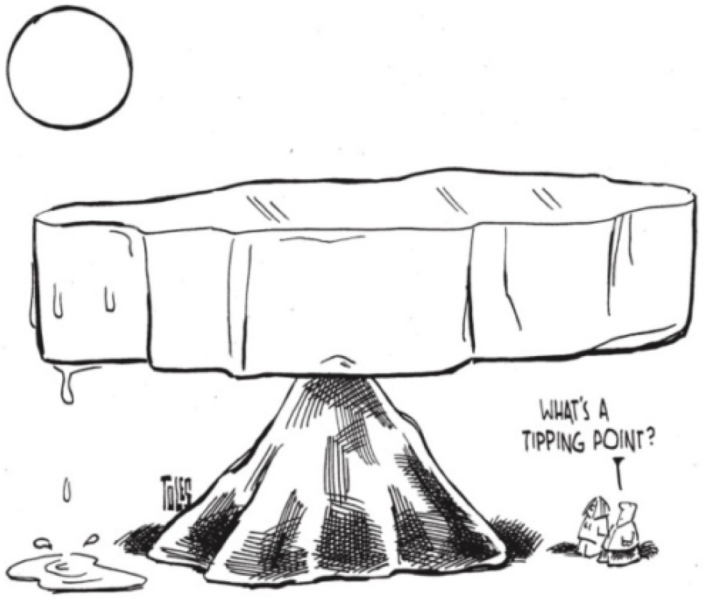

Class 17: Projections II – Tipping Points

- What are runaway positive feedbacks?
- What specific tipping points are we most worried about?

Learning Objectives

1. Understand the concept of runaway feedbacks
2. Distinguish between reversible and irreversible tipping point systems
3. Explain why tipping point thresholds are hard to identify and predict
4. Identify one reversible and one irreversible tipping point in the global climate system

Thanksgiving Assignment

One way of communicating what you have learned about climate, climate change, and why it matters. Good conversation starter if you parents ask you what you've been doing at UVM all semester after the BIG meal.

How do people communicate their opinions to the public?

OP-ED, page opposite the Editorial Page in a paper, but now gone digital

Minneapolis Star Tribune

Chilly, Drama-Free Halloween - Remembering Halloween ...

An Op-Ed at South Bend Tribune (Indiana) resonated; here's an excerpt: "...As a result of climate change, the Midwest is projected to ...

4 days ago

Environmental Health News

Op-ed: Natural gas vs. renewable energy — beware the latest gas industry talking points

Op-ed: Natural gas vs. renewable energy — beware the latest gas industry talking points. By keeping Americans focused on the climate benefits of gas vs. coal, ... of methane are contributing to climate change, which is

2 weeks ago

InsideEVs

Top Democratic Senator Proposes $454-Billion EV Stimulus Strategy

A way to speak your mind and present your arguments in a public forum

A relevant example…

The New York Times

Opinion

Climate Change Will Cost Us Even More Than We Think

Economists greatly underestimate the price tag on harsher weather and higher seas. Why is that?

By Naomi Oreskes and Nicholas Stern

Dr. Oreskes is a professor of the history of science at Harvard. Professor Stern is chair of the Grantham Research Institute on Climate Change and the Environment.

Oct. 23, 2019

Lead sentence to grab reader attention

For some time now it has been clear that the effects of climate change are appearing faster than scientists anticipated. Now it turns out that there is another form of underestimation as bad or worse than the scientific one: the underestimating by economists of the costs.

Why it matters

The result of this failure by economists is that world leaders understand neither the magnitude of the risks to lives and livelihoods, nor the urgency of action. How and why this has occurred is explained in a recent report by scientists and economists at the London School of Economics and Political Science, the Potsdam Institute for Climate Impact Research and the Earth Institute at Columbia University.

What's going on

One reason is obvious: Since climate scientists have been underestimating the rate of climate change and the severity of its

Assignment to prepare for end of class and Final Paper

1. **List the name of your home town paper and its URL (presuming it's on-line).**

2. **Got your paper's web site and find its policy for public letters, often called an OP-ED, opinion, or an extended letter to the editor. You are looking for a means by which the paper will allow you to voice your opinion. Find that policy and copy it as your answer to this question.**

3. **Read several OP-EDs or extended letters to the editor in your home town paper. In ONE SHORT PARAGRAPH, pick the one you find most convincing, provide the title in your answer and tell us what it was about the writing style and presentation that made the OP-ED so convincing.**

DUE TUESDAY DECEMBER 3 - we will announce FINAL PAPER topic then – it will be due TUESDAY DECEMBER 10 and be 400-600 words.

Climate in the News

ENGLISH ESPAÑOL 中文

The New York Times

Tuesday, November 5, 2019

Trump Serves Notice to Quit Paris Climate Agreement

- The United States formally notified the United Nations that it would leave the Paris climate agreement, starting the clock on a yearlong withdrawal process.
- The move leaves foreign diplomats to plan a way forward without the cooperation of the world's largest economy.

9h ago 1373 comments

President Trump returned to the White House on Sunday. Pete Marovich for The New York Times

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Climate in the News

ENVIRONMENT

Finding The Right Chunk Of Arctic Ice

November 1, 2019 · 5:07 AM ET
Heard on Morning Edition

RAVENNA KOENIG

MOSAiC – Multidisciplinary drifting Observatory for the Study of Arctic Climate

Climate scientists freezing a ship into sea ice for a year

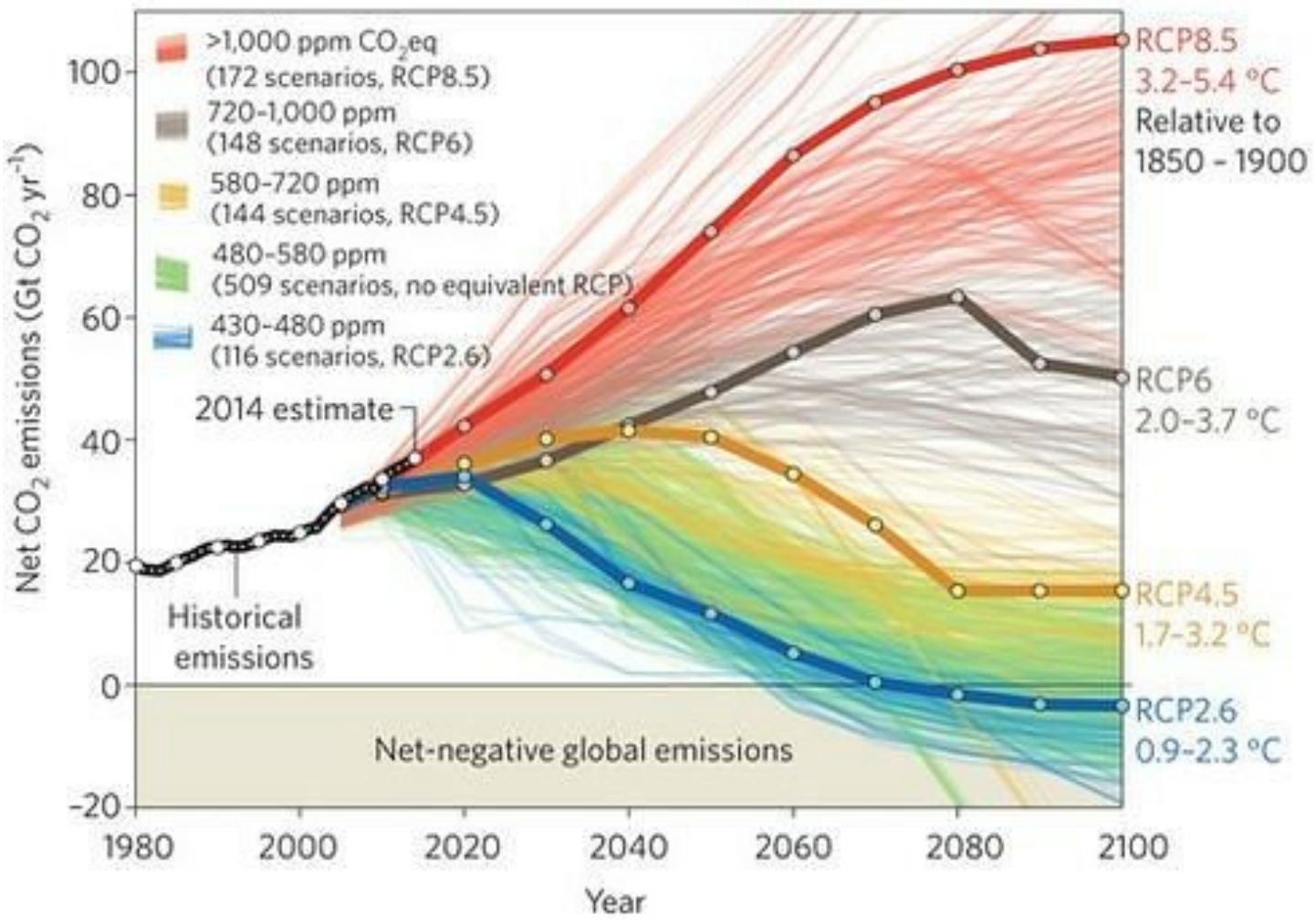
All about improving our models

"We need this information because the Arctic is changing so rapidly and it's a place that we have not observed very well in the past," says Matthew Shupe, an atmospheric scientist with the University of Colorado and the National Oceanic and Atmospheric Administration, and the co-coordinator of MOSAiC.

"This whole project is aimed at improving our models and how our models represent the global system, but importantly, the Arctic and its role in the global system," he says. "The data from MOSAiC will ultimately make those models better at doing things like forecasting the weather, forecasting sea ice, predicting the climate," he says.

Review: Projections I

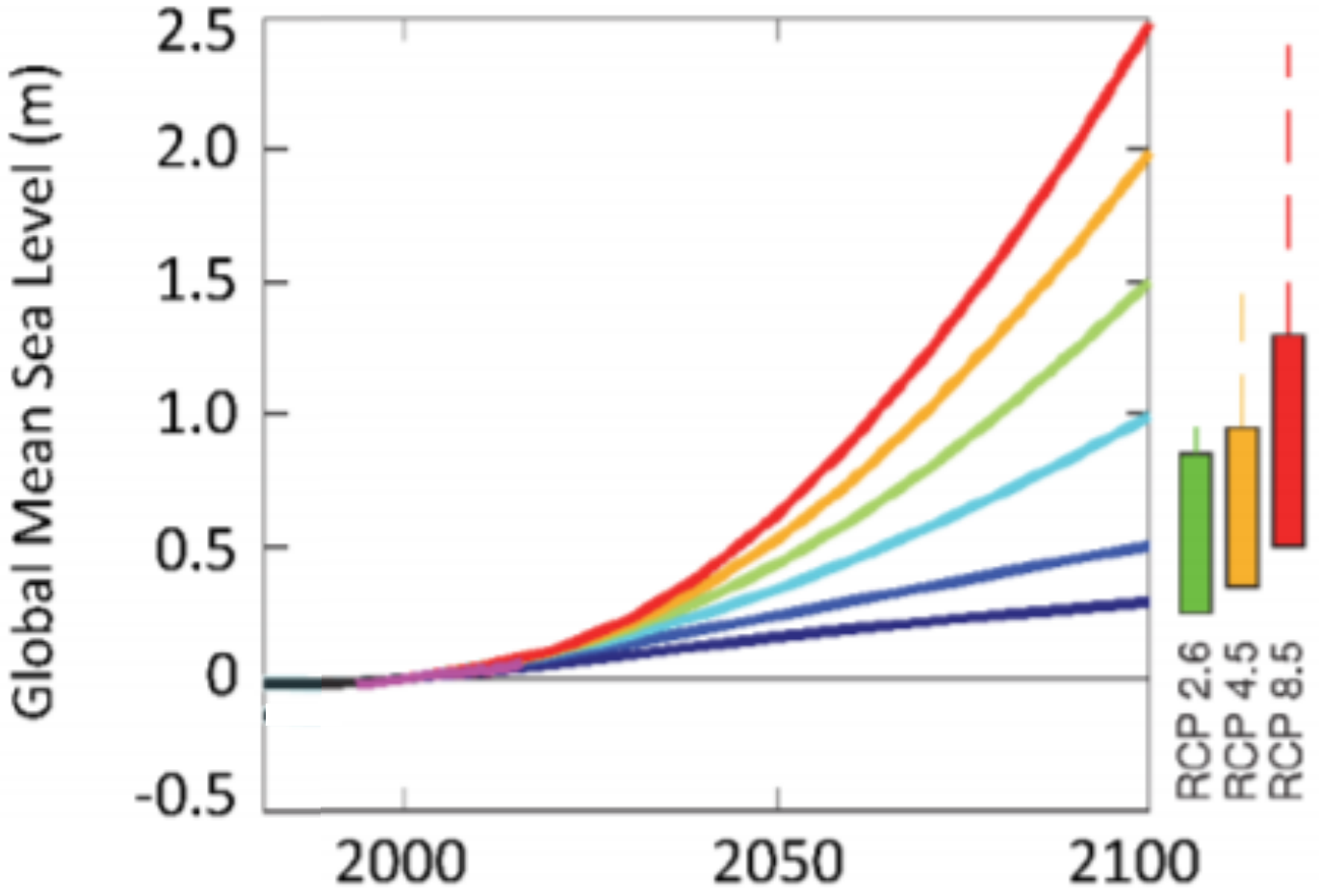
- To simulate future climate change, climate models run with different emission scenarios
- Higher number = more emissions = more warming



Review: Projections I

Sea Level Rise:

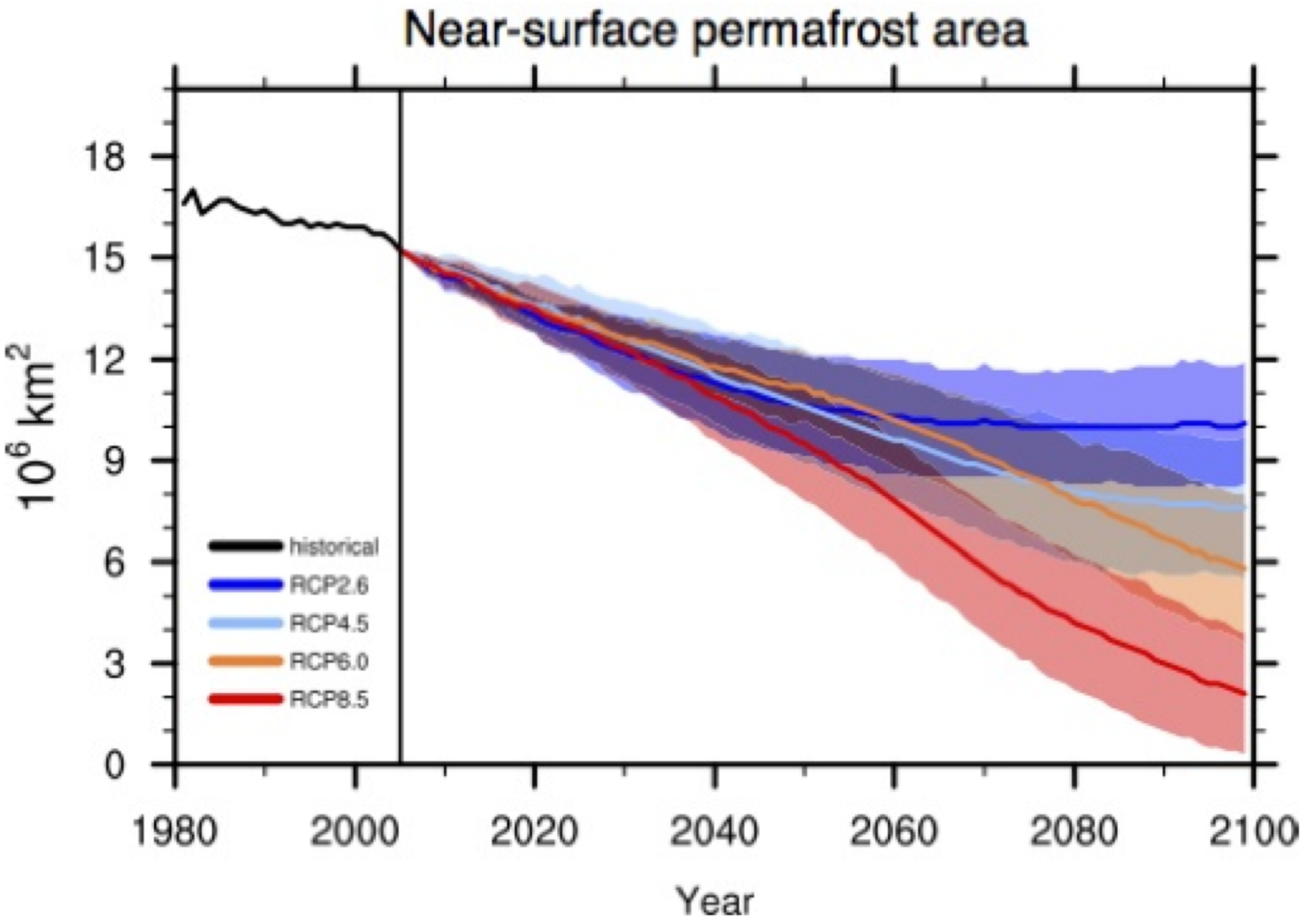
- IPCC says < 1 meter
- NOAA says 0.5 – 2 meters
- Either way, more emissions = more sea level rise



Review: Projections I

Permafrost:

- Low emission scenario = >30% decrease
- High emission scenario = >85% decrease
- Either way, more emissions = more permafrost loss

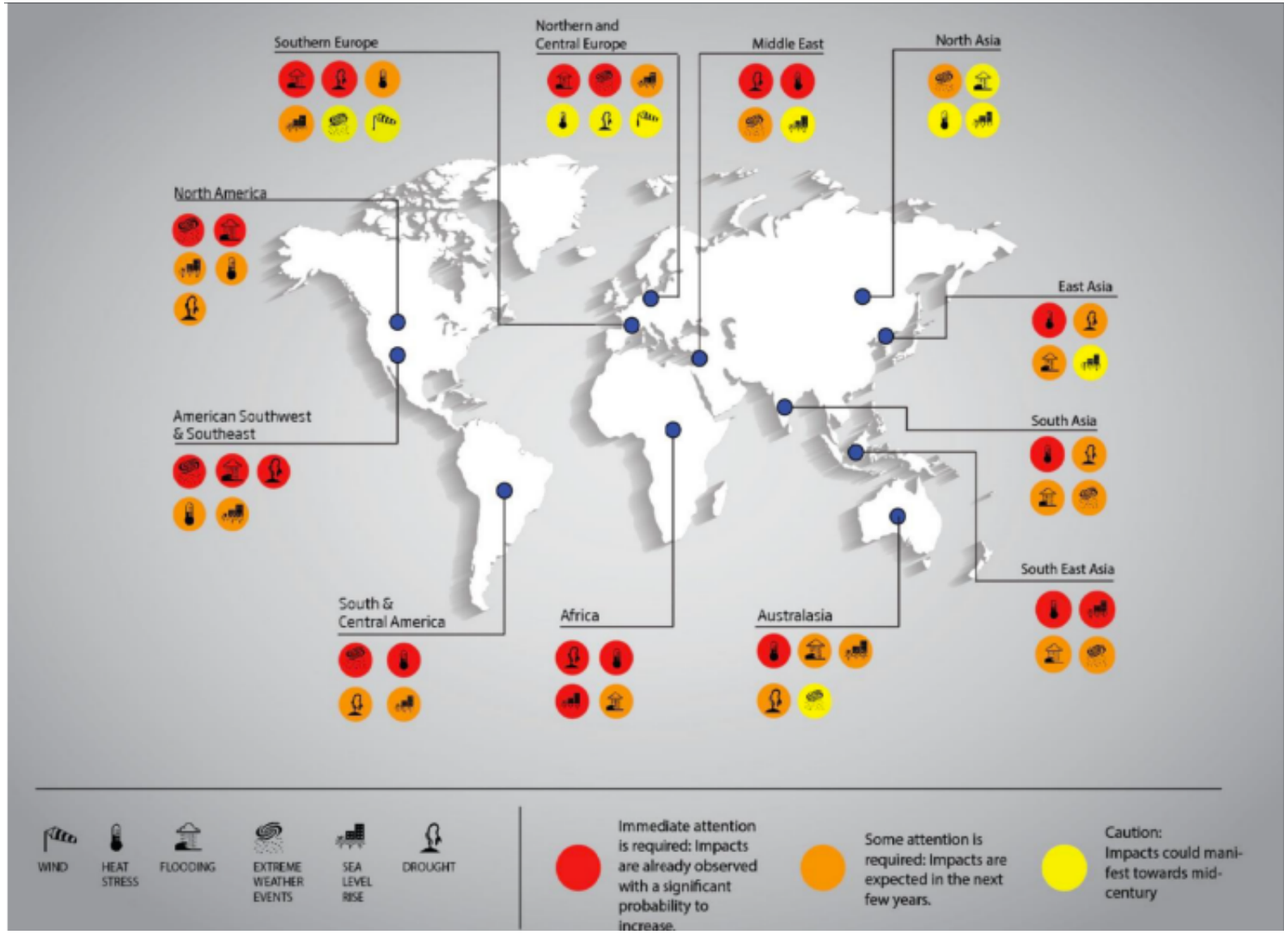


Review: Projections I

Climate impacts expected by 2100 vary depending on region

In North America:

- Extreme Weather
- Flooding
- Sea level rise
- Heat stress (worst in Southern US)
- Drought



Today’s Class: Projections II – Tipping Points

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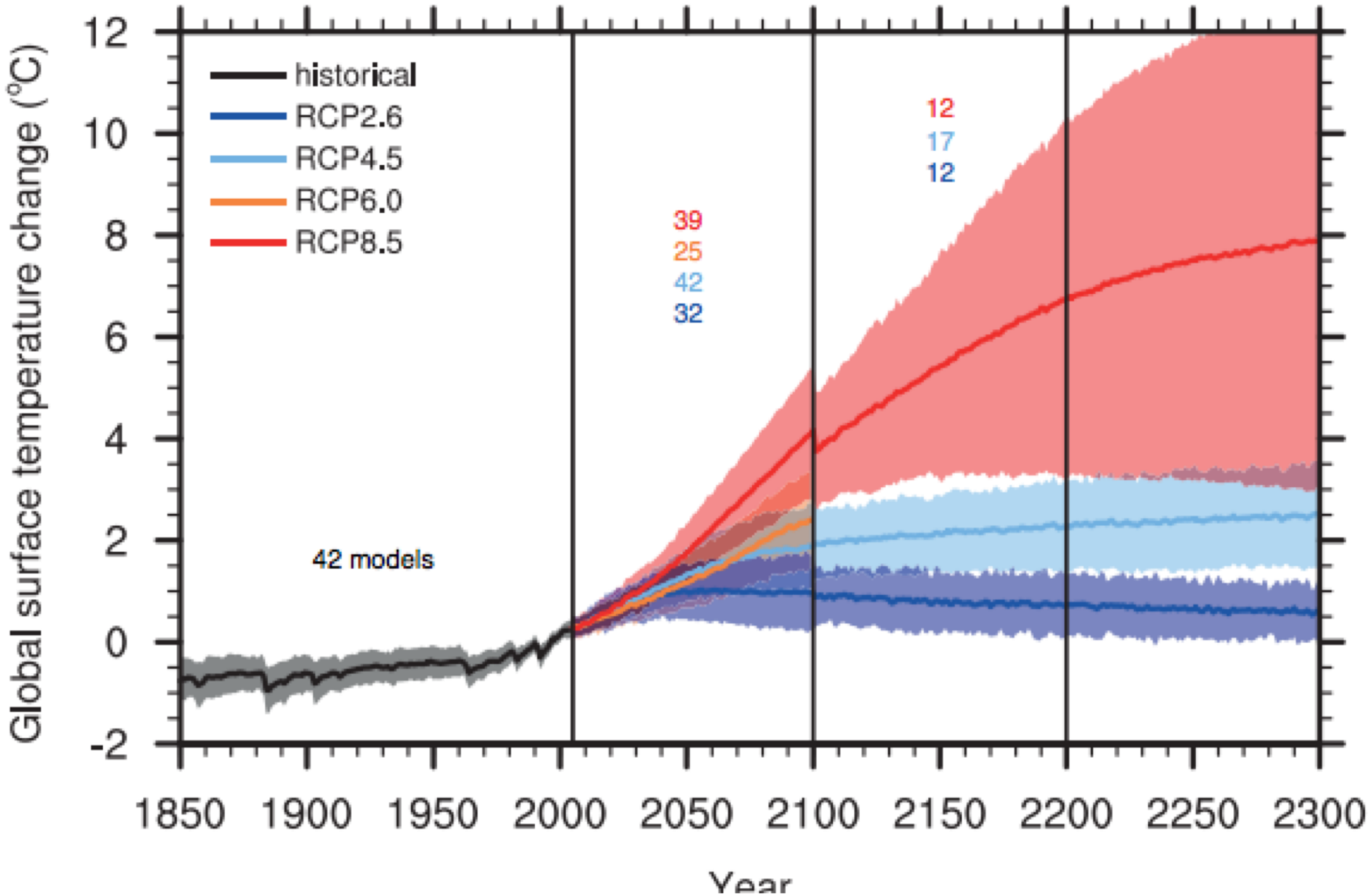
Uncertainty due to feedbacks

At that level of warming, are we going to trigger runaway feedbacks?



