A NEW SIMPLE PARAMETER TO CLASSIFY SEAFLOOR STATE

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ABSTRACT

We present a new and simple parameter dependent only on wave height, depth, and sediment grain size to classify the seafloor state into one of three categories: rippled, washout, or relict. Wave-generated vortex ripple existence is predicted from critical thresholds of ripple formation and washout. If the ripple reset parameter is greater than the critical value for ripples and less than a critical value for washout, then the ripple length and height can be calculated from a ripple model (e.g., Kearney and Penko, 2022, Nelson and Voulgaris, 2015). If the ripple reset parameter is less than the critical value, then the ripples could be relict and time dependent information is required to predict the ripple geometry.

INTRODUCTION

Traditionally, non-dimensional parameters relating the mobilizing to the stabilizing forces on the seafloor have been used to determine the motion of sediment and formation of ripples. A threshold value of the Shields parameter is typically used to indicate the initialization of sediment mobilization and is also common in ripple formation threshold equations. Similarly, the mobility number (Brebner, 1980) also includes the wave orbital excursion length, a parameter important in ripple formation. Thresholds of other non-dimensional parameters such as the period parameter (Mogridge et al., 1994) and the Sleath number (Sleath, 1984) number have also been previously used to indicate when ripples will form. However, all these parameters require an estimation of shear stress at the seabed, a quantity difficult to measure, and that requires an iterative solution. To address this problem, we introduce a simple, robust method to predict the change in wave-generated ripples on the seafloor. A ripple reset parameter is used to estimate whether the present wave conditions at a particular location will cause a change in the ripples on the seafloor. The parameter can quickly estimate a change and can therefore be implemented in stochastic or ensemble model without imposing a computational expense associated with an iterative solution.

METHODS

To reduce the complexity and the empirical parameters necessary for calculating an evolution threshold, we derive a simple ripple reset parameter as a function of surface wave conditions, water depth, and grain size. We focus on shallow water waves where we can make the following assumptions: $\sinh kh \sim kh + O(kh)^2$ and $L = T(gh)^{0.5}$, where k is the wave number, L is the wave length, T is the wave period, g is the acceleration due to gravity, and h is the water depth. The wave orbital excursion, A, can then be reduced to,

$$A = \frac{HT}{4\pi}\sqrt{\frac{g}{h}}. \tag{1}$$

Substituting A into the mobility number equation, we can derive a ripple reset parameter, Λ, applicable in shallow water as,

$$\Lambda = \frac{H^2}{4hd_{50}}, \tag{2}$$

where d_{50} is the mean sediment grain size. The limited amount of information required for seabed change is ideal for simple, quick estimates of the effect of waves on ripple formation. Here we show the validity of this method at several field sites with different depths and grain sizes.

RESULTS

The validity of the parameter to predict ripple changes was assessed by comparing the observed changes in ripple wavelength with the times at which the ripple reset parameter exceeded an arbitrary threshold. By varying the critical threshold of ripple reset, we can examine the application of the parameter to predict ripple resets under different conditions. We compared the predicted times of ripple reset to observations of time-varying ripple wavelength. The observations were made in the Gulf of Mexico off the coast of Panama City, FL (Target and Reverberation Experiment - TREX13 (Penko et al., 2017)), and in the western Atlantic Ocean off the coast of Assateague Island - ASIS15 (Trembanis et al., 2019; DuVal et al., 2021)) in water depths up to 14m. Wave conditions (height, period) and ripple geometry (length) were measured with acoustic instruments for 4-8 weeks during each of the deployments.

