Aeolian Research 15 (2014) 311–318

Contents lists available at ScienceDirect

Aeolian Research

journal homepage: www.elsevier.com/locate/aeolia

# From particle counts to flux: Wind tunnel testing and calibration of the 'Wenglor' aeolian sediment transport sensor

Thomas E. Barchyn [a,b,*], Chris H. Hugenholtz [a,b], Bailiang Li [c,1], Cheryl McKenna Neuman [c], R. Steven Sanderson [c]

[a] Department of Geography, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta T1K 3M4, Canada
[b] Department of Geography, University of Calgary, 2500 University Drive NW, Calgary, Alberta T2N 1N4, Canada
[c] Department of Geography, Trent University, 1600 West Bank Drive, Peterborough, Ontario K9J 7B8, Canada

ARTICLE INFO

*Article history:*
Received 28 August 2013
Revised 7 May 2014
Accepted 24 June 2014
Available online 1 August 2014

*Keywords:*
Aeolian sediment transport
Wenglor particle counter
Saltation
Particle counters
Sensor testing

ABSTRACT

Despite almost a century of study, aeolian sediment transport remains difficult to measure. Low temporal resolution sediment traps filter sub-second scale variability hypothesized to be important, and high resolution electronic sensors are poorly tested, inconsistent, and often produce incomparable particle count outputs. No sediment transport prediction model can be validated or applied without quality empirical transport measurements. Here, we test a popular electronic laser gate sensor (Wenglor YH03PCT8, 'the Wenglor') in a wind tunnel. We have 3 goals: (i) assess the reproducibility of Wenglor measurements, (ii) examine saturation potential, and (iii) relate trap-measured sediment flux to particle counts. To assess reproducibility we measured particle counts with two co-located Wenglors. Temporally-autocorrelated sections of the time series occurred where one Wenglor deviated; this is likely the result of lens contamination. To examine saturation potential, we measured saltator velocity to calculate particle concentration within the airstream. Particle concentrations suggest the mean number of particles within the laser sampling volume is consistently less than one. To relate trap-measured sediment flux to particle counts, we used particle size samples to calculate an average mass per counted particle. We relate count predicted mass fluxes to trap-measured mass fluxes with linear regression and obtain the relation: trap flux = 2.1 * Wenglor predicted flux ($r^2 = 0.99$). The constant represents aspects of the Wenglor operation that cannot be directly evaluated. Together, these investigations suggest the Wenglor provides a consistent and low-cost method to measure aeolian saltation flux at a high resolution in non-dusty settings.

© 2014 Elsevier B.V. All rights reserved.

## 1. Introduction

Aeolian processes are widespread across Earth and Mars, and are important drivers of dune movement (e.g., Bagnold, 1941), land degradation (e.g., D'Odorico et al., 2013), atmospheric dust fluxes (e.g., Shao et al., 2011), hydrologic dynamics (e.g., Skiles et al., 2012), and hazardous dust emissions (e.g., Soukup et al., 2012). Although aeolian processes have been studied intensely for almost a century (Kok et al., 2012), our capacity to model aeolian sediment flux remains limited (Sherman and Li, 2012; Sherman et al., 2012; Li et al., 2013). Many of the challenges are attributable to the difficulty of collecting quality empirical sediment transport data (Baas, 2008). Without quality empirical data, no model can be tested or relied upon to make derivative or societally-relevant predictions.

