Applications of Lidar for understanding coastal change and vulnerability: an update from the National Assessment of Coastal Change Hazards project

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U.S. Geological Survey

USGS National Assessment of Coastal Change Hazards

Extreme erosion during Hurricane Irene
Rodanthe, NC

Long-term cliff erosion
Pacifica, CA

Goal: Identify, quantify, and model the vulnerability of the U.S. shorelines to coastal change hazards

Ongoing Science Tasks

- Impacts of severe storms & hurricanes
- Long-term coastal change
- Coastal vulnerability to sea level rise

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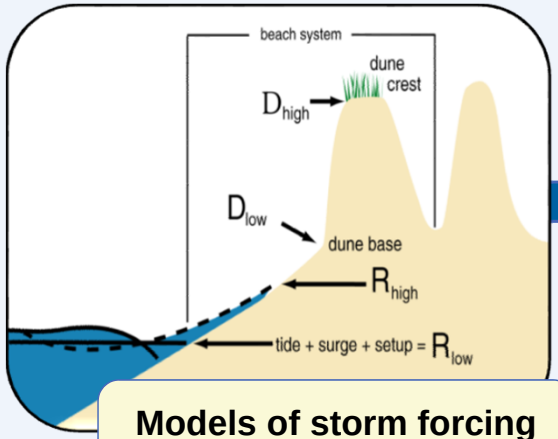
Predictions of Coastal Change during Storms

The beach response to storms is dependent, in part, on the interactions between local morphology and the offshore forcing.

These data are used by sophisticated models to simulate and predict the type/magnitude of coastal changes that may be expected during storms.

Approaching storm (waves, surge)

Beach morphology (slope, dune height)



Models of storm forcing and beach response

Coastal change (overwash, erosion)

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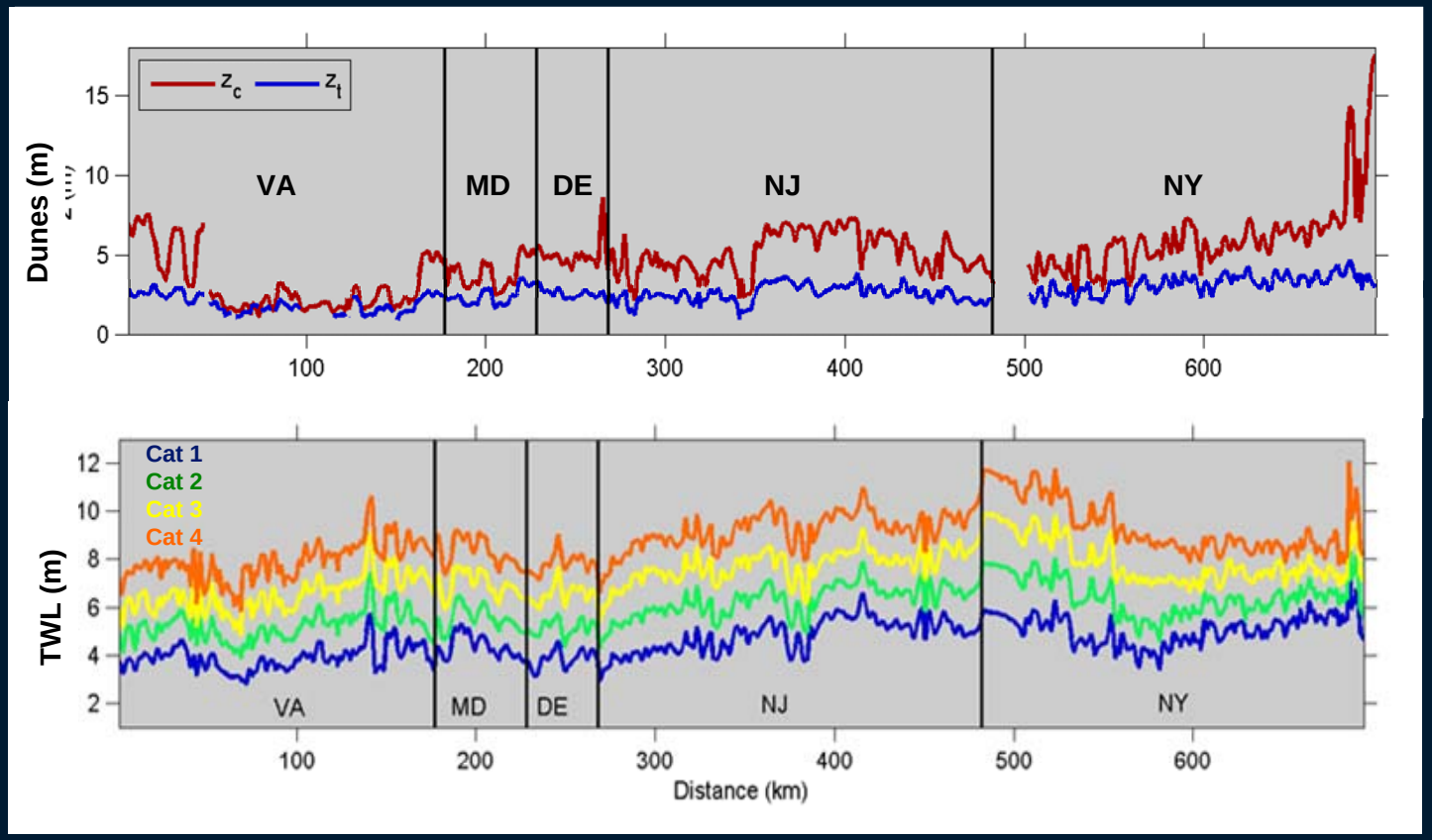
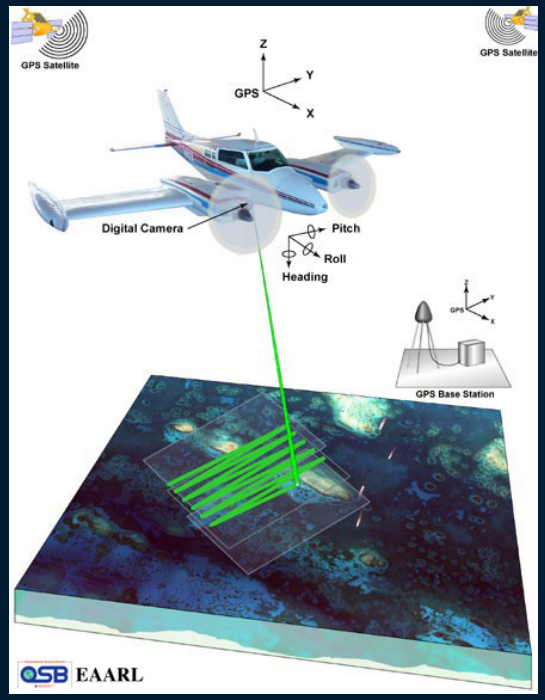
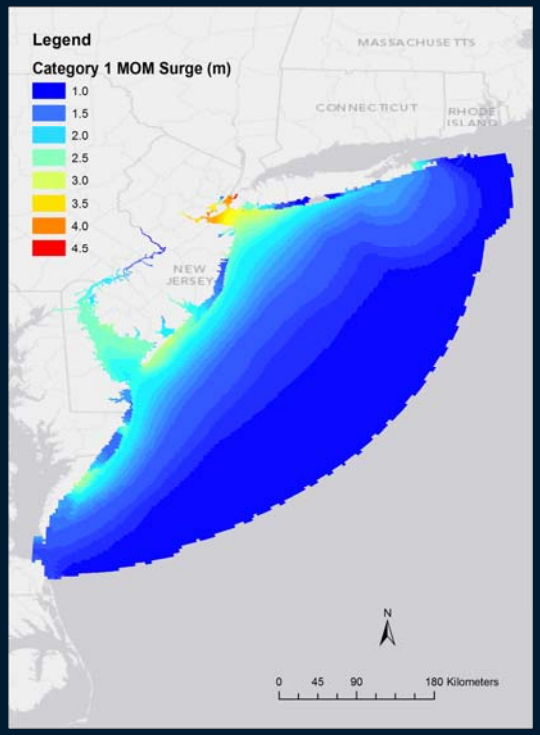
Elements of coastal change forecasts

Dune crest and toe elevations - Lidar-based topography surveys
(USGS, NOAA, USACE)







Total water levels - Wave and surge models
(USGS, NOAA)

USGS

Probabilities of coastal change

What is the likelihood that storm-induced total water levels will exceed the elevation of the base and crest of protective sand dunes?

