# Climate Change Decision Support for the Navy
# With a Focus on Extreme Events

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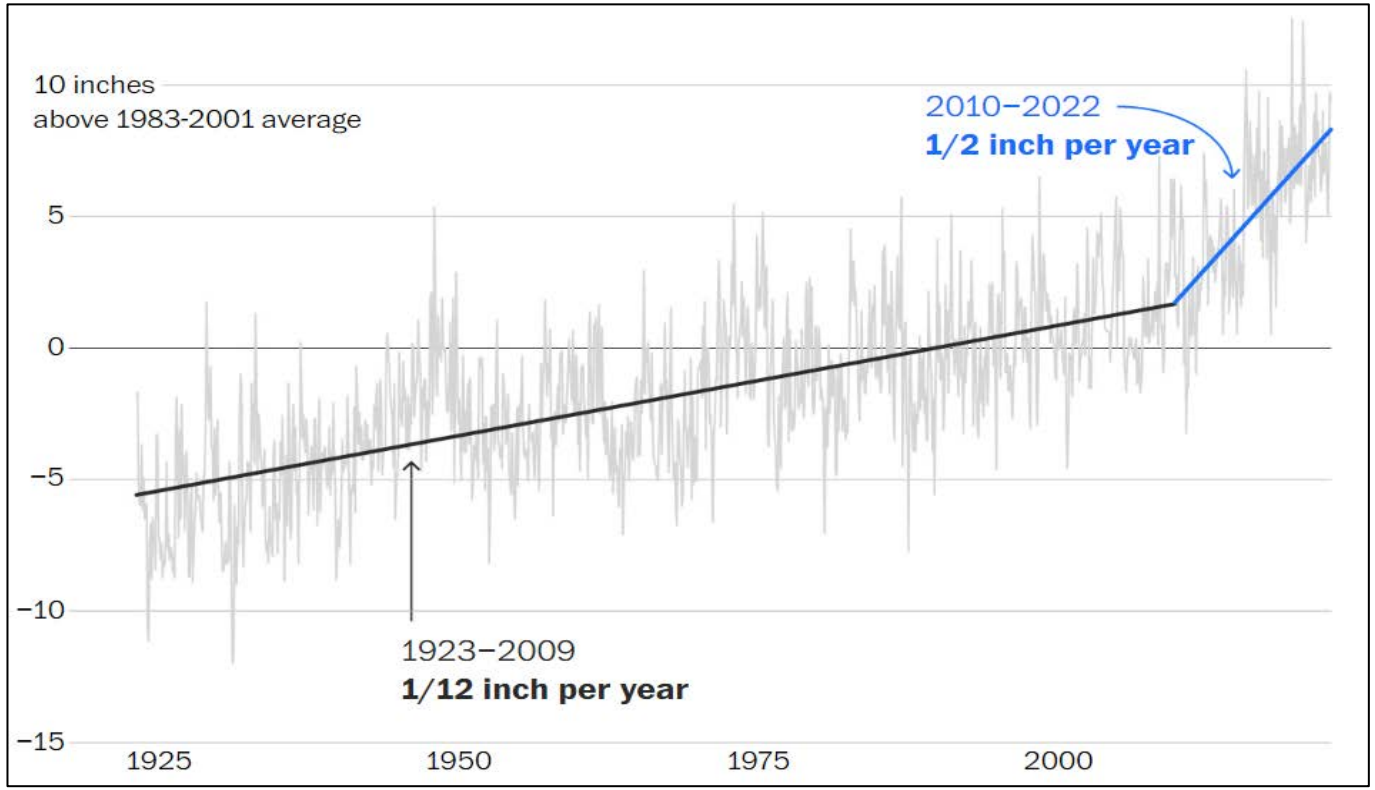
**Presentation for Department of the Navy Climate Change Tabletop Exercise II**
**April 27-28, 2023 / Naval Postgraduate School, Monterey, CA**

