Coastal Inundation Mapping Workshop

National Oceanic and Atmospheric Administration (NOAA)

Coastal Geotools 2009

Monday, March 2

NOAA Coastal Services Center
LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

Agenda

8:30 – 9:30 a.m.

- Welcome and Introductions
- Workshop Overview
- Intro to Coastal Inundation
- Breakout Sections Overview

9:30 – 10:30 a.m.

- Breakout Sections

10:30 – 10:40 a.m.

- Short Break

10:40 – 11:30 a.m.

- Breakout Sections

11:30 a.m.

- Workshop Wrap-up

Agenda

1:00 – 2:00 p.m.

- Welcome and Introductions
- Workshop Overview
- Intro to Coastal Inundation
- Breakout Sections Overview

2:00 – 2:50 p.m.

- Breakout Sections

2:50 – 3:00 p.m.

- Short Break

3:00 – 4:00 p.m.

- Breakout Sections

4:00 p.m.

- Workshop Wrap-up

NOAA Coastal Services Center

LINKING PEOPLE, INFORMATION, AND TECHNOLOGY

Support the environmental, social, and economic well-being of the coast by linking people, information, and technology.

Deliver and evolve the nation's foundation of reference for latitude, longitude, height, velocity, shoreline, and gravity throughout the U.S.

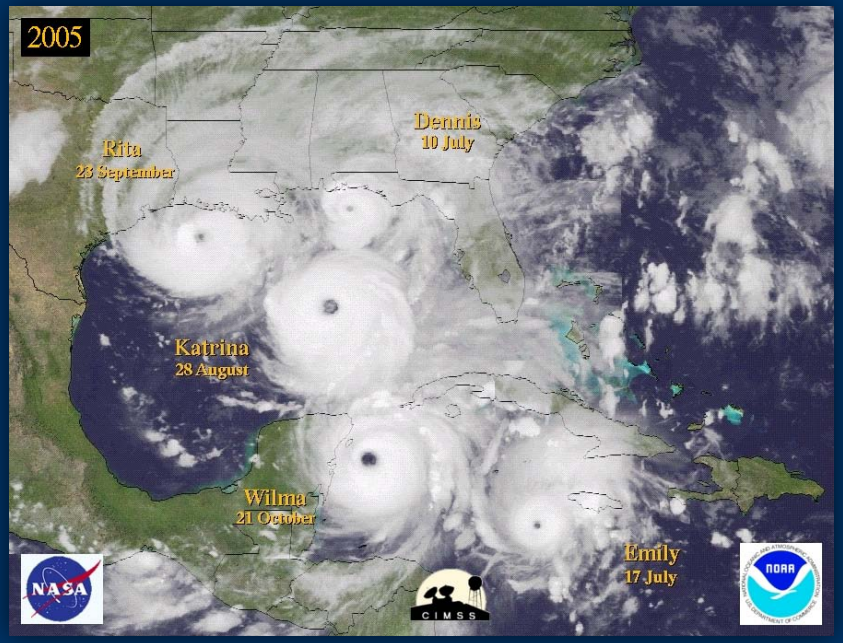
Providing weather, hydrologic, and climate forecasts and warnings for protection of life and property and the enhancement of the national economy.

Workshop Overview

Goal: To build awareness of the products and services that can aid in mapping and visualizing inundation

Workshop Focus:

- What is coastal inundation?
- Types of inundation products
- Elevation data and spatial referencing
- Inundation mapping and risk and vulnerability assessments



Inundation Mapping: What Are the Issues?

- Vertical datums
- Data availability, accuracy, accessibility
- Numerous map products – Use? Access? Limitations?
- Models – Types? Limitations?
- Visualizing what flooding “looks” like and its impacts
- Coordination and collaboration
- Risk and vulnerability assessment tools for planning

Introduction to Coastal Inundation

Doug Marcy

NOAA Coastal Services Center

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Inundation

What Is Inundation?

Inundation is a condition in which water overtakes normally dry land, primarily caused by severe events along rivers or the coast (source: NOAA FAQ / State of Science: Inundation) .

- Storm Surge
- Tsunami
- Inland Flooding
- Shallow Coastal Flooding
- Long Term: Relative Sea Level Change (not covered in this course)

New Orleans neighborhoods after Hurricane Katrina.
Source: NOAA Photo Library

Inundation

Why is Understanding and Predicting Inundation Important?

- Inundation-related deaths make up the largest portion of natural hazard-related deaths in this country.
- Three-fourths of all presidential disaster declarations are associated with flooding.
- In most years, inland floods cause more damage than any other severe weather-related event – an average of $6.9 billion a year for the period 1976 to 2006.
- U.S. weather-related losses are growing ten times faster than the nation's overall economy.

I-10 bridges outside of New Orleans after Hurricane Katrina.
Source: NOAA Photo Library

Mapping Inundation

Why Map Inundation?

- Have the ability to visualize where water will flood by showing the potential height and extent of the water
- Better understand the consequences or potential impacts of flooding
- Use for long-term land use planning, risk and vulnerability assessments
- Use for evacuation, education and awareness, conveying risk
- Have the ability to overlay impacted areas with other GIS hazard data for decision-making

Mapping versus Modeling

Mapping

- The process of creating a graphical representation of the physical features on Earth's surface (i.e., our real world)
- Features (points, lines, polygons) represented by a defined size, color, shape, and pattern
- Reference or thematic
- Based on model output

Modeling

- Process of simulating reality to gain a better understanding of the physical phenomena under investigation and their impacts on the physical and societal environment
- Often implies simulation or prediction
- Model output only as good as the input

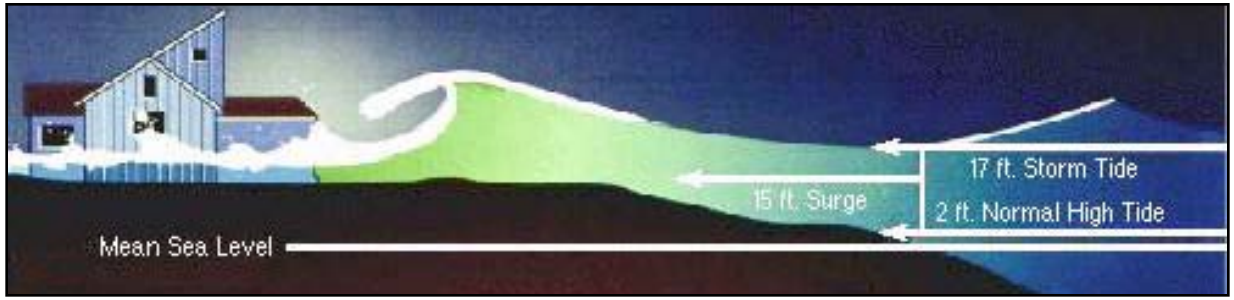
- Examples: SLOSH and ADCIRC

Storm Surge

A. Definition

- *Storm surge* results from severe storms such as tropical cyclones, whose strong winds, combined with low pressure, drive water onshore (source: NOAA FAQ / State of Science: Inundation).
- *Storm tide* is the water surface elevation produced from storm surge added to the astronomical tide.
- Wind-driven waves are superimposed on the storm tide, causing higher water levels (i.e., wave setup).
- These conditions are often caused by tropical storms, hurricanes, or nor'easters

Source: The National Hurricane Center's Hurricane Preparedness Site. Image is not to scale.

