The science of climate change

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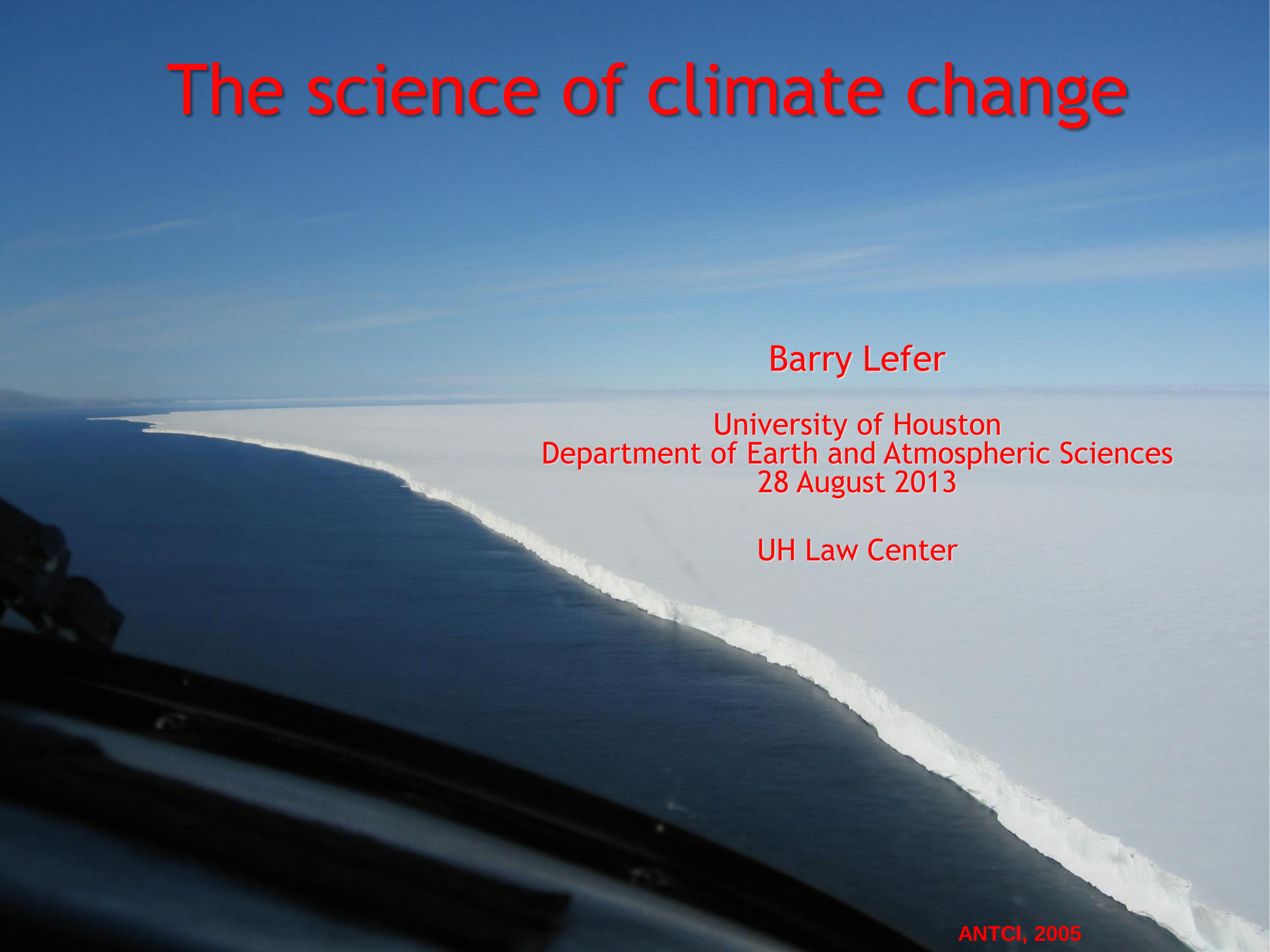
28 August 2013

UH Law Center



ANTCI, 2005

The science of climate change

I. Basics of Earth System Science

II. Climate change on geologic and historical time scales

III. Natural and anthropogenic causes of climate change

IV. Consequences of future climate change

ANTCI, 2005

Studies Say Airborne Particulates Increase Risk of Death

A study published August 2 in the journal Environmental Health Perspectives, finds a positive correlation between black carbon pollution levels and mortality in US cities. A mixture of substances emitted by combustion from cars, trucks, factories and the burning of organic matter, particulate matter pollution exacerbates and contributes to respiratory illnesses. Scientists from the Johns Hopkins and Harvard Schools of Public Health and the Yale School of Forestry studied the causes of mortality between 2000 and 2005 in 72 urban areas, focusing on the relationship between the individual pollution components and the mortality rate. The findings indicate that some forms of particulate matter are more harmful than others, leading the authors to suggest that current air pollution regulations that regulate only the amount of particulate matter are inefficient at protecting human health. Public health officials are also concerned about the effect that climate change will have on human populations, increasing heat stroke, respiratory illness, even famine. Dr. Linda Rudolph, of the Public Health Institute, an Oakland, California non-profit, commented on the link between climate change and public health, stating, “if we don't act urgently and dramatically to reduce greenhouse gas emissions, climate change will undermine many of our other public health efforts and have many grave health consequences."

For additional information see: Environmental Health News, Study, San Francisco Gate

Northern forest growth slowing down

In related news, a recent study published August 18 in Nature Climate Change found that European forests have reached their carbon saturation point as trees are being destroyed in insect infestations, fires and extreme weather events. After WWII, Europeans planted thousands of trees during a continent-wide effort to replenish damaged forests, but the aging trees are no longer absorbing as much carbon, and are releasing stored carbon as they die. The study concludes that the carbon saturation point of forests could be passed in 2030, unless European governments took action to rebuild forests. The authors of the report stated, "These regrowing forests have shown to be a persistent carbon sink, projected to continue for decades, however, there are early signs of saturation. Forest policies and management strategies need revision if we want to sustain the sink."

For additional information see: LA Times, Science Daily, Science Magazine, Sydney Morning Herald, Study

Climate change debate

All climate scientists agree that:

1) Earth's average surface temperature has warmed by 0.7°C since 1900, a conclusion based on direct measurements.

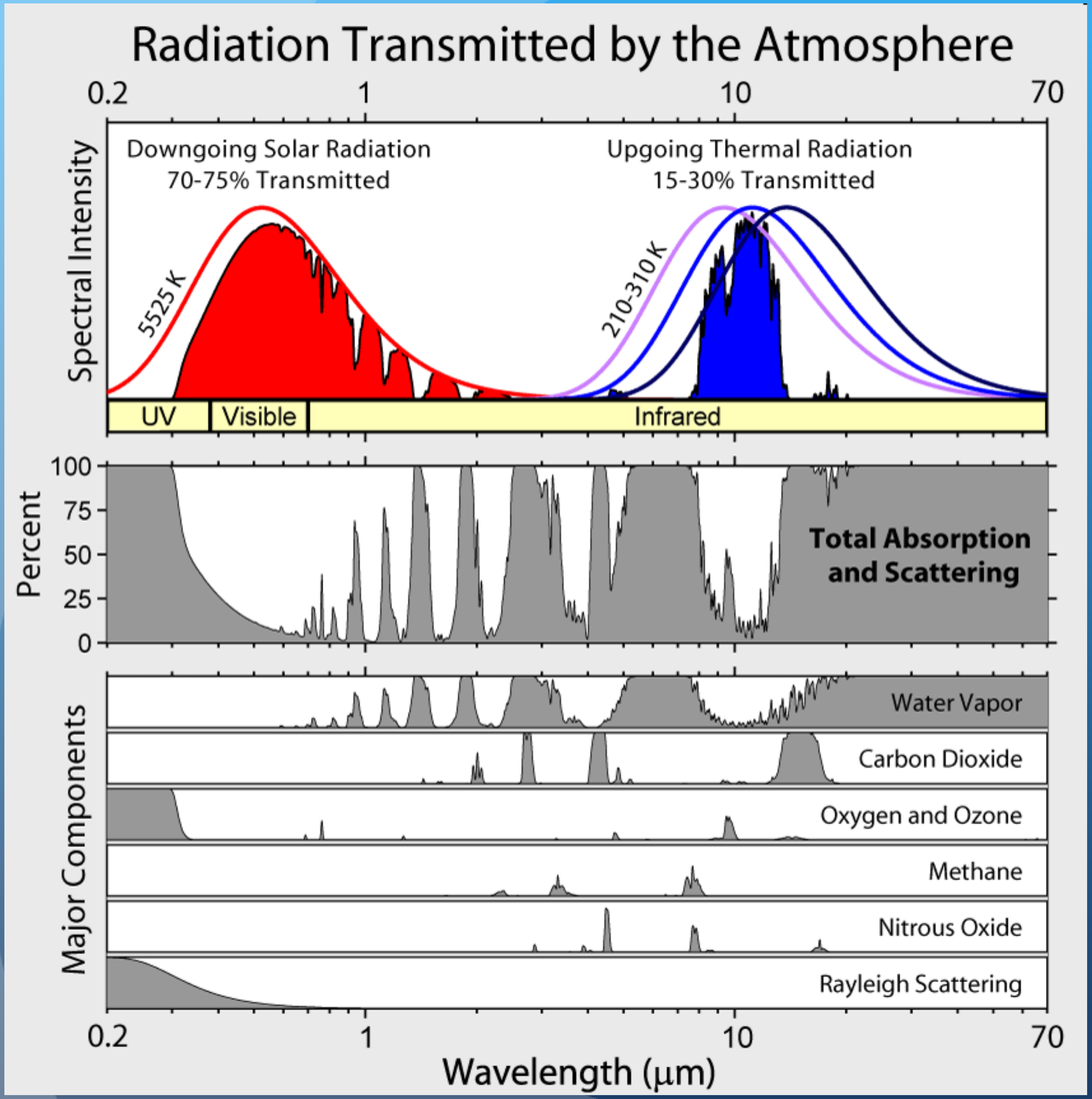
2) concentrations of CO_2, CH_4, N_2O, and other greenhouse gases have built up in the atmosphere over the last 100 years due to human activities.

The issue at the heart of the greenhouse debate is not whether rising greenhouse gas levels have contributed to the warming, but rather the magnitude of the amplification of the warming by various feedbacks.

Climate vs. weather

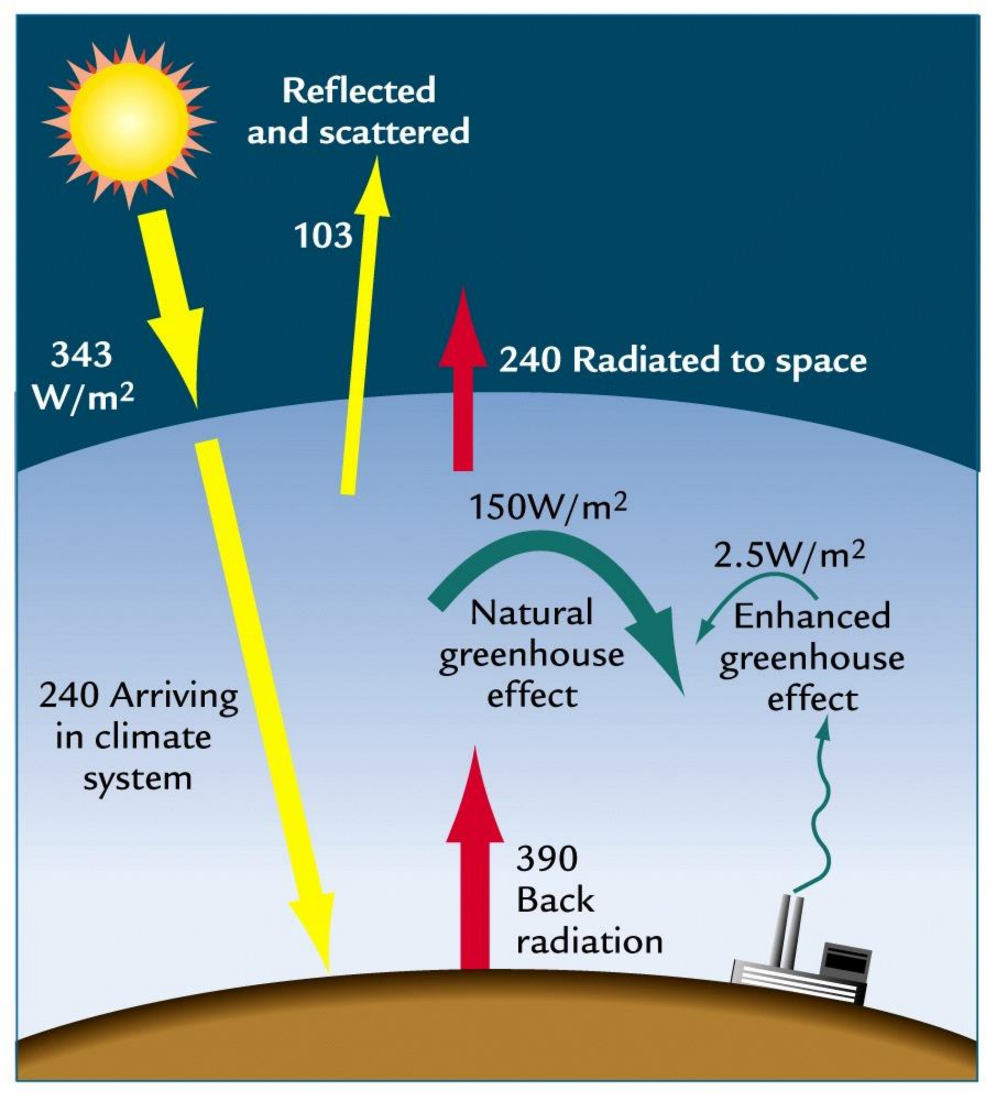
Weather	Climate
Shorter-term fluctuations	Longer-Term Changes
Current atmospheric conditions (e.g., temp, press, ws, wdir, rainfall, etc.)	Broad composite of average (or mean) condition of a region (e.g., temp, rain, snowfall, ice cover, winds)
Hours, Days, Weeks	Years (and longer), Typically 30 yr ave.
Specific location for specific time	Mean state of a specific region (e.g., continent, ocean, or entire planet)

What is a greenhouse gas?



globalwarmingart.com

Greenhouse gas warming

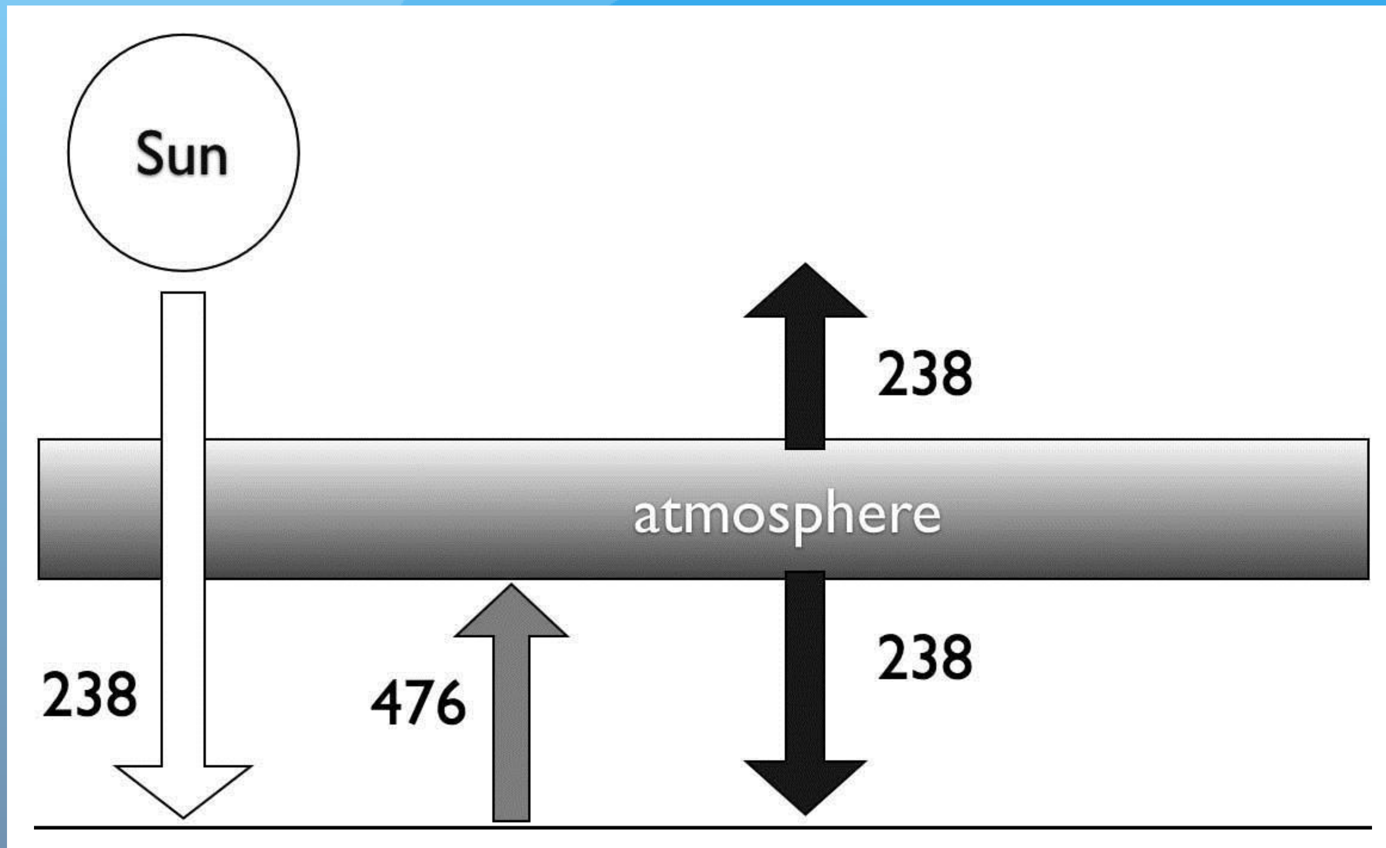


Earth's Ave. Temperature = 15ºC

Natural GH Effect = 31ºC Warming

Ruddiman, 2008

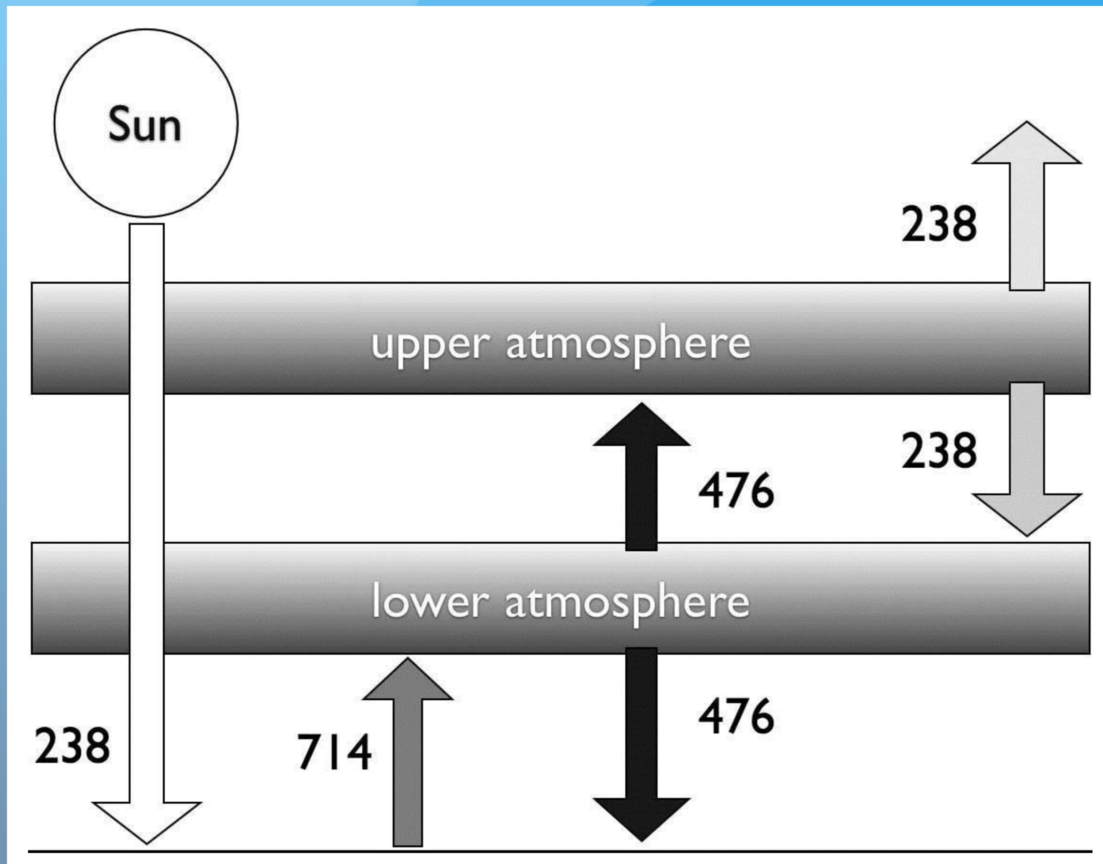
Greenhouse gas warming



$$\frac{P}{a} = \sigma T^4 = 476\ W/m^2 = E_{out}$$

$$T_{one\_layer} = \sqrt[4]{\frac{476}{5.67 \times 10^{-8}}} = 302.7K$$

Greenhouse gas warming



$$T_{two\_layers} = \sqrt[4]{\frac{714}{5.67 \times 10^{-8}}} = 335K = 62^{\circ}C$$

