The State of the Climate

David Herring
NOAA Climate Program Office
David.Herring@noaa.gov

September 26, 2013

Overview

1. NOAA’s roles in climate science and services

1. Drivers of climate change in Earth’s history

1. Natural climate variability

2. Extreme weather & climate events

3. The state of the climate today

NOAA is mandated by Congress to deliver climate services to society

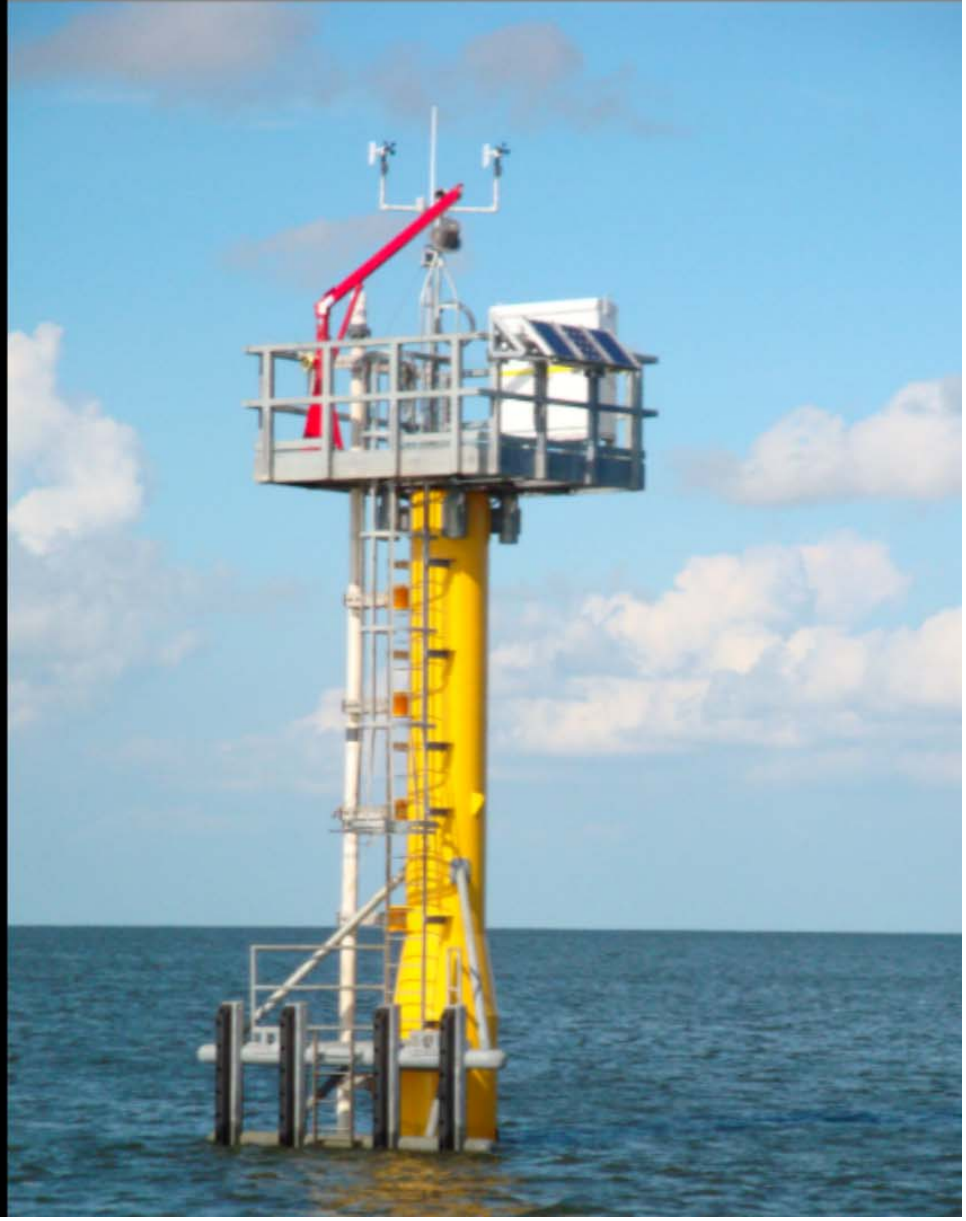
- National Weather Service Organic Act of 1890
- Marine Mammal Protection Act of 1972
- National Marine Sanctuaries Act of 1972
- Coastal Zone Management Act of 1972
- Endangered Species Act of 1973
- Magnuson-Stevens Fishery Conservation & Management Act of 1976 (Amended 1996)
- National Climate Program Act of 1978
- Global Change Research Act of 1990
- Hydrographic Services Improvement Act of 1998
- Coral Reef Conservation Act of 2000
- National Integrated Drought Information Services Act of 2006
- America Competes Act of 2007

Consistent, repeated, long-term observations of weather are the foundation of climate science.

We collect climate data from observing stations across our country and around the world

A network of automated stations collect precise climate data on land

…and in the ocean



Instruments on buoys gather data from the depths of the ocean and at its surface

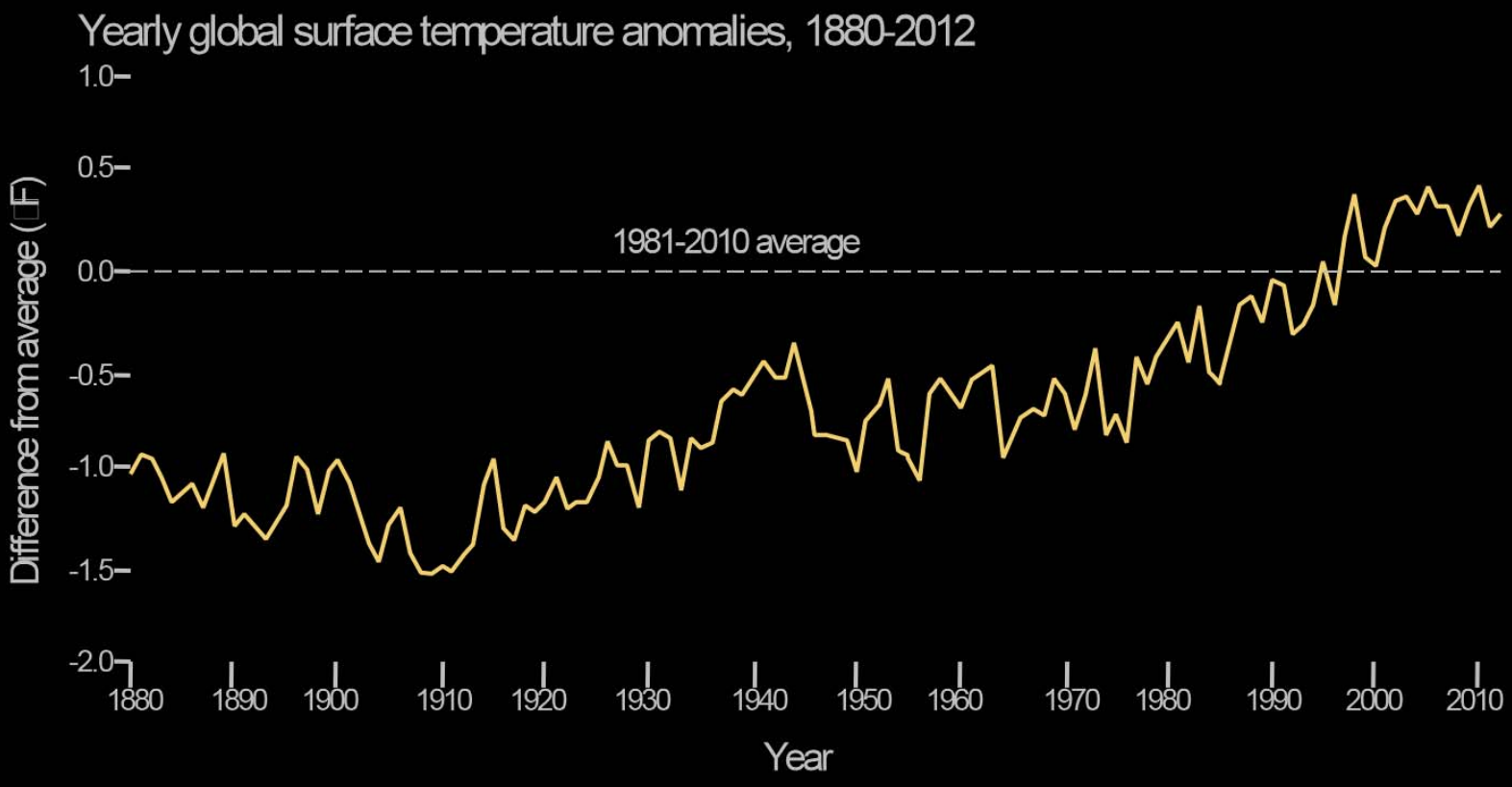
Human efforts facilitate and complement automated data collection

Balloons and rockets carry data-gathering instruments into the upper atmosphere

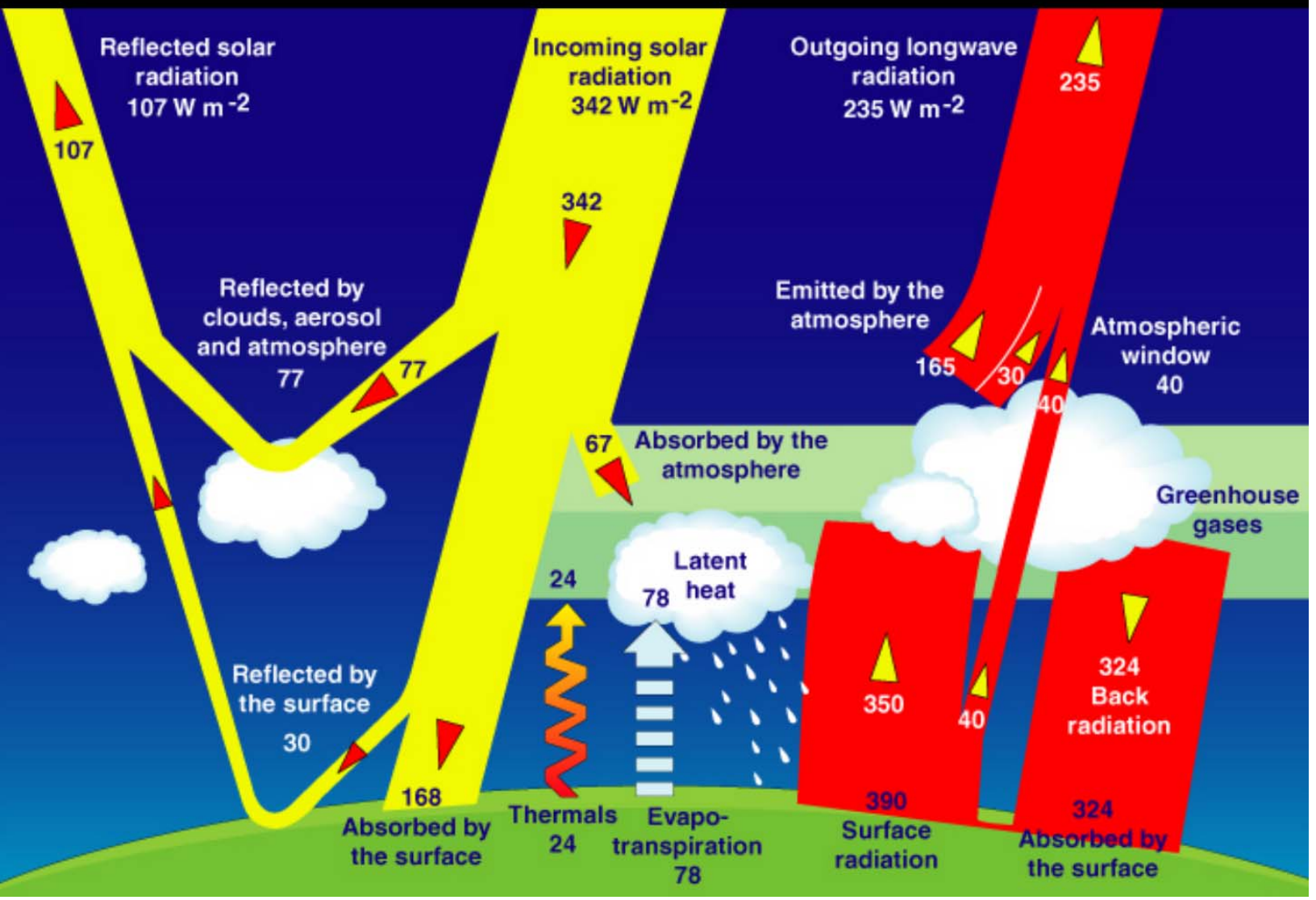
Instruments on satellites monitor weather, climate & environmental conditions on Earth

From the bottom of the ocean to the top of the atmosphere, we monitor Earth's climate system