Collision

Waves/surge collide with the dune base, leading to erosion.

Overwash

Waves/surge overtop dune crest, moving sand landward.

Inundation

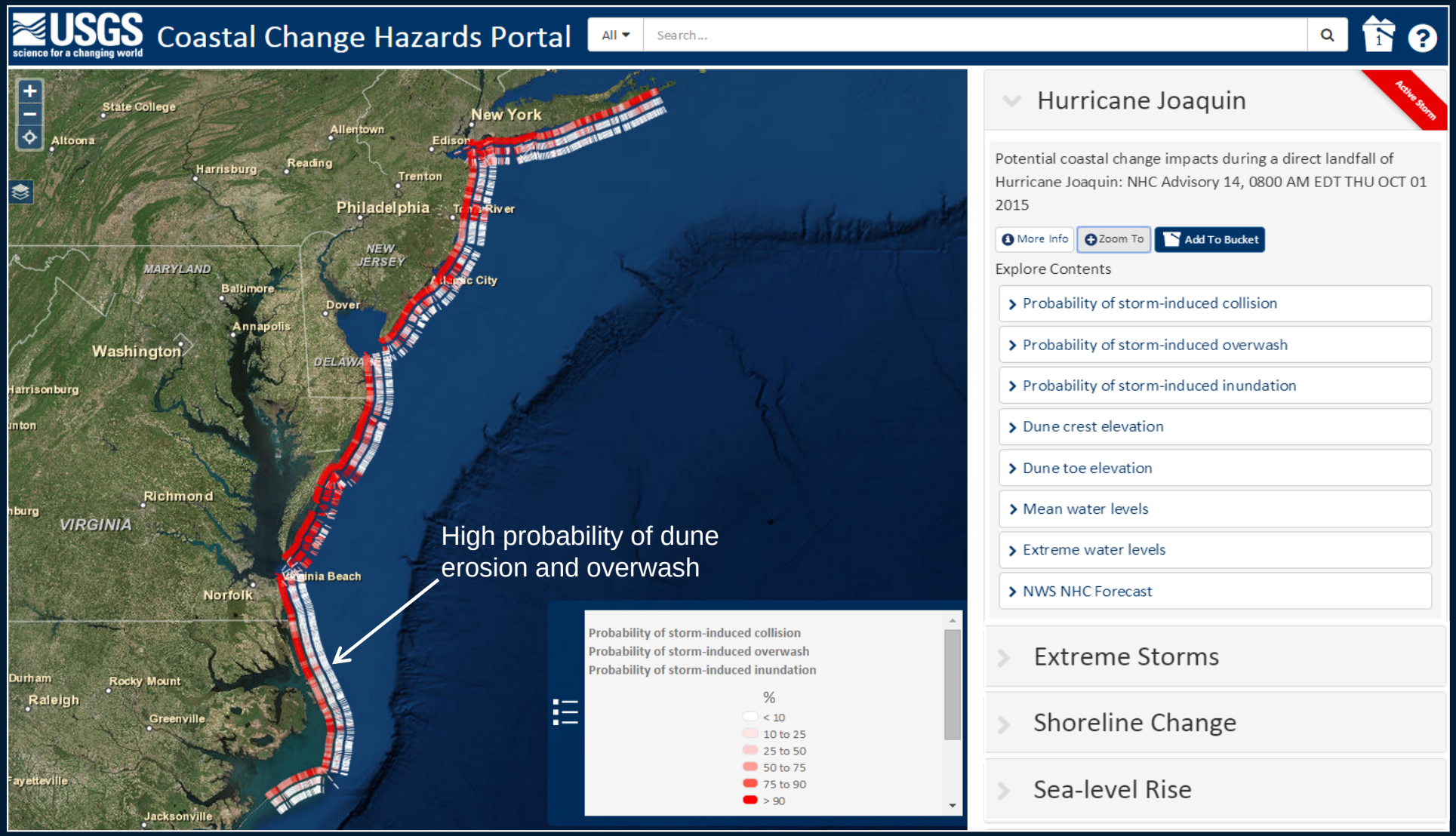
Surge is higher than dune crest, submerging beach system.

1) Real-time mode for approaching storms
2) Scenario-based approach for generalized storms

USGS

Real-Time Coastal Change Forecast: Joaquin (2015)

- Assessments, data, and web mapping services available online for the first time
- Includes probability of collision, overwash, and inundation, as well as lidar-derived dune elevations and storm-specific total water levels



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http://marine.usgs.gov/coastalchangehazardsportal/

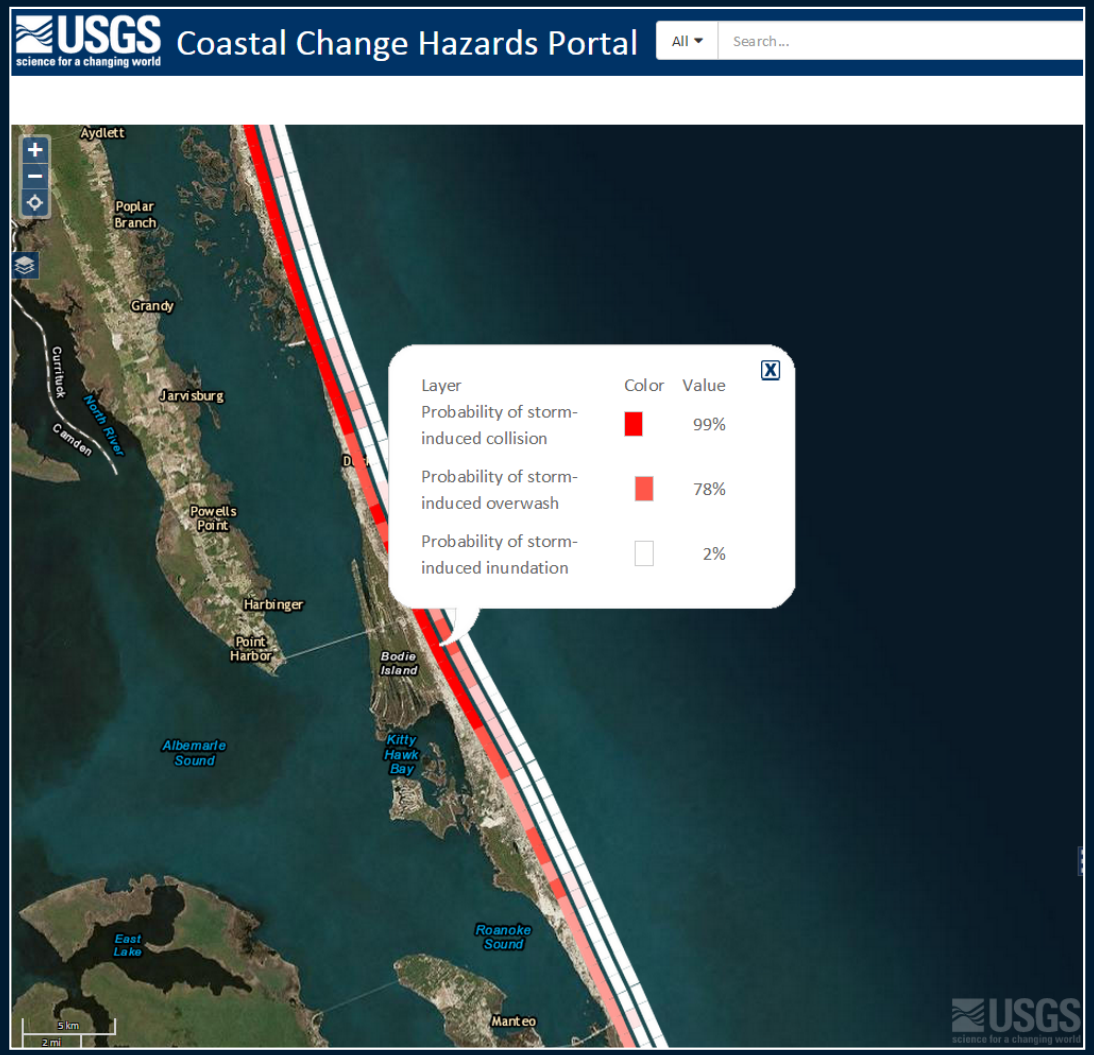

Photo credit: National Weather Service

- Overwash of HWY 12 was observed in Kitty Hawk, NC during Joaquin. USGS models indicate the probability of overwash in this region was ~75%.
- Extensive dune erosion was also observed, consistent with model forecasts indicating that the probability of dune erosion was >95% for this entire region.

