Coastal Hazard Mitigation: Factors Influencing the Effectiveness of Surge Barriers in Reducing Back Bay Flooding

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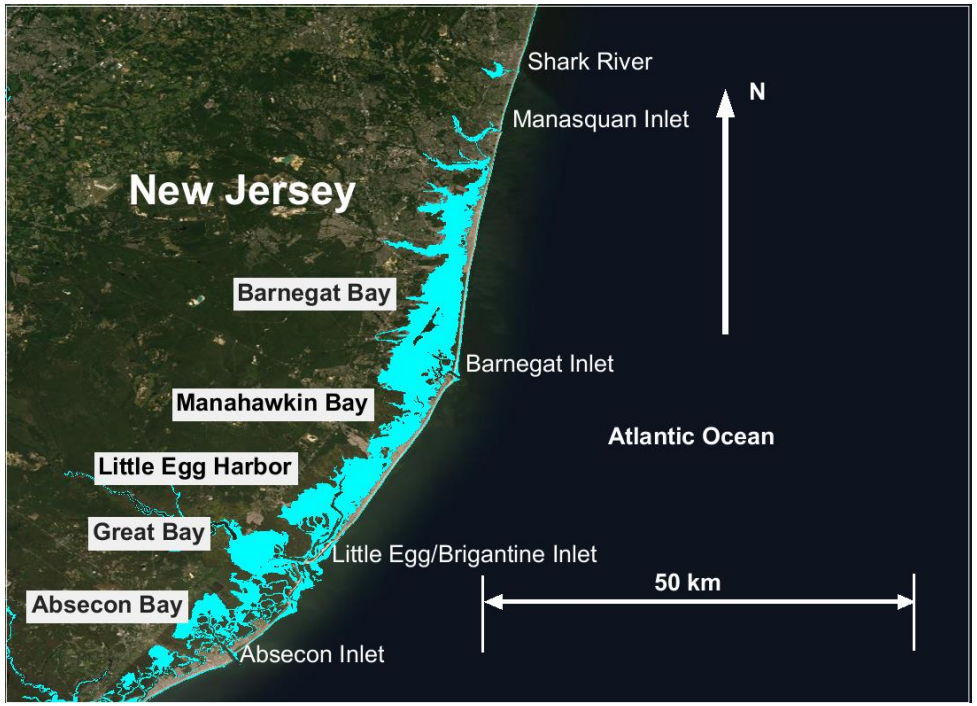

US Army Corps of Engineers®

Waves and Coastal Hazards Conference • Melbourne, Australia • 11-15 November 2019

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Presentation Topics

Why
- Research Background/Basis

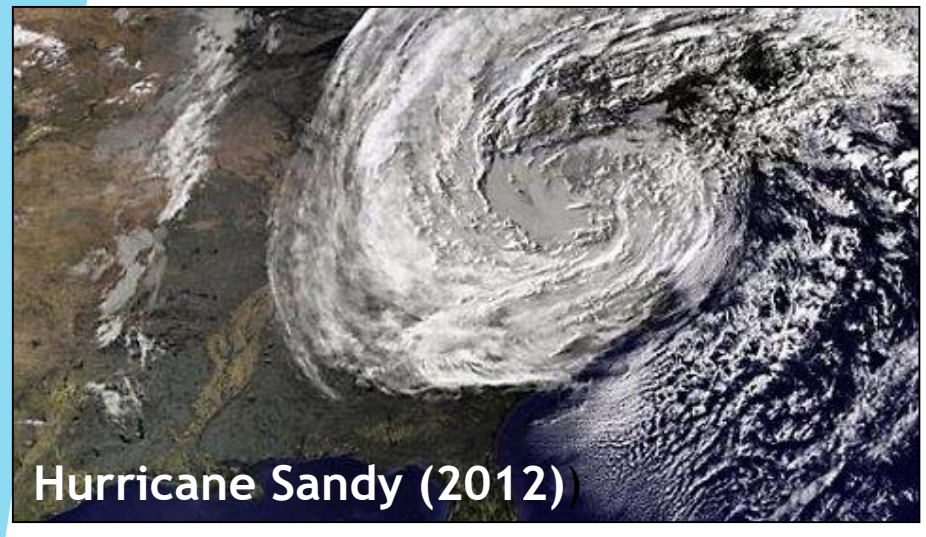
Where
- The Setting

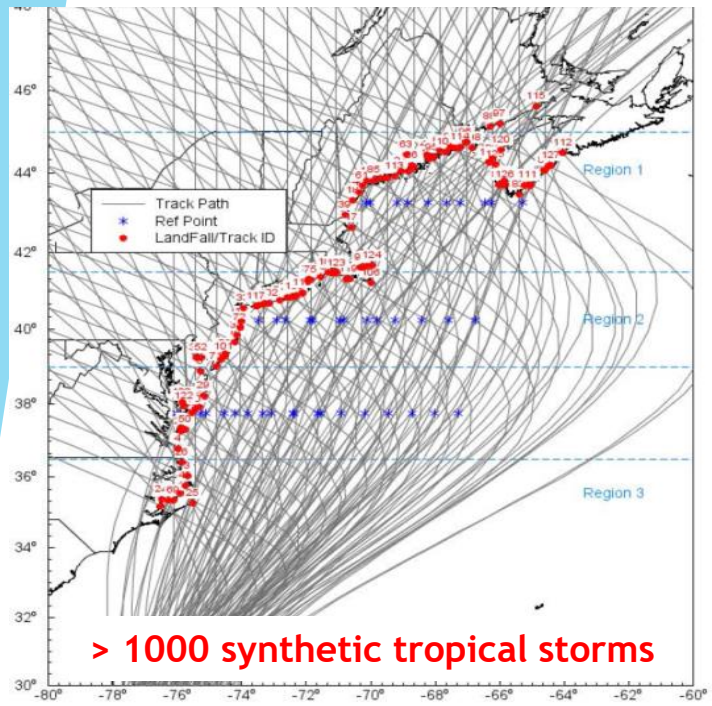
How
- Surge Barrier Study Plan
  - The Selected Storms
  - Numerical Mesh and Surge Barriers

What
- Results
  - Analysis of Maximum Surge Envelopes (visual and quantitative)
  - Analysis Locations/Percent change
  - Time Series