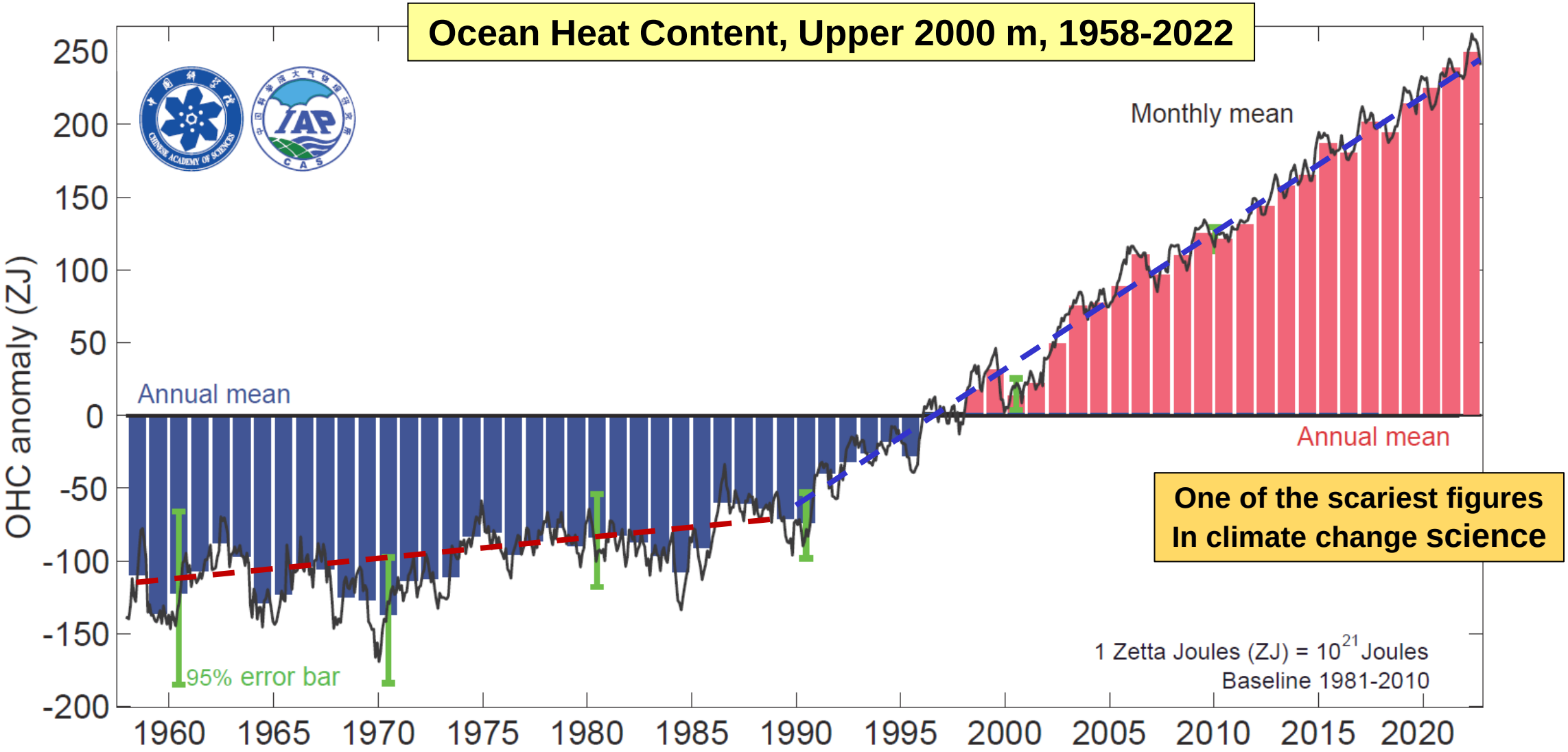



Sea level rise, Pensacola, Florida, 1925-2022

Damage from Hurricane Michael, Florida Panhandle, Oct 2018

See additional information in slide notes (e.g., credits, sources, references, comments).

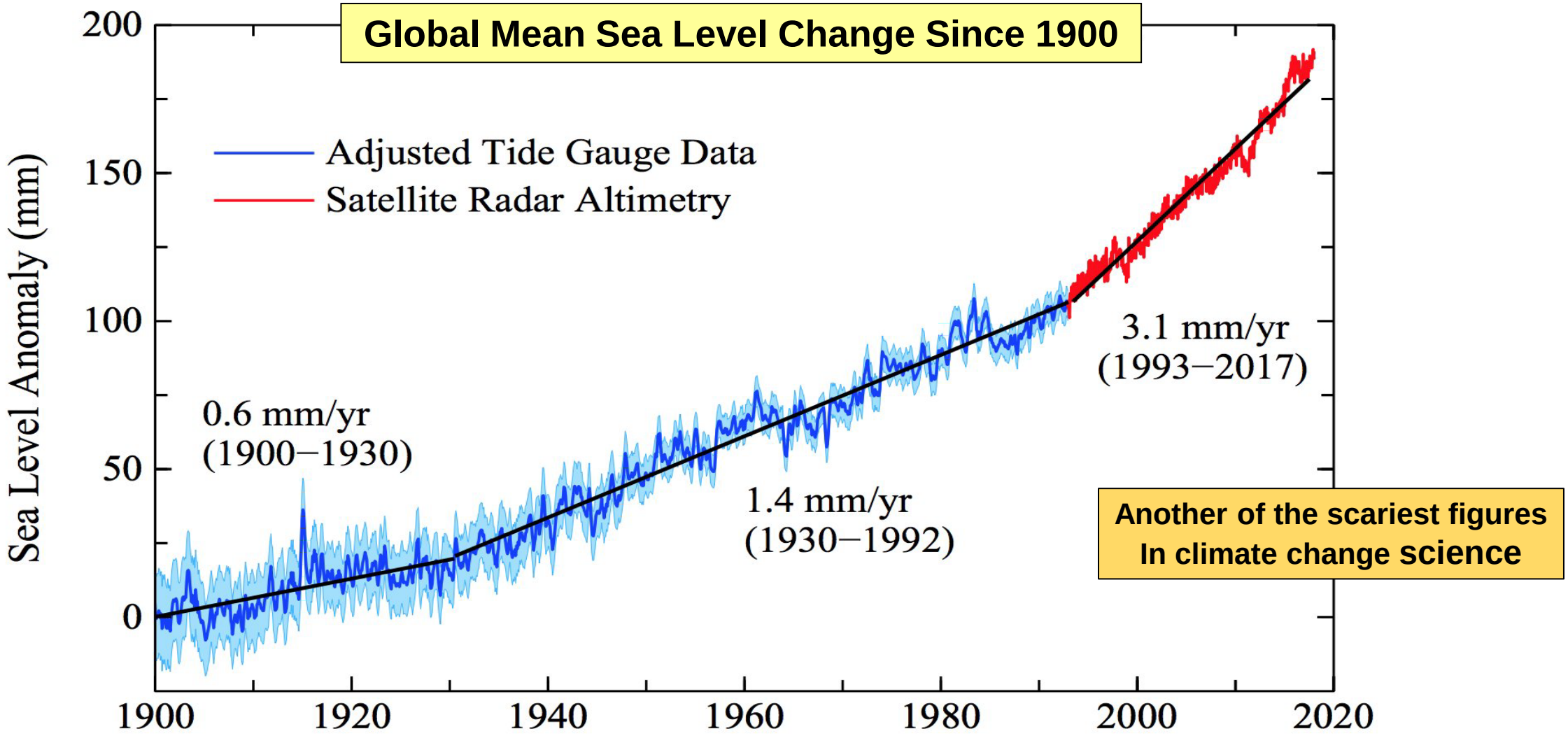
# Climate Change: Ocean Temperature Increases




