City of Jacksonville
Storm Resiliency and Hardening Project

Storm Resiliency and Hardening Workshop on Future Climate Scenarios

July 22, 2020 | 1:00 – 4:00 p.m. EDT

For optimum viewing, please adjust your Zoom settings to the following:

1. Ensure your camera is on and microphone remains muted. These controls are at the bottom left of your screen.
2. At the top center of your screen, click View Options and select Side by Side mode.

Climate Scenarios Workshop

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Laurens Van der Tak, PE
David Spector, LEED-AP ENVSP

July 22, 2020

CDM Smith

Jacobs

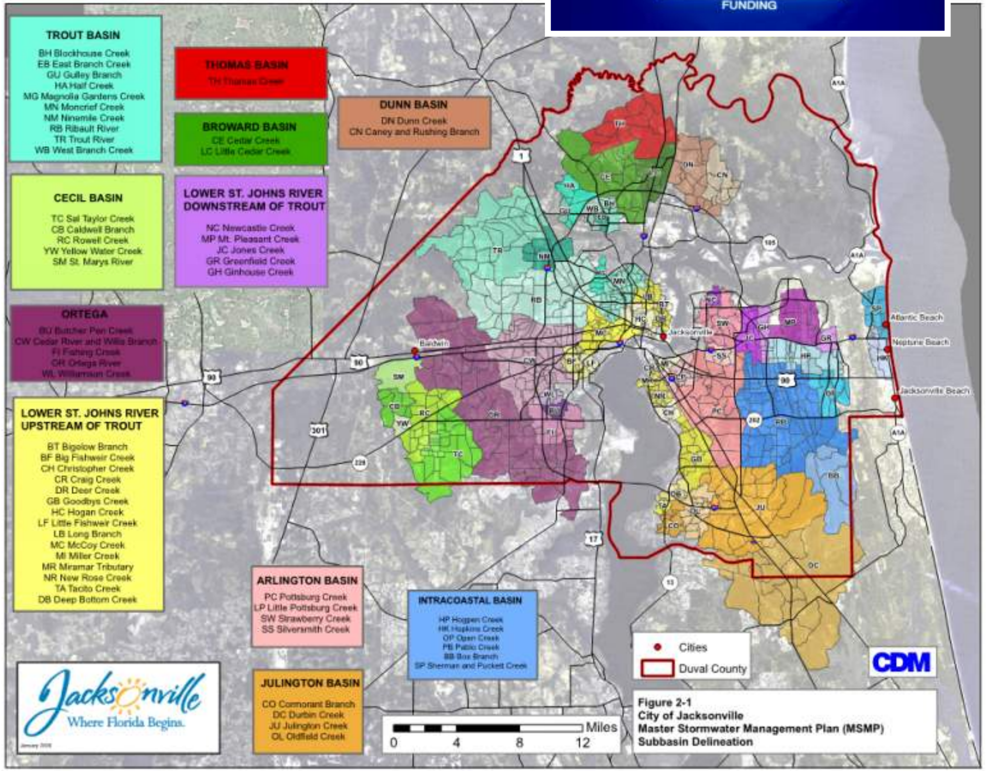
Agenda

- Project Context
- Climate Science Primer
- Questions and Break
- Sea Level and Rainfall Projections
- Storm Surge Projections
- Feedback Discussion
- Recommended Scenarios for City of Jacksonville
- Feedback Discussion
- Project Look-Forward

Project Context

Jacksonville Master Stormwater Management Plan (MSMP)

- 800 Square Miles
- 64 Subbasins for the Primary System
- Models focus on main creeks and tributaries
  - pipes >2ft
  - Hydrologic units appx 100ac
- Implementation of MSMP recommendations
  - $150M in projects
  - Development Criteria
    - Volume-time Detention
    - 100-yr Floodplain Protection



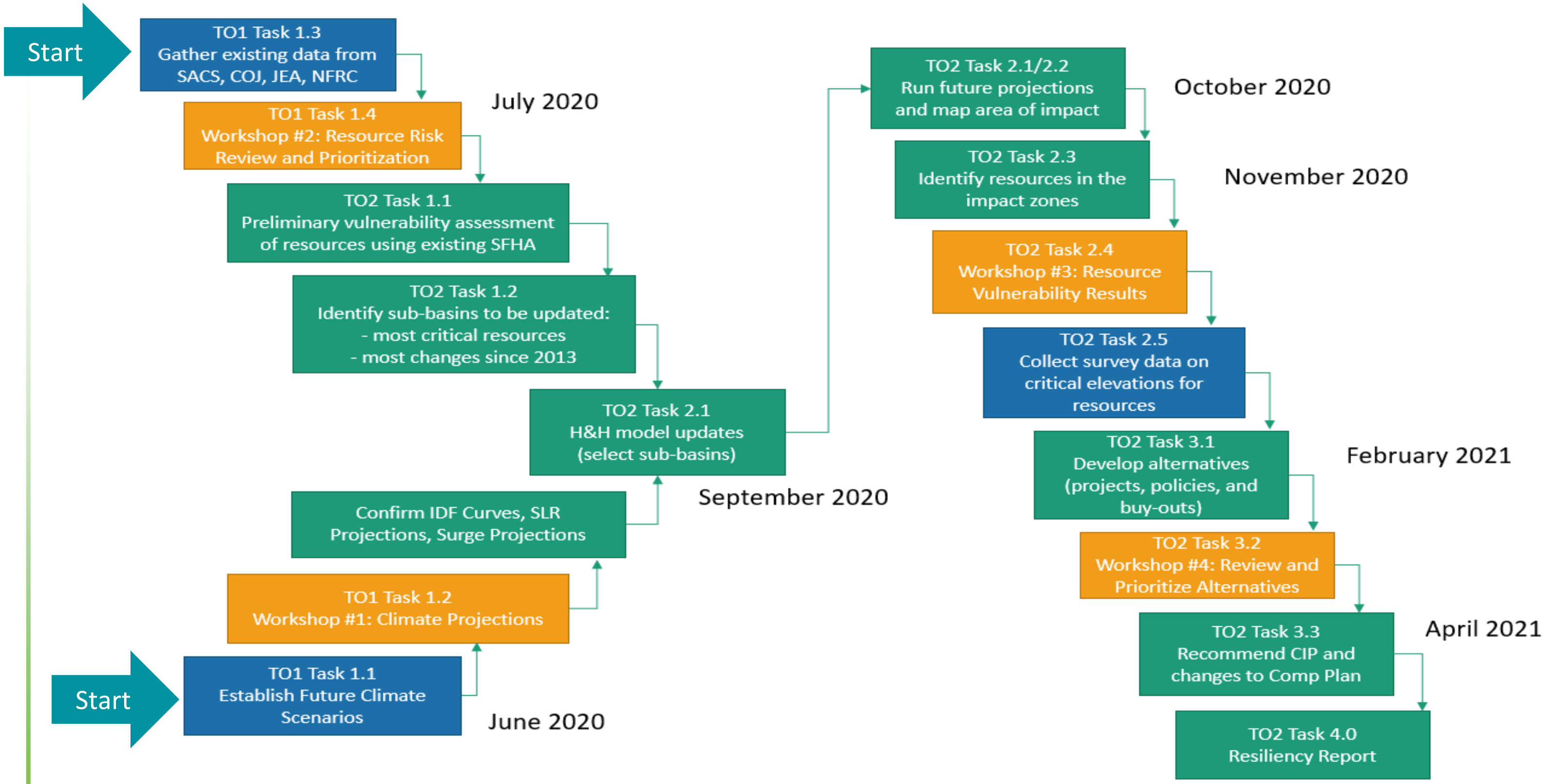
Jacksonville Master Stormwater Management Plan (MSMP)

- Models from 1987 were expanded and updated in 2011 and 2014
- Integrated models solve the entire system, not as individual branches
- Utilizes tidal stillwater elevation >2.7ft above normal FEMA riverine levels
- Effective SFHA incorporates MSMP results
- Successful model field verifications
- Models are used throughout Public Works planning efforts

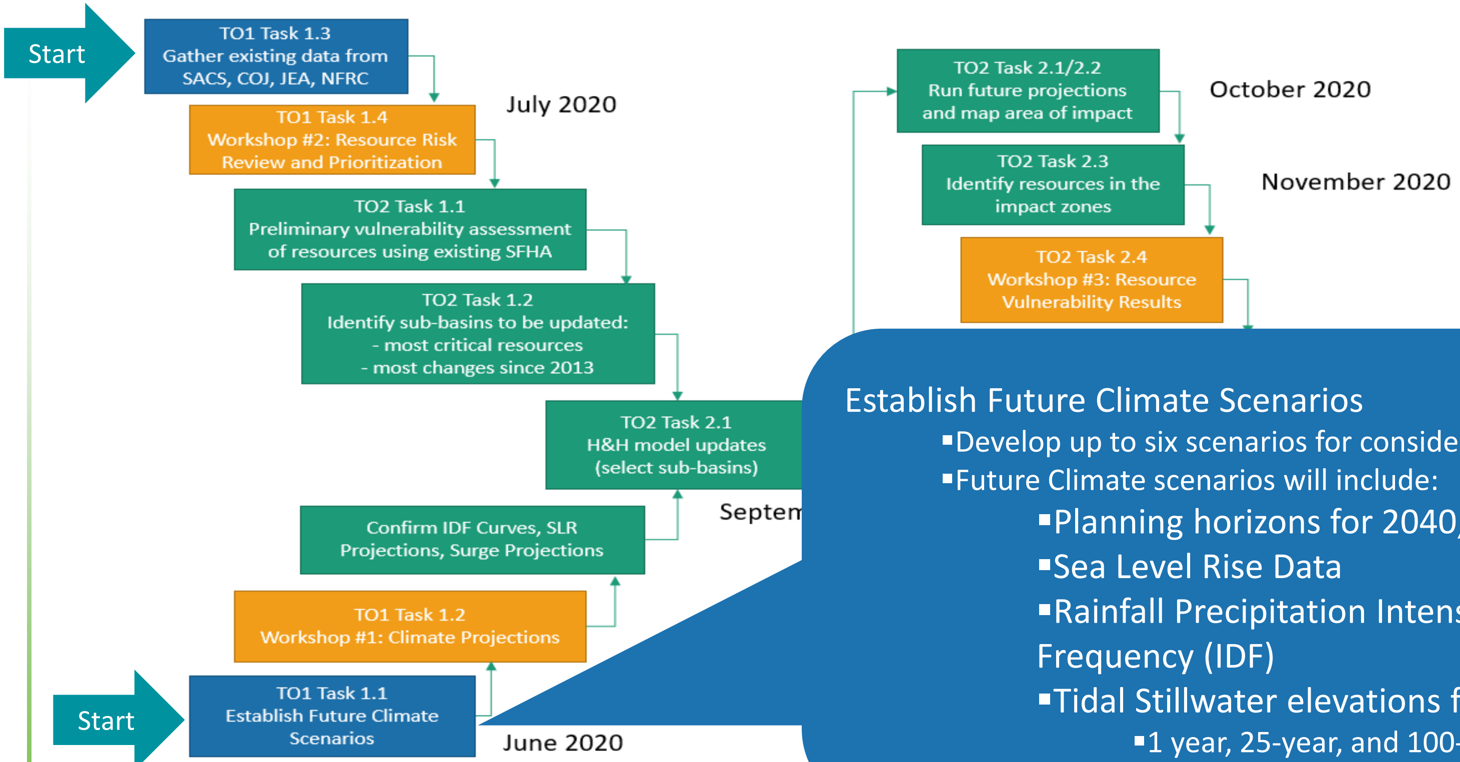
JEA summary

- Conducted a Vulnerability Analysis in 2019-2020
- Established climate scenarios
  - Sea Level Rise
  - Rainfall
  - GHG Projections
  - Coastal Surge
- Identified JEA critical and vulnerable infrastructure

Jacksonville Resiliency Planning Scope



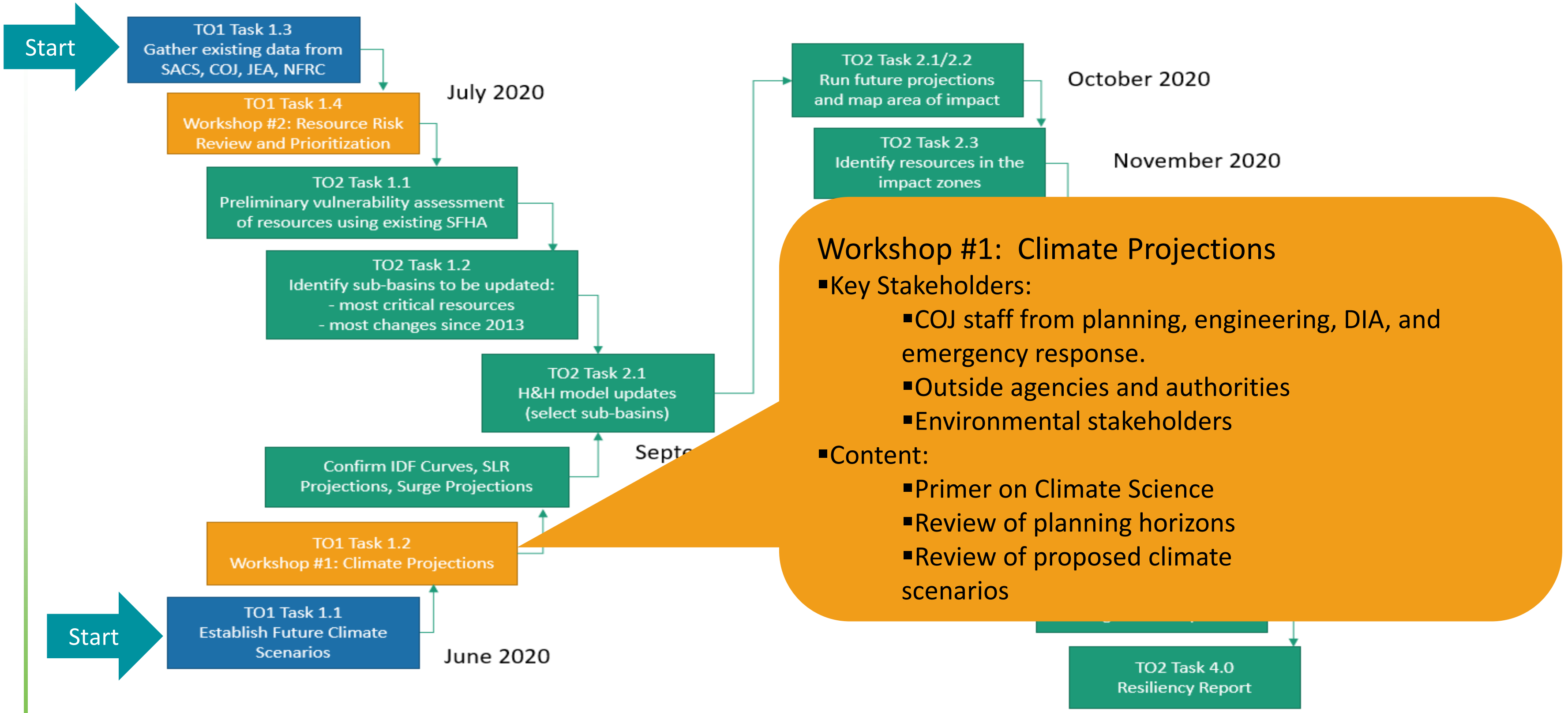
Jacksonville Resiliency Planning Scope



Establish Future Climate Scenarios

- Develop up to six scenarios for consideration.
- Future Climate scenarios will include:
  - Planning horizons for 2040, 2070, and 2100
  - Sea Level Rise Data
  - Rainfall Precipitation Intensity-Duration-Frequency (IDF)
  - Tidal Stillwater elevations from storm surge
    - 1 year, 25-year, and 100-year frequencies

Jacksonville Resiliency Planning Scope



Climate Science Primer

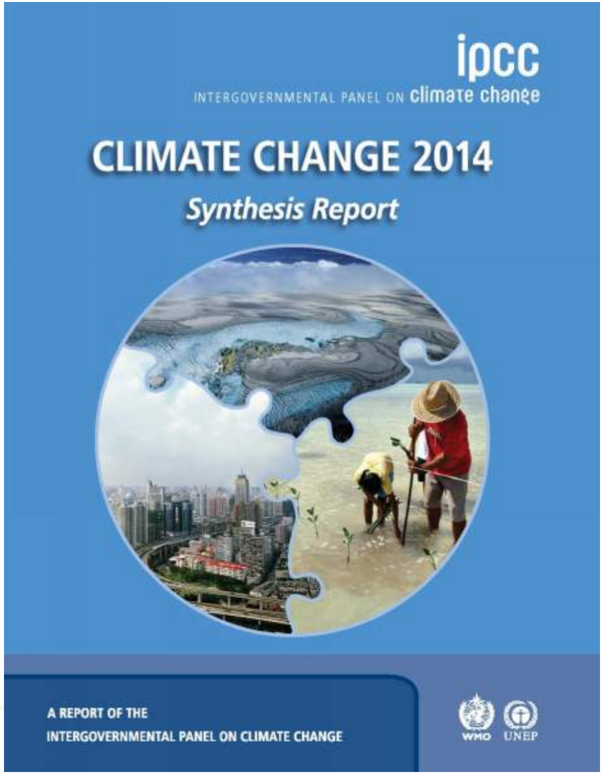
Climate Hazards

Climate influences many aspects of infrastructure planning, design, and operations

