Bharathidasan University

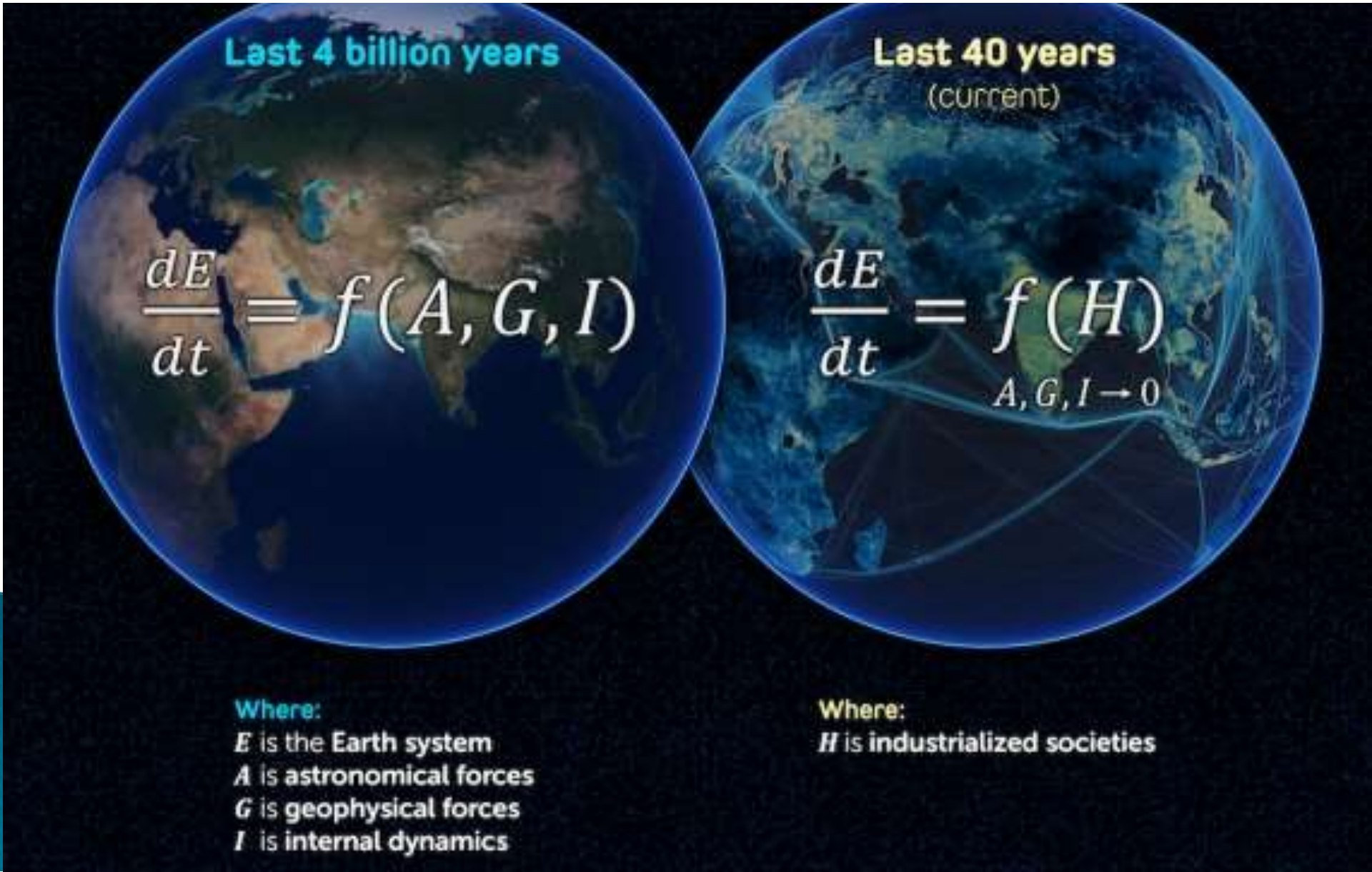
Programme: MSc Environmental Science and Sustainable Management

