Planetary Dunes Analogs using laboratory experiments and numerical simulations.

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Our work deals with the morphology of solitary dunes under non-unidirectional winds and present experimental and numerical analogs to planetary dunes. We show that barchanoids shapes observed on Mars can be reproduced with bimodal wind regimes and that their morphology depends on the angular separation of the 2 directions of wind. Thus, the observation of these morphologies can indicate the mean direction of sand transport but can also give an idea of the variability in wind direction of the wind regimes responsible for their formation. This study can be extended to more complex wind regimes like the ones required for the formation of star dunes. Our approach could help to create, and complete, a *database* of analogs of prime interests in the interpretation of dune observations.

Introduction

In the aeolian case, dunes are large structures with long time-scales of formation and evolution. When the access to the sedimentary structure of the dune help to retrieve information on dunes history, it remains difficult to achieve,from fields study only, a global understanding of the physical processes involved in the selection of the various morphologies documented. Furthermore, the conditions are complex in the field and it can be difficult to discriminate between the various factors affecting the morphology. Therefore it appears interesting to reproduce dunes under controlled conditions using laboratory experiments and numerical simulations. These tools provide well-known analogs that can then be compared to real dunes observed in the field. We can then assume that similar morphologies can be linked to comparable conditions of formation and evolution which lead to the determination of constraints on the wind regimes. This reverse analysis is especially interesting in planetary sciences where *in situ* measurements are not always available and remote sensing is the only way to study these aeolian features.

Methods

We use underwater laboratory experiments in order to decrease the length- and time-scales involved in dunes formation and evolution. When we observe a typical wavelength of instability of about $10\,m$ for the aeolian case on Earth, a wavelength smaller than $1\,cm$ is observed with such an approach. Our experimental setup comprises a moving baseplate immersed in a water tank. The translation of this baseplate is tuned to reproduce a unidirectional wind regime. The sand is placed on a central disk which orientation can be modified allowing to change the relative direction of the strokes of wind. Therefore, we are able to simulate various wind regimes and study their influence on dunes morphology. We complete these laboratory experiments with numerical simulation based on a continuous dunes model [1].

Results

In a previous work [2], we have shown that the study of dunes fields can provide global constraints on wind regimes. For instance, the observation of longitudinal dunes on Titan's surface implies, if *sand* transport is still active, that variations in the wind direction of more than 90^o occur in its lower atmosphere. Looking at smaller scale features and isolated dunes, we can infer local constraints. In particular, we studied the evolution of the morphology of the barchanoids formed under bimodal wind regimes (FIG.1). When the barchan shape is observed for unidirectional wind, this morphology is modified for various angular separations, θ, between the 2 wind directions. For low values of θ, barchanoids dunes are modelled with progressively smaller horns and slip face and a predominant back for increasing angular separation. Around 90^o, the 2 horns join in a central tip aligned with the mean wind direction creating a *chestnut*-like shape. For larger θ, the central tip develops downwind and a longitudinal dune is formed. These 3 kinds of morphologies are observed on Mars respectively in Hellespontus, Wirtz crater and Noachis Terra indicating that the winds blowing over these aeolian structures are likely to verify these 3 domains of angular separation.

Going a bit further in wind regimes complexity, we can complete the list of analogs to compare to field observations. For instance, star dunes analogs to the ones observed in the field are obtained under winds changing between 3 directions (FIG.2). Both our laboratory experiments and numerical model allow to produce a great variety of dunes which can therefore be studied in details

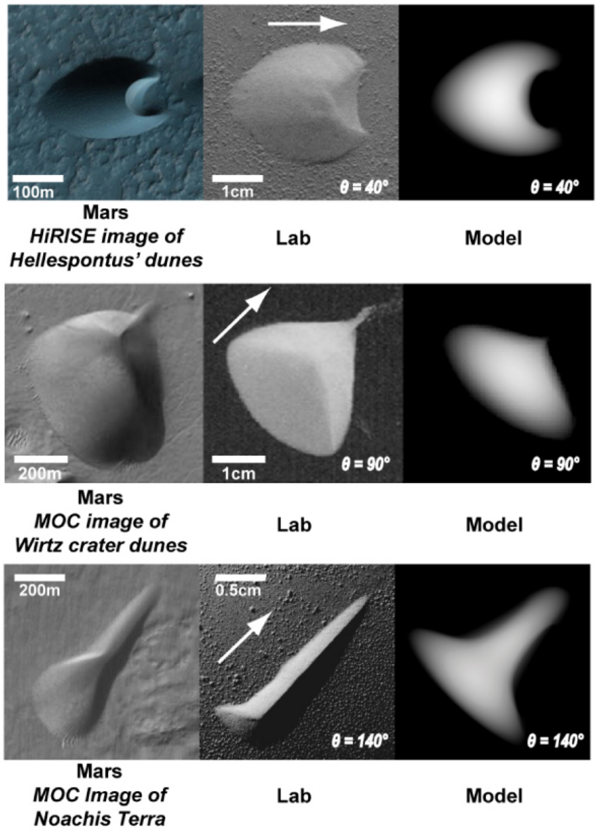

Figure 1: Barchanoids observed on Mars and proposed analogs obtained in the lab and using numerical simulations under bimodal wind regimes. The white arrows indicate the mean wind direction and θ corresponds to the angular separation between the 2 wind directions.

[3] and compared to planetary dunes.

Discussion

Looking at dunes formed for various wind regimes under controlled conditions help understanding the physical processes involved in the selection of morphology. It could be used to determine constraints on the wind regimes from dunes observation. As dunes of different sizes integrate the wind regimes on different time-scales, the characteristic time of adaptation of the smaller ones being shorter, they could be use to retrieve information about the wind regimes on these different time-scales. In the meantime, looking at dunes fields or solitary dunes provides constraints on different spatial scales.
Finally, the morphology of dunes also depends on the supply of sand, their interactions within the dunes field (sand exchange, collision) or with the topography, even if the wind regimes appear to be the motor of their formation. It would be interesting to test our laboratory and numerical models in these more realistic conditions.

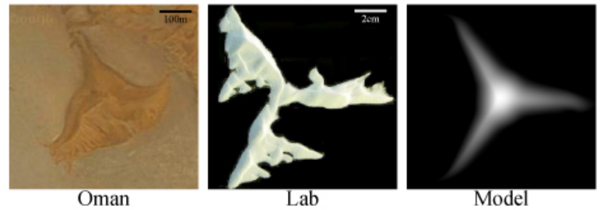

Figure 2: Star dunes in Oman. Laboratory (provided by Raphaël Clément) and numerical analogs formed under winds alternating between 3 directions. These directions are aligned with each of the arms of the star dune for our lab experiment and numerical simulations.

References

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