… and not all are impacted the same …

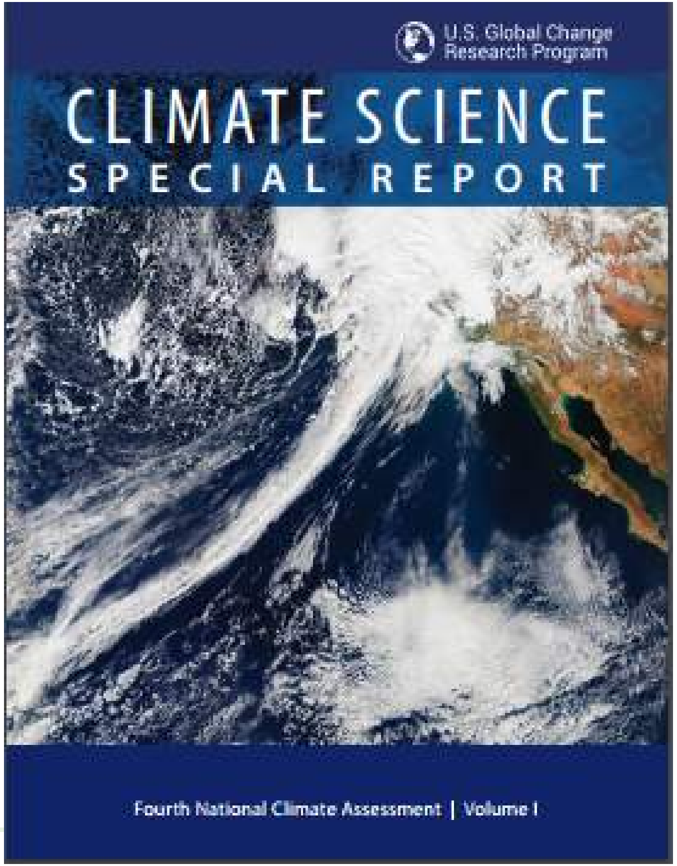
Climate Change Science Research: Intergovernmental Panel on Climate Change (IPCC) 6th Assessment is Underway

- IPCC Fifth Assessment Report (AR5) documents the state of knowledge concerning the science of climate change
- Three Working Groups:
  - Physical Science Basis
  - Impacts, Adaptation and Vulnerability
  - Mitigation of Climate Change



Climate Change Science Research in the US

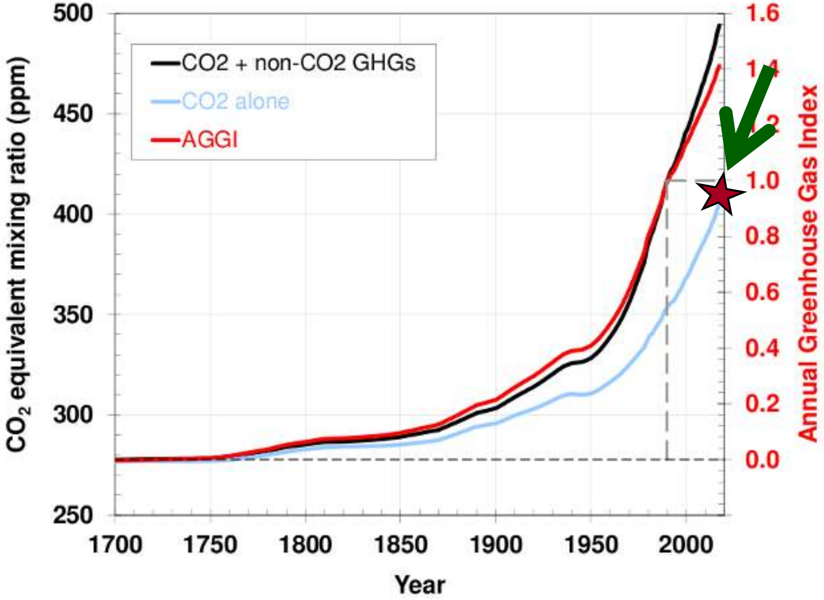
- U.S. Global Change Research Program https://science2017.globalchange.gov/
  - Mandated to prepare National Climate Assessments (NCA)
  - 4th NCA: Global Climate Change Impacts in the U.S. 2017
  - NCA5 expected in 2023
  - Extreme Events, Sea Level Rise, GHG Emissions trends, Best Practice Approaches, Decision Support, plus much more.
  - Regional US analysis.



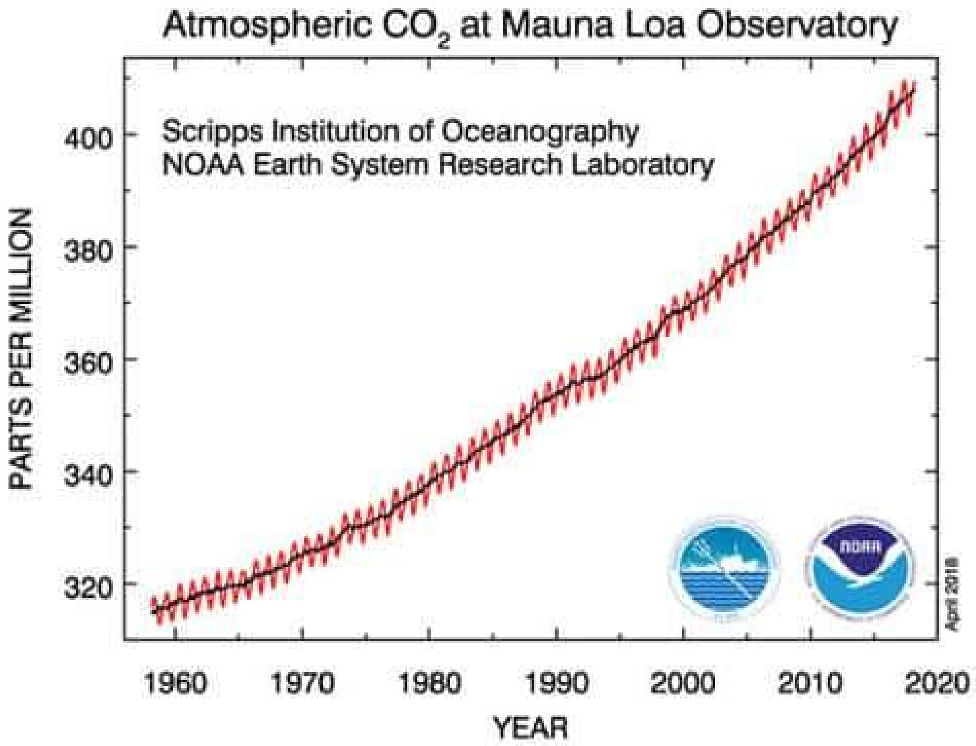
Observed GHG Concentrations Derived from Ice Cores and Direct Measurements

- Carbon Dioxide (ppm)
- Methane (ppb)
- Nitrous Oxide (ppb)
- Global Warming Potential/ Lifetimes in atmosphere
  CO2/~100 yrs.
  Methane 28/100+ yrs
  Nitrous Oxide 265/100+ yrs.
- Increases since 1750 attributed to human activities in industrial era

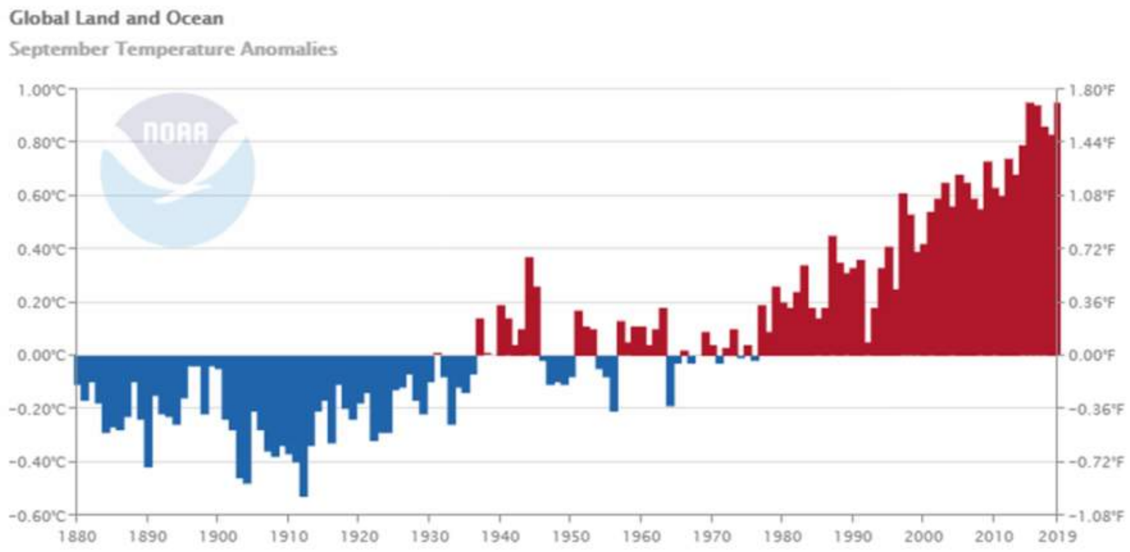
October 19, 2018 406.14 ppm Daily Avg.
(NOAA ,Mauna Loa, HI)



Observed Carbon Dioxide Gas Concentrations at Mauna Loa Observatory



Increasing GHG Concentrations Lead to Warming Atmosphere

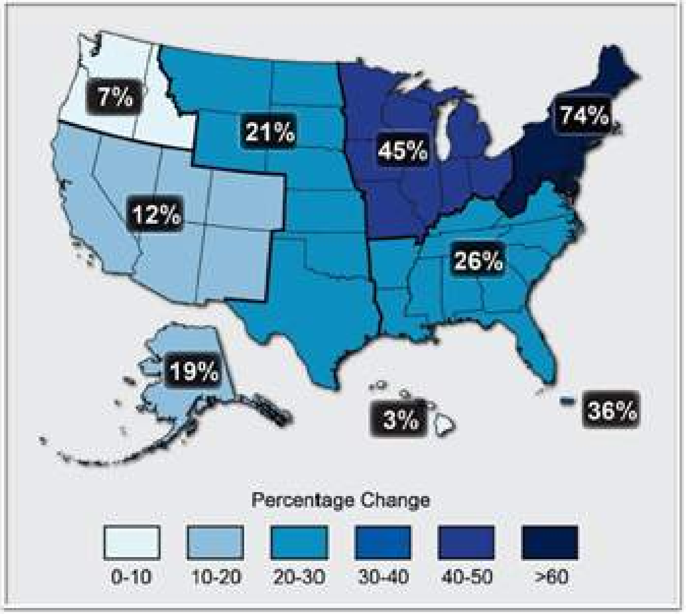


Warming atmosphere

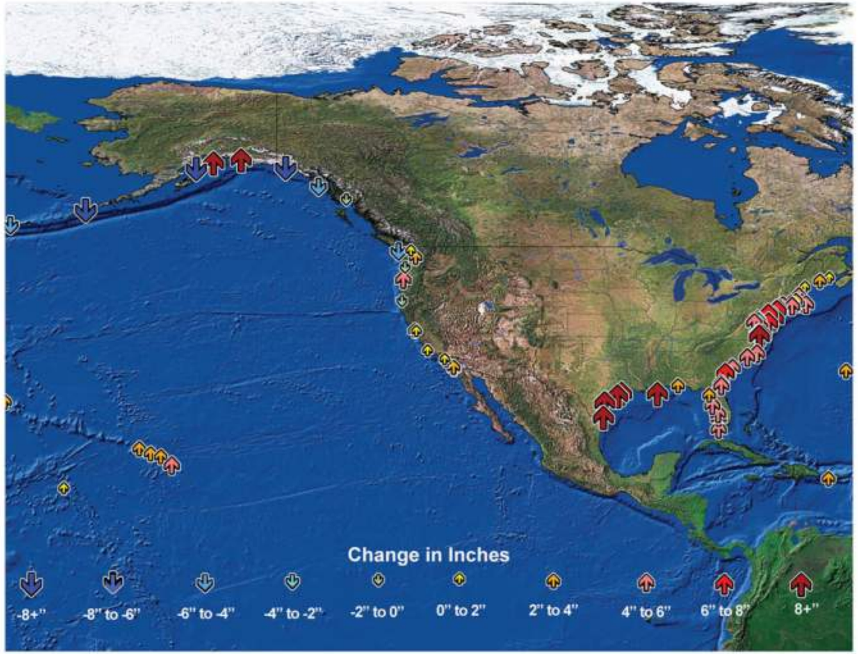
- Rising sea levels
- Changing precipitation patterns
- Changed (increased) flooding

Observed Changes in Precipitation and Sea Level

Observed Increases in
Very Heavy (top 1%) of Daily Precipitation
(1958 to 2011)

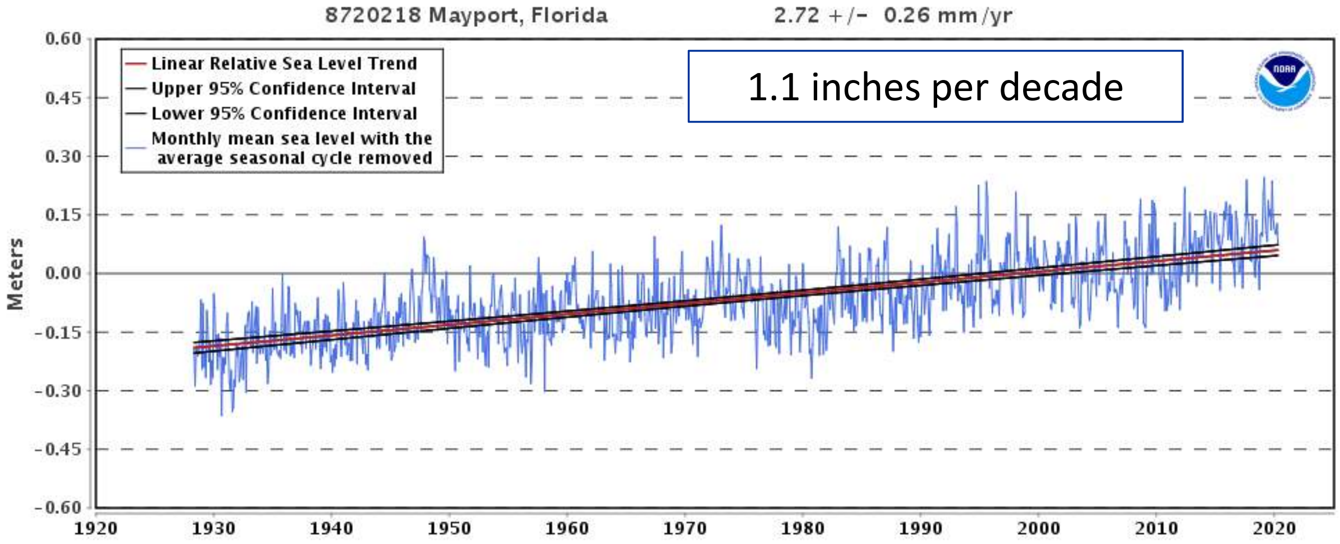


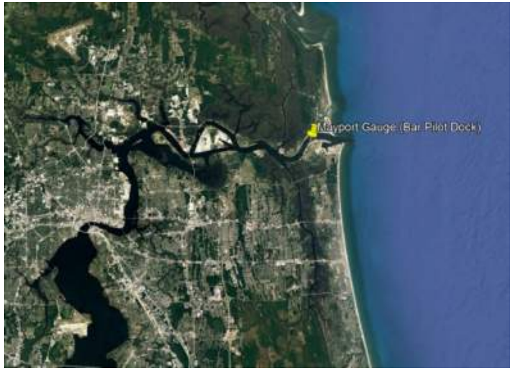
Observed changes in sea level (1958 to 2008)



Source: USGCRP (2009)

