ATM 241, Spring 2020
Lecture 13
Climate Change

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IPCC 5th Assessment Report WG1
https://www.ipcc.ch/report/ar5/wg1/

In this section…

Questions

- What is the Intergovernmental Panel on Climate Change?
- Are human activities responsible for warming the Earth?
- What are the major drivers of anthropogenic climate change?
- How do we experience climate change?

Intergovernmental Panel on Climate Change

The IPCC was established in 1988 by two United Nations organizations: The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

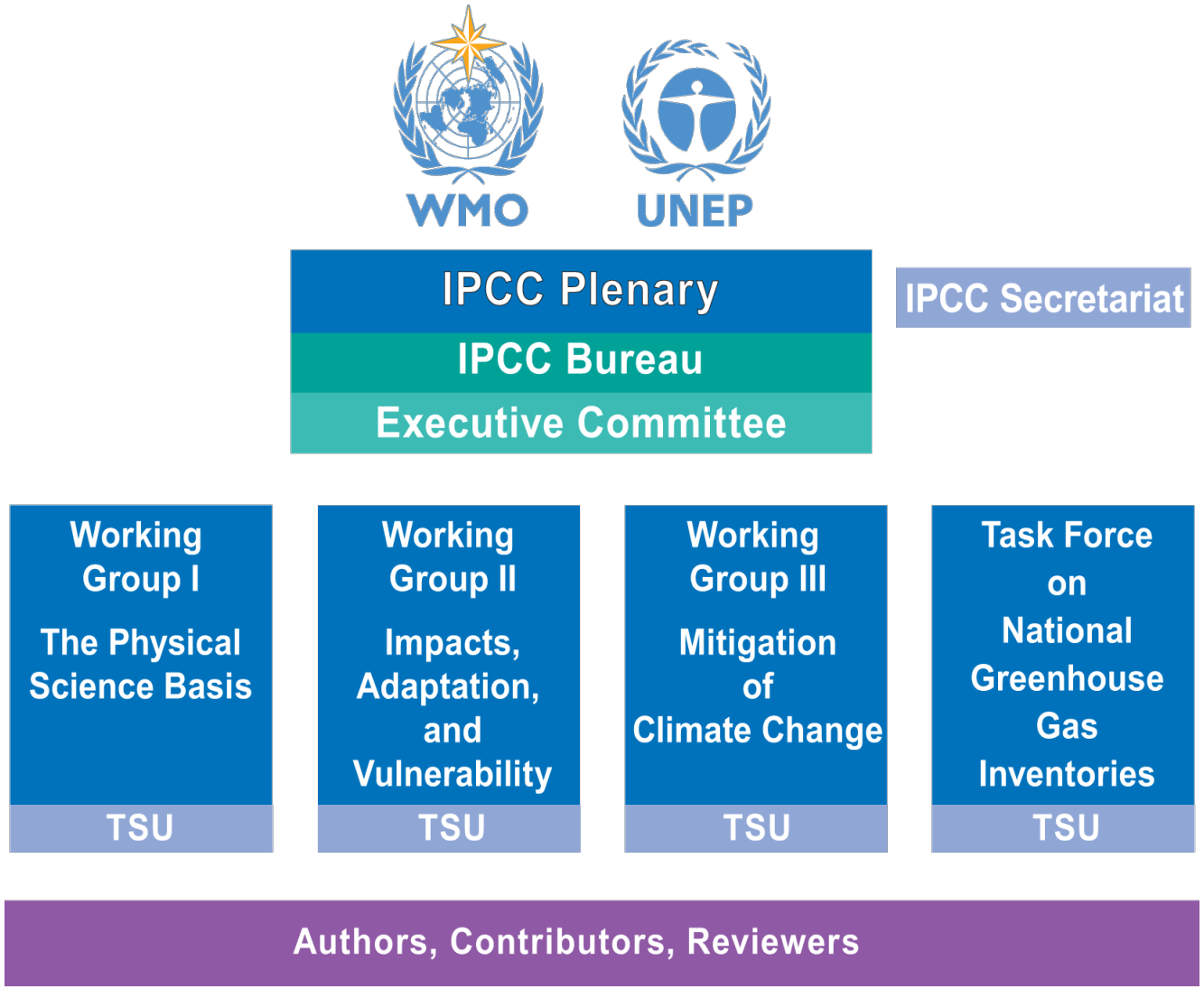
IPCC Mission

To provide comprehensive scientific assessments of current scientific, technical and socio-economic information worldwide about the risk of climate change caused by human activity, its potential environmental and socio-economic consequences, and possible options for adapting to these consequences or mitigating the effects.

Note: The IPCC does not conduct research on climate change, but instead in based on the comprehensive peer-reviewed literature on climate change.

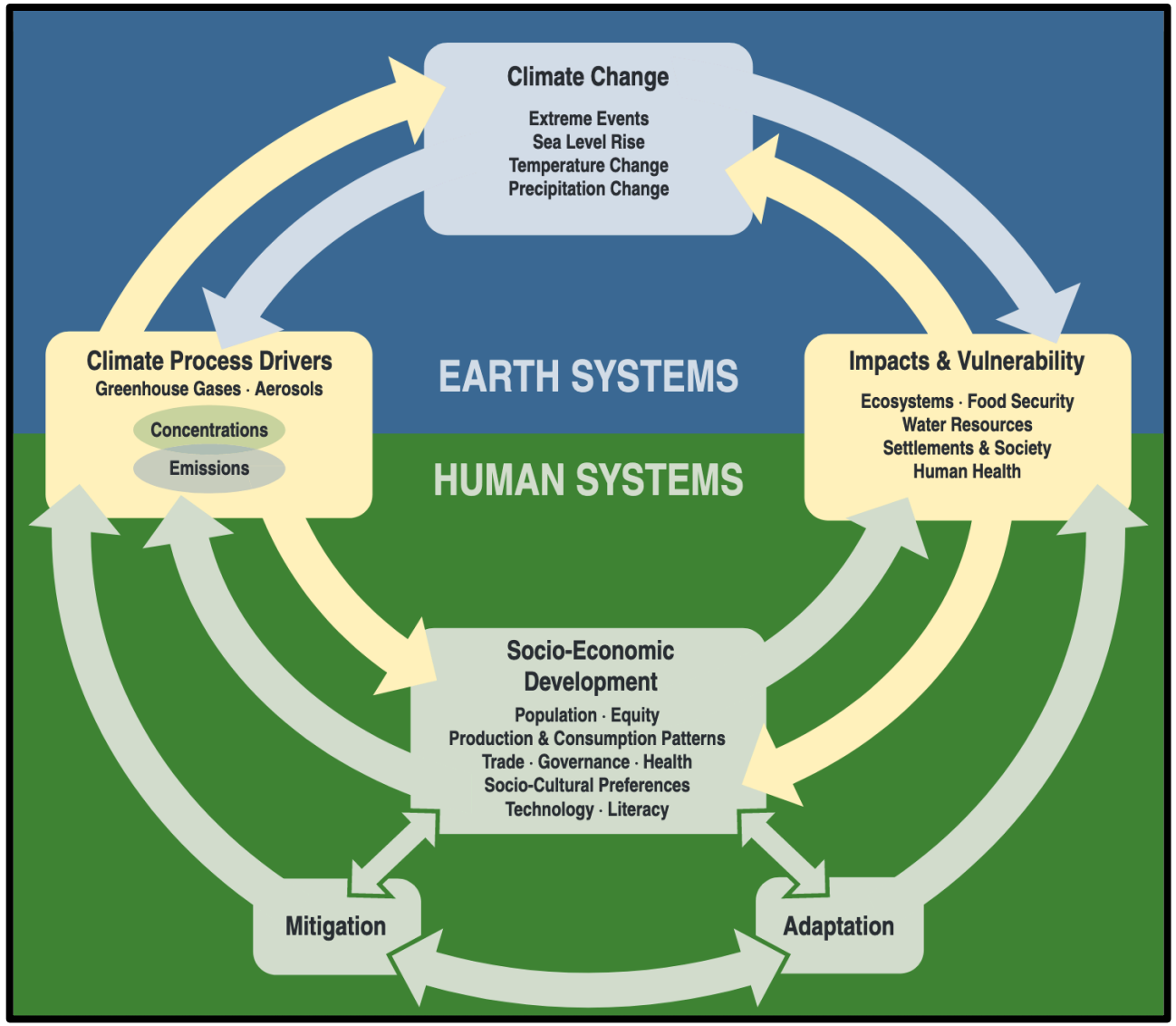
Intergovernmental Panel on Climate Change

Figure: Administrative structure of the IPCC.



Intergovernmental Panel on Climate Change

Figure: Schematic framework representing anthropogenic drivers, impacts of and responses to climate change, and their linkages.



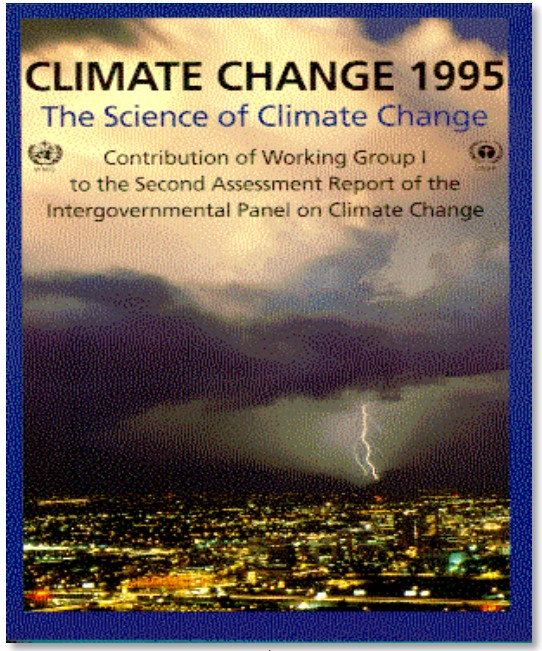
IPCC: Fifth Assessment Report

Published from September 2013 through October 2014 in “chunks.” Three main working groups:

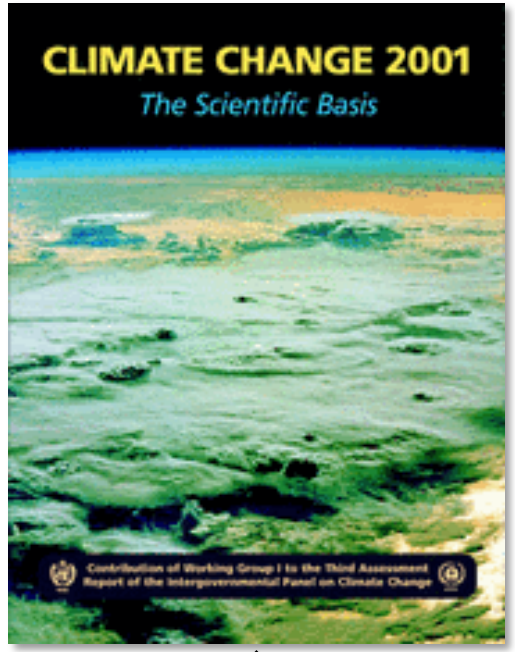
- WG I: The Physical Science Basis
  September 2013
- WG II: Impacts, Adaptation and Vulnerability
  March 2014
- WG III: Mitigation of Climate Change
  April 2014
- AR5 Synthesis Report (SYR)
  Finalized 31 *October 2014*

The IPCC Sixth Assessment Report will be published in late 2020/2021.

