

# Sea Level Rise In Calvert County

Basics/Background  
Global Contributions

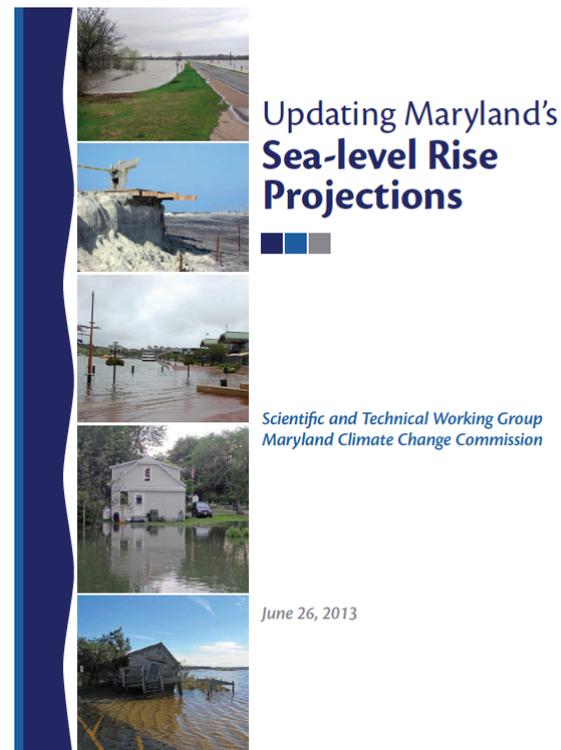
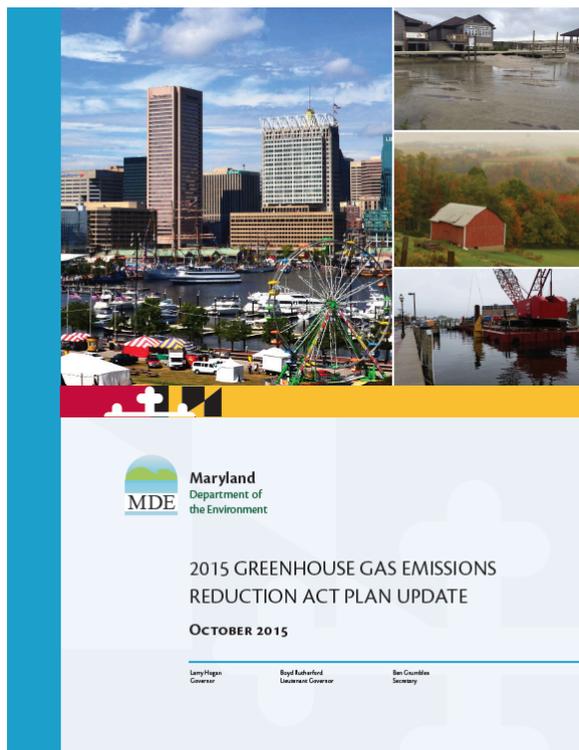
Regional Considerations  
Future Projections



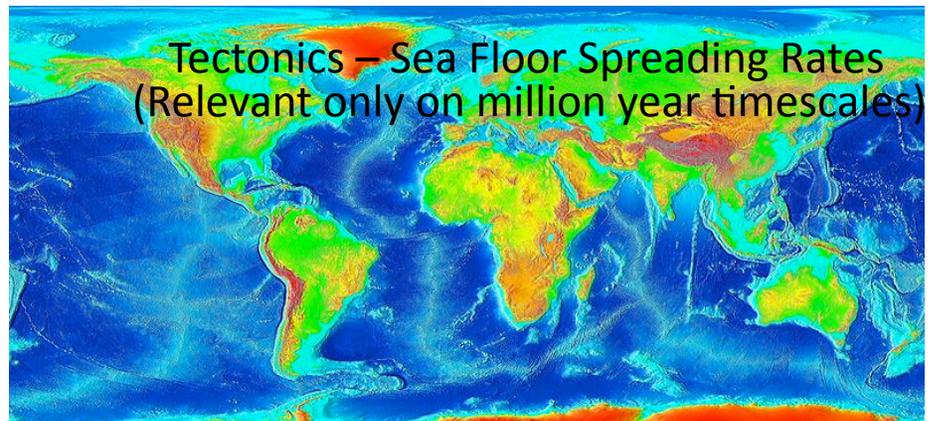
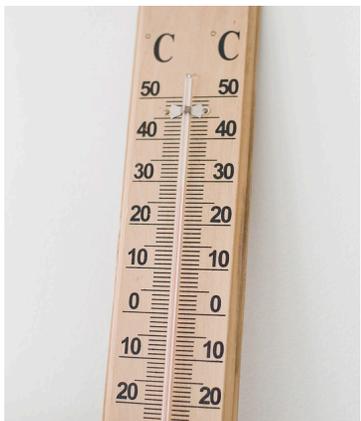
Solomons Boardwalk with high water from Hurricane Isabel 2003, 1.3m surge

2015: Maryland General Assembly codified the Commission on Climate Change and section § 2-1306 of the statute mandates that "the University of Maryland Center for Environmental Science [UMCES] shall establish science-based sea level rise projections for Maryland's coastal areas and update them at least every 5 years."

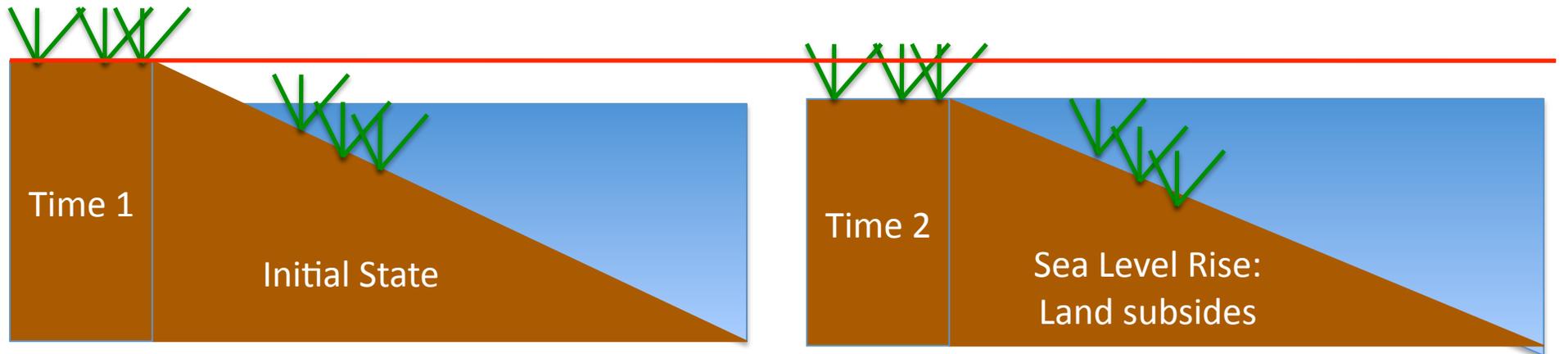
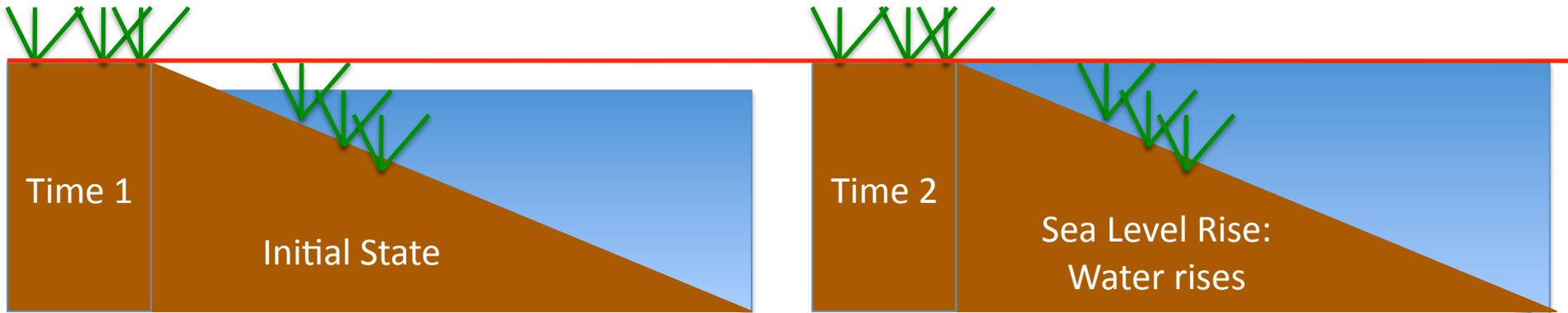
The team meets Oct 11, 2018



# Primary Causes of Global (Eustatic) Sea Level Change

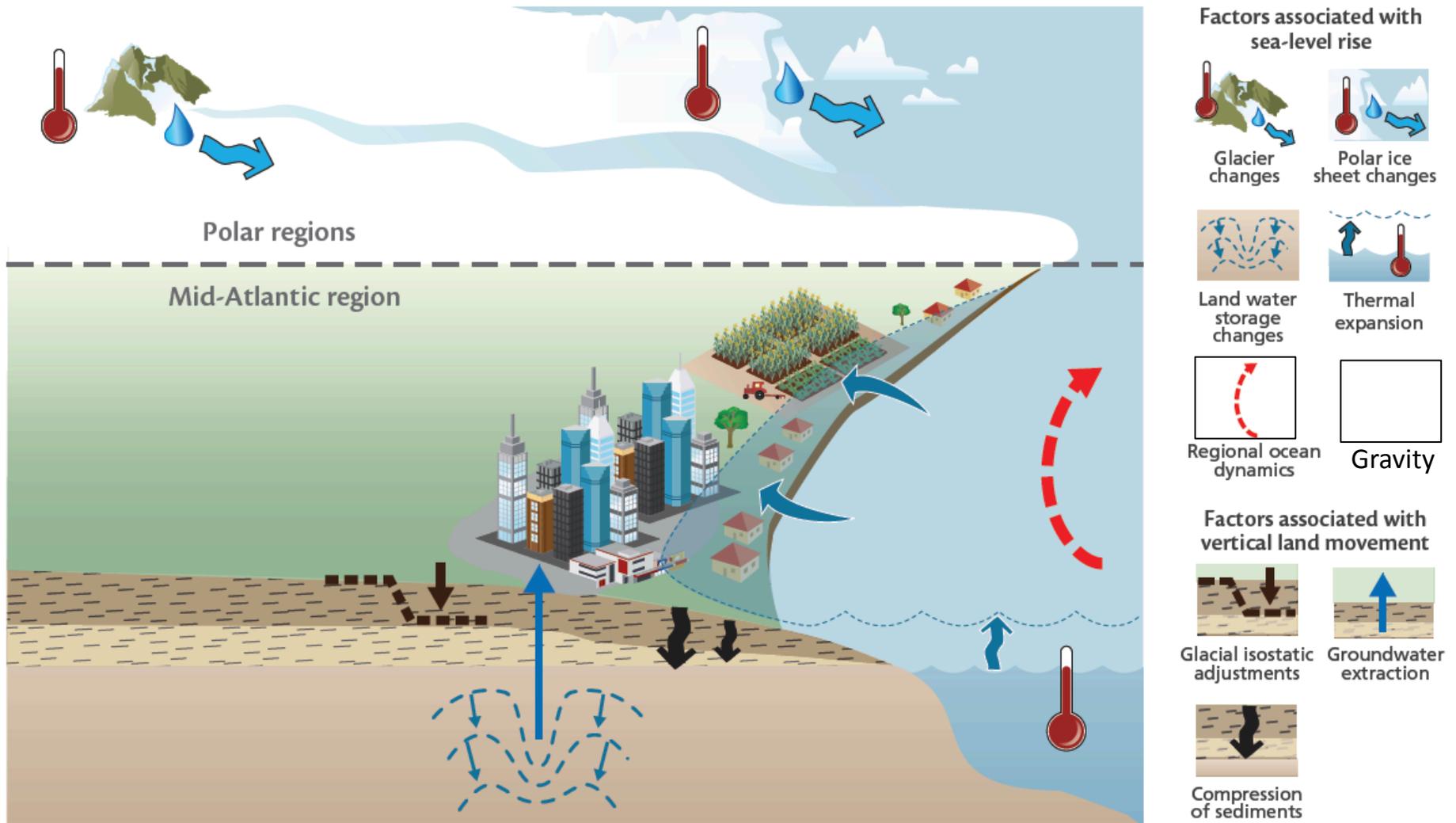


# Relative Sea Level Rise (Land or Sea moves?)

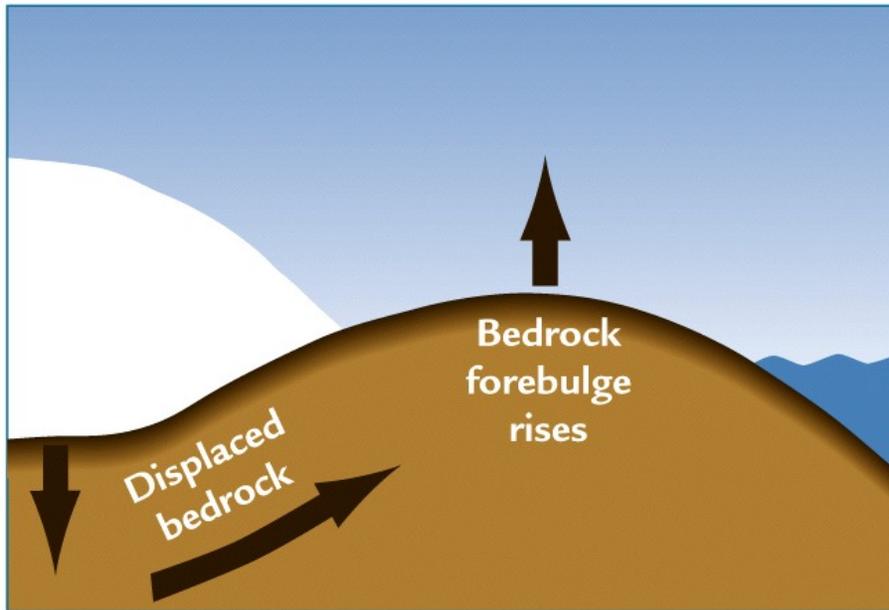


# Factors that Influence Modern Local Sea Level in the Mid Atlantic

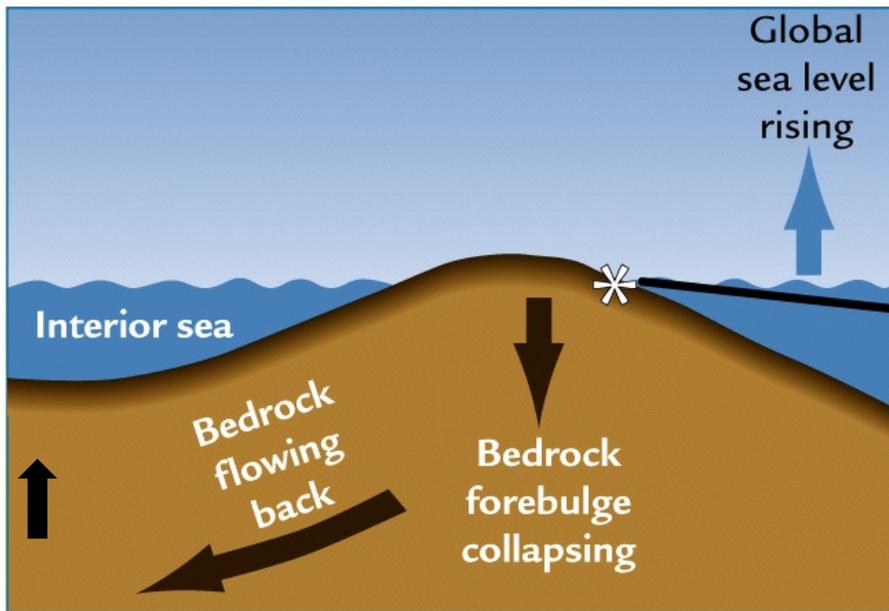
Local factors cause sea level in our region to be slightly higher than global sea level



