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Numerical modelling of rivers on Titan

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Abstract

The differences in evolution of rivers on the Earth and on Titan are investigated. Series of short (from one to several hours) and long (up to 67 days) simulations have been performed. We have found that three different liquid hydrocarbons considered for Titan's rivers give similar velocity field. It is also found that the suspended load is the main way of transport in Titan's rivers while in terrestrial ones, for the same discharge, the bedload could be of the same order as suspended load. Moreover, we suppose that for specific boundary conditions, the evolution of rivers on the Earth promotes developing of braided rivers, while for the same conditions evolution on Titan favours regular meandering rivers.

1. Introduction

Titan is the only celestial body, beside the Earth, where liquid is present on the surface. The liquid is composed mostly of light hydrocarbons. It forms a number of lakes and rivers. However sedimentary processes depend on many parameter, e.g. gravity, fluid viscosity and density, density of solid material etc. Therefore processes on Titan could evolve in different way and rate than similar processes on the Earth. We use numerical model to determine differences in evolution of rivers on the Earth and on Titan. The dynamical analysis of rivers is performed using the numerical package modified for specific conditions on Titan. The model is based on the Navier-Stokes equations for depth-integrated two dimensional, turbulent flow and on three dimensional convection-diffusion equation of sediment transport [1].

2. Results

The results of some of our calculation of sediment transport are seen on Figures 1 and 2. The first conclusion is that on Titan the transport of sediment is more efficient than on the Earth and the main way of transport on Titan is suspended load [2,3]. Another statements is that different combination of initial conditions of suspended and bedload for the Earth and Titan is able to reconstruct sedimentation of meandering rivers. For the conditions considered in our research evolution of terrestrial river leads to quasi-braided river, while for Titan we still have typical meandering river for the whole simulation time. Also simulations of flow show many interesting conclusions as relationship between initial total discharge and gravity acceleration. Most of the results of our models could be explained theoretically considering different values of gravity, density and viscosity of fluids, density of sediments and different buoyancy forces for Titan and the Earth. This simulation was performed for water (for the Earth) and for liquid corresponding to rain for Titan.

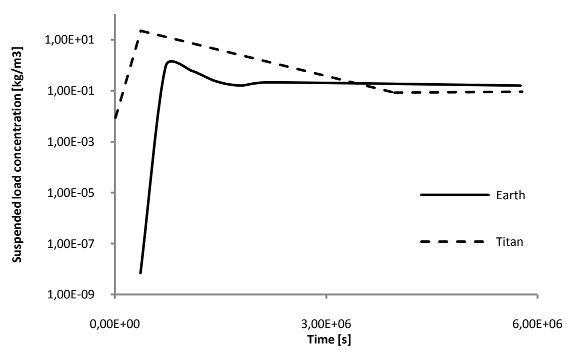

Figure 1: Suspended load concentration versus time for mesh node number 5620 for simulations 1T_6 and 1Z_6

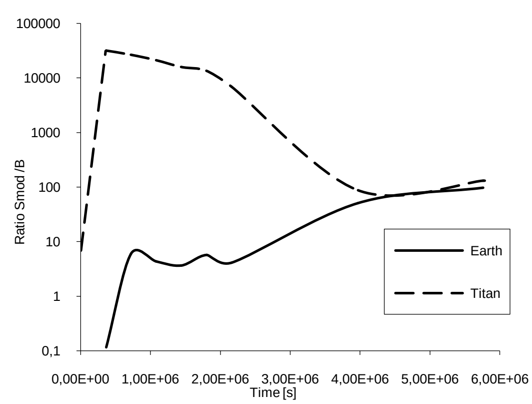

Figure 2: Ratio of modified suspended load concentration S_{mod} to bedload transport rate B versus time for mesh node number 5620 for simulations 1T_6 and 1Z_6

3. 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. [4]).

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	$1{,}61\times10^{-3}$

4. Laboratory model

We are developing the laboratory facilities for modeling extraterrestrial rivers. Although the size and discharge of the model are negligible comparing to real rivers, the experimental results are of great importance. They could be used for testing methods of scaling as well as the results of numerical models.

5. Conclusions

The results of our simulation show the differences in behaviour of the flow and of sedimentation on Titan and on the Earth. Our preliminary results indicate that transport of material by Titan's rivers is more efficient than by terrestrial rivers for the same geometry parameters and initial conditions. Suspended load is the main way of transport in Titan's simulated rivers. For the Earth the behaviour of the considered ratio is more complicated. The suspended load S_{mod} could be of the same importance as the bedload, lower, or significantly higher but not higher than ~100 B. The bedload transport rate is also much bigger on Earth than on Titan, the maximal value is around 0.3 kg m^{-1} s^{-1} on Earth and negligible on Titan. Also for the conditions considered in our research evolution of terrestrial river leads to quasi-braided river, while for Titan we still have typical meandering river for the whole simulation time.

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