What's New in Climate Science?

Kathleen C. Weathers, Cary Institute of Ecosystem Studies, Millbrook, NY

What Might Eleanor Say?

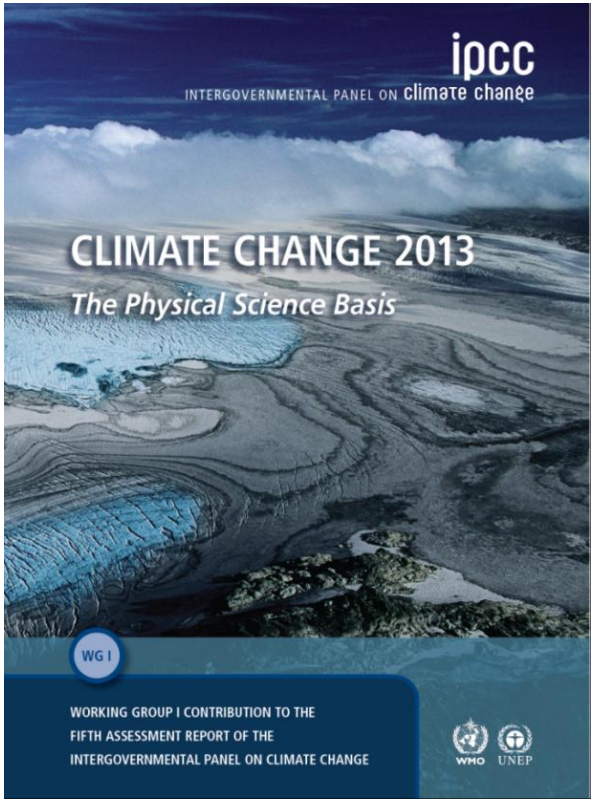
Knowledge is power; knowledge undergirds responsible and targeted action

Change…?!

http://docs.fdrlibrary.marist.edu/images/photodb/09-2442a.gif

What's New?

- Consensus Reports: IPCC and National Climate Assessment
- Human influence on climate system is clear (IPCC)
- Oceans are acidifying
- Extreme weather
- Model improvements



Context (scientific culture)

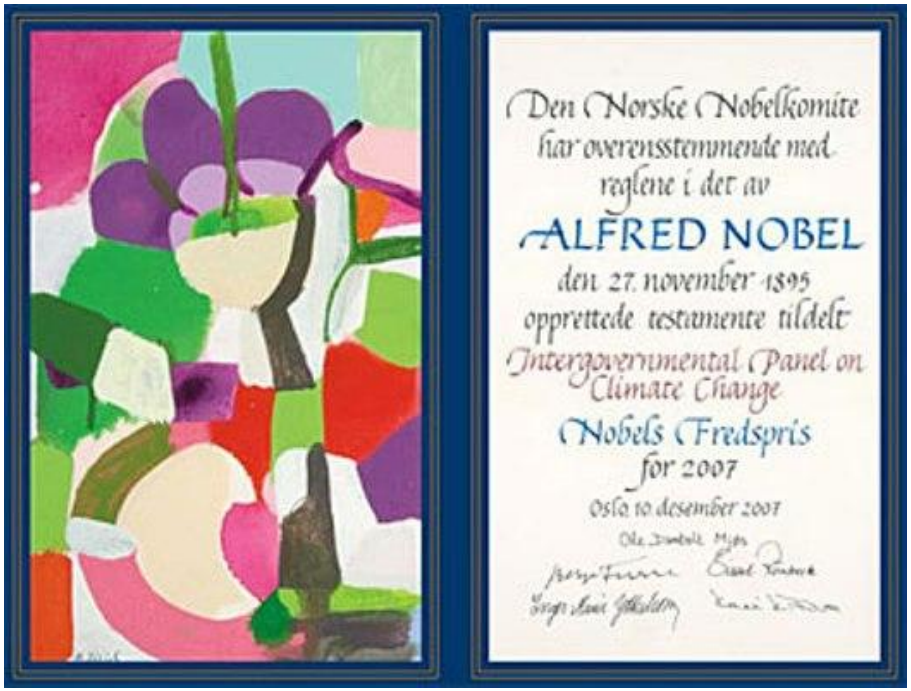
Milton Visiting Galileo when a Prisoner of the Inquisition

photo credit: Wellcome Library

Scientific Consensus?

New in the last 25 years

- Inter governmental Panel on Climate Change (IPCC) created in 1988—WMO and UNEP
- Reports
  - 1990
  - 1995
  - 2001
  - 2007
  - 2013-2014

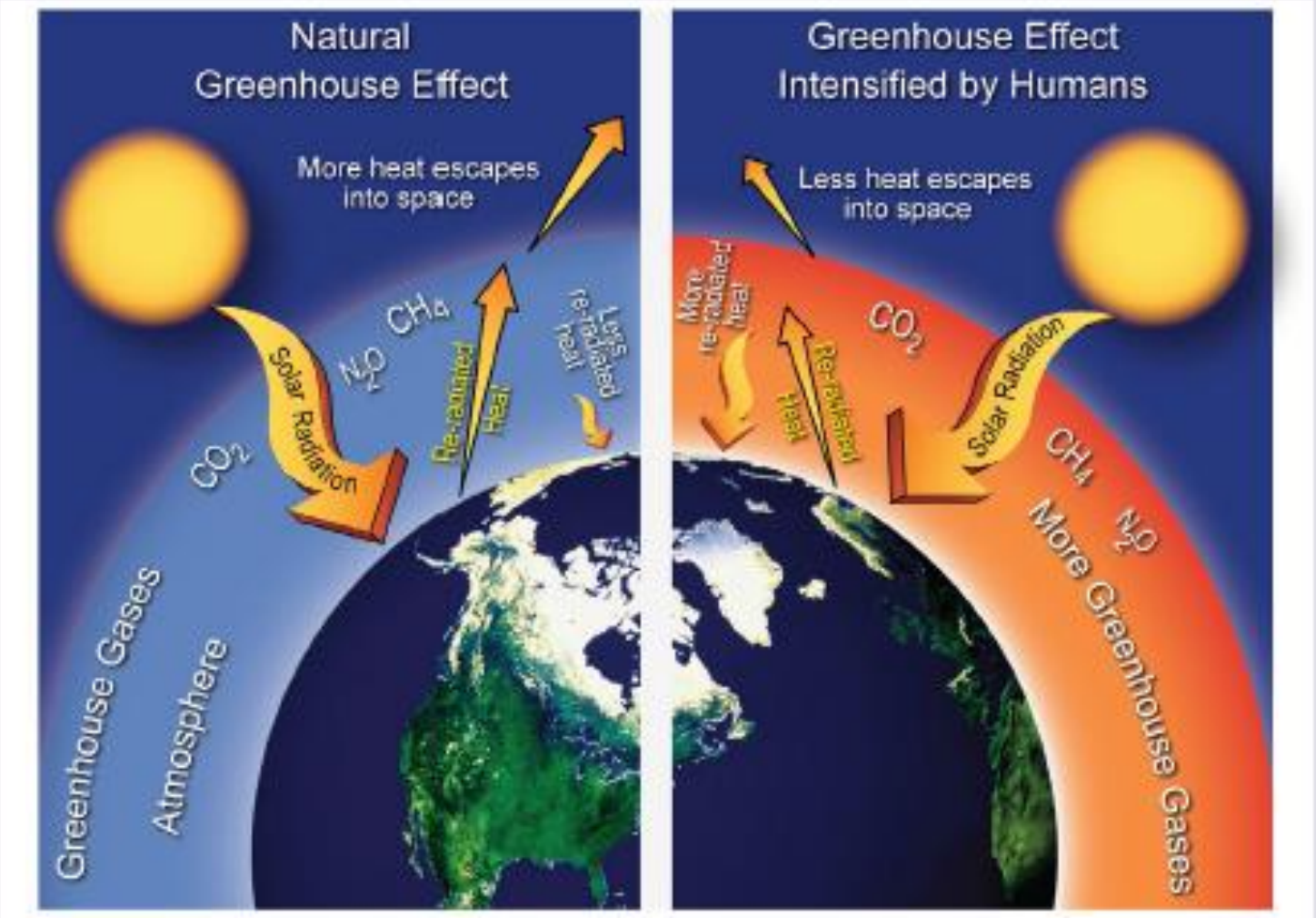


Science of Climate Change: What Do We Know?

Bottom lines throughout talk drawn from IPCC and NCA reports
http://www.ipcc.ch/ ; http://nca2014.globalchange.gov/

- Human activities have increased greenhouse gases (GHG)
- Greenhouse gases:
  - strengthen greenhouse effect
  - contribute to global warming
- Atmosphere and oceans have become warmer
- Snow and ice have diminished; Glaciers are melting
- Sea level is rising
- Ocean is becoming more acidic

