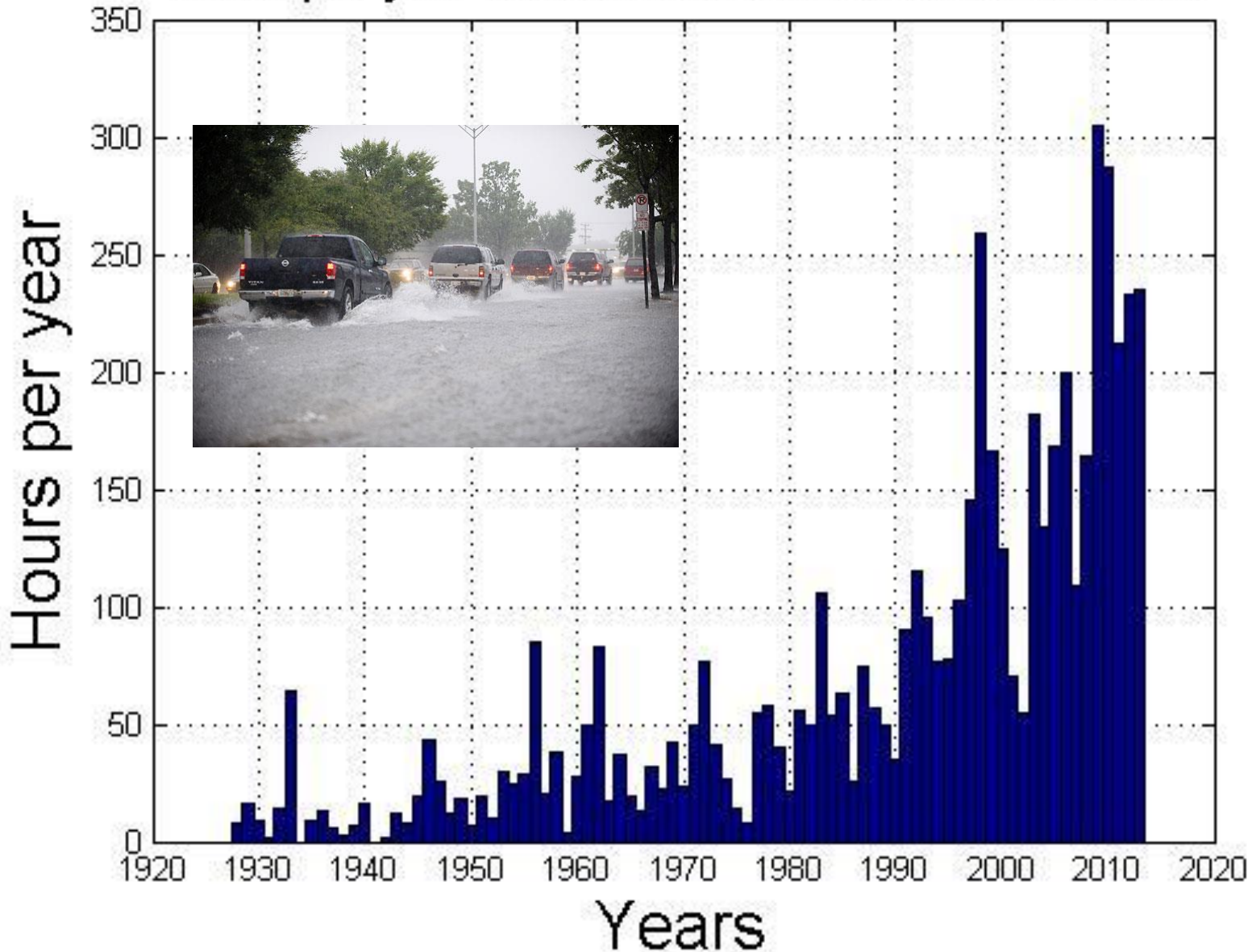




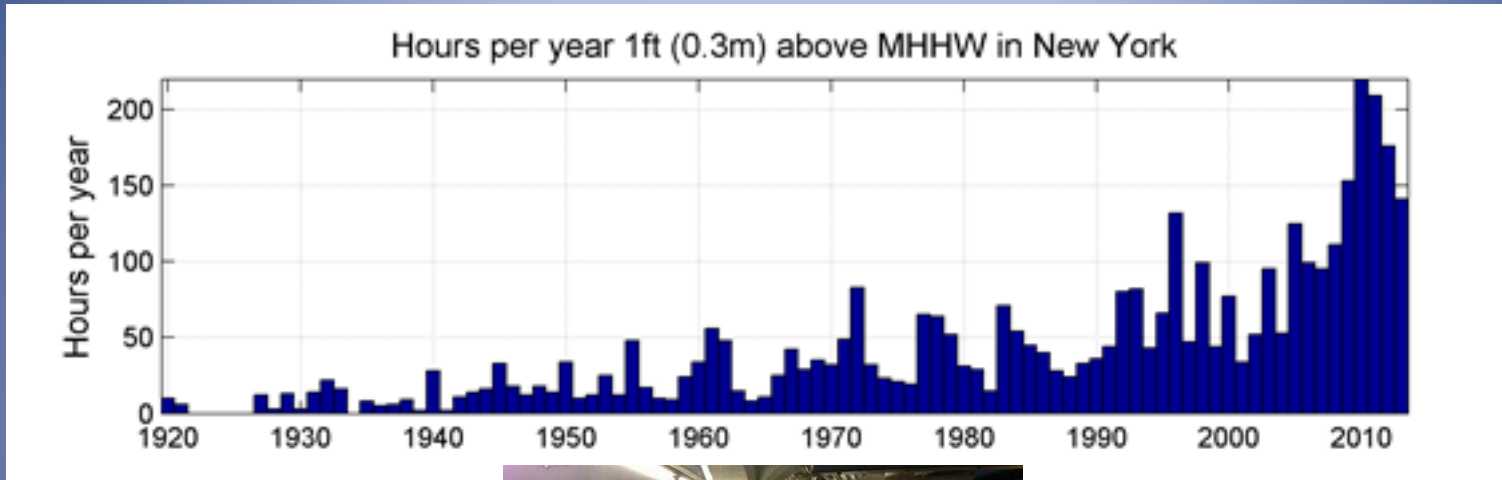
# The Latest on Sea Level Rise

Dr. Larry Atkinson  
Slover Professor of Oceanography  
Old Dominion University  
Norfolk, Virginia

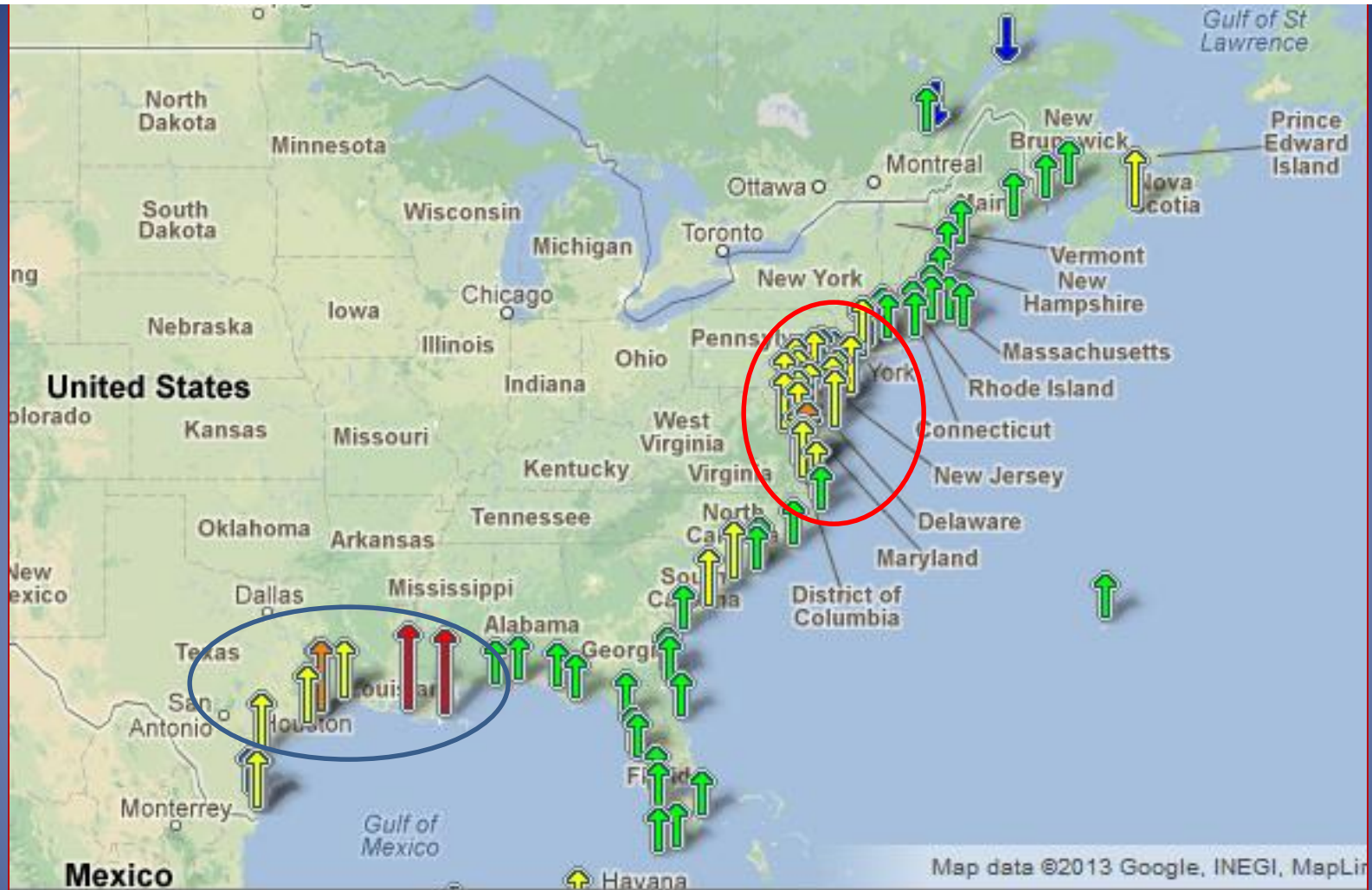
# Hours per year that Norfolk streets started to flood



# We are not alone - NYC



Sea level rise rates at points along the US East Coast are relatively higher than in other places



The above illustrates regional trends in sea level, with arrows representing the direction and rate of change. Click on an arrow to access additional information about that station.

