CAPE COASTAL CONFERENCE

Linking Science with Local Solutions and Decision-Making

Storm Surge Risk Modeling and Coastal Engineering Adaptations in a Changing Climate

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Outline

1. Combined Sea Level Rise and Storm Surge Risk
2. Preparedness Planning
3. Vulnerability Assessment
4. Engineering Adaptation Options and Examples

Photo by John Minchilo, AP

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Background on Sea Level Rise

- Sea Level Rise (SLR)
  - Thermal expansion of ocean water
  - Increased input of water from land-based sources
- Northeast SLR is higher than global average
  - 1.75 mm/yr (Maine) to 6.05 mm/yr (Virginia)
  - Changes in Ocean Circulation (Yin et al., 2009)

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Background on Sea Level Rise

- Eustatic versus Relative SLR
  - Eustatic => Increase in Ocean Volume (SLR)
  - Relative => SLR and local land movement (local tide gauges)

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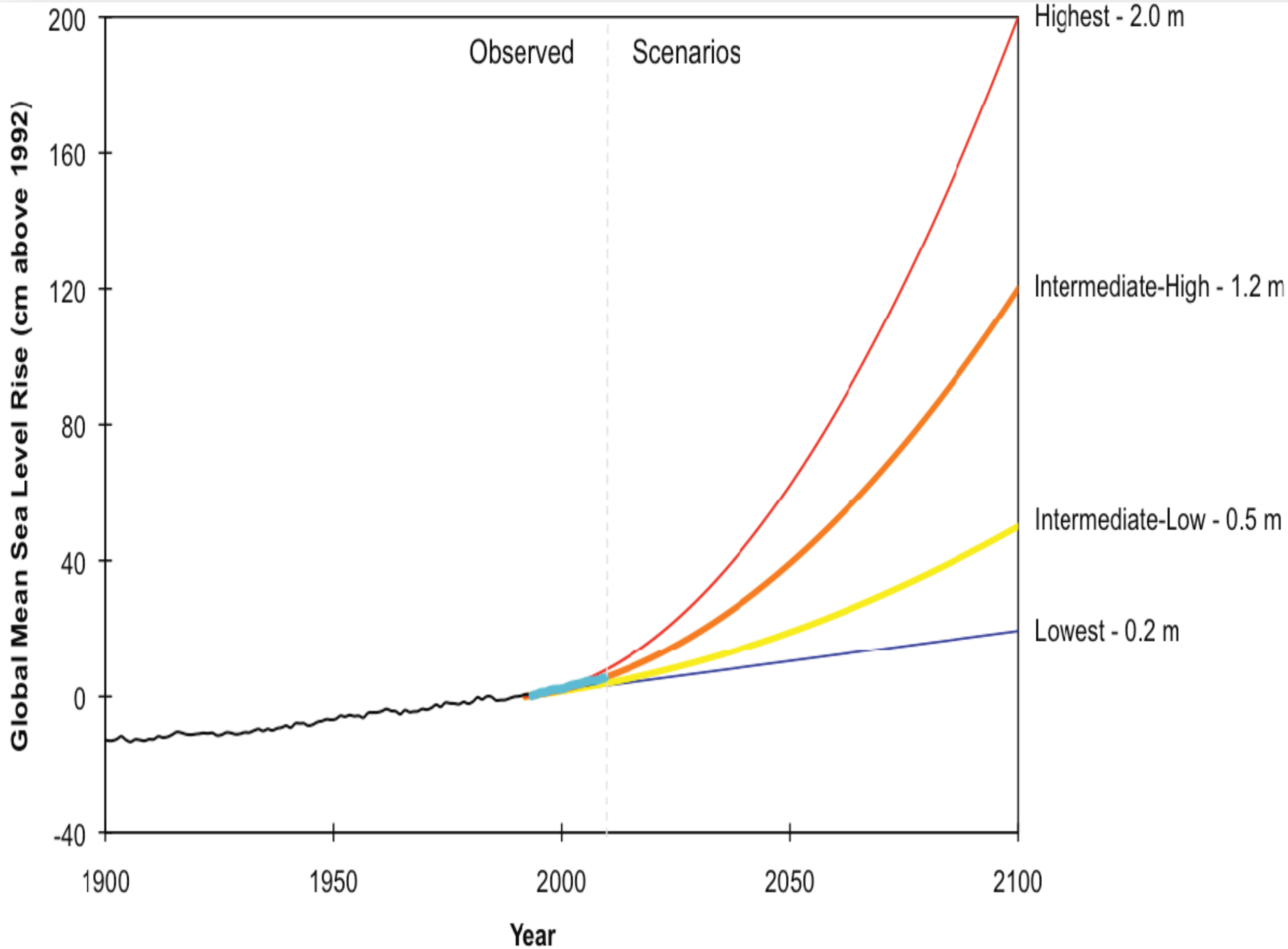
Wide Range of Projections



(NOAA, 2012)

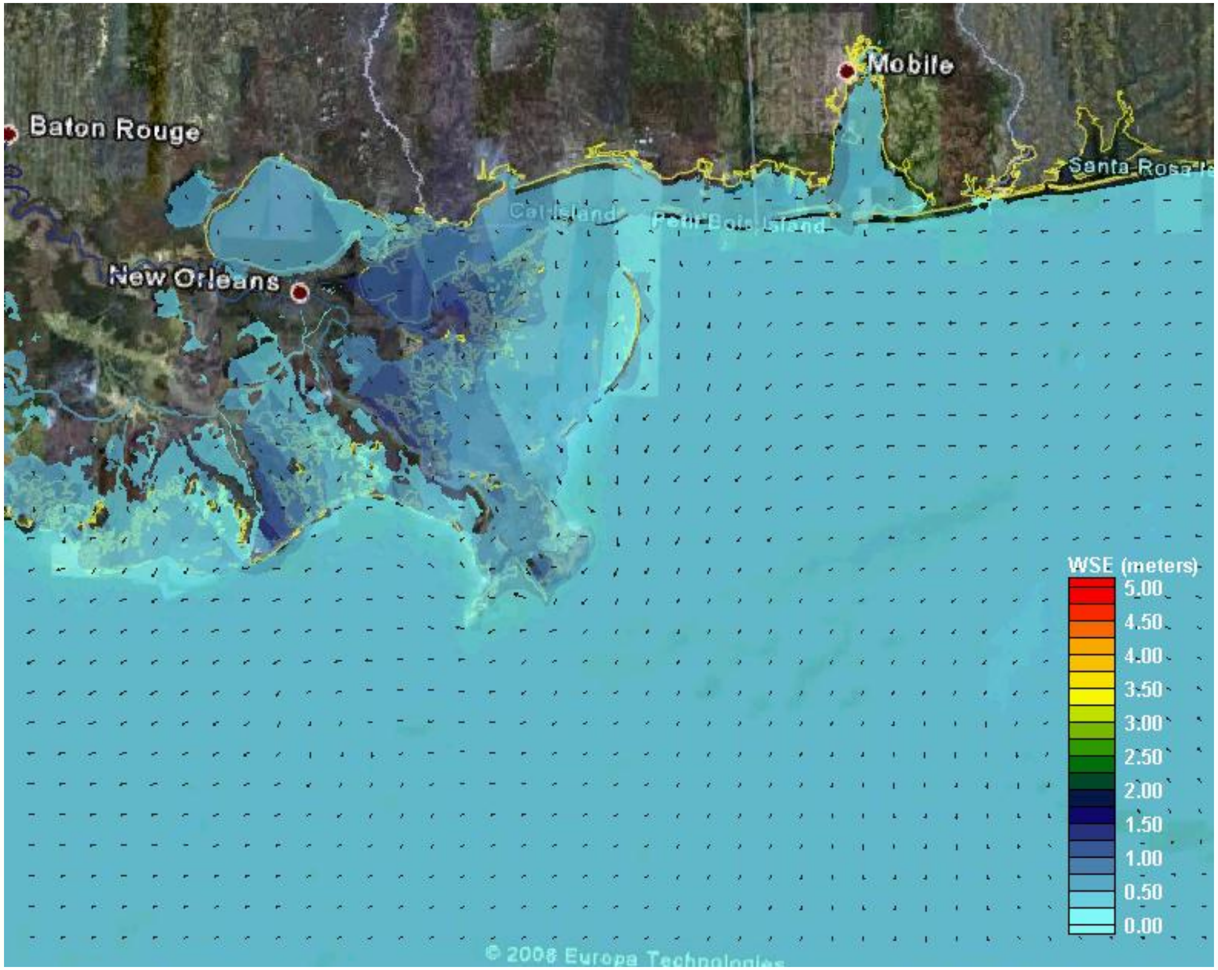
Pfeffer et al.

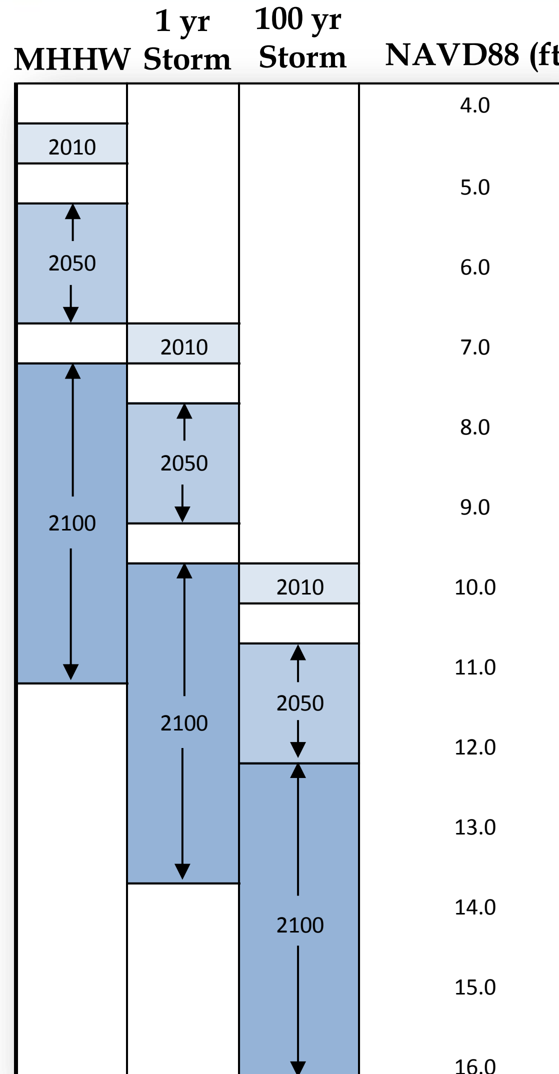
Average of:

Vermeer & Rahmstorf
Horton et al.
Jevrejeva et al.
Grinsted et al.

