



Talking about Sea Level Rise and Climate Change

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University of South Florida**



The Greenhouse Theory is too new to trust!

The first paper was by Fourier in ...1827

Arrhenius computes the Earth's average surface temperature from the CO₂ concentration in ...1896

New?

NO, this is 19th century physics.

So Why the Fuss?

I think it's because of confusion about
“Climate Sensitivity”.

I weigh myself every morning ...

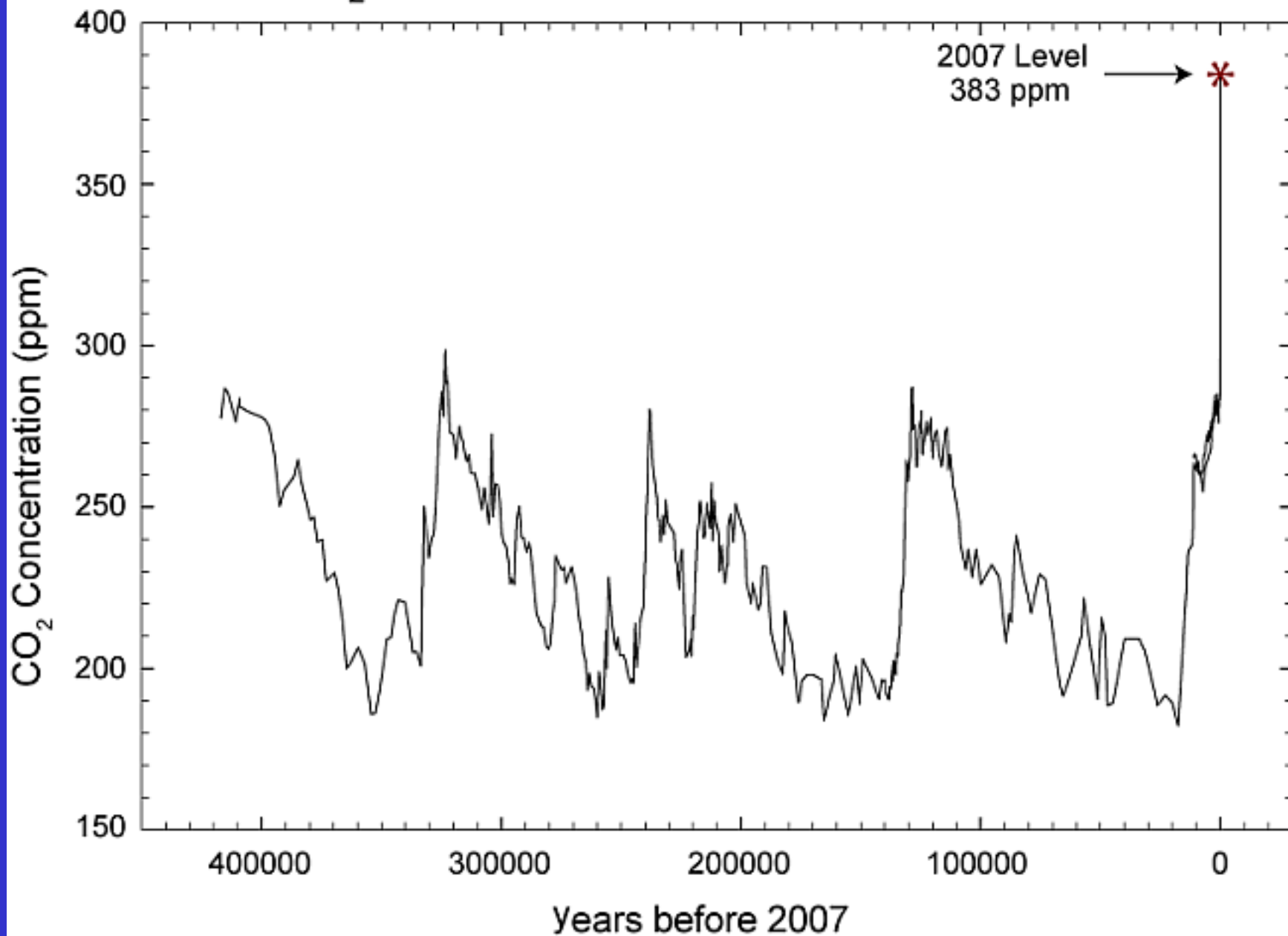
The argument is that if a model is not perfect,
it's wrong, which is wrong ...

CO₂ changes are natural!

Haven't you ever heard of ice ages?

You must be ignorant or just a
“fake” scientist ...

CO₂ Over Past 420 Thousand Years



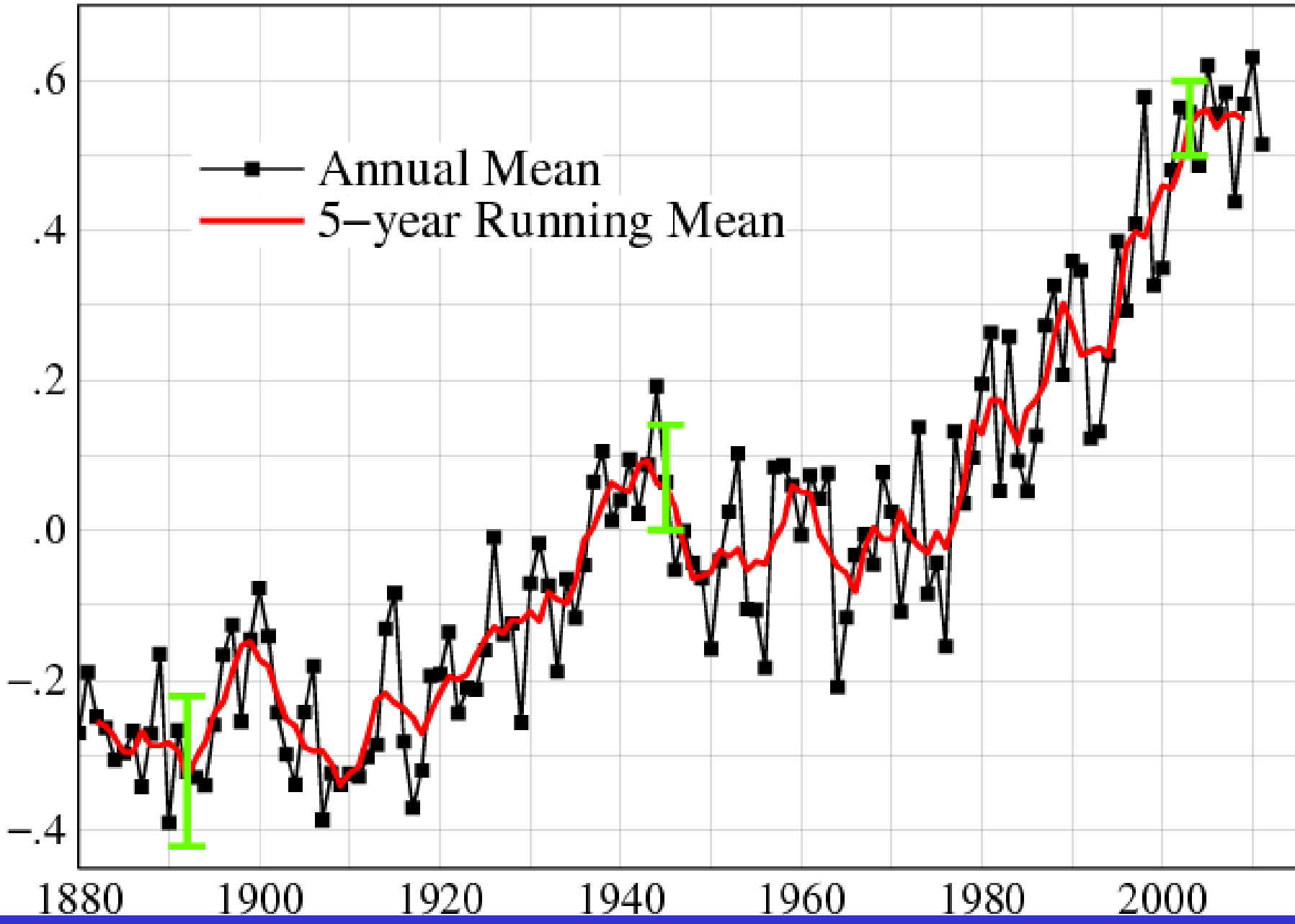
None of this CO₂ Stuff Matters

Because the air temperature changes
don't agree with the theory ...

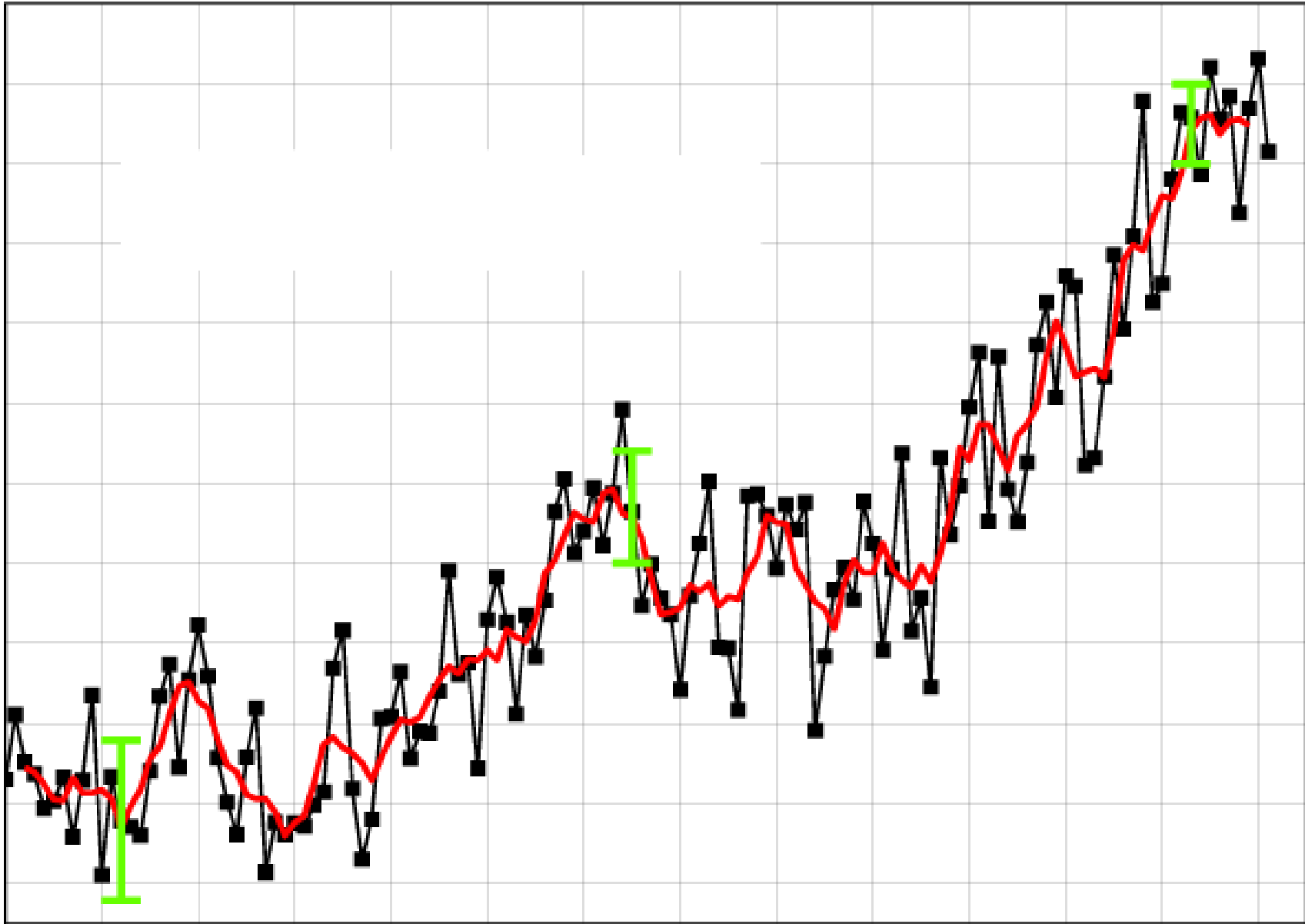
This assumes that there is no “noise”.
Remember my bathroom scale?

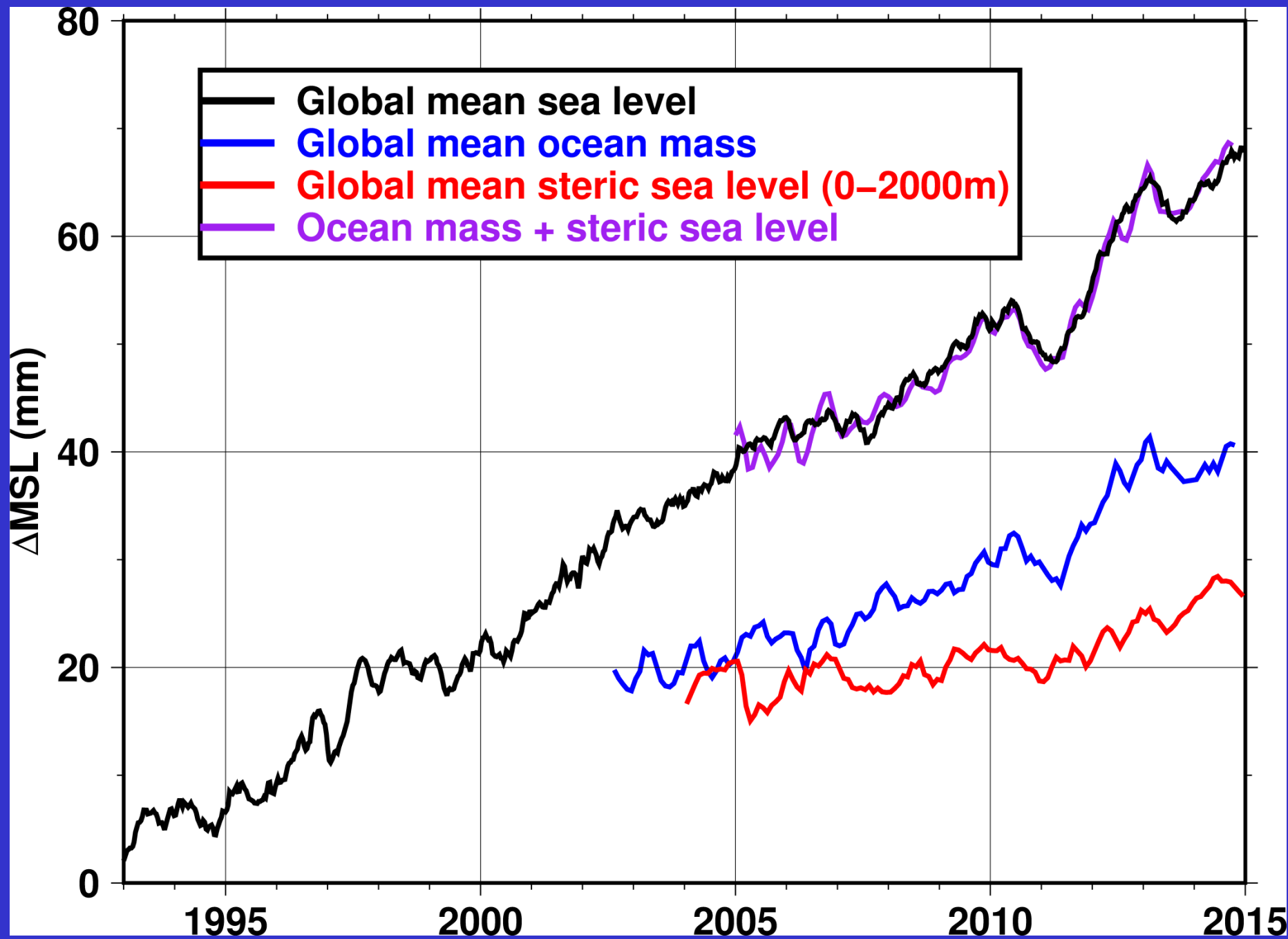
Global Land–Ocean Temperature Index

Temperature Anomaly (°C)



