Global resource estimates for adapting seaports to climate change: Connecting science, engineering, and policy

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Understanding Climate Change Effects on San Francisco Bay: What can modeling offer?
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Stanford University's projects on engineering and policy responses to climate change (SUPERSLR)

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www.seaports2100.org
I. What are the resource implications of adapting ports to sea level rise?

I. What are port authorities doing about climate change adaptation?

I. What are the viable strategies decision makers can utilize to build resilience on a long time horizons?
Why ports?

• Critical infrastructure in local and global economy
  o 80-90% of world freight moves by ship
  o Jobs, critical resources, facilitate trade

• Dependent on specific locations
  o Deep water, protective harbors, multi-modal connections

• Highly vulnerable locations
  o Often estuaries or river deltas that provide ecosystem services
  o Prone to flooding, storm surge, and SLR

NO PLAN B

(IMO 2008; EPA 2009; Transportation Institute 2008)
Climate change scenarios

• Sea levels to rise .6 – 2 meters by 2100
  – Regional differences
• Doubling of Cat 4 and 5 storms
• Ocean storm tracks shifting
• Inland flooding

(Rhamstorf 2007; Bender, Knutson et al. 2010; NRC 2010; IPCC 2007)
Part I. “Upper-bound estimates” to protect the world’s ports

Modeling the land-side implications of sea level rise

155 ports – Top 50 by throughput and all ports in city with >1m people

- Heads-up digitized port infrastructure
- Assumed 2-meter rise in sea levels
- Option 1 – “Minimum-criteria design dike”
- Option 2 - Modeled an “2m elevation” strategy
Option 1: Build a dike
Preliminary finding 1:
Concrete required to dike top 155 ports

Dike all 155 ports = 528 million m³ of concrete

Three Gorges Dam = 26 million m³ of concrete

Equivalent of 20 Three Gorges Dams!

20% of all world concrete produced in 2008
Option 2: Elevate the port
Preliminary finding 2: Material to elevate top 155 ports by 2m

4.9 billion m$^3$ of fill material
OR
1867 Giza Pyramids

Middle East 33
South America 44
Africa 69
Oceania 94
Europe 277
North America 351
Asia 1000
How can hydrodynamic modeling help?

How does elevating or diking impact the surrounding land areas and estuary?

How high should the dikes be?
  - Effect of SLR on surge and tide
  - Surge scenarios

How high is too high?

How will flood waters be displaced?
Part II. What are ports doing now?

Finding 1: Survey respondents concerned, but felt uninformed

Impacts of climate change is something that needs to be addressed by the port community. 81%

I feel sufficiently informed about how climate change will impact my port operations. 31%

N = 93
Finding 2: How much sea level rise would be a problem at your port?

58% of ports feel they would have a problem

39% of ports feel they would have a problem

12% of ports feel they already have a problem

Expected life of infrastructure (50-100 years+)

Chart Source: Vermeer M, Rahmstorf S. PNAS 2009, 106:21527-21532
Finding 3 – Ports are building infrastructure
Design standards do not address climate change

Plans for new construction in the next 10 years*

*16% are also building storm protections
How can port decision systems address the kinds of problems that climate change will create?
Case study of Gulfport’s plan to elevate to 25 feet (7.6 meters)

Port of Gulfport
Mississippi State Port Authority

2008 Revenues
Business: $183m
Local Purchases: $15m
State/Local Taxes: $27m
Federal taxes: $51m

2010: 208,000 TEUs
Primary Freight: Containers, bulk freight
Imports: Fresh fruit, raw materials, garments, ore, lumber
Exports: Products primarily to South and Central America
Over 2m tons of cargo
Conducted 57 interviews of key decision makers

- What are the impacts of major storm events?
- What are strategies to build resilience?
- What are the barriers to implement these strategies?

Respondents by scale of governance
- Federal
- State
- Local
- Port Operations

Respondents by case study
- Gulfport
- Providence

Respondents by sector
- Public
- Private
- Non Profit
- Academic
Impacts noted by respondents

- Change in political environment
- New business can result from catastrophic event
- Insurance issues
- Non-port related impacts
- Supply chain interruptions
- Environmental impacts
- Damage to intermodal system (inc. channel)
- Business impacts
- Local and regional impacts external to port
- Direct damages to port
- Debris

Hazardous materials in the waterway
Damage to adjacent land areas
Loss of protective wetlands
Costs of environmental cleanup
Resilience strategies mentioned

- Incentives
- Macro-level philosophies
- Fatalistic approach (i.e., what's the point)
- Research (inc. risk assessment, forecasting improvements, and projections)
- Funding options
- Process (including coordination, commissions, outreach, education)
- Plans and planning efforts
- Constructions and design
- Practice (current and potential)
- Policies (including insurance, design standards, zoning)

More accurate forecasting
Better mapping of flood-prone areas
Scenario modeling
Simulation tools

# of respondents

Gulfport
Providence

Visualizations
How can hydrodynamic modeling help?

*SF Bay ports less at risk, though options will ultimately be similar*

1) Visualizations of local impacts of SLR and storm surges!
   - Debris fields
   - Wave and surge models

1) Fine-grained models would give more confidence to global estimates
   - Local and regional storm probability scenarios
   - Sea level rise interactions with tides and surge
   - Sea level and surge impacts on sediment loading and dredging requirements
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Extra slides below