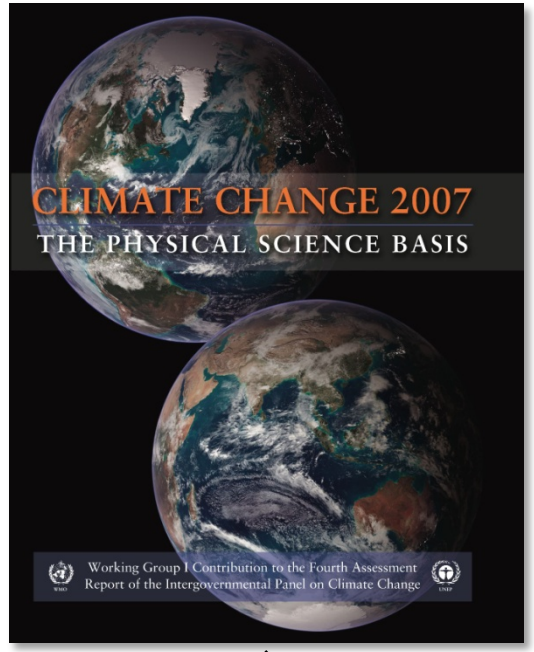
IPCC Statements on Climate Change



"The balance of evidence suggests a discernible human influence on global climate"

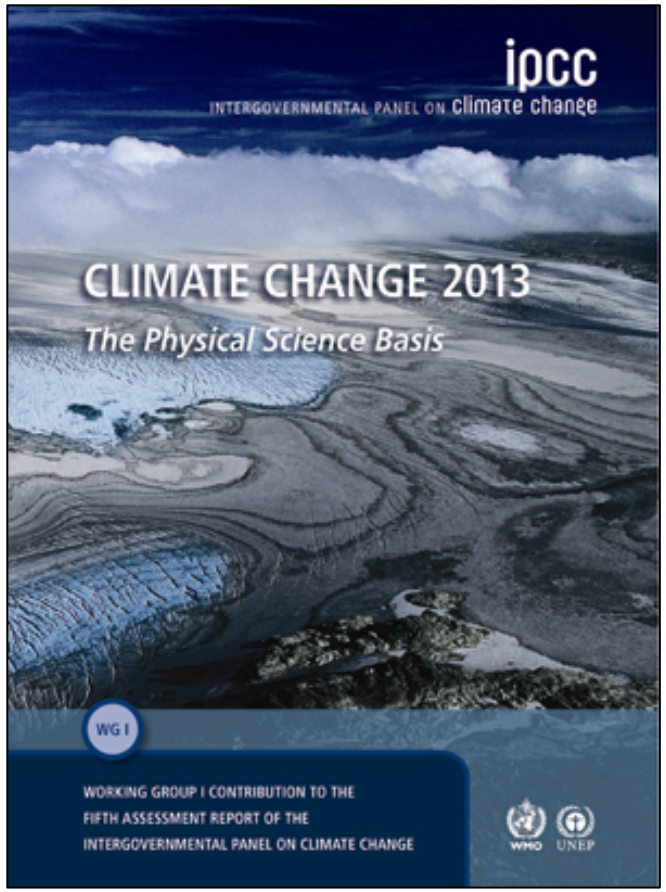


"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities"



"Most of the observed increase in globally averaged temperatures since the mid-20th century is *very likely** due to the observed increase in anthropogenic greenhouse gas concentrations"

IPCC Statements on Climate Change

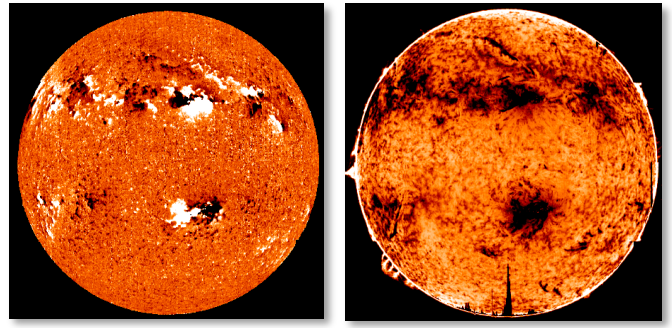


"…the science now shows with **95 percent certainty** that **human activity is the dominant cause of observed warming since the mid-20th century**. The report confirms that warming in the climate system is unequivocal, with many of the observed changes **unprecedented over decades to millennia**: warming of the atmosphere and the ocean, diminishing snow and ice, rising sea levels and increasing concentrations of greenhouse gases. **Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850.** "

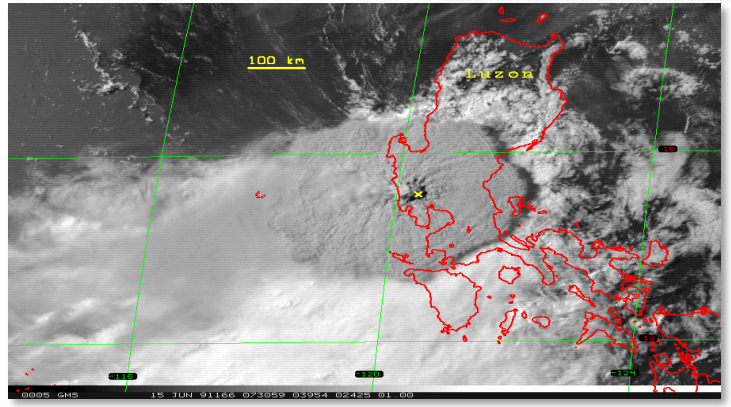
Drivers of Climate Change

Natural mechanisms influence climate

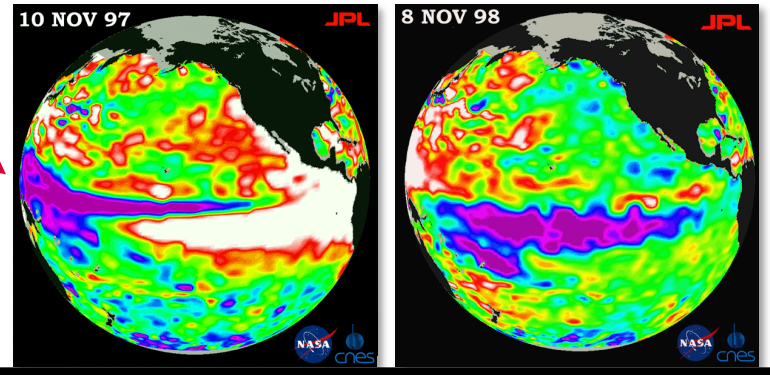
Changes in solar forcing



Changes in the amount of volcanic dust in the atmosphere



Internal variability of the coupled atmosphere-ocean system



Source: Ben Santer, 2012.

Drivers of Climate Change

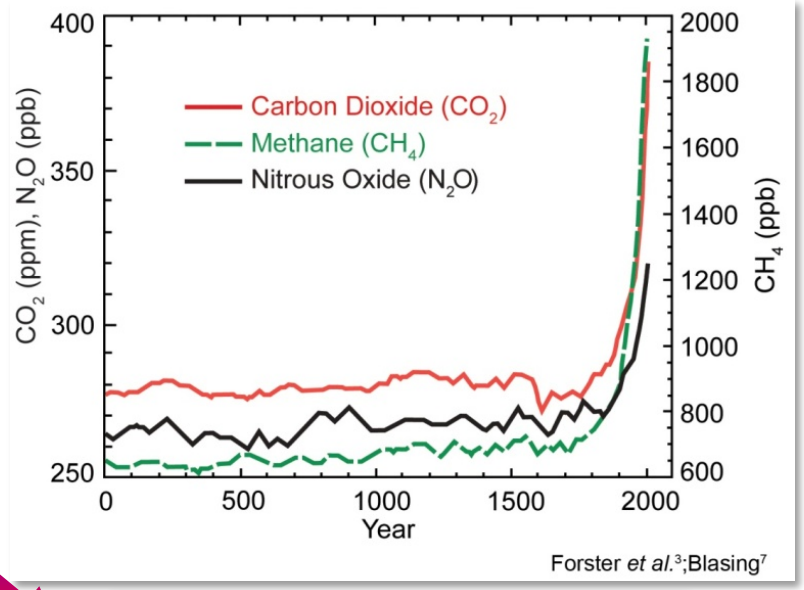
Anthropogenic mechanisms also influence climate

Changes in atmospheric concentrations of greenhouse gases

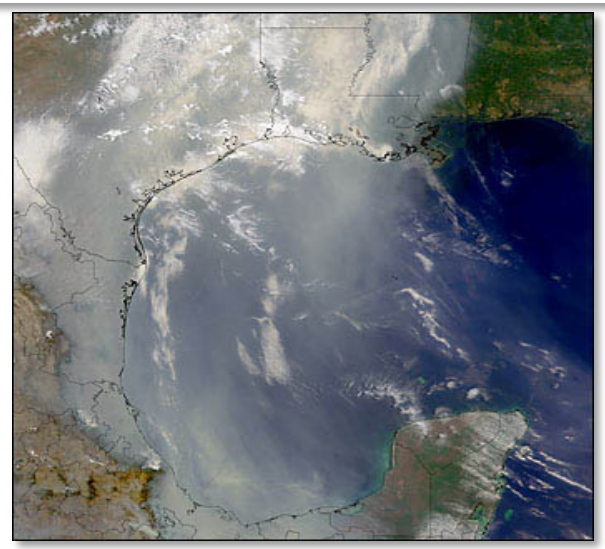
Changes in aerosol particles from burning fossil fuels and biomass

Changes in the reflectivity (albedo) of the Earth's surface

Source: Ben Santer, 2012.



Before After



Smoke from fires in Guatemala and Mexico

Recent Climate Forcing (AR5)

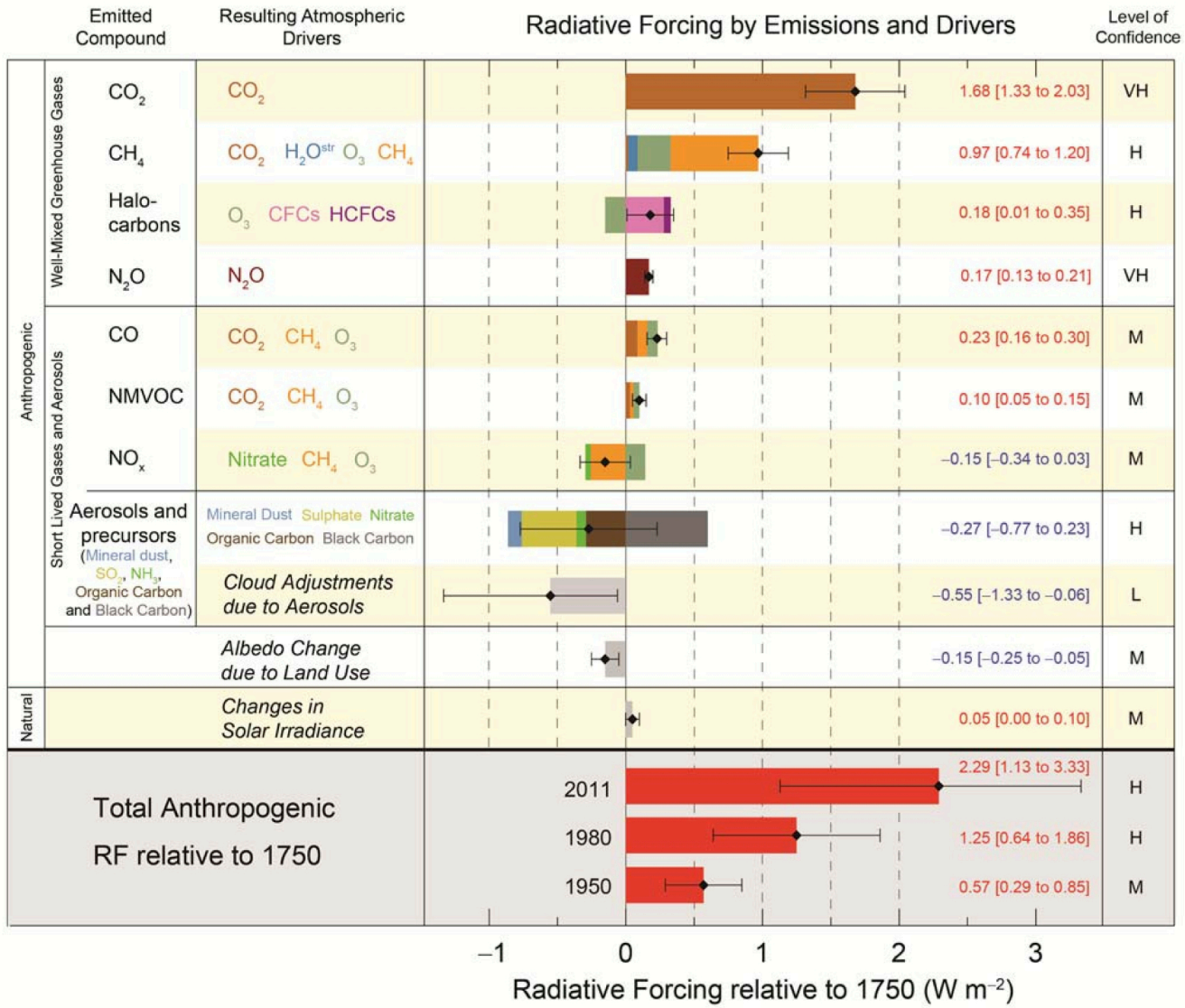
Figure: Recent contributions to radiative forcing at the surface relative to preindustrial (1750).

