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RPPR Final Report
as of 04-Sep-2018

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STEM Degrees: **STEM Participants:**

Major Goals: The wind velocity profile and the turbulent shear stresses exerted on the ground that drive aeolian sediment transport depend on the value of the aerodynamic roughness length, z0. The goal of this work was to better understand the controls on z0 values, especially in landscapes with multi-scale topography and in the presence of aeolian sediment transport. Multi-scale topography is ubiquitous in nature, yet previous empirical models for predicting z0 rely on the concept of a dominant roughness element or scale of roughness that must be assumed a priori. Aeolian transport has long been known to increase z0, but the relative importance of topography and sediment transport had not been determined under field conditions prior to this study.

Accomplishments: This study provided 9 months of salary support for postdoctoral scientist Jason P. Field. Two published papers resulted from the work (Pelletier and Field, 2016; Field and Pelletier, 2018).

Pelletier and Field (2016) documented the development and performance of a new predictive formula for z0 that uses the amplitude and slope of all wavelengths of the topography to estimate the microtopographic controls on z0 values. This approach is a significant improvement over previous empirical formulae for z0 since it uses information on the topography at a range of scales, rather than requiring a user to estimate the dominant scale of roughness a priori. The new equation was developed by using computational fluid dynamics (CFD) modeling to quantify the effective z0 value of sinusoidal microtopography as a function of the amplitude and slope. The effective z0 value of landscapes with multi-scale roughness is then given by the sum of contributions from each Fourier mode of the microtopography. Predictions of the equation were tested against a large (~105 samples) database of z0 values measured from southwestern U.S. playa surfaces that differ in their roughness by two orders of magnitude, i.e., from surfaces with relief of ~1 mm to 10 cm. Our equation is capable of predicting z0 values to 50% accuracy, on average, across a four order-of-magnitude range. We also analyzed our data to provide an alternative formula based on the slopes of a dominant scale of roughness, thereby providing a formula that is more similar to classic approaches. This alternative formula is somewhat less accurate than the one obtained from a full multi-scale analysis, but has the advantage of being simpler and easier to apply.

Field and Pelletier (2018) documented the results of a field campaign designed to quantify the relative importance of microtopography and aeolian sediment transport on z0 values. Jason Field and I measured velocity profiles and aeolian sediment transport simultaneously over an evolving ripple field during several days of variable wind speeds. Faster winds cause more vigorous aeolian sediment transport, but they also generate larger ripples. As such, z0 values increase during faster winds for reasons related both to topography and sediment transport. Values of z0 were determined from the velocity profiles using the fully rough form of the law of the wall, and the evolving topography was measured repeatedly using a terrestrial laser scanner. This study was the first we are aware of to use a disdrometer (an instrument capable of measuring particle size and velocity simultaneously) to measure sediment transport. The topographic contribution to z0 was determined using the formula developed by Pelletier and Field (2016). Our measurements demonstrated that the increase in z0 during periods of aeolian sediment transport is approximately one to two orders of magnitude greater than the increase attributed to microtopography (i.e. evolving sand ripples). Our results also reveal differences in transport as a function of grain size. Each grain size fraction exhibited a difference dependence on shear velocity, with the saltation intensity of fine particles (diameters ranging from 0.125 to 0.25 mm) saturating and eventually decreasing at high shear velocities, which we interpret to be the result of a limitation in the supply of fine particles from the bed at high shear velocities due to bed armoring. Our findings improve knowledge of the controls on aerodynamic roughness length and the grain-size dependence of aeolian sediment transport. The results should contribute to the development of improved sediment transport and dust emission models.

Training Opportunities: Postdoctoral scholar Jason P. Field was trained in the use of field instrumentation to measure wind profiles, aeolian sediment transport, and high-resolution topography, and in the analyses of the data collected.

Results Dissemination: Nothing to Report

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PARTICIPANTS:

Participant Type: PD/PI
Participant: Jon D Pelletier
Person Months Worked: 3.00 **Funding Support:**
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Article Title: Controls on the aerodynamic roughness length and the grain-size dependence of aeolian sediment transport

Authors: Jason P. Field, Jon D. Pelletier

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Abstract: Estimates of the wind shear stress exerted on Earth’s surface using the fully rough form of the law-of-the-wall are a function of the aerodynamic roughness length, z0. Accurate prediction of aeolian sediment transport rates, therefore, often requires accurate estimates of z0. The value of z0 is determined by the surface roughness and the saltation intensity, both of which can be highly dynamic. Here we report field measurements of z0 values derived from velocity profiles measured over an evolving topography (i.e. sand ripples). The topography was measured by terrestrial laser scanning and the saltation intensity was measured using a disdrometer. By measuring the topographic evolution and saltation intensity simultaneously and using available formulae to estimate the topographic contribution to z0, we isolated the contribution of saltation intensity to z0 and document that this component dominates over the topographic component for all but the lowest shear velocities.

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Nothing to report in the uploaded pdf (see accomplishments and products).