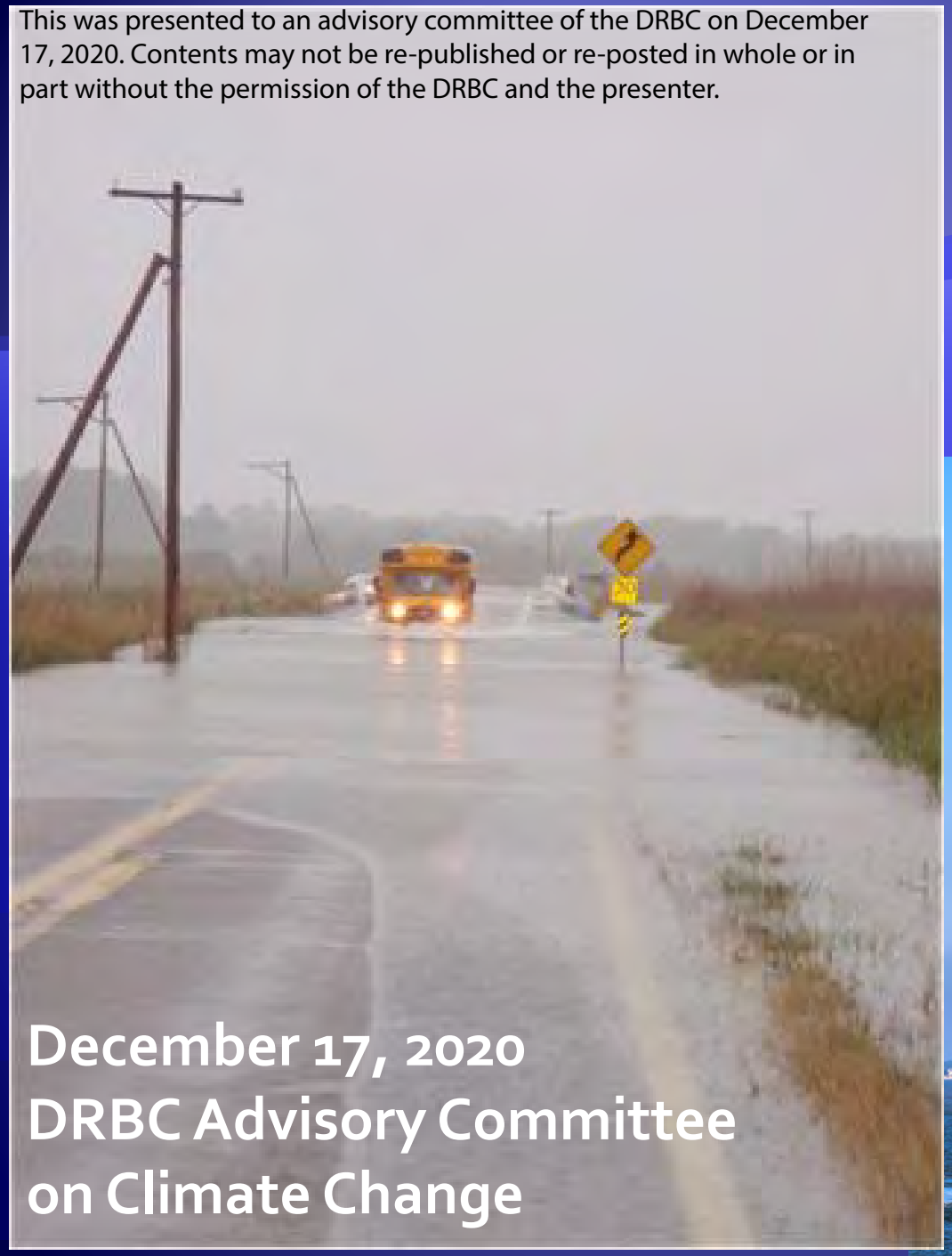


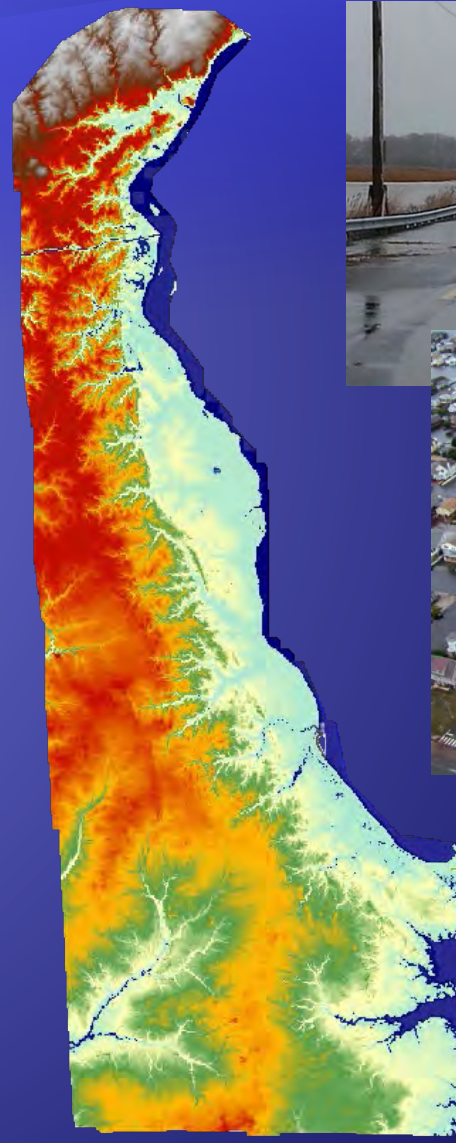
DETERMINING FUTURE SLR PLANNING SCENARIOS FOR DELAWARE

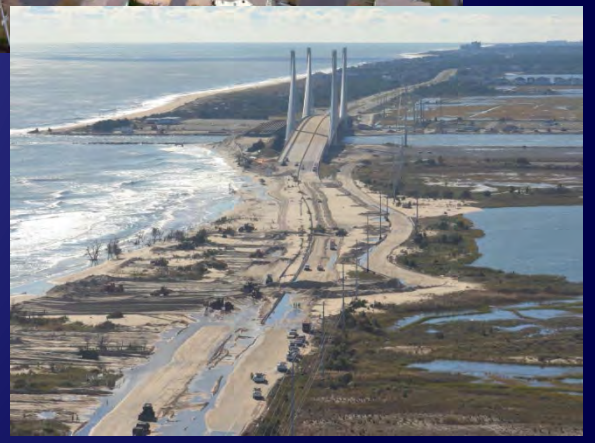
John A. Callahan
Delaware Geological Survey
University of Delaware

December 17, 2020
DRBC Advisory Committee
on Climate Change

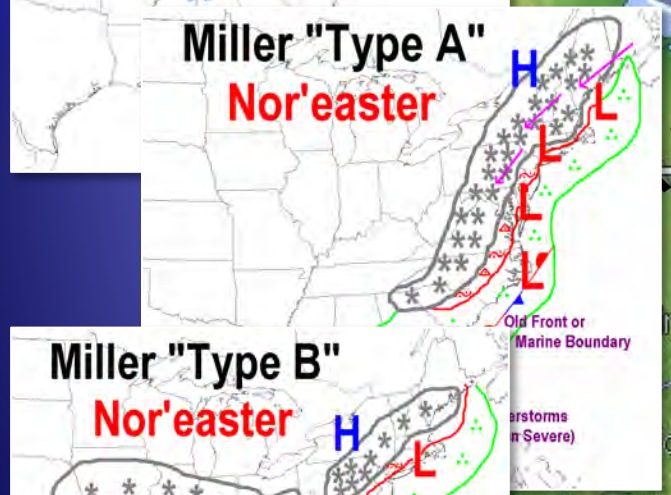
Delaware is vulnerable to coastal storms

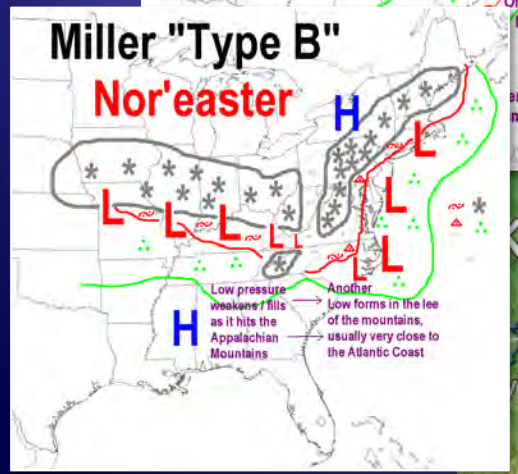
- Low, flat topography
- Large fetch of bay/ocean
- Coastal-based public infrastructure and economy (recreation, aquaculture, beach-driven tourism)

