ELONGATION AND STABILITY OF A LINEAR DUNE. O. Rozier[1], C. Narteau[1], C. Gadal[1], P. Claudin[2] and S. Courrech du Pont[3], [1]Institut de Physique du Globe de Paris, Université de Paris, CNRS (F-75005 Paris, France, rozier@ipgp.fr), [2]Physique et Mécanique des Milieux Hétérogènes, CNRS, ESPCI, PSL, Sorbonne Université, Université de Paris (10 rue Vauquelin, 75005 Paris, France, claudin@pmmh.espci.fr), [3]Laboratoire Matière et Systèmes Complexes, Université de Paris, CNRS (Bâtiment Condorcet, 10 rue Alice Domon et Léonie Duquet, 75205 Paris Cedex 13, France, sylvain.courrech@univ-paris-diderot.fr).

Introduction: Elongating linear dunes are individual sand ridges aligned near the resultant transport direction (Figure 1a). Also referred to as seif dunes [1] when they are sinuous, these finger-like structures are widespread on Earth and other planetary bodies. They develop on non-erodible beds submitted to multidirectional flow regimes thanks to the deposition at the dune tips of the sediment transported along the crests [2,3]. Sometimes the upstream source of sediment is fixed, like for lee dunes elongating behind a topographic obstacle. In such a situation, there is no lateral migration of the dune body which can preserve its shape over tens of kilometers [4,5]. Understanding the sediment budget along these longitudinal dunes and the conditions leading to morphodynamic stability is key to assess time and length scales associated with the mechanism of dune growth by elongation.

Methods: Numerical simulations are performed using a cellular automaton dune model that accounts for feedback mechanisms between the flow and the bed topography [6,7].

In all simulations, we set an asymmetric bidirectional wind regime of period T. Over a wind cycle, two winds of the same strength blow alternatively with a divergence angle of 120°. The duration of the primary wind is twice that of the secondary wind, resulting in a mass transport ratio N=2 on a flat bed. The two winds are oriented such that the dune elongates along the main axis of the cellular space of the model.

In our setup, the simulated field is a corridor with open boundary conditions. Sediment is injected locally from a fixed circular source near the upstream end of the field at a constant volume rate.

Results:

Stabilization. As soon as sediment begins to accumulate in the injection area, a sand pile forms and elongates under the action of successive winds. As in laboratory experiments [2], the elongating linear dune has a finger-like structure at all times with a straight crest line, sharp boundaries, and a reversing slip face. Eventually, it reaches a steady state (Figure 1b). Under open boundary conditions, the total sediment loss increases with an increasing dune length, until it balances the influx coming from the injection area. The intensity of the outflux along the dune body (Figure 1c) is uniform and stationary when averaged over a wind cycle. This property simplifies the derivation of dune elongation which is governed by the overall sediment budget [8].

Morphology. We find that the height and width of cross sections decrease almost linearly with distance up to the dune tip [8].

Despite the asymmetry of the wind regime, sections have a rather symmetric shape with slip faces in the lower part of both sides. These lower parts are barely reworked by winds contrary to the upper area where the crest line moves back and forth. At the end of each period of constant wind orientation, the elevation profile of this reworked area resembles the central slice of a barchan dune. The crest reversal distance Δ_c is constant for all dune sections.

While the shape of large cross sections is controlled by the reversing distance Δ_c, it is not the case for the small cross sections close to the dune tip. Below the minimum size for dunes (~10m on Earth), the cross section has a dome dune shape with no slip face.

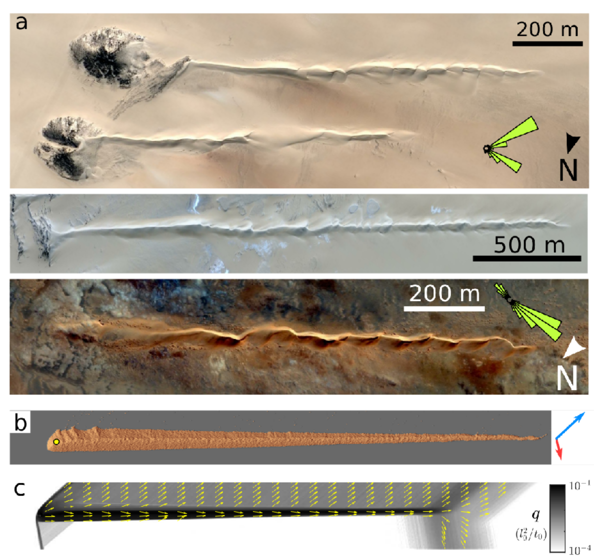

Figure 1: (a) Elongating linear dunes and sand flux roses in terrestrial dune systems: (top-middle) Niger (16° 52′ N, 13° 20′ E, and 18° 21′ N, 13° 07′ E), (bottom) Mauritania (23° 12′ N, 10° 50′ W). (b) Steady-state dune shape and transport vectors in the numerical model. (c) Intensity and direction of the average sand flux.

Concluding remarks: An elongating linear dune, also described as a finger dune by [2], can be seen as an elementary dune type. It is a simple, non-compound dune that forms on a non-erodible bed (Figure 1). In this regard, it represents the counterpart in a multidirectional wind regime of the crescentic barchan dune. These two elementary dune types differ not only in their morphology but also in their dynamics and stability.

We anticipate that remote measurements of length and width of isolated linear dunes at steady state could be used to estimate the free sand flux in zones of low sand availability on Earth and other planetary bodies.

References: [1] Tsoar H. (1982) *J. Sed. Res.*, 52, 823–831. [2] Courrech du Pont S. et al. (2014) *Geology*, 42, 743–746. [3] Gao X. et al. (2015) *Scientific Reports*, 5, A14677. [4] Lucas A. et al. (2015) *Geology*, 43, 1027-1030. [5] Lü P. et al. (2017) *Nat. Comm.*, 8, 14239. [6] Narteau C. et al. (2009) *JGR*, 114, F03006. [7] Rozier O. and Narteau C. (2014) *ESPL*, 39, 98–109. [8] Rozier O. et al. (2019) *GRL*, 46, 14521-14530.