**One of the scariest figures In climate change science**

- **Approximately 90% of Earth's warming in the last 150 years has occurred within the ocean.**
- **Note the acceleration of ocean warming starting in the late 1980s.**
- **Most of the ocean warming has occurred in the upper ocean.**

# Climate Change: Sea Level Rise




- Sea level has been rising globally for many years.
- The rise has accelerated and is now five times greater than it was 100 years ago.
- Sea level rise has major impacts on flooding, water resources, infrastructure, habitability, and more.

# Climate Change and Extreme Events

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**Extreme Drought**
**Horn of Africa, 2020-2022**

**Climate change made this East African drought 100 times more likely.**

Dayniile displaced people camp in the Mogadishu region, Somalia. Image by Ismail Taxta, ICRC..

# Climate Change and Extreme Events

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**Extreme High Temperatures**
**Pakistan and India, Mar-May 2022**

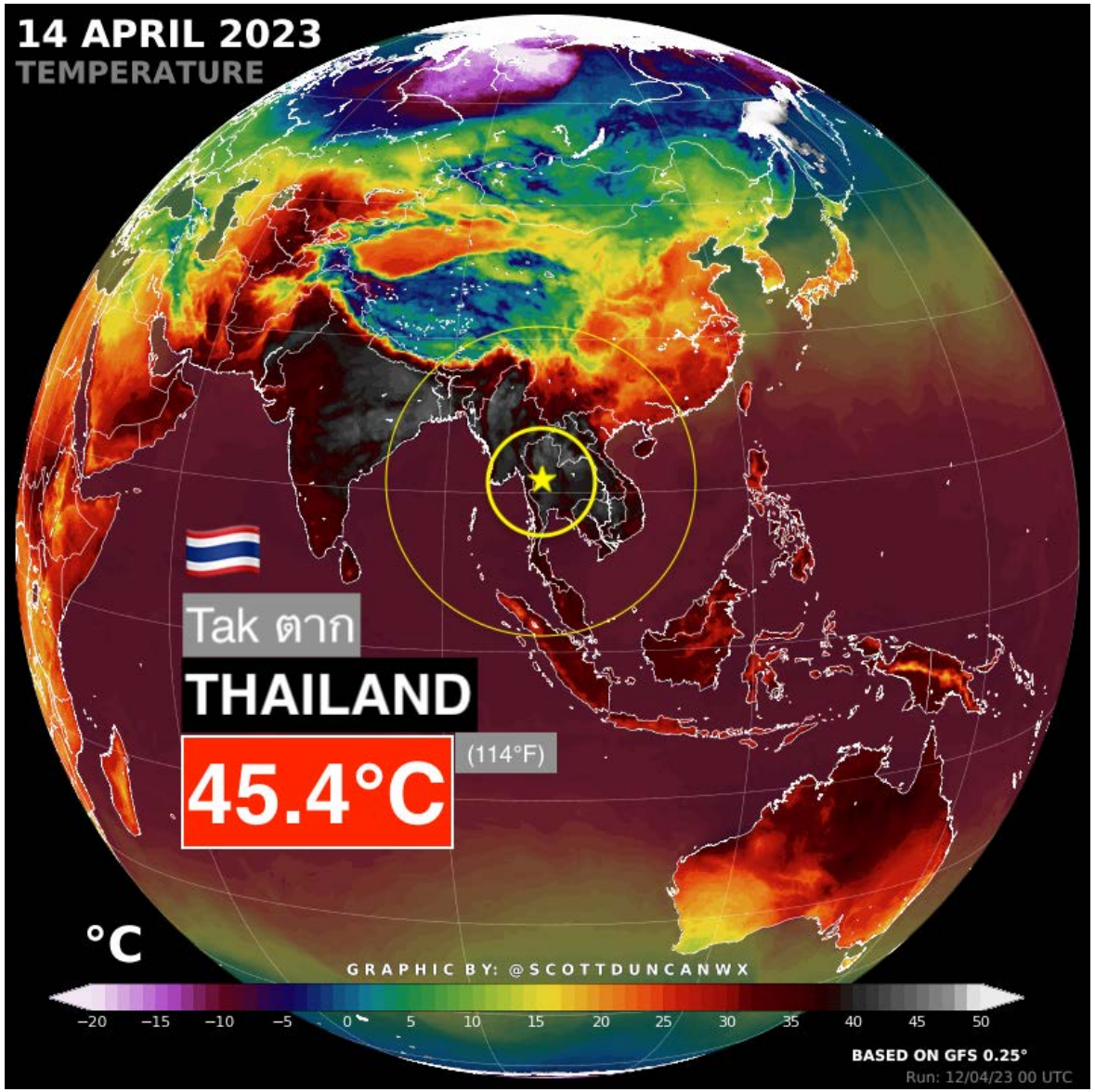

**Climate change made devastating early heat in India and Pakistan 30 times more likely.**

# Climate Change and Extreme Events

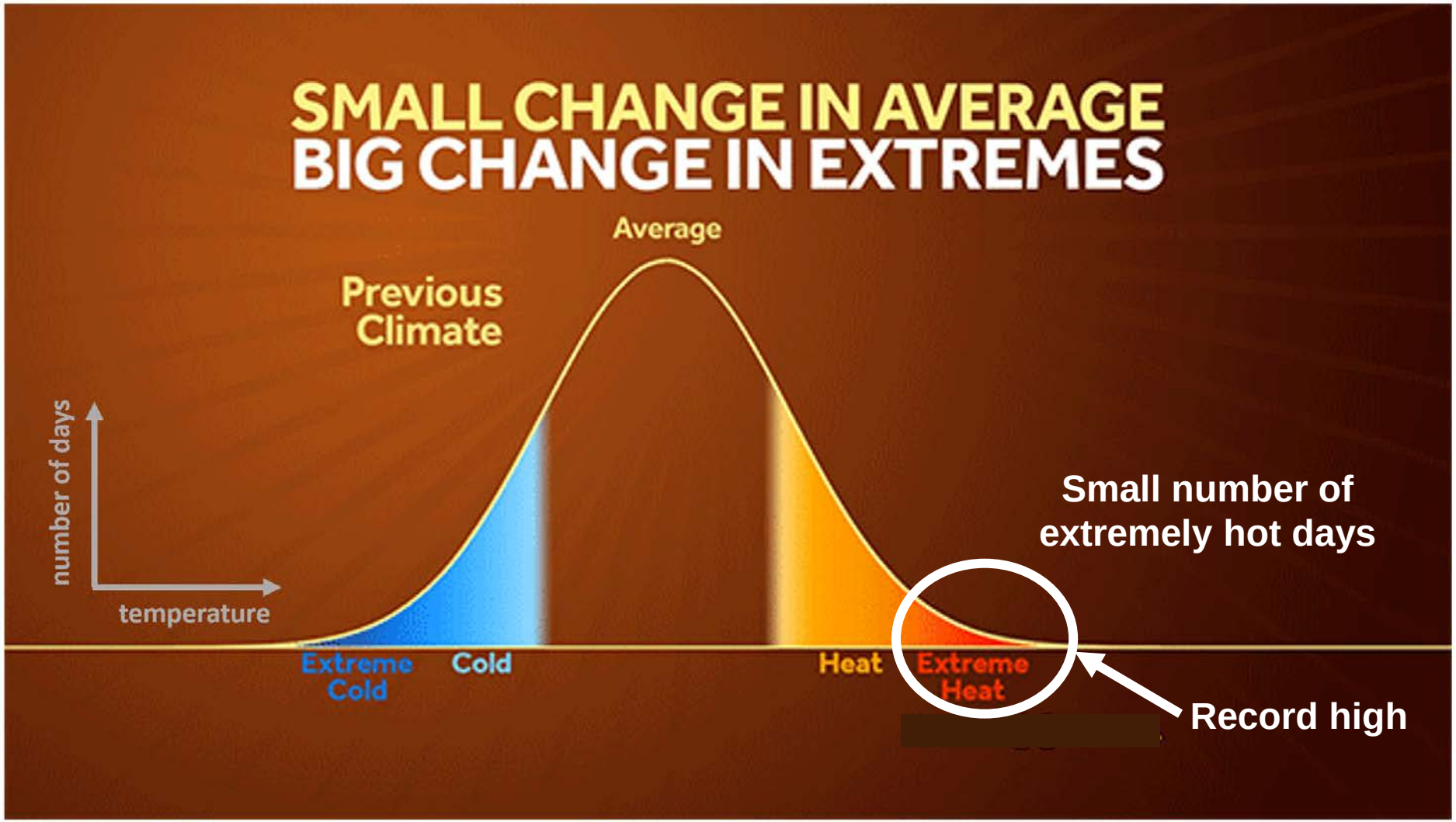
## Historic Asia heat breaks hundreds of records, with extremes in Thailand and China