Globally averaged annual temperature has risen by 1.3 °F since 1880



Factors influencing Earth's energy budget & temperature



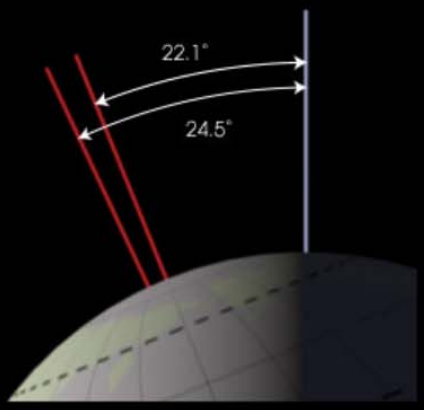
Earth's orbital mechanics: 'Milankovitch Cycles'

Eccentricity

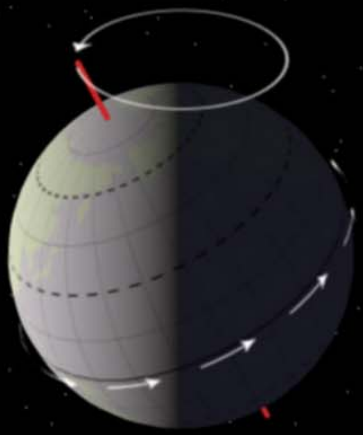
eccentricity = 0

eccentricity = .5

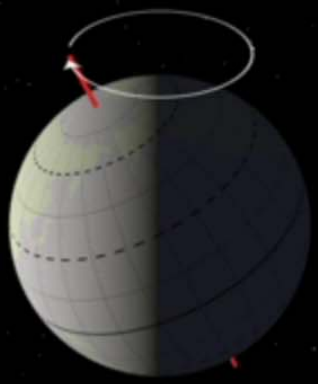
Axis Tilt (Obliquity)

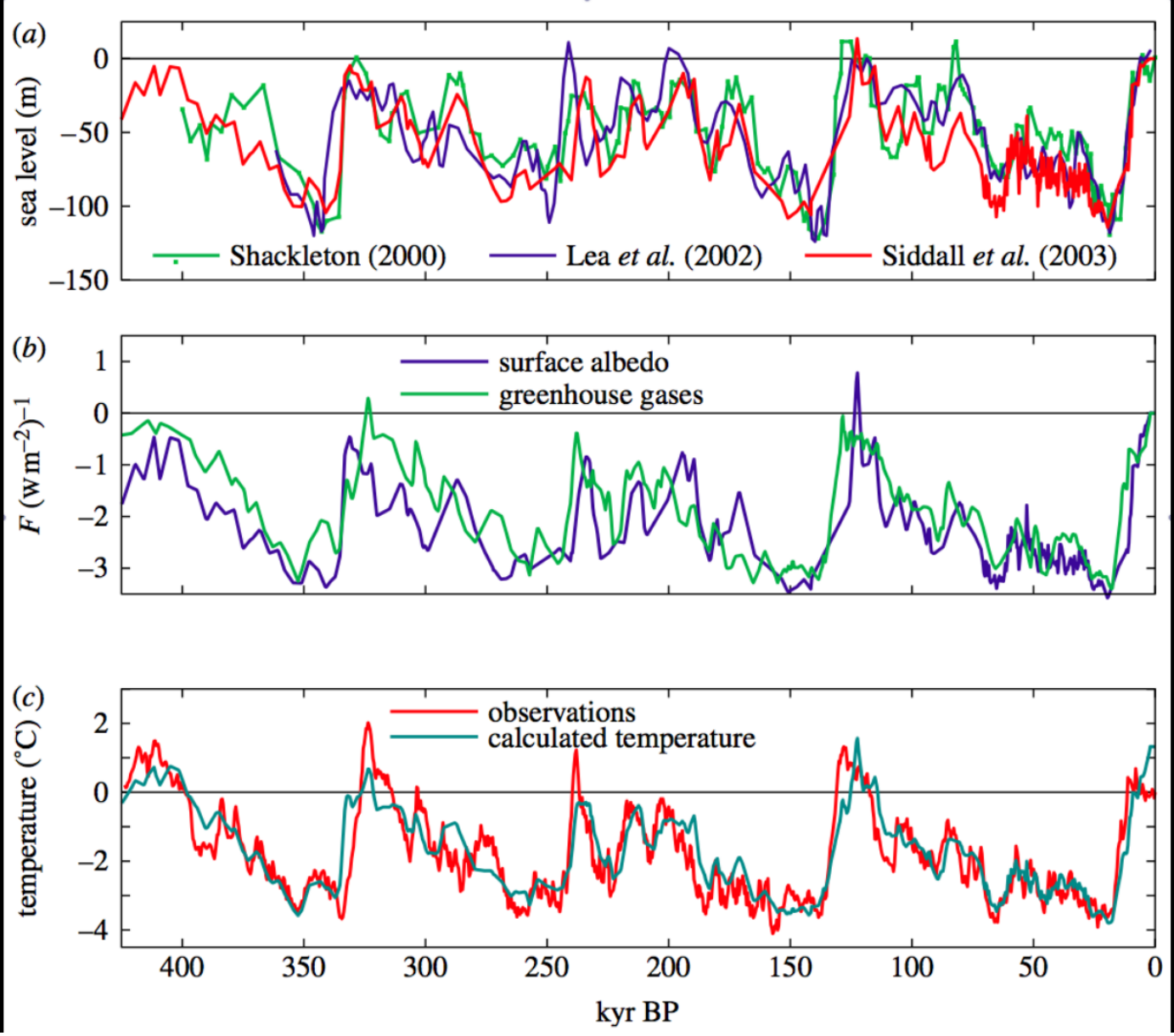


Precession



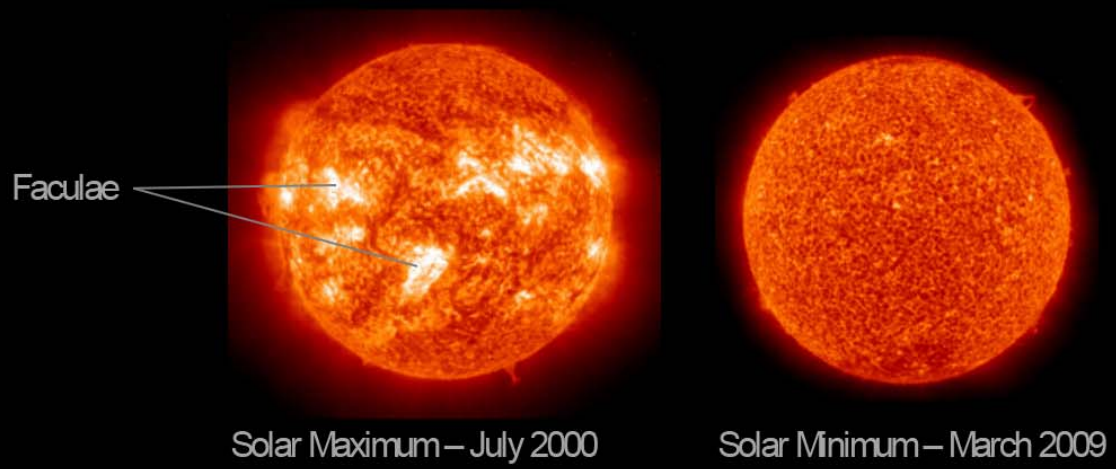
Precession



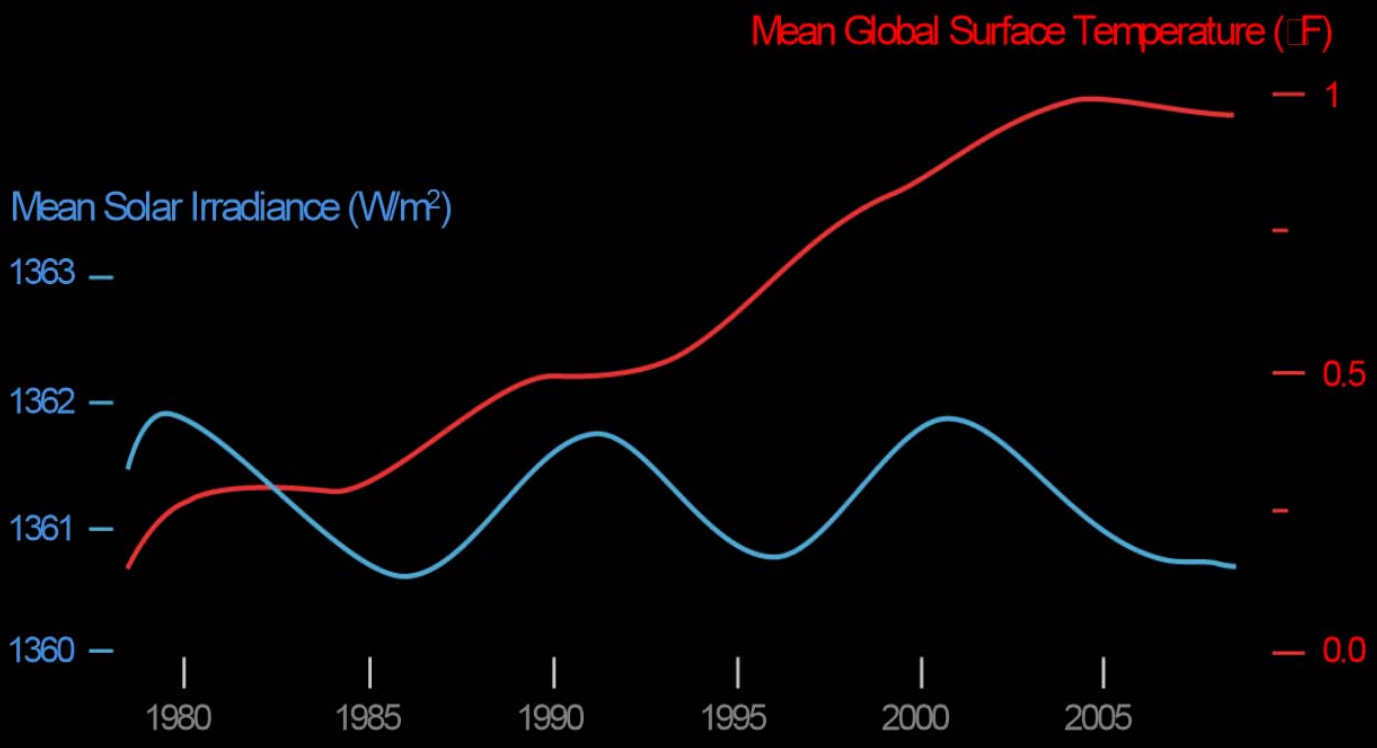


Credit: James Hansen, NASA GISS

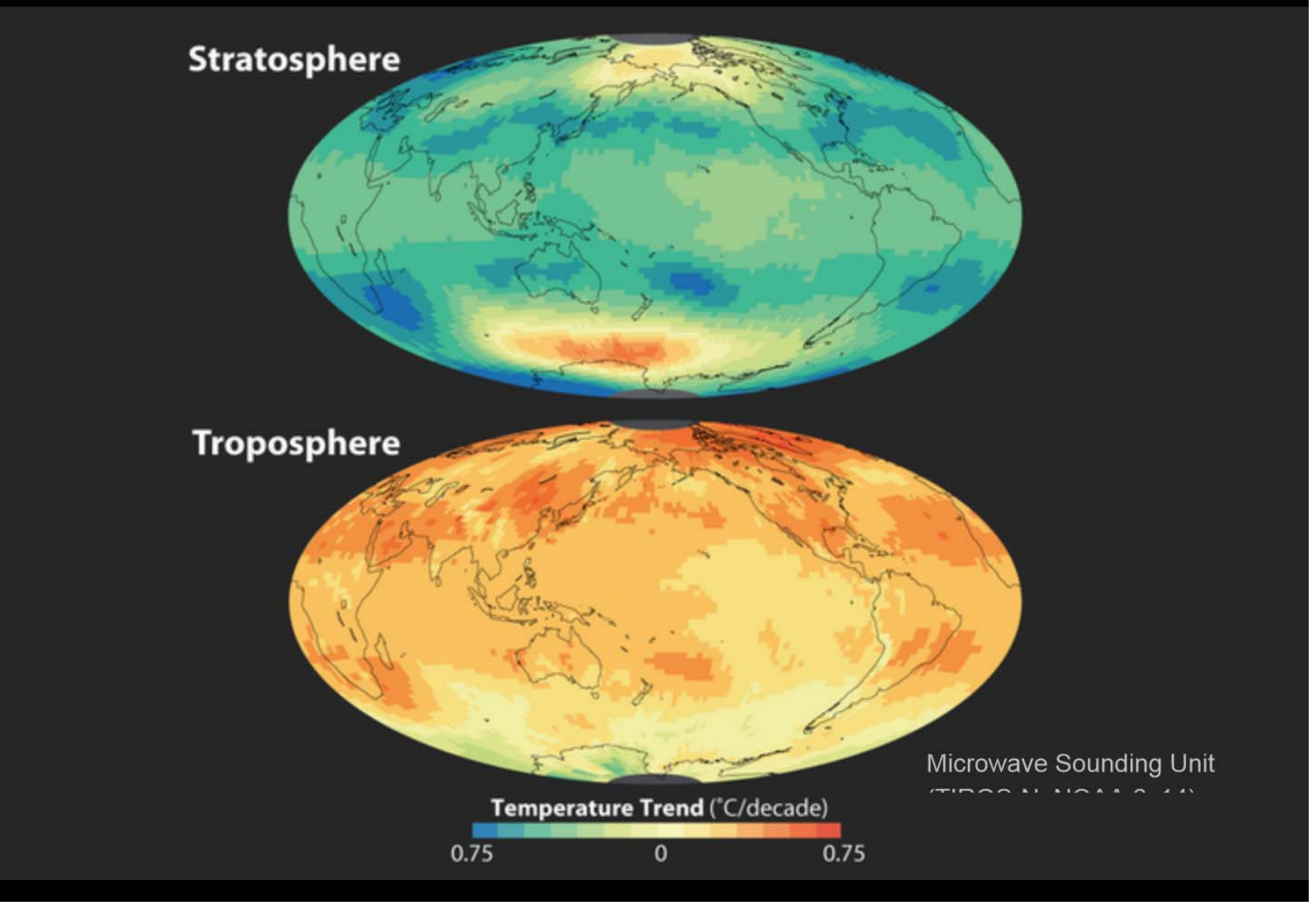
400 years of total solar irradiance data



