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Experimental study on transient and steady-state dynamics of bedforms in supply limited configuration

J. Dreano (1), N. Le Dantec (1), C. Cassar (2), A. Valance (1), and D. Lague (2)

(1) Institut de Physique de Rennes, CNRS UMR 6251, Université Rennes 1, 35042 Rennes, France, (2) Géosciences Rennes, UMR CNRS 6118, Université Rennes 1, 35042 Rennes, France

The purpose of the present study is to investigate experimentally the development of underwater bedform instabilities in a configuration where the sediment supply is limited. The experimental setup consists in a rectangular closed duct combining two key features: an innovative system to control the rate of sediment supply Q_{in}, and a digitizing system to measure the real time, three-dimensional bed topography. A suite of experiments were carried out varying three parameters: the sediment size d (either 100 μm or 500 μm), the sediment supply rate Q_{in} and the water flow rate, yielding a total of 46 different configurations. In all the experiments, a transient phase was followed by the establishment of steady and stable bedforms of various shapes (barchans, transverse dunes or bedload sheets, depending on the experimental parameters). The morphological parameters of the equilibrium bedforms (the equilibrium height H_{eq}, length and spacing) as well as their migration speed V_d were carefully examined in relationship with Q_{in}. Two regimes were identified: (i) a linear regime where H_{eq} increases with Q_{in} and (ii) an invariant regime where H_{eq} is almost independent of Q_{in}. The saturation of H_{eq} is interpreted as the transition from a supply-limited regime to a transport-limited regime in which the bedload flux has reached its maximum value under the prevailing flow conditions. Additionally, in the linear regime, a simple scaling law is proposed for H_{eq} as a function of Q_{in}, d and the cube of the shear flow velocity $u_\star$. In this regime, V_d also increases linearly with Q_{in}, d and $u_\star^3$. The controlled and well-documented experiments reported herein provide a thorough quantitative assessment of the factors governing the equilibrium height and migration speed of bedform deposits in supply-limited conditions against which theoretical and numerical models can be tested.