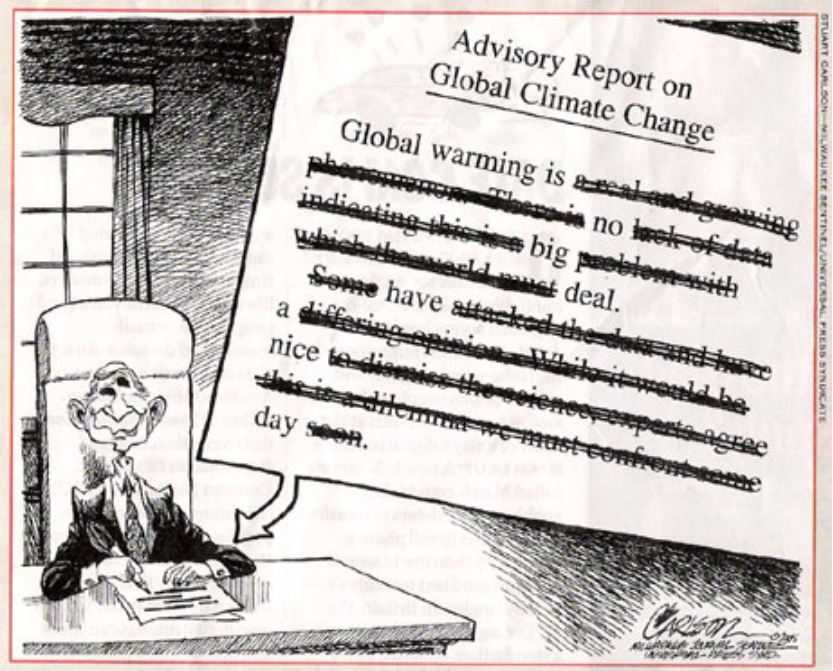
Chapter 14: The Changing Climate

Detecting Climate Change

Natural Causes of Climate Change

Anthropogenic Causes of Climate Change

Possible Consequences of Global Warming



Climate Change?