Greenhouse gases are the dominant contributors to warming.

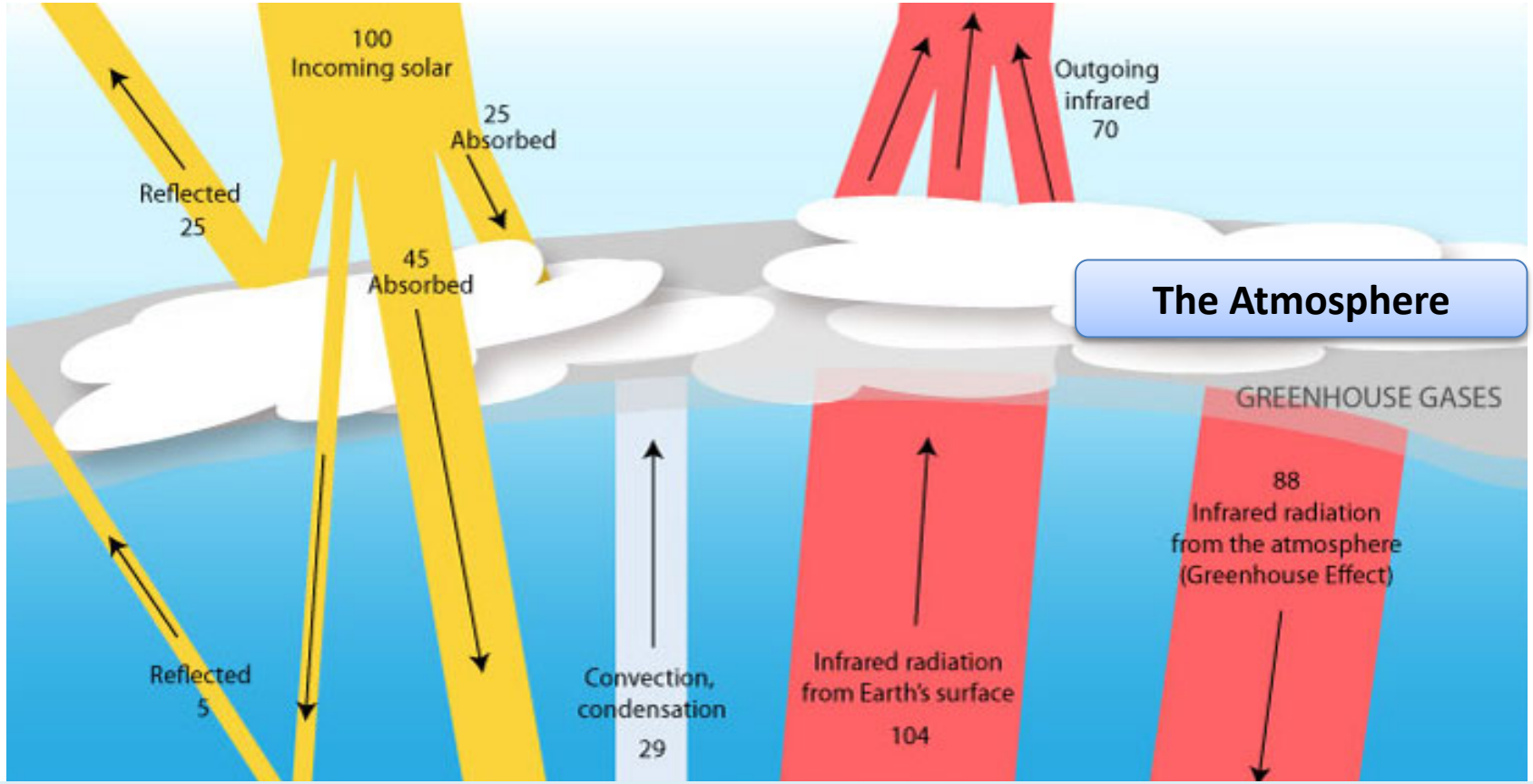
Aerosols (except for black carbon) generally lead to cooling.

Cloud adjustments and land use change also tend to be cooling factors.

Changes to solar irradiance are very small.



Greenhouse Effect



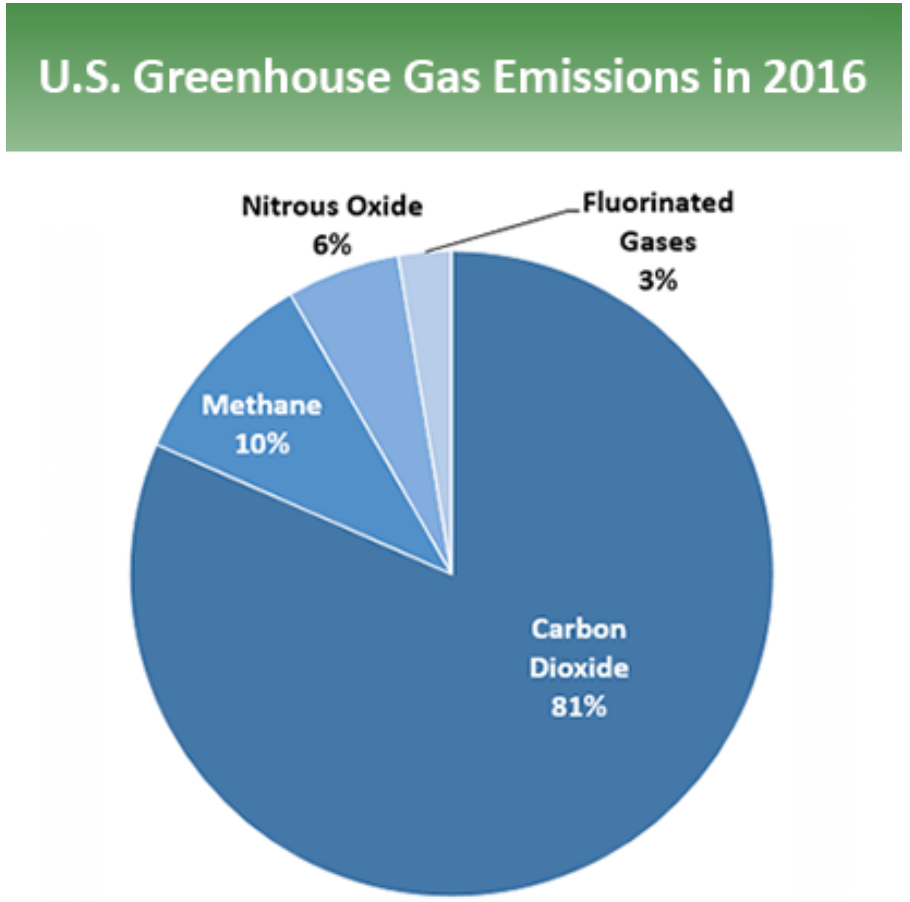
Normalized so incoming solar ($S_0/4$) = 100

Definition: The **greenhouse effect** refers to the "trapping" of terrestrial radiation by greenhouse gasses in the atmosphere. This causes the surface to be much warmer than it would be if no atmosphere was present (emission temperature).

Greenhouse Gases

Water Vapor (H_2O): The strongest greenhouse gas. But one that is regulated by the climate system.

Carbon Dioxide (CO_2): Comes from burning fossil fuels (coal, natural gas, and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.



Total Emissions in 2016 = 6,511 Million Metric Tons of CO_2 equivalent.

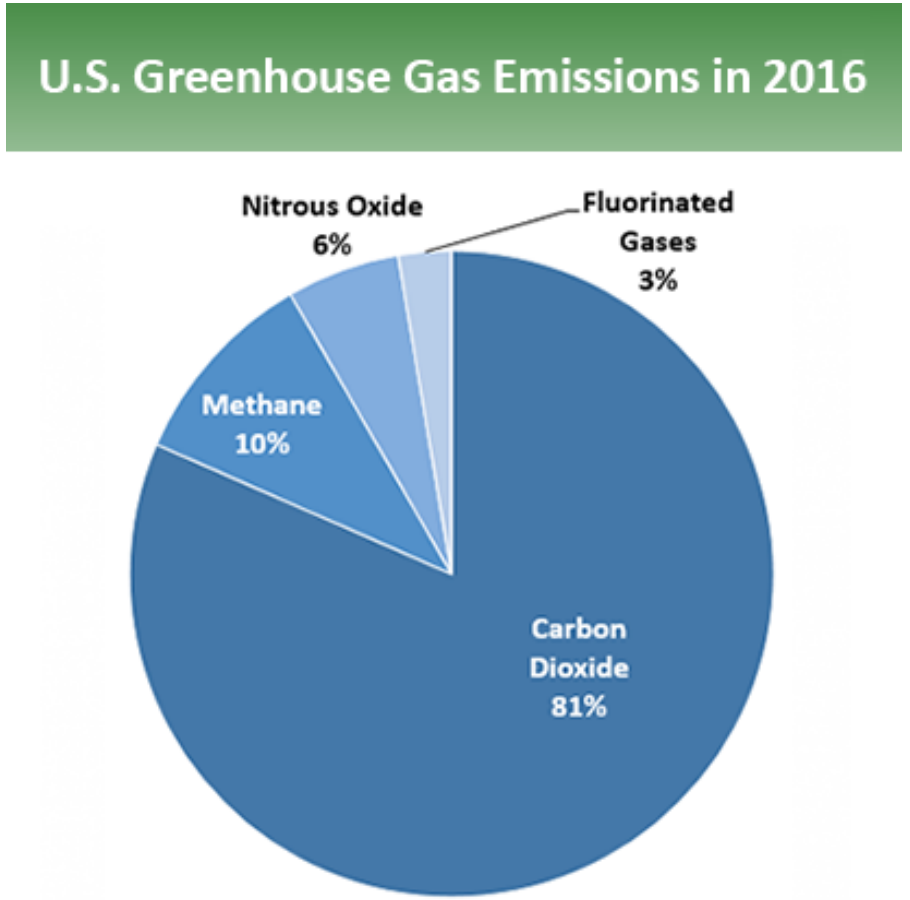
https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Greenhouse Gases

Methane (CH_4): Methane is emitted during the production and transport of coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.

