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Exploring river bifurcations response to time-dependent external forcings

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River bifurcations play a crucial role in the morphodynamics of multi-thread channel systems such as braiding or anastomosing rivers, deltas and alluvial fans, as they guide the downstream distribution of water and sediment fluxes. Several experimental and theoretical studies have highlighted the unstable character of bifurcations, even in the case of a symmetric planform configuration and steady boundary conditions, which results in a differential erosion/deposition in the downstream channels and leads to equilibrium states where the flow distribution can be highly unbalanced, sometimes causing the complete closure of one of the anabranches. However, the dynamics of natural bifurcations are always influenced by external unsteady forcing factors, such as water discharge variations due to the hydrological regime, changes in downstream water depth (e.g. because of tidal excursions or interactions between discharge variations and local constraints) and the presence of migrating bedforms. The effect of such factors on the bifurcation's evolutionary process velocity and equilibrium states' flow balance remains widely unexplored: in this work we seek to address this gap, also focusing on the interplay between the factors' characteristic timescales and the bifurcation's "intrinsic" timescale (i.e. the one related to its autogenic instability mechanism). In particular, we investigate the effect of a time-dependent downstream water surface elevation H_d on the behaviour of a simple bifurcation. To this purpose, we model the upstream channel and the two anabranches employing a 1-D shallow-water numerical scheme, coupled with the two-cell nodal point relationship proposed by Bolla Pittaluga et al. (2003) to determine water and sediment partition at the bifurcation node. Starting from a stable, unbalanced equilibrium configuration, we let H_d vary according to linear and sinusoidal functions of time, with the aim of reproducing –in a very simplified fashion– natural phenomena such as backwater effects in braided rivers. Bifurcations response shows a strong dependence on the forcing timescale: specifically, the system reacts accordingly to the ratio between the rate of change of H_d and the bifurcation's intrinsic timescale. In particular, when the two scales show comparable values, the system behaviour is governed by the competition between the external forcing and the intrinsic dynamic response. Such competition allows the bifurcation to reach a regime configuration, whose water and sediment partitionings differ from the initial conditions: specifically, a steady increase of H_d leads to a more balanced configuration, while a decrease of H_d enhances system asymmetry. On the other hand, when variations of H_d are fast with respect to the intrinsic timescale, the bifurcation response increases in magnitude, often leading to an

avulsion. This dual behaviour is closely related to the width-to-depth ratio β; specifically, the rate of change at which avulsion occurs is lower for higher values of β. Ultimately, this modelling framework can be extended to model the unsteady response of fluvial bifurcations to a variety of possible deterministic and stochastic forcing conditions, including hydrological variations of flow discharge.