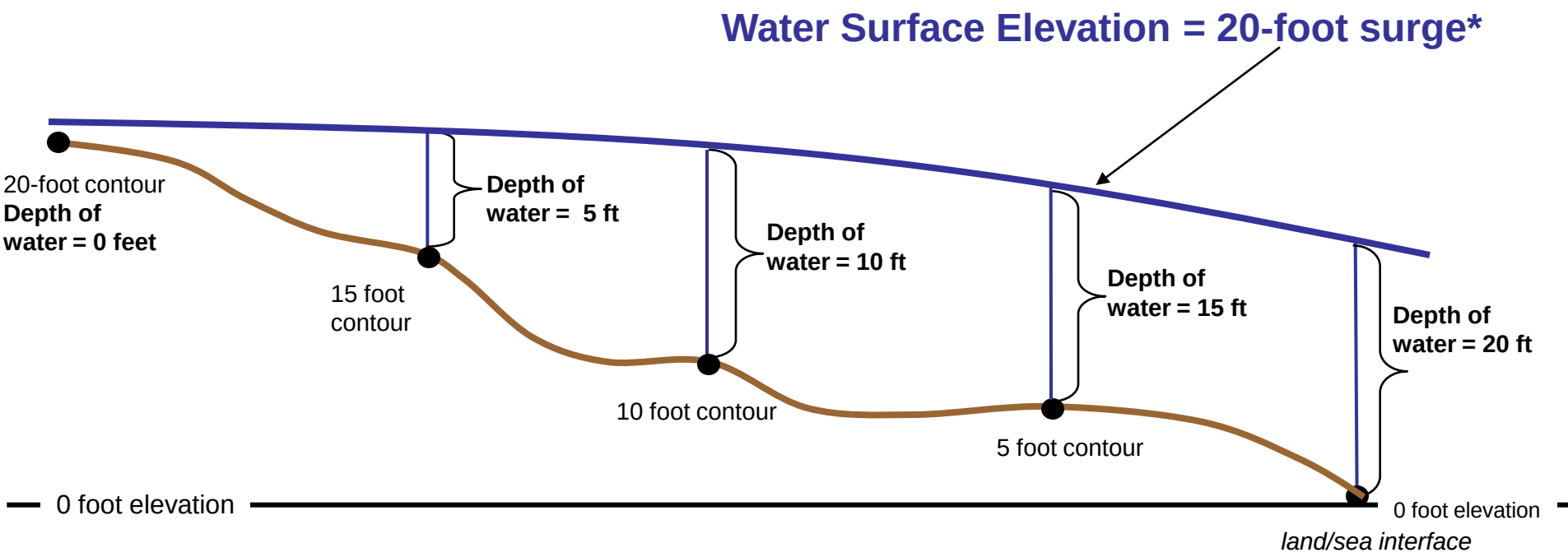


Storm Surge + Astronomical Tide = Storm Tide

Storm Surge

What does a 20-foot storm surge really mean to your location?

Storm surge models output water surface elevations for a specific area (grid cell)



***This only represents surge. There may be waves on top of the surge.**

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Storm Surge

B. Examples of Events

- Hurricane Katrina
  - 24-28 feet of surge elevation estimated in Mississippi
  - Surge caused Lake Pontchartrain to rise and protective levees to breech, causing extensive inundation of New Orleans

- Hurricane Hugo
  - 20 feet of surge near McClellanville, SC, highest recorded surge on the East Coast

- "The Perfect Storm" – the Halloween Storm
  - Two storms combined into a massive storm
  - The East Coast from North Carolina to Nova Scotia was subject to abnormally high waves

Storm surge in Miami during a 1945 storm. Source: NOAA Photo Library

Storm Surge

C. Examples of Impacts

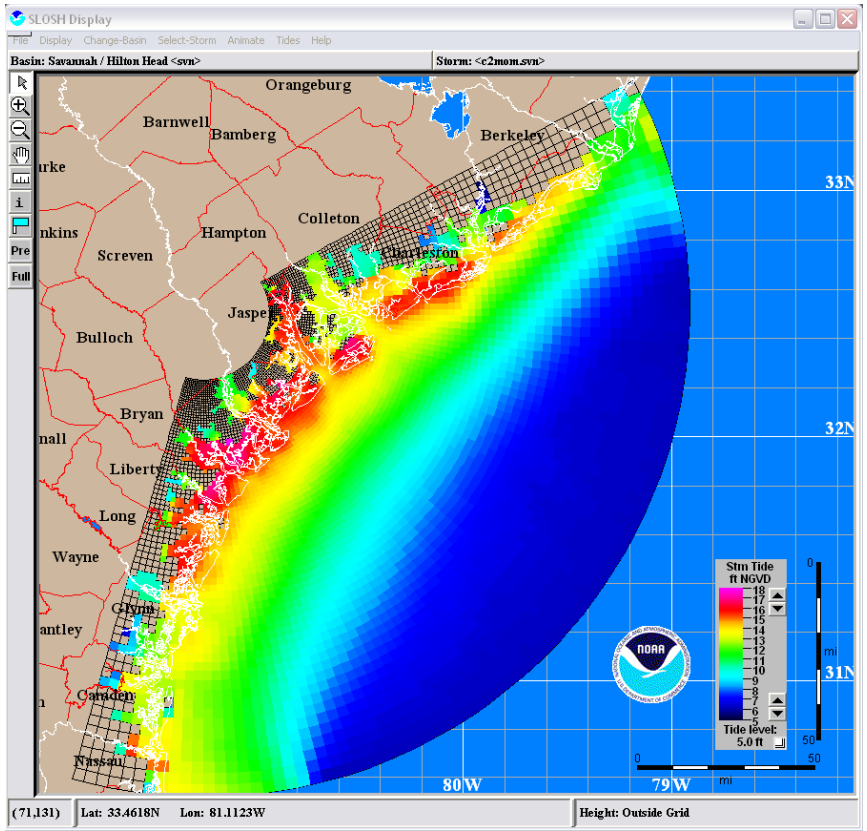
- Homes destroyed
- Bridges destroyed
- Levee breaches
- Loss of historical back-barrier vegetation
- Loss of critical coastal habitats

Images – Above: FEMA Gulf Coast Mississippi after Hurricane Katrina, 2005. Left: Ben Sawyer Bridge near Charleston, SC, after Hurricane Hugo, 1989. Source: NOAA Photo Library

Storm Surge

D. Tools for Modeling and Mapping Products

- SLOSH output – Sea, Lake, and Overland Surges from Hurricanes
  - Typically used to model events
- ADCIRC model output – Advanced Circulation Model
  - Typically used to model events, frequency events, and scenarios

