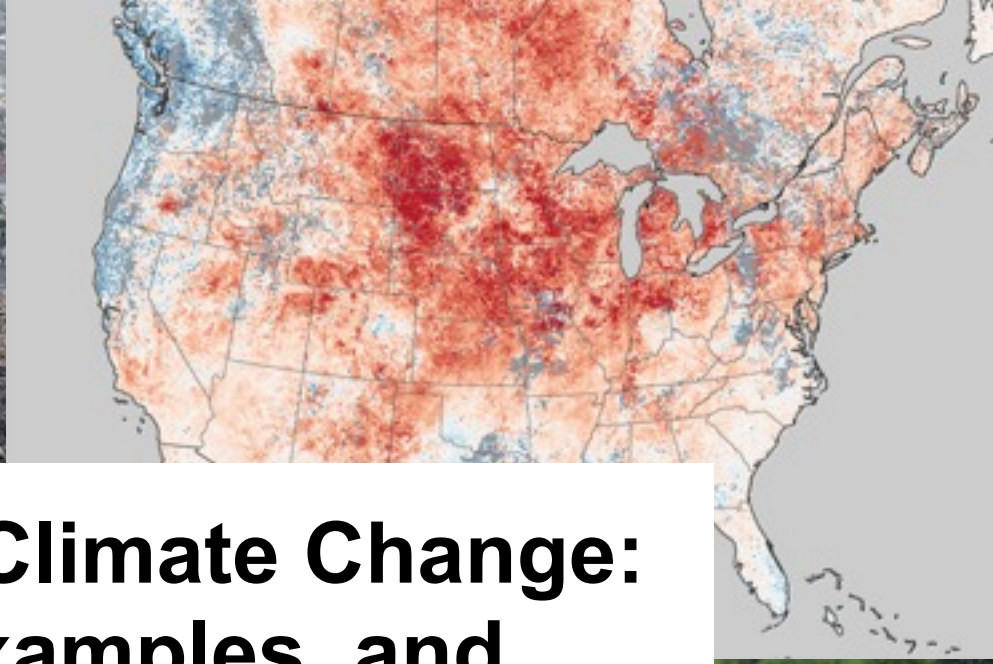
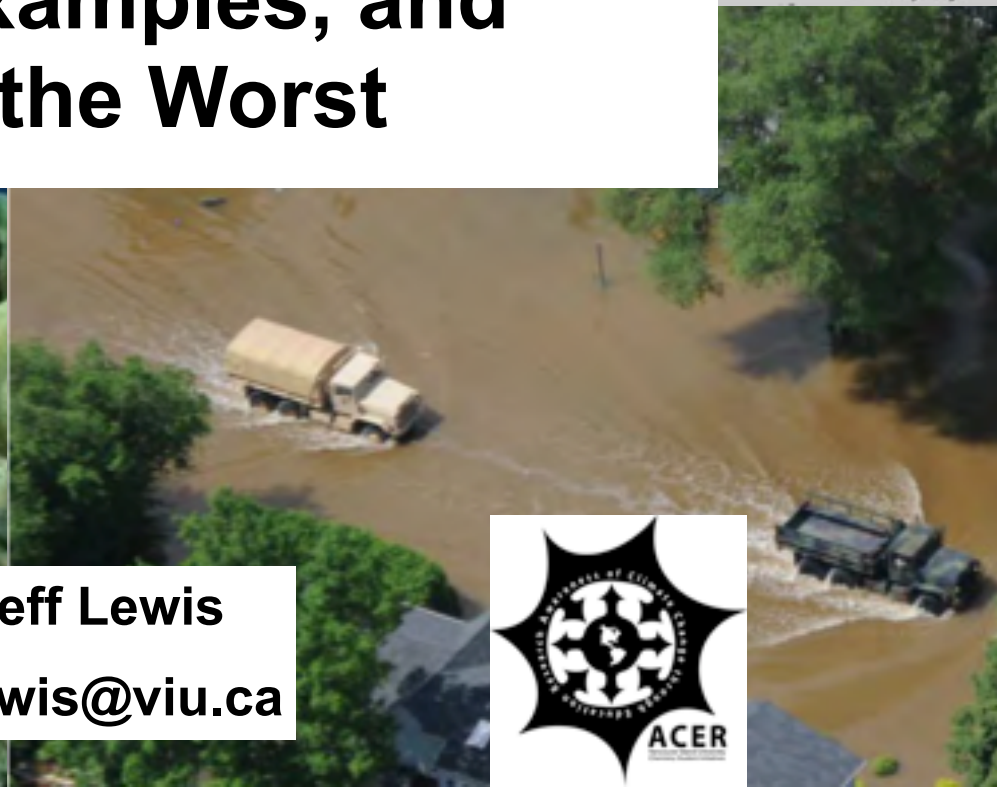


The Science of Climate Change: Evidence, Examples, and Avoiding the Worst



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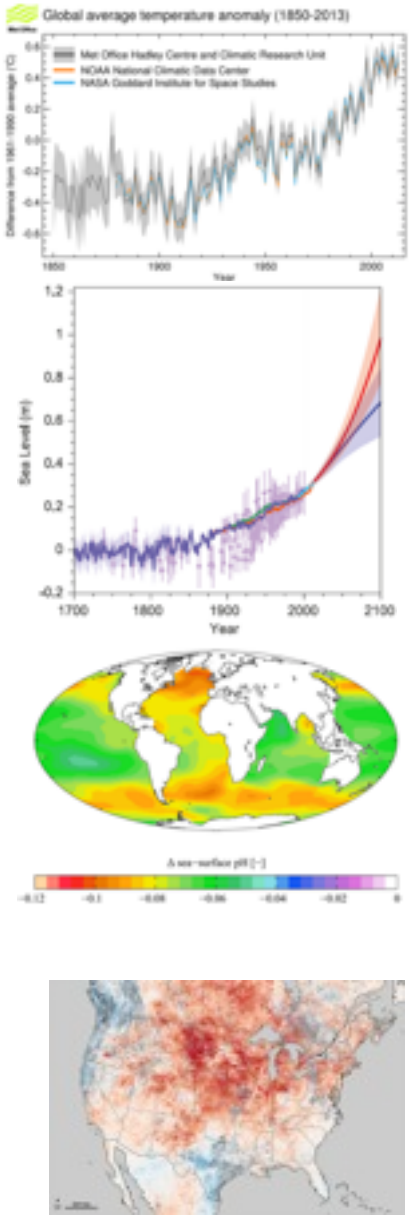
ACER

Outline

- Overwhelming burden of evidence
- Main driving forces of climate change
- Examples of present day climate change
  - Global temperature increase
  - Sea level rise
  - Increasing ocean acidification
  - Increasing extreme events
- Avoiding more extreme climate change
- Summary



Overwhelming Burden of Evidence

Intergovernmental Panel on Climate Change (IPCC) www.ipcc.ch

2007: "Most of the observed increase in globally averaged temperatures since the mid-20th century is very likely **[>90%]** due to the observed increase in anthropogenic greenhouse gas concentrations"

2014: "It is extremely likely **[>95%]** that human influence has been the dominant cause of observed warming since the mid-20th century"

•National science academies explicitly endorse the IPCC consensus and stress that the scientific understanding of climate change is sufficiently clear to justify nations taking prompt action.

Canada, US, UK, China, India, France, Germany, Italy, Japan, Russia, Brazil…

DEPARTMENT OF DEFENSE

2014 CLIMATE CHANGE ADAPTATION ROADMAP

- The U.S. military refers to climate change as a **“threat multiplier”**
- “Among the future trends that will impact our national security is climate change.”
- “Rising global temperatures, changing precipitation patterns, climbing sea levels, and more extreme weather events will intensify the challenges of global instability, hunger, poverty, and conflict.”

Overwhelming Burden of Evidence

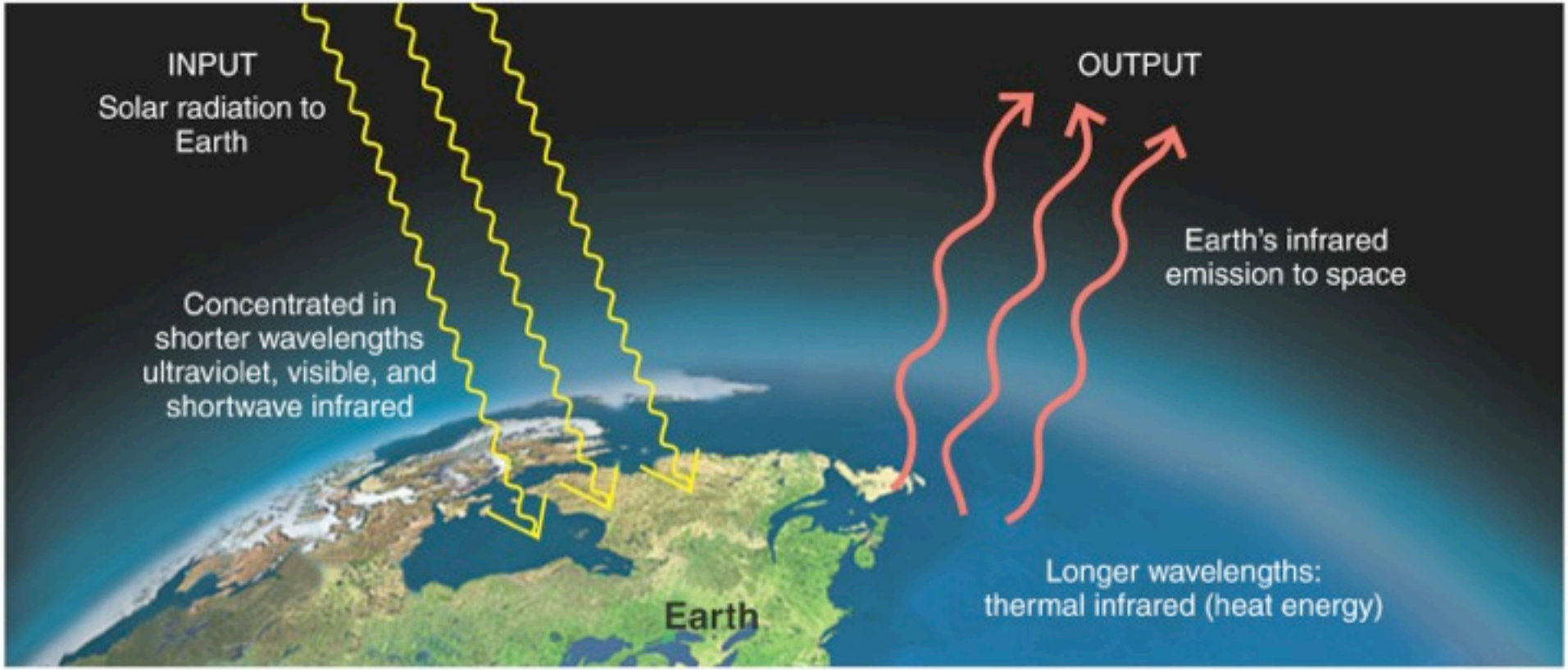
Intergovernmental Panel on Climate Change (IPCC) www.ipcc.ch

