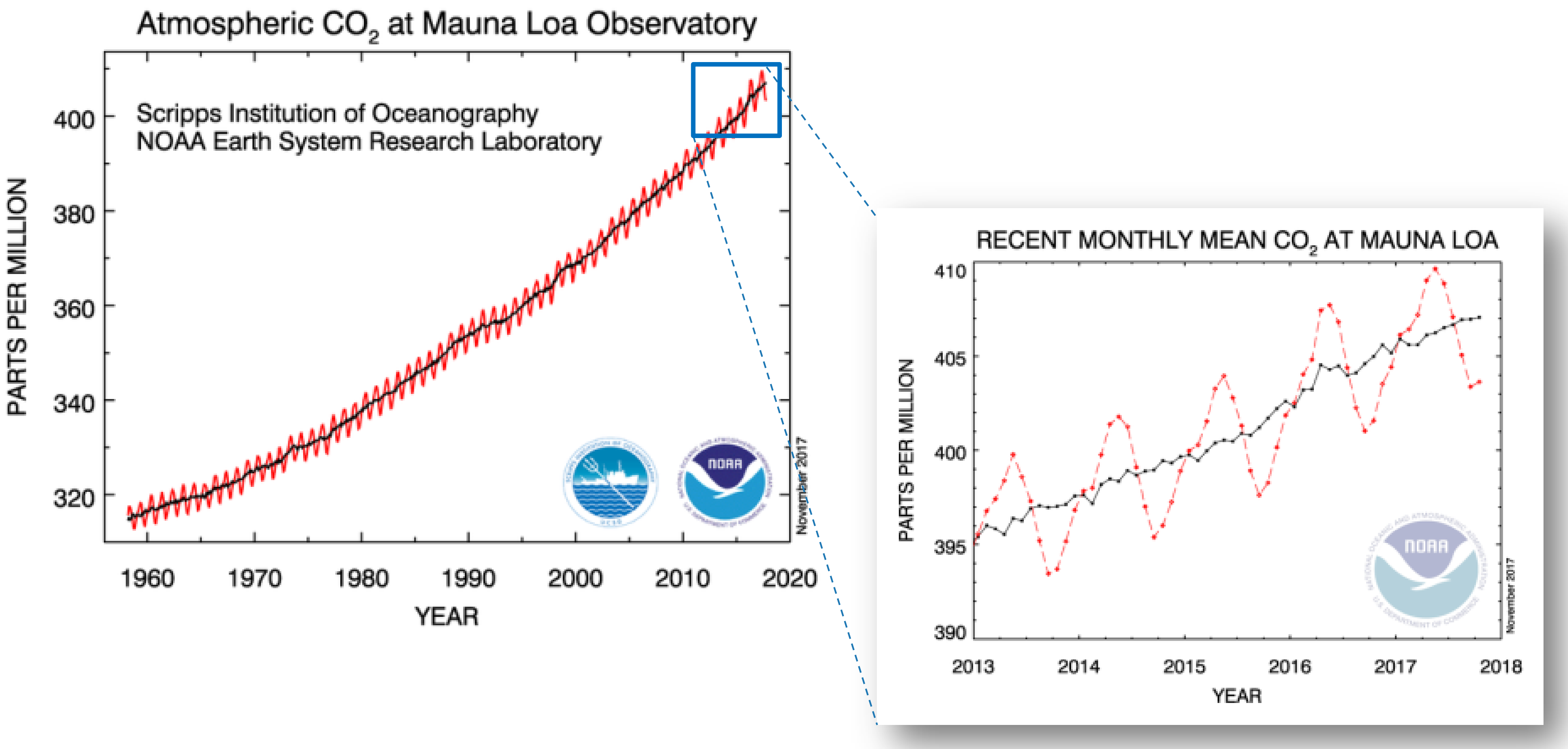
The Global Climate system and global change

Colin Jones

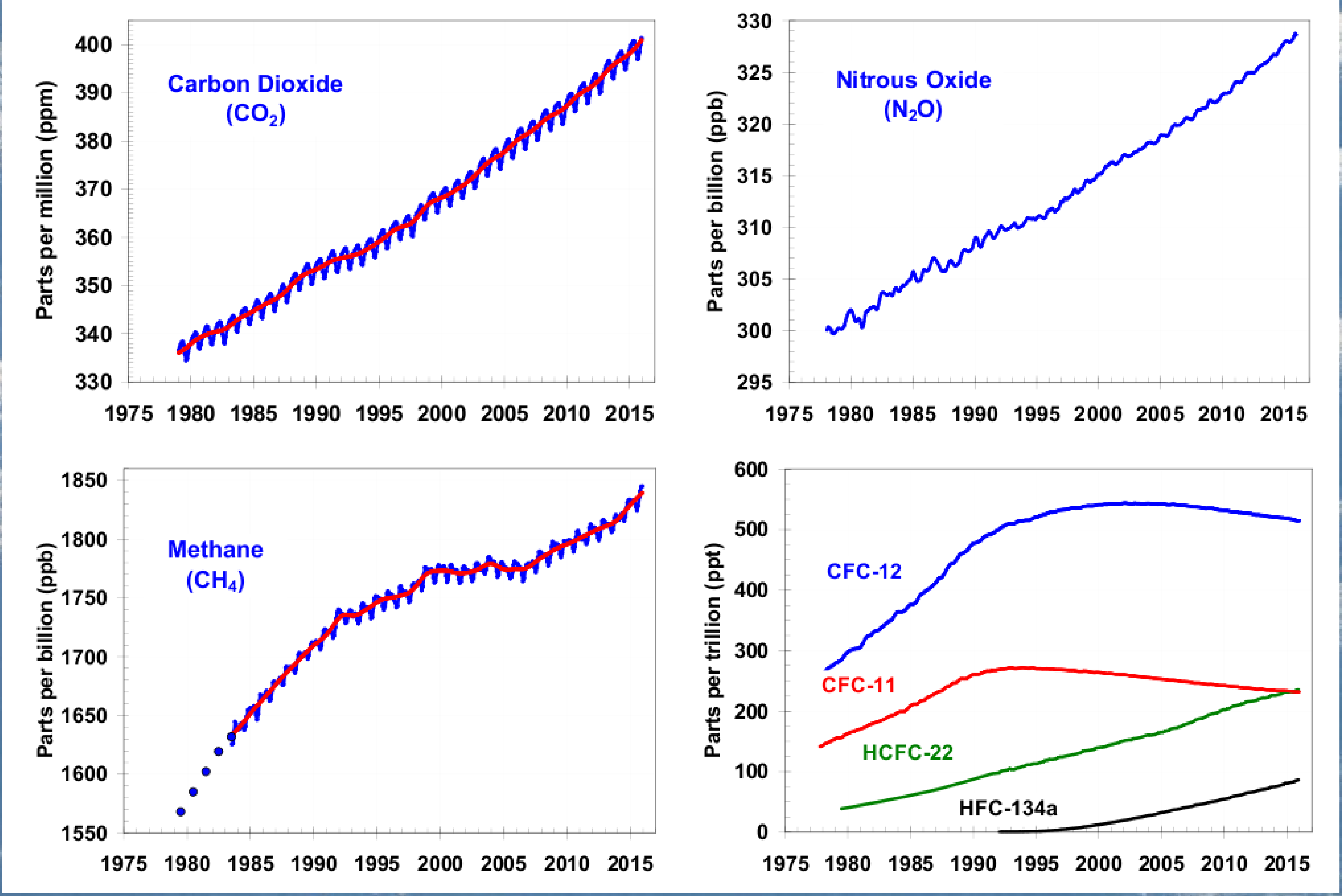
Atmospheric CO_2 has been measured around the world since 1957