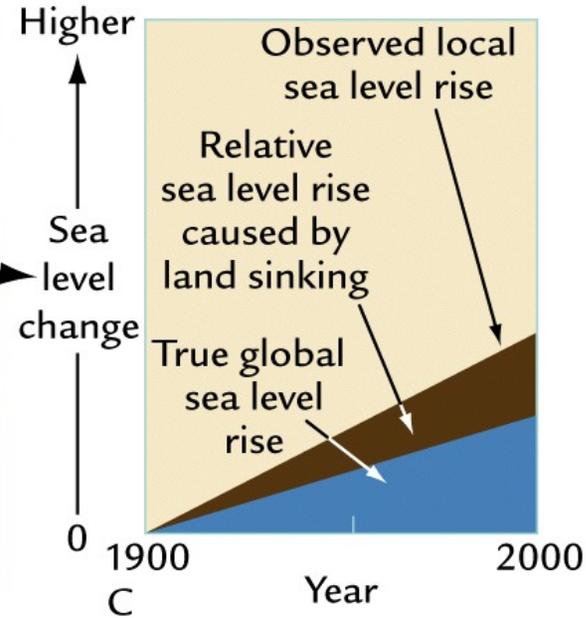
# Glacial Isostatic Adjustment



A Last glaciation (21,000 years ago)



B Today

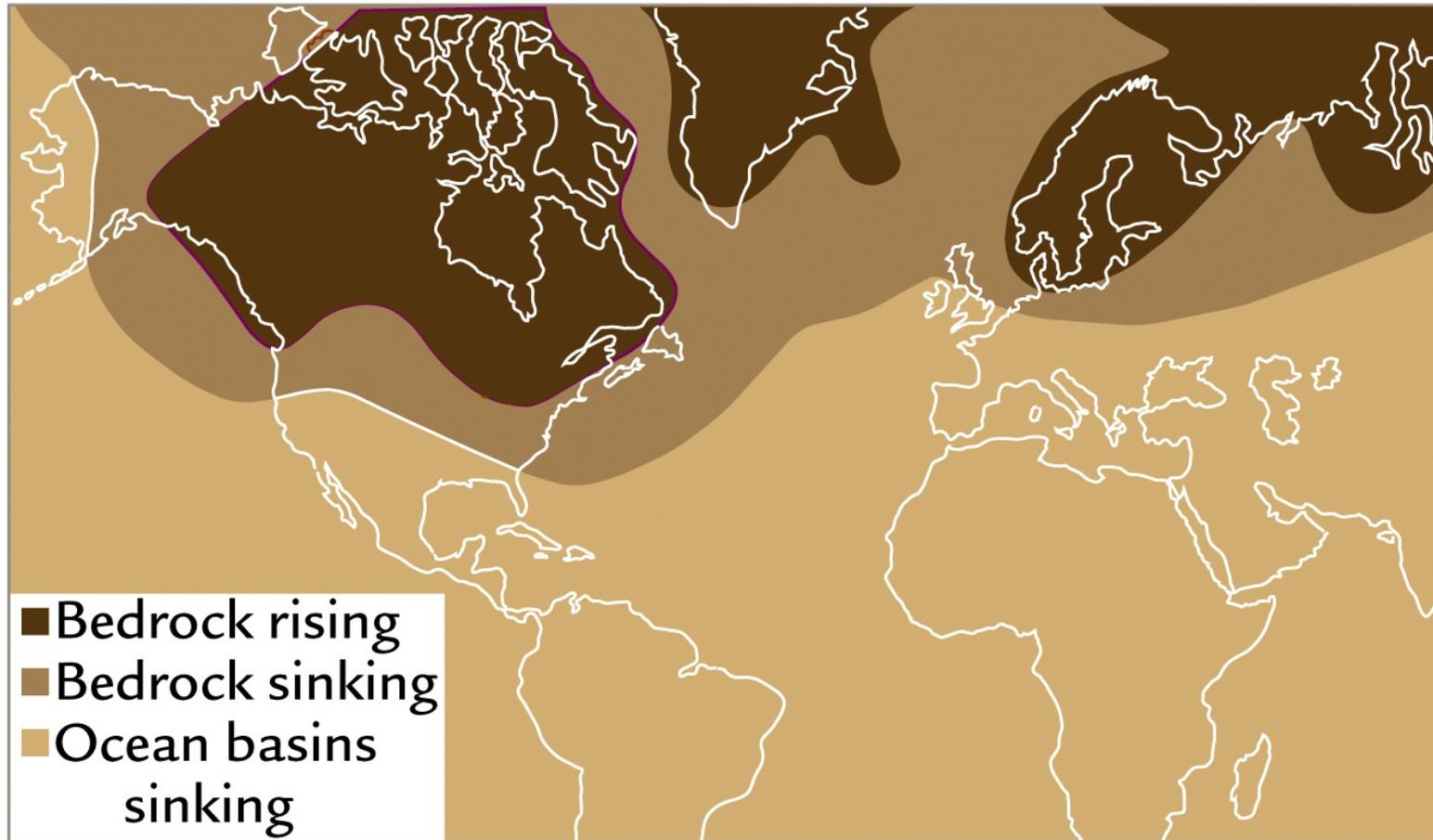


C

# Glacial Isostatic Adjustment

Areas where there were ice sheets are now rising

Areas on the edge of former ice sheets are now sinking



The depth of the sediments influences how much ground lowering subsidence can occur.

The southern Chesapeake has an ancient crater disrupting the bedrock and making the sediments deeper.

This likely makes the southern Chesapeake region more prone to subsidence.

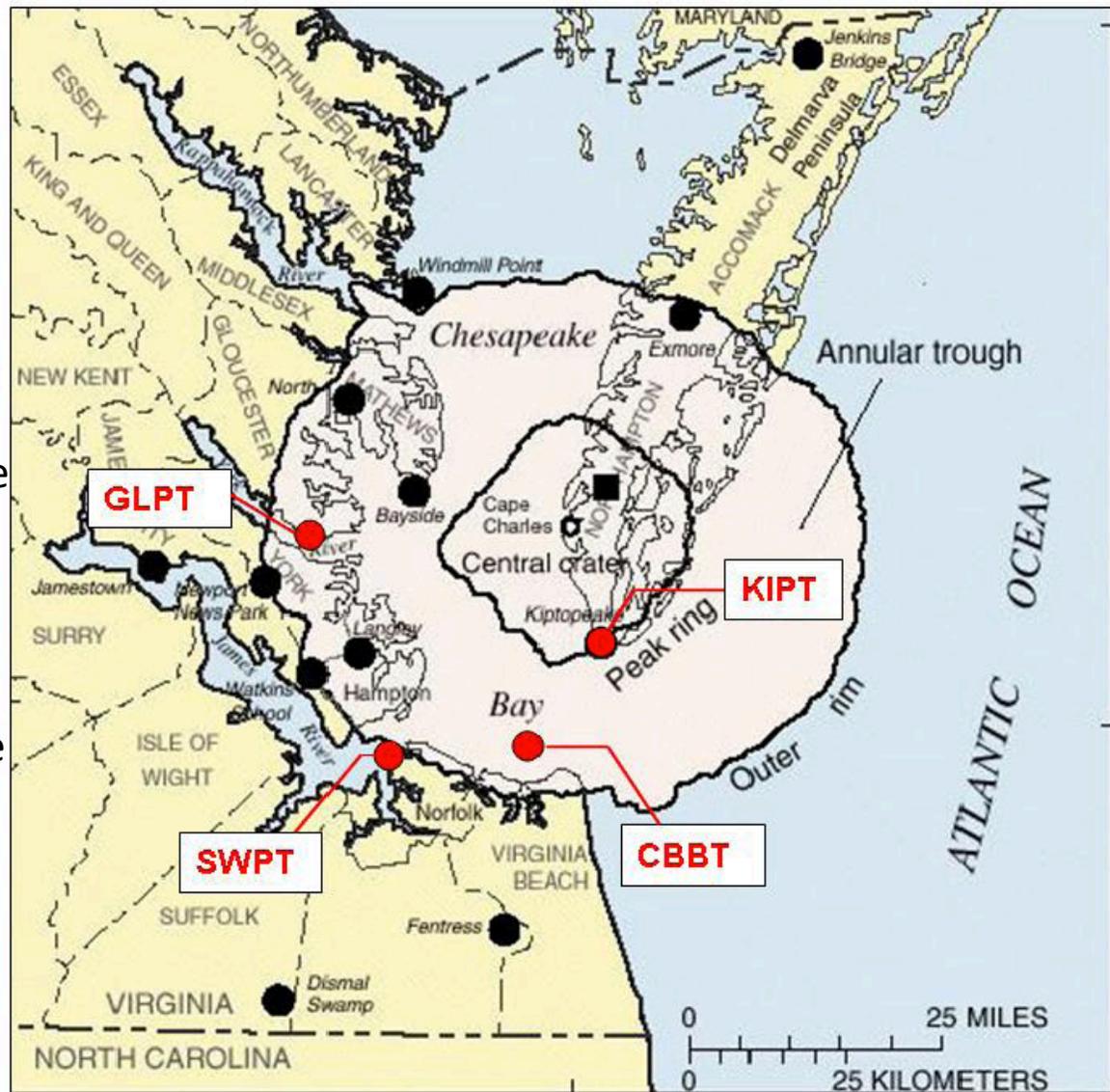
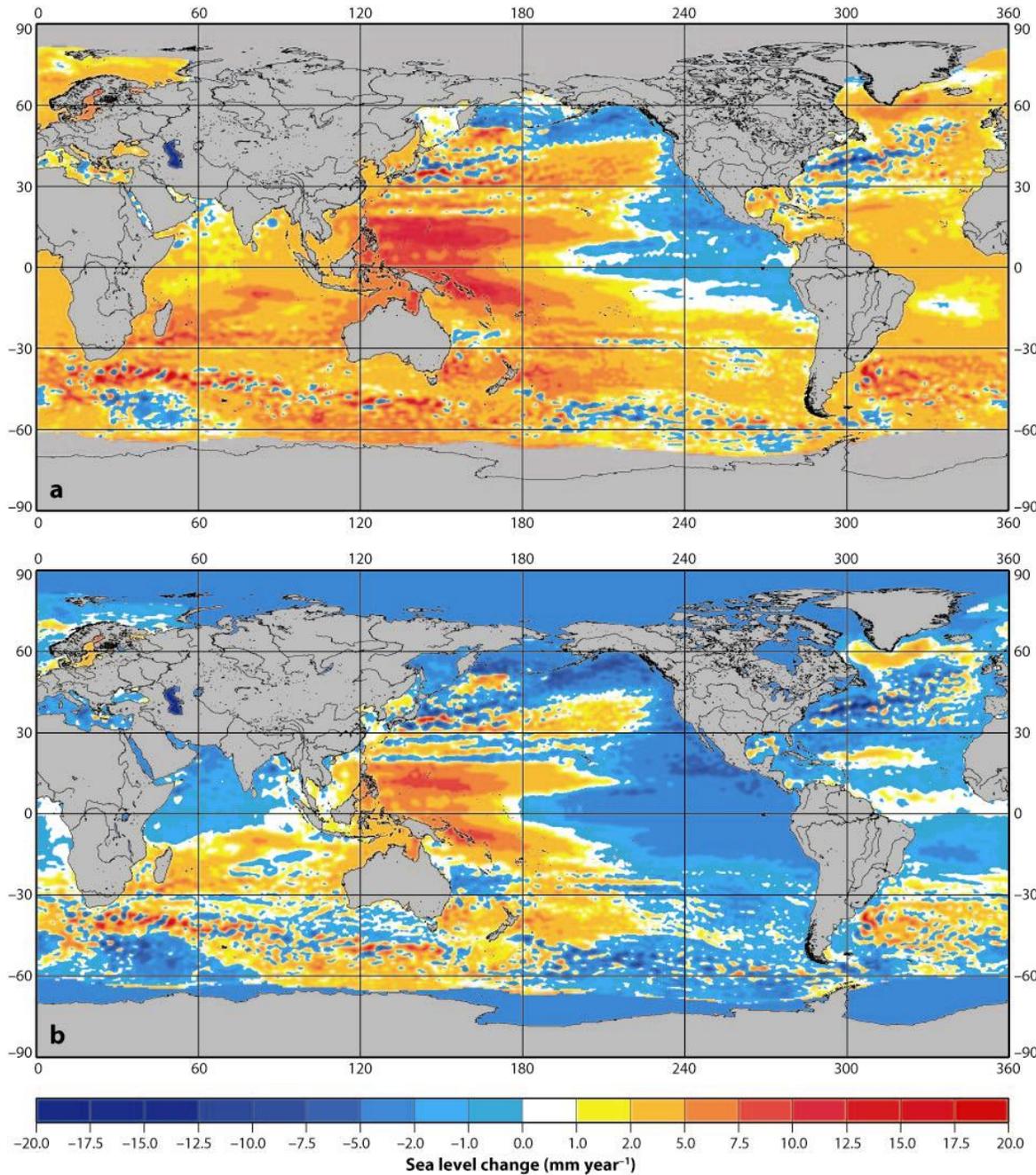


Figure 17. Map showing subsurface extent of the Chesapeake Bay Impact Crater. NWLON stations at Sewells Point (SWPT), Chesapeake Bay Bridge Tunnel (CBBT), Kiptopeke (KIPT) and Gloucester Point (GLPT) are shown by red dots. Black dots are core sampling stations used in studies of the subsurface geology.



The effects of ocean circulation, heat and fresh water induced expansion are not the same everywhere.

(a) Map of satellite altimeter-based spatial trend patterns of observed sea level between January 1993 and December 2008.

