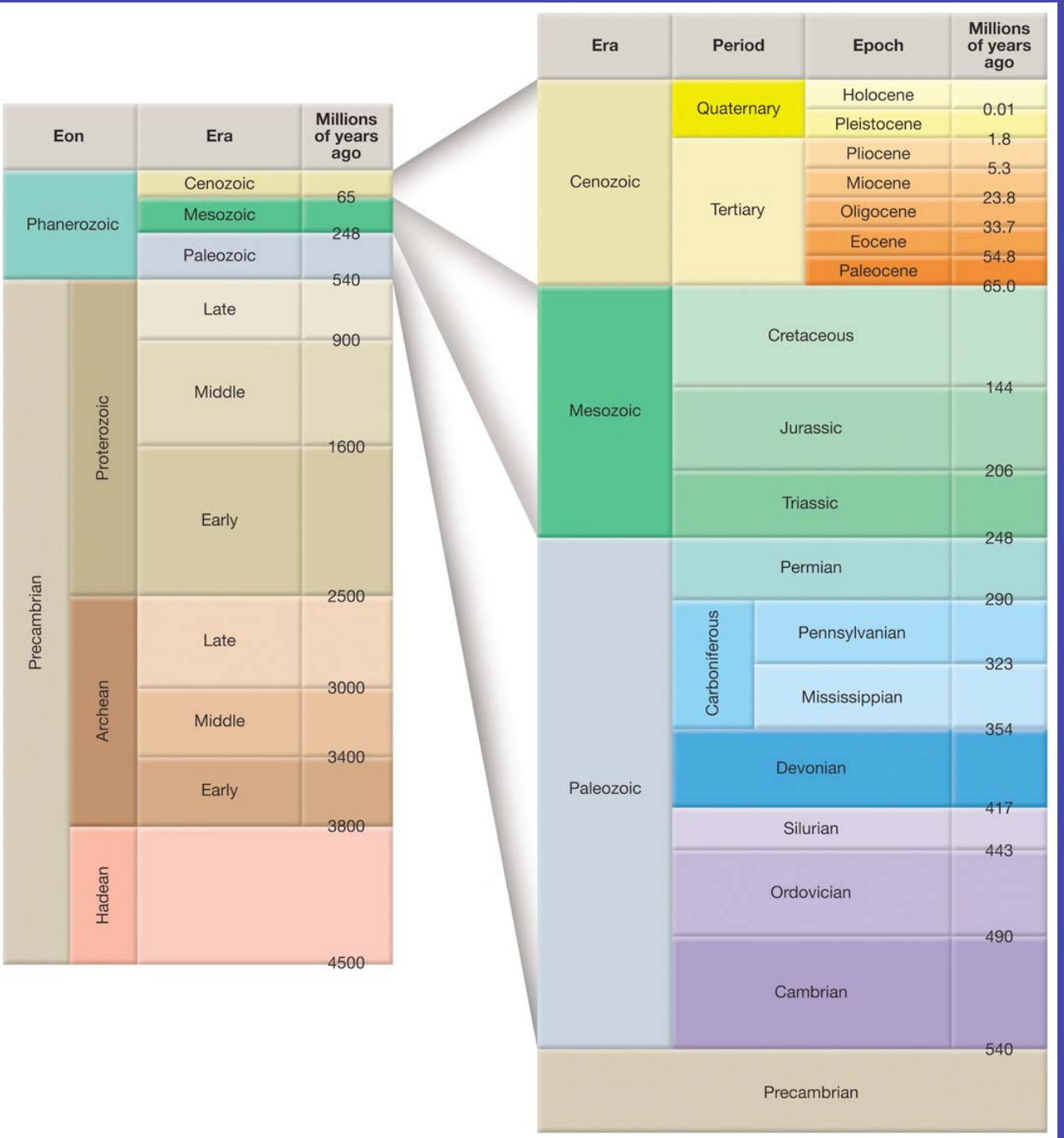
# Why should a geologist be studying climate?






**CLIMATE**

**change**

**is responsible for the organization of the**

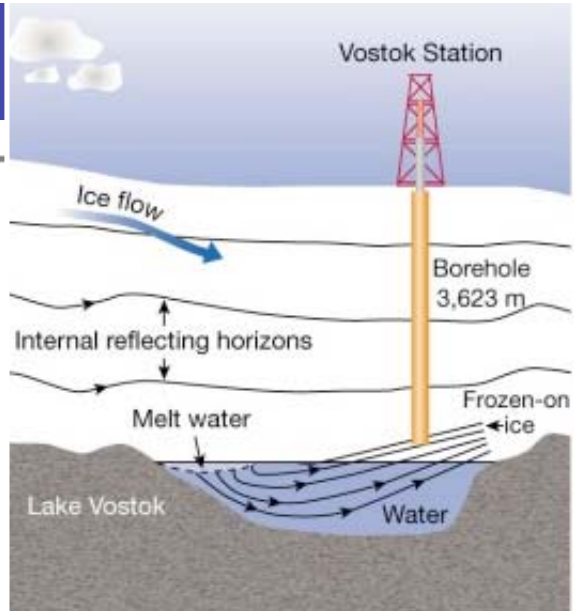
**GEOLOGIC**

**timescale**

# Past climate changes may help us to predict the future



# Vostok Antarctica Ice Core




Δ Temperature (°C)

4
2
0
-2
-4
-6
-8

$CO_2$ (ppmv)

260
240
220
200

Dust (ppm)