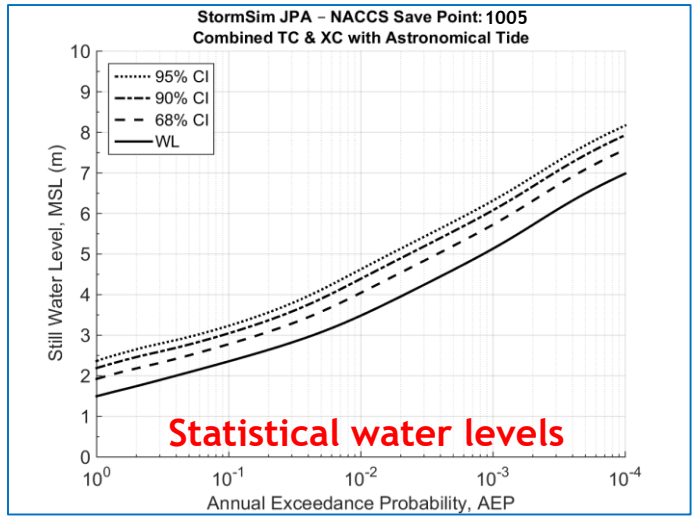
So What
- Summary

Research Background/Basis

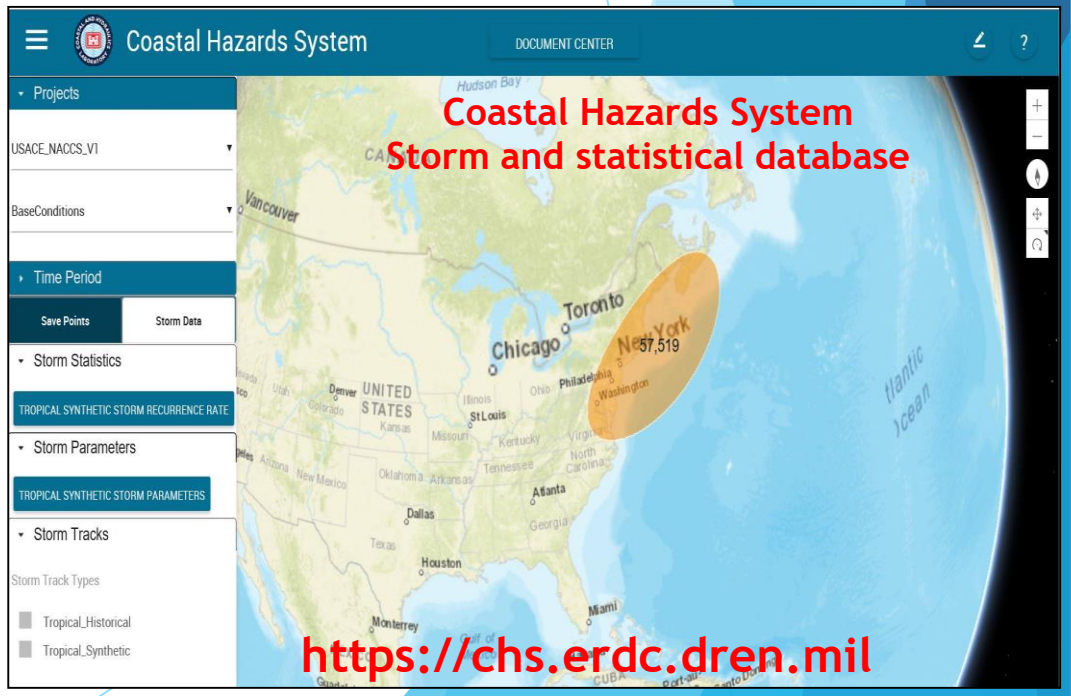




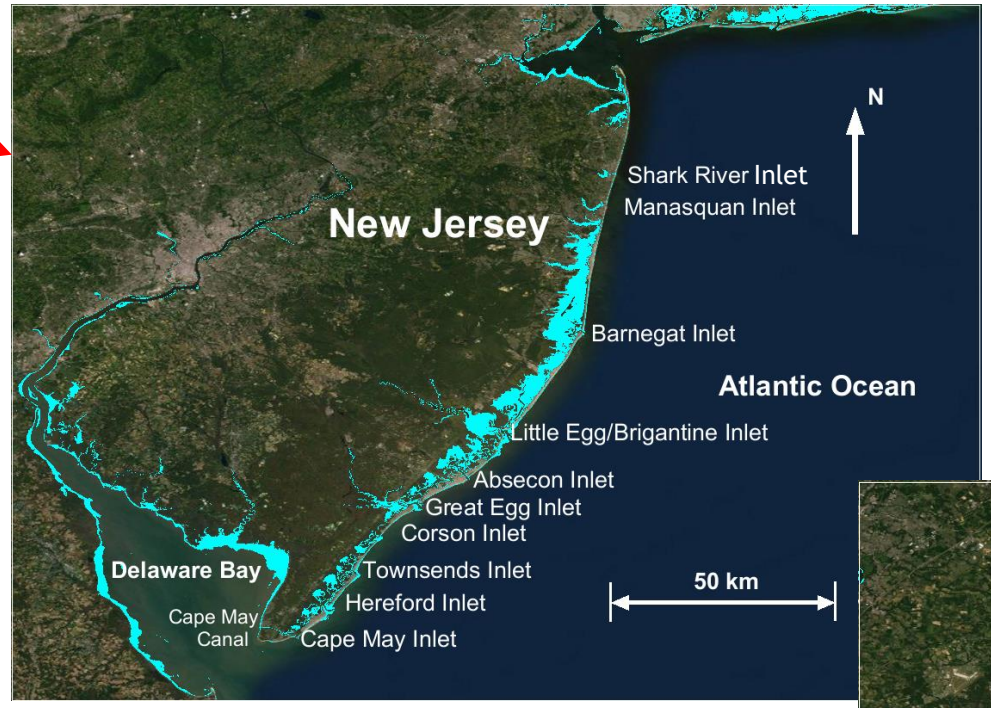
North Atlantic Coast Comprehensive Study (NACCS)

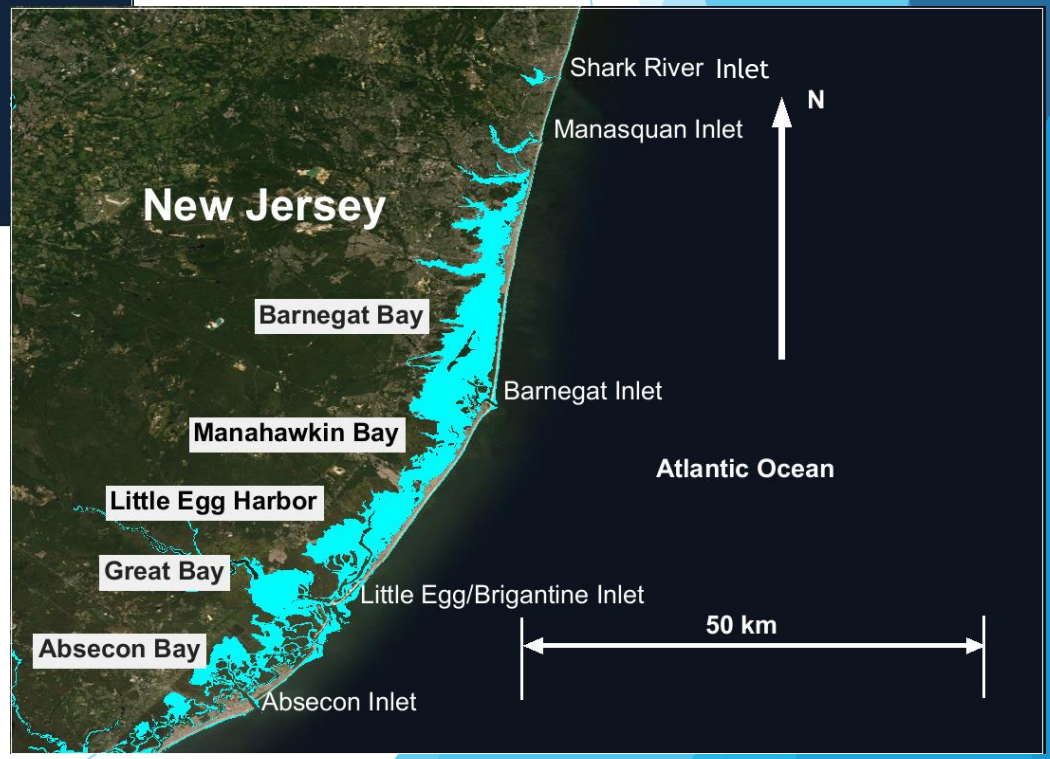


NACCS: coastal flooding
NJBB: high risk/back bay flooding
CSRM: surge barriers



The Setting: New Jersey Back Bays, U.S.A.





- Two rivers: Shark and Manasquan
- Barnegat Bay: largest 59 sq mi
- 3-Bays: 126 sq mi; 68%
- Southern: closely spaced; connected; 1/3 of total bay area
- Little Egg/Brigantine – widest opening

Surge Barrier Research Plan (1 of 2)

Numerical Evaluation of 11 storm **surge barriers** at 11 NJ inlets

- Individual
- Combinations

Purpose: potential **flood risk reduction** to:

- Coastal population
- Property
- Infrastructure
- Ecosystems

Two-dimensional, depth averaged **ADCIRC** hydrodynamic model to simulate surge propagation in response to forcing from synthetic tropical cyclone events

Synthetic tropical storms generated jointly by OceanWeather Inc. (OWI)/ERDC as part of the NACCS

Surge Barrier Research Plan (2 of 2)

Ten synthetic tropical storms from NACCS selected to minimally cover the range of

- Storm size
- Direction
- Intensity

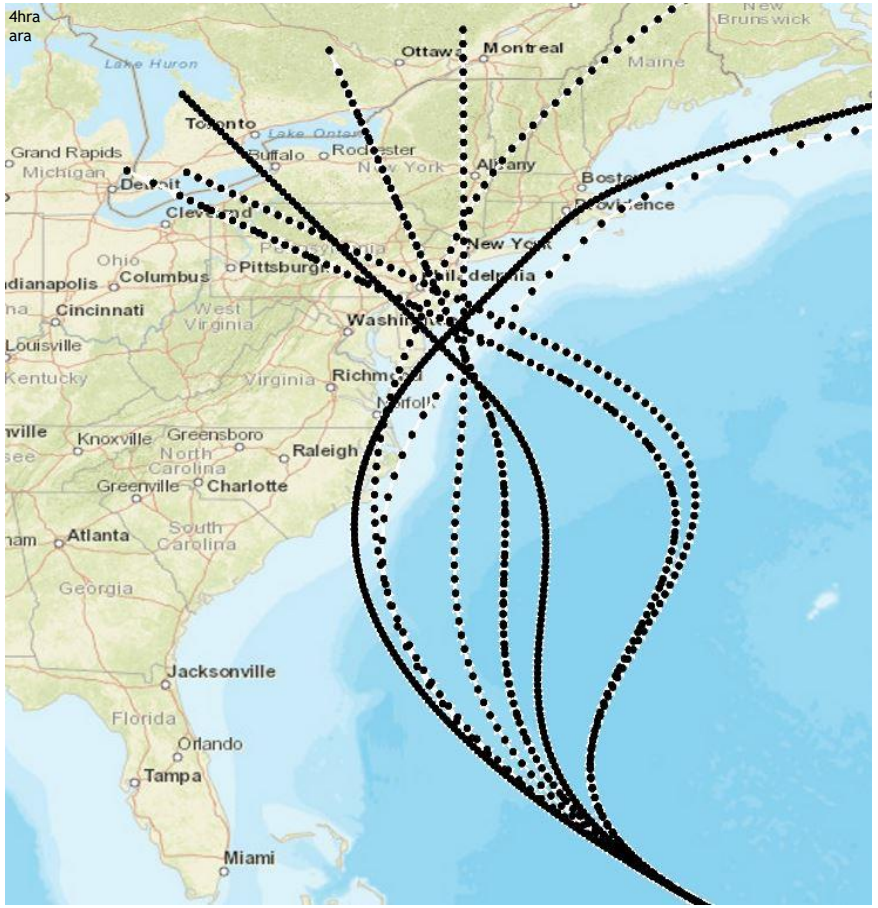
for the NJ coastal region and demonstrate the varying surge response in this region

Simulations did NOT include the effects of waves or tides

Assumed the effect of waves on water level in the bays would not change significantly with the closures in place

Tides could have appreciable contribution to water level in this region depending on the timing of the surge event and closure relative to maximum flood tide into the bays…could be considered in a follow-on study

