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Barchans of Minqin: Sediment transport

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Abstract

Spatial changes in the rates of sand transport are a fundamental control of dune morphology. A detailed field measurement of sand flux along the brink of a barchan was performed to explore the spanwise property of sand flux on the barchan surface. Setting the arc length of the brink at the tip of the longer horn to zero, it was found that the value of sand flux increases with the arc length of the brink at first and then decreases at both low and high wind speeds. The maximum occurs at the crest. Our result suggests that the spanwise distribution of sand flux cannot be neglected in the study of transverse dunes.

Keywords: Barchan; Sand flux; Spanwise; Brink

1. Introduction

Dune dynamics involve wind flow, dune morphology, sediment transport and their interactions. Although physical and numerical models offer more detailed information of these complex processes (Stam, 1997; Momiji and Warren, 2000; Shao, 2000; Parsons et al., 2004; Schwämmle and Herrmann, 2005), field investigation is still the dominant approach in the studies of transverse dunes (Livingstone et al., 2007).

Spatial changes in the rates of sand transport are a fundamental control of dune morphology (Lancaster, 1995). The streamwise characteristics of sand flux vary remarkably under the influence of barchan dunes as obstacles. It has been shown that the sandflux increases to a maximum at the crest or brink along the barchan centre-line (Lancaster et al., 1996; Wiggs, 2001). As barchans occur while sand supply is limited, the streamwise change of the sand flux from undersaturated to saturated has also been observed (Lancaster et al., 1996). If the sand flux is uniformly spanwise or transverse, the streamwise measurements associated with field observations on the wind velocity and surface shear stress will suffice in understanding barchan dynamics. However, the sediment transport by wind is not isotropic even on the flat sandy bed because of the existence of sand streamers (Baas, 2003). Here we present a detailed field measurement of sand flux along

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the brink of a barchan for the purpose of exploring the spanwise properties of sand flux on the barchan surface.

2. Field methods

A dust storm broke out on the afternoon of 27 March 2007 at Minqin oasis. One observation (run A) was taken at the beginning of the storm, the other (run B) when the storm was strongest. To reduce the influence of sand traps on the local wind velocity, we selected a large bare barchan, No. A5 in our previous study (Wang et al., 2007). The test site (38° 47′ 22″ N, 102° 29′ 25″ E) lies in the southeastern margin of Badain Jaran Desert, a large mobile desert in Northwest China, see Fig. 1 in Wang et al. (2007). This isolated barchan is 93 m high with a horizontal distance of 94 m along the axis of symmetry from the trailing edge to the upper edge of the slipface. The crest coincides with the top of the slipface. One horn is 90 m wide and 92 m long. The other is 76 m wide and 79 m long. There are some small fixed dunes less than 2.0 m high downwind of the barchan, see Fig. 1. The surface is hard and flat within 50 m upwind of the toe of windward slope.

The movement of the barchan takes place by means of erosion on the windward slope and simultaneous deposition at the lee side. The brink, the boundary between the slipface and the windward slope, is an ideal curve to perform the test. Setting the arc length of the brink at the tip of the longer horn to zero or $s=0$ m, the crest location is $s=135$ m. The distribution of the mean grain size d along the brink (Fig. 2) shows that the grain size profile is disordered when $s<80$ m and the grains at $s=130$–180 m are slightly larger in size than those at $s=80$–130 m and $s=180$–260 m. The average grain diameter of 16 samples taken from the surface of centre-line is $d=414.33$ μm. It is well-known that the threshold friction velocity u_{*t} for medium and coarse sand can be computed by (Wang, 2006)

$$u_{*t} = A\sqrt{\frac{\rho_s}{\rho_a} gd} \tag{1}$$

where the value of empirical coefficient A is approximately 0.1, ρ_s, ρ_a and g are sand density, air density and the acceleration of gravity, respectively. Substituting parameter values into Eq. (1), we obtain $u_{*t}=0.30$ m/s.

The sand traps were placed at:

$$s = \begin{cases} 9.6(i-1) & i \le 3 \\ 6.0(i-4) + 28.8 & i \ge 4 \end{cases} \tag{2}$$

where s is in meters, and i is an integer. In the test, we adopted the MWAC type of aeolian sand trap recommended by Goossens et al. (2000). Five plastic bottles (9.0 cm in diameter, 25 cm in height) with an inlet/outlet diameter of 2.0 cm/3.6 cm, were installed horizontally at heights of 6 cm, 16 cm, 26 cm, 36 cm and 46 cm above the surface at each site to measure the vertical profile of sand flux density (of dimensions M L^{-2} T^{-1}). The sand flux density at the surface was obtained by linear extrapolation of the data given by two lower catchers. Based on the results of 6 points, we can easily calculate the sand flux through the numerical integration of a trapezoidal rule. The incoming flow speeds were recorded using anemometers placed at the centre-line upwind of the barchan. The distance between the anemometer mast and the barchan was 3 times of the dune height. We expect that the

Fig. 1. Photograph of the study site, Minqin, China.