Numerical Modeling of Fire Island Inlet, New York, for Coastal Erosion Control and Inlet Sediment Management

ERDC
Engineer Research & Development Center

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Coastal Sediments 2023
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US Army Corps of Engineers®

Outline

- Background & Objectives
- Available Field Data
- Coastal Modeling System (CMS)
- Numerical Simulations
- Summary & Conclusions

Background

- Fire Island Inlet, located at the south shore of Long Island, NY, is the primary outlet for the Great South Bay connecting to the Atlantic Ocean.
- Net longshore transport, approx. 300k cy/yr is directed westward at the inlet. Fire Island was extended westward at more than 200 ft per year prior to the Federal Jetty completed in 1941 (the northern segment was quickly damaged and reconstructed in 1950).
- The sand dike at the north shore of the inlet was built in 1959 causing down-drift erosion.
- The inlet channel, sharply turned from E-W to S-N heading out of the inlet, requires more frequent dredging from sediment shoaling.

Objectives

- Conduct numerical modeling of coastal wind, waves, tides, storms, hydrodynamics, and littoral processes at Fire Island Inlet, NY.
- Calibrate and validate Coastal Modeling System (CMS) with field measurements; apply the CMS to simulate sediment transport and morphology change at the inlet.
- The USACE ERDC is assisting the New York District (NAN) to investigate non-structural alternatives to reduce dredging cycle and optimize sand borrow site at the inlet in support of storm damage risk management projects on the south shore of Long Island.

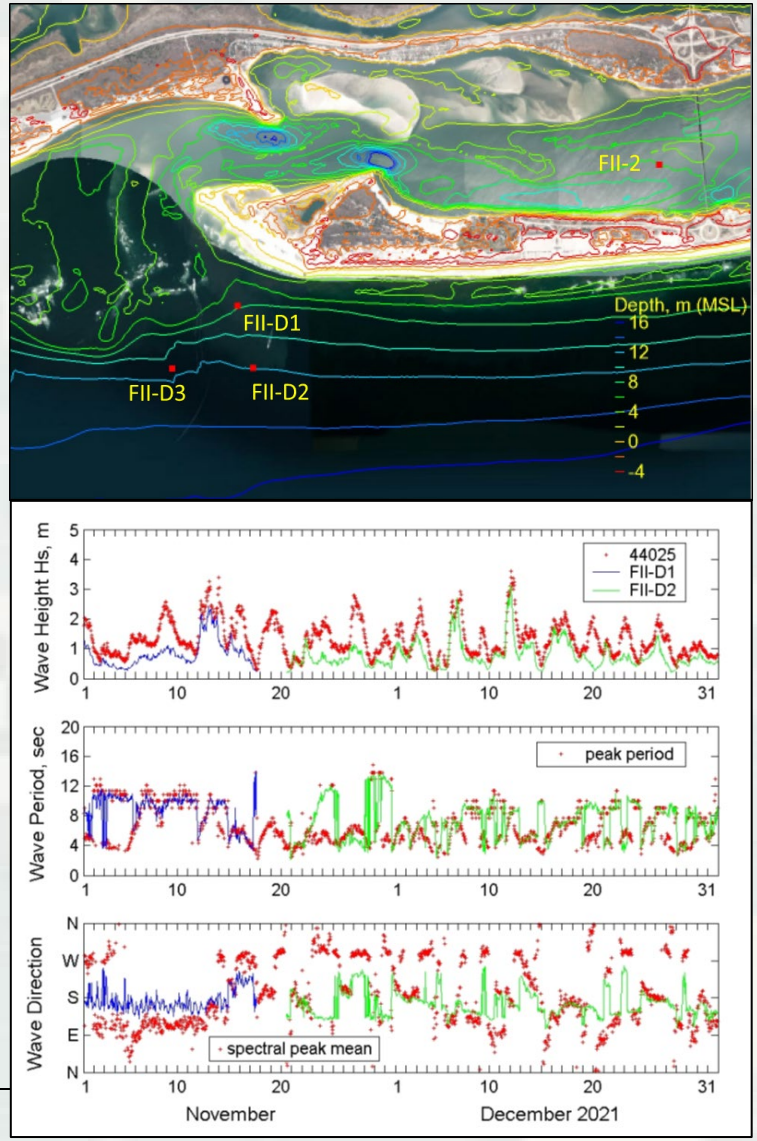
Available Field Data for the Study

- NOAA coastal station SDHN4 (long-term wind, air pressure & water level data).
- NDBC coastal buoys 44069 (wind data), 44025 and 44065 (wind, air pressure & wave data).
- USGS coastal stations 01310521, 01309225, 01306402, 01305575, 01304920 (wind & water level data)
- NOAA Coastal Relief Models (DEM) and 2020 Lidar data, USACE recent channel surveys (2011 - 2021).

Recent Nearshore Measurements

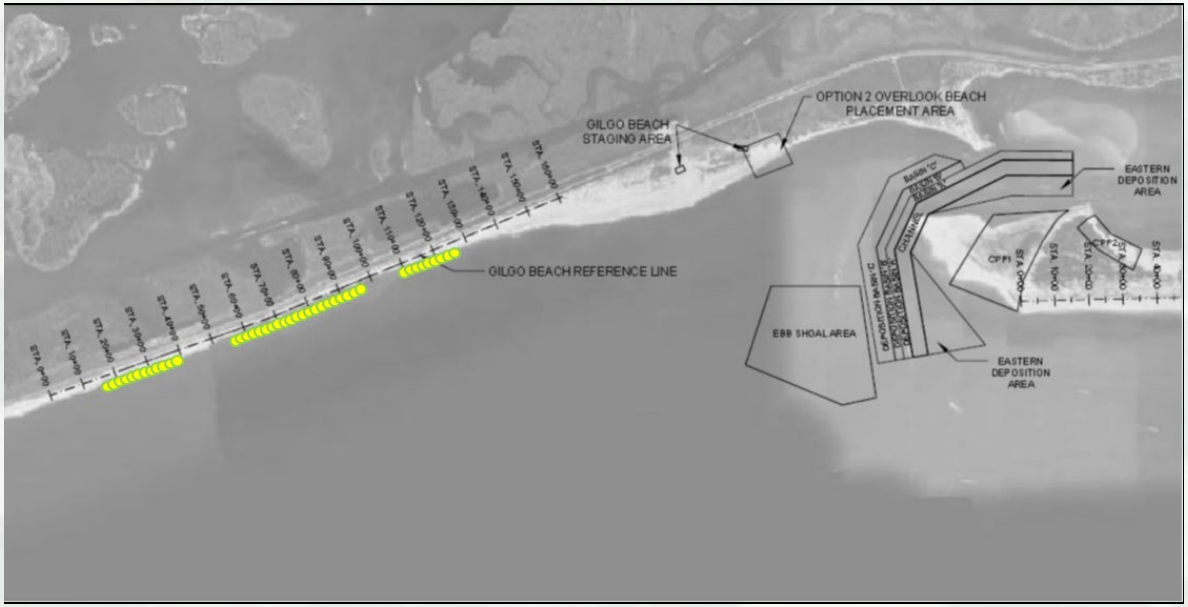
Fire Island Inlet Field Data Collection

- Water level data at FII-2 inside the inlet and at FII-D1, D2, and D3 outside inlet since August 2021
- Wave and current data at FII-D1 from August to November 2021
- Wave and current data at FII-D2 from November 2021 to February 2022
- Wave and current data at FII-D3 from May to October 2022



