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From Generic to Field-Scale Modeling of Submarine Upper-Regime Bedforms

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Submarine upper-regime bedforms are an important mechanism of evolution of deep-sea systems. Yet, our knowledge on submarine upper-regime bedforms is very limited and often relies on the analogy with their fluvial relatives, which is not necessarily straightforward. In rivers, only the streamwise pull of gravity, bottom friction and downslope pressure gradient control the hydrodynamic response of a supercritical inflow to bed configurations that typically generate upper-regime bedforms. In deep seas, two additional forces (i.e. interfacial friction due to water entrainment and net deposition of sediment on the bed) impact this response. Submarine turbidity currents are also more biased toward supercritical flows than rivers. Herein, we discuss how physically-based numerical modeling, alone or in combination with the field information, can be used to: a) broaden our understanding of the physics and key parameters governing the formation, migration, and architecture of submarine upper-regime bedfroms; and b) discriminate between the flow regimes that sculpt upper-regime bedforms in various deep-sea settings, including flanks of leveed channels, continental slopes and channel thalwegs. According to the latest results, turbidity current sediment waves on levees are unambiguously identified as cyclic steps over a broad range of flow conditions. Upper-regime transitional bedforms can be generated on levees only by very thick overflows, with the depths of the order of the main channel relief. In contrast, the hydrodynamic response of turbidity currents to sediment waves on continental slopes can span from antidunes to cyclic steps. The fairly high likelihood of thick turbidity currents and high-gradient beds on continental slopes sways the interpretation toward that of transitional bedforms and possibly antidunes. Crescent-shaped bedforms observed in the thalwegs of many active submarine channels likely indicate the channel inception and maintenance by means of cyclic steps. Furthermore, numerical modeling reveals that deep-sea antidunes and cyclic steps of the same magnitude are unlikely to form within a single train of sediment waves. Rather, cyclic steps undergo the process named here ”enlargement of cyclic steps”, which involves merging several undulations into one bigger step as the flow energy diminishes. This process possibly explains how sediment waves evolve over time.