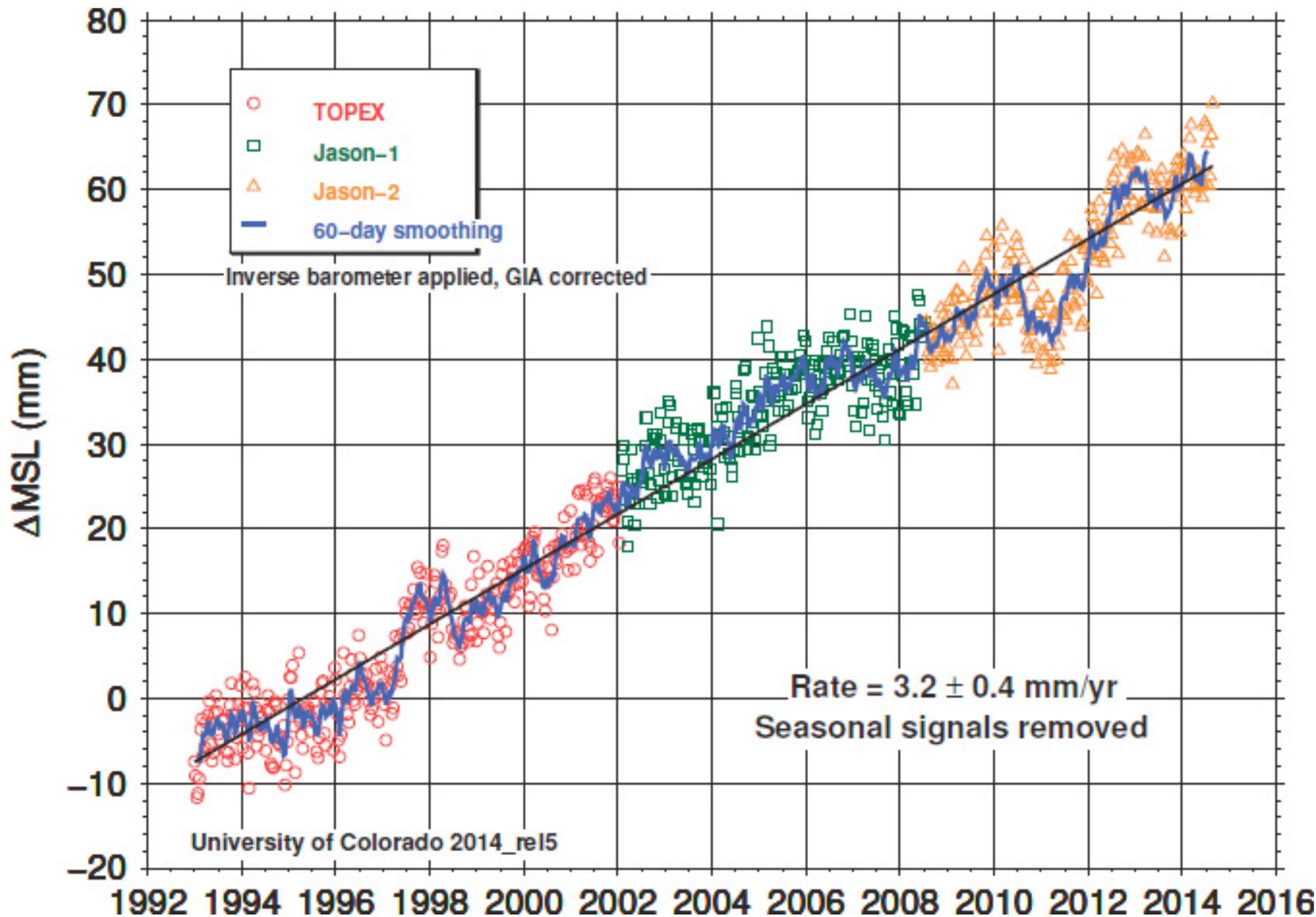
(b) Same as (a) but a uniform global mean trend of 3.4 mm year<sup>-1</sup> has been removed.

Tropical West Pacific has warmed considerably.

South of Greenland has freshened

Areas with strong currents have lots of variability

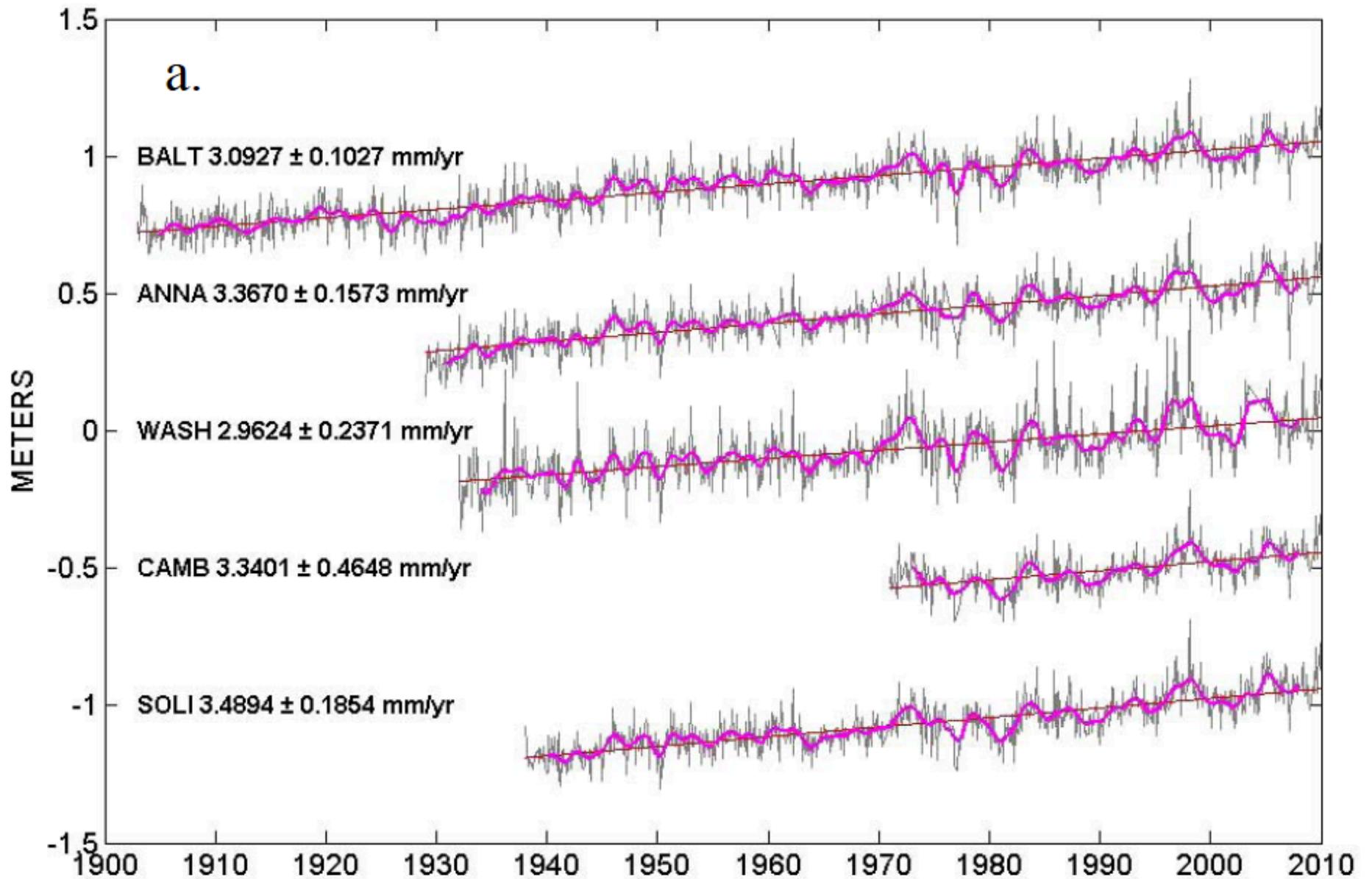
What is happening to  
sea levels now?



**FIGURE D.1** Global mean sea level record from a series of satellite altimetry missions. SOURCE: R.S. Nerem, D. Chambers, C. Choe, and G.T. Mitchum, Estimating mean sea level change from the TOPEX and Jason altimeter missions, *Marine Geodesy* 33(1 Supp 1):435, 2010.

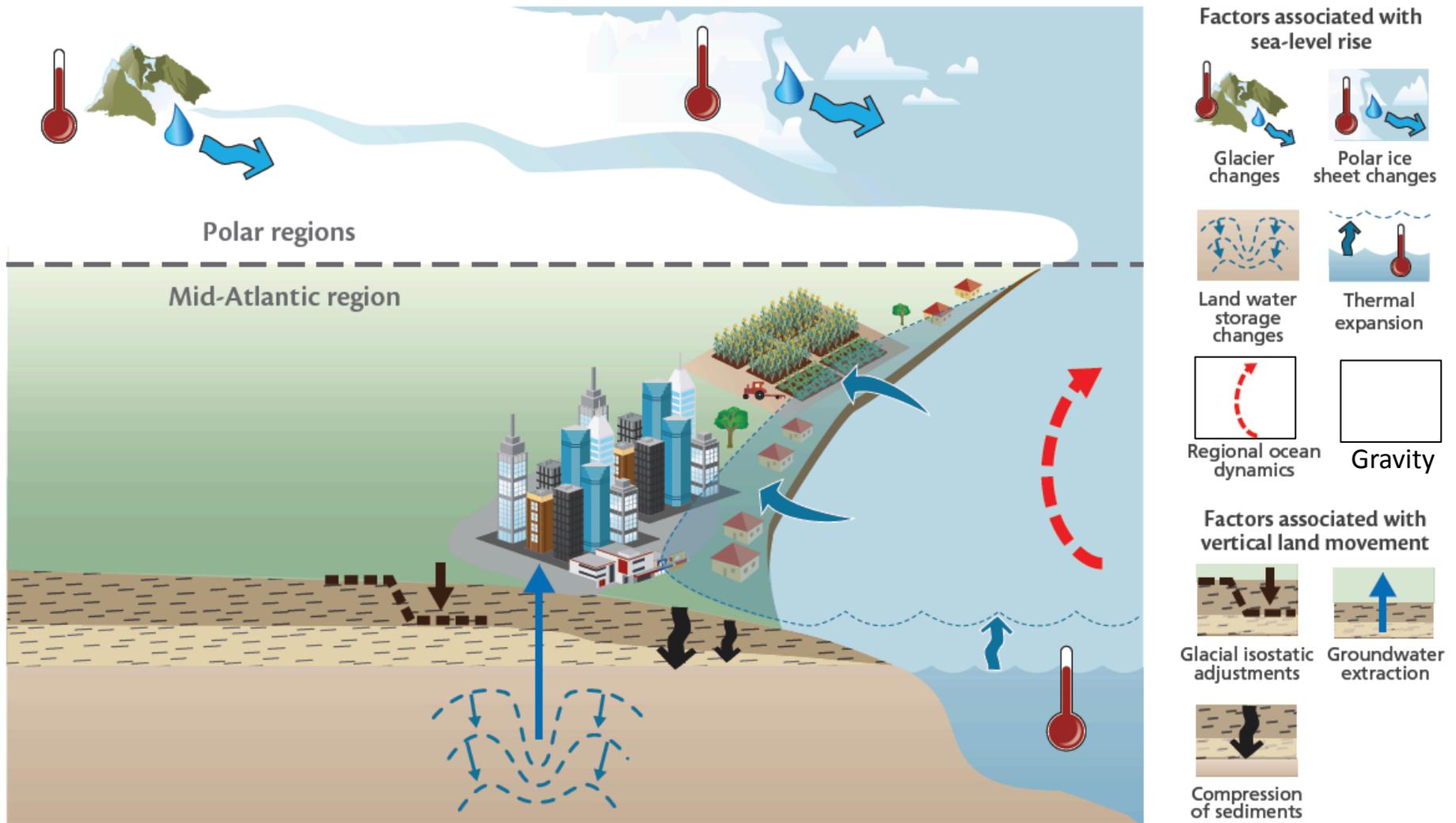
National Academy Press: [Continuity of NASA Earth Observations from Space: A Value Framework \(2015\)](#)