1.5
1.2
0.9
0.6
0.3

0 50 100 150 200 250 300 350 400

Thousands of Years Ago

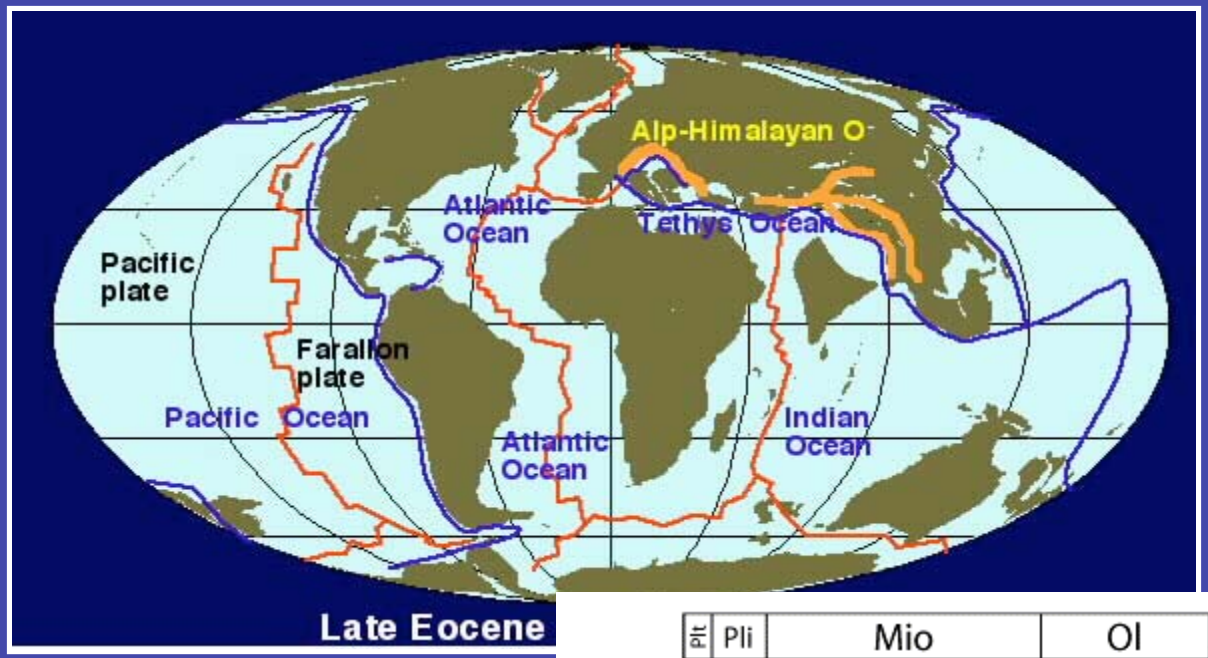





**Glacial remnants in Africa are explained by:**

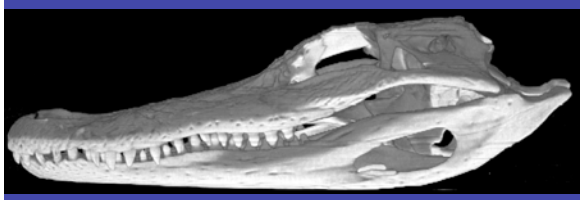
**1) plate tectonics**

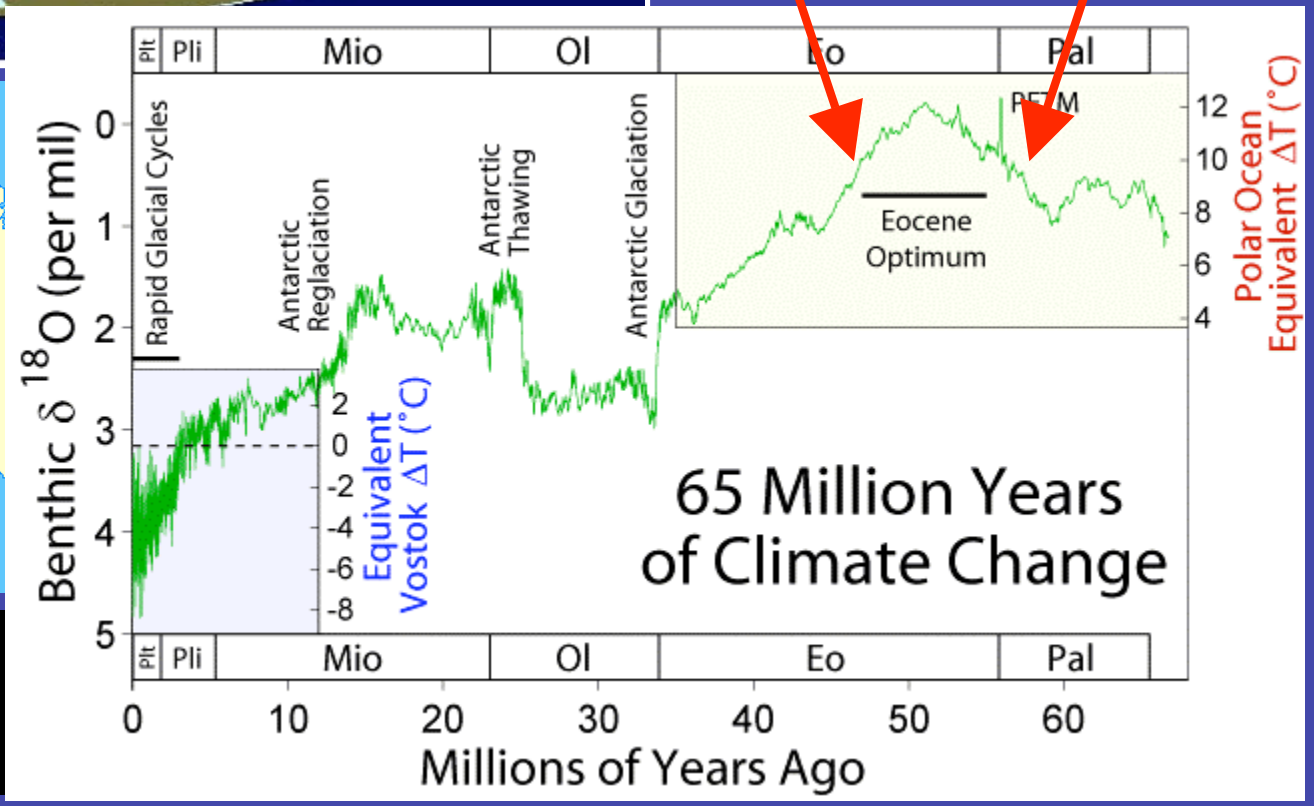


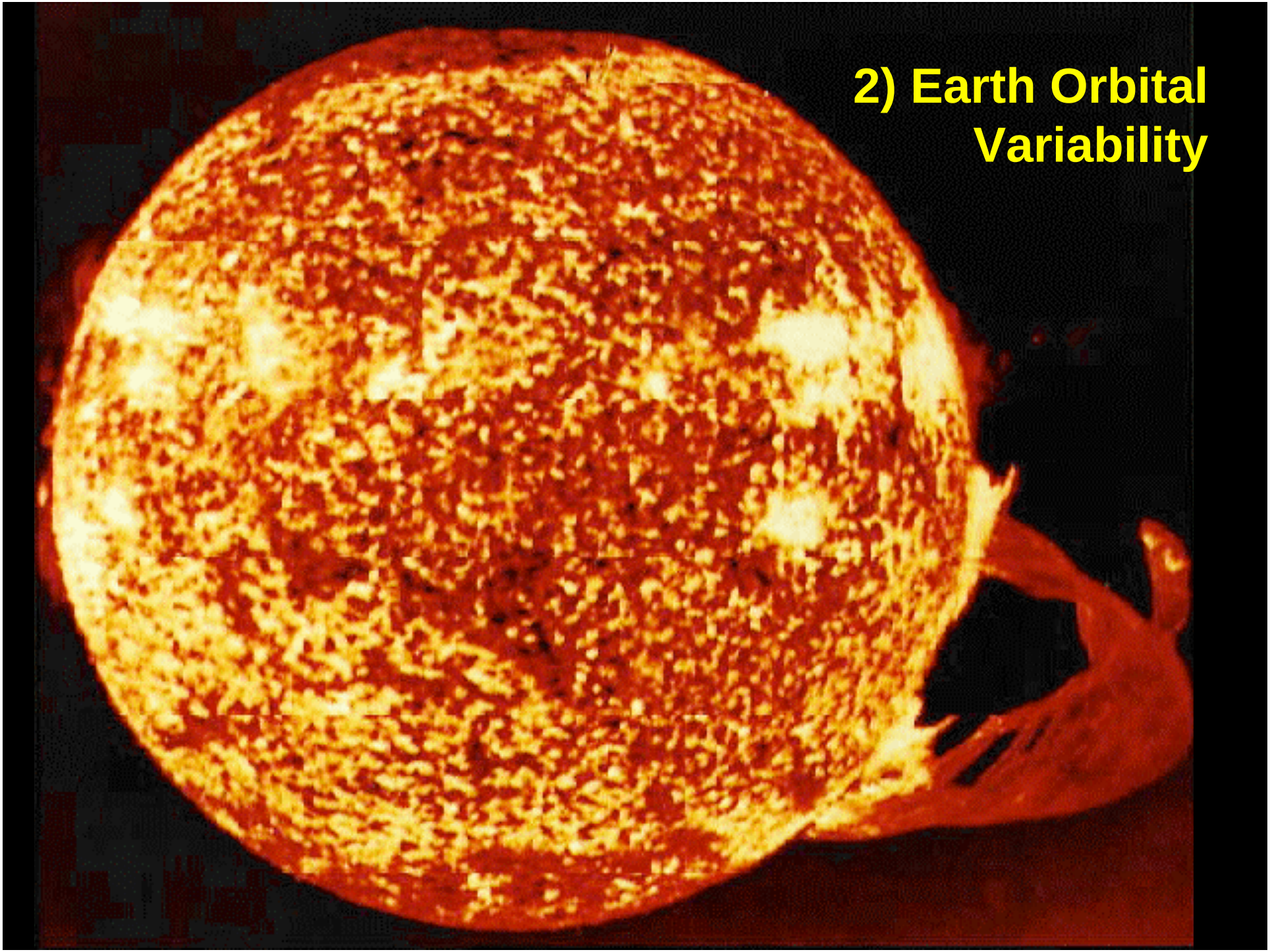



**What was going on here to change global temperature?**



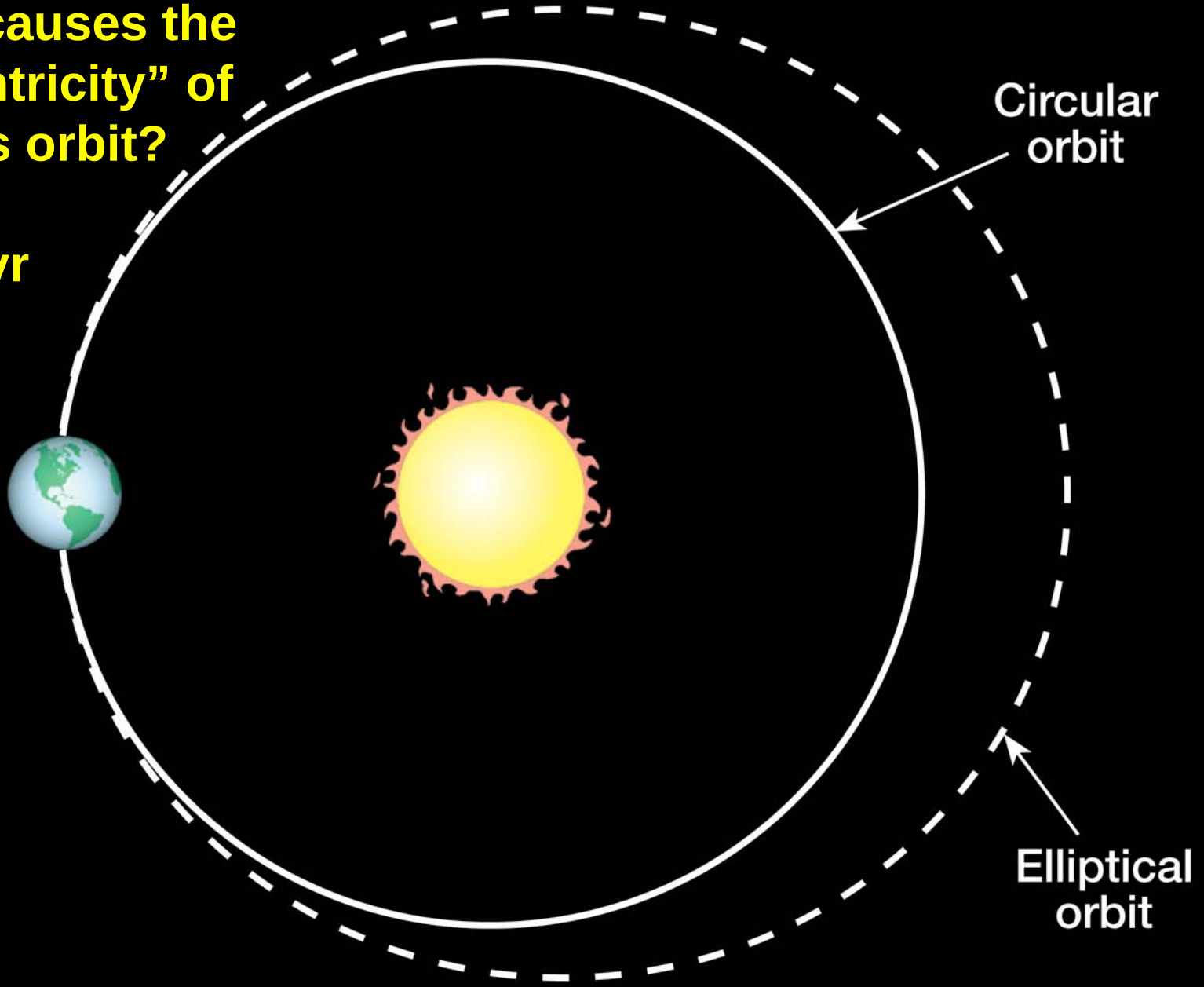





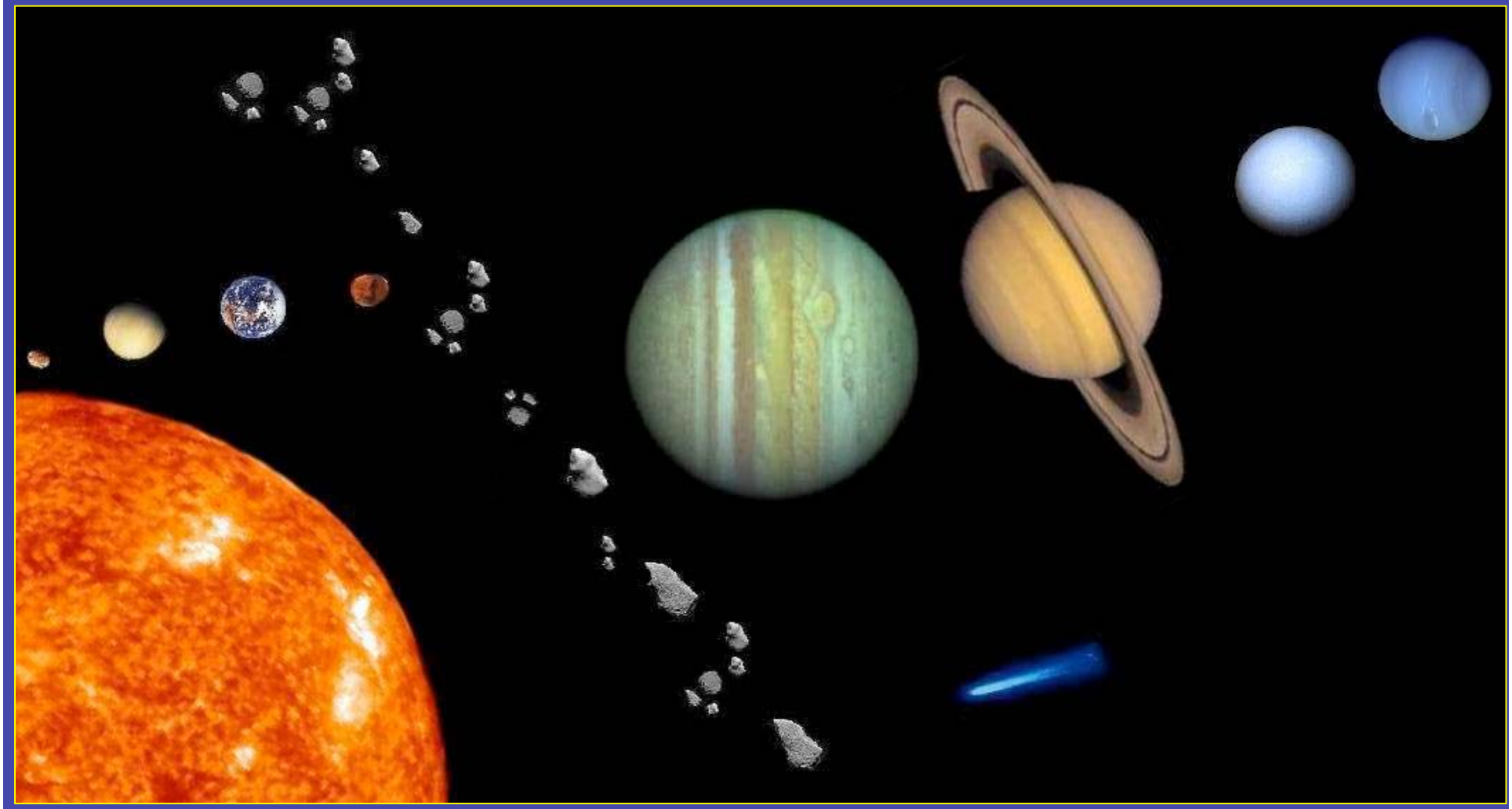

2) Earth Orbital
Variability

**What causes the "eccentricity" of Earth's orbit?**

**~100kyr**

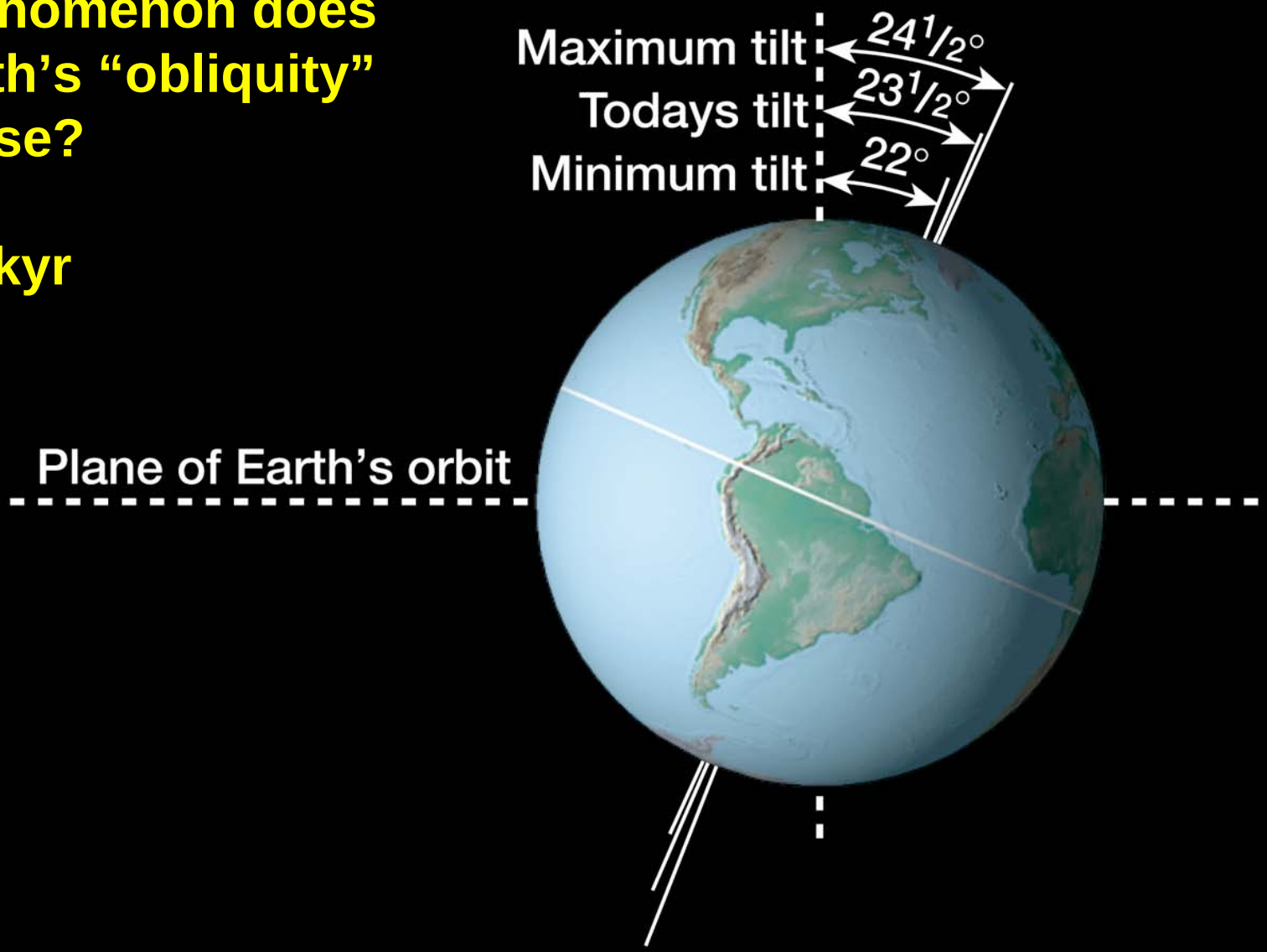


# Gravitational interactions with the orbits of Jupiter and Saturn



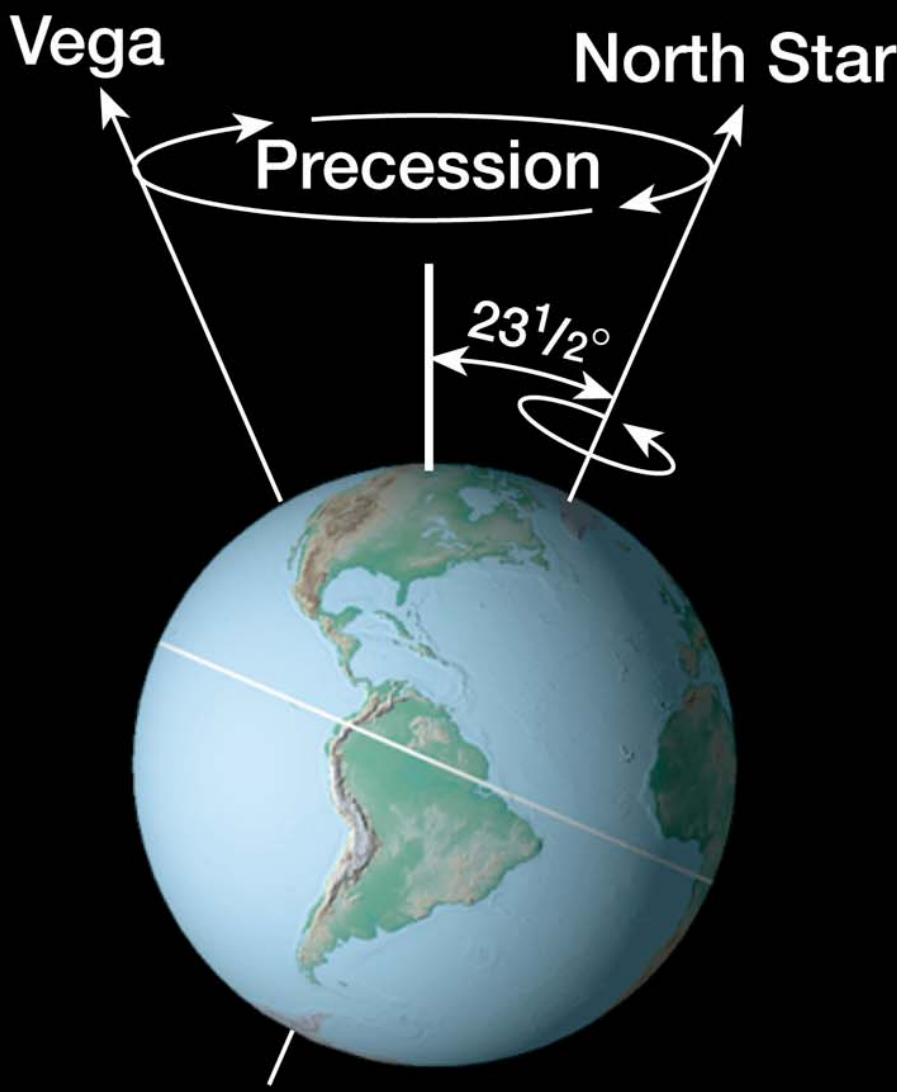
**What familiar climate phenomenon does Earth's "obliquity" cause?**

**~40kyr**

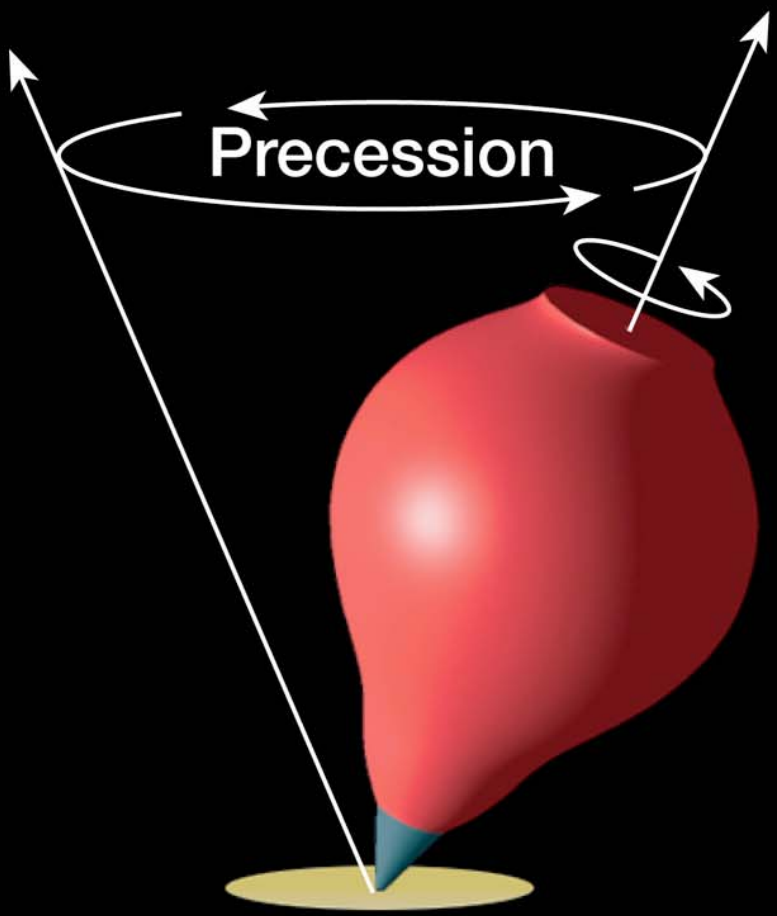



Seasonality results from Earth’s obliquity

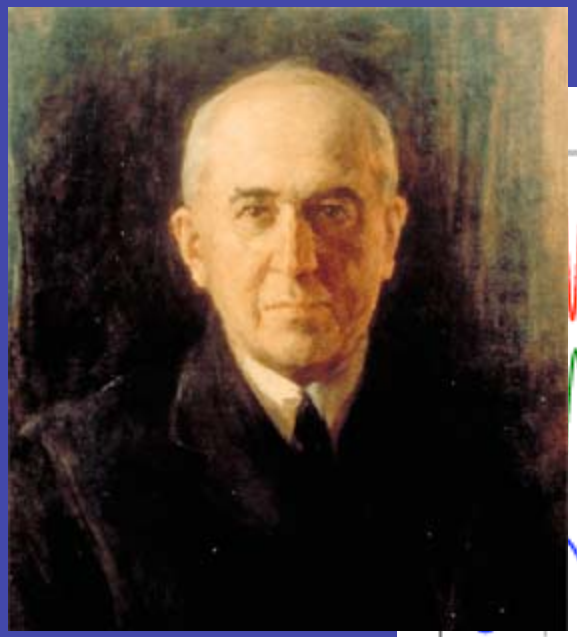
**“Precession” of the equinoxes occurs due to tidal forces from Sun and Moon**



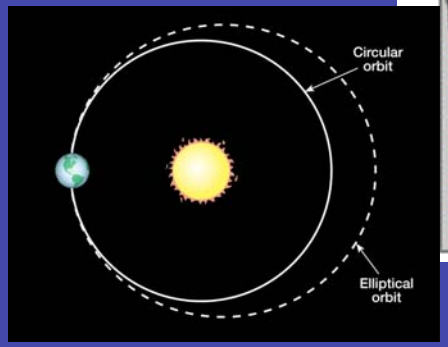

**~20kyr**

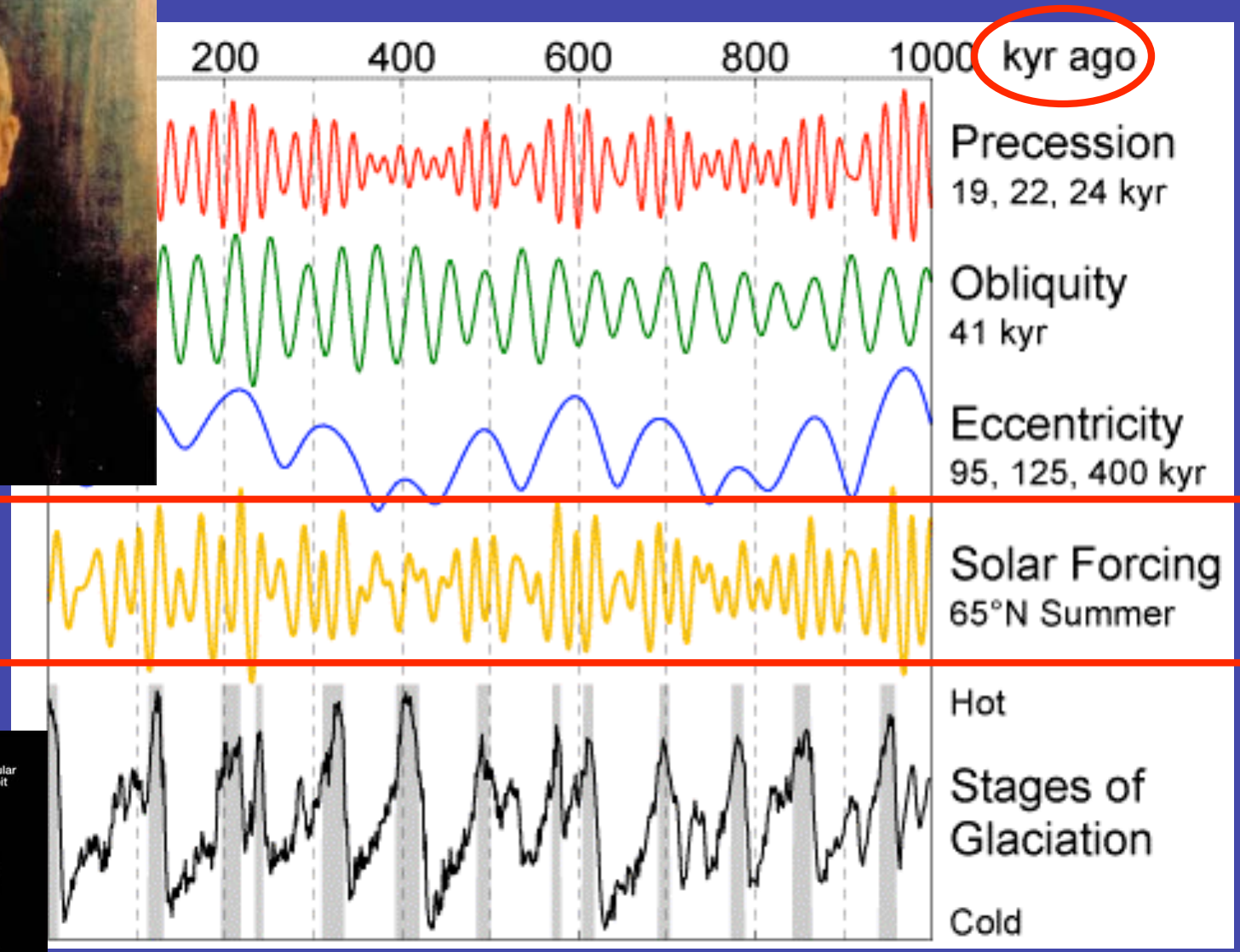


# Combined solar forcing known as “Milankovitch cycles”
# 1920



Serbian engineer, climatologist, geophysicist



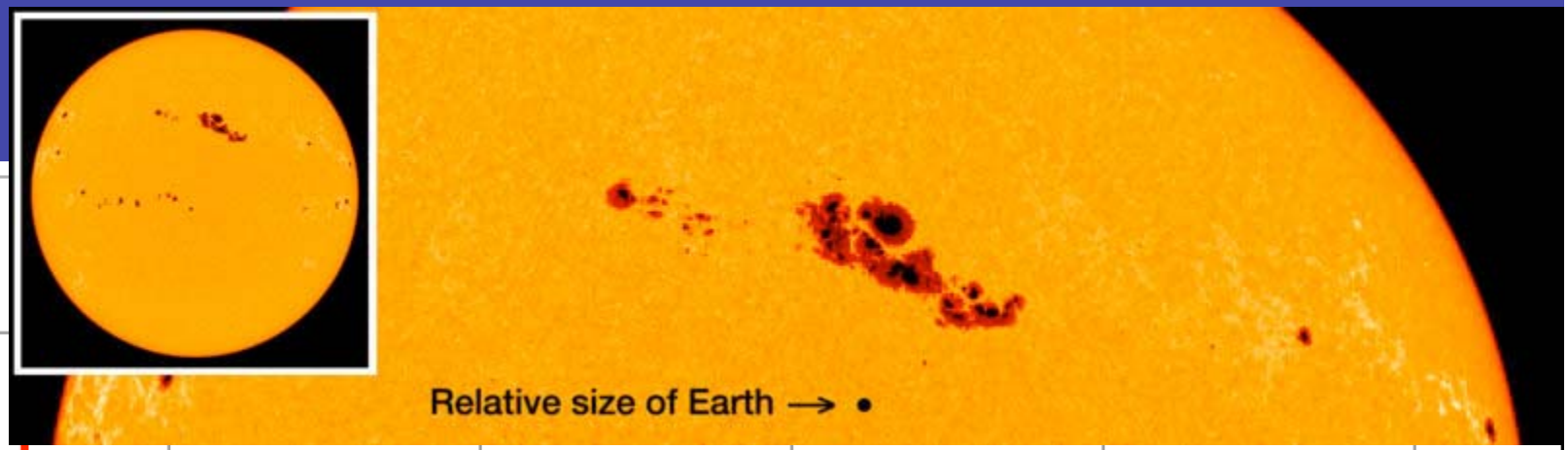
# Deep sea sediments record Milankovitch cycles over 500 Kya