Hawaii is the oldest continuous observing station

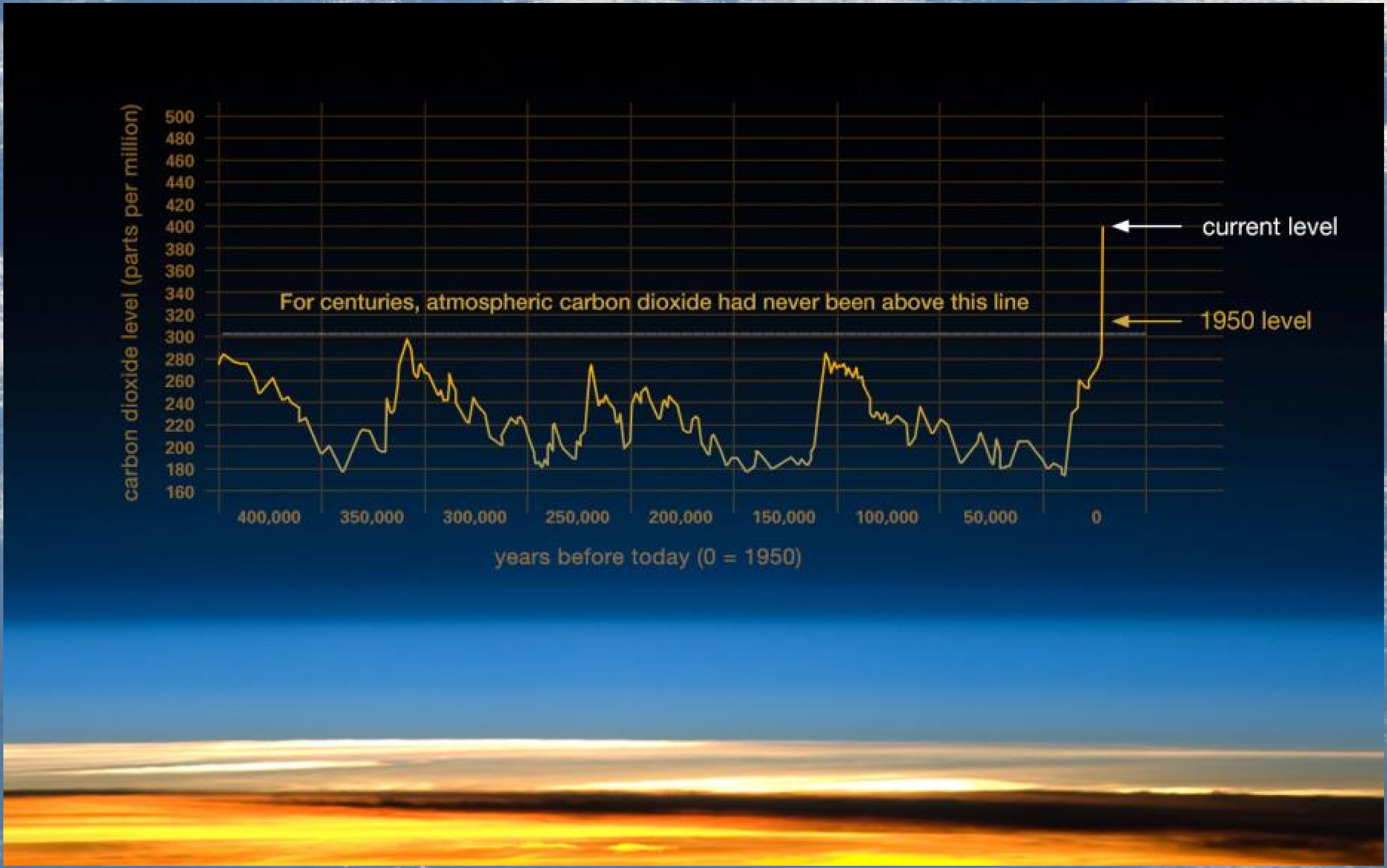


NOAA 2017

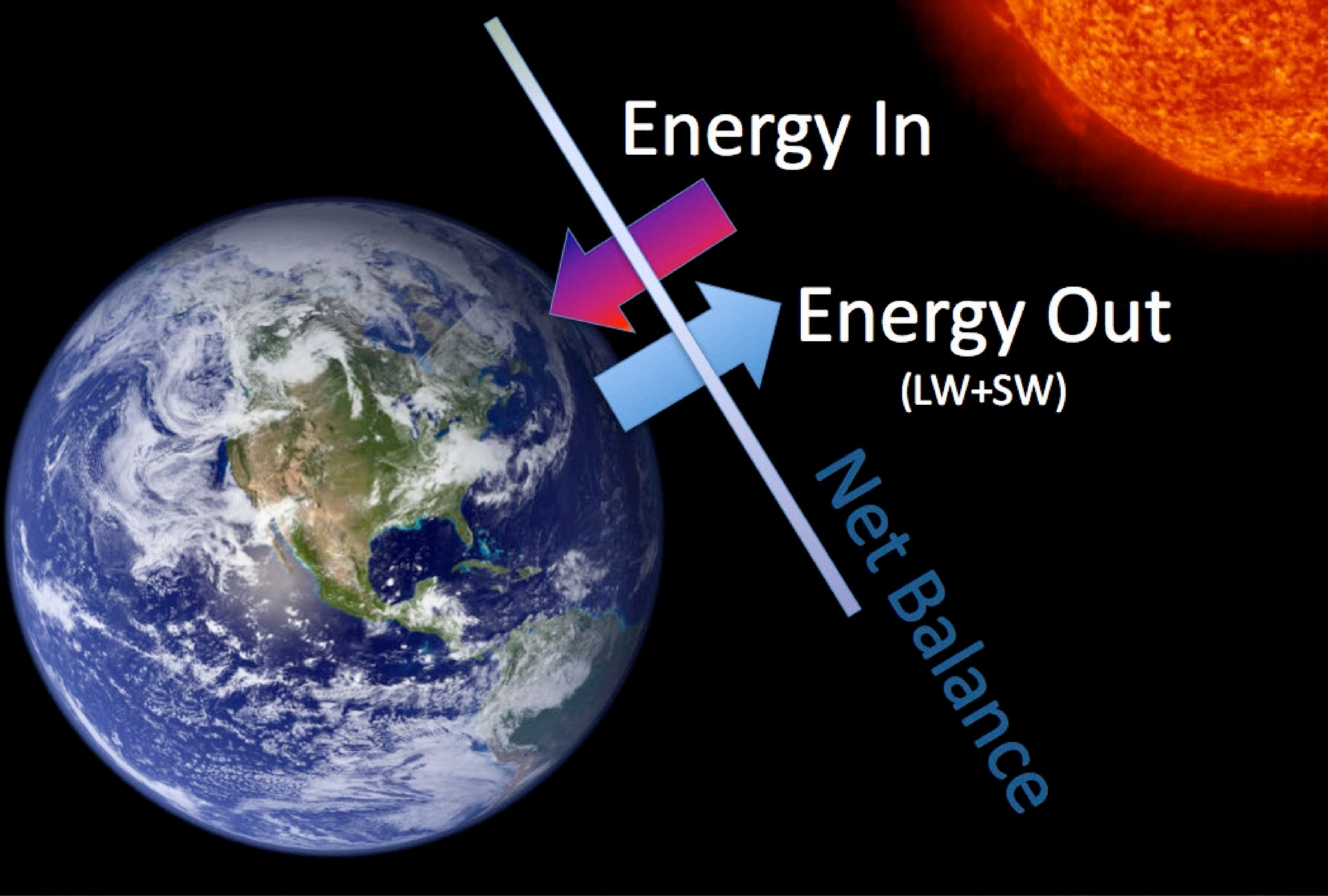
Other atmospheric gases have increased over the past decades linked to human activities



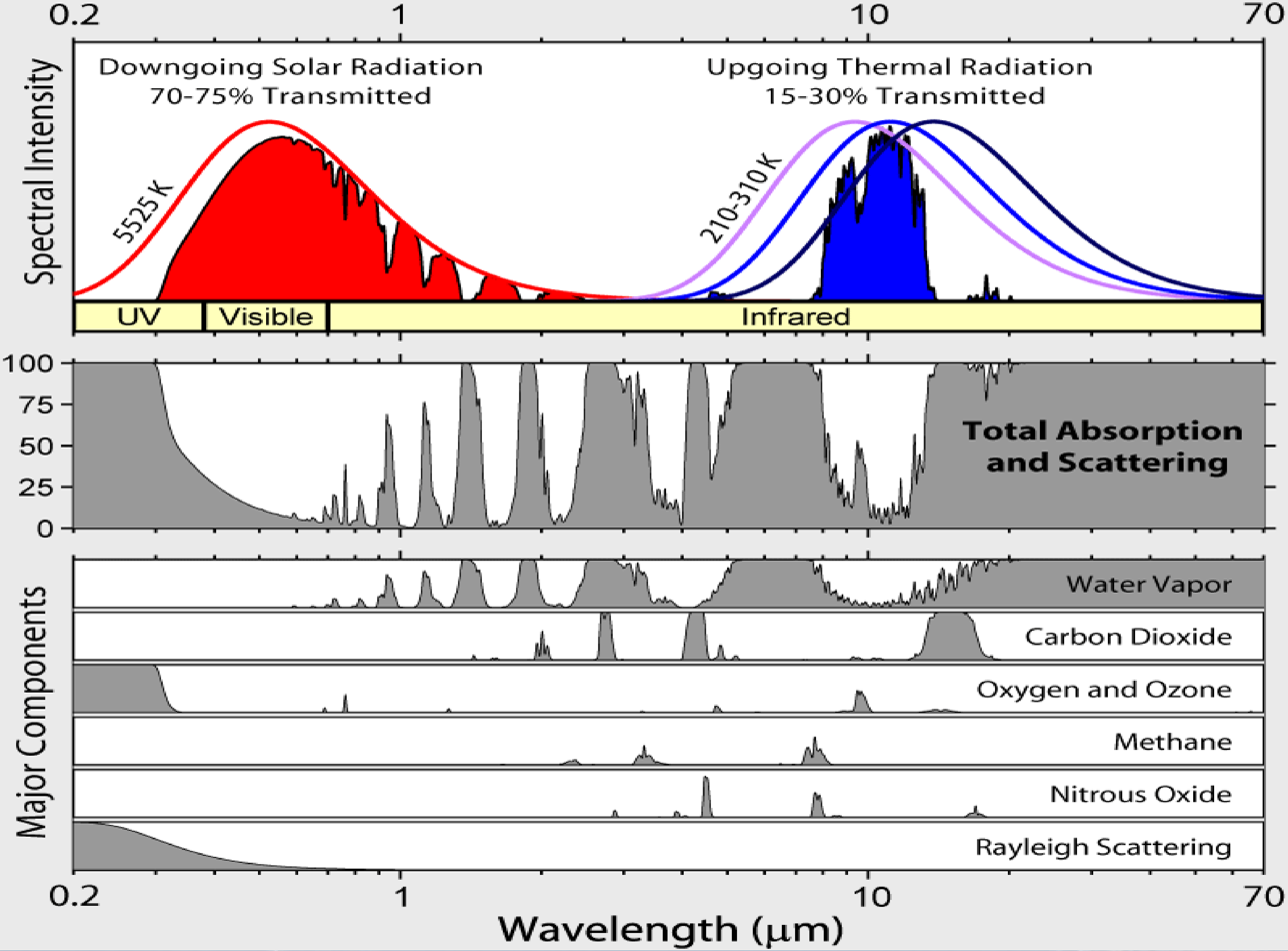
Atmospheric CO_2 amounts are higher than they have ever been over at least the past 500,000 years

