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Benchmarking numerical morphodynamic models with analytical morphodynamic theories

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Aim of this work is to suggest a methodological approach for testing new and already established numerical morphodynamic models. The approach is based on a series of benchmark tests directly derived from analytical morphodynamic theories and has the primary aim to check which basic physical processes can be adequately reproduced by the numerical application in the limit cases when analytical theories can be applied and which ones need further improvements.
With this perspective, the work focuses on the mathematical system which couples the shallow water equations with the Exner equation. The numerical morphodynamic model used for assessing the proposed methodological approach is GIAMT2D [1], which solves the above system following a fully coupled approach and using a finite volume method on unstructured triangular grids.
As “morphodynamics benchmarks” we have chosen three analytical solutions that refer to basic, reach-scale 2D morphodynamic processes that have been subject to extensive theoretical and experimental investigations in the past decades. Under the assumption of homogeneous sediments size, theoretical understanding of these processes can be considered quite well-established also thanks to the received quantitative experimental support.
The first test is aimed at checking to which extent model results agree with the results of linear stability analyses when simulating the initial development of free alternate bars. The second test focuses on the occurrence of steady alternate bars in straight channels with localized planform discontinuities, a process taking place at markedly different locations in the case of wide-shallow (i.e. “super-resonant”) and of narrow-deep (i.e. “sub-resonant”) channels, also known as “overdeepening” or “2D morphodynamic influence” [2]. The third test deals with the stability of channel bifurcations.
The performed, extensive, numerical experiments suggest that the proposed methodology shall be more routinely employed by users of numerical morphodynamics models to understand the level at which the basic morphodynamic processes occurring at the reach scale are numerically reproduced and which is the accuracy of their description, thus facilitating the identification of strengths and weaknesses of the numerical model.

[1] A. Siviglia, G. Stecca, D. Vanzo, G. Zolezzi, E.F. Toro, M. Tubino (2013) Numerical modelling of two-dimensional morphodynamics with applications to river bars and bifurcations Adv. Wat. Res. 52, pp 243–260.