Stock Market Index





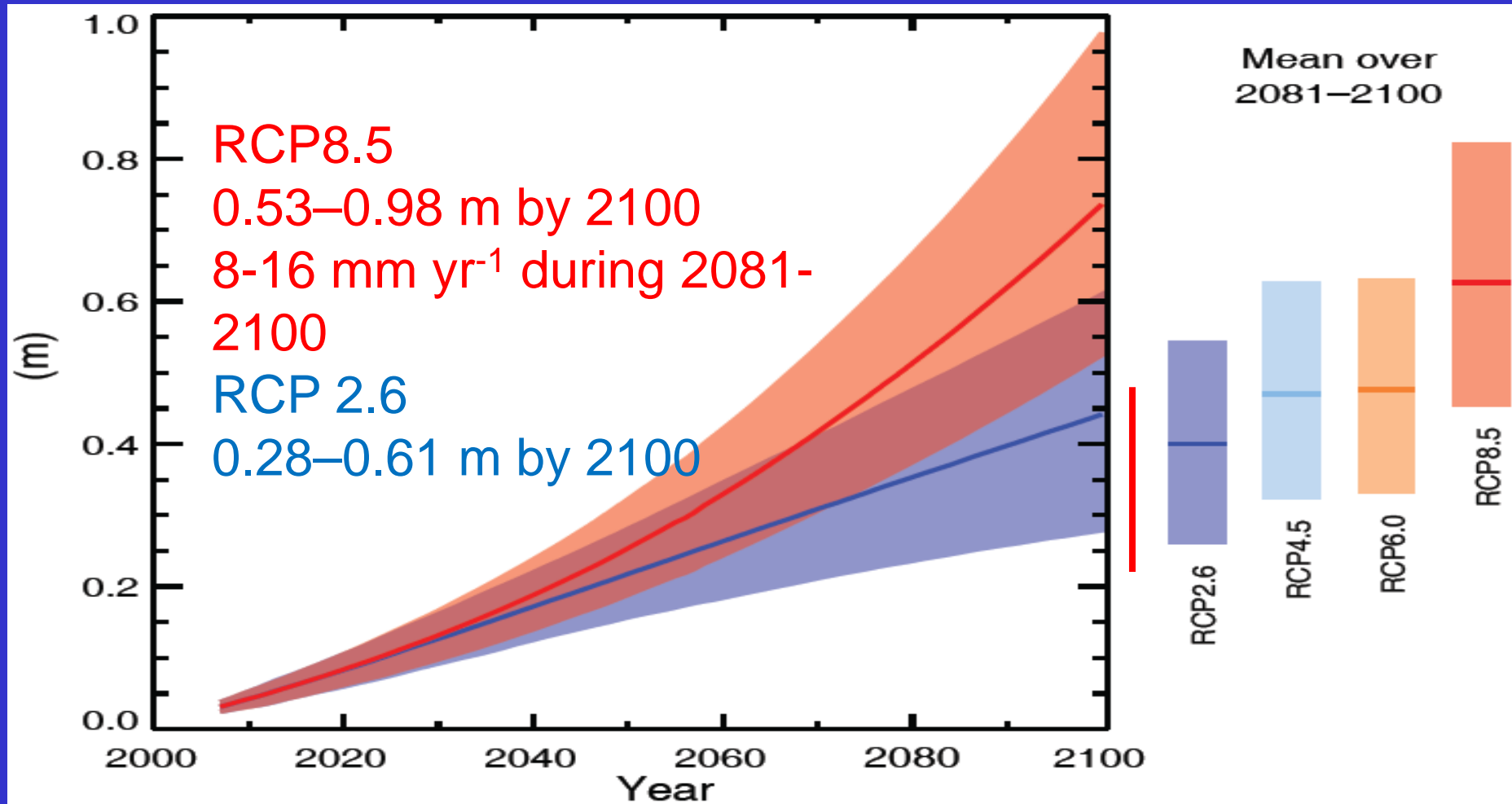
Okay, but 3 mm/yr amounts to about 1 foot
of increase in a 100 years.

Who cares?

But it's not just rising, it's accelerating.

This is hard to explain to many people.

Projections of 21st-century GMSLR under RCPs



“Global mean sea level will continue to rise during the 21st century. Under all RCP scenarios the rate of sea level rise will very likely exceed that observed during 1971–2010 due to increased ocean warming and increased loss of mass from glaciers and ice sheets.”

But that's all from computer models
and I don't trust those.

Why can't we see it in the data?

This is a fair, and very scientific, question.

According to the data ...

Climate-change–driven accelerated sea-level rise detected in the altimeter era

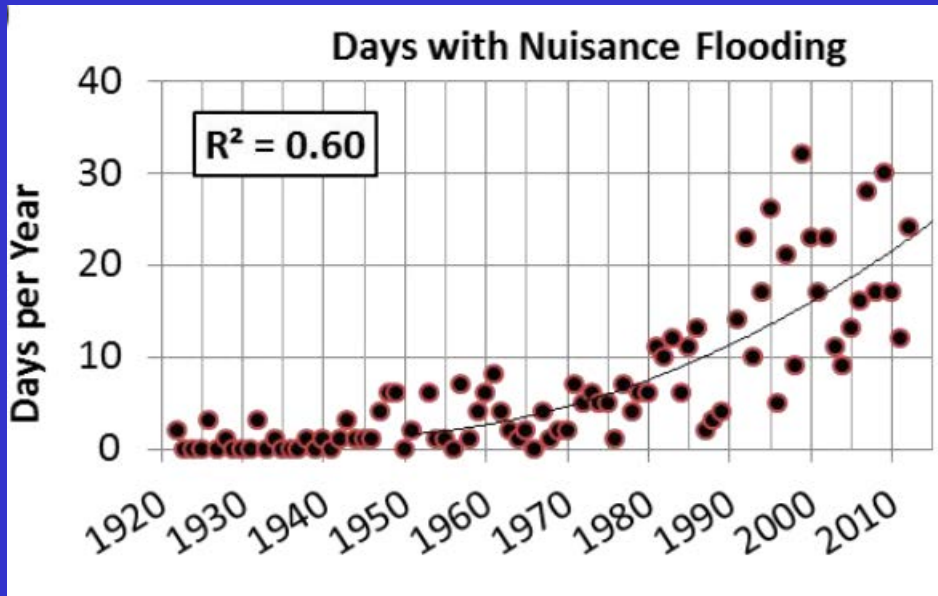
R. S. Nerem^{a,1}, B. D. Beckley^b, J. T. Fasullo^c, B. D. Hamlington^d, D. Masters^a, and G. T. Mitchum^e

^aColorado Center for Astrodynamics Research, Ann and H. J. Smead Aerospace Engineering Sciences, Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO 80309; ^bStinger Ghaffarian Technologies Inc., NASA Goddard Space Flight Center, Greenbelt, MD 20771; ^cNational Center for Atmospheric Research, Boulder, CO 80305; ^dOld Dominion University, Norfolk, VA 23529; and ^eCollege of Marine Science, University of South Florida, St. Petersburg, FL 33701

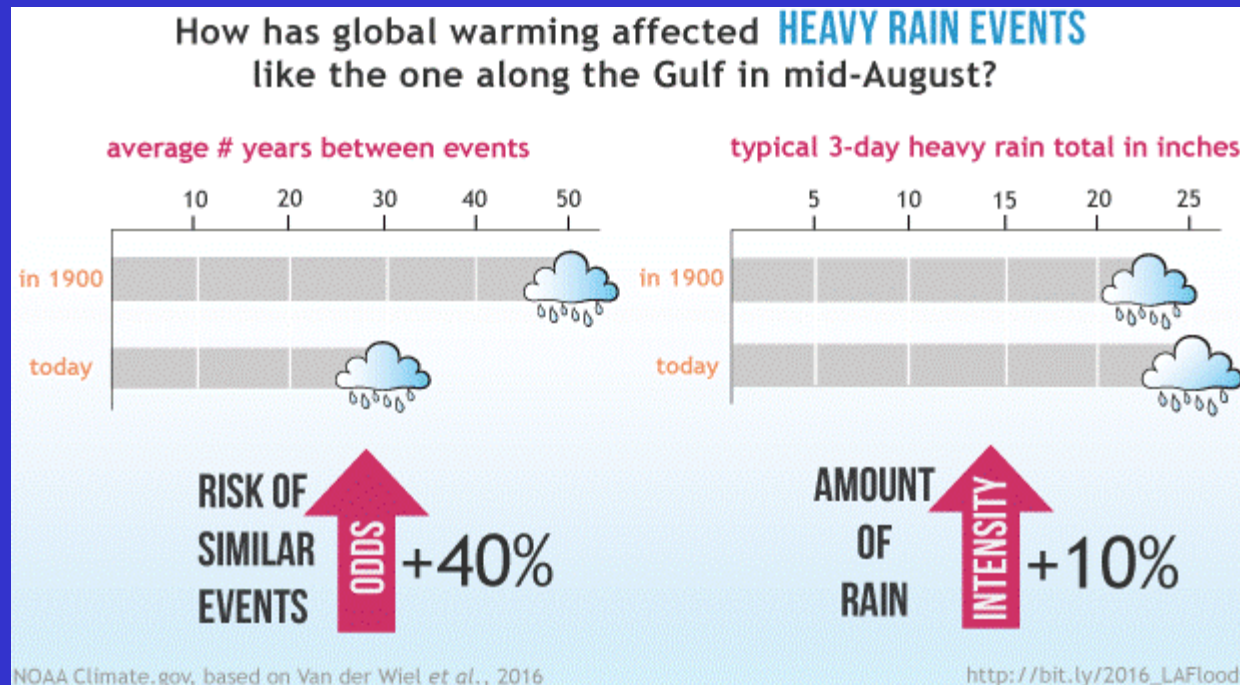
This article appeared in February 2018 in the
Proceedings of the National Academy of Sciences

Well, I don't really care about sea level 100
years from now.

Climate change is NOT just sea level rise, and
it's not just 100 years from now.



Flooding events are having large impacts on our cities, and are occurring more frequently. They are asking for guidance, which presents a challenge to our data networks and systems.





CONTINENTAL UNITED STATES LANDFALLING HURRICANES 1950-2004



NOAA'S NATIONAL CLIMATIC DATA CENTER, ASHEVILLE, NORTH CAROLINA

Protecting the Past... Revealing the Future



Invasive species



The background features a series of concentric circles in light gray, some solid and some dashed, creating a ripple effect. A large blue callout box is centered on the page, containing the main text.

Regional Resilience

Environmental Planning and Community Resilience Division

Broward County



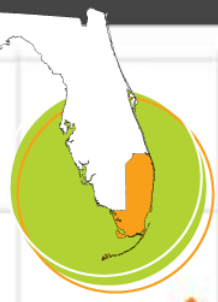
Man-made problems have
engineered solutions.

Need them to be cost-effective.

Unified Sea Level Rise Projection

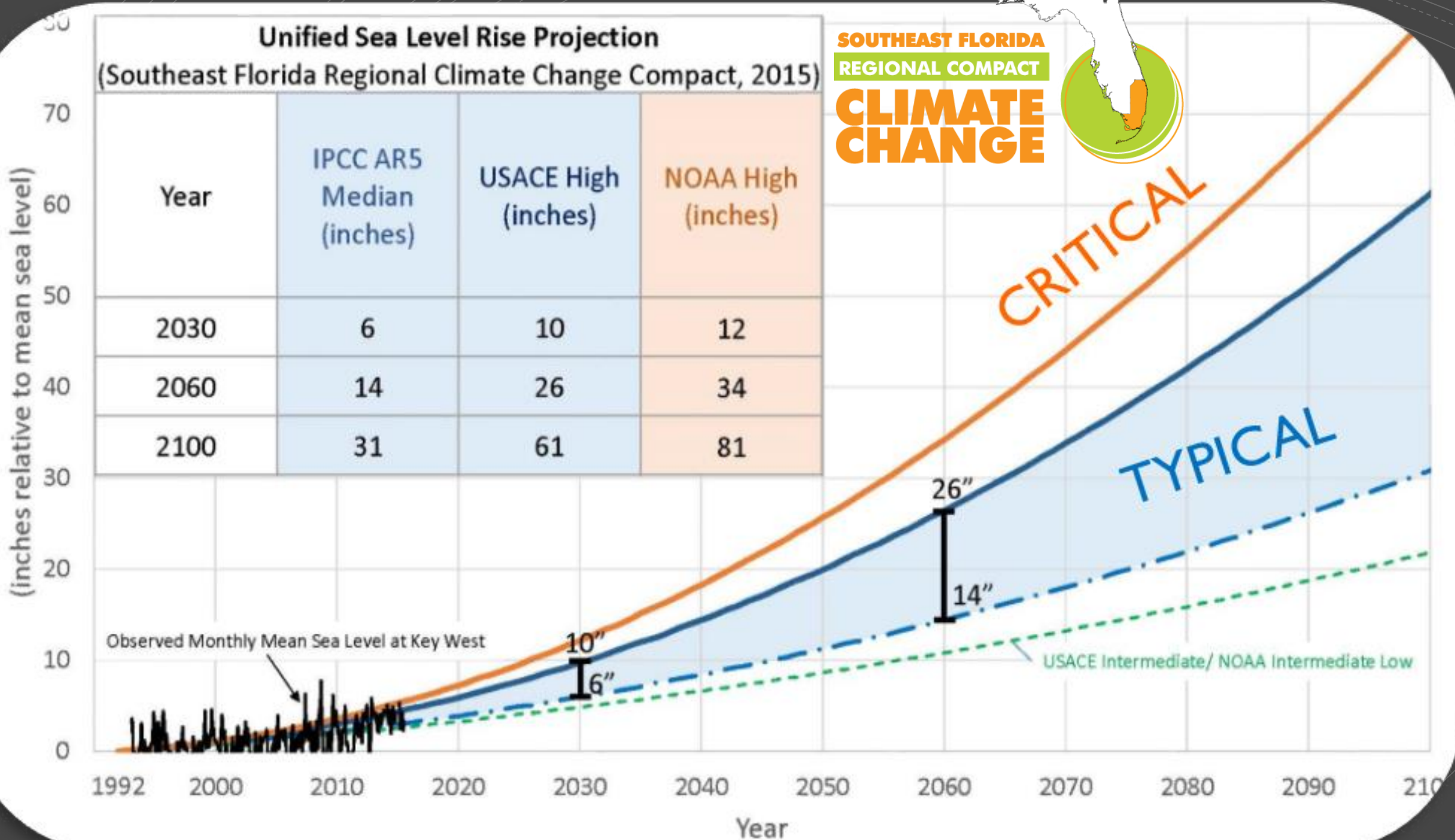
(Southeast Florida Regional Climate Change Compact, 2015)

**SOUTHEAST FLORIDA
REGIONAL COMPACT
CLIMATE
CHANGE**



Year	IPCC AR5 Median (inches)	USACE High (inches)	NOAA High (inches)
2030	6	10	12
2060	14	26	34
2100	31	61	81

Relative Sea Level Rise near Key West, FL
(inches relative to mean sea level)



CRITICAL

TYPICAL

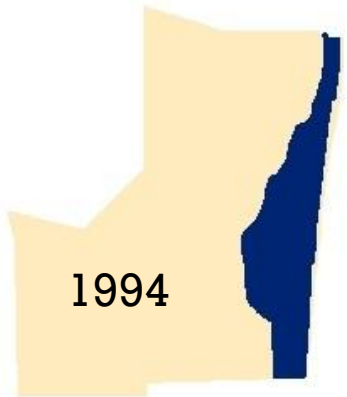
USACE Intermediate/ NOAA Intermediate Low

Observed Monthly Mean Sea Level at Key West

Year

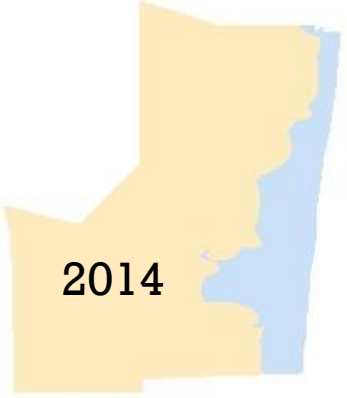
Water Supply

72 Miles²

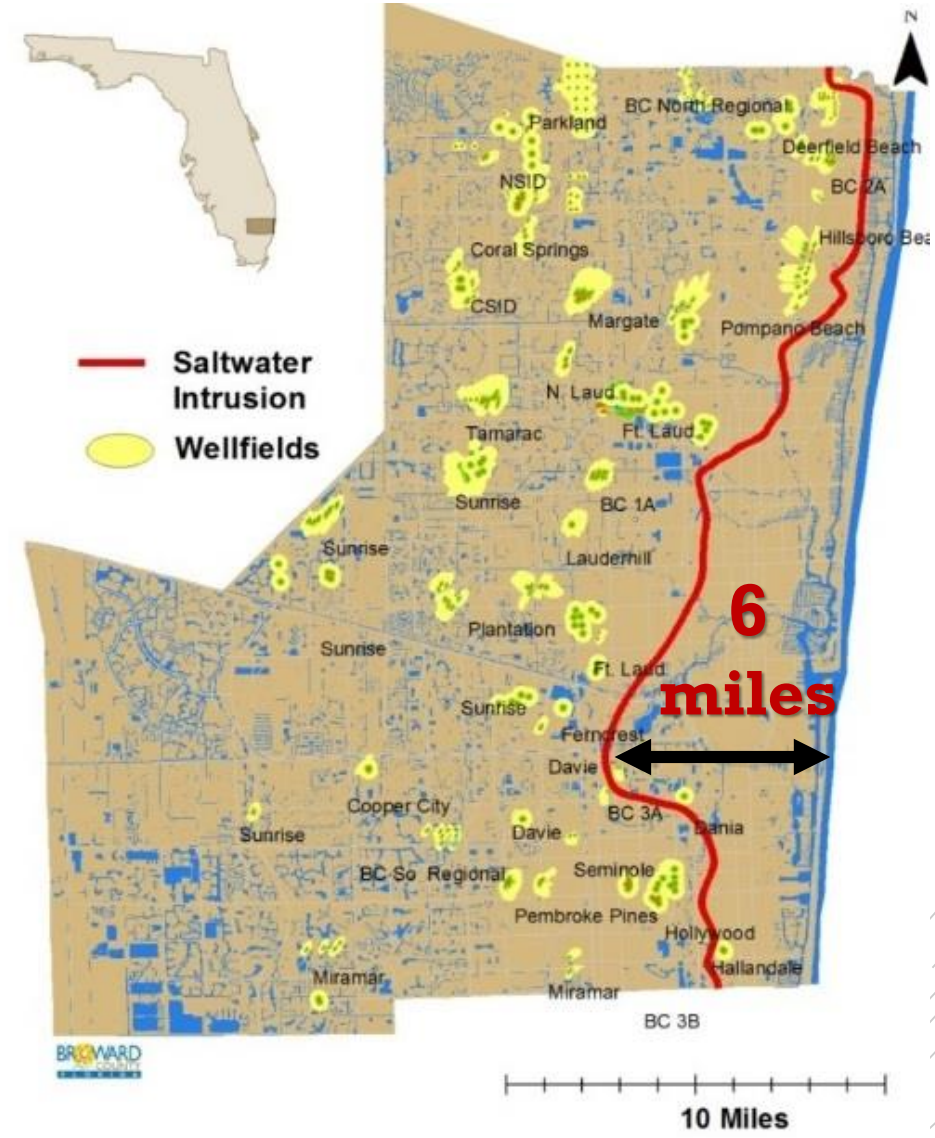


Source: Broward County

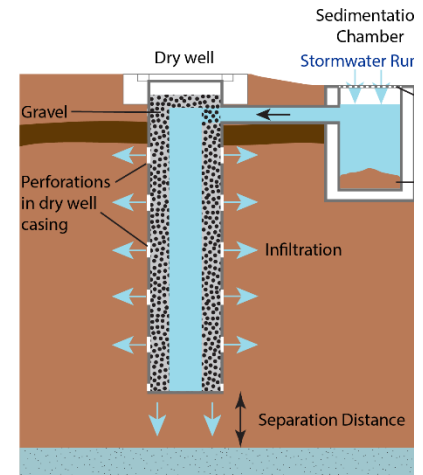
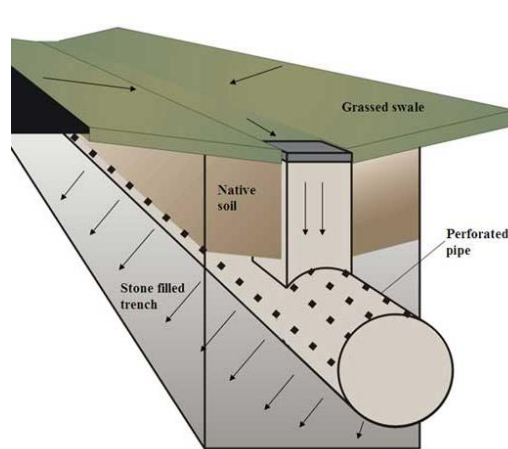
83 Miles²