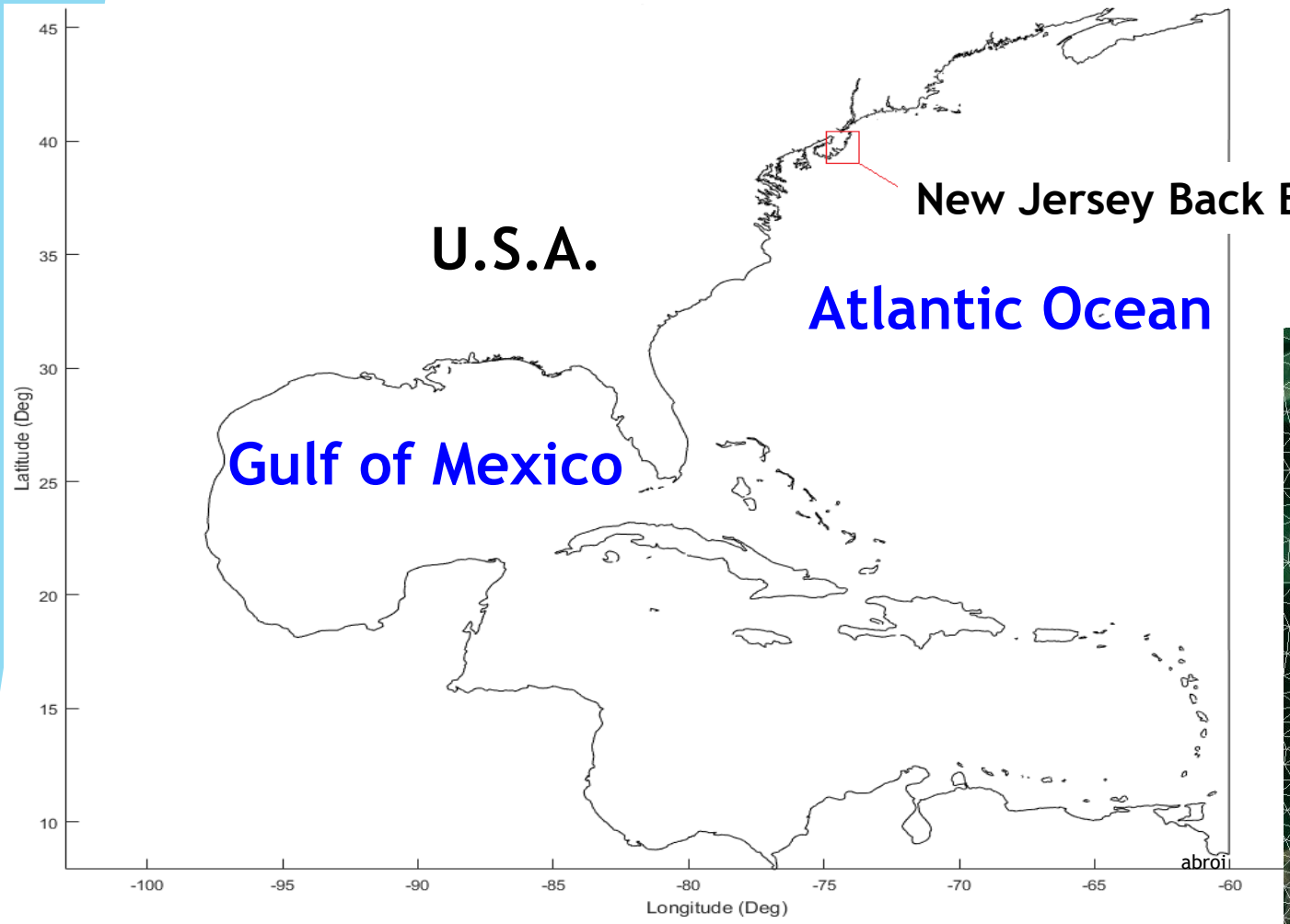
Selected Storms



NJBB Storms	Landfall Angle (deg N)	Central Pressure Deficit (hPa)	Rmax (km)	Forward Speed (km/hr)
1	-40	88	65	16
2	-60	78	125	65
3=350	-60	68	52	26
4	-60	58	88	28
5	-20	88	55	62
6	-20	78	82	27
7	0	78	74	38
8	20	78	73	38
9=636	40	78	47	14
10	40	83	67	59

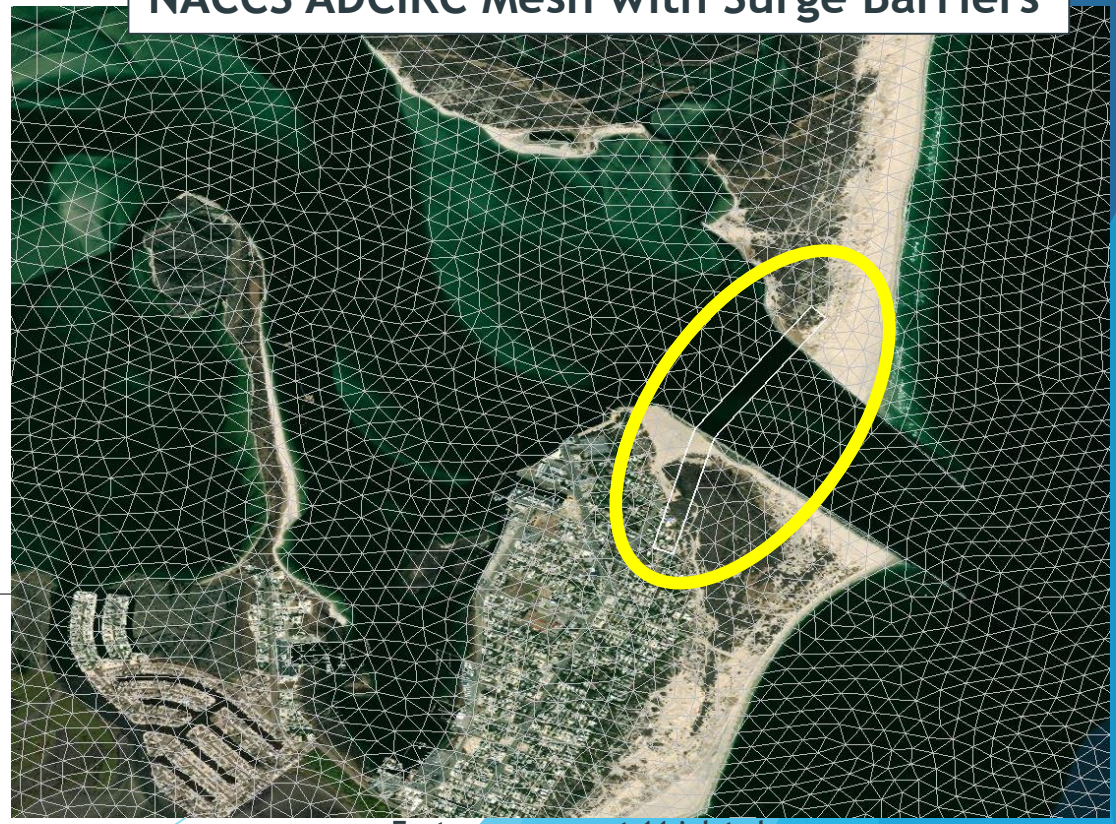
- JPM-OS: requires MANY storms to cover forcing probability space
- Design of Experiment (DoE): uses surrogate modeling and NACCS storm database
  - Optimized storm selection capability
  - Replicate full storm hazard curves

Numerical Mesh and Surge Barriers



- Include surge barriers (11)
- De-refine far field (reduce resolution)
  - Reduce simulation time
  - Maintain flow volume exchange
  - 24% reduction in number of nodes

NACCS ADCIRC Mesh with Surge Barriers

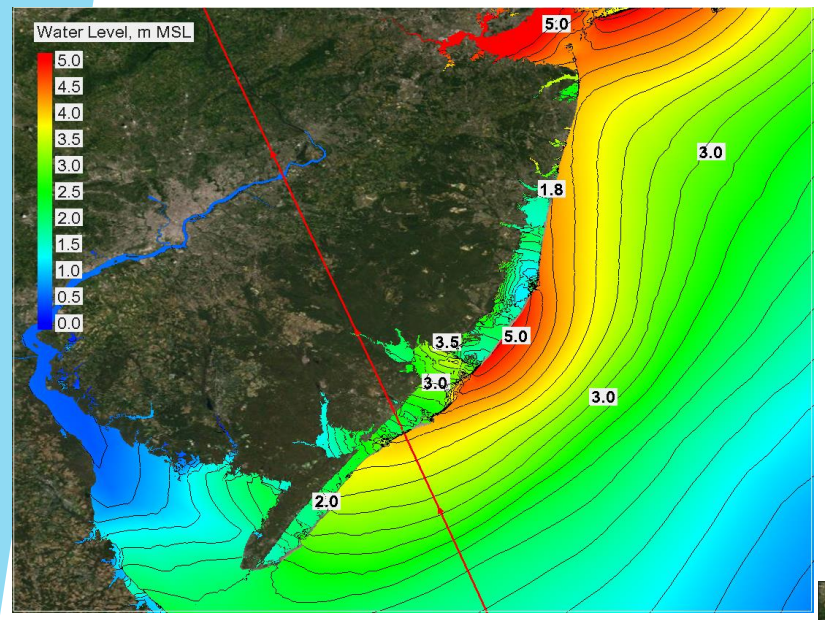


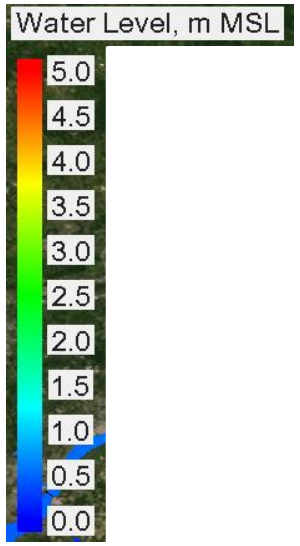
Features represent 11 inlet closures

Maximum Surge Envelopes

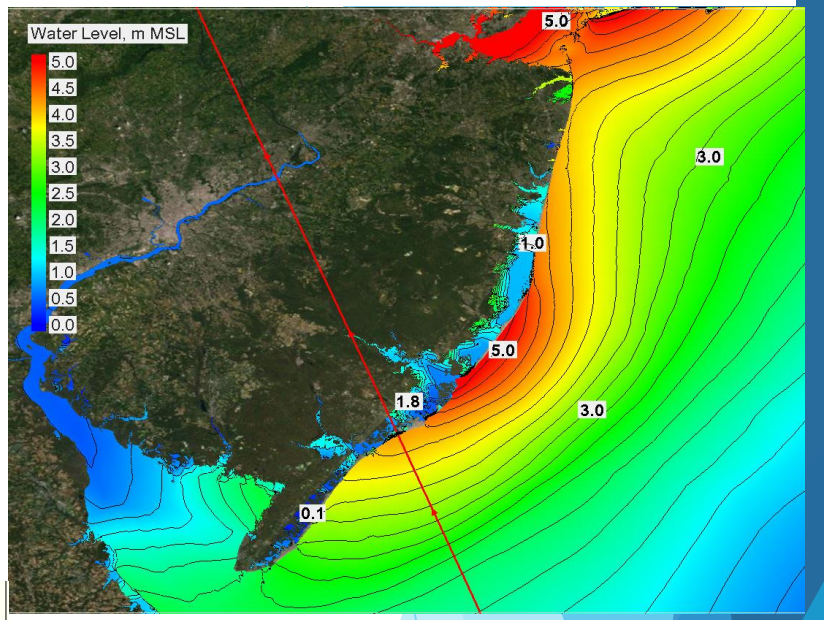
Storm 433

All Inlets Open

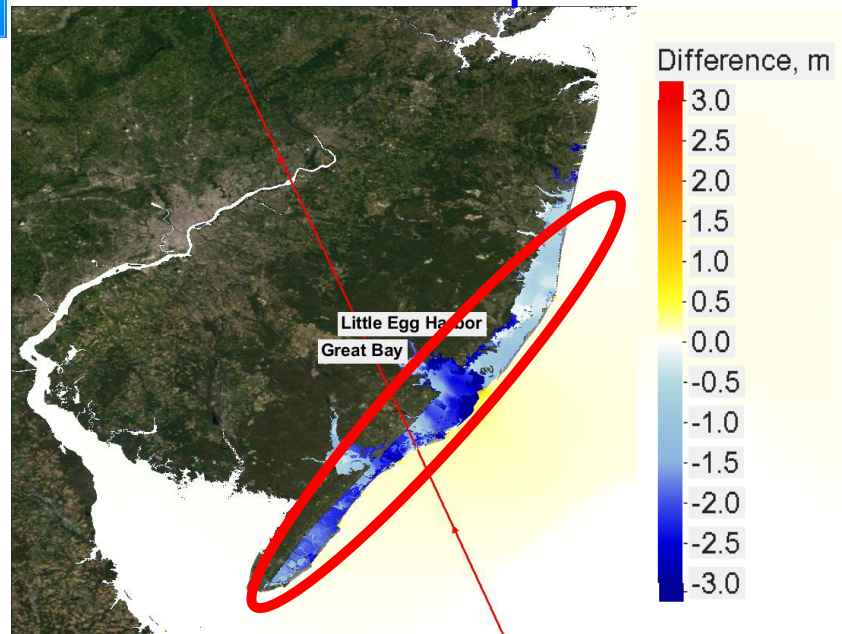




Surge Barriers (All Inlets Closed)



