Sea-Level Rise in New Jersey
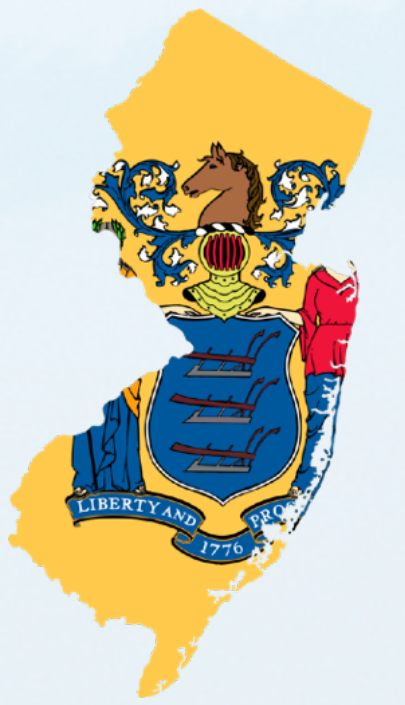
Robert Kopp

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Atmospheric Sciences

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@bobkopp@fediscience.org

Association of New Jersey Environmental Commissions
May 10, 2023
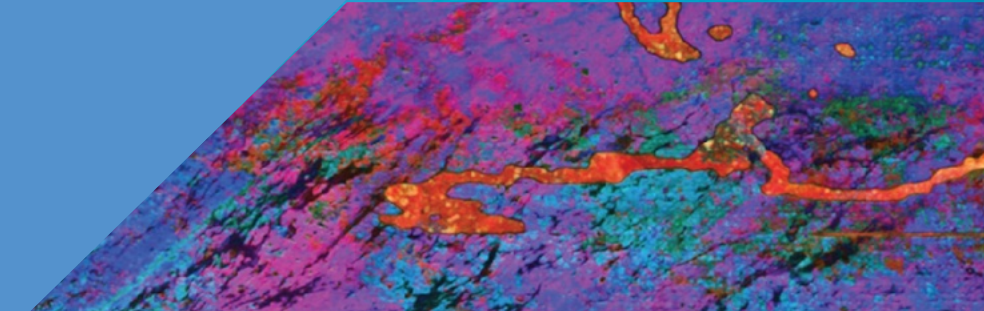
The IPCC Sixth Assessment

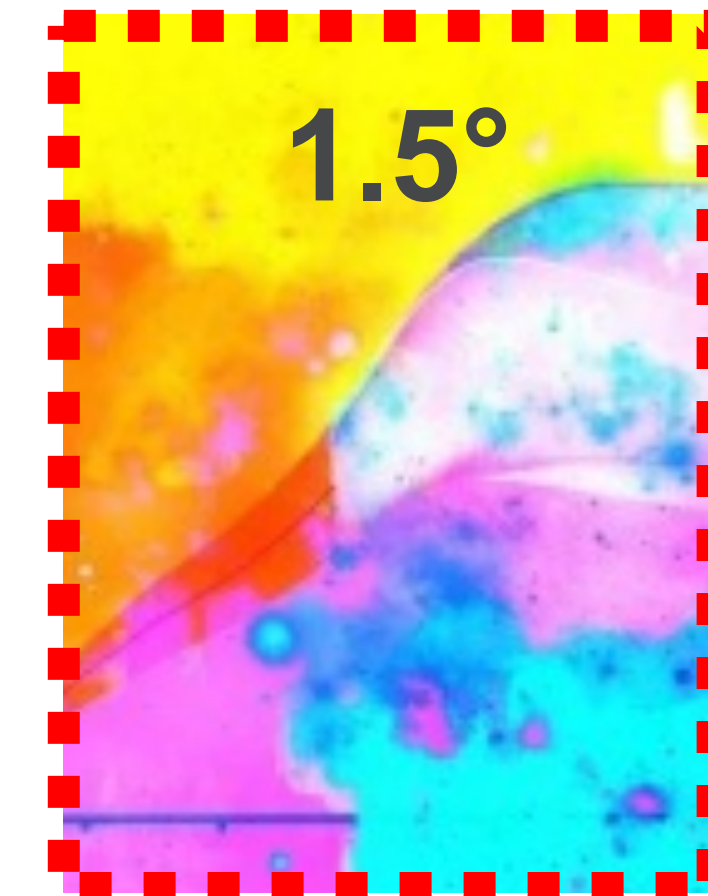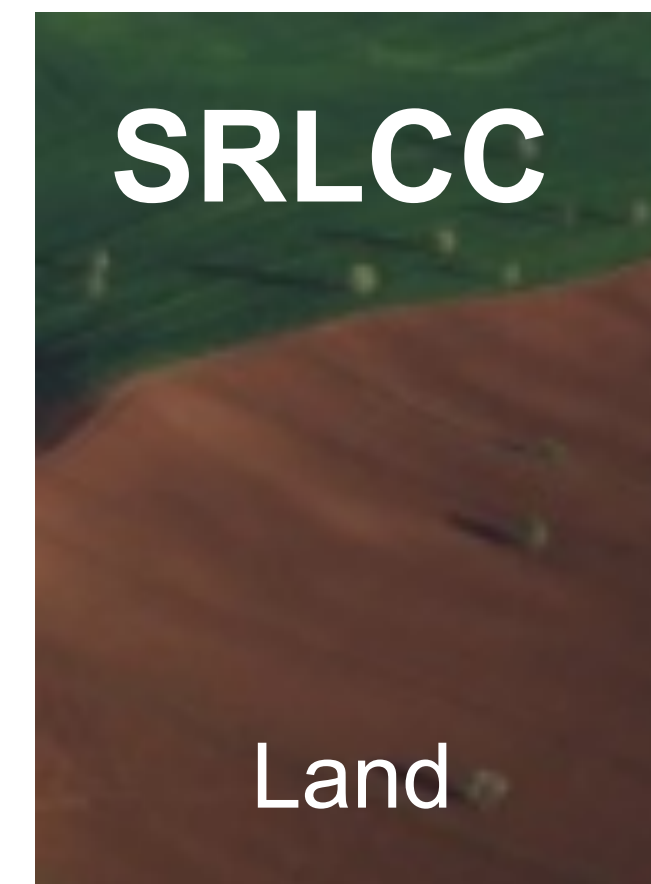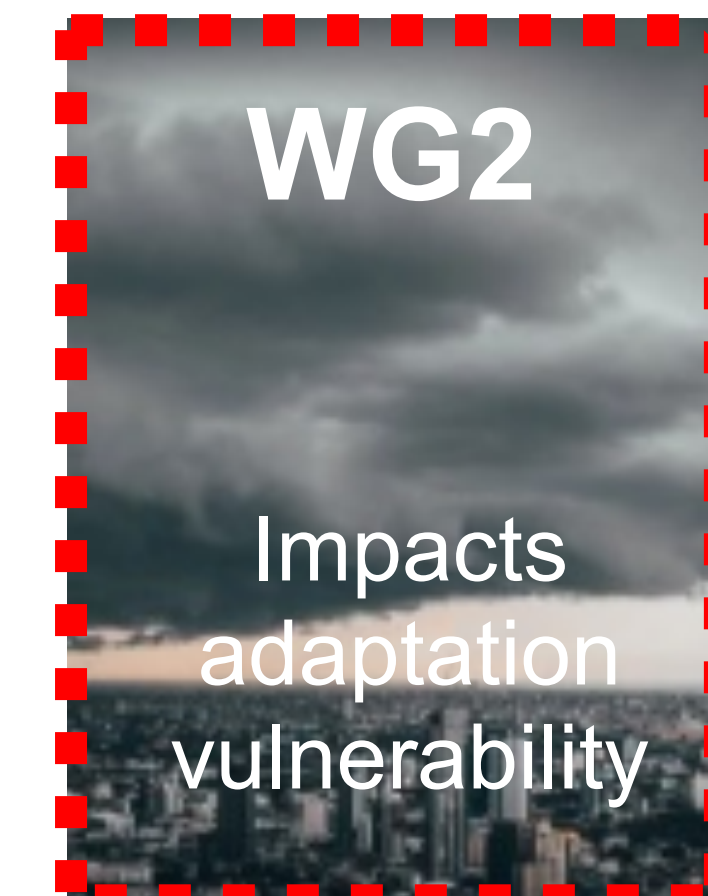- Most accurate and up-to-date global synthesis on climate science, impacts, adaptation and mitigation (assessment of research literature, **not** original research)

- Informs governments and other decision-makers about consequences of decisions (policy relevant, not policy prescriptive)

- Sixth Assessment Report: 721 scientists from 90 countries

- Working Group 1: 234 authors from 65 countries analysed 14,000 studies over 3 years

- Sea-level rise implications in WG1, WG2, SR1.5°C and SROCC

Special reports

SRLCC
Land

1.5°

SROCC
Ocean & Cryosphere

Assessment report

WG1
Climate Science

WG2
Impacts adaptation vulnerability

WG3
Mitigation

[Credit: NASA]

"Recent changes in the climate are widespread, rapid, and intensifying, and unprecedented in thousands of years.

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INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Global sea level has been rising at an accelerating rate since about 1970, and over the last century it's risen more than in any century in at least 3000 years.

AR6 WGI Ch2, Ch9

Global sea level has been rising at an accelerating rate since about 1970, and over the last century it's risen more than in any century in at least 3000 years.

1.3 mm/yr (0.5 in/decade) over 1901-1971

AR6 WGI Ch2, Ch9, CCB 9.1

Global sea level has been rising at an accelerating rate since about 1970, and over the last century it's risen more than in any century in at least 3000 years.

1.3 mm/yr (0.5 in/decade) over 1901-1971
1.9 mm/yr (0.7 in/decade) over 1971-2006
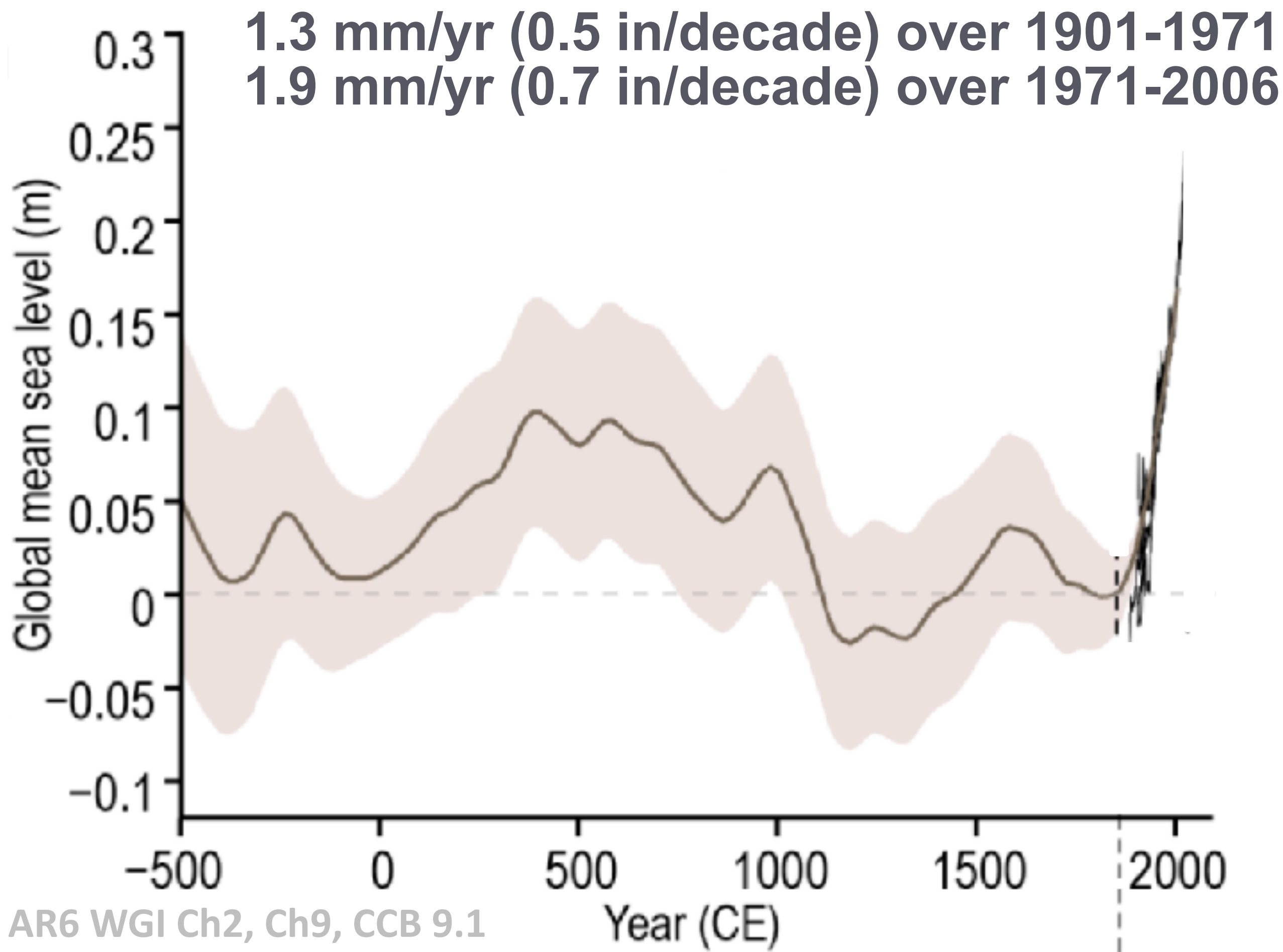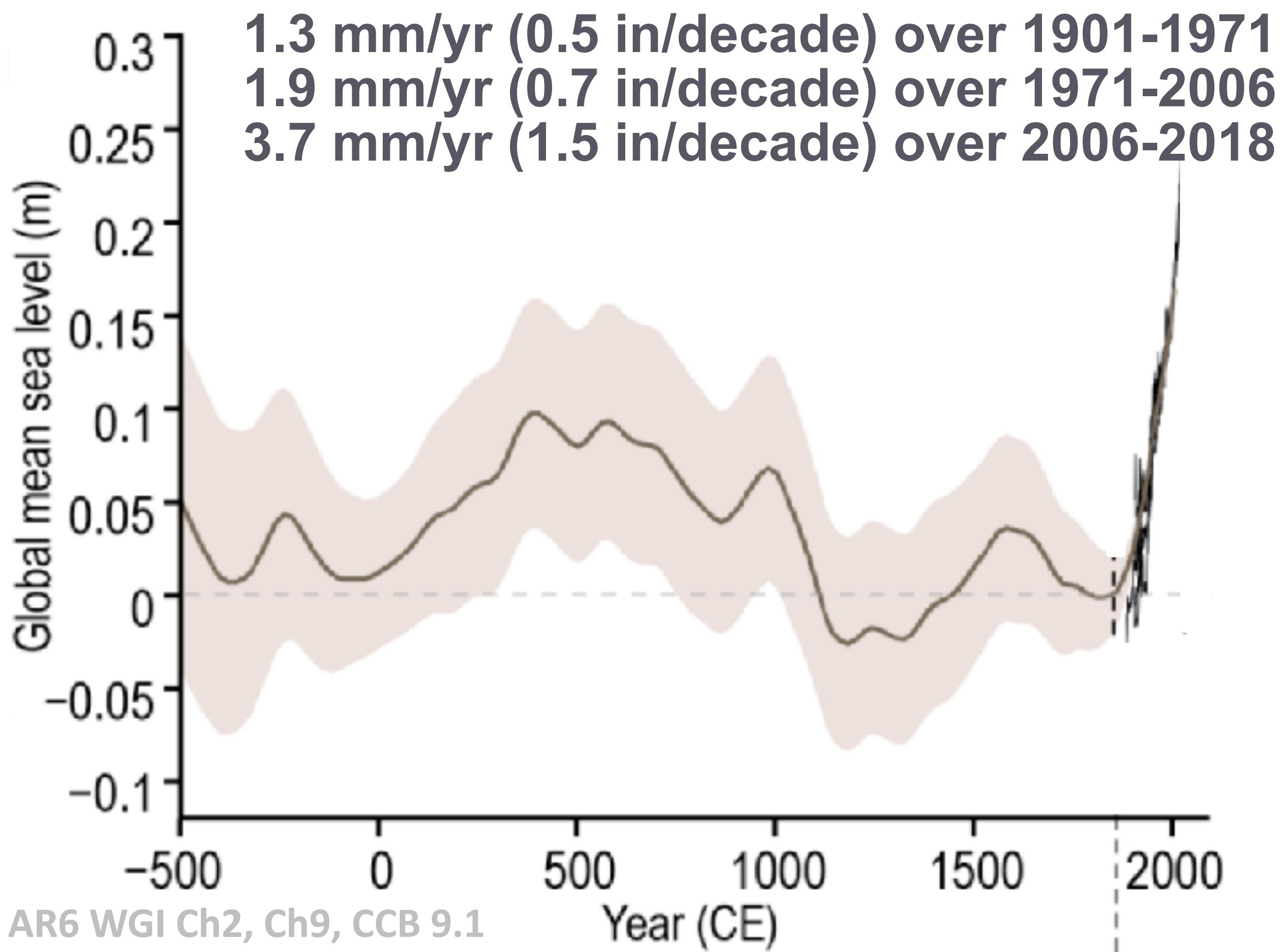

AR6 WGI Ch2, Ch9, CCB 9.1

Global sea level has been rising at an accelerating rate since about 1970, and over the last century it's risen more than in any century in at least 3000 years.

1.3 mm/yr (0.5 in/decade) over 1901-1971
1.9 mm/yr (0.7 in/decade) over 1971-2006
3.7 mm/yr (1.5 in/decade) over 2006-2018

AR6 WGI Ch2, Ch9, CCB 9.1

Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming.