# Northern Chesapeake Sea Level Records

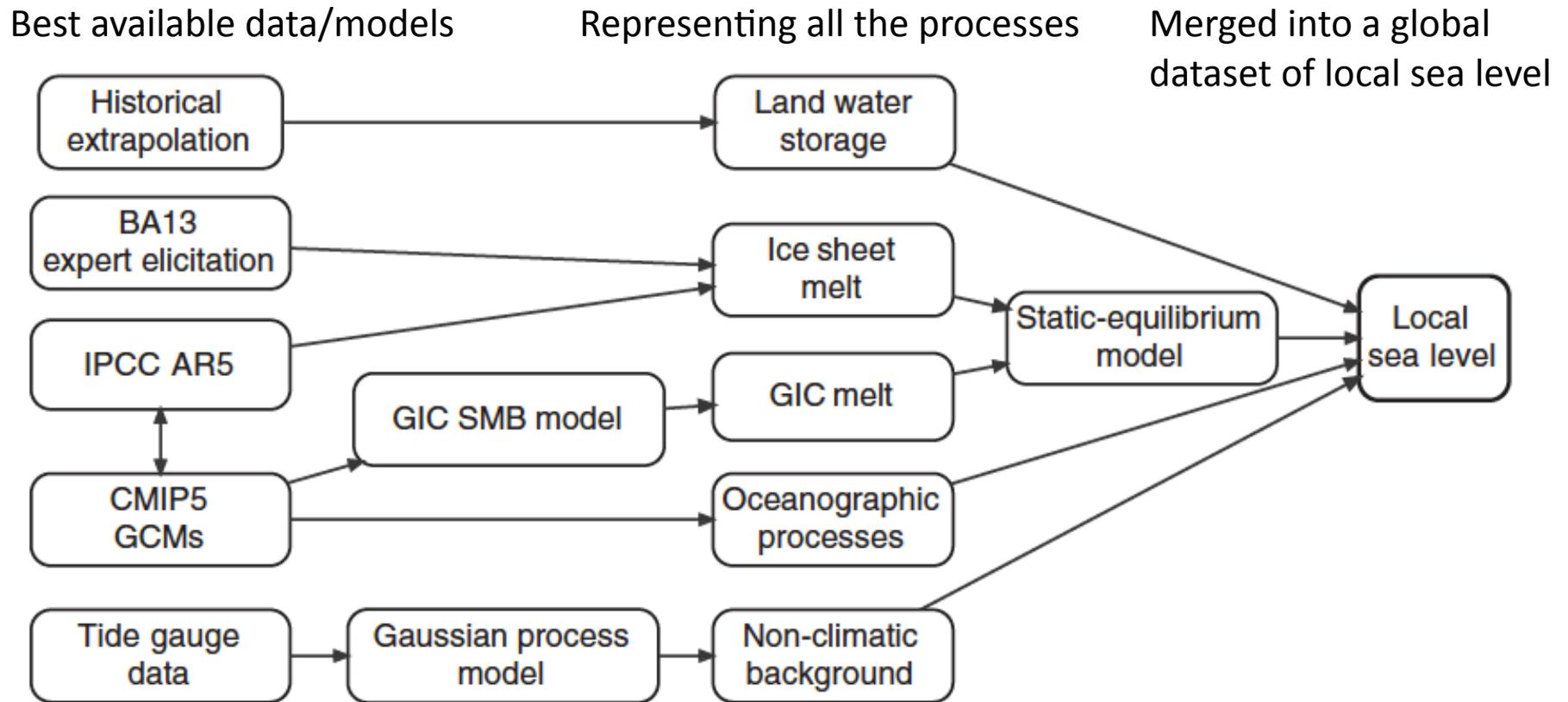


# Future Projections

# Projections of Future Sea-Level Rise Account for Many Factors

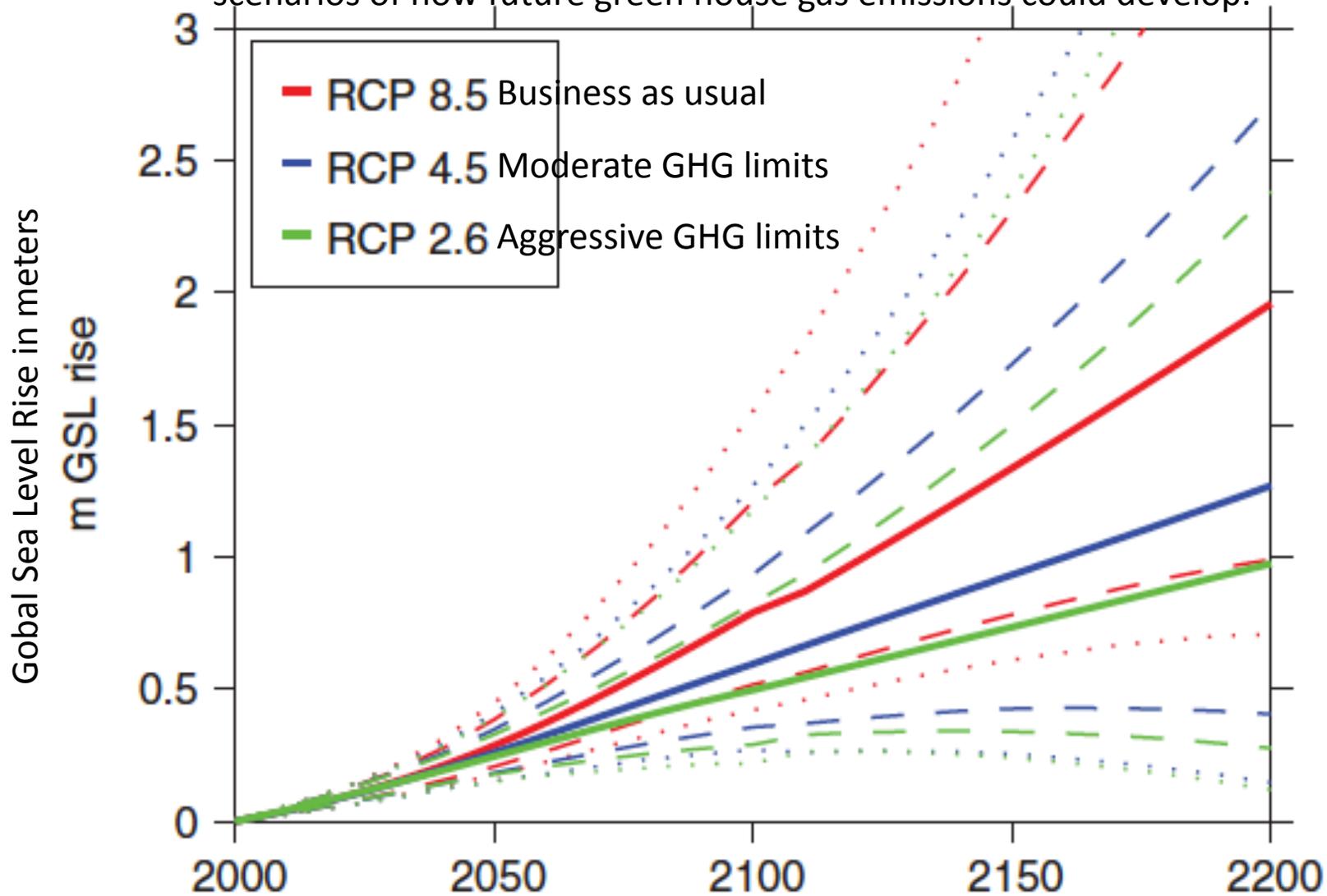


# Kopp et al. 2014 Probabilistic modeling of Sea Level Changes

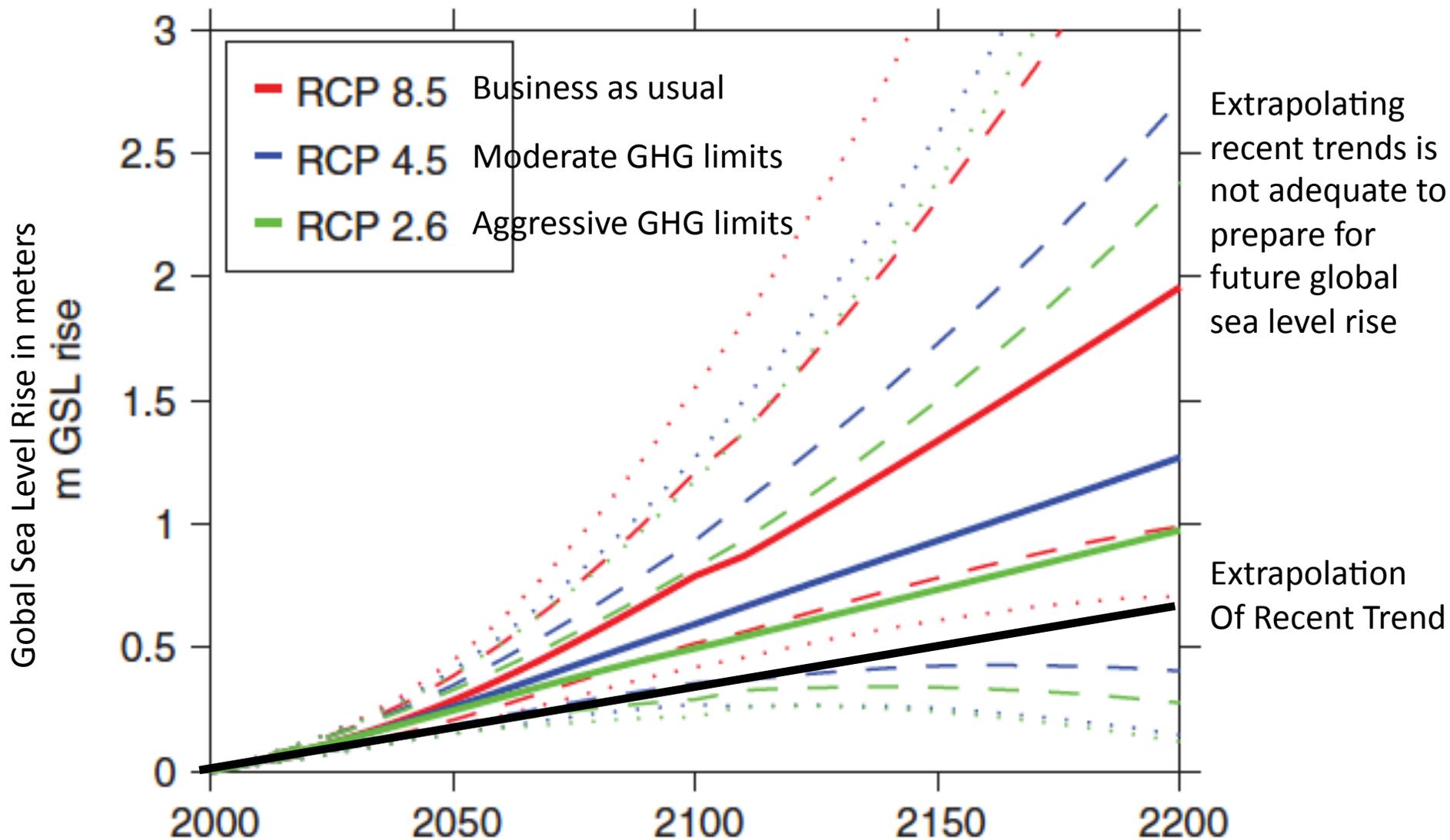


**Figure 1.** Logical flow of sources of information used in local sea-level projections. GCMs, global climate models; GIC, glaciers and ice caps; SMB: surface mass balance.

Kopp et al., 2014 projections based on Representative Carbon Pathways – scenarios of how future green house gas emissions could develop.

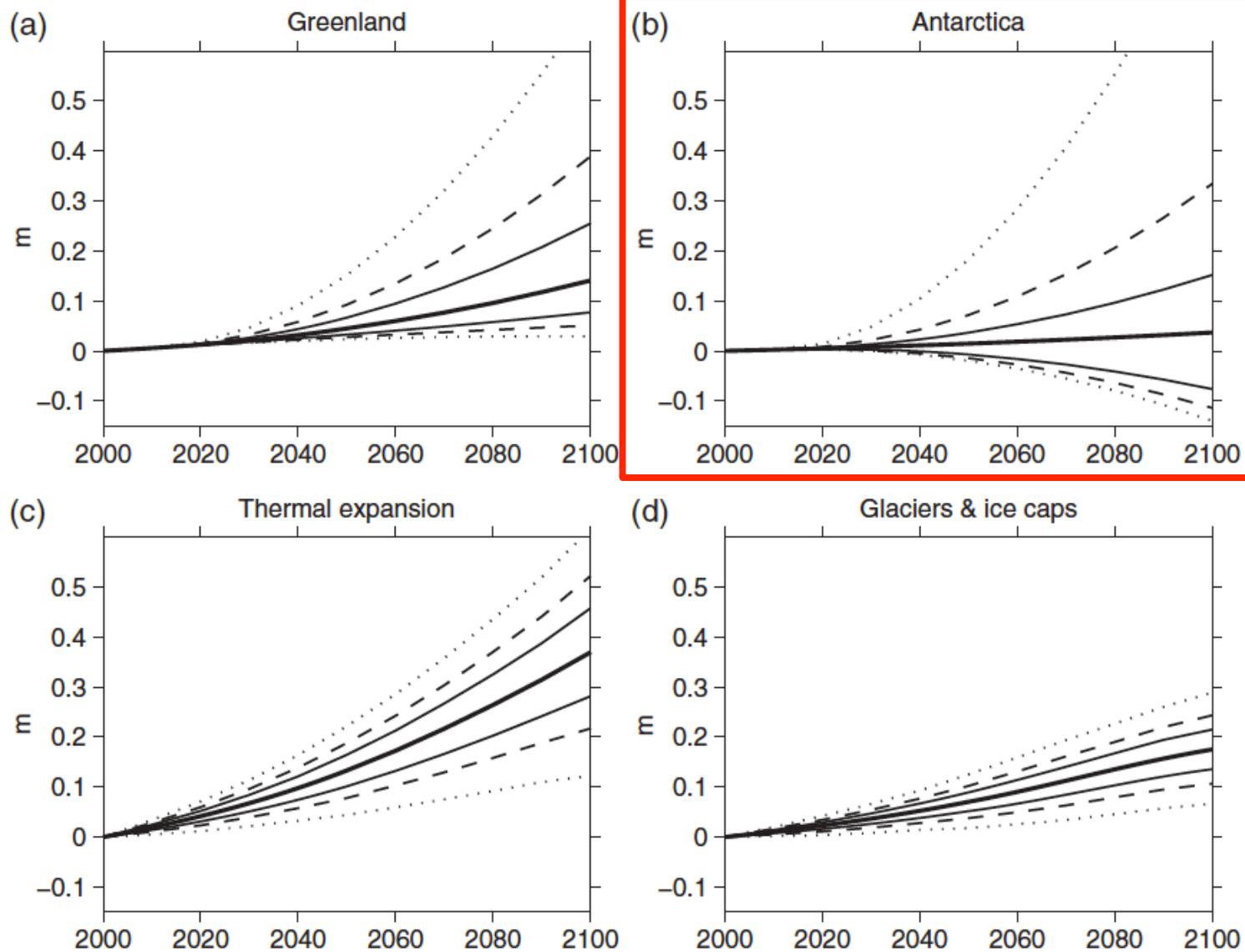


**Figure 3.** Projections of GSL rise for the three RCPs. Heavy = median, dashed = 5th–95th percentile, dotted = 0.5th–99.5th percentiles.



**Figure 3.** Projections of GSL rise for the three RCPs. Heavy = median, dashed = 5th–95th percentile, dotted = 0.5th–99.5th percentiles.

## Major Contributions to Future Sea Level Rise



**Figure 2.** Projections of cumulative contributions of (a) the Greenland ice sheet, (b) the Antarctic ice sheet, (c) thermal expansion, and (d) glaciers to sea-level rise in RCP 8.5. Heavy = median, light = 67% range, dashed = 5th–95th percentile; dotted = 0.5th–99.5th percentiles.

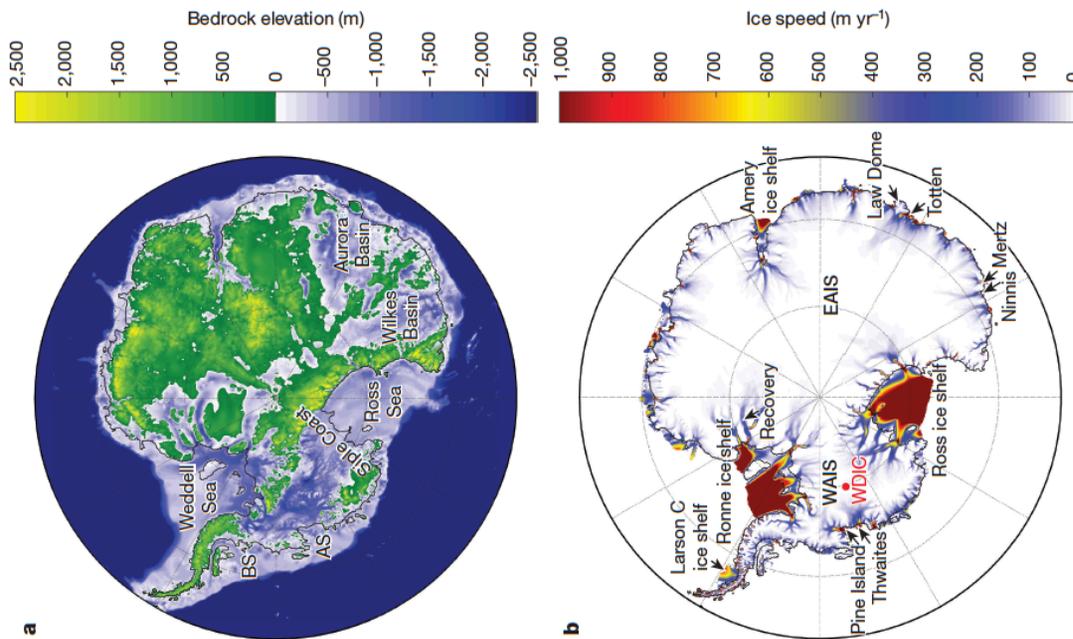
A 2016 article in Nature demonstrated that recent advances in understanding ice sheet physics enabled researchers to accurately model historical ice sheet behavior.

doi:10.1038/nature17145

## Contribution of Antarctica to past and future sea-level rise

Robert M. DeConto<sup>1</sup> & David Pollard<sup>2</sup>

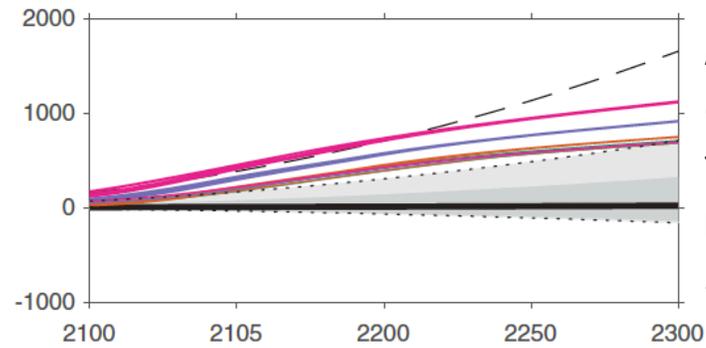
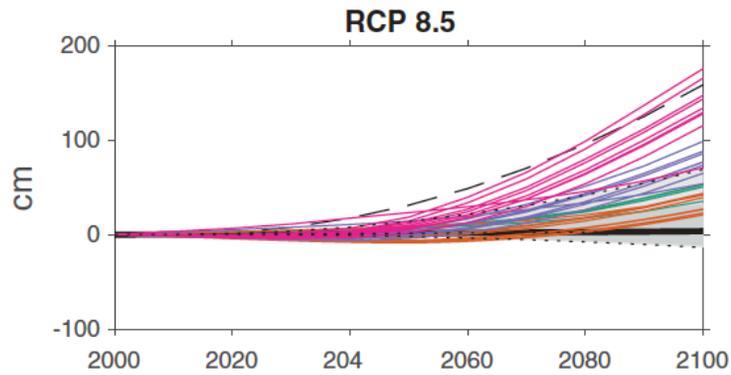
Polar temperatures over the last several million years have, at times, been slightly warmer than today, yet global mean sea level has been 6–9 metres higher as recently as the Last Interglacial (130,000 to 115,000 years ago) and possibly higher during the Pliocene epoch (about three million years ago). In both cases the Antarctic ice sheet has been implicated as the primary contributor, hinting at its future vulnerability. Here we use a model coupling ice sheet and climate dynamics—including previously underappreciated processes linking atmospheric warming with hydrofracturing of buttressing ice shelves and structural collapse of marine-terminating ice cliffs—that is calibrated against Pliocene and Last Interglacial sea-level estimates and applied to future greenhouse gas emission scenarios. Antarctica has the potential to contribute more than a metre of sea-level rise by 2100 and more than 15 metres by 2500, if emissions continue unabated. In this



