The Impacts of Extreme Weather Events on Ports

The Example of Mobile, Alabama

Innovative Technologies for a Resilient Marine Transportation System 3rd Biennial Research and Development Conference

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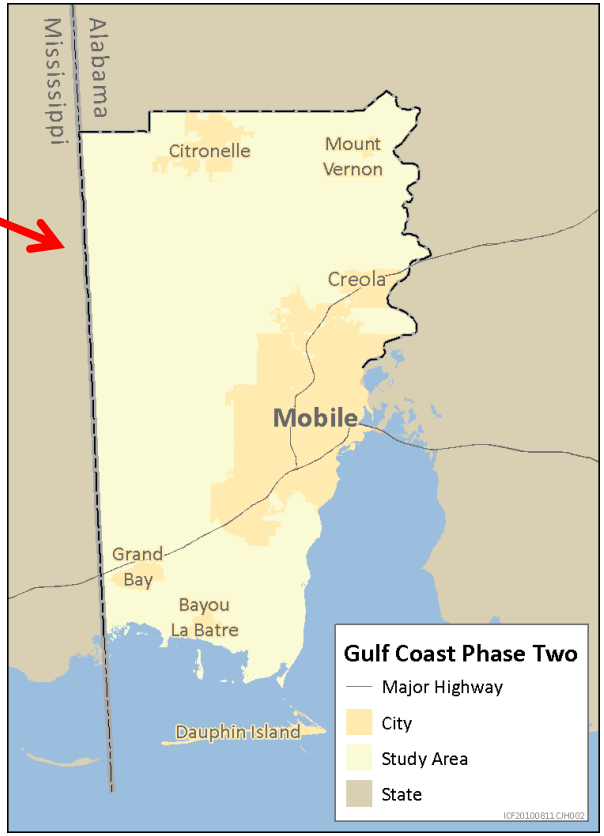
Presentation Outline

- **Update on Recent Work**
  - Gulf Coast Study, Phase 2
  - Mobile ports vulnerability assessment
- **Where do we go from here?**
  - New tools and resources available
  - Asset management strategies

The Gulf Coast Study

- **Gulf Coast Study, Phase 2: Vulnerability Assessment**



Pilot in one metropolitan area (Mobile, AL)

Tools and Strategies that will be transferable to other areas

Share lessons learned and tools

Mobile Vulnerability Assessment Approach

1) High-level vulnerability screen

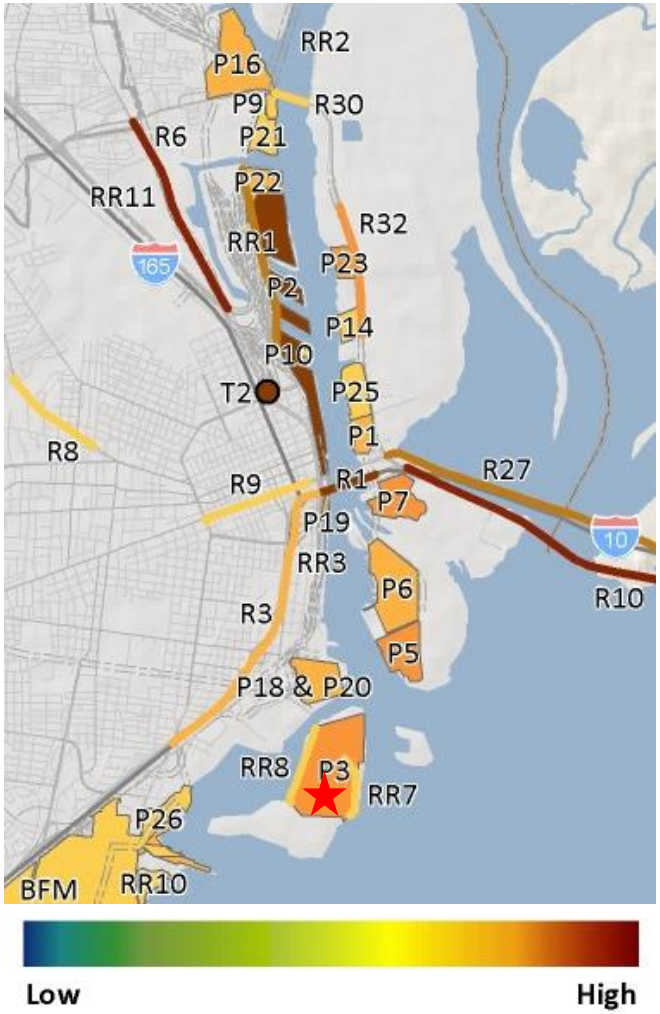
Which port assets are most vulnerable to which events?

- Identify vulnerability ***indicators***
- Collect data on indicators
- Use indicators to derive a ***vulnerability score*** for each port

2) Detailed engineering analysis:

How is this asset vulnerable to this event?

