# Seaports and the Climate Change Challenge

*Worldmaritimenews.com – Port of Oakland*

THE UNIVERSITY OF RHODE ISLAND
DEPARTMENT OF MARINE AFFAIRS

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Metcalf Institute for Marine & Environmental Reporting
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# Outline

The Marine Transportation System

The Climate Change Challenge for Seaports

A Global Survey of Port Authorities

Can All Ports Adapt in Time?

Ongoing Research

Photo: E. Mclean

# Marine Transportation System (MTS)

## The Global MTS Consists of:

**Navigable Waterways** – coastal and associated inland waterways

**Ports** – private and public operations

**Intermodal Connections** – railroad, shipping, trucking, pipeline, air freight and access routes

**Vessels**

**Users** – direct (operators) and indirect (consumers)

# International Seaborne Trade 1980 – 2015 (UNCTAD) [2]

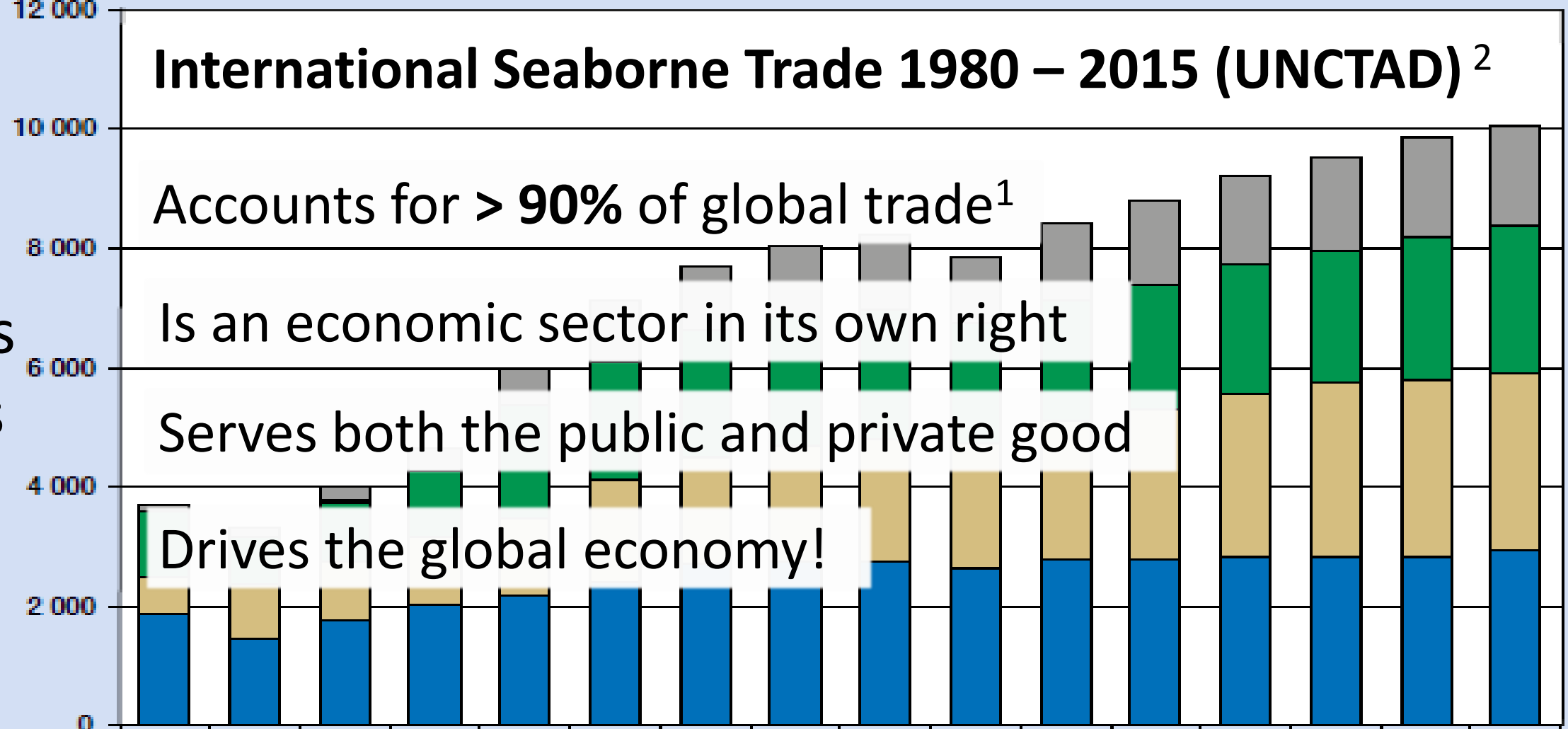
Accounts for **> 90%** of global trade[1]

Is an economic sector in its own right

Serves both the public and private good

Drives the global economy!

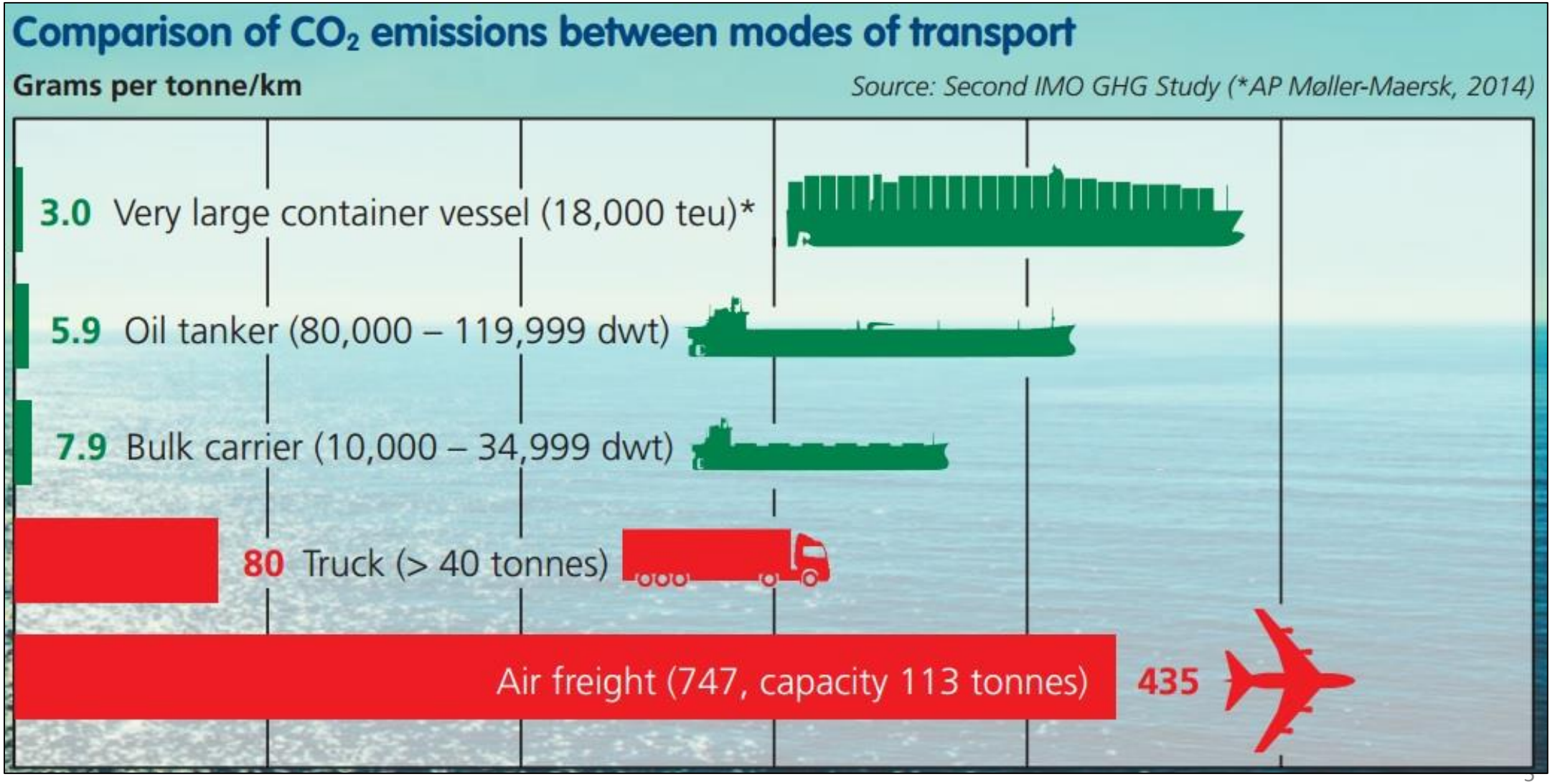
Millions of Tons




| | 1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Containers | 102 | 152 | 234 | 371 | 598 | 1 001 | 1 076 | 1 193 | 1 249 | 1 127 | 1 280 | 1 393 | 1 464 | 1 544 | 1640 | 1687 |
| Dry cargo other than main bulk commodities | 1 123 | 819 | 1 031 | 1 125 | 1 928 | 1 975 | 2 112 | 2 141 | 2 173 | 2 004 | 2 022 | 2 112 | 2 150 | 2 218 | 2393 | 2463 |
| Main bulk commodities | 608 | 900 | 988 | 1 105 | 1 295 | 1 711 | 1 814 | 1 953 | 2 065 | 2 085 | 2 335 | 2 486 | 2 742 | 2 923 | 2985 | 2951 |
| Oil and gas | 1 871 | 1 459 | 1 755 | 2 050 | 2 163 | 2 422 | 2 698 | 2 747 | 2 742 | 2 642 | 2 772 | 2 794 | 2 841 | 2 829 | 2 825 | 2 947 |

1. IMO, 2012: International Shipping Facts and Figures – Information Resources on Trade , Safety , Security , Environment, 47 pp.
2. Asariotis, R., and Coauthors, 2016: Review of Maritime Transport, 20169211128102.

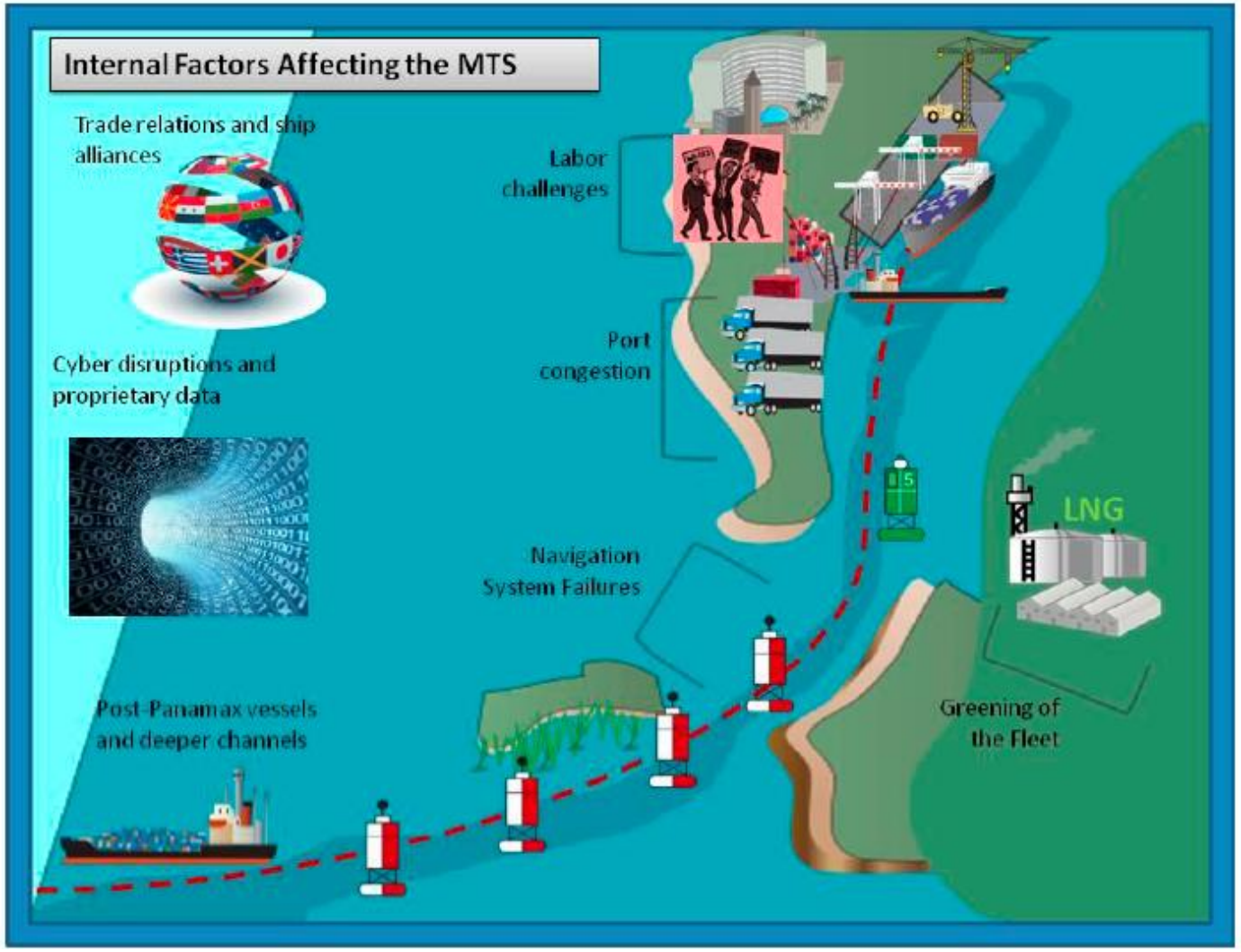
# Maritime transport offers the ***lowest*** $CO_2$ **emissions per ton-km** of any form of transport[1]




1. IMO, 2012: International Shipping Facts and Figures – Information Resources on Trade , Safety , Security , Environment, 47 pp.

