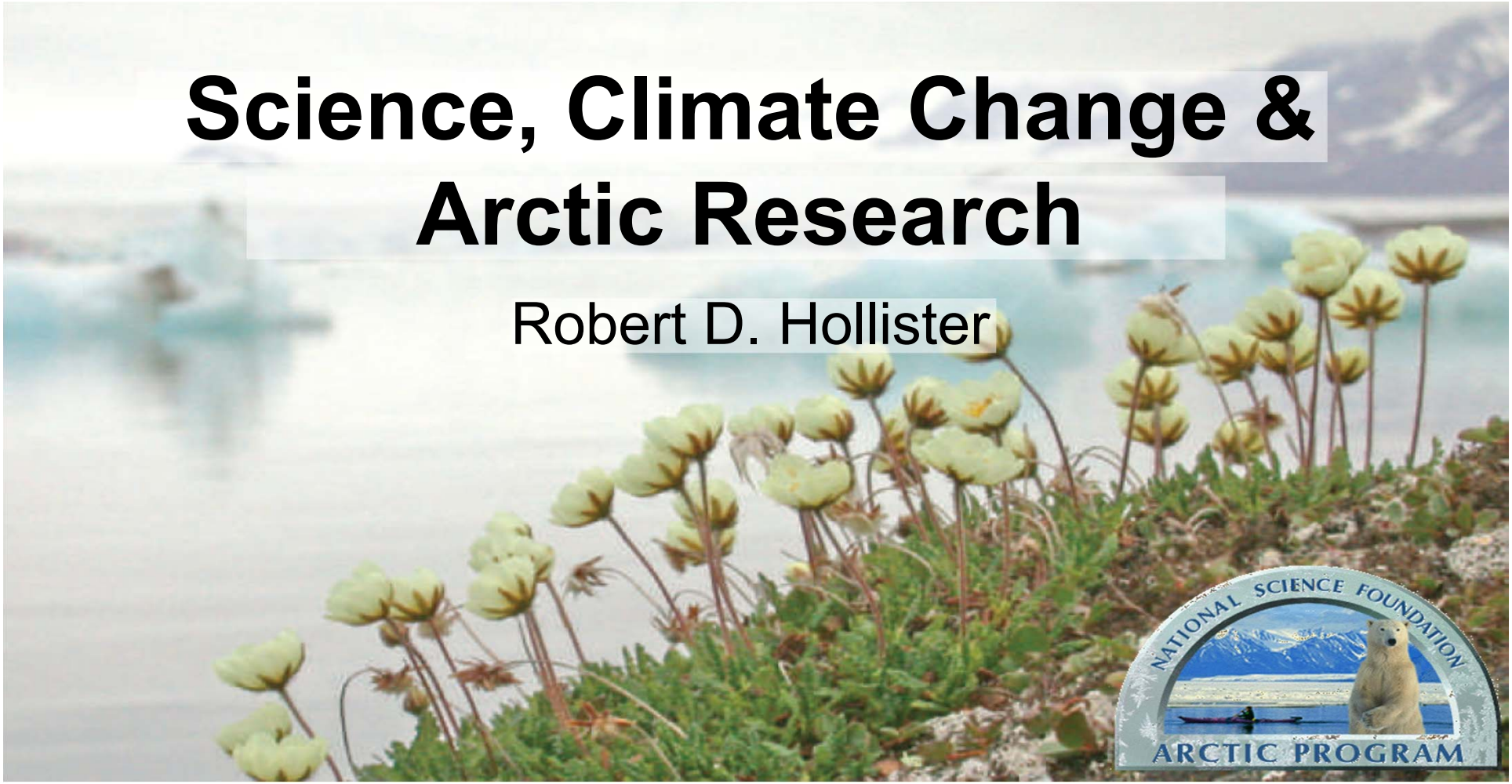
Science, Climate Change & Arctic Research

Robert D. Hollister



ARCTIC ECOLOGY

GRAND VALLEY STATE UNIVERSITY

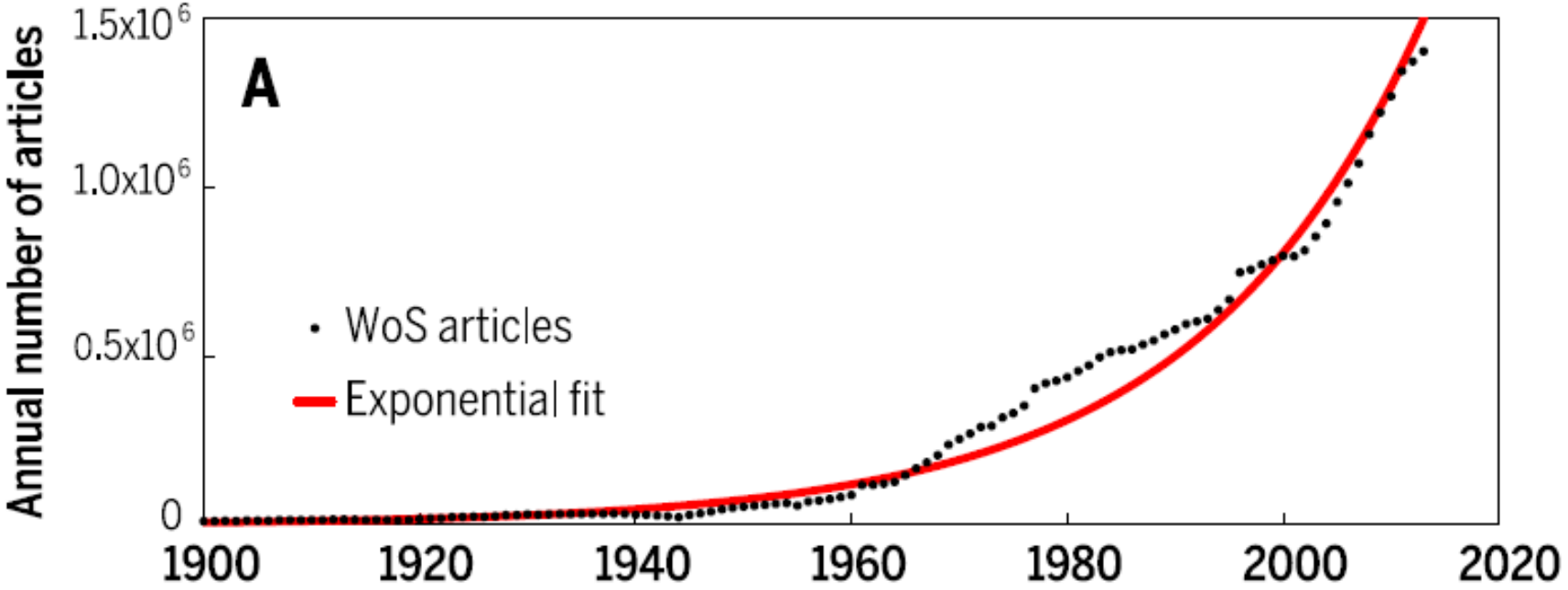
NATIONAL SCIENCE FOUNDATION

Outline

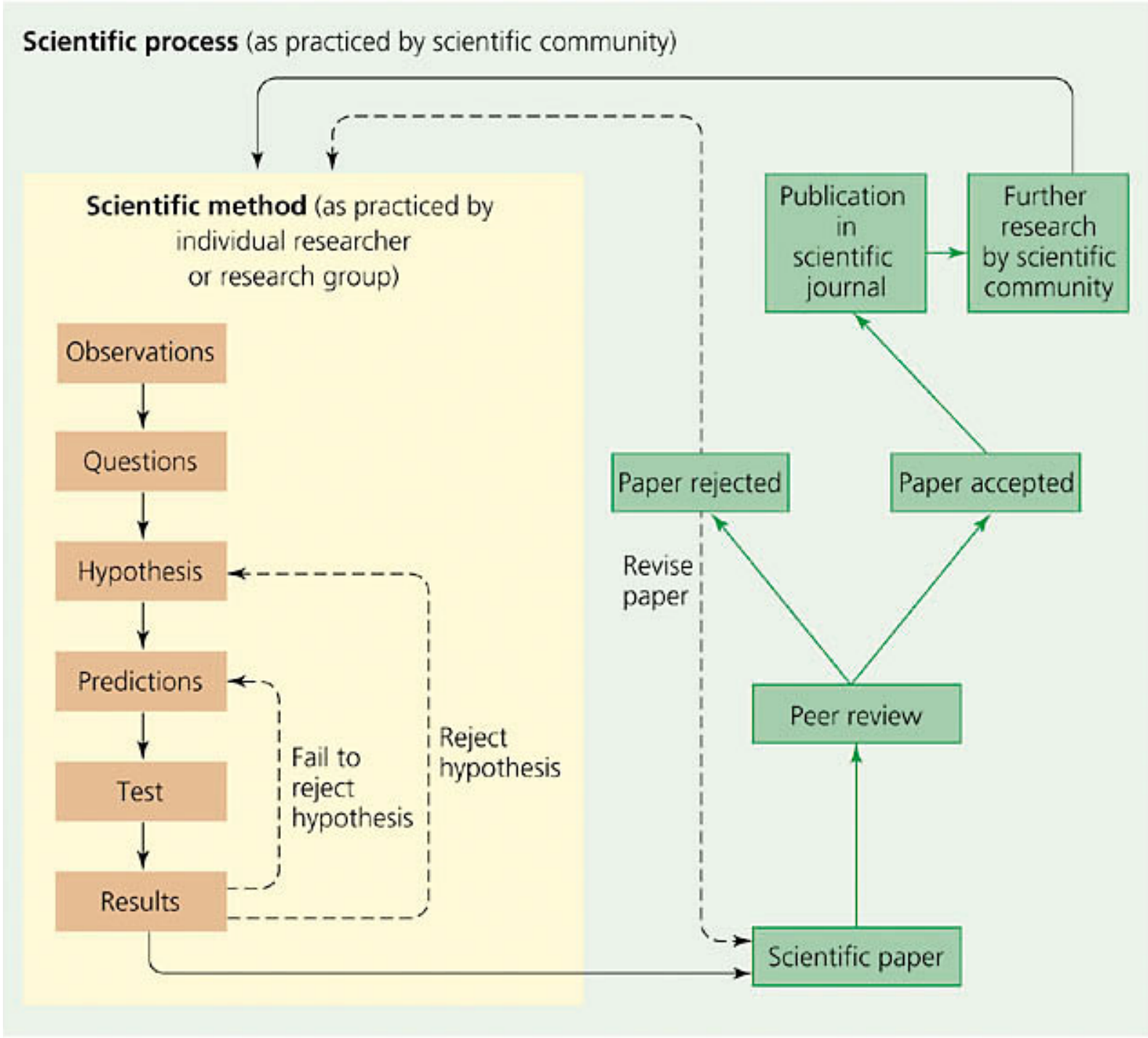
- How Science Works
- Climate Change
- Changes in the Arctic
- My Research

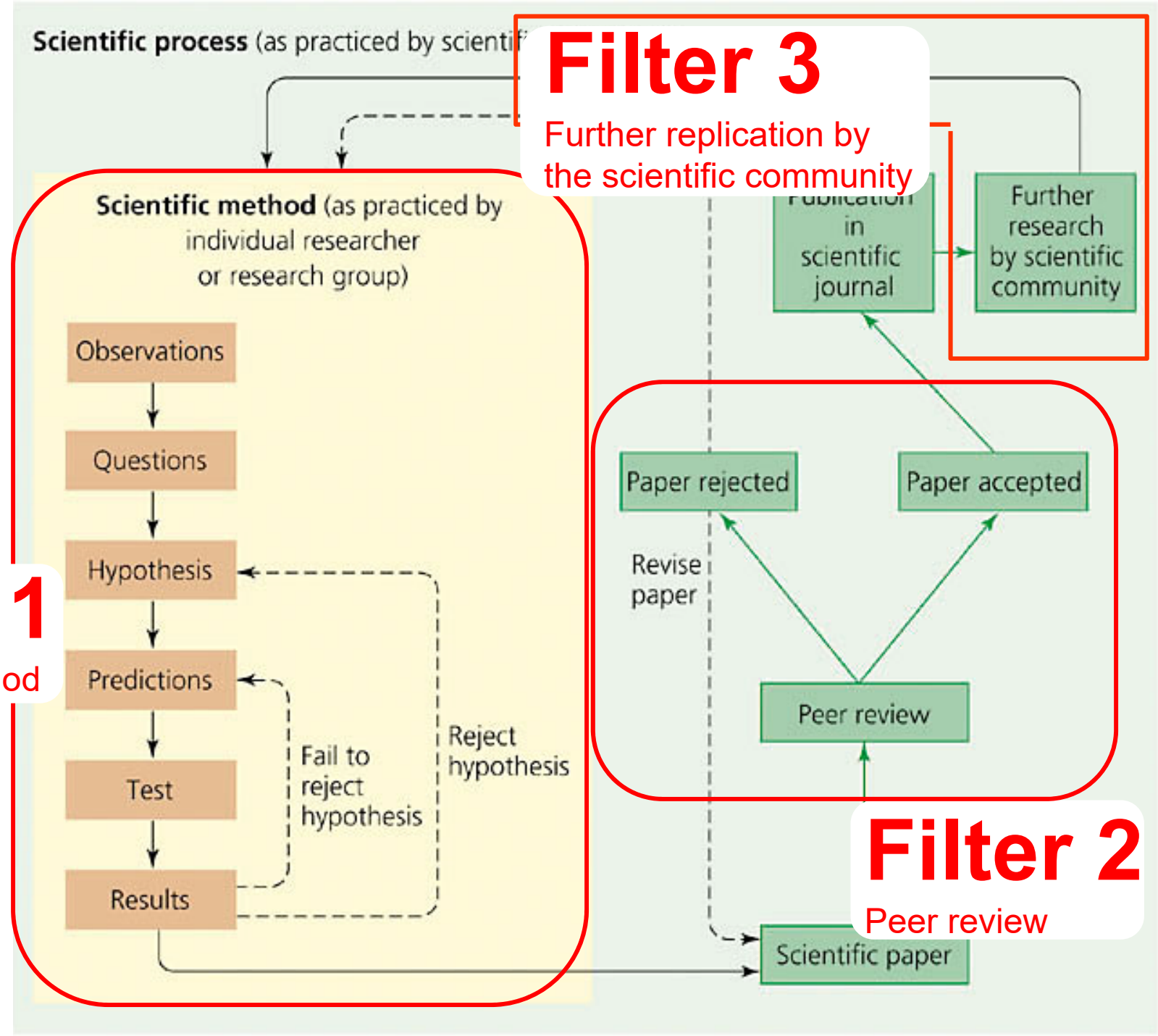
How Science Works

Growth in Science

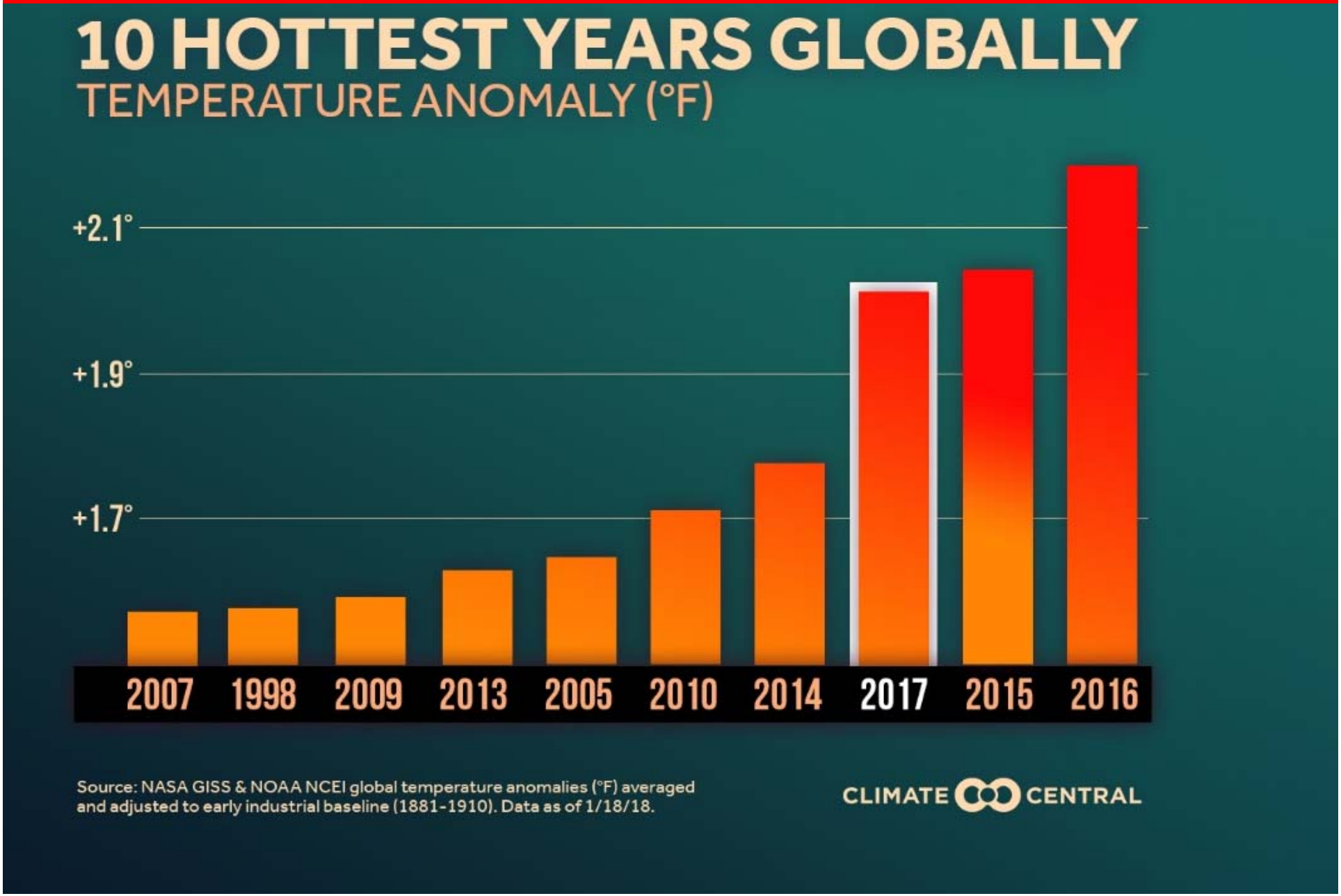


Fortunato *et al.*, *Science* **359**, eaao0185 (2018) 2 March 2018

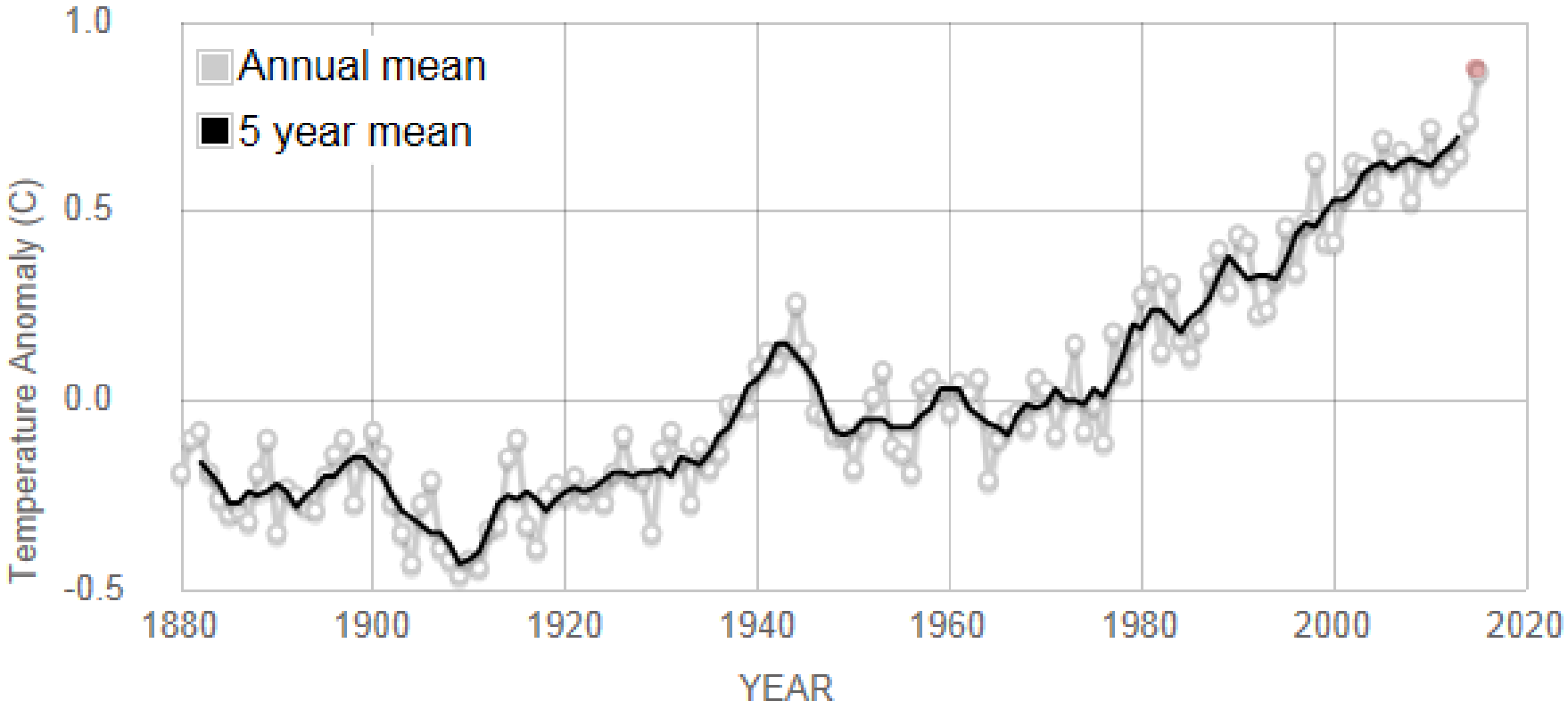

Scientific process (as practiced by scientific community)
Scientific method (as practiced by individual researcher or research group)
Observations
Questions
Hypothesis
Predictions
Test
Results
Fail to reject hypothesis
Reject hypothesis
Publication in scientific journal
Further research by scientific community
Paper rejected
Paper accepted
Revise paper
Peer review
Scientific paper

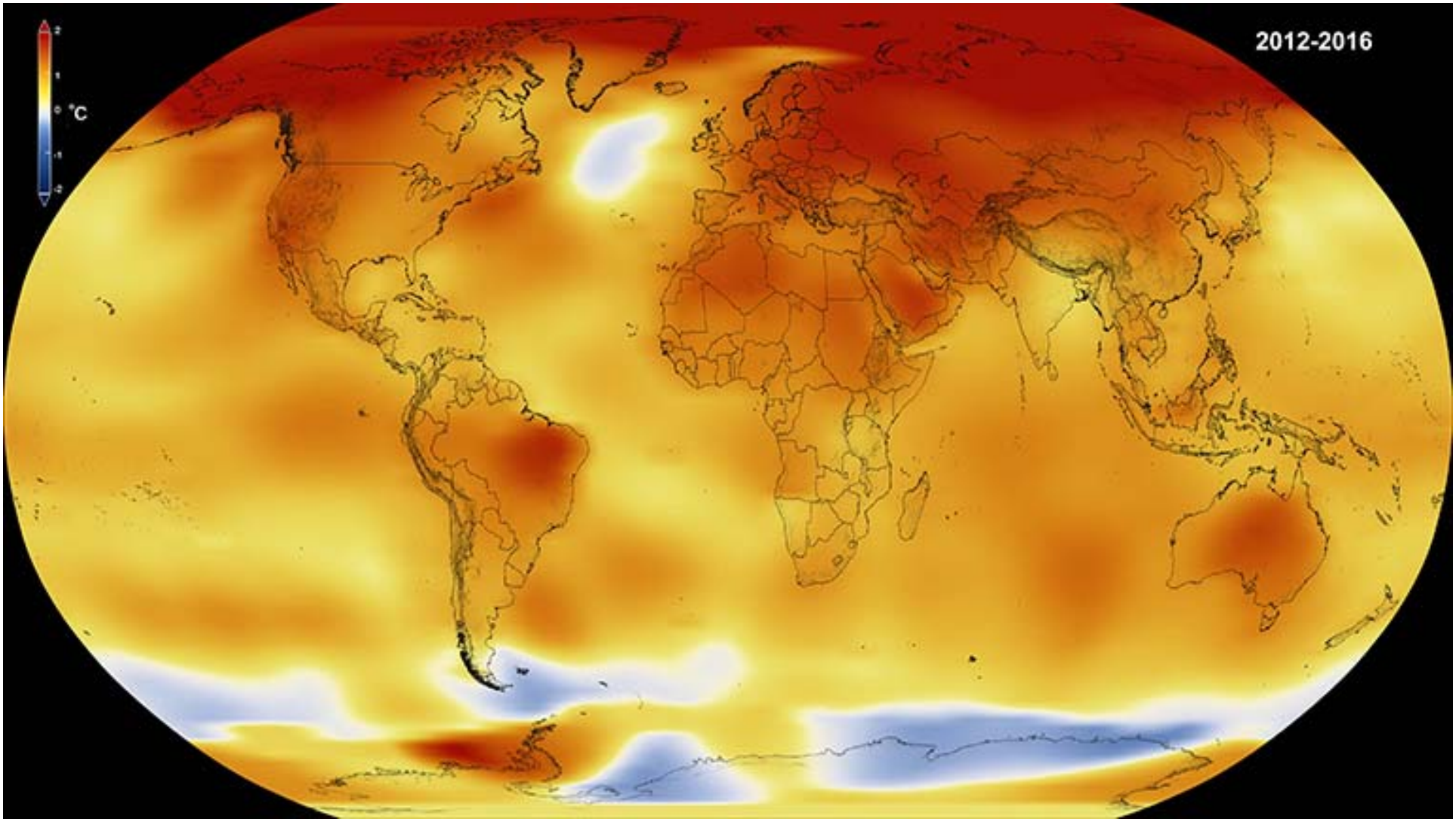

Scientific process (as practiced by scientif
Filter 3
Further replication by the scientific community
Scientific method (as practiced by individual researcher or research group)
Observations
Questions
Hypothesis
Predictions
Test
Results
Fail to reject hypothesis
Reject hypothesis
Publication in scientific journal
Further research by scientific community
Paper rejected
Paper accepted
Revise paper
Peer review
Scientific paper
Filter 1
Scientific Method
Filter 2
Peer review

