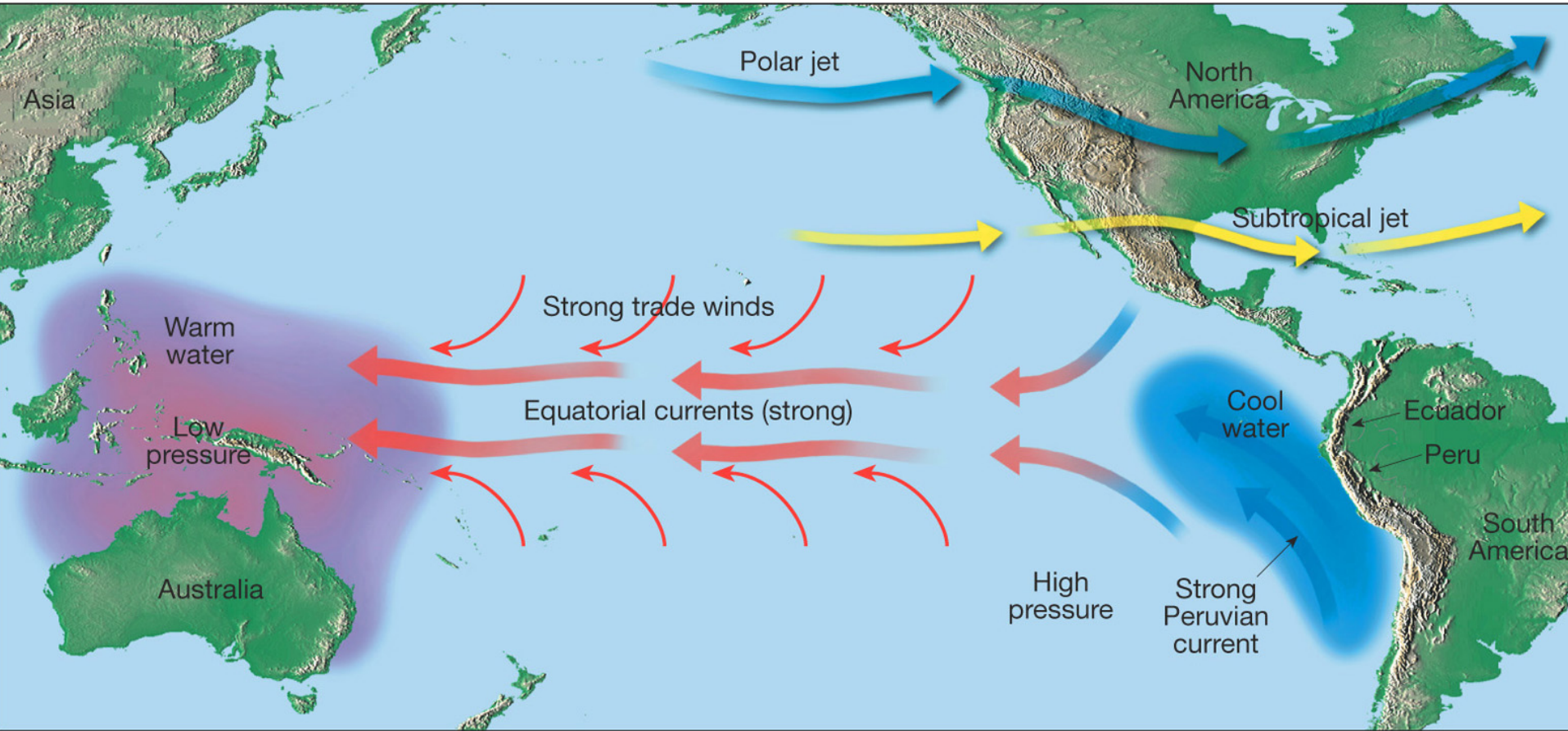


Climate Variability

El Niño-Southern Oscillation

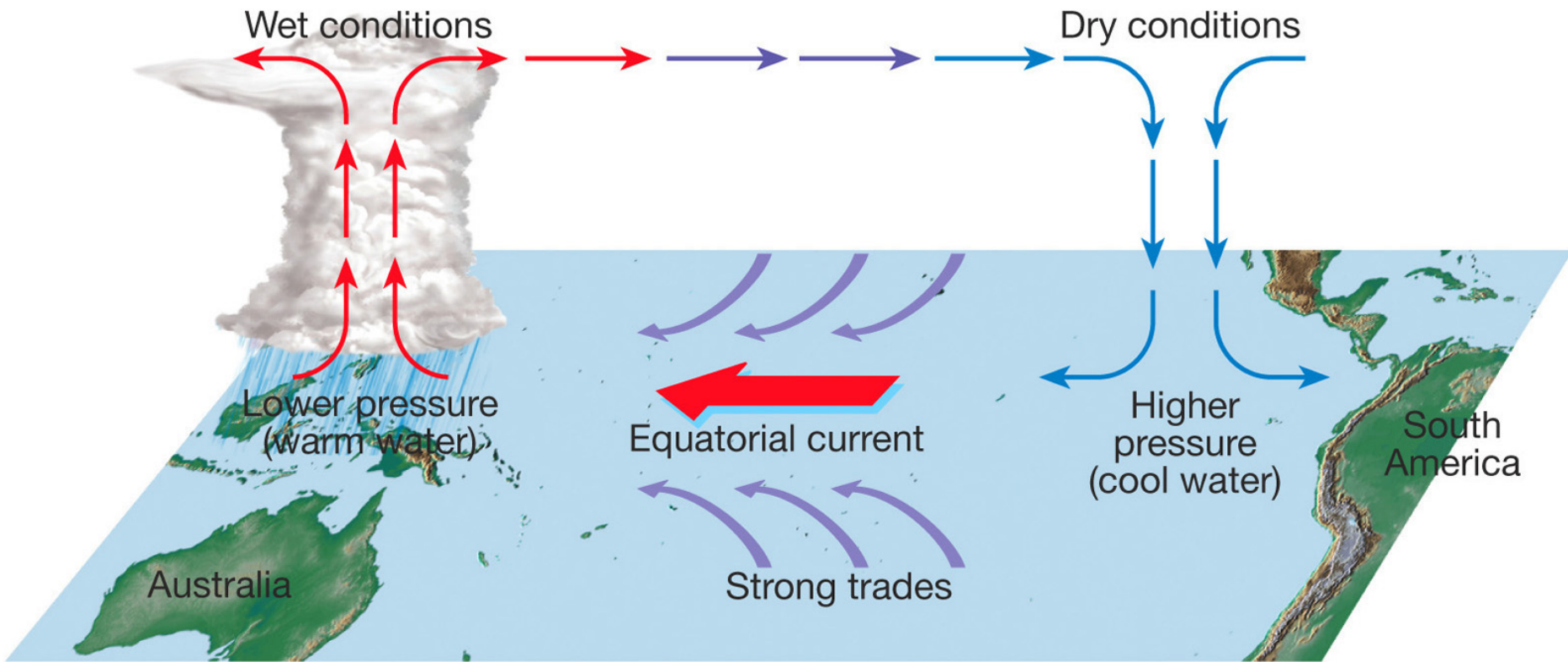
Human-caused climate change

Alternative Energy sources

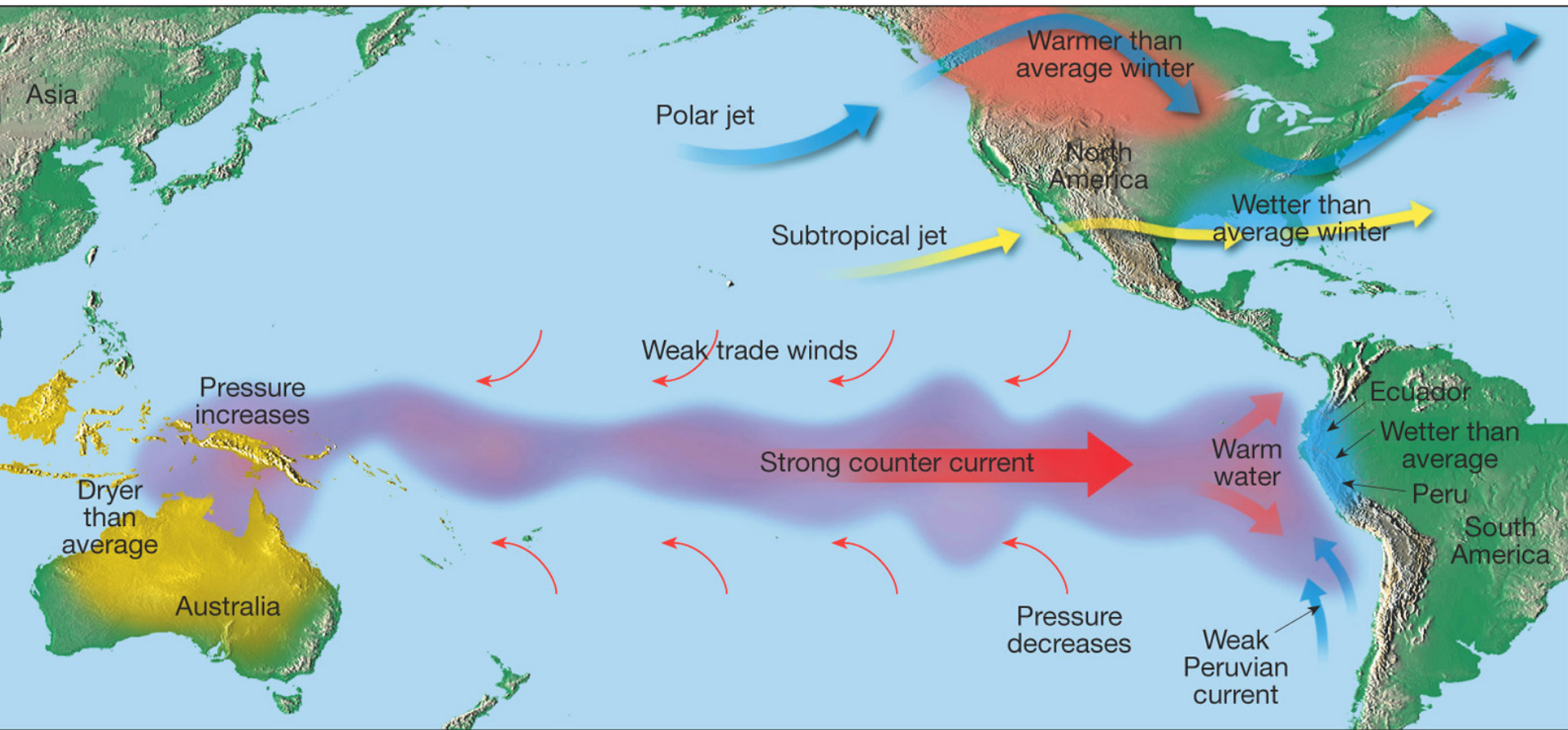


A. Normal conditions

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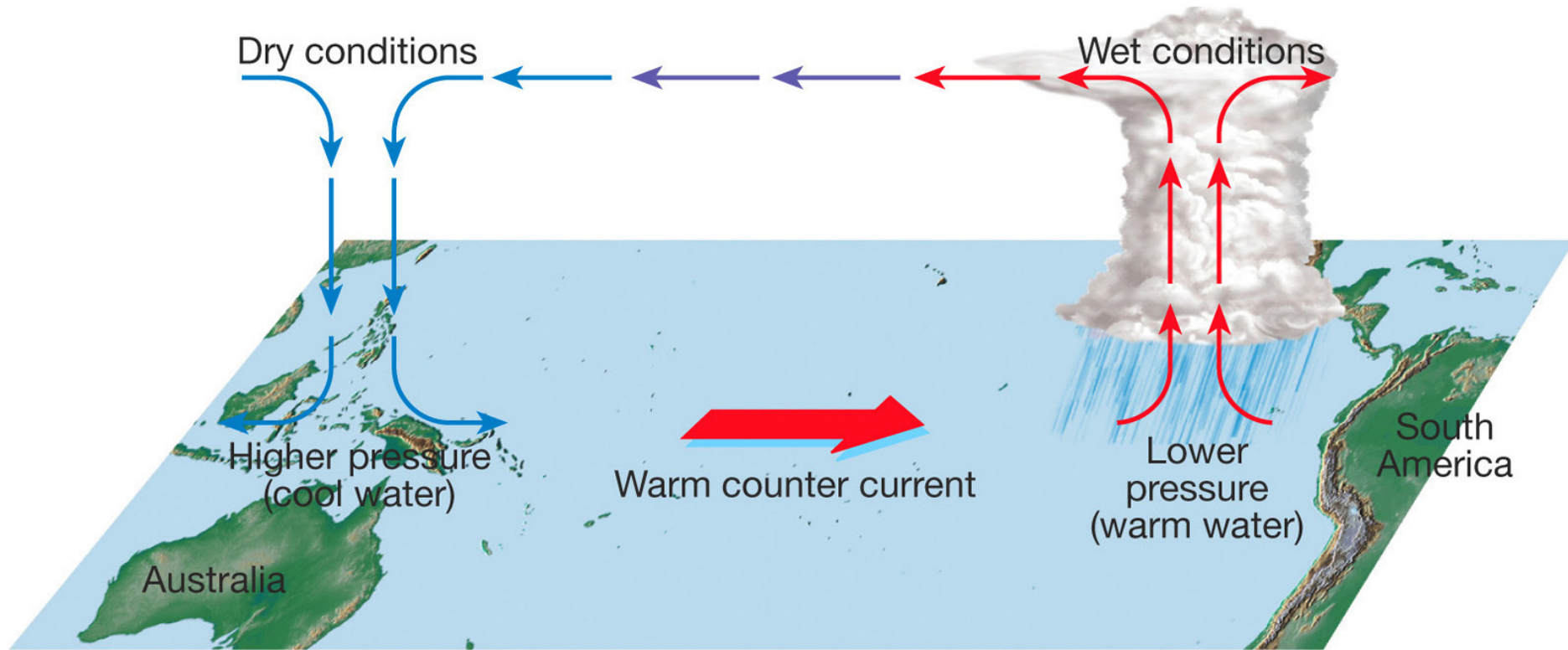


A. Normal years



. El Niño

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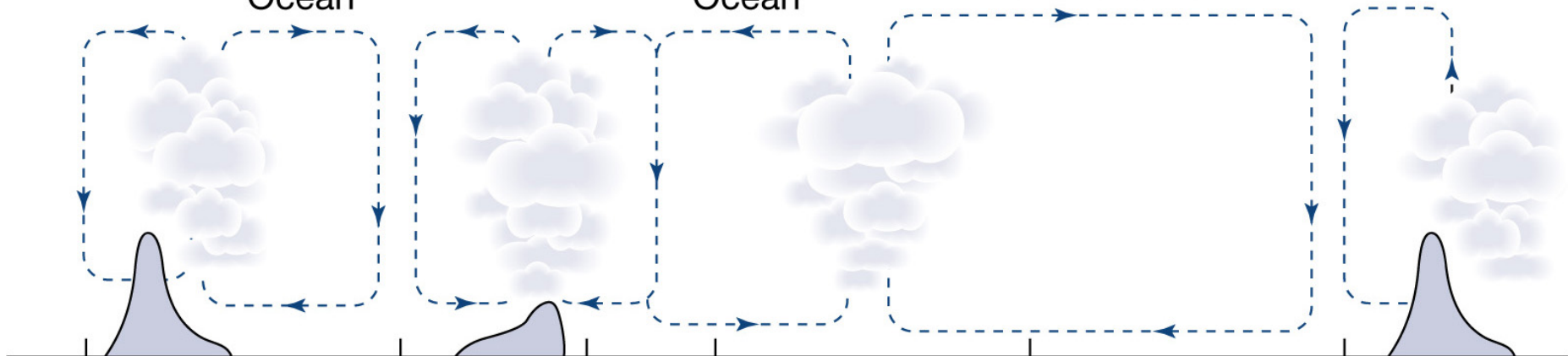
B. El Niño years

