

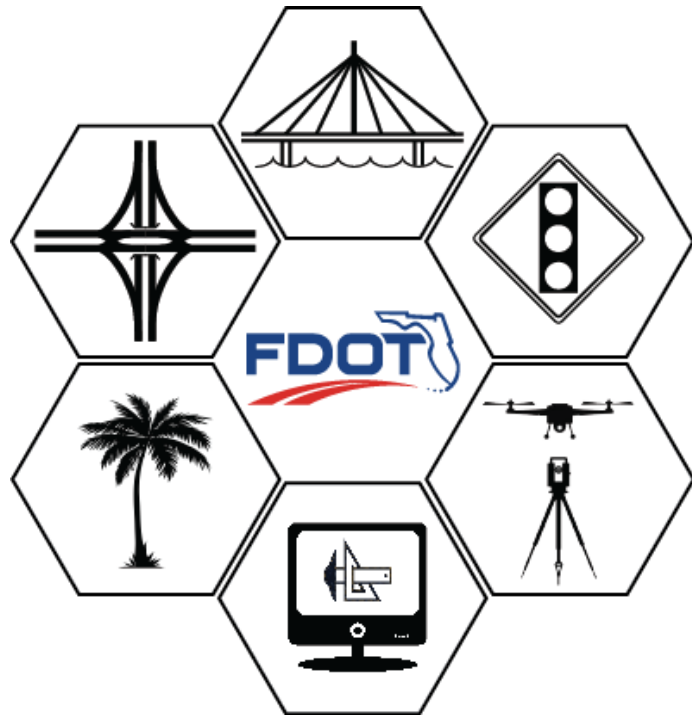
TRANSPORTATION SYMPOSIUM

2020 Webinar Series

Toward a Resilient Transportation System

Jennifer Carver, Crystal Goodison, Jayantha Obeysekera

August 25, 2020



TRANSPORTATION SYMPOSIUM

2020 Webinar Series

Toward a Resilient Transportation System

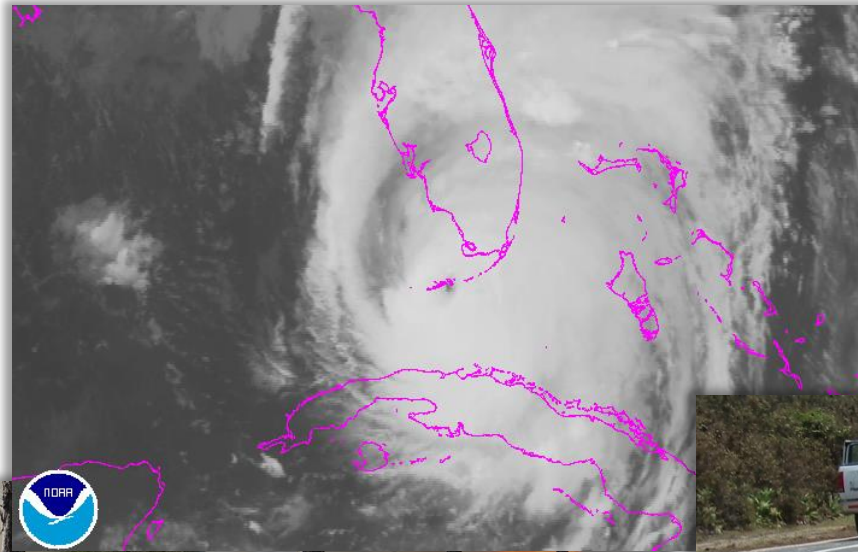
Jennifer Z. Carver, AICP

August 25, 2020

Natural Hazards Impacting Florida

- Hurricane Storm Events
- Precipitation Events
- Sea Level Rise
- Wildfires
- Drought
- Sinkholes

Irma making landfall in the Florida Keys
Credit: NOAA



A law enforcement vehicle patrols a flooded street in Everglades City, Florida, U.S., September 11, 2017. REUTERS/Bryan Woolston



Credit: Florida Forest Service



US 98 in Franklin County. FDOT

Presenters



Jennifer Z. Carver, AICP
Florida Department of
Transportation



Crystal Goodison
GeoPlan Center
University of Florida



Jayantha Obeysekera, Ph.D., P.E.
Sea Level Solutions Center
Institute of Environment
Florida International University

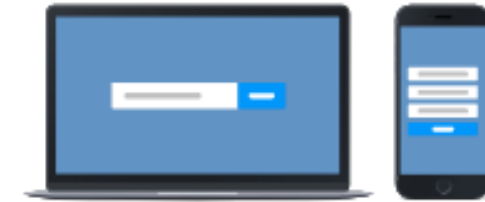
Sharing Our Ideas

Poll Everywhere – multiple ways to access the polls:

- Visit www.PollEv.com/fdotplanning from your phone, tablet, or laptop to access the polling questions
- Text “FDOTplanning” to 22333 to join the poll and respond to the polls via text message

Important note: A record of the poll responses will be kept for statutory records retention requirements

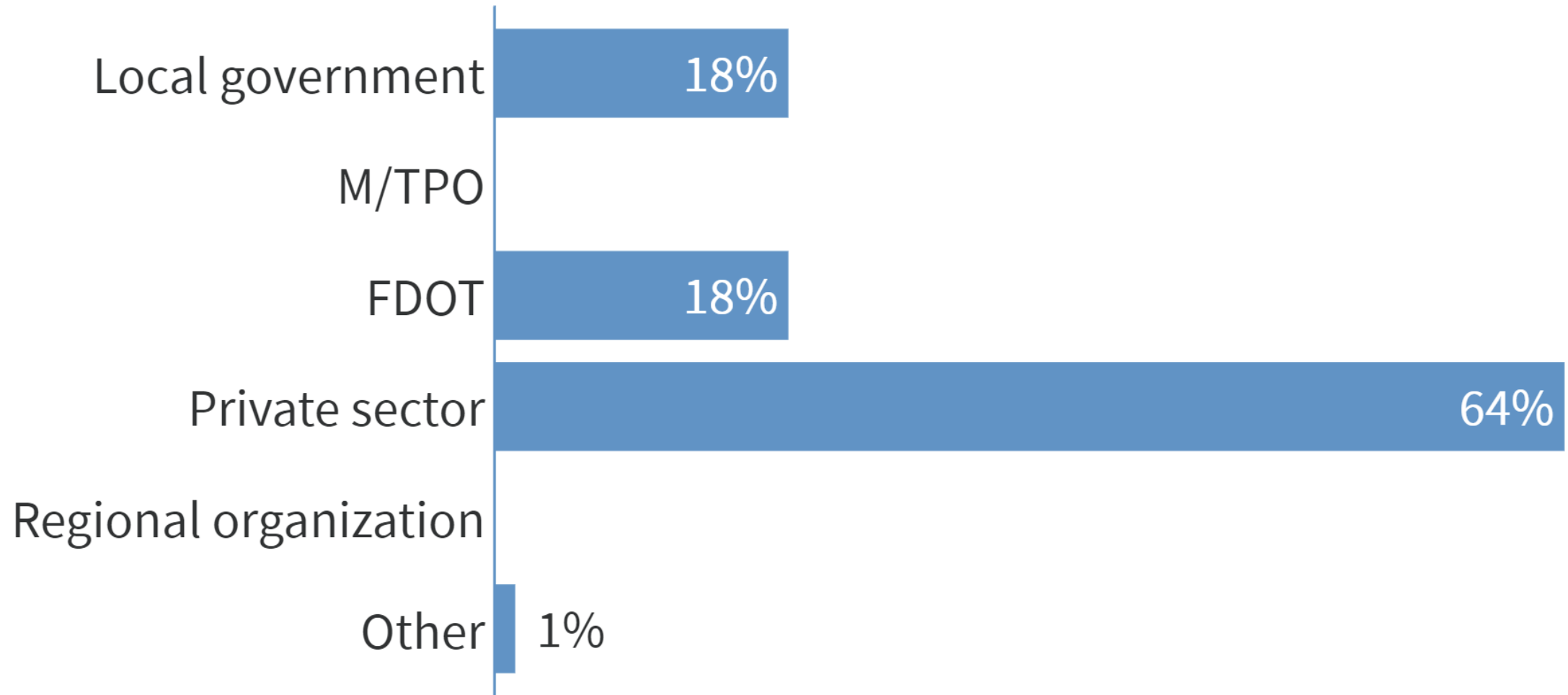
Web



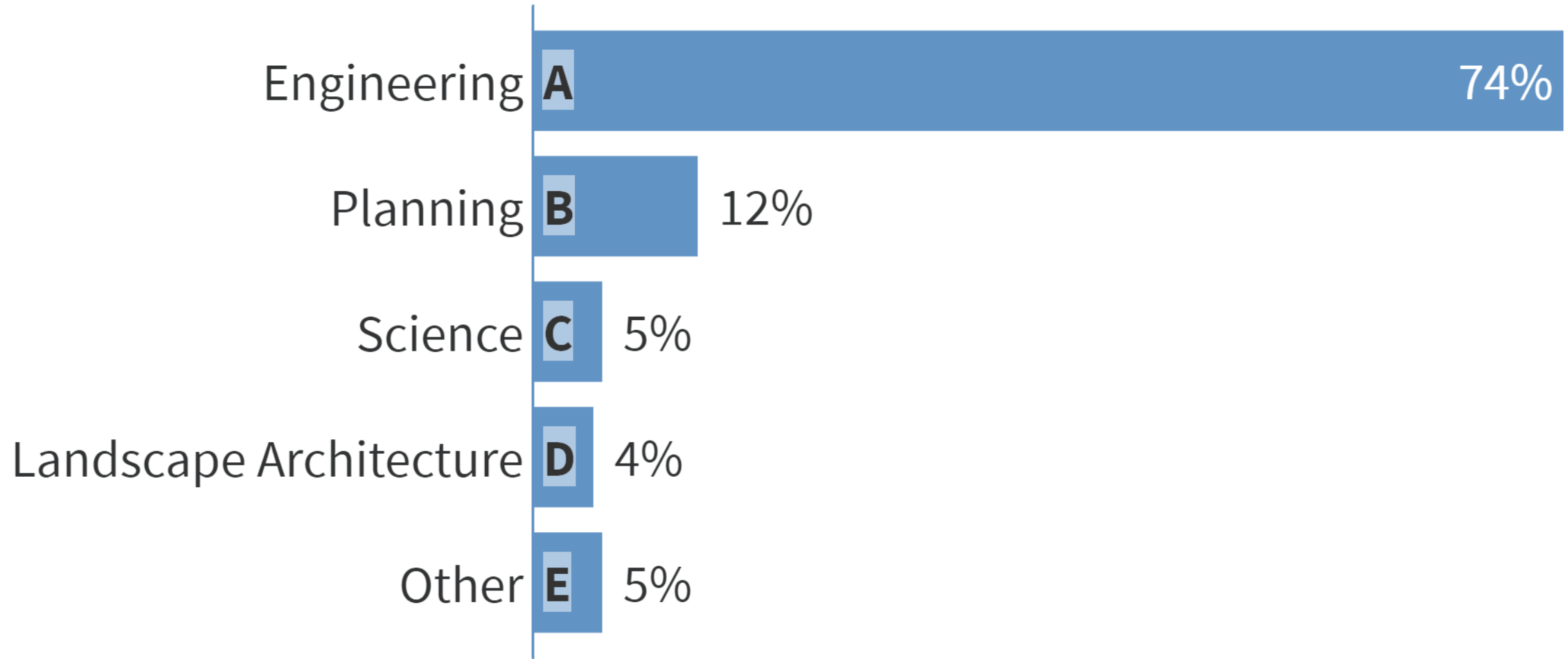
Text



What type of organization do you represent?



What is your professional area of expertise?



Why Resiliency?

Resiliency -- The ability of the transportation system to adapt to changing conditions and prepare for, withstand, and recover from disruptions.

Why? Mitigate risk, make wiser investment decisions, and provide more reliable transportation.

Fixing America's Surface Transportation (FAST) Act

- Resiliency/reliability; reduce stormwater impacts; reduce vulnerability

FDOT 23 Code of Federal Regulations (CFR) Part 667

- Evaluate options for facilities that have been repaired/reconstructed 2+ times due to emergency events



FDOT Resiliency Initiatives

Statewide Planning

- Florida Transportation Plan
- Transportation Asset Management Plan (TAMP)

FDOT Resiliency Policy

SIS Vulnerability Assessment

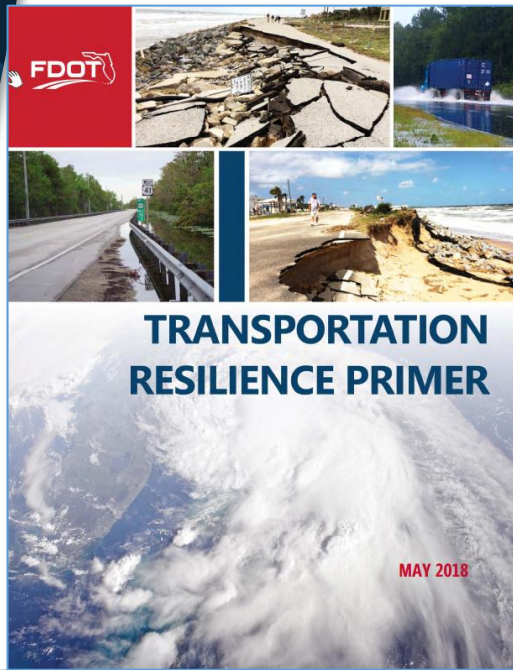
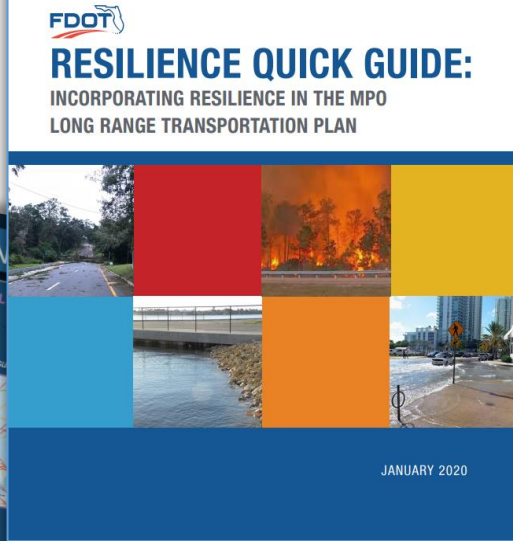
Tools, Guidance, Standards

- Guidance for MPOs
- Sea Level Scenario Sketch Planning Tool
- Case Studies/Adaptation Planning

Research

Interagency Coordination/Collaboration

Projects



Florida Transportation Plan

SAFETY AND SECURITY FOR
RESIDENTS, VISITORS, AND BUSINESSES

TRANSPORTATION
SOLUTIONS THAT
ENHANCE FLORIDA'S
ENVIRONMENT



AGILE, RESILIENT,
AND QUALITY
TRANSPORTATION
INFRASTRUCTURE

TRANSPORTATION
SYSTEMS THAT
ENHANCE
FLORIDA'S
COMMUNITIES



2020
FLORIDA
Transportation Plan



CONNECTED,
EFFICIENT, AND
RELIABLE MOBILITY
FOR PEOPLE
AND FREIGHT

TRANSPORTATION
SOLUTIONS THAT
STRENGTHEN
FLORIDA'S ECONOMY

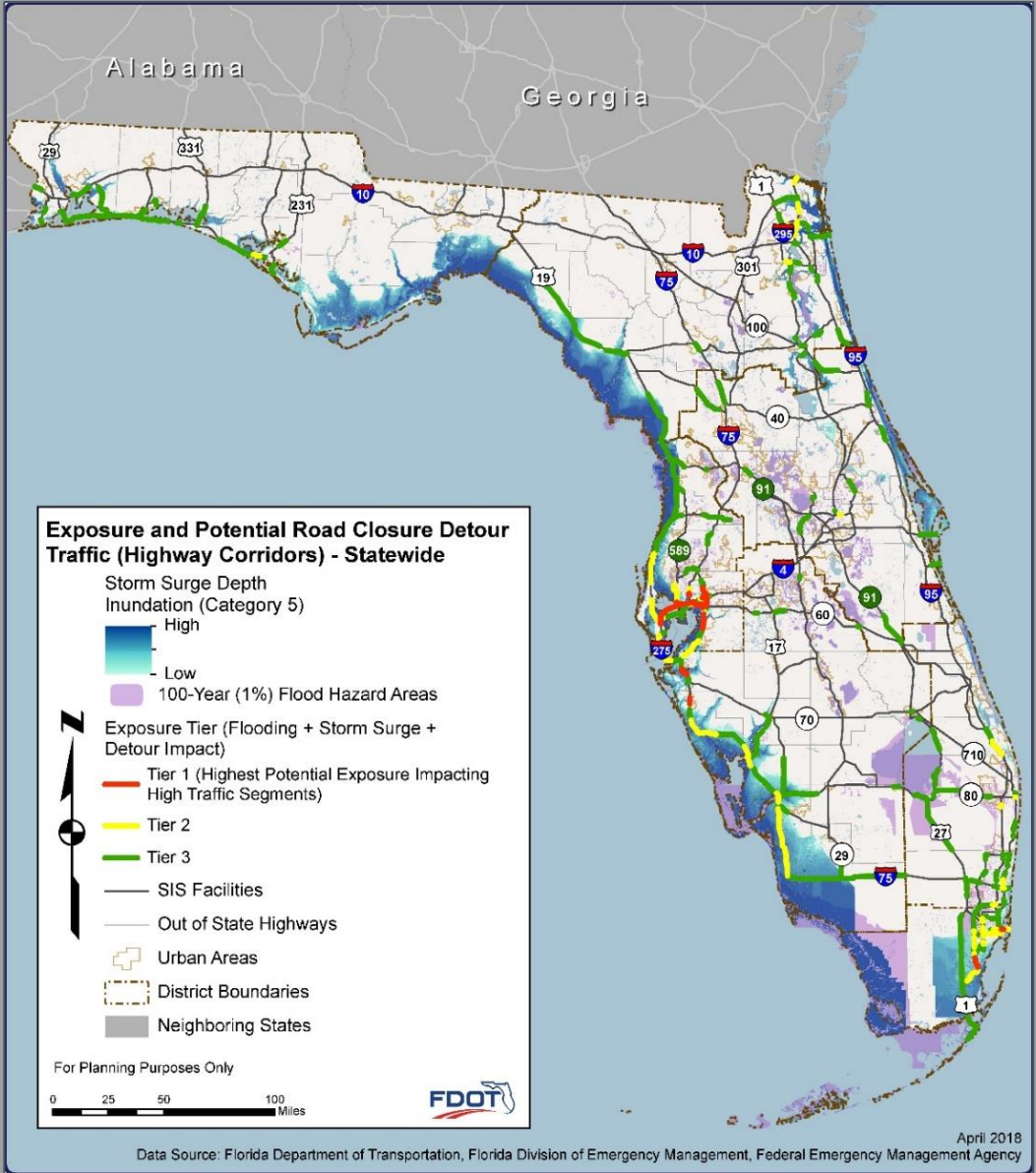


TRANSPORTATION
CHOICES THAT
IMPROVE ACCESSIBILITY
AND EQUITY



www.floridatransportationplan.com

Strategic Intermodal System (SIS) Vulnerability Assessment



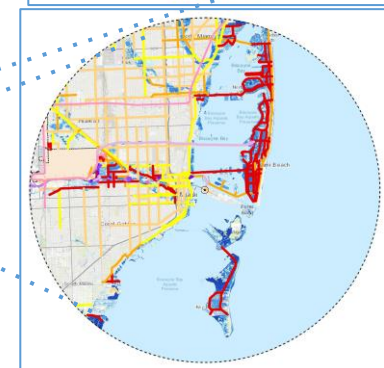
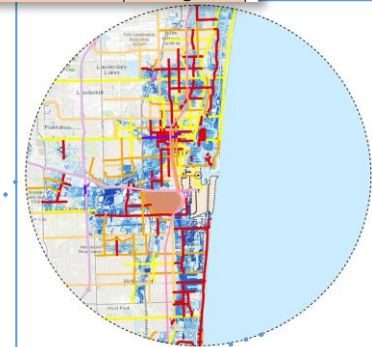
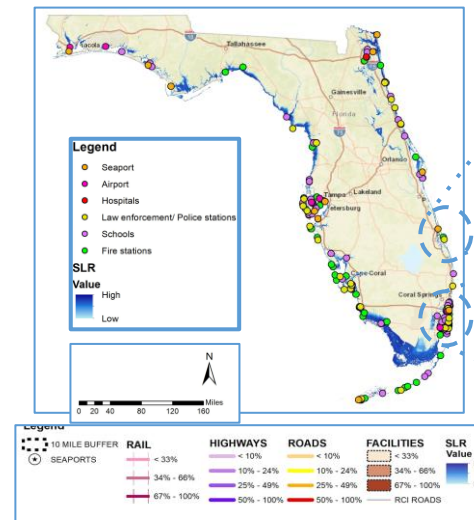
Research

