Sea Level Rise in Monroe County

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Florida Keys County Commissioners
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OUTLINE

- Drivers of Sea Level Rise (SLR)
- Global SLR Curves
- Regionalized Projections
- Risk management
- Q&A

Source: Rob O'Neal
Increasing Sea Level

Historical Global Mean Sea Level

Sweet et al. (2017): Chapter 12 (Sea Level) in the NCA4 Volume 1: Climate Science Special Report
Increasing (Accelerating) Global Sea Level

Frederikse et al. (2020): The causes of sea-level rise since 1900
Increasing Carbon Dioxide (ppm)

CO₂ during ice ages and warm periods for the past 800,000 years

- Warm period (interglacial)
- Ice age (glacial)

Years before present:
- 800,000
- 700,000
- 600,000
- 500,000
- 400,000
- 300,000
- 200,000
- 100,000
- 0

Carbon dioxide (ppm):
- 400
- 350
- 300
- 250
- 200
- 150

Highest previous concentration (300 ppm)

2017 average (405.0)

~420 in June 2021
Increasing Temperatures

Projected Global Temperatures

NCA4 Volume 1: Climate Science Special Report

Drivers of SLR  Global SLR Curves  Regionalized Projections  Risk Management
SLR, Carbon Dioxide, & Temperature

Sweet et al. (2017): Chapter 12 (Sea Level) in the NCA4 Volume 1: Climate Science Special Report
Primary Causes of Water/Sea Level Rise

Drivers of SLR
- Global SLR Curves
- Regionalized Projections
- Risk Management
Future Uncertainty: Greenland

Drivers of SLR  Global SLR Curves  Regionalized Projections  Risk Management
Future Uncertainty: Antarctica

4 feet of global sea level rise right in this vicinity (16 feet within West Antarctica)
Sea Level is Not Rising at the Same Rate Everywhere
Measurement of Sea Level Rise

Drivers of SLR Risk Management

- Measurement of Sea Level Rise
- Ocean and Land Height Changes
- Ice Melt
- Thermal Expansion

Drivers of SLR
- Global SLR Curves
- Regionalized Projections
- Risk Management
Measurement of Relative Sea Level Rise (including land motion)

https://tidesandcurrents.noaa.gov/sltrends/sltrends.html

Subsidence contributes about 0.5 mm/yr to sea levels in South Florida
Global Sea Level Rise Curves

Regional Sea Level Scenarios for Coastal Risk Management:
MANAGING THE UNCERTAINTY OF FUTURE SEA LEVEL CHANGE AND EXTREME WATER LEVELS FOR DEPARTMENT OF DEFENSE COASTAL SITES WORLDWIDE

Hall et al. (2016)

Global and Regional Sea Level Rise Scenarios for the United States

Sweet et al. (2017)
**Global Sea Level Rise Curves**

Table 4. Probability of exceeding GMSL (median value) scenarios in 2100 based upon Kopp et al. (2014).

<table>
<thead>
<tr>
<th>GMSL rise Scenario</th>
<th>RCP4.5</th>
<th>RCP8.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (0.3 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate-Low (0.5 m)</td>
<td></td>
<td></td>
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<tr>
<td>Intermediate (1.0 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate-High (1.5 m)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High (2.0 m)</td>
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<td></td>
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<tr>
<td>Extreme (2.5 m)</td>
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</tbody>
</table>

- Considered ‘likely’ under NCA4 lower & higher emissions

Sweet et al. (2017)
Global Sea Level Rise Curves

NOAA (2017) Global Sea Level Rise Scenarios and Altimetry

- Altimetry
- Intermediate Low
- Intermediate
- Intermediate High

Mean Sea Level (feet)

2000 2010 2020 2030 2040 2050

95% Confidence Interval

(Hamlington et al., Submitted)
Relative Sea Level Rise Projections

Regional Sea-Level Rise
Factors that Affect Regional and Local Sea Level

- Vertical Land Movement: subsidence, tectonic land movement, water and resource extraction, and glacial isostatic adjustment
- Ocean Circulation Dynamics: surface and deep ocean circulation changes
- Ice Melt Effects: gravitational and other changes due to redistribution of land-based ice mass
Relative Sea Level Rise Projections

Ratio of regional rise associated with global contribution (e.g., meters)

Greenland Ice Sheet (gravity)

West Antarctic Ice Sheet (gravity)

East Antarctic Ice Sheet (gravity)

Median Glaciers and Ice Caps (gravity)

Components inherent to the Intermediate Scenario (1 m by 2100)

Antarctic Ice Sheet (gravity)

Greenland Ice Sheet (gravity)

Glaciers and Ice Caps (gravity)

Ocean Heat/Circulation

Sweet et al. (2017)
Relative Sea Level Rise Projections

Adjust Global SLR for:

1. Ocean Circulation
2. Earth’s Gravitational Field & Rotation
3. Vertical Land Movement

Sweet et al, 2017
Regional Sea Level Rise (Now Accelerating)

U.S. Coastal (median) Sea Levels and NOAA (2017) Projections

- Intermediate Low
- Intermediate
- Intermediate High
- US Relative Sea Level

Drivers of SLR  Global SLR Curves  Regionalized Projections  Risk Management
Regional Sea Level Rise

South Florida Coastal Sea Levels and NOAA (2017) Projections

- Intermediate Low
- Intermediate
- Intermediate High
- US Relative Sea Level

South Florida Locations’ projections are nearly identical to national median

- Virginia Key
- Vaca Key
- Key West
- Naples
Future Impacts of Sea Level Rise

- SLR increases perennial inundation
- SLR exacerbates extreme probabilities
- SLR intensifies high tide flooding

Source: Getty Images
How Will Coastal Risk Change with SLR?