Numerous April heat records were set in China, while Thailand recorded its all-time hottest temperature

**Record high temperatures across much of central and southern Asia, April 2023**

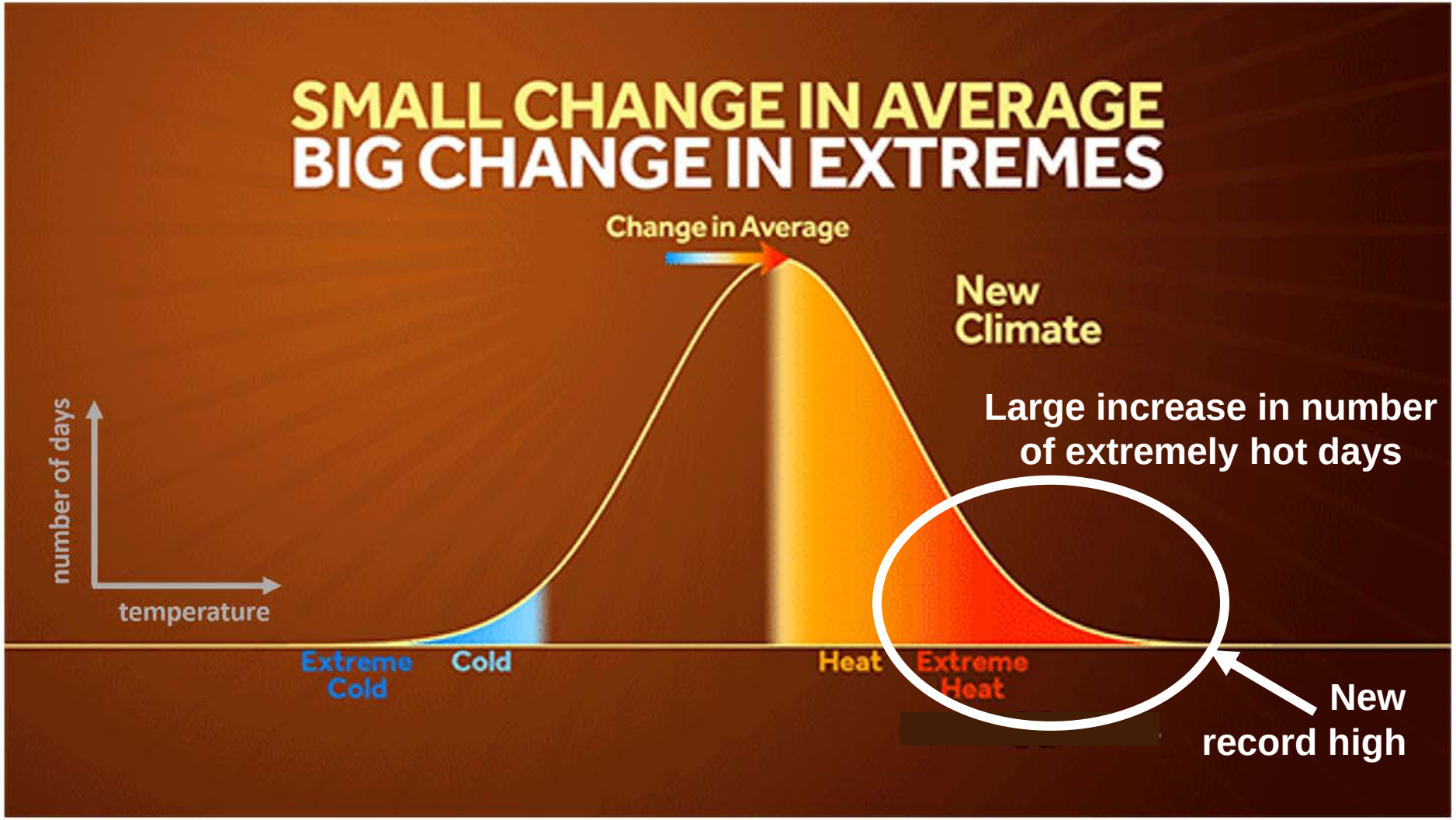


# Climate Change and Extreme Events




- Climate change tends to cause relatively small changes in mean conditions.
- But these small changes lead to large changes in the number and intensity of extreme events.

