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.

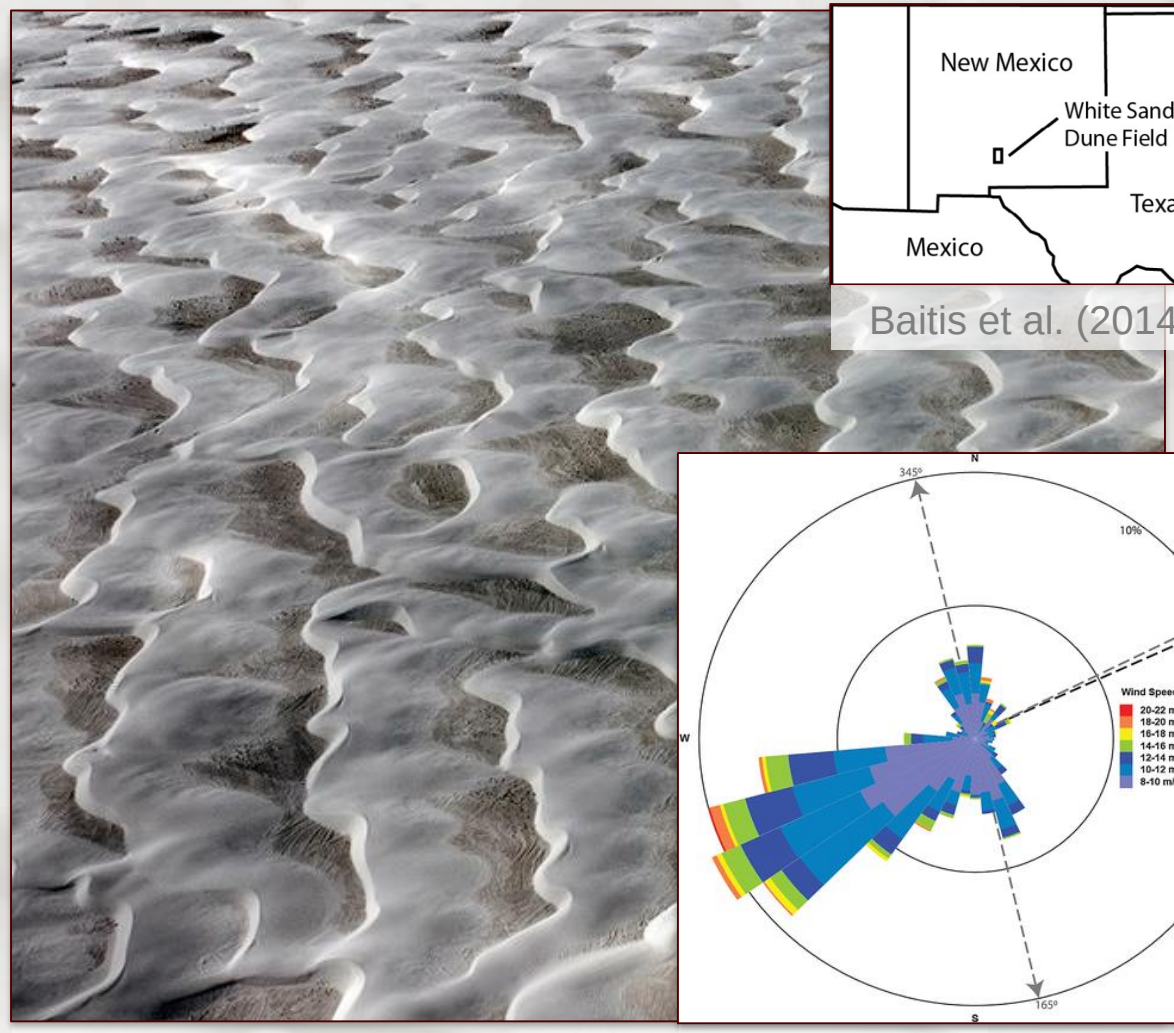
Study Area, Data

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



Eolian Topographic Structure