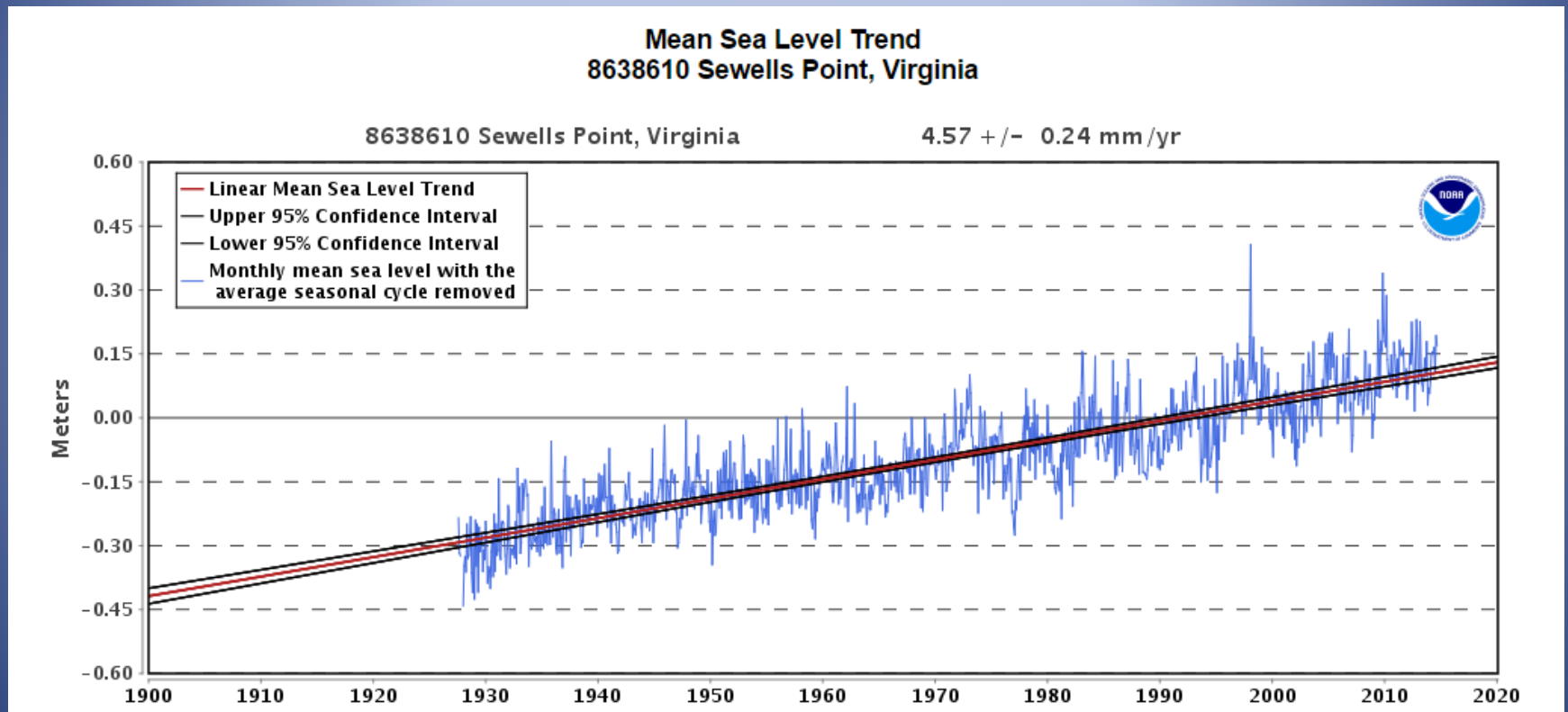


# NOAA Water Level Station at the Navy Base

- Stations like these provide water levels real time
- From these we know how often there is flooding
- NOAA surveys these regularly so we know the measurements are good