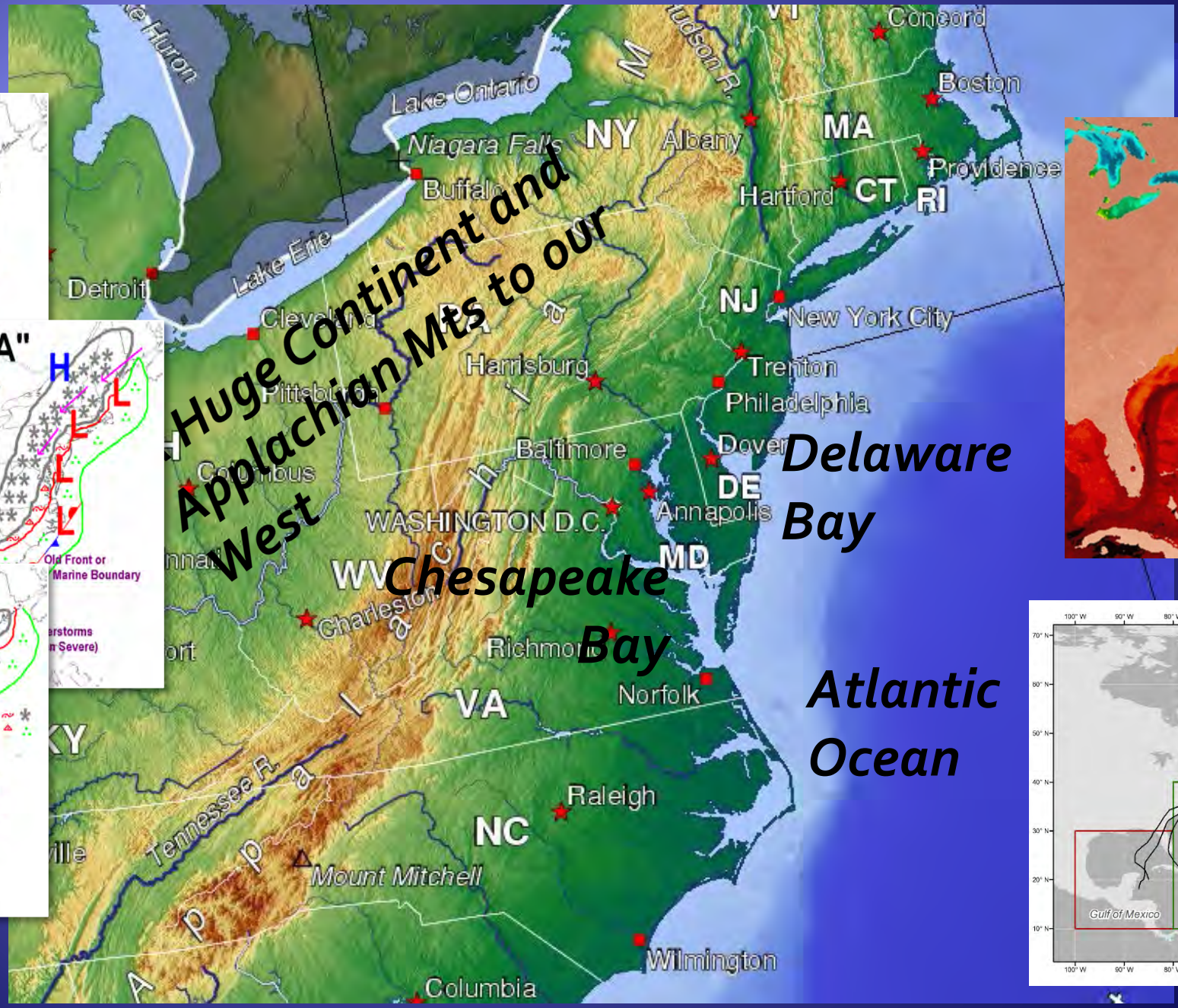


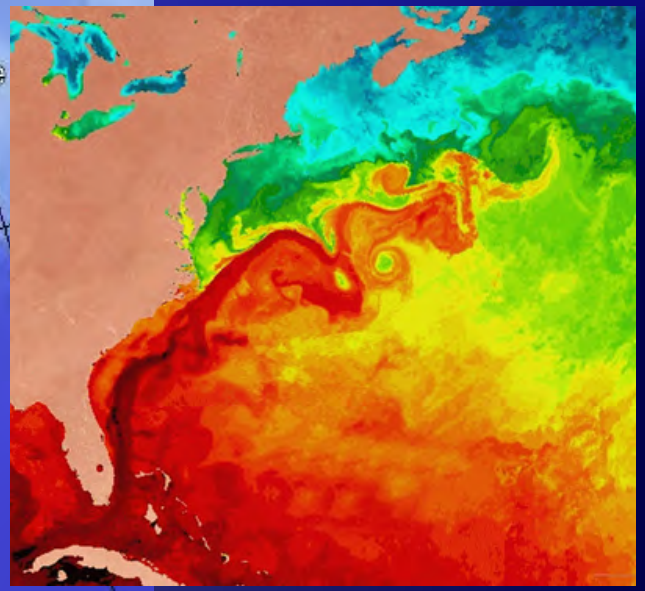


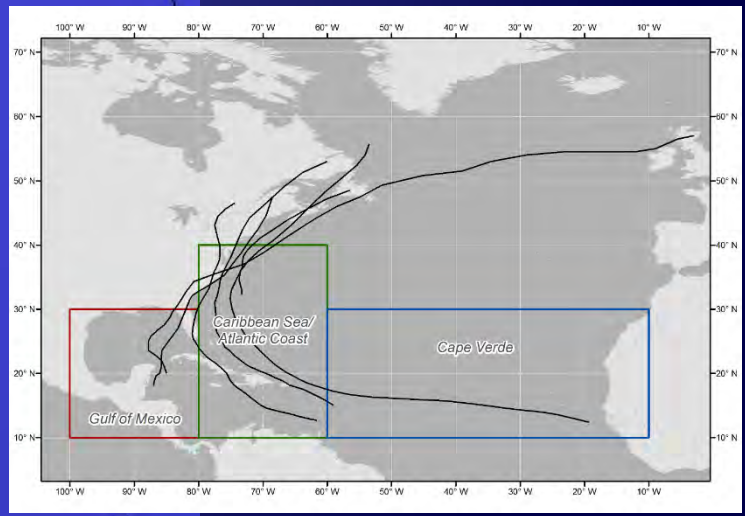
Our region's complicated climate system….

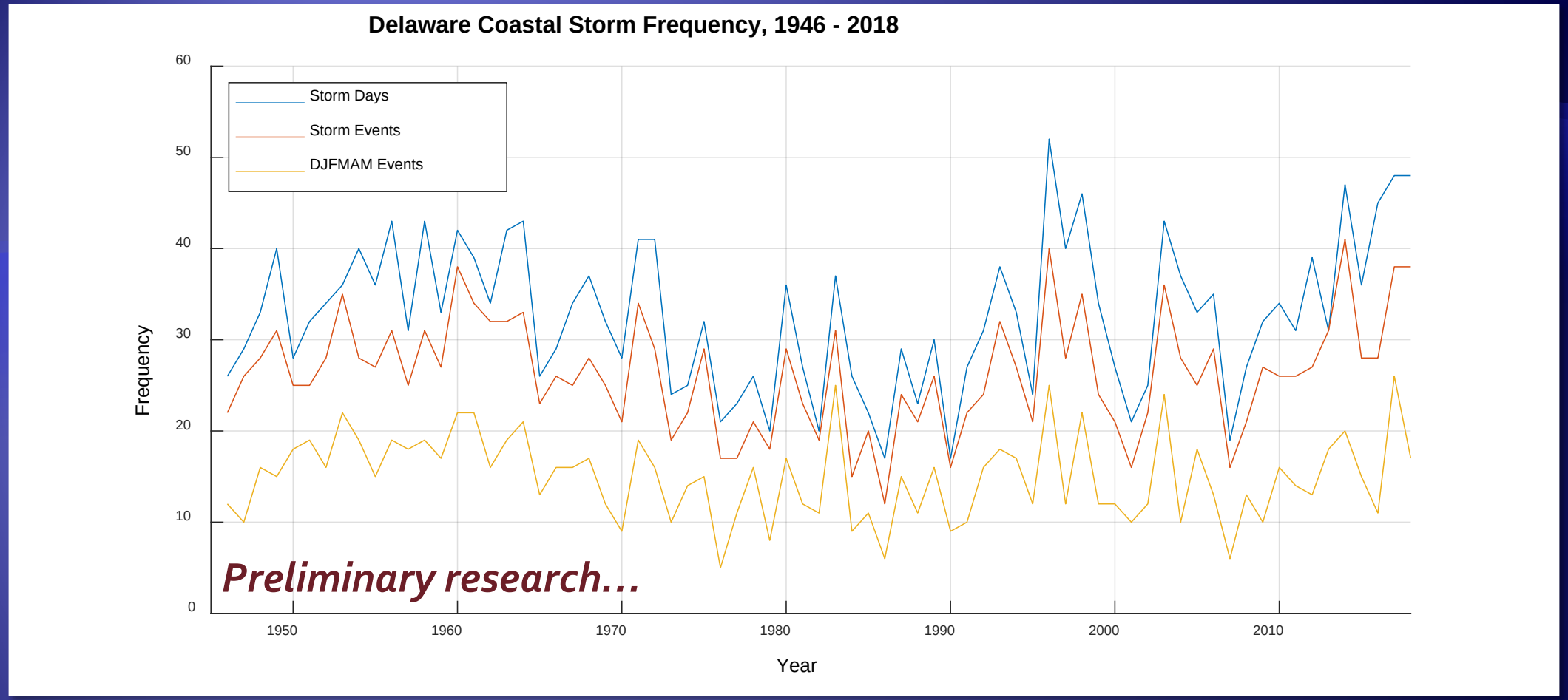










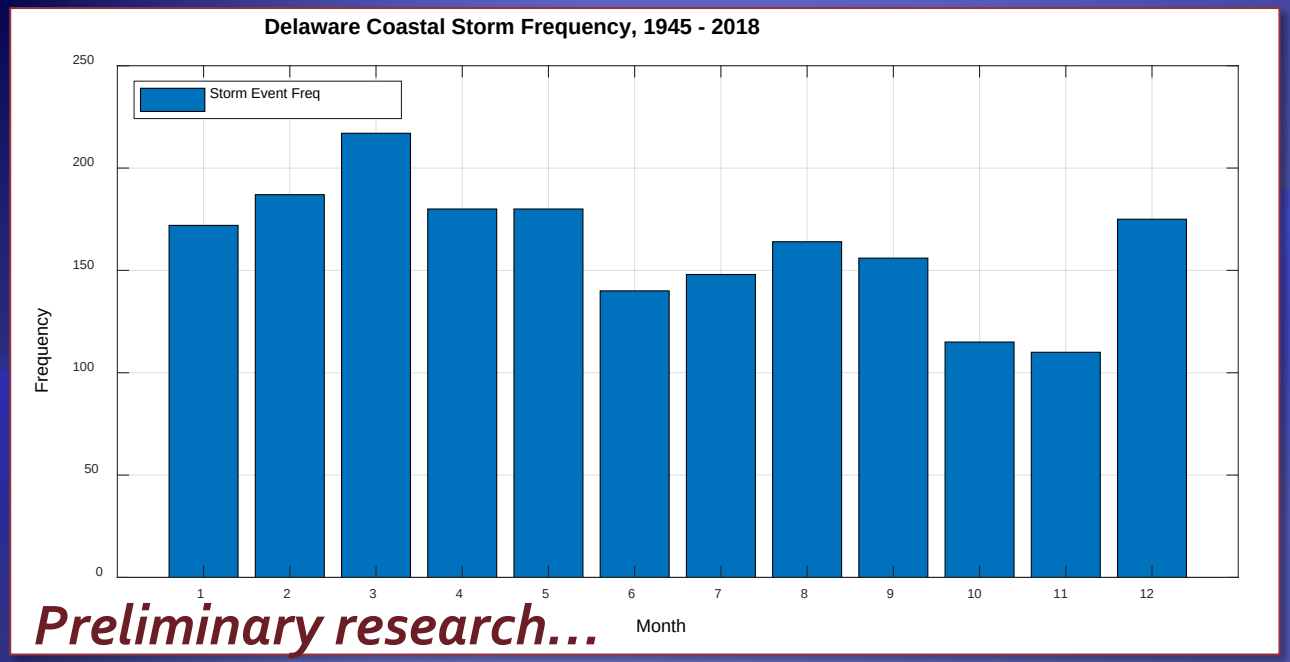


CEMA

http://cema.udel.edu/

Delaware is impacted quite often by coastal storms
33 days, 26 events, 15 Dec-May events per year

"Storm" defined by closed low-pressure center off coast of Lewes, DE.



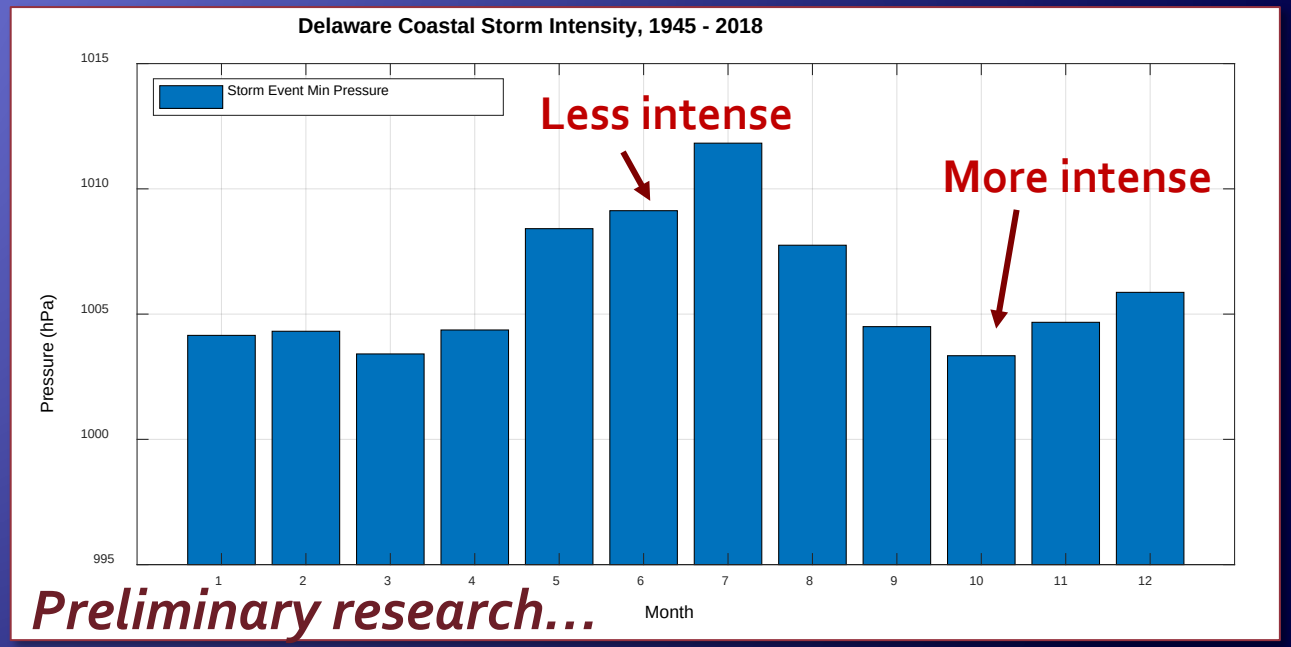
Preliminary research…

Storm frequency

- Winter/spring (mid-lat cyclones)
- Late summer/fall (tropical)