# Internal Factors Affecting the Resilience of the MTS

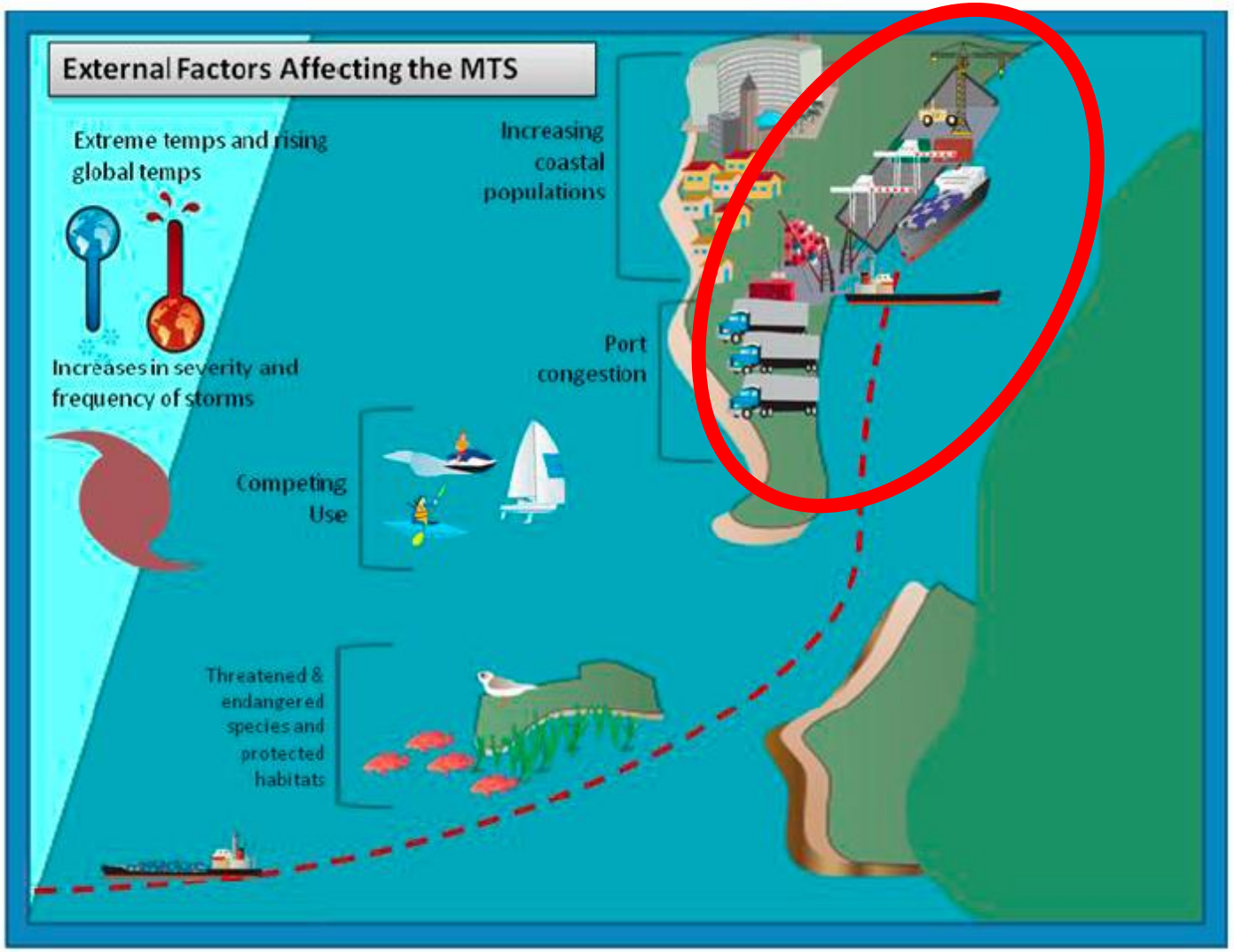
- Trade relations
- Cyber disruptions
- Labor challenges
- Congestion
- Post-Panamax, deeper draft vessels
- Greening of the fleet
- Navigation system failures




Figure, USCMTS, 2015: Marine Transportation System Performance Measures: Executive Summary.

# External Factors Affecting the Resilience of the MTS

- Climate Change
- Competing uses for space
- Sensitive habitats
- Increasing coastal populations
- Changing global trade patterns



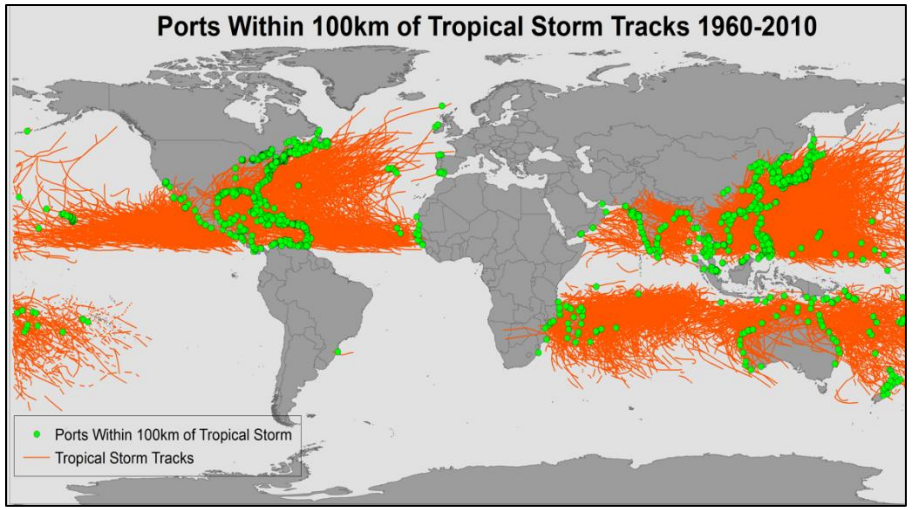

Figure, USCMTS, 2015: Marine Transportation System Performance Measures: Executive Summary.

# The Climate Change Challenge for Seaports

## Seaports are:

- **Critical**: > 99% of the volume of U.S. overseas trade enters or leaves by ship[1]
- **Constrained**: unable to retreat from water's edge
- **Exposed**: Ports face impacts from today's weather extremes & tomorrow's climatic changes in:

  - storm frequency & intensity
  - sea level
  - wave height
  - salinity and acidity
  - tidal regime
  - sedimentation rates
  - precipitation
  - temperature extremes



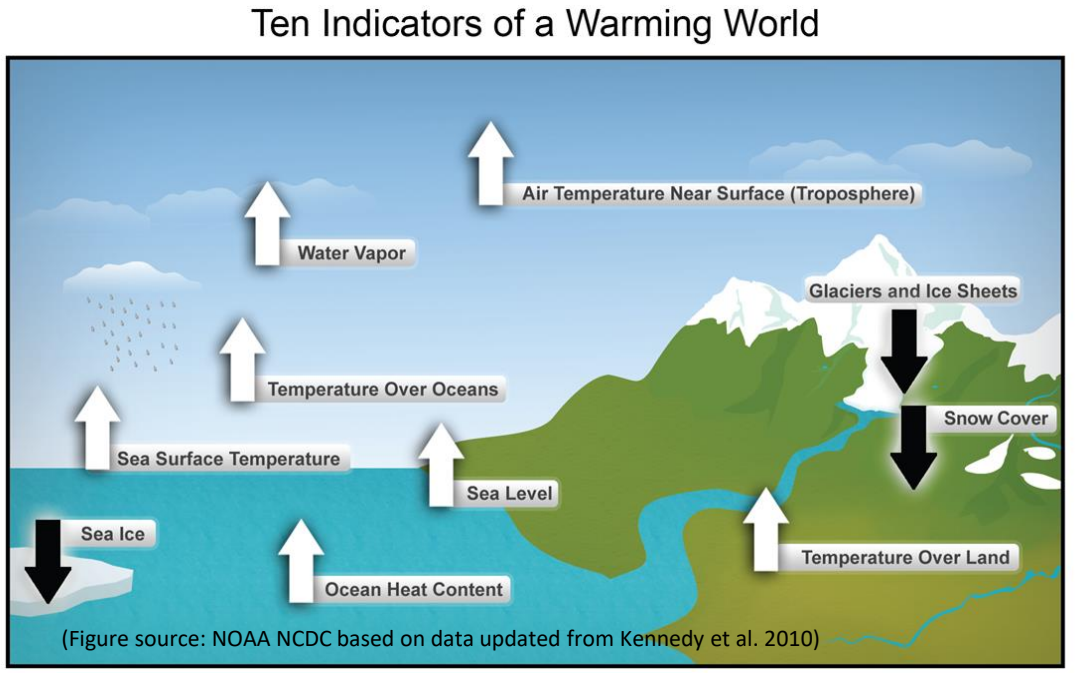



1. MARAD. 2016. "Marine Transportation System (MTS)." Maritime Administration. https://www.marad.dot.gov/ports/marine-transportation-system-mts/.

# Findings of the Third U.S. National Climate Assessment[1]

"Infrastructure is being damaged by sea level rise, heavy downpours, and extreme heat; damages are projected to increase with continued climate change." [1]

"Sea level rise, coupled with storm surge, will continue to increase the risk of major coastal impacts on transportation infrastructure, including both temporary and permanent flooding of airports, **ports and harbors**, roads, rail lines, tunnels, and bridges." [1]






1. Melillo, J. M., T. T. C. Richmond, and G. W. Yohe, 2014: Climate Change Impacts in the United States9780160924026, 841 pp.

# Coastal Hazard Challenges for Ports



More intense tropical storms

1-in-100 year storm event of today

Sea levels to rise 0.[illegible]1.9 meters by 2100

1-in-3 year storm event of 2100

Inland flooding



*(Bender et al. 2010; Grinsted et al. 2013; Rahmstorf 2010; Emanuel 2013; IPCC 2012; Tebaldi et al. 2012)*

*(Images from Bender et al. 2013)*

# Cascading Consequences for Port Cities

Photograph GP_ 11

**1) Direct damages**

structures, equipment, freight, land, etc.