- Analyze implications of specific scenarios on a specific asset

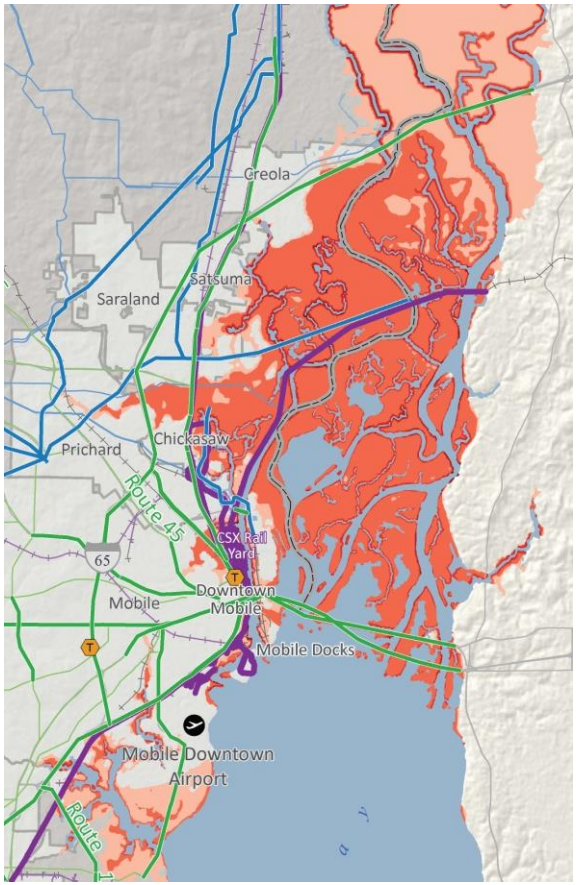


Storm surge vulnerability screen results (red star = detailed assessment)

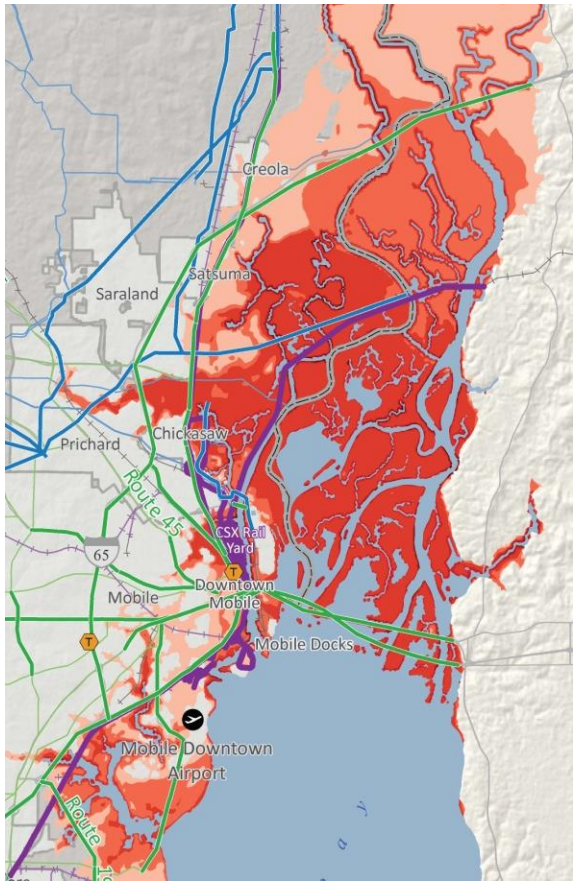
Vulnerability Screen – Exposure Analysis

Modeled storm surge depth

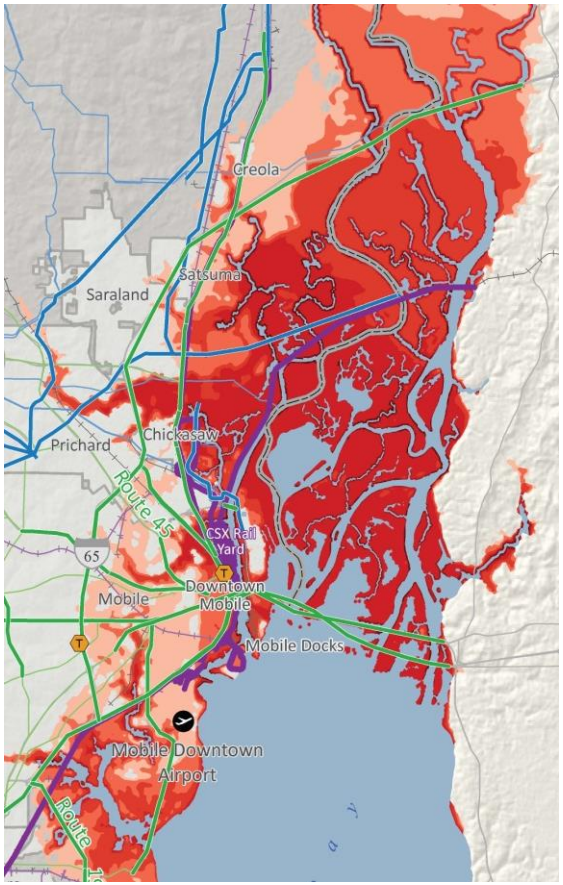
Hurricane Katrina, natural path



Hurricane Katrina, shifted to direct hit on Mobile



Hurricane Katrina, shifted, intensified, and with SLR



Also modeled exposure to sea level rise, wind speeds, extreme heat, and heavy precipitation