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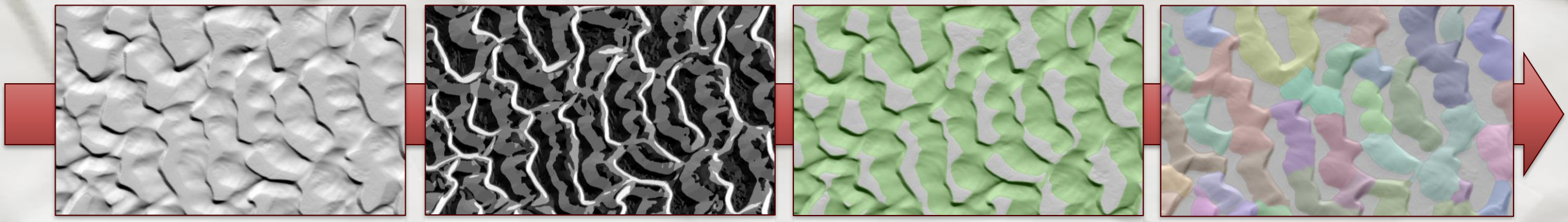
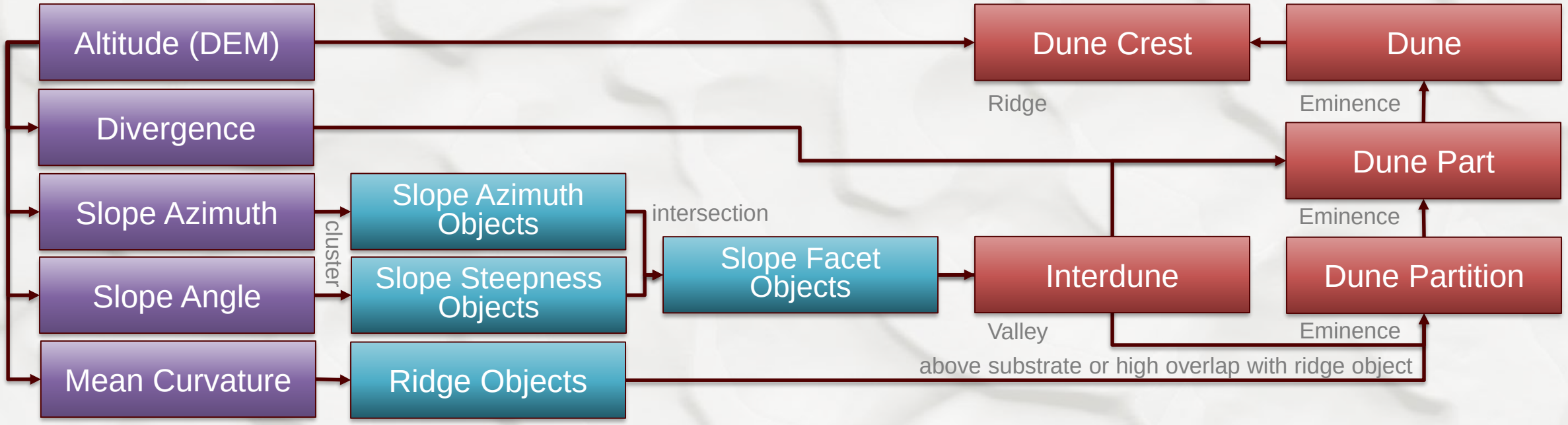
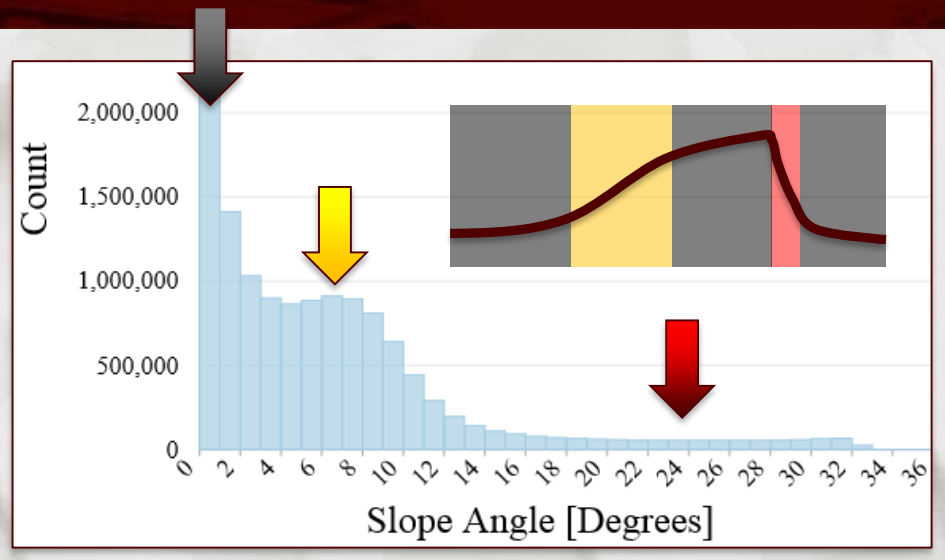




