

CONTINUOUS FIELD MEASUREMENTS OF DUNE SLUMPING DURING STORM SURGES

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INTRODUCTION

On sandy coastlines, dunes frequently serve as the main line of defense against coastal storms. During a storm, wind and wave setup result in an increased water or surge level, which submerges the beach, allowing waves to collide with and impact the dune face (van Wiechen *et al.*, 2023a). As a consequence, masses of sediment become unstable and these masses, henceforth called slumps, slide down the dune face. These slumps temporarily defend the dune face until they are suspended in the water column and transported offshore by waves and currents, leaving room for new slumps to slide down. (van Gent *et al.*, 2008). This cycle can persist until waves finally wash over the remaining dune, leading to dune failure.

The speed of dune face erosion partially depends on the size of the slumps and the frequency with which slumping events occur. Field measurements during storms of slump volumes and frequencies are rare due to (1) the unpredictability of storms, (2) the risks storms pose for observers, and (3) the difficulty of recording profile transects continuously during a storm without disturbing the dune face.

This study presents new data of the dune slumping process collected during the RealDune/REFLEX field experiments. Data were collected on the Sand Engine, the Netherlands, from October 2021 to January 2022 (van Wiechen *et al.*, 2023b). Two artificial dunes were constructed above the high-water line and monitored for three months. We measured hydrodynamic and morphodynamic conditions during passage of three storms: one (each) in November, December, and January. During the December and January storms, one

dune face was monitored by a line-scanning lidar (O'Connor & Mieras, 2022), enabling the quantification of slump volumes through profile cross sections (Figures 1 and 2).

ANALYSIS AND CONCLUSIONS

Visual observations from GoPro images of the December storm (Figure 1), and profile cross sections based on the lidar data of both storms, collectively indicate that slumping is triggered when the dune face has a nearly vertical or overhanging profile. Water levels recorded by a pressure sensor on the beach in front of the dune reveal that a slumping event can occur before, during, and after wave uprush, implying that there is no direct wave-related trigger that initiates slumping. The total slump volumes are discontinuous, varying in size and frequency over the course of the storms (Figure 2b for the January storm). On the contrary, the total dune volume decreases continuously, following an S-shaped curve (Figure 2a). The inflection point of this curve approximately coincides with the maximum water level recorded by the pressure sensor in front of the dune.

Based on these observations, we propose the concept of a sediment pathway with three stages that may explain the development of dune erosion in the collision regime (Figure 3). Stage 1 is the dune system, which can be regarded as a large sediment source for the entire system. From Stage 1, sediment can move to Stage 2, the dune base, through slumping. The dune base functions as an intermediate stage or buffer of sediment. From Stage 2, hydrodynamic action suspends sediment into the water column, which is Stage 3. Once suspended into the water column (*i.e.*, in Stage 3), the sediment is transported offshore and away from the dune.



Figure 1 – a) GoPro image of the dune face during the December storm on Dec-02 00:00:55 with the lidar position in white and transect in green. b) GoPro image during wave impact at 00:00:58. c) GoPro image at 00:01:03 with lidar transect after wave impact which caused a slump to drop down (dotted white).