2014: 5th Assessment Report (AR5) Summary

- Humans have caused the majority of present day climate change
- The warming is largely irreversible
- Most of the heat is going into the oceans
- Current rates of ocean acidification are unprecedented
- To stay below 2°C of warming, most fossil fuels must stay buried in the ground

Main driving forces of climate change

When the net outgoing thermal energy is equal to the net incoming solar radiation the Earth is in radiative equilibrium



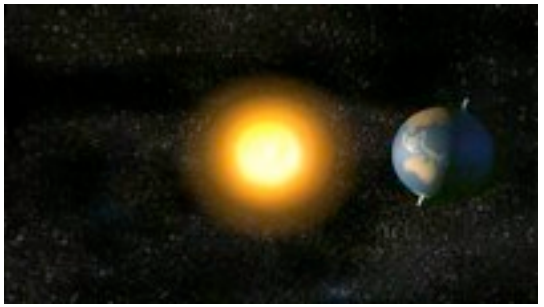
Main driving forces of climate change

When the net outgoing thermal energy is equal to the net incoming solar radiation the Earth is in radiative equilibrium

Deviations from equilibrium imply a radiative forcing

Forcings may be external:

1. Changes in solar output
2. Changes in orbital parameters

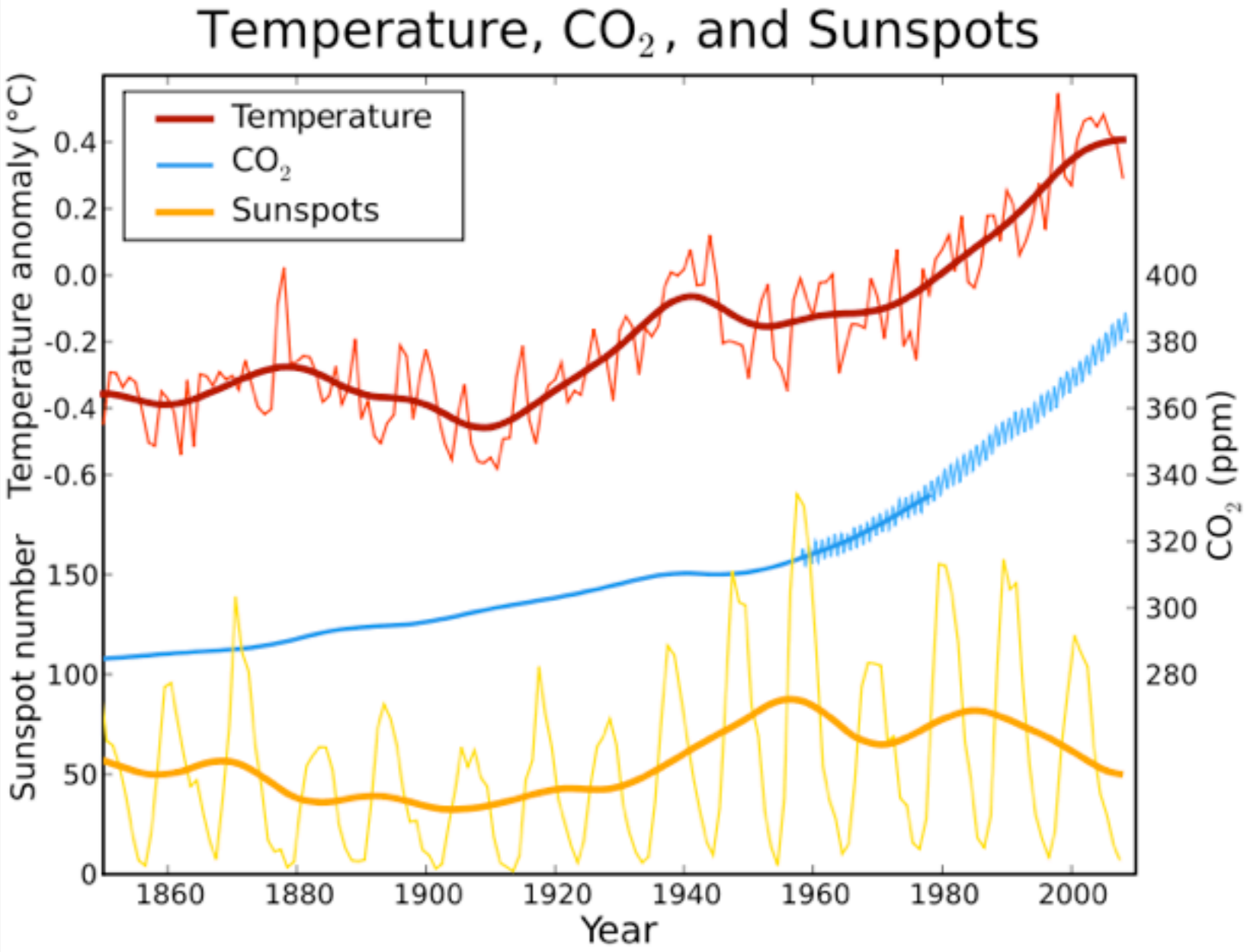


or internal:

3. Changes in surface energy balance
4. Changes in circulation
5. Changes in atmospheric composition

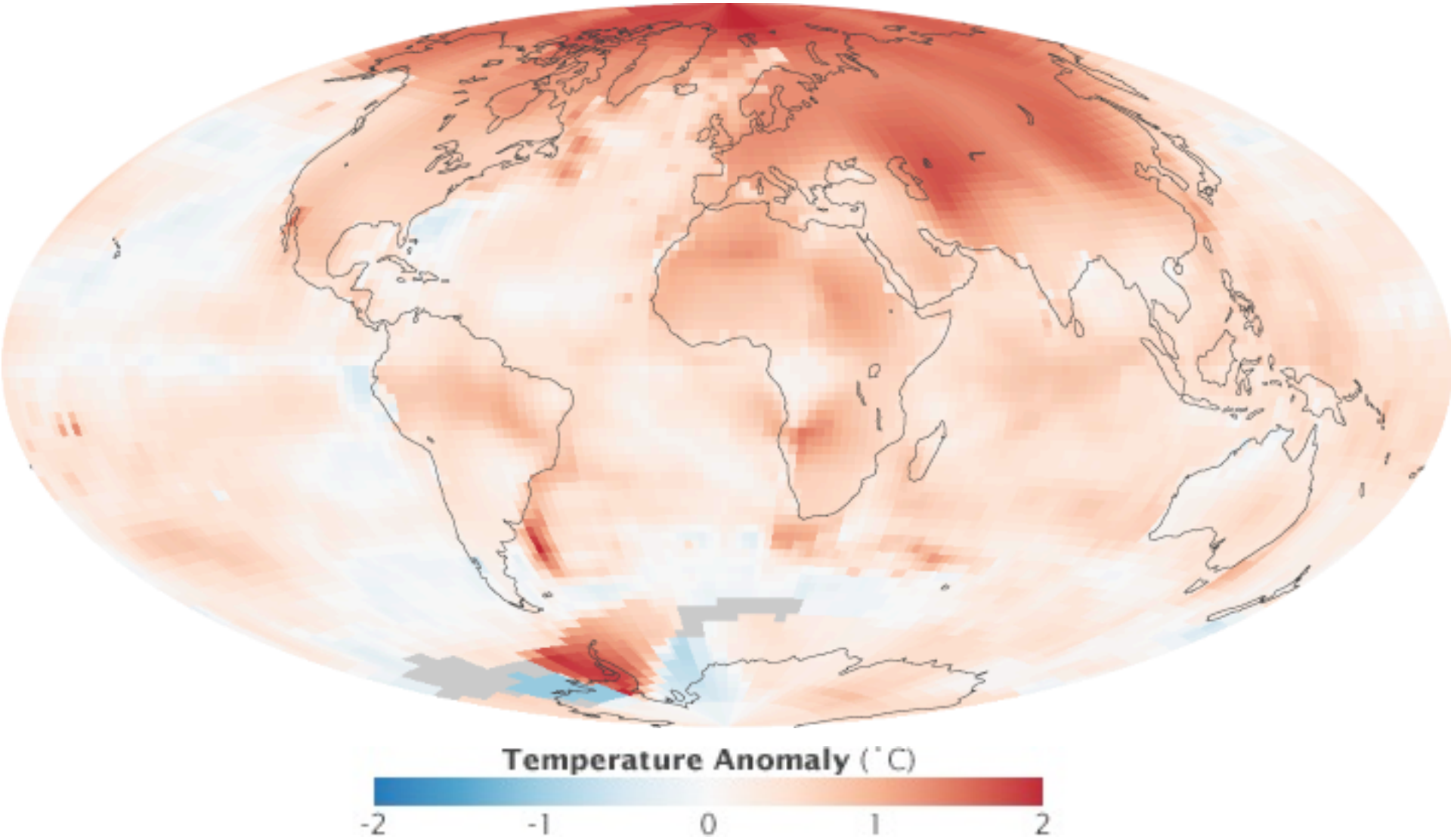
All act all the time but at varying strengths and time scales