Vulnerability Screen – Asset-Level Indicators

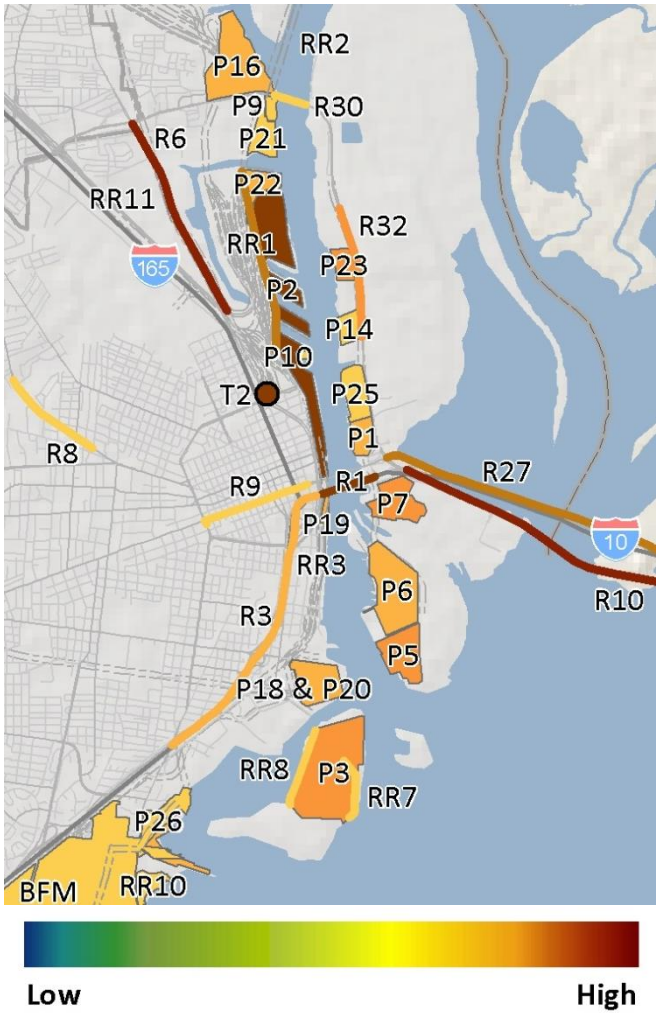
- **Vulnerability = *ƒ* (Exposure, Sensitivity, Adaptive Capacity)**
- **Asset-specific characteristics serve as *indicators* of their sensitivity and adaptive capacity**

Ports Storm Surge Sensitivity Indicators	Ports Adaptive Capacity Indicators
• Previous damage from storm surge? • Shoreline protection? • Infrastructure elevation above sea level • Asset age • Asset condition • Dependence on electrical power • Materials handled	• Ability to shift operations internally • Ability to shift operations externally • Estimated disruption duration from storm surge impacts

- **Project developed methodology to derive *vulnerability score* for each port based on exposure, sensitivity, and adaptive capacity indicators**

Vulnerability Screen Results

- **Alabama State Port Authority (ASPA) State Docks facility was most vulnerable**
  - Highly exposed
  - Demonstrated sensitivity in the past
  - Low-lying assets
  - Relatively inflexible operations
- **Most vulnerable ports those with:**
  - Location on lower Mobile River
  - History of flooding
  - Reliance on electricity
  - Lack of redundancy
- **Results limited by data availability/survey responses**

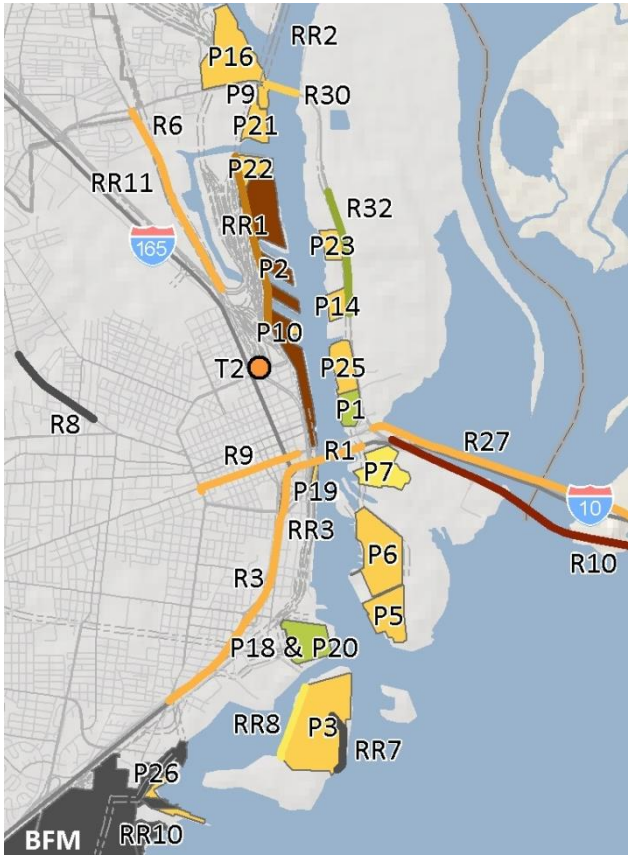


Additional detail on methods and results available in GC2 'Screening for Vulnerability' Report

Low High

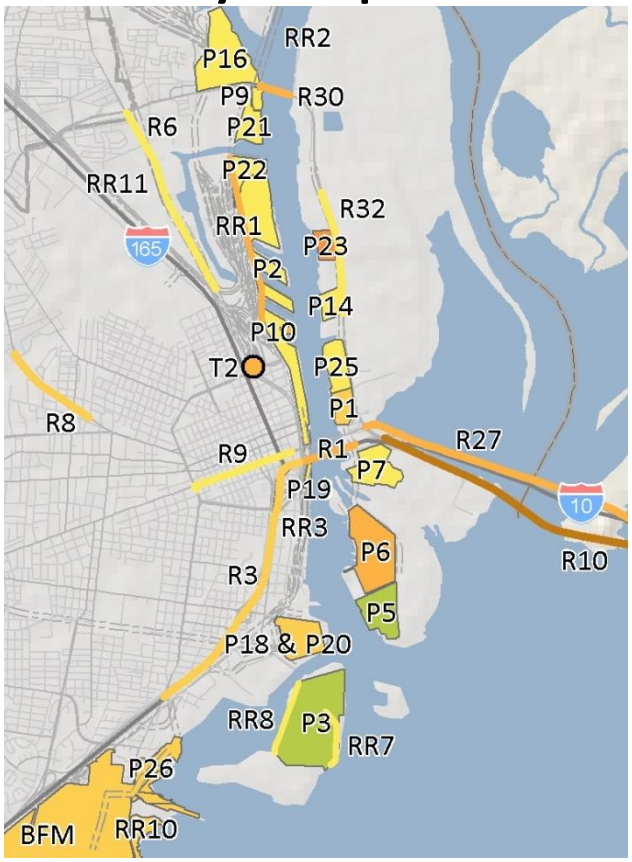
Vulnerability Screen Results – Other Stressors

