Bay side flooding on a developed barrier island during a hurricane

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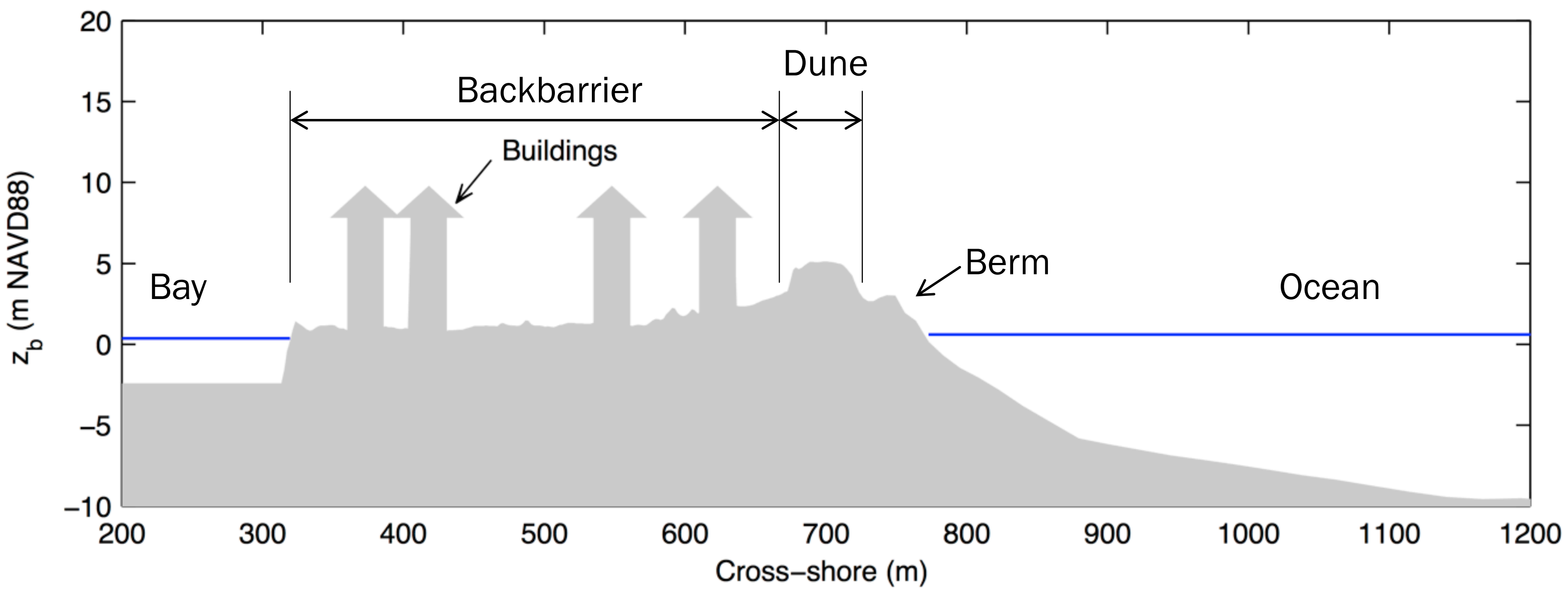
Overview

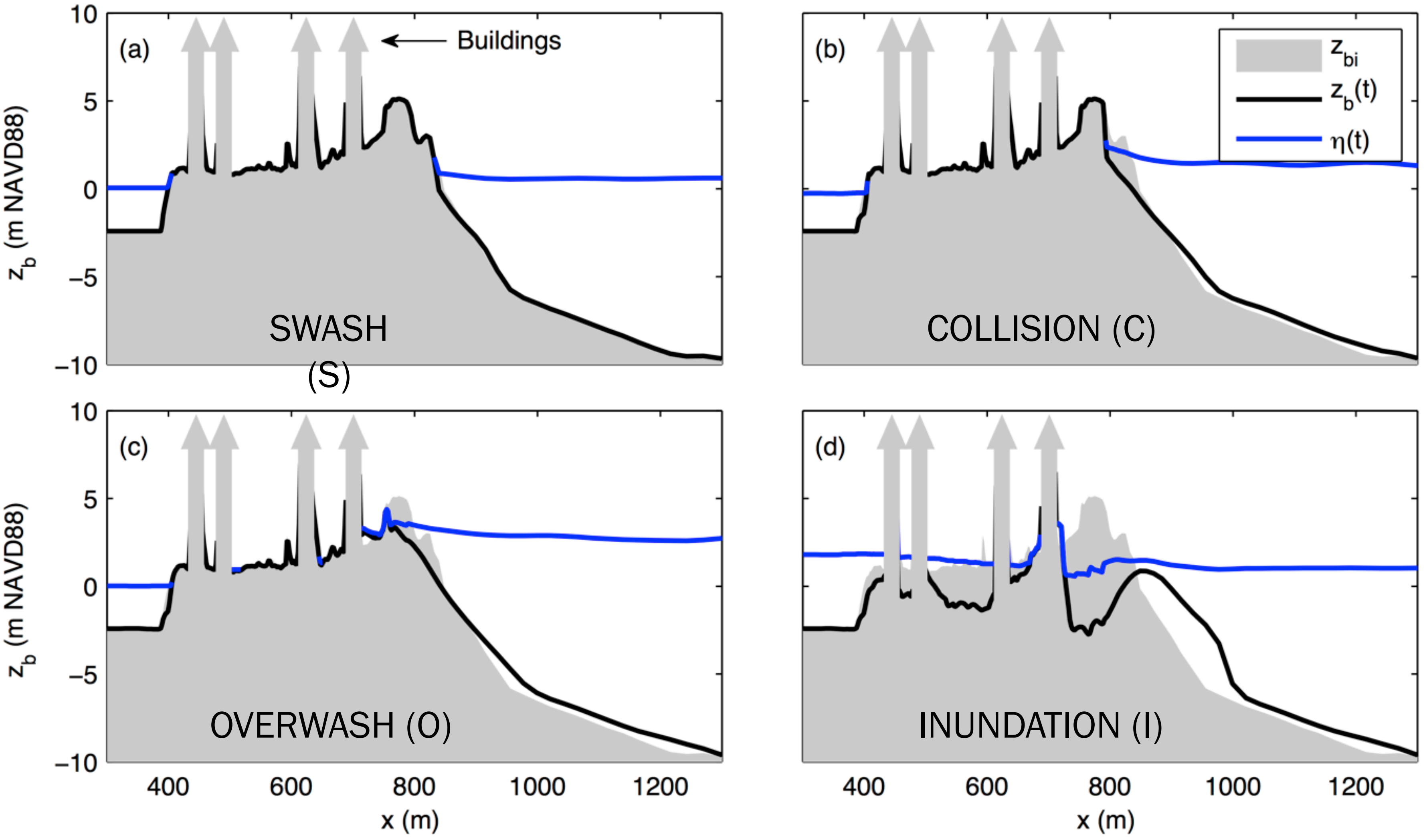
- Introduction
- Model setup and validation
- Morphological response to Hurricane Sandy
  - Bay surge inundation
- Conclusions