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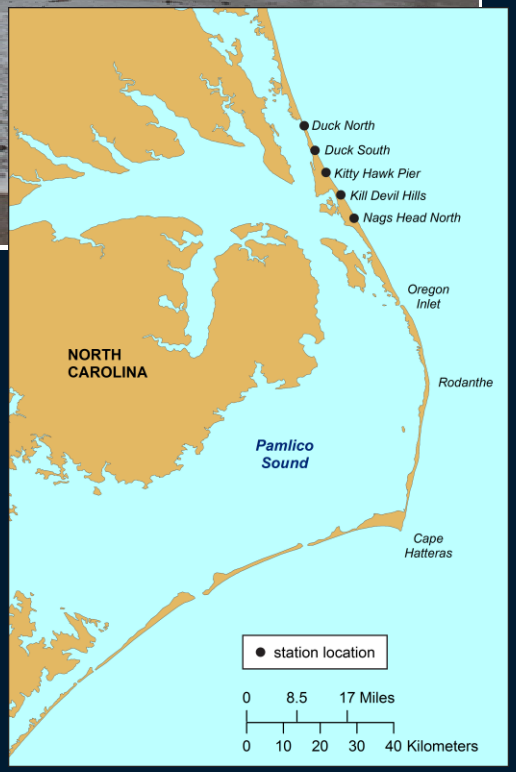
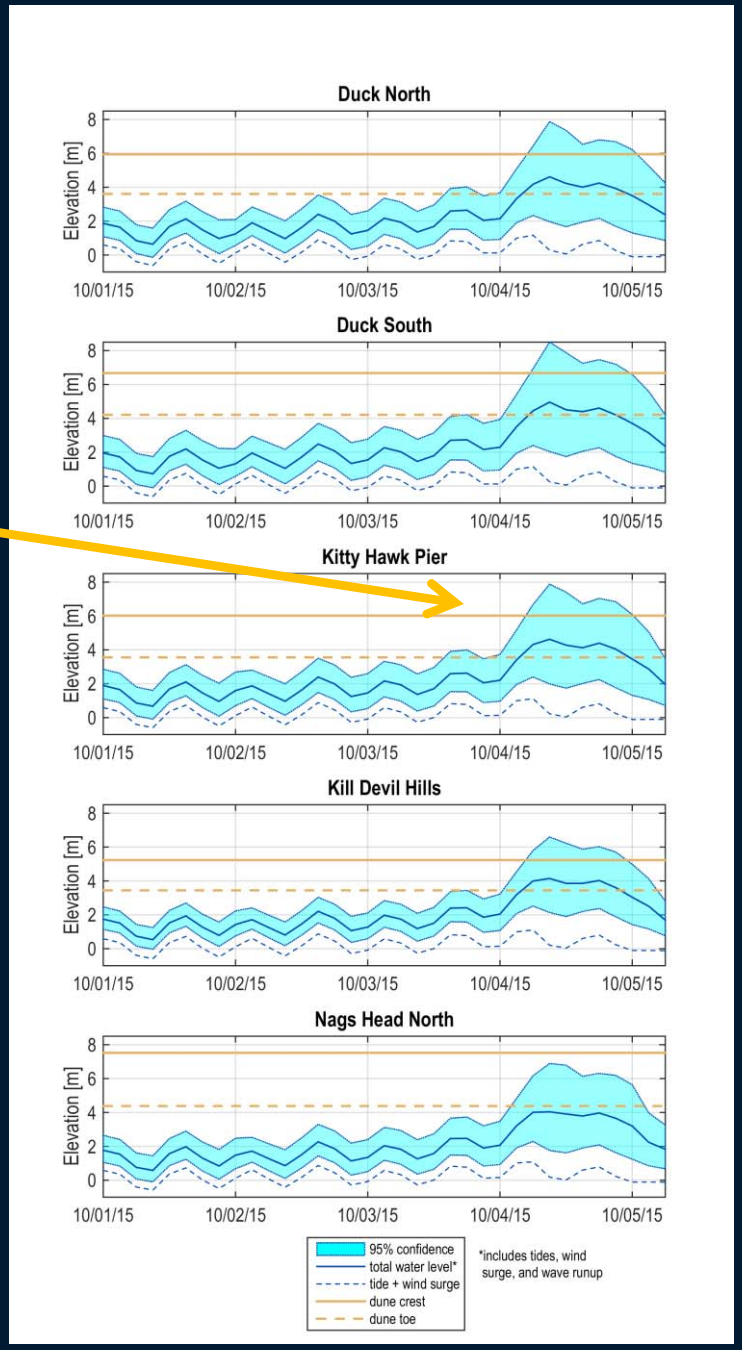
Operational Total Water Level Model: Hurricane Joaquin (2015)

Photo credit: Dare County Emergency Management





Operational forecasts of total water levels can warn local officials of potential overwash, such as that observed along HWY 12 in Kitty Hawk.

(USGS collaboration with NOAA, NWS)