Dessler, 2012

Some basic "reactions"

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{heat}$

$H_2O + CO_2 + \text{sunlight} \rightarrow C_6H_{12}O_6 + O_2$

$C_6H_{12}O_6 + O_2 \rightarrow CO_2 + H_2O + \text{heat} + NO + SO_2$

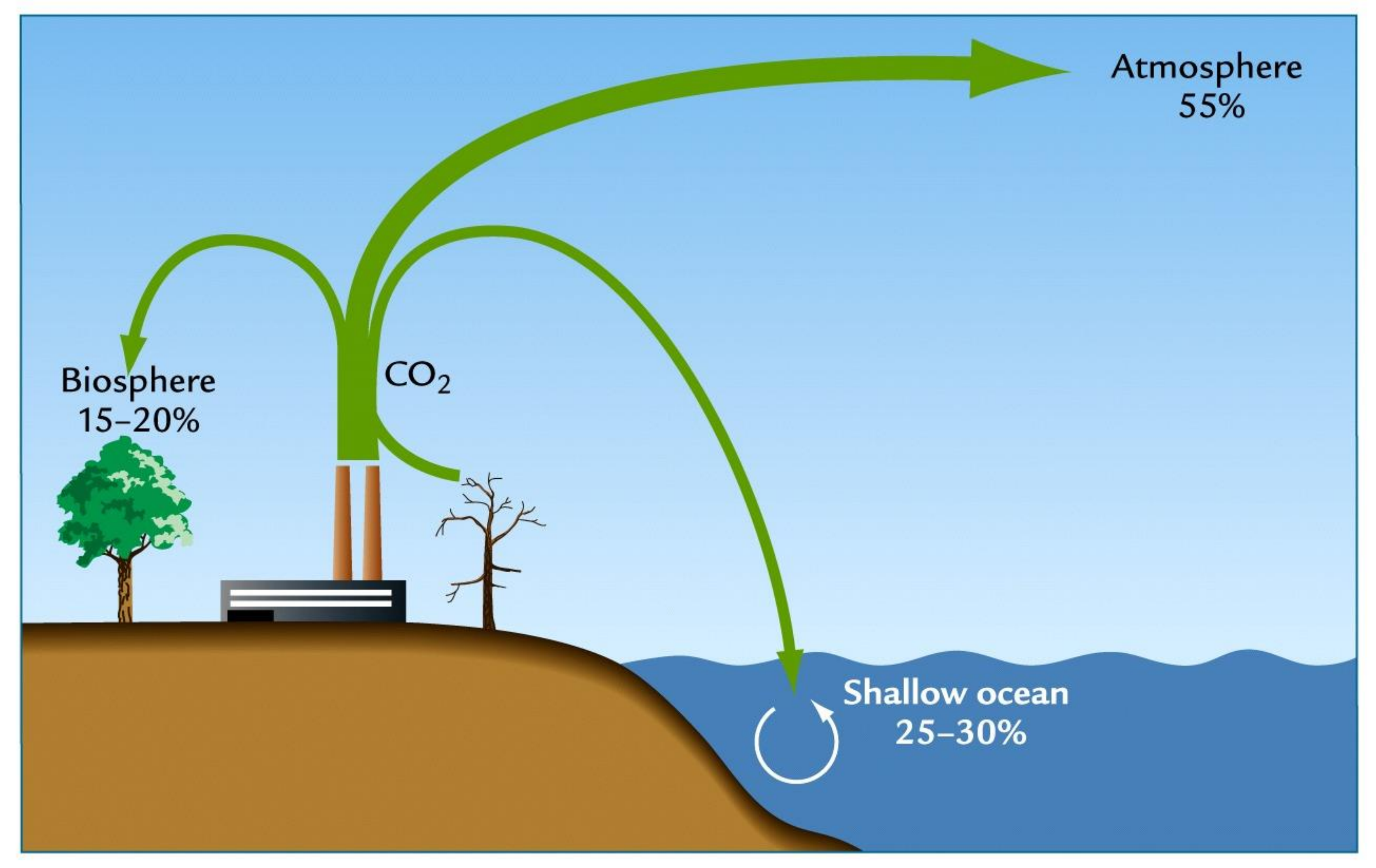
$NO \rightarrow NO_2 \rightarrow HNO_3$

$SO_2 \rightarrow H_2SO_4 \rightarrow \text{sulfate aerosol}$

$NO_X + \text{VOCs} + \text{sunlight} \rightarrow O_3$

$CO_2 + H_2O = HCO_3^- + H_2CO_3$

Where does atmospheric CO_2 go?

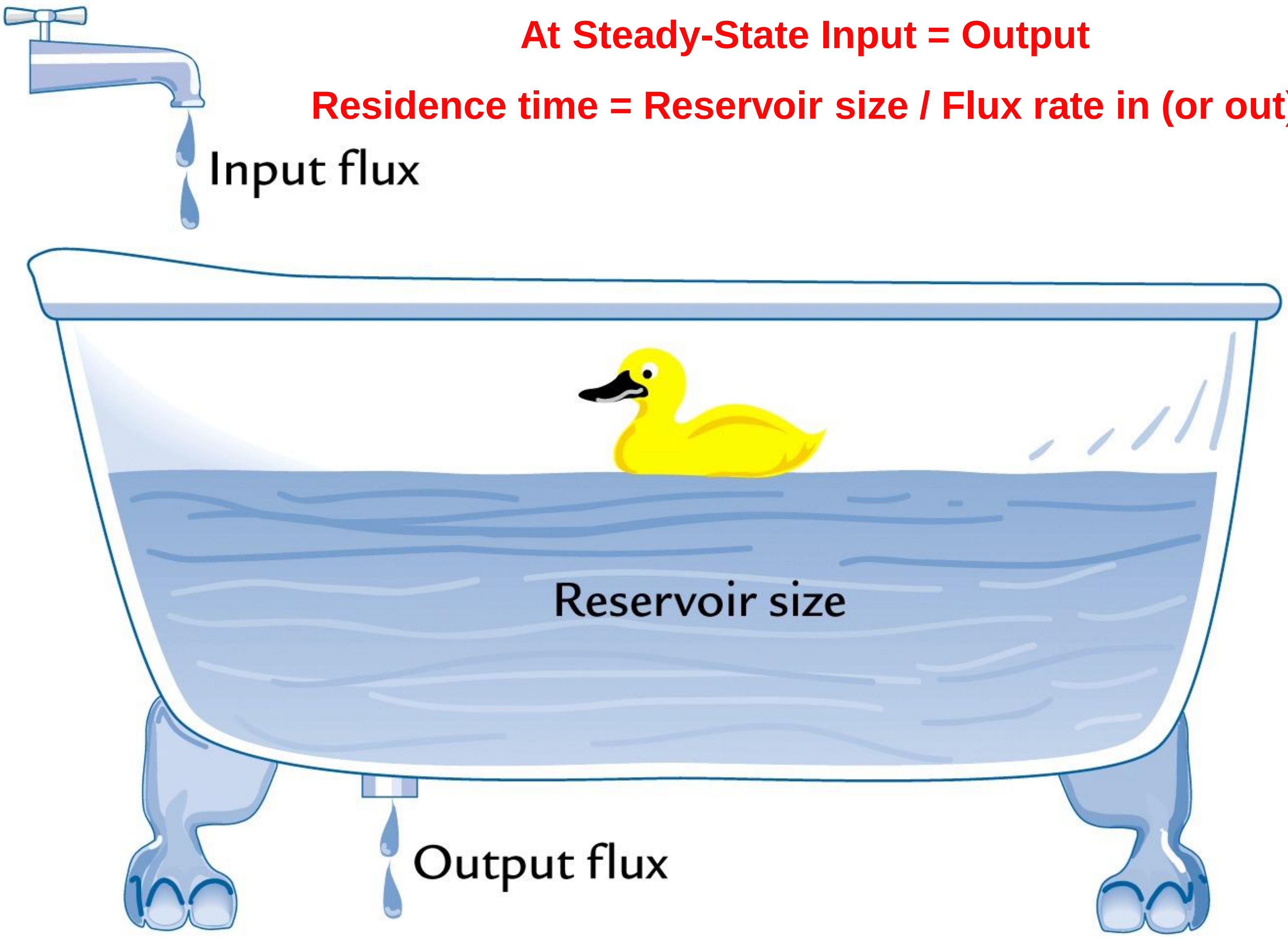


Ruddiman, 2008

Geochemical reservoir and fluxes

At Steady-State Input = Output

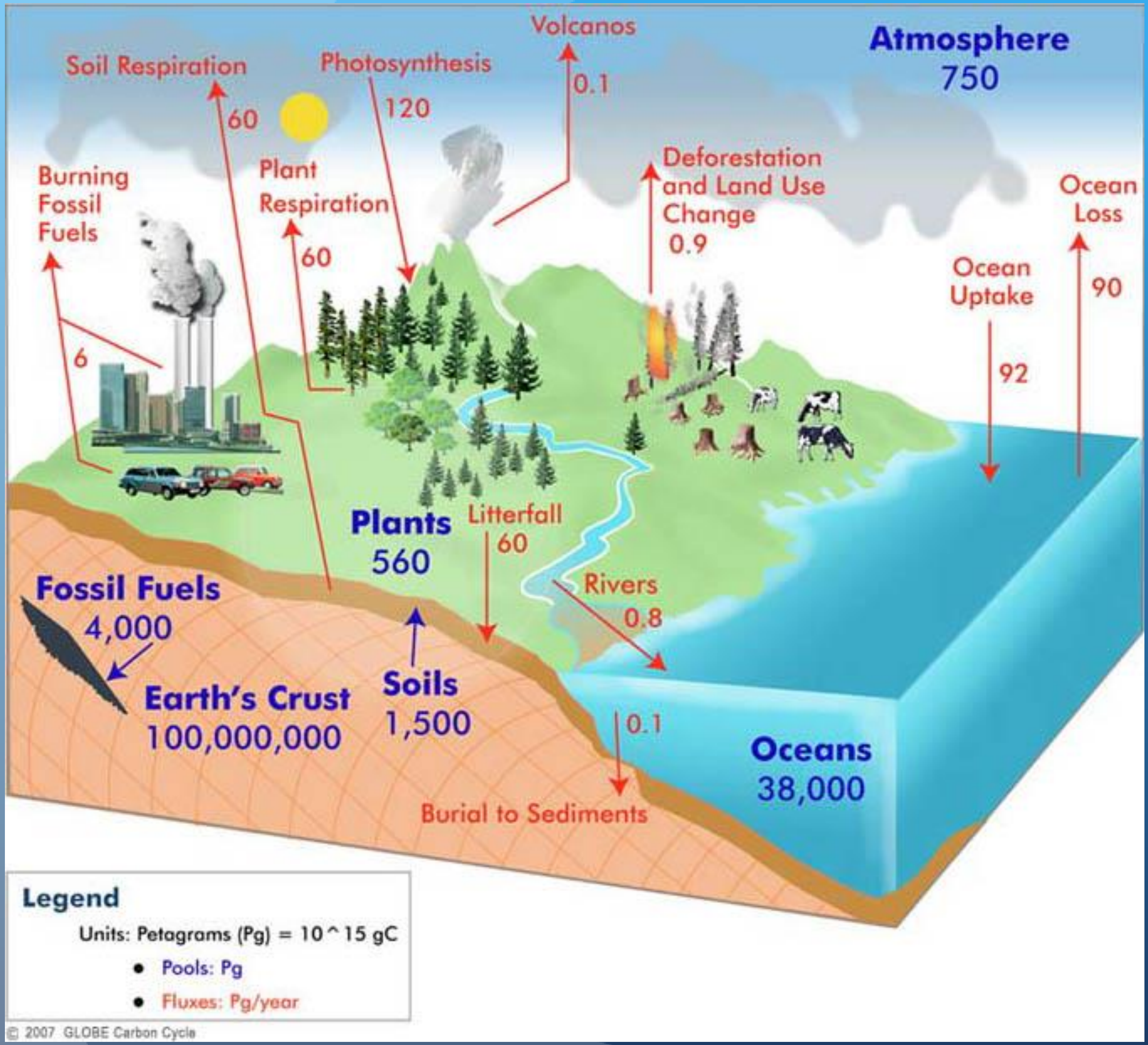
Residence time = Reservoir size / Flux rate in (or out)



Ruddiman, 2008

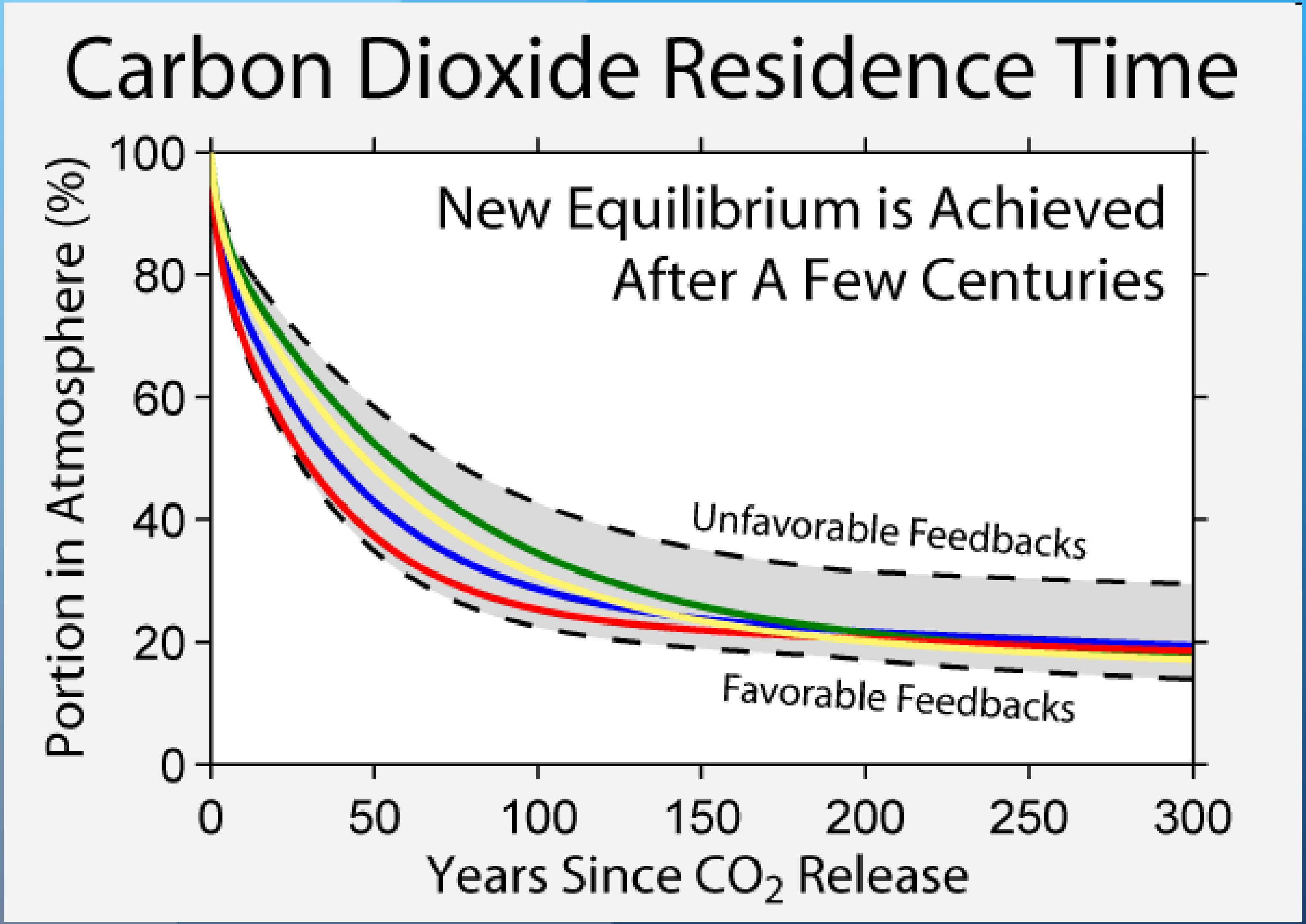
Global Carbon Cycle

8.3 Pg C
2011



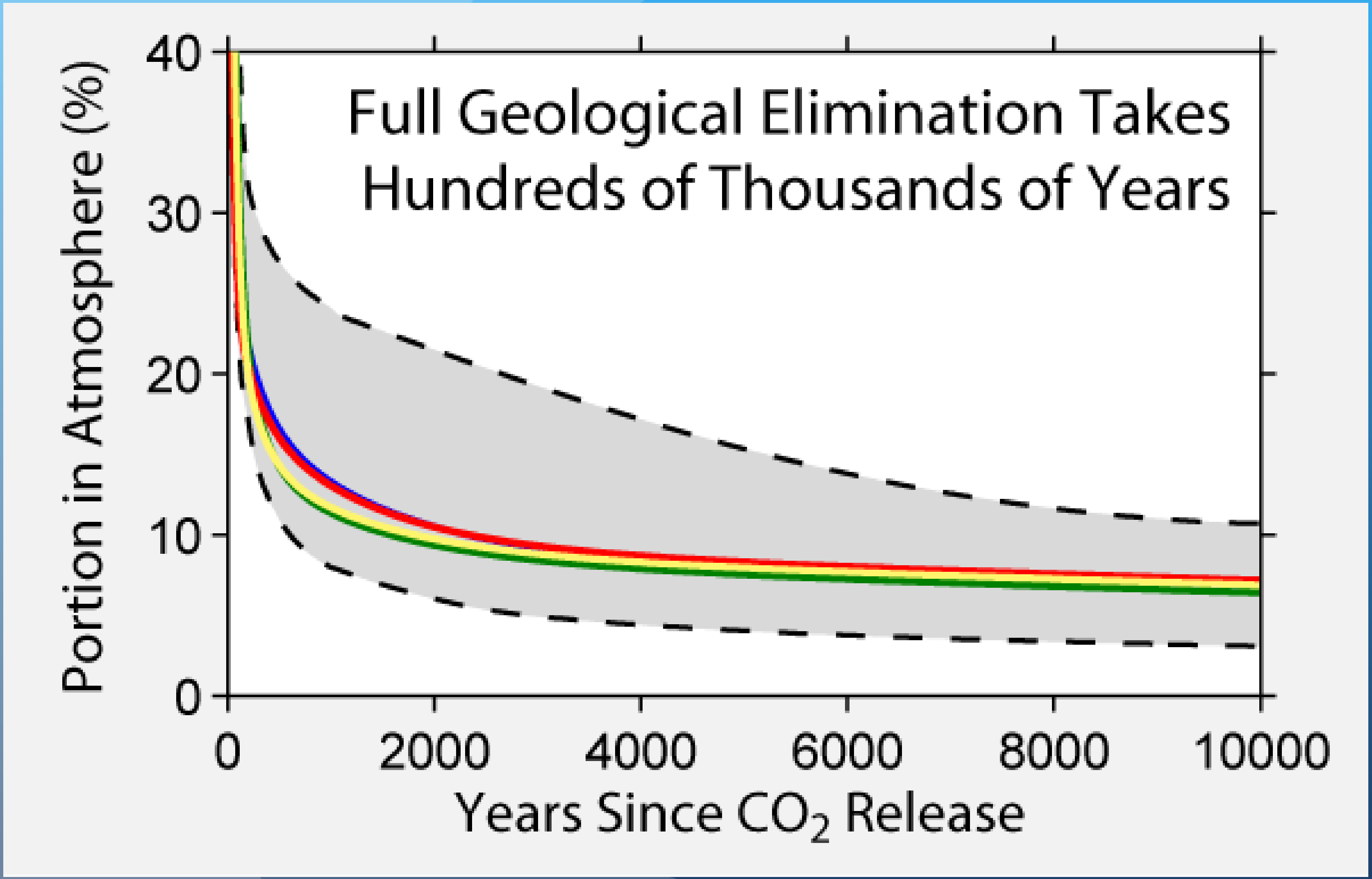
GLOBE, 2007

How long is CO_2 in the atmosphere?