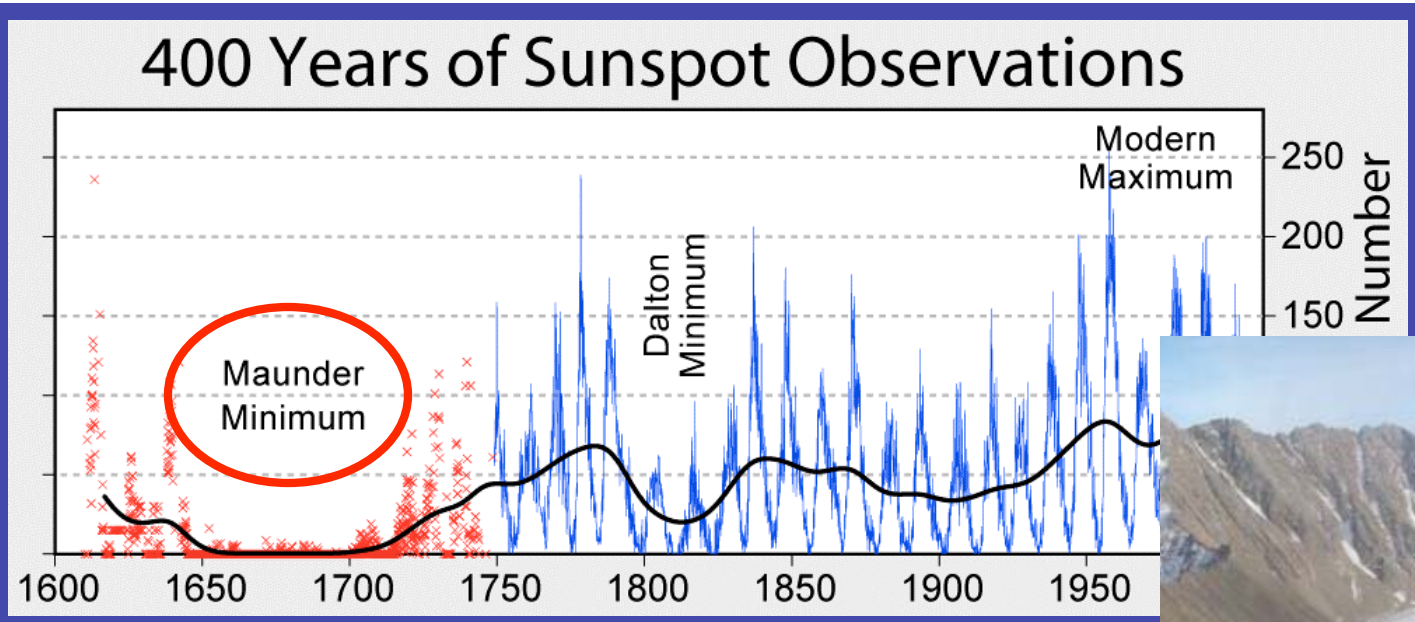


# 3) Variations in solar intensity…sunpot activity

11 yrs

10,000 yrs






**Little Ice Age (~1550-1850 AD) caused by low sunspot count**







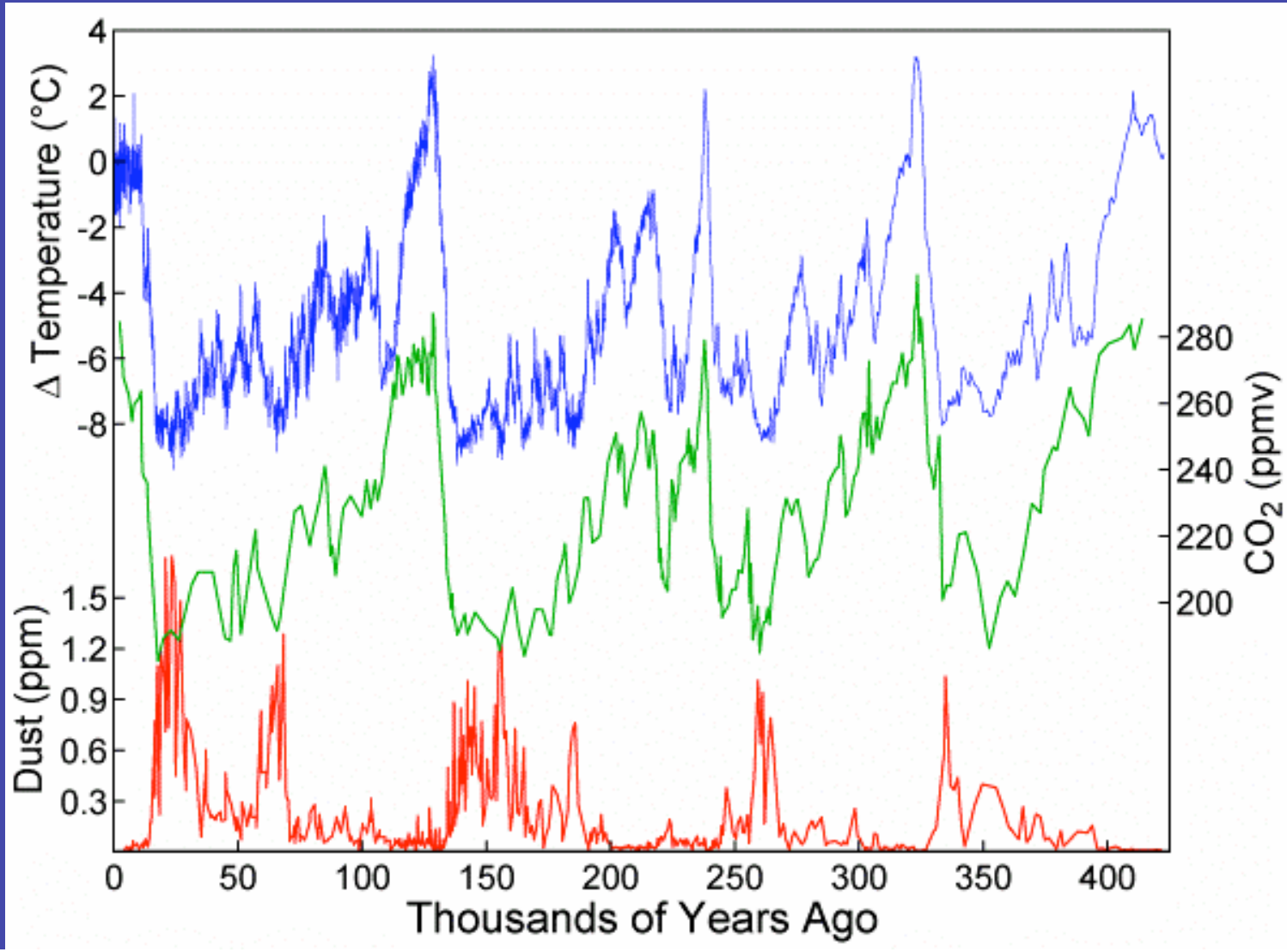
**Mt. Tambora 1815**

**NATURAL causes of global climate change:**

**1) plate tectonics** (100s of millions of years)

**2) orbital changes** (100s of thousands of years)

**3) solar intensity** (10s of thousands of years)



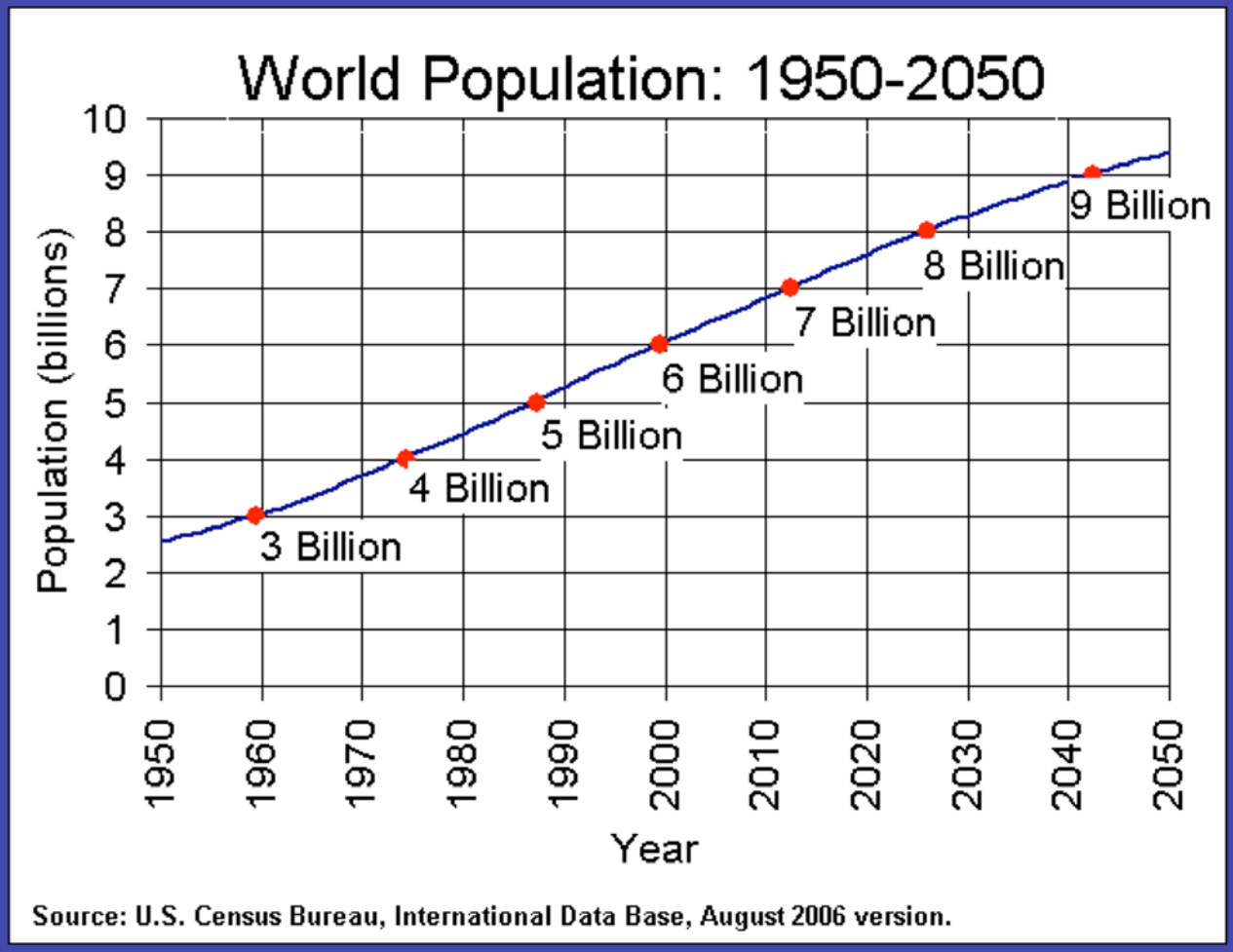
# How many humans can our planet support?
# A) 6 billion, B) 9 billion, C) 12 billion, D) 18 billion



# How many humans can our planet support?
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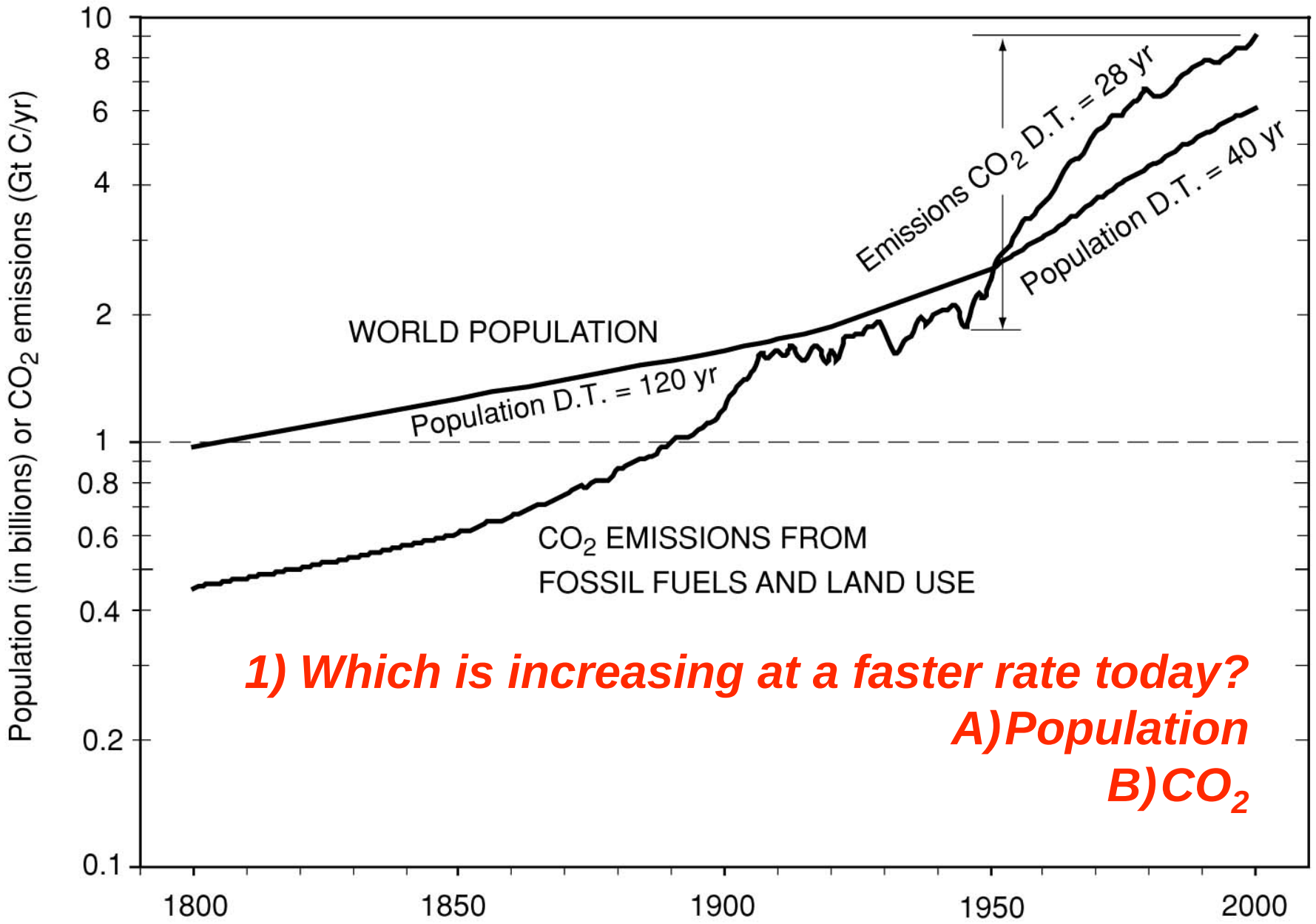


## Earth's population today = 6.66 billion




## How many people will Earth hold in our lifetimes?

# Historic world population and $CO_2$ emissions




***1) Which is increasing at a faster rate today?***

***A)Population***

***B)$CO_2$***





**2) What is the primary source of $CO_2$ today?**
**A) Land clearance**
**B) Fossil fuels**

**Is this going to change?**

# Who is burning these fossil fuels?

















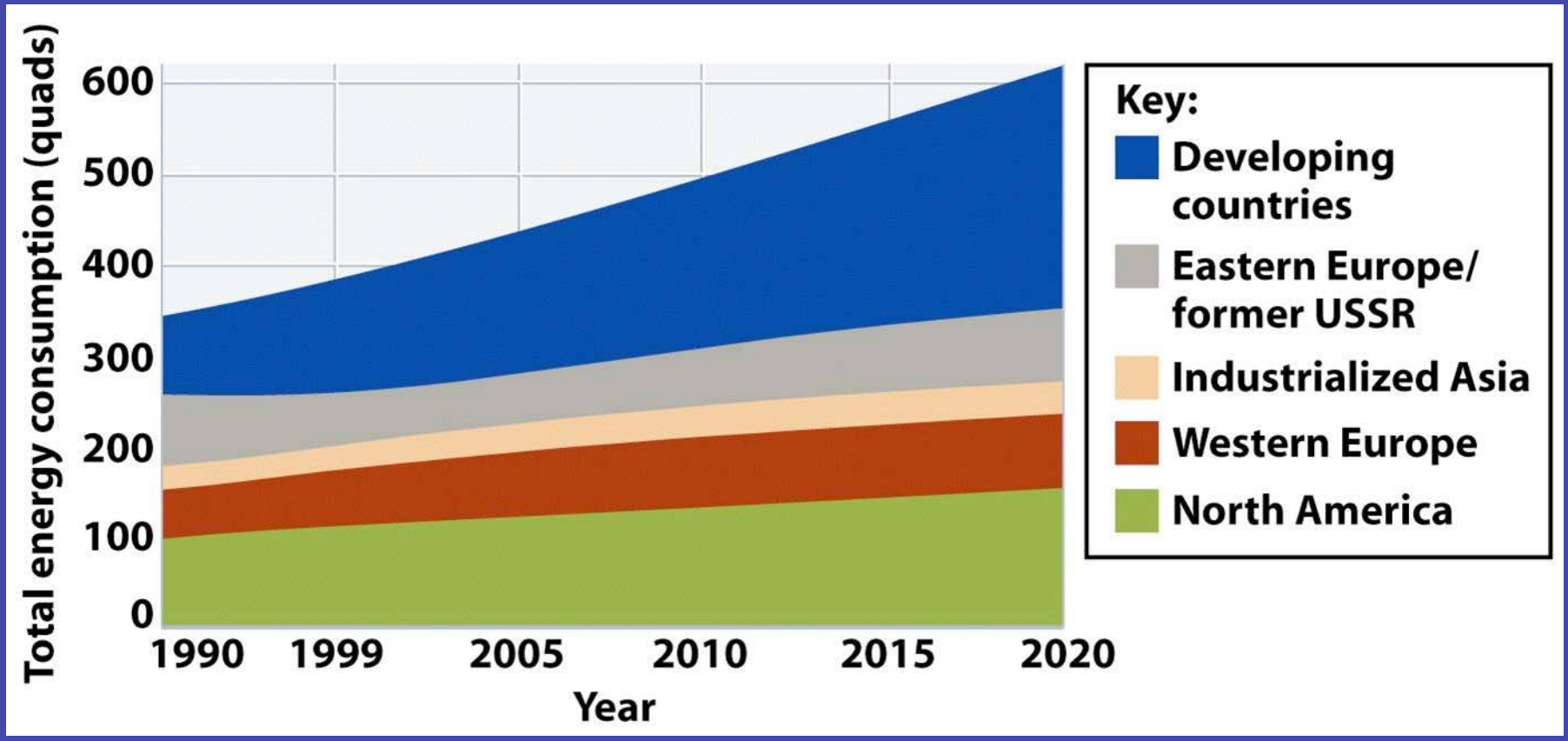

## Energy Statistics > Oil consumption by country

VIEW DATA: **Totals** | Per capita | Definition | Source | Printable

Bar Graph | Pie Chart | Map | Corre

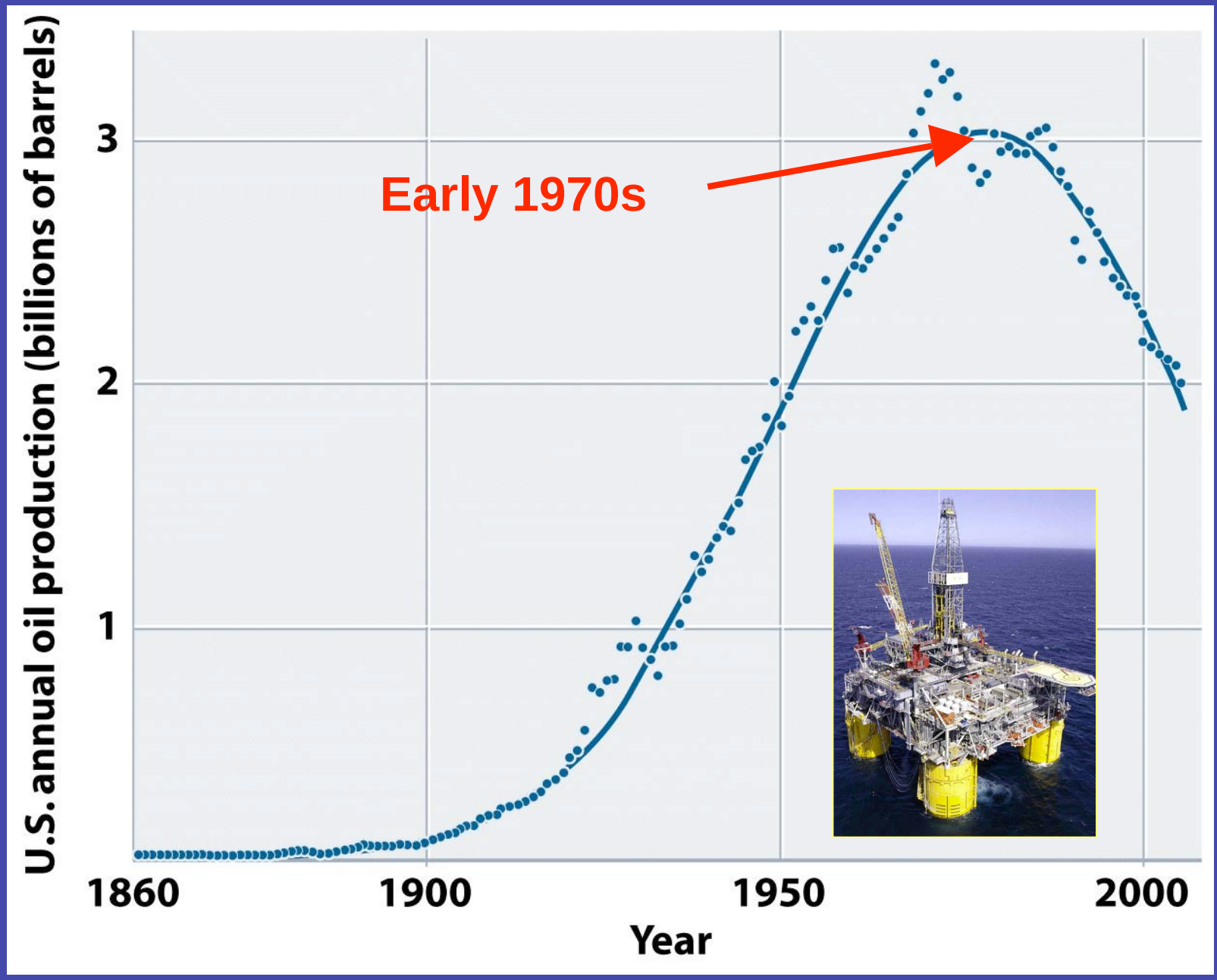
| Rank | Countries | Amount (top to bottom) |
|---|---|---|
| #1 | United States | 20,030,000 barrels per day |
| #2 | China | 6,391,000 barrels per day |
| #3 | Japan | 5,578,000 barrels per day |
| #4 | Russia | 2,800,000 barrels per day |
| #5 | Germany | 2,677,000 barrels per day |

3x


Total energy consumption (quads)
600
500
400
300
200
100
0
1990
1999
2005
2010
2015
2020
Year
Key:
Developing countries
Eastern Europe/ former USSR
Industrialized Asia
Western Europe
North America



# In 1956, Hubbert correctly predicted the peak in US oil production



# What is the effect of “Peak Oil” going to be on our planet?



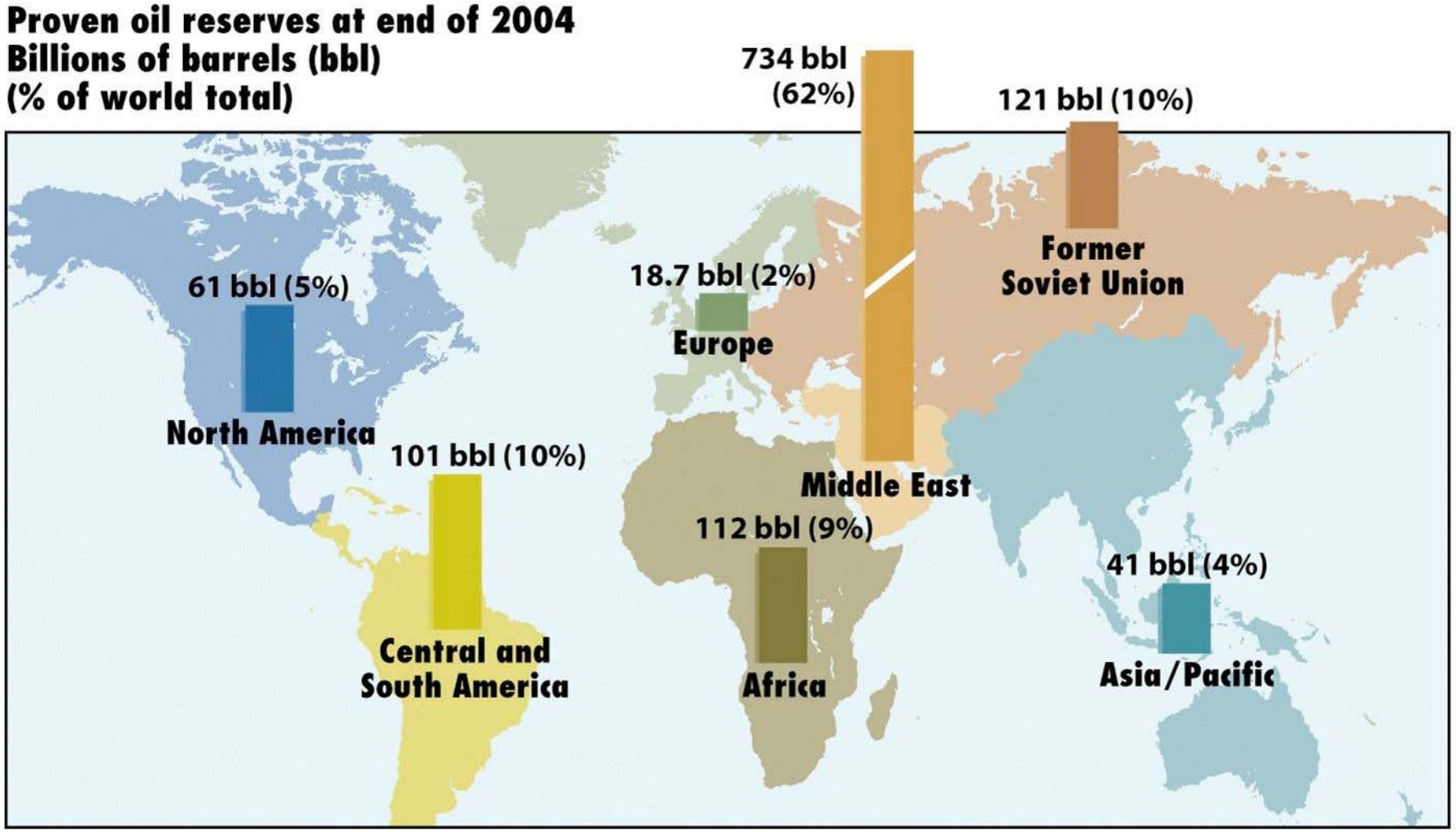







# 3) Who controls the world's oil?

## A) N. America, B) C.&S. America, C) Africa, D) Middle East, E) Fmr USSR



## Greatest Oil Reserves by Country, 2006

| Rank | Country | Proved reserves (billion barrels) |
|---|---|---|
| 1. | Saudi Arabia | 264.3 |
| 2. | Canada | 178.8 |
| 3. | Iran | 132.5 |
| 4. | Iraq | 115.0 |
| 5. | Kuwait | 101.5 |
| 6. | United Arab Emirates | 97.8 |
| 7. | Venezuela | 79.7 |
| 8. | Russia | 60.0 |
| 9. | Libya | 39.1 |
| 10. | Nigeria | 35.9 |
| 11. | United States | 21.4 |
| 12. | China | 18.3 |
| 13. | Qatar | 15.2 |
| 14. | Mexico | 12.9 |
| 15. | Algeria | 11.4 |
| 16. | Brazil | 11.2 |
| 17. | Kazakhstan | 9.0 |
| 18. | Norway | 7.7 |
| 19. | Azerbaijan | 7.0 |
| 20. | India | 5.8 |