December–February

Atlantic Ocean

Indian Ocean

Pacific Ocean



December–February

Atlantic Ocean

Indian Ocean

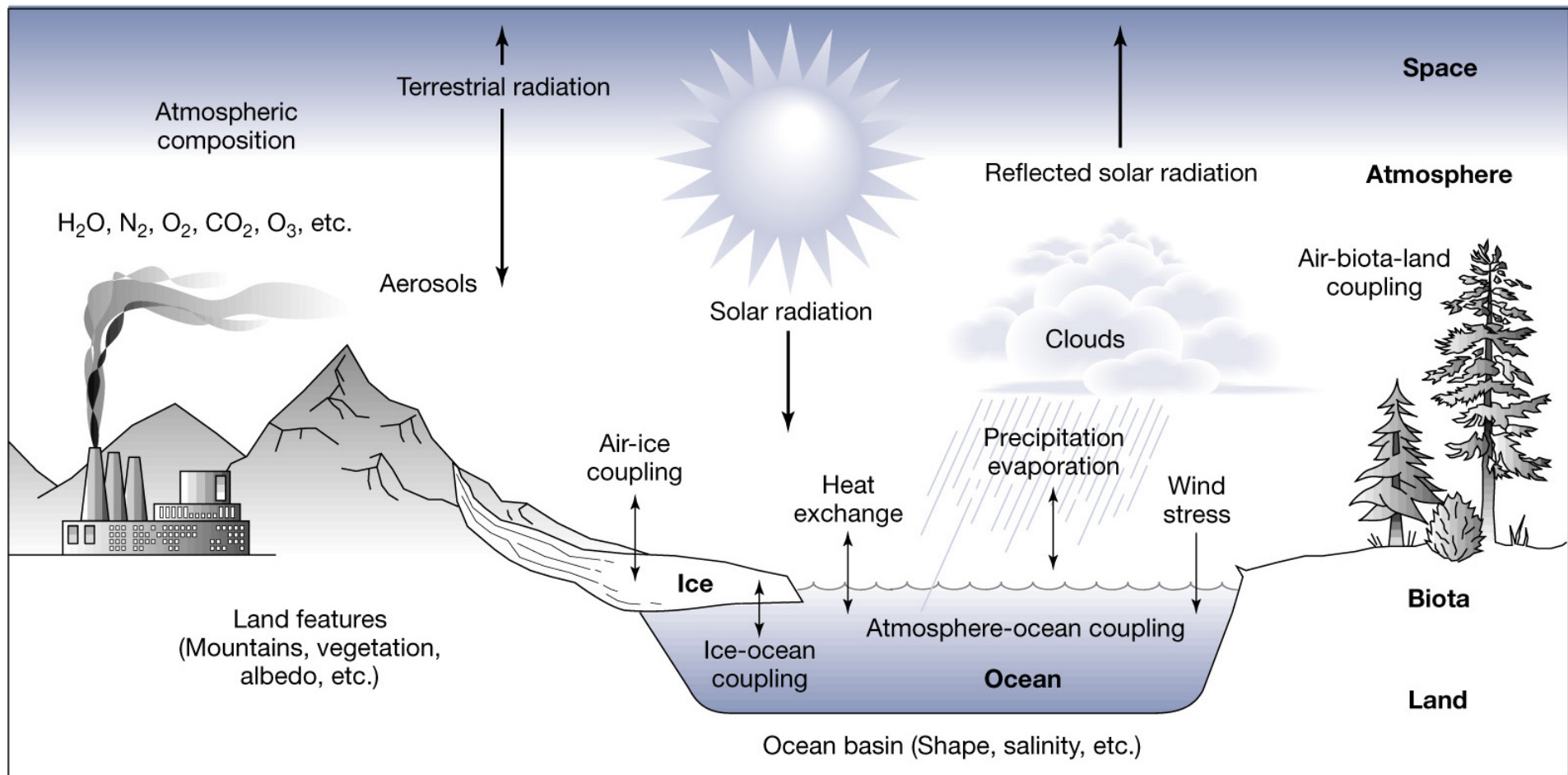
Pacific Ocean



90°W 0° 90°E 180° 90°W

↑ ↑ ↑ ↑

South America Africa Australia South America



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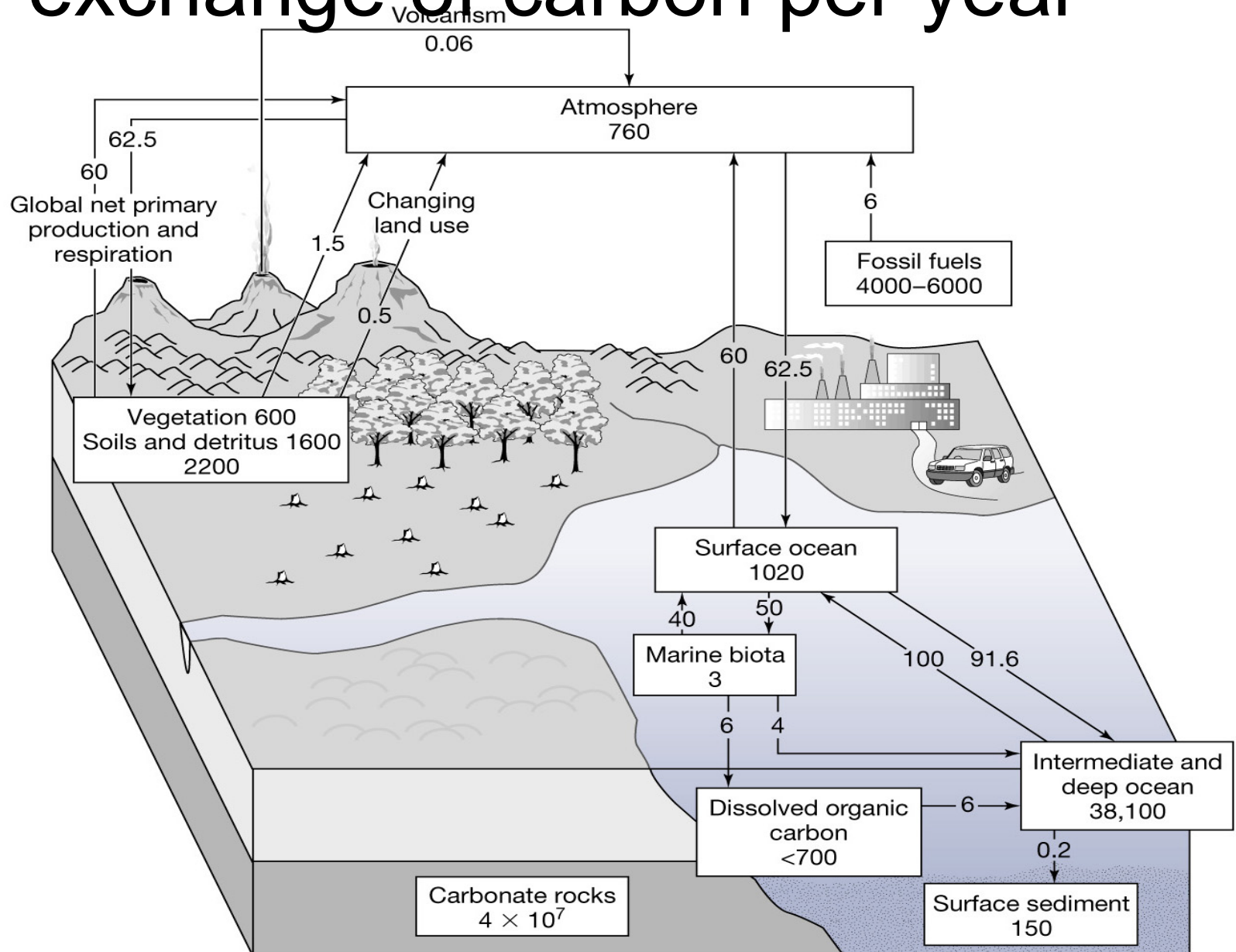
Human contributions to climate change

- Fire
- Deforestation
 - Agriculture
 - Overgrazing
- Cities
 - Heat island
 - Particulates
- Carbon dioxide

Carbon dioxide

- Sources
 - Volcanic gases
 - Respiration
 - Decay
 - Combustion of carbon compounds
- Removing fixation organisms decreases removal from atmosphere
 - Forests: tropical and temperate

Carbon cycle—gigatons and exchange of carbon per year

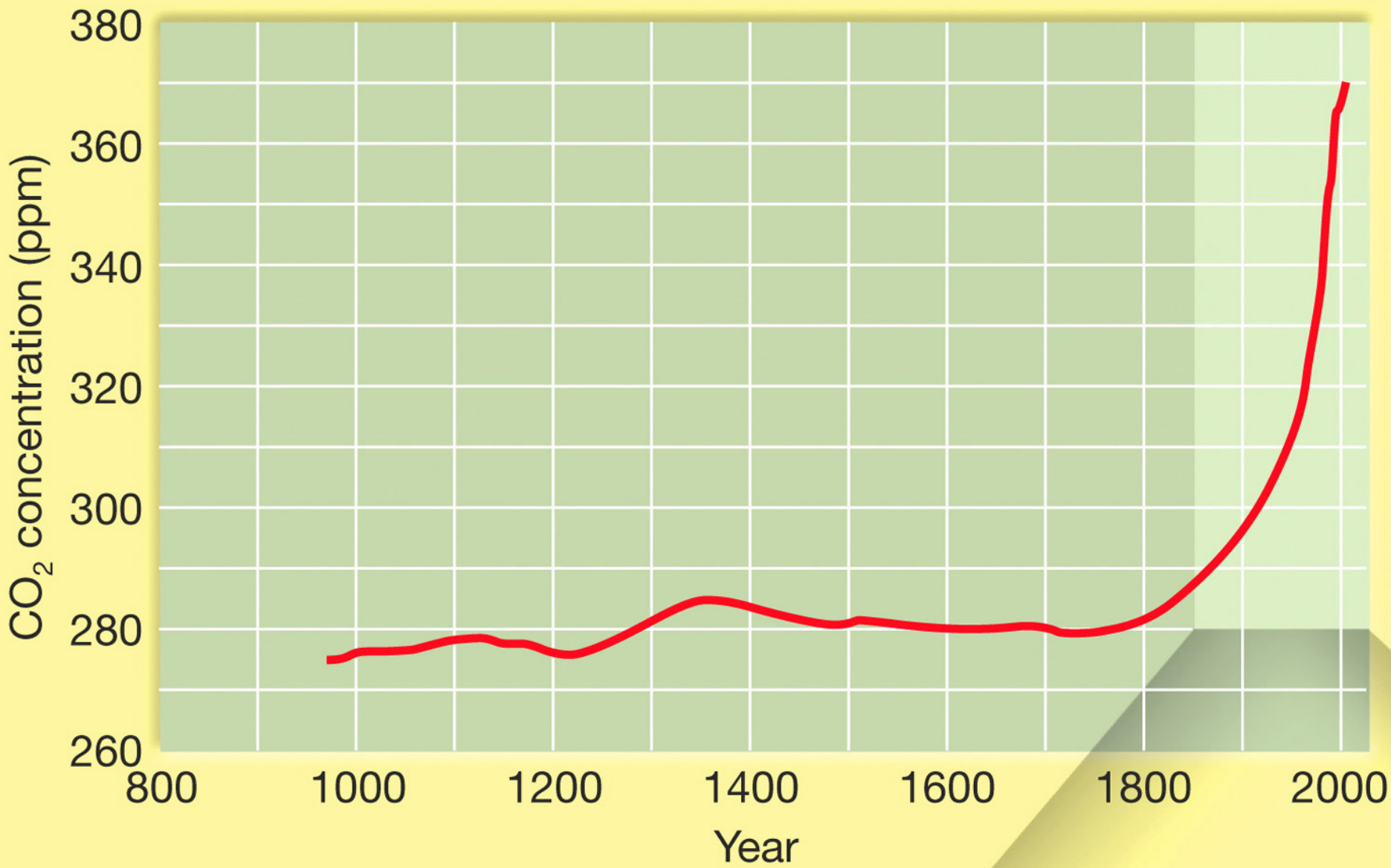


Greenhouse gases

- Transparent to visible light
- Opaque to re-emitted heat energy
- Carbon dioxide is powerful greenhouse gas

Carbon Dioxide

- Human-caused increase in CO₂
 - From 280 ppm to 380 ppm in 200 years
 - Increases plant vigor—negative feedback
- Carbon ‘reservoirs’
 - Dissolve in ocean
 - Dissolution of carbonate minerals
 - Sinking of carbonate skeletons, tests



Fossil fuel CO₂ emissions
(billions of metric tons)