Sweet et al. (2018)

Diagram: Comparison of tidal levels in the 1960s and 2010s, showing increased risk due to sea-level rise (SLR). The graph illustrates higher probabilities of high tide floods in the 2010s compared to the 1960s, with a significant increase in the threshold for major floods due to SLR.

NOAA Tide Gauge Norfolk, VA

Above High Tide (m)

-0.9  -0.6  -0.3  0.0  0.3  0.6  0.9  1.2

1960s  2010s

High Tide Flood

Disruptive to Destructive

Major Flood
SLR Will Make Future Storms Worse

FIGURE 3: Storm Surge and High Tides Magnify the Risks of Local Sea Level Rise

Sea level sets a baseline for storm surge—the potentially destructive rise in sea height that occurs during a coastal storm. As local sea level rises, so does that baseline, allowing coastal storm surges to penetrate farther inland. With higher global sea levels in 2050 and 2100, areas much farther inland would be at risk of being flooded. The extent of local flooding also depends on factors like tides, natural and artificial barriers, and the contours of coastal land.

Local factors such as tides and coastal profile will influence extent of floodplain.
### Coastal Flooding Thresholds

**National Weather Service Wakefield, Virginia**

<table>
<thead>
<tr>
<th>Minor</th>
<th>Moderate</th>
<th>Major</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Picture</strong></td>
<td><img src="image" alt="High Tide Flood" /></td>
<td><img src="image" alt="Moderate Flooding" /></td>
</tr>
<tr>
<td><strong>Hazard</strong></td>
<td>Shallow flooding in the most vulnerable locations near the waterfront and shoreline resulting in a low threat of property damage.</td>
<td>Widespread flooding of vulnerable areas will result in an elevated threat of property damage.</td>
</tr>
<tr>
<td></td>
<td>Up to 1 foot of inundation in shoreline and vulnerable areas.</td>
<td>1 to 2 feet of inundation primarily in shoreline and vulnerable areas.</td>
</tr>
<tr>
<td><strong>Impact</strong></td>
<td>A few shoreline and vulnerable roadways and adjacent properties will experience shallow flooding.</td>
<td>Inundation of roads and low lying property near the waterfront.</td>
</tr>
<tr>
<td></td>
<td>Minor beach erosion with possible erosion to the front of vulnerable dune structures.</td>
<td>Flooding will extend along tidal rivers and creeks resulting in some road closures, flooding of vehicles, and some property.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Severe beach erosion and considerable erosion of dunes, especially during long duration events.</td>
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</tbody>
</table>

In South Florida: these heights (above high tide) are:
- **Minor**: 0.5 m
- **Moderate**: 0.8 m
- **Major**: 1.2 m

Some *surface* flooding occurs about 0.3-0.4 m above high tide.
Critical Thresholds Reached More Often

Drivers of SLR
Global SLR Curves
Regionalized Projections
Risk Management
How Will Coastal Risk Change with SLR?

High Tide Flood Days measured by NOAA Tide Gauge Virginia Key, FL
(water levels exceeding 1.75 feet above highest tide)

2021/22 Outlook
4-7 flood day

NOAA/Sweet et al. (In Press). U.S. State of High Tide Flooding with a 2021 Outlook
How Will Coastal Risk Change with SLR?

Projected High Tide Flood Days in 2020

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100
- 100 - 120
- 120 - 140
- 140 - 160
- 160 +

Year | Flood Days
--- | ---
2019 | 9 (Broke Record)

Projected High Tide Flood Days

- 2020 | 3 - 6
- 2030 | 2 - 5
- 2050 | 10 - 55

Average No. of flood days in 2000: 0
Record No. of flood days: 9

Flood threshold is 0.52m above MHHW

https://tidesandcurrents.noaa.gov/HighTideFlooding_AnnualOutlook.html
A (realtime) Baseline to Assess Future Impacts

Drivers of SLR  Global SLR Curves  Regionalized Projections  Risk Management
### How Will Coastal Risk Change with SLR?

<table>
<thead>
<tr>
<th>NCA5 Region</th>
<th>1990</th>
<th>2020</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td>1.2</td>
<td>2.7</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Pacific Is.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE US</td>
<td>0.9</td>
<td>2.0</td>
<td>&gt;10</td>
</tr>
<tr>
<td>SE US</td>
<td>0.2</td>
<td>0.3</td>
<td>2 to 5</td>
</tr>
<tr>
<td>S. Great Plain</td>
<td></td>
<td>0.05</td>
<td>0.1 to 0.3</td>
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<tr>
<td>SW US</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>NW US</td>
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<td>Alaska</td>
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<td>US Carib</td>
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**Annual Event (~2 days/event)** Frequency in 1990, 2020, *likely* by 2050 (NOAA/Sweet et al., In Prep)

- **Once in 5 years** for 1990, **Once in 3 years** for 2020, and **2-5 per year** for 2050.
To Conclude:

Already flood risk from compounding factors (e.g., sea level, groundwater, rainfall) is increasing in many locations like South Florida.

Annual variability is now affecting flood risk, commerce & budgeting.

Stay tuned on ice sheet science and emissions:

• The exact future is unknown, but ‘when not if’ scenario planning can help frame ‘futures’.

To manage risk, multiple SLR scenarios can help communities think about their risk tolerance:

• If low cost, short-lifetime asset, Intermediate Low curve might be fine
• If high cost, long-lifetime/critical asset, Intermediate-Int. High projections can help minimize risk and add protection from compounding risks
Questions?

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