Climate Change

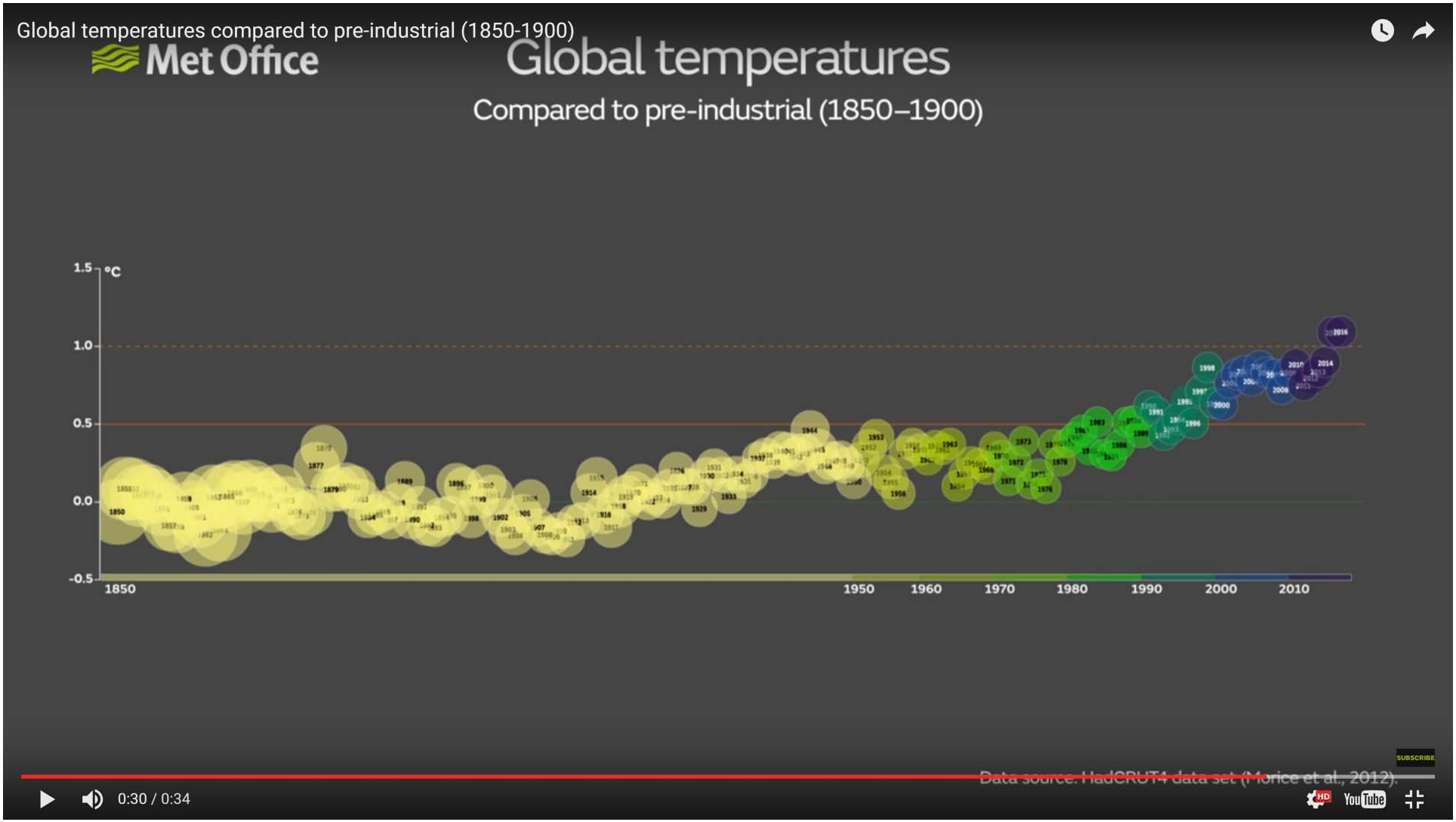


Data source: NASA's Goddard Institute for Space Studies (GISS).
Credit: NASA/GISS

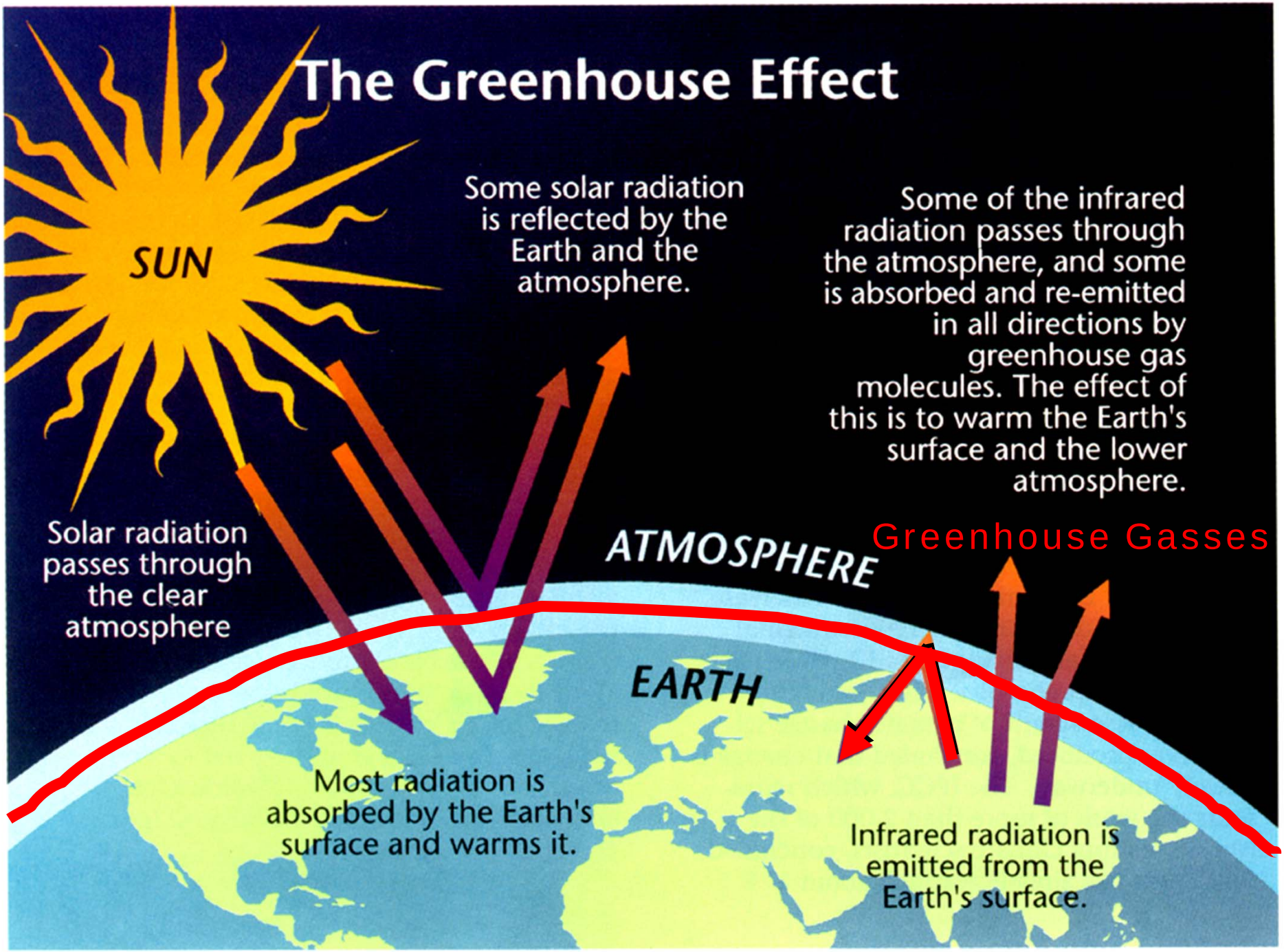


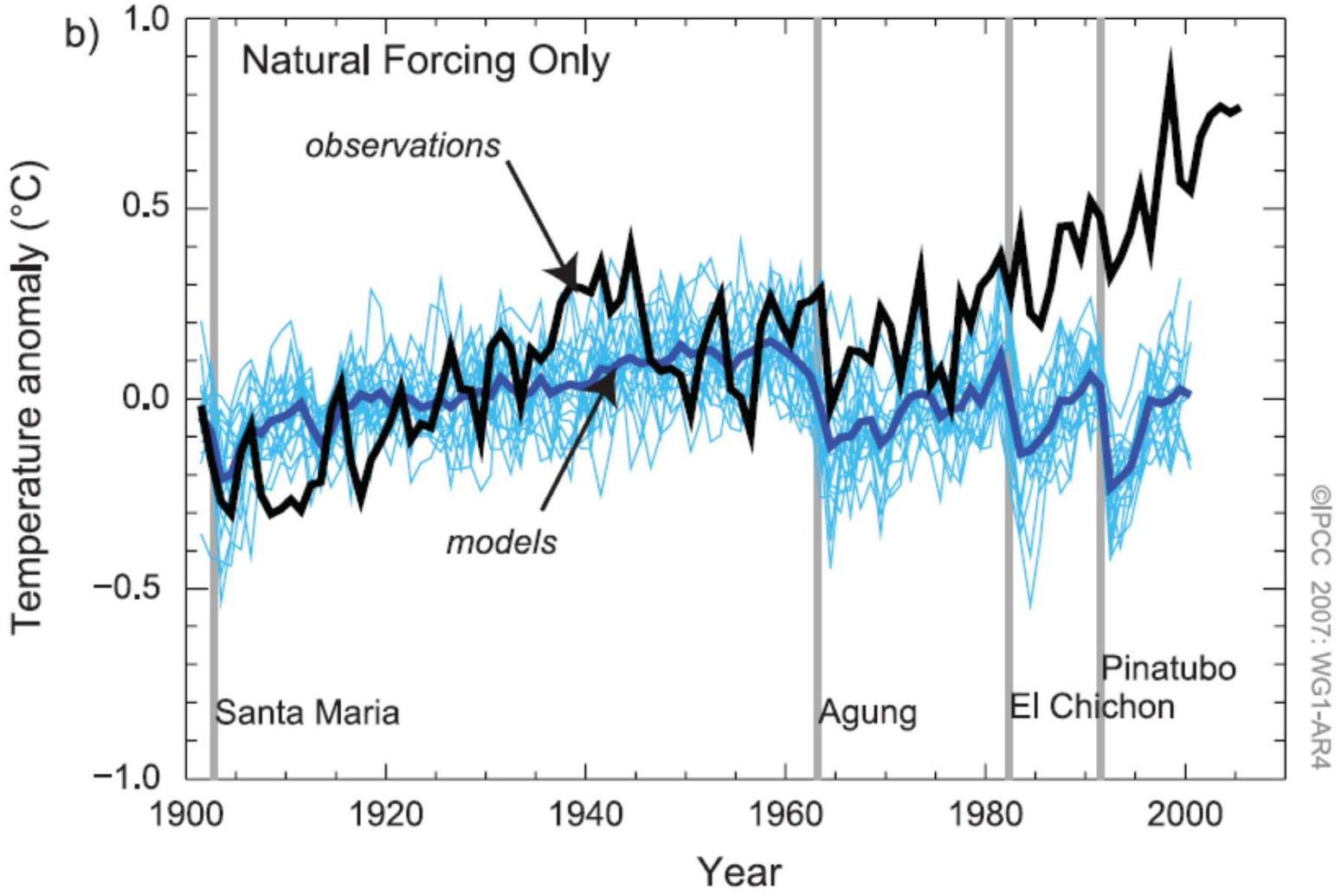


https://www.youtube.com/watch?v=bCVXnrQfzgA

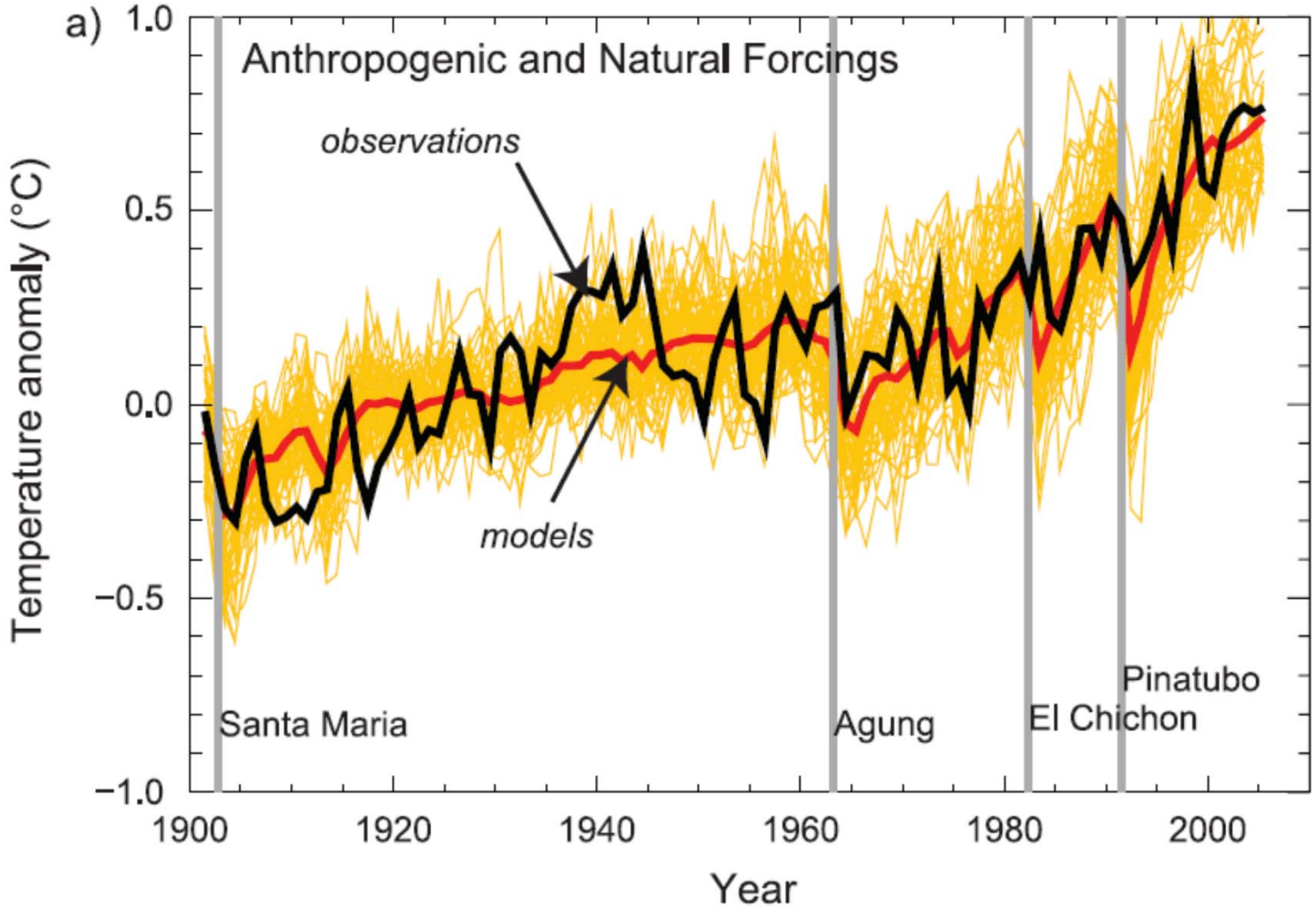

Global temperatures compared to pre-industrial (1850-1900)
Met Office
Global temperatures
Compared to pre-industrial (1850–1900)
1.5 °C
1.0
0.5
0.0
-0.5
1850
1950
1960
1970
1980
1990
2000
2010
Data source: HadCRUT4 data set (Morice et al., 2012).
0:30 / 0:34

Why We Believe the Observed Warming is due to Humans


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere, and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
Greenhouse Gasses
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.



IPCC (Intergovernmental Panel on Climate Change) 2007.



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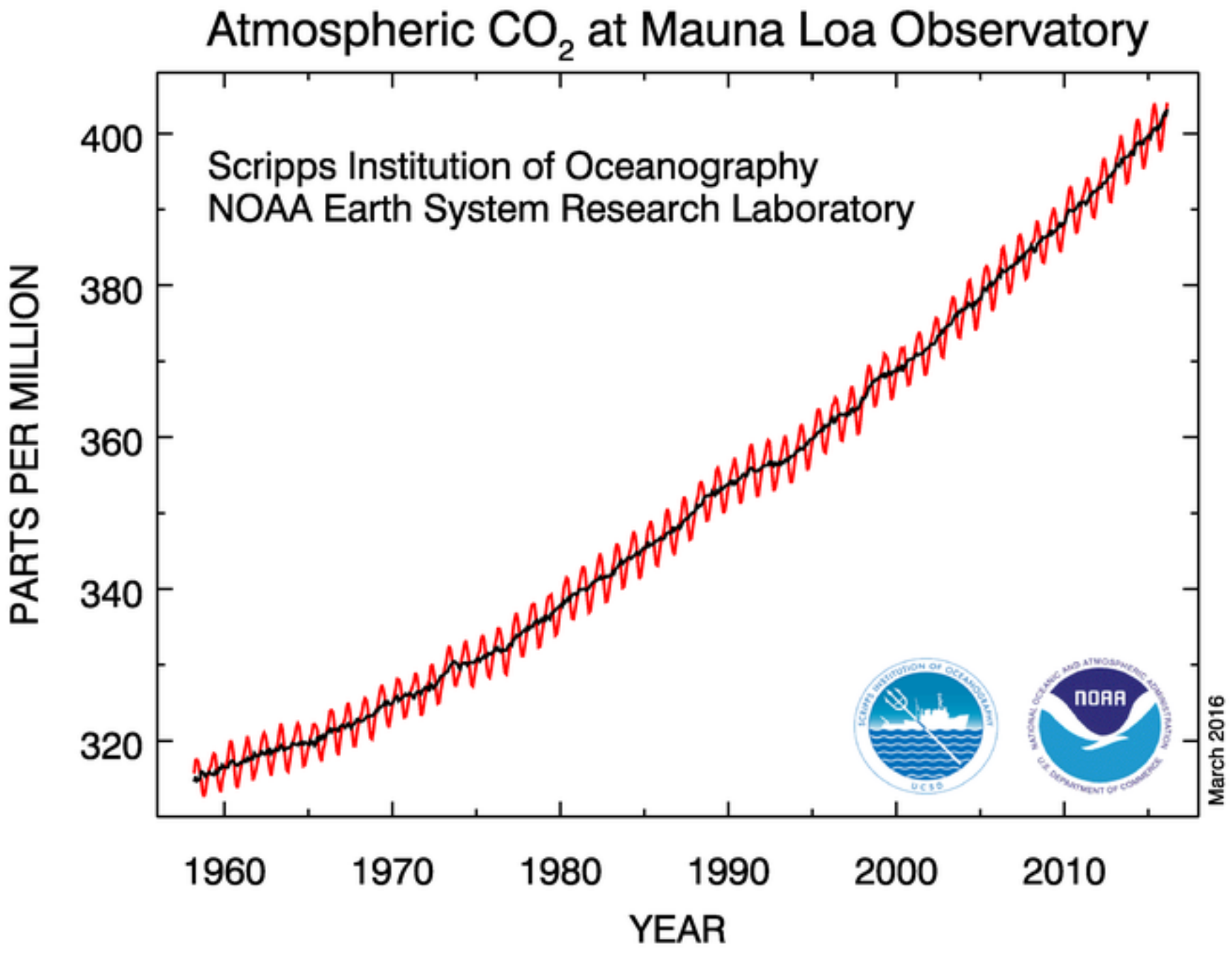
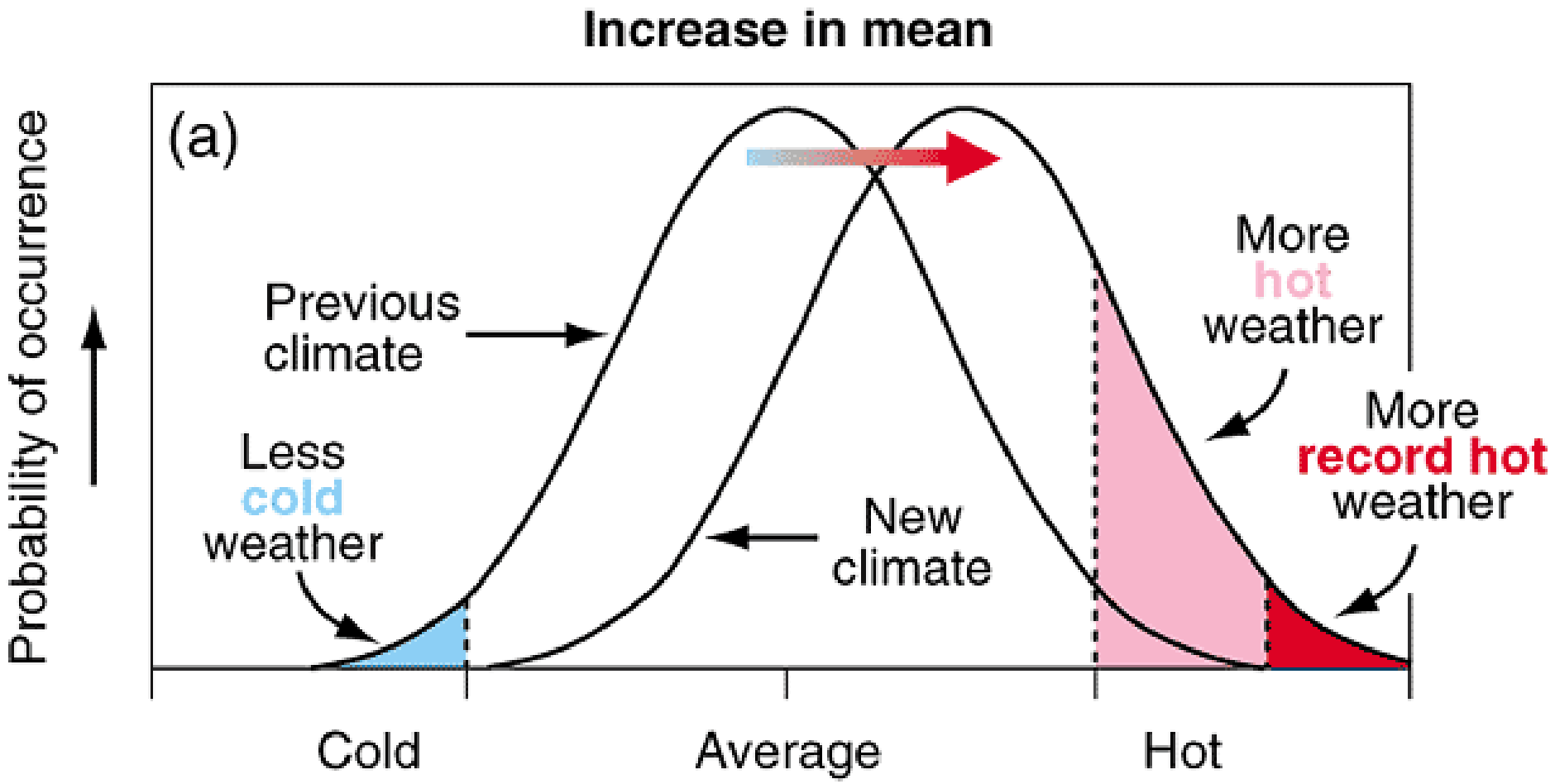
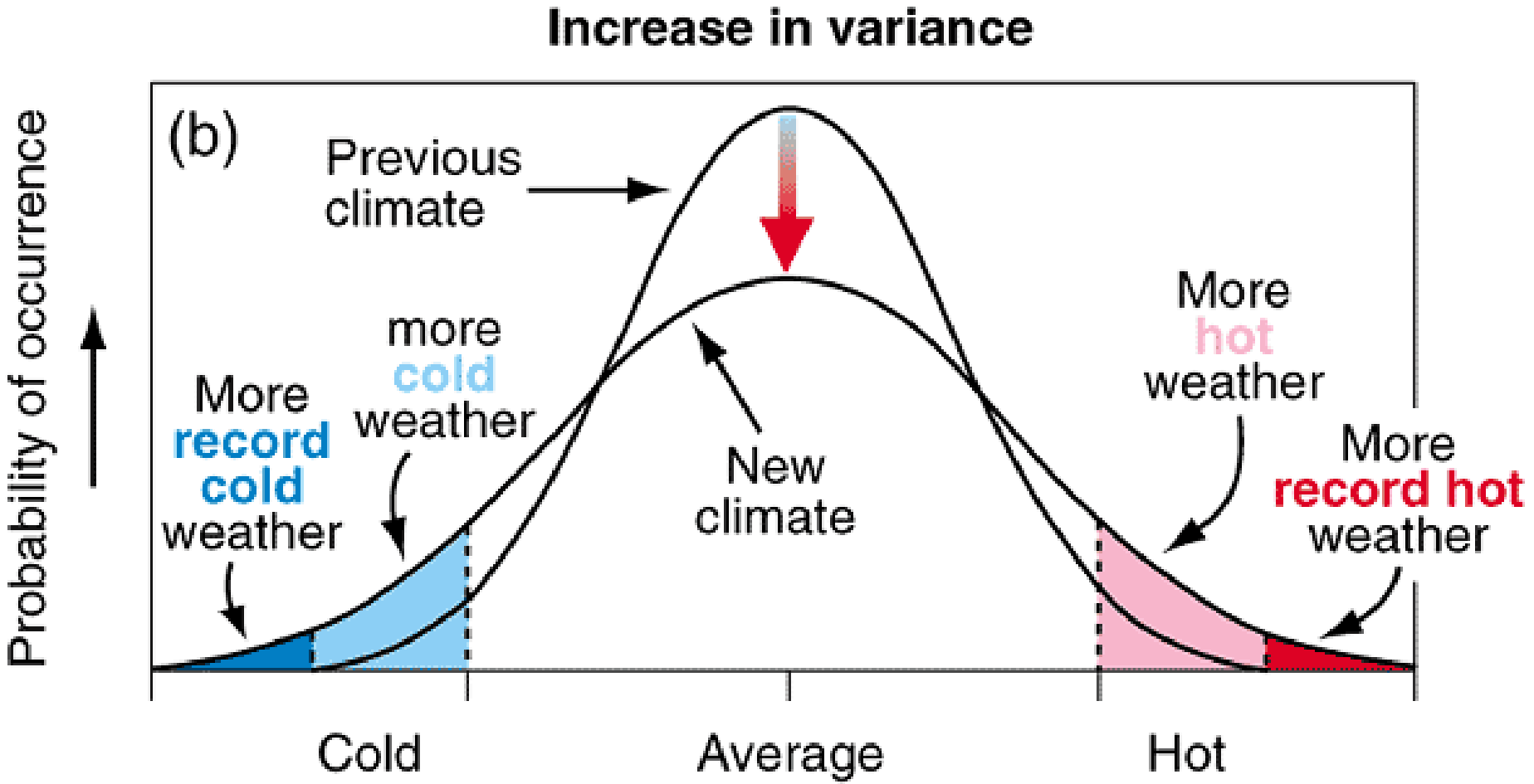
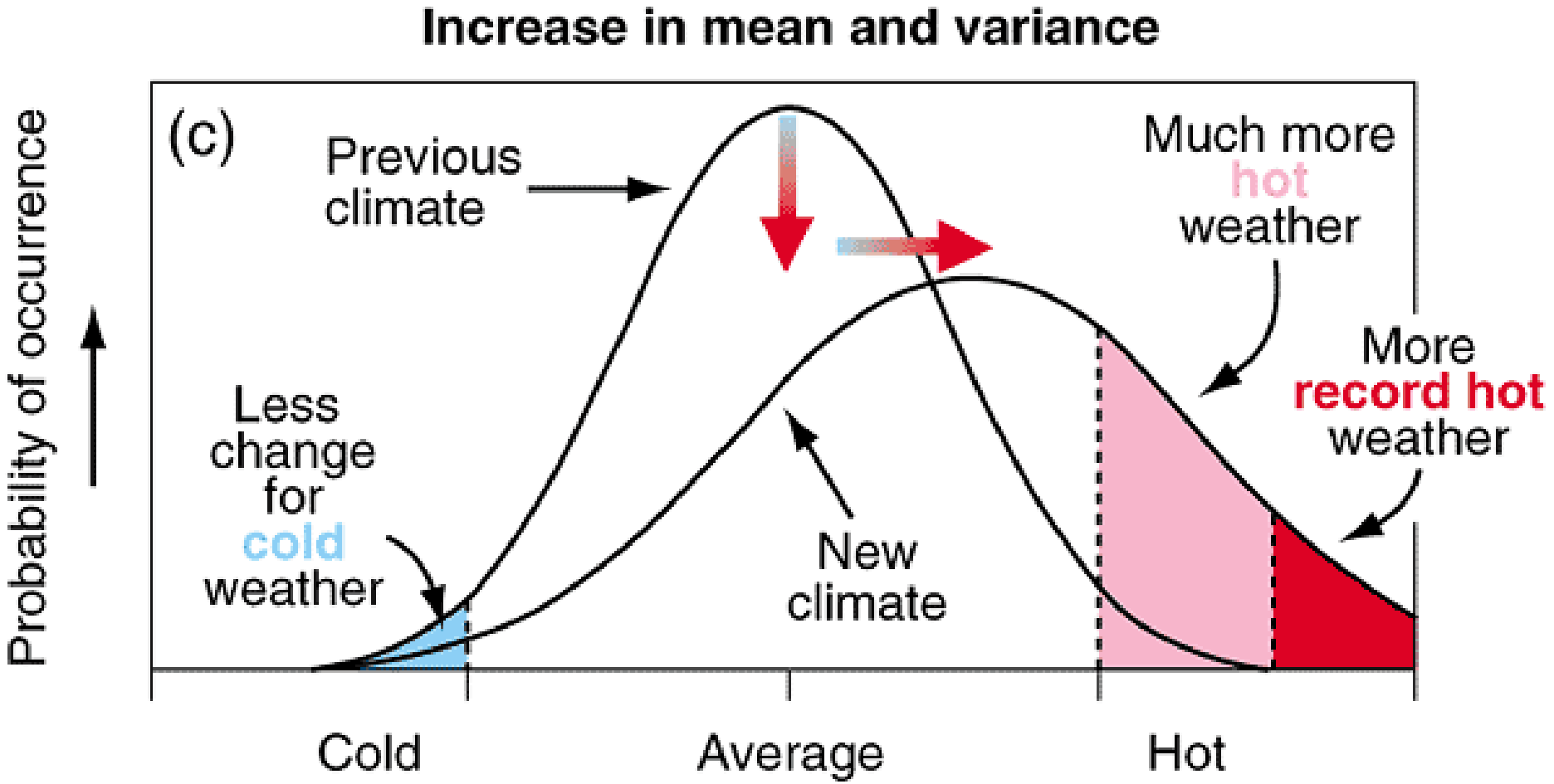

