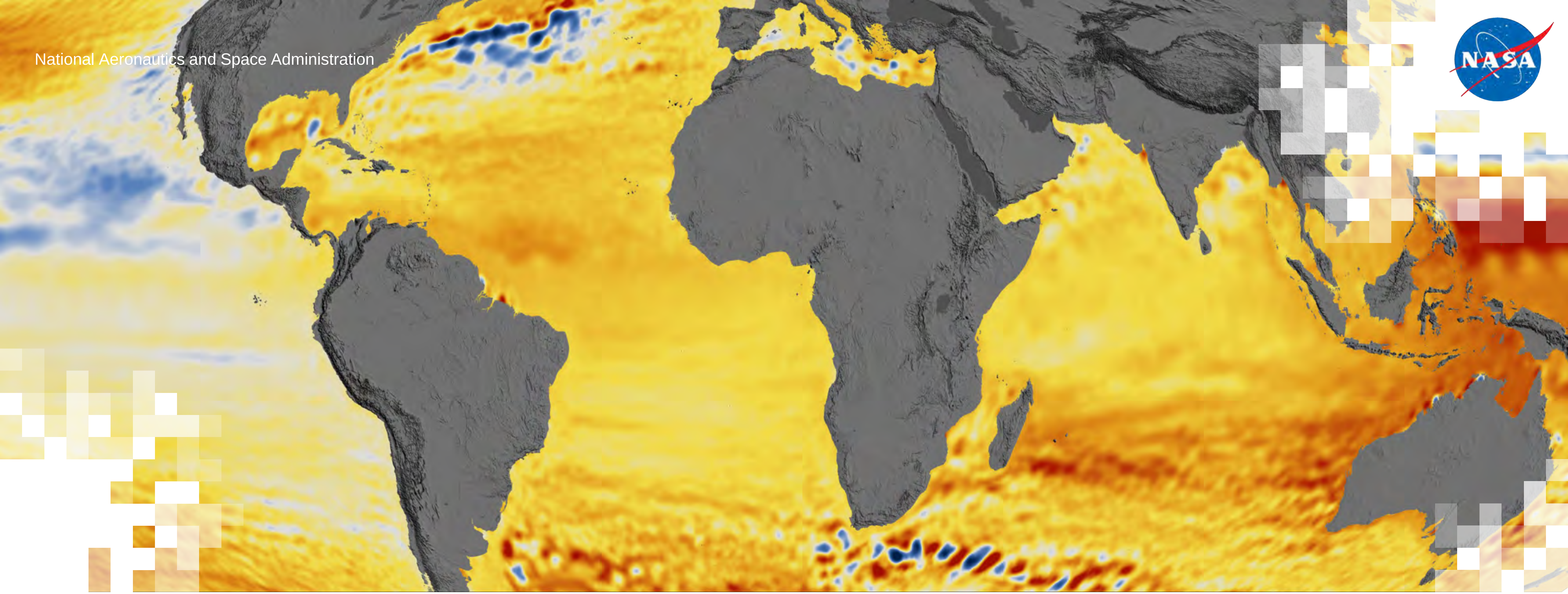
National Aeronautics and Space Administration

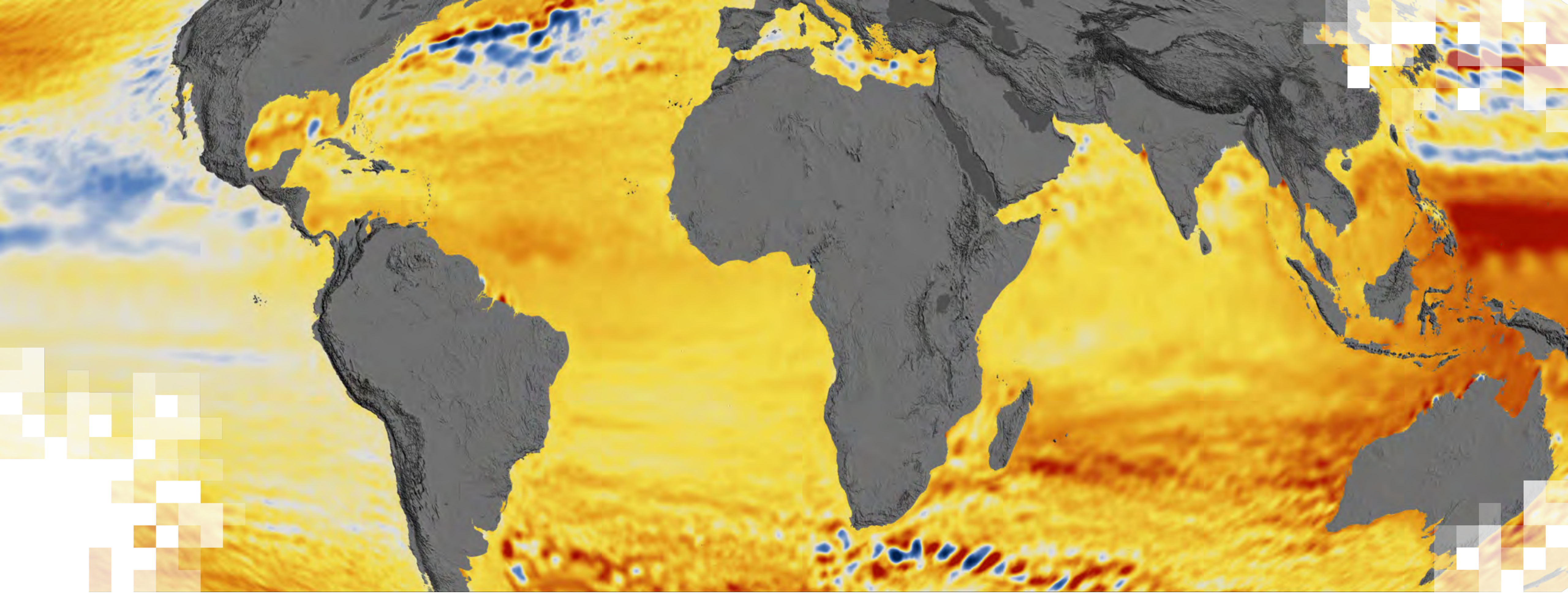


Sea-Level Change Tools for Planning and Decision Support

Part 2: Assessment Tools for Sea Level Change

Robert Kopp, PhD (Rutgers University), Phil Thompson, PhD (University of Hawai‘i), Denis Felikson, PhD (NASA GSFC), & Sean McCartney (NASA GSFC/SSAI)

June 17, 2025



Sea-Level Change Tools for Planning and Decision Support

Overview

Overview

- Earth's seas are rising because of a changing climate, and this rate is projected to increase over the next century.
- Due to the warming atmosphere and ocean, ice sheets and mountain glaciers are melting, resulting in the addition of fresh water into the ocean.
- Ocean water expands as it absorbs trapped heat, causing sea levels to rise.
- Data on this increase in the rate of global sea level rise is critical to planners understanding the trajectory of future sea level rise.

Credit: Chris Larsen, NASA's Operation IceBridge mission

Training Learning Objectives

By the end of this training, participants will be able to:

- Identify underlying Earth processes contributing to relative sea-level change at global and regional scales.
- Recognize remote sensing and modeled data used for assessing sea level change on a regional to global scale.
- Describe how coastal communities and infrastructure can be impacted by flooding caused by sea level change.
- Demonstrate how to assess the processes contributing to past and future sea-level change with the Sea Level Explorer tool–at global and regional scales.
- Demonstrate how to access future projections of relative sea-level change under different emissions scenarios with the IPCC AR6 Projection Tool.
- Visualize oceanic and groundwater flooding maps with the Pacific Islands Flooding Tool.

Prerequisites

- Fundamentals of Remote Sensing

Training Outline

Part 1

Overview of Sea Level Change – Regional to Global

June 10, 2025

Part 2

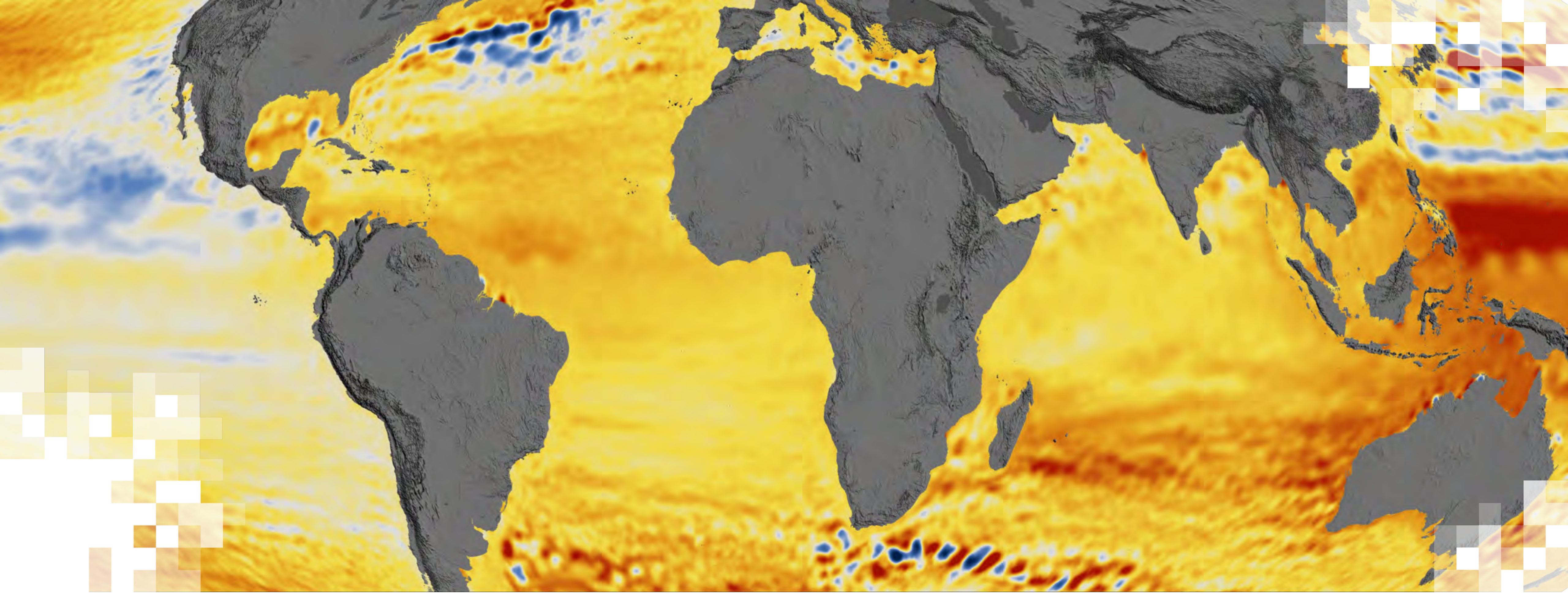
Assessment Tools for Sea Level Change

June 17, 2025

Homework

Opens June 17 – **Due July 1** – posted on training webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.



Sea-Level Change Tools for Planning and Decision Support

Part 2: Assessment Tools for Sea Level Change

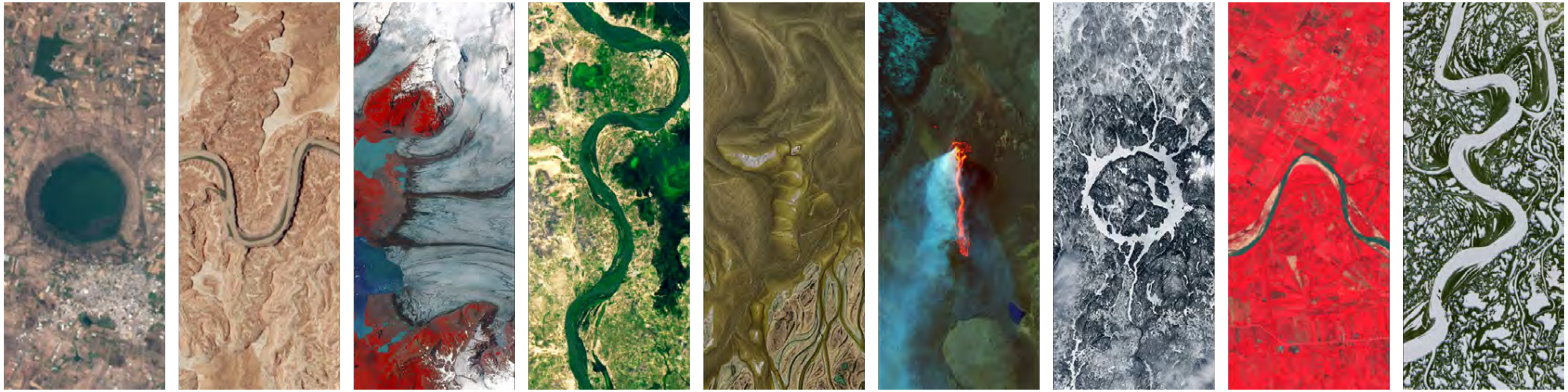
Part 2 Objectives

By the end of Part 2, participants will be able to:

- Demonstrate how to access future projections of relative sea-level change under different emissions scenarios with the IPCC AR6 Projection Tool.
- Visualize oceanic and groundwater flooding maps with the Pacific Islands Flooding Tool.

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



Credit: [Your Name In Landsat]

Part 2 – Guest Instructors

Dr. Robert Kopp

Distinguished Professor

Department of Earth and Planetary Sciences, Rutgers University

Dr. Phil Thompson

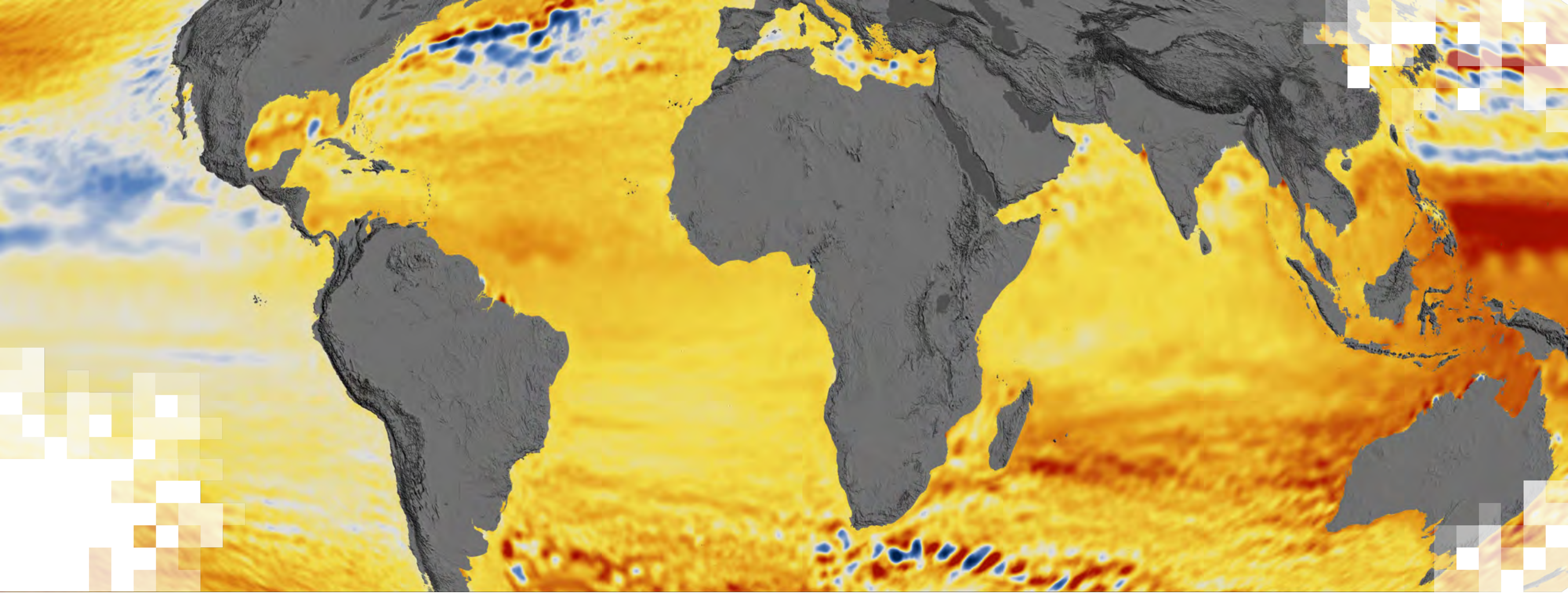
Associate Professor

Department of Oceanography, University of Hawaiʻi at Mānoa

Dr. Denis Felikson

Research Scientist

NASA GSFC

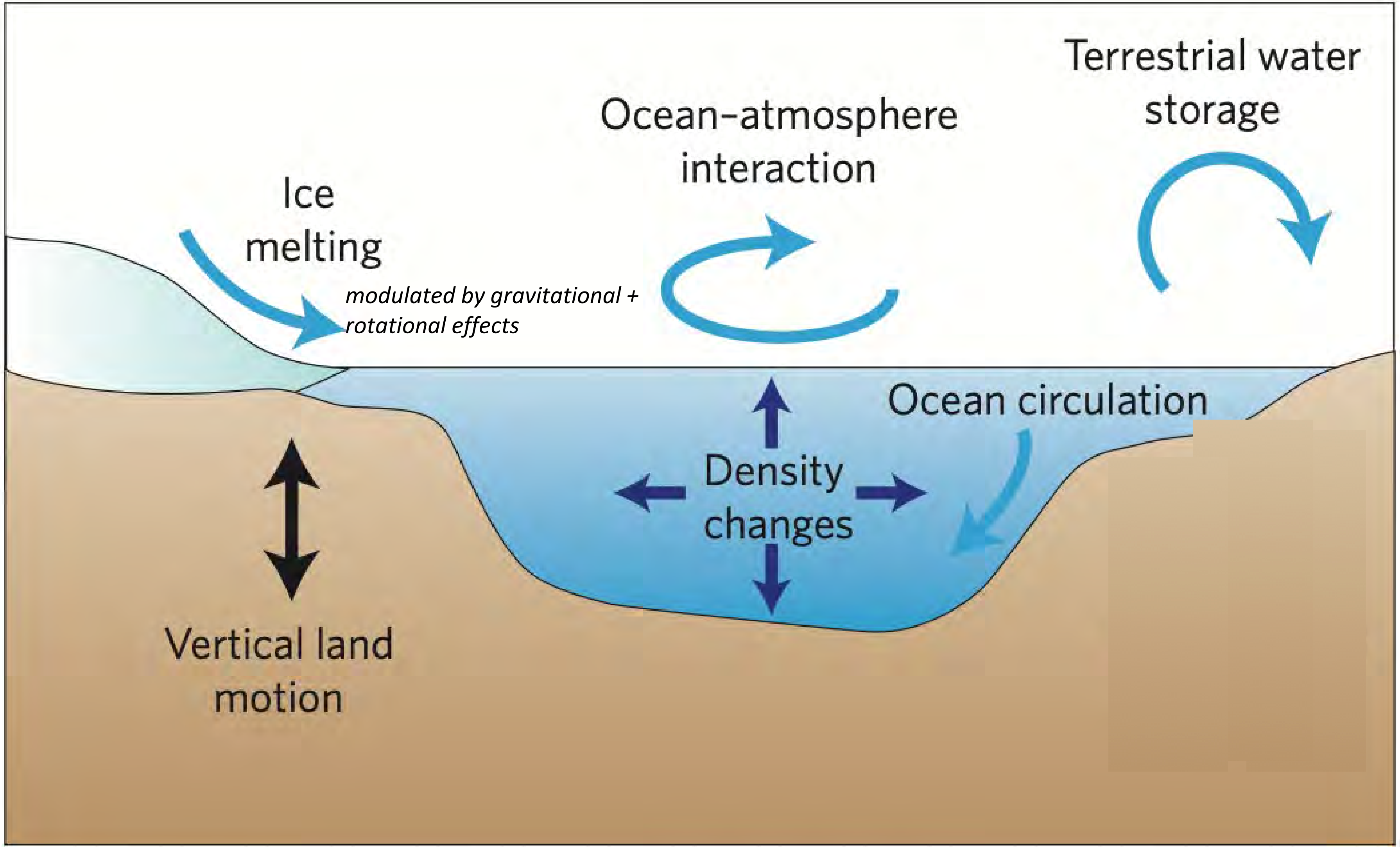


Projecting Future Sea-Level Change

Prof. Robert Kopp
Co-Lead, NASA Sea-Level Change Team
Lead Author, Chapter 9, IPCC AR6 Working Group 1
Rutgers University

Climate Impact Lab
MACH Megalopolitan Coastal Transformation Hub
NASA
RUTGERS NEW BRUNSWICK

To project future sea-level changes, we need to integrate information about different processes and from different sources.