Introduction

- 6.5% of coastlines are barrier islands
- Protects mainland from storm impacts
- Vary by several island characteristics and regional hydrodynamics



Storm Impact Regimes



Sallenger (2000)

Protection Against Storm Impacts

Nature-based

(e.g. beach nourishment)

- reduces impacts of flooding and wave attack
- sediment easily mobilized
- requires renourishment

Hard structures

(e.g. seawall)

- protects against high wave energy
- increases erosion rates
- reduces beach access

Combinations of nature-based and hard structures

(e.g. armored dune)

- protects from wave attack
- beach is accessible

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No protection from bay side hydrodynamics

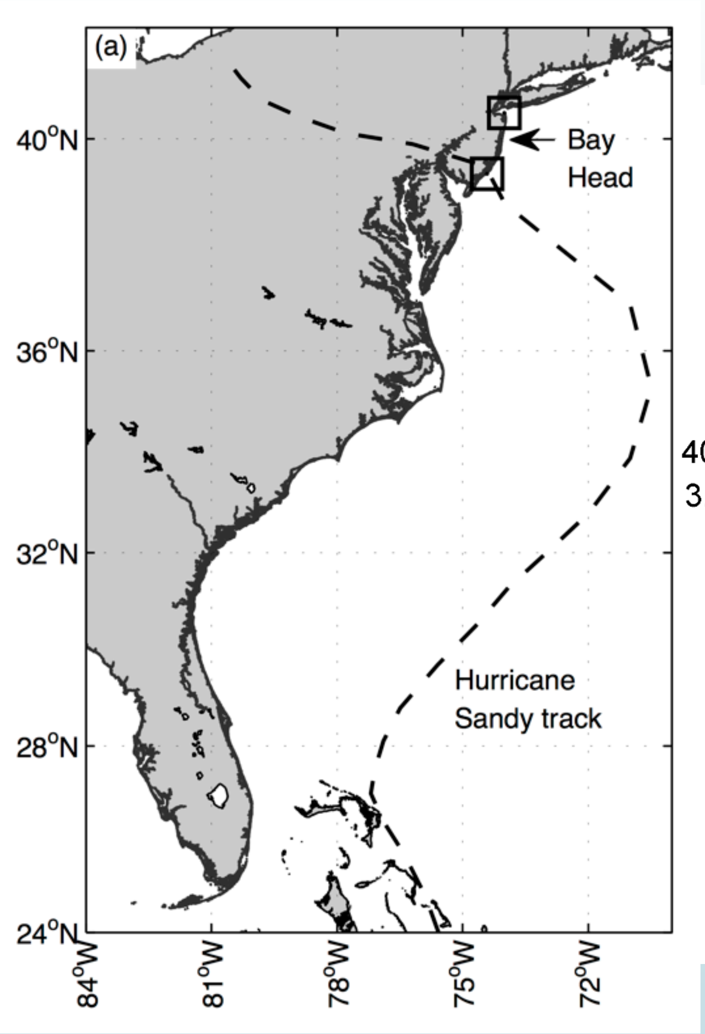
Hurricane Sandy

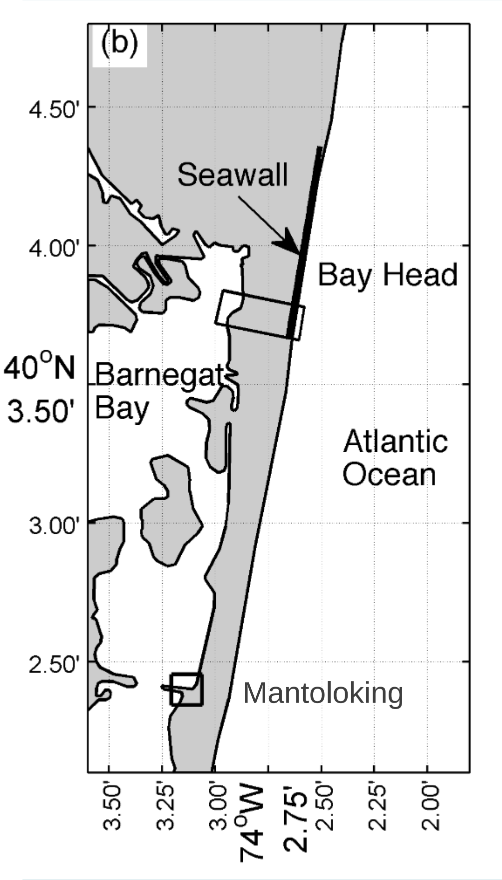
- Landfall: 29 October 2012 at 2330 GMT
- Hybrid hurricane + Nor’easter
- 280 km radius
- 130 km/h maximum sustained winds
- 945 mb minimum pressure
- 159 fatalities
- $67 billion in damages
- Impacted 24 states in U.S.