-Paleo studies show climate varies on every temporal scale

-Human activities are changing climate

-Recent data indicates climate is becoming more variable

-modern record is ~200 years

-satellites 1980s

Measuring Climate Change

-Seafloor sediments

-Oxygen isotope ratios

-Old Soils

-Tree Rings: Dendrochronology

-Historical documents

Sea-Floor Sediments

Organisms at the surface

Balance between ocean surface waters and the atmosphere

As climate changes so does the composition of the surface organisms

Recorded in sediments as the organisms die

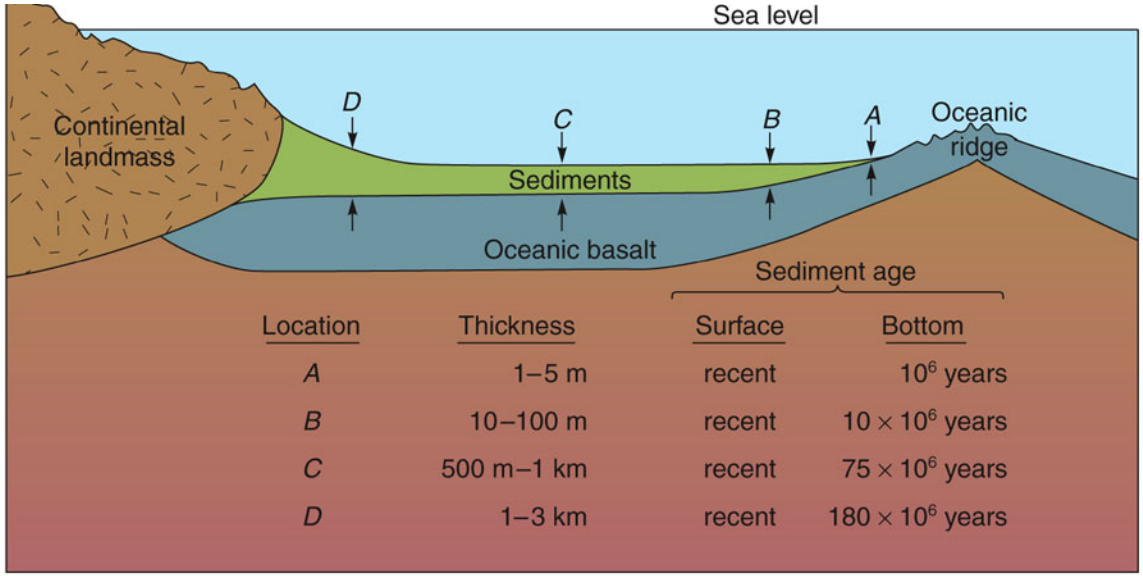
Rates of Sedimentation

0.5 – 1.0 cm/ 1000 years

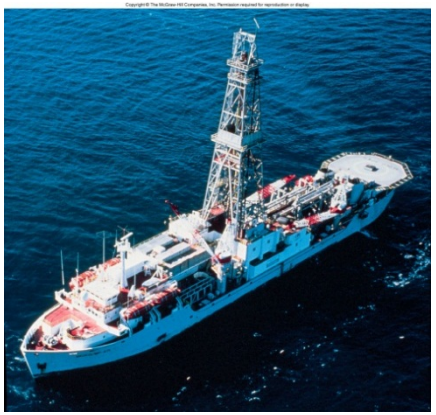
Average Accumulation 500 – 600 m

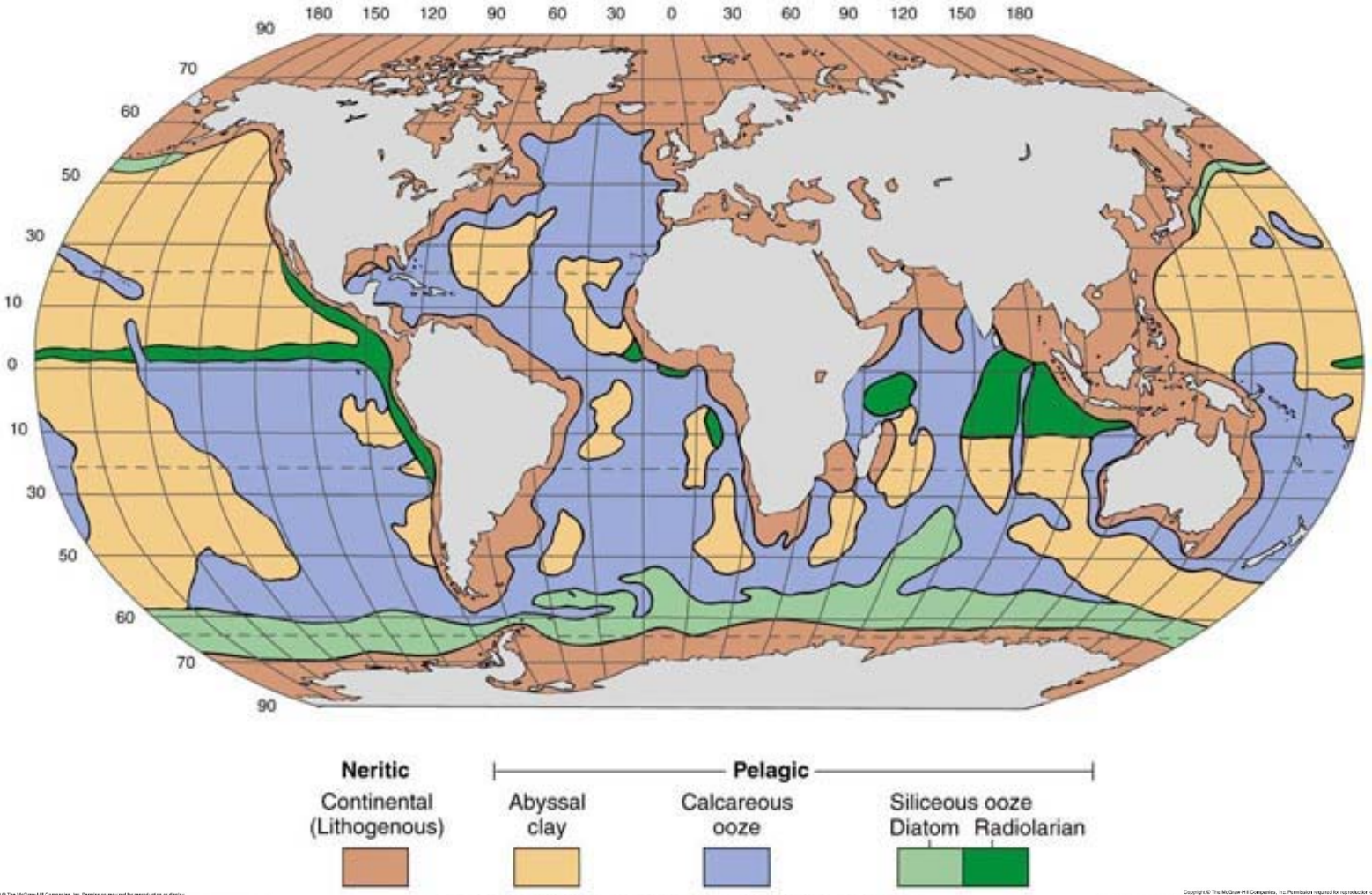
Thickness depends on age

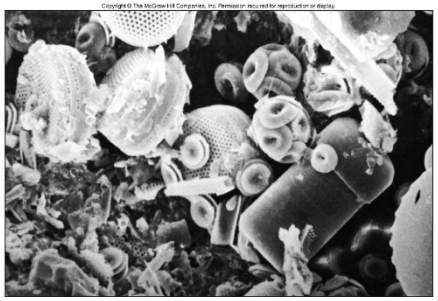
Oldest sea floor is 200 million years



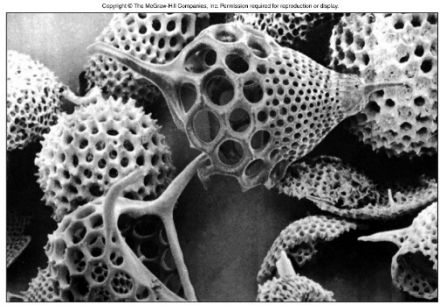
Location	Thickness	Surface	Bottom
A	1–5 m	recent	10^6 years
B	10–100 m	recent	10×10^6 years
C	500 m–1 km	recent	75×10^6 years
D	1–3 km	recent	180×10^6 years







Calcareous ($CaCO_3$)



Siliceous (SiO_2)

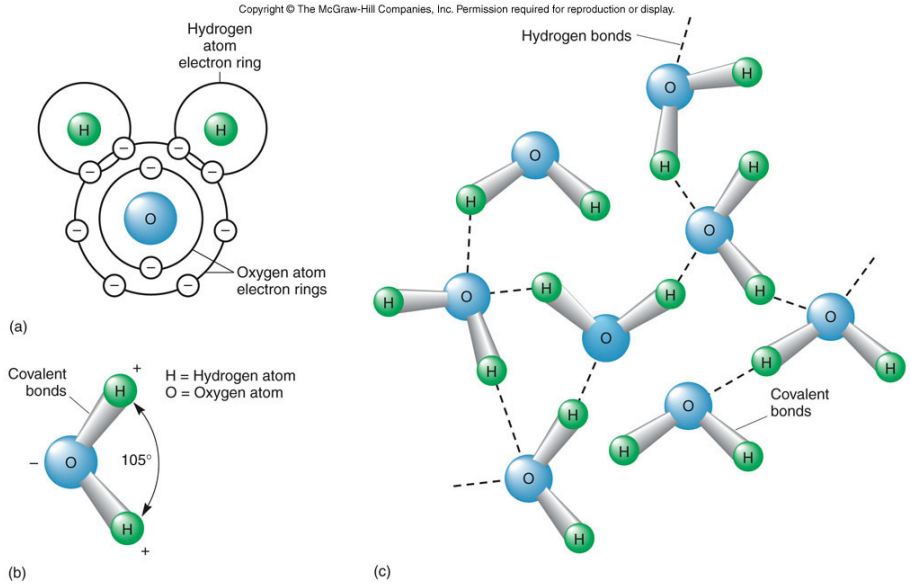
Oxygen Isotope Analysis from Ice Cores

Isotope = One of two or more atoms having the same atomic number (number of protons) but different mass numbers (protons + neutrons)

^{18}O ^{16}O ratios

Water forms with either

^{16}O evaporates easier



Oxygen Isotope Analysis from Ice Cores

Precipitation & glacial ice are enriched in ^{16}O

Oceans are enriched in ^{18}O

Ocean

^{18}O ice ages

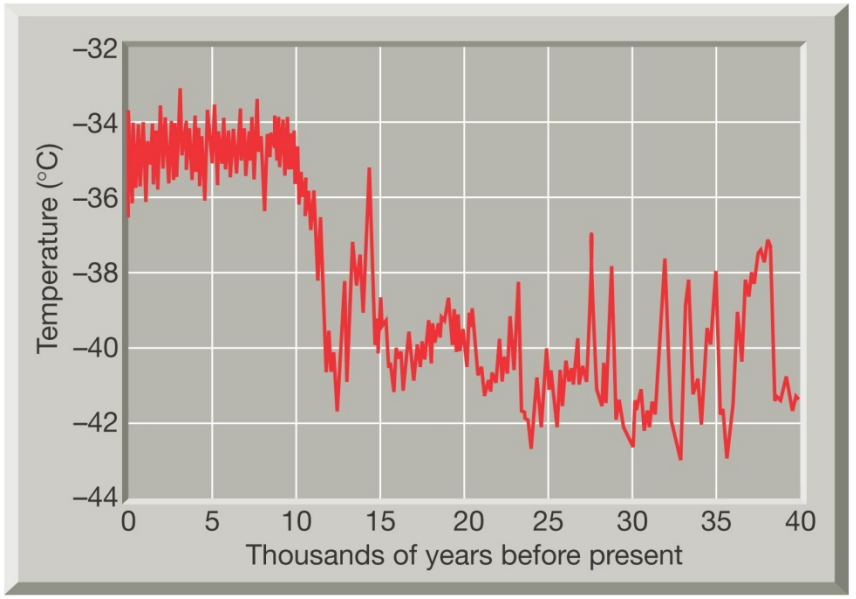
^{16}O increases warmer periods

cocolithophorids, pteropods, foraminifera = record ratios in their shells ($CaCO_3$)