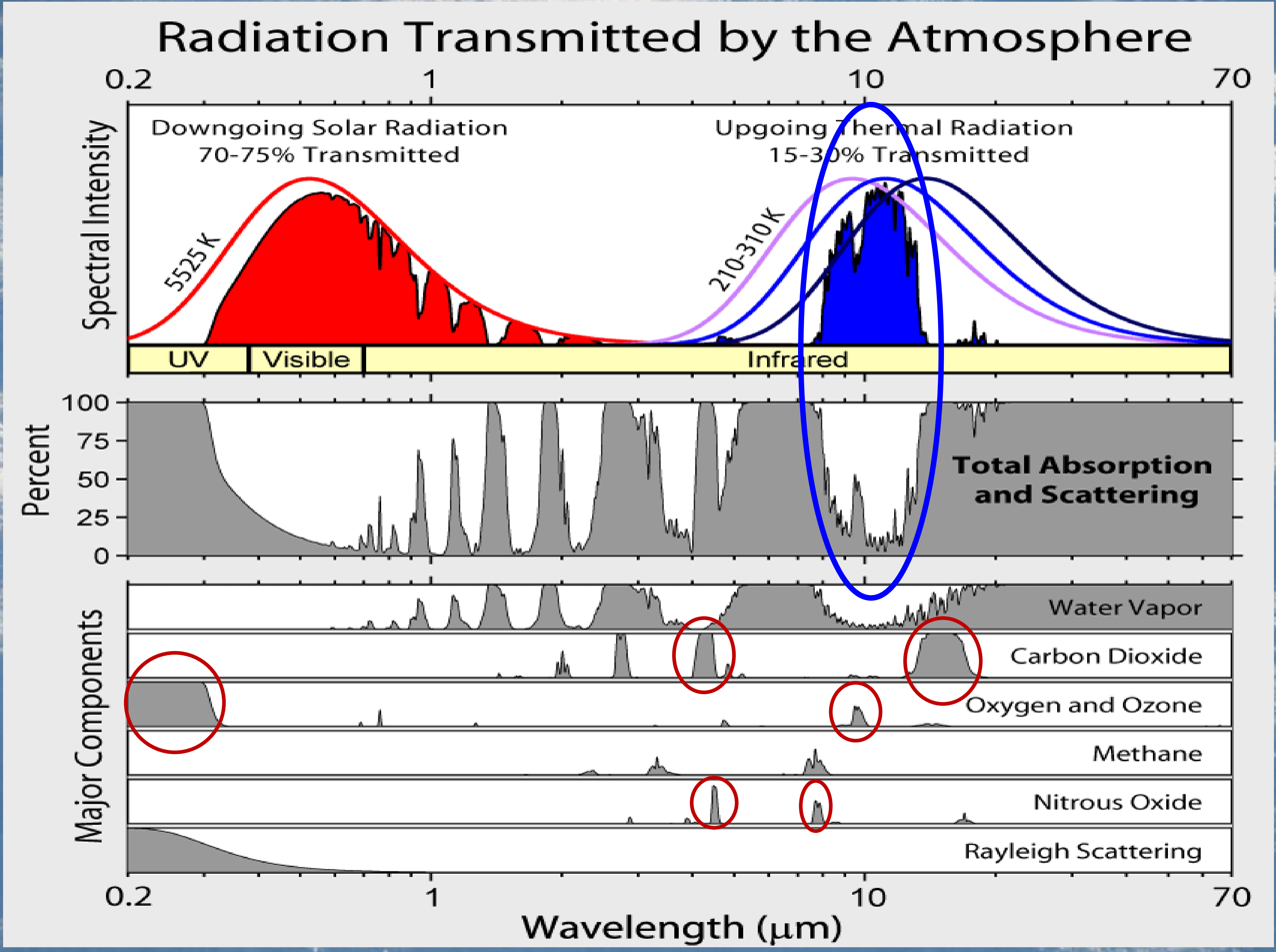


To be in thermal balance the Earth emits the same amount of radiant energy as it receives from the sun. If it did not it would cool or warm to naturally achieve such a balance