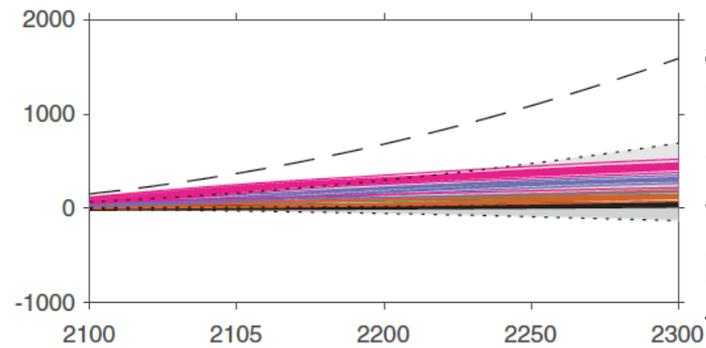
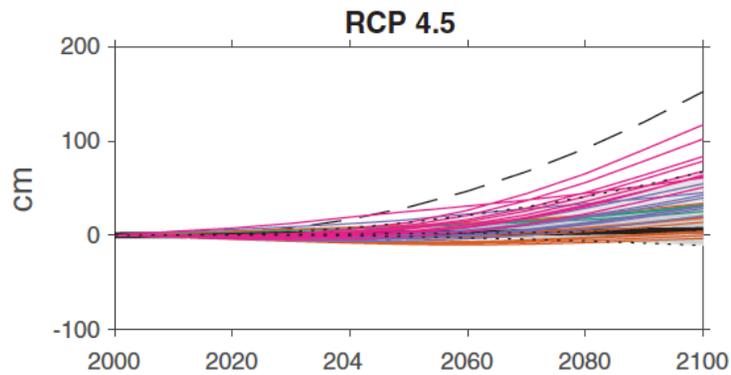
**Figure 1 | Antarctic sub-glacial topography and ice sheet features.** a, Bedrock elevations<sup>13</sup> interpolated onto the 10-km polar stereographic ice-sheet model grid and used in Pliocene, LIG, and future ice-sheet simulations. b, Model surface ice speeds and grounding lines (black lines) show the location of major ice streams, outlet glaciers, and buttressing ice shelves (seaward of grounding lines) relative to the underlying topography in a. Features and place names mentioned in the text are also shown. AS, Amundsen Sea; BS, Bellingshausen Sea; WDC, WAIS Divide Ice Core. The locations of the Pine Island, Thwaites, Ninnis, Mertz, Totten, and Recovery glaciers are shown. Model ice speeds (b) are shown after equilibration with a modern atmospheric and ocean climatology (see Methods).

Incorporating the new understanding of Antarctic ice sheet behavior in response to warming leads to higher estimates of future sea level rise,

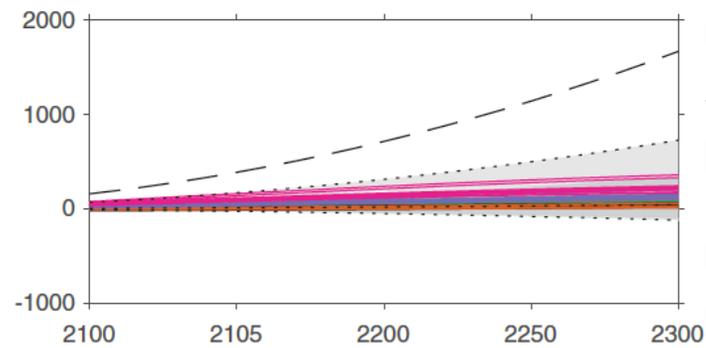
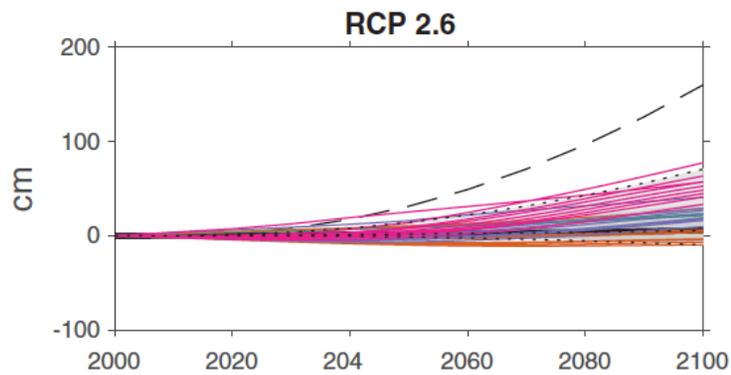
making the new estimates more in line with evidence of past sea level rise from the geologic past.



Antarctic contribution to the Kopp 2014 modeling scheme.

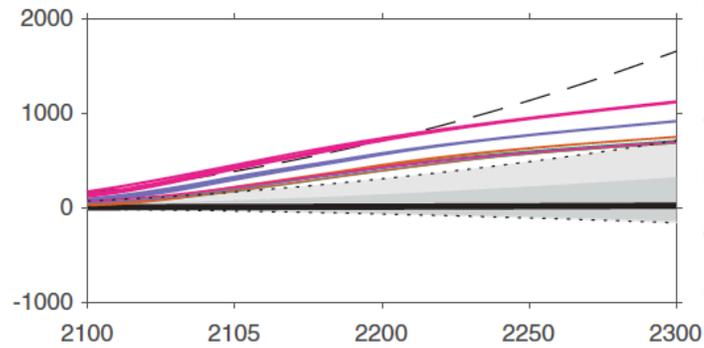
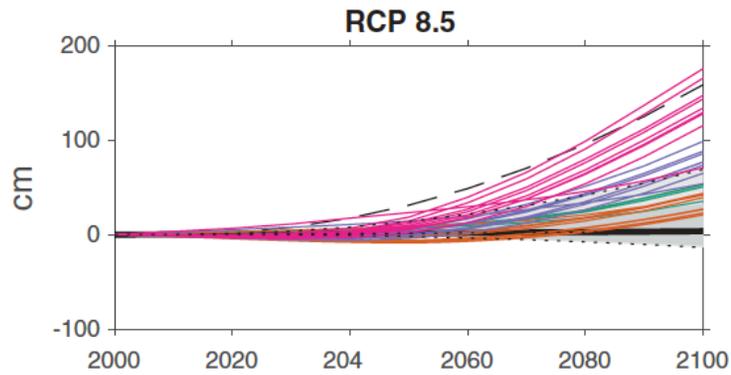


Black lines and grey shading are Kopp 2014 estimates whereas colored lines are results from Antarctic model runs incorporating ice sheet collapse physics.

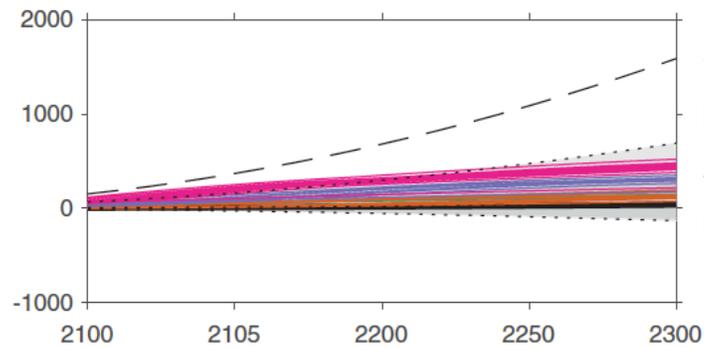
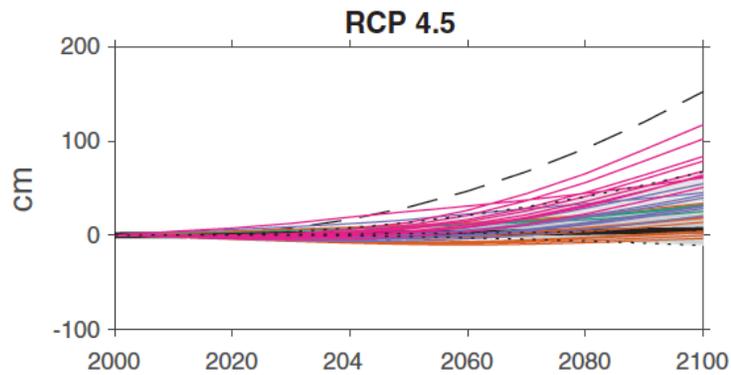


Under RCP2.6, ice sheets don't collapse, resulting in no change

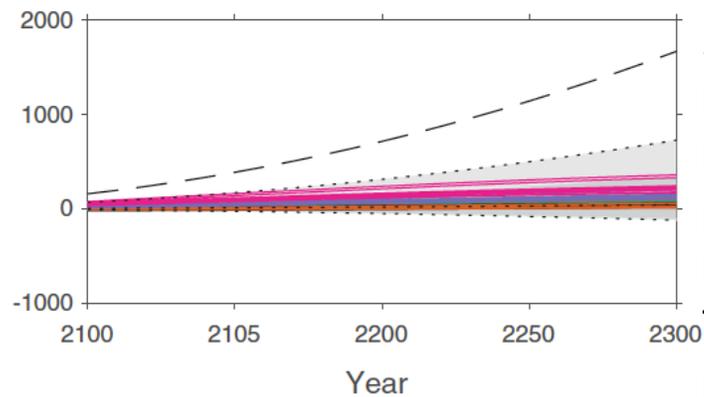
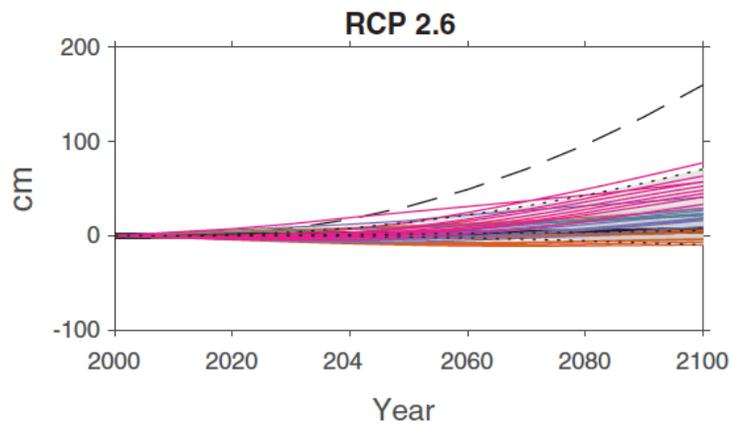
**Figure 2.** Projections of the Antarctic ice-sheet contribution to global-mean sea-level (GMSL) under three Representative Concentration Pathways (RCPs). Dark/light shaded areas represent 5–95th and 0.5th–99.5th percentile of K14. Dotted black line represents 99.9th percentile of K14. Colored curves are DP16 runs, with colors reflecting different maximum rates of ice-cliff collapse (green: no ice cliff collapse; orange: 1 km/yr; purple: 3 km/yr; magenta: 5 km/yr). Left panels show 2000–2100, right panels show 2100–2300. Note change of horizontal and vertical scales.



Under RCP2.6, ice sheets don't collapse, resulting in little change from earlier estimates



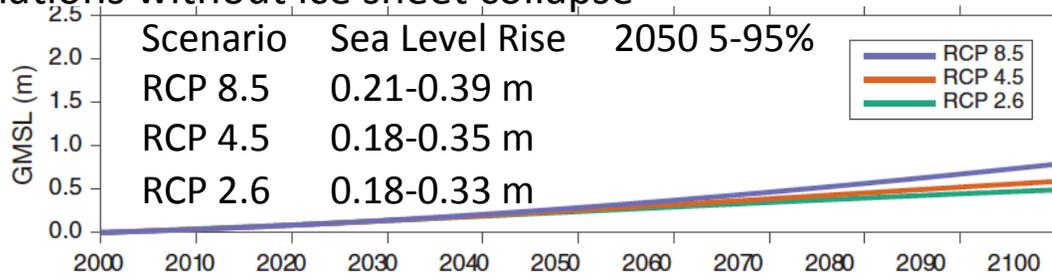
Under RCP 4.5 and 8.5, the probability of ice sheet collapse increases after 2050.



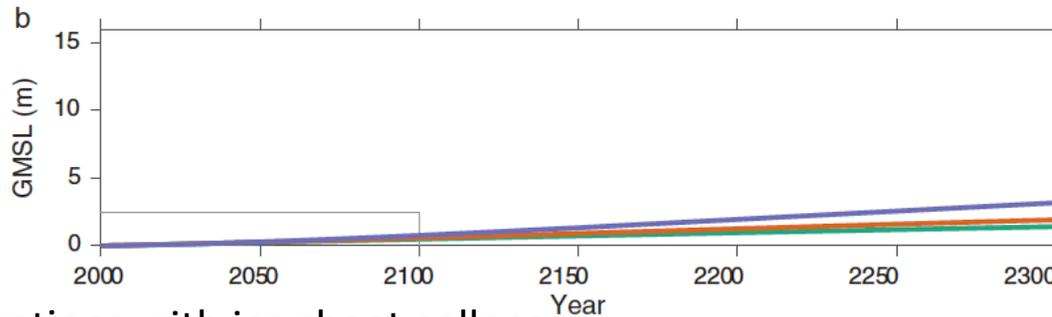
Under RCP8.5 ice sheet collapse becomes more likely, increasing projected sea level rise by 2100. The sea level rise increases to nearly 10 m (30 ft) by year 2300.

**Figure 2.** Projections of the Antarctic ice-sheet contribution to global-mean sea-level (GMSL) under three Representative Concentration Pathways (RCPs). Dark/light shaded areas represent 5–95th and 0.5th–99.5th percentile of K14. Dotted black line represents 99.9th percentile of K14. Colored curves are DP16 runs, with colors reflecting different maximum rates of ice-cliff collapse (green: no ice cliff collapse; orange: 1 km/yr; purple: 3 km/yr; magenta: 5 km/yr). Left panels show 2000–2100, right panels show 2100–2300. Note change of horizontal and vertical scales.