Source: sfwmd



Drainage



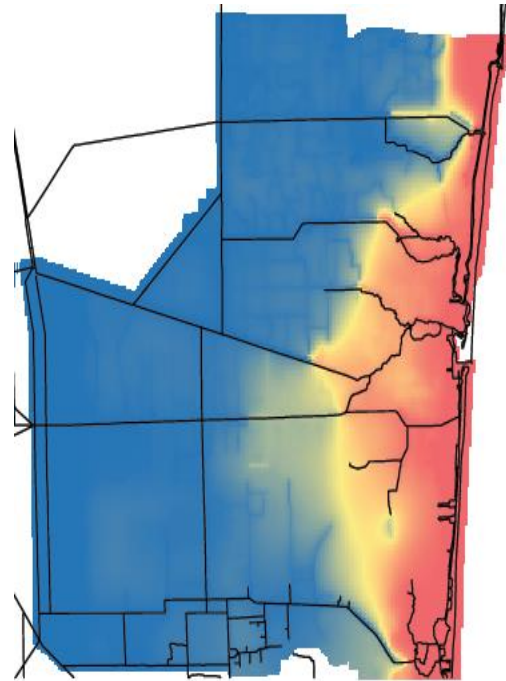


**Harrison Street looking east
Towards the Intracoastal on
October 5, 2017**

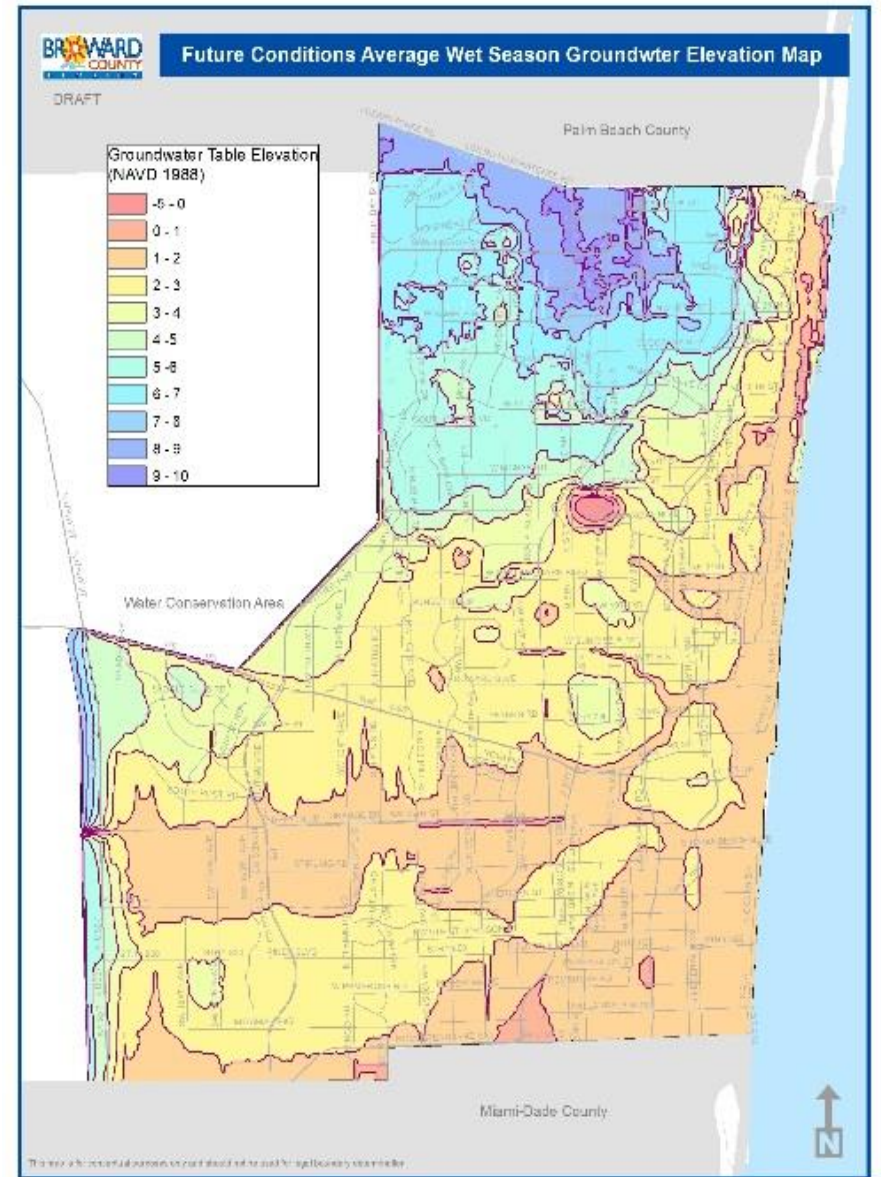


**Home along the street with
vehicle wake into front yard**

Future Conditions Map Series



***This is not
surface flooding,
but water table
response**



**0-3% up-front cost increase;
\$6 avoided damage for \$1 spent**



Seawalls, Flood Barriers



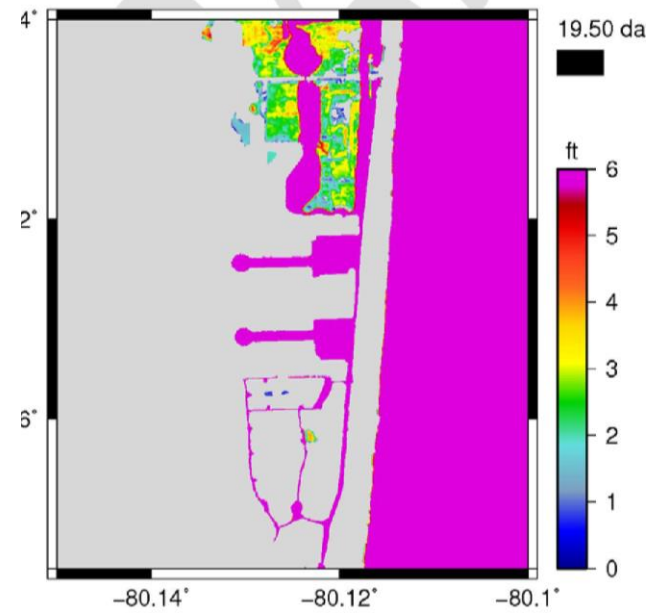
ACTIVE REDEVELOPMENT



- 4 feet NAVD by 2035
- 5 feet NAVD by 2050

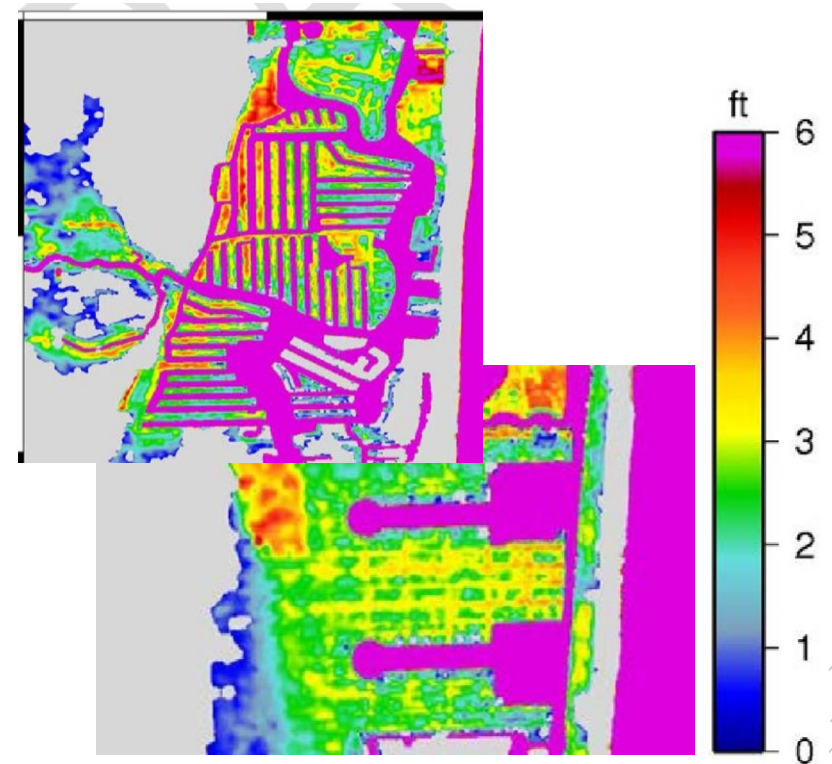
Regional Resilience Standards

*Seawalls raised to 4' NAVD



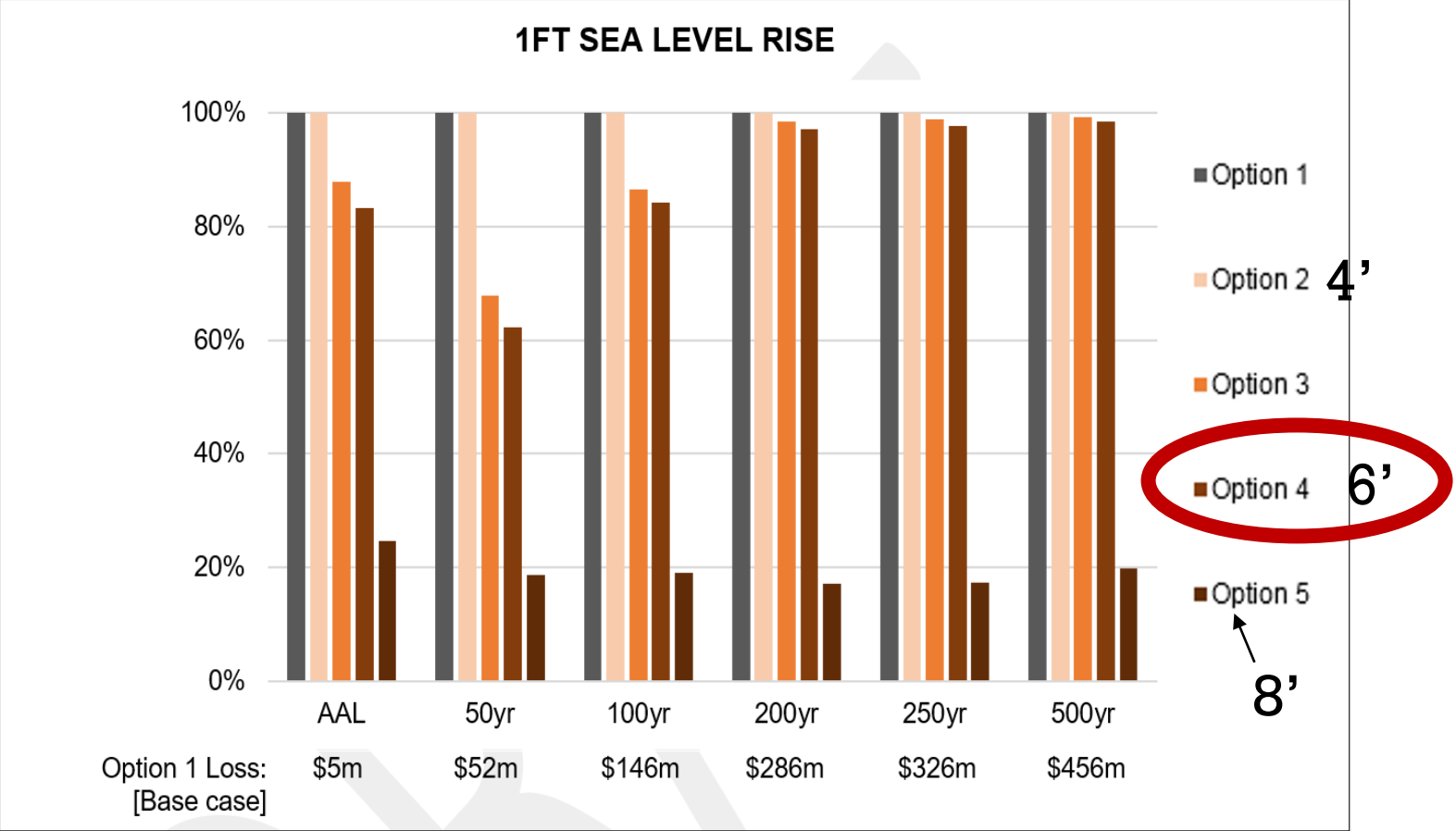
Maximum Water Depth, Hollywood Lakes; Storm 276; Alternative 2 Mesl

No Overtopping
in Hollywood Lakes
during King Tide 2070



Overtopping
in Las Olas and Hollywood
with storm surge

Catastrophic Loss



Seawalls >4' provide some economic loss protection even from catastrophic storms

FIGURE 11: AVERAGE ANNUAL LOSS AND RETURN PERIOD LOSSES UNDER VARIOUS SEAWALL OPTIONS, AS PERCENTAGE OF CORRESPONDING OPTION 1 (BASE CASE) LOSS – 1FT SLR SCENARIO

Information was provided by the County's Consultant, Risk Management Solutions, Inc. (RMS). In no event shall RMS (or its affiliated companies) be liable or direct, indirect, special, incidental or consequential damages with respect to any decisions or advice made or given as a result of the contents of the Information or use thereof. The full report (once complete) with the complete disclaimer statement, will be available on the County's webpage located at <http://www.Broward.org/NaturalResources/Pages/Default.aspx>.



