Chesapeake Coastal Community Flood Vulnerability: Prediction and Evaluation

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and the CCRM Coastal Resource Management Clinic
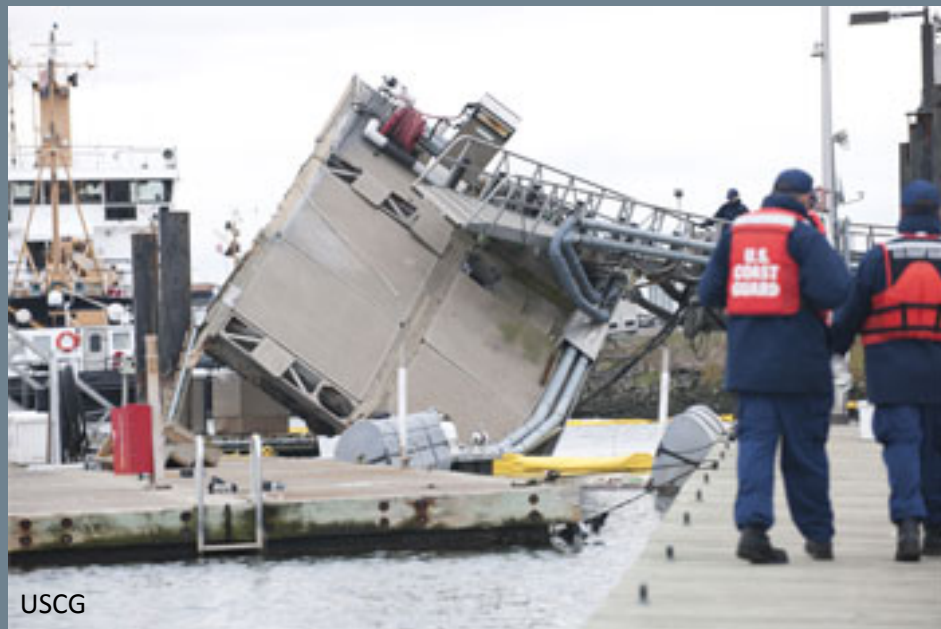
June 21, 2016

From Sail to Satellite: Delivering Solutions for Tomorrow's MTS

FEMA/Andrea Booher

Overview

USCG
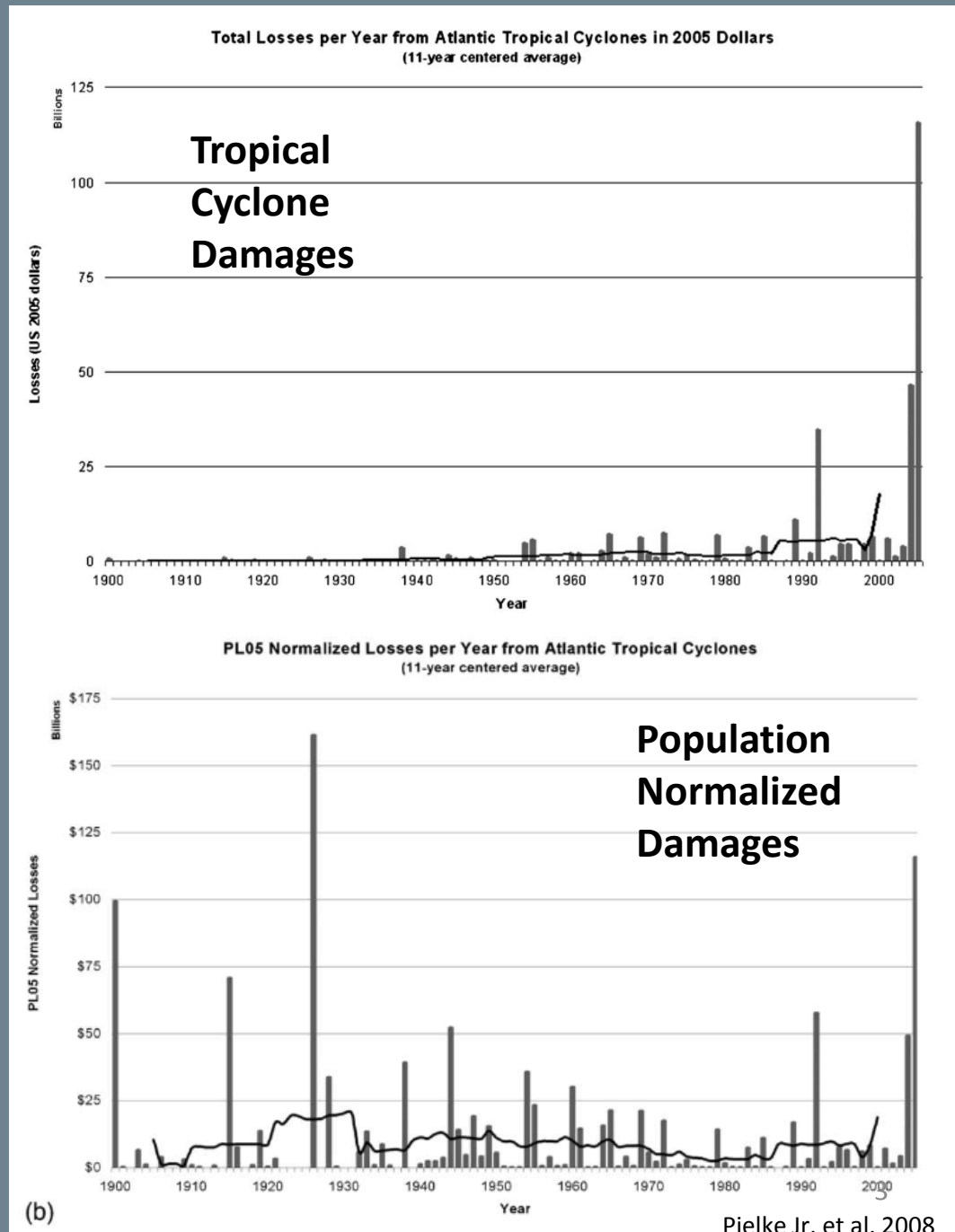
- Vulnerability Index Review

- Chesapeake Bay Vulnerability Characterization

- Coastal Flood Index Verification Case Study

Vulnerability

the degree to which a system, or a part of it, is likely to experience harm due to exposure to a hazard . . .
(Turner et al. 2003)

Tropical Cyclone Damages

Population Normalized Damages

Pielke Jr. et al. 2008

Relevance to Resilience

Rosati et al. 2015

Vulnerability (y-axis)

Resiliency (x-axis)

Avoid: Severe hazard impacts and limited ability to respond

The Goal: Issues are there but you can handle them

Limited Issues: Not resilient but limited hazards to worry about

The ideal: Resilient to what could come but not much does

Index Evolution

- Transition from qualitative to quantitative
  - Index – composite measure of multiple indicators into one value