2.3 mm/yr (0.9 in/decade) over 1971-2018

Contributions

cm of sea level rise (since 1971)

- Antarctic ice sheet
- Greenland ice sheet
- Glaciers
- Ocean thermal expansion
- Water stored on land

AR6 WGI CCB 9.1, FAQ 9.2

Heating of the climate system has caused global mean sea level rise through ice loss on land and thermal expansion from ocean warming.

2.3 mm/yr (0.9 in/decade) over 1971-2018

Human influence was *very likely* the main driver of global mean sea-level increases since at least 1971.

Contributions

cm of sea level rise (since 1971)

■ Antarctic ice sheet
■ Greenland ice sheet
■ Glaciers
■ Ocean thermal expansion
■ Water stored on land
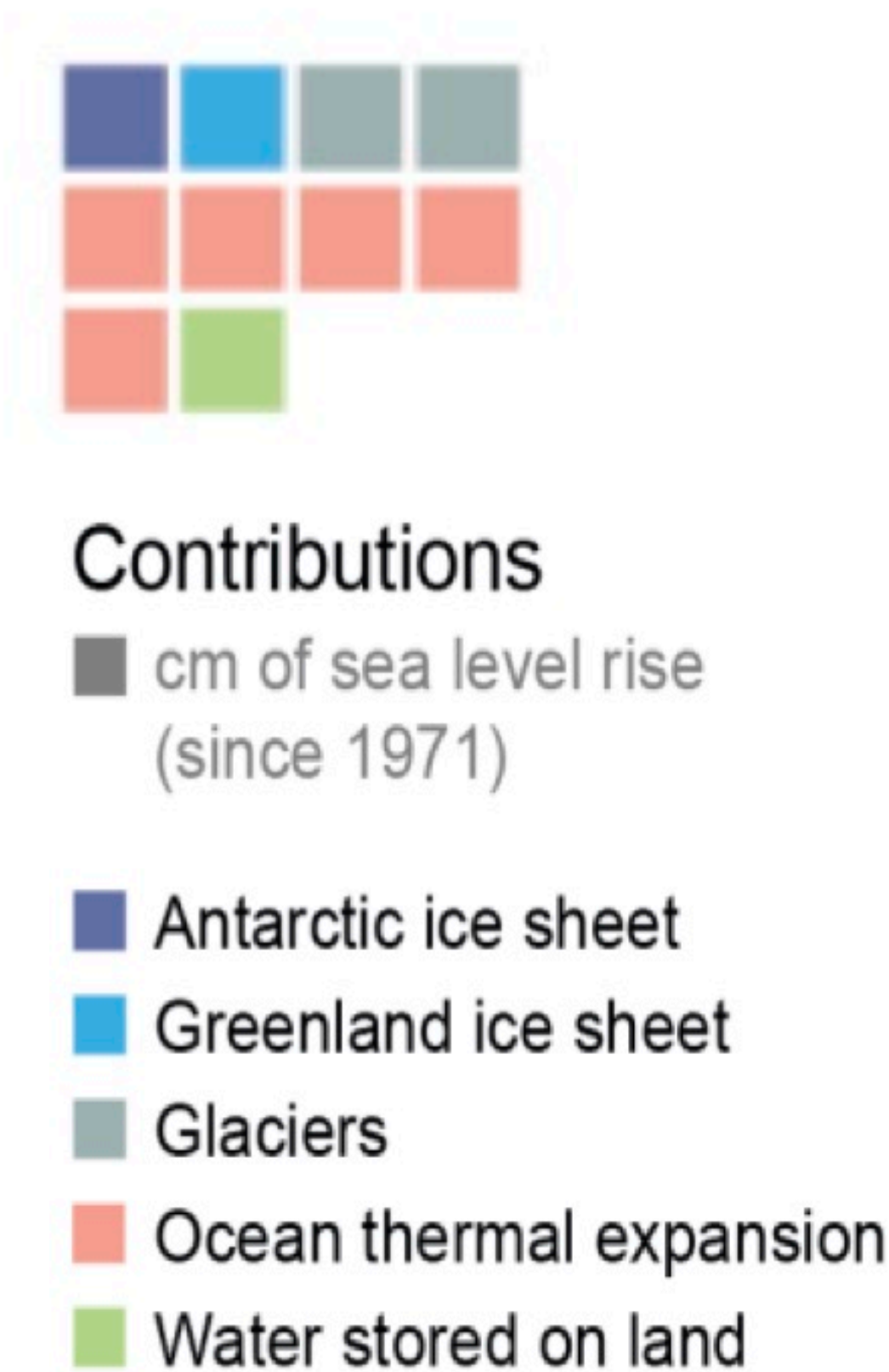
Sea level is rising even faster here in New Jersey than in the global average.

Source: New Jersey's Rising Sea STAP Report (2019)
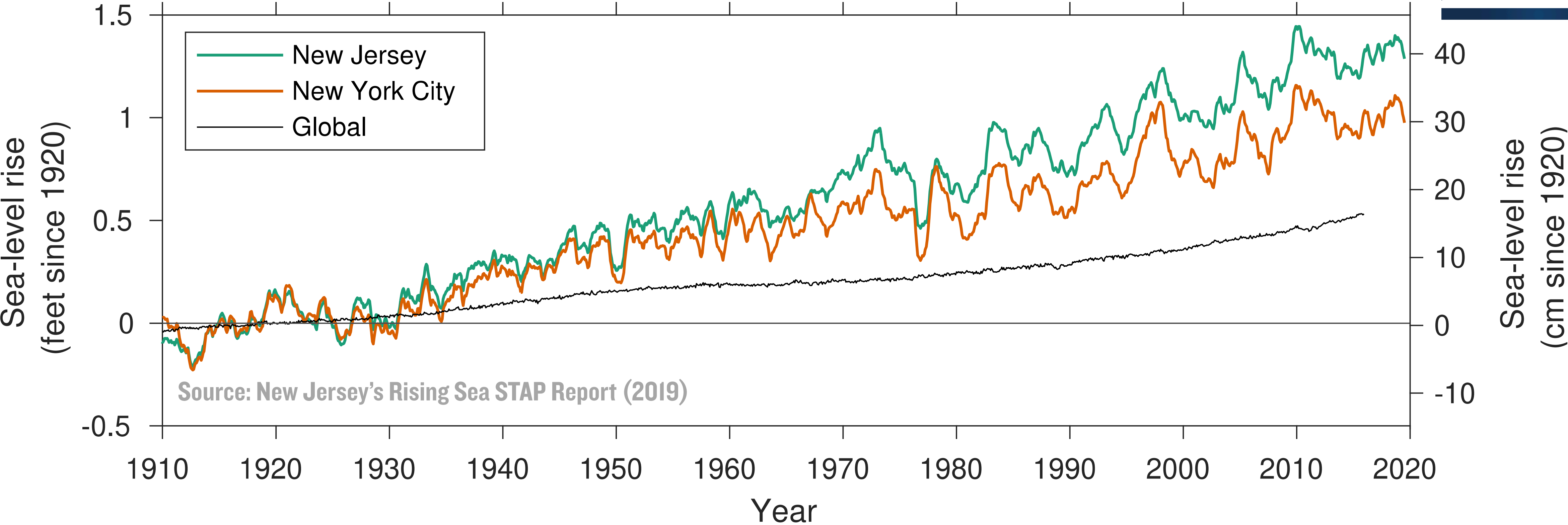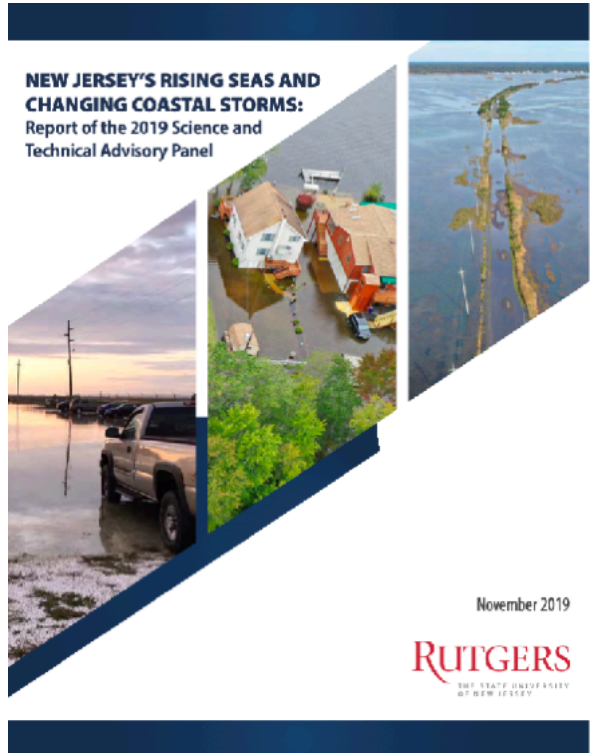
Since 1911, sea level in coastal New Jersey has risen by about 18 inches, compared to about 8 inches in the global average. The difference is largely due to natural land subsidence (about 7 inches), enhanced by groundwater withdrawal (about 3 inches).

The factors that affect sea level are more complex in specific places than in the global average.

Legend (left pie):
- Ice melt
- Thermal Expansion
- Land Water

Left pie chart values:
- 51%
- 34%
- 15%
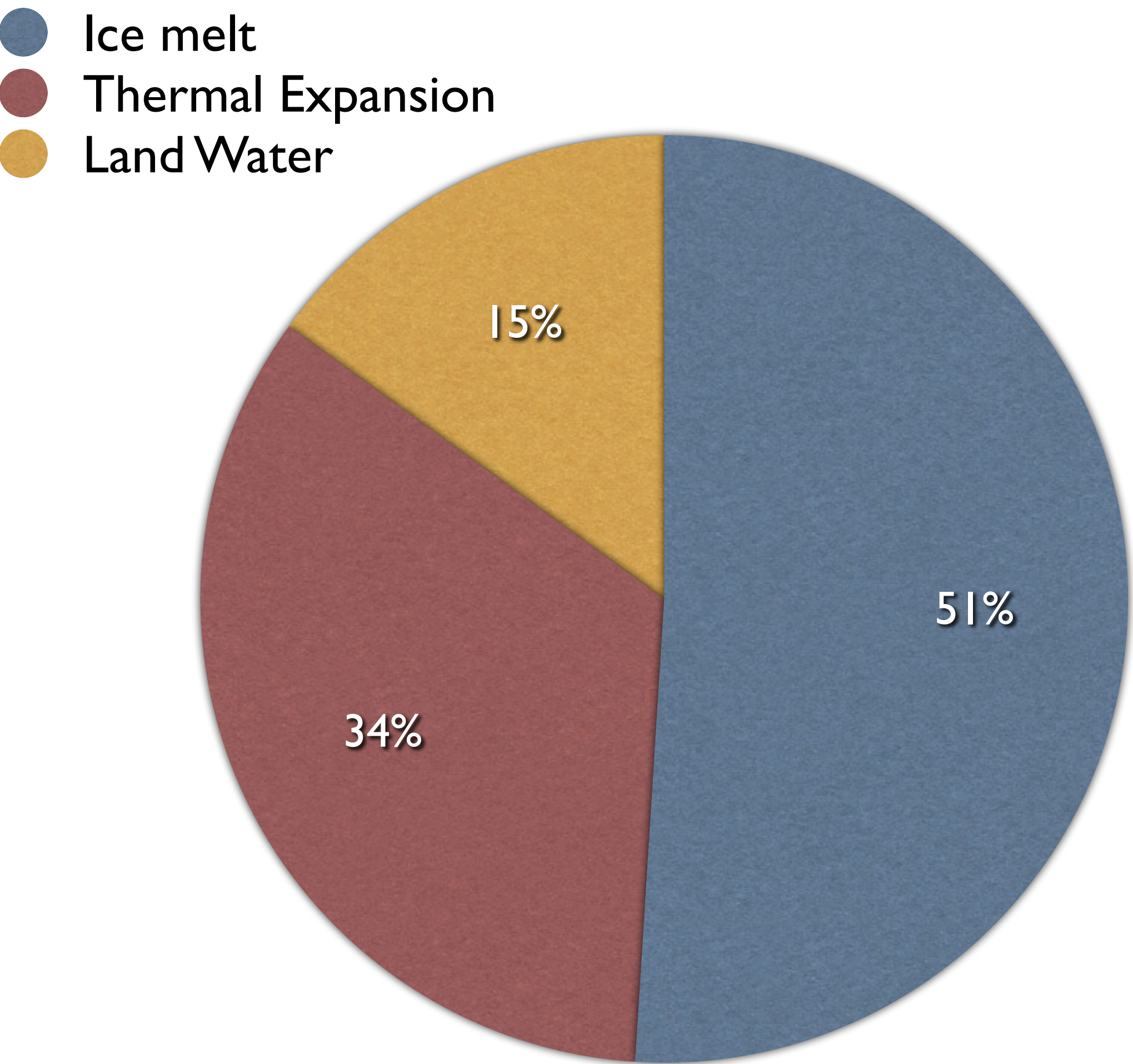
Contributions over 2006–2018 out of 1.7 inches total globally

Legend (right pie):
- Ice melt
- Thermal Expansion
- Winds, Currents, Land Water
- Sinking Land

Right pie chart values:
- 24%
- 22%
- 26%
- 28%
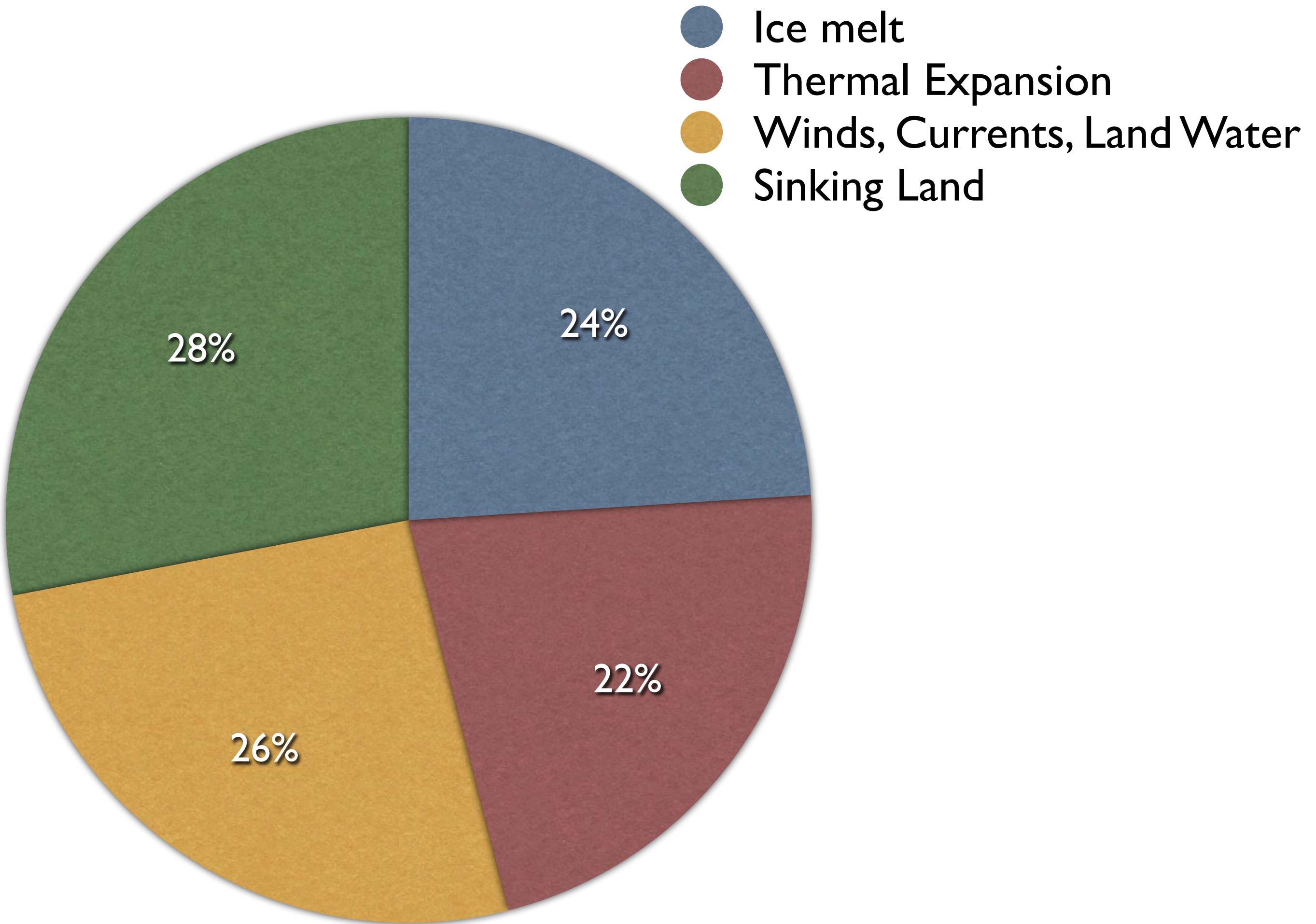
Contributions over 2006–2018 out of 2.0 inches at Atlantic City

Sea-level rise is making
high-tide flooding
more common.

Ventor, NJ
Nov. 5, 2017

The number of high-tide flooding days in Atlantic City has increased from less than 1/year in the 1950s to an average of 8/year over the last decade – a period over which sea level rose by about 9 inches.

Sea-level rise is making high-tide flooding more common.