Nitrous oxide (N_2O): Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

Fluorinated gases: Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride are synthetic, powerful greenhouse gases that are emitted from a variety of industrial processes.



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Greenhouse Gases

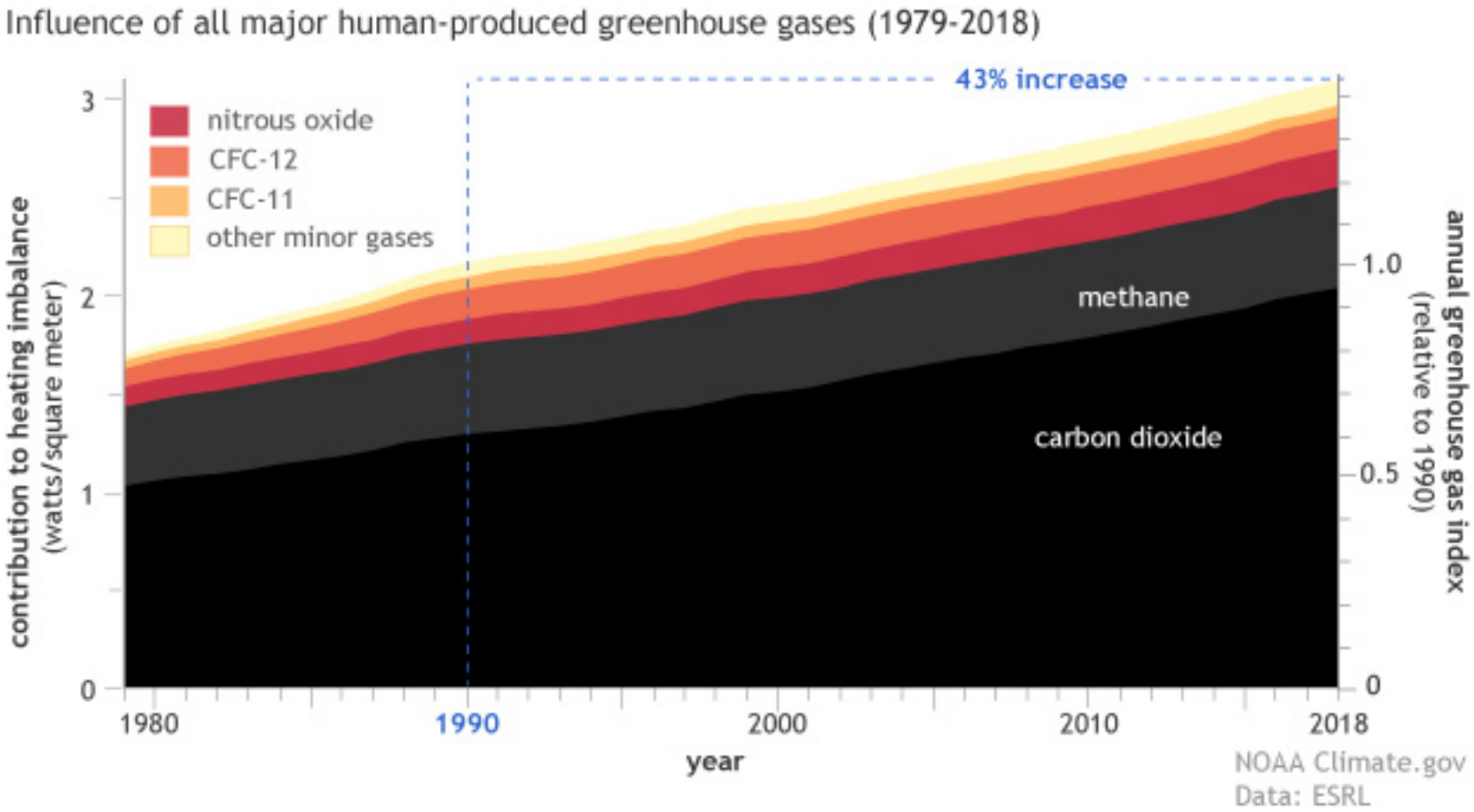


Figure: The heating imbalance in watts per square meter relative to the year 1750 caused by all major human-produced greenhouse gases.

Carbon Dioxide

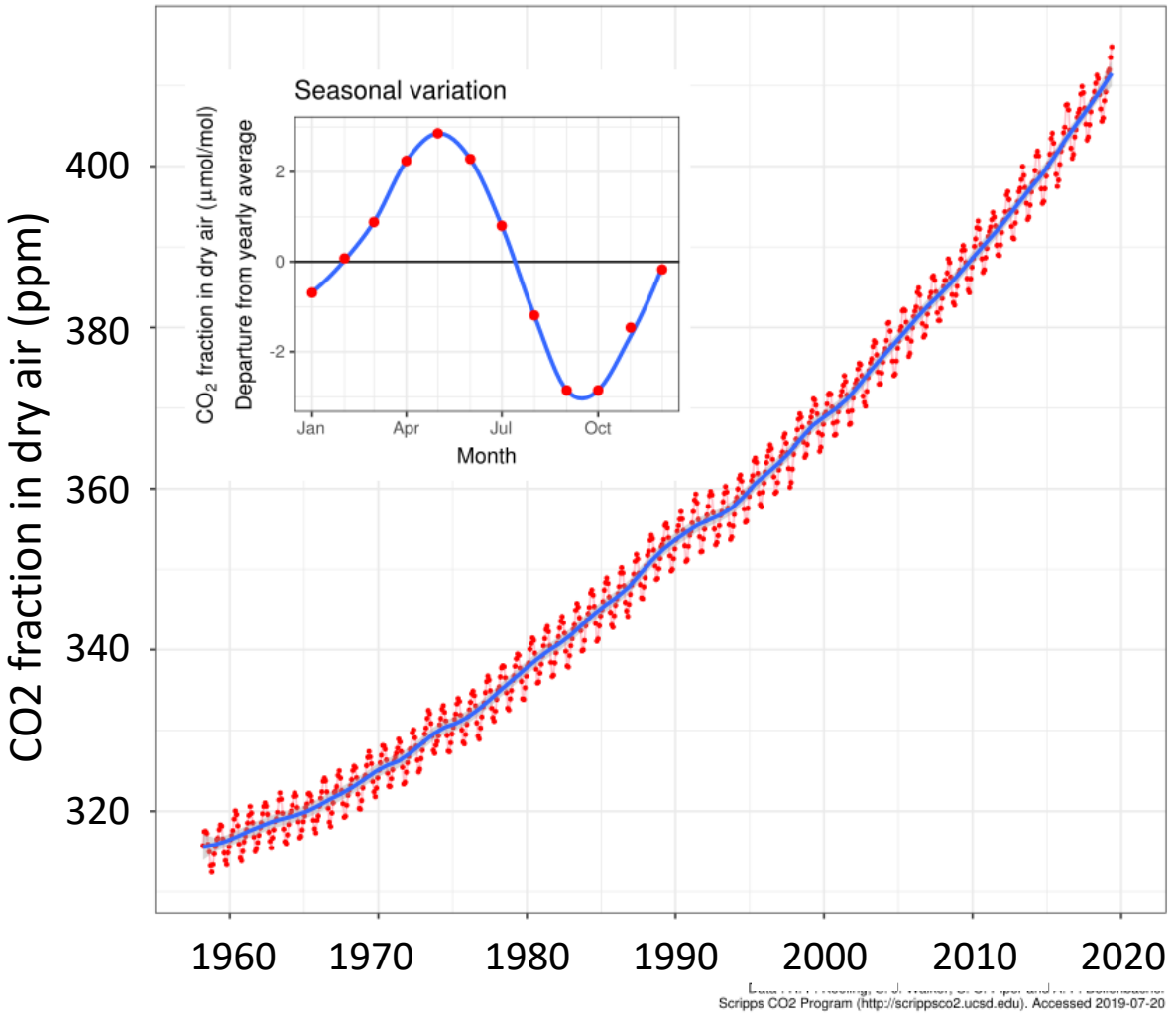
The **Keeling Curve** is named after Charles David Keeling, who started the CO_2 monitoring program at Mauna Loa Observatory in 1958 and supervised it until his death in 2005.

Carbon dioxide levels typically reach a maximum in the Northern Hemisphere Spring and minimum in the Northern Hemisphere Fall.

As of 2020, CO_2 has reached approximately 410ppm concentration. This is above pre-industrial levels of 280ppm and glacial periods when CO_2 concentration was closer to 180ppm.

