



Antidunes and cyclic steps in open channels: their formative conditions and the geometrical features

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A wide variety of upper-regime antidune-like bedforms including upstream migrating antidunes, downstream-migrating antidunes and cyclic steps can be observed in open channels. Though a number of experimental studies on their formative conditions are available, there are very few comparative studies of the differences in hydraulic conditions and morphologic features of bed- and water-surface waves associated with cyclic steps and antidunes. In this study, features of both bed and water surfaces as well as hydraulic conditions are examined over a wide spectrum ranging from upstream-migrating antidunes to cyclic steps. Experiments performed with the use of a flume in Osaka Institute of Technology illustrate a wide variety of antidunes and cyclic steps, including upstream-migrating antidunes (UMA) with breaking waves, UMA with hydraulic jumps, stable UMA, downstream-migrating antidunes (DMA), cyclic steps, chute-and-pool bedforms, and bedforms intermediate between antidunes and cyclic steps. We classified their regimes of formation/maintenance in terms of three non-dimensional parameters, i.e. Froude number (Fr), suspension index (SPI, ratio of shear velocity to fall velocity), and non-dimensional Chezy resistance coefficient (Cz). The SPI serves as a scale to quantify the spectrum between antidunes and cyclic steps. The use of this parameter also helps verify that suspension plays an important role in the formation and maintenance of cyclic steps. The parameter Cz , on the other hand, serves as a scale to quantify whether antidunes migrate while preserving shape, or undergo periodic formation and collapse. We relate this latter behavior to the results of a weakly nonlinear stability analysis of finite-amplitude bedforms. In addition, we compared the geometry of these bedforms, using the parameters such as non-dimensional wave number, and wave steepness of the bed-waves. As a result, UMA, DMA, and cyclic steps are classified into the different regimes. UMA shows relatively low wave steepness and middle wave numbers while DMA shows a higher but relatively wide range of wave steepness and higher wave numbers. Cyclic steps show low wave numbers and middle of the wave steepness. These geometrical features are useful to infer the geological records.