IPCC uncertainty guidance defines separate scales of confidence and likelihood

Relationship of Evidence & Agreement Statements to Confidence

Agreement			
	High agreement Limited evidence	High agreement Medium evidence	High agreement Robust evidence
	Medium agreement Limited evidence	Medium agreement Medium evidence	Medium agreement Robust evidence
	Low agreement Limited evidence	Low agreement Medium evidence	Low agreement Robust evidence

Evidence (type, amount, quality, consistency)

Likelihood Scale

Term	Likelihood of Outcome (probability)
Virtually certain	99–100%
Very likely	90–100%
Likely	66–100%
About as likely as not	33–66%
Unlikely	0–33%
Very unlikely	0–10%
Exceptionally unlikely	0–1%

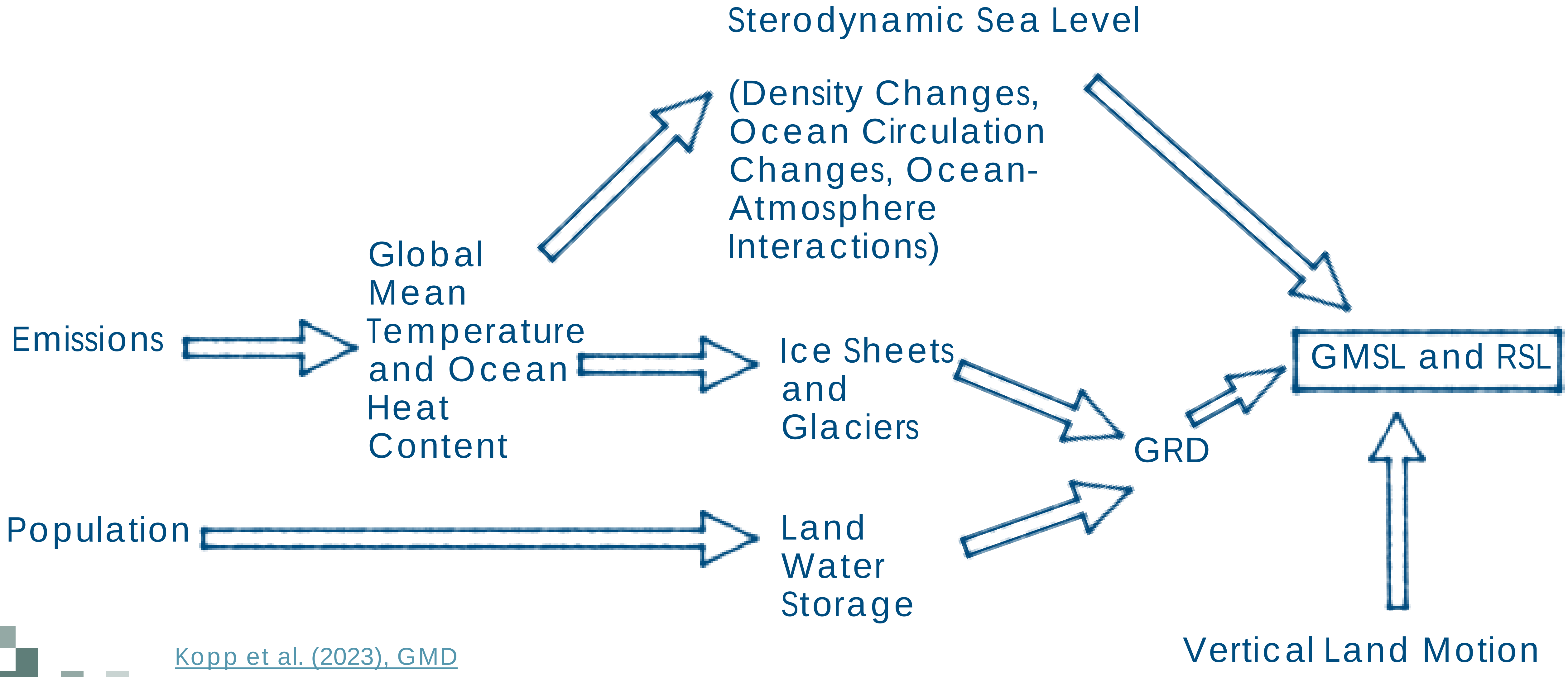
Mastrandrea et al. (2010)

Concepts of Deep Uncertainty

Deep uncertainty occurs when **"analysts do not know, or the parties to a decision cannot agree on,**

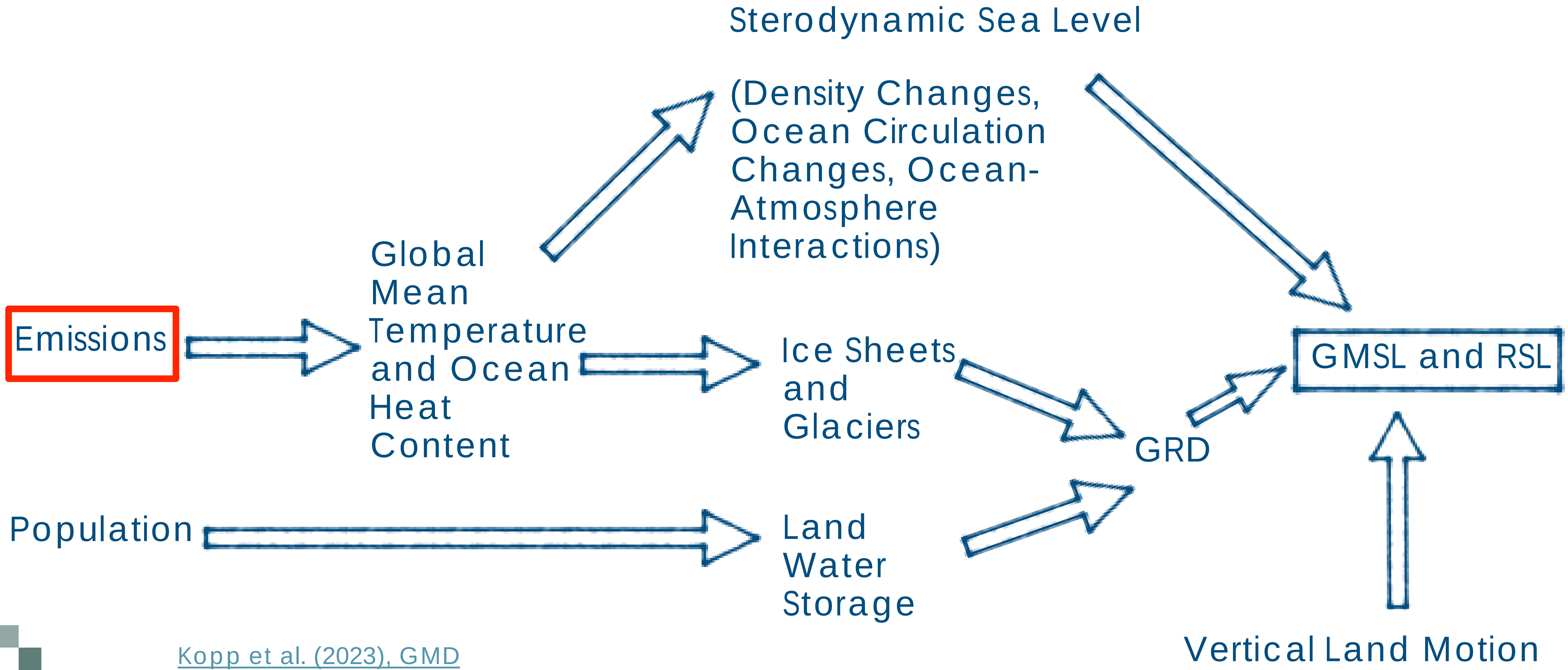
- **(1) the appropriate models to describe the interactions among a system's variables,**
- **(2) the probability distributions to represent uncertainty about key variables and parameters in the models,** and/or
- **(3) how to value the desirability of alternative outcomes."**

A typical experiment in FACTS, the Framework for Assessing Changes To Sea-level



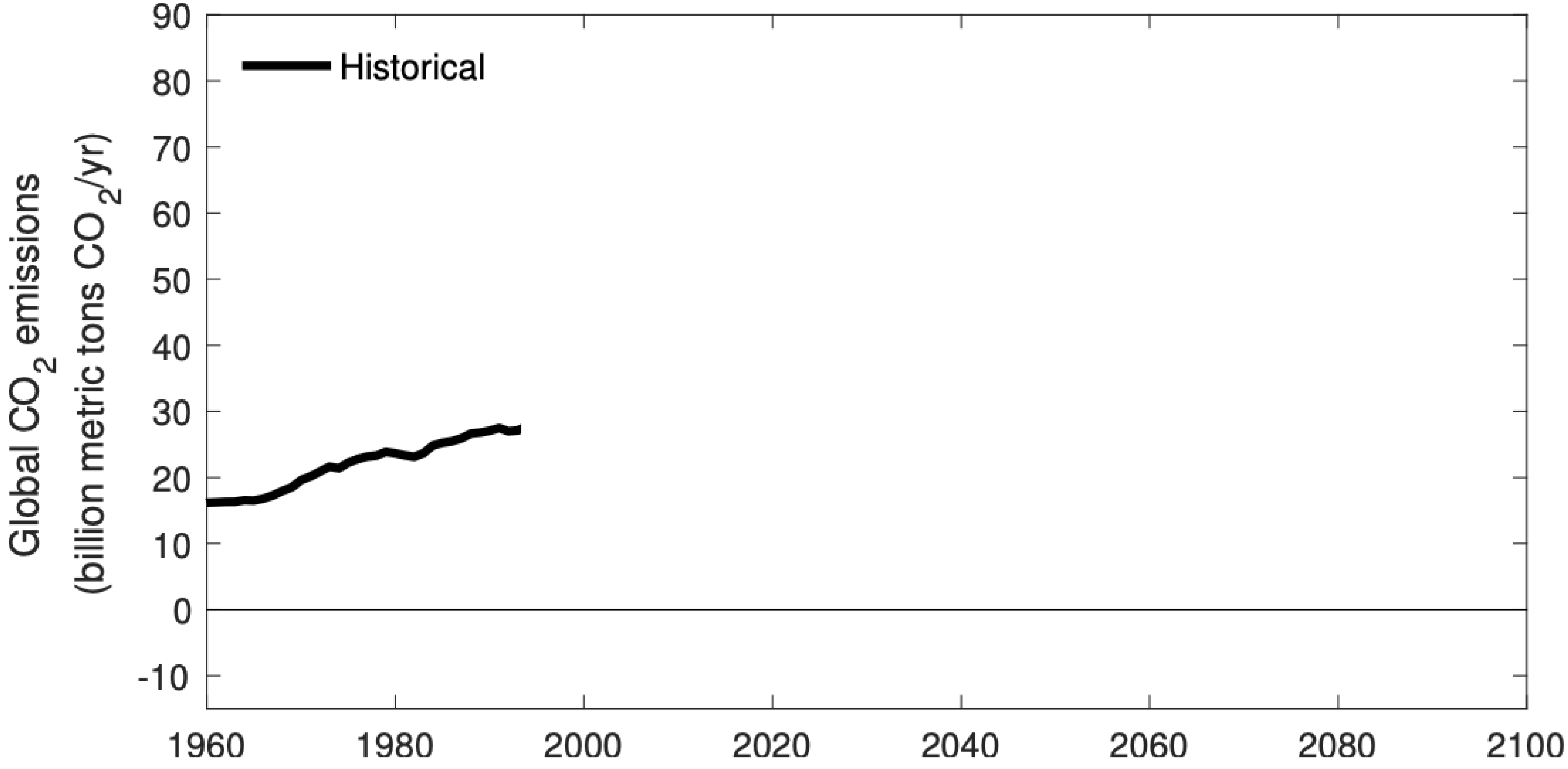
[Kopp et al. (2023), GMD]

A typical experiment in FACTS, the Framework for Assessing Changes To Sea-level



Kopp et al. (2023), GMD

A key driver of the range of possible futures is the range of possible human emissions