Human Influence on the Greenhouse Effect

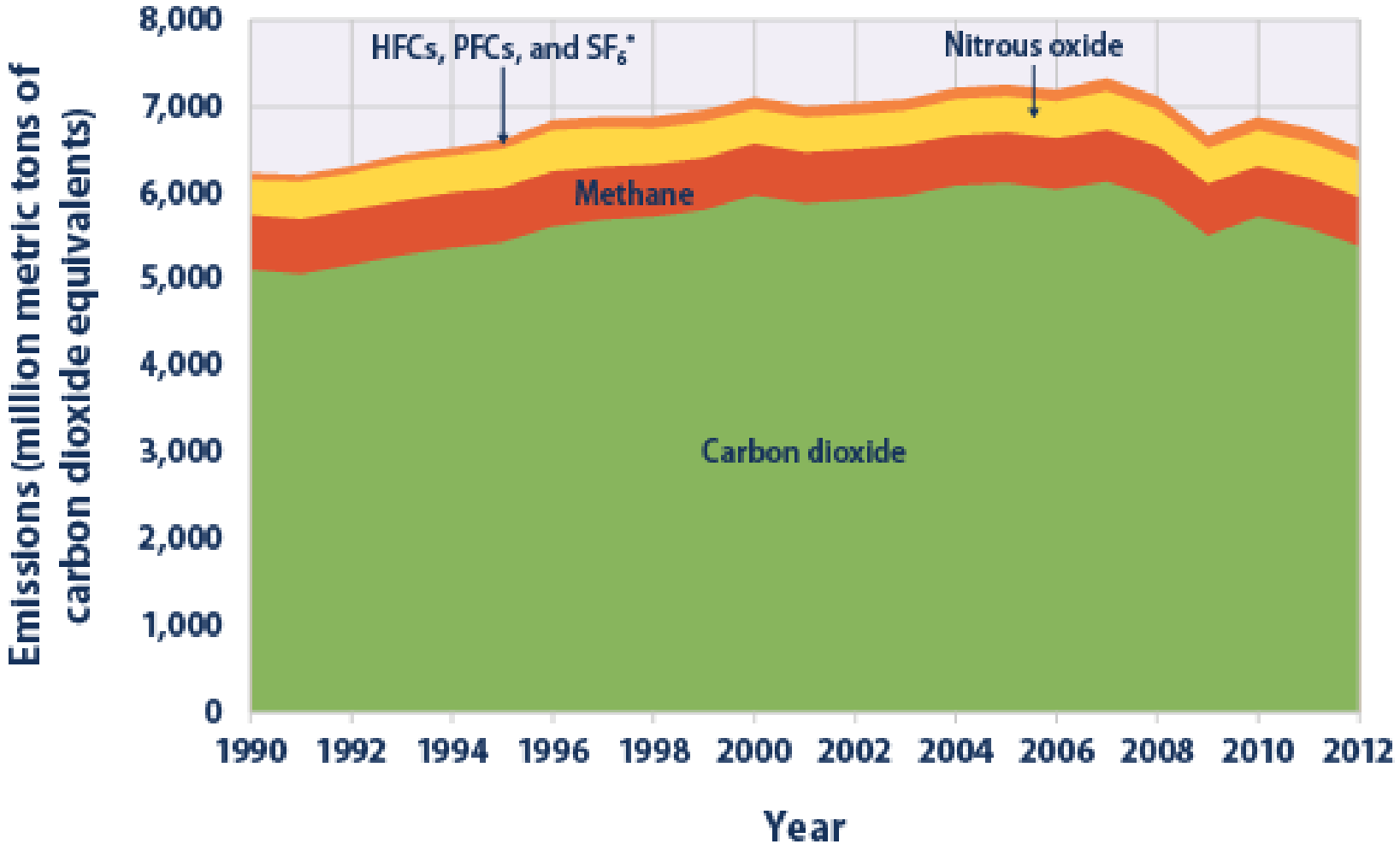


Credit: Will Elder, National Park Service

Greenhouse Gases

- **Carbon Dioxide**
- Nitrous Oxide
- Methane
- Ozone
- Others (HFCs, etc)
- (water)

Figure 1. U.S. Greenhouse Gas Emissions by Gas, 1990–2012



Source: US EPA: http://www.epa.gov/climatechange/science/indicators/ghg/us-ghg-emissions.html

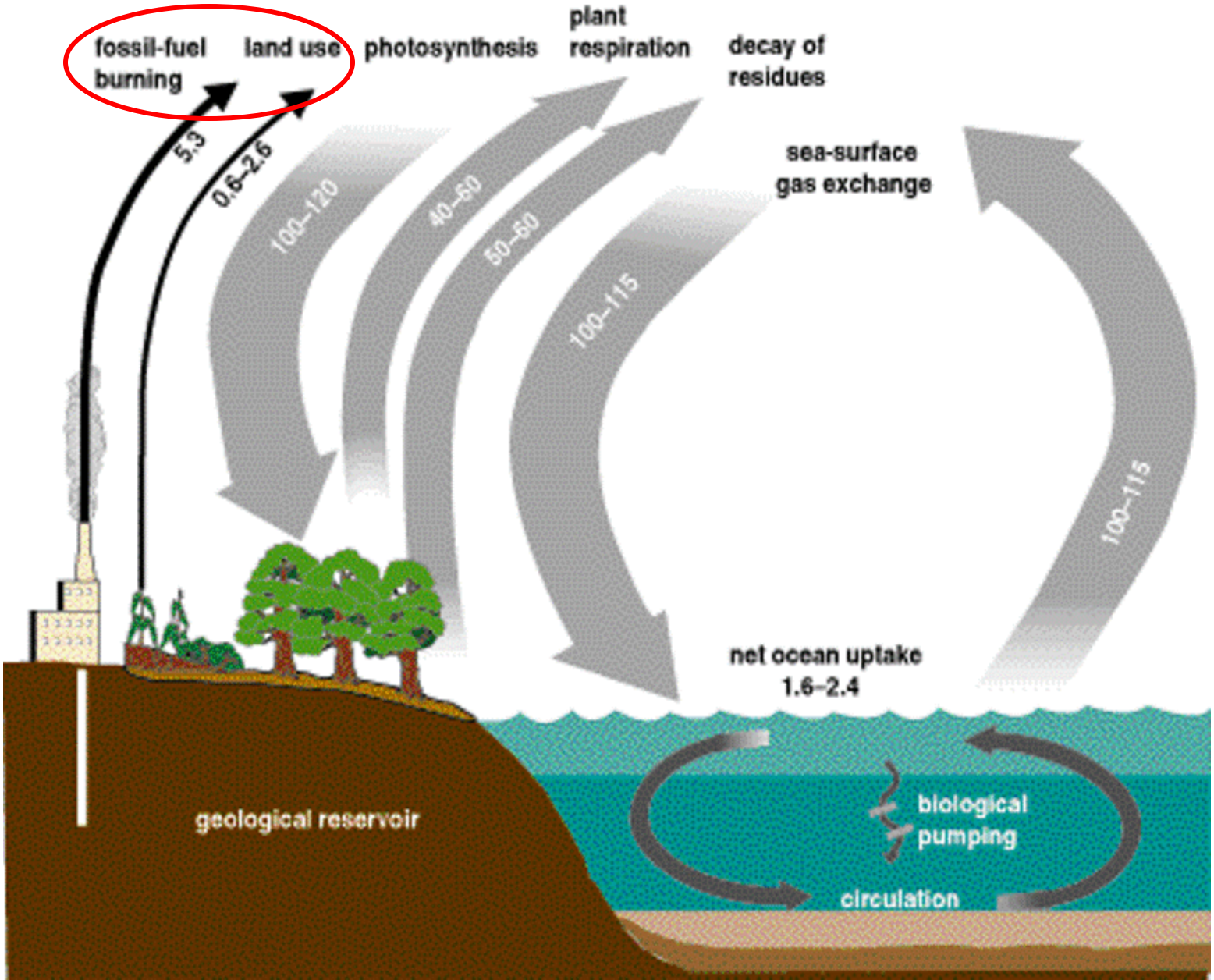
* HFCs are hydrofluorocarbons, PFCs are perfluorocarbons, and SF_6 is sulfur hexafluoride.

Sources

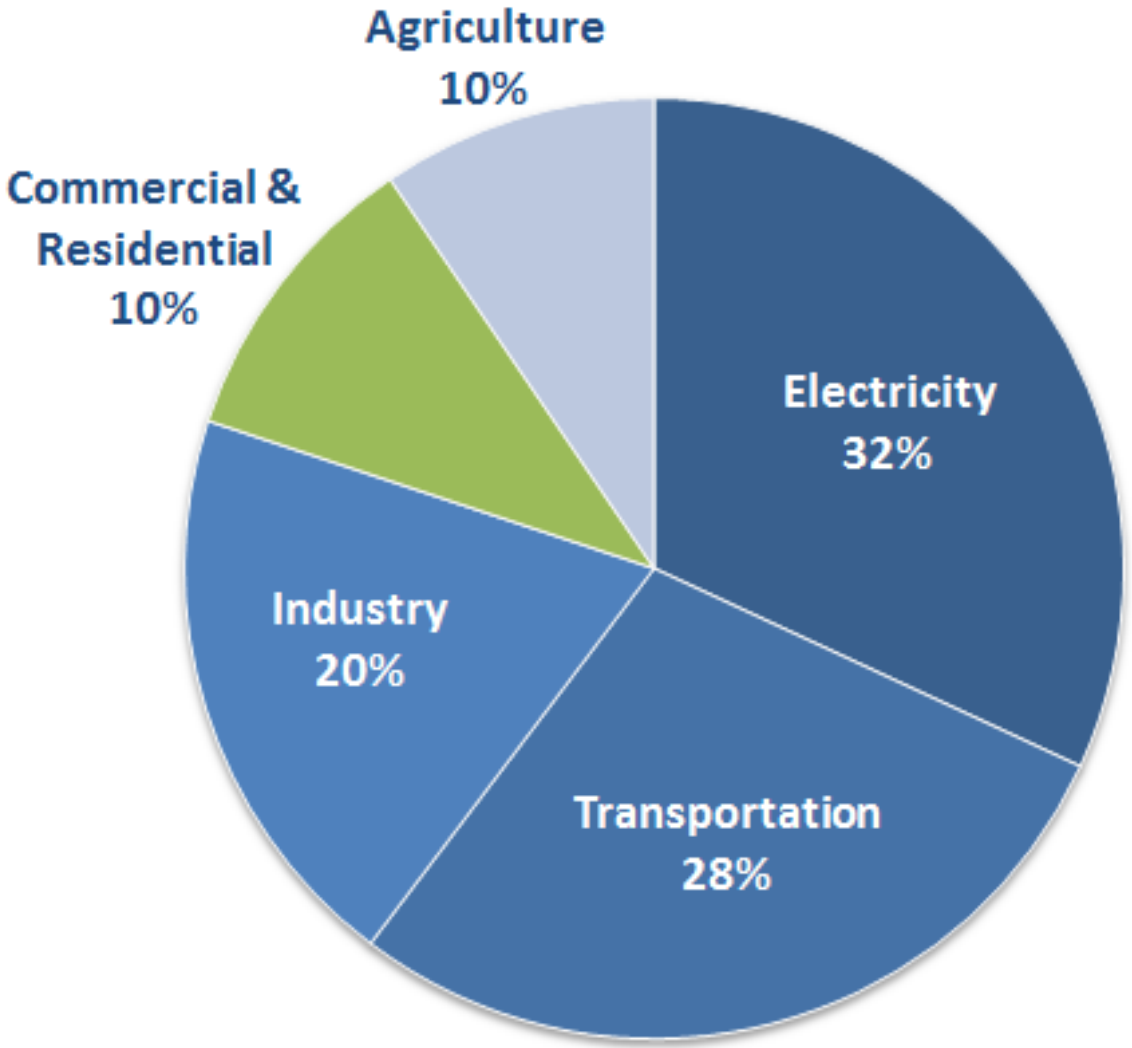
What are the Sources of Carbon Dioxide (CO_2) in the Atmosphere?