- From elevation maps to complex hydrodynamic models to social elements

- Issues
  - Limited application to coastal Chesapeake
  - Physical & social vulnerability scale mismatch
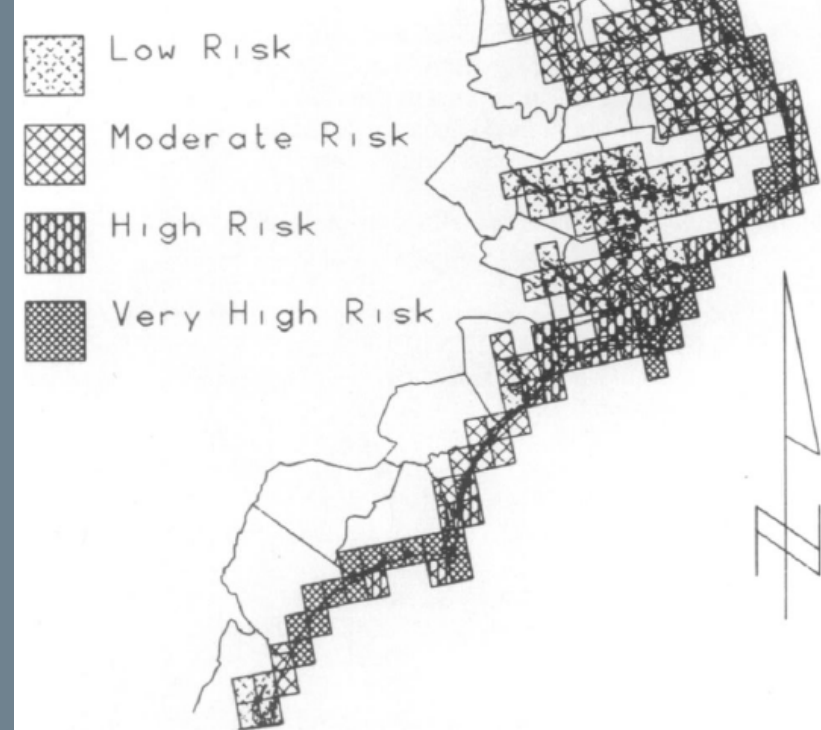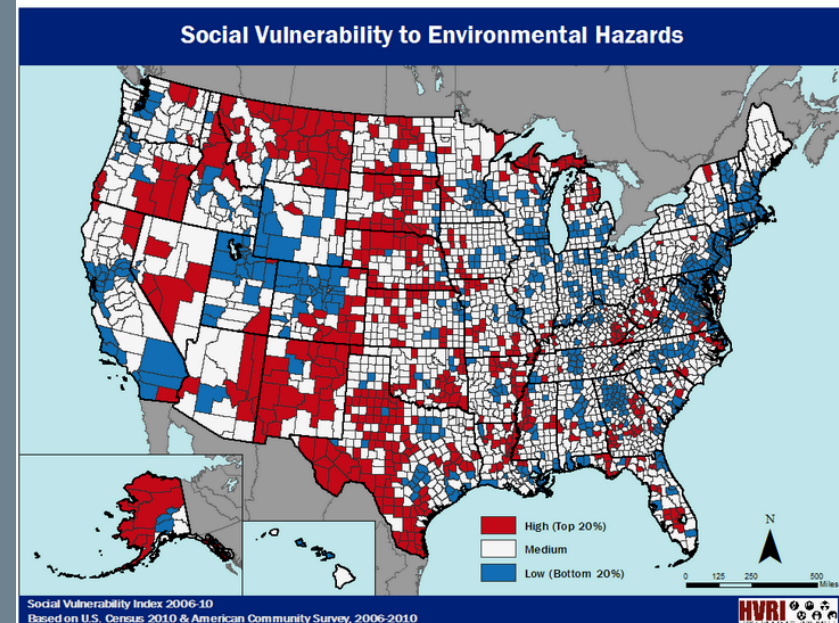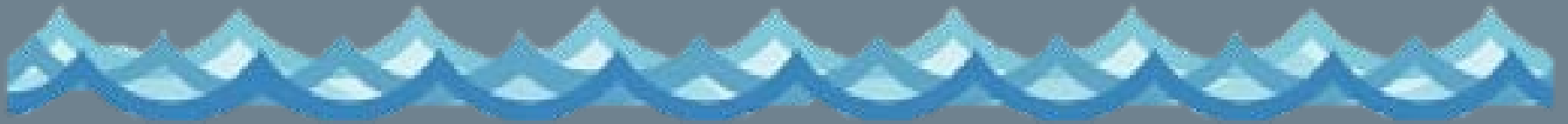 - Limited index verification

Low Risk

Moderate Risk

High Risk

Very High Risk

Figure 6g. Distribution of low, moderate, high, and very high risk shorelines (South Carolina and North Carolina).

Gornitz et al. 1994

Social Vulnerability to Environmental Hazards

High (Top 20%)

Medium

Low (Bottom 20%)

Social Vulnerability Index 2006-10
Based on U.S. Census 2010 & American Community Survey, 2006-2010

HVRI

Chesapeake Vulnerability Characterization

- Index development/application
  - Vulnerability distribution
    - Approach Application
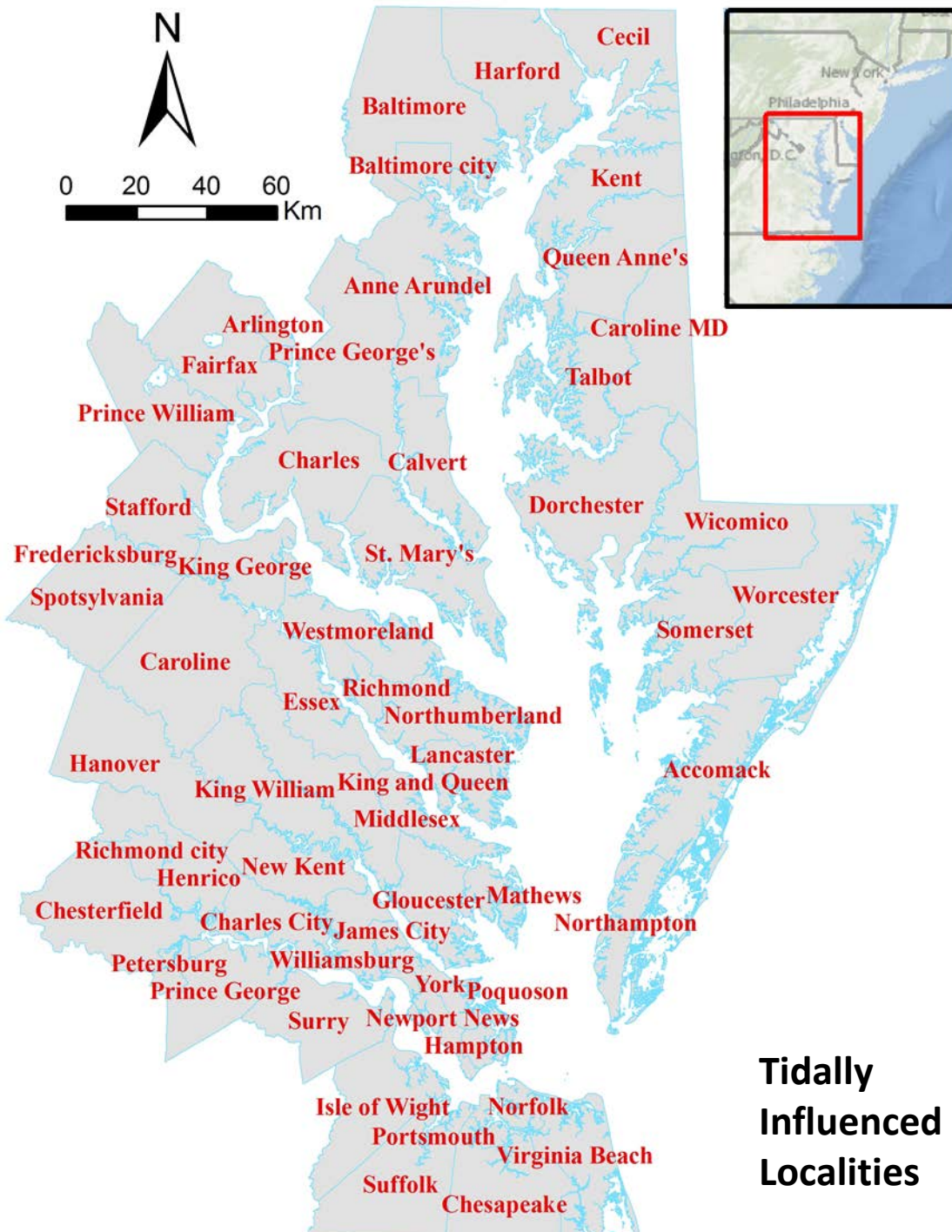
Study Area
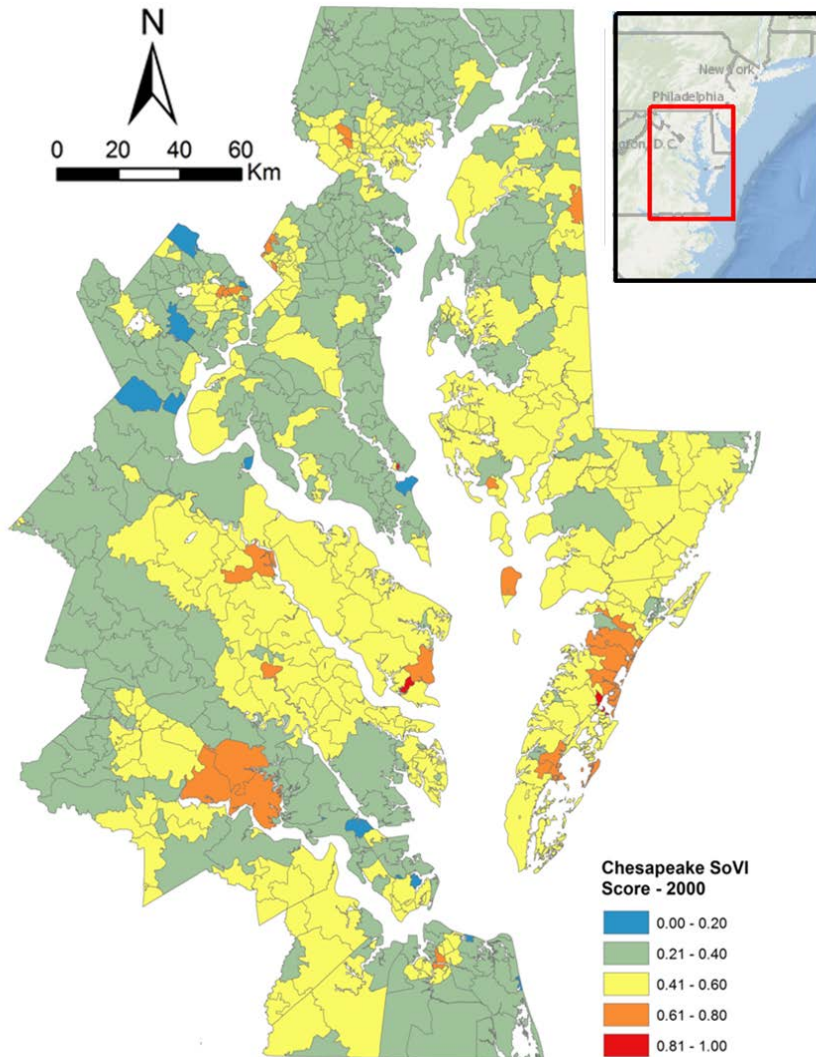
- Coastal Chesapeake