FDOT – Completed/Ongoing

- Development of a Methodology for the Assessment of Sea Level Rise Impacts on Florida's Transportation Modes and Infrastructure
- Development of GIS-Based Tool for Assessment of SLR Impacts
- Risk in Transportation Planning & Implications for Planning and Project Implementation
- Transportation Resilience and Vulnerable Populations
- Resilience Index for Transportation System

NCHRP Projects

	Risk Event	Likelihood	Consequence	Vulnerability	Overall Risk	Time frame	Risk Level	Consequence Management
security for residents, visitors, and businesses	Threats							
	Hacking and cybersecurity threats to public and private transportation	4	4	5	80	E	Extreme Risk	Avoid
	New technology causes investment to be prematurely obsolete	4	4	5	80	E	Extreme Risk	Avoid
	Intensification of development in high hazard areas	5	4	4	80	C	Extreme Risk	Avoid
	Aging population causes surge in demand for safe mobility options	5	4	3	60	E	High Risk	Coordinate
	Wildfires disrupt major transportation routes and reduce visibility	4	3	4	48	U	Moderate Risk	Mitigate
	New technology systems perform unsafely or increase liability	3	5	3	45	U	Moderate Risk	Avoid
	Failure to evacuate vulnerable populations due to evacuation routes in high hazard areas	2	5	4	40	U	Moderate Risk	Coordinate
	Arterial flooding disrupts major transportation routes and systems	4	3	3	36	C	Moderate Risk	Mitigate



Upcoming FDOT Projects

Research

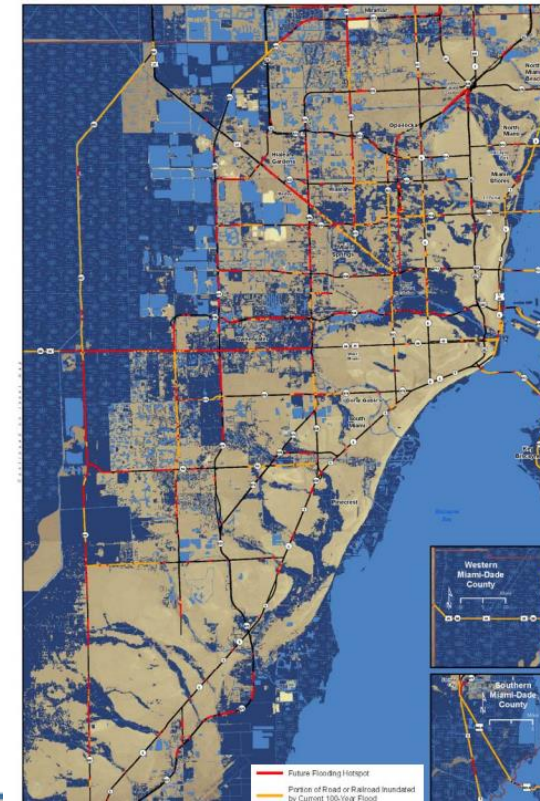
- Incorporation of Climatic and Hydrologic Nonstationarity into FDOT Planning and Design Guidelines & Processes
- Florida Sea Level Scenario Sketch Tool Updates & Enhancement

Study

- Integrating Resiliency in the Transportation Planning Process: A Baseline Assessment of Florida's MPOs



Figure 7: Future flooding "hot spots" in Miami-Dade County.



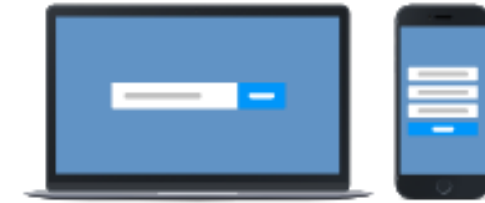
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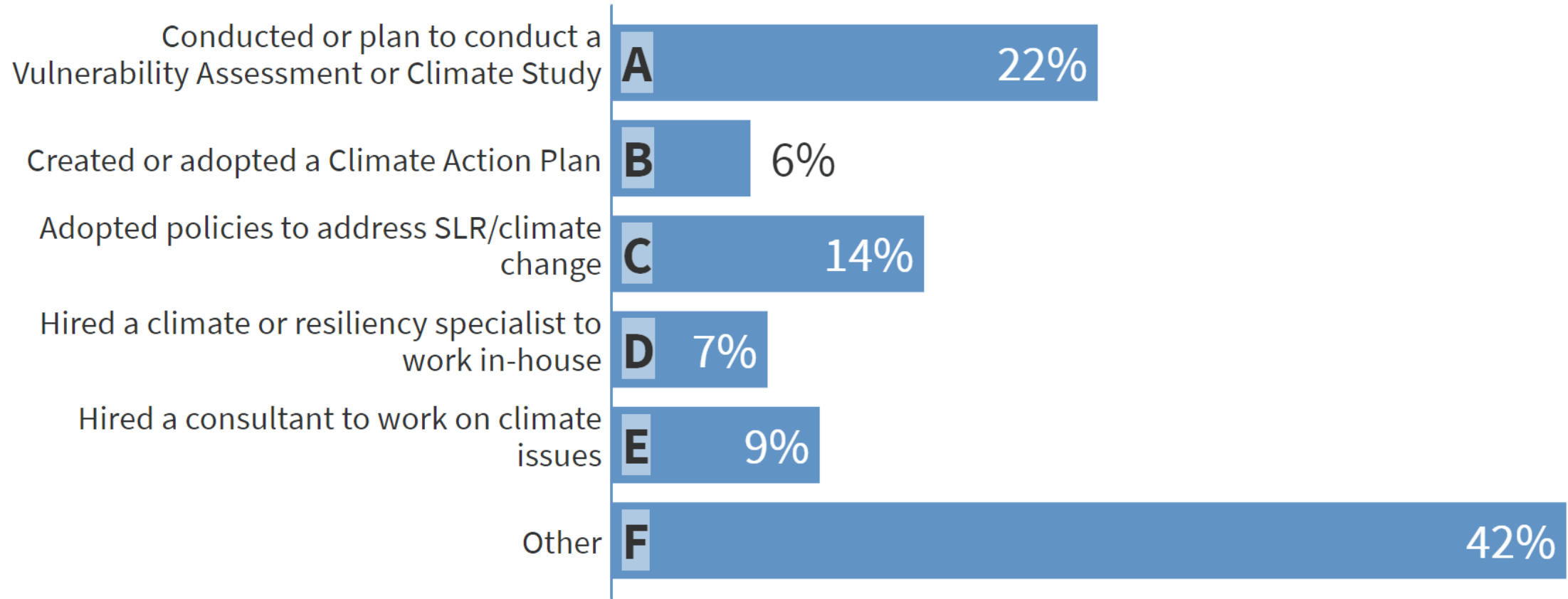
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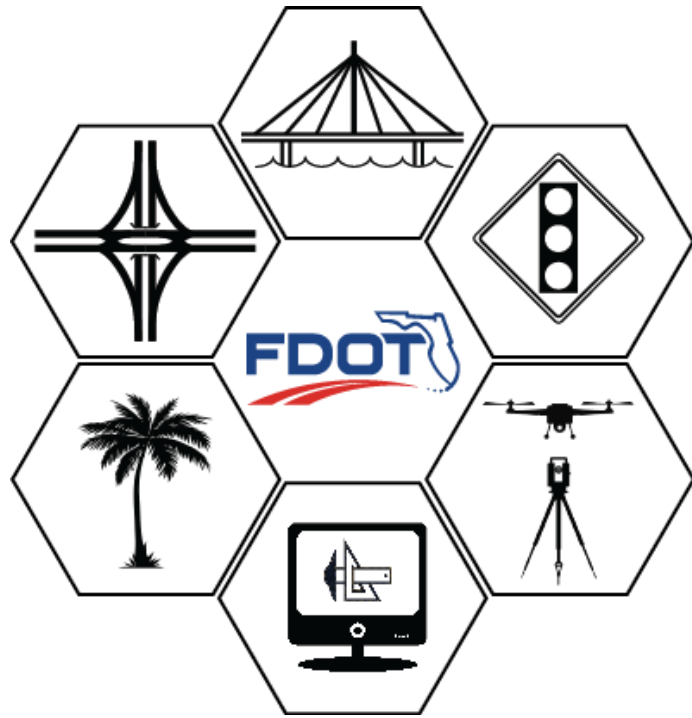


Text



What methods does your organization use to address climate change including sea level rise?





TRANSPORTATION SYMPOSIUM

TOWARD A RESILIENT TRANSPORTATION SYSTEM

Crystal Goodison,
Associate Director + Associate Scholar, UF GeoPlan Center

UNIVERSITY OF FLORIDA GEOPLAN CENTER

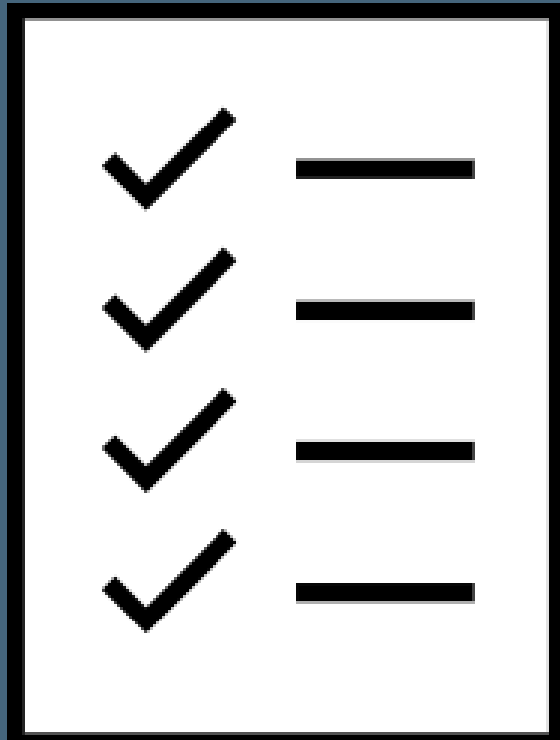
The GeoPlan Center is a **geospatial research and teaching facility**, in the UF School of Landscape Architecture & Planning.

We support land use, transportation, and environmental planning in the State through the following activities:

- Standardize, enhance, and distribute geospatial data
- Design and maintain enterprise mapping systems and tools for visualization, analysis, and decision support
- Turn data into information
- Training and education



OUTLINE OF PRESENTATION



History of UF GeoPlan resiliency work with FDOT

Sea Level Scenario Sketch Planning Tool

- Current Features
- Updates coming

Upcoming Work:

- Assessing MPO Data Needs for Transportation Resiliency
- Research Project – Framework for Project Level Analysis

WHERE WE'VE BEEN

2011-13:

Initial Sketch
Tool Build.
USACE 2013
Projections

2013-15:

FHWA Pilots,
Data scale,
Feedback

2016-17:

NOAA 2012
projections,
new map
viewer

2017:

Training
workshops
around State

2019-20:

NOAA 2017
projections,
data update,
training

SEA LEVEL SCENARIO SKETCH PLANNING TOOL

- Geospatial tools and data to assess potential impacts of current and future flooding on the transportation system
- Planning-level analyses shows where and when sea level rise is projected to occur in Florida under various SLR scenarios
- Data available statewide, but use local SLR projections
 - Publicly accessible tool & data:
sls.geoplan.ufl.edu



Map Viewer: Visualize areas of inundation and affected infrastructure



GIS Data Layers: SLR Inundation Surfaces & Affected Infrastructure layers



SLR Calculator: Create custom inundation layers

Scenario Selector

Agency

Projection Curve(NOAA)

Time Period

Show Results

Layers

- SLR 2080 USACE High MHHW (3.4 - 3.7 ft)
- Affected Transportation
- RSLR by County (2080 C4)
- SLR Depth Inches (2080 C4)
- Current Flood Risk
- Florida Base Layers

Legend

Florida Base Layers

Coastal Areas Mapped

SLR 2080 USACE High, MHHW

Affected Transportation

Map navigation controls: +, -, search, home, refresh, expand.

Jump to: COUNTY [dropdown] BAY [dropdown]

Basemaps [dropdown]

DATA AVAILABLE IN THE MAP VIEWER

Data Available

- 35 coastal counties mapped
- 5 Sea Level Rise Projections
- Four time periods: 2040, 2060, 2080, 2100

Transportation Analyses

Segment-level analysis of current & future flood risk:

- Future flood risk: from 20 SLR scenarios
- Current flood risk: 100-year & 500-year floodplains, storm surge zones

Base transportation data used:

- Focus on State owned facilities (RCI on and off system)

Scale bar: 6km / 4mi

Coordinates: 1:288.895 29°56'10.718" N 81°44'15.011" W

SLR PROJECTIONS MAPPED

Current SLR projections in Sketch Tool:

USACE 2013

- Upper curve ~ 5ft (1.5m) by 2100

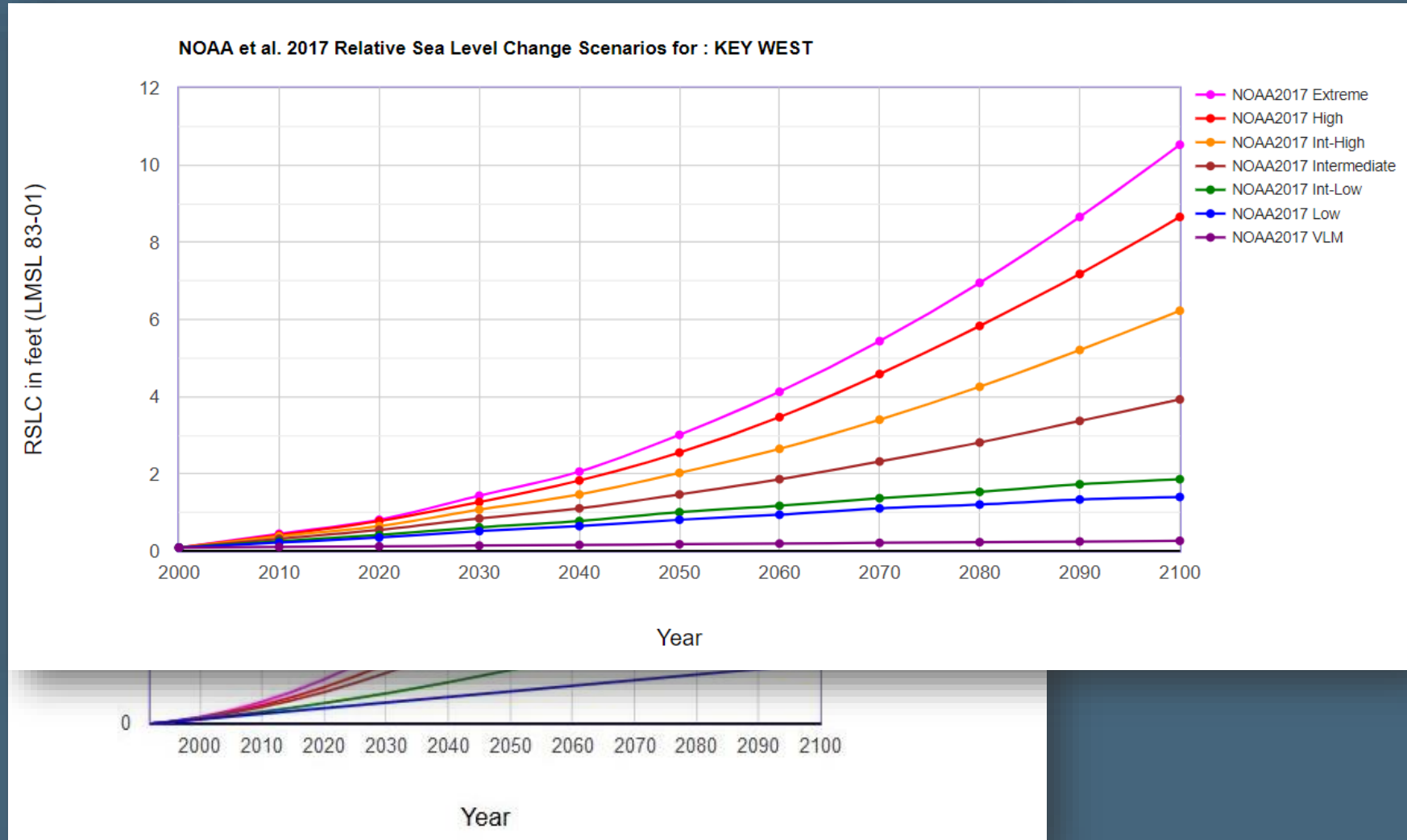
NOAA 2012:

- Upper curve ~ 6ft (2m) by 2100

Coming:

NOAA 2017:

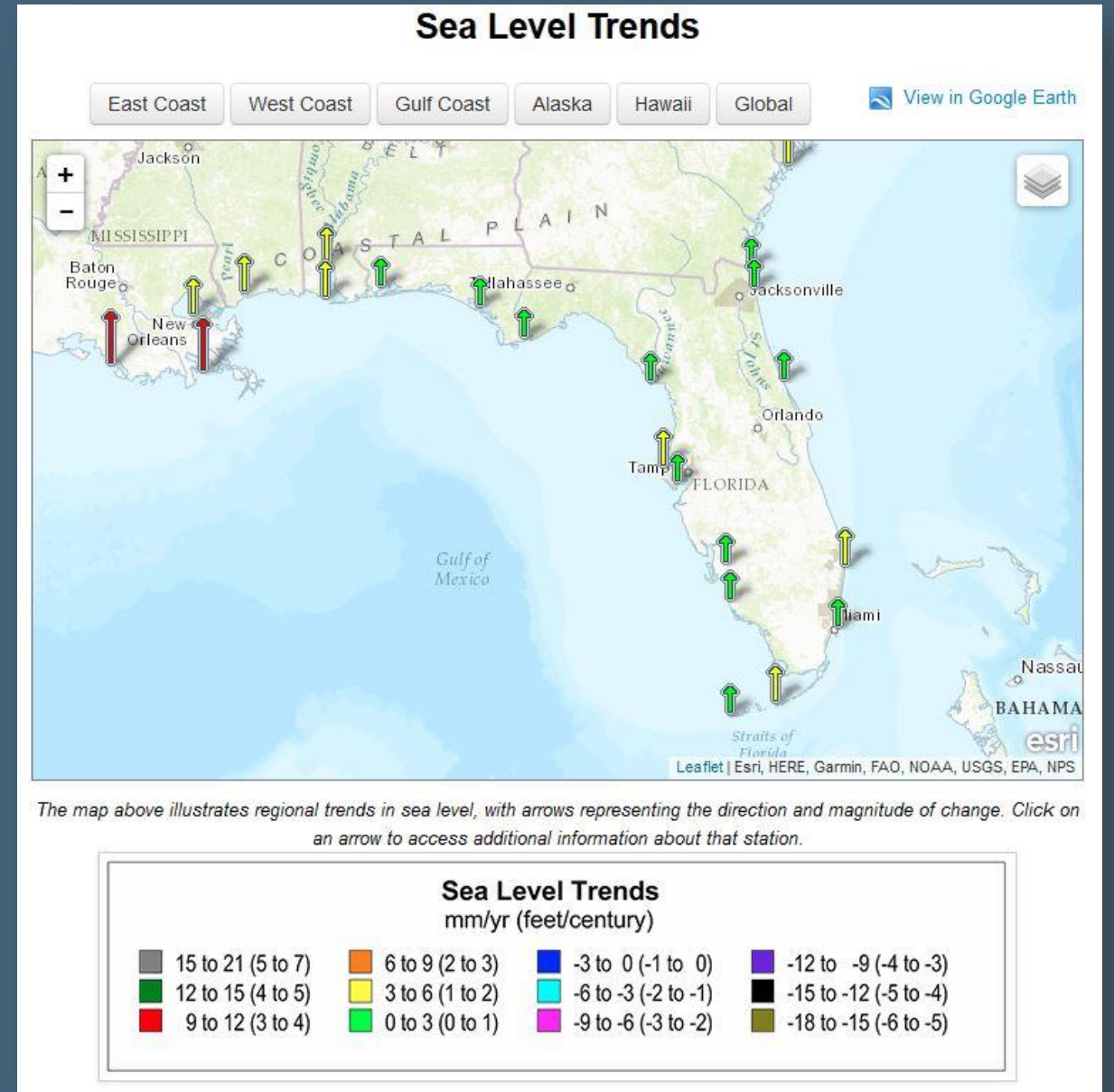
- Upper curve ~ 10ft (3m) by 2100



MAPPING INPUTS

1. USACE Sea Level Change Calculator (calculates USACE & NOAA SLR Projections) http://corpsmapu.usace.army.mil/rccinfo/slc/slcc_calc.html
2. NOAA Sea Level Trends
3. NOAA Tidal Grids (regional MHHW conditions)
4. High resolution elevation data

Consider regional Unified SLR Projections when choosing inputs



MAP VIEWER FEATURES

Select a scenario

UFGEOPLAN CENTER Florida Sea Level Scenario Sketch Planning Tool [Help](#) [About](#)

Scenario Selector

Agency:

Projection Curve(NOAA):

Time Period: 2080

Jump to: COUNTY BAY

Basemaps

Layers

- SLR 2080 NOAA High (C5) MHHW (4.5 - 4.8 ft)
 - Affected Transportation
 - RSLR by County (2080 C5)
 - SLR Depth Inches (2080 C5)
- Current Flood Risk
- Florida Base Layers

Legend

Florida Base Layers

Coastal Areas Mapped

SLR 2080 NOAA High, MHHW

Affected Transportation Roads (2080 C5)

- < 10%
- 10% - 24%
- 25% - 49%
- 50% - 100%

Map of Florida showing sea level rise scenarios. Major cities labeled include Tallahassee, Gainesville, Ocala, Orlando, Tampa, and Jacksonville. Major roads shown include 19, 28, 301, 401, 40, 207, 528, 60, and 27. A scale bar shows 60km and 30mi. Coordinates: 1:2,311,162 27°33'42.561" N 83°51'00.764" W.

EXPLORE THE DATA

UFGEOPLAN CENTER Florida Sea Level Scenario Sketch Planning Tool [Help](#) | [About](#)

Scenario Selector

Agency:

Projection Curve(NOAA):

Time Period: 2080

Layers

- SLR 2080 NOAA High (C5) MHHW (4.5 - 4.8 ft)
- Affected Transportation
- RSLR by County (2080 C5)
- SLR Depth Inches (2080 C5)
- Current Flood Risk
- Florida Base Layers

Legend

Florida Base Layers

Coastal Areas Mapped

Jump to: COUNTY BAY

Basemaps

Roads (2080 C5)

Name	FT PICKENS RD
Functional Class	RURAL: LOCAL
Feet Affected (2080 C5 Mhwh)	32526
% Affected (2080 C5 Mhwh)	56
Begin Mile Pt	0
End Mile Pt	11.09
Length Of Segment (feet)	58506.111731
Type	RCI OFF
Evacuation Route	YES
County	ESCAMBIA
Avg Daily Traffic - Min	7300
Avg Daily Traffic - Max	24000
Min Lanes	1

Zoom to

1:144,448 30°22'52.629" N 87°04'13.207" W

EXPLORE & EXPORT ATTRIBUTE TABLE

UFGEOPLAN CENTER Florida Sea Level Scenario Sketch Planning Tool [Help](#) | [About](#)

Scenario Selector

Agency:

Projection Curve(NOAA):

Time Period:

Jump to: COUNTY

Coordinates: 1:144,448 30°23'03.488" N 87°08'31.988" W

Layers

- SLR 2080 NOAA High (C5) MHHW (4.5 - 4.8 ft)
 - Affected Transportation
 - SIS Highways (2080 C5)
 - Roads (2080 C5)
 - < 10%
 - 10% - 24%
 - 25% - 49%
 - 50% - 100%
 - SIS Rails (2080 C5)
 - SIS Facilities (2080 C5)
 - RSLR by County (2080 C5)
 - SLR Depth Inches (2080 C5)
 - Current Flood Risk
 - Florida Base Layers

Roads (2080 C5)

NAME	Functional Class	Feet Affected (2 % Affected (208	Begin Mile Pt	End Mile Pt	Length of Segn	TYPE	Ev	
VIA DE LUNA DR	URBAN: MAJOR CO...	16,332	91	0.000	3.394	17,871.680	RCI OFF	NC
FT PICKENS RD	RURAL: LOCAL	32,526	56	0.000	11.090	58,506.112	RCI OFF	YE
BAY ST	URBAN: LOCAL	4,637	50	0.000	1.755	9,200.008	RCI OFF	NC
VIA DE LUNA DR	RURAL: MAJOR CO...	8,274	15	0.000	10.274	54,157.604	RCI OFF	NC
ORIOLE BEACH RD	URBAN: LOCAL	575	14	0.000	0.763	4,053.071	RCI OFF	NC
CORONADO DR	URBAN: LOCAL	149	7	0.000	0.457	2,244.339	RCI OFF	NC
INNERARITY POINT ...	URBAN: MAJOR CO...	1,286	3	0.000	9.732	51,119.324	RCI OFF	NC
W SUNSET AVE	URBAN: LOCAL	90	1	0.000	1.220	6,470.771	RCI OFF	NC
PERDIDO KEY DR	URBAN: PRINCIPAL	1,000	1	0.000	18.808	99,288.244	RCI ON	YE

1 - 9 of 9 results

COMPARE SCENARIOS WITH SWIPE TOOL

UFGEOPLAN CENTER Florida Sea Level Scenario Sketch Planning Tool [Help](#) | [About](#)

Scenario Selector

Agency: **USACE** | NOAA

Projection Curve(USACE): **Low** | Intermediate | High

Time Period: 2100

Show Scenario

Layers

- SLR 2040 USACE Low and NOAA Low (C1) MHHW (0.3 - 0.4 ft)
 - Affected Transportation
 - RSLR by County (2040 C1)
 - SLR Depth Inches (2040 C1)
- SLR 2100 USACE High (C4) MHHW (5 - 5.3 ft)
 - Affected Transportation
 - RSLR by County (2100 C4)
 - SLR Depth Inches (2100 C4)
- Current Flood Risk
- Florida Base Layers

Jump to: COUNTY | BAY

Basemaps

Orchid

Red Stick Golf Club

Bent Pine Golf Club

Indian River Shores

Gifford

Palm Bay

Exit Layer Swipe

1:144,448 27°41'30.09" N 80°23'17.761" W

GET THE DATA...

The image shows a screenshot of the ArcMap software interface. The main window displays a map of Florida with various data layers overlaid, including a color-coded SLR Depth Inches layer. The 'Table of Contents' pane on the left lists the layers, with 'SLR Depth Inches (2080 C5)' selected. A context menu is open over this layer, with the 'Download' option highlighted in a red box. The 'Layers' pane on the left also shows the layer list, with a red box around the menu icon for the selected layer. The 'Scenario Selector' pane at the top left shows settings for Agency (USACE, NOAA), Projection Curve (NOAA), and Time Period (2080). The 'Legend' pane at the bottom left shows 'Florida Base Layers' with 'Coastal Areas Manned' selected. The status bar at the bottom right displays coordinates: -70890.734 565567.793 Meters.

UF **GEOPLAN CENTER** Florida Sea Level Rise

Scenario Selector

Agency: USACE NOAA

Projection Curve(NOAA): Low Int Low Int High High

Time Period: 2080

Show Scenario

Layers

- SLR 2080 NOAA High (C5) MHHW (4.5 - 4.8 ft)
- Affected Transportation
- RSLR by County (2080 C5)
- SLR Depth Inches (2080 C5)
- Current Flood Risk
- Florida Base Layers

Legend

Florida Base Layers

Coastal Areas Manned

Table Of Contents

- SLR 2080 NOAA High (C5) MHHW (4.5 - 4.8 ft)
- Affected Transportation
- RSLR by County (2080 C5)
- SLR Depth Inches (2080 C5)

Value

High : 92

Low : 0

Download

Remove Layer

Results ArcToolbox Table Of ... Catalog

-70890.734 565567.793 Meters

1:144,448 30°23'16.629" N 87°14'34.777" W

WHAT'S COMING: THIS FALL



NOAA
2017



UPDATED
BASE DATA



LOCAL
ROADWAYS



TRAINING
WEBINAR

Our website:
sls.geoplan.ufl.edu

Crystal Goodison,
cgoody@ufl.edu

WHERE WE'RE GOING



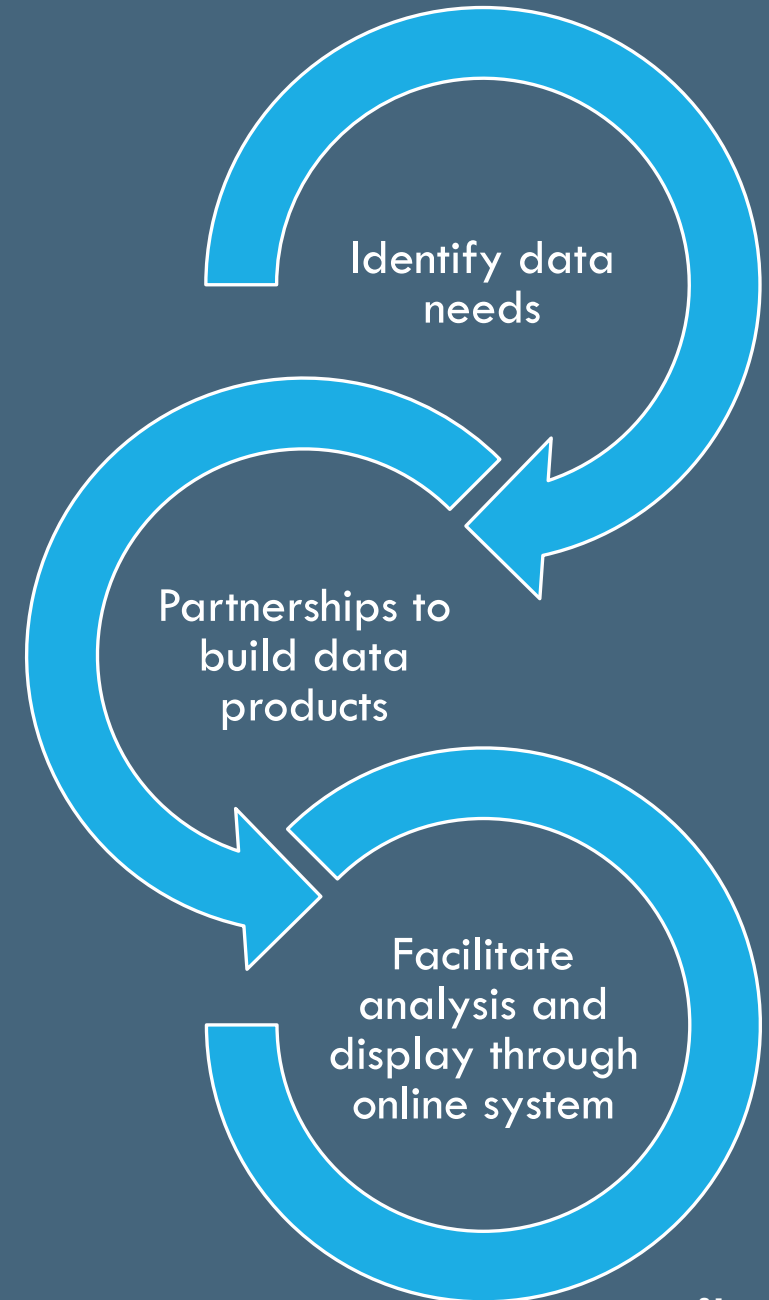
UPCOMING RESEARCH (2020 - 22)

2020-21: State of the Practice & Data Needs for MPO Resiliency

- Deep dive into resiliency activities in FL, obstacles, and data needs for implementing resiliency into the planning process

2021 -22: Building Geospatial Framework to Move from Planning to Project Scale

- Expanding beyond SLR to incorporate other data sources/climate. For ex: precipitation, inland flooding, etc.
- Looking for partners to help us develop data and determine interoperability
- Building online tool and geoprocessing framework to facilitate on-demand analysis of specific transportation projects and more comprehensive consideration of future conditions



QUESTIONS



What are the challenges in applying resiliency principles in project designs?

“Awareness” “Funding” “lack of a consistent method in applying risk mitigation costs” “Unknowns” “Paying now for later” “Project scope requirements & funding limitations” “Identifying countermeasures” “Budget”

“questionable data” “Existing policies, current government approach is not set up to accommodate” “\$\$\$” “funding” “Money” “Politics” “Cost” “how to design for the UNKNOWN” “Money.” “Value added”

“Cost and resistance” “Changing Directions” “Infrastructure planning is not set up to look at long-term; too focused on near-term, especially infrastructure in coastal areas” “Funding” “Money budget” “policy” “Collaboration”

“POLITICS AFFECTING GUIDANCE” “we can do it, but others may not, so what is the point” “Funding and politics” “Funding” “cost-effective solutions” “being able to predict the future” “Insurance” “Politics and money”

“low buildings” “Balancing cost vs. benefit” “Concurrence” “Cost” “Uncertainty” “Reality” “Money” “Funding - Cost” “Lack of standards” “Ever changing conditions” “PD&E studies used old information”

“Money” “There aren't really design standards related to resiliency.” “Agreement on SLR Scenarios by Government Agency Stakeholders” “Elevating roadways and treatment facilities along side existing development/topography due to increased tailwater.”

“designing for unknown” “Budget” “Getting agency direction on how to address.” “The design time frame longer than 20/30 years may not be realistic. Advances in technology and real time conditions may change the scenario.” “Buy in” “future”

“forecasting parameters may change drastically” “Unclear targets” “Funding” “Politics.” “Funding” “Uncertainty” “Understanding of priority” “money” “Justifying the Cost” “Funding & politics”

“Funding, sufficient data to make decisions on a project level. There is no universal definition of resiliency.” “Subsurface infrastructure maintenance” “Policy” “roadway specs” “Budgeting these requirements” “Funding” “Money”

“technology changes in future” “No standards for design” “Point of diminishing returns” “Accepting change by public” “Funding!!!! These are expensive projects.” “D” “feasible design criteria” “Drainage challenges”

“Politics” “Funding” “Public perception” “FDOTPLANNING” “Geometric constraints” “guidance and cost.” “Politics” “Funding” “Cost. lack of Consistency or Policy” “Politics” “Funding”

“Amount of existing R/W or the need to pay for additional R/W to allow for a resilient TF.” “modeling inaccuracies” “knowledge” “Public perception” “funding” “Data” “Budget constraints” “Unknowns”

“Lack of projects demonstrating success” “Impacts to adjacent land uses” “Money”

“Green infrastructure designs that are seen as more resilient are more maintenance intensive. There is a lack of long-term maintenance data.” “Current land use.” “New poll” “Scope” “Money” “being flexible, learning to address uncertainty”

“justification for return on investment. making a case.” “Funding” “funding”

Towards a Resilient Transportation System in a Changing Environment of Climate Change: **Paradigm Change**

Jayantha Obeysekera ('Obey'), Ph.D., P.E.
Director and Research Professor
Sea Level Solutions Center
Institute of Environment

FDOT Transportation Symposium

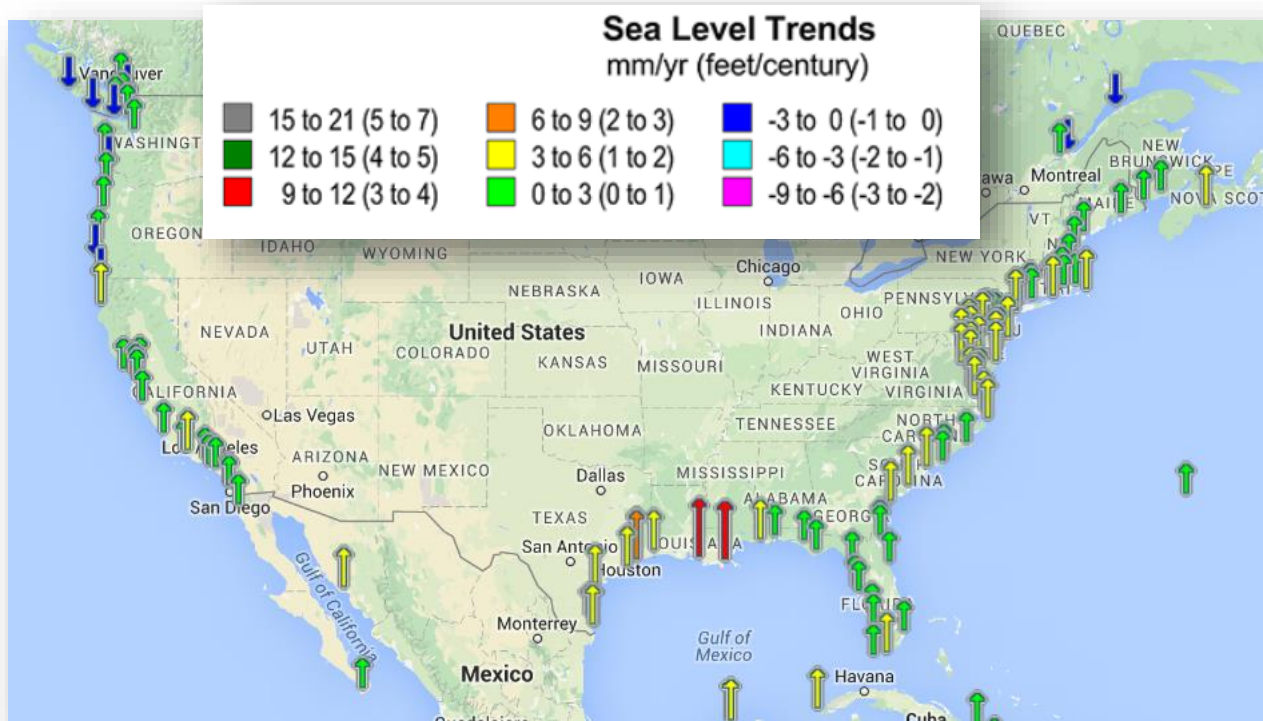
Web: <https://environment.fiu.edu> | <http://slsc.fiu.edu> Facebook: @FIUWater | Twitter: @FIUWater