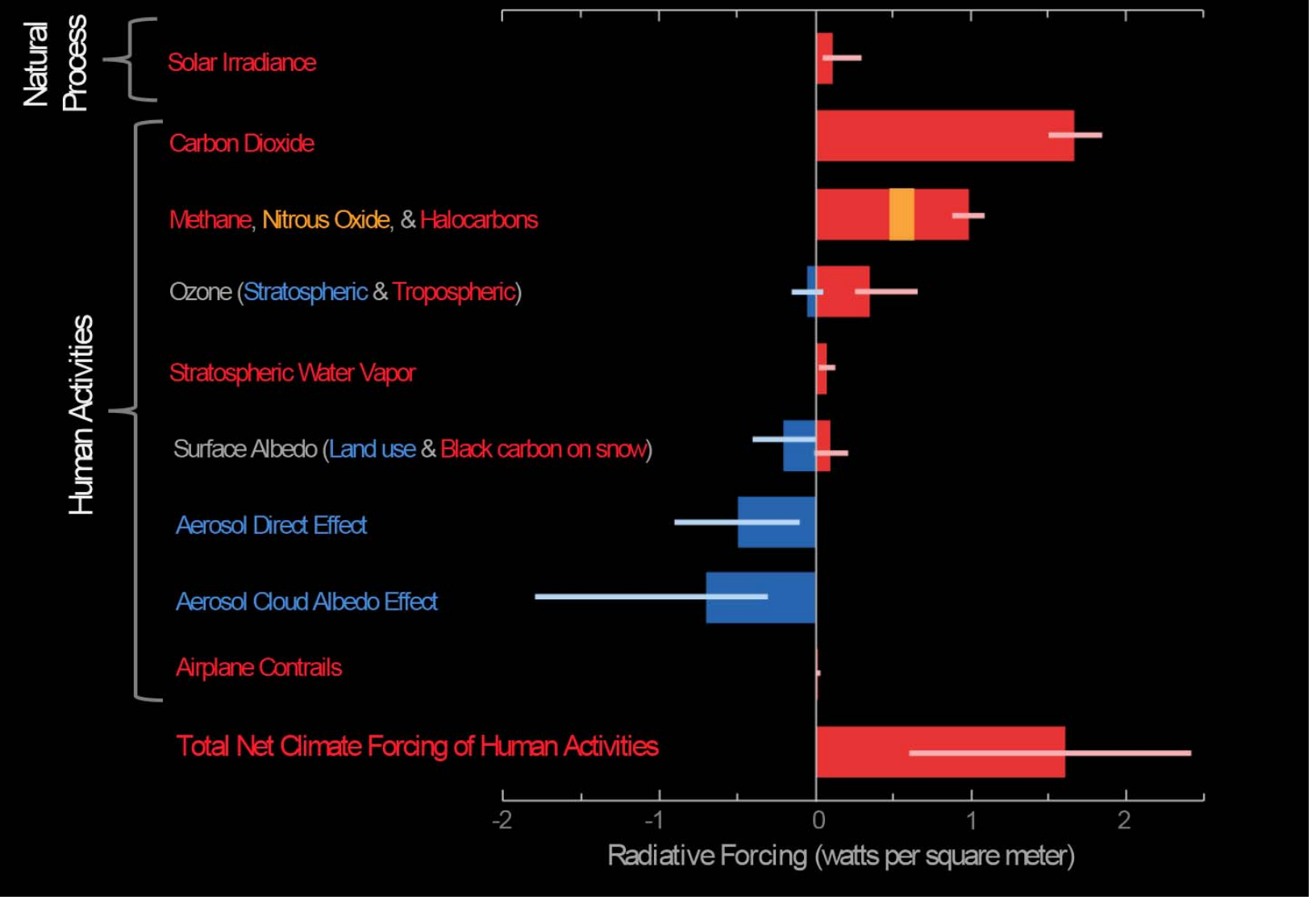
Since 1978, incoming sunlight hasn't changed much while global temperature has increased dramatically

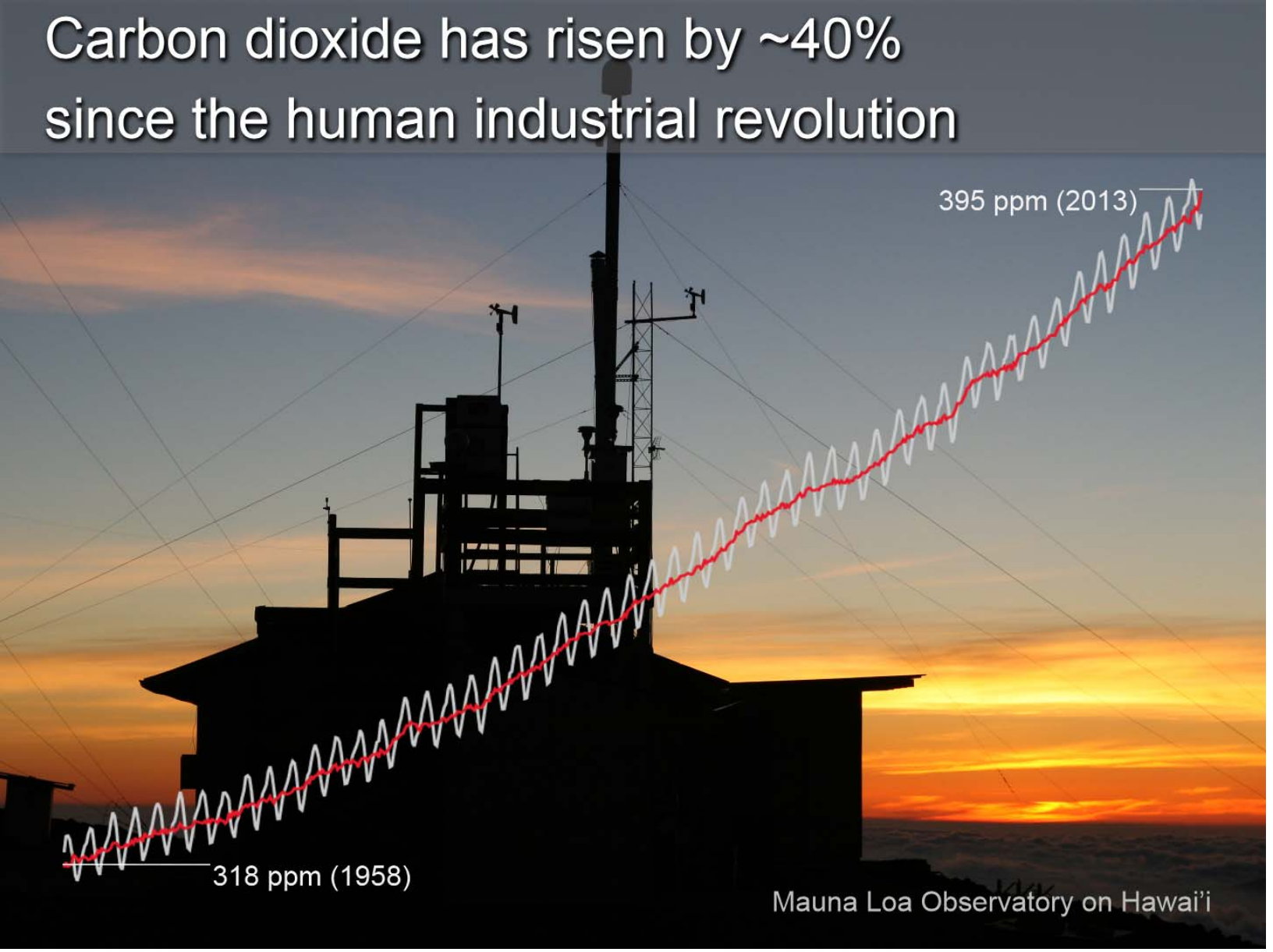


Satellite evidence suggests greenhouse gas warming

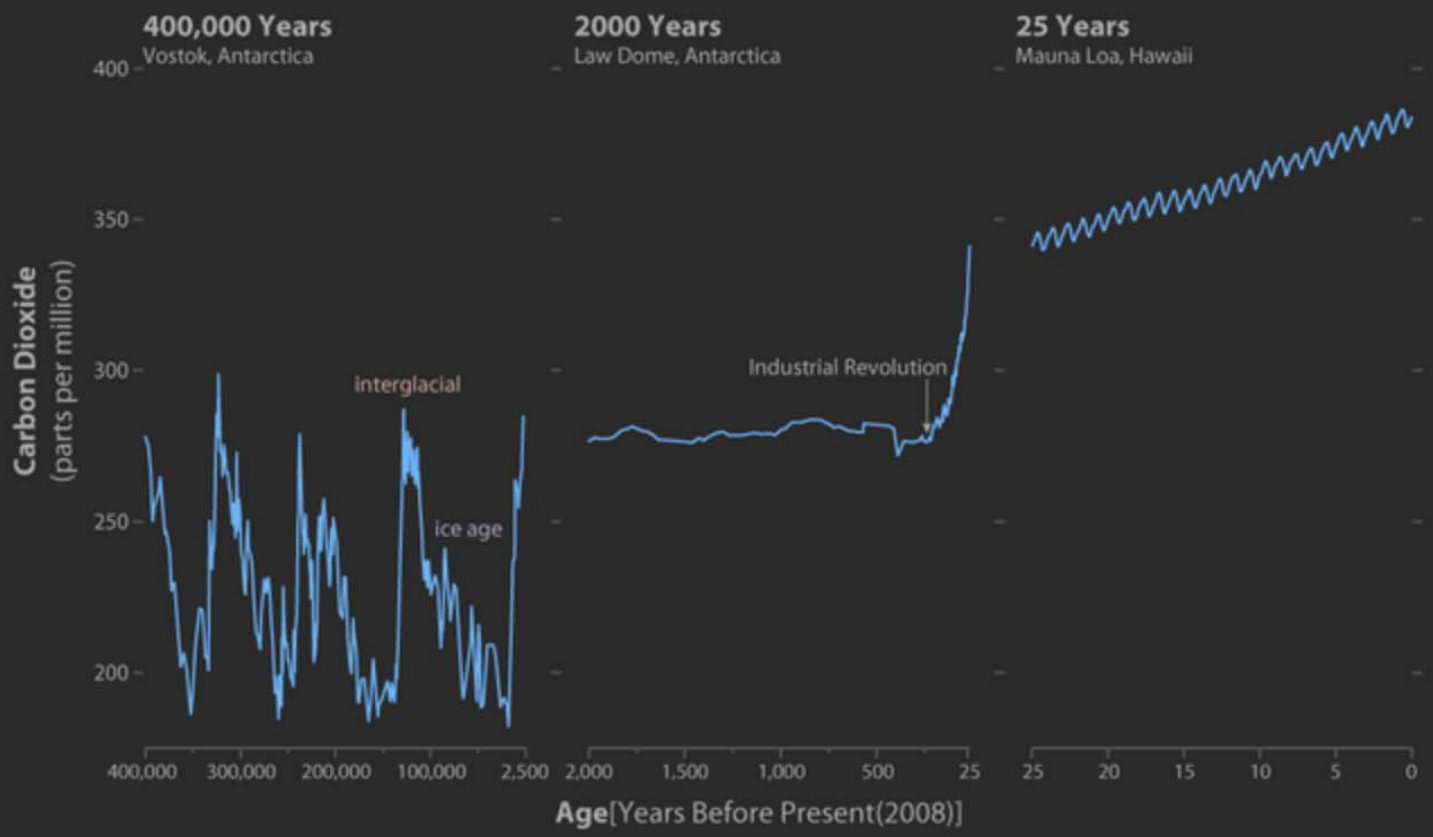


Relative measures of Earth's climate forcings




Carbon dioxide has risen by ~40%
since the human industrial revolution
395 ppm (2013)
318 ppm (1958)
Mauna Loa Observatory on Hawai'i

Today's carbon dioxide trend is unusual compared to the last ~800,000 years on Earth