- Dead things rotting
- Live things respiring (including plants)
- Water bodies (belching)
- Burning (biomass)
- Burning of fossil fuels
  - electricity
  - transportation

Global Carbon Dioxide (CO_2) Cycling



Energy Production is the Largest Driver of GHG Emissions: Human Influence



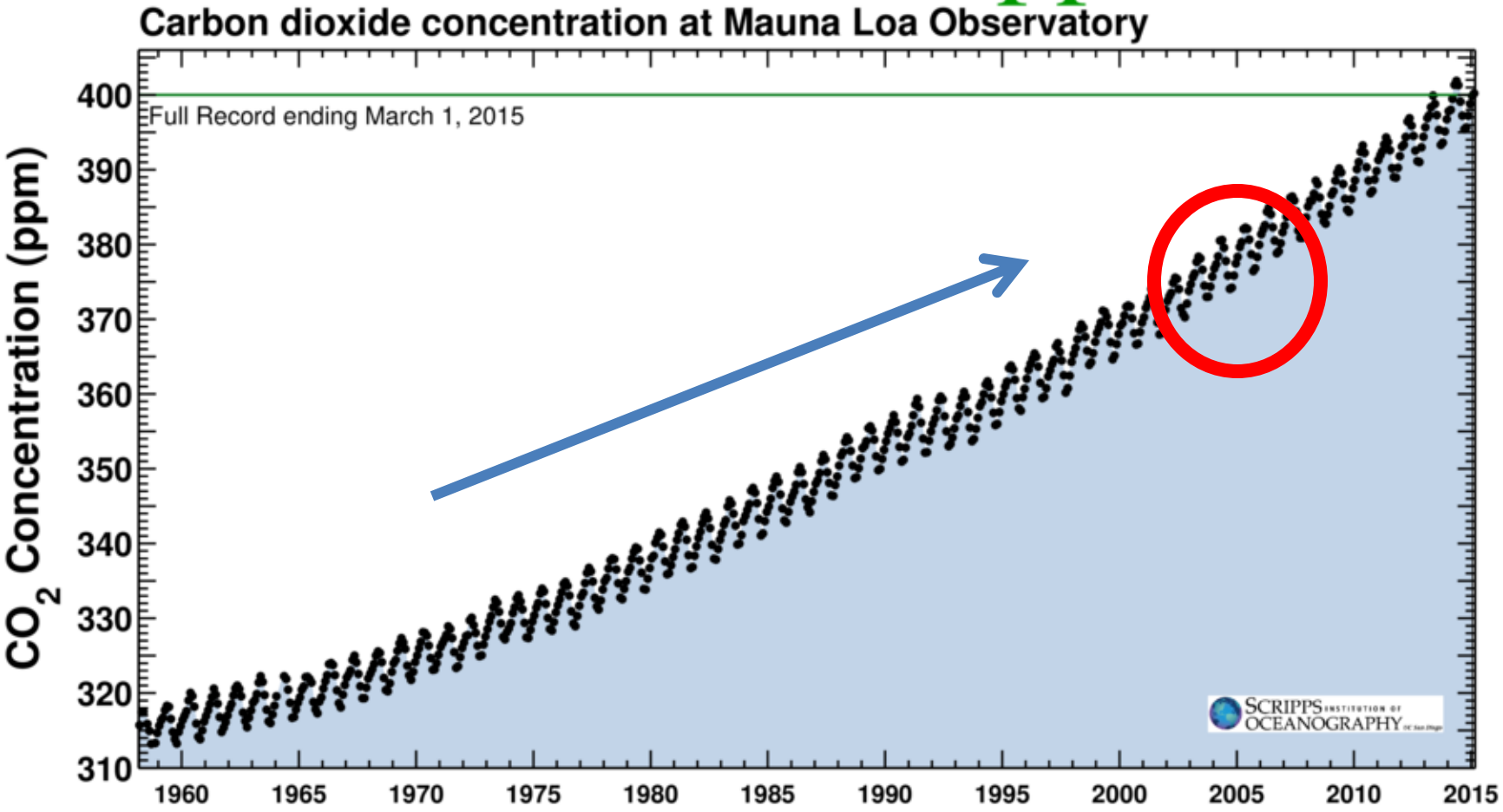
Total US GHG Emissions by Sector, 2012. Source: EPA

Trends

Carbon Dioxide

Latest CO_2 reading
March 01, 2015

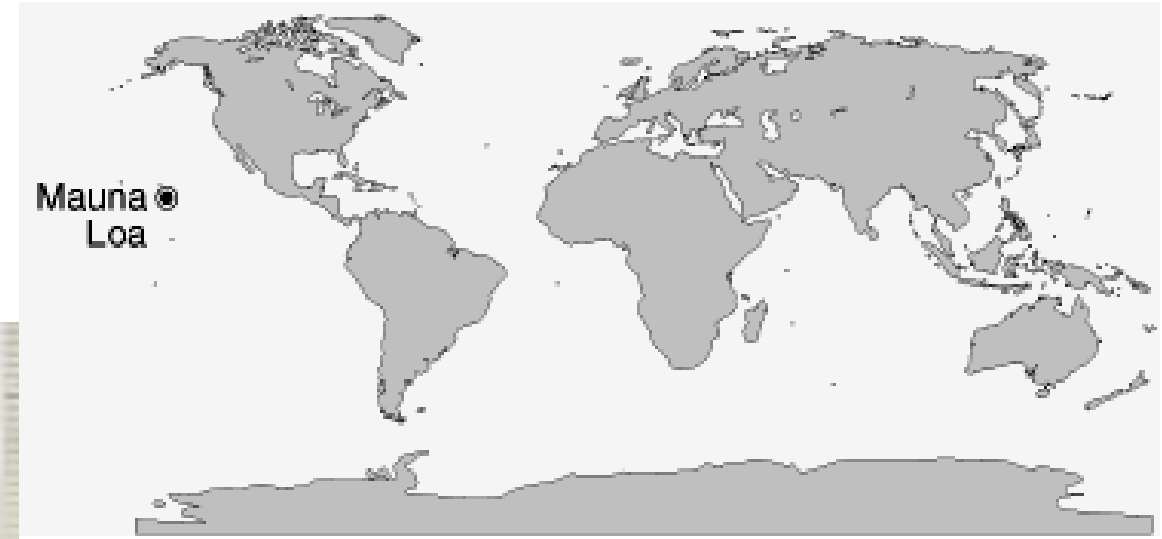
400.73 ppm



Pre-Industrial CO_2 = 280 ppm

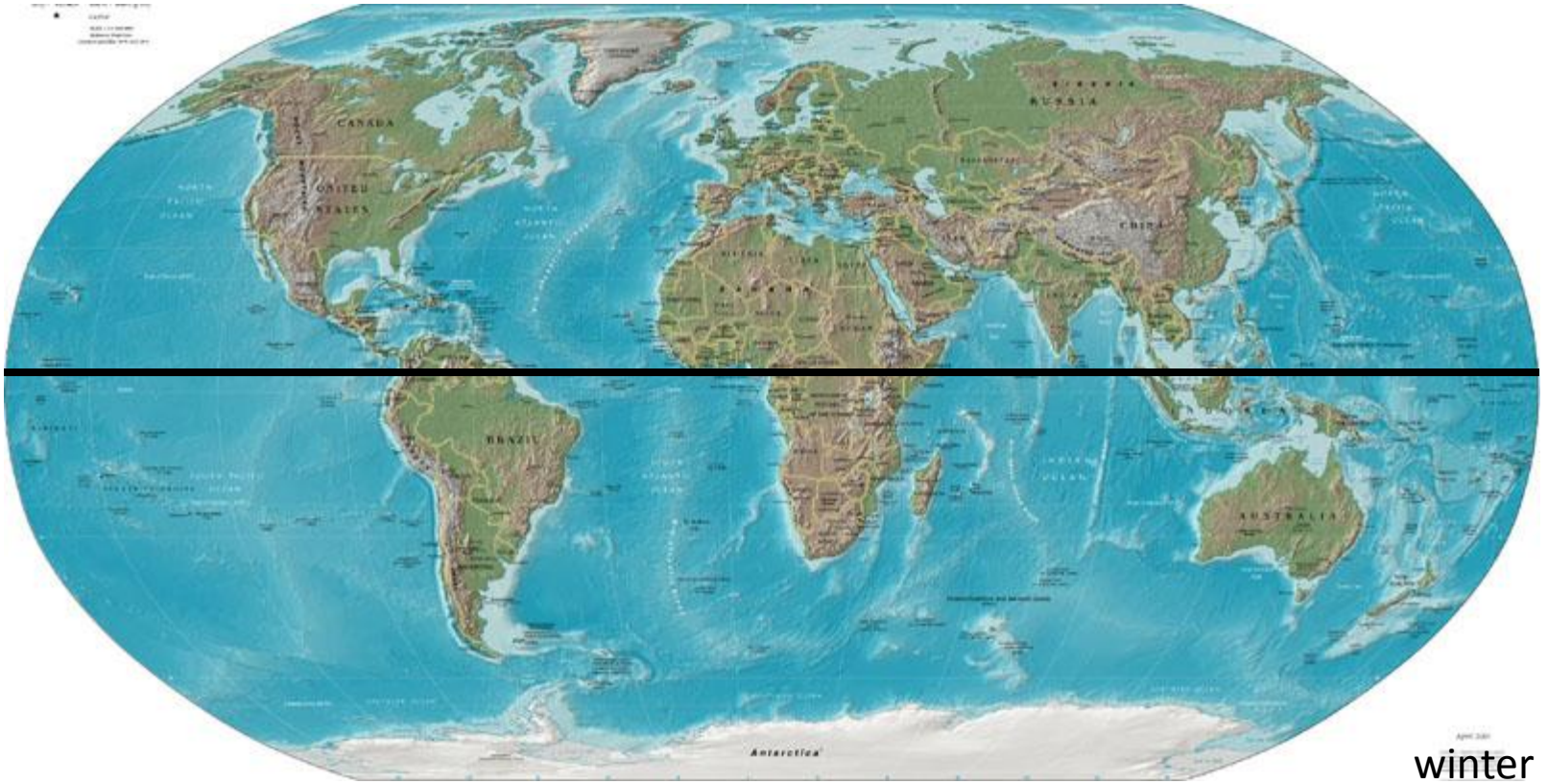
https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/mlo_full_record.png

