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Evolution of river deltas on Titan and Earth – similarities and differences

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Transport of sediments by rivers result in formation of river deltas or alluvial fans. These landforms have been observed on Earth and Mars, and recently on the surface of Titan, the largest moon of Saturn. The Cassini Probe has observed lakes and channels of fluvial origin on this giant moon; some channels are connected to the lakes. The liquids flowing on the surface of Titan are light hydrocarbons, and they may transport sediments composed of icy grains or possibly heavy organic compounds. Large hydrocarbon lake in the southern polar region of the moon, named Ontario Lacus has a feature identified as two-lobed river delta at its south-western shore.

We model deposition of material transported by the river at the river/lake interface and the development of the delta under Titanian and terrestrial conditions. Our numerical model is based on the Navier-Stokes equations for depth-integrated two dimensional, turbulent flow and three dimensional convection-diffusion equation to describe movement of sediments: bed-load transport, suspended sediment transport and deposition. The sediments are divided into different classes by the size of the grain.

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

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

$$\frac{\partial Z}{\partial t} + \frac{\partial (uh)}{\partial x} + \frac{\partial (vh)}{\partial y} = 0, \quad (3)$$

$$\frac{\partial c_k}{\partial t} + \frac{\partial (uc_k)}{\partial x} + \frac{\partial (vc_k)}{\partial y} + \frac{\partial (wc_k)}{\partial z} - \frac{\partial (\omega_{sk} c_k)}{\partial z} = \frac{\partial}{\partial x}\left(\epsilon_s\frac{\partial c_k}{\partial x}\right) + \frac{\partial}{\partial y}\left(\epsilon_s\frac{\partial c_k}{\partial y}\right) + \frac{\partial}{\partial z}\left(\epsilon_s\frac{\partial c_k}{\partial z}\right), \quad (4)$$

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; τ_{bx} and τ_{by} are shear stresses at the bottom in the x and y directions, respectively, c_k is concentration for k-th size class, ω_{sk} is terminal velocity of sediment and ϵ_s is turbulent diffusivity.

We explore the flow properties and the deposition of material as a function of several parameters.

The transport rate of icy sediments on Titan is determined to be higher than for quartz sediments on Earth. This conclusion has a profound impact on the formation and development of river deltas on both celestial bodies. The persistent flow of the liquid is able to build and change these landforms faster on Titan than on Earth.