Flood and Sea Level Rise Mapping Methodologies: The Way Forward

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Interagency Coordination Meeting on
Sea Level Rise and Inundation Modeling and Mapping

Narragansett Bay Commission Conference Room
Narragansett Bay Commission

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Outline

- FEMA FIRMS Issues and Problems for RI (Northeast), Critique by NRC
- Use of Bath tub inundation models (guidelines for use)
- Storm Inundation and SLR Modeling Overview, Army Corp of Engineers, North Atlantic Coast Comprehensive Study and NERACOOS Northeast Coastal Ocean Forecasting System (NECOFS)
- STORM TOOL Vision and Status

Brief FEMA Coastal Flood Mapping History

- Early 1970s, Extremal analysis methods based on observations at NOAA water level stations, engineering tools to estimate wave conditions
- Mid 1970s, 2-D storm surge models, parametric hurricane forcing models, engineering tools to estimate wave conditions
- Late 1970s – early 1980s, joint probability methods used for tropical and extra-tropical storm forcing
- 2005 NRC review (recommend development of WHAFIS)
- Early to mid 2000s, Development and use of CHAMP/WHAFIS, modeling of surge and waves (no coupling), forcing using joint probability methods

Brief FEMA Coastal Flood Mapping History

- NRC 2009 review, *FEMA should use coupled 2-D surge and wave models to reduce uncertainties associated with the use of a 2-D surge model and the 1-D WHAFIS model.*
- Use coupled ADCIRC- SWAN (2-D finite element models of surge and waves) and WHAFIS for all FEMA regions in Gulf of Mexico and Atlantic, except New England (Region 1).

Region 1 uses methods from 1970s.

Method Used in Washington County, Flood Insurance Study(FIS) 2012

- Estimate water levels for various return periods for storms at NOAA primary water level stations: New London, CT; and Newport and Providence, RI using L Moment Method

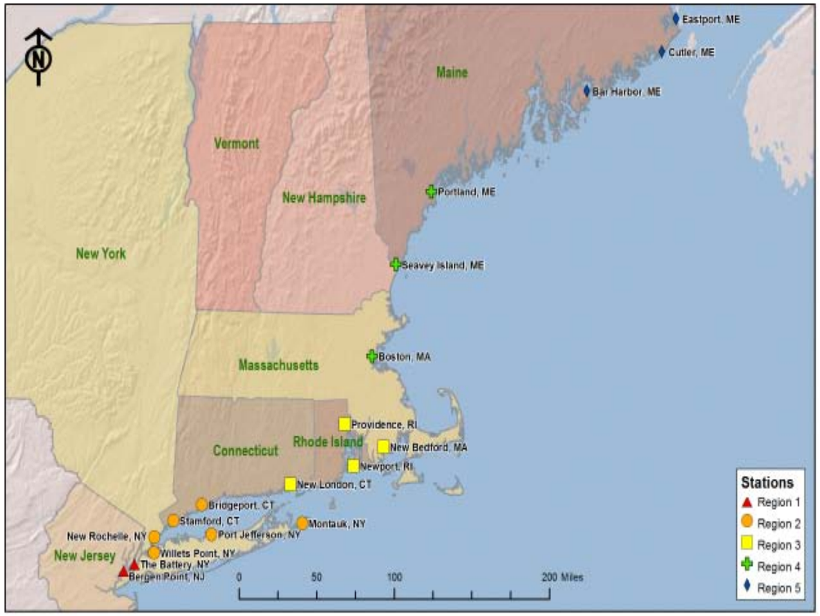
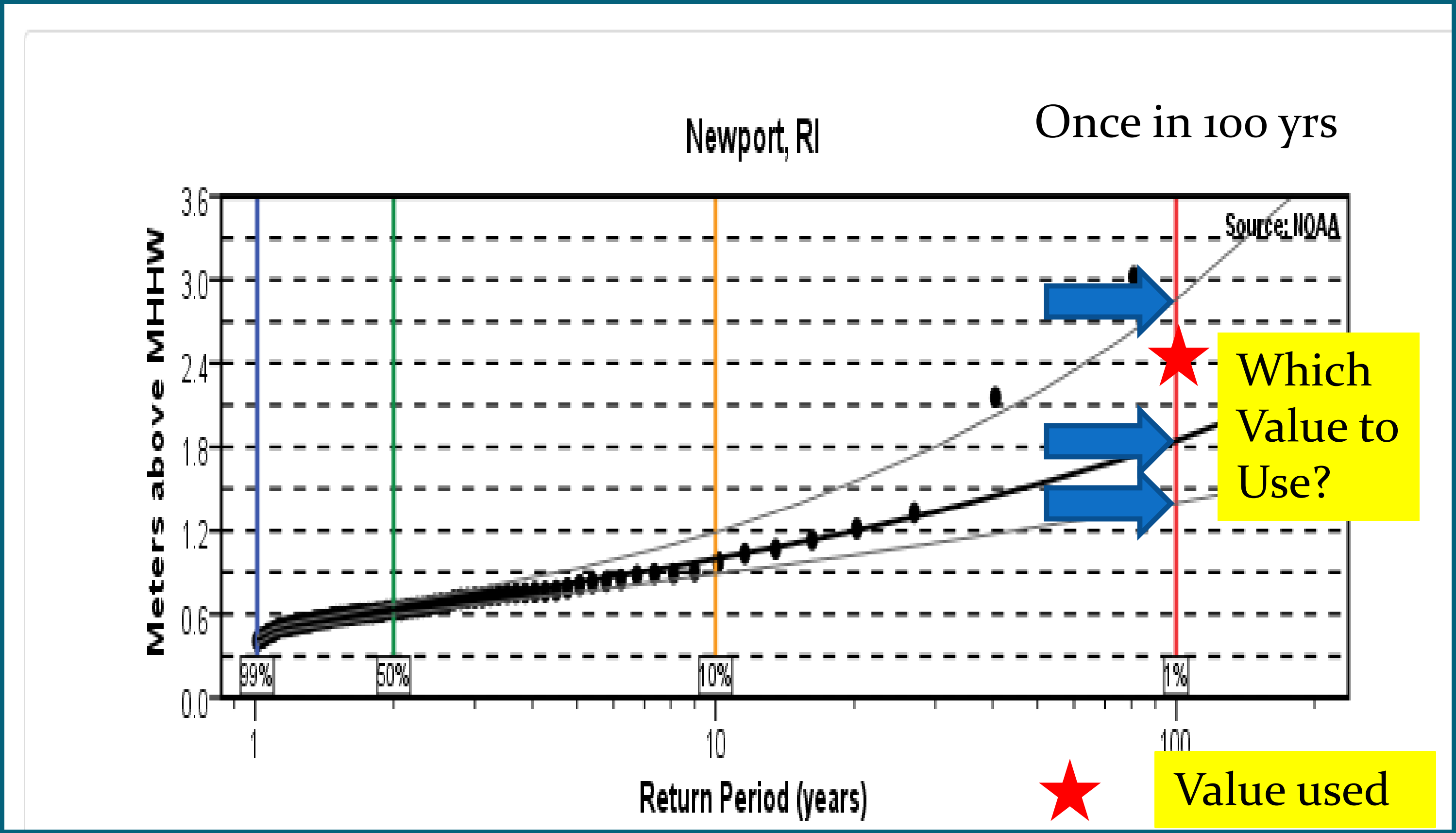


Figure 1. Location of the 18 long-term stations used in the frequency analysis.