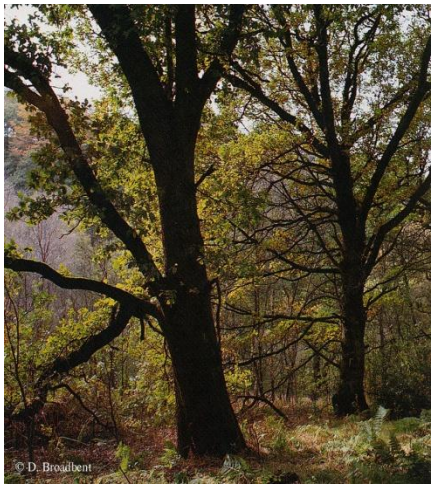
DISCOVERY

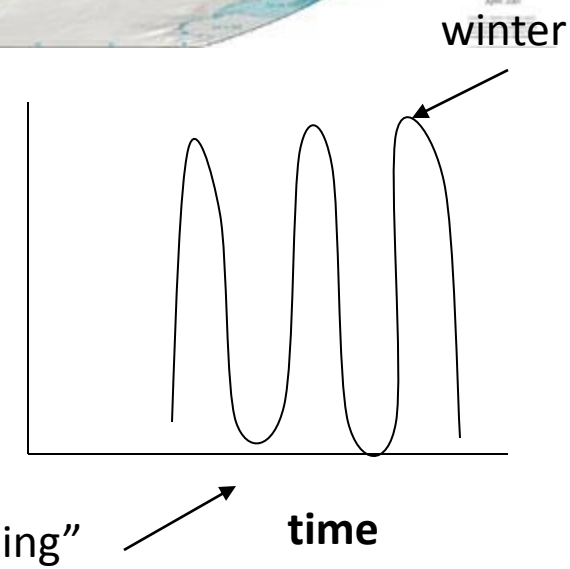


Biological Signal

- All living things breathe, rot, respire
  - Give off CO_2
- Green plants
  - Take up CO_2

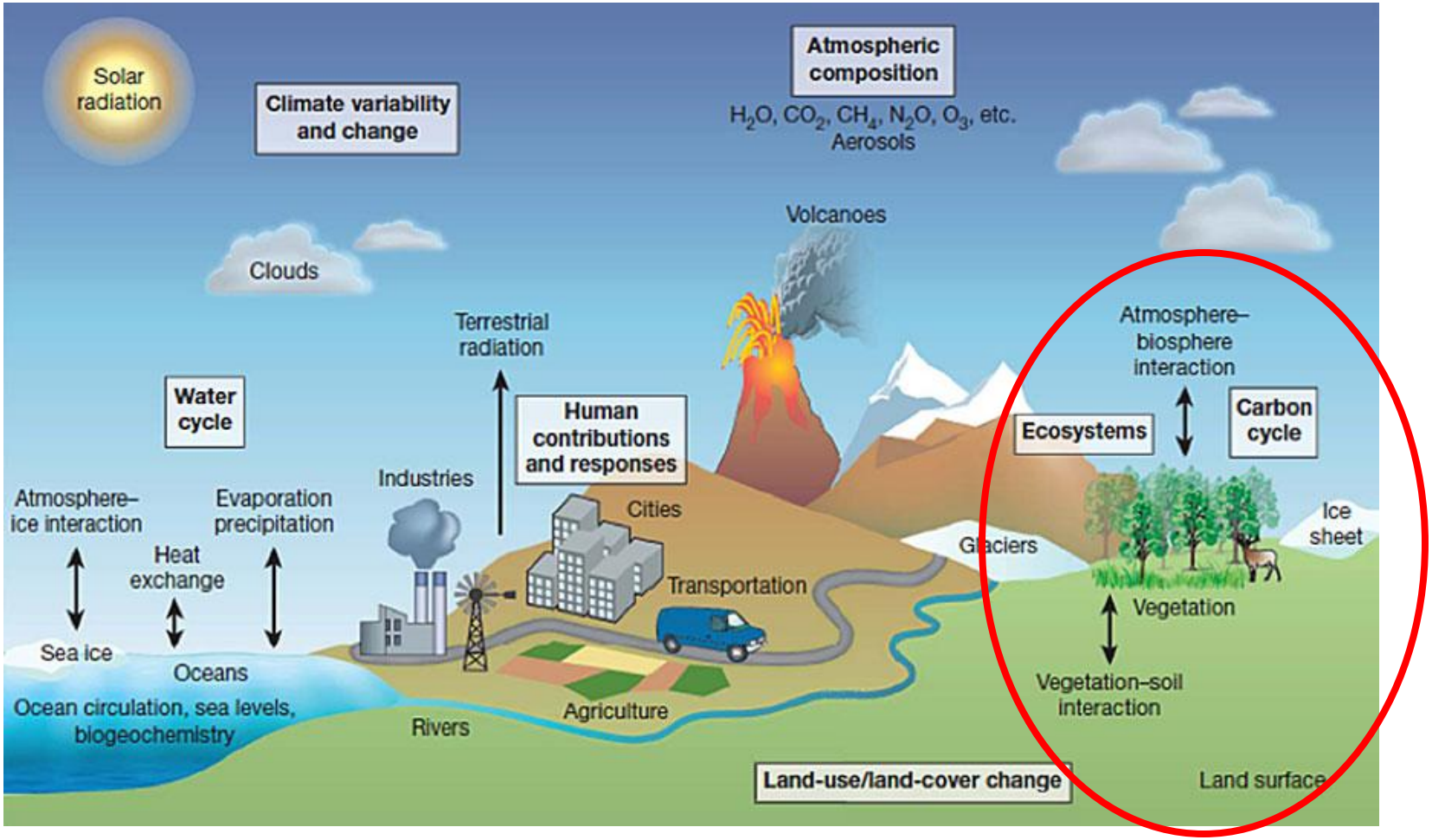






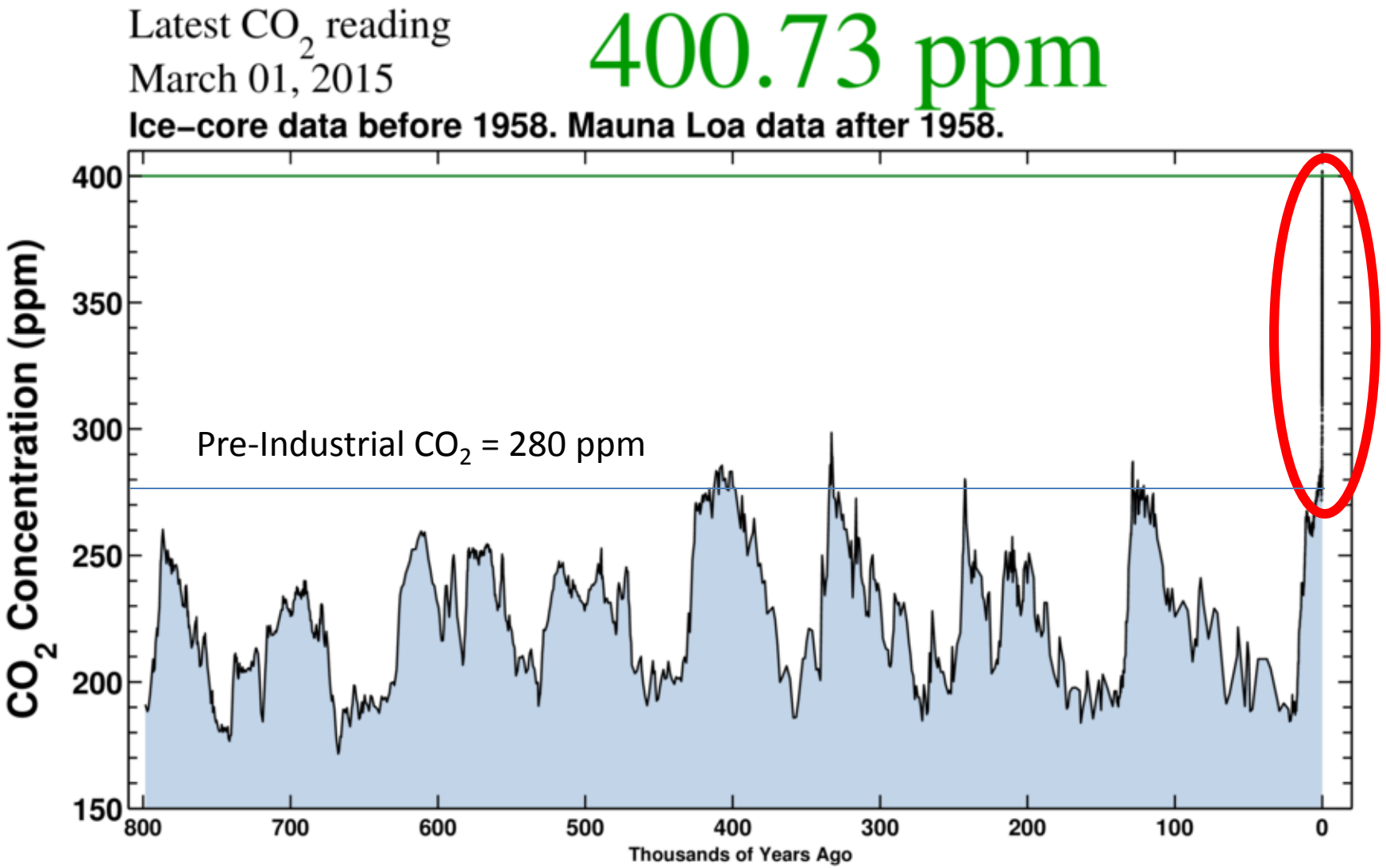
Vegetation “breathing”