Course Title: ECOSYSTEM SERVICES AND SUSTAINABILITY
Course Code: 21PGEC04-1

Unit- IV Conservation of Ecosystem services

Prof. R. Mohanraj
Dept. of Environmental Science and Management

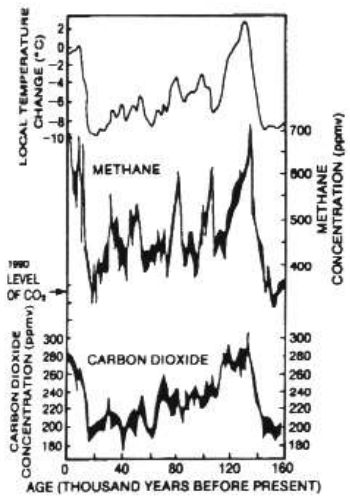
Climate Drivers: Past & Present

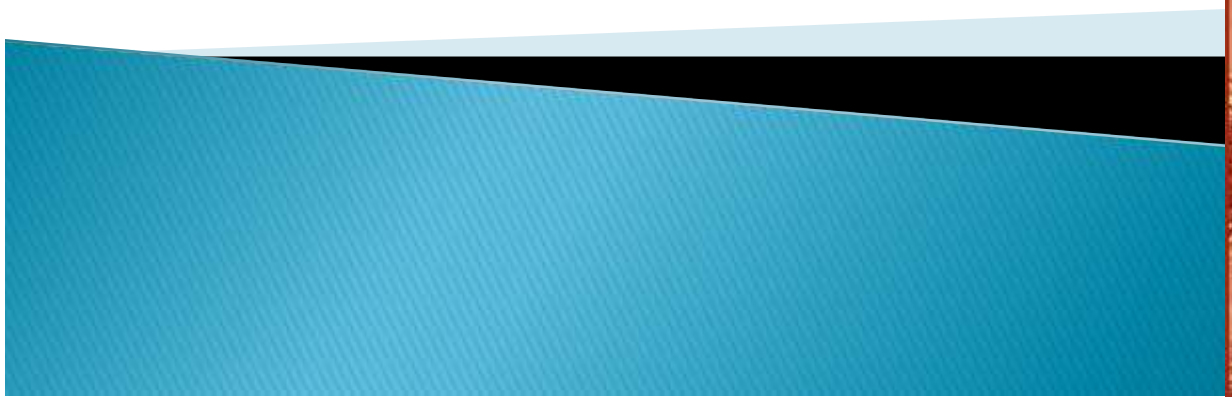


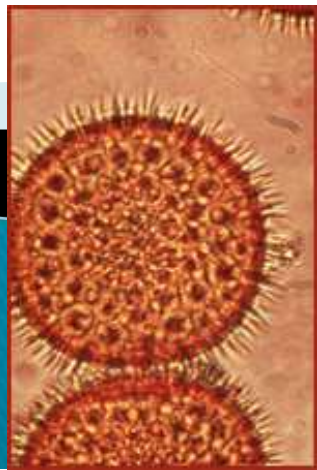
Natural Drivers of Global Climate

The ways in which global climate may be influenced include:

- changes in Earth's orbit
- variable solar output
- changes in ocean circulation patterns
- albedo (reflectivity) effects
- greenhouse effect