http://www.globalwarmingart.com/images/4/48/Carbon_Dioxide_Residence_Time.png

CO_2 lifetime in the atm-ocean system



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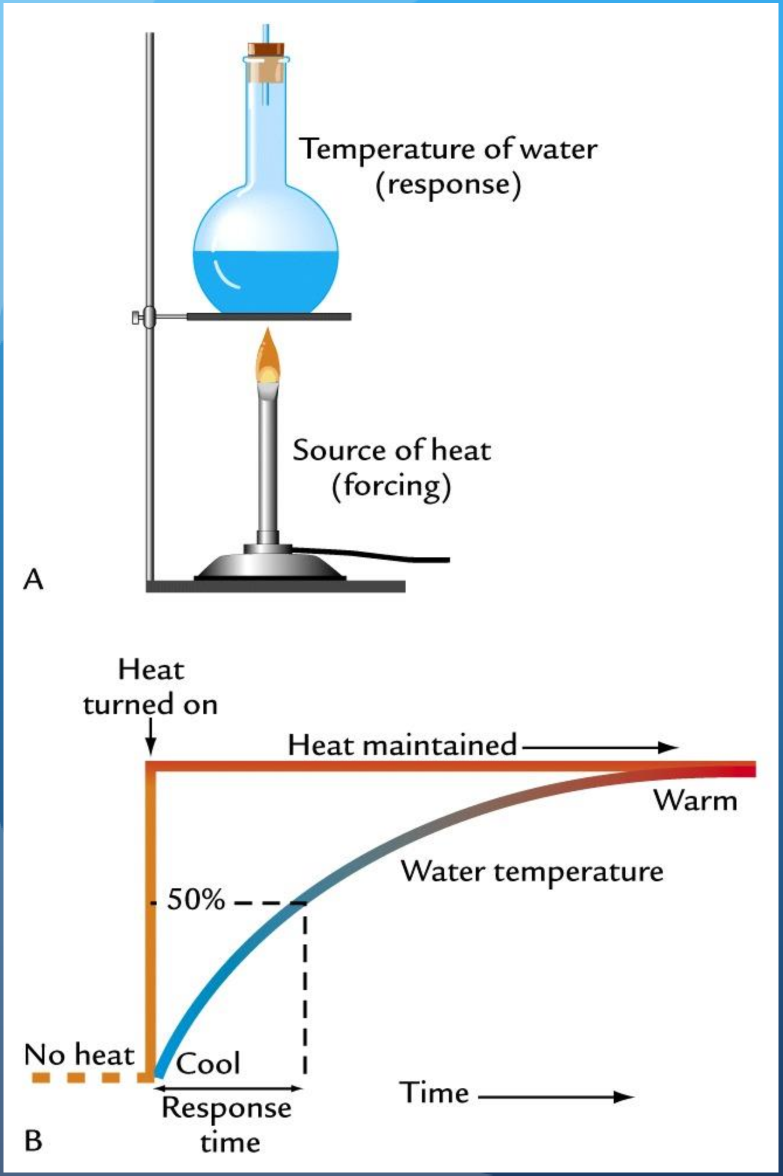
Climate system response



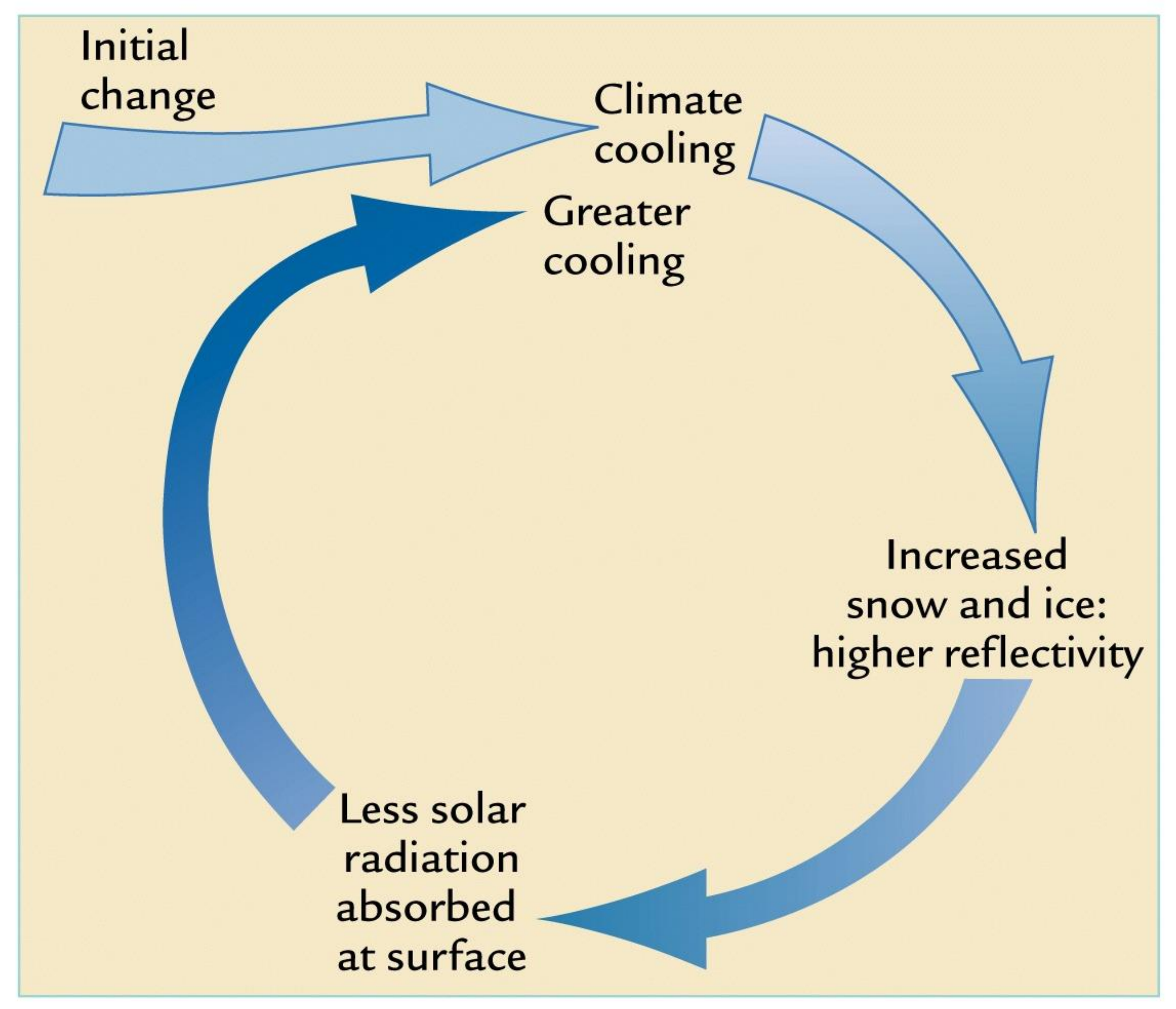
Ruddiman, 2008

Response times of climate system components

Component	Response time (range)	Example
	Fast responses	
Atmosphere	Hours to weeks	Daily heating and cooling Gradual buildup of heat wave
Land surface	Hours to months	Daily heating of upper ground surface Midwinter freezing and thawing
Ocean surface	Days to months	Afternoon heating of upper few feet Warmest beach temperatures late in summer
Vegetation	Hours to decades/centuries	Sudden leaf kill by frost Slow growth of trees to maturity
Sea ice	Weeks to years	Late-winter maximum extent Historical changes near Iceland
	Slow responses	
Mountain glaciers	10–100 years	Widespread glacier retreat in 20th century
Deep ocean	100–1500 years	Time to replace world's deep water
Ice sheets	100–10,000 years	Advances/retreats of ice sheet margins Growth/decay of entire ice sheet

