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Turbulent wind flow and sediment transport over a terrain with sand fences: Coupled simulations using CFD and a morphodynamic model

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Sand fences are often erected to reduce wind velocity and induce aeolian sand deposition and dune formation in areas affected by desertification. However, the search for the most efficient array of sand fences by means of field experiments alone poses a challenging task given that field experiments are affected by weather conditions.

Therefore, in the present work, we apply Computational Fluid Dynamic simulations to investigate the three-dimensional structure of the turbulent wind field over an array of fences of different height, porosity and spacing. We find that the area of soil protected against direct aerodynamic entrainment has two regimes, which depend on the spacing L_x between the fences. When L_x is smaller than a critical value L_{xc}, the wake zones associated with each fence are inter-connected (regime A). However, these wake zones appear separated from each other (regime B) when L_x exceeds the aforementioned critical value of spacing. The system undergoes a second order phase transition at $L_x = L_{xc}$, with the cross-wind width of the protected zone scaling with $[1 - L_x/L_{xc}]^{\beta}$ in regime A, with $\beta \approx 0.32$.

In order to compute the evolution of the sand terrain in presence of the fences, we couple our CFD simulations with a numerical tool for the simulation of sediment flux and the concatenated dune morphodynamics. In previous work, we have applied this tool to model the morphology and dynamics of different types of dune, such as the barchan, seif and transverse dune, thereby obtaining quantitative agreement with field measurements. In particular, our morphodynamic model incorporates an analytical description for the sediment flux, which explicitly accounts for saturation transients associated with grain saltation, and has proven to correctly predict the minimal size of aeolian dunes. We compute the sand flux profile at different positions within an array of fences and compare our predictions with field measurements at Oceano Dunes, Oceano, CA, by Gillies et al. (2017) [Journal of Wind Engineering & Industrial Aerodynamics 168, 247-259].

Our findings have implication for a better understanding of sediment transport in the presence of fences, as well as to optimize strategies to protect soils from aeolian erosion.