Atmospheric CO_2 at Mauna Loa Observatory
Scripps Institution of Oceanography
NOAA Earth System Research Laboratory
PARTS PER MILLION
400
380
360
340
320
1960
1970
1980
1990
2000
2010
YEAR
March 2016



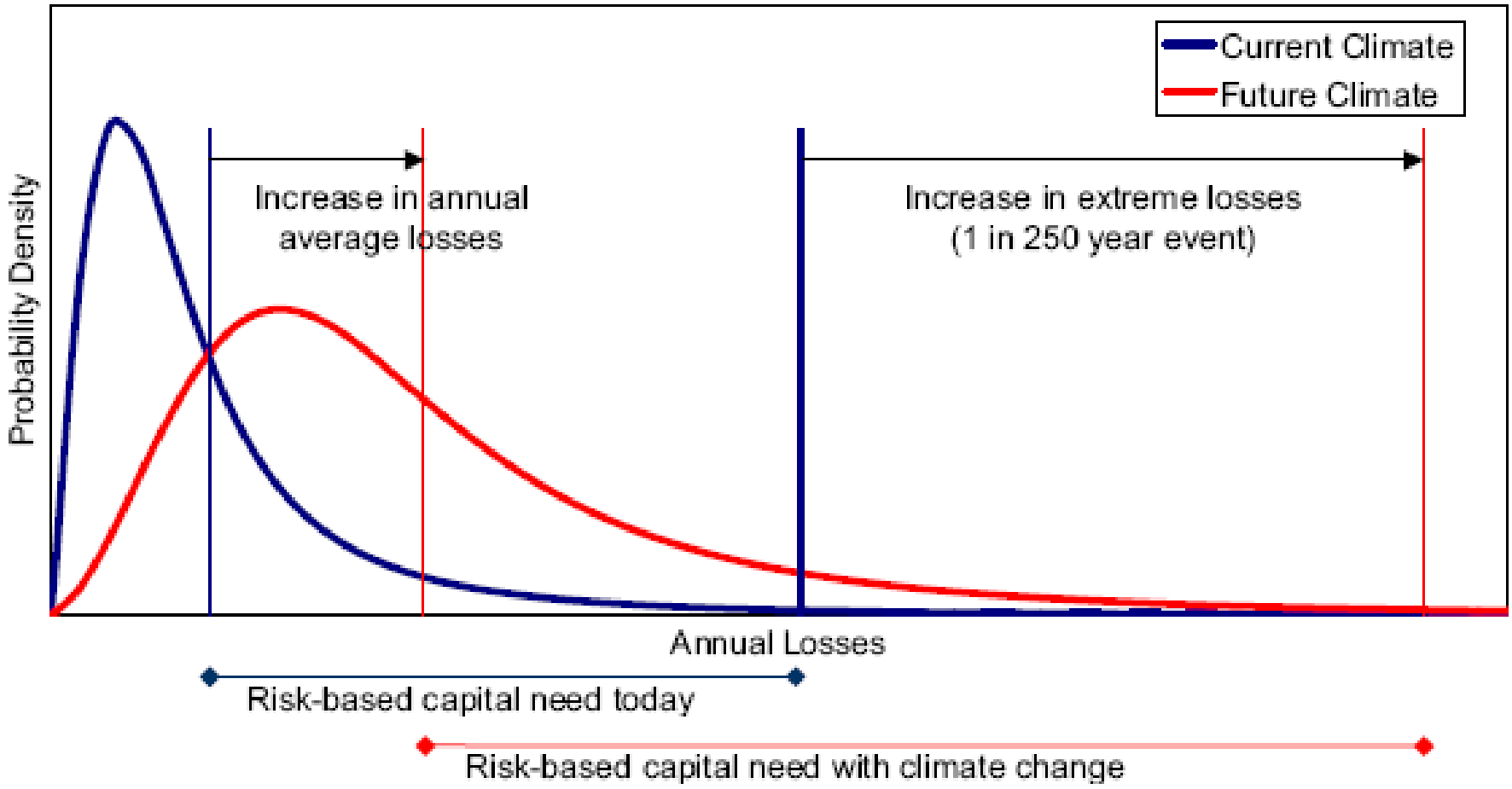
IPCC (Intergovernmental Panel on Climate Change) 2001. Climate Change 2001: The Scientific Basis



IPCC (Intergovernmental Panel on Climate Change) 2001. Climate Change 2001: The Scientific Basis

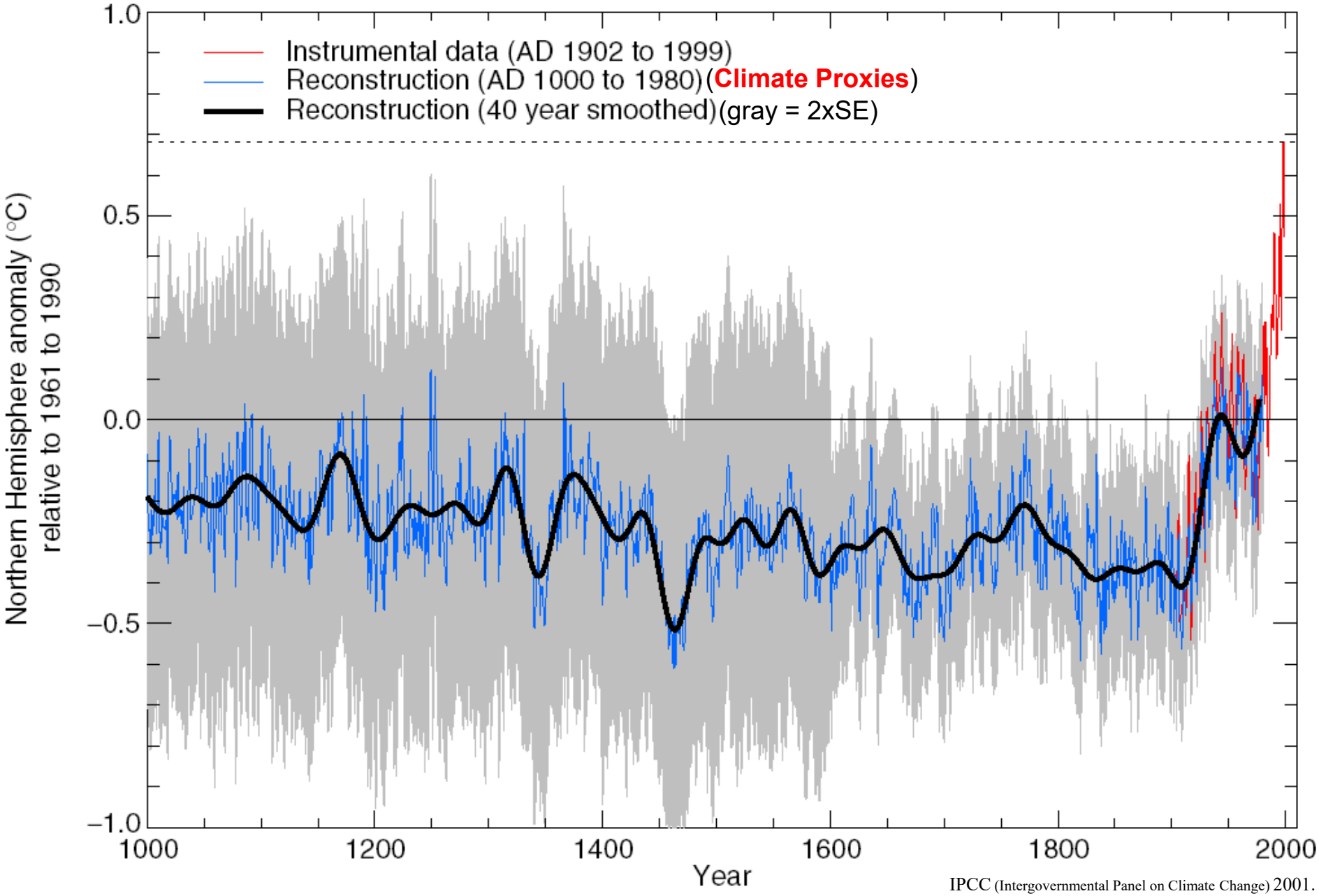


IPCC (Intergovernmental Panel on Climate Change) 2001.
Climate Change 2001: The Scientific Basis



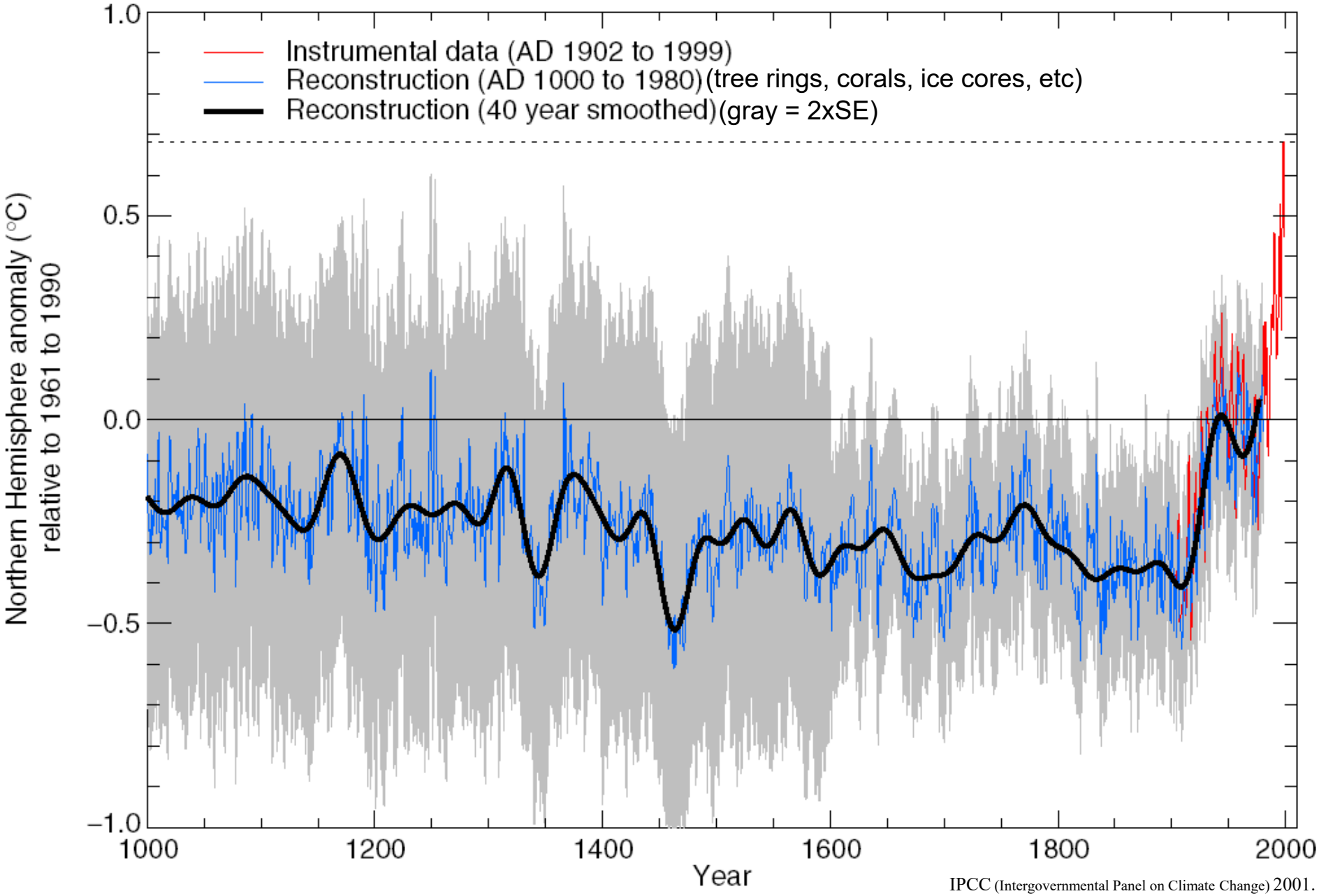
Stern Report 2006

Northern Hemisphere Temperature Anomalies



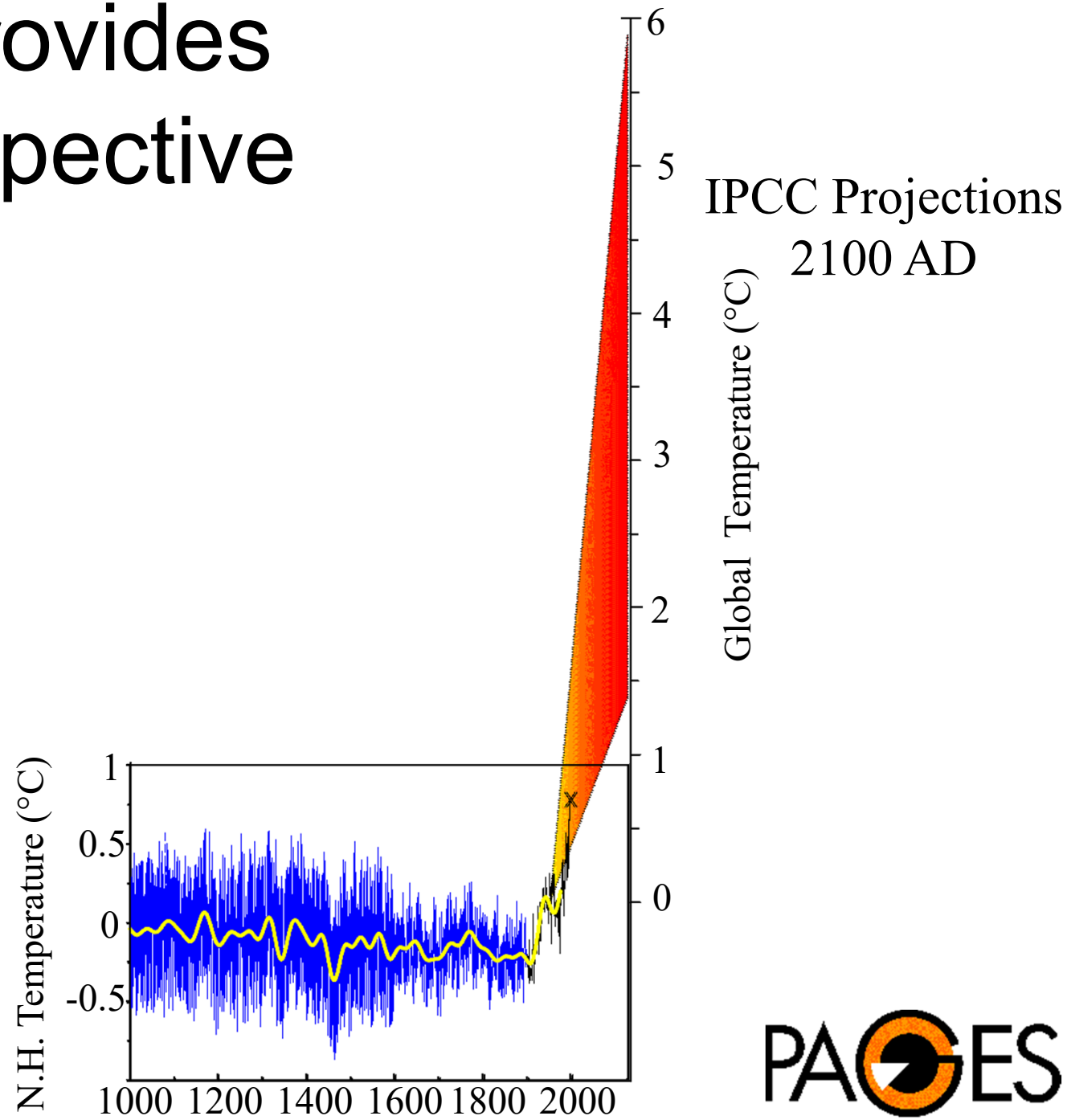
IPCC (Intergovernmental Panel on Climate Change) 2001.
Climate Change 2001: The Scientific Basis

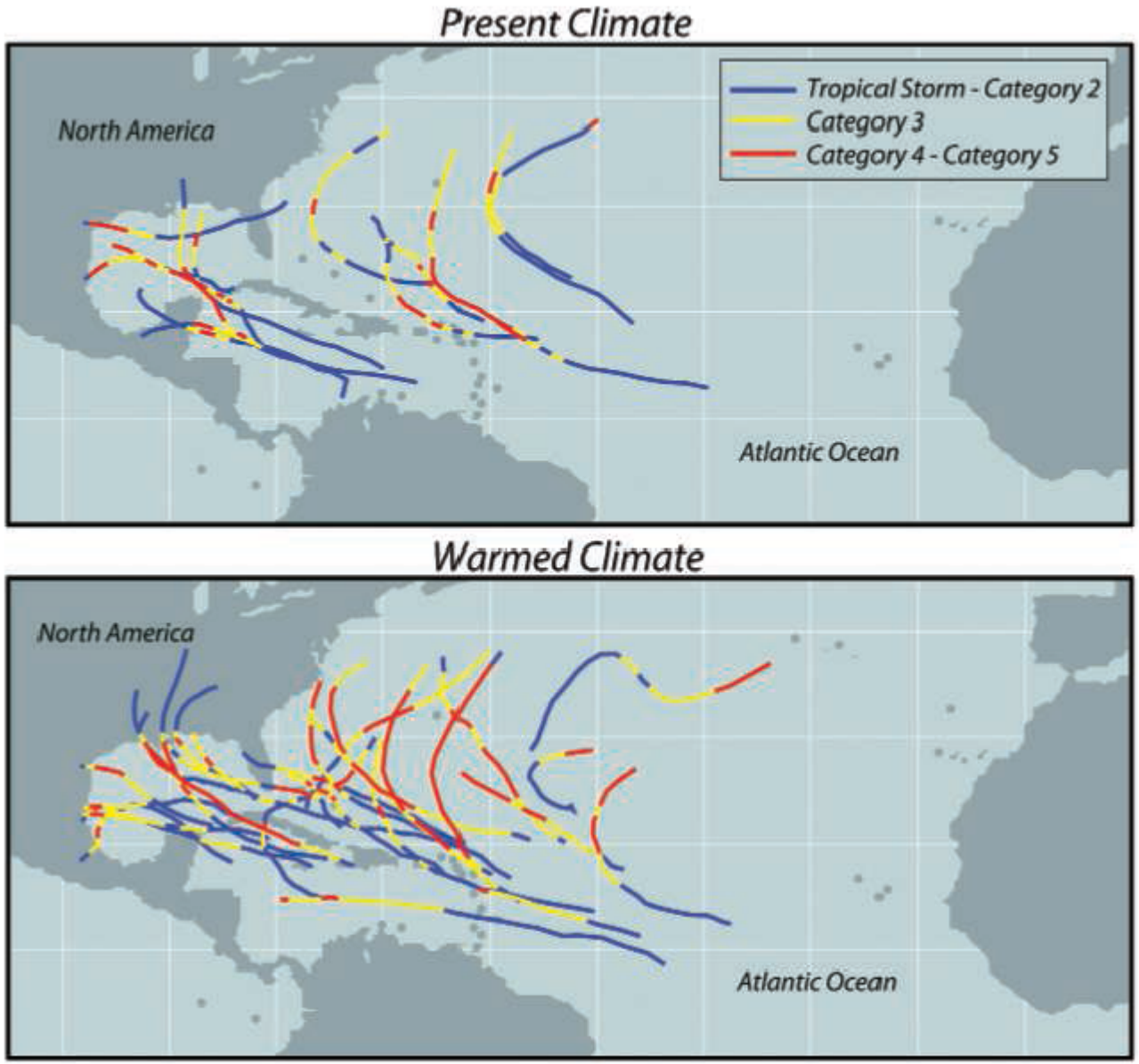
Northern Hemisphere Temperature Anomalies



IPCC (Intergovernmental Panel on Climate Change) 2001.
Climate Change 2001: The Scientific Basis