https://en.wikipedia.org/wiki/Keeling_Curve

Monthly mean CO2 concentration, Mauna Loa 1958-2019



Carbon Dioxide

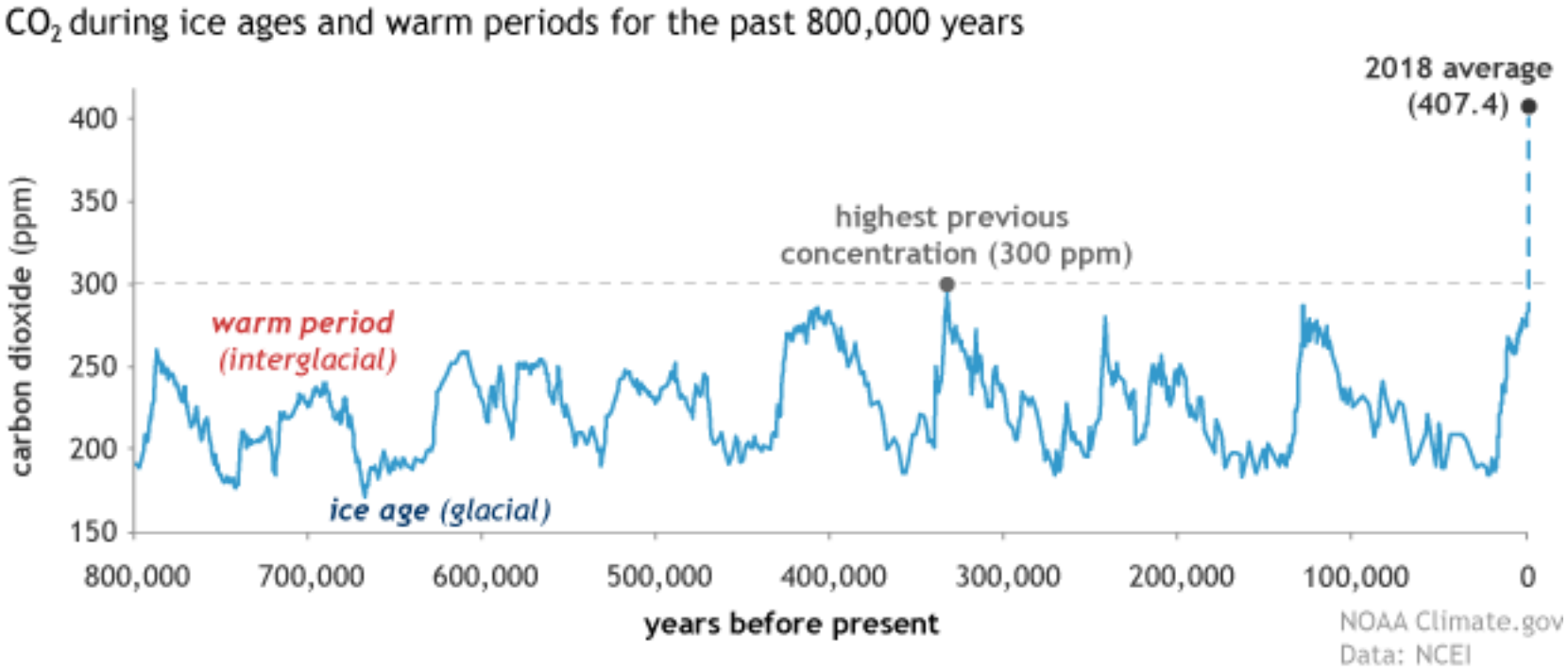
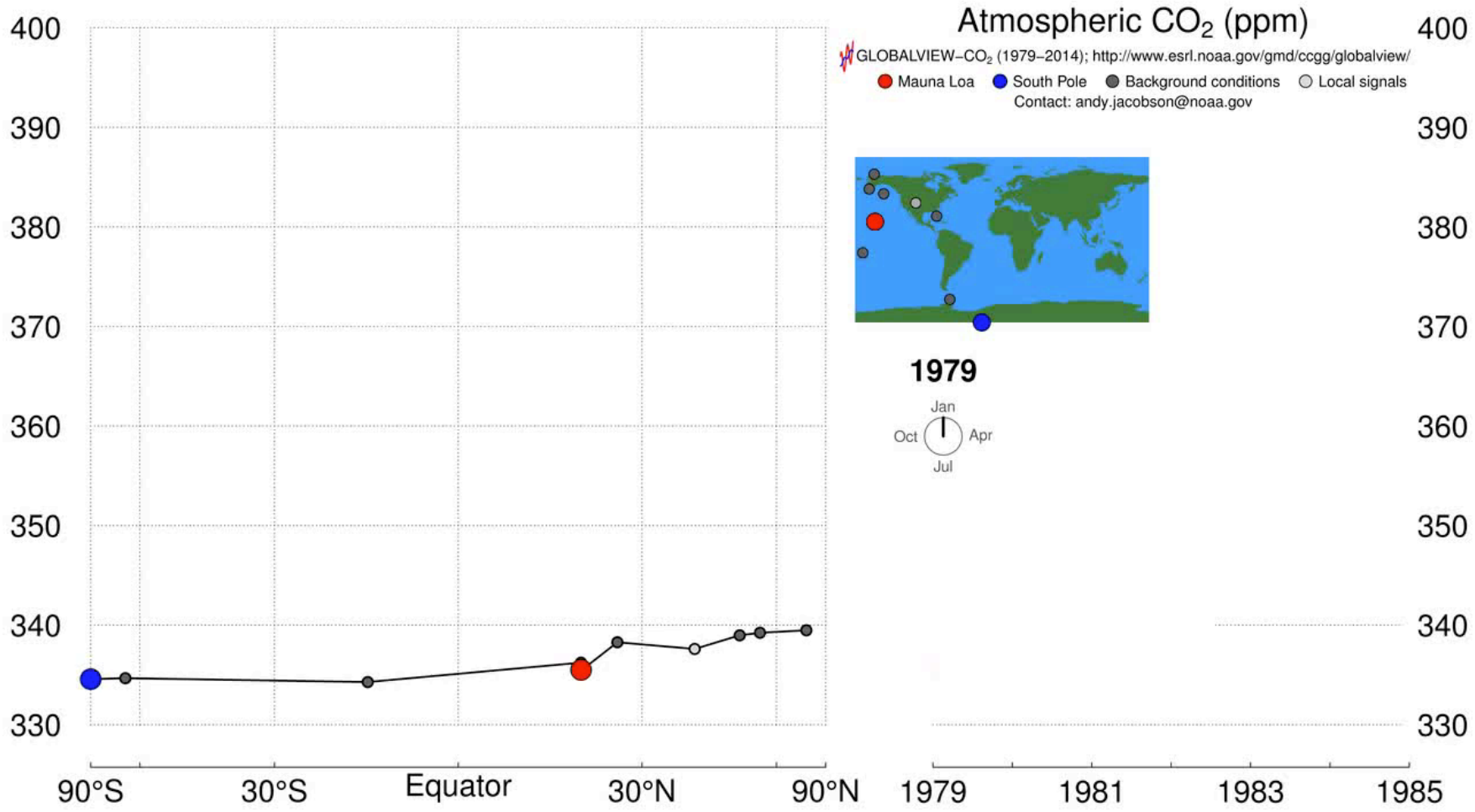


Figure: Global atmospheric carbon dioxide concentrations (CO_2) in parts per million (ppm) for the past 800,000 years.

Science Says: Current atmospheric levels of CO2 have not occurred for at least the last 800,000 years

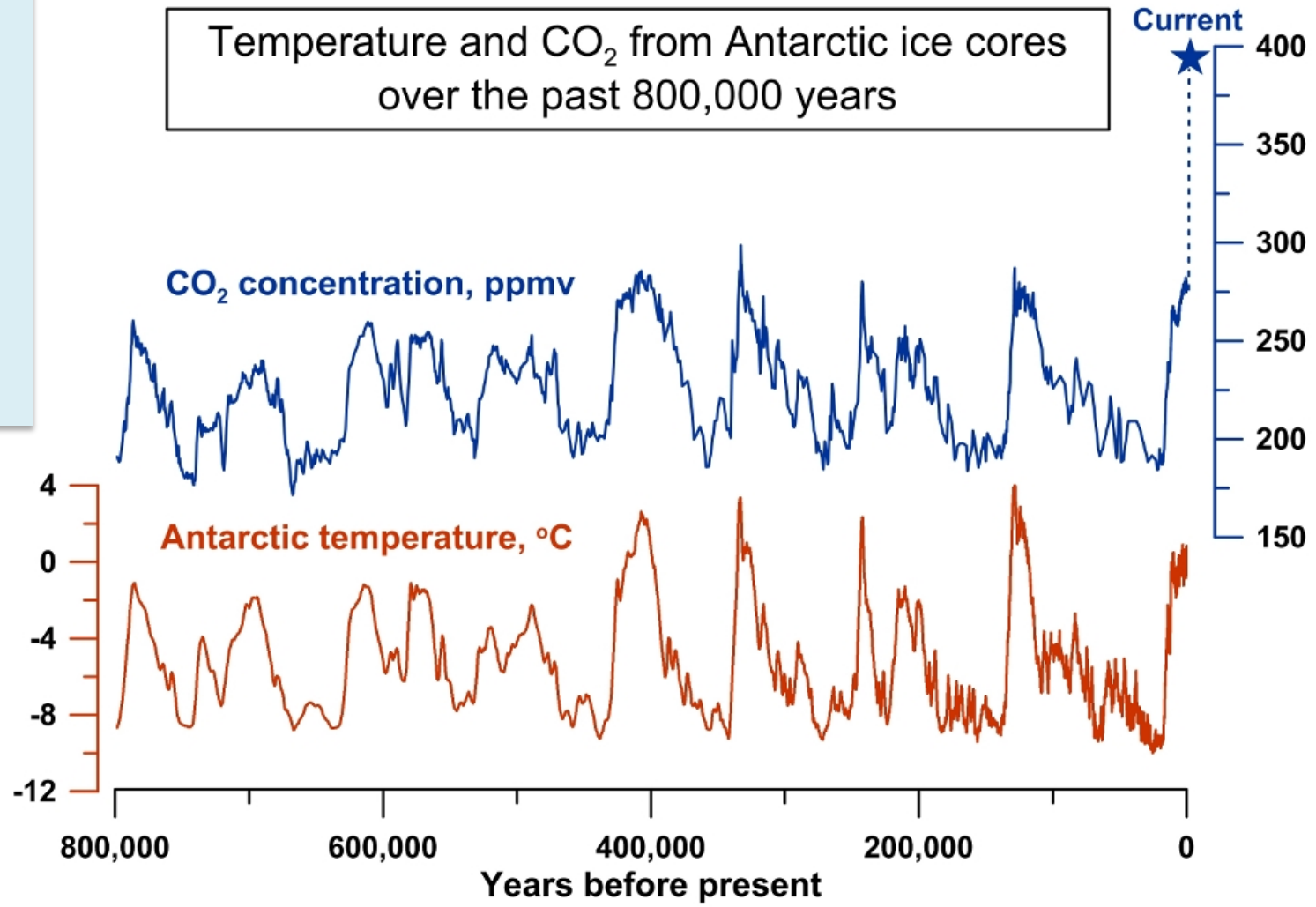
Historical Carbon Dioxide



Movie: Carbon Dioxide Pumphandle 2019 https://www.youtube.com/watch?v=1ZQG59_z83I

Historical Carbon Dioxide

Science Says: Atmospheric CO_2 concentration and temperature are self-reinforcing. Higher atmospheric CO_2 concentrations lead to warming. Higher temperatures lead to warmer oceans, which naturally release dissolved CO_2.



Temperature-CO_2 Feedback (Warming)