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'Rocking the Boat' – How some climate systems change → Reversible vs. irreversible system changes → Identifying & predicting tipping points → Tipping point examples

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Rocking the Boat – How Some Climate Systems Change

- Two stable states
  - “Upright”
  - “Flipped”
- A threshold between these states
- Once threshold is crossed, transition to the other state

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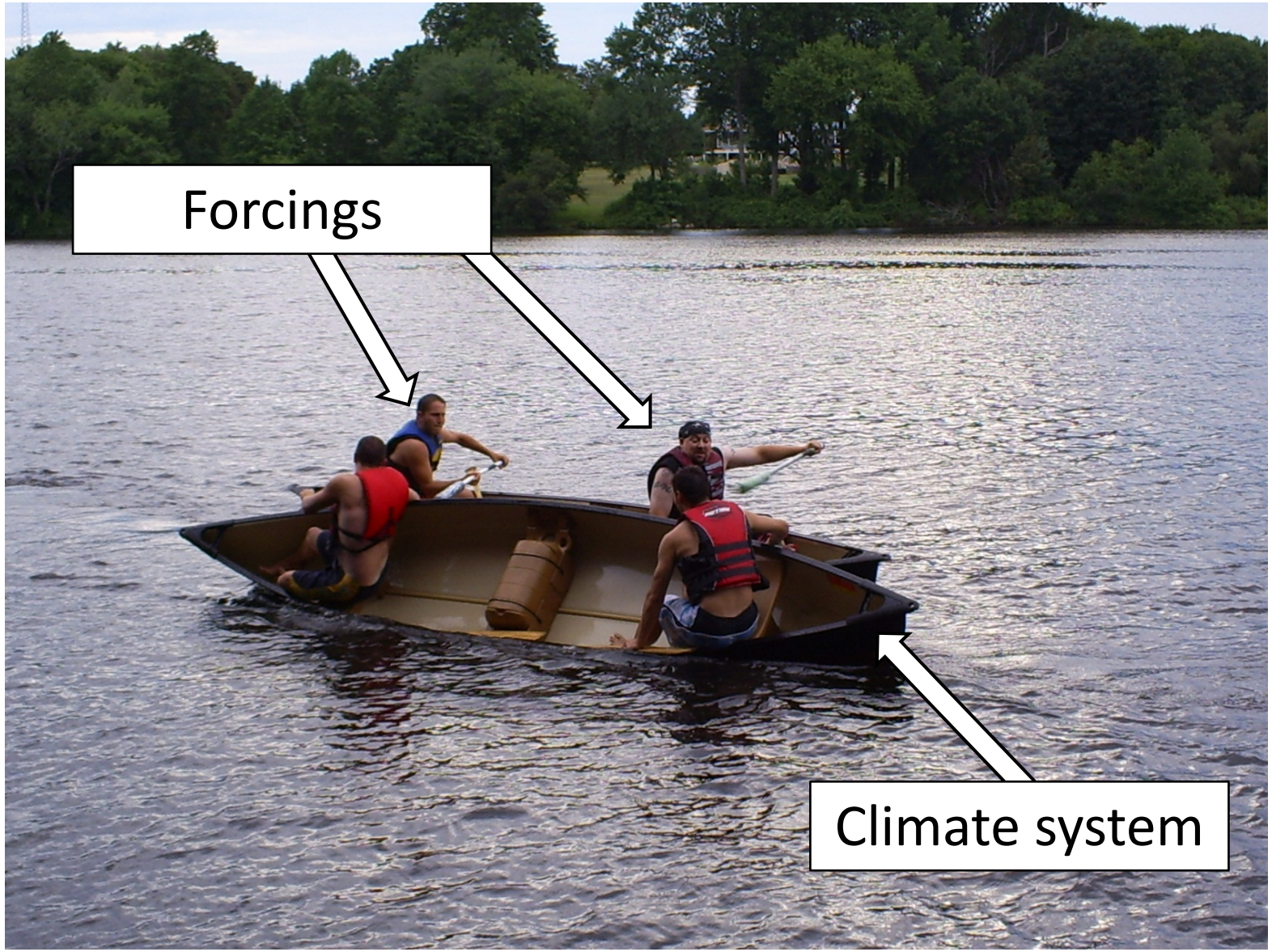

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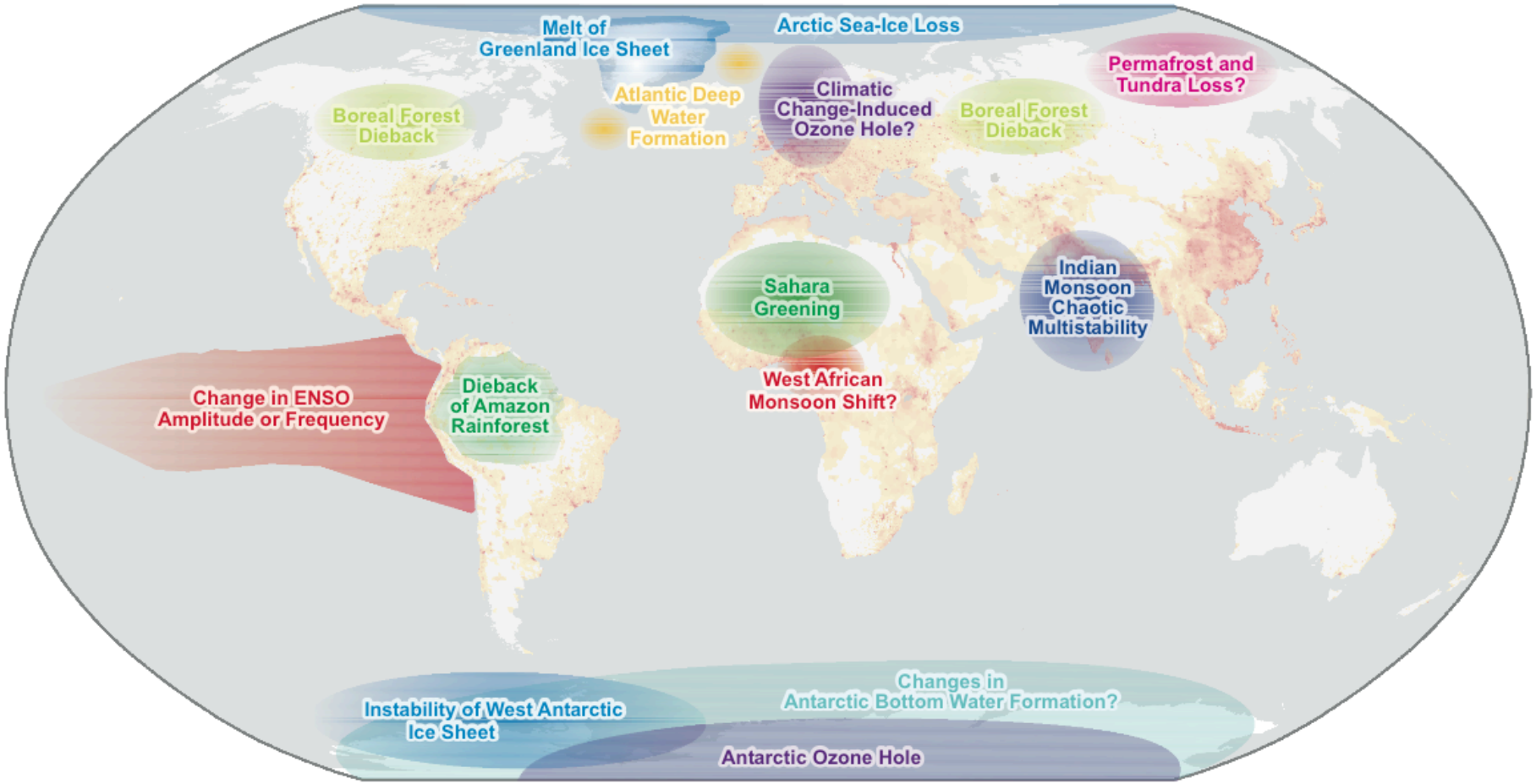
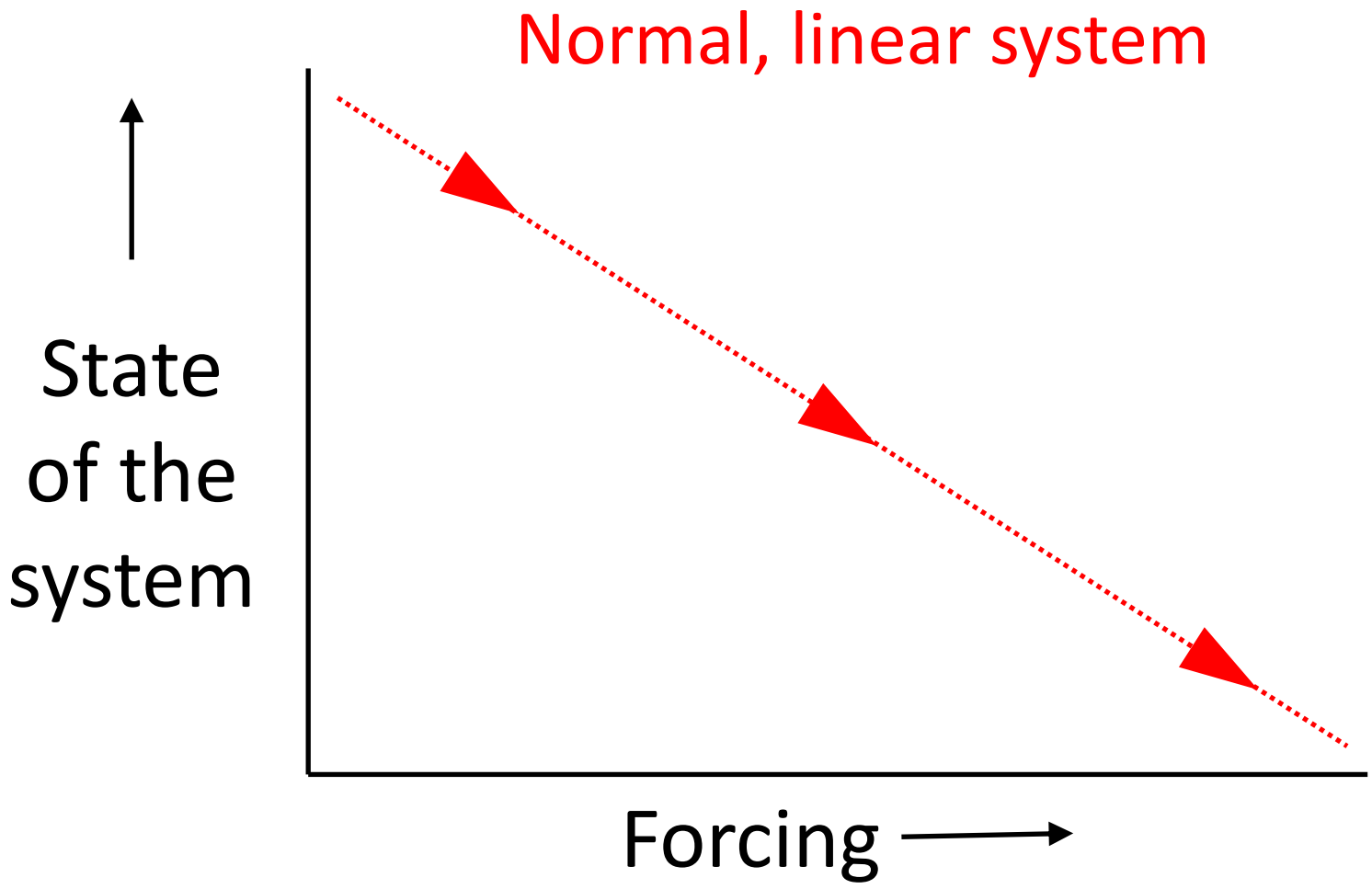


Image from GlobalChange.gov

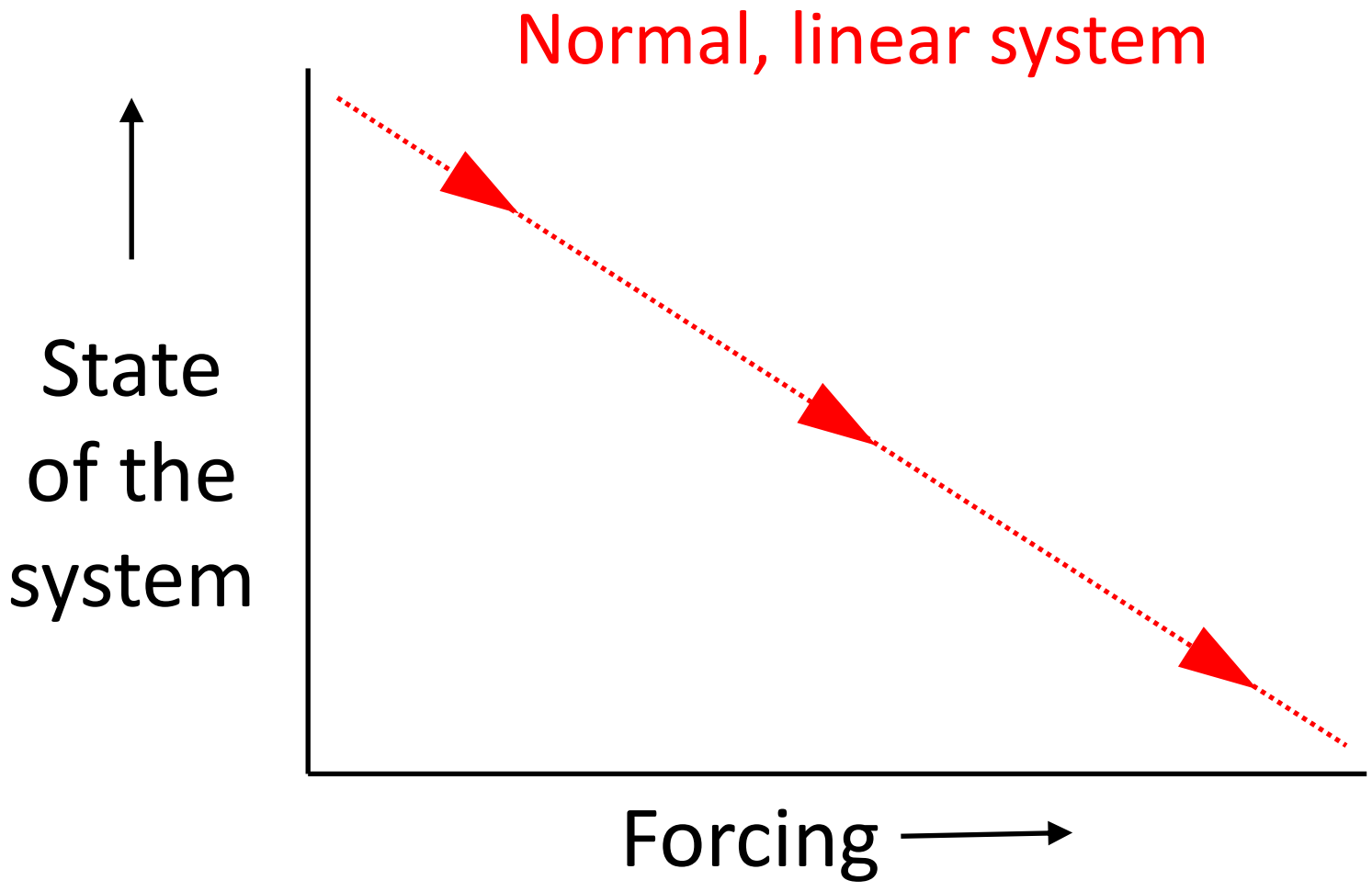
Linear vs. Tipping Point Climate Systems

- Each forcing ‘nudge’ pushes the system a bit farther



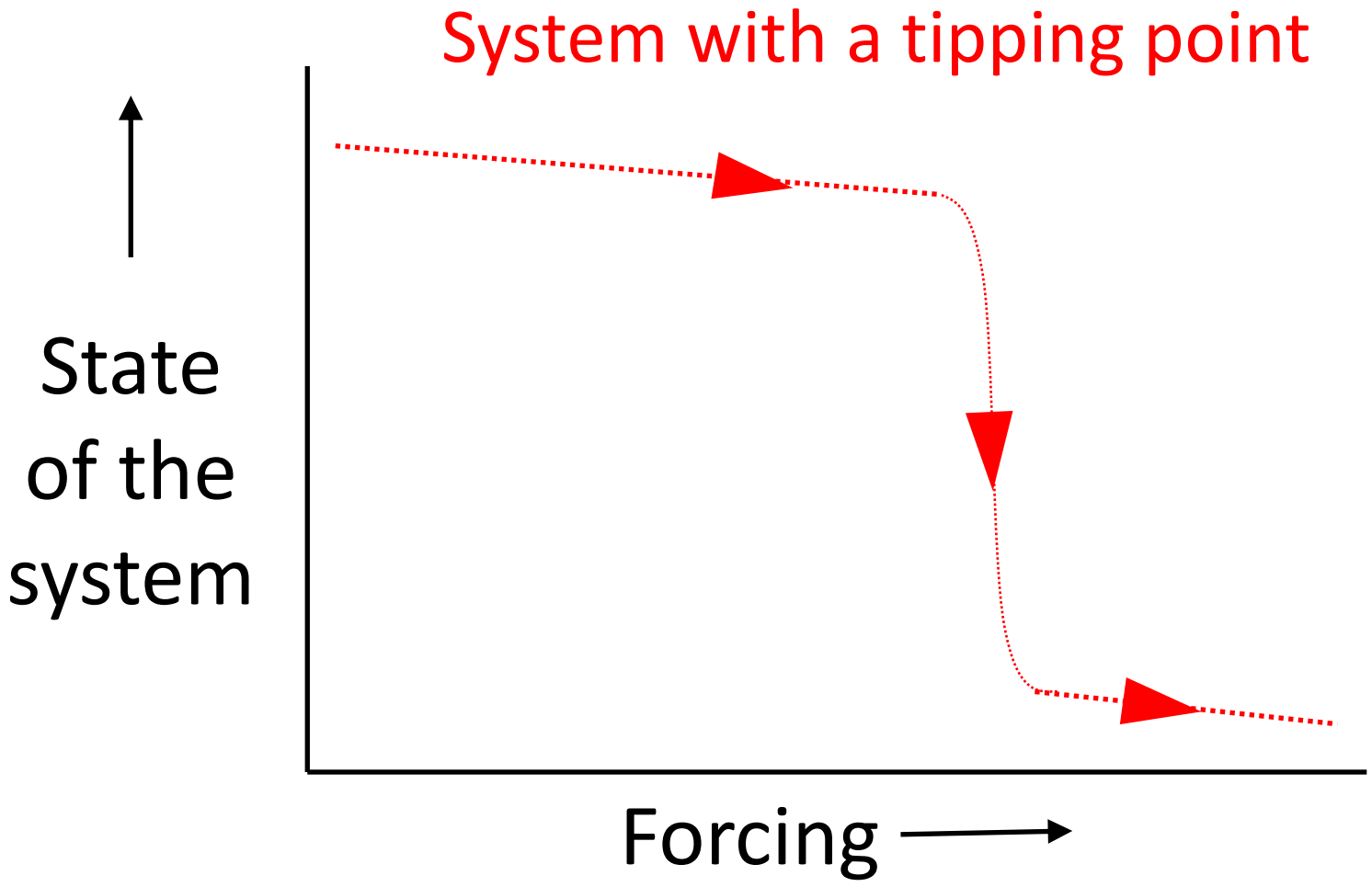
Linear vs. Tipping Point Climate Systems

- Each forcing ‘nudge’ pushes the system a bit farther
- Example: chemical weathering and atmospheric CO_2
- More chemical weathering = less CO_2 in atmosphere



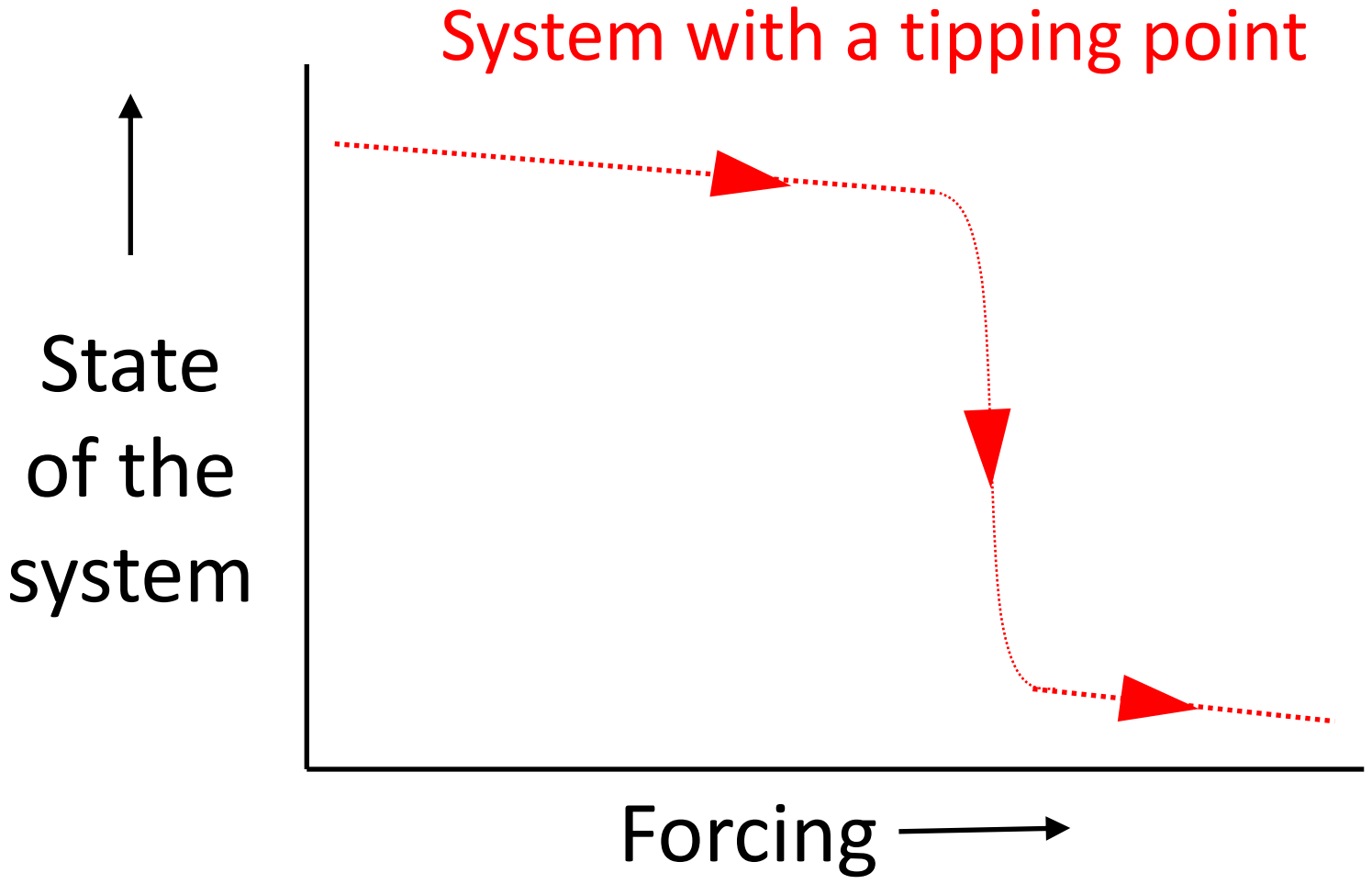
Linear vs. Tipping Point Climate Systems

- A nudge past the threshold makes the system jump states
- "The straw that broke the camel's back"



Linear vs. Tipping Point Climate Systems

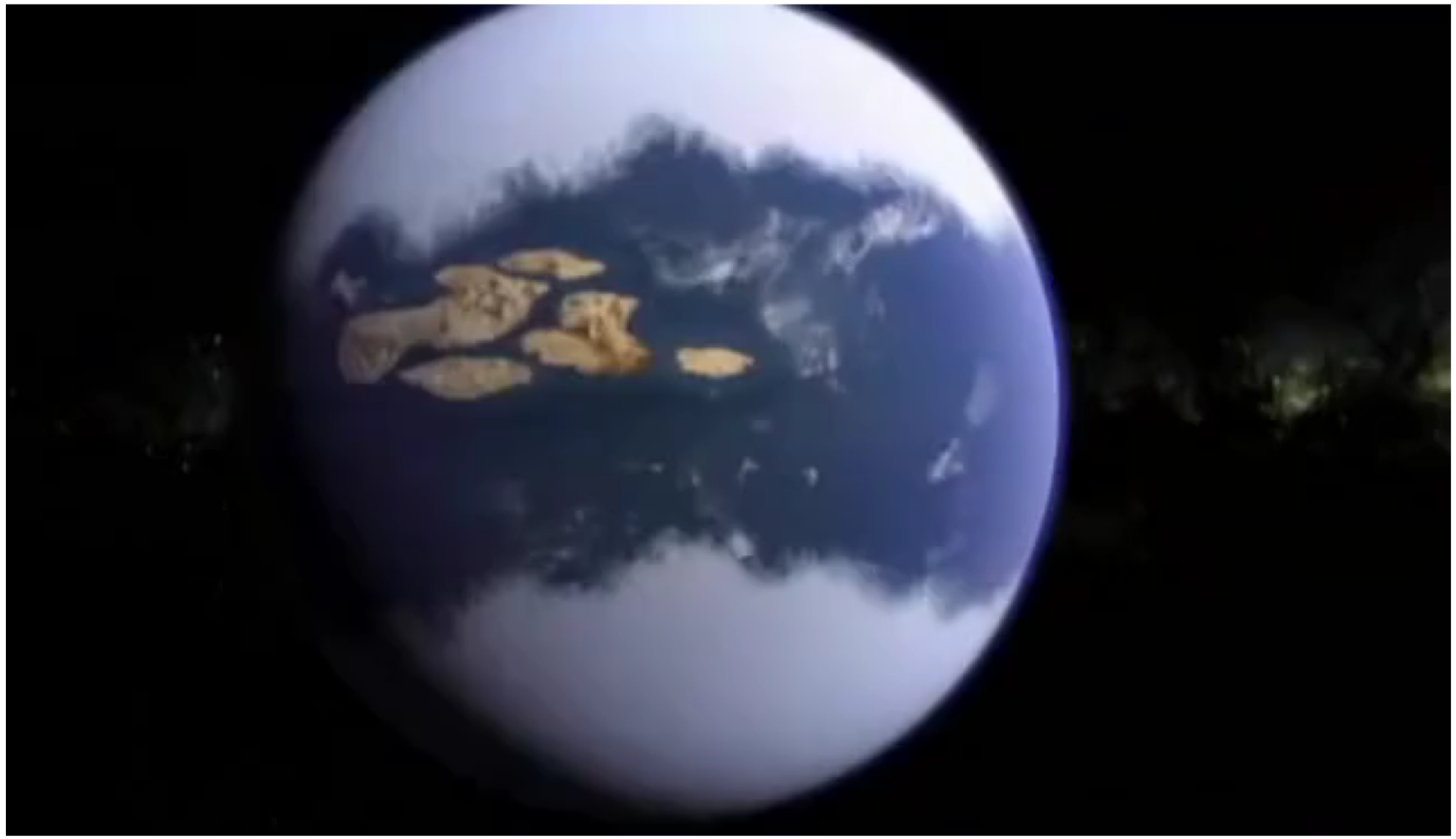
- A nudge past the threshold makes the system jump states
- "The straw that broke the camel's back"
- Runaway positive feedbacks!
- No extra forcing needed