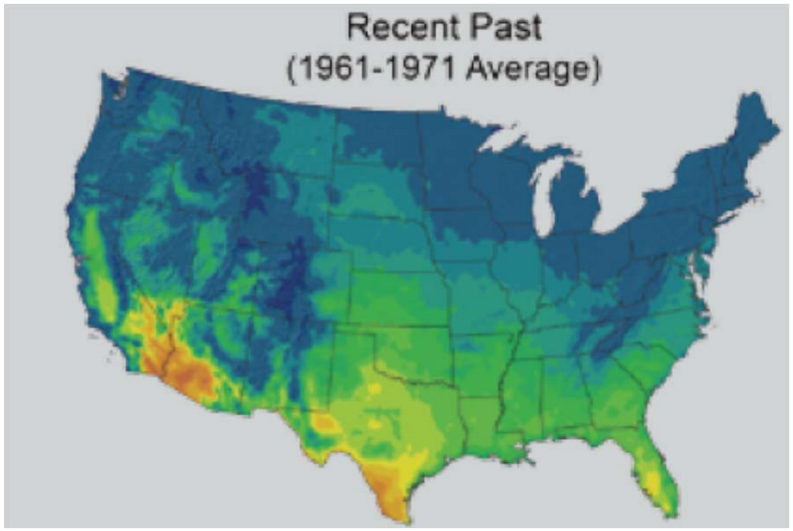
...Provides Perspective



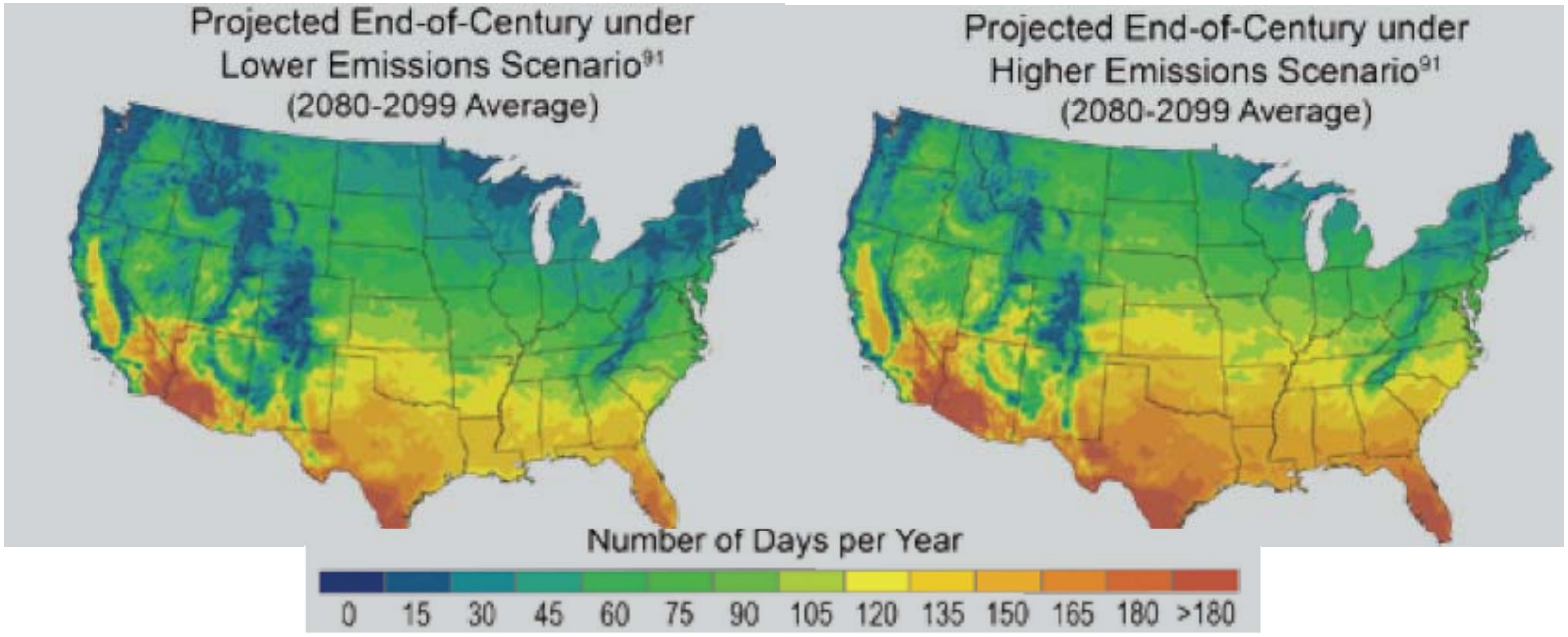


More big blows in the greenhouse. Computer simulation of the most intense hurricanes shows an increase from today (*top*) to a warmer world at the end of the century (*bottom*).

"We find that human-induced climate change likely increased the chances of the observed precipitation accumulations during Hurricane Harvey in the most affected areas of Houston by a factor of at least 3.5." Rissen & Wehner AGU in Press

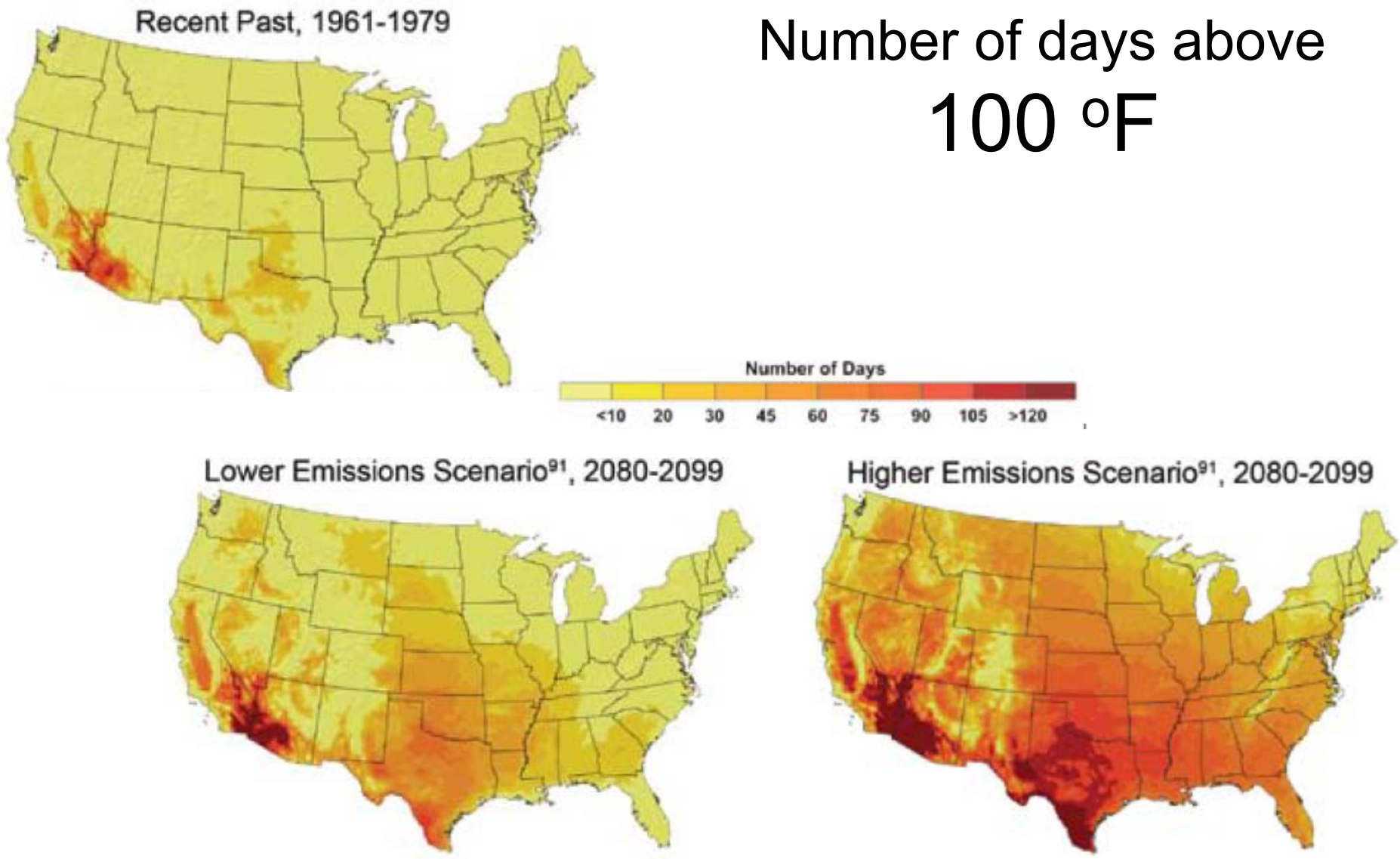


Number of days above 90 ºF

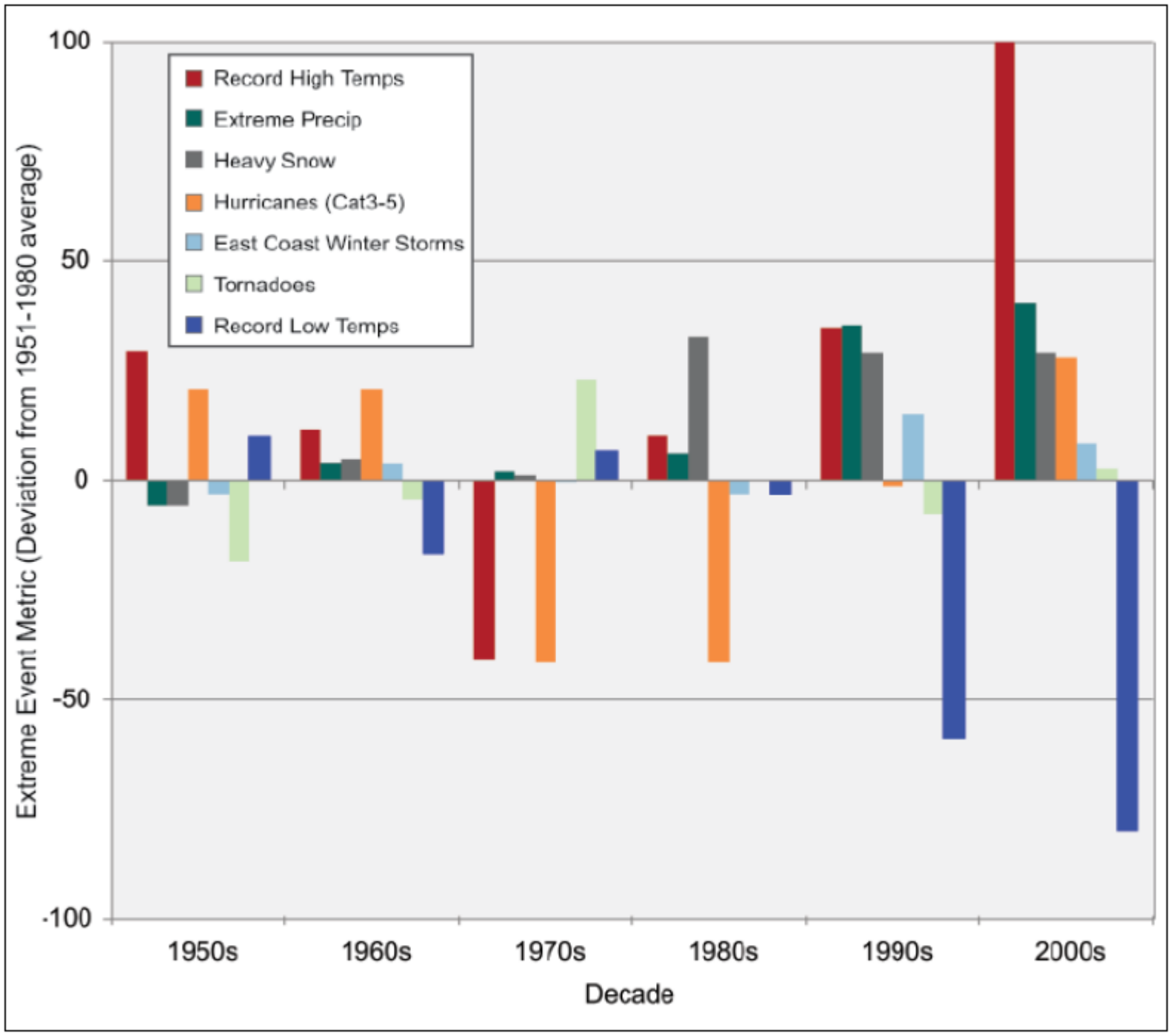


www.globalchange.gov/usimpacts

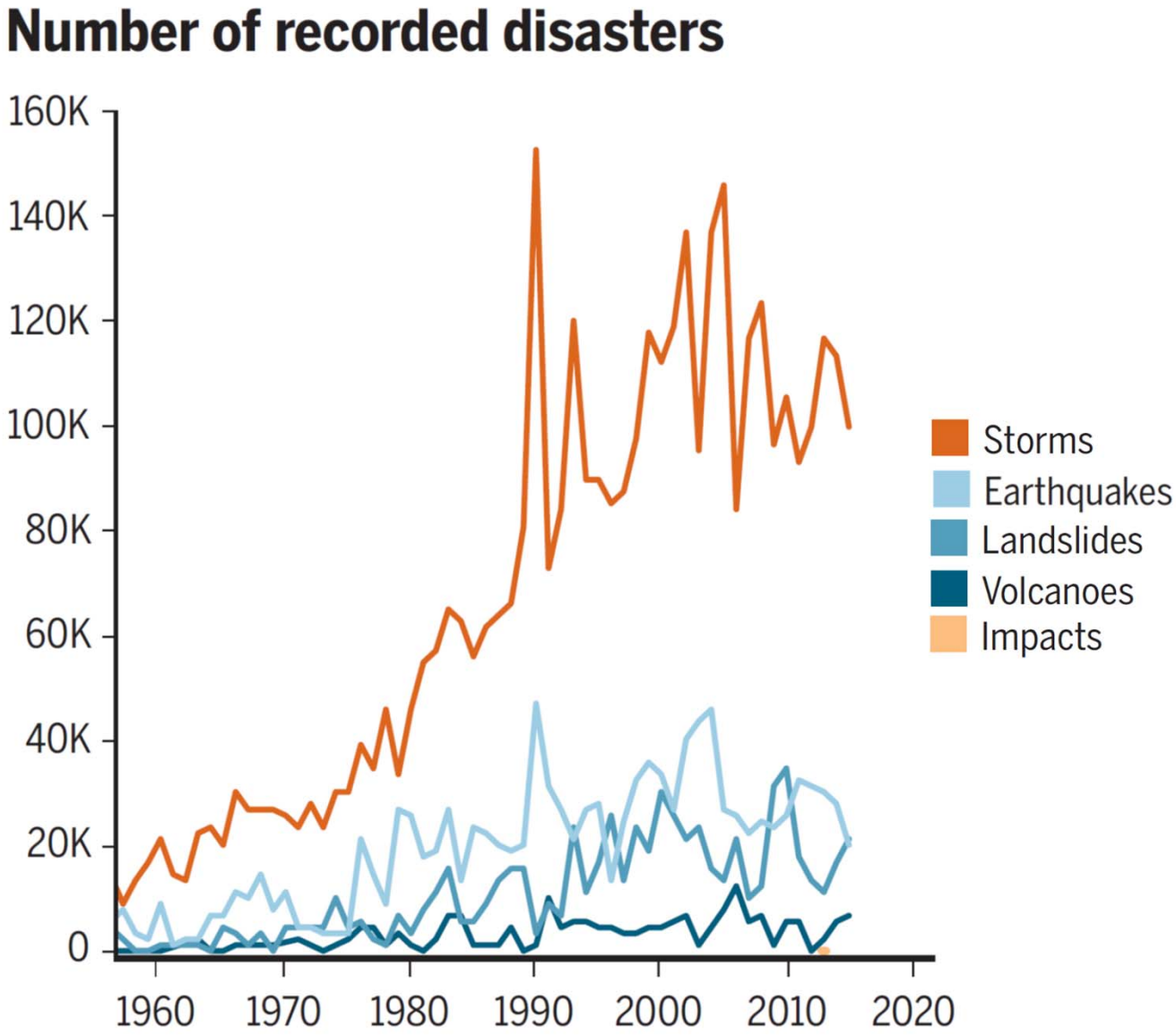
Number of days above 100 °F



www.globalchange.gov/usimpacts

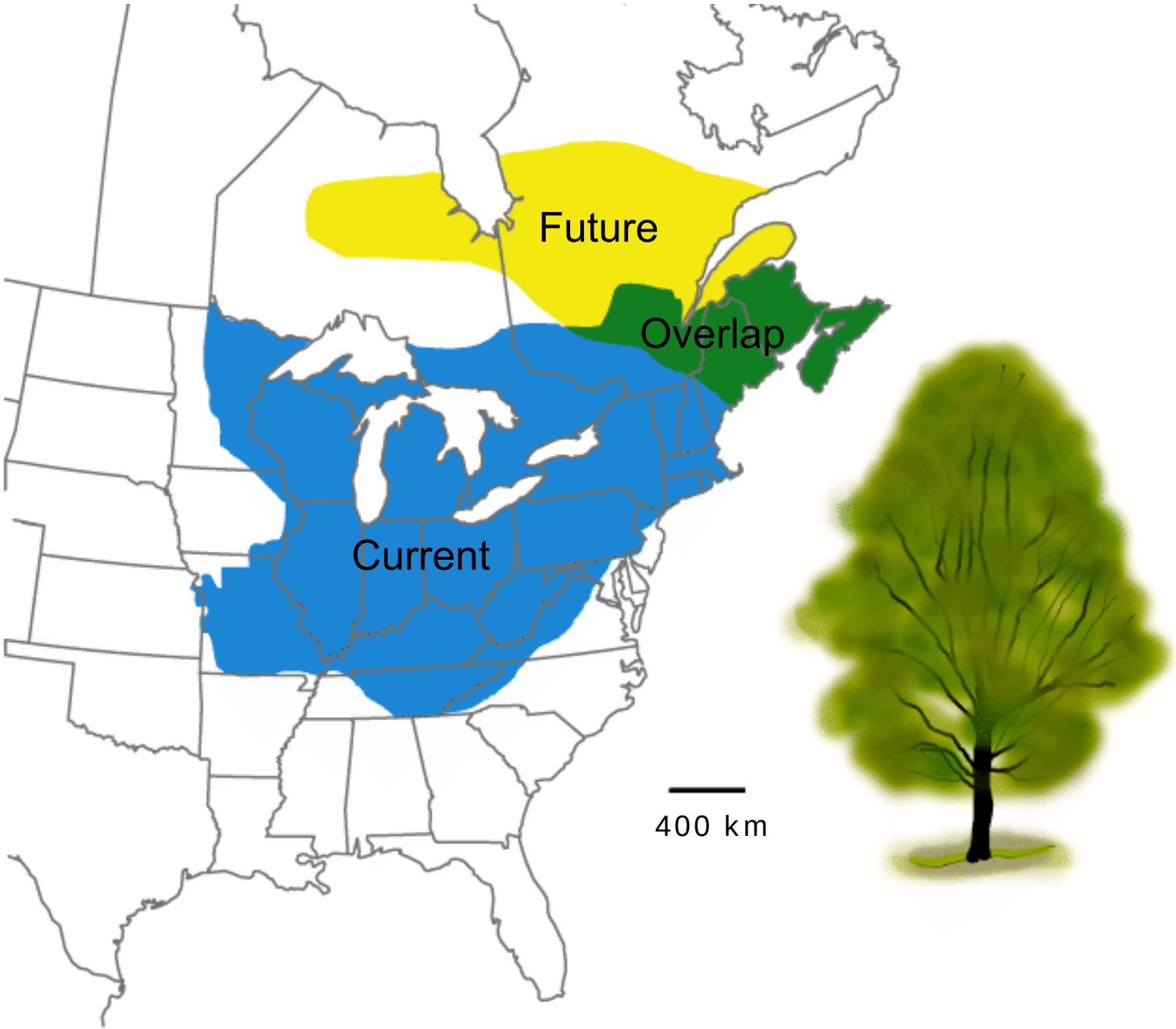


EOS 2014
95(18):1

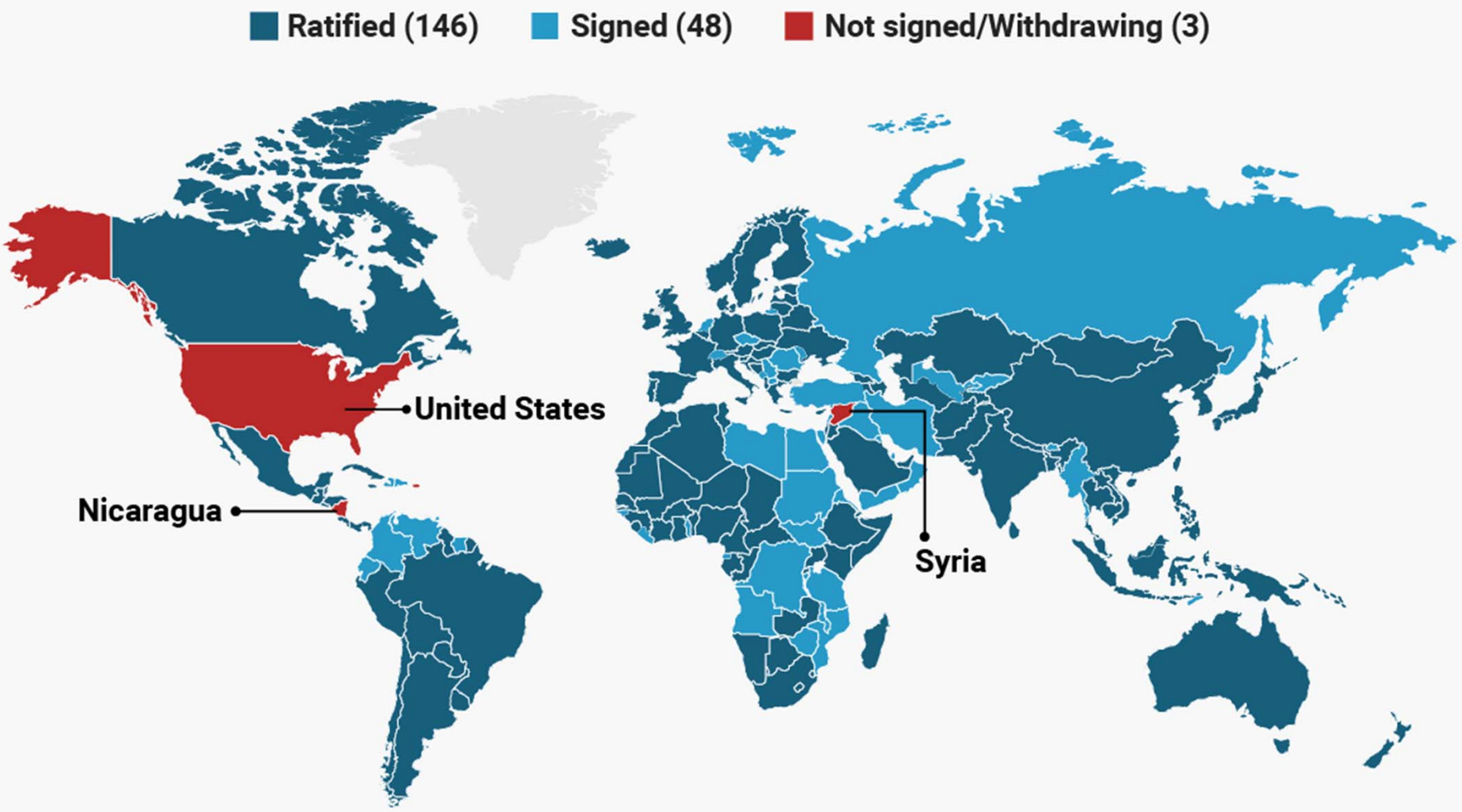


Rosen (2016) *Science* 353(6296):232-237

Change in the distribution of sugar maple



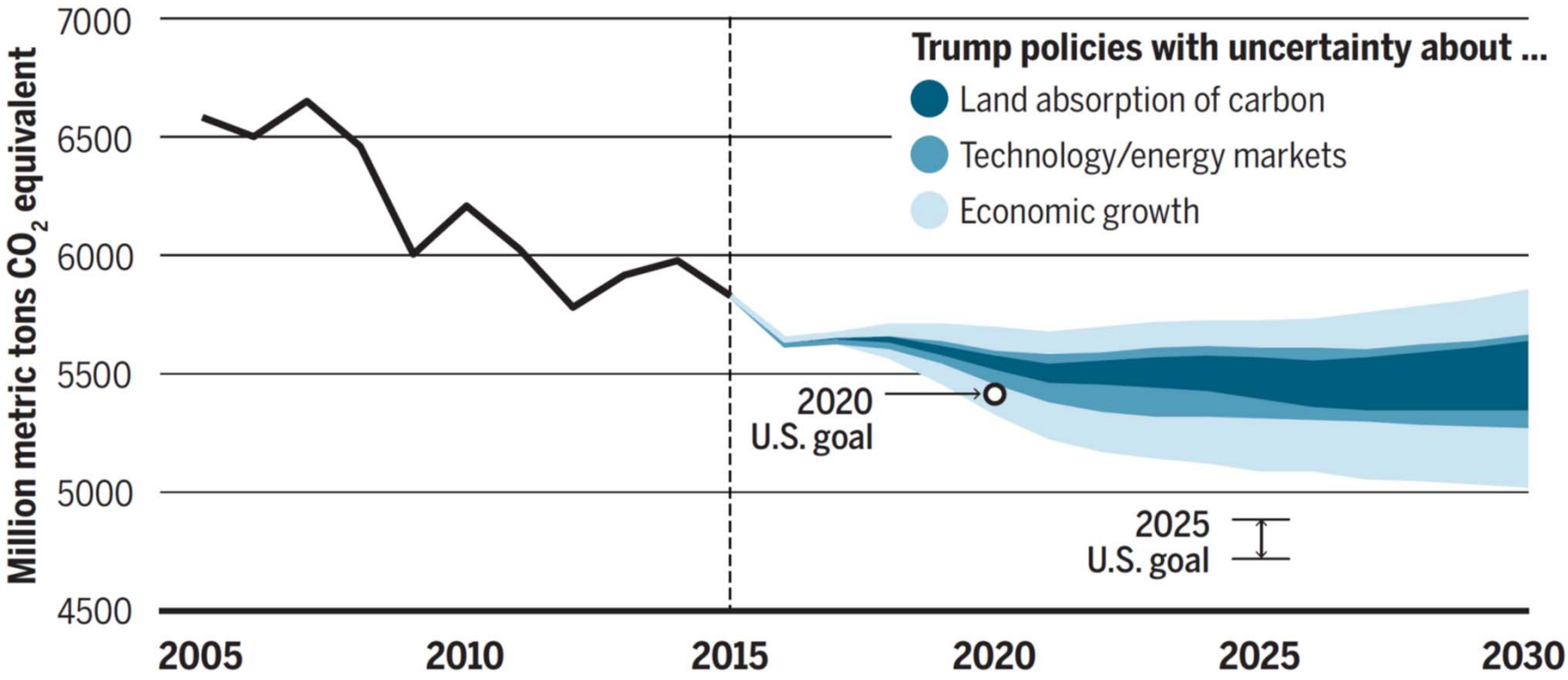
COUNTRIES THAT JOINED THE PARIS CLIMATE AGREEMENT



SOURCE: UNFCCC **NOTE:** Denmark's agreement excludes Greenland. Map is updated as of May 31, 2017.