Closed minus Open



Storms (10) simulated using ADCIRC

Closure Configurations (14 meshes)

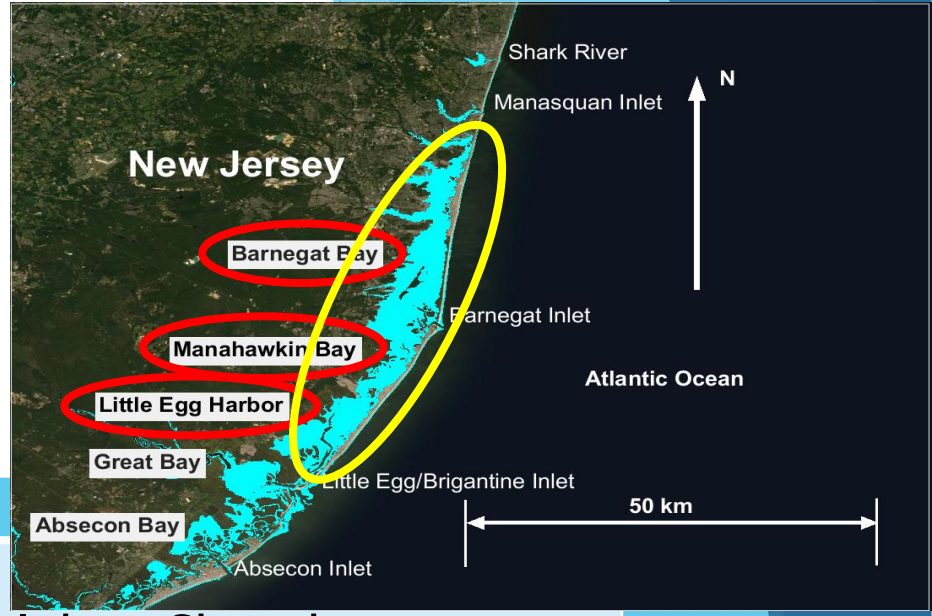
- Open
- Individual (11 closures)
- All Closed
- Combination (9 closed/2 open)

Influence of SB on surge propagation

Average Back Bay Reduction

Storm 433: 1.49 m
All Storms: 1.27 m

Average changes in maximum water level with closures relative to the base (meters)

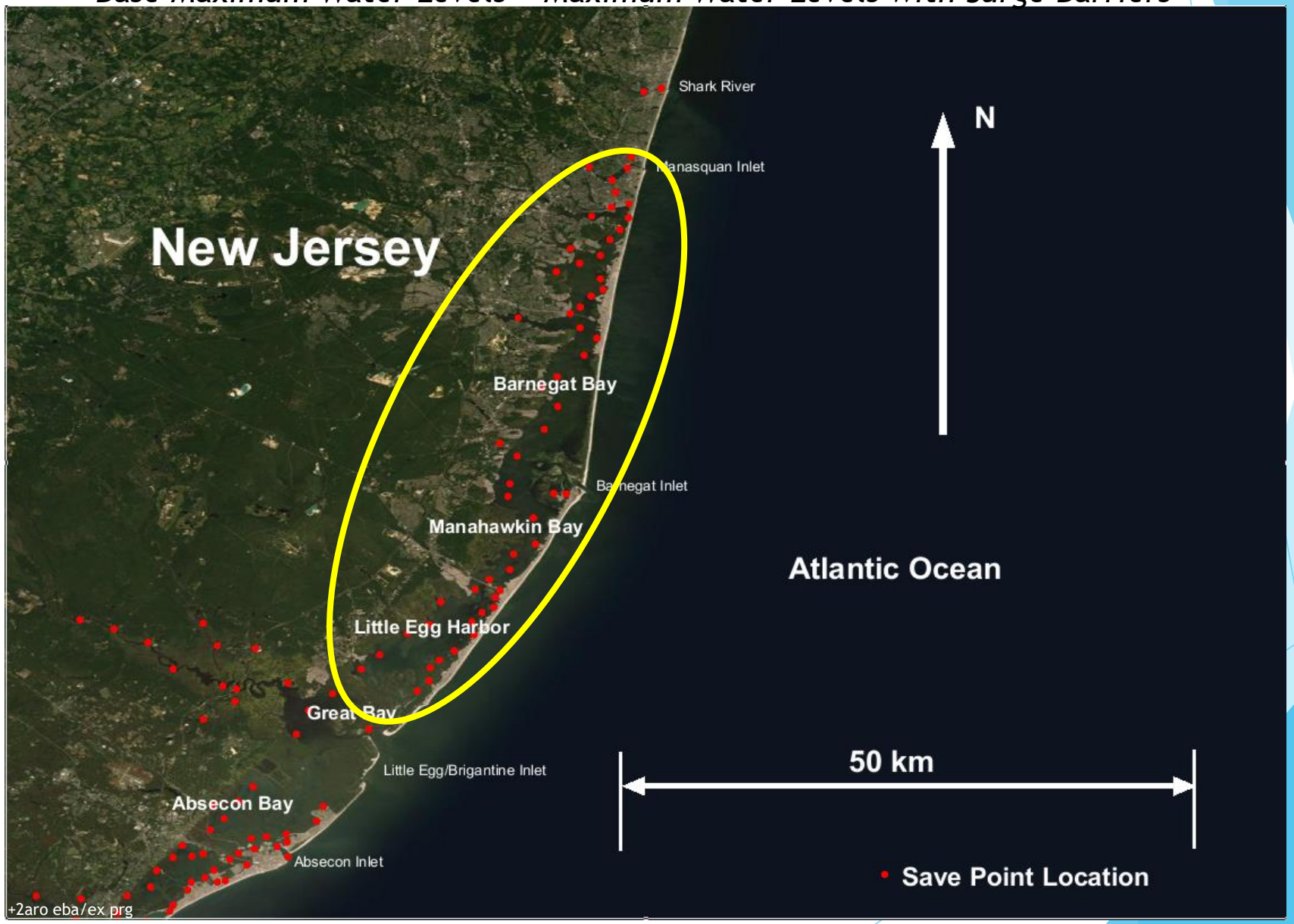


	Barnegat Inlet Closed				All Inlets Closed			
	LEH	Man	Barn	All3	LEH	Man	Barn	All3
433	-0.11	-0.23	-0.39	-0.29	-0.97	-0.62	-0.52	-0.67
Avg.	-0.15	-0.34	-0.46	-0.37	-0.73	-0.71	-0.68	-0.70

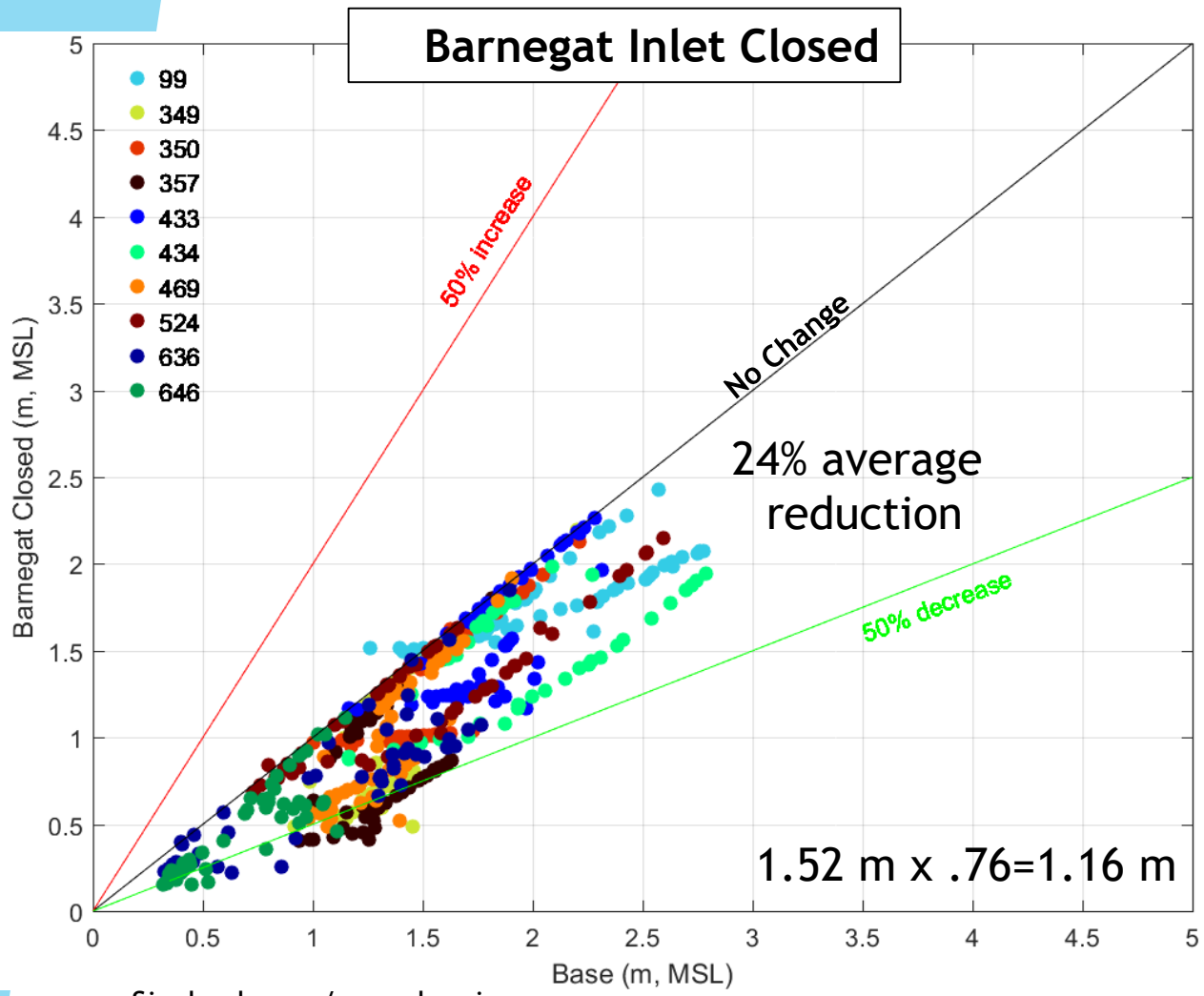
LEH: Little Egg Harbor
Man: Manahawkin Bay
Barn: Barnegat Bay

