

Welcome to
Climate Change: Causes, Consequences, and Solutions
Osher Lifelong Learning Institute

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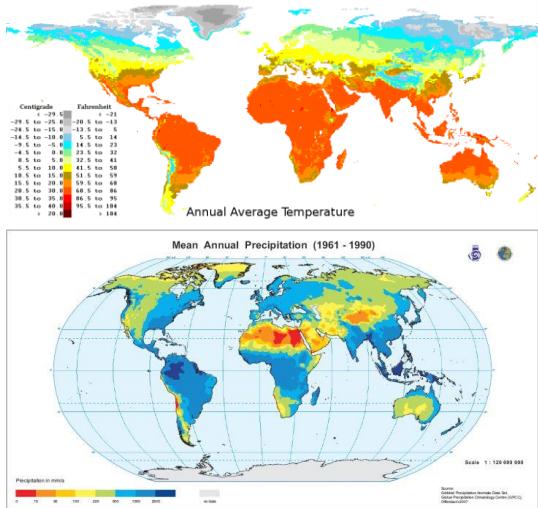
Course Goals:

1. Understand both certainties and uncertainties about climate change and its consequences,
2. Accurately evaluate cutting-edge information about the causes and consequences of climate change,
3. Understand both the prominent arguments of climate change deniers and the scientifically appropriate responses to those arguments,
4. Objectively evaluate the costs and benefits of commonly discussed technological approaches for mitigating climate change,
5. Objectively evaluate the advantages and disadvantages of proposed social and political approaches for mitigating climate change, and
6. Be able to communicate effectively about all of the above

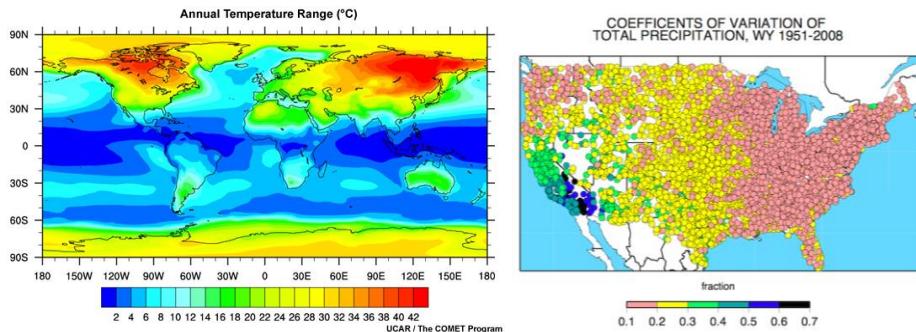
Climate Change: Past, Present, Future

What is Climate?

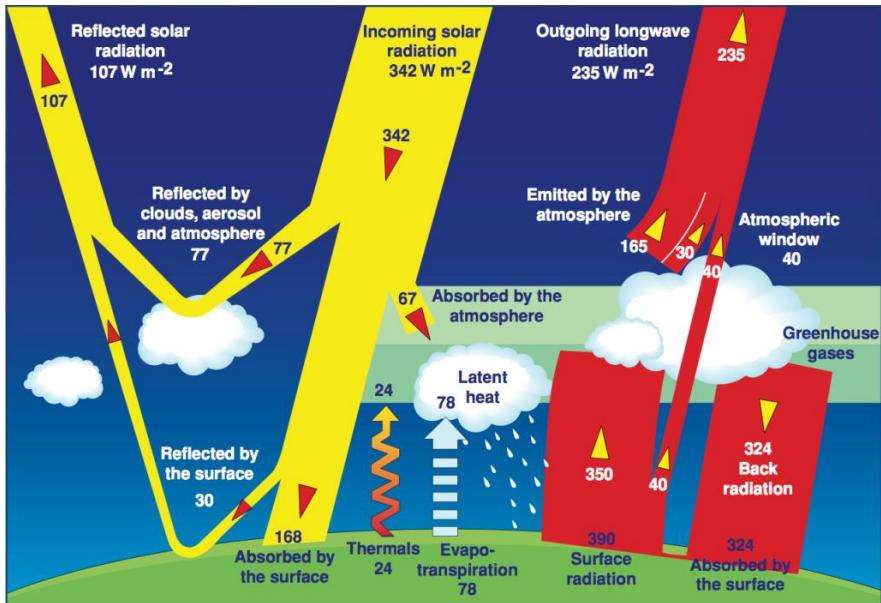
A description of the mean and variability in weather (temperature, precipitation, wind, sunlight, humidity, etc.) over a 30 year period



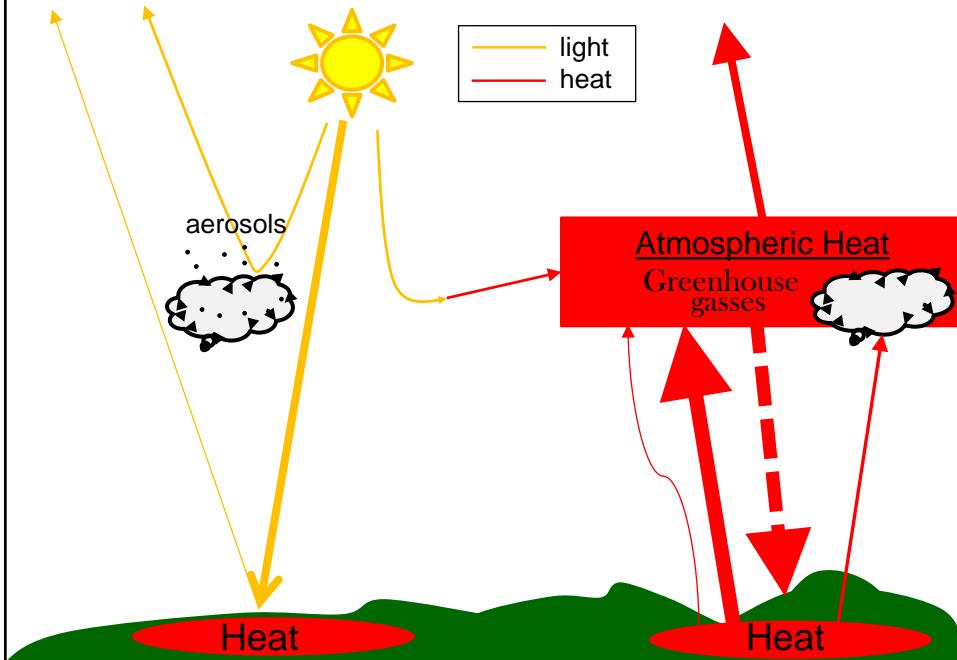
Variability in weather, within and between years, is also an important component of climate



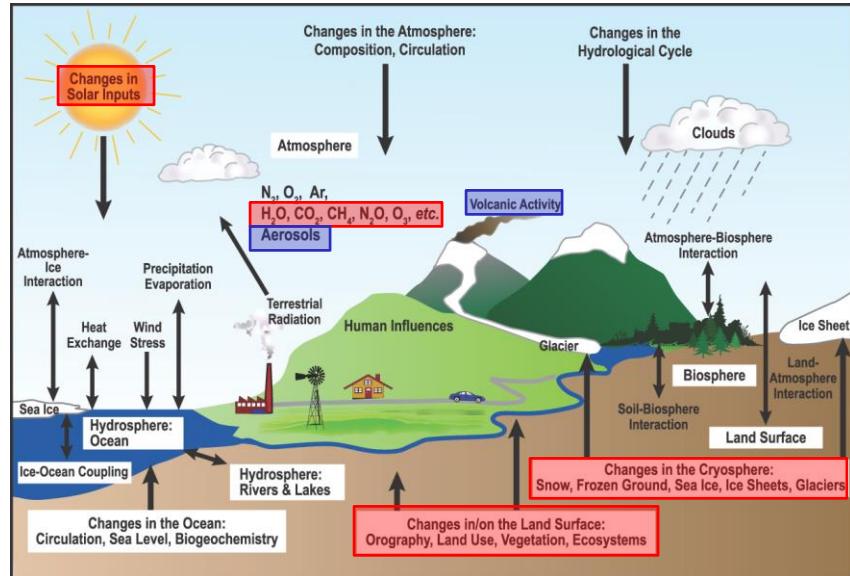
Earth's radiative balance determines global temperature



Earth's radiative balance determines global temperature

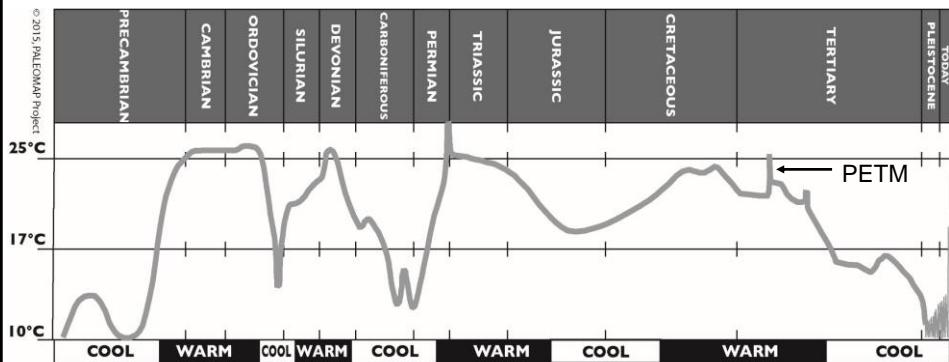


Which drivers of global climate have changed since 1900?



Earth's Climate History

For most of the past 600,000,000 years, Earth has been warmer than today

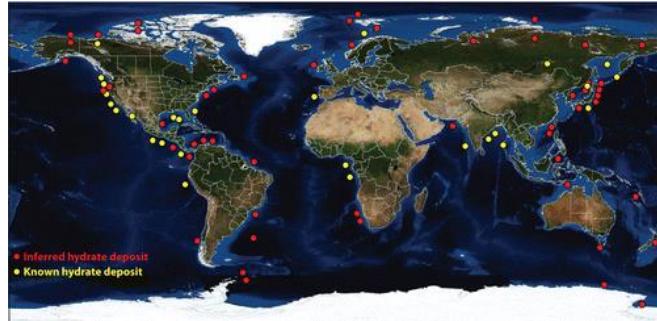


Paleocene-Eocene Thermal Maximum (PETM)

- 55,000,000 years ago
- “abrupt” global warming of 4-8 °C over 1,000-10,000 years

What caused the PETM?