Historical Trends in Sea Level Rise in Jacksonville, FL

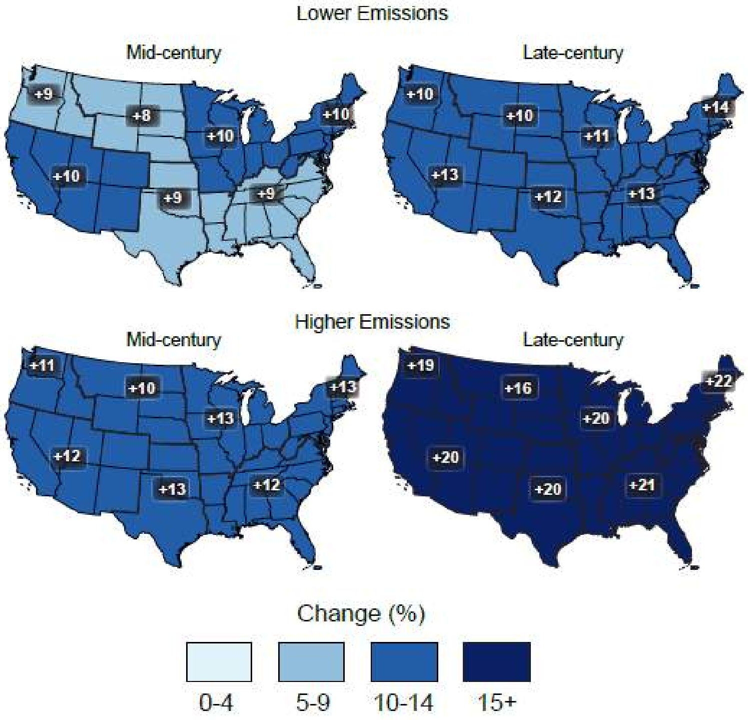




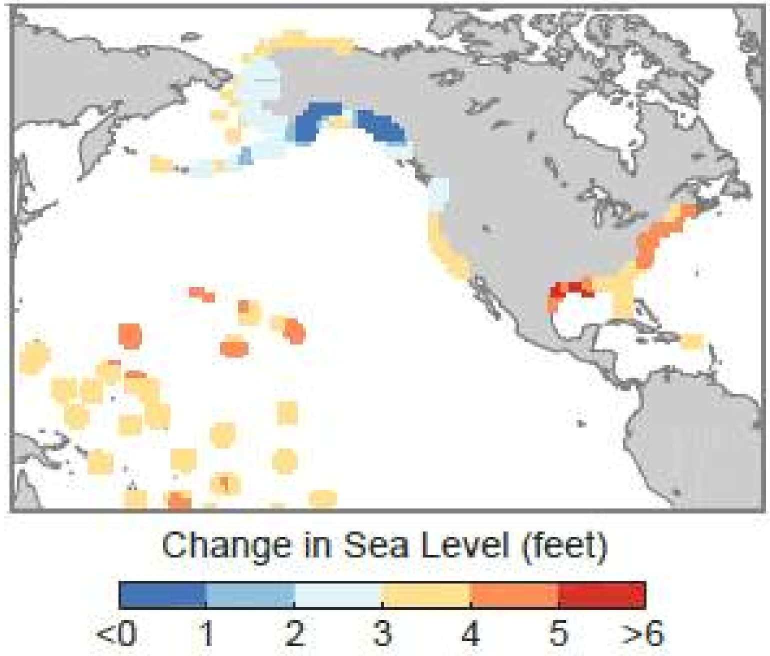
The relative sea level trend is 2.72 millimeters/year with a 95% confidence interval of +/- 0.26 mm/yr based on monthly mean sea level data from 1928 to 2019 which is equivalent to a change of 0.89 feet in 100 years.

Projected Changes

Projected Change in Daily, 20-year Extreme Precipitation

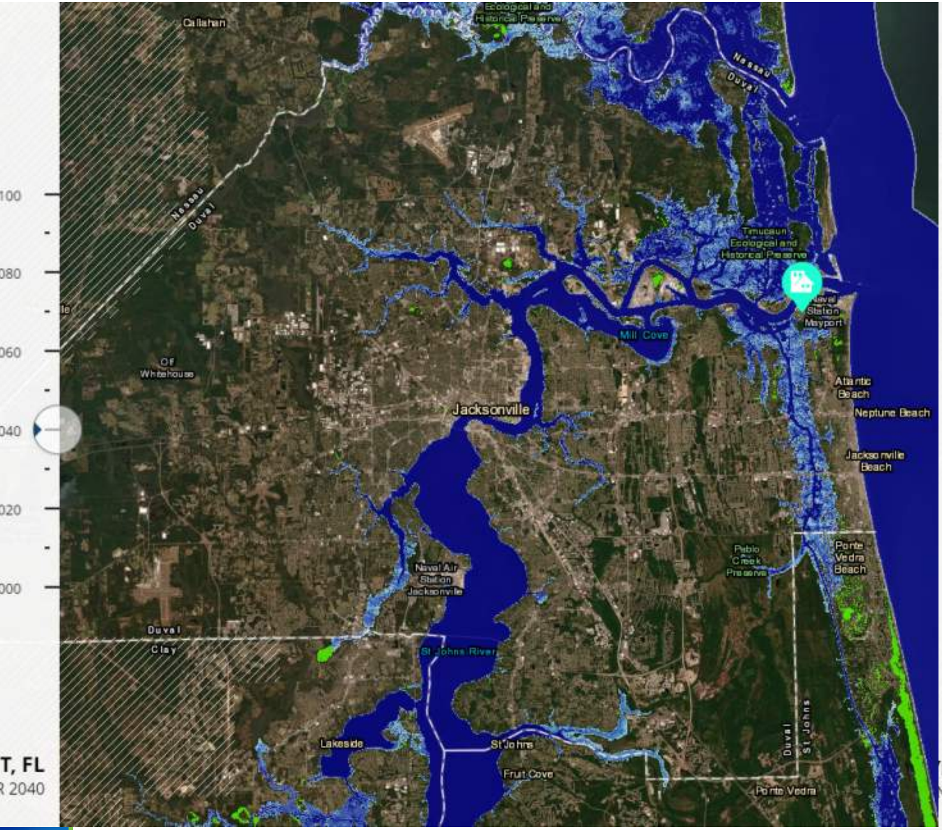


Projected Change in Relative Sea Level by 2100

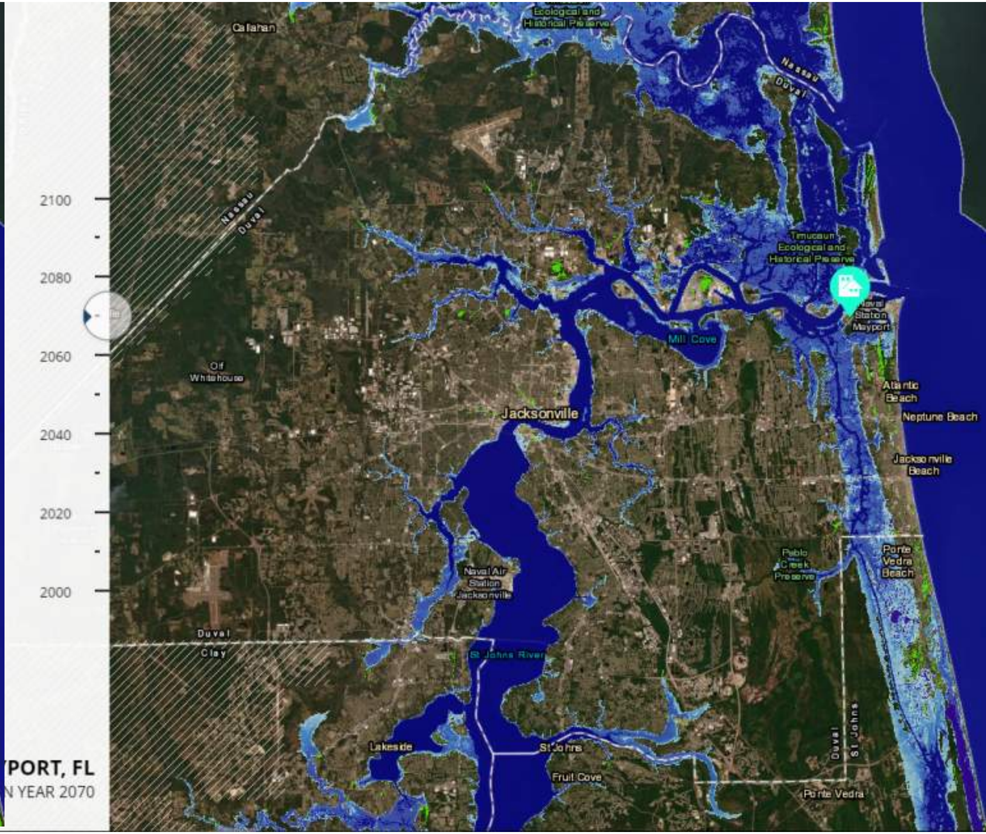


(Figure source: Sweet et al. 2017)

Projected Tidal Flooding in 2040 and 2070



2040



2070

Focus of Resiliency Plan is to Improve Jacksonville's Flood Readiness Given an Uncertain Climate Future

Mitigation/Adaptation for Extreme Weather and Climate Risks

- Extreme Tides (astronomical)
- Extreme Rainfall (intensity and volume)
- Storm Surge (tropical systems)
- Sea Level Rise (based on high likelihood scenarios across asset lifespans)

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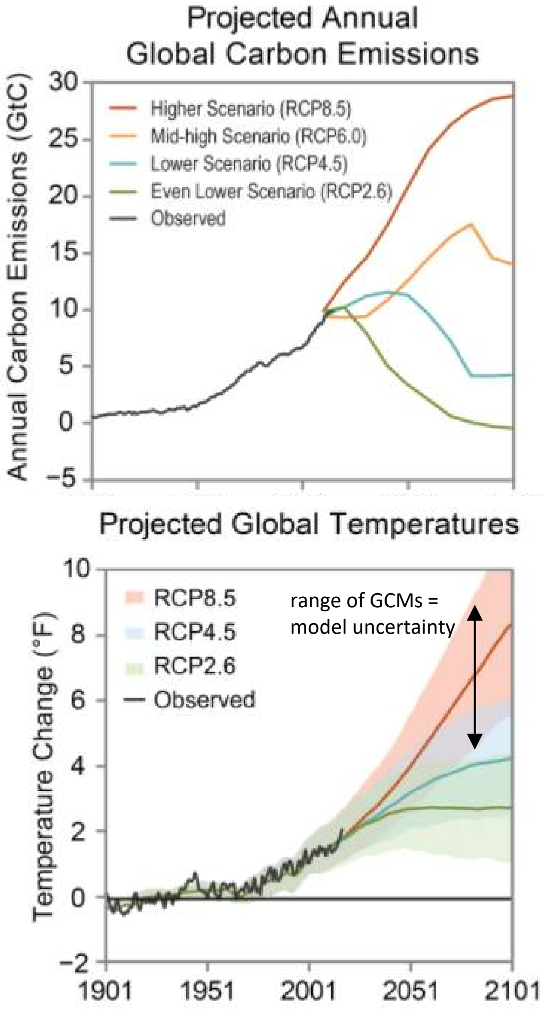
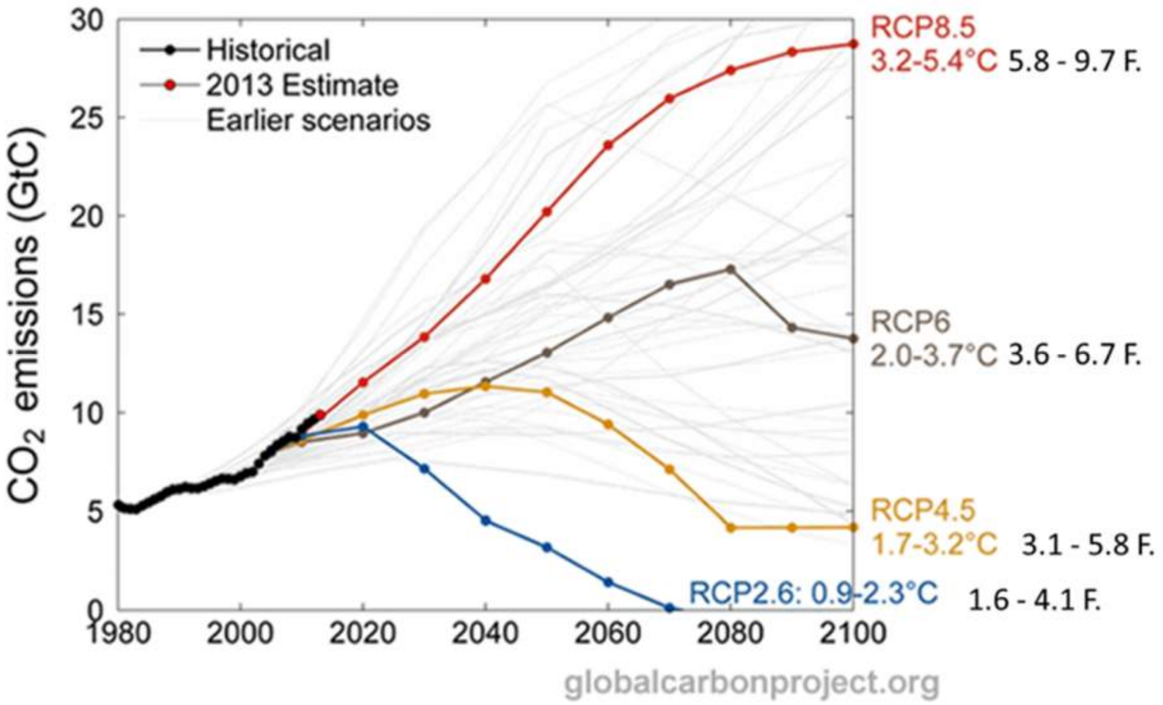
Projections and Uncertainty

- Projected GHG Emissions: *Representative Concentration Pathways* (RCPs)
  - RCP 8.5 – “business as usual”
  - RCP 6.0 – moderate GHG reduction
  - RCP 4.5 – substantial GHG reduction
  - RCP 2.6 – likely not attainable
- Climate model uncertainty
  - Multiple *Global Circulation Models* (GCMs)
  - Best practice: ensemble method

(NCA 2017)



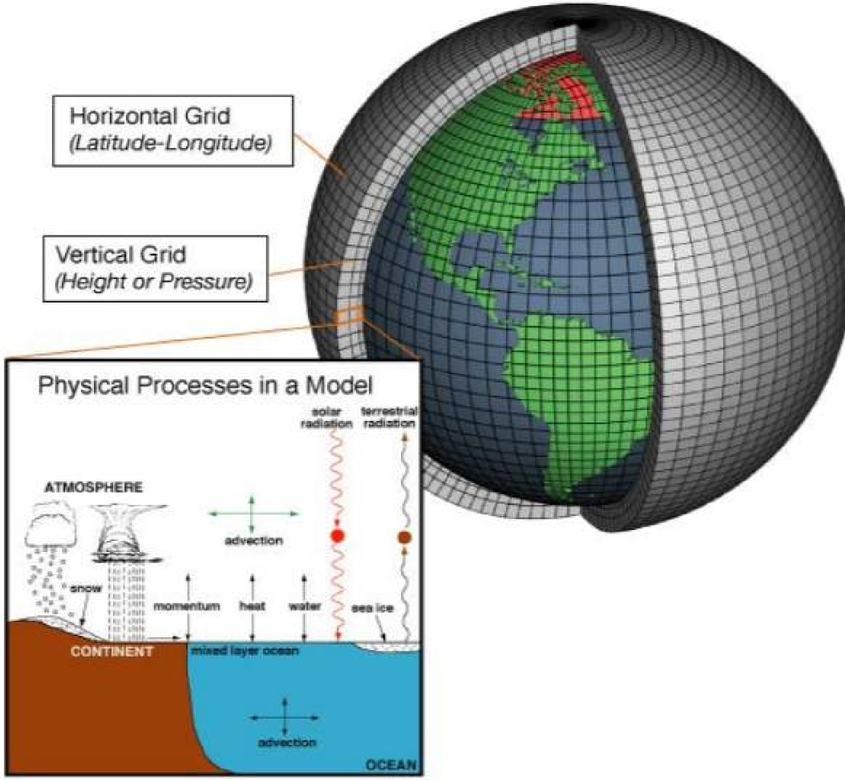
IPCC projected range of global temperature change relative to the 1901-1960 average, for different GHG emission scenarios



Source: Globalcarbonproject.org

Global Circulation Models (GCM) and Regional Circulation Models (RCMs)