What's New: Earth System Modeling



Source: NOAA

Atmospheric CO_2 Over 800,000 Years

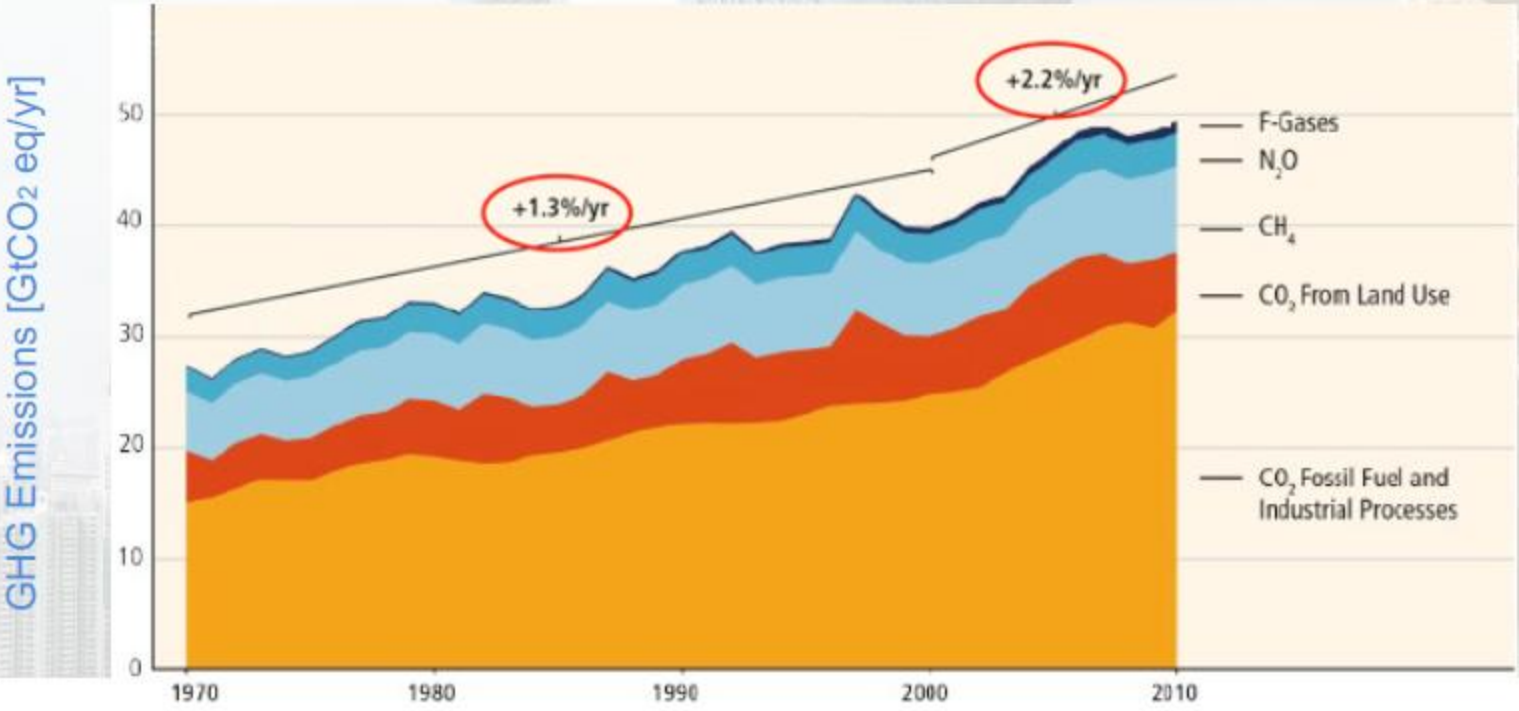


https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/co2_800k.png

GHG Emissions: What's New?

HUMAN INFLUENCE: Anthropogenic GHG emissions have increased since the pre-industrial era, driven largely by economic and population growth

The atmospheric concentrations of carbon dioxide, methane and nitrous oxide that are unprecedented in at least the last 800,000 years.

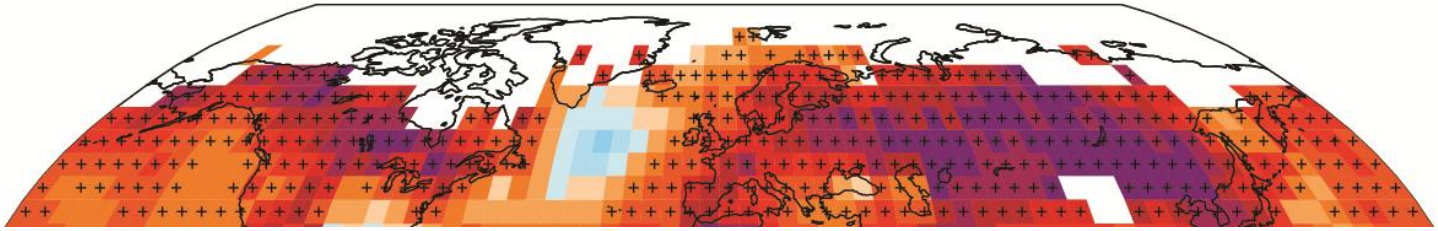


IPCC AR5 Synthesis Report

ipcc
INTERGOVERNMENTAL PANEL ON climate change

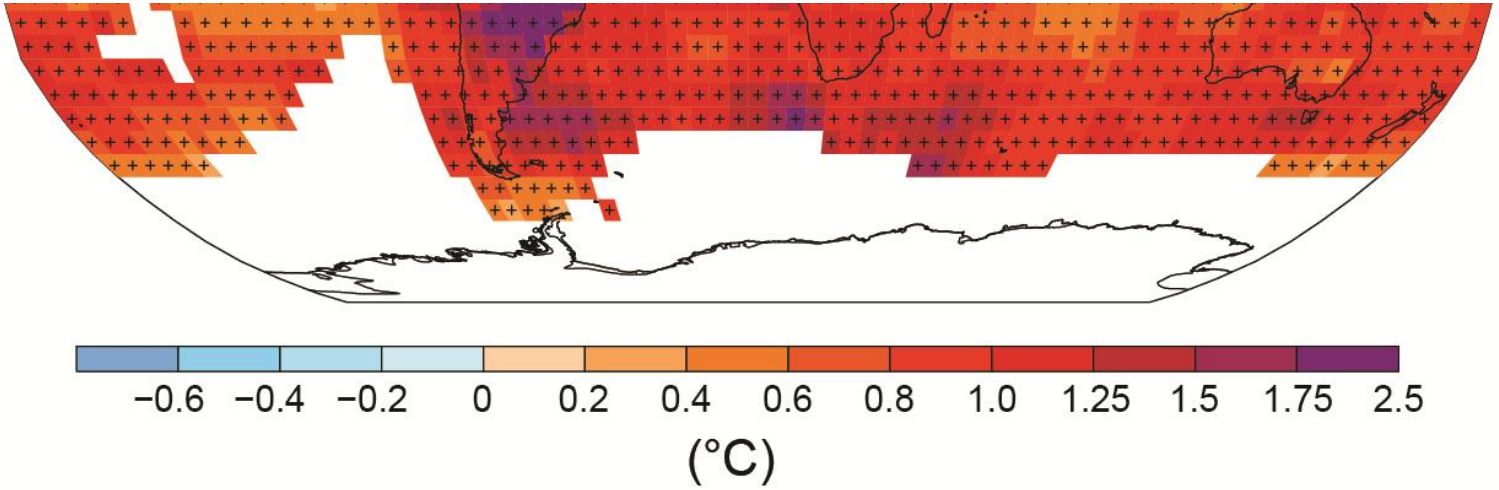
WMO UNEP

Observed change in surface temperature 1901–2012



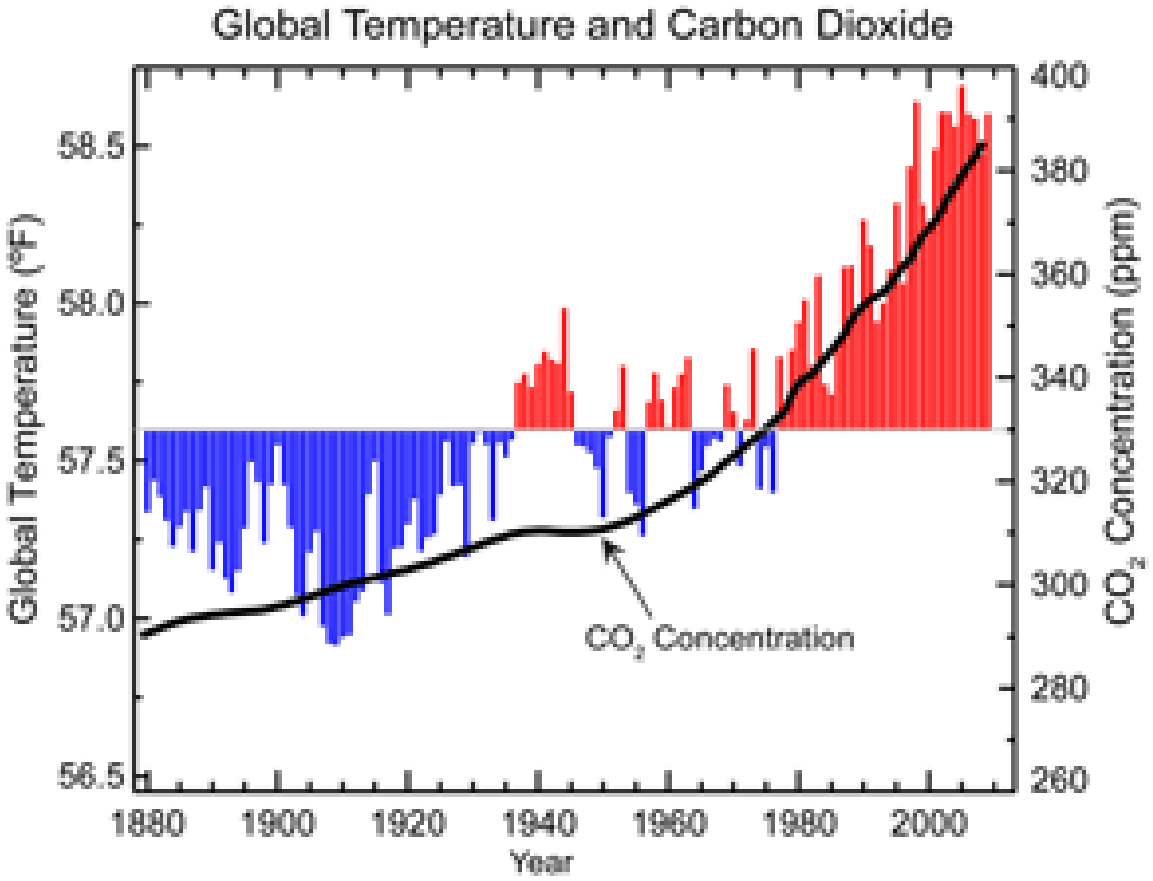
Global surface temperature change for the end of the 21st century is likely to exceed 1.5°C relative to 1850 to 1900 (IPCC FAQ)