- The right geography for the right data

Chesapeake SoVI

Chesapeake SoVI
Score - 2000

- 0.00 - 0.20
- 0.21 - 0.40
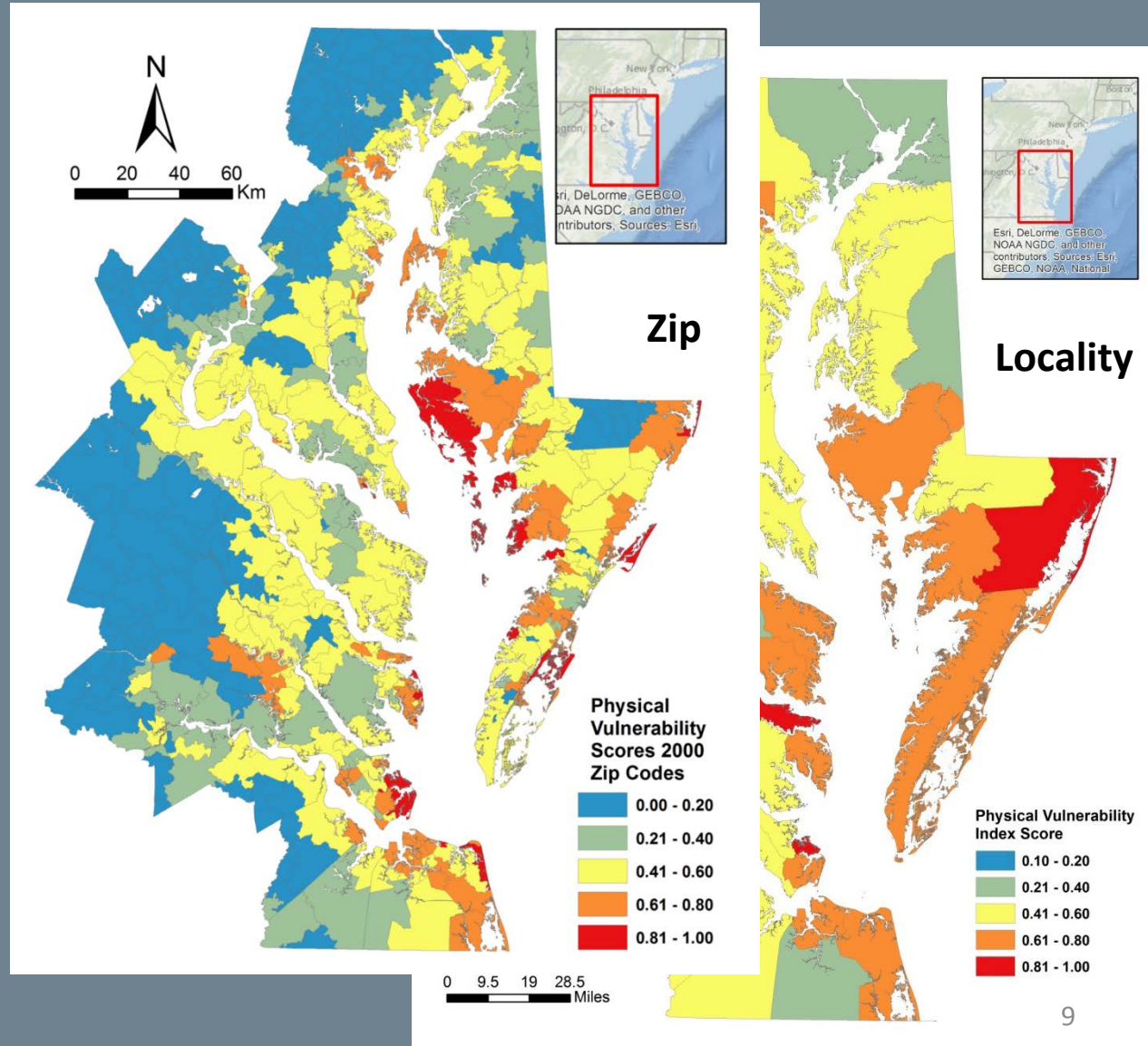- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Census data
+
Z-score standardization
+
Principal Component
Analysis
+
Determining factors
& impact direction
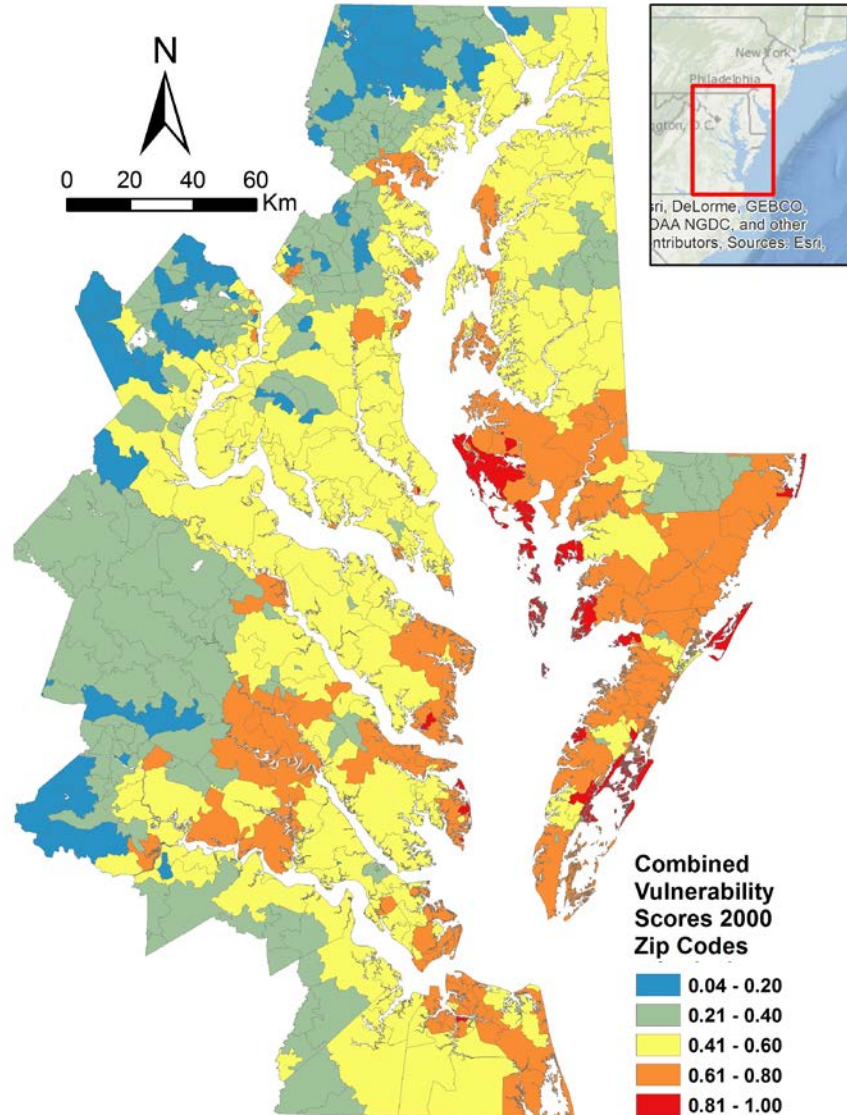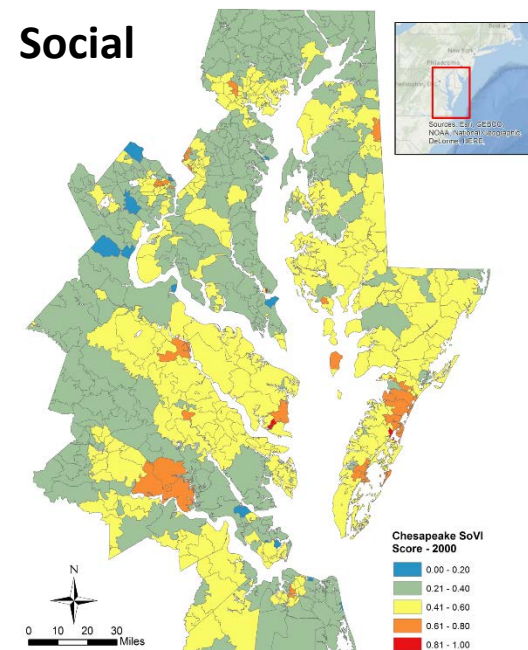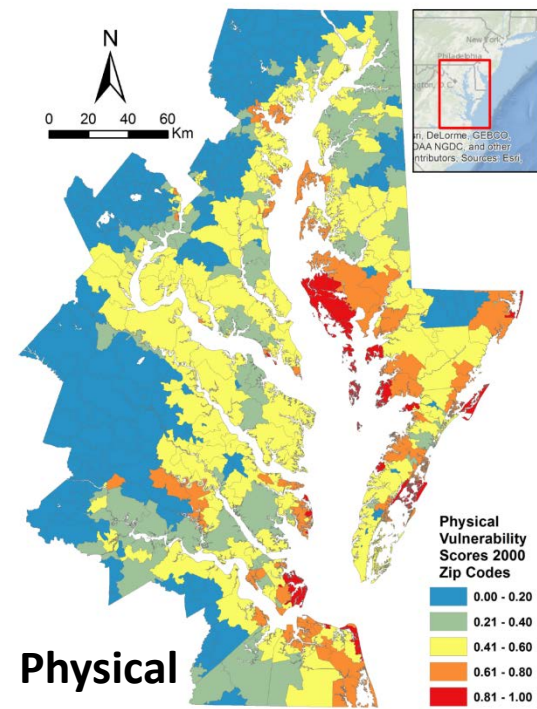+
Equally summing
factors