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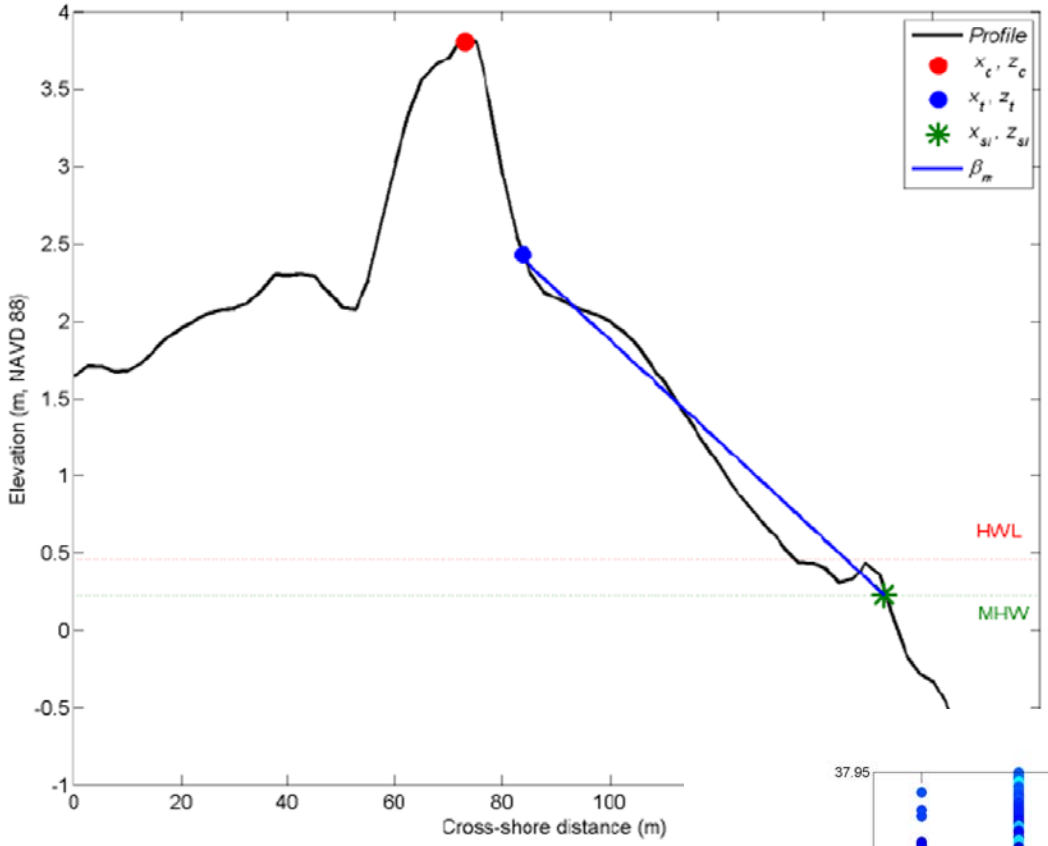
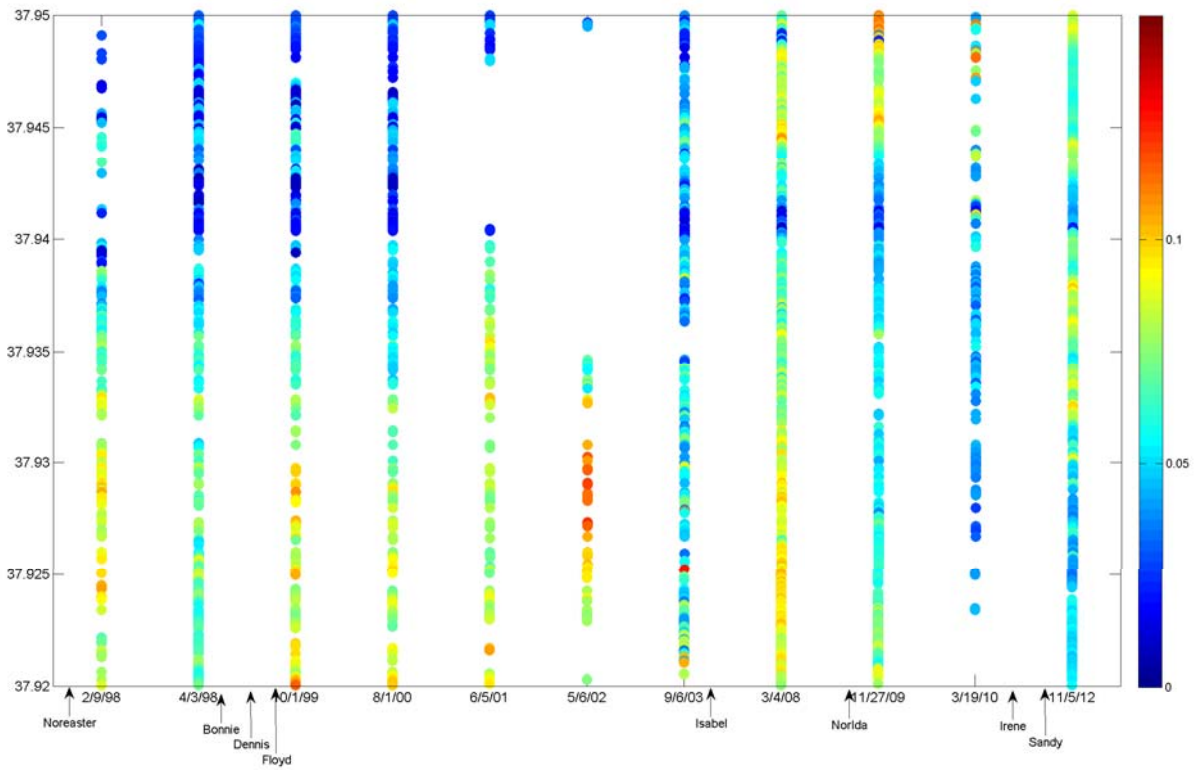

Profile
x_c, z_c
x_t, z_t
x_{si}, z_{si}
β_m
HWL
MHW
Elevation (m, NAVD 88)
Cross-shore distance (m)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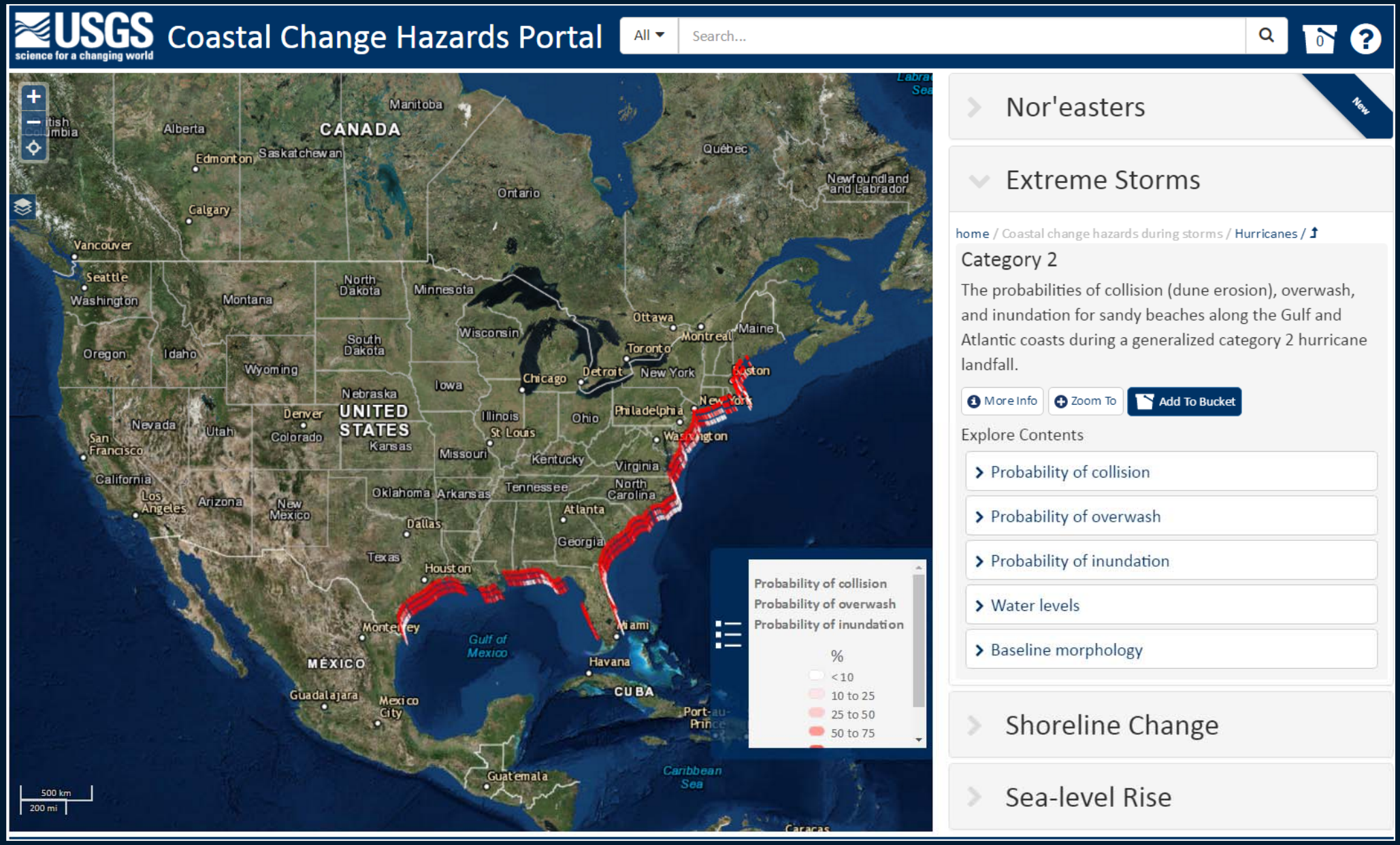
4/3/98
10/1/99
8/1/00
6/5/01
5/6/02
9/6/03
3/4/08
11/27/09
3/19/10
11/5/12
Noreaster
Bonnie
Dennis
Floyd
Isabel
Noriida
Irene
Sandy

Coastal Change Hazards Portal

Scenario-based coastal change forecast: category 2 storm on post-Sandy beaches and dunes