Storm intensity

- Less intense May-Aug
- More intense Oct-Apr

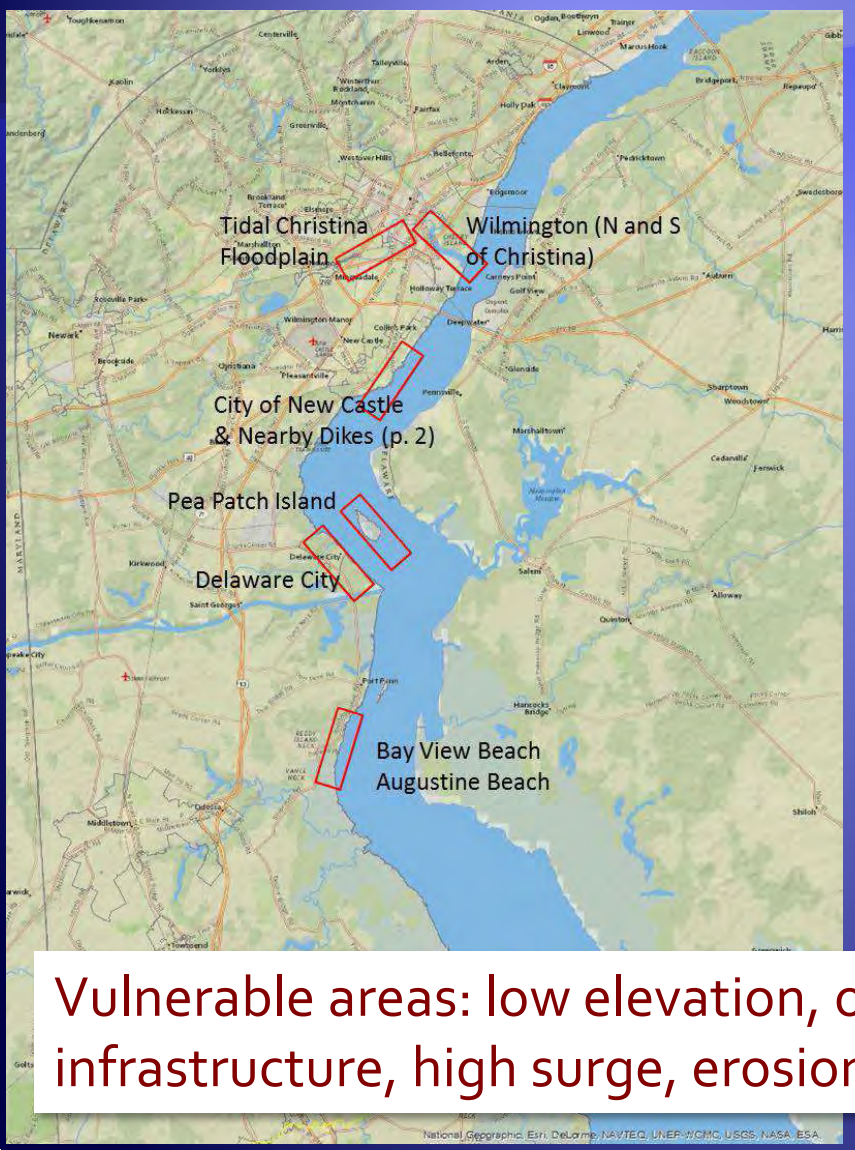


Preliminary research…

CEMA

http://cema.udel.edu/

USACE Delaware Inland Bays and Delaware Bay Reconnaissance Study, Focus Area of the North Atlantic Coastal Comprehensive Study (2015)



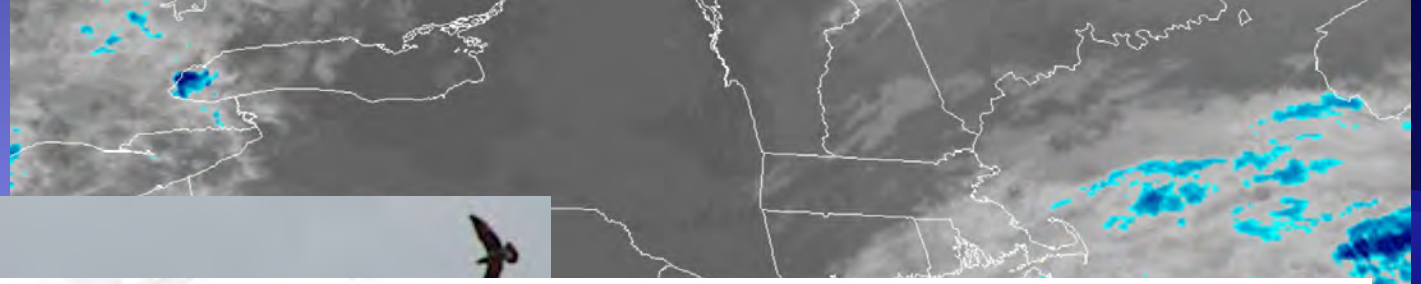
Vulnerable areas: low elevation, overtopped dikes, exposed infrastructure, high surge, erosion, limited dunes/berm protection

SLR Impacts on Delaware

1. Long-term, gradual impacts:
   - High tide flooding frequency
   - Loss of low-lying ag fields, forests/wetlands
   - Saltwater intrusion into groundwater
2. Short-term, episodic impacts:
   - Damage to property from surge flooding
   - Rapid erosion, beach sand loss, dune breaches
3. Economic and societal (indirect) impacts through tourism, real estate, social services, safety

SLR enhances the risk potential…

http://www.dgs.udel.edu/slr



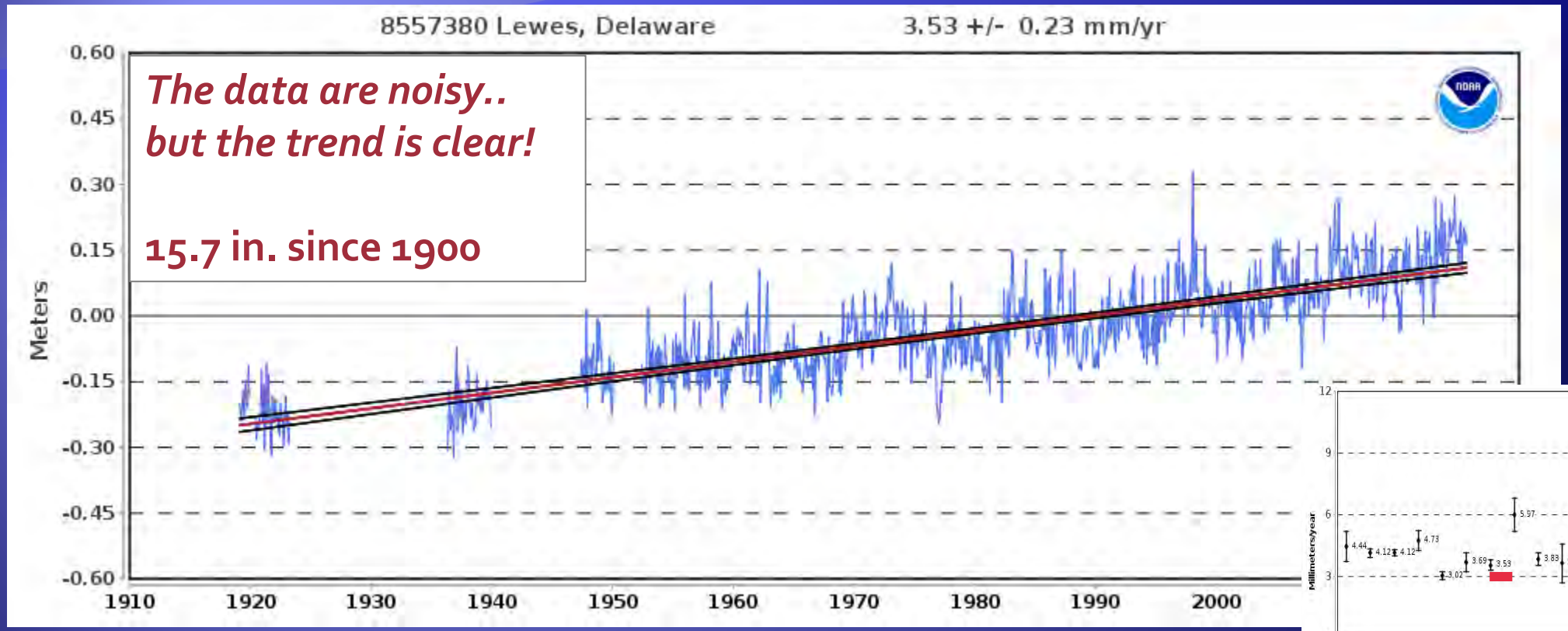
Overall Risk Ranking for the State of Delaware by County and Statewide

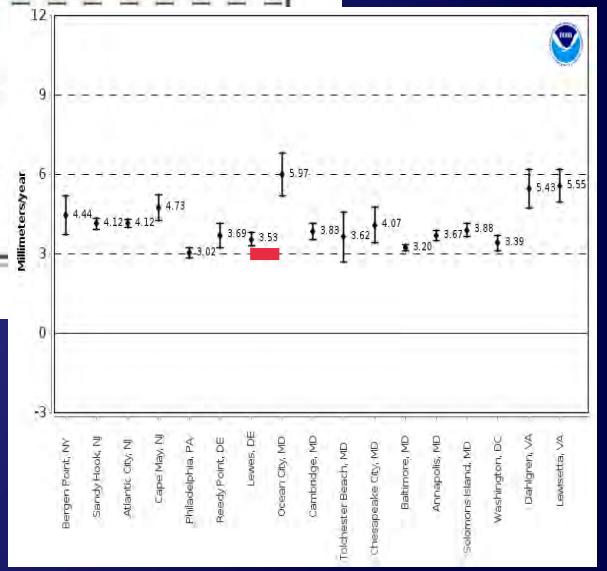
Hazard Ranking	Kent County	New Castle County	Sussex County	Statewide
1	Flood	Flood	Flood	Coastal Flooding
2	Drought	Coastal Wind	Thunderstorm	Nor'easters & ET Storms
3	Coastal Wind	Winter Storm	Hurricane Wind	Huricanes & Tropical Storms
4	Earthquake	Thunderstorm	Extreme Heat/Cold	Winter Precipitation
5	Winter Storm	Tornado	Drought	Coastal Erosion
6	Thunderstorm	Earthquake	Winter Storms	Inland Flooding
7	Tornado	Drought	HazMat Incident	Severe Thunderstorms
8	Hail	Hail	Tornado	Extreme Heat
9	Extreme Heat/Cold		Hail	Extreme Cold
10	Wildfire		Tsunami	Tornadoes

Delaware Emergency Management Agency (DEMA)


Exposure to Surging Seas
Population less than 4 ft above the rising tide
CA
VA
NY
CT
FL
Florida
- 2.4 million
NC
MA
TX
NJ
Louisiana
SC
GA
MS
CLIMATE CENTRAL
© Climate Central

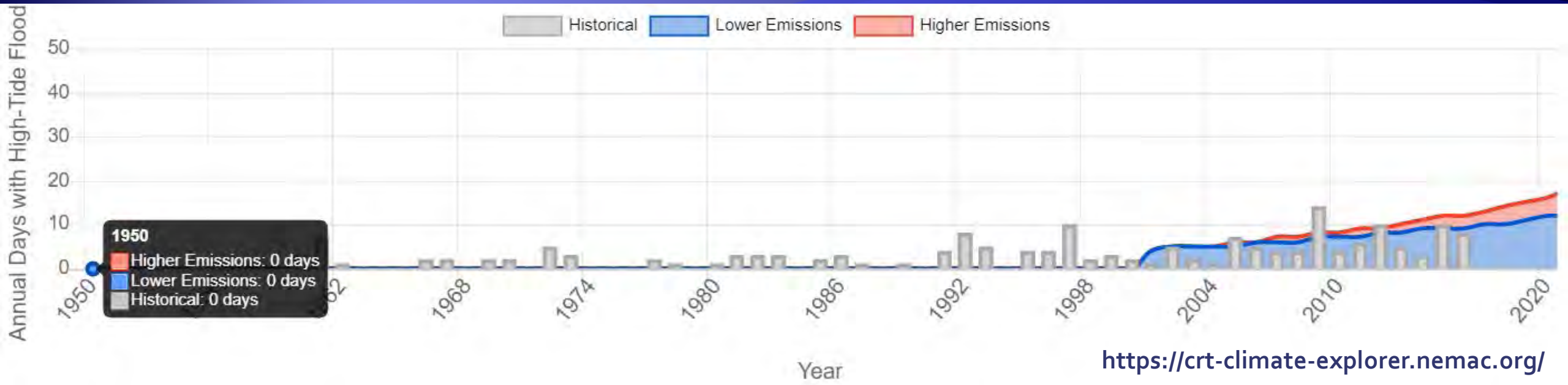
What have we seen in Delaware?





https://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?id=8557380

Coastal Flood Frequency



https://crt-climate-explorer.nemac.org/

What have we done in Delaware?