Gutro (2013)

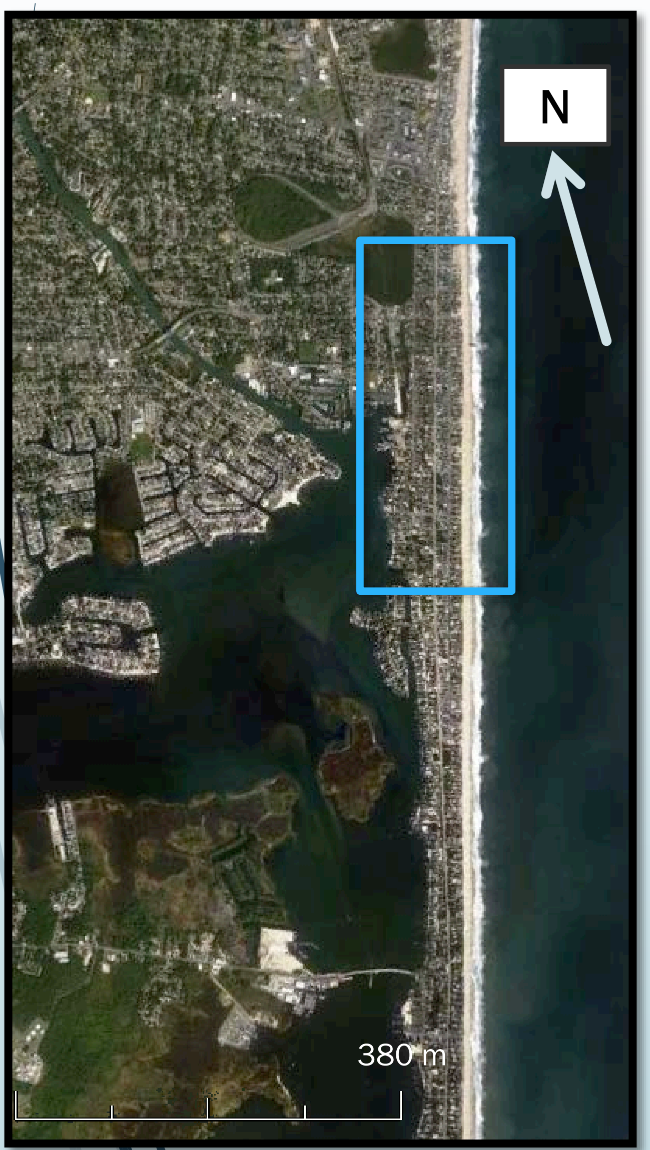
Study Area

- Bay Head, NJ
- 1260 m rock seawall buried beneath dunes
- Seawall often exposed during storms
- Model domain length = 190 m