Chesapeake Physical Vulnerability Index

Phys. Vuln =

Sub-10 ft area
+
Inverse
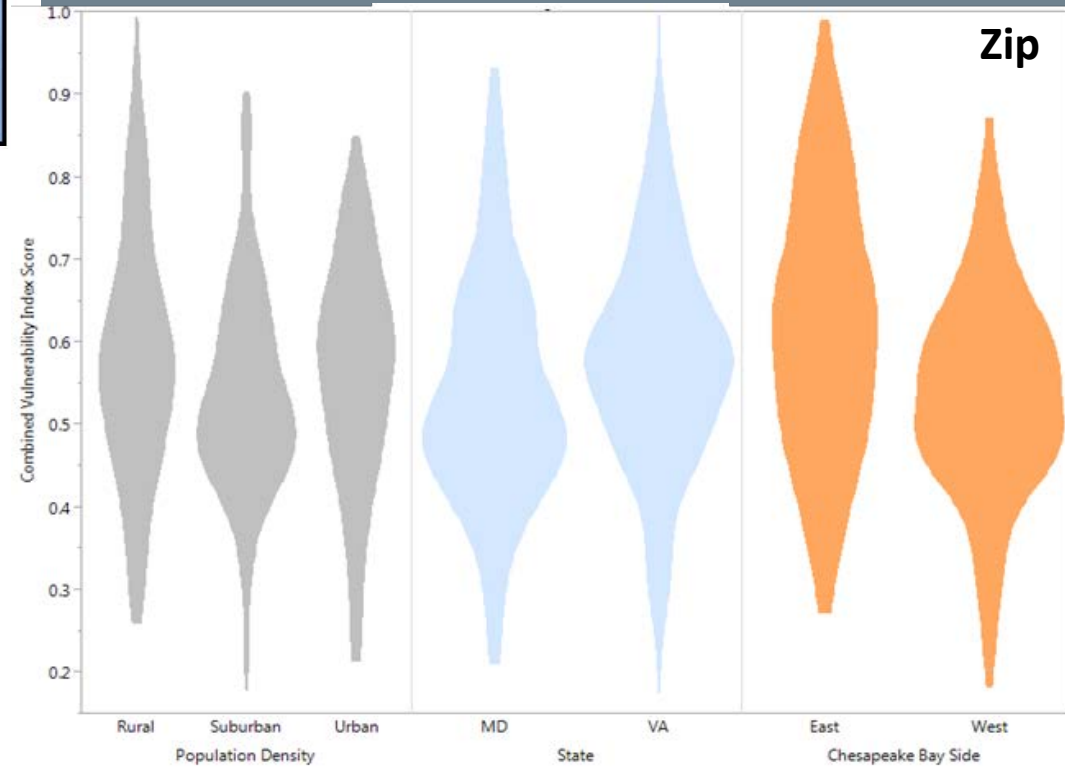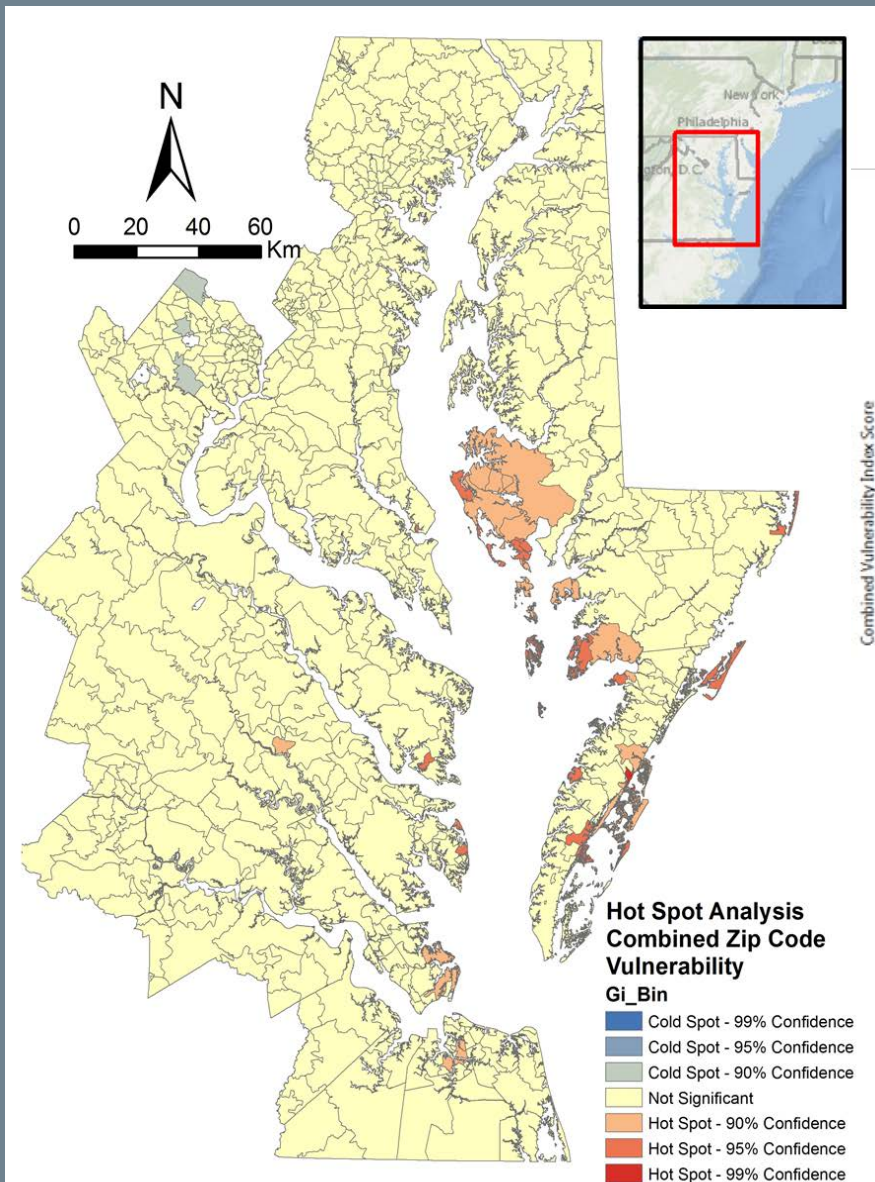Volume/area
+
Developed land
+
Wave Energy
+
Inverse Tidal Range