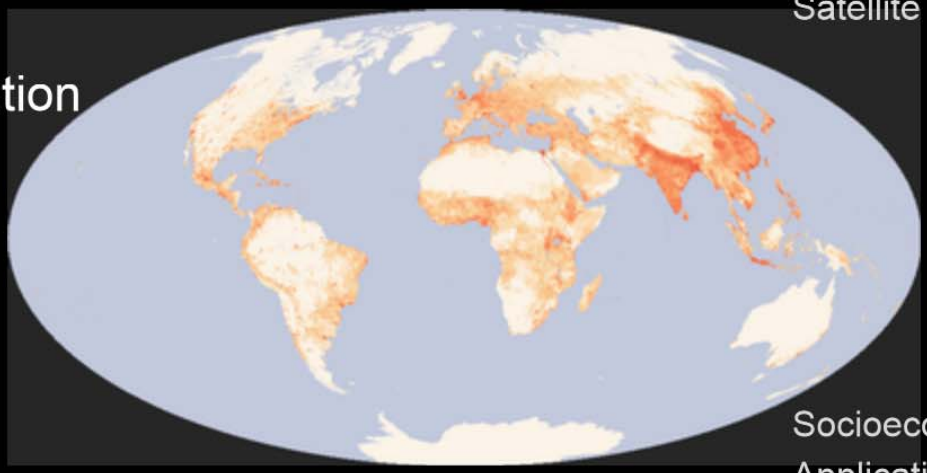


Global maps of humanity's 'footprint'

City Lights

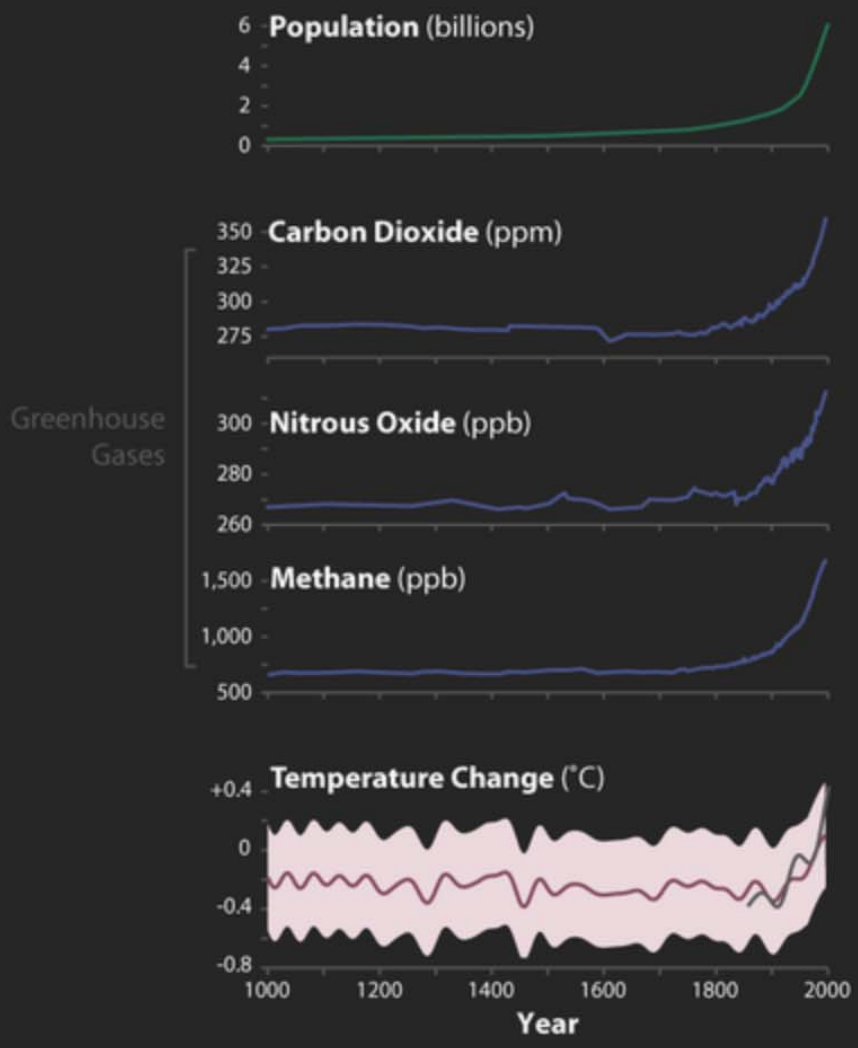
Operational Line Scanner
Defense Meteorological
Satellite Program

Population



Socioeconomic Data and
Applications Center

Human ‘fingerprints’ on the climate system

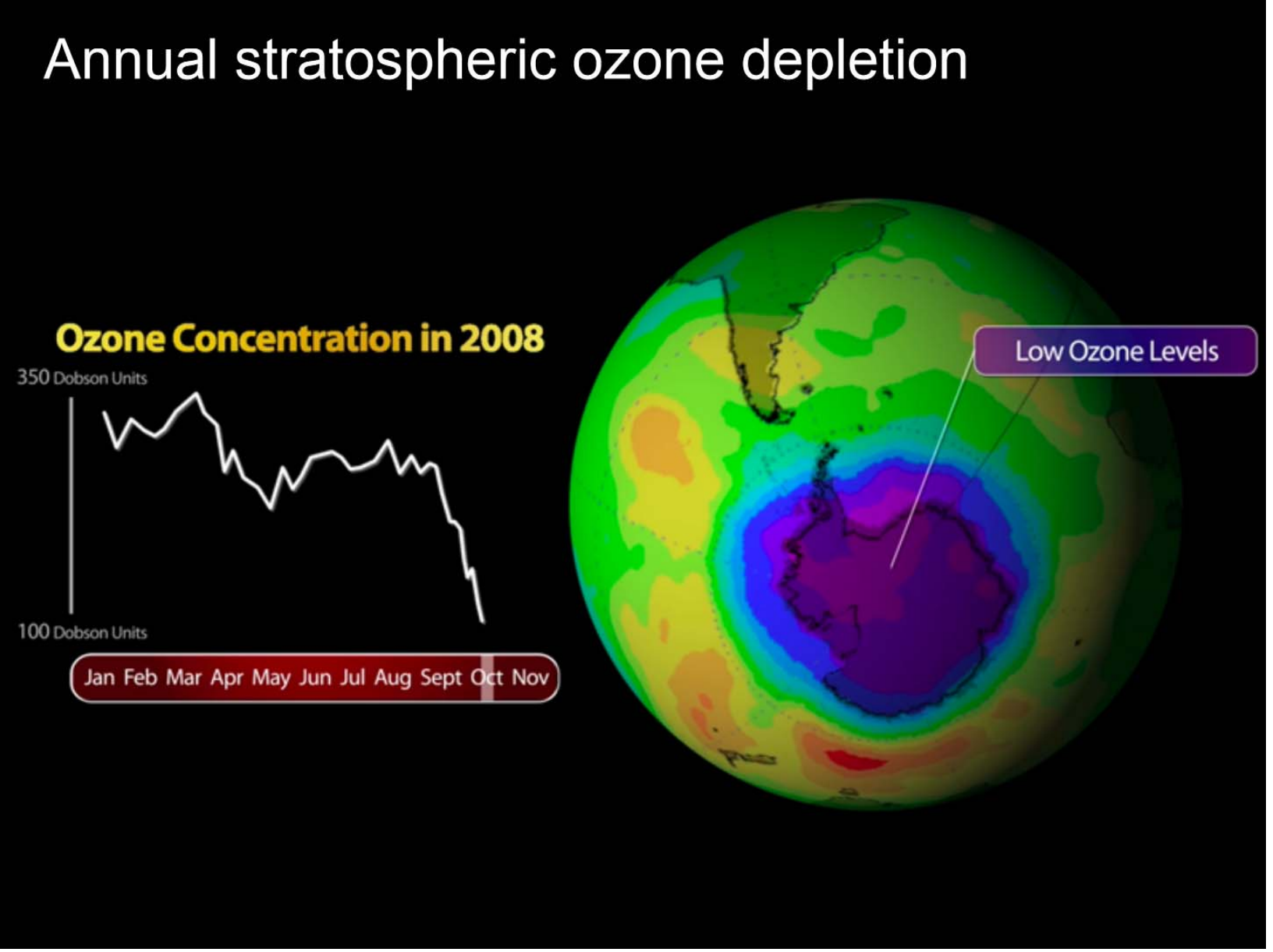


Population doubled & then doubled again over the last century—from 1.65 billion to more than 6 billion inhabitants.

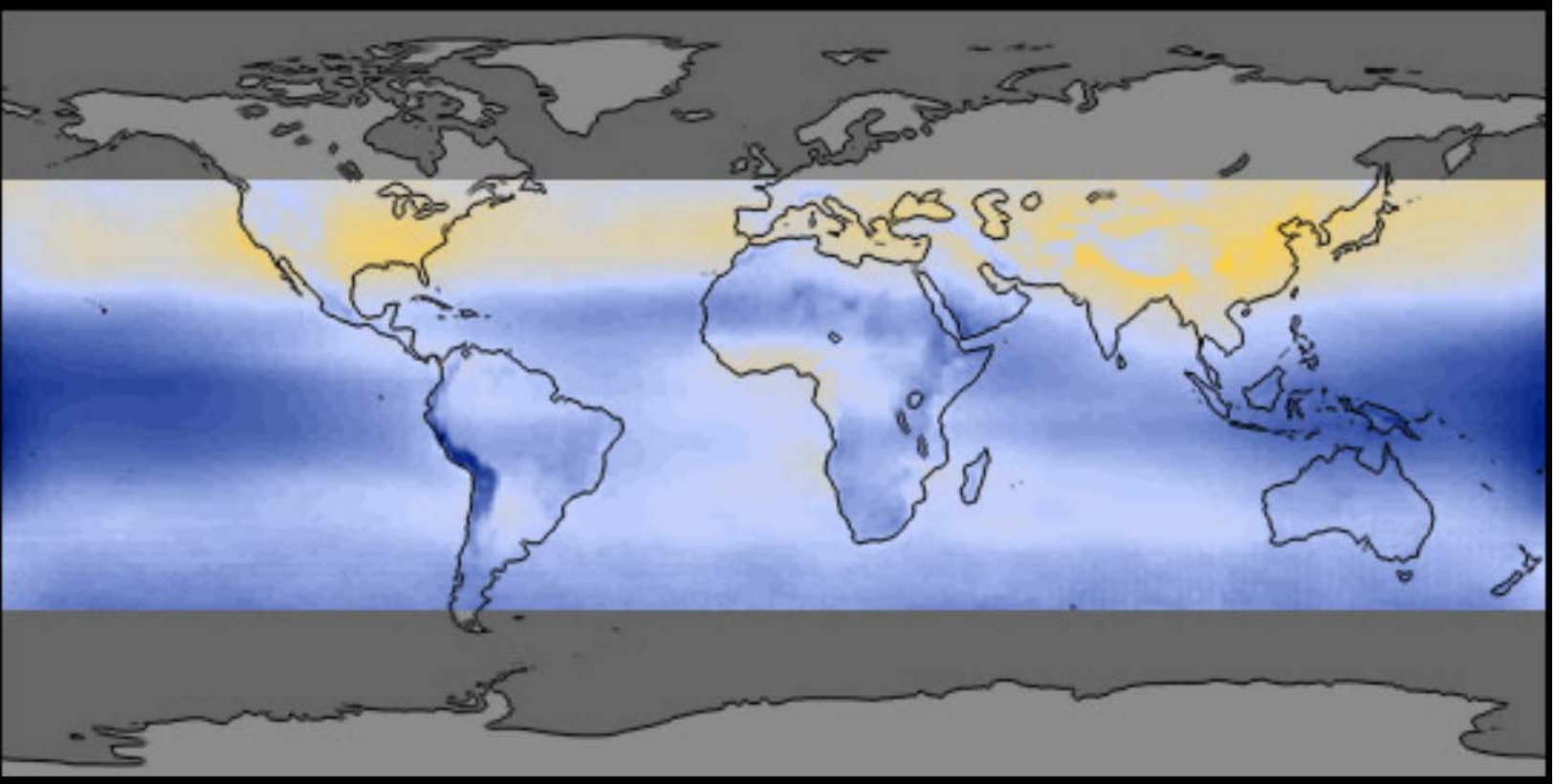
In that same time span, there was a rise in the three most abundant human-emitted greenhouse gases, mirroring the growth in human population. Isotopic analysis and carbon cycle models established that the increase in carbon dioxide was due to fossil fuel combustion.

With the rise in those greenhouse gases, Earth experienced an unusually rapid rise in its average temperature—increasing 0.7□C since 1880.