Sea Level Rise



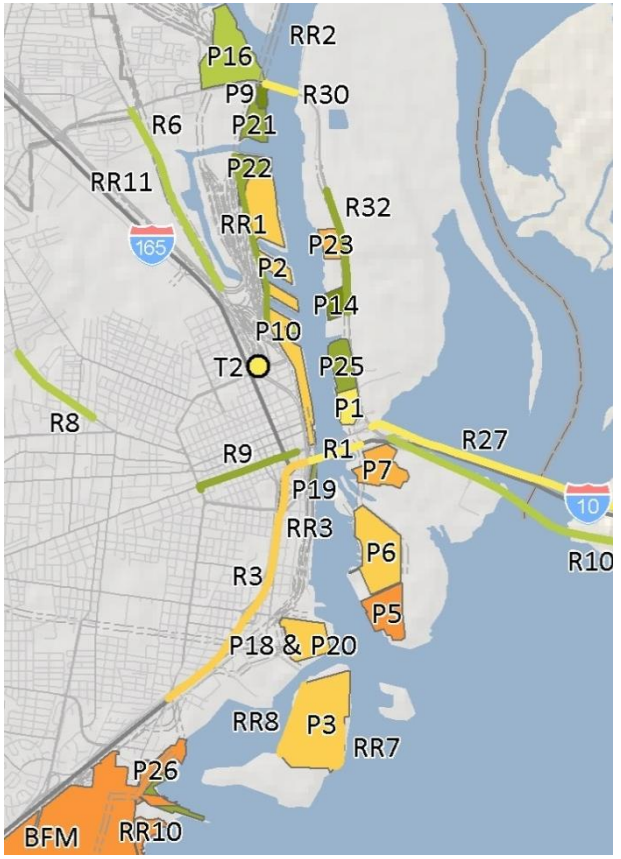
- Low elevation

Heavy Precipitation



- Demonstrated flood-prone

Heat

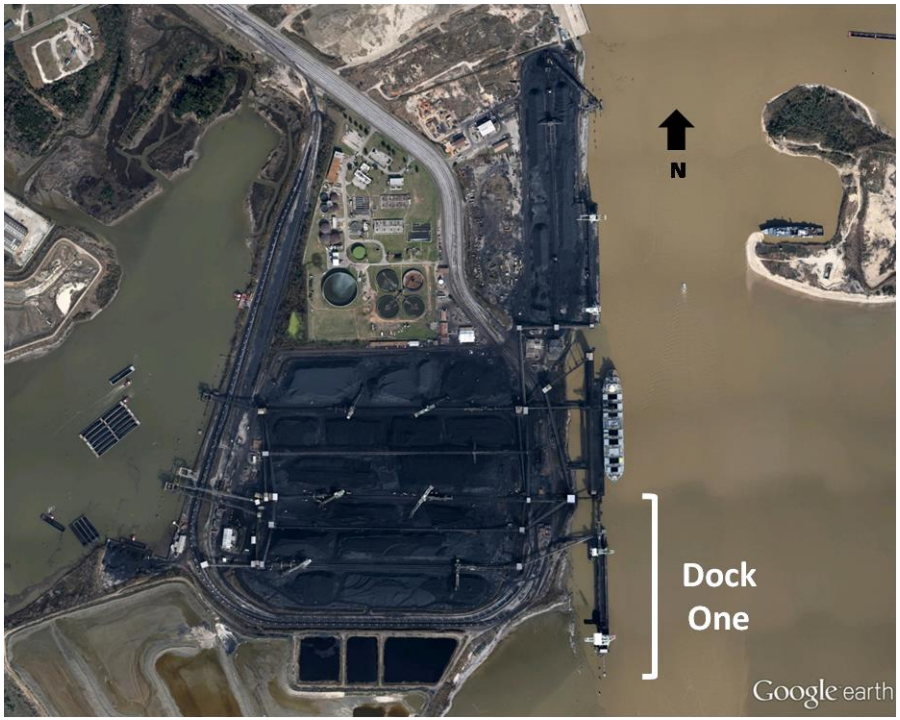


- Heat-sensitive materials

Drivers

Engineering Assessment – Dock One at the McDuffie Coal Terminal

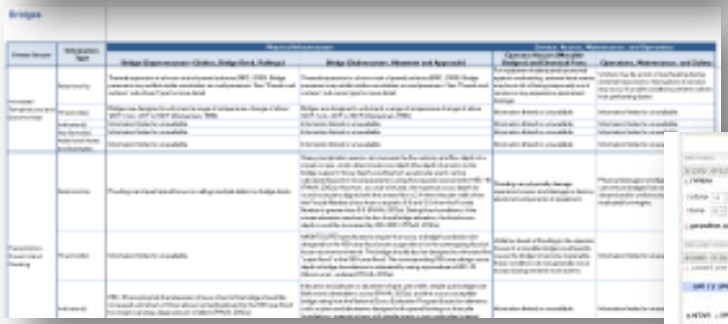
- **Assessed vulnerability of shipping pier to storm surge**
- **Major consequences if damaged:**
  - 50% of ASPA revenue from McDuffie Coal Terminal
  - Service outages at terminal can lead to local coal shortage and brown-outs
- **Analysis found <u>low vulnerability</u> to damage from storm surge**
  - Designed for very large loads
  - Surges so high, wave forces do not interact with pier