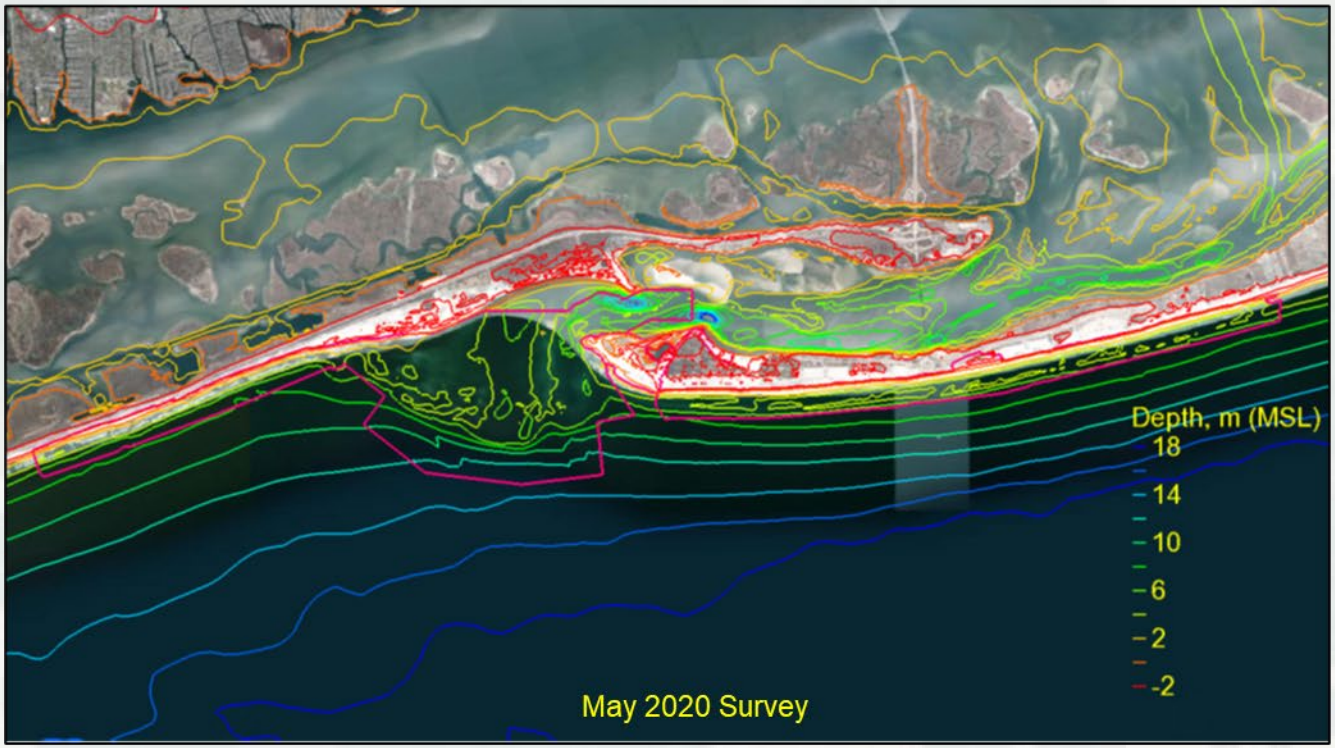
Beach/Nearshore Sediment Data

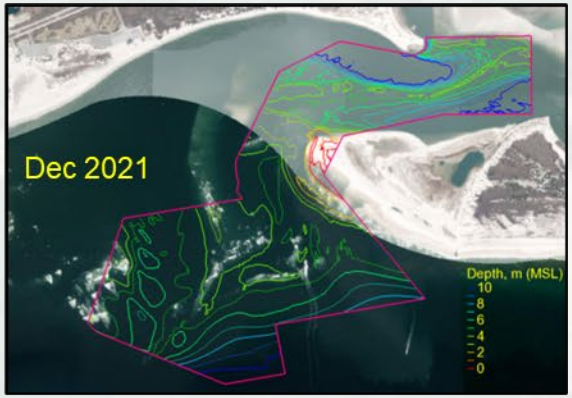
Sediment Samples (December 2021) Median Size (d50)
Nearshore and Beach/Berm Locations

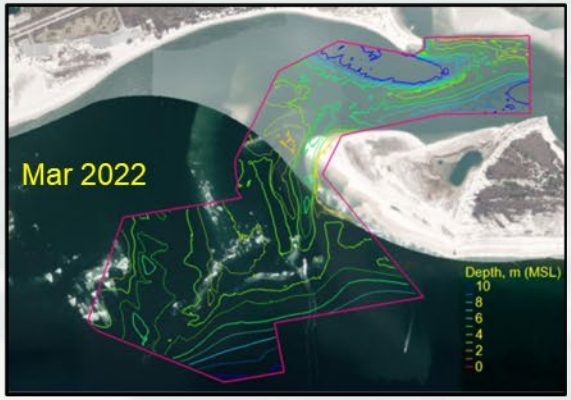


- Sta 16-38 (50-75% sand)
  d50 ~ 0.3 to 0.4 mm
  (mean = 0.33 mm)
- Sta 56-96 (45-75% sand)
  d50 ~ 0.35 to 0.53 mm
  (mean = 0.42 mm)
- Sta 110-126 (45-75% sand)
  d50 ~ 0.35 to 0.50 mm
  (mean =0.46 mm)

Beach/Nearshore Survey Data



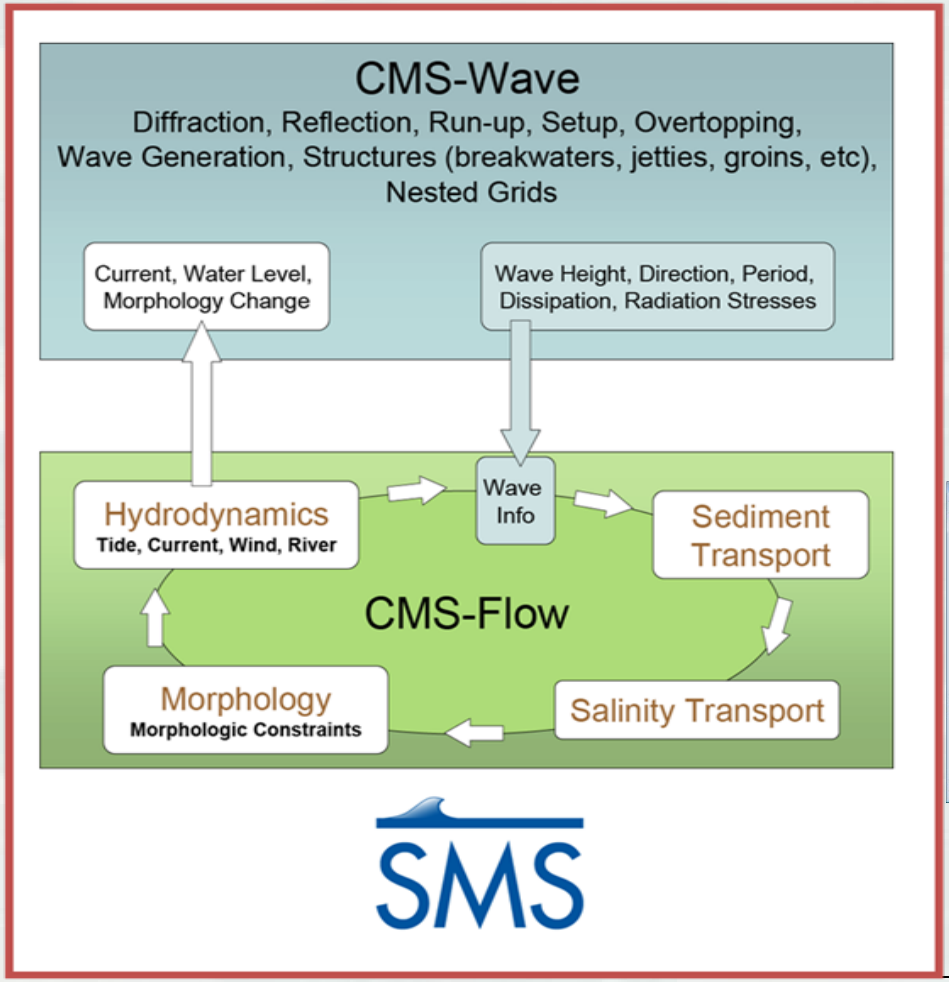


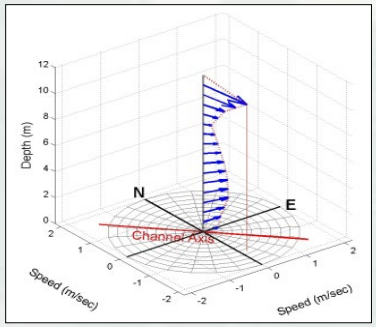


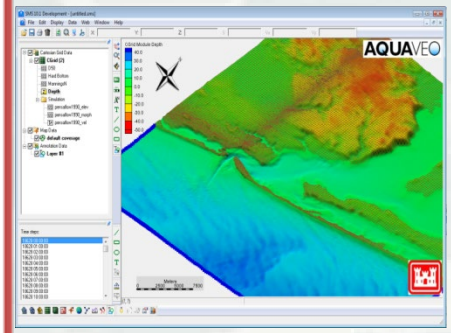
(a broader Inlet survey cover ebb shoal, updrift & down-drift beach and shore)