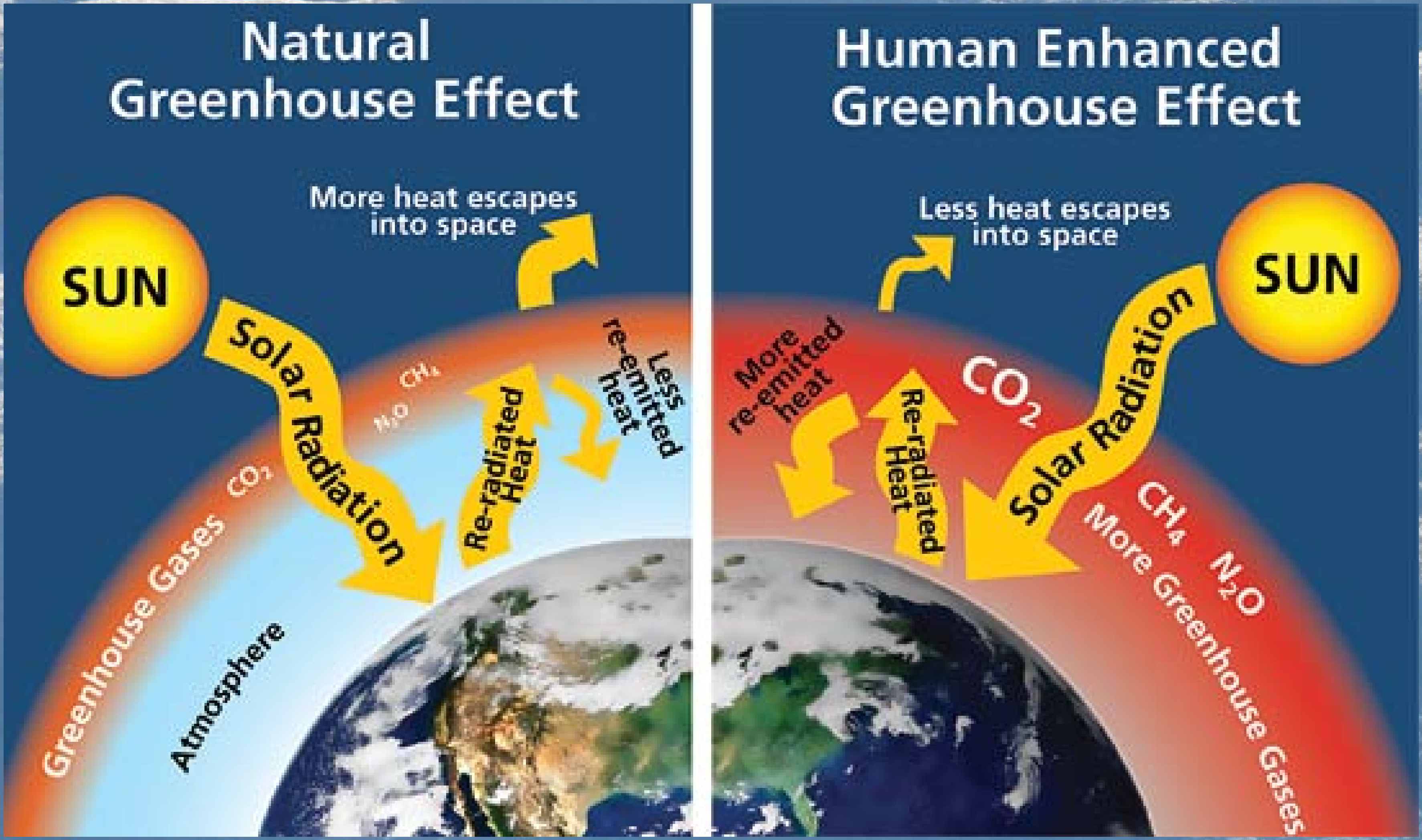


Radiation Transmitted by the Atmosphere



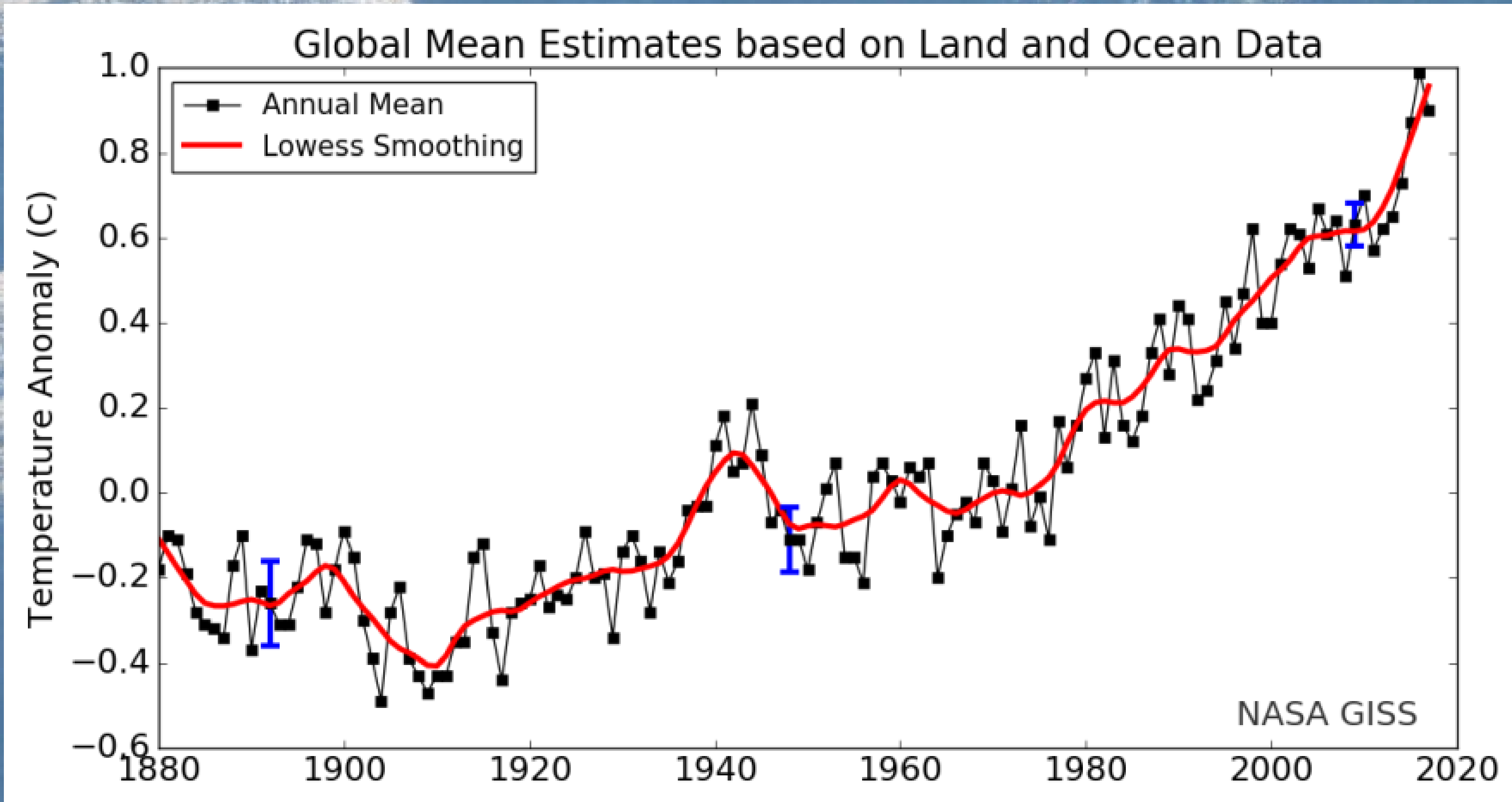

Radiation Transmitted by the Atmosphere
0.2
1
10
70
Spectral Intensity
Downgoing Solar Radiation
70-75% Transmitted
Upgoing Thermal Radiation
15-30% Transmitted
5525 K
210-310 K
UV
Visible
Infrared
Percent
100
75
50
25
0
Total Absorption and Scattering
Major Components
Water Vapor
Carbon Dioxide
Oxygen and Ozone
Methane
Nitrous Oxide
Rayleigh Scattering
Wavelength (μm)

CO_2, O_3, CH_4 are greenhouse gases, more of them in the atmosphere increases the natural greenhouse effect. Less of Earth's emitted radiation can get out through the atmosphere. Some of this trapped radiation is emitted back to the surface, warming it, so more radiation is emitted and a new balance is reached at the top of the atmosphere with a warmer Earth's surface



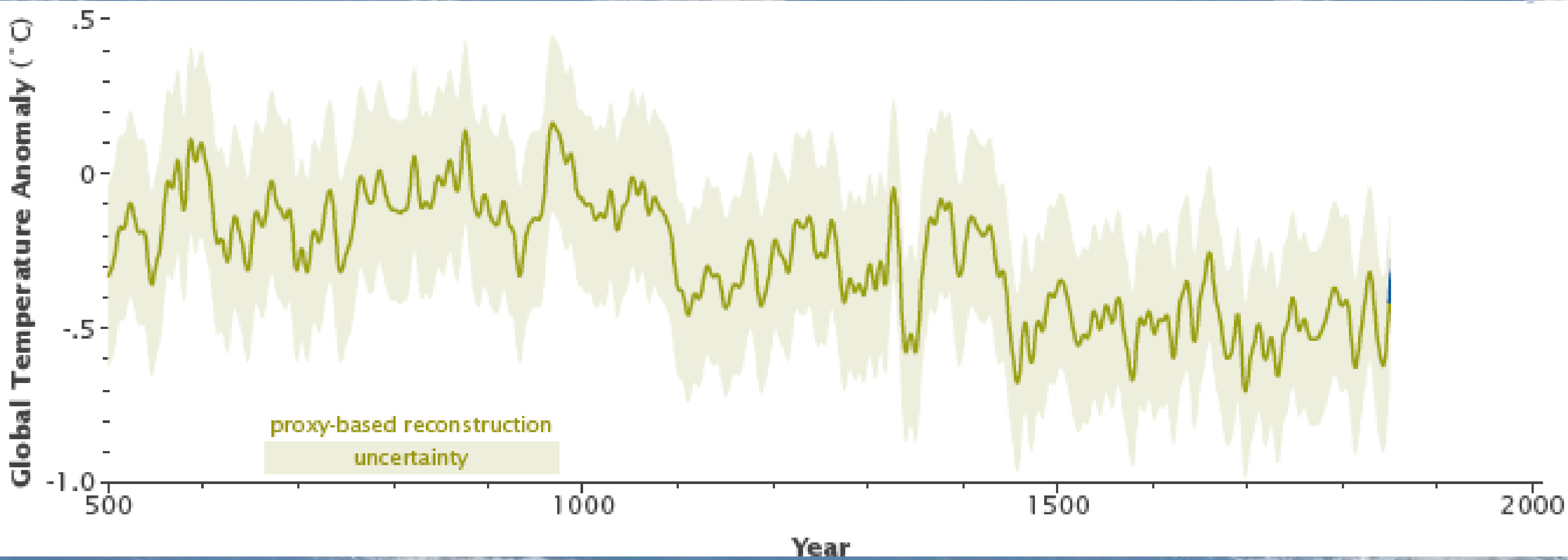
Scientists often refer to anomalies (differences) in various measures of the climate relative to a long-term (often 30 year) average of the same measure.

Global Mean Surface Temperature anomaly relative to the 1951-1980 average



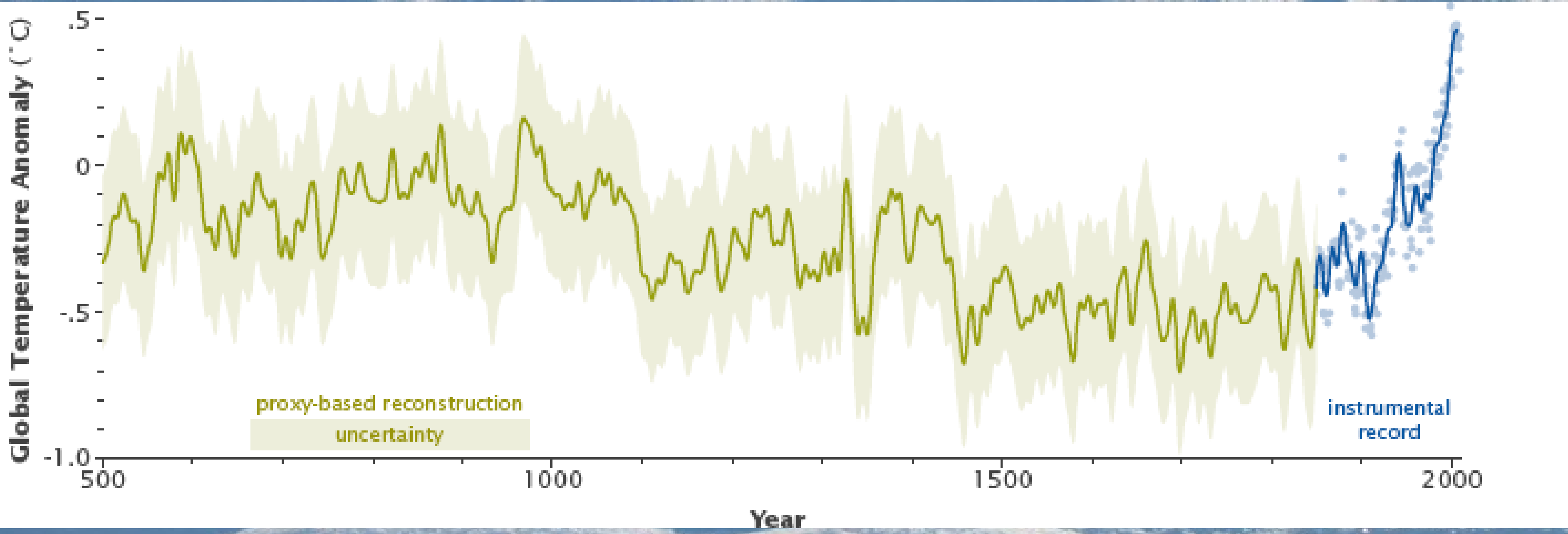
A longer view

Reconstructed global surface temperature anomalies: 500 to 1980 A.D relative to 1961-1990 average values



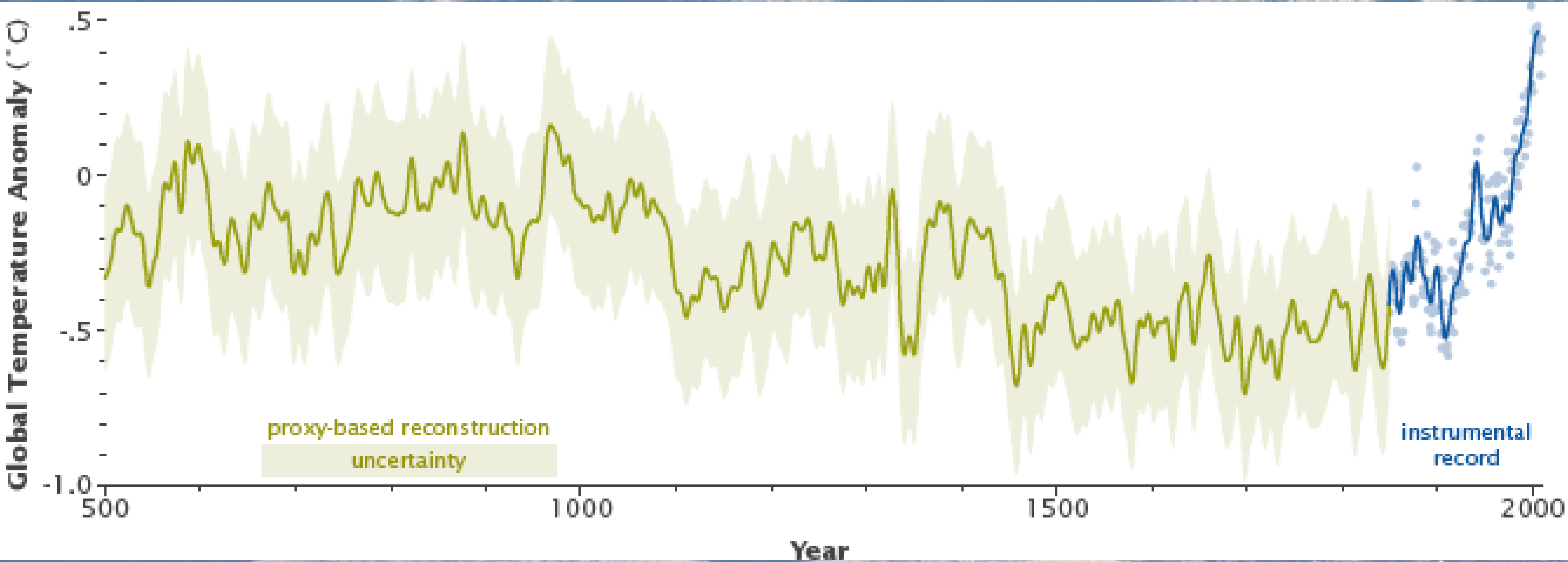
Shading indicates level of uncertainty: this increases further back in time

Reconstructed global surface temperatures: 500 to 2005 A.D.