- most likely, a large release of frozen methane (CH_4) from ocean deposits called clathrates (methane hydrates)

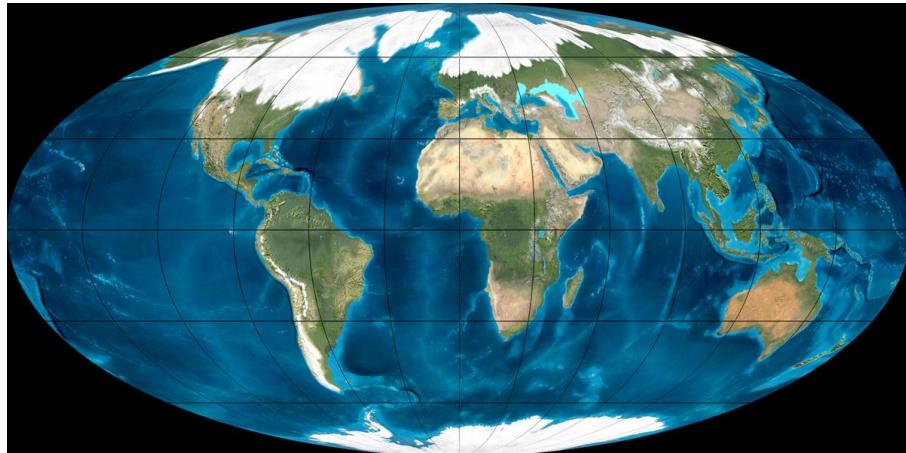


- CH_4 is a strong greenhouse gas, and was converted to CO_2

How does estimated carbon release during PETM compare to fossil fuel emissions expected during 21st century?

About the same!

During the Pleistocene (last 2 million years),
Earth has had repeated glaciations

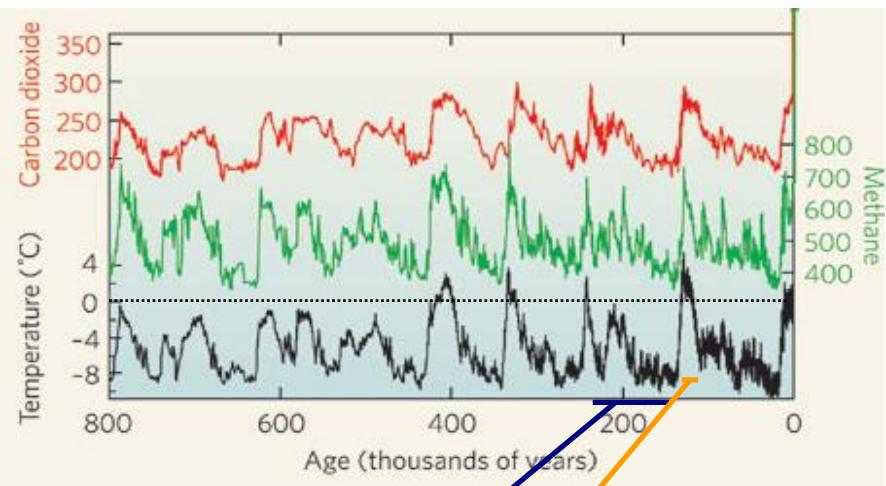


Ice cores give a very detailed record of Earth's temperature over the past 800,000 years



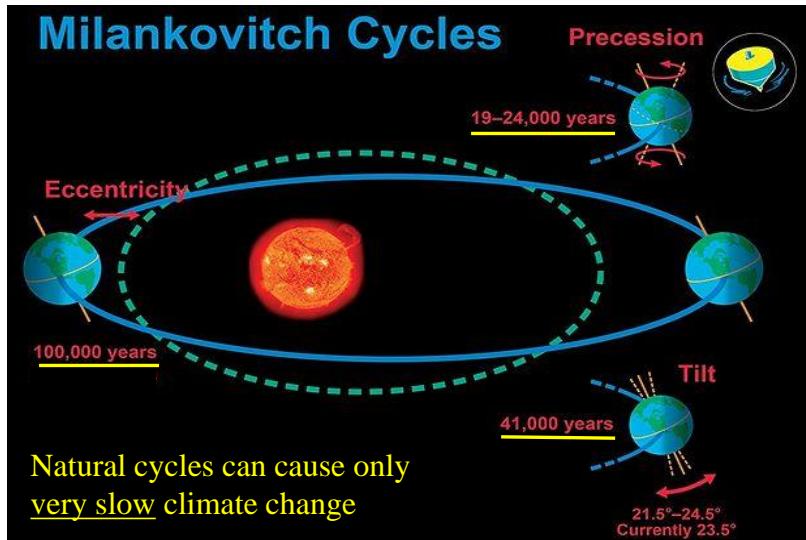
- use annual ice rings together with oxygen isotope ratios
- O^{18}/O^{16} ratio changes with temperature
- air bubbles trapped in ice reveal past CO_2 , CH_4 levels

Antarctic ice cores show repeated climate cycles over the last 800,000 years



~ 100,000 yr glacial/interglacial cycles

Pleistocene glacial cycles were caused by very gradual cycles in orbital eccentricity, axial tilt, and precession of the equinoxes



The current interglacial started about 18,000 years ago

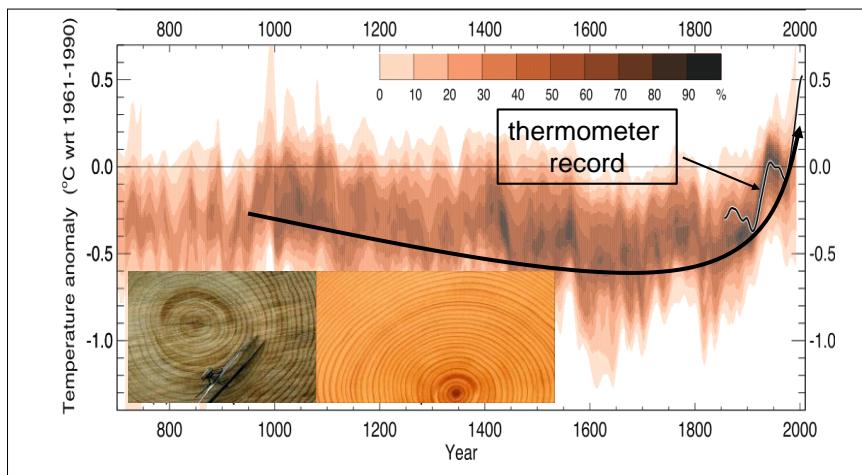


How much lower was global temperature than today?

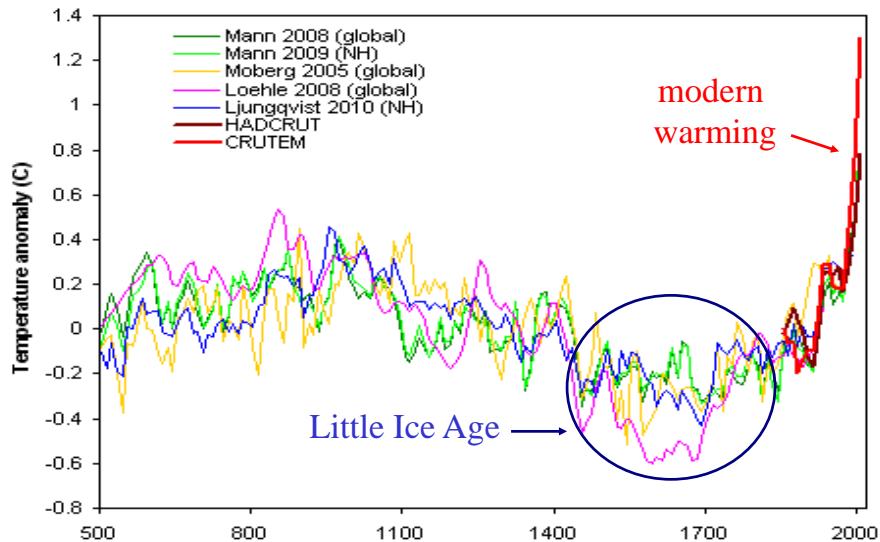
About 5° C

<https://www.youtube.com/watch?v=C3Jwnp-Z3yE>

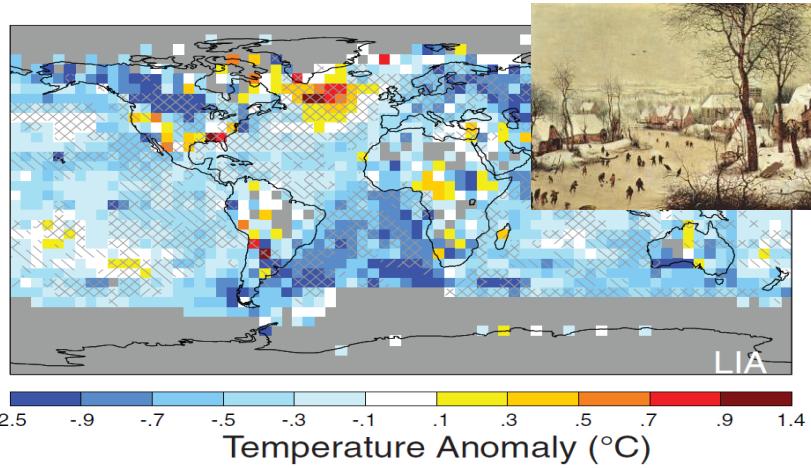
Based on tree rings over the past ~1,000 years, Northern Hemisphere temperatures show a “hockey stick” pattern