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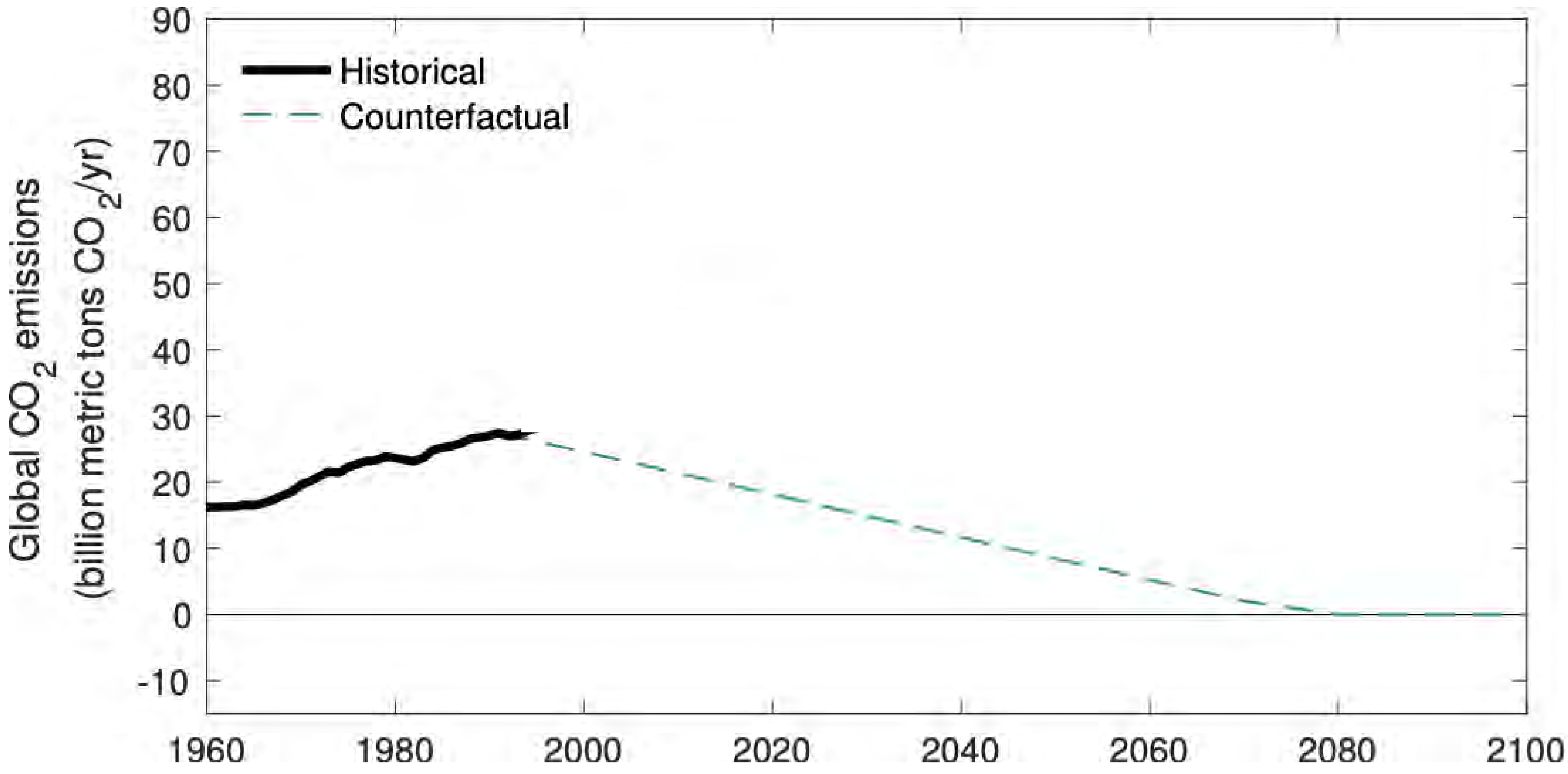
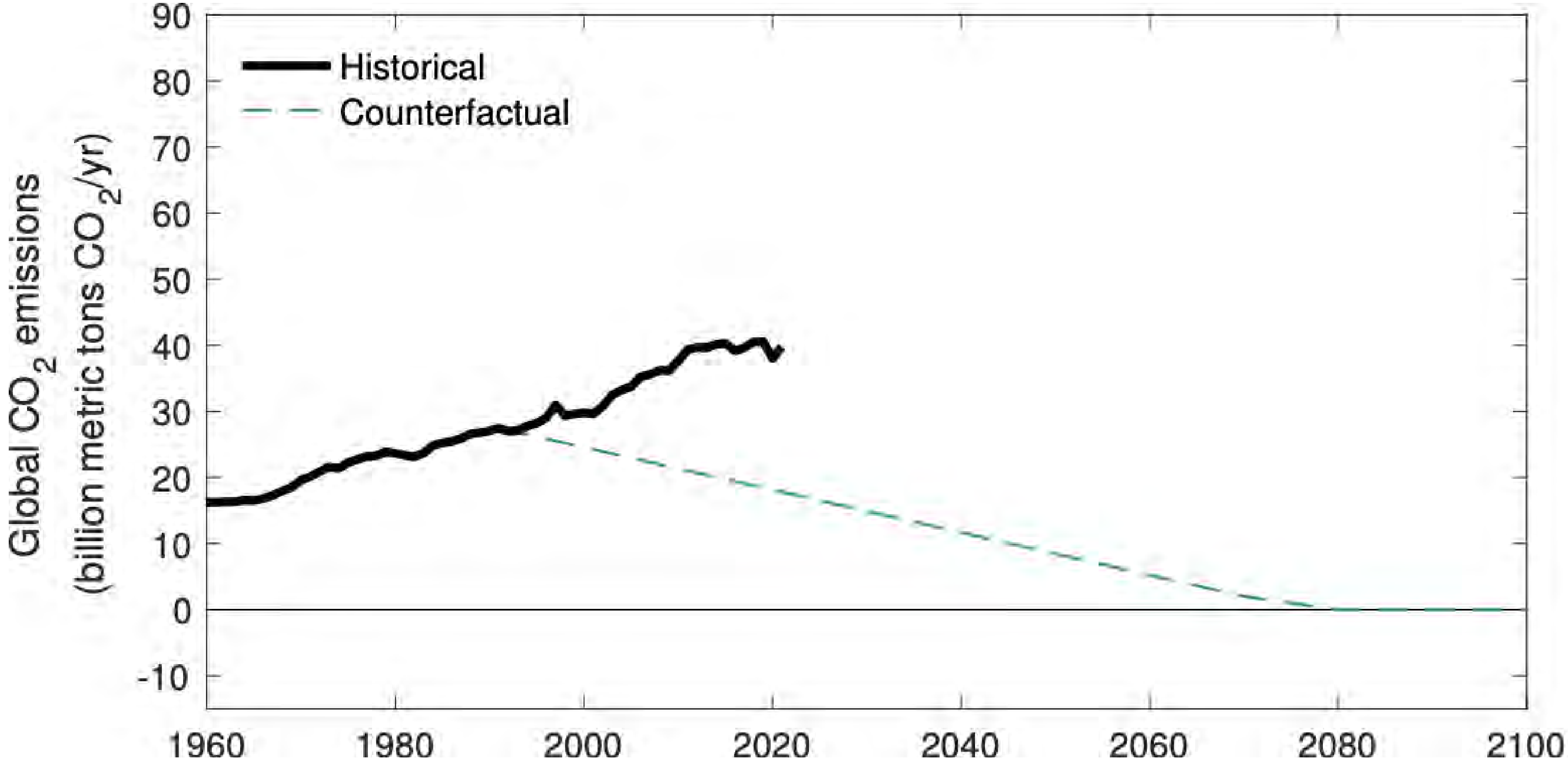


2°C compatible:
1.8°C (1.3–2.4°C)
3.2°F (2.3–4.3°F)

A key driver of the range of possible futures is the range of possible human emissions



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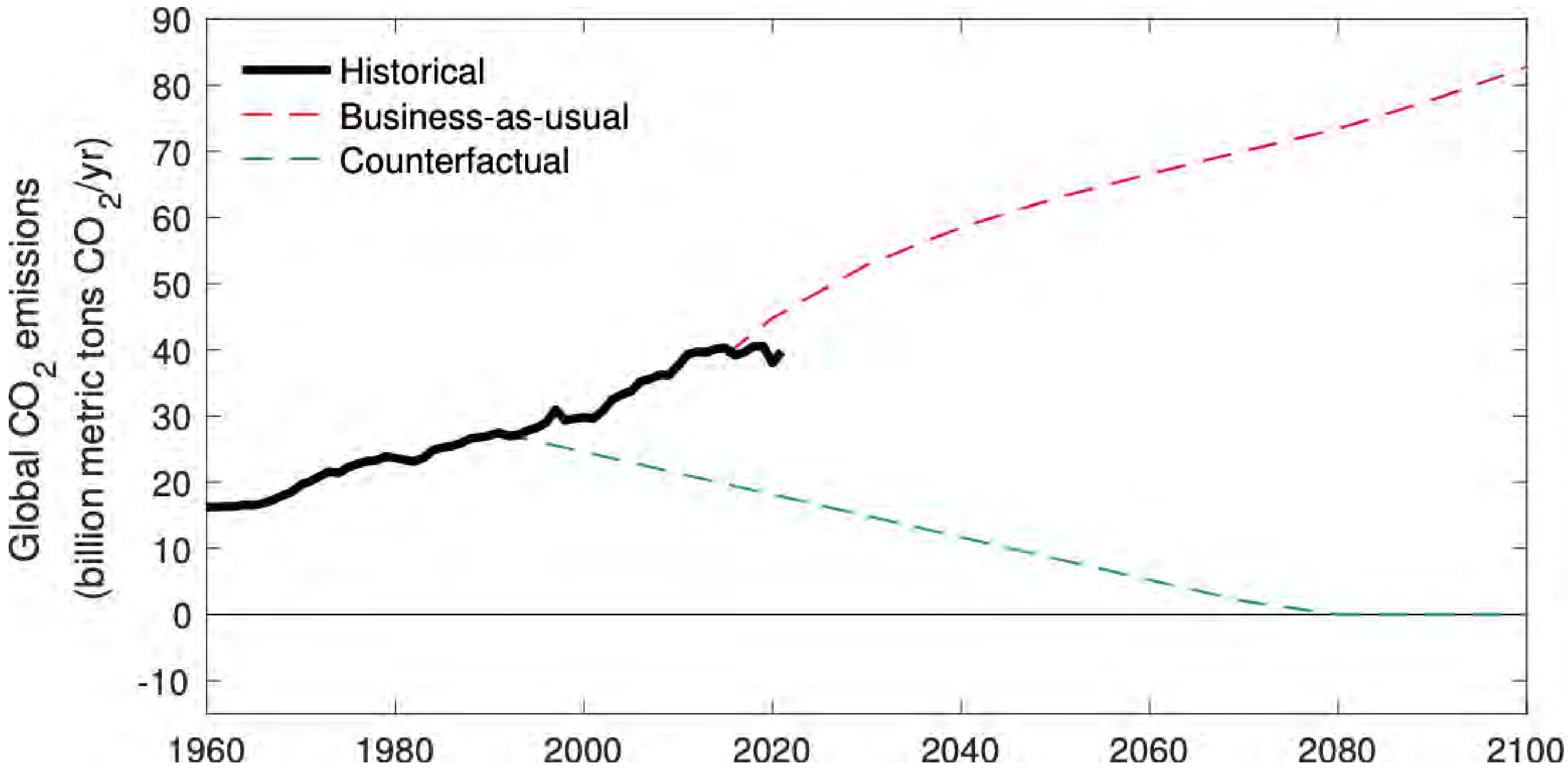

Old "Business-as-Usual" (SSP3–7.0):
3.6°C (2.8–4.6°C)
6.5°F (5.0–8.3°F)

2°C compatible:
1.8°C (1.3–2.4°C)
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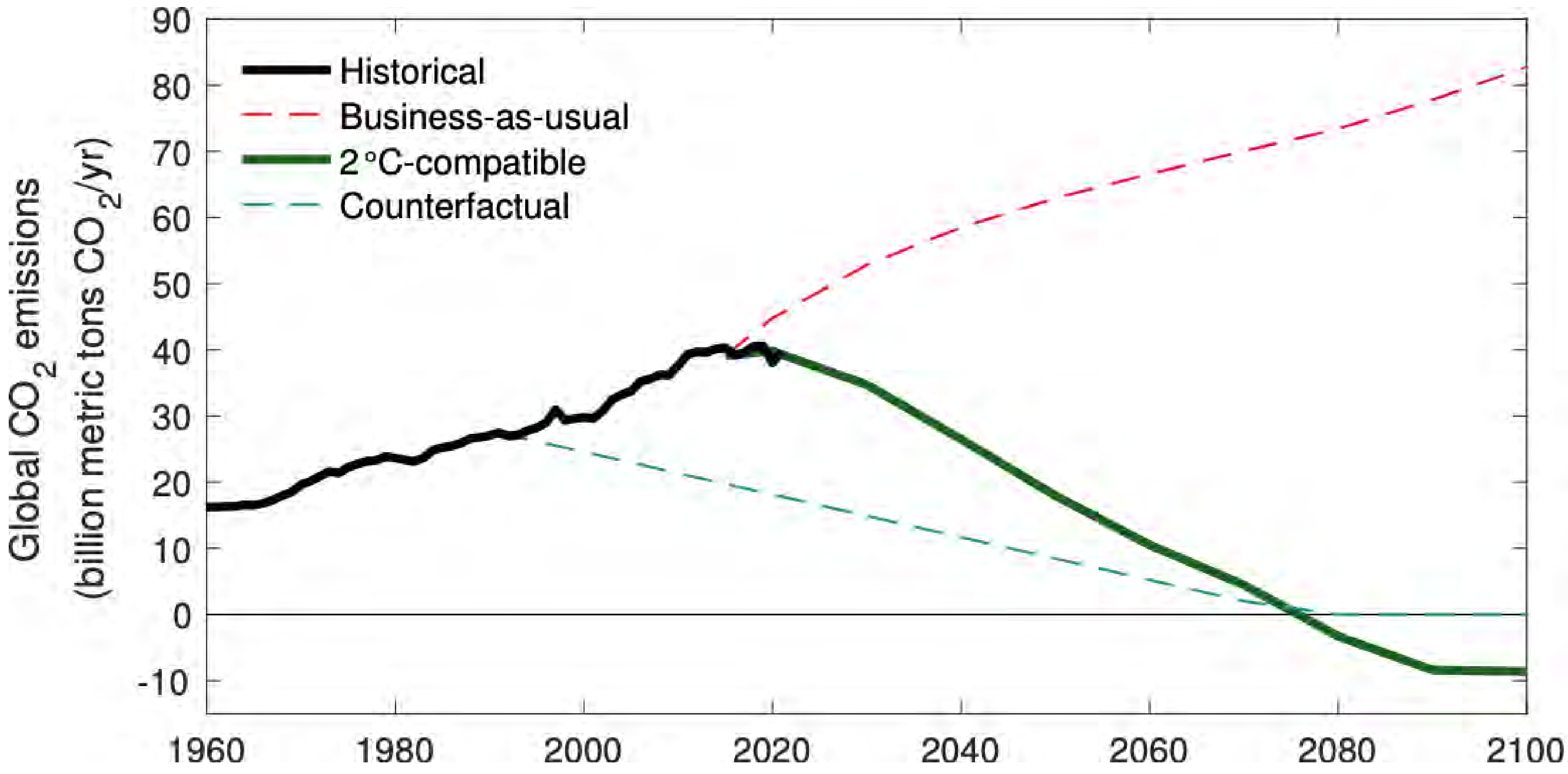
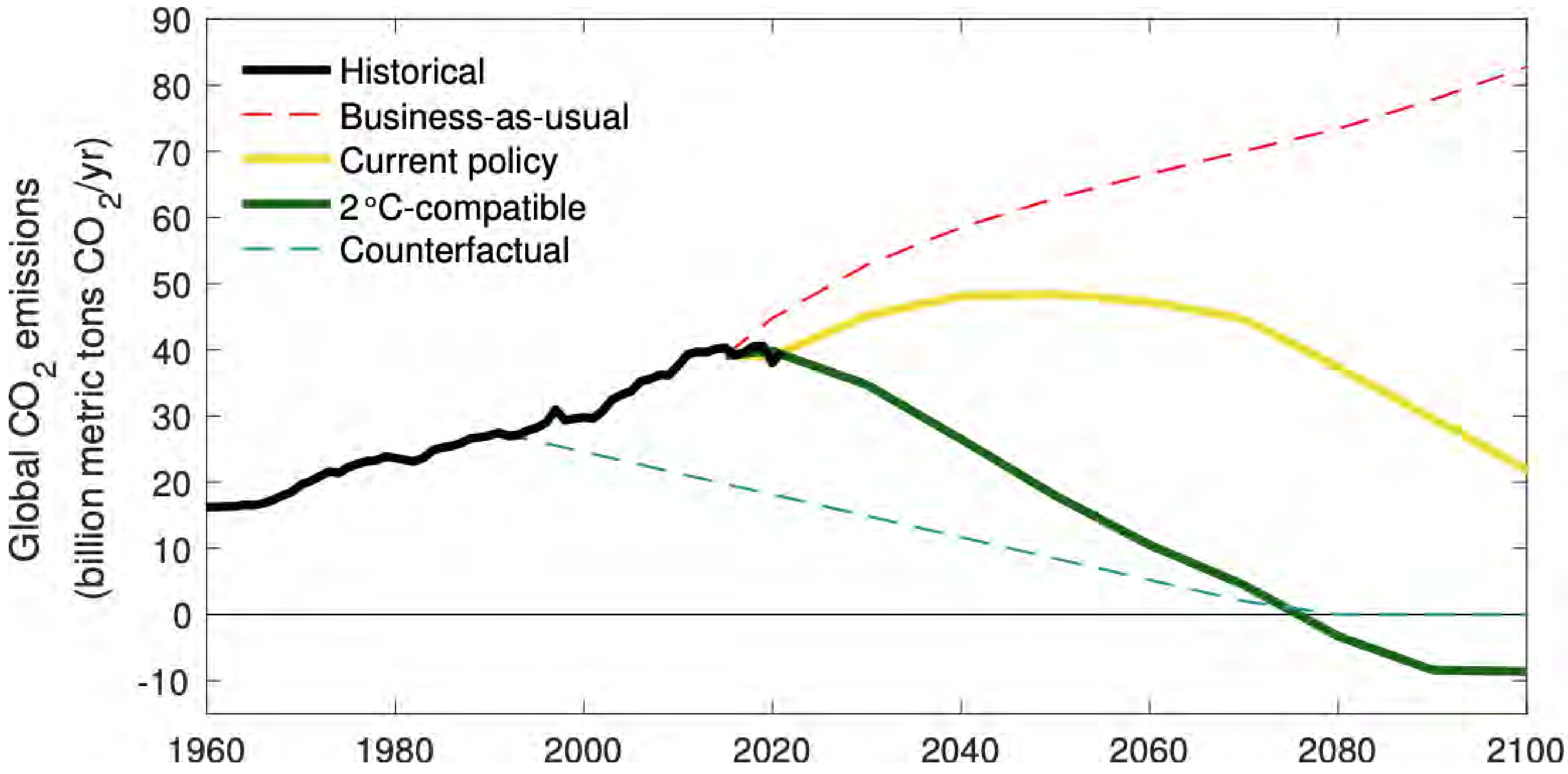
A key driver of the range of possible futures is the range of possible human emissions



Old “Business-as-Usual” (SSP3–7.0):
3.6°C (2.8–4.6°C)
6.5°F (5.0–8.3°F)

2°C compatible (SSP1–2.6):
1.8°C (1.3–2.4°C)
3.2°F (2.3–4.3°F)

A key driver of the range of possible futures is the range of possible human emissions

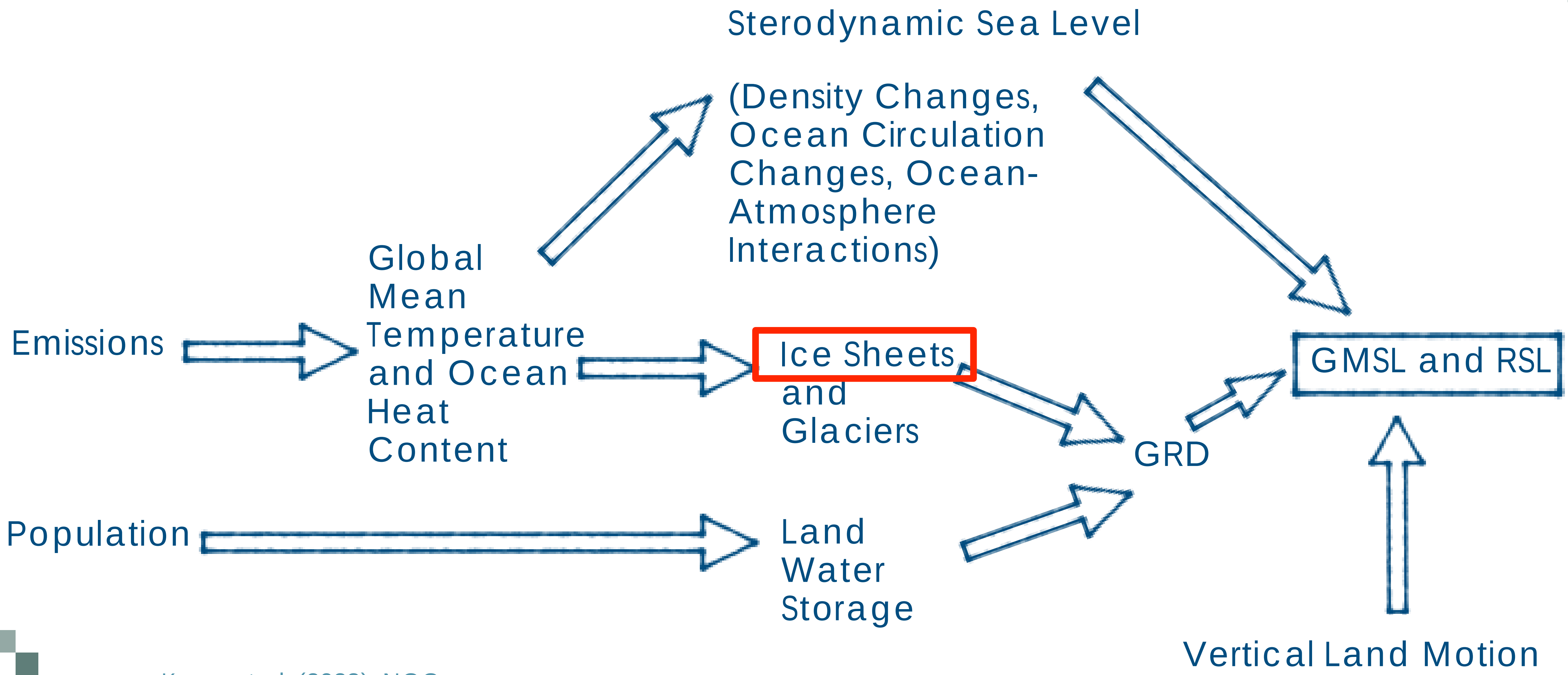


Old “Business-as-Usual” (SSP3–7.0):
3.6°C (2.8–4.6°C)
6.5°F (5.0–8.3°F)