12x

5x

3 year supply

# United States has 1:3 production/consumption gap

## Energy Statistics > Oil consumption by country

VIEW DATA: Totals | Per capita | Definition | Source | Printable ve

Bar Graph | Pie Chart | Map | Correlat

| Rank | Countries | Amount (top to bottom) |
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| #5 | Germany | 2,677,000 barrels per day |

3x

View the rest of the list (206 more countries) »

# P/C gap growing 5% per year

# P/C gap cost $192 billion in 2007

*($240 billion per year spent in Iraq war so far)*
*($100 billion to provide universal health care)*
*($6 billion spent on cancer research)*

**Why is Hawaii particularly at risk in scenarios like this?**









**Hawaii has one of the highest rates of per capita oil consumption in the world**

**2x U.S. average**
**4x Europe average**
**28x China average**

**1. transportation and electricity-generating plants**

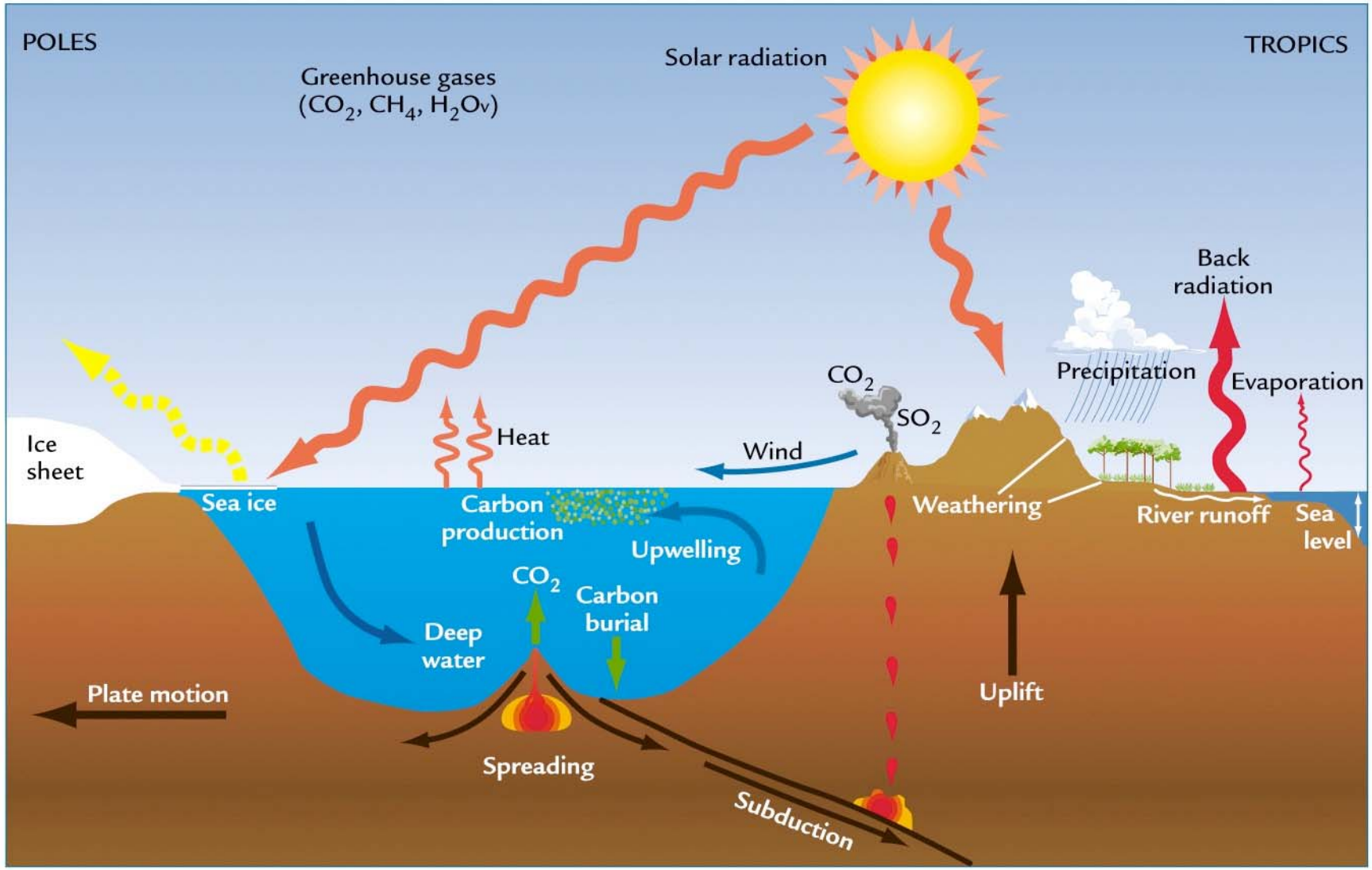
**2. airplanes that fuel our tourist-based economy**

**3. almost all of our food and consumer goods**

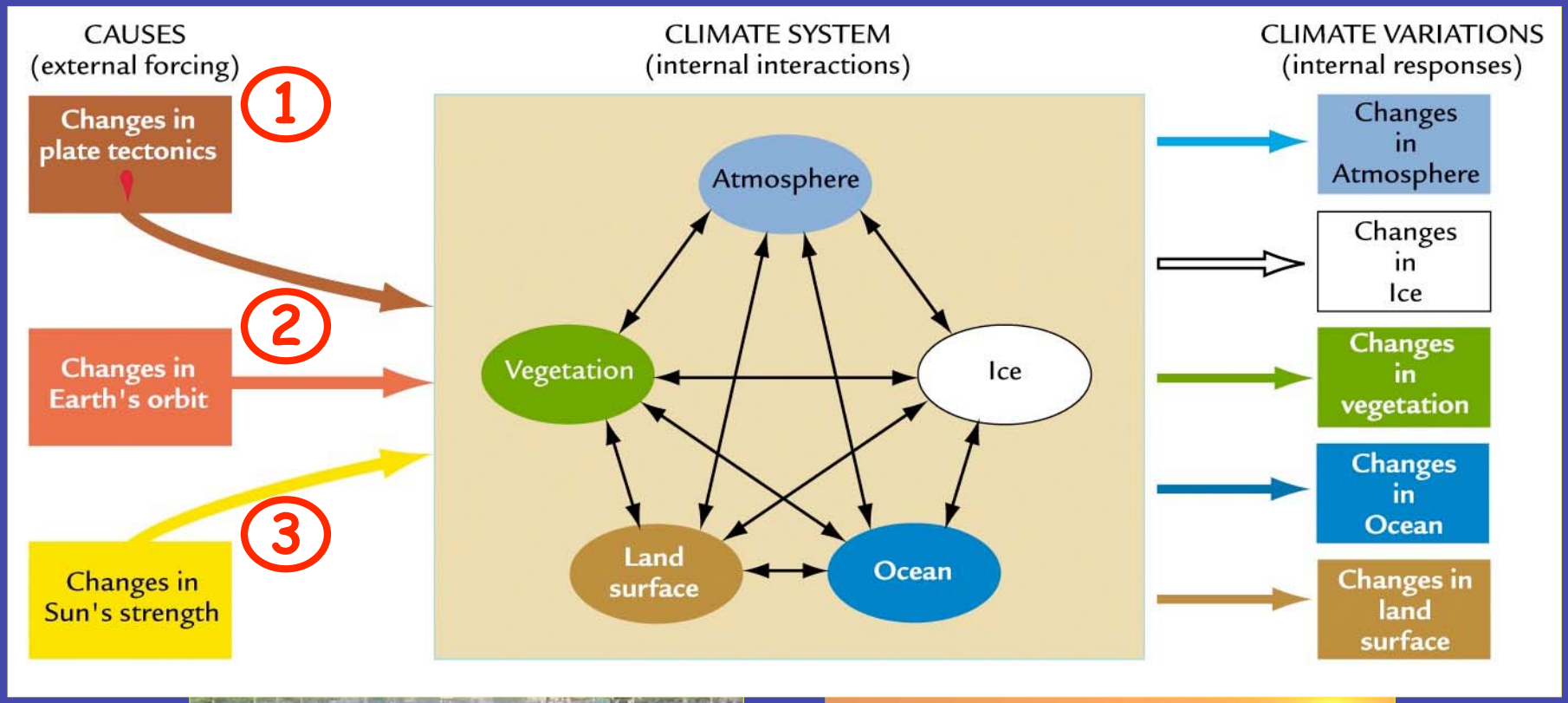
# How are human actions affecting our environment?



# Climate system is complicated - how can we simplify?



# Forcings (causes) Responses (effects)




4





# Speed of Forcing

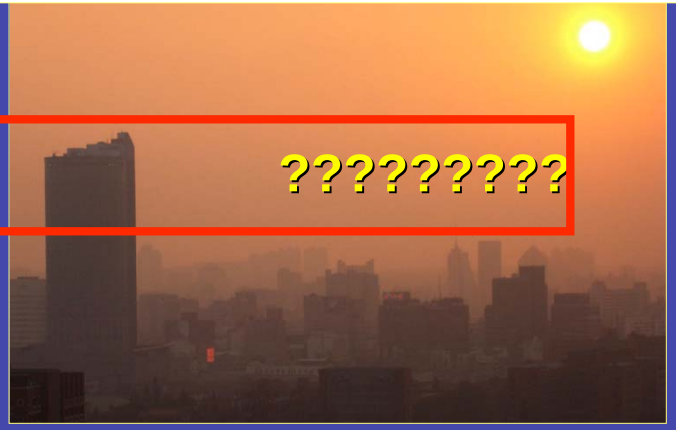
# Speed of Response

CAUSES
(external forcing)

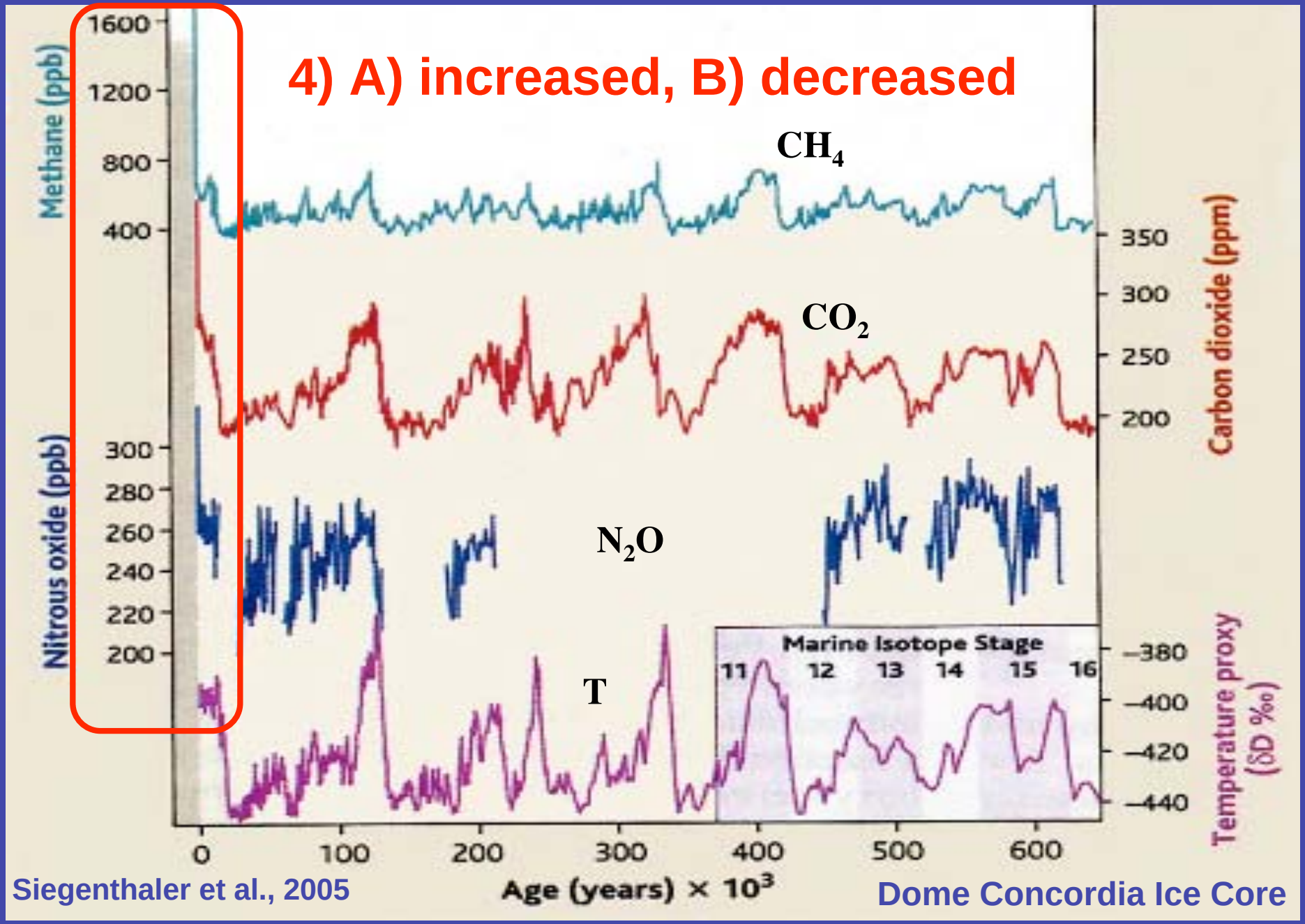
CLIMATE VARIATIONS
(internal responses)

| | | | |
|---|---|---|---|
| Changes in plate tectonics | 100's of millions of yrs | Hours to Weeks | Changes in Atmosphere |
| | | Hours to 10,000 yrs | Changes in Ice |
| Changes in Earth's orbit | 100,000s of yrs | Hours to Centuries | Changes in vegetation |
| | | Days to 1,500 yrs | Changes in Ocean |
| Changes in Sun's strength | 10,000s of yrs | Hours to Months | Changes in land surface |



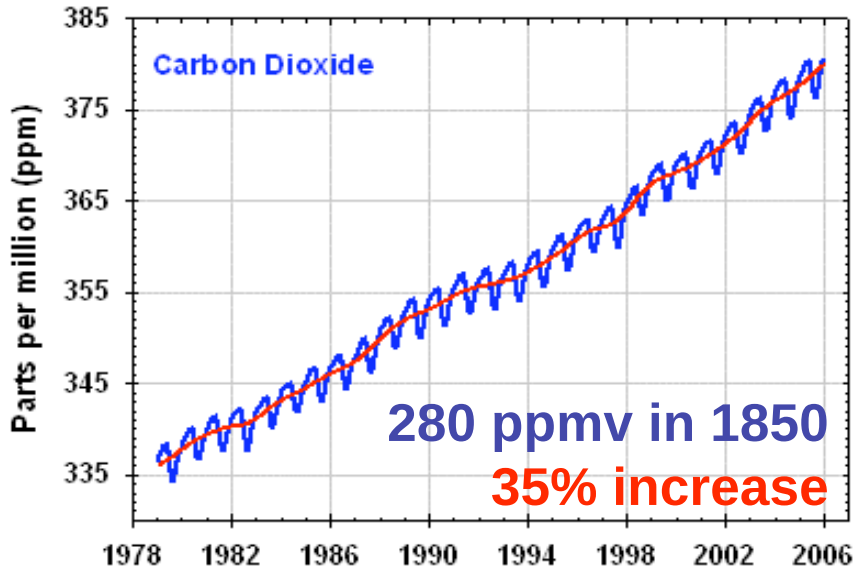
# Greenhouse gas concentrations in atmosphere have recently:

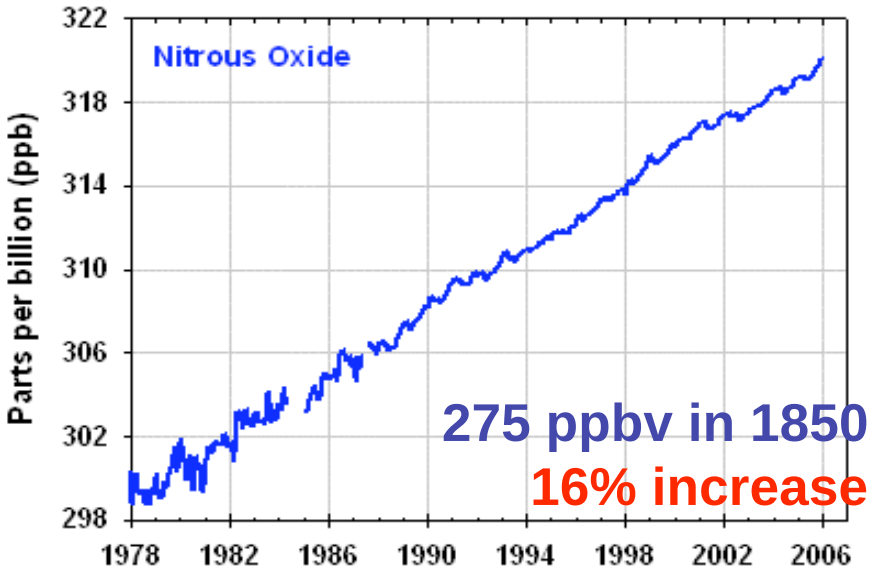


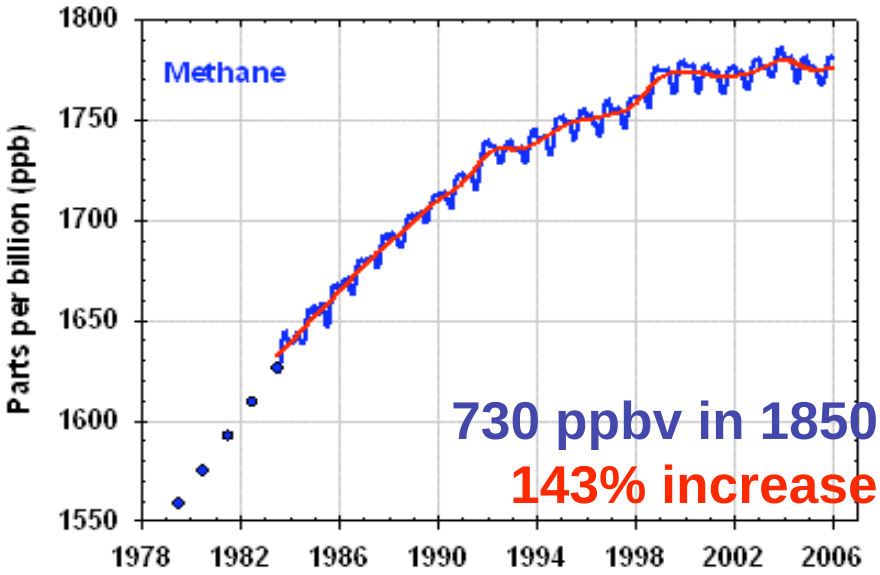

Siegenthaler et al., 2005

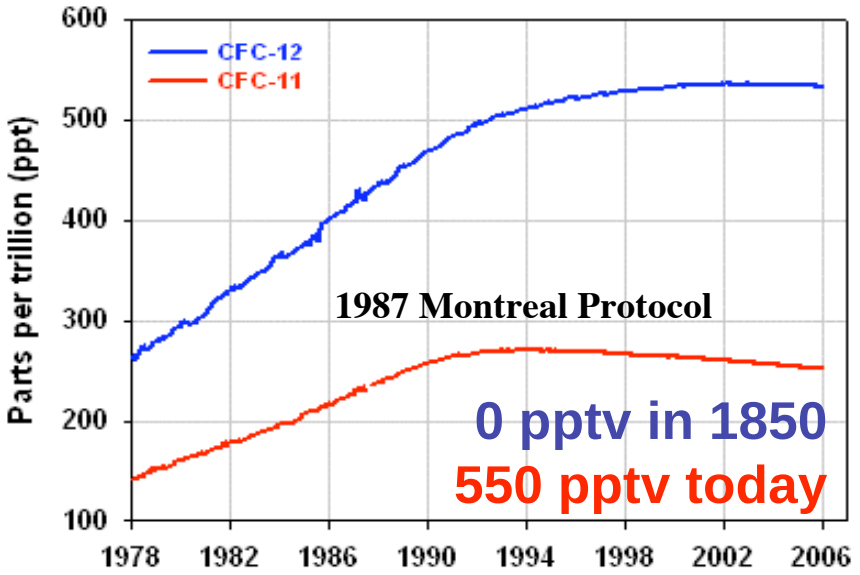
Dome Concordia Ice Core

# Without doubt human activities have changed atmospheric chemistry



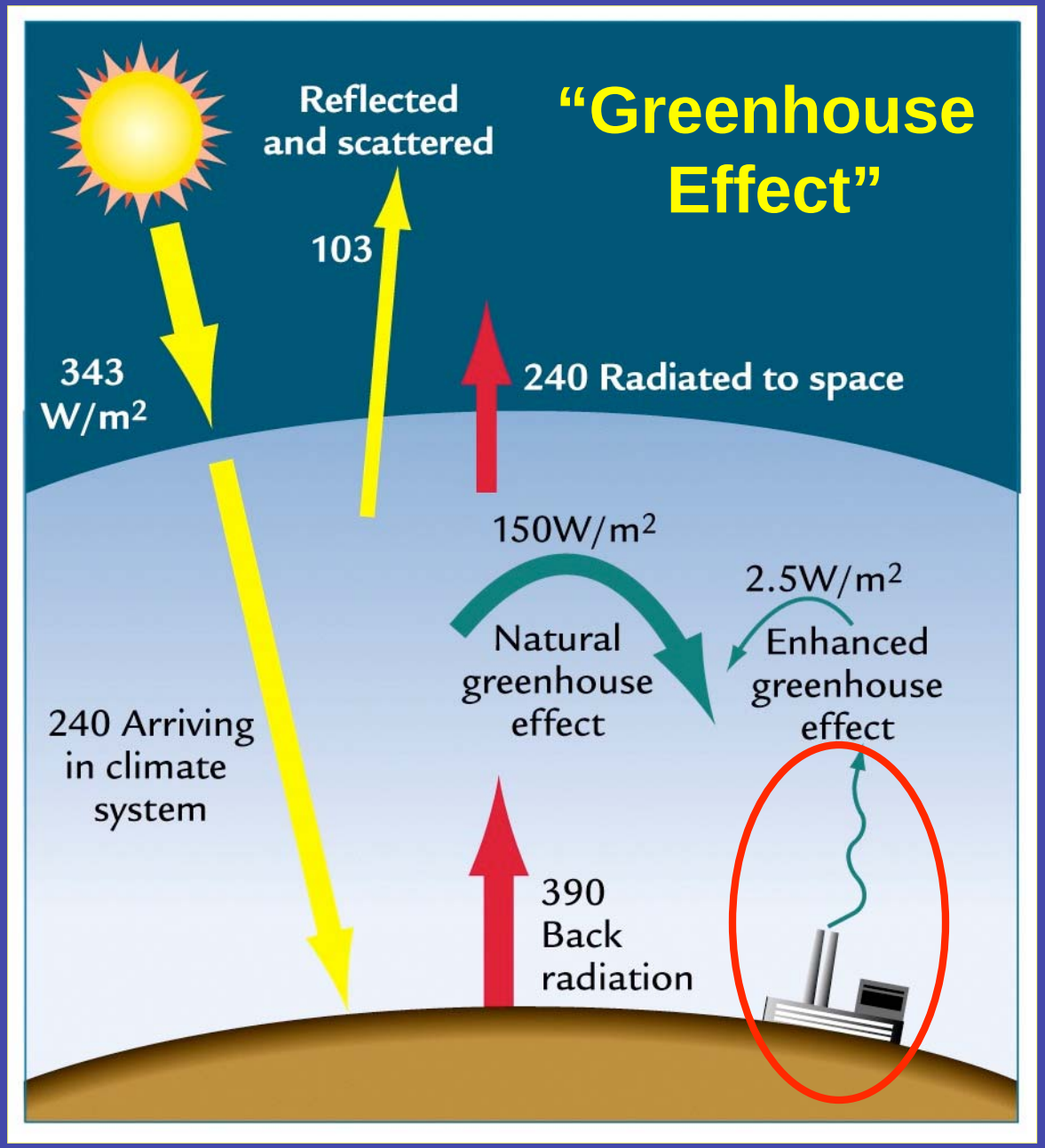




CDIAC, 2006

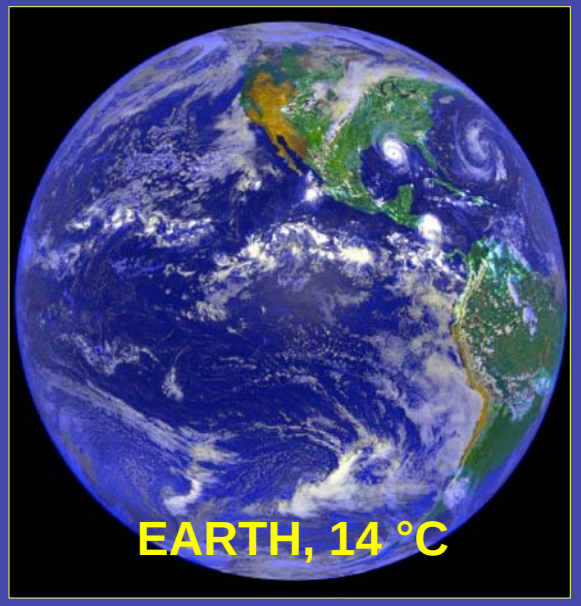
# What allows Earth to support life?