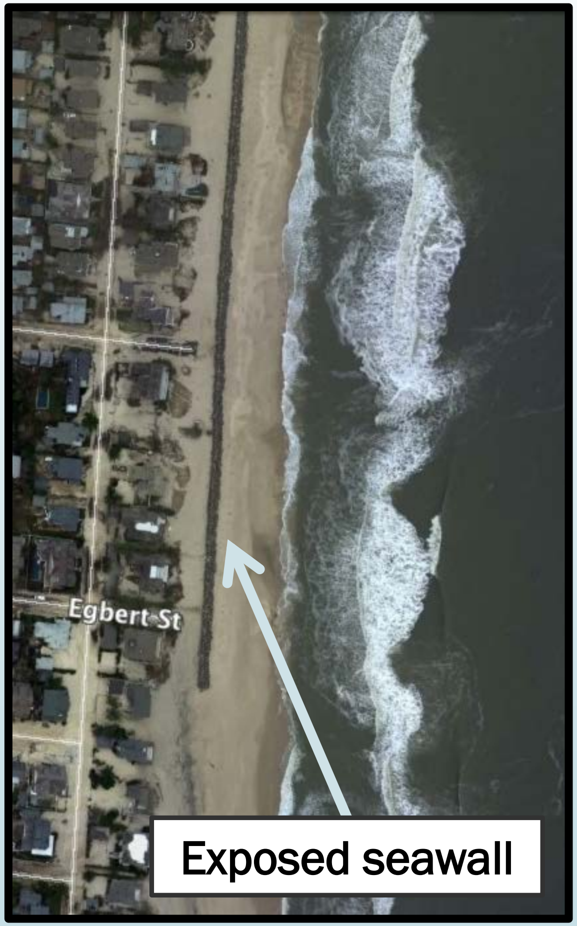


Bay Head, NJ



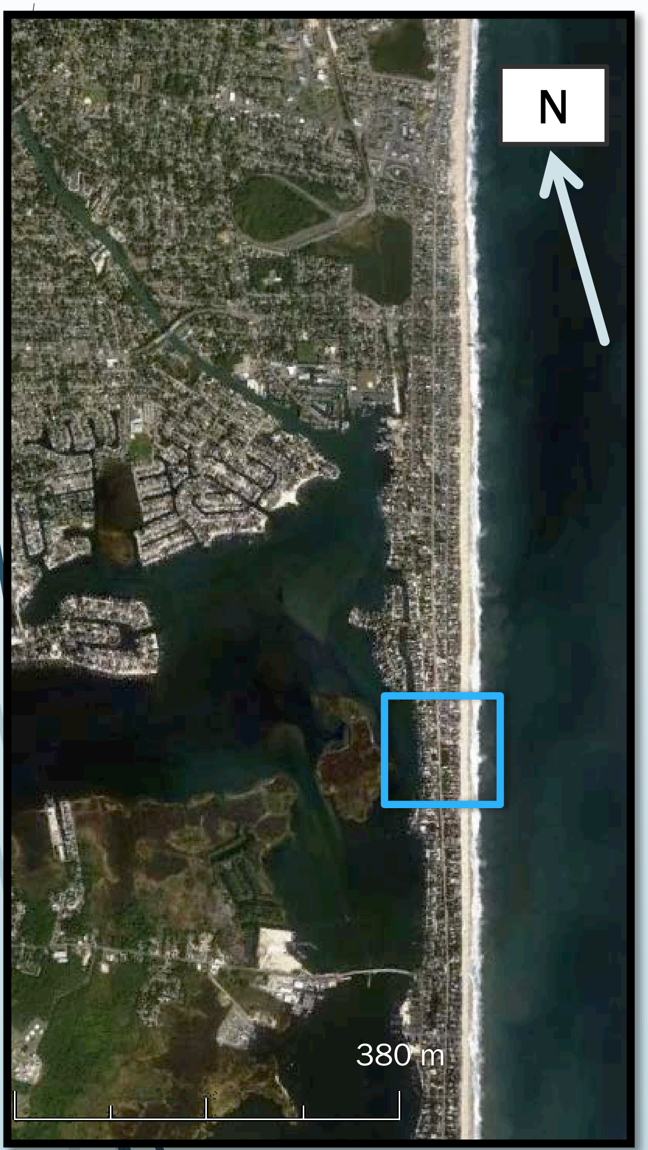
Pre-Hurricane Sandy

Post-Hurricane Sandy



Images from Google Earth (2016)

Mantoloking, NJ



Images from Google Earth (2016)

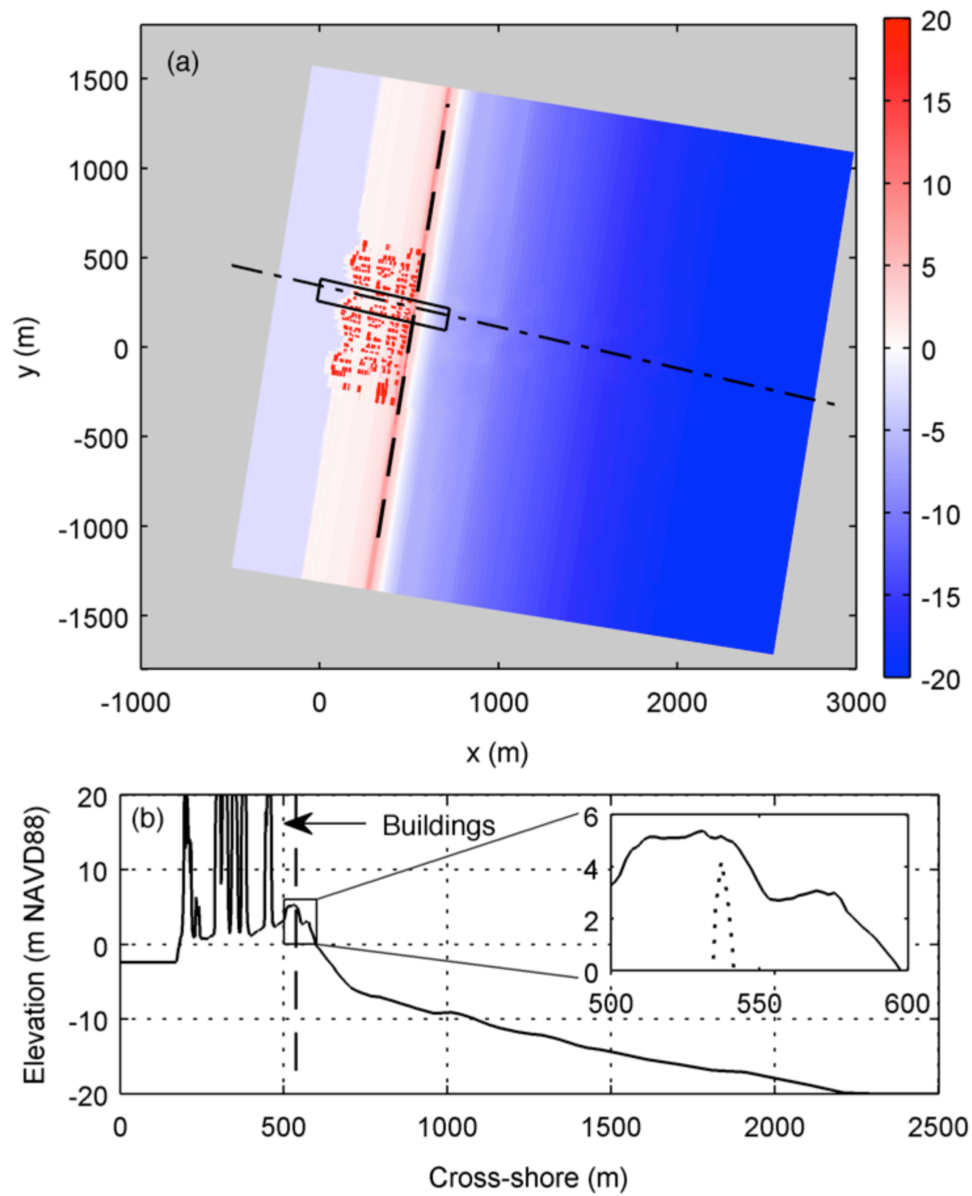
Numerical Model XBeach (Roelvink et al., 2009)

XBeach used to simulate hydrodynamics and morphology 2DH (depth-averaged) model solves