Main driving forces of climate change

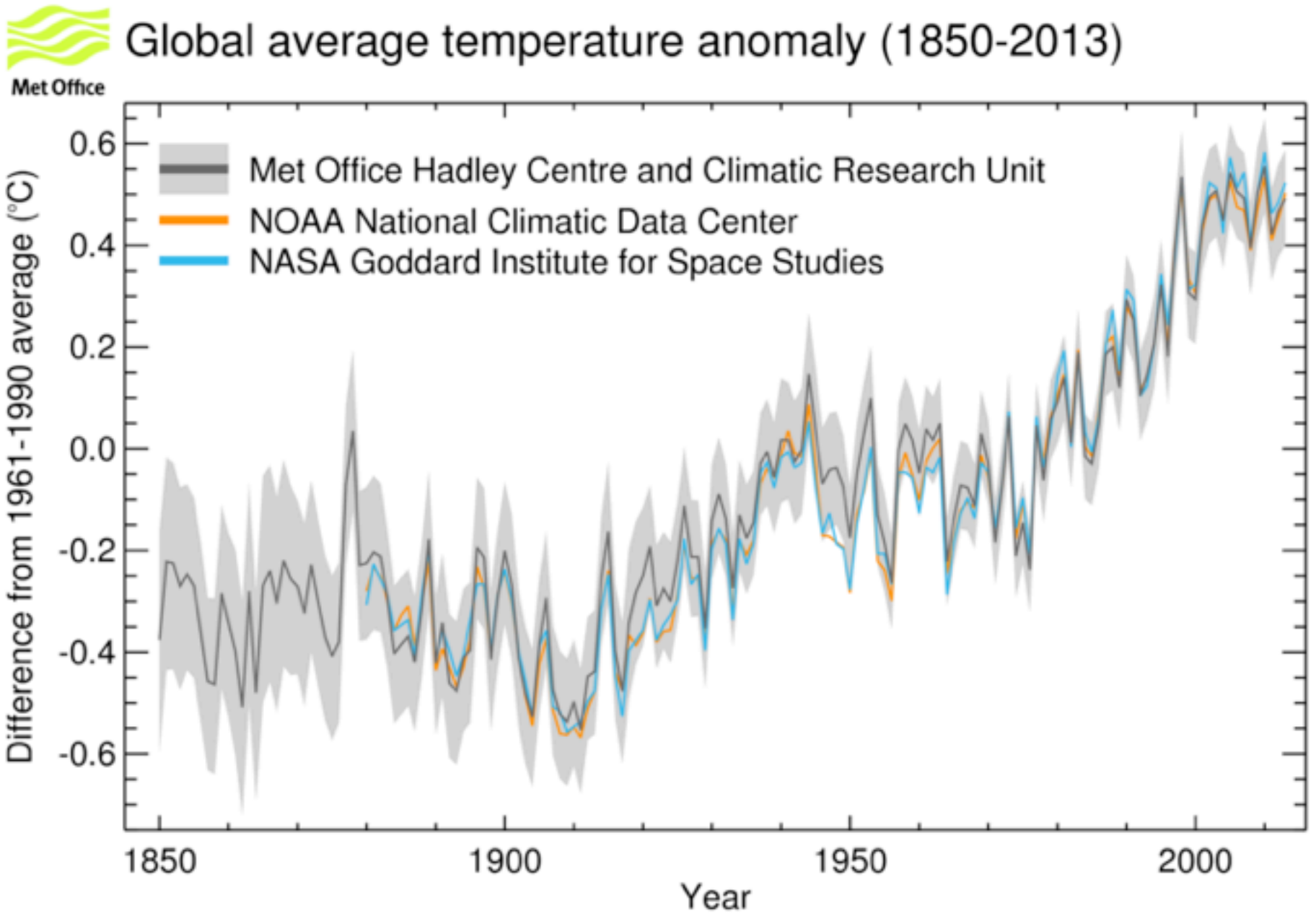


Global Temperature Increase

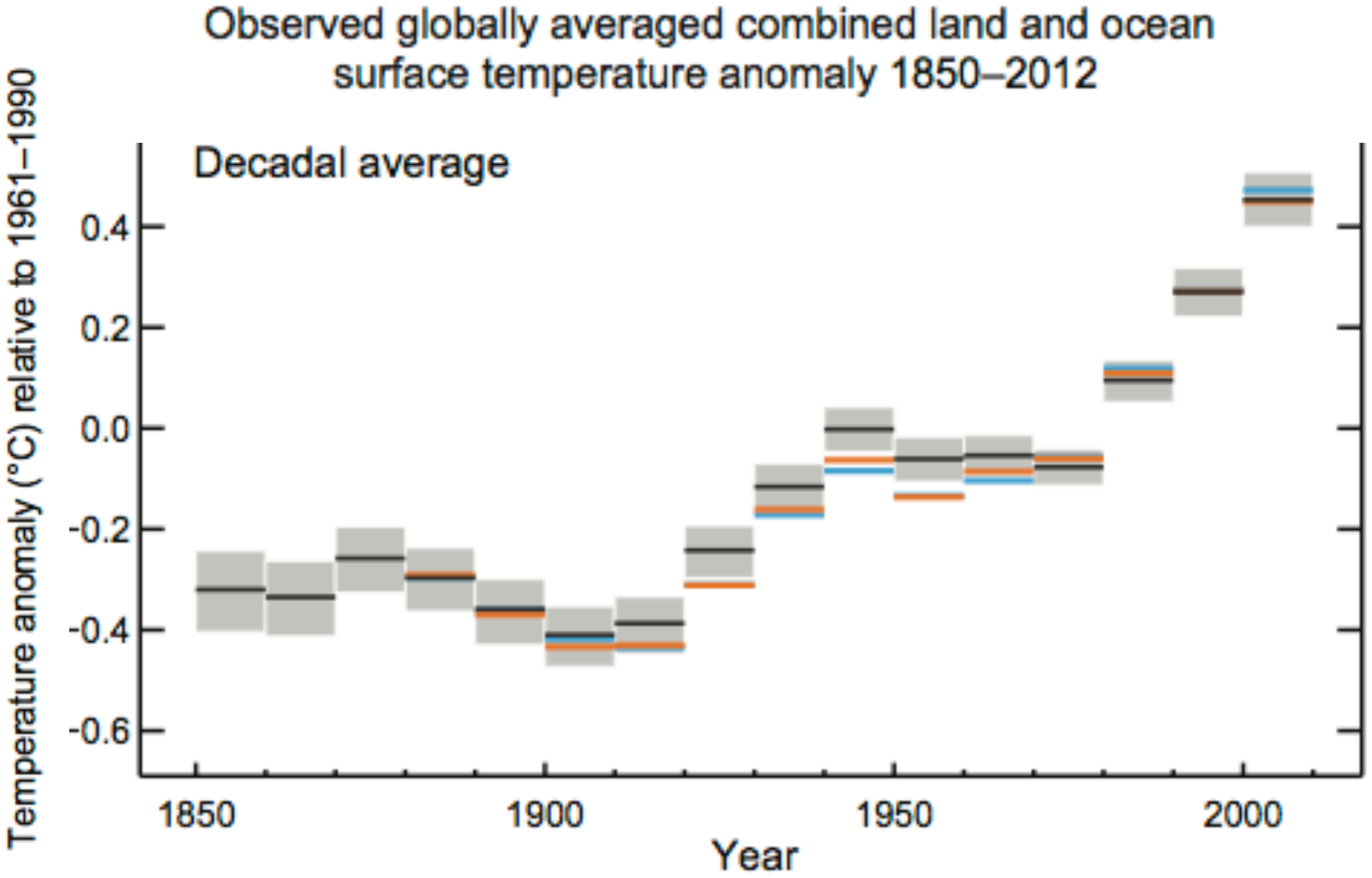
2000-2009 compared to the average of 1951-1980