Shading indicates level of uncertainty: this increases further back in time

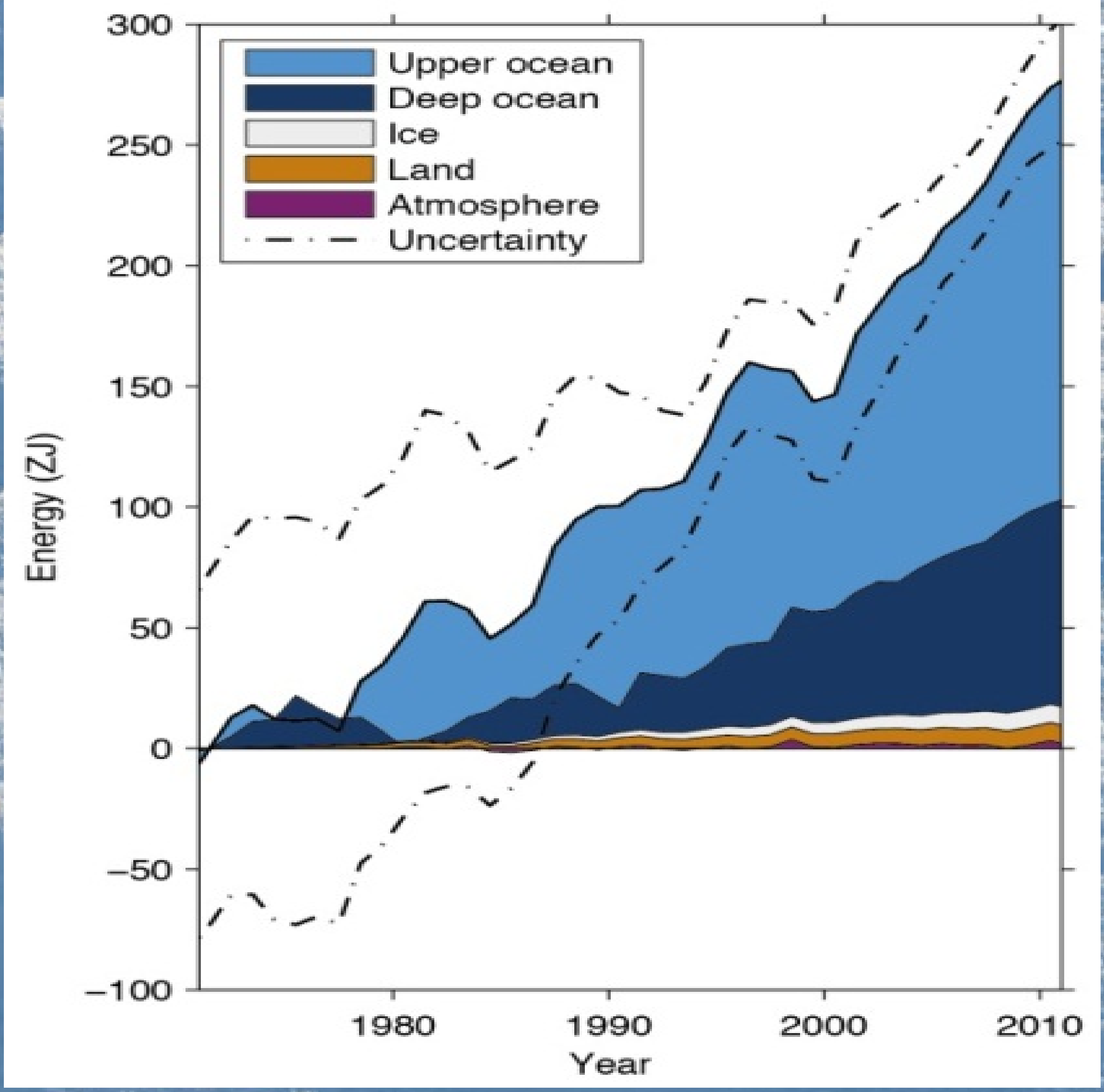
Reconstructed global surface temperatures: 500 to 2005 A.D.



Shading indicates level of uncertainty: this increases further back in time

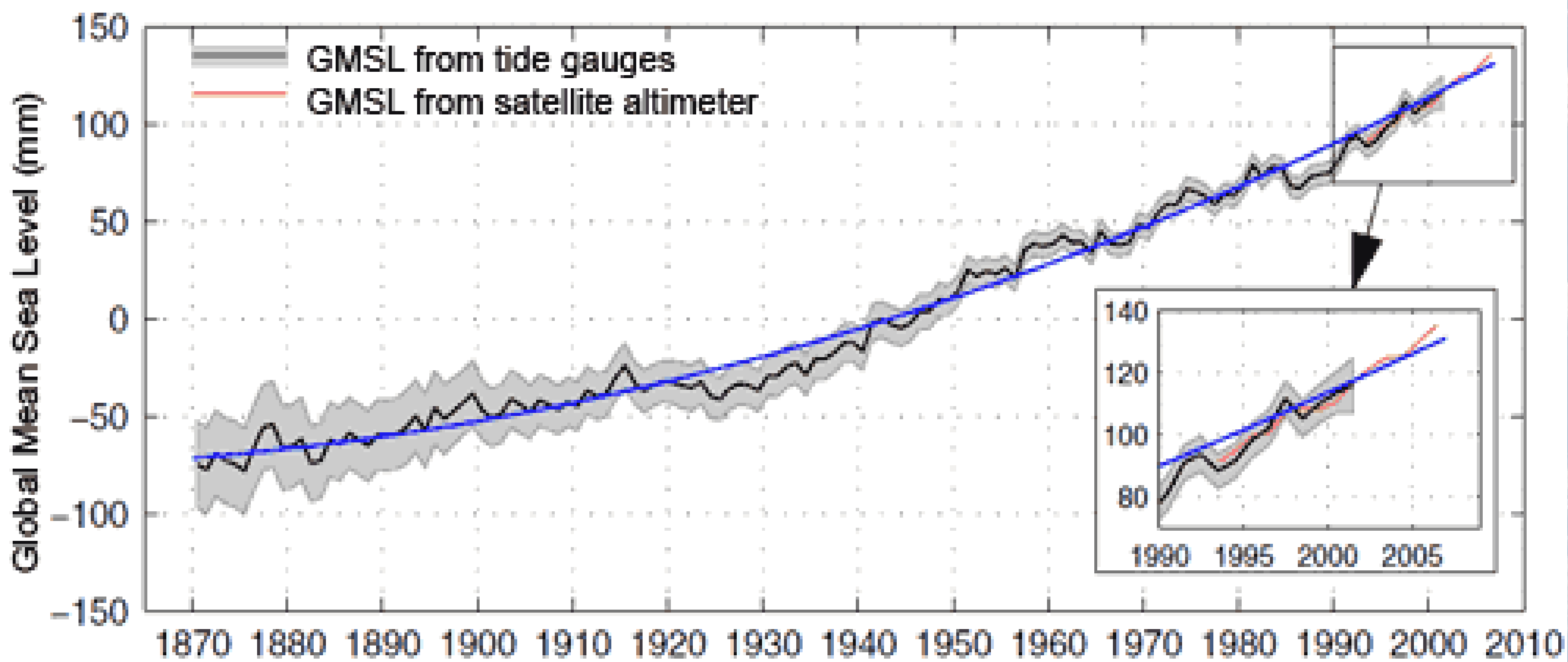
The oceans absorb 90% of the heat in the climate system

They have been continually warming since the 1970's



Global Sea level is a good indicator of the temperature of the planet

Global mean Sea level anomaly versus 1940-1950 average



~50% of the rise is due to ocean warming and 50% melt of Land Ice (glaciers)

Detailed calculations show that the direct radiative effect of doubling atmospheric CO_2 will lead to a global surface warming of ~1-1.5°C