- Coupled short wave energy
- Sediment transport
- Bed level change
- Flow
- Infragravity wave propagation

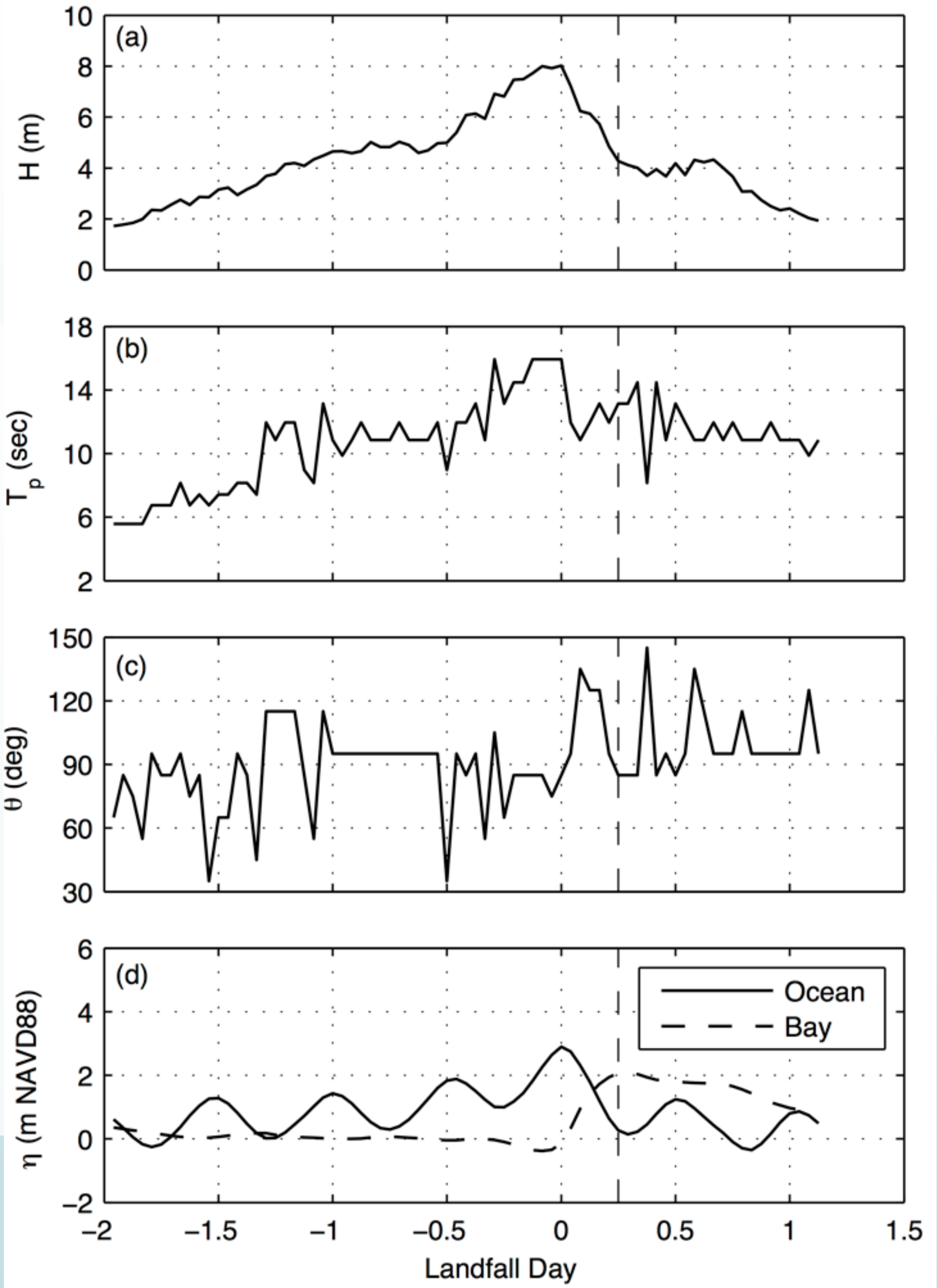
Model Setup

- 2012 "non-bare earth" lidar for dunes and beach
- 2010 "bare earth" lidar for backbarrier
- 2012 bay bathymetry
- 2012 survey of nearshore region
- Coastal Relief Model for offshore bathymetry
- Hard structures are indestructible