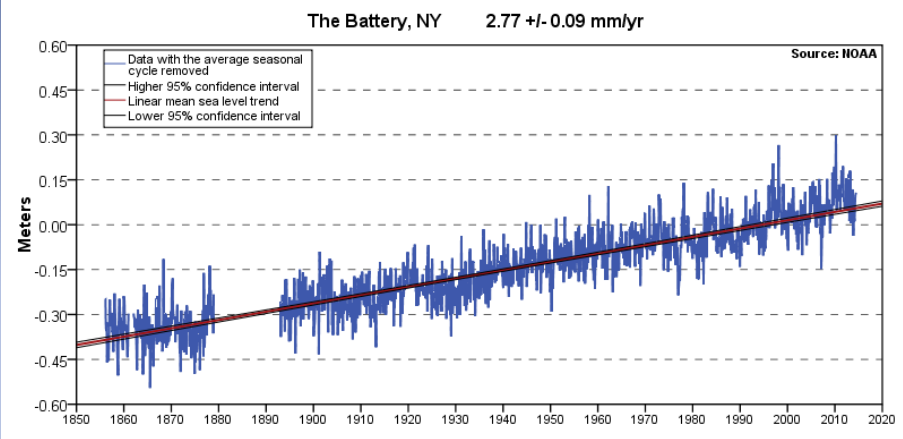
# 1.5 feet per 100 years at Navy Base



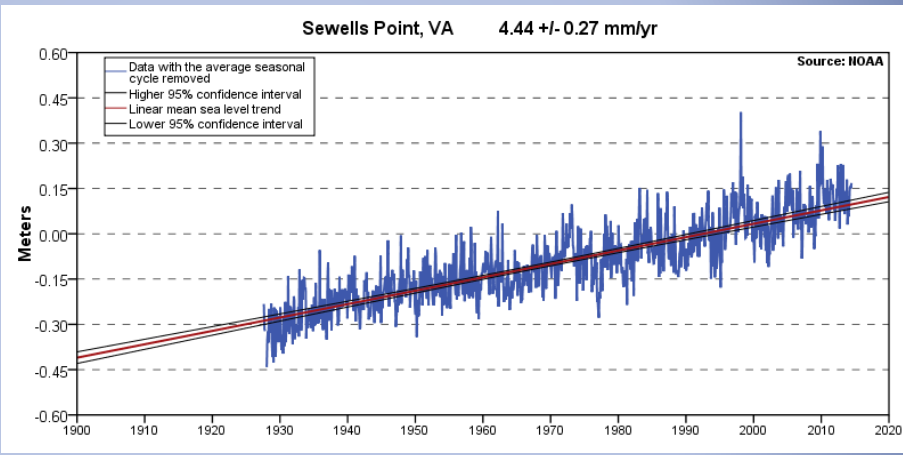
So we know about whole oceans

Regional SLR is different

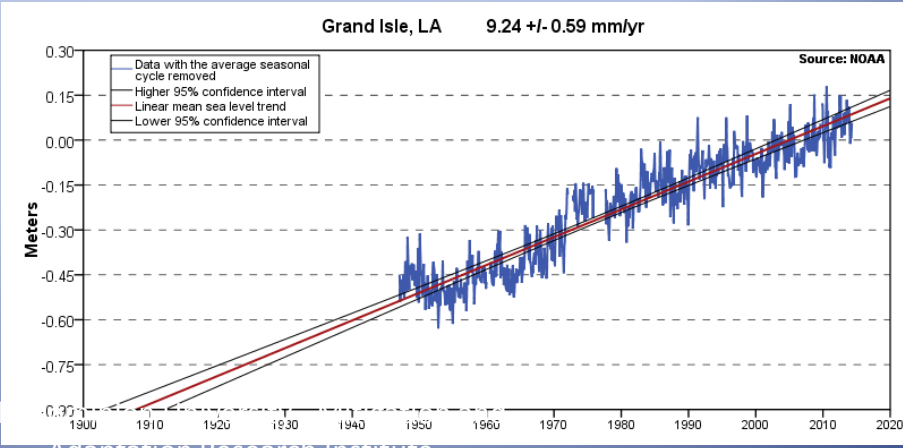
The Battery, NYC  
0.9 feet per century



Norfolk Virginia  
1.5 feet per century



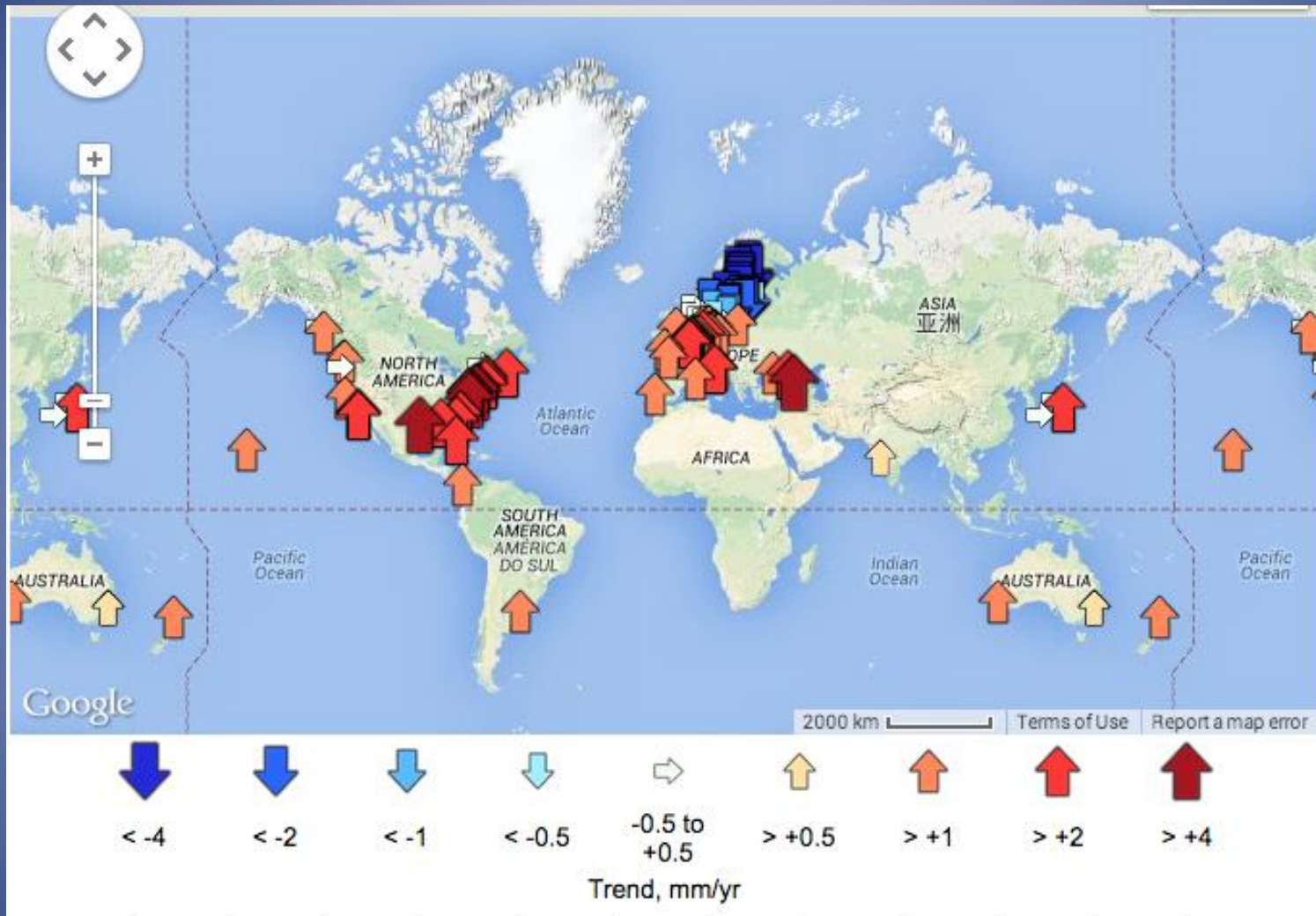
Coastal Louisiana  
3.0 feet per century



WHY?

O

# And Globally



Data <http://www.psmsl.org/>



# Science of Sea Level Rise

- We can measure it – easily it turns out
- It is rising along our coasts
- And appears to be rising faster (accelerating)
- Reasons
  - Geology – glaciers gone, ground water withdrawal
  - Global Sea Level Rise and movements of the ocean
- Take home – understand your specific situation

# Two ways we think about SLR

- The global ocean is filling and warming and moving around
- Locally at your coastal region other things are happening.
- So let's quickly look at global then to regional/local

# Land Ice is melting 'filling the global bathtub' – the ocean

If all ice melted

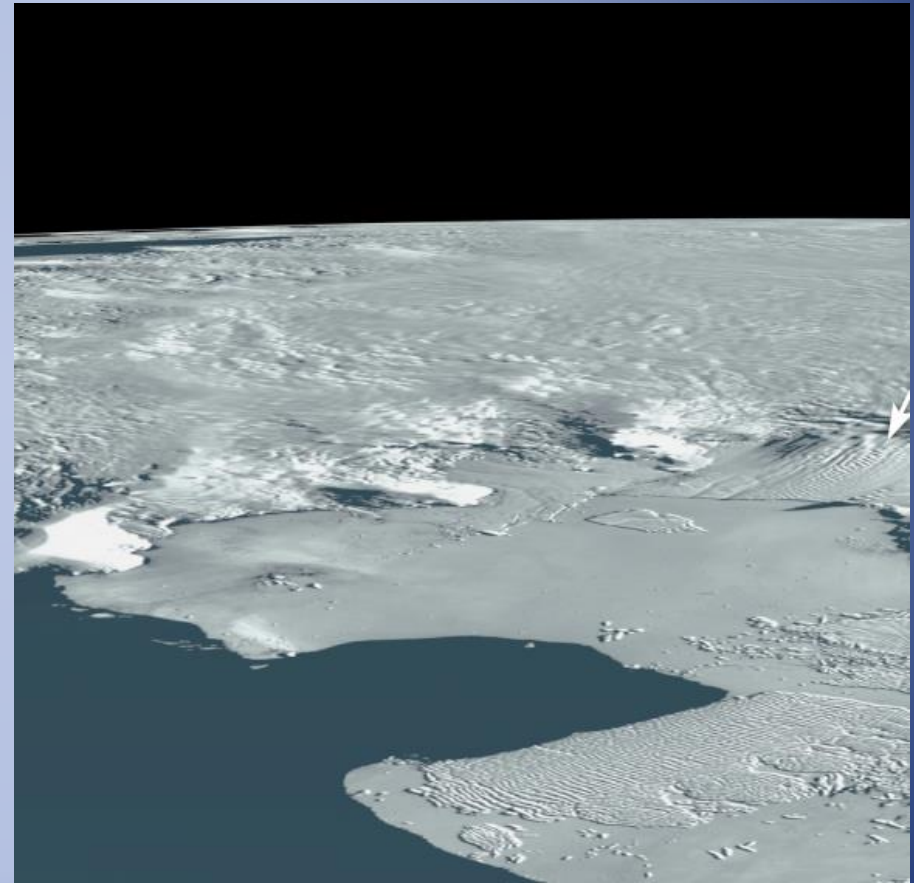
Antarctic – 200 foot sea level rise

Greenland – 20 foot rise

That will not happen for centuries

Small ice melt can lead to significant SLR – and that will (with very high certainty) happen.

This is why you hear so much in the news about ice sheets in Greenland and the Antarctic

