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RESEARCH STATEMENT

Aeolian sand dunes or sand patterns, which develop in Shallow River, are the signature of the action of a fluid flow on a granular layer. These morphologies arise because in turbulent flows, grains of sediment layer are put into motion and, by complex games of erosion-deposition, the sand bed profile transforms itself. Reciprocally, the flow's streamlines are sensitive to the sand bed topography. Therefore, there is an active interaction between the landscape and the flow development. Understanding that interaction can lead to direct applications in the management of coastal areas (for example The Netherlands) or desert land (North Africa, Chile, China...). Moreover, the instability between granular media and Newtonian fluids represent interesting fundamental achievements for physicists.

An attractive candidate to study this interaction/instability is the barchan dune, which has a crescentic shape and moves downwind. Actually, barchans develop under a mono directional wind and on a firm ground, leading to a simple context for studying the interaction between the airflow and the dune's shape. Experimental and theoretical works have been conducted since the pioneering work of R.A. Bagnold, but many fundamental questions remained unsolved, because of the inherent limitations of fieldwork. Thereby, the existence of a minimal size for barchans, their genesis on seashore, or their interactions between neighbours, are still opened issues. Given these difficulties, a proper study requires controlling the wind flow.

The first objective of my PhD thesis was to create an experimental device, which can reproduce barchan dunes in the laboratory. A possible, but technically difficult, solution was to use a wind tunnel larger than barchan's minimal size (10 m wide and long for one meter high). A more interesting approach was to change the nature of the fluid by using a water flow instead of turbulent airflow. This idea lies on the hypothesis that the relevant length-scale for Aeolian barchan dunes (the saturation length) varies like the density ratio of the sand and the fluid times the grain diameter. Preliminary experiment with a prototype engine showed that under a mono-directional water flow, crescentic shapes appear at a centimetric scale. More precisely, those laboratory barchans have a comparable morphology than Aeolian ones, once rescaled by the saturation length. This confirmed the deep link between small-scale structures under water, and larger scales Aeolian dunes, that is to say that the saturation length was indeed the relevant length-scale to understand sand dunes physics.

Another way to study barchans was to develop numerical models. Starting from existing 2D numerical models used to describe Aeolian dunes, a simple 3D modelling was built. It used the standard 2D description along the wind direction, and a lateral sand flux is added to get 3D effects. Crescentic shapes were recovered whatever the initial sand-pile shapes. Moreover, it showed that this crescentic shape was the result of the competition between speed dispersion (the horns are faster than the center part of the barchan, giving the crescentic shape) and the existence of a lateral sand flux, which slows down the horns by feeding them. Finally, the complementary approach of experimental and numerical works was successful to understand conveniently the shape of barchans.

However it appeared that contrarily to what observed in desert, numerical results were unable to reproduce corridor of dunes. Starting from many small sand-pile, the final state was a very large barchan, resulting from the coalescence of all the small barchans, rather than the expected macro-pattern composed of individual barchans interacting each other. This result put the stability of barchans and barchan corridor on the scene. If barchans should not be stable with a constant wind, its fluctuations of direction or intensity, or even the interactions between barchans could explain the apparent stability of those objects.

Therefore, numerical and experimental methods had been used to investigate the dynamics of solitary barchan under different situations, such as collisions or changes in the wind strength and direction. Each of those perturbations showed that barchan shape could survive to external perturbation, but that during shape adaptation, the mass balance between the inflex and the output-flux might be altered. Those studies also shed lights on the mechanisms of barchan adaptation. For example, the result of a collision of two barchans did not appear to be a simple merge, but rather a complex process of absorption/emission. Preliminary quantitative results suggest that to understand the patterns and macro-patterns seen on the field, the classical vision of barchans dune propagating steadily should be abandoned, and that the history of perturbations must be taken into account. This conclusion opens the way for future research concerning the shape of barchan dunes, or more generally the shape evolution of sand waves.

In summary, experimental and numerical works have shown that barchans dynamics and shape were strongly dependent on external wind properties. Furthermore, the results of those investigations were in particular to observe directly in the laboratory very complex processes that could not be studied directly in desert, leading to a better understanding of the barchans shape and dynamics.

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