IPCC 95% CI

Importance of Storms





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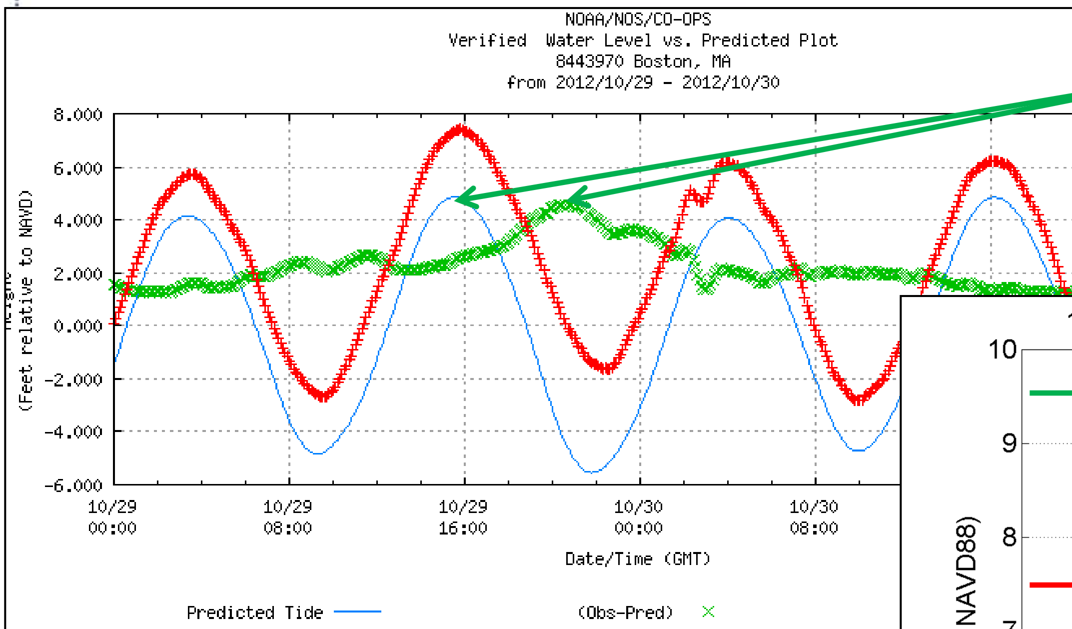
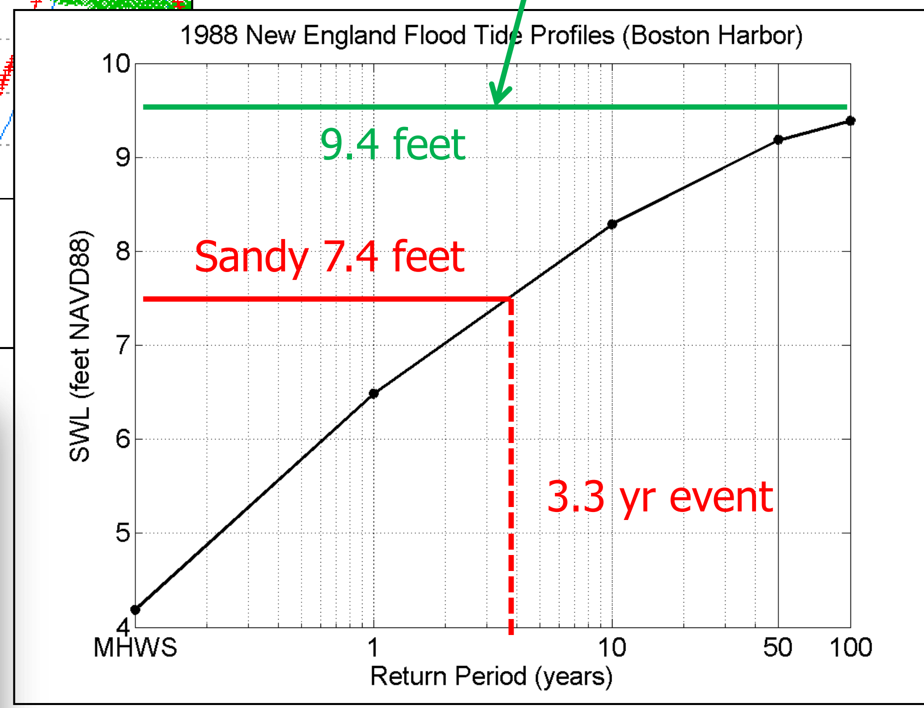
Sandy in Boston



If peaks were simultaneous…



$50 billion damages in NYC

Climate Change Preparedness

1. Vulnerability Assessment
   - Assess current vulnerabilities
   - Project future conditions
   - Evaluate processes and flood pathways
   - Analyze system sensitivity and resiliency

Small Change -> large system response (sensitivity)

System is prepared to accommodate (resiliency)

2. Develop Preparedness Plan over Time and Scale
   - Managing risk in the face of uncertainty
   - Multiple scales: National down to individual buildings
   - Times to re-act: Actions now and into the future
   - Balance of robustness and flexibility
   - Identify adaptation options based on risk tolerance
     1. No Action
     2. Accommodate ("Living with water")
     3. Protect ("Keep water out")
     4. Retreat

Range of adaptation options (Accommodate, Protect)

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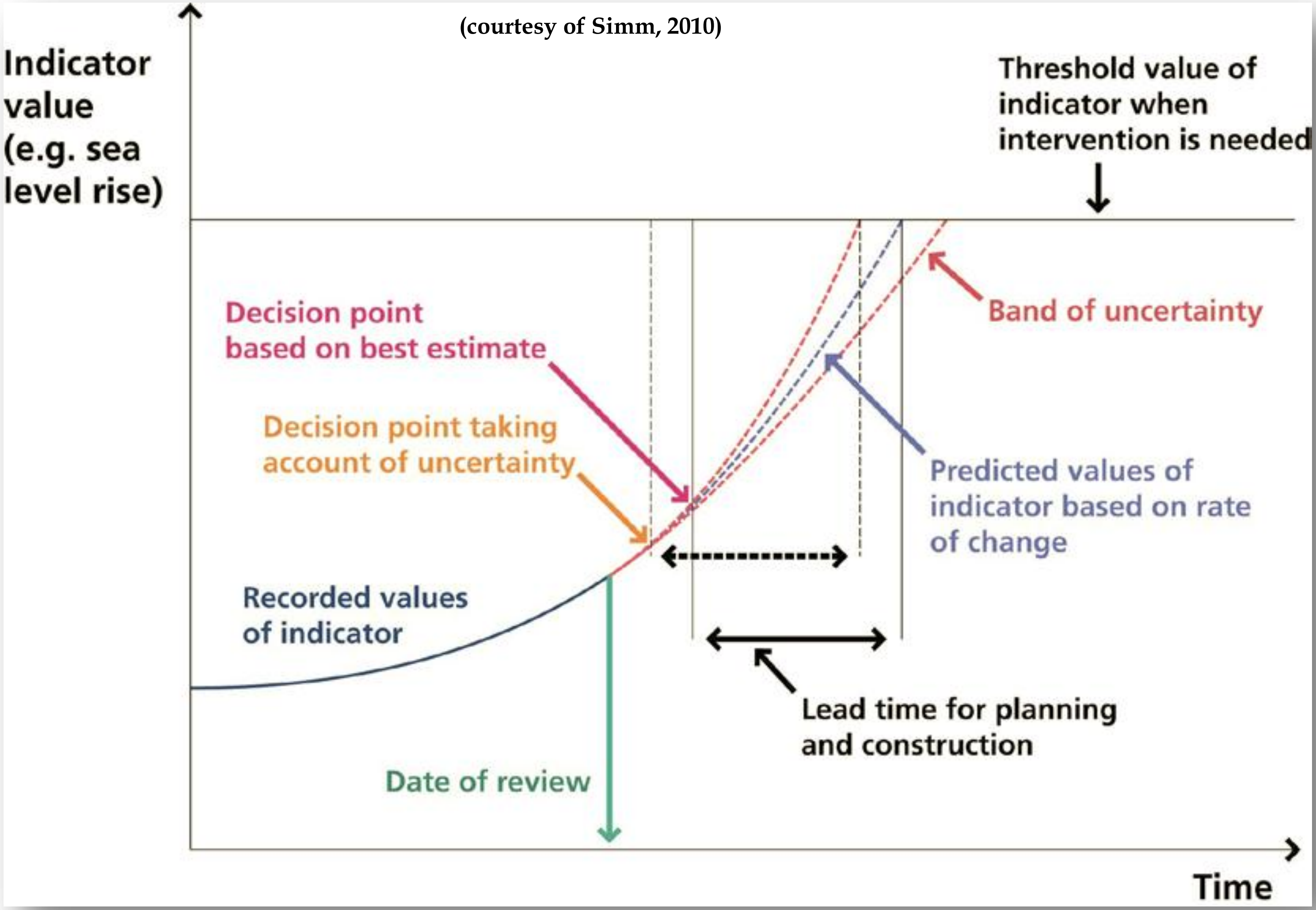
SLR Planning Process

(courtesy of Simm, 2010)



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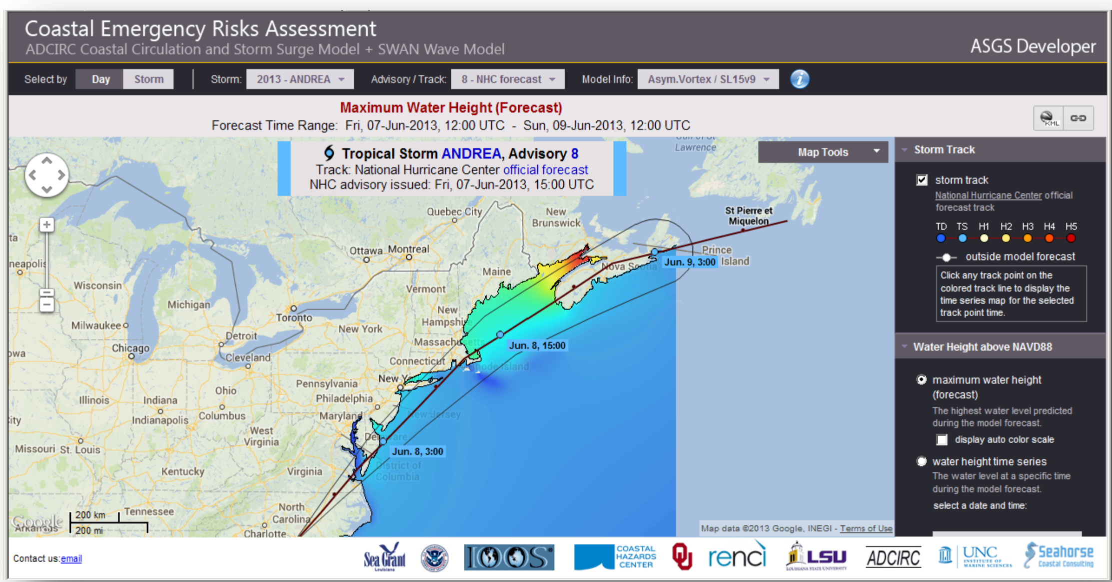
Vulnerability and Adaptations