Oxygen Isotope Analysis

Temperature Variations

^{18}O more easily evaporated during warm periods



Ice cores record the warm periods

Pockets of air within the crystal lattice yield gasses (CO_2 and CH_4), pollen, ash, pollutants

Link between CO_2 and CH_4 concentrations and temperature changes

Natural Causes of Climate Change

-Plate Tectonics

-Volcanic Activity

-Variations in the Earth's orbit

-Solar variability

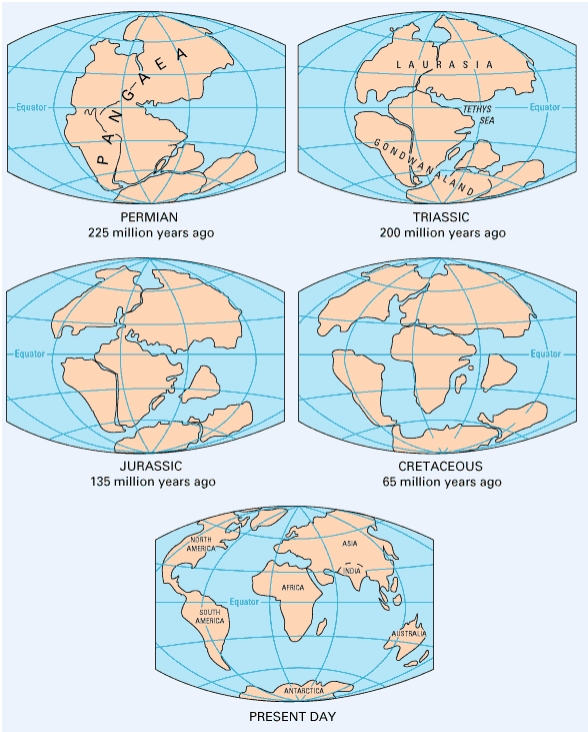
* All theories can explain some portion of climate variability, but no one theory can explain all of the observed changes.

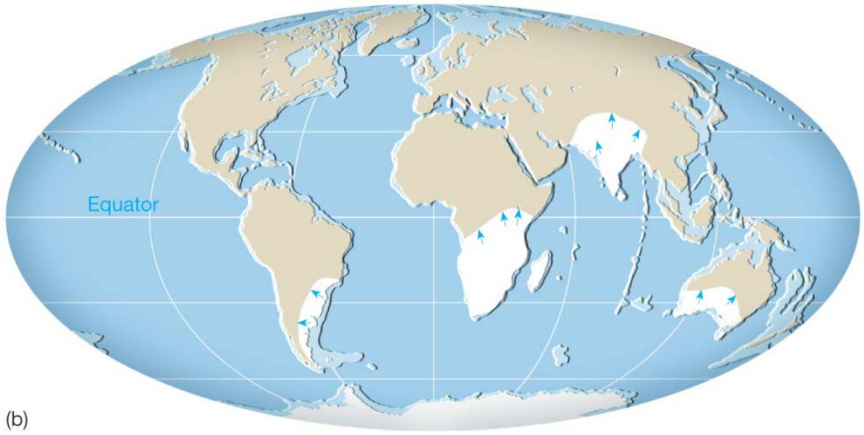
Plate Tectonics

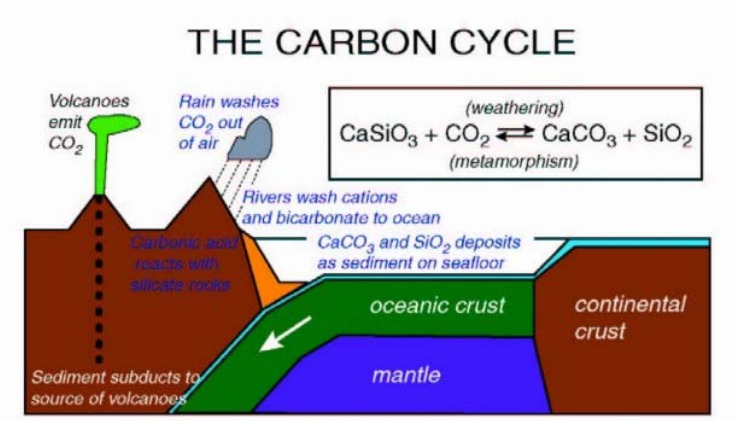
-Distribution of Land

-Growth of Ice Sheets

-Change in ocean circulation







Carbon-Silicate Weathering Cycle (O millions of years)

Volcanic Eruptions

Gasses, ash

Ejected into stratosphere

Sulfur dioxide:
remains in suspension
reflects solar radiation
reduce surface temperatures

(b)