Outline

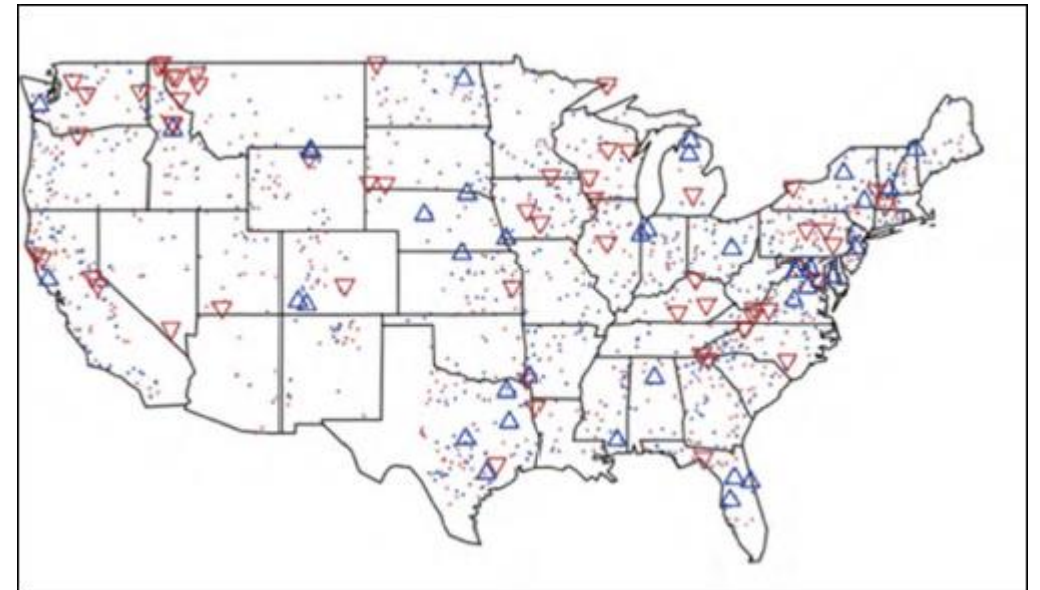
- Changing environment: Need a new paradigm for infrastructure design (coastal and interior regions)
- Rising Sea Levels
- Changing Rainfall Extremes
- Dealing with Uncertainty: Dynamic Adaptive Pathways in Project Implementation

Drivers of Change: Sea Level Rise and increases in Riverine Flooding

Sea Level Rise Trends



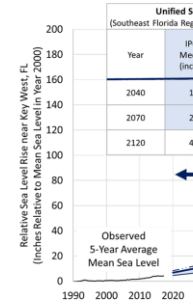
Peak Flow Trends



Impacts of Changing Climate and Rising Sea Levels



Heat waves



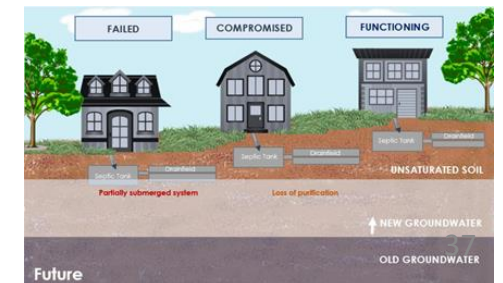
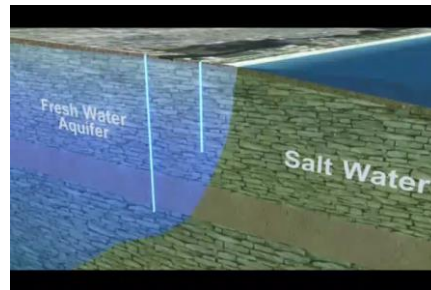
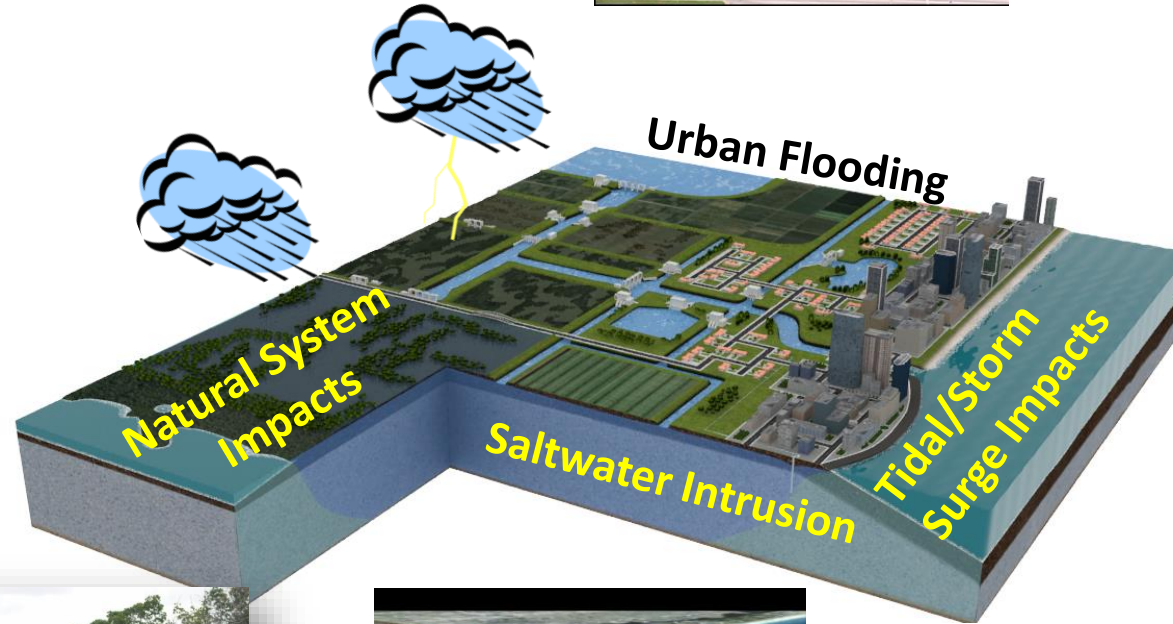
Rising sea levels



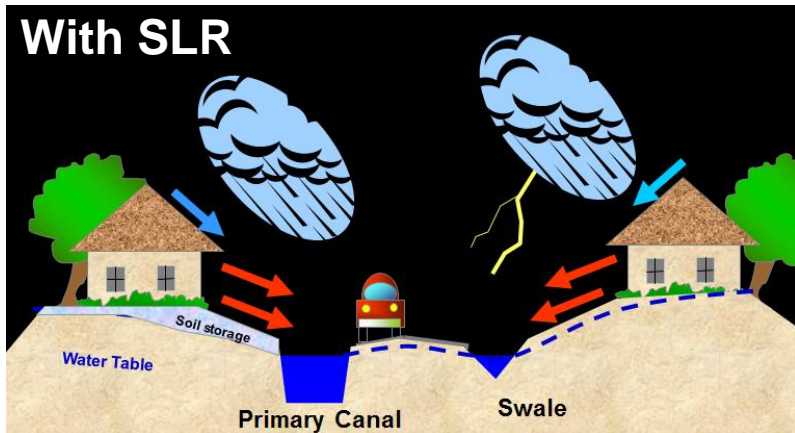
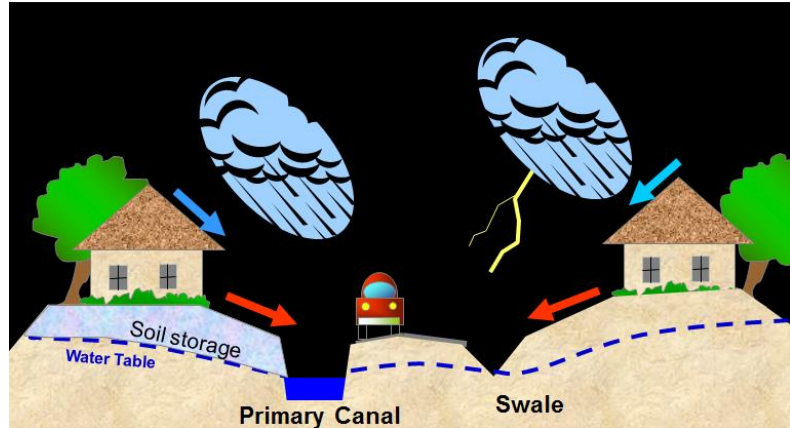
Intensity of precipitation



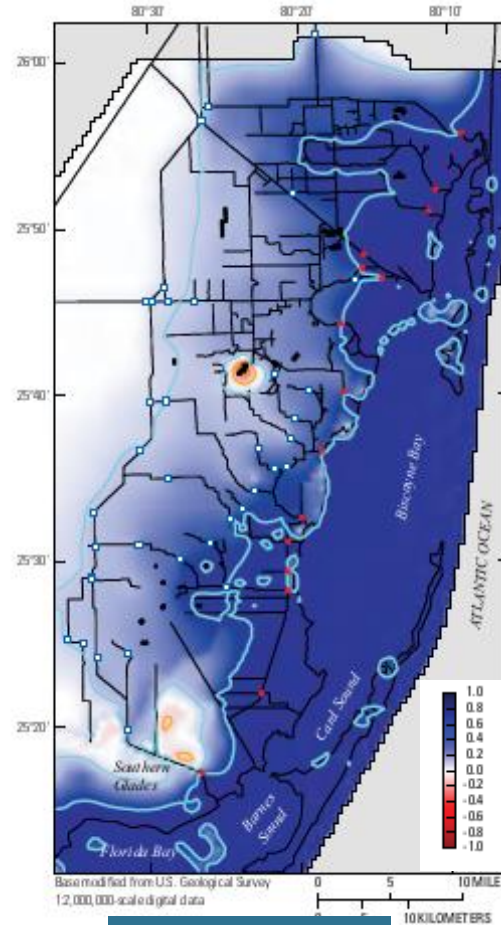
More frequent hurricanes



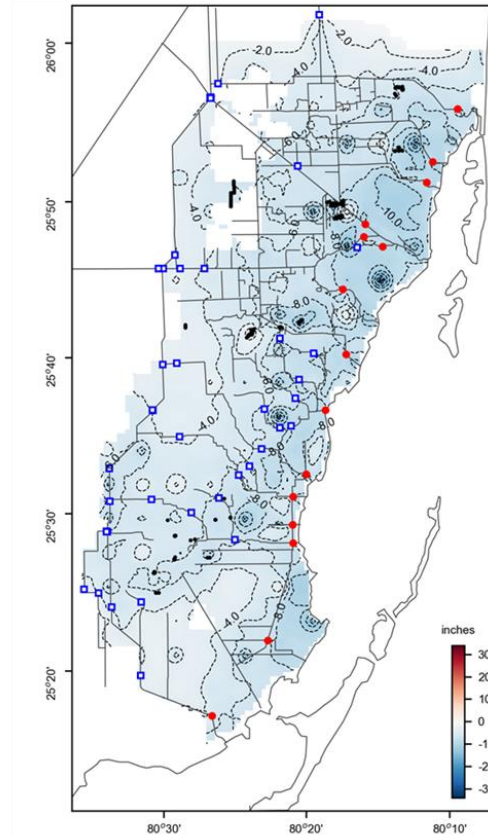
Non-uniform water table increase: modeling results (Miami Dade)



Higher water table
& more runoff

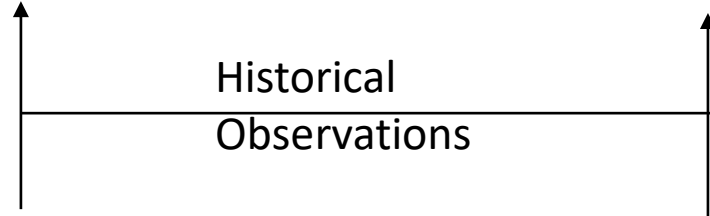


Difference in wet season soil storage
HIGH SLR – CALIBRATION (inches)



Loss of Soil Storage

Hydrologic Design: Moving from Stationarity to Nonstationarity



TYPE STORM DRAIN	FREQUENCY
General design	3-year
<ul style="list-style-type: none"> General design work that involves replacement of a roadside ditch with a pipe system by extending side drain pipes General design on work to Interstate Facilities 	10-year
<ul style="list-style-type: none"> Outfalls 	25-year
<ul style="list-style-type: none"> Interstate Facilities for which roadway runoff would have no outlet other than a storm drain system, such as in a sag inlet or cut section Outlets of systems requiring pumping stations 	50-year

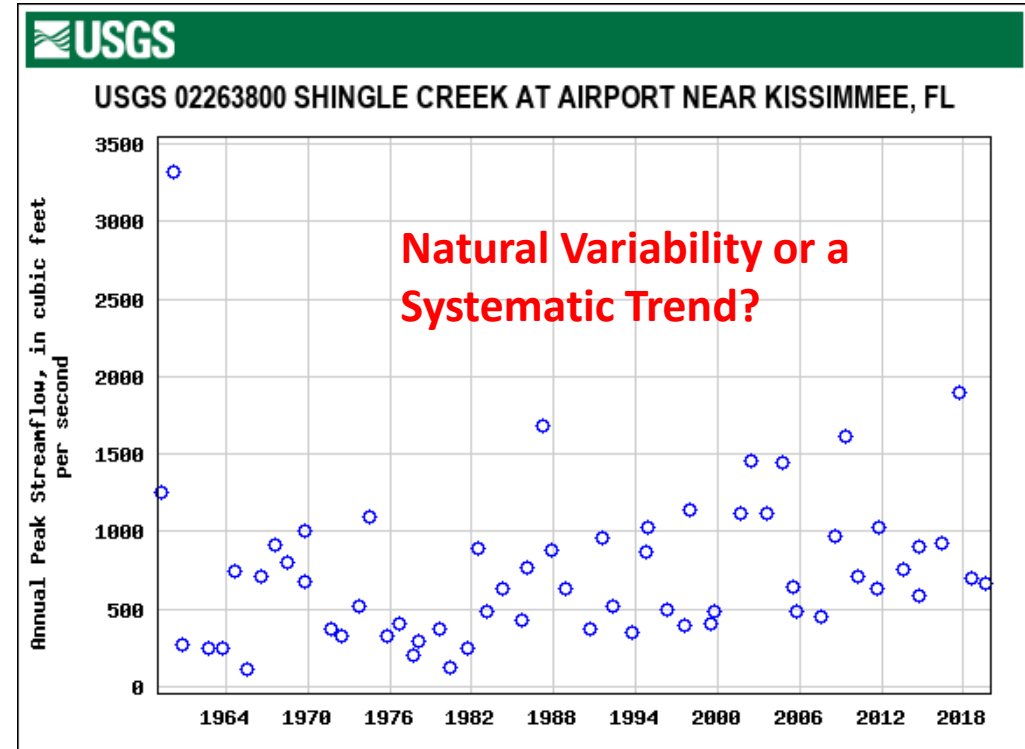
Relevant FDOT Literature

- FDOT Drainage Manual dated January 2020
- **FDOT Drainage Design Guide dated January 2020**
- Regional guidance documents developed by regional district, if applicable
- **FHWA Hydraulic Engineering Circular No. 17, 2nd Edition**
- **FHWA Hydraulic Engineering Circular No. 25, Second Edition or any updates**
- Design Storm Surge Hydrographs For the Florida Coast (September 2003)
- **NOAA ATLAS 14 Point Precipitation Frequency Estimates**
- NOAA Sea Level Trends at Tide Gages around Florida
- **NOAA Regional Sea Level Projections**
- Regional Sea Level Projections published by various organizations such as the SE Florida Climate Compact in Florida and the Tampa Bay region.