Method Used in Washington County, Flood Insurance Study(FIS) 2012

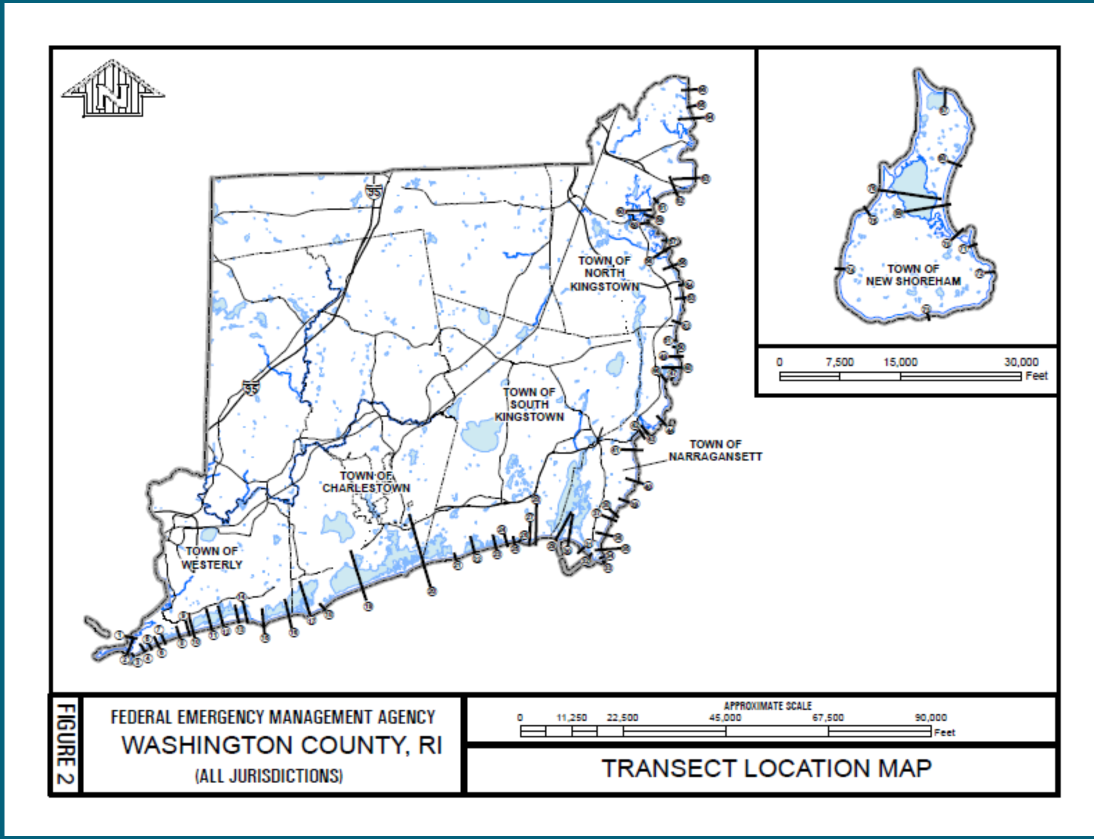


From NOAA NOS COOPS web site Extreme Values Section

Method Used in Washington County, Flood Insurance Study(FIS) 2012

- Select transects along coast to represent wave induced processes

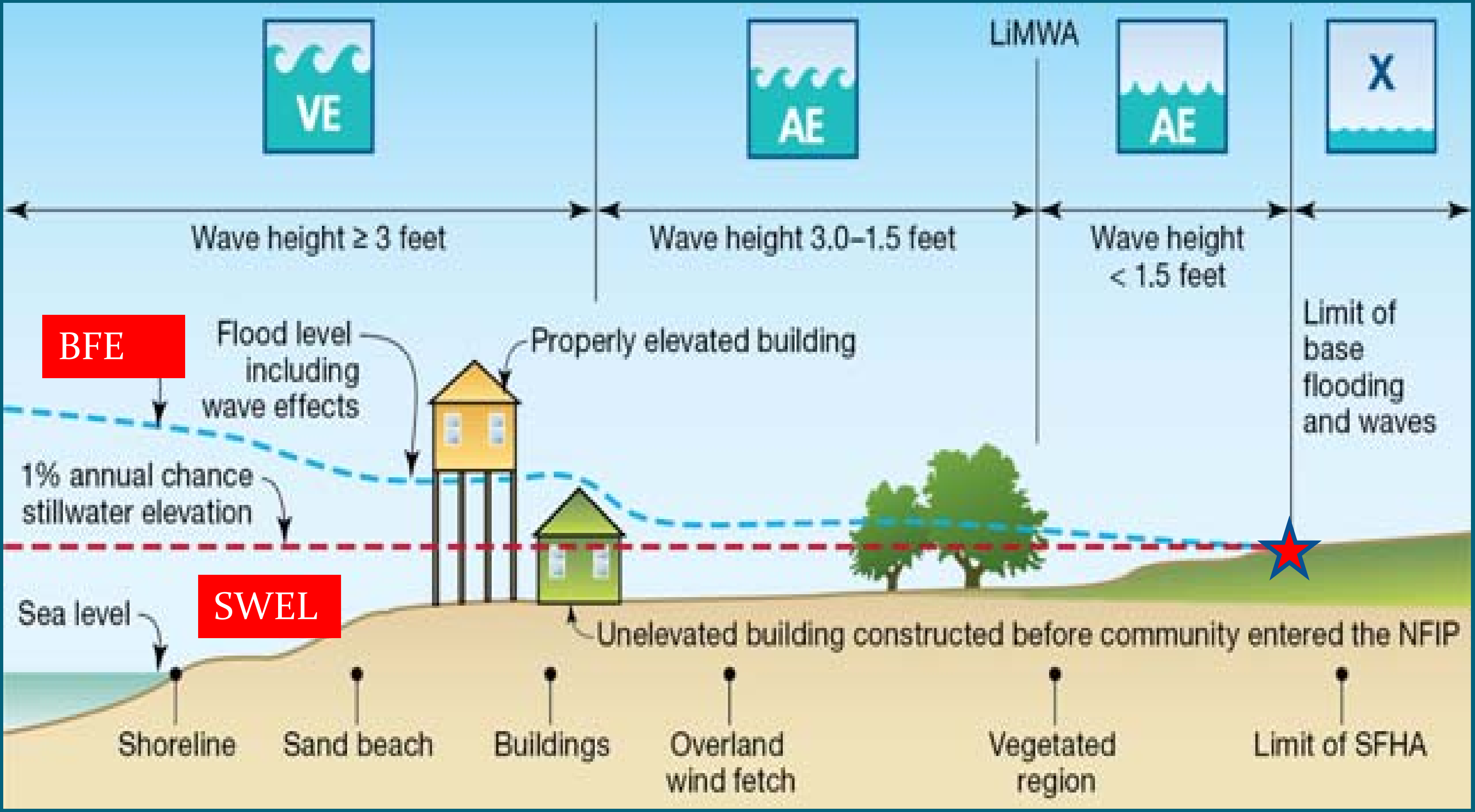
- Use linear inter-polation to estimate Still Water Levels (SWL) at seaward end of transect



Transects to 2-D mapping in FIS (2013) for Washington County, RI

- Use Coastal Hazards Analysis and Mapping Program/ Wave Height Analysis for Flood Insurance Studies (CHAMP/WHAFIS) to estimate Base Flood Elevations (BFE) and wave conditions along each transect to map various flood zones.
- Convert locations of transitions between zones from 1-D transects to 2-D maps (Digital Flood Insurance Rate Maps, DFIRMS)

Flood Zone Definitions



http://www.r3coastal.com/home/coastal-hazard-analysis-mapping/coastal-flood-hazard-mapping

Definitions of FEMA Flood Zones

Risk Type	Zone	Description
Low to Moderate	X (unshaded)	Area of minimal flood hazard
Low to Moderate	X (shaded)	0.2% Annual Chance Flood
High Risk	A	1% Annual Chance Flood *Inland floodplains that do not have a base flood elevation (BFE)*
High Risk	AE	1% Annual Chance Flood *Special flood hazard area that has a determined elevation & wave height < 3 ft*
High Risk - Coastal	VE	1% Annual Chance Flood *Velocity zone that has a determined elevation & wave height > 3 ft*

Bath Tub Models for Coastal Flooding

Definition: Cut of topography (digital elevation model, DEM) at fixed elevation.

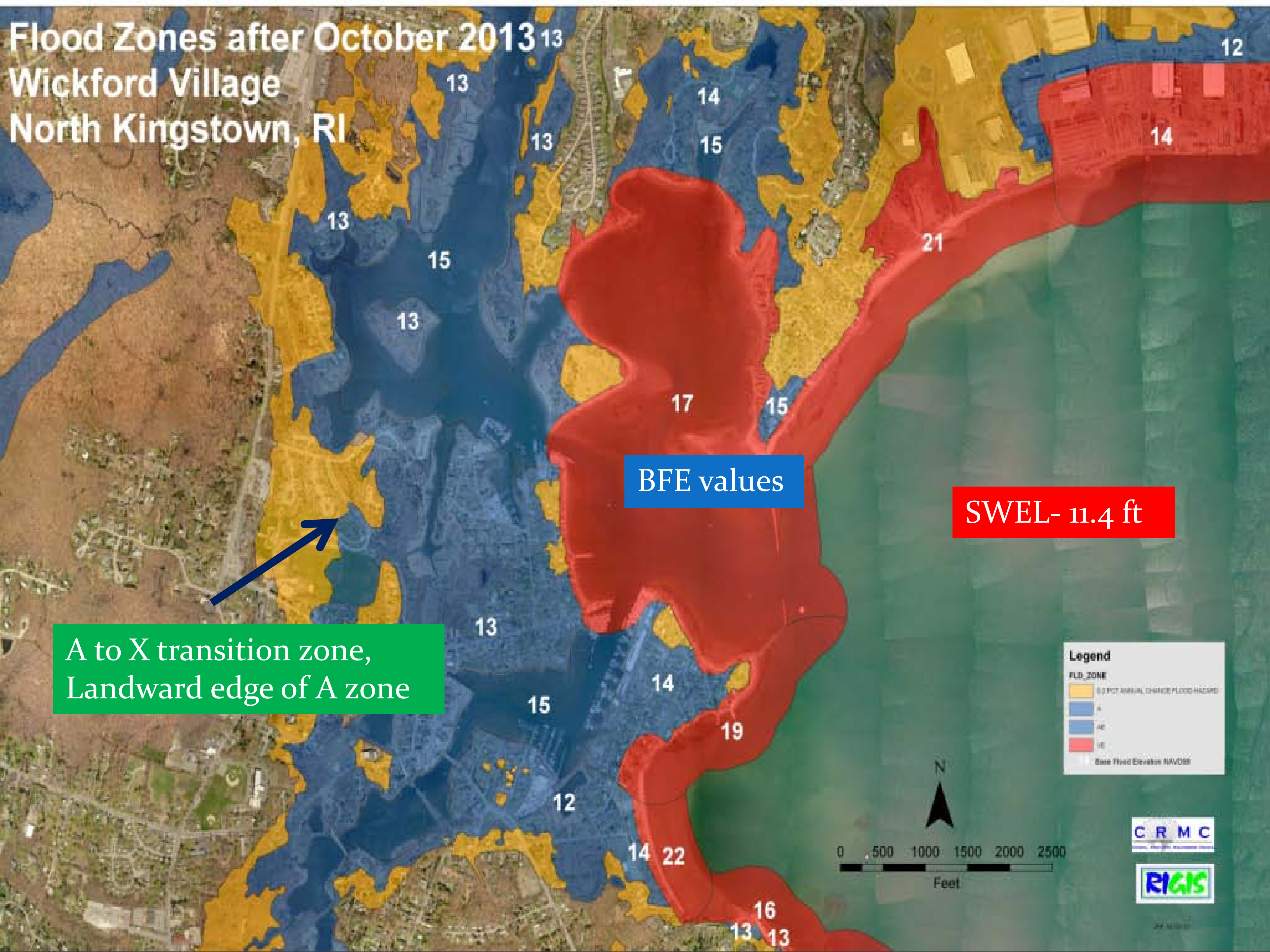
When they work:

* Still water level elevation (SWEL)/sea level rise (SLR) shows very small spatial variation (spatial scales ≤ 30 km) (e.g. SWEL increases linearly with distance up Narragansett Bay (20 % higher in Providence relative to Newport)

* Waves have no effect on water level (no wave set up or run-up)

* Area must be connected to sea (no lakes, ponds, or low lying depressions)(no multi -connected domains)

★ Reasonable proxy for landward edge of ***AE*** zone (with or without sea level rise).


Flood Zones after October 2013
Wickford Village
North Kingstown, RI
BFE values
SWEL- 11.4 ft
A to X transition zone,
Landward edge of A zone
13
13
13
13
13
15
13
12
14
15
14
21
17
15
13
14
15
19
12
14
22
16
13
13
Legend
FLD_ZONE
N
0 500 1000 1500 2000 2500
Feet
CRMC
RIGIS

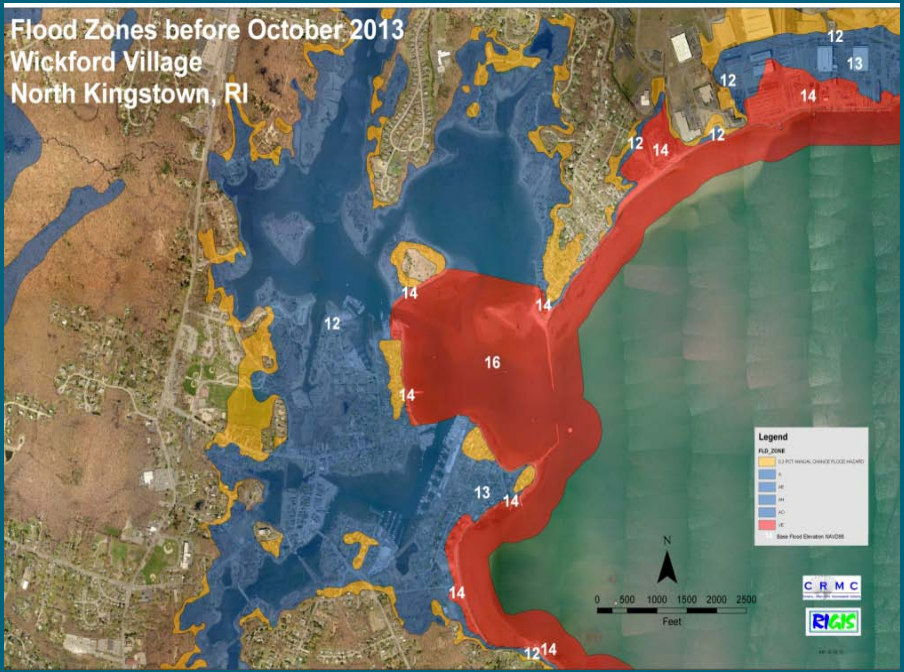
Comparison of FIRMs and Bathtub Model for Wickford Harbor

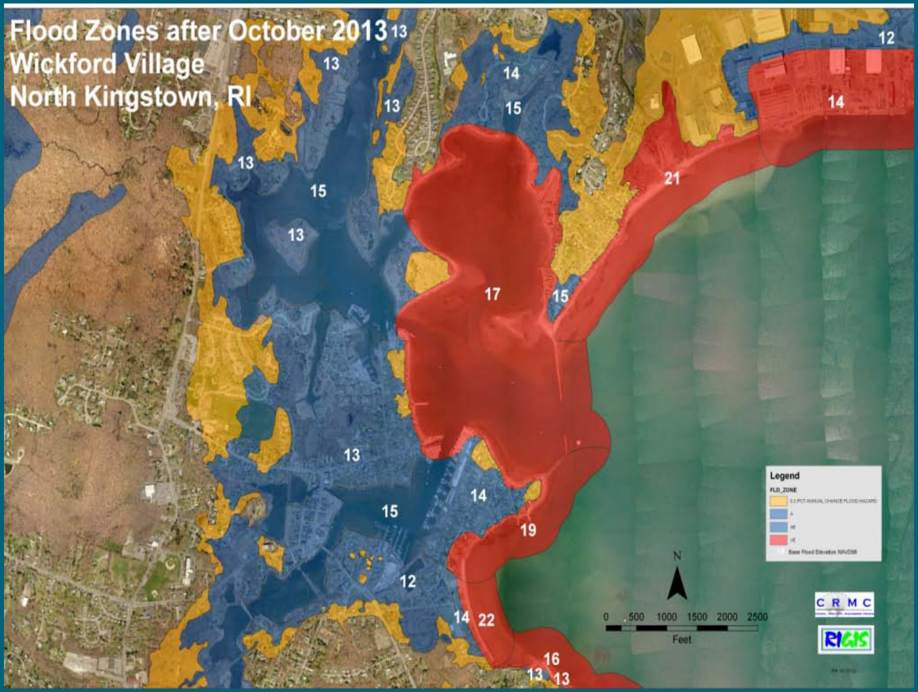
Bathtub Model - AE Zone

FEMA 2012 FIRM AE and VE Zones

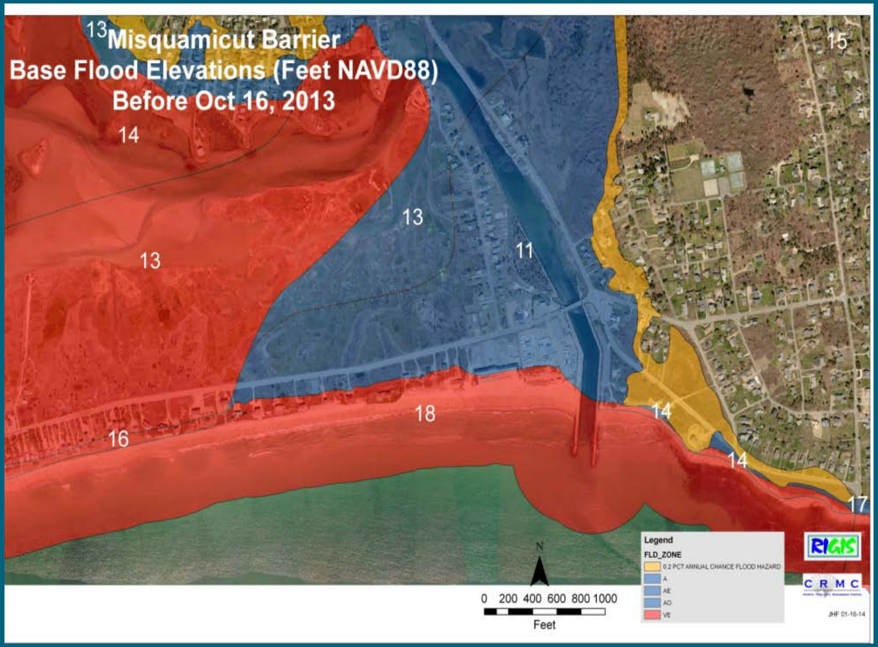
2014 Ocean Engineer Senior Design

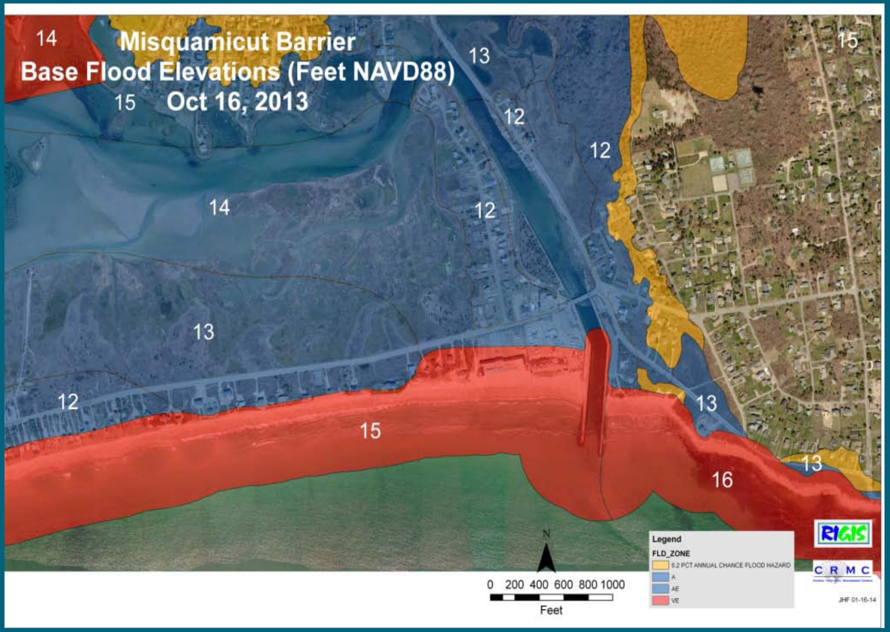
Flood Zones(2009, left and 2013 right) Wickford, RI



