Polar Ice melt and Sea Level Rise

Antarctic Ice Sheet (Visualization from NASA's mission Operation IceBridge dataset BEDMAP2)
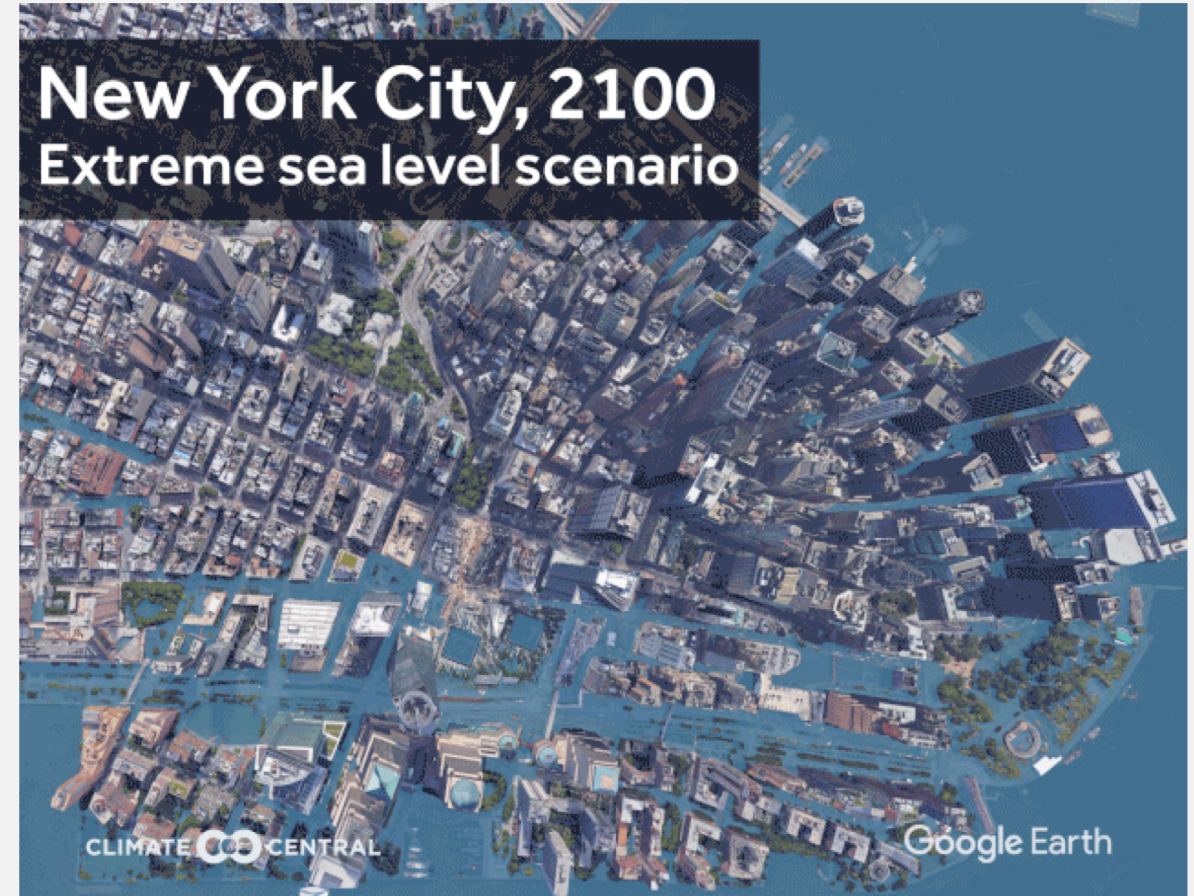
Learning Objectives and Module Overview

In this module you will explore:

- Why is sea level rising and how are polar regions contributing?

- What is storm surge and how will it affect us?