**2) Indirect costs**

lost wages, business interruptions, cleanup costs

**Rotten Meat From Katrina Still In Gulfport Neighborhood**

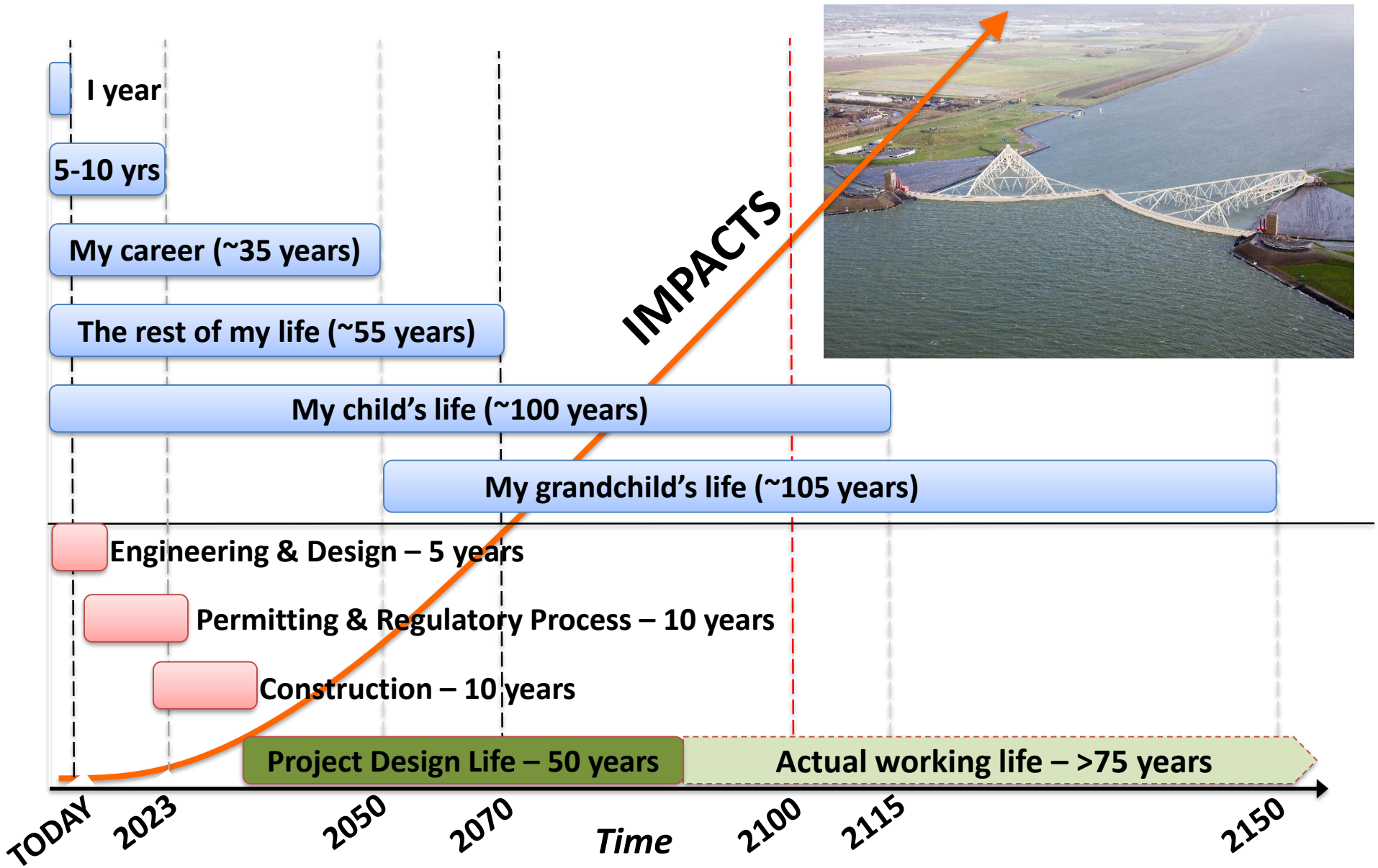
We're now just ten days away from the beginning of the 2006 Hurricane Season, and rotting chicken still remains untouched in various pools on abandoned sites throughout a West Gulfport neighborhood surrounding Regnault Avenue.

"It's nine months now. They say, 'Well, you ought to be used to it by now.' You ain't gonna get used to that smell. My gosh," said resident Gary Tatum.

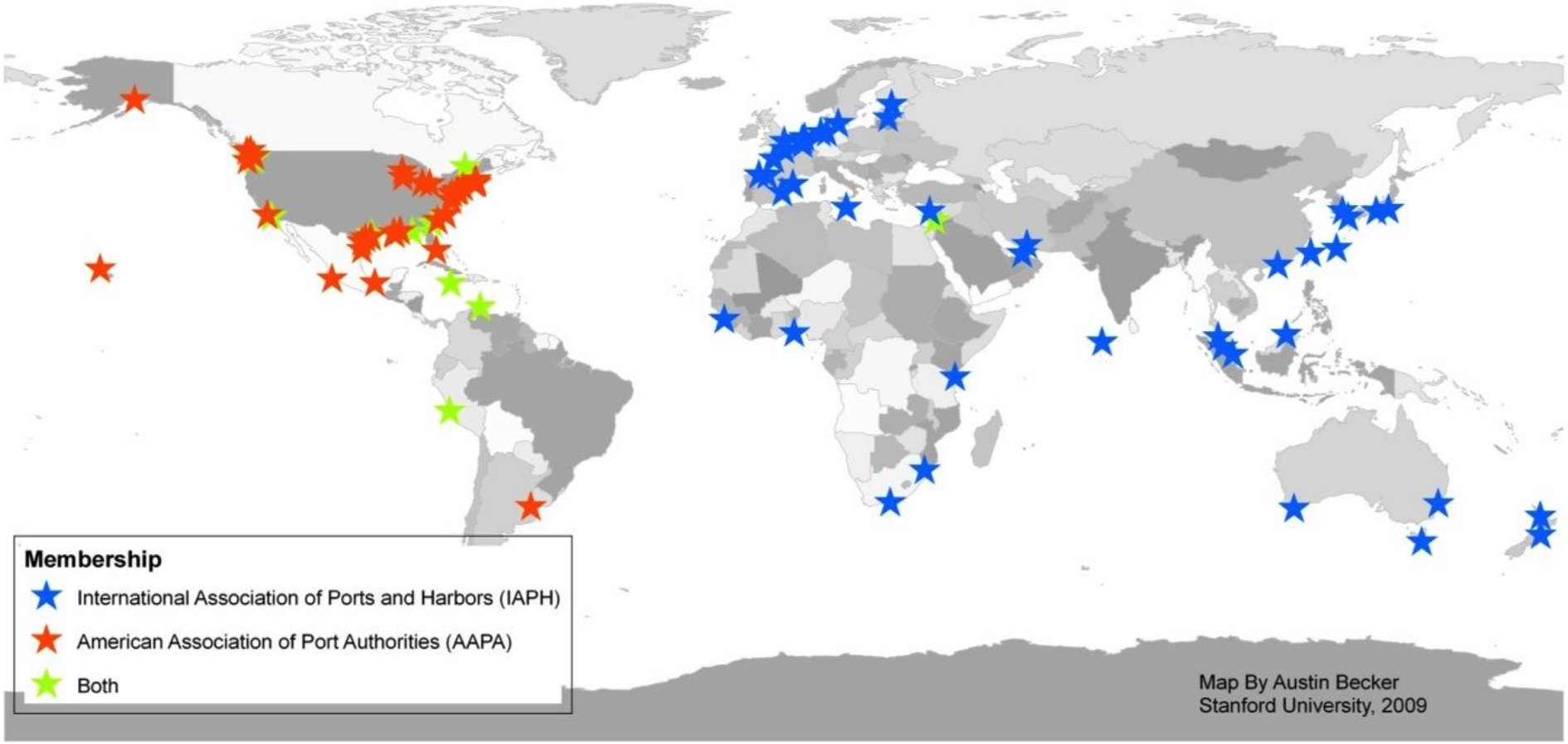
**3) Intangible consequences**

quality of life, environmental damages, loss of essential services

# Timescale for Large Infrastructure Climate Adaptation



# How are ports considering adaptation in their planning?




**350 IAPH/AAPA members**

**Online survey**

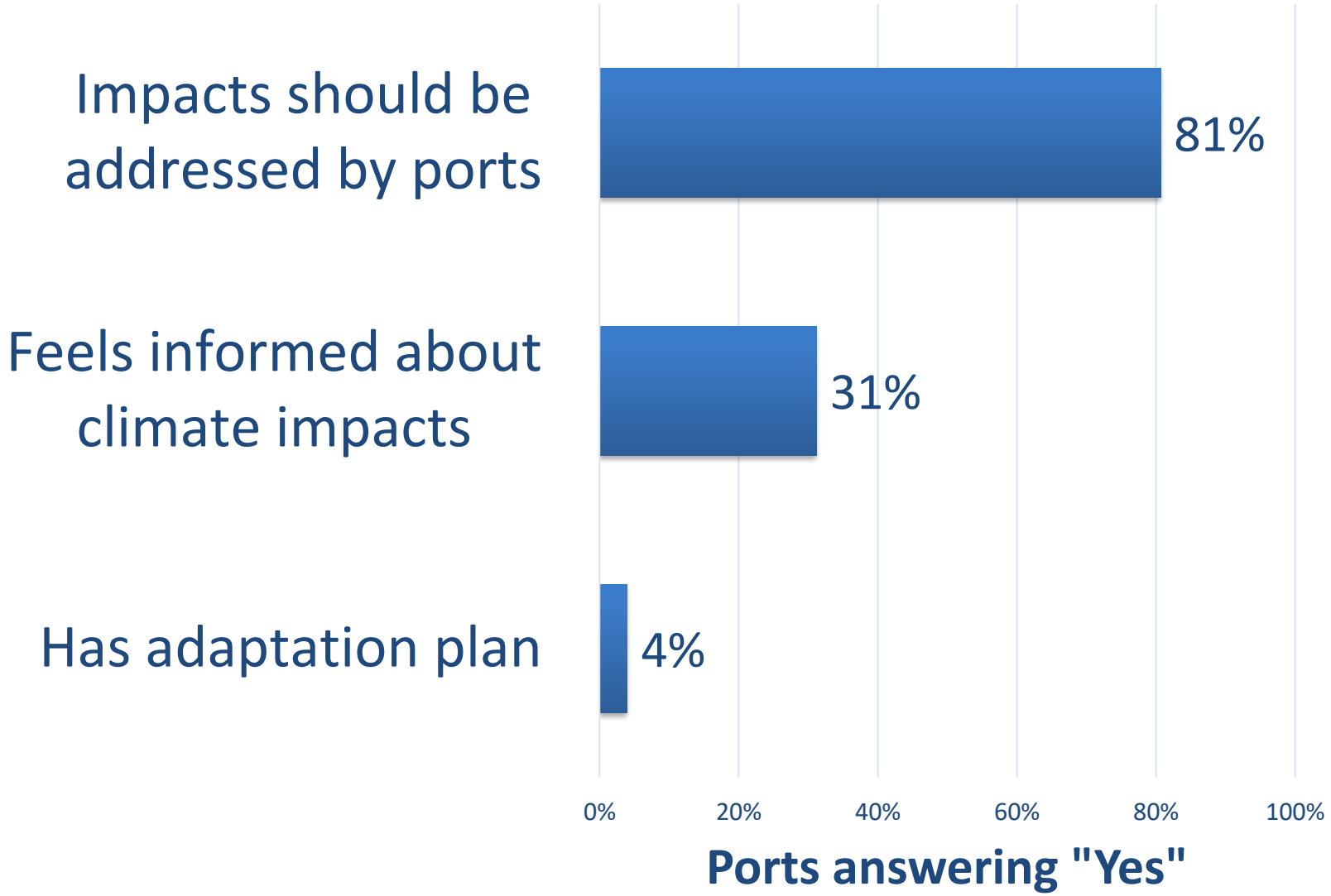
**30 Questions**

**93 Usable Responses**



Becker, A., et al. (2012), 'Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators', *Climatic Change,* 110 (1), 5-29.