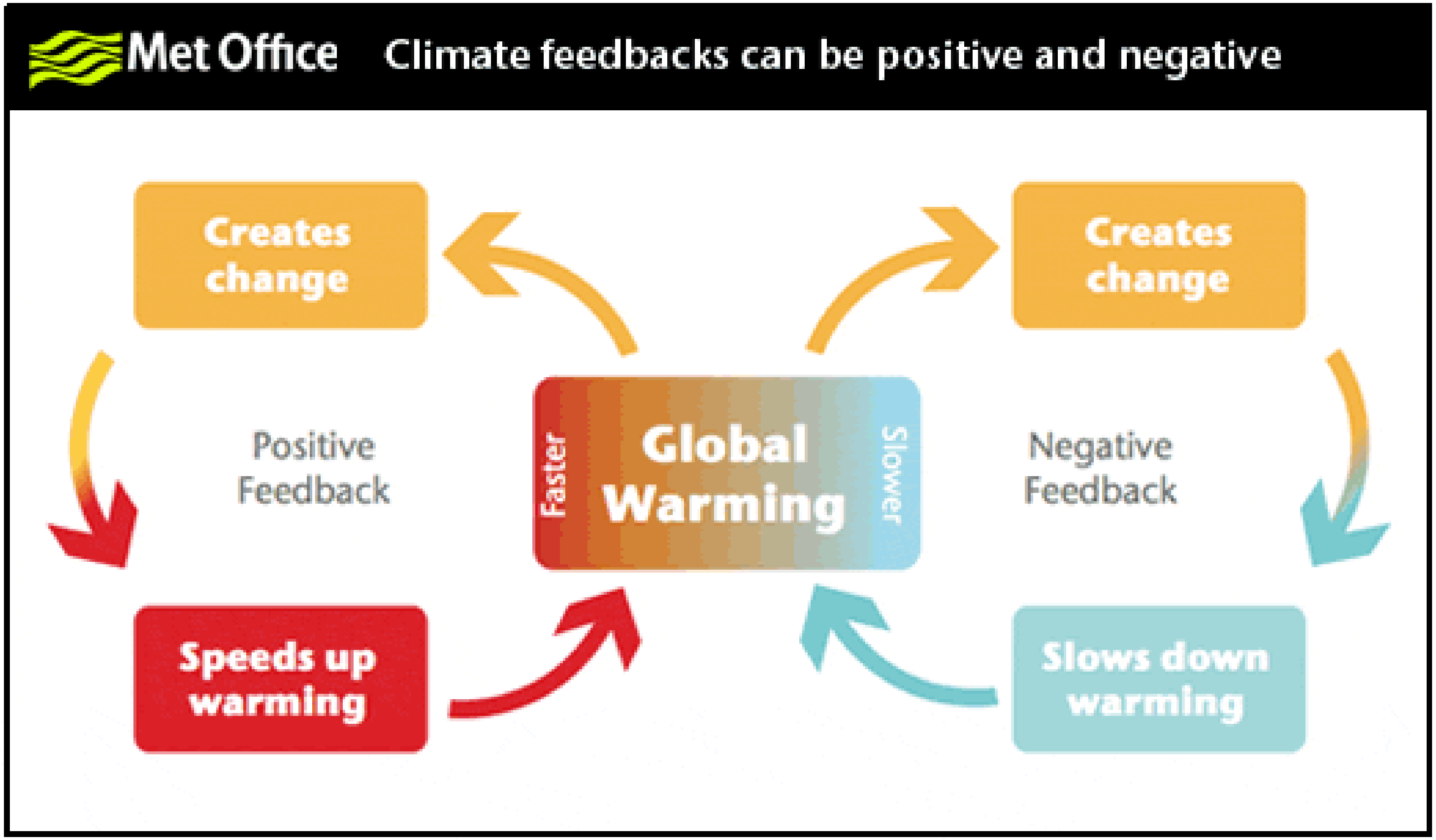
On present emission rates a doubling of atmospheric CO_2 relative to pre-industrial (~1800) conditions will occur between 2050-2060 (in 35 years).

Global Climate Models suggest the likely global surface warming at a doubling of CO_2 is more likely to in the range 2 to 5 °C

What causes this large amplification ?

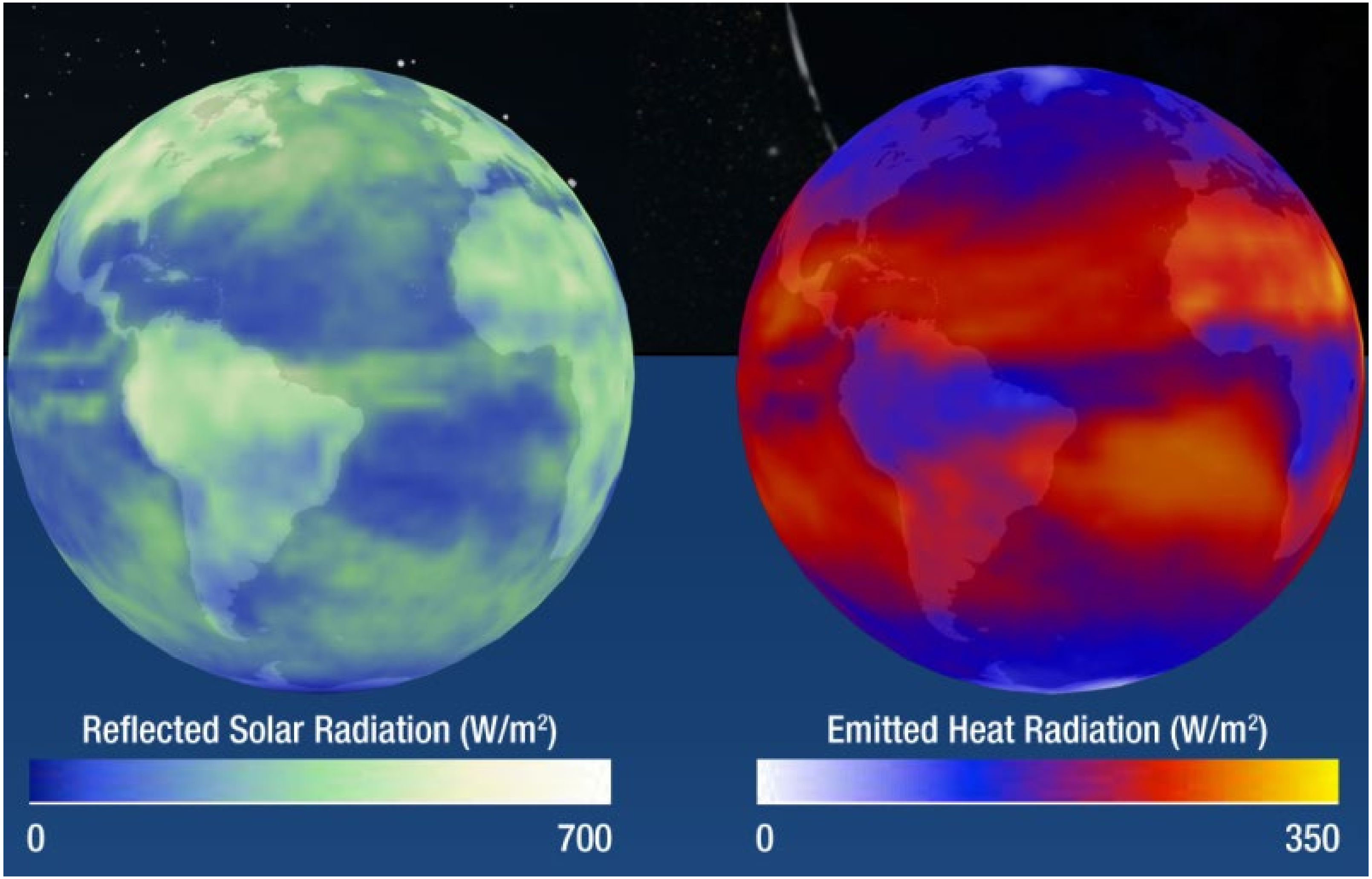
Internal climate feedbacks

A feedback is an **internal** response of the climate system to an **externally imposed (e.g. radiative forcing)** change that amplifies or damps the direct response



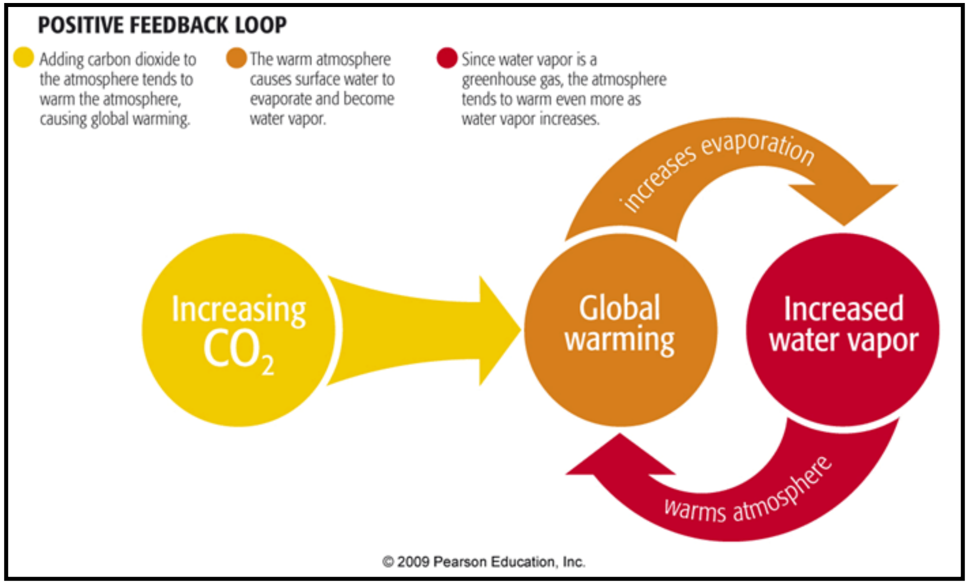
Generally defined in terms of the amplification/damping of the global mean surface temperature response to radiative forcing

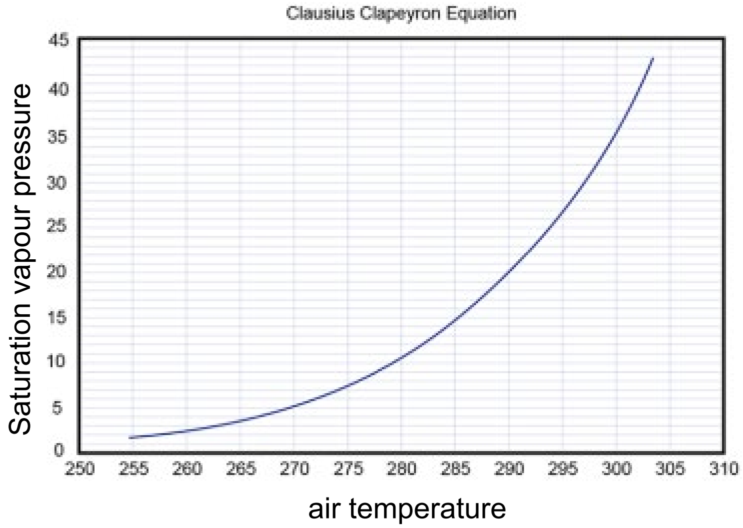
A warming Earth will more strongly emit radiation, cooling in the process
This is by far the largest negative feedback in the climate system