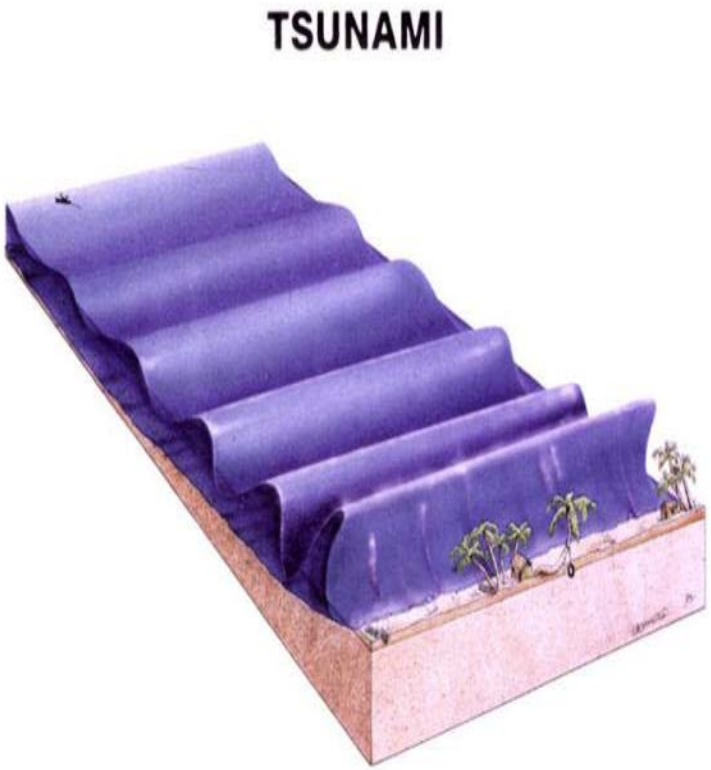


SLOSH display

Tsunami

A. Definition

- Large waves generated by an abrupt disturbance of the sea surface (e.g., from earthquake or landslide) (source: NOAA FAQ / State of Science: Inundation)
- Local tsunami arrive within minutes of the event while distant tsunami appear hours after generation; both continue for up to 12 hours
- Sometimes referred to incorrectly as tidal waves, tsunamis have nothing to do with tides
- Japanese word meaning “harbor wave”



Source: International Institute of Earthquake Engineering and Seismology

Tsunami

B. Examples of Events

- 2004 Indian Ocean Tsunami
  - Generated by the earthquake off the coast of northern Sumatra
  - 9.0 magnitude earthquake

- 1964 Prince William Sound, Alaska
  - Generated from earthquake in Prince William Sound
  - 9.2 magnitude earthquake

Thailand (2004) – These photos show the retreating water and the breaking wave at the horizon, indicating a tsunami is approaching

Tsunami

C. Examples of Impacts

- Severe damage or loss of buildings
- Loss of vegetation
- Loss of life
- Catastrophic

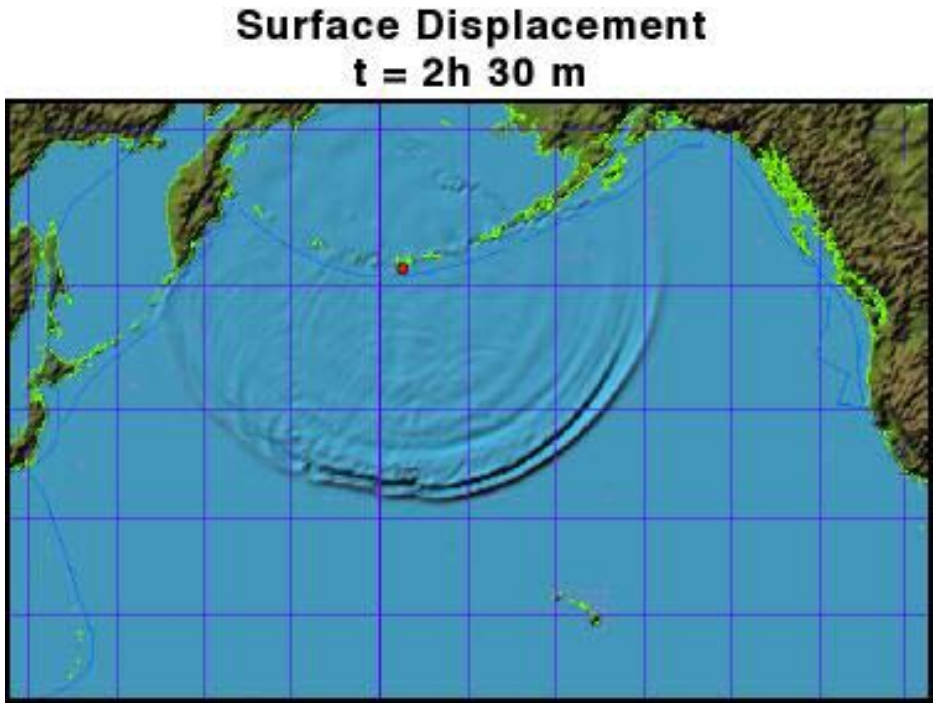
Before 2004 Tsunami Banda Aceh. Source: DigitalGlobe

After 2004 Tsunami Banda Aceh. Source: DigitalGlobe

Tsunami

D. Tools for Modeling and Mapping Products

- Method of Splitting Tsunami (MOST) model
- Deep-Ocean Assessment for Reporting of Tsunamis (DART)
- Tsunami animations
- Tsunami forecast modeling



Source: NOAA Pacific Marine Environmental Laboratory, Center for Tsunami Research, Adreanov tsunami model animation from MOST model

Riverine Flooding

A. Definition

Inland floods occur when moderate precipitation falls over several days, intense precipitation falls over a short period, or an ice or debris jam or dam or levee failure causes a river to overflow. (source: NOAA FAQ / State of Science: Inundation)

Flooding that occurred along the Tar River in North Carolina as a result of Hurricane Floyd in 1999.