Tree ring and thermometer records indicate two anomalous periods since 500 AD



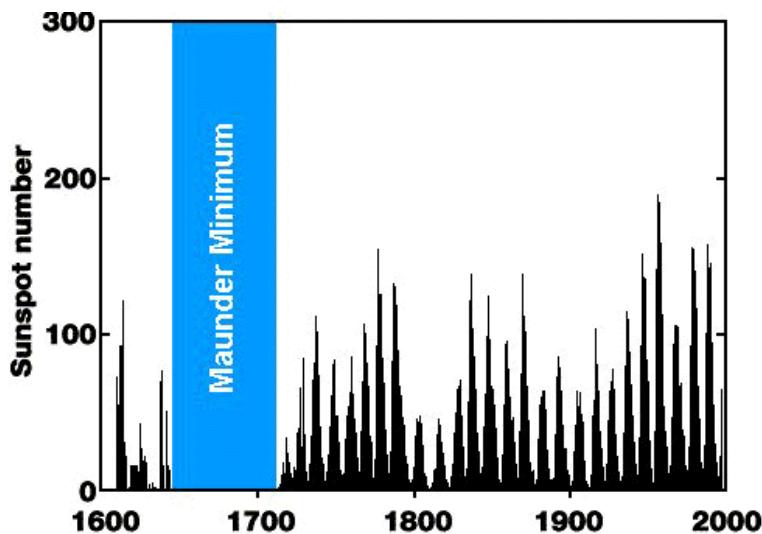
“Little Ice Age” from ~1500-1800 AD



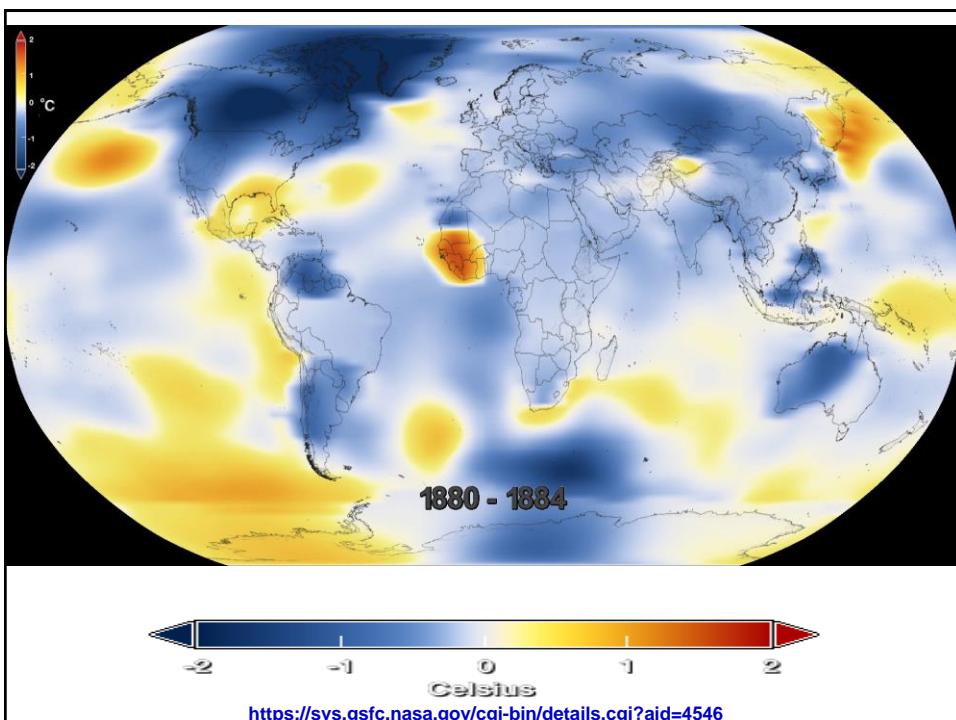
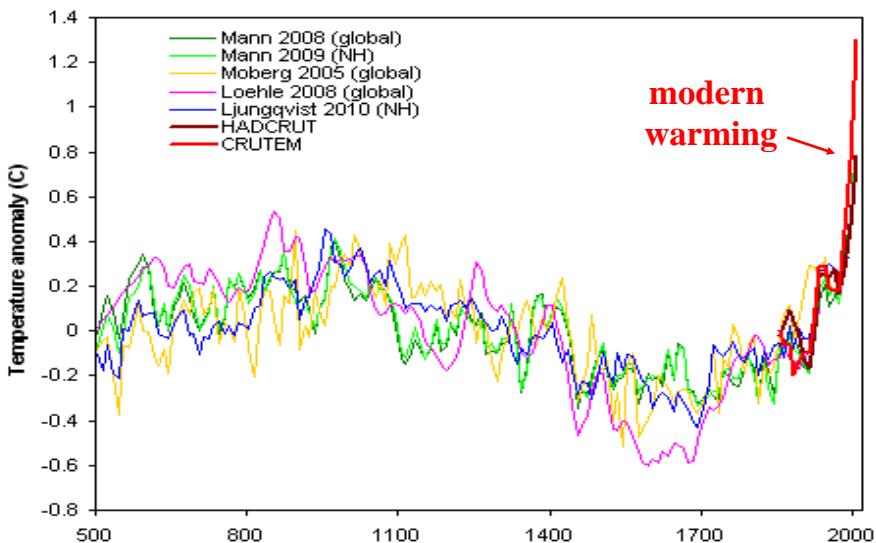
- global temperature was $\sim 1\ ^{\circ}\text{C}$ cooler than today

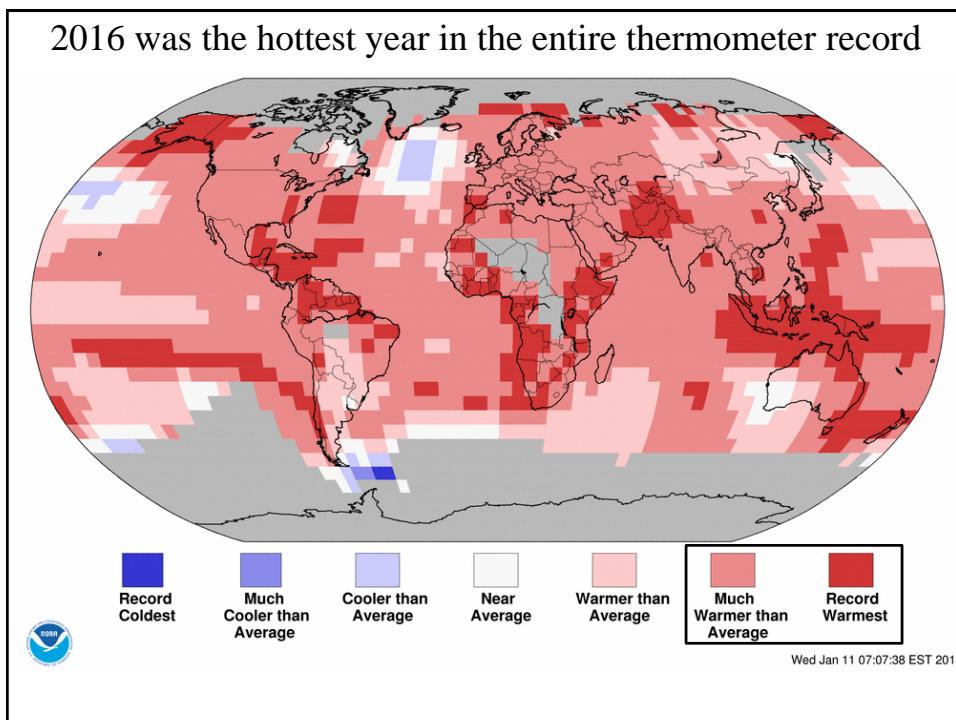
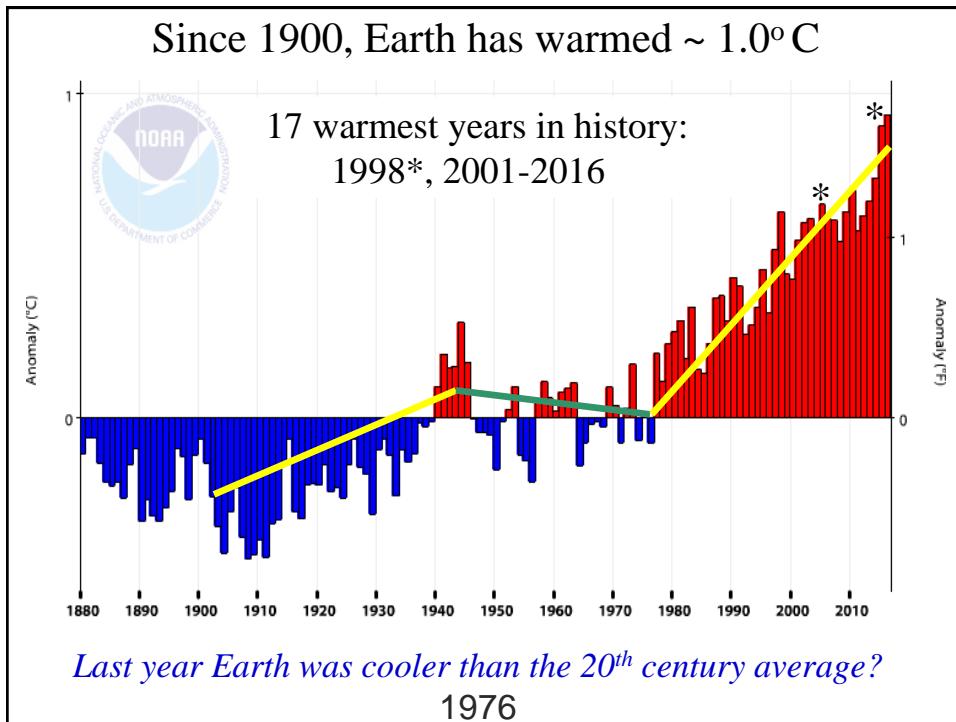
Little Ice Age was due to decreased solar activity

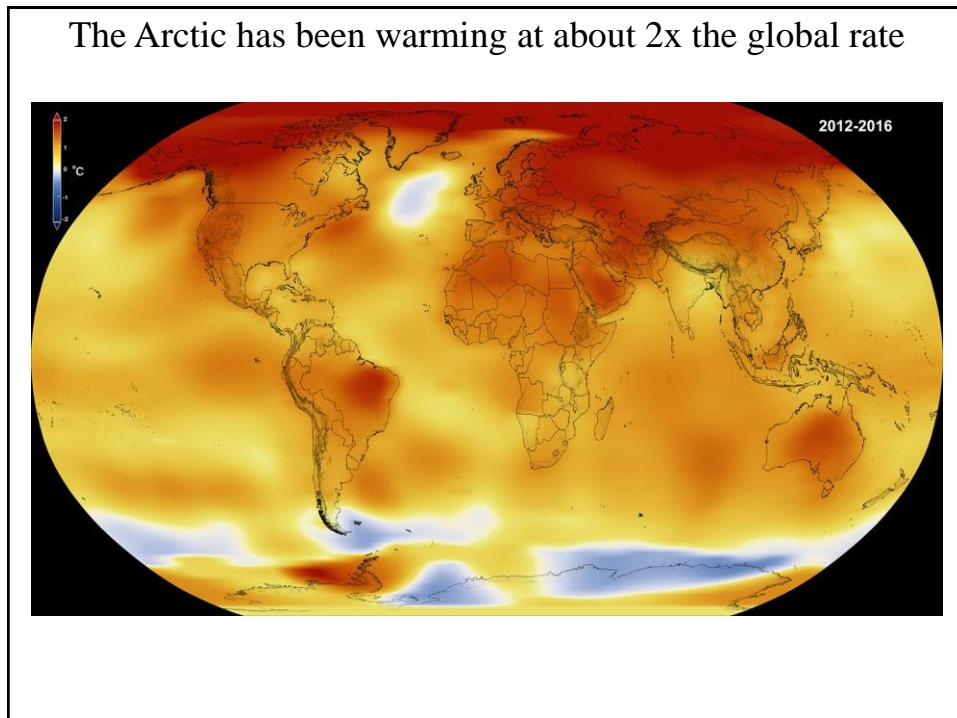
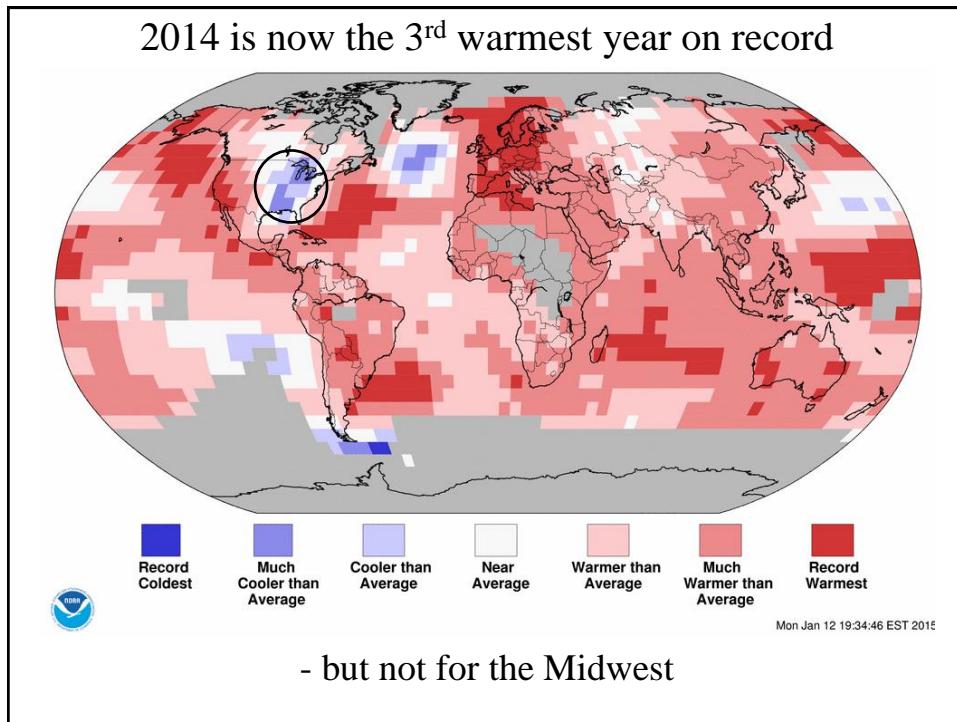
- absence of sunspots during the “Maunder Minimum”



