MORPHODYNAMICS OF DOME DUNES UNDER UNIMODAL WIND REGIMES. C. Narteau[1], X. Gao[2] and O. Rozier[1] [1]Institut de Physique du Globe de Paris, Sorbonne Paris Cité, Univ Paris Diderot, UMR 7154 CNRS, 1 rue Jussieu, 75238 Paris, Cedex 05, France (narteau@ipgp.fr), [2]Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, 818 South Beijing road, Urumqi 830011, China (gxwlch2003@163.com).

Introduction: Dome dunes are individual sand piles with a rounded shape and no slip face. They are not only incipient or disappearing dunes, they can also reach a steady-state or a giant size (Fig. 1c) . They are frequently observed in dune systems on Earth and Mars [1,2]. Nevertheless, unlike other dune types, dome dunes cannot be classified according to the orientation and/or the sinuosity of their crestlines. Hence, they have not been the subject of intense research and there are still uncertainties about the conditions under which they develop.

Mainly observed in zones of low sediment availability, dome dunes are not isolated objects. They generally occur in dome-dune fields, in which all individual structures share common morphological properties (e.g., size, shape, planar contour), as in star-dune fields [3]. In addition, they often coexist either with barchan or linear dunes along the sediment transport pathways. This indicates that the shape and the spatial distribution of dome dunes are not randomly selected and, as for the other dune types, their morphology and dynamics are likely to reflect the wind regimes under which they develop.

The relation between dune shapes and wind regimes has always been a major issue in aeolian geomorphology. For obvious reasons of simplicity, most studies have concentrated on unidirectional [4] and bidirectional wind regimes [5]. Under bidirectional wind regimes, steady-state dome dunes have been reported in laboratory and numerical experiments for divergence angle smaller than 90° [6,7]. In all other cases, dunes show always a clear orientation which can be theoretically related to two independent dune growth mechanisms according to sand availability [8,9]. It appears that, more than the number of winds [3], the dispersion of the distribution of sand flux orientation could be the main control parameter for the systematic development of dome dunes. However, such a dispersion have never been investigated before.

Here we analyze the morphology of dome dunes and the wind regimes in different arid deserts on Earth using satellite imagery and the surface winds of the ERA-Interim project [10]. We compare these observations to the output of a numerical dune model in which the sole control parameter is the standard deviation of a normal distribution of sand flux orientation. Using this so-called unimodal wind regimes, we study the conditions for the development of dome dunes and show how the dispersion of sand flux orientation could be derived from field observations.

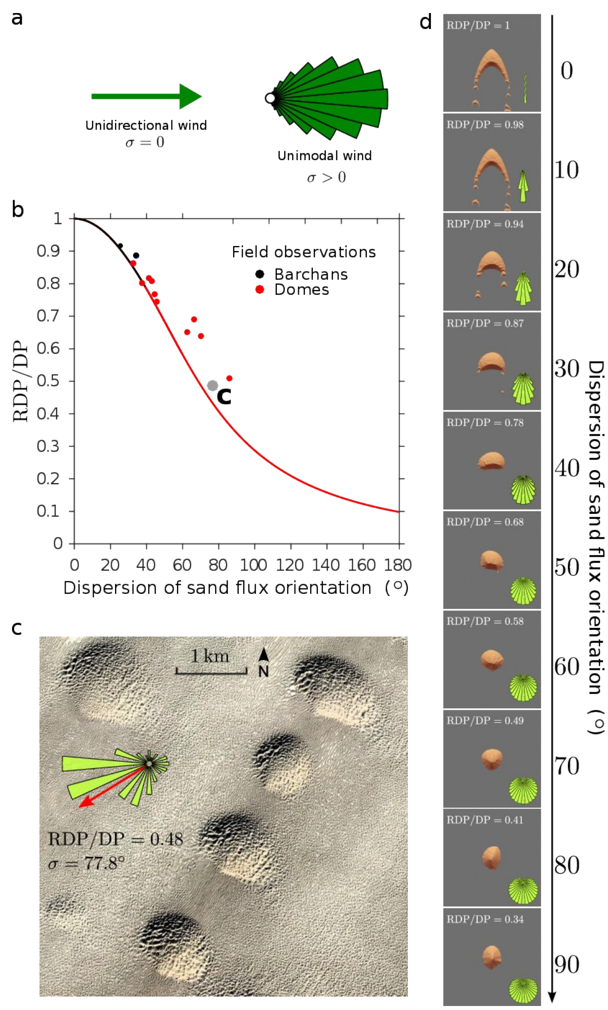

*Figure 1: **Transition from barchan to dome dunes** (a) Flux roses of normal distributions of sand flux orientation with different standard deviations. (b) The RDP/DP-value with respect to the dispersion of sand flux orientation in different terrestrial dune fields (circles) and for normal distributions (line). (c) Example of a population of giant dome dunes in the Taklamakan (40°14' N, 83°31' E). (d) Steady-state dunes using a cellular automaton dune model [11].*