- How should we prepare?
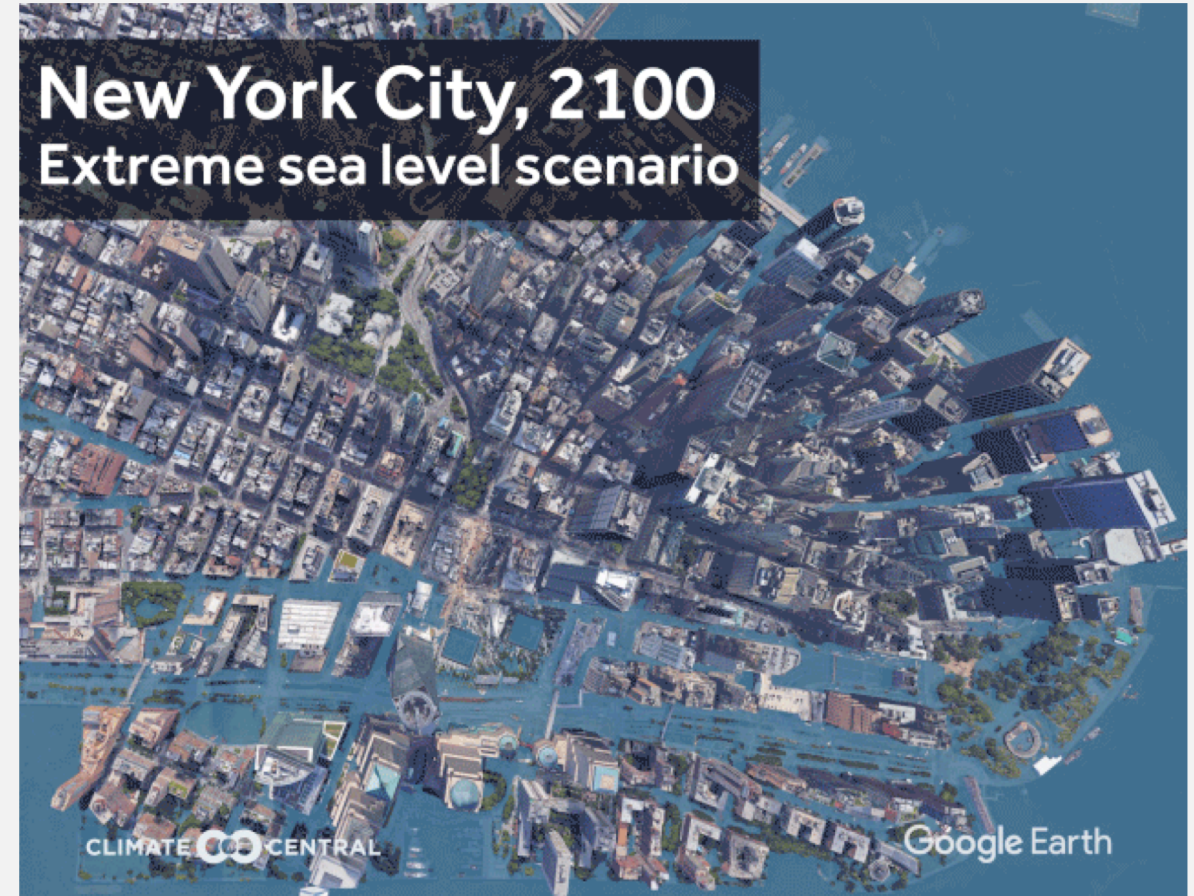

New York City, 2100
Extreme sea level scenario

From Climate Central (https://www.climatecentral.org/outreach/alert-archive/2017/2017SeaLevelCM-TVM.html)

Learning Objectives and Module Overview

In this module you will explore:

- Why is sea level rising and how are polar regions contributing?

- **What is storm surge and how will it affect us?**

- How should we prepare?

From Climate Central (https://www.climatecentral.org/outreach/alert-archive/2017/2017SeaLevelCM-TVM.html)

Storm Surge

- Storm surge is a rise in sea level due to an intense storm.
- Sea level rise adds to storm surge.
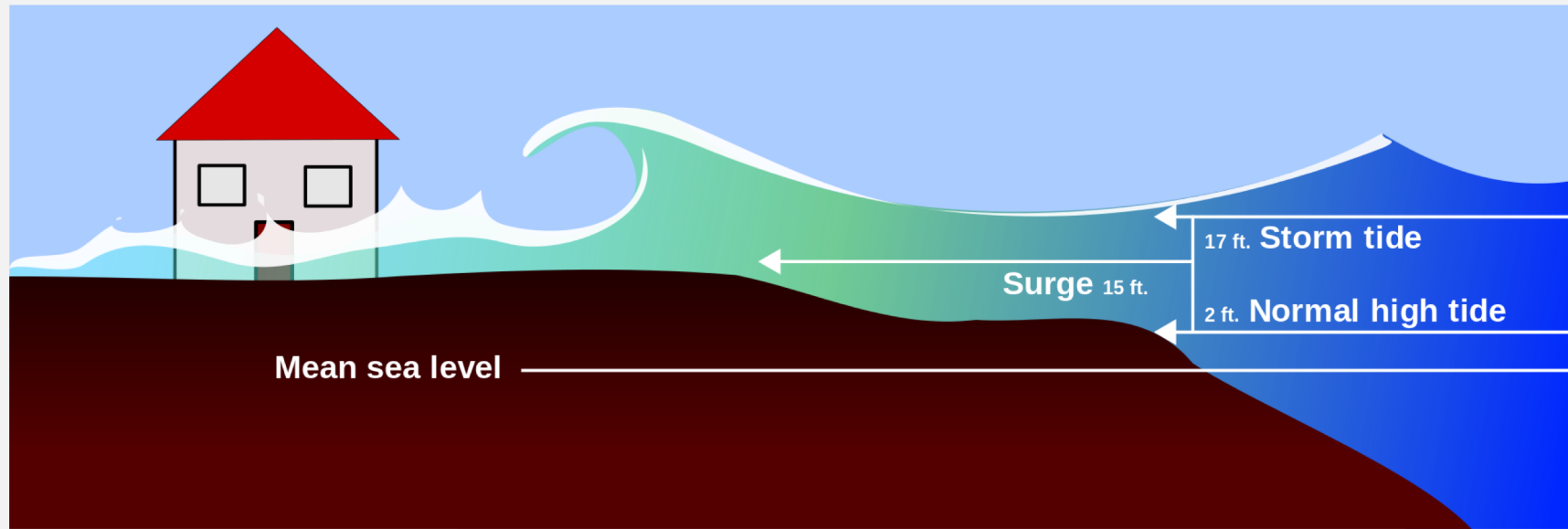
- Flooding
- Severe damage
- Loss of lives

By SuperManu - Image:Surge big.jpg by Robert Simmon, NASA GSFC, via NOAA. Uploaded by Pierre cb, Public Domain, https://commons.wikimedia.org/w/index.php?curid=2264485

Storm Surge

Katrina (2005)

- 26 feet
- Levees breached
- $125 billion

Hurricane Sandy (2012)

- 9 feet
- $65 billion

Hurricane Harvey (2017)

- 10 feet
- $125 Billion

Damage from Hurricane Ike's storm surge (2008).
Picture courtesy of the U.S. National Weather Service.

https://www.britannica.com/event/Hurricane-Katrina
https://www.nhc.noaa.gov/news/UpdatedCostliest.pdf
https://www.weather.gov/okx/HurricaneSandy
https://www.nhc.noaa.gov/data/tcr/AL182012_Sandy.pdf
https://www.nhc.noaa.gov/data/tcr/AL092017_Harvey.pdf

Local Sea Level Rise Impacts

How will sea level rise impact your local region through increased storm surges and flooding?

