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Deposition and erosion in river deltas on Titan and Earth

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Abstract

Titan is the only celestial body other than Earth where liquids exist and flow on the surface. We model erosion, transport and deposition in rivers of Titan and Earth and we compare similarities and differences between them.

1. Introduction

The formation of deltas and alluvial fans is result of transport and deposition of the material by flowing fluid. These forms are known to exist not only on Earth, but also on other celestial bodies where liquids could exist under the surface conditions. The lakes and rivers of liquid hydrocarbons are observed on Titan, a satellite of Saturn. We consider delta-like forms observed at the south-western shore of Ontario Lacus, the feature interpreted as an alluvial fan at the north-eastern shore of Ontario Lacus, and the alluvial fans at the end of some other channels.

2. Sample results

Figures 1 and 2 show results of simulations with the same channel geometry, initial liquid level and discharge, but for two different planets. Note that more material has been displaced on Titan (Figure 2).

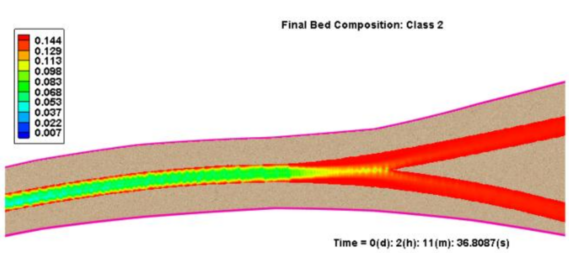

Figure 1: Result of sediment transport simulation for the fraction of diameter 30 μm under terrestrial conditions.

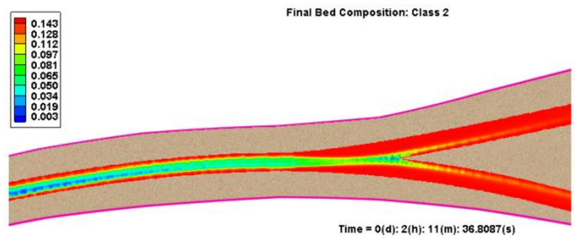

Figure 2: Result of sediment transport simulation for the fraction of diameter 30 μm under Titan's conditions.

3. Parameters of the models

The tables included below summarize the properties of liquids considered for our modeling (e.g. [1]).

Table 1: Composition of liquids that may form the rivers on the surface of Titan

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

Table 2: Material properties of considered liquids

Name	Viscosity [Pa s]	Density [kg m^{-3}]	Heat capacity [J kg^{-1} K^{-1}]	Thermal expansion coefficient [K^{-1}]
Water (at 5ºC)	$1{,}52\times10^{-3}$	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	$1{,}61\times10^{-3}$

4. Basic equations

We use two-dimensional depth-averaged hydrodynamic numerical model, based on the Reynolds approximation of momentum equations and the continuity equation.

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

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

$$\frac{\partial Z}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \quad (3)$$

Where u and v are depth-averaged velocity components in the x and y directions, respectively; t is time; Z is the fluid surface elevation; h is the local fluid depth; g is the gravitational acceleration; τ_{ij} are the depth integrated Reynolds stresses; and τ_{bx} and τ_{by} are shear stresses at the bottom in the x and y directions, respectively.

Additional equations are used to describe bed-load transport, suspended sediment transport and deposition (see e.g. [2]).

5. Summary and Conclusions

Our simulations show that on Titan the material is transported more easily than on Earth. This result is in agreement with earlier models [3].

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