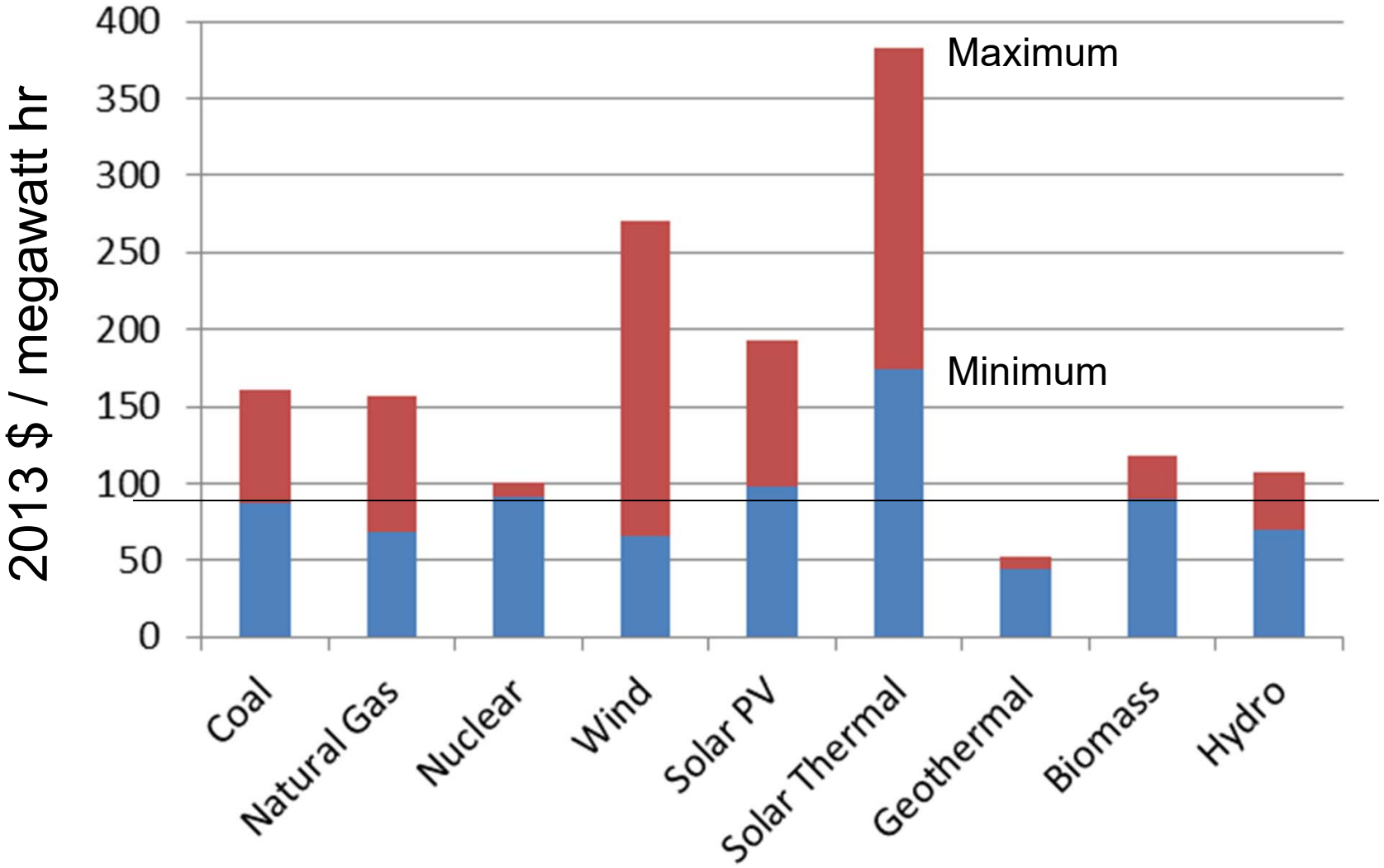
BUSINESS INSIDER

U.S. Carbon emissions and Paris Goals



Science 9 June 2017 356(6342): 1000

Cost of a new Power Plant

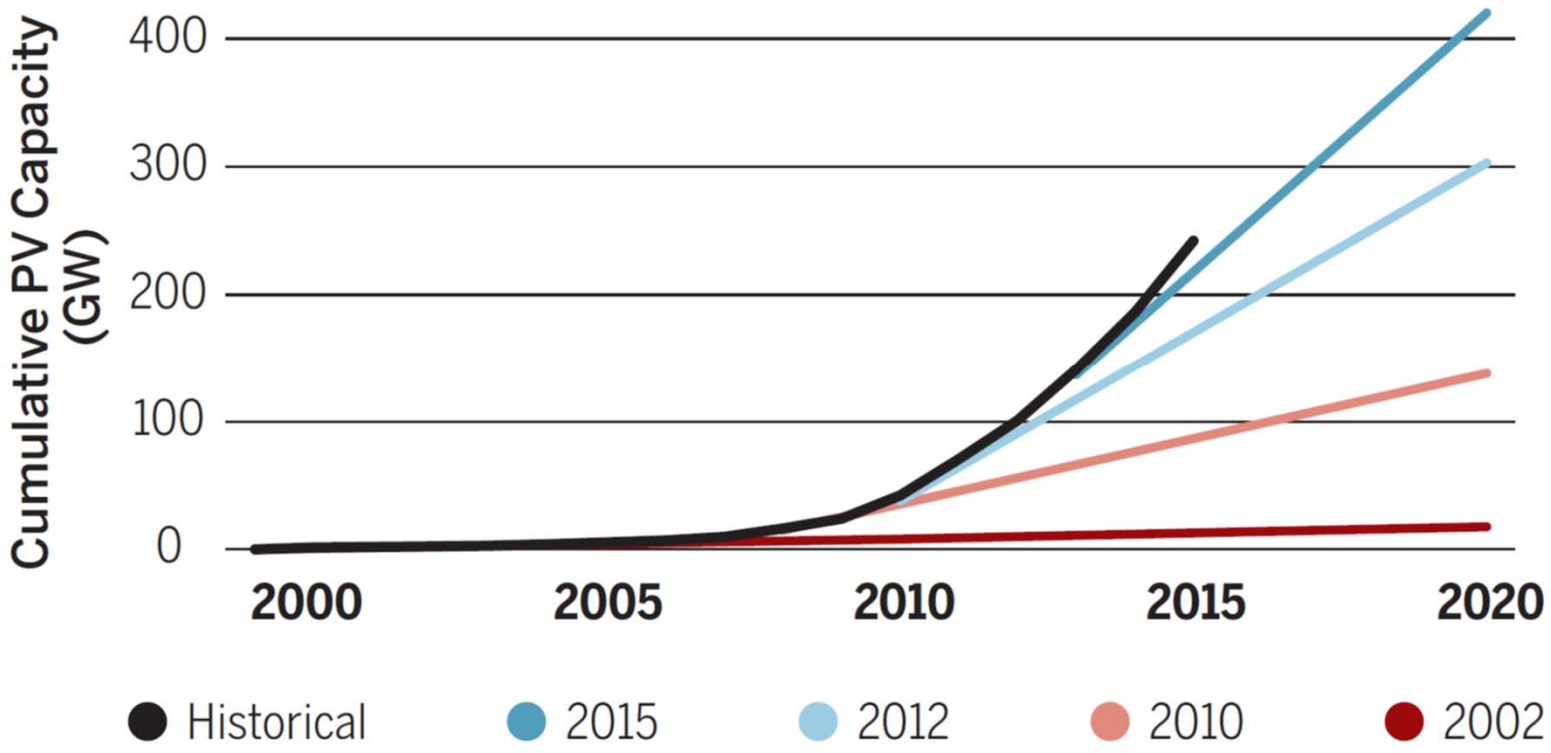


US Energy Information Administration

Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015

Solar adoption has outpaced projections

Projected (year of IEA publication) versus actual (historical)



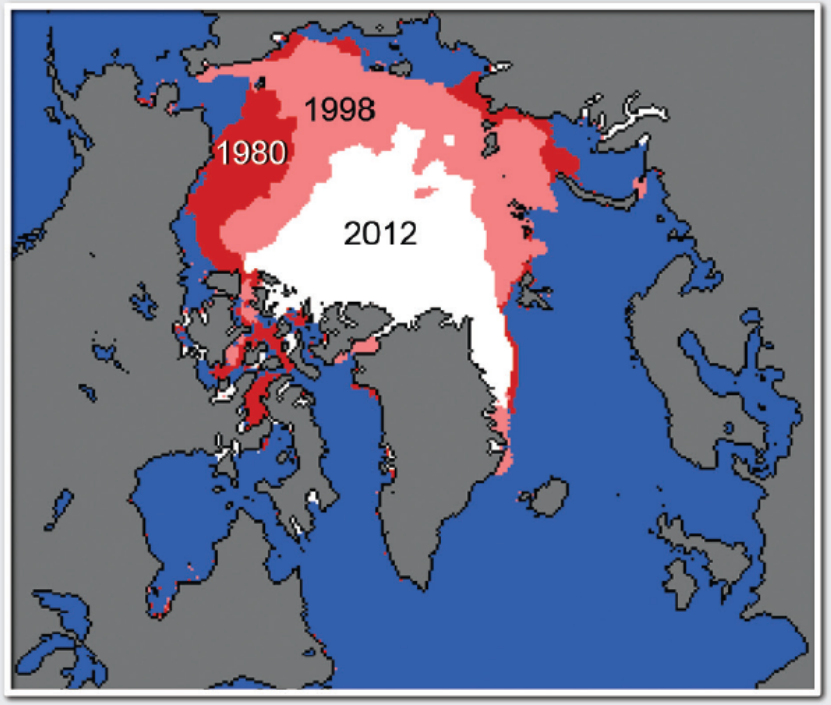
Science 14 April 2017 356(6334): 141-143

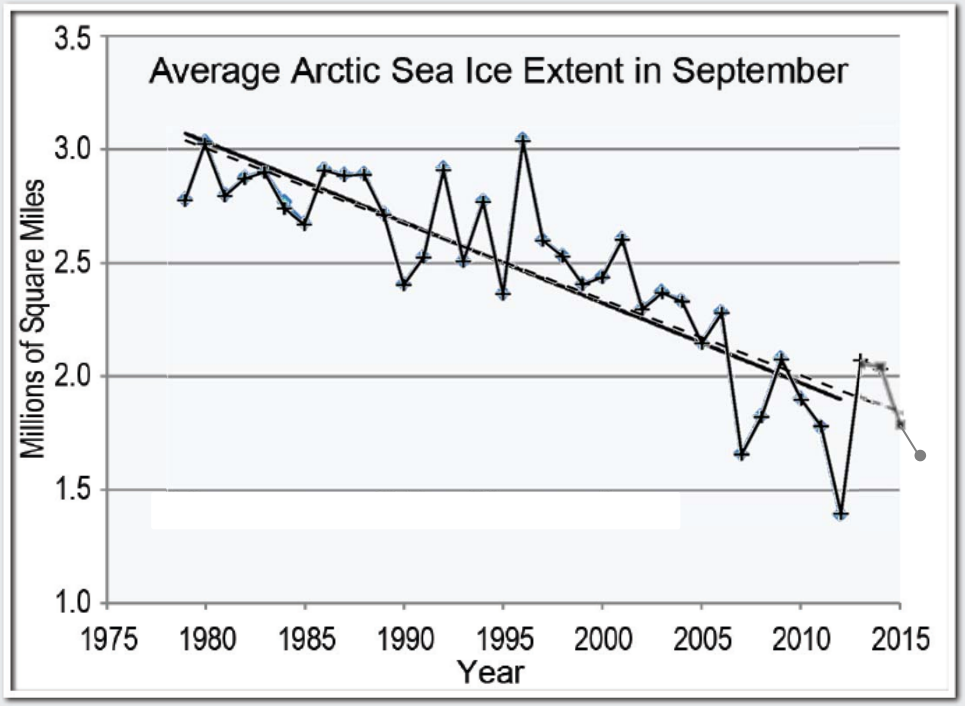
Changes in the Arctic

Sea Ice (Including thickness)

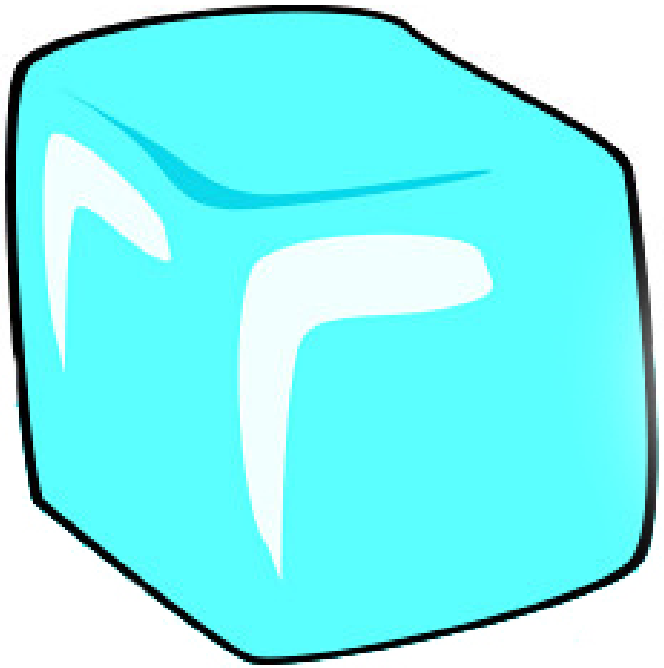
https://www.youtube.com/watch?v=8auMIfF50Ng

Arctic Sea Ice Decline

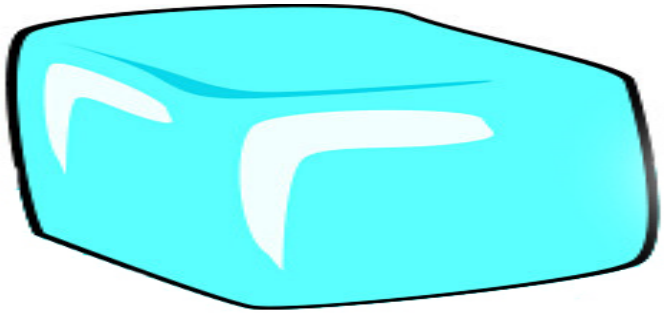




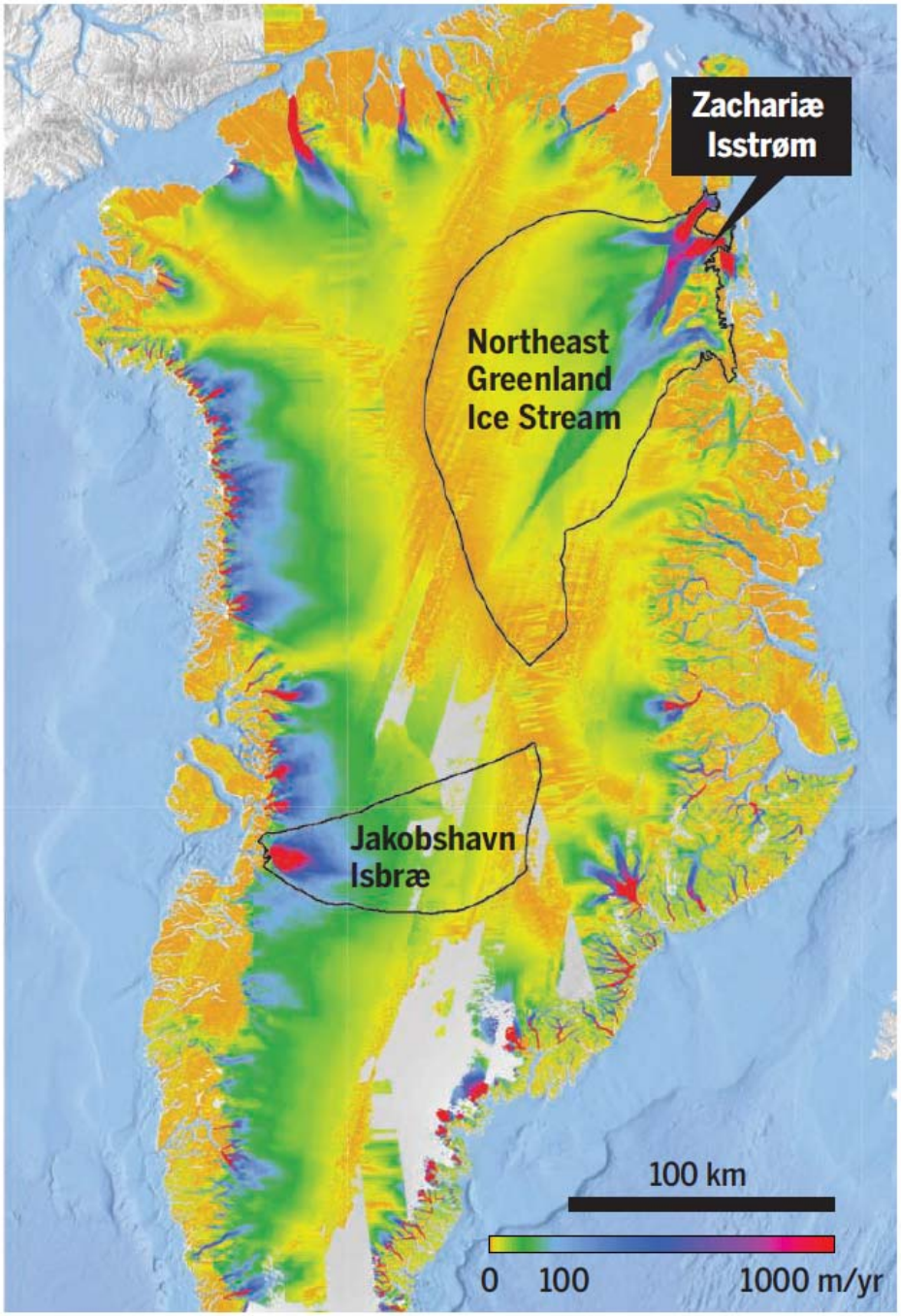
Which do you expect to melt faster?