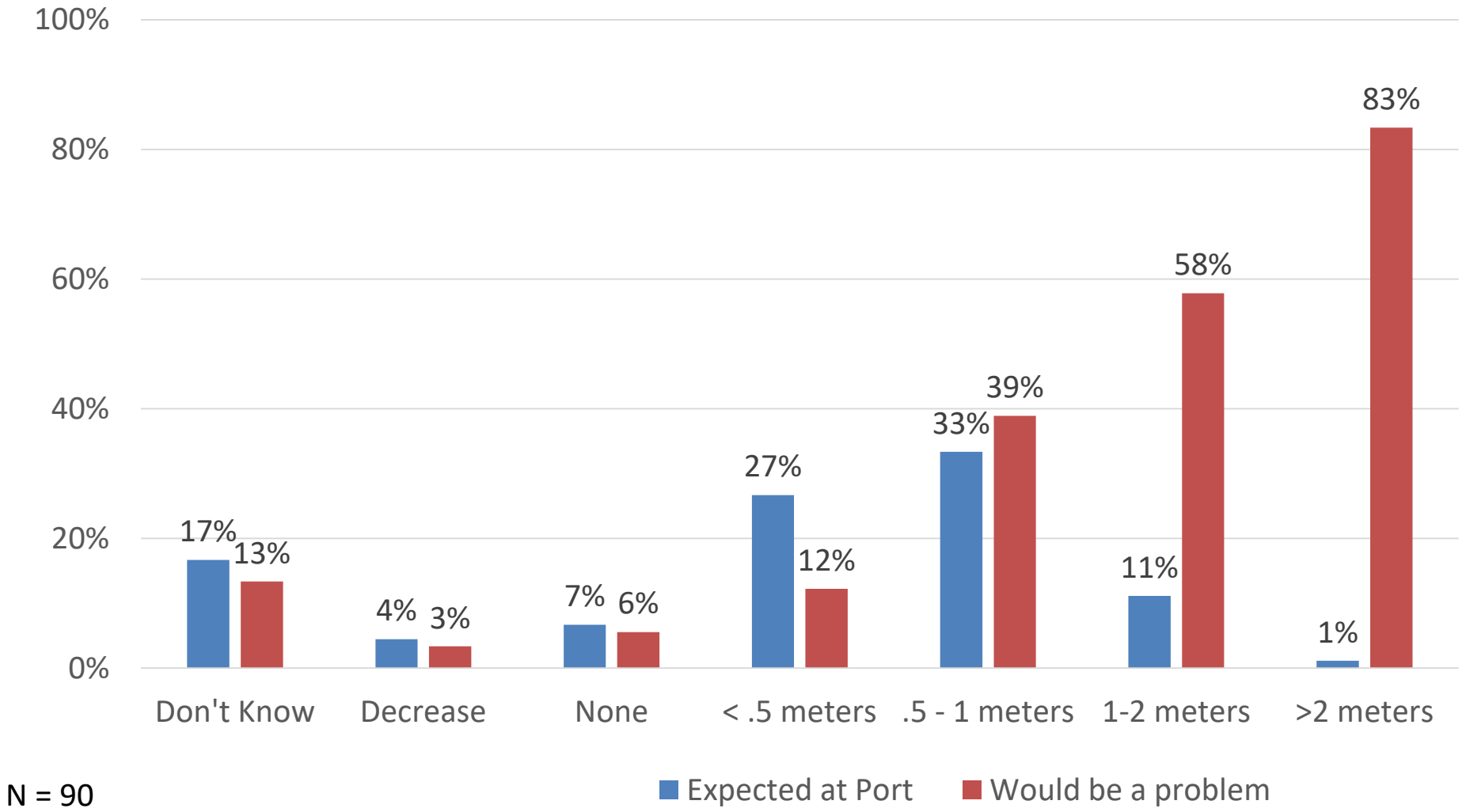
# Ports concerned, but little action thus far






1. Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2011: Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change, 110, 5-29.

# 69% felt EXPECTED SLR would not be a problem

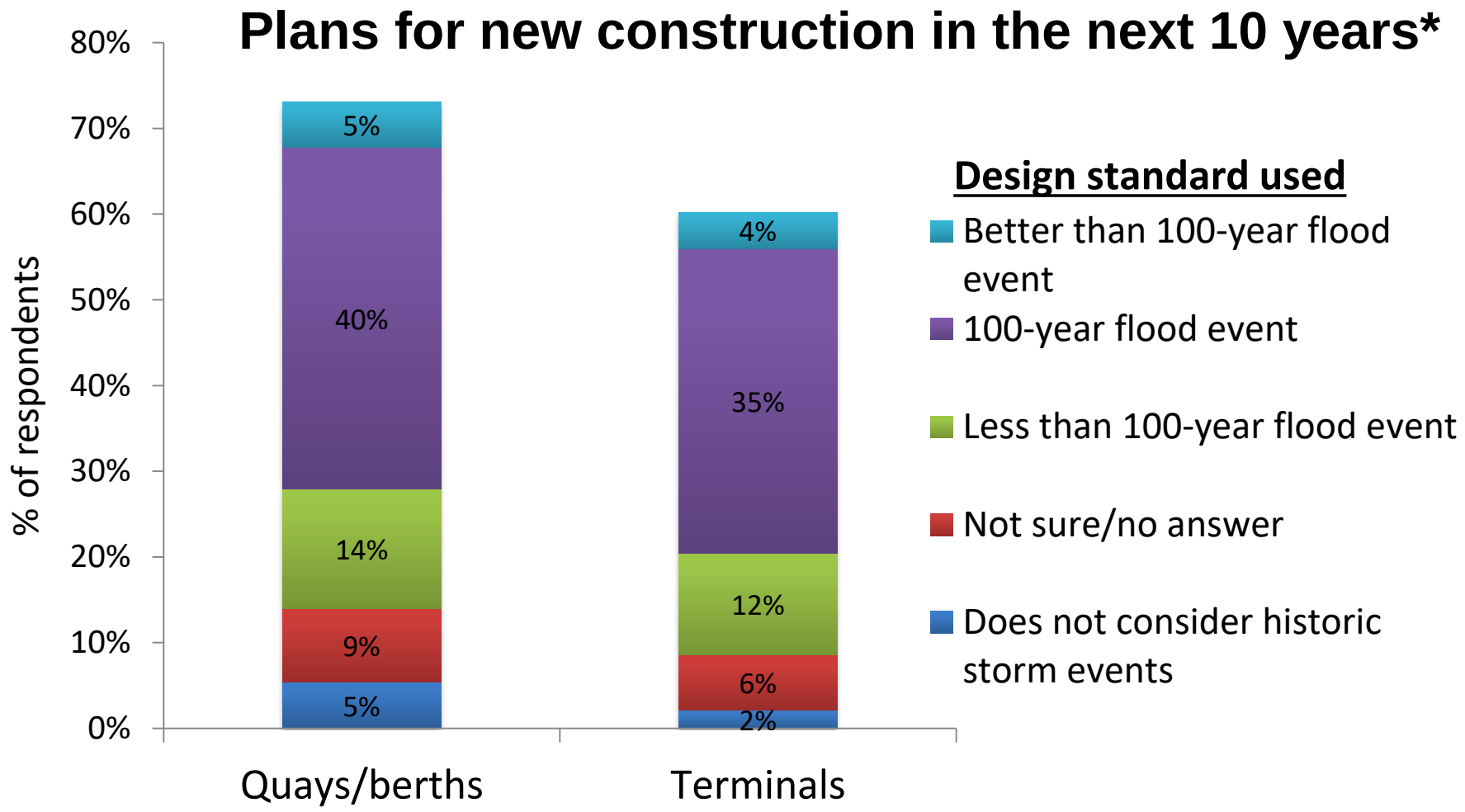



N = 90



1. Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2011: Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change, 110, 5-29.

# Ports are building infrastructure, but..
# Design standards do not address climate change

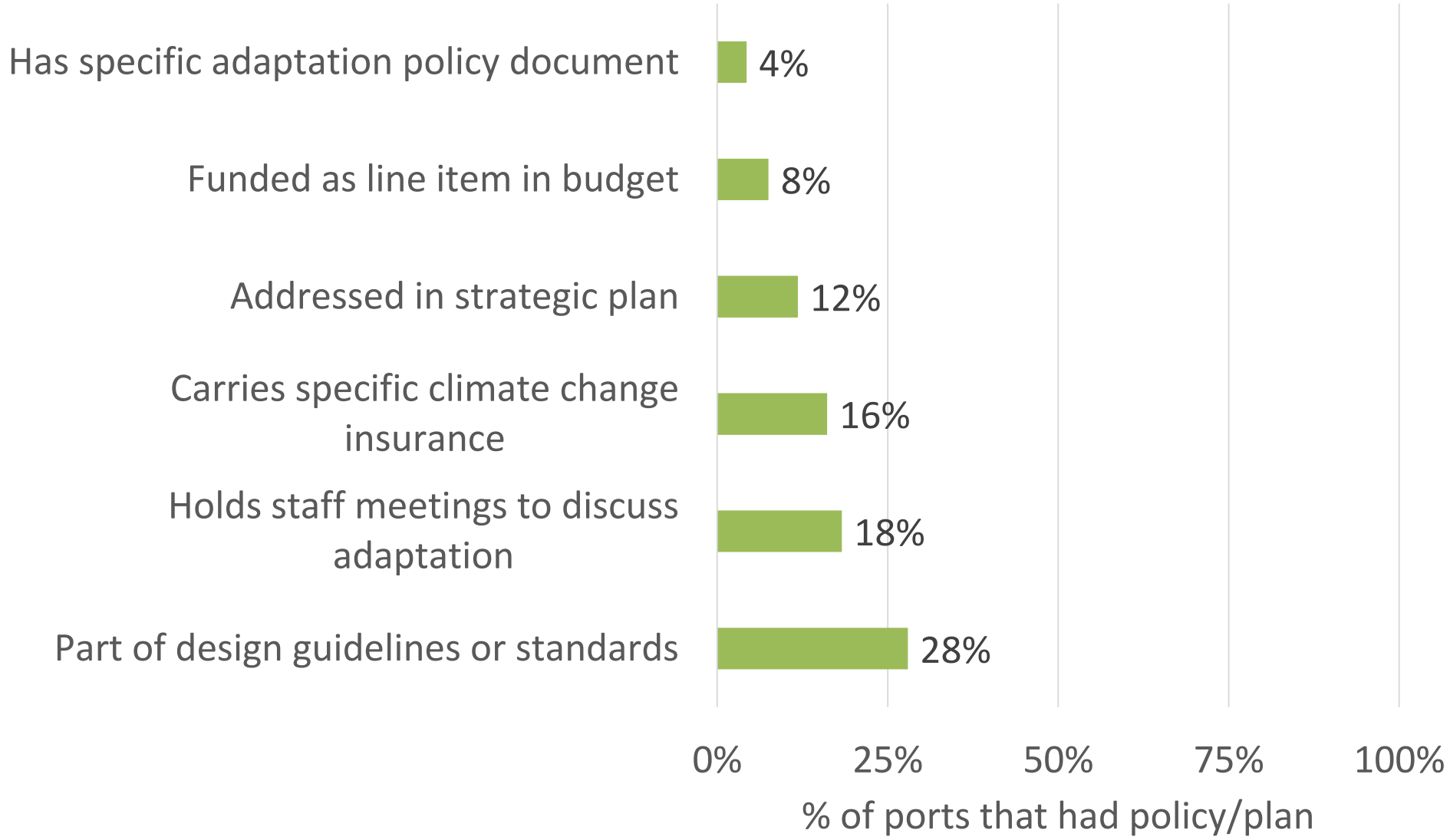



**16% of these also plan new storm protection*



1. Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2011: Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change, 110, 5-29.

# Ports have few formal plans that address adaptation






1. Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2011: Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change, 110, 5-29.