Riverine Flooding

B. Examples of Events

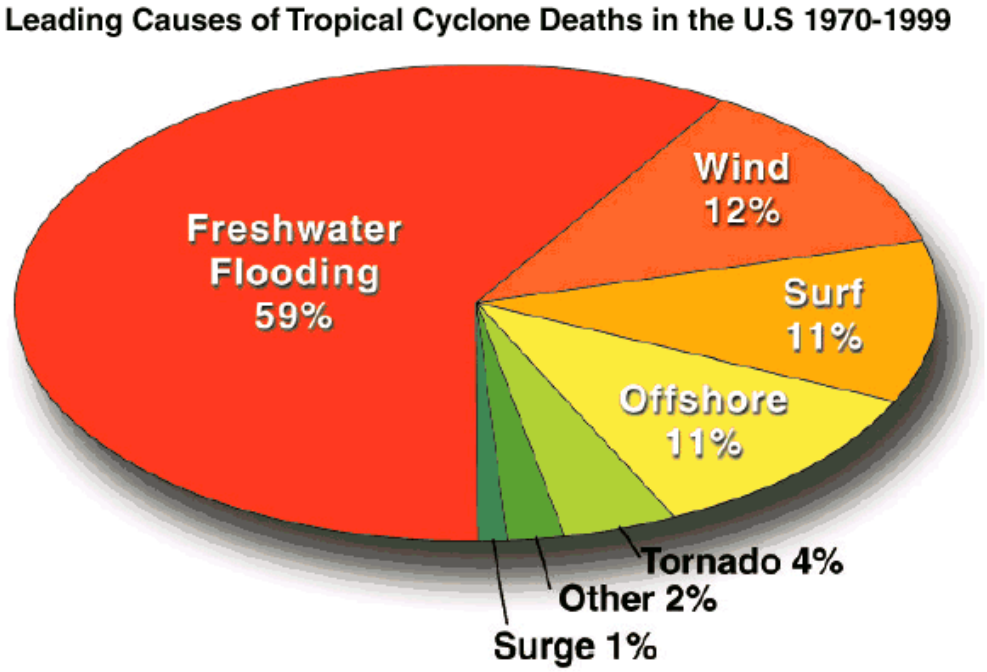
- Hurricane Floyd – 1999
  - Record flood levels in North Carolina
- Tropical Storm Allison – 2001
  - Heavy rainfall and catastrophic floods
- Hurricane Diane – 1955
  - Heavy rainfall in Pennsylvania, New York, and New England

Flooding that occurred in North Carolina as a result of Hurricane Floyd in 1999.

Riverine Flooding

C. Examples of Impacts

- Damage to property
- Damage to roadways and bridges
- Agricultural effects
- Loss of life

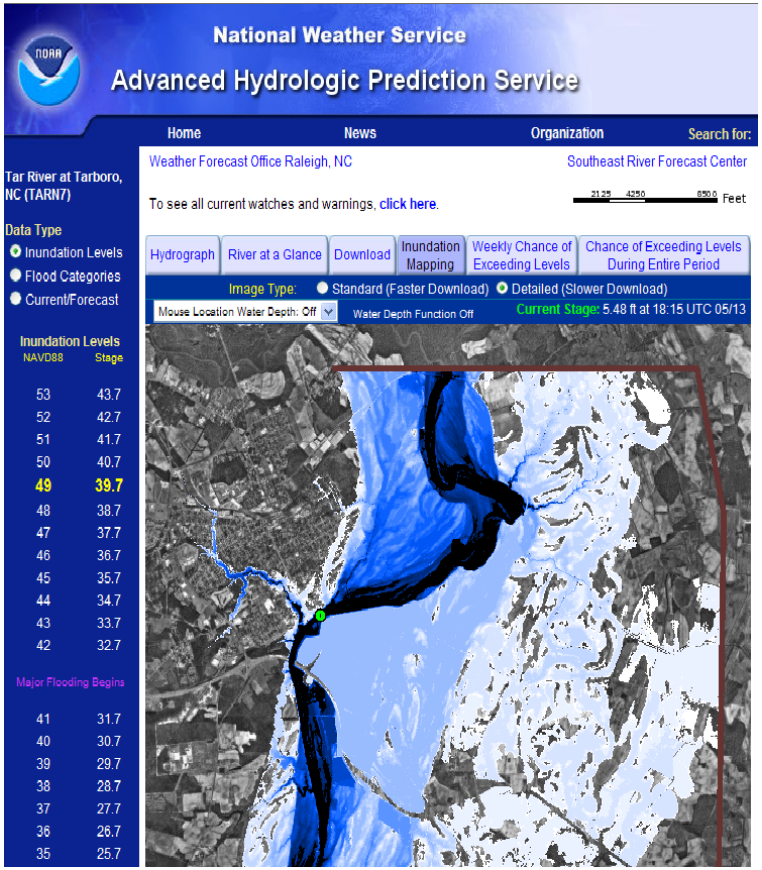


Rappaport, E. N. 2000. "Loss of Life in the United Sates Associated with Recent Atlantic Tropical Cyclones." *Bulletin of the American Meteorological Society,* 81. Pages 2005 to 2073.

Riverine Flooding

D. Tools for Modeling and Mapping Products

- *Floodplain Management Requirements: A Study Guide and Desk Reference for Local Officials*
- National Weather Service (NWS) Flood Severity Inundation Maps
- National Weather Service River Forecast System



NWS Inland Flood Severity Map

www.weather.gov/ahps/inundation.php

Shallow Coastal Flooding

A. Definition

The inundation of land areas along the coast caused by sea water above normal tides

Shallow Coastal Flooding in Charleston, SC, as a result of high tide and a coinciding rain event. Source: *Post and Courier* at *Charleston.net*

Shallow Coastal Flooding

B. Events

- Localized flooding
- Often coincide with spring high tides and rain events

Shallow Coastal Flooding in Charleston, SC, as a result of high tide and a coinciding rain event. Source: *Post and Courier* at *Charleston.net*

Shallow Coastal Flooding

C. Examples of Impacts

- Vehicle damage
- Potholes
- Severe injury
- Electrocution
- Drowning

Images of a shallow coastal flooding event in Charleston, SC, as a result of high tide and often a coinciding rain event.

Shallow Coastal Flooding

D. Examples of Products

- NWS Coastal Flood Statement
- NWS Flood Advisory

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COASTAL HAZARD MESSAGE
NATIONAL WEATHER SERVICE CHARLESTON SC
1125 AM EDT FRI JUN 15 2007

GAZ117-119-139-141-SCZ048>051-152130-
/O.CON.KCHS.CF.S.0012.070615T2300Z-070616T0300Z/
COASTAL BRYAN-COASTAL CHATHAM-COASTAL LIBERTY-COASTAL MCINTOSH-
BEAUFORT-COASTAL COLLETON-CHARLESTON-COASTAL JASPER-
1125 AM EDT FRI JUN 15 2007

SHALLOW COASTAL FLOODING IS EXPECTED ONCE AGAIN THIS EVENING
ALONG THE SOUTHEAST SOUTH CAROLINA AND SOUTHEAST GEORGIA COASTS.

THE COMBINATION OF ASTRONOMICAL HIGH TIDES AND ONSHORE FLOW WILL
ONCE AGAIN CREATE ELEVATED WATER LEVELS AND SHALLOW COASTAL
FLOODING THIS EVENING.

THE HIGHEST WATER LEVELS WILL OCCUR AROUND THE TIME OF HIGH TIDE
THIS EVENING. HIGH TIDE IN CHARLESTON HARBOR IS EXPECTED AT
912 PM EDT AND HIGH TIDE ON TYBEE ISLAND IS FORECAST TO OCCUR AT
915 PM EDT.