Methods

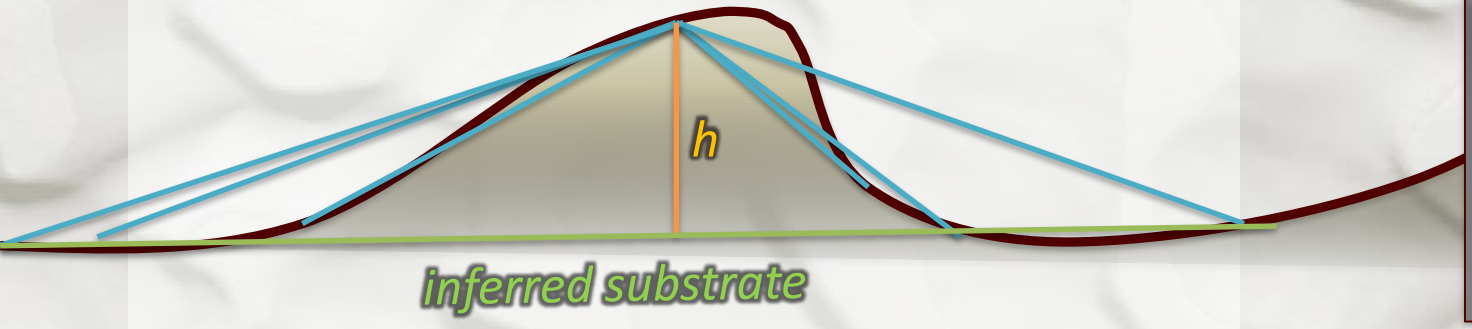
Self-organization

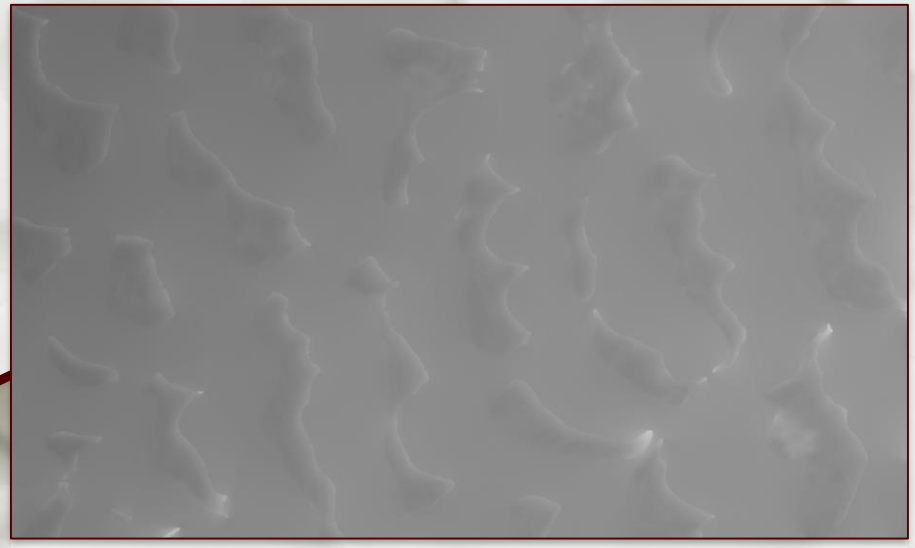
- Slope angle distribution



Topology/Context

- Above substrate