EARTH, 14 °C



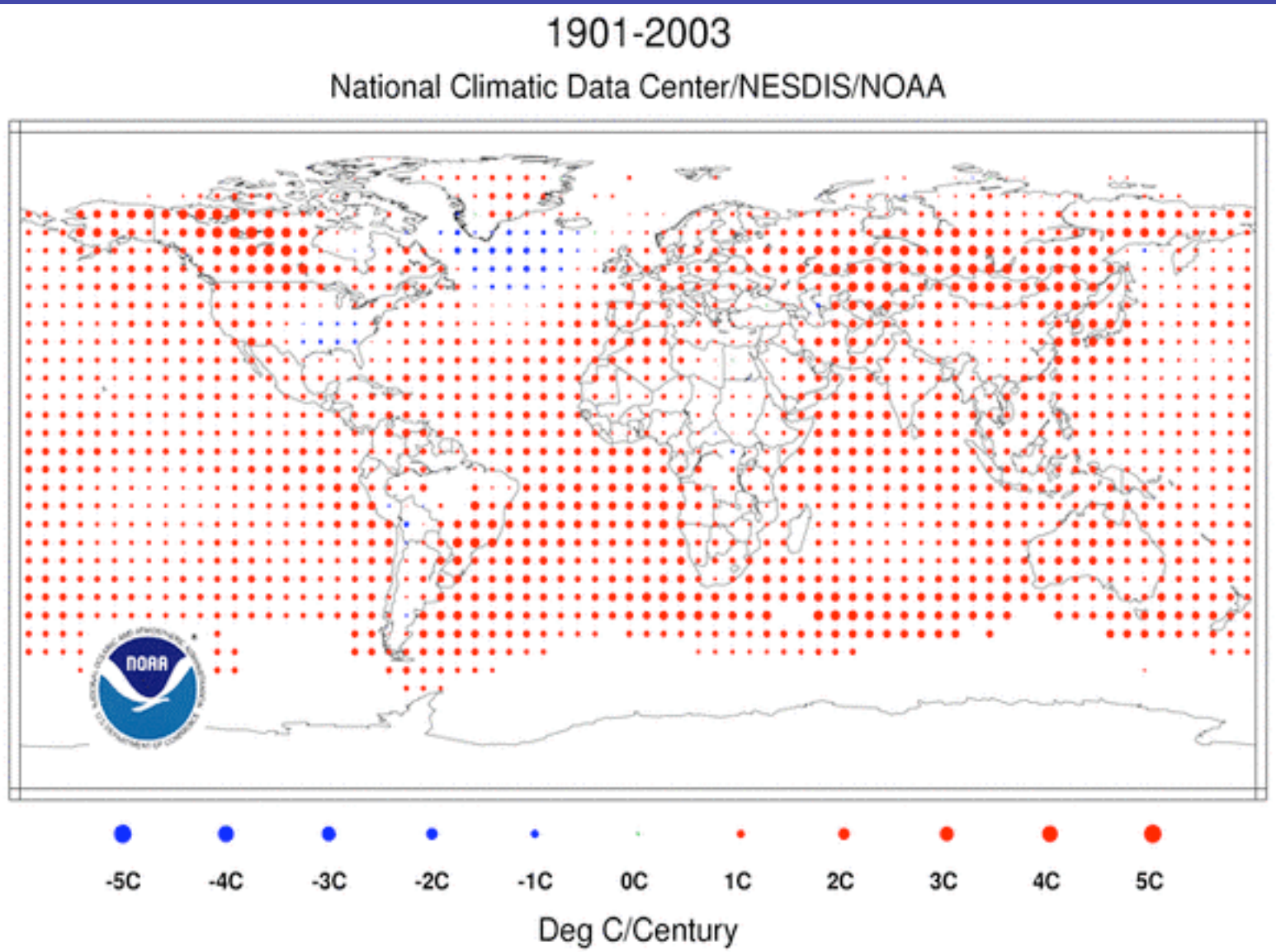

# "Greenhouse Effect"



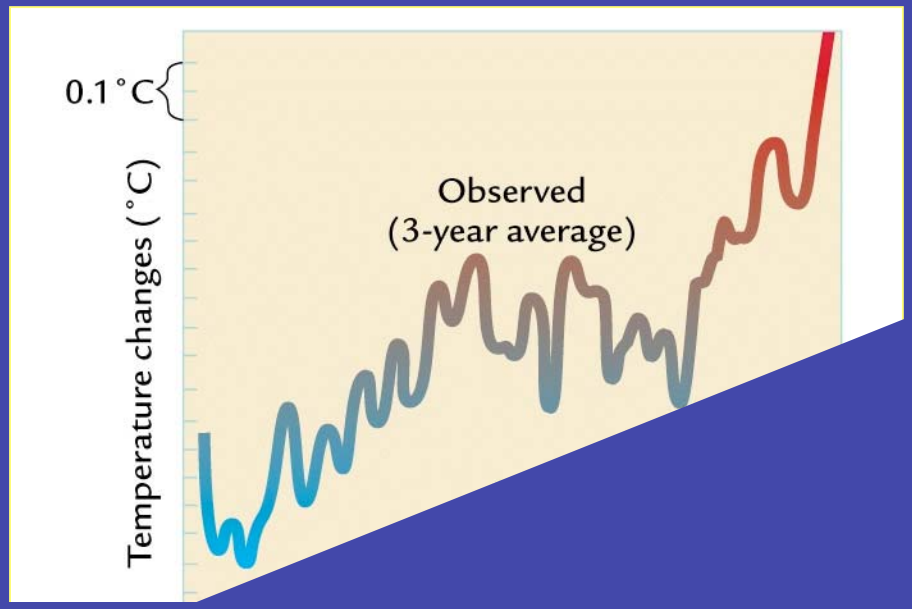

**Earth's own Greenhouse Effect is**

**NATURAL and NECESSARY**

# 5) What is 100-year trend in annual temperature?
# A) increase, B) decrease

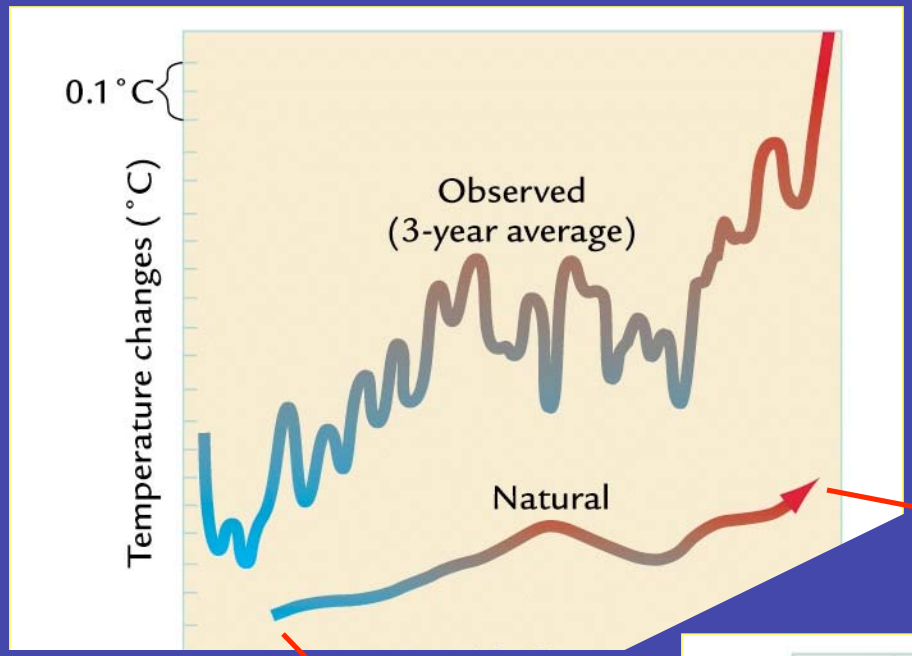


# GREENHOUSE MATH PROBLEM




**Observed Temperature (1900-2000)**

# GREENHOUSE MATH PROBLEM

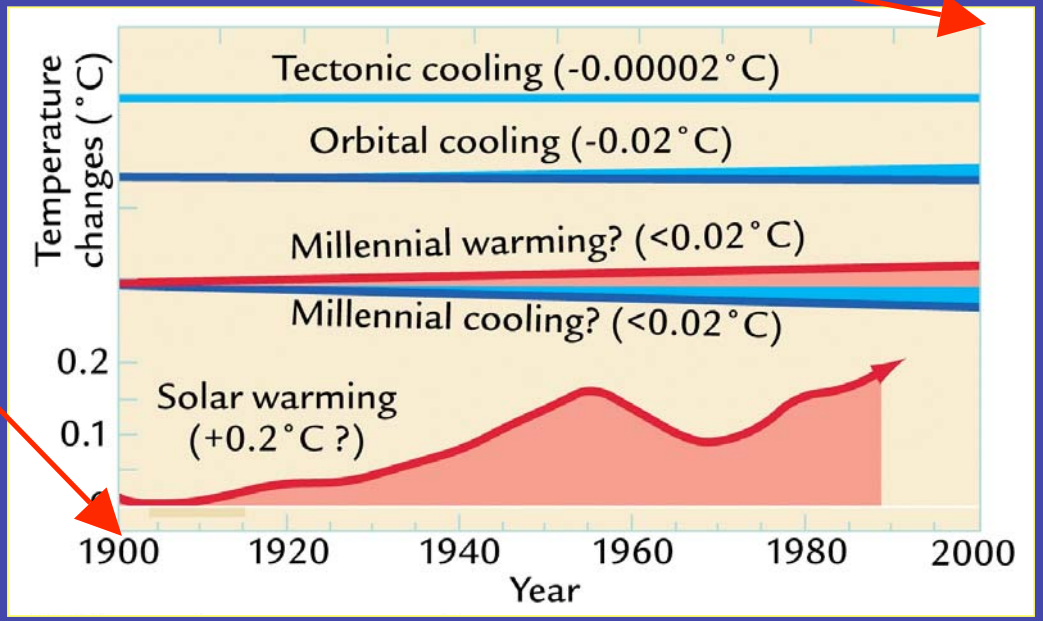



**Observed Temperature**

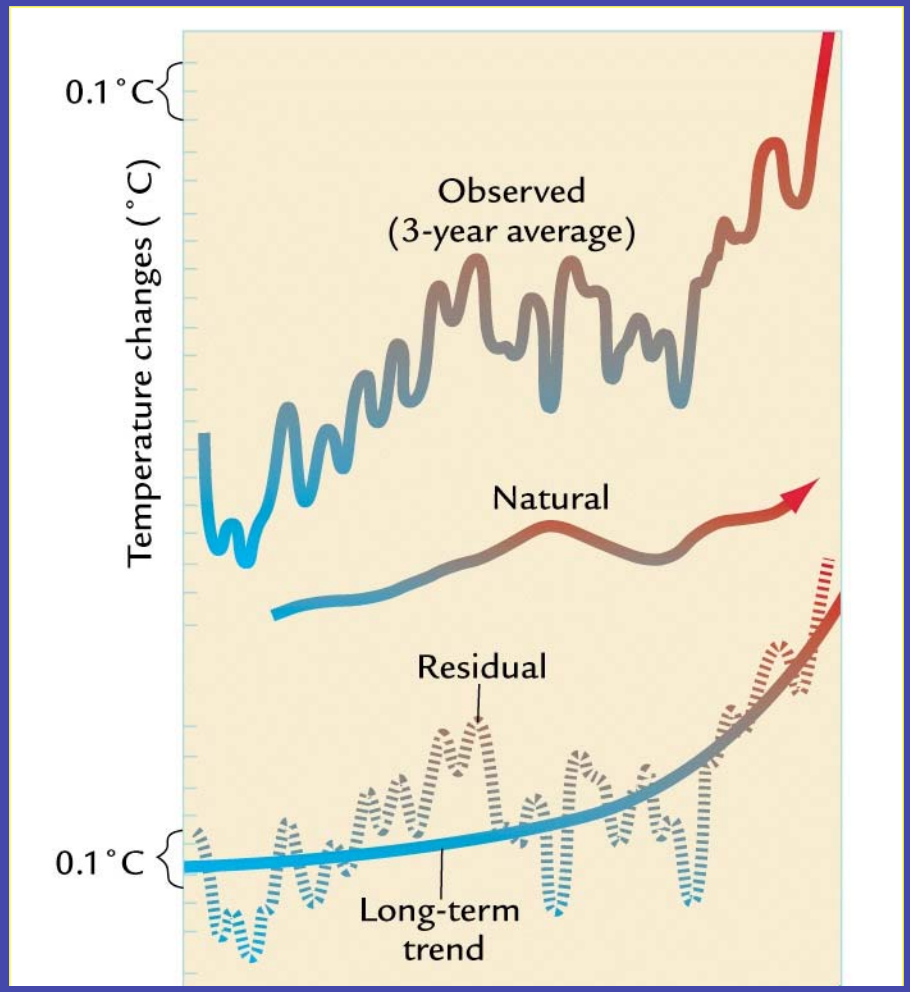
**...minus...**

**Natural Warming**

**tectonic**
**orbital**
**millenial**
**solar**



# GREENHOUSE MATH PROBLEM




**Observed Temperature**

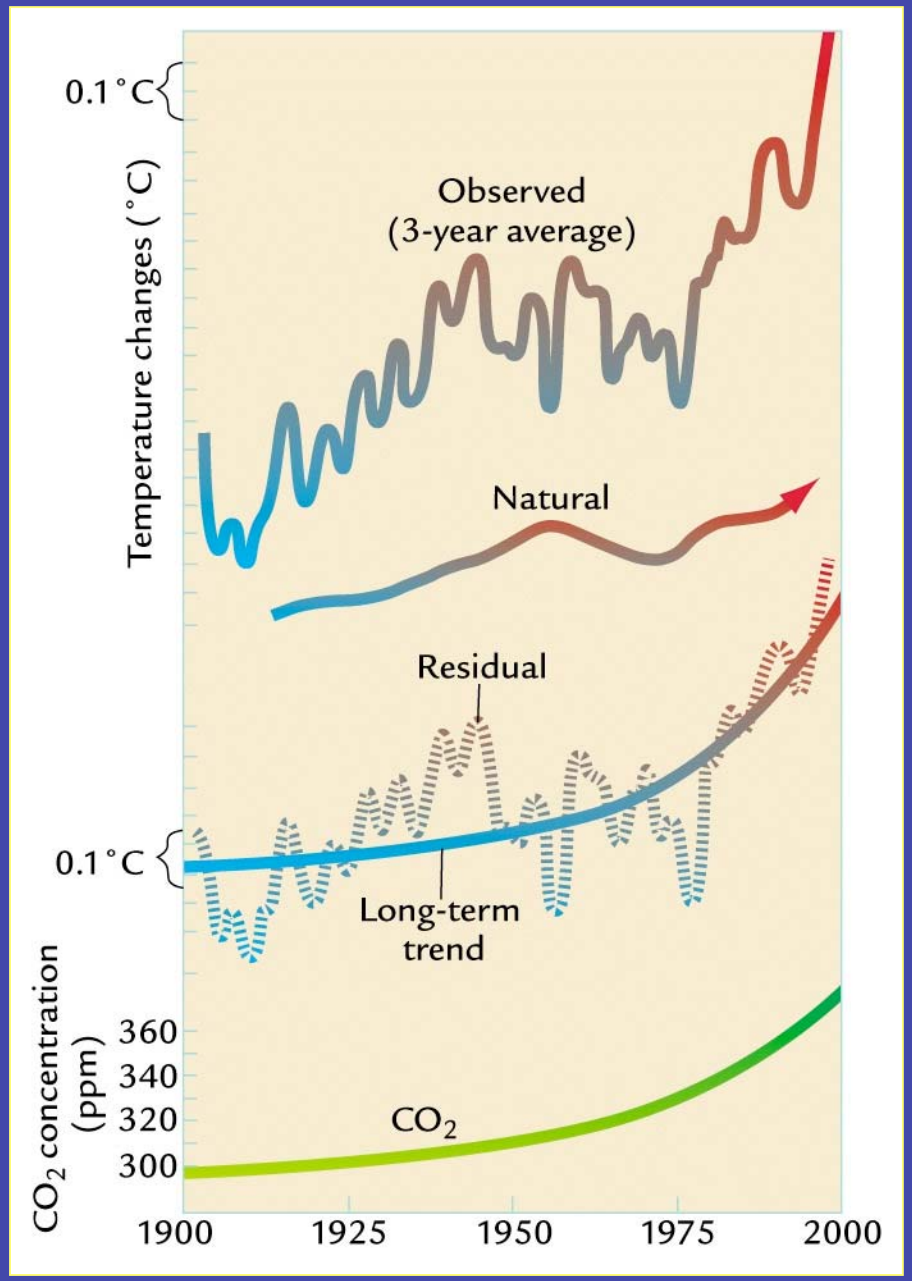
**...minus...**

**Natural Warming**

**...equals...**

**Residual (Human Effects)**

# GREENHOUSE MATH PROBLEM




**Observed Temperature**

**...minus...**

**Natural Warming**

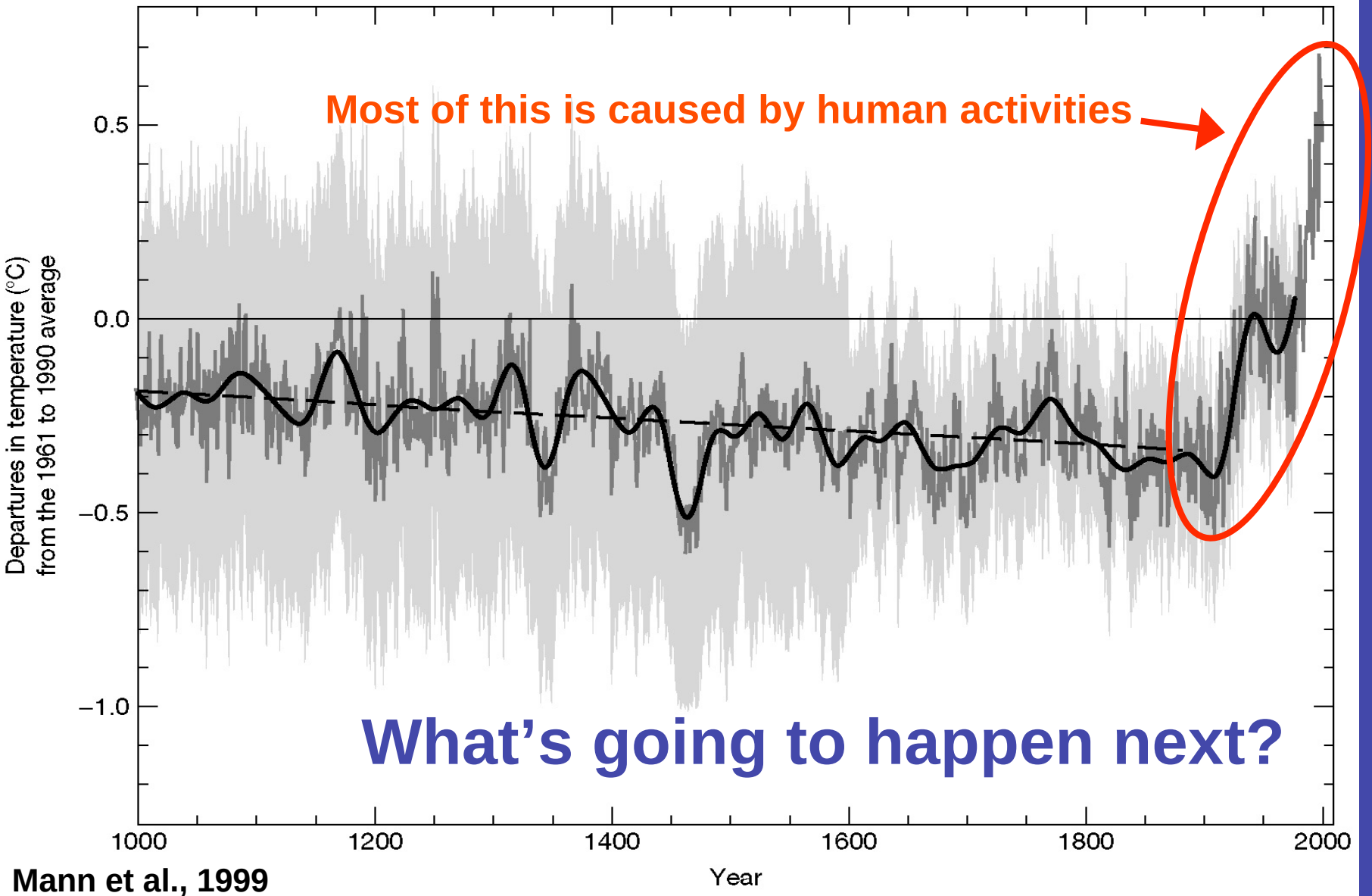