Methods: We study 12 barchan and dome dune fields on Earth: Chad (16°41' N, 17°54' E), Sudan (21°14' N, 27°12' E), Egypt (26°46' N, 30°00' E; 20°30' N, 27°07' E), Mauritania (26°41' N, 16°26' W; 26°28' N, 16°17' W; 21°07' N, 14°07' W; 19°30' N, 15°28' W; 22°11' N, 12°05' W; 19°53' N, 14°09' W;

18°59' N, 14°09' W), China (40°14' N, 83°31' E). For all these dune fields, we compute the distribution of sand flux orientation, its standard deviation and the corresponding RDP/DP-values using the 10 m surface wind of the ERA-Interim project and the same transport law as in [8,9]. From satellite imagery, we extract the planar contour shape of different dunes to estimate the dune shape asymmetry, i.e. the coefficient of variation of the distances between the center of mass of the dune and points regularly spaced on its contour.

We run numerical simulations using a cellular automaton dune model [11] and a normal distribution of sand flux orientation (Fig. 1a). The initial condition is a conical sand pile. Its volume is much larger that the volume of sand transported by individual winds to ensure that the dune keeps a memory of its shape over the period of wind reorientation. To reach a steady-state dune morphodynamics, all the sediment which is ejected downstream is randomly reinjected upstream. When a statistical steady-state is reached, we estimate the dune migration rate as well as the dune asymmetry using the same method as in natural dune fields (see above).

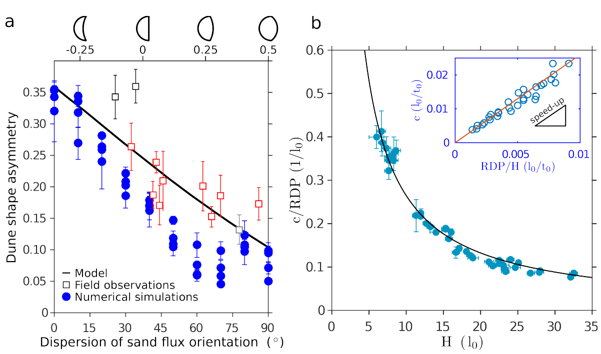

Figure 2: ***Morphodynamics of dome dunes.*** *(a) Asymmetry of the planar contour shapes with respect to the standard deviation of the distribution of sand flux orientation, The black curve corresponds to a model of planar contour shape shown on the top x-axis. (b) Migration rate of numerical dome dunes with respect to their height for different standard deviations of a normal distribution of sand flux orientation.*

Results: Fig. 1b shows the RDP/DP-values with respect to the dispersion of sand flux orientation in the different dune fields (points) and for normal distributions of sand flux orientation (curve). There is a transition from barchan to dome dunes when the standard deviation exceeds 40°. This is confirmed by the numerical simulations that also show the disappearance of the slip face above 40° (Fig. 1d). This dispersion correspond to a RDP/DP-value of 0.8, a threshold value commonly used to limit the domains of occurrence of barchan and linear dunes in bidirectional wind regimes. Here we show that it is also the same value in unimodal wind regimes to limit the domains of occurrence of barchan and dome dunes.

Fig. 2a shows dune asymmetry with respect to the dispersion of sand flux orientation both in natural dune fields (squares) and in the numerical simulations (circles). A simple model for planar dune-contour is also superimposed to this relation (line) to capture the transition from crescentic to ovoid shapes through a single parameter which characterizes the downstream arc of the planar dune-contour. These relations show that the dune asymmetry can be used to estimate the dispersion of sand flux orientation. In the numerical simulations, smaller dome dunes are faster than larger ones (Fig. 2b). Taking into account this dependence on dune height, the migration rate is proportional to the RDP-value (inset in Fig. 2b). This is in agreement with results obtained from barchan dunes [12], confirming that a speed-up ratio of 1.6 is a reasonnable value in the model [9].

Conclusion: In this study, we start to document the impact of the variability of sand flux orientation on dune morphodynamics. Considering only unimodal wind regimes described through a normal distribution of sand flux orientation, we characterize the transition between barchan and dome dunes. Then, the comparison between field observations and numerical experiments show how dome dune morphodynamics (size, shape and migration rate) is sensitive to the dispersion of the distribution of sand flux orientation and the subsequent resultant sand flux. We conclude that, in combination with other dune types (barchan, linear and star dunes), dome dunes could serve as a working template to integrate the variability of wind directionality in aeolian geomorphology. However, a number of important issues remain for future investigation. The most important is related to the seasonal variability of wind orientation which imply multimodal distributions of sand flux orientation.

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