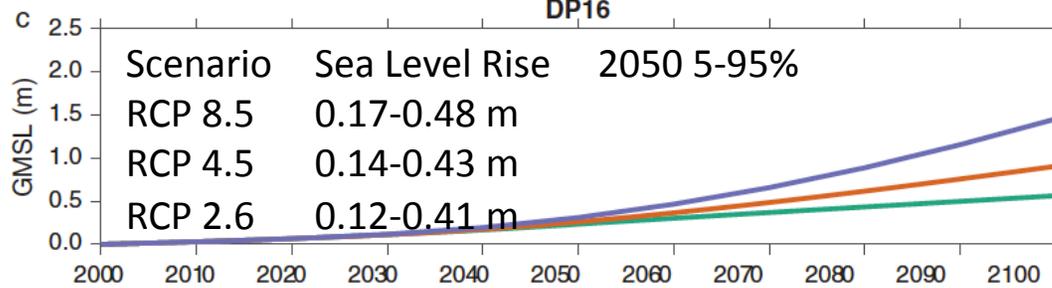
### Estimations without ice sheet collapse



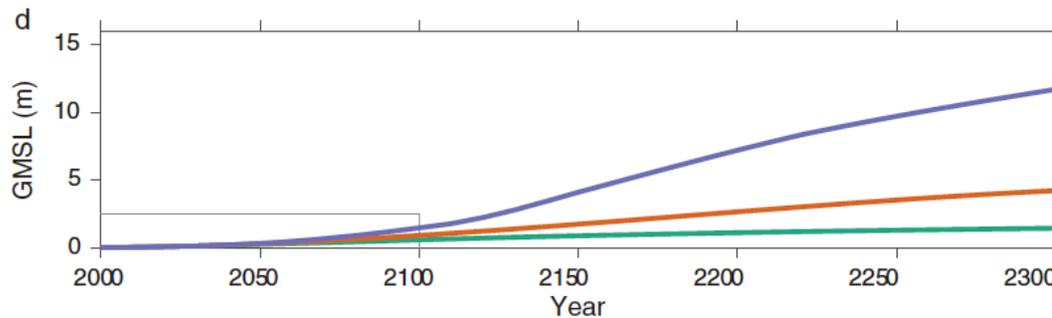
Scenario	Sea Level Rise	Median
RCP 8.5	0.51-1.23 m	0.79 m
RCP 4.5	0.35-0.95 m	0.59 m
RCP 2.6	0.28-0.84 m	0.49 m



### Estimations with ice sheet collapse



Scenario	Sea Level Rise	Median
RCP 8.5	0.93-2.43 m	1.46 m
RCP 4.5	0.50-1.58 m	0.91 m
RCP 2.6	0.26-0.98 m	0.56 m



**Figure 3.** Projections of global-mean sea-level (GMSL) rise for three Representative Concentration Pathways (RCPs) under K14 (a, b) and DP16 (c, d). Lines indicate median; boxes indicate 5th–95th percentile range for 2100 (a, c) and 2300 (b, d). Light gray lines in (b) and (d) indicate axes limits of (a) and (c).

# Putting Projections into the Long Term Context

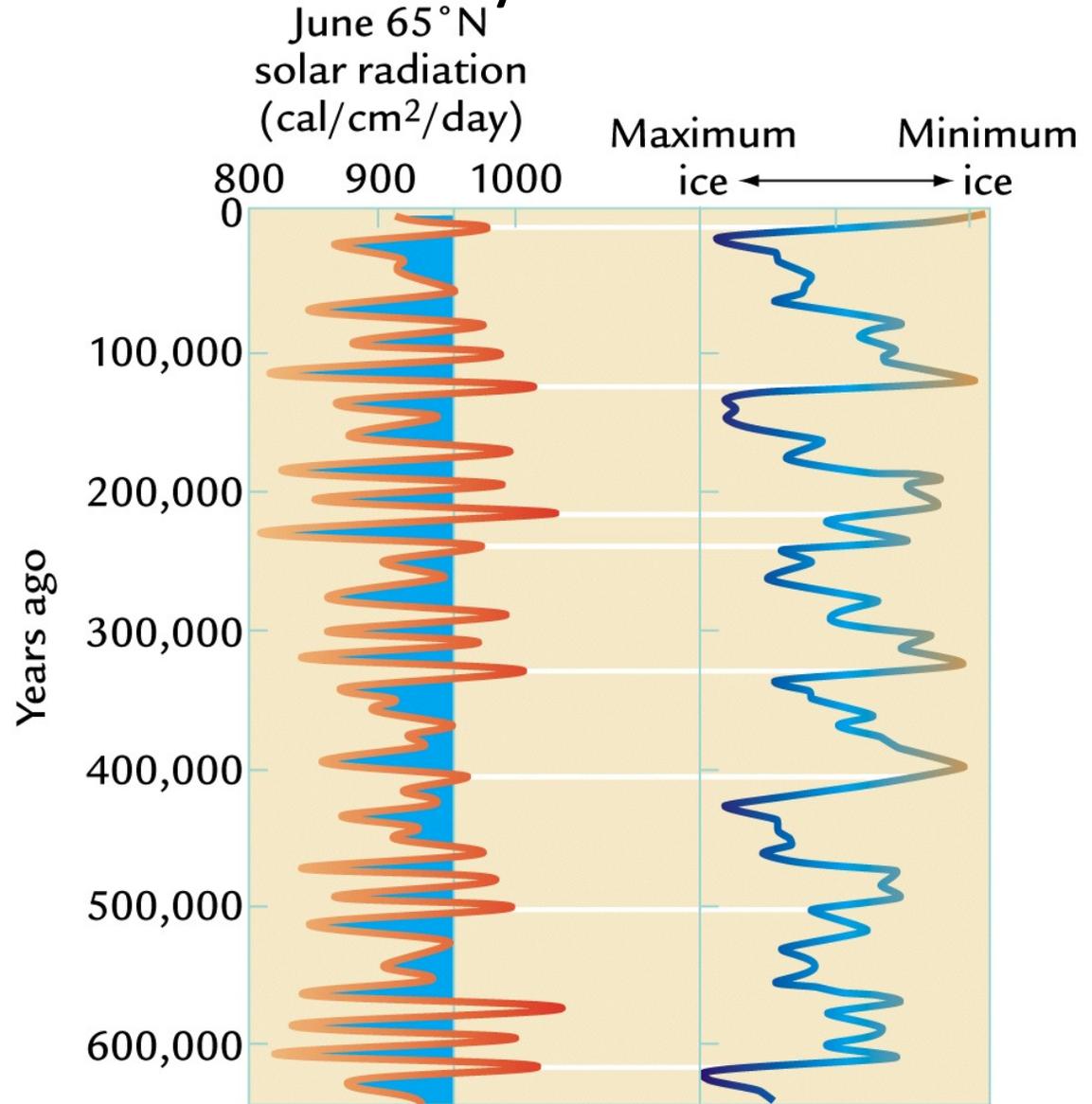
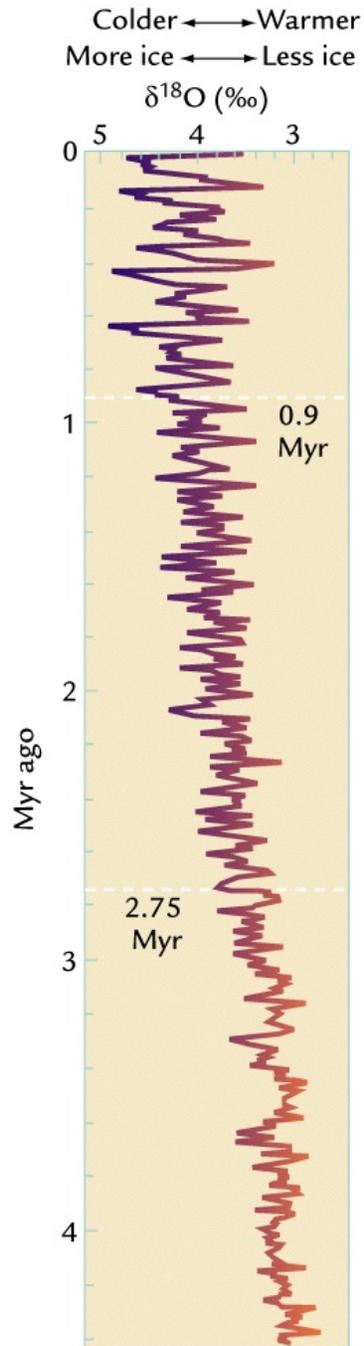


We have evidence sea levels were much higher in the geologic past. Our own Calvert Cliffs are marine sediments laid down approximately 15 Million years ago when our region was submerged under the ocean (when Earth had no Greenland ice and less Antarctic ice).

# Calvert Cliffs *Marine* Fossils



# Past Global Sea Level Variations Controlled by Ice Volume

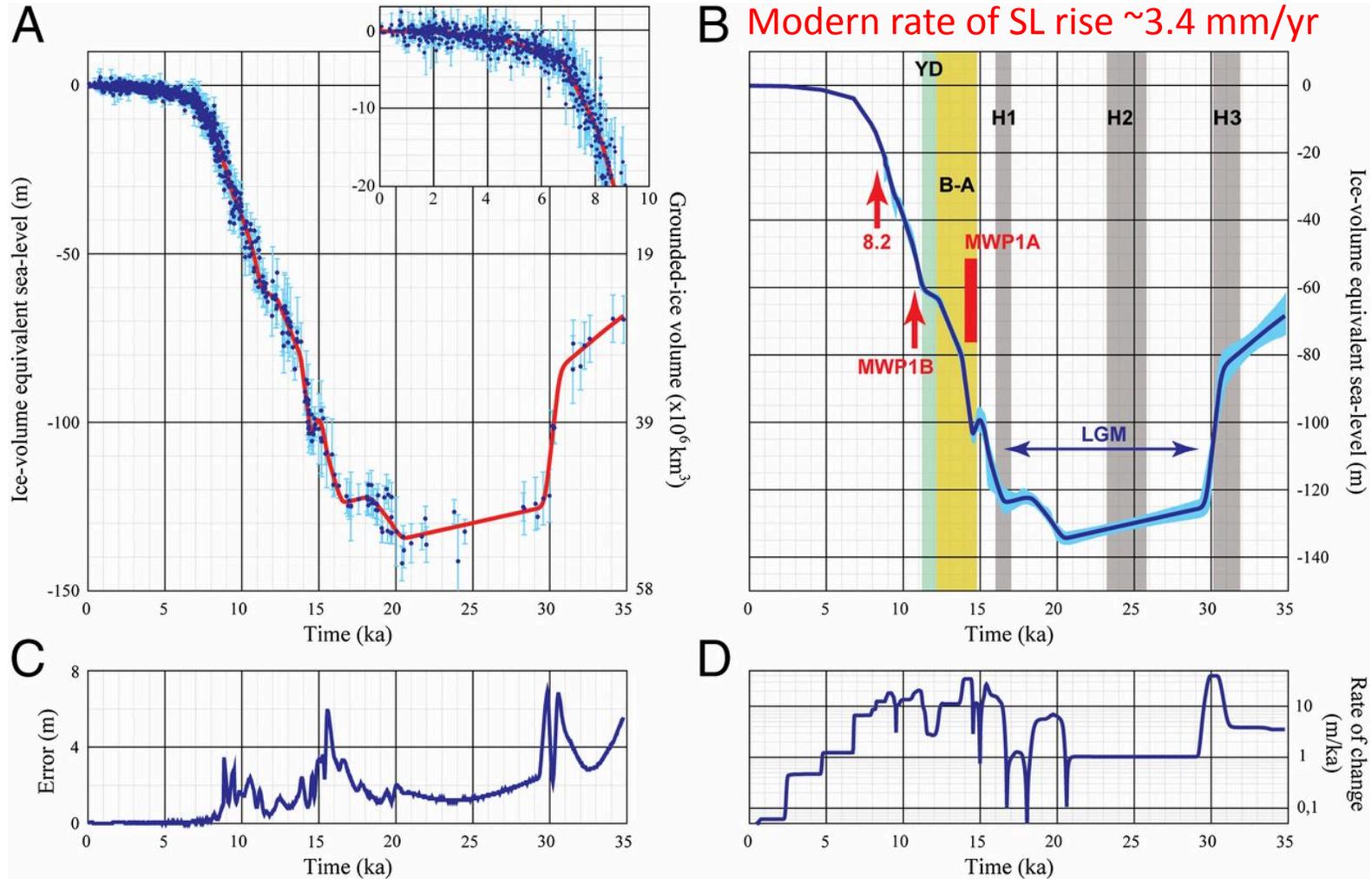


# Sea levels rose greater than 120 m when we came out of the last ice age

Average deglacial SL rise  $\sim 9.3$  mm/yr (17-4ka)

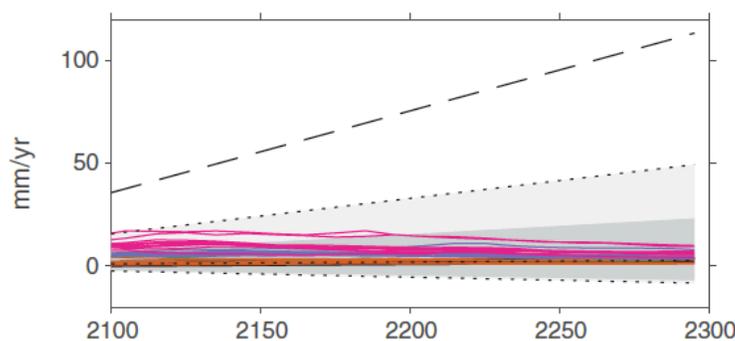
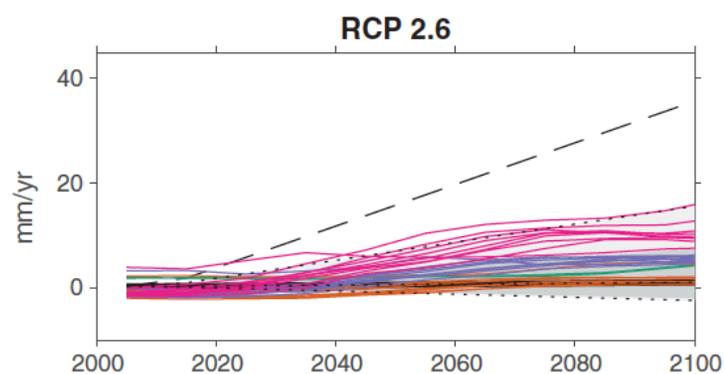
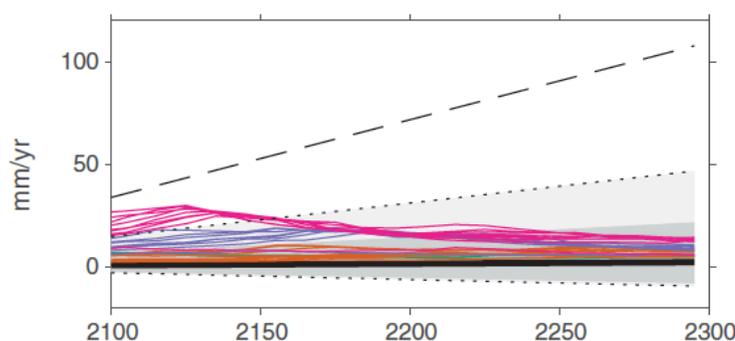
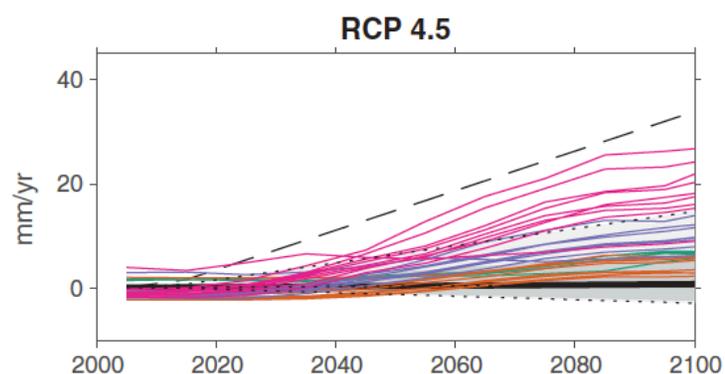
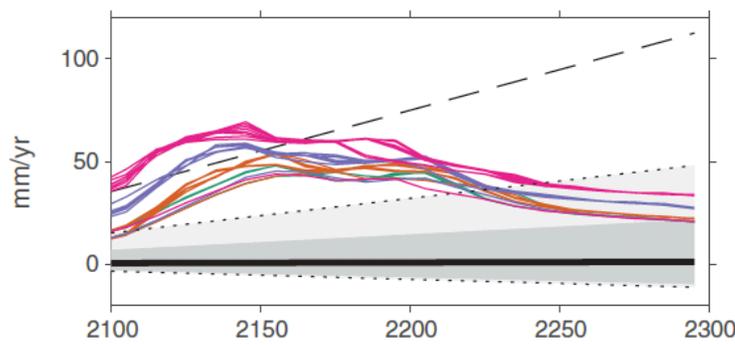
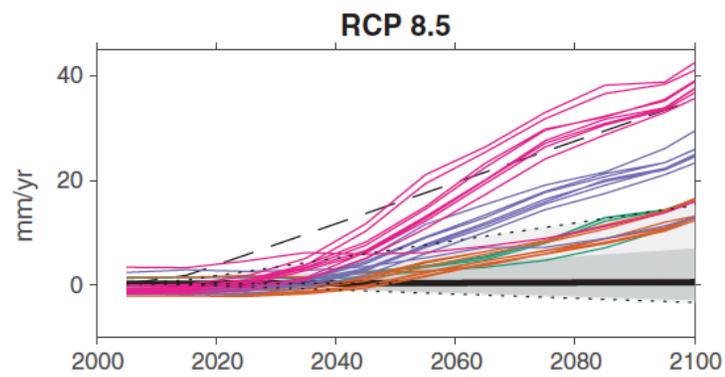
Max rate of SL rise  $\sim 40$  mm/yr (MWP1A)

Modern rate of SL rise  $\sim 3.4$  mm/yr



Kurt Lambeck et al. PNAS 2014;111:43:15296-15303

PNAS



Rates of sea level rise in the new projections are of similar order of magnitude as we saw during the last deglaciation

The warming today is much faster, but ice sheets can only melt so fast, so the estimated future rates are likely reasonable.