Numerical Models

Coastal Modeling System (CMS)







- A suite of time-dependent flow, salinity, wave, & mixed sediment transport models
- Physics-based to simulate complete coastal processes
- Integrated with visual interface thru Surface-water Modeling System (SMS)

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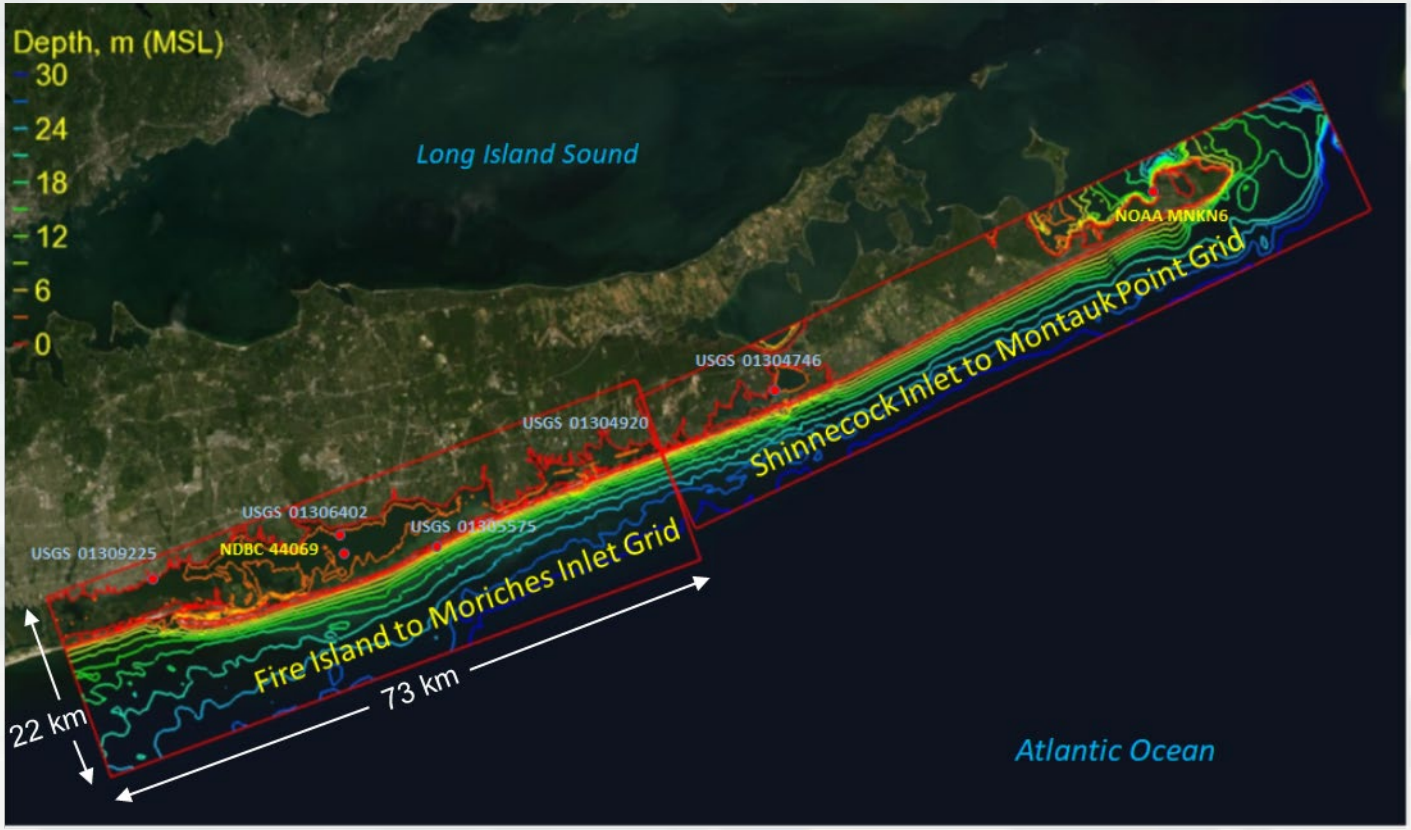
CMS-Wave Model Grid Domain



CMS Fire Island Inlet to Montauk Point CMS Grid system

Fire Island Inlet Grid:

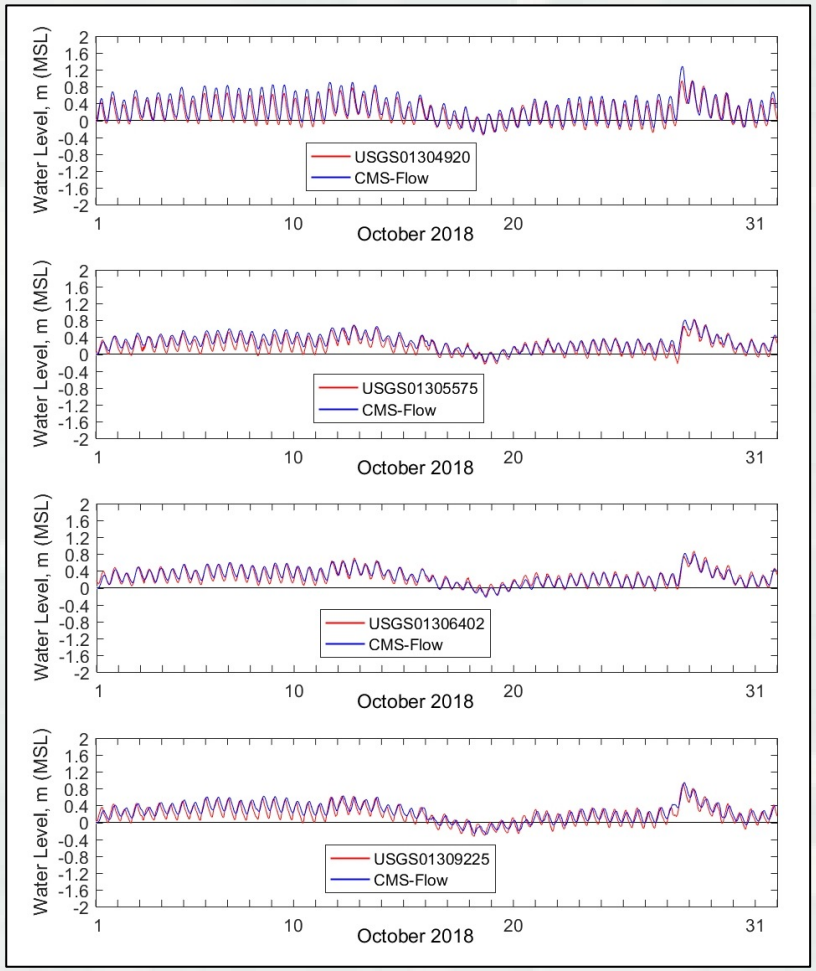
Area ~ 22 km x 73 km

Variable spacing
~ 20 m around inlet
~ 120 m to offshore

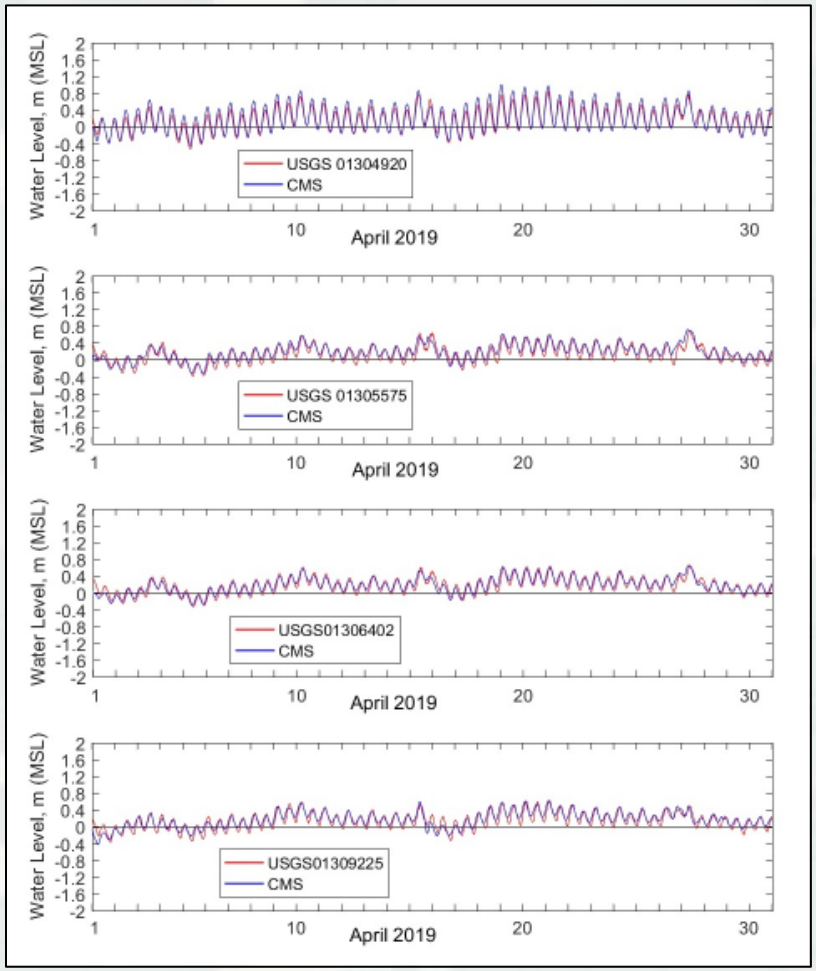
Manning's coefficient
n (bottom friction)
~ 0.015 in the bay
~ 0.025 in the ocean

