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Does sediment transport depend on the vertical force in estuarine and coastal flows?

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Abstract

Tidal bores are sudden discontinuities in water depth, and can be classified as undular and breaking bores when tidal waves propagate upstream in a river mouth and on beaches. The impact of different types of forces under bores on sediment transport is not clear, hence specially designed experiments were conducted to clarify the mechanism of sediment initiation, although some physical experiments were performed during the last two decades. In wave condition similar to a steady flow, all the previous studies had used averaged lift force to understand the mechanism of incipient motion. In this study, a laser Doppler anemometer, a highly sensitive force sensor, and ultrasonic displacement meters accompanied by video recordings were used to investigate simultaneously the incipient motion of sediment under tidal bores. No sediment motion was observed during the initial steady flow, but a transient sediment sheet flow motion was observed advected upstream during the breaking bore, however, only a few particles changed their initial position during the undular bore. Visual observation demonstrated two different stages of sediment movement that phenomena were also verified with the measured observations. According to the experimental results, upward vertical force due to swelling in free water surface (stage 1) before the roller toe was the main force in destabilizing the particles. Later, a large upstream longitudinal force was found to be the dominant cause promoting upstream particle motion during the breaking roller passage (stage 2). Furthermore, phases of both horizontal and vertical forces play an important role in tidal bore propagation. It is interesting to note that by using the measured force, the observed phenomenon can be well explained by the Shield threshold criterion.

Keywords

Tidal bore, Hydrodynamic forces, Incipient motion, Physical modelling