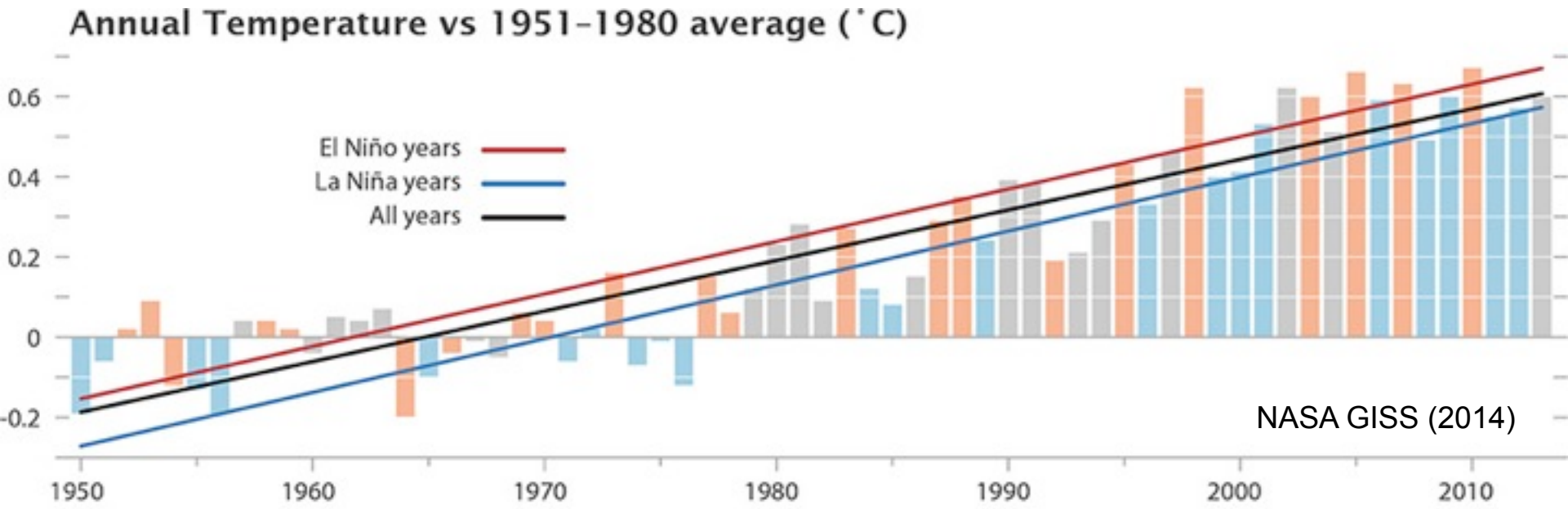
Global Temperature Increase



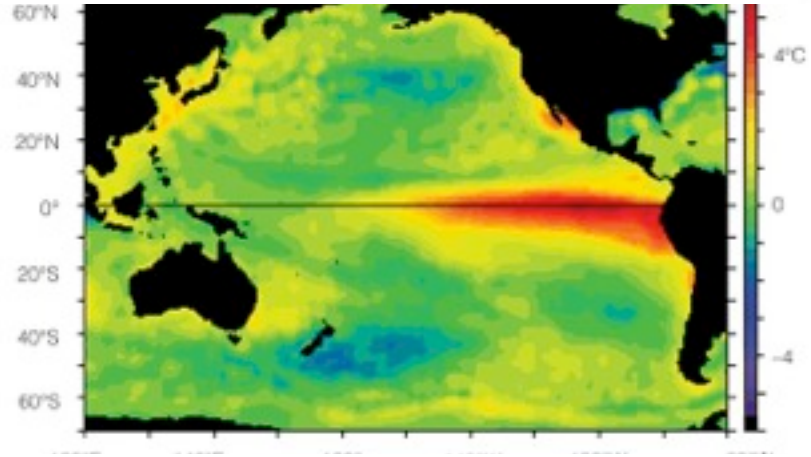
Global Temperature Increase



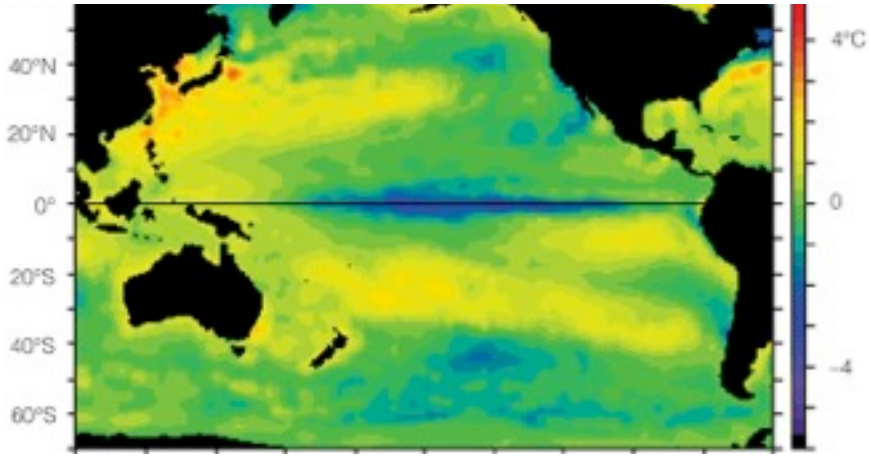
Global Temperature Increase



NASA GISS (2014)

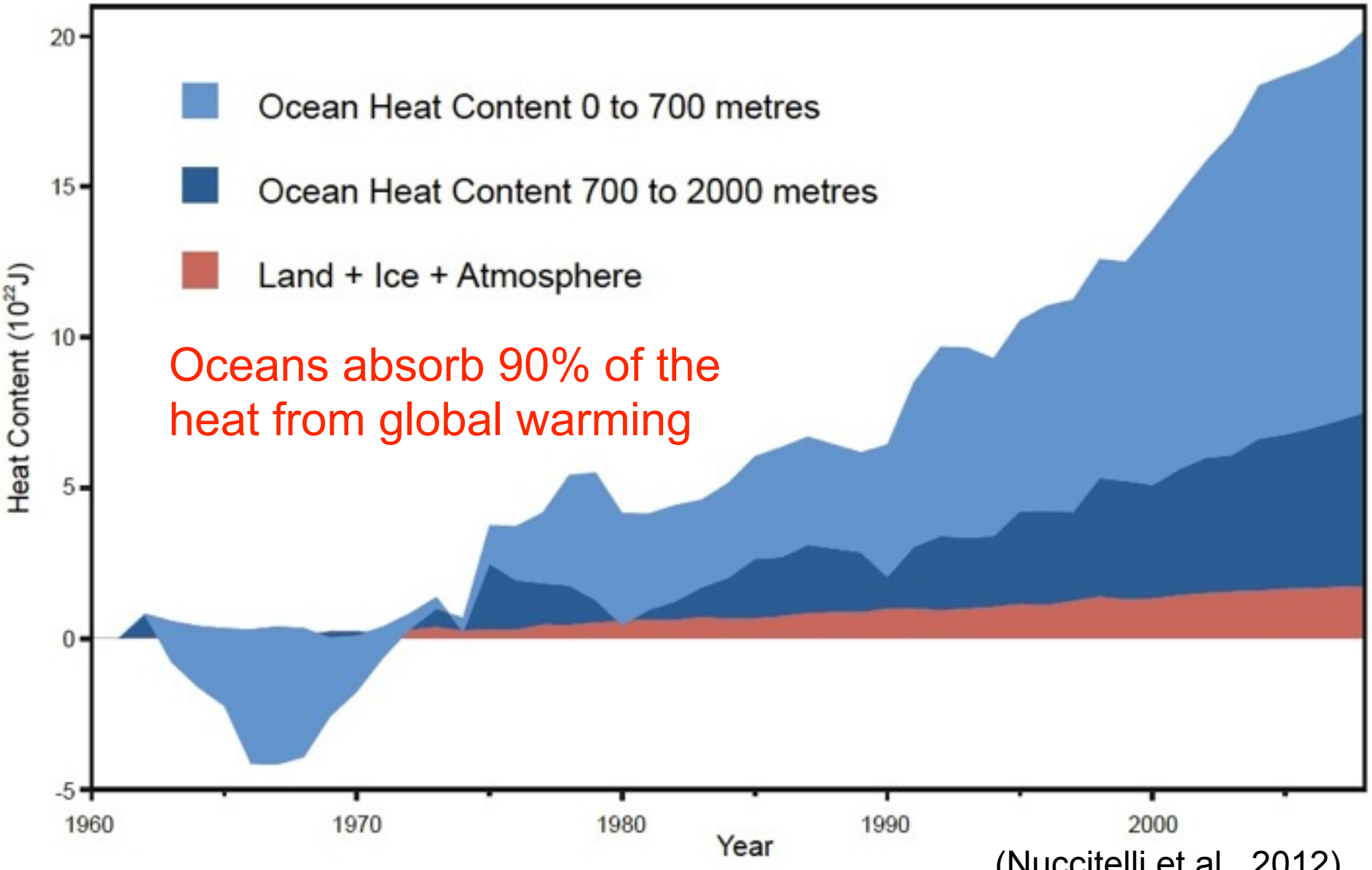


El Niño



La Niña

Global Temperature Increase



(Nuccitelli et al., 2012)

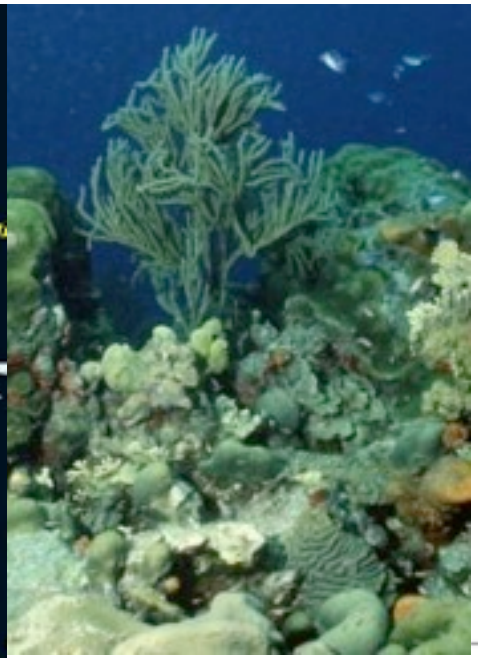
Sea Level Rise

- 20 cm of sea level rise in the last century
- Sea level rise is currently rising at 3.4 cm per decade
- Average rate from 1950 – 2009 was 1.7 cm per decade