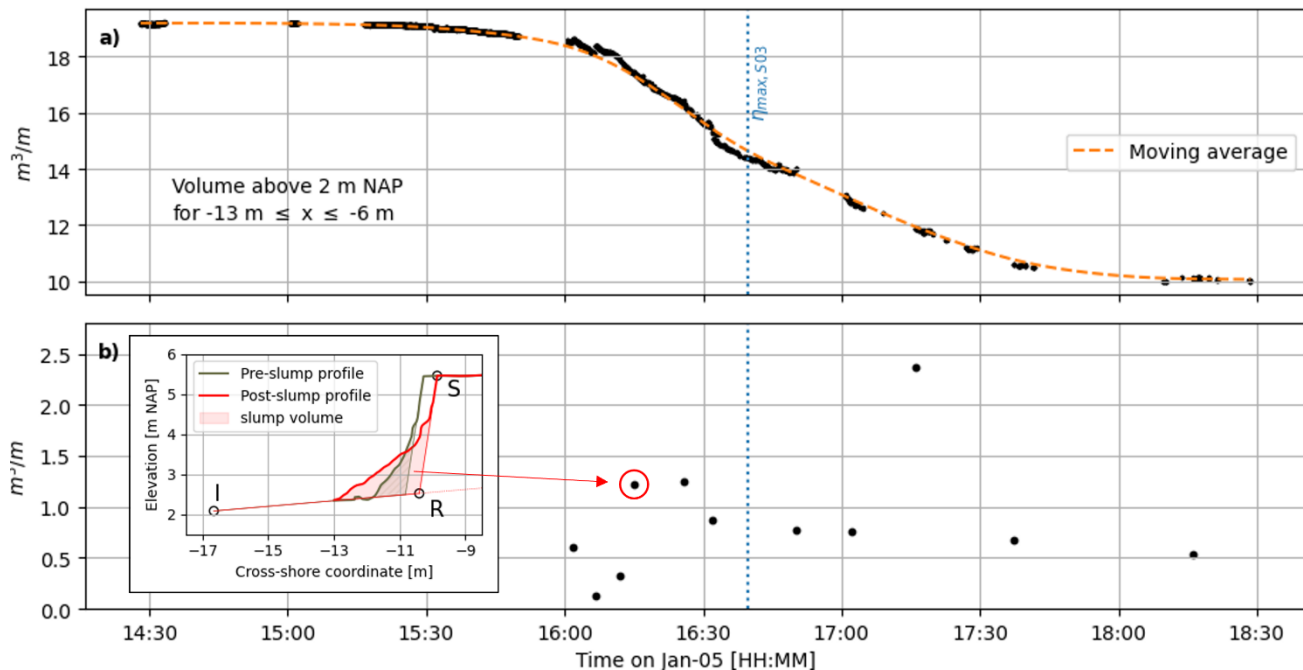


Figure 2 - a) Total sediment volume of the dune in m^3/m between cross-shore coordinates -13 and -6 m, above 2 m NAP (Dutch coordinate system), over the course of the January storm. The dune volumes were computed shoreward of -13 m, because seaward of -13 m water and swash motion continuously disturbed the lidar profile cross-sections. b) Individual slump volumes during the January storm. Volumes represent the red area in the inset Figure, minus sediment that is still present in the profile of a previous slump (hatched green).

Stage 1 is schematized as the area below and right of the boundary made up of points I, R, and S (Figure 3). Stage 2 is schematized as the area above and left of this boundary. Point I is seaward of the dune, on the plane with which the dune toe retreats. This plane is under a slope equal to the wet slope of the dune sediments. Point S is the crest of the dune scarp. Point R is the intersection between the line that runs upward from I under the wet slope of the dune sediments, and the line that runs downward from S under the dry slope of the dune sediments.

The total dune volume loss is continuous, which implies there is a continuous suspension of sediment from Stage 2 to Stage 3 (Figure 2a). In contrast, sediment transport due to slumping (Stage 1 to 2) is more irregular and discontinuous (Figure 2b). Thus, there is a storage buffer in Stage 2 for the surplus of sediment that slumps down but is not immediately suspended towards Stage 3. The storage volume of this buffer in Stage 2 varies with time

depending on the size of the slumps that replenish it. At times when the buffer is nearly diminished, indicated by a nearly vertical or overhanging profile, a new slump supplies sediment to the buffer so that it does not run empty. Slumps may also drop down sooner when there is still sufficient sediment in the buffer.

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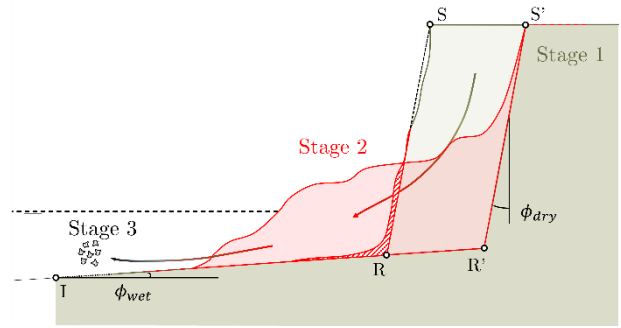


Figure 3 - The sediment pathway as proposed in this abstract. Sediment moves from Stage 1 to Stage 2 through slumping (light green area between RS and R'S' becomes red), decreasing the volume of sediment in Stage 1 (light green to dark green), but increasing the volume in Stage 2 (hatched red to red). The sediment moves from Stage 2 to Stage 3 when it is suspended into the water column. I-R-S is the boundary between Stage 1 and 2 of the pre-slump profile of the dune. I-R'-S' is the boundary between Stage 1 and 2 of the post-slump profile of the dune.