# Summary of ports' plans for climate change

Respondents felt concern about climate change impacts

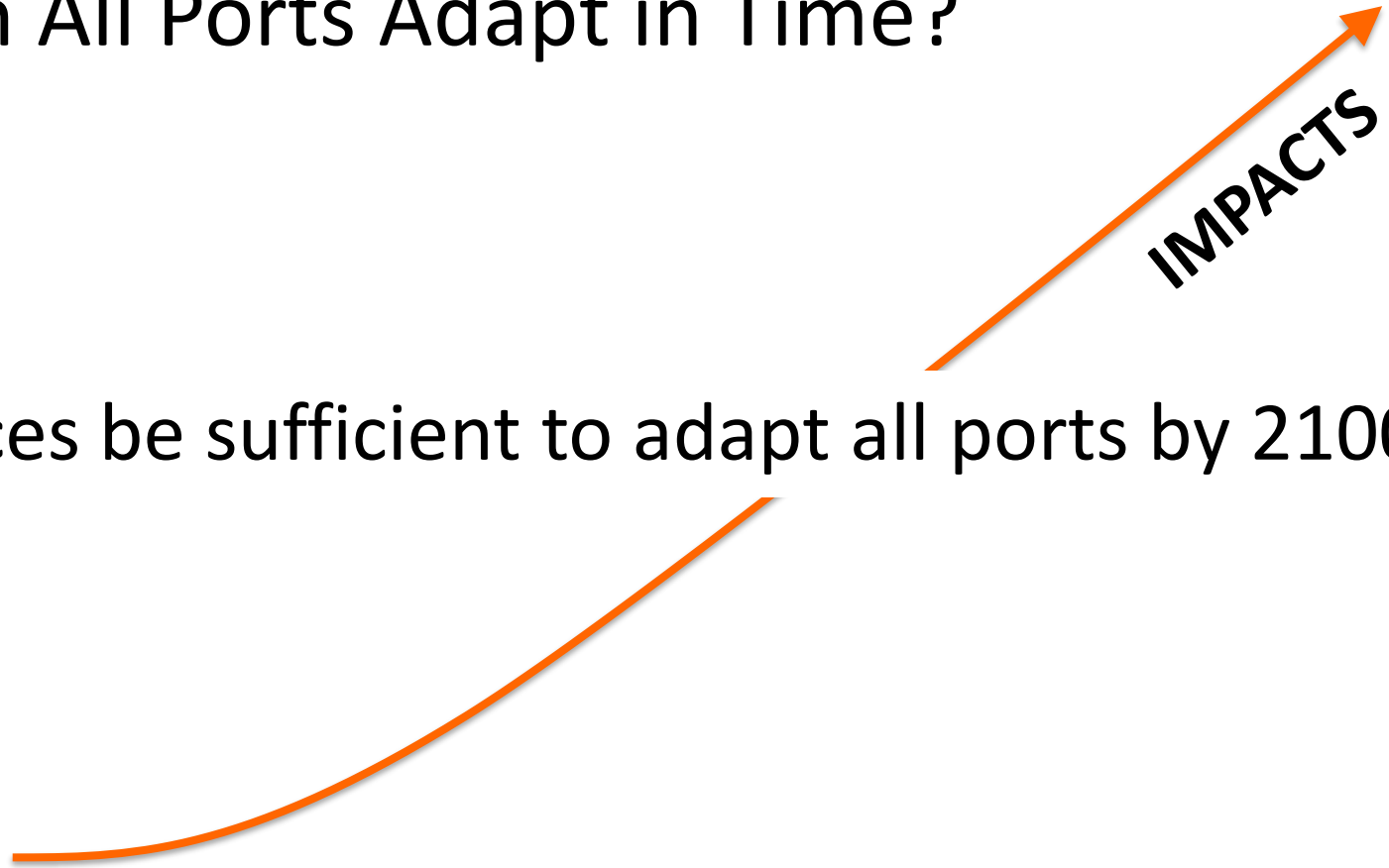
Respondents felt under-informed

Very few plans or policies explicitly address climate adaptation



Photo: Kris Allred

# Can All Ports Adapt in Time?




Will global resources be sufficient to adapt all ports by 2100?

Need estimates!



# Estimating construction materials to protect world seaports from a 2m sea level rise

~3,500 ports in the world; > 90% world trade

All ports would need to do *something* if SLR > 2 meters[1]

Are global resources sufficient to adapt all ports in time?

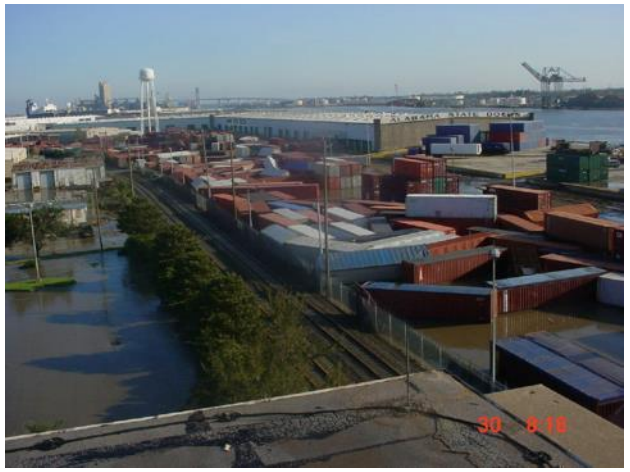


1. Becker, A., S. Inoue, M. Fischer, and B. Schwegler, 2011: Climate change impacts on international seaports: knowledge, perceptions, and planning efforts among port administrators. Climatic Change, 110, 5-29.