~Current Policy (SSP2–4.5):
2.7°C (2.1–3.5°C)
4.9°F (3.8–6.3°F)

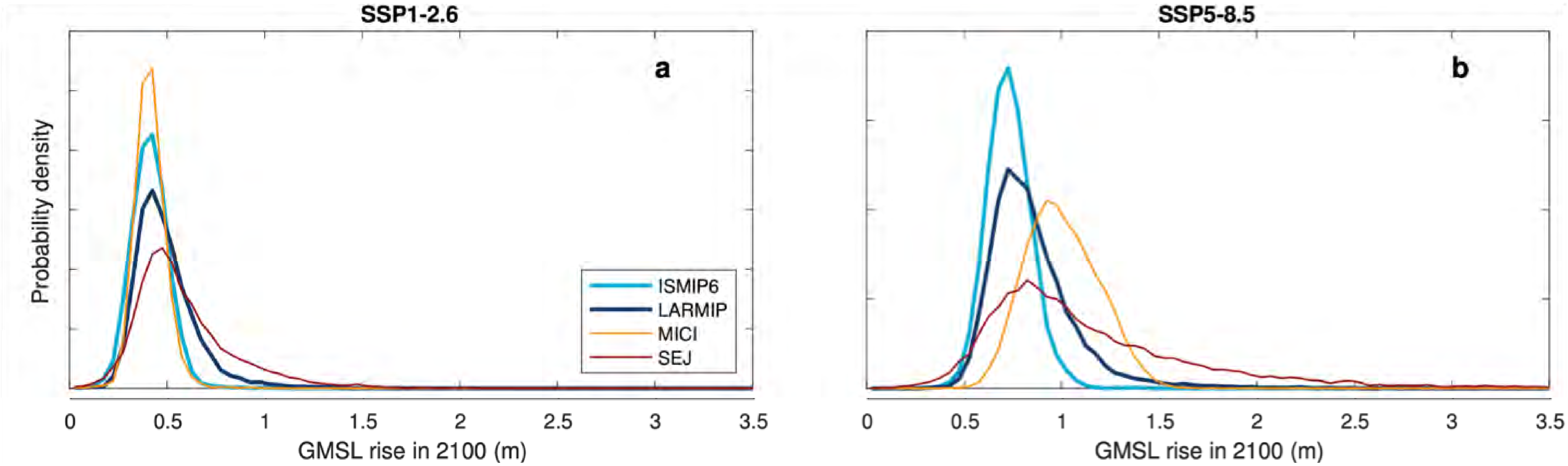
2°C compatible (SSP1–2.6):
1.8°C (1.3–2.4°C)
3.2°F (2.3–4.3°F)

A typical experiment in FACTS, the Framework for Assessing Changes To Sea-level



Kopp et al. (2023), NCC

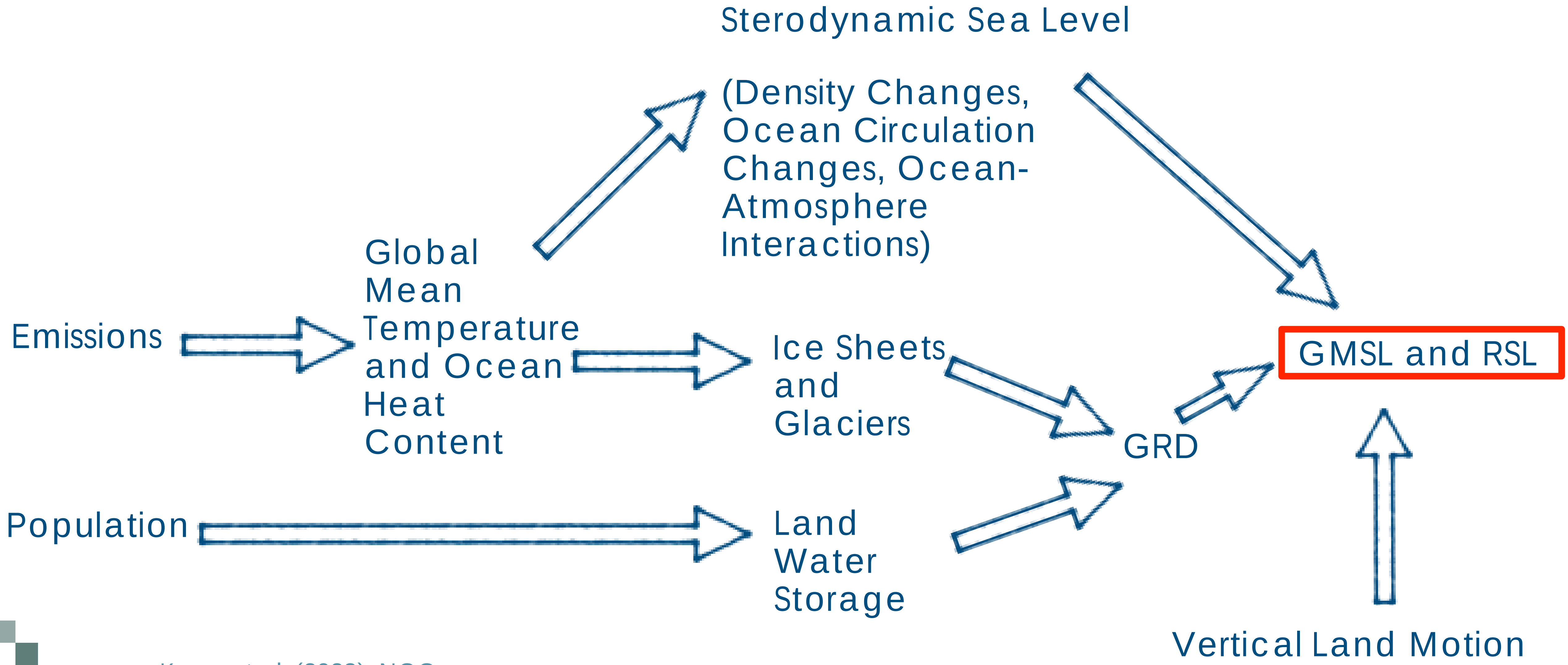
Different ice-sheet modeling approaches yield different sea-level distributions



'ISMIP6' and 'LARMIP' methods employ multi-model ice-sheet ensembles and are judged to capture processes in which there is at least ***medium agreement*** and ***evidence,*** thus ***medium confidence***. 'MICI' and 'SEJ' provide limited evidence for processes in which there is ***low confidence*.**

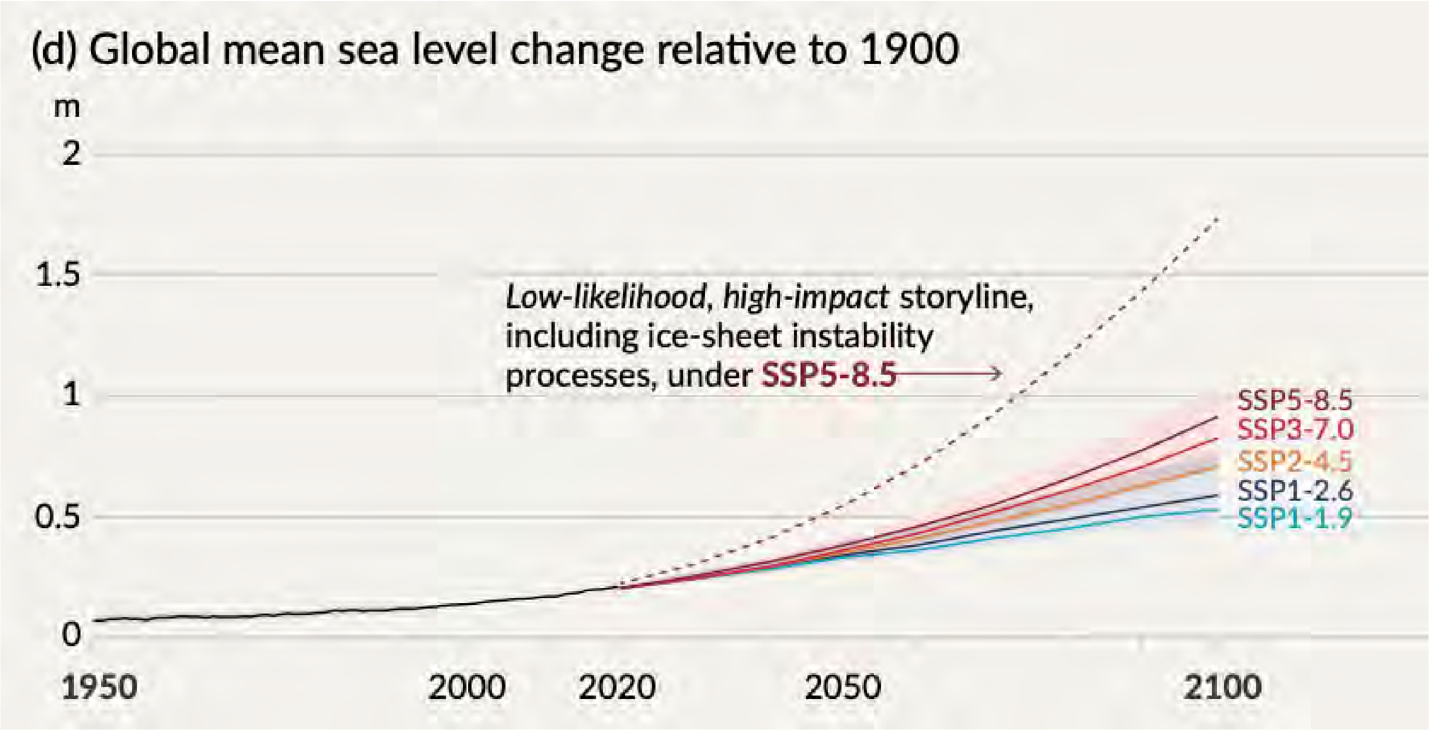
Kopp et al. (2023), NCC

A typical experiment in FACTS, the Framework for Assessing Changes To Sea-level



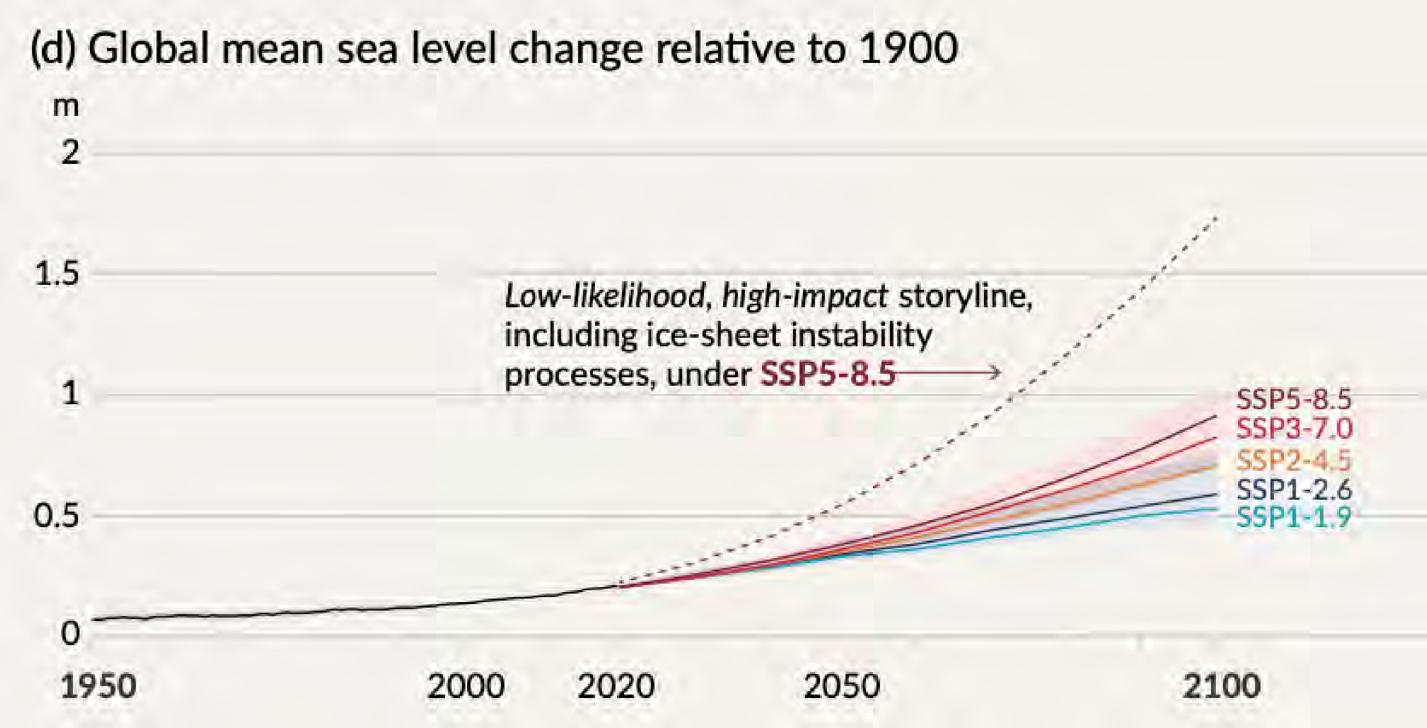
Kopp et al. (2023), NCC

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



AR6 WGI SPM, Box TS.4. Ch9

Through the middle of the century, sea level projections exhibit limited sensitivity to plausible changes in greenhouse gas emissions.



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

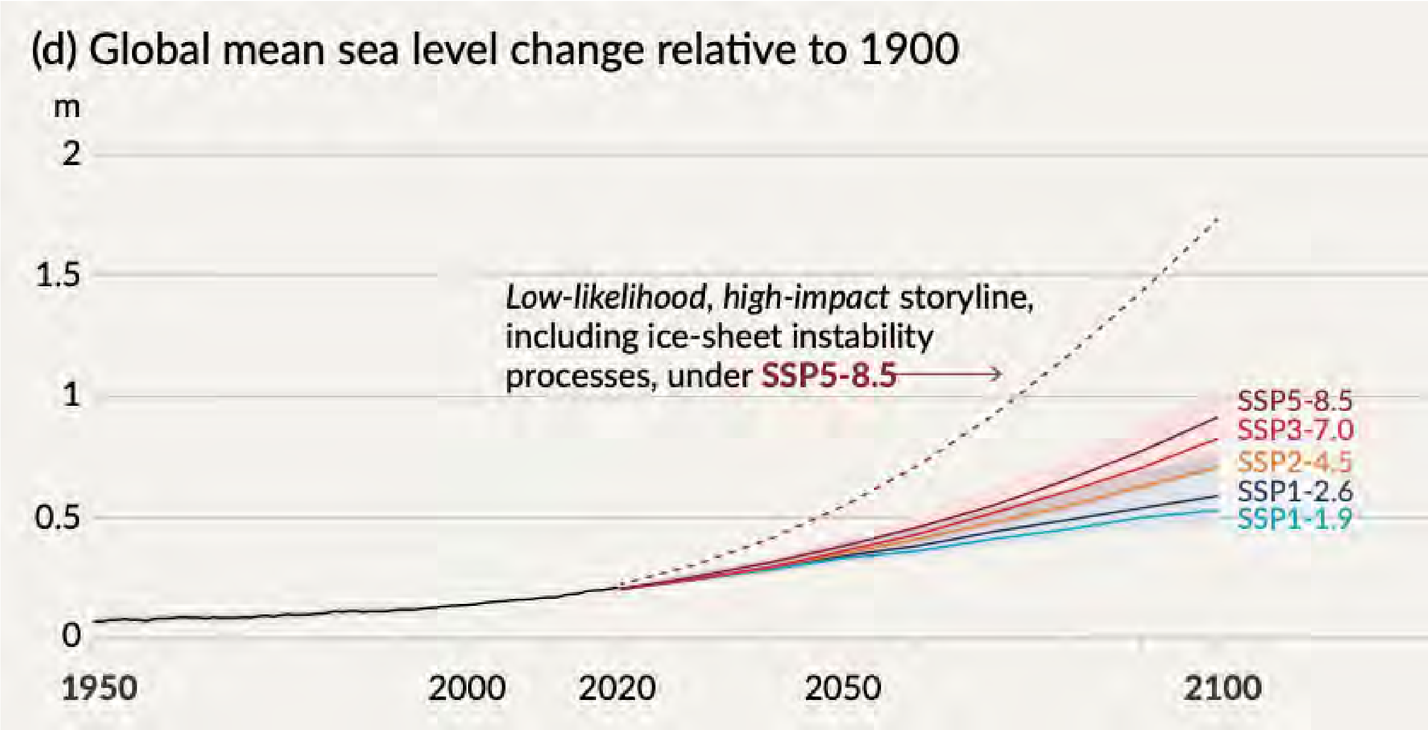
- 0.18–0.27 m (0.6–0.9 ft) under a high emissions scenario (SSP3–7.0)
- 0.16–0.25 m (0.5–0.8 ft) under a low emissions scenario (SSP1–2.6).