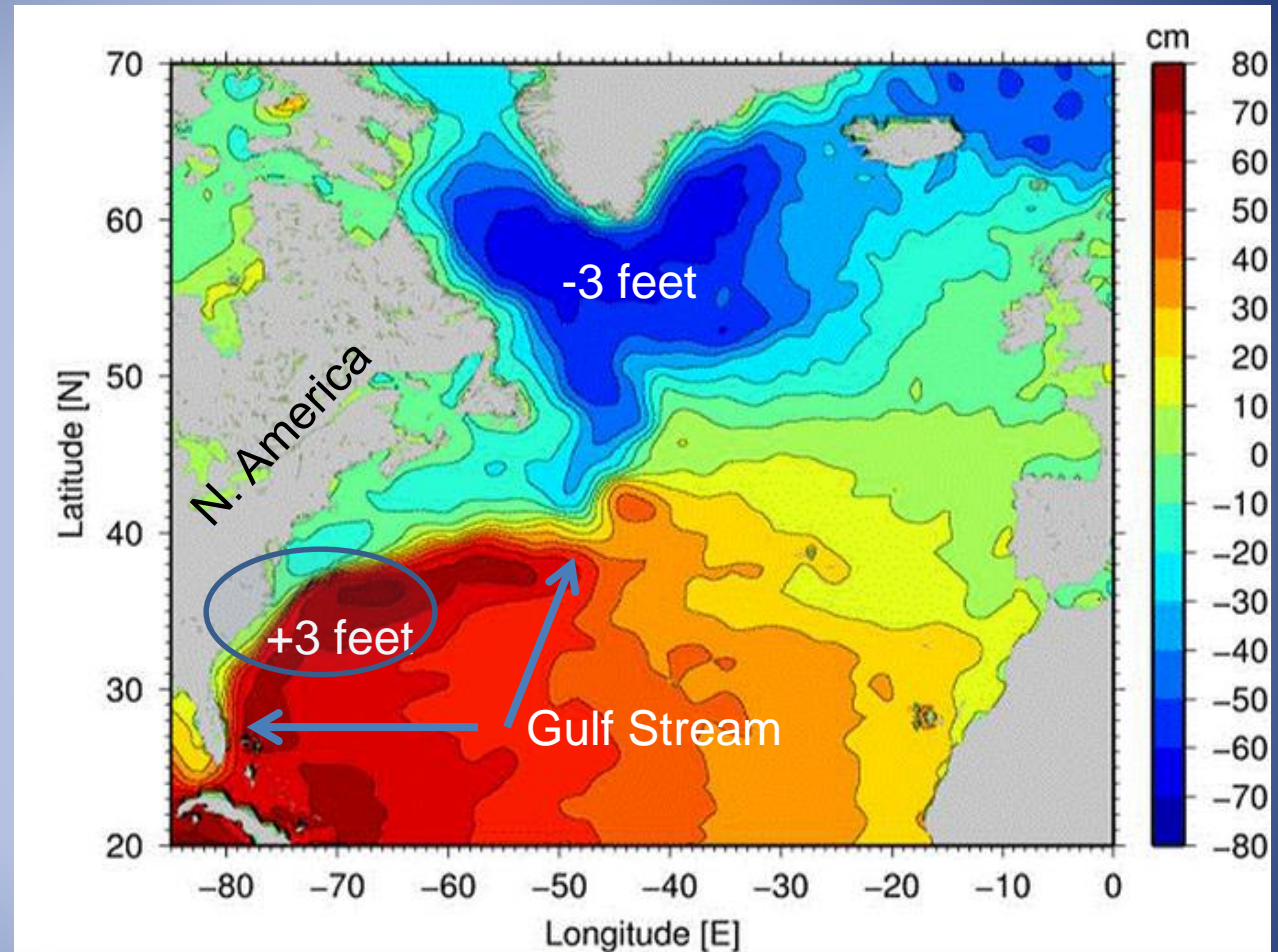


# The Ocean is not flat

## Topography of the ocean surface

The red is 6 feet higher than the blue area.

Small changes in ocean currents cause big changes in coastal sea level



[http://blogs.nature.com/news/2011/03/goce\\_mission\\_reveals\\_the\\_true.html](http://blogs.nature.com/news/2011/03/goce_mission_reveals_the_true.html)

# But we care about changes in coastal flooding exacerbated by local SLR

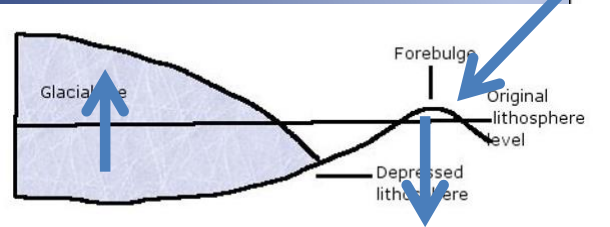
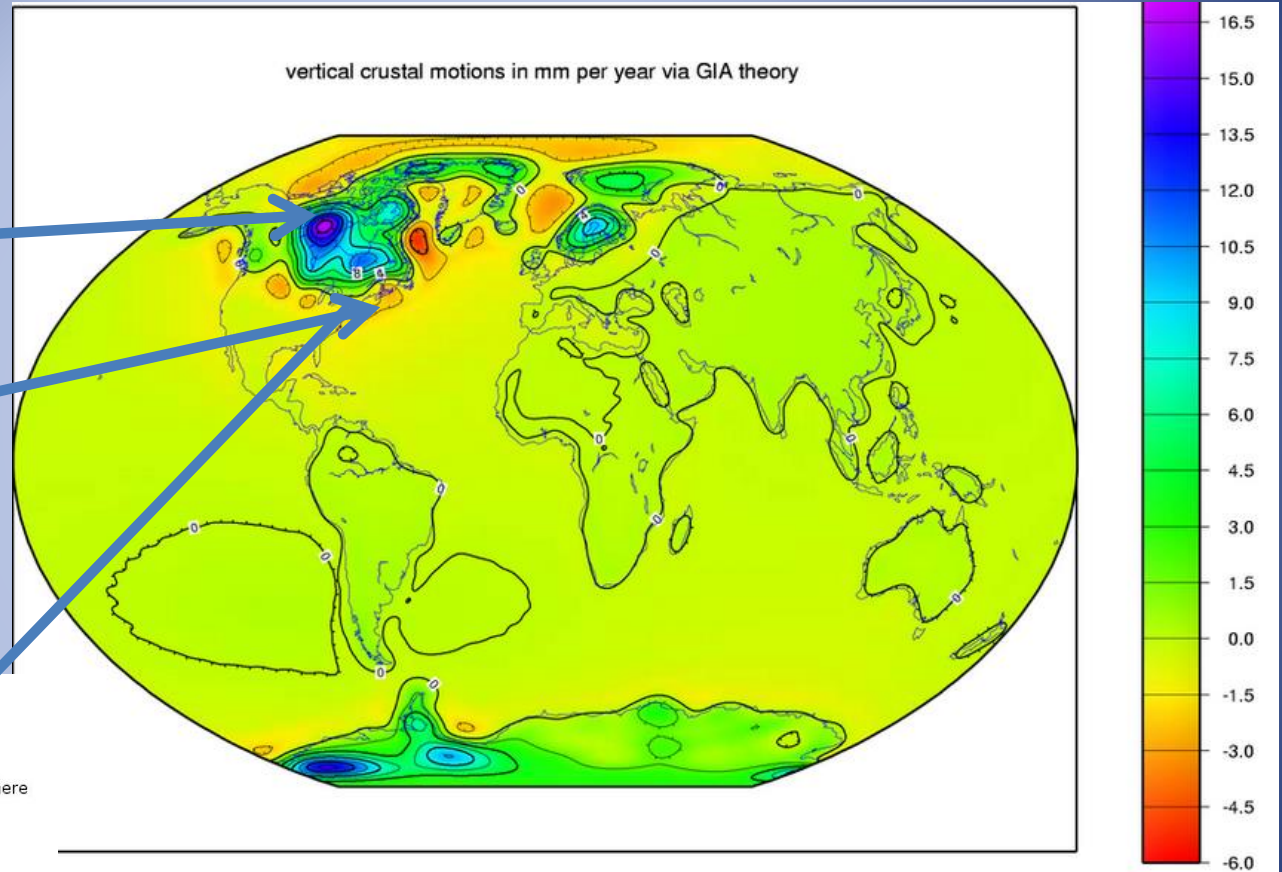


Annapolis – photo by Amy McGovern

# The land is moving - adjustment to last glaciation – mid-Atlantic sinking a bit

Rising where glaciers are gone

Sinking where glacial forebulge was



Wadoski UMaine

[ftp://podaac.jpl.nasa.gov/allData/tellus/L3/pgr/browse/PGR\\_Paulson2007\\_Rate\\_of\\_Lithospheric\\_Uplift\\_due\\_to\\_PGR.png](ftp://podaac.jpl.nasa.gov/allData/tellus/L3/pgr/browse/PGR_Paulson2007_Rate_of_Lithospheric_Uplift_due_to_PGR.png)

Old Dominion University - Mitigation and  
Adaptation Research Institute

# Subsidence (land sinking) causes

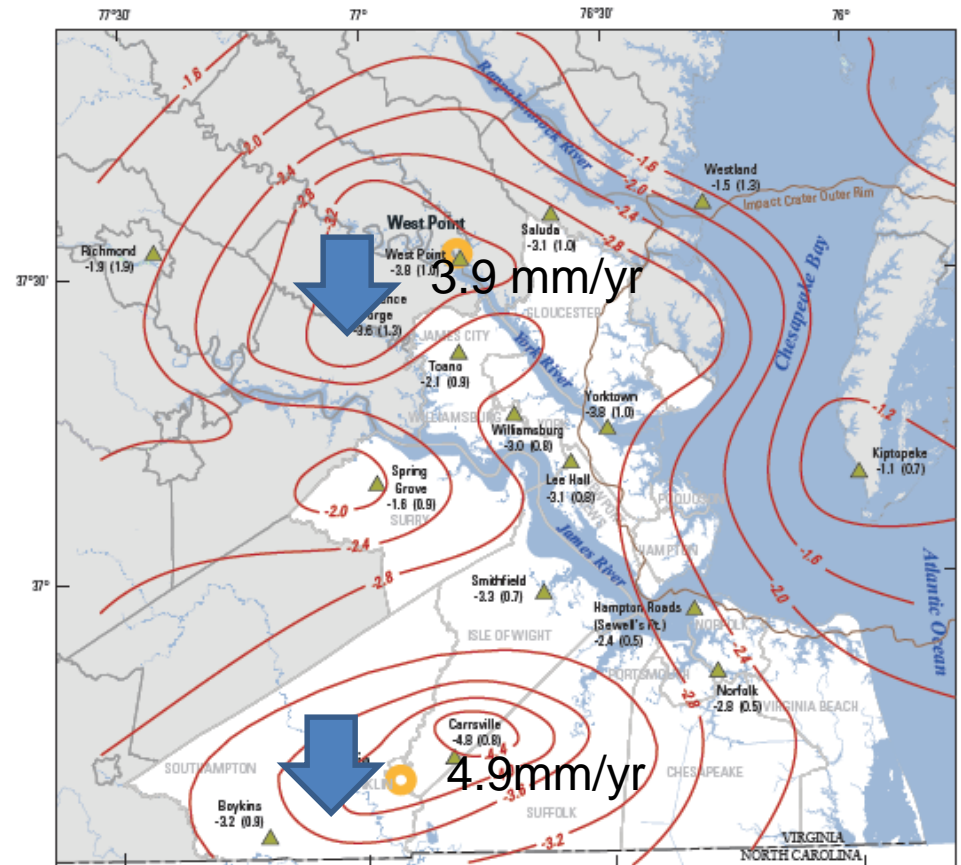
- Aquifer-system compaction from groundwater withdrawals
  - water-level decline,
  - sediment compressibility, and
  - sediment thickness



Photograph from Galloway and others (1999), USGS.