SHALLOW COASTAL FLOODING BEGINS ALONG THE SOUTHEAST SOUTH
CAROLINA AND SOUTHEAST GEORGIA COASTS WHEN WATER LEVELS PUSH PAST
7 FEET MEAN LOWER LOW WATER IN CHARLESTON HARBOR AND 9.2 FEET
MEAN LOWER LOW WATER AT TYBEE ISLAND. TIDE LEVELS THURSDAY
EVENING TOPPED OUT AT 7.78 FEET MEAN LOWER LOW WATER IN
CHARLESTON HARBOR AND 9.73 FEET MEAN LOWER LOW WATER ON TYBEE
ISLAND. WE RECEIVED REPORTS OF FLOODED ROADWAYS LAST NIGHT IN
ISLE OF PALMS...DOWNTOWN CHARLESTON AND TYBEE ISLAND. TIDES ARE
EXPECTED TO RUN CLOSE TO THESE LEVELS AGAIN TONIGHT...CAUSING
SHALLOW COASTAL FLOODING ANYTIME FROM 6 PM TO MIDNIGHT.
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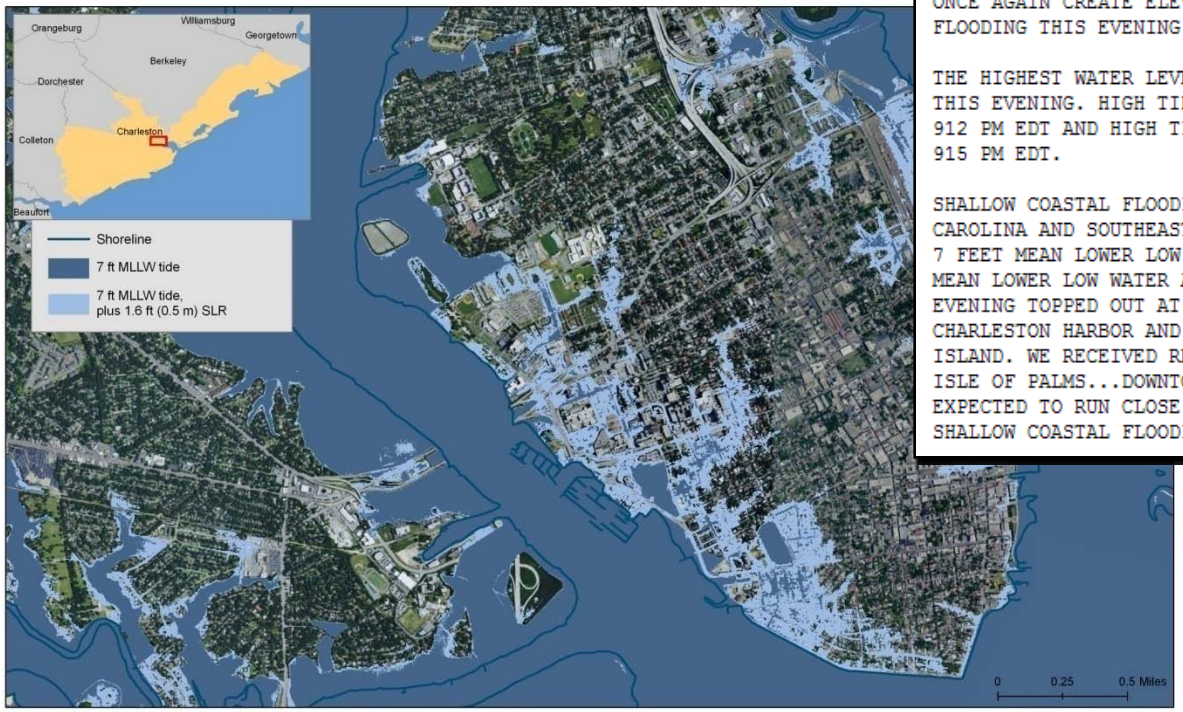
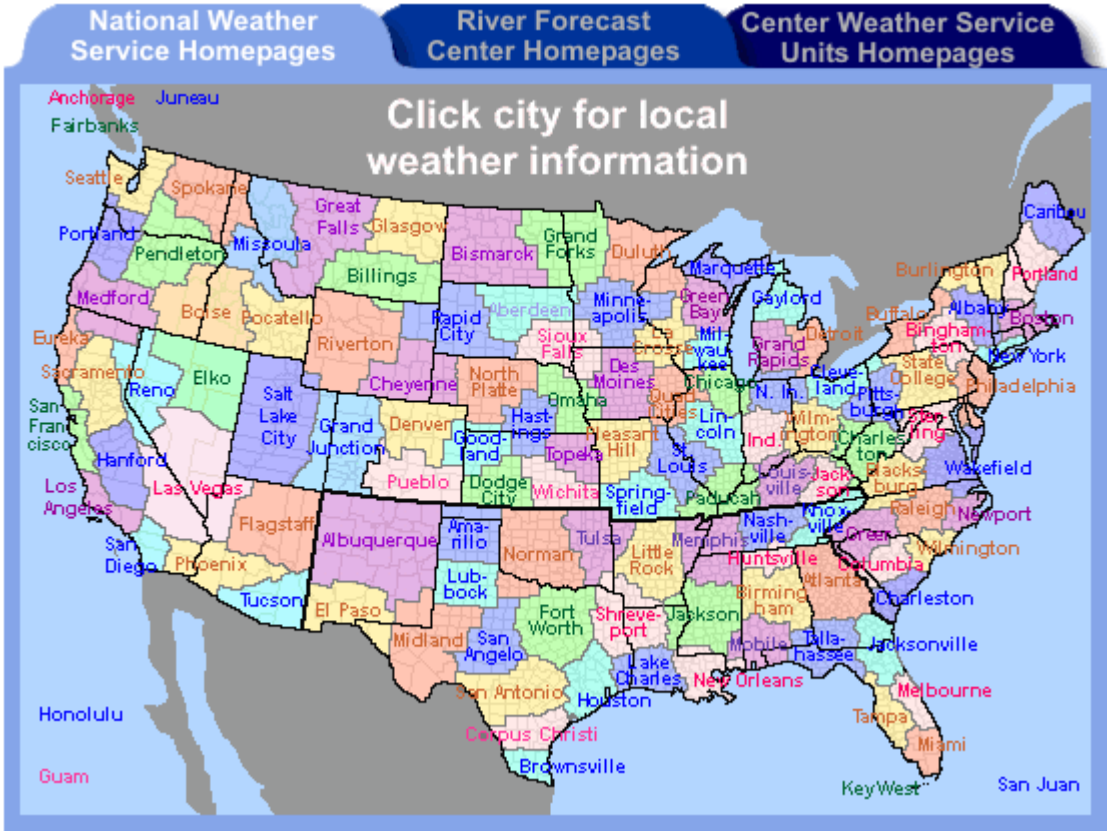


Shallow Coastal Flooding

E. Examples of Resources

- NWS Weather Forecast Offices
- Local Emergency Management Offices
- Department of Transportation



Map of the weather forecast office regions.

Sea Level Change

Simulation of Sea Level Rise in Charleston, SC.

