# The Flow Structure of Interacting Barchan Dunes

J.A. Palmer, J.L. Best, K.T. Christensen & Y. Wu
*University of Illinois at Urbana-Champaign, IL, USA*

ABSTRACT: Barchan dunes are formed in both aeolian and subaqueous environments where the sediment supply is limited, with isolated barchans being able to interact as they migrate. Past work has shown that when two isolated barchan dunes collide, they can produce several differing patterns of morphologic change, including dune splitting and coalescence. While the morphology and movement of barchan dunes have been detailed and revealed some fascinating aspects to such barchan collisions, few studies have investigated the flow fields of interacting barchan dunes. In this study, we utilize idealized fixed models of differing barchan sizes to investigate the influence of barchan spacing, and relative dune size, on flow over two barchan dunes. We investigate the fluid dynamics of such interactions by experimentation in a wind tunnel using particle imaging velocimetry, in order to detail the changes to the mean and turbulent flow field as barchan spacing changes. Results will be presented of these flow fields and the generation, and interaction, of vorticity between the barchans. These fixed-bed models allow discussion of how such flow-field interactions may control the observed kinematic behavior of dunes under mobile bed conditions. Such bedform interactions, although idealized in these simple barchan experiments, may have general applicability for a wide range of superimposed bedforms in many aqueous and aeolian boundary layers.

## 1 INTRODUCTION

Barchans are crescent-shaped dunes found in both aeolian and subaqueous environments, characterized by a diminished sediment supply and a unidirectional flow (Figure 1). Collision between individual barchans is facilitated by their tendency to migrate. While the morphology of interacting barchans is well documented, much less is known about the flow structure of such interactions. Without understanding the effect of the flow on the dunes and vice versa, the mechanisms responsible for these different behaviors observed remains elusive.

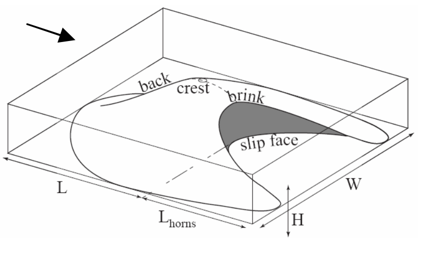

Figure 1. Representation of a simple barchan dune. Four parameters are defined: the length L, width W, height H and the averaged horn length, $L_{horns}$ [from Andreotti *et al.*, 2002].

Two classification schemes exist that describe the morphology of interacting barchans. Endo *et al.* (2004), observed three behaviors, namely absorption, ejection and splitting. According to these authors, both the relative and absolute sizes of the barchans determine the interaction. Duran *et al.* (2005) proposed a model which identified four behaviors: coalescence, breeding, budding and solitary wave. Comparisons may be drawn between absorption and coalescence, ejection and breeding, and splitting and budding. Coalescence is the absorption of the small dune by the large dune. Breeding is coalescence accompanied by the downstream ejection of a small dune, followed by two additional small dunes exiting from the horns. Budding produces two small dunes. Solitary wave produces only one dune of similar proportions to the larger dune. For the present paper, we will adopt the terminology of Duran *et al.* (2005).

The production of multiple dunes post-collision has implications for barchan fields. It is important to note that most past experiments and models assume a coaxial collision between the two barchans, suggesting an added complexity once the initial dunes are offset. Past numerical models assume the flow over interacting barchans behaves in the same manner as flow over individual barchans (Duran *et al.*, 2005); however, the lack of empirical flow field data of interacting barchans undermines this assumption. In addition, the only flow parameter often considered is shear stress which disregards the potential role of turbulence and large-scale vorticity. For instance, it still remains unclear as to the role of flow separation at the brink of one dune in its effect on the flow field of the downstream barchans. Another consideration is calculating the separation distance or wavelength at which the flow begins to interact with the second barchan.

With further examination of the flow field over two interacting barchan dunes, we hope to address the influence of turbulence, vorticity, and flow separation on the downstream dune, as well as determine the initial point of interaction.

## 2 METHODOLOGY

The principal objective of this study is to characterize the flow over two barchan dunes as a function of dune spacing and relative size. Combinations of idealized barchan models, replicating the volumetric ratios reported by Duran *et al.* (2005), have been placed in an Eiffel-type, open circuit wind tunnel with a working test-section 6090 mm long by 914 mm wide by 457 mm high with a free-stream turbulence intensity of 0.16%. PIV measurements of the mean and turbulent flow field will be made in the streamwise-wall normal plane, along the centerline and the horn of the barchans, as well as the cross-stream-wall normal plane. The PIV experiments will be performed at a flow Reynolds number of c. 29,000 based upon flow conditions in prior experiments (Endo *et al.*, 2004). The dimensions of the models are based upon previous studies (Hersen, 2004; Sauermann *et al.*, 2001; Hesp and Hastings, 1996). This paper will present details of the flow fields of simple barchan interactions and how these vary with dune spacing.

Table 1. Dimensions of Barchan Models.

| Dune No. | Volume ($cm^3$) | Height (cm) | Relative Volume (dune # /dune #1) | Behavior (Duran *et al.* 2005) |
|---|---|---|---|---|
| 1 | 764.14 | 2.00 | 1.00 | ------ |
| 2 | 229.24 | 1.12 | 0.30 | Solitary Wave |
| 3 | 129.90 | 0.94 | 0.17 | Budding |
| 4 | 45.85 | 0.60 | 0.06 | Coalescence |

## 3 PURPOSE

This poster will present the first preliminary results of flow between two interacting barchans. Based on past research, the behavior of colliding dunes is hypothesized to be a function of their spacing and relative volume. We will examine the mean and turbulent flow fields, including Reynolds stress and turbulence intensity, as the distance between the barchans decreases.

## 4 ACKNOWLEDGEMENTS:

We thank Mauricio Perillo and Jorge Abad for technical assistance.

## 5 REFERENCES

Andreotti, B., Claudin, P., Douady, S. 2002. Selection of dune shape and velocities part 2: A two-dimensional modelling. *European Physical Journal B* 28:341-352.

Bagnold, R.A. 1941. *The Physics of Blown Sand and Desert Dunes*. London: Methuen.

Duran, O., Schwämmle, V., Herrmann, H.J. 2005. Breeding and solitary wave behavior of dunes. *Physical Review E – Statistical, Nonlinear, and Soft Matter Physics* 72:1-5.

Endo, N., Taniguchi, K., Katsuki, A. 2004. Observation of the whole process of interaction between barchans by flume experiments. *Geophysical Research Letters* 31: L12503.

Hersen, P. 2004. On the crescentic shape of barchan dunes. *European Physical Journal B* 37:507-514.

Herrmann, H.J., Sauermann, G., Schwämmle, V. 2005. The morphology of dunes. *Physica A: Statistical Mechanics and its Applications* 358:30-38.

Hesp, P.A., Hastings, K. 1998. Width, height and slope relationships and aerodynamic maintenance of barchans. *Geomorphology* 22:193-204.

Sauermann, G., Rognon, P., Poliakov, A., Herrmann, H.J. 2000. The shape of the barchan dunes of Southern Morocco. *Geomorphology* 36:47-62.