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A Lightweight, Autonomous, Down-looking Wave Gauge Array in Shallow Lakes

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Abstract

Spatially and temporally distributed in-situ wave data is difficult or expensive to collect, however, such a dataset is important for understanding wave propagation and validating numerical models. Here we explored an alternative to array of underwater pressure gauges, consisting of cheap and easy-to-install ultrasonic wave gauges mounted on tripods above the water surface, measuring the downward distance, equipped with telecommunication modules and solar panels. In a pilot application, these wave gauges were deployed in a shallow lake, and their data was compared to those collected simultaneously with an underwater, upward looking echosounder. The presented network proved to be able to provide an accurate picture of the sea state at a fraction of the cost of a “professional” instrumentation.

Keywords: wave gauge, acoustic surface tracking, ultrasonic distance measurement.

1. INTRODUCTION

In the presence of patchy emergent vegetation, for example, the wave field has a high spatial and temporal variability, as it is influenced by refraction and diffraction. In order to sample wave characteristics at many frequent combinations of wind and mean water level on the field with high enough likelihood, sufficiently long-term and spatially distributed measurements must be performed. In order to reduce the costs of such a survey, we developed solar-powered, networked ultrasonic wave gauges, whose low cost make them affordable for array measurements, e.g. in a regular pattern just a few hundred meters from each other. The paper describes the technical details and the validation through a pilot study.

2. MEASURING INSTRUMENTS

Our wave gauges track the distance of the water surface from a fixed point above the water surface with a ubiquitous ultrasonic car parking sensor, same as those integrated into bumpers. The instrument is equipped with a battery, a solar panel, a microcontroller including a time module, an SD card and a radio communication module. Earlier the gauges were successfully operated at a frequency of 1 min^{-1} in order to observe slower wind-induced water level fluctuations in a channel system connected to a lake (Krámer et al. 2020). In this study, the gauges were adapted to measuring wave parameters using 5 Hz sampling frequency.

For validation, we carried out a pilot study in a bay of Lake Fertő (Austria/Hungary). The average water depth of the measurement area was only between 60 and 80 cm. The transducer of the gauges was placed above the water level, on aluminium tripods, looking down vertically towards the water surface. Moreover, a single Nortek Signature 100 acoustic Doppler current profiler placed on a cross-shaped platform on the lake bottom, was operated simultaneously to validate one of the down-looking gauges. Due to the constraining shallowness, the only useable information from this instrument was the ultrasonic surface tracking. Additionally, the wind was recorded close to measuring area by a sonic anemometer placed on a 4 m tall mast.

3. RESULTS

Figure 1 gives insight into the validation through the derived bulk wave parameters from spectra at one of the gauges for a three-day-long period. The Nortek Signature surface tracking was considered an accurate and detailed reference. The estimation of significant wave height H_{m0} from the down-looking gauges was found to be accurate and unbiased. Whereas the wave period

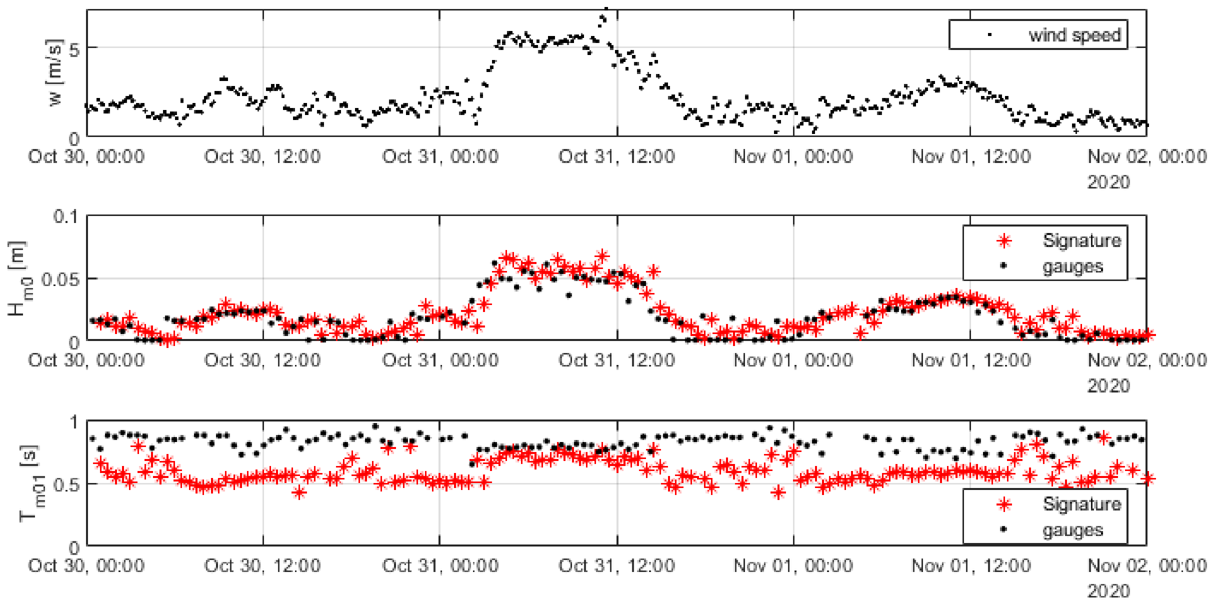

Fig. 1. Measured time series between 30 October and 2 November 2020. From top to bottom: wind speed, significant wave height H_{m0}, and wave period T_{m01}. Red – underwater surface tracking by the Nortek Signature, black – down-looking gauges.

T_{m01} was also quite well resolved during wind speeds exceeding 5 m/s, it was overestimated during calm periods. As is known, unlike H_{m0}, the wave period T_{m01} depends not only on the zero-order, but also on the first-order moment of the power spectrum, and so, it is sensitive to high-frequency noise. The low accuracy during weaker winds is not seen as a major drawback when the impact of waves on sediment motion must be characterised, as waves below 2 centimetres do not generate significant turbulence near the bed anyway.

4. OUTLOOK

The easy deployment and the successful validation of the lightweight down-looking wave gauges encourages their application in lake studies. Thanks to their low cost, the gauges can be deployed in large numbers in this shallow, fetch-limited environment. The solar panels ensure that their operation is autonomous, which helps lower total costs further. As the next step of the development, the low-power wide-area LoRa (Long Range) module installed on the gauges to provide online communication with the gauges will be tested, with the vision of real-time processing and visualisation of the sea state.

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