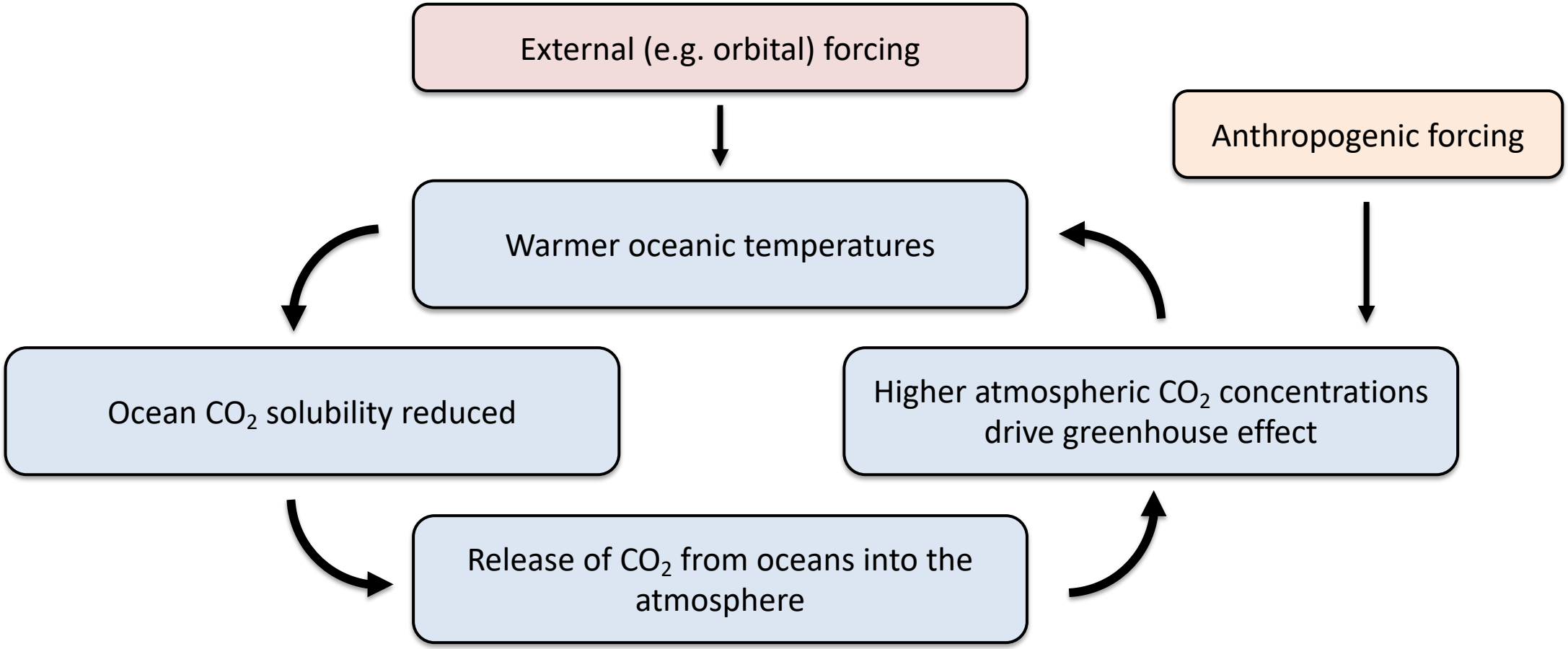
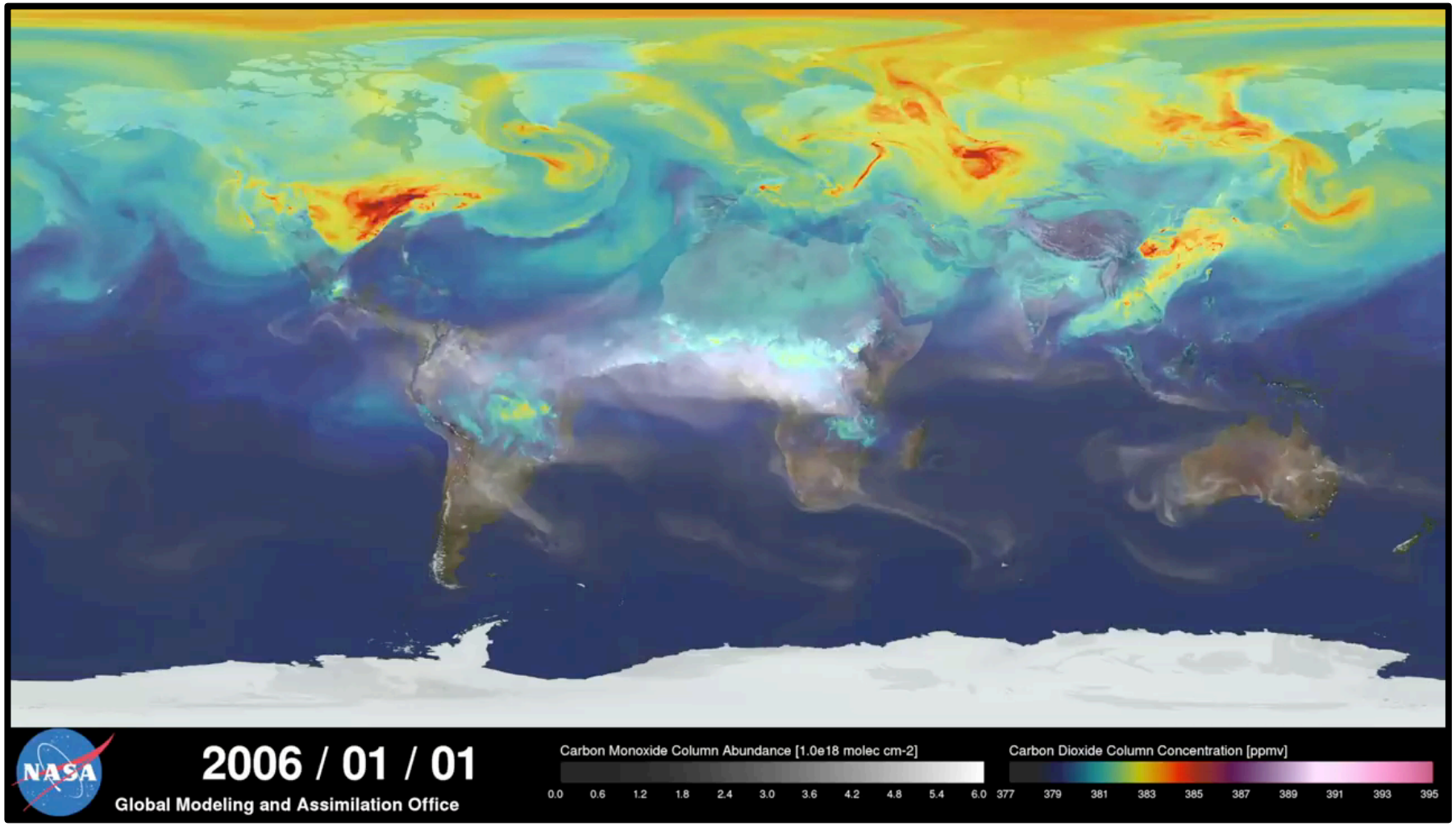


Figure: Positive cycle of the Temperature-CO_2 feedback.

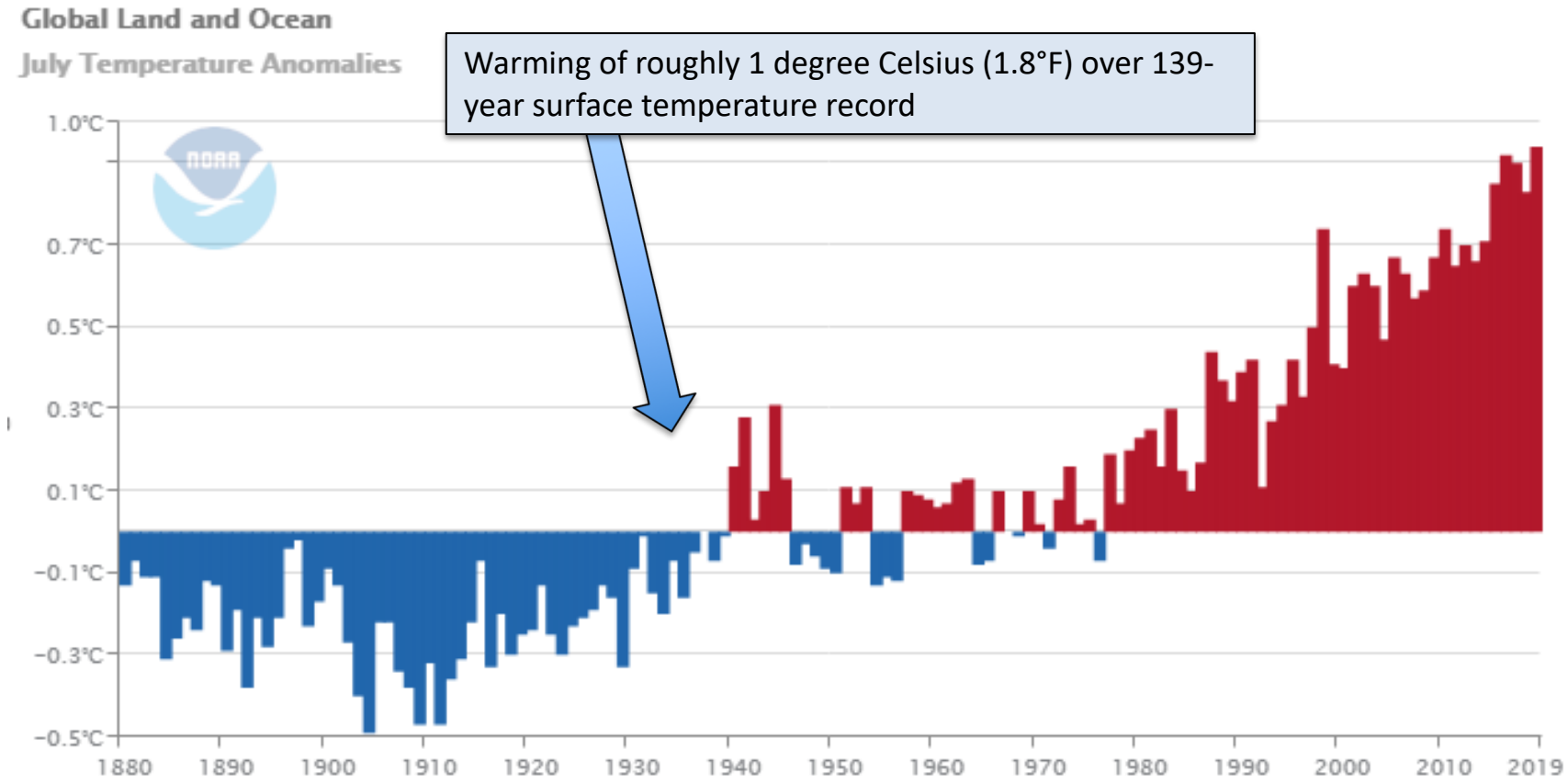
A Year in the Life of Carbon Dioxide



https://www.youtube.com/watch?v=x1SgmFa0r04

Climate Change

Warming of the Earth's land and ocean surface is "unambiguous"

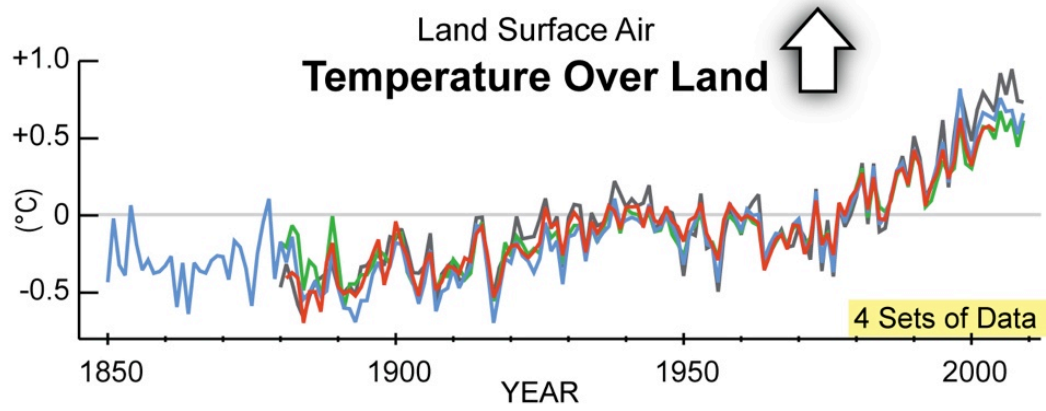


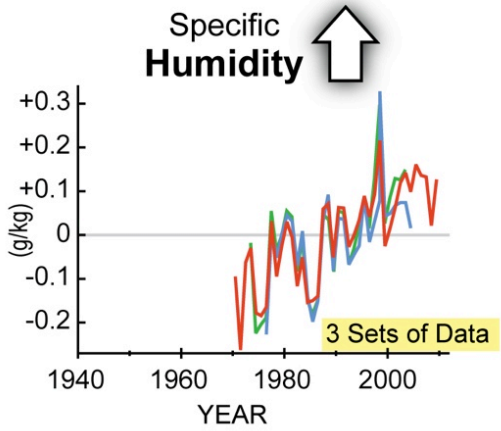
Source: https://www.ncdc.noaa.gov/sotc/global/201907

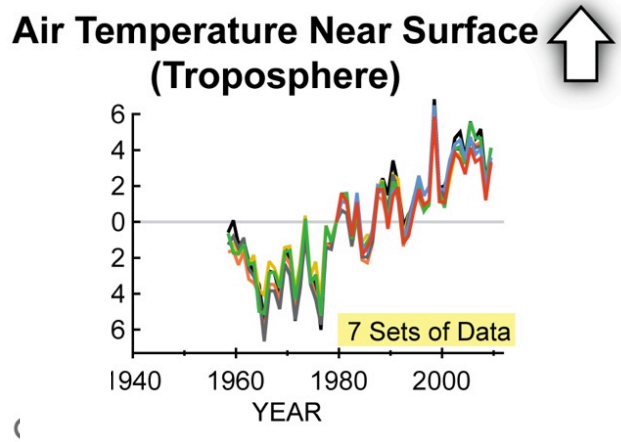
Climate Change

Observed changes in many different aspects of the climate system are internally and physically consistent

Land and atmospheric climate change indicators that should be increasing <u>are</u> increasing







Source: State of the Climate in 2009 (Bulletin of the American Meteorological Society, July 2010)

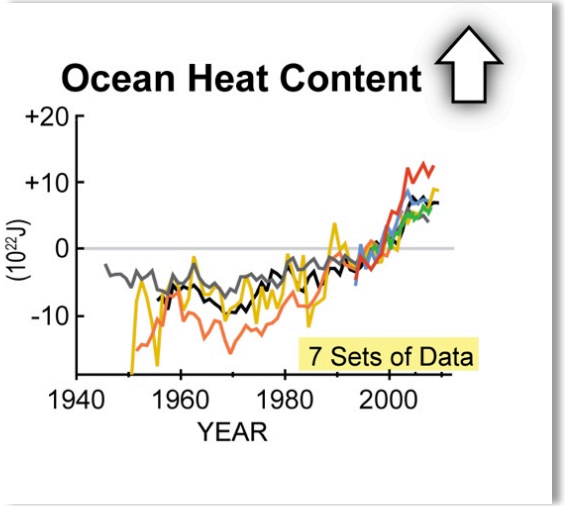
Slides by Ben Santer, 2012.

