EVOLUTION OF TITAN'S WEATHER PATTERNS AND ACCOMPANYING SURFACE CHANGES IN THE WAKE OF THE SEASONAL SHIFT OF THE INTERTROPICAL CONVERGENCE ZONE.

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Introduction: Post-equinox changes in atmospheric circulation brought clouds and extensive methane rain to Titan's low latitudes, and large low-latitude clouds observed in Sept.-Oct. 2010 (Fig. 1) were quickly followed by changes (Fig. 2) attributed to extensive methane rainfall darkening the surface [1, 2]. Cassini Imaging Science Subsystem (ISS) observations in Oct. 2010 revealed differences in surface brightness in Concordia Regio, along the southern boundary of Belet one of Titan's largest dune fields. An area 510,000 ± 20,000 km^2, extending ~2000 km east-west and >130 km across, darkened >10%, while adjacent areas remained unchanged (Fig. 2).

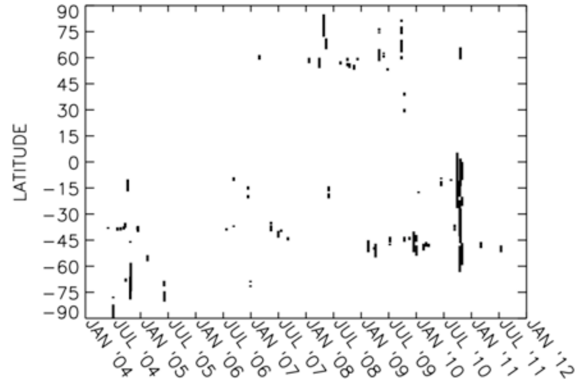

Figure 1: Latitudes of clouds observed by Cassini ISS through January 2012.

Interpretation: It is likely that much of the darkening was caused by surface wetting [2], although runoff and ponding may have occurred in some areas, explaining the variation in the rates at which the surface has reverted to its original brightness as different areas drain (by overland flow or infiltration) or dry at different rates (Fig. 2). Several smaller areas that brightened relative to their original appearance have persisted longer than most of the darkened areas, but also appear to be reverting to their original appearance. Cassini Visual and Infrared Mapping Spectrometer (VIMS) spectra of these regions do not match those of other surface units [3]. Interpretations include surfaces brightening as the result of cleaning by runoff (potentially exposing water ice [4]) or possibly deposition of fresh methane ice [3]; subsequent fading may be the result of re-deposition of hydrocarbon materials.

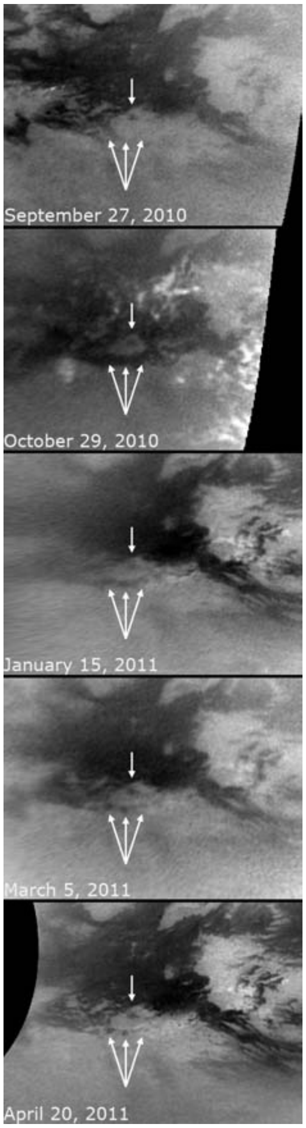

Figure 2: Sequence of ISS observations of Belet (large dark dune field across top center), Adiri (large bright feature at right), and Concordia Regio (bright terrain south of Belet). Single arrow indicates unchanged area between Belet and the darkened swath (29 Oct. 2010) through Concordia Regio. Triple arrow highlights the darkened swath and evolution thereof. Grey and darker shades are surface features. Bright features on 27 Sept. and 29 Oct. 2010 are methane clouds. Bright features on 15 Jan., 5 Mar., and 20 Apr. 2011, predominantly in Adiri (Fig. 3), are areas of surface brightening.

The frequency and amount of precipitation from storms at low latitudes during the equinoctial transition have important implications for Titan's methane cycle, atmospheric circulation, and rates of geologic modification. Previously, liquids had only been observed to exist on the surface at high latitudes [5], although fluvial channels are observed at all latitudes [6] and the Huygens Probe detected methane moisture in the shallow subsurface [7–9] of the flood plain where it landed at ~10° S [10, 11]. Vast equatorial areas of long-lived longitudinal dunes [12] indicate low latitudes are predominantly arid [13], but do not preclude occasional precipitation. Indeed, infrequent, but intense, equinoctial rainstorms, like the one observed in Fall 2010, are predicted by atmospheric models [14-16] and would be sufficient to form the observed channels.