Case Study-  
ground water  
withdrawal in  
coastal Virginia

Two large pulp  
mills draw water  
from aquifer  
causing land to  
subside around  
the wells.



Map made from U.S. Geological Survey and Virginia Department of Game and Inland Fisheries data  
Virginia State plane projection  
Virginia south Federal Information Processing Standard (FPS) 4502  
North American Datum 1983 (NAD83)

Geodetic leveling from Holdahl and Morrison (1974)

**EXPLANATION**

- -3.2 — Line of equal land elevation change rate interpolated from leveling station measurements—Shown in millimeters per year. Interval is variable
- Groundwater withdrawal center
- ▲ Leveling station, and land elevation change rate in millimeters per year (standard deviation)

**Figure 12.** Land elevation change rates from 1940 through 1971. Adapted from Holdahl and Morrison (1974). Contours indicate lines of equal land elevation change rate (mm/year) and negative elevation change rates indicate subsidence. Values in parentheses are standard deviations.



## Sea Level Rise and Nuisance Flood Frequency Changes around the United States



City Dock in Annapolis, Maryland. Photo Credit: Amy McGovern.

Silver Spring, Maryland

June 2014



**noaa** National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF COMMERCE

National Ocean Service

Center for Operational Oceanographic Products and Services

‘Nuisance Flooding’

Sea level rise and these anomalies related to Gulf Stream slowing was topic of reports and papers.

Investigation and  
Institute

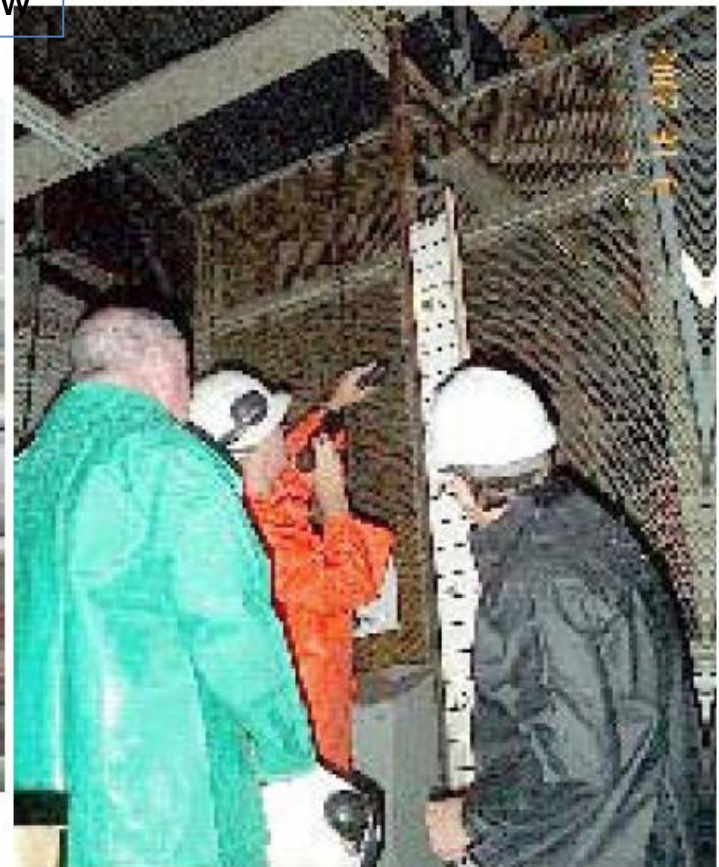
# Regional downscaling and its applications to sea-level rise impacts

## Impacts of Hurricane Isabel on the Northrop Grumman Ship Yard

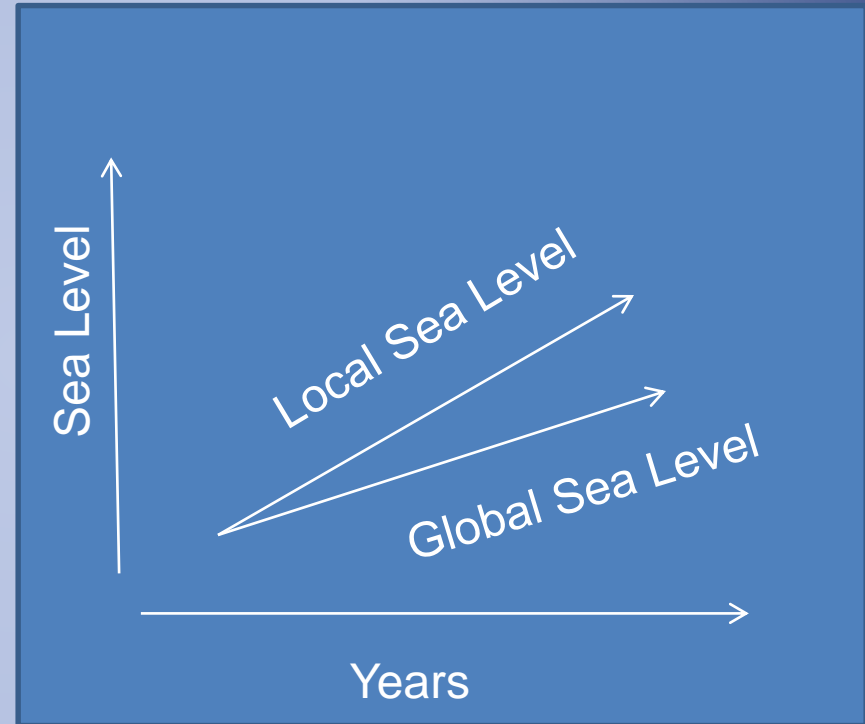
Flooding that might occur every 80 years  
Will occur every 2 years 50 to 100 years from now

Record high water level at the Shipyard

James River spilling into dry dock #1



- So now we know
  - Local SL rising faster than global in many cases
  - Subsidence is causing part of this but apparently not all.
  - The ocean is not flat so the added water and expansion does not necessarily lead to equal rise along the coasts.



**ELEVATED EAST COAST SEA LEVEL ANOMALY:  
June – July 2009**



**Silver Spring, Maryland  
August 2009**



**noaa** National Oceanic and Atmospheric Administration

U.S. Department Of Commerce  
National Ocean Service

Center for Operational Oceanographic Products and Services

Elevated Sea Level  
related to

- slowing of Gulf Stream,
- coastal wind direction,  
and
- possible strength of  
coastal currents.
- ODU has experts  
working on this

# Regional Response

- Hampton Roads Planning District Commission – Formed - Special Committee
  - Plan for both recurrent flooding
  - developing policy
  - Advocating for state and federal support
  - Primary regional contact for coordinating efforts
  - Members of the Committee - local government staff from across Hampton Roads representing various departments (such planning, public works, and economic development) and military.

# Flooding Mitigation and Insurance is at City Level



A to Z Ask a Question Departments



Brochures

FEMA Mitigation Links

Flood Insurance

Hazard Mitigation Assistance (HMA)

Flood Zones/Regulations

Flood Prone Areas

Flooding CIP Projects

Flooding Strategy

Homeowner's Role

Historical Photos

Partners & Outreach

Reports & Studies

Storm Surge Maps

What the City is Doing

Home > Community > Flooding Awareness & Mitigation



## Flooding Awareness & Mitigation

### Flood Awareness

Like any other low lying coastal area, Norfolk's elevation and its proximity to the Chesapeake Bay and several rivers make it susceptible to flooding. Nearly every year, and sometimes several times throughout the year during periods of heavy rain, hurricanes or nor'easter storms, residential and commercial properties are threatened with the potential of precipitation, tidal and/or wind-driven flooding and/or low-land flooding, particularly in neighborhoods around Norfolk's many waterways.

### Common Flooding Types and Definitions

- **Precipitation Flooding** - Occurs when rain intensity exceeds capacity of our storm drain systems due to blockages or naturally depressed elevations.
- **Storm Flooding** - Is caused by storm surges resulting from events such as hurricanes and nor'easters and is directly related to land elevation and proximity to coastline. High tides magnify this storm damage.
- **Tidal Flooding** - Is caused by tidal variations and is directly related to land elevation and proximity to coastline. Tidal flooding may occur on a regular basis due to normal moon cycles and is exacerbated by wind speeds and directions, sea level rise, and other types of flooding.