# Adaptation Options

1. Protect


2. Elevate



3. Design for submersion

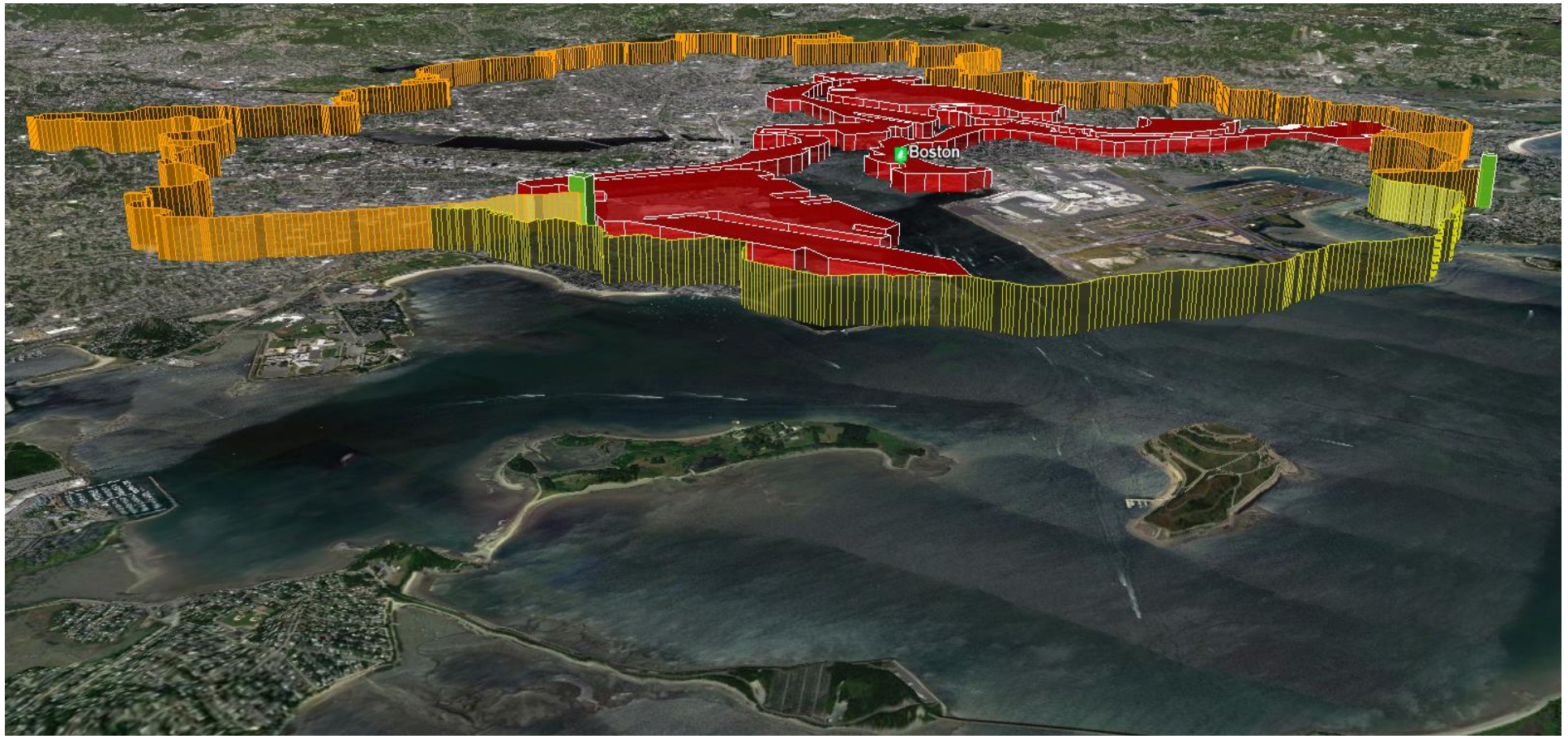
4. Abandon

*Photo from Alabama State Port Authority*

# A Generic Seawall Approach to Test Resource Demand


Find Port Footprint

# A Generic Seawall Approach to Test Resource Demand




Generate ‘minimum credible design’ engineered protection

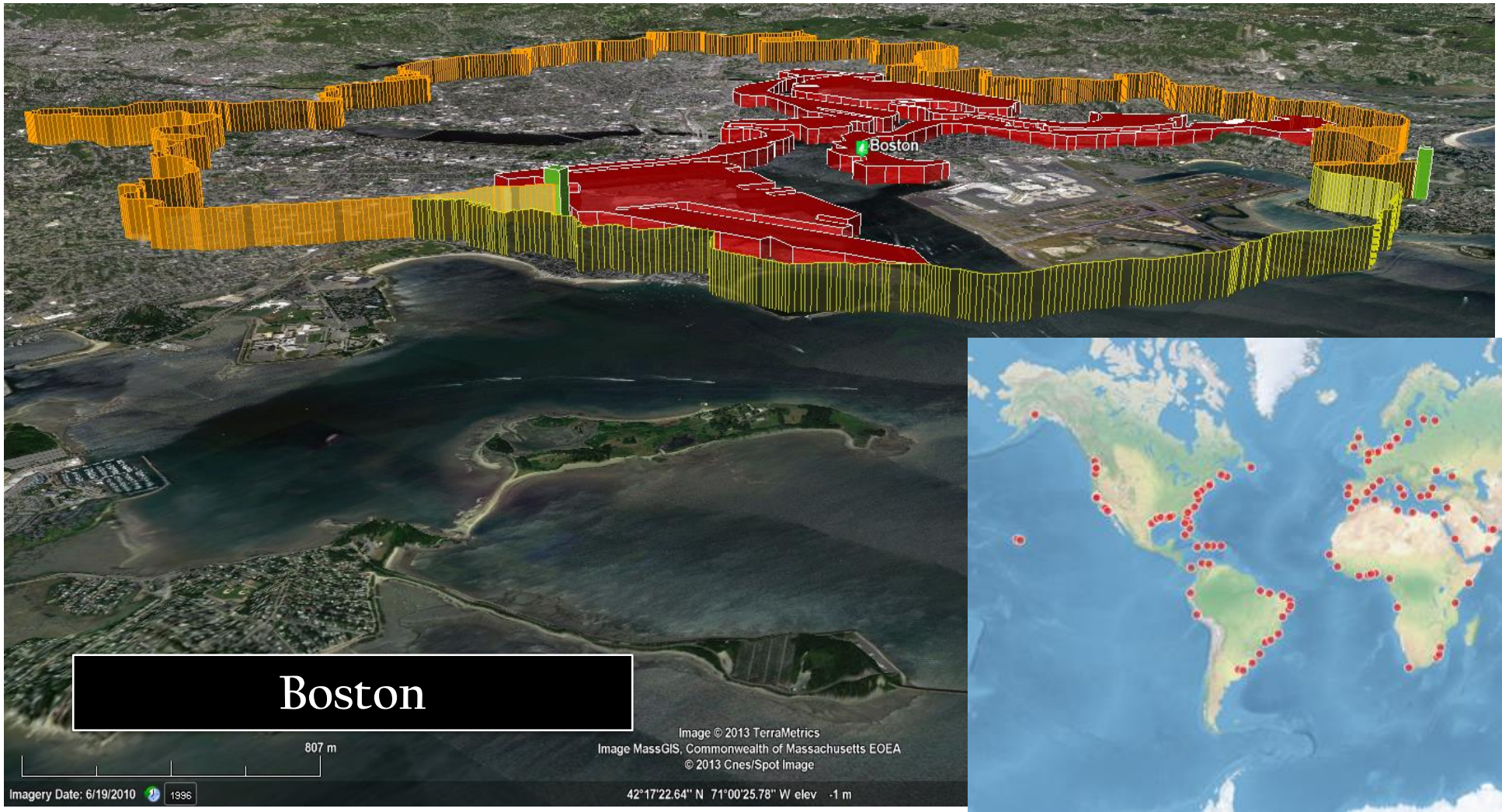
Boston



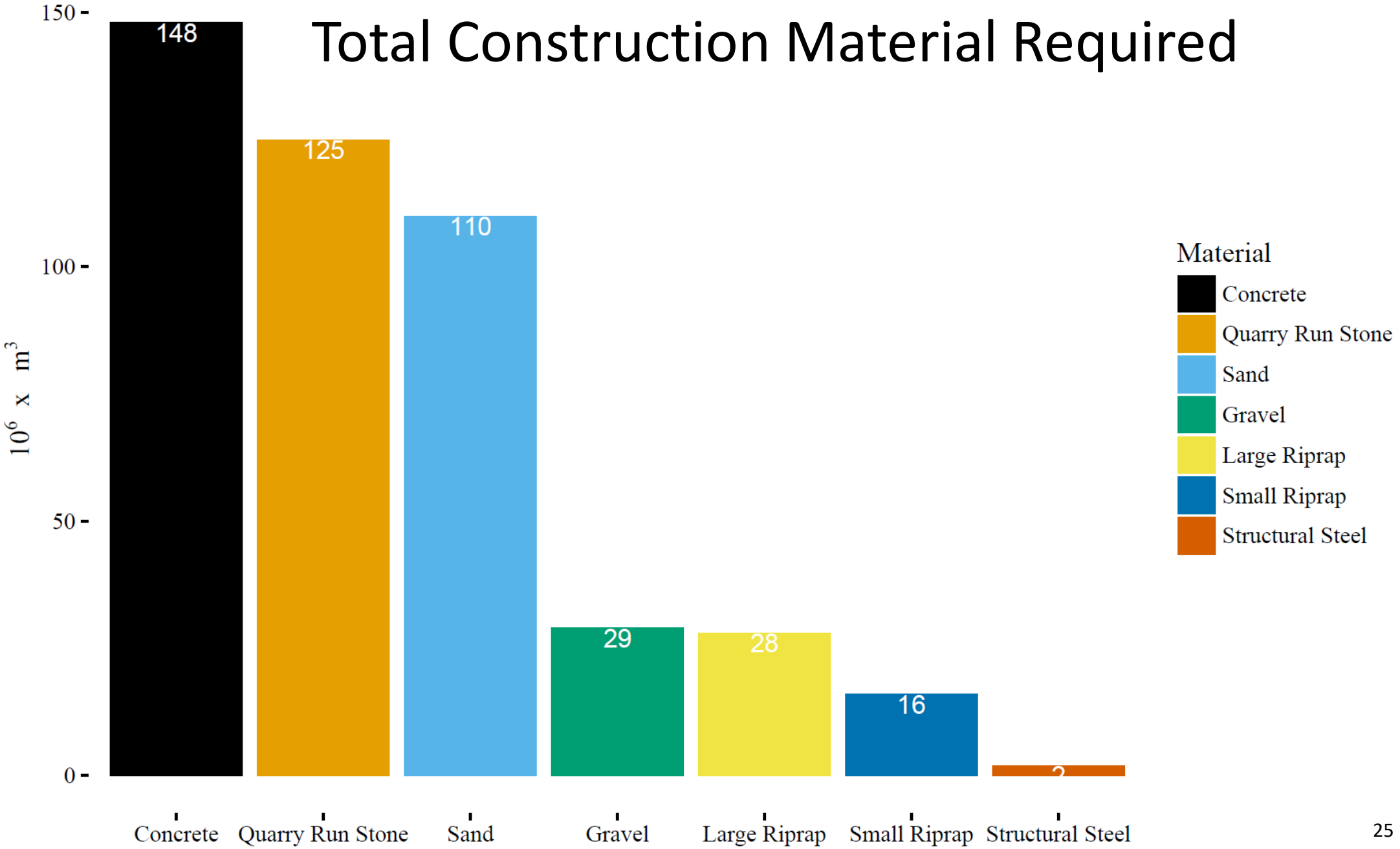
1. Becker, A., N. T. Chase, M. Fischer, B. Schwegler, and K. Mosher, 2016: A method to estimate climate-critical construction materials applied to seaport protection. Global Environ Chang, 40, 125-136.

# What if 221 Major World Ports Were to Build This?

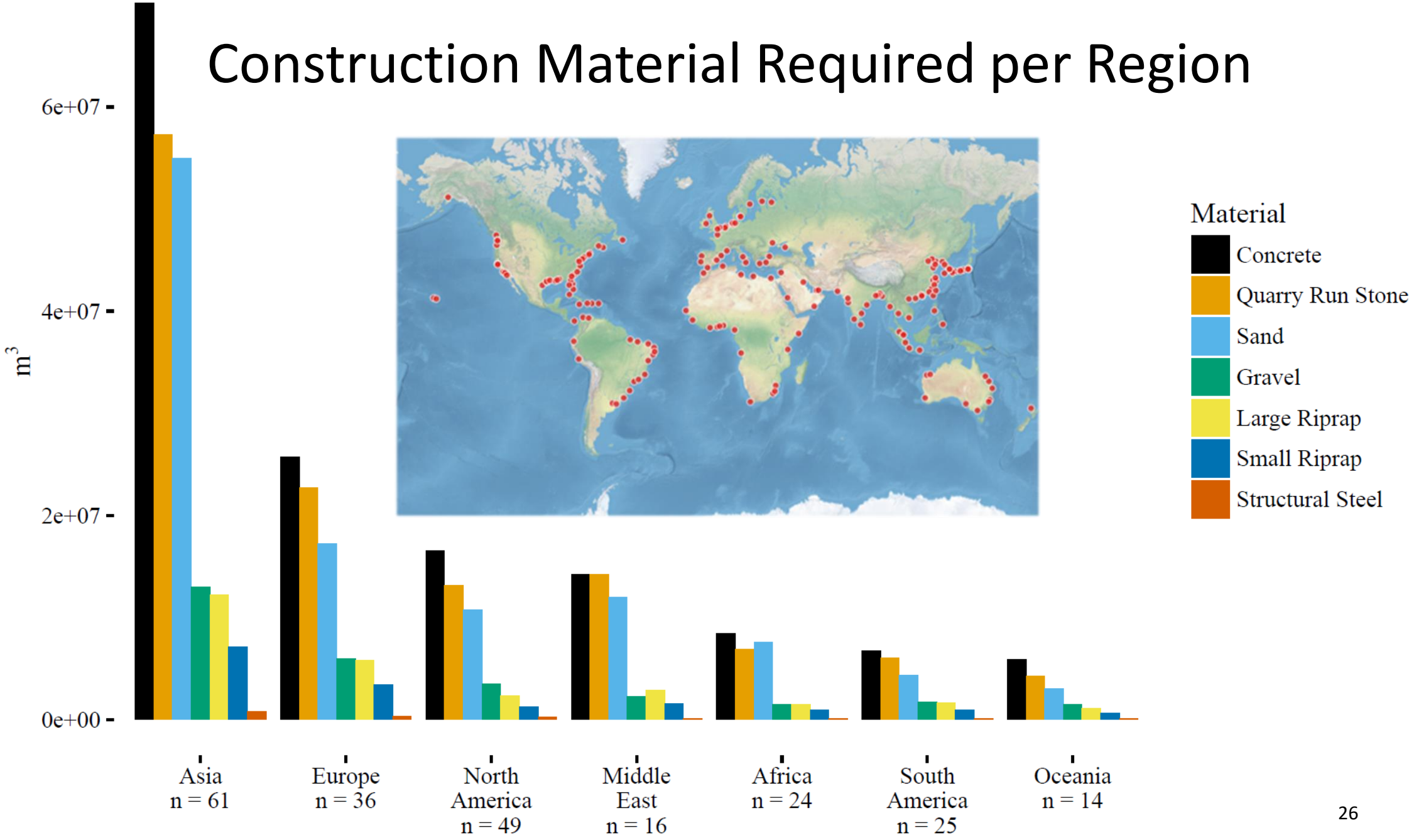
# Is there sufficient construction material globally?



# Total Construction Material Required

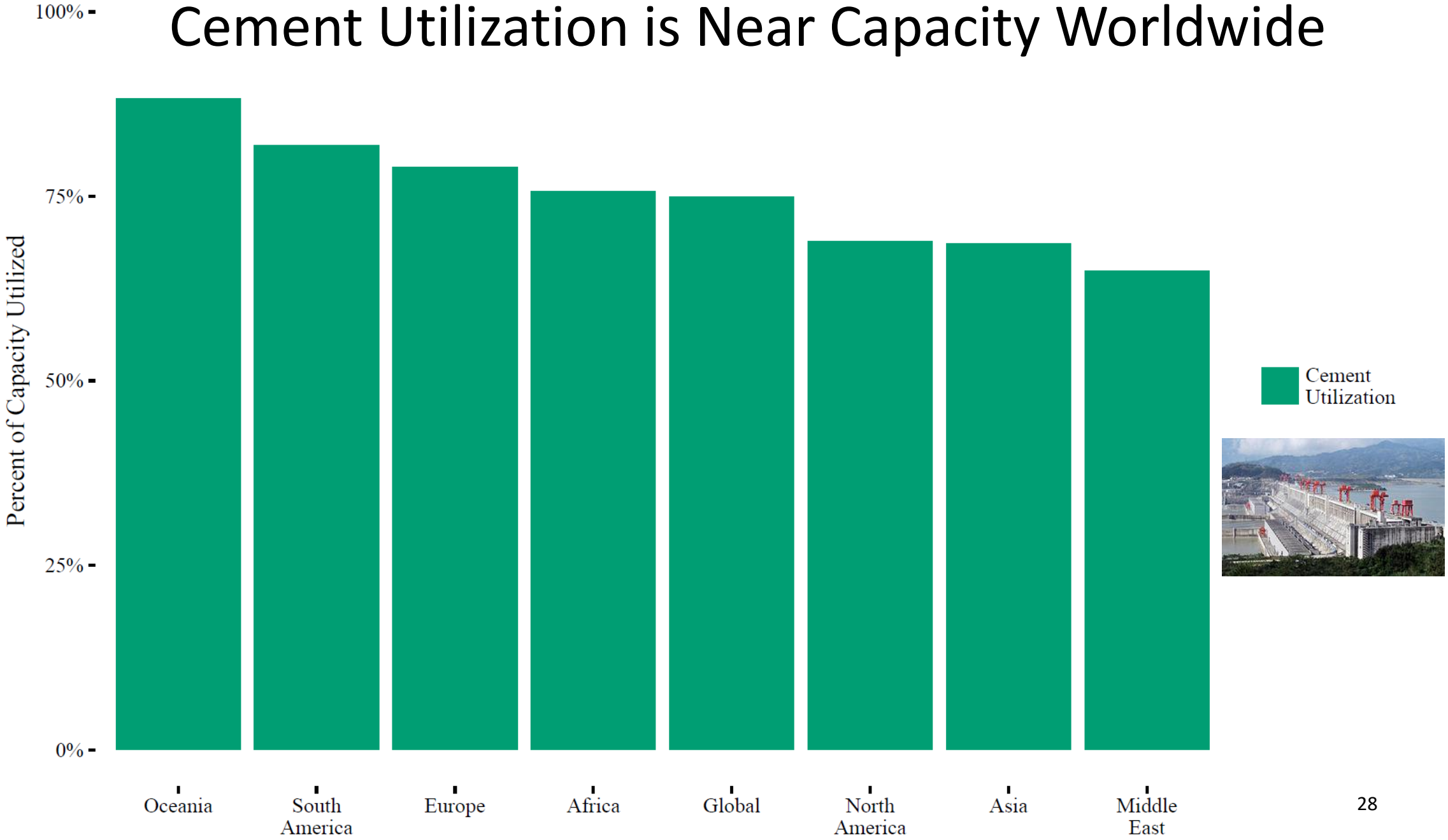


# Construction Material Required per Region



# Linear Kilometers of Structure Required per Region

# Cement Utilization is Near Capacity Worldwide



# Cement Required per Region

# What if 221 Major World Ports Were to Build This? Is there sufficient construction material globally?

Estimates suggest[1] local or global supply and production capacity may be insufficient