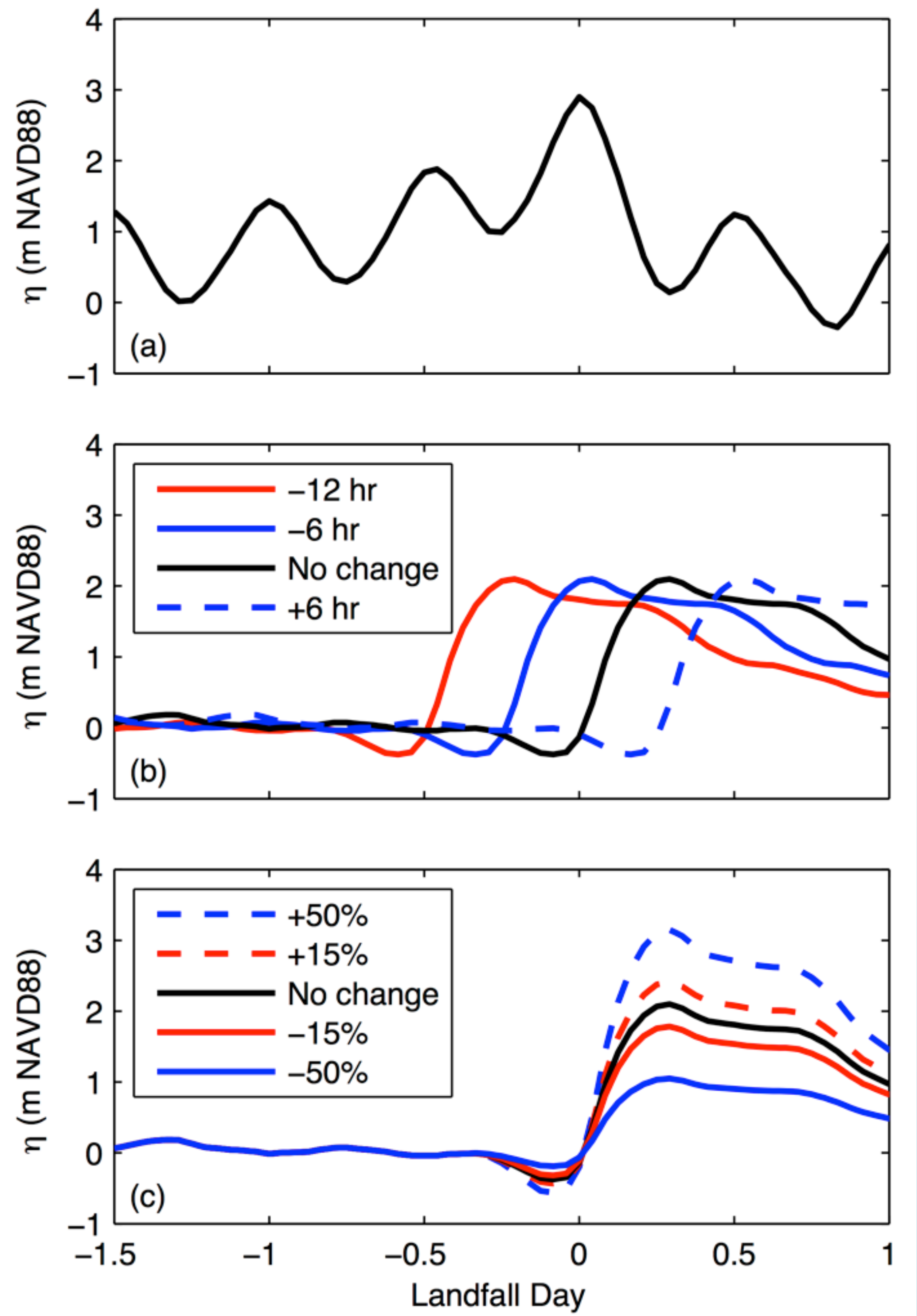
Model Setup

- 74-hour storm
- Spectral waves
  - NDBC buoy 44025
  - Transformed from 40 m depth to 20 m depth with SWAN
- Ocean surge from sECOM model
- Bay surge from USGS tide gauge



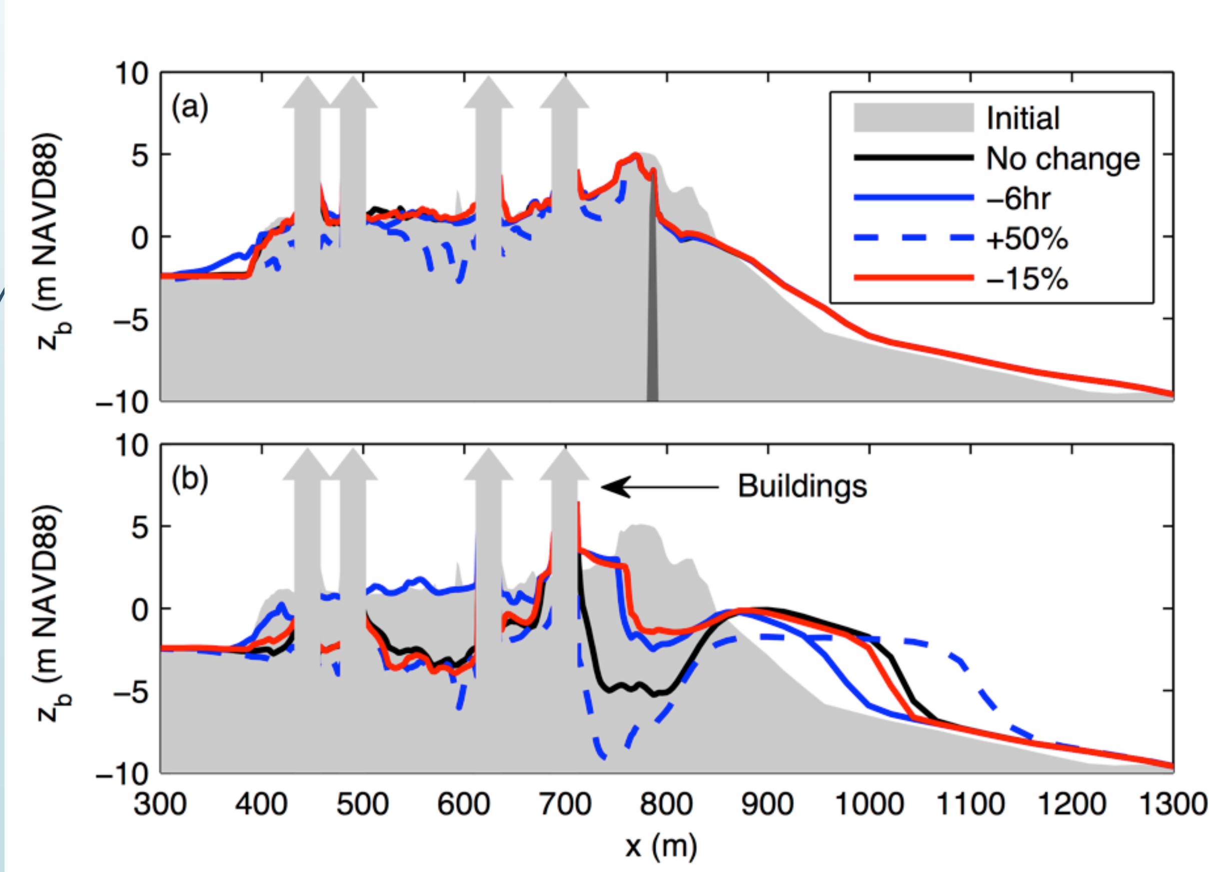
Bay surge inundation

- Ocean forcing remains the same
- Timing of peak bay surge shifted -12 hr, -6 hr, and +6 hr
- Bay surge magnitude increased 15% and 50% and decreased 15% and 50%