*Building elevations
need to consider
future conditions*

FLOOD RISK REDUCTION AND INSURANCE SAVINGS

100-Year
Community
Flood Map

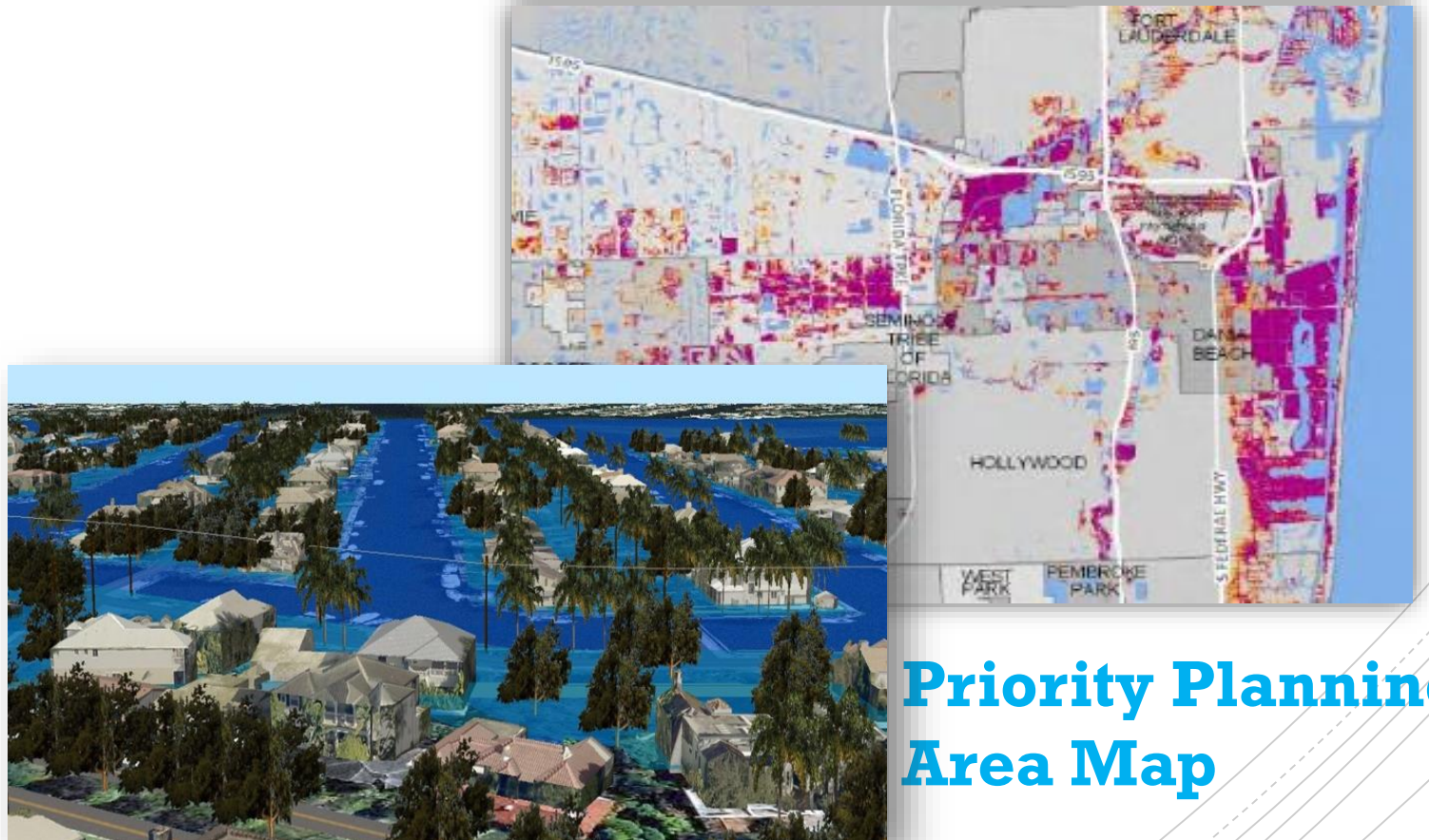


40% of loss can be averted; insurance for remainder

Land Use Plan Amendment Process

Losing 10% of GDP to climate;
opportunity is in redevelopment

- Priority Planning Area Map- 2' sea level rise
- Density change triggers review
- If vulnerable, must meet resilience criteria
- County, city, developer coordination



**Priority Planning
Area Map**

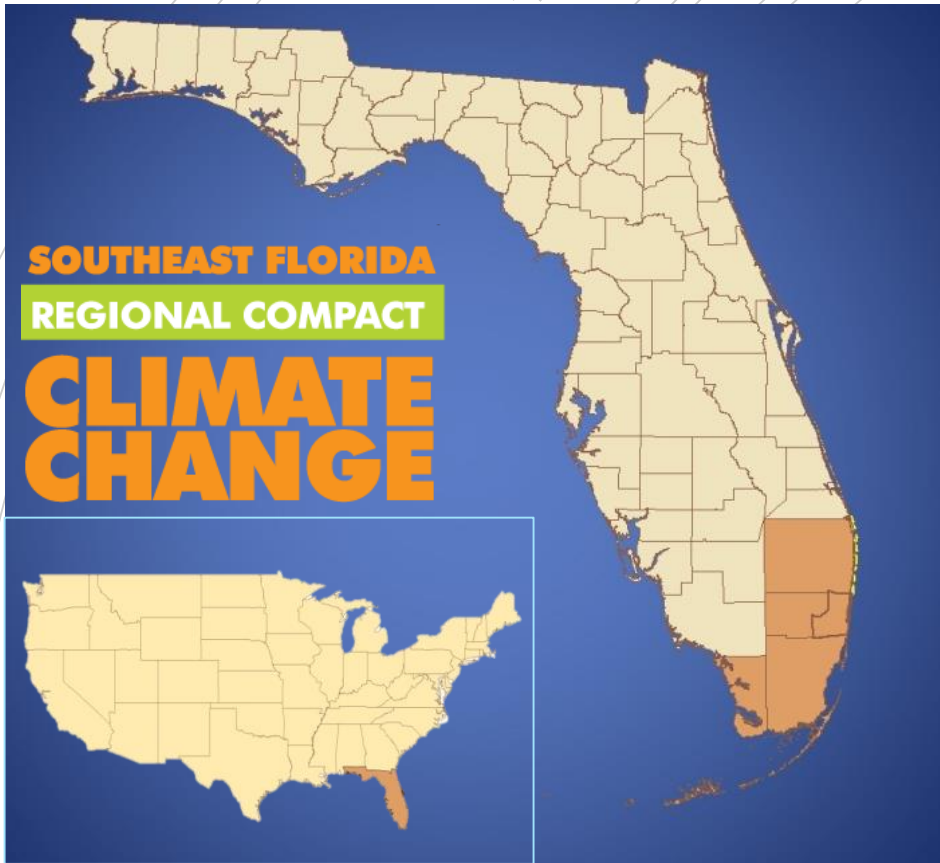


SOUTHEAST FLORIDA

REGIONAL COMPACT

**CLIMATE
CHANGE**

RCAP2.org



4 Counties, 109 Cities

- **Policy Collaboration**
- **Regional Planning Baselines**
 - **Unified Sea Level Rise Projection**
 - **Inundation maps**
 - **GHG Emissions Baseline**
- **Regional Climate Action Plan**
- **Leadership Summits**

Regional Climate Action Plan 2.0

SEVENTH FLORIDA REGIONAL COMPACT CLIMATE CHANGE

RCAP RESOURCES NEWS THE SUMMIT ABOUT CONTACT US

RECOMMENDATIONS MUNICIPALITIES CASE STUDIES GET STARTED

Welcome to RCAP 2.0

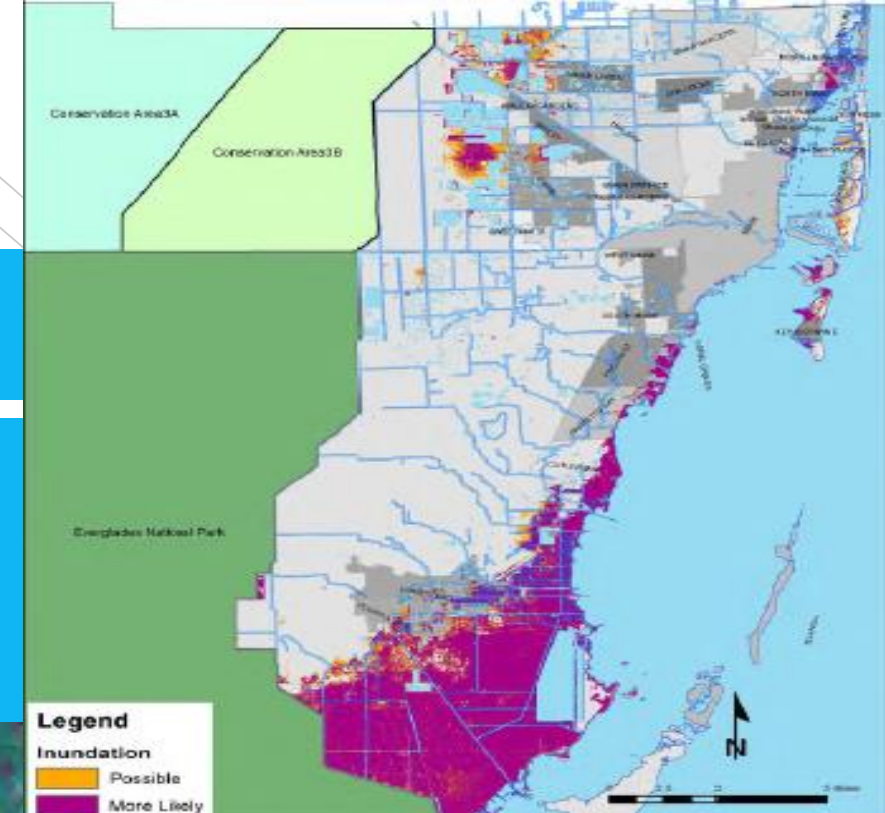
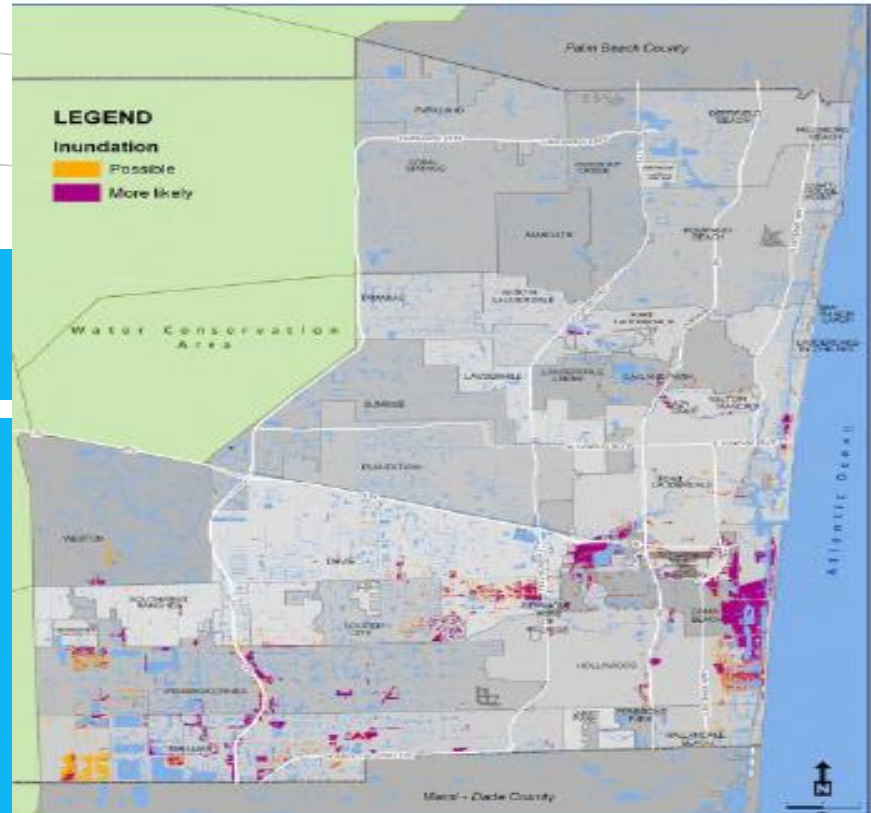
[BUILD YOUR OWN PLAN](#) [GET STARTED](#)

Regional Climate Action Plan

The Regional Climate Action Plan (RCAP) is the Compact's guiding tool for coordinated climate action in Southeast Florida to reduce greenhouse gas emissions and build climate resilience. The RCAP provides a set of recommendations, guidelines for implementation, and shared best practices for local entities to act in-line with the regional agenda.

[LEARN MORE](#)

RCAP2.org



2 feet by 2060



Roadway Elevation & Condition

Adjacent Property Elevation

Driveway Access

Space for Drainage Improvements

ROW Requirements

Electrical And Water/Sewer Utilities

Elevation of Water Table

Water Quality Requirements For Permitting

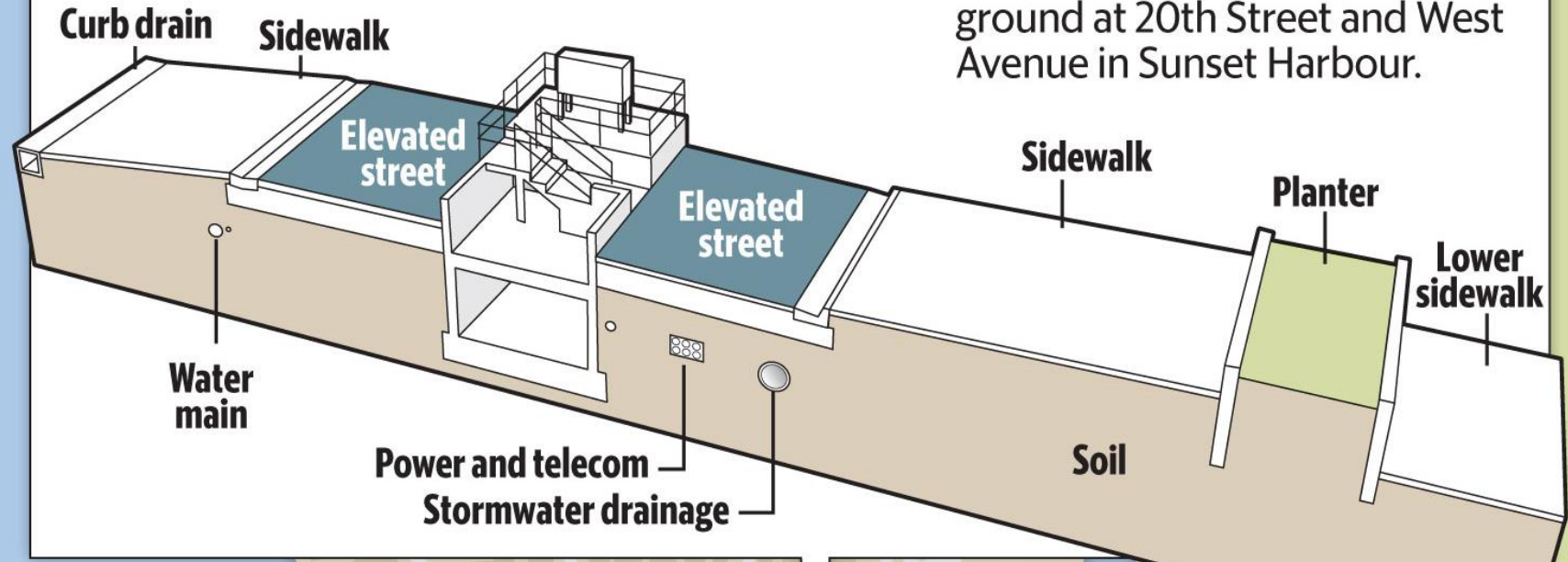
Stormwater System Maintenance Costs Including Staff

MIAMI BEACH RISING ABOVE



20th Street at pump station 3

The control panel for a pump station now rises out of the ground at 20th Street and West Avenue in Sunset Harbour.



Source: City of Miami Source: City of Miami Beach

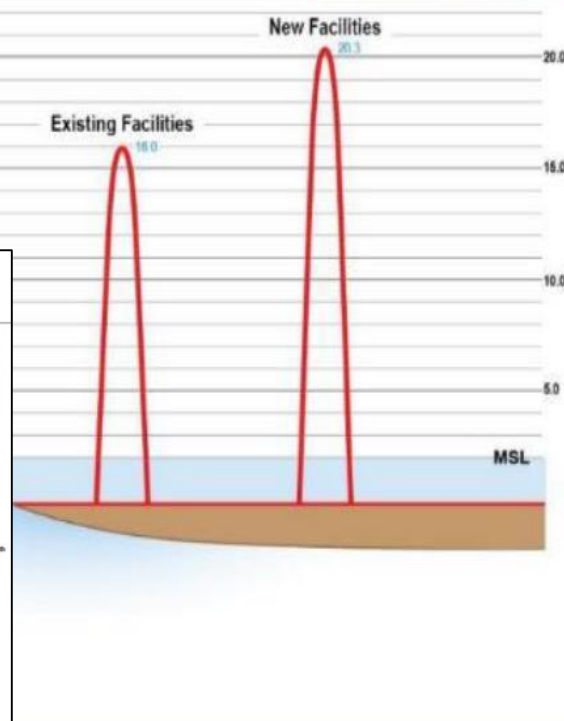
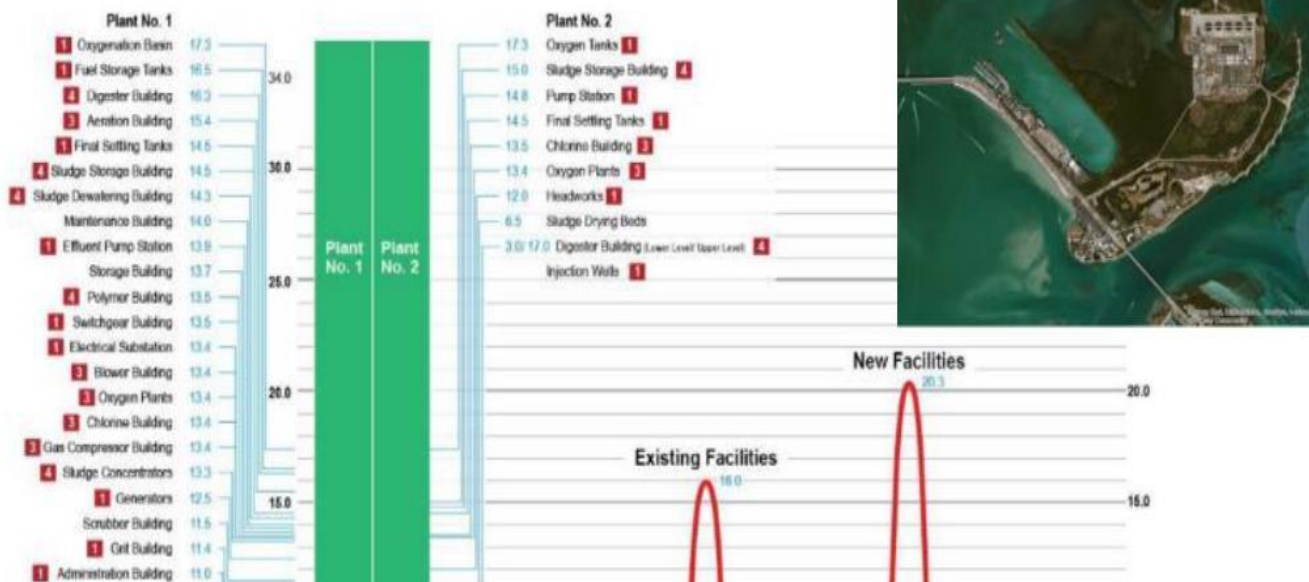
MARCO RUIZ mruiz@miamiherald.com