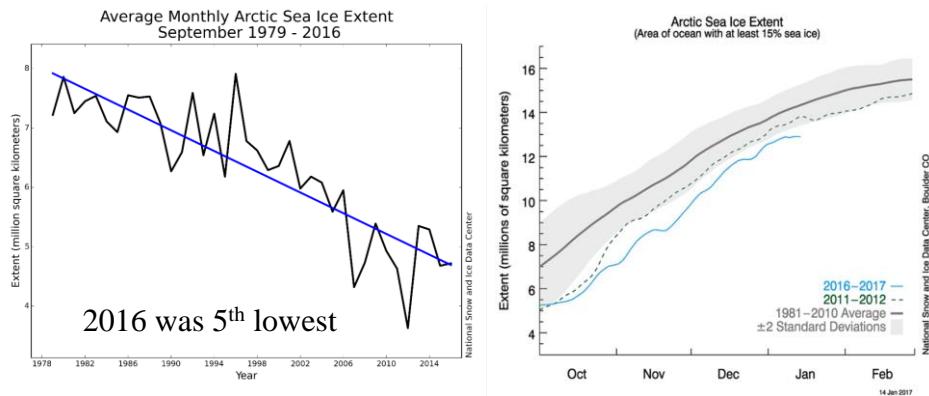
Tree ring and thermometer records indicate two anomalous periods since 500 AD





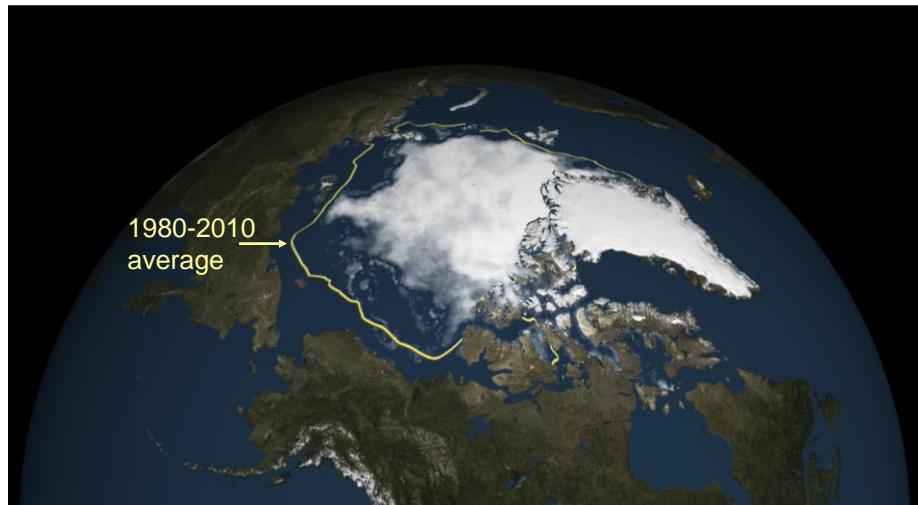


Arctic summer sea ice area has been decreasing by ~13% per decade



- however, October through December were all record lows

Loss of sea ice creates a positive climate feedback called the “albedo effect”



sea ice converts ~10% of sunlight to heat
open ocean converts ~90% of sunlight to heat

Glaciers have been retreating worldwide

e.g. Muir Glacier, Alaska

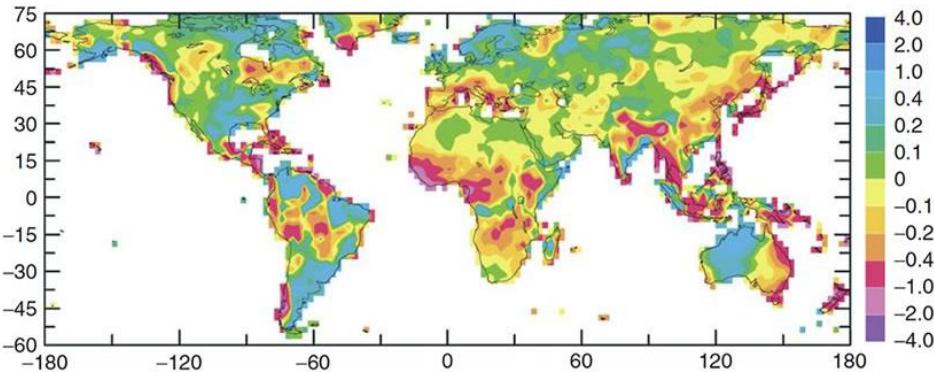


1941



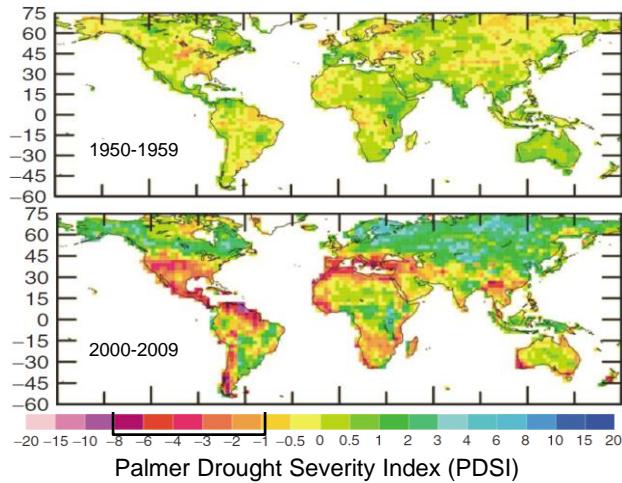
2004

Since 1950, total precipitation has increased in mid-latitudes of the Northern Hemisphere



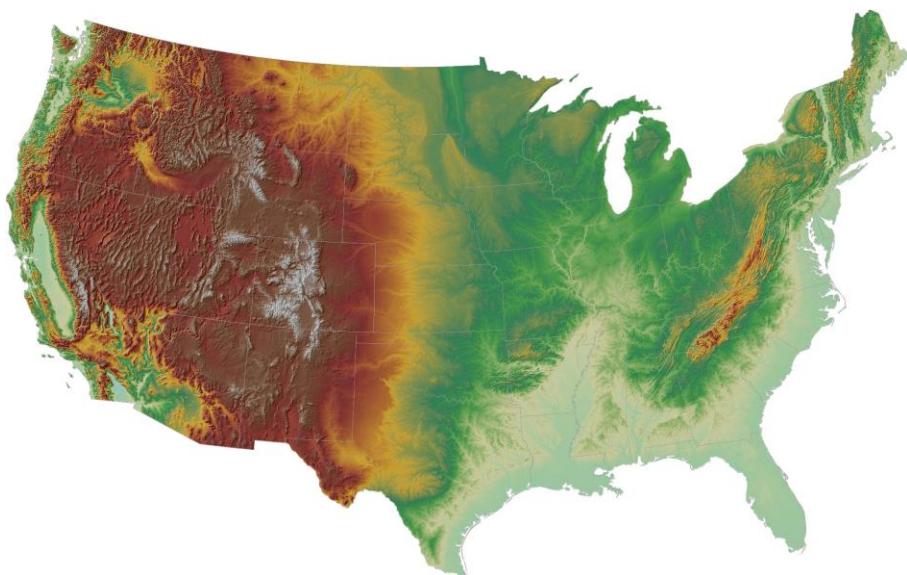
- but has decreased in tropics and sub-tropics

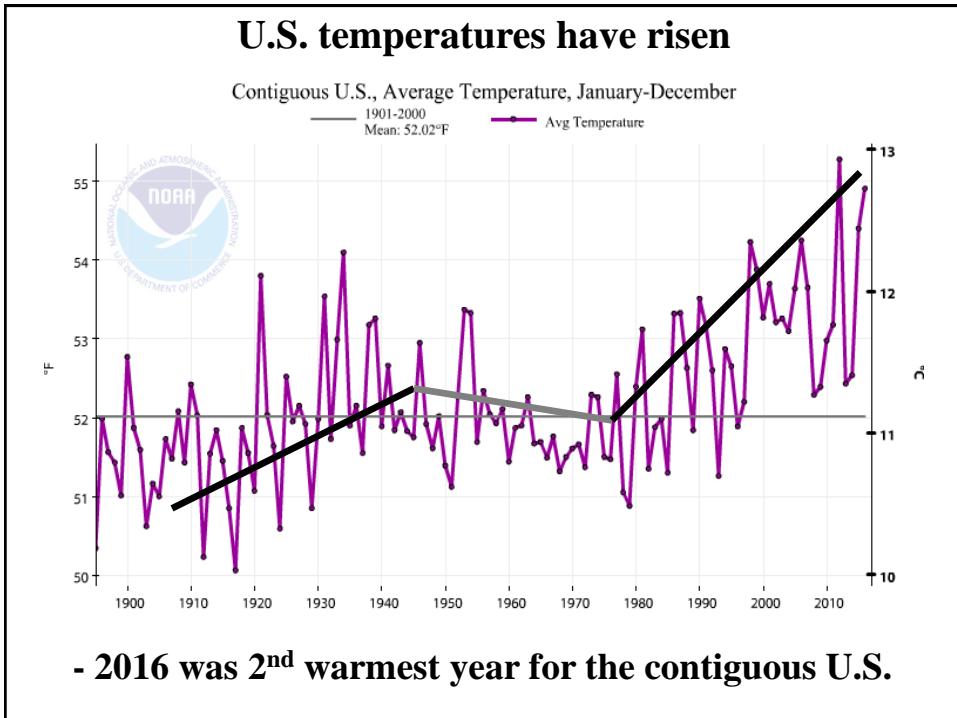
But much of the world is also experiencing more frequent and stronger droughts