Sand size D50 (mm)
~ 0.3 Fire Island
~ 0.4 Moriches Inlet

Model Water Levels and Data Comparison

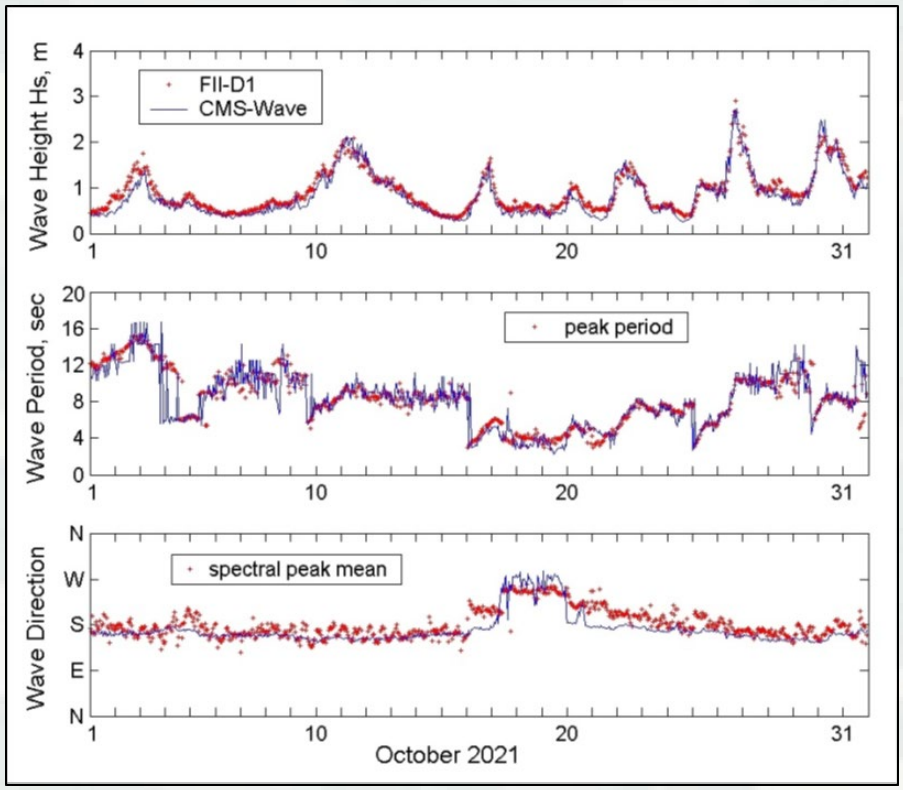


Model Calibration

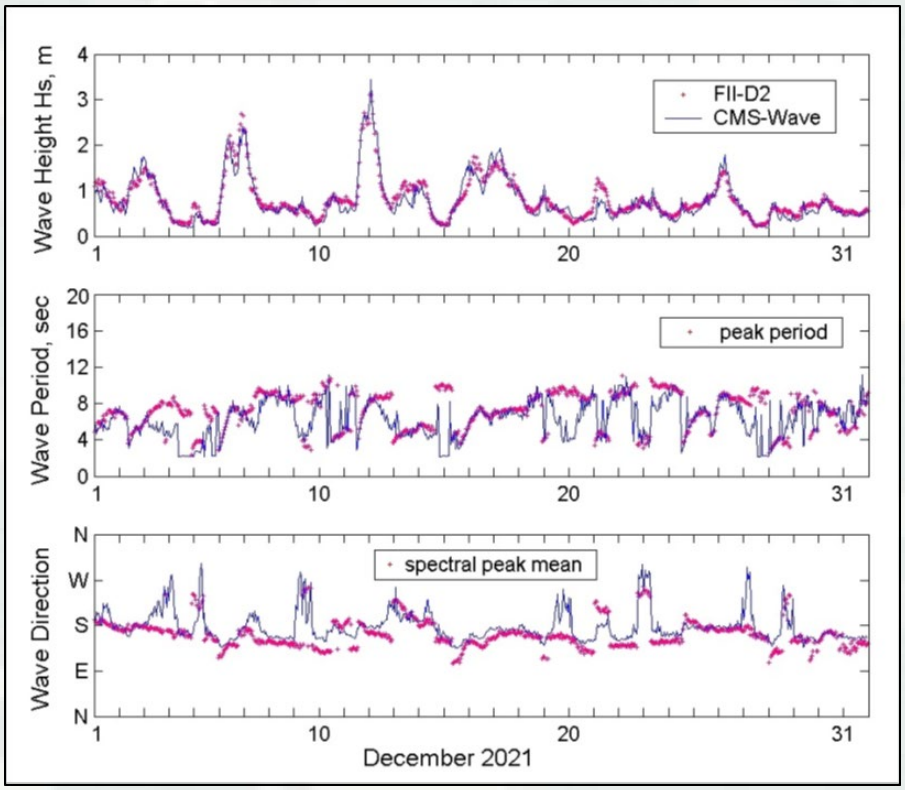


Model Validation

Model Wave and Data Comparison

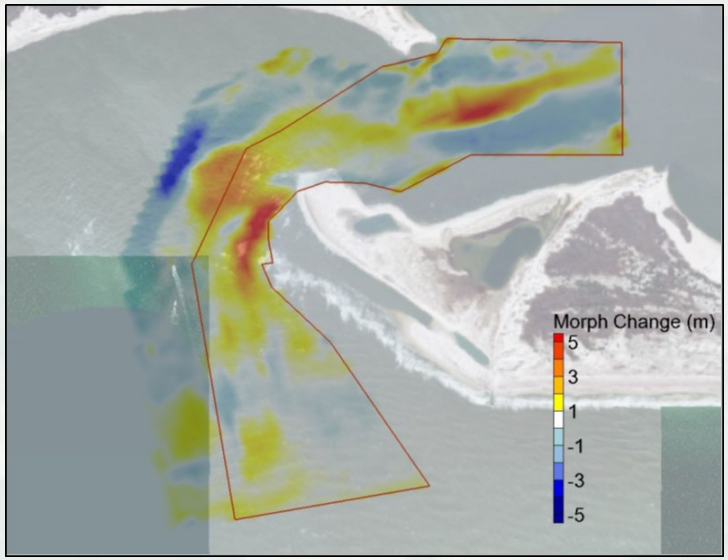


Model Calibration

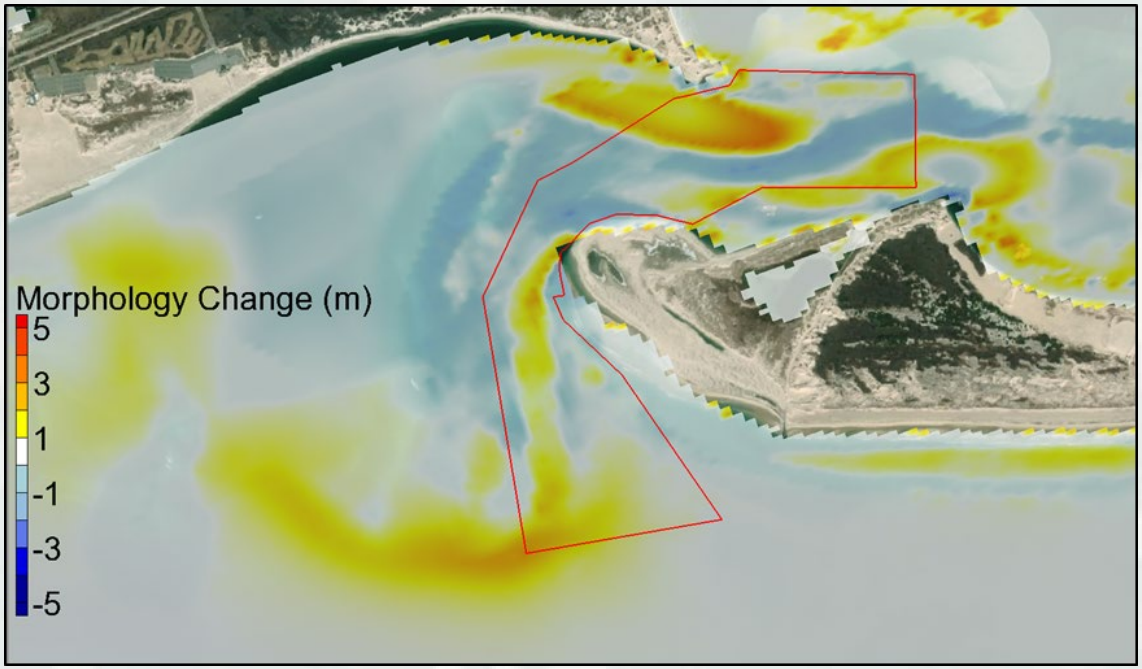


Model Validation

Model Morphology Change versus Data
April 2019 - March 2020



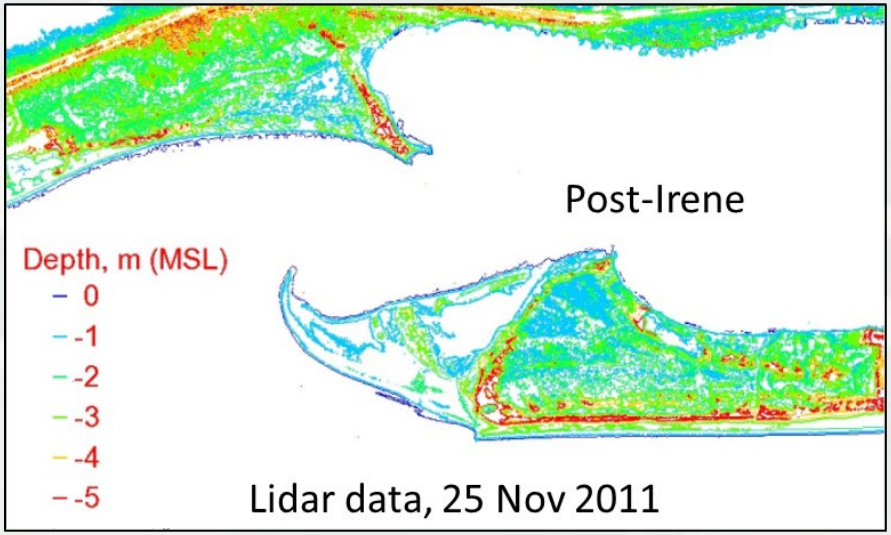
Local bathymetric changes based on NAN April 2019 & March 2020 surveys



Model (12-month) morphology change
- bedload dominated according to modeling

(Red polygon covers inlet channel and deposition basin survey area in March 2020)

Aerial Photos (26 May 2011, 3 Nov 2012) Lidar Data (Nov 2011)



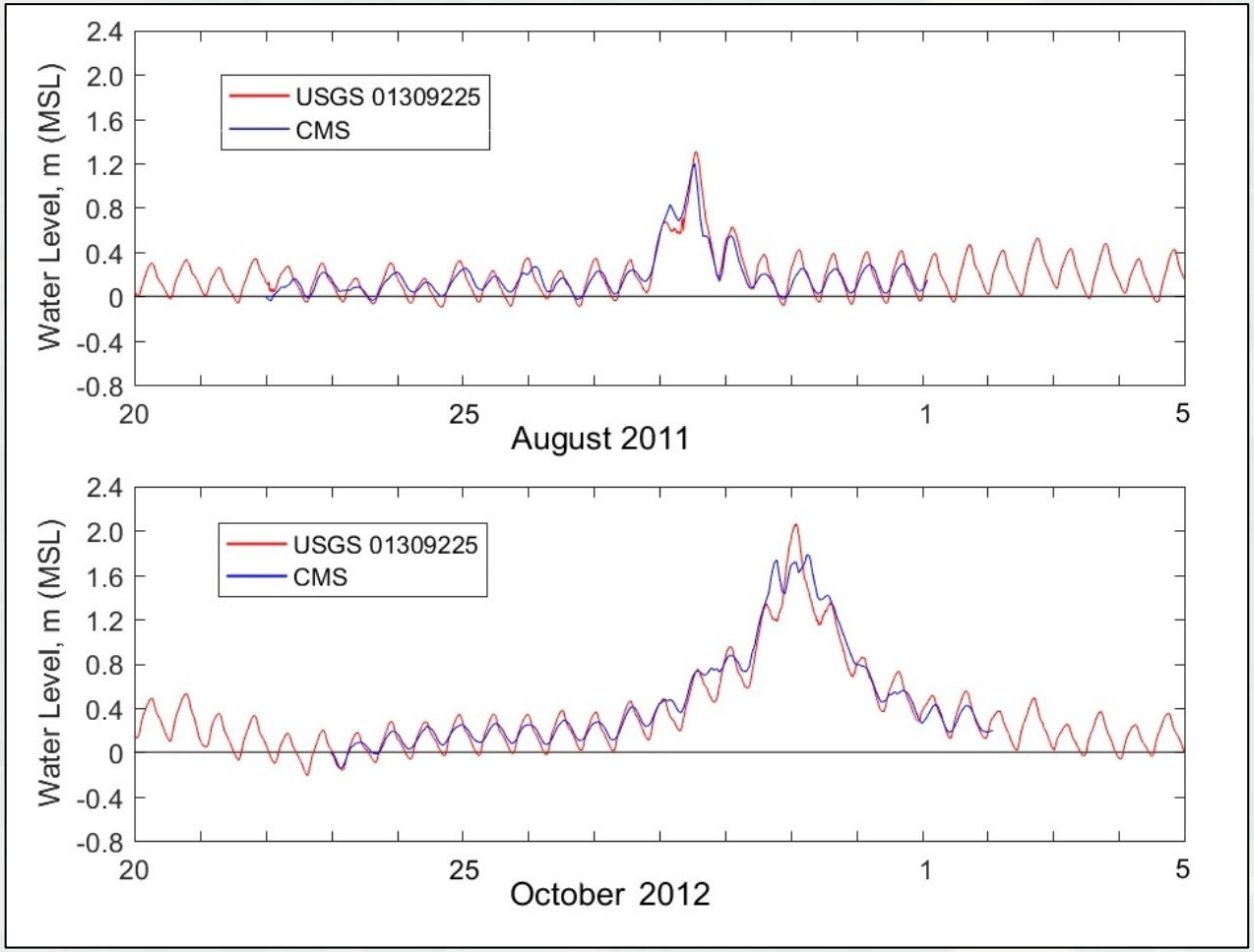
Hurricane Irene (22 Aug - 1 Sep 2011)