- Ties to human scale data

- Calculable at different scales

Zip

Locality
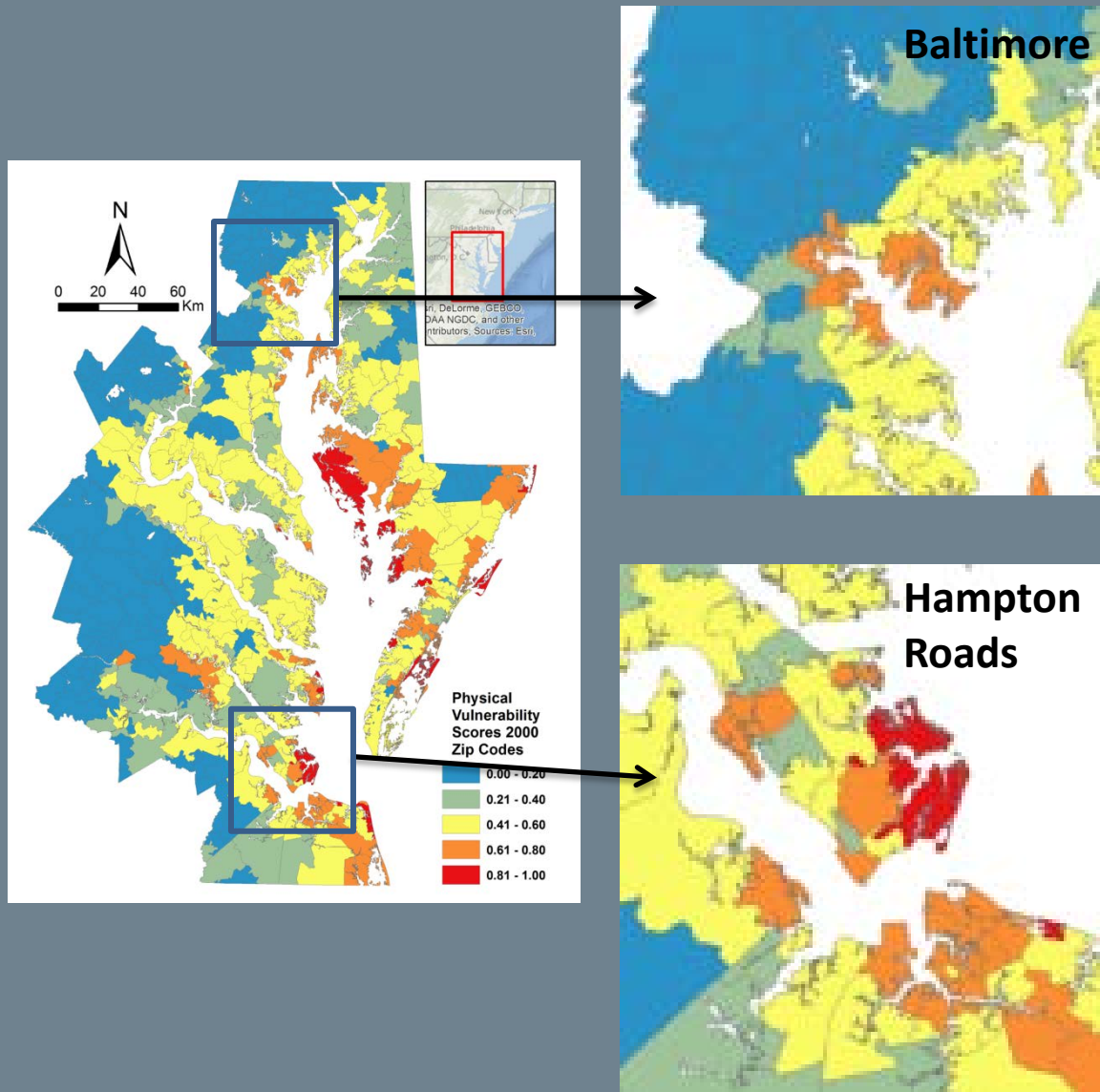
Physical Vulnerability Scores 2000 Zip Codes

- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Physical Vulnerability Index Score

- 0.10 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Combined Vulnerability

Physical

Physical Vulnerability Scores 2000 Zip Codes
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Social

Chesapeake SoVI Score - 2000
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Combined Vulnerability Scores 2000 Zip Codes
- 0.04 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Vulnerability Distribution Analysis

Combined vulnerability data

Chesapeake Bay Port Regions

Physical Vulnerability Scores 2000 Zip Codes
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Baltimore

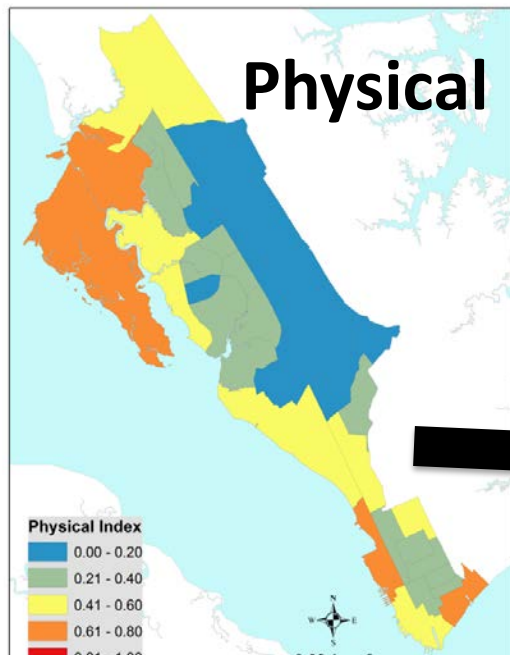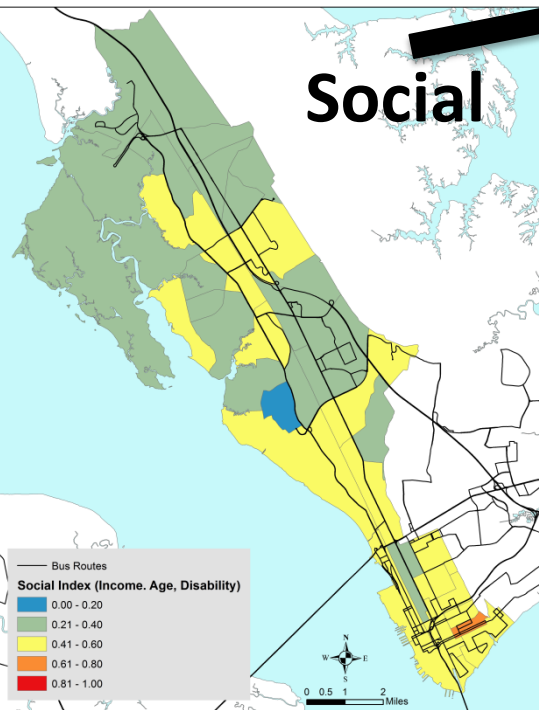**Hampton Roads**