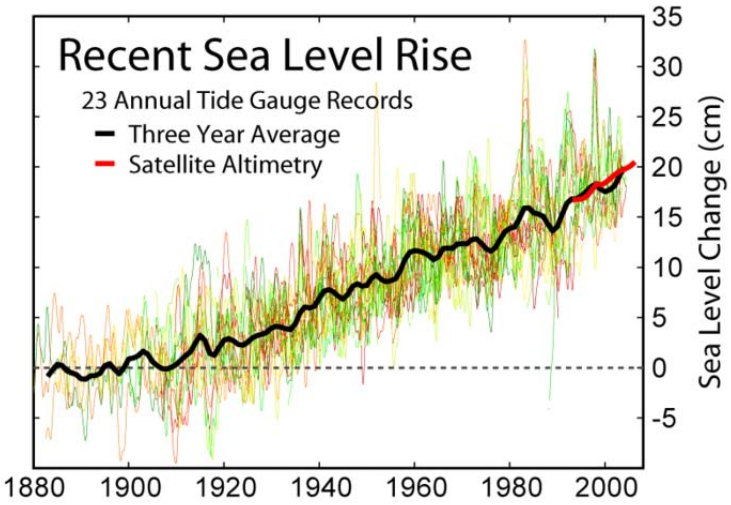
Sea Level Change

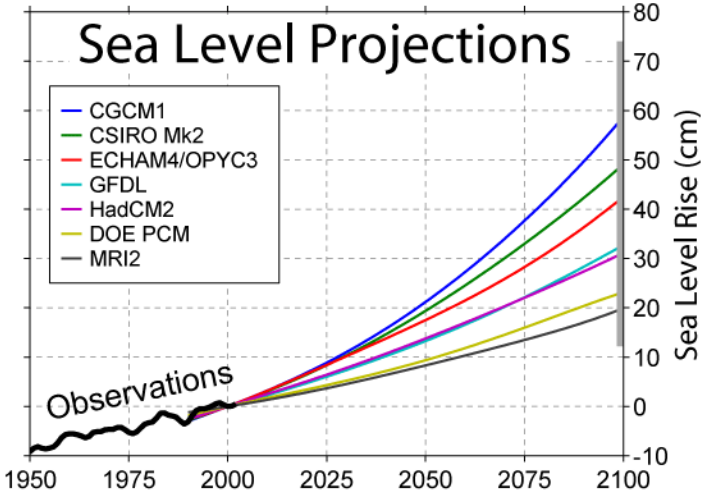
A. Definition

- *Relative sea level change* is caused by the combined effects of global sea level variations (due to climate change) and local vertical land movement (due to subsidence or isostatic rebound, for example).

- When sea level rises, it amplifies all types of coastal inundation and associated impacts.

- When sea level falls, it causes bluff failure from decreased hydrostatic pressure, reduced wetland habitat, loss of recreational access (docks and piers), and increased pollutants.





Source: Robert Rohde, UC Berkeley. Prepared from published data.

Sea Level Change

B. Current and Projected Rates

- Intergovernmental Panel on Climate Change (IPCC) scenarios
- More extreme scenarios taking into account more rapid ice melt and glacier collapse (Greenland collapse = ~7m rise)
- California executive order (16 inches by 2050 and 1.4m by 2100)
- Local scenario planning

Sea Level Rise (m at 2090-2099 relative to 1980-1999)	
Case	**Model-based range excluding future rapid dynamical changes in ice flow**
B1 Scenario	**0.18 – 0.38**
A1T scenario	**0.20 – 0.45**
B2 Scenario	**0.20 – 0.43**
A1B scenario	**0.21 – 0.48**
A2 scenario	**0.23 – 0.51**
A1FI scenario	**0.26 – 0.59**

Sea Level Change

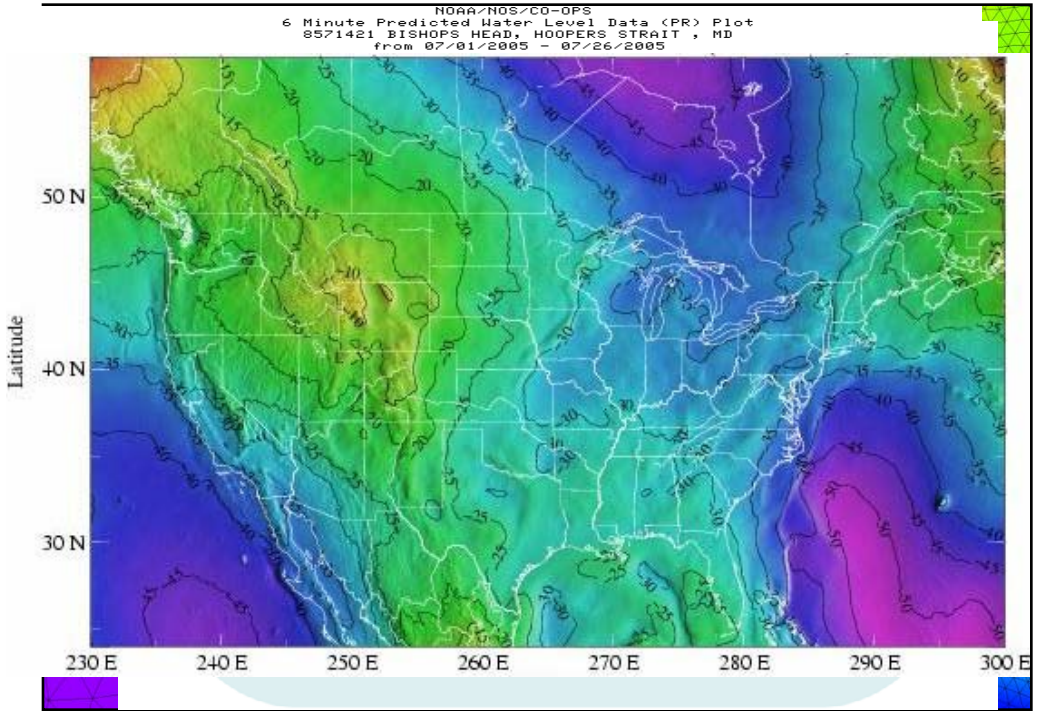
C. Examples of Impacts

- Increased coastal flooding
- Loss of saltwater marsh habitat
- Saltwater Intrusion
- De-watering and bluff failure (dropping lake levels)
- Coastal erosion
- Property loss
- Threat to critical infrastructure