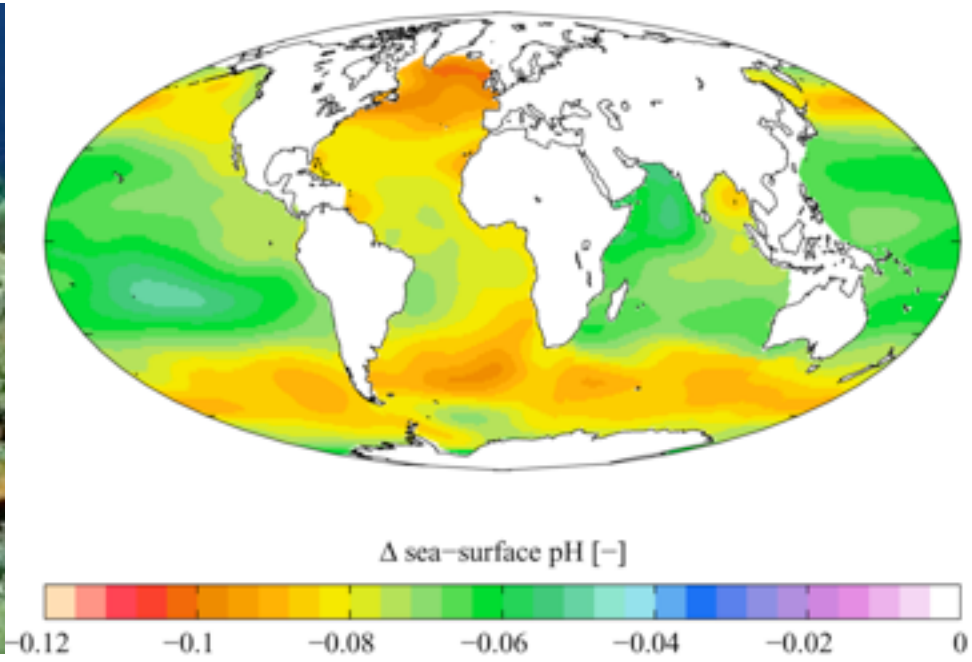
Increasing Ocean Acidification

- Carbon dioxide dissolves in water to make carbonic acid
- Dissolves the shells of many marine organisms

Plankton
(Calcite)



Corals
(Aragonite)



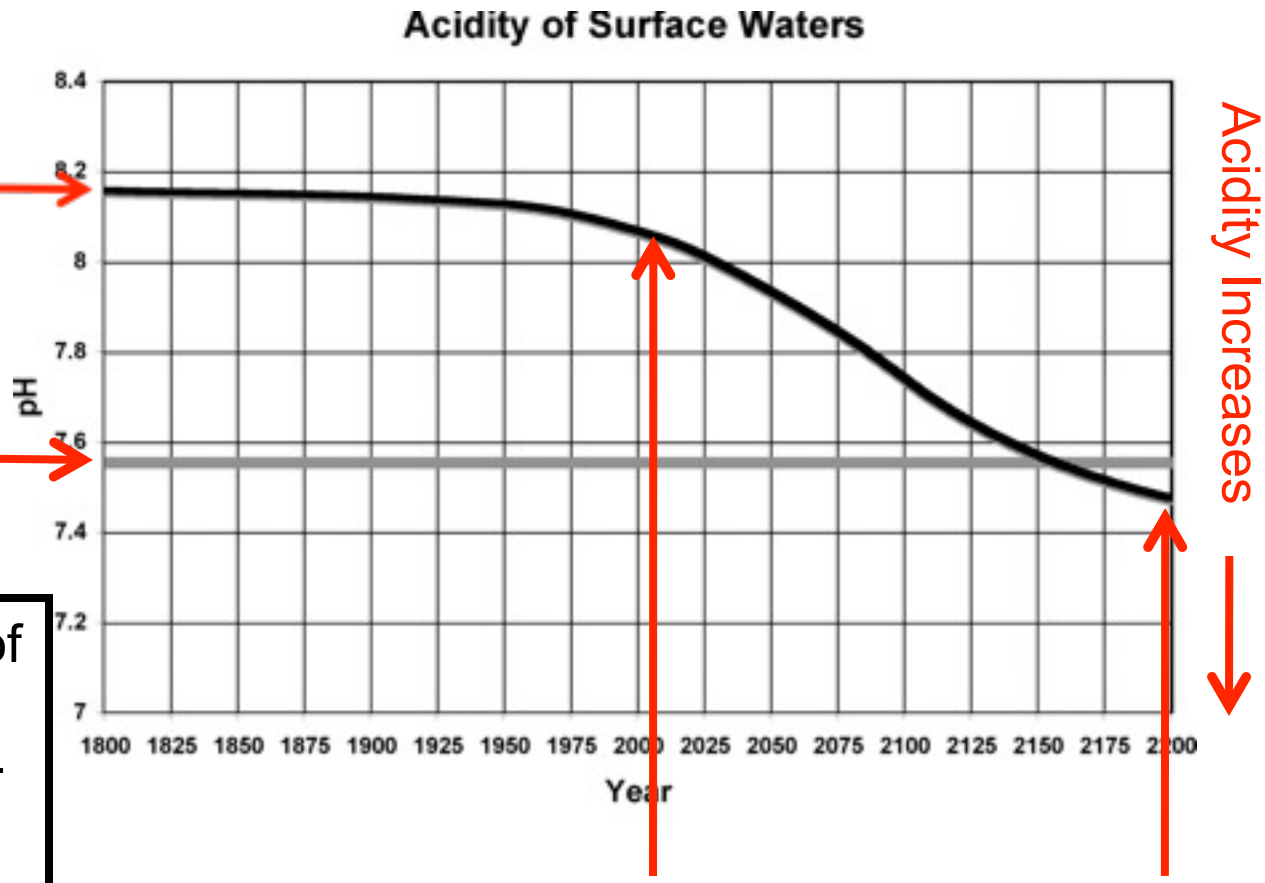
← Increasing Acidity

Increasing Ocean Acidification

Ocean acidification

pH of preindustrial surface ocean

pH 0.6 below preindustrial value



"There is no evidence of pH values more than 0.6 units below the pre-industrial pH during the past 300 million years "

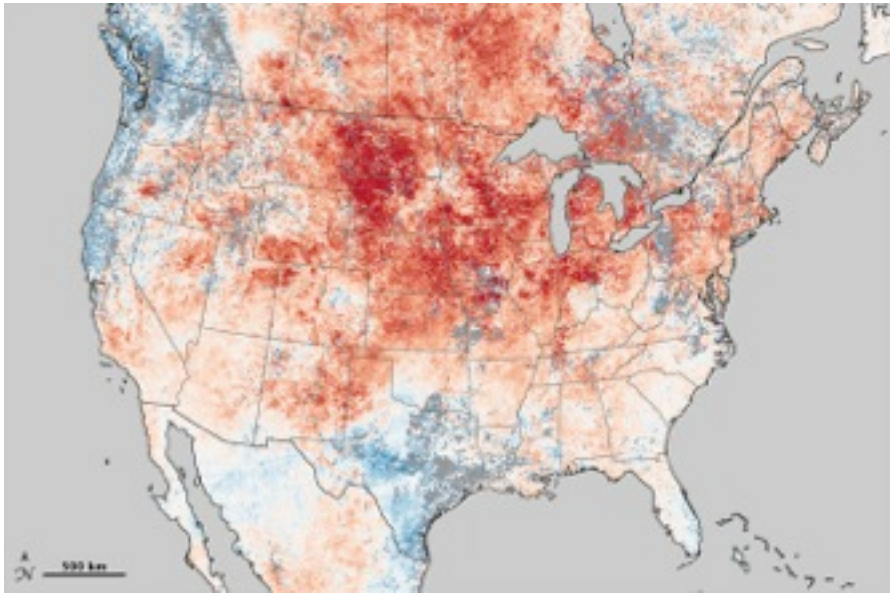
IPCC AR4, 2007

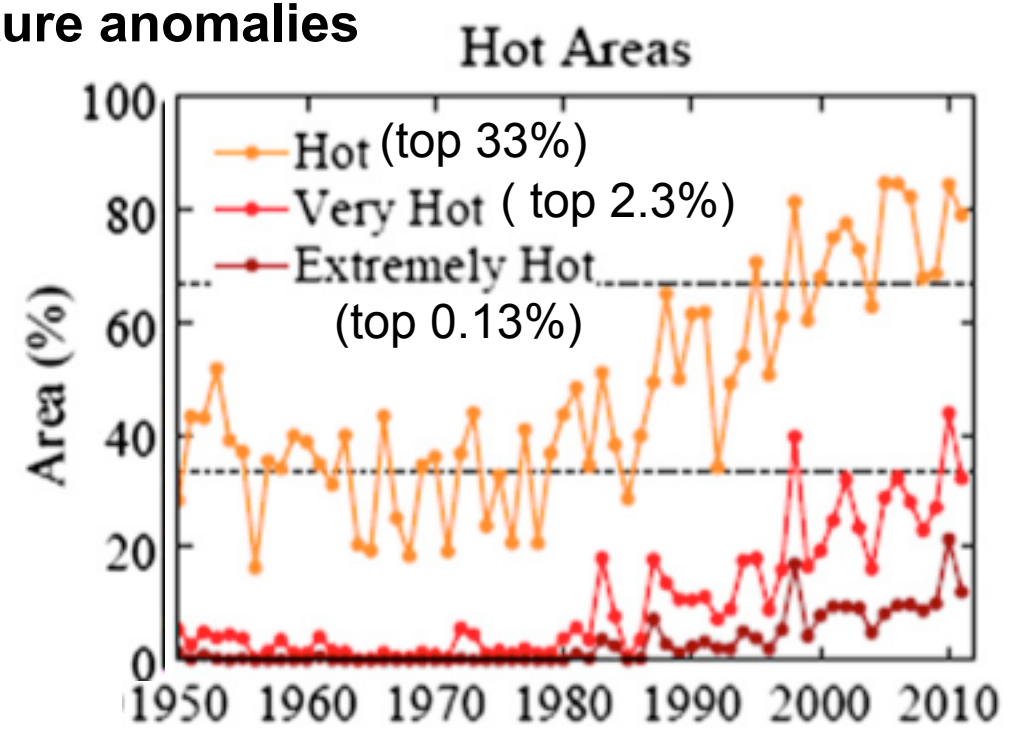
pH drop of 0.1 since preindustrial times (30% increase in ocean surface acidity)