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

* "*Likely*" = at least a 2-in-3 chance

AR6 WGI SPM, Box TS.4. Ch9

Beyond 2050, sea level projections are increasingly sensitive to differences between emissions paths.



The *likely* global mean sea level rise is

by 2100:

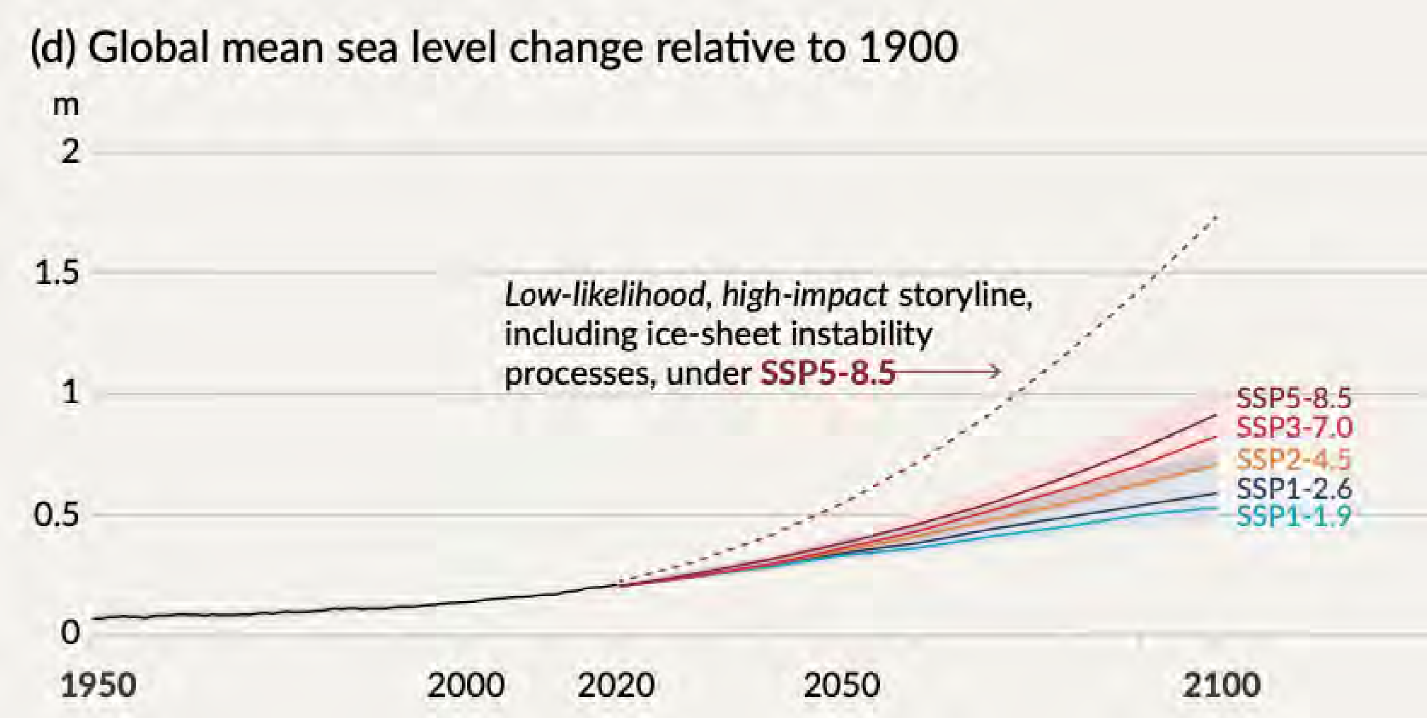
- 0.55–0.90 m (1.8–3.0 ft) under a high emissions scenario (SSP3–7.0)
- 0.32–0.62 m (1.0–2.0 ft) under a low emissions scenario (SSP1–2.6)

by 2150:

- 0.98–1.88 m (2.9–5.4 ft) under a high emissions scenario (SSP3–7.0)
- 0.46–0.99 m (1.5–3.2 ft) under a low emissions scenario (SSP1–2.6)

AR6 WGI SPM, Box TS.4. Ch9

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.



Post-IPCC work by our group suggests that, for intermediate emissions (SSP2–4.5), corresponding numbers are 1.5 m (5 ft) by 2100 and 3.6 m (12 ft) by 2150.

AR6 WGI SPM, Box TS.4. Ch9

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 melt and runoff from Greenland

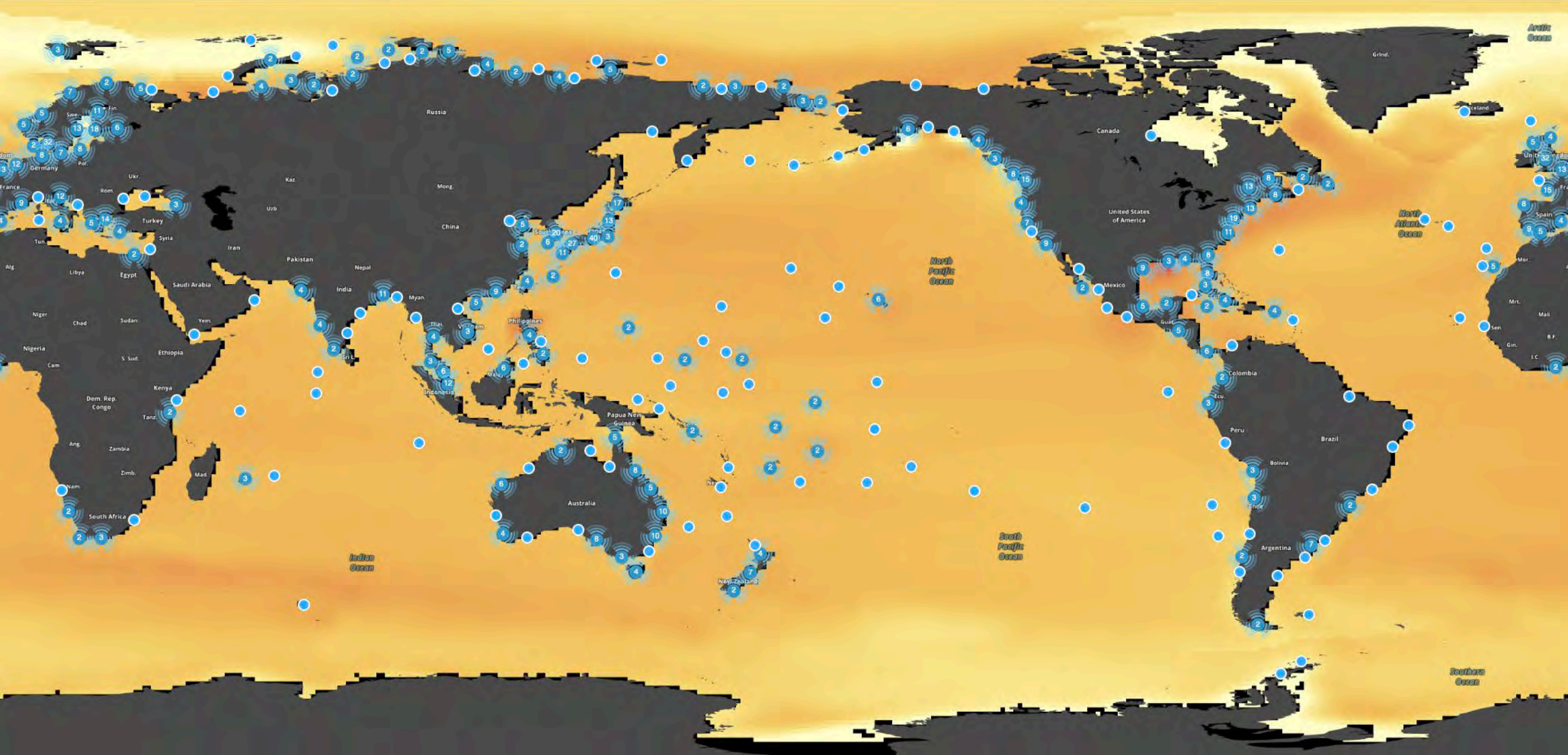
Global mean sea level rise above the *likely* range – approaching 2 m (7 ft) by 2100 and 5 m (16 ft) by 2150 under a very high GHG emissions scenario (SSP5-8.5) – cannot be ruled out.

EARTHDATA

SEA LEVEL CHANGE
Observations from Space | ipcc

Sea Level Projection Tool

sealevel.nasa.gov/ipcc



EARTHDATA

SEA LEVEL CHANGE
Observations from Space

ipcc

Sea Level Projection Tool

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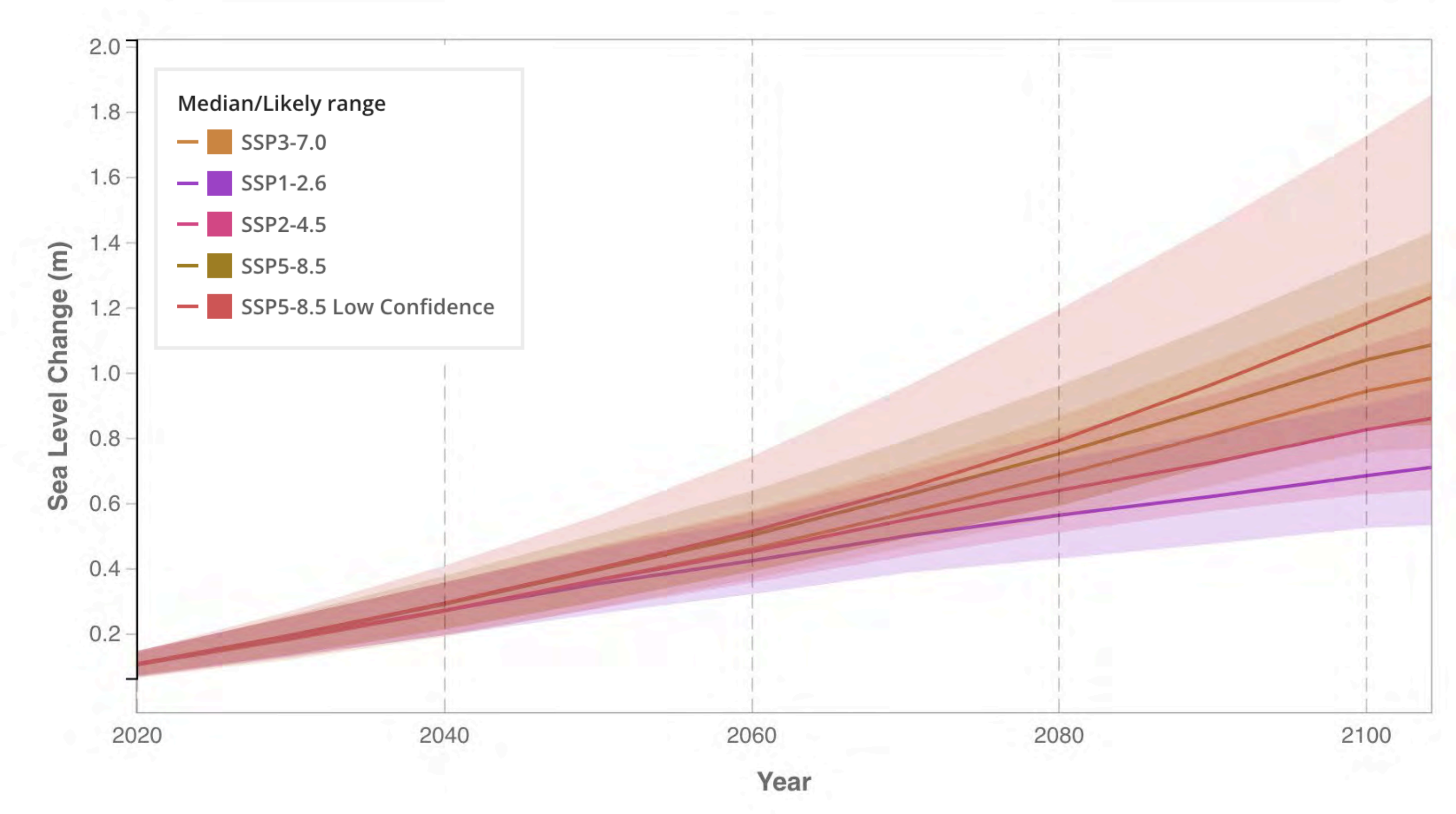
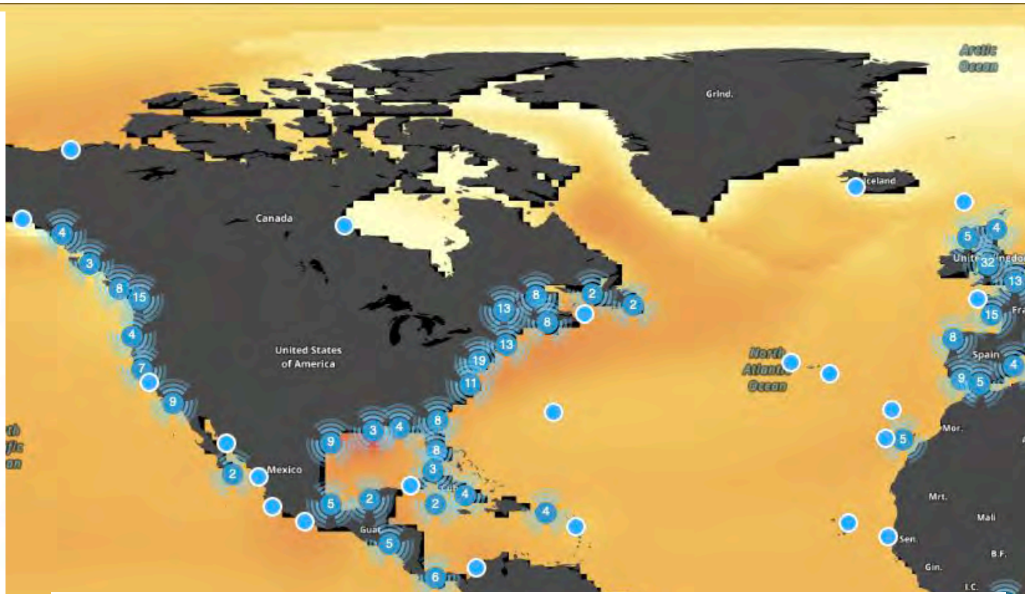




The *likely* Washington, DC, sea level rise by 2100 is:

- 0.76–1.21 m (2.5–4.0 ft) under a high emissions scenario (SSP3–7.0)
- 0.52–0.90 m (1.7–3.0 ft) under a low emissions scenario (SSP1–2.6)

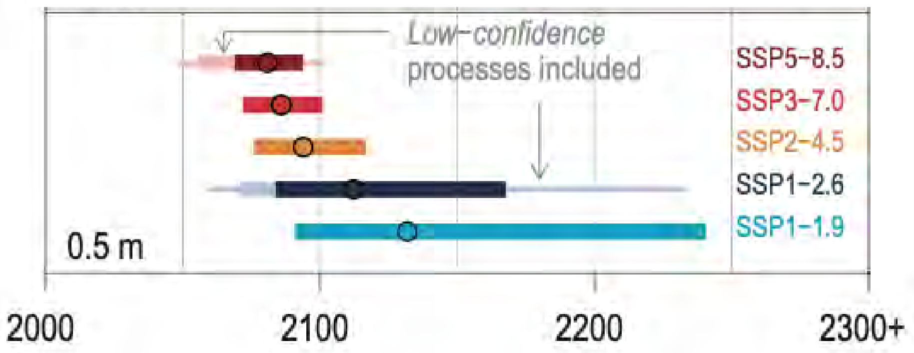
Sea-level rise exceeding 1.7 m (5.5 ft) (at the 83rd pecentile, under very high emissions) cannot be ruled out.