### Flood Mitigation

Flood Mitigation involves cost-effective measures taken now to avoid the loss of life and reduce future damages to public facilities, homes, and other improved property. By implementing flood mitigation measures you may prevent future damage to your property resulting from flood and potentially lower your flood insurance premium. You may want to consider discussing mitigation options with your flood insurance agent. Additionally, should your property qualify the [Hazard Mitigation Assistance \(HMA\) Grant Program](#) may

### CONTACT US

Flooding Information  
757-823-4000  
[Email](#)

### QUICK LINKS

- [FEMA Flood Maps, Insurance, and Information](#)
- [Federal Alliance for Safe Homes](#)
- [Flood Smart-Flood Insurance](#)
- [Flooding Terms](#)
- [Storm-wise Tips](#)

[VIEW ALL](#)

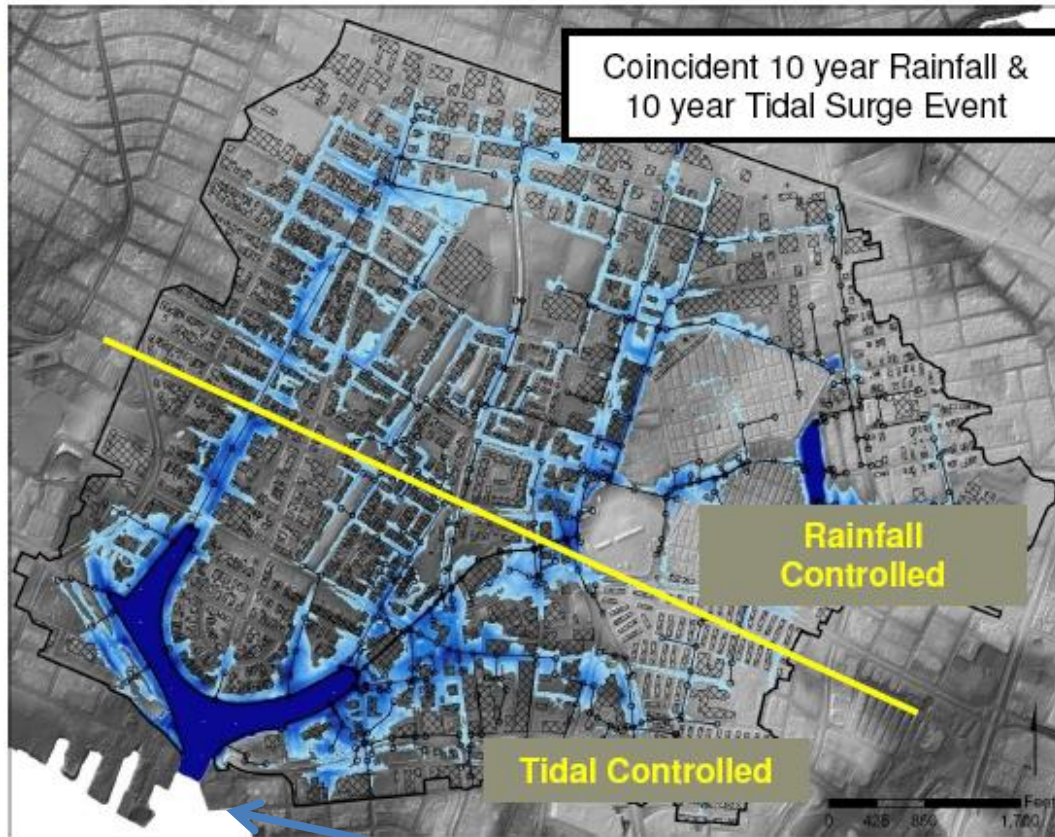
### FAQs

- [What can you do about street flooding?](#)
- [Do I need flood insurance?](#)
- [What is the difference between a firm map and a surge map?](#)
- [What is my flood zone?](#)
- [Are there grant programs available to assist with flood mitigation \(elevation, flood proofing, etc.\)?](#)

[VIEW ALL](#)



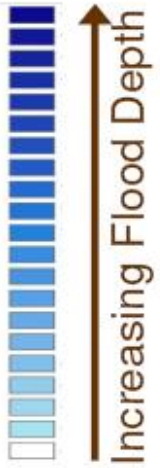
**Storm water  
Infrastructure  
Model**



**Coincident 10 year Rainfall &  
10 year Tidal Surge Event**

**Rainfall  
Controlled**

**Tidal Controlled**



Tidal surge:  
 1) Increases area of rainfall flooding  
 2) Increases depth of rainfall flooding and  
 3) Holds water upstream longer and increases duration of flooding



City of Norfolk and Fugro Atlantic

Light Rail  
extensions can also  
be flood structures





# Adapting to Flooding



11/12/2014

Old Dominion University - Climate Change  
and Sea Level Rise Initiative

By [Sarah Hutchins](#)  
The Virginian-Pilot  
© August 22, 2011  
Photos by D Miller

# Relevance to your business

- Water level (sea level) is rising at most locations in the lower 48 – we can measure it
- There will be more ‘nuisance flooding’ and more severe storm flooding
- There will be more rain water flooding
- New regulations will require more storm water management.

# Thanks

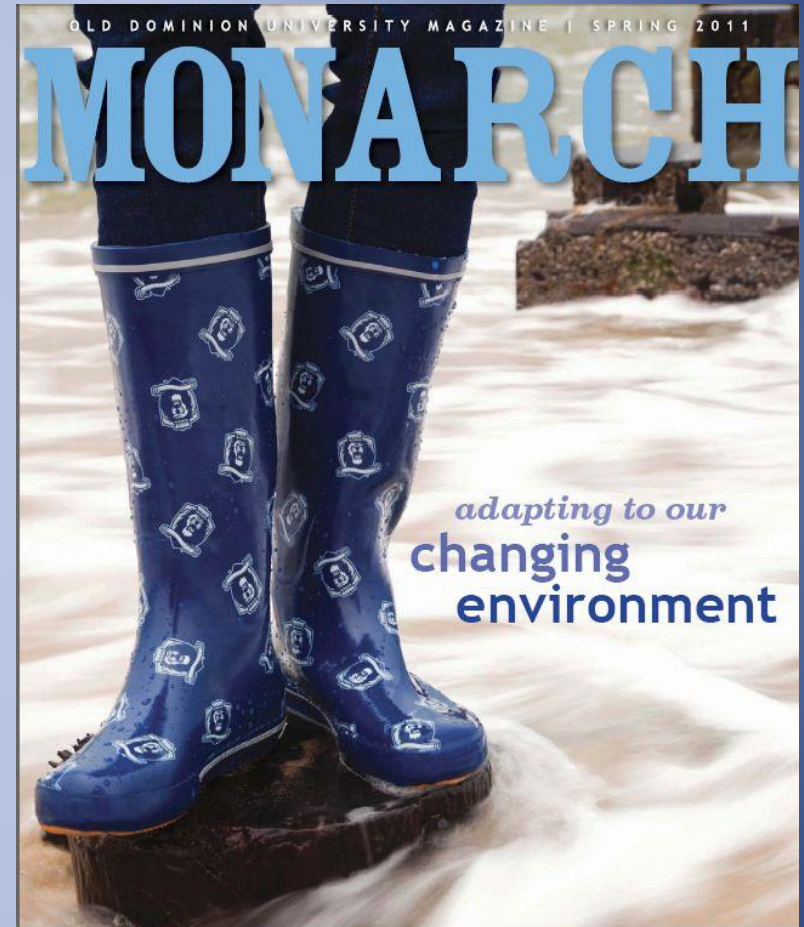
Larry Atkinson

[latkinso@odu.edu](mailto:latkinso@odu.edu)

And colleague

Tal Ezer

[tezer@odu.edu](mailto:tezer@odu.edu)