Representative Locations

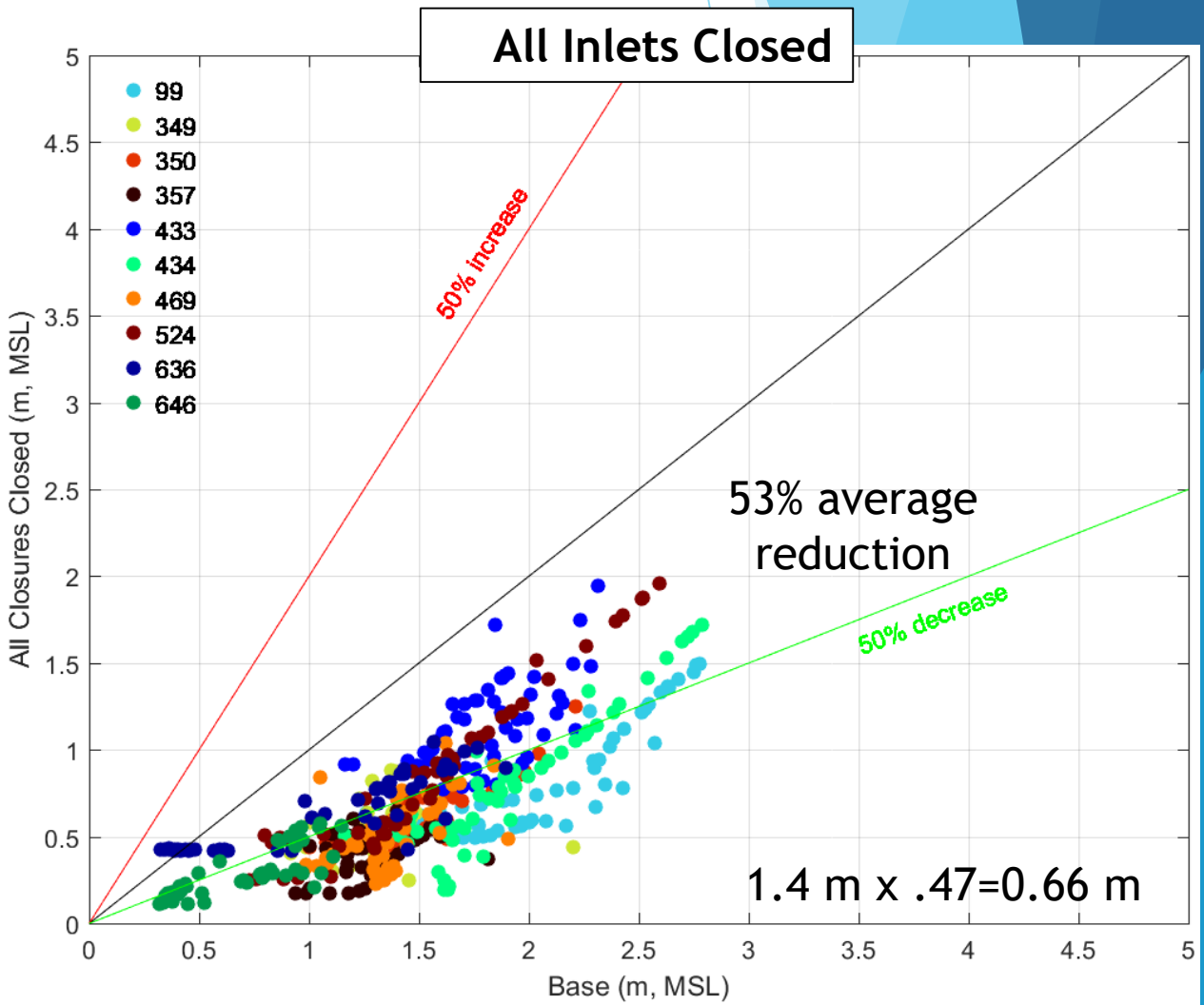
Base Maximum Water Levels ^ Maximum Water Levels with Surge Barriers



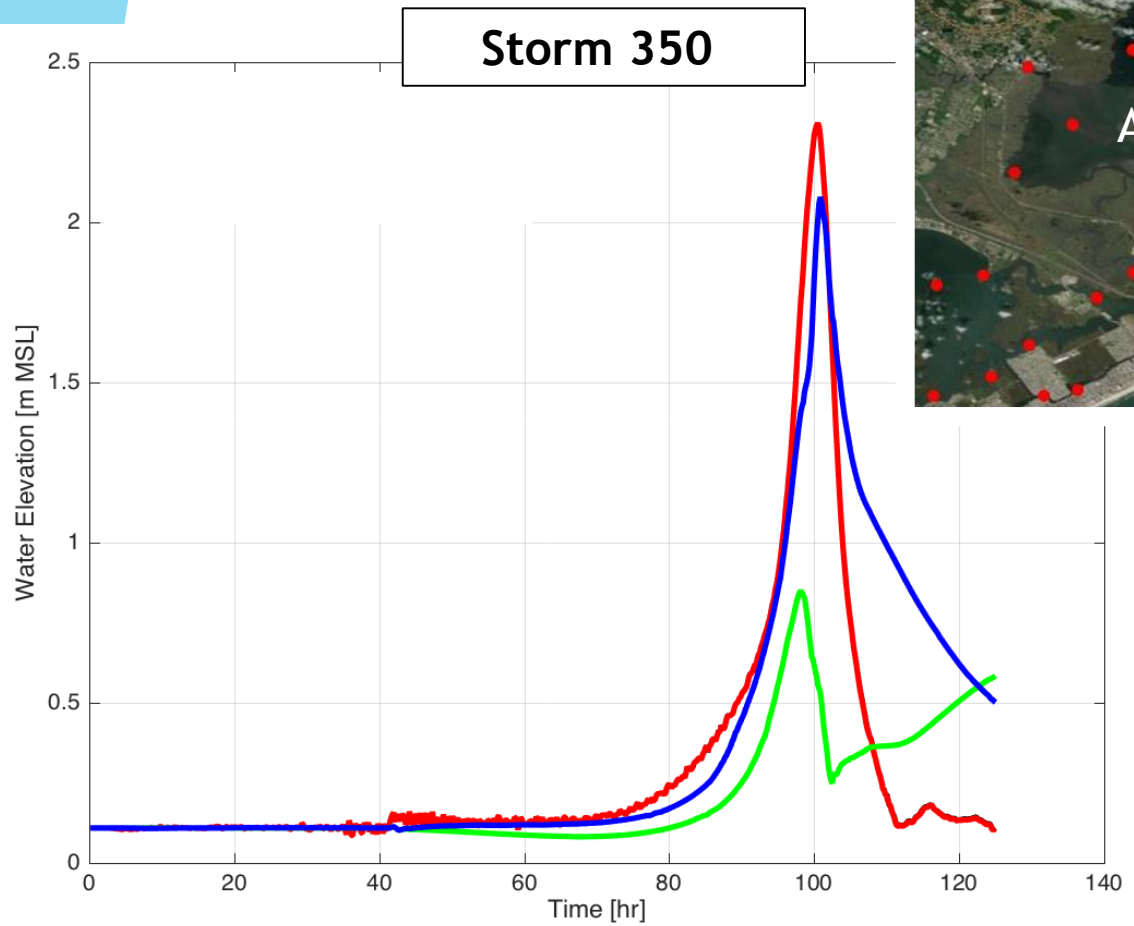
Save Point Comparisons

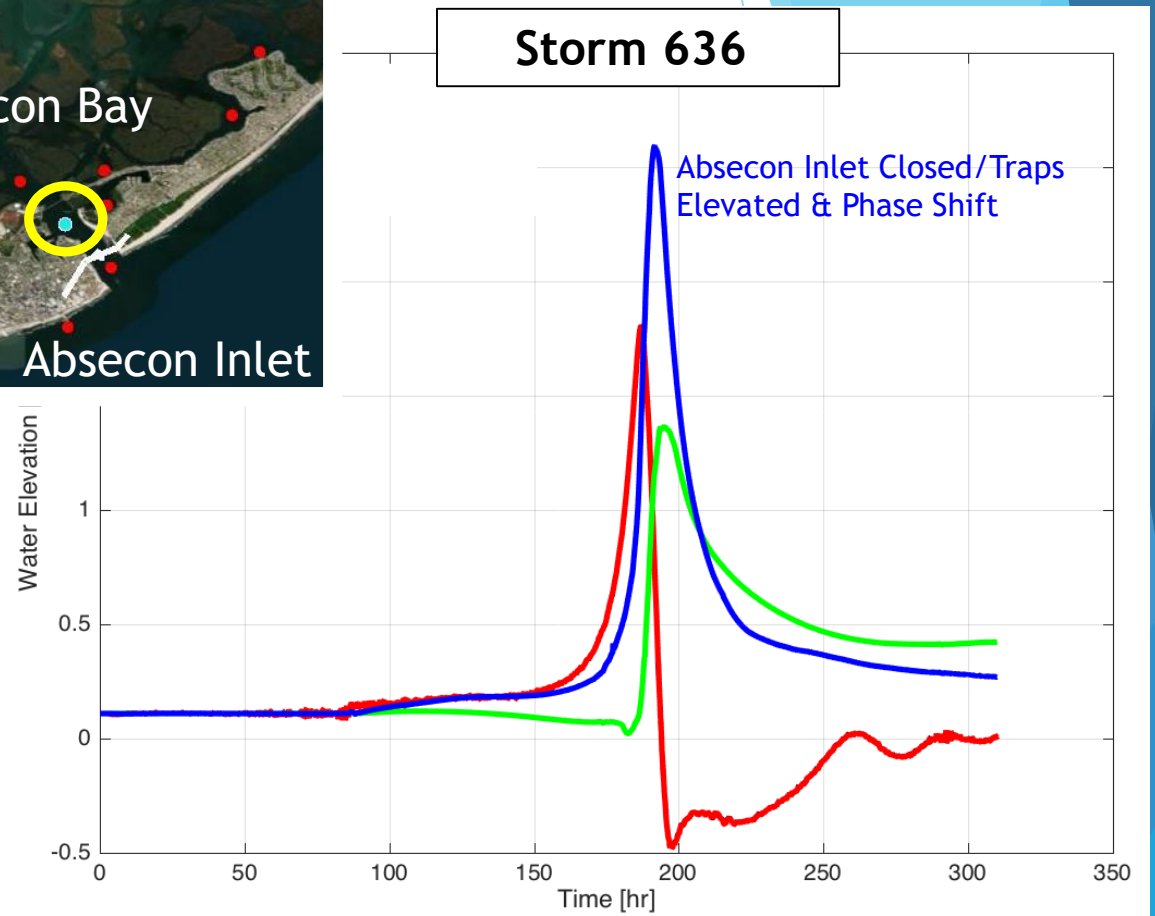


- Single closure/surge barrier
  - Reduce back bay flooding
  - Other inlet opening -> less significant reduction
  - Avg percent reduction 24%
  - Little Egg/Brigantine -> minimizes surge protection from BI
- Additional closures/all inlets closed with surge barriers
  - Avg percent reduction 53%