- Vulnerable Communities around Baltimore and Norfolk/Newport News/Portsmouth

- Differing challenges – e.g. community evacuation

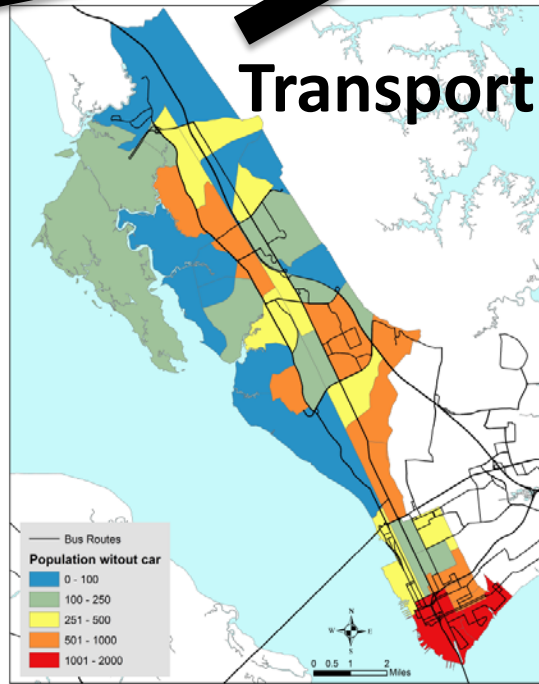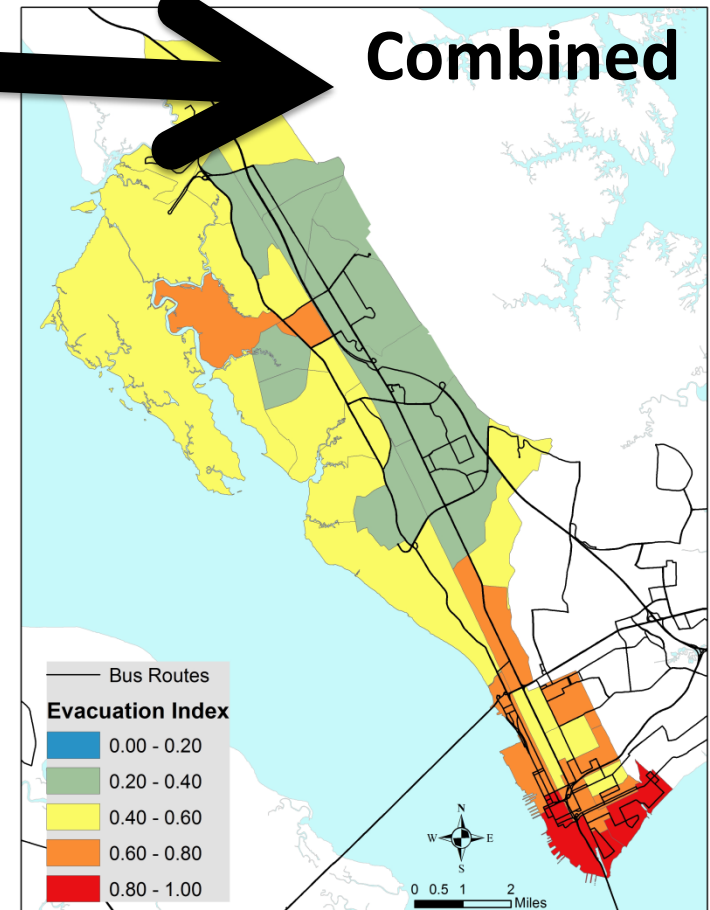# Community Application – Newport News Evacuation Vulnerability

Physical

Physical Index
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80

Social

Bus Routes
Social Index (Income. Age, Disability)
- 0.00 - 0.20
- 0.21 - 0.40
- 0.41 - 0.60
- 0.61 - 0.80
- 0.81 - 1.00

Transport

Bus Routes
Population witout car
- 0 - 100
- 100 - 250
- 251 - 500
- 501 - 1000
- 1001 - 2000

Combined

Bus Routes
Evacuation Index
- 0.00 - 0.20
- 0.20 - 0.40
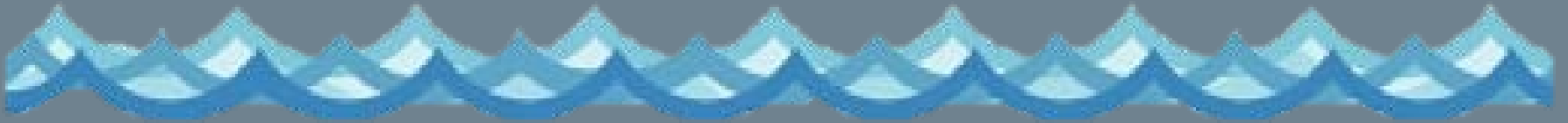- 0.40 - 0.60
- 0.60 - 0.80
- 0.80 - 1.00

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Vulnerability Application Take Aways

- Quantitative tier 1 human scale approach to regional vulnerability

- Combined vulnerability broadens areas of concern

- Solid platform for evaluation of Chesapeake region

Coastal Flood
# Index Verification
Case Study

- Hurricane Isabel Flooding (2003)
  - Verification Data
  - Impact/Index Interactions

Vulnerability Measurement Efforts

- Follow up surveys specific to certain areas following disasters

- Hard to duplicate, extend and heavily resource dependent

- Effort to indicate indicators from already collected data/test response
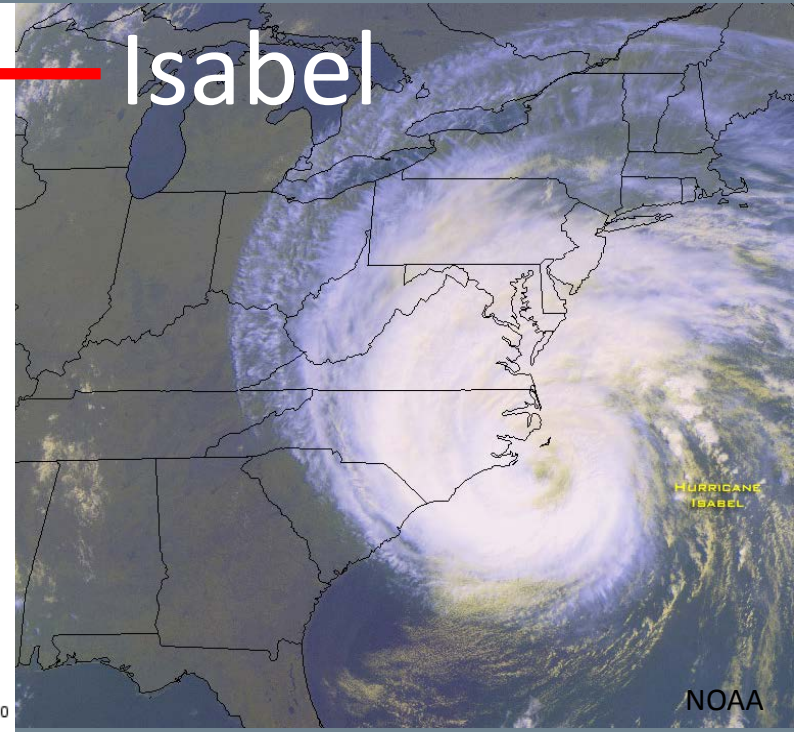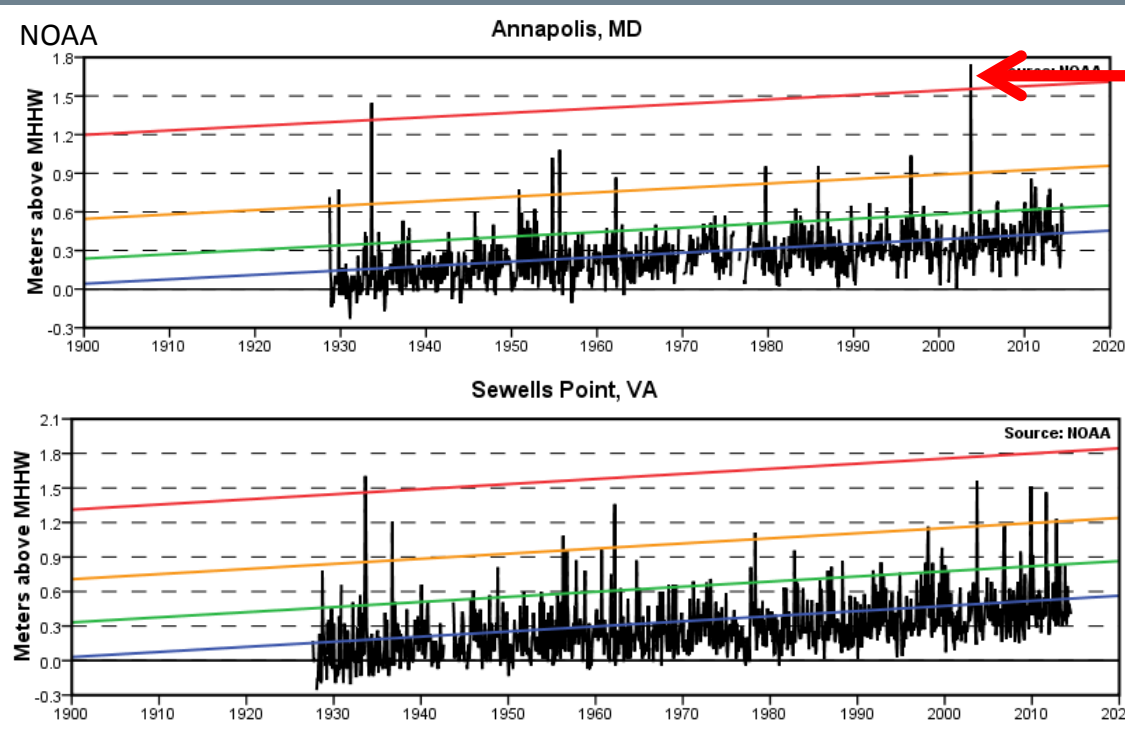