Annual stratospheric ozone depletion



Increasing tropospheric ozone

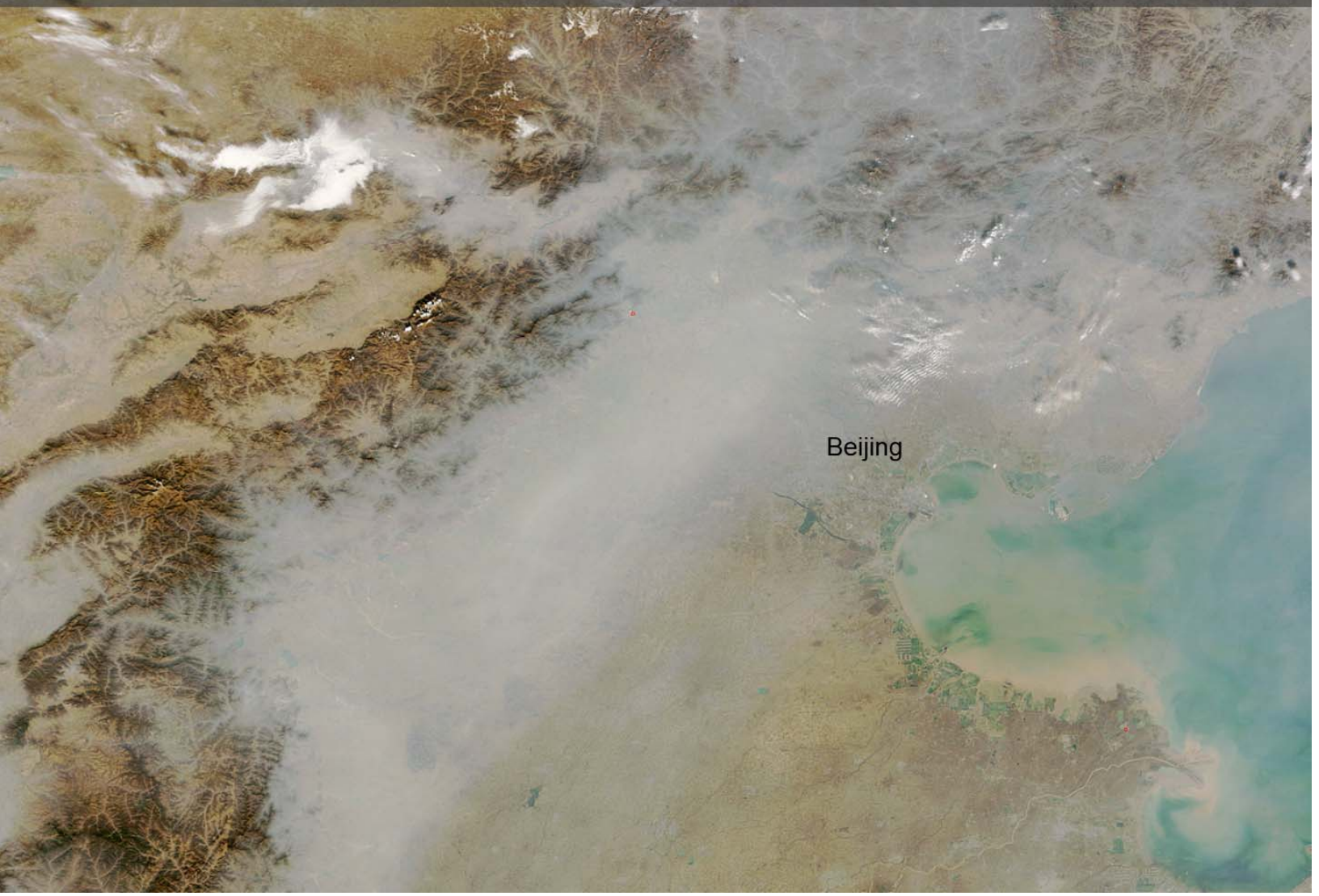


Tropospheric Ozone (Dobson Units)

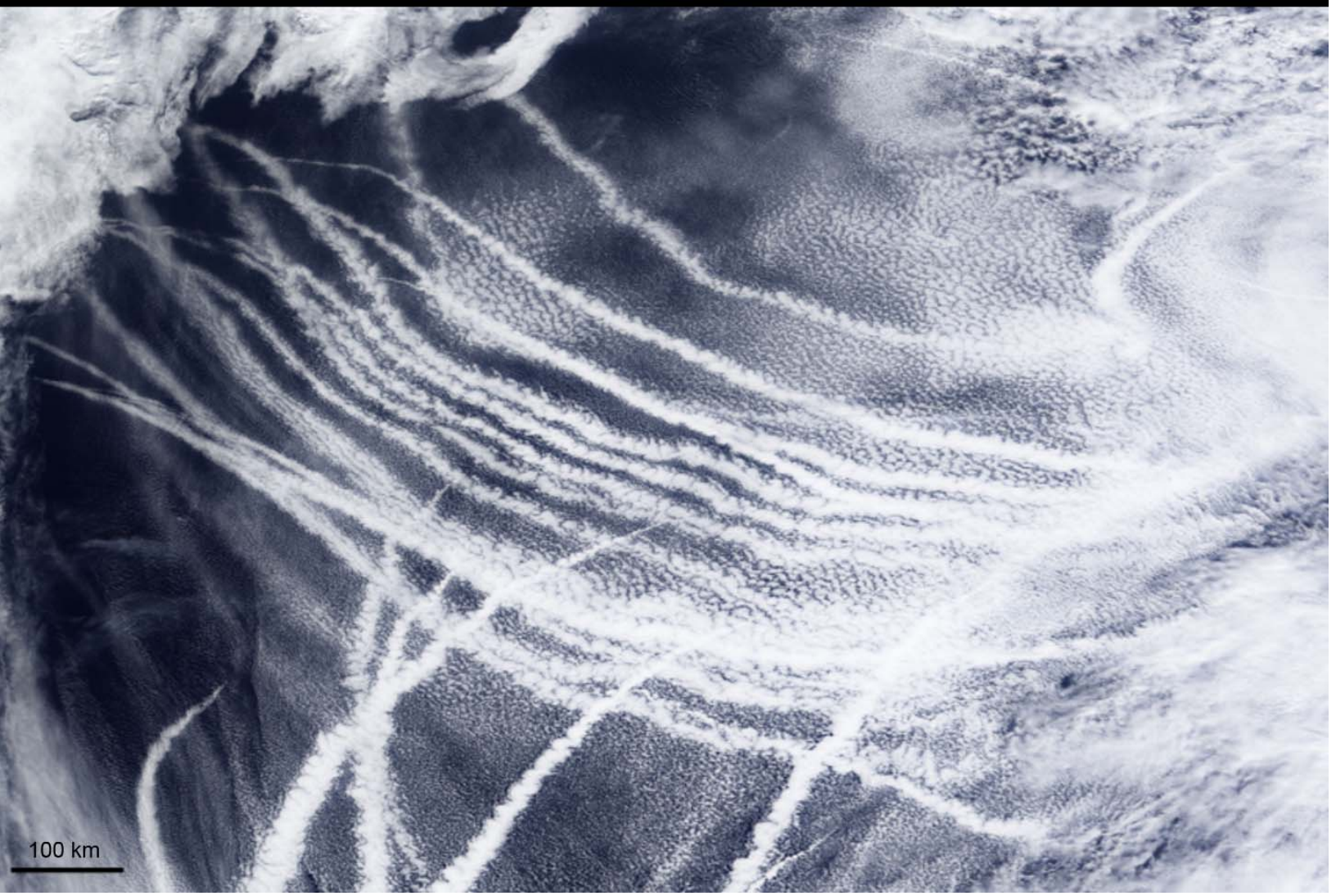
12 55

Surface Albedo: Land Use Changes

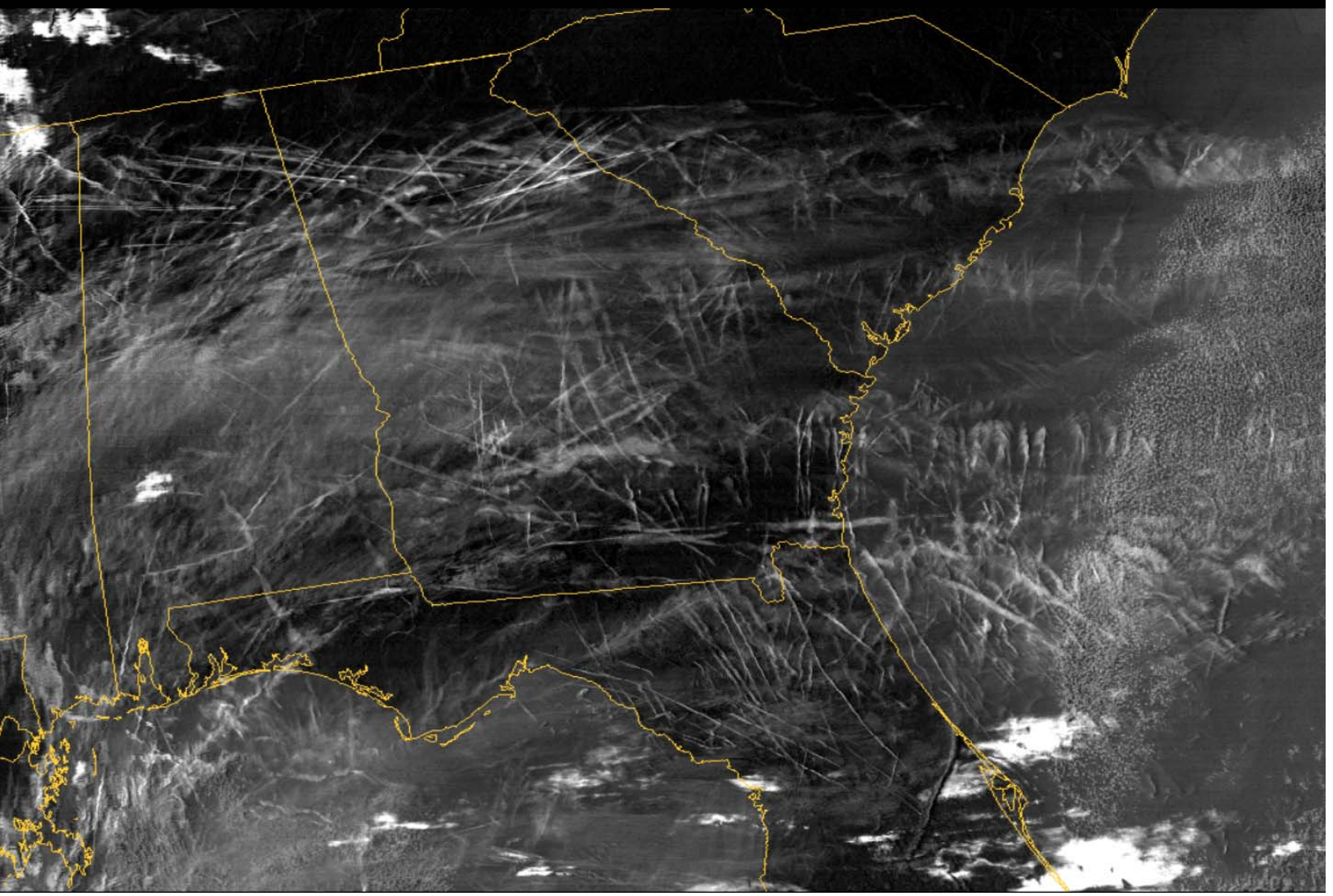
Aerosol direct effect: Industrial & Urban Pollution