Measurement of aeolian sediment transport is performed in both wind tunnels (e.g., McKenna Neuman et al., 2012) and field settings (e.g., Baas and Sherman, 2005). Although wind tunnels allow precise control over environmental conditions and detailed study of the physics of saltation, models must be eventually tested in the field to be vetted for general application. Field measurement of aeolian sediment transport is substantially more difficult as equipment must be robust and transport is uncontrolled. Field measurement has been approached at a variety of scales: from sub-second/centimeter scale (e.g., Barrineau and Ellis, 2013), to decade/dune field scale (Vermeesch and Drake, 2008). Recent research has suggested detailed analysis of near-surface turbulence and sediment transport could yield new insight into aeolian sediment transport prediction (Baas and Sherman, 2005; Baas, 2008; Davidson-Arnott et al., 2012; Wiggs and Weaver, 2012; Li and McKenna Neuman, 2012; Chapman et al., 2013). Pertinent

---

* Corresponding author at: Department of Geography, University of Lethbridge, 4401 University Drive, Lethbridge, Alberta T1K 3M4, Canada. Tel.: +1 403 332 4043.
*E-mail address:* tbarchyn@gmail.com (T.E. Barchyn).

[1] Present address: Department of Environmental Sciences, Xi'an Jiaotong-Liverpool University, Suzhou 215123, China.

http://dx.doi.org/10.1016/j.aeolia.2014.06.009
1875-9637/© 2014 Elsevier B.V. All rights reserved.

near-surface atmospheric turbulence occurs on timescales >1 Hz, and this has led to a need for high resolution (yet robust) aeolian sediment transport sensors.

Measurement of sub-second variability in aeolian sediment transport has been approached with electronic sensors that generally fall within one of four categories: (i) electronic traps (e.g., Bauer and Namikas, 1998; McKenna Neuman et al., 2000; Namikas, 2002; Ridge et al., 2011), (ii) piezoelectric impact sensors (Stockton and Gillette, 1990; Baas, 2004; Udo, 2009; Van Pelt et al., 2009; Barchyn and Hugenholtz, 2010), (iii) acoustic impact sensors (Spaan and van den Abeele, 1991; Ellis et al., 2009; Schönfeldt, 2012), and (iv) optical gate sensors (Mikami et al., 2005; Ishizuka et al., 2009; Hugenholtz and Barchyn, 2011a).

Electronic traps can reliably measure mass flux, but are generally unsuitable for measurements >1 Hz because of the time lag from particles entering the trap and being registered by the load cell (Namikas, 2002; McKenna Neuman et al., 2000).

Piezoelectric sensors are remarkably robust for long term field deployments (e.g., Barchyn and Hugenholtz, 2012), but have not been demonstrated to have consistent response, both among sensors of different types (Van Pelt et al., 2009; Barchyn and Hugenholtz, 2010), and among sensors of the same type (e.g., Baas, 2004). Further, there is a well-acknowledged dependency in popular cylindrical piezoelectric sensors (e.g., 'Sensit': Stockton and Gillette, 1990; 'Safire': Baas, 2004) between the sampling area and particle momentum, which is a function of particle mass and velocity (see discussion by Baas, 2004; Barchyn and Hugenholtz, 2011). Particle momentum is not reliably predicted in field situations.

Acoustic impact sensors consist of a microphone that records particle impacts by producing an analog voltage output. A threshold is used to convert the analog signal to discrete particle counts. Acoustic impact sensors can be less robust than other sensors (some lasting only minutes in saltation, e.g., Ellis et al., 2009), but have been sampled at very high resolutions (e.g., Barrineau and Ellis, 2013). Dependencies between particle momentum and counting efficiency are commonly addressed in post-processing of the analog acoustic signal, but remain inextricably linked to the physical properties of the instruments (e.g., Sherman et al., 2011). We believe that further testing of the consistency in the sensor performance is desirable to constrain the variability associated with using different sensors and the issues with microphone degradation (see Sherman et al., 2011; Hugenholtz and Barchyn, 2011b; Li et al., 2011).

