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The effect of flood events on the altimetric response of river alternate bars

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Alternate bars are large bedforms, characterized by an ordered sequence of scour and deposition zones, which often appear in rivers. It is well proved by many experimental, theoretical and numerical works that the formation of migrating alternate bars results form an intrinsic instability mechanism occurring when the width-to-depth ratio of the channel is larger than a critical threshold. Although a large amount of literature is available to describe equilibrium bar properties under steady flow conditions, much less information exists about the evolution of bars when flow discharge is variable in time. In a recent work we investigated how the long-term, average properties of bars respond to changes of the hydrological regime. This average state represents the net result of a multitude of flood events, each of them producing a different morphological alteration. However, a systematic description of how changes of the bar properties depend on the characteristics of the individual floods is still missing, as existing studies are limited to a small number of flood events, not sufficient to make a statistical description of the riverbed response. In this work, we aim at studying the time evolution of the bar amplitude in a relatively straight, channelized reach of a gravel bed river. Specifically, we considered a 10 km-long reach of the Alpine Rhine River, for which a detailed record of flow stages is available for the period from 1984 to 2010. This is accomplished by modelling the bed evolution through the theoretically-based model of Colombini et al. (1987), here applied by considering a time-varying basic flow and numerically integrating the bar amplitude. Compared with classical approaches based on numerically solving the two-dimensional shallow-water equations, our procedure allows for calculating the bar response over long periods of time with a very low computational cost. This enables for modelling different scenarios of hydrological alterations, due to dam constructions or climate changes, and to statistically analyse the expected impact on bar evolution. Assuming that bars cannot evolve when the flow is too low to fully submerge the bar crests, we identify 200 morphologically-active flood events, covering about 1.1% of the total duration of the flow series. Model results reveal that moderate flow events tend to increase the bar amplitude, while larger floods reduce the bar height. However, the value of the peak discharge alone is not sufficient to explain the morphological changes, as an important (and opposite) role is also played by the duration of the events. Specifically, longer floods tend to promote an increase of the bar height during the receding phase, which implies that a strong reduction of the bar amplitude requires intense, but relatively short flood events.