Ventor, NJ
Nov. 5, 2017

Sweet and Park (2014)

Due to sea-l
experience

355 **646** | **371** **810** | **705** **927** | **963** **1,264** | **1,751** | **2,390** | **2,442**

Cumberland Burlington Camden Gloucester Salem Monmouth Atlantic Cape May Ocean

FIGURE 3

Change in New Jersey annual flood risk

Number of current properties at risk of annual flooding, by county, comparing sea levels in 1980 to sea levels today

■ 1980 Sea Levels
■ Current Sea Levels

31,931

21,572

19,232

16,221

13,159

8,225
6,644 **7,744**

3,050
964 **1,118** **913** **1,243** **761** **1,304** **1,338** **1,615** **2,498**

Cumberland Burlington Camden Gloucester Salem Monmouth Atlantic Cape May Ocean
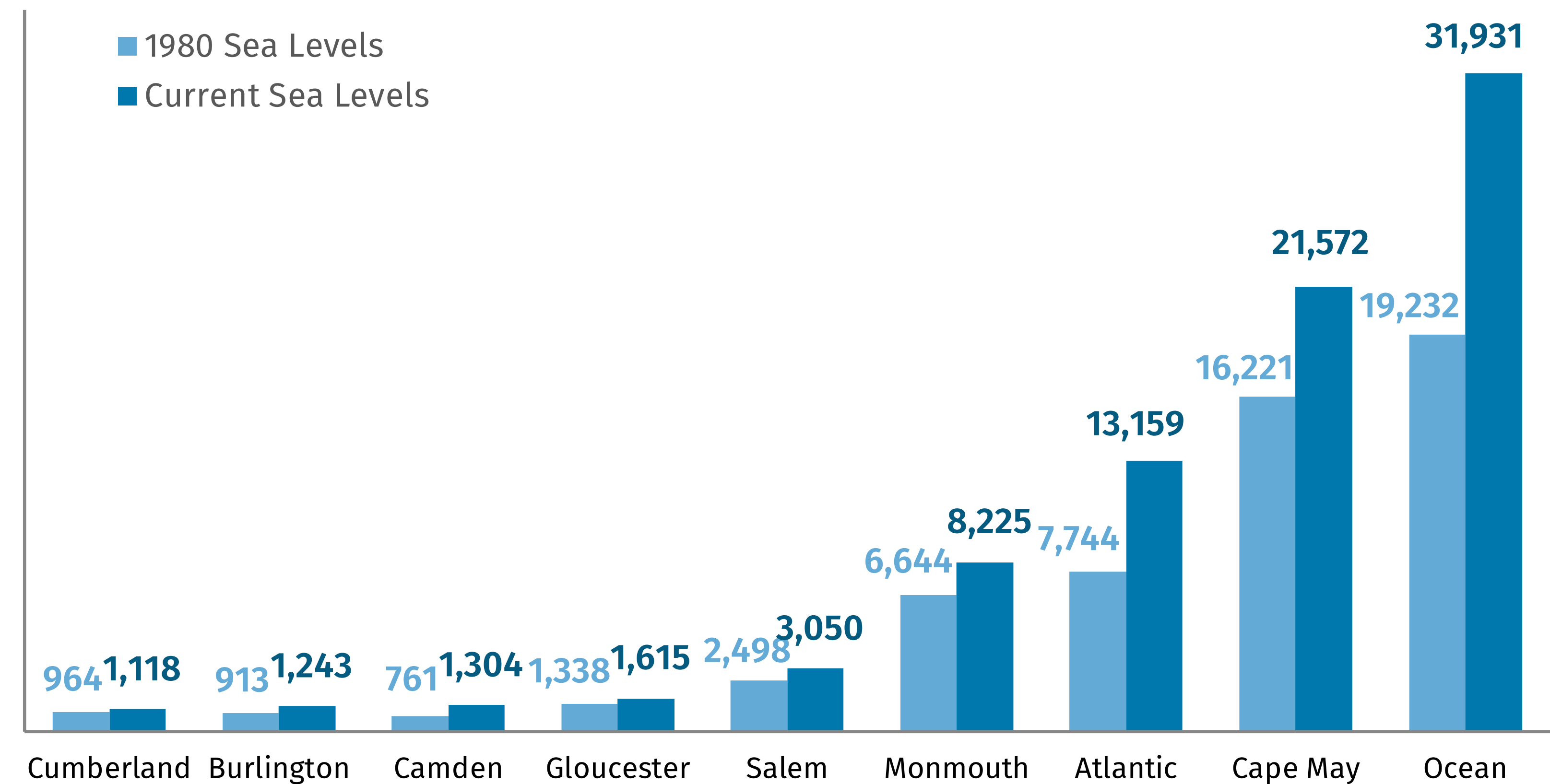
Source: Rhodium Group and First Street Foundation analysis
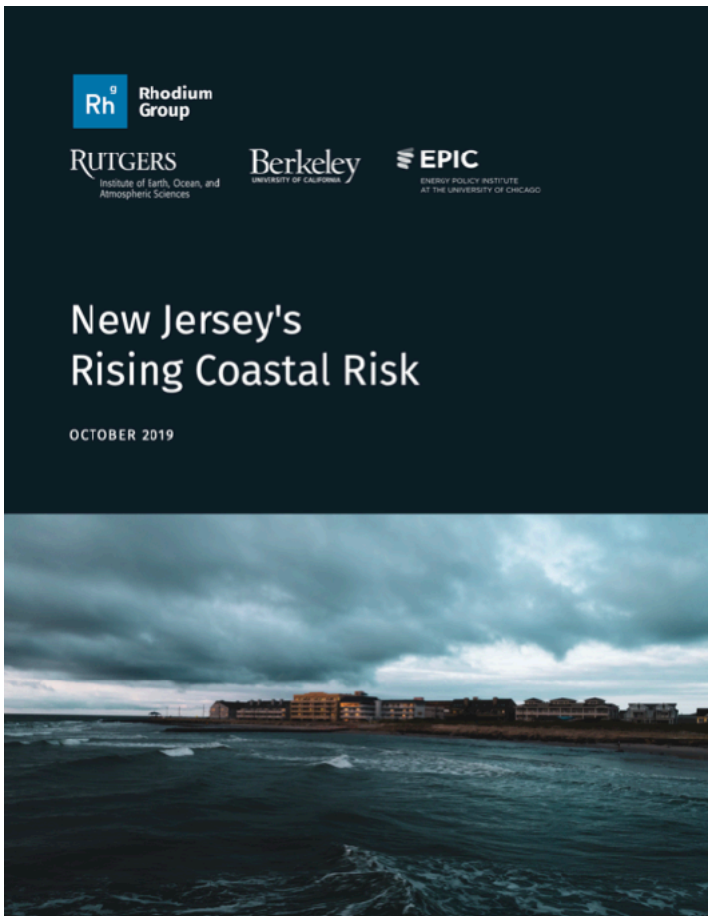
New Jersey's
Rising Coastal Risk
OCTOBER 2019

Sea-level rise is enhancing storm-driven flooding.

FDR Drive, Manhattan
October 30, 2012

David Shankbone / WikiCommons ; Strauss et al. (2021)

Human-caused sea-level rise was responsible for about 13% ($8 billion) of the property damage caused by Sandy in New York and New Jersey and exposed about 70 thousand people to Sandy's flooding.

Sea-level rise is enhancing storm-driven flooding.

FDR Drive, Manhattan
October 30, 2012
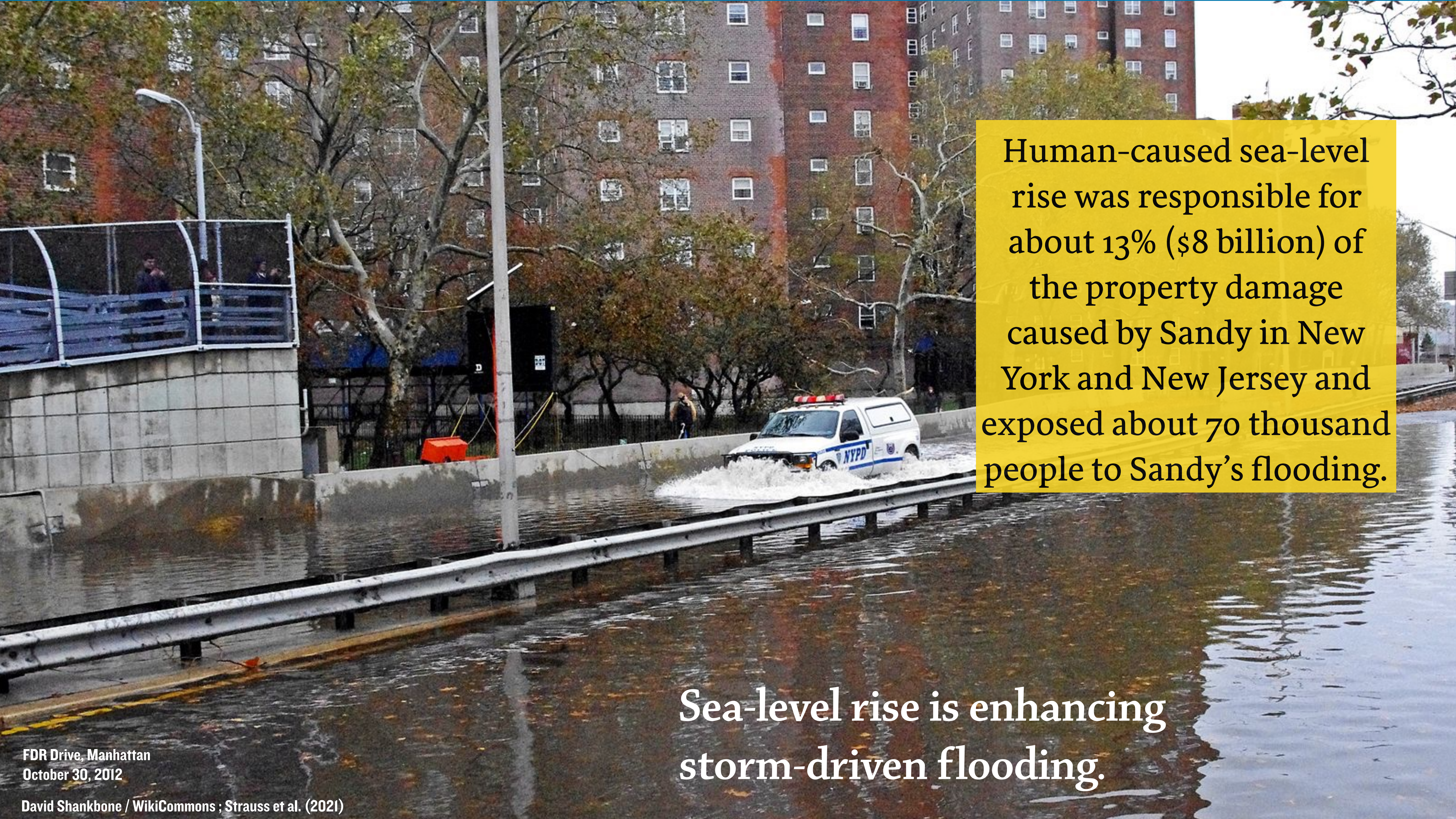
David Shankbone / WikiCommons ; Strauss et al. (2021)

Due to sea-level rise and climate change, NJ's average annual losses from hurricanes have increased about $1 billion since the 1980s.

FIGURE 7

Change in expected average annual loss from hurricanes, absolute

Increase in expected average annual loss, in million USD, by county due to changes in sea level and expected hurricane activity since the 1980s
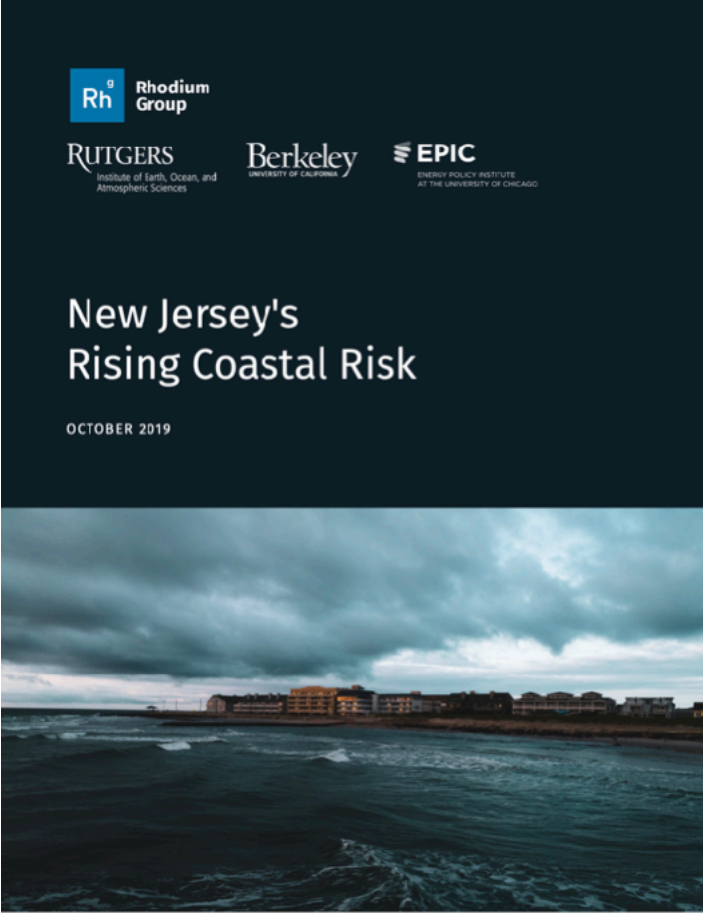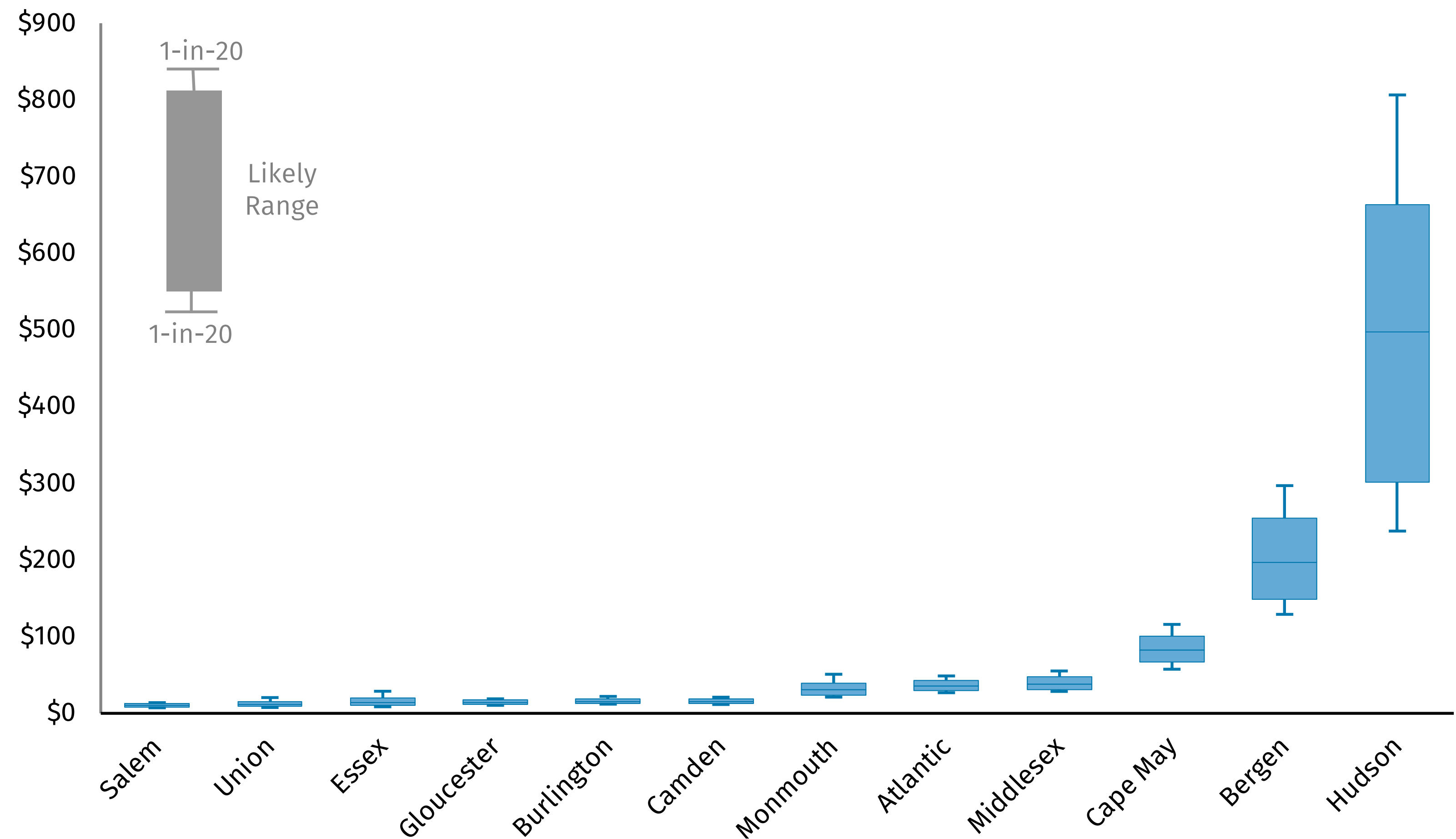
[Credit: Shari Gearheard | NSIDC]

" There's no going back from some changes in the climate system. However, some changes could be slowed and others could be stopped by limiting warming.