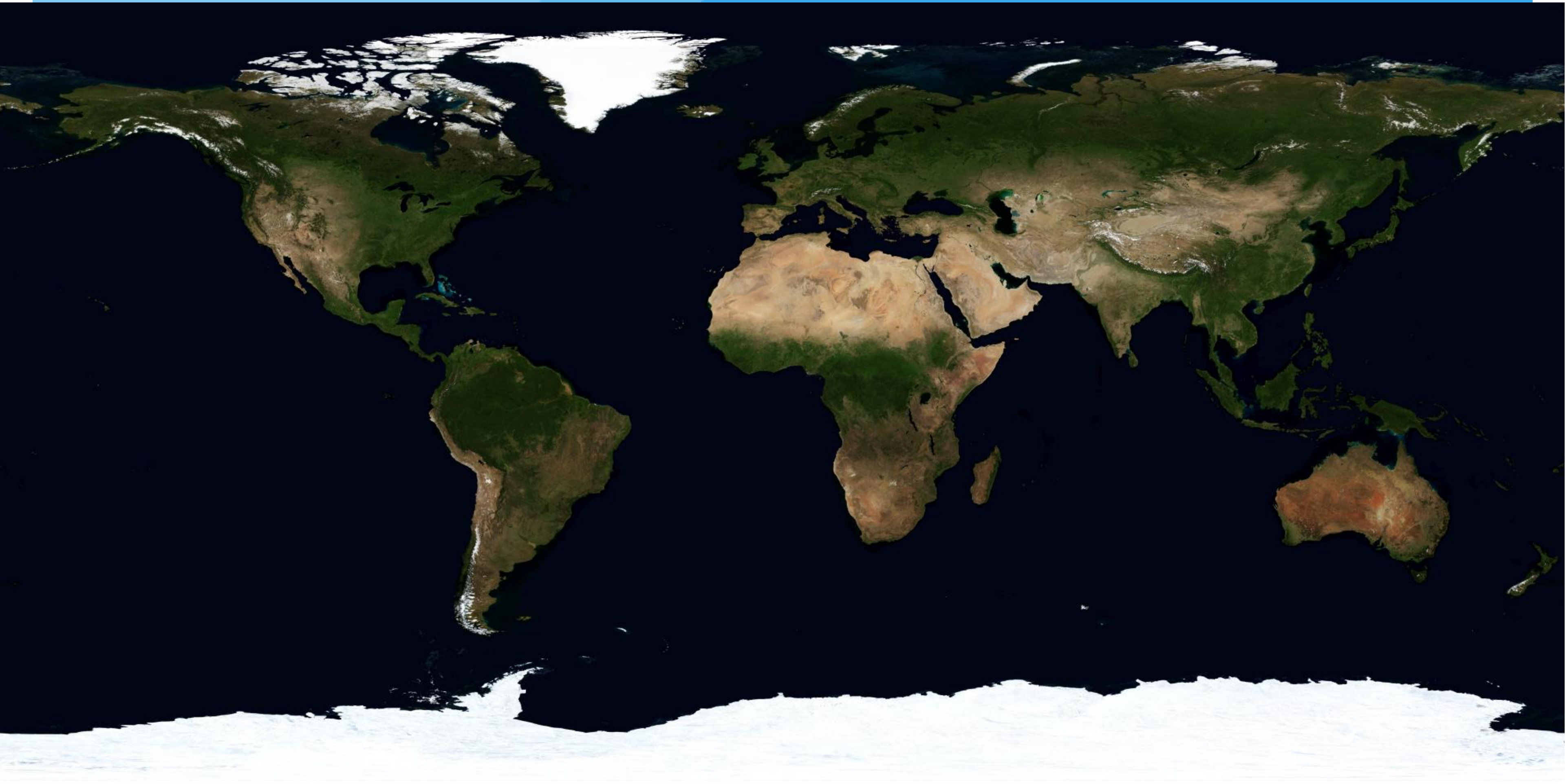
Ruddiman, 2008

Albedo-temperature feedback



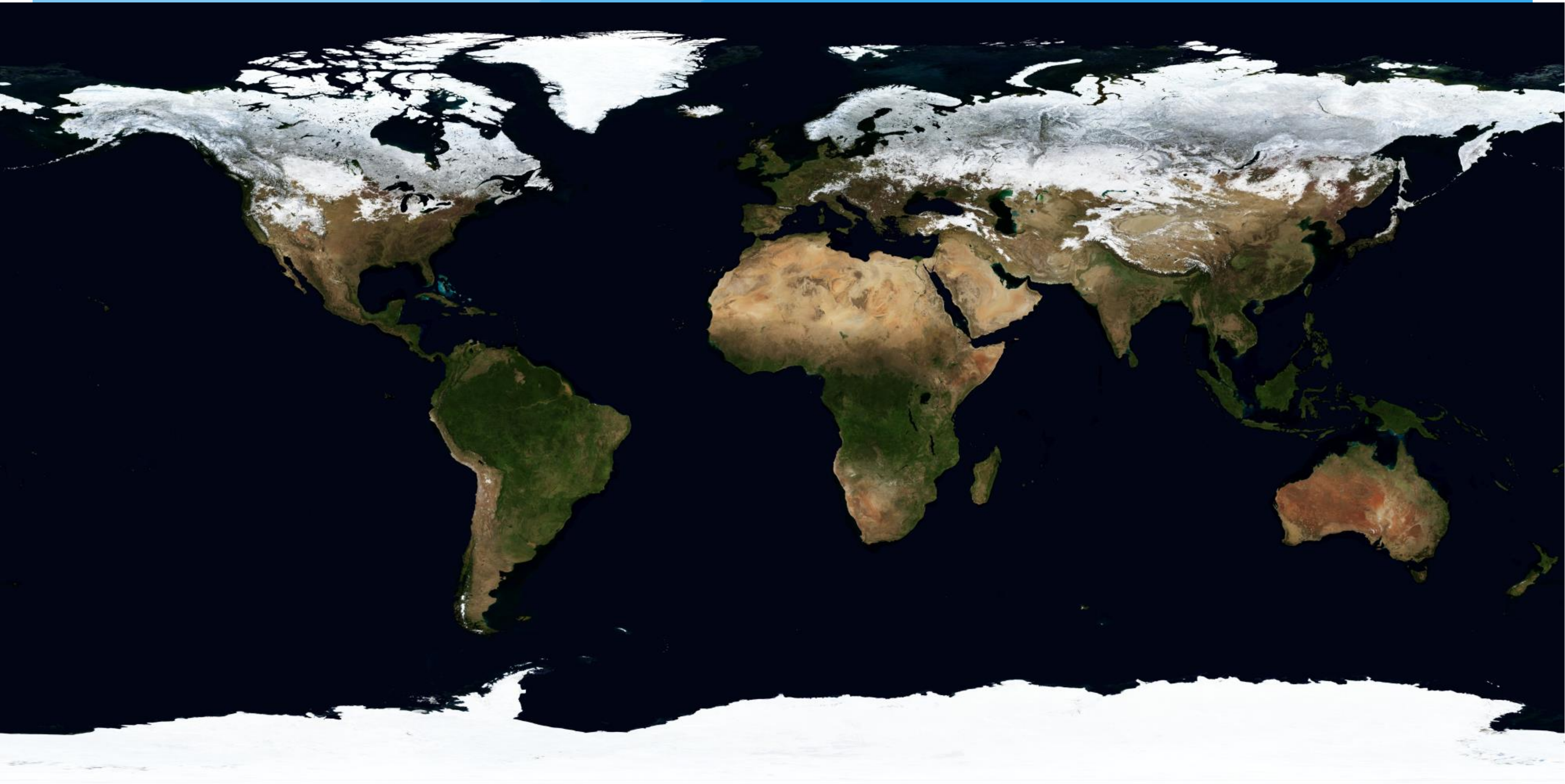
Ruddiman, 2008

Albedo-temperature feedback



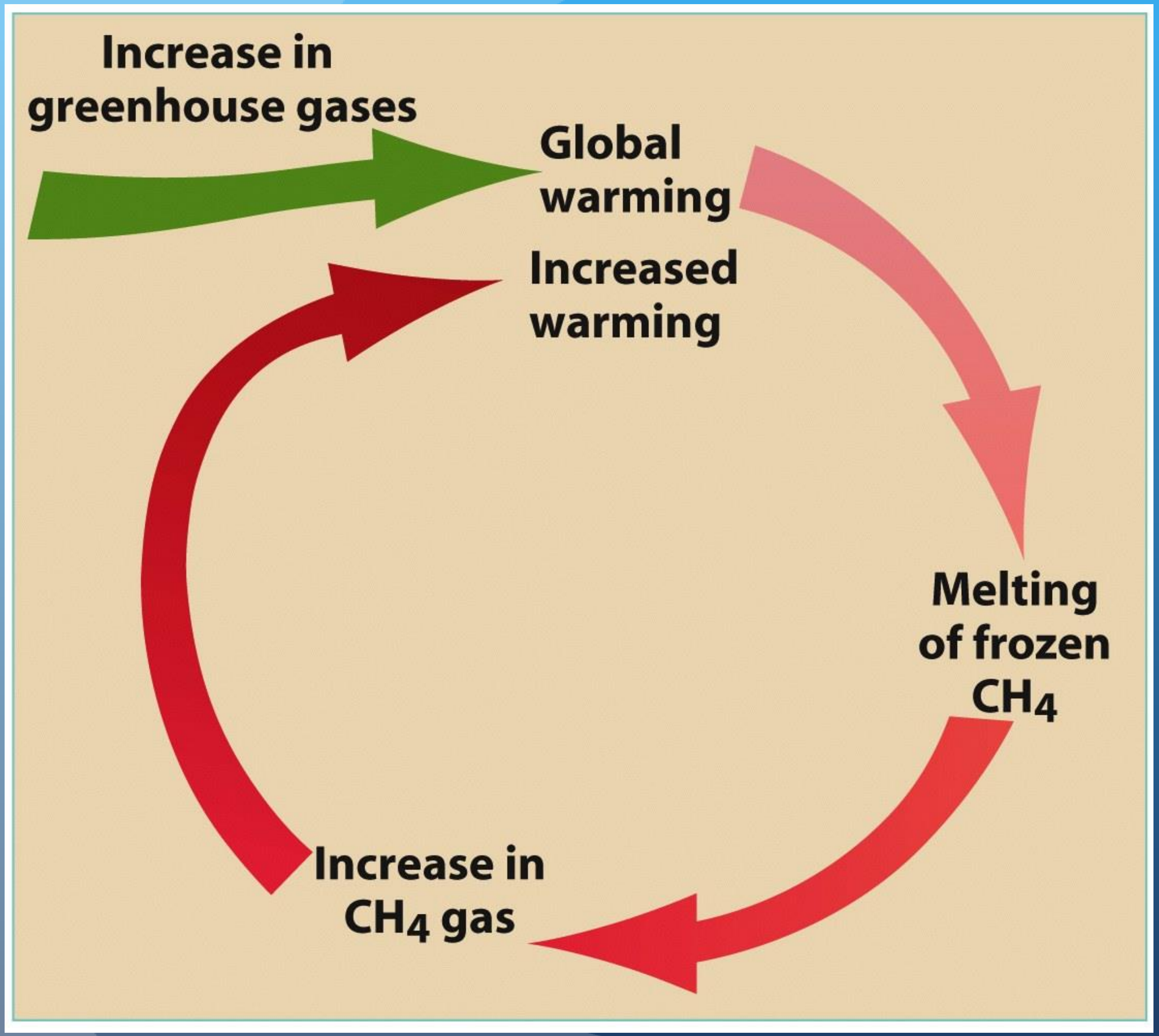
Source: NASA

Albedo-temperature feedback



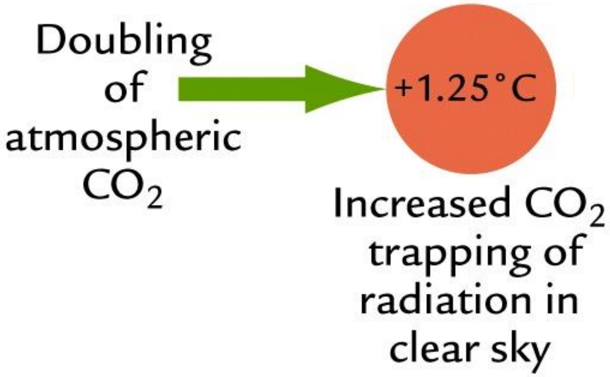
Source: NASA

Another positive feedback



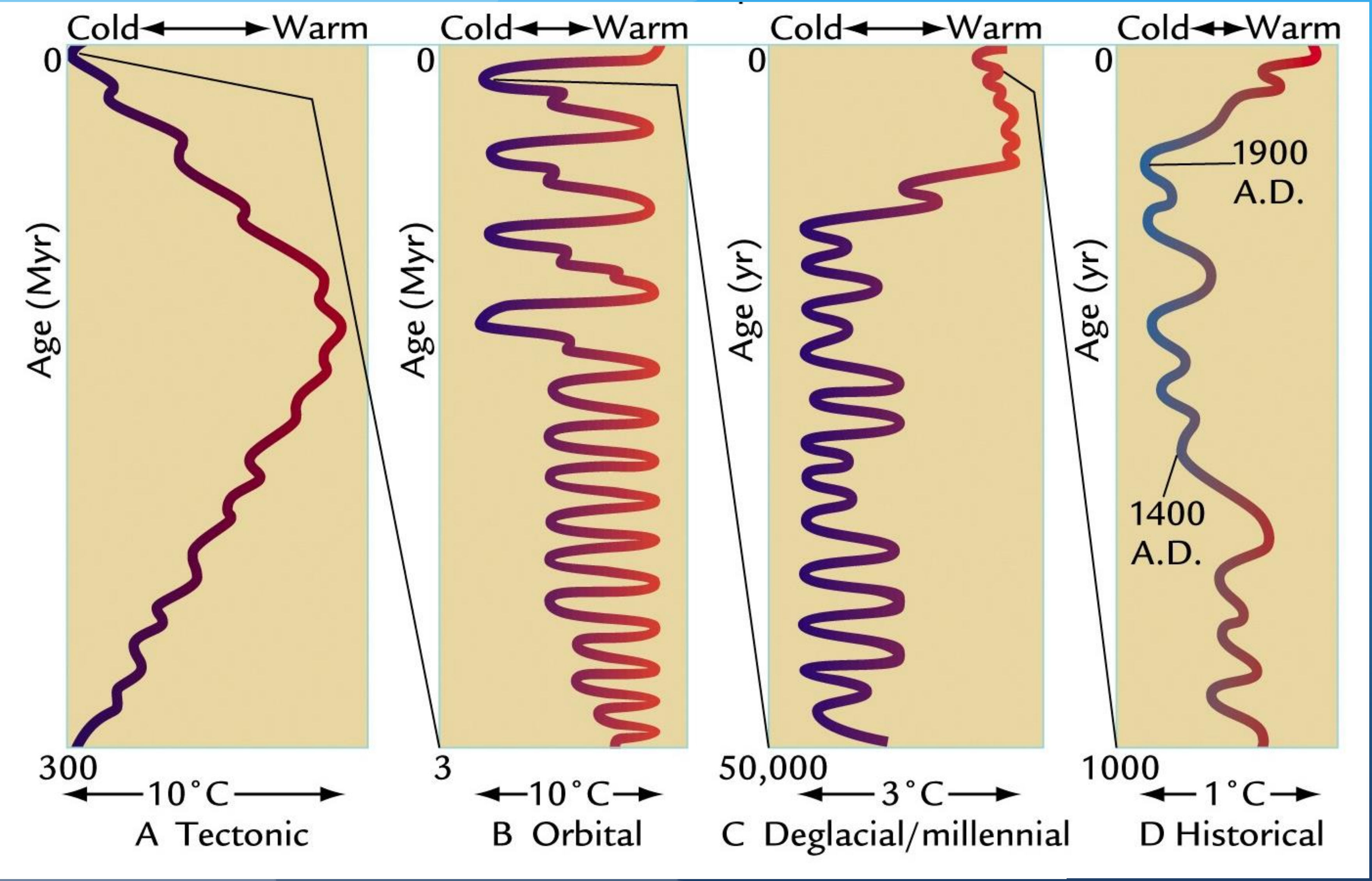
Ruddiman, 2008

Positive and negative feedbacks



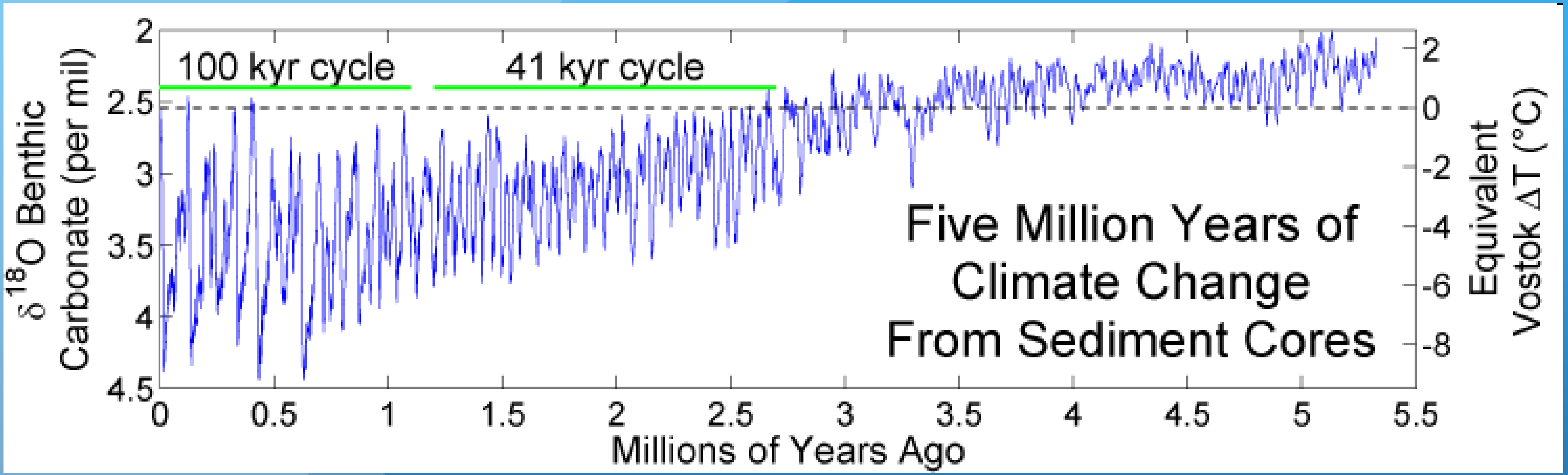
Ruddiman, 2008

Time scales of climate change



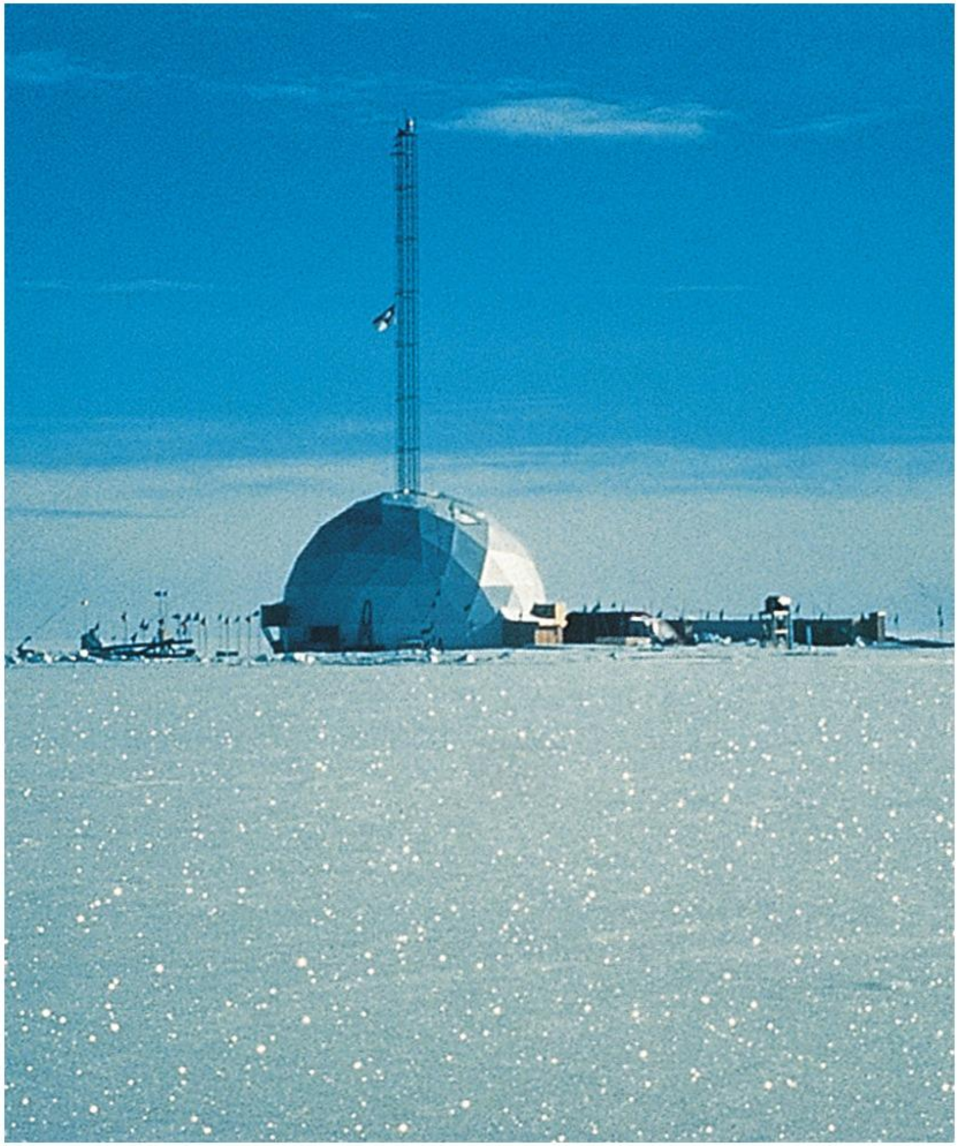
Ruddiman, 2008

Ocean sediment core record



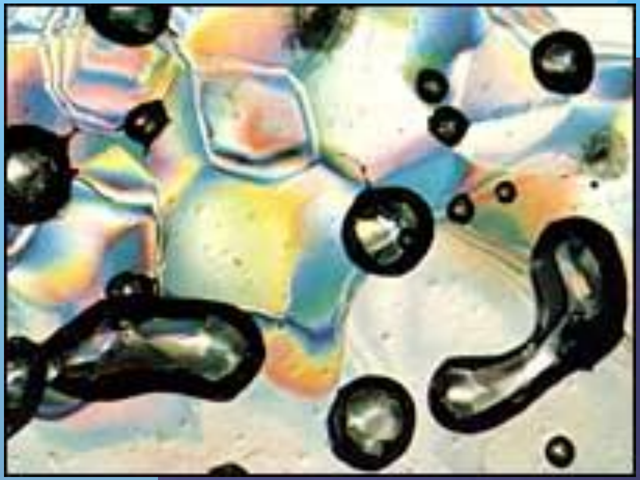
GlobalWarming Art (t), Ruddiman, 2008 (b)

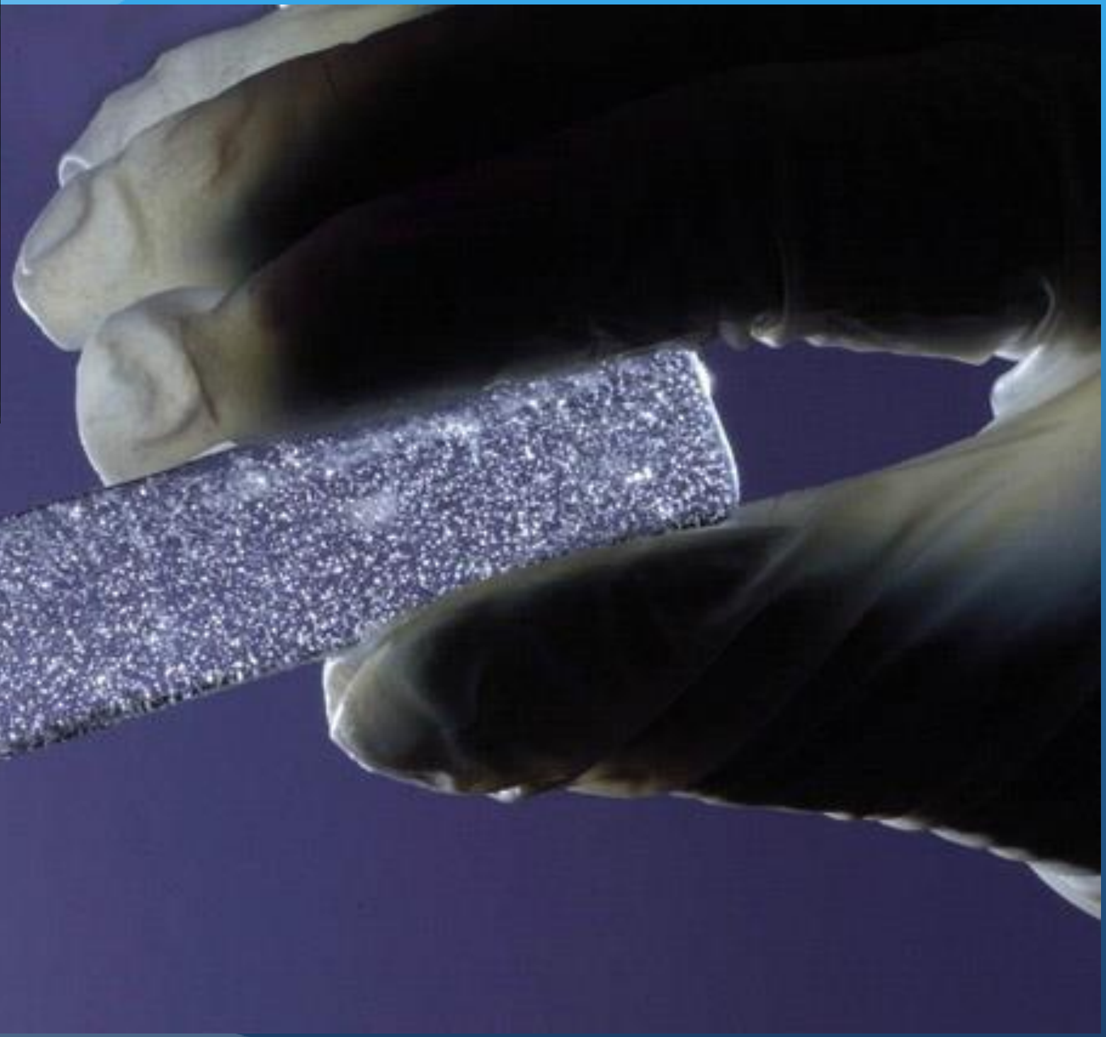
Coring Earth's ice sheets



Twickler – GISP2 SMO (1994)