*“..sea level rise coupled with storm surges can **inundate coastal roads that would not have inundated in the past, necessitate more emergency evacuations, and require costly, and sometimes recurring, repairs to damaged infrastructure.** Inland flooding from unusually **heavy downpours** can disrupt traffic, damage culverts, and reduce service life. **High heat can degrade materials, resulting in shorter replacement cycles and higher maintenance costs.**” (HEC-17)*

Causes & Detection of Nonstationarity

Natural Factors	Atmospheric and oceanic (climate) variability Wildfires and forest fires Volcanic eruptions and earthquakes Land subsidence Landslides
Anthropogenic (Human-Induced) Factors	Land use changes Climate Change Development of water resources projects



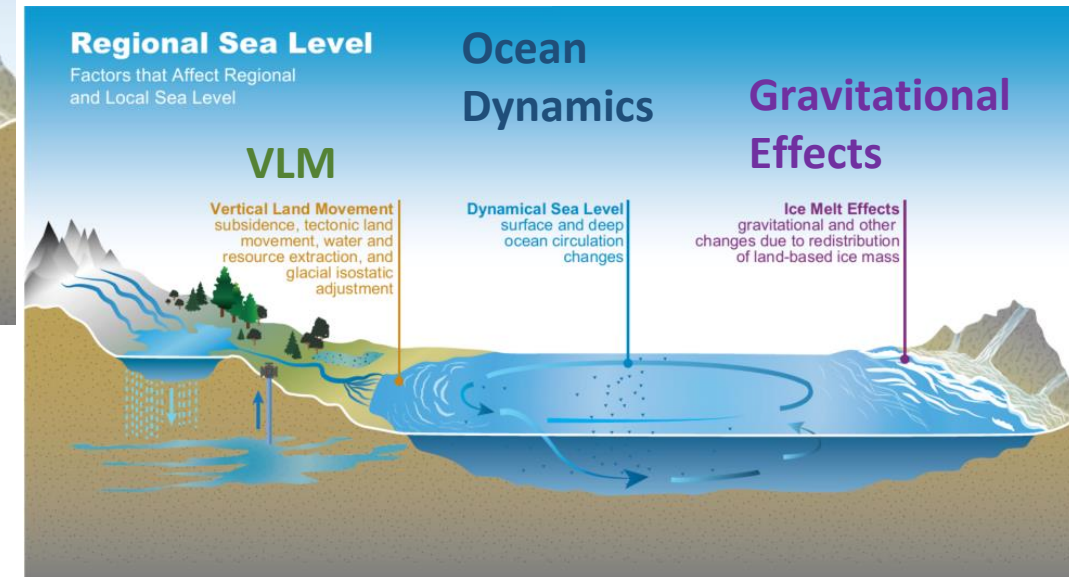
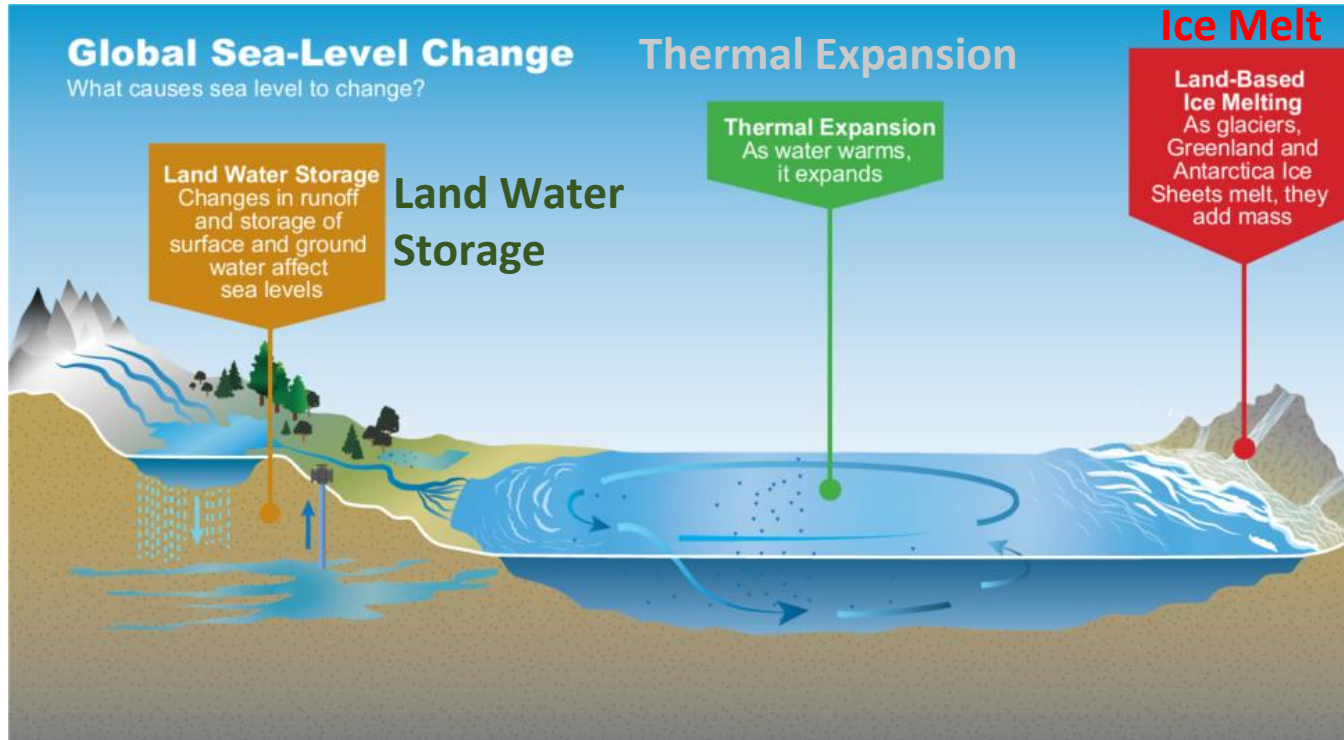
Statistical Methods: **Parametric & Nonparametric**

US Army Corps of Engineers:

Nonstationarity Detection Tool (NSD) – PROD

http://corpsmapu.usace.army.mil/cm_apex/f?p=257:1:0

Sources of Global and Regional Sea Level Change



Planning for Sea Level Rise

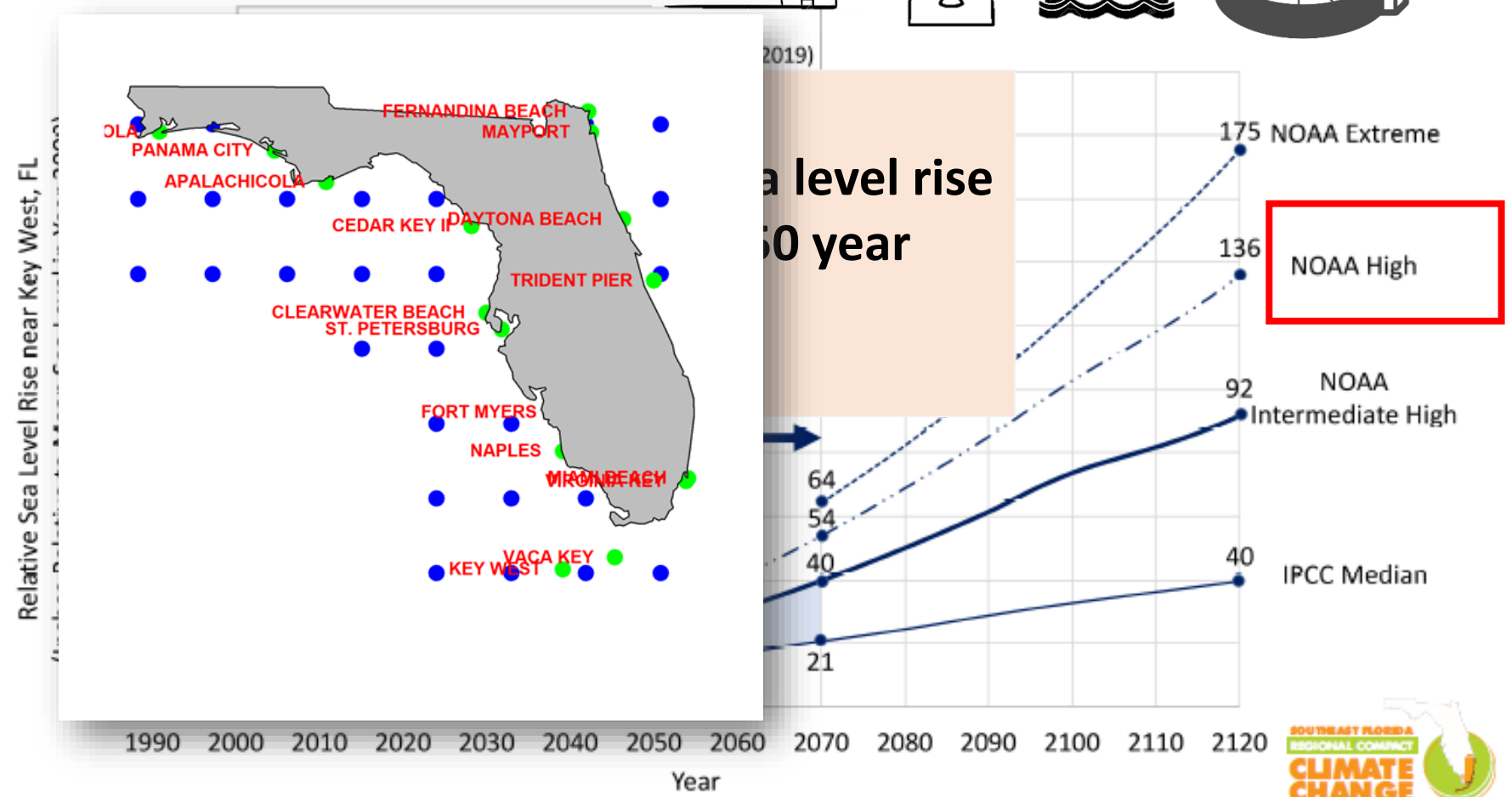
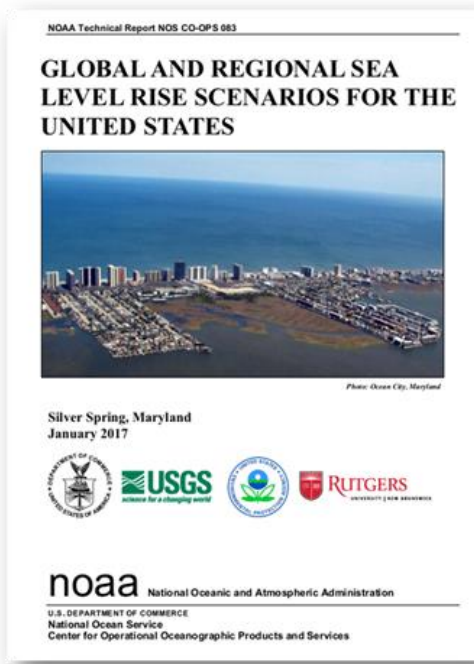
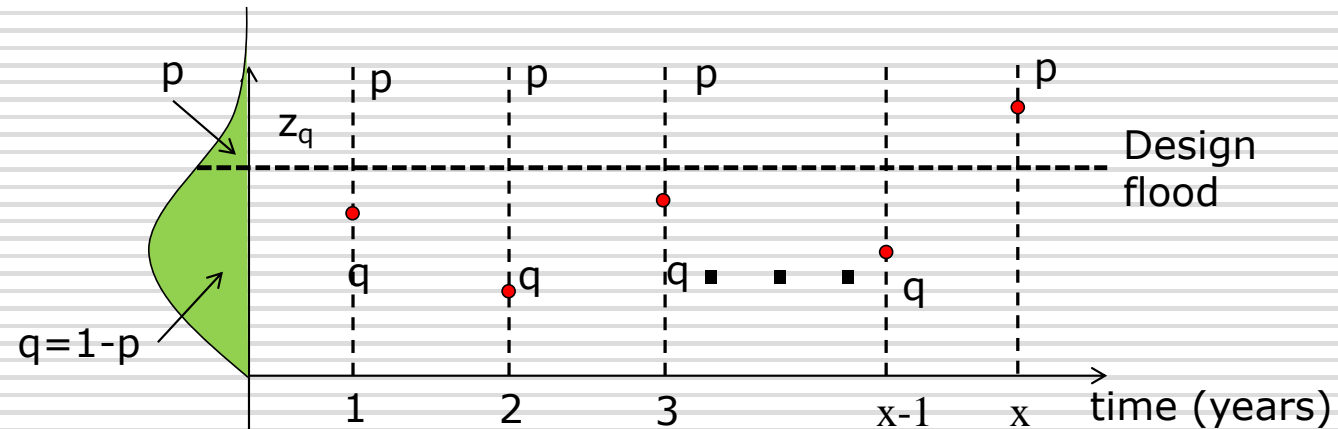


FIGURE 1: Unified Sea Level Rise Projection

Return Period under Stationarity

- No-Flood/Flood occurrence



Event	NF	NF	NF	...	F	
Probability	1-p	1-p	1-p	...	p	

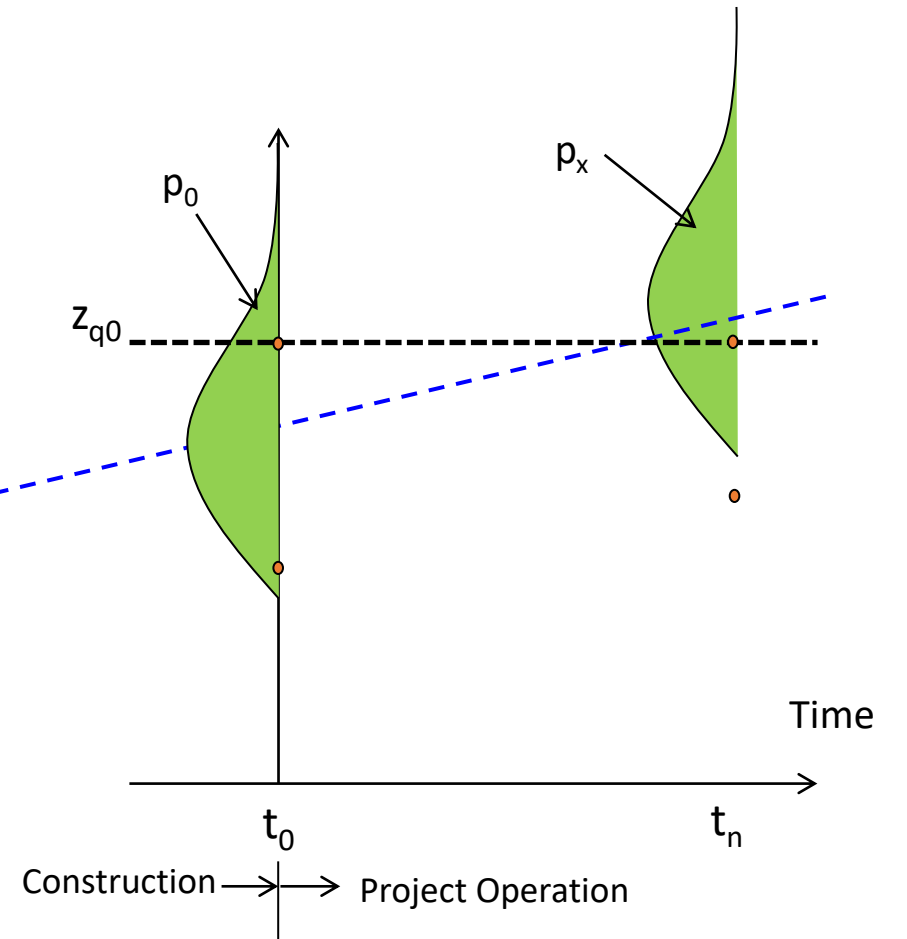
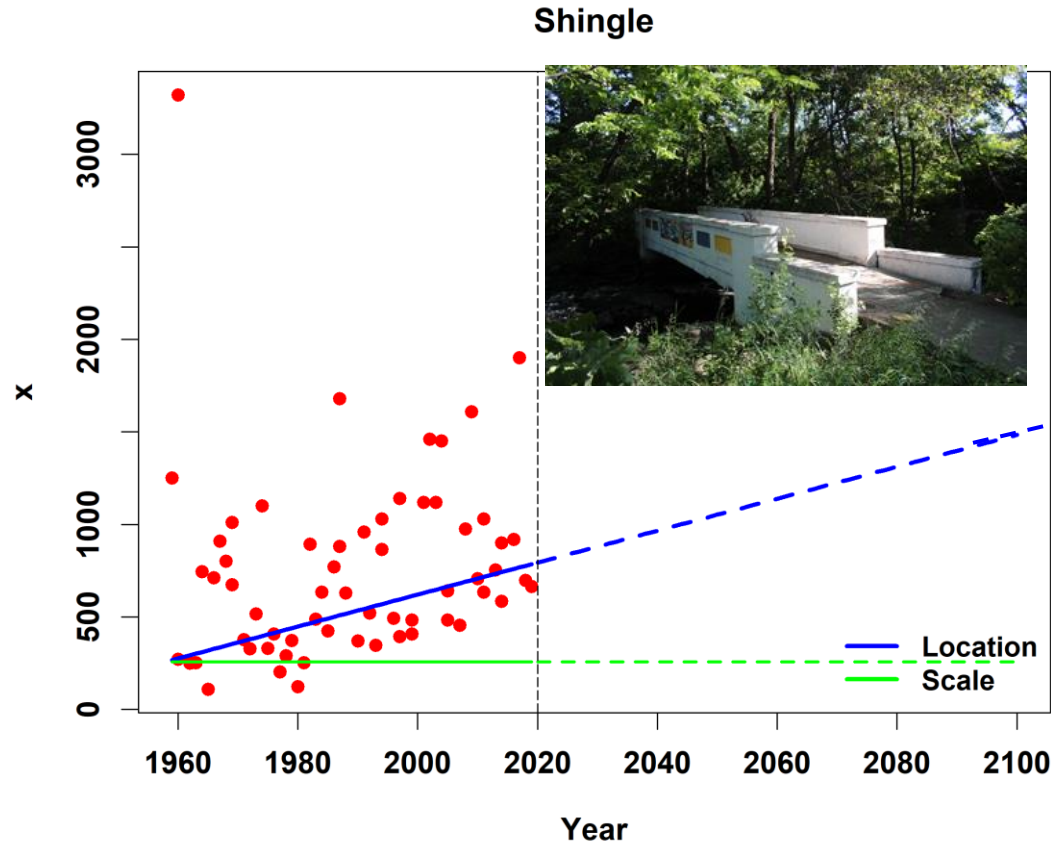
NF = No flood event exceeding z_q F = Flood event exceeding z_q

**Geometric
Distribution:**

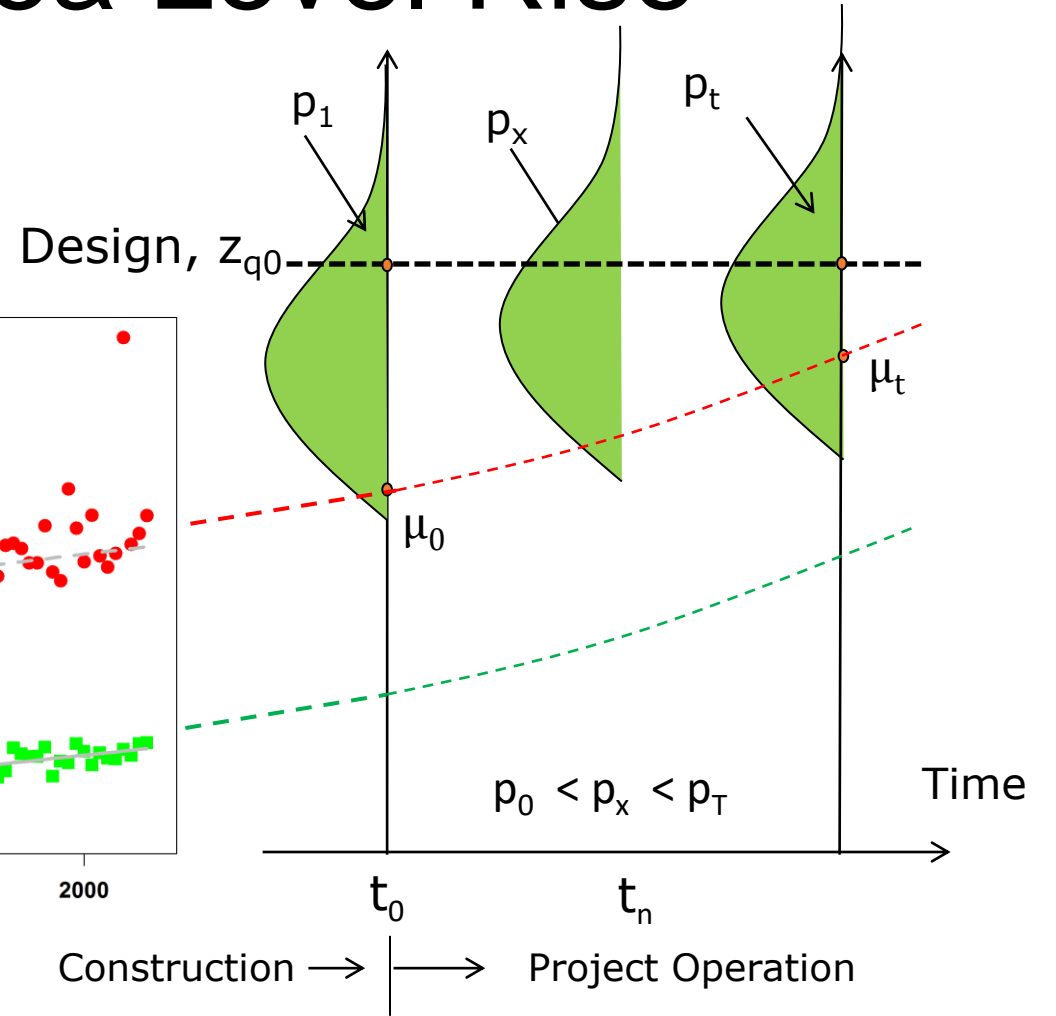
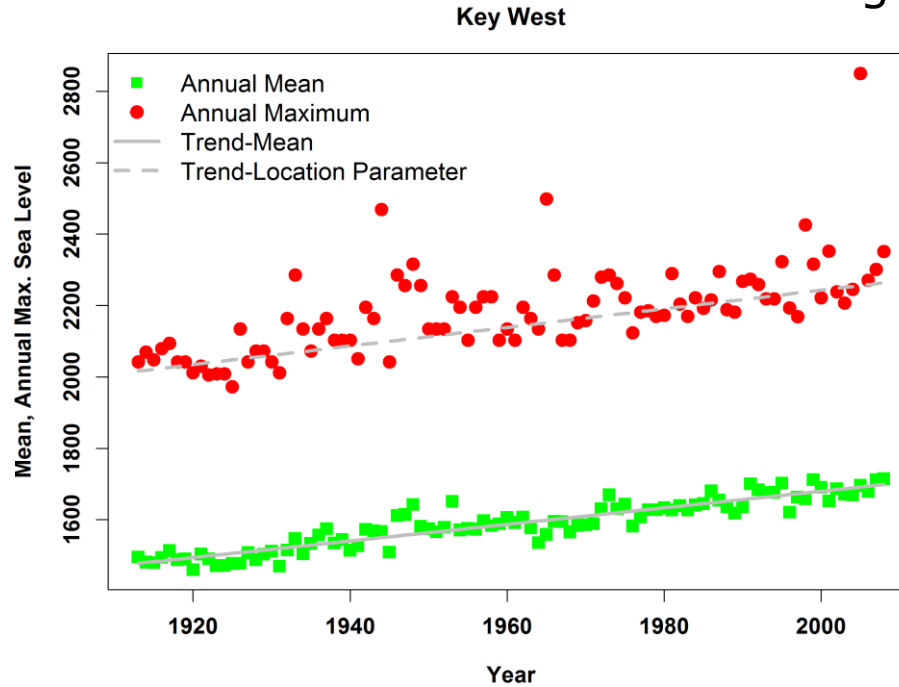
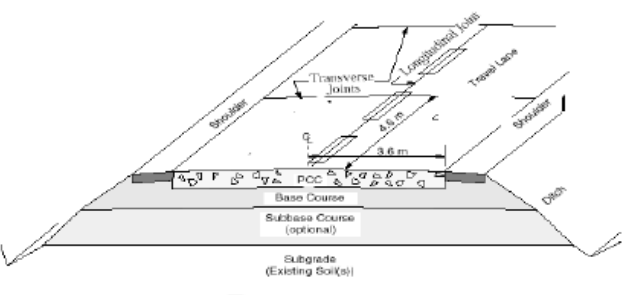
**Return Period:
 $T = 1/p$**