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INTERGOVERNMENTAL PANEL ON climate change
WMO UNEP

Sea level is going to continue to rise for many centuries to come, creating an escalating hazard for coastal communities.

d) Global mean sea level change relative to 1900
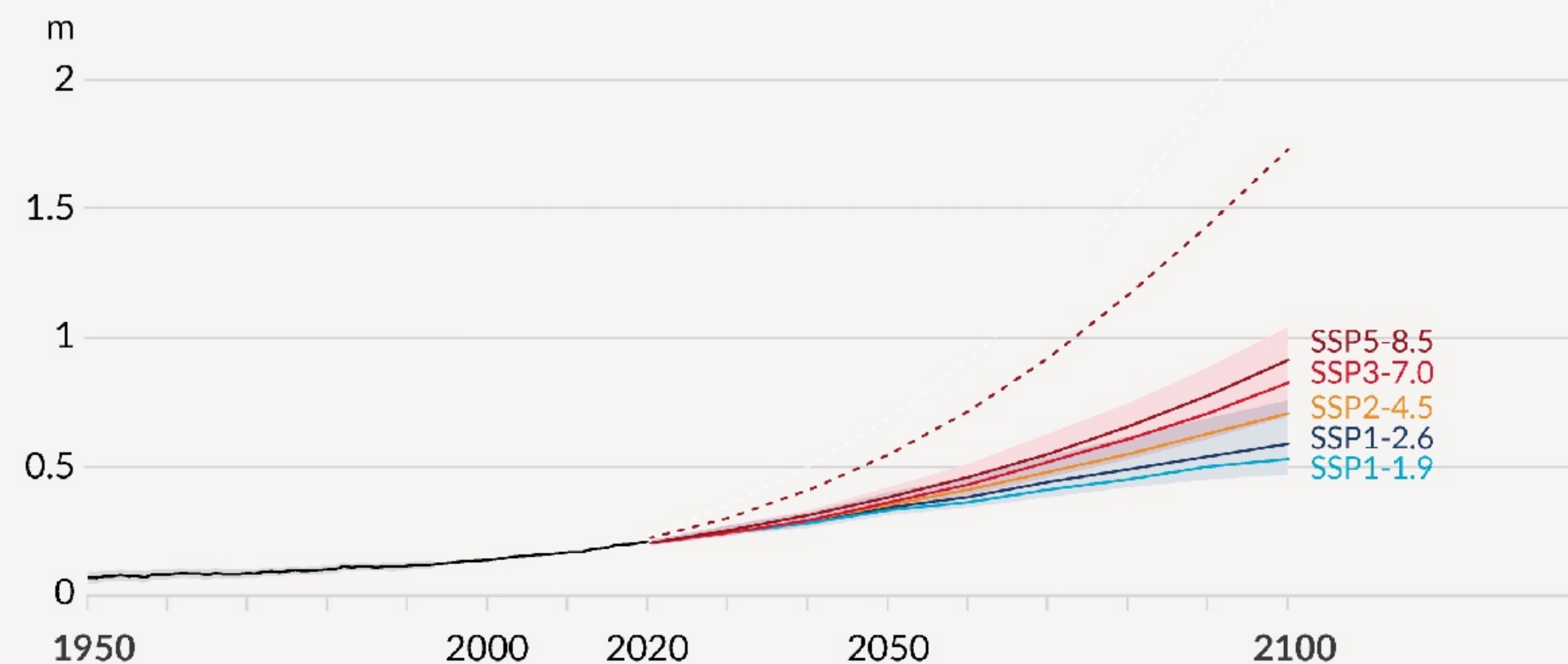
SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Through the middle of the century, sea level projections exhibit limited sensitivity to emissions scenario.

d) Global mean sea level change relative to 1900

Through the middle of the century, sea level projections exhibit limited sensitivity to emissions scenario.
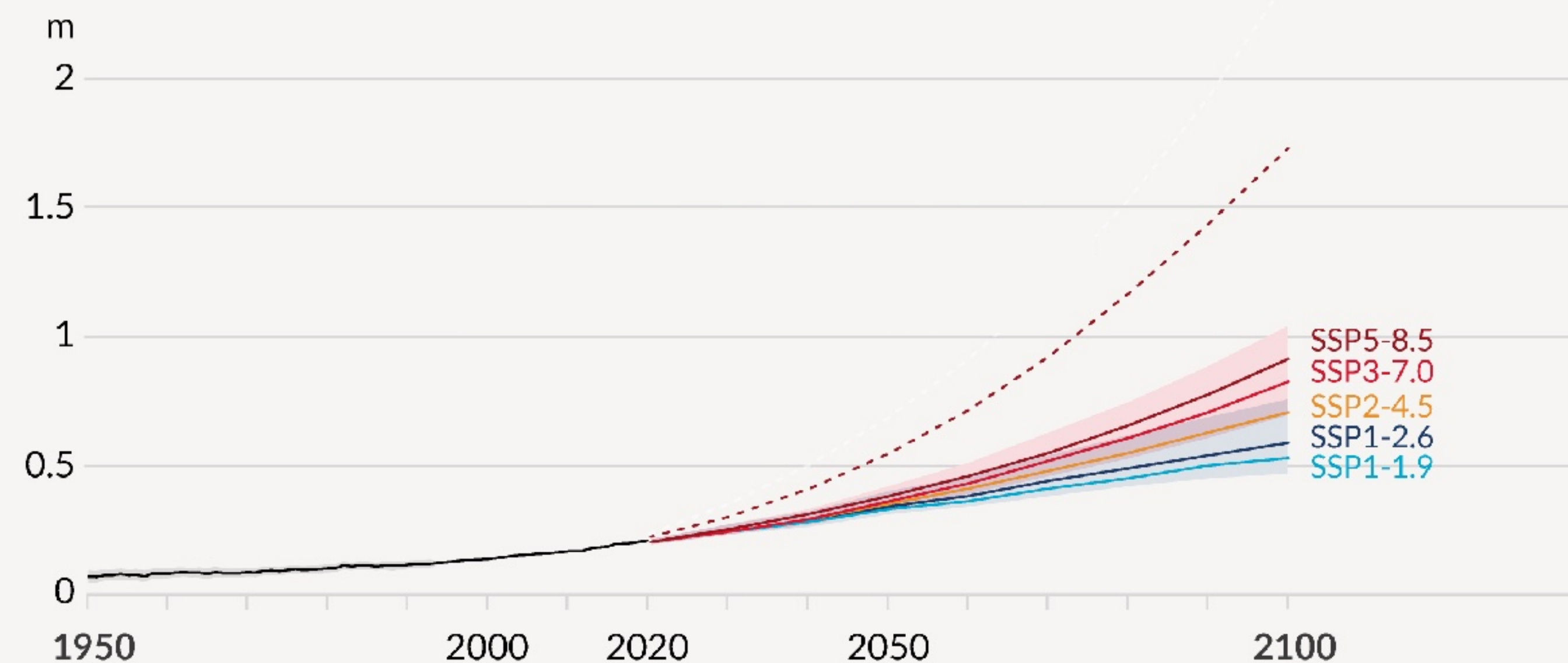
d) Global mean sea level change relative to 1900

Relative to 1995-2014, the *likely* global mean sea level rise by 2050 is:

Through the middle of the century, sea level projections exhibit limited sensitivity to emissions scenario.

d) Global mean sea level change relative to 1900

Relative to 1995-2014, the _likely_ global mean sea level rise by 2050 is:

- 0.18-0.27 m (0.6-0.9 ft) under the high GHG emissions scenario (SSP3-7.0)

Through the middle of the century, sea level projections exhibit limited sensitivity to emissions scenario.

d) Global mean sea level change relative to 1900
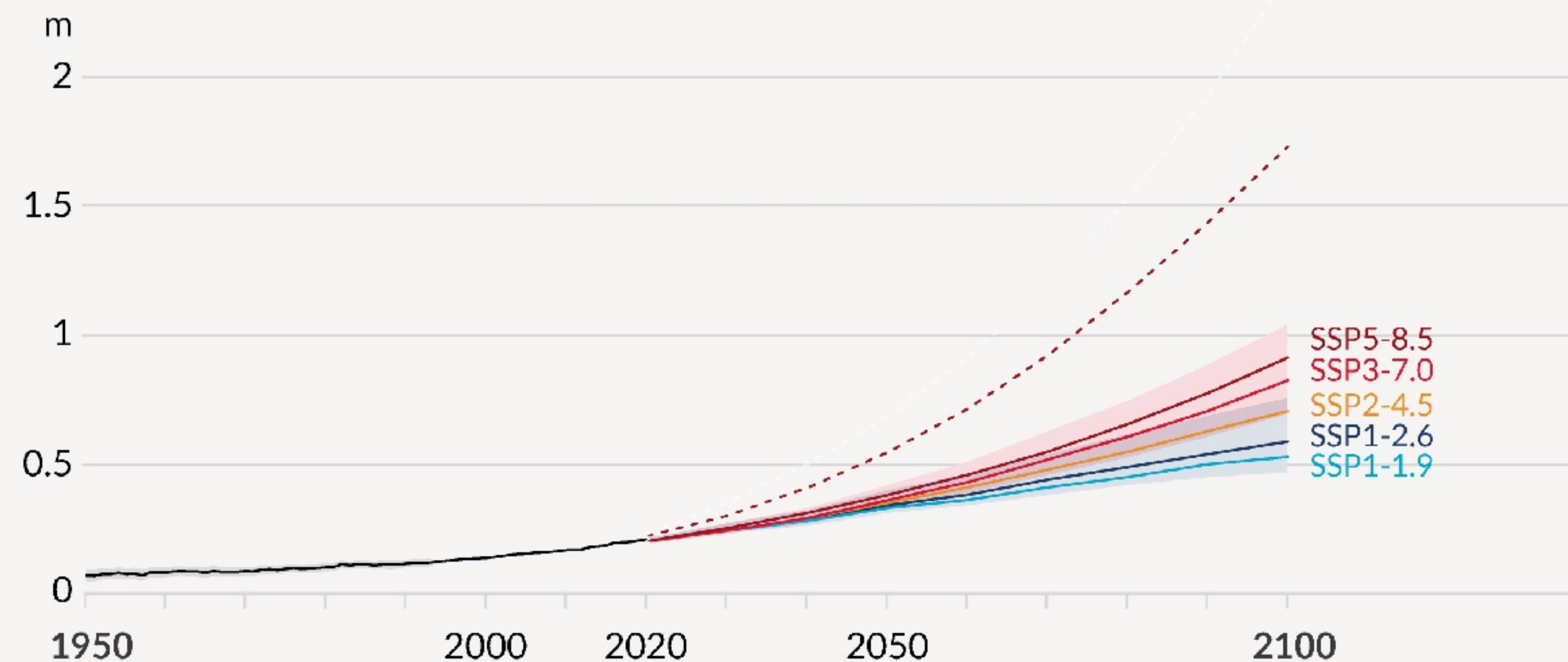
Relative to 1995-2014, the *likely* global mean sea level rise by 2050 is:

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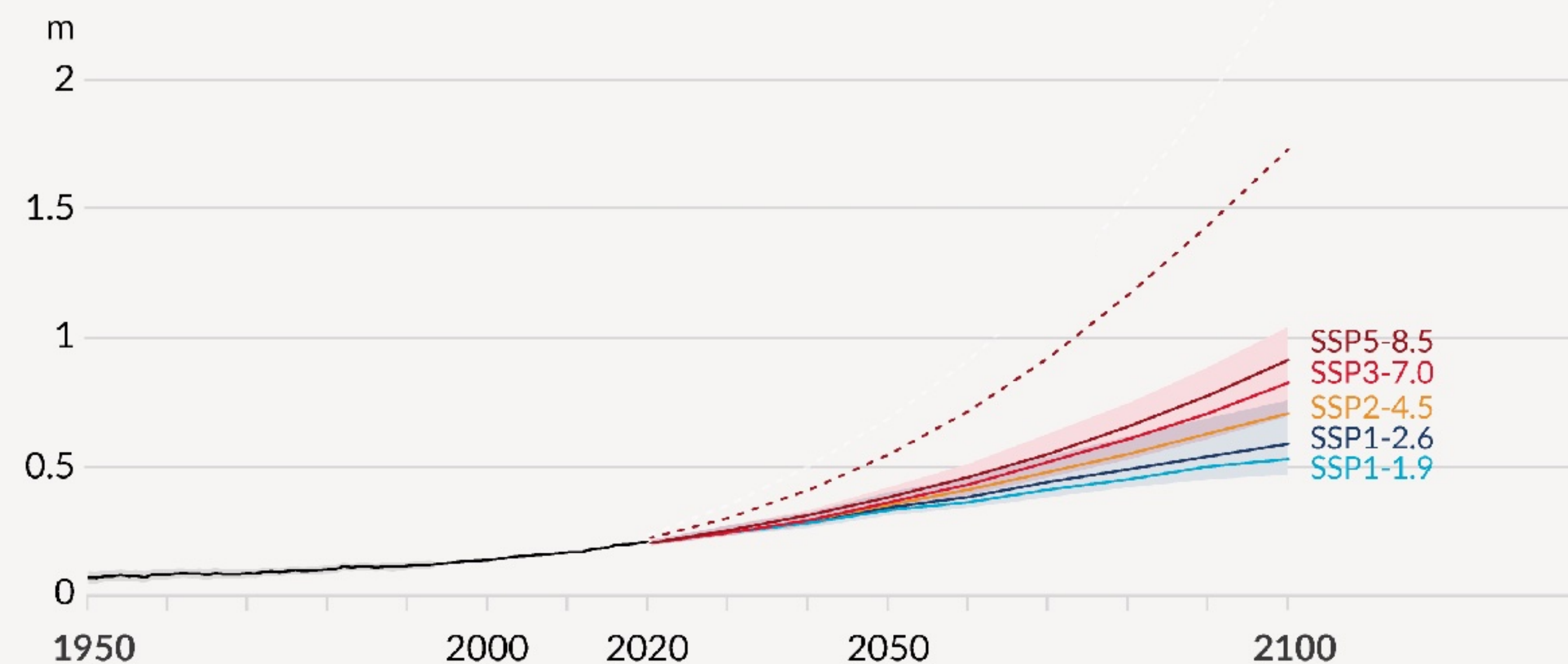- 0.16-0.25 m (0.5-0.8 ft) under the low emissions scenario (SSP1-2.6).

Through the middle of the century, sea level projections exhibit limited sensitivity to emissions scenario.

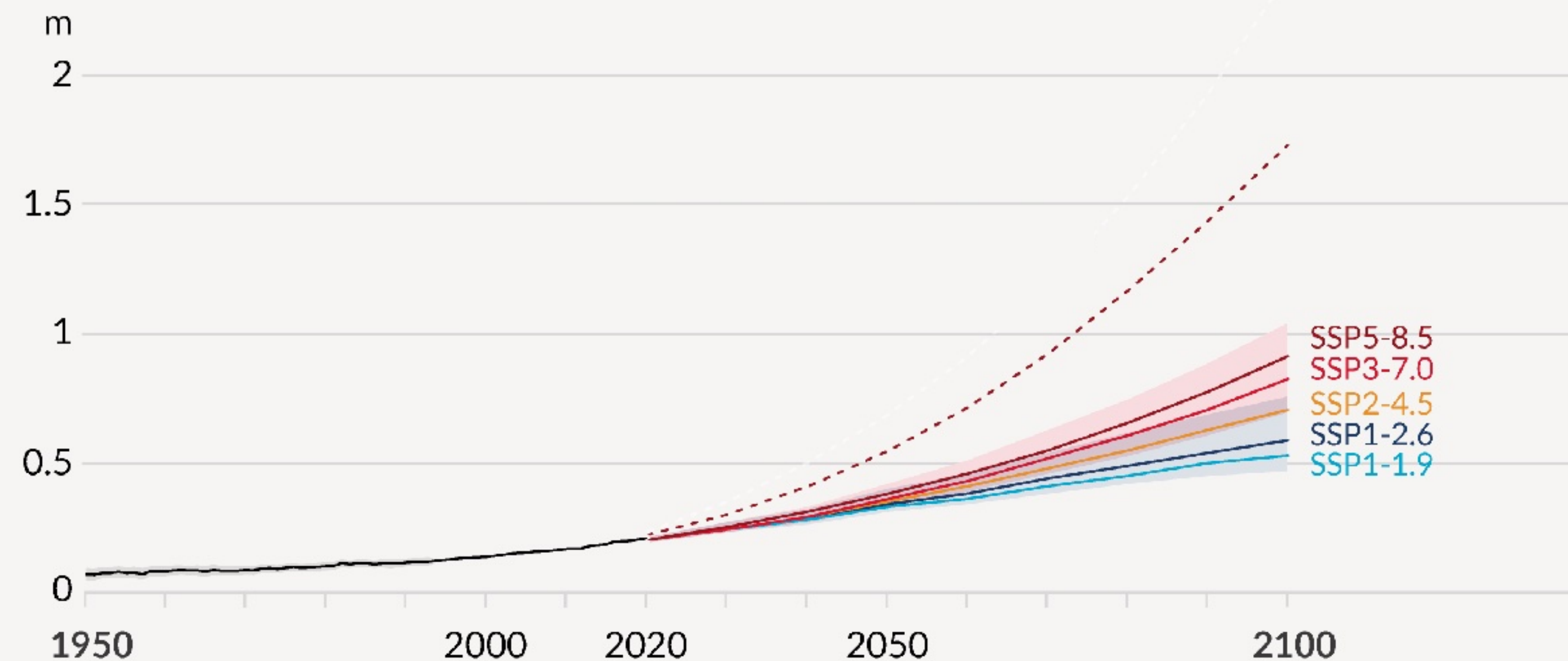d) Global mean sea level change relative to 1900

Relative to 1995-2014, the *likely* global mean sea level rise by 2050 is:

- 0.18-0.27 m (0.6-0.9 ft) under the high GHG emissions scenario (SSP3-7.0)
- 0.16-0.25 m (0.5-0.8 ft) under the low emissions scenario (SSP1-2.6).