Sea Level Change

D. Data for Modeling and Mapping Products

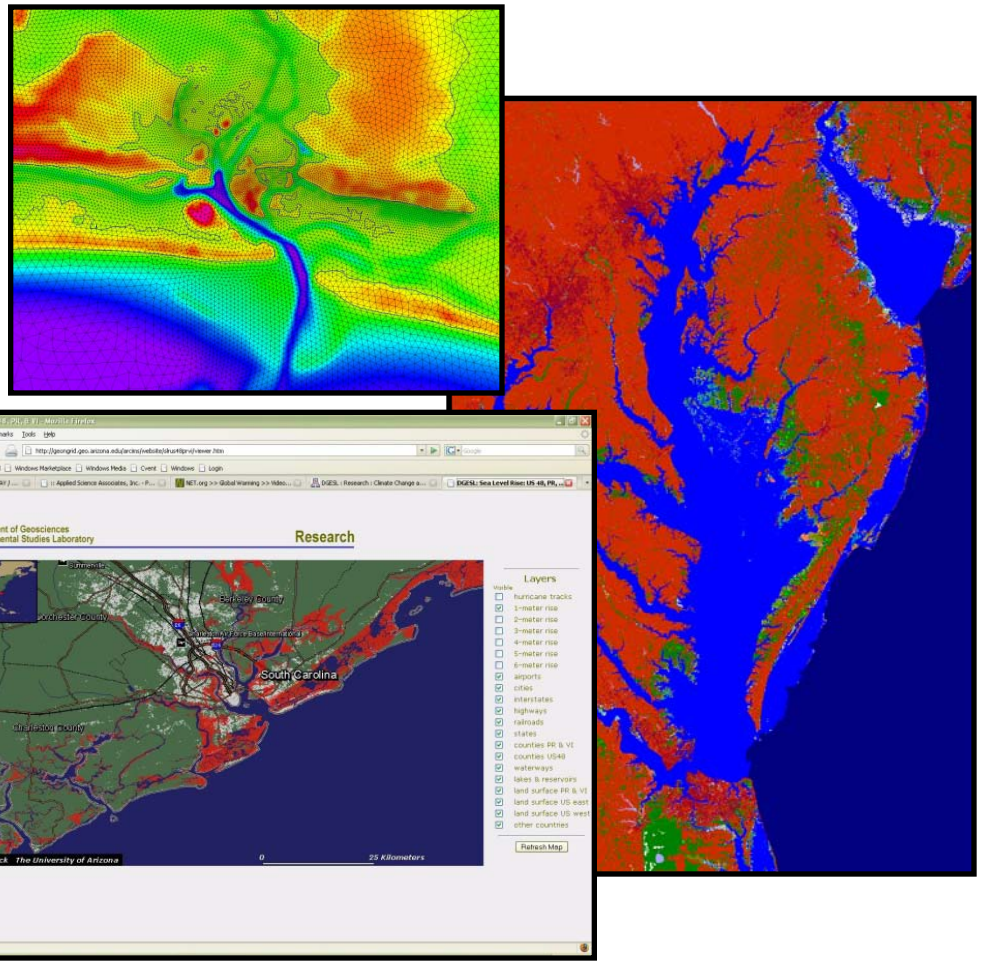
- Water level data
- Elevation and geodetic data
- Geophysical data
- Models (climate predictions and water surface)
- Datum transformations



Sea Level Change

E. Tools for Modeling and Mapping Products

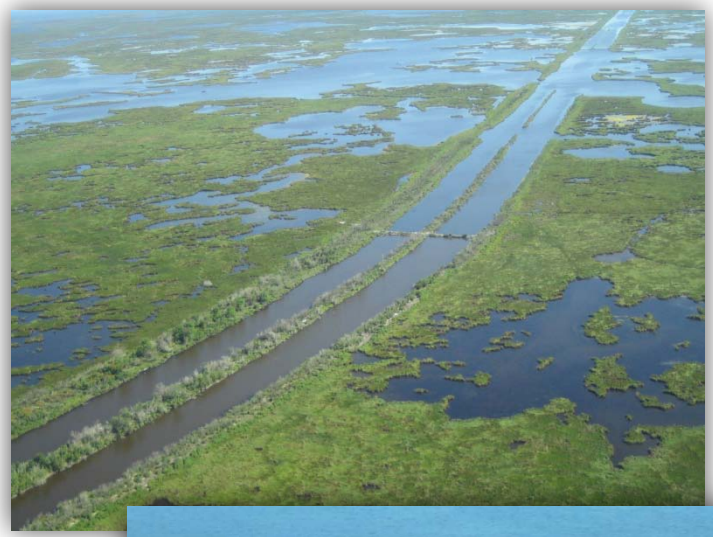
- SLRRP (Sea-Level Rise Rectification Program)
- SLAMM (Sea Level Affecting Marshes Model)
- ADCIRC (Advanced Circulation Model)
- Bath Tub Simulations
- Geomorphologic Modeling



Sea Level Change

E. Examples of Resources

- NOAA Center for Operational Oceanographic Products and Services (CO-OPS)
- NOAA National Centers for Coastal Ocean Science (NCCOS)
- NOAA Climate Program Office
- USGS Coastal Geology Program
- National Climatic Data Center (NCDC)
- Climate Change Science Program (CCSP)



Marsh loss in Louisiana.

Breakout Sections Overview

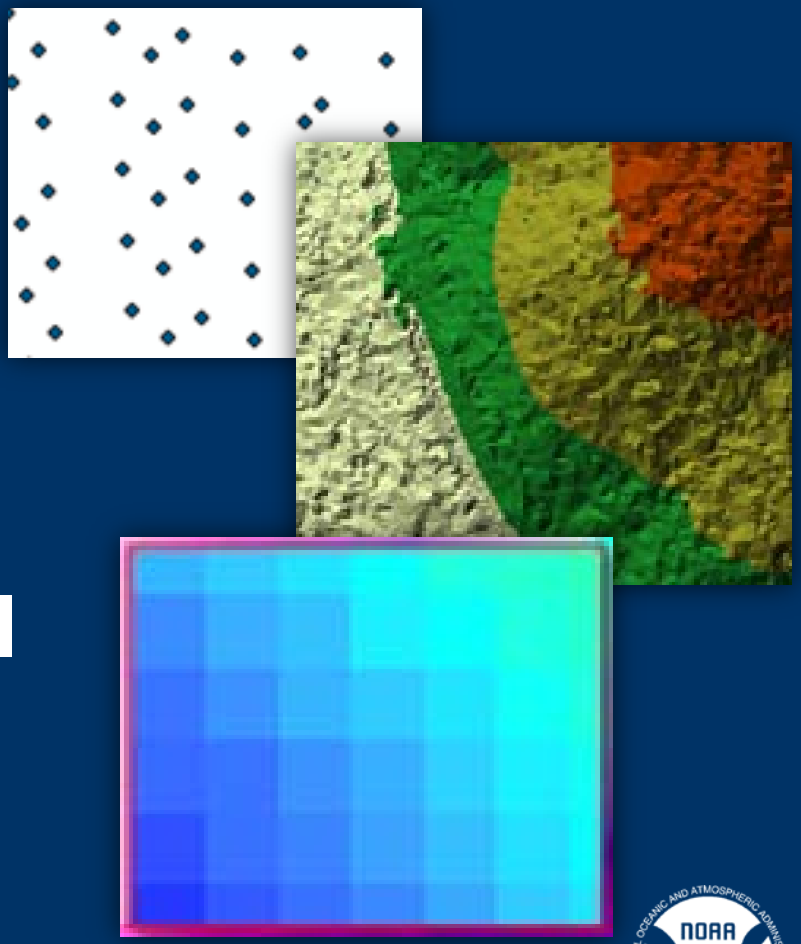
Breakout Stations

- **Station # 1**
  - Elevation Products and Sources
- **Station # 2**
  - Coastal Inundation Map Product Types
- **Station # 3**
  - Mapping Fundamentals / Creating Inundation Maps
- **Station # 4**
  - Risk and Vulnerability Assessments