Orbital Variations: Milankovitch Cycles

-eccentricity variation in the shape of Earth's orbit

-obliquity axial tilt

-precession wobble

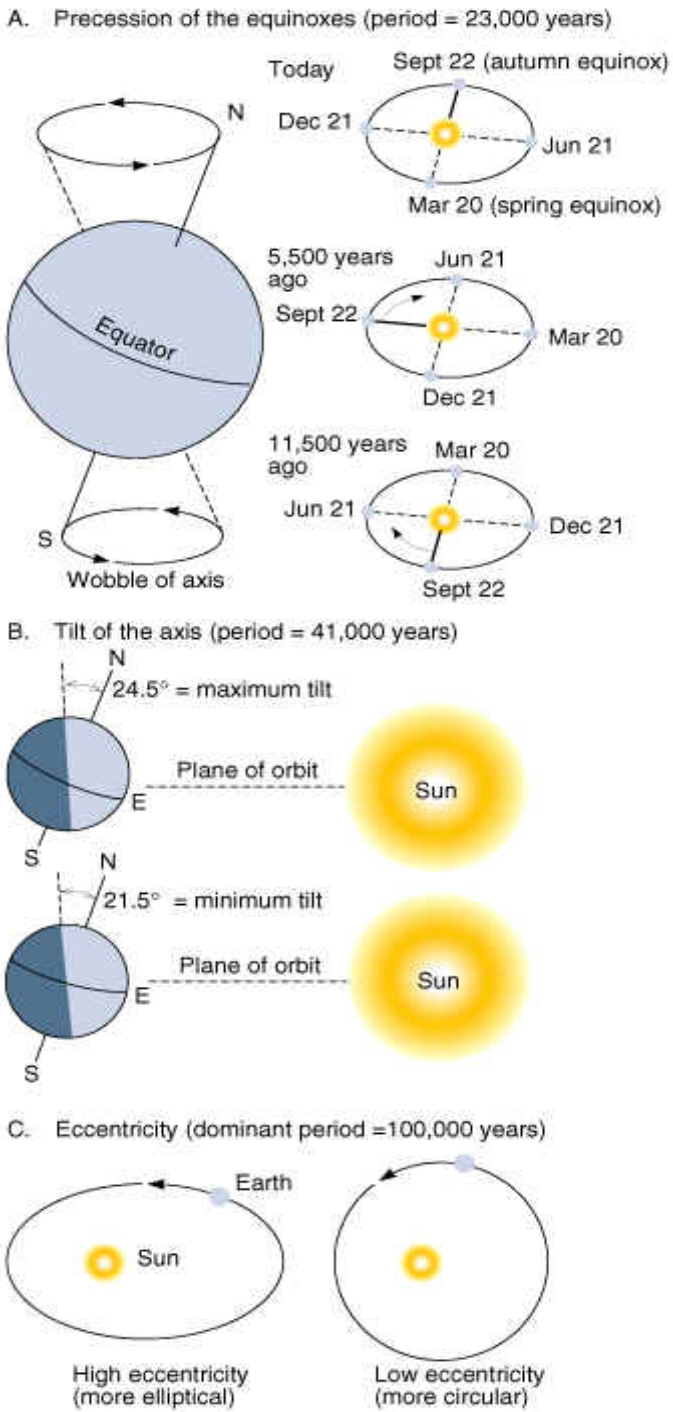
Correlated with climate predicted by deep sea sediments