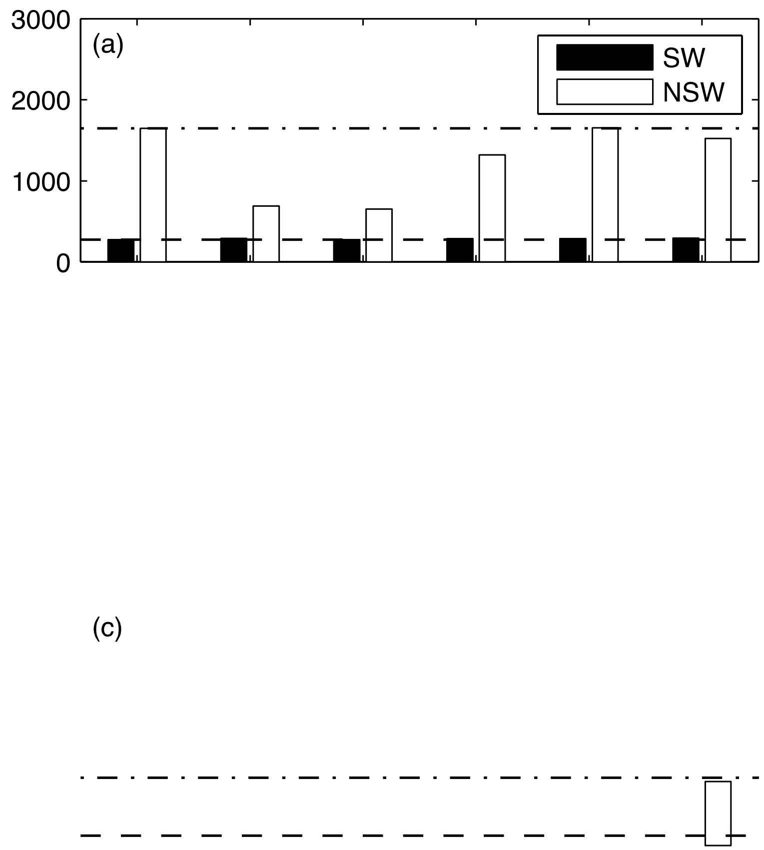
Bay surge inundation

- Seawall preserves dune system and prevents backbarrier erosion
- Erosion on dune and backbarrier greatly reduced when peak surge coincides with peak ocean surge



Bay surge inundation

- Volumetric bed level change, *V*, a proxy for damage: $V(t) = \int_{y_1}^{y_2} \int_{x_1}^{x_2} |z_b(t) - z_{bi}| \, dx \, dy$



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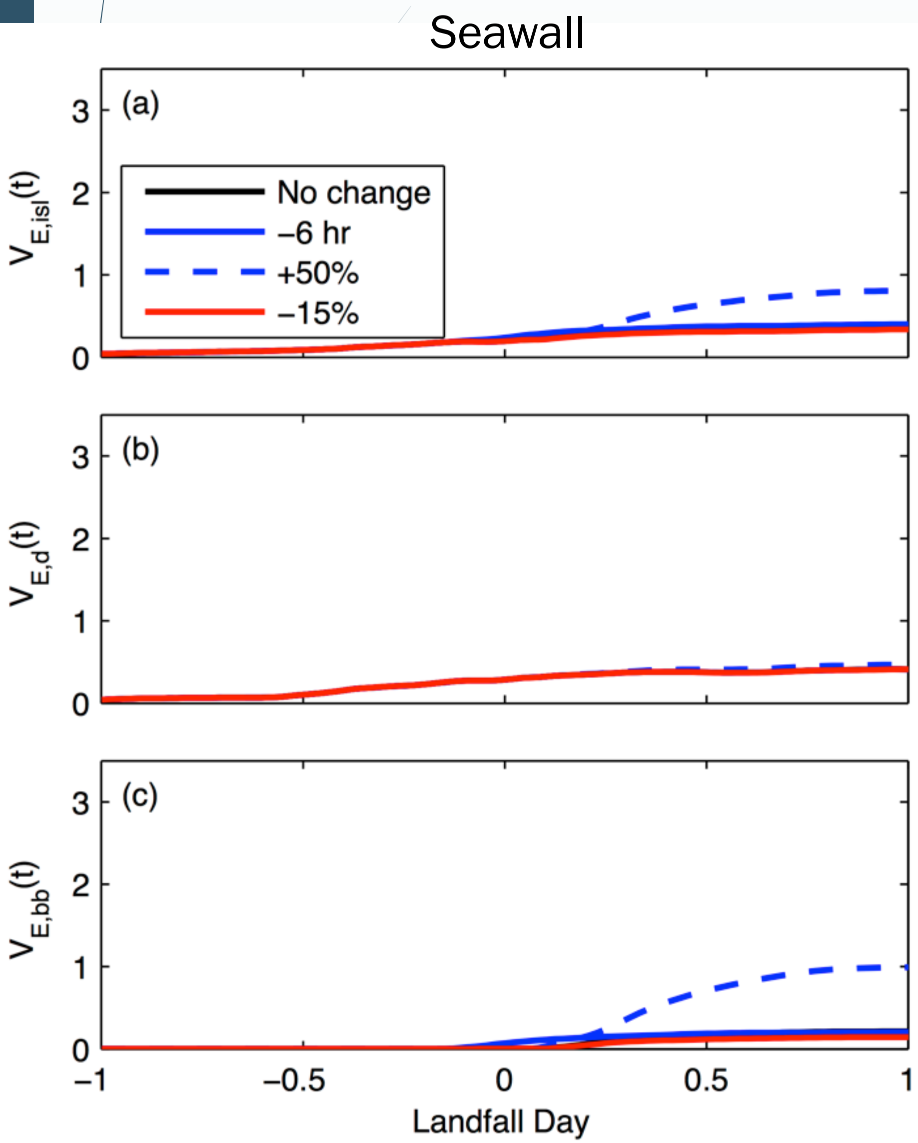