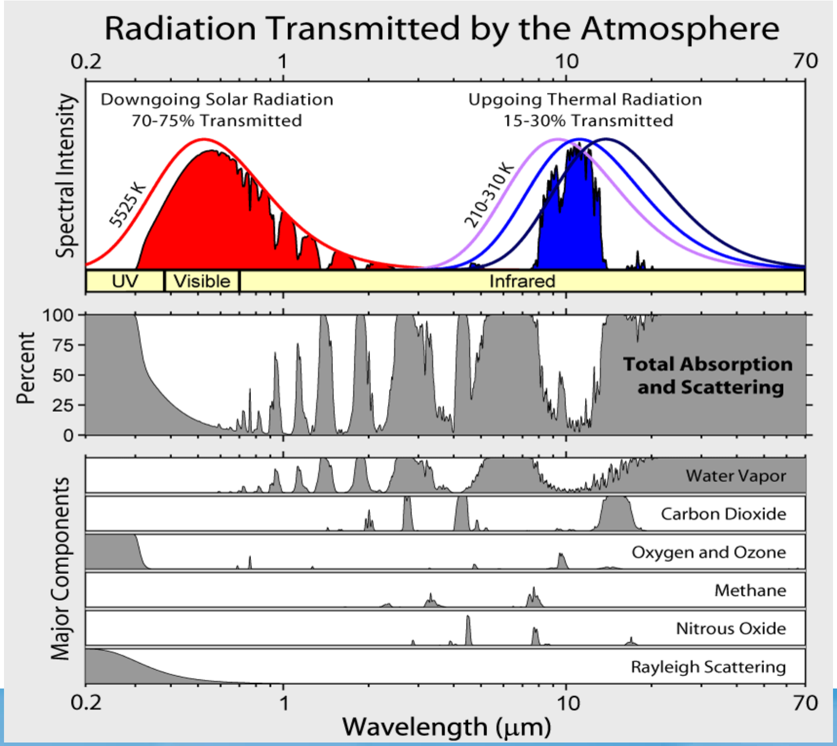


The water vapour feedback

Roughly doubles the direct radiative warming due to a doubling of CO_2

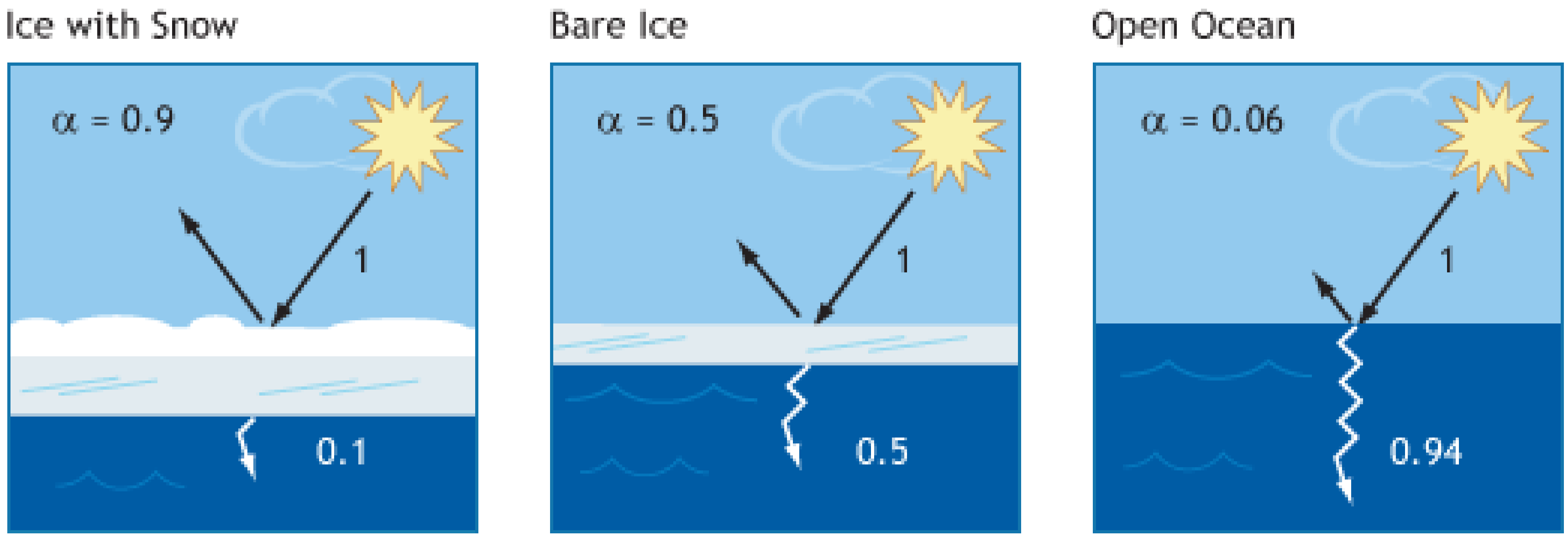






Sea Ice (and snow) albedo feedback

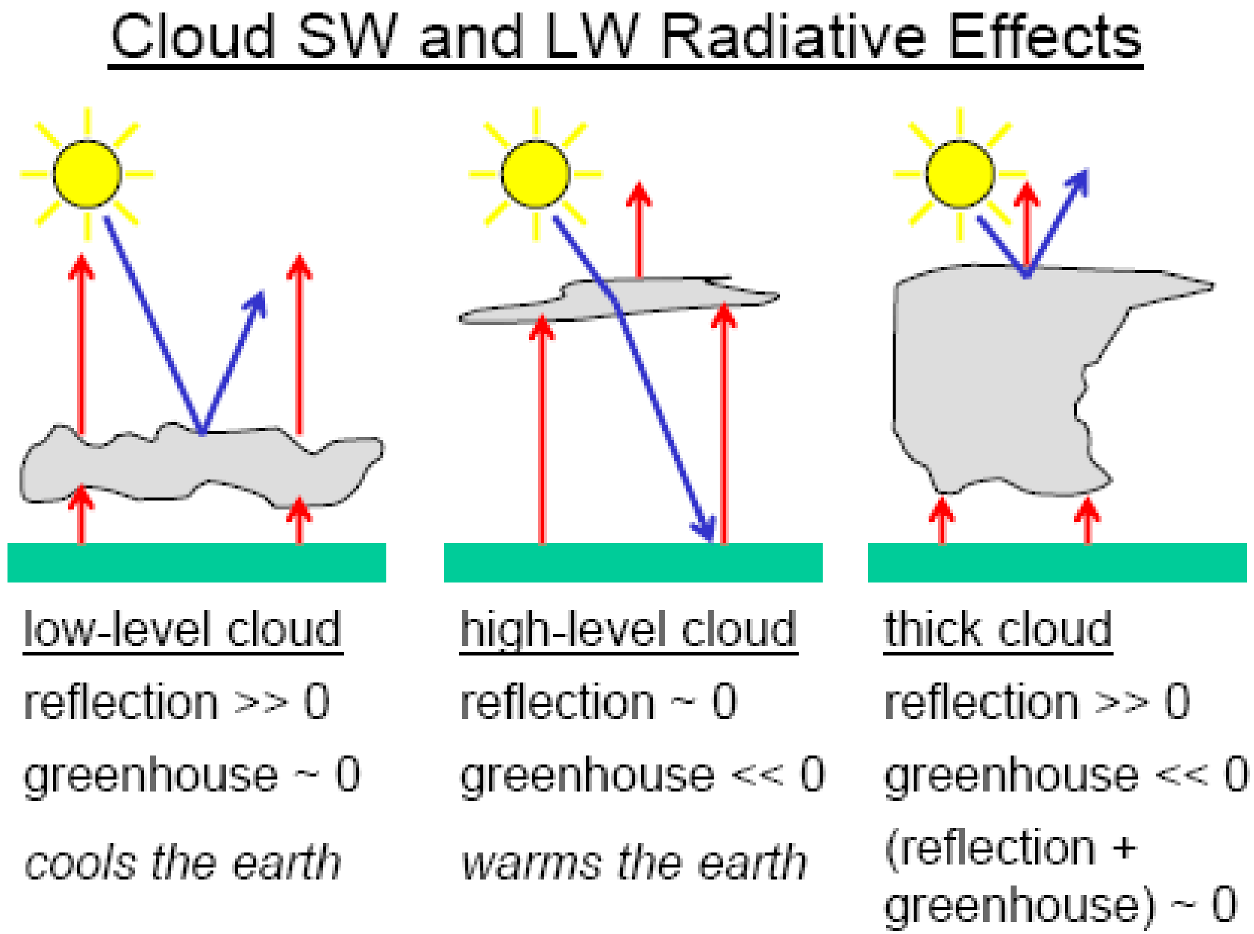
Positive (locally amplifies) an initial warming



Progressively increasing ocean absorption of solar radiation with decreasing ice cover

