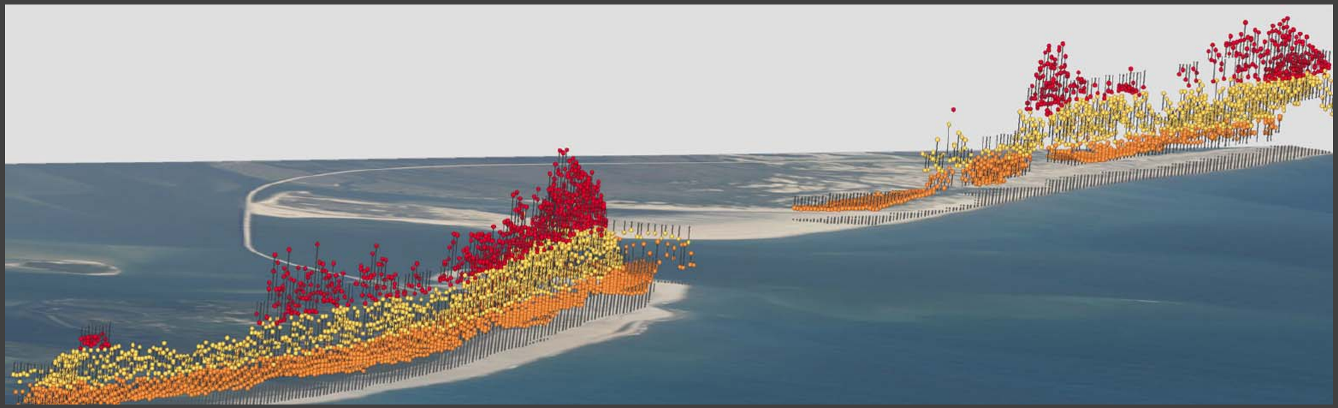

Summary Visualizations for Coastal Spatial-Temporal Dynamics

October 24 2011

Providence, RI

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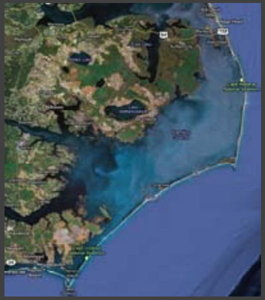
VisWeek 2011 VIS • INFOVIS • VAST

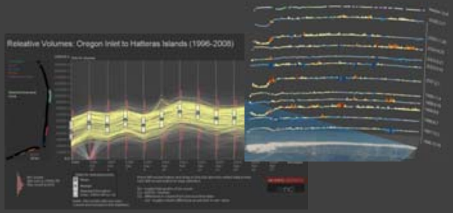
Overview

Motivation

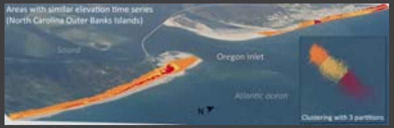
Case Study



Visualization approaches



Discussion



Motivation

- Coastal landscapes are dynamic
  - wind, water, gravitation, plants, animals, and humans
  - continuously changing landscapes
- Open questions
  - Land surface processes poorly understood.
  - Predictive capabilities limited.
  - Management decisions based on insufficient information.
- Data
  - Digital scans of coastal regions
  - High resolution (as low as 0.5 m^2)
  - Span an unprecedented number of years.
- Visualization needs
  - Standard raster-based analysis…too much info?
  - Need tools to highlight important attributes
  - Need to summarize and provide information about error and uncertainty.

Case Study: barrier islands

Study area:

- North Carolina Outer Banks
- long narrow strip of sandy barrier islands

Focus region:

- near Oregon Inlet
- exhibits significant terrain changes over 10 years.

Dynamic topography:

- sand is redistributed by wind, waves, storm surge

Vulnerable:

- coastal erosion, sea level rise, inundation, breach
- First line of defense against storms

Pop quiz

- Which of these natural disasters occurred on the U.S. east coast in 2011?
  A. Plague of locusts.
  B. Earthquake.
  C. Forest fires.
  D. Hurricane.
  E. All of the above.

Expensive Damage

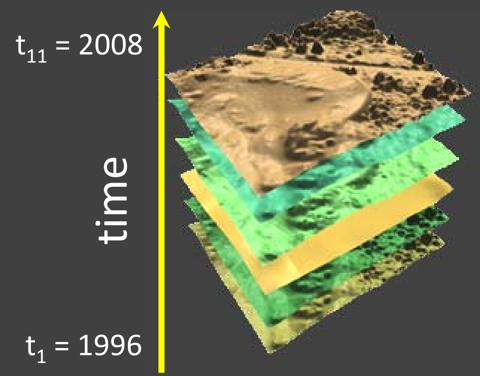
August, 2011
Hurricane Irene caused breaches in the Outer Banks…

…the only road destroyed.

Hurricane haven
2003 Isabel
1999 Dennis
1996 Edouard
…

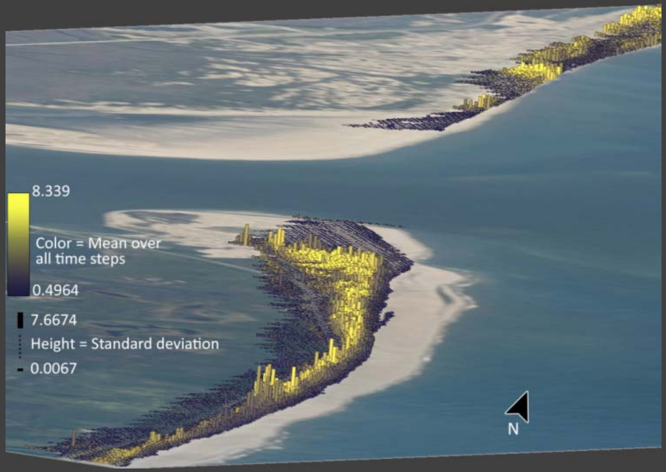
Data

DEMs
•11 digital elevation models
•Years 1996 -2008, uneven intervals
•Derived from LiDAR surveys [1]
•0.5 m^2 resolution



Transects
•Line segments perpendicular to the shoreline
•U.S. Geological survey transects [2]
•50 m intervals

Imagery
•2009 aerial photo
•National Agriculture Imagery Program [3]

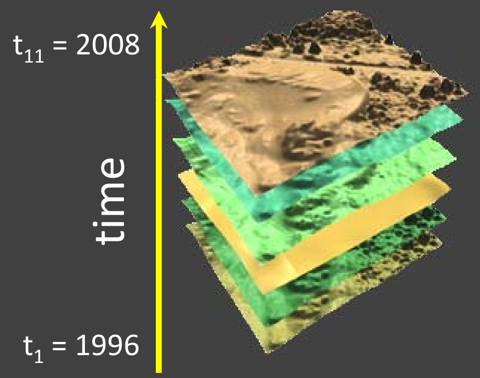


[1] Mitasova H., Hardin E., Kurum, M., and Overton M., 2010, Geospatial analysis of vulnerable beach-foredune systems from decadal time series of lidar data, Journal of Costal Conservation, Management and Planning, 14 (3), p.161-172.

[2] Morton, R. and Miller, T. (2005). NC TRANSECTS ST Short-term shoreline change rates for NC Atlantic coast generated at a 50m transect spacing, 1970-97. Technical report, USGS Open-File Report 2005-1326.

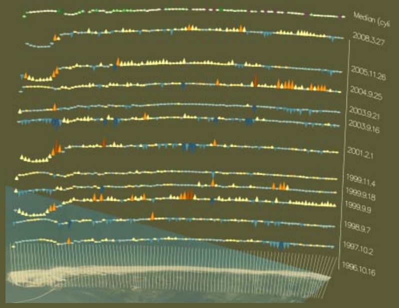
[3] Imagery source: http://www.lib.ncsu.edu/gis/hyperspectral.html