8
6
4
2
0

1850

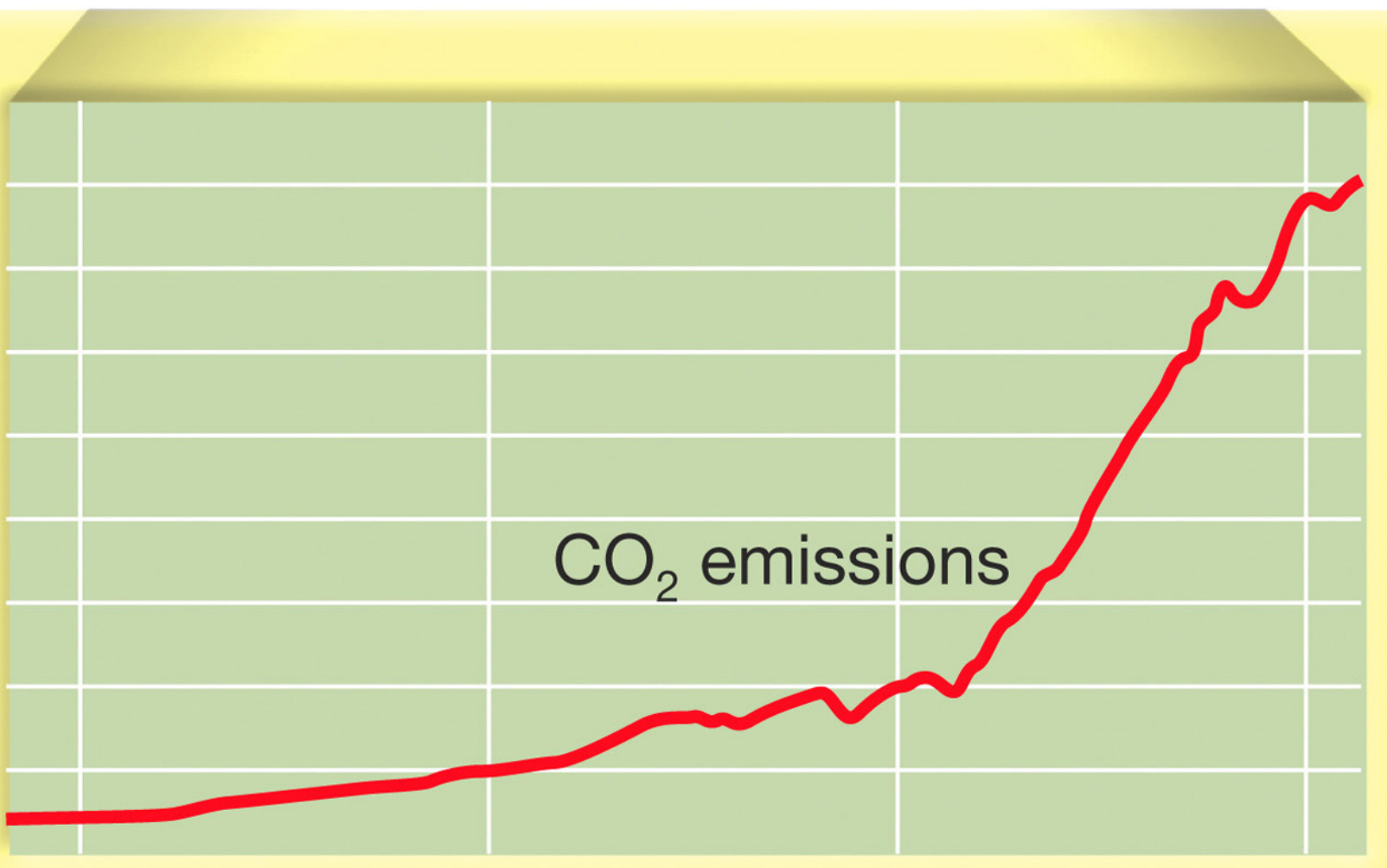
1900

1950

2000

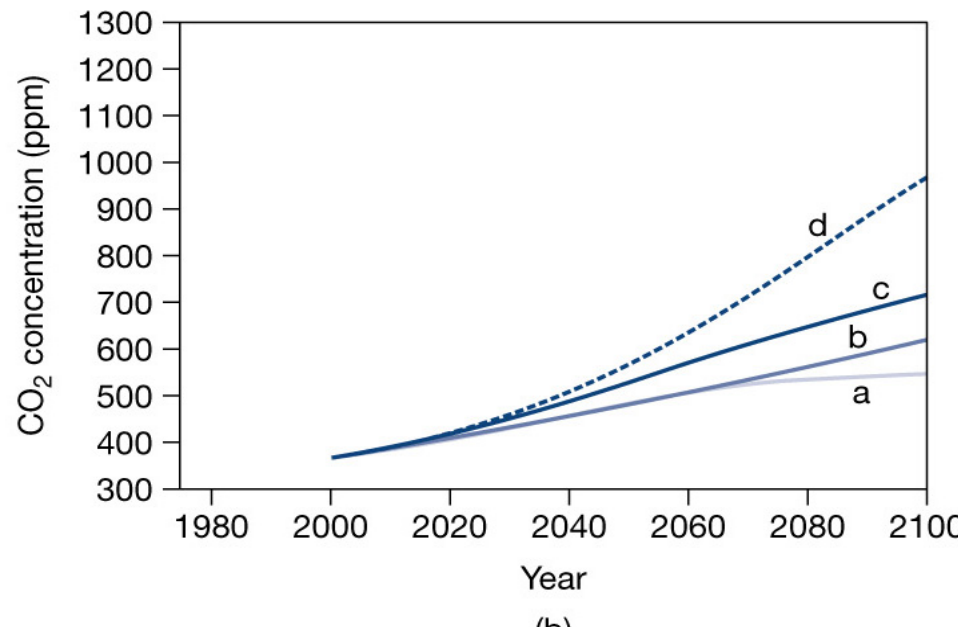
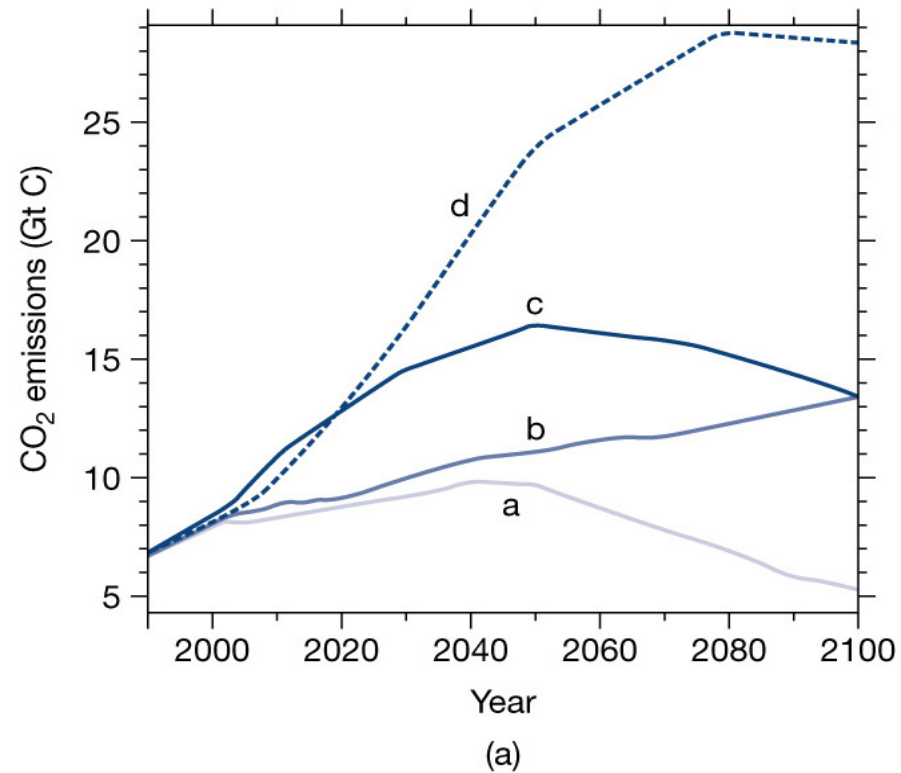
Year

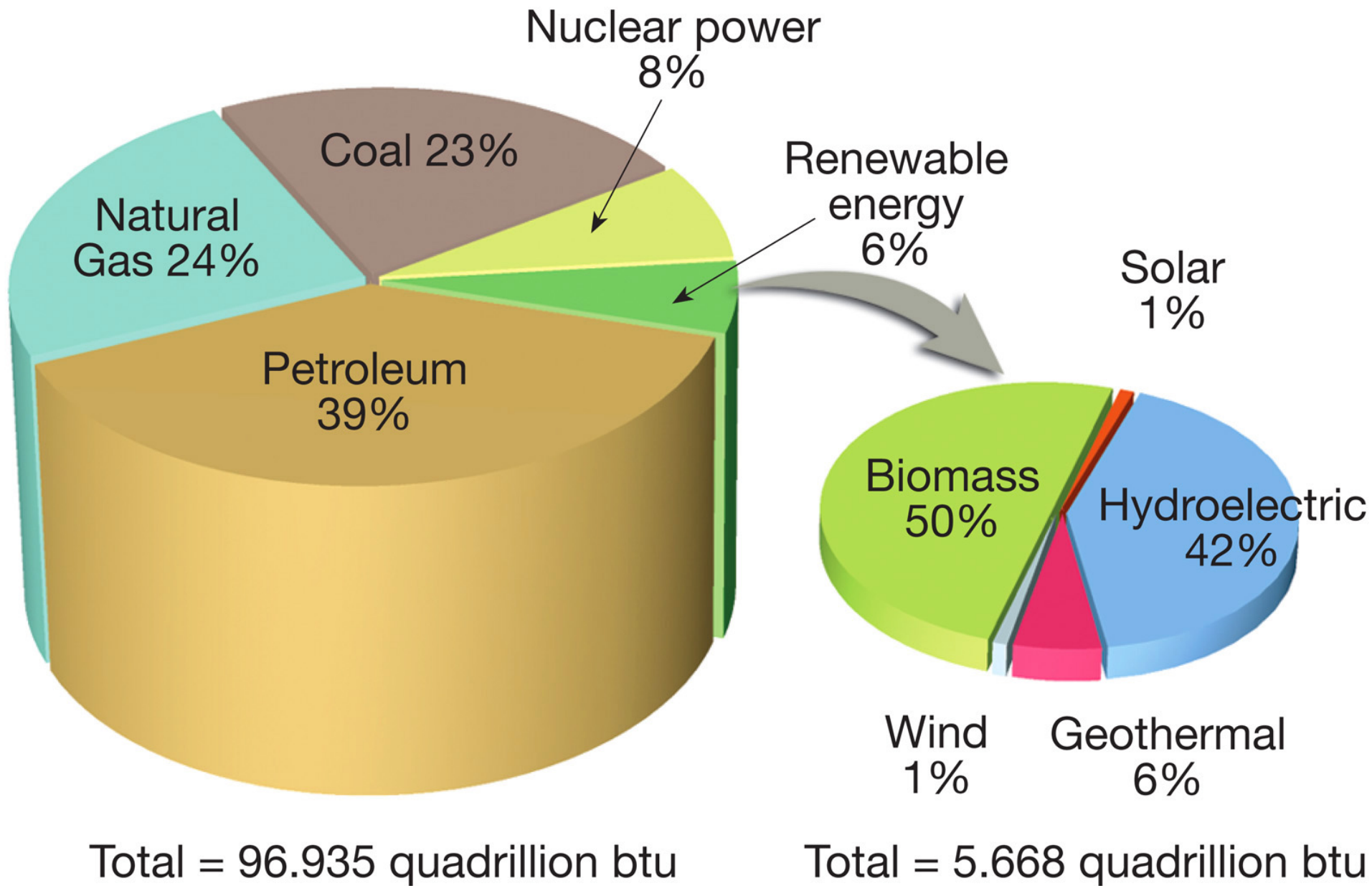
CO₂ emissions



CO₂ emissions

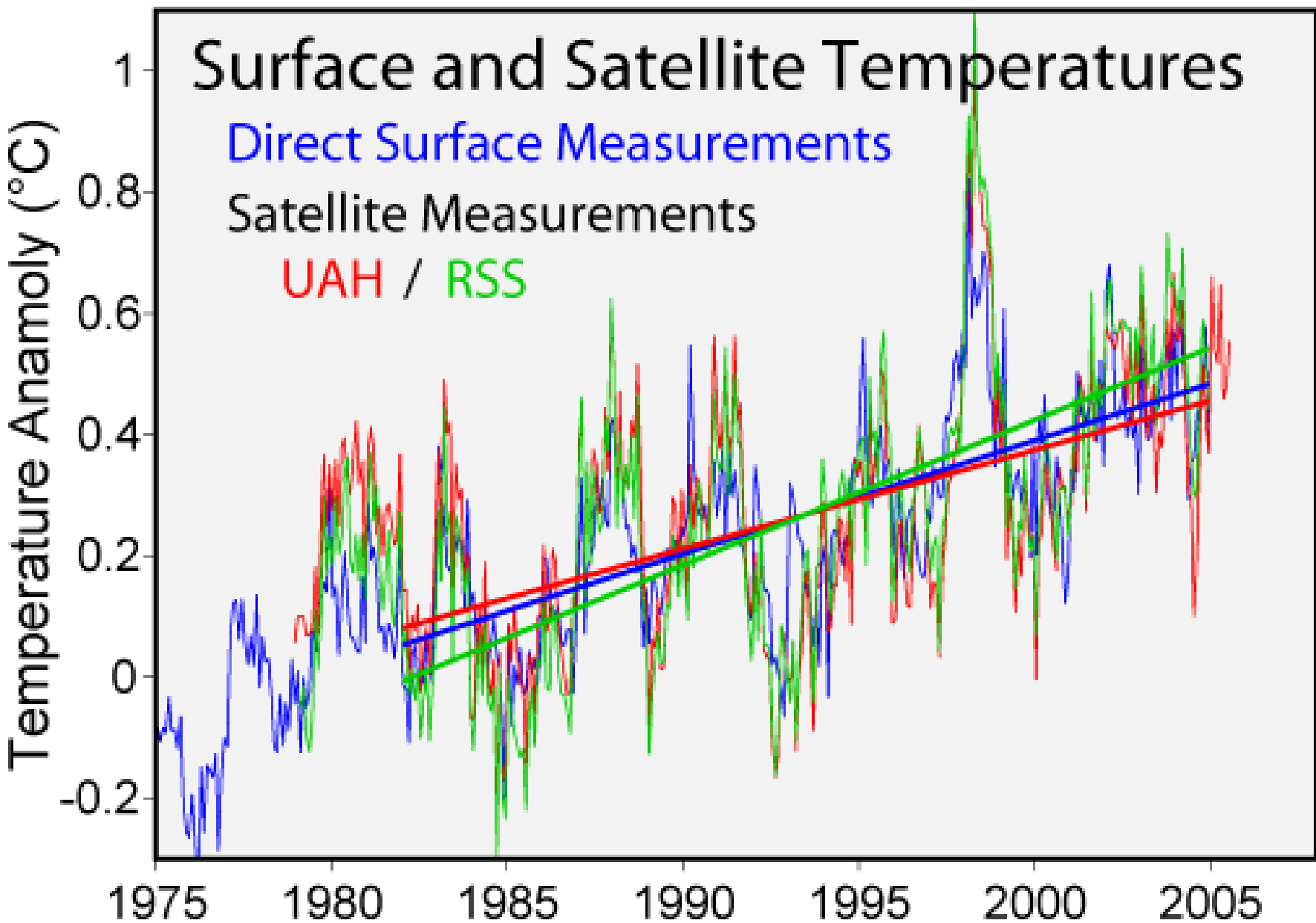
- a. 7 Gt → 10 Gt → 5 Gt
- Curb carbon fuel use
 - Reforestation
- b. +0.7%/yr → 13 Gt
- Modest pop. growth
- c. 7 Gt → 17 Gt → decline
- Rapid pop. growth
 - Variety of sources
- d. 7 Gt → 28 Gt by 2080
- Rapid pop. growth
 - Fossil fuel use