Figure 5 Recovery score determination*

Recovery Score = 0

Diamondhead

Pass C

Waveland

Recovery Score = 25

Recovery Score = 75

Recovery Score = 100
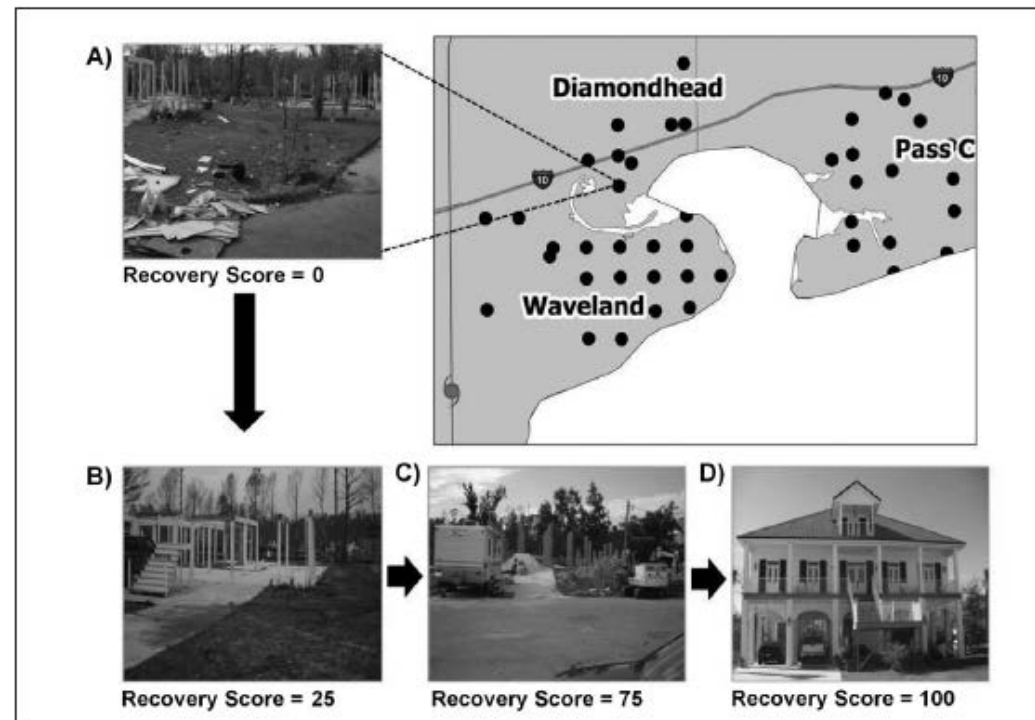
Note: * A) October 2005; B) March 2006; C) October 2006; D) October 2007.

Burton et al. 2011

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Storm Selection: Isabel


NOAA

Annapolis, MD

Sewells Point, VA

Source: NOAA
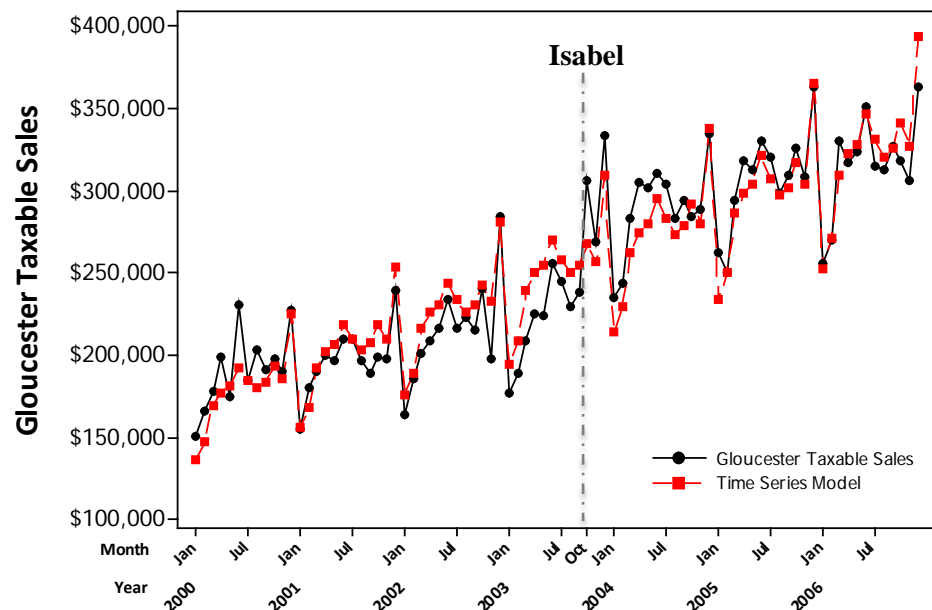
Isabel

NOAA

- September 2003
- Strongest Atlantic hurricane since 1999
- Worst Chesapeake region storm since 1933
- 8+ ft storm surge in Chesapeake Bay

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Determining Impacted Communities

- Apply a hydrodynamic model applied to the Bay
  - SCHISM/SELFE model (Zhang)
  - Successfully hindcasts storm flooding
  - Translate to geographic areas as percent flooded

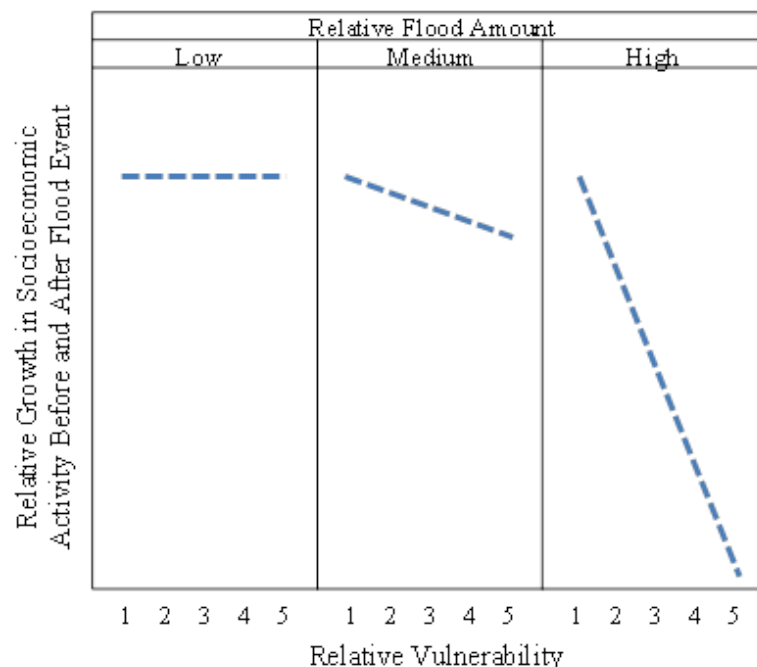- Maximum flood area = approximate potential damage