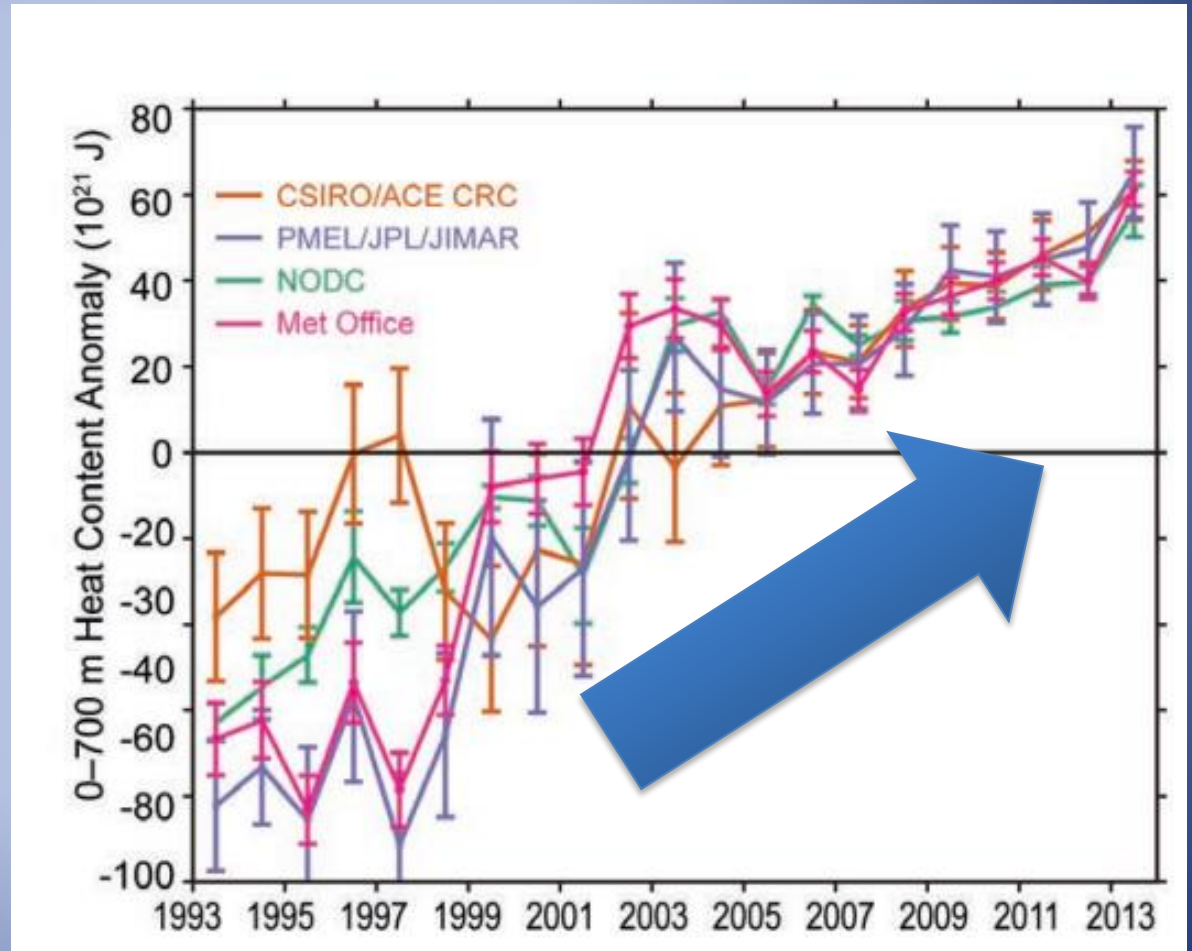


- Flooding more
- We measure it
- Why
- Rain flooding and tidal flooding
- What state and region is doing – needs fed/state/regional approach but it is all local/city by city – make sure one project doesn't cause harm elsewhere.
- Relevance to Ready Mix – more surface flooding – part of CRS (flooding) – more **stormwater management - opportunities**

# The Ocean is Warming – and expanding

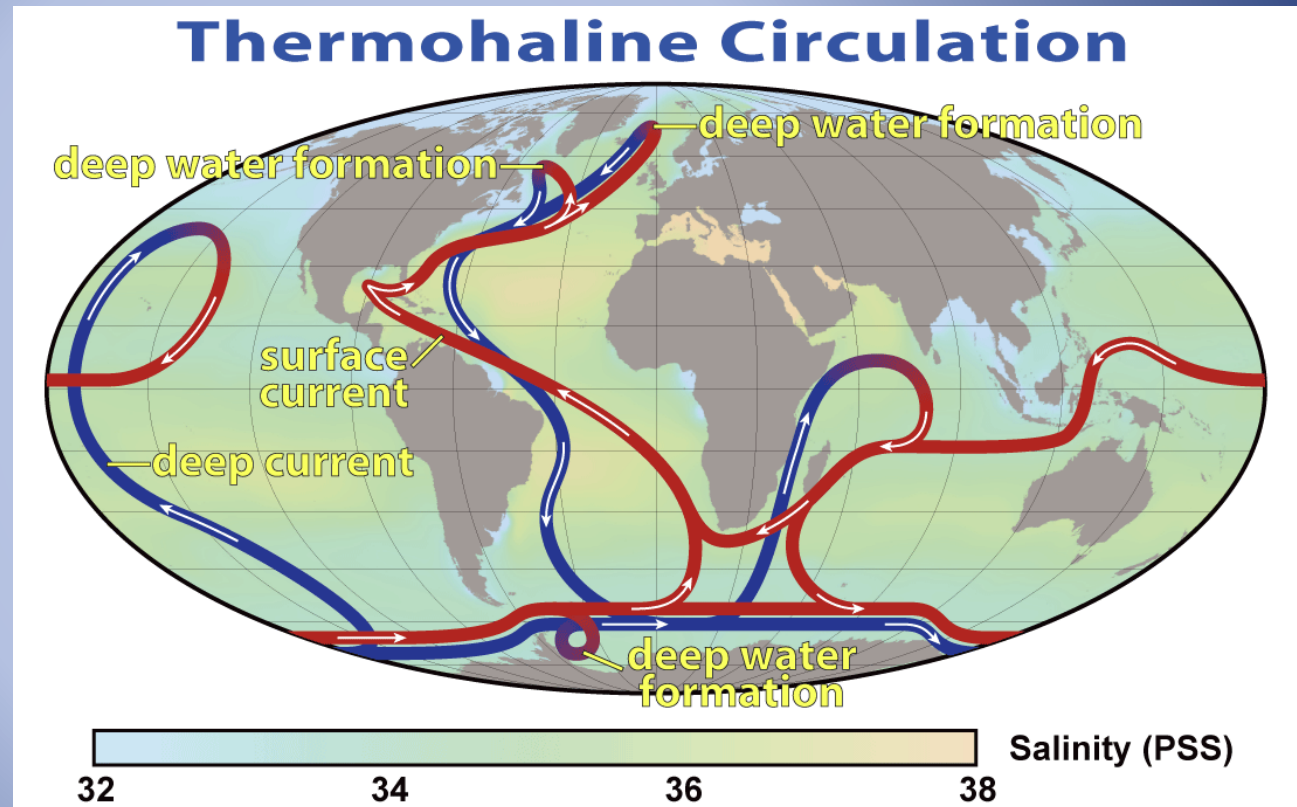
Increasing heat content of the global ocean

As the ocean heats up it expands



Or the global conveyor belt slowing down – affecting coastal sea level

This is a very active area of research right now.



# Flood Insurance will make decisions for US

**PilotOnline.com**

## **Cost of flood insurance poised to rise for thousands**

By Sarah Kleiner Varble  
The Virginian-Pilot  
© September 24, 2013

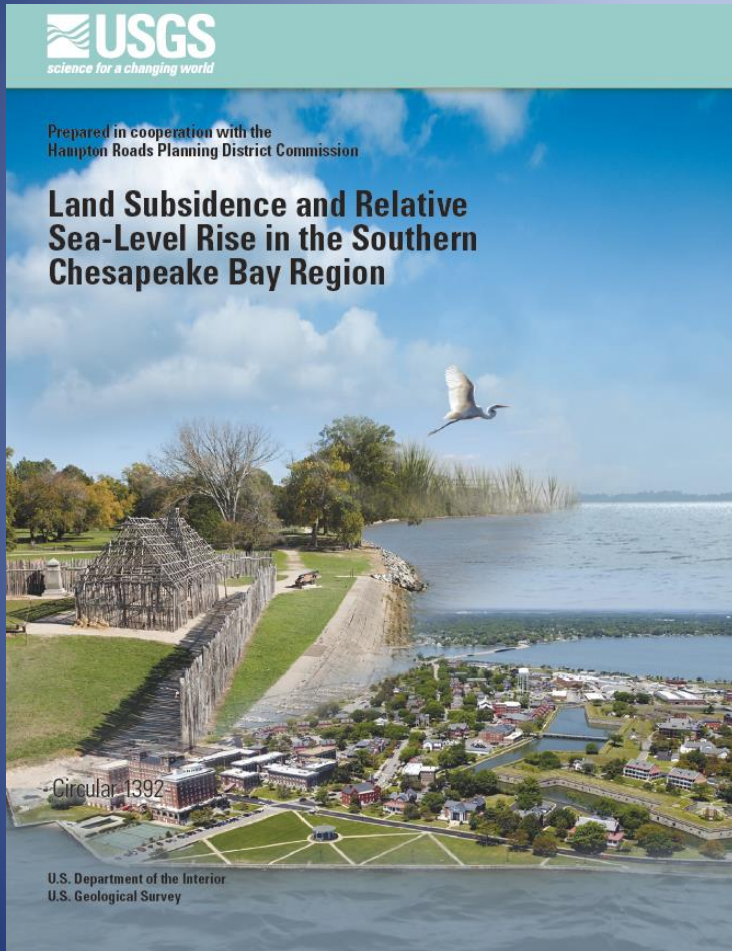
Mother Nature has spared U.S. coastal cities from devastating hurricanes this season, but some local homeowners should brace themselves nonetheless.

The cost of flood insurance for thousands of properties in South Hampton Roads soon could go up - significantly in some cases.

Subsidies that have kept insurance costs down for many homeowners across the country will be phased out beginning Oct 1. And those discounts no longer will be transferable from owner to owner, which will add hundreds or thousands of dollars to the annual out-of-pocket costs for buyers of such homes.

On top of that, the Federal Emergency Management Agency is redrawing flood zone boundaries. Houses that aren't in a flood zone now might find themselves on the riskier side of the line once the maps are finalized in 2014. Those homes will have to be insured against flooding.