pH drop of 0.7 by year 2200

Increasing Extreme Events

Summer temperature anomalies

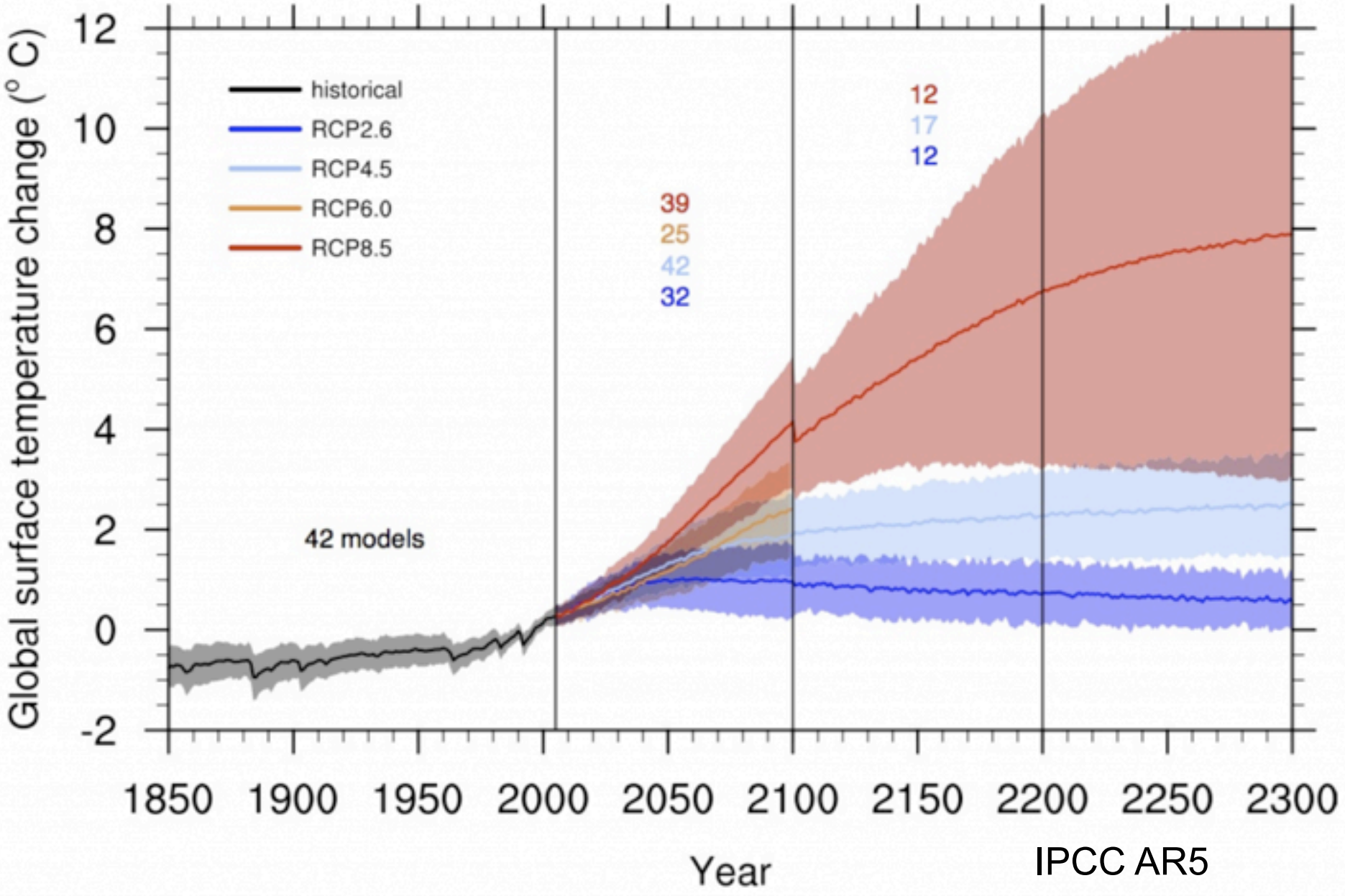




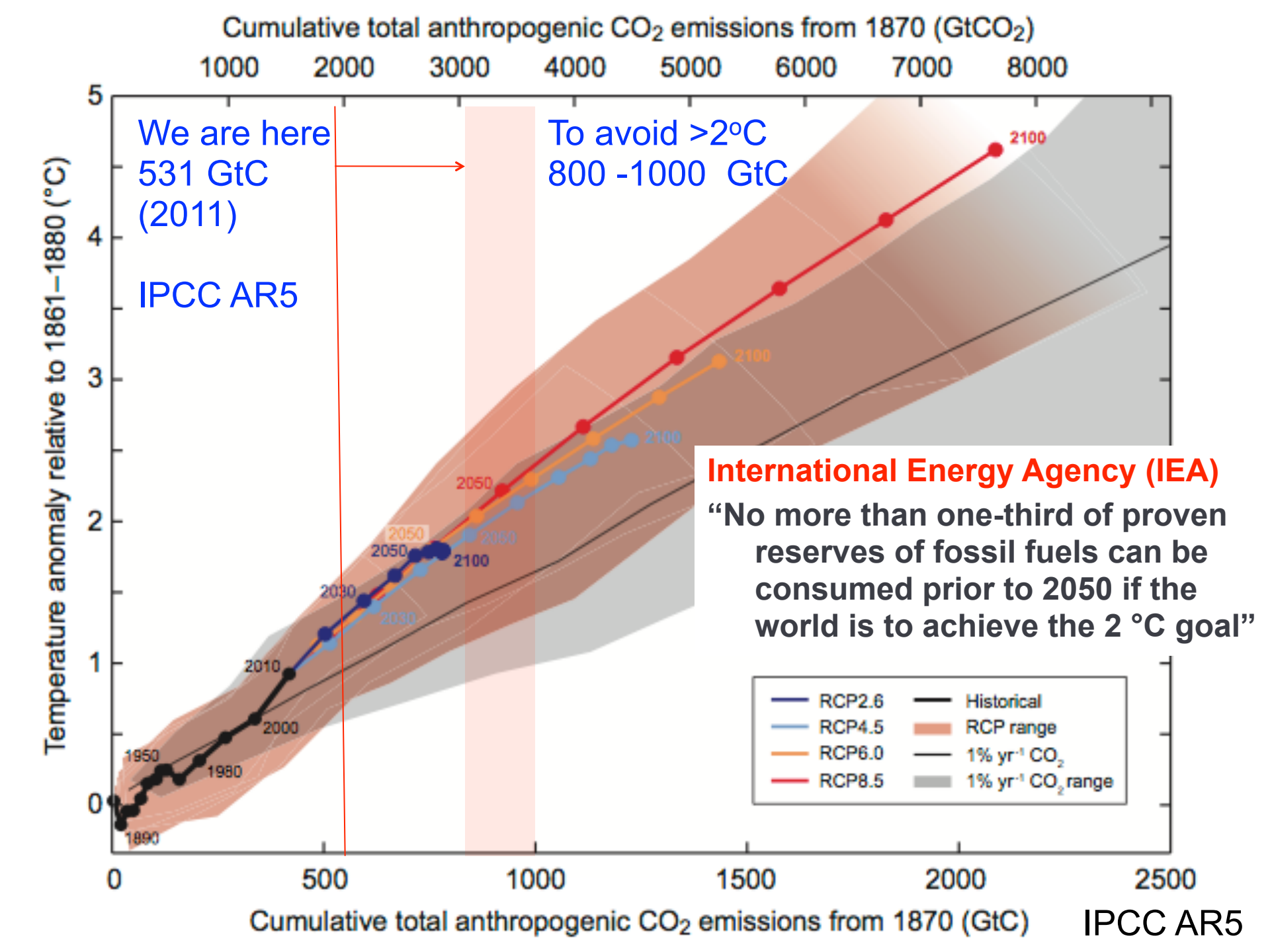
(Hansen et al., 2012)

- Instead of asking “Was this event caused by climate change”
- Ask “What is the chance that this event would occur without climate change?”
- Extreme temperature events are 10 times more common

Avoiding more extreme climate change



IPCC AR5


Cumulative total anthropogenic CO_2 emissions from 1870 ($GtCO_2$)
1000
2000
3000
4000
5000
6000
7000
8000
We are here
531 GtC
(2011)
IPCC AR5
To avoid >2°C
800 -1000 GtC
2100
2100
2100
2050
2050
2050
2050
2030
2030
2010
2000
1980
1950
1890
International Energy Agency (IEA)
"No more than one-third of proven reserves of fossil fuels can be consumed prior to 2050 if the world is to achieve the 2 °C goal"
RCP2.6
RCP4.5
RCP6.0
RCP8.5
Historical
RCP range
1% yr⁻¹ CO_2
1% yr⁻¹ CO_2 range
Temperature anomaly relative to 1861–1880 (°C)
0
1
2
3
4
5
0
500
1000
1500
2000
2500
Cumulative total anthropogenic CO_2 emissions from 1870 (GtC)
IPCC AR5