Hazards

Climate

Sea-Level Rise

Delaware Executive Order 41 (Sep 2013)

- *Delaware State Agencies…to address the causes and consequences of climate change*
- *Including …to avoid and minimize flood risks due to sea-level rise*

STATE OF DELAWARE

EXECUTIVE DEPARTMENT
DOVER

EXECUTIVE ORDER
NUMBER FORTY-ONE

TO: HEADS OF ALL STATE DEPARTMENTS AND AGENCIES

RE: PREPARING DELAWARE FOR EMERGING CLIMATE IMPACTS AND SEIZING ECONOMIC OPPORTUNITIES FROM REDUCING EMISSIONS

WHEREAS, burning fossil fuels causes the release of heat-trapping greenhouse gases that contribute to a changing climate, which presents both economic opportunities for new jobs and industries, as well as challenges to protecting public health and safety, supporting a vibrant economy, and conserving natural resources; and

WHEREAS, Delaware's greenhouse gas emissions have decreased by more than any state in the nation (29.7% from 2000 to 2010) and recent investments to modernize our energy system and efforts by several of Delaware's major employers and institutions of higher learning will result in significant additional reduction, however more must be done; and

WHEREAS, initiatives to responsibly reduce greenhouse gas emissions and prepare Delaware for climate impacts present significant economic development and employment opportunities in infrastructure construction, energy efficiency, clean energy, and advanced transportation; and

WHEREAS, as a low-lying coastal state with the lowest average land elevation in the United States and significant population living along 381 miles of shoreline, Delaware is vulnerable to coastal erosion, storm surge, flooding, saltwater intrusion, and tidal wetland losses, all of which will be exacerbated by sea-level rise; and

WHEREAS, Delaware's critical infrastructure, including roads, bridges, dams, dikes, impoundments, energy distribution systems, emergency services, outdoor recreation facilities, drinking water and wastewater treatment facilities, industrial sites, and landfills are at-risk to climate change impacts; and

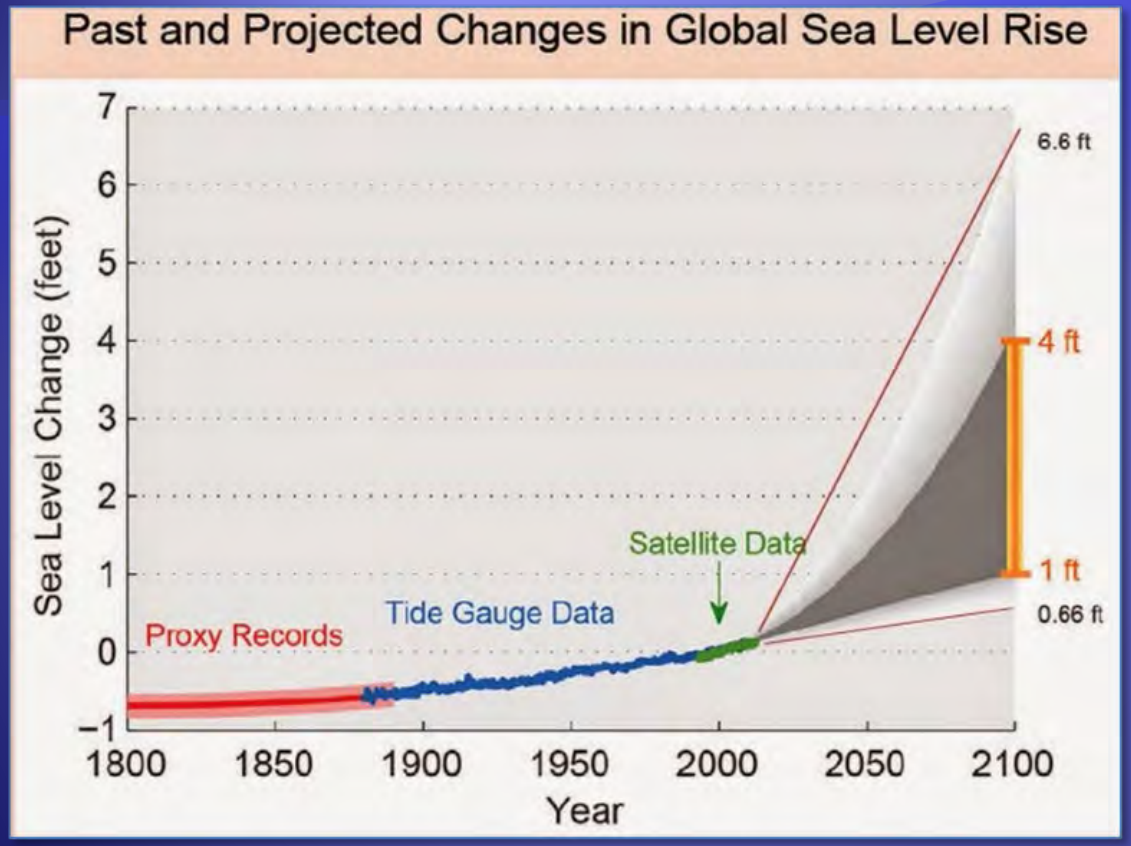
WHEREAS, Delaware's Bayshore and Inland Bays communities have experienced saltwater intrusion into drinking water supplies and irrigation systems, and climate impacts could negatively affect the availability and reliability of the groundwater aquifers that provide water to many municipalities, residents, and farmers; and

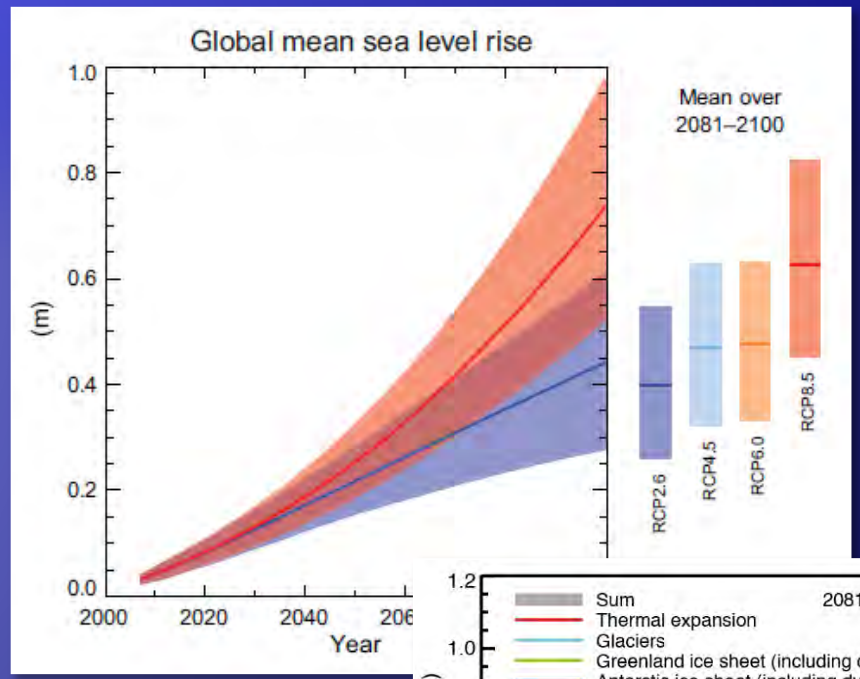
Delaware SLR Technical Committee - 2017

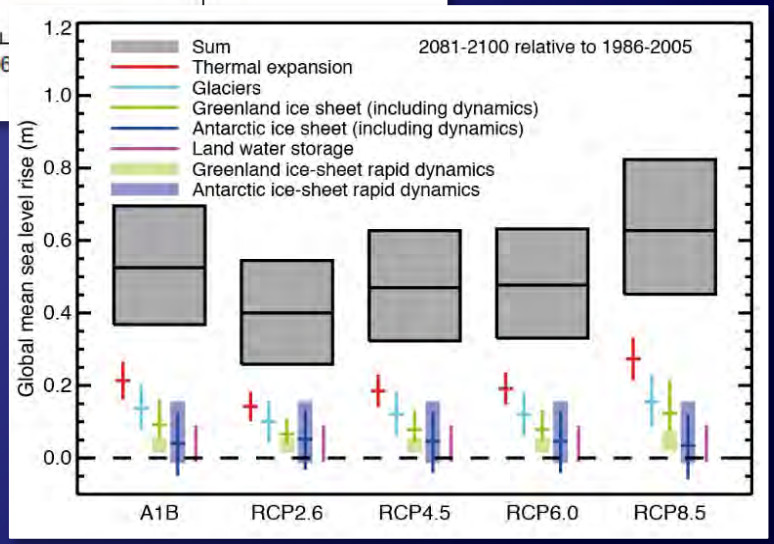
- 13 members, scientists and planners
- DNREC Delaware Coastal Programs sponsored
- Delaware Geological Survey-led committee
- Task: To update future SLR projections for Delaware to be used in planning activities.

What did we look at?