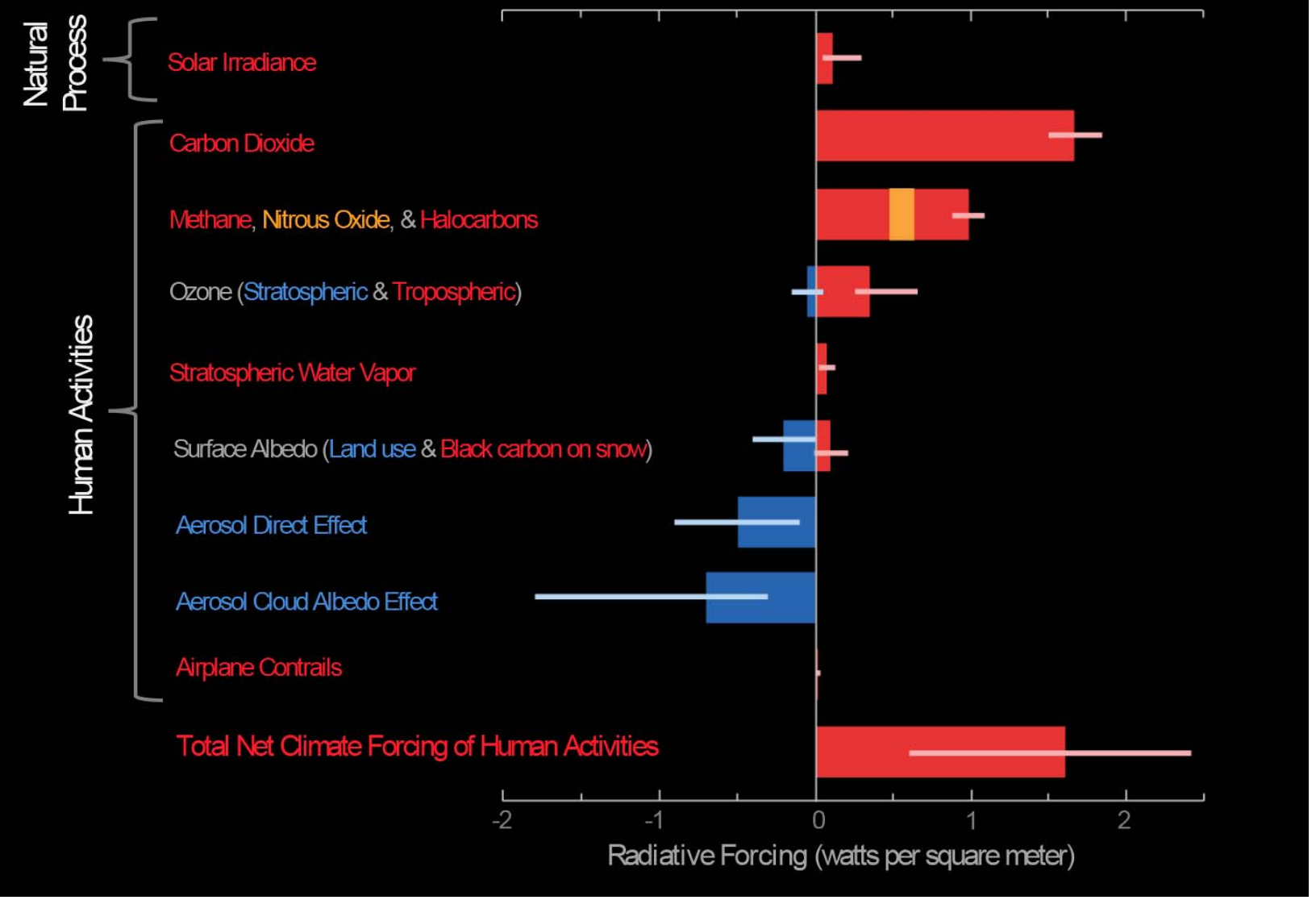
Cloud Albedo Effect: Ship Tracks



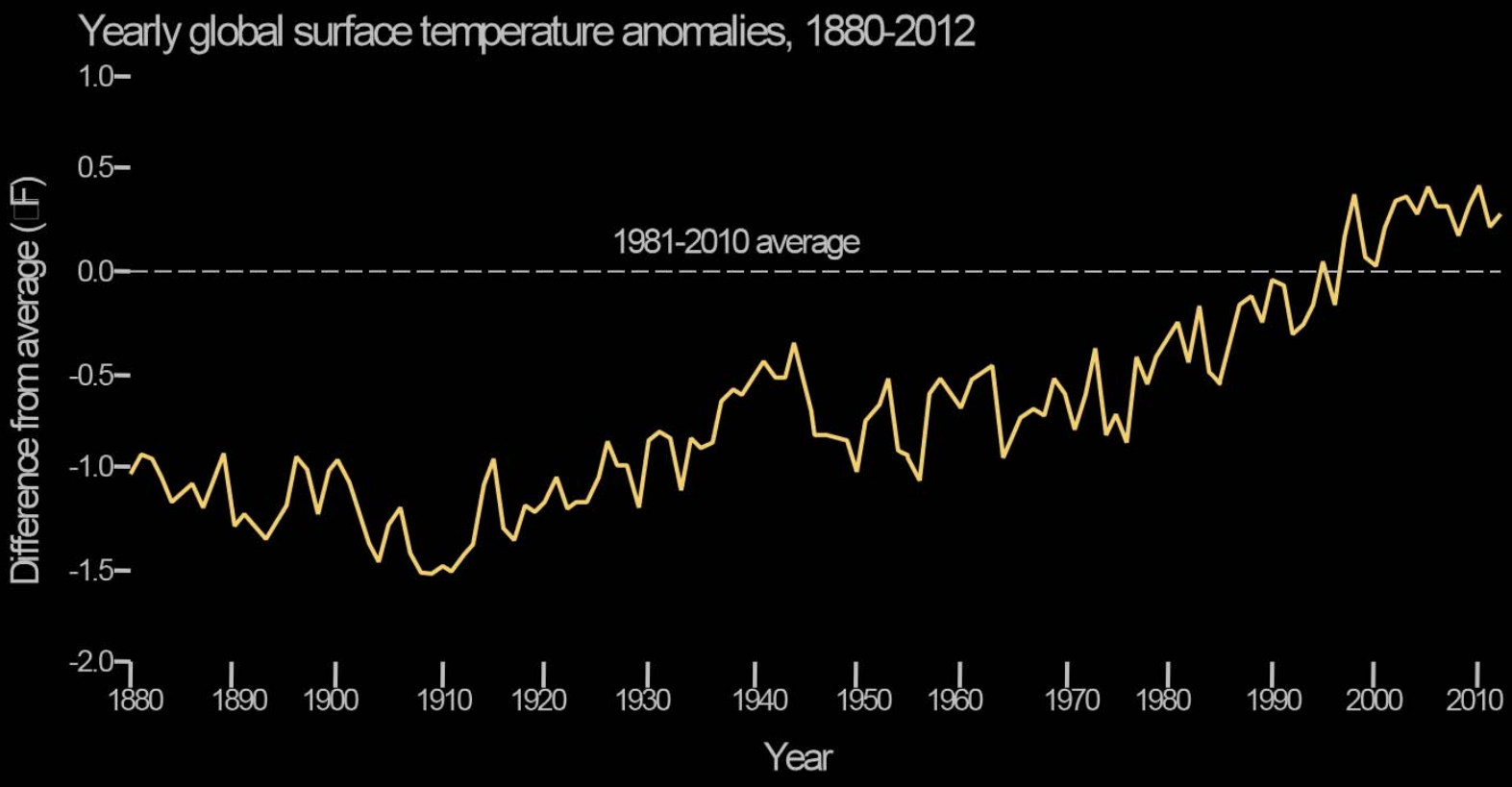
Airplane contrails



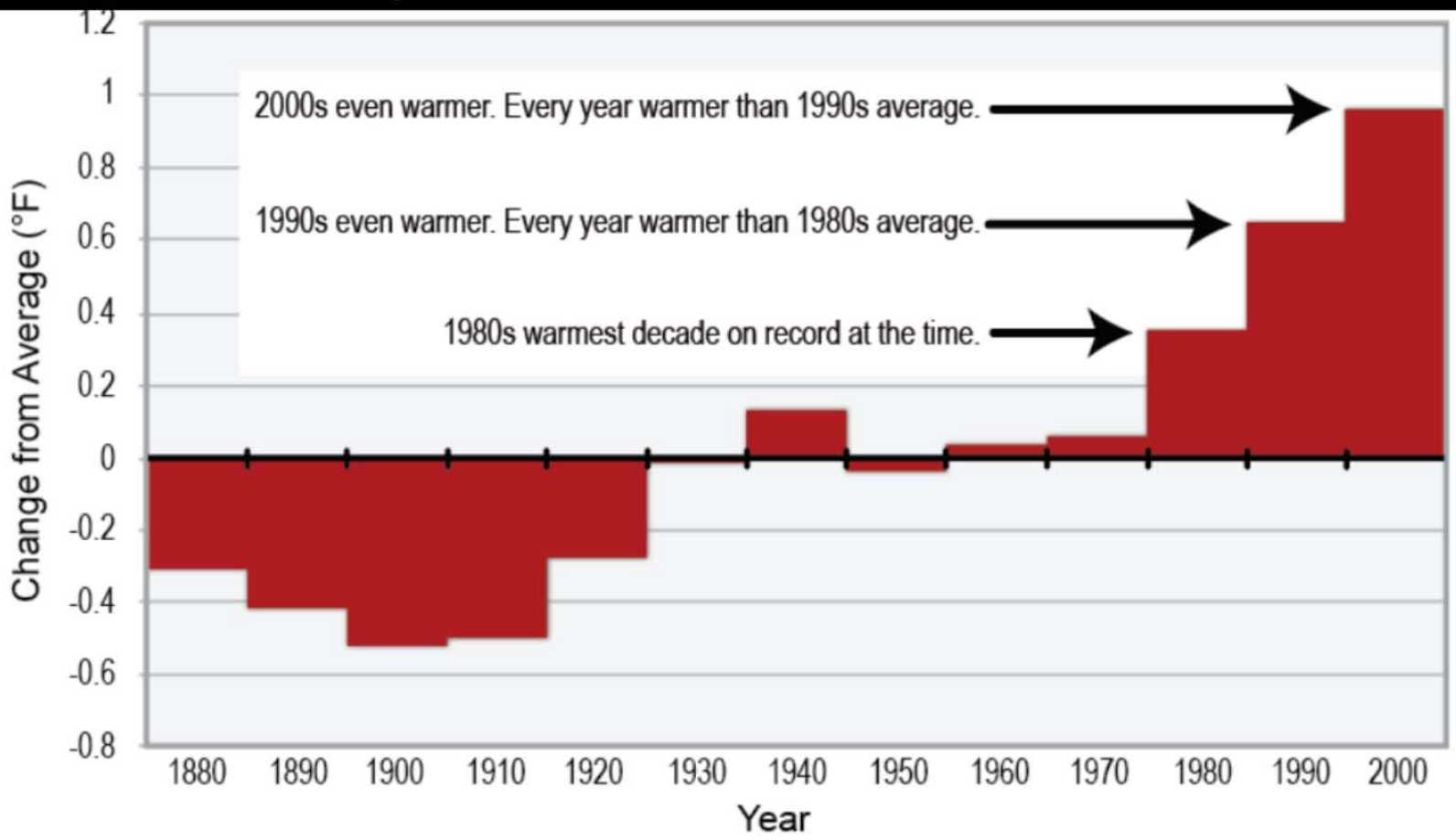
Relative measures of Earth's climate forcings



Globally averaged annual temperature has risen by 1.3 °F since 1880

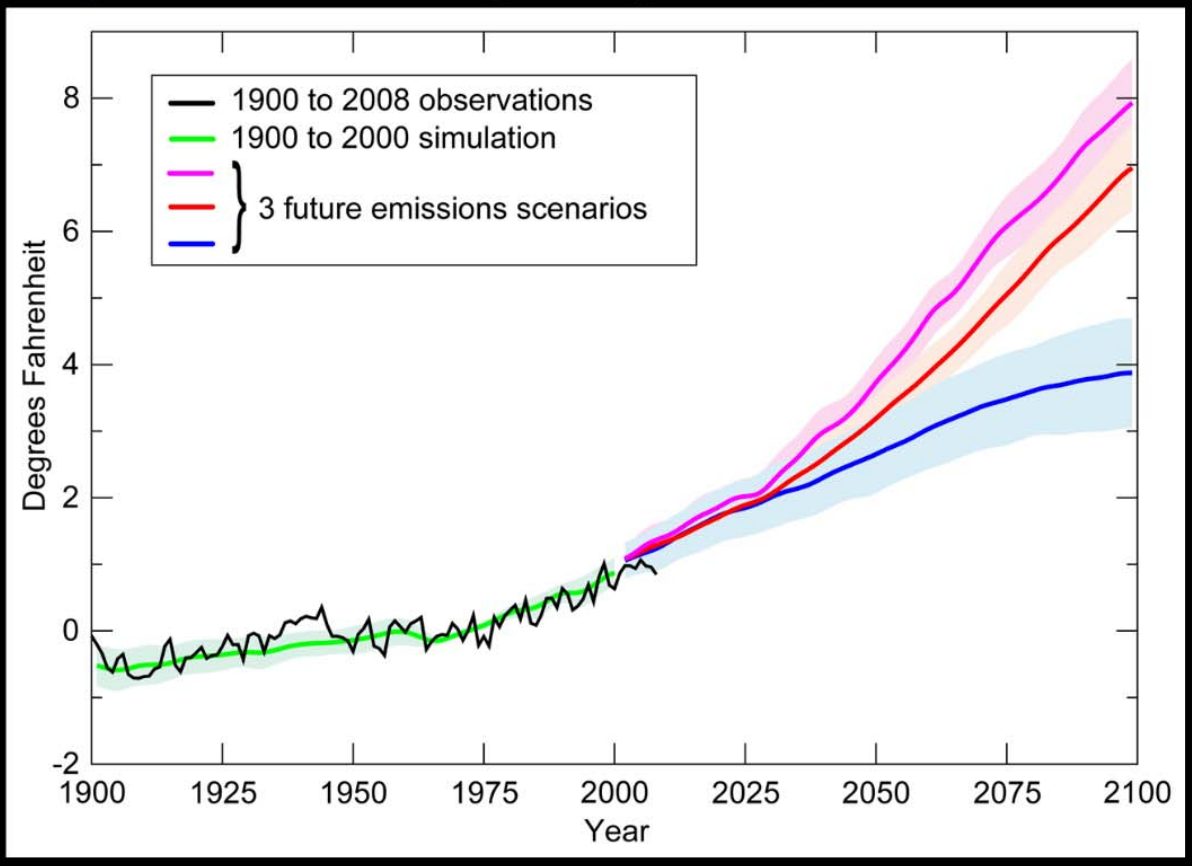


Globally averaged annual temperature has risen by 1.3°F since 1880



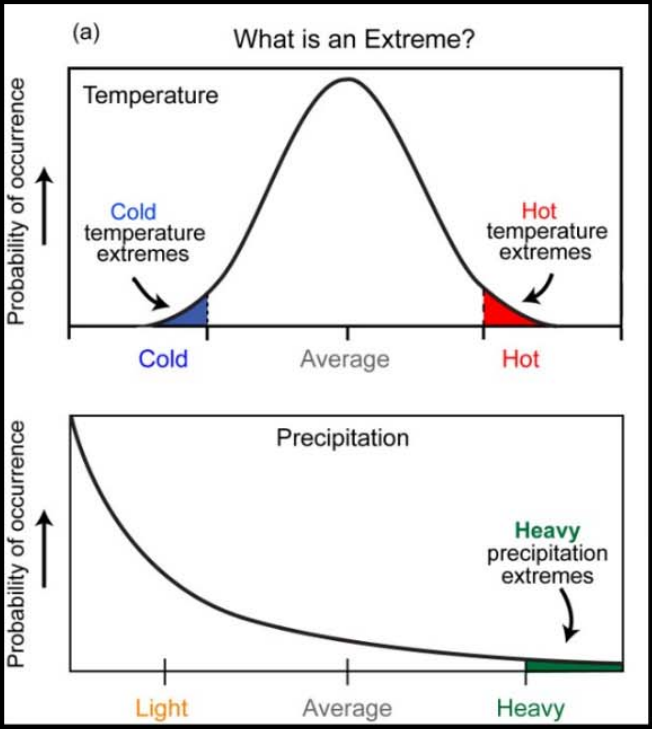
Scientists project another 2 to 9 °F (1.1 to 5.4 °C) global warming by 2100 due mainly to GHGs