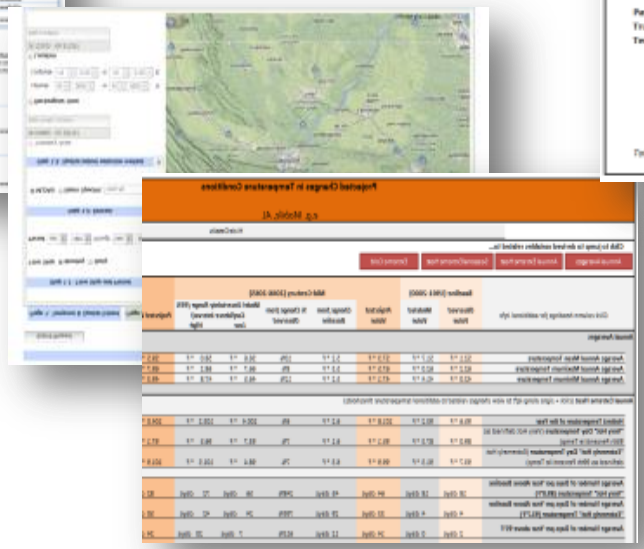
Where do we go from here?

Tools and Resources for Other Ports

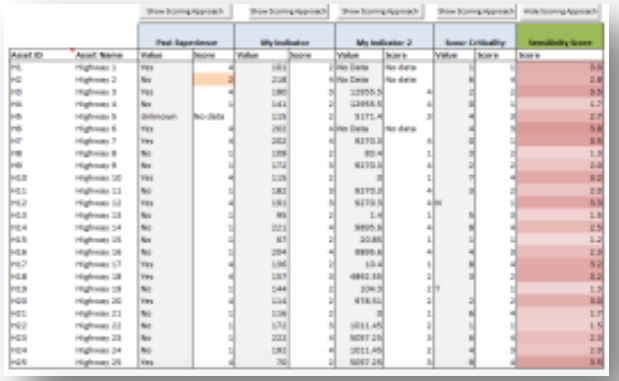
U.S. DOT Gulf Coast Study Tools



Transportation Climate Change Sensitivity Matrix



CMIP Climate Data Processing Tool



Vulnerability Assessment Scoring Tool (VAST)

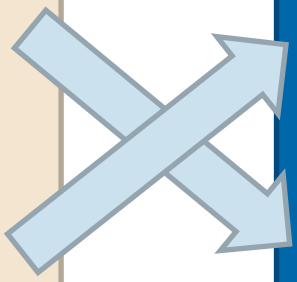
Transportation Climate Change Sensitivity Matrix

What are the potential impacts?

- **Spreadsheet-based reference tool, covering…**

Effects of:

- Extreme Heat
- Heavy Precipitation
- Sea Level Rise
- Storm Surge
- Wind
- Drought
- Dust Storms
- Wildfires
- Winter Storms
- Changes in Freeze/Thaw
- Permafrost Thaw



On:

- **Marine Ports, Terminals, and Waterways**
- Terminal Buildings
- Channels
- Piers, wharves, and berths
- Port services and equipment (e.g., cranes)
- Operations, maintenance, and safety

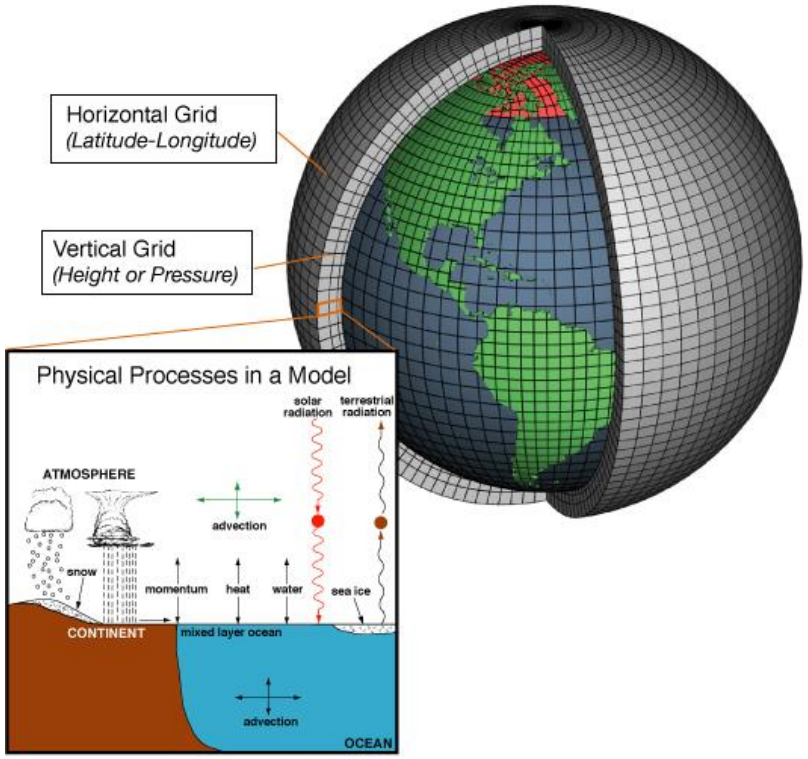
Transportation Climate Change Sensitivity Matrix