- High overlap with Ridge Objects





Substrate

Methods

Field & Object Properties

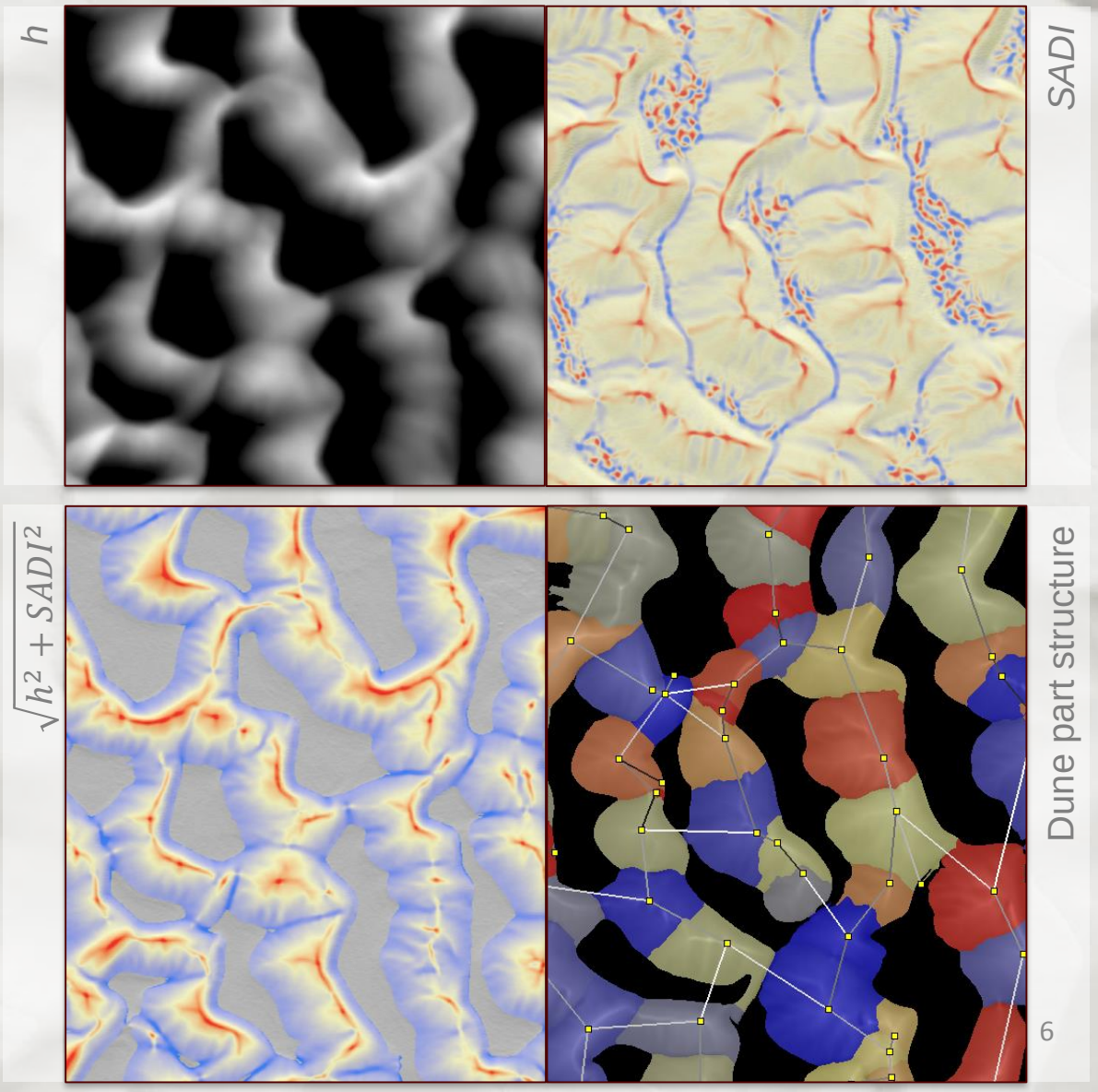
- Local volume, dune height (*h*)
- Divergence (*SADI*)