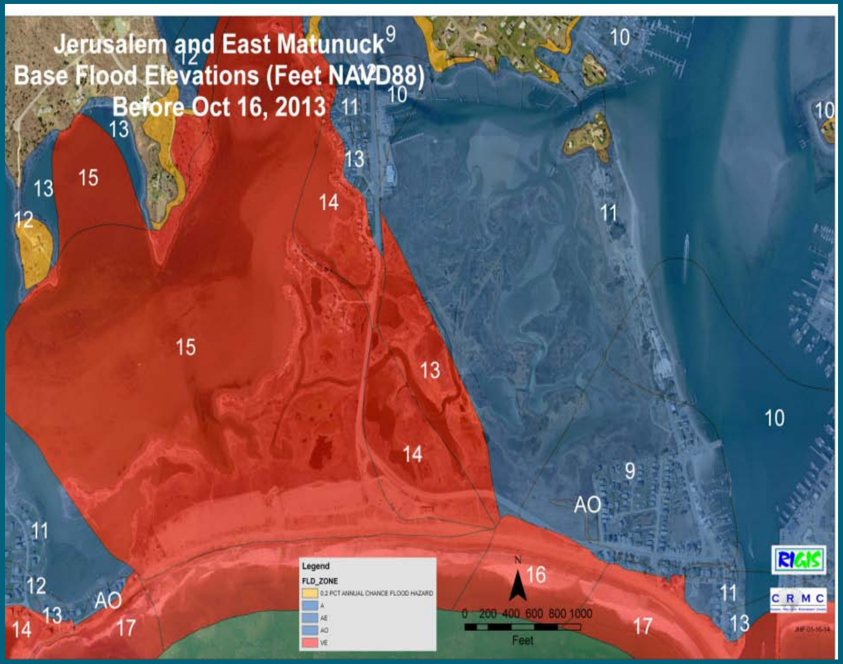


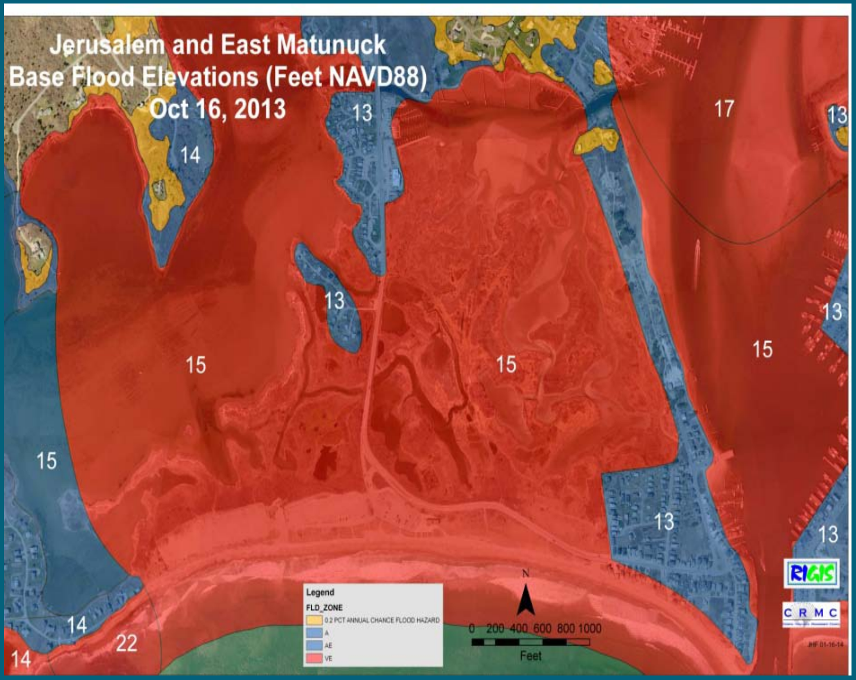
Flood Zones(2009, left and 2013, right) Misquamicut Barrier





Flood Zones(2009, left and 2013 right)





Key Question on 2013 RI FIRMS

- Why have FIRM maps changed so significantly between 2009 and 2012? Decreased BFE along southern RI coastline but increased inside Narragansett Bay. This in context of Super-Storm Sandy impacting the area but no significant change in extreme storm events in water level records used as input to the analysis.

NRC(2009) Review of Flood Mapping Methods

Recommendations from Section 5, Coastal Flood Mapping

- *FEMA should use coupled 2-D surge and wave models to reduce uncertainties associated with the use of a 2-D surge model and the 1-D WHAFIS model. Before choosing which models to incorporate into mapping practice, an analysis of the impact of various uncertainties on the models should be undertaken.*
- *FEMA should work toward a capability to use coupled surge-wave-structure models to calculate base flood elevations, starting with incorporating coupled two-dimensional surge and wave models into mapping practice.*
- *FEMA should expand collection of high-resolution topographic data to all coastal counties and require collection of post-storm topographic data to validate storm surge and wave models and improve their accuracy.*
- *FEMA should work with NOAA and the USACE to acquire high-accuracy bathymetric data in coastal, estuarine, and riverine areas.*
- *FEMA should commission an external advisory group to conduct an independent, comprehensive assessment of coastal flood models to identify ways to reduce uncertainties in the models and to improve the accuracy of BFEs.*

NRC (2009) Comments on CHAMP/ WHAFIS Transect Method

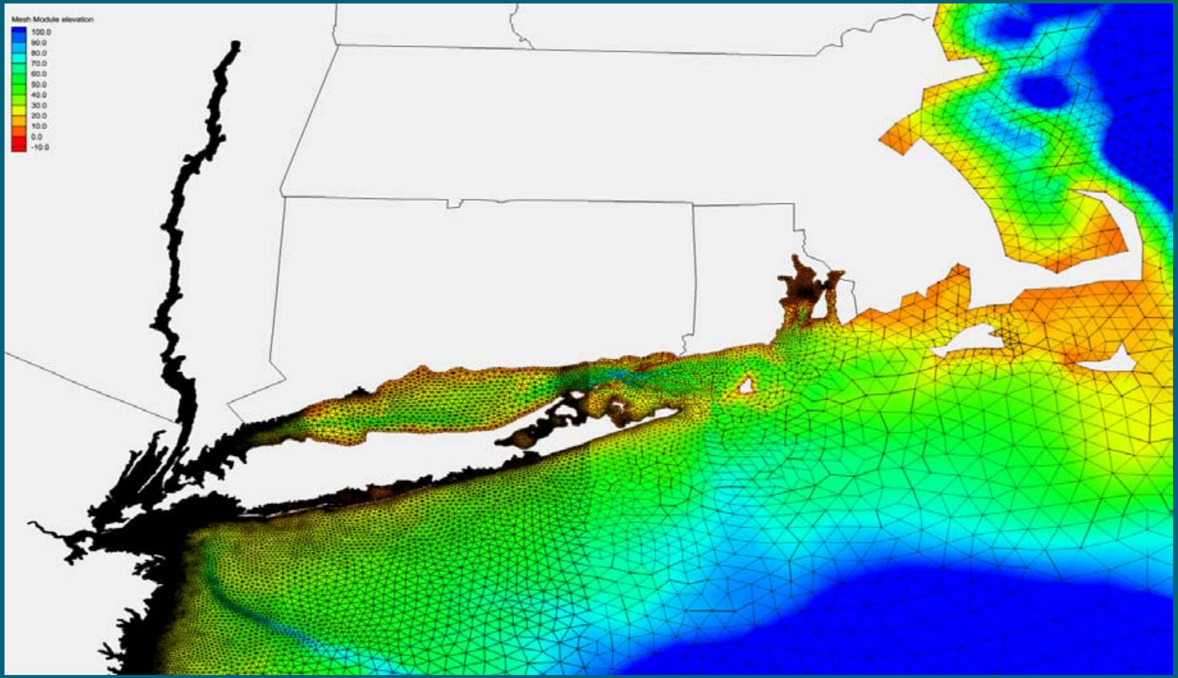
Wave crests calculated by CHAMP/WHAFIS have not been sufficiently validated, creating potentially significant uncertainties in BFE (base flood elevations) estimates. Factors that contribute to the uncertainty of WHAFIS wave crest calculations include the following:

- *Wave transformation is a 2-D process that cannot be represented in a 1-D model.*
- *WHAFIS wave crests and BFEs are not 1 percent annual chance values (i.e., probabilistic wave conditions are not incorporated in the WHAFIS calculations).*
- *Surge and wave are completely decoupled, which may lead to over- or underestimates of the BFE.*
- *The 540-square-foot rule for dune erosion (i.e., a dune exceeding a cross-sectional area of 540 square feet will not be breached in a 1 percent annual chance storm) has not been validated.*
- *The approach for wave dissipation by vegetation, buildings, and levees has not been validated.*
- *One-dimensional transects do not reflect 2-D terrain.*
- *Manual interpolation of 1-D results to two dimensions is subjective.*

Flood Mapping Methods Used in FEMA Region 2

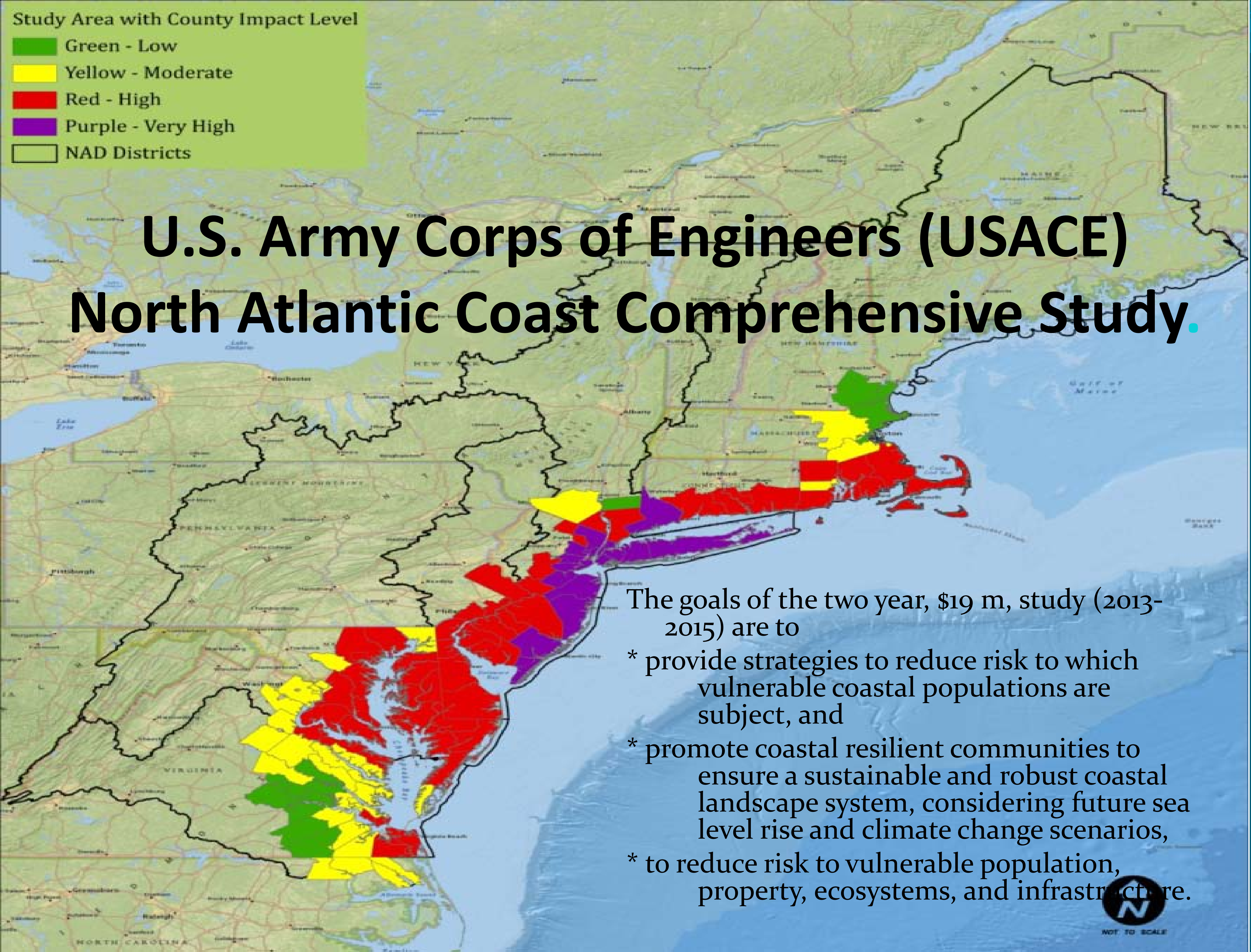
- Employ ADCIRC and UNSWAN 2-D storm surge and wave models on high resolution grid for study area covering region inundated during storms (9 m above NAVD 88) finest resolution 80 m.
- Use Joint Probability Method – Optimum Sampling – Quadrature to generate synthetic storm forcing
- Validate hydrodynamic model for tidal and storm forcing
- Perform simulations for synthetic storms and generated surge water levels and waves
- Perform near-shore assessment using WHAFIS on selected transects
- Generate FIRMs from transects.

ADCIRC-UnSWAN Grid for FEMA Region 2



Note high resolution grid from NY Bight/Jamaica Bay and SW and very coarse grid to E and NE.

U.S. Army Corps of Engineers (USACE) North Atlantic Coast Comprehensive Study.



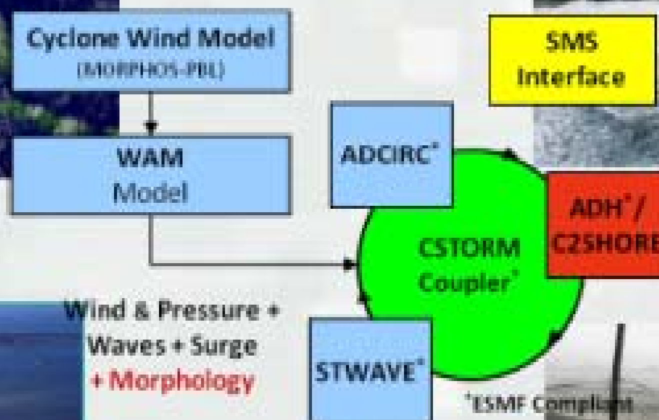
The goals of the two year, $19 m, study (2013-2015) are to

* provide strategies to reduce risk to which vulnerable coastal populations are subject, and
* promote coastal resilient communities to ensure a sustainable and robust coastal landscape system, considering future sea level rise and climate change scenarios,
* to reduce risk to vulnerable population, property, ecosystems, and infrastructure.

ERDC's Coastal Storm-Modeling System

(ERDC CSTORM-MS)

Application of high-resolution, highly skilled numerical models in a tightly integrated modeling system with user friendly interfaces



Not just hurricanes and not just in the Gulf of Mexico.

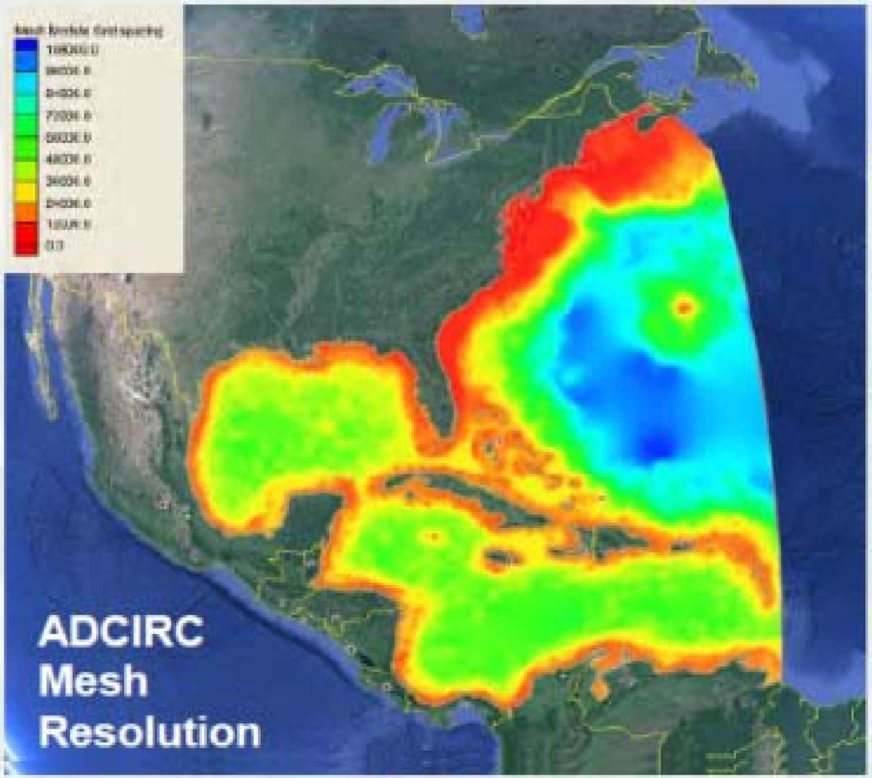
Expandable and upgradeable system.