Projected Global Average Temperature, 1900 to 2100



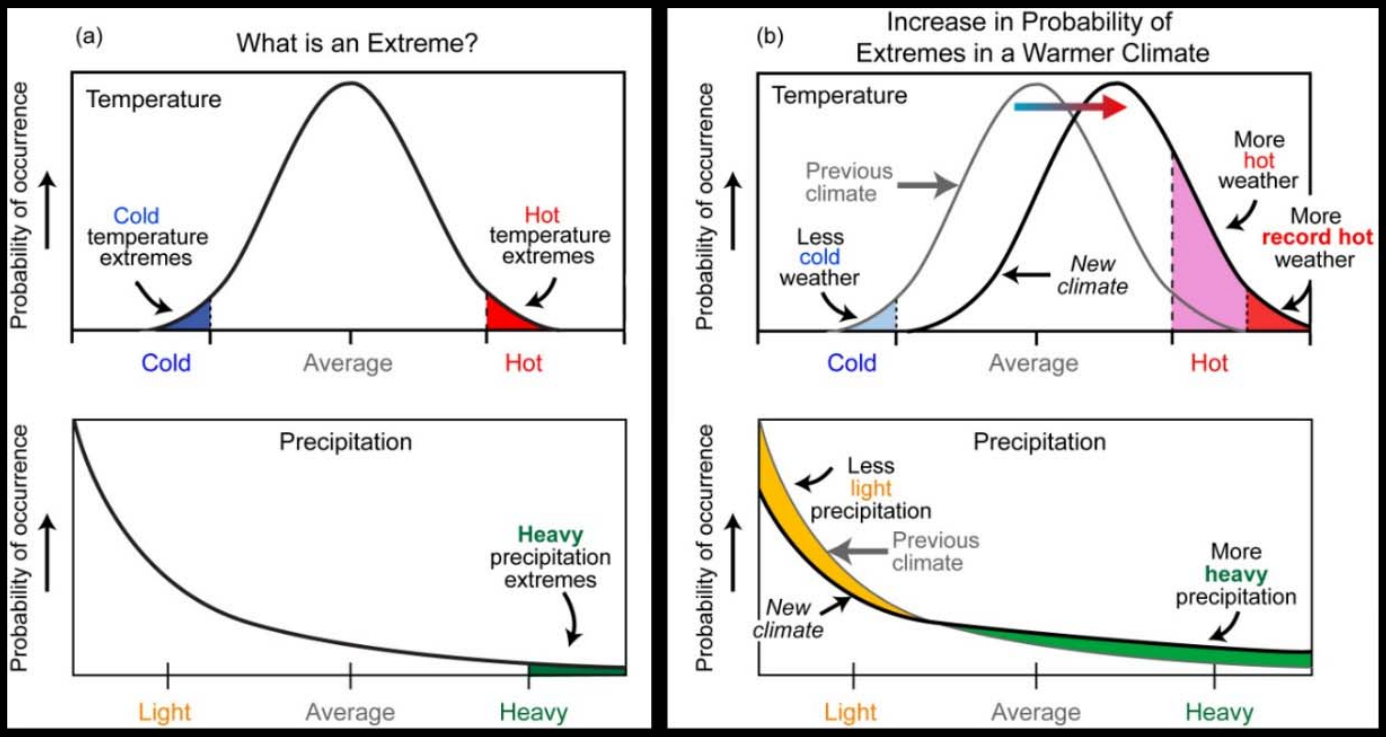
What is an ‘extreme event’?

An ‘extreme event’ is a time and place in which weather, climate or environmental conditions — such as temperature, precipitation, prolonged drought, or coastal flooding — rank among the highest or lowest of historical measurements.



What is an ‘extreme event’?

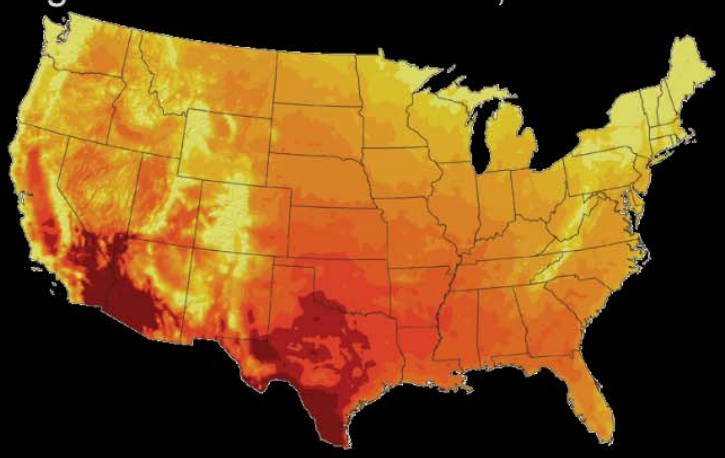
An ‘extreme event’ is a time and place in which weather, climate or environmental conditions — such as temperature, precipitation, prolonged drought, or coastal flooding — rank among the highest or lowest of historical measurements.



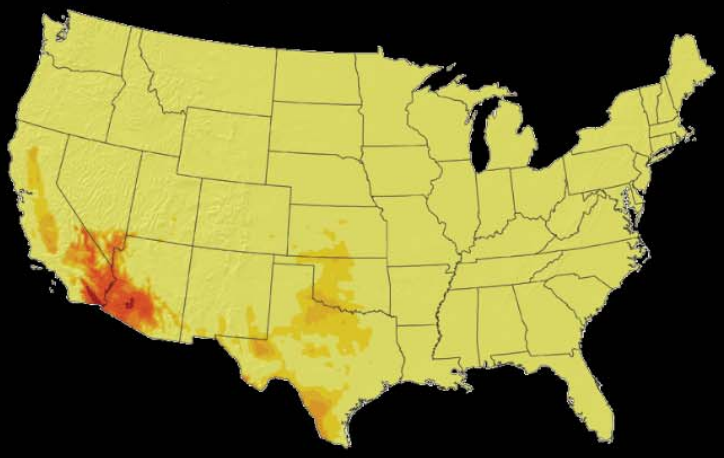
Scientists project a dramatic increase in days with temperatures over 100 □F in the United States