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

Considering only *medium confidence** processes, global mean sea level rise is *likely* to exceed 0.5 m (1.6 ft) between:

- about 2080 and 2170 under low emissions (SSP1–2.6)
- about 2070 and 2090 under very high emissions (SSP5–8.5)

(c) Projected timing of sea level rise milestones



* "*Medium confidence*" = medium amount of evidence, medium degree of agreement

AR6 WGI Box TS.4, Ch9

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

Considering only *medium confidence** processes, global mean sea level rise is *likely* to exceed 0.5 m (1.6 ft) between:

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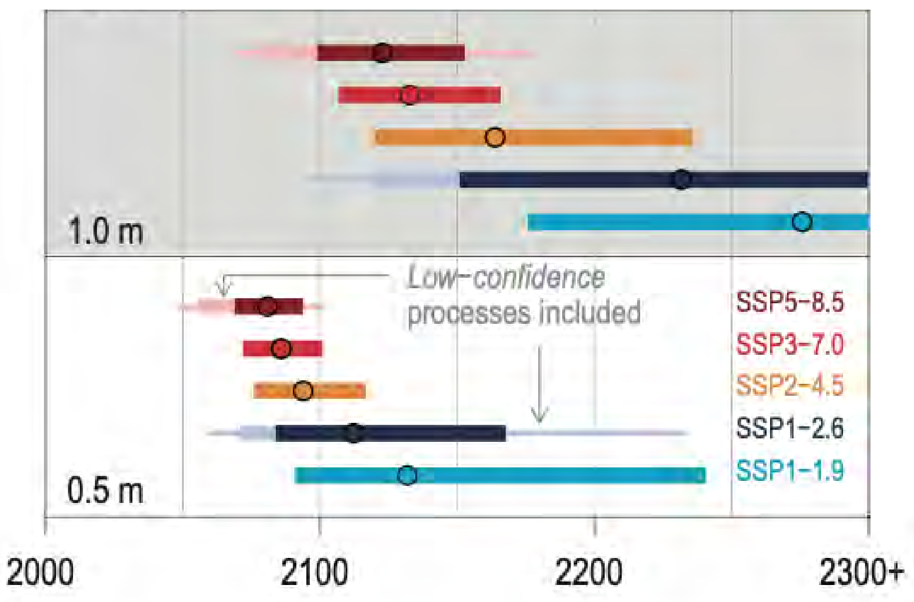
It is *likely* to exceed 1.0 m (3.3 ft) between:

- about 2150 and some point after 2300 under low emissions
- about 2100 and 2150 under very high emissions

(c) Projected timing of sea level rise milestones



AR6 WGI Box TS.4, Ch9

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

Considering only *medium confidence** processes, global mean sea level rise is *likely* to exceed 0.5 m (1.6 ft) between:

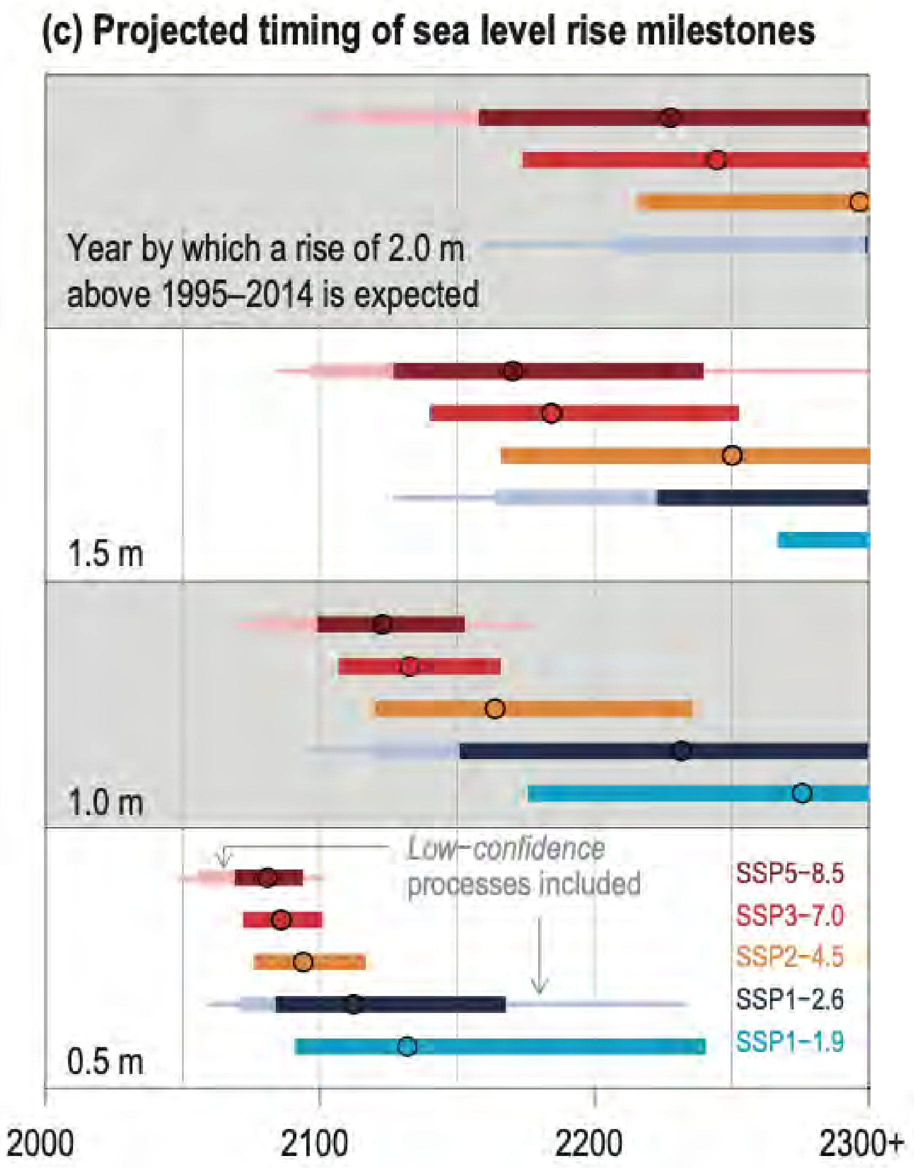
- about 2080 and 2170 under low emissions (SSP1–2.6)
- about 2070 and 2090 under very high emissions (SSP5–8.5)

It is *likely* to exceed 1.0 m (3.3 ft) between:

- about 2150 and some point after 2300 under low emissions
- about 2100 and 2150 under very high emissions

Considering also processes in whose projections there is *low confidence**, a the 83rd percentile under very high emissions:

- 1.0 m (3.3 ft) could be exceeded by about 2080
- 2.0 m (6.6 ft) could be exceeded by about 2110



* "*Low confidence*" = limited evidence, low level of agreement

AR6 WGI Box TS.4, Ch9

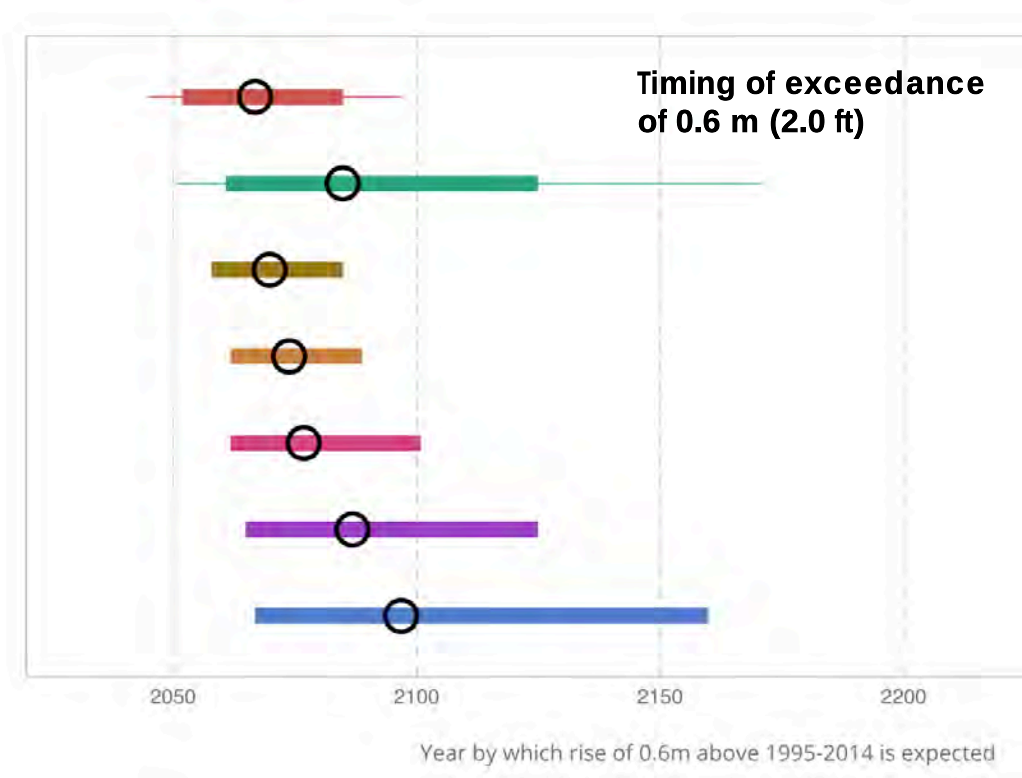
EARTHDATA

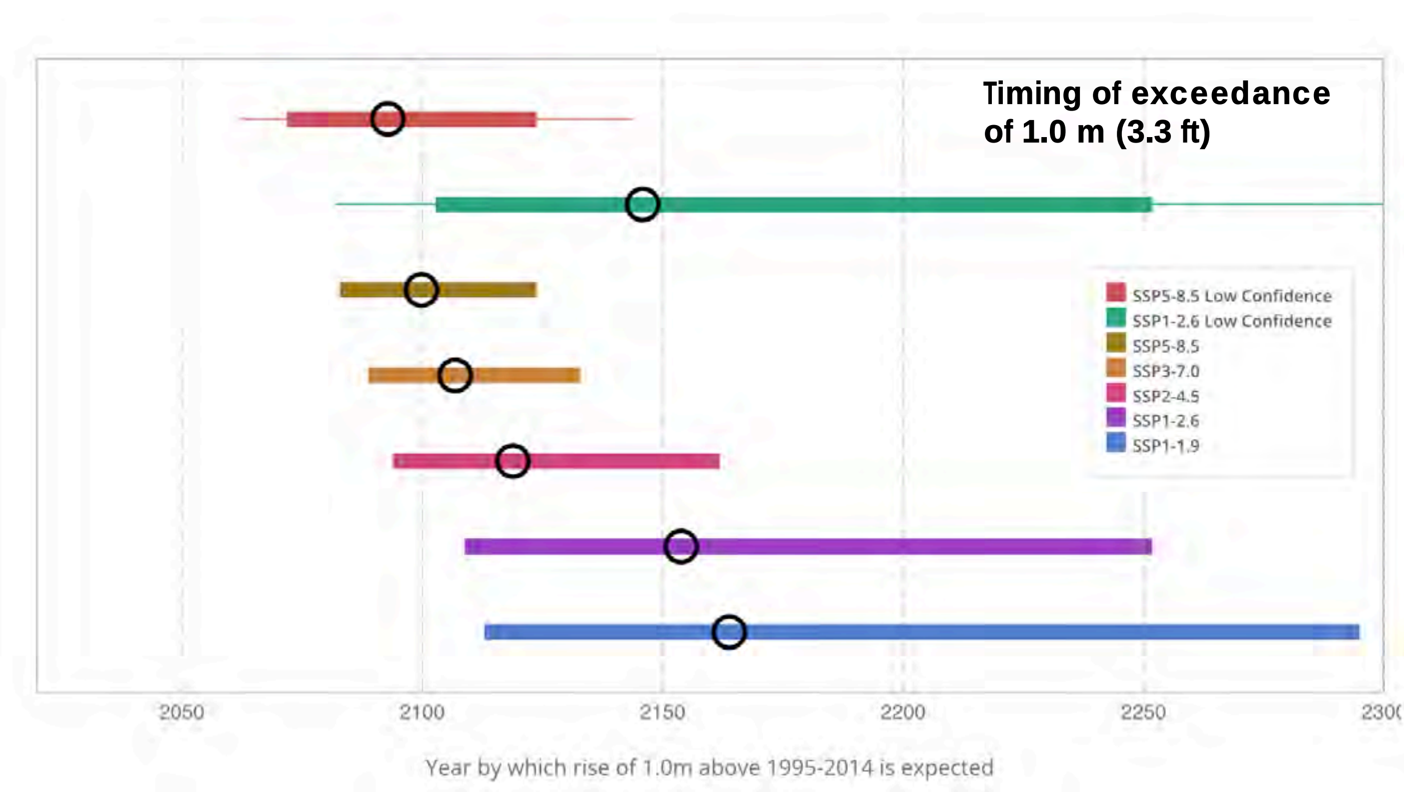
SEA LEVEL CHANGE Observations from Space | ipcc

Sea Level Projection Tool

sealevel.nasa.gov/ipcc

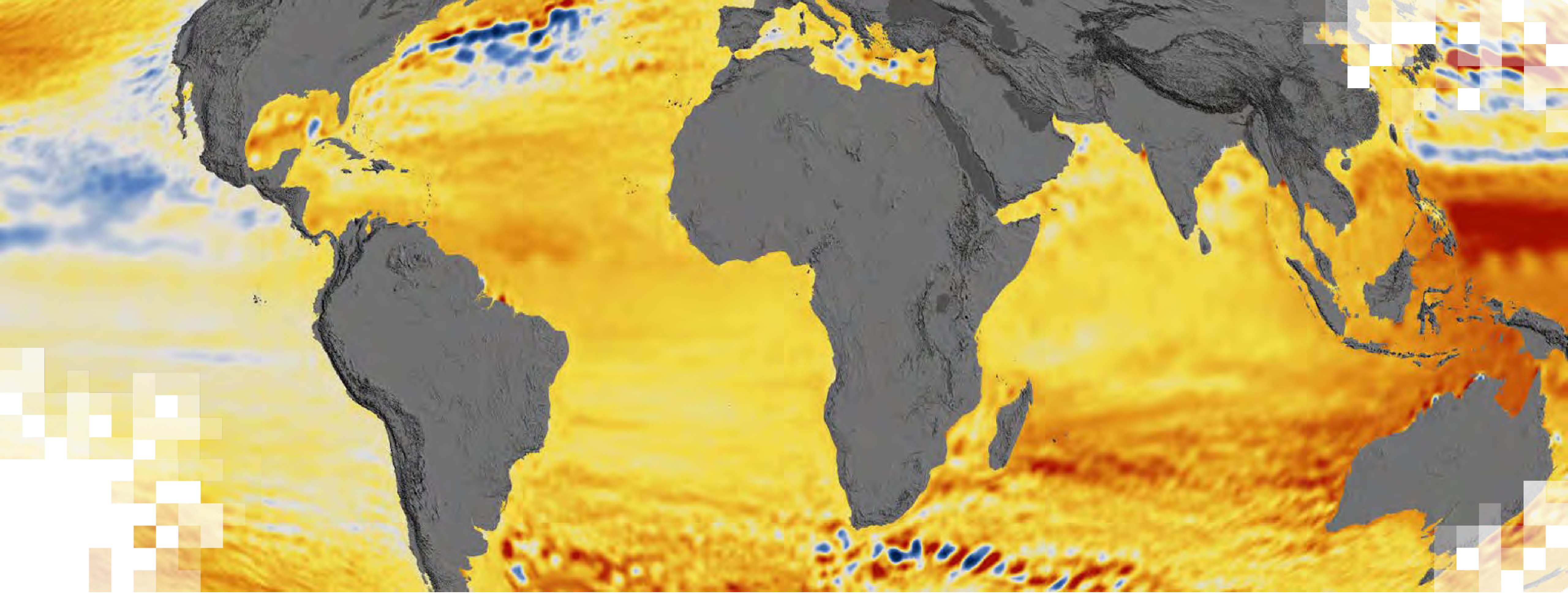
Washington, DC





Under intermediate emissions (SSP2–4.5) at Washington, DC, considering only *medium* and *high confidence* processes:

- **0.6 m (2.0 ft) of sea-level rise will *likely* be exceeded between about 2060 and 2100**
- **1.0 m (3.3 ft) of sea-level rise will *likely* be exceeded between about 2090 and 2170.**



Pacific Islands Flooding Analysis Tool

Phil Thompson, PhD
University of Hawaiʻi at Mānoa

Sea-Level Rise (SLR) → More Severe, More Frequent Flooding

- What do we care about most from an **impacts** perspective?
  - Average or mean sea level
  - Average or mean high tide (i.e., Mean Higher High Water)
  - High tides above flooding thresholds

Sea-Level Rise (SLR) → More Severe, More Frequent Flooding

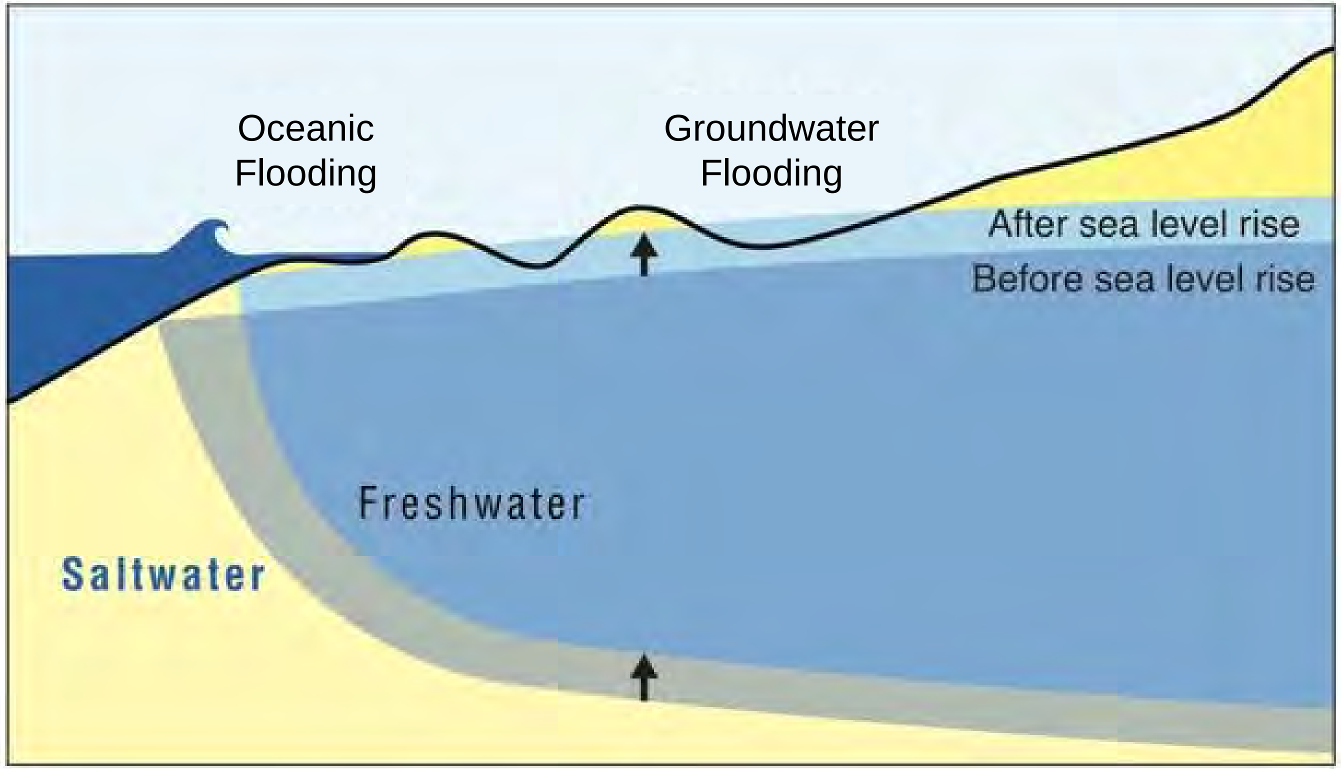
- What do we care about most from an **impacts** perspective?
  - Average or mean sea level
  - Average or mean high tide (i.e., Mean Higher High Water)
  - **High tides above flooding thresholds ✓**

- NASA flooding analysis tools focus on the **number of days per year that high tide exceeds a threshold**.
  - Roughly 25 days per year is considered “chronic” flooding
  - 50–100 days of flooding per year makes land unusable

- There are two NASA Flooding Analysis Tools
  - One is focused on **Pacific Islands** and IPCC AR6 projections.
    - We’ll focus on this one—it has a mapping component.
  - The other is focused on **US coastlines** and US SLR scenarios.