Methods

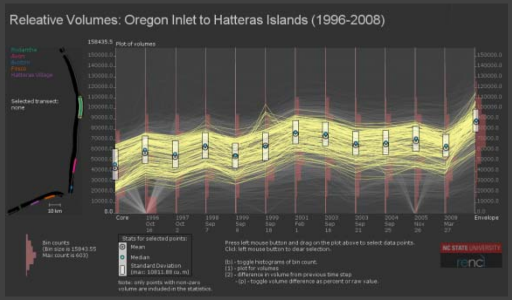


DATA

Space-time cube



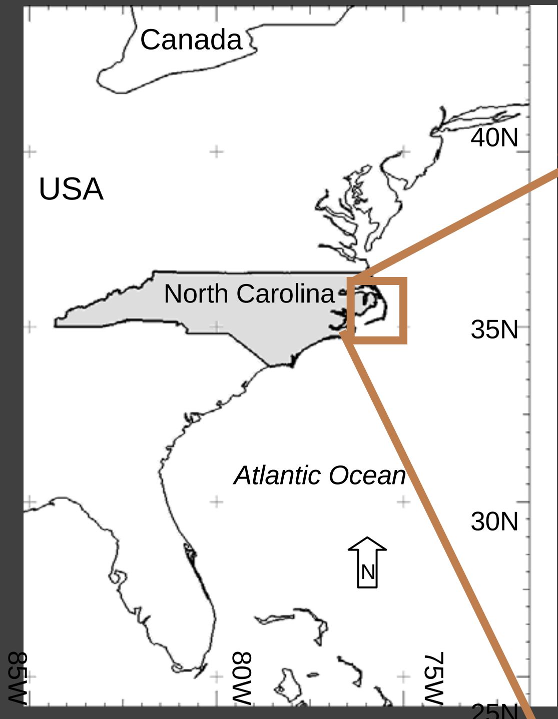
Summary plots



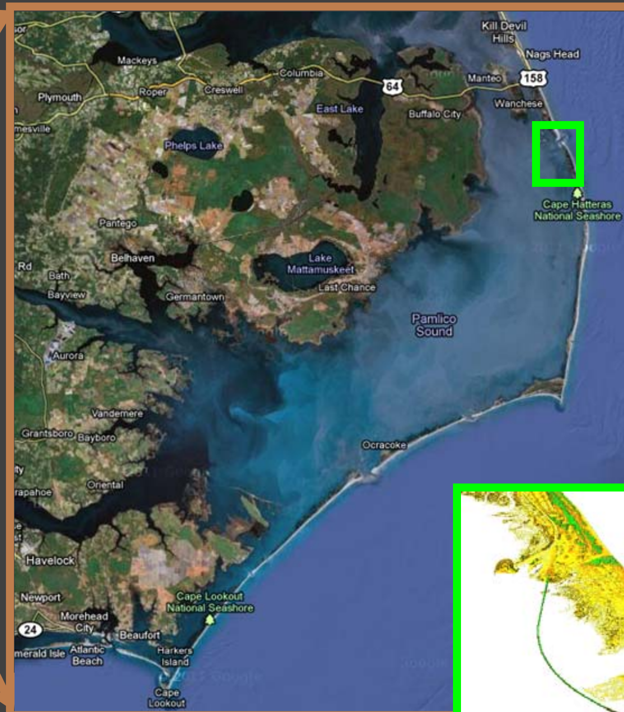
Clustering & error

VISUALIZATIONS

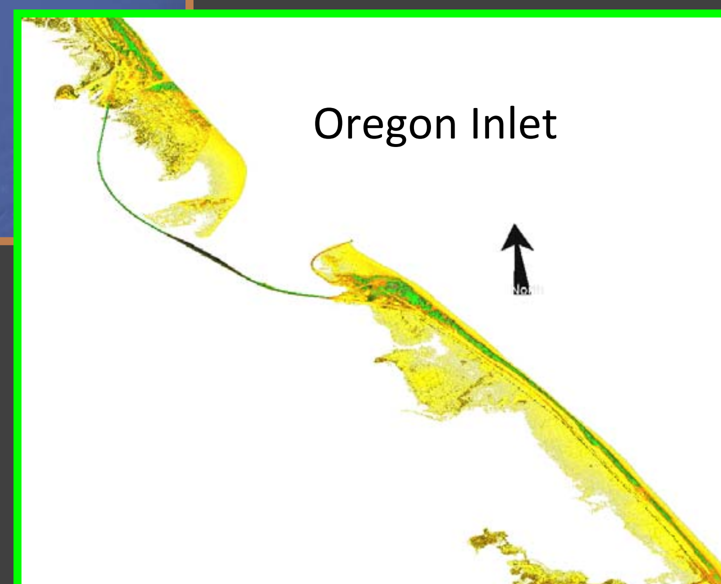
Study region: Oregon Inlet



North Carolina barrier islands

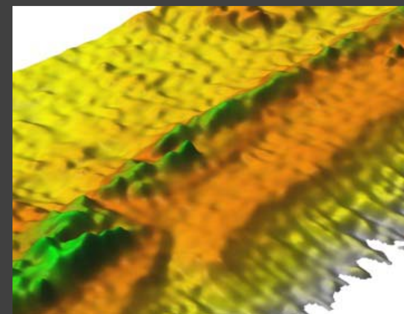


Outer Banks

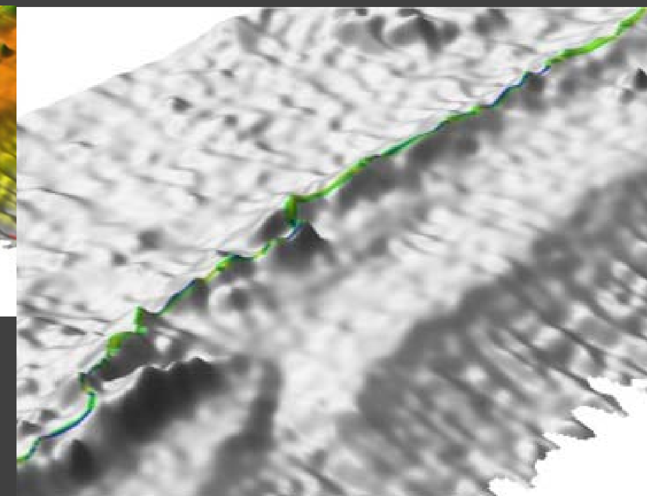


Dune ridge elevation

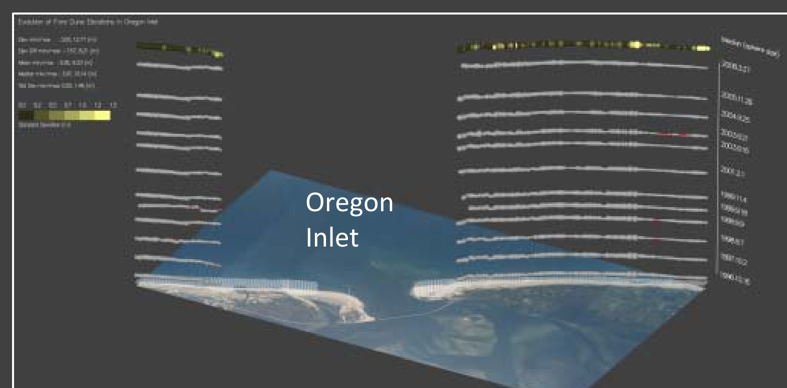
- Importance
  - vulnerability indicator
- Construction
  - derived from DEM
  - sampled at transects
- Display
  - space -time cube technique (STC)
  - glyph position + visual features