Global SLR Projections – NCA3 and IPCC AR5

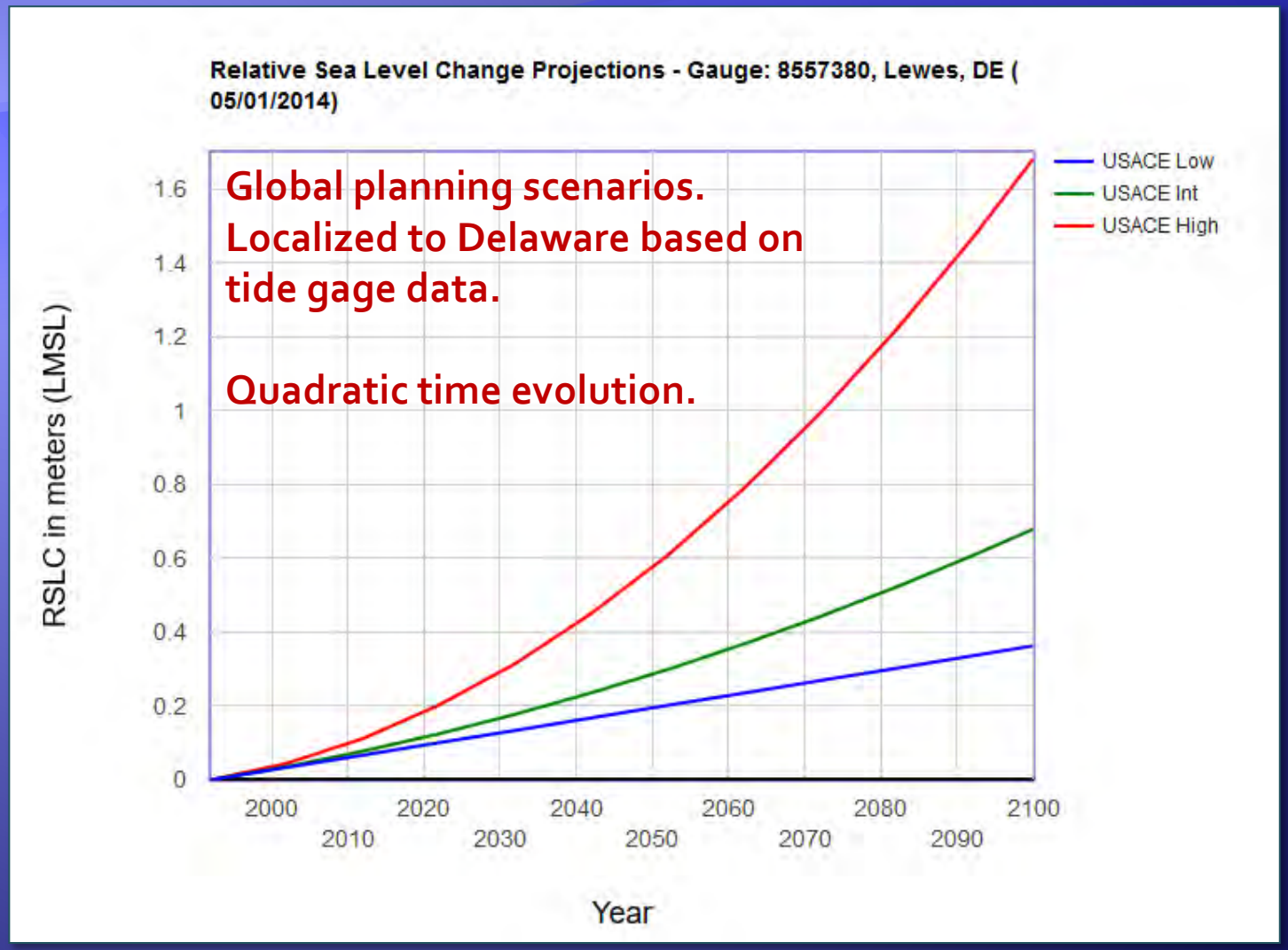






Planning Scenario vs Process-Model
Need to be localized to Delaware!

Global + Local SLR Projections – USACE



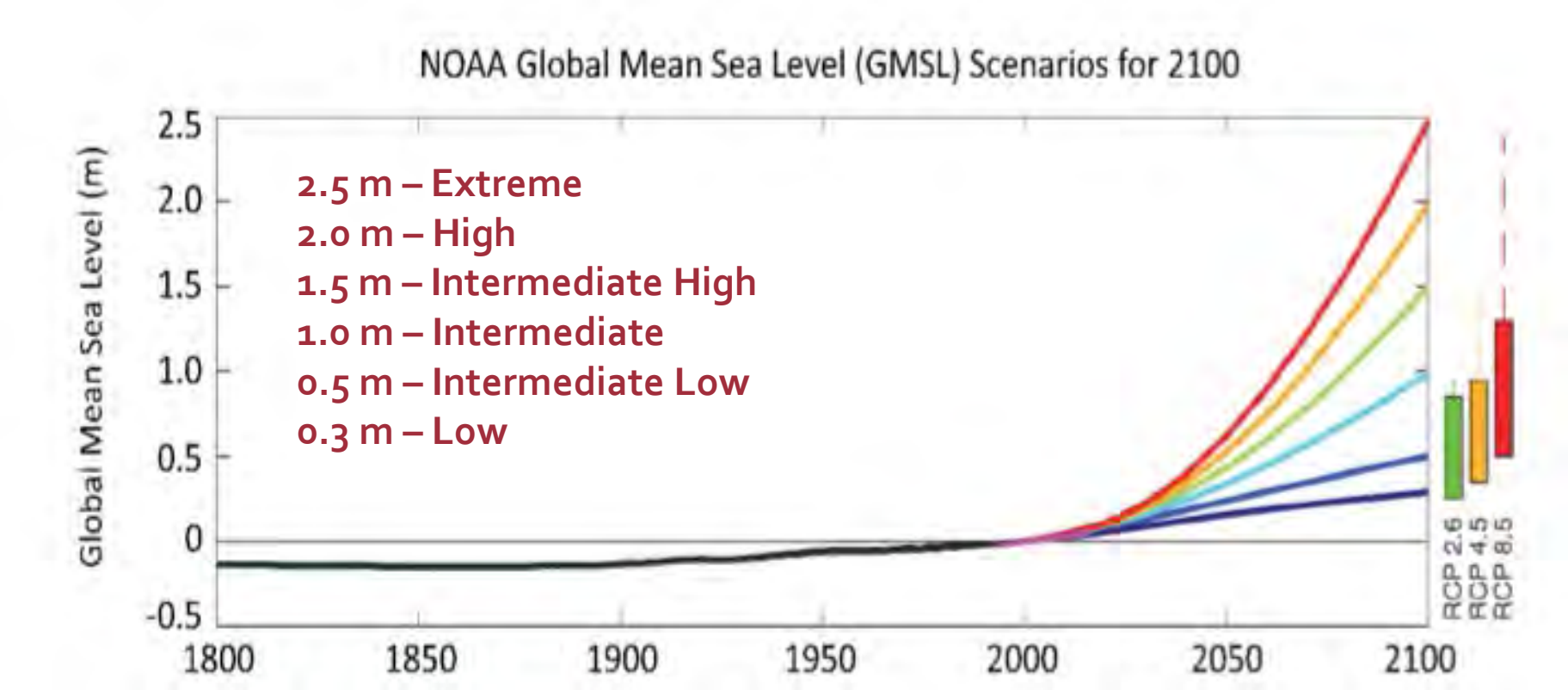
SLR Projections – Semi-empirical models

- Statistical relationship between global temperature (or associated forcing) and global sea levels.

$$\frac{d}{dt}H(t) = a\,(T(t) - T0) + b\frac{d}{dt}T(t),$$

Maybe simple relationship is best in a complex system?

NOAA Global SLR Planning Scenarios



Scenario-driven (realistic range, no probabilities)

NOAA Tech Report 083 (Sweet et al., 2017)
Global and Regional SLR Scenarios for the U.S.

Delaware 2017 SLR Scenarios – Kopp et al (2014)

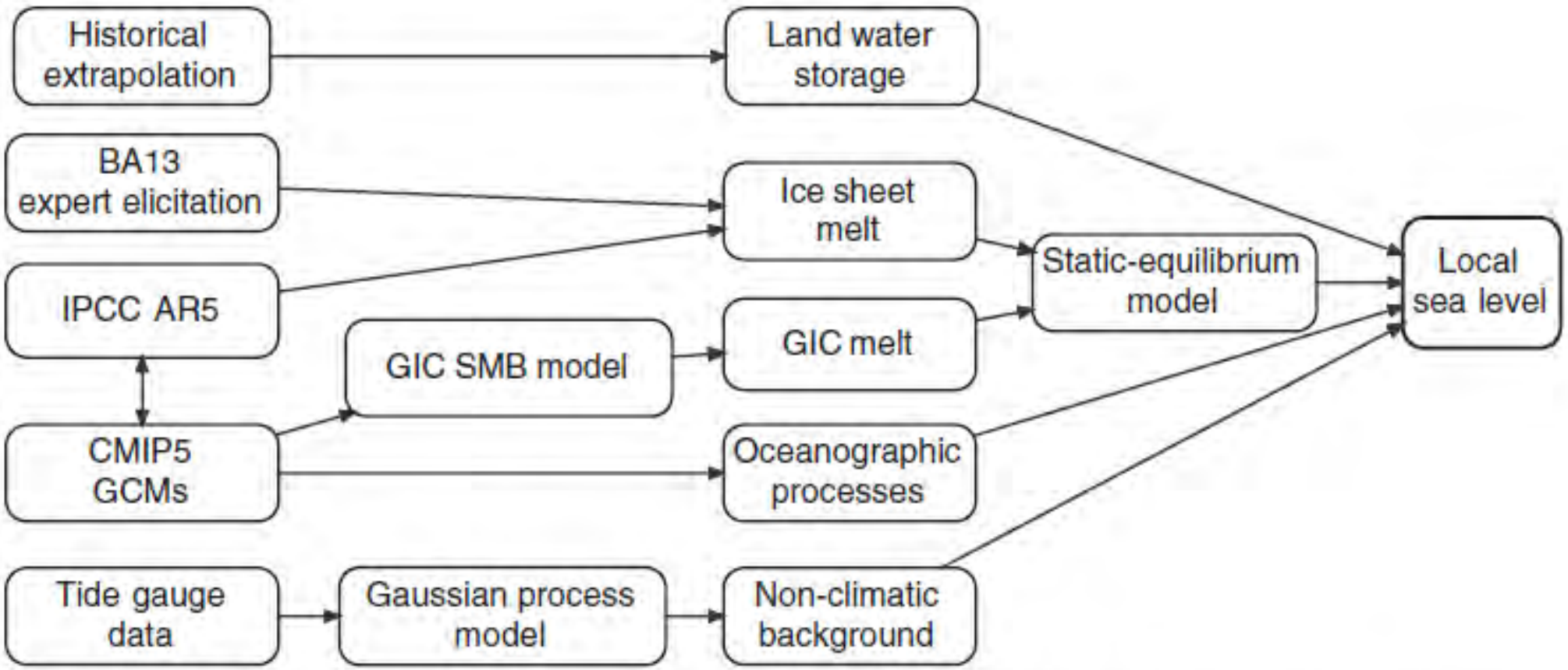
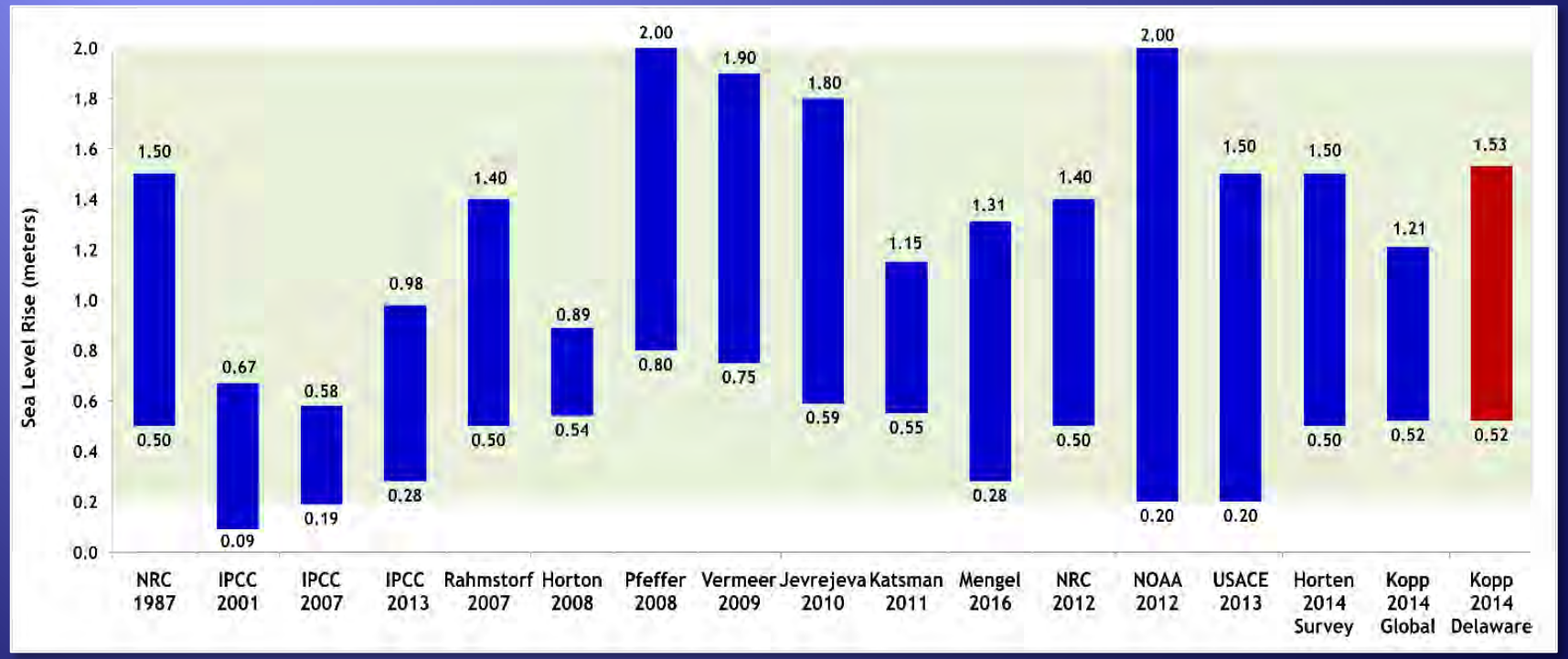


Figure 1. Logical flow of sources of information used in local sea-level projections. GCMs, global climate models; GIC, glaciers and ice caps; SMB: surface mass balance.