Evolution of Surface Changes: Observations over more than a year since the storm have revealed that in most of this area the changes have been short-lived: only a few darkened patches persisted through Fall 2011. In an unsaturated permeable medium, vertical infiltration rates will be high (>20 mm/week [17]). So persistence of surface liquids over a timescale of several months strongly suggests either a shallow impermeable layer or that the local methane table lies close to the surface. Evaporation rates of >1 mm/week are predicted in equatorial regions [16] (rates of 20 mm/week have been documented at Titan’s poles [18]), thus areas where darkening has persisted must be saturated ground at the level of a methane table or have had ponded liquid of 2.5-50 cm depth.

Areas of surface brightening have been observed at ~20° S across Yalaing Terra, Hetpet and Concordia Regios, and slightly further north in Adiri (Fig. 3). In general, surface brightening has persisted longer than darkening (Figs. 2, 3). Rates at which brightened areas revert to their original appearance could provide constraints on the rate of re-deposition of darker hydrocarbon materials on Titan's surface by precipitation of aerosols from the atmosphere and/or aeolian transport.

Evolution of Weather Patterns: We have continued to monitor Titan frequently (at least a few times per month), but little cloud activity has been observed since Fall 2010 (Fig. 1). The recent lack of clouds may indicate that the outbreak removed enough methane from the atmosphere and the lapse rate stabilized sufficiently that activity will not resume until the onset of convection at mid-northern latitudes later in the spring. A similar lapse in cloud activity followed the large outbreak of south-polar clouds in Fall 2004 [19], which also appeared to produce significant rainfall [20].

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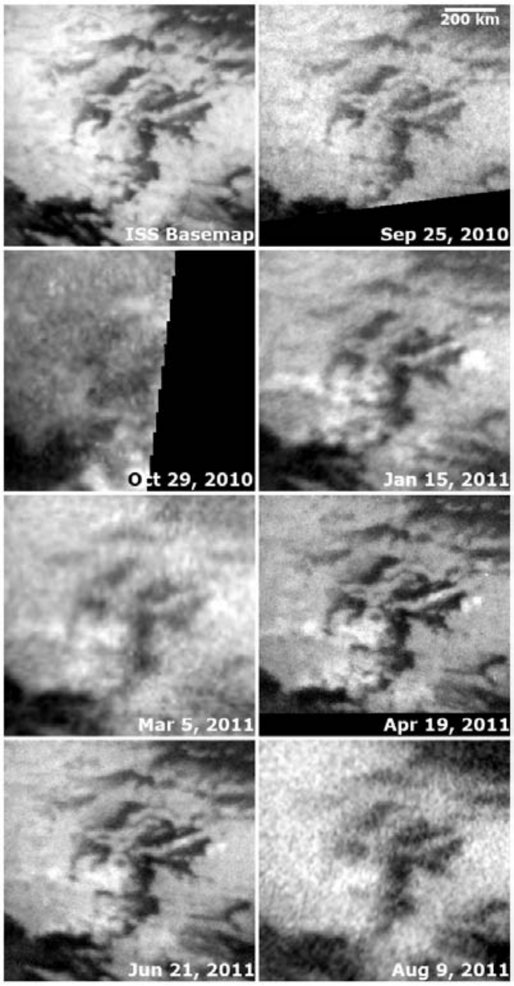

Figure 3: Sequence of ISS images of areas of brightening observed in Adiri.

References: [1] Turtle *et al.* (2011) *GRL 38*, L03203, doi:10.1029/2010GL046266. [2] Turtle *et al.* (2011) *Science 331*, p. 1414, 10.1126/science.1201063. [3] Barnes *et al.* (2012) *LPSC XXXXIII*. [4] Clark *et al.* (2010) *JGR 115*, E10005. [5] Lopes *et al.* (2010) *Icarus 205*, p. 540. [6] Lorenz *et al.* (2008) *PSS 56*, p. 1132. [7] Karkoschka and Tomasko (2009) *Icarus 199*, p. 442. [8] Lorenz *et al.* (2006) *Meteorit. Planet. Sci. 41*, p. 1705. [9] Niemann *et al.* (2005) *Nature 438*, p. 779. [10] Soderblom *et al.* (2007) *PSS 55*, p. 2015. [11] Tomasko *et al.* (2005) *Nature 438*, p. 765. [12] Lorenz and Radebaugh (2009) *GRL 36*, L03202. [13] Lorenz *et al.* (2006) *Science 312*, p. 724. [14] Mitchell (2008) *JGR 113*, E01805. [15] Mitchell *et al.*, (2011) *Nature Geos. 4*, DOI: 10.1038/ NGEO1219. [16] Schneider *et al.* (2012) *Nature 481*, doi:10.1038/ nature10666. [17] Hayes *et al.* (2008) *GRL 35*, L09204. [18] Hayes *et al.* (2011) *Icarus 211*, p. 655. [19] Schaller *et al.* (2006) *Icarus 184*, p. 517. [20] Turtle *et al.* (2009) *GRL 36*, L02204, doi:10.1029/ 2008GL036186.