**...equals...**

**Residual (Human Effects)**

**...looks a lot like...**

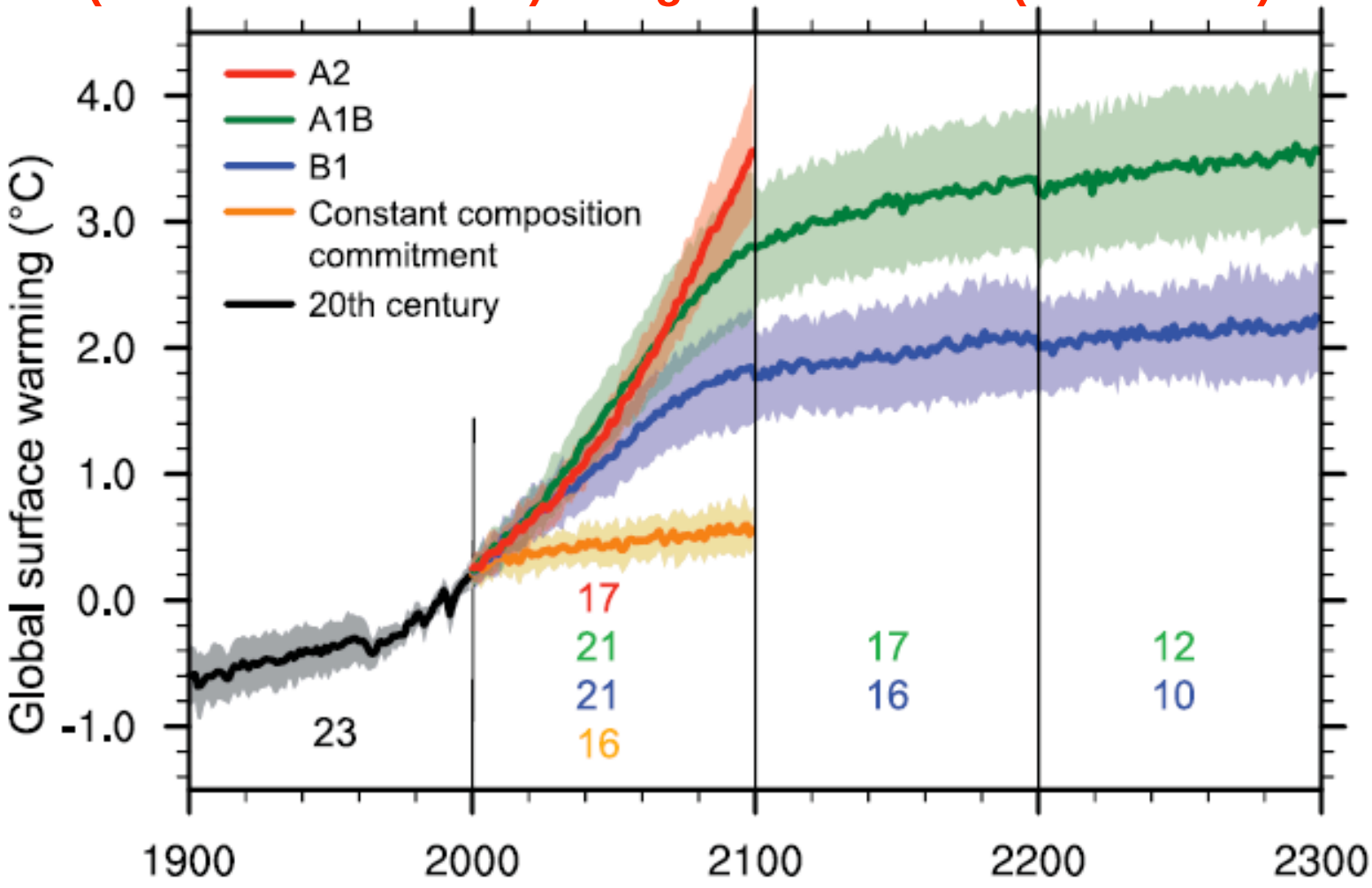
**Carbon Dioxide Increase**

# Northern Hemisphere temperature record




Mann et al., 1999

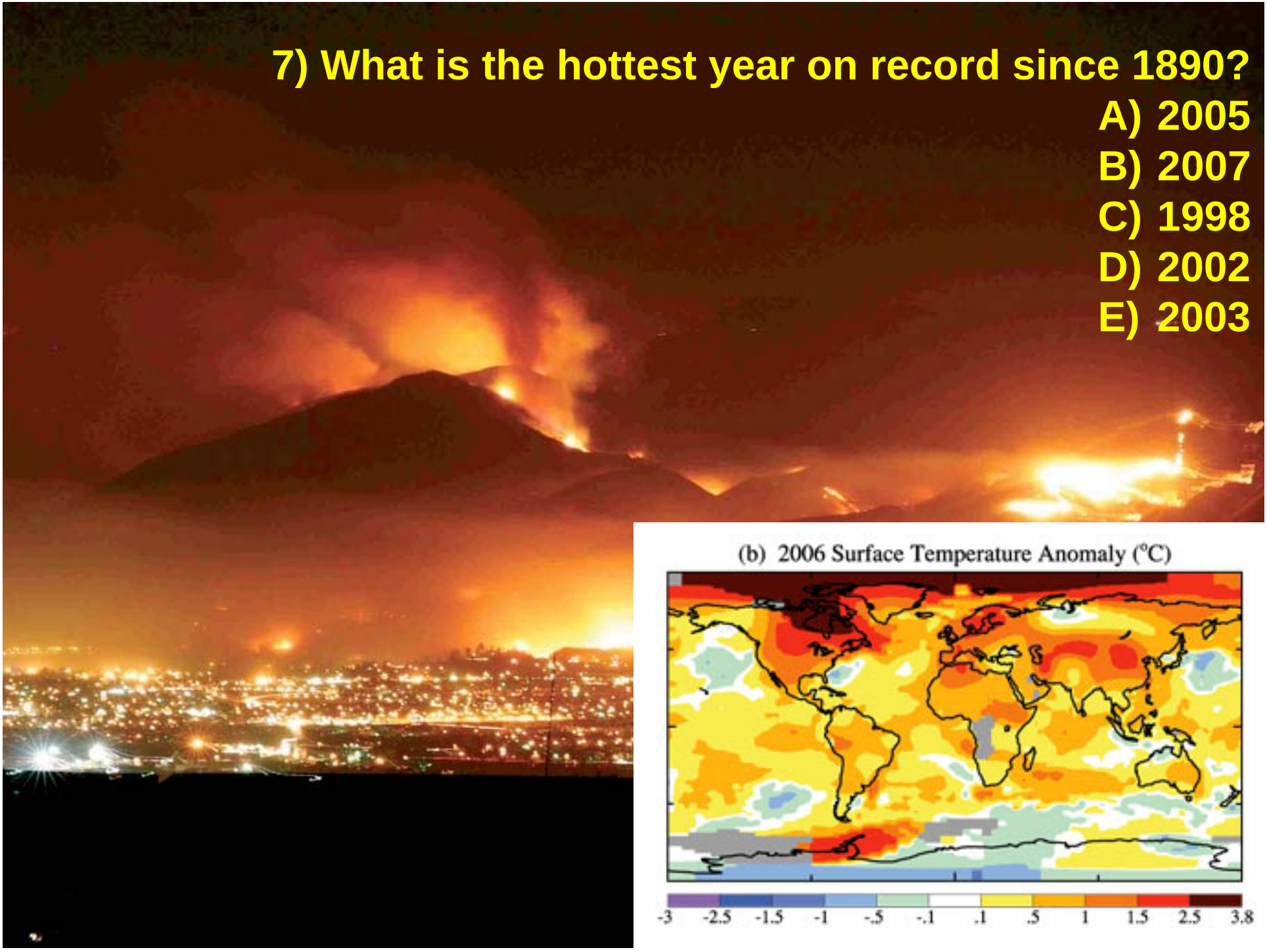
**6) How much is temperature projected to change in our lifetimes (between 2000-2060) using A1B scenario (IPCC 2007)?**




**A) 0.0°C, B) 0.5°C, C) 1.5°C, D) 2.0°C, E) 3.0°C**

**7) What is the hottest year on record since 1890?**

**A) 2005**
**B) 2007**
**C) 1998**
**D) 2002**
**E) 2003**



# What are the impacts of human-induced temperature rise?

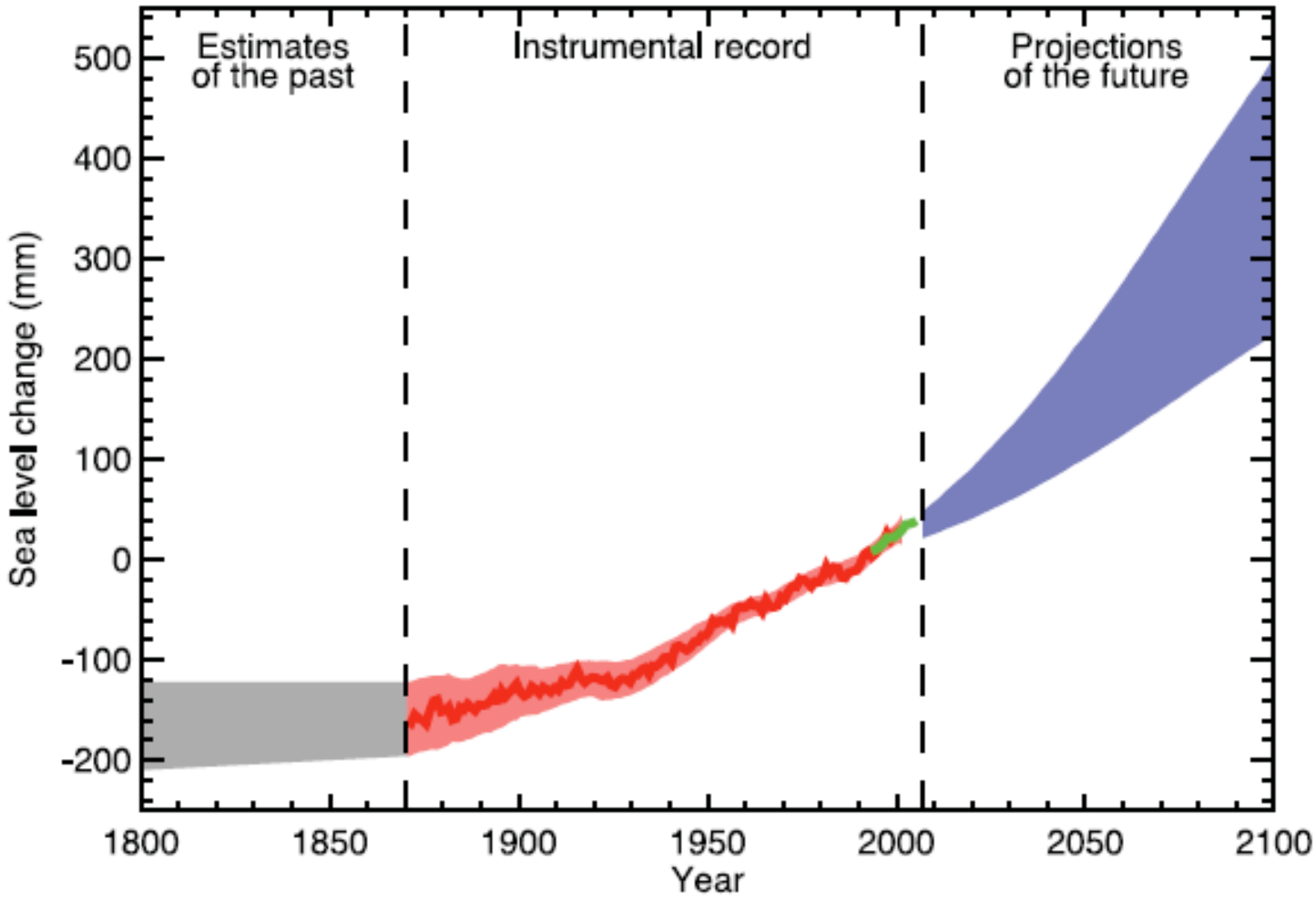








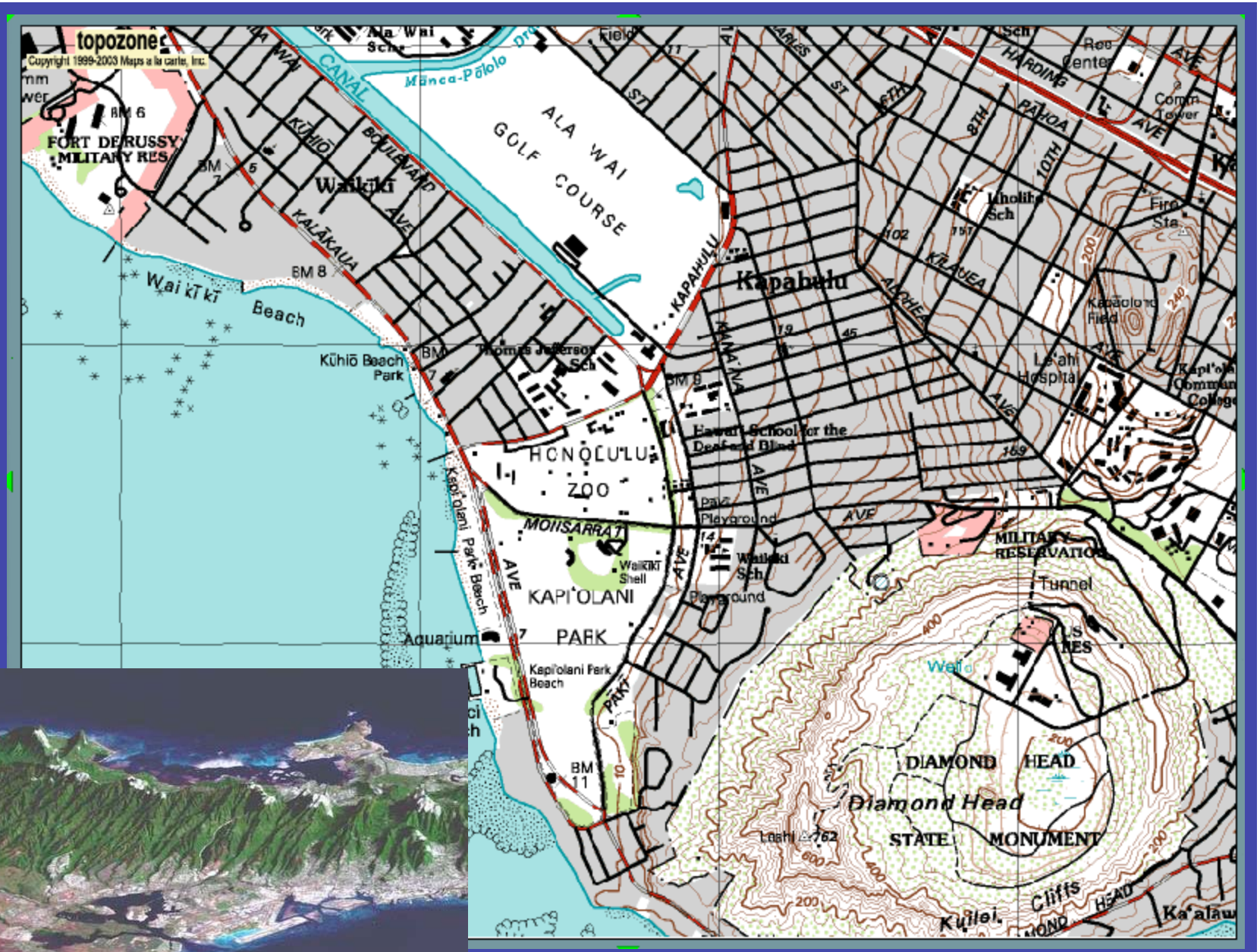
# How is sea level projected to change in our lifetimes?