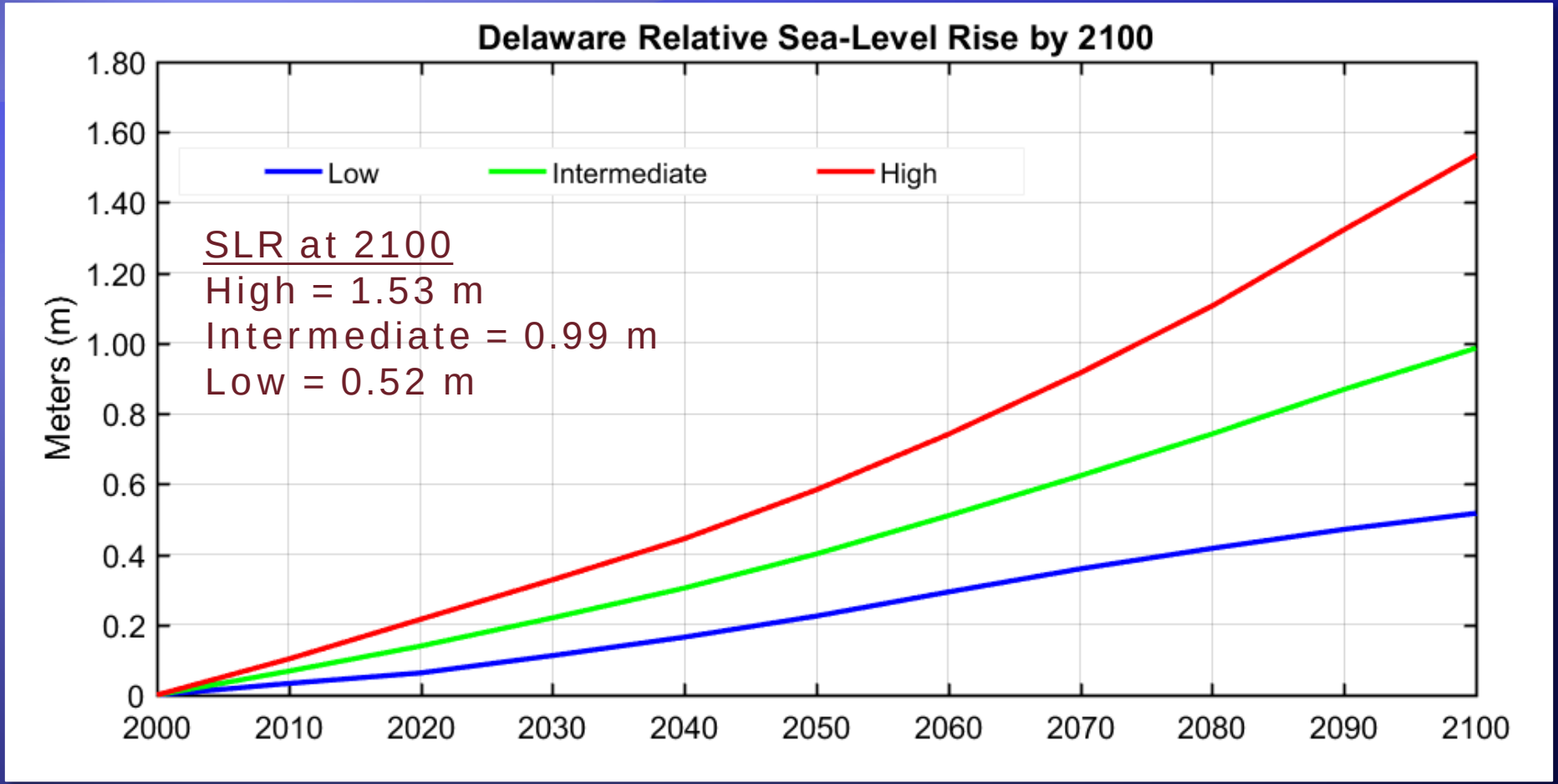
Kopp et al. (2014)

Delaware 2017 SLR Scenarios – Kopp et al (2014)

SLR Planning Scenario	Probability	SLR by 2100
Low Scenario	5%	0.52 m
Intermediate Scenario	50%	0.99 m
High Scenario	95%	1.53 m

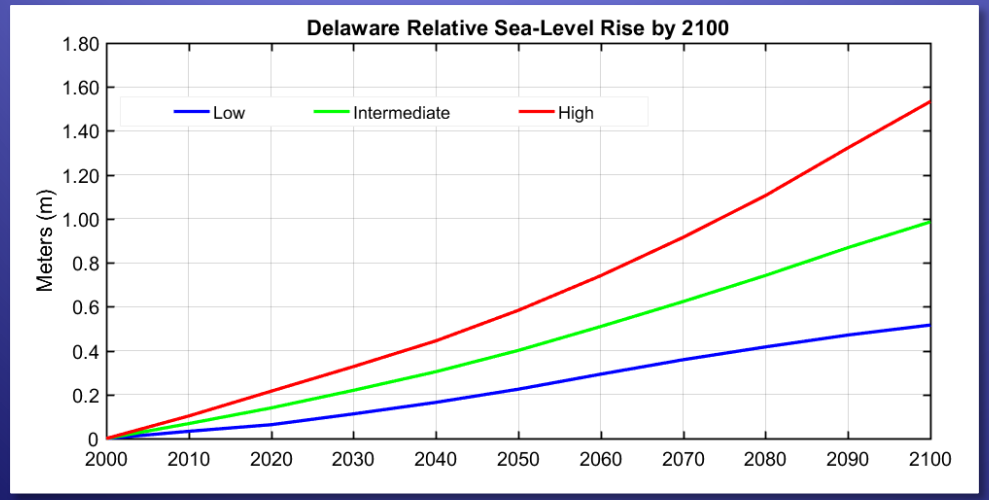


Delaware 2017 SLR Scenarios – Kopp et al (2014)



Perspectives – Scenario as Risk Tolerance

- Select an appropriate time horizon for planning or design
- Think of scenarios to represent risk tolerances…, NOT as predictions!
- Different scenarios for different projects!



Perspectives – Scenario as Risk Tolerance

	USGCRP NCA (2014) Max	NOAA SLR (2017) Max	NOAA SLR (2017) 99.9%	Miller et al (2013) Max	Jevrejeva et al (2014) Max	Jackson and Jevrejeva (2016) 99%	Kopp (2014) 99.0%	Kopp (2014) 99.5%	Kopp (2014) 99.9%
Global	2.00	2.50	2.40	2.70	1.90	2.22	1.55	1.76	2.47
Delaware		3.44	3.28				1.93	2.13	3.01

- "Long tail" effect of risk distribution
  - SLR > 95% is still 1:20 chance
  - Small odds vs severe consequences
- High uncertainty in ice sheets
  - Greenland and West Antarctica

Greenland Is Melting at Some of the Fastest Rates in 12,000 Years

If greenhouse gas emissions do not decline, melt rates could quadruple and further add to sea level rise

By Chelsea Harvey, E&E News on October 1, 2020

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Going, Going ... Gone: Greenland's Melting Ice Sheet Passed a Point of No Return in

Antarctica's colossal Thwaites Glacier is melting fast -- and scientists may have discovered why

By Emma Reynolds, CNN

A view of the sea ice from the Nathaniel B. Palmer icebreaker on the way to Thwaites Glacier.

ng retreat and thinning of

NATIONAL GEOGRAPHIC

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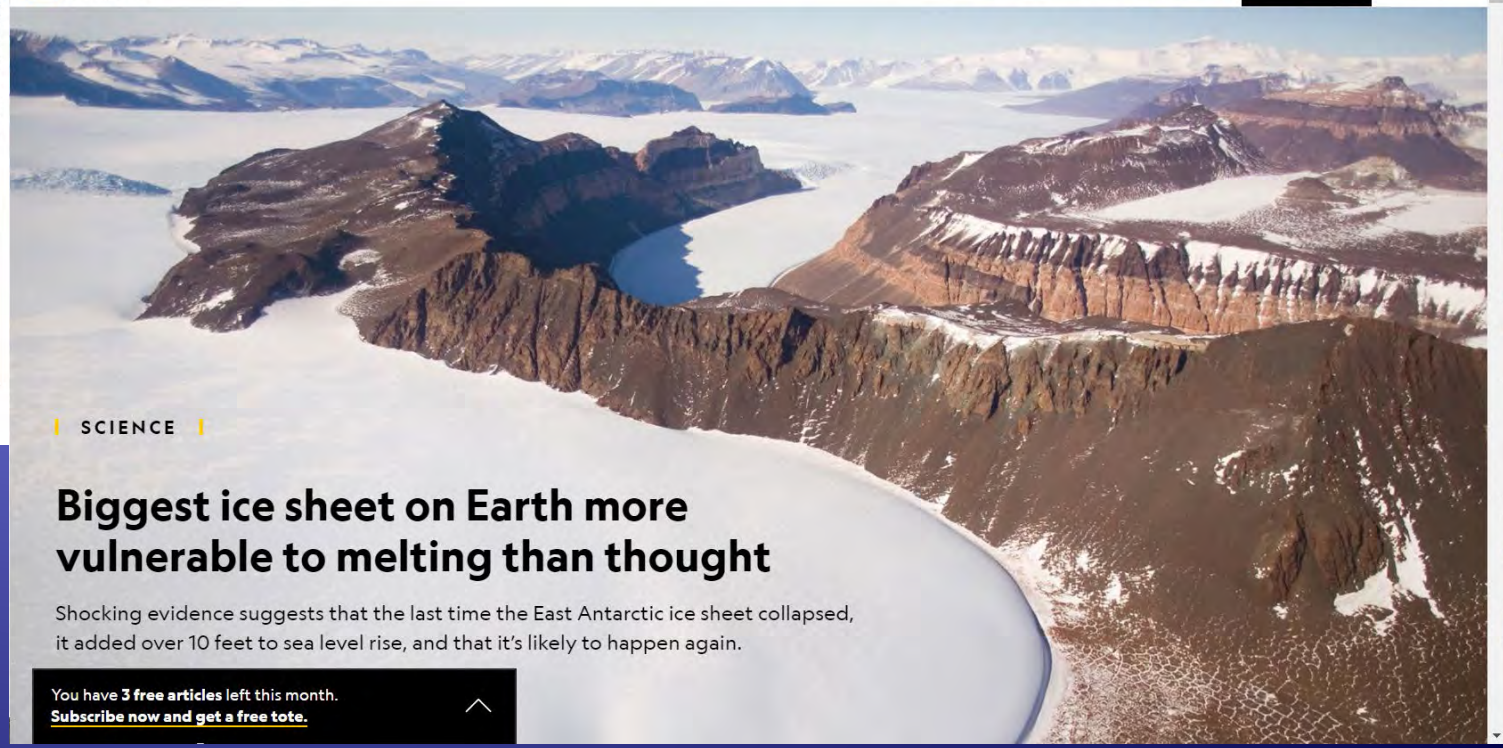

SCIENCE

Biggest ice sheet on Earth more vulnerable to melting than thought

Shocking evidence suggests that the last time the East Antarctic ice sheet collapsed, it added over 10 feet to sea level rise, and that it's likely to happen again.