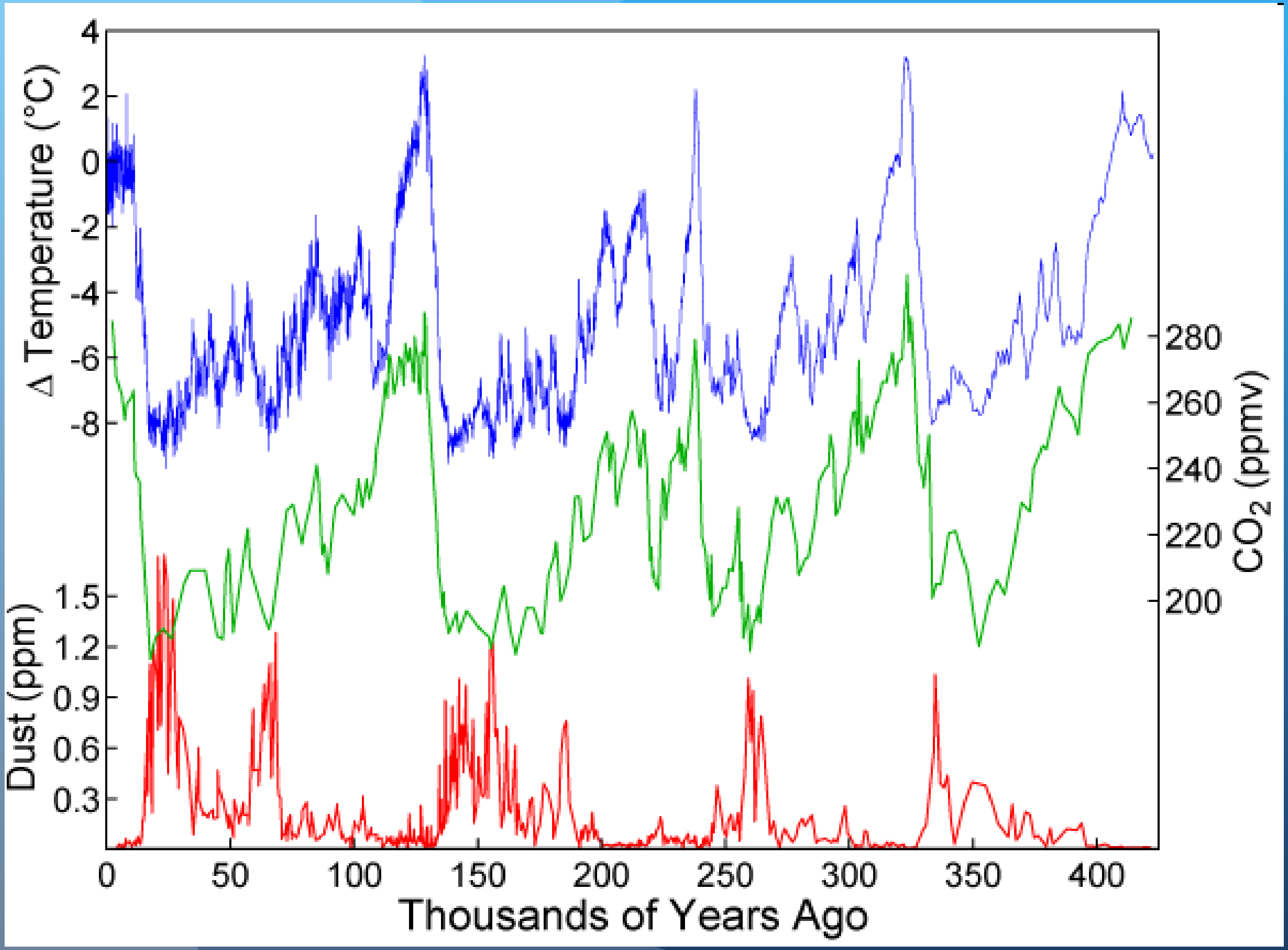
Bubbles trapped in ice core





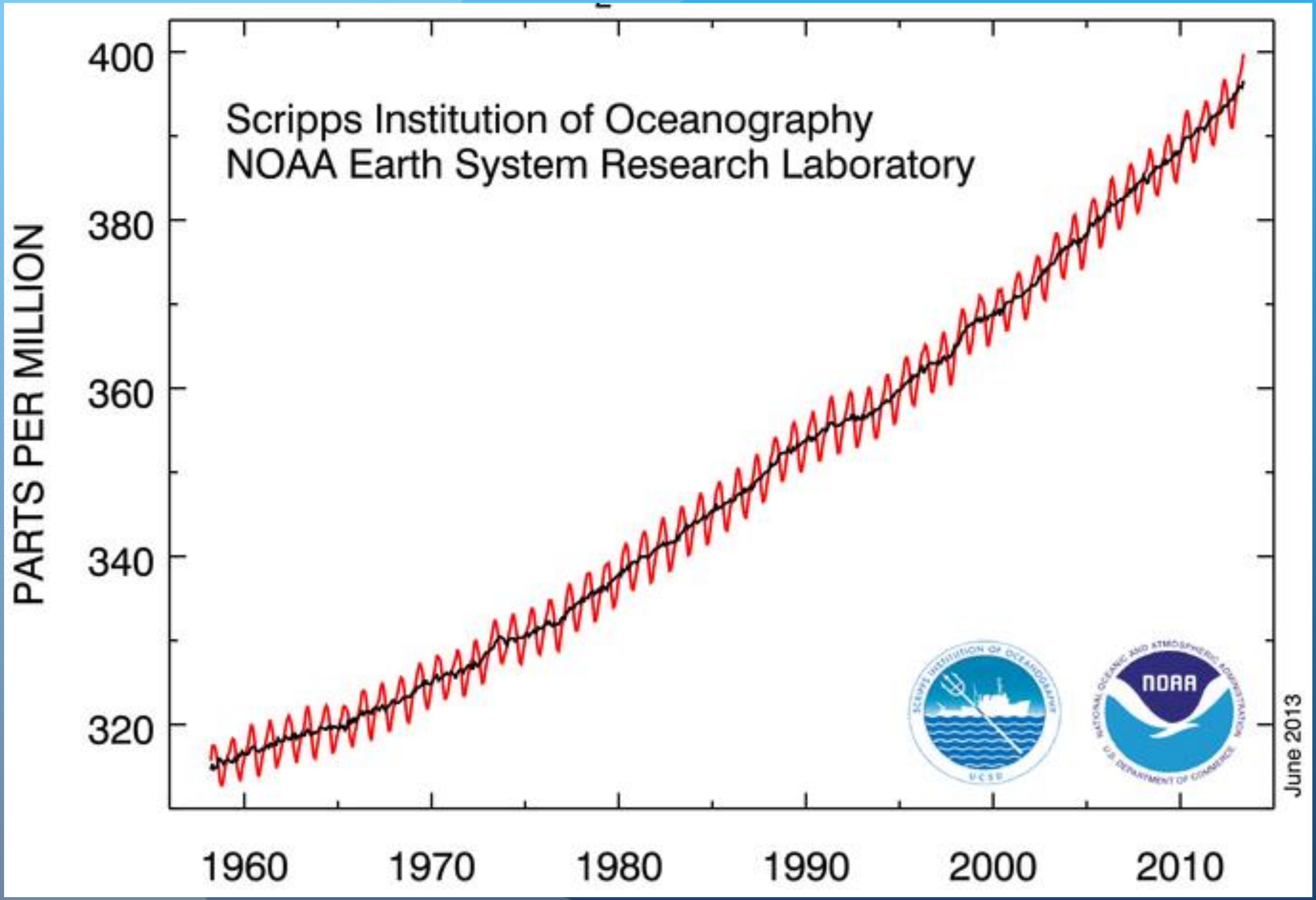
EPICA (2004)

Ice core proxy T, CO_2, dust record

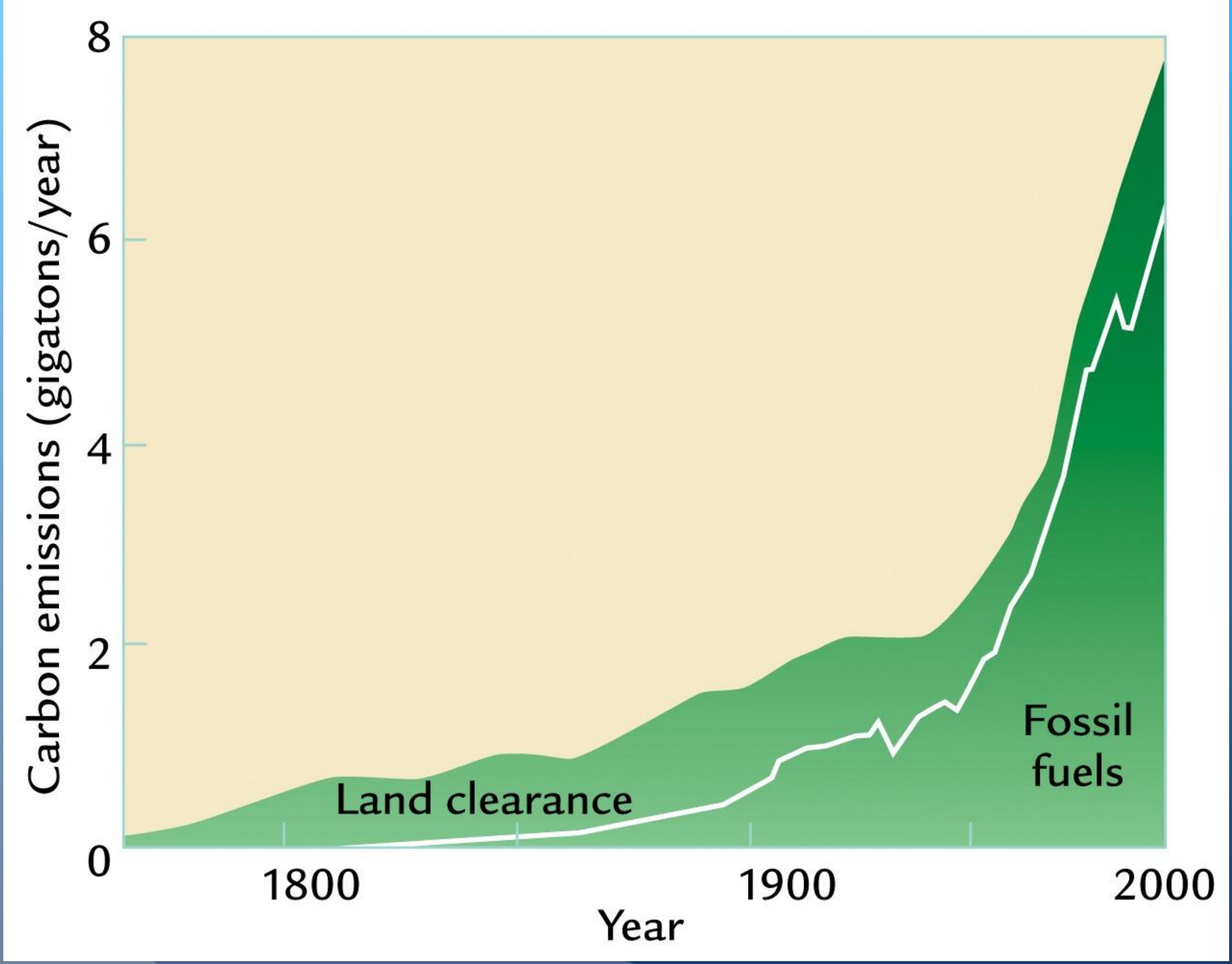


GlobalWarmingArt.com

Atmospheric CO_2 measurement record



Anthropogenic CO_2



Ruddiman, 2008

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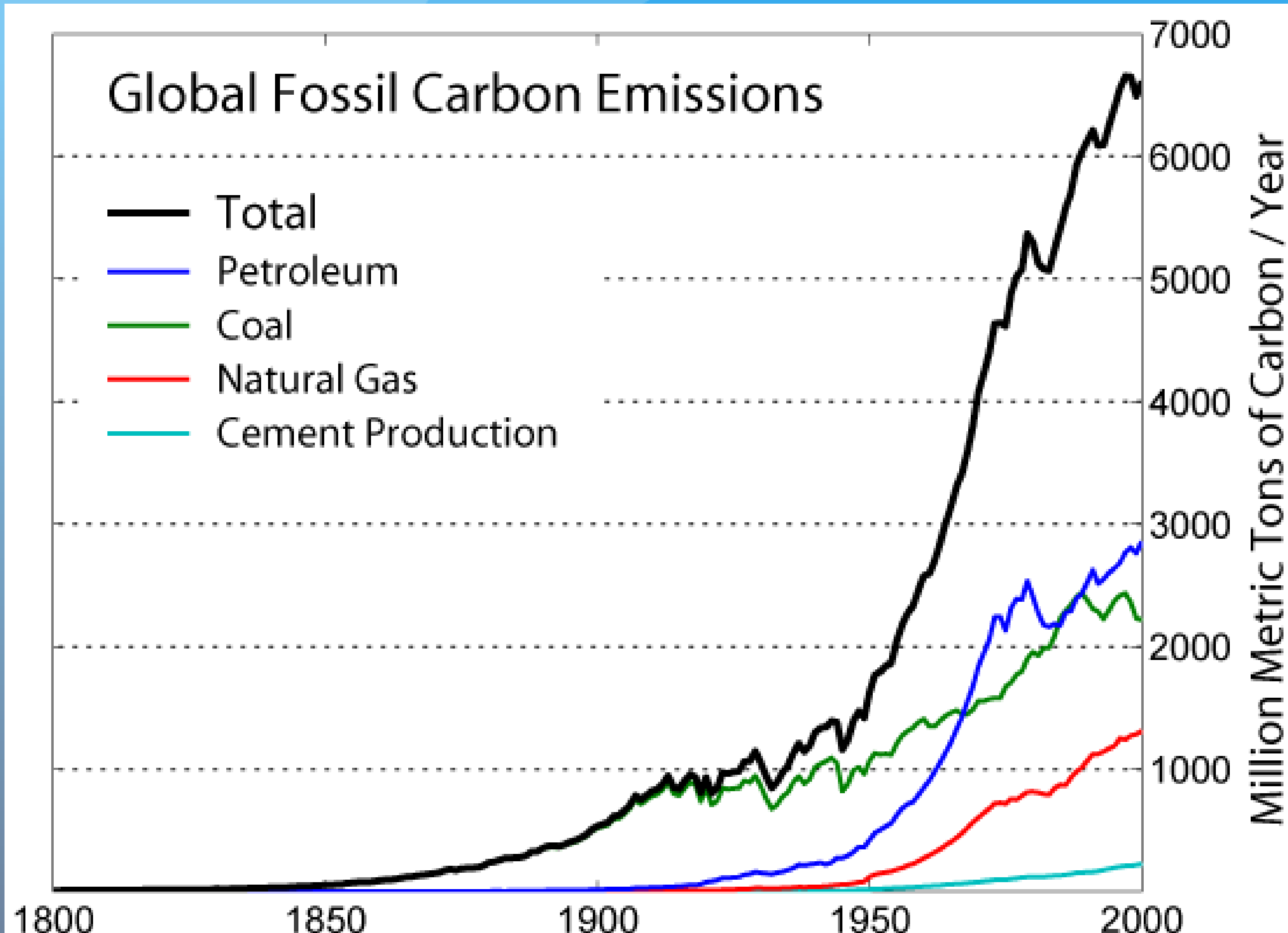
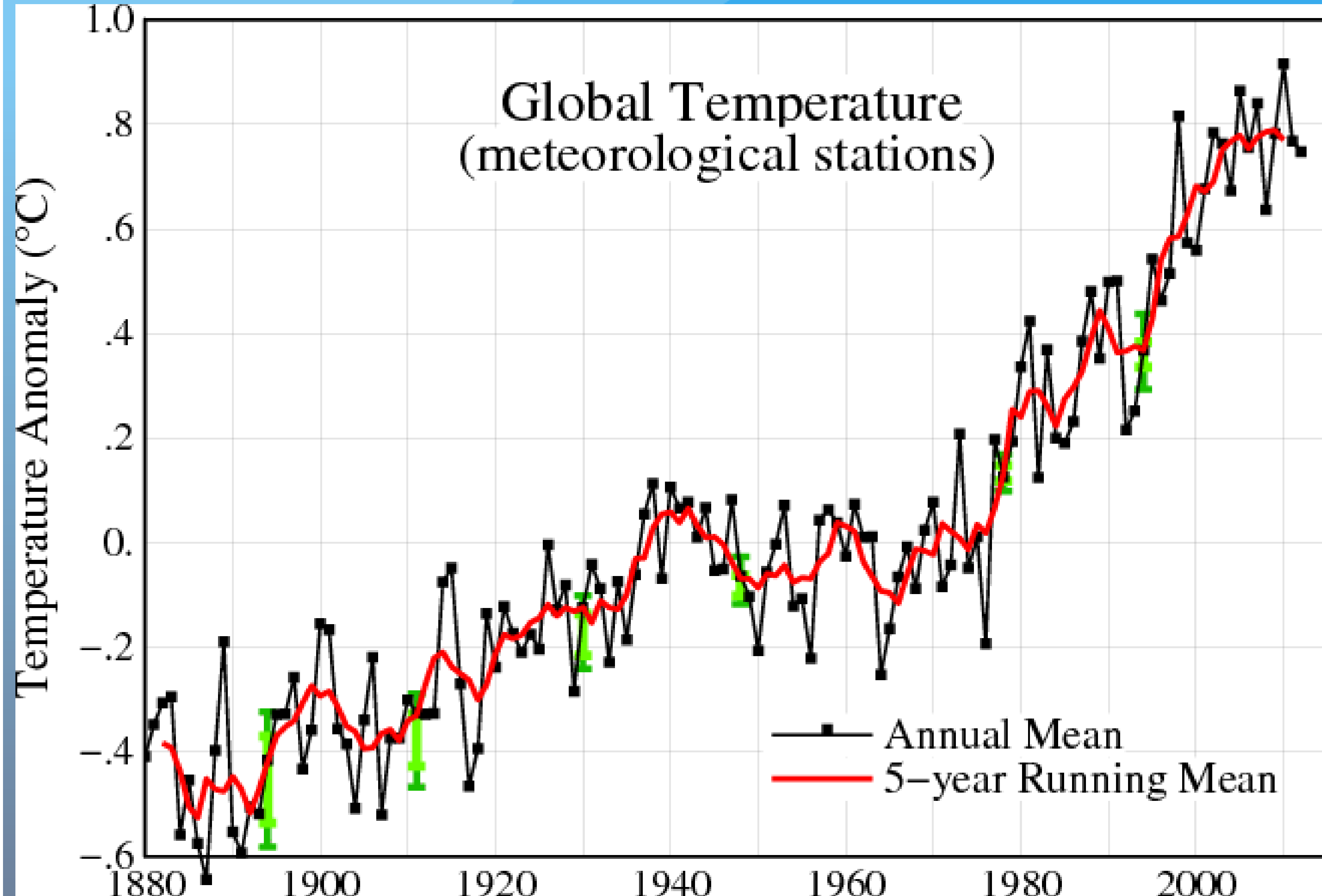