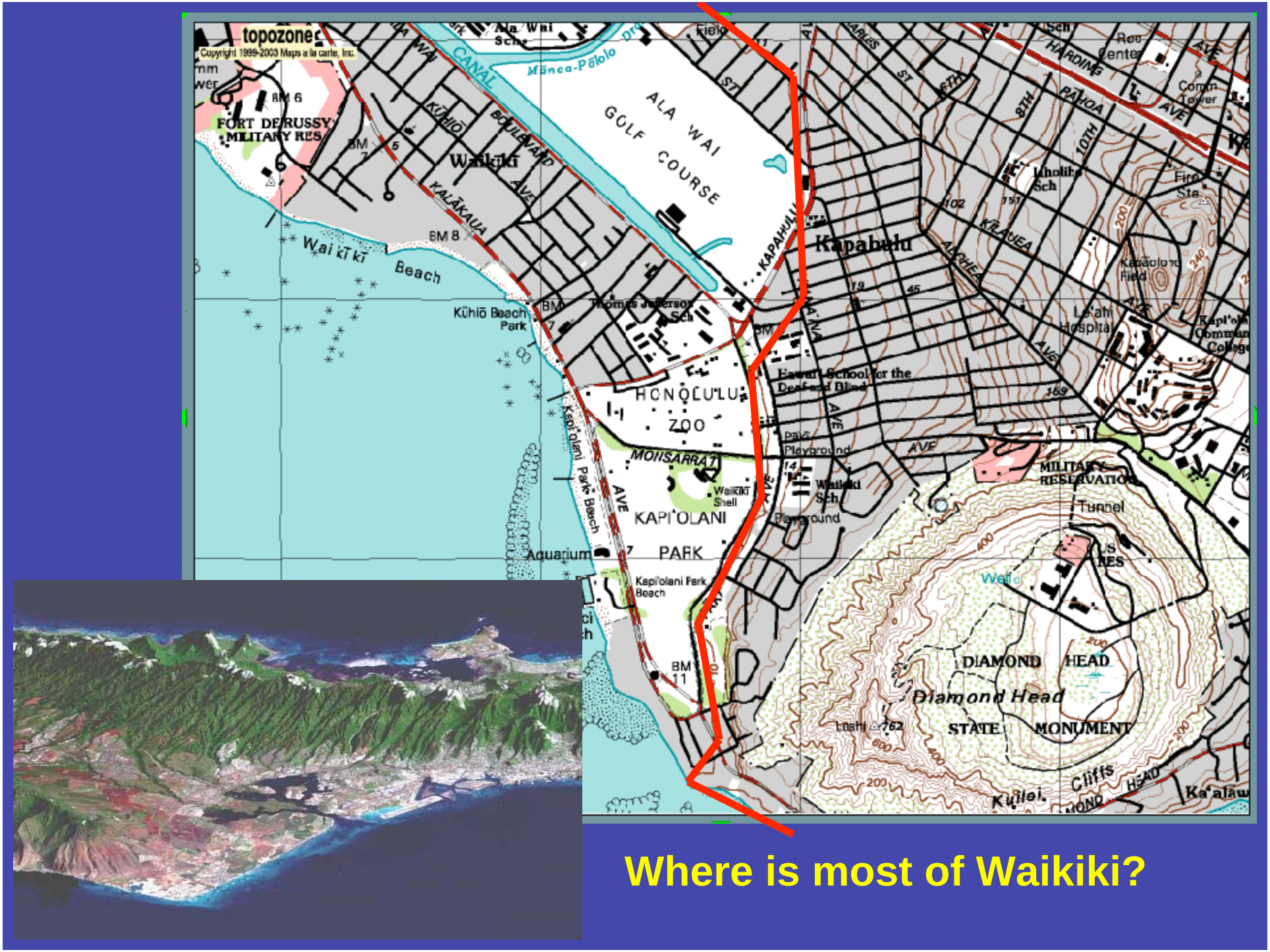

**IPCC projection includes only thermal expansion of seawater**

***What's missing?***



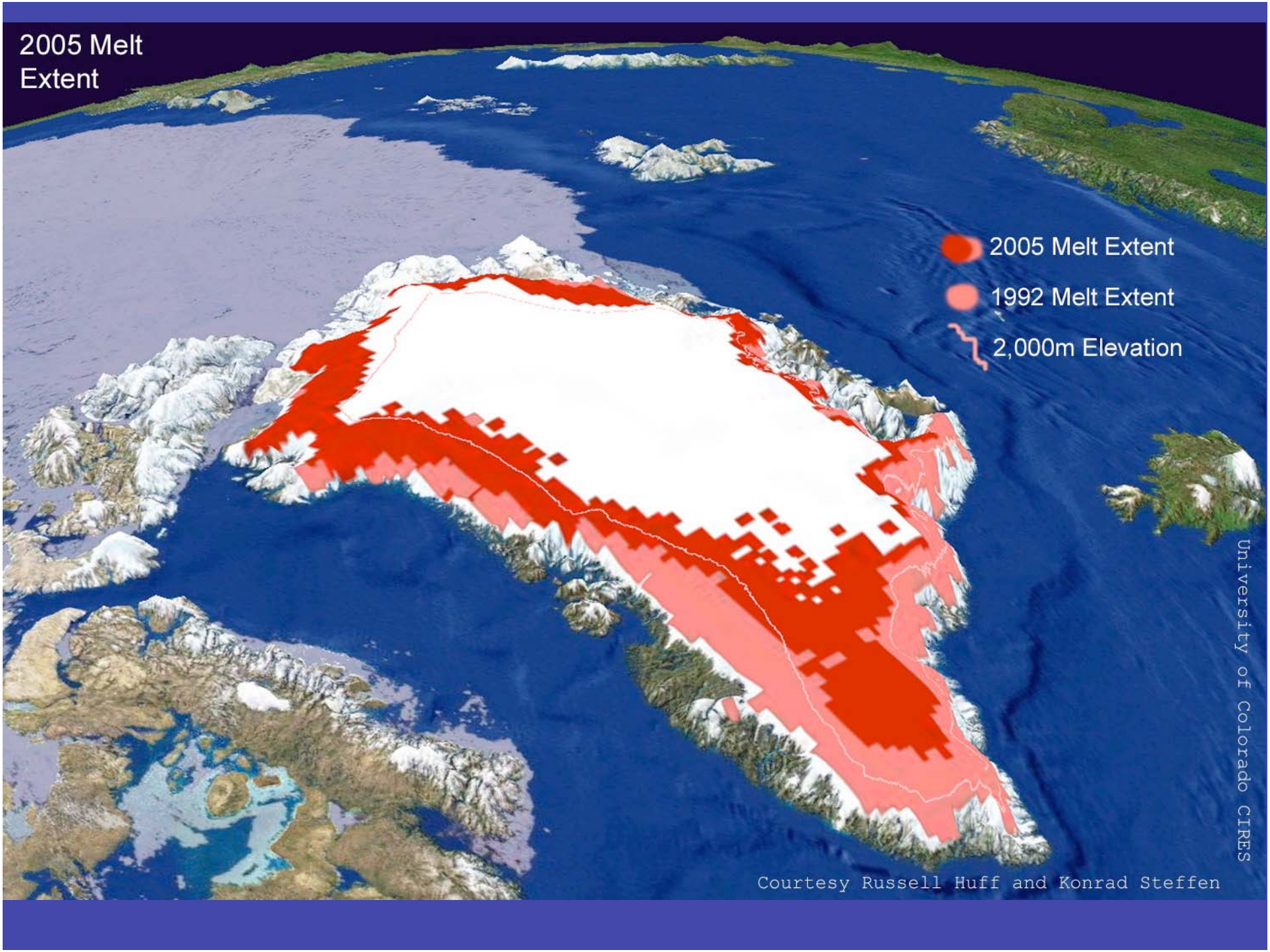



**Where is 1m of sea level rise?**

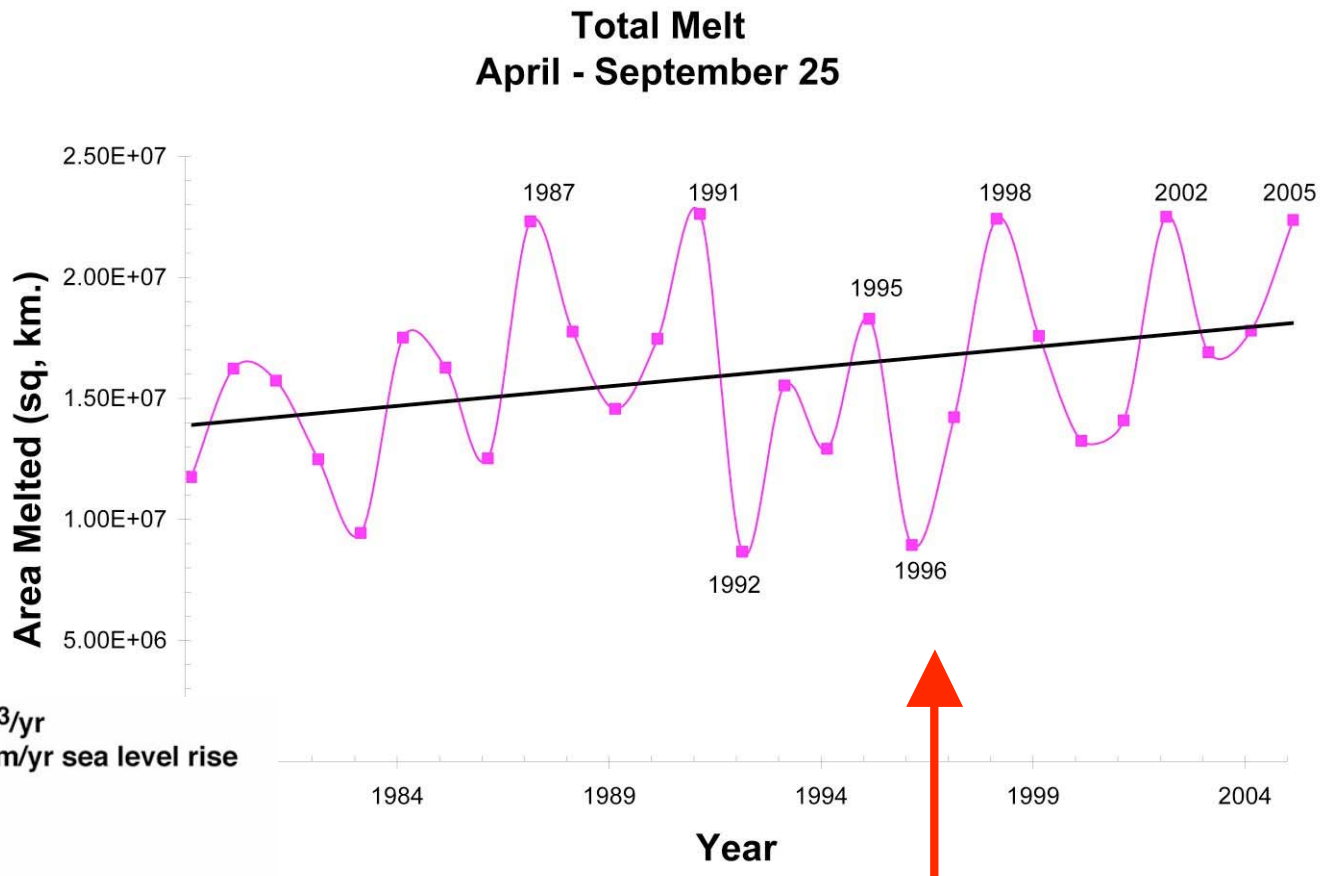

topozone
Copyright 1999-2003 Maps a la carte, Inc.
FORT DERUSSY MILITARY RES
Waikīkī
Wai kī kī Beach
Kūhiō Beach Park
ALA WAI GOLF COURSE
Mānoa-Pālolo Drainage Canal
Kapahulu
HONOLULU ZOO
KAPI'OLANI PARK
Kapi'olani Park Beach
Aquarium
MILITARY RESERVATION
Tunnel
DIAMOND HEAD
Diamond Head
STATE MONUMENT
Kuilei Cliffs
Ka'alawa
Where is most of Waikiki?

# Possible sea level rise in our lifetimes - where is your house?

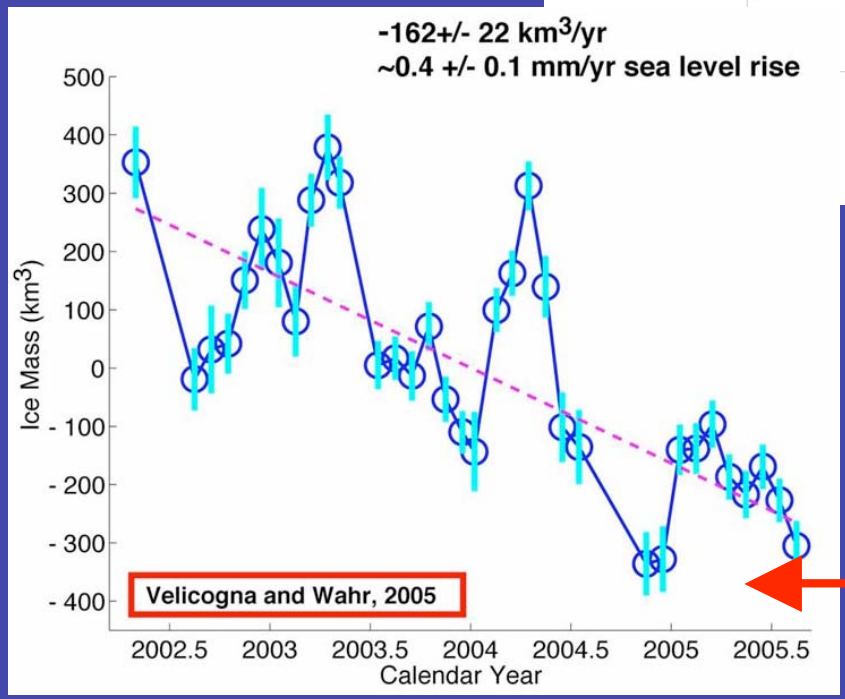



2005 Melt Extent
2005 Melt Extent
1992 Melt Extent
2,000m Elevation
Courtesy Russell Huff and Konrad Steffen
University of Colorado CIRES

# Greenland ice is melting



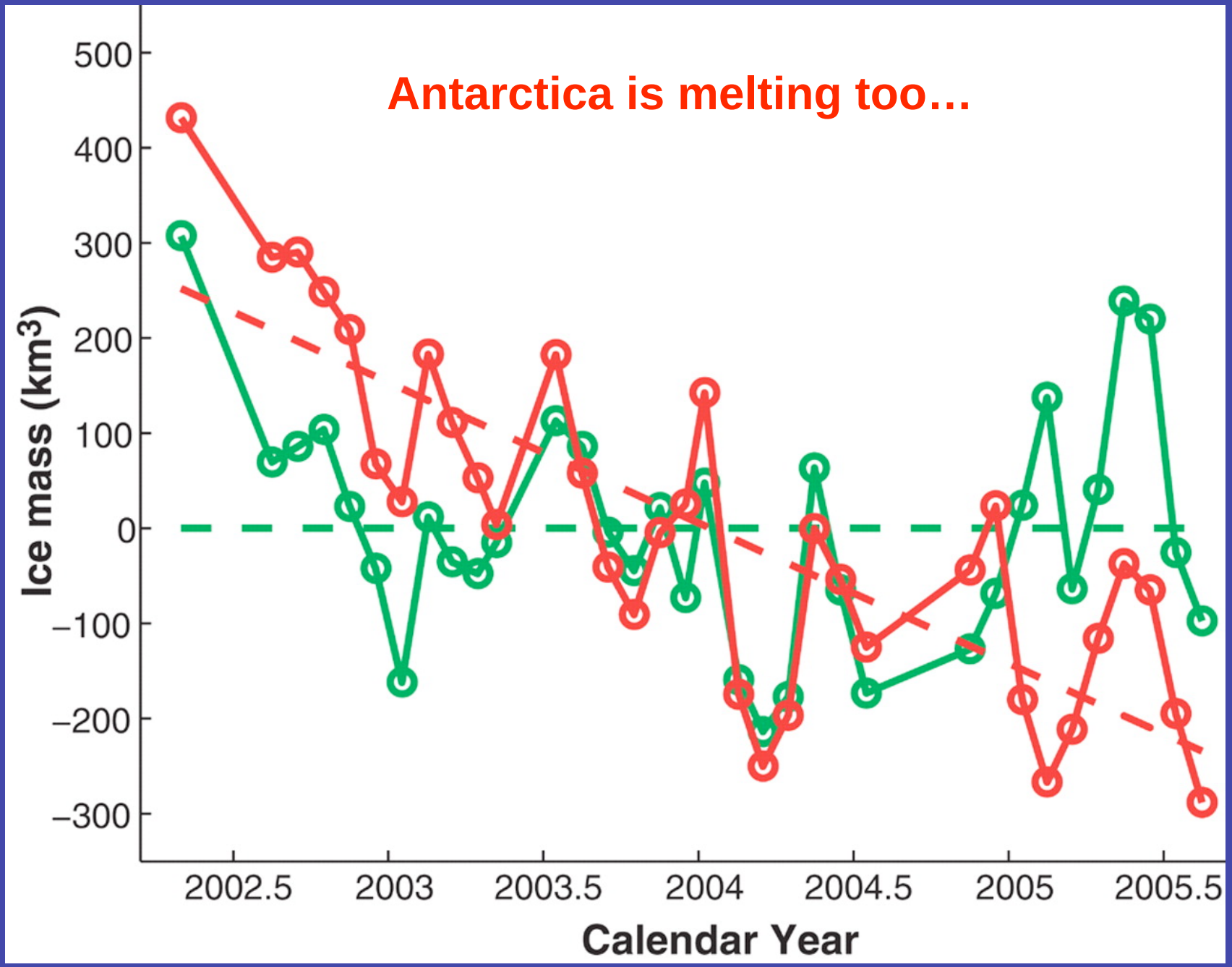

Total melt area




Ice volume

## How about Antarctica?




Antarctica is melting too…
500
400
300
200
100
0
−100
−200
−300
Ice mass (km3)
2002.5
2003
2003.5
2004
2004.5
2005
2005.5
Calendar Year

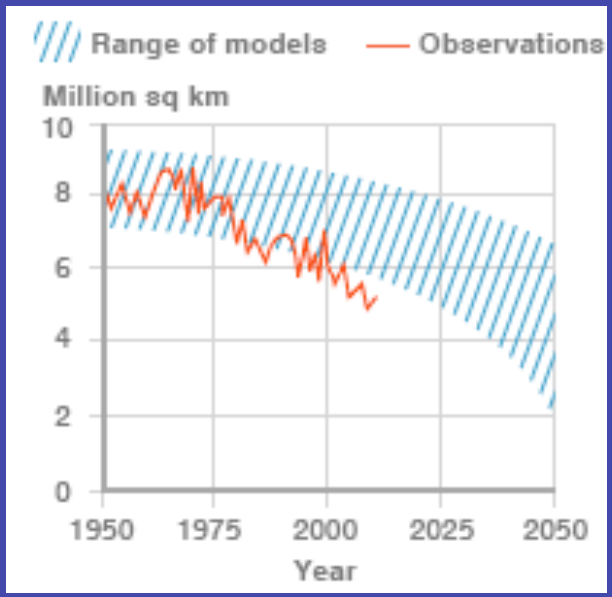
# Greenland or West Antarctica - 21 feet (7 meters)



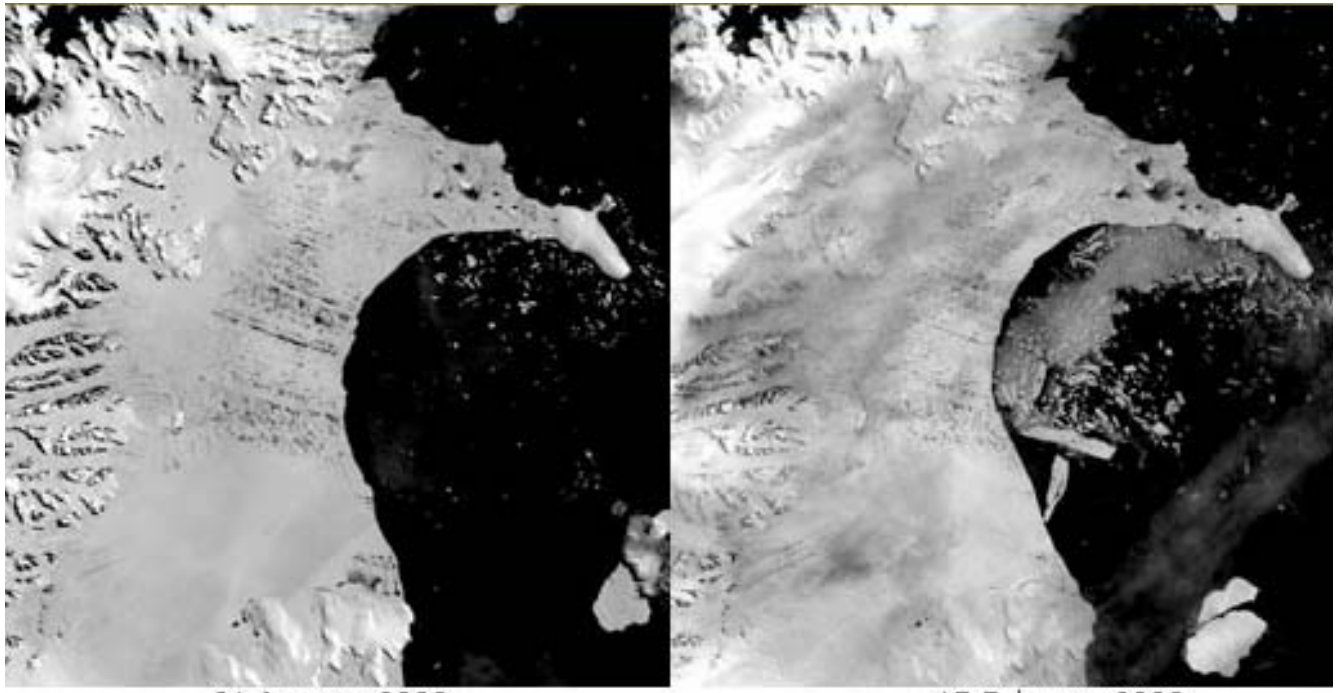


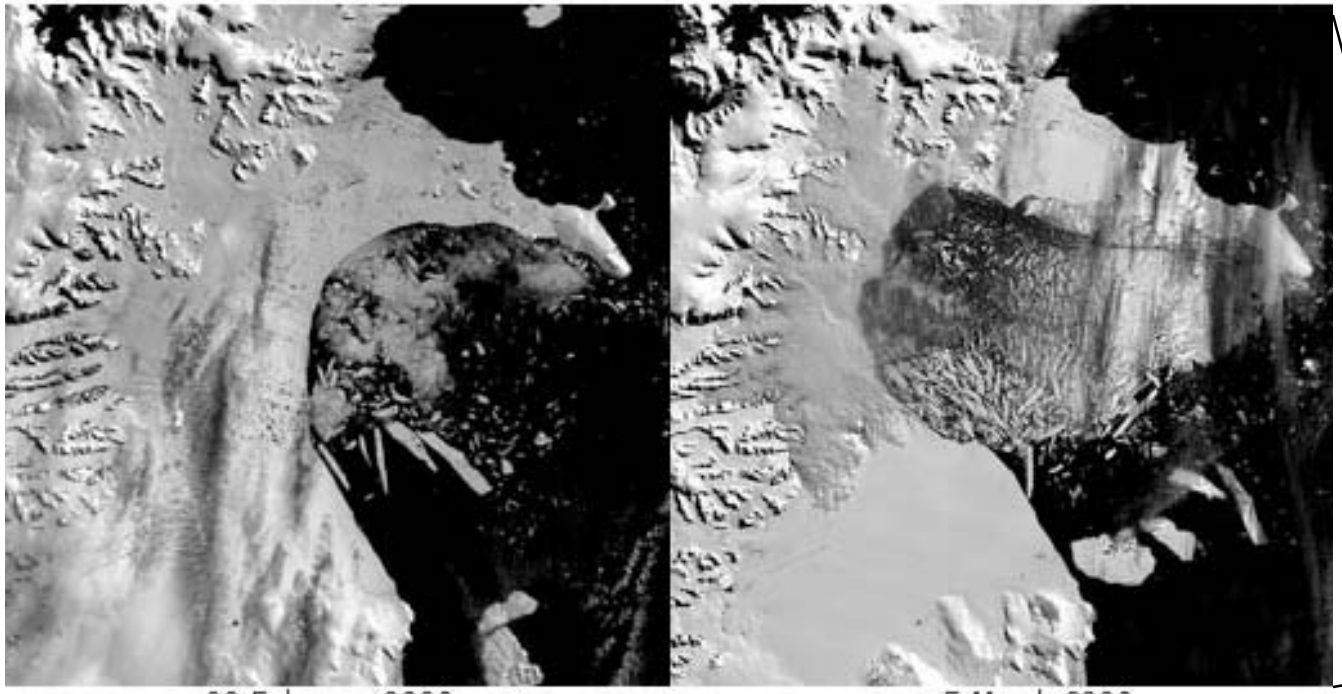
# Don’t fall in this!

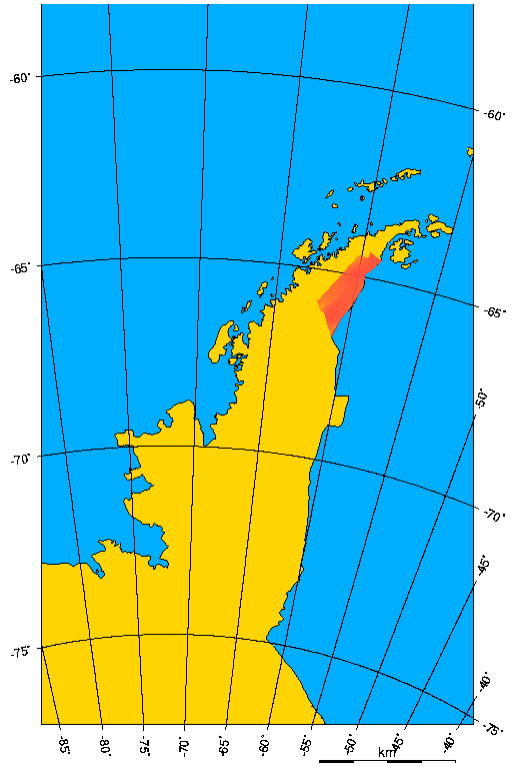
## What does all this water do to ice flow speeds?