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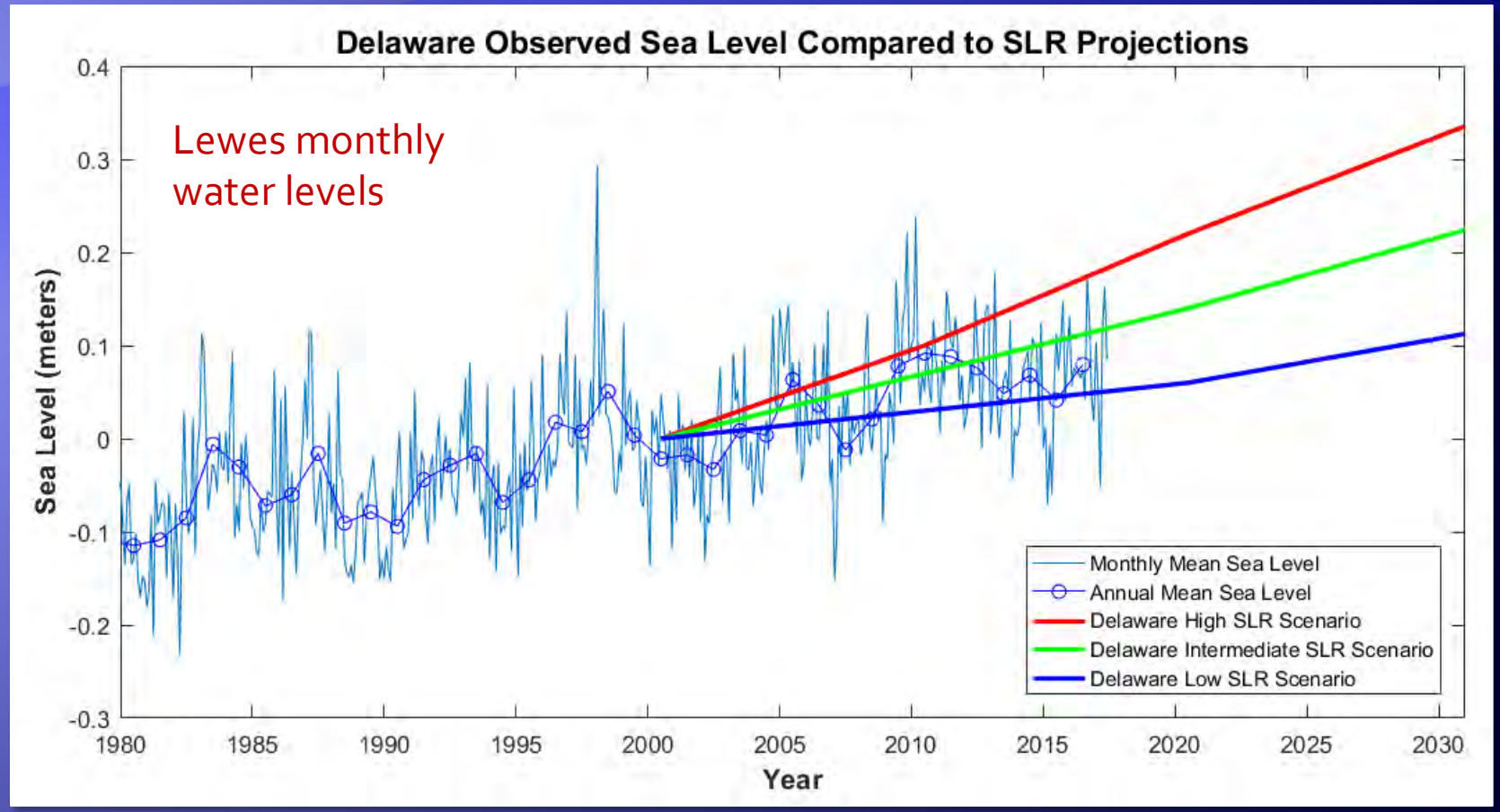
Perspectives – Scenario as Risk Tolerance

Not only is there high uncertainty about SLR upper bound, but each year is highly variable!

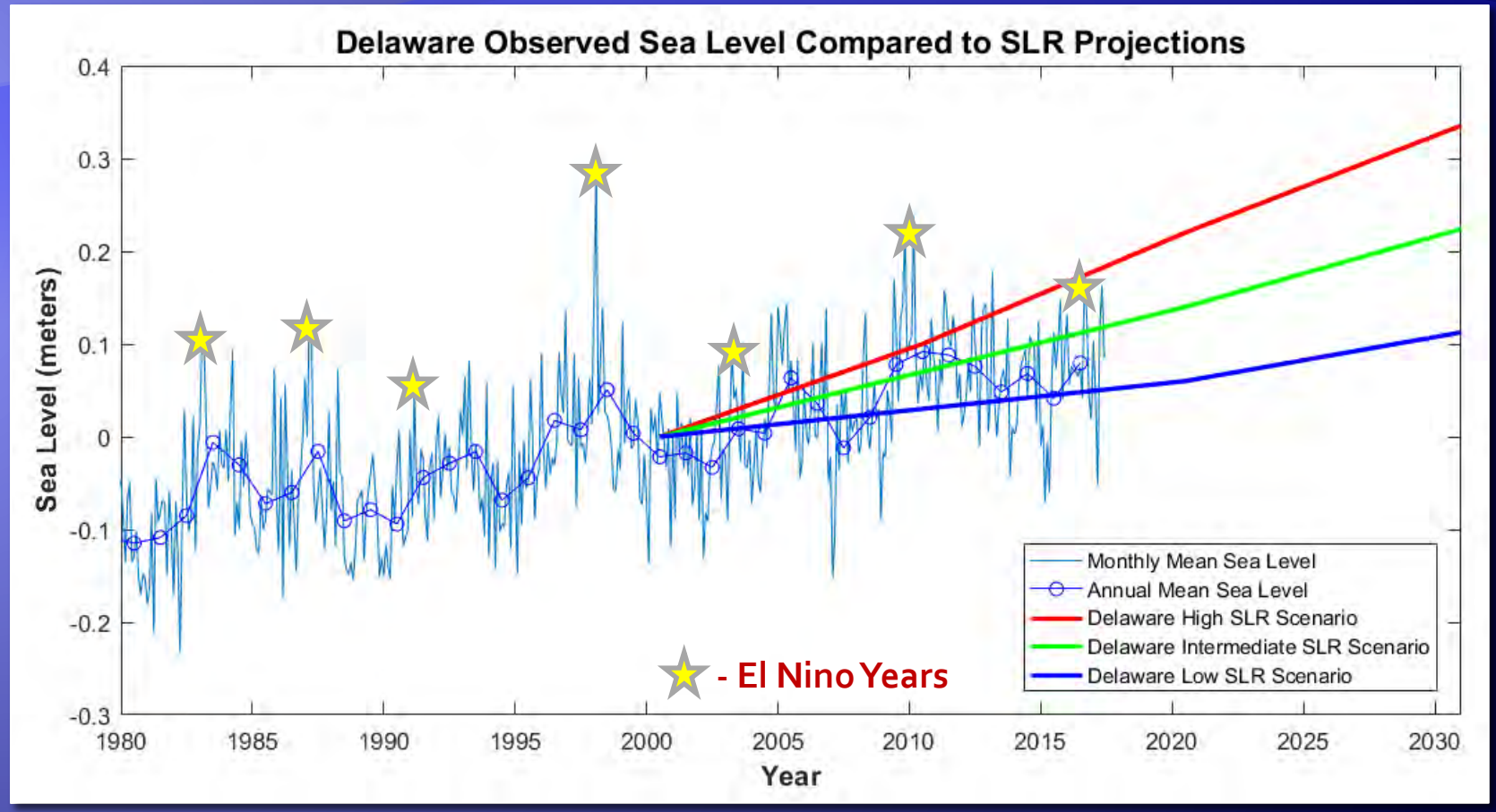


Natural variability can be larger than signal/trend.

Projections are a baseline on which variability acts.

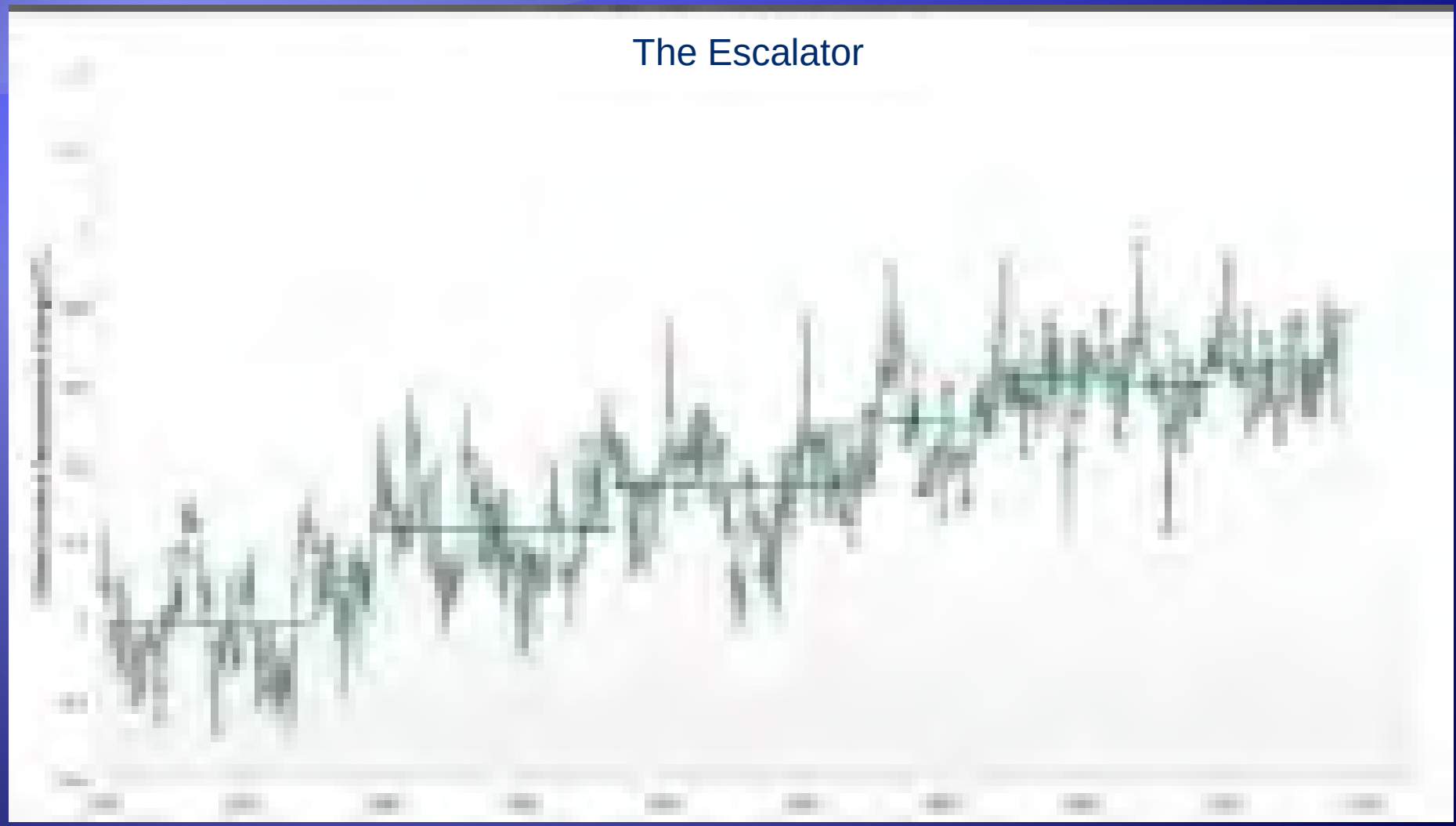
Perspectives – Scenario as Risk Tolerance

Not only is there high uncertainty about SLR upper bound, but each year is highly variable!



Natural variability is not completely random!

Because of the year-to-year variability, time scale is very important when looking at trends!



https://skepticalscience.com/escalator

What about the future in DE?