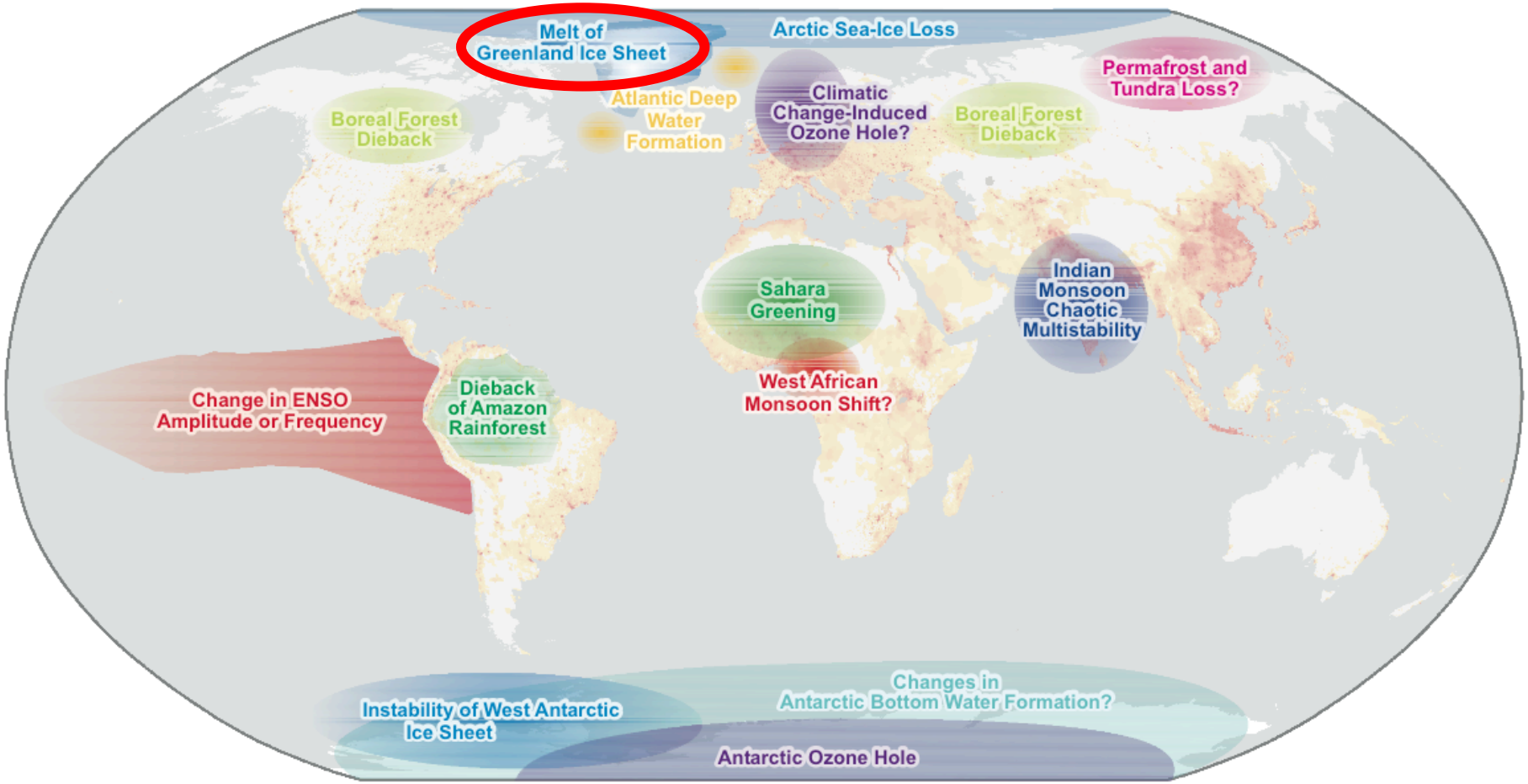
Linear vs. Tipping Point Climate Systems

Extreme paleo-example:

- Snowball earth (850-550 million years ago)
- Runaway ice-albedo feedback

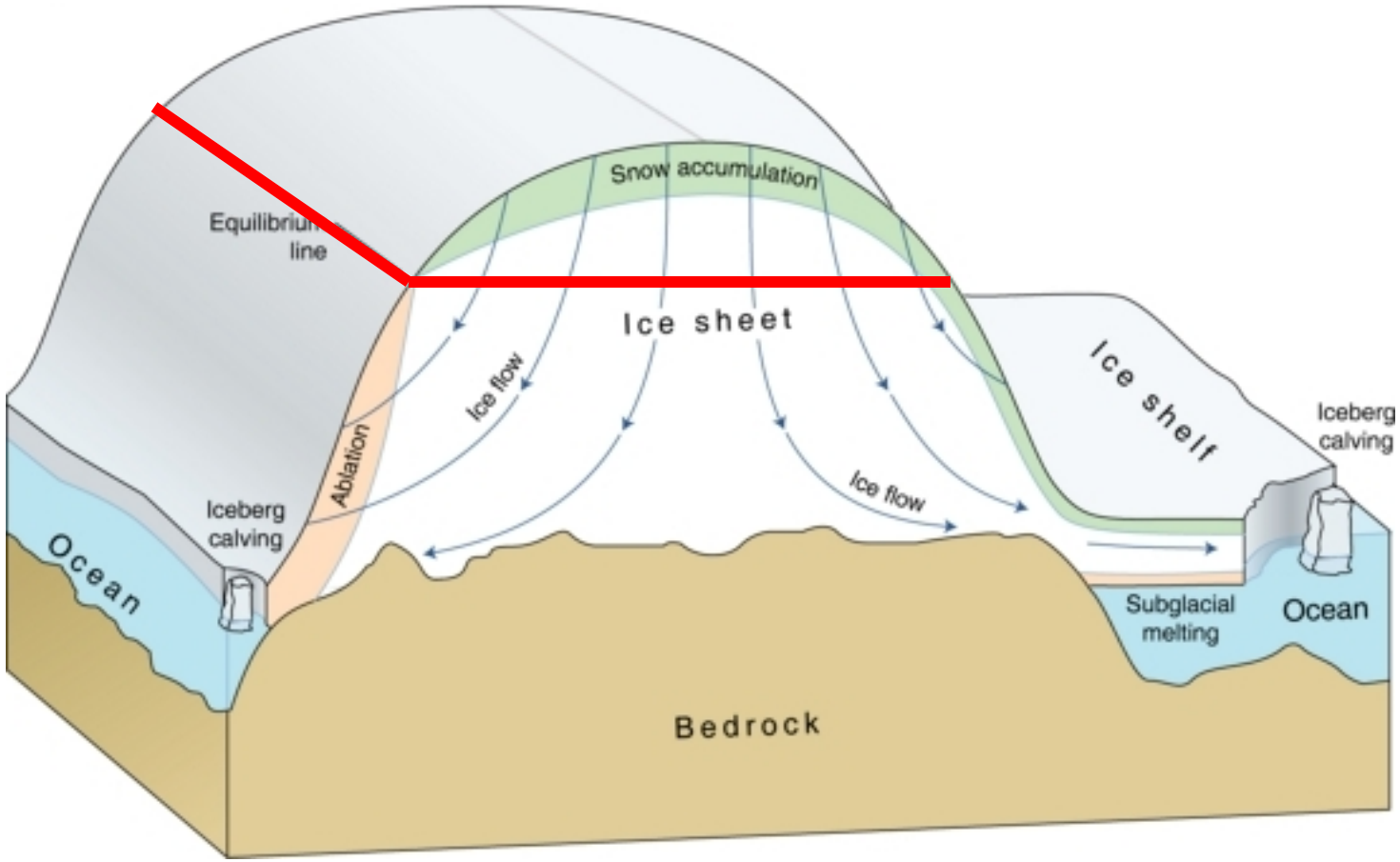


Tipping Point Example – Greenland Melt



Tipping Point Example – Greenland Melt

- Reminder: Ice sheets have an ‘equilibrium line’ separating zones of snow accumulation vs. melting



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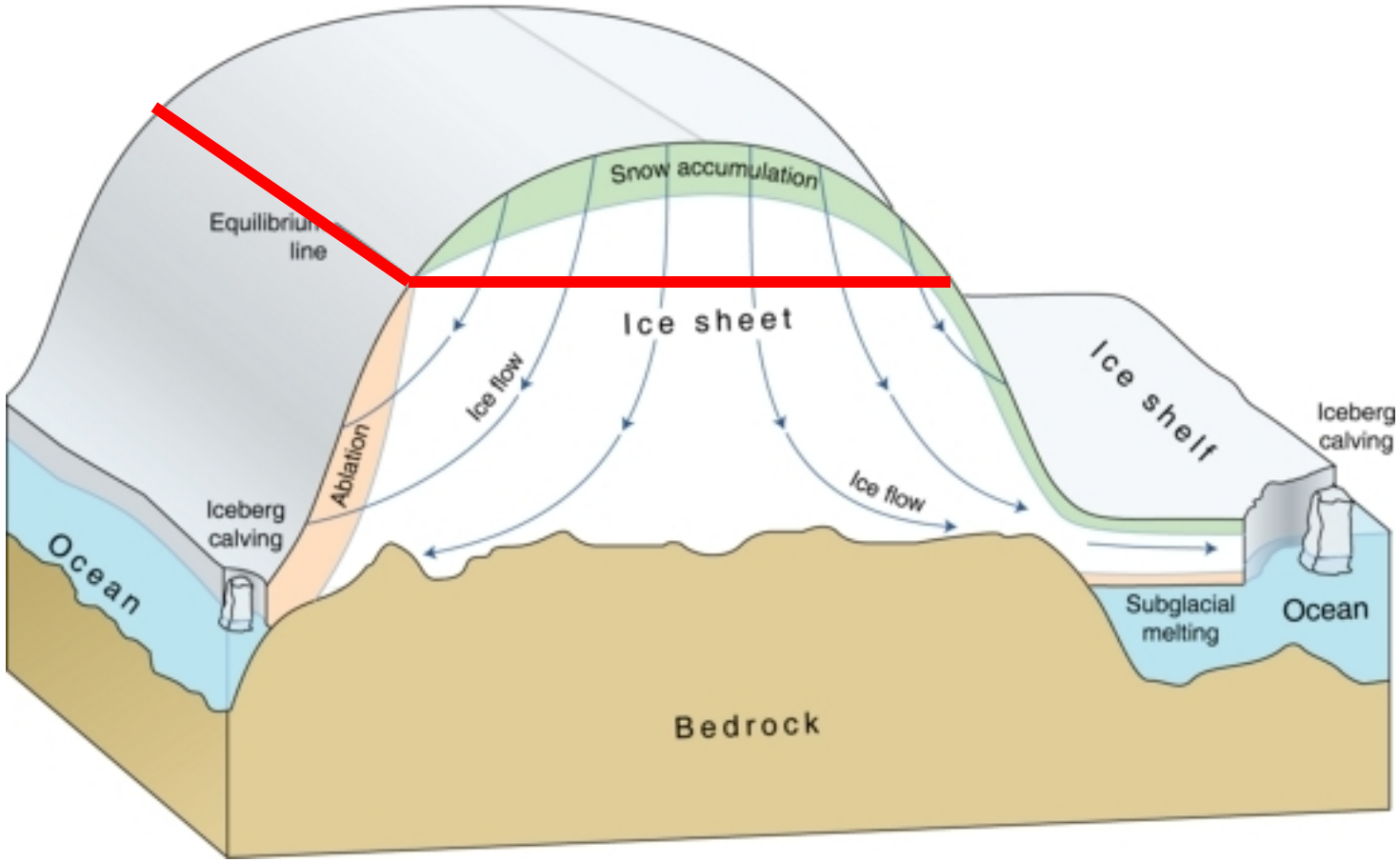
- Warming causes:
  - Increased elevation of equilibrium line
  - Lowering of ice sheet



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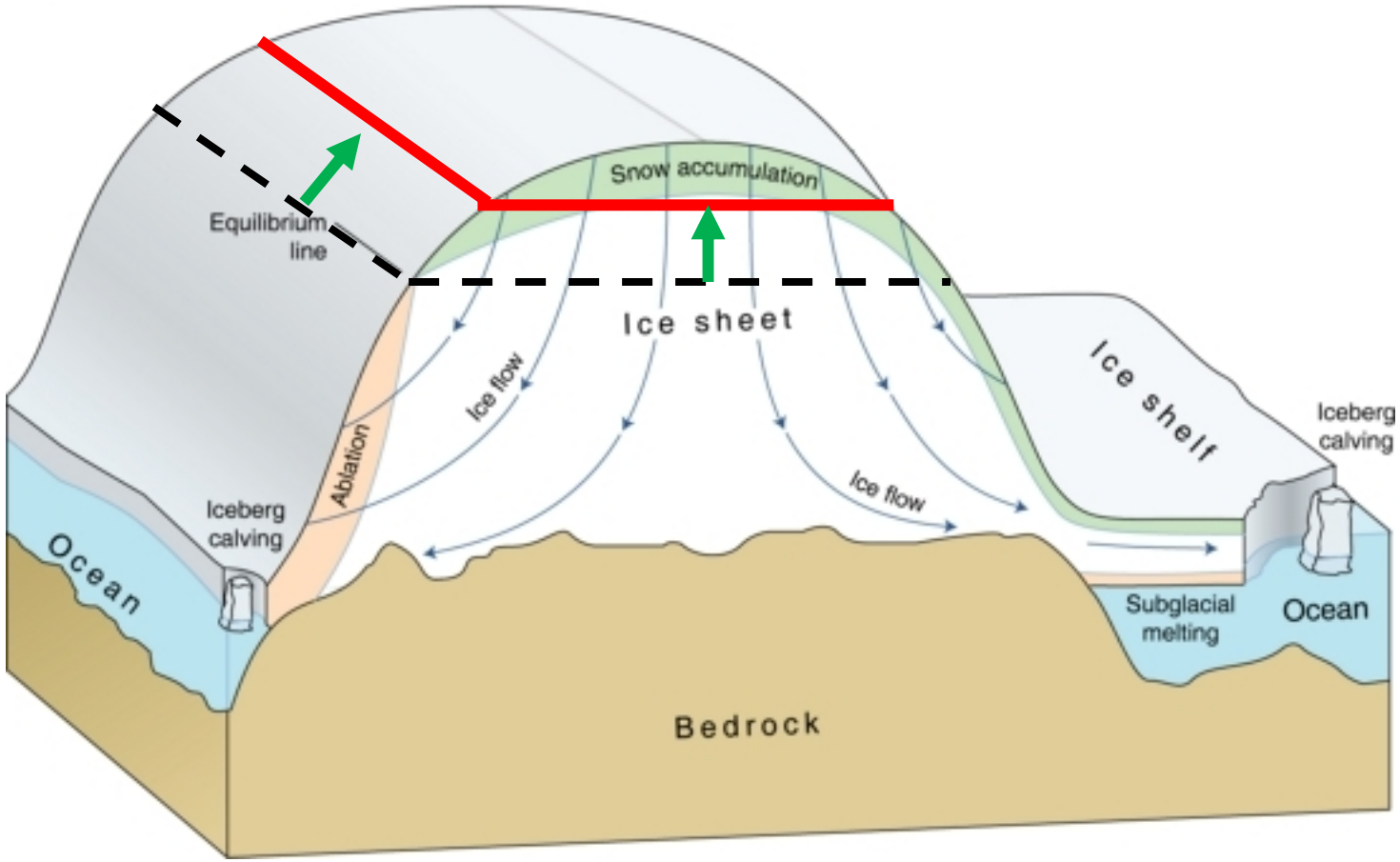

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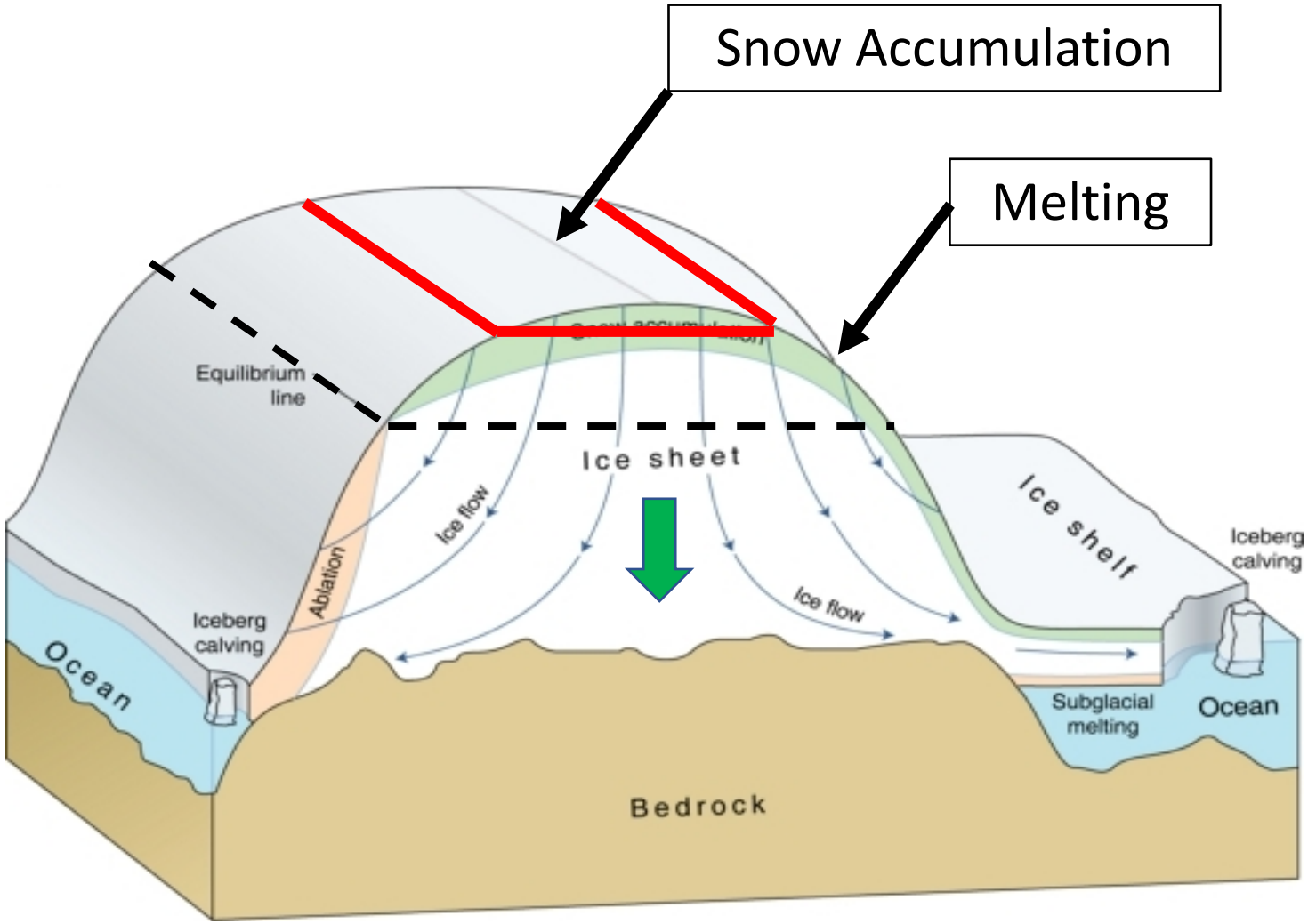

Tipping Point Example – Greenland Melt

- Reminder: Ice sheets have an ‘equilibrium line’ separating zones of snow accumulation vs. melting
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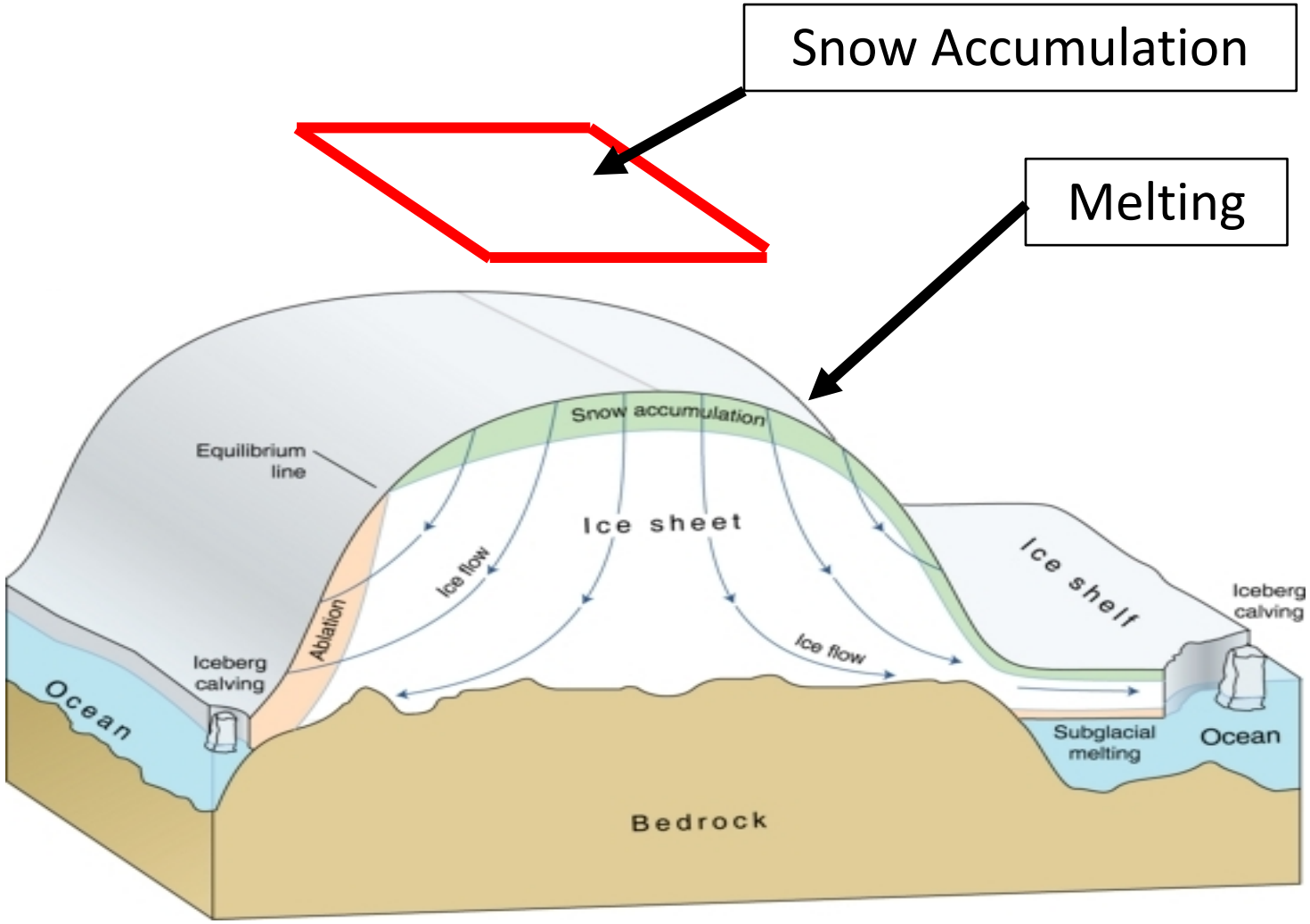
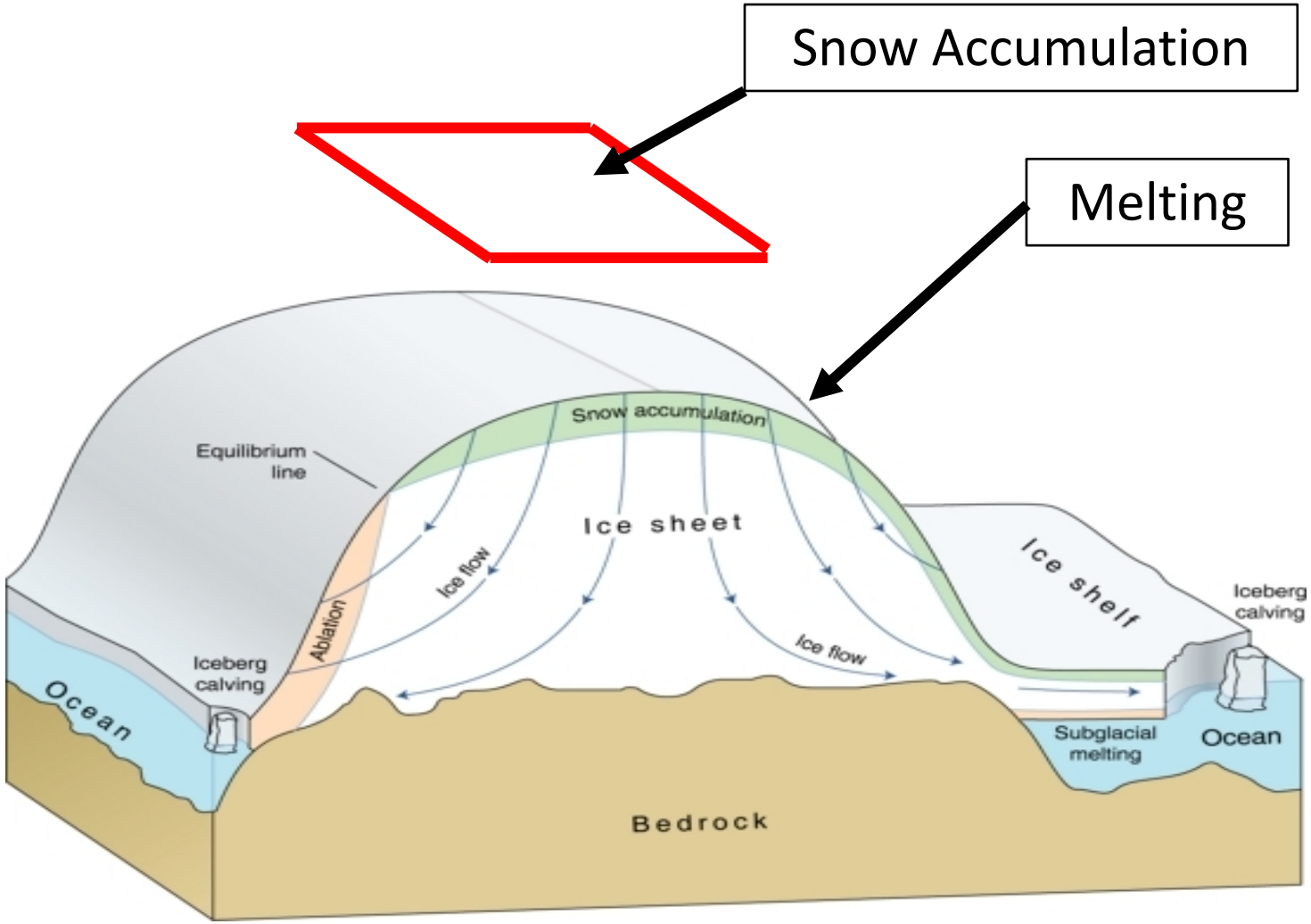
- If warmed enough, runaway positive feedback