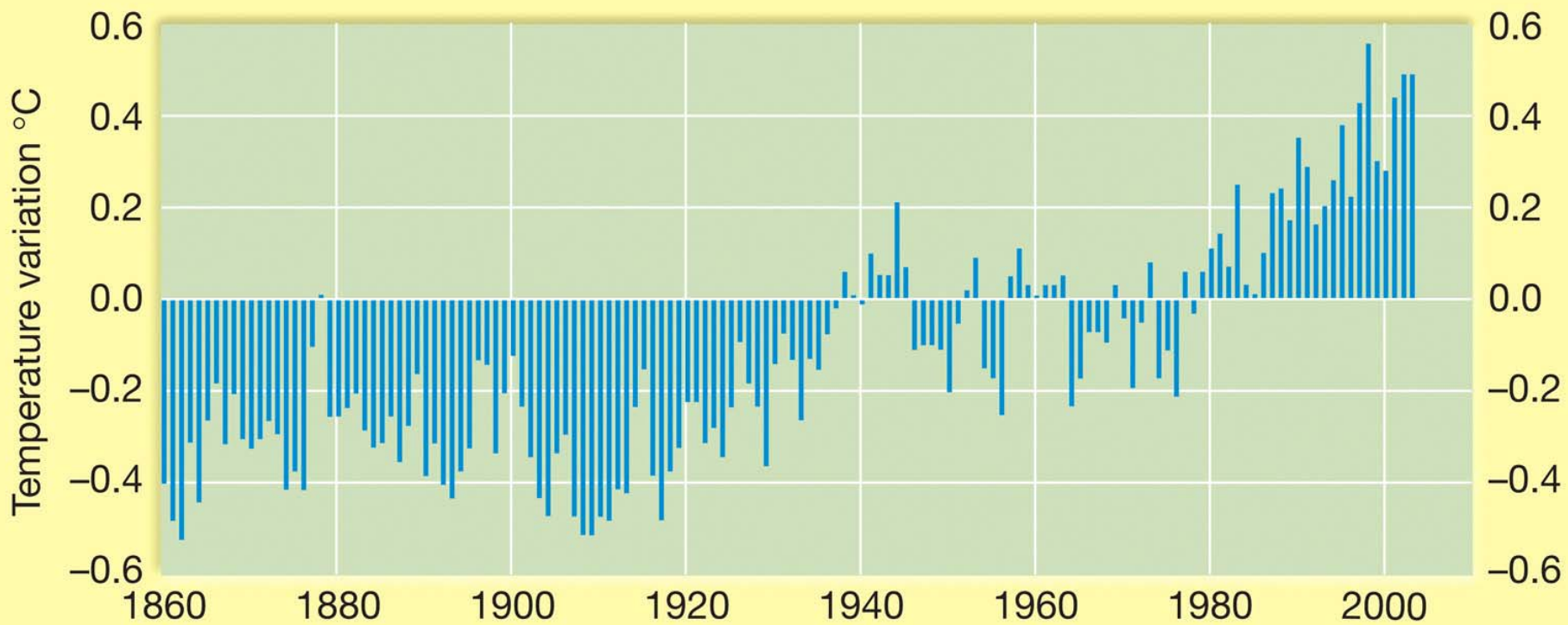




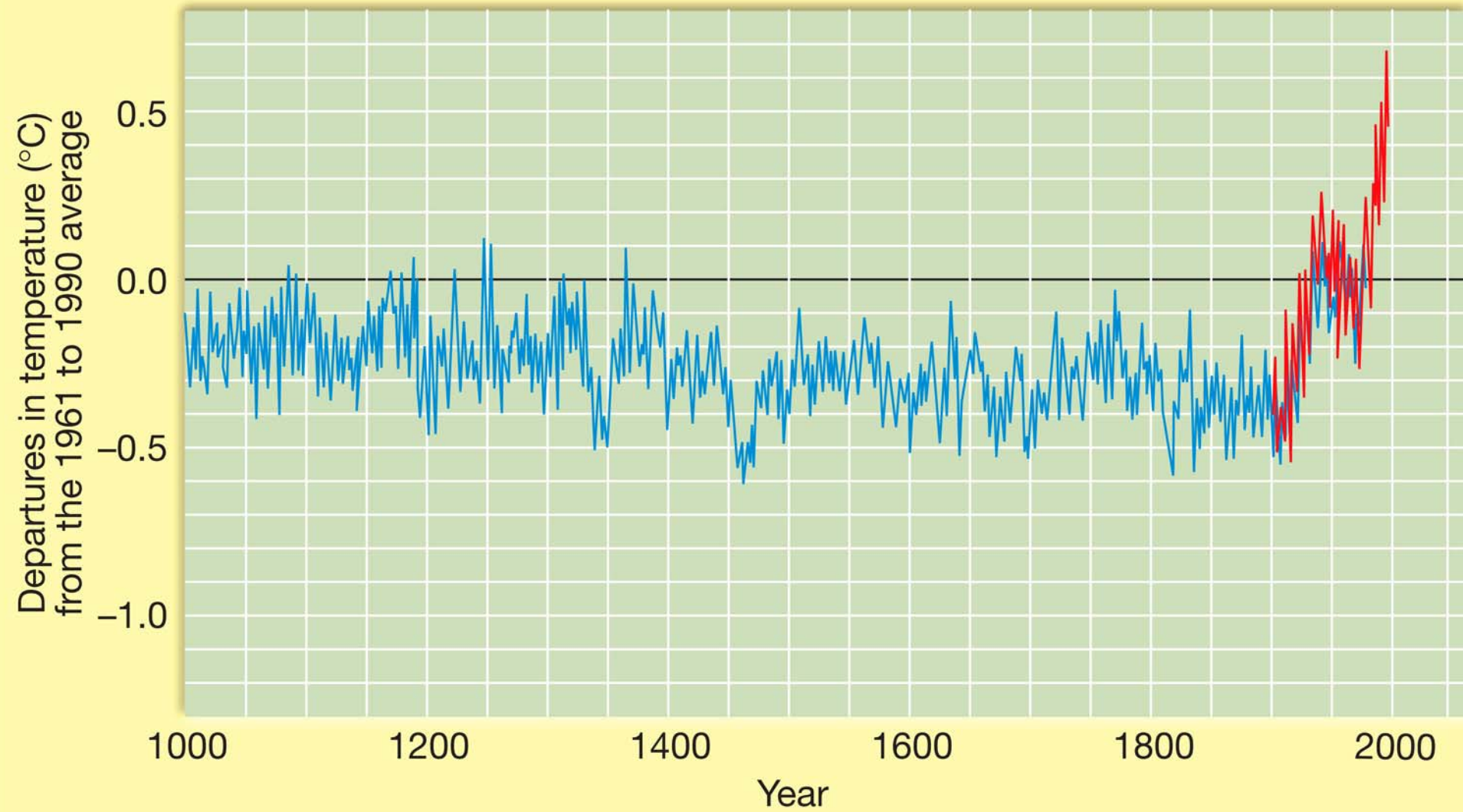
Increase in surface temperature

- Methane increase
 - From agriculture
 - From warming of permafrost (but more formed on sea floor, causing reduction?)
- Ozone depletion allowing more energy to reach Earth's surface
- Variance in solar intensity
- Positive feedback mechanisms
 - Albedo decline results in warming
 - Increased temperature causes more rainfall and reduces iron fertilization of sea



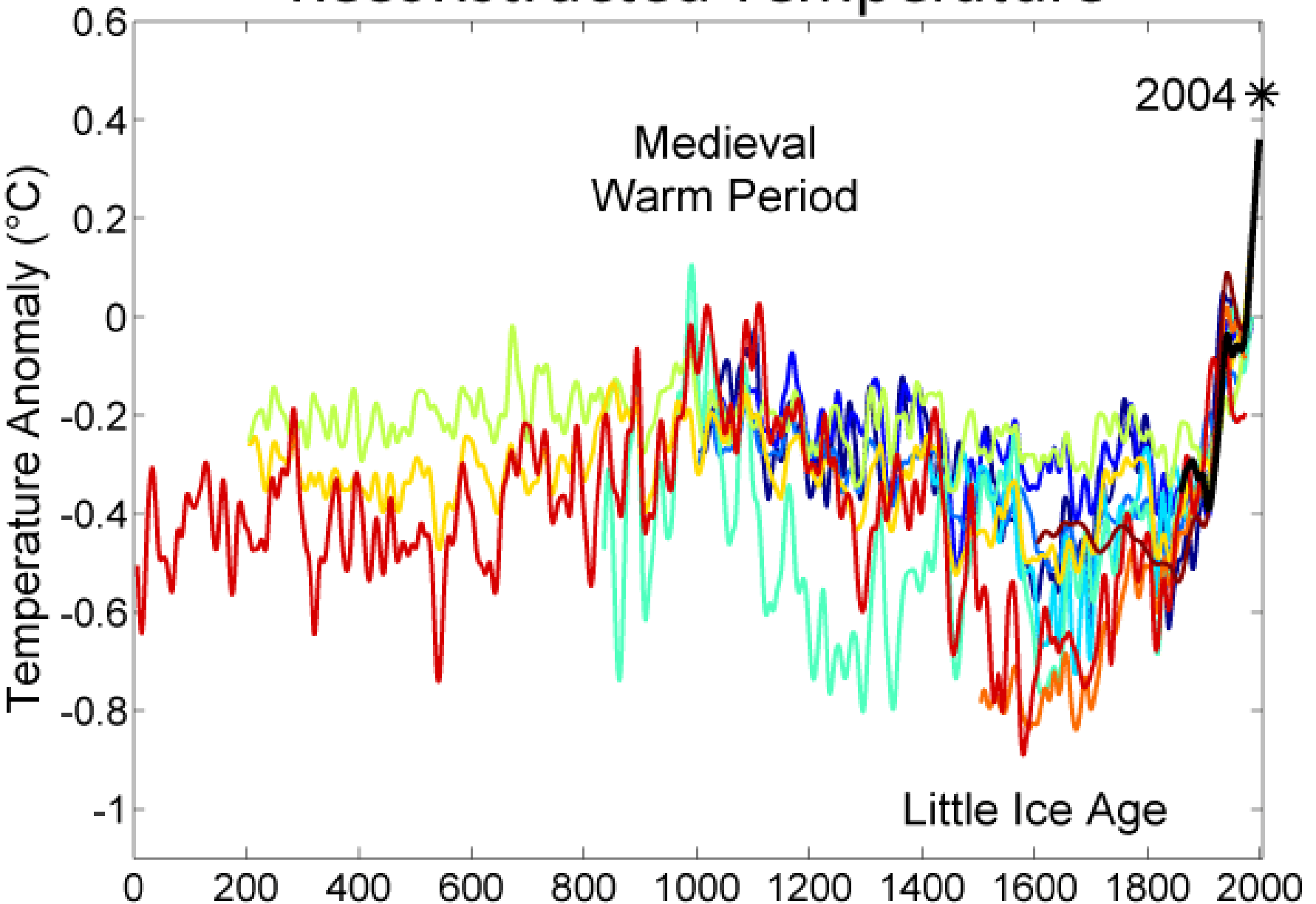


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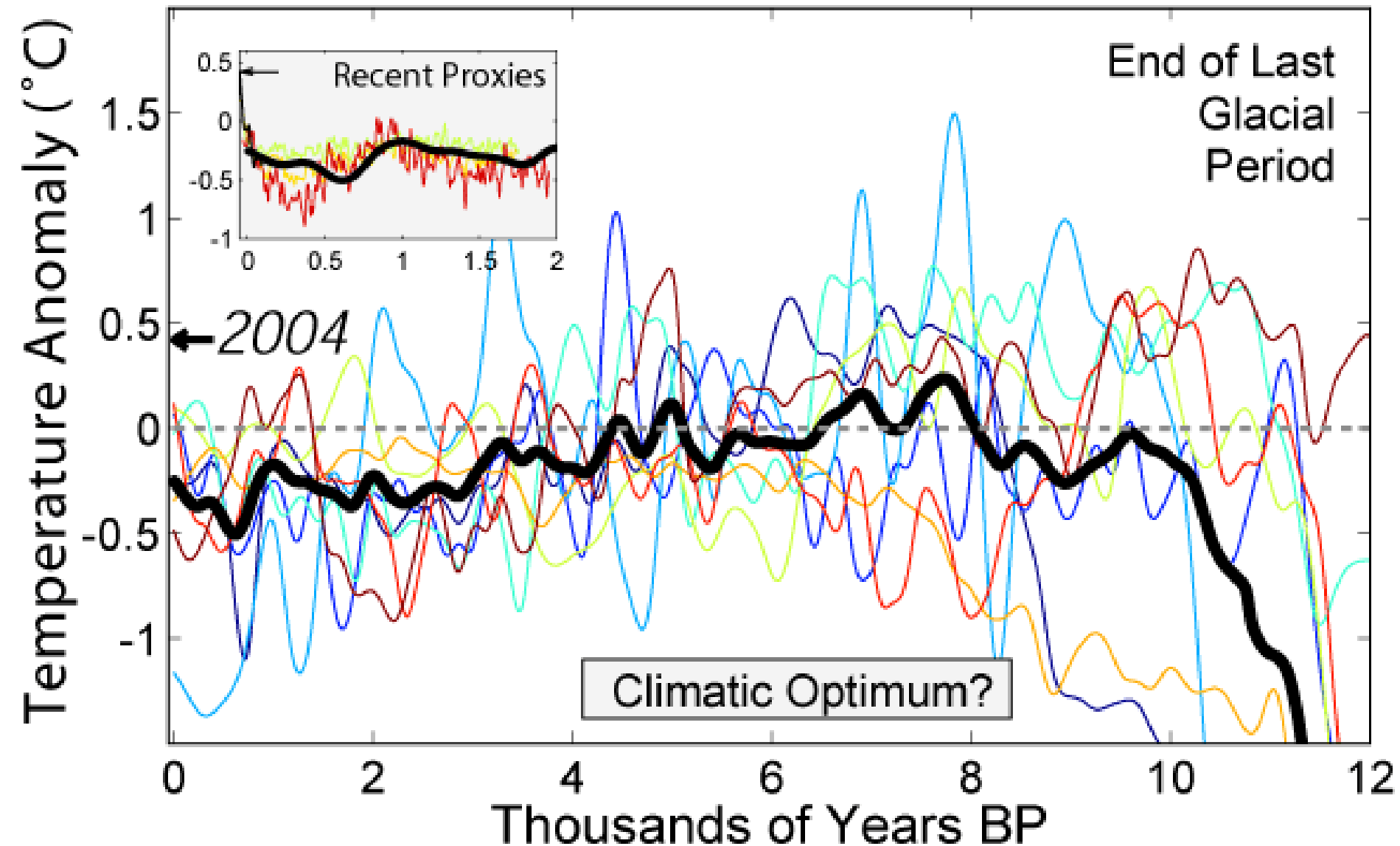


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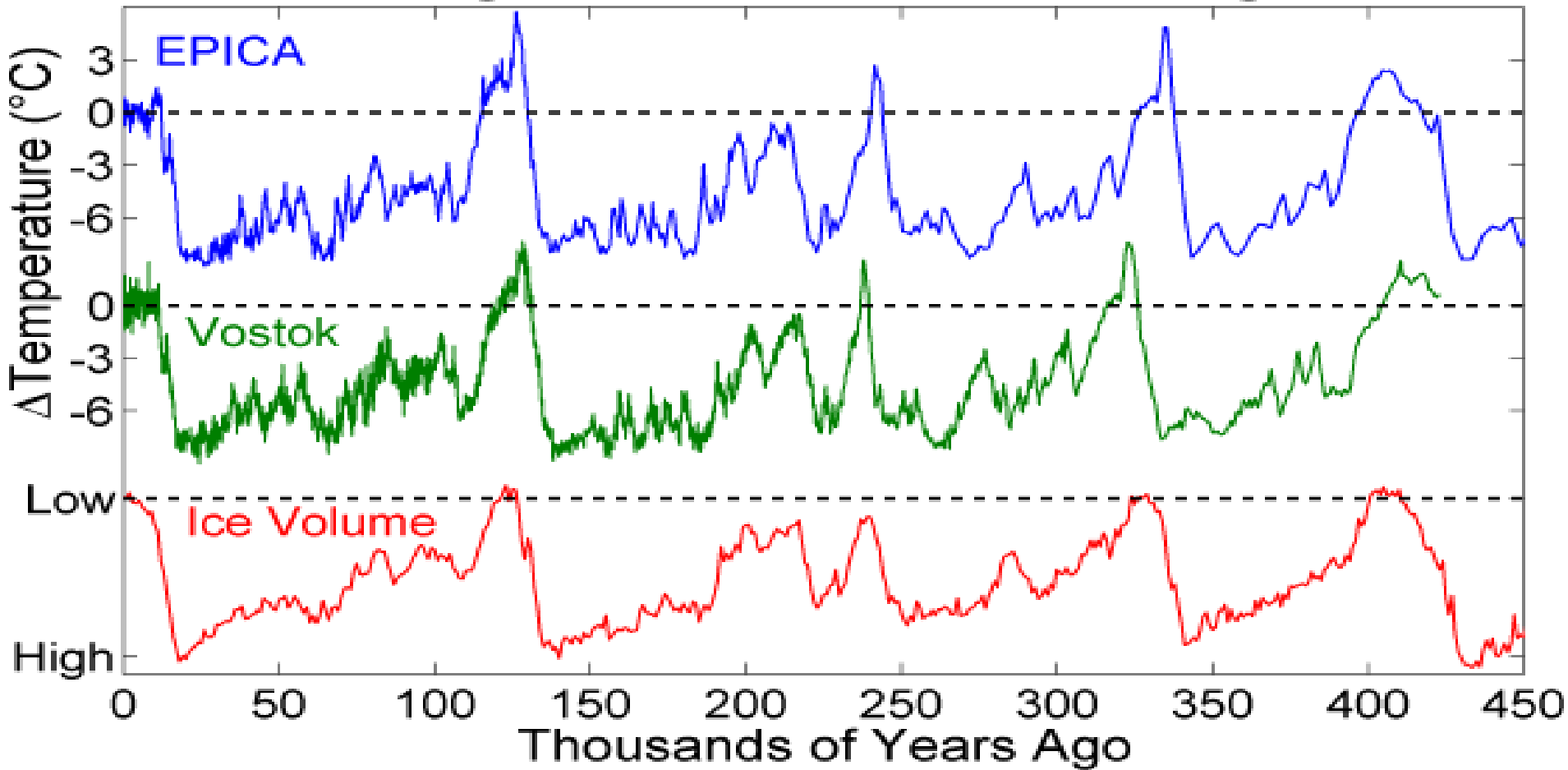
Reconstructed Temperature