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

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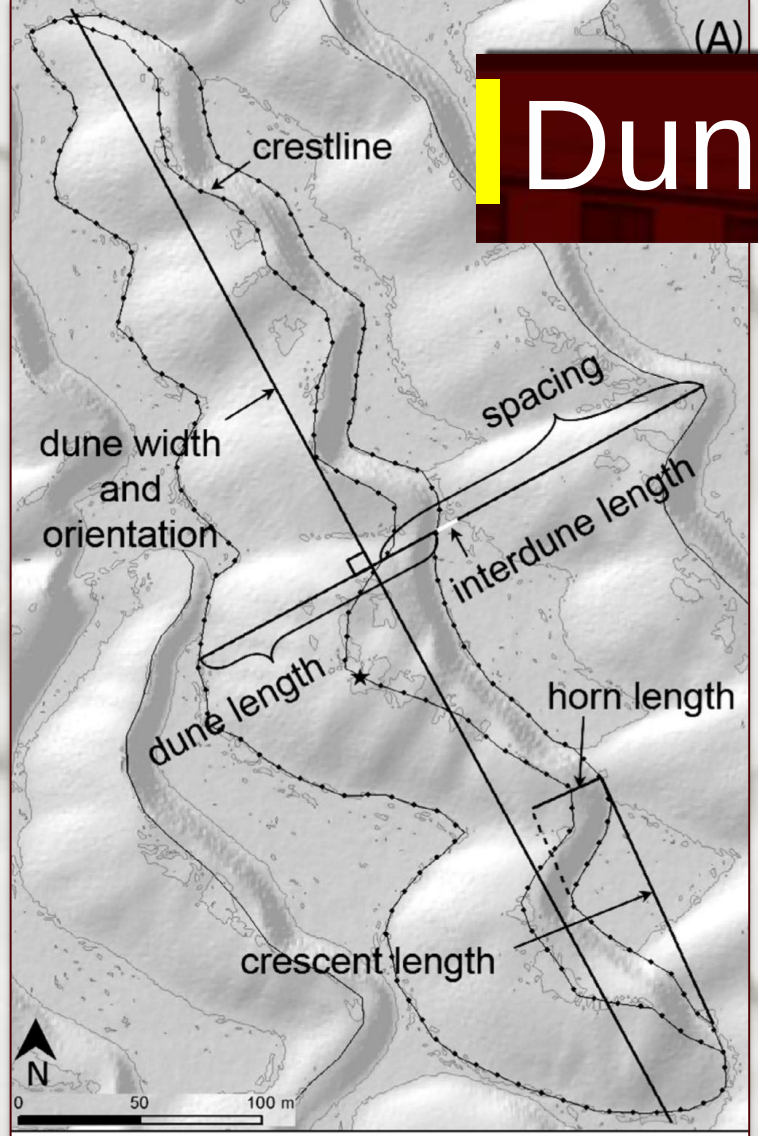