Tipping Point Example – Greenland Melt

Runaway Positive Feedbacks:

- Once past a ‘threshold’, no more forcing is needed for the system to keep changing
- Eventually a new ‘stable’ state will be reached



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Runaway Positive Feedbacks:

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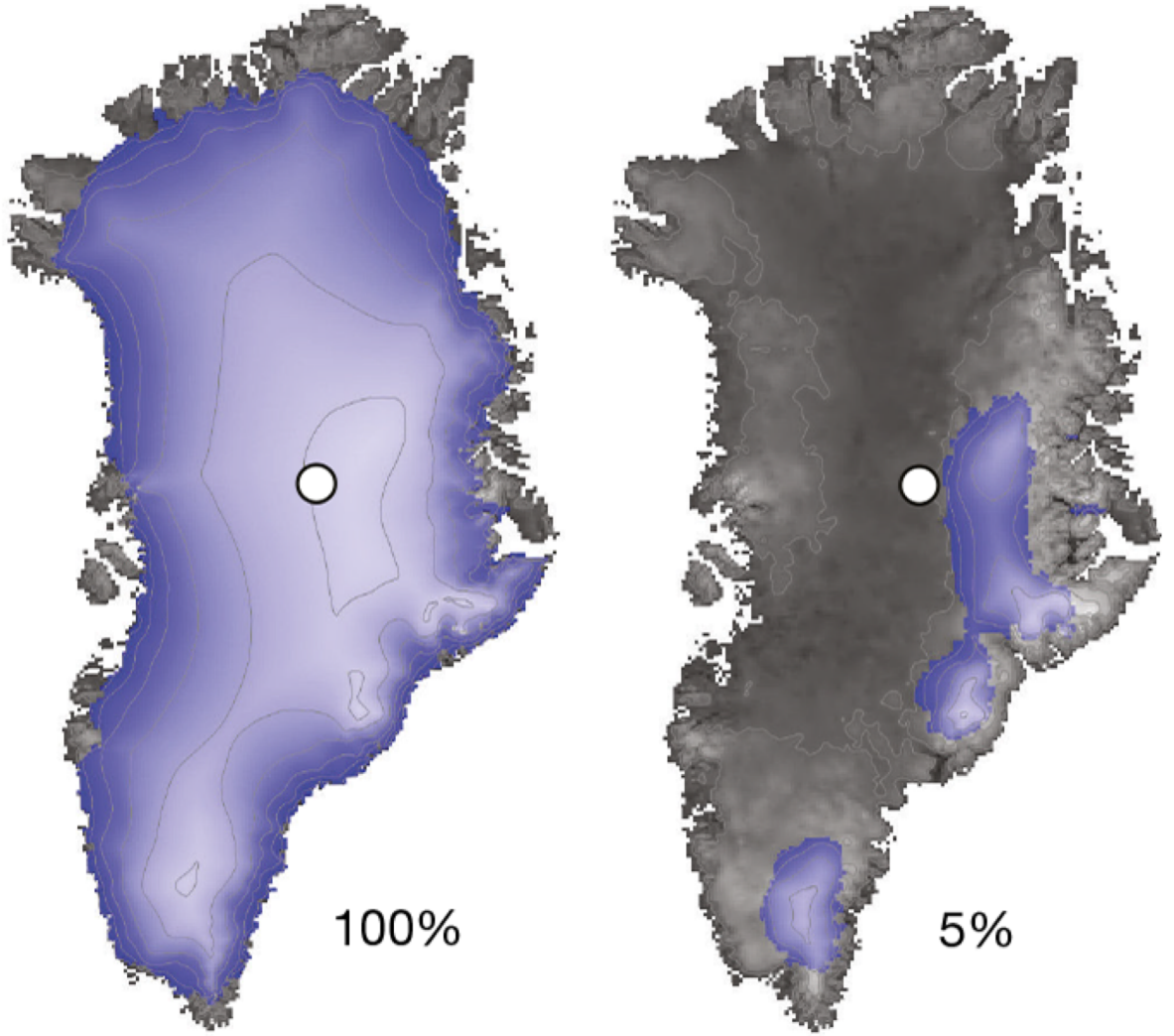
- In this case: Greenland mostly melted



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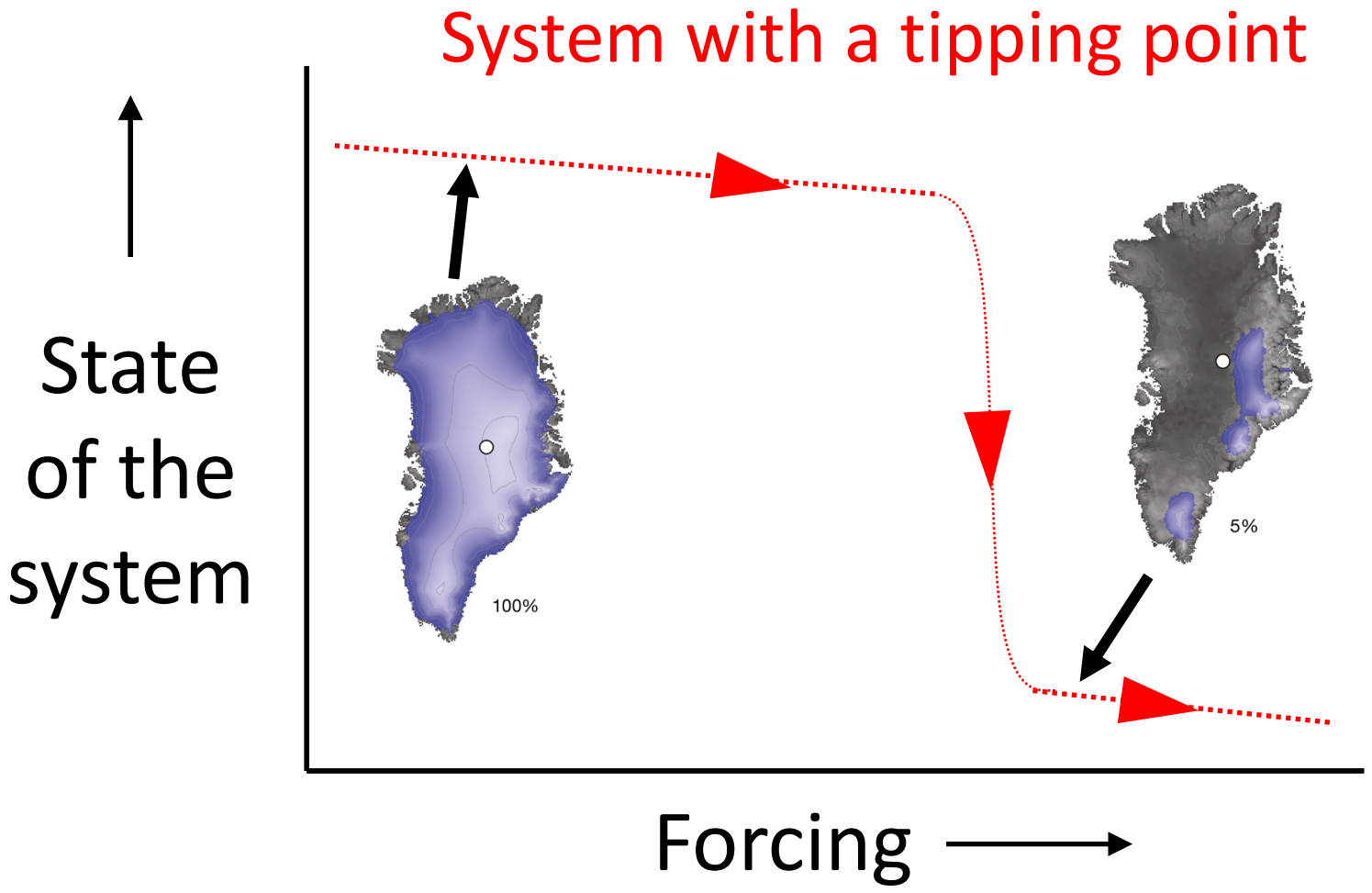

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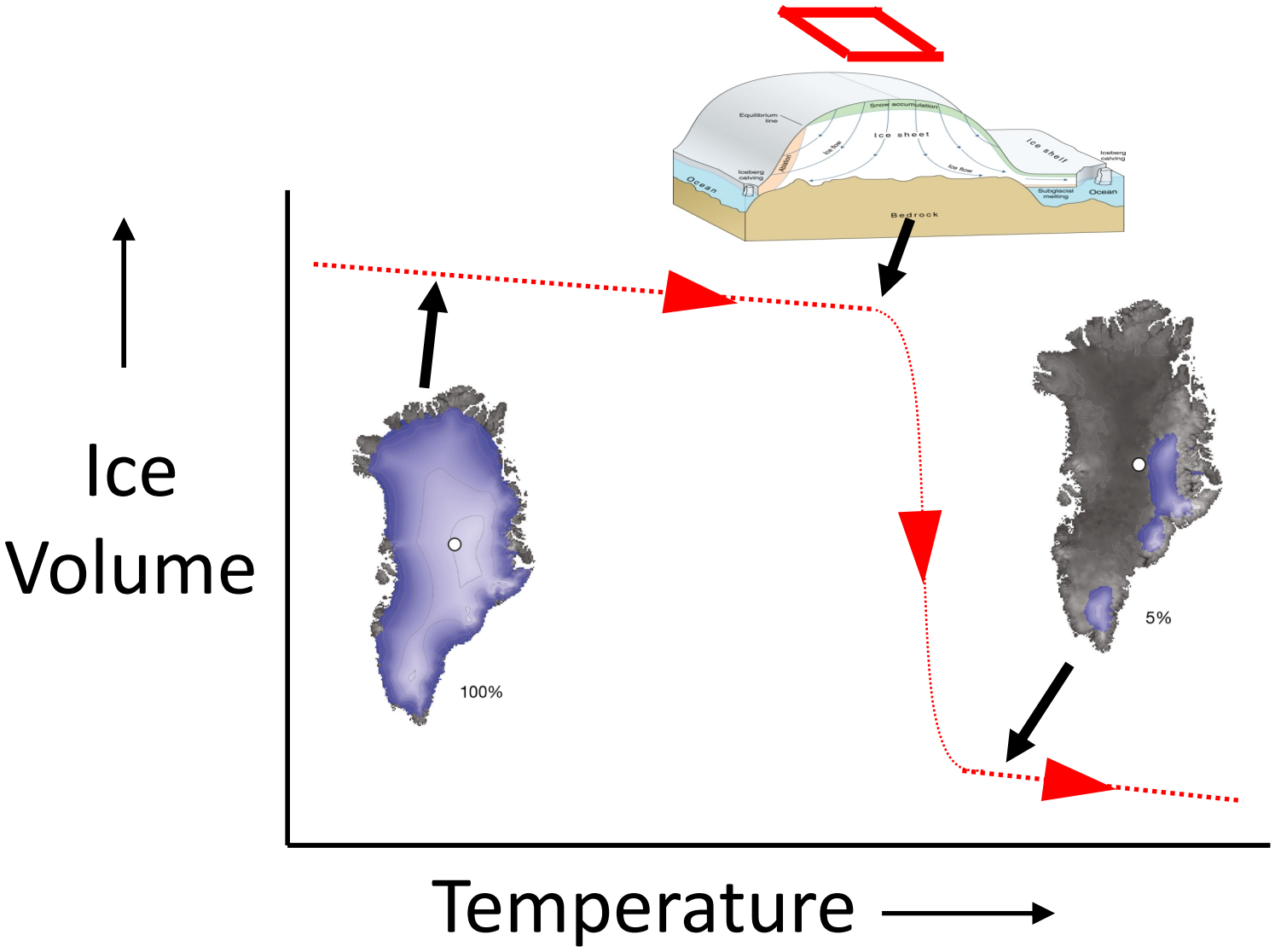

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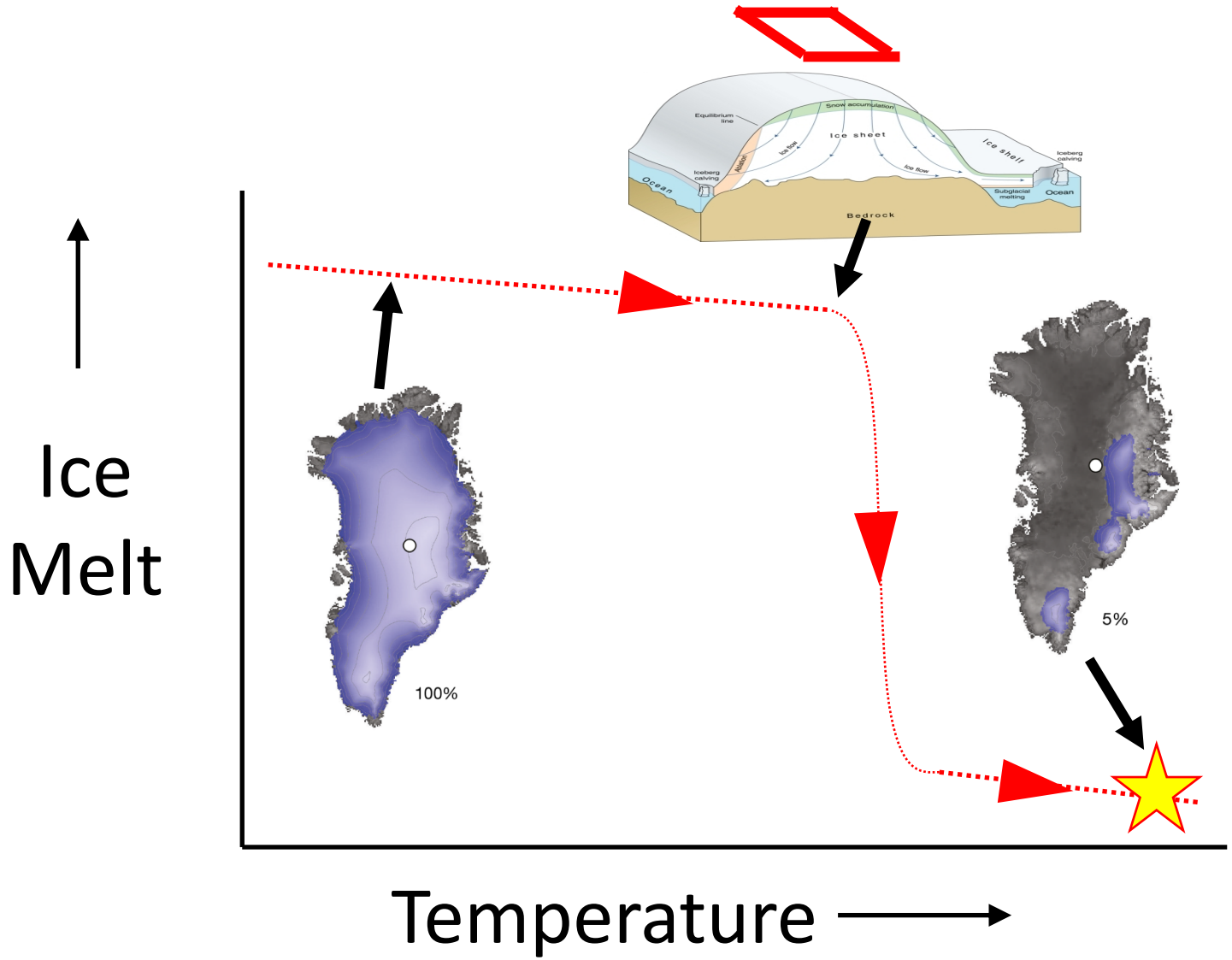
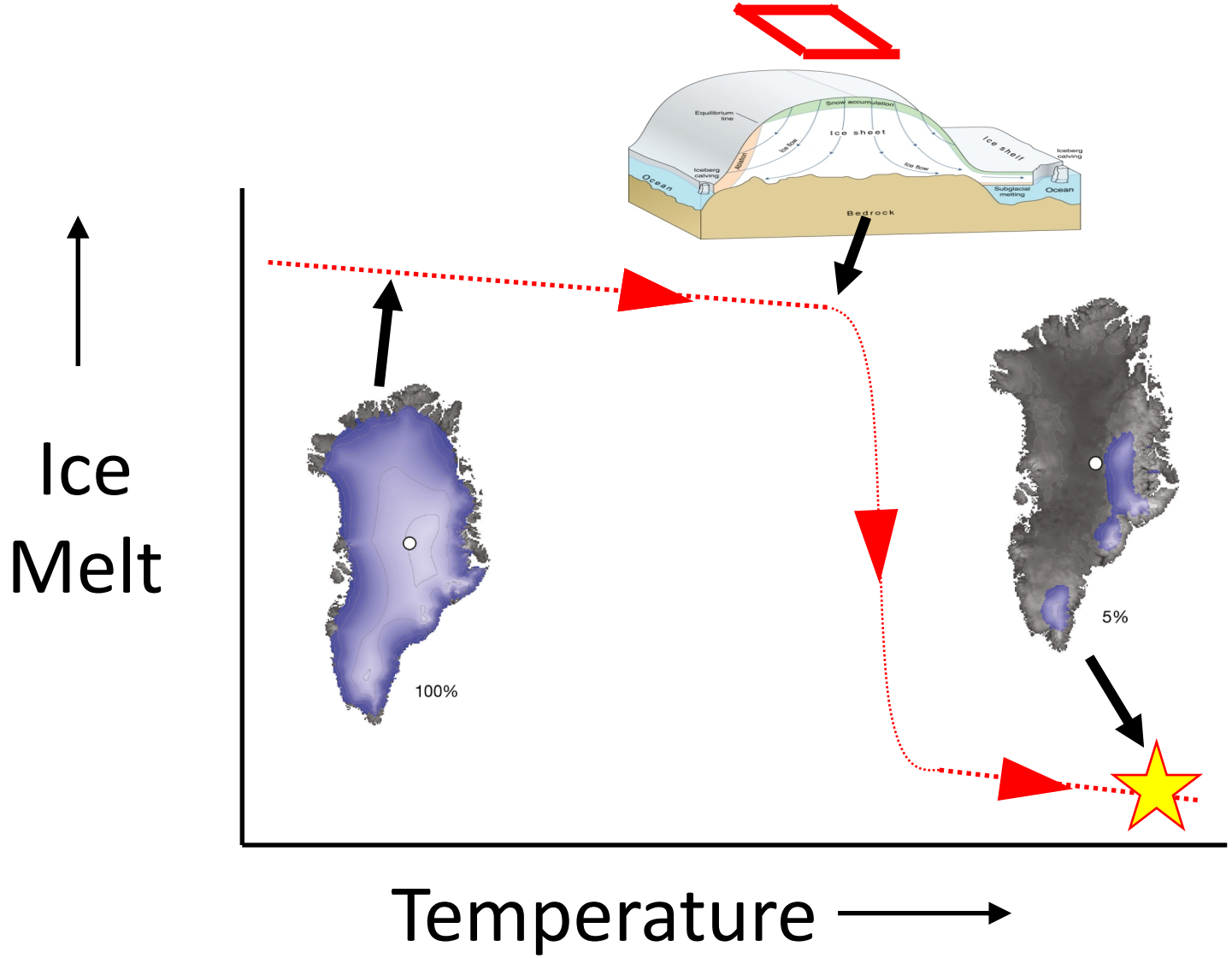
Reversible vs. Irreversible System Changes

- Ok… so we melted Greenland



Reversible vs. Irreversible System Changes

- Ok… so we melted Greenland
- Let’s cool down the planet and grow it back



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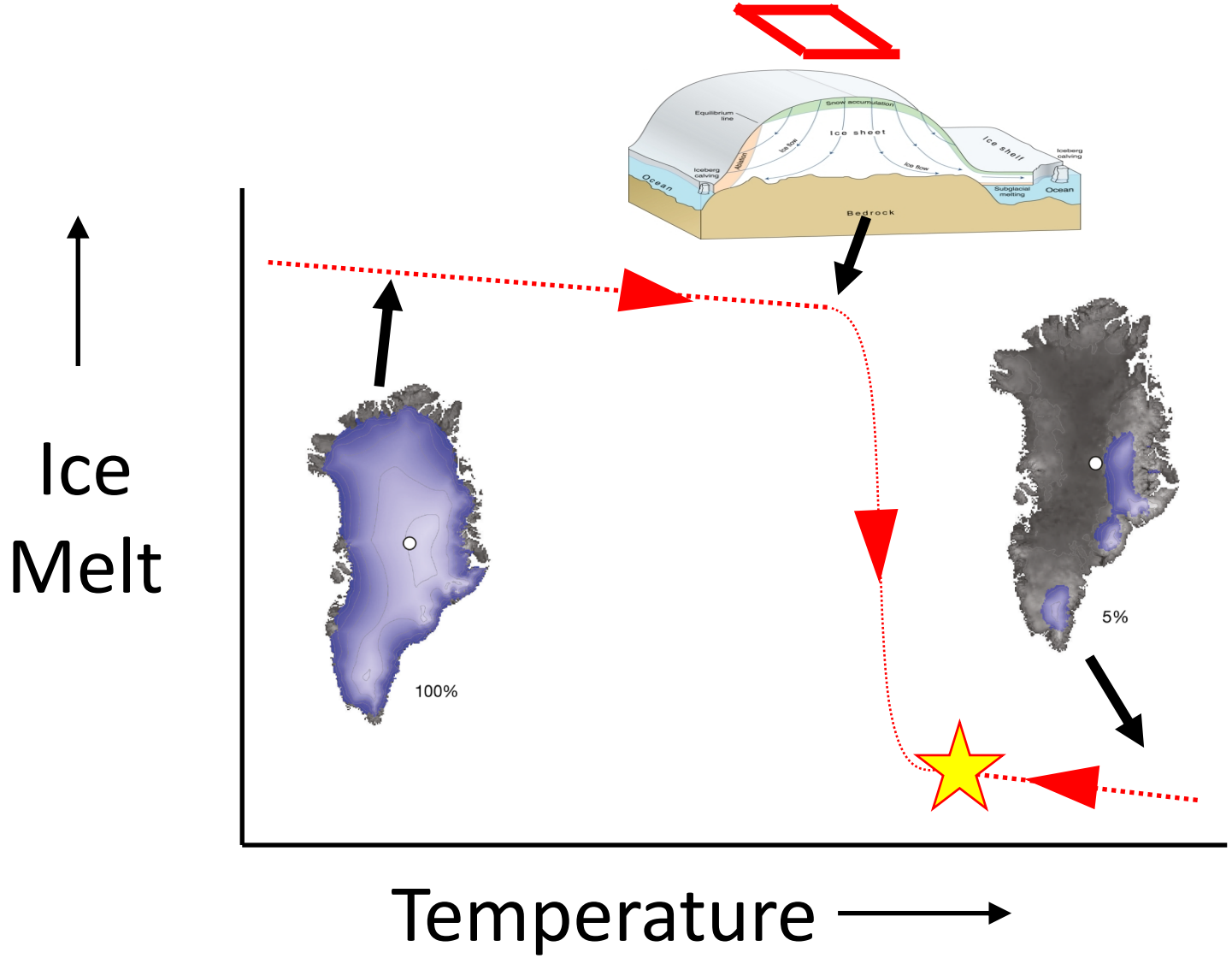
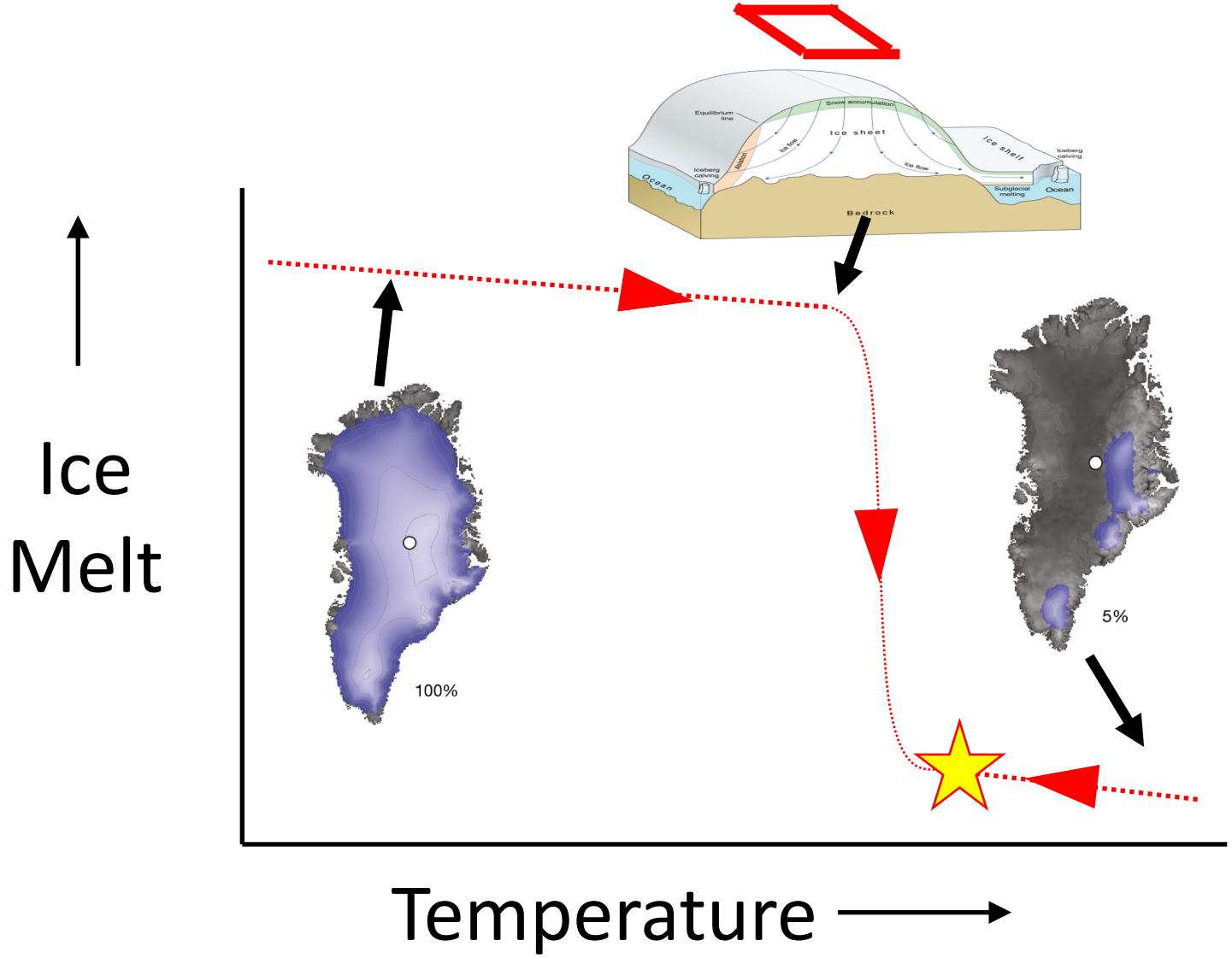