Two Types of Flooding Exposure

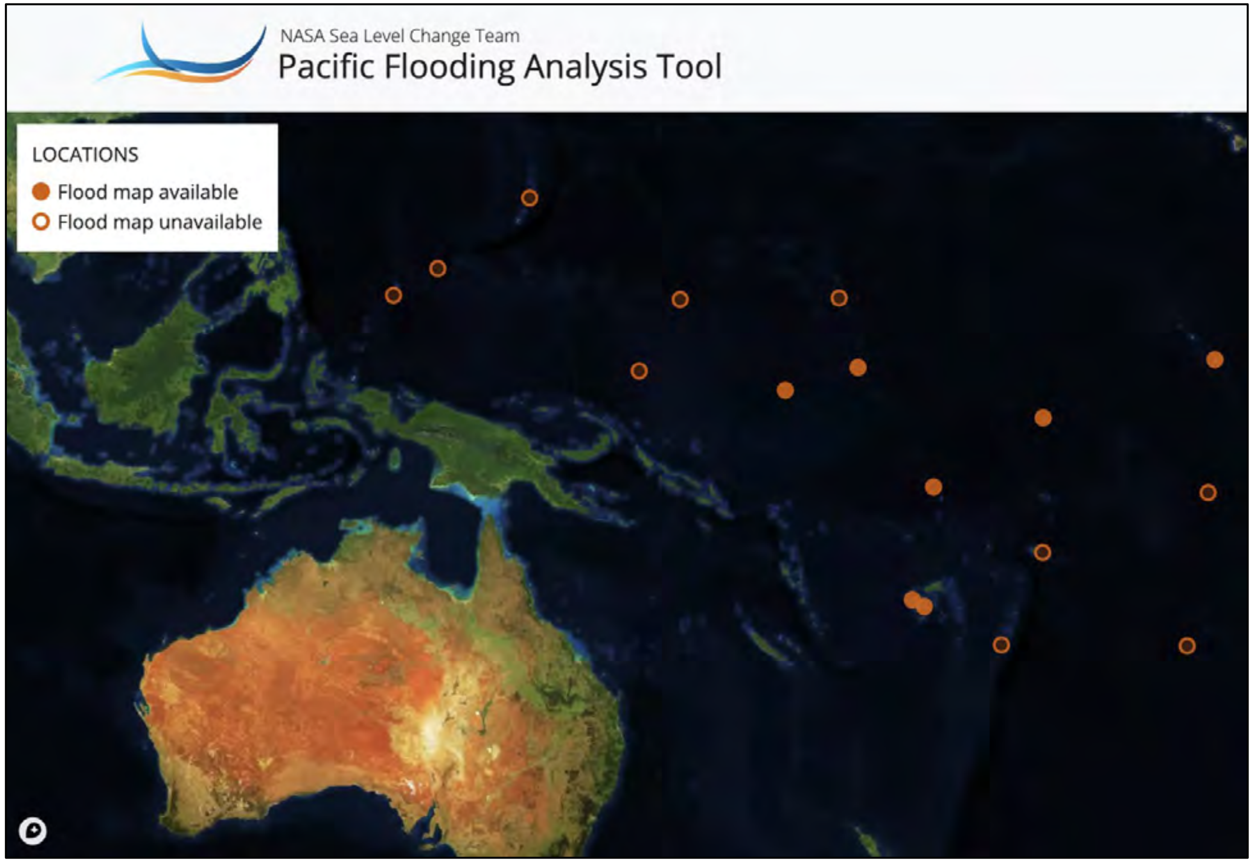
- **Oceanic Flooding**
  - Occurs due to flow of ocean water onto land.
- **Groundwater Flooding**
  - Occurs due to groundwater rising from below to the surface.
- The **Pacific Islands Flooding Analysis Tool** includes both.
  - Exposure to groundwater flooding is harder to estimate.
  - The tool **does not include** the impact of **waves**.



Projecting Future Flooding Frequency

Step 1: Choose a location

- This one is obvious …
  - Note that **only certain islands have mapping capability** at present.
  - We will expand to more locations soon and include as many as possible locations going forward.

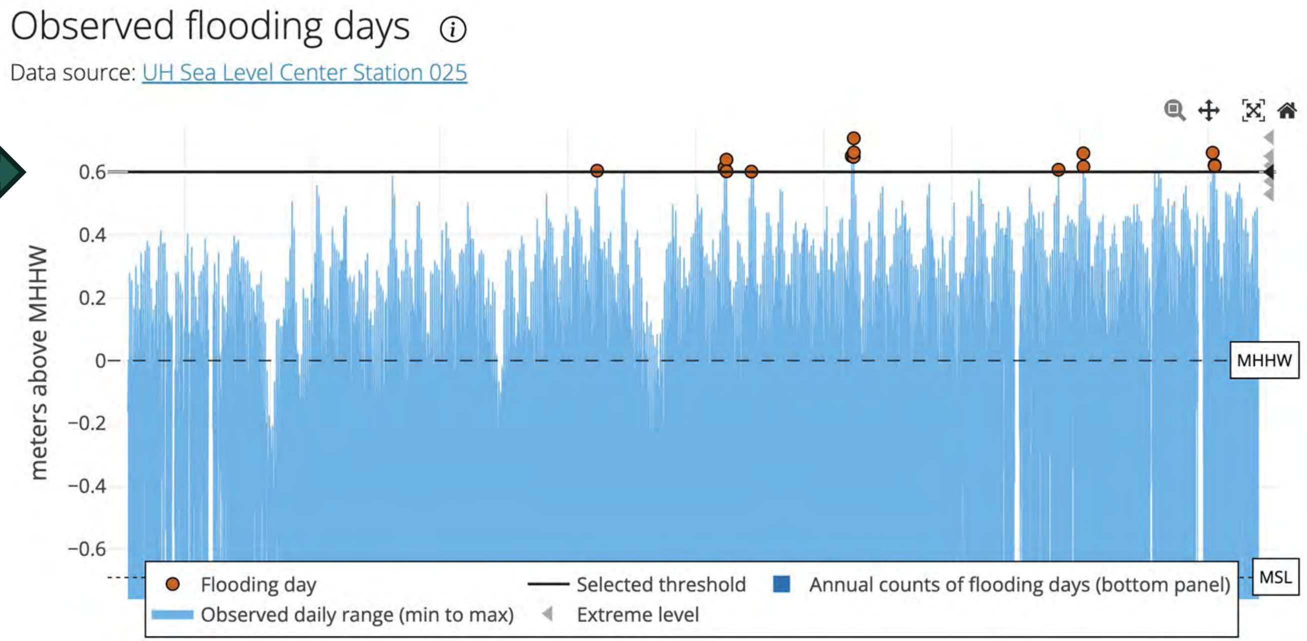


Pacific Flooding Analysis Tool

Projecting Future Flooding Frequency

Step 2: Choose a flooding threshold

- The Pacific Islands tool allows you to choose a **flooding threshold** for assessment.
- To help **choose a relevant threshold**, you can …
  - See when the threshold was exceeded in the past using tide gauge observations.
  - See the extent of flooding associated with this threshold in the map.
- Note the flooding extent shows oceanic and groundwater flooding exposure in different colors.

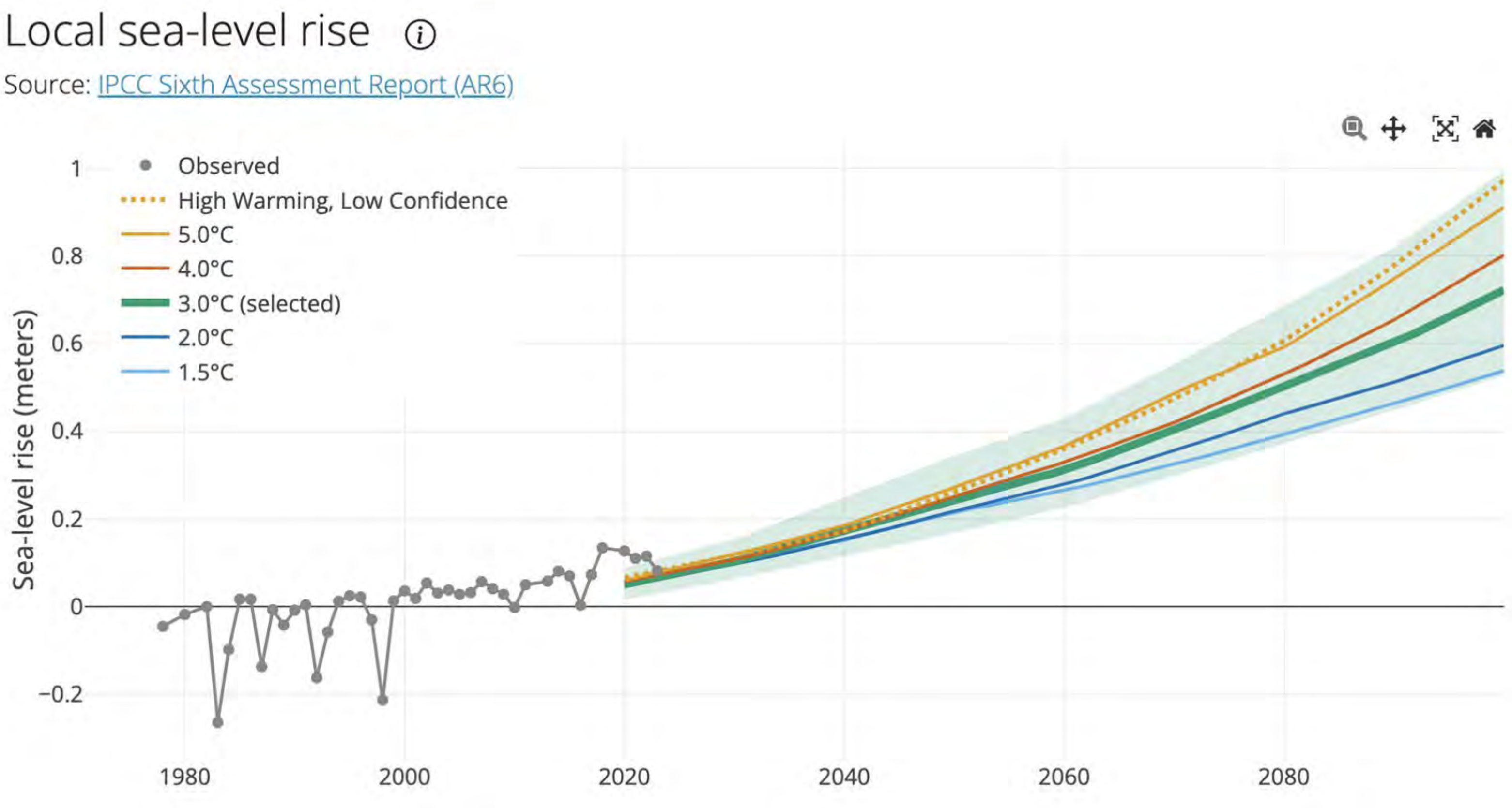


Projecting Future Flooding Frequency

Step 3: Choose a sea-level rise projection/scenario

- The Pacific Islands tool allows you to choose a SLR projection based on **end-of-century warming level** from the IPCC AR6 report.

- These are the same projections offered in the **IPCC AR6 Projections Tool** described in the previous training section.



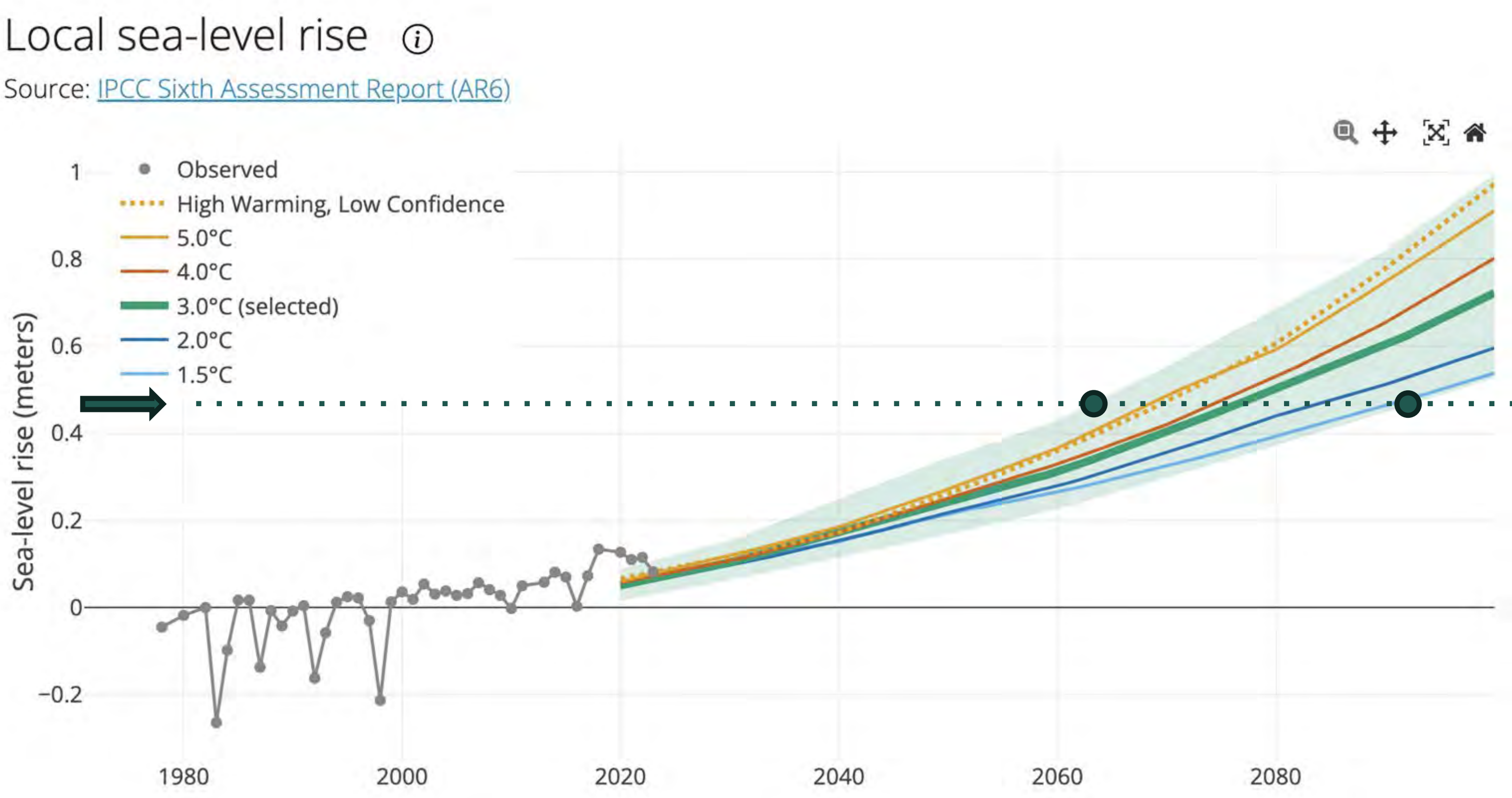
Projecting Future Flooding Frequency

Step 3: Choose a sea-level rise projection/scenario

- The Pacific Islands tool allows you to choose a SLR projection based on **end-of-century warming level** from the IPCC AR6 report.

- These are the same projections offered in the **IPCC AR6 Projections Tool** described in the previous training section.

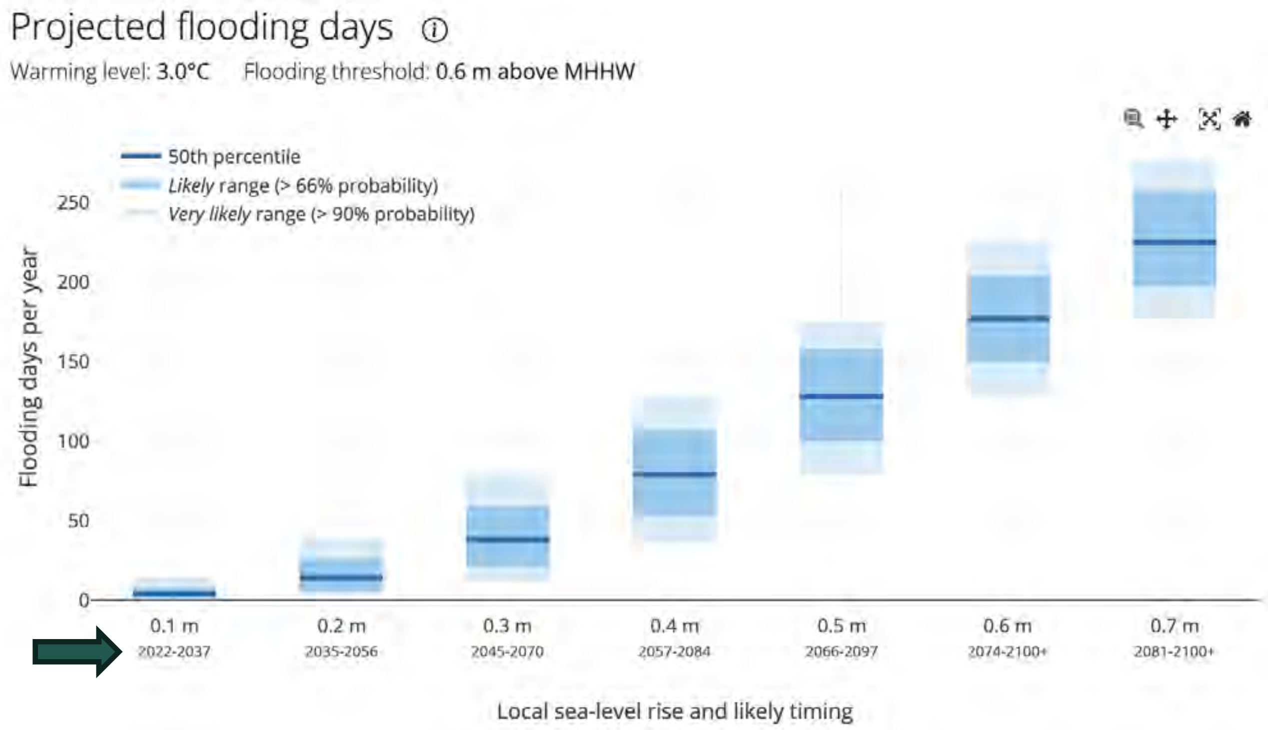
- These projections provide a range of possibilities for each warming scenario.
  - Any **specific amount of SLR** could occur by a **range of possible years**.

