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A new analytical framework for understanding the tidal damping in estuaries

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Tidal dynamics in estuaries have long been the subject of intensive scientific interest, particularly to analyse the environmental impact of human interventions. In many estuaries, there are increasing concerns about the impacts on the estuarine environment of, e.g., sea-level rise, water diversion and dredging. However, before predictions about hydraulic responses to future changes can be made with any confidence, there is need to achieve an adequate understanding of tidal wave propagation in estuaries.

In this study, we explore different analytical solutions of the tidal hydraulic equations in convergent estuaries. Linear and quasi-nonlinear models are compared for given geometry, friction, and tidal amplitude at the seaward boundary, proposing a common theoretical framework and showing that the main difference between the examined models lies in the treatment of the friction term. A general solution procedure is proposed for the governing equations expressed in dimensionless form, and a new analytical expression for the tidal damping is derived as a weighted average of two solutions, characterized by the usual linearized formulation and the quasi-nonlinear Lagrangean treatment of the friction term (Savenije et al., 2008). The different analytical solutions are tested against fully nonlinear numerical results for a wide range of parameters, and compared with observations in the Scheldt estuary. Overall, the new method compares best with the numerical solution and field data (Cai et al., 2012a). The new accurate relationship for the tidal damping is then exploited for a classification of estuaries based on the distance of the tidally averaged depth from the ideal depth (relative to vanishing amplification) and the critical depth (condition for maximum amplification). Finally, the new model is used to investigate the effect of depth variations on the tidal dynamics in 23 real estuaries, highlighting the usefulness of the analytical method to assess the influence of human interventions (e.g. by dredging) and global sea-level rise on the estuarine environment.

Subsequently, the analytical framework has been extended to take account of the effect of river discharge (Cai et al., 2012b). The analytical solutions with and without the effect of the river discharge are compared with observed data of the Modaomen and Yangtze estuaries in China, showing that the proposed hybrid model fits the observations with realistic roughness values upstream where the influence of river discharge is measurable.

A new asymptotic solution of the tidal amplitude is found that reflects the balance between friction and channel convergence when distance approaches infinity. Moreover, the usual assumption that the tidal amplitude and velocity amplitude along the estuary axis can be described by an exponential function appear only to be valid for an ideal or frictionless estuary.

References

Cai, H., H. H. G. Savenije, and M. Toffolon (2012a), A new analytical framework for assessing the effect of sea-level rise and dredging on tidal damping in estuaries, Journal of Geophysical Research, 117, C09023, doi:10.1029/2012JC008000.

Cai, H., Savenije, H.H.G., Yang, Q., Ou, S., Lei, Y. (2012b), Influence of River Discharge and Dredging on Tidal Wave Propagation: Modaomen Estuary Case, Journal of Hydraulic Engineering, 138(10), 885-896, doi: 10.1061/(ASCE)HY.1943-7900.0000594.

Savenije, H. H. G., M. Toffolon, J. Haas, and E. J. M. Veling (2008), Analytical description of tidal dynamics in convergent estuaries, Journal of Geophysical Research, 113(C10), doi:10.1029/2007JC004408.