Miami Dade County

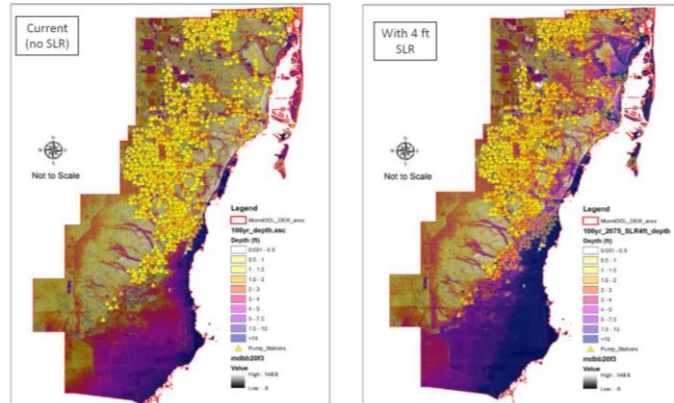


Asset Resilience Hardening Design Guidelines

- Facility flood control costs developed for critical facilities above design flood elevation
- Example for Central District WWTP
 - Existing Facility @16 NGVD
 - New Facility a@ 20.3 NGVD
- Includes
 - Free Board of 2 feet (ASCE)
 - Safety Factor of 1 foot (based on mean high water)
 - Sea Level Rise of 4 feet (USACE High in 2075)



Inland Flooding with Flood Modeler Pro: 100-year Storm Depth from Rainfall, Surge, with/without Sea Level Rise



Palm Beach County

- Shoreline Protection and Living Shorelines
- Microregional Collaboration- Southeast Palm Beach County
- Chamber Engaged on Economic Resilience



©2017 Forest Johnson

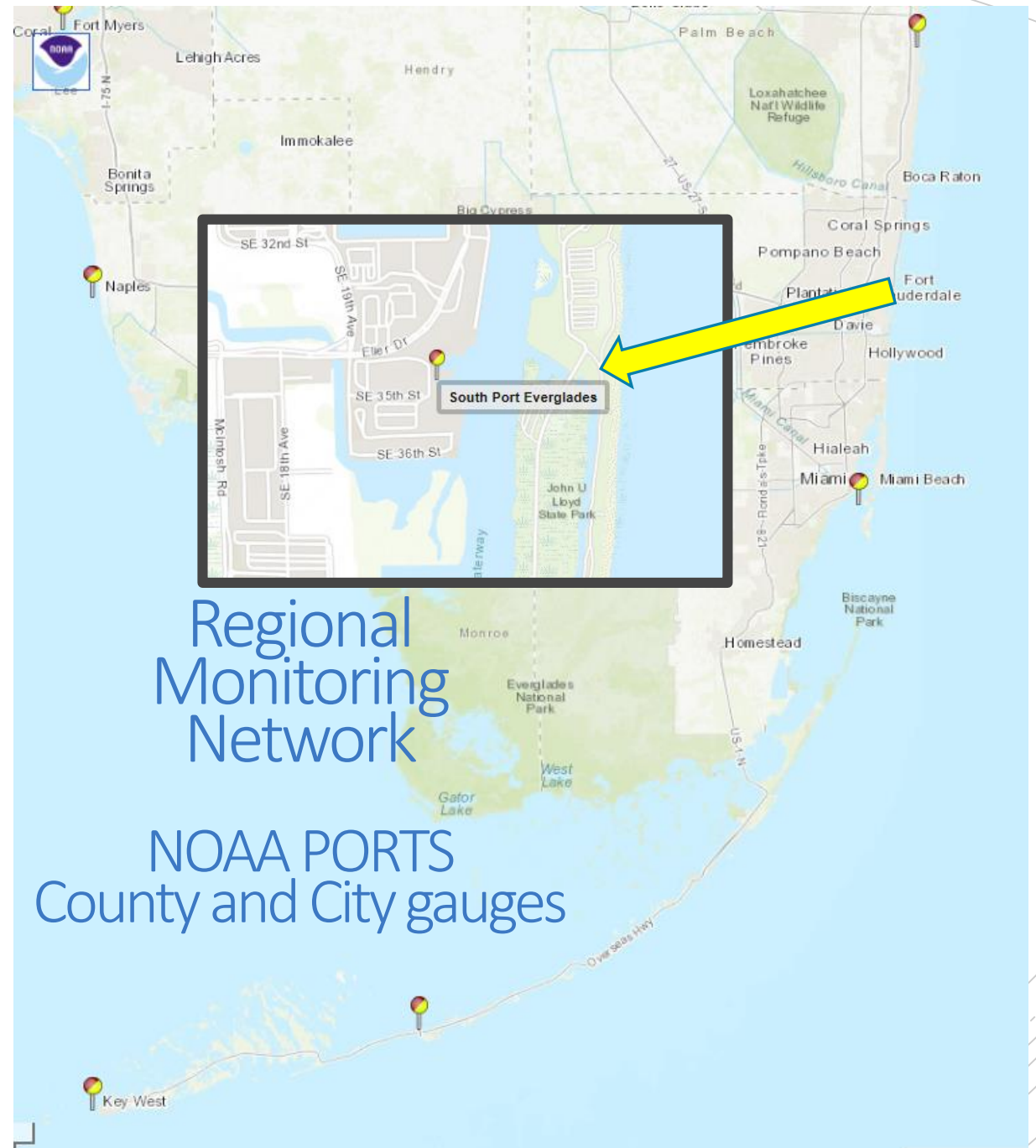
Visitflorida.com





Moving forward

Filling Data Gaps



Regional Energy Resilience

- **Utility and Property Scale Solar**
- **Emergency Backup**
- **Electric Vehicle Charging Networks**

- **Emissions Reduction**
- **~8 tons/ person annually (SE FL)**
 - **Under 2 MOU (→ 1.5 tons per person)**
- **Facing more than 2 feet of sea level rise (IPCC, 2018)**
 - **Need 2x \$\$ for energy efficiency by 2040**



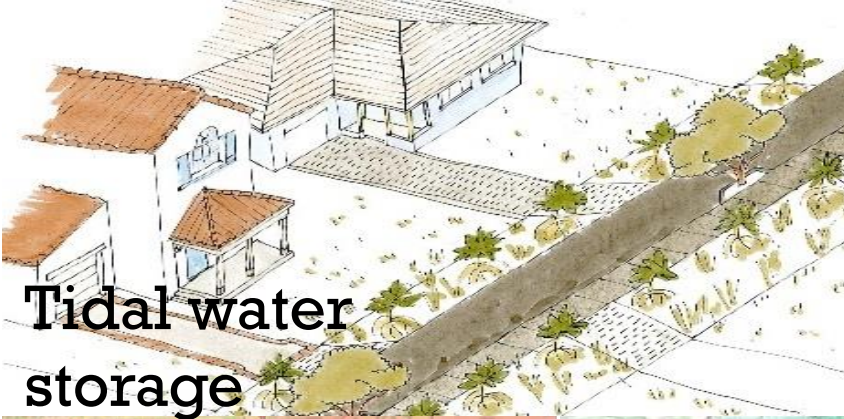
Regional Economic Resilience

- **Consistent informative, proactive messaging**
 - **Aligned advocacy for investment**
 - **Broaden participation**
 - **Impact Studies**
-
- **Quantify benefits of adaptation**
 - **Reduce climate risk across sectors**
 - **Reduce shocks to insurance premiums**
 - **Sustain financial and real estate markets**

Flood Control

- **USACE South Atlantic Division Resiliency Study**
- **SFWMD- Deltares Study of C-7 Basin, Miami**
- **Need Central and Southern Florida Flood Control Update**
- **Need appropriations**

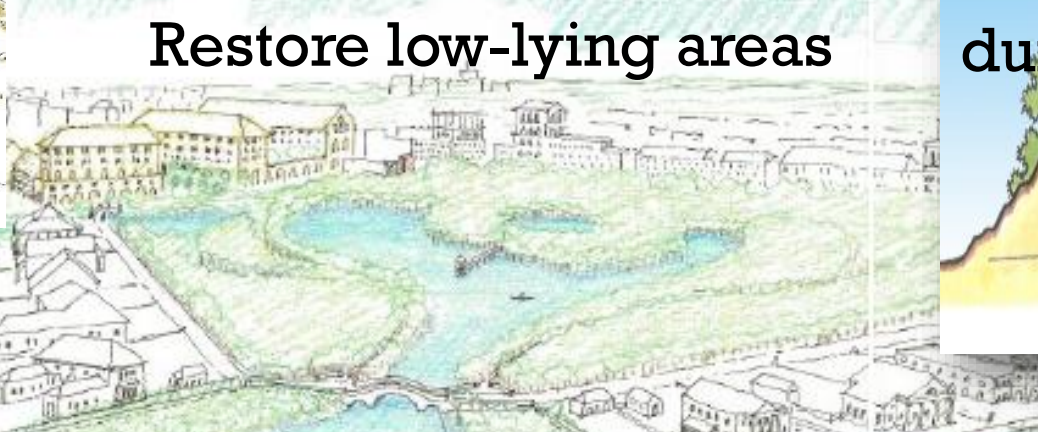
Resilient Redevelopment



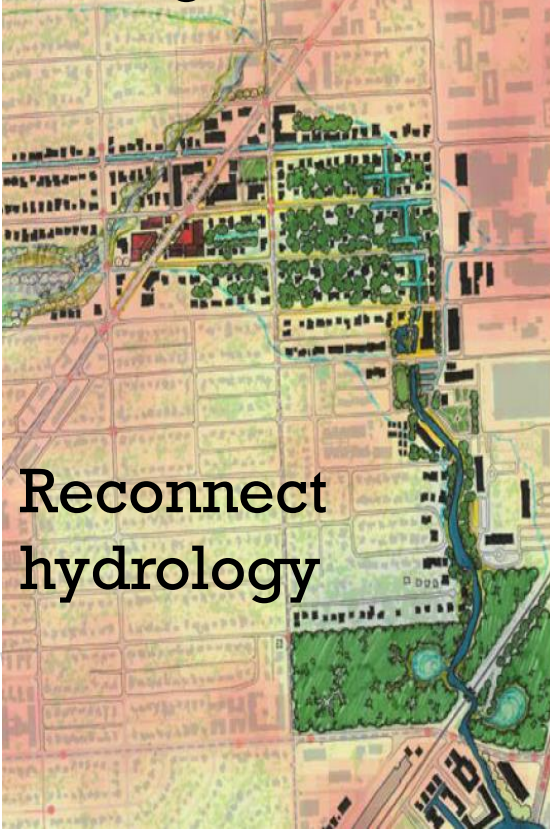
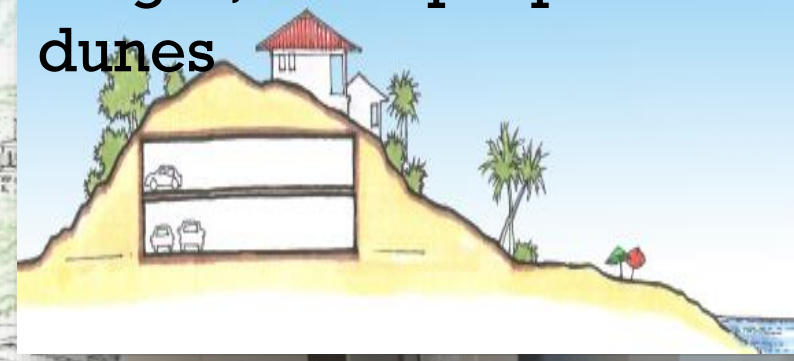
Interconnected water storage



Restore low-lying areas



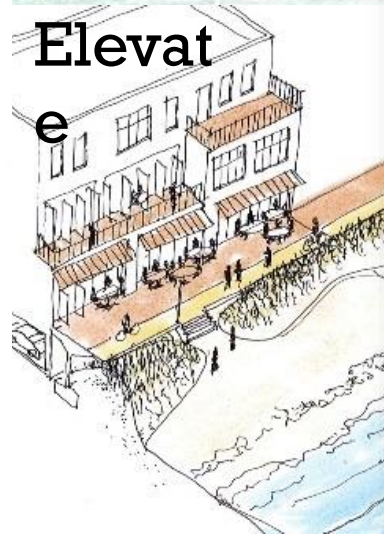
Larger, multi-purpose dunes



New living shorelines



Elevated



Broward.org/Climate



theinvadingsea.com

**SOUTHEAST FLORIDA
REGIONAL COMPACT**

**CLIMATE
CHANGE**



RCAP2.org



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Sea Level Rise and Coastal Resiliency



Dr. Paul Tschirky



October 23, 2019

- Sea Level Rise in Context of other Coastal and Climate Change Risks
- Coastal Resiliency for Sea Level Rise
 - Definition
 - Approaches
- Some Examples



D+



2017

- 16 weather and climate events
- 362 deaths
- \$306 billion in damages
- Hurricane Irma >\$6 billion property damage in Florida

“Two of the greatest challenges facing the nation are recognizing the magnitude of risk posed by flooding and motivating the public and decision-makers to make the investments and difficult policy decisions required to reduce flood risk.”



Flood Risk Management Priorities

Risk - Growing Coastal Populations

Coastline Population by State: 1960 to 2008

Area	Year						Change, 1960 to 2008	
	1960	1970	1980	1990	2000	2008	Number	Percent
United States	179,323,175	203,211,926	226,545,805	248,709,873	281,421,906	304,059,724	124,736,549	69.6
Coastline counties . . .	47,448,231	56,715,415	63,587,555	73,048,655	82,124,392	87,423,833	39,975,602	84.3
Atlantic	26,665,037	30,449,628	31,943,197	35,231,154	39,215,349	41,584,799	14,919,762	56.0
Gulf of Mexico	5,562,984	6,936,997	9,149,249	10,723,973	12,557,407	13,920,664	8,357,680	150.2
Pacific	15,220,210	19,328,790	22,495,109	27,093,528	30,351,636	31,918,370	16,698,160	109.7
Maine	439,851	464,883	548,040	623,198	682,814	713,357	273,506	62.2
New Hampshire	99,029	138,951	190,345	245,845	277,359	297,350	198,321	200.3
Massachusetts	2,597,027	2,862,290	2,932,393	3,095,930	3,317,771	3,414,730	817,703	31.5
Rhode Island	859,488	946,725	947,154	1,003,464	1,048,319	1,050,788	191,300	22.3
Connecticut	1,588,514	1,882,926	1,935,906	2,030,017	2,120,734	2,170,444	581,930	36.6
New York	10,557,830	11,341,996	10,544,051	10,806,642	11,685,650	12,181,502	1,623,672	15.4
New Jersey	3,290,028	3,750,347	3,831,213	4,005,994	4,367,129	4,479,494	1,189,466	36.2
Delaware	446,292	548,104	594,338	666,168	783,600	873,092	426,800	95.6
Maryland	2,026,229	2,294,049	2,399,856	2,582,753	2,761,143	2,911,538	885,309	43.7
Virginia	1,325,584	1,683,387	1,967,642	2,487,459	2,827,481	3,050,717	1,725,133	130.1
North Carolina	441,605	477,404	563,609	679,075	792,902	909,106	467,501	105.9
South Carolina	403,667	441,785	532,498	621,683	742,274	877,921	474,254	117.5
Georgia	267,305	281,108	326,382	386,415	439,154	475,764	208,459	78.0
Florida	3,835,751	5,388,107	7,664,458	10,066,203	12,285,697	13,871,629	10,035,878	261.6
Alabama	363,389	376,690	443,536	476,923	540,258	580,748	217,359	59.8
Mississippi	189,050	239,944	300,217	312,368	363,988	349,294	160,244	84.8
Louisiana	1,192,074	1,385,438	1,575,797	1,550,498	1,610,435	1,426,150	234,076	19.6
Texas	2,305,308	2,882,491	3,795,011	4,314,492	5,126,048	5,871,839	3,566,531	154.7
California	12,254,192	15,645,052	18,008,000	21,748,651	24,135,820	25,161,295	12,907,103	105.3
Oregon	371,256	426,780	538,930	550,921	611,645	643,872	272,616	73.4
Washington	1,785,633	2,245,116	2,649,169	3,227,795	3,863,160	4,250,984	2,465,351	138.1
Alaska	176,357	243,281	334,319	457,932	529,474	574,021	397,664	225.5
Hawaii	632,772	768,561	964,691	1,108,229	1,211,537	1,288,198	655,426	103.6

Source: U.S. Census Bureau, Decennial Census of Population and Housing: 1960 to 2000; Population Estimates Program: 2008.