Land temperatures were at an all time high in 2014



http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

Global Temperature - Carbon Dioxide Emissions Are Closely Linked



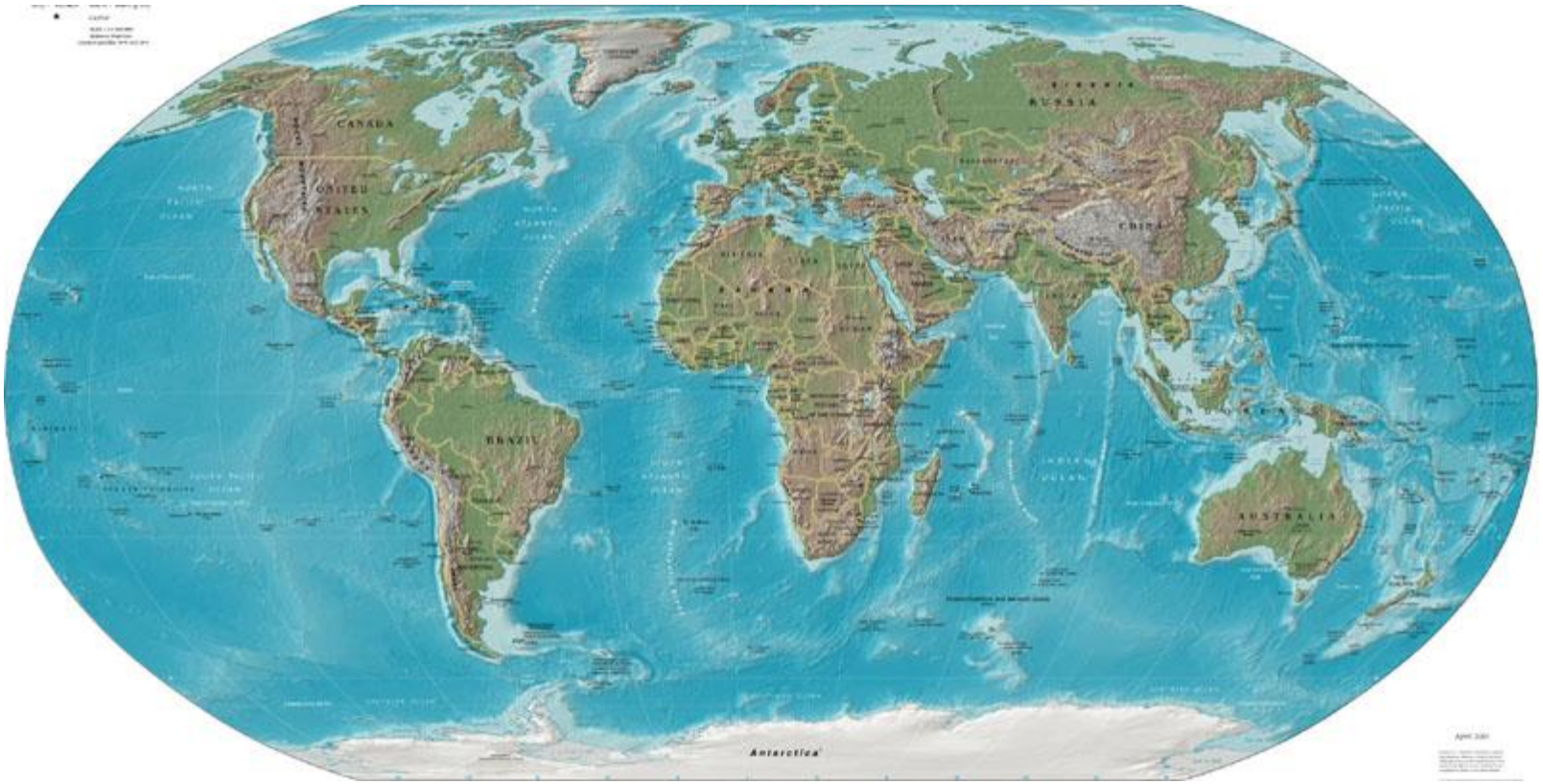
Warming of the climate system is unequivocal

Since 1950s many of observed changes are unprecedented over decades to millenia

Source: IPCC and NOAA

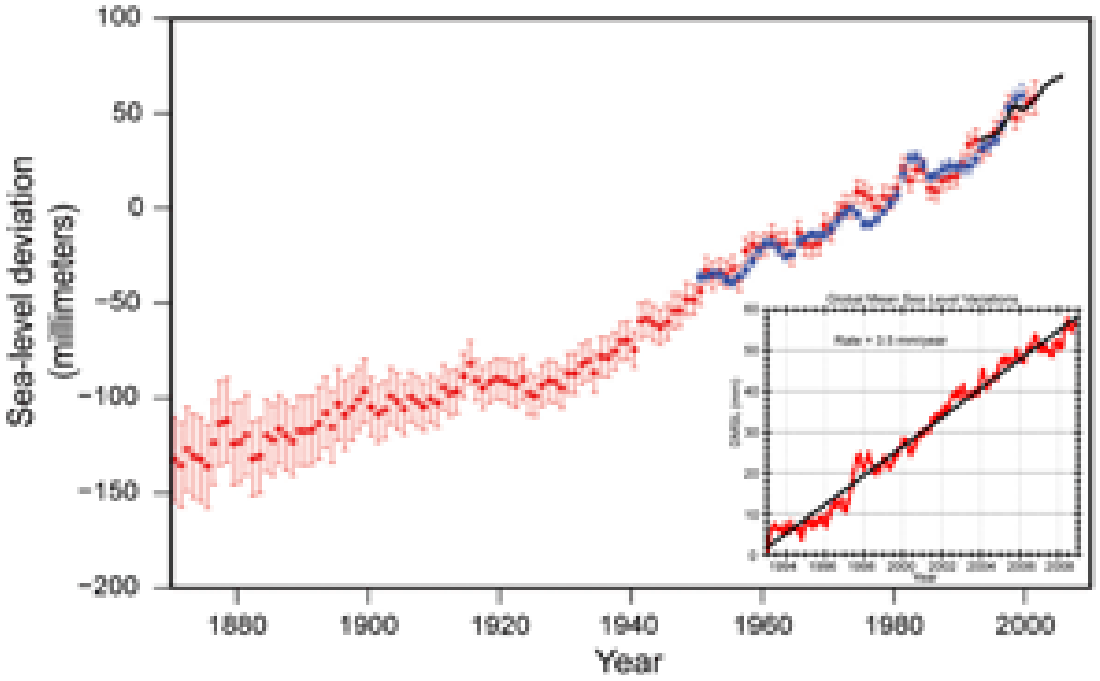
What's New: Oceans Absorb Most of the Heat:

Ocean warming dominates the increase in energy stored in the climate system, accounting for more than 90% of the energy accumulated between 1971 and 2010 (high confidence)



http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

Sea Level Is Rising

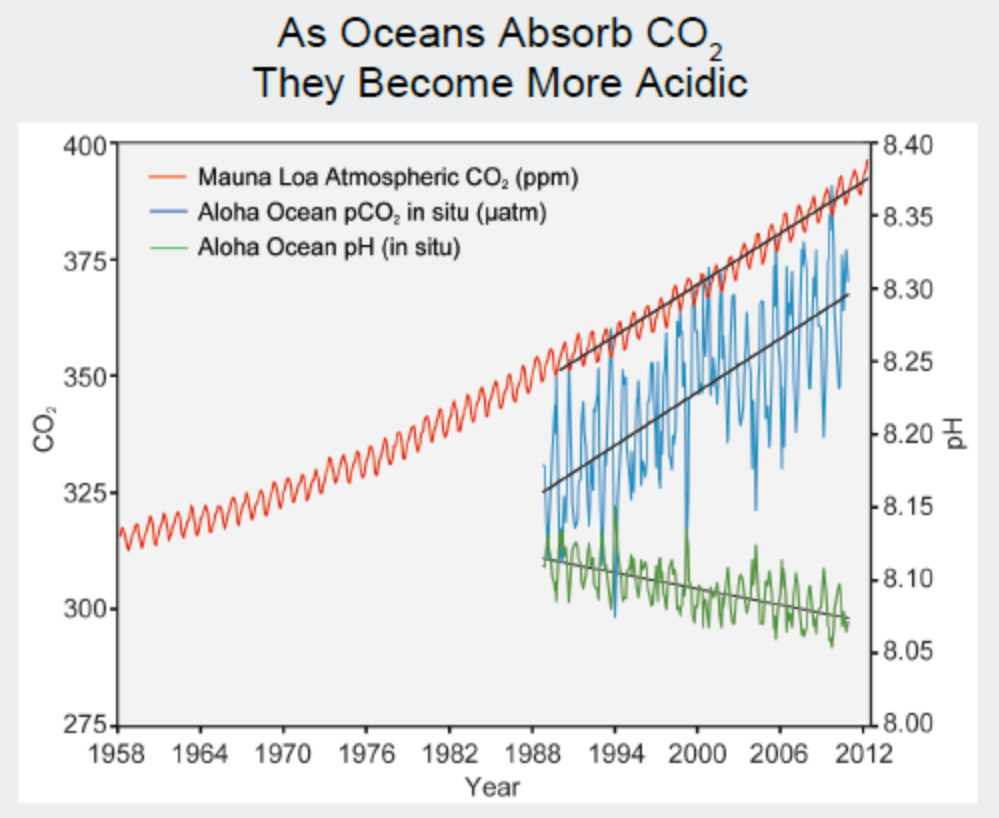


High Confidence in Thermal Expansion (IPCC)