1. Go to the Surging Seas Risk Finder website that shows various impacts from flooding in coastal cities in the U.S. (https://riskfinder.climatecentral.org/)

2. Type in your city of interest (e.g. Tacoma)

3. Watch the video Intro to riskfinder website, then take 5 minutes to explore the website. (video URL: https://people.nwra.com/rowe/public/penguin/high/sea_level_rise/SLR2a_surgingSeasIntro.mov)

From Climate Central (https://riskfinder.climatecentral.org/)
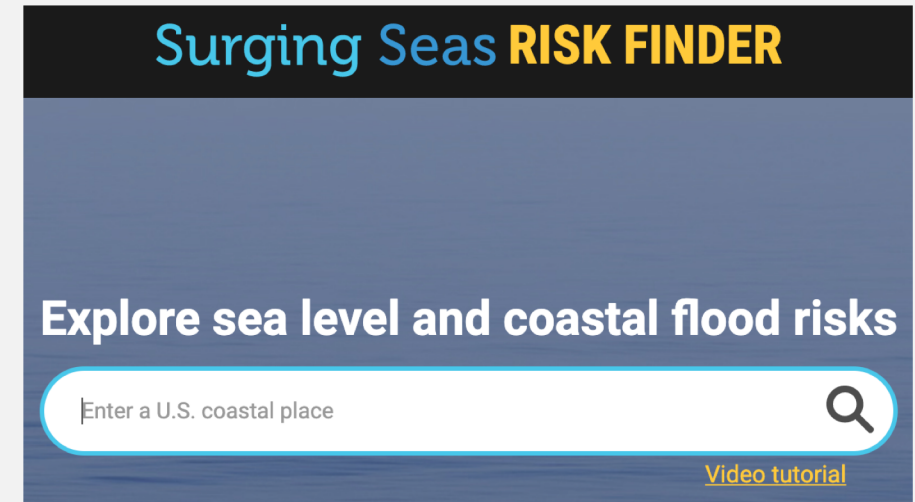
Local Sea Level Rise Impacts

Exploring the Risk Finder website:

4. Watch the video about When are the Risks?
    (video URL: https://people.nwra.com/rowe/public/penguin/
    high/sea_level_rise/SLR2b_surgingSeasWhen.mov)

From Climate Central (https://riskfinder.climatecentral.org/)

Local Sea Level Rise Impacts

NOAA Global Mean Sea Level (GMSL) Scenarios for 2100

Figure 8. This study's six representative GMSL rise scenarios for 2100 (6 colored lines) relative to historical geological, tide gauge and satellite altimeter GMSL reconstructions from 1800–2015 (black and magenta lines; as in Figure 3a) and central

Adapted from Sweet, William V., et al, Global and regional sea level rise scenarios for the United States (2017). NOAA report.

Local Sea Level Rise Impacts

NOAA Global Mean Sea Level (GMSL) Scenarios for 2100

Figure 8. This study's six representative GMSL rise scenarios for 2100 (6 colored lines) relative to historical geological, tide gauge and satellite altimeter GMSL reconstructions from 1800–2015 (black and magenta lines; as in Figure 3a) and central

Adapted from Sweet, William V., et al, Global and regional sea level rise scenarios for the United States (2017). NOAA report.
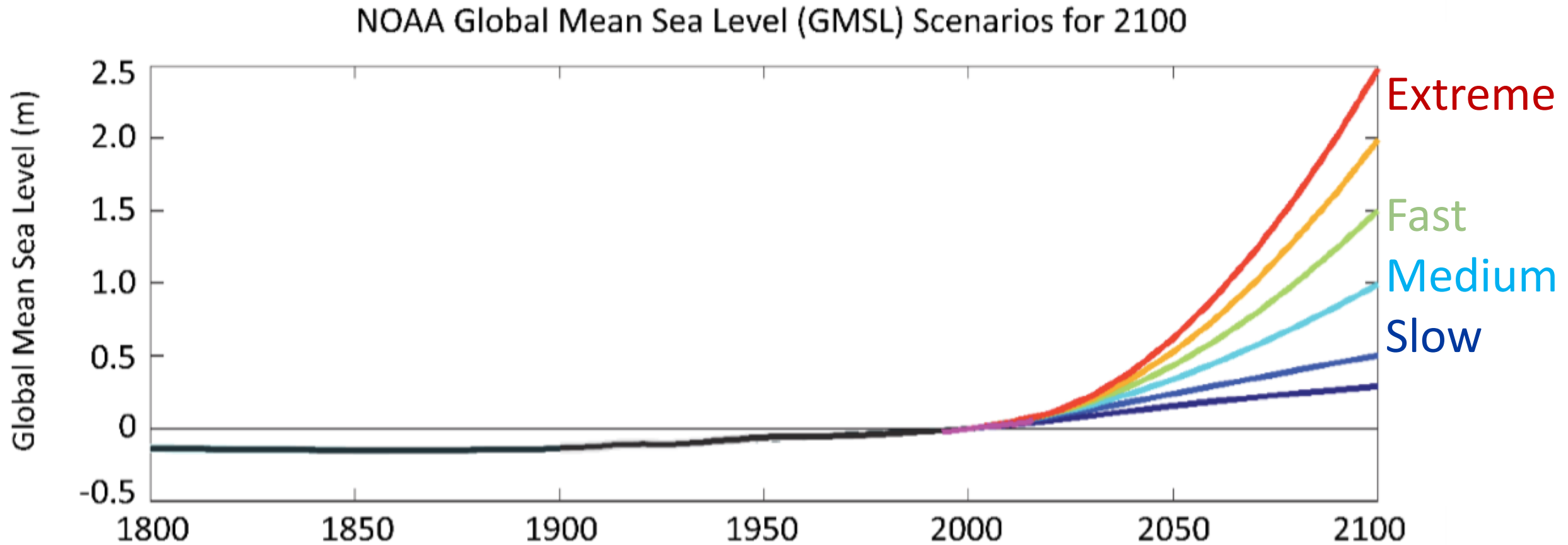
Figure 8. This study's six representative GMSL rise scenarios for 2100 (6 colored lines) relative to historical geological, tide gauge and satellite altimeter GMSL reconstructions from 1800–2015 (black and magenta lines; as in Figure 3a) and central

