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# Laser particle counter validation for aeolian sand transport measurements using a highspeed camera

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ABSTRACT

Measuring aeolian sand transport rates in the field has been a long-standing challenge. In this paper, we present the results of a laboratory experiment to test the ability of a laser particle counter sensor (*Wenglor*) to accurately count sand grains of various grain size classes and stainless steel beads. We compared the count data collected by the *Wenglor* with images from a *Highspeed camera* which revealed the actual number of grains passing the laser beam. A *Silicon photodiode* was used to record the laser intensity reduction induced by the sand grain passage through the laser beam to derive the minimal necessary reduction for the *Wenglor* to count grains.

For the two possible settings of the *Wenglor*, i.e., Minimal Teach-in or Normal Teach-in, a minimum of 18% and 78% blocking of the laser beam was required for recording a count. This implies that the minimum grain size that can be observed by the *Wenglor* is $210 \pm 3\mu m$ and $495 \pm 10\mu m$ for the two settings respectively, which is considerably coarser than previously assumed. Due to the non-uniform power distribution of the laser sensor intensity, at the detection limit of 210 μm, only grains passing through the centre of the beam will be counted.



## 1. Introduction

Quantitative prediction of aeolian transport rates on beaches remains difficult. To validate new approaches to calculate aeolian transport, *in situ* field measurements are needed. Various instruments are available to measure rates of sand transport and every instrument has its own limitations (Sherman et al., 2011; Hugenholtz and Barchyn, 2011b). Typical instruments used include sand traps, impact detectors *(Miniphone, Buzzer disc, Safire, Sensit)* and optical sensors (*Wenglor* fork sensor).

Over the last decade, the *Wenglor* sensor has been used in various studies to obtain rates of aeolian sand transport in the beach-dune environment (Davidson-Arnott et al., 2012; Sherman et al., 2011; Hugenholtz and Barchyn, 2011b; Delgado-Fernandez et al., 2012; Bauer and Davidson-Arnott, 2014). This sensor has been developed for industrial applications, such as: sorting extremely small parts; recognising slots, holes and notches; and supply control. In search of better aeolian transport sensors these are now being used in sand transport measurements. These are off-the-shelf sensors, not tested by the vendor for such applications. However, the sensors have been tested in wind tunnels (Barchyn et al., 2014), resulting in positive conclusions regarding its suitability to record aeolian sand transport. Also field applications of the sensor reported in the literature seemed to provide realistic results. However, in a transport sensor comparison in the field reported by Sherman et al. (2011) the *Wenglor* strongly underestimated the transport compared to other sensors. Subsequently, it was reported that during these field experiences the *Wenglor* was used in Normal Teach-in mode which is the least sensitive mode of the *Wenglor* for detecting particles (Hugenholtz and Barchyn, 2011a; Li et al., 2011).

The basic principle of this optical sensor is that a grain is counted when it blocks a sufficient area of a 0.6 mm diameter laser beam. This principle suggests that a sensitivity to grain size exists. The *Wenglor* has two possible switching settings, i.e. Normal Teach-in and Minimal Teach-in. It is assumed that Normal Teach-in requires 50% blocking and Minimal Teach-in requires 10% blocking (Hugenholtz and Barchyn, 2011b). Barchyn et al. (2014) and Hugenholtz and Barchyn (2011b) assumed (stated in manufacturer's data sheet) that the minimum possible grain size in the case of sand grain is $40\mu m$.

Leonard et al. (2012), Bellot et al. (2013) and Naaim-Bouvet et al. (2014) show the potential use of *Wenglor* sensor in drifting snow measurements when that sensor is compared with a *Snow particle counter* (SPC). In these studies, they found that the minimal

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snowflakes particles size that it is possible to count or see with the *Wenglor* (threshold for Minimal Teach-in) is 224 μm, 213 μm and 206 μm respectively. However these are snowflakes, which are not necessarily comparable to sand grains. It remains unclear how shape, opacity and diffraction around natural sand grains may affect the visibility of sand grains crossing the laser beam.

The goal of this paper is to assess the ability of the *Wenglor* sensor to detect sand grains of differing diameters using laboratory experiments, including the use of a *Highspeed camera*.

This paper is organised as follows. In Section 2, the experimental methods and materials are detailed. In Section 3, the main results of the data collected are presented and its corresponding discussion appears in Section 4. Finally, in Section 5 a summary and the main conclusions of this study are presented.

## 2. Instrumentation, data acquisition and processing

To test the ability of the *Wenglor* sensor to count sand particles, we set up a simple experiment in the laboratory as shown in Fig. 1 (a). The experimental setup is as follows. A funnel is filled with polydisperse sand grains or monodisperse stainless steel beads. The grains dropped through the sensor and simultaneously a high-speed camera is used to capture images of the laser beam area. At the same time, we directly measure the reduction of the laser intensity – using a photodiode – to obtain the exact value of this reduction while a particle is crossing the laser beam of the *Wenglor*.

In the following sub-sections, we describe the granulometry of the particles used in the experiments, and the configuration of the three data acquisition instruments: *Wenglor*, highspeed camera and photodiode.