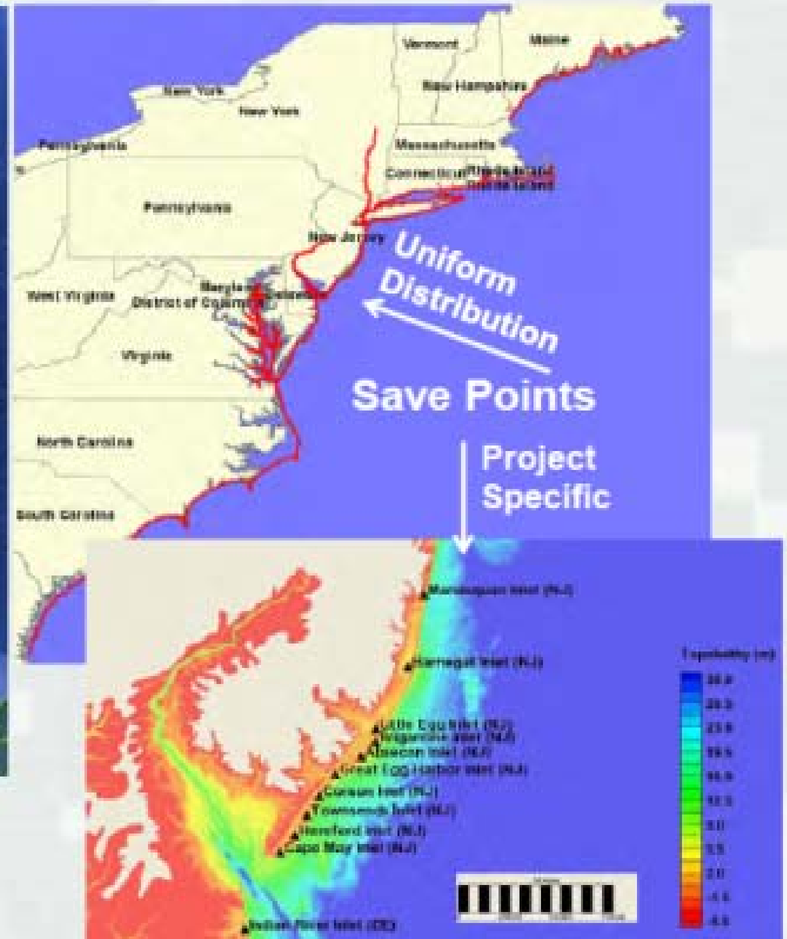
Next Generation Workflow

Provides for a robust, standardized approach to establishing the risk of coastal communities to future occurrences of storm events.

CSTORM-MS COASTAL STORM MODELING SYSTEM

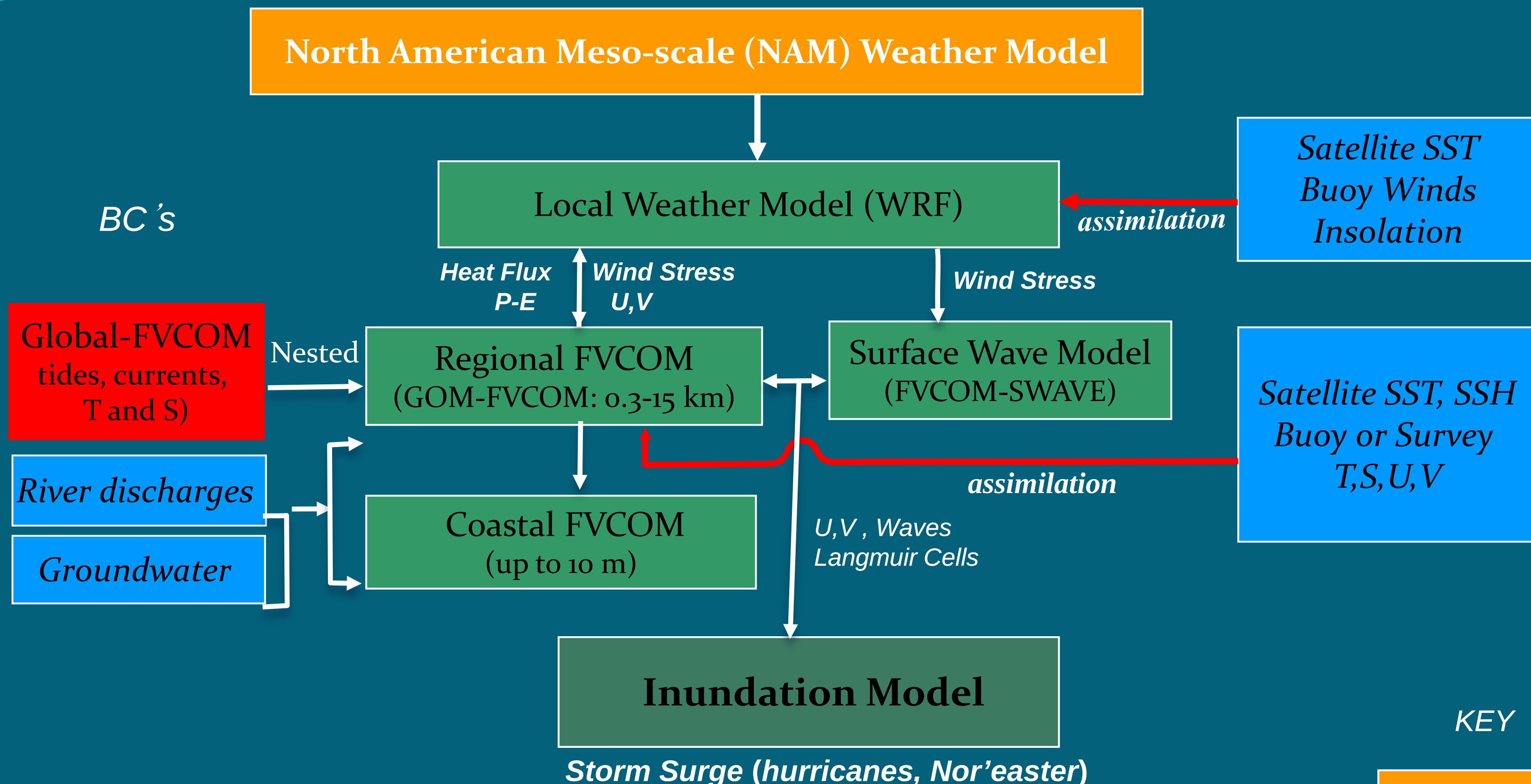
Grids and Save Points





~ 6.2 million nodes
Resolution from 10 m to 100 km

Northeast Coastal Ocean Forecast System (NECOFS)

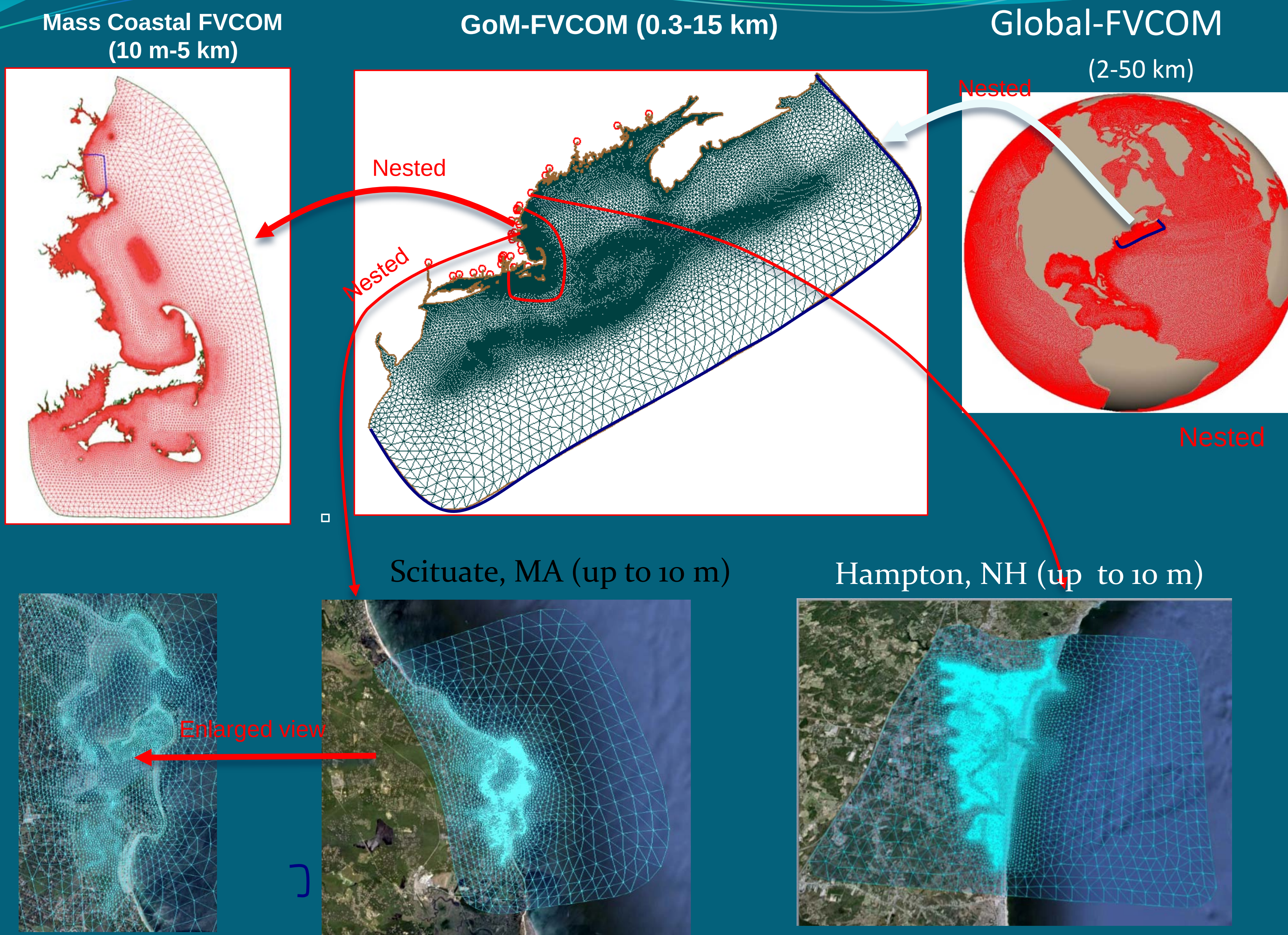


Products:
Weather: winds, air temperature, air humidity, air pressure, heat flux, E-P
Oceans: sea level, currents, T, S, wave heights, wave frequencies, icing
Lands: inundation areas