Adapted from Sweet, William V., et al, Global and regional sea level rise scenarios for the United States (2017). NOAA report.
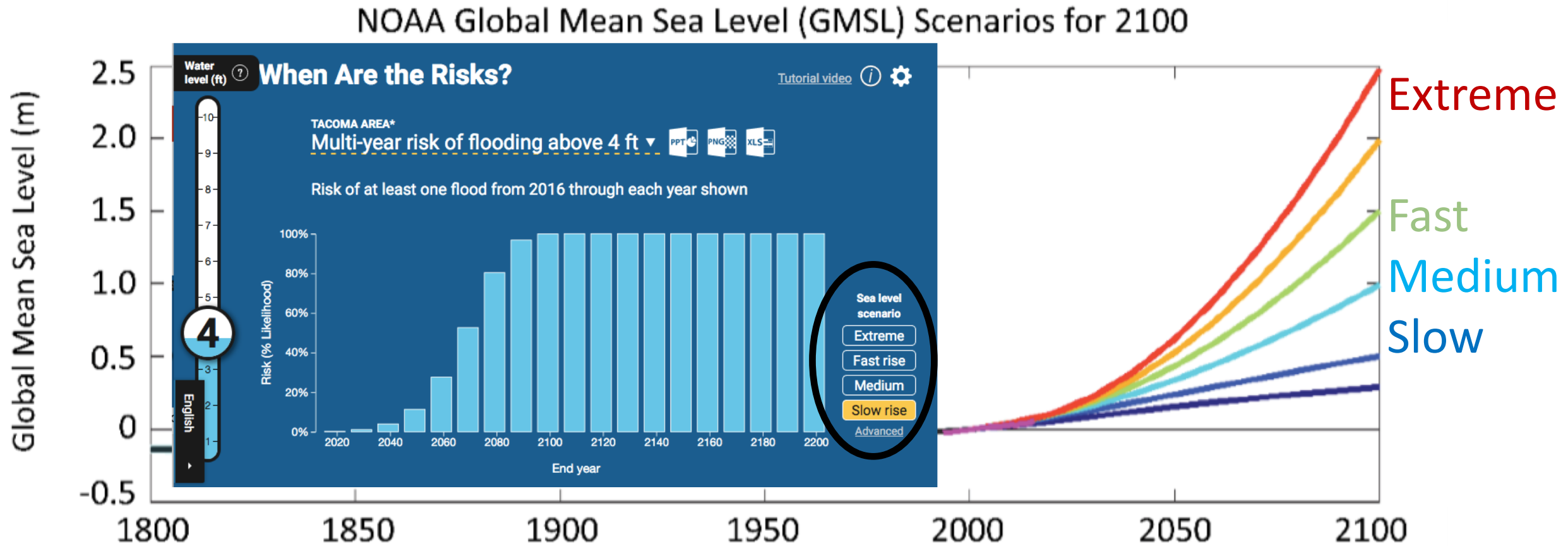
Local Sea Level Rise Impacts

Pause for Analysis 3: What are the sea level rise scenarios?

From Climate Central (https://riskfinder.climatecentral.org/)
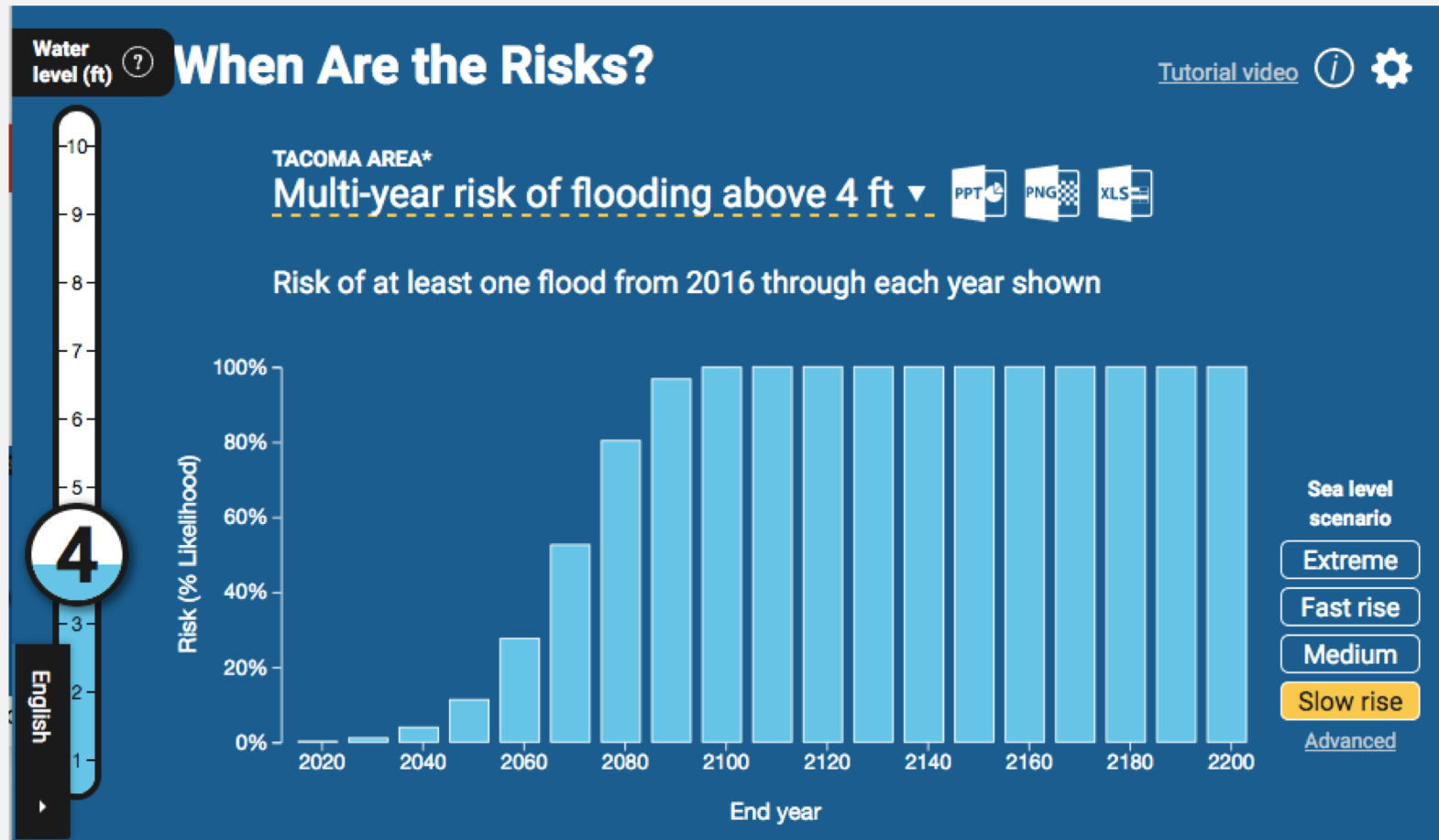
Local Sea Level Rise Impacts