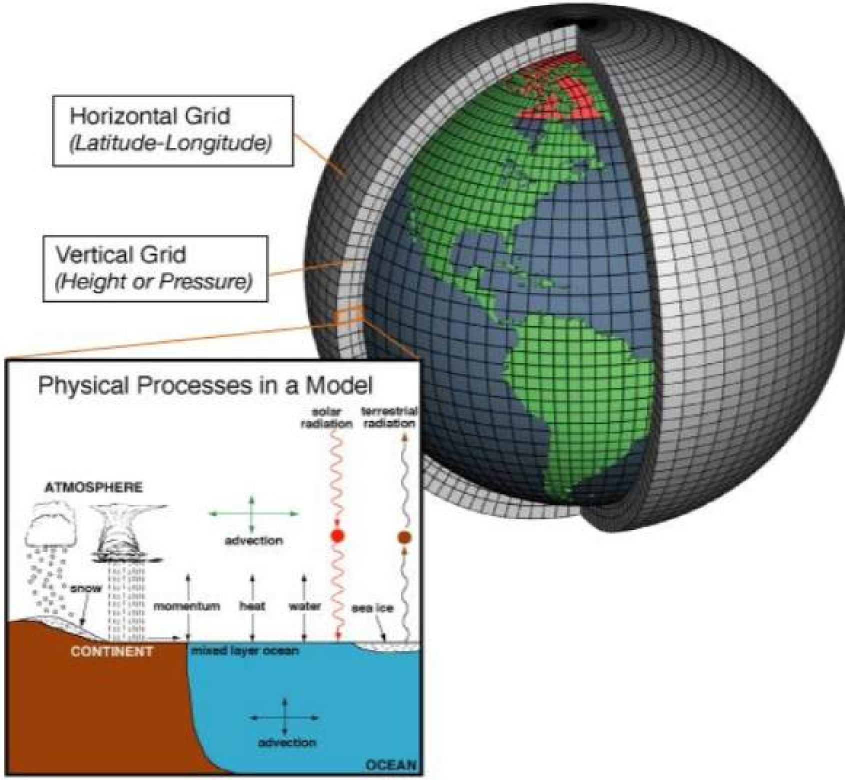
- Solve equations of motion for pressure, temperature, moisture, ocean flux, wind, etc.
- 35+ GCMs exist in research centers around the globe
- GCMs are refined continuously as science improves and computer processing power increases



Source: National Oceanic and Atmospheric Administration (NOAA), 20

Global Circulation Models (GCM) and Regional Circulation Models (RCMs)

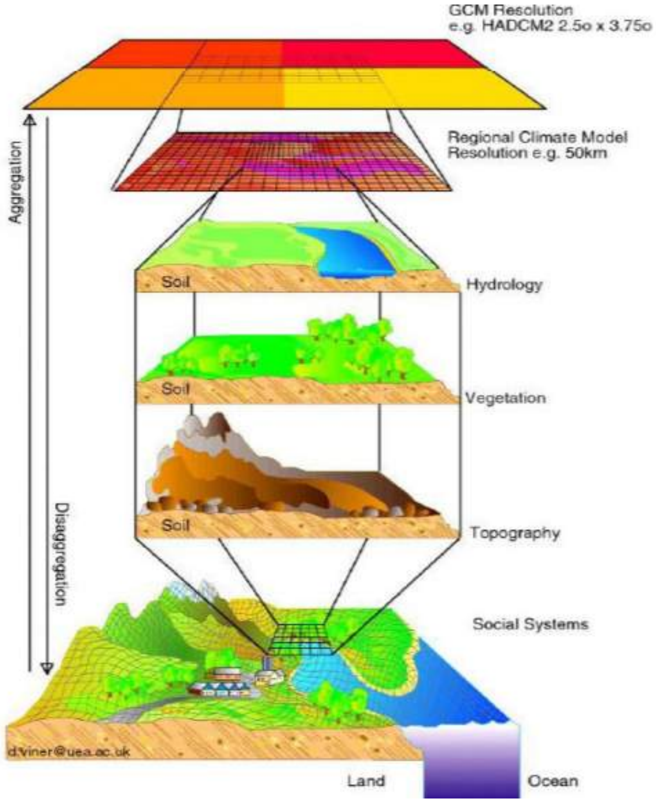
- Spatial Resolution
  - Atmospheric resolution of 150 to 300 km grid, 19 levels
  - Oceanic resolution of ~100 km, 60 mi, 20 depths
- Temporal Resolution
  - varies by climate parameter from 6 hours to monthly means



Source: National Oceanic and Atmospheric Administration (NOAA), 20

GCMs are "downscaled" using RCMs and local observations to derive finer resolution projections

- Dynamical downscaling uses RCM nested within a GCM
- Statistical downscaling uses statistical correlations between observations and large scale GCM gridded data



Questions

Climate Change Threats

Rainfall, Extreme Storms, and Sea Level Rise

Precipitation Driven

Stormwater/ Drainage

2- to 25-year storms

Localized flooding

Riverine

100-year storms

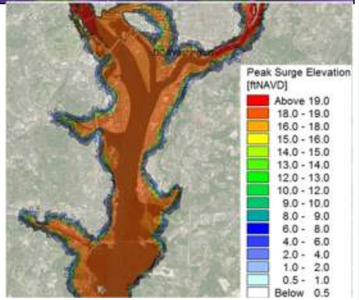
Regional flooding

Coastal

Sea Level Rise

Flooding from increased tide levels

Storm Surge



Coastal flooding

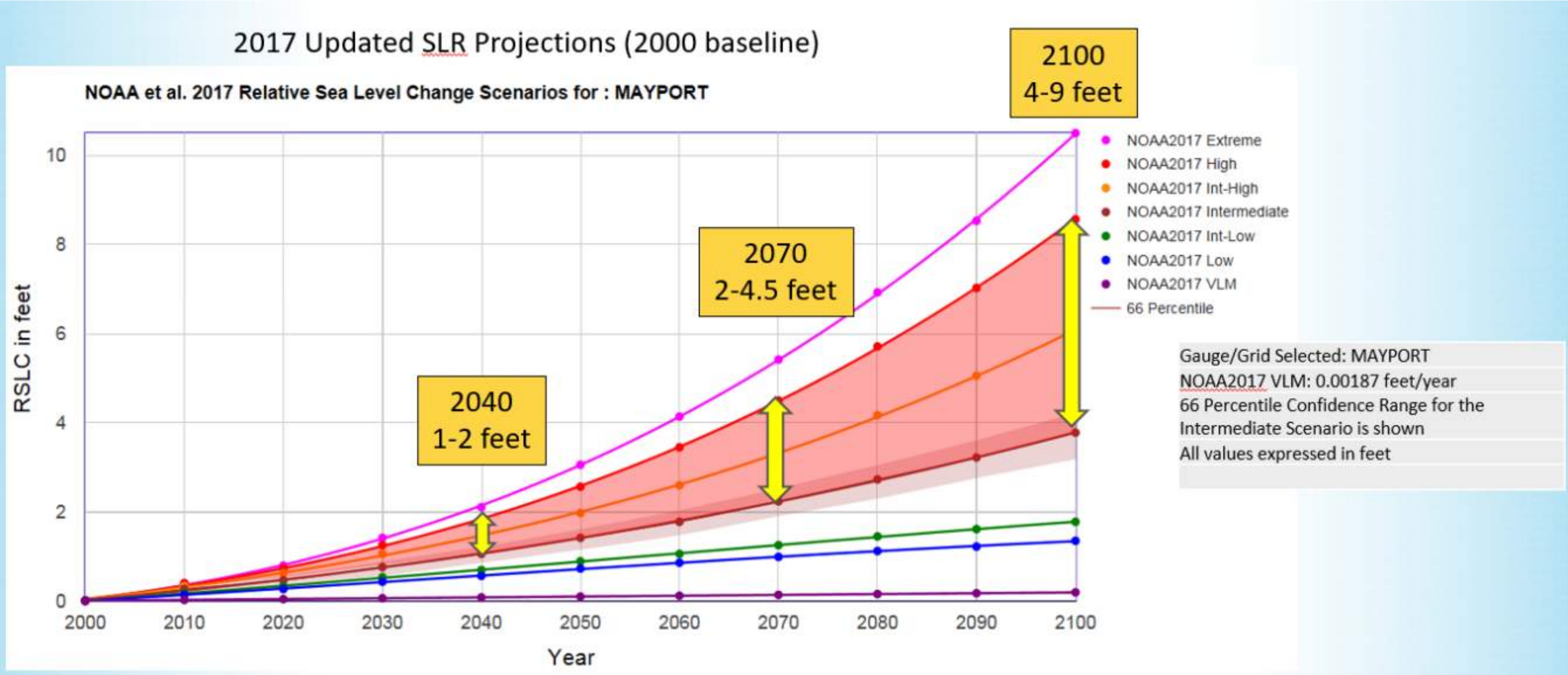
Sea level and precipitation projections for City of Jacksonville

(based on JEA Resilience Plan, Jacobs 2020)

Climate Scenarios are Used to Bracket Range of Uncertainty in Climate Projections

- Summary of climate scenario factors:
  - Planning Time Horizons - Short, mid and long-term planning
  - Greenhouse Gas (GHG) scenarios: RCP8.5 and RCP6.0
  - Global Climate Model (GCM) summaries: 50% and 90% non-exceedance
- Summary of Sea Level Rise projections
- Summary of rainfall projections

Sea Level Rise: Updated Projections

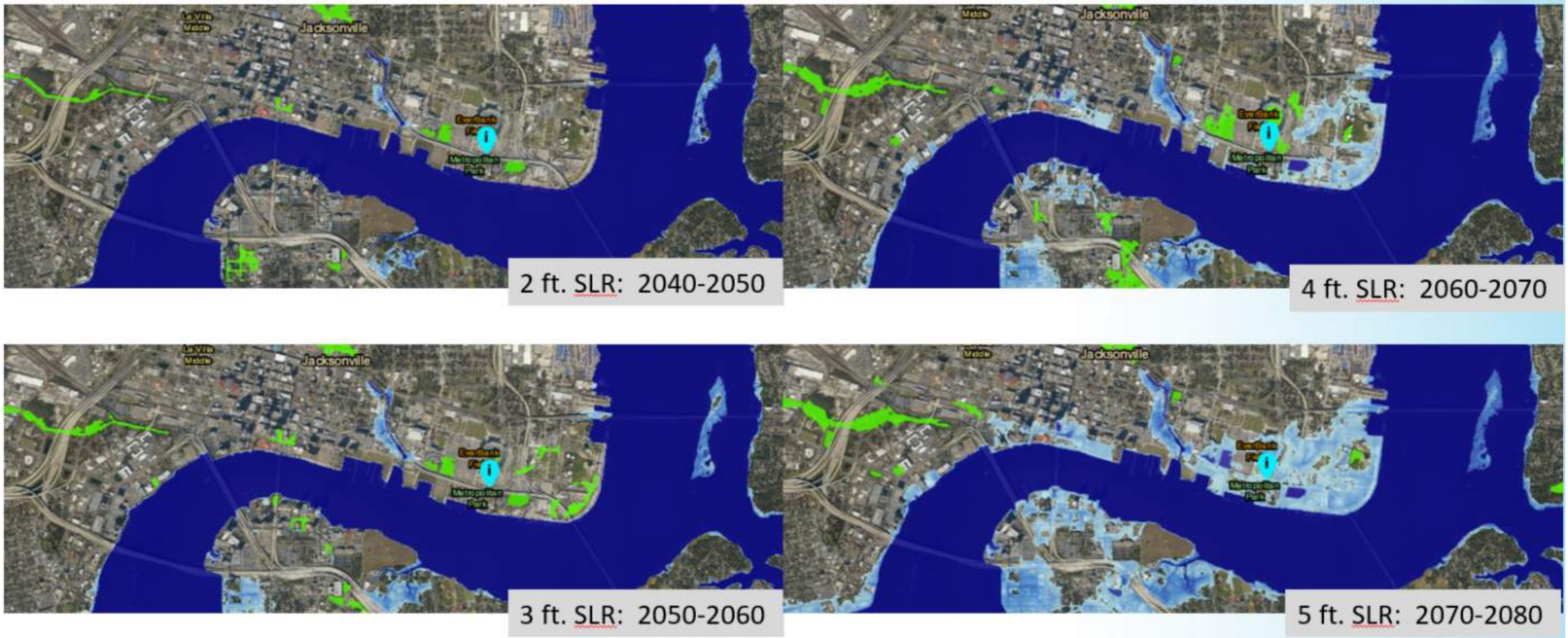


SLR – Updated Projections

2017 Updated SLR Projections (2000 baseline)

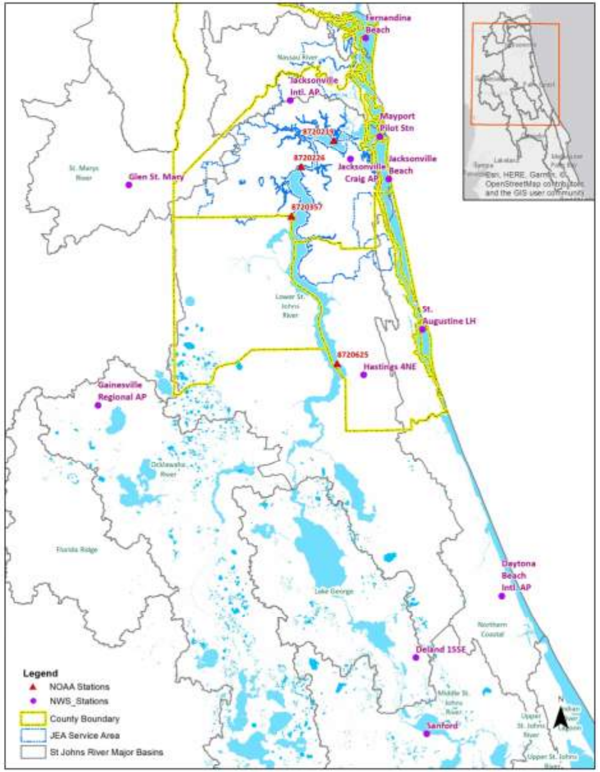
Year	NOAA 2017 Low	NOAA 2017 Int-Low	NOAA 2017 Intermediate	NOAA 2017 Int-High	NOAA 2017 High	NOAA 2017 Extreme
2000	0	0	0	0	0	0
2010	0.13	0.16	0.26	0.33	0.39	0.39
2020	0.26	0.33	0.46	0.62	0.72	0.79
2030	0.43	0.52	0.75	1.05	1.25	1.41
2040	0.56	0.69	**1.05**	**1.44**	**1.8**	2.1
2050	0.72	0.89	1.41	1.97	2.56	3.05
2060	0.85	1.05	1.77	2.59	3.44	4.13
2070	0.98	1.25	**2.23**	**3.31**	**4.49**	5.41
2080	1.12	1.44	2.72	4.17	5.71	6.92
2090	1.21	1.61	3.22	5.05	7.02	8.53
2100	1.35	1.77	**3.77**	**6.07**	**8.56**	10.5

SLR – Updated Projections

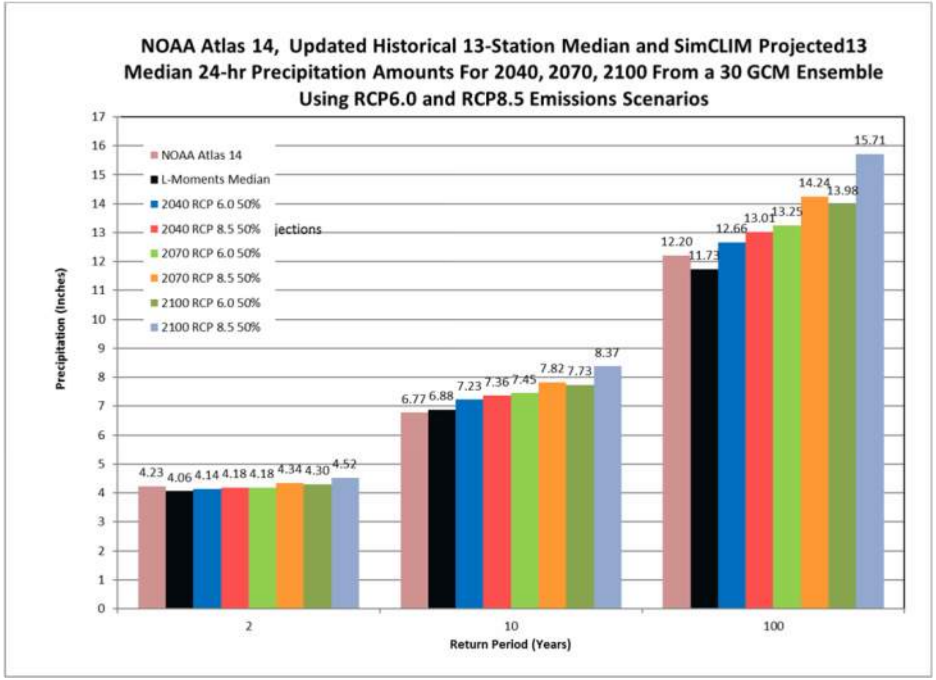


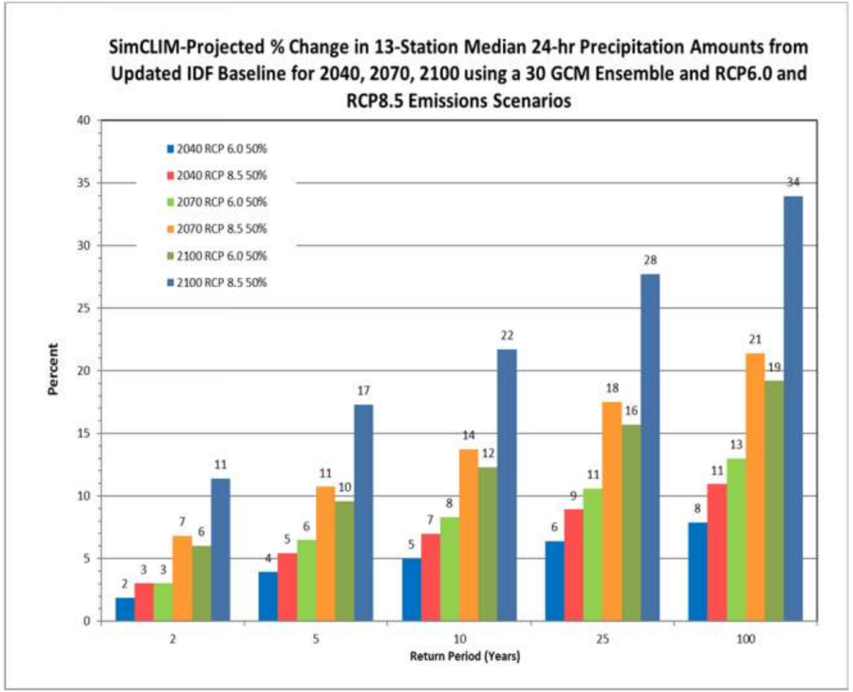
Rainfall Analysis and IDF Projections (based on work for JEA's Resilience Plan Project)