Station # 1 Elevation Products

Kirk Waters

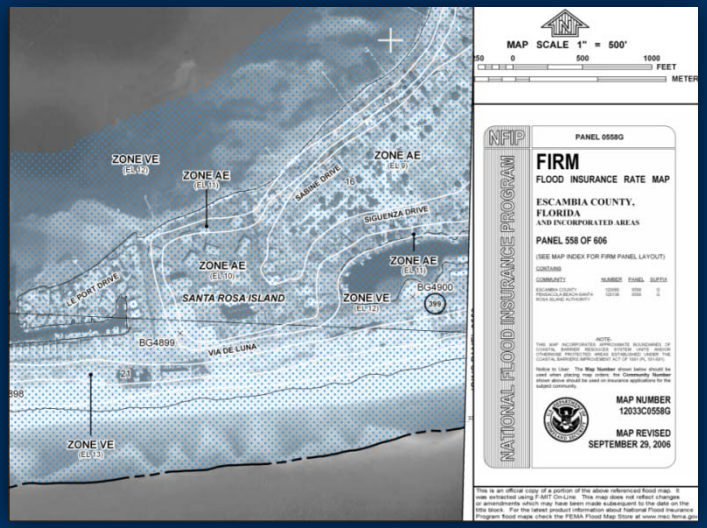
- **Elevation Formats**
- **Data Resources**
- **Example Data Retrieval**
  - Digital Coast

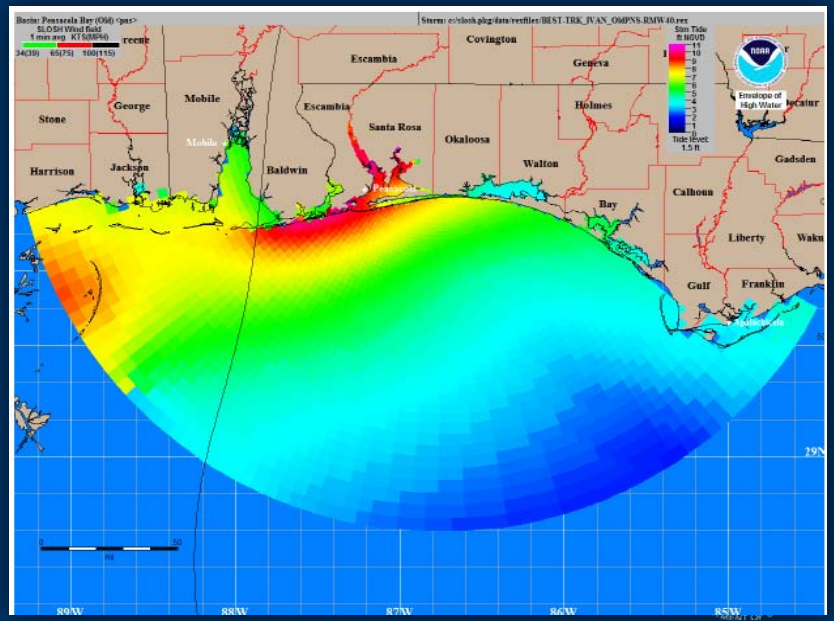


Station # 2 Map Product Types

Tara Miller

- **Different Map Product Types**
  - Risk-Based, Scenario-Based, and Event-Based
- **Applications and Limitations of Products Types**





Station # 3 Mapping Fundamentals / Creating Inundation Maps

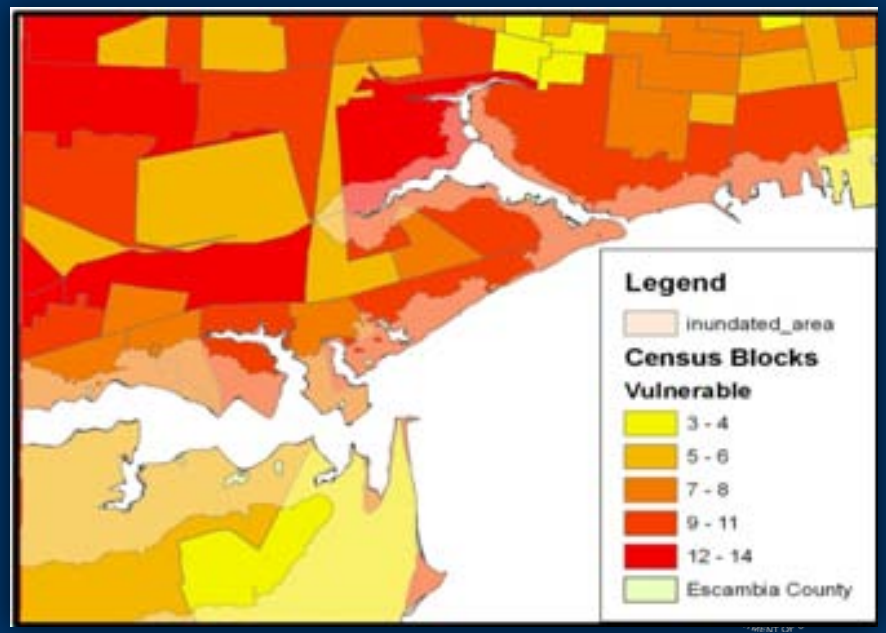
Matt Pendleton

- **Mapping Fundamentals**
- **Datums and Transformation Tools**
- **Height Modernization Program**
- **Creating Inundation Polygons**
- **Creating Inundation Depth Grids**
- **Visualizing Results**

Station # 4 Risk and Vulnerability Assessments

Lindsay Goodwin

- **Risk Assessment Overview**
- **Risk Mapping**
- **Social Vulnerability Assessment**



Breakout Sections

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Workshop Wrap Up

Coastal Inundation Mapping Course

Intended Audience:

NWS, county, state officials, floodplain managers, GIS staff

Teach practitioners how to:

- Map water level using GIS techniques
- Determine the differences among and uses of various inundation products
- Access water level, topography, bathymetry, base layer data
- Conduct a risk and vulnerability assessment

Coastal Inundation Mapping Course

Course Topics:

- **Types of Coastal Inundation**
- **Coastal Elevation Data**
- **Integrating Elevation Data**
- **Coastal Inundation Mapping**
- **Risk and Vulnerability Assessment**

Workshop Wrap-Up

- **Questions**
- **Evaluation**

Thank You For Attending

NOAA Coastal Services Center

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