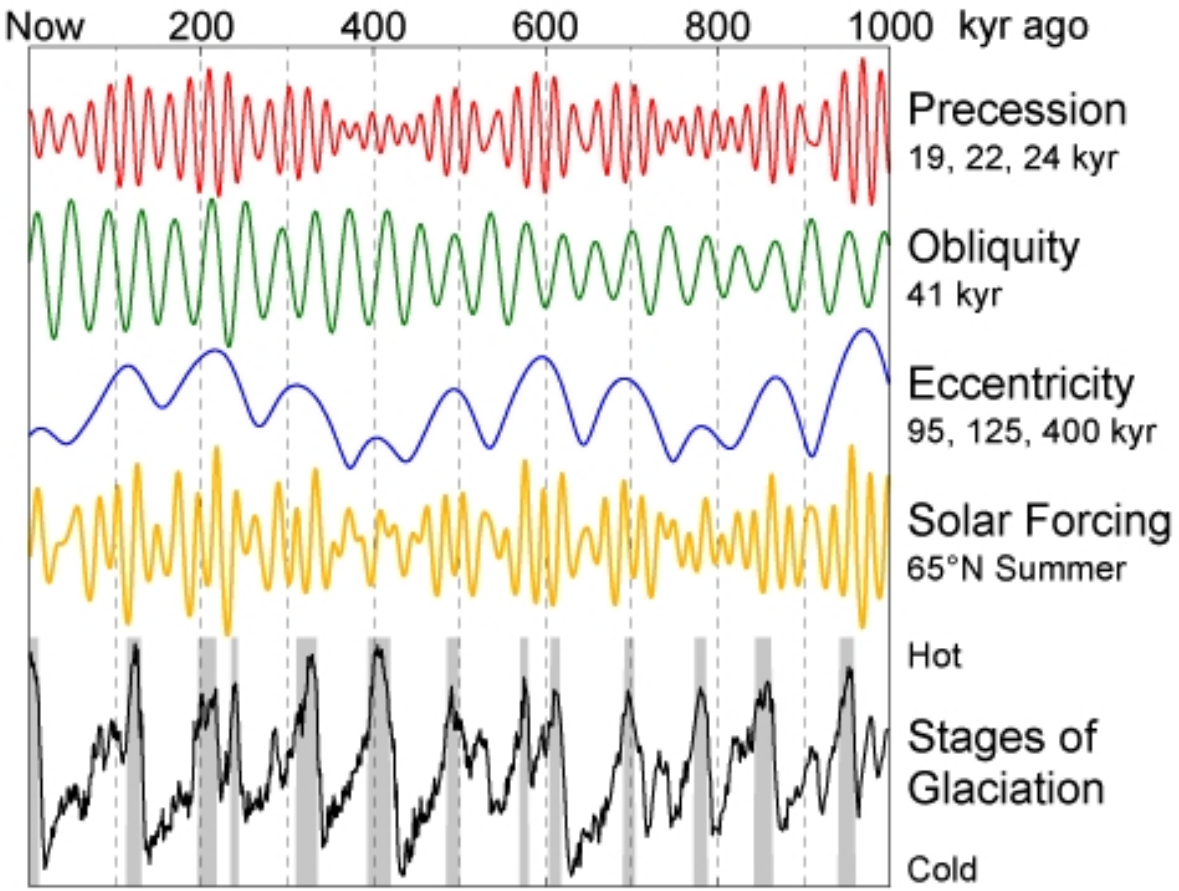
Quaternary ice ages

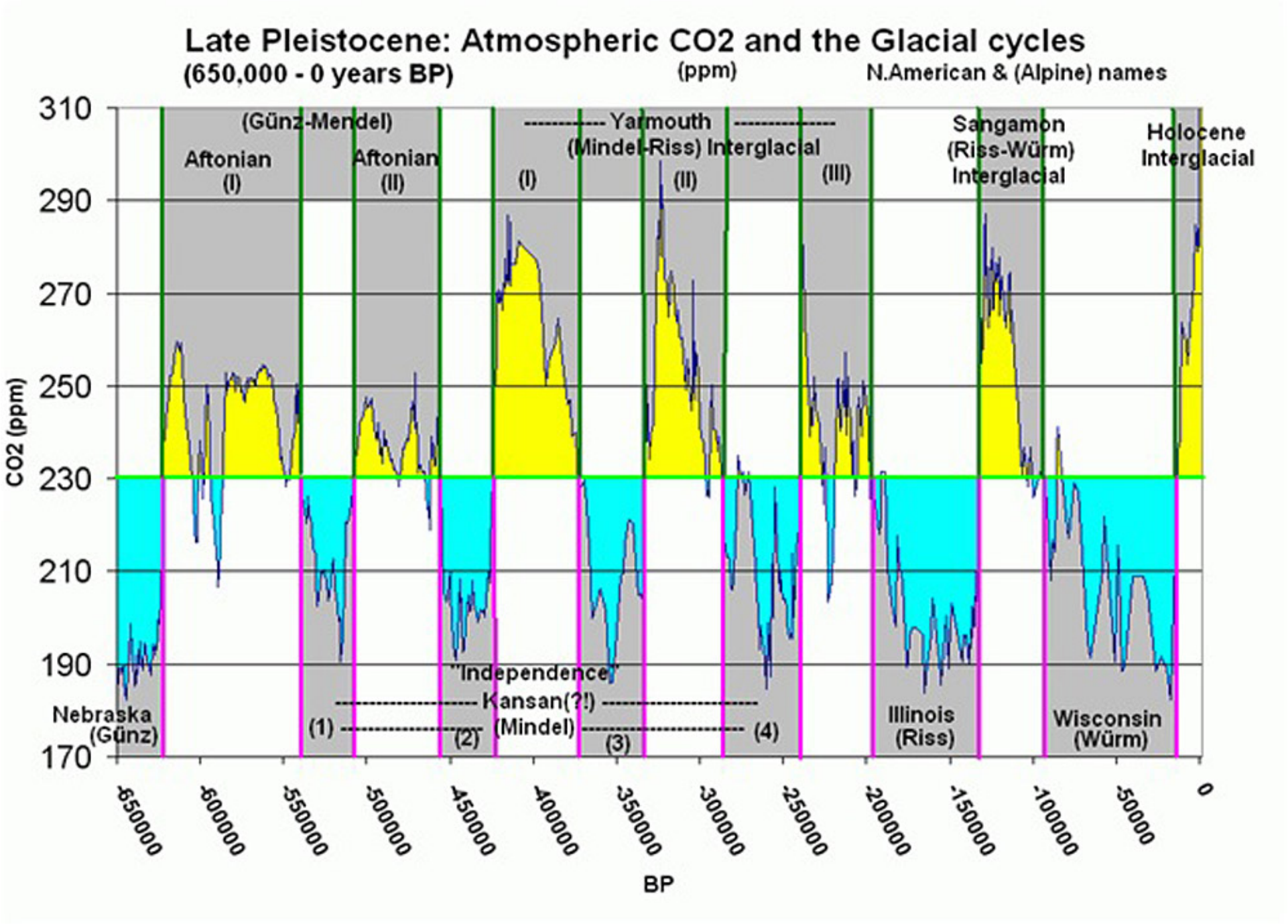
Predicts a cooling period

Needs land mass near the poles to support ice sheets

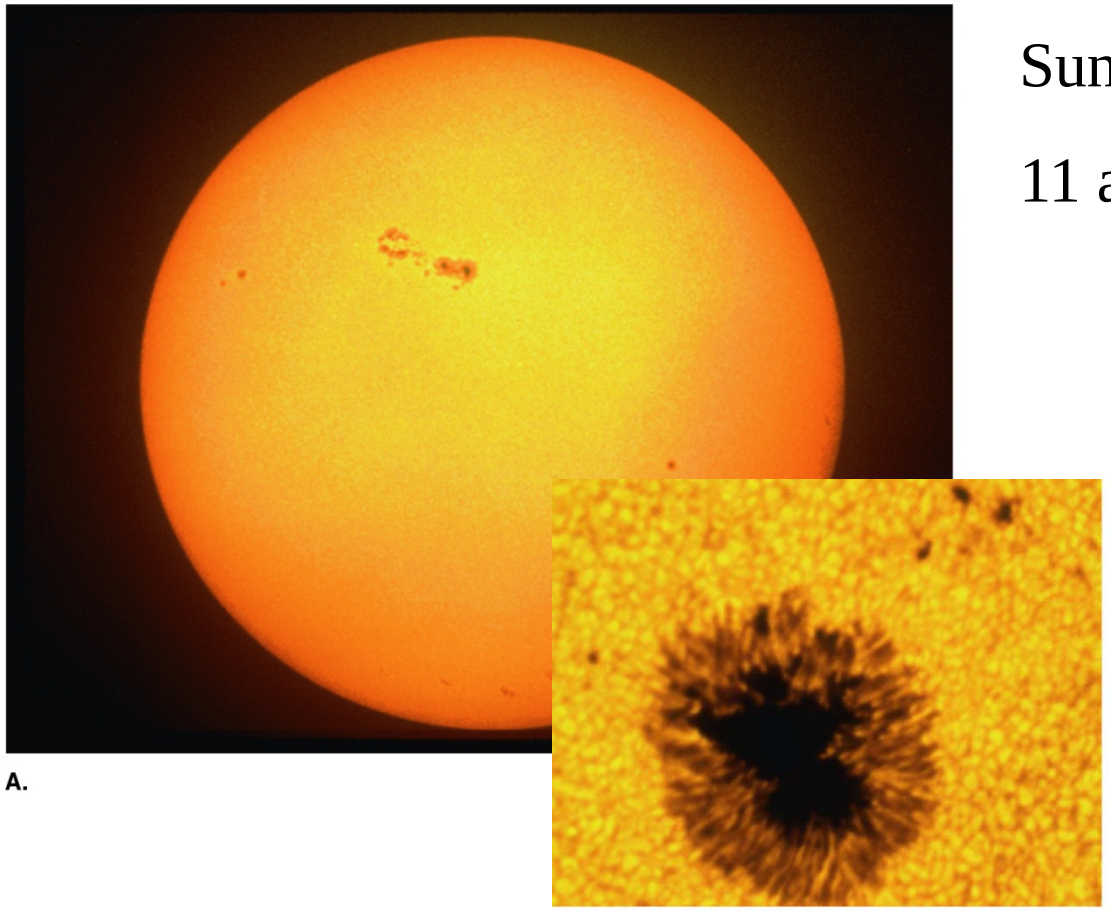
No human influence


A. Precession of the equinoxes (period = 23,000 years)
Today
Sept 22 (autumn equinox)
N
Dec 21
Jun 21
Mar 20 (spring equinox)
5,500 years ago
Jun 21
Sept 22
Mar 20
Dec 21
Equator
11,500 years ago
Mar 20
Jun 21
Dec 21
Sept 22
S
Wobble of axis
B. Tilt of the axis (period = 41,000 years)
N
24.5° = maximum tilt
Plane of orbit
Sun
E
S
N
21.5° = minimum tilt
Plane of orbit
Sun
E
S
C. Eccentricity (dominant period =100,000 years)
Earth
Sun
High eccentricity (more elliptical)
Low eccentricity (more circular)


Now
200
400
600
800
1000 kyr ago
Precession
19, 22, 24 kyr
Obliquity
41 kyr
Eccentricity
95, 125, 400 kyr
Solar Forcing
65°N Summer
Hot
Stages of Glaciation
Cold


Late Pleistocene: Atmospheric CO2 and the Glacial cycles
(650,000 - 0 years BP)
(ppm)
N.American & (Alpine) names
CO2 (ppm)
310
290
270
250
230
210
190
170
(Günz-Mendel)
Aftonian
(I)
Aftonian
(II)
Yarmouth
(Mindel-Riss) Interglacial
(I)
(II)
(III)
Sangamon
(Riss-Würm)
Interglacial
Holocene
Interglacial
"Independence"
Kansan(?!)
(Mindel)
Nebraska
(Günz)
(1)
(2)
(3)
(4)
Illinois
(Riss)
Wisconsin
(Würm)
650000
600000
550000
500000
450000
400000
350000
300000
250000
200000
150000
100000
50000
0
BP

Solar Variability: solar output varies through time, correlated with climate changes in Europe and North America



A.