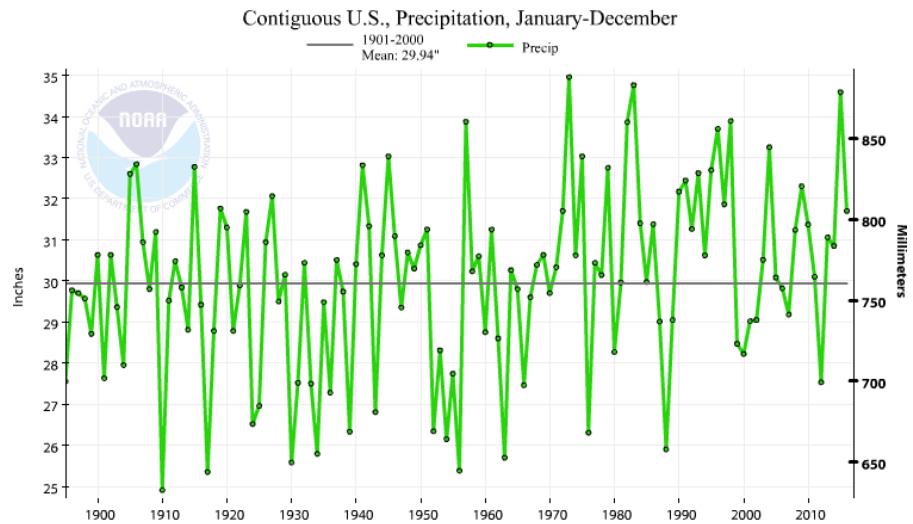
- since 1970, global land surface area in at least moderate drought increased from ~20% to ~30%

What's been happening in the U.S.?



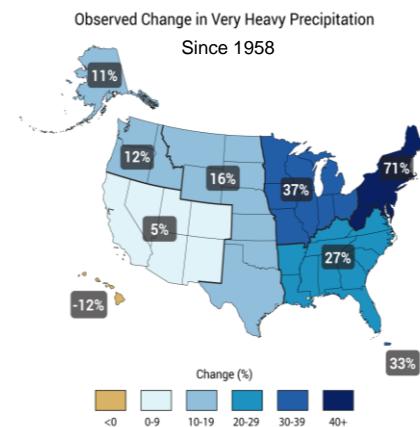


Total annual precipitation has not changed consistently



- 2016 was 23rd wettest year

But precipitation extremes have increased

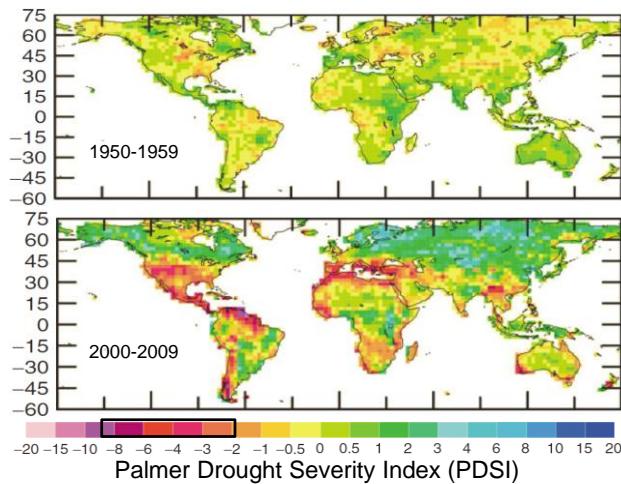


- especially in Northeast, Midwest

As a result, many areas have had extensive flooding



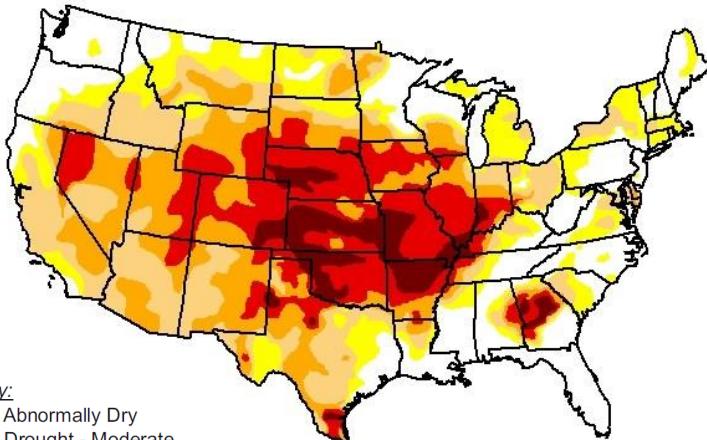
But much of the world is also experiencing more frequent and stronger droughts



- since 1970, global land surface area in at least moderate drought increased from ~20% to ~30%

Since 2011, much of the U.S. has been in major drought

August 2012

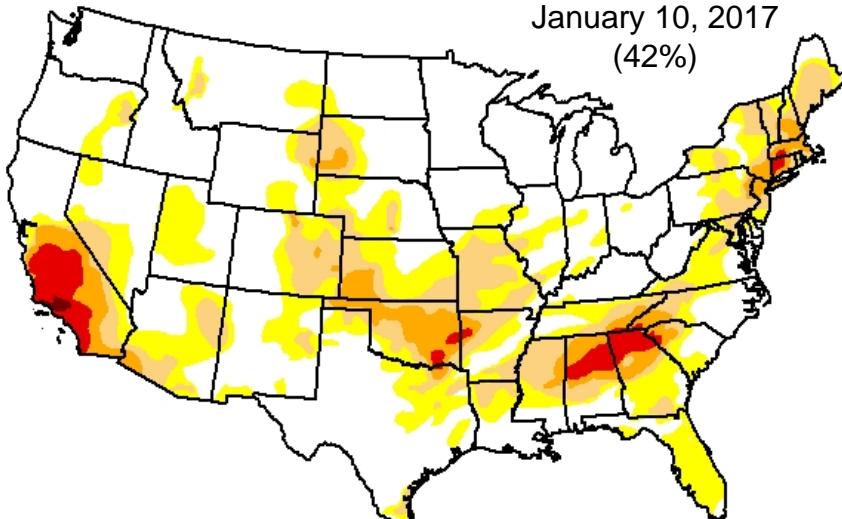


Intensity:

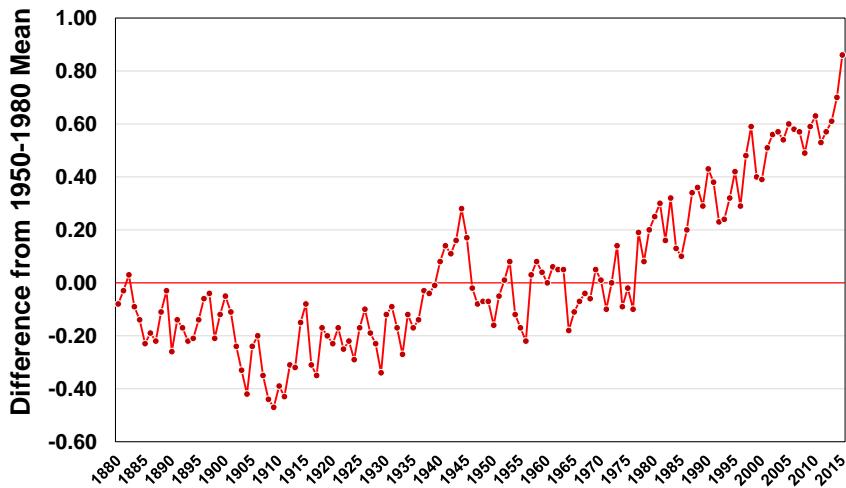
- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Recent rains have eased the drought somewhat

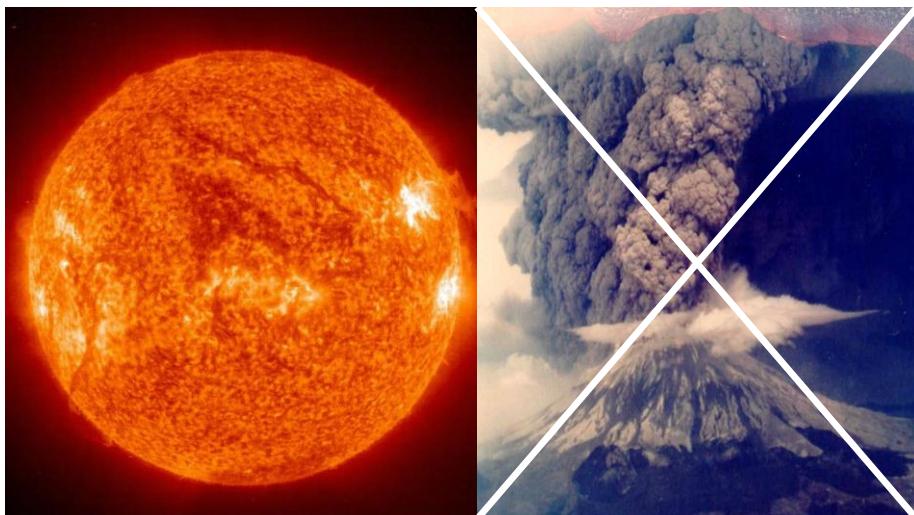
January 10, 2017
(42%)



Attribution: determining the cause(s) of climate change

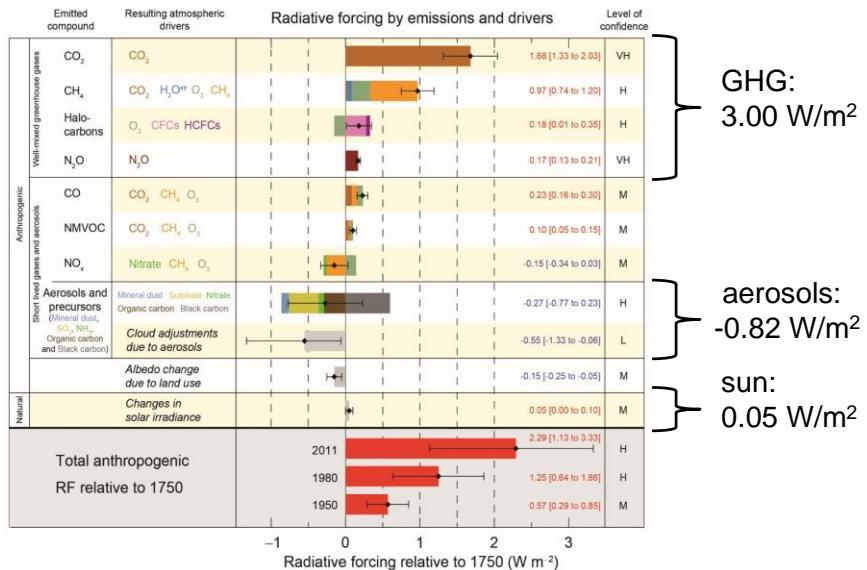


Can climate change be due to “natural variation”?