Global Climate Change



Hurricanes and Tropical Storms



Storm Surge and Waves



Sea-Level Rise



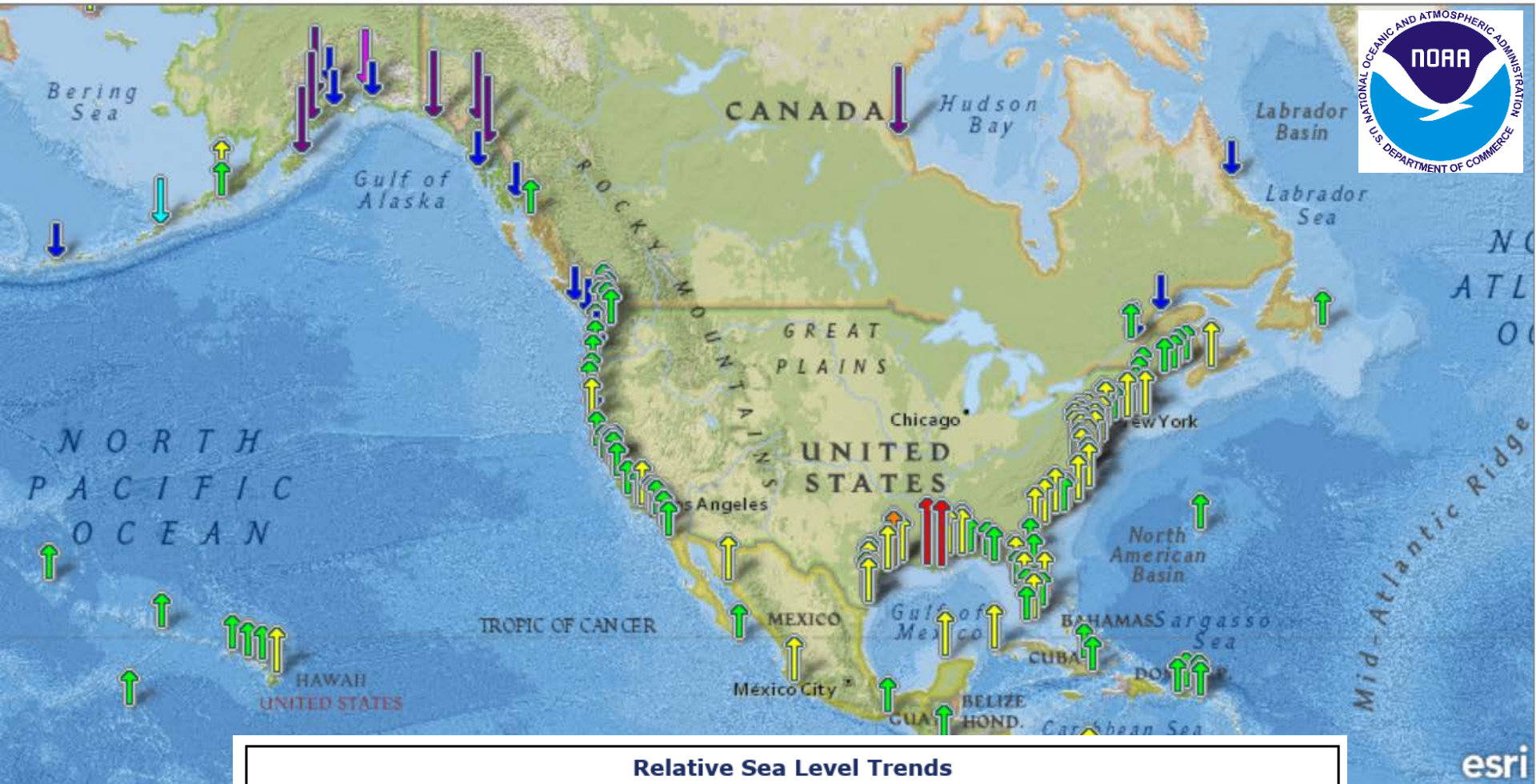
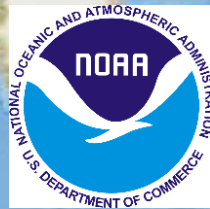
Rainfall (changes in intensity and distribution)



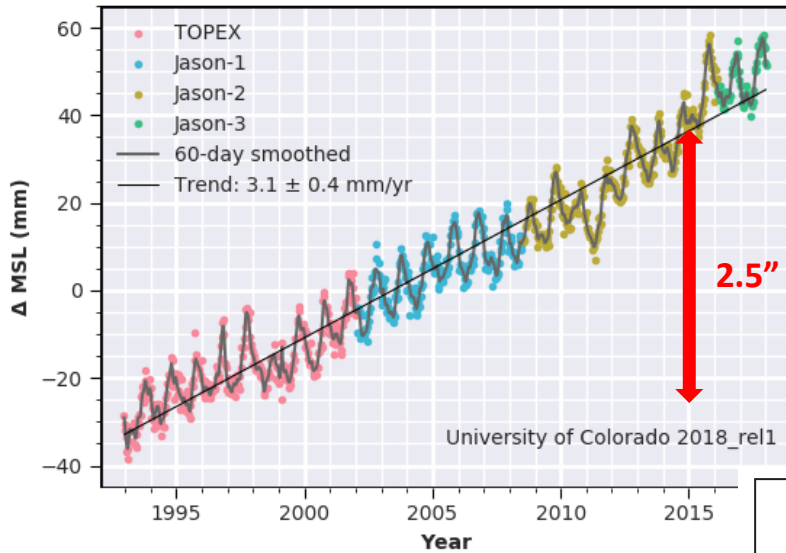
Growth in coastal population

**UNDERSTAND,
QUANTIFY, AND
ASSESS RISKS**

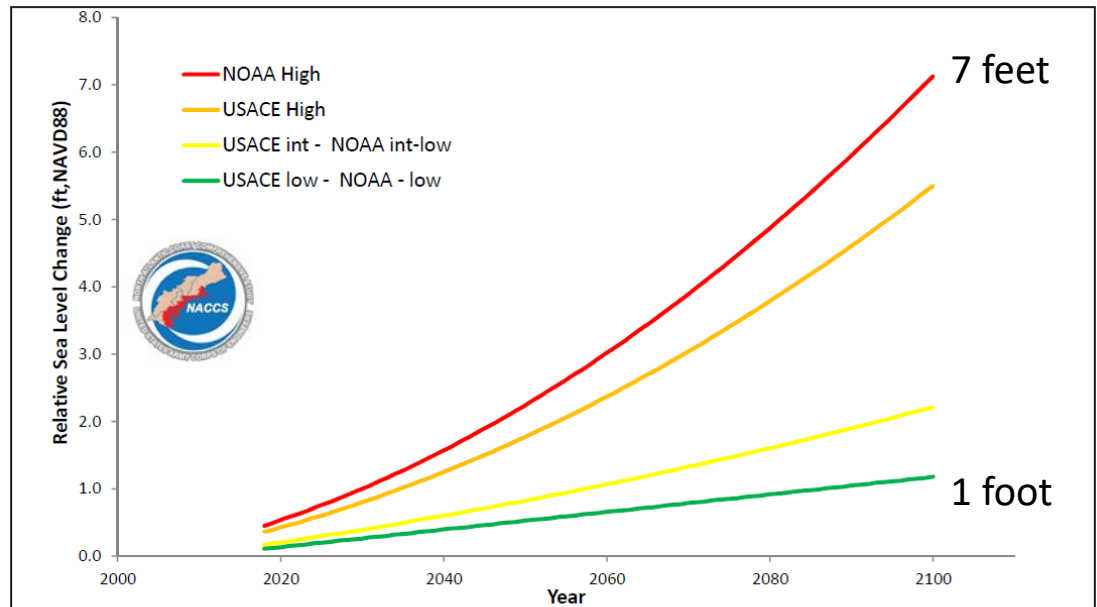
Rising Seas



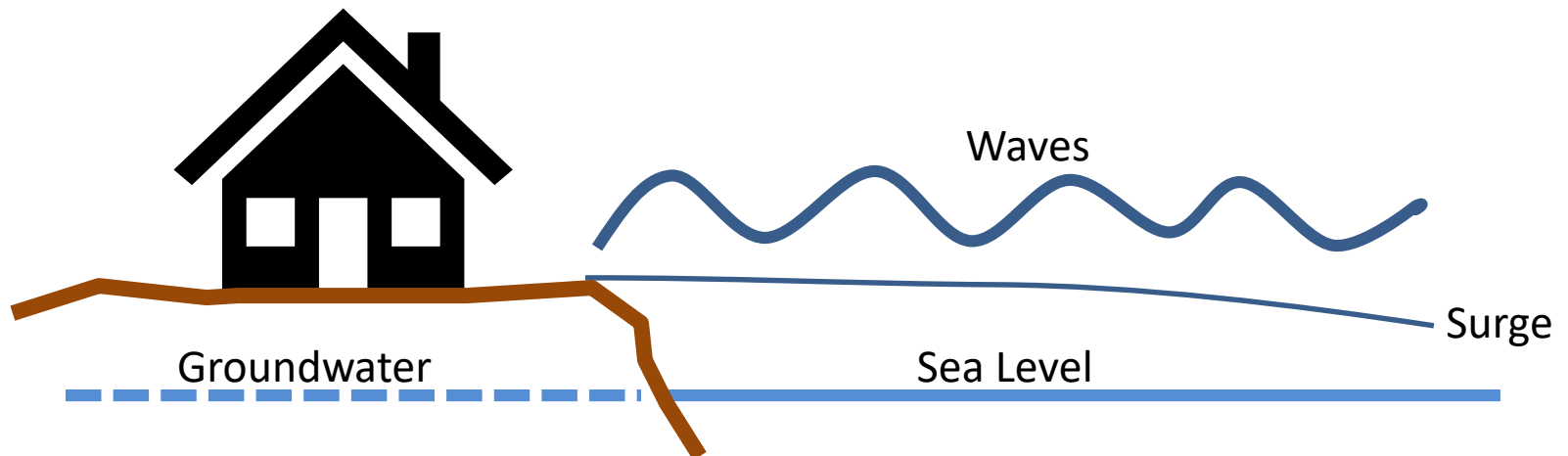
Estimates of Future Sea Levels



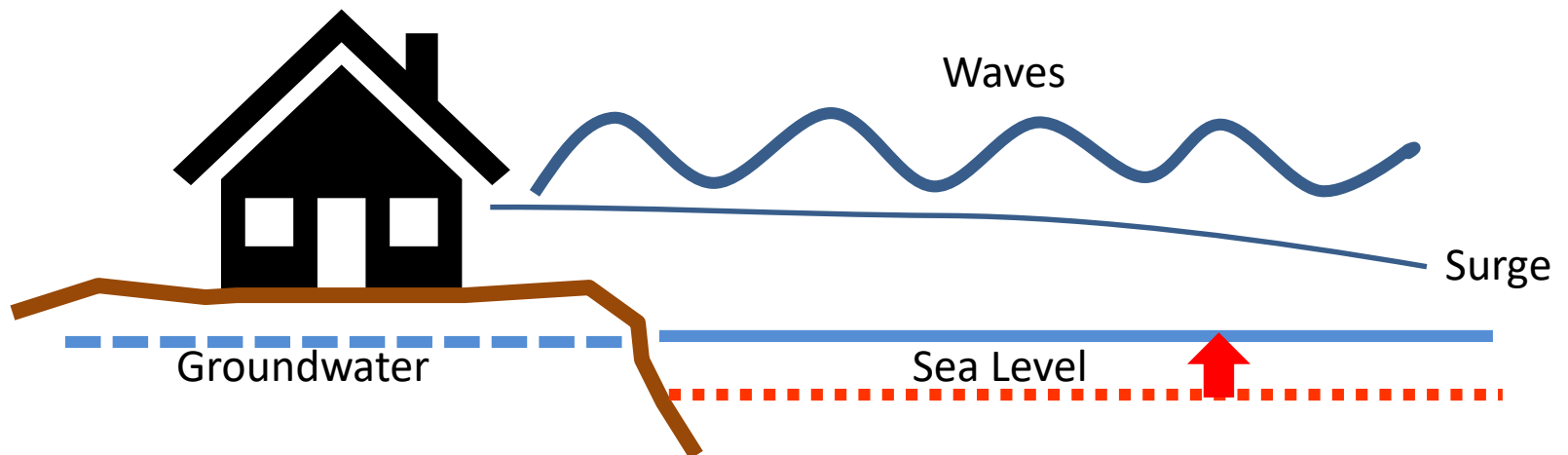
- Science of sea level rise is continuously evolving
- Many forecasts available
- Future projections are highly variable
- Based upon models, assumptions, vigorous debate



- Sea Level Rise is the base on which other coastal hazards will be magnified



- Sea Level Rise is the base on which other coastal hazards will be magnified

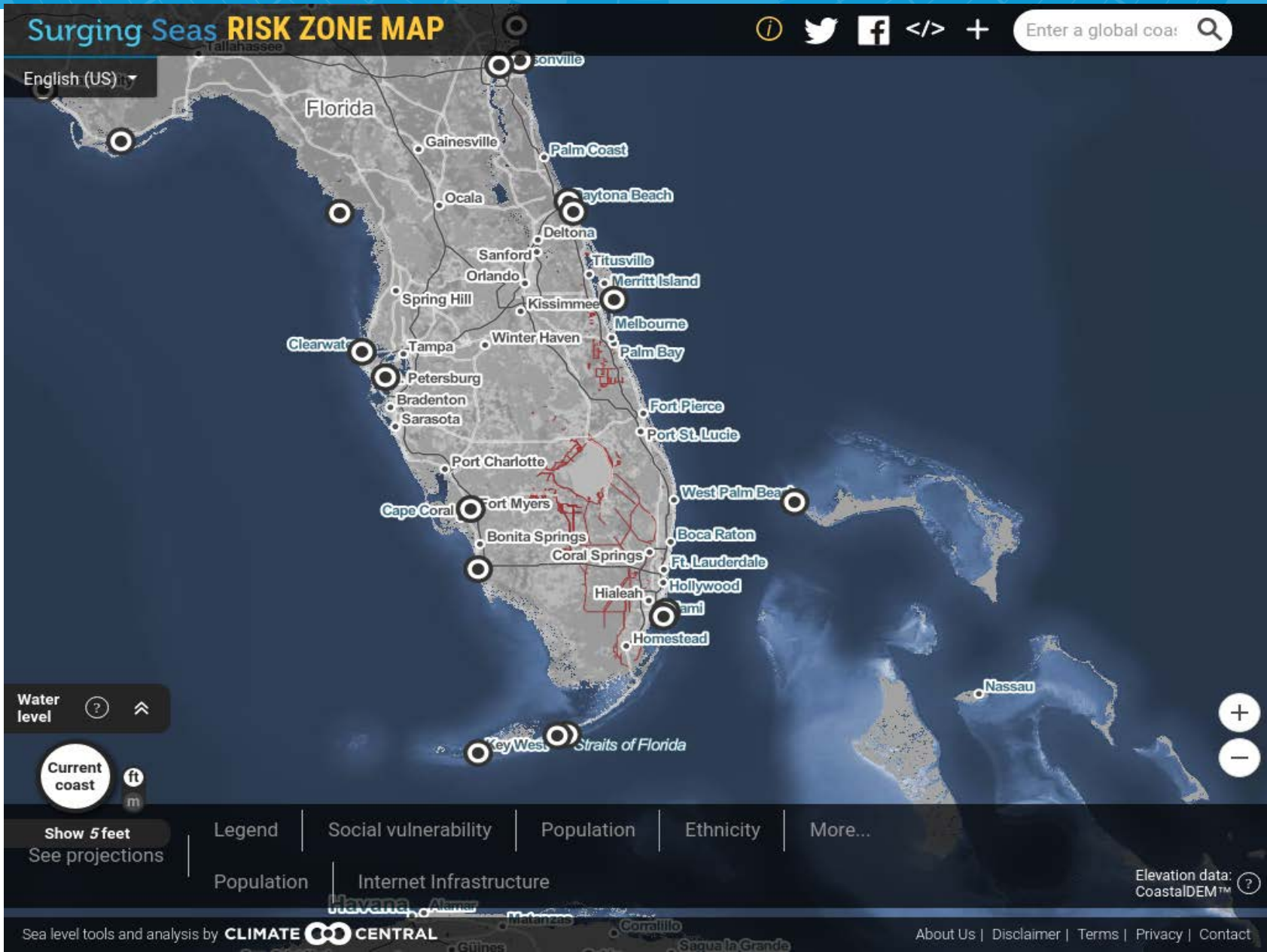


What are the effects of sea level rise?