Reversible vs. Irreversible System Changes

- Ok… so we melted Greenland
- Let's cool down the planet and grow it back
- Problem:



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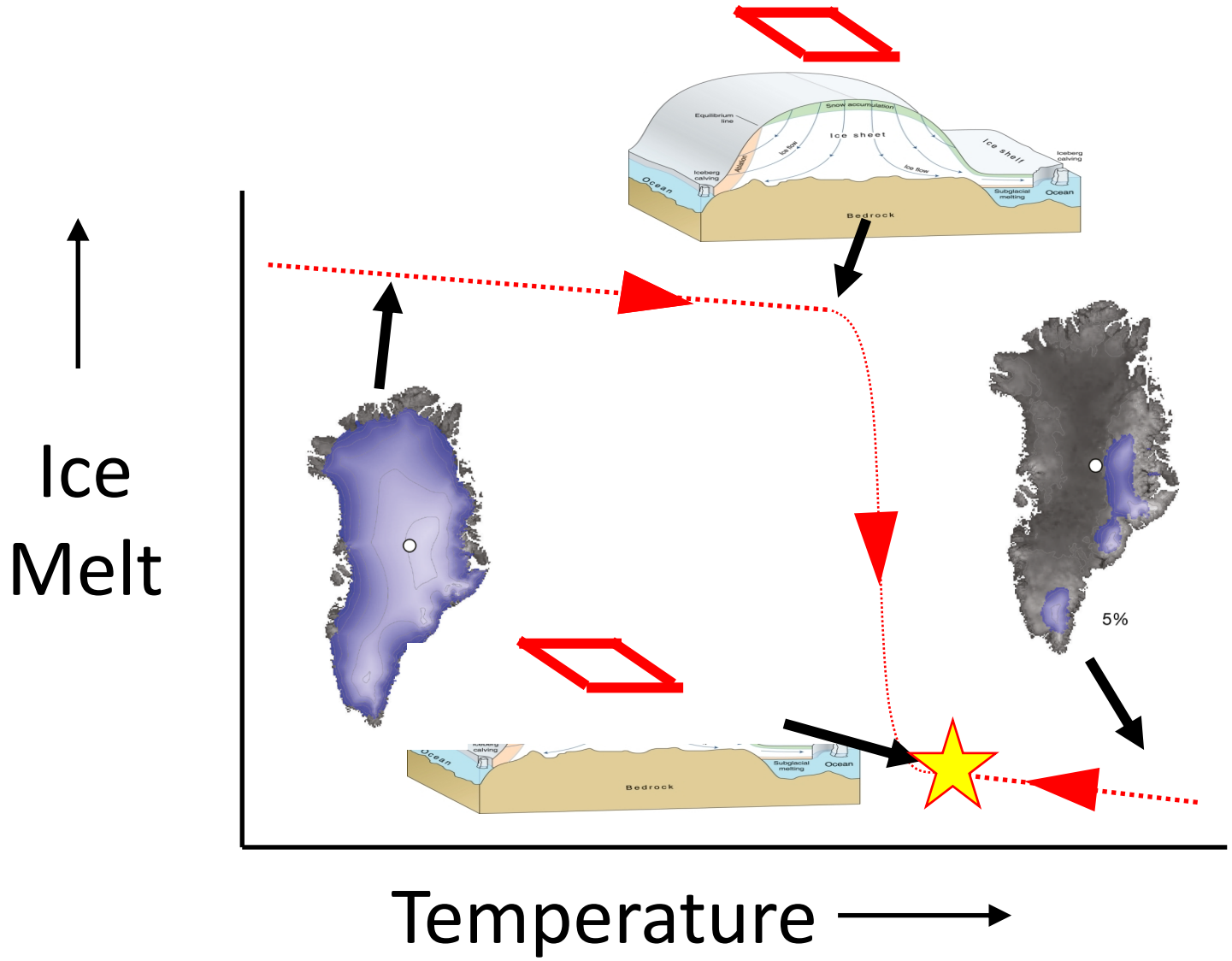

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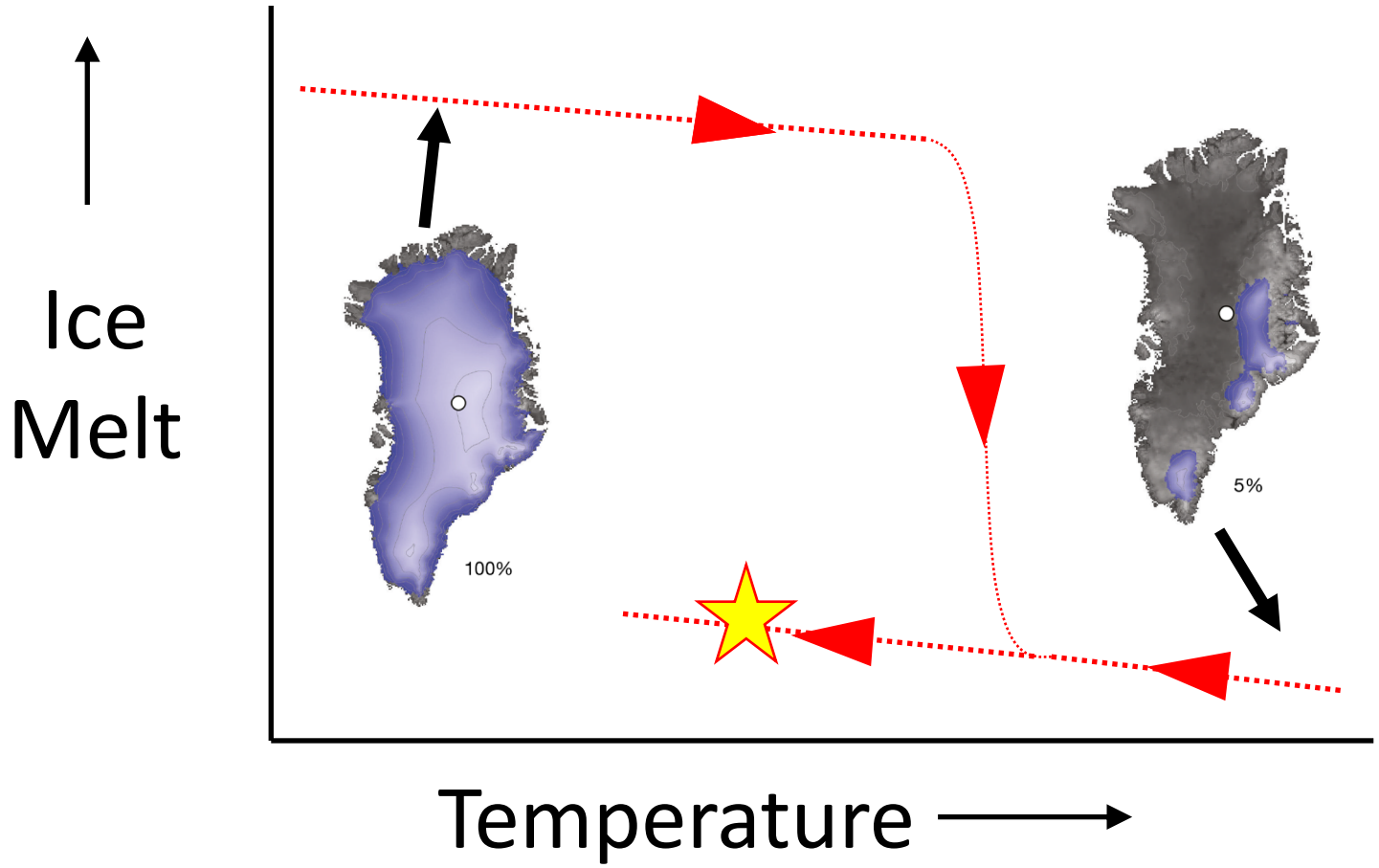
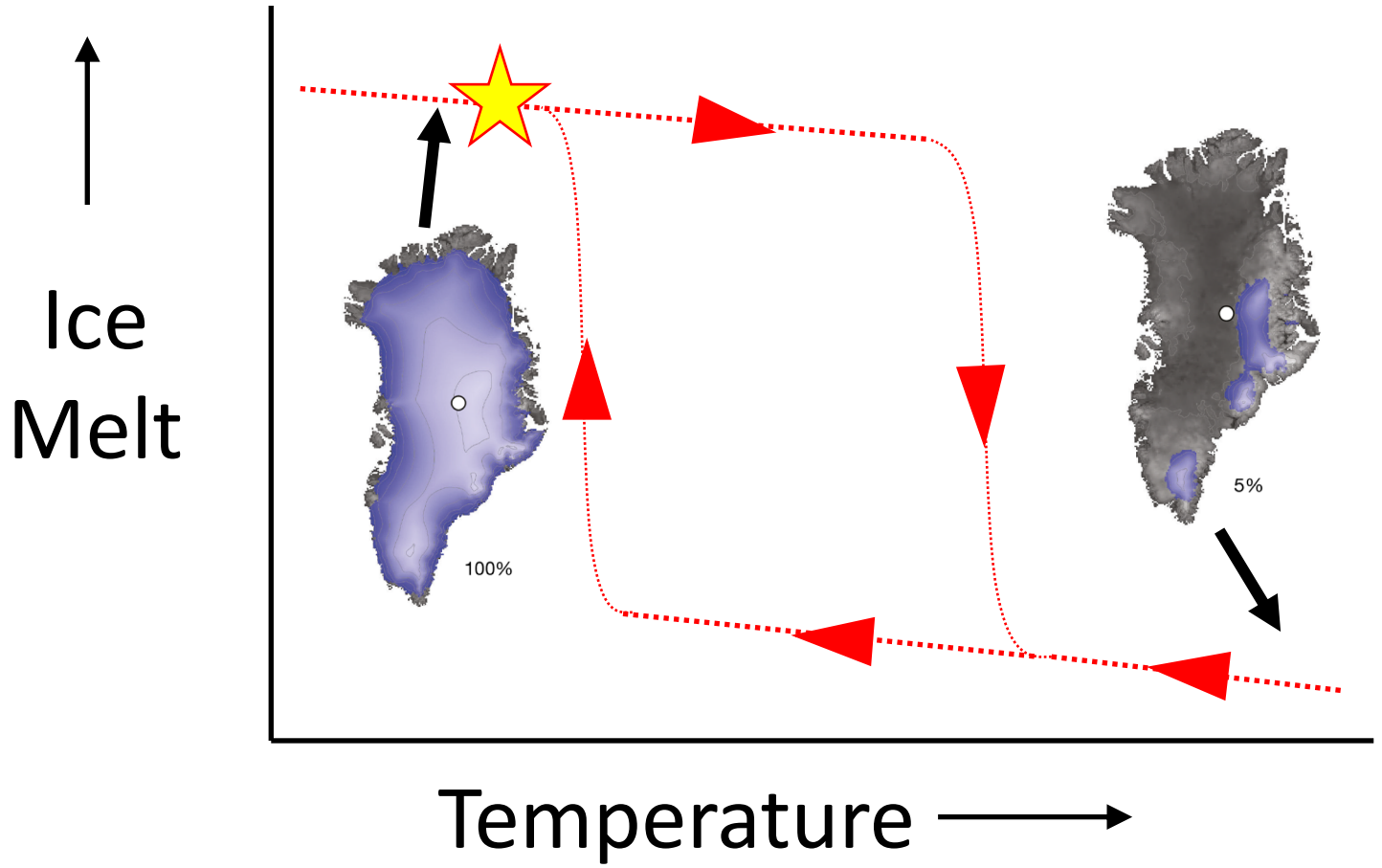
  - Needs to be a lot colder to grow again



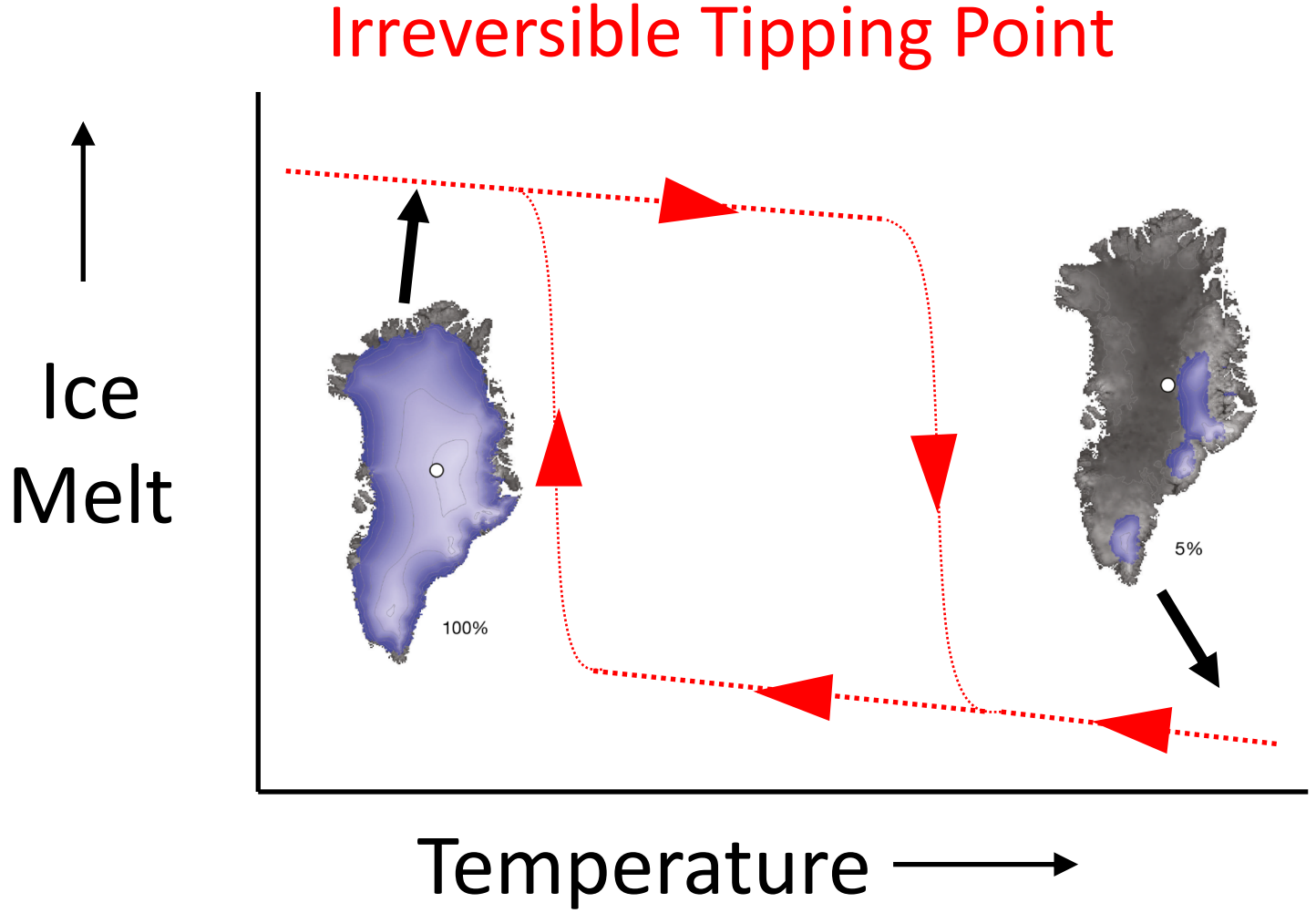
Reversible vs. Irreversible System Changes

- Ok… so we melted Greenland
- Let's cool down the planet and grow it back
- Problem:
  - Trying to grow an ice sheet at sea level now
  - Needs to be a lot colder to grow again
- Eventually pass 2nd threshold



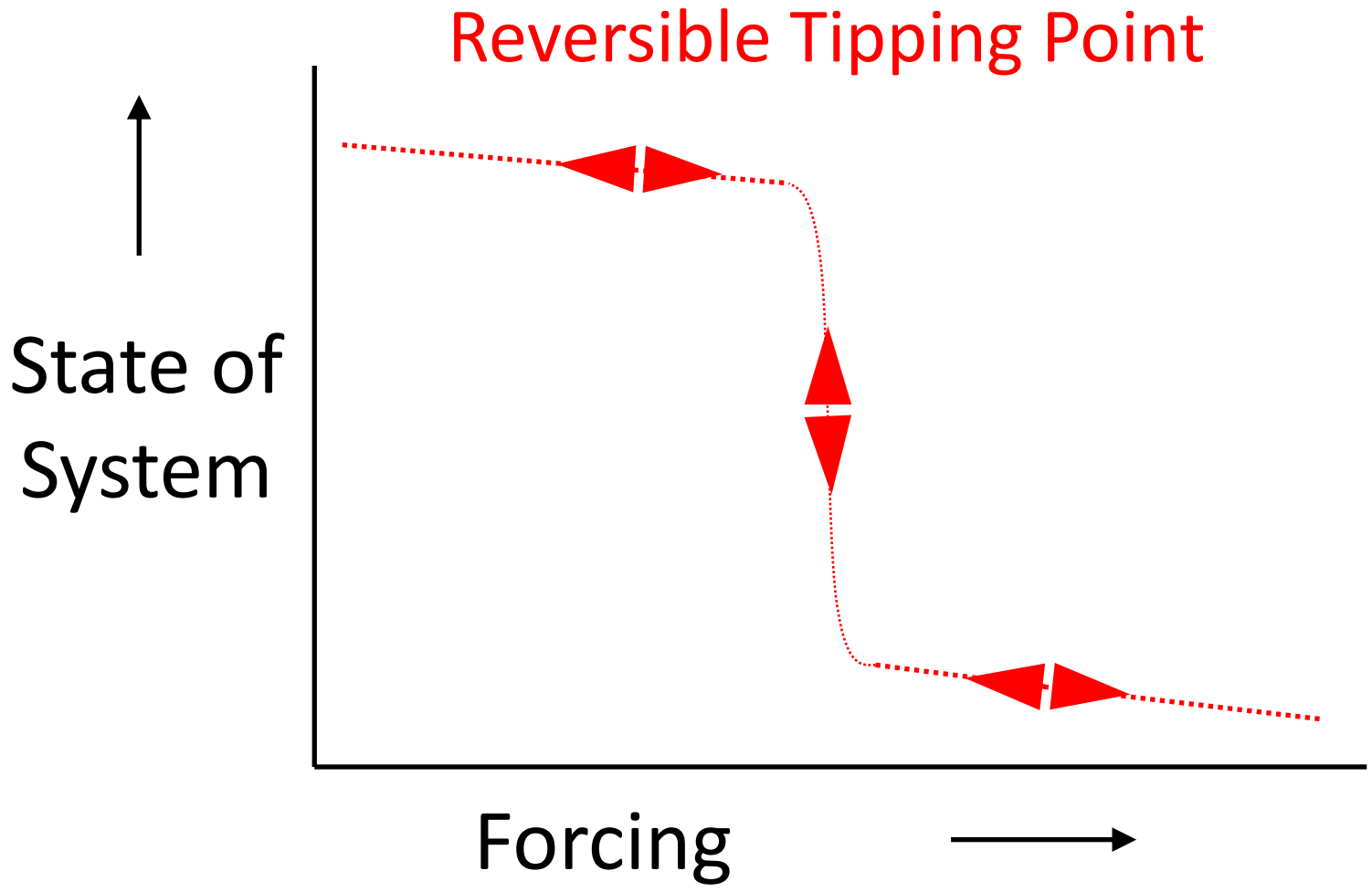
Reversible vs. Irreversible System Changes

- This is an **irreversible** tipping point system
- There is a different threshold to flip the system back
- This dynamic in a system is called **hysteresis**



Reversible vs. Irreversible System Changes

- **Reversible** system: Same threshold going each way

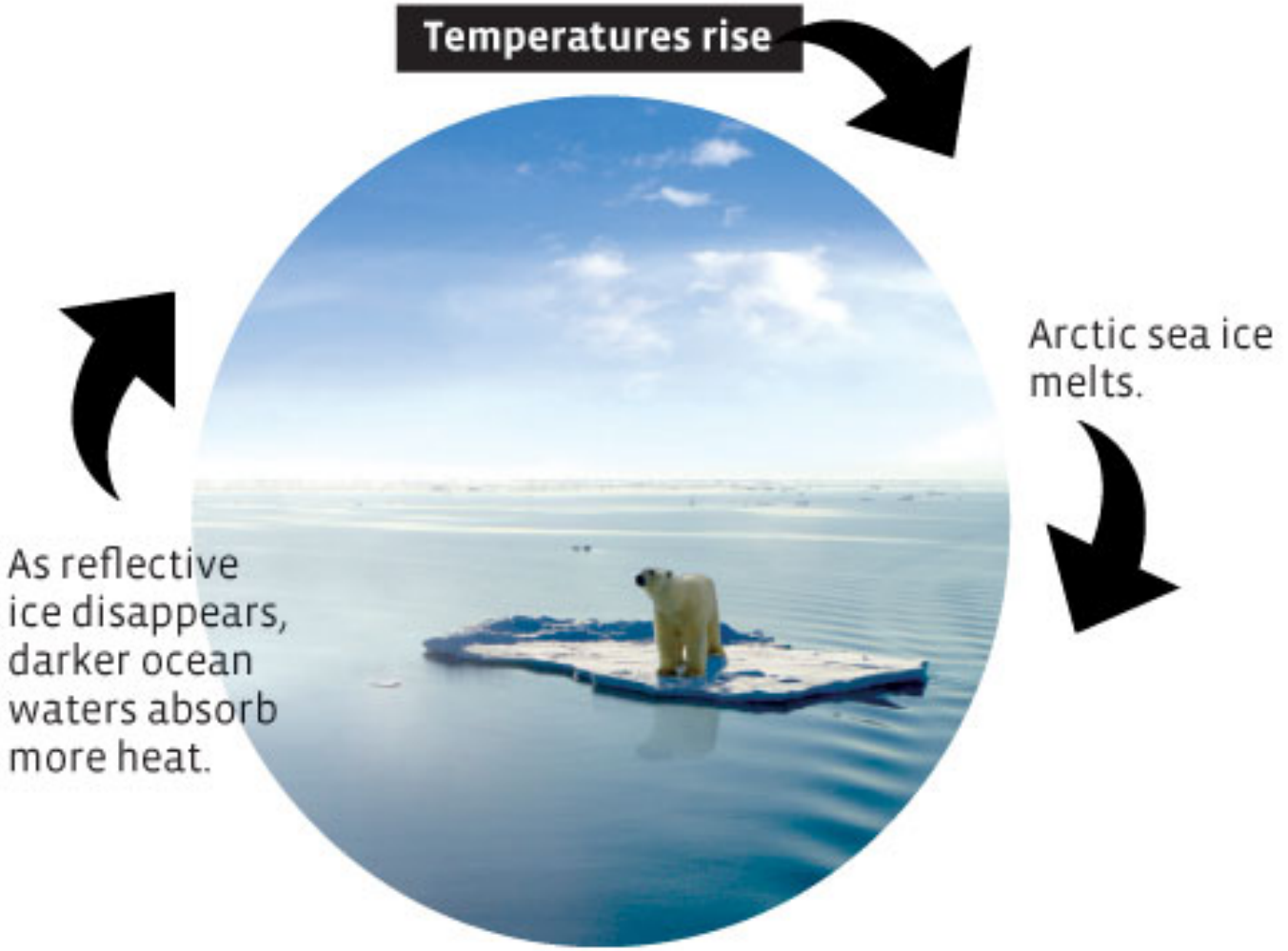


Think, Pair, Share

Arctic sea ice melt is believed to have a tipping point

- Ice/albedo feedback loop

Is this tipping point system **reversible** (same threshold to flip system back) or **irreversible** (different, lower threshold to flip system back)?