Climate Stressor	Information Type	Physical Infrastructure	
		Terminals and Other Buildings	Channels and Waterways
Storm Surge	Relationship	Storm surge and direct wave action can damage marine port buildings (Nadal et al., 2010). Roof covers, walls, and doors are often the most sensitive (Curtis, 2007). Fast moving water can undermine or damage building foundations (U.S. CCSP, 2008).	Storm surge can wash debris and sedimer shipping channels, necessitating dredging the storm. In some cases, such as in the G intercoastal waterway, a combination of s and sea level rise can destroy barrier isla eliminating waterway systems entirely, ar ships to navigate open water (NRC, 2008).
	Threshold(s)	If the storm surge overtops the elevation of the port, damage is likely to occur due to a combination of flooding and wave action. Wave damage (driven by wind) to port facilities is possible when wave heights reach 4-6 feet, and likely when wave heights reach 6-12 feet. When wave heights exceed 10-12 feet, there can be structural damage to larger vessels and their cargo (Peterson et al., 2008; OFCM, 2002). However, wave height thresholds are location-specific as the height of wharf decks above the water surface differs from one port to another and one terminal to another (Beckstrom, 2013). Wave heights also assume a mean sea level. As the mean sea level changes, wave height thresholds will also change (Savonis, 2013).	The extent to which sediment build-up nec dredging is location-specific and depends sedimentation rate, (2) dredging frequenc as part of regular maintenance, and (3) pr deep water berths and channels to shallo (Beckstrom, 2013). The frequency of dredg in part on whether the largest ships that tl usually accommodates can berth at the pc 2013).
	Indicator(s)	Roll-up door openings proved to be a weak design element in Gulfport, MS, in Hurricane Katrina. When the doors failed, wind, waves, and debris entered and damaged the buildings. High wind-rated roll-up doors can mitigate some impacts.	Shallower channels are more likely to req dredging after storms due to debris. Overc dredging (advance maintenance dredging) dredging needs after storms. The Army Cor
	Key Source(s)	ASCE 24-05 Flood Resistant Design and Construction (FEMA, 2011a)	NRC, 2008; Smythe, 2013
		During Hurricane Katrina, building walls, doors, and roof covers were heavily damaged in Gulfport, MS. However, building columns, roof purlins, and roof structures performed well (Curtis, 2007). Five years after Katrina, Port of Gulfport operated at only 80% of its pre-Katrina volume and plans to build	After Hurricane Katrina, Port of Mobile off estimated that dredging expenses, includi removal of branches, sand, and silt from p would exceed $7.5 million (GAO, 2007)

CMIP Climate Data Processing Tool – Background

What are the projected changes?

- **Potential future temperature and precipitation conditions come from global climate models (GCMs)**
- **GCMs are frequently *downscaled* to higher resolution for use at the local level**
- ***Acquiring* and *processing* downscaled GCM data can be very resource-intensive (time, computing, technical expertise)**
  - **Acquiring** – Bureau of Reclamation's Downscaled CMIP3 and CMIP5 Climate and Hydrology Projections (DCHP) website
  - **Processing** – CMIP Climate Data Processing Tool



CMIP Climate Data Processing Tool

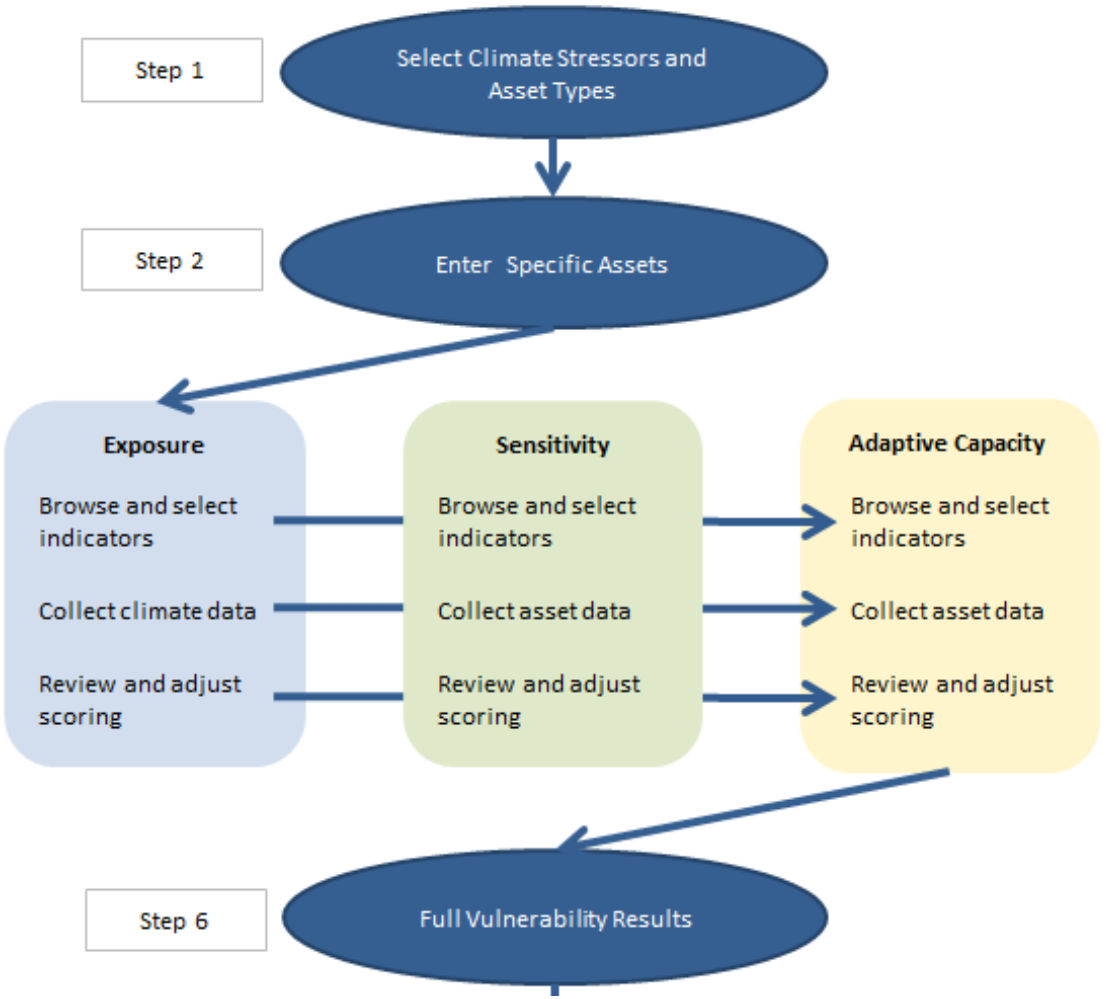
- **Excel-based tool**
- **User selects location on a map, downloads data for downscaled (56 sq. mile) "grids"**
- **Tool translates climate model data into more relatable terms**
- **Outputs change at the local level in 58 specific variables relevant to transportation practitioners**
  - e.g., Change in number of very hot days
  - e.g., Change in 1% precipitation events