Hurricane Sandy (23 Oct - 2 Nov 2012)

Additional pre-Irene & pre-Sandy Lidar data

- Aug 2010
- Dec 2011 - Feb 2012

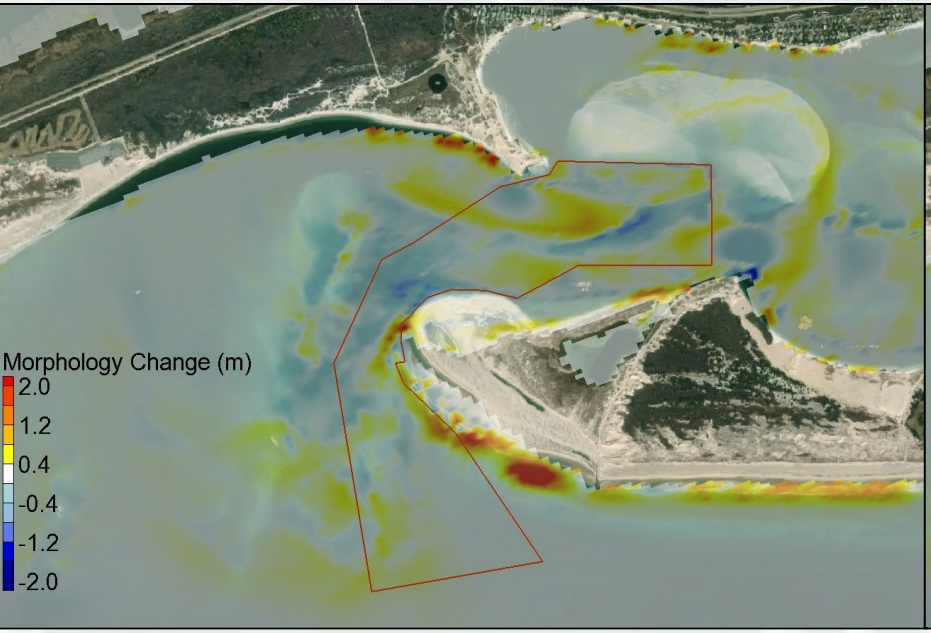
Model Water Level and Data Comparison for Irene and Sandy



(USGS 01309225 is located at the northwest shore of Great South Bay)

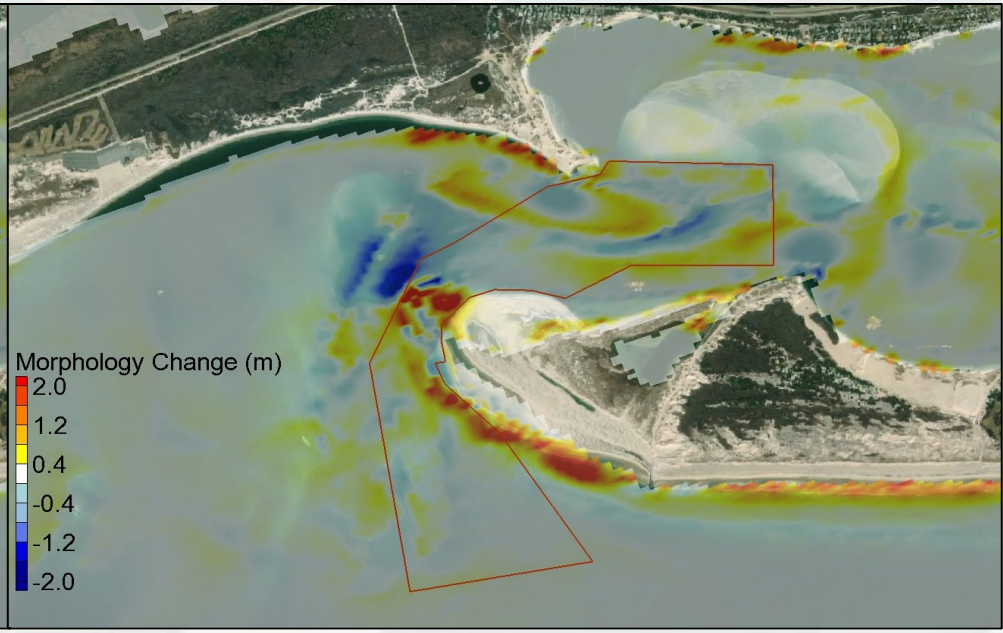
Model Morphology Change for Irene and Sandy

Model Irene (22 Aug - 1 Sep 2011)



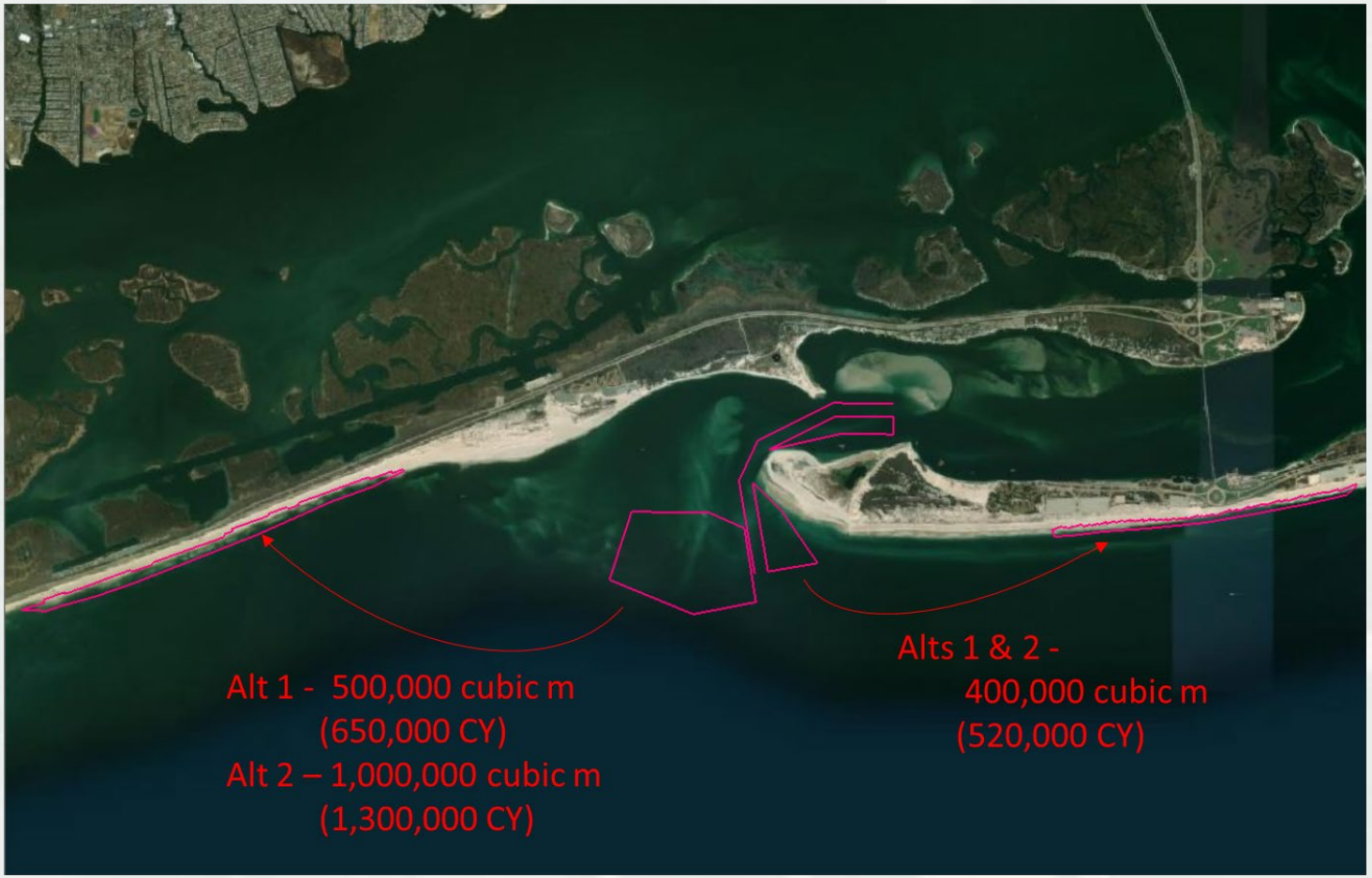
Total volume accretion in the inlet
And deposition basin (red polygon)
~ 148,000 m^3 (10-day simulation)

