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Introduction : Dunes result of the complex interaction of the wind regime with the topography of the dunes themselves. Variations of wind strength and direction are responsible for the types of morphologies sculpted and the evolution of dunefields. In the field, for the aeolian case, the time-scales involved in their evolution from their initial states to a mature dunefield make it difficult to have access to the whole history of the sandbed. When the study of the dunes stratigraphy gives access to a part of their history [1,2], laboratory and numerical modeling can provide the whole time-line for ideal case-study analogs that can be used to complete and better understand the ground truth observations. Recent works, whether experimental or numerical, have allowed to study and constrain the relation between dunes morphology and wind regime under controlled conditions [3,4,5,6,7]. However, the evolution of dunefields has been rarely studied using these new tools so far. Here, laboratory experiments have been realized to form dunefields under symmetrical bidirectional wind regimes, i.e with a wind switching between 2 distinct directions of identical weight. The evolution of these experimental dunefields has been monitored.

Data: The experimental setup consists of a moving baseplate immersed in a water tank. By conducting the experiments underwater, the typical length-scale and consequently the corresponding time-scale of evolution are reduced and centimeter-scale dunes analogs are formed [4,8]. The motion of the baseplate produces a unidirectional wind by successive strokes combining a fast active translation phase to a slow translation to bring it back to its initial position. A disk on which the sand is placed and which orientation can be modified is located in the middle of the baseplate. By changing its orientation, respectively to the direction of the translation of the baseplate, the direction of the simulated wind can be selected. This setup allows then to apply controlled wind regimes that can be tuned at will by choosing the orientations of the wind relative to the sandbed and the number of strokes spent in each of these orientations. Here, a set of laboratory experiments has been conducted for a wind regime composed of 2 wind directions of same number of strokes. The influence of θ, the angular separation between the 2 directions of wind, has been explored for values ranging from 0° to 172°. The evolution of an initial flat sandbed under these conditions of winds and without external sand flux has been monitored.

Dunefields evolution : In agreement with previous works, transverse and longitudinal dunefields are formed for small and large angular separations respectively. For intermediate values of θ, both transverse and longitudinal structures are clearly observed within the same sandbed and squared pattern dunefields are formed. For all of the angular separations, the evolution of the dunefields is accompanied by the growth of the amplitude of the dunes, the coherence of the dune pattern and of its main wavelength. However, one can notice that longitudinal structures develop more rapidly than transverse ones until saturation is eventually reached. The evolution of the main wavelength, taken before the saturation, is presented in figure 1 and illustrates this difference of coarsening rate.

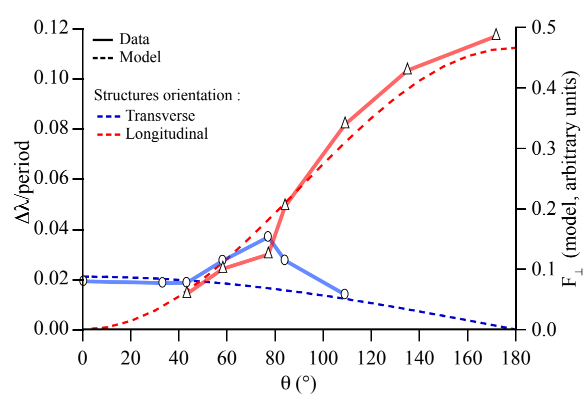

Figure 1: Variation of the wavelength in transverse and longitudinal modes for various values of θ, the angular separation between the 2 directions of wind. The observed slower evolution of the transverse structures in comparison to evolution of the longitudinal can be understood using a simple model.

The coarsening of a dune is proportional to the flux perpendicular to its crest. In order to explain the observed asymmetric behavior, the role of the angular separation in this perpendicular flux appears not sufficient. One has to also consider the role of the slope of the dune viewed by the wind in the contribution to the flux feeding the dune and therefore participating to its growth. In the case of transverse structures, the wind blows always on the back of the dunes which is more adapted to the wind. On the contrary, it changes periodically of side for longitudinal dunes and blows on the slipface developed under the previous wind orientation. The slipface is steeper than the back of the dune and is not adapted to the current wind direction. This higher slope viewed by the wind implies more efficiency to make the structures grow. In a first order approach, this perpendicular flux can therefore be written, for the transverse and longitudinal structures respectively, as $f_{\perp}^{T} \propto \cos(\theta/2) \times \cos(\theta/2)\tan(\mu_b)$ and $f_{\perp}^{L} \propto \sin(\theta/2) \times \sin(\theta/2)\tan(\mu_s)$, where μ_b is the slope of the back of the dune and μ_s the slope of its slipface. This model is compared to the experimental data in figure 1 for the values of μ_b and μ_s measured in our experiments. This simple model provides a satisfactory match to the difference observed between transverse and longitudinal structures. However, one has to notice that this is valid because the period duration of the wind regime used here is small in comparison to the time of adaptation of the dunes to a change in wind conditions. For longer period durations, as the slope of the dunes evolves as the wind blows and the dunes adapt to the current wind direction, the expressions are likely to be more complex. Nevertheless, this simple model suggests that longitudinal structures will develop more rapidly and could be predominant even for angular separations smaller than 90° for small period durations. For longer periods, a more symmetrical behavior relatively to $\theta/2$ is expected with a coarsening of longitudinal structures of the same order than the one observed for their transverse counterparts.

Conclusion : The evolution of dunefields produced in the laboratory for symmetrical bidirectional wind regimes has been followed. Based on indicators of the evolution such as the wavelength, the laboratory experiments suggest that transverse and longitudinal structures within dunefields develop at different rates under symmetrical bidirectional wind regimes. The longitudinal structures appear to grow faster than transverse ones. For the former, the larger is the angular separation between the wind and the more the pattern evolves rapidly. This distinction can be understood by the consideration of the wind efficiency and the resulting sand flux that feeds the structures. A simple model taking into account the slope of the dunes viewed by the wind for the various angular separations reproduces convincingly the observed ratio measured between the growth of the wavelength of transverse and longitudinal structures. This discrepancy in coarsening will depend on the angular separation between wind directions and the duration of the period of the wind regime. One of the consequences, is the potential variation of the transition angle between a dunefield mainly composed of transverse dunes and a dunefield dominated by longitudinal structures. It will be particularly interesting to better constrain the role of this wind efficiency for further studies on more complex wind conditions such as asymmetrical bidirectional wind regimes.

References : [1] Bristow C. et al., Nature 406, 2000. [2] Rubin D. M. and Hunter R. E., Sedimentology 32, 2000. [3] Rubin D. M. and Ikeda H., Sedimentology 37, 1990. [4] Hersen P., JGR 110, 2005. [5] Parteli et al., PNAS 106, 2009. [6] Reffet et al., Second Planetary Dunes Workshop, 2010. [7] Reffet et al., Geology 38, 2010. [8] Claudin P. and Andreotti B., EPSL 252, 2006.