Extreme sea levels that occurred once per century in the recent past will occur about 20–30 times more frequently by 2050.

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

d) Global mean sea level change relative to 1900

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

The *likely* global mean sea level rise is

d) Global mean sea level change relative to 1900

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

The *likely* global mean sea level rise is

d) Global mean sea level change relative to 1900

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

The *likely* global mean sea level rise is

by 2100:

d) Global mean sea level change relative to 1900

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

d) Global mean sea level change relative to 1900

The *likely* global mean sea level rise is
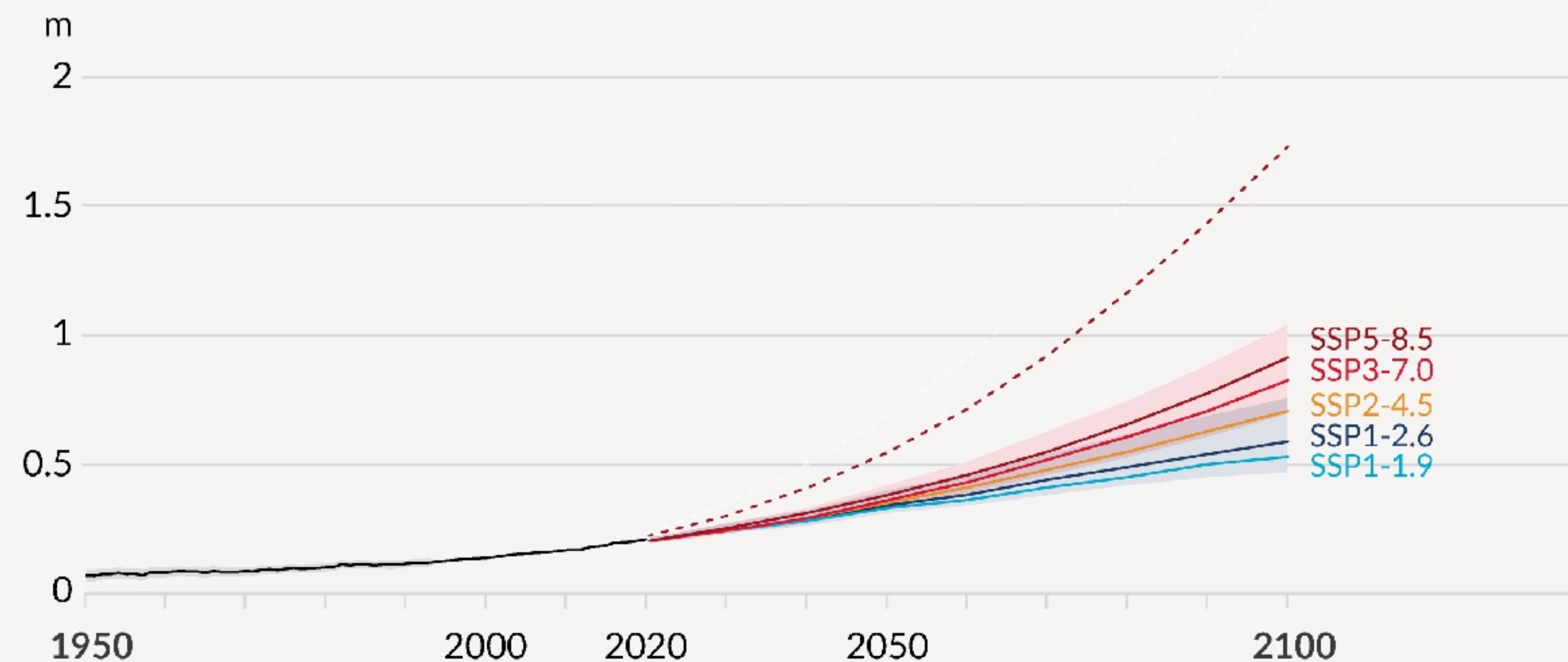
by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.
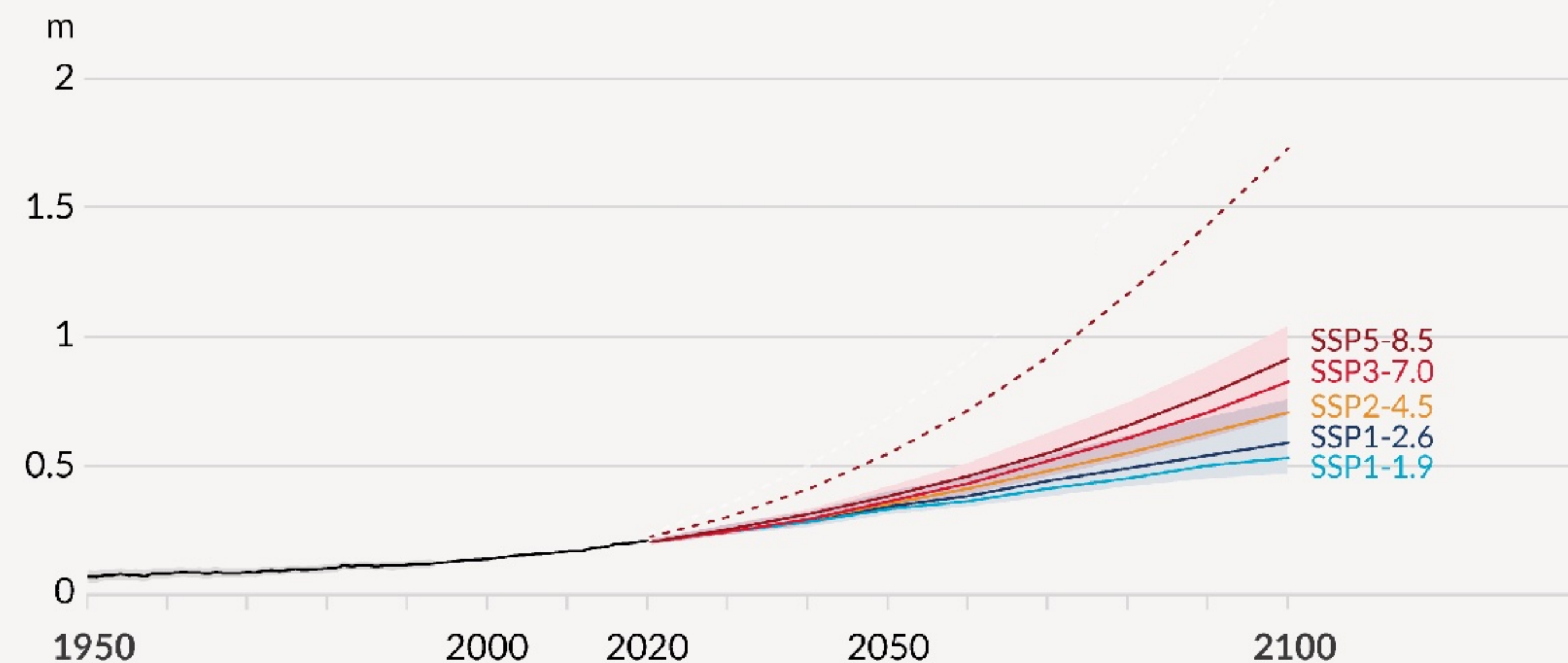

d) Global mean sea level change relative to 1900

The *likely* global mean sea level rise is

by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)
- 0.32-0.62 m (1.0-2.0 ft) under the low emissions scenario (SSP1-2.6)

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

The *likely* global mean sea level rise is by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)
- 0.32-0.62 m (1.0-2.0 ft) under the low emissions scenario (SSP1-2.6)

d) Global mean sea level change relative to 1900
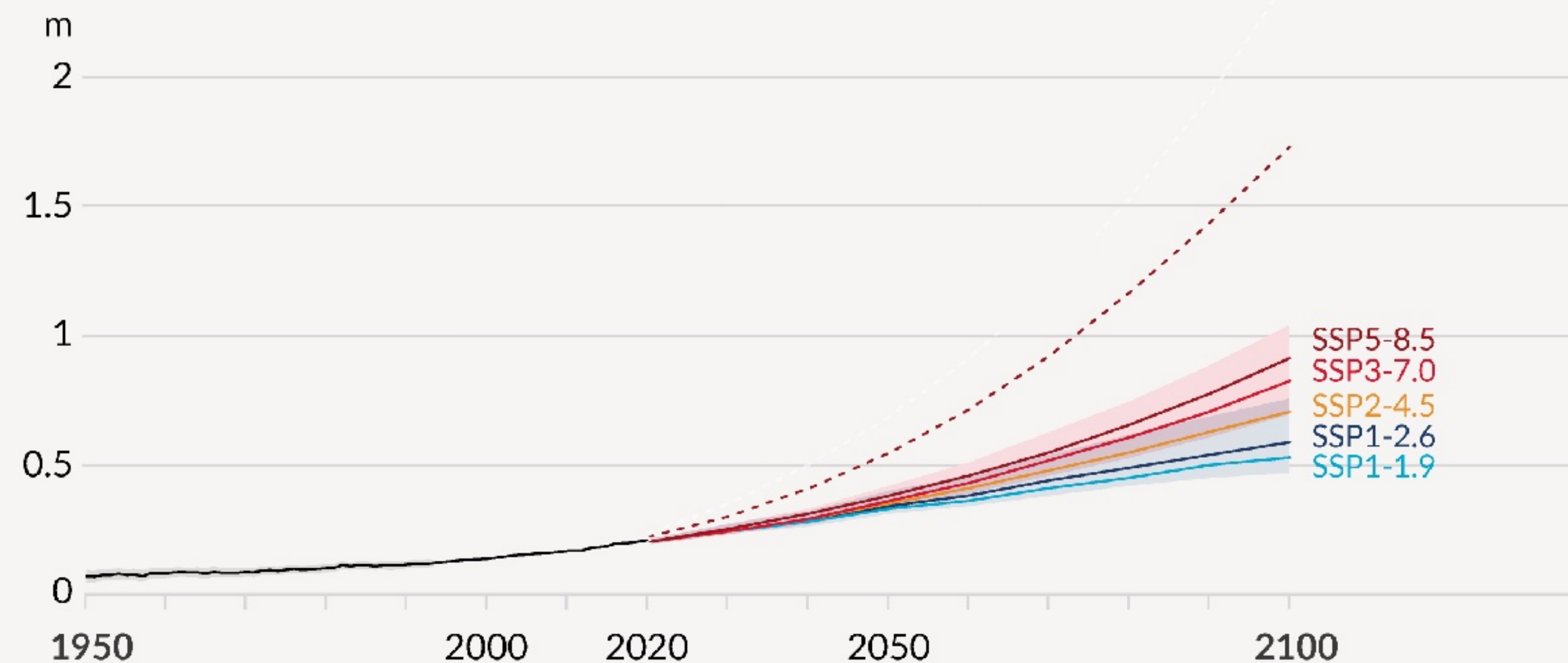
SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

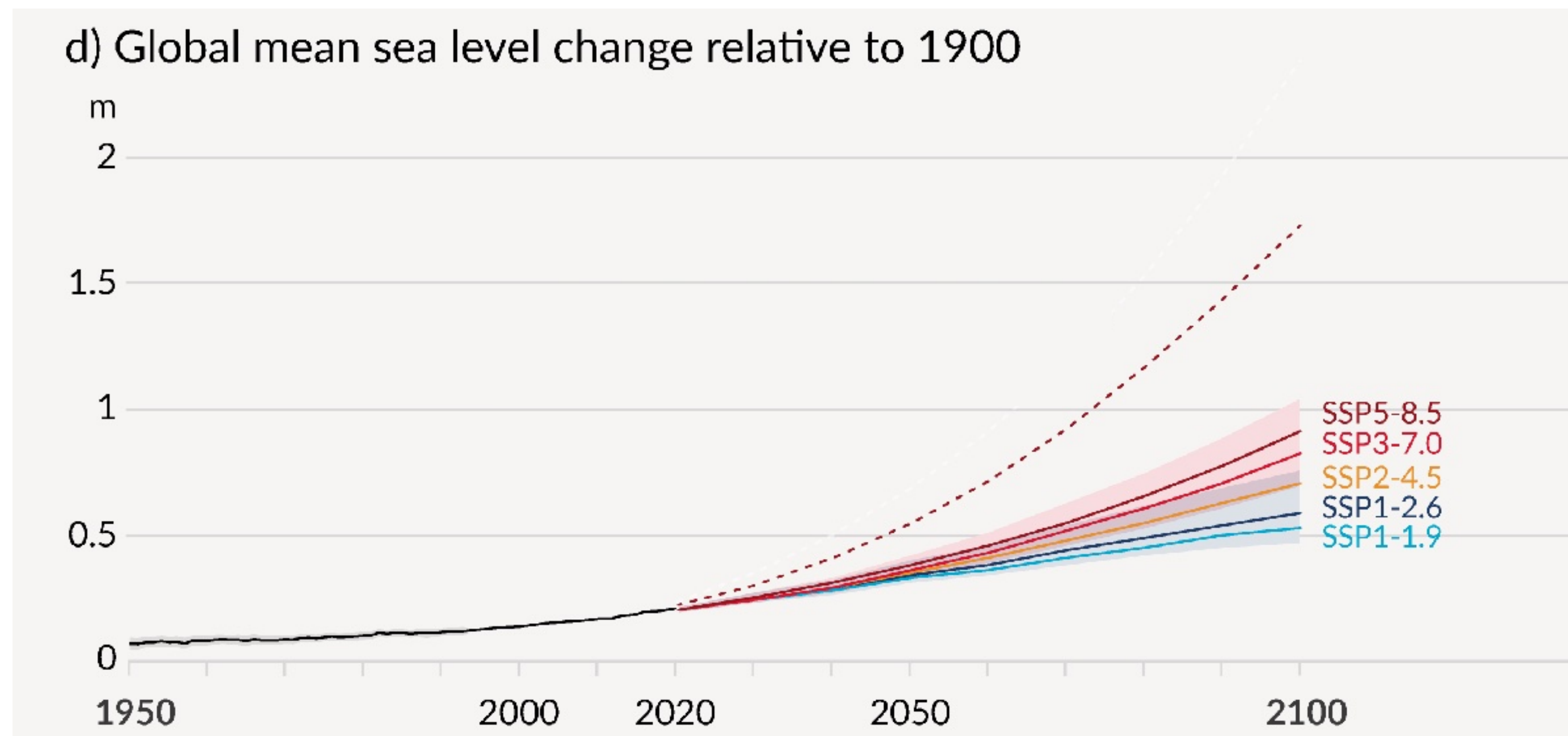# Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

d) Global mean sea level change relative to 1900

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

The *likely* global mean sea level rise is

by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)
- 0.32-0.62 m (1.0-2.0 ft) under the low emissions scenario (SSP1-2.6)

by 2150:

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.
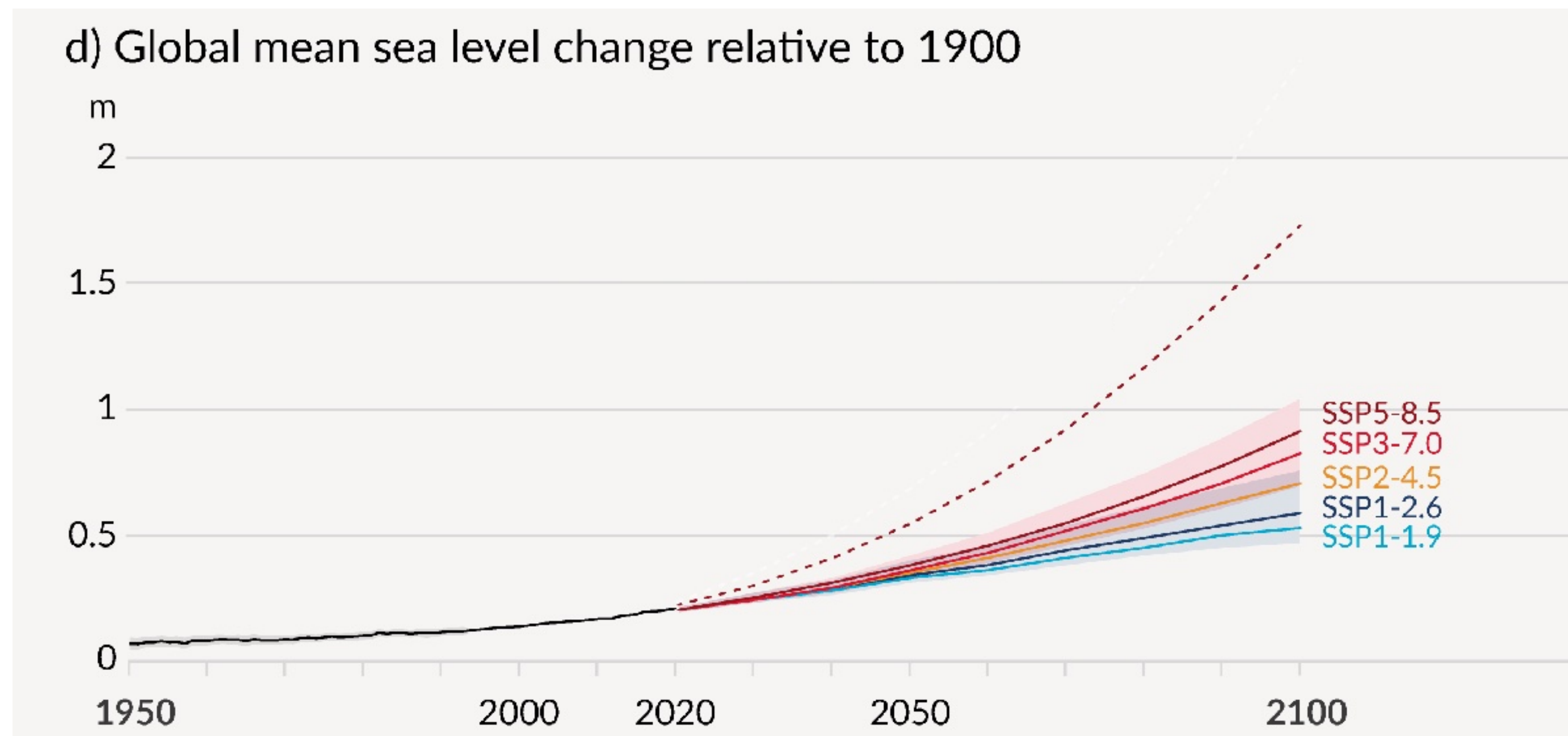

d) Global mean sea level change relative to 1900

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

The *likely* global mean sea level rise is

by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)
- 0.32-0.62 m (1.0-2.0 ft) under the low emissions scenario (SSP1-2.6)

by 2150:

- 0.98-1.88 m (2.9-5.4 ft) under the high emissions scenario (SSP3-7.0)

Beyond 2050, sea level projections are increasingly sensitive to emissions scenario.

d) Global mean sea level change relative to 1900

The *likely* global mean sea level rise is

by 2100:

- 0.55-0.90 m (1.8-3.0 ft) under the high emissions scenario (SSP3-7.0)

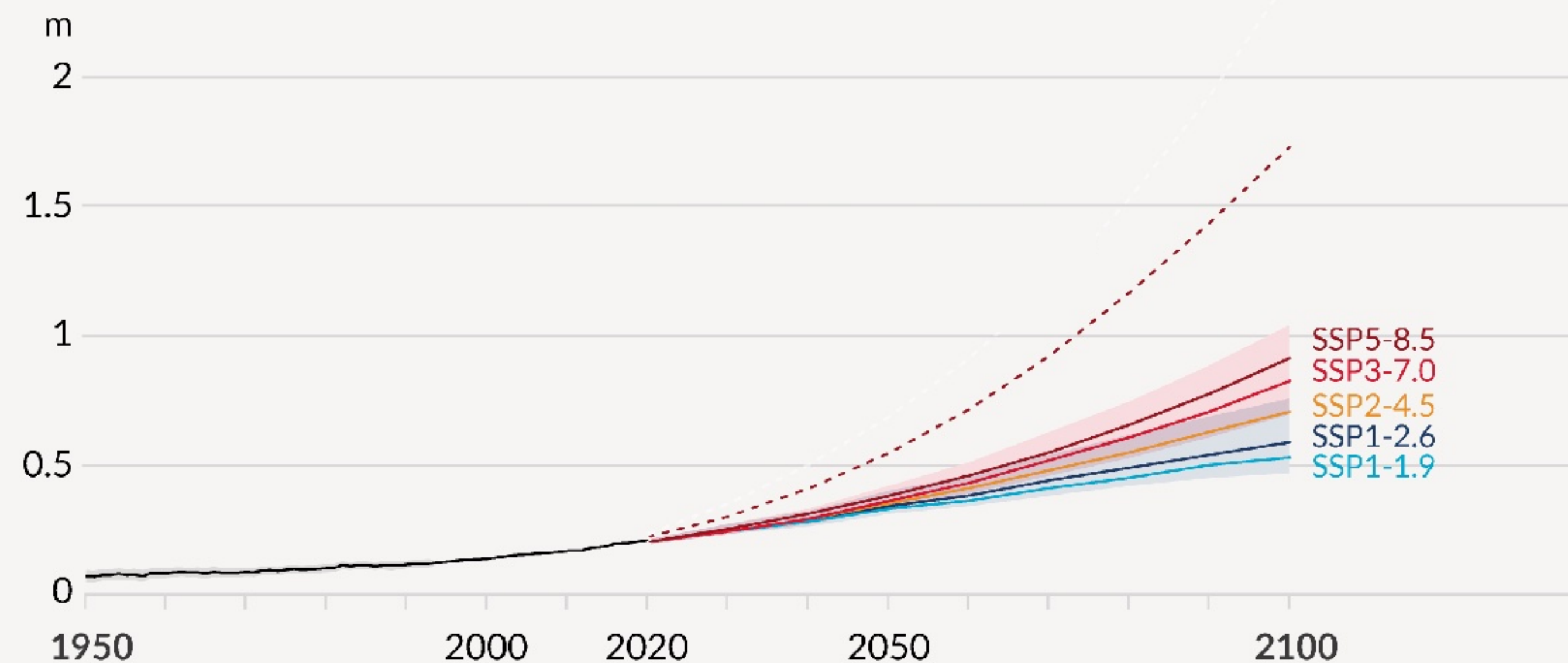- 0.32-0.62 m (1.0-2.0 ft) under the low emissions scenario (SSP1-2.6)

by 2150:
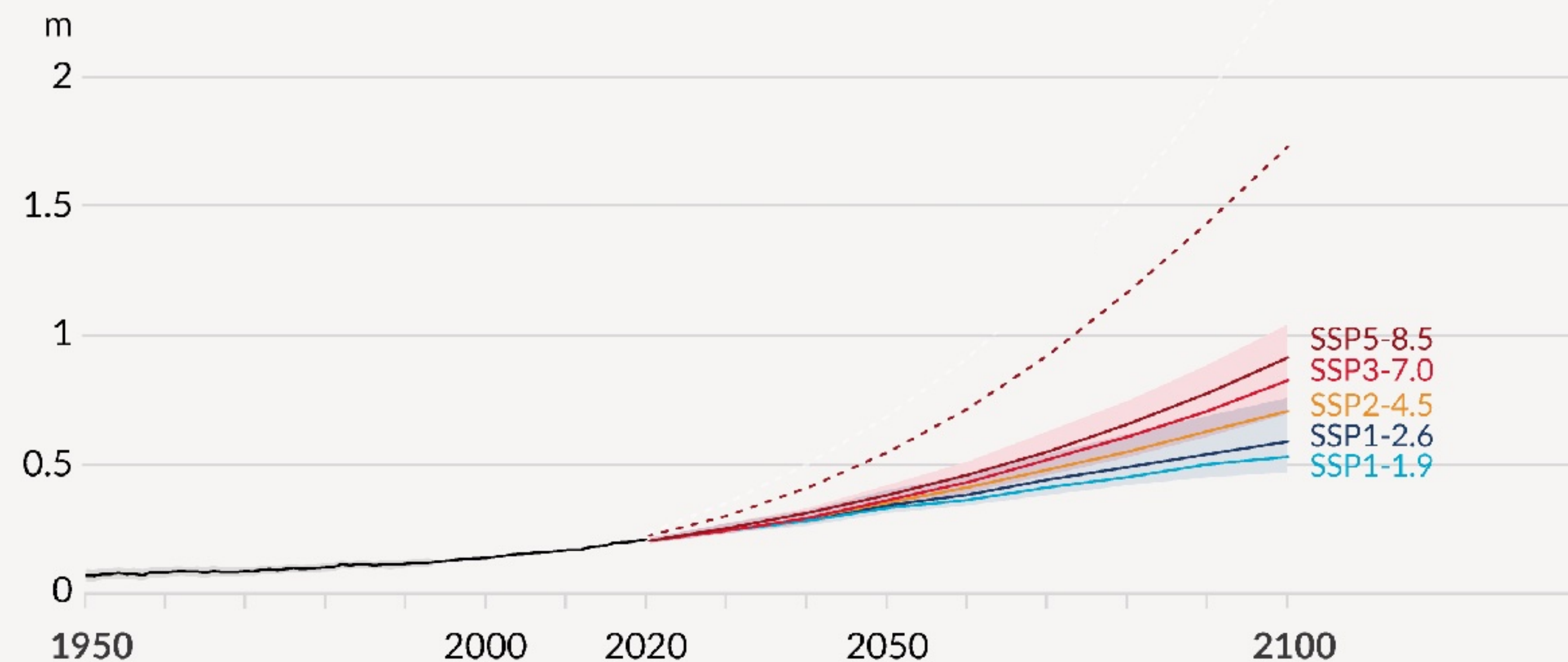
- 0.98-1.88 m (2.9-5.4 ft) under the high emissions scenario (SSP3-7.0)

- 0.46-0.99 m (1.5-3.2 ft) under the low emissions scenario (SSP1-2.6)

The more we limit our emissions, the lower the chance we trigger instabilities in the polar ice sheets that could substantially increase sea-level rise.

d) Global mean sea level change relative to 1900

Low-likelihood, high-impact storyline, including ice sheet instability processes, under **SSP5-8.5**

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9
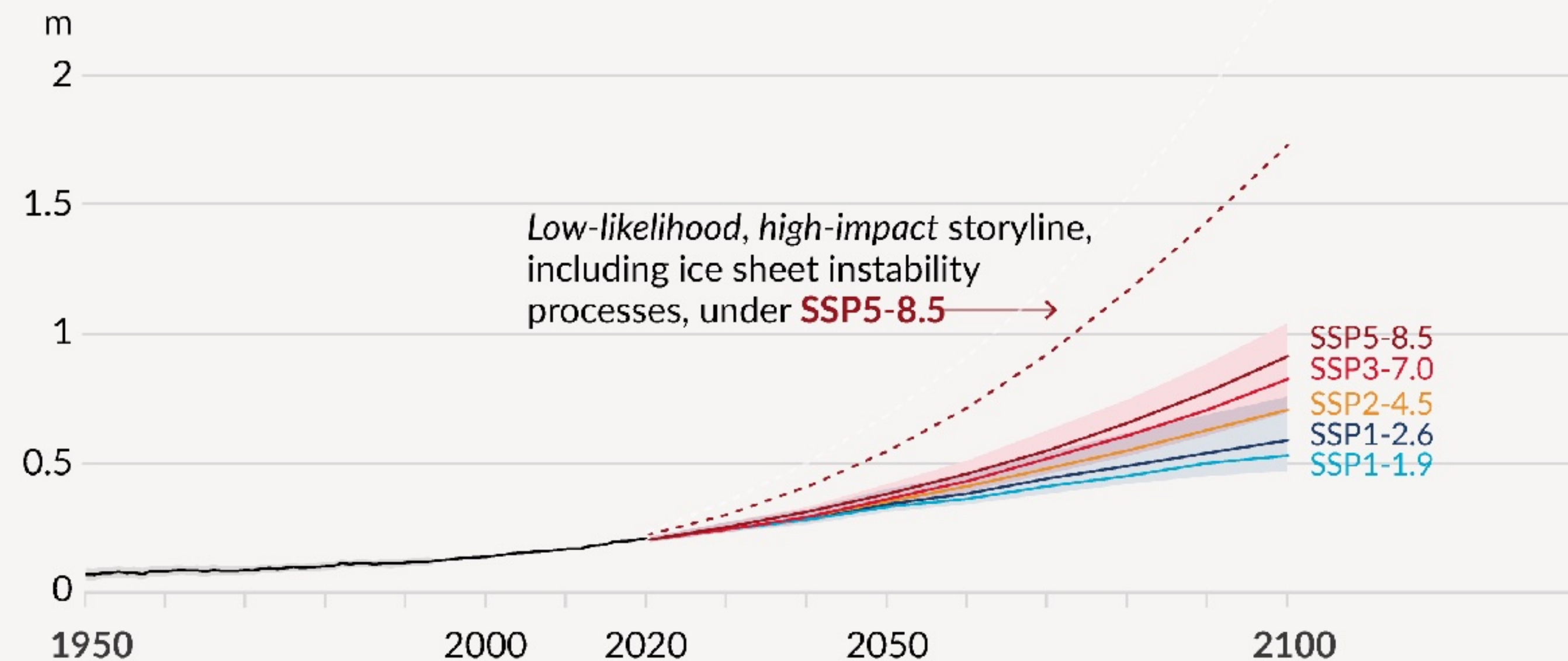
The more we limit our emissions, the lower the chance we trigger instabilities in the polar ice sheets that could substantially increase sea-level rise.

Higher global mean sea level rise before 2100 could be caused by:

d) Global mean sea level change relative to 1900

Low-likelihood, high-impact storyline, including ice sheet instability processes, under **SSP5-8.5**

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

The more we limit our emissions, the lower the chance we trigger instabilities in the polar ice sheets that could substantially increase sea-level rise.

d) Global mean sea level change relative to 1900

Higher global mean sea level rise before 2100 could be caused by:
- earlier-than-projected disintegration of marine ice shelves and the abrupt, widespread onset of marine ice sheet instability and/or marine ice cliff instability around Antarctica

The more we limit our emissions, the lower the chance we trigger instabilities in the polar ice sheets that could substantially increase sea-level rise.

d) Global mean sea level change relative to 1900

Low-likelihood, high-impact storyline, including ice sheet instability processes, under **SSP5-8.5**

SSP5-8.5
SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

Higher global mean sea level rise before 2100 could be caused by:

- earlier-than-projected disintegration of marine ice shelves and the abrupt, widespread onset of marine ice sheet instability and/or marine ice cliff instability around Antarctica
- faster-than-projected changes in the surface mass balance and discharge from Greenland

The more we limit our emissions, the lower the chance we trigger instabilities in the polar ice sheets that could substantially increase sea-level rise.

d) Global mean sea level change relative to 1900

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- earlier-than-projected disintegration of marine ice shelves and the abrupt, widespread onset of marine ice sheet instability and/or marine ice cliff instability around Antarctica
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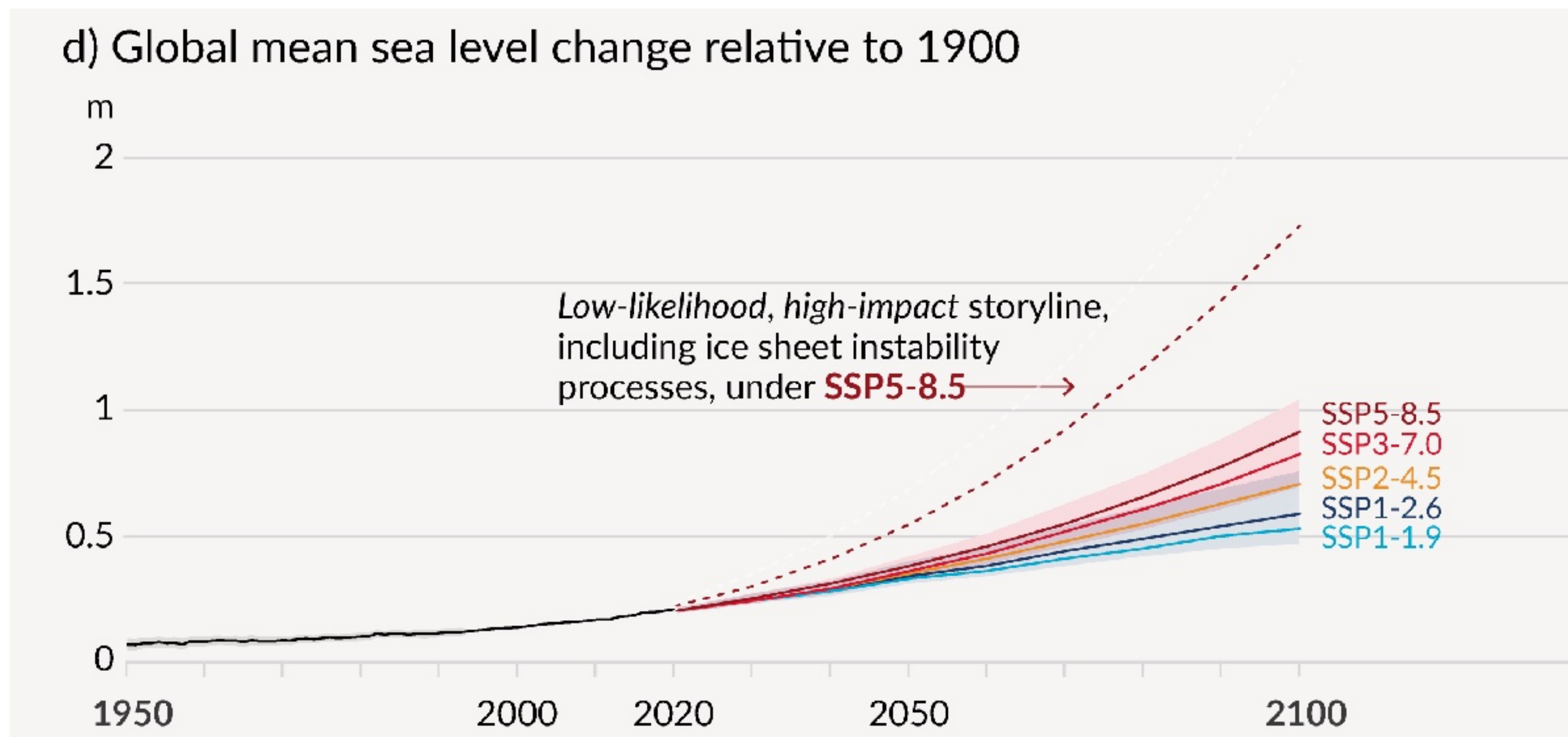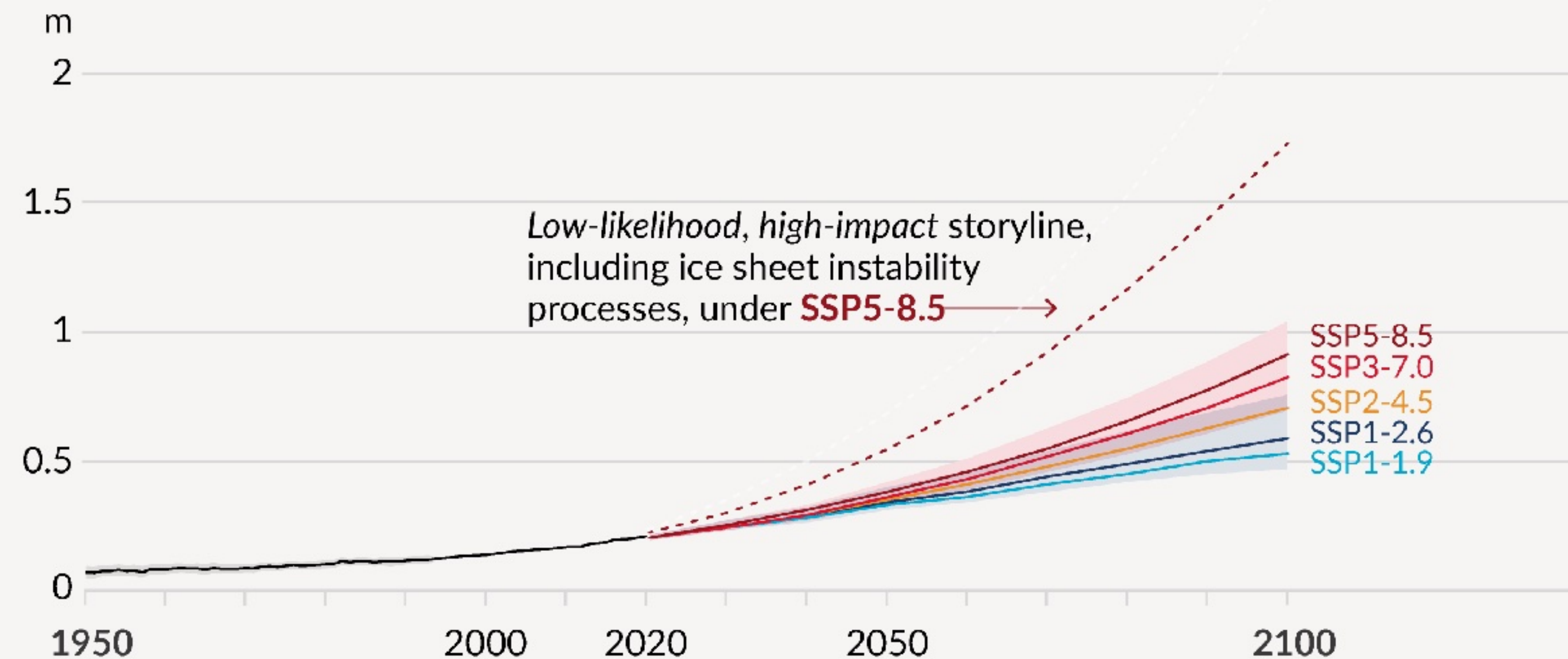
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d) Global mean sea level change relative to 1900