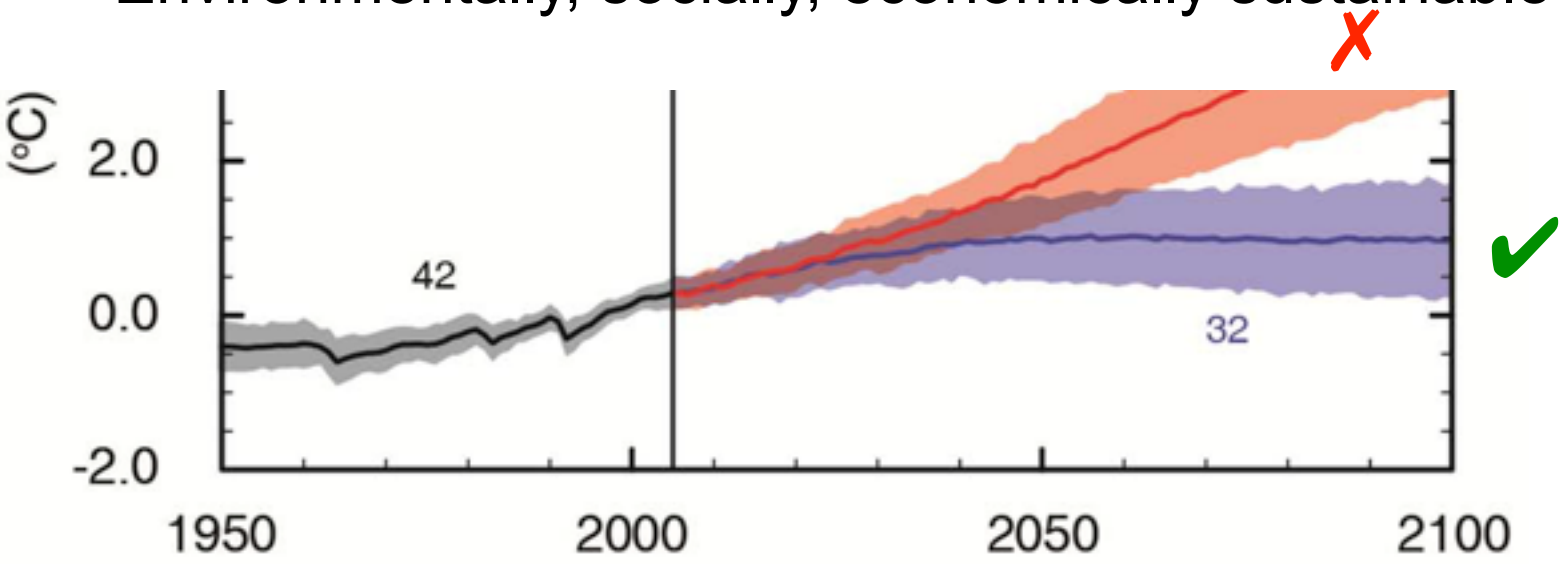
Avoiding more extreme climate change

"I have a dream…" Martin Luther King, Jr (1963)

The best strategy is a vision, not a plan

A sustainable vision for the future has to be:

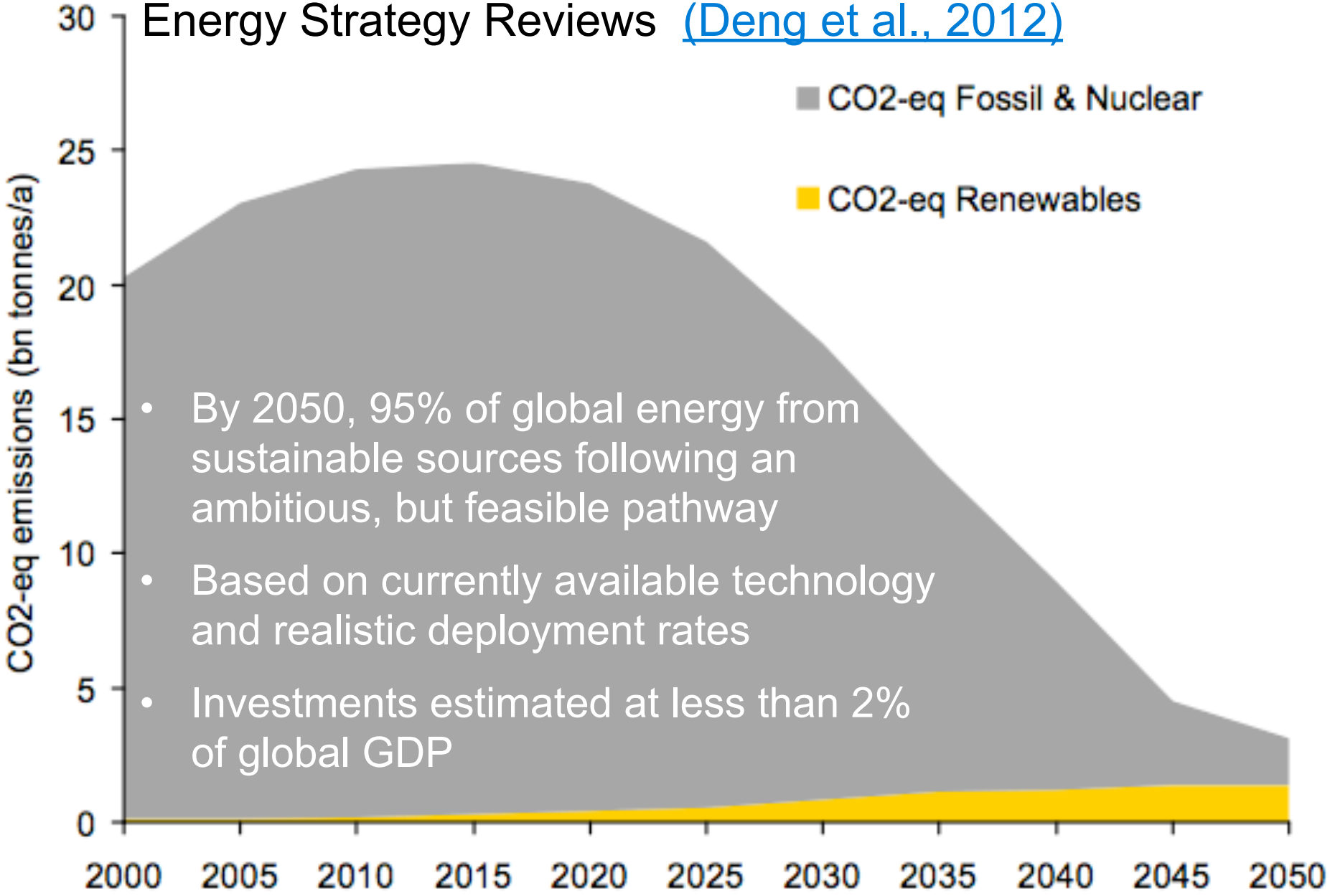
1) highly positive
2) believable
3) responsive (addresses multiple issues)
   - Environmentally, socially, economically sustainable



We need to actively advertise an attractive future!

Transition to a fully sustainable global energy system:

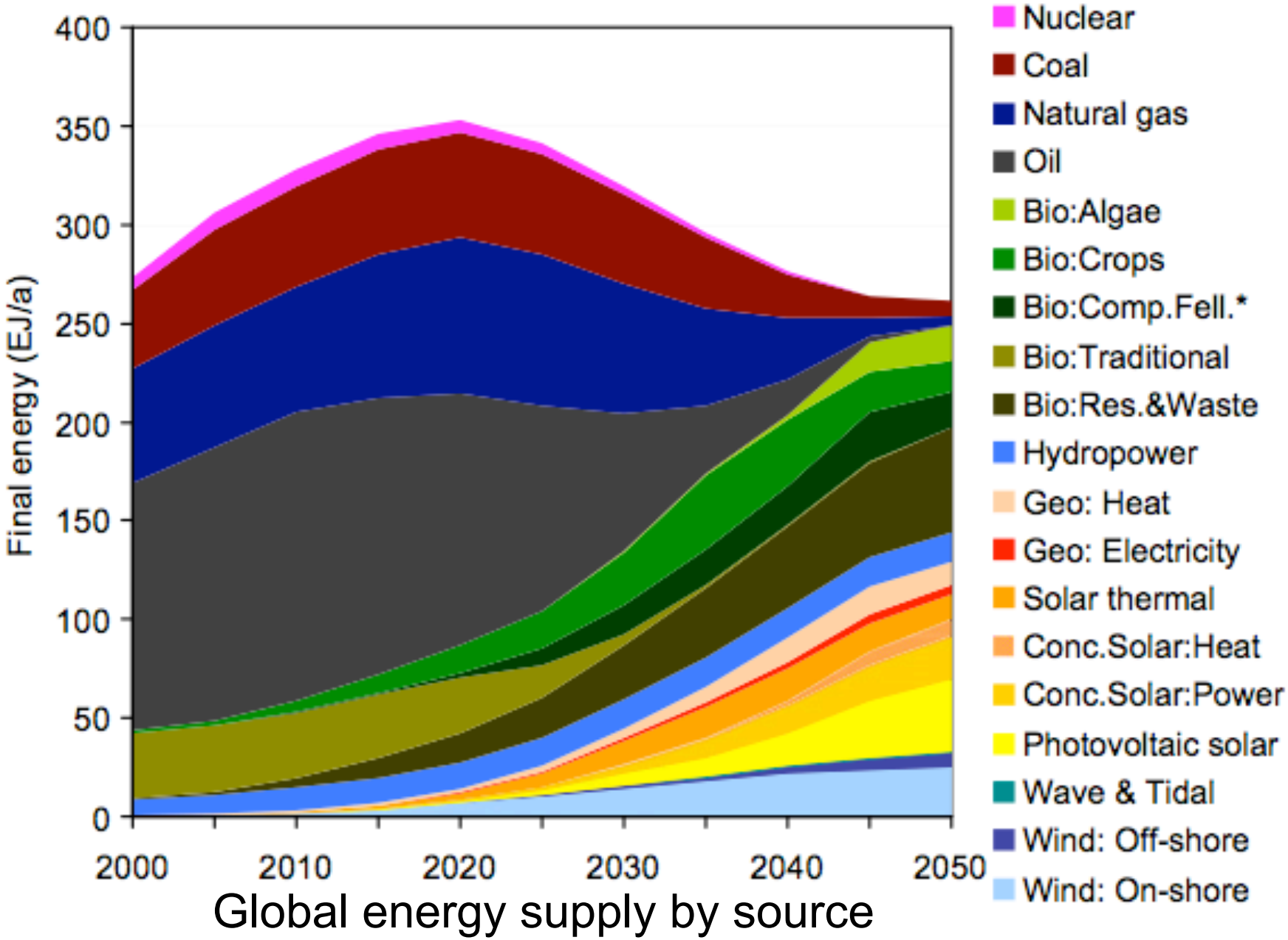
Energy Strategy Reviews (Deng et al., 2012)