- Post Katrina forensic studies
- Louisiana FIRM appeals
- Coastal Emergency Risks Assessment (ASGS operation)
- Combined SLR and surge risk for EPA's National Coastal Property Model
- Groton and Groton Long Pt, CT
- East Boston and Long and Central Wharves, MA
- Shinnecock Nation, Long Island
- Boston Harbor Association - Preparing for the Rising Tide
- MassDOT-FHWA Boston Central Artery Pilot Project



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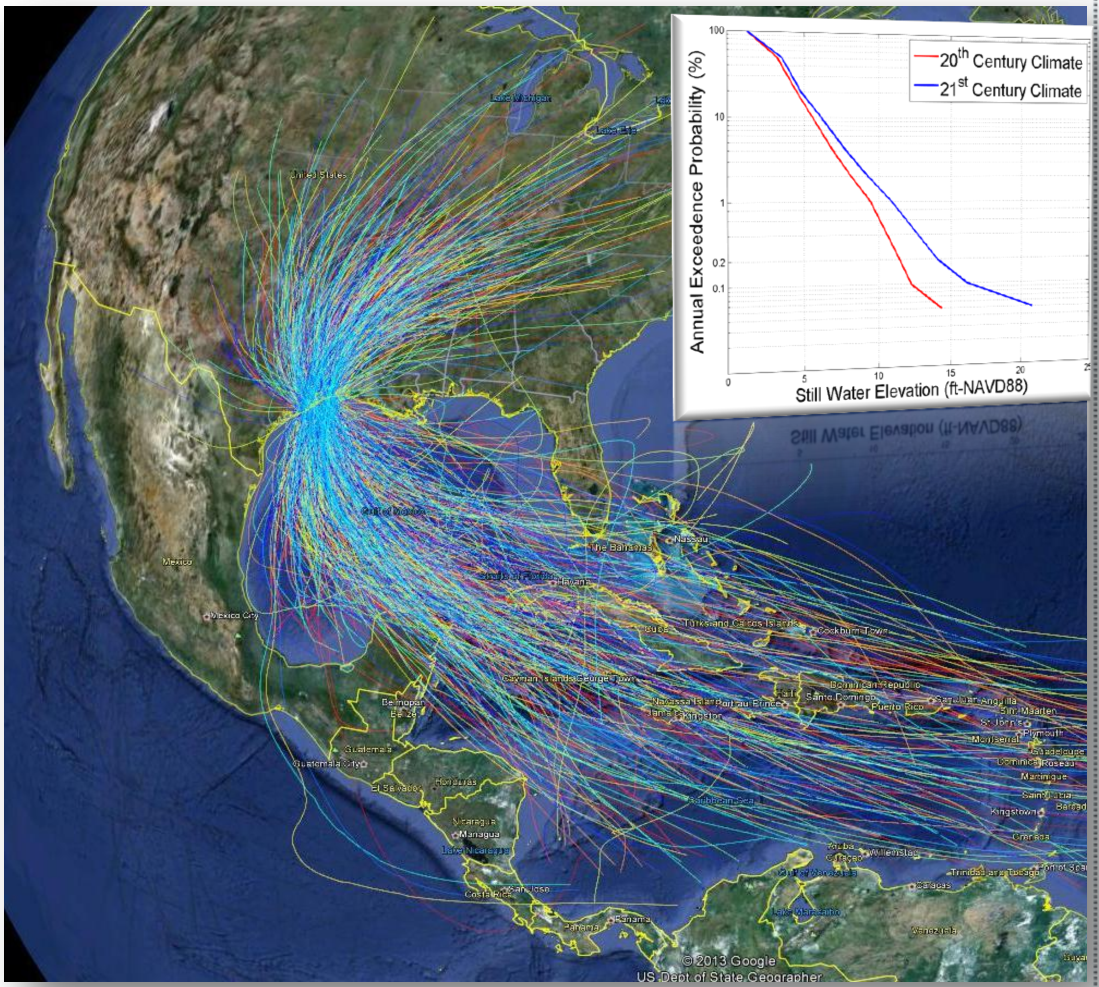
Vulnerability Assessment

- Includes all relevant physical processes (tides, storm surge, wind, waves, wave setup, river discharge, sea level rise)
- Inundation maps based on standard “bathtub” model do not reflect dynamic nature of coastal flooding (e.g., bathymetry, coastal geometry, infrastructure, frictional effects, and processes)
- FEMA is only backward looking
- A large statistically robust set of storms (Emanuel, et al., 2006)
- Present and future climate scenarios simulations
- Develop water level cumulative distribution functions



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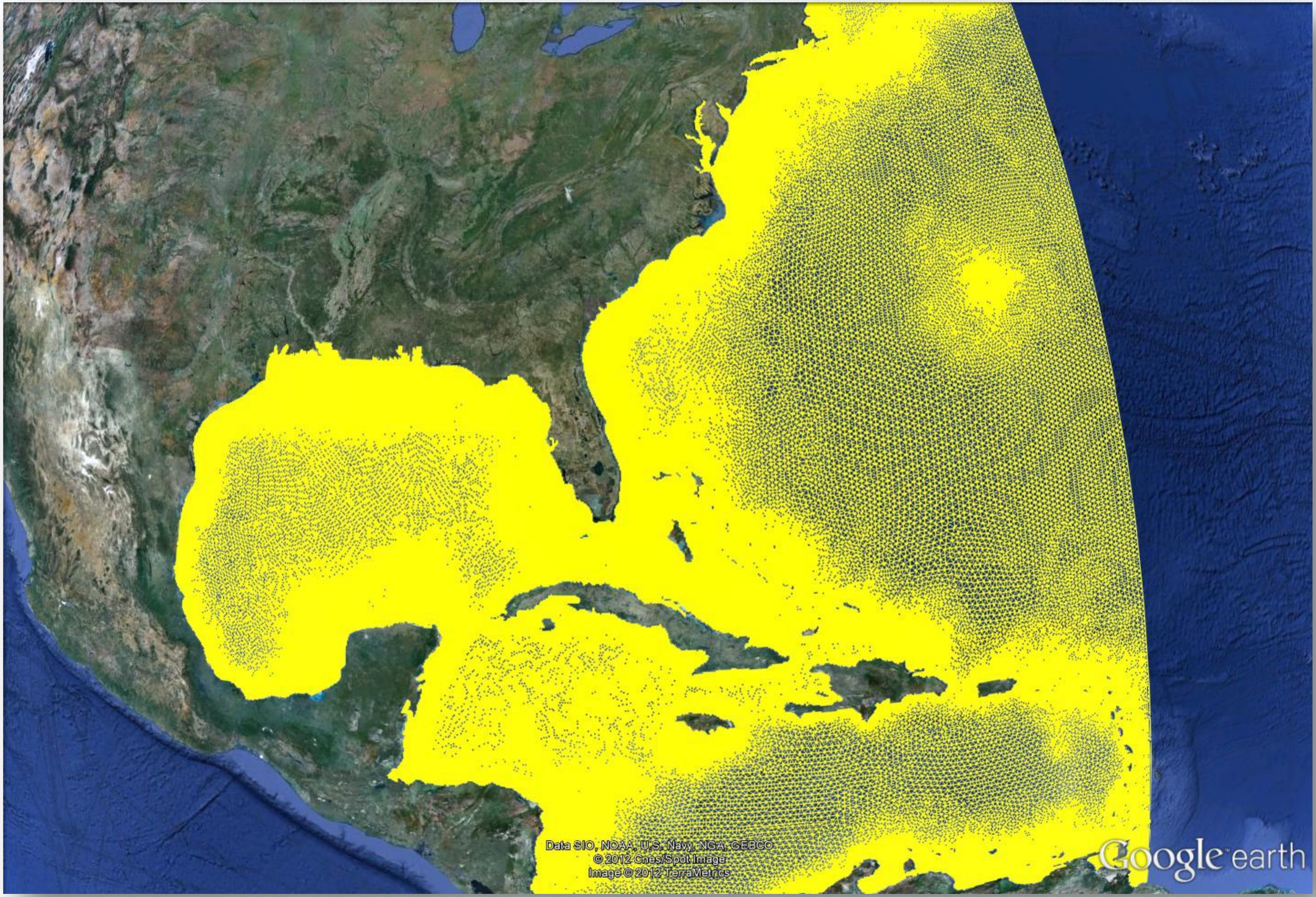
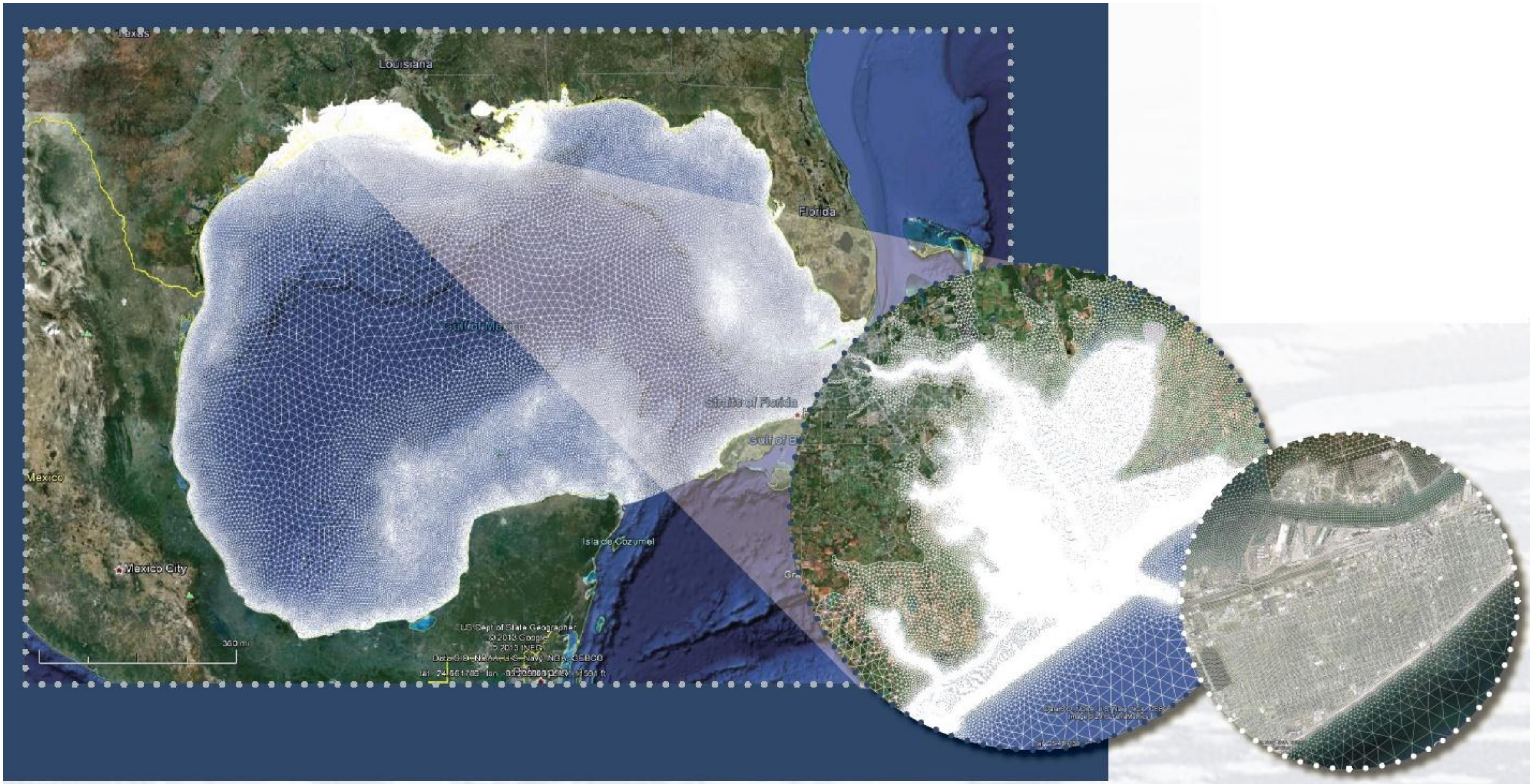
Storm Surge Modeling



