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Linear stability analysis of a 1-D two-phase morphodynamical model

MASSIMO GRECO, *Dipartimento di Ingegneria Civile, Edile e Ambientale, Università di Napoli "Federico II", Via Claudio 21, 80125, Napoli, Italy.* grecom@unina.it

MICHELE IERVOLINO, *Dipartimento di Ingegneria Civile, Design, Edilizia e Ambiente, Seconda Università di Napoli, Via Roma 29, 81031, Aversa (CE), Italy*. michele.iervolino@unina2.it

ANDREA VACCA, *Dipartimento di Ingegneria Civile, Design, Edilizia e Ambiente, Seconda Università di Napoli, Via Roma 29, 81031, Aversa (CE), Italy*. vacca@unina.it

River flows may develop a variety of bed forms, such as ripples, dunes and antidunes with different characteristic lengthscales. According to Gradowczyk (1968), one of the conditions for the validity of the shallow water model concerns the perturbation wave number– evaluated on the ratio of the wavelength to the flow depth - which has to be less than 1. Indeed, experimental findings indicate that dunes and ripples exhibit wave number values generally larger than 1, whereas antidunes satisfy the above criterion (e.g. Raudkivi, 1990). Therefore, one-dimensional shallow water models could be confidently employed to describe the antidunes occurrence. However, morphodynamical models assuming immediate adaption of sediment load to transport capacity are able to predict only hydrodynamic instabilities. On the other hand, if the immediate adaption hypothesis is removed, i.e. non-equilibrium sediment transport is accounted for, the shallow water model may describe the occurrence of morphodynamical instabilities associated to antidunes (Parker, 1975; Di Cristo et al., 2006; Vesipa et al., 2012). In the present paper a linear stability analysis of a recently developed two-phase depth-averaged model, which accounts for variable bed-load sediment concentration, is presented. A distinct phase velocity is considered for the bed load. The entrainment/deposition of sediment between the bottom and the bed-load layer is based on a modified van Rijn transport parameter. Two types of unstable perturbations are detected. One propagates downstream at high Froude numbers (gravity wave), the other - related to bed elevation - propagates upstream at low Froude numbers. The comparison with experimental evidence allows interpreting this kind of bed instability as antidunes.

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