Climate Change

Slides by Ben Santer, 2012.

Observed changes in many different aspects of the climate system are internally and physically consistent

Oceanic climate change indicators that should be increasing <u>are</u> increasing



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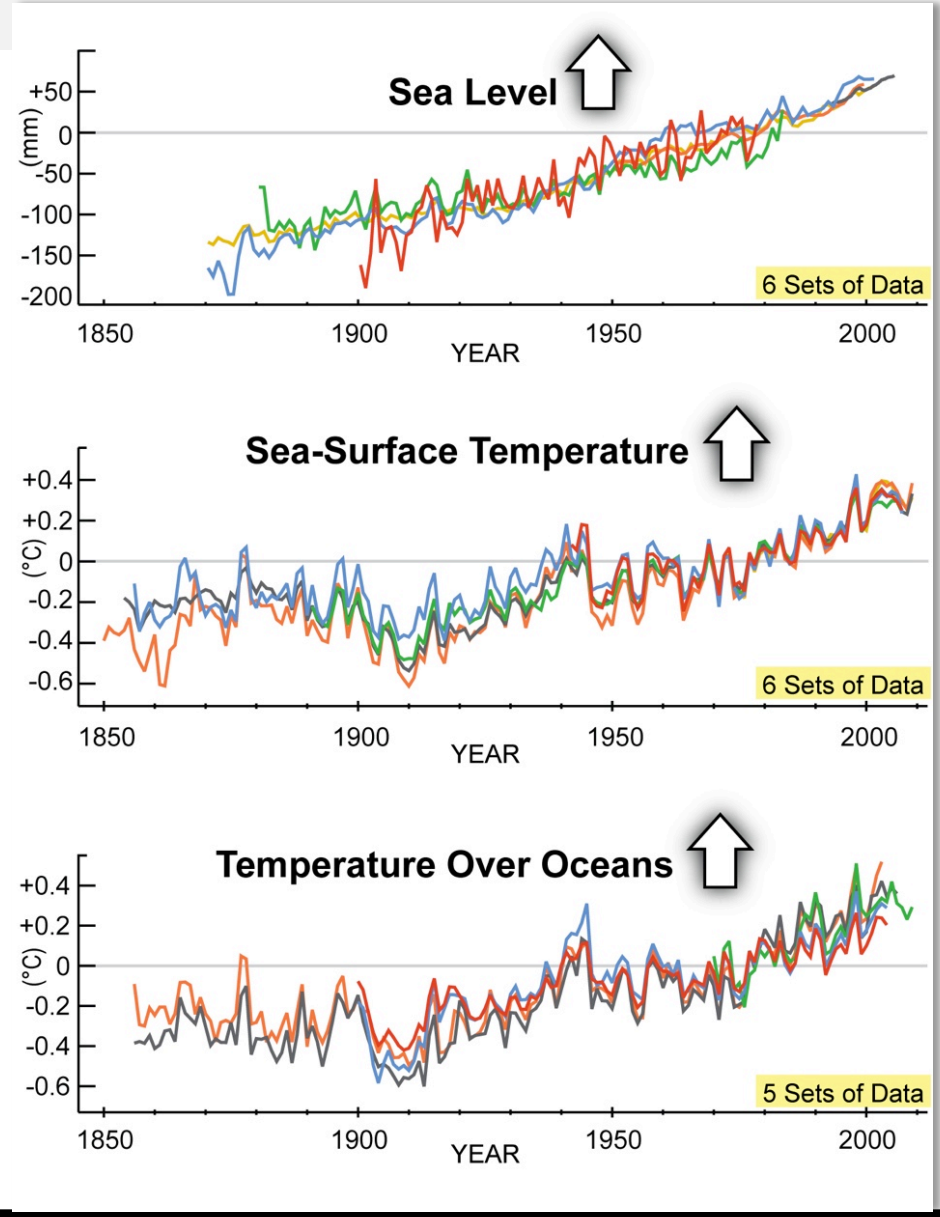
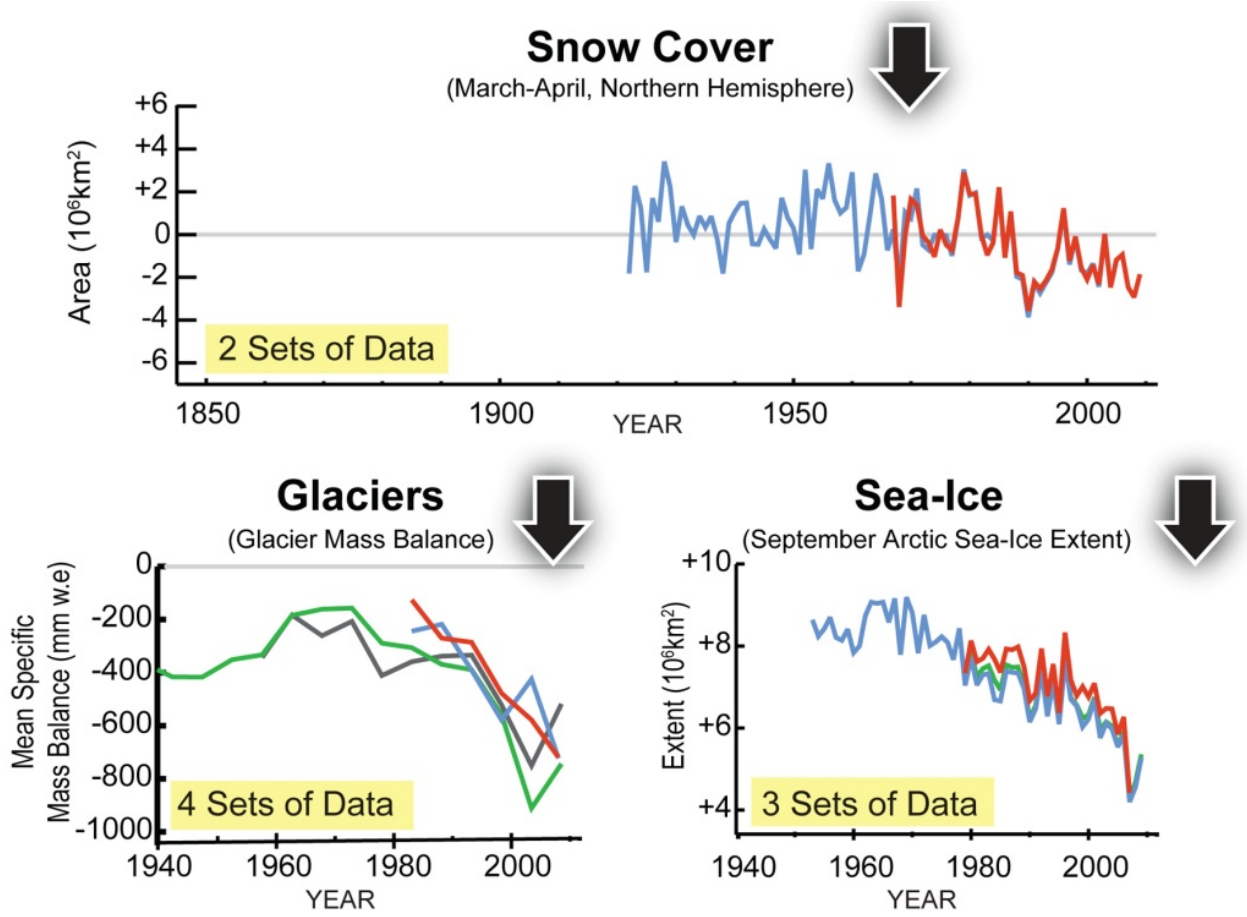


Climate Change

Source: Ben Santer, 2012.

Observed changes in many different aspects of the climate system are internally and physically consistent

Climate change indicators that should be decreasing <u>are</u> decreasing

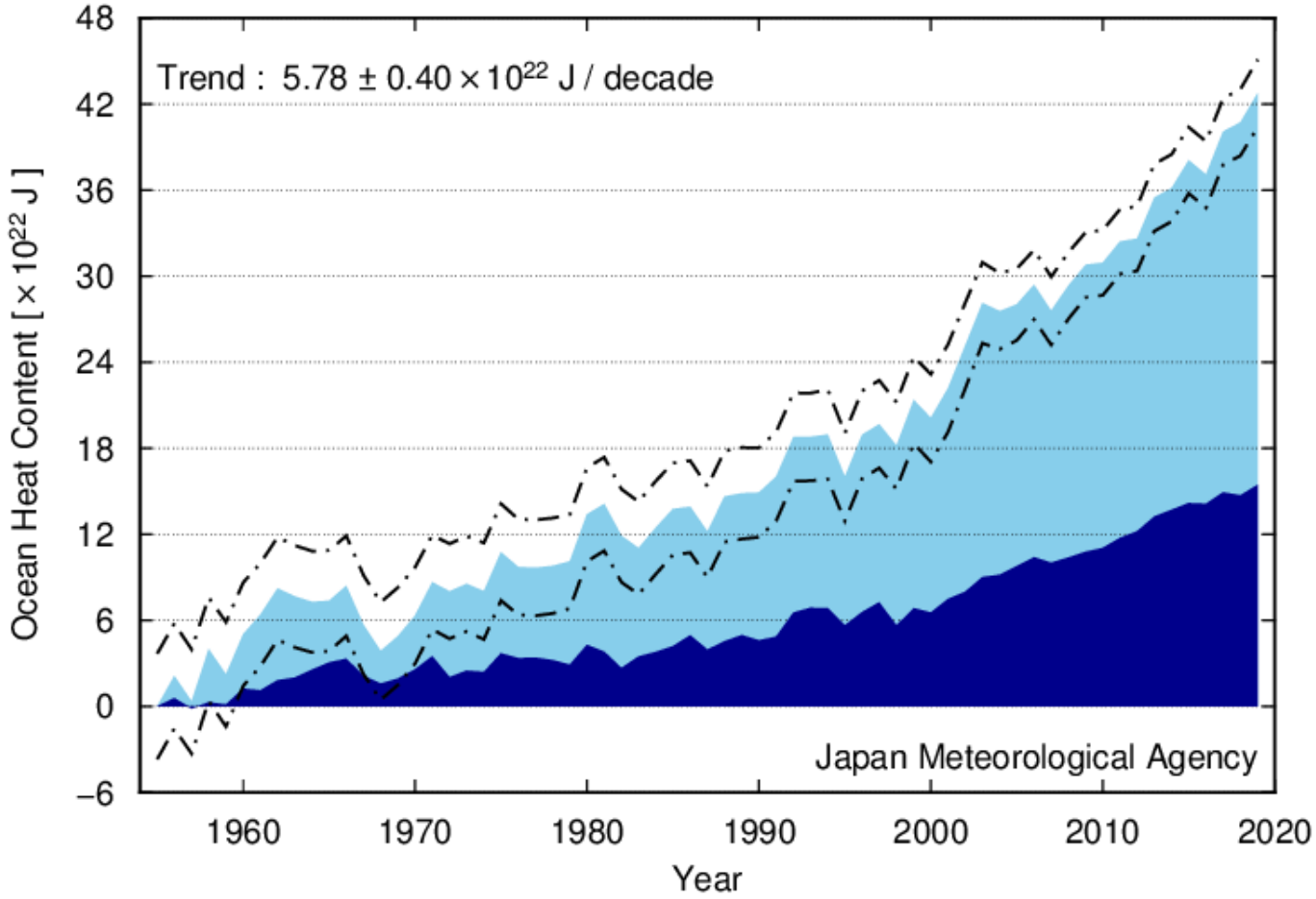


Source: State of the Climate in 2009 (Bulletin of the American Meteorological Society, July 2010)

Climate Change: Ocean Heat Content

Figure: Time series representation of the globally integrated ocean heat content. Light blue shading shows change above 700m depth. Dark blue shading shows change between 2000m and 700m depth.