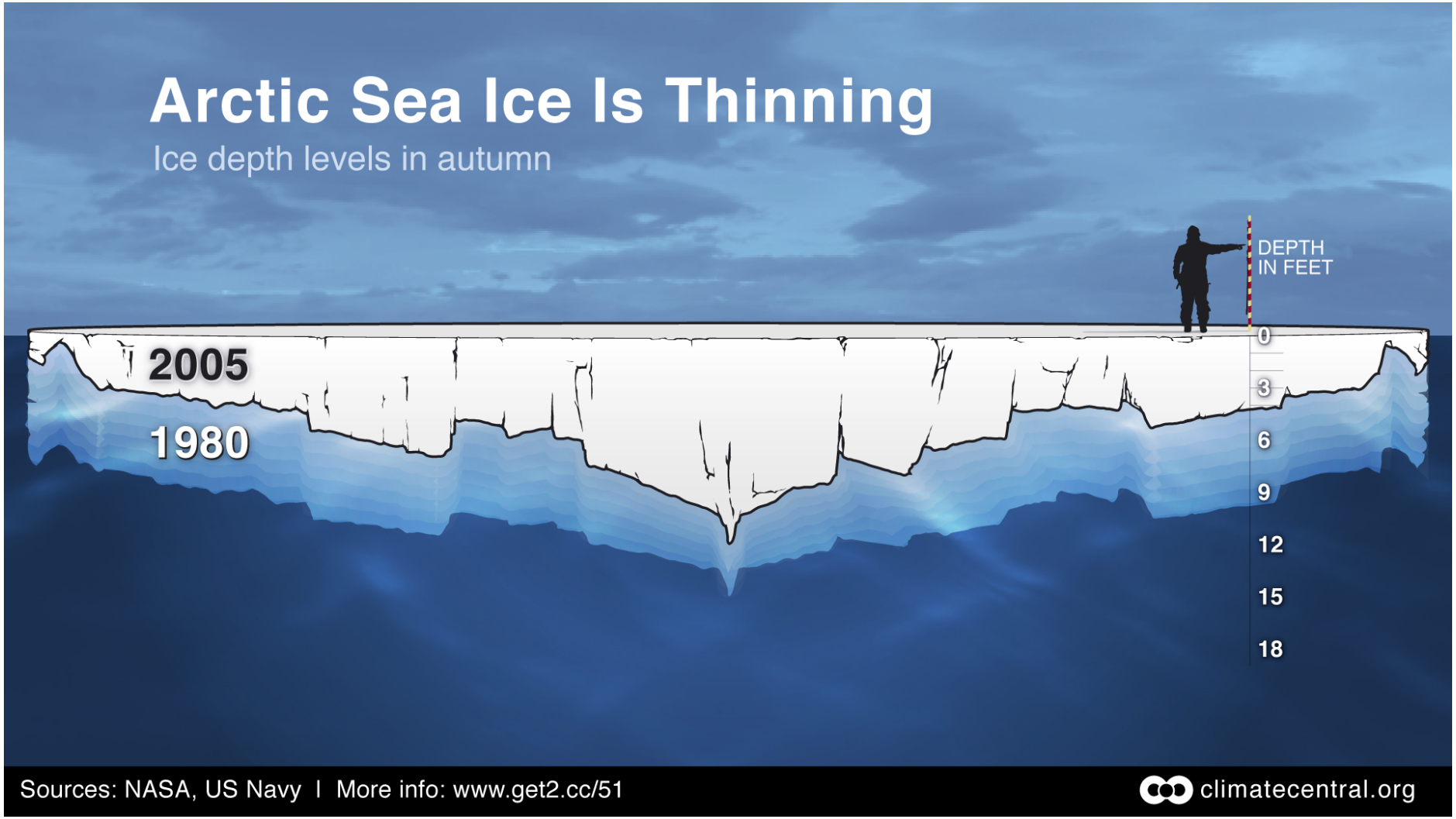


Think, Pair, Share

Reversible

Sea ice is always formed at sea level

Easy to grow back if temps cool and albedo rises



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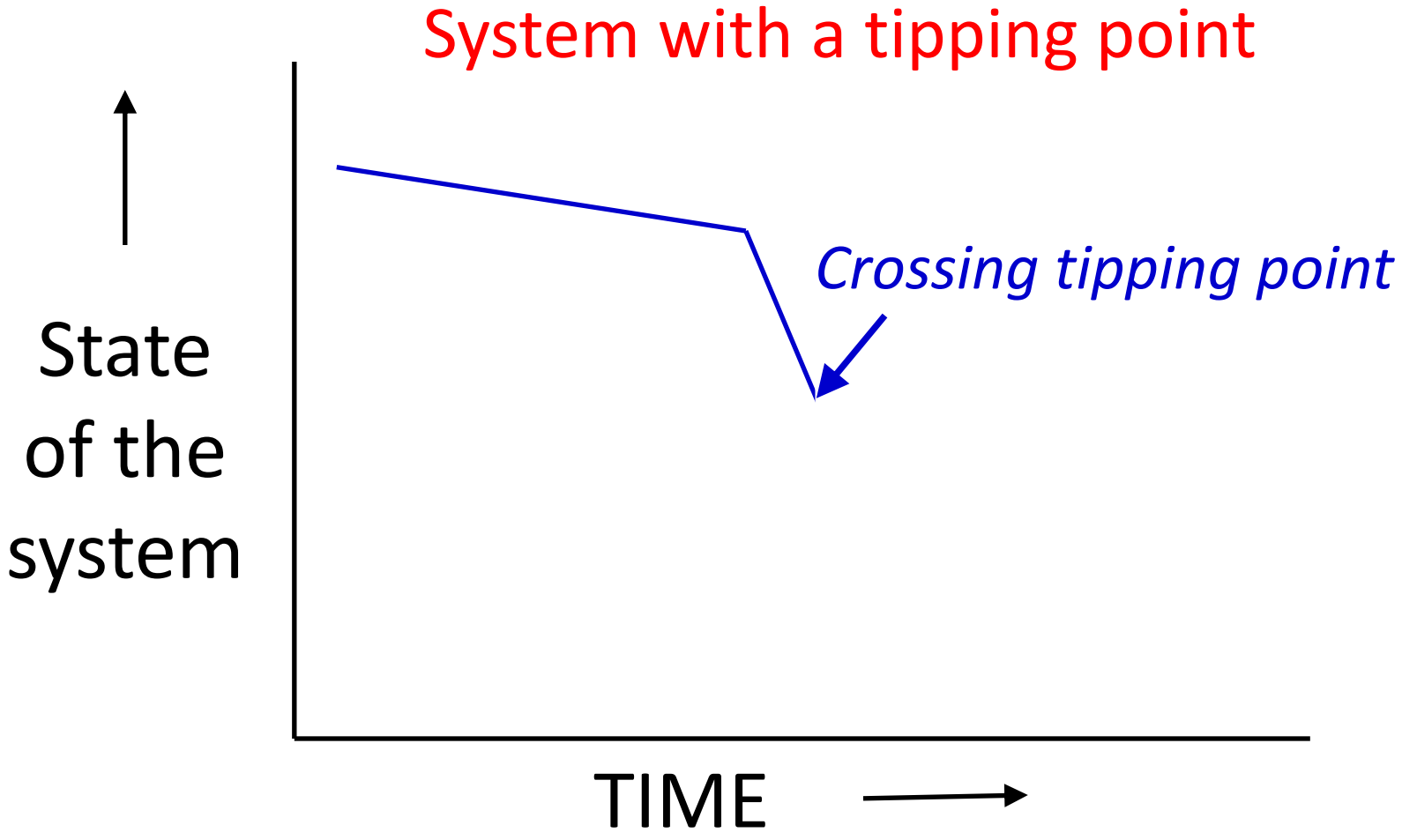
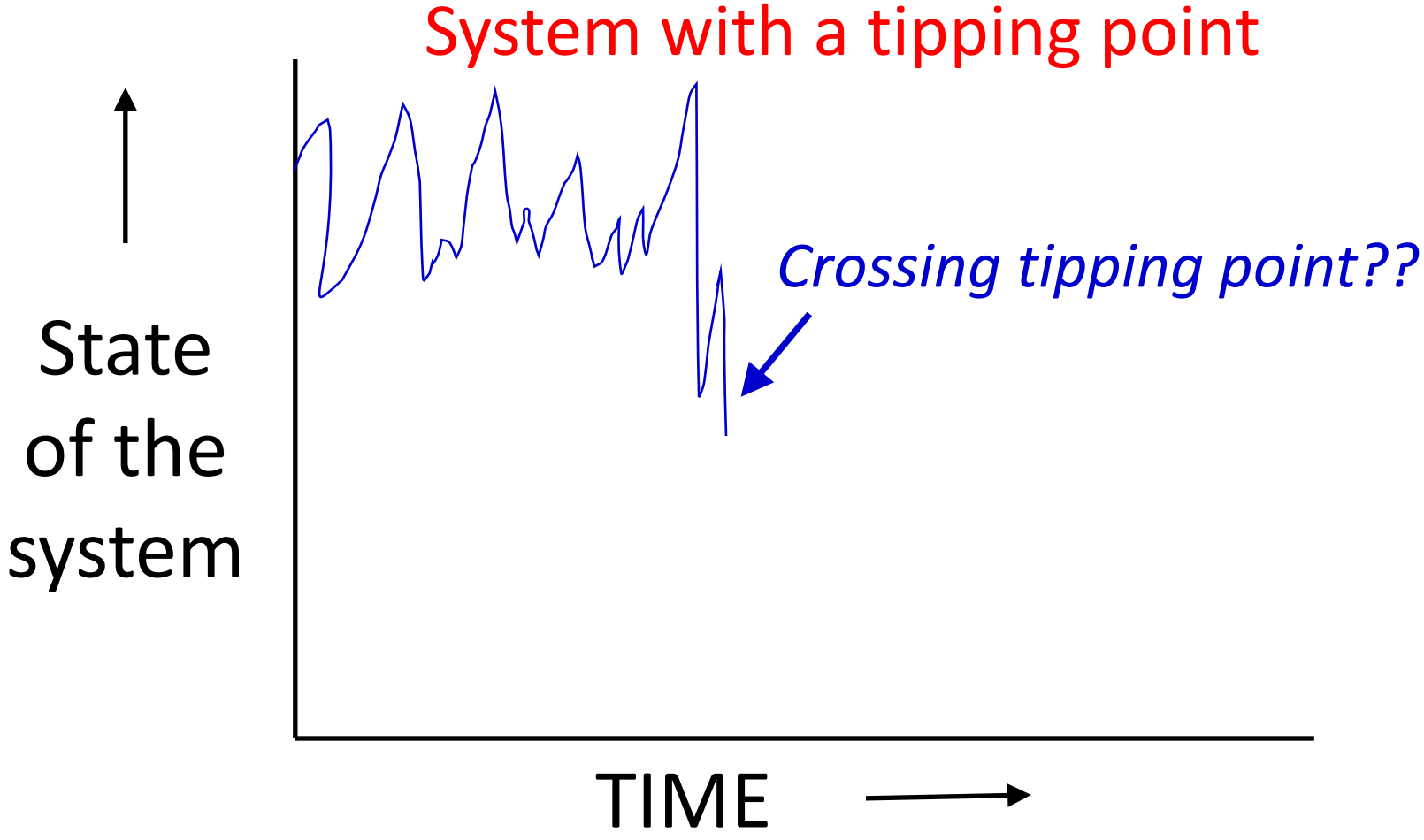
Identifying Tipping Points

- Tipping point might not be clear until **after you've already passed it**



Identifying Tipping Points

- Tipping point might not be clear until **after you've already passed it**
- Because the real world is noisy!



Identifying Tipping Points

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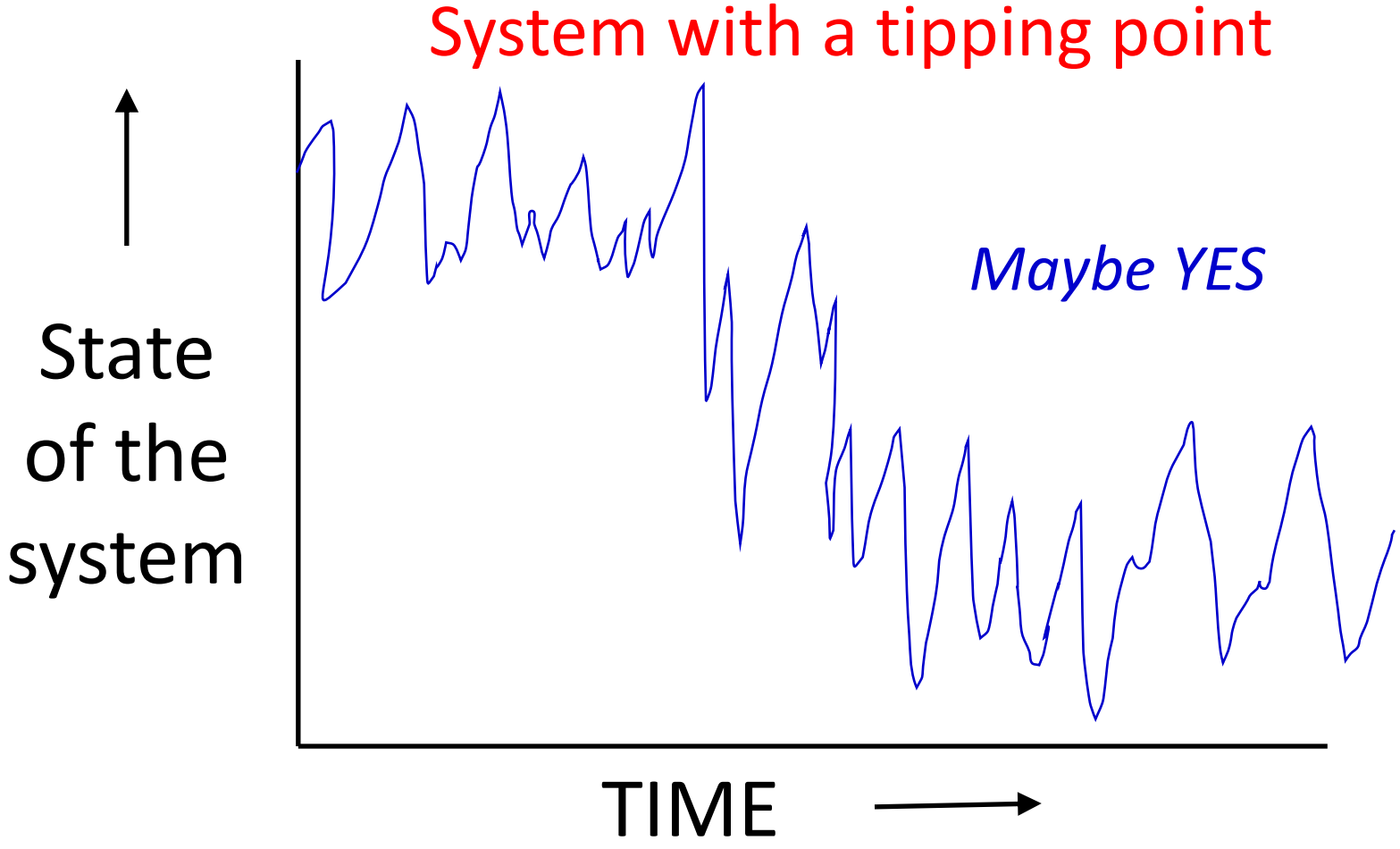

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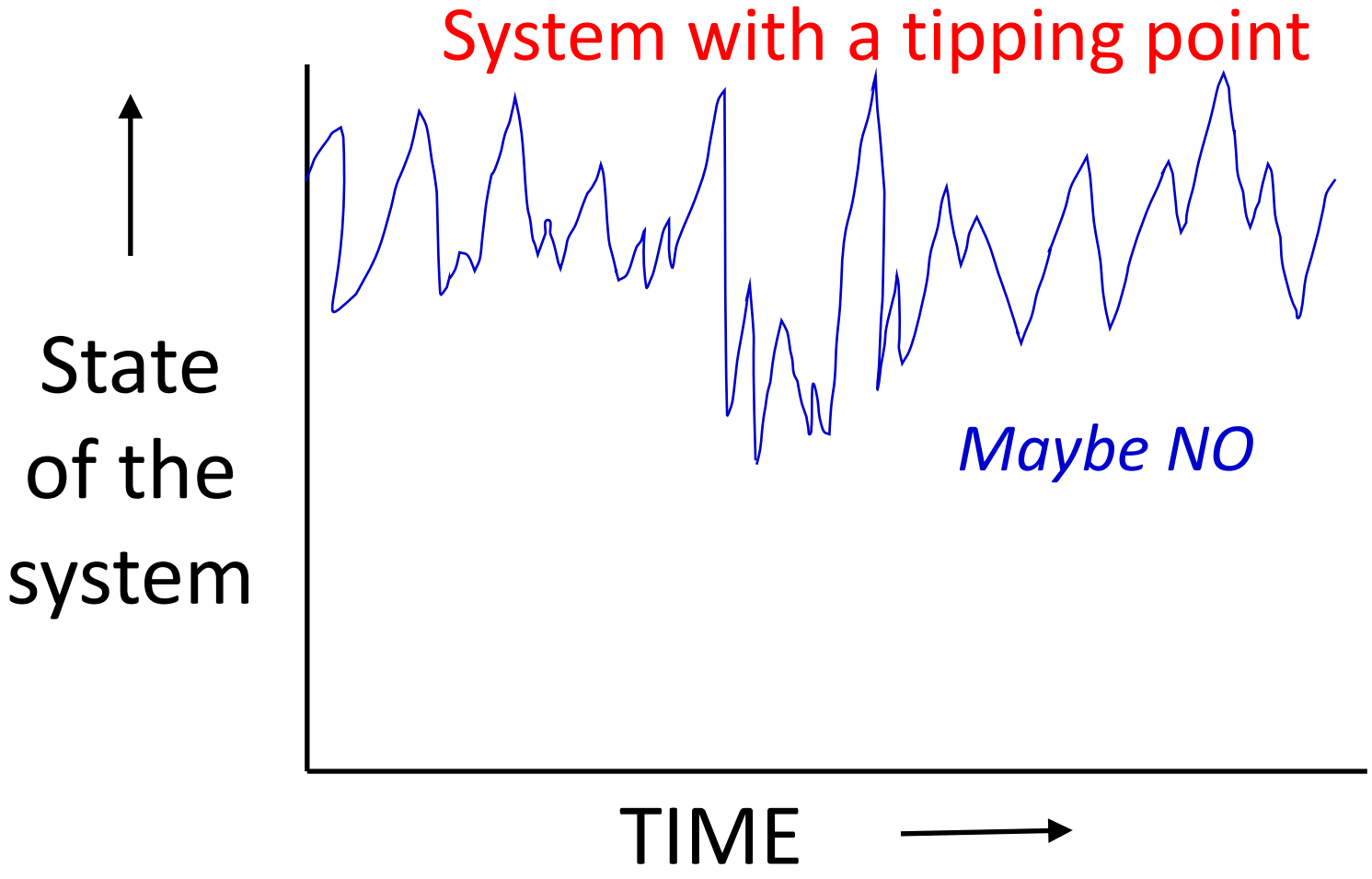

Identifying Tipping Points

- Tipping point might not be clear until **after you've already passed it**
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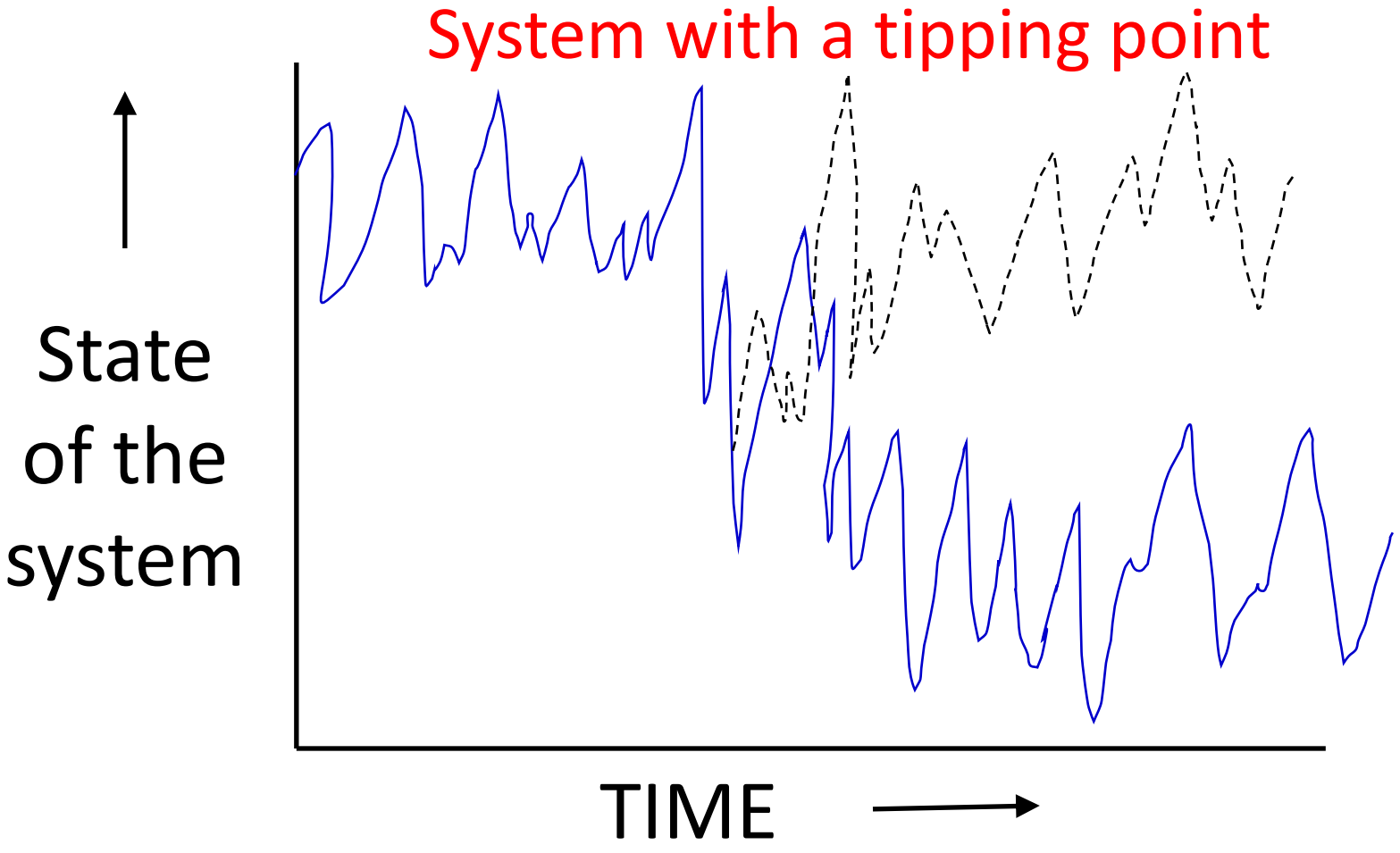
One clear thing:

- The harder you push the system, the more likely you are to cross a tipping point



Predicting Tipping Points

- Modeling systems with feedbacks is *very* difficult
- Strength and speed of feedbacks are hard to predict

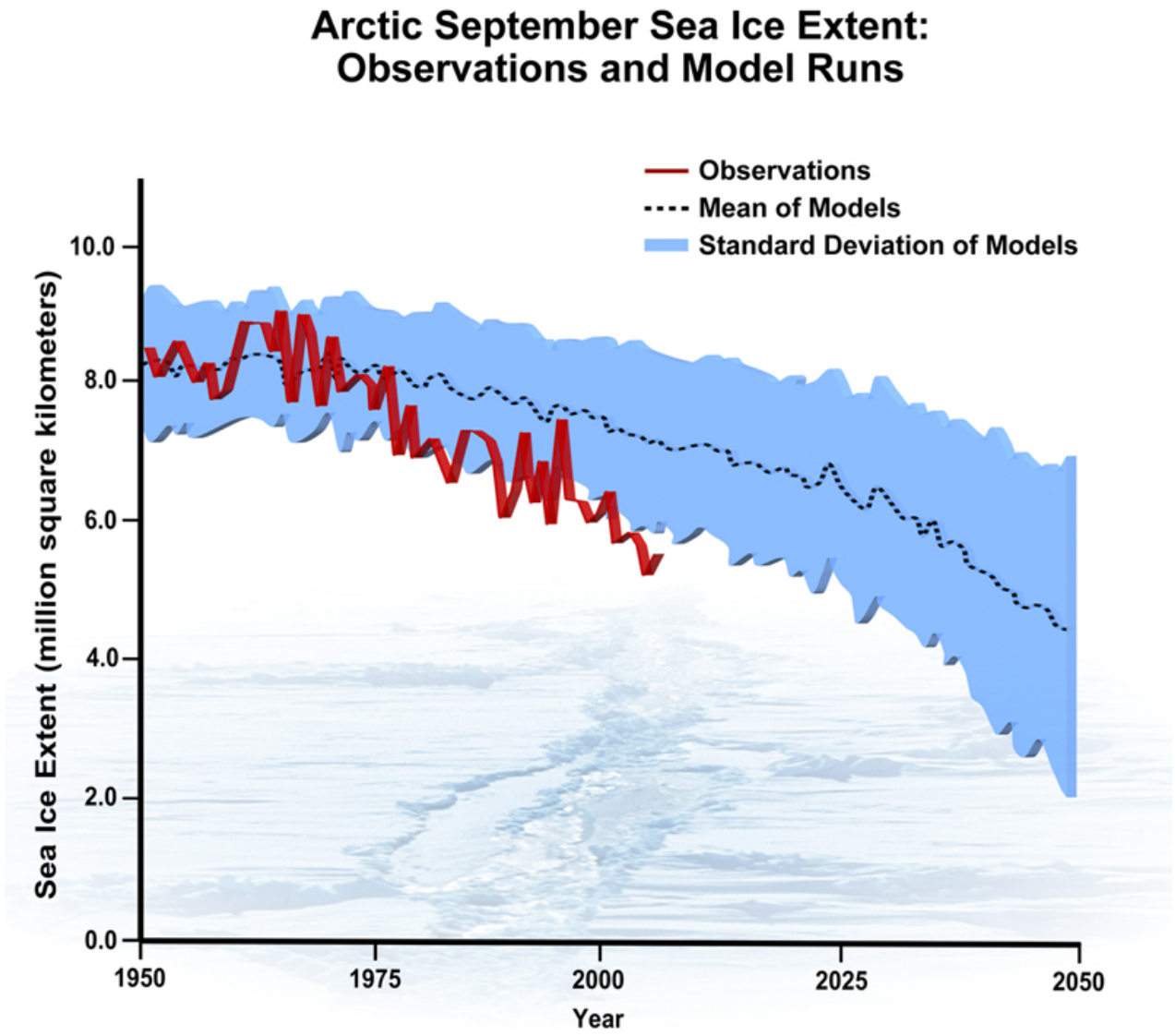


Image from UCAR.edu

Predicting Tipping Points

- Modeling systems with feedbacks is *very* difficult
- Strength and speed of feedbacks are hard to predict
- Models of systems almost always *underpredict* the strength and speed of system response