Elevation color map

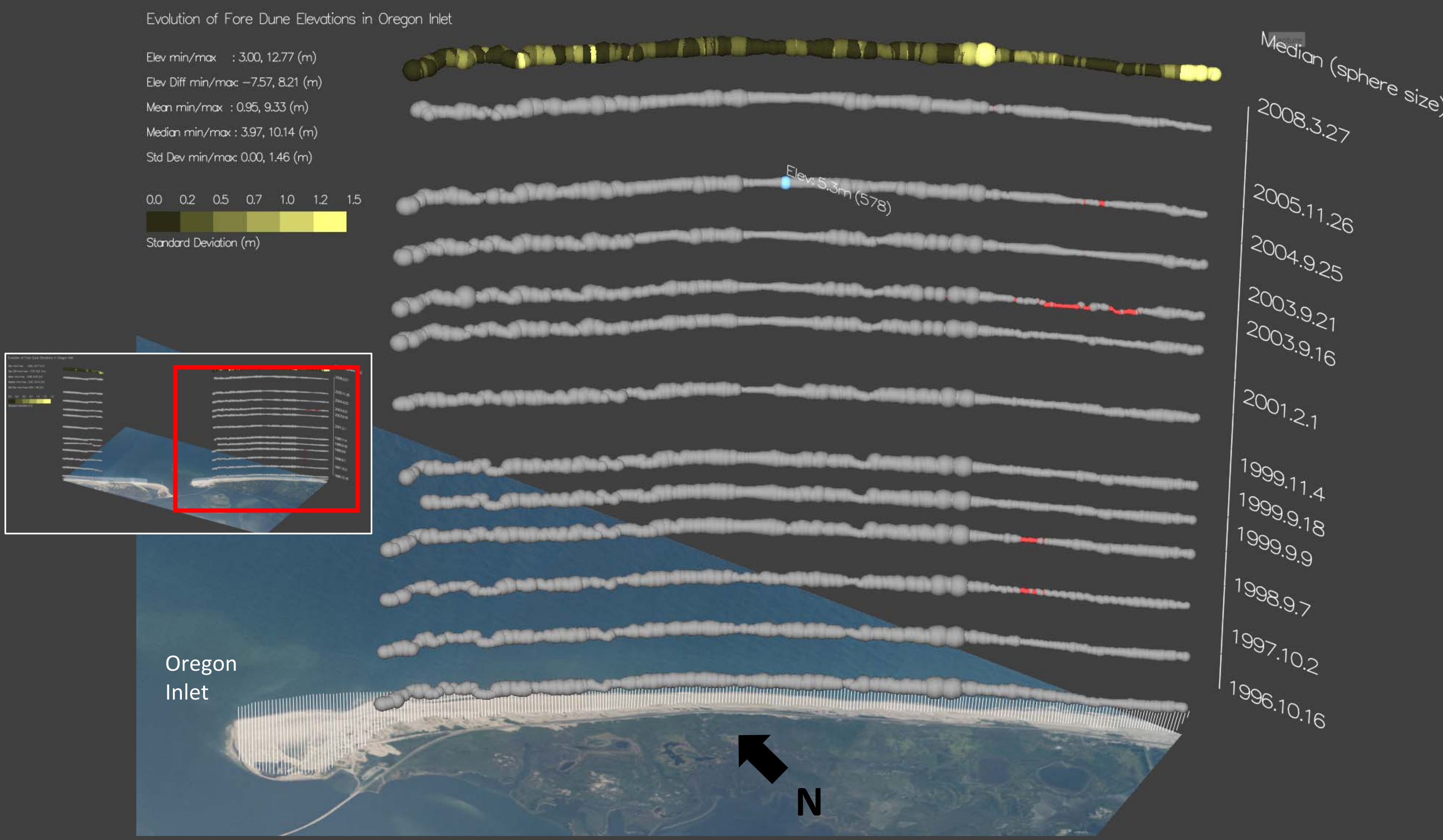


Ridge line: optimally high elevation path

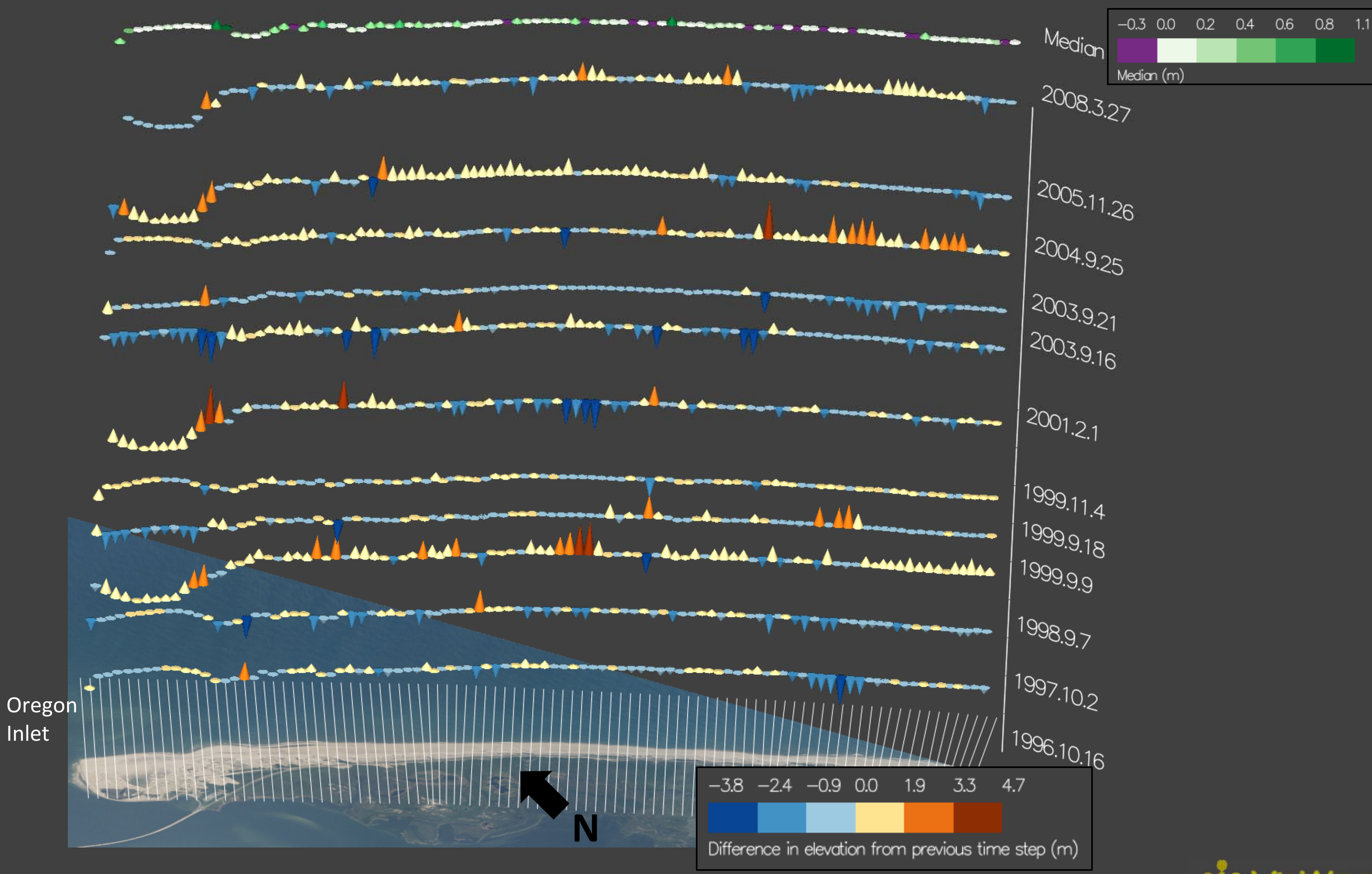


STC dune ridge elevation near Oregon Inlet

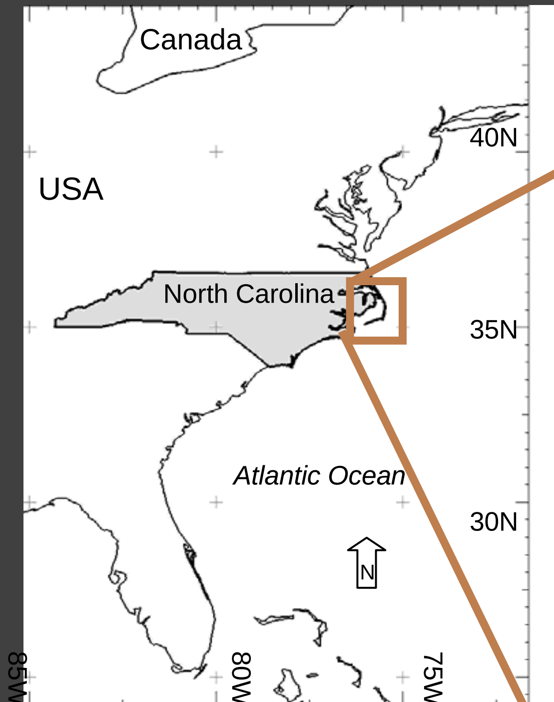
STC Ridge Elevation



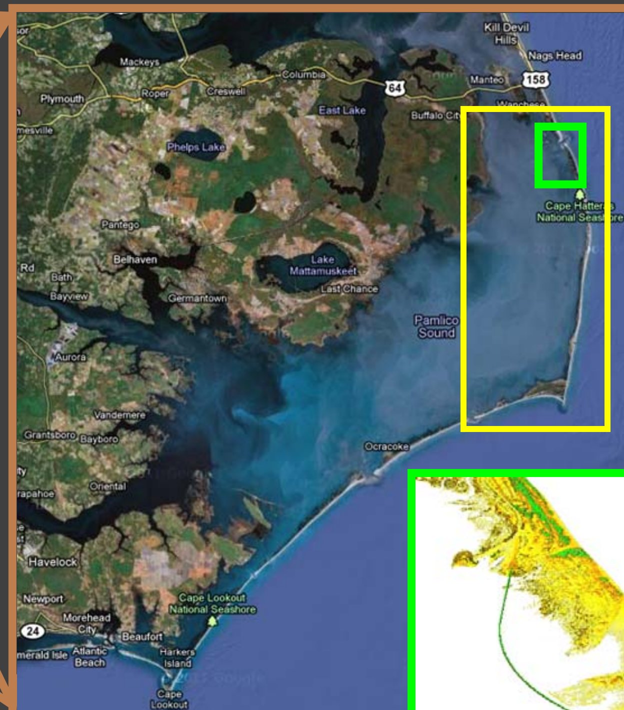
STC Differences in Elevation



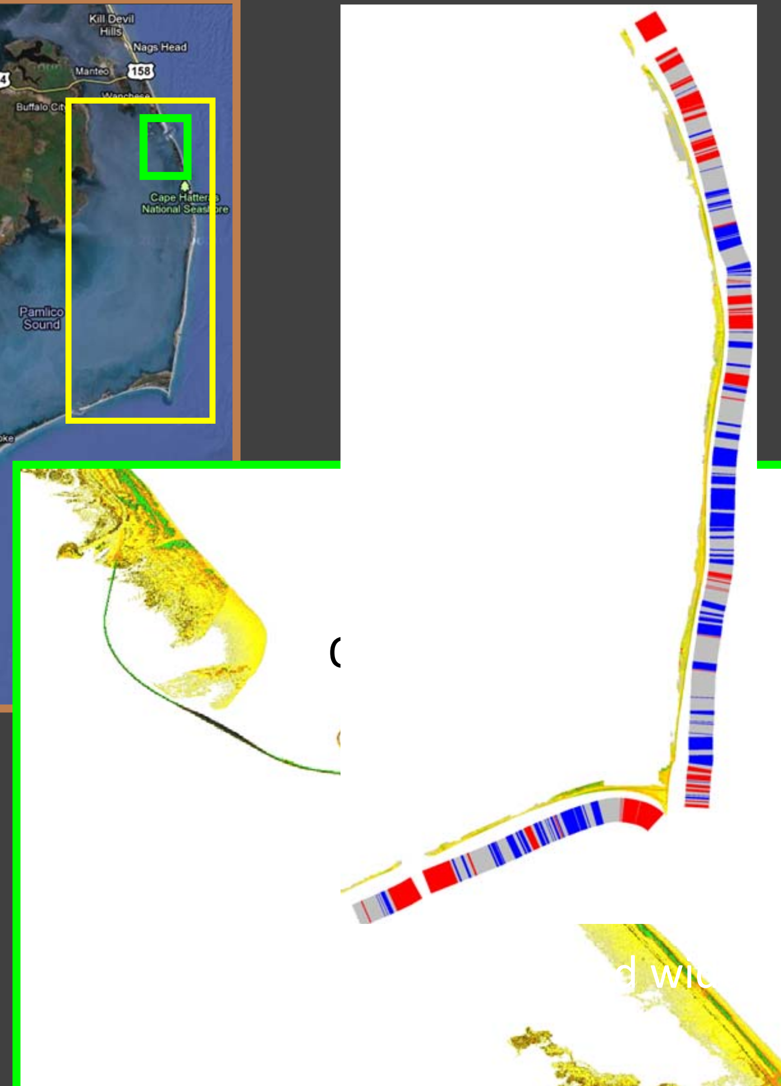
Study region: Outer Banks



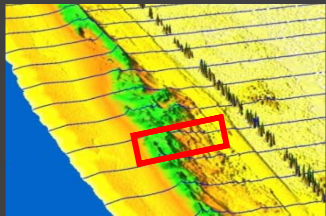
North Carolina barrier islands

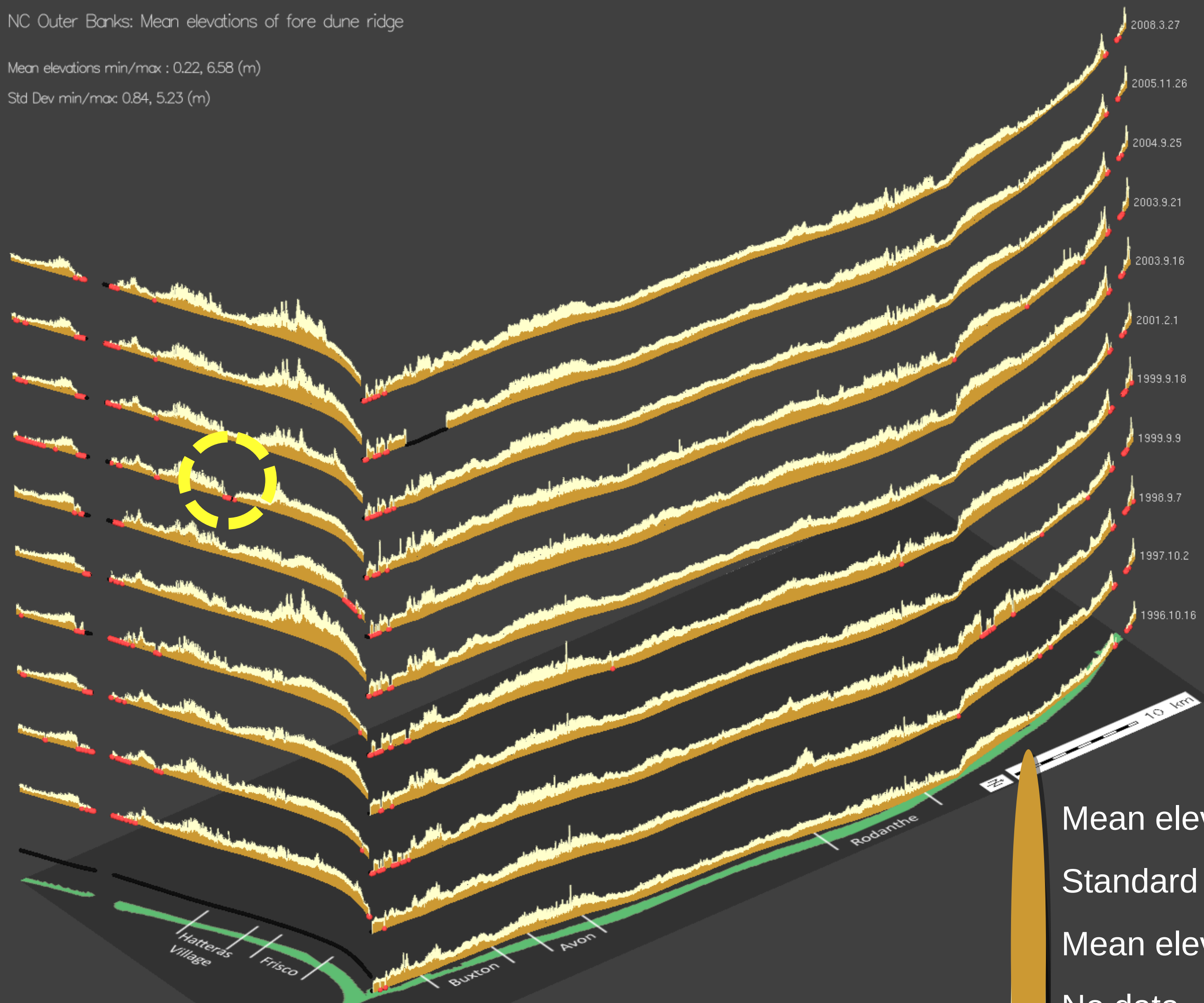


Outer Banks



STC Mean Elevation





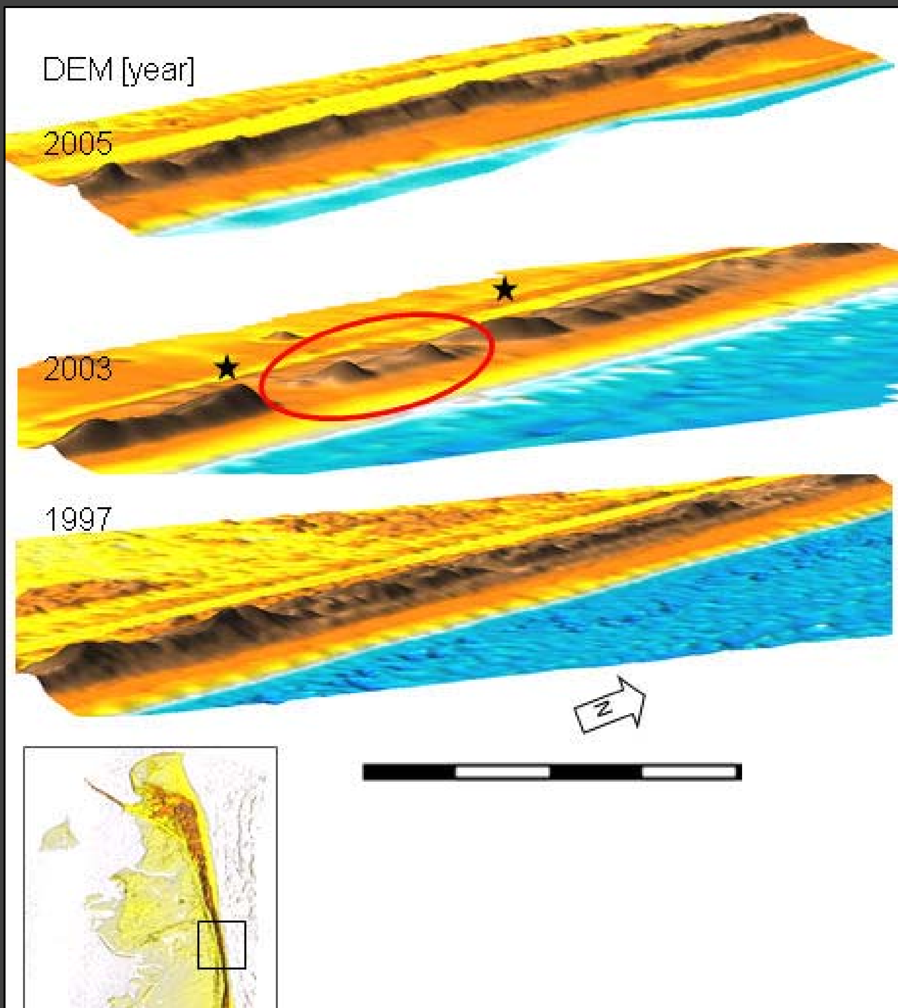
Mean elevation