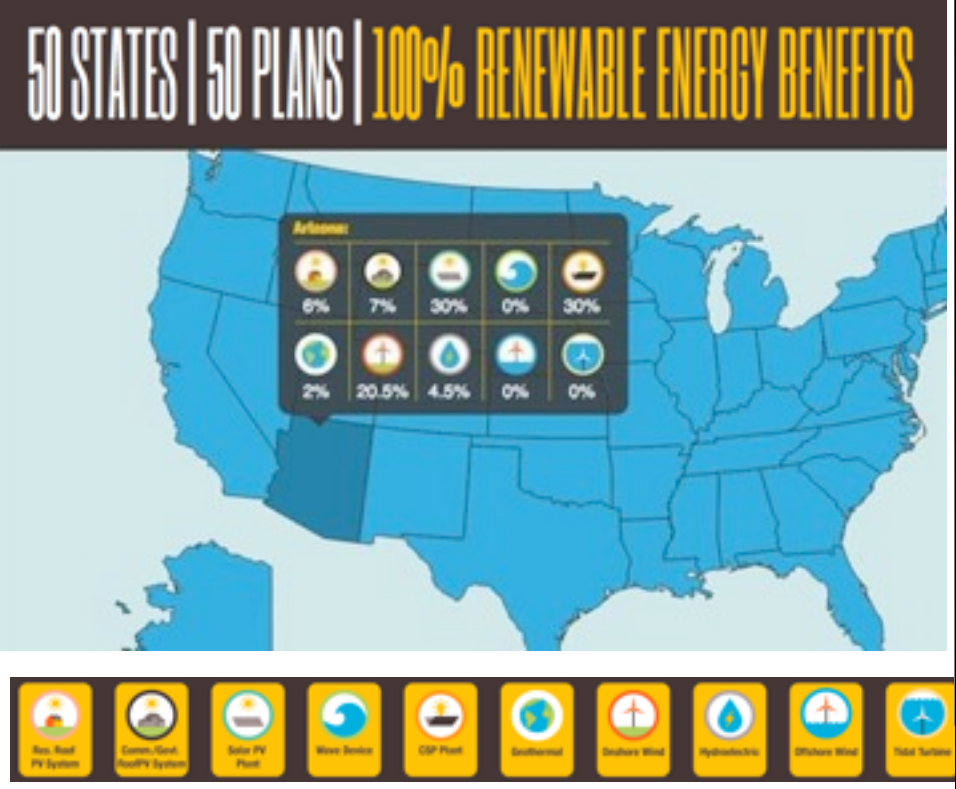
Global GHG emissions from energy system

Transition to a fully sustainable global energy system:

Energy Strategy Reviews (Deng et al., 2012)



Global energy supply by source



BETTER GROWTH BETTER CLIMATE

The New Climate Economy Report

1

To slash or to trim

Emission reductions by policies/actions, bn tonnes CO_2 equivalent

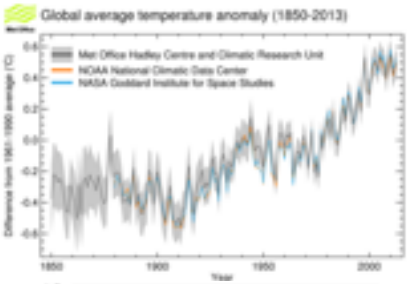
The Economist

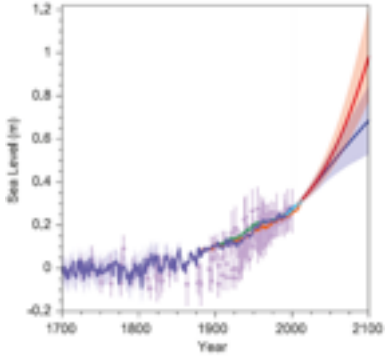
Policy/Action	Cumulative emissions	Period	Annual emissions*
Montreal protocol[1]	135.0bn	1989-2013	5.6bn
Hydropower worldwide[2]	2.8bn	2010	2.8bn
Nuclear power worldwide[2]	2.2bn	2010	2.2bn

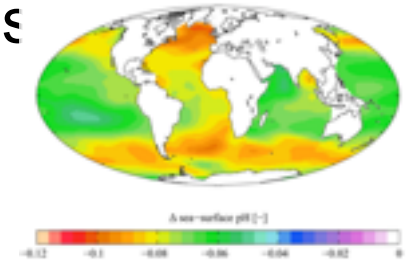
Policy can make a significant difference!

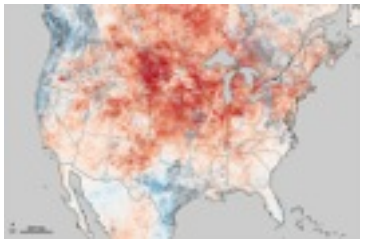
Summary

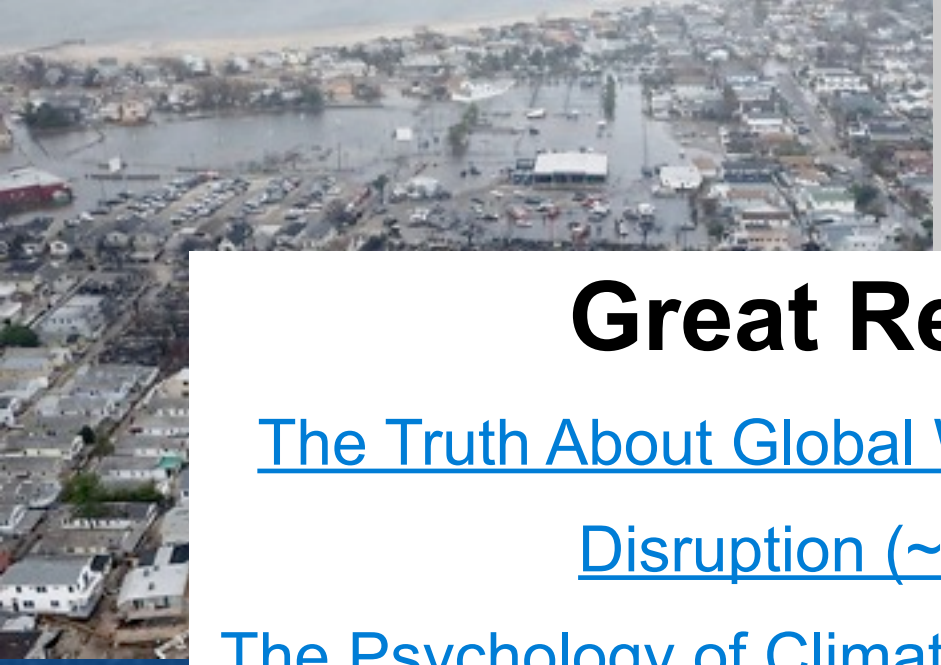
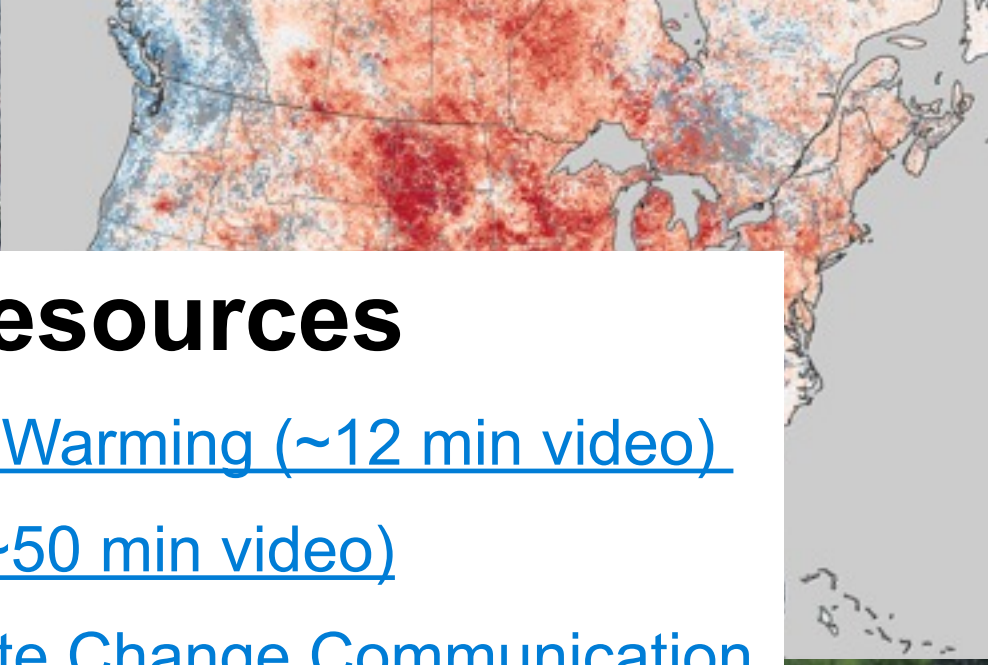
- Humans have caused the majority of present day climate change
- Sea level is rising
- Oceans are becoming more acidic
- The frequency of extreme events is increasing
- To stay below 2°C of warming, most fossil fuels must stay buried in the ground
- We have a positive, sustainable vision for the future that can be implemented with existing technology









Great Resources

[The Truth About Global Warming (~12 min video)]

[Disruption (~50 min video)]

[The Psychology of Climate Change Communication]

[Skeptical Science]

[IPCC]