Optional:

Watch the video about [What are the Risks?](#)
(video URL: https://people.nwra.com/rowe/public/penguin/
high/sea_level_rise/SLR2c_surgingSeasWhat.mov)

- How many people in the population of your city are at risk given a water level of *6 ft*?

- How many homes are at risk given *8 ft* of flooding?

From Climate Central
(https://riskfinder.climatecentral.org/)
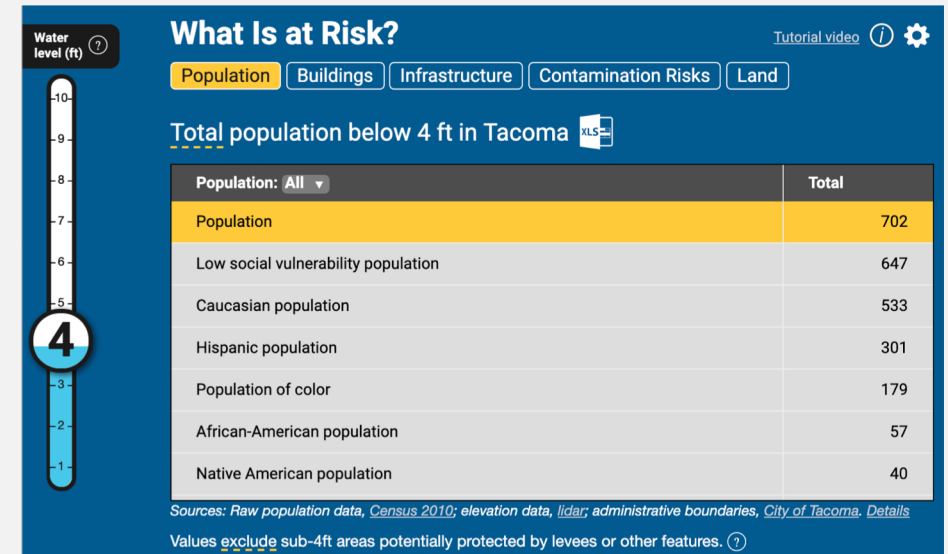
Local Sea Level Rise Impacts

With higher sea levels come increased storm surge and flooding. What will the damages be?

Our end goal is to calculate the Marginal Damage. *For this project, the Marginal Damage is the extra damage for every additional foot of sea level rise.* We'll compare the marginal damage to the cost of building a sea wall.

> **Pause for Analysis 4: Write down the meaning of Marginal Damage given above. Discuss or think about what marginal damage is and how you would calculate it, and how you would compare it to the cost of avoiding the damage.**

We will calculate marginal damage by estimating the damage to homes for each level of flooding based on
- Median home value and
- The number of additional homes impacted at each flood level.

Local Sea Level Rise Impacts

Median Home Value

- For Tacoma in 2020: Assume a median home value of $350,000

- For other locations or dates: look up the median home value from Zillow (https://www.zillow.com/home-values/).

From Climate Central (https://riskfinder.climatecentral.org/)