# Climate Change and Extreme Events




**Similar changes in extremes occur for rainfall, flooding, drought, sea level, winds, waves, storm surge, and other climate system variables.**

# Operational Importance of Extreme Events

1. Extreme events are rapidly becoming more common and more extreme.
2. Many of the extremes are unlike anything we've ever experienced.
3. Record extreme events are events never observed in the historical record (black swans).
4. So extreme events are very likely to be ones for which we have not prepared.
5. Many extreme events occur in combination – for example:
    a. summer high T combined with low precip and low humidity, leading to flash droughts, wildfires
    b. winter or spring high T combined with high precip leading to high snow melt and flooding
6. For many extreme events, especially combined events, the operational impacts are:
    a. large
    b. persist long after the event has ended
7. Human systems, and human bodies, are not able to withstand many of the extremes, especially combined extremes.
8. So extreme events tend to lead to extreme human system failures.

**Extreme events are one of the most operationally important aspects of climate change.**

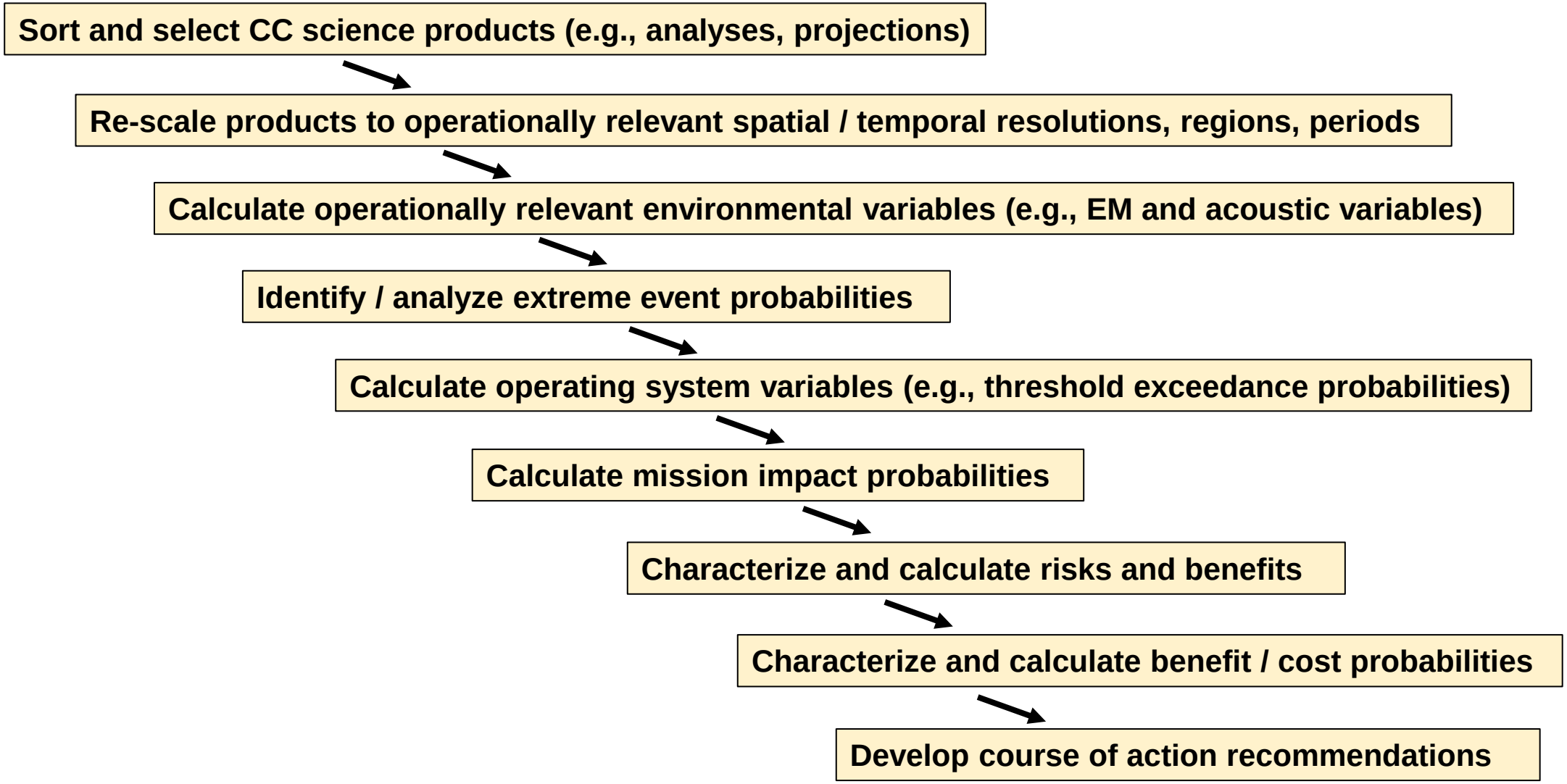
# Climate Change Decision Support: Motivation and Proposal

1. The ability to predict extreme events is limited but rapidly improving.
2. Navy needs to better leverage existing and emerging climate change (CC) science capabilities.
3. Focus: develop climate change decision support systems, especially for extreme event impacts.
4. First step: extensively sort, synthesize, adapt, and translate the existing and emerging science for operational use.
5. Examples of this research-to-operations (R2O) work:
    a. derive Navy relevant variables and spatial / temporal resolutions
    b. adapt science for maritime regions and less developed nations
    c. translate environmental probabilities into variables / metrics useful in decision making (e.g., manpower, time, & dollars needed to restore mission readiness after extreme event)
6. Need a multi-disciplinary, multi-institutional effort: CC science, data analysis, OR, decision theory, systems engineering, organizational management, risk management, benefit / cost modeling, ….
7. Learn from and partner with other organizations doing related CC R2O efforts (insurance, finance, energy, water resources, agriculture, disaster / risk management, USAF, other federal agencies, state and regional agencies).