Thick glacier

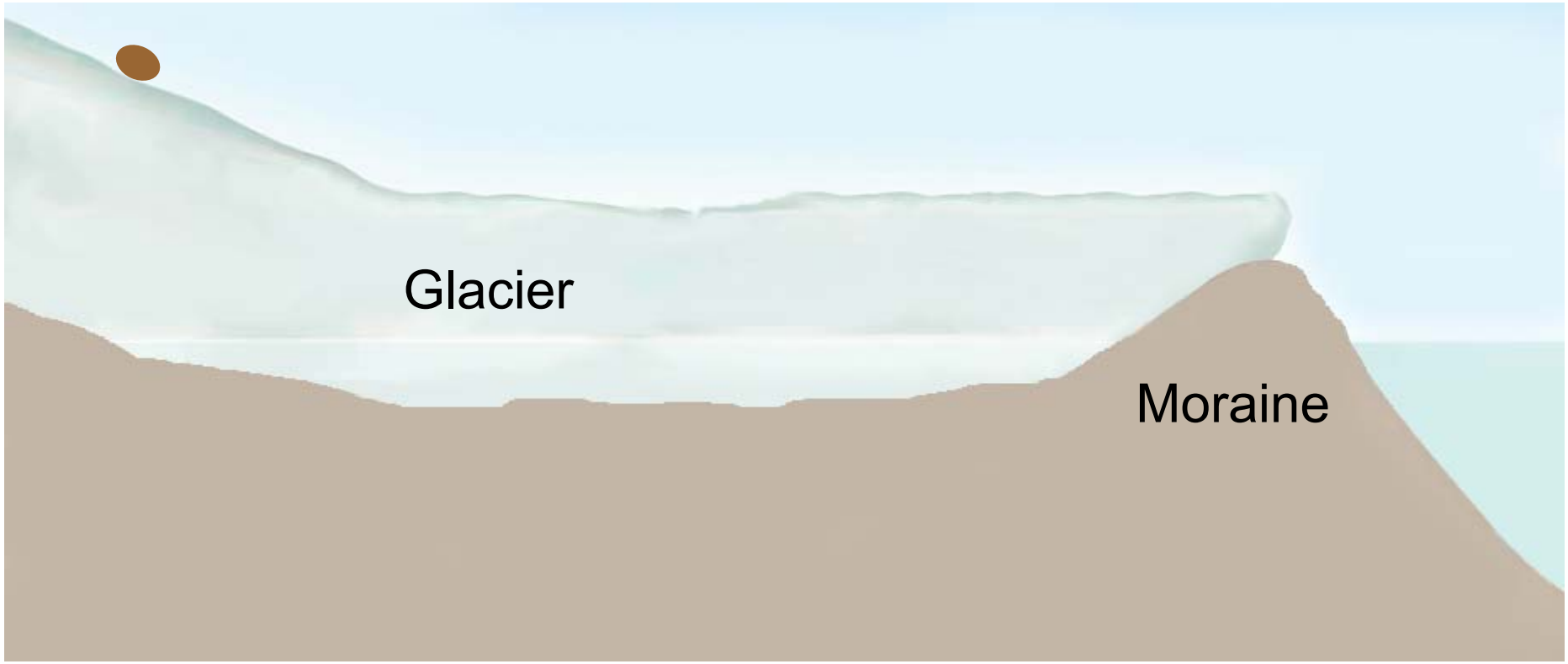


Thin glacier

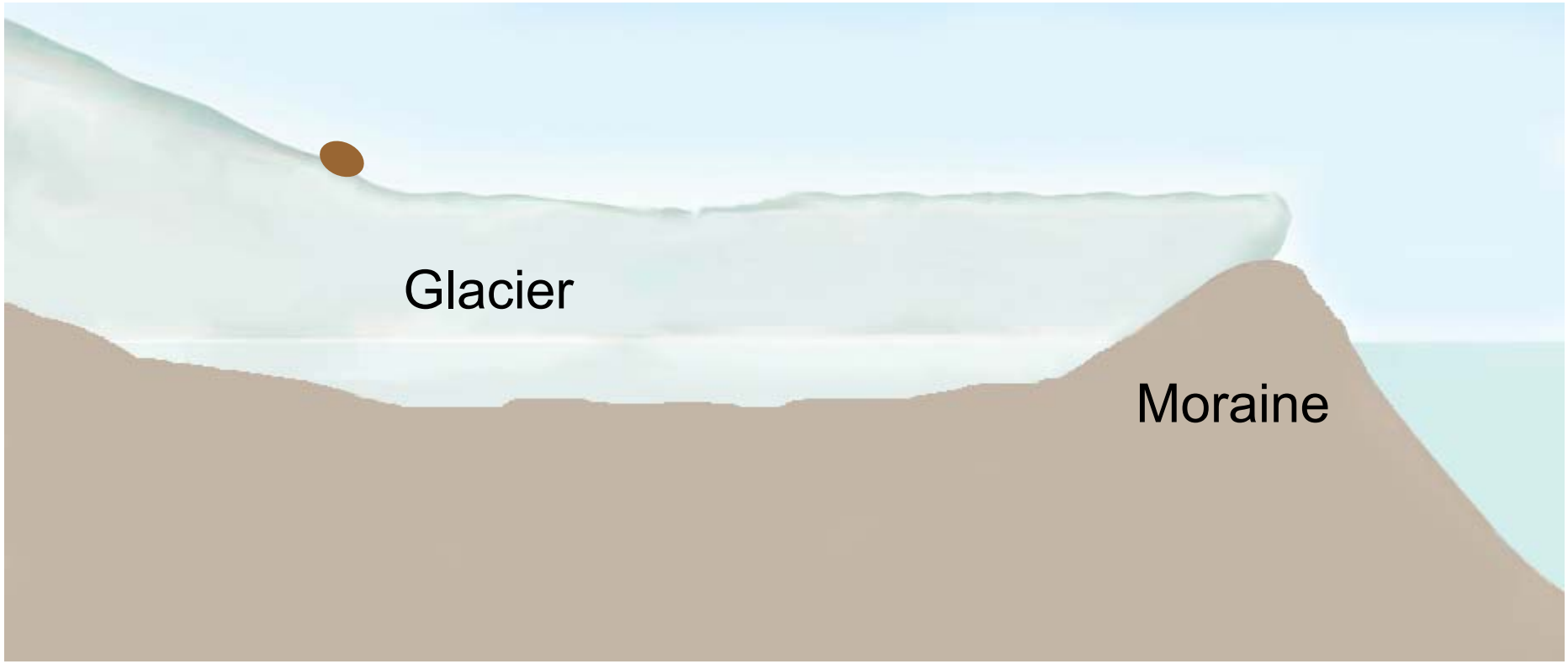


Greenland Ice Flows

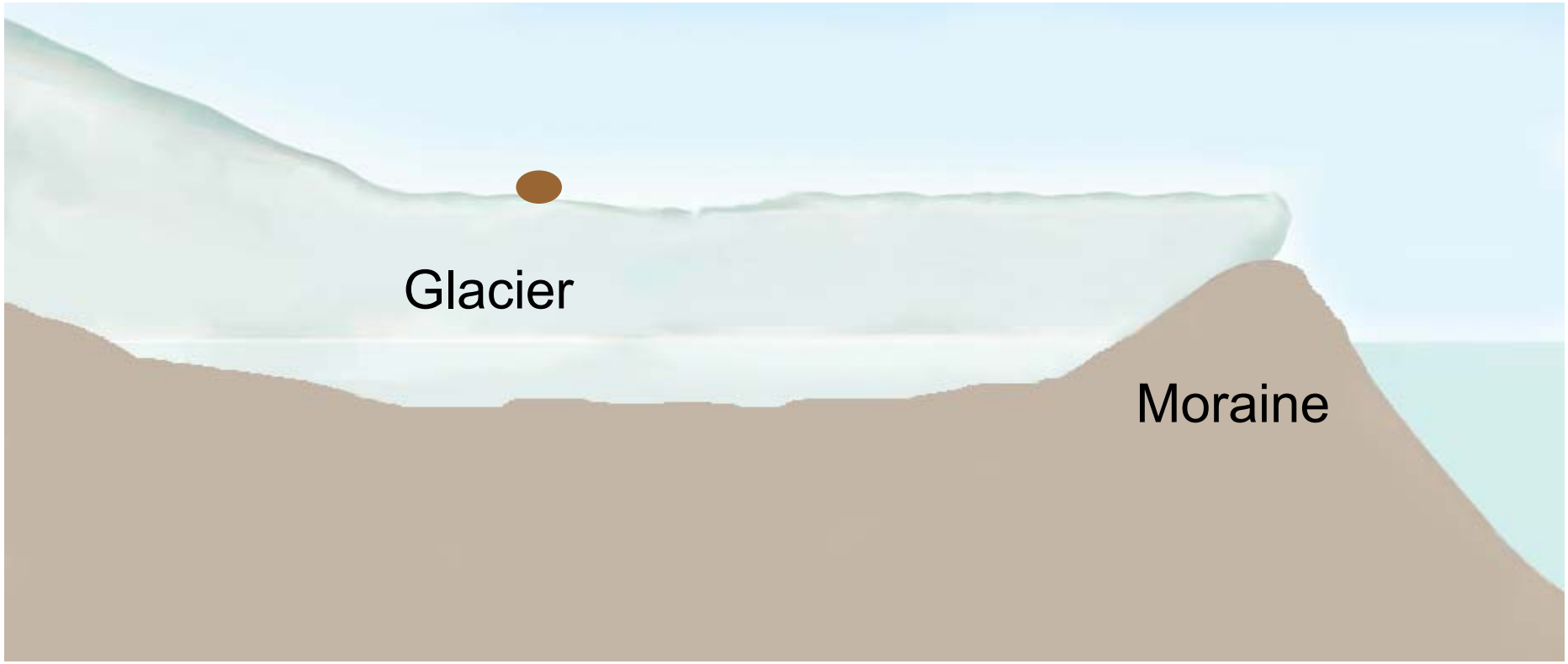
How Glaciers Work



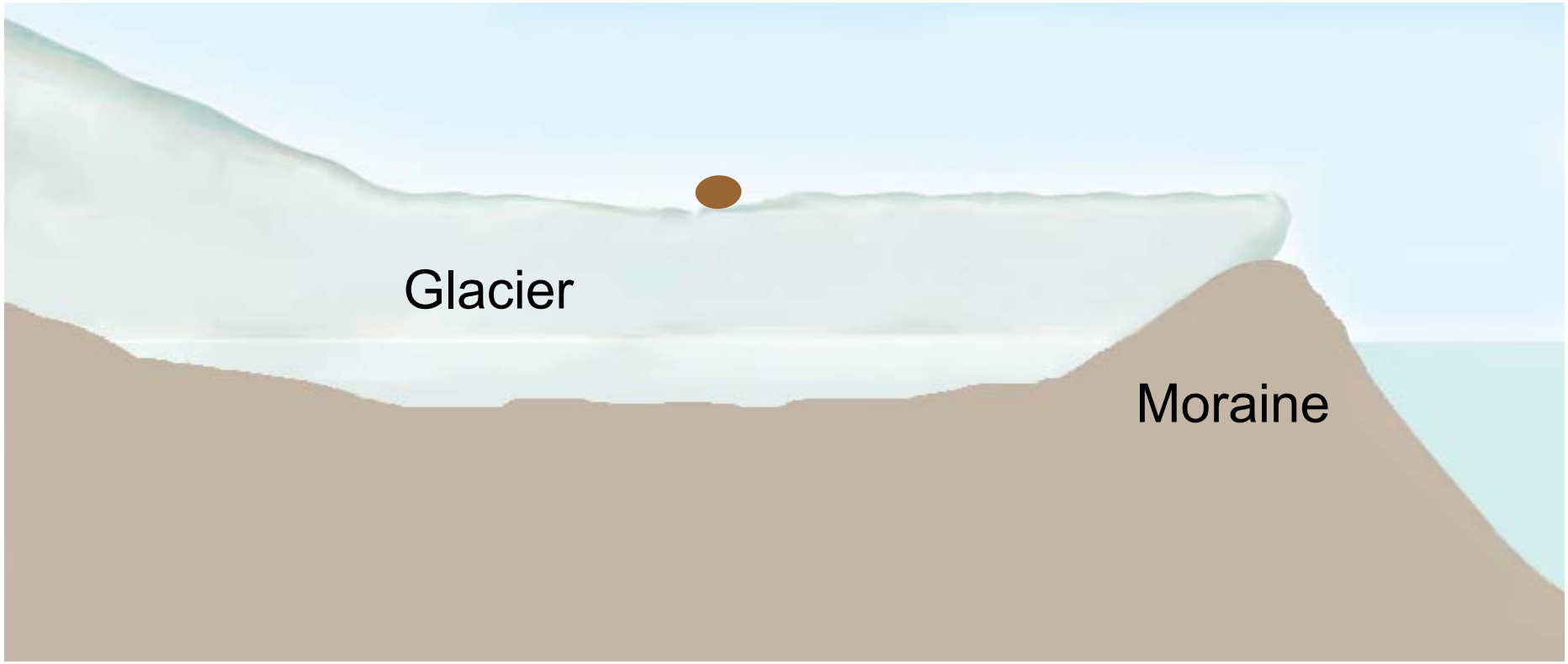
How Glaciers Work



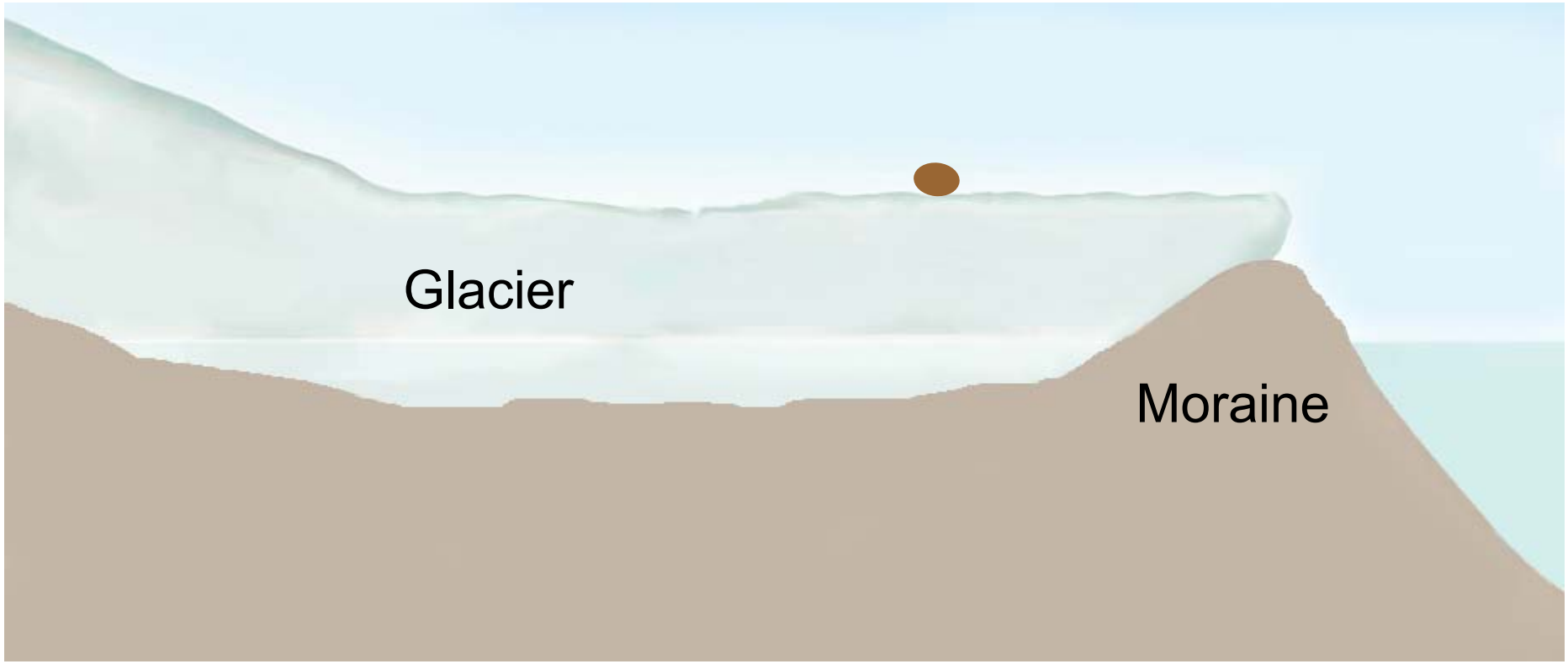
How Glaciers Work



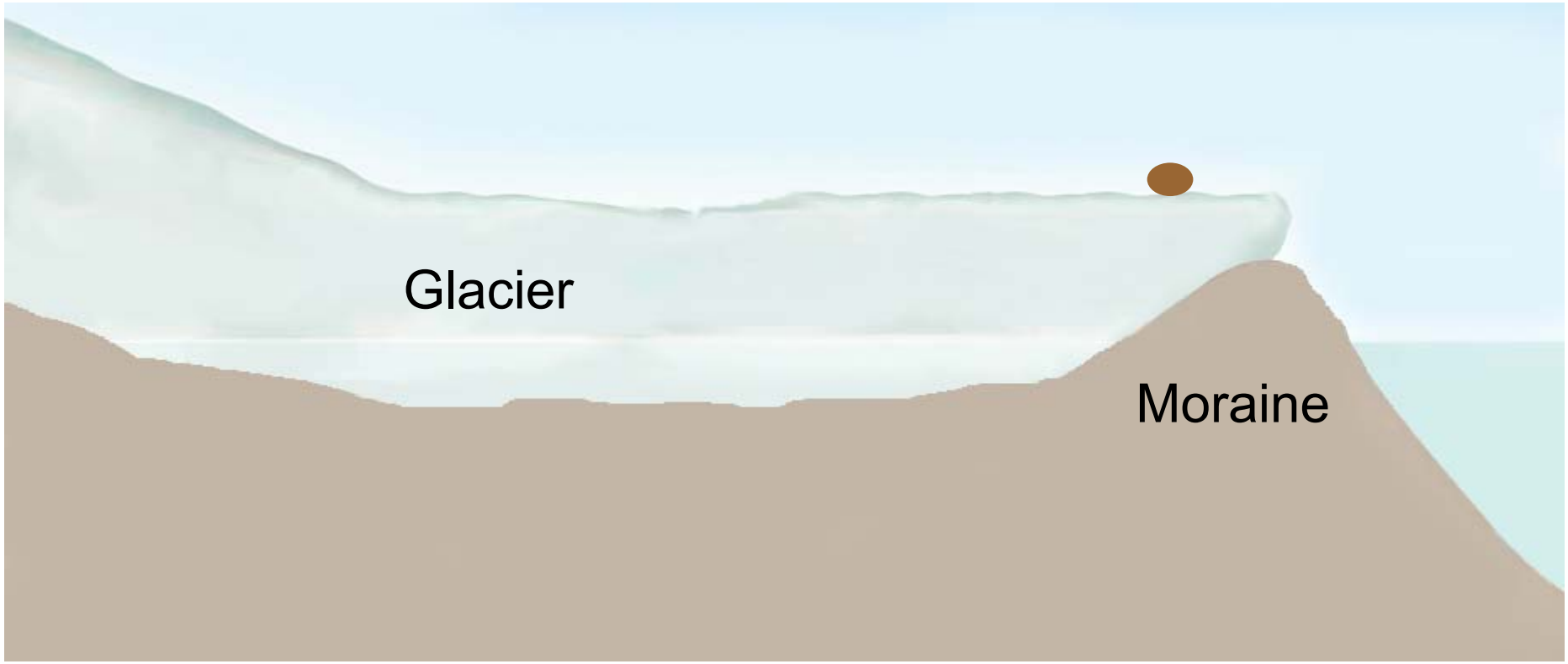
How Glaciers Work



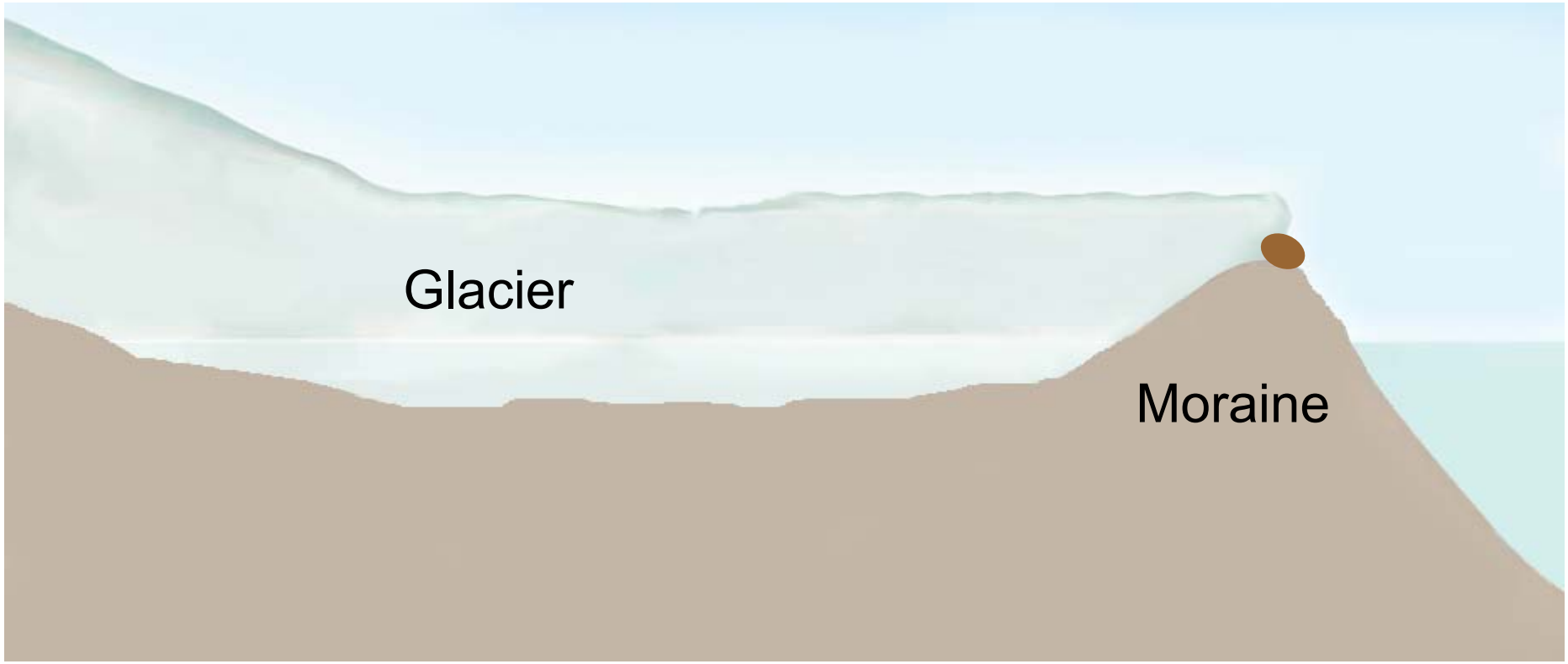
How Glaciers Work



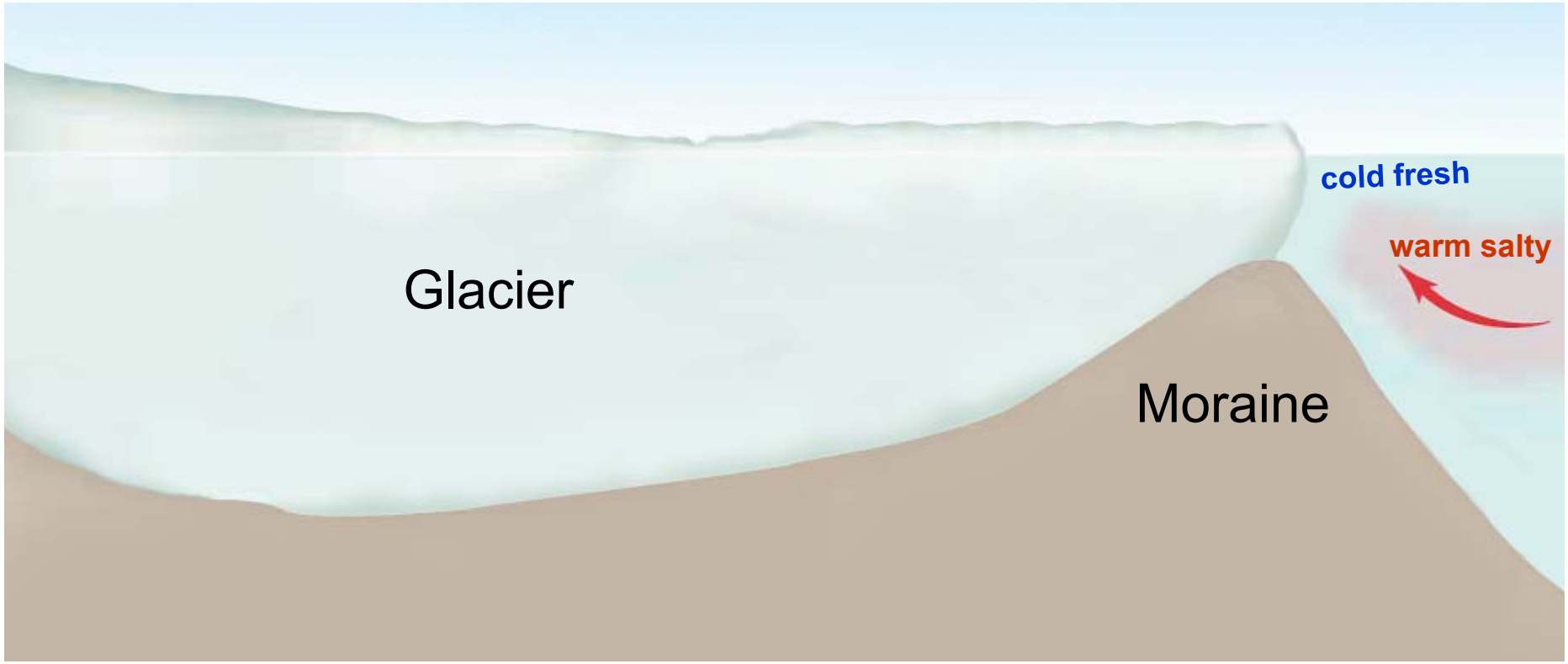
How Glaciers Work



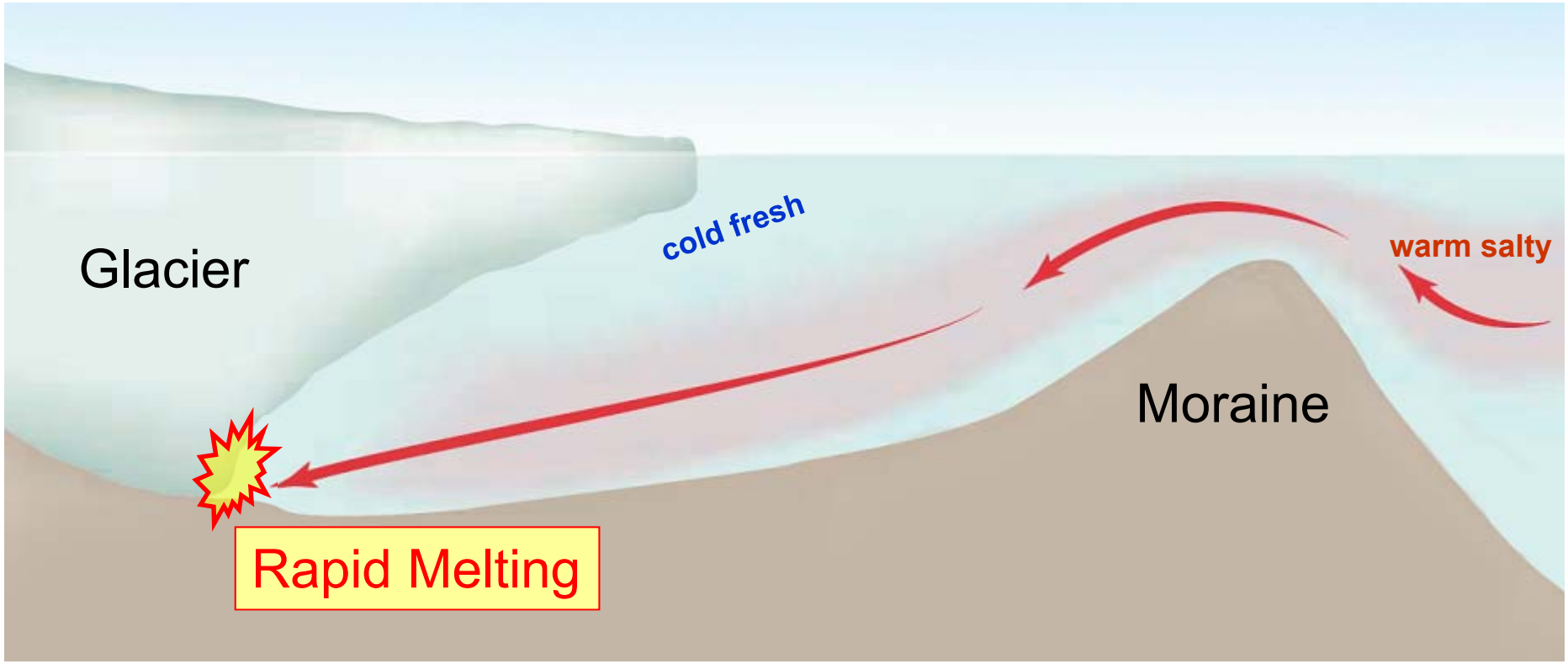
How Glaciers Work



Deep Outlet Glaciers

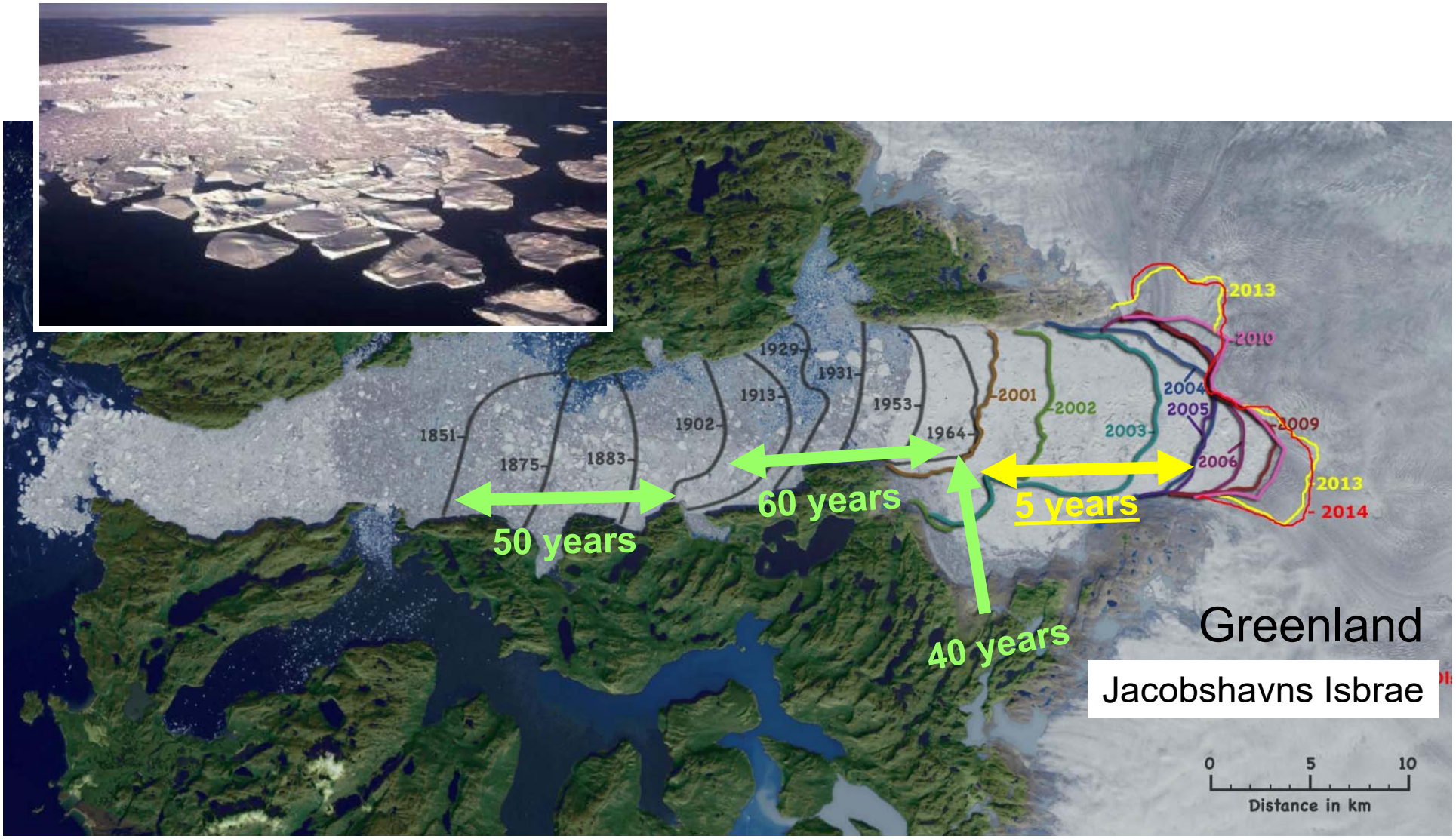


Deep Outlet Glaciers

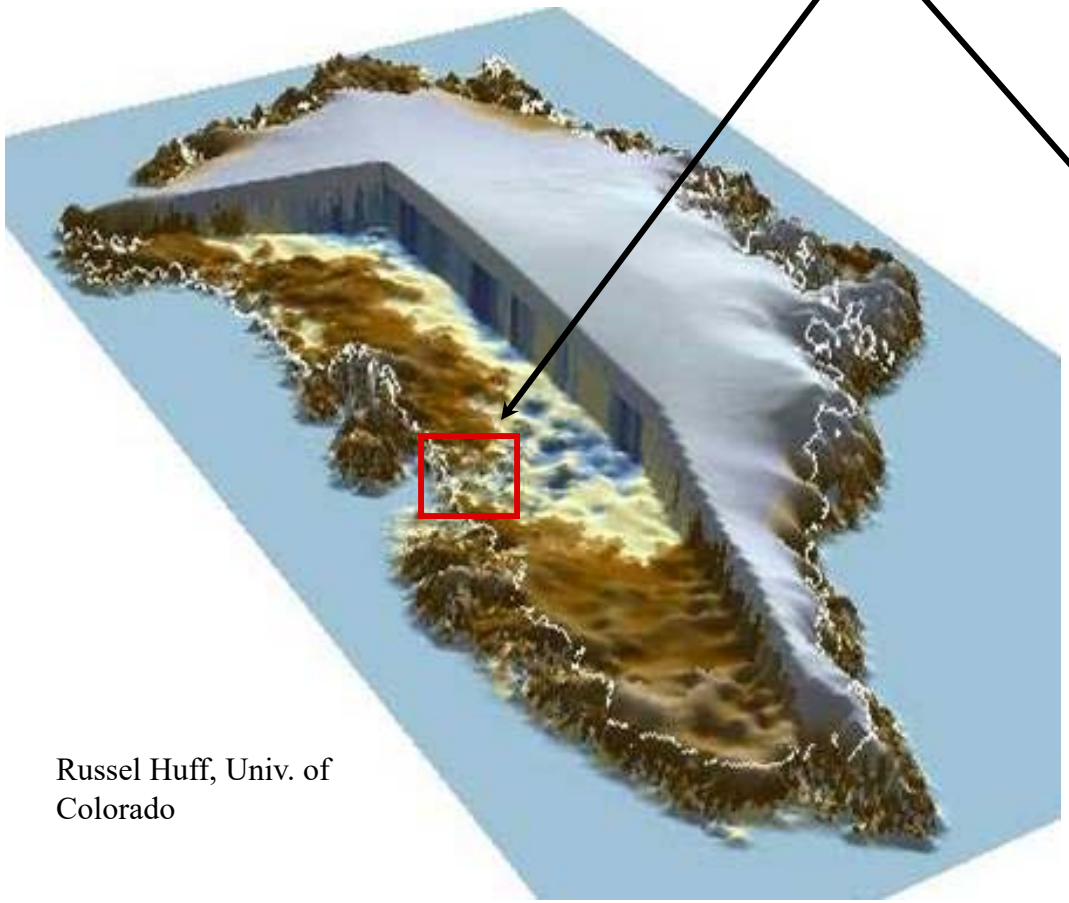


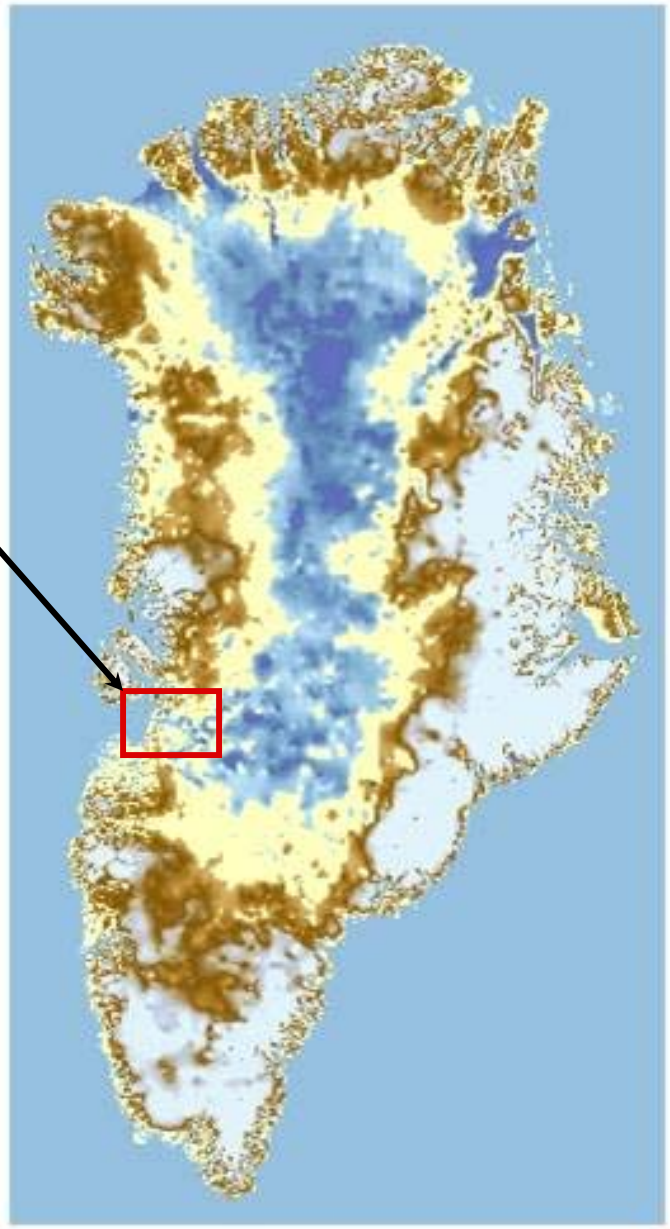
https://www.youtube.com/watch?v=hC3VTgIPoGU

Rapid Retreat

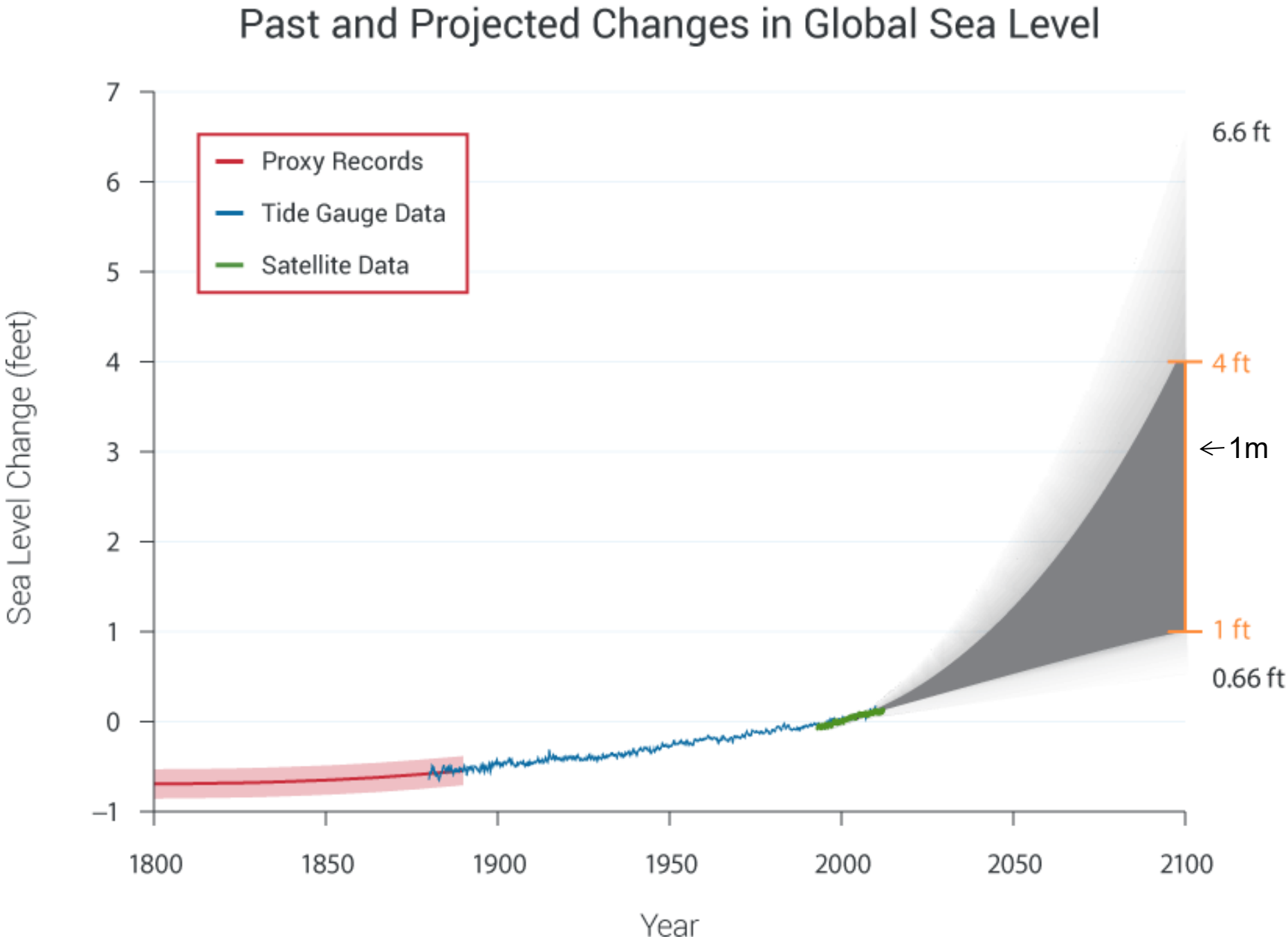


- Jacobshavns Isbrae occupies subglacial channel