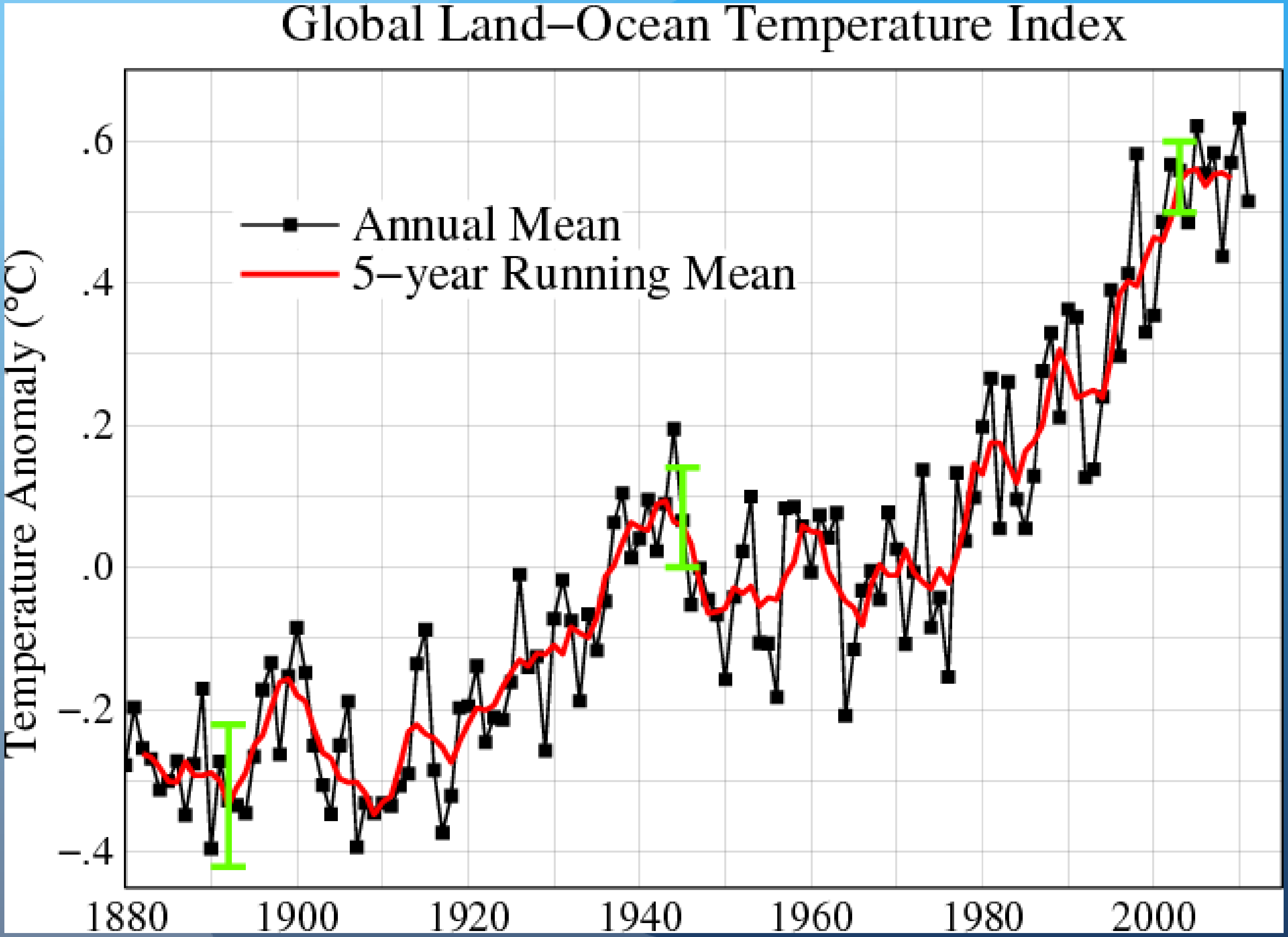
GlobalWarmingArt

Global Temperature Anomaly

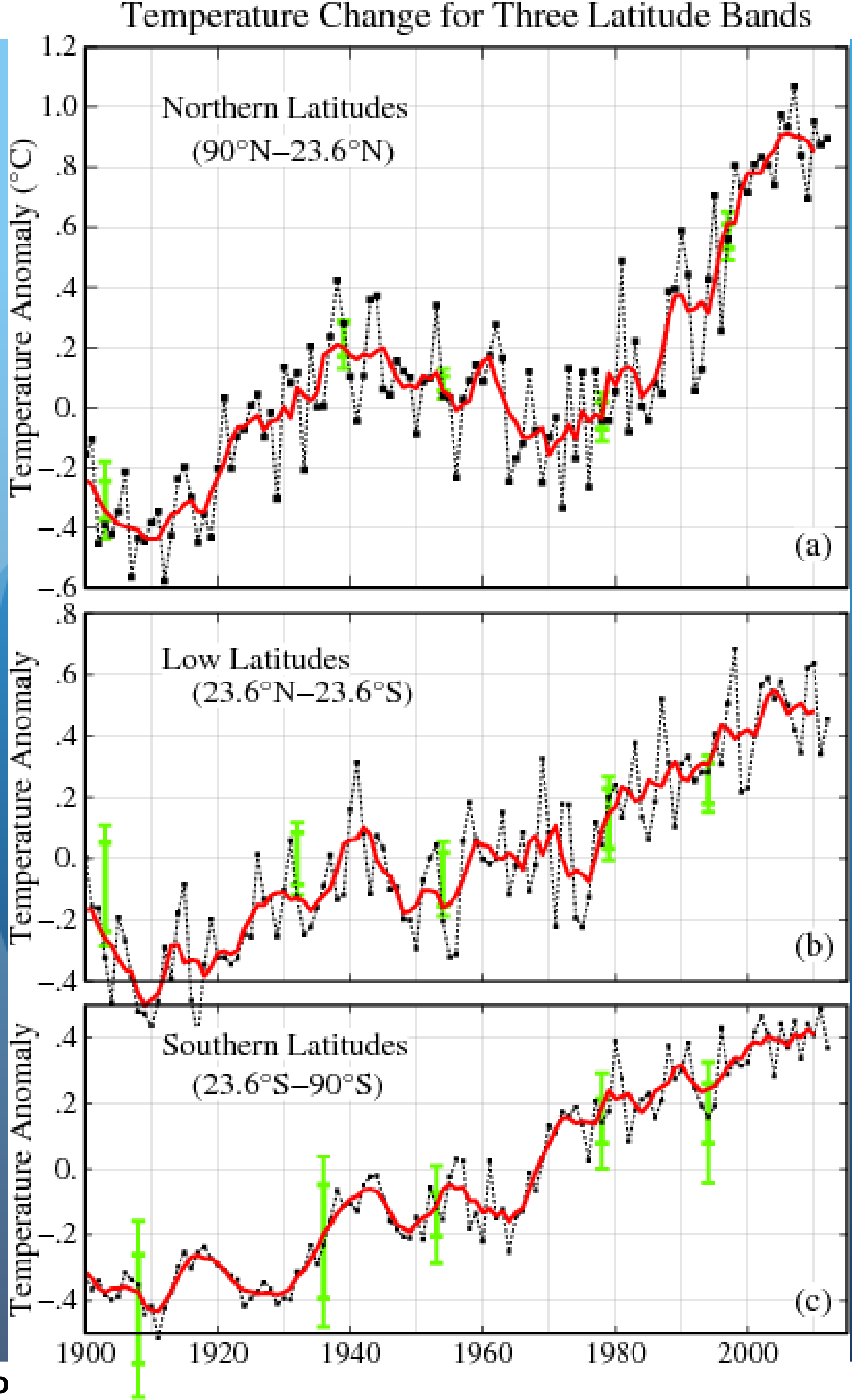


NASA GISS

Global Temperature Anomaly



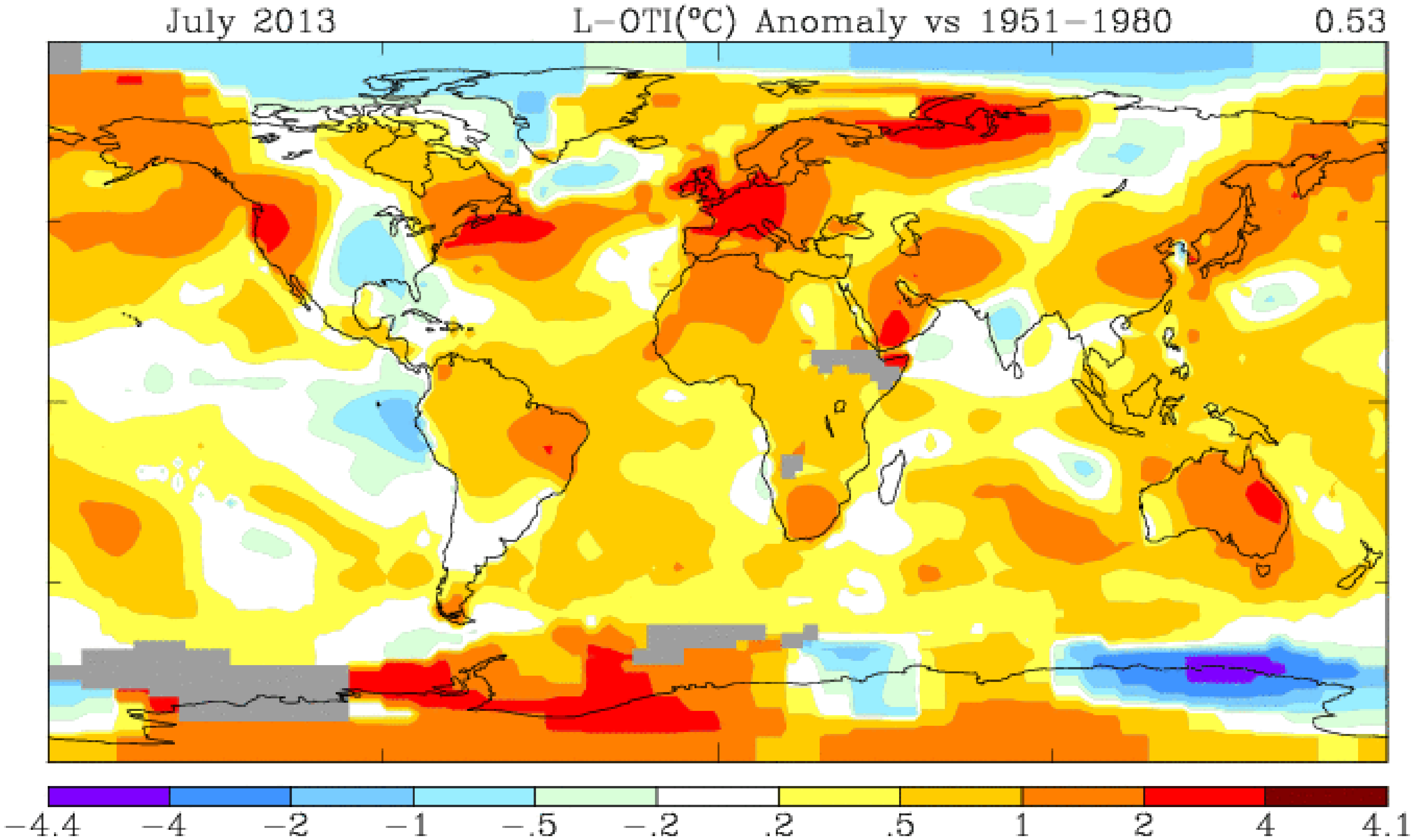
NASA GISS



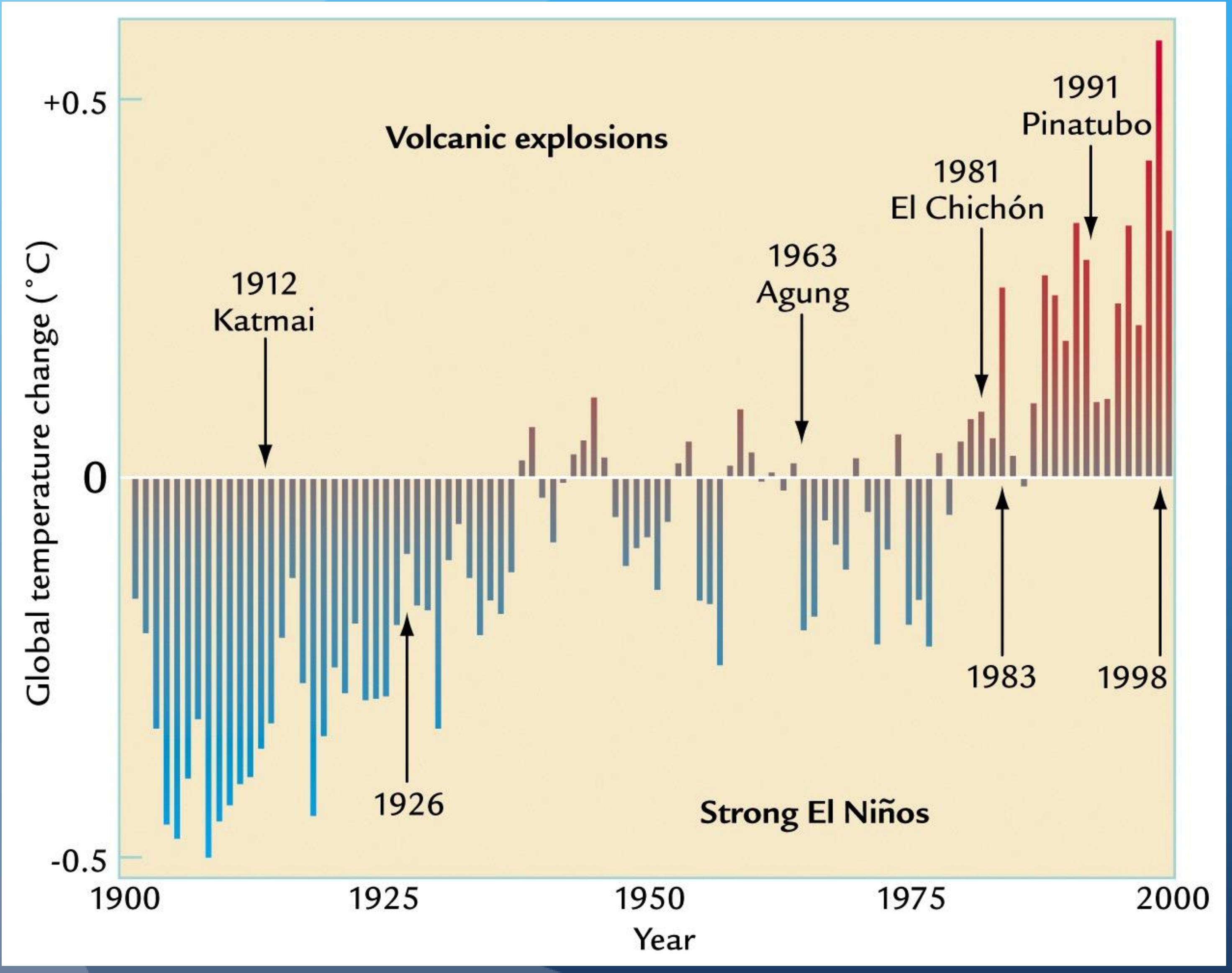
Lefer 27 – iii. natural & anthro

NASA GISS

Global Temperature Anomaly - April 2013

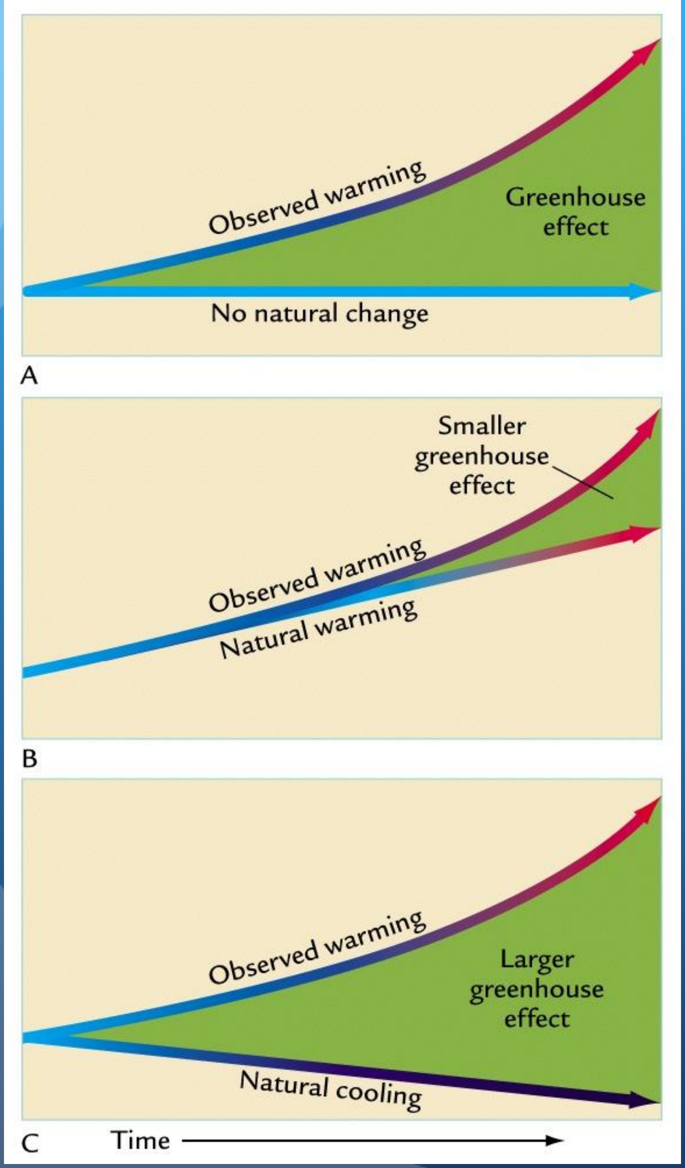


Volcanic cooling and El Niño warming



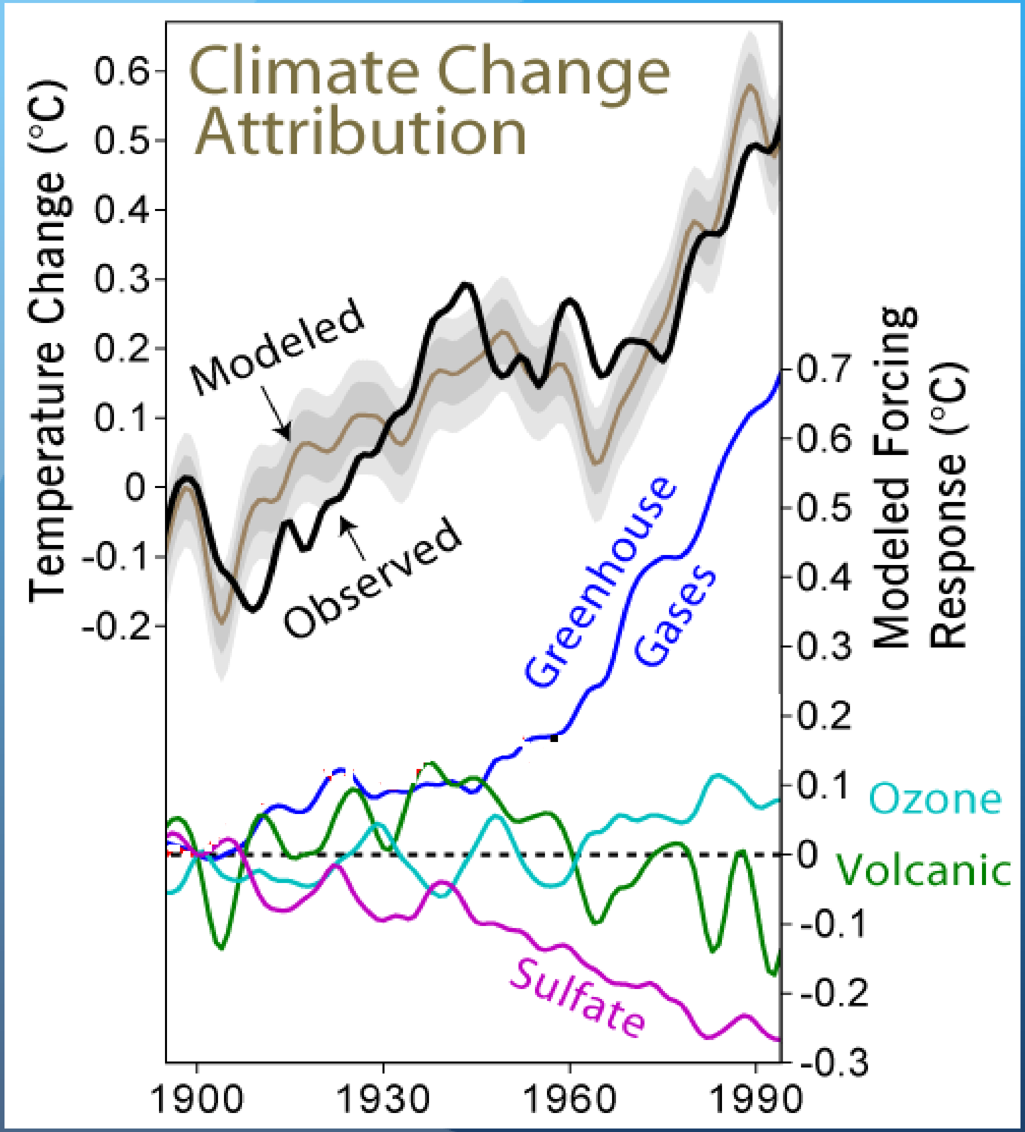
Ruddiman, 2001

Natural warming and greenhouse effects



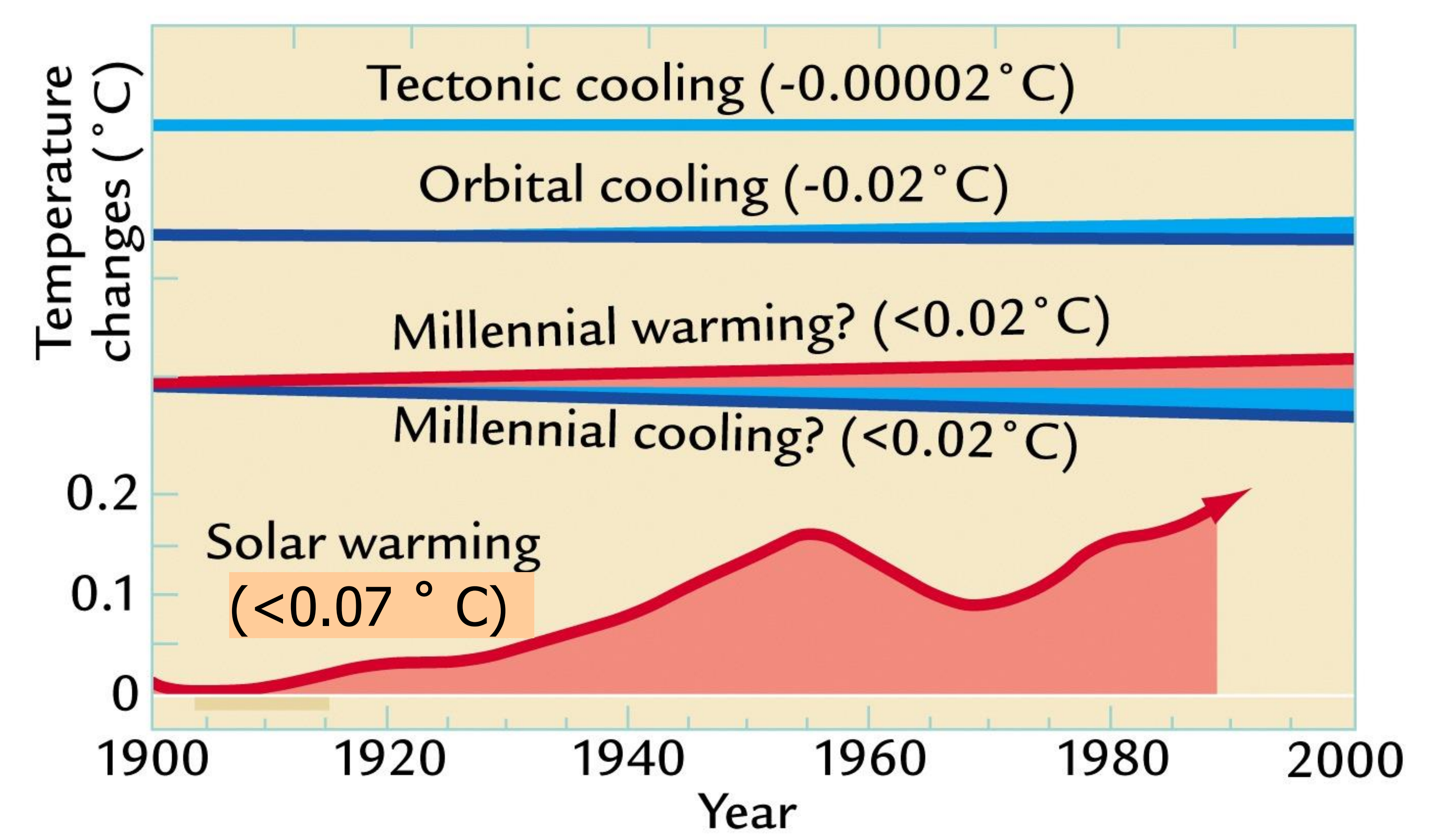
Ruddiman, 2008

Modeling climate change attribution



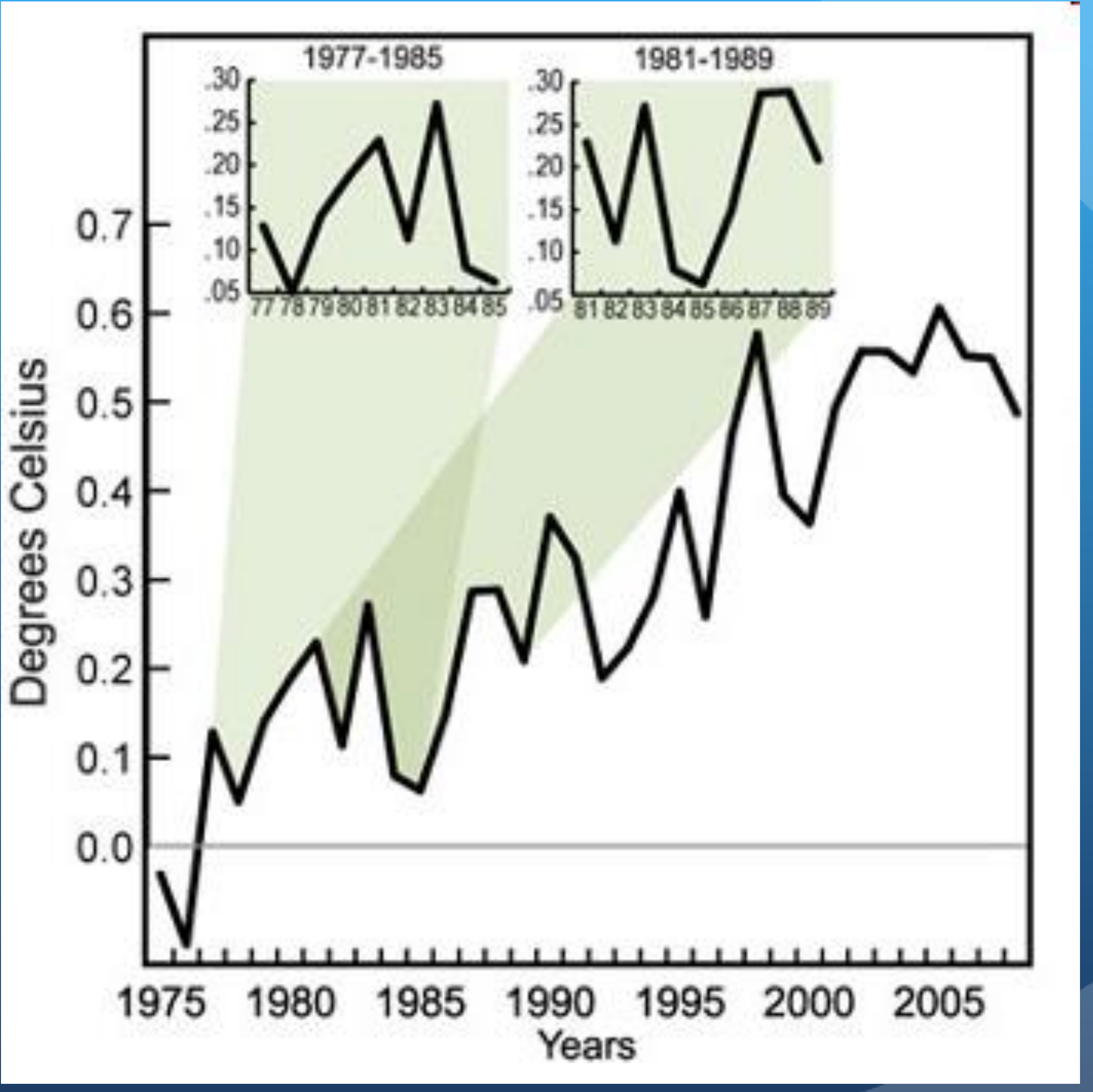
http://www.globalwarmingart.com/

Natural temperature changes



Ruddiman, 2008

Natural interannual variability



Science, 2010

Apple Stock Price – June 2013

NASADAQ, 2013

Apple Stock Price – today

490.90 +2.31 (0.47%)

After Hours: 490.41 -0.49 (-0.10%)
Aug 28, 5:55PM EDT
NASDAQ real-time data - Disclaimer
Currency in USD

Range	486.00 - 495.80	Div/yield	3.05/2.49
52 week	385.10 - 705.07	EPS	40.04
Open	486.00	Shares	908.44M