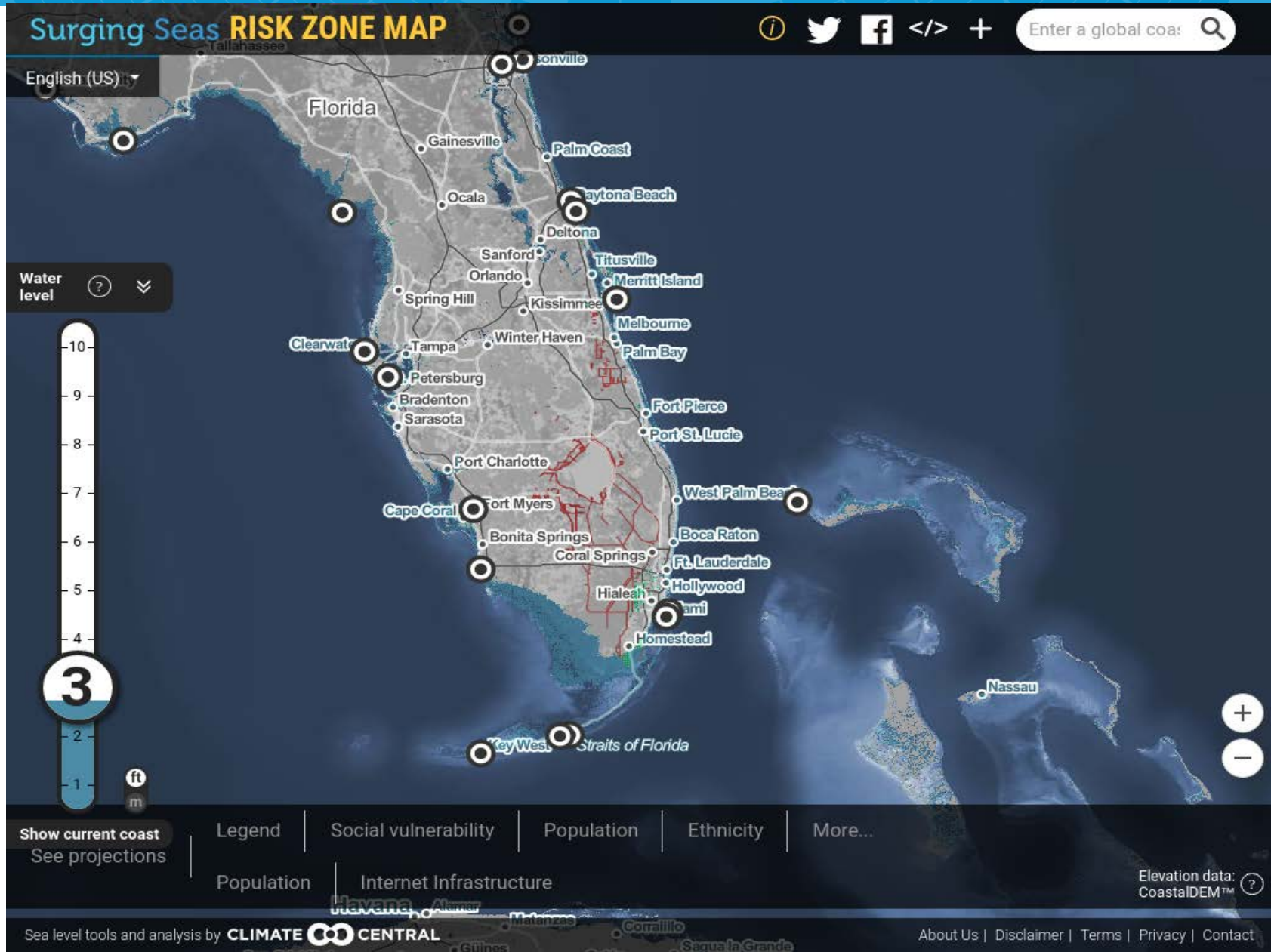
- Storm water/municipal drainage no longer works during high tide
- Increasing frequency of flood events
- Inundated roads (nuisance flooding)
- Salt-water intrusion
 - Rivers and aquifers becoming more saline
 - Re-location of municipal drinking wells
- Coastal flooding and erosion
- Plant, tree, and habitat mortality (mangrove retreat, coral reef degradation, etc.)
- Lowland fields no longer suitable for agriculture



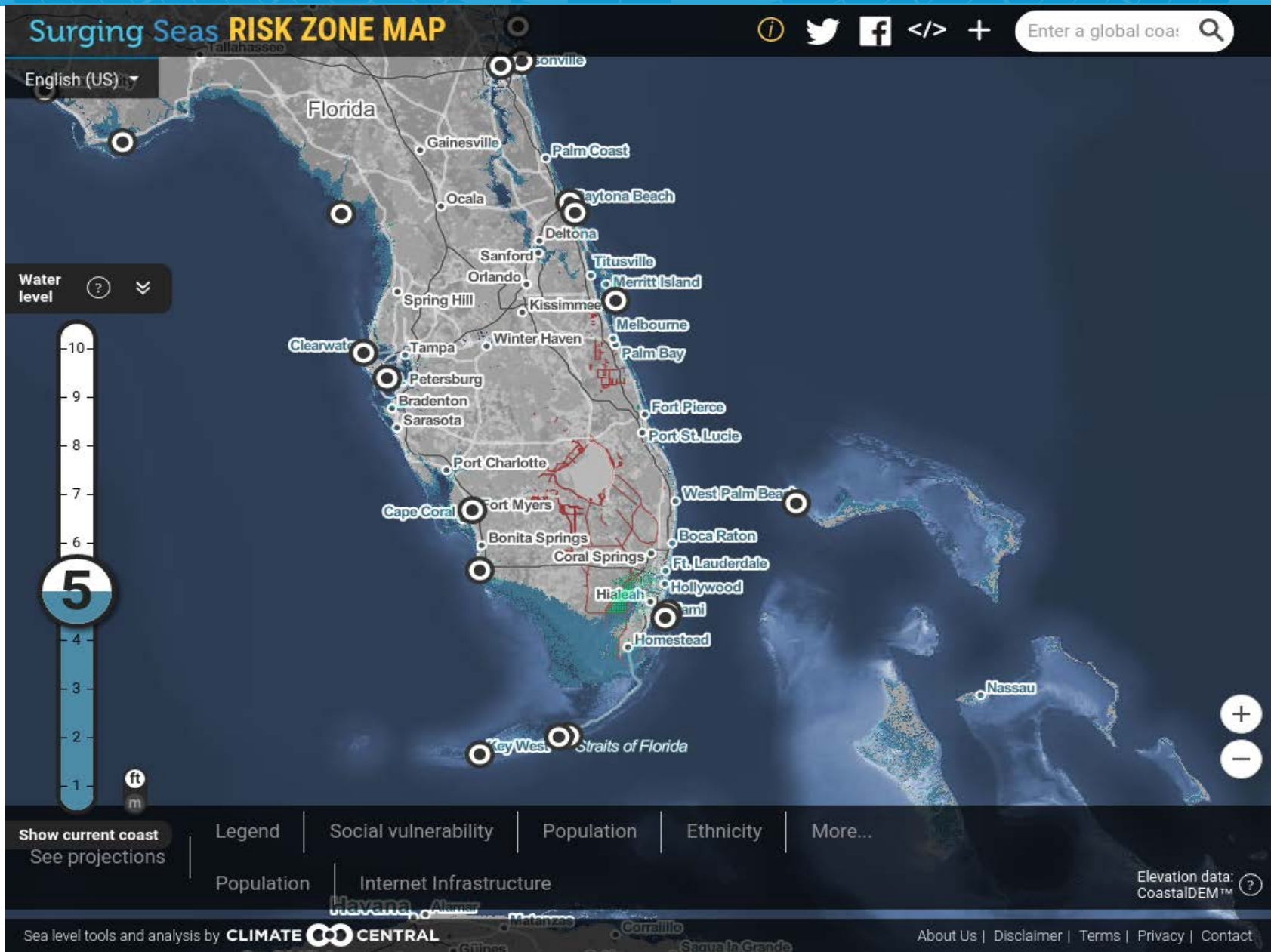
Sea Level Rise Estimates



Sea Level Rise Estimates



Sea Level Rise Estimates



Assessing Risk



Hazard

Probability

Vulnerability

Consequence

Criticality

Risk





- Define SLR Projection Curves using technical references
- Identify local tide gauging stations/data
- Adjust SLR projections to reflect local conditions

- Identify Climate factors that may contribute to flooding
- Identify nature, frequency, and magnitude of flood impacts
- Identify vulnerable elements

- Identify baseline mitigation
- Develop Operation, Maintenance, and Monitoring Plan
- Update and refine Flood projections and vulnerabilities

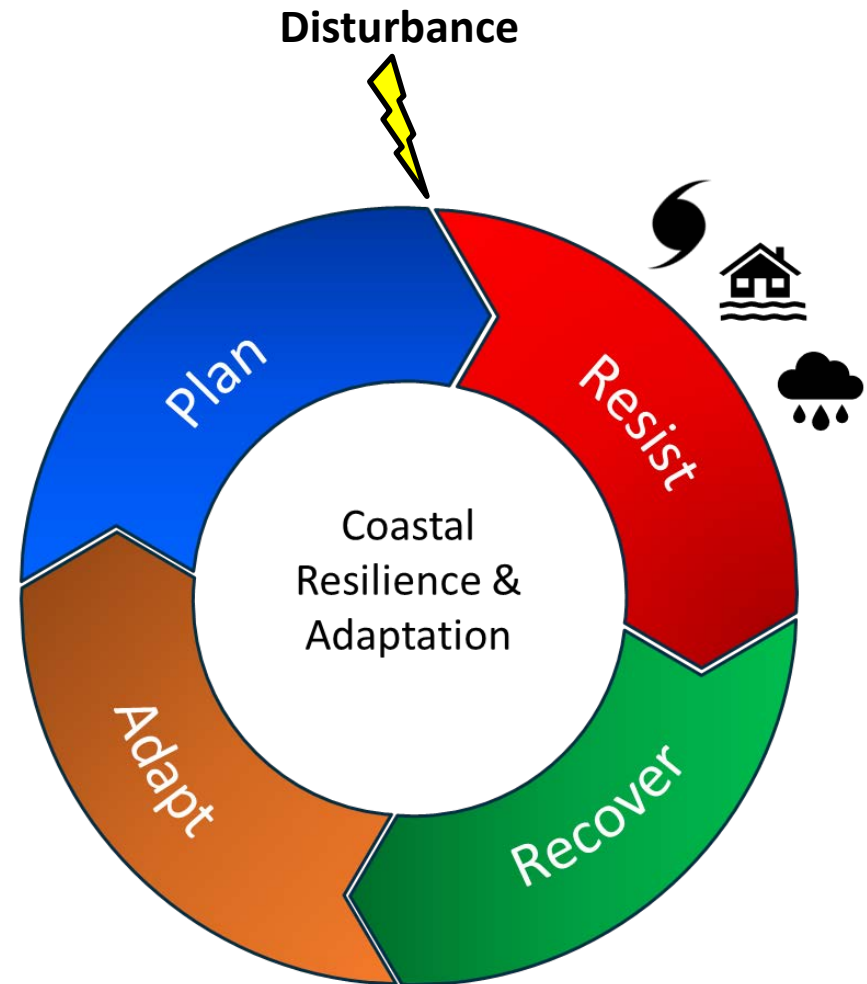
- **Rising sea level (foundation for all other flood components)**
- Exceptionally High Tides – “King tides” (typically occur 2x/year)
- Storm surge (occurs with every major storm)
- Major precipitation events (Hurricanes, Tropical Storms, 25/50/100-year storm events)
- Rising Groundwater
- Other factors

Resiliency

the ability of a natural or built system to recover from an extreme load or event

Adaptation

adjustment in response to changes in the factors that impact the functionality of a natural or built system



TRADITIONAL ENGINEERING WORKS

- Usually designed to withstand events with a given probability of occurrence at the time of their construction
- Accept failure under more severe conditions

RESILIENCY

- Prepare for unknown (plan and evaluate projects for events outside likely scenario)
- Design for adaptability
- System response



Industrial
Facilities



Transportation



Water /
Wastewater



Public
Facilities



Utilities



Police and Fire



Schools



Hospitals



Government
Infrastructure



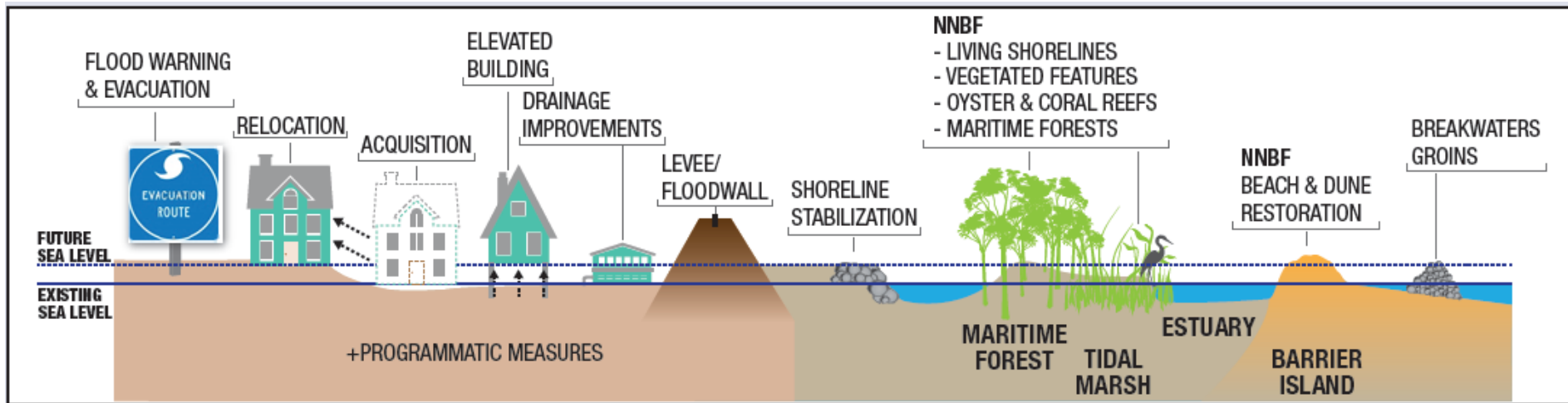
Beaches
Tourism

Florida's generally low lying topography increases coastal vulnerability

Public assets and infrastructure at risk from coastal flooding

Need for resilient and adaptive planning and design





~ FIGURE: North Atlantic Coast Comprehensive Study (USACE, 2015)

Inner Layer (Local)

- Smaller-scale solutions
- Protect critical infrastructure
- Integrating water management and urban planning

Middle Layer (Regional)

- “Transition” zone
- Floodwalls, marshes, levees (multifunctional), beaches

Outer Layer (Large Area)

- Larger, engineered solutions
- Storm surge barriers, sea gates, Offshore structures, pump and levee systems