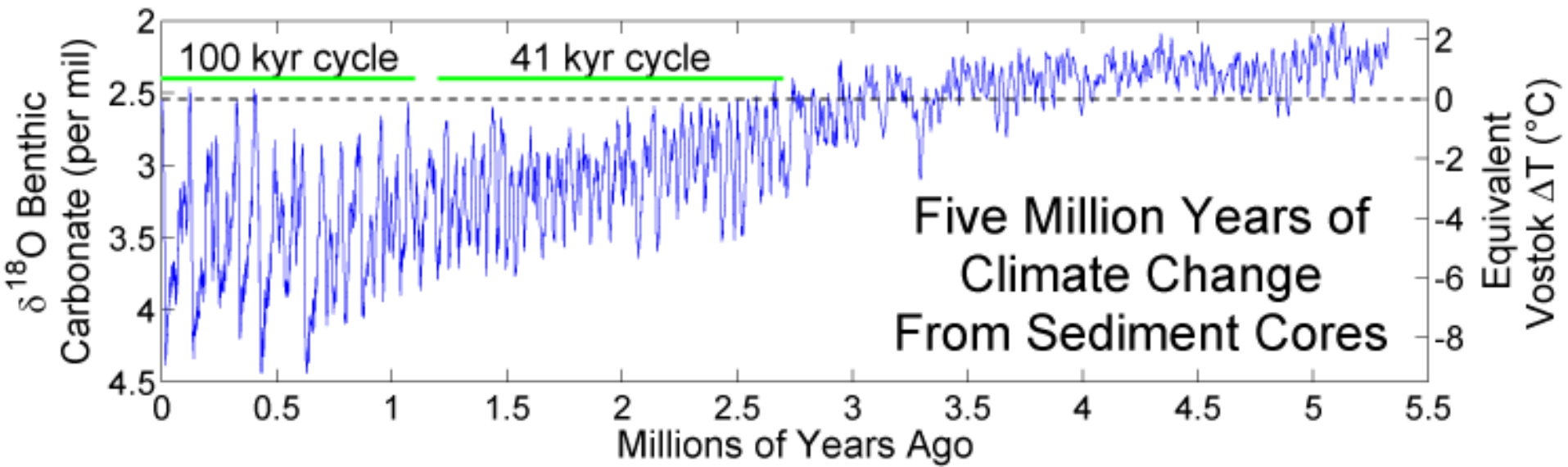
Holocene Temperature Variations

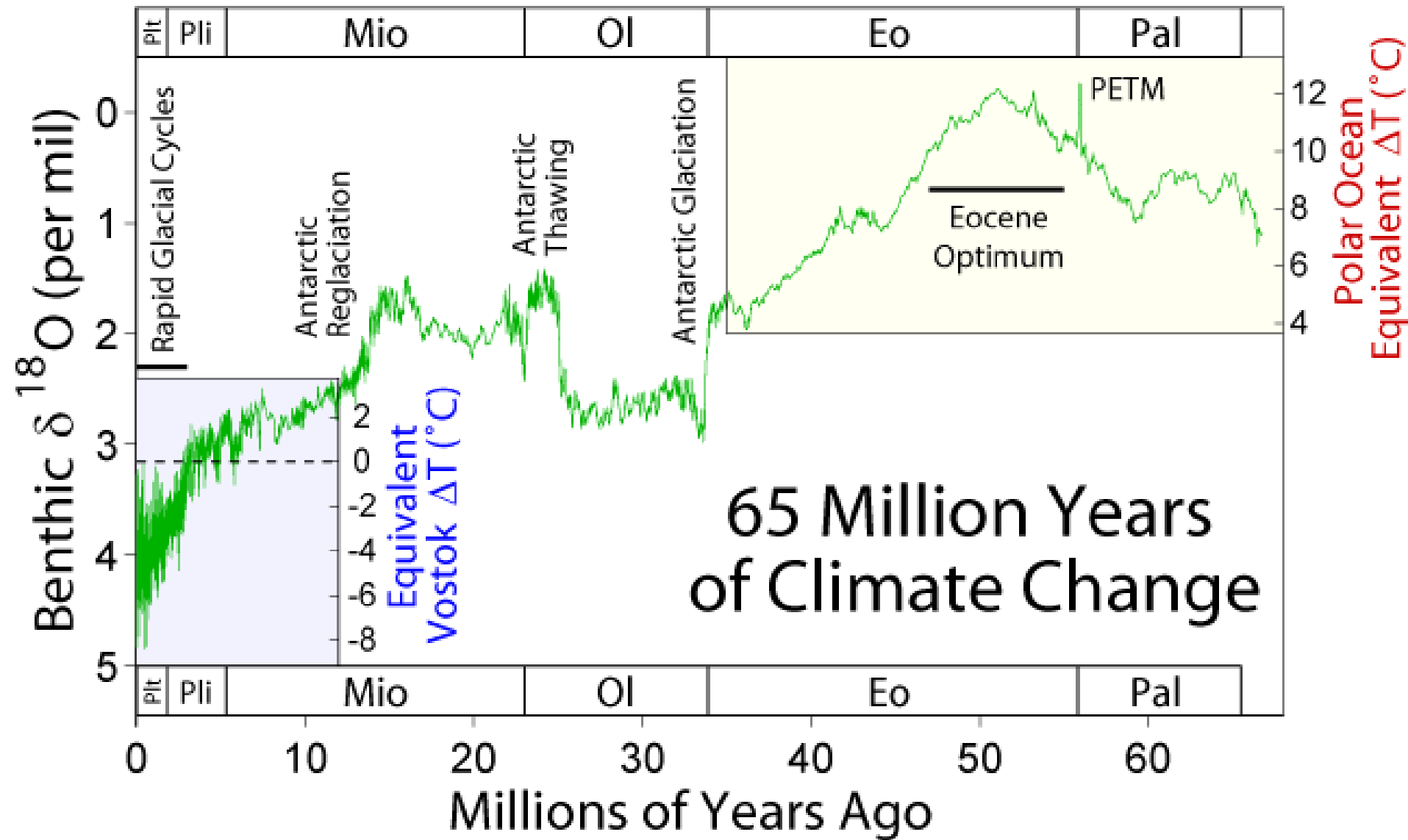


Ice Age Temperature Changes

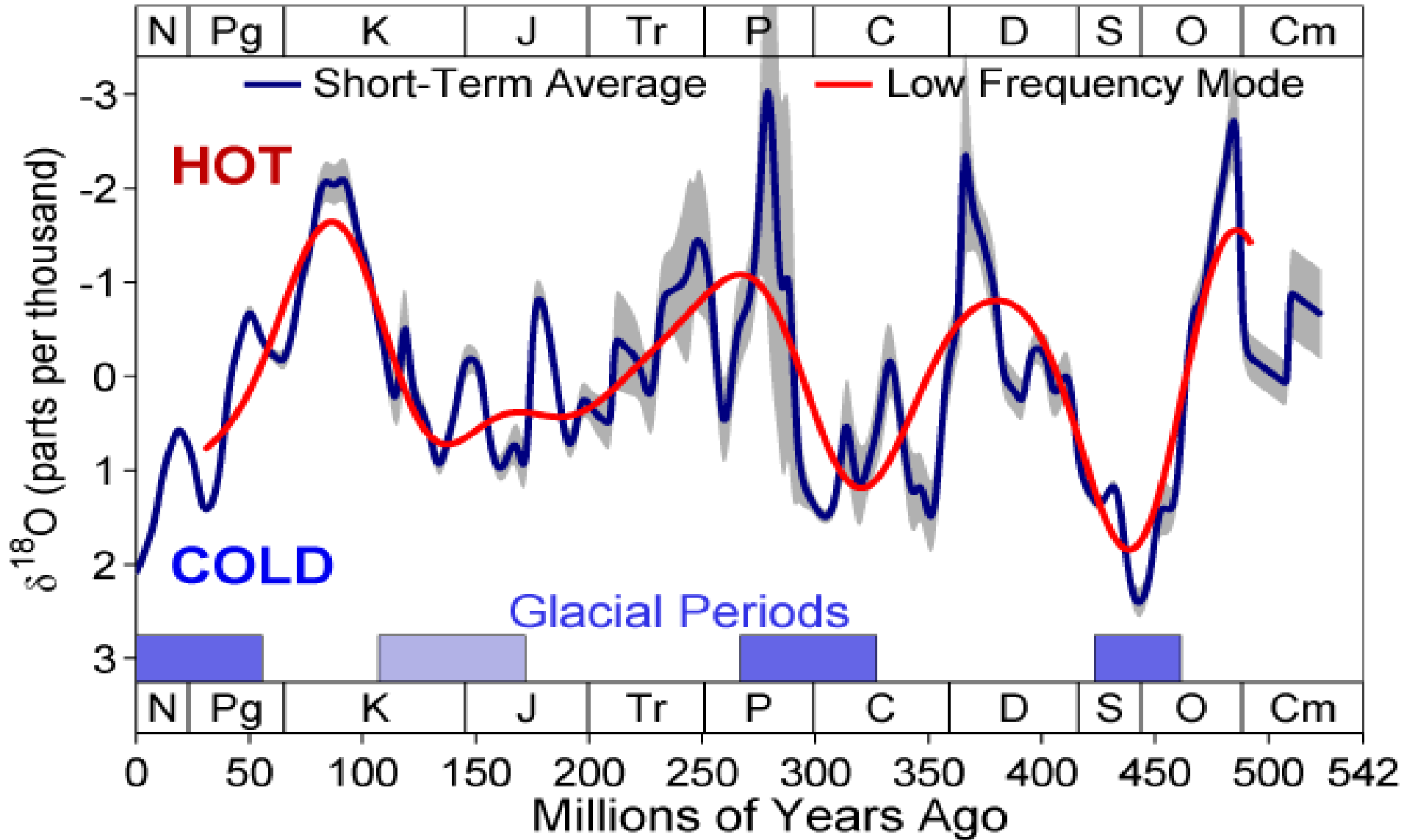


- Curves of reconstructed temperature at two locations in Antarctica and a global record of variations in glacial ice volume. Today's date is on the left side of the graph

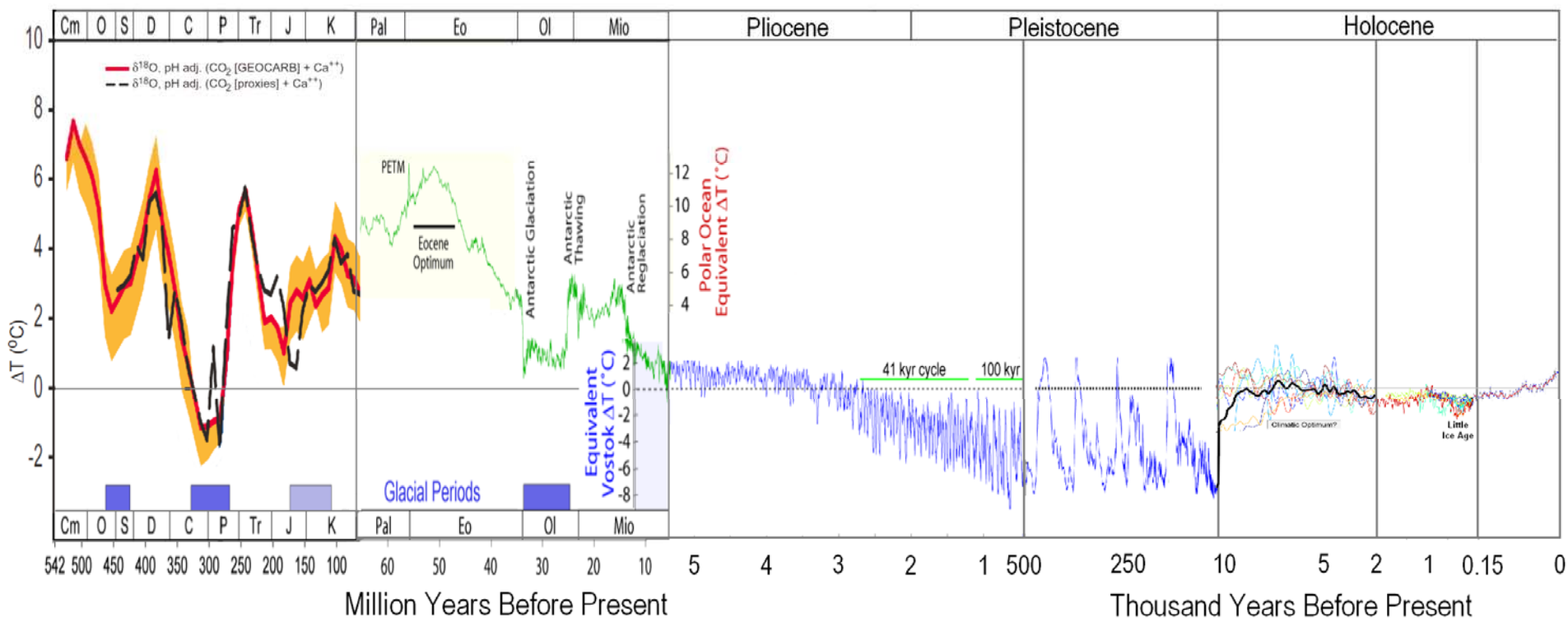




Phanerozoic Climate Change



Temperature of Planet Earth



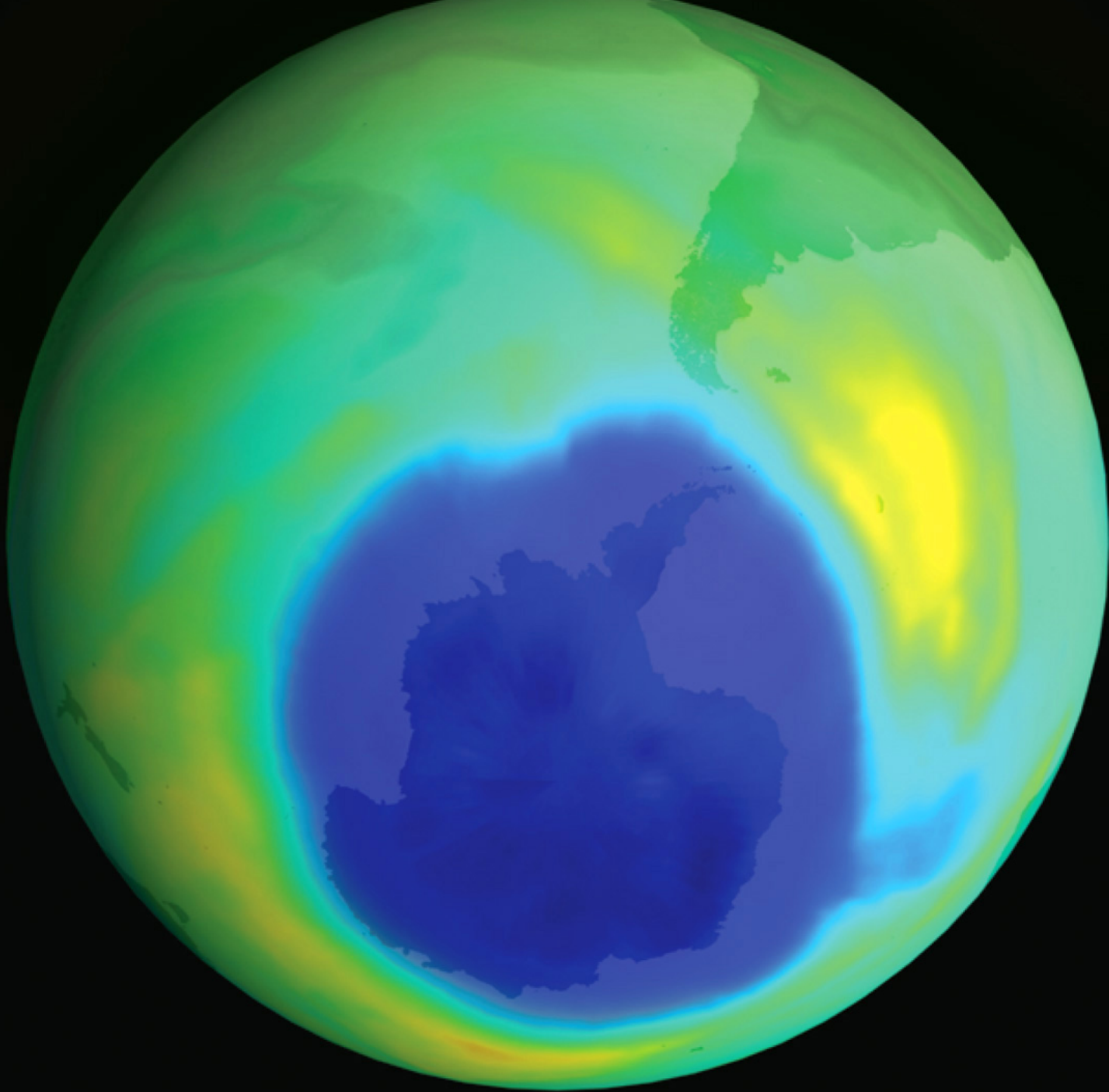
Other greenhouse gases

- Water vapor
- Methane
- Chlorofluorocarbons (CFCs)
- Nitrogen oxides

Carbon Dioxide-Water system

- $\uparrow \text{CO}_2 \rightarrow \uparrow T \rightarrow \uparrow \text{evaporation} \rightarrow \uparrow T$
- $\uparrow \text{evaporation} \rightarrow \uparrow \text{cloud cover, albedo}$
 $\rightarrow \downarrow T$
- Positive outweighs negative feed back