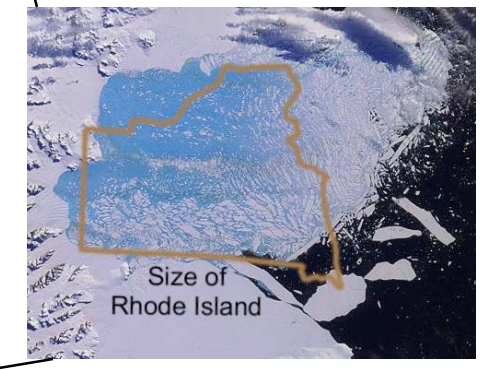
# Larsen Ice Shelf




# 35-day collapse



# In a warming climate, cyclone intensity A) increases, B) decreases



*5/4/08*
*Cyclone Nargis*
*Myanmar*
***22,500 dead***
*41,000 missing*

Cyclone Kills Thousands in Myanmar

May 4, 2008





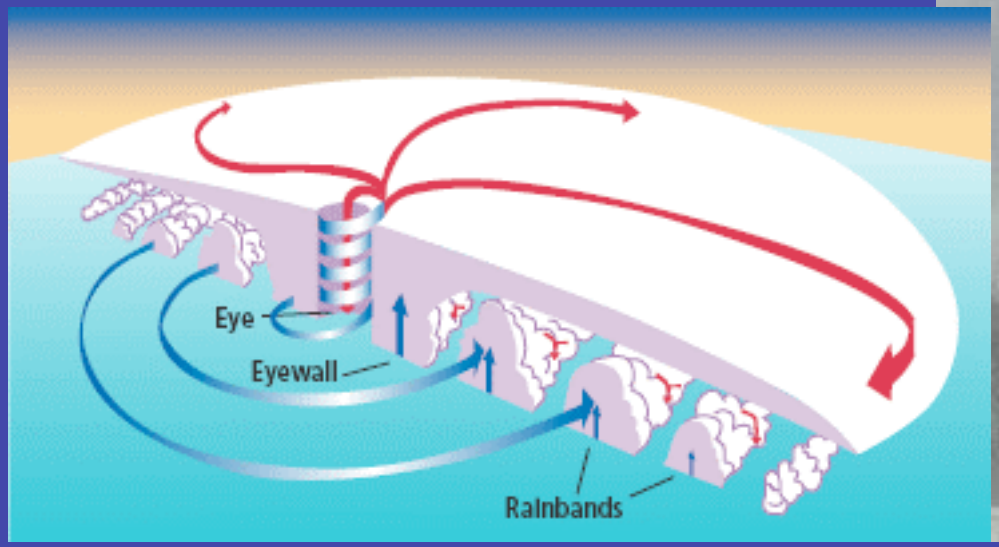
# Hurricane
# Cyclone
# Typhoon

1) warm ocean temperatures

2) low vertical wind shear

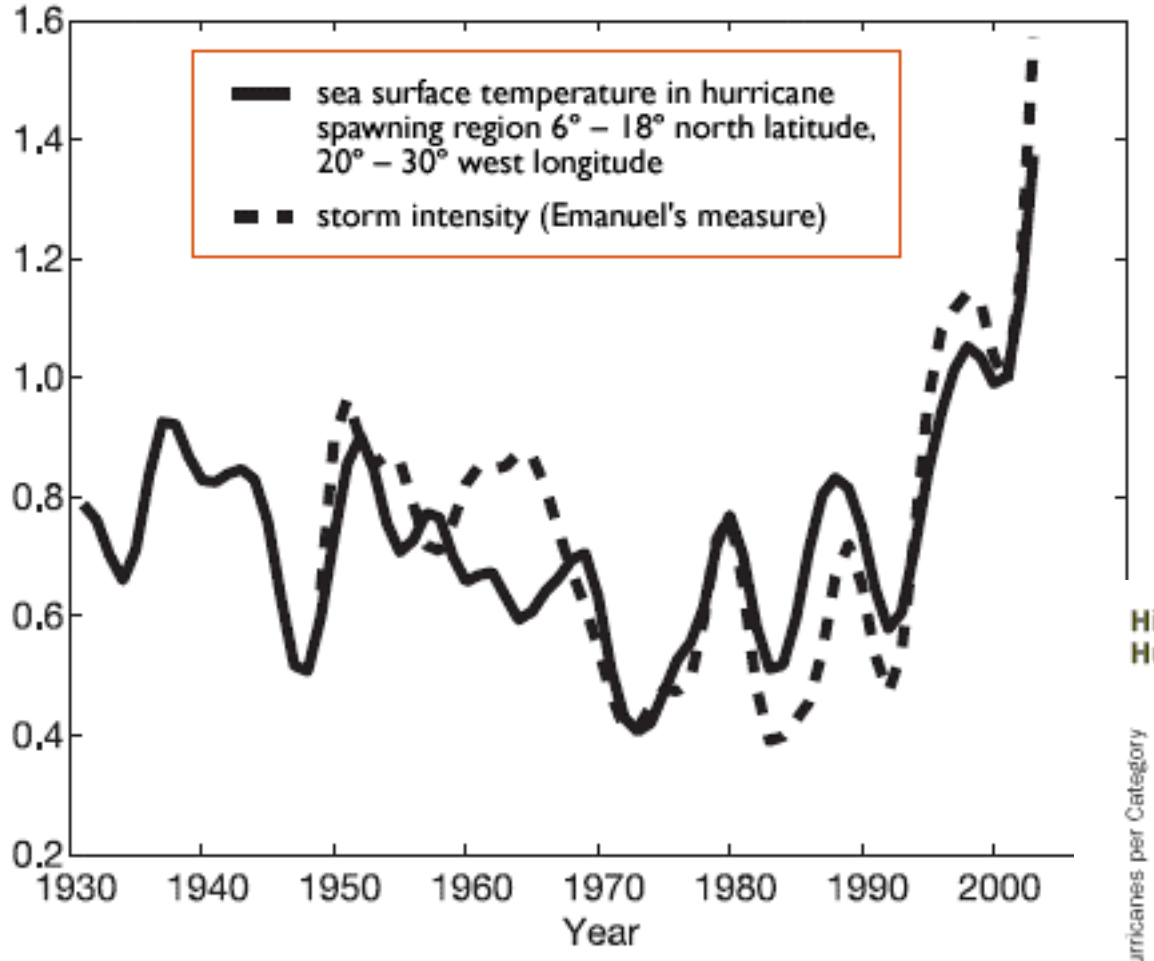
(i.e., no strong change in wind speed or direction between two different altitudes)

3) high humidity

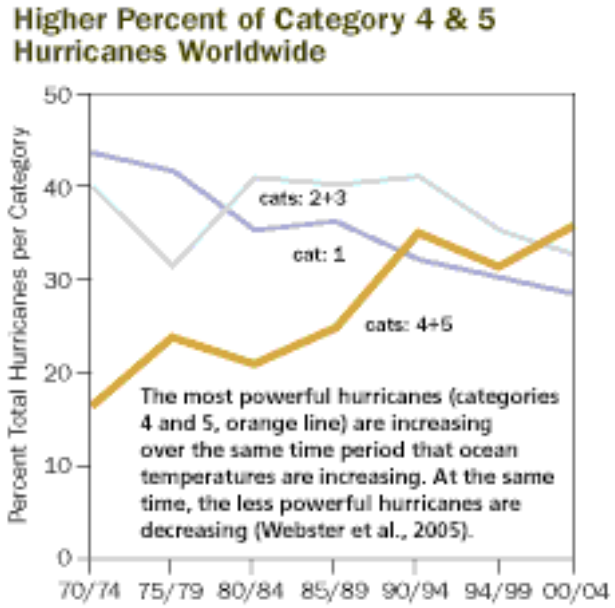





## Hurricane intensity vs. ocean temperature




# Storm Intensity Is Increasing



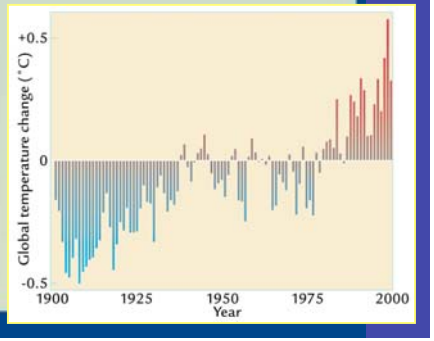
## Global costs of extreme weather events (inflation-adjusted)

**Storm frequency increasing?**



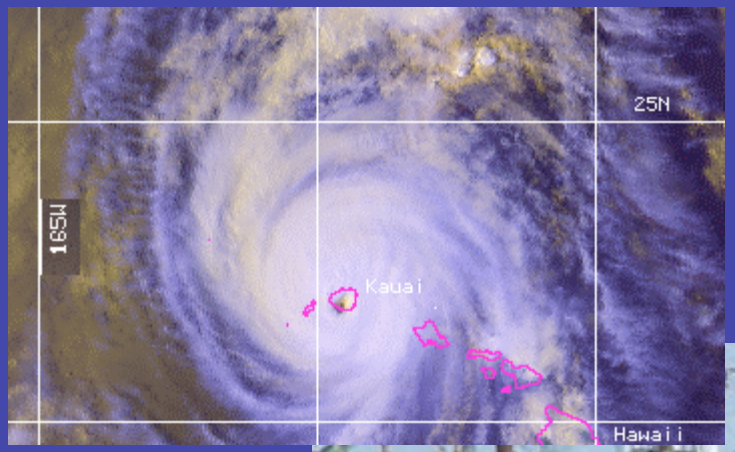



IPCC, 2001



## Category Five Hurricane

- Winds greater than 155 mph (135 kt or 249 km/hr).
- Storm surge generally greater than 18 ft above normal.
- Complete roof failure on many residences and industrial buildings.
- Some complete building failures with small utility buildings blown over or away.
- All shrubs, trees, and signs blown down.
- Severe and extensive window and door damage.
- Low-lying escape routes are cut by rising water 3-5 hours before arrival of the center of the hurricane.
- Major damage to lower floors of all structures located less than 15 ft above sea level and within 500 yards of the shoreline.
- Massive evacuation of residential areas on low ground within 5-10 miles (8-16 km) of the shoreline may be required.




# How many Inikis (C4) can our islands handle?

**Sept. 11 1992**

**$2.6 billion**



# Category 4-5 projected storm surge heights 6m



Lanikai





Bellows

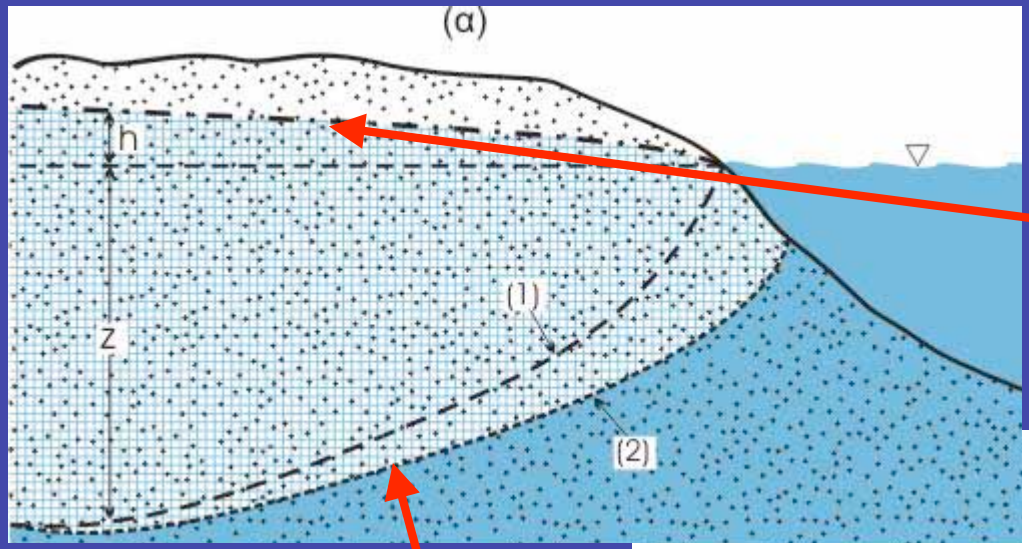
# Coral bleaching





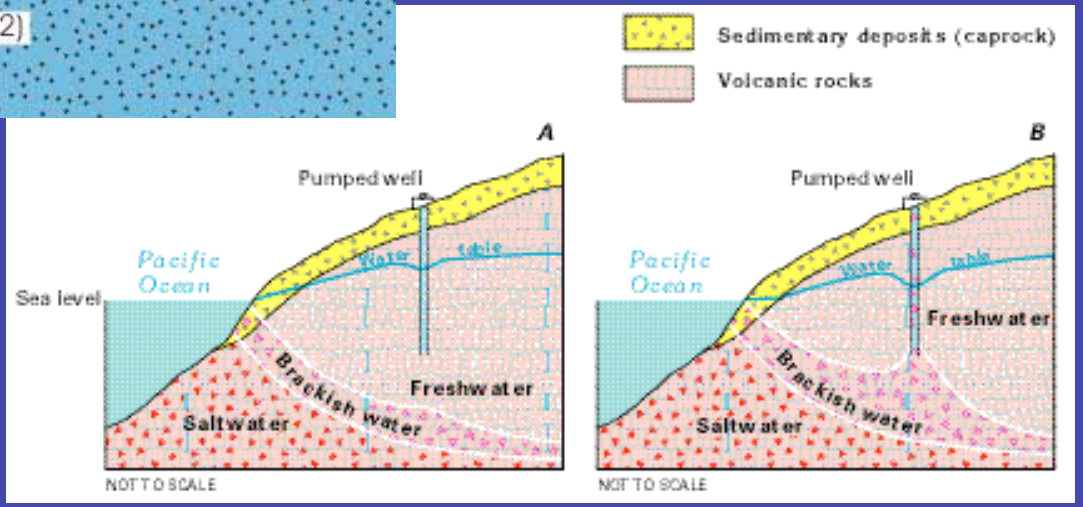


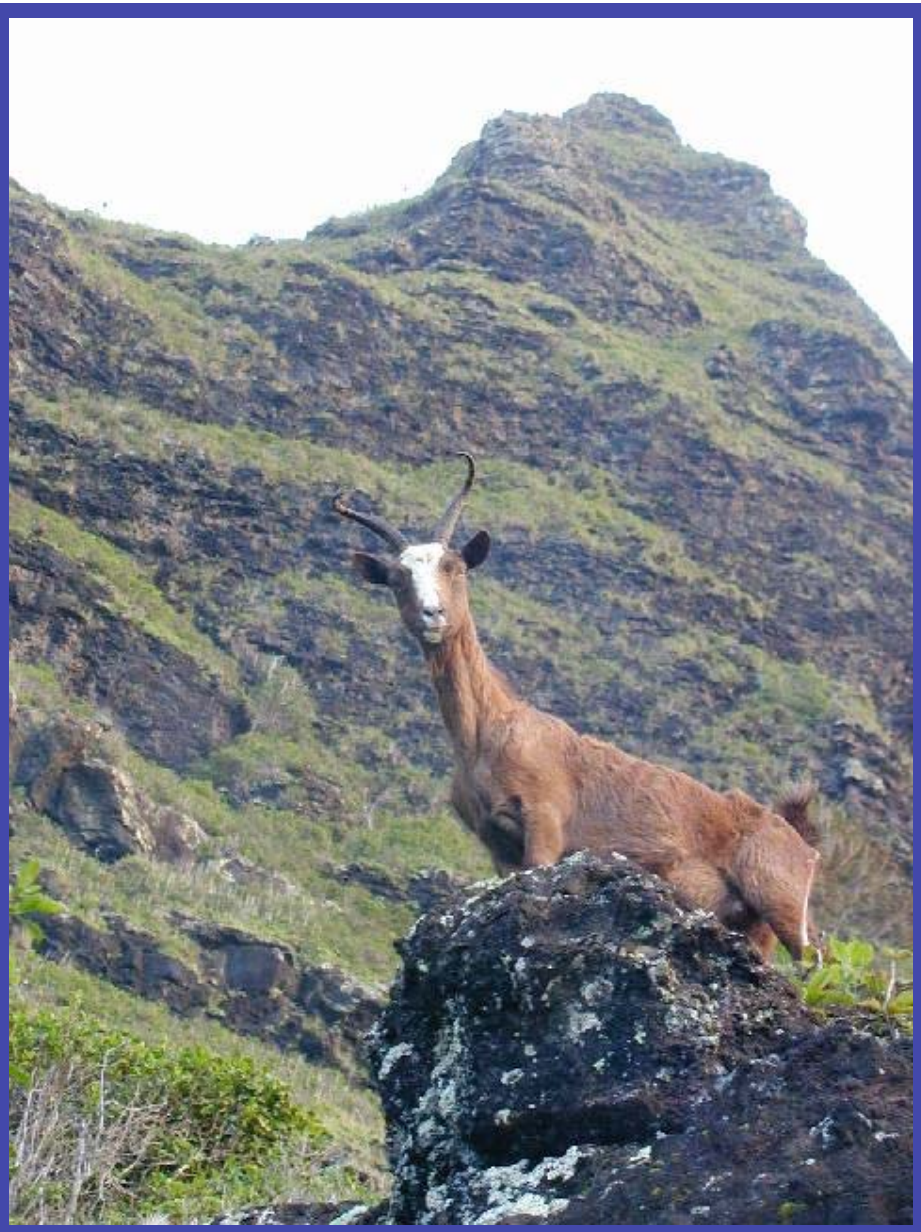
# What happens when you decrease rainfall and increase sea level?




Depth to water table increasing

Depth to salt water decreasing





**Invasive species encroachment**

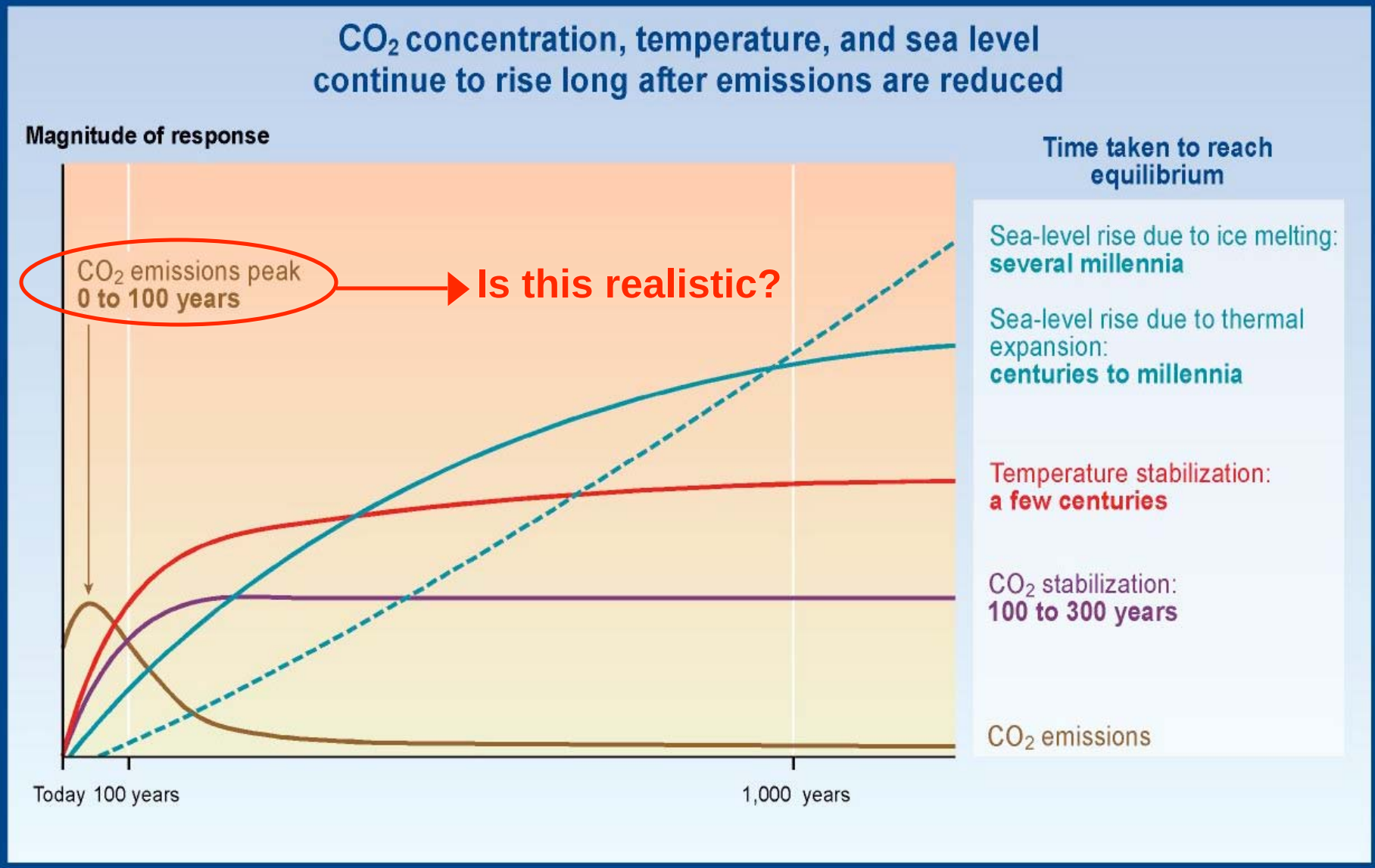








# Lag time of climate components




IPCC, 2001

# Human/Climate Analogy

**What happens when you put a frog in a pot of boiling water?**

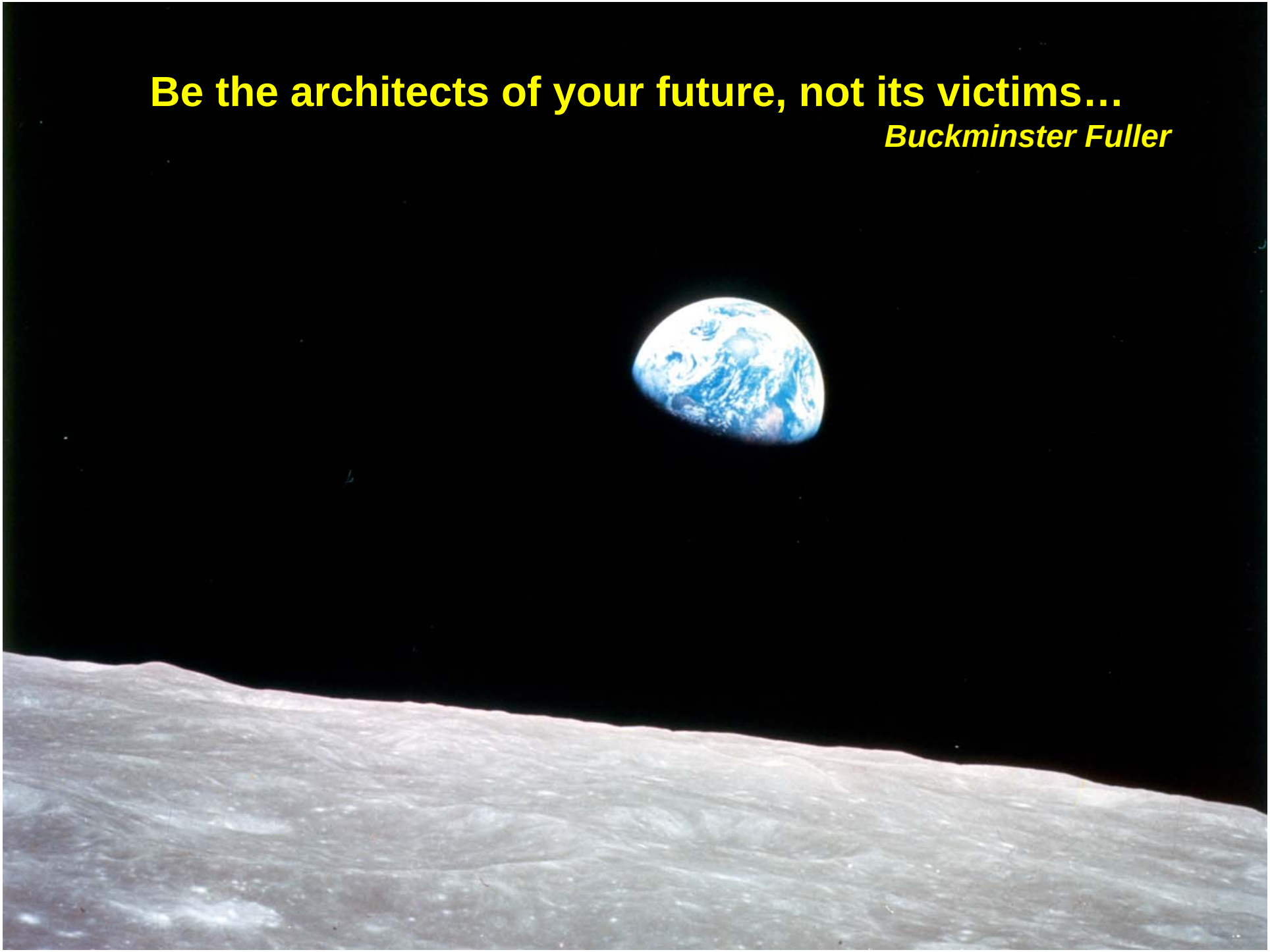




**What happens when you put a frog in cold water then bring it to a boil?**

# What percentage are we of the geologic record?




Be the architects of your future, not its victims…
Buckminster Fuller