Can be significantly offset by increased cloud formation of newly open water

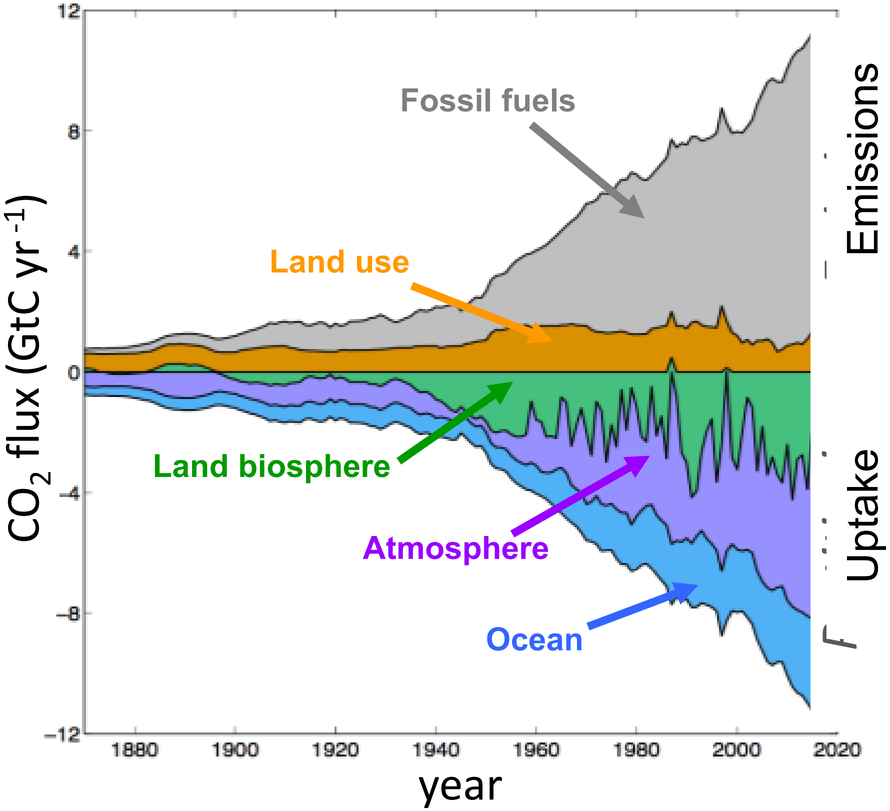
Cloud feedbacks can be both positive and negative depending on cloud type/altitude and radiation stream considered (LW or SW)



Only ~50% of the CO_2 emitted by human activities actually stays in the atmosphere

The other ~50% is absorbed by the terrestrial biosphere and the global oceans

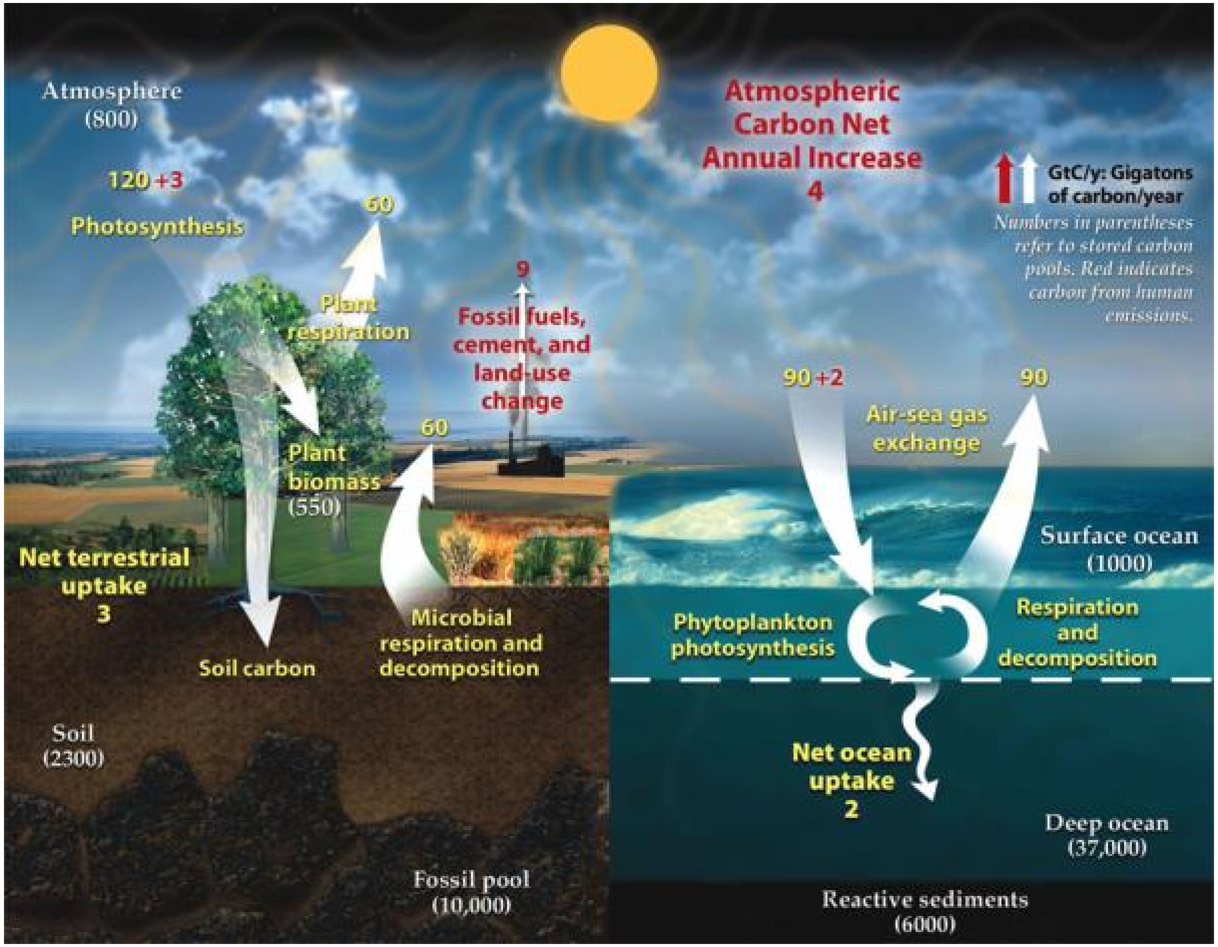
This is a strong negative feedback on climate warming resulting from CO_2 emissions



If the efficiency of these sinks changes in the future a larger/smaller fraction of CO_2 may stay in the atmosphere amplifying/decreasing warming per unit of emitted CO_2

Carbon stores and fluxes per year in the global carbon cycle.

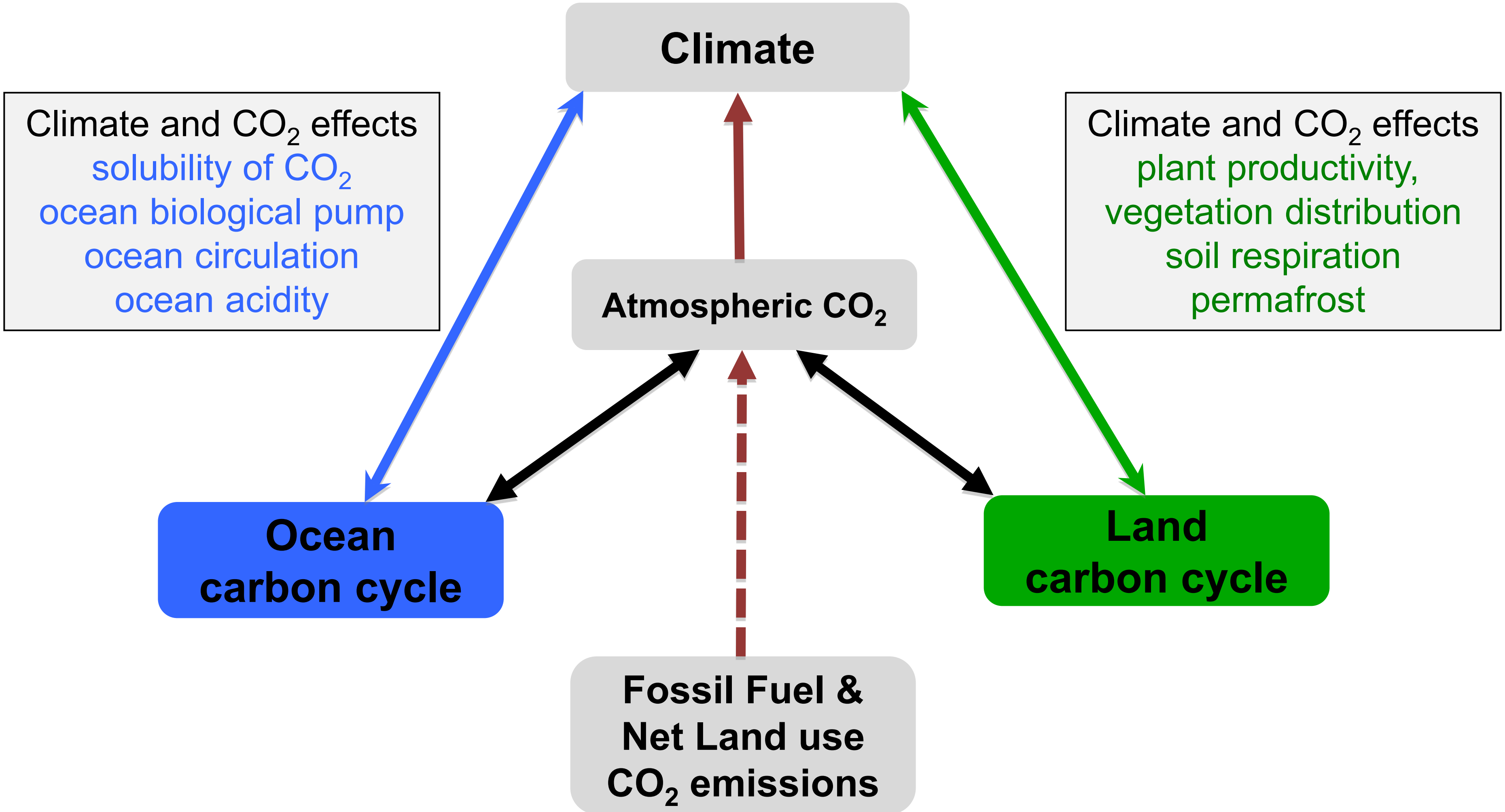
White: stores, yellow natural fluxes, red anthropogenic fluxes: (Gigatonnes)



Anthropogenic CO_2 emissions are a small perturbation of the natural global carbon cycle

Small changes in the efficiency of natural C sinks will have a large impact on atmospheric CO_2

Feedbacks involving a warming climate, increasing CO_2 concentrations and the Earth's carbon cycle



Developing models that accurately represent processes underpinning these feedbacks and their sensitivity to future GHG emissions is the crux of Earth system model development