- Historical Rainfall Data
  - Daily precipitation from NWS
  - 13 stations with up to 126 years of data
- Data and Process Validation
  - Data validated with NOAA Atlas 14 through 2010
  - Additional data through 2017 added to the updated IDF analysis.
- Future Projections
  - RCP 6.0 and 8.5 emissions scenarios
  - 2040, 2070, 2100
  - Ensemble of 30 general circulation models
- IDF Curve Development using SimCLIM
  - Return period/event frequency

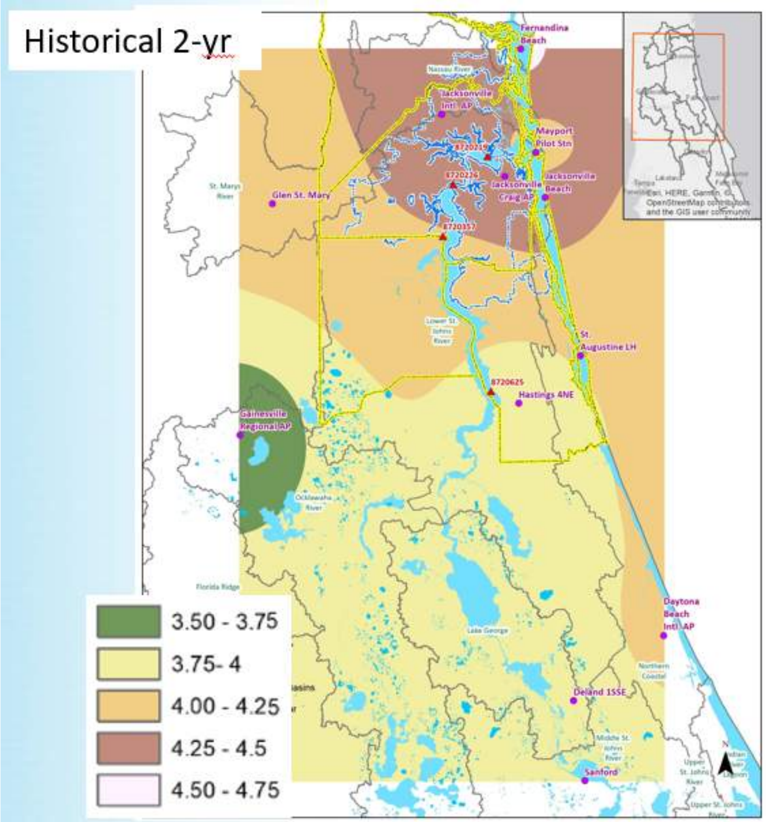


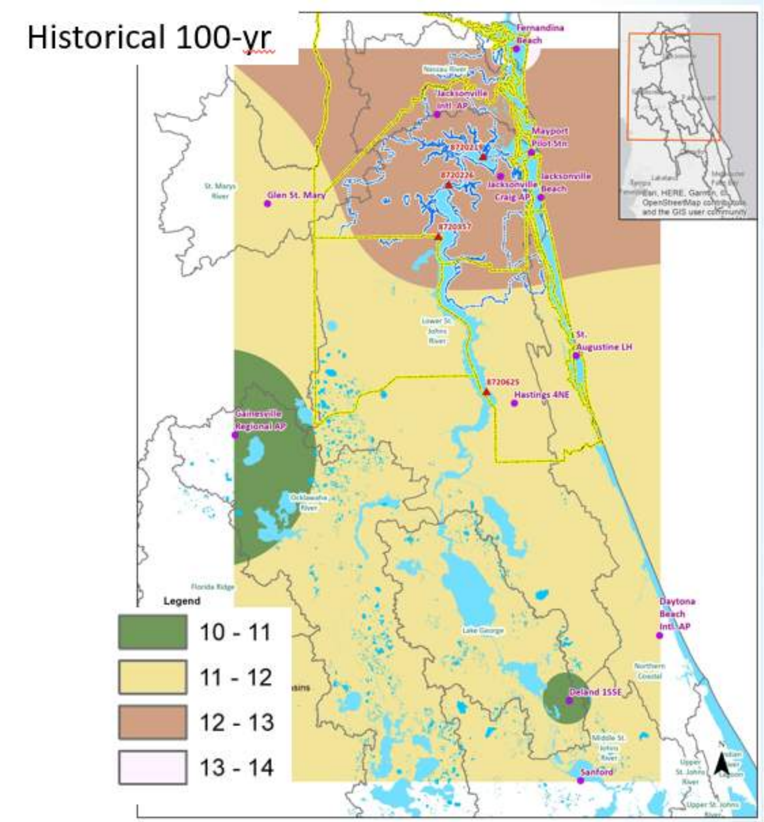
Rainfall IDF Projection Results (depth for 24-hr storms) Median of Global Climate Model Projections



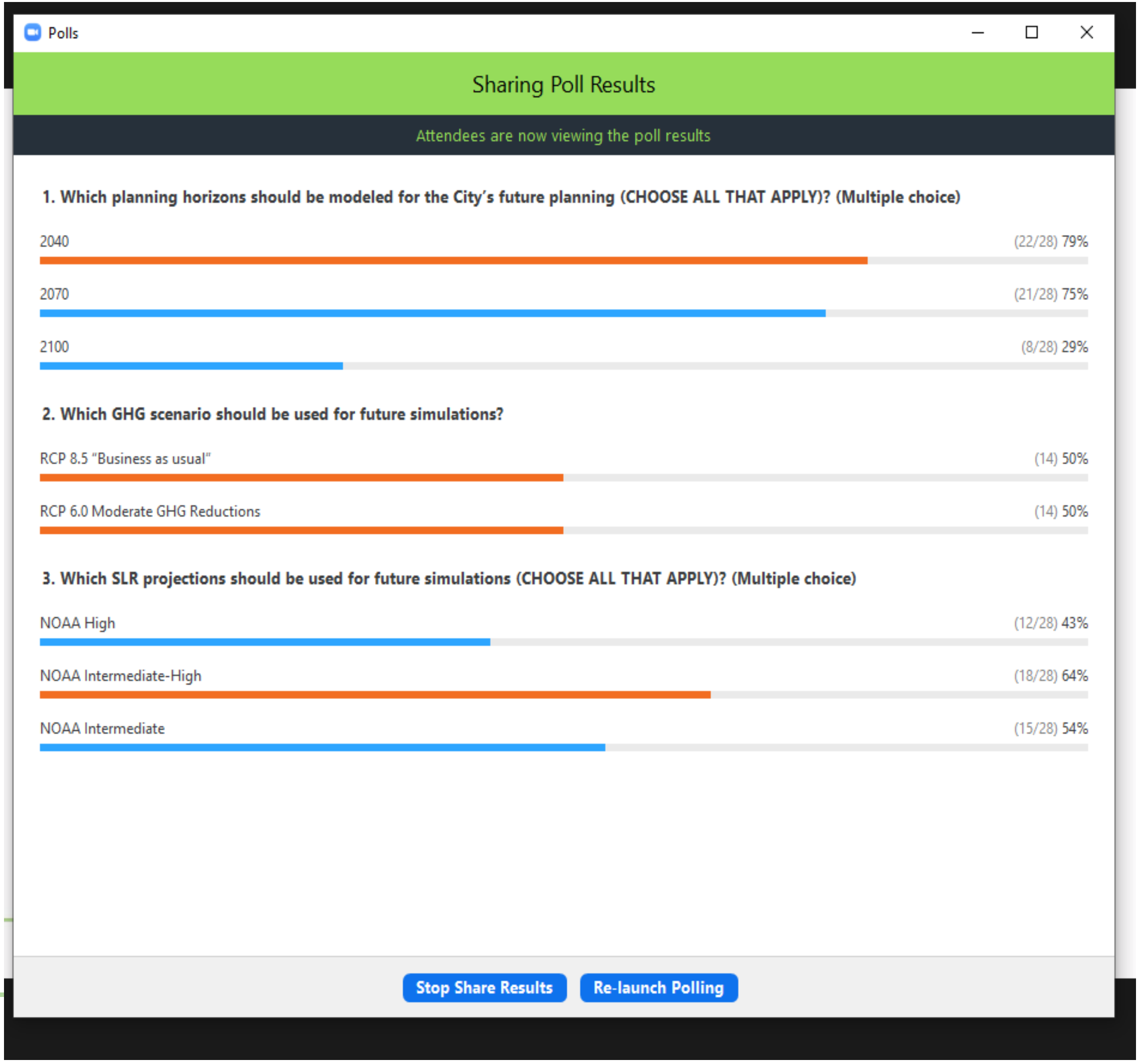


Rainfall Contours – spatial variability





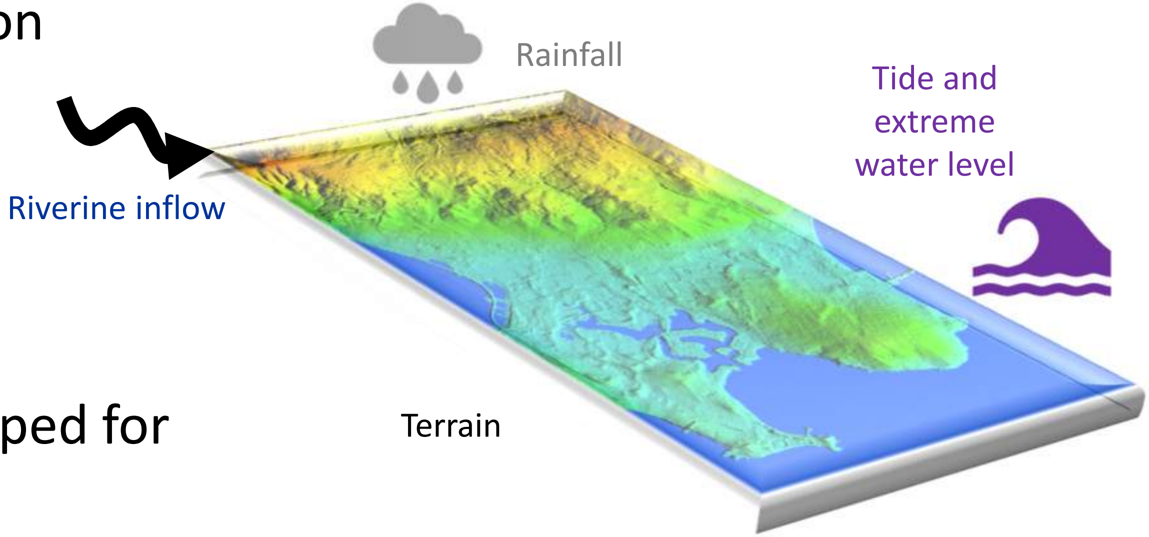
Poll


Polls
Sharing Poll Results
Attendees are now viewing the poll results
1. Which planning horizons should be modeled for the City's future planning (CHOOSE ALL THAT APPLY)? (Multiple choice)
2040 (22/28) 79%
2070 (21/28) 75%
2100 (8/28) 29%
2. Which GHG scenario should be used for future simulations?
RCP 8.5 "Business as usual" (14) 50%
RCP 6.0 Moderate GHG Reductions (14) 50%
3. Which SLR projections should be used for future simulations (CHOOSE ALL THAT APPLY)? (Multiple choice)
NOAA High (12/28) 43%
NOAA Intermediate-High (18/28) 64%
NOAA Intermediate (15/28) 54%
Stop Share Results
Re-launch Polling

Surge and Coastal Scenarios

Parameters needed for coastal surge model

- Terrain
- Rainfall (24-hour design storms)
- Tidal boundary condition



- MIKE21 model developed for Lower St Johns Basin

Flood Modeling Calibration for MIKE21

- Model Calibration using monitoring station data for:
  - Rainfall analysis
  - Sea level rise analysis
  - Coastal surge analysis
  - St. Johns River surge analysis
  - Inland flooding analysis

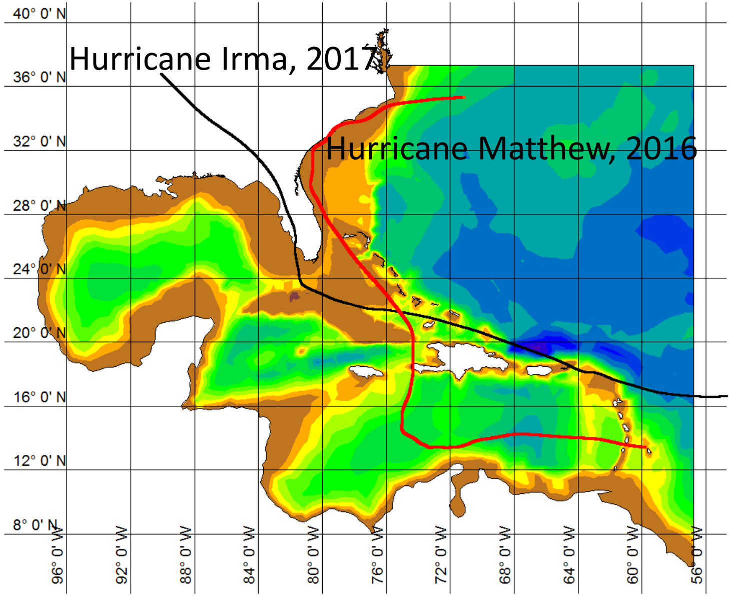
Source: JEA

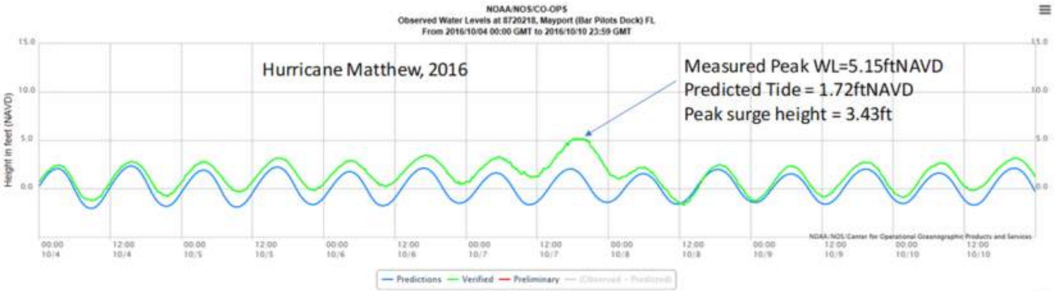
Flood Modeling Calibration for MIKE21

- Model Calibration/Validation to Current Conditions:
  - Hurricane Irma
  - FEMA 100-year and 500-year elevations at selected transects
  - FEMA 100-year and 500-year flood maps

Source: www.s.w-x.co/wu/jax-flooding-sheriff-9.11.17

Surge Modeling Performed of Historical Hurricane Events (used as base set)





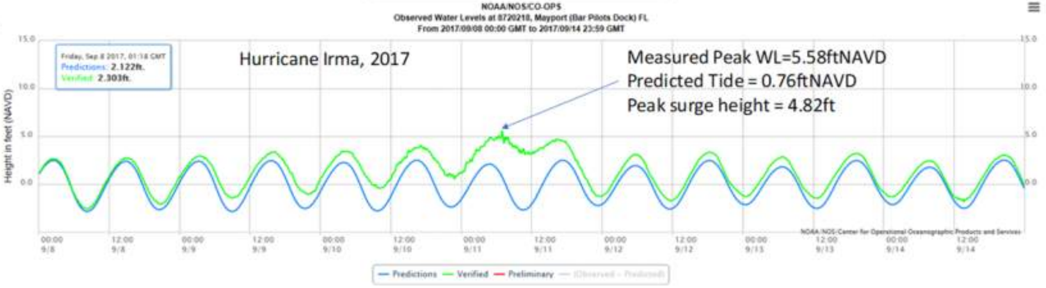
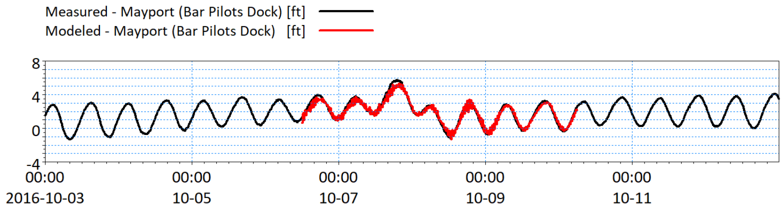
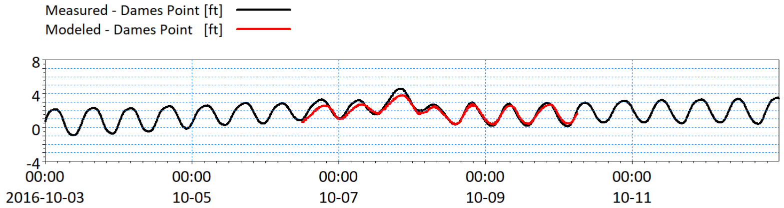


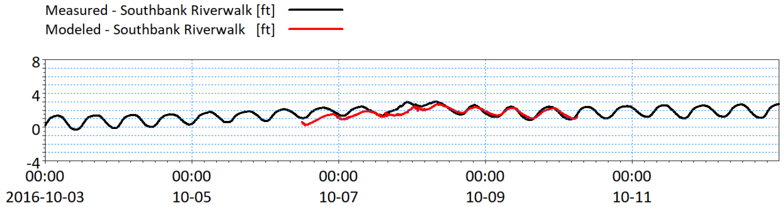
Image: Bathymetry of Gulf of Mexico, Caribbean and Eastern Atlantic, with Hurricane Matthew and Irma tracks.

