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Hydrokinematic regions within the swash zone

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Abstract

A method for delimiting the swash zone and regions within is presented. Two regions are recognized and distinguished by their differing flow kinematics. The outer swash region involves wave-swash interactions and related processes, whereas the inner swash region consists of pure swash motion (i.e., free from interaction with subsequent waves). The boundary between these two hydrokinematic regions can be determined from shoreline elevation time series. The vertical extent of the outer swash was found to scale directly with inner surf zone wave variance and beach slope. Since the vertical extent of the entire swash zone also varies directly with the former, the relative extents of the outer and inner swash are approximately constant for the range of beach slopes investigated here. The efficacy of a previously utilized method for determining the location of instruments in the swash zone, based on the percentage of time the bed is inundated, is established here for the first time. A new method for determining the location of an instrument station within either of the hydrokinematic regions is also presented, and requires only a single pressure sensor time series. The data discussed here include over 140 runup time series collected from five different sandy beaches with beach face gradients ranging from 0.03 to 0.12. The results are expected to be generally applicable to swell-dominated sandy beaches, where swash is driven by a combination of short and long waves in the inner surf zone. The applicability of the results at either extreme of the reflective–dissipative continuum remains to be established.
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1. Introduction

The swash zone is located between the continuously wet inner surf zone and the continuously dry sub-aerial beach. It is the zone that is periodically swept by shoreline motion, and is thus alternately submerged and dry. The mean position of the shoreline is approximately located where the mean water surface in the surf zone due to wave setup intersects the beach face (Guza and Thornton, 1981; Nielsen, 1989). The shoreline motion about this mean position occurs in relation to waves of varying frequency (wind waves, swell, and infragravity waves) as well as the tide (Guza and Thornton, 1982; Hughes and Turner, 1999; Elfrink and Baldock, 2002). The term swash is generally used to collectively describe both the shoreline motion and the flow within the relatively thin lens of water that moves up and down the beach in connection with the shoreline (e.g., Hughes and Turner, 1999; Butt and Russell, 2000; Elfrink and Baldock, 2002; Masselink and Puleo, 2006).

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Recent studies of flow kinematics and sediment transport have identified clear differences in the nature of the outer and inner swash zone. For example, Masselink et al. (2005) reported the net sediment flux to be directed offshore in the outer swash (their 'transition zone between inner surf and swash') and onshore in the inner swash. Aagaard and Hughes (2006) reported similar results, but found that the net sediment flux in the outer swash could also be directed onshore if the beach face morphology included an inter-tidal bar. Aagaard and Hughes (2006) presented data showing that the turbulence structure can also differ between the outer and inner swash. Masselink and Russell (2006) demonstrated that the magnitude of the velocity skewness at their field sites was larger in the outer compared to the inner swash, but negative in both cases. All the three studies either imply or explicitly state that the outer swash included wave-swash interactions and the inner swash included only pure swash motion (i.e., free from interaction with subsequent waves). While it is clear that there are two distinct regions distinguished by their flow kinematics, nothing is presently known about the relative extents of these two regions and whether they vary according to beach type. Before this can be investigated further the boundary between these two hydrokinematic regions must be defined precisely.

Due to the randomness of natural waves, it can be difficult to successfully install fixed instrument stations to measure swash processes for any significant length of time. The extent and position of the swash zone varies considerably with each successive short wave (wind wave and swell) as well as with lower-frequency infragravity waves and tides. The fact that one swash cycle often does not complete before the arrival of the next wave complicates the situation further. A fixed instrument station on the beach face may at one time be experiencing only fluid motion due to swash and at other times it may be experiencing waves overrunning a preceding swash lens. Earlier on or later in the tide cycle it may be in the inner surf zone or on the subaerial beach. Such complications can confound the direct comparison of data at different times within the one-field deployment as well as between different beaches.

Given the differing nature of the outer and inner swash and the fixed location of instrument stations relative to the moving boundary between the two, it is important to describe where data was obtained (instrument station was located) within the swash zone, but few studies have done this in a quantitative way. Those that have, determined the percentage of time that the instrument station (bed) was inundated to indicate approximate position (Masselink et al., 2005; Aagaard and Hughes, 2006). The premise being that a large percentage of time inundated means the instruments are located toward the seaward boundary of the swash zone and a small percentage of time inundated means they are located toward the landward boundary. The efficacy of this approach has not been established to date. The way that inundation time varies across the swash zone is unknown, as is its consistency across beach types. While this approach is useful to some extent, one drawback is that it does not explicitly indicate whether the instrument station is situated in either the outer or inner swash.

This paper identifies a means for delimiting the outer and inner swash regions, and investigates their relative extents. It establishes the efficacy of the presently available approach for identifying the location of an instrument station within the swash zone (viz., percentage of time the instruments are inundated), and also provides a new method for identifying where an instrument station is located relative to the outer or inner swash. These issues are addressed using field experiments measuring both the shoreline motion and water depth at many positions across the swash zone on a wide range of sandy beach types.

2. Definitions and concepts

2.1. Definition of terms

Fig. 1 defines the terms used throughout this paper. A *swash cycle* is defined in terms of shoreline oscillations and involves a single landward then seaward movement of the shoreline (Fig. 1a). There is no requirement for the shoreline to return to the original elevation. Swash cycles are, therefore, delimited by consecutive shoreline minima with one intervening shoreline maxima. On this basis there are three swash cycles shown in Fig. 1a. *Swash events* at a specified elevation on the beach face are defined by periods of bed immersion (water depths greater than zero), and separated by periods of zero water depth. The beginning of a local swash event is marked by a rise from zero water depth and the conclusion by a return to zero water depth. If there are no overrunning waves passing the specified

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