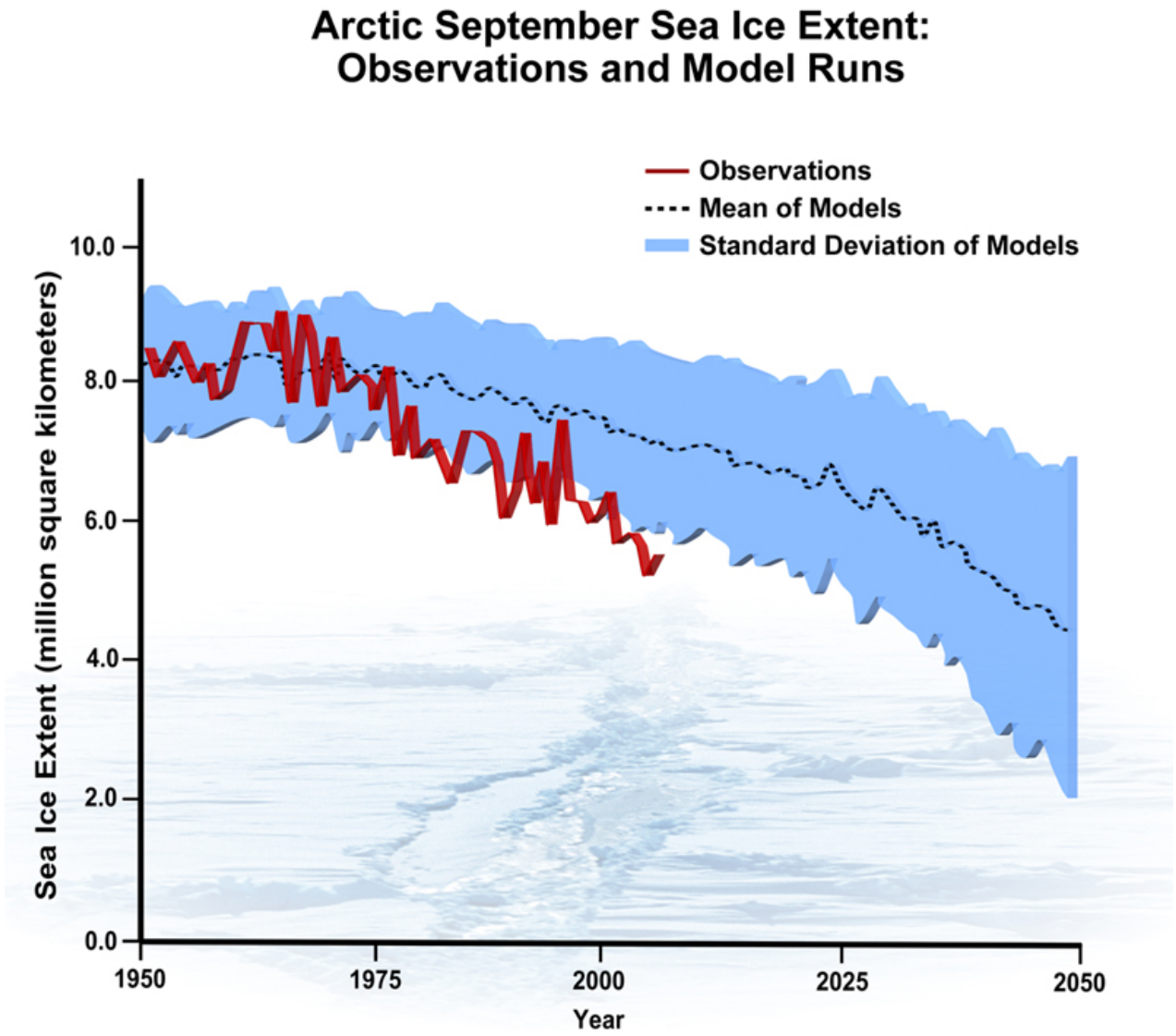


Image from UCAR.edu

Think, Pair, Share

The West Antarctic Ice Sheet has a tipping point (‘marine ice shelf instability’)

Look at the Antarctic mass loss over time, **have we crossed that tipping point?**

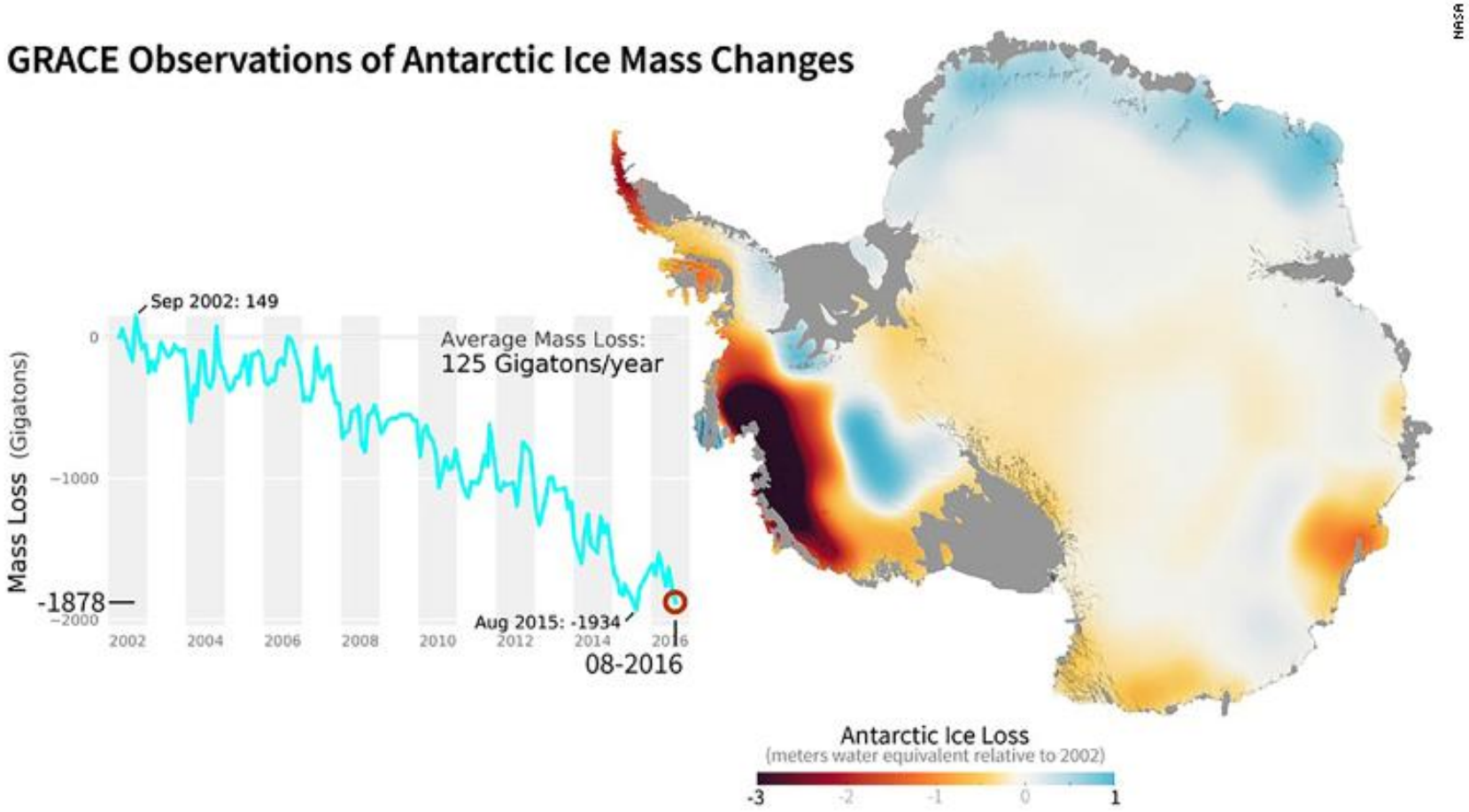


Image from NASA.gov

Today's Class: Projections II – Tipping Points

Learning Objectives

1. Understand the concept of runaway feedbacks
2. Distinguish between reversible and irreversible tipping point systems
3. Explain why tipping point thresholds are hard to identify and predict
4. Identify one reversible and one irreversible tipping point in the global climate system

'Rocking the Boat' – How some climate systems change → Reversible vs. irreversible system changes → Identifying & predicting tipping points → Tipping point examples

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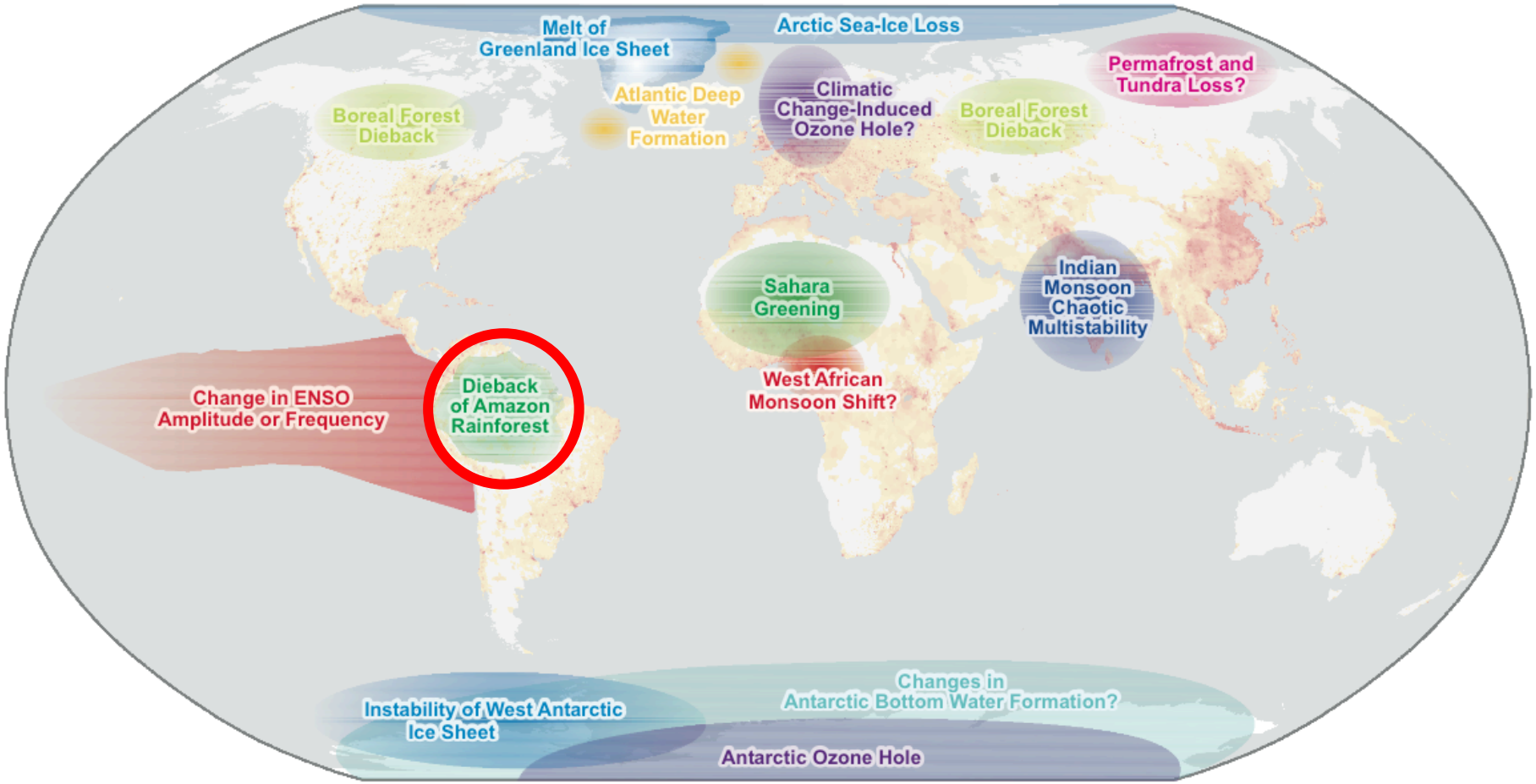
Tipping Point Examples



Amazon Rainforest Retreat

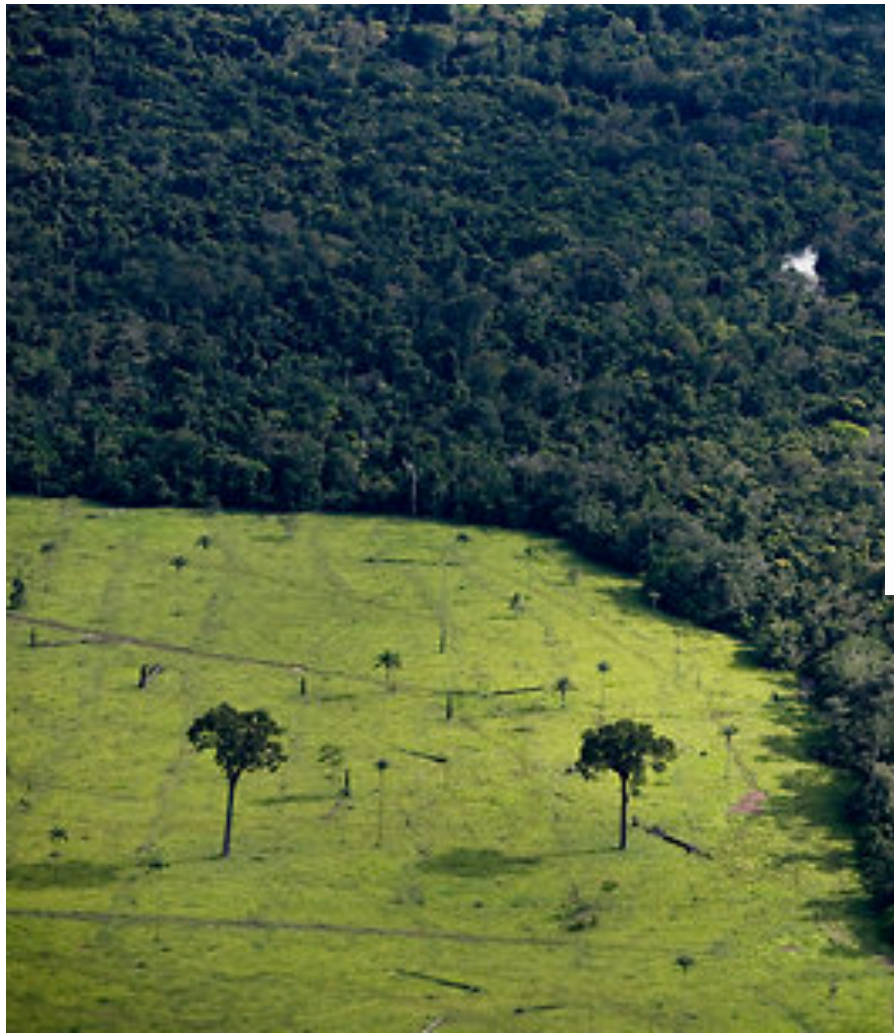
- Amazon rainforest creates its own climate
- Plants release water vapor during photosynthesis
- So much photosynthesis happens in the Amazon, the trees create more clouds/rain

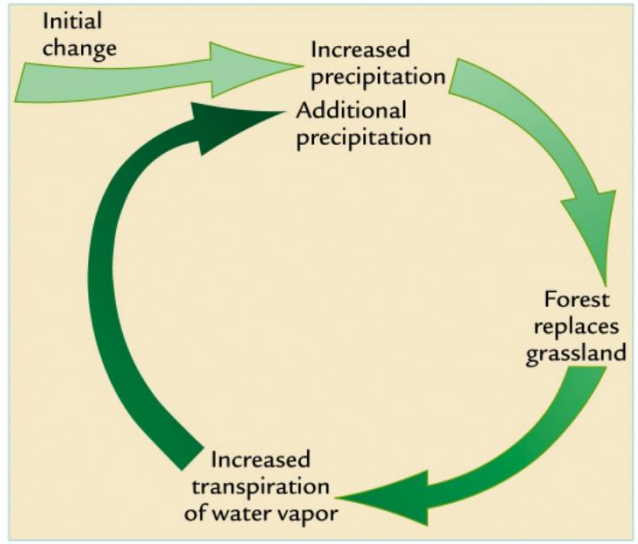
Amazon Rainforest Retreat

- Some models show rainforest area shrinking with global warming
- Fewer trees = less precipitation = fewer trees, etc.

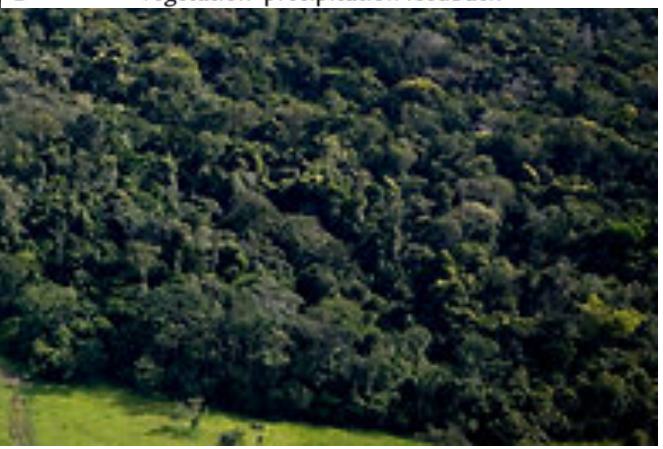
Amazon Rainforest Retreat

- Some models show rainforest area shrinking with global warming
- Fewer trees = less precipitation = fewer trees, etc.
- **Reversible** tipping point



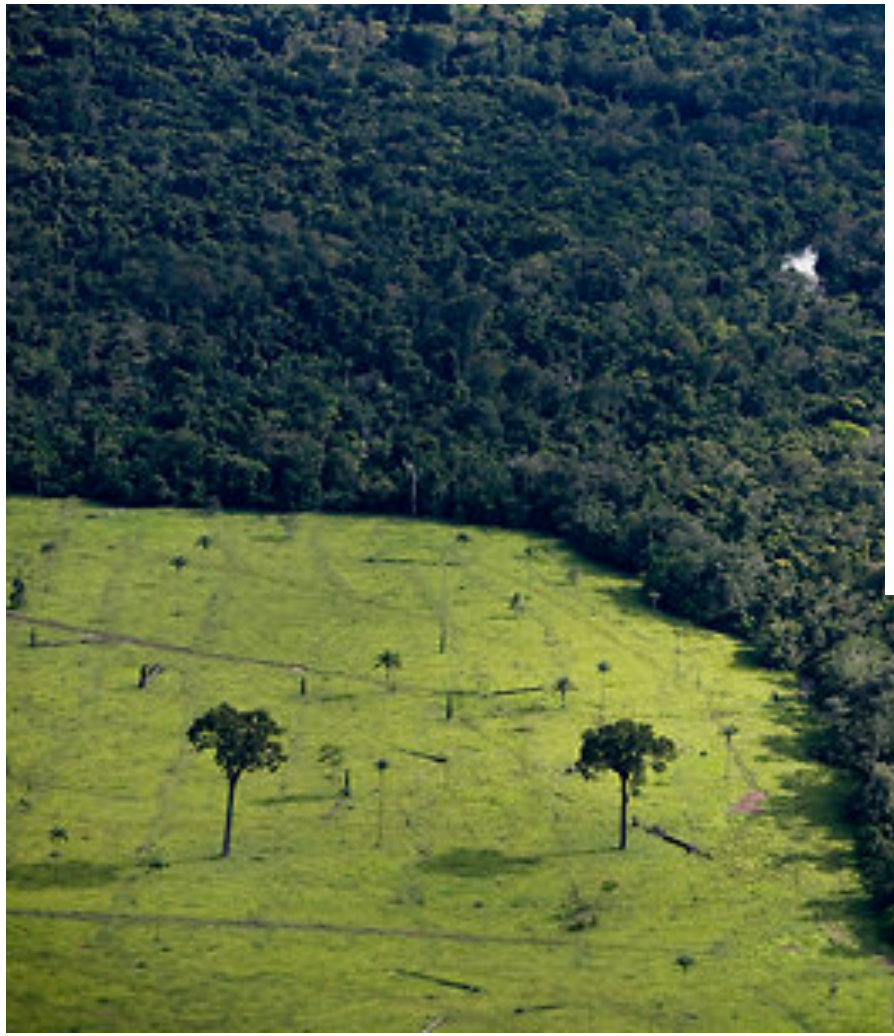


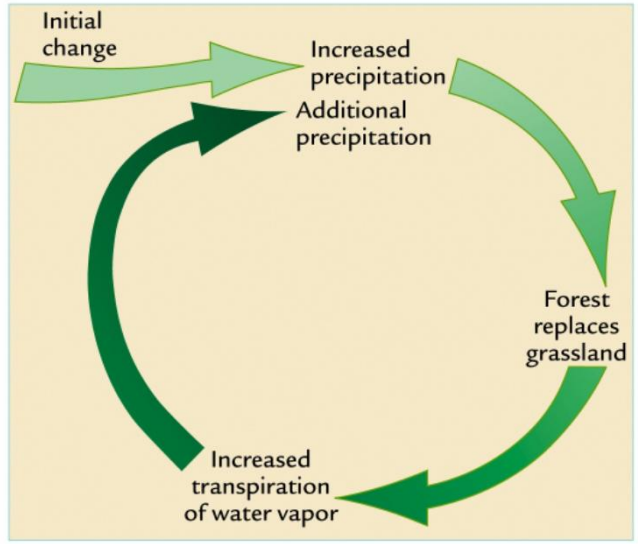
B Vegetation–precipitation feedback



Amazon Rainforest Retreat

- Some models show rainforest area shrinking with global warming
- Fewer trees = less precipitation = fewer trees, etc.
- **Reversible** tipping point
- …if humans were not cutting down extra trees