Model Sandy (23 Oct - 2 Nov 2012)



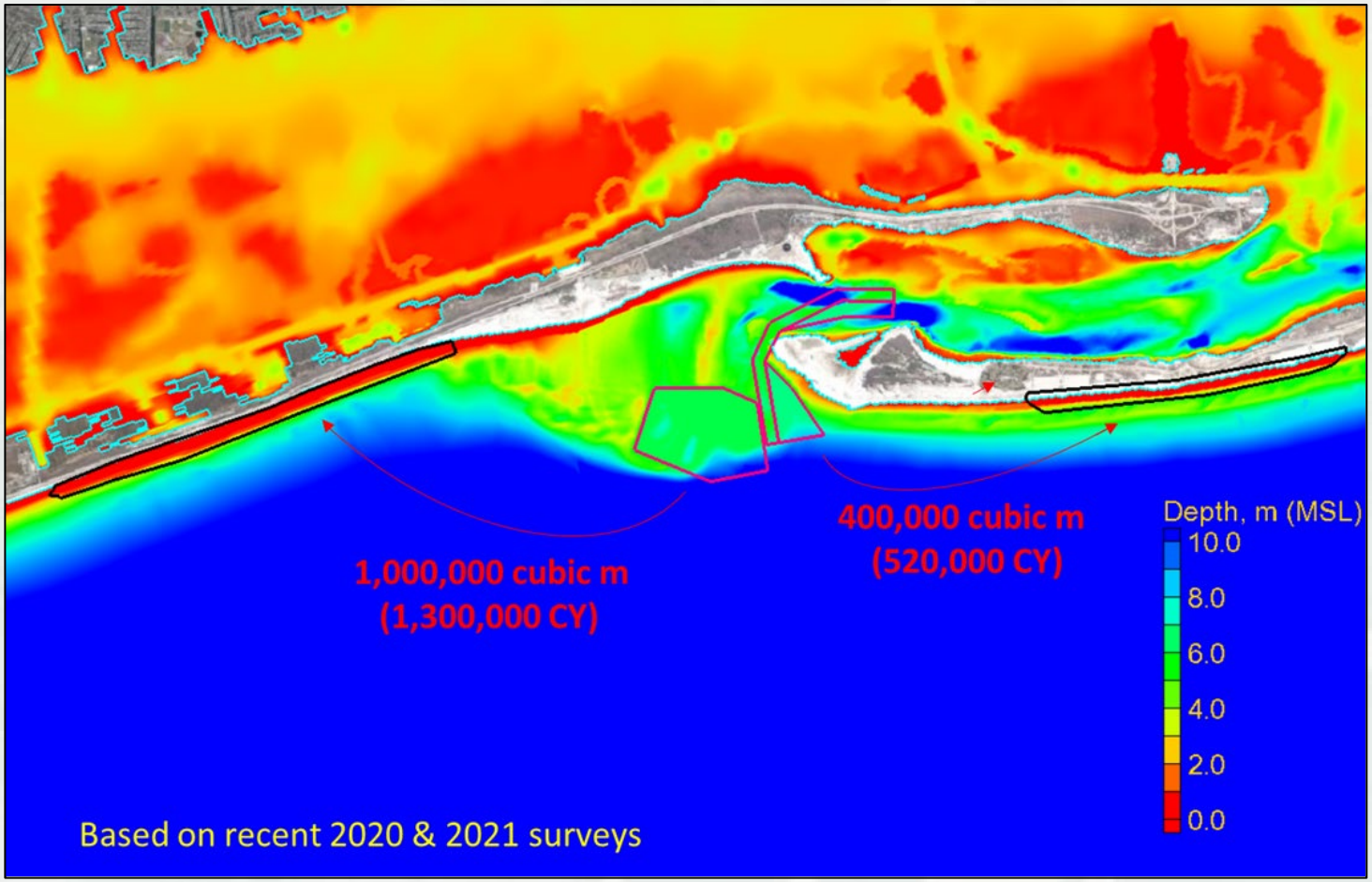
Total volume accretion in the inlet
And deposition basin (red polygon)
~ 256,000 m^3 (10-day simulation)