**If $T=100$ yr then
event has 1/
%
chance of
exceedance**

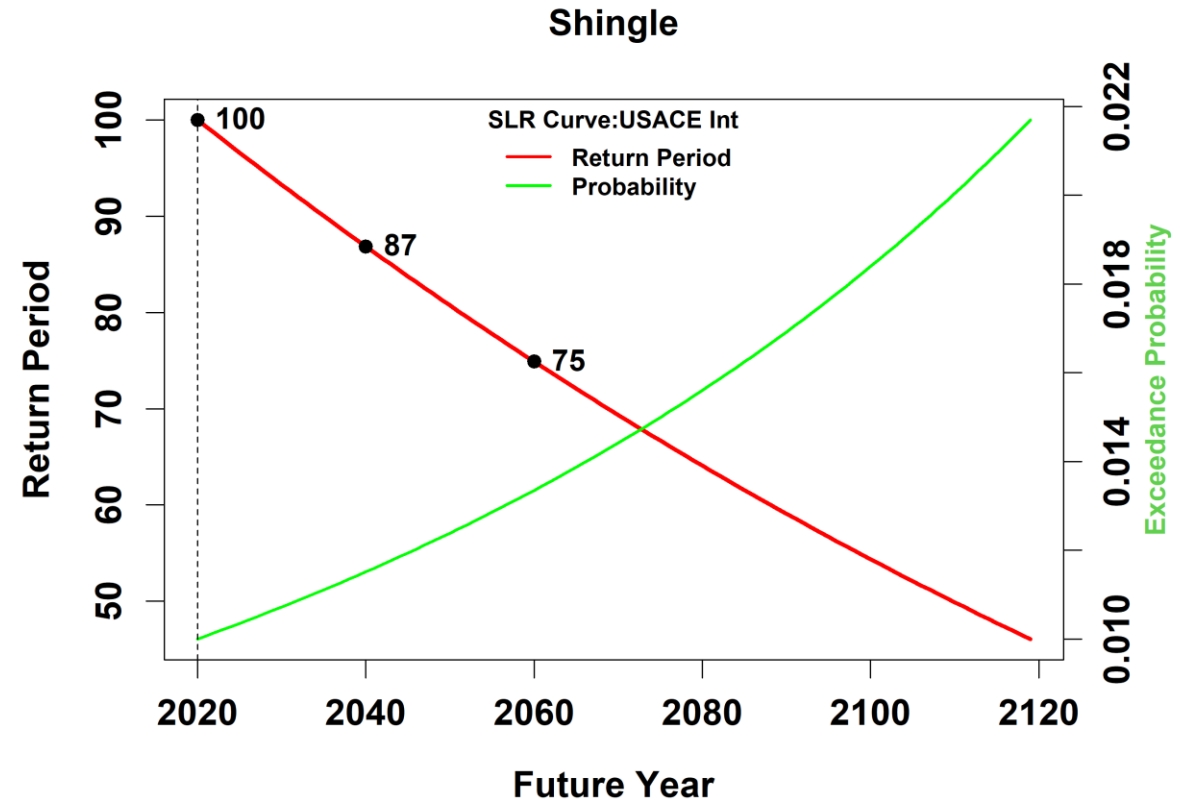
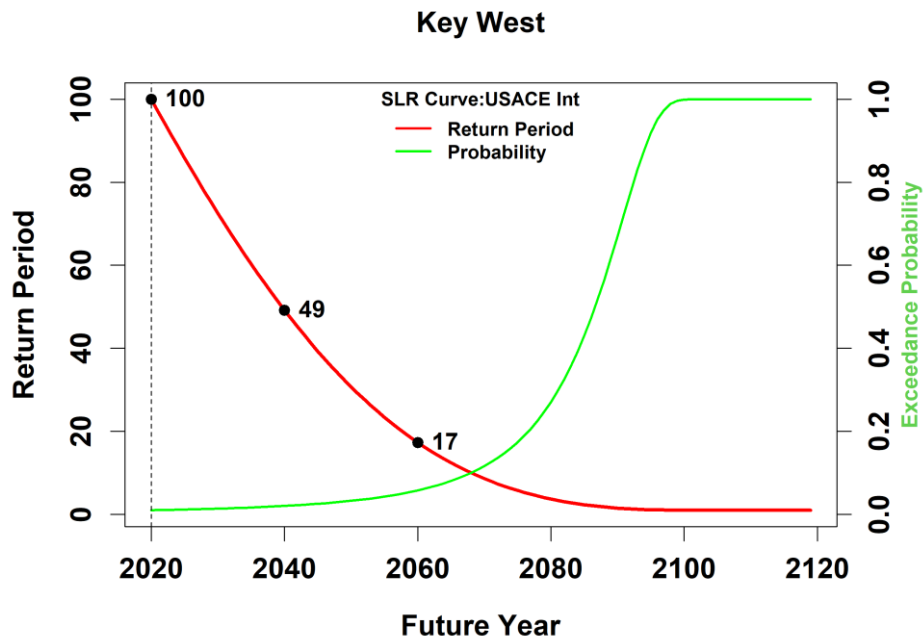
Nonstationarity: Extreme Floods



Nonstationarity: Sea Level Rise



Why Designs under Stationary assumption may fail?



New Paradigm: Return Period and Risk under Nonstationarity

- Return Period is defined as the “expected time for the first exceedance” (expected waiting time)

$$T = E X = 1 + \prod_{t=1}^{\infty} (1 - p_t)$$

- Risk

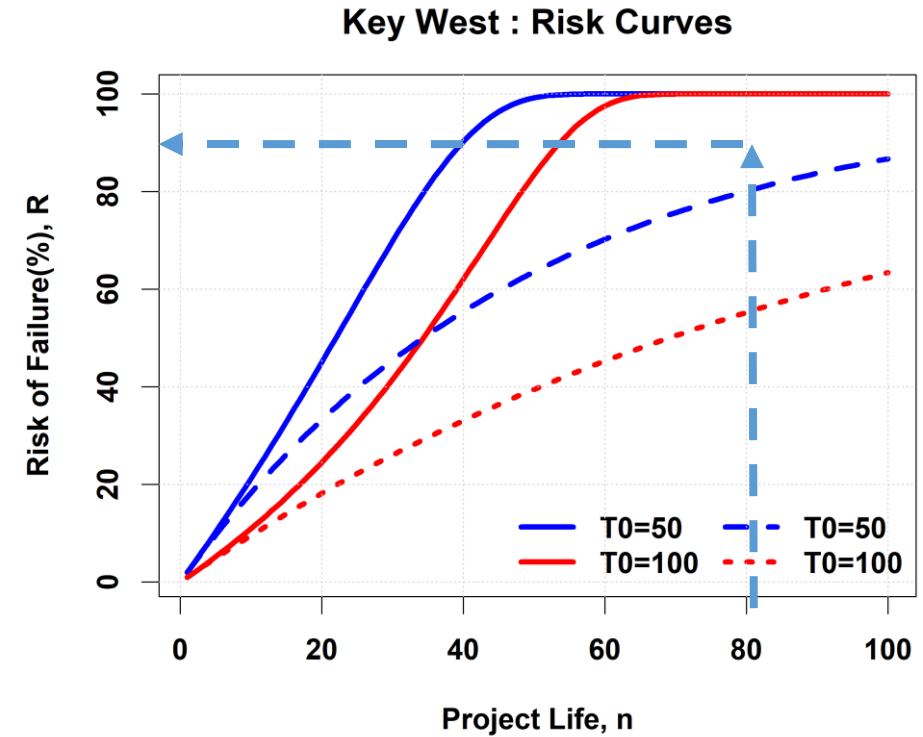
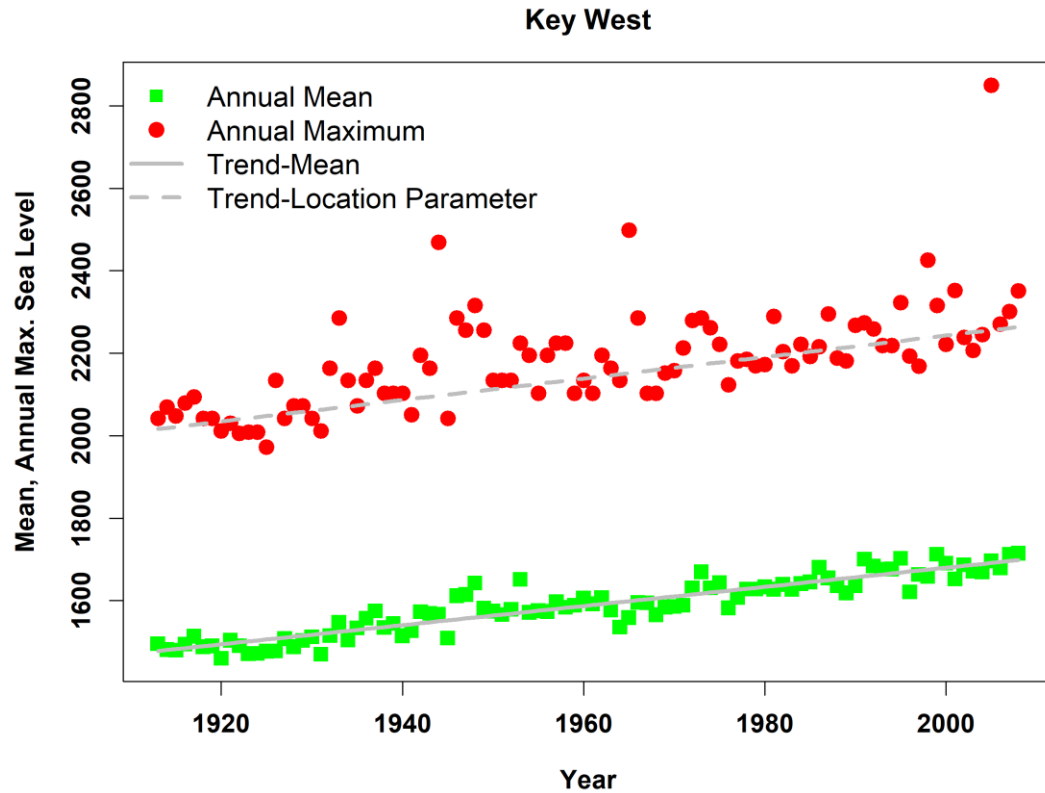
$$R = 1 - \prod_{i=1}^n (1 - p_i)$$

Methods under stationarity

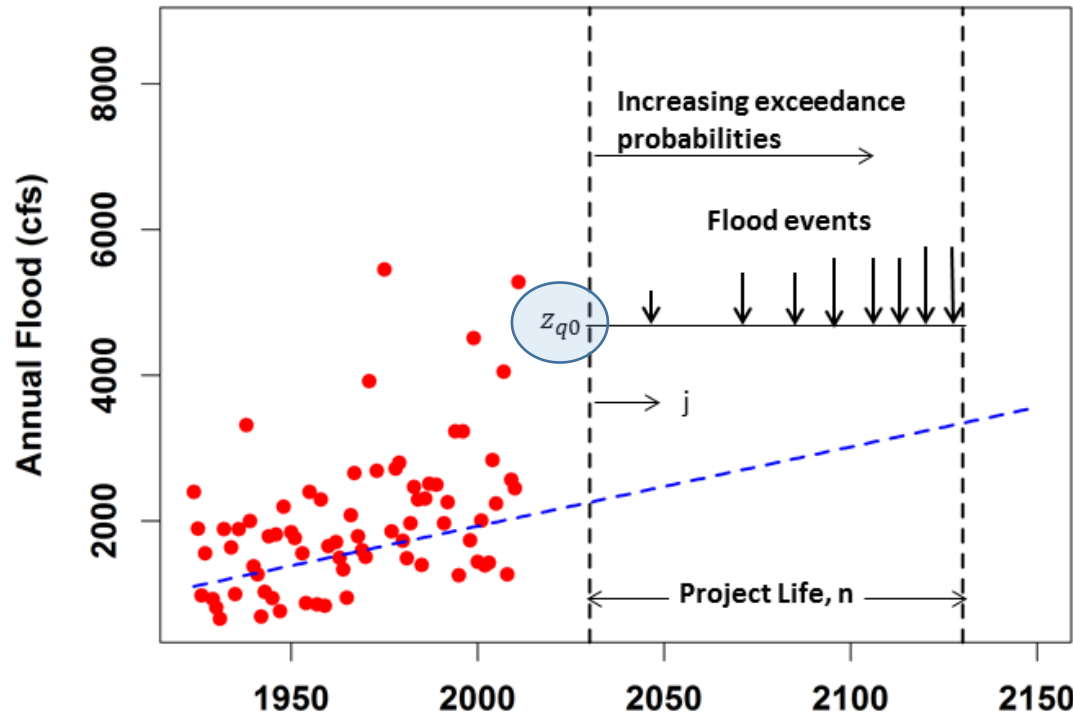
$$T = 1/p$$

$$R = 1 - (1 - p)^n$$

Example: Key West

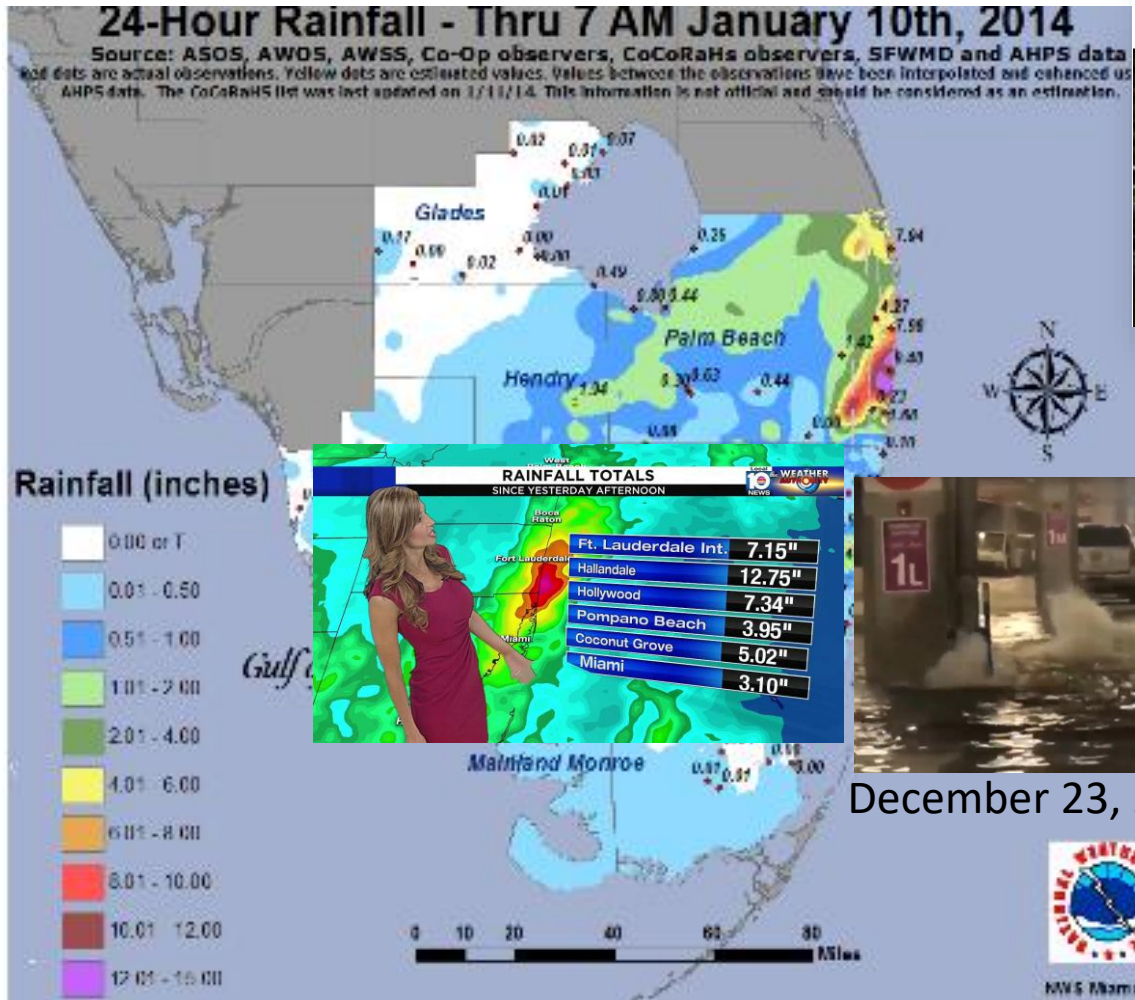


Hydrologic Design considering Nonstationarity



- ❑ Expected Waiting Time – Return Period (**EWT**)
 - ✓ Waiting time for the first exceedance
- ❑ Expected Number of Events (**ENE**)
 - ✓ Tolerance for frequency of flooding
- ❑ Design Life Level (**DLL**)
 - ✓ Design for a specified risk (say, 5%)