Sunspots = magnetic storms

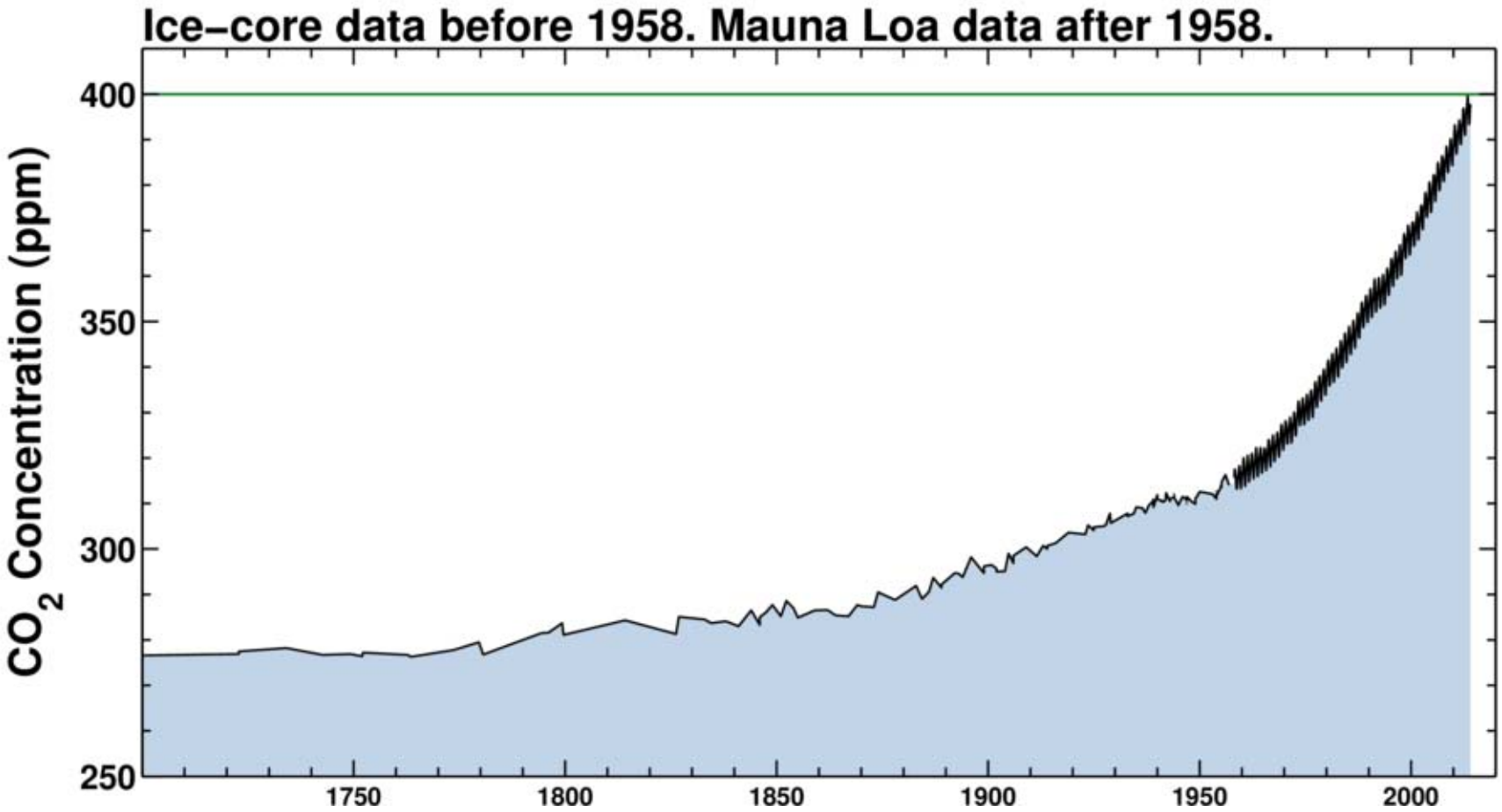
11 and 22 year cycles

Human Impact on Global Climate Change

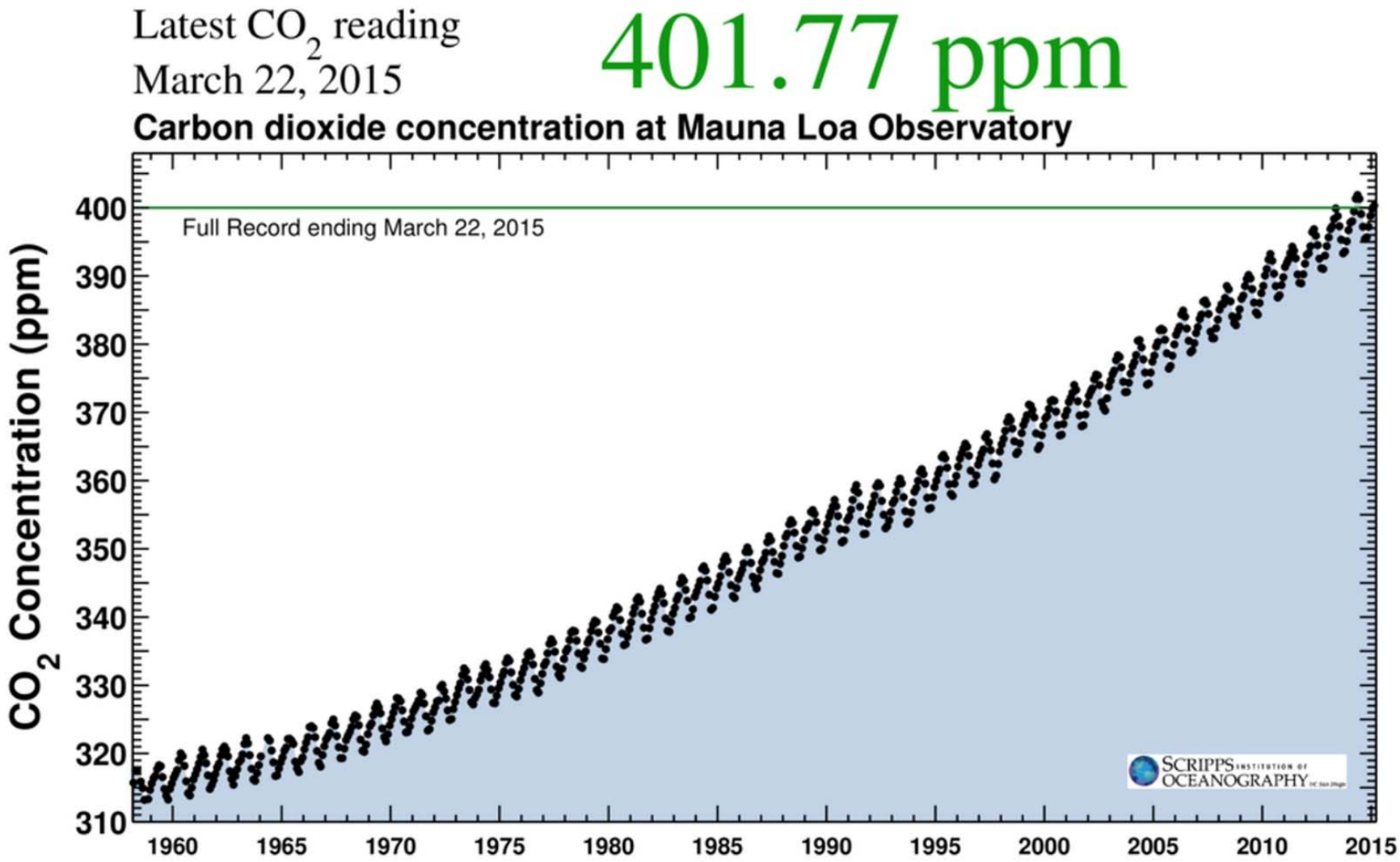
Increase in CO_2 and other Greenhouse Gasses