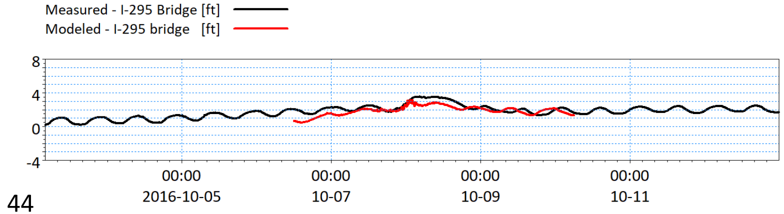
Note: "Predicted Tide" refers to NOAA prediction of astronomical tide based on harmonic analysis of measured water level data, without meteorological disturbances such as surge.

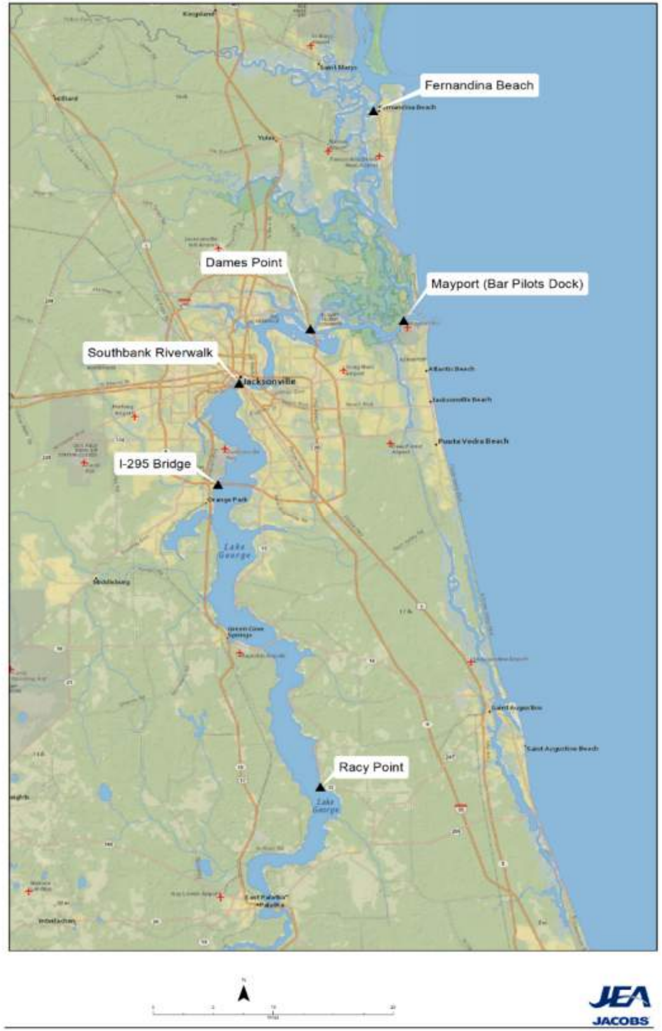
Calibration – Historical Event: Hurricane Matthew



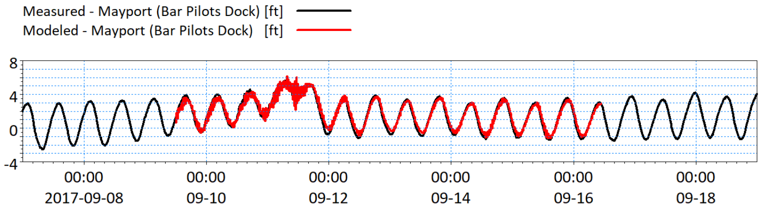


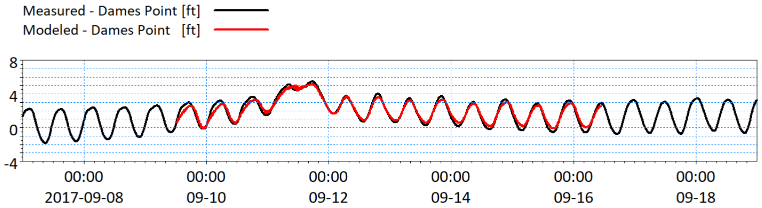


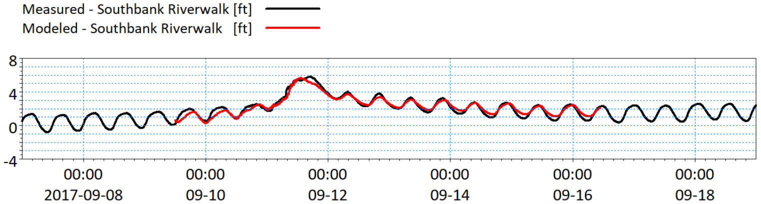


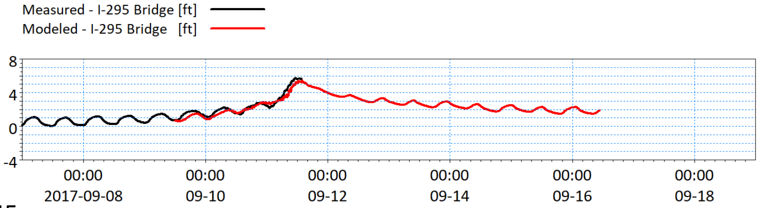


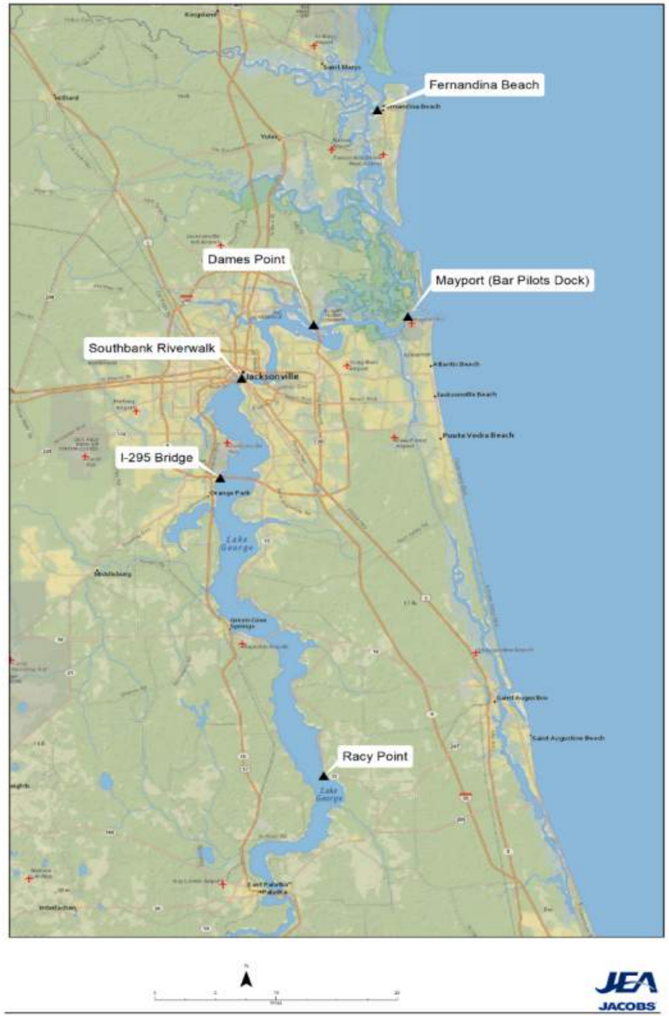
Validation – Historical Event: Hurricane Irma





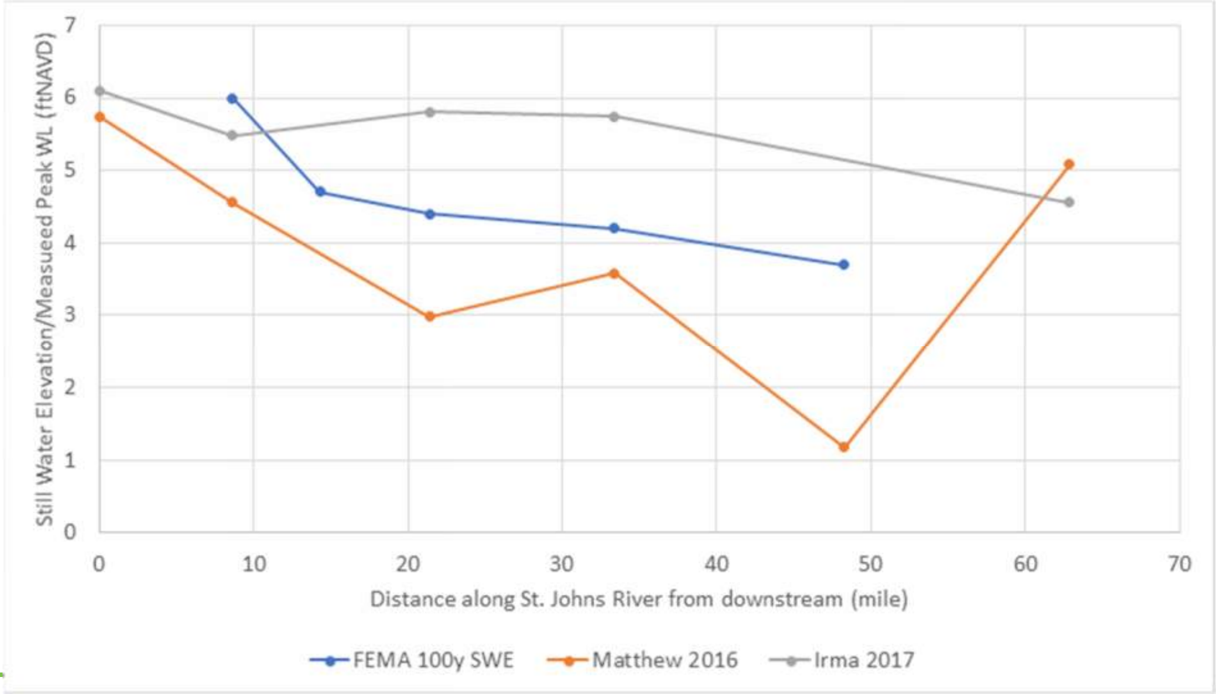


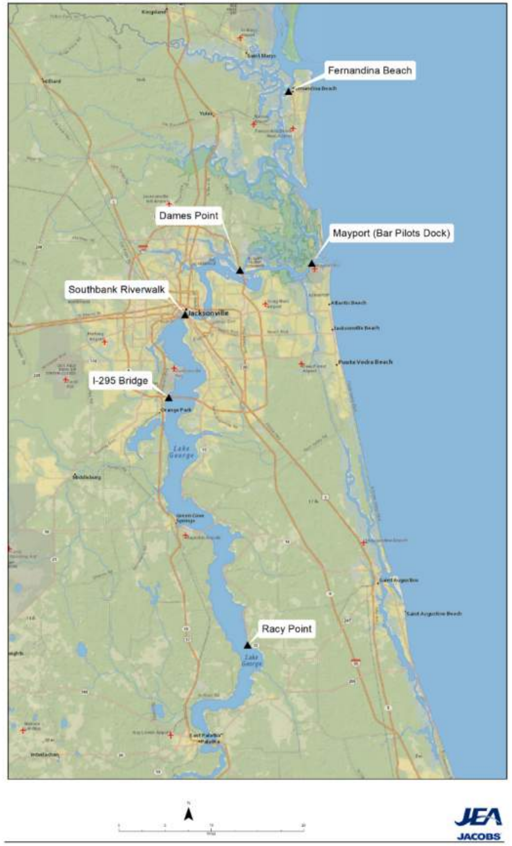




Longitudinal Profiles for FEMA SWE and Hurricanes Irma and Matthew

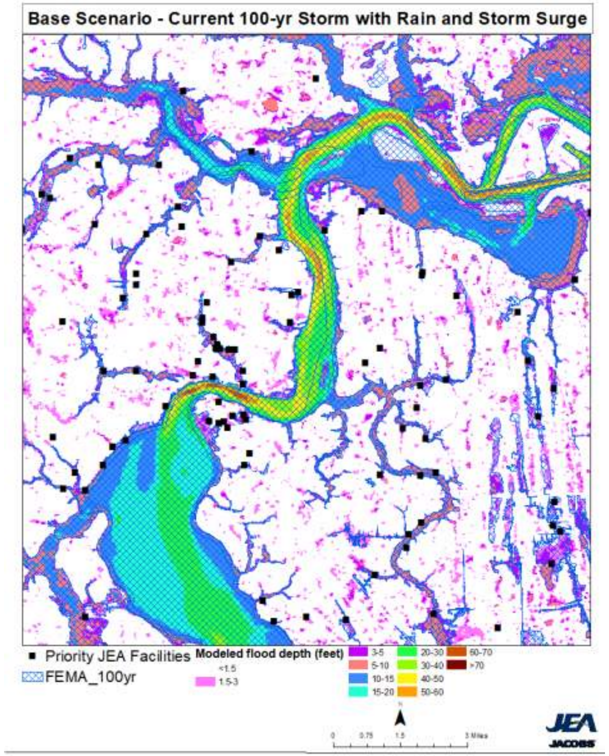
Longitudinal profiles for FEMA SWE and Hurricanes Irma and Matthew show complex hydrodynamics because of storm track, and generally declining water levels moving upstream.

