Utilizing Topographic Structure for Characterizing and Mapping Dunes, White Sands National Monument, New Mexico

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Introduction

Motivations
Dune morphology governed by:
- Climate
- Multi-scale wind conditions
- Sediment supply
- Vegetation
- Dune field hydrology

Dune field resilience to change?

Consistent characterization of dune morphology is necessary to understanding eolian system dynamics

Challenges
- Semantics
- Subjective mapping
- Limited, arbitrary sampling
- Scale-dependent characterization

Objectives
- Mathematically formalize characterization of dune morphology to understand dune-field systems
- Automate dune characterization in a repeatable fashion.
Study Area, Data

White Sands National Monument, New Mexico
- Gypsum sand dunes
- Pleistocene Lake Otero
- Shallow water table

1 m LiDAR
- Chihuahuan Desert Inventory & Monitoring Program, June 2007

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Baitis et al. (2014)
Pedersen et al. (2015)
Methods

Self-organization
• Slope angle distribution

Topology/Context
• Above substrate
• High overlap with Ridge Objects
Field & Object Properties
- Local volume, dune height \((h)\)
- Divergence \((SADI)\)

Boundary Properties
- “Divisiveness,” \(D_B = A_X / A_{X0}\)
  - \(A_X\) = cross-sectional area
  - \(A_{X0}\) = prototypical area

Spatial Structure
- Merge across small \(D_B\)
- Divide junctions at maximum \(D_B\)
Dune Morphometry

- Vegetation
- Water quality (Langford et al., 2009)
- Paleo-shorelines? (Baitis et al., 2014)

Swanson et al. (2016) study area

- Mean 2.8 m
- Max 14 m

- 27,013,668 m²
- 79,508,993 m³
Dune Morphometry

- 098 mean lee slope azimuth
  - 33° from Pedersen et al.’s (2015) 065 measured wind direction
  - 43° from Swanson et al.’s (2016) 055 measured lee slope azimuths
Semantic Issues

Boundaries
- Which parameters?
- Different criteria for different boundaries?

Crestlines
- Assumption of smooth continuity beyond plane of 2D cross-section

Dune Orientation & Sinuosity
- Crestline? Dune footprint/perimeter?

Dune Spacing & Interdune Length
- Which other dunes are measured to?
- What are the points of reference?
- Direction-dependent
Conclusions

Objective, automated approach for characterizing dune field morphometry
• Based on theory for hierarchical topographic spatial structure
• Mitigate sampling bias

Semantic and ontological issues in dune mapping and characterization (and geomorphological mapping in general):
• Boundaries
• Crestlines
• Interdune length & dune spacing
• Prototypical outliers are not representative

White Sands dune field exhibits
• Dune field is spatially variant
• Less dune height in vegetated areas (less saline water?)
• Crescent dunes distinguished by high surface area / planimetric area
Acknowledgments

National Park Service

David Bustos
Area \((A)\)
Perimeter \((P)\)
Shape-Compactness \((C = 4\pi A / P^2)\)
Surface Area \((A_{surf})\)
Substrate
Peak Height \((h_{max})\)
Mean Height \((\bar{h})\)
Volume \((V)\)
Width \((W)\)
Length \((L = A / W)\)
Orientation Azimuth \((\varphi)\)
Mean Lee Slope Azimuth \((\varphi_{lee})\)
Crestline Length \((L_{crest})\)
Sinuosity
Interdune Length
Mean Base Spacing \((\lambda_0)\)