Water Level Time Series





Base: No Surge Barriers

Absecon Inlet Closed

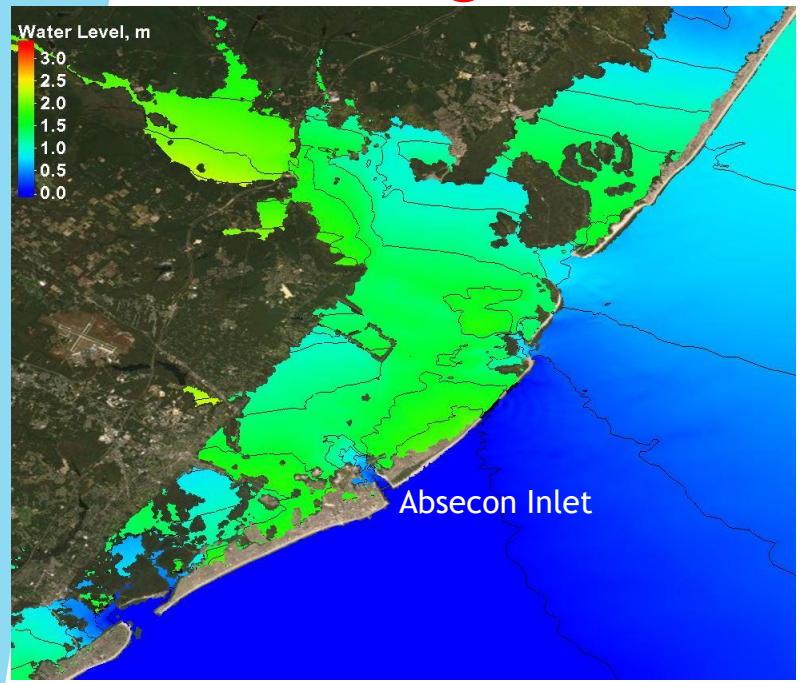
All Inlets Closed

Consider:

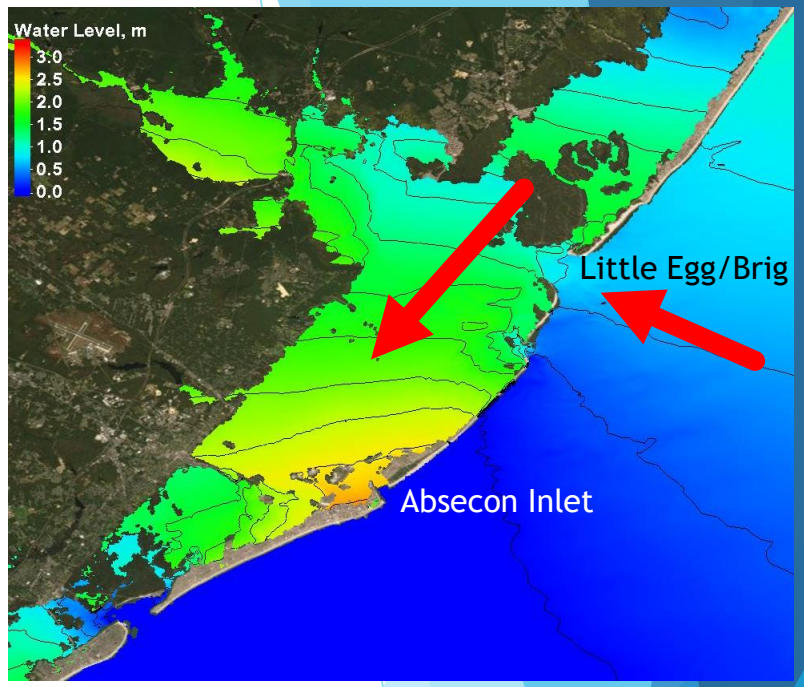
- Timing of closure/re-opening
- All hydraulic openings
- Storm Conditions (e.g. wind direction)