Rainfall Flooding and Heat Stress

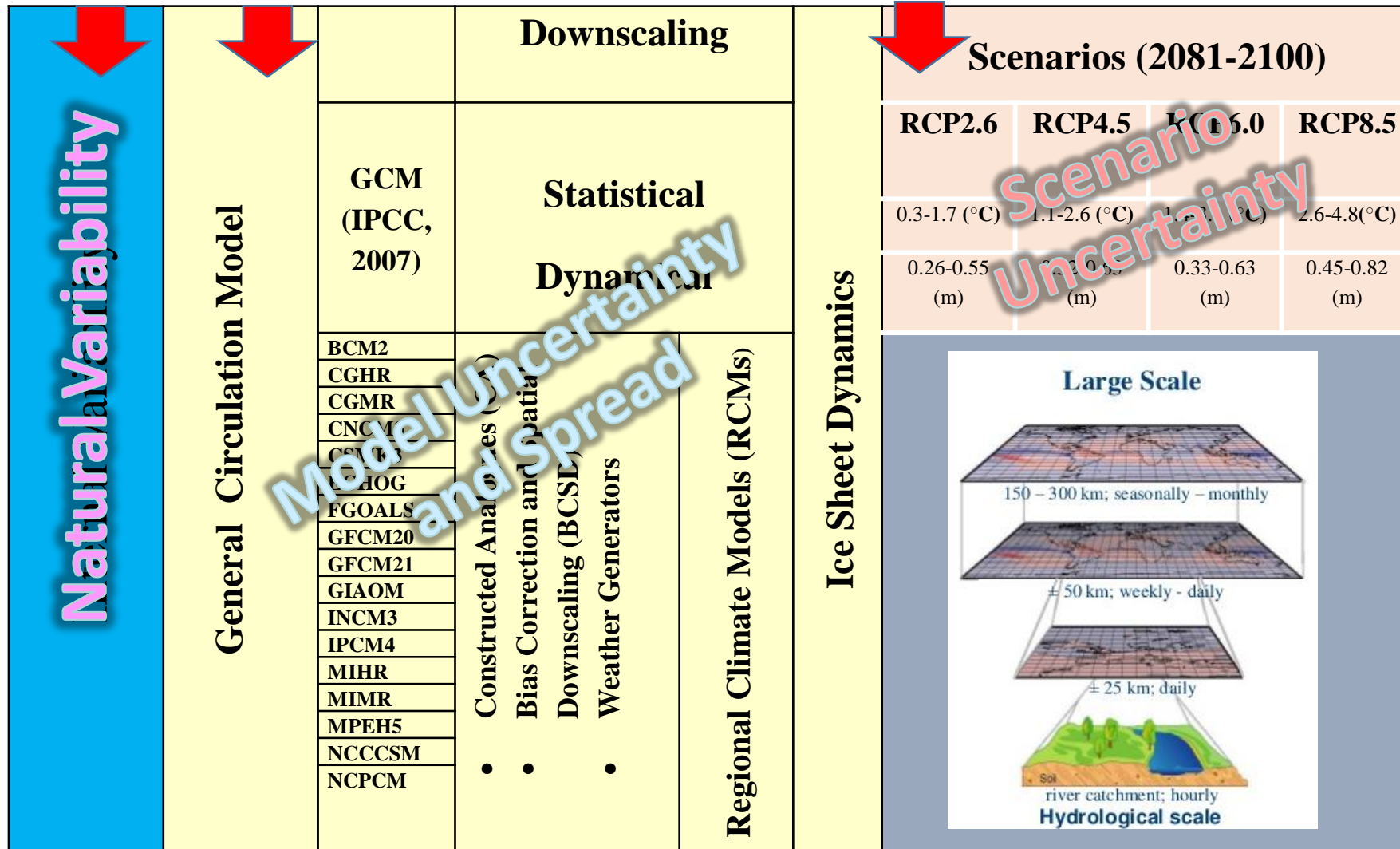


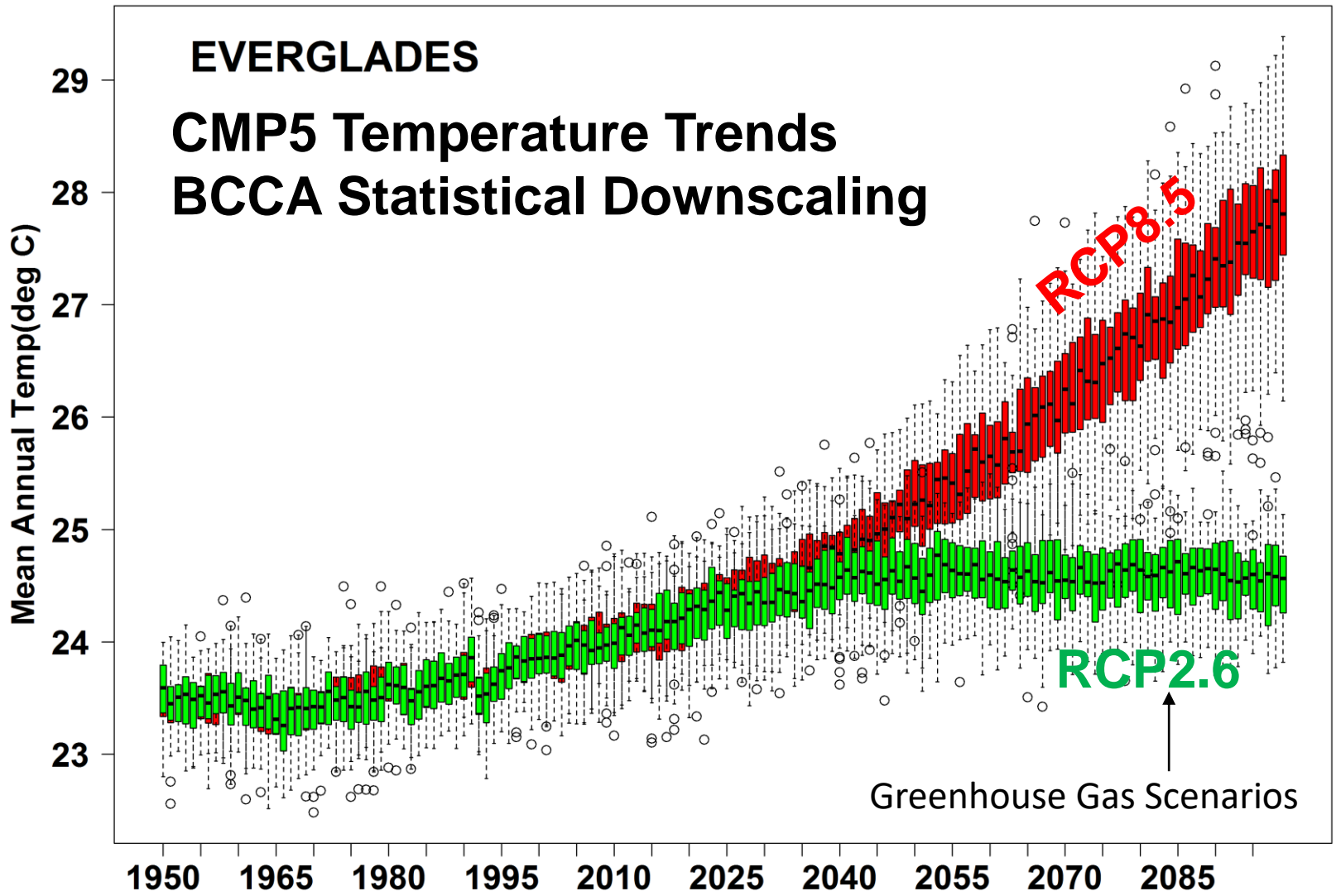
Historic Palm Beach Flooding January 9-10 2014



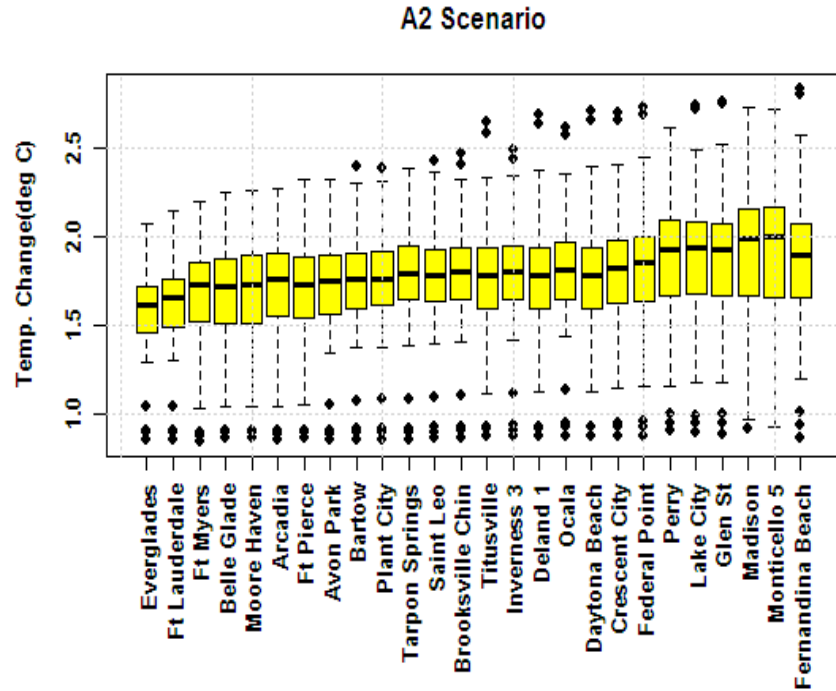
Heat index above	Historical	By midcentury	By late century	By late century, if we limit warming to 2°C
90°F	150 days per year	183 days per year	198 days per year	179 days per year
100°F	34 days per year	126 days per year	160 days per year	108 days per year
105°F	5 days per year	79 days per year	131 days per year	51 days per year

Climate Projection Uncertainties

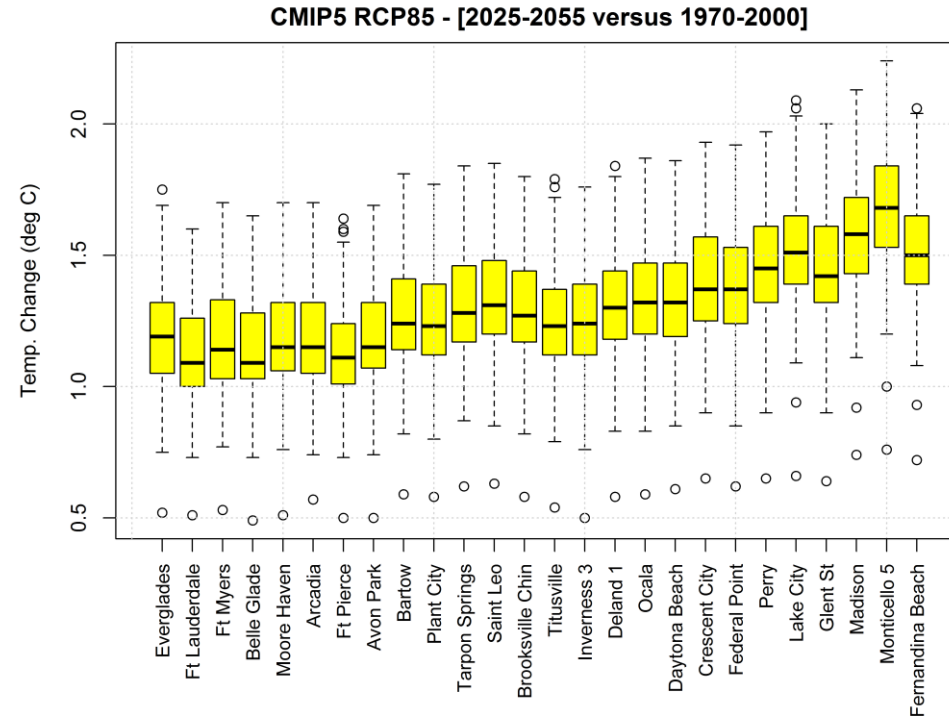




Spatial Trends in Florida (Temperature)

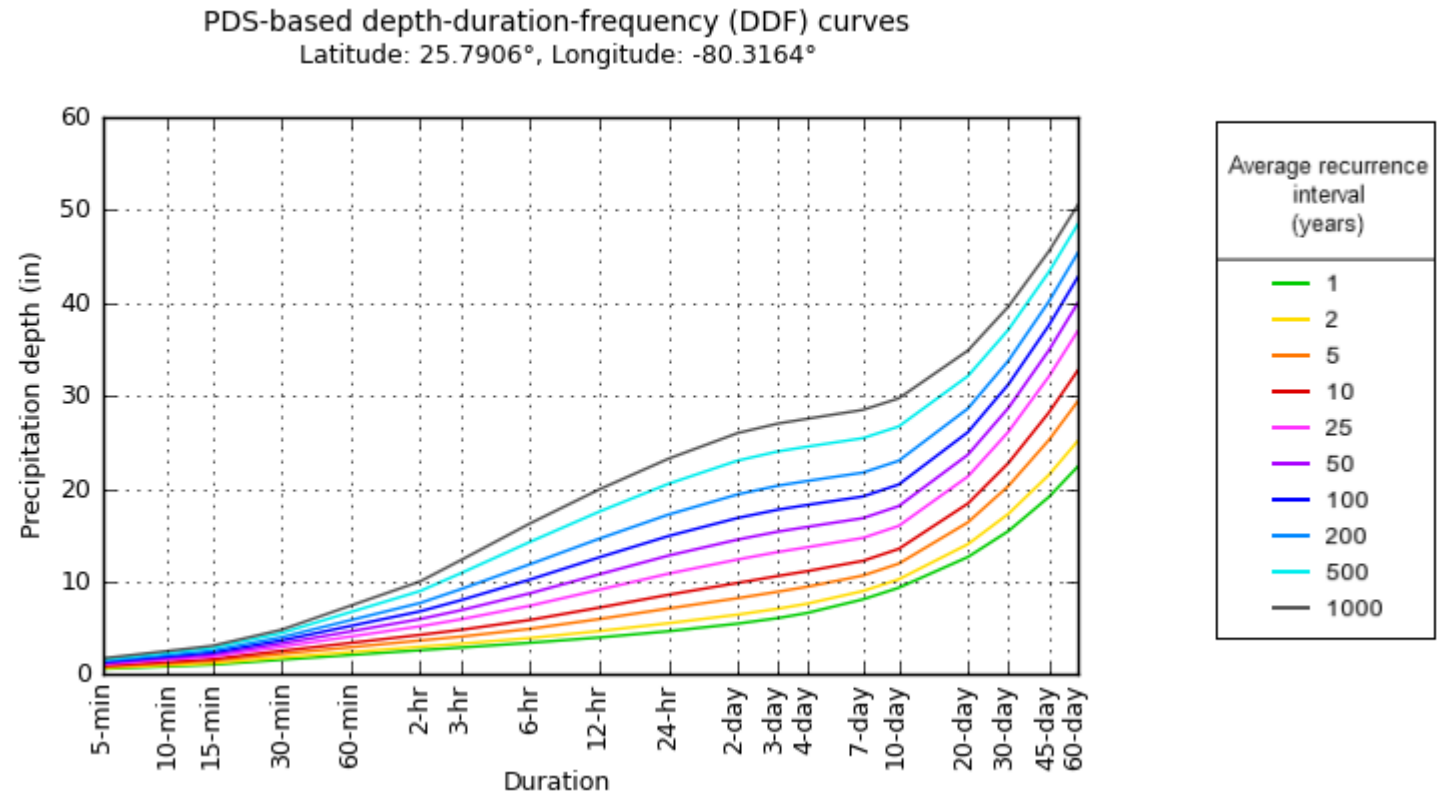
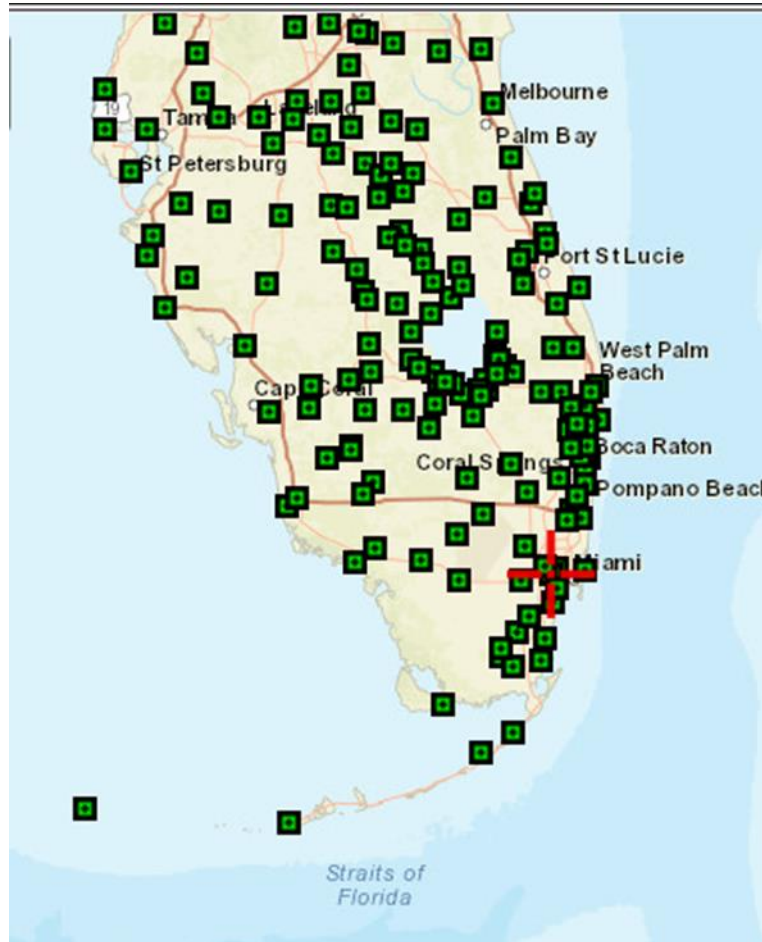