- Central Greenland is below sea level





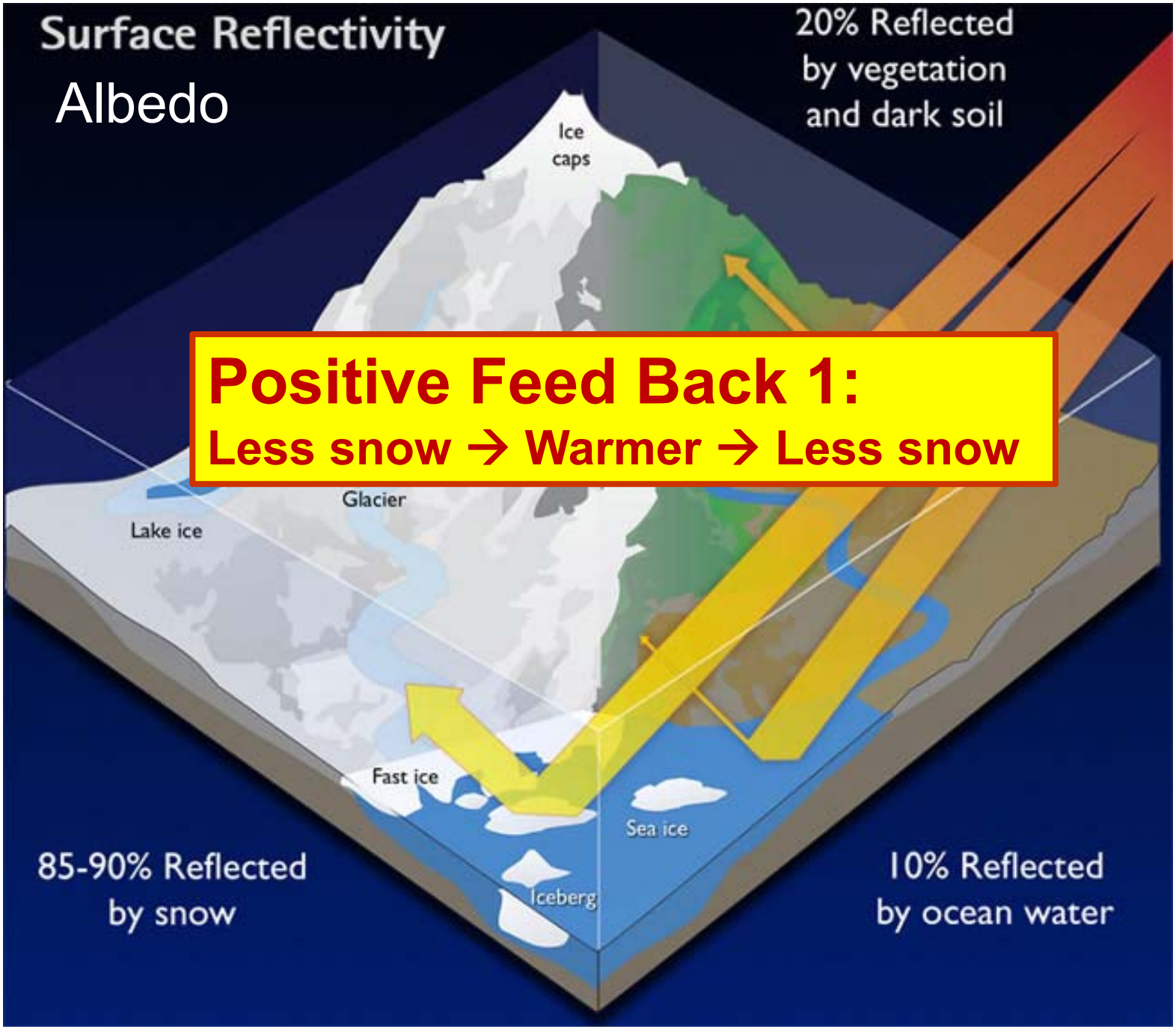
Russel Huff, Univ. of Colorado

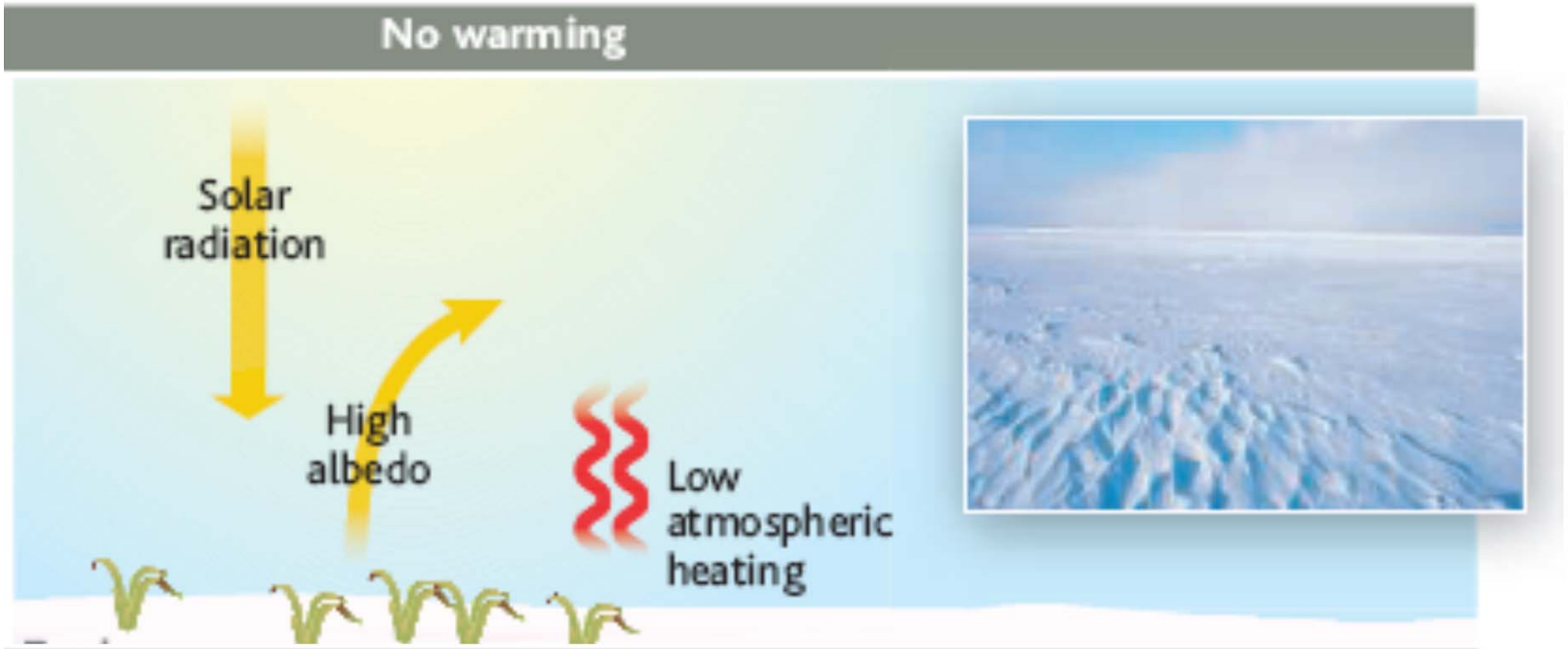

Past and Projected Changes in Global Sea Level
Proxy Records
Tide Gauge Data
Satellite Data
Sea Level Change (feet)
7
6
5
4
3
2
1
0
−1
1800
1850
1900
1950
2000
2050
2100
Year
6.6 ft
4 ft
←1m
1 ft
0.66 ft

The Global Role of Snow

NASA animation showing positive feedback

As the snow melts more solar radiation is absorbed and more snow melts


Surface Reflectivity
Albedo
20% Reflected
by vegetation
and dark soil
Ice
caps
Positive Feed Back 1:
Less snow → Warmer → Less snow
Glacier
Lake ice
Fast ice
Sea ice
Iceberg
85-90% Reflected
by snow
10% Reflected
by ocean water



Positive Feed Back 2:

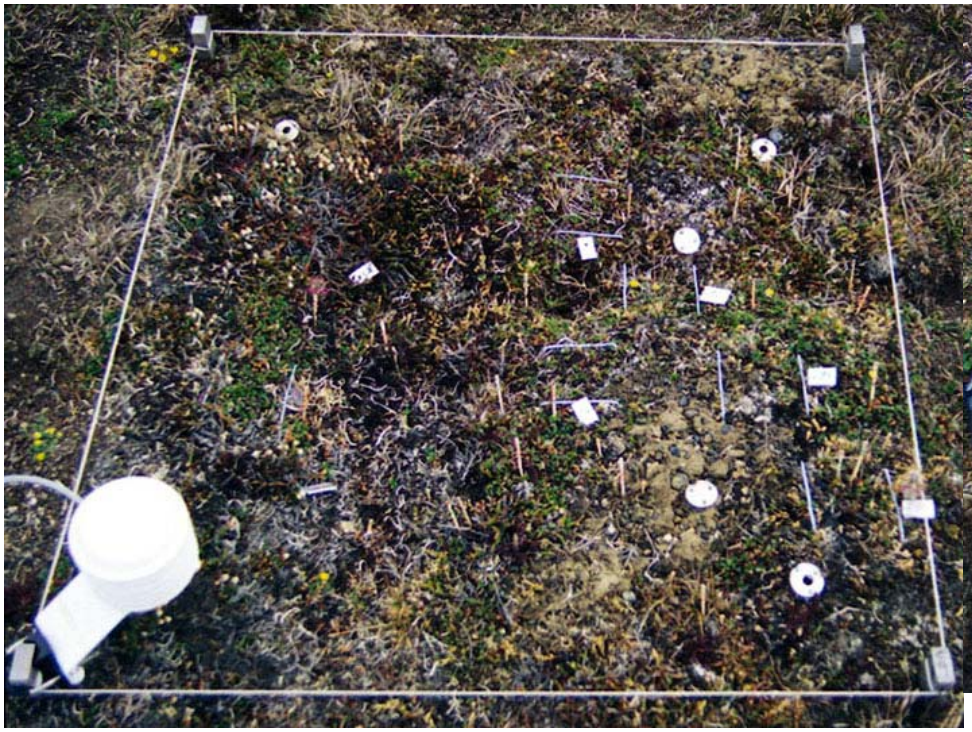
Taller plants → Warmer → Taller plants

Carbon Release

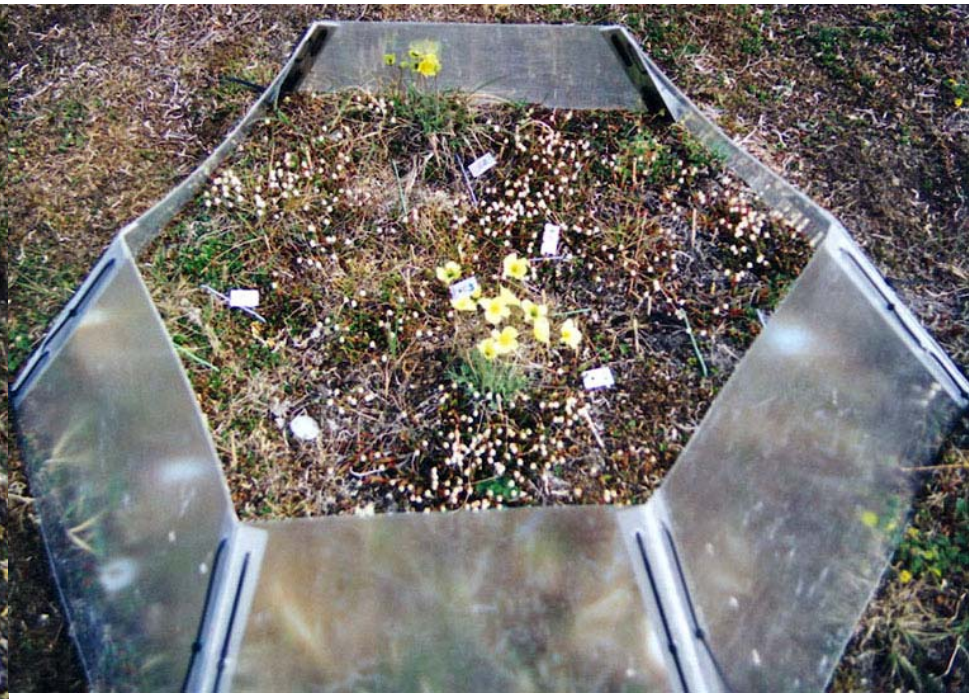
My Research

Transparent!