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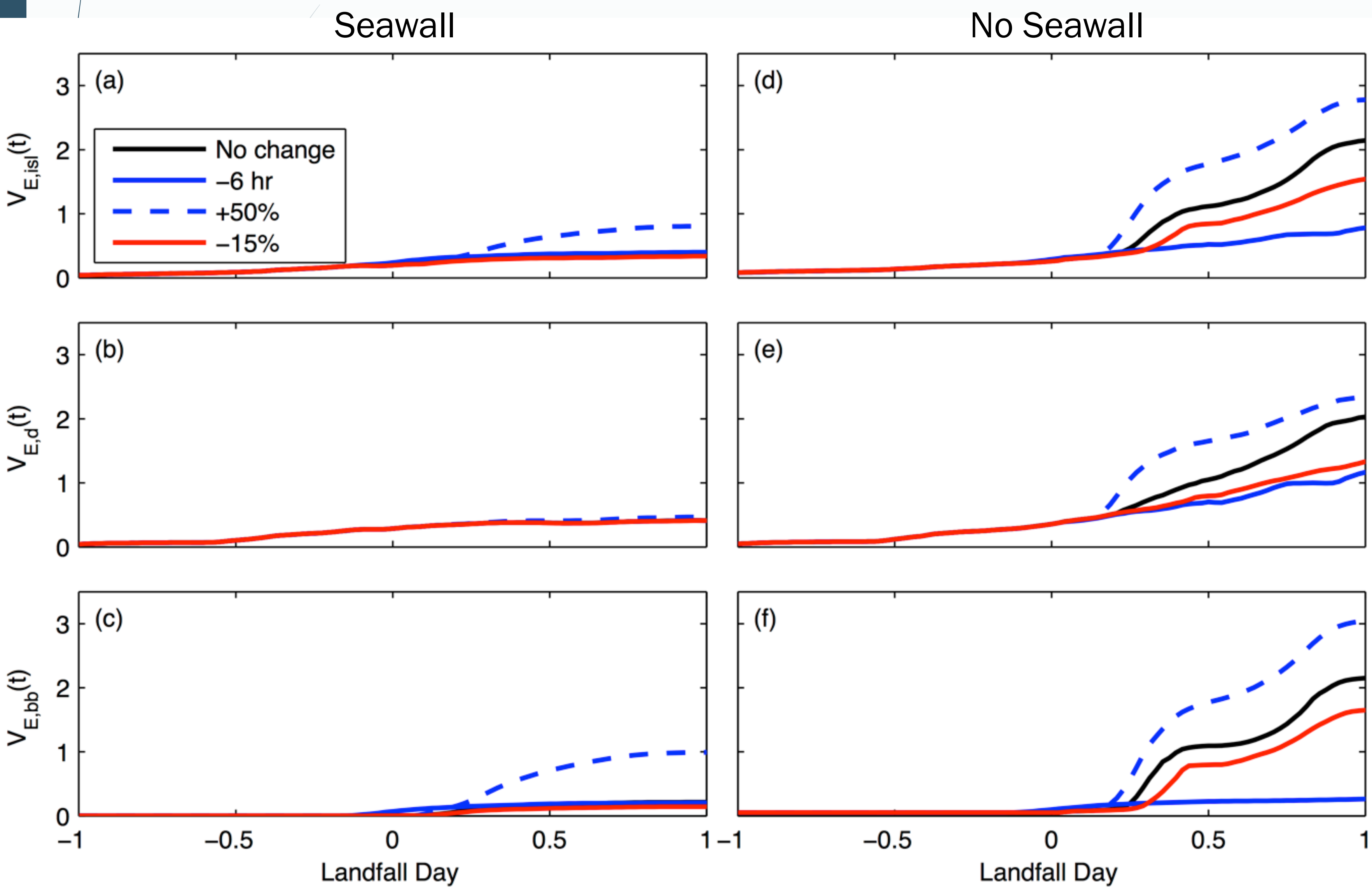

Conclusions

- Seawall reduces damage due to ocean storm surge and waves while also minimizing impacts of bay side flooding
- Timing and magnitude of bay surge relative to ocean surge is critically important for damage on barrier islands

Future Work

- Effect of buildings and vegetation cover on morphological response to storm forcing
- Flow channelization in bay and its effect on barrier island breaching

Questions

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References

den Bieman, J., et al. (2013). "Delft Software Days 2013: XBeach Advanced Course", Deltares, Delft Software Days 2013, Delft, Netherlands.

Gutro, R. (2013). Hurricane Sandy (Atlantic Ocean). *NASA's Goddard Space Flight Center,* http://www.nasa.gov/mission_pages/hurricanes.

Spoto, M. (2014). Construction starts on steel wall for Mantoloking-Brick oceanfront. http://www.nj.com/ocean/index.ssf/2014/07/construction_starts_on_steel_wall_for_mantoloking-brick_oceanfront.html