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Measuring oblique wave run-up and overtopping with laser scanners

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The Eems-Dollard estuary in the Netherlands is a highly complex estuary of deep channels and tidal flats, which is part of the Wadden Sea. A particular aspect for this area is that the design conditions are characterized by very obliquely incident waves, up to 80° relative to the dike normal. Wind, water levels, currents, waves and wave run-up and overtopping are being measured in an extensive field measurement project in this estuary for the coming 12 years, starting in 2018. In the project, wave overtopping is measured with wave overtopping tanks built into the dike. This is a robust but also expensive method. Moreover, with overtopping tanks the velocities of up-rushing waves are not measured. An alternative system to measure wave run-up and overtopping at a dike in real situations with oblique wave attack is being developed and is the objective of this paper. It includes the first validation with real oblique waves on an actual dike slope.

The system uses two terrestrial laser scanners (SICK LMS511pro HR LIDARs). Laser scanners are often used for bathymetry measurements, but have also been used to measure the water surface, waves or wave run-up. The system consists of the two laser scanners, attached to an easily relocatable pole, see the left panel of Figure 1 for a schematic set-up and the right panel of Figure 1 for a validation set-up at a real dike. The laser scanners measure the distance to a surface by measuring the time that the reflection of a laser pulse takes to reach the scanner again. Furthermore, the reflected signal intensity is measured, which provides information on the type of surface (e.g. wet or dry). The scanners use a mirror that rotates at a frequency of typically 50 Hz. Hence, the laser scanners scan along a line, in this case running from the dike toe to the crest (dashed lines in left panel of Figure 1). The distance between both scanned lines can be adjusted by changing the angle of the laser scanners relative to the pole.

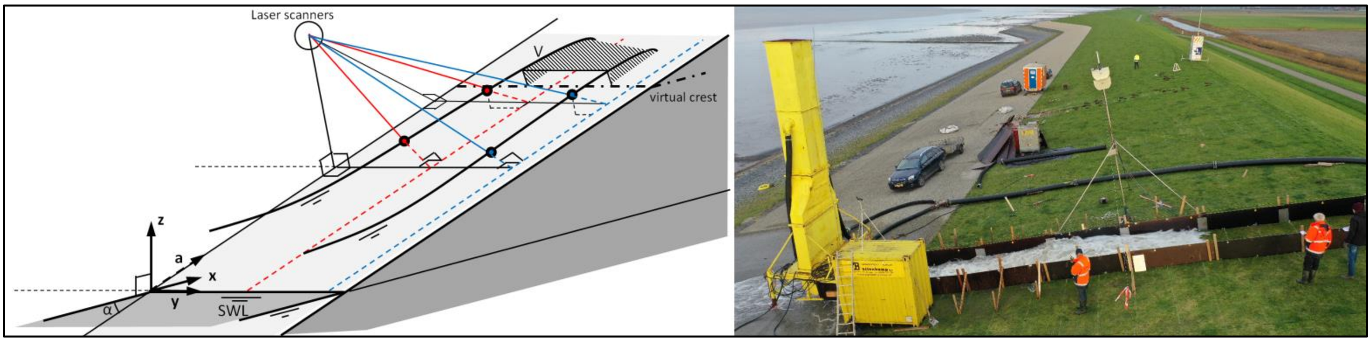

Figure 1. Left: Schematised set-up of 3D measurement system with two laser scanners, based on Hofland et al. (2015). Red and blue dashed lines represent scanning laser lines, red and blue dots represent scanned points on the water surface. Still water level (SWL), virtual crest level and overtopping volume (*V*) are indicated as well. Right: Drone shot of set-up of laser scanner system and run-up simulator on actual dike during tests with normally incident waves.

The system was first tested with the wave run-up simulator (Van der Meer, 2011) on the grass slope of a dike. First, tests were done for normally incident waves, where the influence of a large range of environmental conditions (e.g. producing artificial wind and rain) and laser scanner parameters were tested and calibrated. After that, the wave run-up simulator was placed under an angle with the dike normal, see the left panel of Figure 2. With this set-up, obliquely incident waves under an angle of 45° were generated and tests were performed with several different distances between the scanned lines.

From the measured signals, the layer thickness is determined, as well as the front velocity. From the layer thicknesses, the run-up can be determined. From layer thickness and velocity, or from volumes in time above a certain virtual crest level, the (virtual) wave overtopping discharge can be calculated at any height (Hofland et al., 2015). From the correlation between the two measured signals, the 3D front velocity, direction and overtopping volumes can potentially be determined as well.

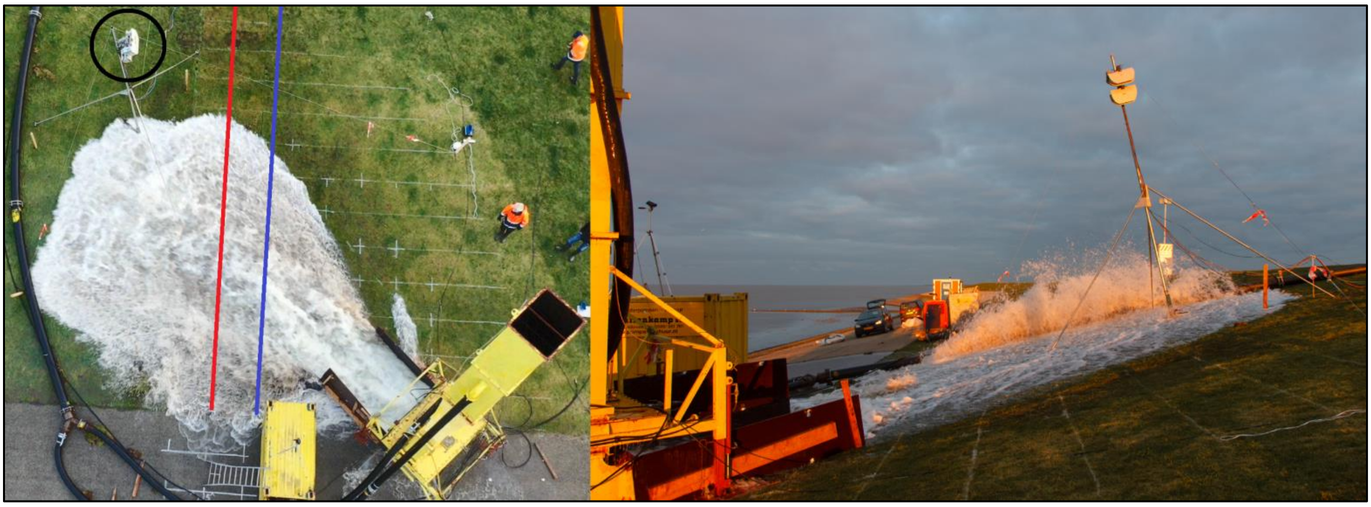

Figure 2. Left: Top view by drone, with the laser scanners (black circle) and the scanning laser lines (red and blue lines) indicated. Right: Side view of laser scanner system and run-up simulator on an actual dike during validation tests with obliquely incident wave run-up.

The paper will present a detailed description of the set-up and analysis of these tests, as well as a validation with measured run-up heights, velocities and layer thicknesses, resulting from additional measurements (e.g. "surfboard" and video data). The validation will support a go/no go decision: if the validation is positive, the system will be placed on a real dike for 3 years to measure wave run-up and overtopping for severe winter storms additional to the measurements with overtopping tanks.

The wave overtopping can potentially be quantified more cost-effectively with this system than with overtopping tanks built into the dike. Furthermore, since the system is mobile, it can measure at several dike locations by moving the system every few years.

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