Global sea level has risen about 8”since reliable record keeping (1880): 1-4’ by 2100 (NCA)

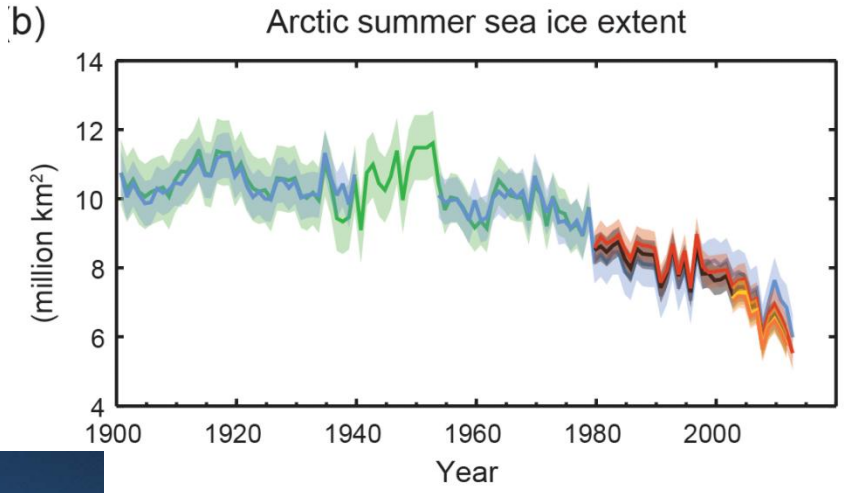
It is very likely that sea level will rise in more than about 95% of the ocean area (IPCC)

Oceans Are Acidifying



Source: NCA
http://nca2014.globalchange.gov/report/our-changing-climate/ocean-acidification#intro-section-2
Adapted from: Ocean Acidification: Present Conditions and Future Changes in a High-CO2 World

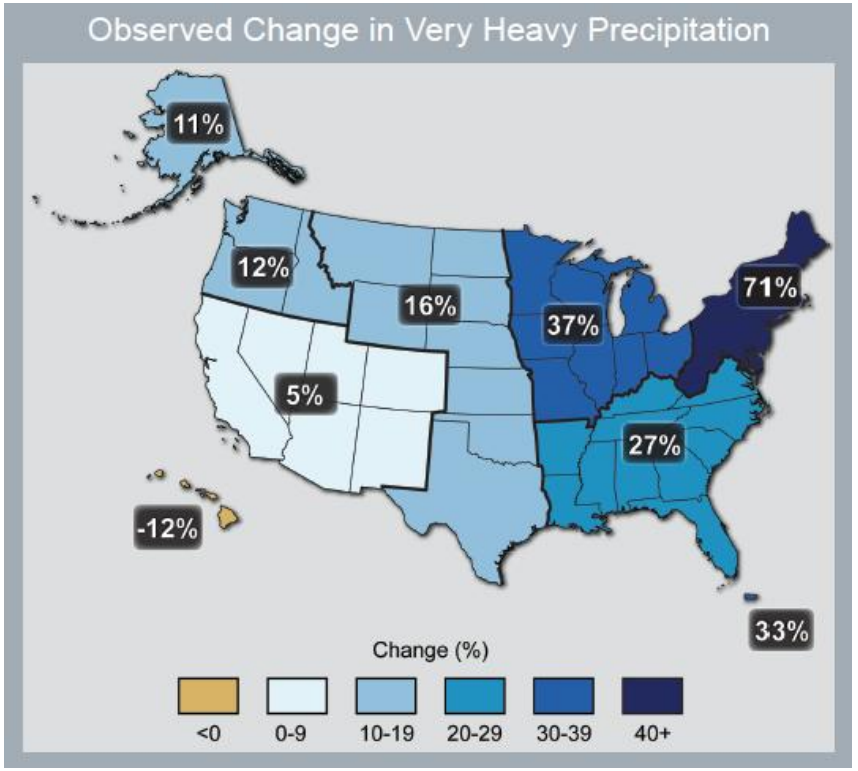
Arctic Sea Ice Is Melting and Calving



Medium Confidence in Projections of Glacier Mass Loss (IPCC)

Extreme Weather

Childe Hassam
Rainstorm in Union Square 1890
(Jim Loy, 2003)



1958-2012 (NCA)

HUMAN INFLUENCE: Some changes in extreme weather and climate events observed since ~1950 are linked to human activity

In a number of regions, impacts are already underway:

- decrease in cold temperature extremes
- increase in warm temperature extremes
- increase in extreme high sea levels
- increase in the number of heavy precipitation events

AR5 WGI SPM

INTERGOVERNMENTAL PANEL ON climate change

ipcc

WMO UNEP

Some Ecological Effects of Climate Change

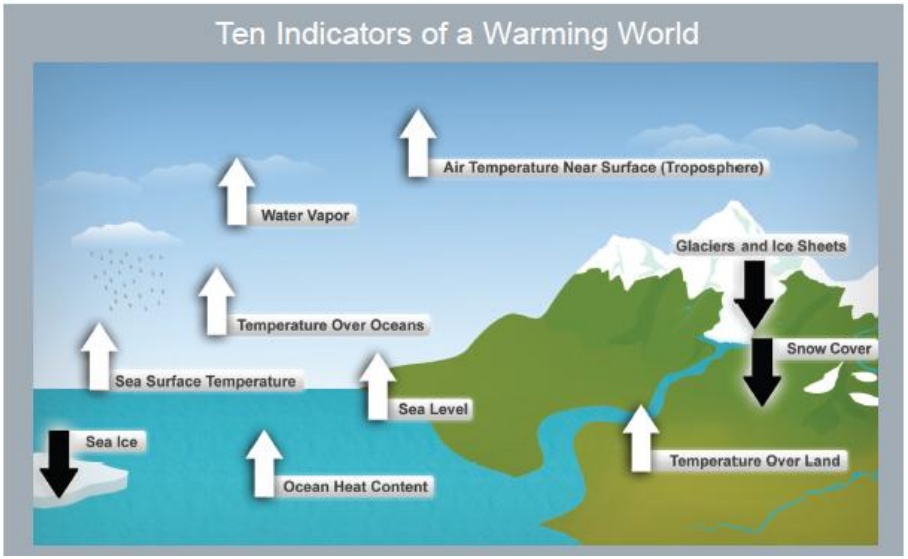
(biology affected by moisture, temperature, chemistry)

- Biodiversity changes/loss
- Increased frequency of fires
- Pest and pathogen outbreaks
- Changes in water quality and quantity
- Agricultural impacts

How Do We Know?