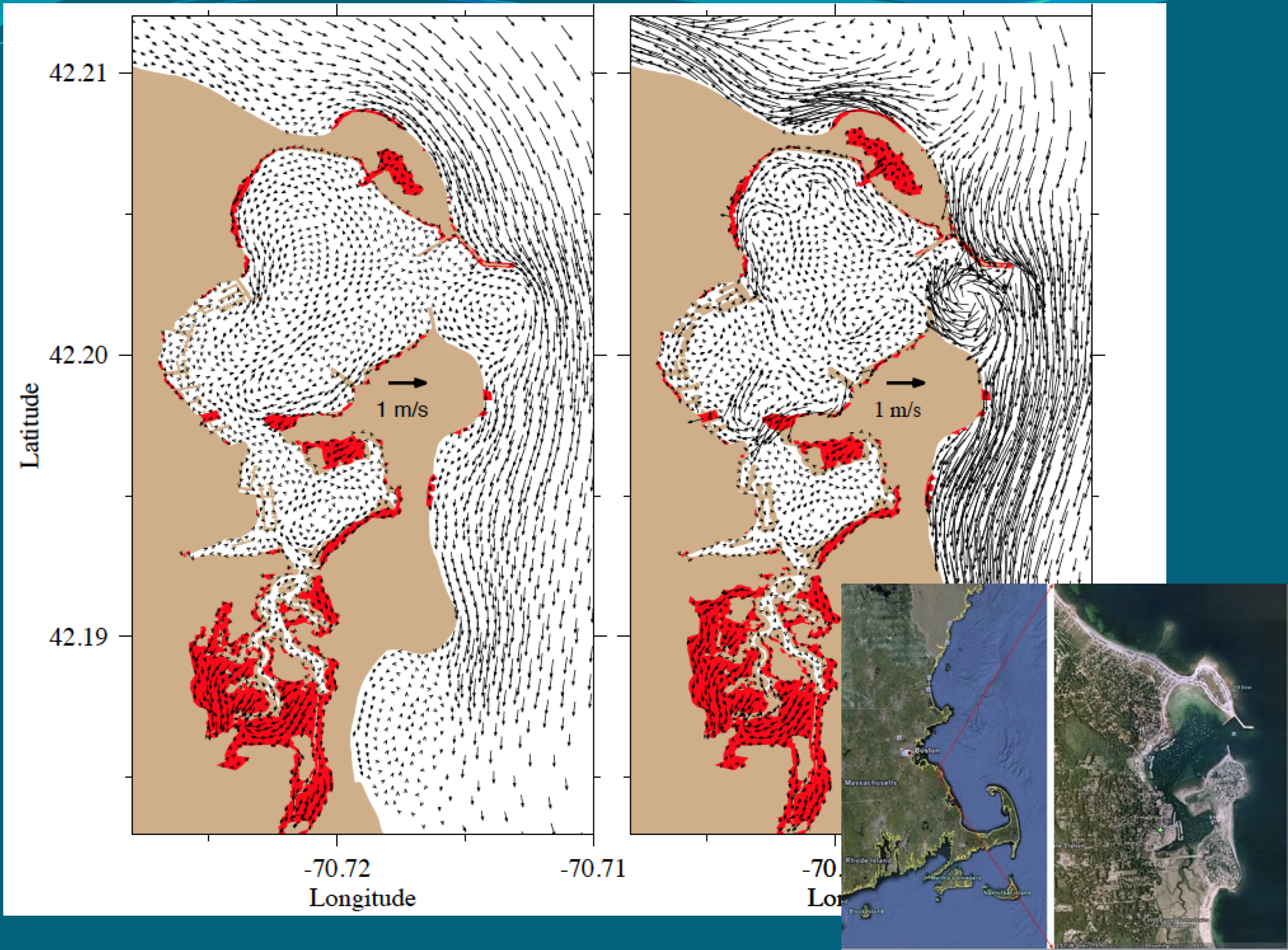
KEY

- **Existing Models**
- **NECOFS**
- **Data**
- **Products**
- **To Be Developed**

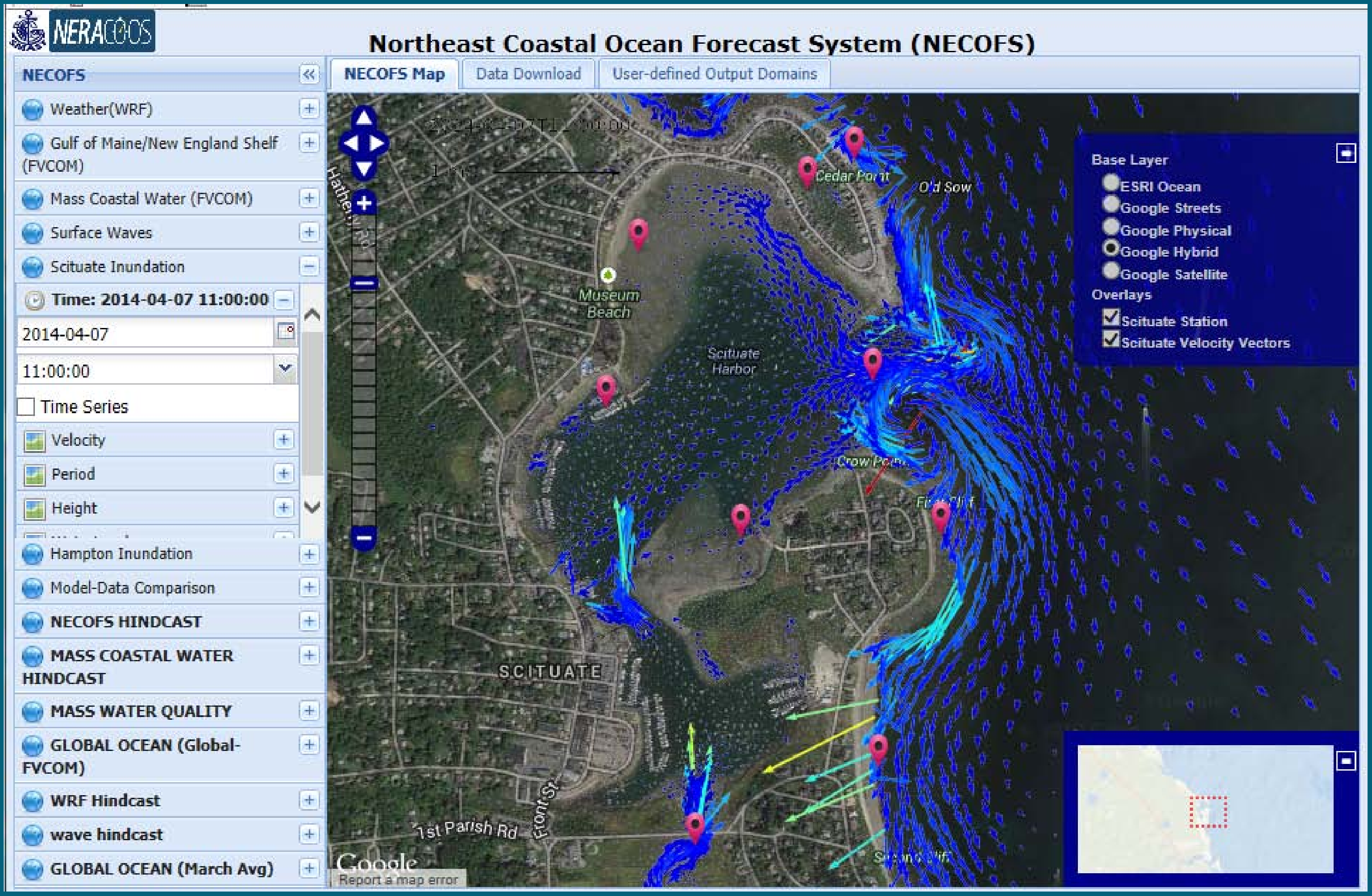
05/29/2013-MIT


Mass Coastal FVCOM
(10 m-5 km)
GoM-FVCOM (0.3-15 km)
Global-FVCOM
(2-50 km)
Nested
Nested
Nested
Nested
Scituate, MA (up to 10 m)
Hampton, NH (up to 10 m)
Enlarged view