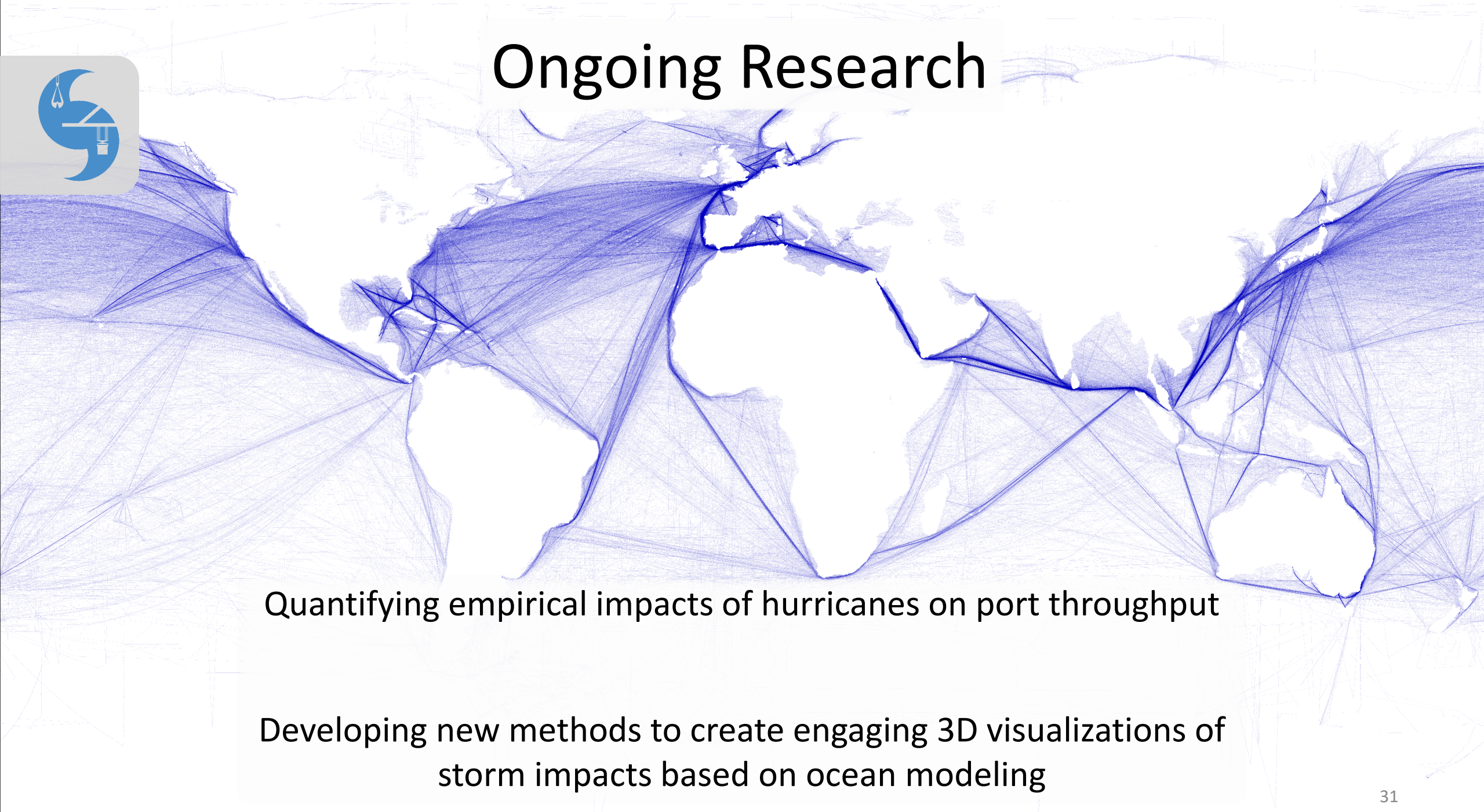
Cement, aggregate, sand, and steel all come with their own unique limitations in different parts of the world

Sand, necessary for the construction of breakwaters, may not be available locally for many seaports in the quantities and quality required



1. Becker, A., N. T. Chase, M. Fischer, B. Schwegler, and K. Mosher, 2016: A method to estimate climate-critical construction materials applied to seaport protection. Global Environ Chang, 40, 125-136.

# Ongoing Research

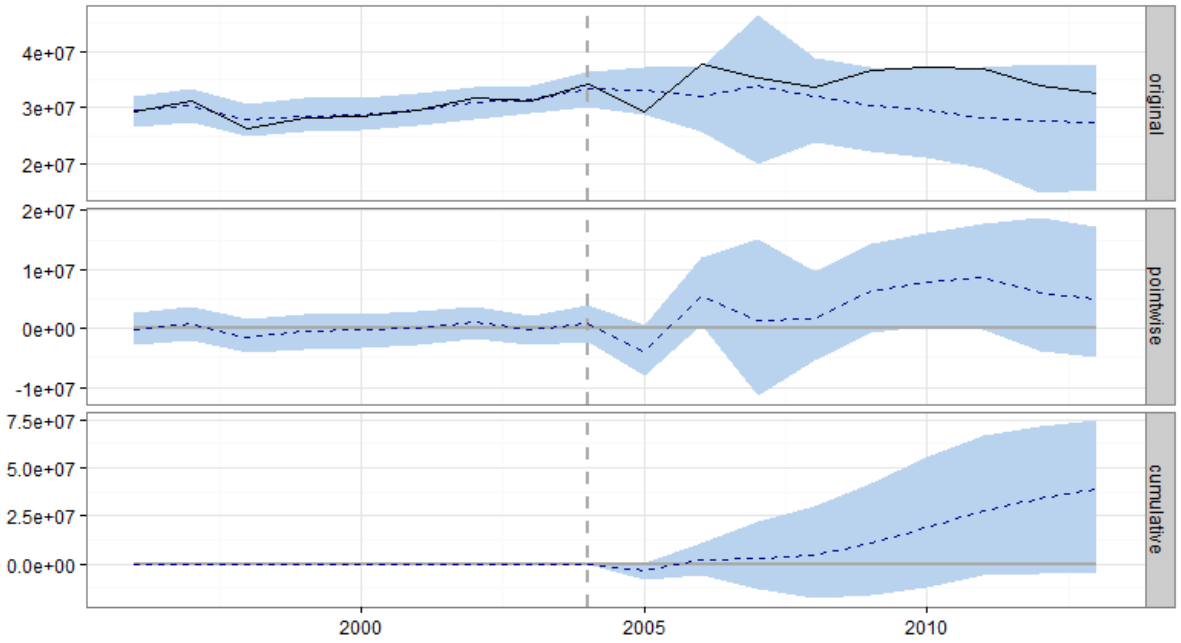


Quantifying empirical impacts of hurricanes on port throughput

Developing new methods to create engaging 3D visualizations of storm impacts based on ocean modeling

# Quantifying Empirical Impacts of Hurricanes on Port Throughput

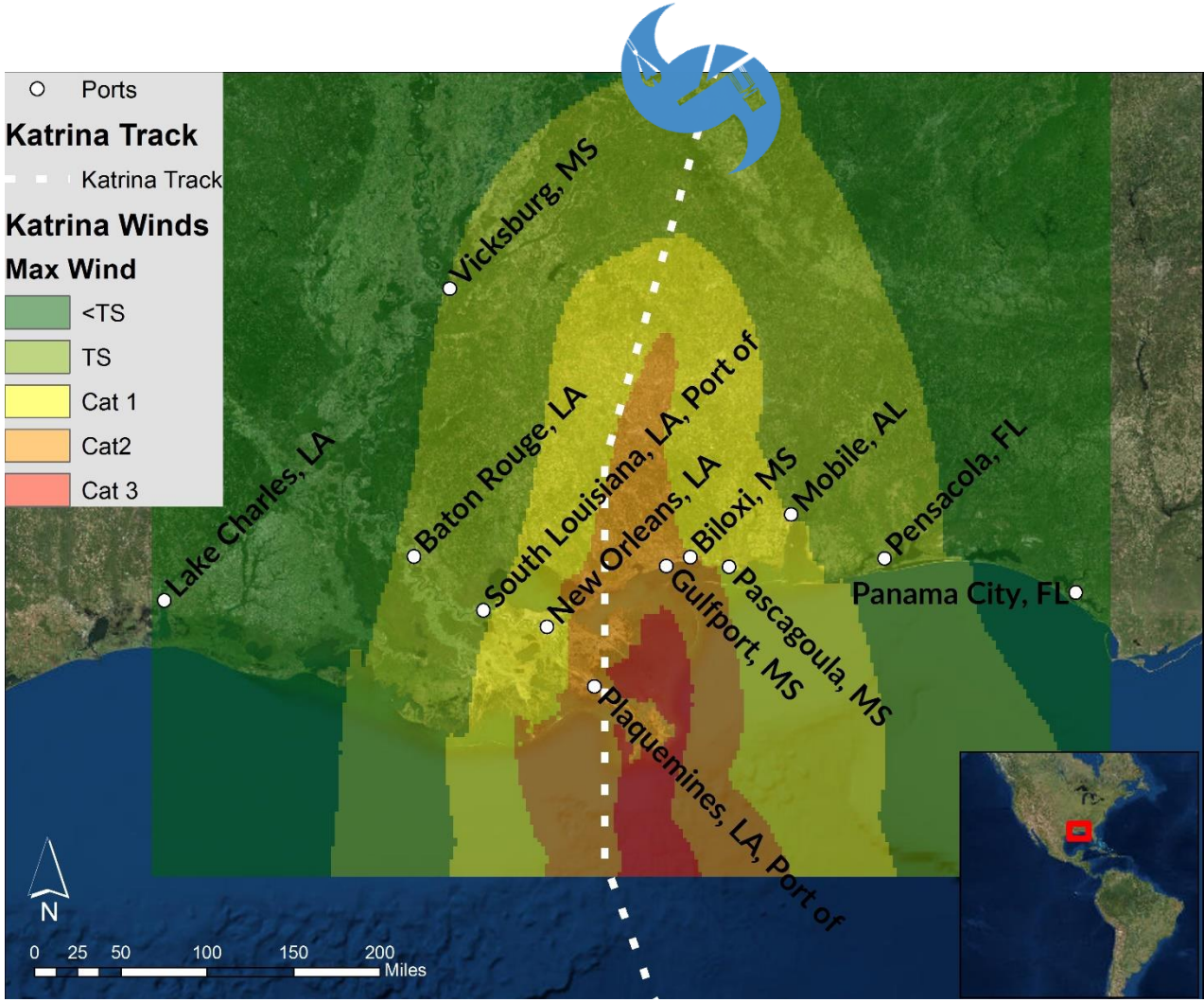
## Pascagoula, MS



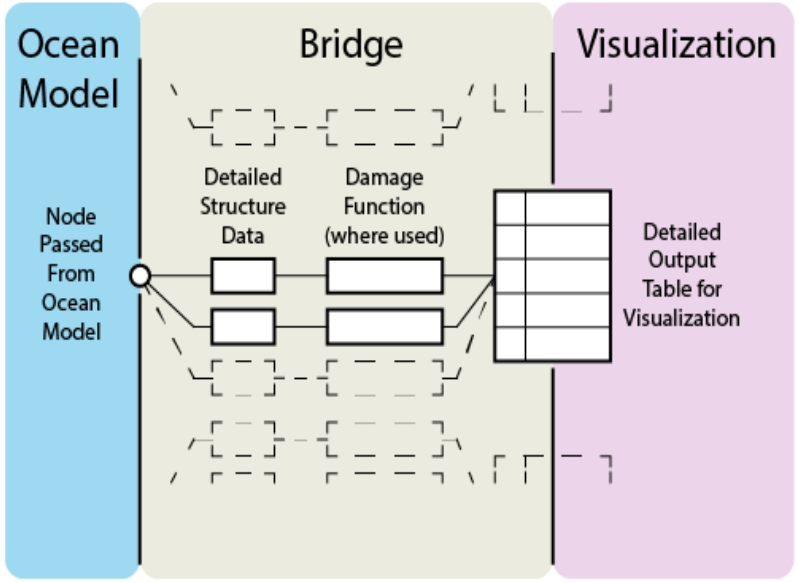

Posterior inference

Effect on average post-event throughput:

