How do dune forms modulate sediment advection?

Sediment is translated downwind in dune fields - how can we quantify it?

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Mauritania, 21.113° N, 13.099° E

1. Approach: The case against 'dunes'

• Treating dunes as discrete 'dune objects' is subjective and error-prone for quantitative analyses.

• Discrete dune forms only work quantitatively with barchan dunes [see *Diniega et al.*, 2010, Geomorphology; *Durán et al.* 2011, Nonlin. Proc. Geophys.].

How many dunes in this image? Cast your vote below.
(Garopaba, Brazil, 28.001°S 48.635°W)

• In transverse, linear, star, or other dune types it is difficult to concretely define dune objects.

• Dune objects change shape and volume through time.

Our solution: treating the downwind translation of sediment (advection) in dune fields with a Eulerian frame of reference. Advection is measured in a defined spatial window - without dune objects.

The challenge: develop an appropriate framework.

Right: Barchan dunes commonly reform and change mass through collisions [see *Hugenholtz and Barchyn*, 2012, GRL]. Walvis Bay, Namibia, 22.992° S, 14.475° E.

2. Classifying dune field components

• Advection of sediment through dune fields can be treated as the sum of classified components. We use simplified rules to classify cells in a DTM.

• We use a spatial mean of advection to define the 'local advection' (200 m radius circle).

code	interpretation	sediment supply?	stoss?	slipface?	surface wind?	Q	%
1	interdune	no	no	no	yes	0	6.3
2	interdune (shadowed)	no	no	no	no	0	2.1
3	lee slope	yes	no	no	yes	1	11.0
4	lee slope (shadowed)	yes	no	no	no	0	2.4
5	slipface	yes	no	yes	yes	1	0.1
6	slipface (shadowed)	yes	no	yes	no	1	4.0
7	stoss slope	yes	yes	yes or no	yes	1	73.7
8	stoss slope (shadowed)	yes	yes	yes or no	no	0	0.4

Data from White Sands, NM, USA, 32.827° N, 106.272° E.

Tentative classification rules:
• sediment supply: defined as >1 m residual from base level surface calculated with minimum filters [see *Hugenholtz and Barchyn*, 2010, ESPL].
• stoss slope: defined as upwind facing aspect.
• slipface: defined as slope >30º and <40º (repose ~34º).
• surface wind: defined with 15º 'raytrace separation cell'.

color codes correspond to classes above

3. Mapping advection reveals spatial variability

• Variability in advection suggests changes in the spatial distribution of sediment in dune fields. Could predictable relations exist that govern widely observed 'clustering' of dune forms?

• raw hillshade: dunes form on edge of sand sheet on left. Dense transverse dunes trend to isolated barchan dunes downwind.

• equivalent sediment thickness (EST): local sediment thickness is highest in transverse dune area.

EST = thickness of sediment that would result if all dunes were flattened [see *Wasson and Hyde*, 1983 Nature; *Hugenholtz and Barchyn*, 2010, ESPL]

• advection: mirrors EST due to supply control. Advection drops once dunes form due to introduction of separation cells and exposed non-erodible basement.

• Advection shows nonlinear relation with EST, indicating the pattern of EST is unlikely to be static.

• The geomorphology of the dune field is controlling sediment advection.