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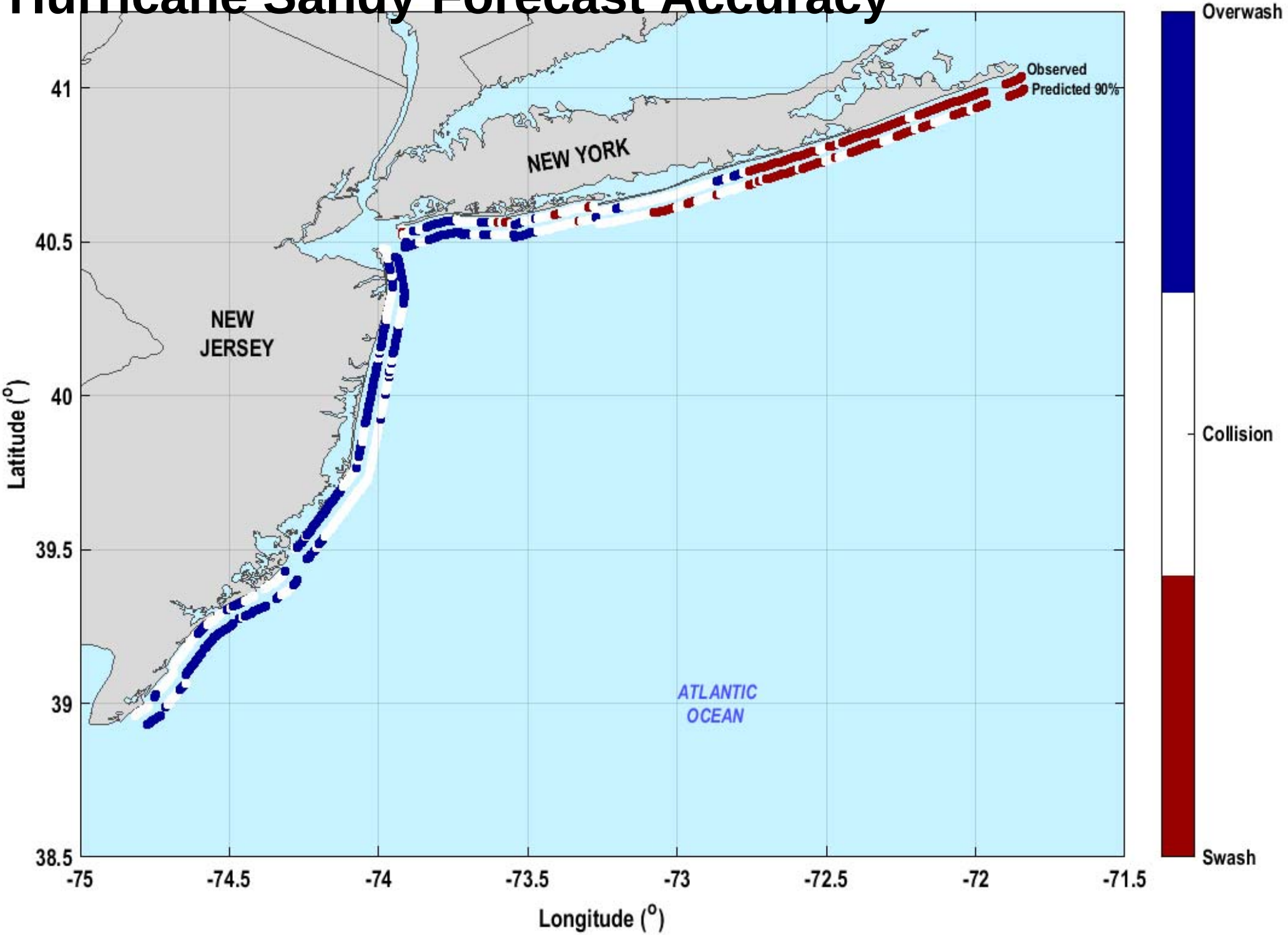
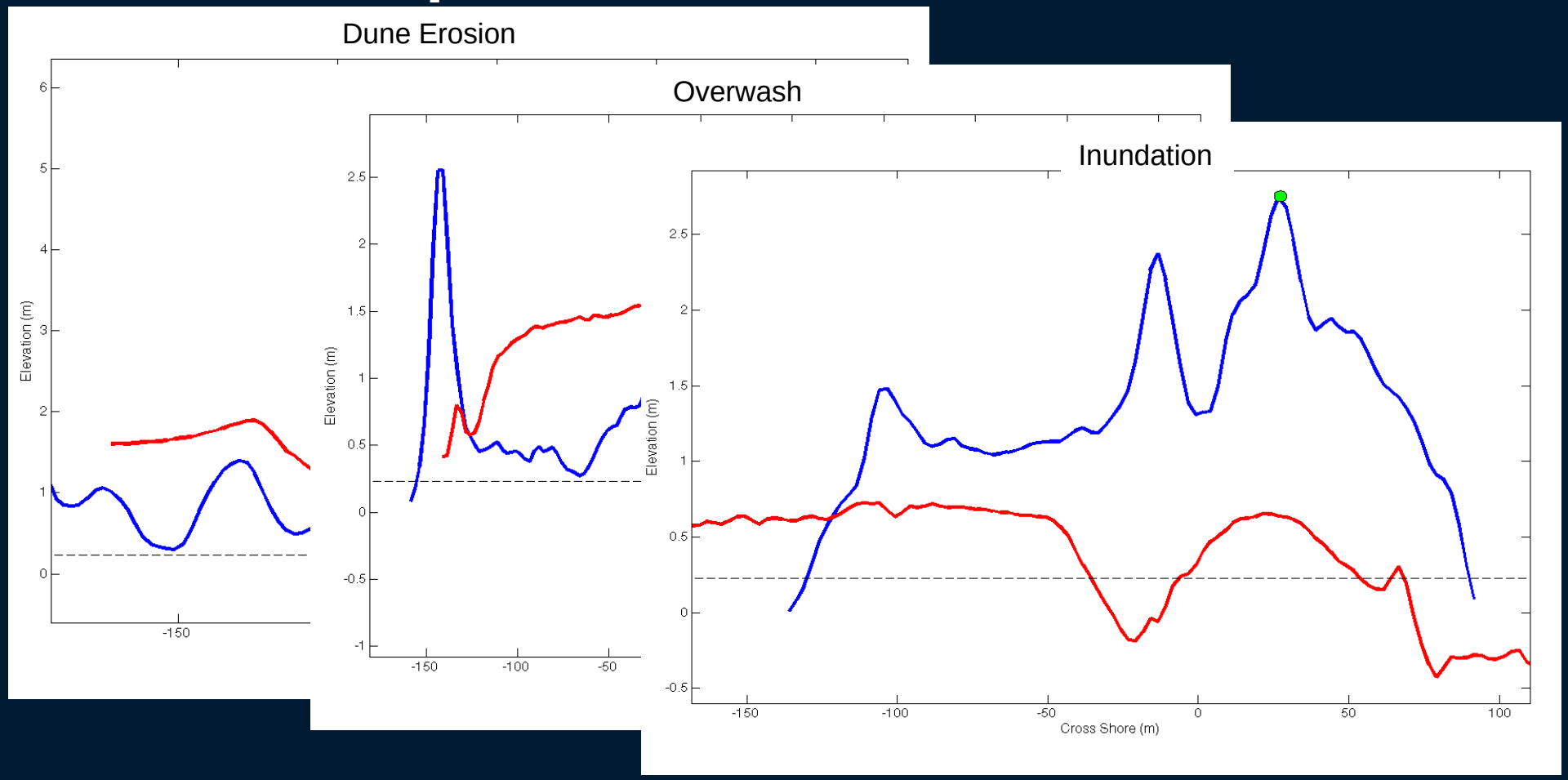
http://marine.usgs.gov/coastalchangehazardsportal/