No waves **With waves**



NECOFS Scituate Harbor Forecast, April 7, 2014



http://fvcom.smast.umassd.edu/necofs/or:
http://porpoise1.smast.umassd.edu:8080/fvcomwms/

Last mile problem

- **North Atlantic Comprehensive Coastal Study** provides quality, state of art predictions along the coast but the resolution is not sufficient for local studies.
- CSTORM-MS program anticipates that this level of analysis will be a local responsibility, funded for a specific project or activity.
- Given the sophistication of the tools and the talent required to make use of them, the cost of analysis is likely to be significant and a barrier to use

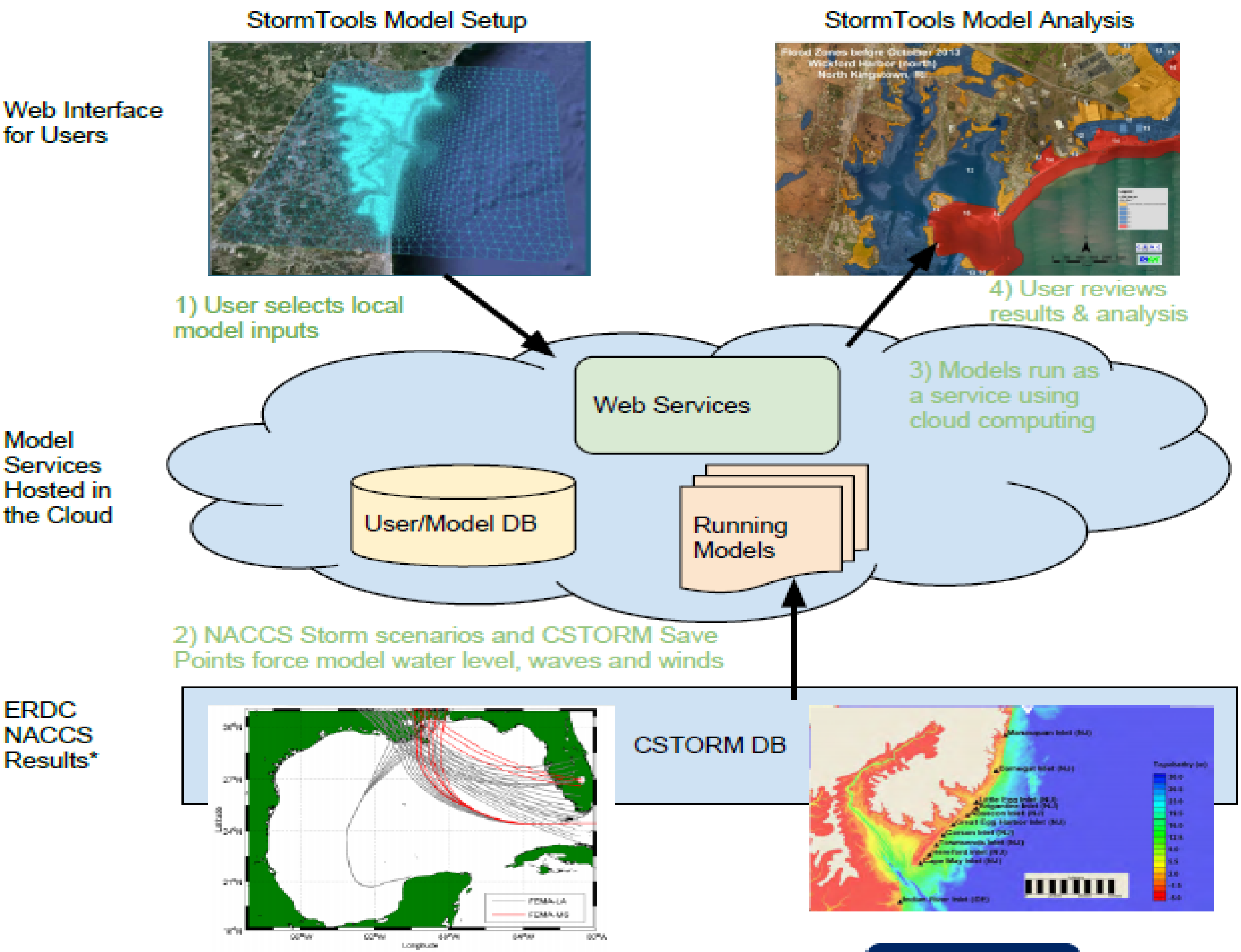
Last Mile : Link CSTORM or similar to local studies

Classic ***downscaling*** problem currently used in assessing climate change impacts on local regions.

Vision for STORM TOOLS

- Develop a system that provides access to a suite of coastal planning tools (numerical models et al) available as a web service that allows wide spread accessibility and applicability at high resolution to user selected coastal areas of interest.
- Tools to predict winds, waves, and currents with and without sea level rise. The models would link directly to the hindcast fields provided at the CSTORM web site or local systems (e.g. NECOFS or other regional association model system).
- The models and associated data bases would reside on the web server site and run remotely via the web. The system could be hosted by NOAA CSC, IOOS RA, Army Corp, et al or on the cloud.

Use STORM TOOLS to generate FIRMS



*Further development will integrate other optional data sources for large scale forcing and inundation scenarios

Web Accessible Tools

- Hurricane and storm wind and pressure fields
- Integrated storm surge and wave models
  - NOAA SLOSH
  - ADCIRC and SWAN (unstructured grid)
  - FVCOM and SWAN (unstructured grid)
  - STWAVES (near shore waves)
  - CHAMP and WHAFIS
- Sea Level Rise Affecting Marshes Model (SLAMM)
- Other emerging model systems

NOAA Digital Coast

- **Approach:** Bring the geospatial and coastal management communities together
- **Outcome:** A constituent-driven, integrated, enabling platform supporting coastal resource management that is used

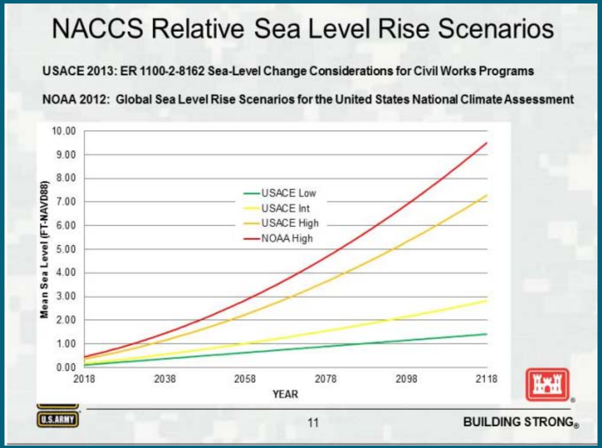
DIGITAL COAST
NOAA COASTAL SERVICES CENTER

Benefits of the approach

- Universal access, with link to CSTORM-MS or NECOFS data or similar regional model.
- Substantial leverage of results from the North Atlantic Comprehensive Study to assist local resilience analysis and planning.
- Applicable to any area, at user defined resolution.
- Ability to develop study area grids at a variety of locations and differing resolutions.
- Allows non specialist to readily access model results and to perform simple simulations. Allows professional to access state of the art simulation tools that have been validated by the government and accepted in the technical community.
- Reduce the cost and time to perform sophisticated analyses for storm surge and coastal sea level rise planning

Incorporation of Sea Level Rise into Flood Mapping

- Estimate sea level rise for area and year of projection (say 1 m by 2050 following NOAA /USACE, standard approach)
- Climate change has additional effects that need to be considered



-Change in rainfall patterns and rates (alters runoff and hence flows for various return periods)

-Change in storm forcing (more intense/frequent storms)

Consider using downscaled IPCC projections

Options for FEMA Flooding Maps

- Current maps serve as FIRMs and also used for planning …different time scales and uses
- Develop two sets of flooding maps

  - FIRMS focused on flood insurance*

  - Flooding with sea level rise using various IPCC scenarios focused on coastal planning

  * Need to consider future sea level rise projections if map revision rate is slow.

Uncertainty and validation of predictions

- No formal treatment of uncertainty in FEMA process

  Sources of uncertainty: BFE, DEMs, wind forcing fields, hydro and wave model predictive performance)

  (note maps are given in terms of BFE/waves vs return probability, so uncertainty inherent in process but not documented).

- Validation is difficult but generally weak, water levels at NOAA stations… temporary surge markers/ water levels USGS.

(http://54.243.149.253/home/webmap/viewer.html?webmap=c07fae08c20c4117bdb8e92e3239837e)

Progress in implementing and testing of STORM TOOLS

- Porting of NECOFS (WRF-FVCOM-SWAN) forecasting system to the cloud in progress.
- Proposals submitted to NWFW and HUD for Sandy Supplement Funds to support application to selected portions of Southern RI and Narragansett Bay coastal areas.
- Application of STORM TOOLS to generate FIRMS for Washington County, RI as a test case, in discussion among RIEMA/CRMC and FEMA.