CMIP3

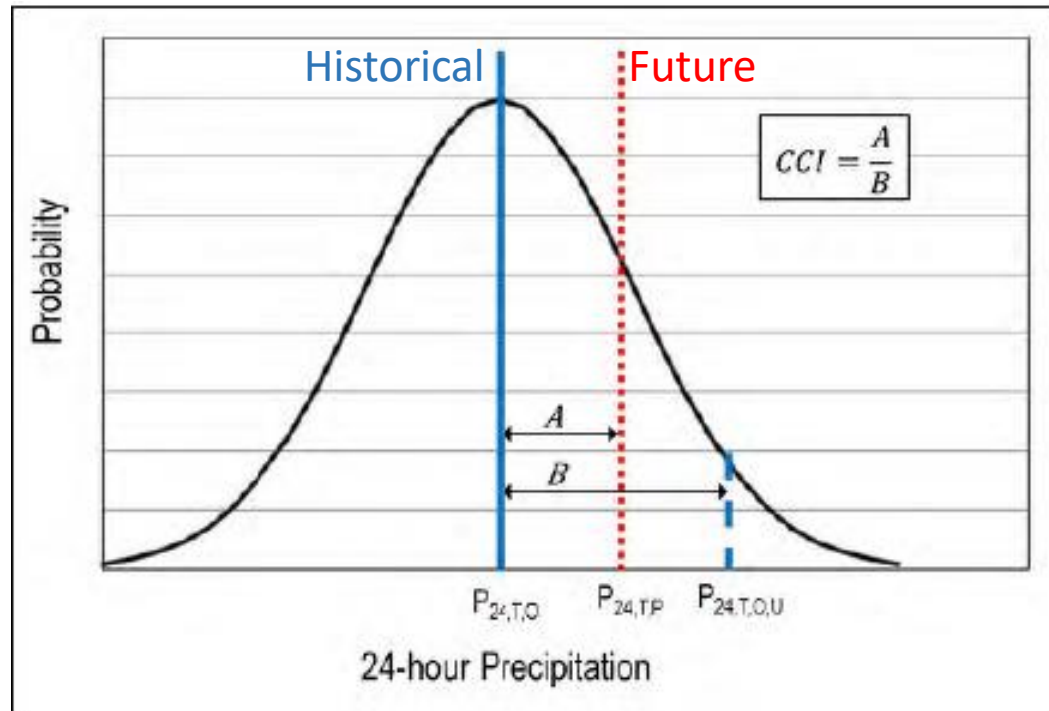


CMIP5

NOAA Atlas 14 Volume 9



HEC-17 Approach: Climate Change Indicator



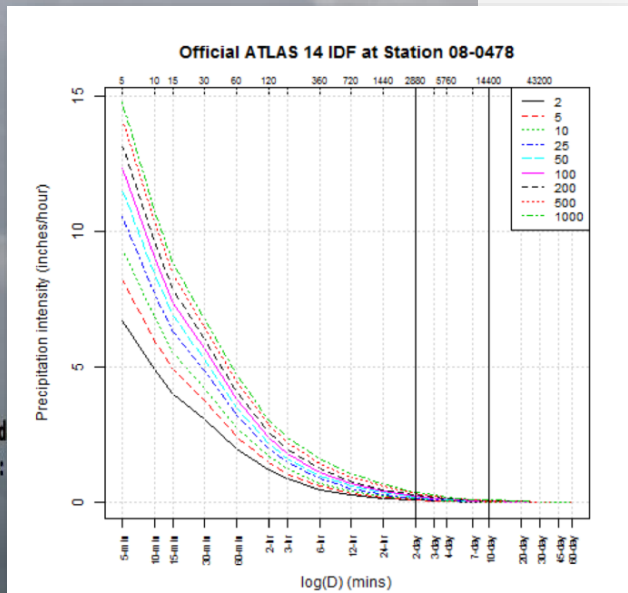
If $CCI < 0.4$, historical data likely sufficient

If $CCI > 0.8$ further analysis of projected conditions may be warranted.

Extreme rainfall: Is there any skill?

Determination of Future Intensity-Duration-Frequency Curves for Level of Service Planning Projects

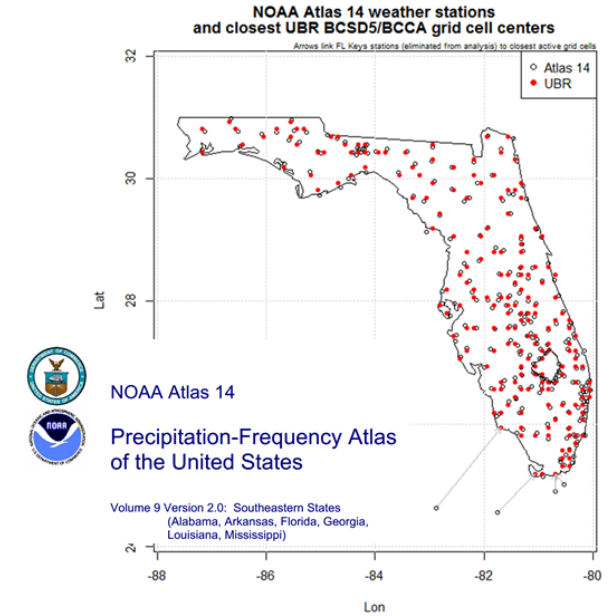
Extreme Rainfall Analysis in Climate Model Outputs to Determine Temporal Changes in Intensity-Duration-Frequency Curves



By:
Michelle M. Irizarry-Consultant
In Collaboration with South Florida
Water Management District Staff:
Jayantha Obeysekera
Tibebe Dessalegne

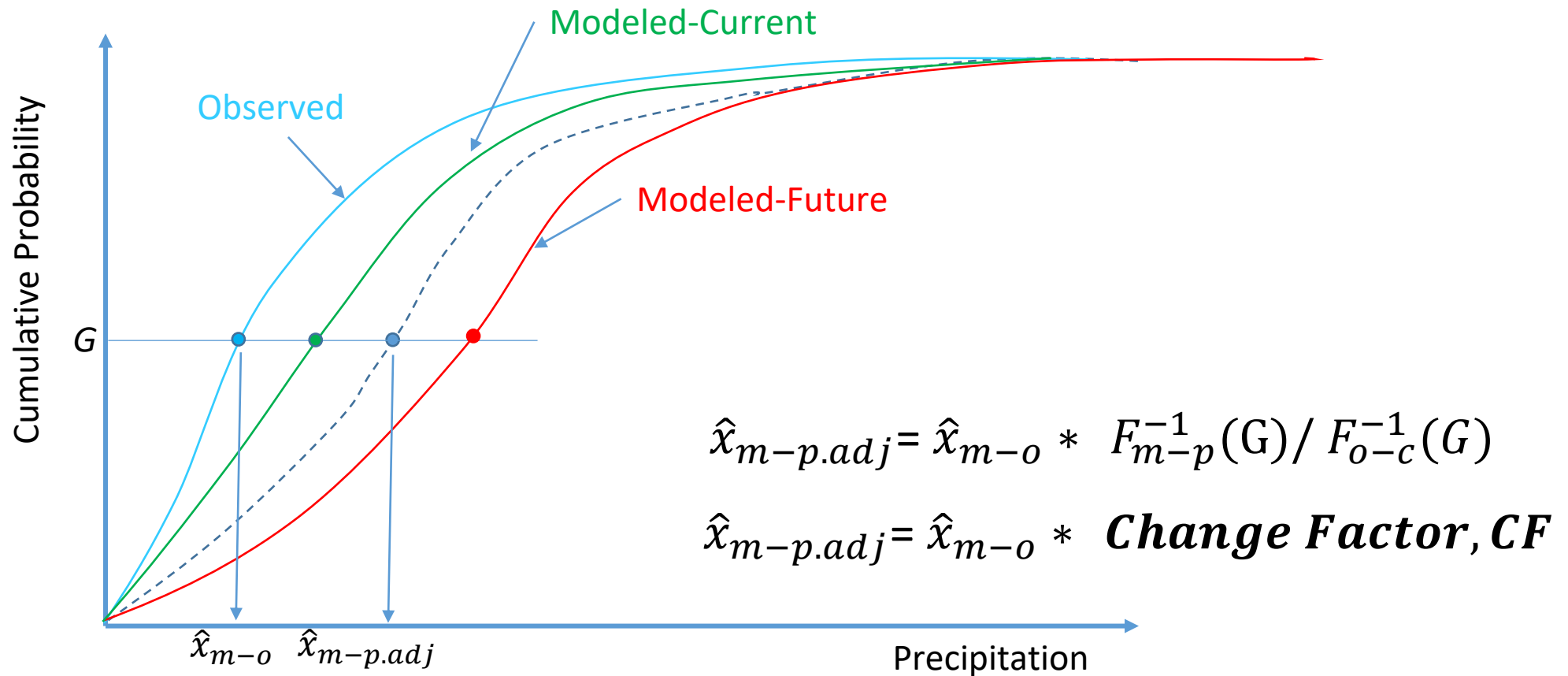
November 10, 2016

- BCCA bias corrected downscaling method used by US Bureau of Reclamation: mute out the extremes
- Much lower and less variable extremes in the downscaled models compared to the observational dataset
- Bias is larger than delta



Perc	24-hr_2-year	24-hr_5-year	24-hr_10-year	24-hr_25-year	24-hr_50-year	24-hr_100-year
5%	-2.35 (-57.4%)	-3.28 (-59.6%)	-3.99 (-60.8%)	-5 (-62.3%)	-5.86 (-63.3%)	-6.82 (-64.2%)
10%	-2.33 (-57%)	-3.25 (-59%)	-3.96 (-60.4%)	-4.94 (-61.4%)	-5.76 (-62.1%)	-6.71 (-62.9%)
50%	-2.25 (-54.9%)	-3.1 (-56.3%)	-3.76 (-57.3%)	-4.67 (-58.1%)	-5.45 (-58.7%)	-6.34 (-59.2%)
90%	-2.19 (-53.5%)	-3.05 (-55.3%)	-3.66 (-55.9%)	-4.53 (-56.3%)	-5.24 (-56.3%)	-6.01 (-55.8%)
95%	-2.16 (-52.9%)	-3.03 (-54.7%)	-3.64 (-55.3%)	-4.43 (-54.7%)	-5.11 (-54.5%)	-5.84 (-54.1%)

Multiplicative Quantile Delta Mapping (probably a better method)



Dynamic Adaptive Policy Pathways (DAPP)

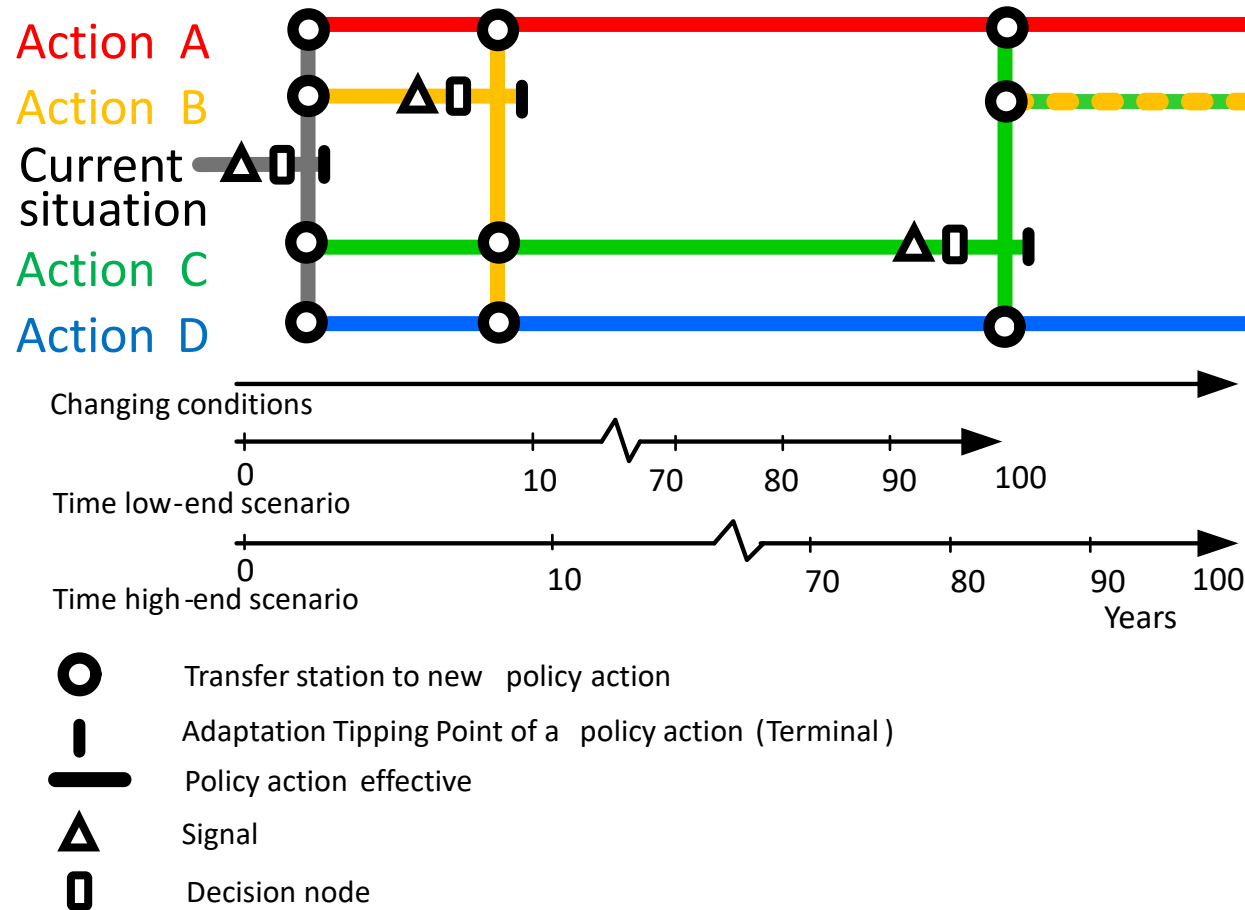
Decisions are made over time in dynamic interaction with the system and cannot be considered independently.

- An approach that explicitly includes decision making over time and sequences of decisions (pathways) under uncertainty.
- Supports planners to design a dynamic adaptive plans: short-term actions, long-term options, adaptation signals.

“Different roads leading to Rome”

Haasnoot et al. (2013) Glob. Env. Change. 10.1016/j.gloenvcha.2012.12.006

Dynamic Adaptive Policy Pathways (DAPP)



Time horizon 100 years

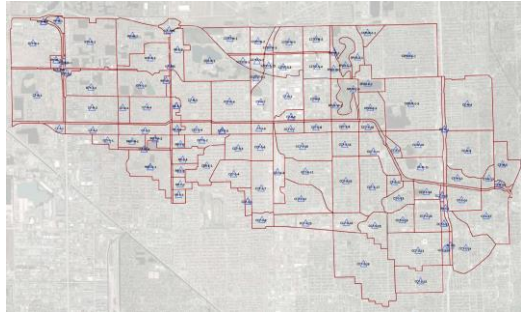
Pathway	Costs	Benefits	Co-benefits
1 ○	+++	+	0
2 ○	+++++	0	0
3 ○	+++	0	0
4 ○	+++	0	0
5 ○	0	0	-
6 ○	++++	0	-
7 ○	+++	0	-
8 ○	+	+	---
9 ○	++	+	---

Pathways that are not necessary in the low-end scenario

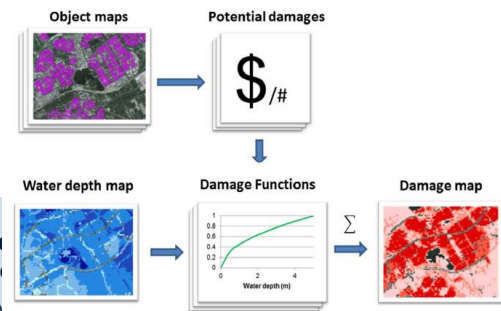
Flood Risk Management in Miami-Dade County : C-7 basin

Hydrologic Drivers:
Rainfall; Storm Surge
Sea Level Rise

Hydrodynamic Model
XPSWMM

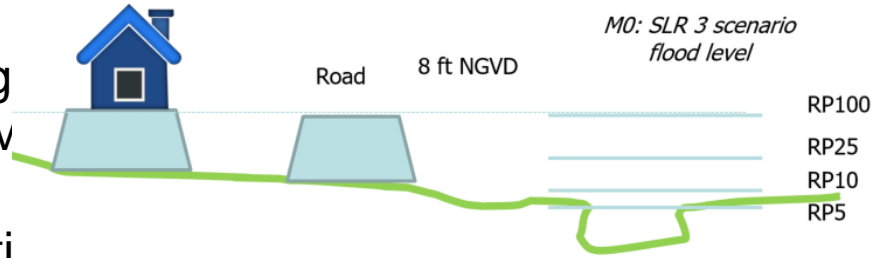


Delft-FIAT damage model



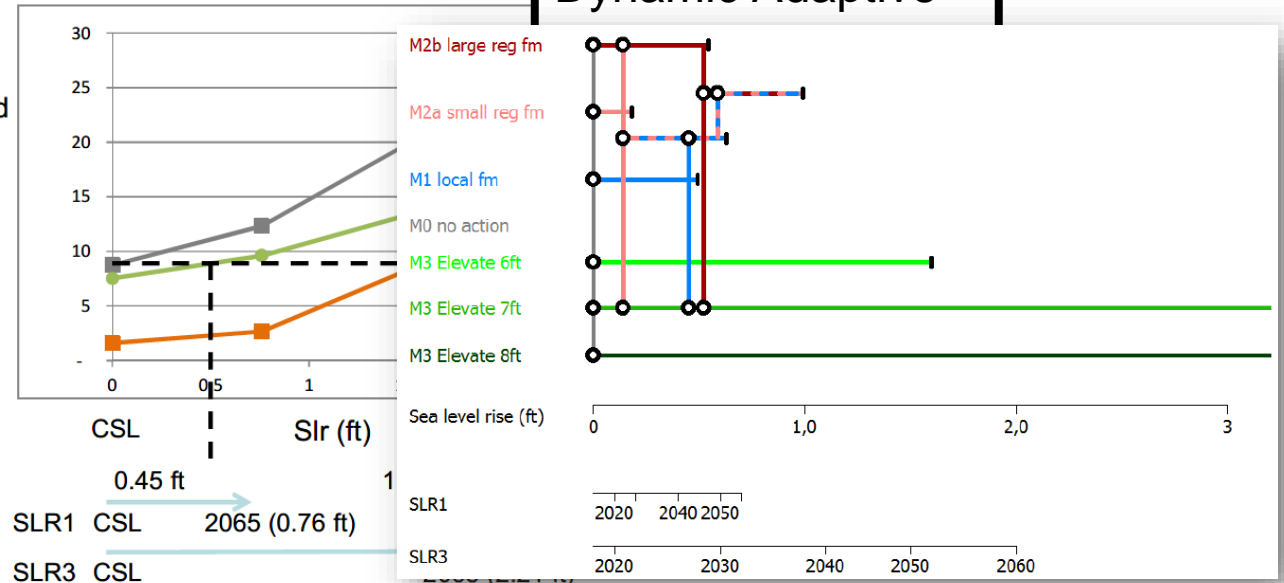
Adaptation Options:

- M1:Local Flood Mitig
- M2:Regional Flood M (at outlet)
- M3:Land-use mitigati (roads)



Dynamic Adaptive

Expected Annual Damage (k\$)



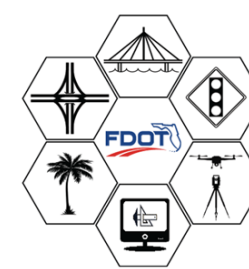
Summary: Five Resilience Principles

- Adopt a system's approach;
- Look at beyond-design events;
- Build and prepare infrastructure according to 'remain functioning'
- Increase recovery capacity by looking at social and financial capital; and
- Remain resilient into the future

Resilience in practice: Five principles to enable societies to cope with extreme weather events

Karin de Bruijn^{a,*}, Joost Buurman^b, Marjolein Mens^a, Ruben Dahm^a, Frans Klijn^{a,c}

Questions?



FDOT
TRANSPORTATION
SYMPOSIUM
2020 Webinar Series

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