Hurricane Sandy Forecast Accuracy



Volume Change

- **A quantitative measure of spatially variable storm response**



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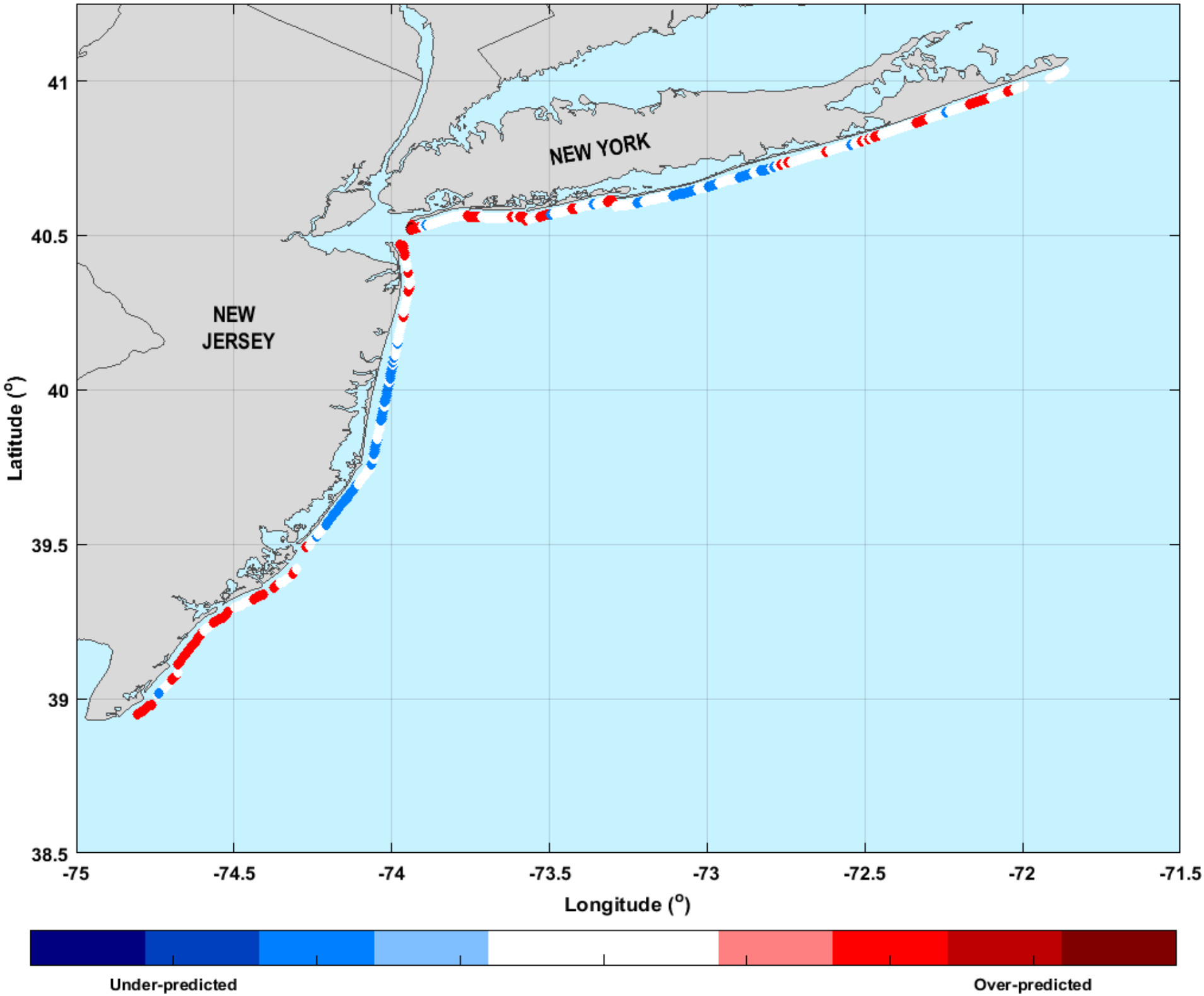
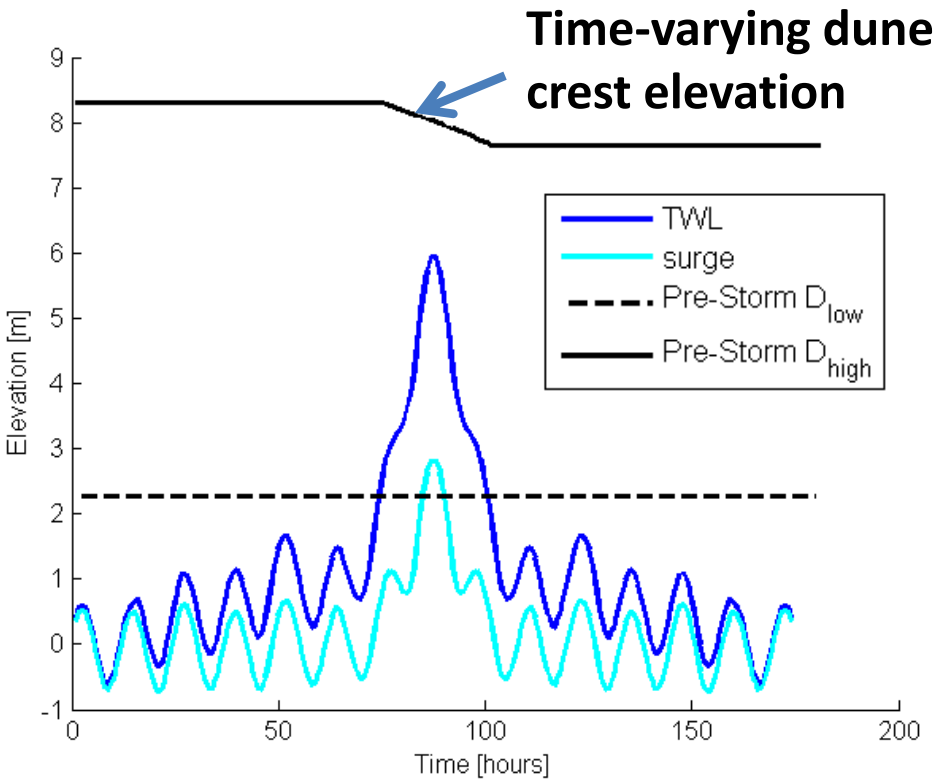
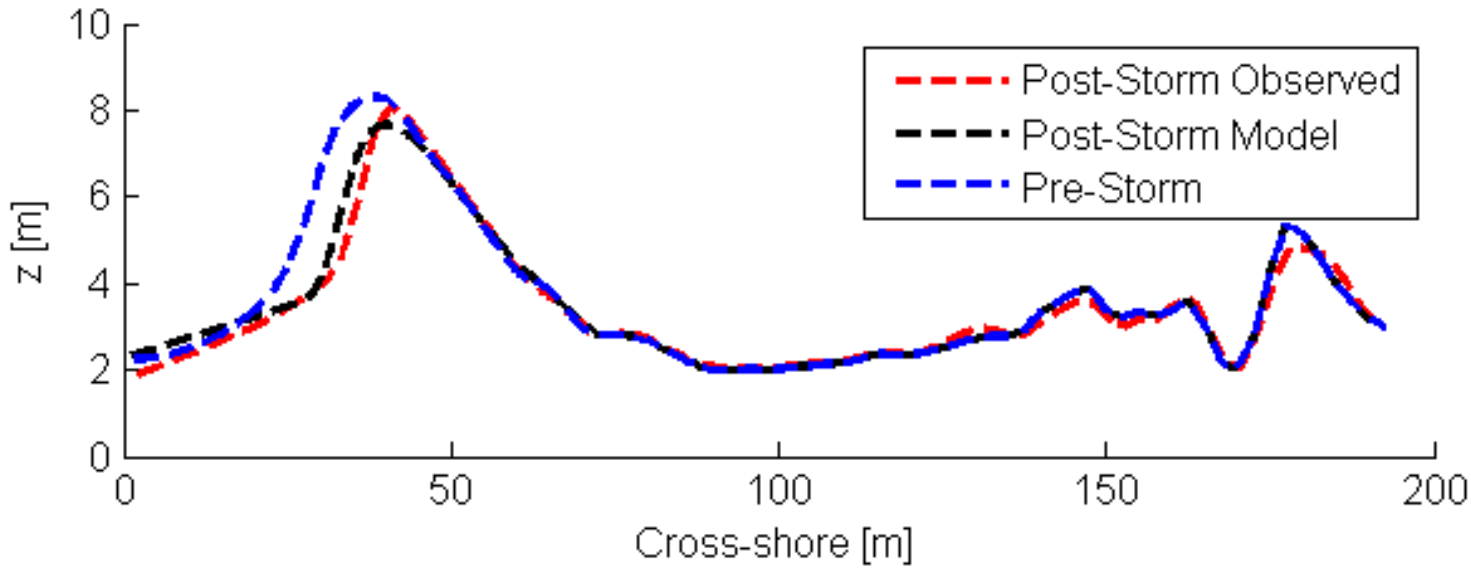

NEW YORK
NEW JERSEY
41
40.5
40
39.5
39
38.5
Latitude (°)
-75
-74.5
-74
-73.5
-73
-72.5
-72
-71.5
Longitude (°)
Under-predicted
Over-predicted