### 2.1. Particle size distribution

Sand grains and stainless steel beads were used during the experiments. The sand grains correspond to typical sand from aeolian sand transport and were collected in sandtraps at Egmond aan Zee (The Netherlands) during autumn 2015. The granulometric curve of this sample is shown in Fig. 2 and the D50 of the sample is 260 μm. The monodisperse stainless steel beads used in the experiments have a diameter of $d = 500$ μm.

The sand sample was divided into five groups using a shaker and new stainless steel sieves of mesh apertures 125, 180, 250, 450 and 500 μm. Fig. 3 shows the granulometric curve for all the groups of sand obtained using the sieves, that is, 125 μm $\leqslant d_1 < 180$ μm, 180 μm $\leqslant d_2 < 250$ μm, 250 μm $\leqslant d_3 < 450$ μm, 450 μm $\leqslant d_4 < 500$ μm and $d_5 \geqslant 500$ μm. These granulometric curves were obtained using a Mastersizer 2000 according to the Fraunhofer diffraction principle (de Boer et al., 1987).

From the granulometry (Fig. 3) it is possible to see that the D50 for the classes is 160, 210, 240, 450 and 500 μm. These granulometries are not fully inside the expected range after the division by sieving but this is normal due to the fact that dry sieving segregates the particles by the length of the smallest and intermediate grain axes (Sahu, 1965). Rodriguez and Uriarte (2009) state that when using dry sieving, non-spherical particles can correspond to a lesser or greater size than spherical particles with an equal volume, and the difference between the sieving and Multisizer or Mastersizer increases when the sphericity of the particles decreases. Fig. 4 presents pictures of the various sand grains used in the experiments, from which the non-sphericity of the particles is clearly visible.

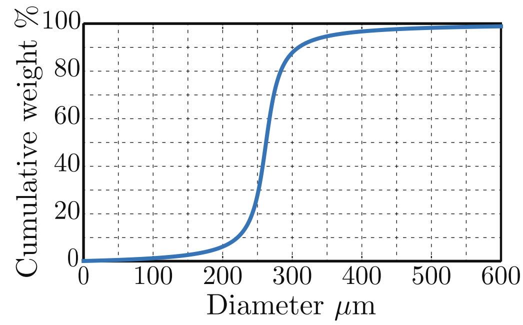


**Fig. 2.** The granulometric curve of the sand sample that was collected using a sandtrap.

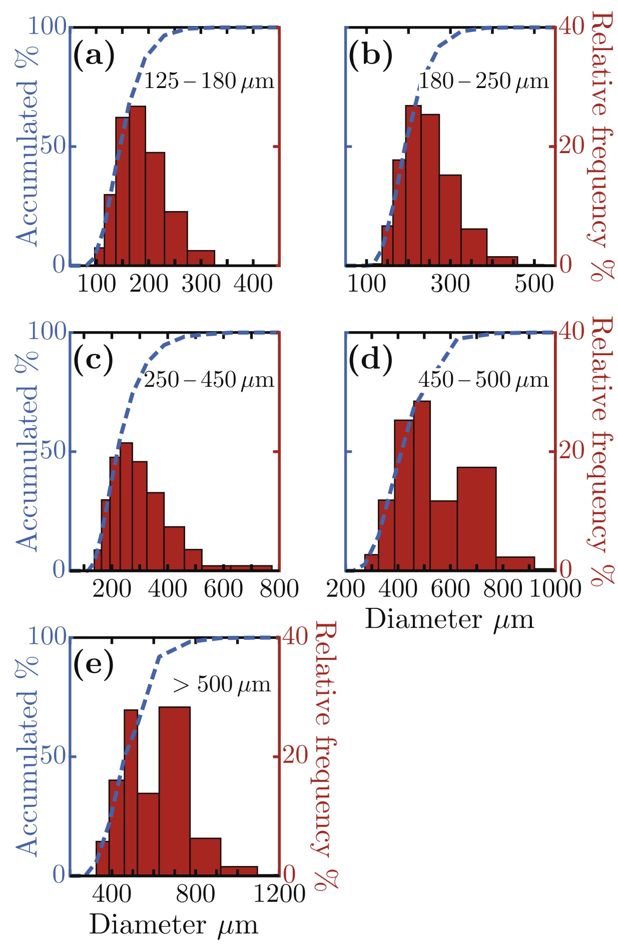


**Fig. 3.** Granulometry of five sieving classes of sand grain samples used in the experiments.

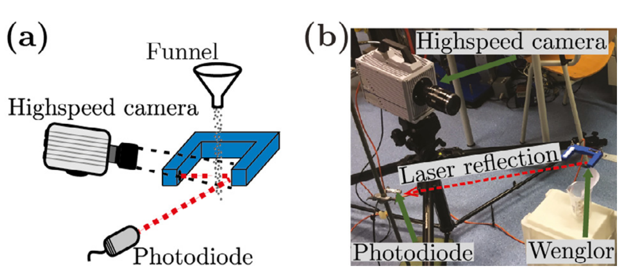


**Fig. 1.** A sketch (a) and a picture (b) of the experimental setup in the laboratory.