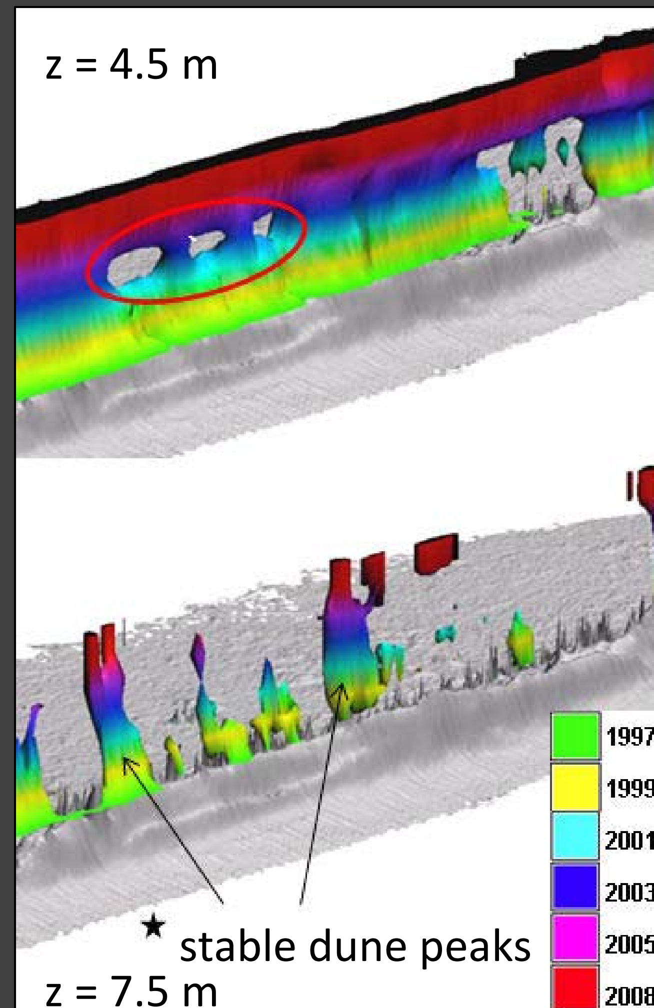
Standard deviation

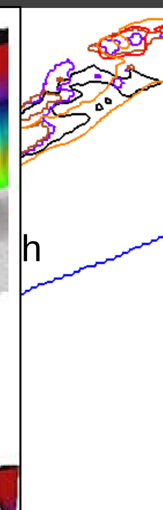
Mean elevation < 3m

No data

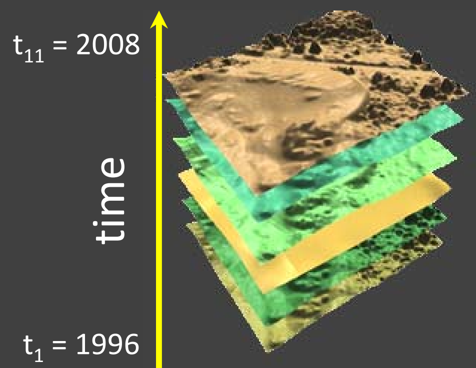
Overwash locations



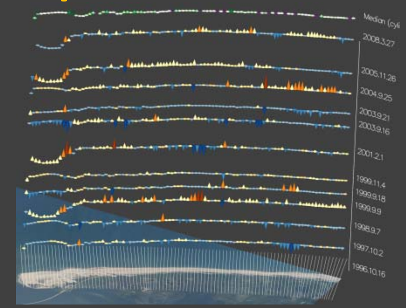




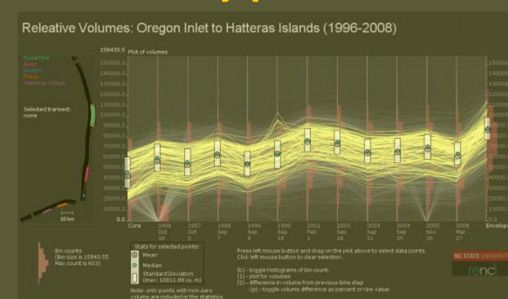
Methods



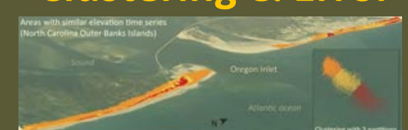
Space-time cube



Summary plots

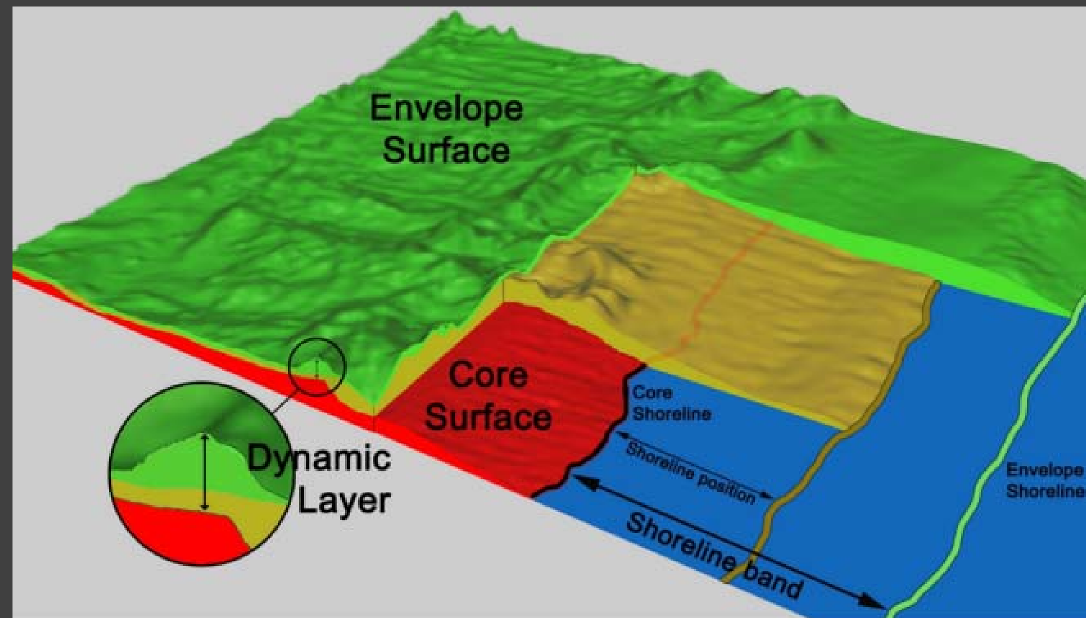


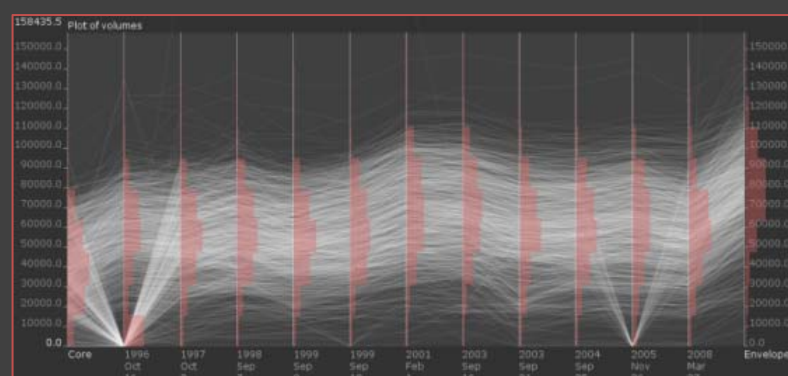
Clustering & Error Visualization



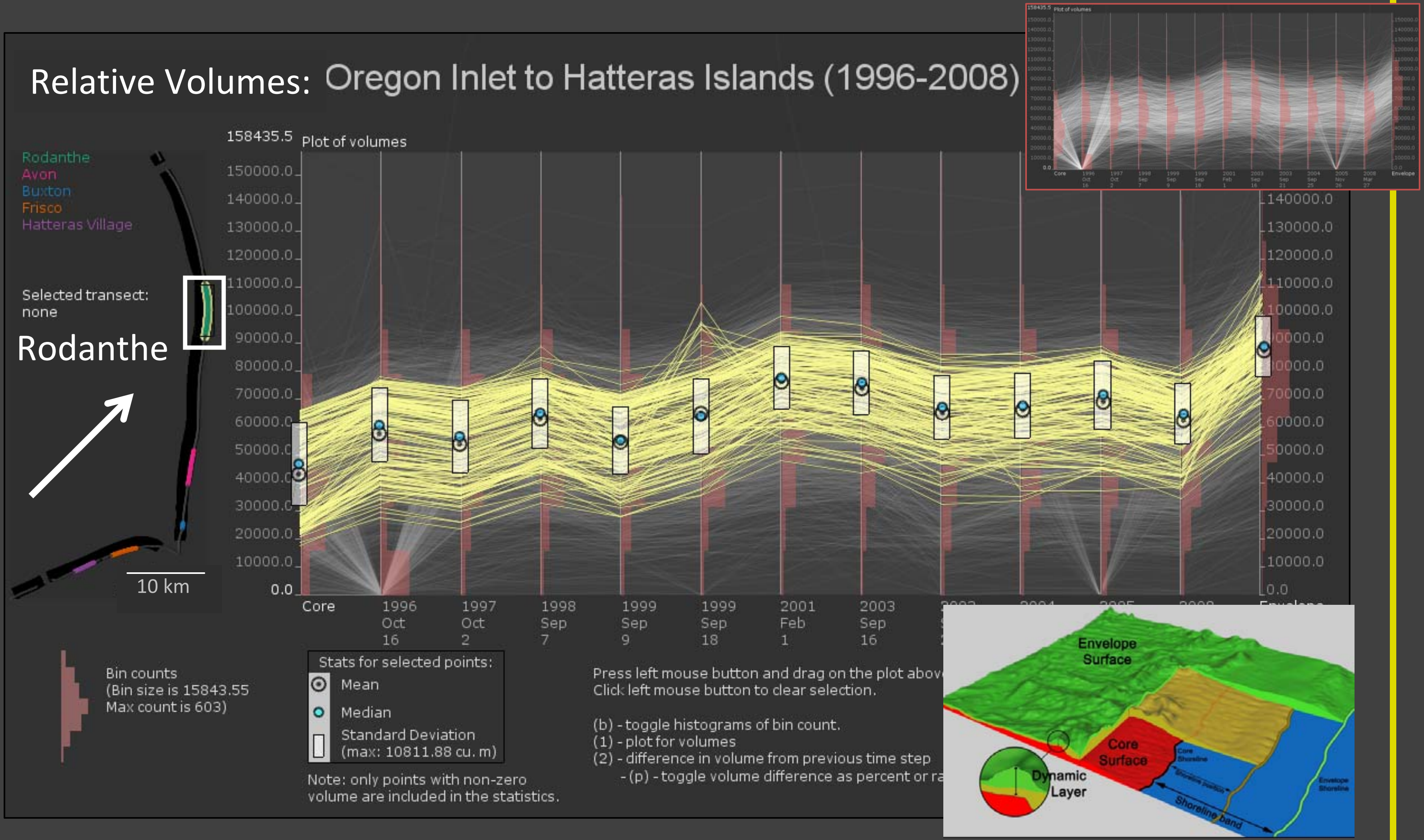
Relative volume

$$V_{rel} = \frac{V_i - V_{core}}{V_{env} - V_{core}}$$