Vol / Avg.	10.97M/12.39M	Beta	1.00
Mkt cap	445.95B	Inst. own	61%
P/E	12.26		

+1 7.7k

Compare: Enter ticker here Add Dow Jones Nasdaq HPQ MSFT INTC SSNLF « less
MMI NOK BBRY

Zoom: 1d 5d 1m 3m 6m YTD 1y 5y 10y All
Aug 28, 2013 - Aug 28, 2013 +2.31 (0.47%)

NASDAQ, 2013

Apple Stock Price – Past Year

NASDAQ, 2013

Apple Stock Price ~ 30 years

490.90 +2.31 (0.47%)

After Hours: 490.41 -0.49 (-0.10%)
Aug 28, 5:55PM EDT
NASDAQ real-time data - Disclaimer
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Range	486.00 - 495.80	Div/yield	3.05/2.49
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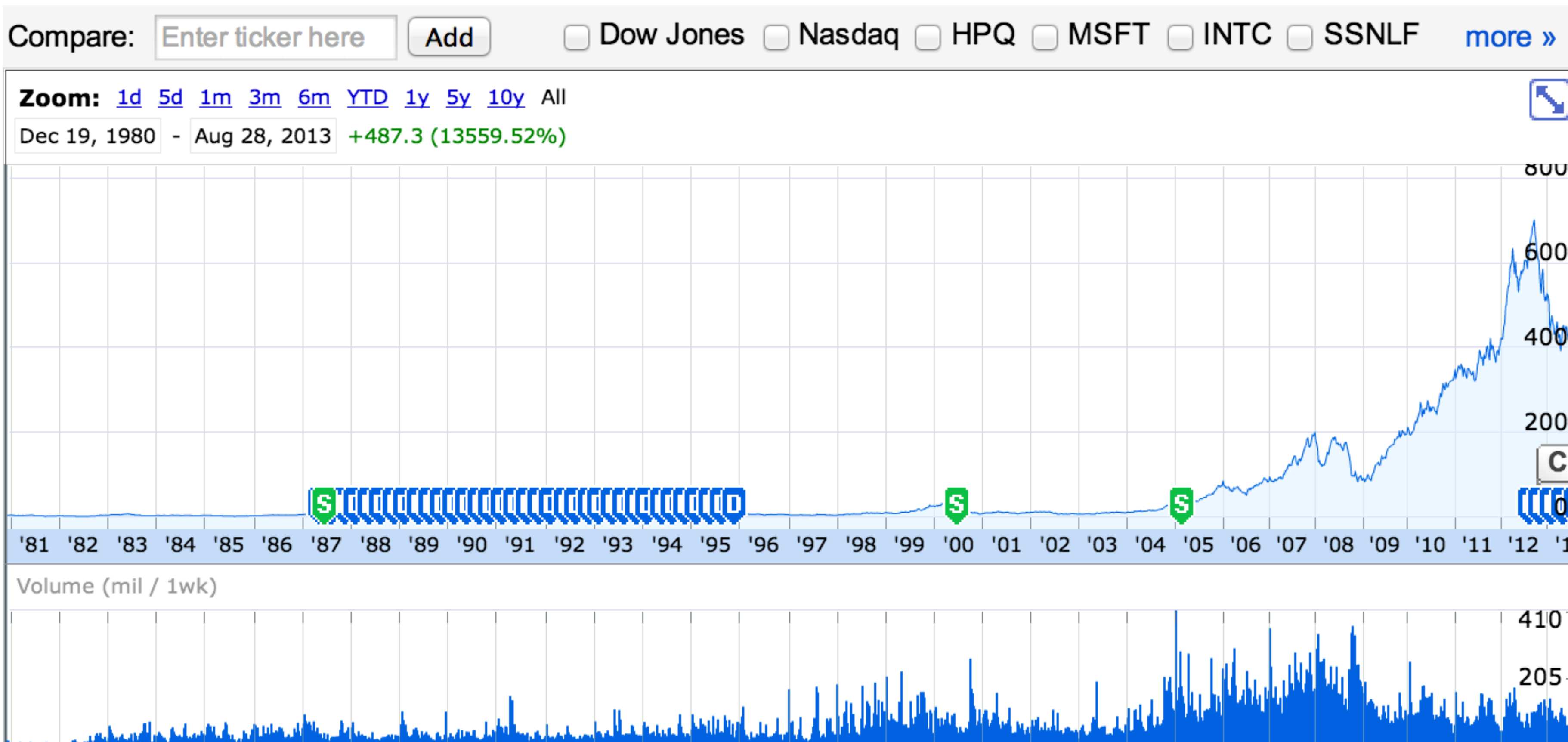
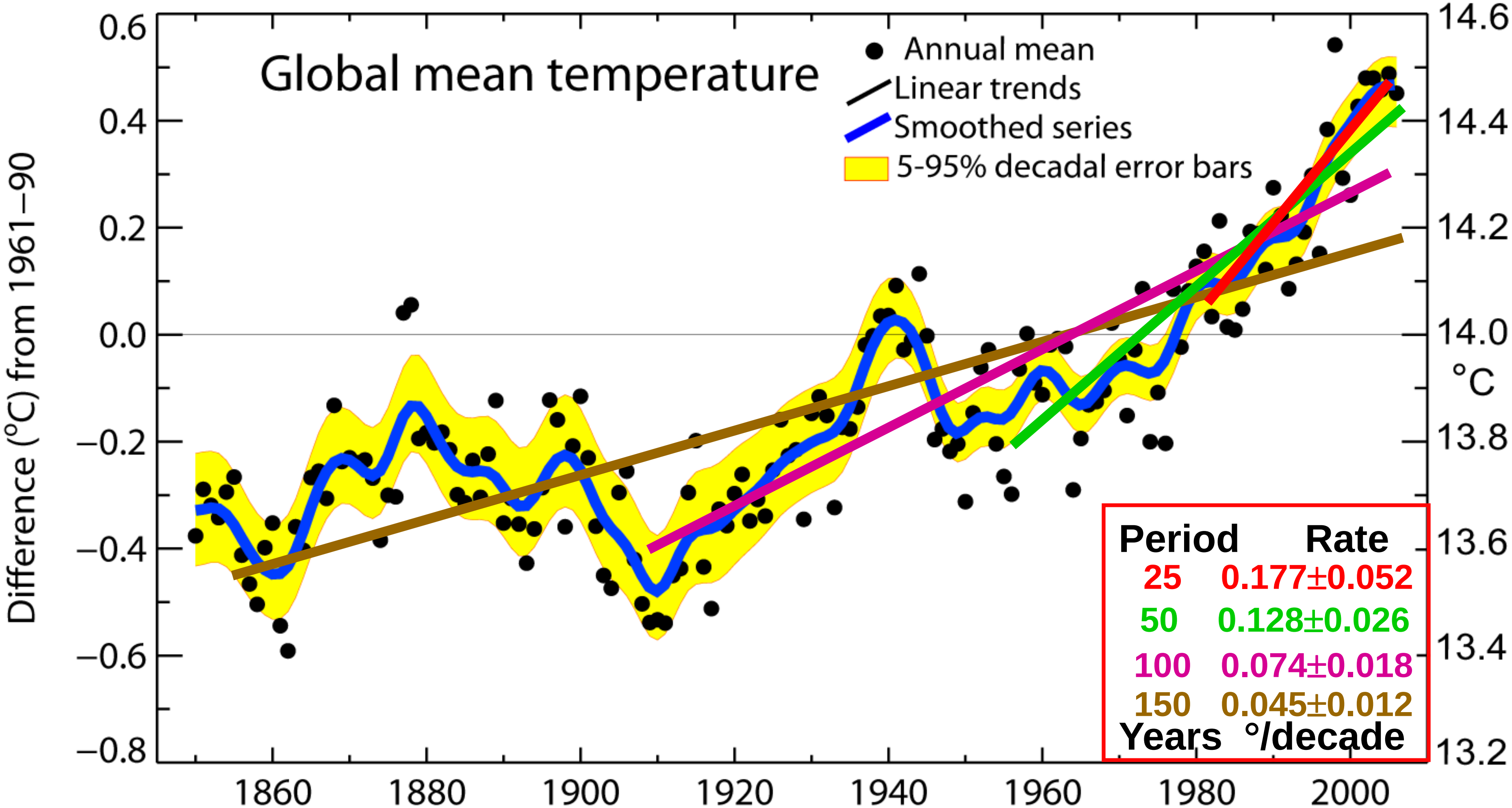


NASDAQ, 2013

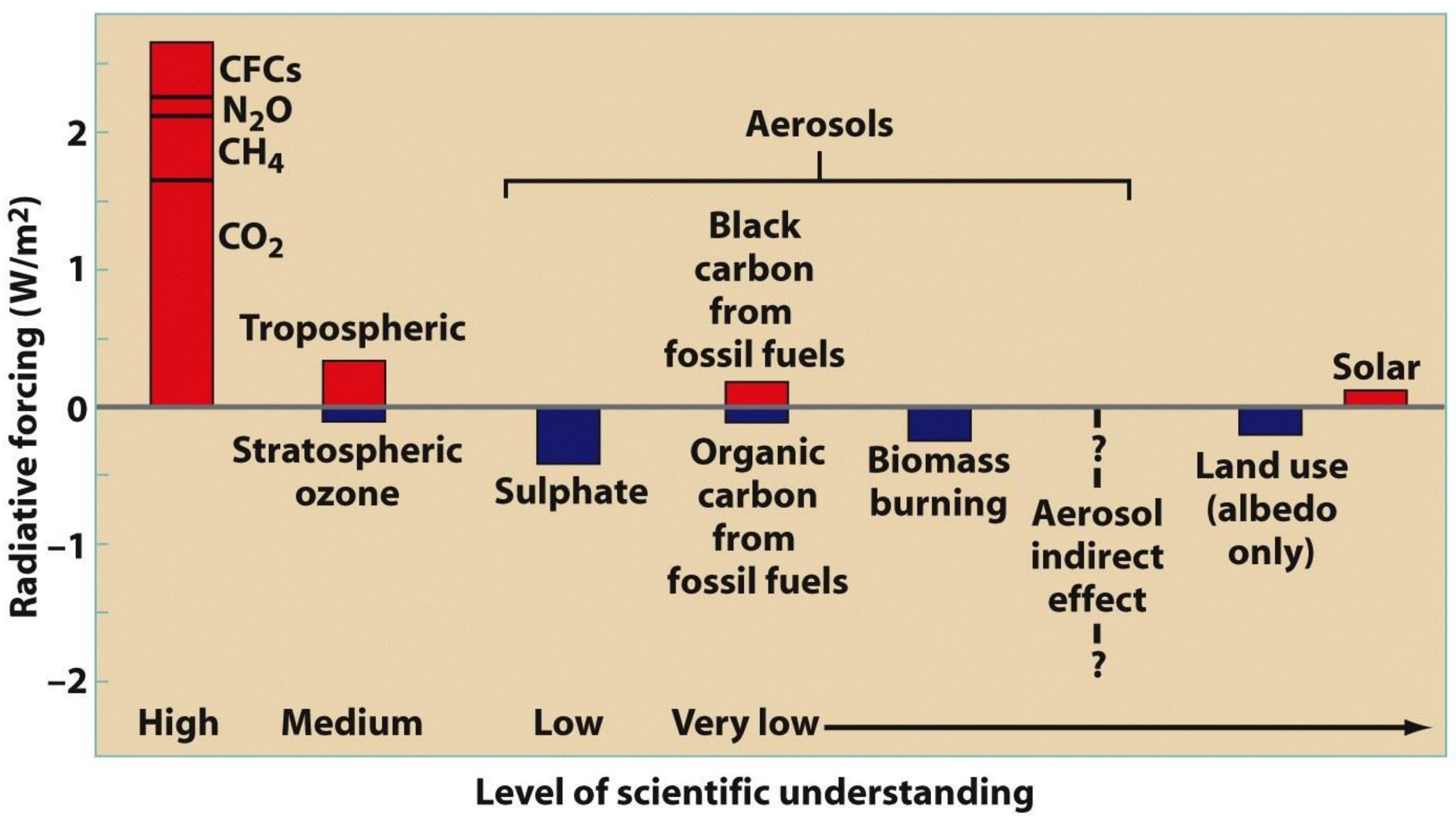
Rate of global temperature rise



Period	Rate
25	0.177±0.052
50	0.128±0.026
100	0.074±0.018
150	0.045±0.012
Years	°/decade

Kevin Trenberth, 2008

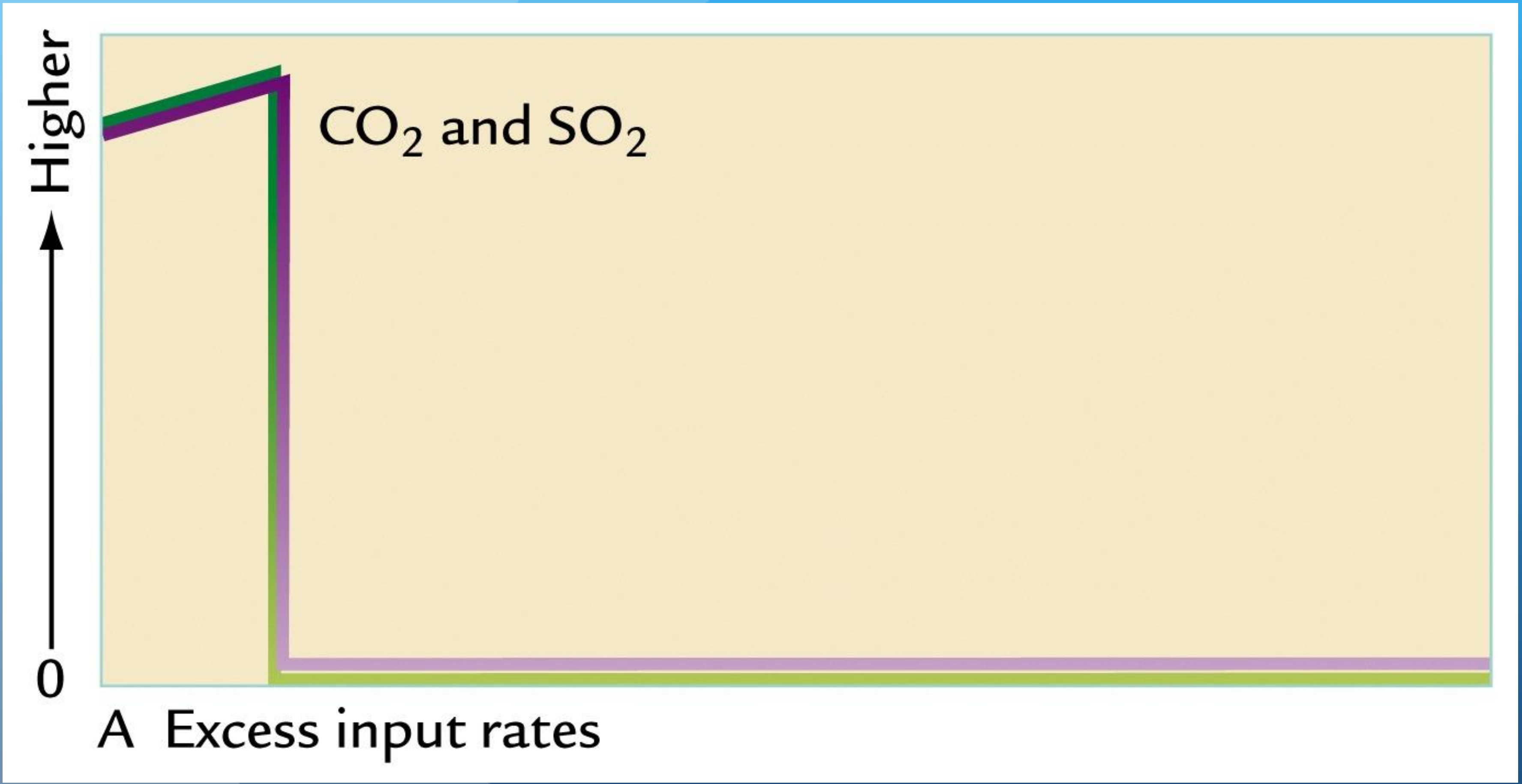
Radiative forcing of recent warming



Box 18-1b
Earth's Climate: Past and Future, Second Edition

 Ruddiman, 2008

Response to abrupt ΔCO_2 and SO_2 emissions?