Modeling Alternatives at Fire Island Inlet



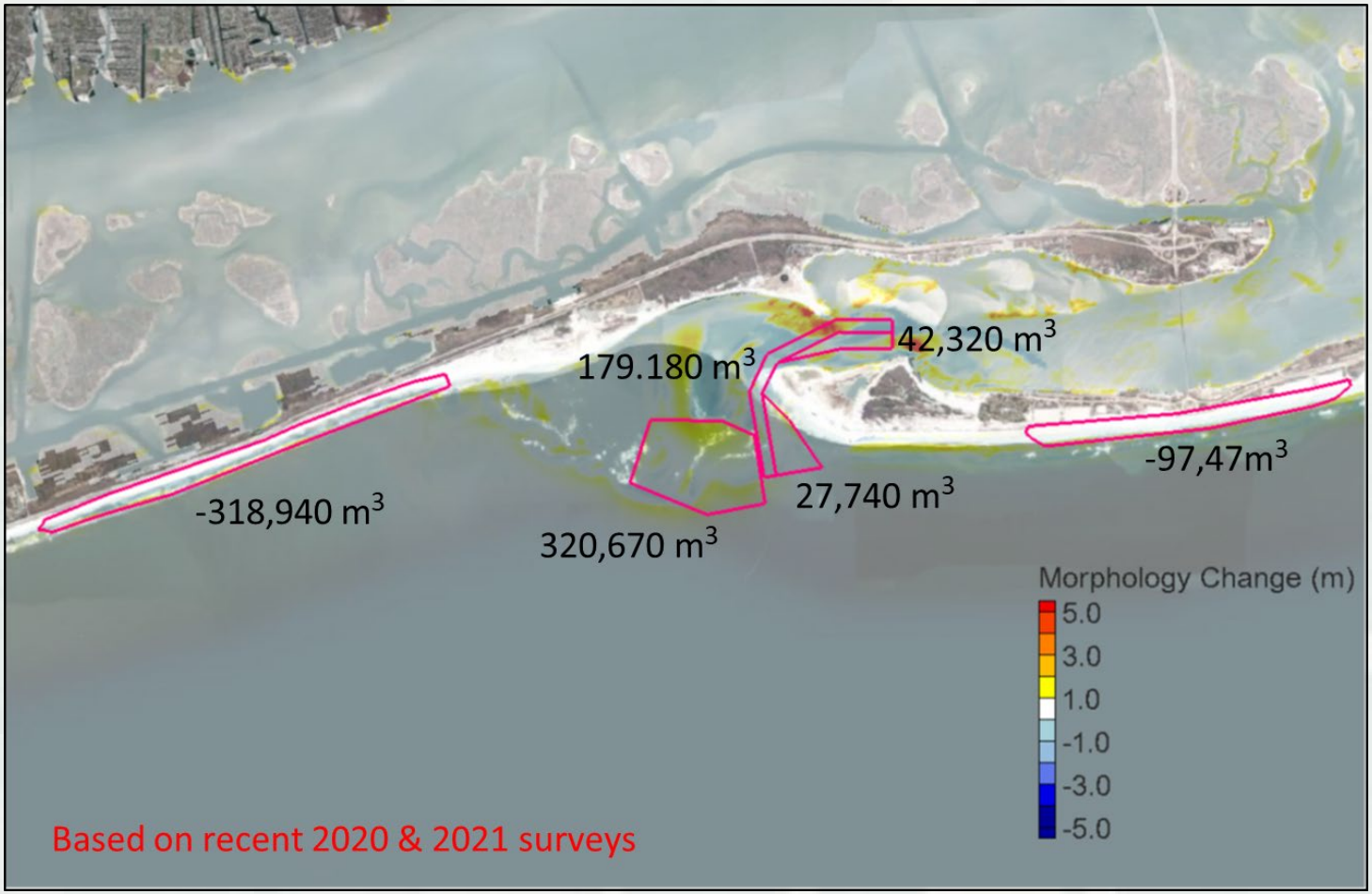
Model Alts 1 and 2

Modeling Alt 2 at Fire Island Inlet



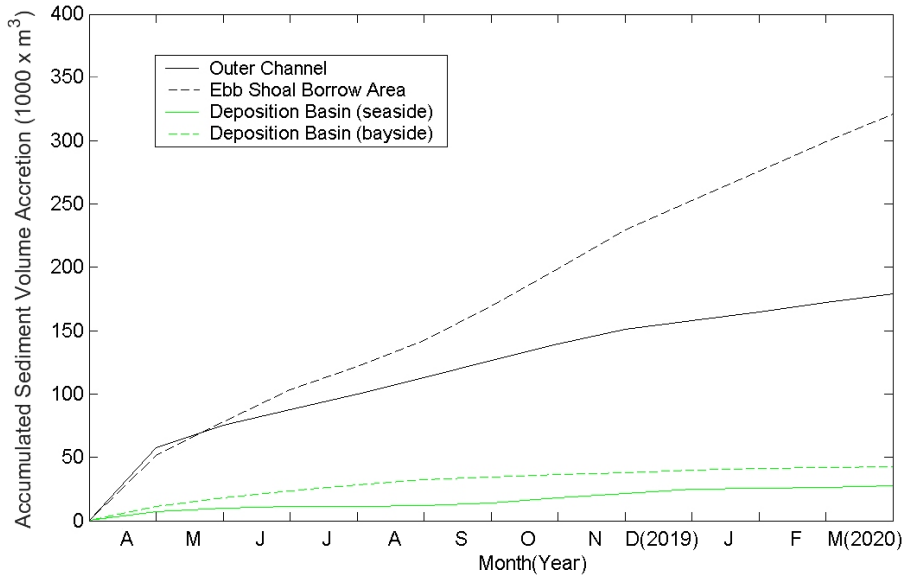
Model Alt 2 initial bathymetry

Modeling Alt 2: 1-Yr Morphology Change (Apr 2019 – Mar 2020)

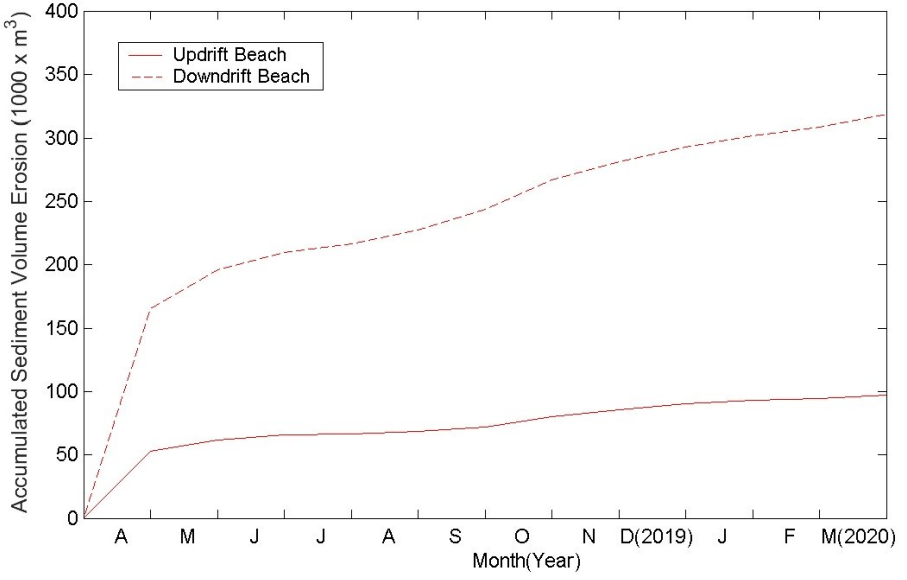


Model Alt 2 one-year simulation

Model Alt 2 Monthly Accretion/Erosion Volumes (Apr 2019 – Mar 2020)



Monthly accumulated accretion at Outer Channel, Deposition Basins, and Ebb Shoal Borrow Area

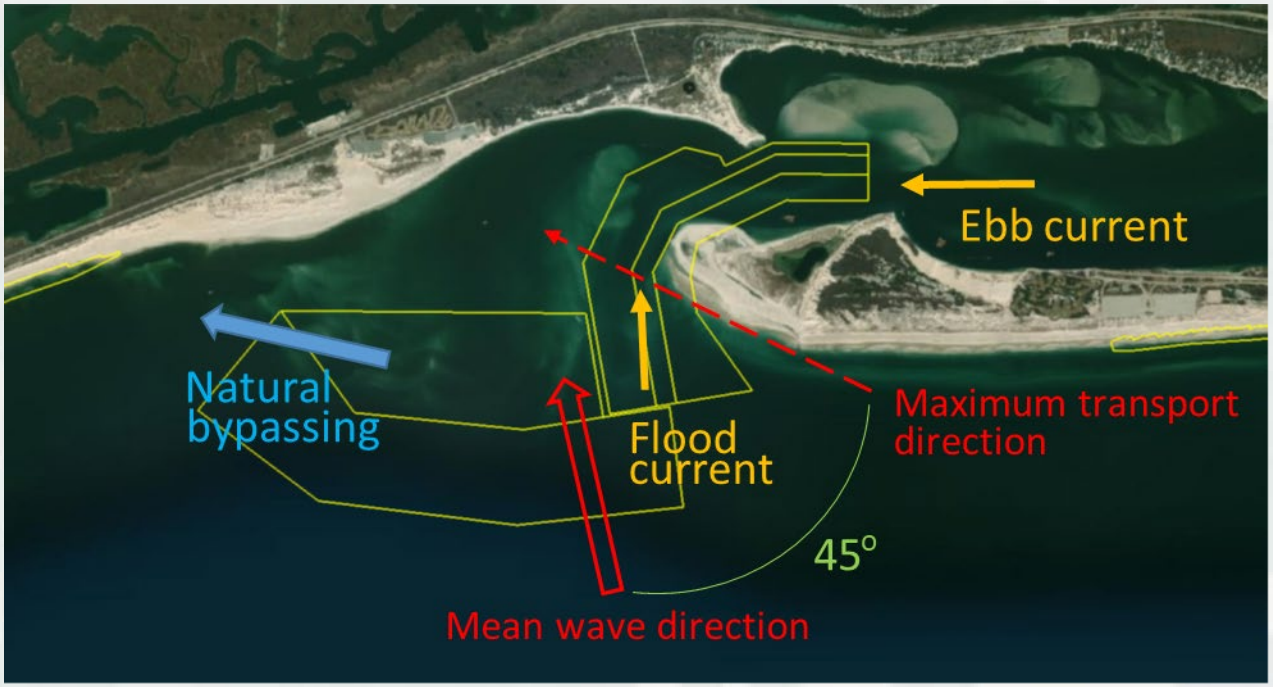


Monthly accumulated erosion at updrift and and downdrift beach fill areas

Summary & Conclusions

- US Army Engineer CIRP is teamed with New York District to investigate the coastal processes at Fire Island Inlet for flood risk reduction and sediment management by numerical modeling.
- The Coastal Modeling System (CMS) was calibrated and validated using the field data (waves, wind, water levels, Lidar & survey data) and applied in the Fire Island Inlet modeling.
- The CMS was conducted to model morphology change under Hurricanes Irene and Sandy, and also 1-yr simulation of April 2019 to March 2020. Model results agree with field observations.
- Modeling non-structural alternatives by the CMS is presently in progress. Model results will be used to assist the O&M and optimization of ebb shoal borrow area at Fire Island Inlet.

Thank you!



Questions?

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