Optical sensors such as the Wenglor (Fig. 1) operate with a laser beam that spans a gate. One side of the gate contains a photo-sensor that records light from the laser, such that when a particle partially blocks the laser the internal electronics output a pulse that is counted by an external data logger. The Wenglor YHO3PCT8 (hereafter: 'the Wenglor') particle counter has recently become popular in aeolian transport research due to its low cost (~$210 USD), demonstrated consistency in output (Hugenholtz and Barchyn, 2011a), and lack of momentum dependencies (Davidson-Arnott et al., 2009, 2012; Hugenholtz and Barchyn, 2011a; Sherman et al., 2011; Bauer et al., 2012; Chapman et al., 2013; Martin et al., 2013). The minimum detectable particle size is not known reliably, but the manufacturer states that the Wenglor can detect transparent particles as small as 40 μm. This suggests that the sensor is reasonably sensitive to the range of particle sizes encountered in wind erosion.

Despite these advantages, select aspects of the performance of the Wenglor remain troublesome. Hugenholtz and Barchyn (2011a), for example, report events where the lens became contaminated and sensor output was unreliable. Hugenholtz and Barchyn (2011a) and Sherman et al. (2011) identify potential issues with saturation of the Wenglor output signal (an effect where multiple particles pass simultaneously through the laser beam). Finally, the Wenglor only outputs particle counts, which are frequently used as a correlate of sediment flux. To apply results, a protocol is required to convert particle counts to a mass-based sediment flux.

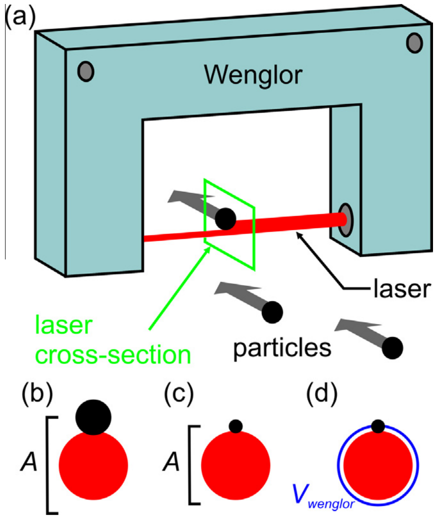

**Fig. 1.** (a) The Wenglor laser particle counter registers particles that pass through a laser spanning a fork. Particles shadow a portion of the laser, causing the internal electronics to register a digital count. The sampling area of the sensor ($A$) depends on the particle size (see Eq. (3)). The sensor will have a larger sampling area with a larger particle (b) than with a smaller particle (c). Similarly, the volume of the airstream where a particle will be detected is dependent on particle size (d) (see Eq. (4)).

The present paper reports on a series of wind tunnel tests. We first evaluate the consistency of the Wenglor response by comparing the particle count data between two sensors co-located within a saltation cloud. Second, we examine the potential for saturation of the instrument signal within a given transport system by independently measuring the particle velocity. Third, we predict the mass flux per unit area from particle count data using estimates of the particle diameter, and then relate these data to measurements obtained directly from a conventional isokinetic trap. Our overarching goal in this work is to understand limitations associated with the performance of the Wenglor sensor and produce measurements of the mass transport rate per unit area.

## 2. Methods

### 2.1. Instruments and wind tunnel experiments

All experiments were carried out in the Trent Environmental Wind Tunnel (TEWT) (Fig. 2), so that precise control over environmental conditions and continuous sediment transport could be attained. The TEWT is an open-loop suction type tunnel. A honeycomb straw filter at the tunnel intake straightens the pre-tunnel airflow and reduces turbulence. The working section is 13.5 m wind-parallel, 0.77 m high, and 0.70 m cross-wind. A boundary layer (depth, $\delta = 0.25$ m) is initiated by creating a shearing flow as the intake air flows over a 2 cm high array of cylindrical dowels mounted on a trip plate. The aerodynamic roughness length ($z_0$) of the test bed was 0.0008 m. Further details about the TEWT laboratory can be found in Nickling and McKenna Neuman (1997).

The instrument package employed in measurement of the particle count rate, particle speed, mass transport rate and wind velocity is described in the following paragraphs. Note that all mass transport rates in this study are represented as mass transport rate

Download English Version:

https://daneshyari.com/en/article/6426381

Download Persian Version:

https://daneshyari.com/article/6426381

Daneshyari.com