Storm Surge Modeling



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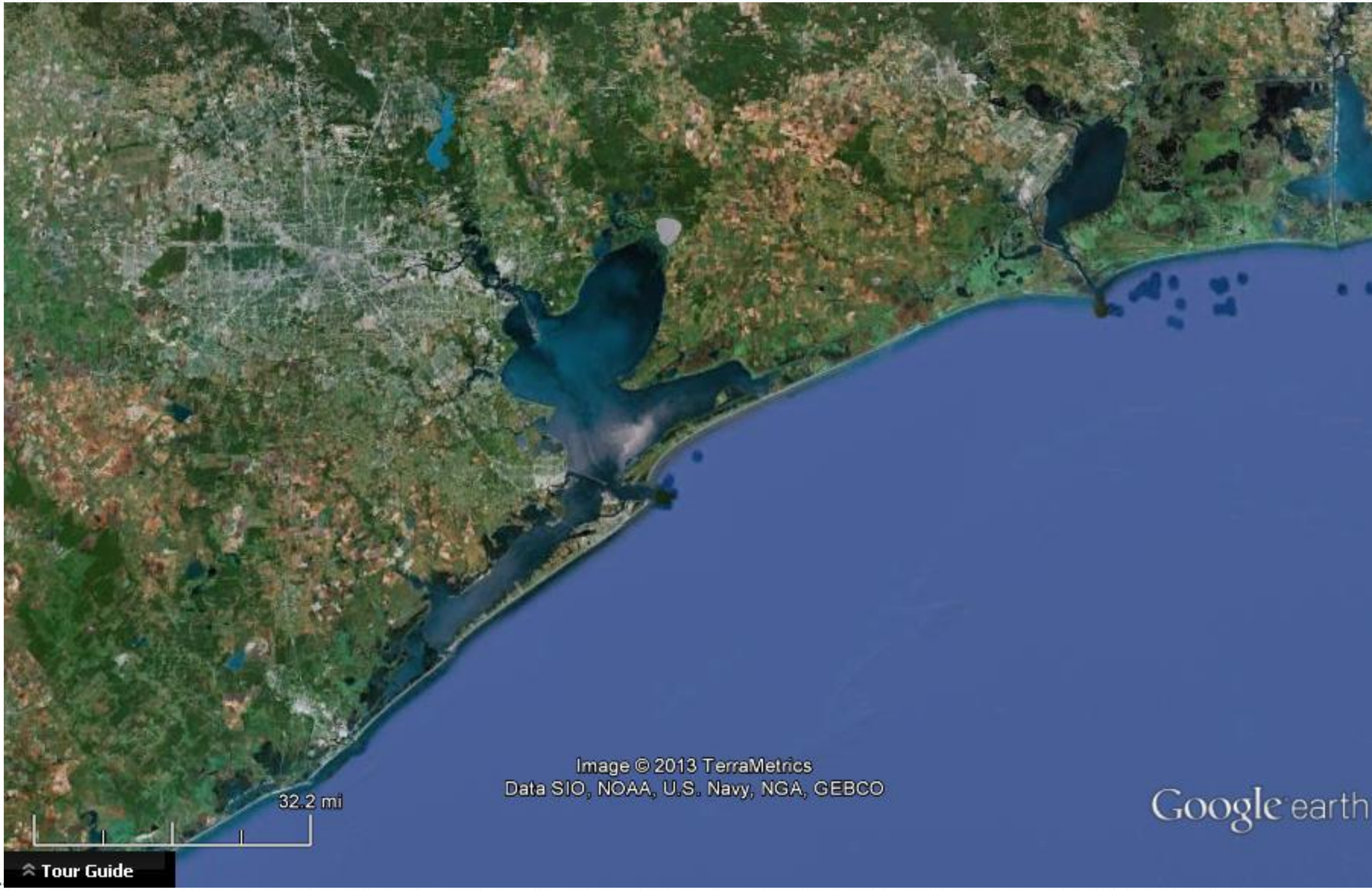
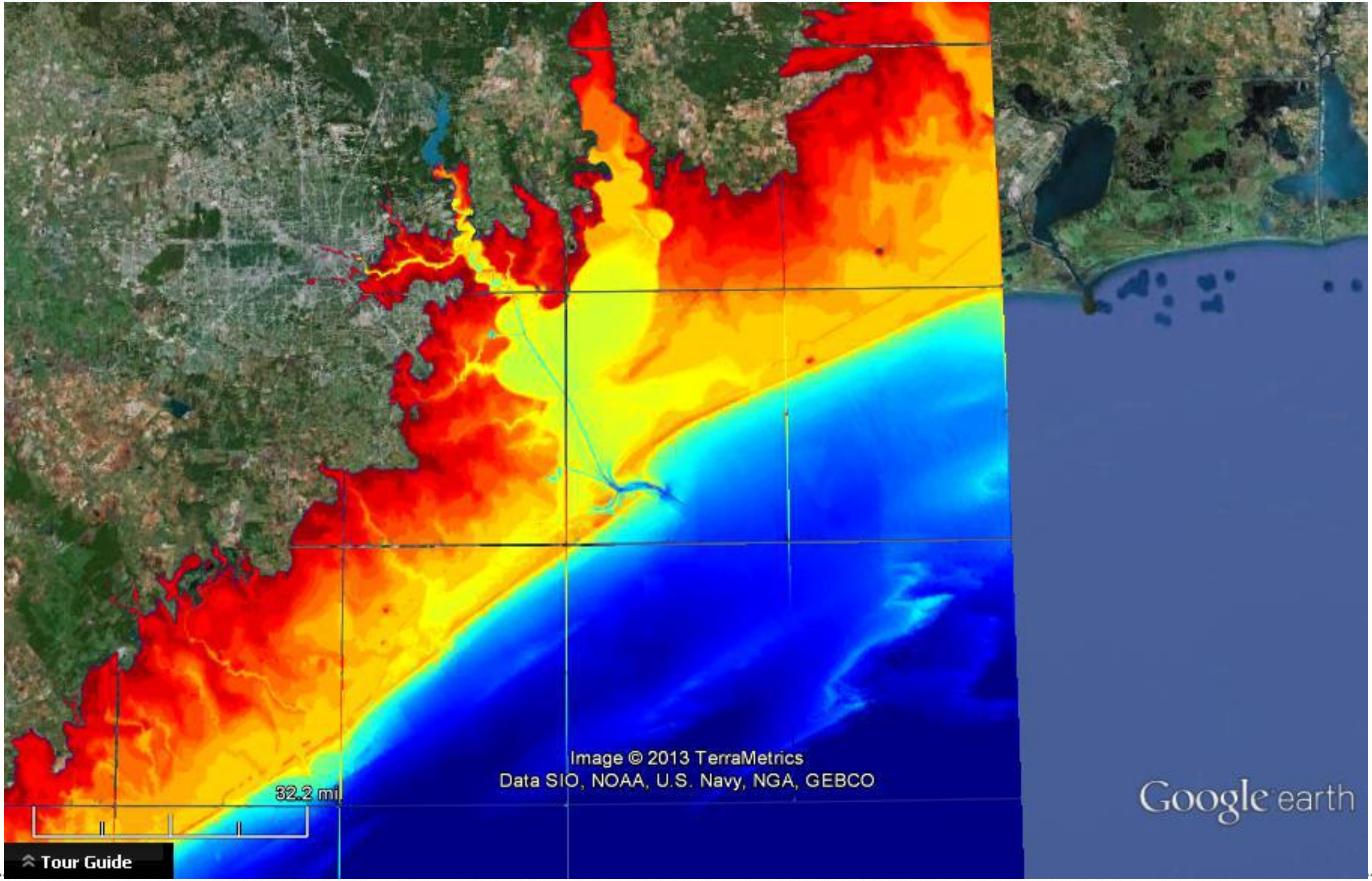
Storm Surge Modeling