Number of Days Over 100 □F

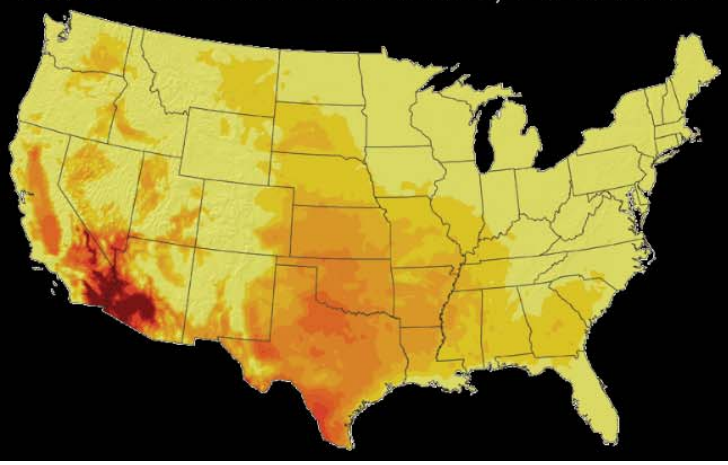
Higher Emissions Scenario, 2080-2099

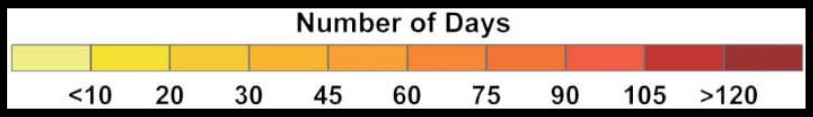


Recent Past, 1961-1979

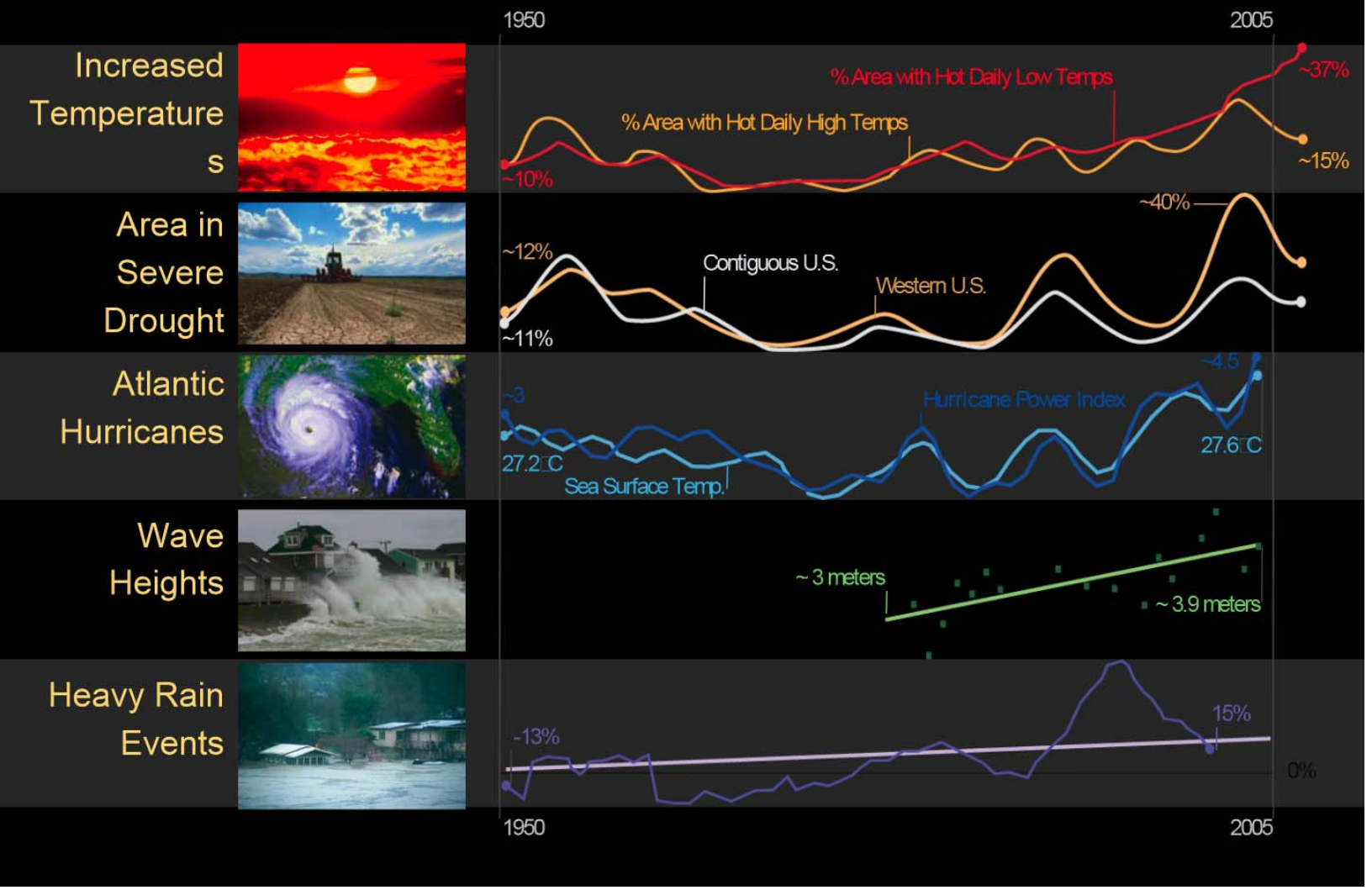


Lower Emissions Scenario, 2080-2099





Climate change brings extreme weather & climate

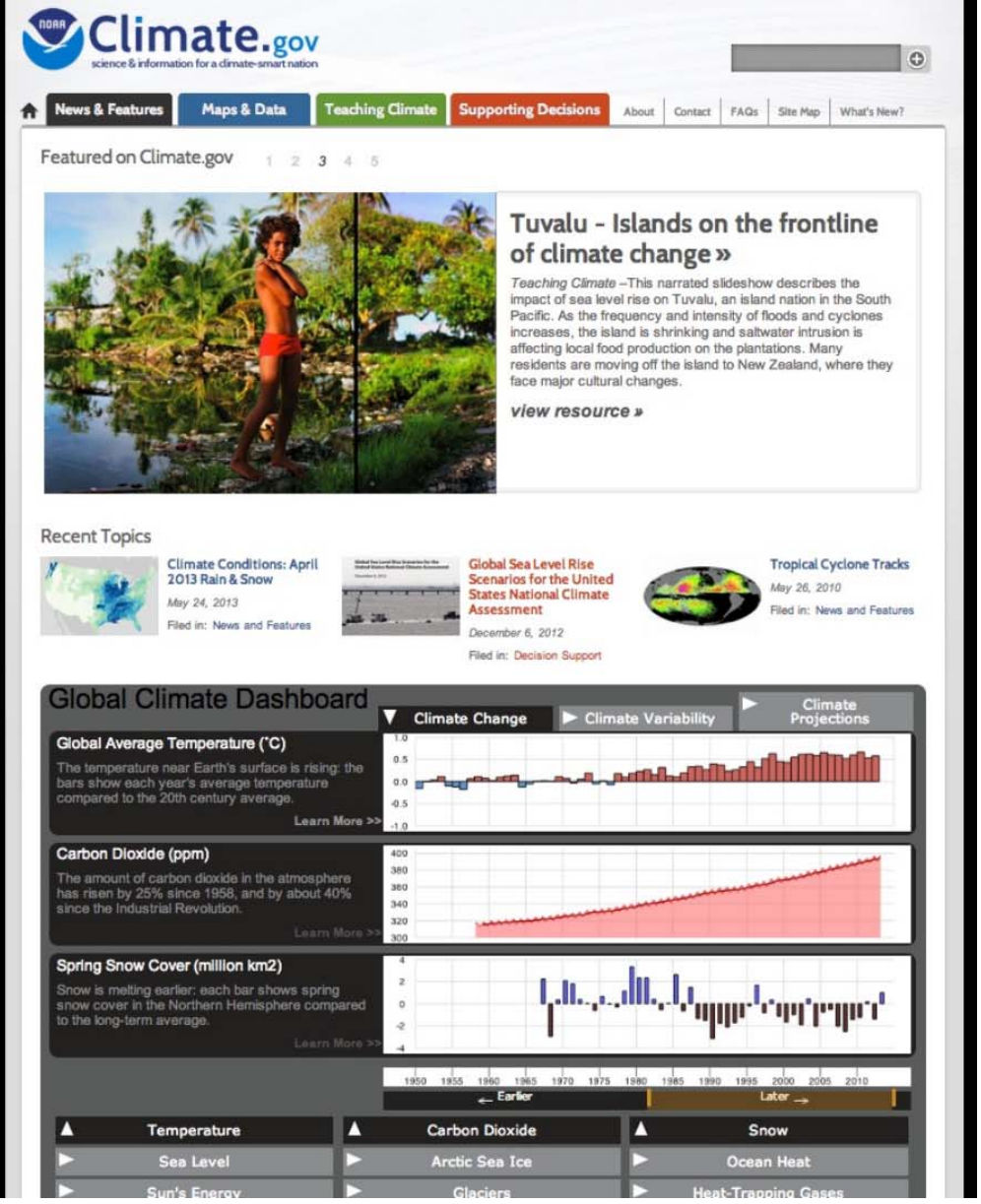


Conclusion, there is a preponderance of evidence that…

- Earth is warming at an accelerating rate
- This warming due to human emission of heat-trapping gases, mainly carbon dioxide
- There have been and will be harmful consequences as a result—we will experience impacts on our health, economy, food and water production, natural ecosystems, etc.
- We understand the problem and we can solve it
- The vast majority of climate scientists agree with all of those four statements

Go online to learn more about climate

www.climate.gov



Thank you!

What can we do to mitigate global climate change?

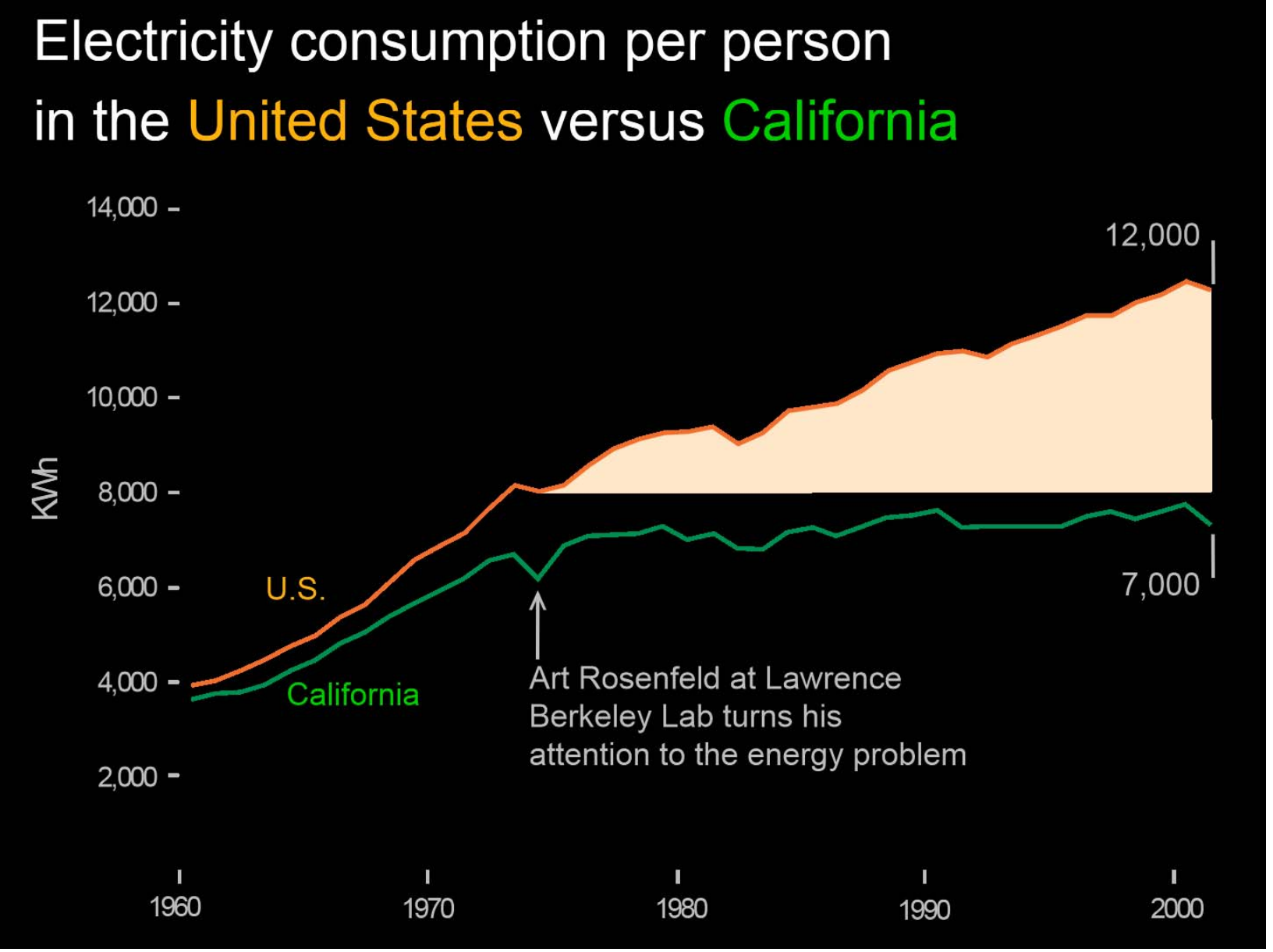
How can we reduce vulnerability & improve resilience to climate-related impacts?

Response strategies

Mitigation – reducing the amount of climate change, for example, by reducing heat-trapping emissions or increasing their removal from the atmosphere

Adaptation – improving our ability to cope with or avoid harmful impacts or taking advantage of newly favorable conditions

Both will be needed.


Electricity consumption per person
in the United States versus California
14,000
12,000
10,000
8,000
6,000
4,000
2,000
KWh
12,000
7,000
U.S.
California
Art Rosenfeld at Lawrence
Berkeley Lab turns his
attention to the energy problem
1960
1970
1980
1990
2000

Let's make smarter choices at all levels of society

Individuals, NGOs and businesses should…

- educate themselves and stay informed about causes and effects of climate change and variability.
- become a trusted source of information about climate for colleagues, friends & family.
- foster / participate in public dialogs about how to mitigate / adapt to climate change and climate impacts.
- let policy leaders & businesses know how you feel.
- vote with your wallet — buy energy efficient products, buy locally grown produce, buy renewable energy, and buy from businesses that sell green products.
- reduce energy consumption in homes / cars / workplaces — adjust thermostats, improve insulation, and eliminate 'vampire appliances'

Let's make smarter choices at all levels of society

Regional, State, and Local Governments should …

- Host public dialogs about mitigation and adaptation options, community planning, resource management, etc.
- Consider win-win strategies to mitigate, that both reduce GHGs in the atmosphere while boosting the economy.
  - Consider investing in solar and wind energy farms.
  - Provide incentives for local businesses to go green.
- Consider win-win strategies to adapt to ongoing or projected impacts, and to address risks, vulnerabilities & opportunities facing their communities, such as…
  - How secure are your water resources?
  - How reliable are your energy sources?
  - How are water and energy supply and demand likely to change given both climate change and population growth patterns?

Let's make smarter choices at all levels of society

National and international-scale governments should …

- Commit to taking incremental steps — slow the rate of GHG emissions, then stabilize the concentration of GHGs in the atmosphere, then reduce atmospheric GHGs.
- Establish a robust verification system capable of observing & quantifying carbon sources & sinks
- Devise / deploy tools designed to help businesses compete and grow the economy while also addressing climate change
  - Invest in new, alternative energy technology research & development
  - Establish ground rules (i.e., cap and trade) to ensure level playing fields
  - Incentivize businesses and consumers (tax breaks for realizing increased efficiencies—i.e., green buildings & homes)
  - Consider investing in options for carbon sequestration and / or other

Frequently Asked Questions

How do we know global mean surface temperature is rising?

- The physics of greenhouse gas absorption of heat energy has been documented and well understood since the mid-1800s.
  - Significantly increasing its abundance in the atmosphere must inevitably lead to global warming unless there's another, equal or greater cooling force at work on the system.
- Globally averaged measurements of surface air temperature show an ongoing warming trend, just as physics theory predicts.
- Modern tools of science — surface observations, with better computer models, with satellite remote-sensing measurements — all line up in good agreement that Earth is warming.

Earth has warmed and cooled throughout its history. So what if it is warming some now?

- Yes, Earth has warmed and cooled throughout history; at times warmer than today, and at other times colder. (See next slide: 'Milankovitch Cycles'.)
- The warming trend Earth has experienced over the last century is unusual and concerning for 3 key reasons:
  1. The rate and magnitude of observed and projected warming in such a short time span is unprecedented in human history.
  2. Humans are the main cause of this warming, due to emissions of heat-trapping gases (GHGs).
  3. Human civilization evolved over the last 10k years in a period of relative climate stability, so our systems of society will be impacted by any "abrupt" changes in climate.
  4. The warming is projected to increase further and at an accelerating

How do we know the rise in GHGs is due to human activities?

- Comparing samples of air today to samples of air trapped ice cores, we know the relative concentrations of GHGs is higher than it has been going back ~1 million years.
- We know the timing of the increase in GHGs perfectly coincides with the industrial revolution — the time when humans experienced non-linear population growth and began burning exponentially greater amounts of fossil fuels and biomass.
- When scientists analyze isotopes of carbon-based molecules in today's air compared to air going back ~1 million years, they find an abrupt change in the ratio of C_{13} to C_{12} along with an overall decline in oxygen—indicating the newer carbon molecules are increasingly produced by combustion (burning fossil fuels and biomass).
- No other source of a non-linear increase in GHGs has been observed, and no other explanation fits the observations as well.

Consensus among climate scientists worldwide that climate change is mainly human-caused

"The size of this warming is broadly consistent with prediction of climate models, but it is also of the same magnitude as natural climate variability."

—IPCC First Assessment Report, 1990

"The balance of evidence suggests that there is a discernable human influence on global climate."

—IPCC Second Assessment Report, 1995

"Most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations."

—IPCC Third Assessment Report, 2001

"Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely (>90% probability) due to the observed increase in anthropogenic greenhouse gas concentrations."

—IPCC Fourth Assessment Report, 2007