# To sum up – subsidence is important



Glacial adjustment 1 mm/yr

Land subsidence 1.1 to 4.8 mm/yr

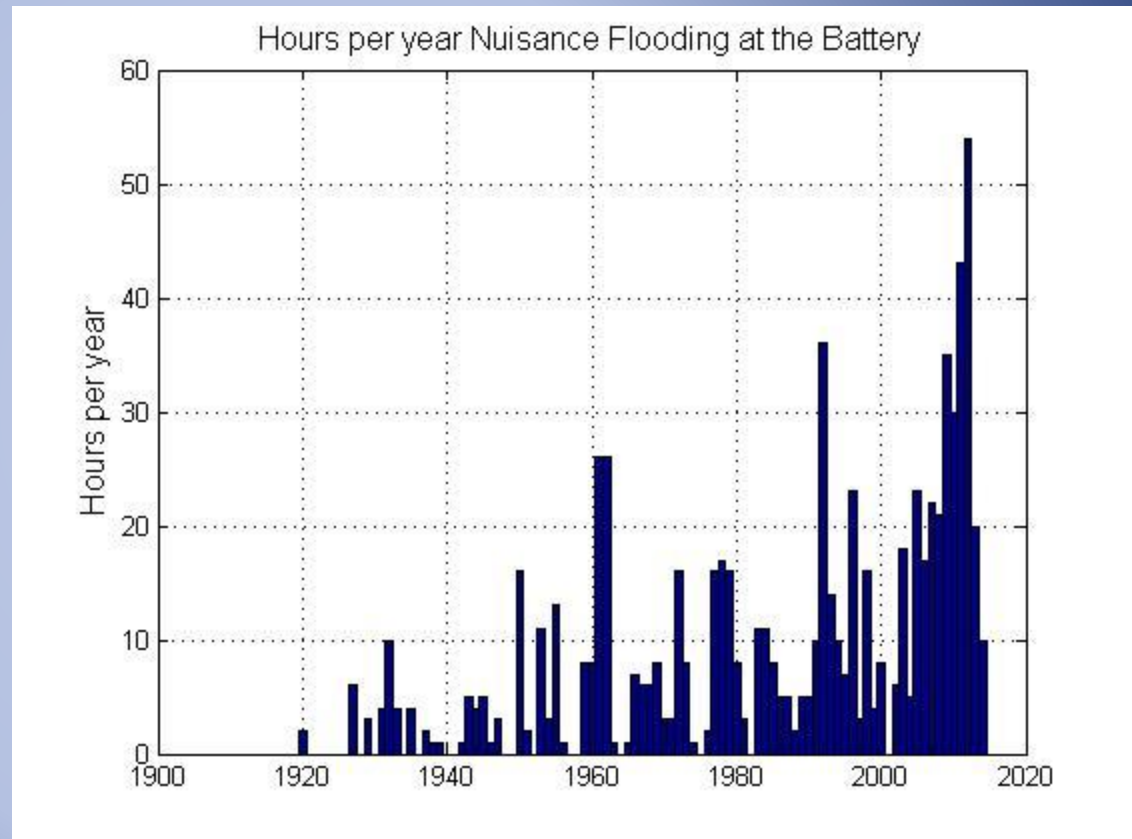
Cities in my region are installing their own water level gauges to get better resolution of subsidence rates

*3 mm/year = about 1 foot per century*



# Regardless of cause we are seeing more flooding

To predict future sea level we need to understand what the ocean is going to do in response to increased GHG's (the elephant in the room).



# RISK & INSURANCE

Emerging Strategies for Risk

## LIU SPECIALTY LINES

- PRIMARY CASUALTY
- EXCESS CASUALTY & UMBRELLA
- E&S PROPERTY
- ENVIRONMENTAL
- RAILROAD
- PRODUCT RECALL
- PRODUCT CONTAMINATION
- PROFESSIONAL LIABILITY
- D&O / FIDELITY / EPLI
- KIDNAP, RANSOM & EXTORTION
- PROGRAMS
- OCEAN MARINE
- CONSTRUCTION
- ENERGY



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## CLIMATE: The Slowing Gulf Stream

*Coastal events like Superstorm Sandy will become more problematic due to higher sea levels from a slowing Gulf Stream.*



By Gregory Morris

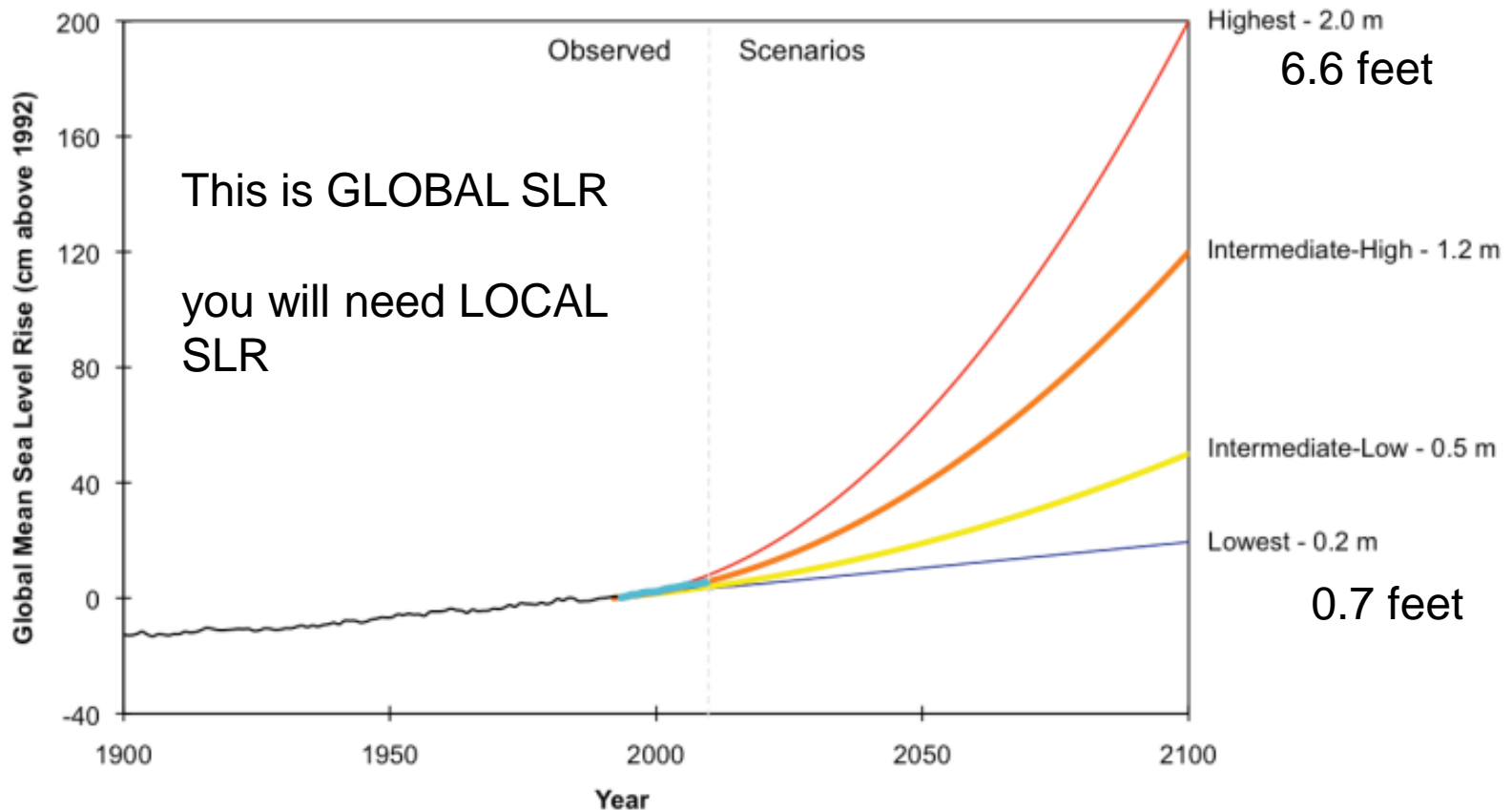
**Scenario:** For most of the U.S. the iconic image from Superstorm Sandy was the beloved roller coaster at Seaside Heights, NJ, half submerged in the Atlantic Ocean after the pier upon which it stood collapsed. For New Yorkers, however, the images seared in mind from the super storm were from Breezy Point, at the very tip of the Rockaway Peninsula, which became practically an island. Hurricane, tidal surge, and raging fires literally levelled the community. When federal and state aid began flowing to repair the Sandy damage, local and city entities at all levels mobilized. Coney Island, at the south end of Brooklyn, had already had its renaissance, and now it was the turn of the Rockaways.



### Magazine Content

- Home
- Features
- Columnists
- Industry Risk Reports
- In-Depth Series
- Special Reports

“We have very high confidence (>9 in 10 chance) that global mean sea level will rise at least 0.2 meters (8 inches) and no more than 2.0 meters” Recent US Assessment



Parris, A., et al. 2012. Global Sea Level Rise Scenarios for the US National Climate Assessment. NOAA Tech Memo OAR CPO-1. 37 pp