**Over-arching goals:**

1. Improve the flow of relevant research to Navy decision makers
2. Improve Navy operational outcomes

# Main Steps in a Climate Change Decision Support System



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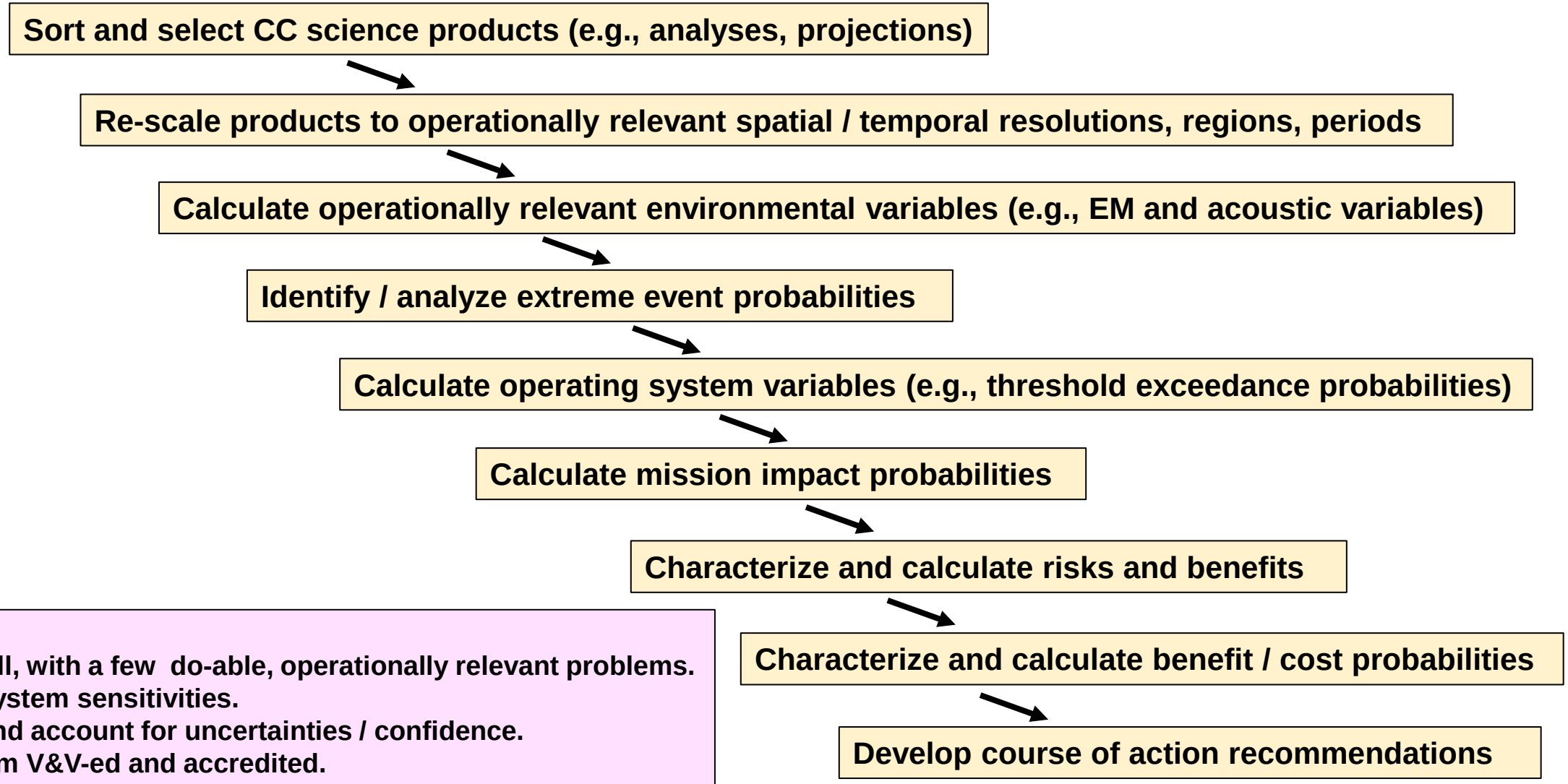


**Notes**

- Start small, with a few do-able, operationally relevant problems.
- Identify system sensitivities.
- Assess and account for uncertainties / confidence.
- Get system V&V-ed and accredited.
- Routinely assess system performance, costs, and benefits.
- Develop corresponding education programs.
- Engage students in system development and applications.
- Develop workforce for supporting CC related decision making.
- Conduct R&D to improve CC decision making capabilities.

