NUMERICAL MODELING OF TITAN FLUVIAL CHANNELS. S.S. Magar[1], V.F. Chevrier[2], R.Ulrich[2], K.L. Howe[3]. [1]Arkansas Center for Space and Planetary Sciences, University of Arkansas (Fayetteville, AR 72701 USA; sxs099@uark.edu)

Introduction: Titan, the only other body in the solar system wih surface liquid, has a thick significant atmosphere like earth with ~95% of molecular nitrogen and ~5% of methane with an average pressure of 1.5 bar. Unlike water on earth, the hydrological cycle on Titan is carried by methane. Rivers, lakes and oceans of liquid hydrocarbons are common and show active morphological processes. Dendritic networks of sinuous, steep sided valleys on the surface of Titan have been observed by the decent imager on the Huygens probe [1] and the radar on the Cassini orbiter [2], while large sinuous low allbedo features have been observed by the Imaging Science Subsystem in Cassini [3]. There was no evidence of any liquid at landing site, as shown by the Descent Imager Spectral Radiometer (DISR) experiment on the Huygens Probe [1], but the gCSM did detect moisture in the subsurface [4][5]. During the descent, DISR has shown networks of channels and valley-like features that strongly suggest fluvial erosion processes of liquids (likely methane and ethane with dissolved nitrogen [6]).

Images taken during the Huygens probe during its descent were at higher resolution than that of the Radar instrument on the Cassini orbiter. Stereo image pairs were also taken that allowed estimation of incision angles of the channels (Figure 1). Geometry of the channels can be constrained by using width and incision angles of the channels. When paired with the fluid characteristics of flowing liquid methane, constraints can then be placed on the grain size that the fluid in the channel can transport. The erosion processes for Earth, Mars and Titan are similar; the same fluid dynamic equations can be used to model the erosion of liquid methane into water ice bedrock [7][8][9]. A model was developed by Chevrier *et al*. (2009) [15], for boulder transport from Martian gully geometry and experimentally determined fluid characteristics. In this work, that model will be modified to determine the fluid characteristics in a channel and the maximum boulder size it can support on Titan. The Huygens probe landing (Figure 1) was used as a starting platform and then modified based on other observations from Cassini orbiter.

The objective of the model is to place minimum constrains on the fluid properties within Titan's large channels in order to identify the maximum boulder sizes the channel could support. A model developed by Chevrier *et al.* (2009) [15] for brines flowing in Martian gullies will be modified for Titan conditions. Equations governing the erosion processes remain the same as used in Martian gully code, but those of fluid characteristics are altered, as are planetary properties.

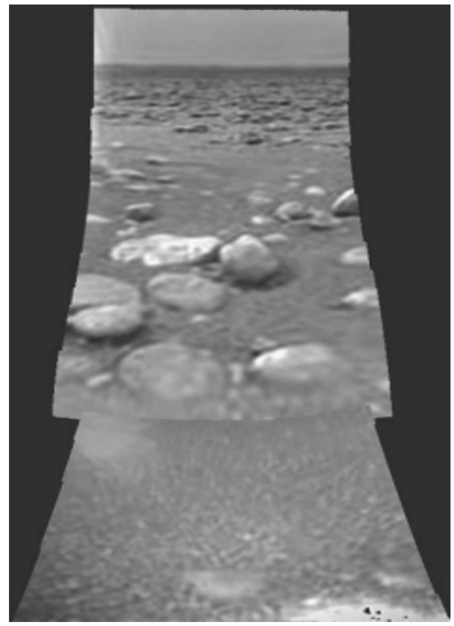


Figure 1: Approximately 15cm diameter boulders seen at the Huygens probe landing site rest on a fine grained matrix. These boulders are rounded, indicating fluvial transport process. NASA image PIA06440

Model: The viscosity of a fluid determines the internal forces of the fluid and how it behaves and thus its classification [10]. Viscosity depends on both temperature and fluid concentration but we only know the temperature effect. Experimental data of pure liquid methane at Titan conditions was obtained from Hanley *et al.* (1997) [11] and used to generate a viscosity equation based on temperature (T): $\mu = 0.0018e^{-0.025T}$. Assuming the friction between the channel and boulder is negligible, once the average velocity (V_{avg}) is known the forces created by the drag force (F_d) and boulder's weight (F_b) can be calculated using the following equations:

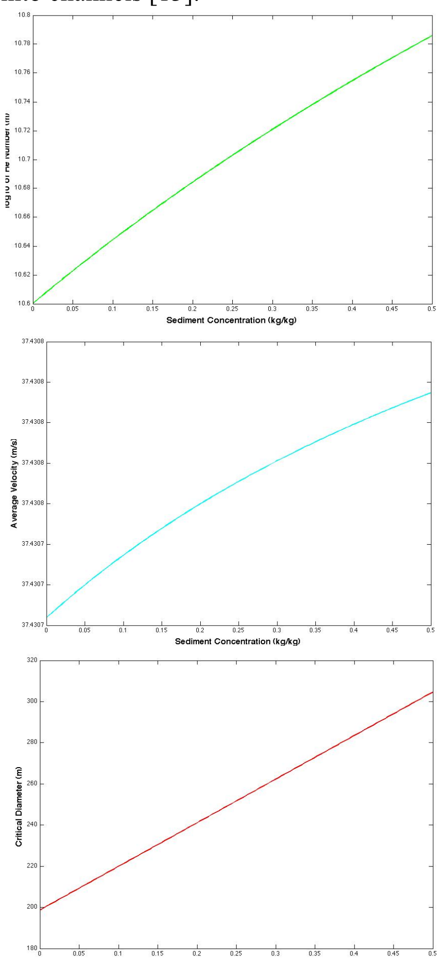
$$F_d = \frac{1}{2}\rho_f C_D V_{avg}^2 S \quad (1)$$

$$F_b = vg(\rho_b - \rho_f) \quad (2)$$

where ρ_f the fluid density (kg/m^3), C_D is the drag coefficient calculated from a matrix created from a graph of C_D versus Reynolds number, S is the bed slope, v is the spherical boulder (figure 2) volume (m^3), g is gravity, ρ_b is the boulder (water ice) density in kg/m^3, and ρ_f is the fluid density (kg/m^3). If $F_d > F_b$, then the boulder is at the maximum size that can be moved by the fluid. With this idea, the diameter of the boulder can be found by setting $F_d = F_b$ and solving for *d*:

$$d = \frac{3\rho_f C_D V_{avg}^2}{4g(\rho_b - \rho_f)} \quad (3)$$

At Huygens landing site, the maximum diameter of boulders is known and a minimum constraint can be set to find a channel depth that is capable of supporting the boulders. Also, parameters required to transport large boulders can be calculated using the Titan fluvial model (Figure 2). As sediment concentration decreases, the amount of fluid needed to transport ~15cm boulders increases. Although it is unknown if the atmospheric methane [12] rains out slowly and continuously or rarely and torrentially, large amounts of fluid in the channels suggest the necessity of rapid runoff into channels [13].



(a) (b) (c)

Figure 2: Results for a flow depth of 350 m and an incision angle of 85º for concentrations 0-50% sediment. These show the trends for (a) Reynolds number (Re), (b) average velocity in the channel (V_{avg}) and (c) critical diameter (C_D). *Re* values for all flows are fully turbulent due to the high velocity and low viscosity of the fluid. Although V_{avg} is different for each channel, the trend is the same in that velocity does not change significantly as concentration increases. The boulder size in which a fluid can carry varies greatly between flows but, again, the trend is the same regardless of the channel geometry.

Conclusion: A modified version of Chevrier *et al.* (2009) [15] will help to create an estimate of the amount of fluid in the channels needed to transport 15cm diameter water ice boulders. Theoretical values suggest that at 25% sediment, the inertial force dominated hyperconcentrated stream flow must be 2.92m high; at 50% sediment, the viscous force dominated debris flow must be 2.55m high; at 75% sediment, the viscous force dominated granular flow must be 2.3m high. Results yielded (Figure 2) a minimal fluid depth of 1.54 m to move a 15.34 cm boulder. This depth is at 100% sediment, which indicates a dry gravity driven process Due to the sinuous nature of the channels, the lower gravity on Titan, the fully turbulent nature and the damp ground at Huygens landing site, it is highly unlikely the channels are formed by dry flow processes. Even at only 10% sediment, the fluid depth needed to move a 15.05 cm diameter boulder is 2.42 m. This yields channel widths that are 0.8-1.3 m wide. These widths are theoretically possible, but not directly observed. Instead, widths and depths from observations are used as model inputs. The high sinuosity of the channels require a fluid with stream flow behavior and thus only sediment concentrations up to 50% are hereafter considered. As the channel morphologies resemble fluvial processes on Earth, it is likely the hill slope processes acting on Titan trend toward the lower sediment concentration spectrum. The amount of fluid needed indicates a large rainfall rate, which is consistent with the modeling of desert rain environments [10].

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