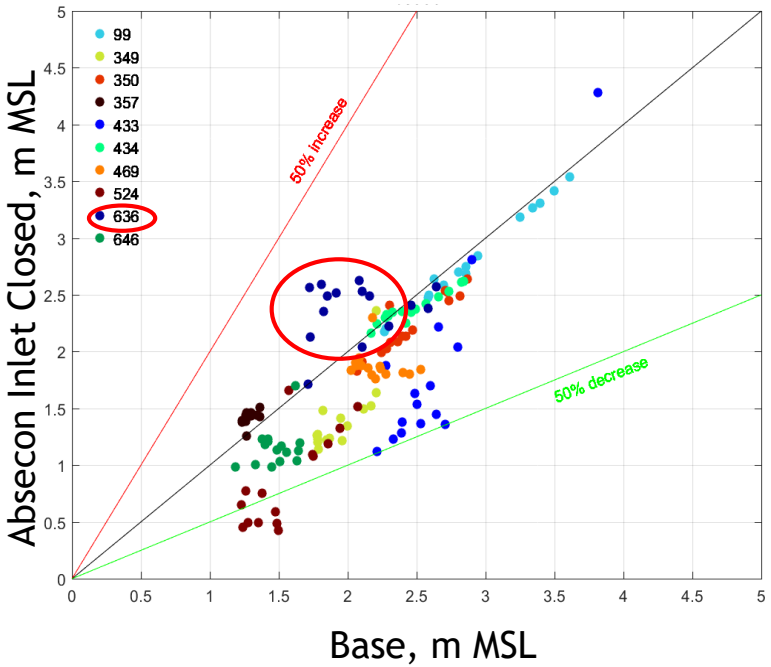
Storm 636

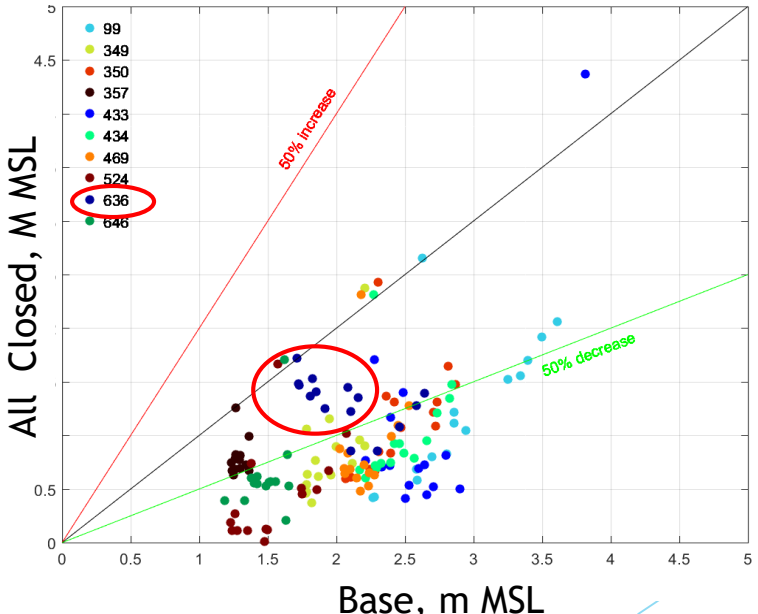
Base: No Surge Barriers



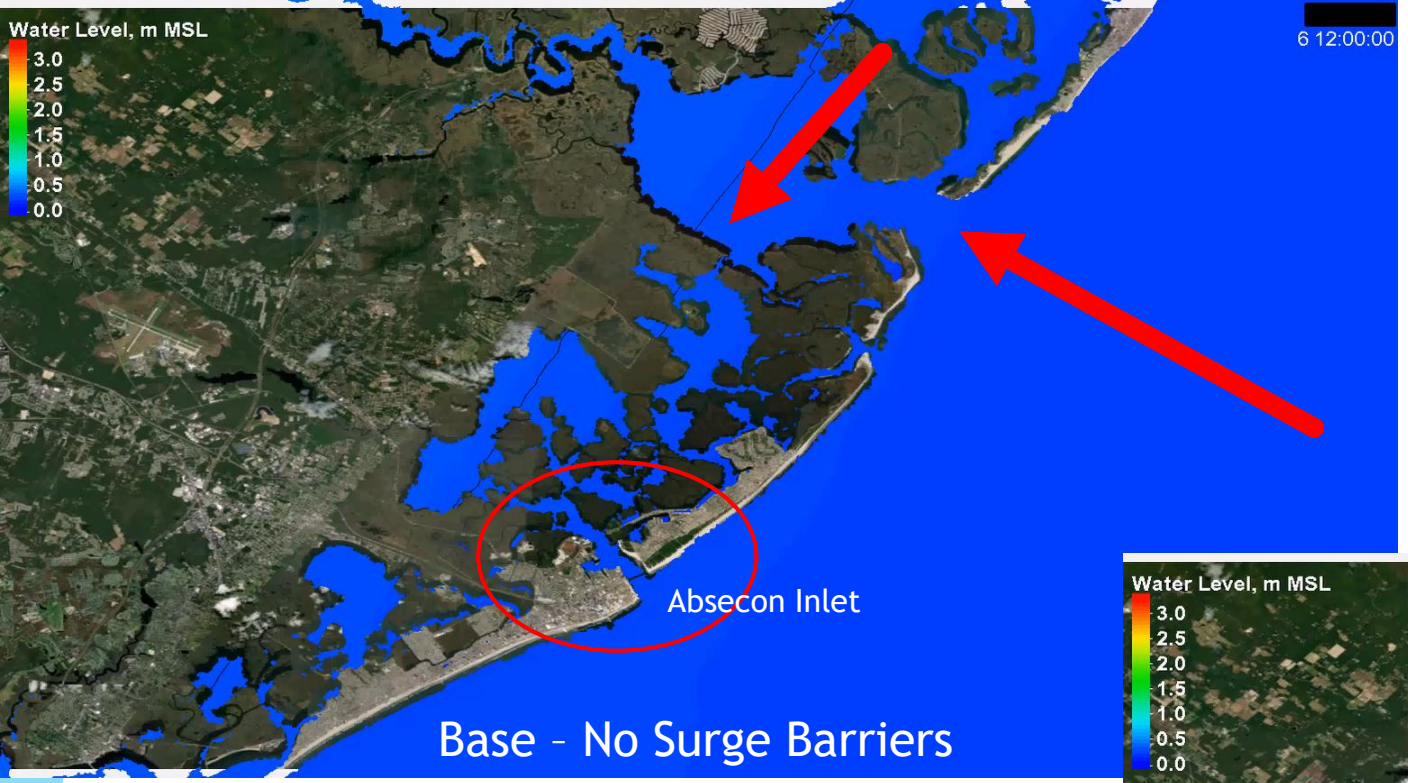
Absecon Inlet Closed



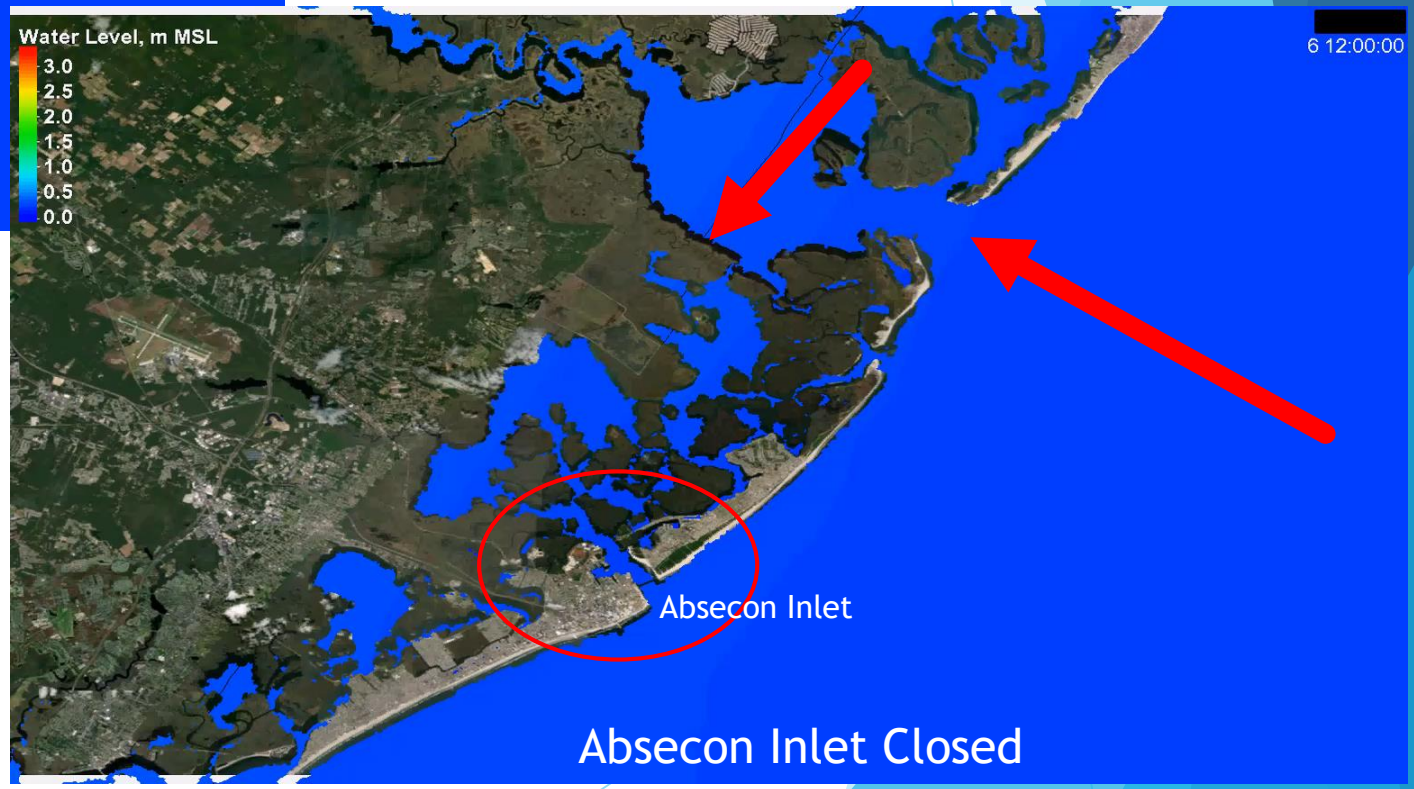




Animations: Storm 636



Base – No Surge Barriers



Absecon Inlet Closed

Water Level Response to Storms in Back Bays

- Greatest reduction: when all inlets are closed with a surge barrier
- Overall average reductions in water level in the 3-bay system is 24% with Barnegat Inlet closed and more than double (53%) with all inlets closed.
- Barnegat Inlet closed: greatest reduction in the northern portion of Barnegat Bay

(surge can still propagate into the bay system through Little Egg/Brigantine Inlet at the southern end of the 3-bay system)

- EXCEPT Storm 636 experienced the greatest differential in maximum water level in the southern portion of the 3-bay system due to the strong north-to-south wind
  - *Base condition flows through Barnegat Inlet transported southward into Manahawkin Bay (high base water levels)*
  - *Inhibited flow entering from the open inlet at Little Egg/Brigantine (low closure water levels)*
- Storm 636 surge entering Little Egg/Brigantine Inlet, propagates southward into Absecon Bay, then is trapped behind the inlet closure at Absecon Inlet.
- *Demonstrates the importance of considering multiple means of flow propagation into an embayment as well as the timing of implementing surge barriers*

Summary

Numerical model study to compare back bay water level response to tropical storm forcing with and without surge barriers at 11 New Jersey inlets

Unique study due to a combination of factors such as:

- *Varying geometric configurations of the inlets and bays in New Jersey*
- *Interconnectivity and hydraulic dependency of adjacent bays*
- *Storm conditions/wave climate in this geographic region*

Surge barriers can reduce back bay flooding significantly, but should consider other mechanisms that may allow flow into the bay:

- *other inlet openings, overwash, breaching, river inflow*
- *mitigate the benefits of surge barrier*
- *prevent return flow out of the bay (Absecon surge barrier)*

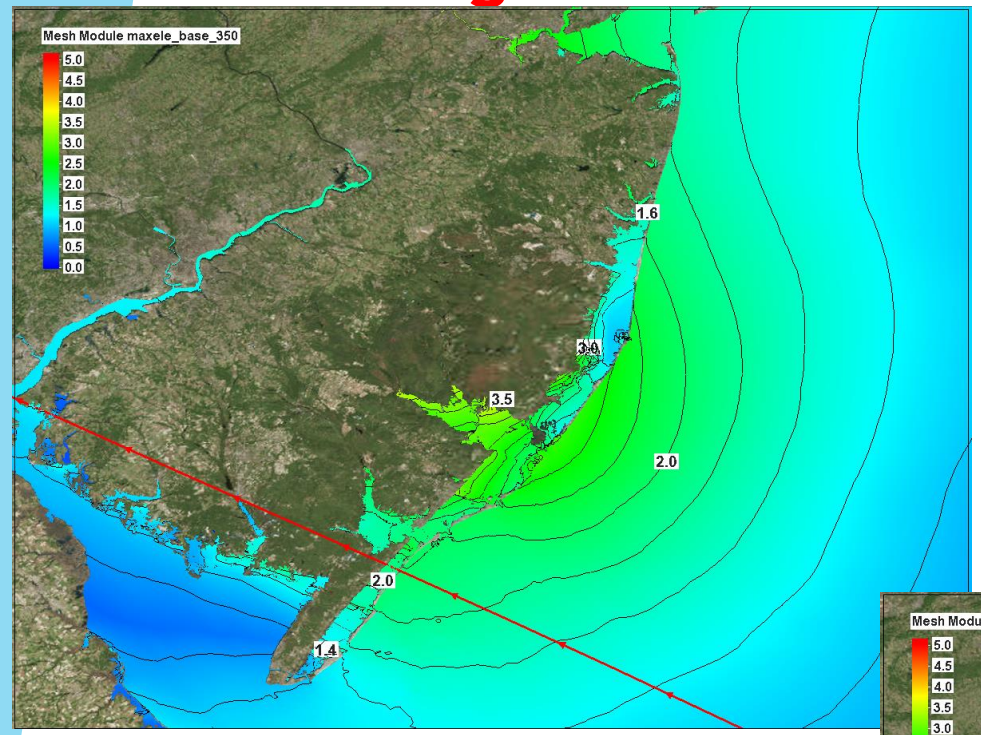
Surge barriers may affect the timing, duration, and magnitude of surge in the back bays

Future Plans: examine the inter-connectivity of smaller bays with closely spaced inlets in the southern portion of the study area. Consider tidal contribution/timing.

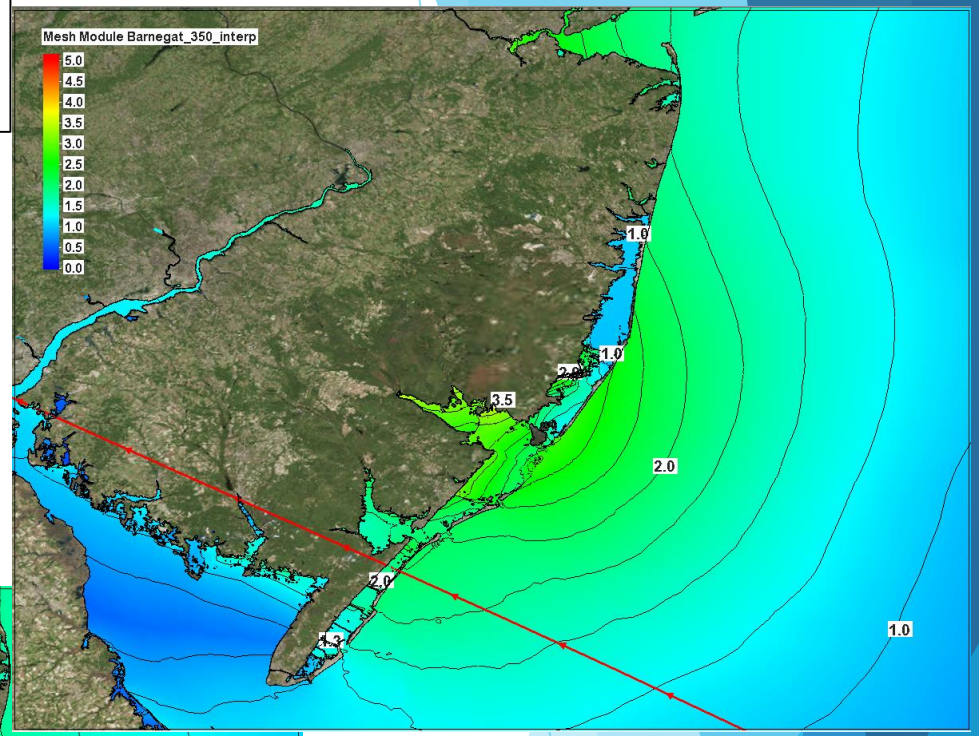

Thank You!!!