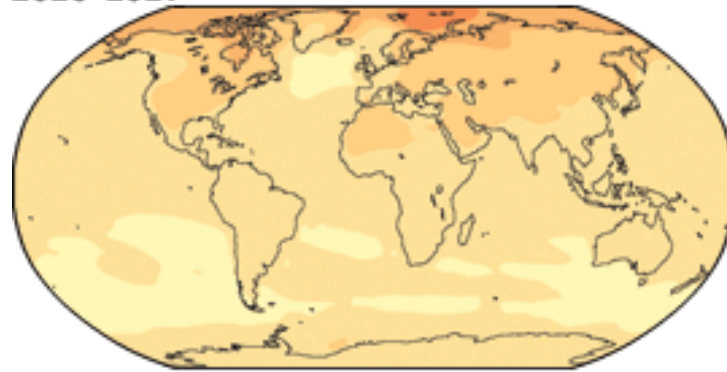




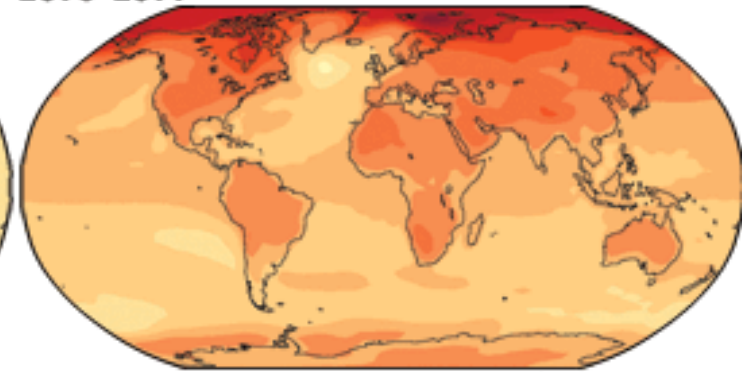
Increase in surface temperature

- Sea level rise
- Shift in climate zones
- Increased intensity of cyclones:
both tropical and midlatitude

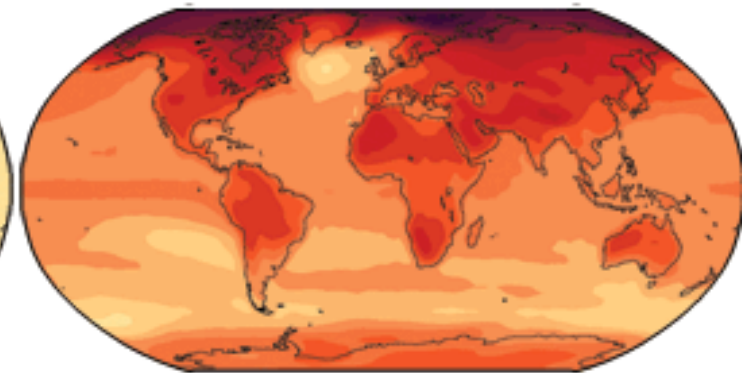
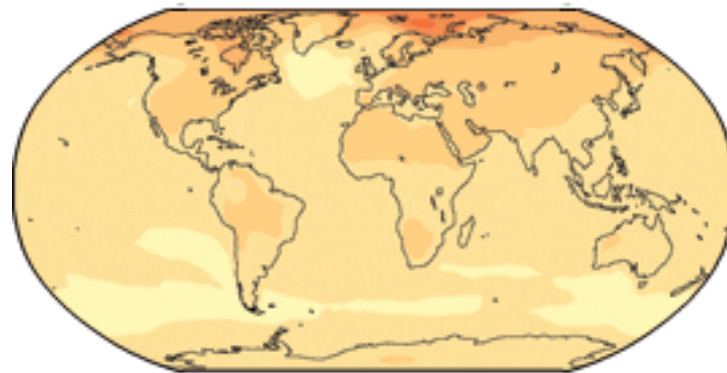
2020-2029



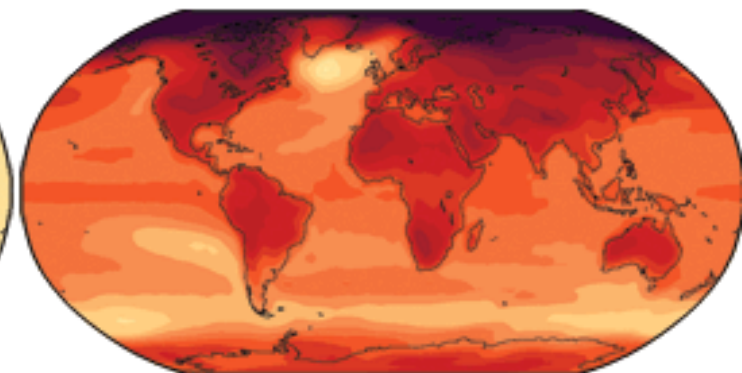
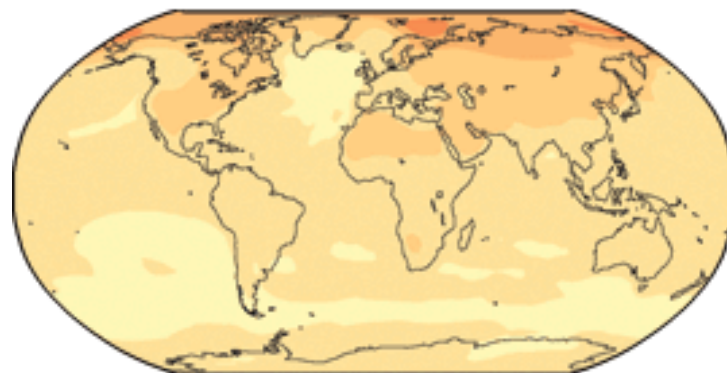
2090-2099



low growth (B1)



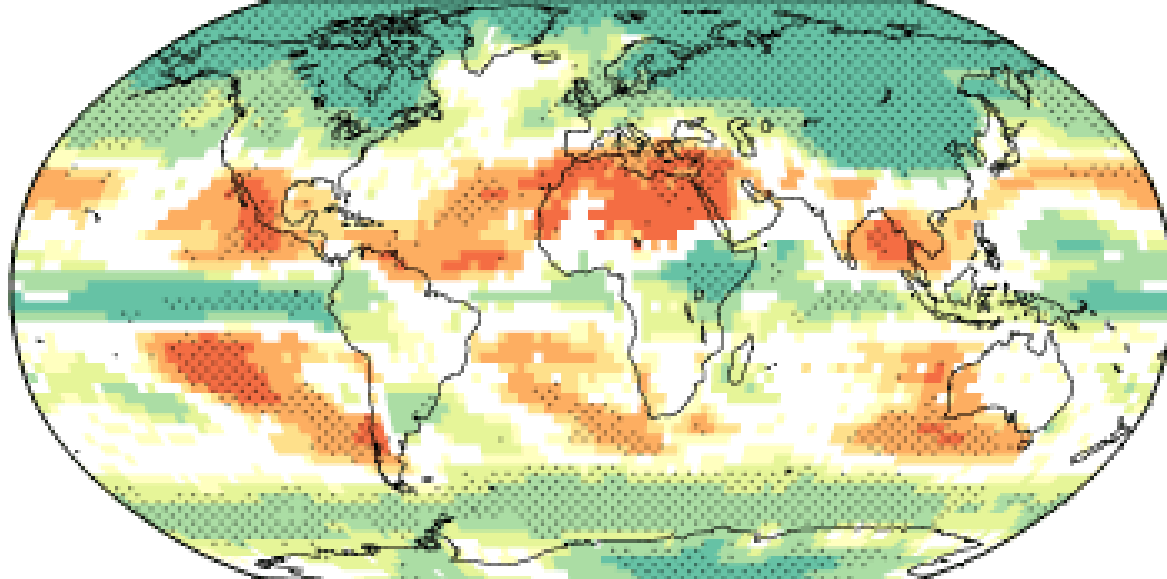
moderate growth (A1B)



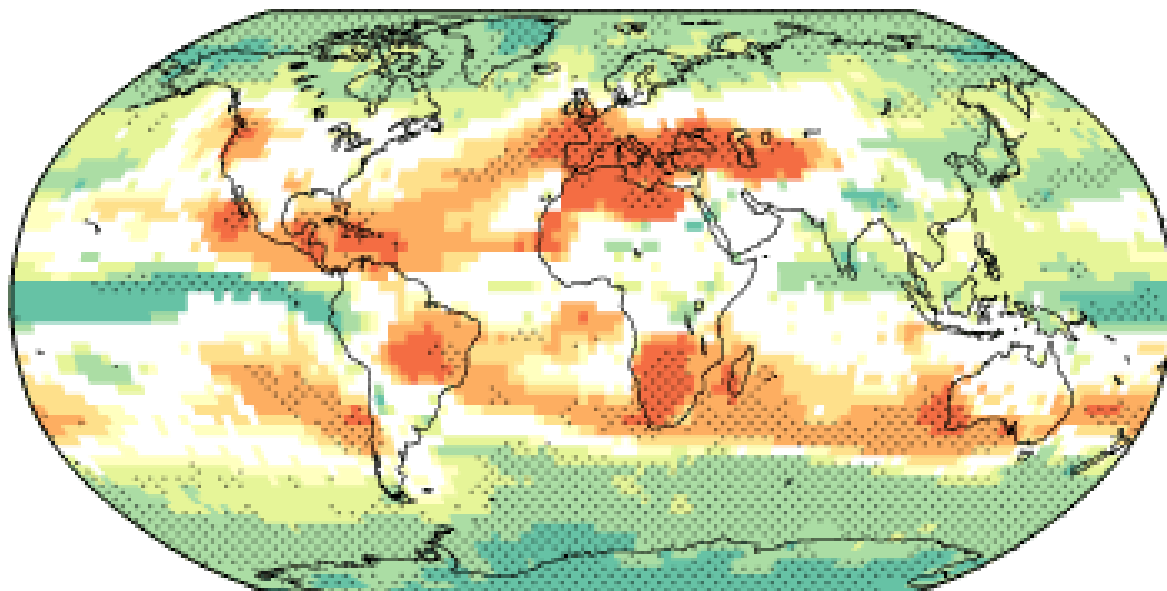
high growth (A2)

Surface Temperature Change (°C)



