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Evolution of Titan's rivers and comparison with terrestrial rivers

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Abstract

Titan is a very special body in the Solar System. As the only one moon, it has a dense atmosphere and liquid on its surface. Through the work of the probe Cassini-Huygens, we know that there are similar geological structures and processes (e.g. meandering, sediment transport, bank erosion) on the Titan as well as on the Earth. This paper is aimed to show the similarity and differences between effects of this processes on this two places.

1. Introduction

Titan is the only celestial body, beside the Earth, where liquid is present on the surface. The liquid is composed of methane and ethane. It forms a number of lakes and rivers. In our research we investigate some chosen rivers observed by Cassini in the vicinity of the Huygens landing site and some other regions of Titan.

2. Geometry characteristic

The radar photos made by Cassini mission are used to calculate the basic characteristics of the considered rivers. The results indicate that the coefficients of the curvature of the considered rivers are higher than 1.5. It means that these rivers could be classified as meandering rivers. Based on geometric characteristic of the presently dry rivers' bed we can assess also the flux of fluid in the past.

3. Results

The results of our calculation of sediment transport are seen on Figure 1 and 2. First statement is that on Titan the transport of sediment is bigger than on Earth, even if Titan's gravity is smaller. This simulation was performed for water (for Earth) and for liquid corresponding to rain for Titan.

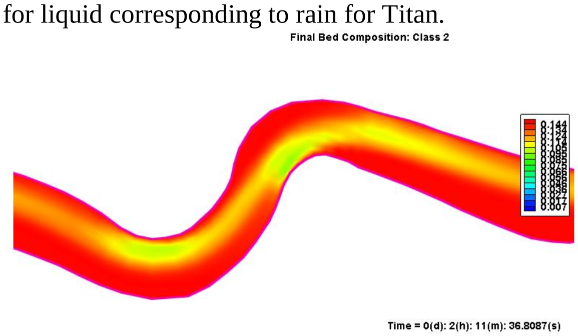

Figure 1: Results of sediment transport for terrestrial river for 3×10^{-5} m diameter.

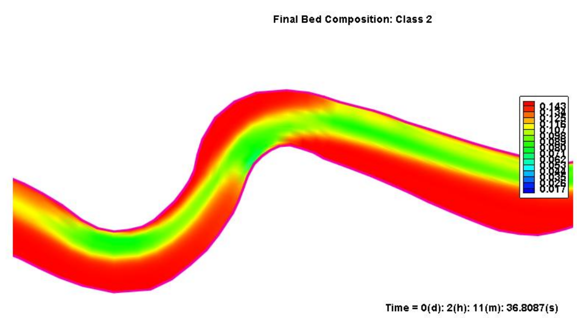

Figure 2: Results of sediment transport for Titan's river for 3×10^{-5} m diameter. Note that in Figure 1 there are only small regions where sediment was eroded (small green spots), when in Figure 2 sediment was eroded on larger region (it is well seen green line).

4. Parameters of the model

A few kinds of liquid are found on Titan. The liquid that fall as a rain has different properties than the fluid forming lakes. To our calculation we use only the liquids mentioned in Table 1 and 2 (e.g. [3]).

Table 1: Composition of two considered liquid existing on Titan's surface.

	Rain	Lake liquid
Methane	75%	10%
Ethane		74%
Propane		7%
Butane		8,5%
Nitrogen	25%	0,5%

Table 2: Material properties of liquids.

	Viscosity [Pa s]	Density [kg m^{-3}]	Heat capacity [J kg^{-1} K^{-1}]	Thermal expansivity [K^{-1}]
Water	$1,52\times10^{-3}$	999,8	4187	$2,07\times10^{-4}$
Rain	$1,51\times10^{-4}$	518	3250	$1,14\times10^{-3}$
Methane	$2,08\times10^{-4}$	454	3290	$3,54\times10^{-3}$
Lake liquid	$1,42\times10^{-3}$	658	2400	$1,61\times10^{-3}$

5. Basic equations of our model

The dynamical analysis of the considered rivers is performed using the package CCHE modified for the specific conditions on Titan. The package is based on the Navier-Stokes equations for depth-integrated two dimensional, turbulent flow (e.g. [1] , [2]).

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-g\frac{\partial Z}{\partial x}+\frac{1}{h}\left(\frac{\partial(h\tau_{xx})}{\partial x}+\frac{\partial(h\tau_{xy})}{\partial y}\right)-\frac{\tau_{bx}}{h\rho} \quad (1)$$

$$\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}=-g\frac{\partial Z}{\partial y}+\frac{1}{h}\left(\frac{\partial(h\tau_{yx})}{\partial x}+\frac{\partial(h\tau_{yy})}{\partial y}\right)-\frac{\tau_{by}}{h\rho} \quad (2)$$

where u and v are the depth-integrated velocity components in the x and y directions respectively; g is the gravitational acceleration; Z is the water surface elevation; ρ is water density; h is the local water depth; τ_{xx}, τ_{xy}, τ_{yx} and τ_{yy} are the depth integrated Reynolds stresses; and τ_{bx} and τ_{by} are shear stresses on the bed surface.

We investigate also the bank erosion and deposition. It enables us to investigate the evolution of the rivers meanders as a function of coefficient of the curvature and of total discharge of the liquid.

6. Conclusions

The results of our simulation show the differences in behaviour of the flow and of sedimentation on Titan and on Earth. Our preliminary results indicate that transport of material by Titan's rivers is more efficient than by terrestrial rivers of the same geometry parameters.

Acknowledgements

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