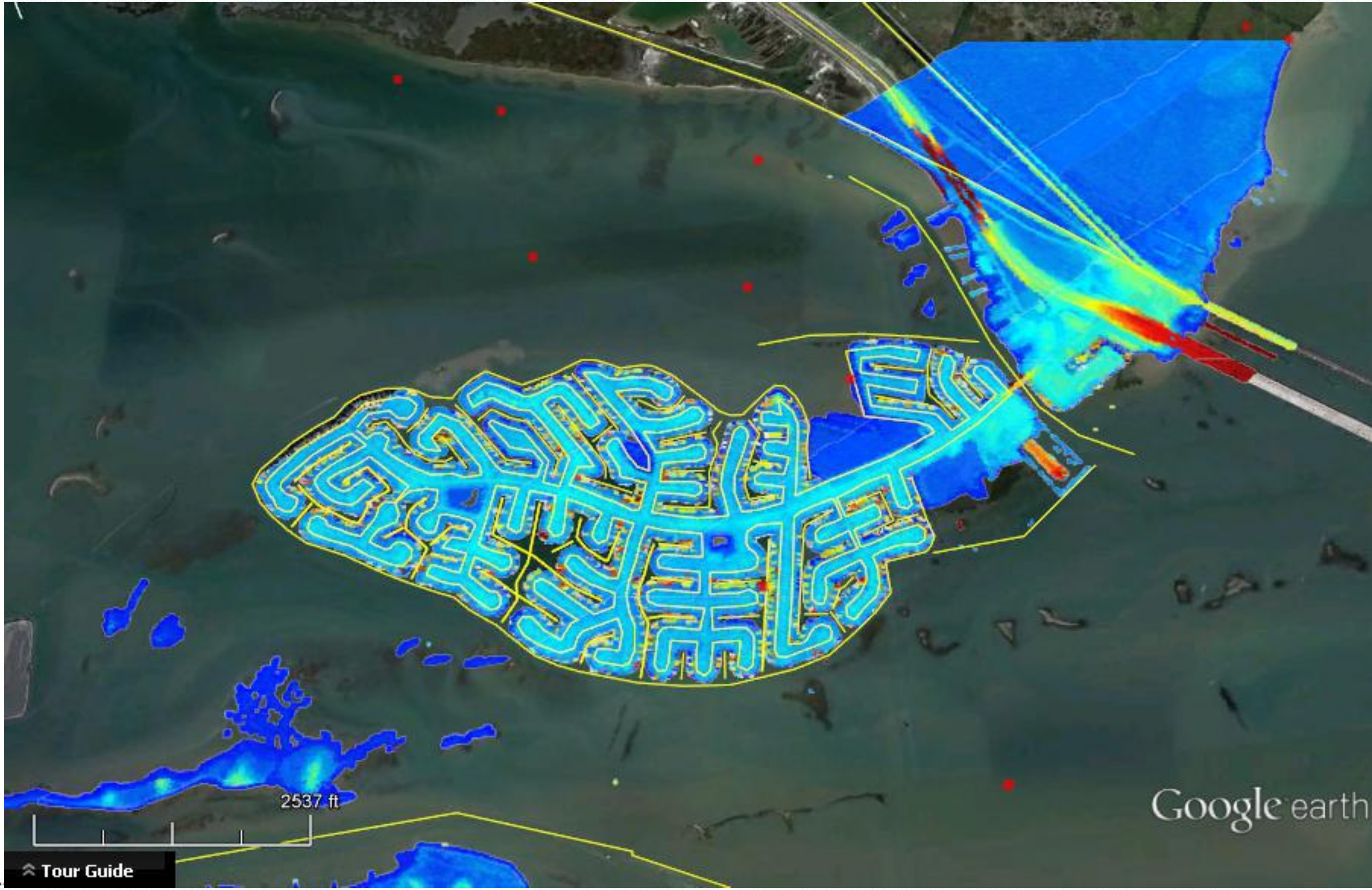
Storm Surge Modeling



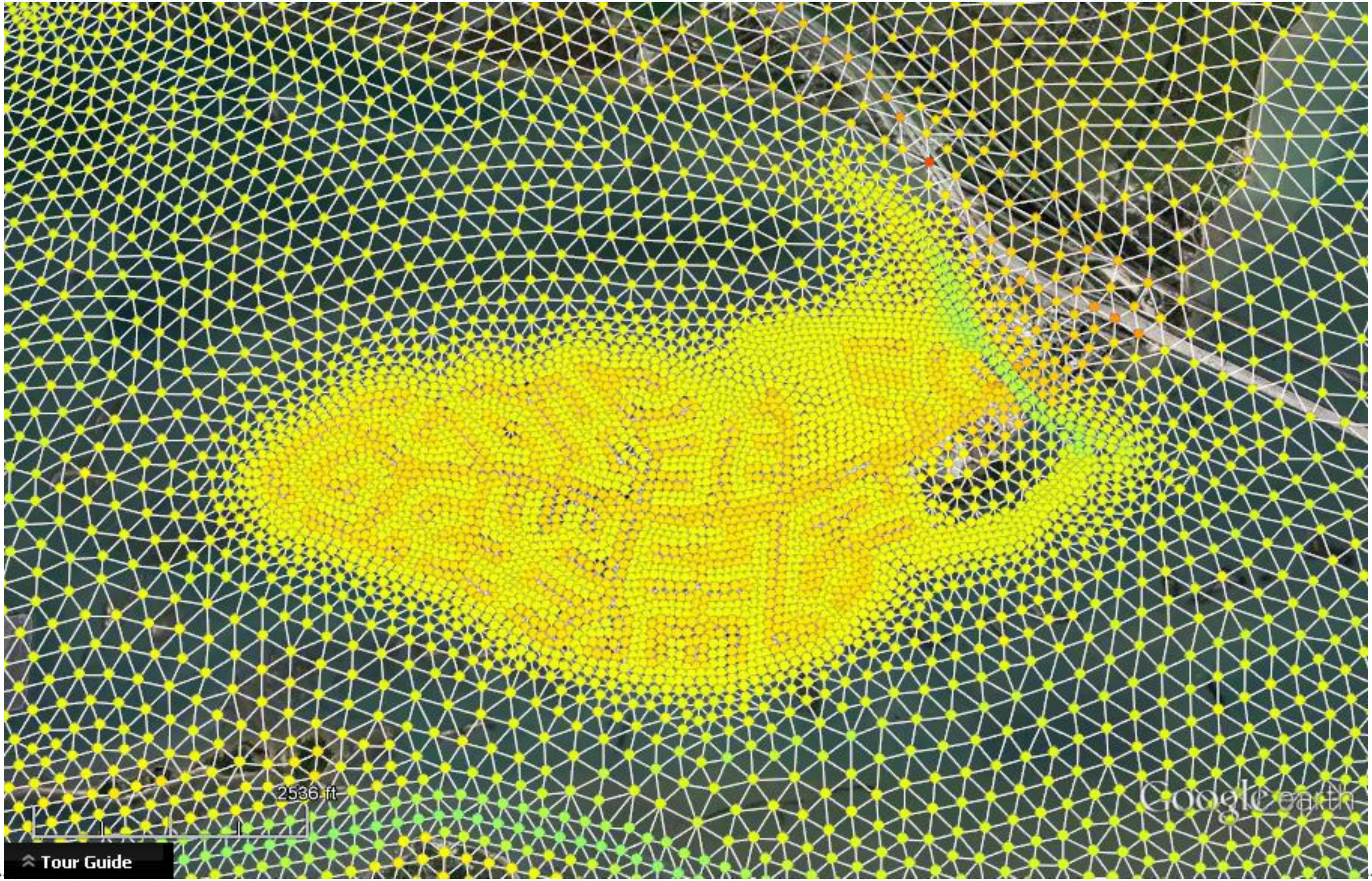
Storm Surge Modeling

- Lidar SuperOverlays

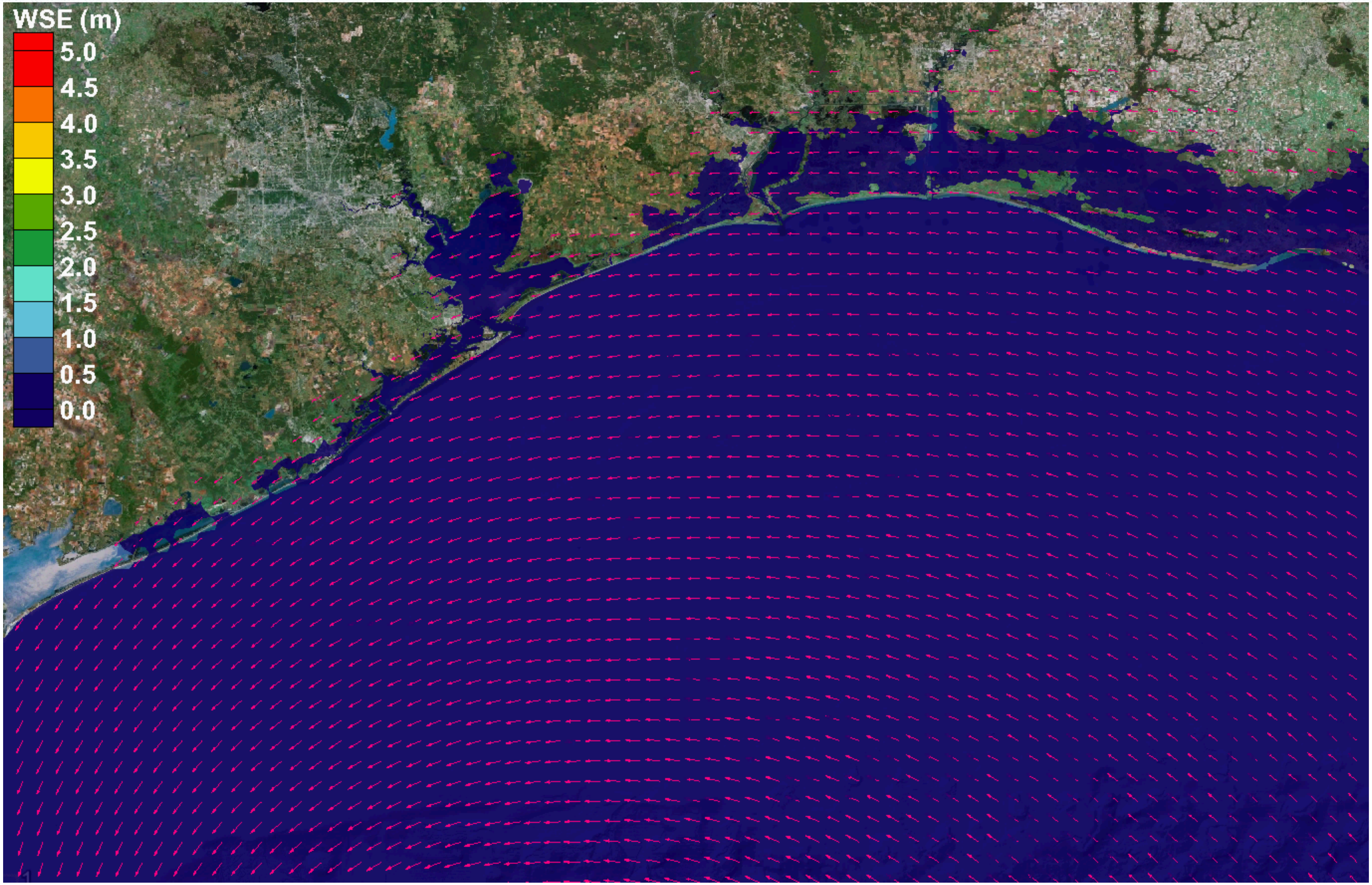
Storm Surge Modeling



Storm Surge Modeling