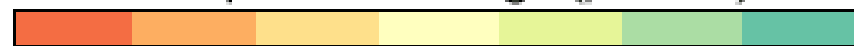


December, January, February

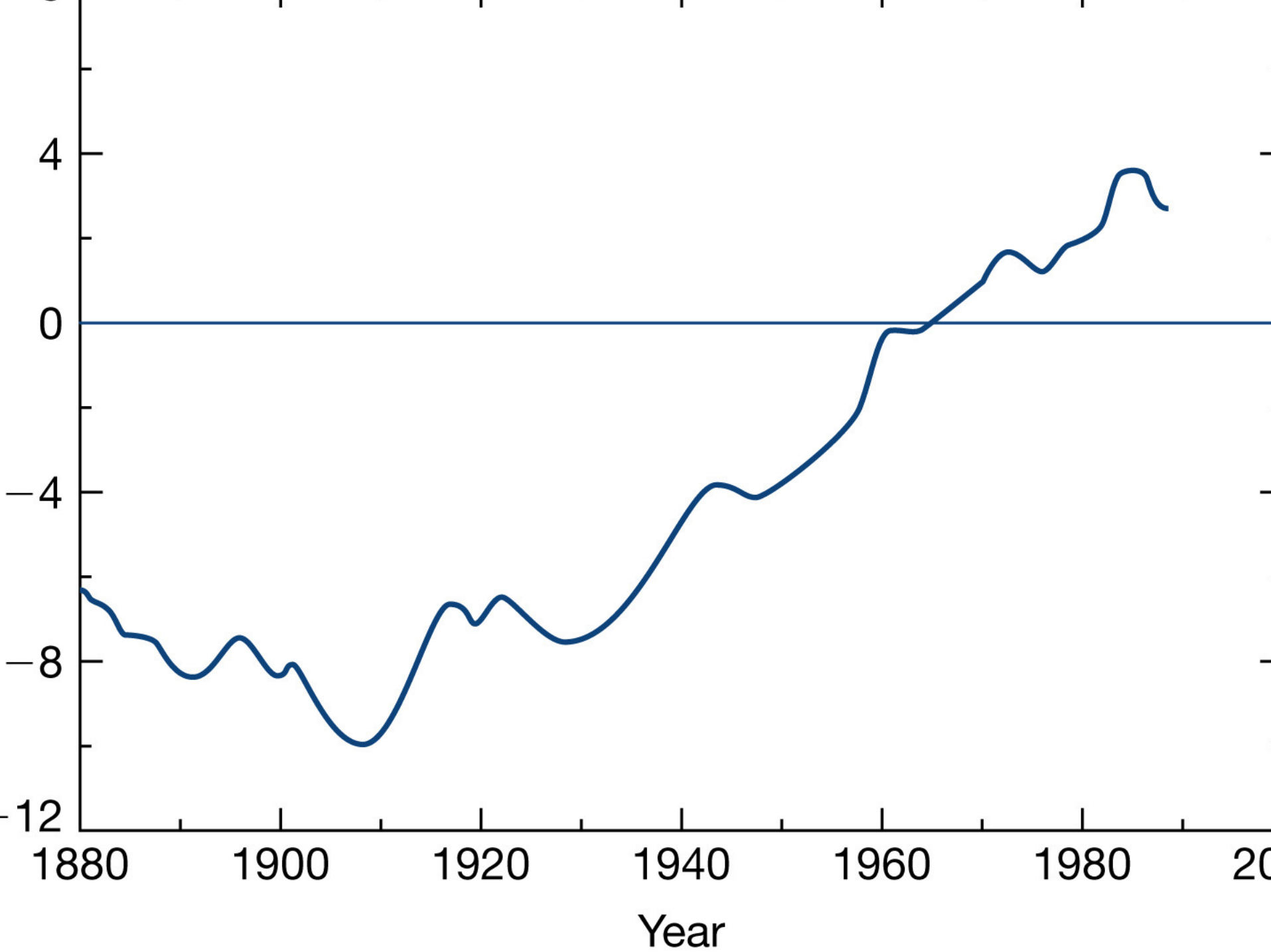


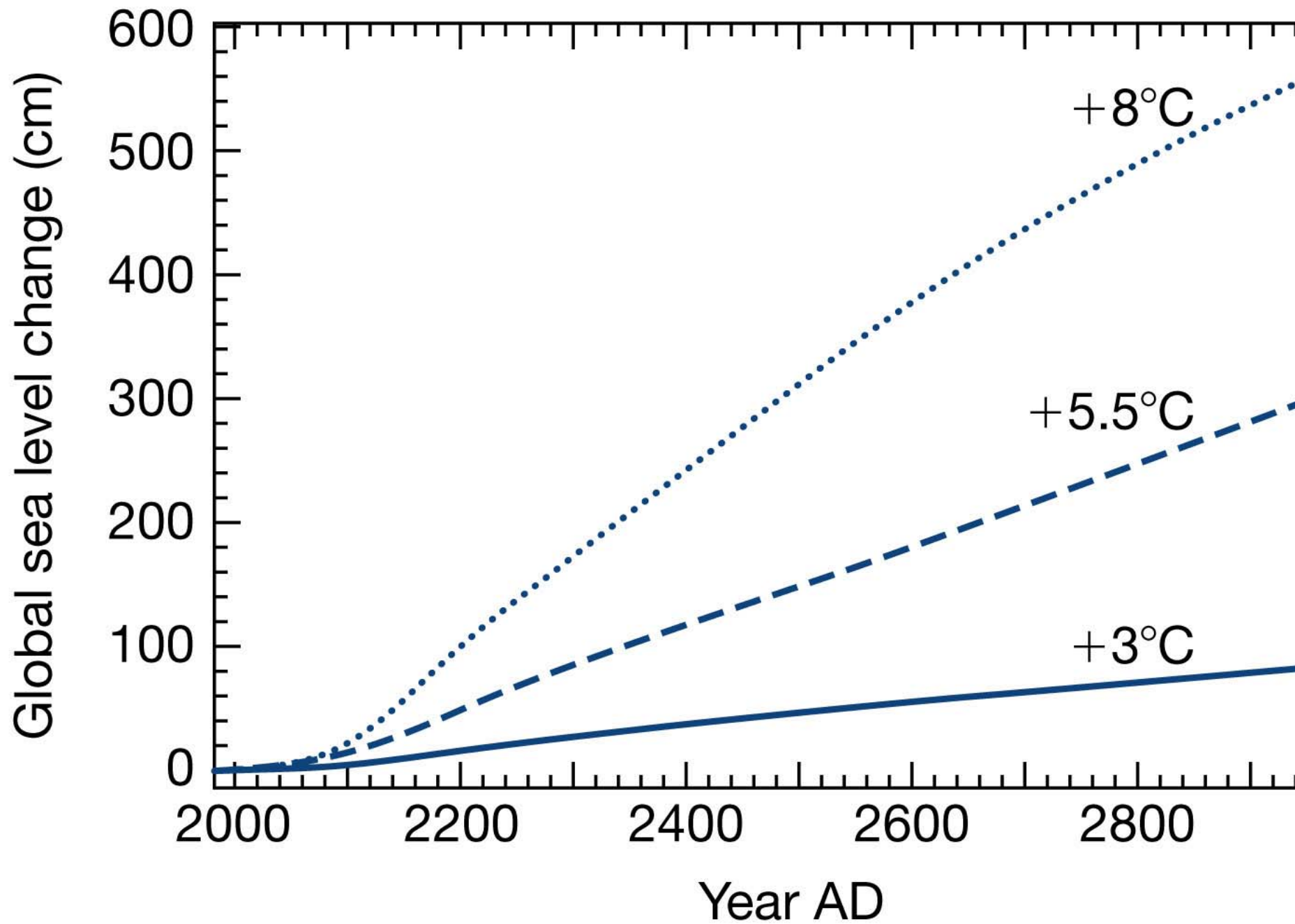
June, July, August

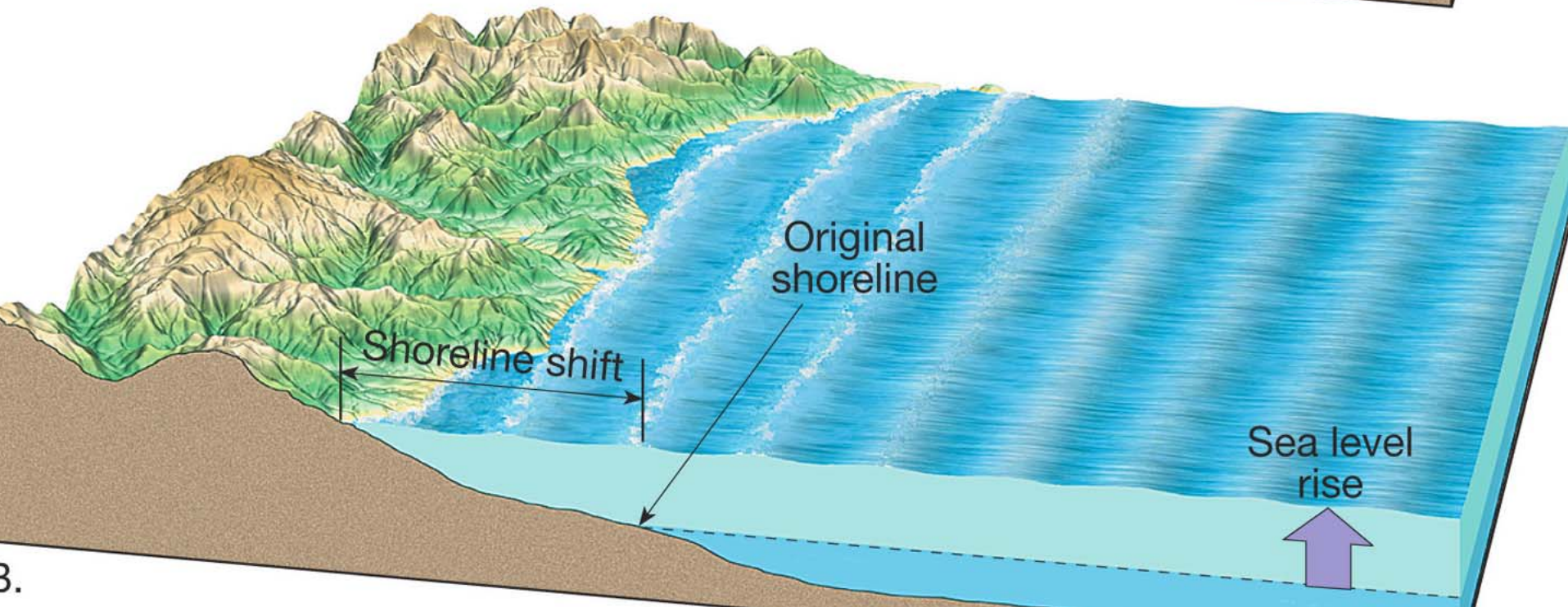
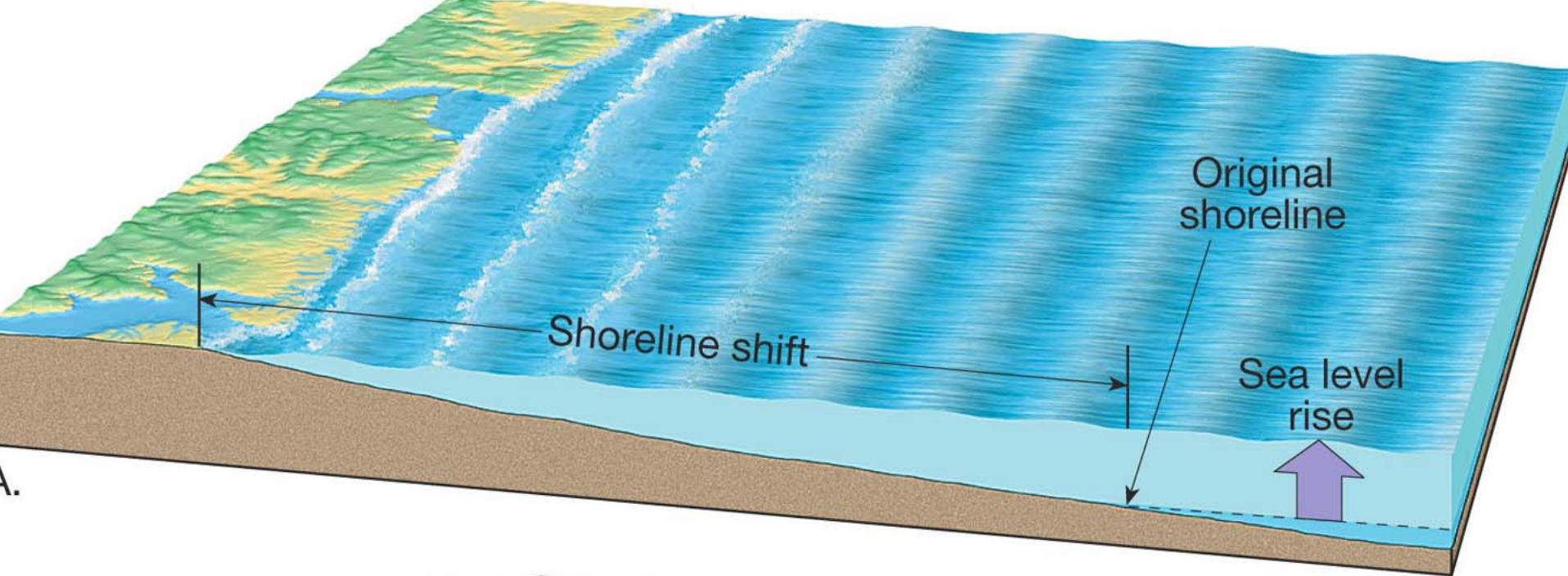
Precipitation Change (percent)



-20 -10 -5 +5 +10 +20









Mitigation

- Reduce fossil fuel use
- Alternative fuels
 - Nuclear power
 - Renewable sources
 - Geothermal
 - Water power
- Plants
 - Forests: reduce logging, plant trees
 - Algae: fertilize sea removes CO₂
 - Biomass energy sources

Current nuclear plant capabilities by country

- 437 nuclear power reactors in operation in 30 countries. These reactors supply about 15.2% of the world's electricity
- France depends on nuclear power for 78% of its electricity supply. In Japan the figure is 30%.
- Emits only 1–6 grams of carbon equivalent per kilowatt-hour. This is about the same negligible emission rate as wind and hydropower

<http://www.iaea.org/NewsCenter/Statements/2007/ebsp2007n011.html>

Nuclear power

- Safety utmost concern
 - Well designed plants with redundant safety mechanisms installed
 - Well constructed and continual inspection
- Determine method of dealing with waste
 - Deep burial popular but short-sighted
 - recycle or breed to short-half-life substances more reasonable
 - Rockets to space seems dangerous



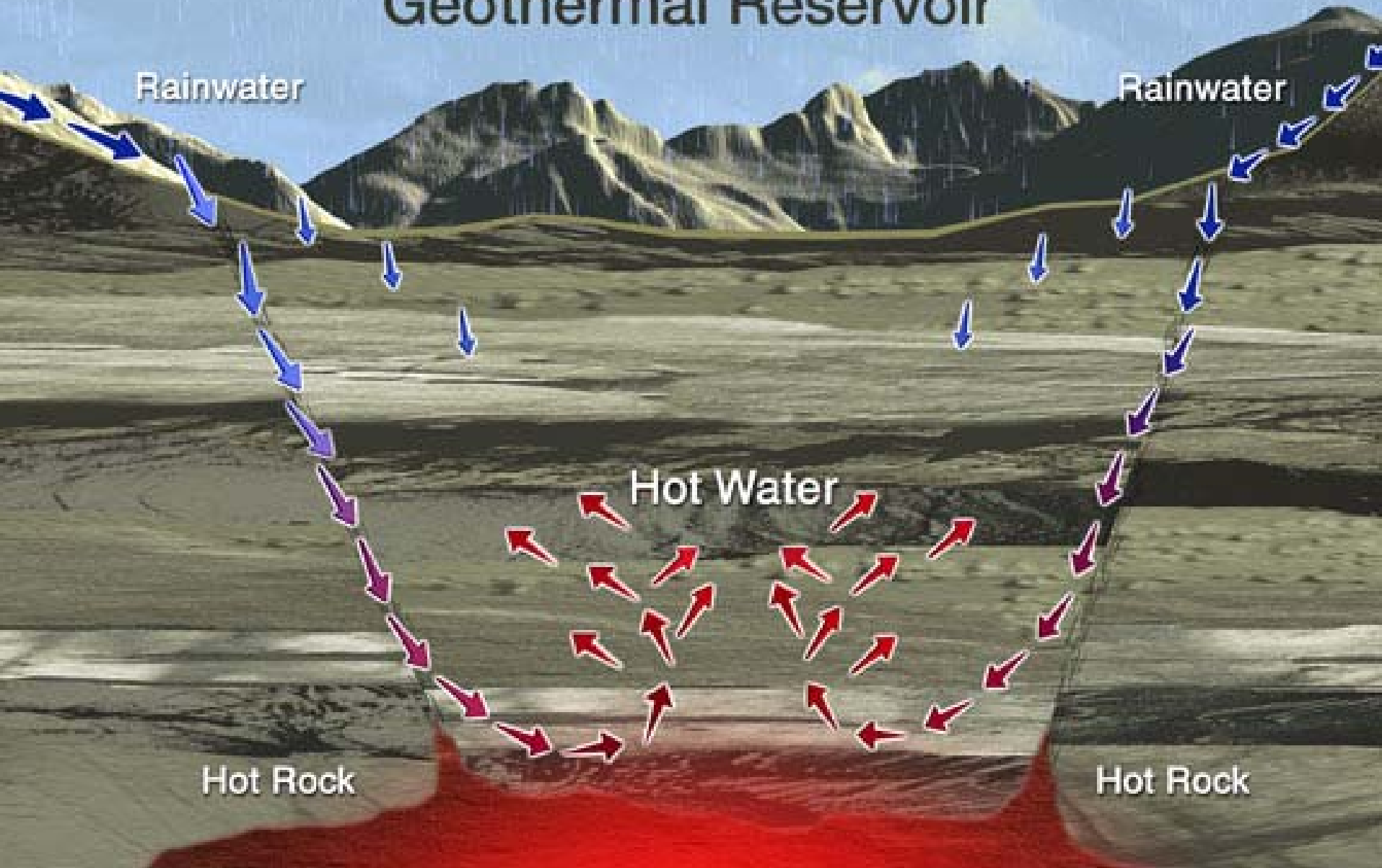
- <http://www.earthship.com/staticpages/index.php?page=sale&osCsid=e2e983564ec7a5b9921a71236bed60c8>
- Building for passive Sun heating
- Photovoltaic and Water heating also incorporated
- Note operable skylight for cooling

Wind Power

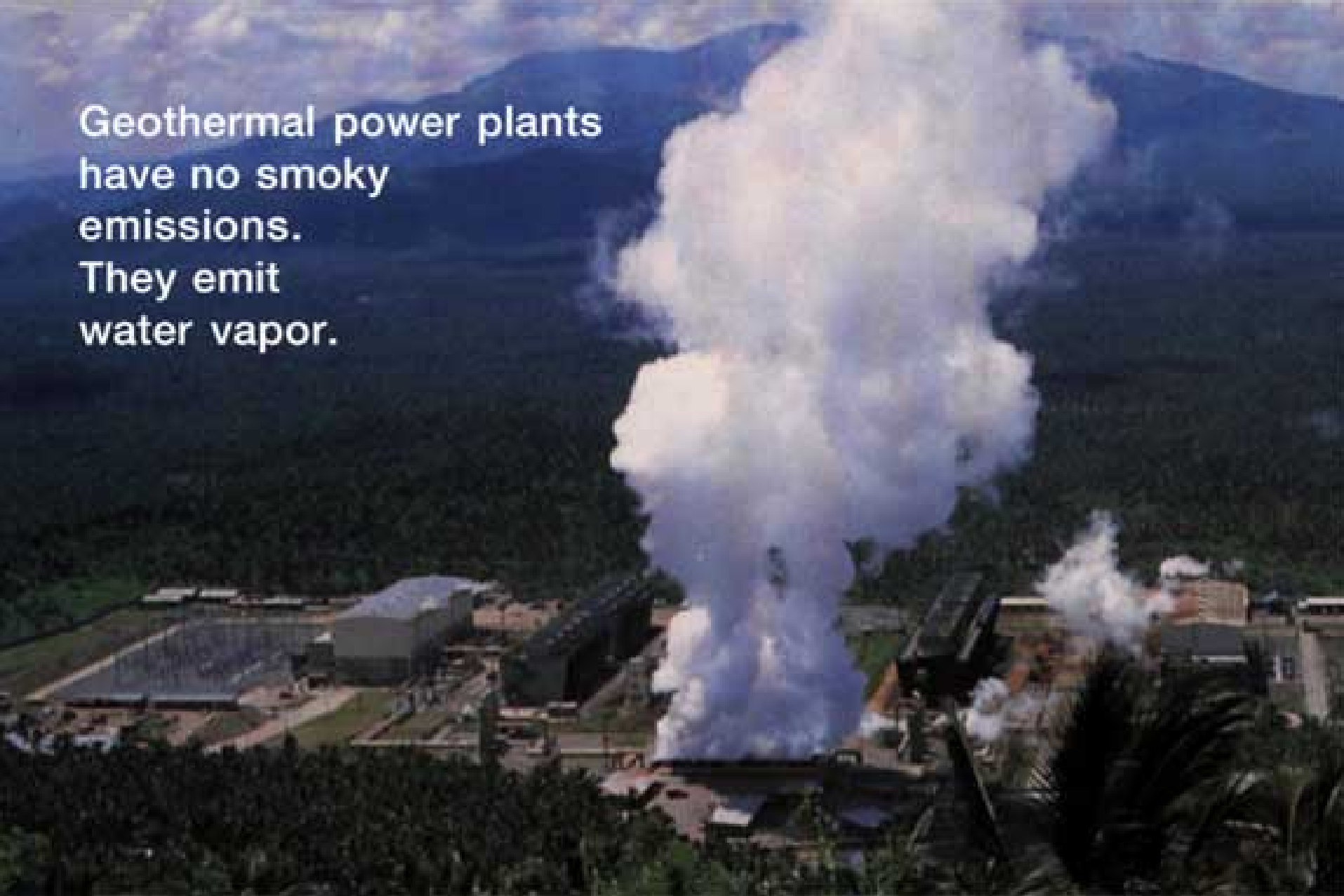


- <http://www.bergey.com/>

Geothermal Reservoir



Geothermal power plants
have no smoky
emissions.
They emit
water vapor.