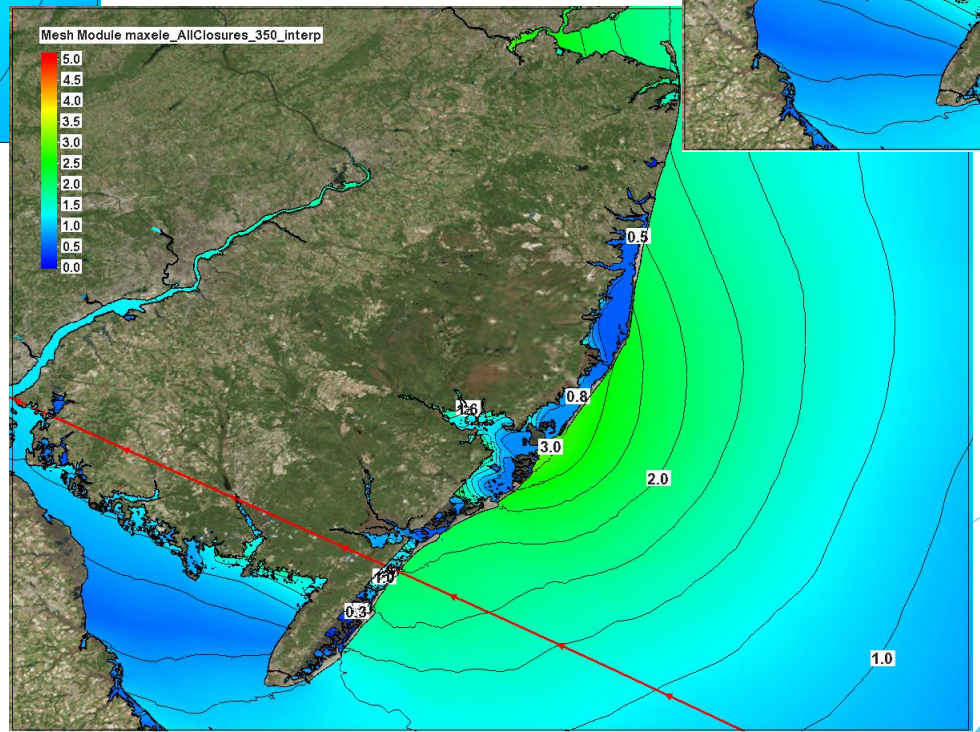
Storm 350

Base: No Surge Barriers



Barn Closed

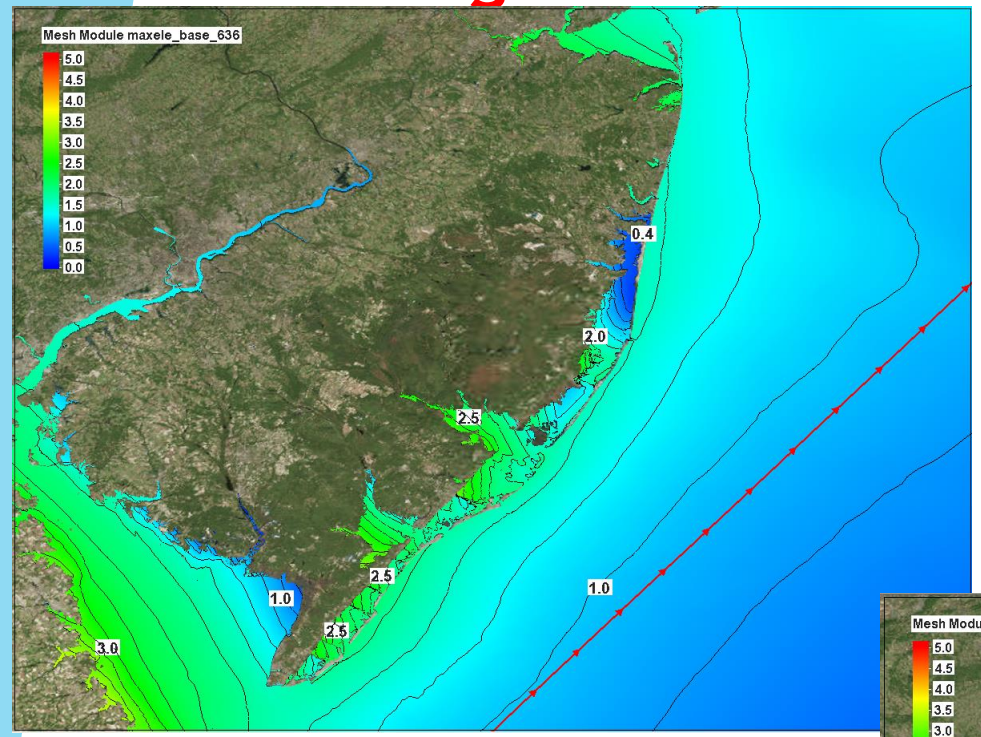




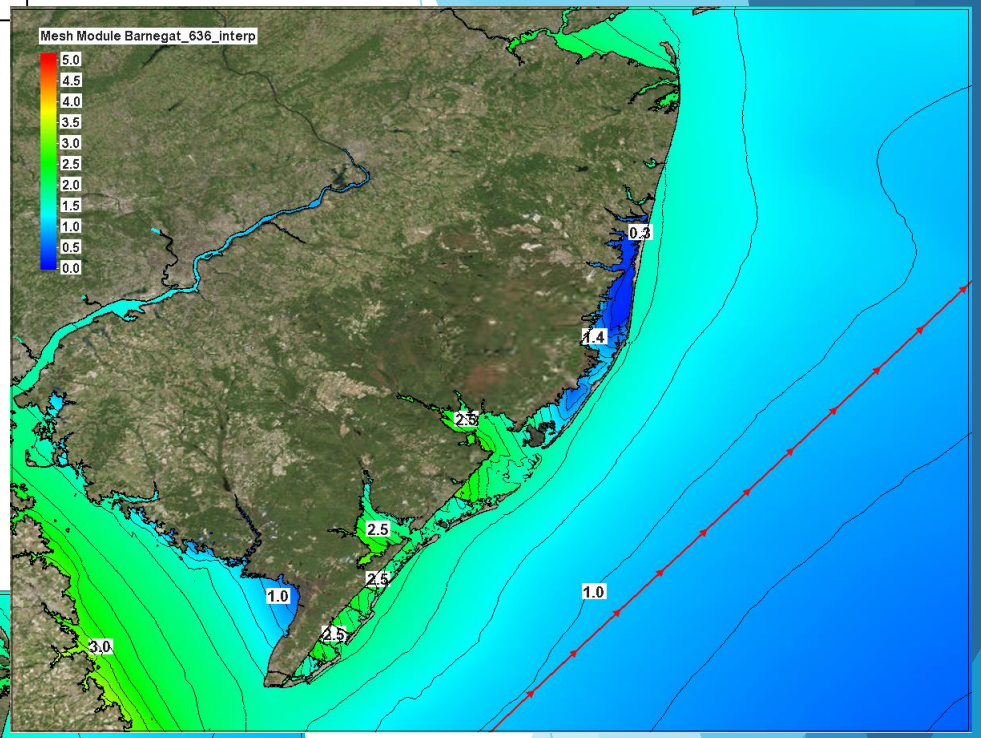
All Closed

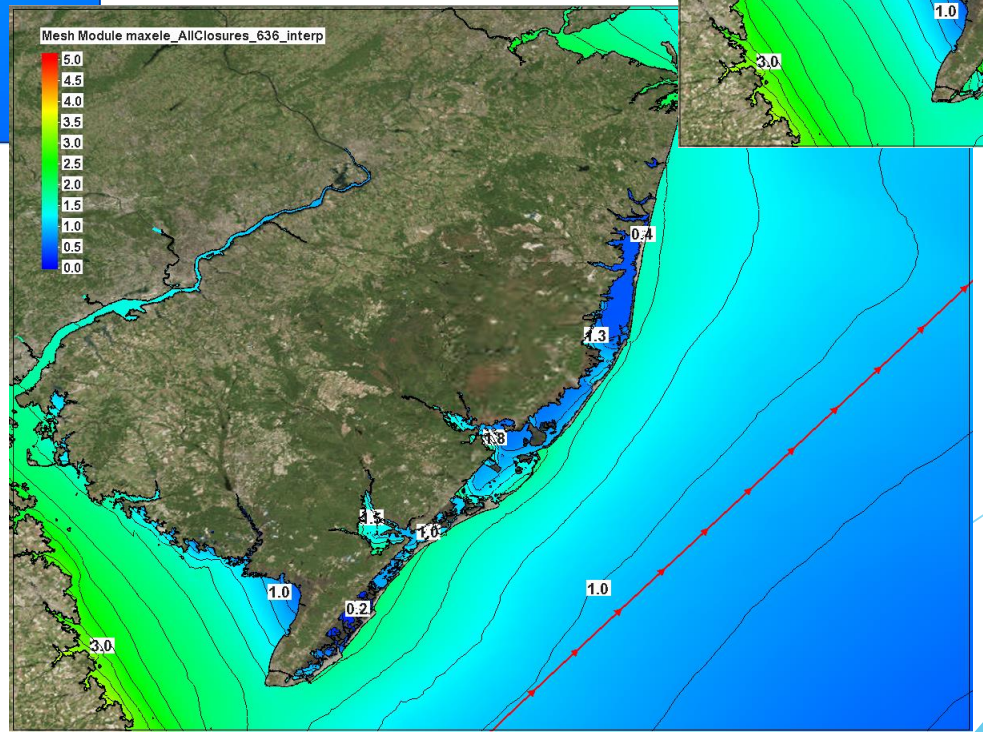
Storm 636

Base: No Surge Barriers



Barn Closed





All Closed