Storm Surge Simulations



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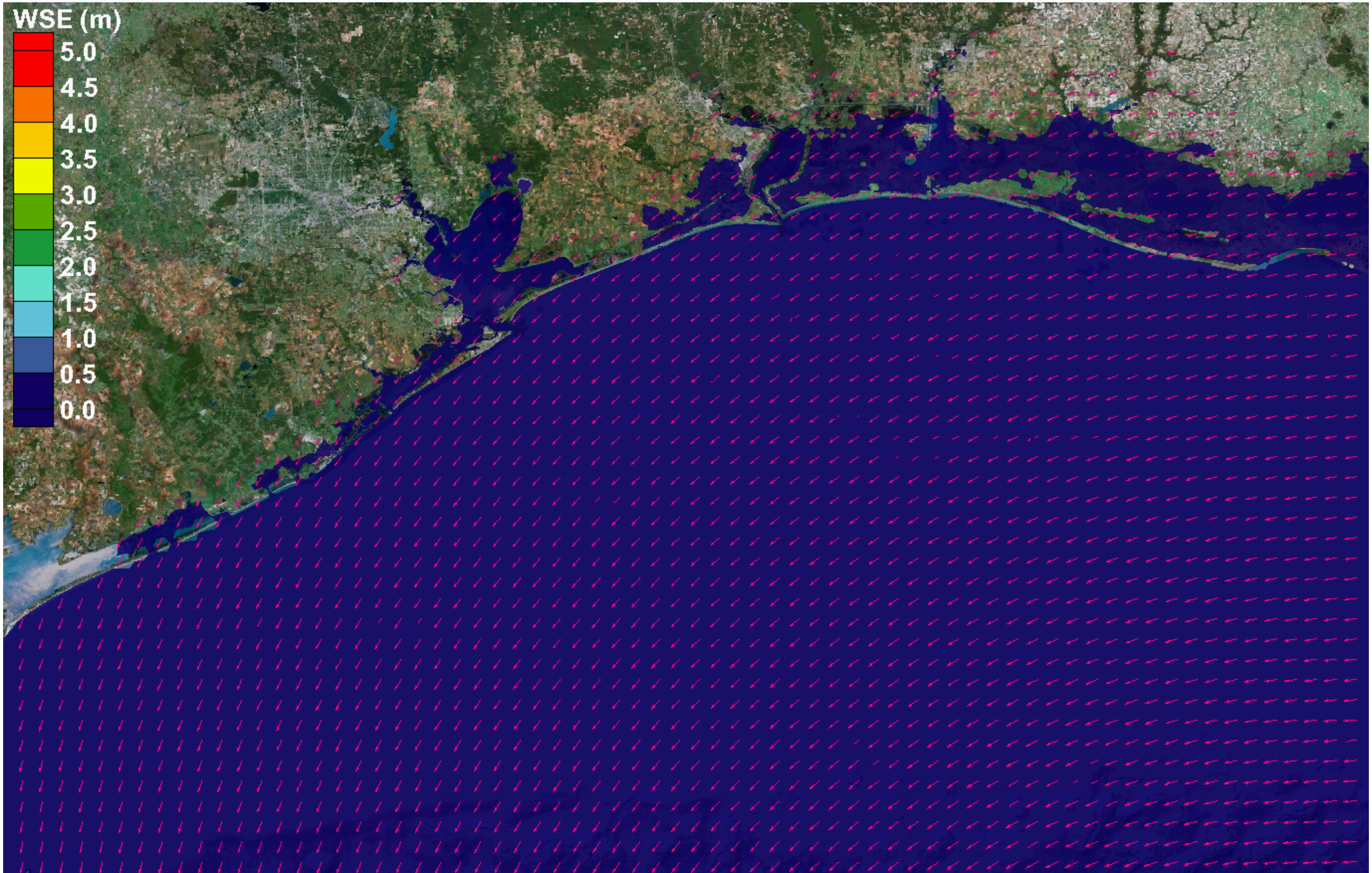

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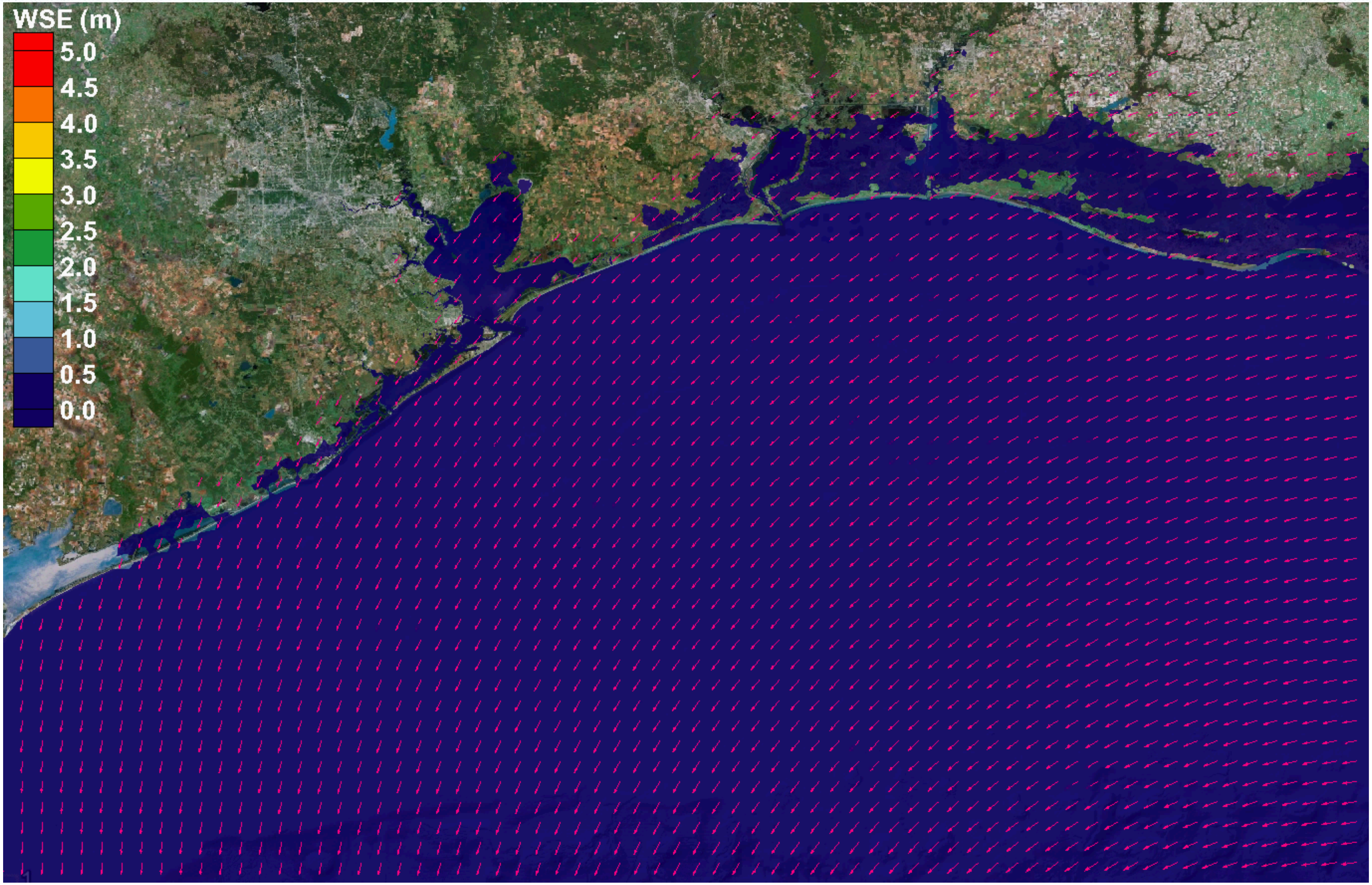
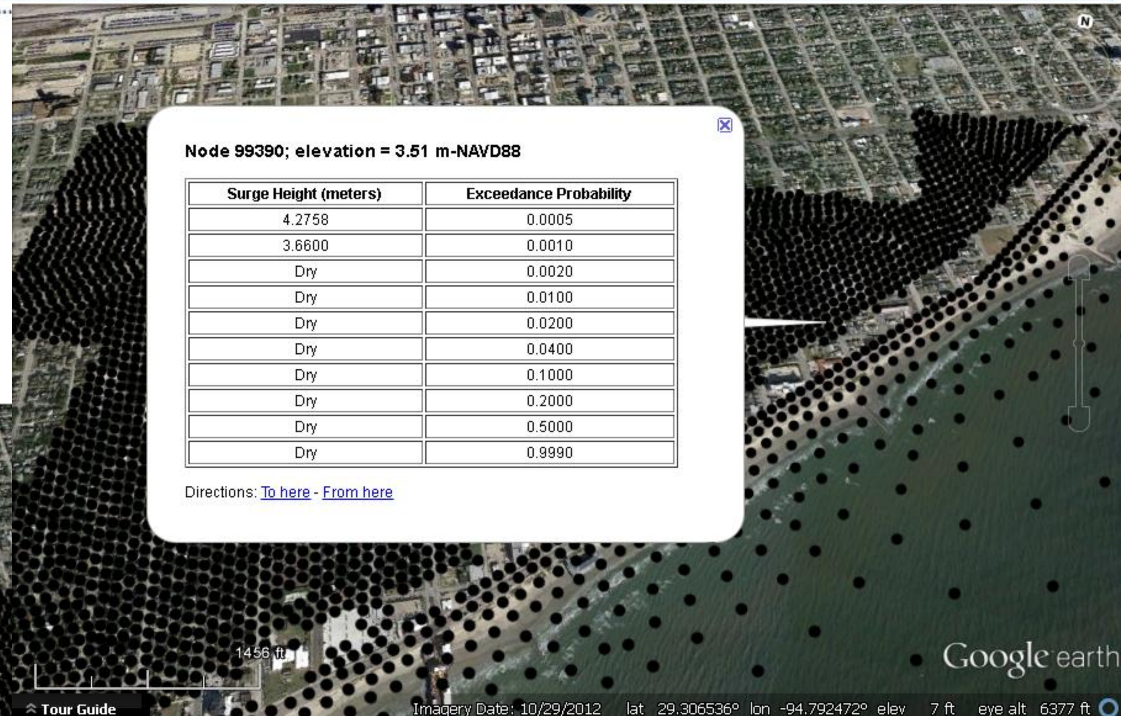


