverage.

In this way we have found changes in a number of regions over the course of the mission, several of which may also have occurred around the time of the rain event observed in Fall 2010. The variety of locations and characteristics of changes (scale, morphology, degree or brightening or darkening, timing, etc.) suggest a few different mechanisms may be responsible.

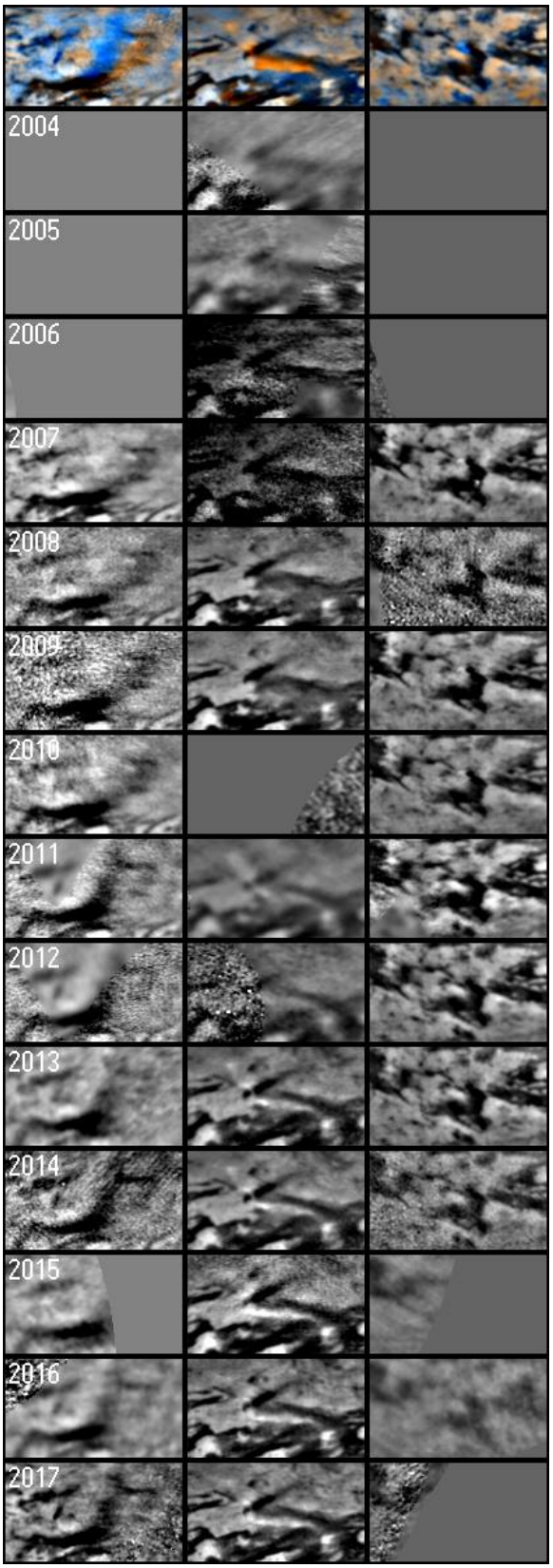
In some cases, dark streaks appear to have changed orientation and in others locations on the surface seem to have darkened subtly. If related to aeolian processes, the pattern of streaks may be related to wind direction. The majority of these streaks occur at mid-northern latitudes with quite consistent directions, and many have remarkably sharp boundaries over long distances. The left panel of Fig. 1 shows a dark streak originating from a dark area, perhaps indicating a source of dark material. The orientation of the dark streak changes from northeast to north in late 2010 or early 2011.

Other changes have more complicated morphologies and histories, e.g. the middle panel of Fig. 1. A narrow, bright streak that extends several hundred kilometers, appears in 2011 and appears to shift in location by ~50 km over seven years while its structure varied.

Even though the detected changes are very subtle, typically on the order of one percent in albedo, our method of stacking images is sensitive enough to clearly show the morphology, distribution and timing of the observed changes, which will provide insight into active processes at work on Titan.

We will analyze the revealed changes in more detail and refine our method to reveal even more subtle changes. We will also revisit changes documented previously with the improved detail now available. An example is shown in the right panel of Fig. 1, which includes features that brightened in 2011 and then subsequently faded (Barnes *et al.* 2013).

Figure 1: The temporal evolution of three regions of Titan centered on 280° West 29° North (left), 85W 34N (middle), and 278W 19S (right). Each panel shows an area of 35°x25°, or about 1300x1100 km. Contrasts are enhanced about 10 times in order to visualize the changes. The top panel shows in color where albedo pattern changes between the time periods of 2004-2010 and 2011-2017 were observed to increase (orange) or decrease (blue). The panels show mosaics of all available images taken during each calendar year as labeled at left, typically hundreds of images per year, but sometimes none. In some years the available data are of better resolution than in others. These mosaics have been passed through a high-pass filter so that features larger than 160 km are subdued. Note that these mosaics are very preliminary, and some artifacts still need to be removed in further processing.



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