- Overcomes major need for easy access to climate data
- Makes a process that took *years* for Mobile take a matter of *hours*

Vulnerability Assessment Scoring Tool (VAST)

What is most vulnerable?

- **Provides a framework for conducting a vulnerability assessment**
  - Guides users through
    - Choosing stressors to evaluate
    - Choosing assets to evaluate
    - Choosing indicators to use
    - Collecting data on indicators
    - Refining method to convert data to scores
    - Reviewing results
- **Outputs: Vulnerability scores for all assets entered**

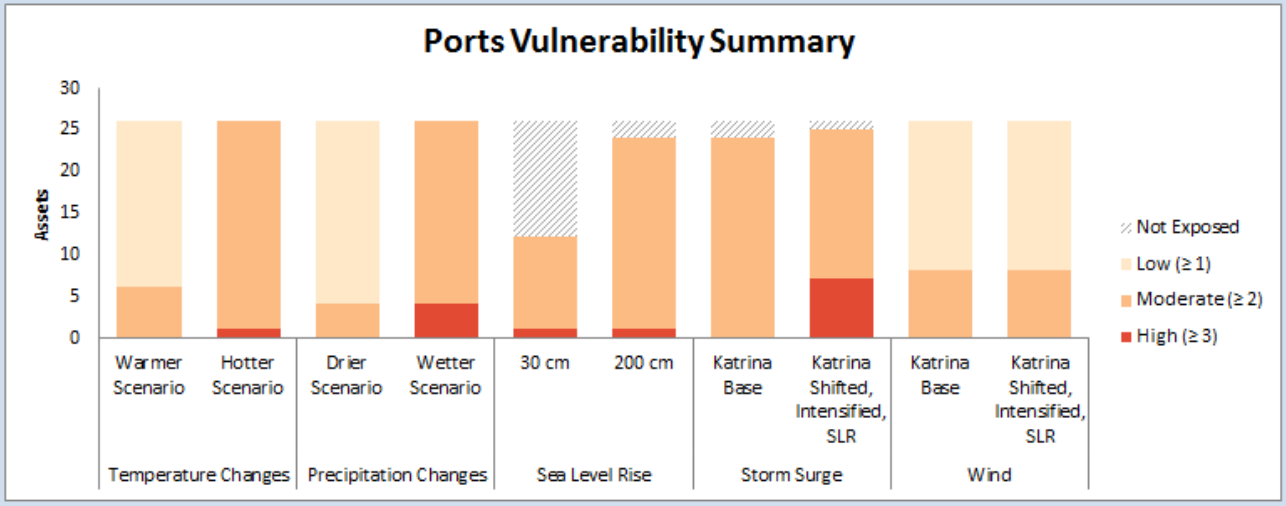


VAST – Example Outputs

View results for...

Ports

Generate PDF



10 Most Vulnerable Assets to Each Stressor
(highlighted assets appear in multiple lists)

◉ Scenario 1 ○ Scenario 2

Temperature Changes

ID	Name	Score
P-5	Alabama State Port Authority (ASPA) - Pinto Island	2.4
P-7	Austal	2.2
P-23	Shell Chemical Co.	2.2
P-2	Alabama State Port Authority (ASPA) - Alabama State Docks	2.1
P-18	Mobile Container Terminal	2.1
P-3	Alabama State Port Authority	2.1

Precipitation Changes

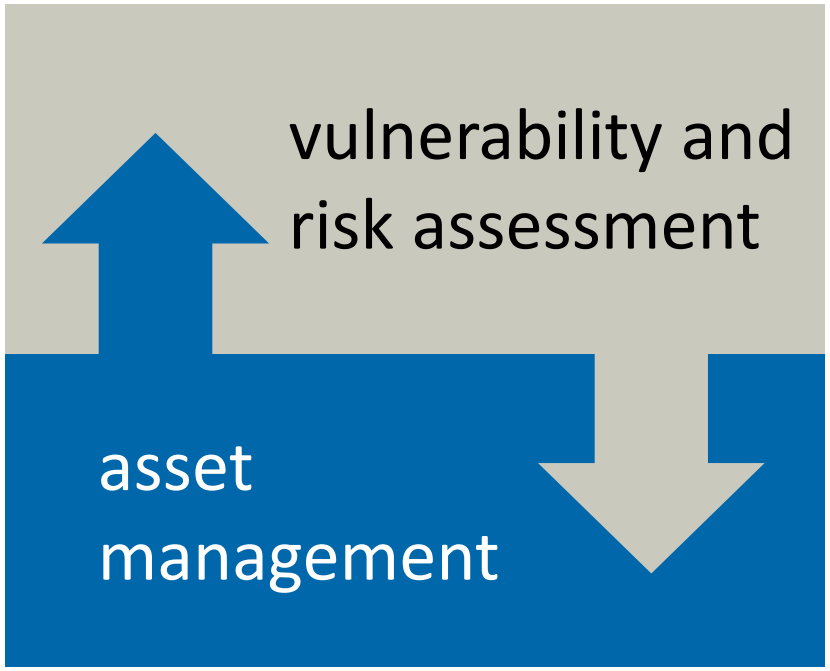
ID	Name	Score
P-6	Atlantic Marine (BAE Systems Southeast Shipyards)	2.2
P-23	Shell Chemical Co.	2.2
P-7	Austal	2.1
P-2	Alabama State Port Authority (ASPA) - Alabama State Docks	2.0
P-5	Alabama State Port Authority	1.9
P-18	Mobile Container Terminal	1.7