Homes Impacted

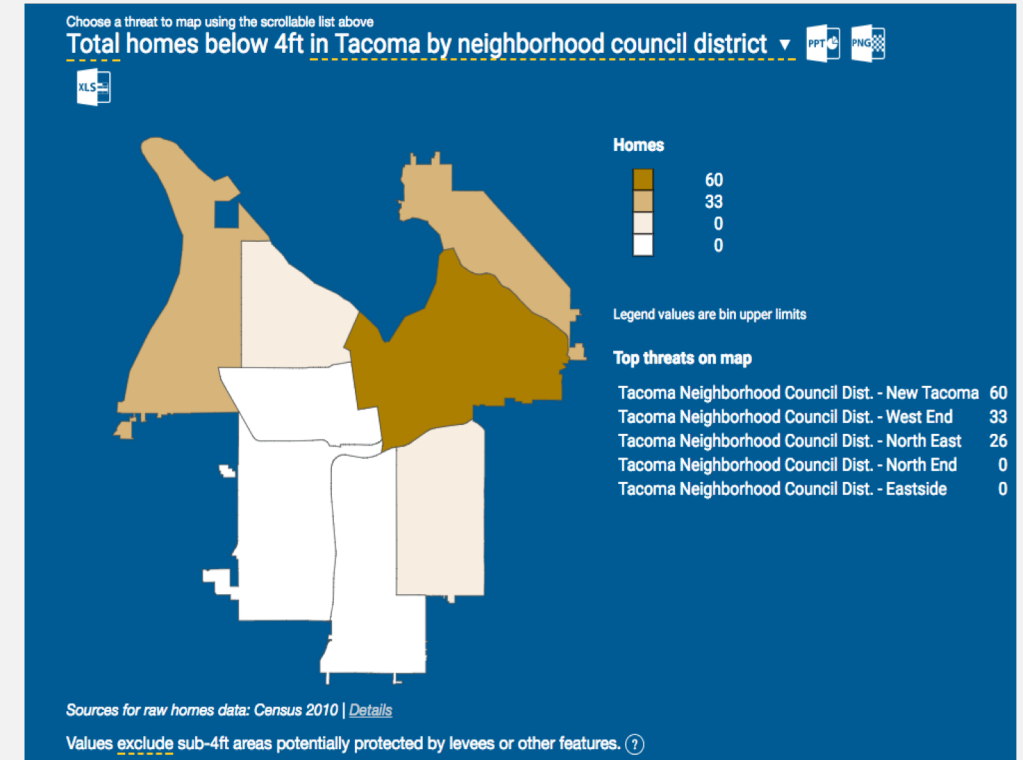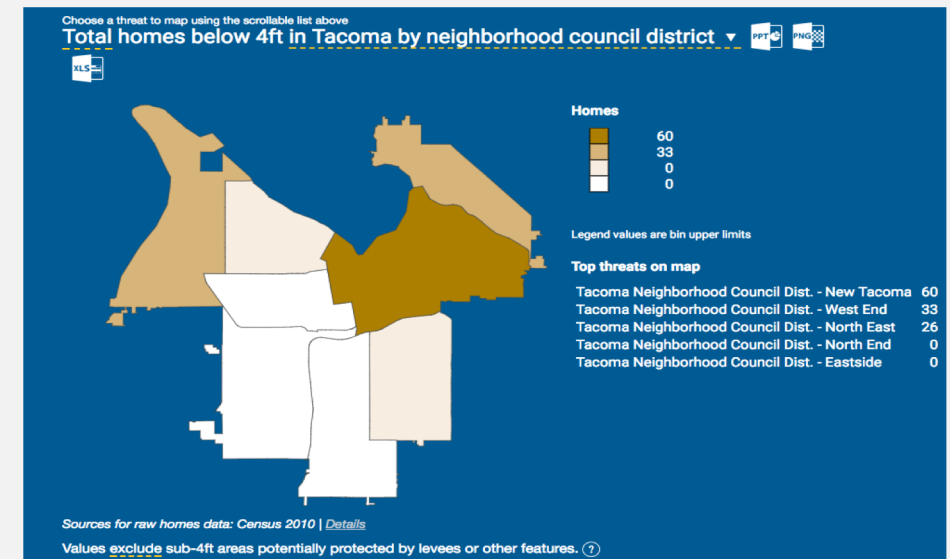1. On the Surging Seas [Risk Finder website](https://riskfinder.climatecentral.org/) (https://riskfinder.climatecentral.org/), scroll down to "What is at Risk?"

2. Open the student worksheet.

3. Make sure you click the tab at the lower left of your worksheet, "Damage Tables."

4. Look at Table 1.

Table 1. Homes exposed to flood and total property values by flood level

Flood Level (ft)	Total homes (number)	Additional homes (number)	Marginal Damage ($)	Marginal Damage (millions of $)
1		0	0	0.0
2		0	0	0.0

Next we will show how we calculated the number of homes affected by 1 foot of sea level rise.

What Is at Risk?

Population | Buildings | Infrastructure | Contamination Risks | Land

Total population below 4 ft in Tacoma

Population: All	Total
Population	702
Low social vulnerability population	647
Caucasian population	533
Hispanic population	301
Population of color	179
African-American population	57
Native American population	40

Sources: Raw population data, Census 2010; elevation data, lidar; administrative boundaries, City of Tacoma. Details
Values exclude sub-4ft areas potentially protected by levees or other features.

Choose a threat to map using the scrollable list above
Total homes below 4ft in Tacoma by neighborhood council district

Homes
60
33
0
0

Legend values are bin upper limits

Top threats on map
Tacoma Neighborhood Council Dist. - New Tacoma 60
Tacoma Neighborhood Council Dist. - West End 33
Tacoma Neighborhood Council Dist. - North East 26
Tacoma Neighborhood Council Dist. - North End 0
Tacoma Neighborhood Council Dist. - Eastside 0

Sources for raw homes data: Census 2010 | Details
Values exclude sub-4ft areas potentially protected by levees or other features.

From Climate Central
(https://riskfinder.climatecentral.org/)

Homes Impacted

1. Go back to "What is at Risk?" on the Risk Finder website.

2. Click Buildings.

3. Click Homes.

4. If needed, click "exclude" to toggle it to read "include."

5. Set the water level to 1 foot.

6. Note the number of homes below the water level.

7. Check out the map to see where the homes are.

Image From Climate Central (https://riskfinder.climatecentral.org/)

What Is at Risk?

Tutorial video ⓘ ⚙

Population | **Buildings** | Infrastructure | Contamination Risks | Land

Total buildings below 2 ft in Tacoma XLS

Buildings: All ▾	Total
Property value	$317 Million
Homes	172

Sources: Raw homes data, *Census 2010*; elevation data, *lidar*; administrative boundaries, *City of Tacoma*. *Details*

Values include sub-2ft areas potentially protected by levees or other features. ?

Water level (ft) ?

Choose a threat to map using the scrollable list above

Total homes below 2 ft in Tacoma by city council district ▾ PPT

PNG XLS

Homes

160
30
0

Legend values are bin upper limits

Top threats on map

Homes Impacted

Enter number of homes.
Click cell, type value, and hit enter.

Table 1. Homes exposed to flood and total property values by flood level

Flood Level (ft)	Total homes (number)	Additional homes (number)	Marginal Damage ($)	Marginal Damage (millions of $)
1		0	0	0.0
2		0	0	0.0

Homes Impacted

Repeat these steps to get total homes for 2 feet of sea level rise. Be sure to select 2 feet in the Riskfinder website. You will need to repeat for 3 feet, 4 feet, etc, up to 10 feet. Work with a friend if possible to speed things up.

Table 1. Regional homes exposed to flood and total property values by flood level

Flood Level (ft)	Total homes (number)	Additional homes (number)	Marginal Damage ($)	Marginal Damage (millions of $)
1	125	125	0	0.0
2		-125	0	0.0
3		0	0	0.0
4		0	0	0.0
5		0	0	0.0
6		0	0	0.0
7		0	0	0.0
8		0	0	0.0
9		0	0	0.0
10		0	0	0.0

Note: your number will differ for 1 foot of sea level rise.