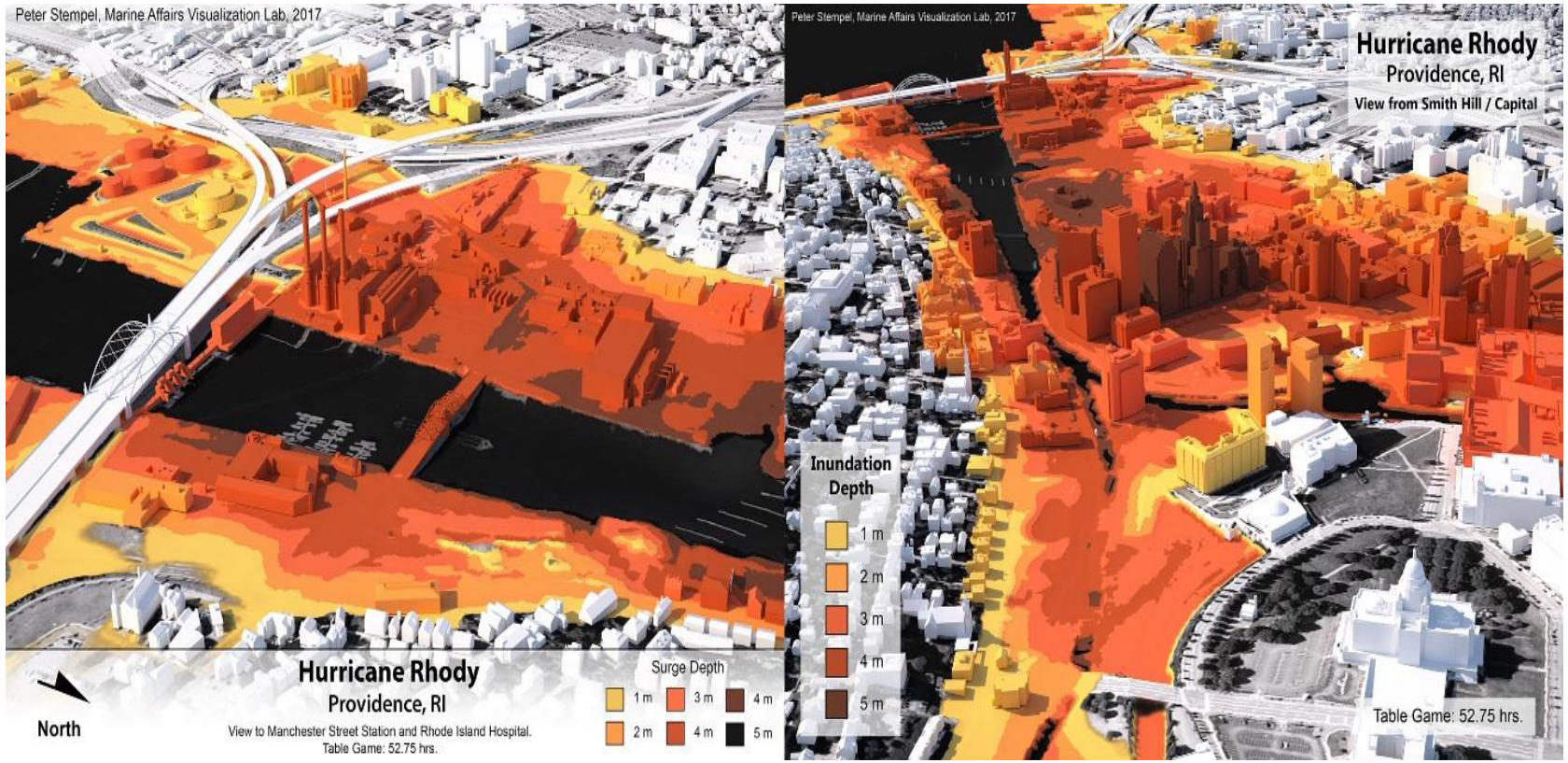
**+14%**



# Linking 3D Visualizations of Storm Impacts to Ocean Modeling



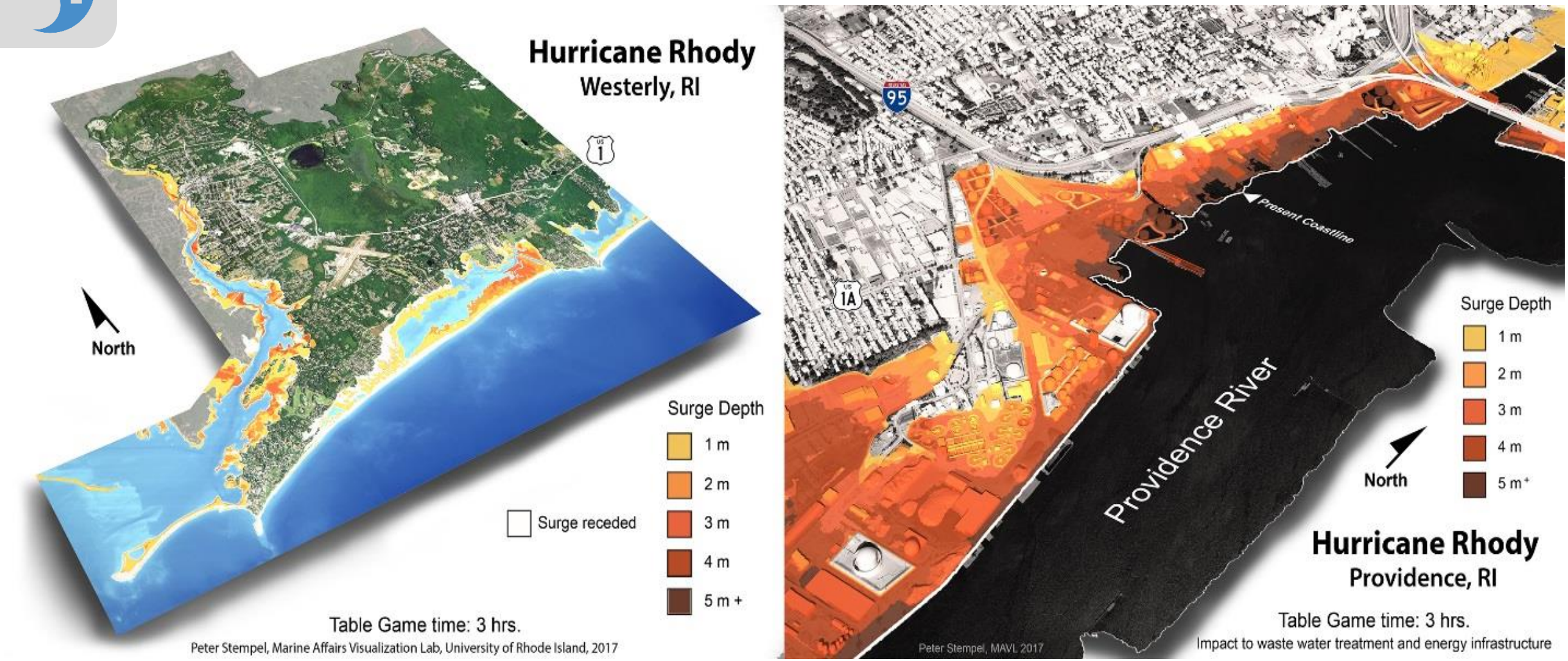

Bridging the gap between ocean modeling and visualization[1]




Inundation effects of a simulated Hurricane and flood barrier failure by MAVL, used in the FEMA IEMC real time exercise

1. Stempel, P. (2016, June 14-15, 2016.). Data Driven Visualization. Paper presented at the ECM14, Estuarine and Coastal Modeling Conference, South Kingstown, RI.
2. Images, Peter Stempel, URI Marine Affairs Visualization Lab (MAVL)

# Linking 3D Visualizations of Storm Impacts to Ocean Modeling




Examples of visualizations showing impact to energy and wastewater treatment facilities in Providence, RI (right), and community scale flooding in Westerly, RI (left).



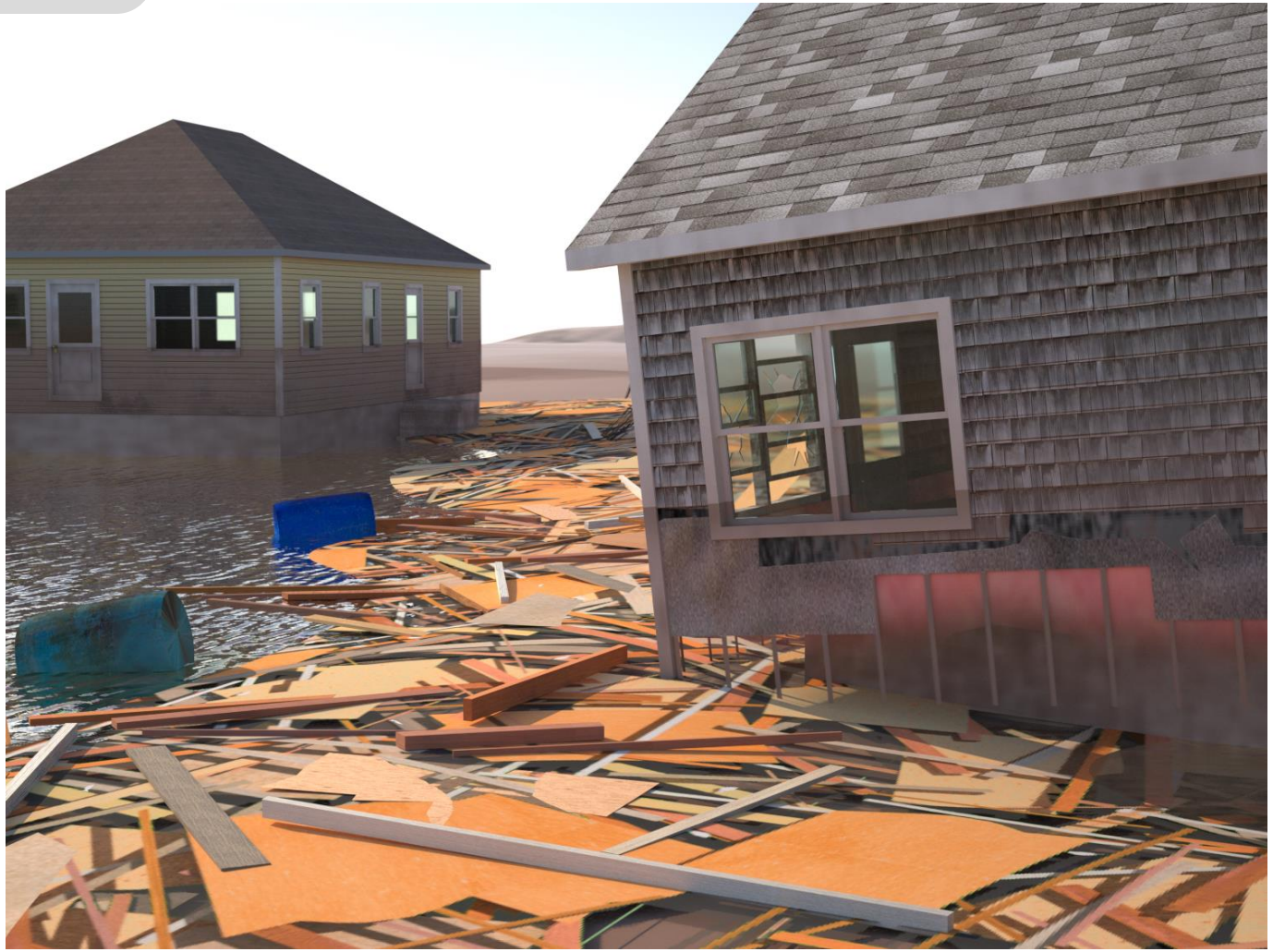
Images, Peter Stempel, URI Marine Affairs Visualization Lab (MAVL)

# Creating Realistic Visualizations
# Driven by Ocean Models and Damage Functions



Images, Peter Stempel, URI Marine Affairs Visualization Lab (MAVL)

# Creating Realistic Visualizations
# Driven by Ocean Models and Damage Functions





Images, Peter Stempel, URI Marine Affairs Visualization Lab (MAVL)

# Thank You

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