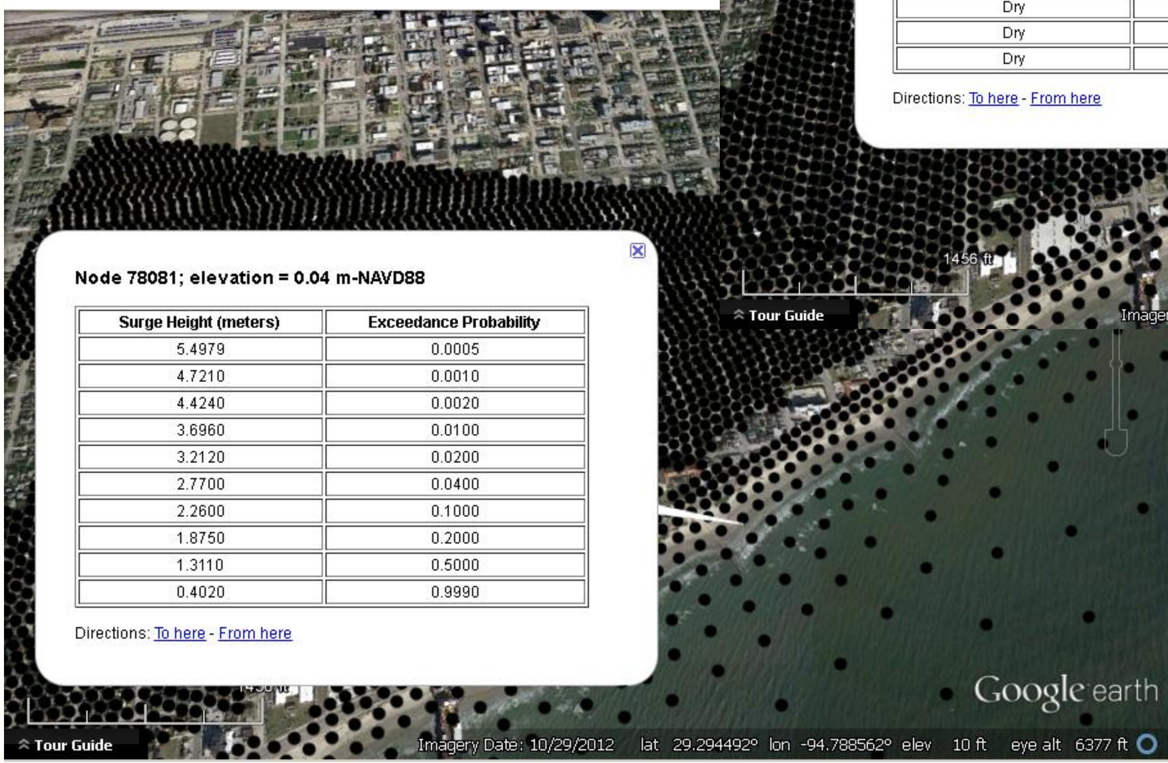
Storm Surge Modeling



Node 99390; elevation = 3.51 m-NAVD88

Surge Height (meters)	Exceedance Probability
4.2758	0.0005
3.6600	0.0010
Dry	0.0020
Dry	0.0100
Dry	0.0200
Dry	0.0400
Dry	0.1000
Dry	0.2000
Dry	0.5000
Dry	0.9990

Directions: To here - From here



Node 78081; elevation = 0.04 m-NAVD88

Surge Height (meters)	Exceedance Probability
5.4979	0.0005
4.7210	0.0010
4.4240	0.0020
3.6960	0.0100
3.2120	0.0200
2.7700	0.0400
2.2600	0.1000
1.8750	0.2000
1.3110	0.5000
0.4020	0.9990

Directions: To here - From here

Types of Engineering Adaptations

- **Strongly consider modular and/or phases approaches**
- **Facility Improvements/Upgrades (Accommodate)**
  - **Floating Developments**
  - **Elevated Developments**
  - **Floodable Developments**
- **Soft Engineering Solutions (Protect)**
- **Hard Engineering Alternatives (Protect)**
- **Managed Retreat (Retreat)**
- **Evacuation Planning (Accommodate)**
- **Co-Benefit Solutions**

Facility Improvements

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Soft Engineering Solutions

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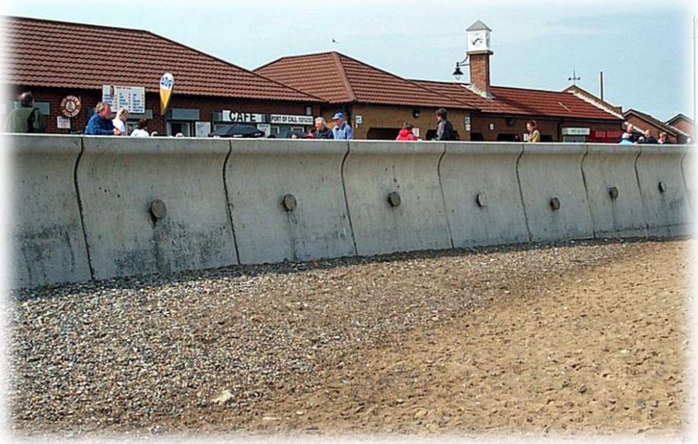
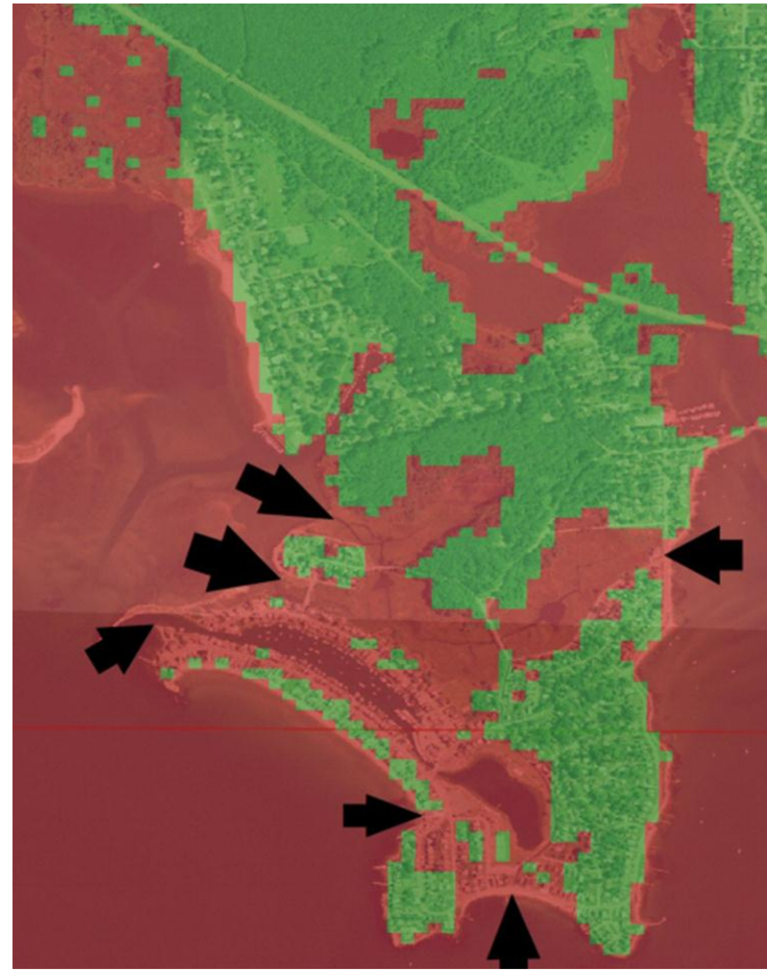
Hard Engineering Solutions