Note: this column will auto-fill as you enter numbers

Additional Homes Impacted

Calculate the number of additional homes affected for each additional foot of sea level rise.

Table 1. Regional homes exposed to flood a...

Flood Level (ft)	Total homes (number)	Additional homes (number)
1	125	125
2	190	65
3	229	39
4	287	58
5	358	71
7	508	508
8	615	107
9	696	81
10	758	62

Note: your numbers will differ.

Additional homes =
        Total homes – Previous total homes

Example for 2 feet of SLR:

Additional homes = 190 homes – 125 homes

This is cell B10 – B9.

This was calculated by clicking on cell C10 and then typing

=B10-B9.

How would you get it for 6 feet?
Check it in the worksheet.

Calculating the Damage Cost of Flooding

Enter the median housing price to calculate the damages from flooding based on the number of homes that will be impacted at various flood levels.

Additional damages = number of additional homes x median home value

	A	B	C	D	E
1	**Part 1: Estimating the expected marginal damages from flooding due to se**				
2					
3	**Median home value in Region (in 2017)**				
4					
5					
6	**Table 1. Regional homes exposed to flood and total property values by flood level**				
7	**Flood Level**	**Total homes**	**Additional homes**	**Additional Damage**	**Additional Damage**
8	**(ft)**	**(number)**	**(number)**	**($)**	**(millions of $)**
9	1	125	125	0	0.0
10	2	190	65	0	0.0
11	3	229	39	0	0.0
12	4	287	58	0	0.0
13	5	358	71	0	0.0
14					
15	7	508	508	0	0.0
16	8	615	107	0	0.0
17	9	696	81	0	0.0
18	10	758	62	0	0.0

Enter the median housing price from the previous slide: click on cell D3, type in the value, then hit 'enter'.

Note that the additional damages fill in automatically.

Pause for Analysis 5: Think about or discuss the following with a partner:

- What assumptions are we making about how flood damages will impact houses?
- What other damages are occurring that we are ignoring? (Look at some of the other tabs on the Riskfinder site, for other types of buildings, infrastructure, etc).
- Do you think this is an over- or under-estimate of flood damages?

With climate change comes a lot of risk and uncertainty.

- How much will sea level rise?
- What is the maximum flood levels associated with each SLR scenario?

One way to incorporate this risk into decision-making is by estimating the **expected damages** given the probability that floods will reach a certain height.

Expected Damage   =   Damage at flood level   x   Probability of flood level

Calculating the Damage Cost of Flooding

Now you will use the formula from the previous slide to calculate the expected additional damages for all the flood levels in Table 2. First we'll examine the table. Note that your numbers may differ.

	A	B	C	D
21	Table 2. Expected marginal damages from flooding by 2050 b			
22		Marginal	Slow	
23	Flood level	Damage	Probability	Exp. Mar. Damage
24	(ft)	(millions of $)		(millions of $)
25	1	43.8	100%	43.8
26	2	35.0		0.0

That's the sea level rise scenario. What other SLR scenarios are in your table?

The flood level was entered in this column

The damage was copied over from Table 1 in this column.

You will need to type in the probabilities here, as shown in the next slide.

In this column we have calculated

Expected damage as Damage x Probability

By entering

= B26*C26

This column will autofill as you go.

Getting the Probability of Flooding

In the Surging Seas Riskfinder website:

1. Make sure the setting is for "Multi-year risk of flooding"
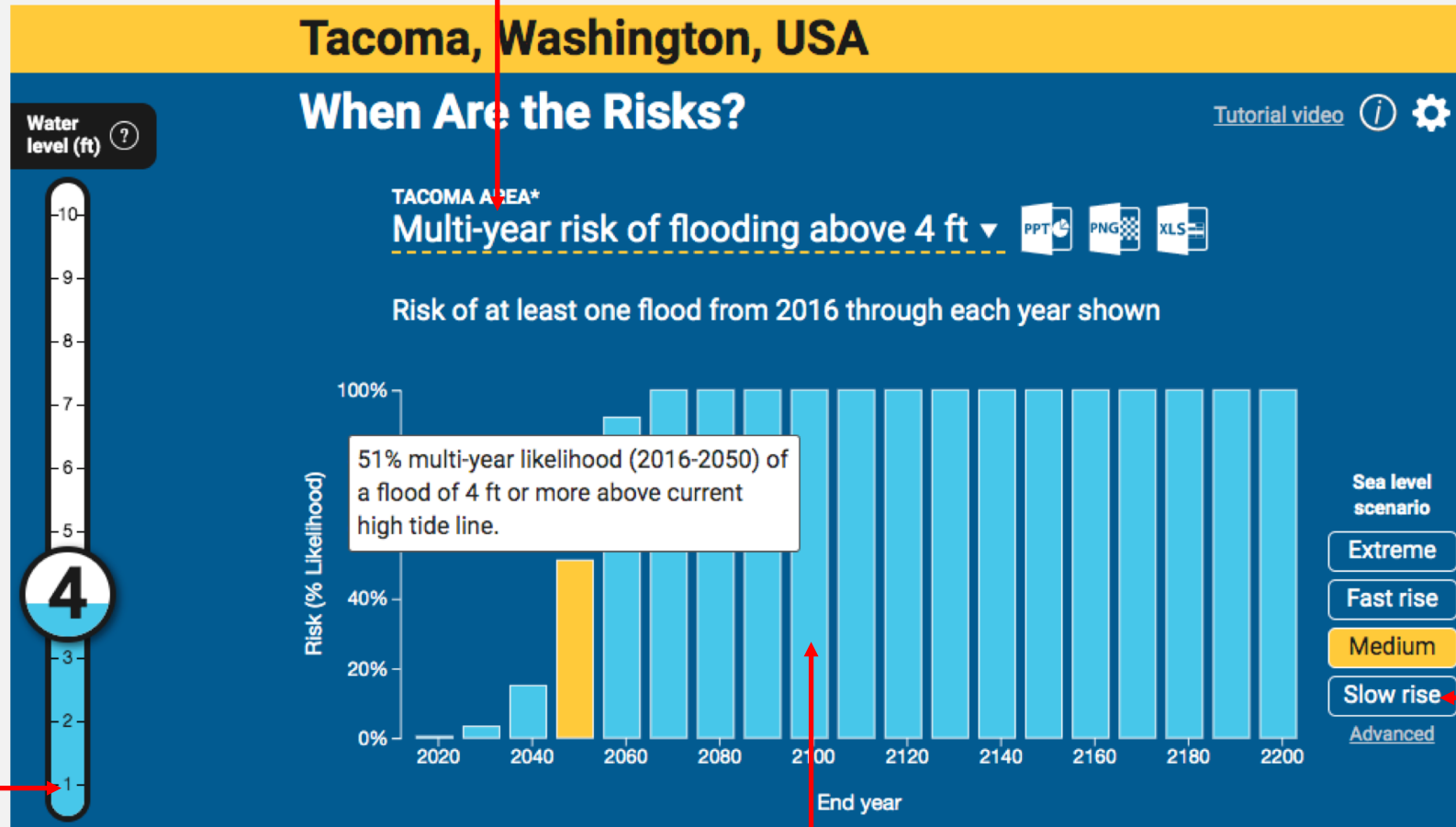
2. Select the water level of your choice.