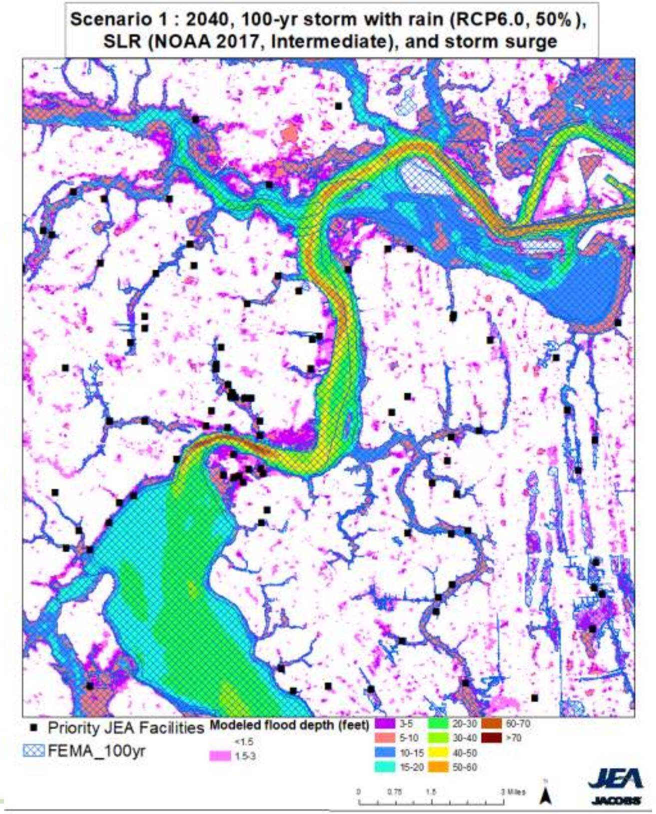




100-year Storm: Base Scenario versus Scenario 1

2040, Rain (lower emissions – RCP6.0), SLR (NOAA intermediate), and Storm Surge





Build on the 8 scenarios Selected by JEA for Resiliency Planning

Time Horizons: 2040, 2070	
Rainfall	**SLR Projections**
RCP6.0 50% non-exceedance	NOAA 2017: Intermediate
RCP8.5 50% non-exceedance	NOAA 2017: High
Source	
Rainfall	
Surge	
Return Period of Surge Event (year)	
25-year (current rain: 8.8”)	
100-year (current rain: 12.3”)	
500-year (current rain: 16.6”)	

- Eight JEA Scenarios bracketed combinations of:
  - Rainfall: RCP6.0 to RCP8.5
  - SLR with Storm Surge: NOAA Intermediate to NOAA High
  - Planning Year: 2040 and 2070
  - Return Period: 25-yr, 100-yr, and 500-yr

Build on the 8 scenarios Selected by JEA for Resiliency Planning (Three 2040 scenarios)

Scenario Description		2040 Low	2040 High
Rainfall	SLR Projections		
RCP6.0 50% non-exceedance	NOAA 2017: Intermediate	✓	
RCP8.5 50% non-exceedance	NOAA 2017: High		✓
Rainfall		✓	✓
Surge		✓	✓
Return Period of Surge Event (year)			
25-year (current rain: 8.8”)		✓	
100-year (current rain: 12.3”)		✓	✓
500-year (current rain: 16.6”)			

2040 Scenarios:

- Low projections based on RCP6.0 (moderate GHG reduction) and intermediate SLR
  - 25-yr
  - 100-yr
- High projections based on RCP8.5 (no GHG reduction) and high SLR

Build on the 8 scenarios Selected by JEA for Resiliency Planning (Four 2070 scenarios)

Scenario Description		2070	
		Low	High
Rainfall	SLR Projections		
RCP6.0 50% non-exceedance	NOAA 2017: Intermediate	✓	
RCP8.5 50% non-exceedance	NOAA 2017: High		✓
Rainfall		✓	✓
Surge		✓	✓
Return Period of Surge Event (year)			
25-year (current rain: 8.8”)			✓
100-year (current rain: 12.3”)		✓	✓
500-year (current rain: 16.6”)			✓

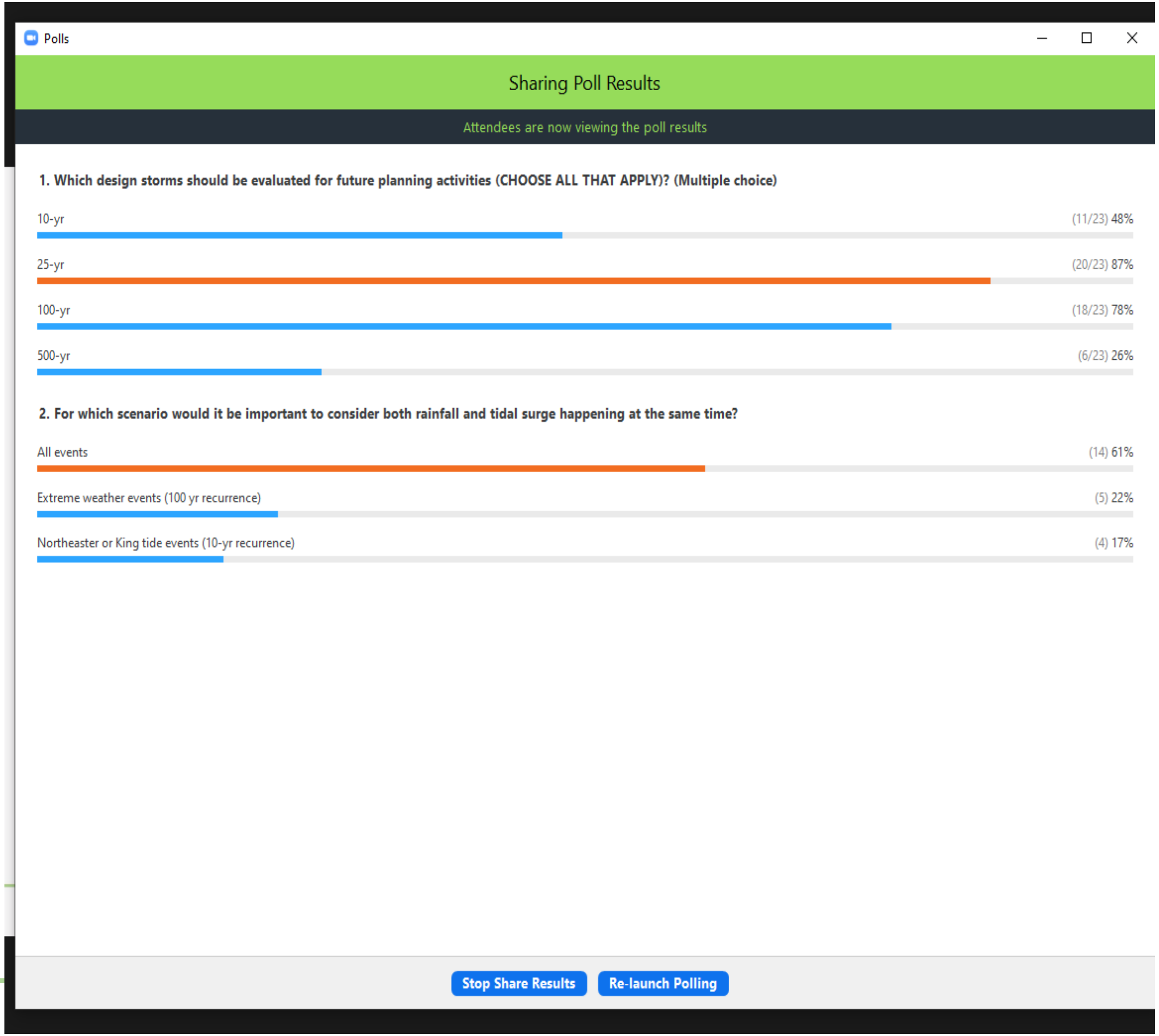
- Low projection based on RCP6.0 (moderate GHG reduction) and intermediate SLR
- High projections based on RCP8.5 (no GHG reduction) and high SLR
  - 25-yr
  - 100-yr
  - 500-yr

Build on the 8 scenarios Selected by JEA for Resiliency Planning (Additional 2070 scenario without surge)

Scenario Description		2070		
		Low	High	
Rainfall	SLR Projections			
RCP6.0 50% non-exceedance	NOAA 2017: Intermediate	✓		
RCP8.5 50% non-exceedance	NOAA 2017: High		✓	✓
Rainfall		✓	✓	✓
Surge		✓	✓	
Return Period of Surge Event (year)				
25-year (current rain: 8.8”)			✓	
100-year (current rain: 12.3”)		✓	✓	✓
500-year (current rain: 16.6”)			✓	

- One additional High scenario was run based on rainfall and SLR only (i.e. no surge component)

Poll

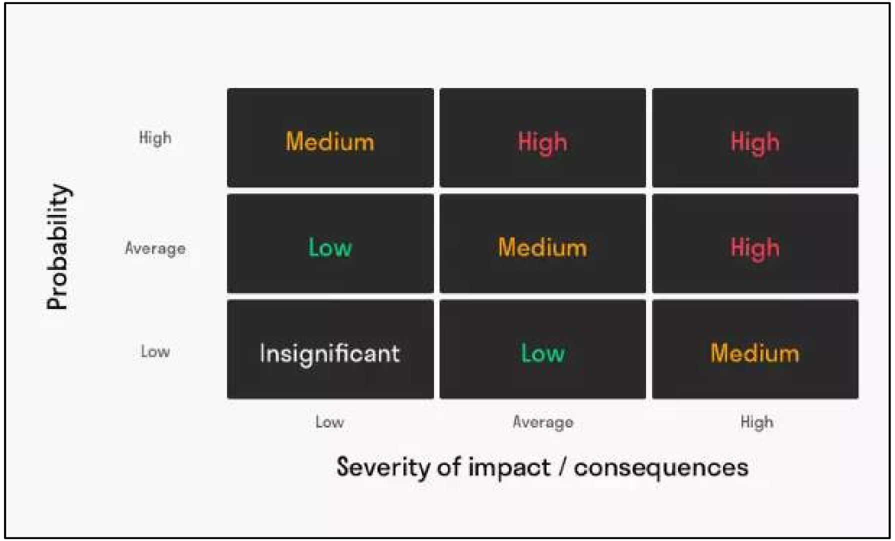


Polls
Sharing Poll Results
Attendees are now viewing the poll results
1. Which design storms should be evaluated for future planning activities (CHOOSE ALL THAT APPLY)? (Multiple choice)
10-yr
(11/23) 48%
25-yr
(20/23) 87%
100-yr
(18/23) 78%
500-yr
(6/23) 26%
2. For which scenario would it be important to consider both rainfall and tidal surge happening at the same time?
All events
(14) 61%
Extreme weather events (100 yr recurrence)
(5) 22%
Northeaster or King tide events (10-yr recurrence)
(4) 17%
Stop Share Results
Re-launch Polling

Recommended Scenarios
for
City of Jacksonville

City of Jacksonville Scenario Drivers

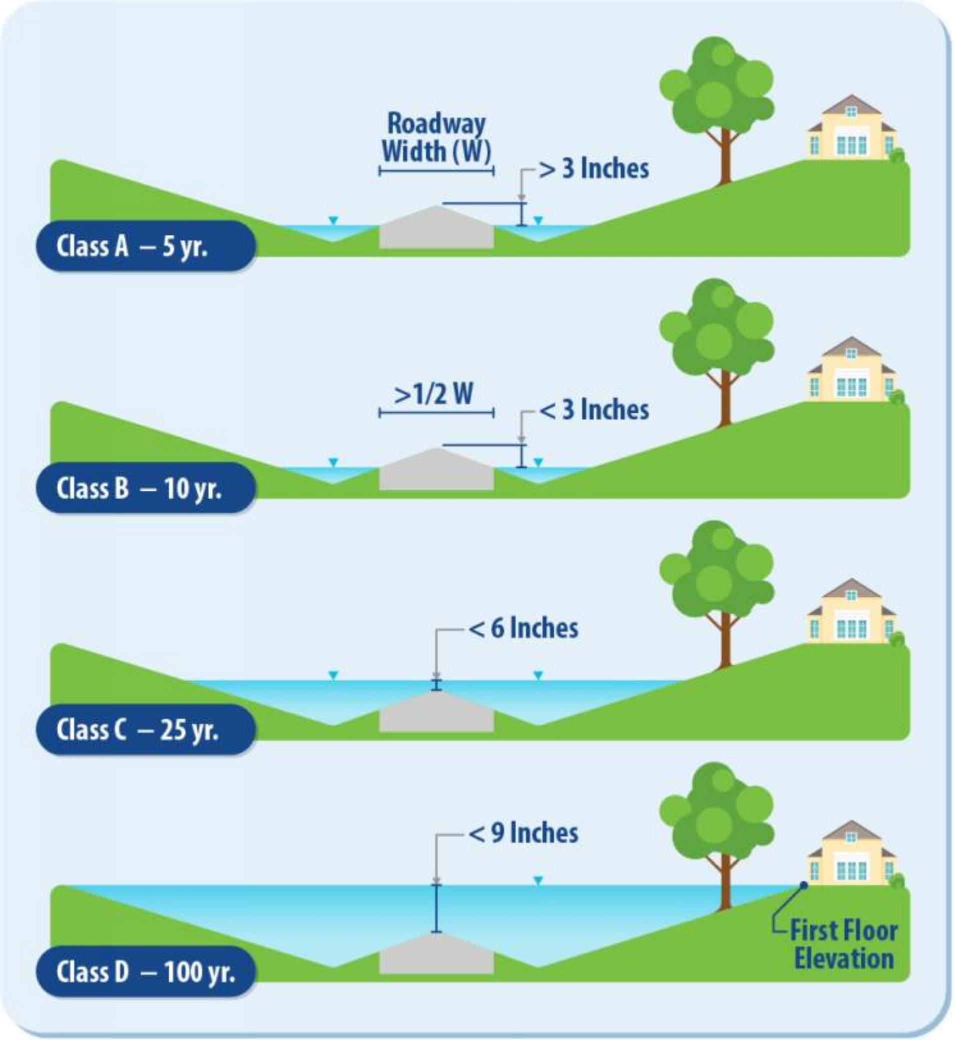
- Match desired levels of service (LOS)
- Baseline scenario for which most resources should be protected
- Consider more extreme event scenarios for higher criticality facilities



Level of Service

	Design Storm[1]	Standing Water
Local Road[2]	5 year	< 3in
Arterial[2,3]	10 year	< 3in
	25 year	< 6 in
	100 year	< 9 in
Structures	25 year	0 ft
	100 year	0 ft

1. All storm durations are 24 hours
2. Local and Arterial roads are defined by the City and the Northeast Florida Regional Planning Council (NEFRPC)
3. Flood inundation limited to each side of the road such that ½ of the roadway width (W) or one travel lane width is not flooded.



City of Jacksonville Vulnerability – 2020 Scenarios (existing condition)

		10-yr	25-yr	100-yr
Rainfall	SJRWMD	7.3	9.0	12.0
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8 ft NAVD		
	SLR	None		
Concurrent Surge Event				

- Based on existing MSMP methodology

City of Jacksonville Vulnerability – 2040 Scenarios (near-term)

		10-yr	25-yr	100-yr
Rainfall	RCP 6.0	7.5	9.6	13.4
	RCP 8.5	7.7	9.8	13.8
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8 ft NAVD		
	SLR	NOAA 2017 Intermediate High 1.4 ft		
Concurrent Surge Event				X

- Assets with 20-yr service life:
  - Pump stations
  - Mechanical equipment
- Rainfall IDF curves based on RCP 8.5 (Business as Usual)
- Tailwater conditions based on Mean Annual Stillwater with NOAA Intermediate High Projections
- Sensitivity run for concurrent surge during extreme weather events to evaluate impact on most critical facilities

City of Jacksonville Vulnerability – 2070 Scenarios

		10-yr	25-yr	100-yr
Rainfall	RCP 6.0	7.8	10.0	14.1
	RCP 8.5	8.2	10.6	15.1
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8 ft NAVD		
	SLR	NOAA 2017 Intermediate High 3.3 ft		
Concurrent Surge Event				X

- Assets with 50-yr service life
  - Buildings
  - Roads
  - Bridges
- Rainfall IDF curves based on RCP 8.5 (Business as Usual)
- Tailwater conditions based on Mean Annual Stillwater with NOAA Intermediate High Projections
- Sensitivity run for concurrent surge during extreme weather events to evaluate impact on most critical facilities

City of Jacksonville Vulnerability – 2100 Scenarios (Long-term)

		10-yr	25-yr	100-yr
Rainfall	RCP 6.0	8.1	10.5	14.8
	RCP 8.5	8.8	11.5	16.7
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8 ft NAVD		
	SLR	NOAA 2017 Intermediate High 6.1 ft		
Concurrent Surge Event				X

- Long-term planning scenarios
- Rainfall IDF curves based on RCP 8.5 (business as usual)
- Tailwater conditions based on Mean Annual Stillwater with NOAA Intermediate High Projections and storm surge
- Concurrent surge during extreme weather events for “worst-case” scenarios

Summary

		2020			2040			2070			2100		
		10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr
Rainfall	RCP 6.0	7.3	9.0	12.0	7.5	9.6	13.4	7.8	10.0	14.1	8.1	10.5	14.8
	RCP 8.5				7.7	9.8	13.8	8.2	10.6	15.1	8.8	11.5	16.7
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8 ft NAVD			Mean Annual 2018 FIS 1.8 ft NAVD			Mean Annual 2018 FIS 1.8 ft NAVD			Mean Annual 2018 FIS 1.8 ft NAVD		
	SLR	None			NOAA Intermediate High 1.4 ft			NOAA Intermediate High 3.3 ft			NOAA Intermediate High 6.1 ft		
Concurrent Surge Event							X			X			X