Human generated aerosols

Modification of the land surface



CO_2 Trace Gasses and Global Climate Change



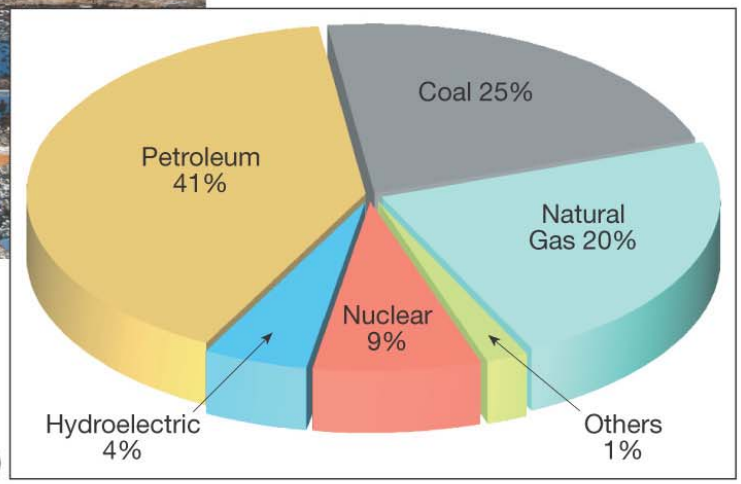
Industrial Sources of Carbon Dioxide

Burning of fossil fuels

Deforestation (38 m.a/y)

45 – 50 % CO_2 remains in the atmosphere

(a)



(b)

IPCC: Intergovernmental Panel on Climate Change

(5th Assessment, 2013)

-established by the United Nations Environmental Program

-assess the state of knowledge of human-induced climate change

*surface temperatures increased 0.6° C during the 20th century

*greatest per century temperature increase in the last 1000 yrs

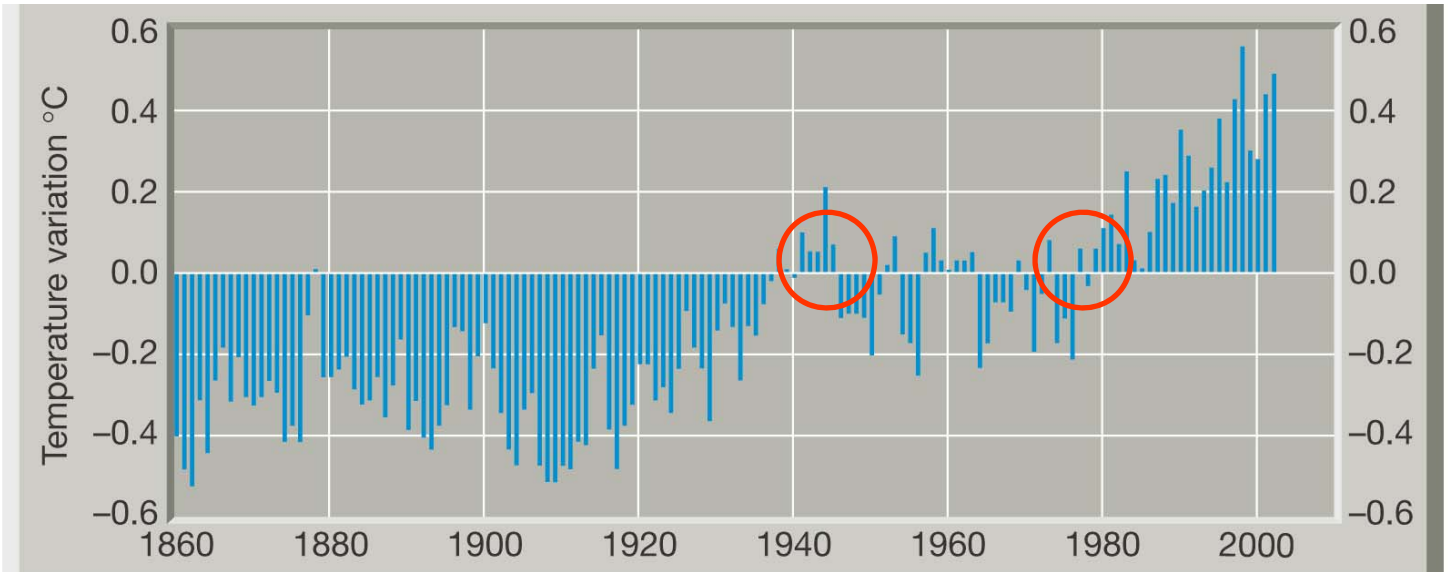
*most of the warming over the last 50 yrs is due to human activity