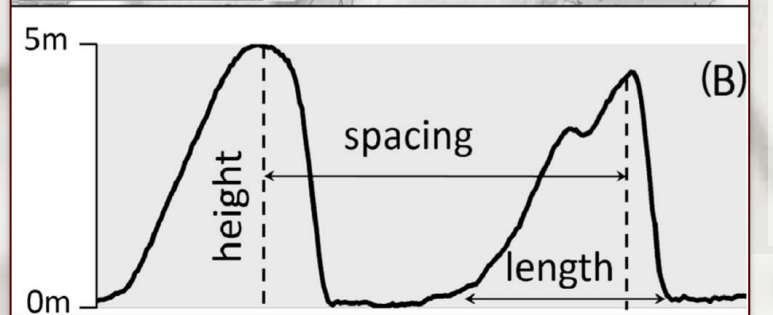
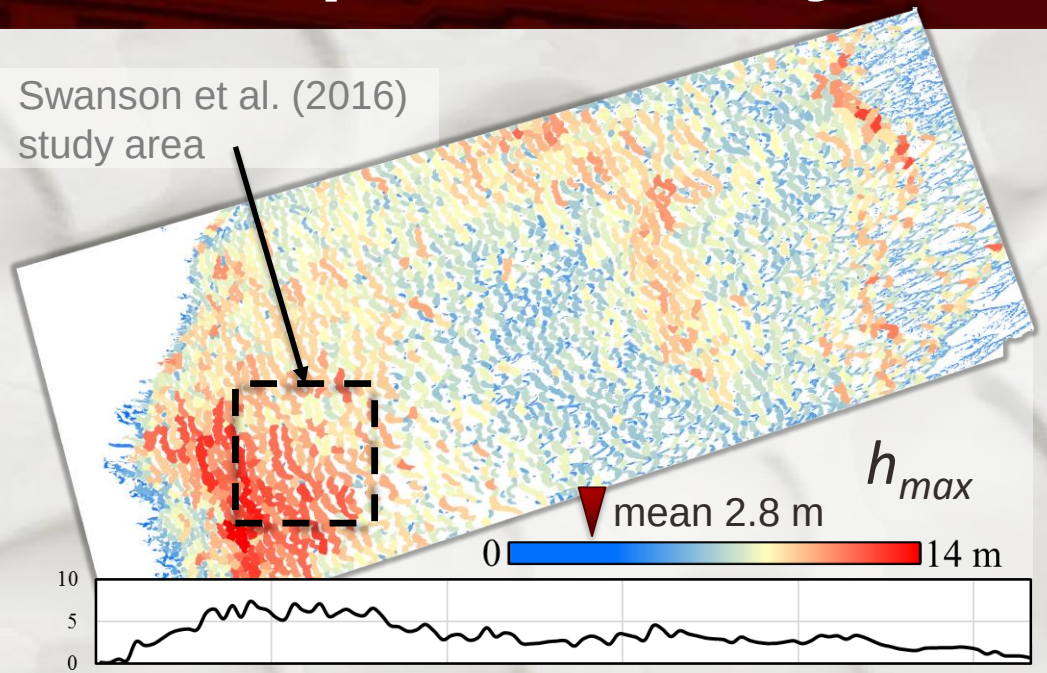
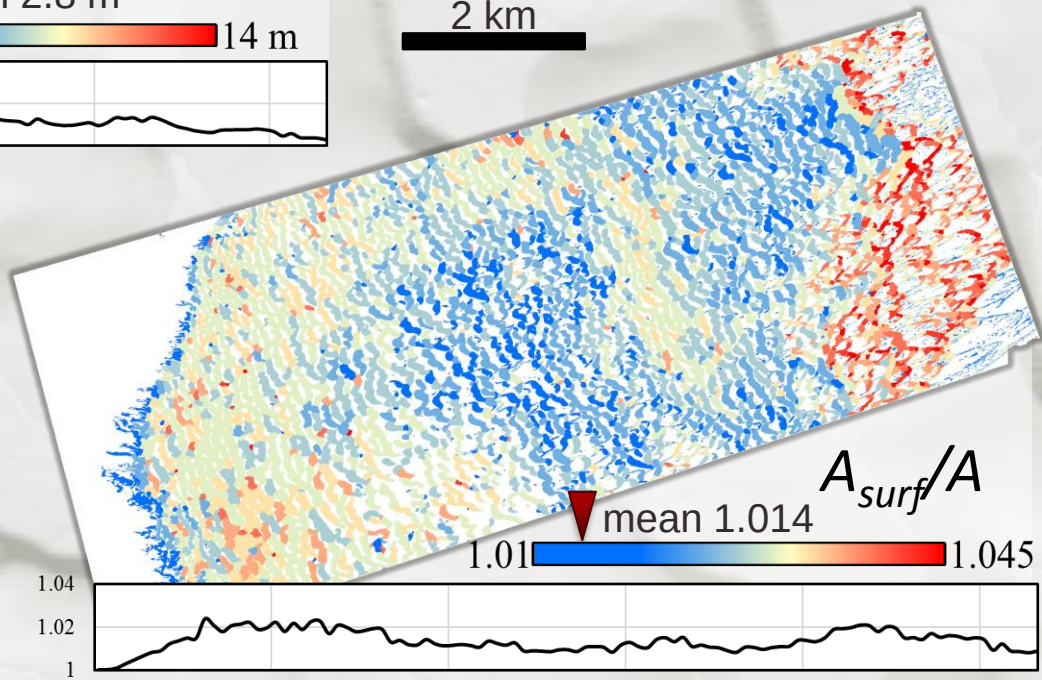