**Figure 1.** Rates of contribution of the Antarctic ice sheet to global-mean sea-level (GMSL) under three Representative Concentration Pathways (RCPs). Dark/light shaded areas represent 5–95th and 0.5th–99.5th percentile of K14. Dashed black line represents 99.9th percentile of K14. Colored curves are DP16 runs, with colors reflecting different maximum rates of ice-cliff collapse (VCLIF) (green: no ice cliff collapse; orange: 1 km/yr; purple: 3 km/yr; magenta: 5 km/yr). Left panels show 2000–2100, right panels show 2100–2300. Note change of horizontal and vertical scales.

# What does it mean for Calvert County?

- Best estimates of global future sea level for 2050 and 2100 are in the table below.
- Sea level in Calvert county will be slightly higher (on the order of a few 0.01-0.1m) because of the additional minor factors influencing sea level in the Mid-Atlantic
- Our current carbon trajectory is greater than RCP8.5, though if all parties follow through with the Paris Agreement, we might be able to keep between RCP4.5-2.6. Keeping to RCP2.6 is impossible unless we stop emissions today and/or start actively taking carbon out of the atmosphere.

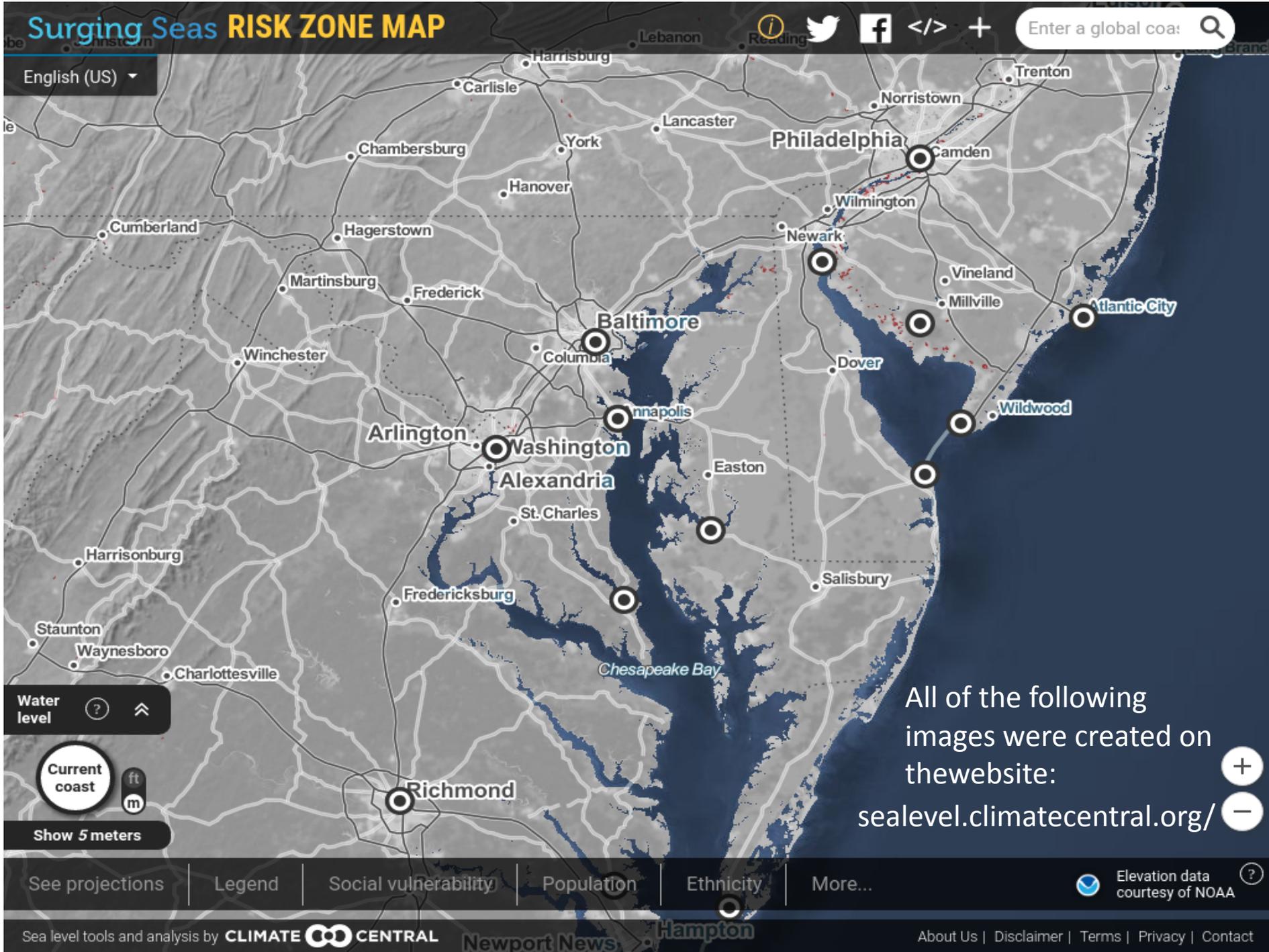
Our Scenario	2050 5-95%		Scenario	2100 5-95%	
	Sea Level Rise	Median		Sea Level Rise	Median
RCP 8.5	0.17-0.48 m	0.31 m	RCP 8.5	0.93- <b>2.43 m</b>	<b>1.46 m</b>
RCP 4.5	0.14-0.43 m	0.26 m	RCP 4.5	0.50-1.58 m	<b>0.91 m</b>
RCP 2.6	0.12-0.41 m	0.23 m	RCP 2.6	0.26-0.98 m	<b>0.56 m</b>
		(11-12inches)			(1.8-4.8ft)

Values in bold, rounded to 2.5, 1.5, 1.0, and 0.5 are used in the following maps

# Surging Seas RISK ZONE MAP

English (US) ▾

Enter a global coa:

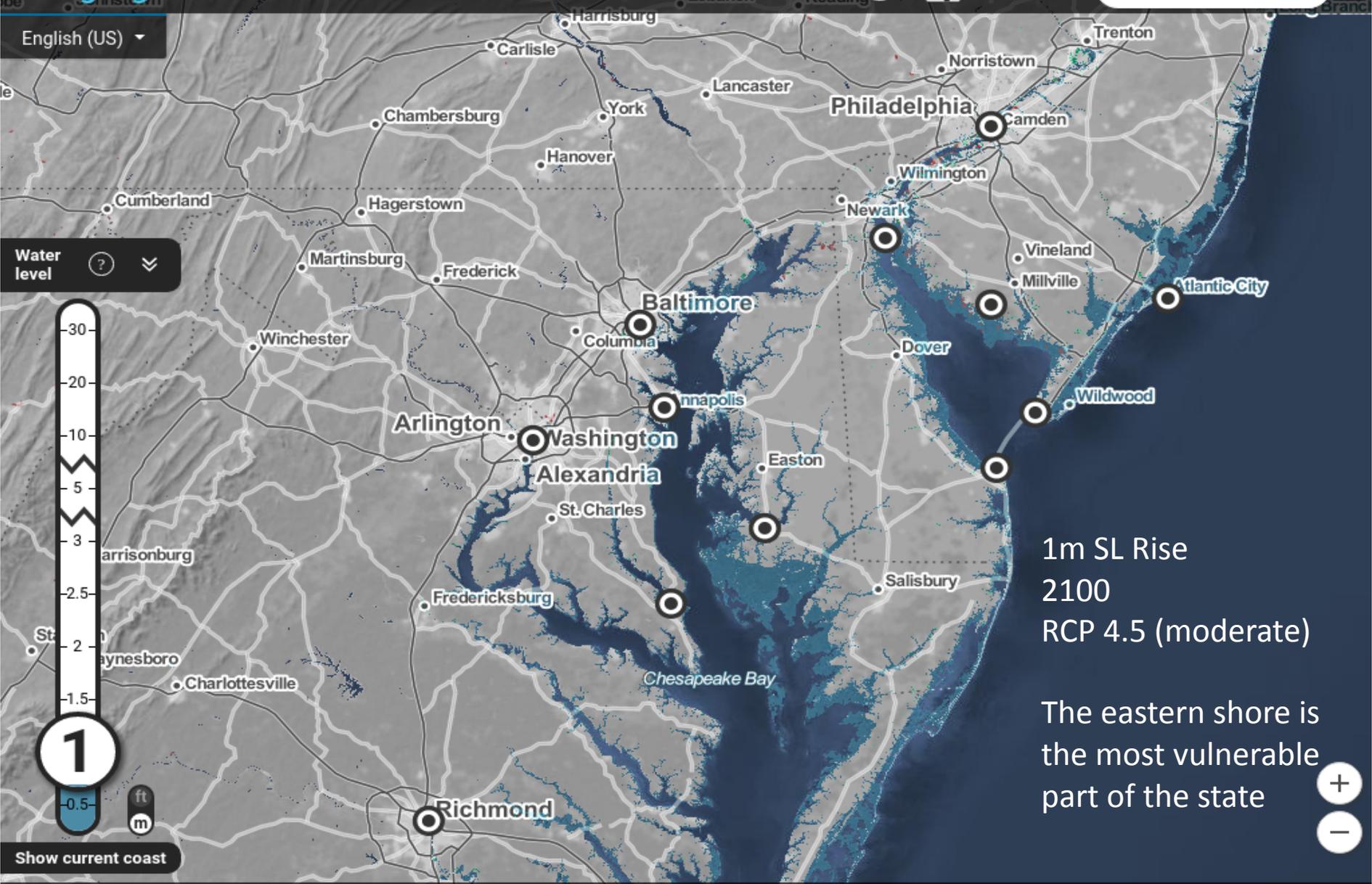


All of the following images were created on the website: [sealevel.climatecentral.org/](https://sealevel.climatecentral.org/)

# Surging Seas RISK ZONE MAP

English (US) ▾

Enter a global coa: 🔍



1m SL Rise  
2100  
RCP 4.5 (moderate)

The eastern shore is  
the most vulnerable  
part of the state

See projections

Legend

Social vulnerability

Population

Ethnicity

More...

Elevation data courtesy of NOAA

# Surging Seas RISK ZONE MAP

Enter a global coa:

[i](#) [Twitter](#) [Facebook](#) [Code](#) [+](#)

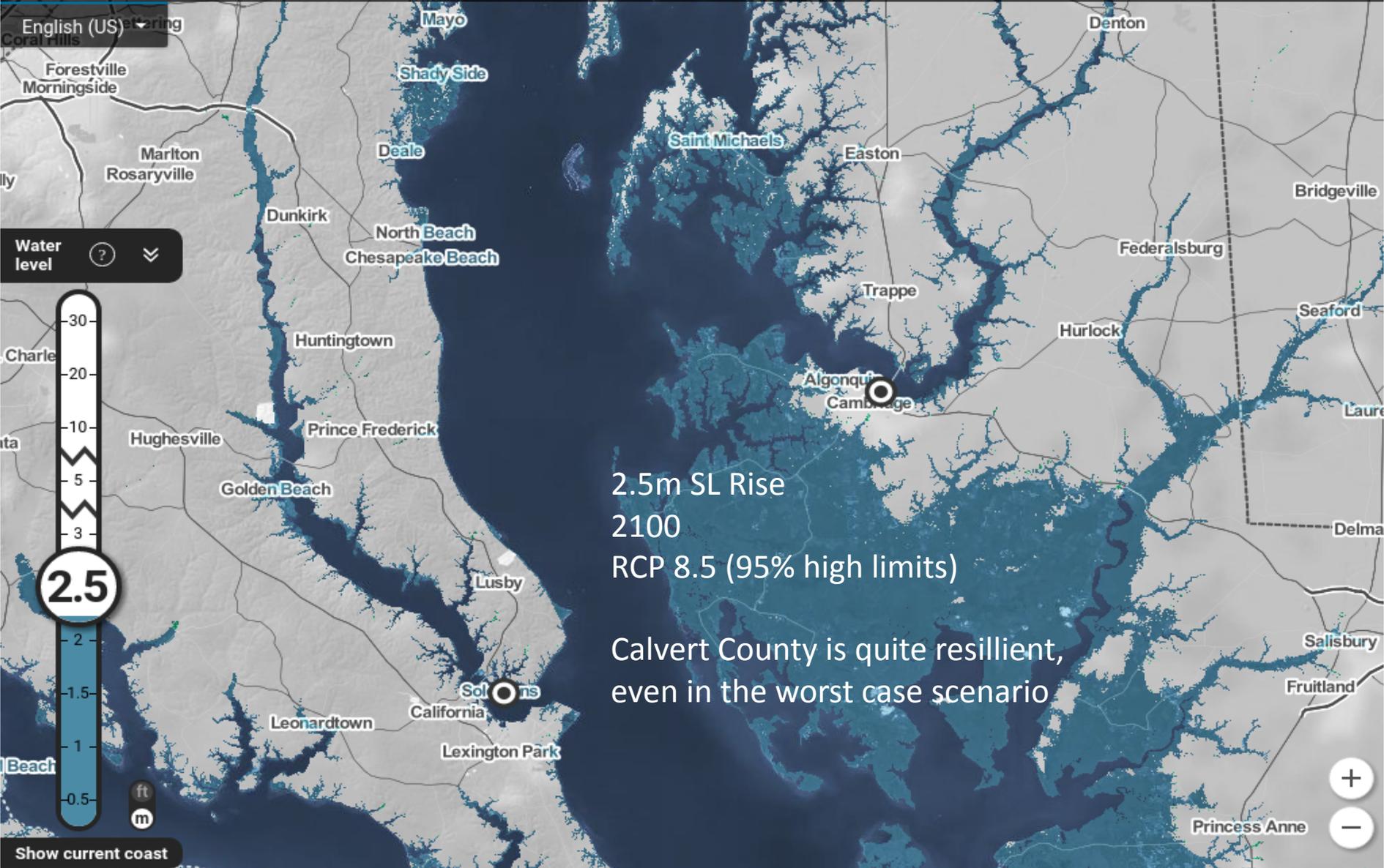


[See projections](#) | [Legend](#) | [Social vulnerability](#) | [Population](#) | [Ethnicity](#) | [More...](#) | [Elevation data courtesy of NOAA](#)

# Surging Seas RISK ZONE MAP

Enter a global coa:

[i](#) [Twitter](#) [Facebook](#) [Code](#) [+](#)



# Surging Seas RISK ZONE MAP



Enter a global coa:

English (US) ▾

Island Creek

Broomes Island Road

A few low-lying areas are still vulnerable and are already identified in the county Flood Plan.