Experimental design



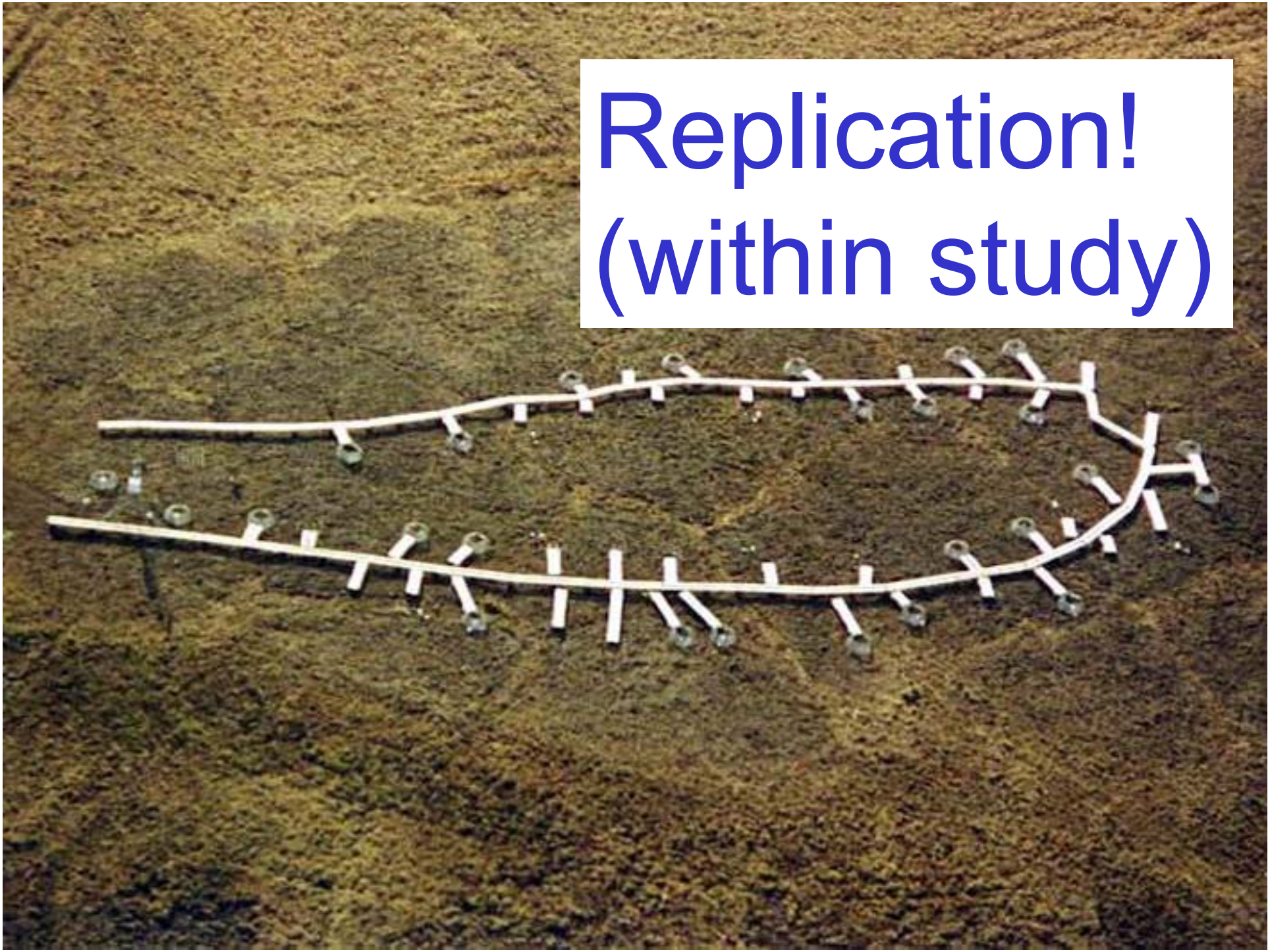
Control



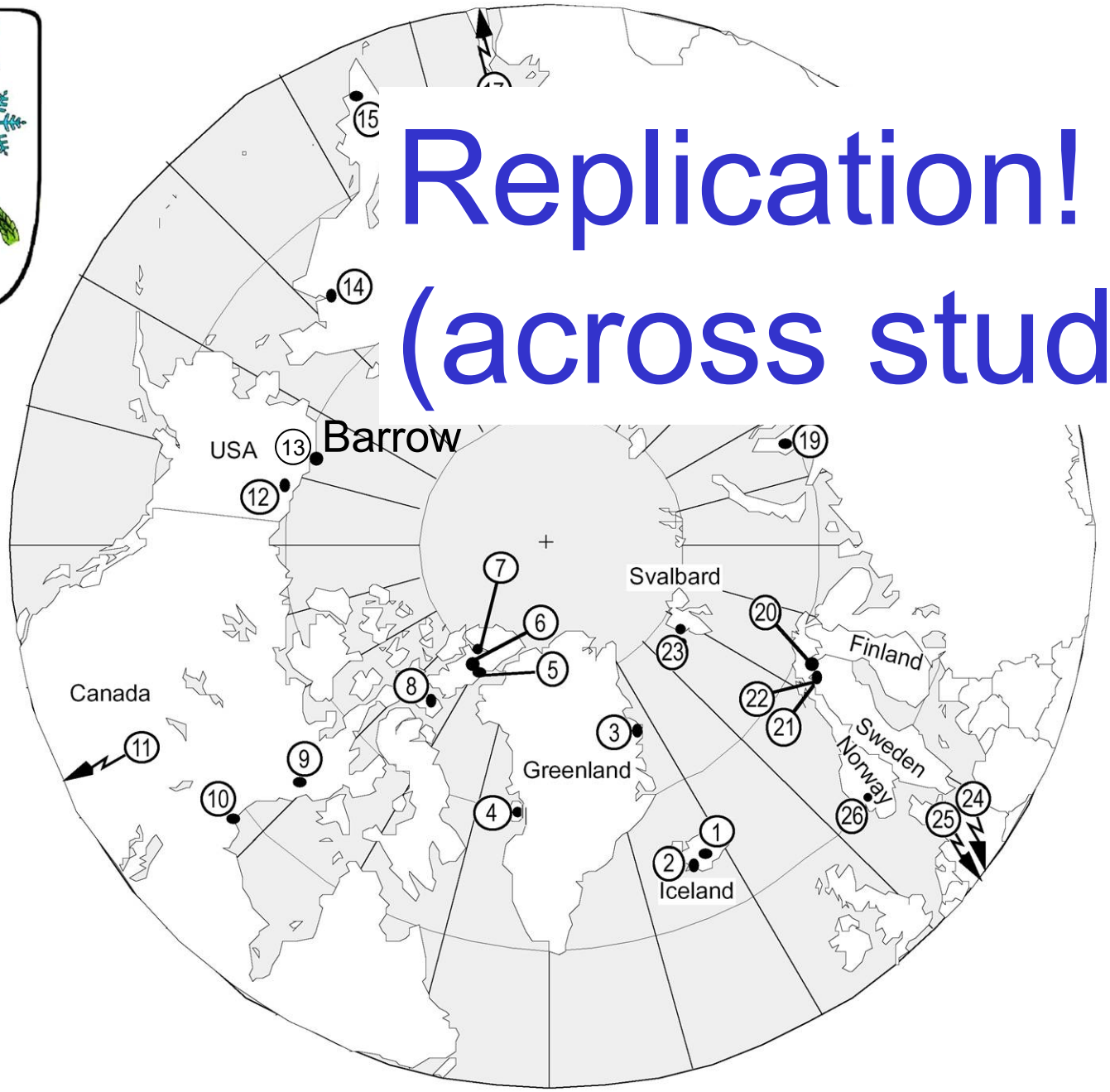
Manipulative warming

Collecting Data / Making Observations

Objective!


Replication!
(within study)

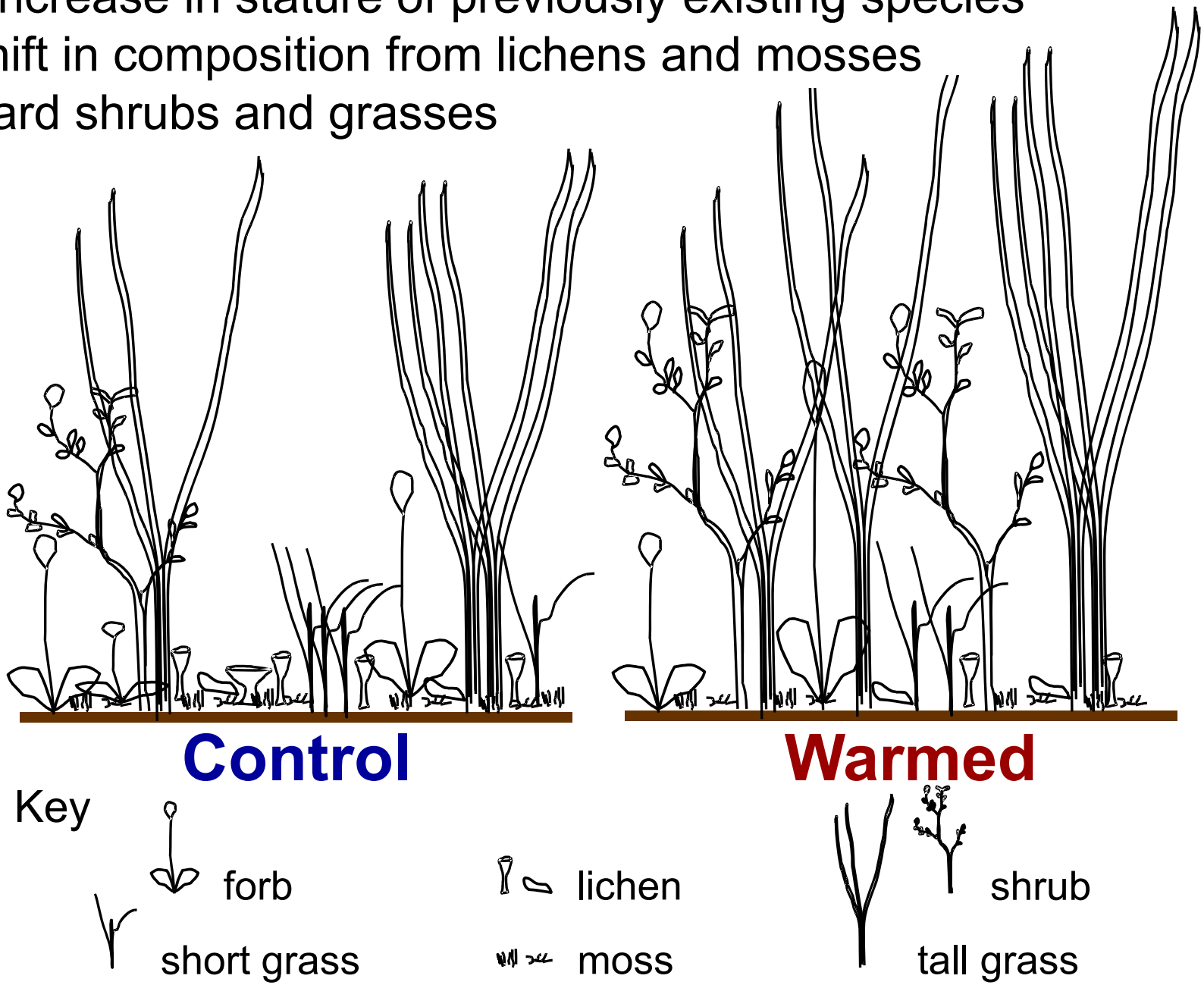
Replication! (across studies)



Study sites conducting similar research.

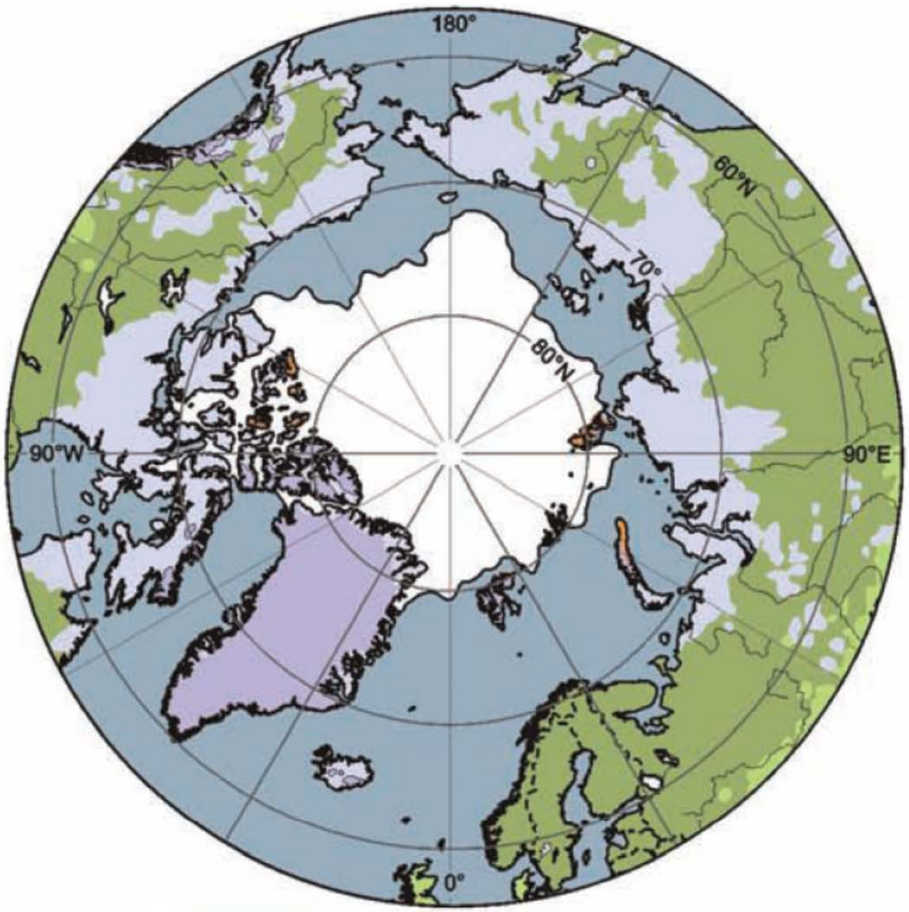
A general increase in canopy height due to:

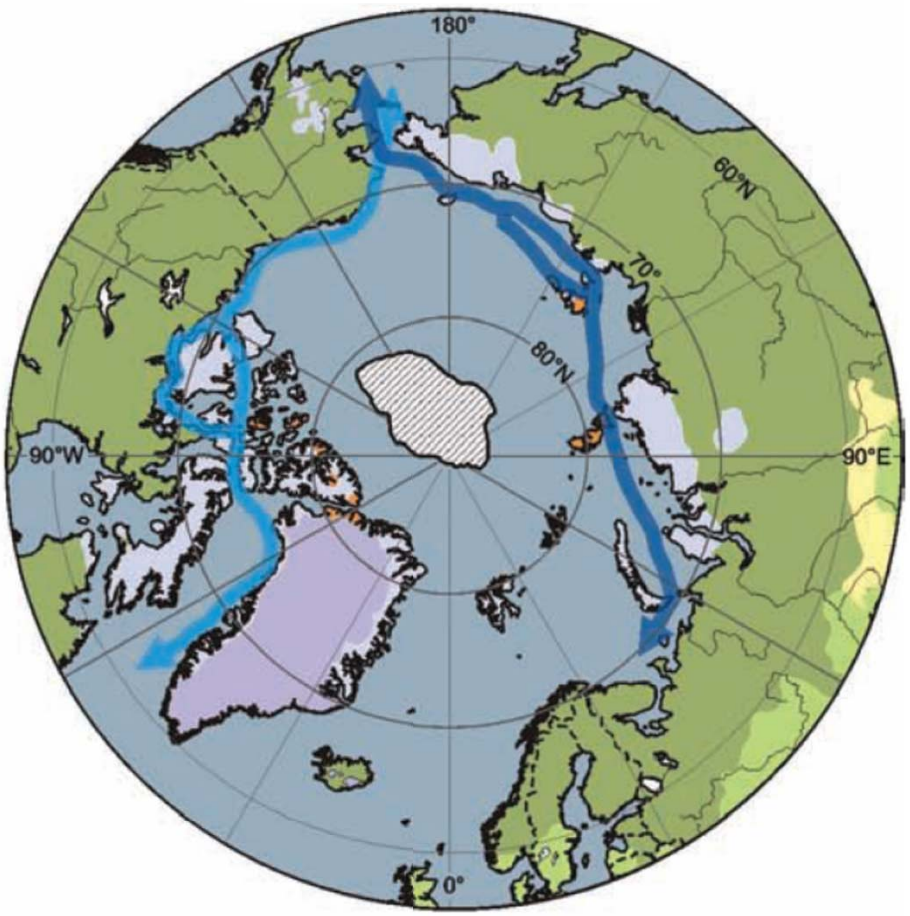
- an increase in stature of previously existing species
- a shift in composition from lichens and mosses toward shrubs and grasses



Current

Projected



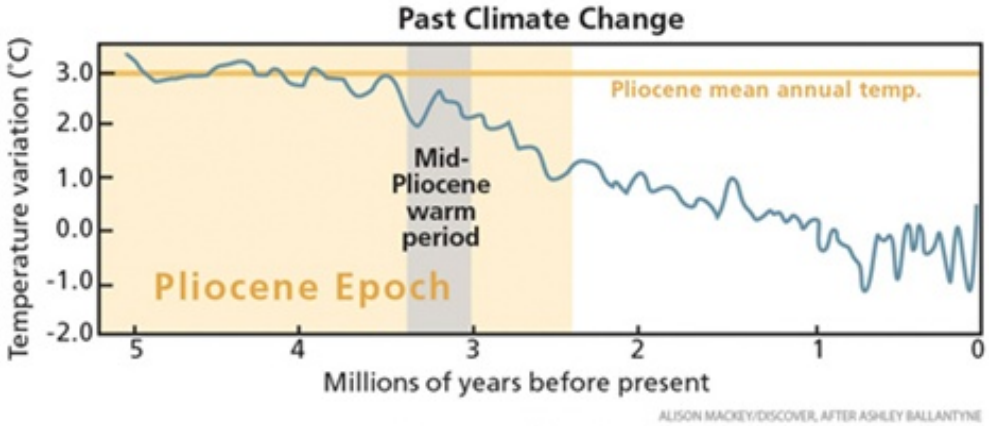


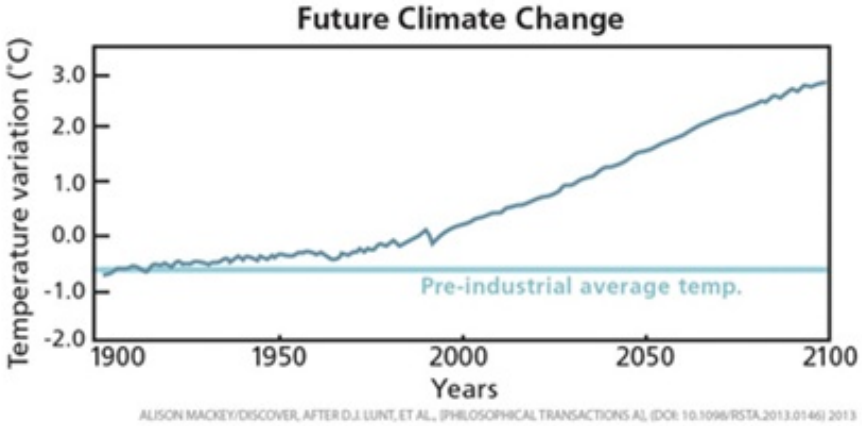
Temperate forest
Grassland
Tundra
Boreal forest
Polar desert/ semi desert
Ice

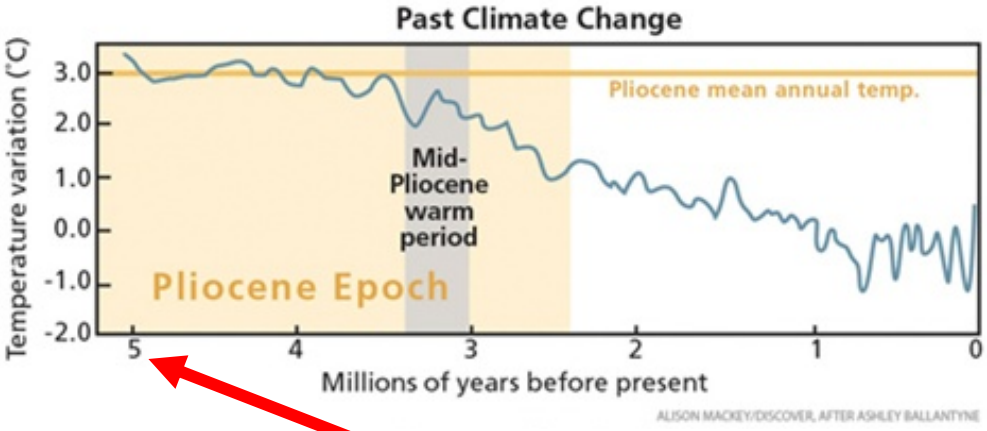
Northwest Passage
Northern Sea Route

Observed ice extent September 2002
Projected ice extent 2080 - 2100

IPCC (Intergovernmental Panel on Climate Change) 2007.


Past Climate Change
Temperature variation (°C)
3.0
2.0
1.0
0.0
-1.0
-2.0
Pliocene mean annual temp.
Mid-
Pliocene
warm
period
Pliocene Epoch
5
4
3
2
1
0
Millions of years before present
ALISON MACKEY/DISCOVER, AFTER ASHLEY BALLANTYNE


Future Climate Change
Temperature variation (°C)
3.0
2.0
1.0
0.0
-1.0
-2.0
Pre-industrial average temp.
1900
1950
2000
2050
2100
Years
ALISON MACKEY/DISCOVER, AFTER D.J. LUNT, ET AL., [PHILOSOPHICAL TRANSACTIONS A], (DOI: 10.1098/RSTA.2013.0146) 2013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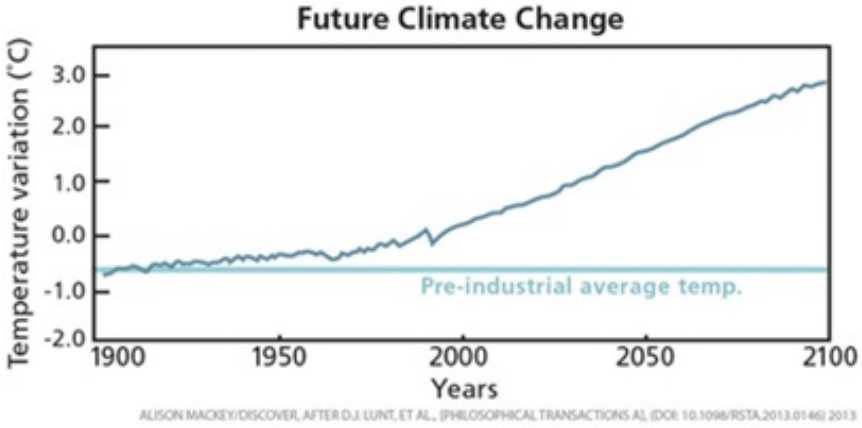
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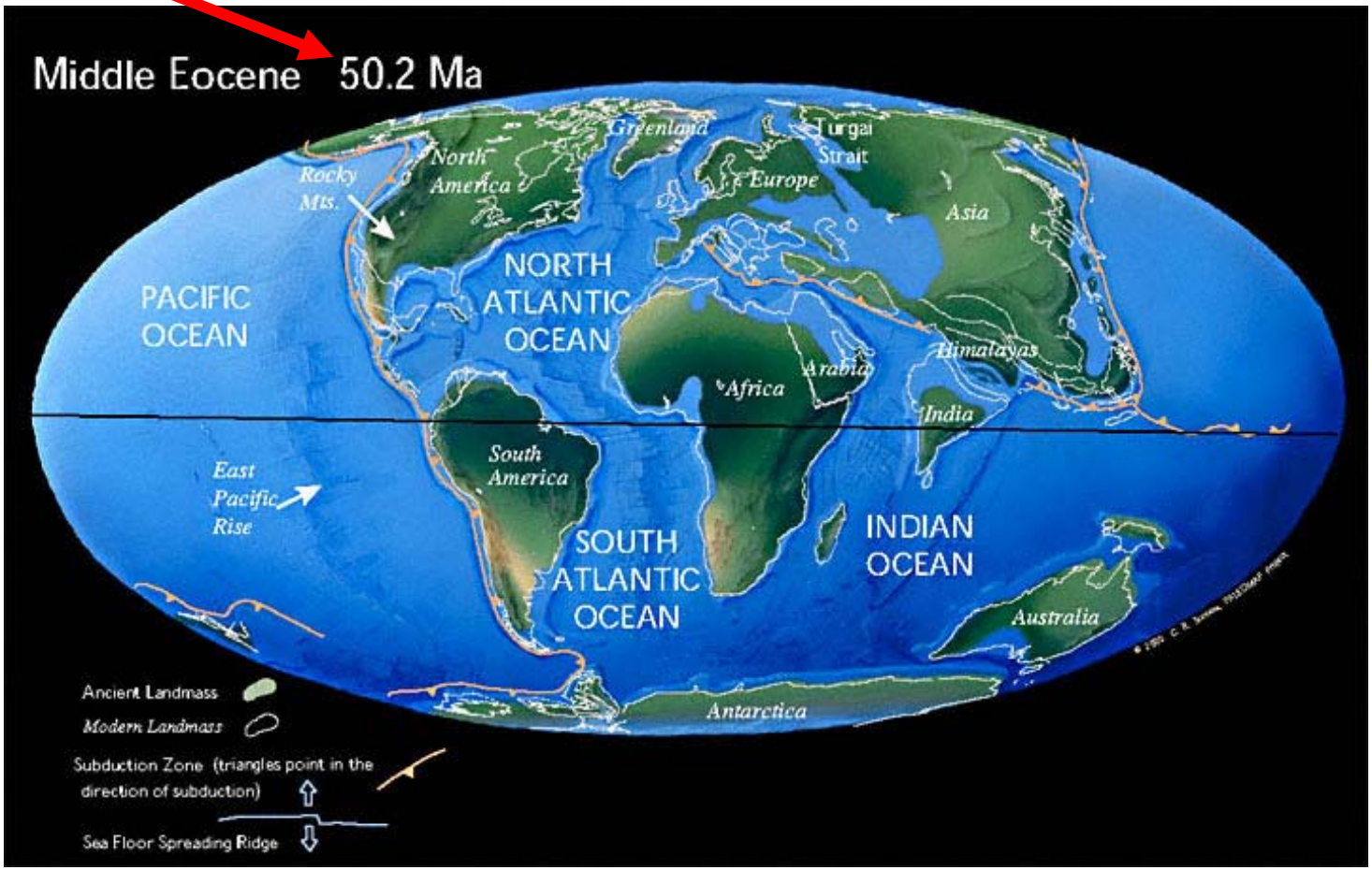
ALISON MACKEY/DISCOVER, AFTER D.J. LUNT, ET AL., [PHILOSOPHICAL TRANSACTIONS A], (DOI: 10.1098/RSTA.2013.0146) 2013


Middle Eocene 50.2 Ma
Greenland
Turgai Strait
North America
Rocky Mts.
Europe
Asia
PACIFIC OCEAN
NORTH ATLANTIC OCEAN
Himalayas
Arabia
Africa
India
South America
East Pacific Rise
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
Australia
Antarctica
Ancient Landmass
Modern Landmass
Subduction Zone (triangles point in the direction of subduction)
Sea Floor Spreading Ridge

Summary

- Science has robust filters
- Climate change is occurring
- Changes in the Arctic will have profound impacts on the rest of the globe