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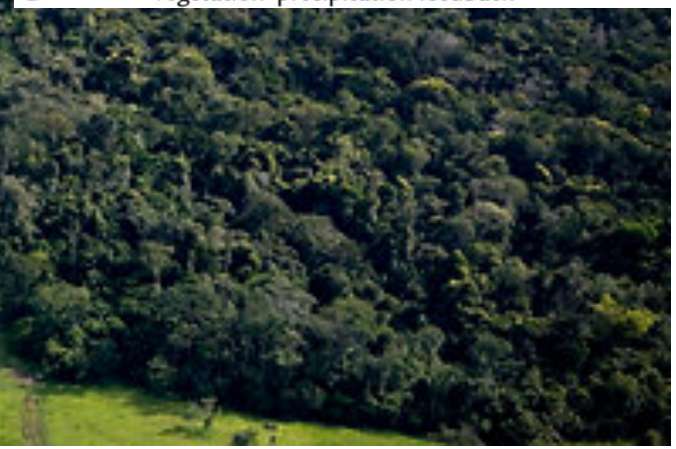
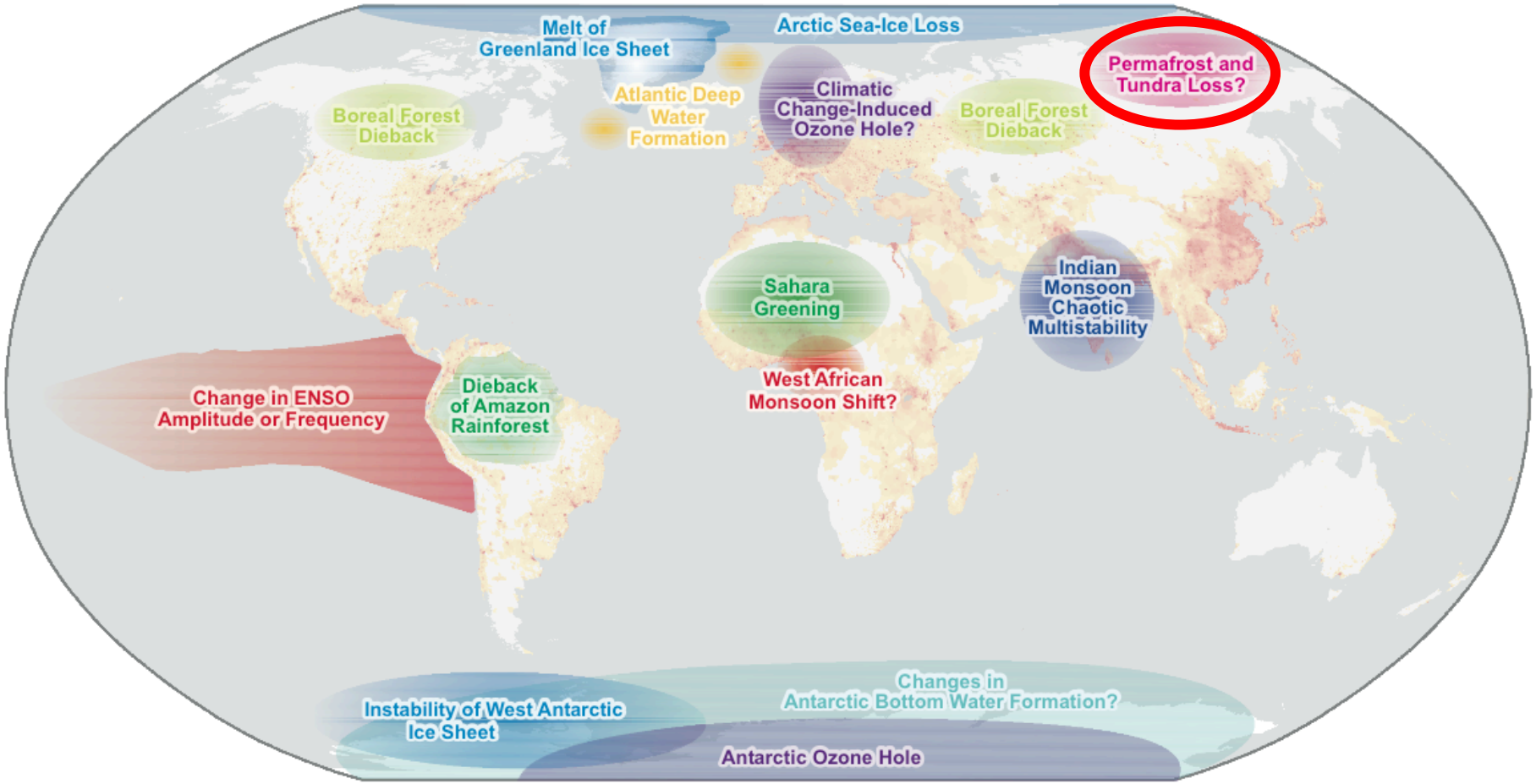
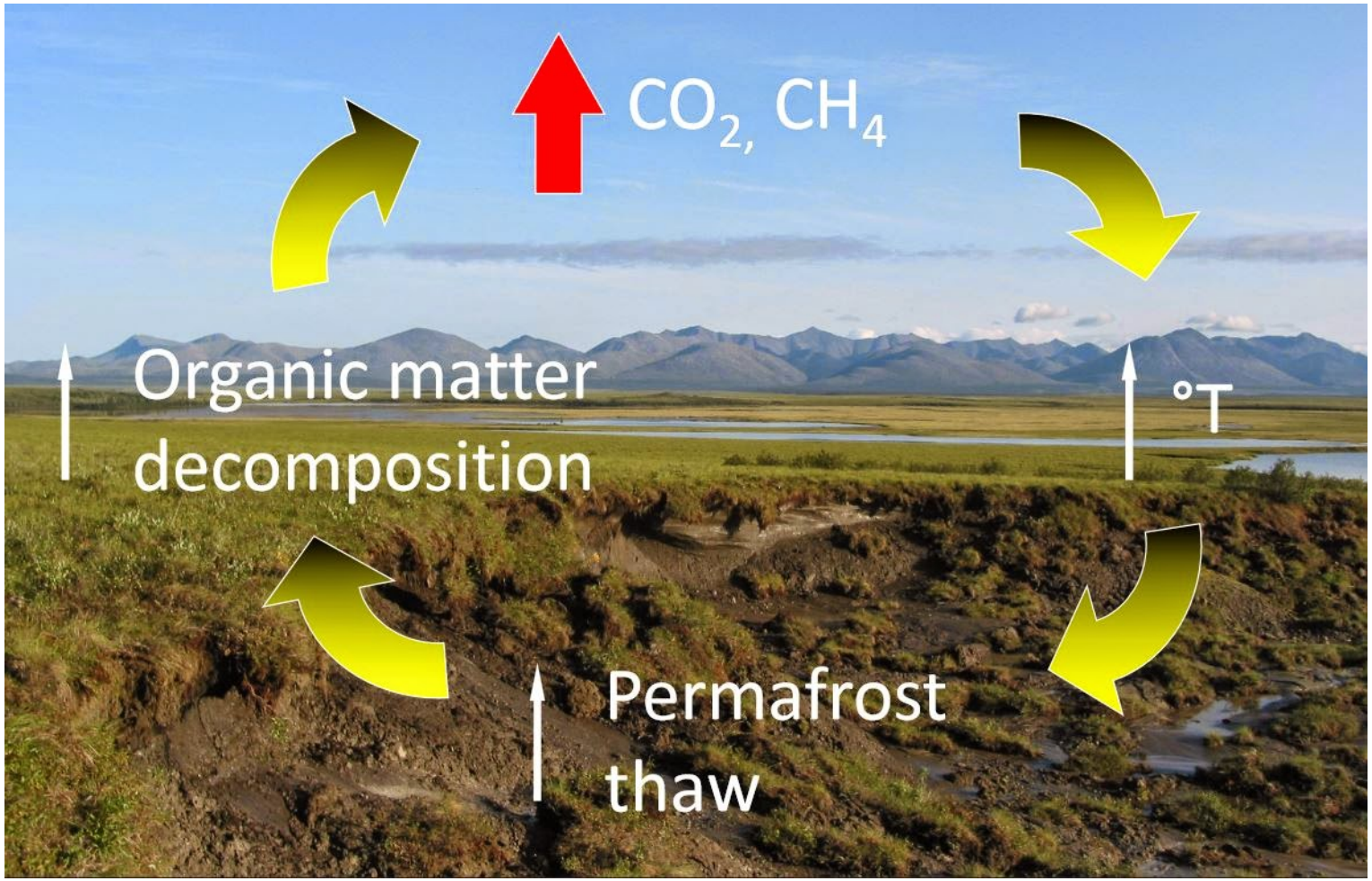


Tipping Point Examples



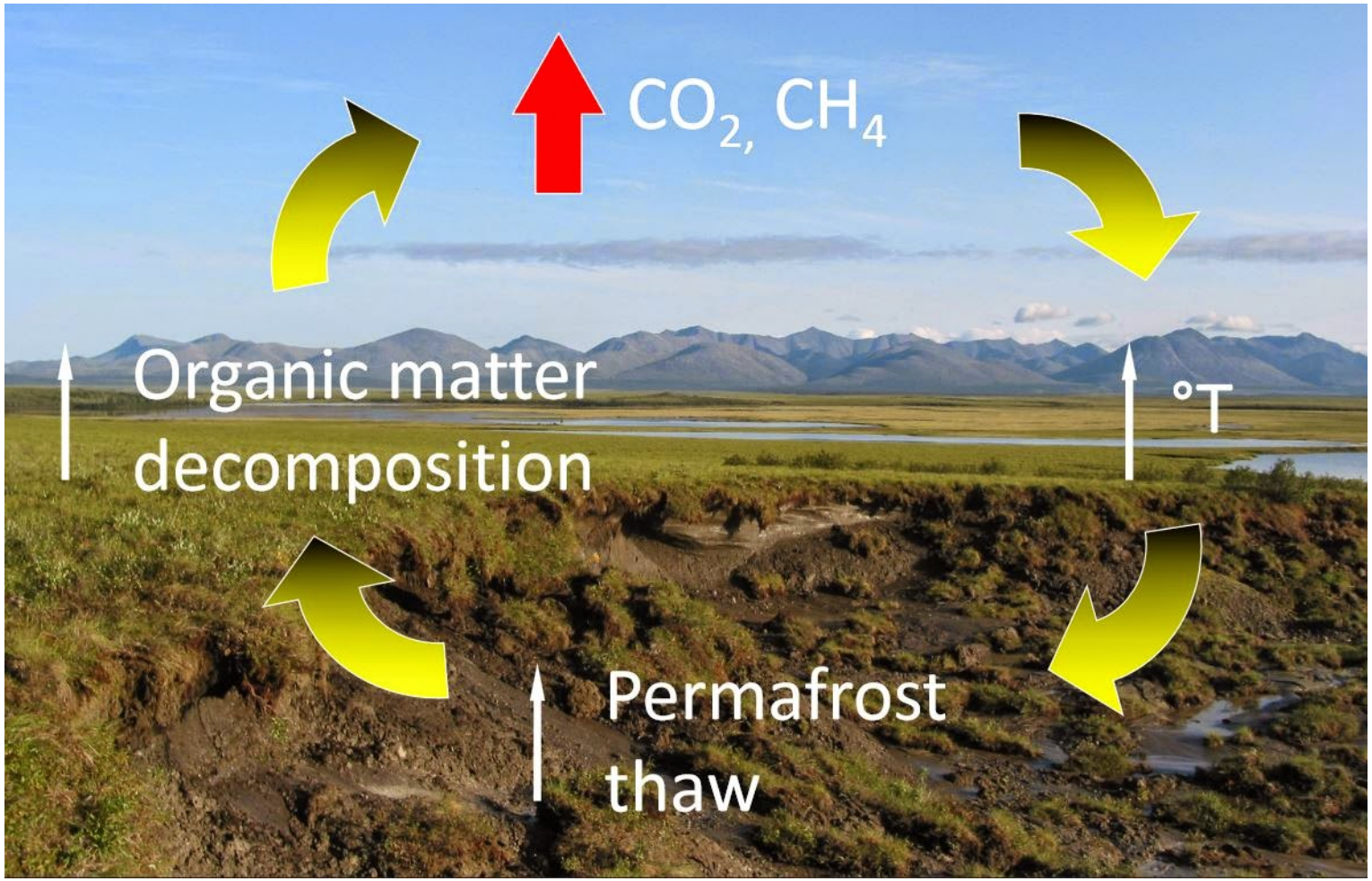
Permafrost Thaw

- Thawing permafrost emits carbon
- More warming = more permafrost thaw = more carbon emitted = more warming



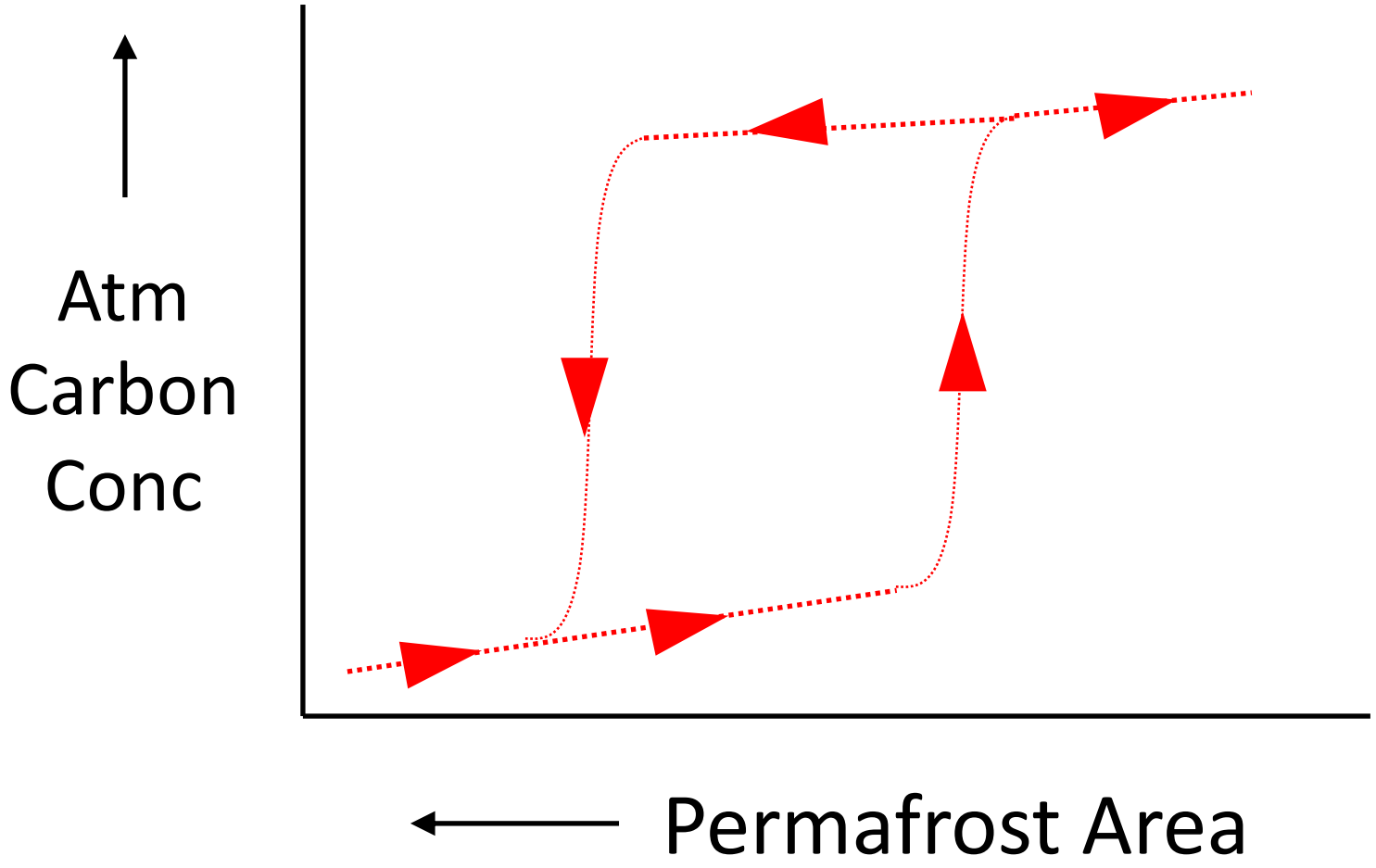
Permafrost Thaw

- Thawing permafrost emits carbon
- More warming = more permafrost thaw = more carbon emitted = more warming
- Tipping point occurs with runaway permafrost carbon emissions



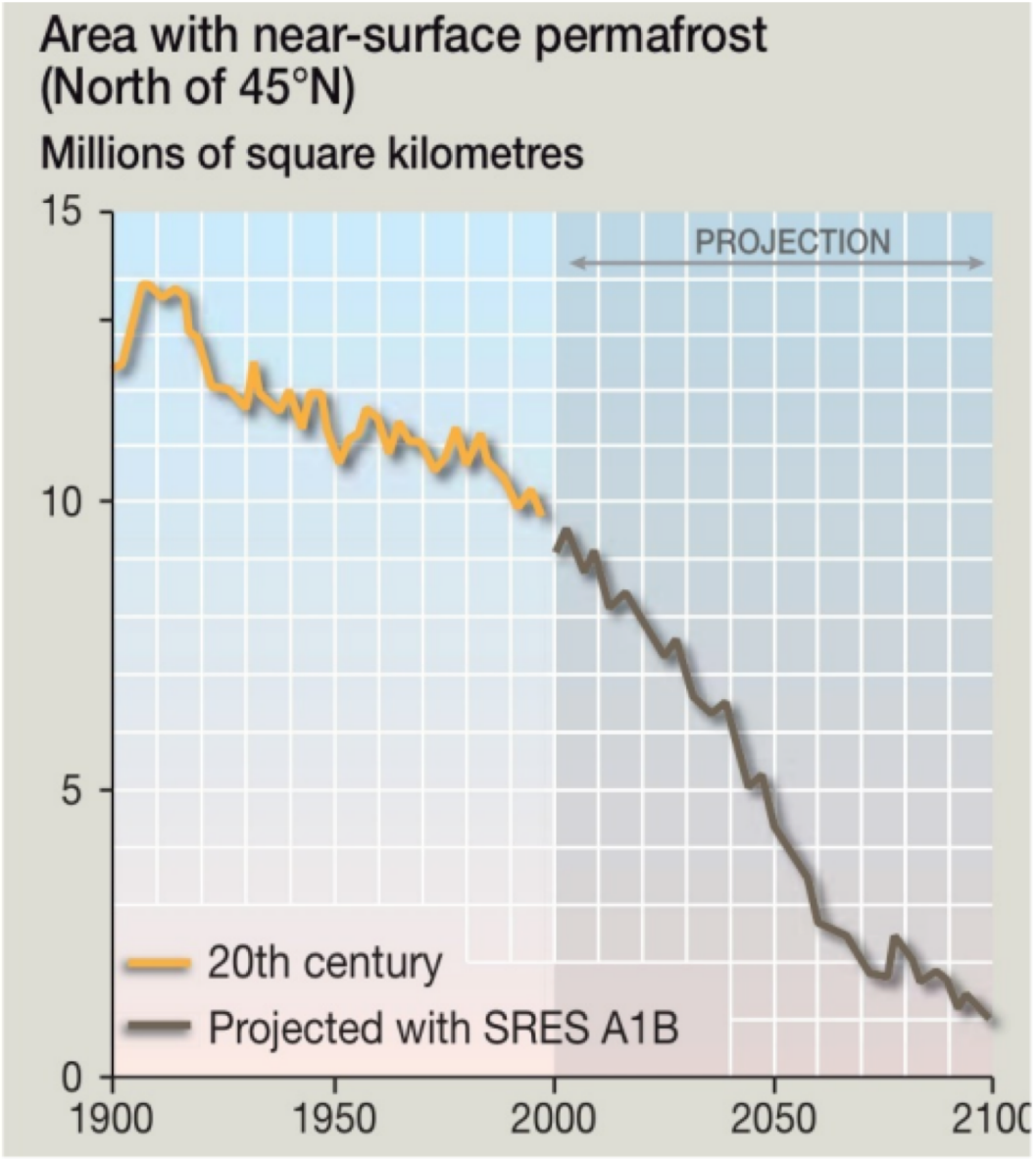
Permafrost Thaw

- **Irreversible** tipping point (has hysteresis)
- Can re-freeze soil/plants
- Harder to lower carbon concentrations

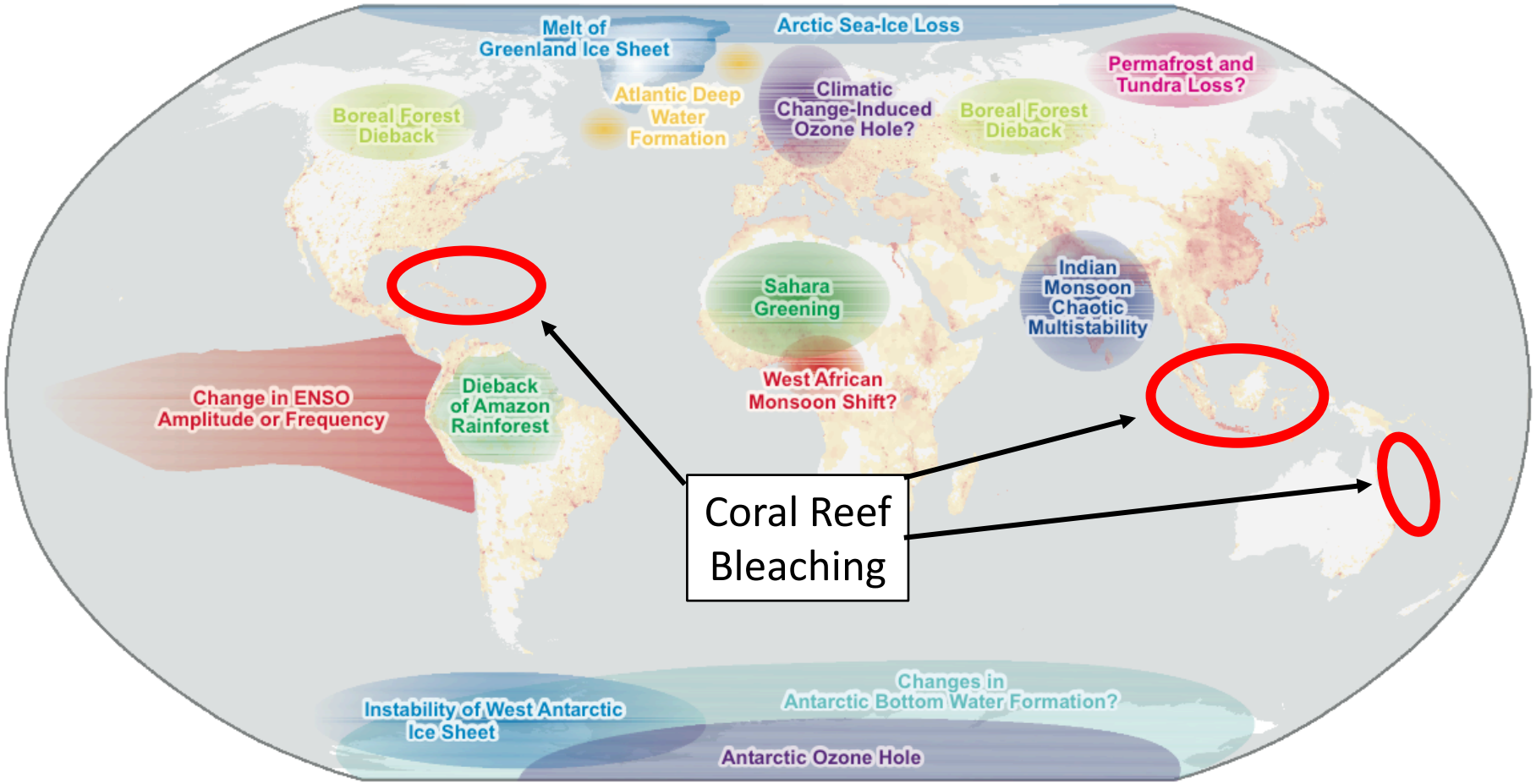


Permafrost Thaw

- Tipping point expected soon
- Could be fast-acting



Tipping Point Examples



Coral Reef Bleaching

- When coral reefs are stressed (due to warm water) they release algae that live inside their tissues
- Bleached corals keep living, but begin to starve
  - They can recover
- Sustained warm water leads to coral death

Coral Reef Bleaching

- **Irreversible** tipping point
- Once dead, the excessive algae in the water coat the coral skeletons
- Need to reduce algae concentration to re-grow corals

Scientist Profile: Dr. Kimberly Selkoe

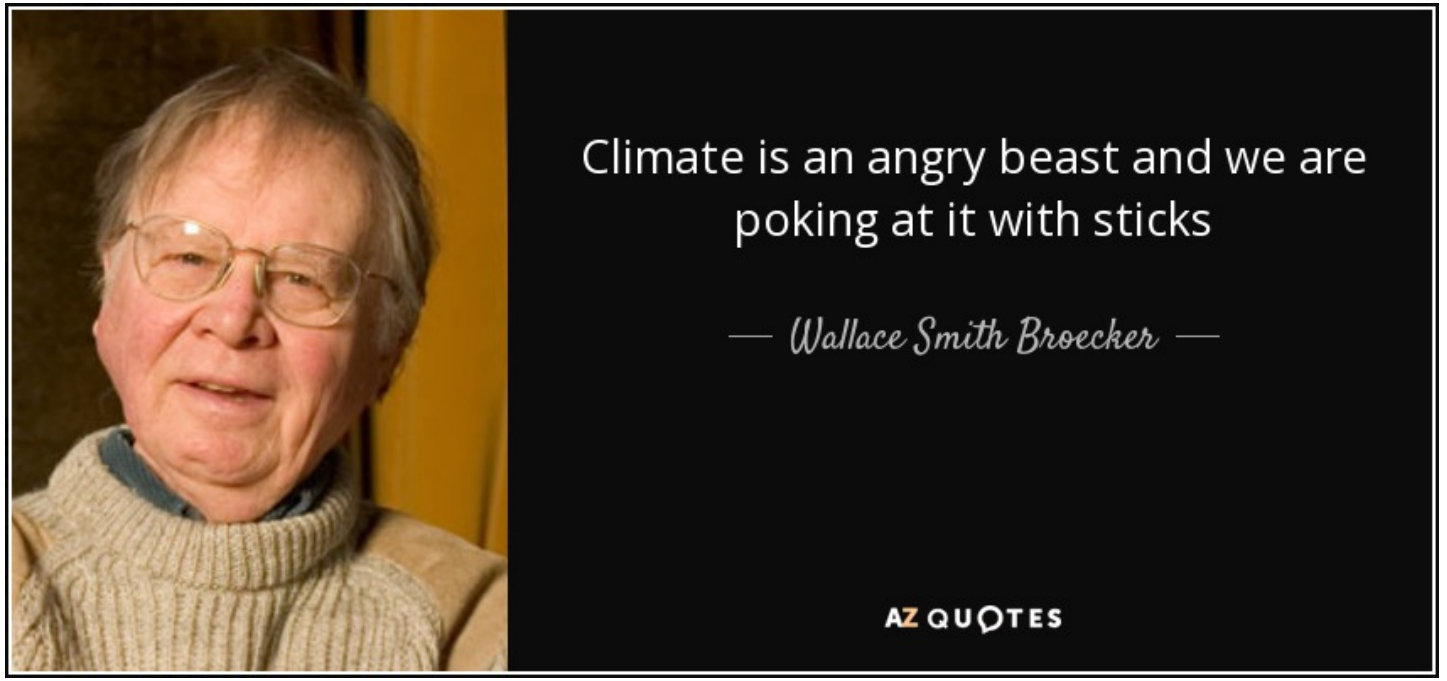
Principles for managing marine ecosystems prone to tipping points

Kimberly A. Selkoe,[1,2,17] Thorsten Blenckner,[3] Margaret R. Caldwell,[4] Larry B. Crowder,[4] Ashley L. Erickson,[4] Timothy E. Essington,[5] James A. Estes,[6] Rod M. Fujita,[7] Benjamin S. Halpern,[1,8,9] Mary E. Hunsicker,[1] Carrie V. Kappel,[1] Ryan P. Kelly,[10] John N. Kittinger,[11] Phillip S. Levin,[12] John M. Lynham,[13] Megan E. Mach,[4] Rebecca G. Martone,[4] Lindley A. Mease,[4] Anne K. Salomon,[14] Jameal F. Samhouri,[12] Courtney Scarborough,[1] Adrian C. Stier,[1] Crow White,[15] and Joy Zedler[16]

Dr. Kimberly Selkoe is a coral reef researcher with joint appointments at the University of California, Santa Barbara, and the Hawai'i Institute of Marine Biology. Her research focuses on identifying coral system tipping points and thresholds. She uses terabytes of existing data on coral reefs to re-create how these fragile ecosystems respond to environmental stressors.

Tipping Points Summary

- Many climate systems have the potential for runaway positive feedbacks
- Beyond a ‘threshold’, these feedbacks take over and no more forcing is necessary to keep changing the system



- Difficult to predict where threshold is, difficult to identify if/when we’ve passed it
- **The harder we push ‘tipping point’ climate systems, the more likely we are to cross thresholds**