Unsubmissive Plant
1961
Remedios Varo

Experiments

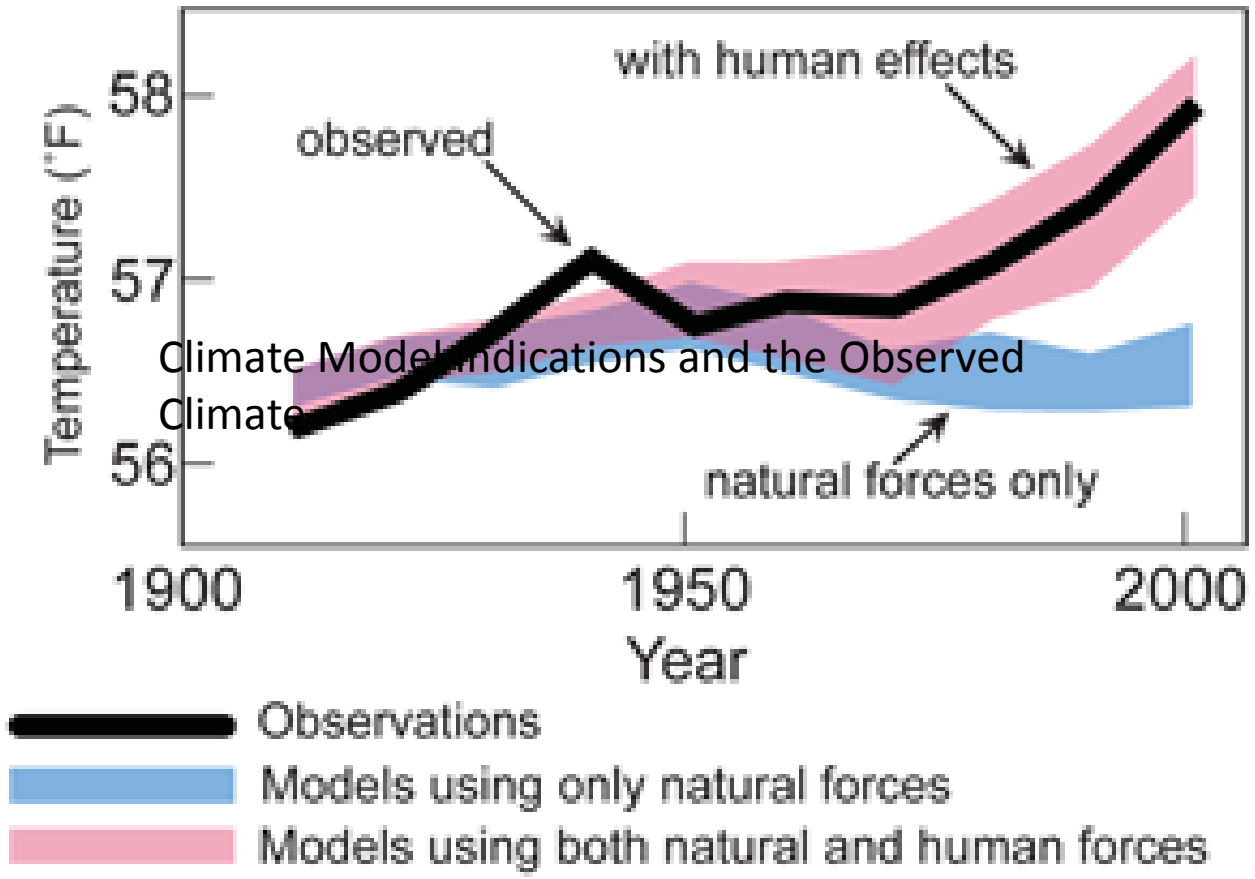


Source: NCA 2014

Observations

Long-term records

Mathematical Models



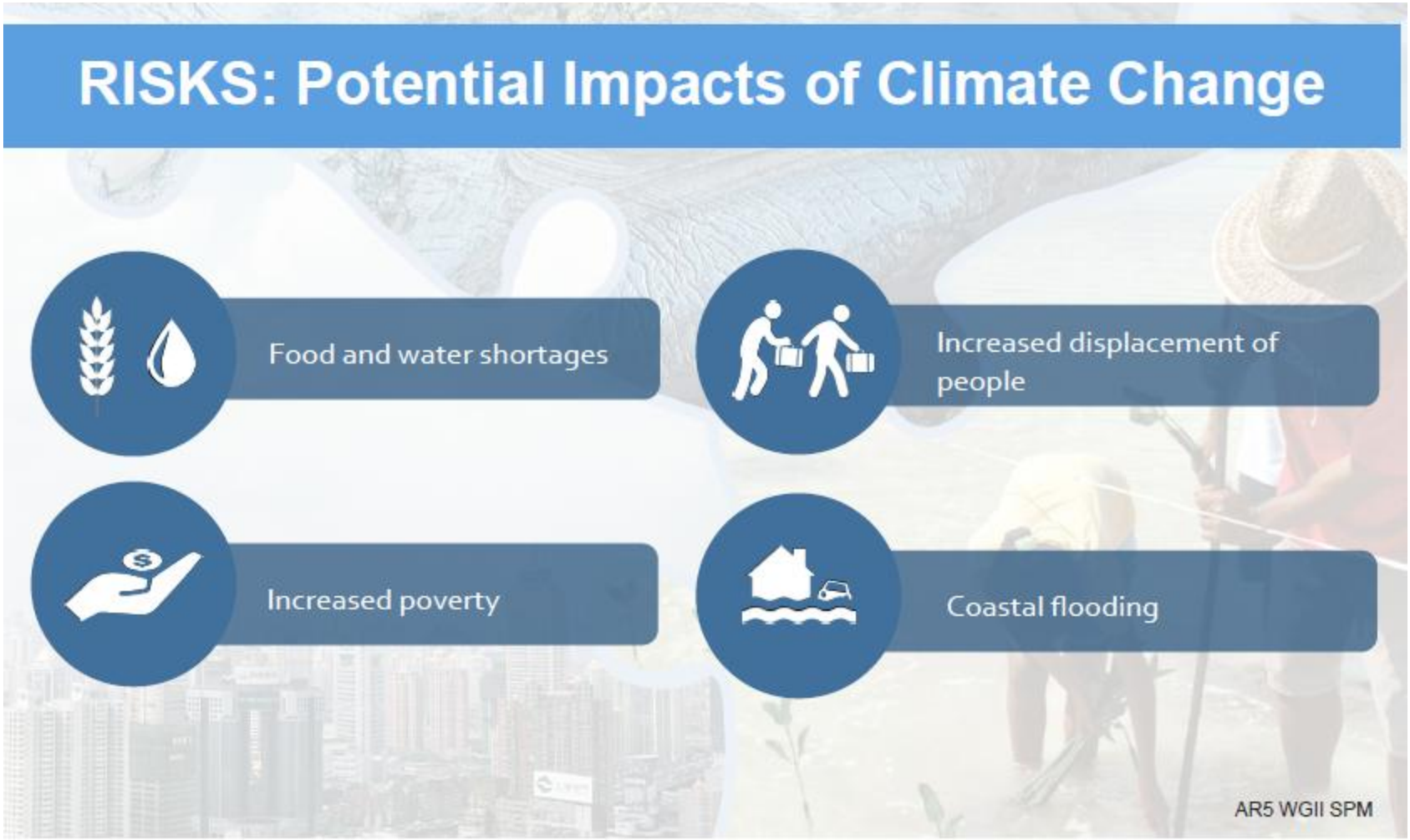
Climate Model Indications and the Observed Climate

Source: NOAA

Science of Climate Change: Some Uncertainties

- Predictions:
  - how much will global temperatures rise?
- Impacts:
  - what does it mean for biological communities?
- Human behavior:
  - emission and land-use changes

RISKS: Potential Impacts of Climate Change



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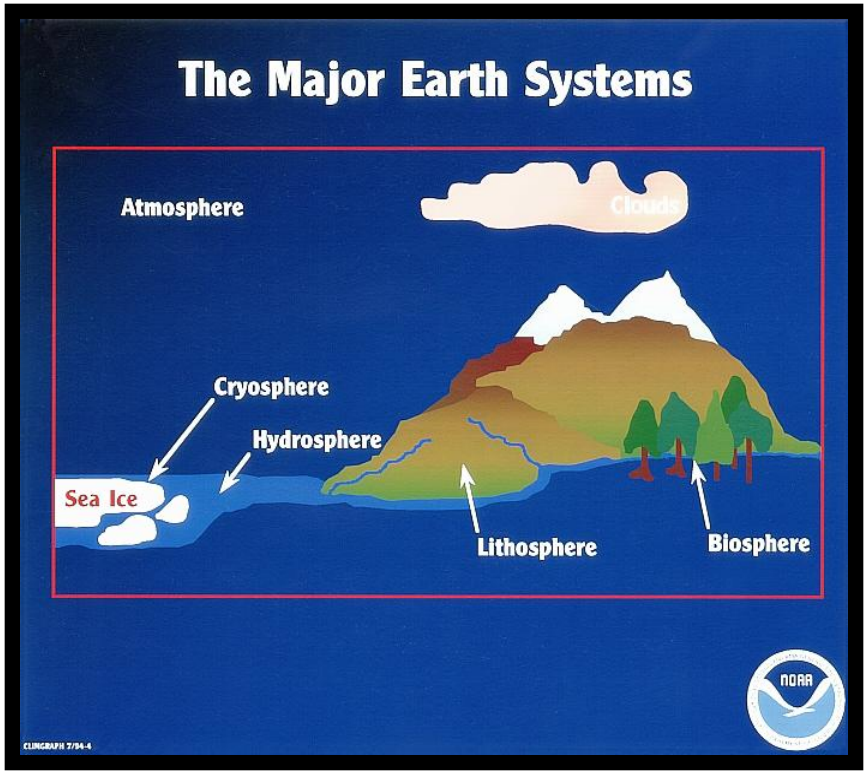
Where’s the Hope?

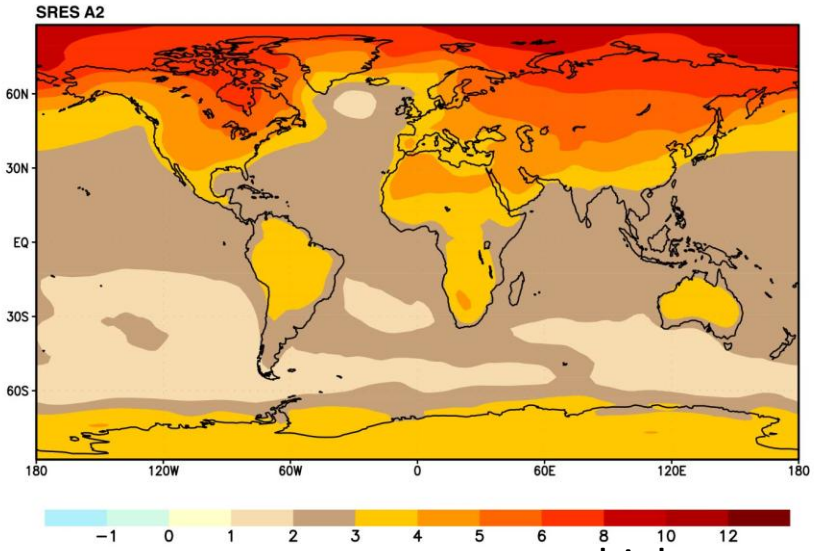


- Earth system knowledge
- Collaboration
  - Across disciplines
  - Across cultures
  - Across political boundaries

Now What?

- The behavior of greenhouse gases in the atmosphere in not going to change

- Humans can



Global temperature predicted increases

What Can We Do to Reduce CO_2: A Suite of "and" Strategies

1. <u>EMIT LESS</u>

reduce, capture

nuclear

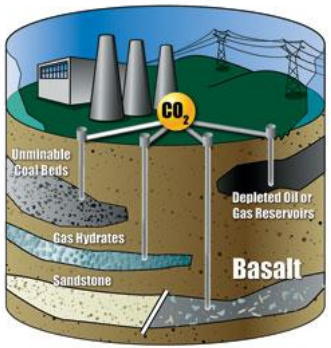
clean renewable

increase efficiency

What Can We Do to Reduce CO_2: A Suite of "and" Strategies

2. "<u>VACUUM</u>"

- biological sequestration
- capture and bury



What Can We Do?

3. Prepare for effects of climate change

What Can We Do?

4. Understand the basics

- access sound science

Communicate

Act

Photo Credit: K. Weathers

Most Americans see combating climate change as a moral duty

By Bruce Wallace

WASHINGTON Fri Feb 27, 2015 1:24am EST

> "The poll of 2,827 Americans was conducted in February to measure the impact of moral language, including interventions by Pope Francis, on the climate change debate. In recent months, the **pope has warned about the moral consequences of failing to act on rising global temperatures**, which are expected to **disproportionately affect the lives of the world's poor**."
>
> "When **climate change** is viewed through a **moral lens** it has **broader appeal**," said Eric Sapp, executive director of the American Values Network, a grassroots organization that mobilizes faith-based communities on politics and policy issues.

Knowledge is Power
Change? Curb and Guide