Examples – Groton, CT



Examples – Groton, CT

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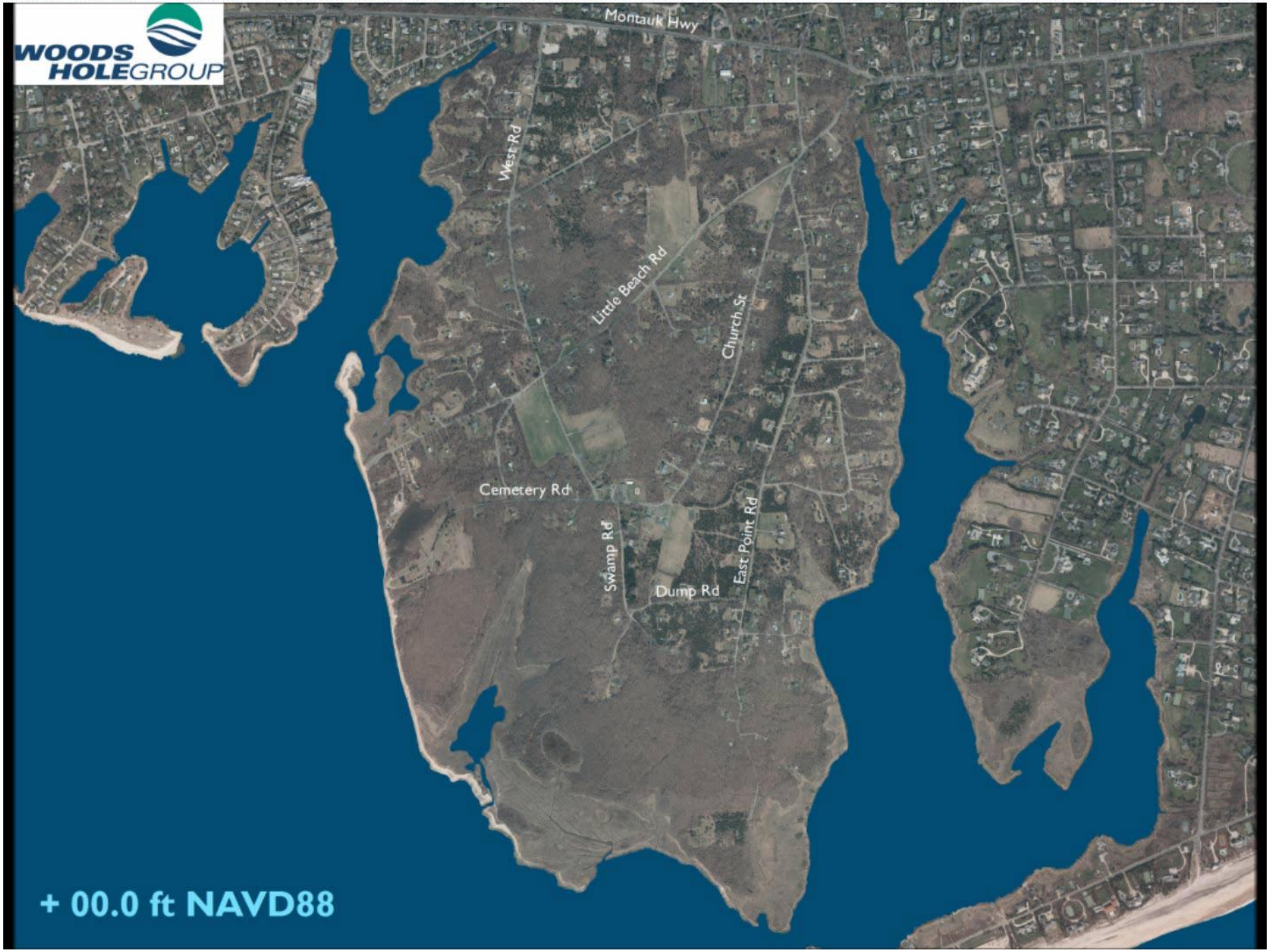
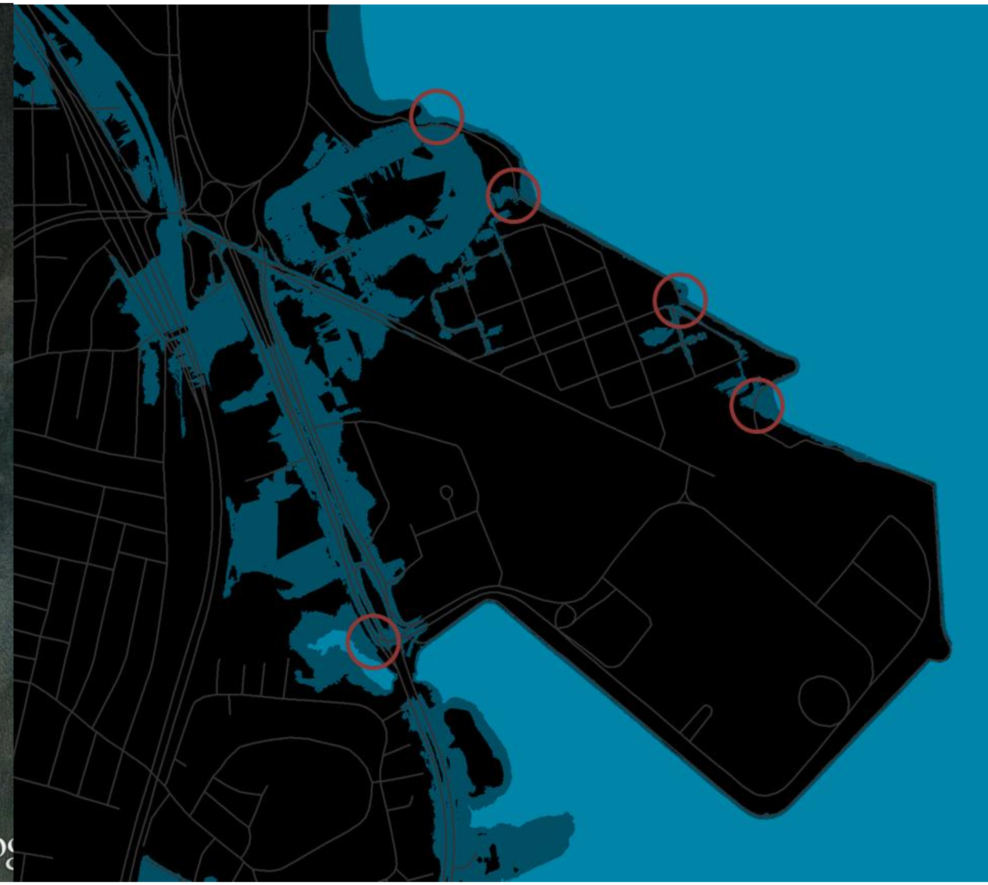
Inundation Maps



Examples – South Boston

Sometimes regional problems can be solved by minor projects



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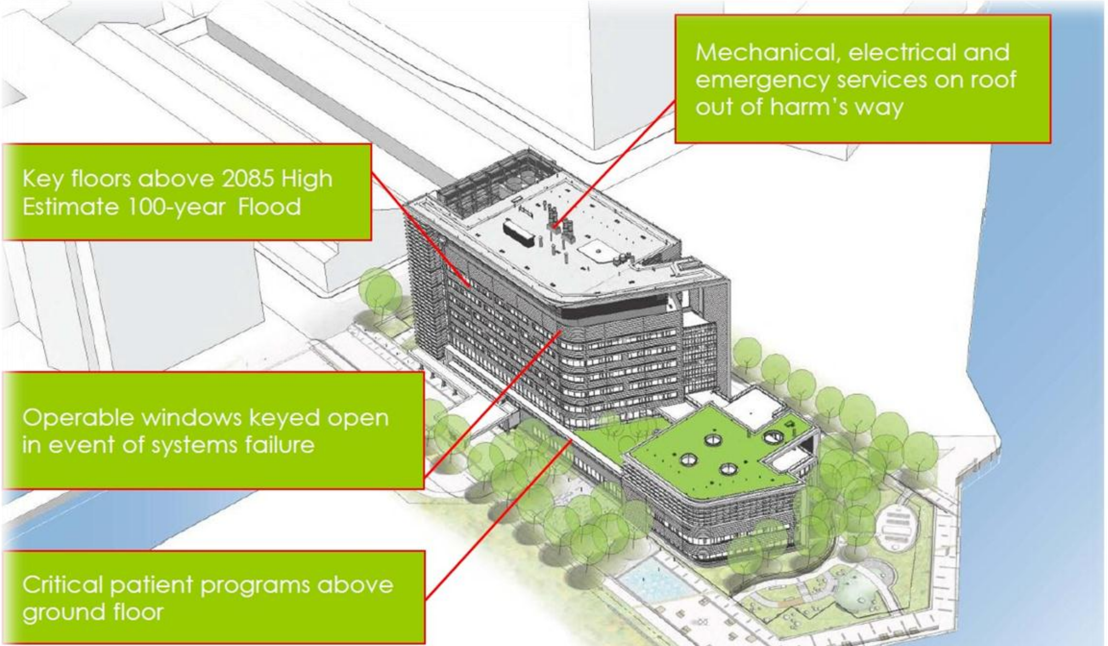
Mean Higher High Water (MHHW) Timeline	Annual (1-year) Storm Surge Timeline	100-year Storm Surge Timeline	Approximate Maximum Water Surface Elevation (ft, NAVD88)	Upland Flooding Potential	Recommended Engineering Adaptations	Estimated Adaptation Cost*	Upland Flooding Potential	Recommended Engineering Adaptations	Estimated Adaptation Cost*
2010			4.0	No Flooding Expected	No Action Required	N/A	Poor Drainage of Bayside Expo Parking areas during heavy rainfall events. No Flooding of areas from Dorchester Bay waters.	Minor flood proofing of structures Installation of a pump house and pumped based-drainage system for parking area[+]	Capital Cost: $ 2.0 Million Annual Maintenance Costs: $ 10,000
			5.0						
2050			6.0						
	2010		7.0	Flooding of Morrissey Blvd. approximately 1/4 mile south of campus entrance. No flooding of campus entrance or campus facilities					
	2050		8.0						
2100			9.0						
		2010	10.0	Flooding of campus entrance. Initially from Patten's Cove (tidal pond to the west of entrance), and subsequently from Savin Hill Cove.	Tidal control structure installation at entrance to Patten's Cove. Soft solution (beach nourishment and vegetation enhancement) along Savin Hill Cove.	Capital Cost: $500-750,000 Annual Maintenance Costs: $10,000	Flooding of Bayside Expo areas from Dorchester Bay. Water overtops harbor walk in places.	Modular seawall installation at critical locations along Harbor walk Seawall extension along Harbor walk as needed	Capital Cost[#]: $1.0-1.5 million (1,000 foot length) Annual Maintenance Costs: $15,000
		2050	11.0						
	2100		12.0						
			13.0	Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing	Widespread flooding of UMASS Boston Campus, Morrisey Blvd. and surrounding areas	In addition to adaptations above, additional flood proofing and elevation of critical infrastructure. Evacuate during storm event and return.	Capital Cost: $20 per square foot of building for wet flood proofing
		2100	14.0						
			15.0						
			16.0						

What are coastal communities doing?

- Deer Island Treatment Plant
- Spaulding Rehabilitation Hospital
- Groton and Groton Point, CT
- Seattle, WA and Charleston, SC
- Central Artery, MA
- Cambridge, MA
- Thames River, England



Spaulding Rehabilitation Hospital, Charlestown Navy Yard, Boston
Architect: Perkins + Will Analytical diagrams P+W / Partners HealthCare

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What can coastal communities do?

- **What should communities be doing?**
  - **Determine regional and site-specific flooding risk through assessment of physical processes**
  - **Identify elevations of flood-prone building and infrastructure**
  - **Identify property specific vulnerabilities to flooding**
  - **Develop cost-effective measures to increase resilience**
  - **Pursue integrated strategy to maximize adaptations (co-benefit solutions)**
- **How?**
  - **Vulnerability Assessments, Preparedness Plans, Adaptation Strategies**
  - **Integrate with ongoing Hazard Mitigations Studies and Projects**
- **Community willingness, but lack of financial resources**

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Conclusions

- **Climate change related coastal flooding is a reality, and predicted to increase**
- **Climate change preparedness plans involve multiple activities from building-specific through regional scales**
- **Preparing for increased coastal flooding involves implementing phased plans and integrated into maintenance plans to lower cost over time**
- **Preparing for the climate of the future will require coordinated efforts among all sectors of individual communities**