Water level ? ⤴

Current coast

ft

m

Show 5 meters



[See projections](#)

[Legend](#)

[Social vulnerability](#)

[Population](#)

[Ethnicity](#)

[More...](#)



Elevation data courtesy of NOAA ?

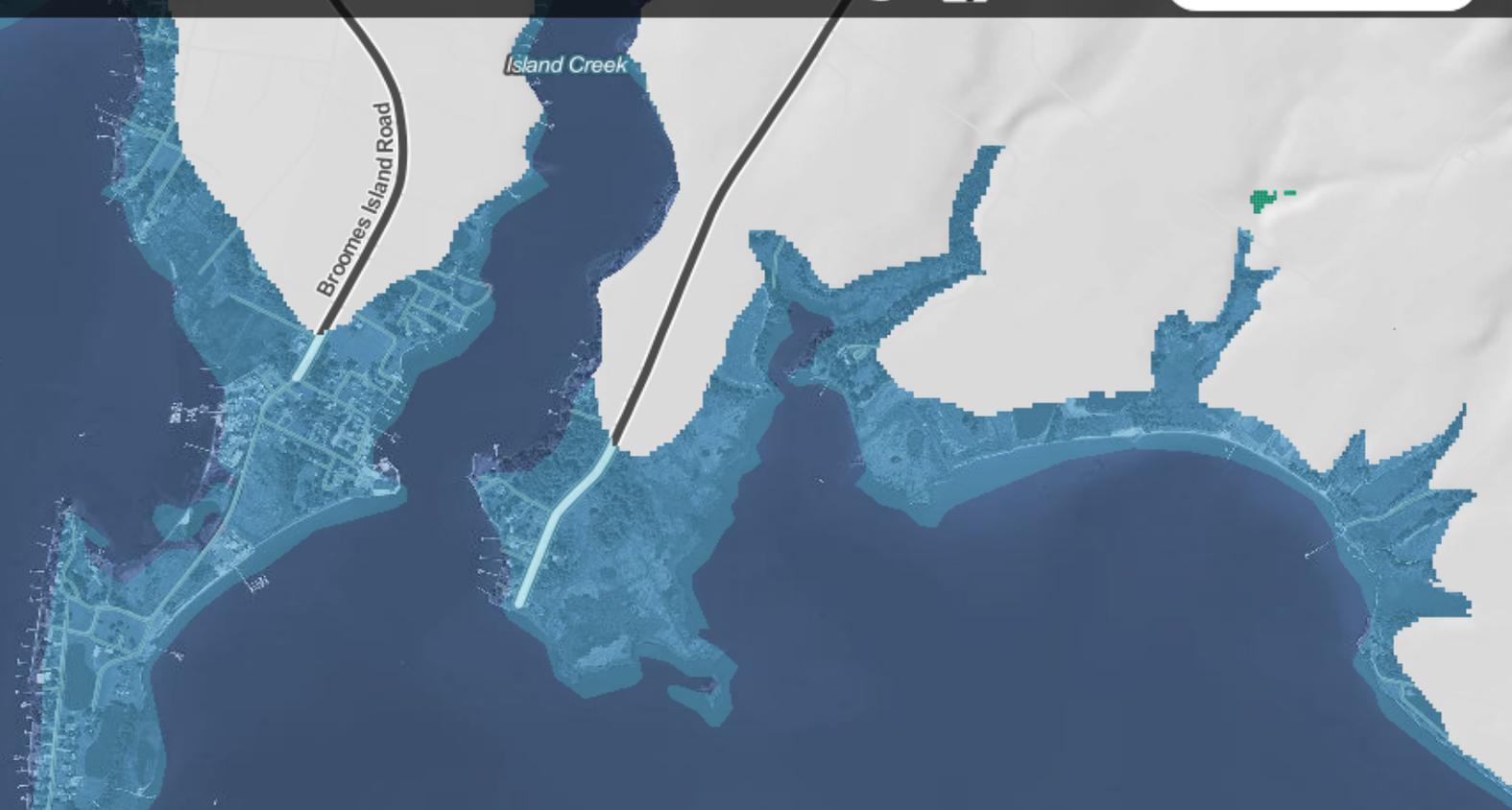
# Surging Seas RISK ZONE MAP

English (US) ▾

Water level ? ▾



Show current coast

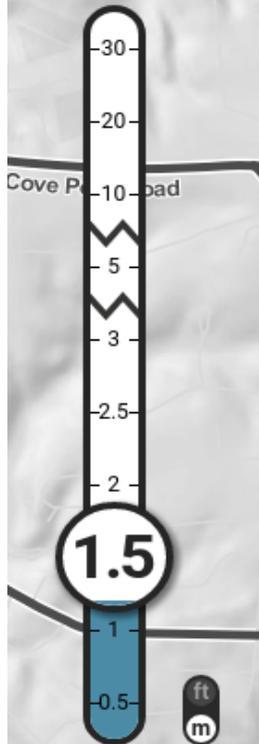


Significant flooding of land occurs at 1m of sea level rise, approximately the median estimate of RCP 4.5 in 2100. People born today on Broomes Island will likely not be able to live there at the end of their life. (1.5 m SL rise is illustrated because of technical difficulties with the 1.0m illustration)

# Surging Seas RISK ZONE MAP

English (US) ▾

Water level [?](#) ▾



Show current coast

[See projections](#) | [Legend](#) | [Social vulnerability](#) | [Population](#) | [Ethnicity](#) | [More...](#)

Elevation data courtesy of NOAA [?](#)

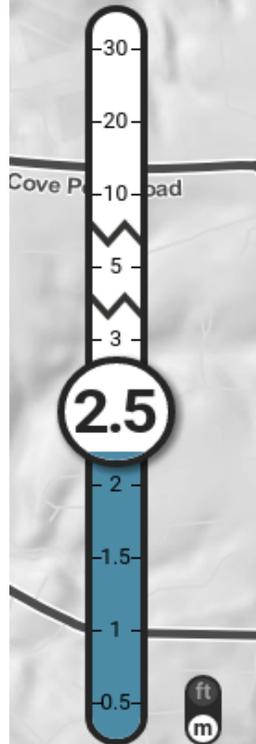
# Surging Seas RISK ZONE MAP



Enter a global coa:

English (US) ▾

Water level ? ▾



Show current coast

[See projections](#)

[Legend](#)

[Social vulnerability](#)

[Population](#)

[Ethnicity](#)

[More...](#)



Elevation data courtesy of NOAA ?

# Surging Seas RISK ZONE MAP

Enter a global coa:

English (US) ▾



Water level ? >>

Current coast  
ft  
m

Show 5 meters

See projections

Legend

Social vulnerability

Population

Ethnicity

More...

Elevation data courtesy of NOAA ?

# Surging Seas RISK ZONE MAP

English (US) ▾

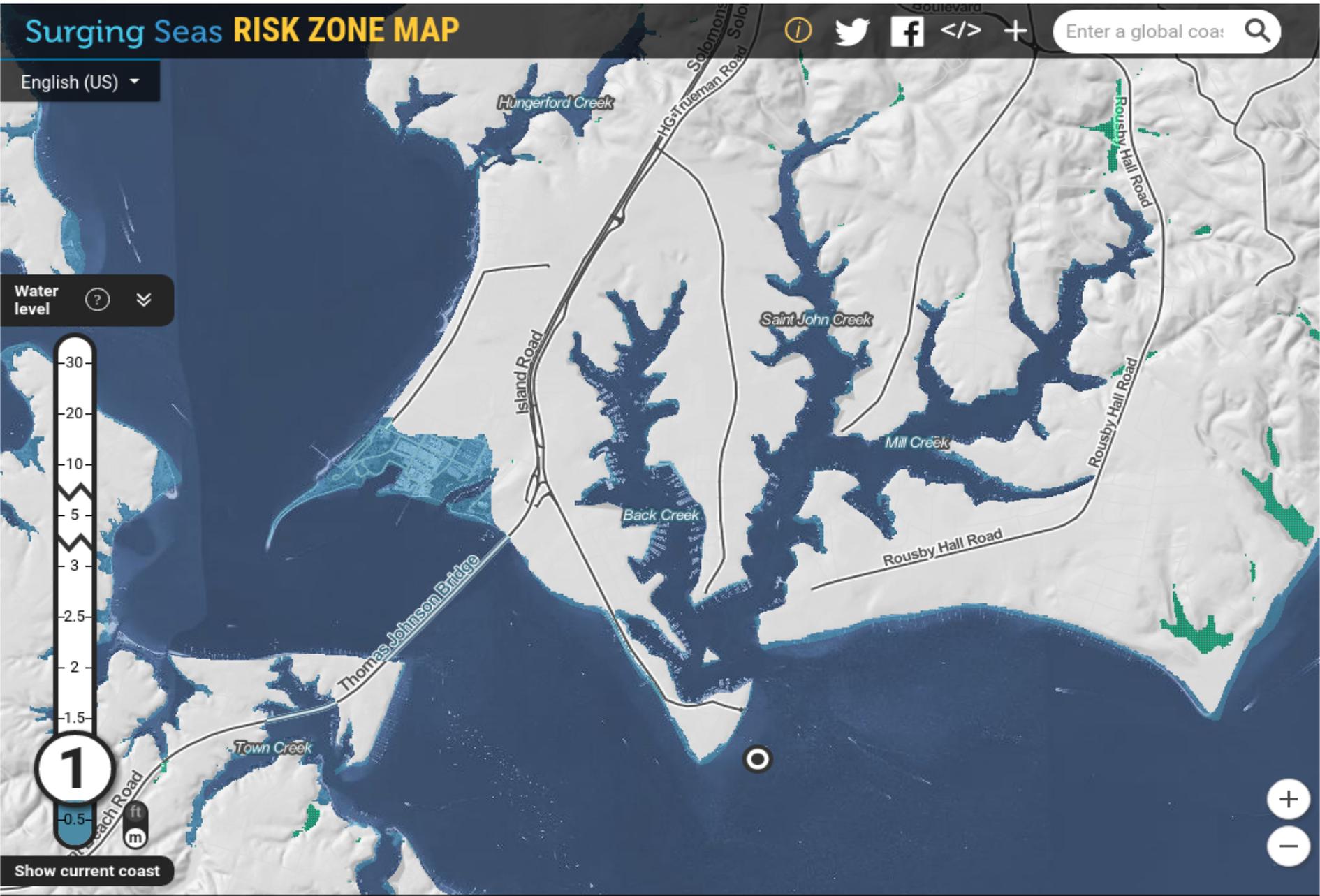
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Water level ? ▾



Show current coast

[See projections](#) | [Legend](#) | [Social vulnerability](#) | [Population](#) | [Ethnicity](#) | [More...](#) | [Elevation data courtesy of NOAA](#) ?



# Surging Seas RISK ZONE MAP

English (US) ▾

[i](#) [Twitter](#) [Facebook](#) [Code](#) [+](#)  [Q](#)

Water level ? ▾



Show current coast

I know that the road by the Tiki Bar on Solomons island floods today at extreme tides, it will not last 1.5 m of sea level rise as indicated by the map. Higher resolution elevation maps are available and should be used for planning.

- See projections
- Legend
- Social vulnerability
- Population
- Ethnicity
- More...

Elevation data courtesy of NOAA ?

# Surging Seas RISK ZONE MAP

English (US) ▾

     Enter a global coa:

Water level  ▾

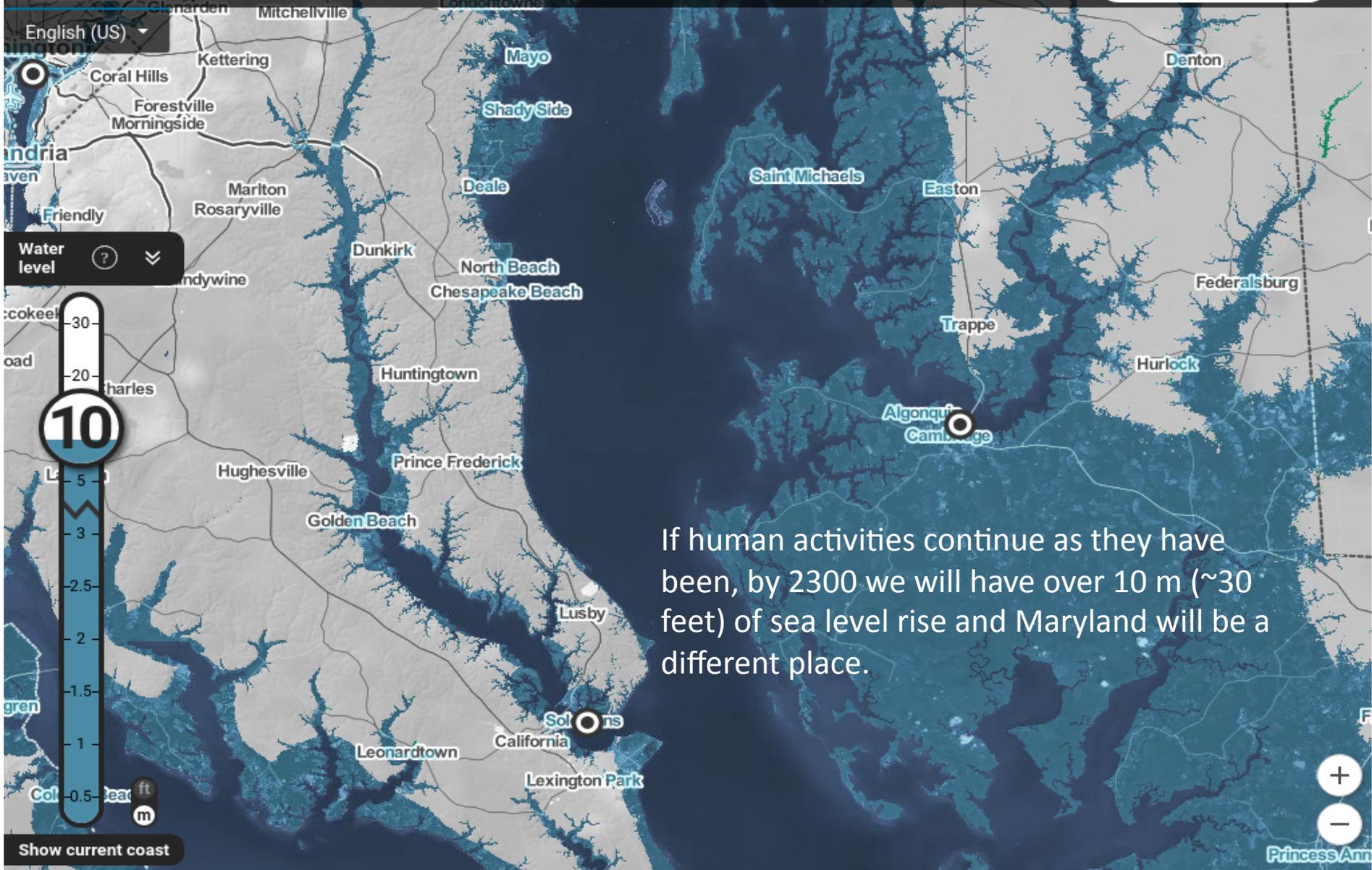


Show current coast

- See projections
- Legend
-  Social vulnerability
- Population
- Ethnicity
- More...

 Elevation data courtesy of NOAA 

# Surging Seas RISK ZONE MAP



If human activities continue as they have been, by 2300 we will have over 10 m (~30 feet) of sea level rise and Maryland will be a different place.