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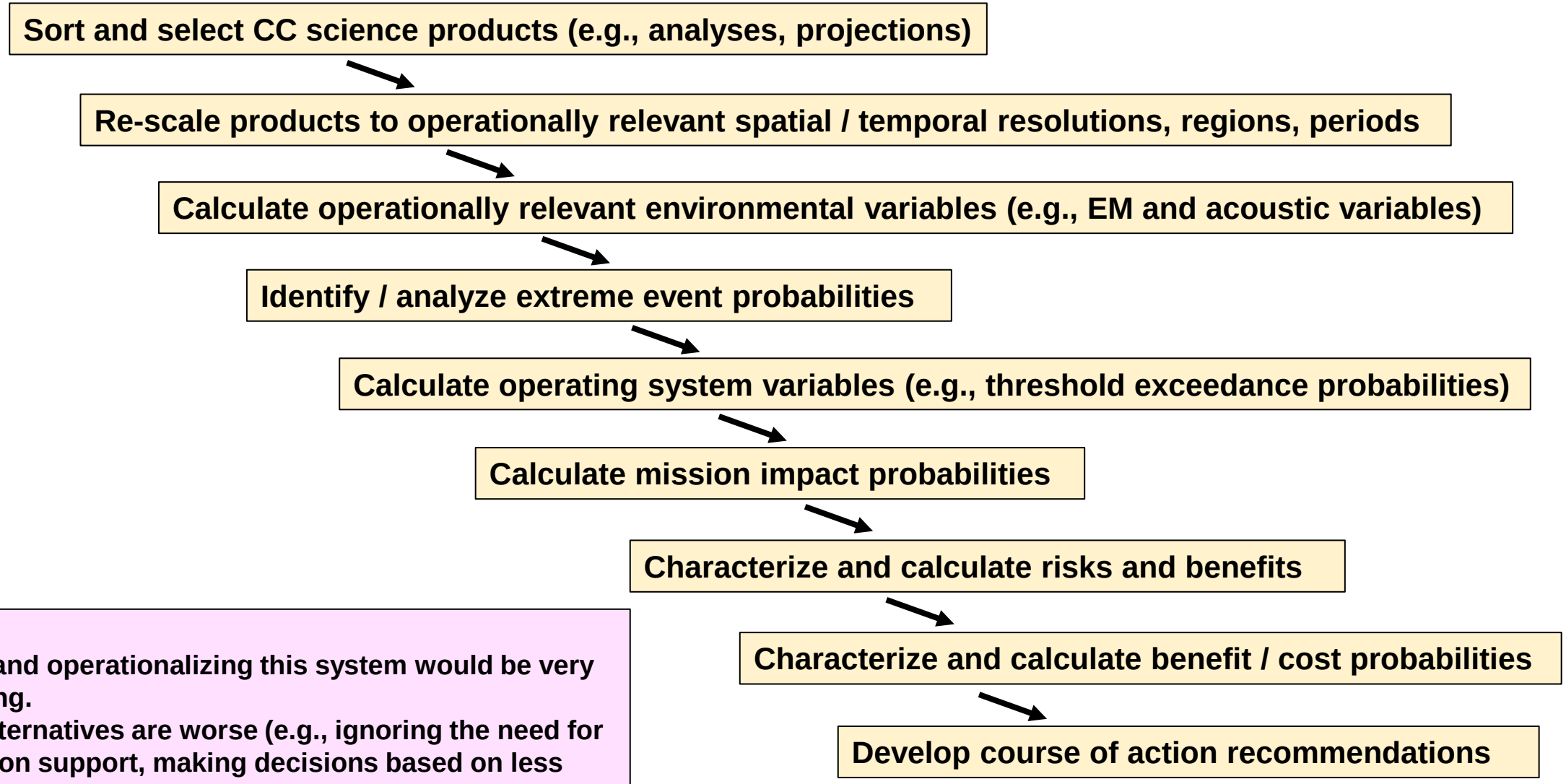


**Notes**

- Creating and operationalizing this system would be very challenging.
- But the alternatives are worse (e.g., ignoring the need for CC decision support, making decisions based on less quantitative and objective methods, taking a piecemeal or case-by-case approach, leaving Navy organizations to their own devices when making with CC decisions, etc.).

# Climate Change Decision Support System: Some Questions

1. What are the challenges in operationally applying CC science in Navy decision making?
2. What are the main CC research-to-operations (R2O) transitions needed by the Navy?
3. What CC decision support does the Navy get now and what does it still need?
4. What CC education does the Navy get now and what does it still need?
5. How might the Navy better leverage existing non-Navy CC products and services?
6. What lessons could the Navy learn from how other organizations get CC decision support?
7. What partnering would be need to implement an operational CC decision support system?
8. Where would such a system be housed and how would it be funded?