THE ROLE OF PRECIPITATION IN LANDFORM EVOLUTION ON TITAN. E. P. Turtle, Johns Hopkins Univ. Applied Physics Lab., 11100 Johns Hopkins Rd., Laurel, MD, 20723. Elizabeth.Turtle@jhuapl.edu

Titan is one of only a few places in the Solar System to currently possess an active hydrologic cycle, including precipitation. And, as on Earth and Mars, Titan's landscape shows significant evidence of surface modification by flowing liquid. Although substantially colder, such that the materials are vastly different -- Titan's bedrock consists of water ice; its substantial atmosphere is composed primarily of nitrogen (>90%), a few percent methane, and lesser amounts of other species [1, 2]; methane and ethane can exist as liquids in the lower atmospheric and on the surface [3]; clouds of methane and ethane are frequently observed [4-8]; and the liquid that falls from the sky [9, 10] and flows across and ponds on the surface [11-14] consists of hydrocarbons (predominantly methane and ethane) -- nonetheless, Titan's fluvial and lacustrine landforms are unmistakable (*e.g.*, Figures 1 and 2).

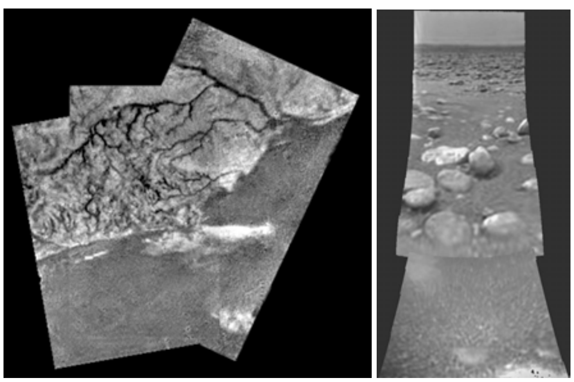

Figure 1: (Left) Channels observed by the Huygens Probe during its descent to Titan's surface. (Right) Cobbles (~10-15 cm in size) and gravel on the flood plain at the Huygens landing site.

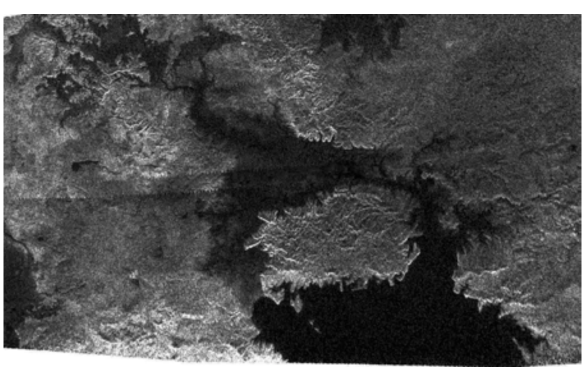

Figure 2: Cassini RADAR SAR image illustrating the intricate shorelines of Titan's Kraken Mare. Above center is Mayda Insula, an island ~90 km by ~150 km, which lies at the northern end of the sea.

At present, surface liquids are primarily observed in the form of lakes and seas at high latitudes [14, 15], although fluvial channels and extensive networks thereof (Figures 1 and 3) are observed at all latitudes [16, 17] and the Huygens Probe detected methane moisture in the shallow subsurface [18–20] of the flood plain (Figure 1) where it landed at ~10°S [21, 22]. Vast equatorial areas of long-lived longitudinal dunes [23] indicate the equatorial areas are predominantly arid [24], but do not preclude occasional precipitation which would be sufficient to form the observed channels [25, 26], similar to the usually dry washes in terrestrial deserts. Indeed, atmospheric models predict infrequent, but intense, low-latitude rainstorms during Titan's equinox seasons [27-29], and rain from one such storm in Fall 2010 covered an area greater than 500,000 km^2 [11].

Clearly precipitation has played, and continues to play, a significant role in the evolution of Titan's surface. It has even been suggested that Titan's geologic activity might be entirely exogenic, with the observed landforms being exclusively the result of fluvial, aeolian, impact cratering, and mass wasting processes (with tectonism driven by orbital dynamics or thermal evolution) [30]; although there is evidence supporting endogenic activity in the form of cryovolcanism [31]. Between 2004 and 2011, Cassini has observed areas of surface darkening following outbursts of cloud activity, which are interpreted to be the result of rainfall wetting the surface [11, 13]. The observational record is likely incomplete, but these events covered 0.7% of the surface in a timespan of 6 years and are consistent with multiple lines of evidence that converge on estimates of rainstorms lasting 2-100 hours occurring at ~100-1000 year intervals globally [32].

Over Titan's year (29.5 Earth years), precipitation varies across the surface, with storms occuring at low latitudes around the equinoxes [*e.g.,* 11] and at the poles during local summer [*e.g.,* 13]; it will be of particular interest to document when it rains at high northern latitudes and the effects thereof as northern summer approaches. In some places Cassini data suggest the presence of evaporite deposits, suggesting drying or draining of lakes [33]. There is some evidence that the shoreline of Ontario Lacus, at high southern latitudes has been receding as southern fall progresses [12, 34]. In general, the persistence of liquids in northern lakes and after precipitation events is indicative of locally shallow methane tables and/or layers of impermeable material near the surface [35], but the degree of subsurface connectivity is not well constrained.

Figure 3: Cassini RADAR SAR images illustrating the wide variety of channel morphologies present on Titan.

Variability in precipitation over much longer timescales, is likely responsible for the marked asymmetry in the number of lakes and seas at Titan's north and south poles [36].

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