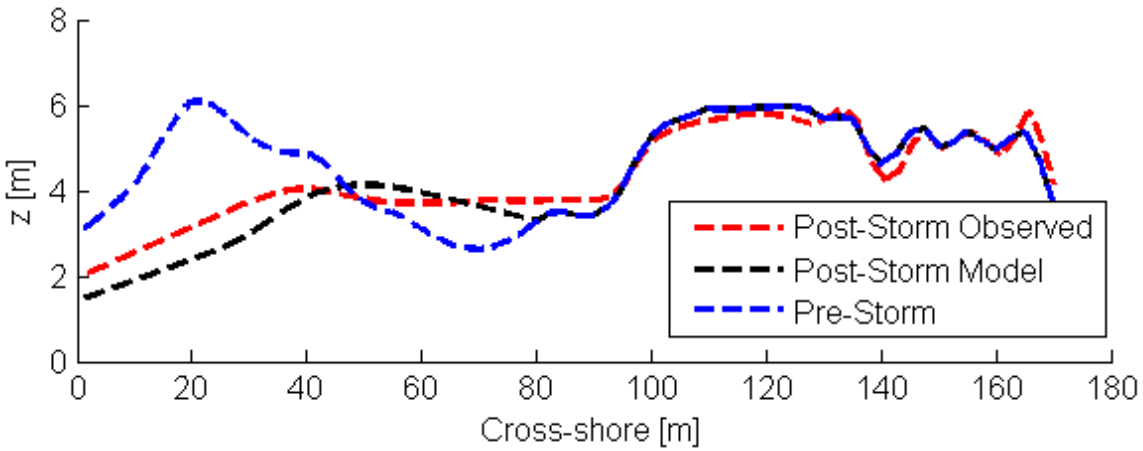
Advection-Diffusion Dune Model: Dune Erosion Regime

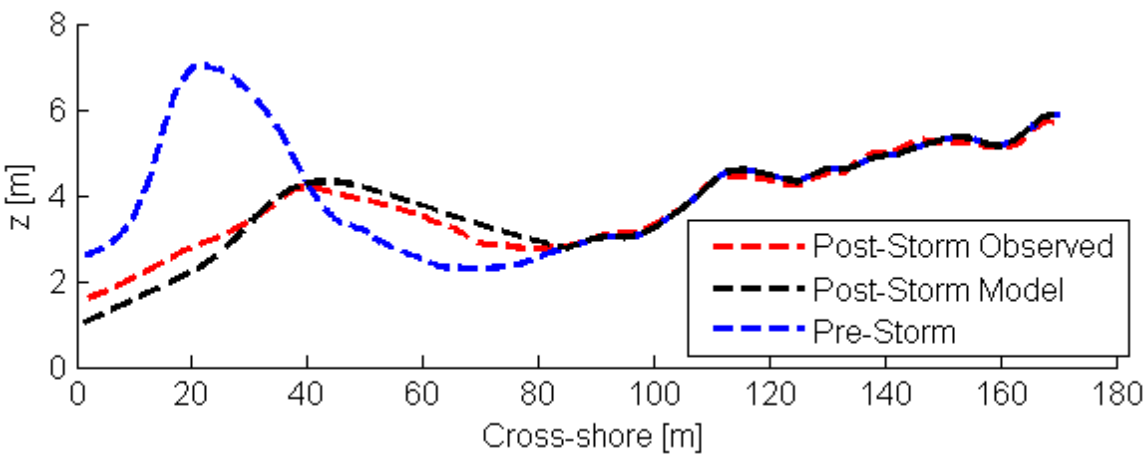


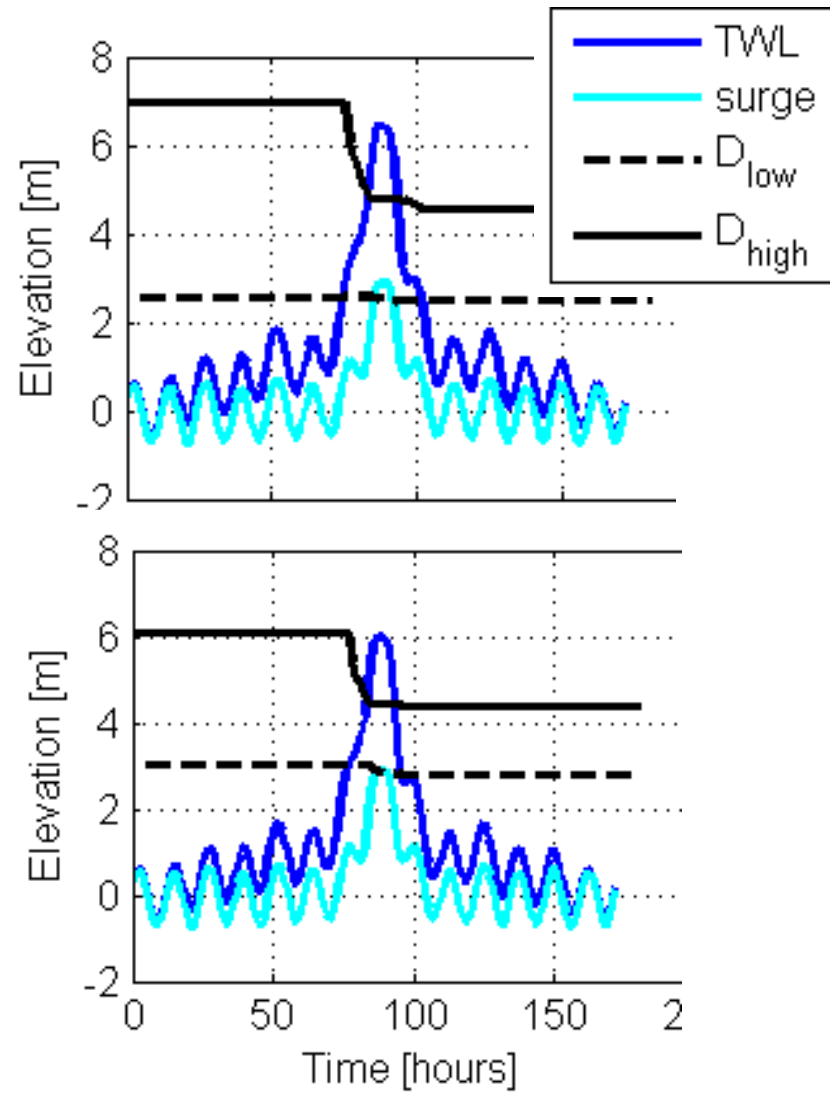
- Coupled with Palmsten and Holman 2012 to remove mass during dune erosion regime
- Diffused front dune face
- Time-varying dune crest elevation



Advection-Diffusion Dune Model: Overwash Regime







- Lowering during dune erosion regime is enough to cause overwash
- Redistribution of mass during overwash (no loss inside boundary)