3. Select the "Slow" sea level scenario

4. Hover over the year 2100 on the bar chart to see the probability of at least one flood of that height by 2100.

Calculating the Damage Cost of Flooding

Finish filling out the row of the table by repeating the steps in the previous slide to fill in the probabilities for the medium scenario, the fast scenario, and the extreme scenario.

Table 2. Expected marginal damages from flooding by 2050 by SLR scenairo									
Flood level (ft)	Marginal Damage (millions of $)	Slow		Medium		Fast		Extreme	
		Probability	Exp. Mar. Damage (millions of $)	Probability	Exp. Mar. Damage (millions of $)	Probability	Exp. Mar. Damage (millions of $)	Probability	Exp. Mar. Damage (millions of $)
1	43.8	100%	43.8		0.0		0.0	1	43.8
2	35.0		0.0		0.0		0.0		0.0
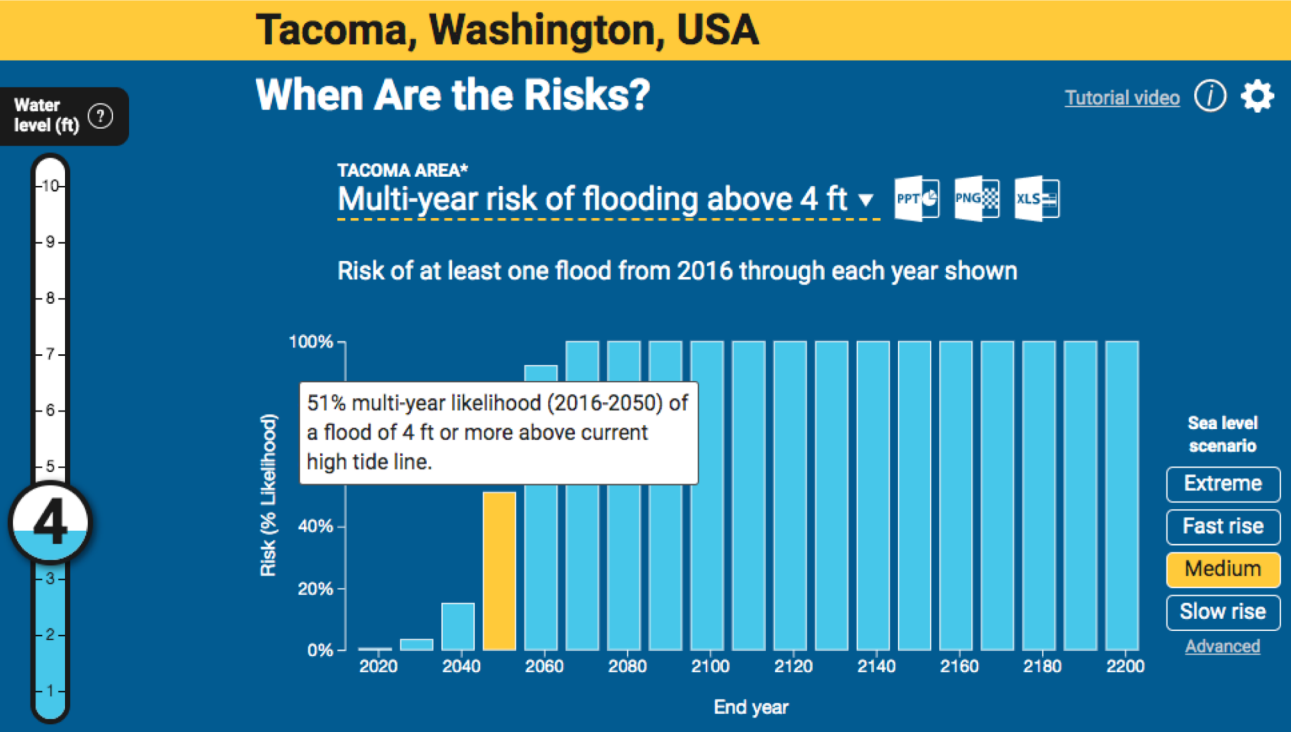
Then fill in the probabilities for the remaining rows, unless your teacher has a key you can use.

When getting the probabilities, be sure to choose the corresponding scenario (Extreme, Fast, Medium, or Slow)

Getting the Probability of Flooding

Pause for Analysis:

- Discuss or think about how you would interpret the expected damage from your table.
- The multi-year likelihood is the probability of at least one flood occurring in the given period (e.g. through 2100), though there could be more.
- Considering the assumptions made in this analysis so far, would more than one flood occurring in the period affect the damage costs?
- Why or why not?

Next time…

In the next PowerPoint, you will use link the expected marginal damages you calculated to possible greenhouse gas pathways.