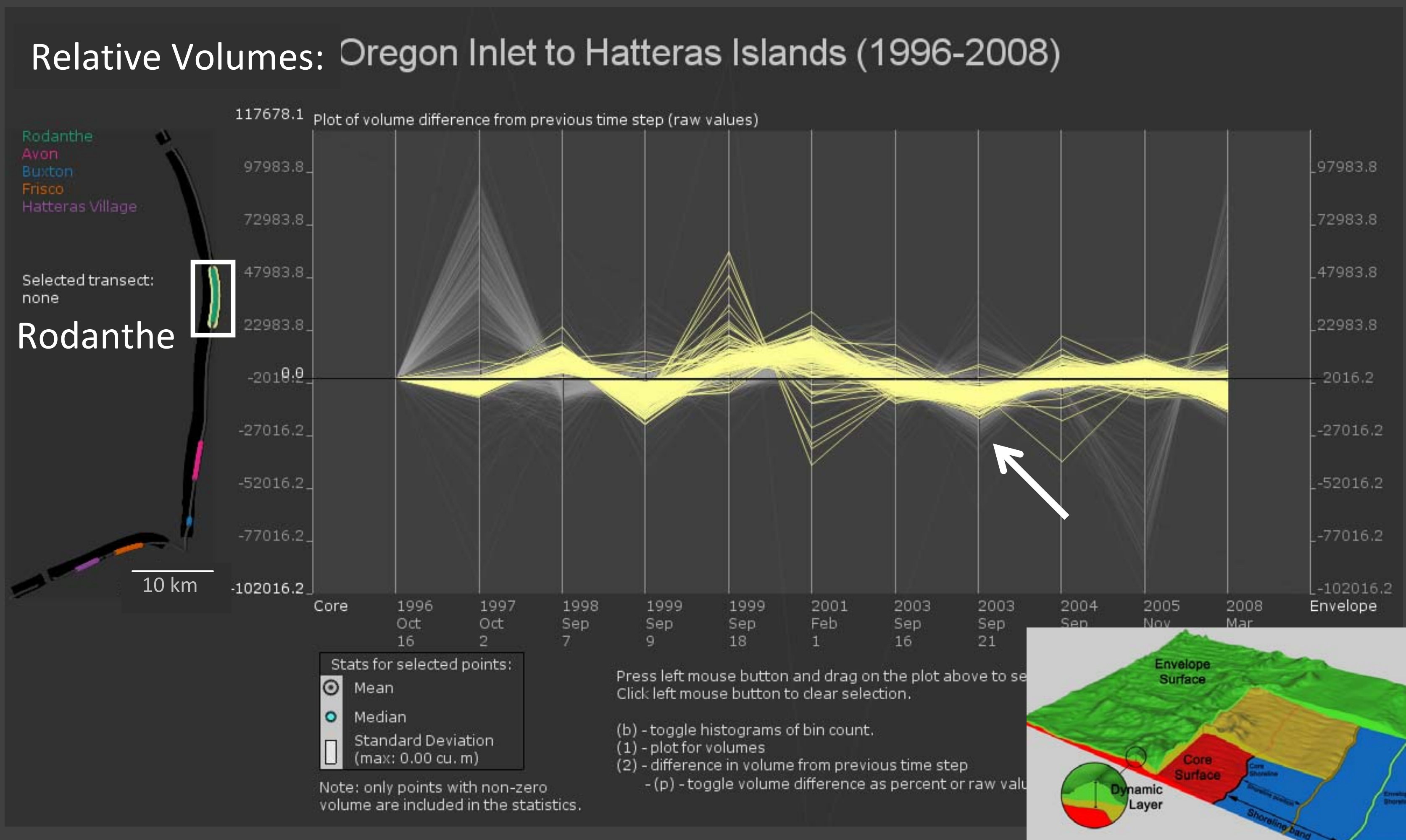


Summary Plots: Relative volume



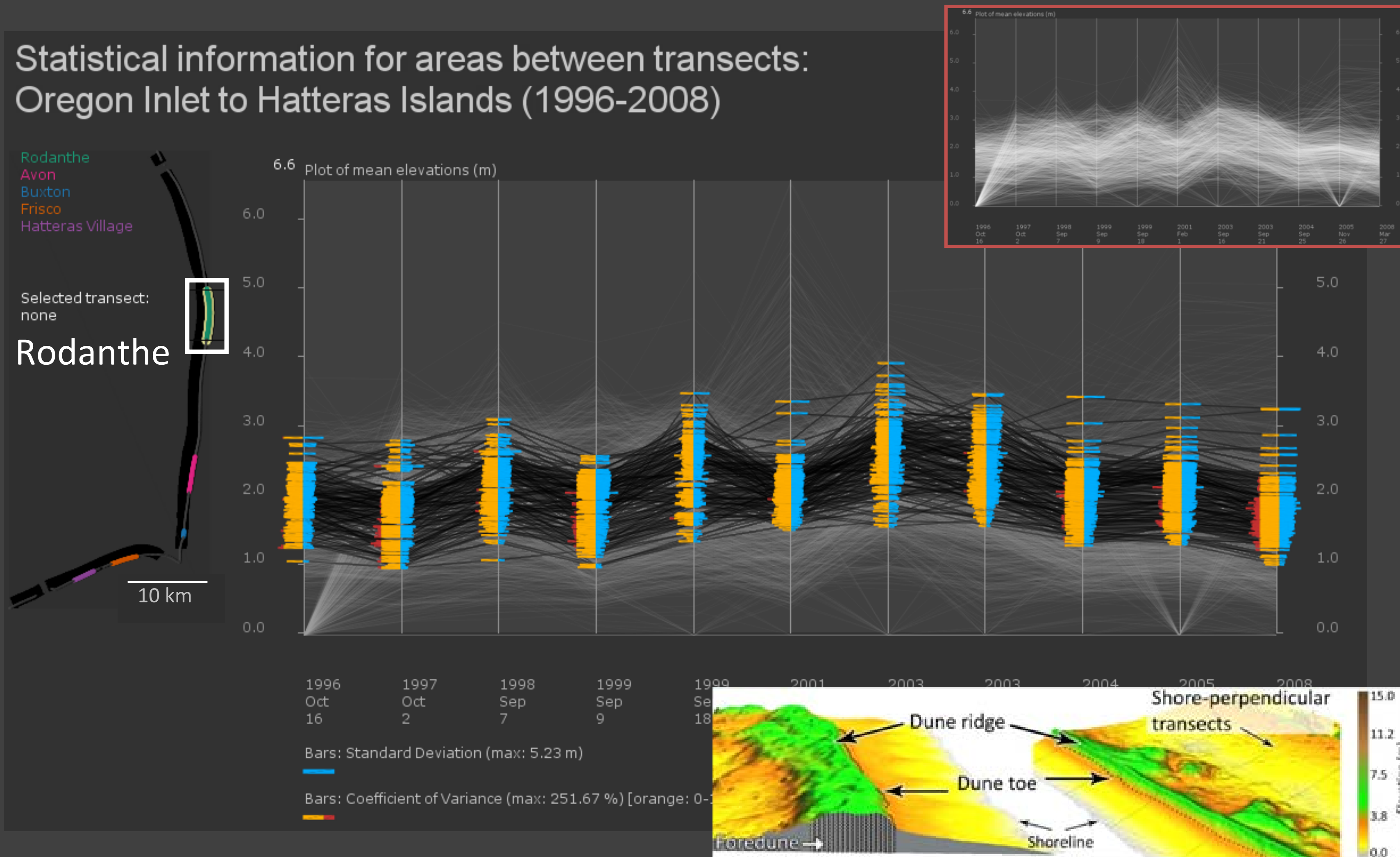
Data: fore dune sampled at 50 m resolution. About 1800 data points.

Summary Plots: Differences in Rel. Vol.



Data: fore dune sampled at 50 m resolution. About 1800 data points.

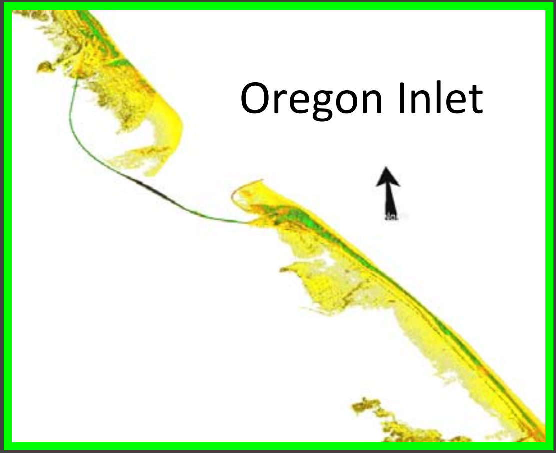
Summary Plots: Dune ridge elevation



Data: raster map sampled at .5 m resolution.

Space-Time Clustering

- Identify clusters of points on a terrain that have similar elevations over all time steps

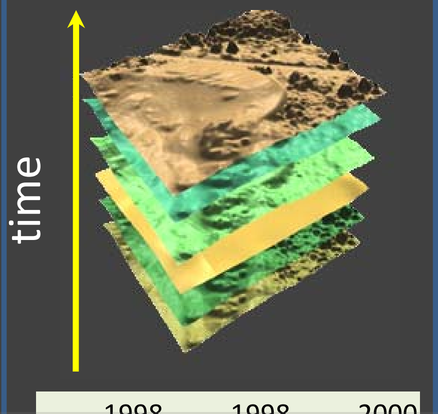


Visualization:

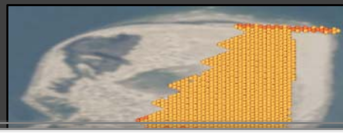
- Apply the clustering technique to visualize clusters of points with similar elevation time series in Oregon Inlet region.
- Develop methods to visualize other attributes such as error within each cluster

Clustering Method

Elevation time series



Distance metric → Pair-wise Similarity score → 2D layout (MDS)



$$D_{xy} = \sqrt{\frac{(m^x - m^y)^2}{max - squared - mean - diff} + \sum_{i=1}^{t}\left(\frac{\left(e_i^x - e_i^y\right)^2}{max - squared - diff} + \frac{\left(\frac{e_i^x}{m^x} + \frac{e_i^y}{m^y}\right)^2}{max - squared - ratio - diff}\right)}$$