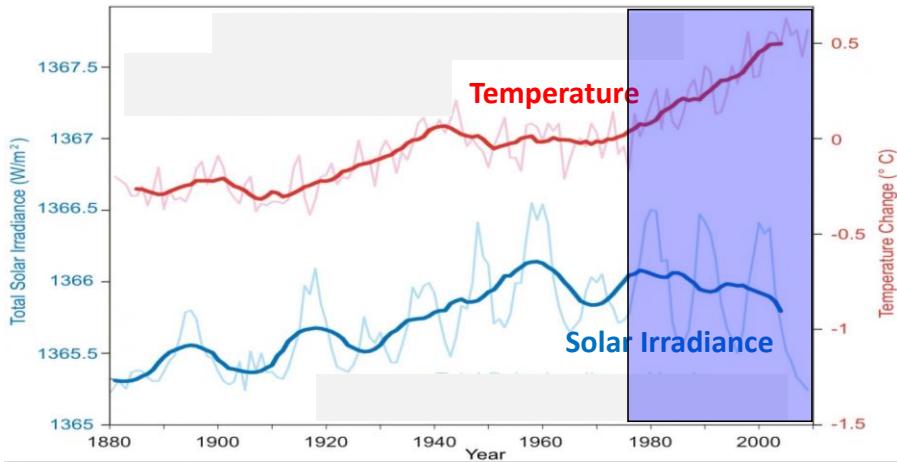


Have we been getting more energy from the sun?

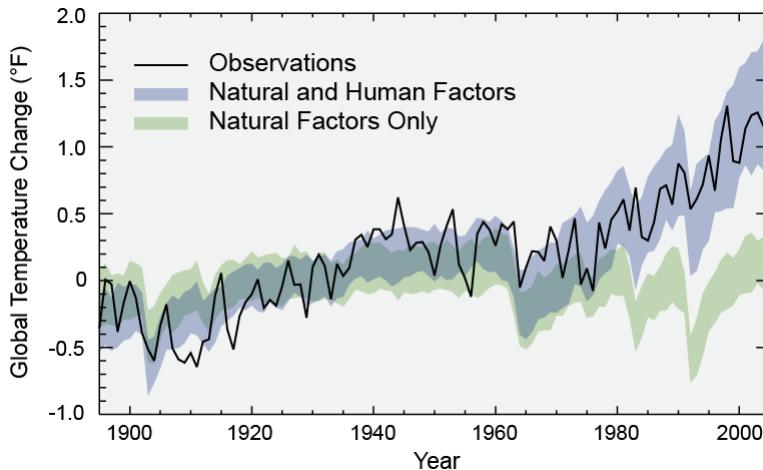
Since 1750, human activities have added much more heat to Earth's climate than have natural factors



Since 1975, while Earth has been warming fastest, solar irradiance has been decreasing



Models must include anthropogenic factors to accurately predict warming since 1900

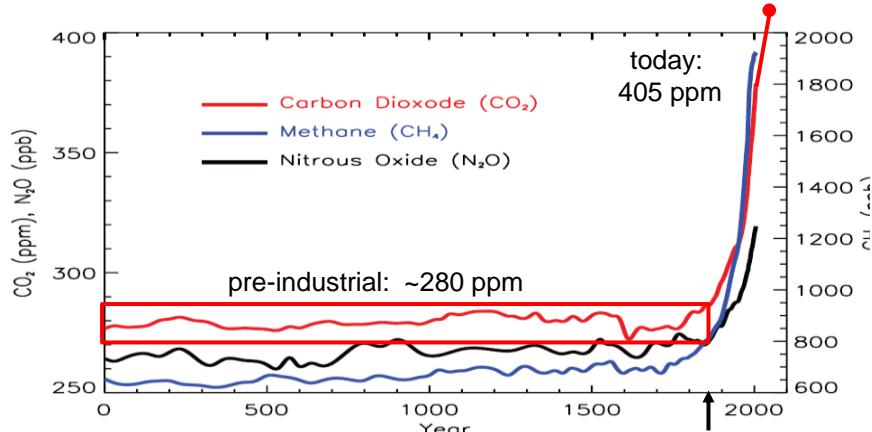


In two major ways, current warming is very different than any warming in at least the last 800,000 years

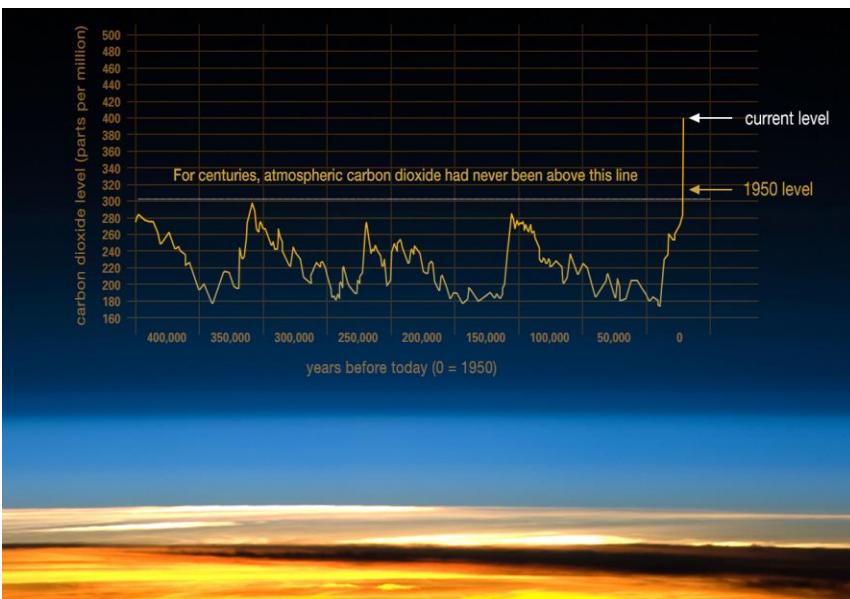
1. It's at least 10 times faster
2. It's happening while solar input is decreasing

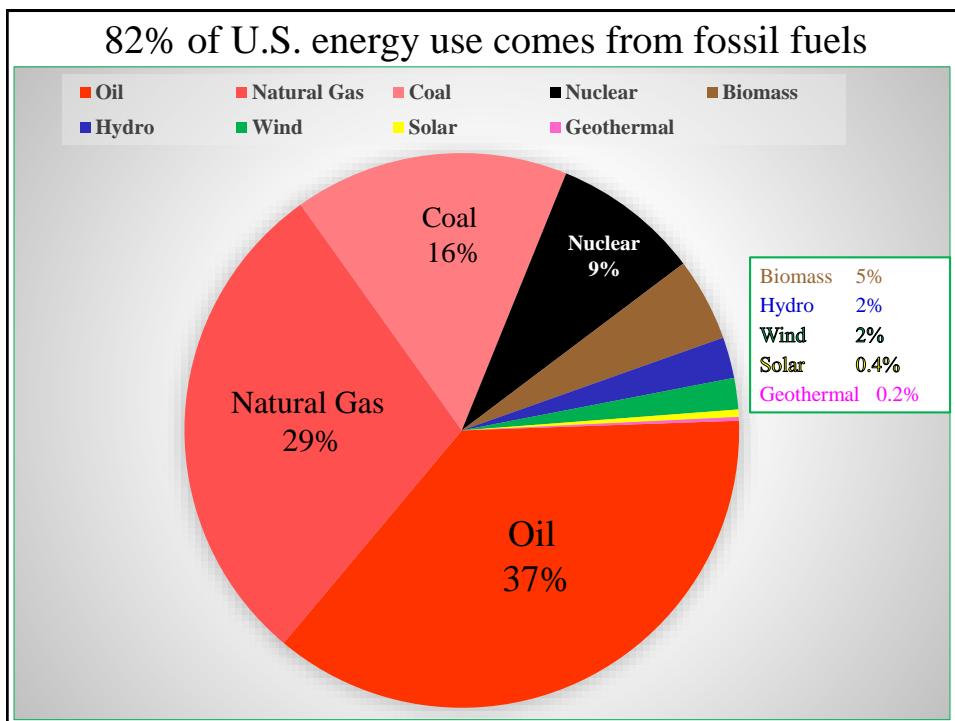
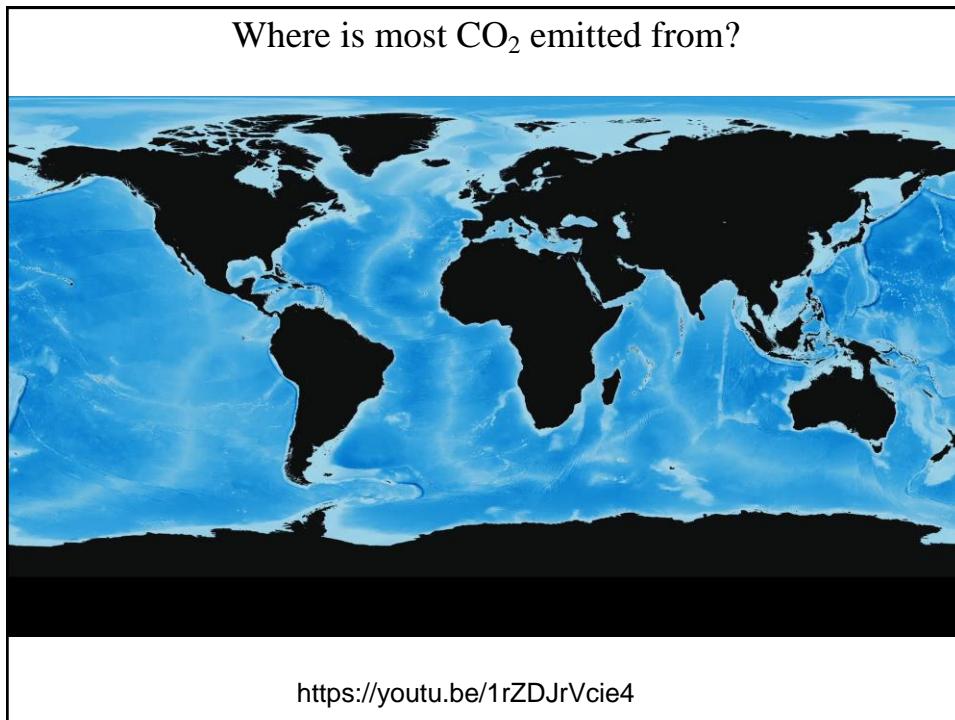
Both of these facts indicate that climate is now changing for a different reason than in the past.