*Snow cover and ice extent have decreased

*Eustatic sea level has risen and ocean heat content has increased

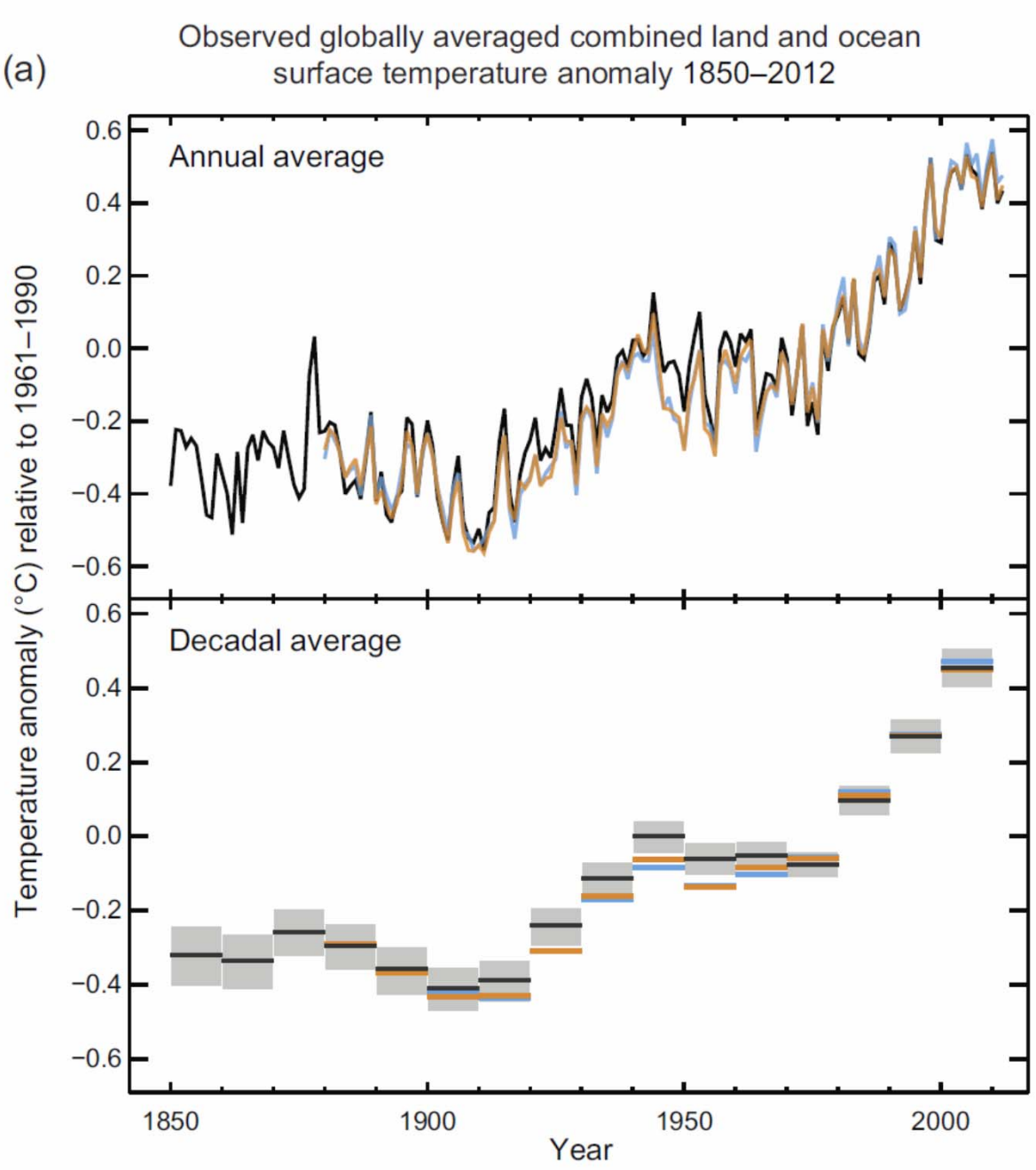
http://www.ipcc.ch/report/ar5/wg1/

Temperature Variations since Industrial Revolution



*surface temperatures increased 0.6^{o} C during the 20th century

*Annual temperatures compared to the (1961-1990) average



* greatest per century temperature increase in the last 1000 yrs

* tree rings, ice cores, corals, historical records

Role of Trace Gasses

-Methane (CH_4)

-Nitrous Oxide (N_2O)

-Chloroflorocarbons (CFCs)

Nitrous Oxide

enters atmosphere in agricultural regions

residence time 150 yrs

projected to have half the green house effect of methane

Methane

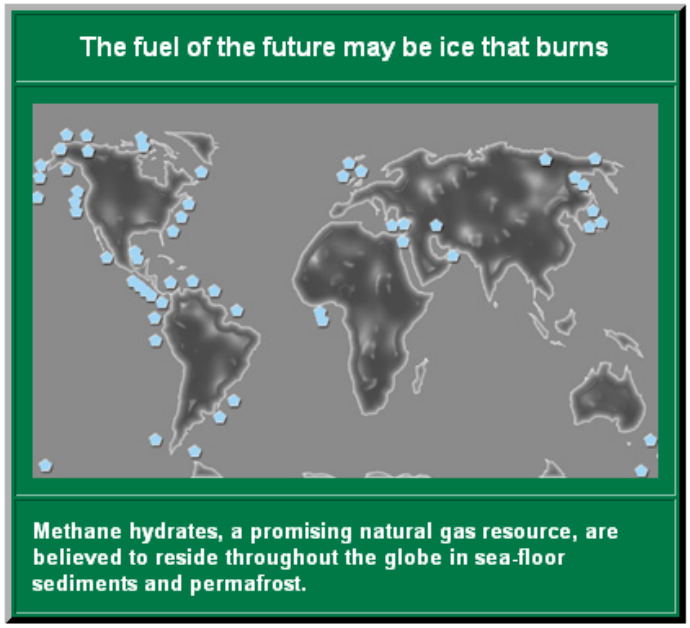
20-30% more effective at absorbing Infrared Radiation than CO_2

anaerobic bacteria in wet places (swamps, bogs, wetlands)

rice paddies fields, animal guts (cattle, sheep)

byproduct of oil, coal, and natural gas formation

atmospheric concentration has doubled since 1800's



Estimates on how much energy is stored in methane hydrates range from 350 years' supply to 3500 years'.

http://www.ornl.gov/info/reporter/no16/methane.htm

Uncertainty in Climate Change

Climate-Feedback Mechanisms

Positive: enhance change in the current direction

Negative: stabilize the system, reduce change

Ex. Warmer Surface Temperatures

increase evaporation

water vapor is a better absorber of outgoing radiation

Ex. Sea Ice/ Glaciers Melt

albedo is reduced

reflective surface replaced with dark soil

Uncertainty in Climate Change

Aerosols

tiny liquid and solid particles suspended in atmosphere

volcanoes, dust storms = fossil fuel, vegetation burning

sulfur dioxide: results in acid precipitation

Ex. Increased Aerosols

reflect solar energy

condensation nuclei

make clouds brighter, increase albedo

*short lifespan (days-weeks) compared to greenhouse gasses (decades), concentrated where emitted