Swanson et al. (2016) study area



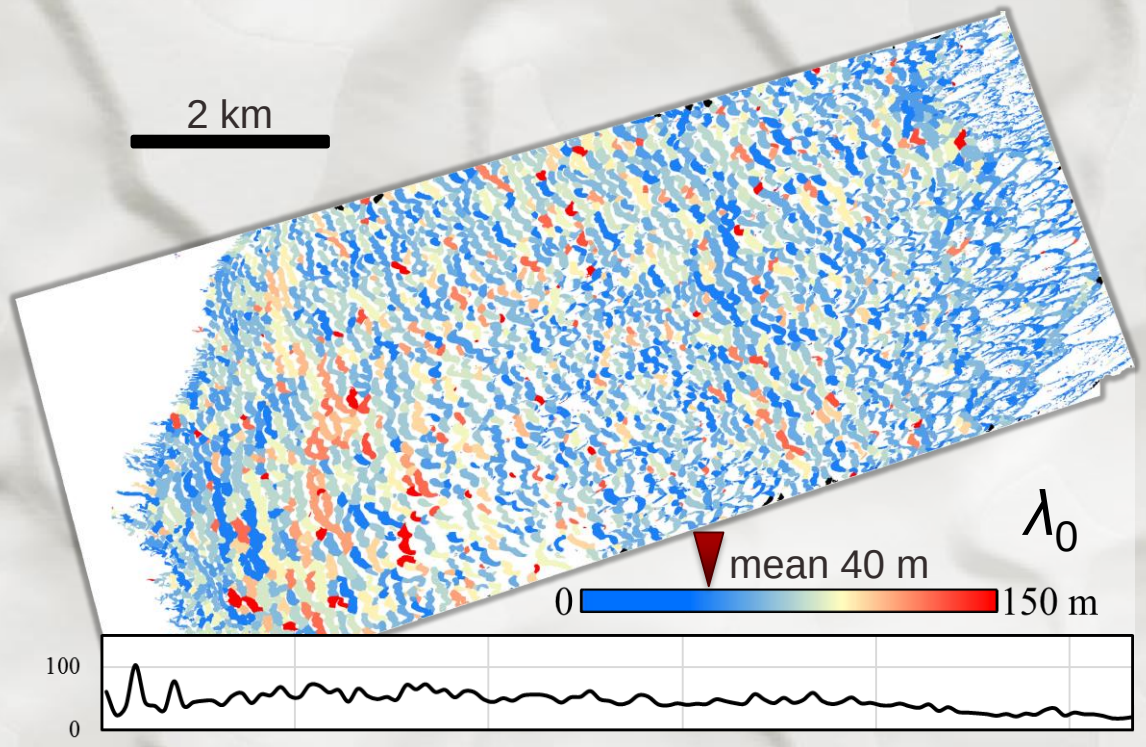
- 27,013,668 m^2
- 79,508,993 m^3

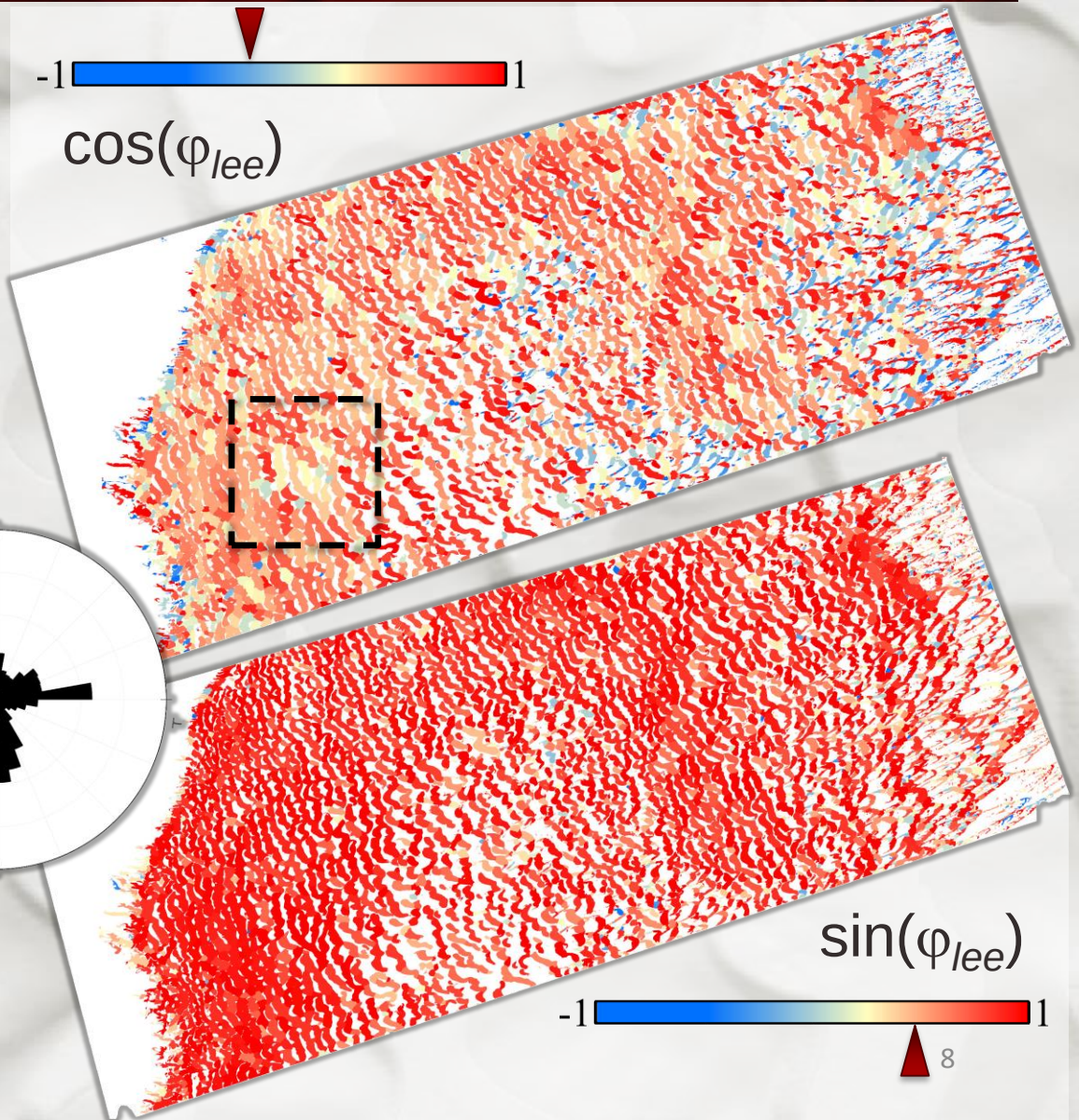


- Vegetation
- Water quality (Langford et al., 2009)
- Paleo-shorelines? (Baitis et al., 2014)