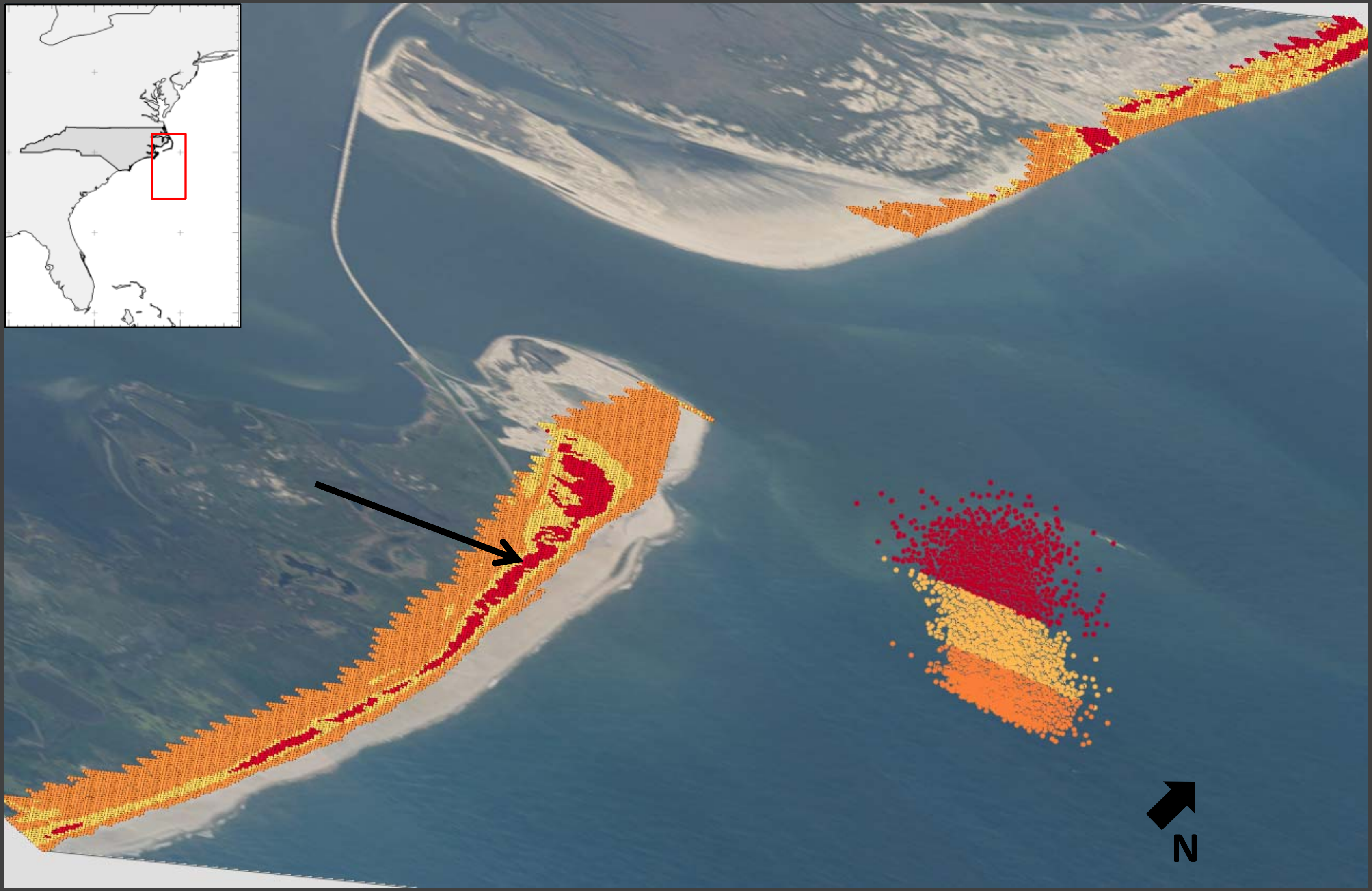
Where

x, y are two time series

m^x, m^y are means of the two time series x,y over all t time steps

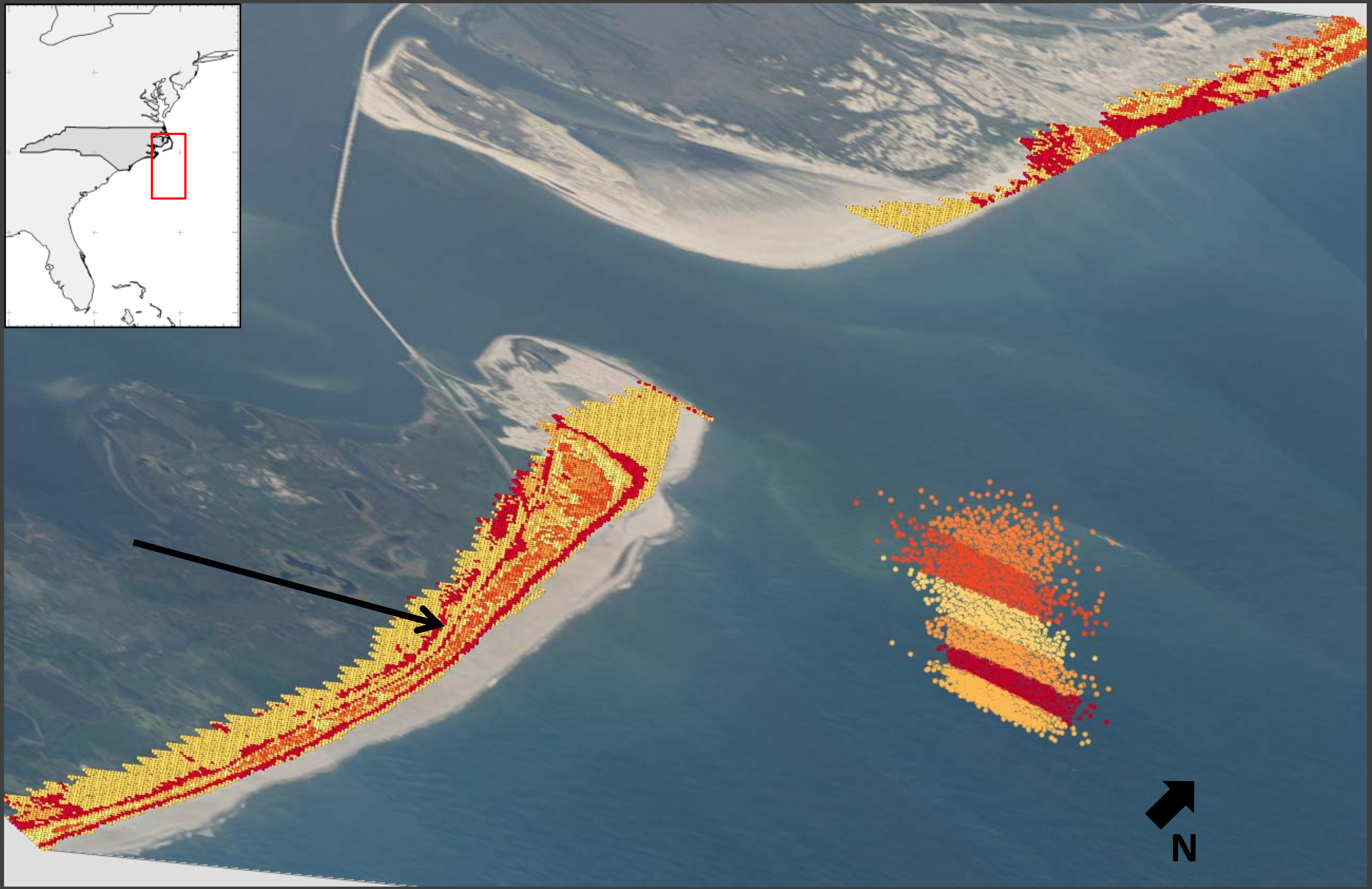
e_i^x, e_i^y are elevation values of the two series at time step i

- Partitioning result with $k = 3$. Note that colors are assigned arbitrarily to the clusters.



Data: raster map sampled at 5m resolution. About 10,000 points on the surface.

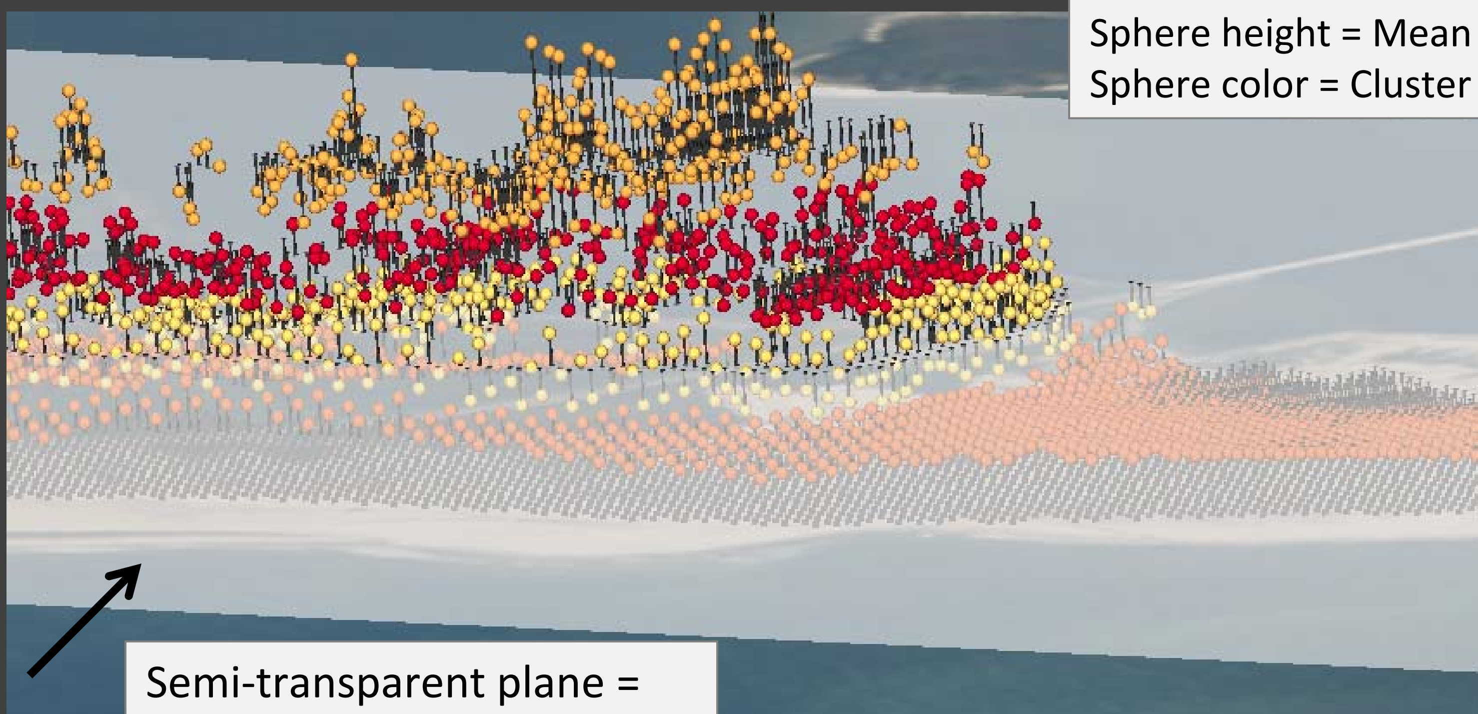
- Partitioning result with *k* set to 6.

