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Boulder displacements along rocky coasts: A new deterministic and theoretical approach to improve incipient motion formulas

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A B S T R A C T

Several impacts of high-energy marine events – tsunamis and storms – which have occurred along the Mediterranean coasts, have determined boulder displacements in different ways, spanning from sliding and overturning to saltation. The dynamics of these transport modes to the incipient motion of boulders, strictly connected to the pre-setting scenarios, has been extensively studied considering the boulder size and the hydrodynamic parameters of high-energy marine events, such as the wave flow velocity. Notwithstanding this, known hydrodynamic relationships provide some unrealistic flow values concerning the real wave flow velocity registered along the Mediterranean coasts. In this work, a new deterministic and theoretical approach has been developed to assess the minimum flow velocities required to move coastal boulders. The proposed approach is based on the introduction of modified parameters, which consider the real dimensional features of the boulders assessed by means of modern geophysical survey techniques, into the incipient motion formulas. To accurately define these parameters, we created a database composed of boulders located along the coasts of Apulia and Sicily (Italy) that were surveyed in previous studies through photogrammetric and Terrestrial Laser Scanner techniques. Results highlighted that the incipient motion formulas, revised with the new proposed parameters, provided minimum flow velocity values for boulder transport initiation, which were significantly lower compared to those calculated using the previous approach. Thus, the proposed modifications are a step forward towards defining the dynamics of boulder displacement.

1. Introduction

Earth surface processes are gradually becoming a predominant threat to human settlements and economic development. Among these, water-related disasters (high-energy events) play an important role because global warming is probably increasing the occurrence frequency and magnitude of these events (IPCC, 2021, 2019; Scicchitano et al., 2021). Furthermore, owing to ongoing global warming, a general mean sea-level rise is expected for the 21st century with a likely range between 0.61 and 1.10 m at 2100 (IPCC, 2021, 2019) or even greater (Bamber et al., 2019; López-Dóriga and Jiménez, 2020; Rahmstorf, 2007). These sea-level rise projections imply that in the near future many coastal areas could be submerged, thereby changing the areas influenced by flooding processes of high-energy events, such as storms, cyclones, and Mediterranean Hurricane (Medicane) (Cavicchia et al., 2014; Conte and Lionello, 2014; Lionello et al., 2017; Mattei et al., 2021; Nastos et al., 2018; Scicchitano et al., 2021). Although along the Mediterranean coasts the occurrence of common storms has caused many boulder detachments and displacements (Biolchi et al., 2019a, 2019b; Mastronuzzi and Sansò, 2004; Piscitelli et al., 2017; Scardino et al., 2020), establishing the relationship between storm wave magnitude and boulder size is a difficult task.

Using boulders as "markers" to predict the local magnitude of modern and past high-energy hydrodynamic events, such as tsunamis (Paris et al., 2010a; Pignatelli et al., 2009; Scicchitano et al., 2007, 2012; Vacchi et al., 2012), large storms including extra tropical cyclones, hurricanes and typhoons (Cox et al., 2018; Hall et al., 2006; Hall, 2011; May et al., 2015; Scicchitano et al., 2020; Terry et al., 2016), water

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