Historic shoreline change

Short-term rate based on data from 1970-1997

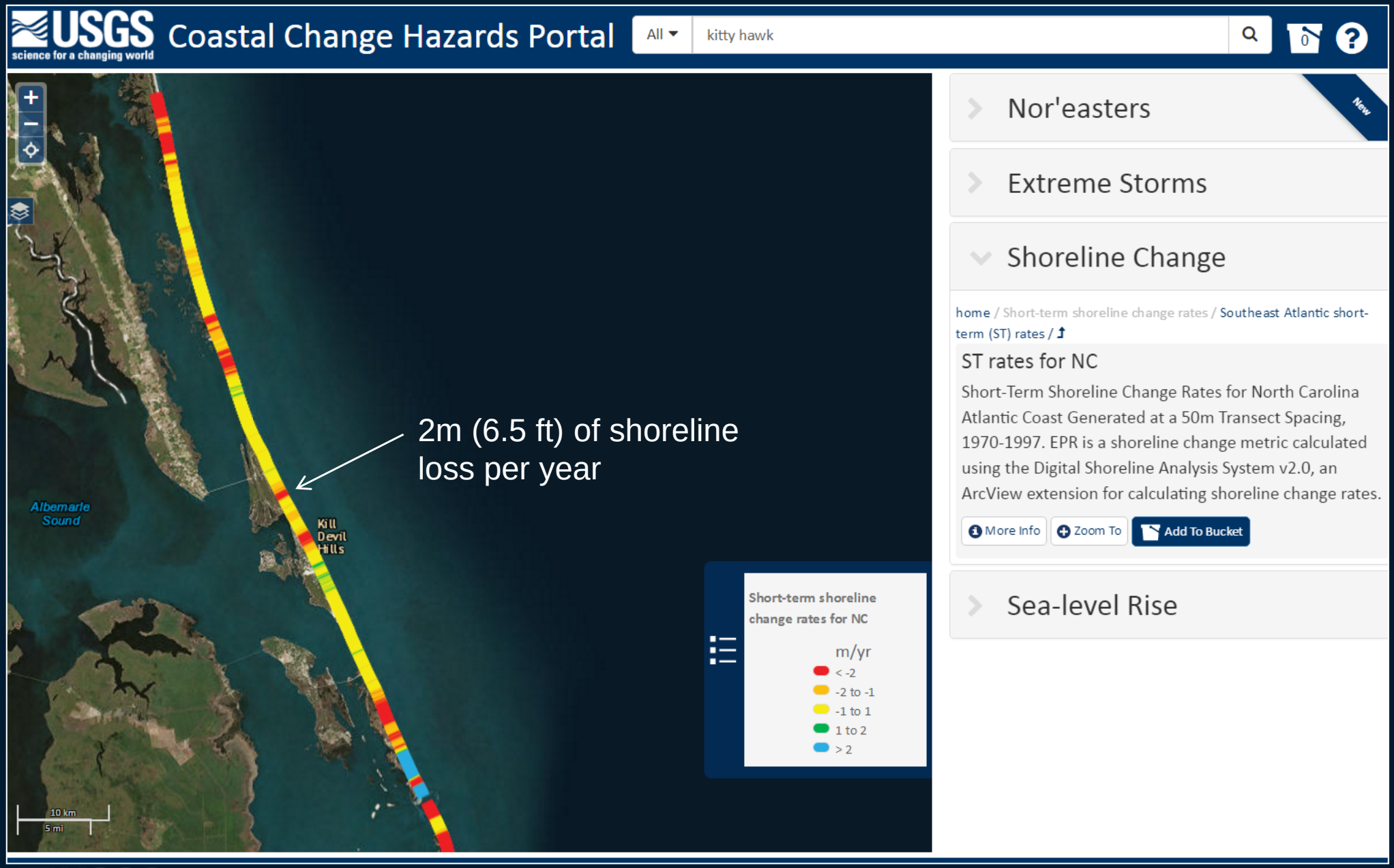


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Table 2. Mean differences in shoreline positions (50 m transect spacing), for the 30Sept2000 lidar survey. Positive numbers indicate that the column method average shoreline position is shifted seaward of the row method shoreline position average (e.g., Grid is landward of Profile20 by 0.17m).

Mean Difference (m)	Grid	Profile20	Profile10	Contour	Smoothed Contour Bend Simplify	Smoothed Contour Smooth Line	Manual
Grid	-------	-------	-------	-------	-------	-------	-------
Profile20	-0.17	-------	-------	-------	-------	-------	-------
Profile10	0.02	0.18	-------	-------	-------	-------	-------
Contour	0.06	0.22	0.03	-------	-------	-------	-------
Smoothed Contour Bend Simplify	0.09	0.26	0.06	0.03	-------	-------	-------
Smoothed Contour Smooth Line	0.06	0.22	0.04	0.00	-0.03	-------	-------
Manual	0.10	0.27	0.07	0.04	0.01	0.04	-------

Table 3. RMS differences in shoreline positions (50 m transect spacing), for the 30Sept2000 lidar survey.

RMS Difference (m)	Grid	Profile20	Profile10	Contour	Smoothed Contour Bend Simplify	Smoothed Contour Smooth Line	Manual
Grid	-------	-------	-------	-------	-------	-------	-------
Profile20	0.54	-------	-------	-------	-------	-------	-------
Profile10	0.55	0.48	-------	-------	-------	-------	-------
Contour	0.64	0.87	0.88	-------	-------	-------	-------
Smoothed Contour Bend Simplify	0.67	0.91	0.89	0.62	-------	-------	-------
Smoothed Contour Smooth Line	0.47	0.75	0.77	0.34	0.48	-------	-------
Manual	0.52	0.79	0.77	0.52	0.53	0.34	-------

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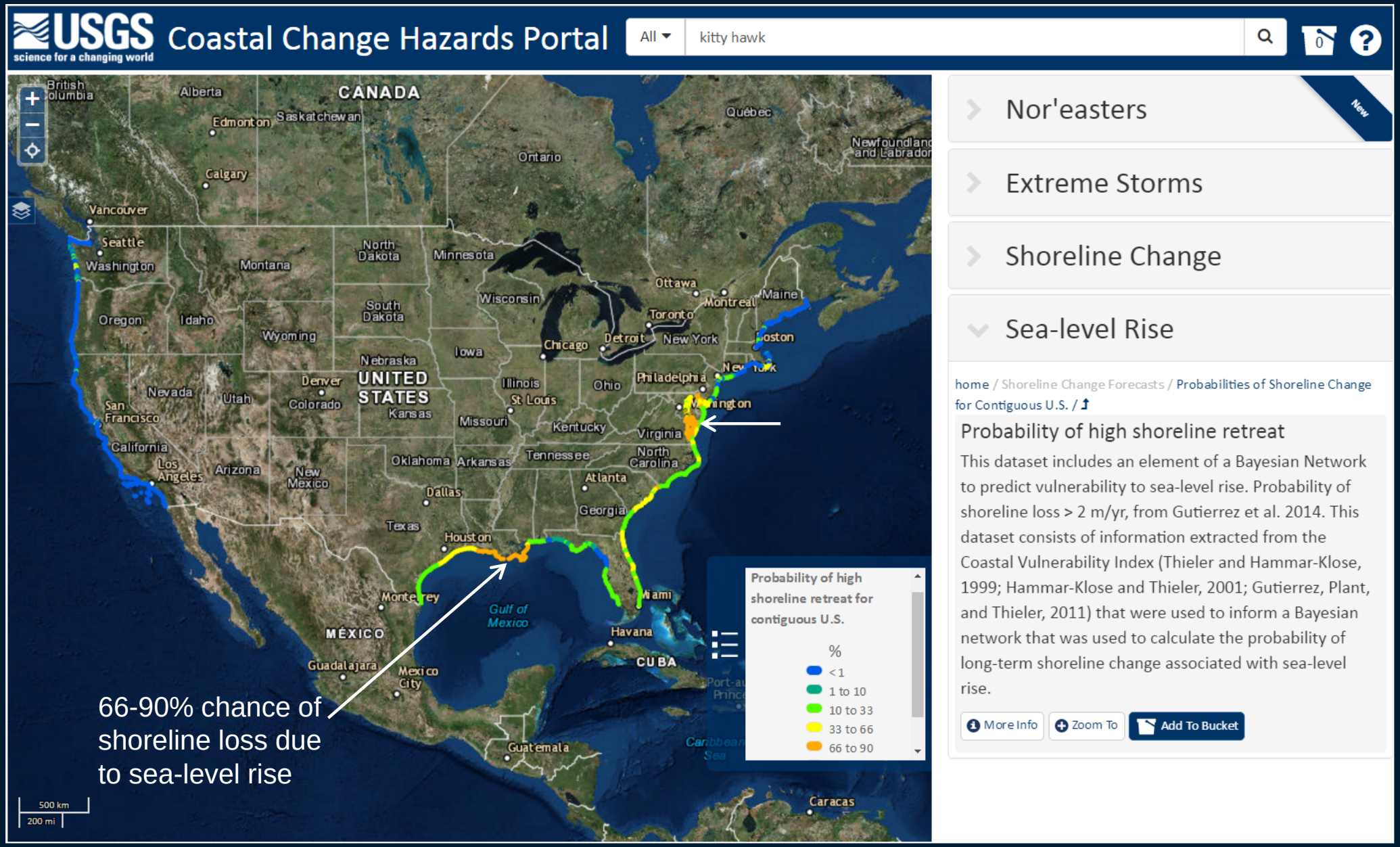
Erosion due to Sea-Level Rise

Probability of more than 2 m/yr (6.5 ft/yr) of shoreline retreat



66-90% chance of shoreline loss due to sea-level rise

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Future Work

- Collaboration between agencies/contractors to extract morphologic features
- Publishing backlog of EAARL data for MS and AL
- West coast scenario-based coastal change forecasts
- Extend coastal change forecasts to marsh and back barrier shorelines

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