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Why do seif dunes meander?

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Seif dunes – which develop in the absence of vegetation and elongate in the resultant sand transport direction – are the prevailing dune type in many deserts of Earth and Mars and display a meandering shape that has challenged geomorphologists for decades. Understanding the factors controlling seif dune morphology may have impact for a broad range of scientific areas, in particular in the investigation of planetary wind regimes, as dune shape is primarily affected by wind directionality. Sand roses of areas hosting seif dunes display, in general, two main wind directions that form a divergence angle larger than 90˚. Indeed, theory of dune formation predicts that longitudinal alignment of aeolian bedforms occurs under obtuse bimodal winds, a prediction that has been confirmed by field observations and numerical simulations of aeolian dunes, as well as by experiments on subaqueous bedforms.

However, numerical simulations and water tank experiments performed under conditions of bimodal flows could never reproduce one of the most salient characteristics of the seif dune shape, which is its meandering. Instead, longitudinal dunes produced in such simulations and experiments display an unrealistic straight shape, which elongates into the resultant transport trend without developing the sinuous morphology of the seif dunes.

Here we show, by means of morphodynamic modeling of aeolian sediment transport and dune formation under directionally varying flows, that the meandering shape of seif dunes can be explained by the action of subordinated sand-moving winds, which occur in addition to both main wind components of the bimodal wind. Because such subordinated winds – inherent to most measured sand roses of seif dune fields – are associated with transport rates much smaller than the sand flux values of the main bimodal wind components – they have been long thought to be negligible for dune shape. However, our simulations show that meandering may be caused by a single secondary wind component in the sand rose with transport rate of about 1/5 of the flux due to the bimodal wind components. To verify our model we calculate dune formation using the sand rose of the seif dune field in Bir Lahfan, Sinai, and find good quantitative agreement between the shape of seif dunes in this field and the dune morphology obtained in the simulations. Our simulations suggest that meandering seif dunes constitute a dune type produced by multimodal wind systems and cannot form under (strictly) bimodal wind regimes.