Our climate is changing today because human activities (especially fossil fuel burning) have caused atmospheric greenhouse gasses to increase dramatically



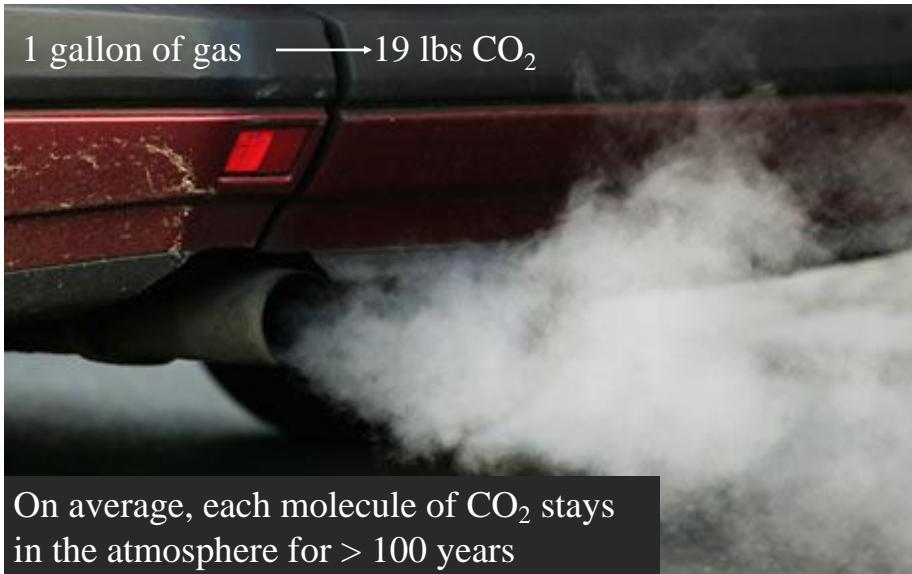
CO_2 levels are higher than anytime in at least 800,000 years





Average US citizen generates 17 tons of CO₂ per year

1 gallon of gas → 19 lbs CO₂



On average, each molecule of CO₂ stays
in the atmosphere for > 100 years

Best estimate: $\geq 95\%$ of current warming is
due to human activities

Greenhouse gas emissions



Deforestation

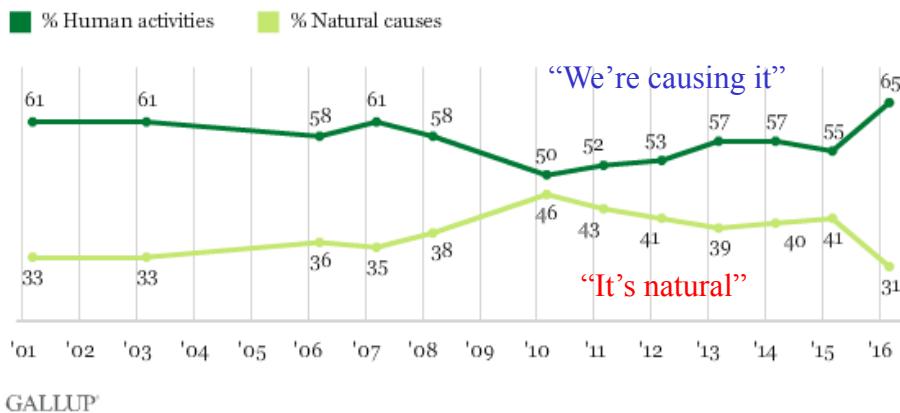


How does our awareness of climate science compare to other countries?

2008 Gallup Poll question:
“Do you think rising temperatures are a result of human activities?”

Japan	91%
Argentina	82%
Ghana	51%
United States	49%
Saudi Arabia	39%

Awareness of human causation has increased recently



Awareness has increased recently for all political affiliations

	<u>2015</u>	<u>→ 2016</u>	<u>Change</u>
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Increased temperatures due to human activities?

Democrats	74%	85%	+11%
Independents	56	68	+12
Republicans	34	38	+4

Worried a great deal/fair amount about global warming?

Democrats	78	84	+6
Independents	55	64	+9
Republicans	31	40	+9

Is there any debate among scientists about whether humans are the primary cause of global warming?

What percent of climate scientists do you think agree that humans are the primary cause of global warming?

- A. Less than 30%
- B. 30-50%
- C. 50-70%
- D. 70-90%
- E. Over 90%

How many scientific societies officially recognize that humans are/aren't the primary cause of global warming?

"Most of the global warming in recent decades can be attributed to human activities."

Scientific organizations endorsing this statement:

United States:

National Academy of Sciences
American Medical Association
American Association for the Advancement of Science
American Meteorological Society
American Institute of Biological Sciences
American Chemical Society
American Geophysical Union
American Institute of Physics

Geological Society of America
American Academy of Paediatrics
American College of Preventive Medicine
American Public Health Association
National Oceanic and Atmospheric Administration
National Aeronautics and Space Administration
Environmental Protection Agency
National Center for Atmospheric Research
University Corporation for Atmospheric Research
Ecological Society of America
American Society of Agronomy
American Society of Plant Biologists
Association of Ecosystem Research Centers
Botanical Society of America
Crop Science Society of America
Natural Science Collections Alliance

American Statistical Association
Organization of Biological Field Stations
American Physical Society
Society for Industrial and Applied Mathematics
Society of Systematic Biologists
Soil Science Society of America
Federation of American Scientists
National Research Council
National Association of Geoscience Teachers
American Quaternary Association
American Association of Wildlife Veterinarians
American Society for Microbiology
Society of American Foresters
American Astronomical Society

Europe:

European Academy of Sciences and Arts
European Science Foundation
European Geosciences Union
European Physical Society
European Federation of Geologists
Royal Society of the United Kingdom
Academie des Sciences (France)
Deutsche Akademie der Naturforscher (Germany)
Accademia dei Lincei (Italy)
Royal Irish Academy
Royal Swedish Academy of Sciences
Royal Academy of Belgium for Sciences and the Arts
Royal Meteorological Society
Norwegian Academy of Sciences and Letters
United Kingdom Institute of Biology

Other countries (≥ 100):

Chinese Academy of Sciences
Science Council of Japan
Russian Academy of Sciences
Indian National Science Academy
Australian Academy of Sciences
Nigerian Academy of Sciences
Ghana Academy of Arts and Sciences
African Academy of Sciences
Africa Centre for Climate and Earth Systems Science
National Academy of Exact, Physical and Natural Sciences,
Argentina
Polish Academy of Sciences
Academia Brasiliera de Ciencias (Brazil)
Royal Society of Canada
Indonesian Academy of Sciences

Scientific organizations holding a dissenting opinion:

2007:

American Association of Petroleum Geologists

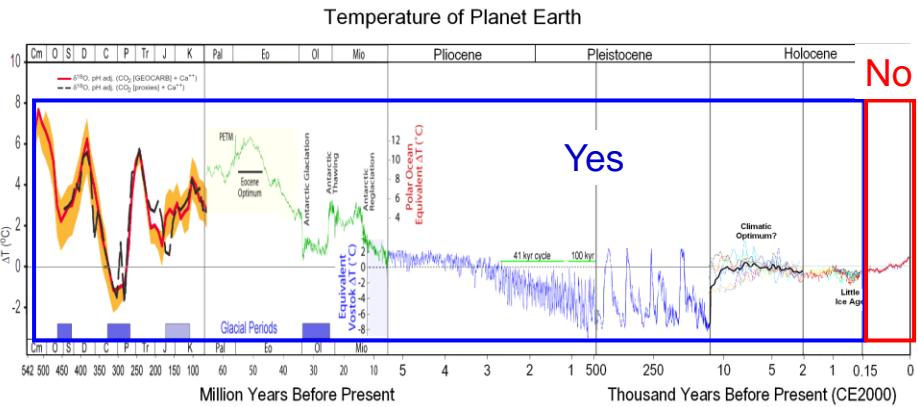
Since 2008:

None

In fact, **97.5%** of climate scientists (the experts) agree

- but fewer than 10% of Americans know this

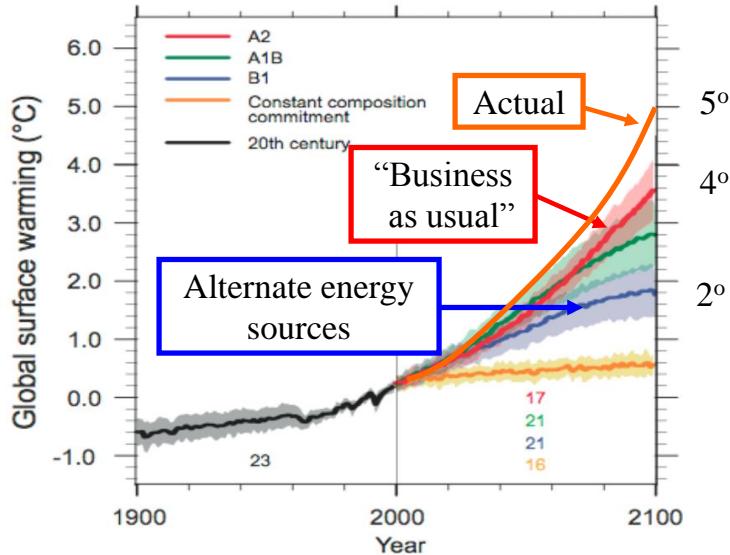
Is climate change due to “natural variation”?



What will the future be like?

**It depends
on our
choices**

Depending on choices we make, Earth is likely to warm by at least 2-5 °C by 2100

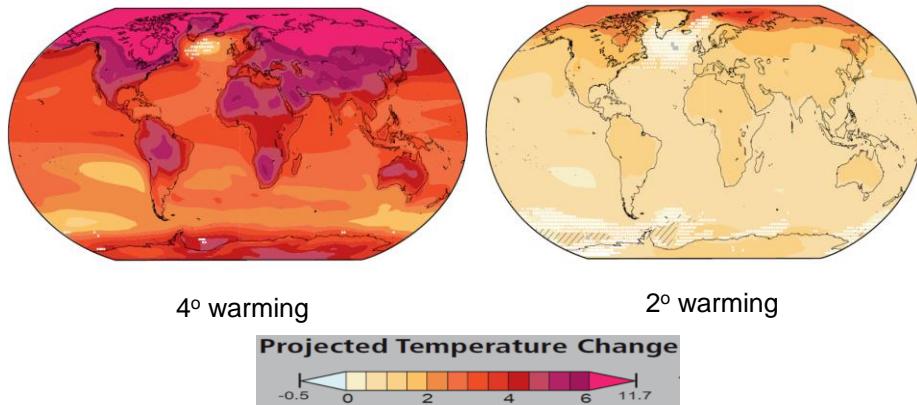


Will a 4-5° temperature rise matter?