Low-likelihood, high-impact storyline, including ice sheet instability processes, under **SSP5-8.5**

SSP5-8.5
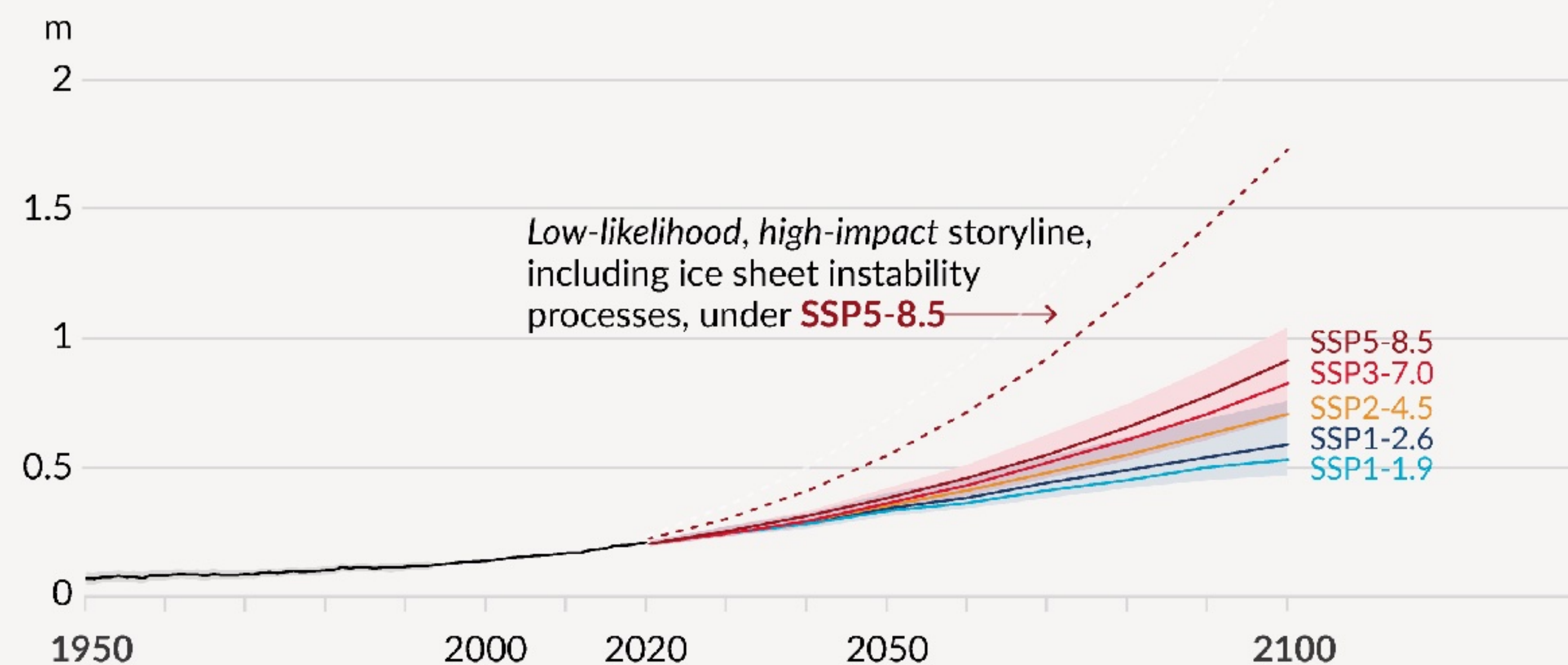SSP3-7.0
SSP2-4.5
SSP1-2.6
SSP1-1.9

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- earlier-than-projected disintegration of marine ice shelves and the abrupt, widespread onset of marine ice sheet instability and/or marine ice cliff instability around Antarctica
- faster-than-projected changes in the surface mass balance and discharge from Greenland

Global mean sea level rise above the *likely* range – approaching 2 m (7 ft) by 2100 and 5 m (16 ft) by 2150 under a very high GHG emissions scenario (SSP5-8.5) – cannot be ruled out.

Through 2050, we are likely looking at 1-2 feet of rise in New Jersey, regardless of emissions.

Projected sea-level rise in New Jersey
Feet above year 2000 baseline

	Chance SLR Exceeds	2030	2050							
Likely Range	> 83% chance	0.5	0.9							
	<17% chance	1.1	2.1							
High End	<5% chance	1.3	2.6	3.2	3.8	4.4	5.0	6.9	8.8	8.0

*2010 (2001-2019 average) Observed = 0.2 ft

Notes: All values are 19-year means of sea-level measured with respect to a 1991-2009 baseline cen...

Kopp...
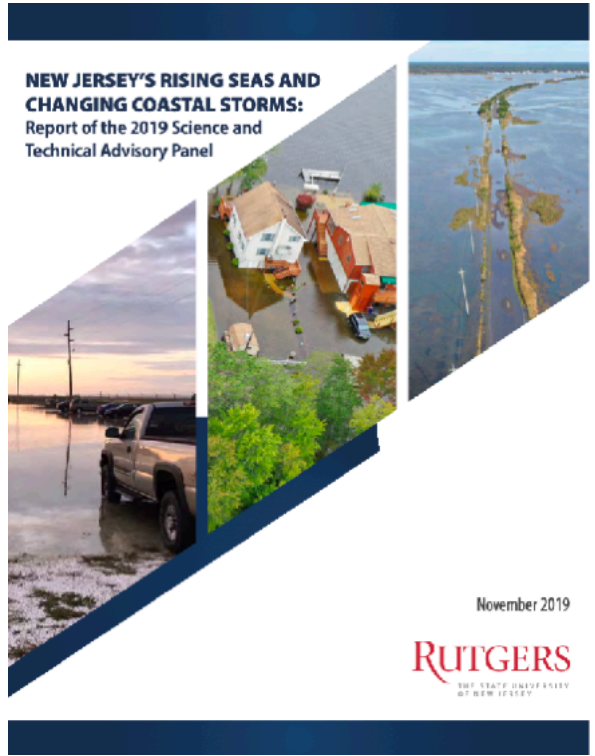
Beyond 2050, projected rise is increasingly sensitive to level of emissions – especially for high-end risks.

Projected sea-level rise in New Jersey
Feet above year 2000 baseline
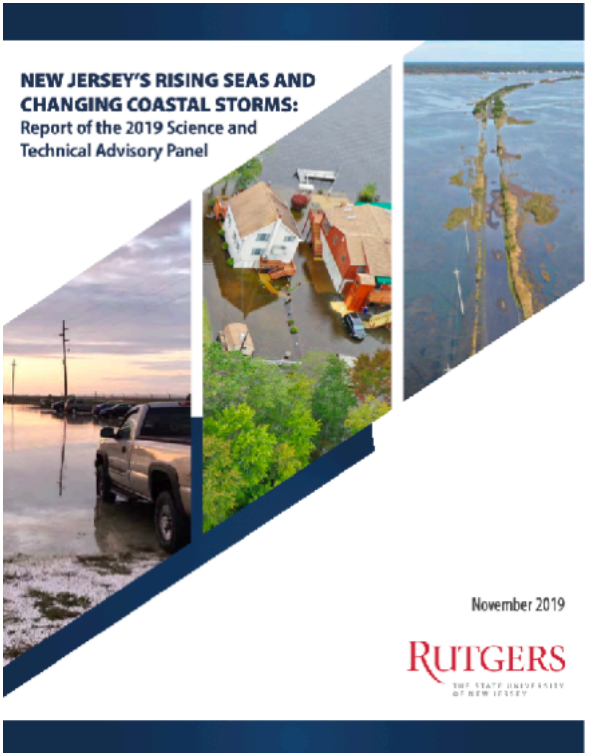
	Chance SLR Exceeds	2030	2050	2070			2100		
				Emissions					
				Low	Mod.	High	Low	Mod.	High
	Chance SLR Exceeds			Low	Mod.	High	Low	Mod.	High
Likely Range	> 83% chance	0.5	0.9	1.3	1.4	1.5	1.7	2.0	2.3
	<17% chance	1.1	2.1	2.7	3.1	3.5	3.9	5.1	6.3
Range	<17% chance	1.1	2.1	2.7	3.1	3.5	3.9	5.1	6.3
High End	<5% chance	1.3	2.6	3.2	3.8	4.4	5.0	6.9	8.8	8.0

*2010 (2001-2019 average) Observed = 0.2 ft

Notes: All values are 19-year means of sea-level measured with respect to a 1991-2009 baseline cen

Expected number of flood events increases significantly with sea-level rise.

Expected number of extreme sea level events at Atlantic City
Water level: Historic 10% probability extreme sea level events (3.3' above high tide line)

Moderate emissions, *likely* rise (1.4' by 2050, 3.3' by 2100)

2000:
10% chance per year

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Moderate emissions, *likely* rise (1.4' by 2050, 3.3' by 2100)

2030:
Annual maximum
high water

2000:
10% chance per year

2055:
Minor tidal flooding level
(~5-10 days/yr)

Expected number of flood events increases significantly with sea-level rise.

Expected number of extreme sea level events at Atlantic City
Water level: Historic 10% probability extreme sea level events (3.3' above high tide line)

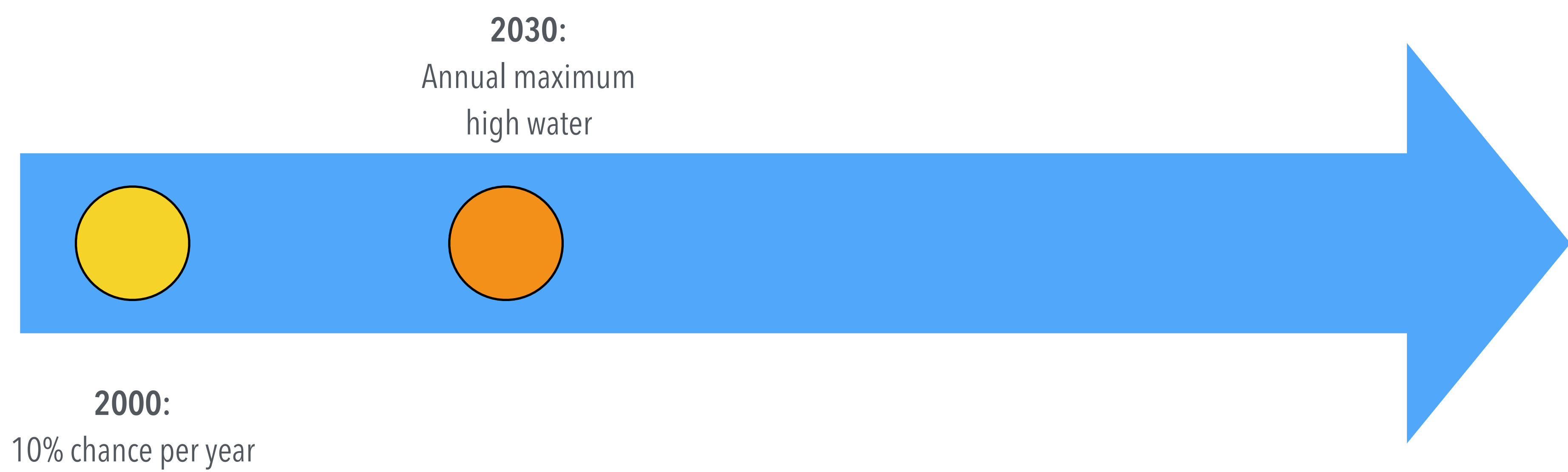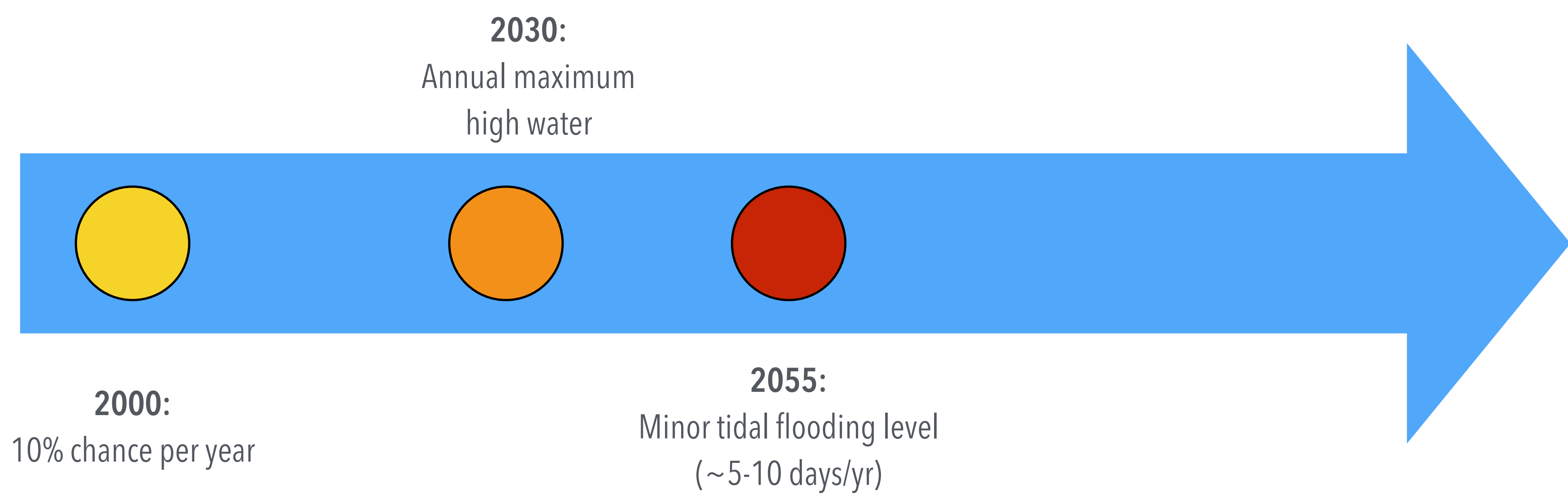**Moderate emissions, *likely* rise (1.4' by 2050, 3.3' by 2100)**

2030:
Annual maximum
high water

2100:
Permanent flooding

2000:
10% chance per year

2055:
Minor tidal flooding level
(~5-10 days/yr)

Projected sea-level rise translates into more frequent flooding.

Projected days/year of high tide flood at Atlantic City
Moderate emissions scenario

Year	Low End > 95% Chance	*Likely* Range			< 17% chance
		>83% Chance	~50% chance	< 17% chance	
2000	2000		5 days		
2010	2010		7 days	7 days	
2020	6 days	9 days	17 days	30 days	30 days
2030	10 days	17 days	35 days	75 days	75 days
2040	17 days	30 days	70 days	150 days	150 days
2050	24 days	45 days	125 days	230 days	255 days
2060					315 days
2070					350 days
2080					**
2090					**
2100					**
2110					**

Even under moderate emissions, there is a good chance minor flooding will be close to daily by 2100.