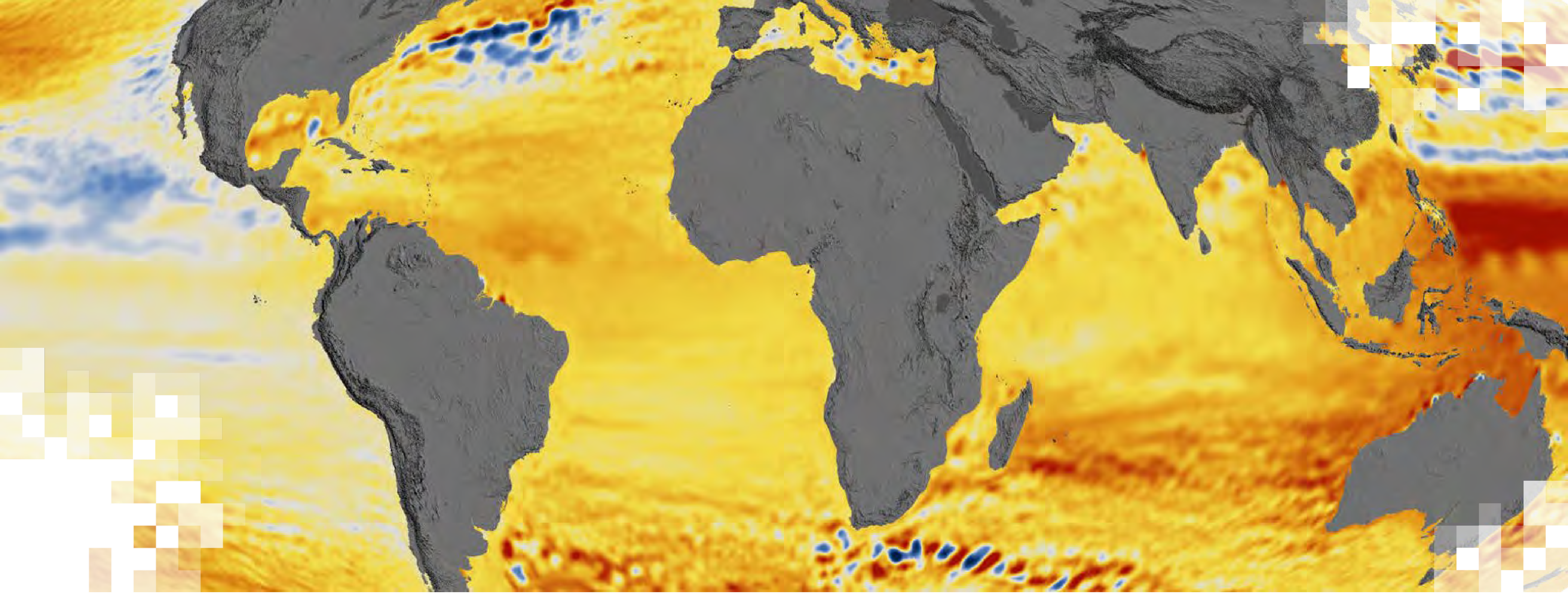


Projecting Future Flooding Frequency

Step 4: Assess changes in flooding frequency

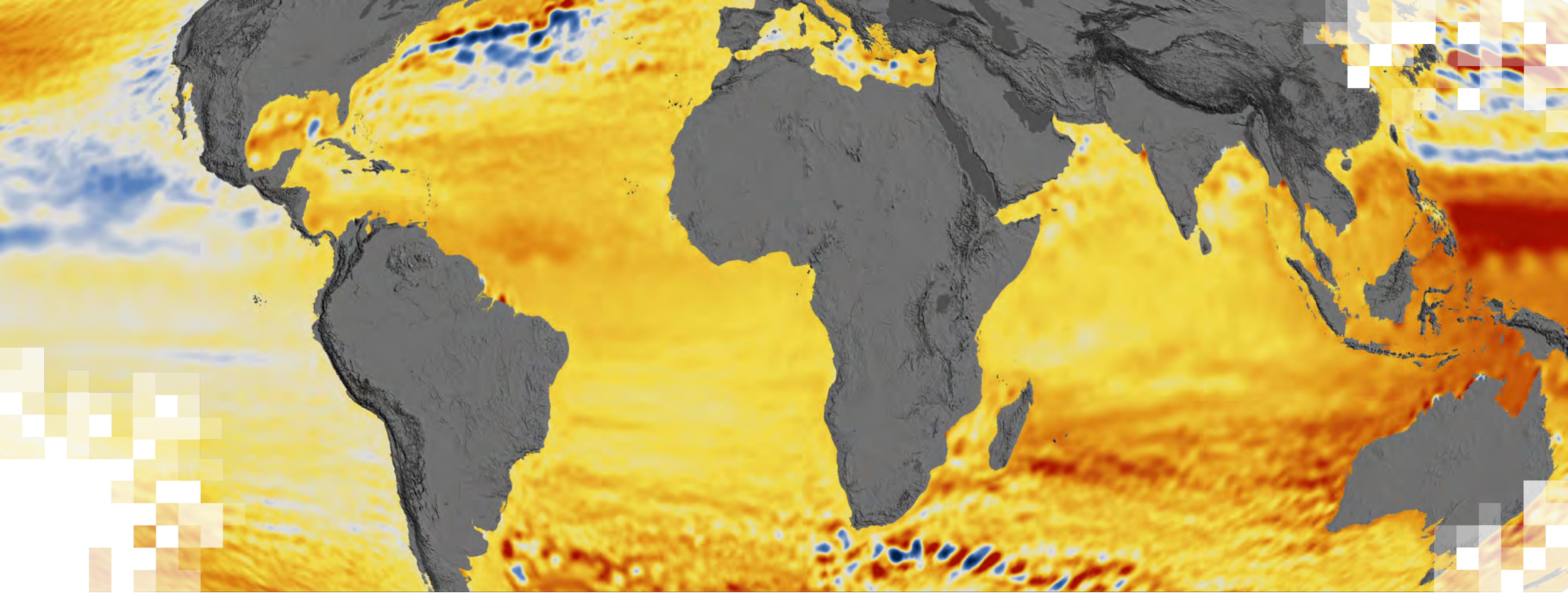
- The **flooding frequency results** are provided as:
  - Number of flooding days per year on the vertical axis.
  - Amounts of SL rise on the horizontal axis.
- The amounts of SLR are associated with **a likely range of possible years** when the SLR will occur.
  - See previous slide.
- The **range in flooding days per year** reflects that mean SL and tidal range vary from year to year.
  - E.g., El Niño events have a big effect on SL.
  - Tidal range fluctuates with changes in the orbits of the Earth and Moon.





Let’s explore the tool ...

https://sealevel.nasa.gov/flooding-analysis-tool-pacific-islands/



Connections to Other ARSET Trainings

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Overview

- Here, we reference and describe other ARSET trainings, which are connected to this present training in one of three ways:
  - They offer introductory and background training.
  - They make direct use the NASA sea-level change tools as part of broader analyses.
  - They provide training on other related applications.

- Many other ARSET trainings exist and can be found on NASA's Applied Sciences Website.

Introductory and Background Trainings

- Introduction to NASA Resources for Climate Change Applications
  - Overview of NASA resources for monitoring climate change and its impacts
  - Role of Earth observations in climate change assessment
  - Overview of NASA climate models suitable for emissions policy, impacts, risk, and resilience applications

- Selecting Climate Change Projection Sets for Mitigation, Adaptation, and Risk Management Applications
  - Resources for choosing climate projection sets for mitigation, adaptation, and risk management applications
  - Distinguishing characteristics of climate projection sets, and then highlight the main benefits and drawbacks of different types of projection sets

Application of Sea-Level Change Tools for Hazard and Risk Assessment

- Satellite Observations for Analyzing Natural Hazards on Small Island Nations
  - Introduction to the data, methods, and tools useful for monitoring natural hazards, with a specific focus on small island nations
  - Case studies on storm impacts, sea level rise, and landslides

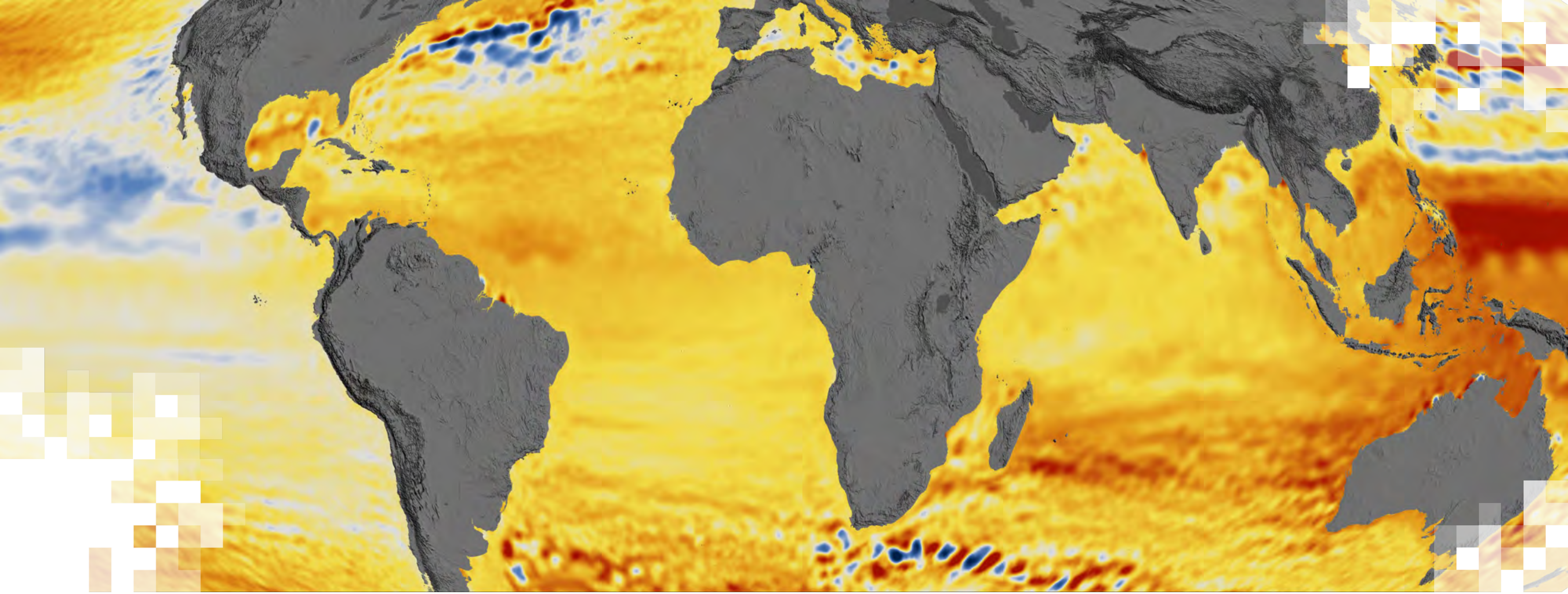
- Building Climate Risk Assessments from Local Vulnerability and Exposure
  - Climate risk assessment approaches, informed by stakeholder expertise in the fundamental climate vulnerability and exposure of their system
  - Utilizing climate observations and projections sets selected to suitably address risks
  - Examples from the NASA Climate Adaptation Science Investigators (CASI) Program that is preparing NASA facilities for future climate resilience, including the use of NASA sea-level change tools to project exposure to sea-level change at NASA facilities

Other Related Applications

- SAR for Detecting and Monitoring Floods, Sea Ice, and Subsidence from Groundwater Extraction
  - Builds on other previous trainings on the use of Synthetic Aperture Radar (SAR) data
  - Two new focus areas in this training: (1) the use of InSAR to measure subsidence due to groundwater extraction, and (2) the use of SAR to detect and monitor sea ice

- The Application of Earth Observations for Assessing Waterborne Disease Risk
  - Remote sensing observations useful as water quality indicators of waterborne diseases
  - Important for monitoring water quality in coastal regions, although this training does not focus specifically on that aspect

- Many other trainings with coastal applications!



Sea-Level Change Tools for Planning and Decision Support

Summary

Training Summary

- Greenhouse gases added to air by human activities are warming the planet
  - Ocean expands as it warms
  - Ice sheets and glaciers melt, adding water to oceans
  - Global sea level rises
- NASA has unique capabilities in remote sensing and modeling for assessing sea level change, e.g.,
  - Radar altimetry (Sentinel-6 Michael Freilich), Laser altimetry (ICESat-2), Gravimetry (GRACE-FO)
- Overview and demonstration of Sea-Level Explorer
  - Provides high-level synthesis of past, present, and future sea-level rise and impacts for coastal locations around the world.
- Overview and demonstration of Sea Level Projection Tool
  - A key driver of the range of possible futures is the range of possible human emissions.
  - The more we limit our emissions, the more time we have to adapt to sea-level rise.
- Overview and demonstration of Pacific Islands Flooding Analysis Tool
  - Assess amounts of sea-level rise expected for various amounts of end-of-century global warming.
  - View maps showing the extent of future high-tide flooding for select locations.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on June 17, 2025
  - Access from the [training webpage]
  - Answers must be submitted via Google Forms
  - **Due by July 1, 2025**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Acknowledgements

Dr. Robert Kopp
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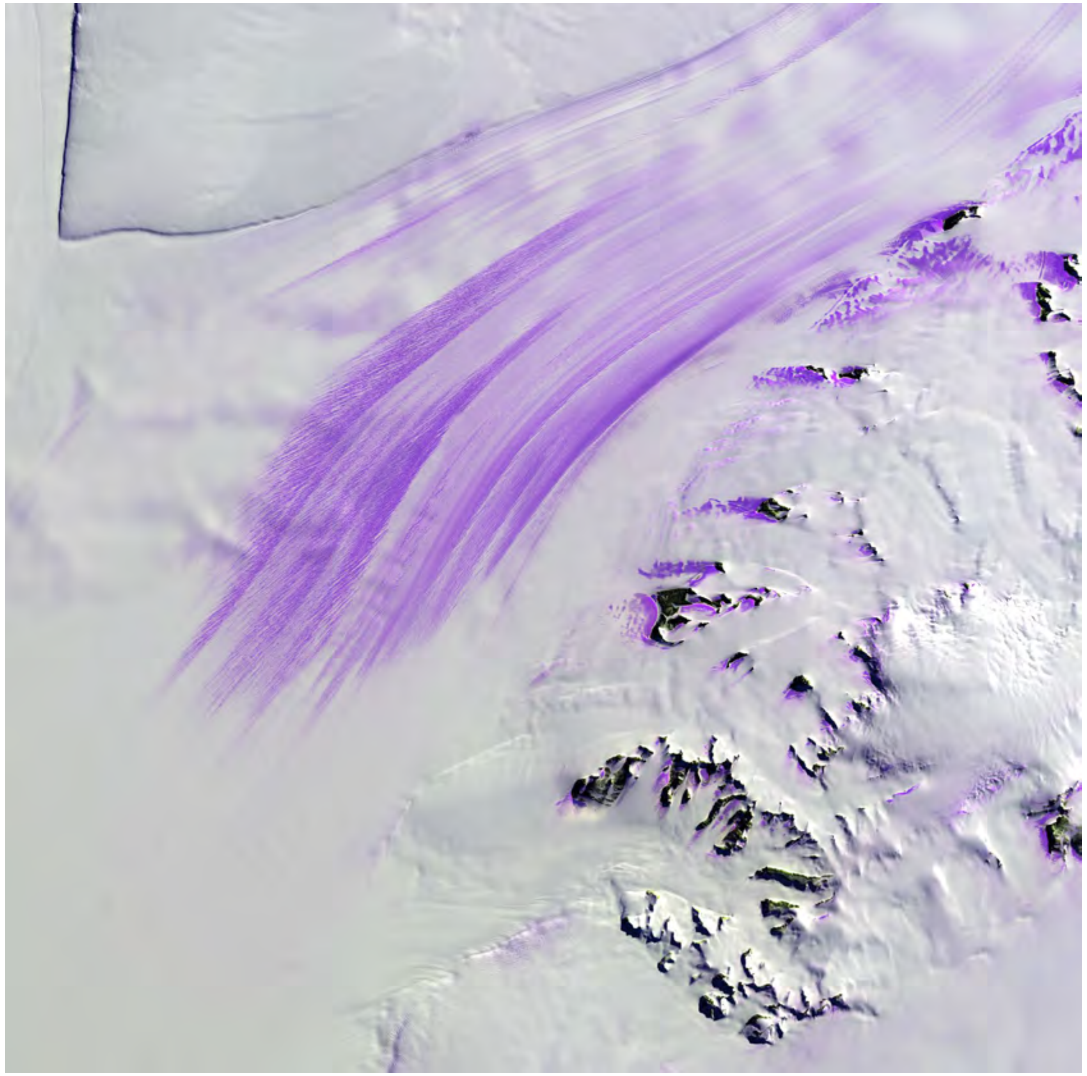
- ARSET Website
- ARSET YouTube

Resources

- NASA/IPCC Sea-Level Projection Tool
- IPCC Sixth Assessment Report
  (see particularly Box TS.4 and links therein)
- Kopp et al. (2023). Communicating future sea-level rise uncertainty and ambiguity to assessment users. *Nature Climate Change* 13, 648–660.
- Everything you need to know about the **NASA Pacific Islands Flooding Analysis Tool** is here: https://sealevel.nasa.gov/flooding-analysis-tool-pacific-islands/about/
  – This link includes:
    - **Instructions** that describe how to use the tool.
    - Background that describes factors affecting flooding frequency.
    - Methodology overview that describes the basic procedure for creating the flooding projections.

Questions?

- Please enter your questions in the Q&A box. We will answer them in the order they were received.
- We will post the Q&A to the training website following the conclusion of the webinar.



Credit: [USGS, Landsat 8]

Thank You!