Sea Level Rise

ID	Name	Score
P-2	Alabama State Port Authority (ASPA) - Alabama State Docks	3.7
P-22	Plains Marketing - South Terminal	2.8
P-5	Alabama State Port Authority (ASPA) - Pinto Island	2.5
P-8	Bayou La Batre	2.5
P-11	Environmental Treatment Team	2.5
P-13	Gulf Atlantic Oil Refining Co.,	2.5

Other Resources – Is there a role for asset management?

- **Strong asset management systems underpin effective vulnerability assessment**
- **Vulnerability assessment and extreme weather risk management can inform transportation asset management**



Roles for Asset Management in Improving Resilience

- **1) Provide data for vulnerability assessments**
  - Asset management systems house data that can be used to determine:
    - Criticality
    - Vulnerability to different extreme weather events or climate changes
- **2) House information on asset vulnerability and risk**
  - From vulnerability or risk assessment, institutional knowledge, or weather-related repair or maintenance records

	Consequence				
Likelihood	Insignificant	Minor	Significant	Major	Catastrophic
Very Rare	Low	Low	Low	Moderate	High
Rare	Low	Low	Moderate	High	High
Seldom	Low	Moderate	Moderate	High	Extreme
Common	Moderate	Moderate	High	Extreme	Extreme
Frequent	Moderate	High	High	Extreme	Extreme

Roles for Asset Management in Improving Resilience

- **3) Provide a means to track critical information**
  - Costs of extreme weather events
  - Weather-related repair or maintenance records
  - Assets with repeated weather issues
  - Extreme weather performance indicators
  - Develop triggers for action

Continually inform and revisit knowledge of vulnerabilities, need for adaptation

Thank you!

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Alternate Screen Shots for VAST

Show Scoring Approach | Show Scoring Approach | Show Scoring Approach | Hide Scoring Approach

Asset ID	Asset Name	Past Experience with Storm Surge: Value	Past Experience with Storm Surge: Score	Shoreline protection: Value	Shoreline protection: Score	Reliance on Electrical Power: Value	Reliance on Electrical Power: Score	Age of Wharves, Structures: Value	Age of Wharves, Structures: Score
P-1	Alabama Bulk Terminal Co. (Hunt	Yes	4	Yes	1	2.0	2	21.0	1
P-2	Alabama State Port Authority (ASF	Yes	4	No	4	3.0	3	84.0	4
P-3	Alabama State Port Authority (ASF	Yes	4	Yes	1	4.0	4	33.0	2
P-4	Alabama State Port Authority (ASF	No data	No data	Yes	1	3.0	3	20.0	1
P-5	Alabama State Port Authority (ASF	No data	No data	Yes	1	4.0	4	1.0	1
P-6	Atlantic Marine (BAE Systems Sou	Yes	4	Yes	1	4.0	4	96.0	4
P-7	Austal	Yes	4	Yes	1	4.0	4	11.0	1
P-8	Bayou La Batre	No data	No data	Yes	1	3.0	3	No data	No data
P-9	BP Oil Co., Mobile Terminal Barge	No data	No data	Yes	1	No data	No data	No data	No data
P-10	Crescent Towing & Salvage Co., Ri	No data	No data	Yes	1	2.0	2	22.0	1
P-11	Environmental Treatment Team W	No data	No data	Yes	1	No data	No data	No data	No data
P-12	Evonik Industries	No data	No data	No	4	3.0	3	19.0	1
P-13	Gulf Atlantic Oil Refi								
P-14	Gulf Coast Asphalt C								
P-15	Holcim Cement Wha								
P-16	Kimberly-Clark Corp								
P-17	Martin Marietta Agg								
P-18	Mobile Container Te								
P-19	Mobile Cruise Termi								
P-20	Oil Recovery Co. of A								
P-21	Plains Marketing - N								
P-22	Plains Marketing - So								
P-23	Shell Chemical Co.								
P-24	Standard Concrete P								
P-25	TransMontaigne Pro								
P-26	U.S. Coast Guard Pie								

Age of Wharves, Structures Scoring Approach ?

Review and adjust value range for each score:

Default scoring ranges based on range of all values

Value range:			Score:
1	25	=	1
25	50	=	2
50	75	=	3
75	96	=	4

Restore Defaults

OR

if indicator has non-numerical values...

Indicators of Ports Sensitivity to Temperature

	Indicator	Description and Rationale	Potential Data Source(s)	Indicator Unit	Value Range
		Potential Indicators and Data Sources			**Exampl**
☐ →	Past Experience with Temperature	Ports that have experienced damage during past heat events have demonstrated sensitivity to heat and are likely to be damaged if exposed in the future.	• Interviews/survey/conversations with operations and maintenance staff • Maintenance or repair records • Emergency response records	Damaged in past? (Yes/No)	No Yes
☐ →	Size of Paved Asphalt Areas	Pavement can buckle or sink in high temperatures. The extent of paved asphalt areas is therefore an indicator of sensitivity to heat.	• Visual inspection of satellite imagery • Port operators		No or negligible asph Small asphalt area Medium asphalt area Large asphalt area
☐ →	Reliance on Electrical Power	Some types of rail, such as continuously-welded rail, are more prone to buckling.	• Port owners and operators in your organization		

View results for...

Ports

30

25