Change in land + ice + atmosphere heat content is around 3 x 10^{22} J over this same time period.

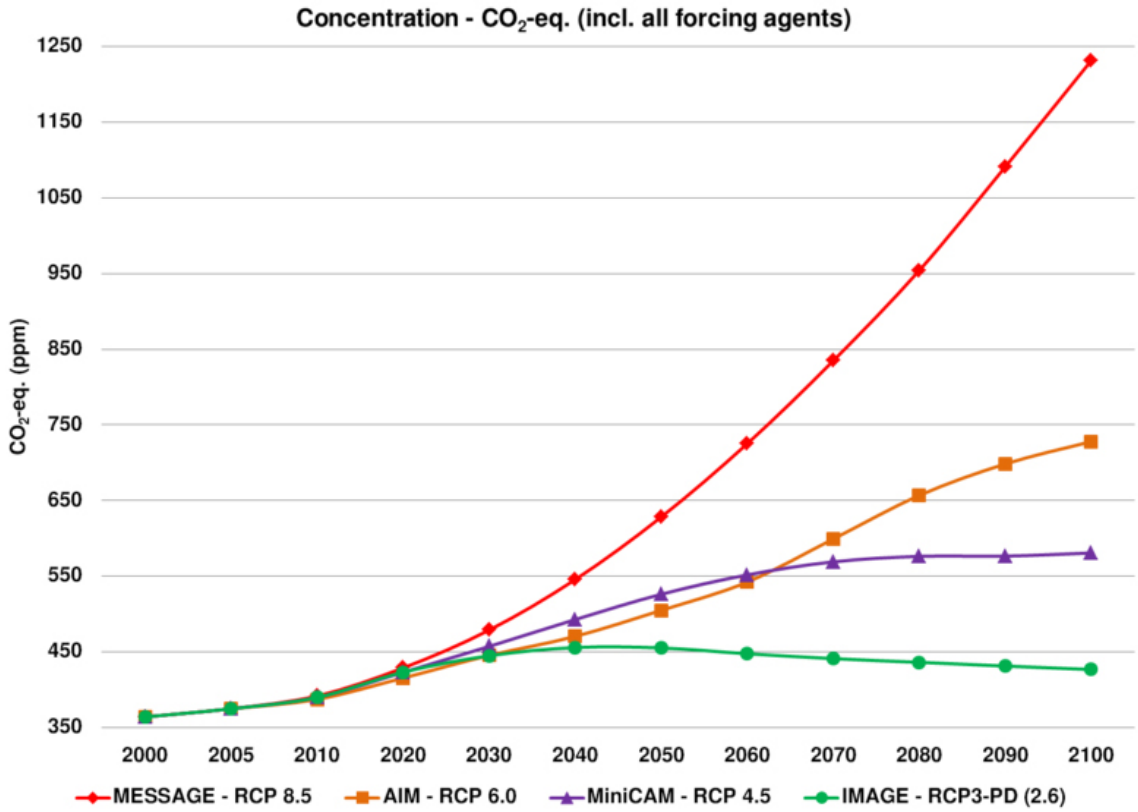


Future Change

Socio-Economic Scenarios → Emissions Scenarios → Radiative Forcing Scenarios → Climate Model Scenarios → Impact, Adaptation, Vulnerability

Definition: Representative Concentration Pathways (RCPs) are estimates of atmospheric greenhouse gas concentrations that would be expected in response to economic growth and policy scenarios.

In the forthcoming 6th assessment report the focus is on **Shared Socioeconomic Pathways (SSPs).**



Future Change

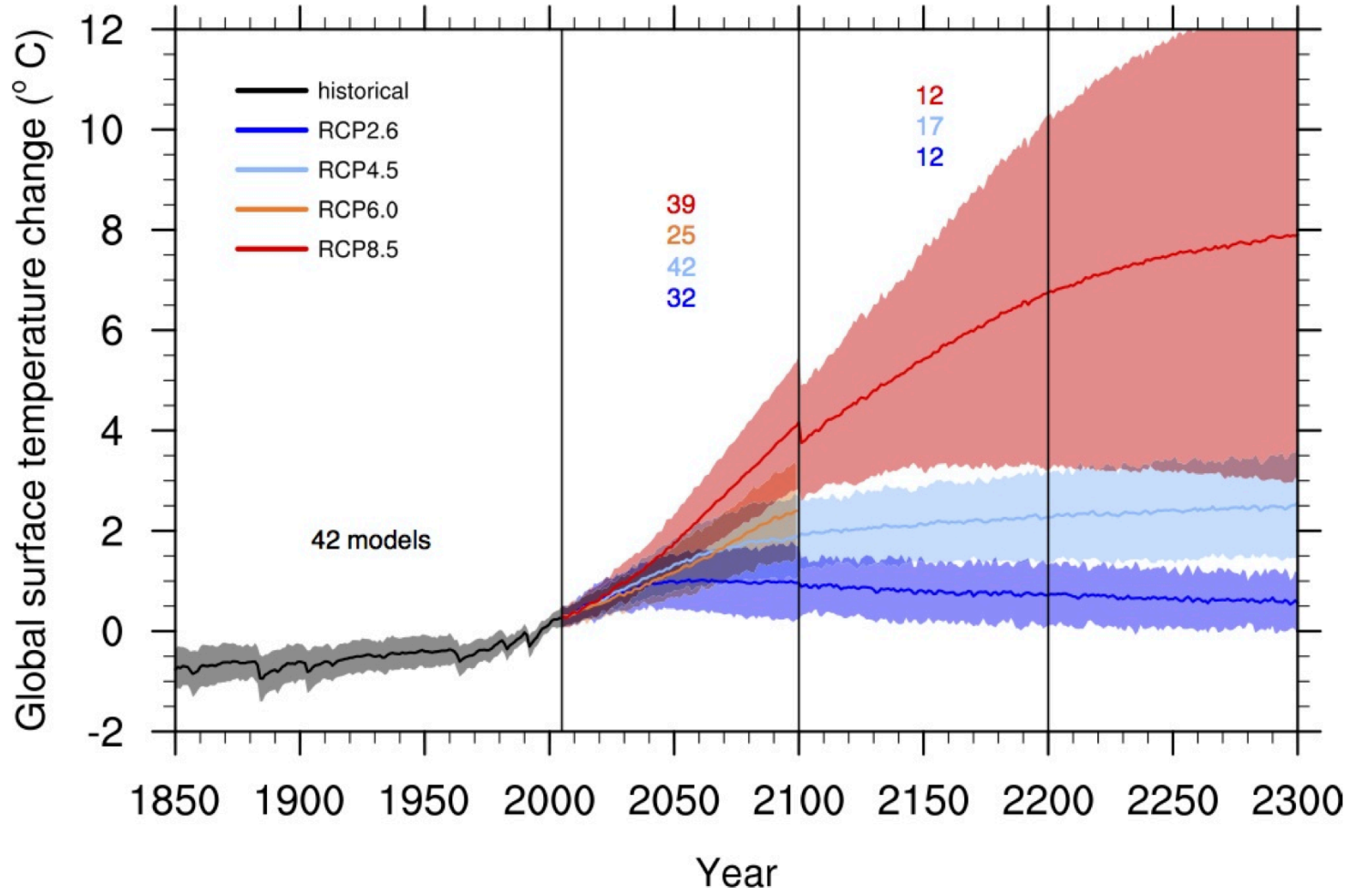


Figure: Future climate warming predicted by multi-model average and assessed ranges for surface warming (IPCC AR5).

Anticipated Changes

Temperature: Global average rise of 0.2°C over the next two decades. Global average rise between **1.8°C (3.2°F)** and **4.0°C (7.2°F)** by end of century, depending on emissions scenario. Temperatures over **land are expected to increase faster than temperatures over the ocean**, and increase is expected to be **larger at higher altitudes** (elevation-dependent warming) and in the **polar regions**.

Source: CSIRO

Source: By D Sharon Pruditt (Pink Sherbet Photography) CC-by-2.0.

Precipitation: Increased temperatures will cause increased evaporation, leading to more water vapor in the air **(~7% per degree C)**, and causing a speed-up of the water cycle. **Expansion of the Hadley cells** may occur leading to an intensified storm track and desertification. Global average precipitation will increase **3-5%**. Actual change is highly dependent on region (generally, **dry areas become dryer**, **wet areas become wetter**).

Anticipated Changes

Cryosphere: Accelerated melting of all aspects of the cryosphere will occur, including snowpack, sea ice and glaciers.

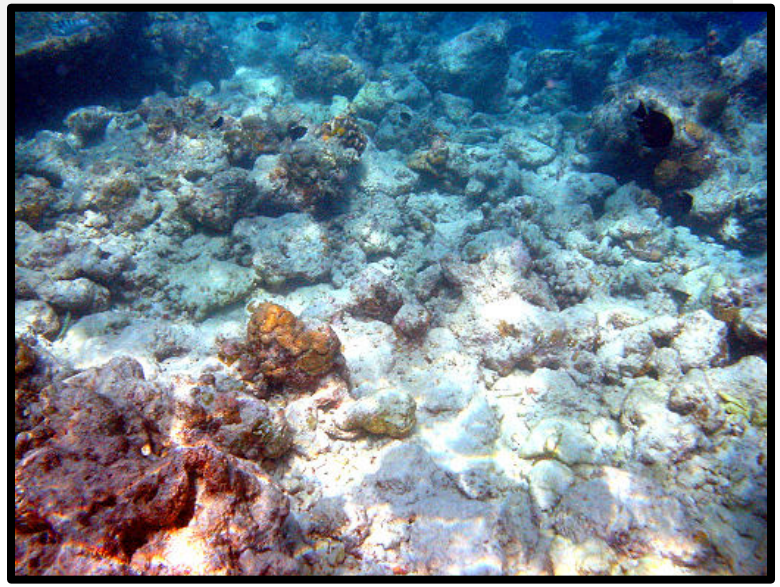
Source: By Jamcib (Own work) [GFDL]

Sea Level: Sea level rises via (1) thermal expansion of the ocean and (2) melt of land ice. During the 20th century, sea level rose about 10 to 20 cm (4 to 8 inches). Thermal expansion and ice melt each contributed about 50% to the rise. By 2100 rise is expected to be between **20 and 50cm (8 to 20 inches)** above 2000 levels. Over this period thermal expansion will contribute about 75% to this rise.

http://scied.ucar.edu/longcontent/predictions-future-global-climate

Anticipated Changes

Ocean Acidification: As the oceans take up more carbon dioxide, this converts to carbonic acid in the oceans. This is thought to have reduced the ocean pH by 0.1 since pre-industrial. Further acidification of 0.14 to 0.35 pH is expected by the year 2100.



Source: By Bruno de Giusti (Own work) [CC BY-SA 2.5 it]

Extreme Weather: Tropical cyclones, extratropical cyclones and atmospheric rivers will be impacted by increased temperatures. Warmer oceans will cause intensification of such storms. However, the frequency of TCs and ETCs may decrease.

http://scied.ucar.edu/longcontent/predictions-future-global-climate

ATM 241 Climate Dynamics
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Thank You!