Summary

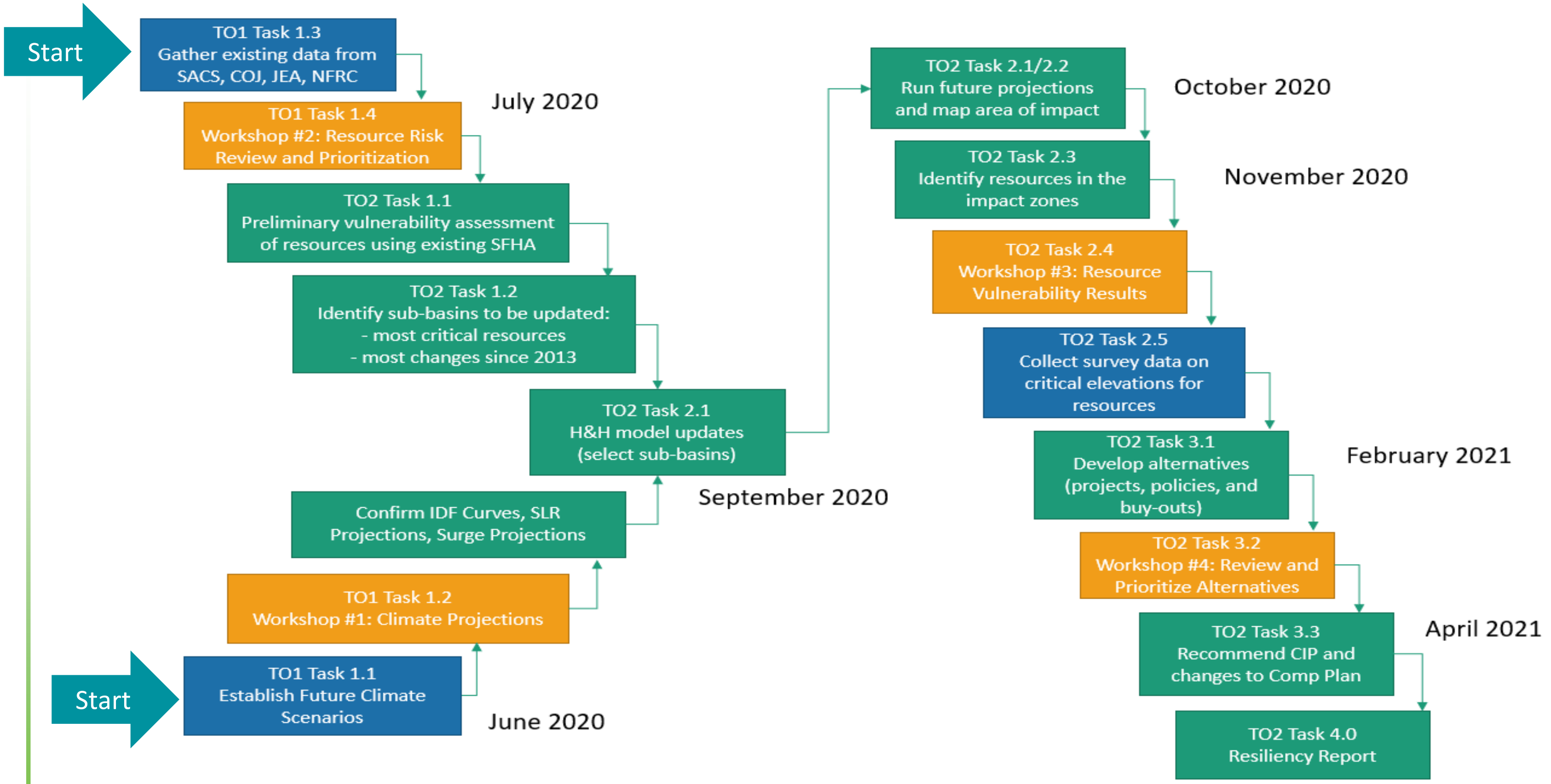
		2020			2040			2070			2100		
		10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr
Rainfall	RCP 6.0	7.3	9.0	12.0	7.5	9.6	13.4	7.8	10.0	14.1	8.1	10.5	14.8
	RCP 8.5				7.7	9.8	13.8	8.2	10.6	15.1	8.8	11.5	16.7
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD		
	SLR	None			NOAA Intermediate High 1.4 ft			NOAA Intermediate High 3.3 ft			NOAA Intermediate High 6.1 ft		
Concurrent Surge Event							X			X			X

Summary

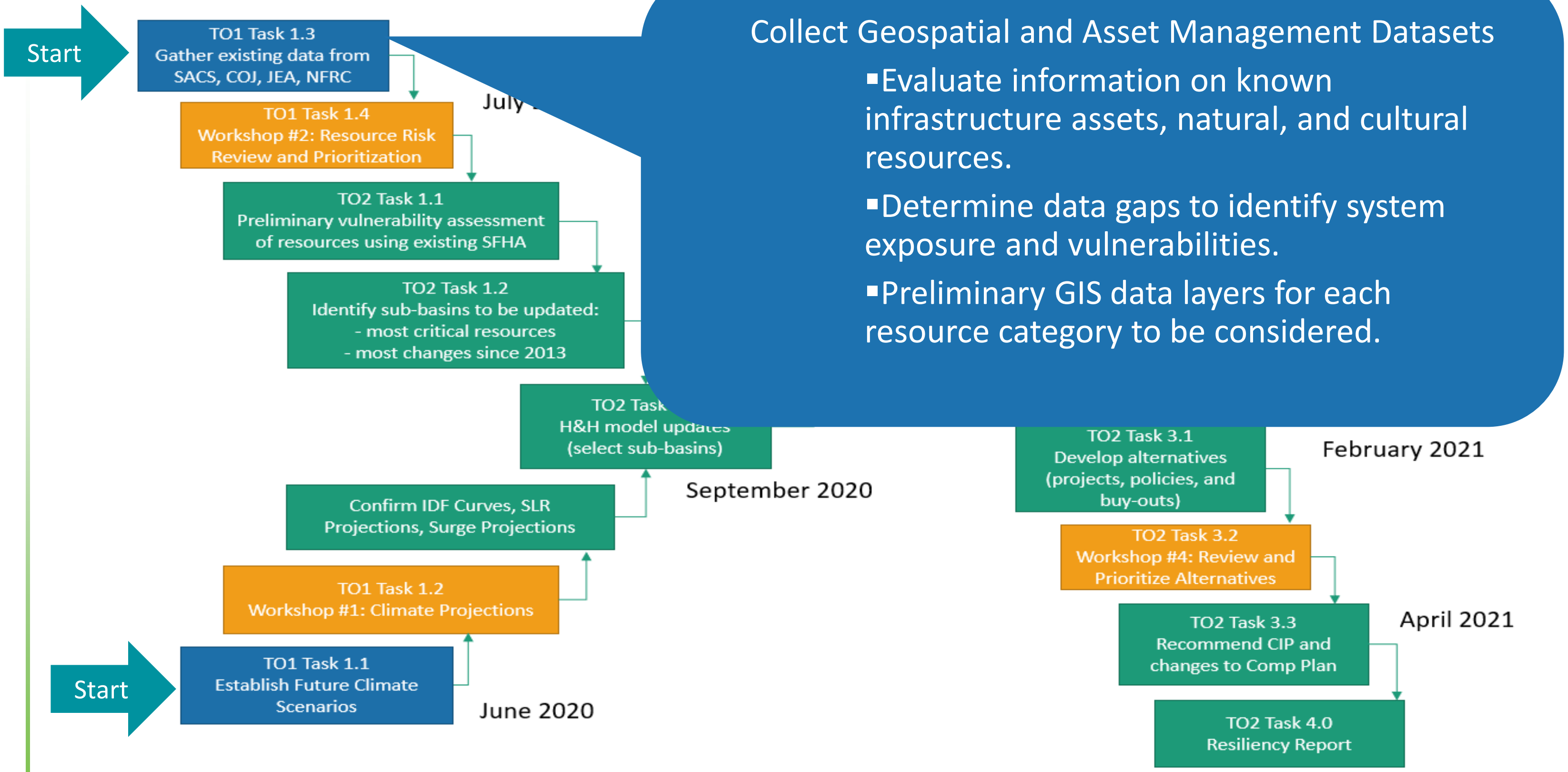
		2020			2040			2070			2100		
		10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr	10-yr	25-yr	100-yr
Rainfall	RCP 6.0	7.3	9.0	12.0	7.5	9.6	13.4	7.8	10.0	14.1	8.1	10.5	14.8
	RCP 8.5				7.7	9.8	13.8	8.2	10.6	15.1	8.8	11.5	16.7
Tailwater Condition	Stillwater	Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD			Mean Annual 2018 FIS 1.8ft NAVD		
	SLR	None			NOAA Intermediate High 1.4 ft			NOAA Intermediate High 3.3 ft			NOAA Intermediate High 6.1 ft		
Concurrent Surge Event							X			X			X

Project Look-Forward

Jacksonville Resiliency Planning Scope



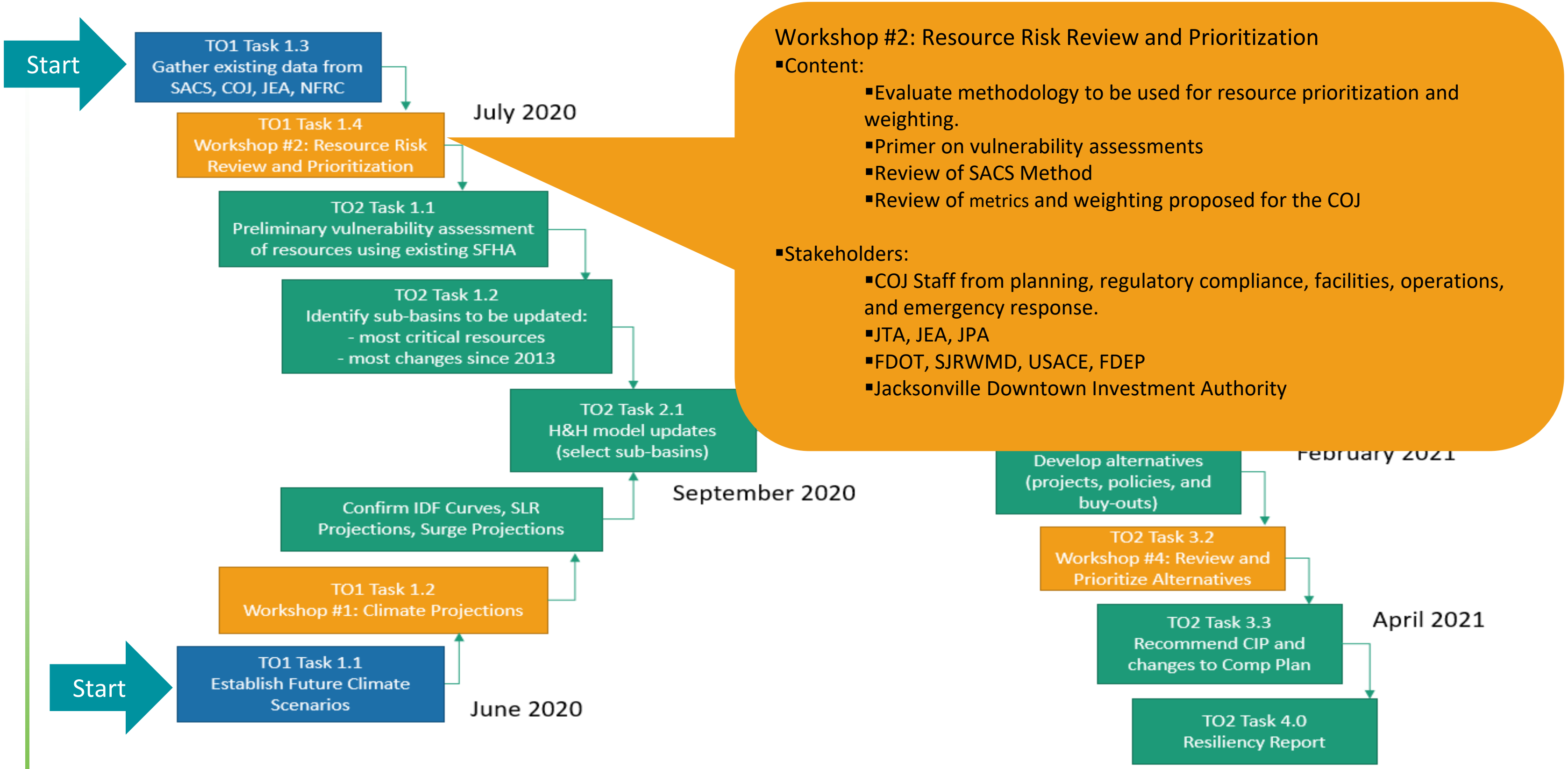
Jacksonville Resiliency Planning Scope



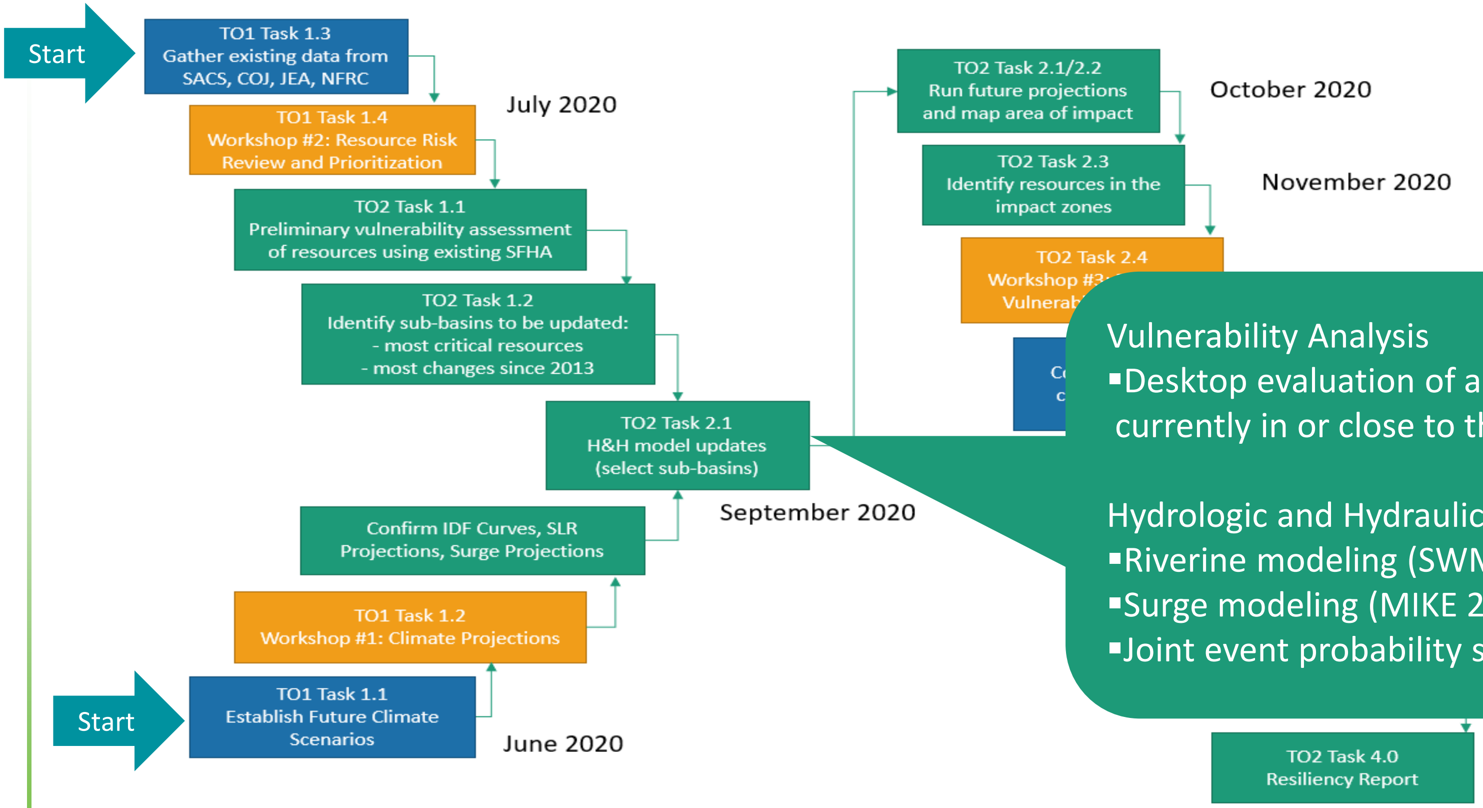
Collect Geospatial and Asset Management Datasets

- Evaluate information on known infrastructure assets, natural, and cultural resources.
- Determine data gaps to identify system exposure and vulnerabilities.
- Preliminary GIS data layers for each resource category to be considered.

Jacksonville Resiliency Planning Scope



Jacksonville Resiliency Planning Scope



Vulnerability Analysis

- Desktop evaluation of assets that are currently in or close to the existing SFHA

Hydrologic and Hydraulic Modeling

- Riverine modeling (SWMM)
- Surge modeling (MIKE 21)
- Joint event probability sensitivity analysis

Thank You

City of Jacksonville
Storm Resiliency and Hardening Project

SAVE THE DATE

Storm Resiliency and Hardening Workshop on Resource Criticality and Prioritization

August 5, 2020 | 1:00 – 4:00 p.m. EDT

The purpose of the workshop is to discuss the methodology for weighting and prioritizing critical resources and infrastructure.