Sandy flood damage by zip code
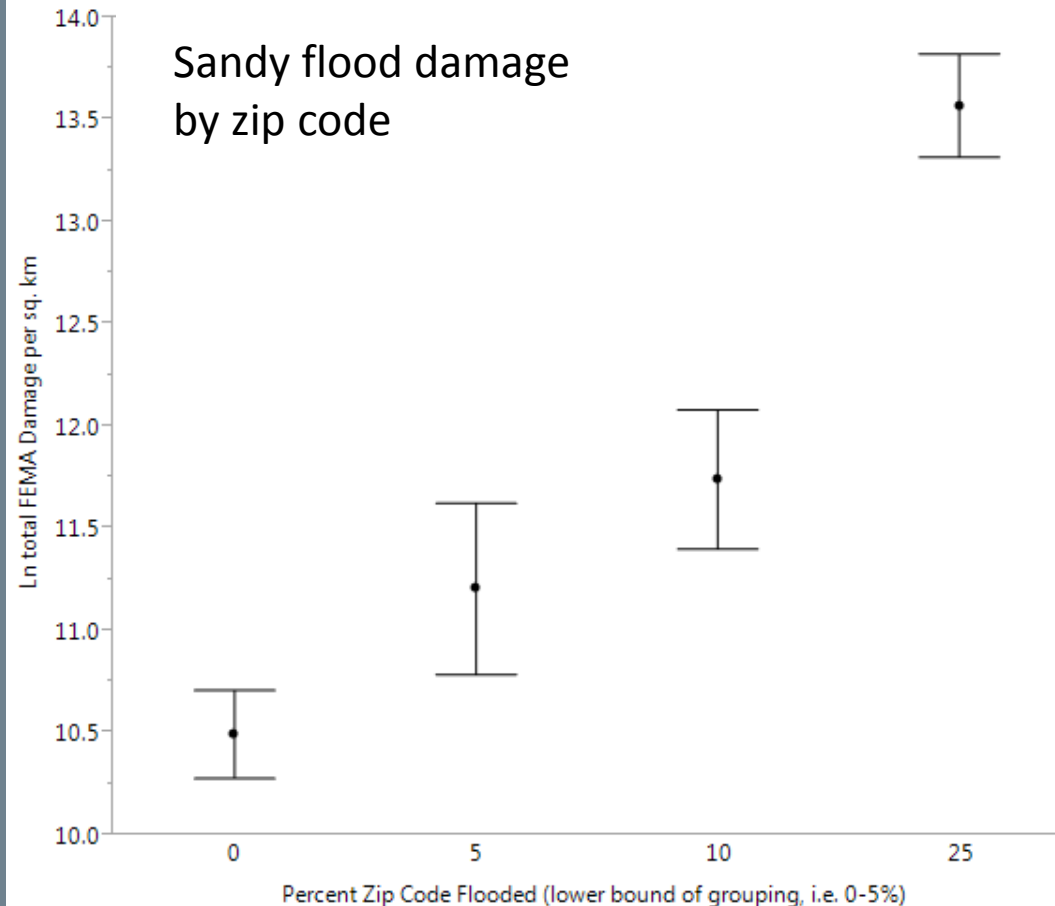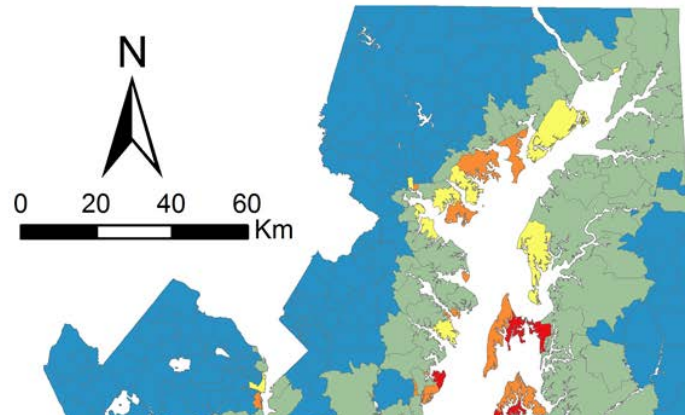
Chesapeake Datasets and Analysis

- Indicator Datasets
  - Zip Code Stats
    - IRS
    - Mean Business Establishment Data
  - Locality Stats
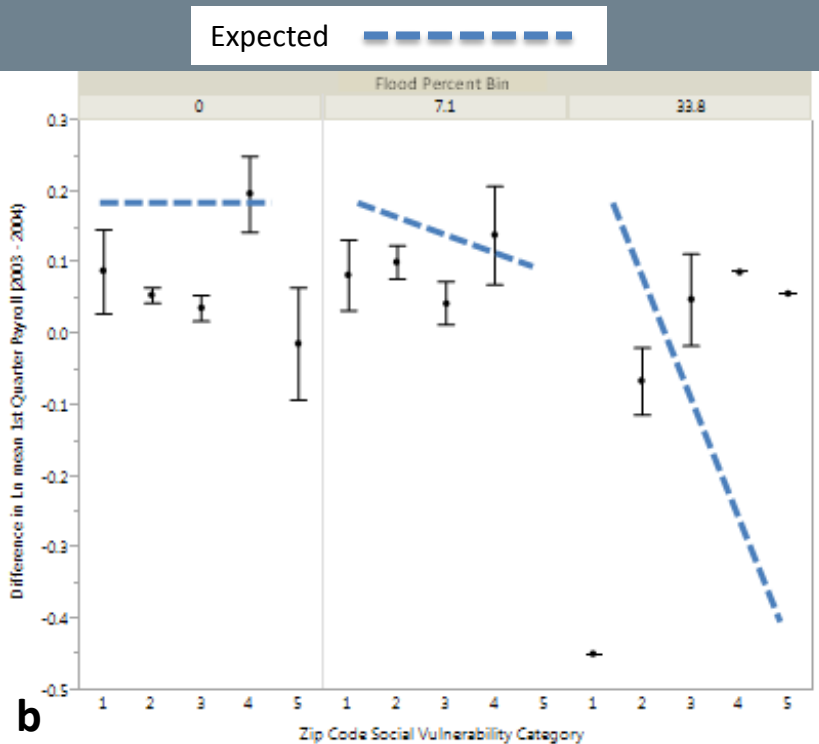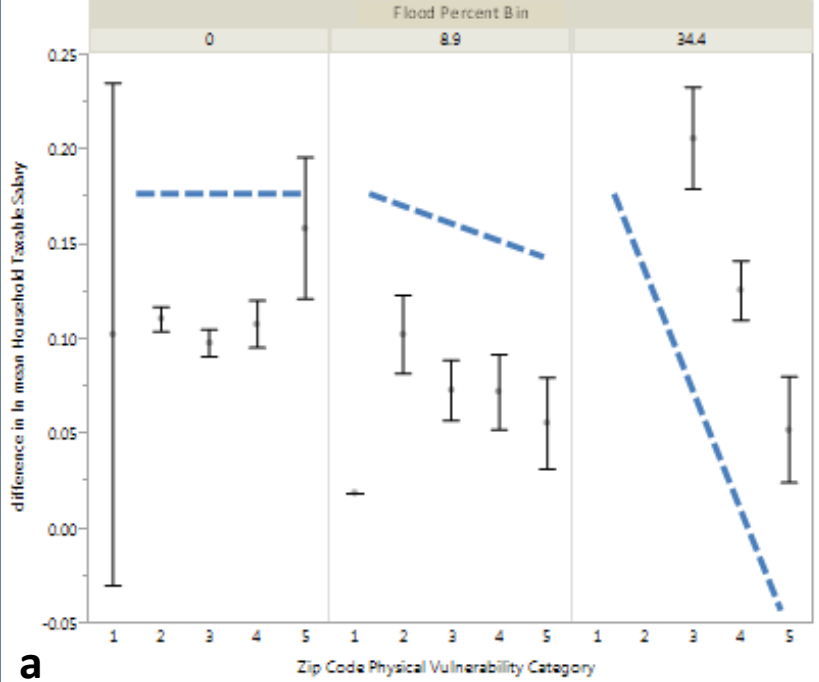   - Taxable Sales, Building Permits, Unemployment, Schools . . .

- Determined significance of Before After Control Impact type test

- Use of repeated measures MANOVA to identify interaction
  - Index scores against change in socioeconomic activity binned by flood experience

a) Physical Index against salary change in flooded zip codes (p=0.04)

b) Social index against salary change and flooded zip codes (p=0.005)

Index Flood & Community Change

- Overall limited index performance
  - Physical Index strongest
  - Social index fairly limited, even when combined

Isabel Verification Take-Aways

- Present vulnerability index scores fail to match real world responses here
  - Lack of meaningful trends
  - Lack of consistency across variables

- Need more standardized information before extending lessons
  - Limits of existing data for the region
  - Develop more sources

High Seas

Summary

U.S. Air Force photo/Tech. Sgt. Ben Bloker

- Chesapeake vulnerability application does target particular vulnerability hot spots

- Index application is exaggerated relative to aggregate community performance

- More standard human behavior data collection is needed to illustrate end regional impacts

Questions?