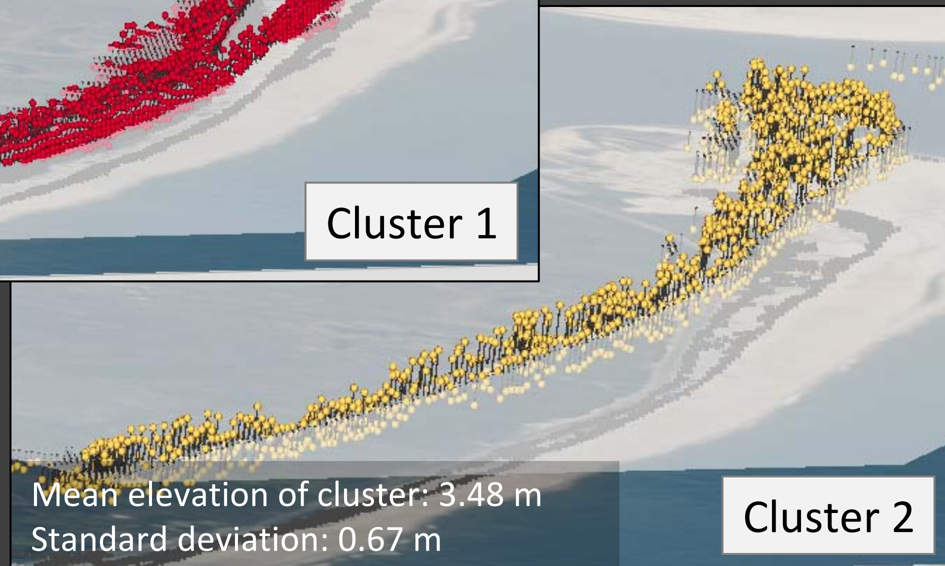


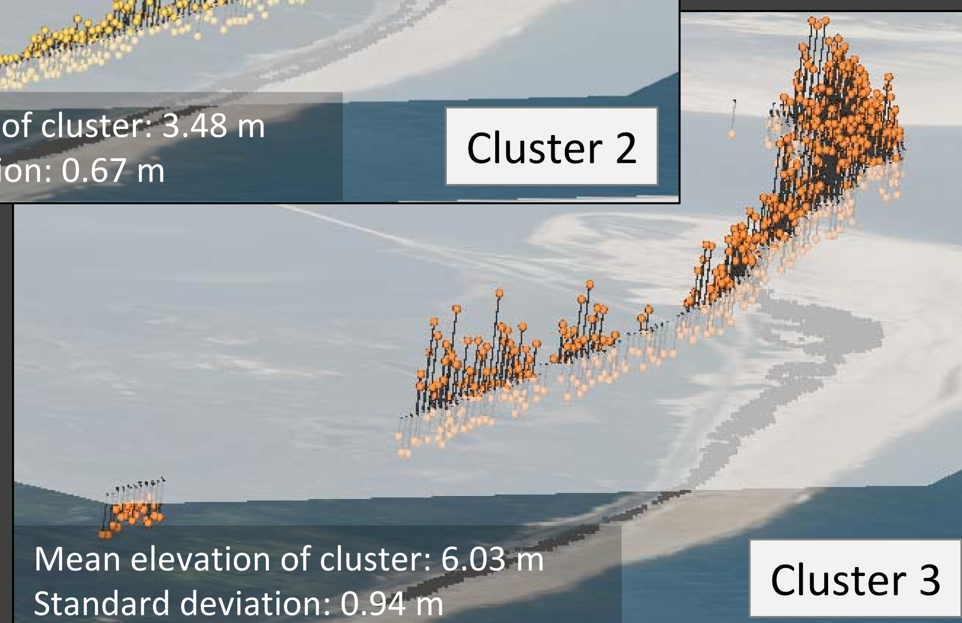
Data: raster map sampled at 5m resolution. About 10,000 points on the surface.

Visualization of Error

- “Error” is introduced due to the summarization process
- One type of error is difference from cluster mean elevation
- Black lines originating from the spheres denote their distance from the mean of corresponding cluster. A white “cutting plane” is drawn to show the mean of the cluster of yellow spheres.

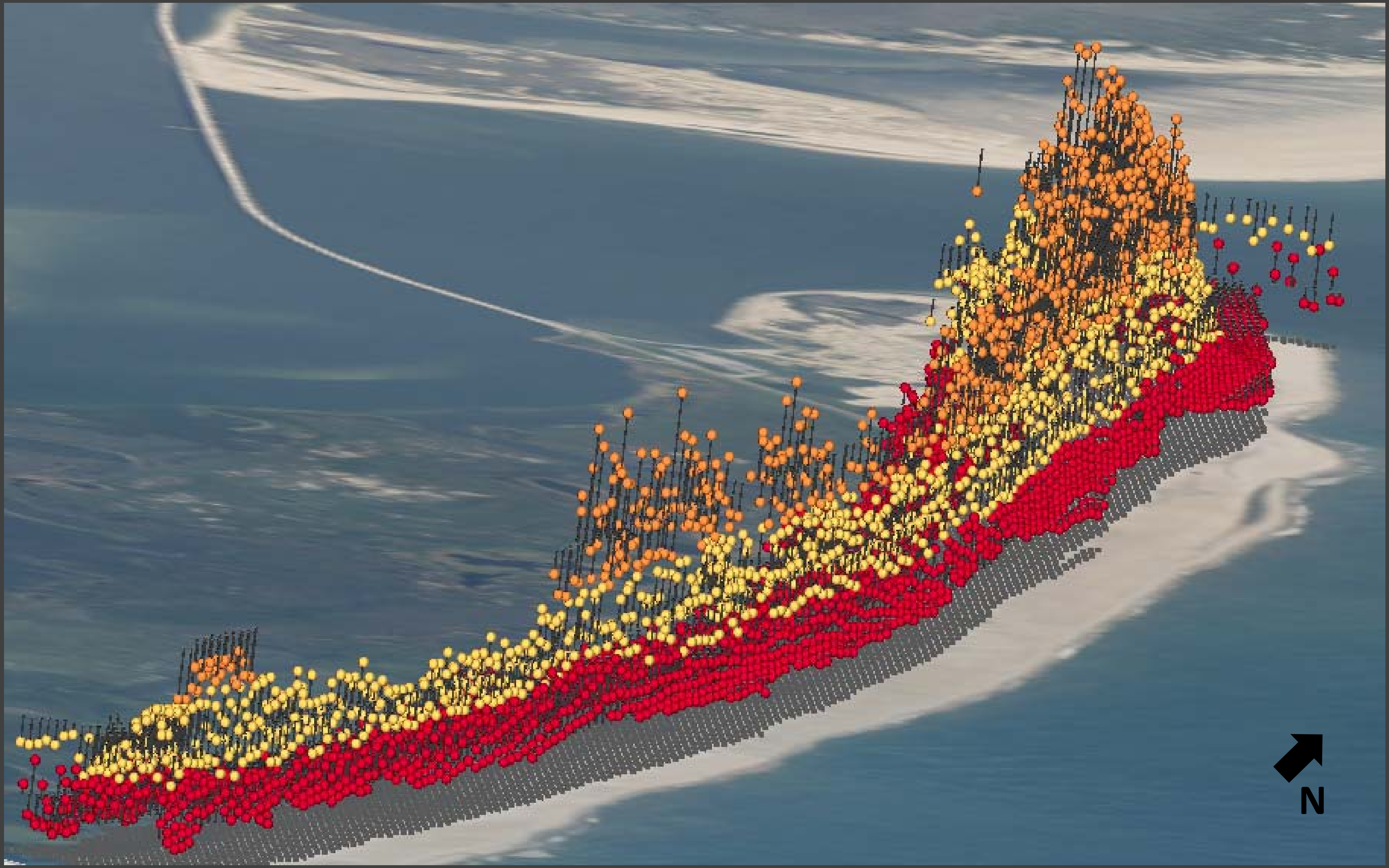






Visualizations of points in individual clusters

- Visualization of points in three clusters obtained by clustering elevations of points on the map over all time steps. Vertical location of sphere represents mean elevations and black lines represent difference of mean from mean of the cluster.



Discussion

- Summarization is necessary because we are dealing with data that have -
  - High resolution + multiple time steps + multiple features
- Summaries are used to
  - verify trends, for example, Hurricane Isabel (2003)
  - Reduce complexity of raster-based displays
- Error is introduced due to summarization process and we visualize this error
- Implications for vulnerability
  - Vulnerability calculated based on factors such as fore dune ridge height, shoreline movement, beach width, fore dune volume

Future work

- Inspect known vulnerable region for patterns
- Incorporate new datasets
- Other metrics
  - beach width, shoreline, slope, gradients over time, horizontal ridge migration
- Other terrain types, for example, land slides in mountainous regions

Thank you

Shackleford Island, Outer Banks, North Carolina