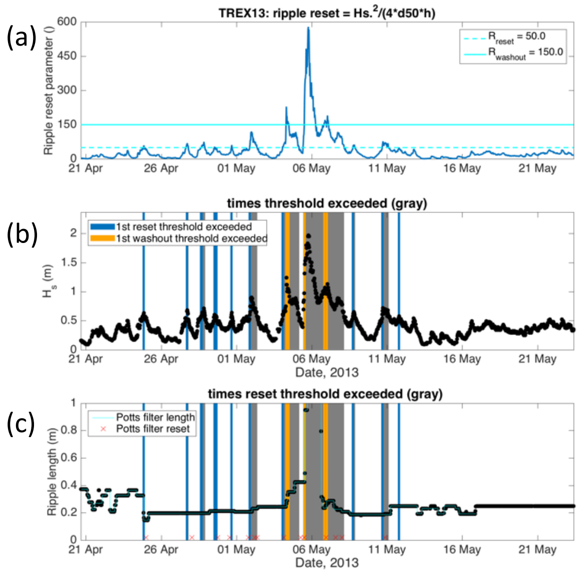

Figure 1. a) Time series plot of the ripple reset number (blue) and chosen reset (dashed teal) and washout (solid teal) thresholds. b) Plot of the significant wave height, Hs, (black dots) with time shaded (gray) when the ripples were predicted to be in motion. The blue and orange lines denote the first times that the critical reset and washout thresholds were exceeded, respectively. C) A plot of the observed ripple wavelength (black dots) with the predicted ripple reset times (gray, blue, and orange shading).

The observed conditions and the calculated ripple reset number are plotted in Figure 1. A critical threshold was selected to indicate ripple formation and evolution (R_{reset}), and an additional threshold to denote when the ripples are completely washed out by the flow ($R_{washout}$). The critical thresholds are plotted with the Ripple Reset number (2) calculated from the time series of wave height (Figure 1a) measured during the TREX13 experiment. The observed significant wave height along with the times at which the ripple reset number exceeds the critical thresholds are plotted in Figure 1b (gray shading). Additionally, the first times at which the ripple reset and washout thresholds are exceeded are plotted as blue and orange lines, respectively (Figure 1b,c).

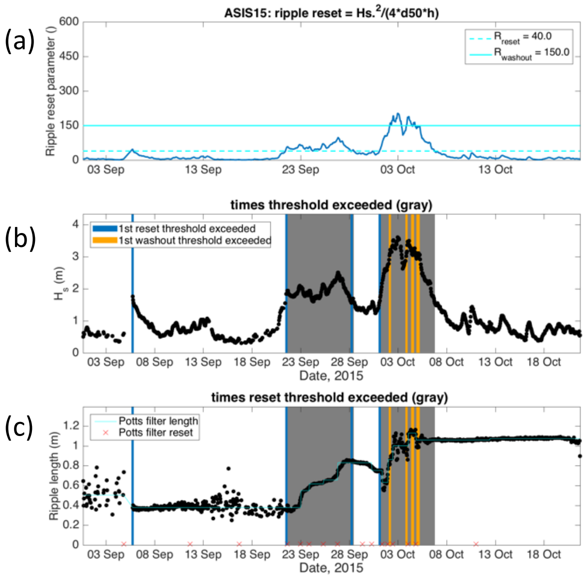

Figure 2. Same as Figure 1 with data collection at the Assateague Island experiment.

The change in the observed ripple wavelength was calculated using a Potts filter to filter out the noise and only retain the large gradients in ripple wavelength (Figure 1c & 2c, teal line). The changes calculated with the Potts filter are denoted with red x's (Figures 1,2c). Qualitatively, the changes in ripple wavelength align well with the shaded regions of times predicted as ripple resets. In some instances, the timing is slightly off. We attribute this discrepancy due to the single-value critical threshold chosen.

A second field experiment was used to compare observations of ripple wavelength change with the predictions of the ripple reset parameter (Figure 2). A slightly lower critical threshold of the ripple reset parameter was chosen for this field site. In this experiment, the ripples evolved constantly within two time periods, with only very small changes in wavelength outside of the two time periods. The parameter predicts the constantly evolving changes well but does not capture the small changes. This discrepancy can also be attributed to the single-value critical threshold applied. Changing the critical value for ripple reset a small amount in either direction will affect both the timing (as seen in Figure 1) and the prediction of the existence of a reset (as seen in Figure 2).

CONCLUSION

Qualitatively, the ripple reset parameter can predict timing of changes in wave-generated ripples. However, the predictions are sensitive to the choice of the critical thresholds, similar to the application of other non-dimensional parameters to predict sediment transport (e.g., Shields parameter). A more practical way to apply the ripple reset number would be to use it to estimate an approximate time of reset and run a stochastic model many thousands of times to provide a distribution of resets. The probability of a change could then be calculated, removing the limitation of a single-value threshold. That method is now possible due to the reduced environmental parameters needed and the fast and simple calculation of the ripple reset parameter.

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