Ruddiman, 2008

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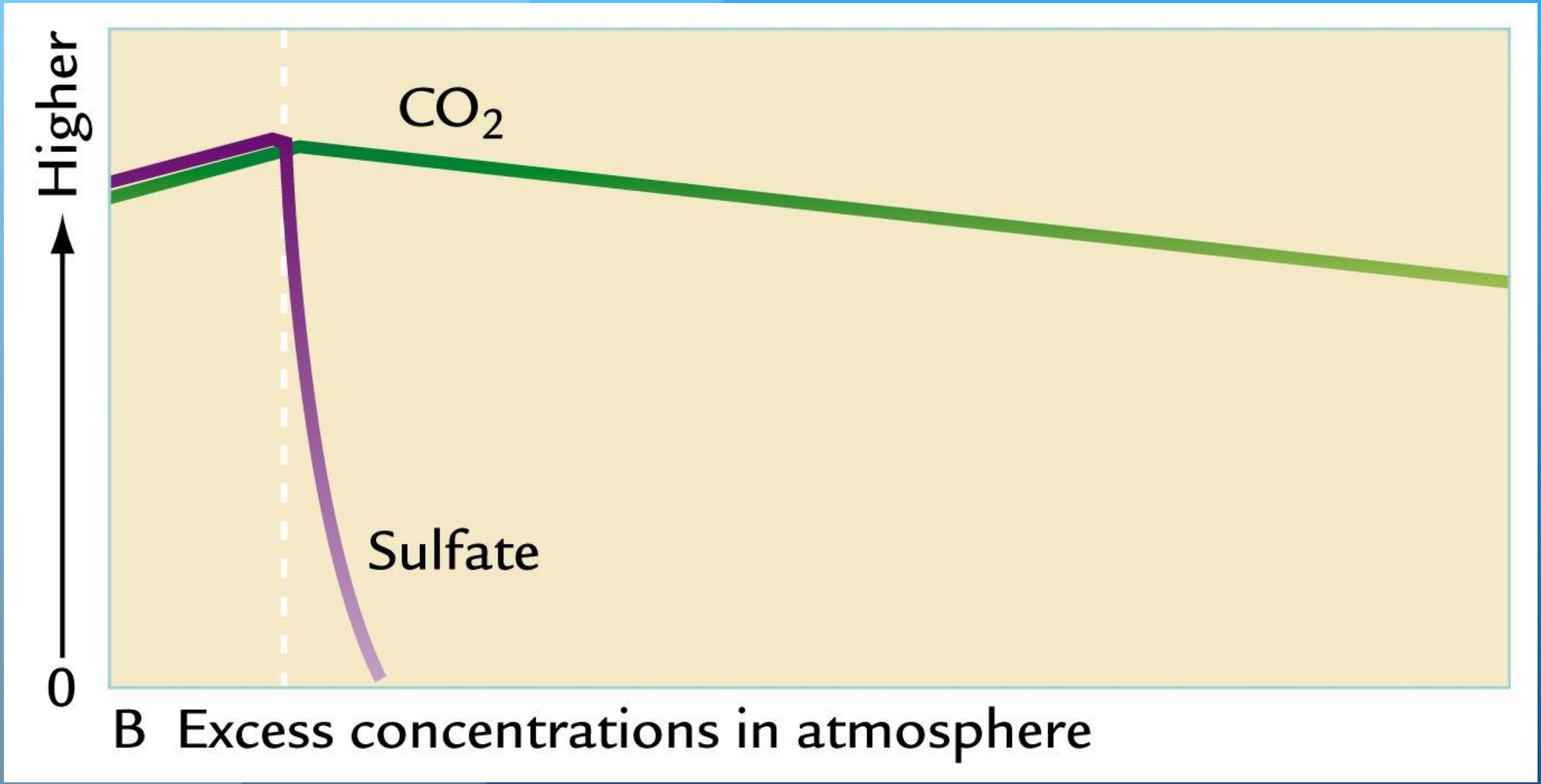

Ruddiman, 2008

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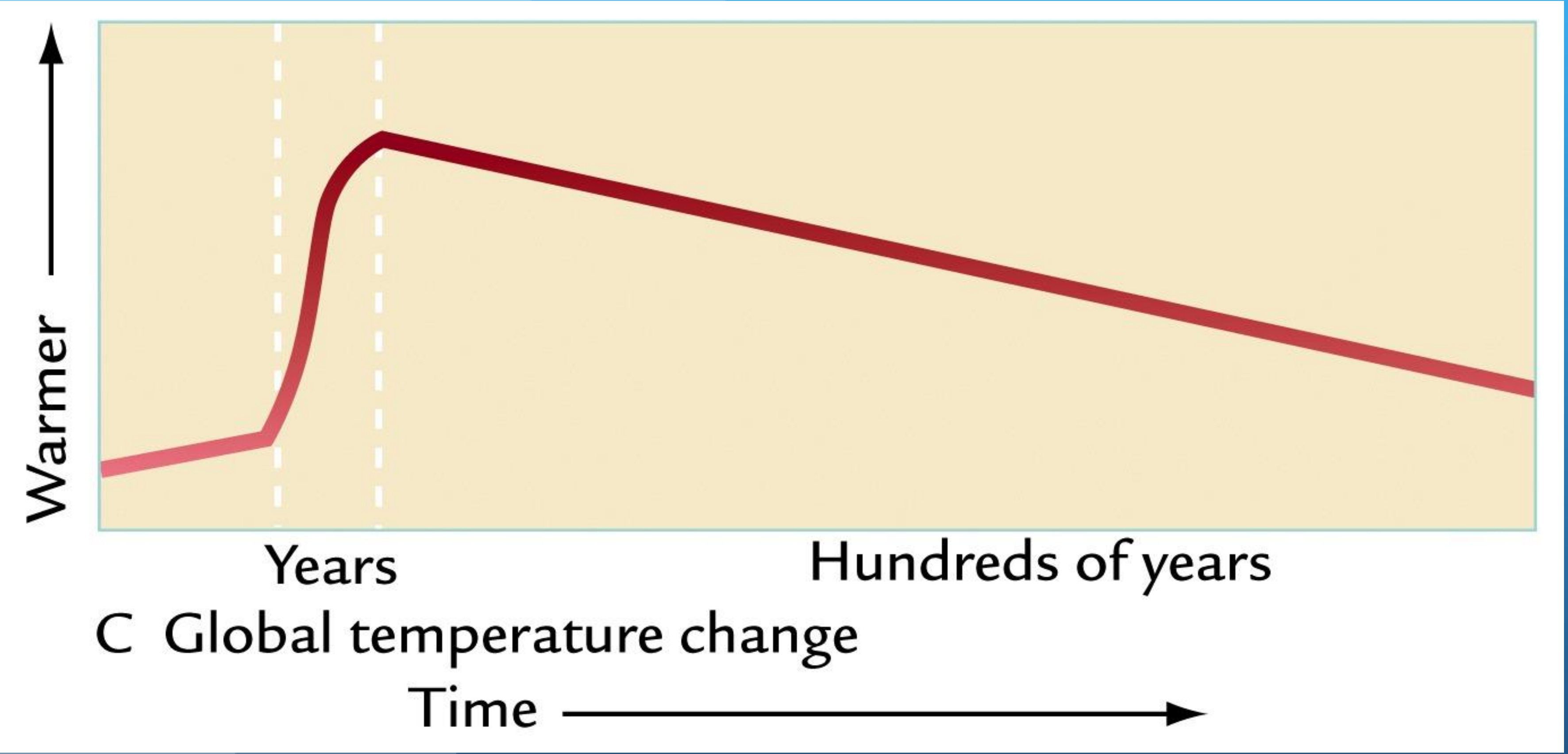
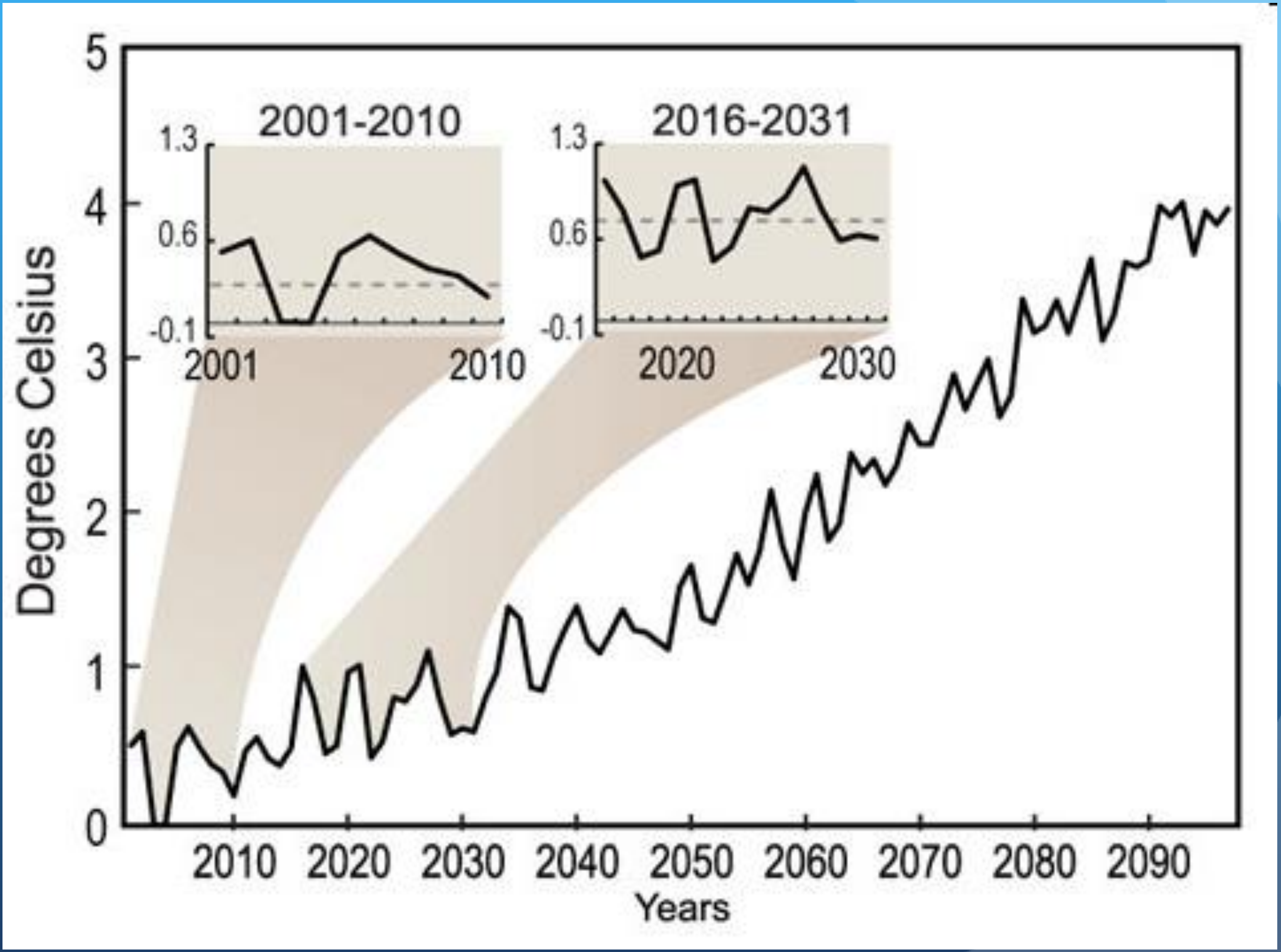


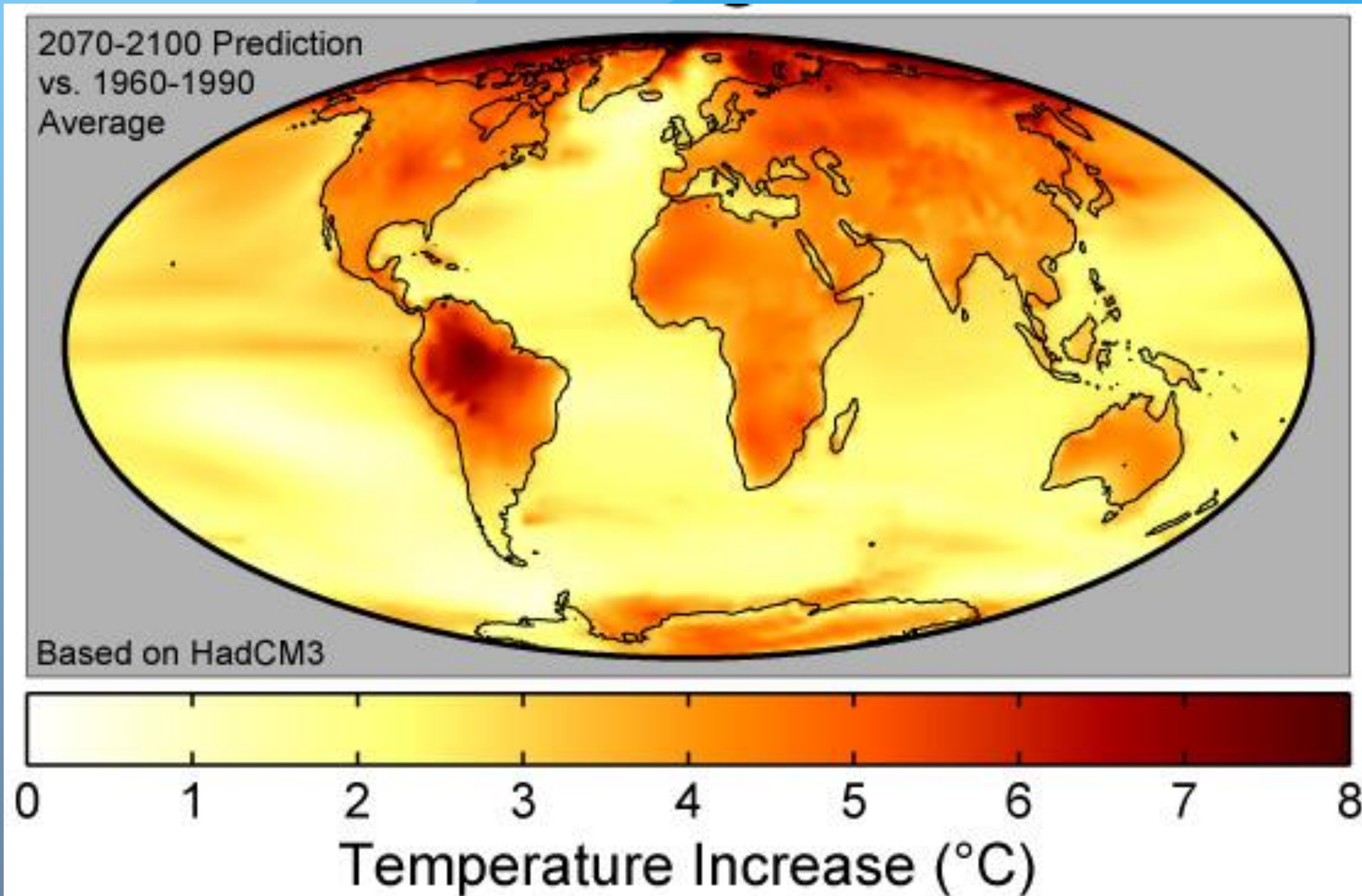
Ruddiman, 2008

A future global temperature forecast



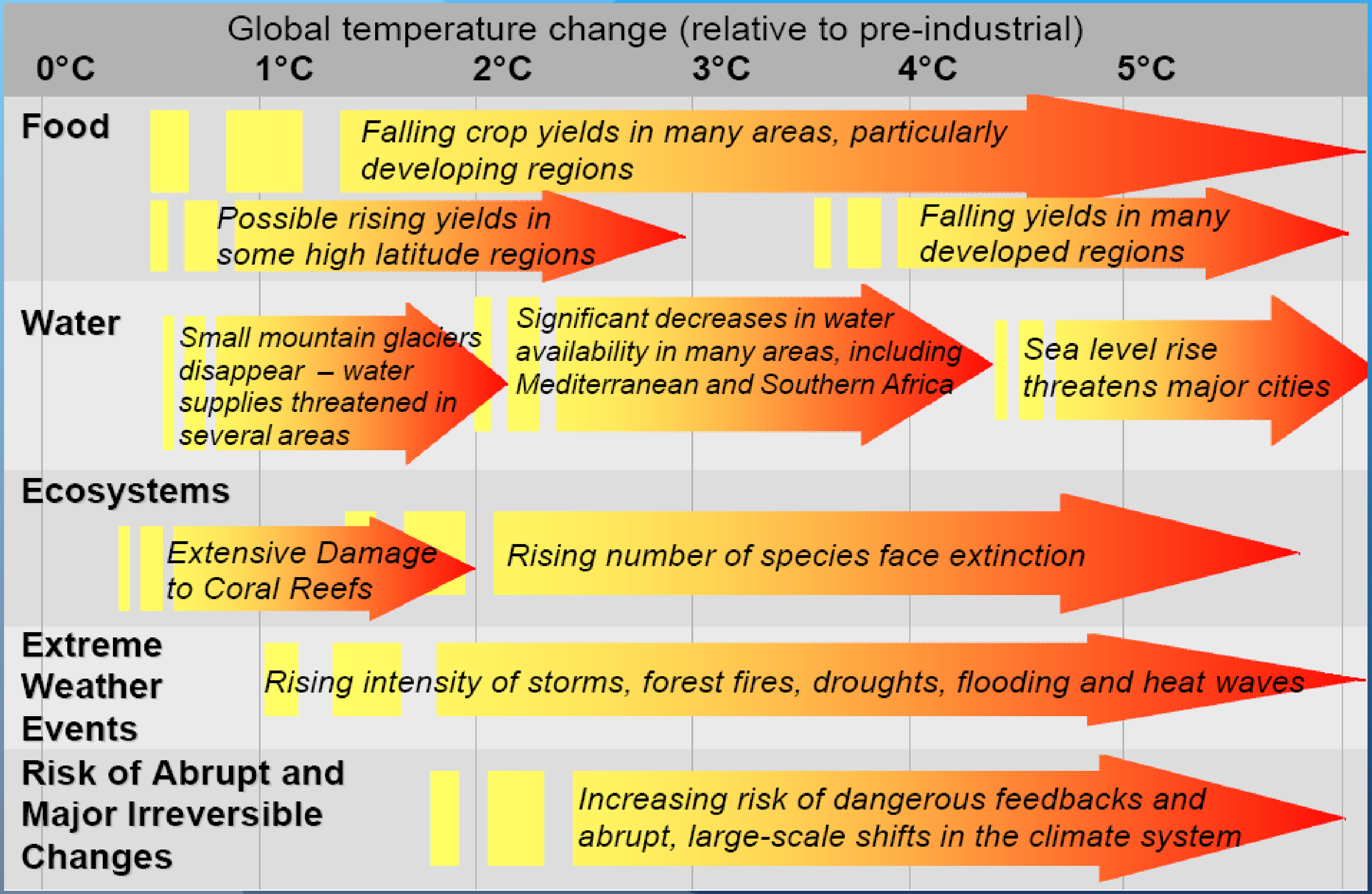
Science, 2010

Another future global temperature forecast



 http://www.globalwarmingart.com/

Projected impacts of climate change



IPCC, 2007

Questions? Thank you.

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Beals, 2008