Baitis et al. (2014)

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

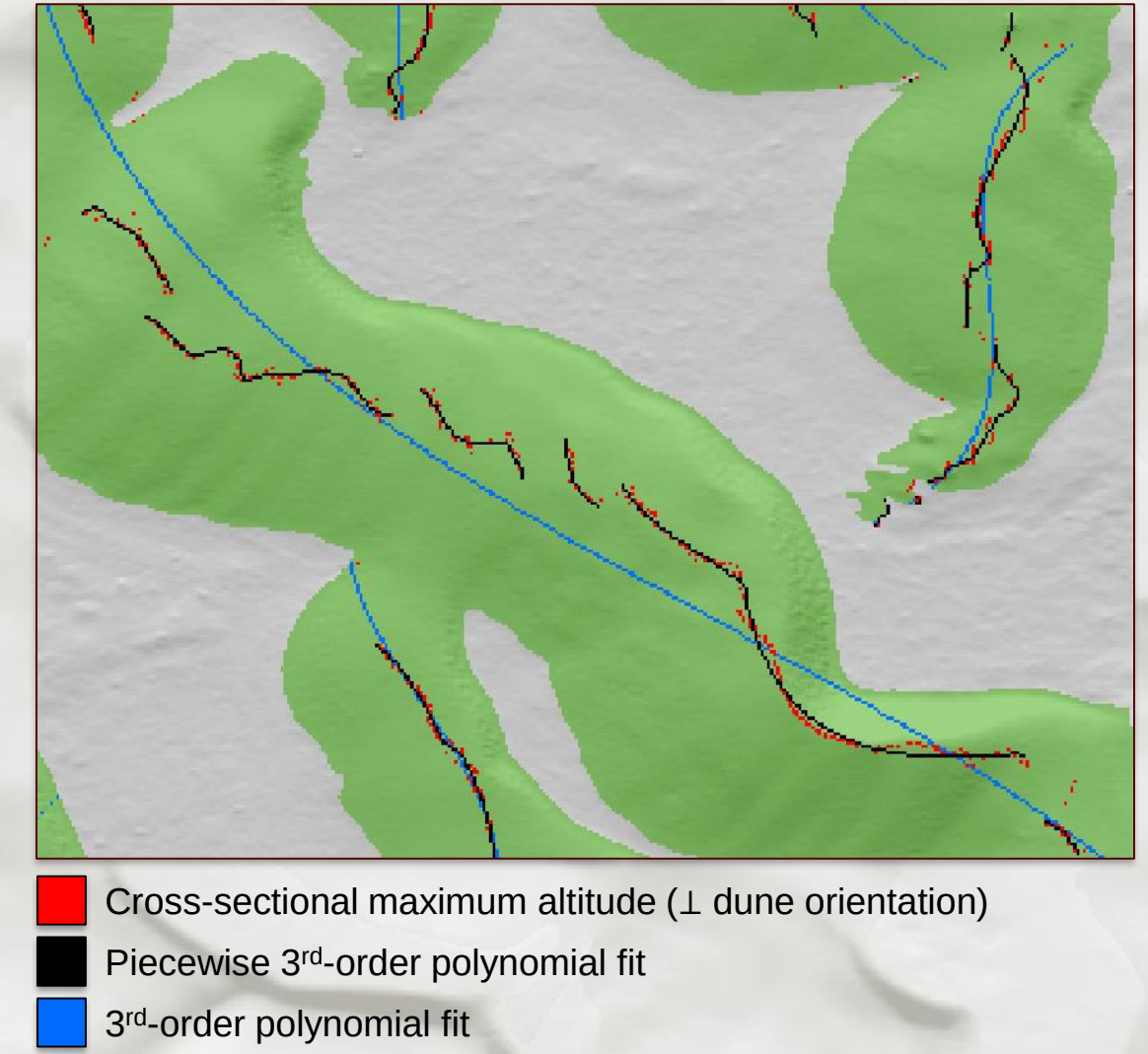
- Assumption of smooth continuity beyond plane of 2D cross-section

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

Dune Morphometry

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 (φ)
Mean Lee Slope Azimuth (φ_{lee})
Crestline Length (L_{crest})
Sinuosity
Interdune Length
Mean Base Spacing (λ_0)