Retreat

move infrastructure from vulnerable areas

Accommodate

modify designs to allow for periodic flooding

Protect

design defenses to reduce flooding

*Everything does not have
to be built now...
but you have to plan for it*



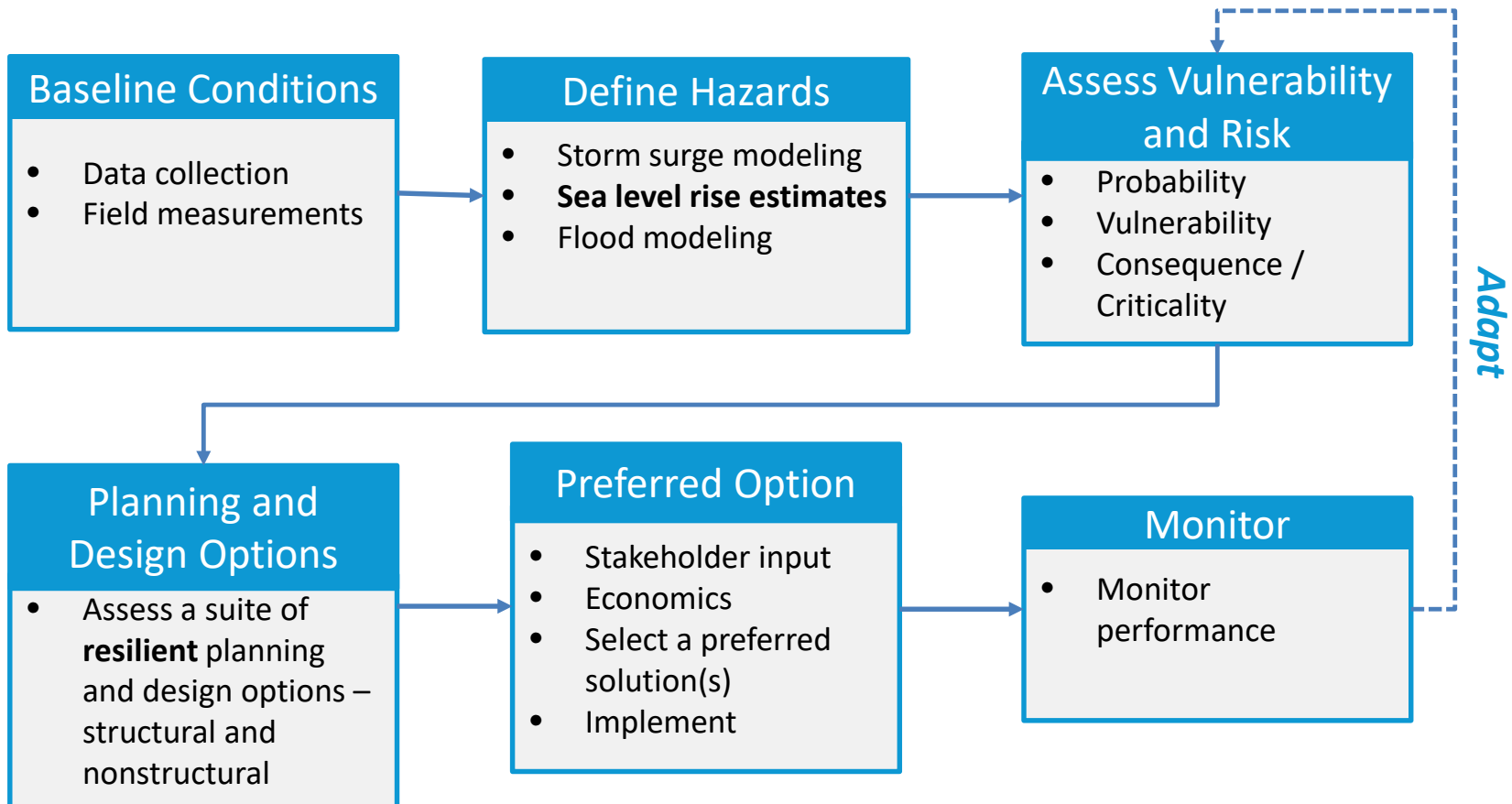
Photo: Viorel Florescu/NorthJersey.com

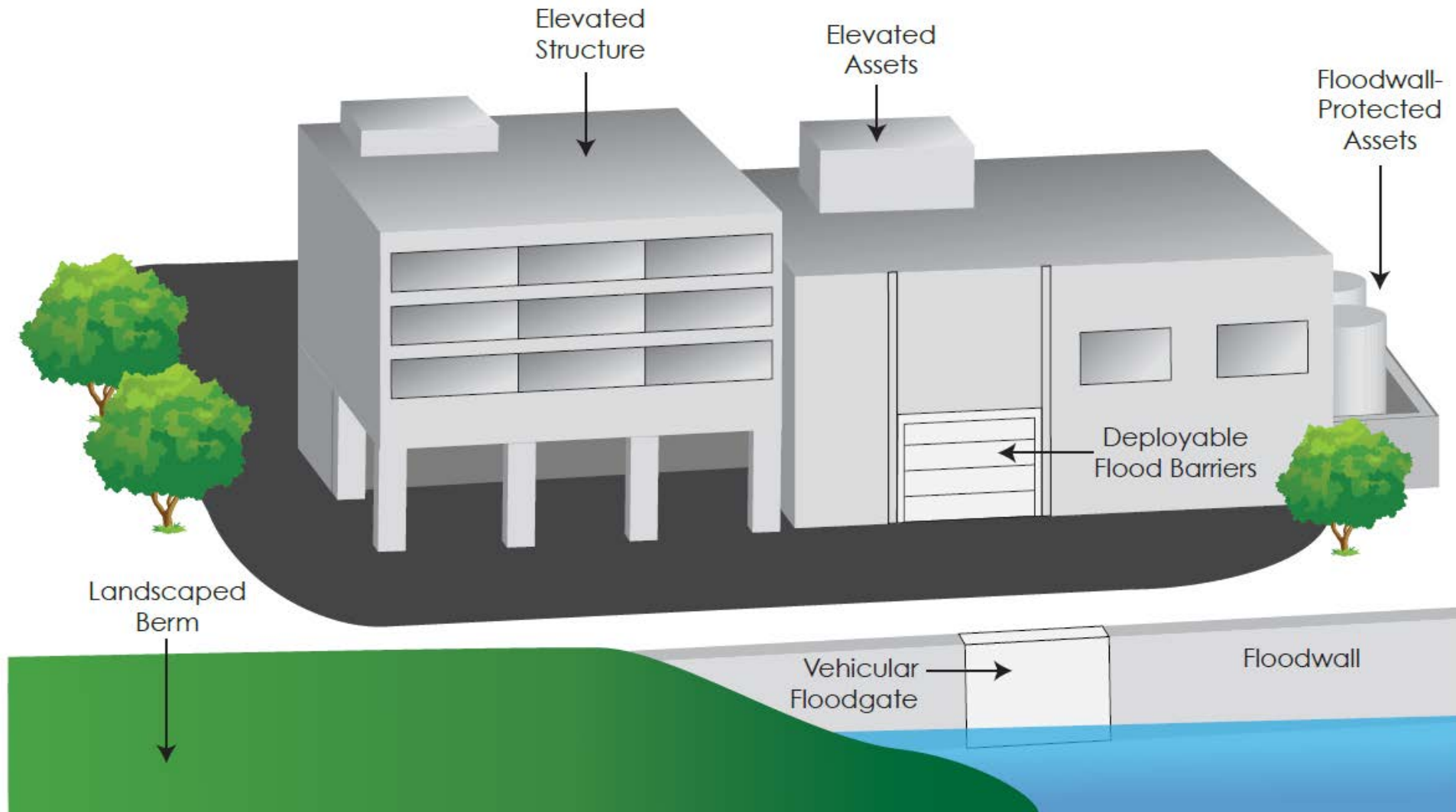


Desmond Brown, IPS

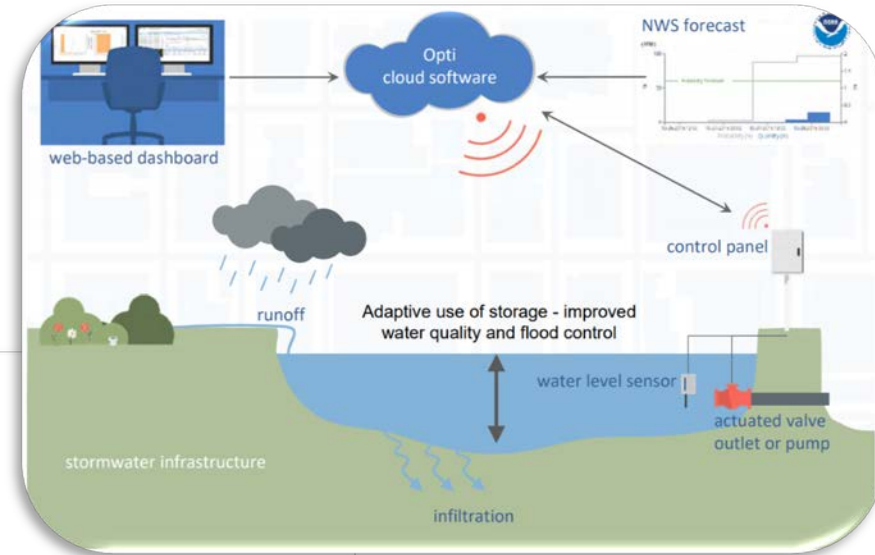
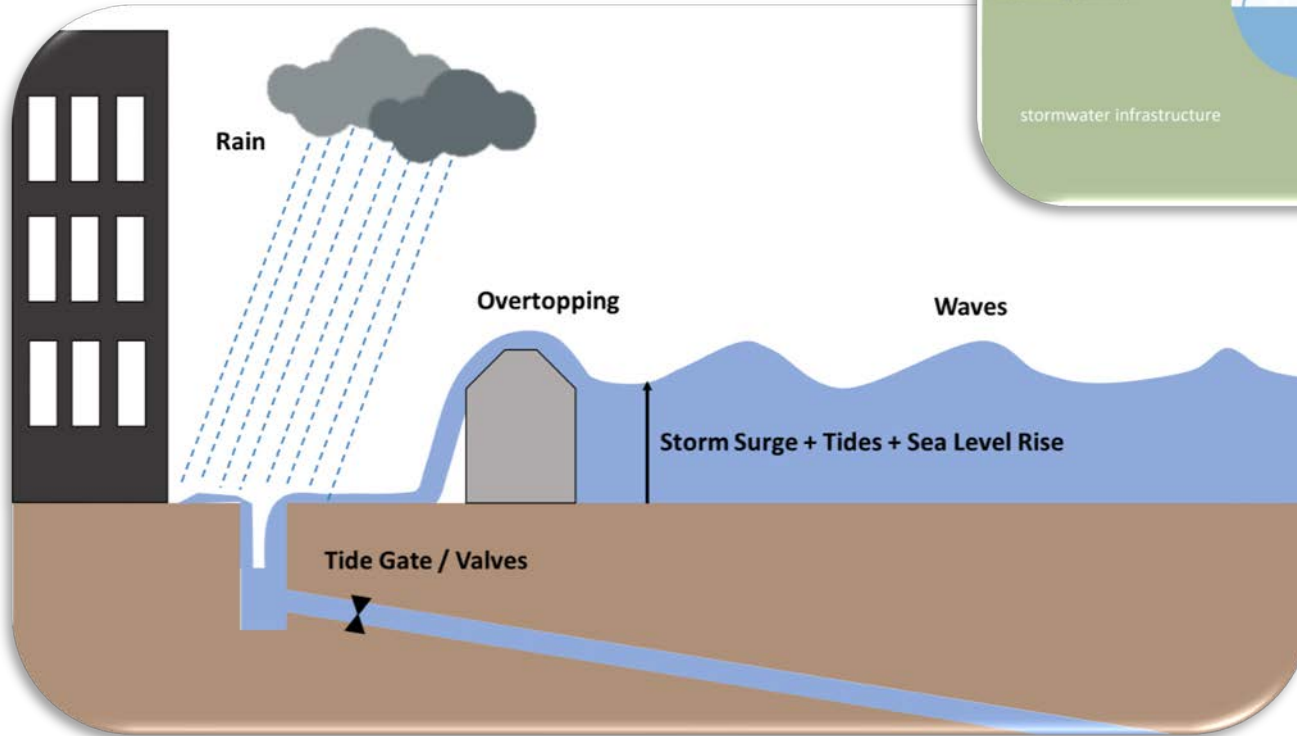
Example: Adaptive Design and Planning of New Hotel Construction

Accommodate	<ul style="list-style-type: none">• Elevate main floor• Below main floor is all low value assets• Electrical servicing, backup, and vital assets on upper levels• Consider future water elevation in design of gravity drainage (storm water and sewage)
Protect	<ul style="list-style-type: none">• Structural elements consider future surge and wave loading• Anticipate possible future flood protection structures and facilities by allowing space around main structure
Adapt	<ul style="list-style-type: none">• Monitor sea level and establish trigger elevation for adaptive action

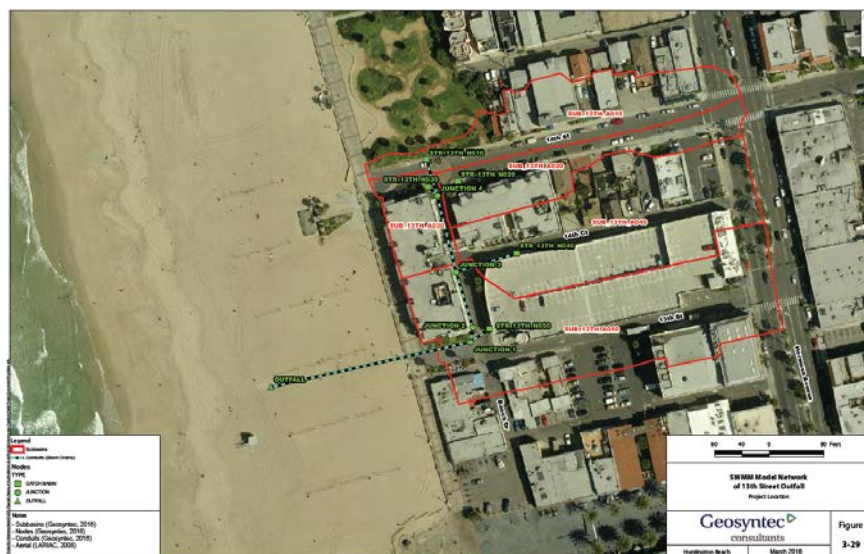




Planning and Designing System



Technology Innovation



Hermosa Beach, California

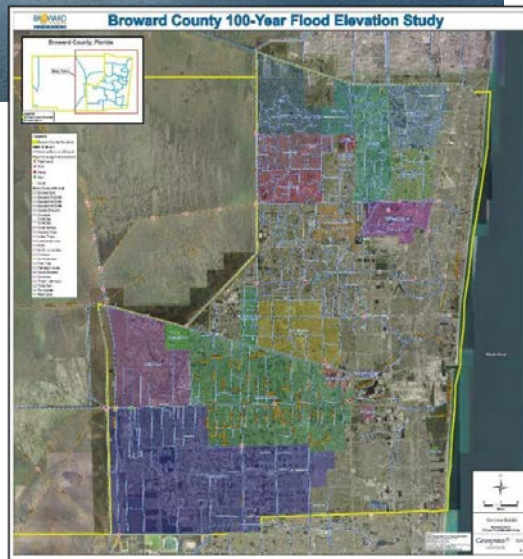
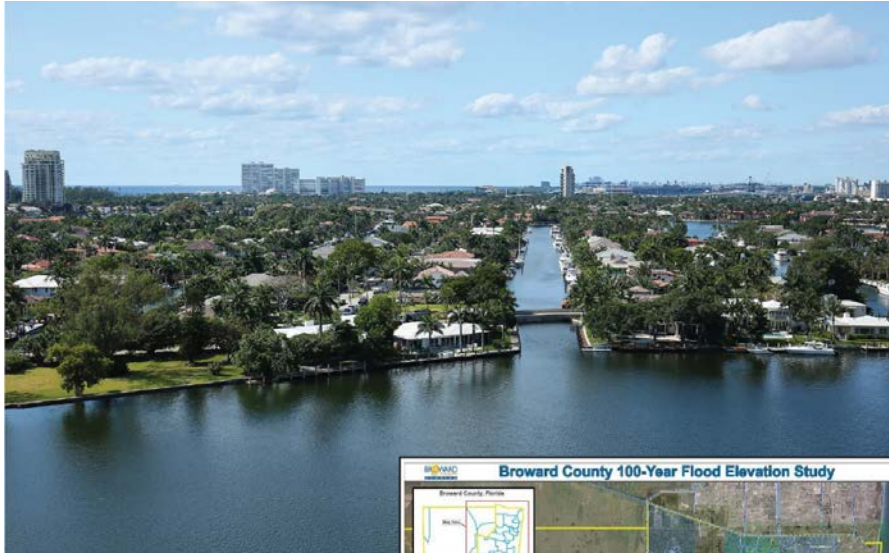
- Large, coastal community affected by sea level rise and salinity in coastal areas.
- Town needed to evaluate how coastal shallow groundwater elevation and salinity responds to projected increases in sea level rise in sandy, low-lying coastal soils and evaluated the vulnerability of existing sanitary sewer and storm drain infrastructure.
- Included:
 - Climate Change Vulnerability Assessment
 - Groundwater Monitoring
 - Stormwater Monitoring
 - Groundwater Elevation & Salinity Intrusion Forecasting

Martinez, California



- Golden Eagle oil refinery
- Refinery needed a closure plan for
 - 12 waste management units (WMUs)
 - **address sea level rise in the design**
 - ensure that wastes contained within the closed units are not released to human or ecological receptors as sea level and climate conditions change
- Study:
 - Site-Specific Sea Level Rise evaluation
 - Developed **SLR vulnerability assessment guidance**
 - Developed **adaptive management strategy** guidance
 - Coordinated aerial king tide and topographic surveys





Broward County, Florida

- Coastal county in southeast Florida, 2 million population
- Experiencing **recurrent flooding and impacts due to sea level rise**
- County needs to update flood maps to inform a comprehensive plan to
 - address sea level rise impacts
 - address impacts of sea level rise on groundwater elevations and subsequent impacts to recurrent flooding
- Develop sea level rise and climate change projections
- Hydrologic & Hydraulic modeling integrating future sea level rise, rainfall intensities, and land use
- Floodplain map update
- Stakeholder engagement and public outreach

St. Augustine, Florida

Goals:

- Coastal resiliency and infrastructure sustainability in the face of **future sea level rise**
- Protection of City assets and structures from high tide and storm impacts
- Systematic identification of critical outfalls and tide valve retrofit options

Tide Check Valve Program Flood Mitigation Project

- Great success has been documented where the valves have been installed (elimination of nuisance tidal flooding)

Next steps – Additional Resiliency Projects

- Master Stormwater Outfall Resiliency Retrofit Plan (prioritize remaining 80+ outfalls)



OF-0142 (After): Crew installing valve into outfall pipe

OF-0142 (After): Crew securing valve with straps onto outfall pipe

Coastal and climate change risks will impact planning standards, design standards, building codes, insurance rates, property values, and municipal bond ratings.

**There's a hidden cost
to climate change**

-Miami Herald

**Sea level suits are the next frontier
in climate change
litigation**

- Daily Journal

**Moody's Warns
Cities to Address
Climate Risks or
Face Downgrades**

- Bloomberg

**S.E.C. Is Criticized for
Lax Enforcement of
Climate Risk Disclosure**

- The New York Times

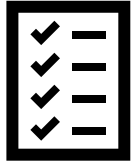


Understand and Quantify
Coastal and Flood Hazards
(Improve science, modeling...)



Educate

Risk

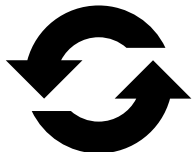


Vulnerability
Consequence
Criticality

Assess and Prioritize



Resilient Planning and Design



Adapt

Geosyntec 

consultants

engineers | scientists | innovators

QUESTIONS ?



www.geosyntec.com

www.geosyntec.com/markets/resilience-and-adaptation