When Earth was 5° cooler:

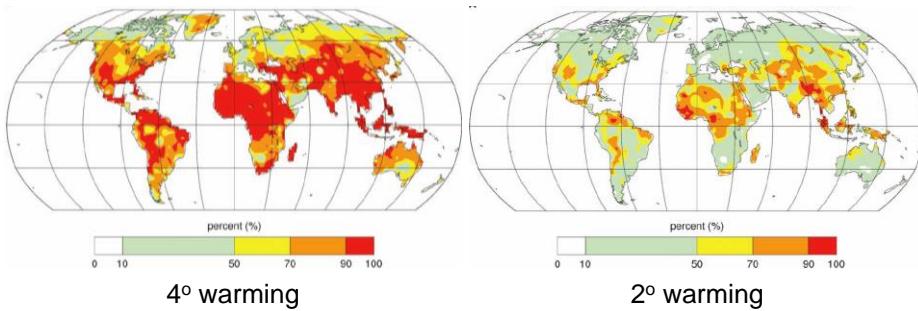


Arctic is likely to warm at about twice the global rate



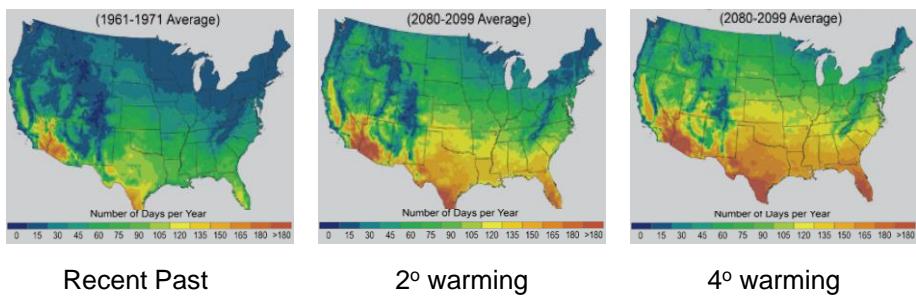
- site of strongest positive albedo feedback

In the future, most summers are likely to be hotter than any experienced thus far



- but not nearly as many with 2° warming

The number of days $> 90^{\circ}$ F will increase

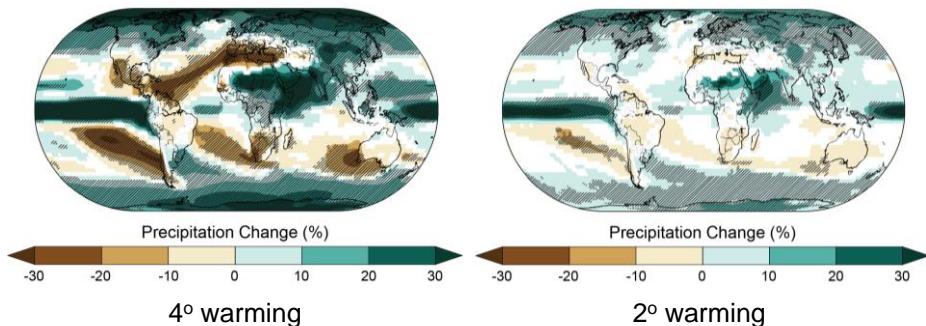


Michigan:

~35 more days per year with 2 °C warming

~75 more days per year with 4 °C warming

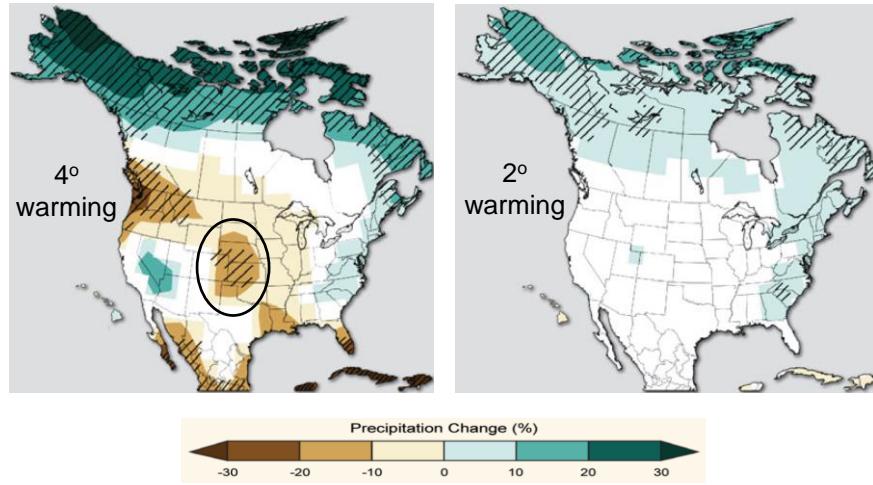
Precipitation changes also depend on future warming



Increased precipitation at high latitudes

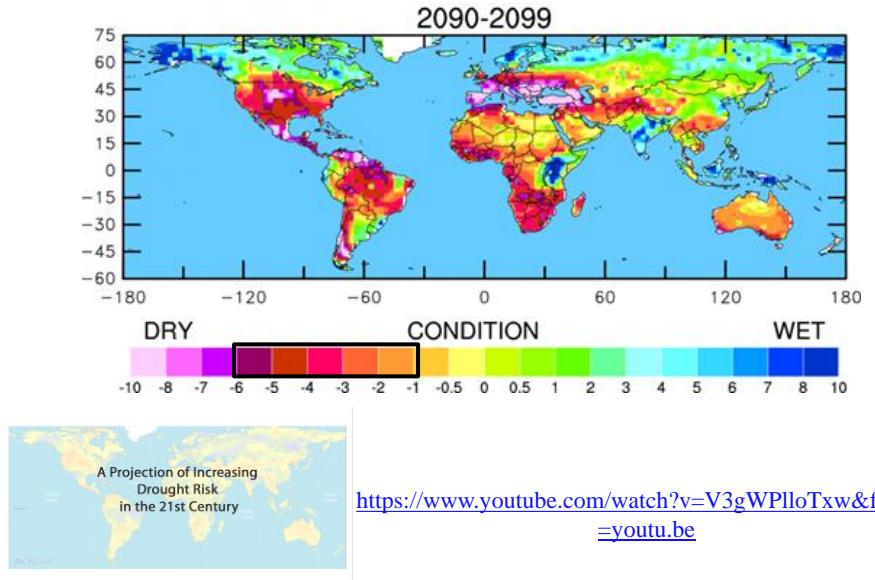
Stable or decreased precipitation in much of tropics and subtropics

With 4° warming, the U.S. breadbasket will dry out



- drying would be much less with 2° warming

With 4° warming, much of the world will experience much more frequent and stronger droughts



The cryosphere will continue to melt

- with 4° warming, arctic summer sea ice predicted to disappear by ~2070

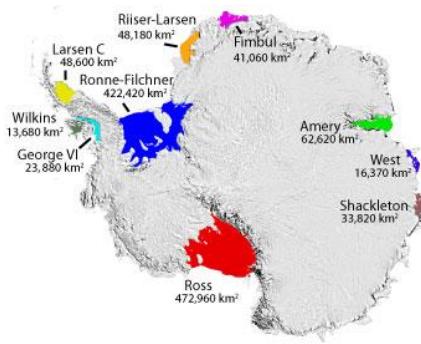
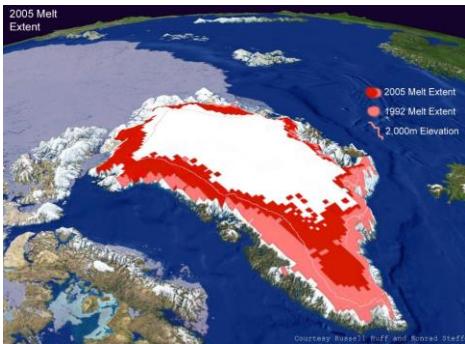


Many glaciers are likely to disappear entirely by 2100



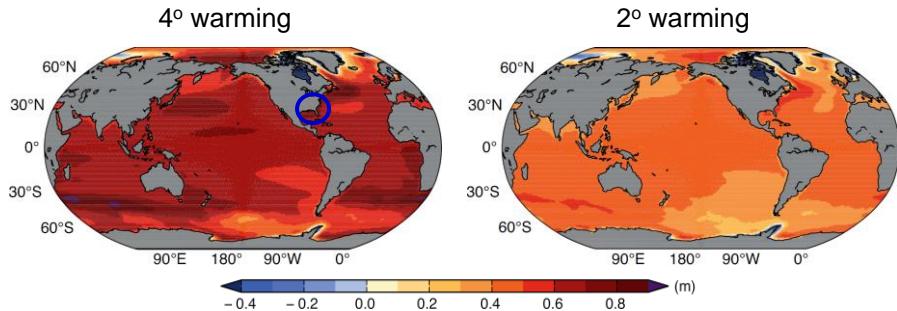
- 750,000,000 people in China and India rely on glaciers and seasonal snowpacks for their water supply

Both of the planet's ice sheets will continue to melt



- full melting of Greenland ice sheet → 7 m sea level rise
- full melting of Antarctic ice sheet → 57 m sea level rise

Sea level rise would be ~ 0.4 meters less with 2° warming than with 4° warming



Much of U.S. would be affected by 1 meter rise



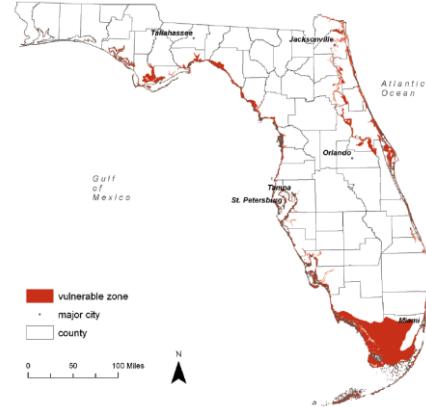
Much of Florida would also be under water



So would much of the east coast



Limiting warming to 2° would save Florida about \$345 billion per year by 2100



- and would save 1.1 million tourism jobs

And would substantially reduce the frequency of 100-yr storm surge events in New York City



4° warming: every 3 years

2° warming : every 30 years