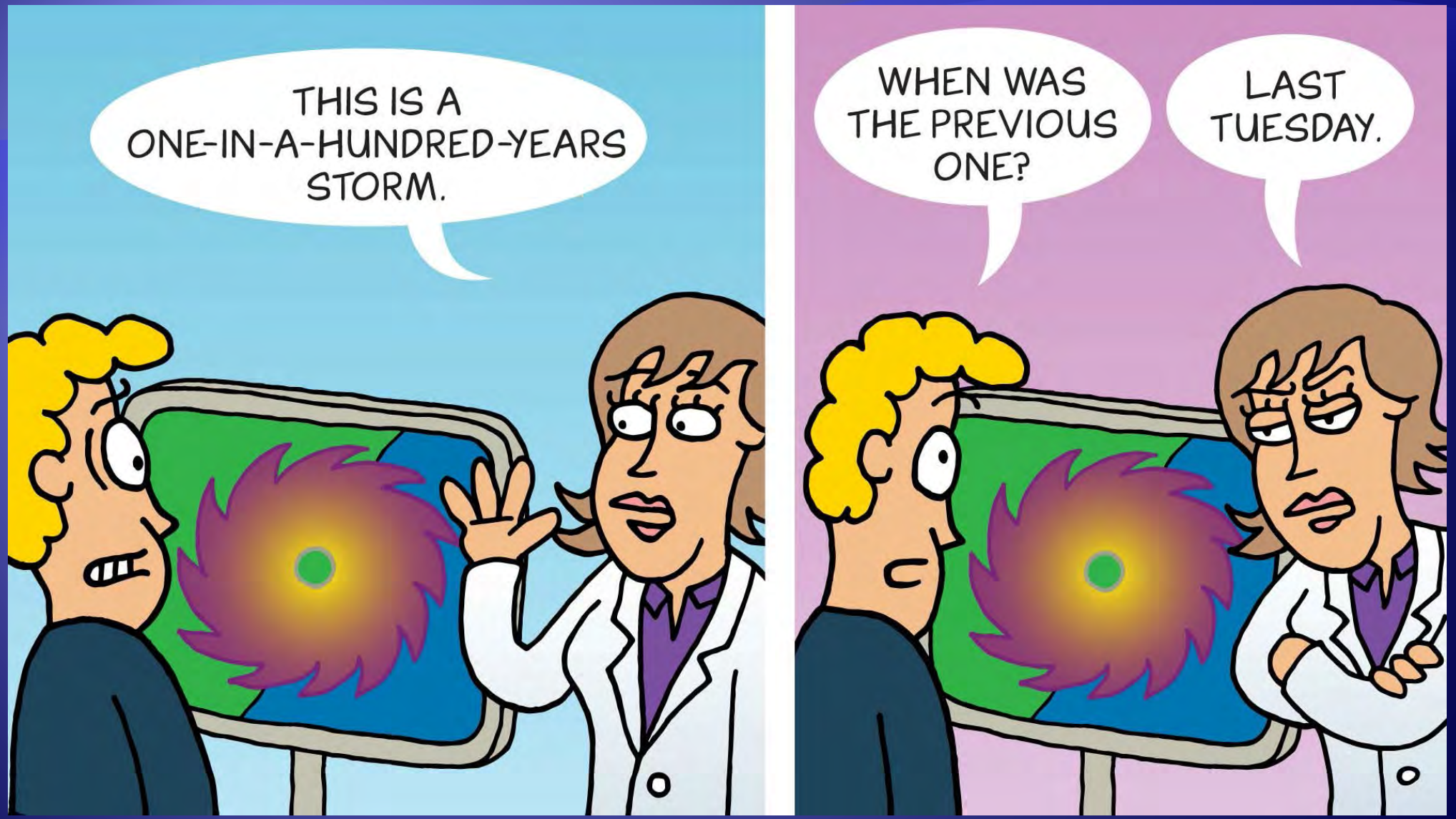
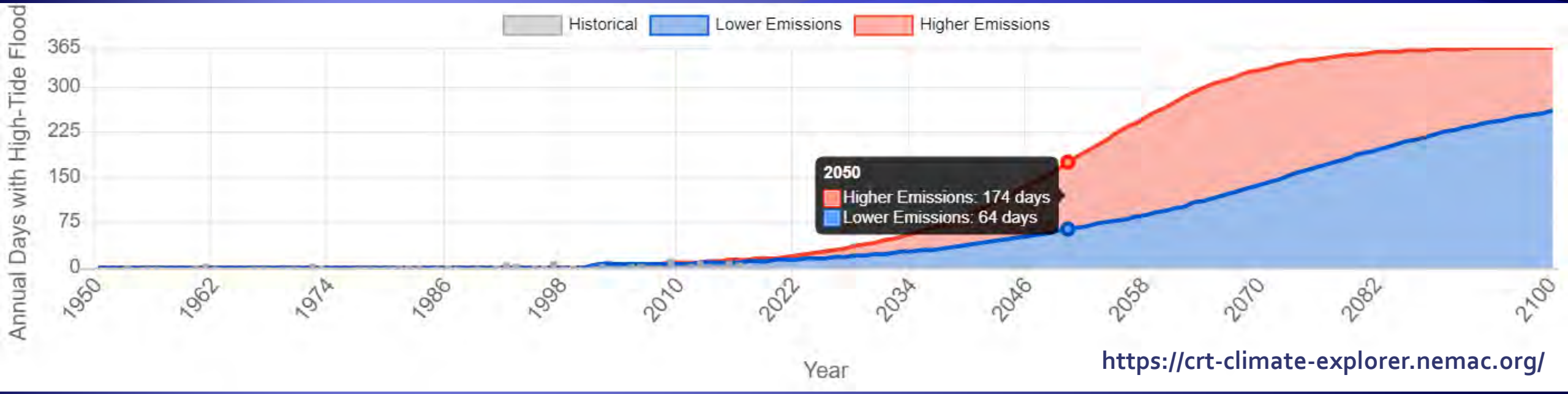


Image source: https://crankyuncle.com/

What about the future? – Sea-Level Rise



https://crt-climate-explorer.nemac.org/

A Plan to Maximize Resilience to Sea Level Rise

http://declimateplan.org/

DELAWARE'S
Climate Action Plan

A 2019 survey of Delawareans underscores the importance of the First State's effort to develop a climate action plan.

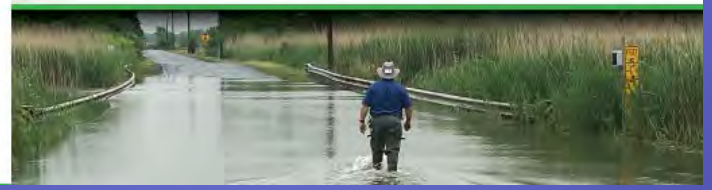
The Threat is Real

3 OUT OF 4

are **CONVINCED** that climate change is happening

77%

think climate change will **HARM FUTURE GENERATIONS**



Delawareans are Already Seeing and Feeling the Impacts

56% Say they have personally experienced or observed local impacts of climate change

47% Say they have personally experienced or observed local impacts of sea level rise — *up from 28% in 2014*

www.declimateplan.org

The Time for Action is Now

70%

agree that we should **TAKE IMMEDIATE ACTION** to reduce the impacts of climate change

64%

say they can **PERSONALLY TAKE ACTION** to reduce the impacts of climate change

Building Resilience

The state of Delaware is exploring actions that they can take to help the state adapt to climate change. The items below represent the seven main areas where actions can be taken to help the state build resilience to sea level rise.

Regulation and/or Policy changes that address protection and conservation of vulnerable and impacted resources.

Facility and Infrastructure Design and Management that accounts for future climate conditions and sea level rise.

Administrative Processes related to operational guidelines and documents on how Agencies do business.

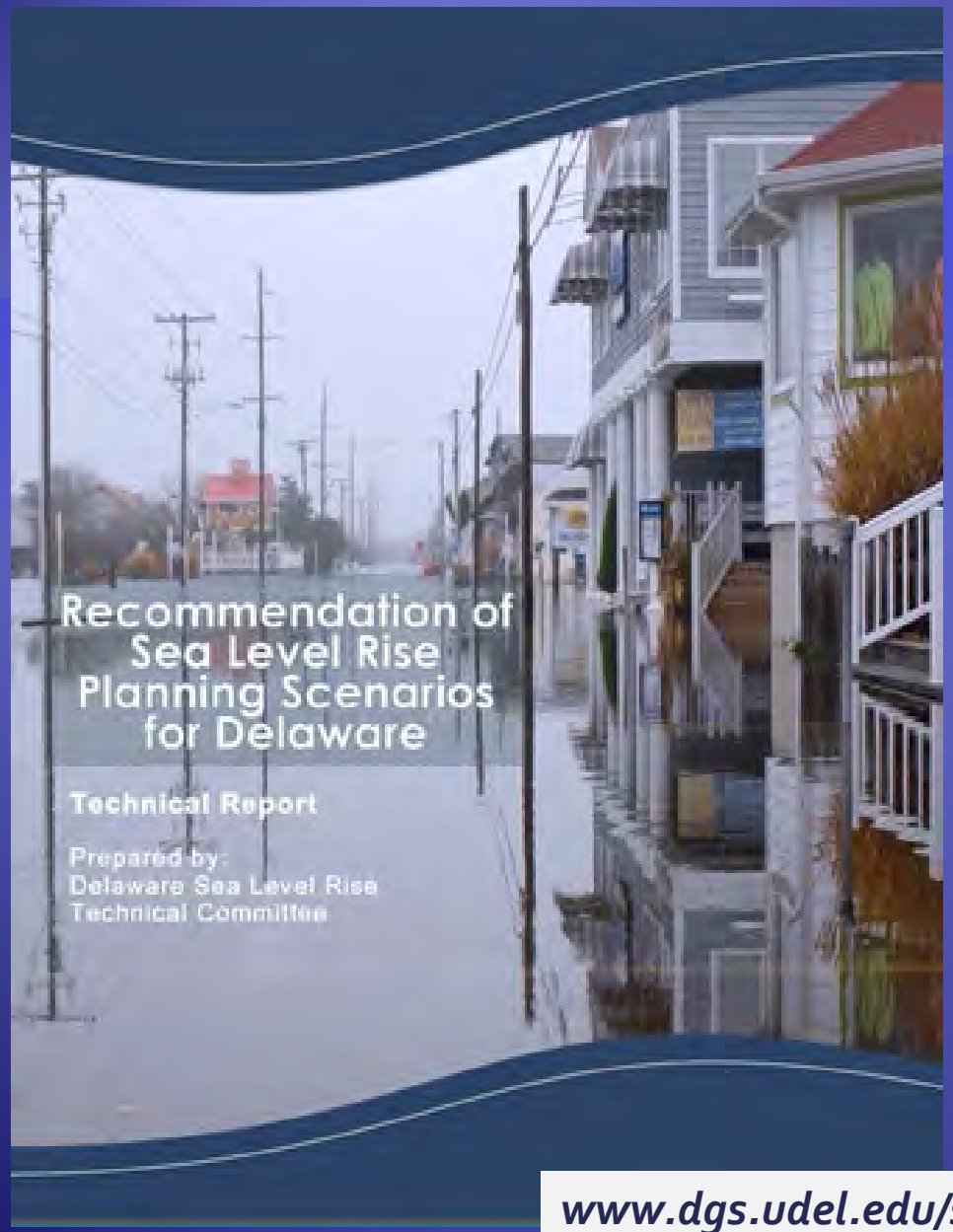
Management Plans for natural resources, emergency response, state facilities, and Agency equipment .

Research and Monitoring that studies the impacts of climate change and methods of adapting.

Support for Communities and Stakeholders in the form of trainings, resources, and technical assistance.

Outreach to stakeholders and the public on climate change impacts and adaptation.

http://declimateplan.org/



www.dgs.udel.edu/slr

Thank You!

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University of Delaware
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http://www.dgs.udel.edu

CEMA

More information on Delaware's climate at http://cema.udel.edu/