World's First **COMMERCIAL
FOOD DEHYDRATION PLANT**

TO BE OPERATED WITH GEOTHERMAL ENERGY

SCHEDULED FOR OPERATION SEPT. 1978

FINANCING BY
NEVADA NATIONAL BANK
WELLS FARGO, N.A.

LOAN GUARANTEED BY
U.S. DEPARTMENT of ENERGY

OWNERS & DEVELOPERS
GEOTHERMAL
FOOD PROCESSORS, INC.

Brady Hot Springs, northern Nevada, dries onions for Burger King

<http://geothermal.marin.org/GEOpresentation/sld087.htm>



Reykjavik Using Fossil Fuels

Reykjavik in the 1930s

<http://geothermal.marin.org/GEOpresentation/sld094.htm>

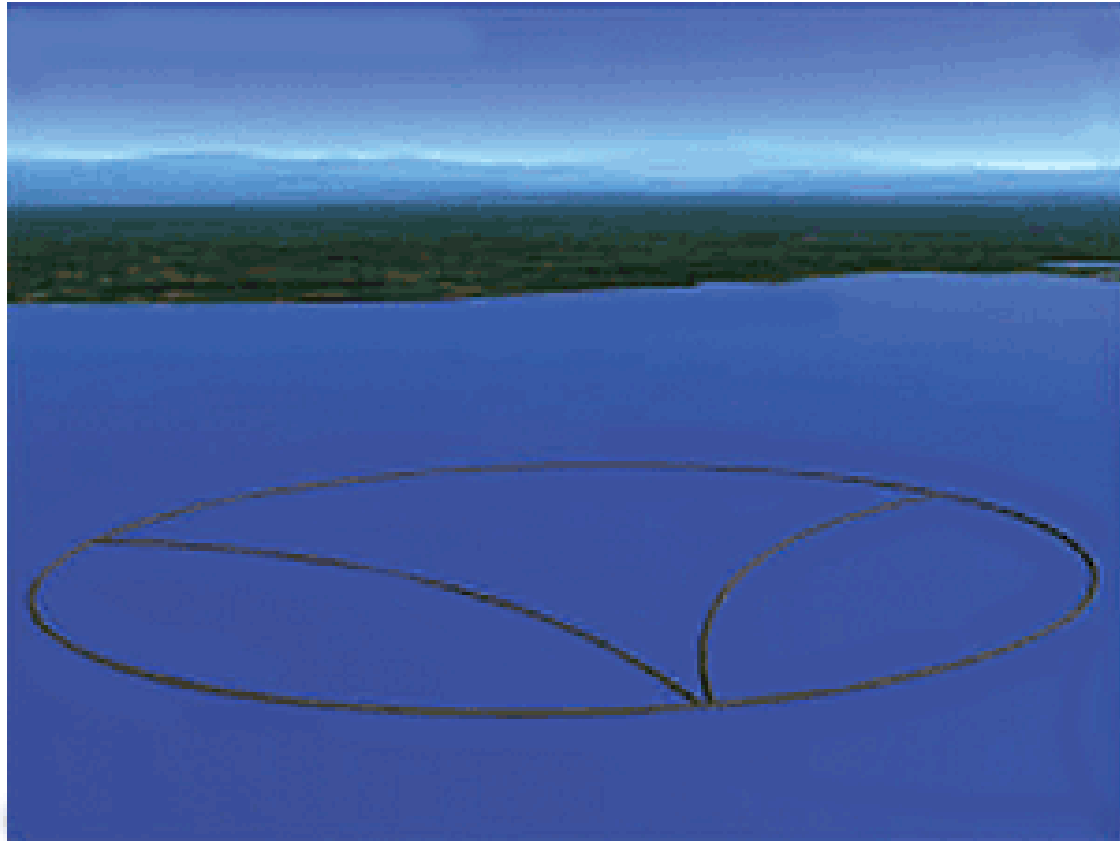


Reykjavik Using Geothermal

Reykjavik today

<http://geothermal.marin.org/GEOpresentation/sld095.htm>

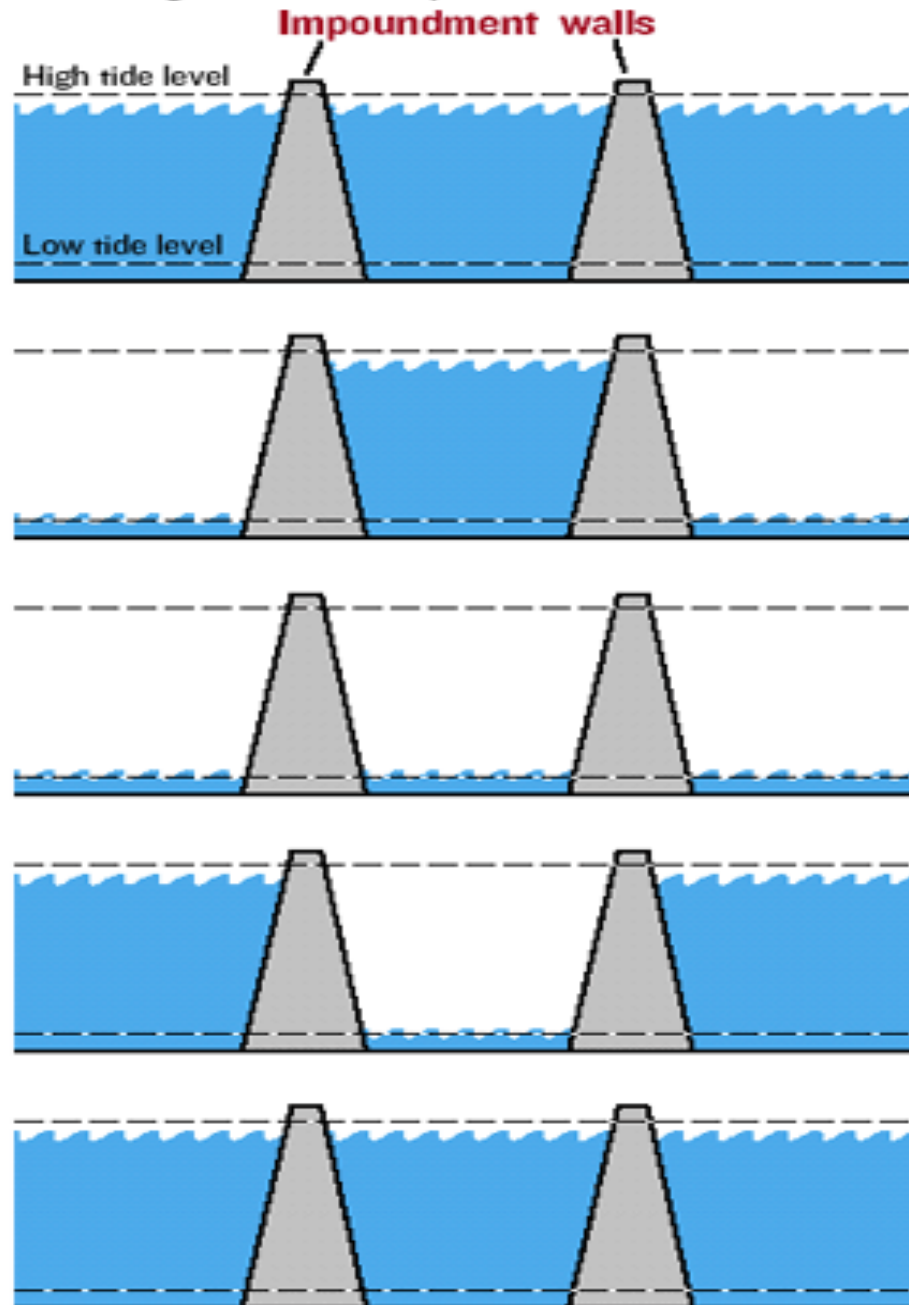
Tidal Lagoon



Artist's impression of a tidal lagoon 2 kilometers offshore.

- <http://www.forbes.com/global/2003/0721/042chart.html>

Power-generation cycle



**Starting point:
High tide,
impoundment full.**



**Tide goes down,
creating "head."**



Power generation.



**Low tide,
impoundment empty.**



**Tide goes up
creating "head."**



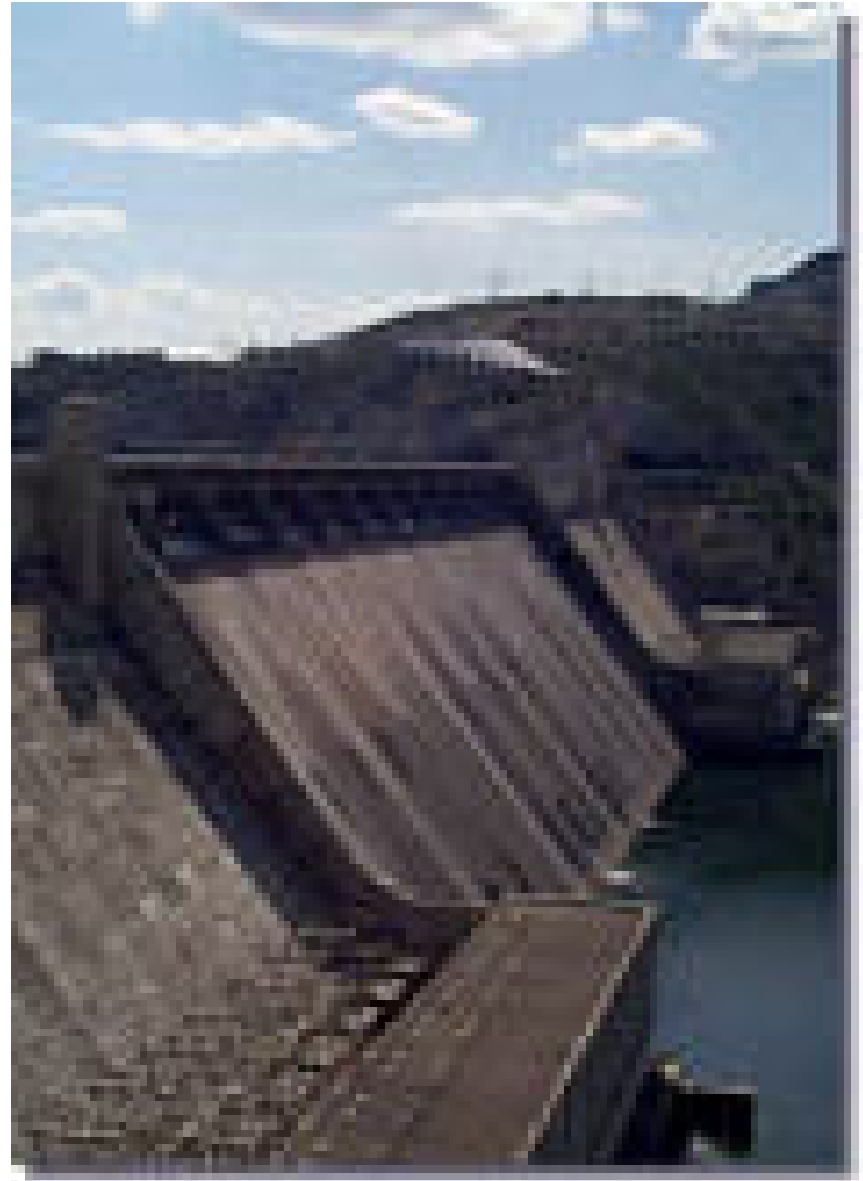
Power generation.



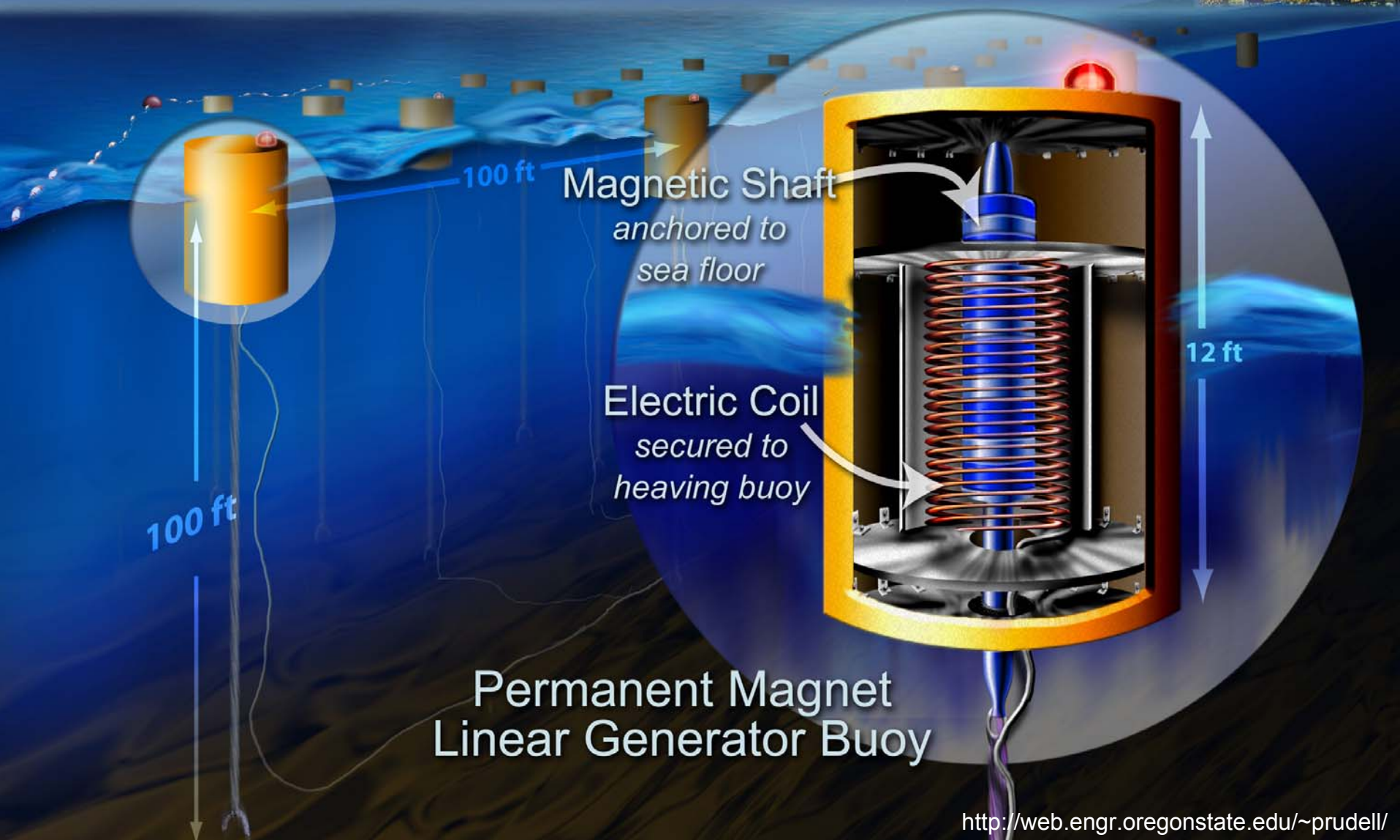
**Return to starting
point.**

Grand Coulee Dam

- Hydroelectric power
- North America's largest concrete structure
- Located on the Columbia River in Central Washington



Oregon State University Conceptual Wave Park



Magnetic Shaft
*anchored to
sea floor*

Electric Coil
*secured to
heaving buoy*

Permanent Magnet
Linear Generator Buoy

Biomass

- Direct burning of plant material
- Oil harvested from seeds
- Plant material converted to
 - Alcohol: methanol and ethanol
 - Converted to methane