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Morphodynamics of Rivers and Turbidity Currents:an Elegant Conversation between Water and Sediment

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The flow of a fluid over erodible boundaries such as sediment or bedrock is capable of creating a kaleidoscope of beautiful patterns, including dunes, bars, meandering, alluvial fans and canyons. The key to the formation of these morphologies is an interaction between the fluid flow and the erodible boundary. The mathematical formulation of the problem involves a coupling between the relevant equations of fluid flow and an equation that describes the evolution of the boundary. The flow changes the boundary via differential erosion/deposition, and the boundary changes the flow by offering a modified bed boundary condition. While the fluid can be as esoteric as liquid methane, and the sediment can be granular particles of ice, as on Titan, the case of interest here is water flow associated with rivers and turbidity currents over an erodible bed composed of natural sediment on Earth. Turbidity currents are the deep-sea analogs of river flows: they consist of bottom-hugging currents driven by the presence of sediment in suspension, which makes the water in the flow heavier than the ambient water. In the case of the great majority of such problems, the fluid mechanics simplify in that the temporal terms can be neglected from all equations except the one that describes the evolution of the boundary. Here the general problem is discussed, and then interest is focused on cyclic steps, a universal rhythmic bedform associated with swift (Froude-supercritical) flow that can be found in mountain bedrock streams, gullies, steep alluvial river flows, and in the deep ocean. A single, unified mathematical formulation provides an explanation of all of these features.