Projected days/year of high tide flood at Atlantic City
Moderate emissions scenario

Year	Low End > 95% Chance	*Likely* Range			< 17% chance
		>83% Chance	~50% chance	< 17% chance	
2000			5 days		
2010			7 days	7 days	
2020	6 days	9 days	17 days	30 days	30 days
2030	10 days	17 days	35 days	75 days	75 days
2040	17 days	30 days	70 days	150 days	150 days
2050	24 days	45 days	125 days	230 days	255 days
2060	40 days	85 days	190 days	315 days	315 days
2070	55 days	120 days	280 days	350 days	350 days
2080	75 days	165 days	320 days	**	**
2090	85 days	200 days	340 days	345 days	**
2100	95 days	240 days	355 days	**	**
2110	150 days	280 days	360 days	360 days	**

Kopp et al. (2019)

25

More than 3,000 homes built in NJ from 2010-2017 will be in the annual flood zone by 2050.

Table 4: States with most new homes in annual risk zone, 2050

State	Number of New Homes in Annual Risk Zone	Value of New Homes in Annual Risk Zone	Housing Growth Rate Ratio for Annual Risk Zone vs. Safer Areas
1. New Jersey	3,087	$3.04 Billion	3.1
2. North Carolina	1,231	$543 Million	0.8
3. Florida	1,069	$1.38 Billion	0.9
4. Delaware	962	$638 Million	2.6
5. Texas	910	$349 Million	0.8
6. South Carolina	597	$656 Million	1.0
7. Virginia	388	$178 Million	1.1
8. Maryland	387	$185 Million	0.9
9. California	330	$688 Million	0.4
10. Louisiana	320	$86 Million	0.7

Data reflect homes built from 2010 through 2016 (for Alabama, Florida, Mississippi, and New York) or through 2017 (for all other coastal states), and a risk zone defined by local ten-percent-annual-chance flood heights added on to median local sea level projections. Housing data source: Zillow (home locations and home values); Zillow and Microsoft (home locations); and ZTRAX (build years).

CLIMATE CENTRAL

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CLIMATE CENTRAL

Compare: between 2013 and 2021, NJ's Blue Acres program had 830 families accept buyouts.

Source: NJ Spotlight, October 19, 2021

About 90,000 properties, worth about $80 billion, will enter into the 1-in-30 year hurricane flood plain by 2050.

FIGURE 10

Projected increase in current New Jersey homes facing hurricane flood risk by 2050
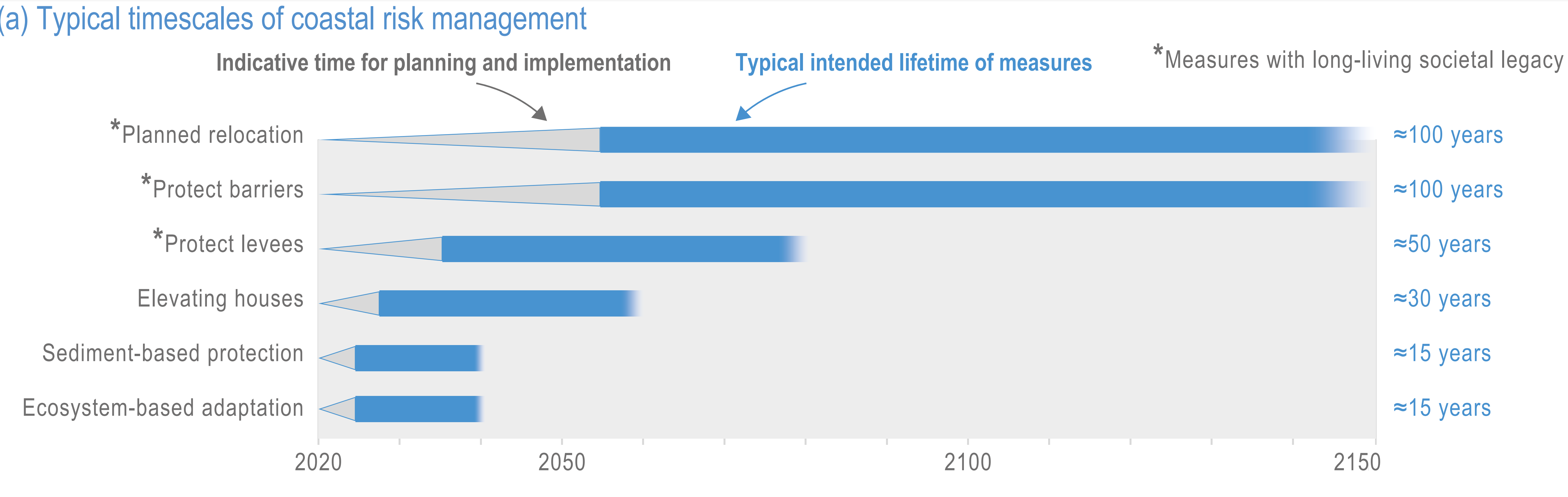
Increase in number of current buildings in the 1-in-30-year floodplain, by county, due to changes in sea level and expected hurricane activity between today and 2050. The range captures uncertainty in sea levels and hurricane activity under a high emissions scenario.
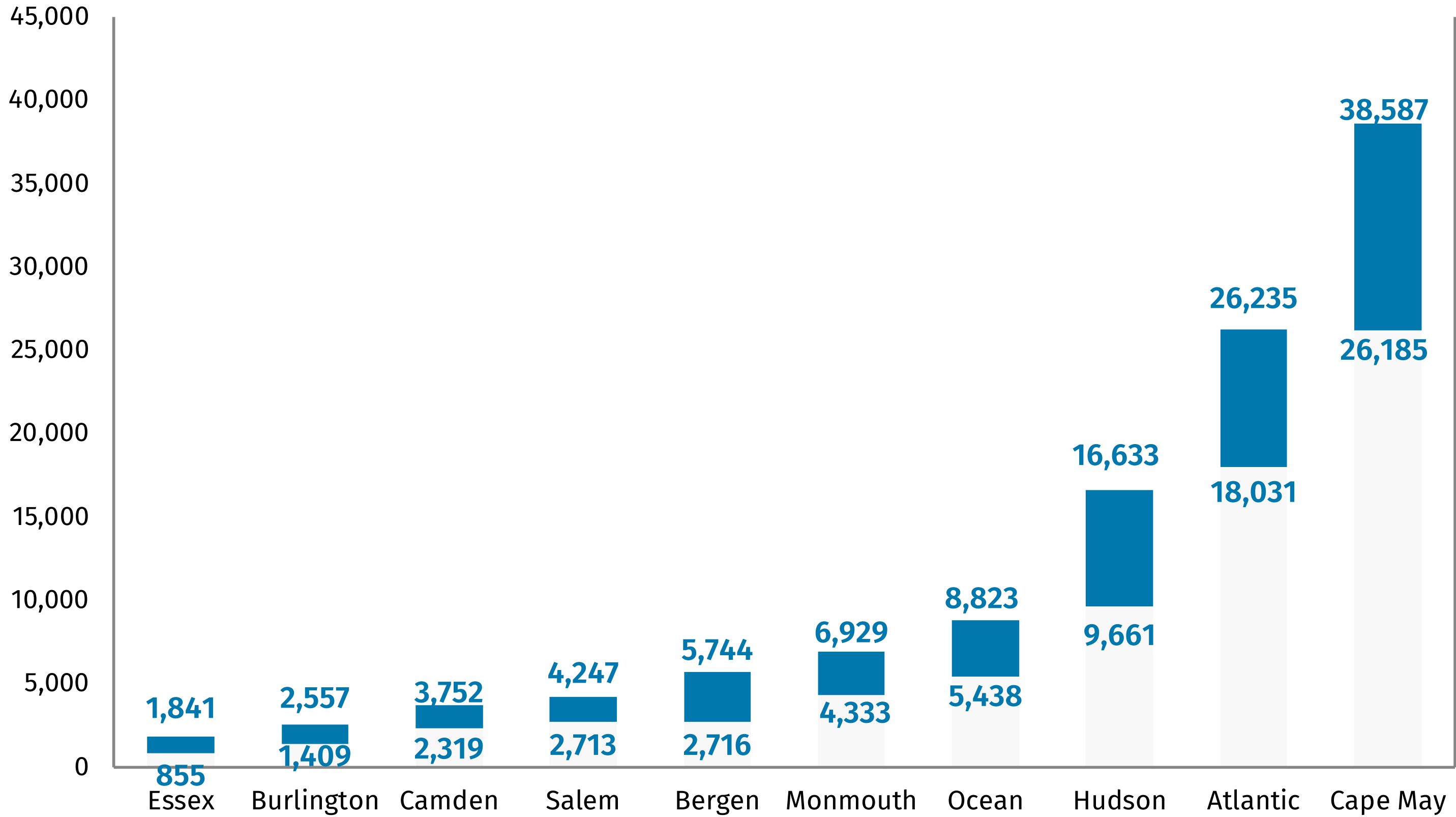

Source: Rhodium Group analysis
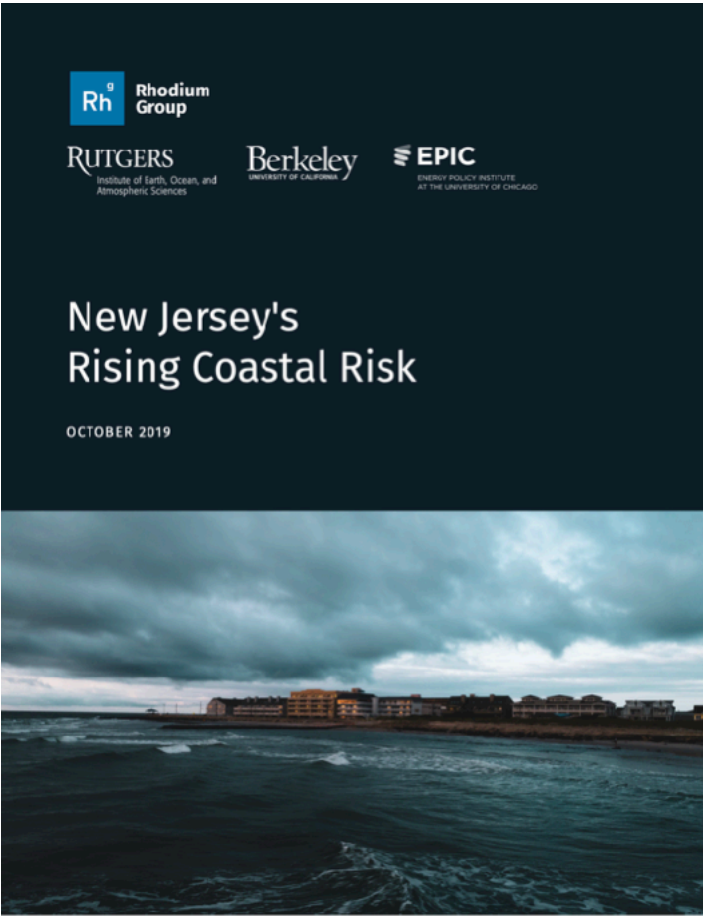
Adaptation capacity and governance to manage sea-level rise risks typically require decades to implement and institutionalize.

(a) Typical timescales of coastal risk management

Indicative time for planning and implementation

Typical intended lifetime of measures

*Measures with long-living societal legacy

*Planned relocation	≈100 years
*Protect barriers	≈100 years
*Protect levees	≈50 years
Elevating houses	≈30 years
Sediment-based protection	≈15 years
Ecosystem-based adaptation	≈15 years

2020   2050   2100   2150

AR6 WGII Ch3 SLR CCB

The more we limit our emissions, the more time we have to adapt.

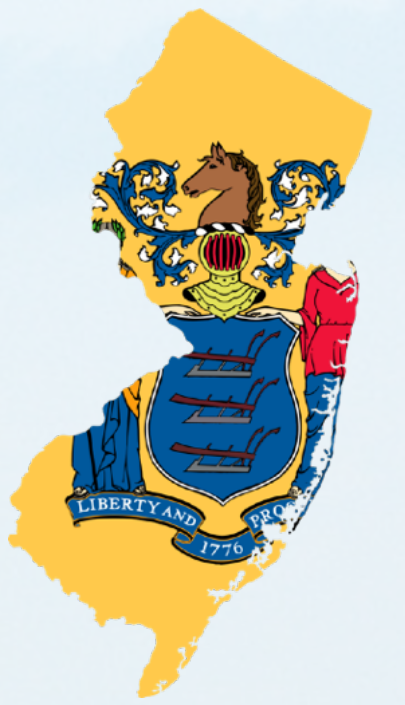| *Likely* timing of exceedance at Atlantic City	Low Emissions (2°C)	High Emissions (5°C)
2 ft.	2060-2100	2050-2090
4 ft.	2100 to after 2150	2080-2150
6 ft.	2140 to after 2150	2100 to after 2150

coastalhub.org
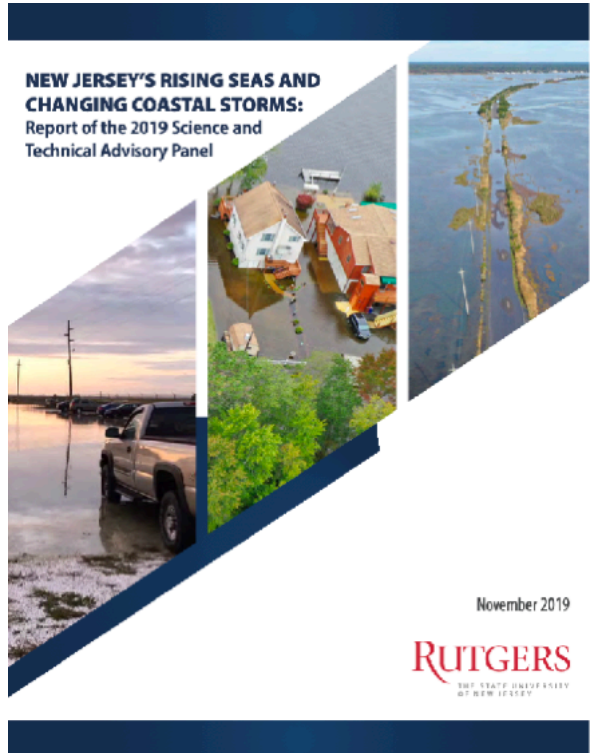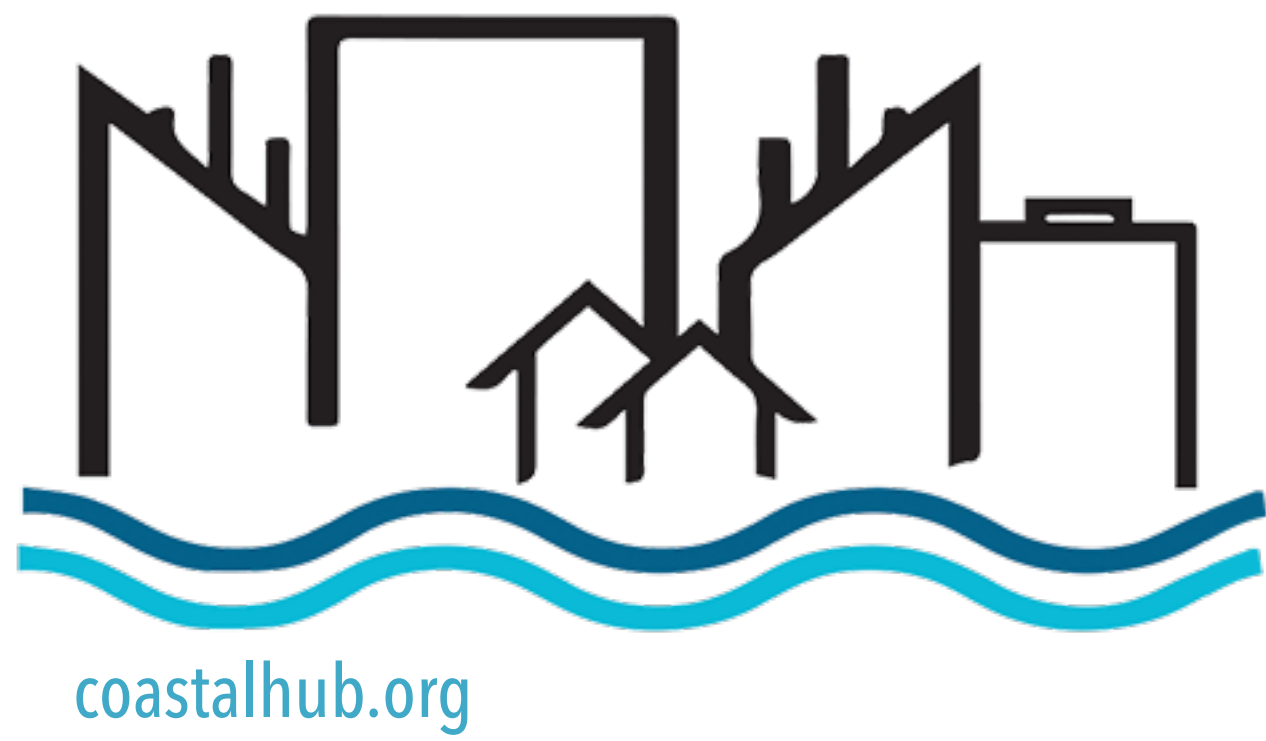
- Advance understanding of how coastal climate hazards, landforms, and human decisions interact to shape climate risk

- Facilitate flexible, equitable, and robust long-term planning to manage climate risk in the New York City-New Jersey-Philadelphia region

- Build an academic/stakeholder partnership model that provides insights for just, equitable, and inclusive climate action in diverse coastal, urban megaregions around the world

- Train the next generation of leaders in transdisciplinary climate research and engagement.

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