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Abstract of Ph.D. thesis

"Numerical simulations of the evolution of single- and multiple-channel rivers on Earth and Titan"

The purpose of this thesis was to: 1) investigate the properties of the rivers and determine their evolution for large slope (ranging from 0.01 to 0.04 rad); 2) to study the properties of rivers on Titan and to investigate their evolution and to compare them with the rivers on Earth (e.g., to understand sedimentation problems and to improve the interpretation of sedimentary structures on Titan); 3) to explore the terrestrial rivers flowing through the basaltic sediments; 4) to consider the classification of the rivers, including to application of the current classifications, to identify their drawbacks and to suggests for some modifications.

The considered rivers flow mainly through alluvial deposits. The work involved the use of numerical simulations as the basic research method (chapters 2 and 3). For this purpose, the package CCHE2D has been adapted and utilized. It was developed by the National Center for Computational Hydrology and Engineering, University of Mississippi. CCHE2D is based on depth averaged two-dimensional Navier-Stokes equations, and a three dimensional, convective-diffusion equation of the sediment transport. The CCHE2D is widely used, also for practical purposes, such as engineering.

The first part of the simulations consisted in verifying the applicability of the program CCHE2D to required tasks. The next point was to determine the appropriate flow and transport parameters needed for the simulation (e.g., density and viscosity of the liquid, grain size distribution) that would fit the current knowledge of Titan and its surface. Then, the long-lasting numerical simulations were carried out, and their results were visualized and analyzed. Of course, the results obtained were also confronted with existing publications and data.

Calculations were performed for different simulation times and different river geometries. The initial, short (up to a few days) simulations were made for the East Fork river geometry. They aimed to discern the dependence of model behavior on considered

parameters. Further simulations, also performed for East Fork geometry, lasted up to 22-66 days. The purpose of this part was to test whether the assumed geometry of the meandering river allows to transform the river into another type and under what conditions it is possible.

The next stage was long simulations (up to about 240 days – Chapter 4), carried out for the author's geometry of the river, with a simple, neutral shape (this shape does not impose a subsequent evolution of the river). Other differences were the sediments consisting of grains of the same size (for the given simulation) and the use of a few different sediment materials. Simulations were made in the case of Earth - for quartz and basalt and for water as a liquid. In the case of Titan, for water ice and liquid that is a mixture of methane and nitrogen, corresponding to the Titan's rain.

As a result of the work, significant differences in the evolution of rivers on Earth and Titan have been confirmed. Firstly, it was found that three different liquids concerned for Titan, give similar flow properties. Secondly, the suspension load is the main way of transporting sediments in rivers on Titan. Both the suspension and the bed load are important on the Earth, with the bed load being significantly higher than on Titan. The differences in the evolution of rivers on the Earth and Titan are due to the different erosion rates of sediments that build the bed of the river and the different transport rates and accumulation of sediments. The simulations show also that different types of rivers could developed for the same discharge on Earth and Titan. This result encouraged the author to investigate the conditions in which various types of rivers occur, especially the single- and the multi-channel rivers.

The long simulations, which included a wide range of parameters, allowed for the initial determination of the parameter areas where the given river type is more likely to occur. Two methods have been used to classify rivers: (1) temporal and spatial variations in the river, (2) values of the braiding factor b. Many rivers obtained in long simulations, classified by one or the other method, constitute transitional rivers. Comparisons with the publications show that the first method gives the results closer to the field classification, while the second method yields results that are less expected. The results allowed us to draw conclusions about the improvement of river classification rules. It was pointed out the need to take better account of the evolution of the river in the classifications. Moreover, it is shown that determination of the type of the river should be done by considering behavior of the river during some

characteristic time scale and/or spatial scale. An attempt was made to determine these scales based on the parameters used in the model.

In conclusion, this work deepens the understanding of the processes that shape Titan's surfaces, points to the similarities and differences in the evolution of the rivers on Titan and Earth. Moreover it extend our understanding of rivers for large slope of the channel and for basaltic sediments. It attempts also to address the drawbacks of some river classifications, and suggests ways to improve them.