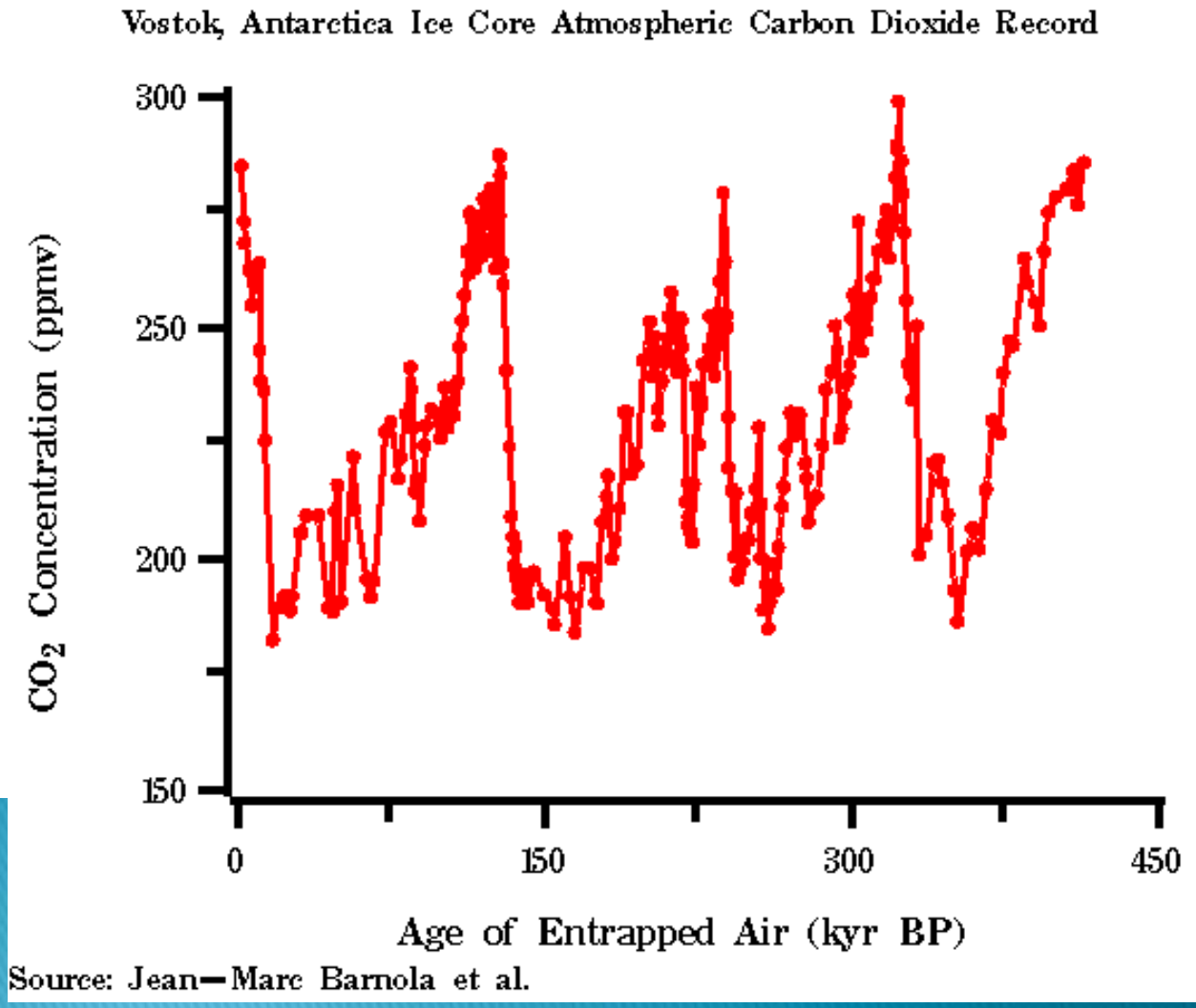






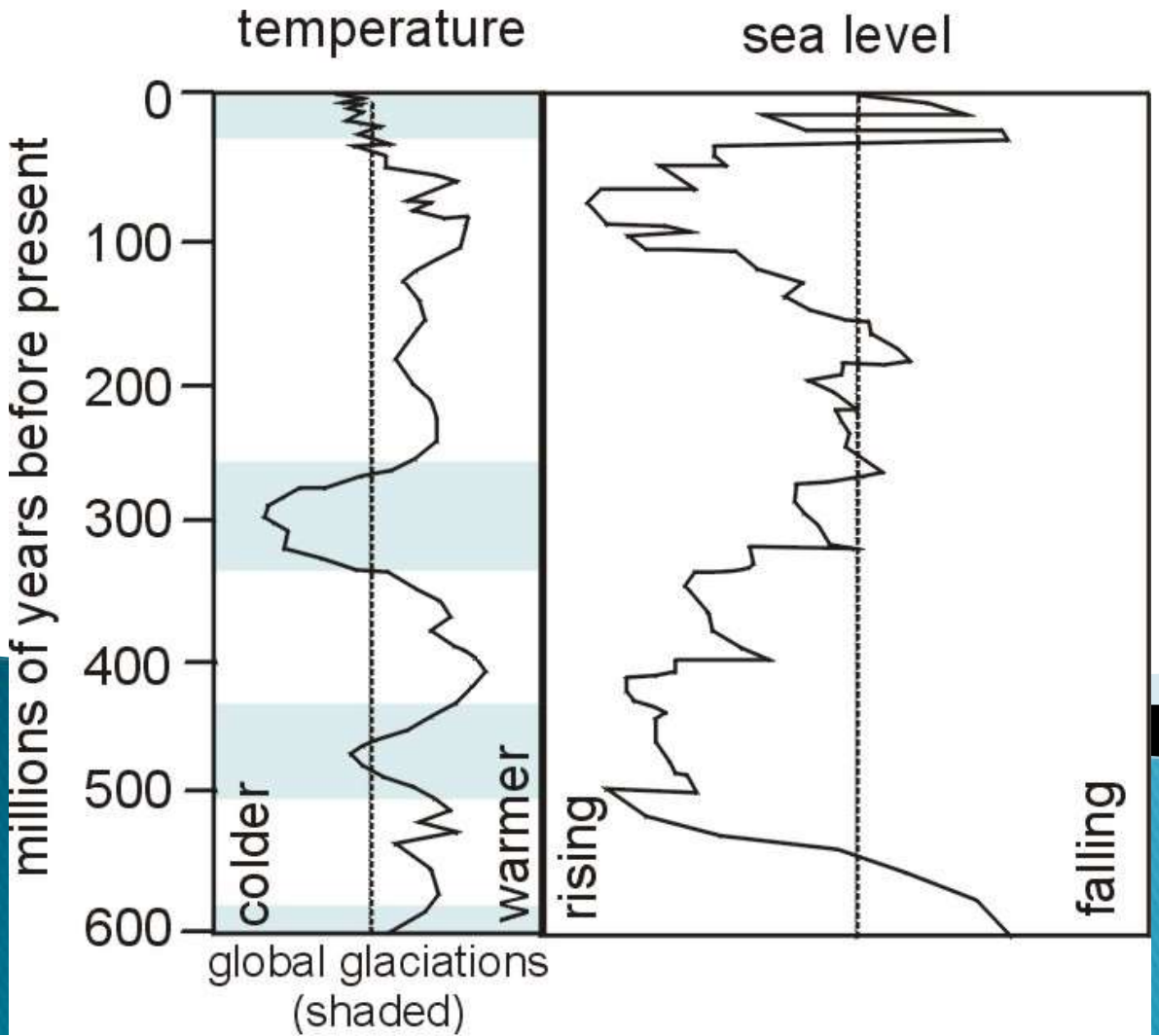
Ice Ages

- First, global climate appears to have been warmer than current through most of the last billion years.
- Second, there have been punctuated periods of global cold temperatures throughout Earth history.
- Causes of these ice ages require some investigation.



Paleoclimate Cycles

During most of Earth history, global temp. was 8-10°C *warmer* than today, but there have been a few long periods of sustained globally cold periods.



ice ages:

2500 Myr,

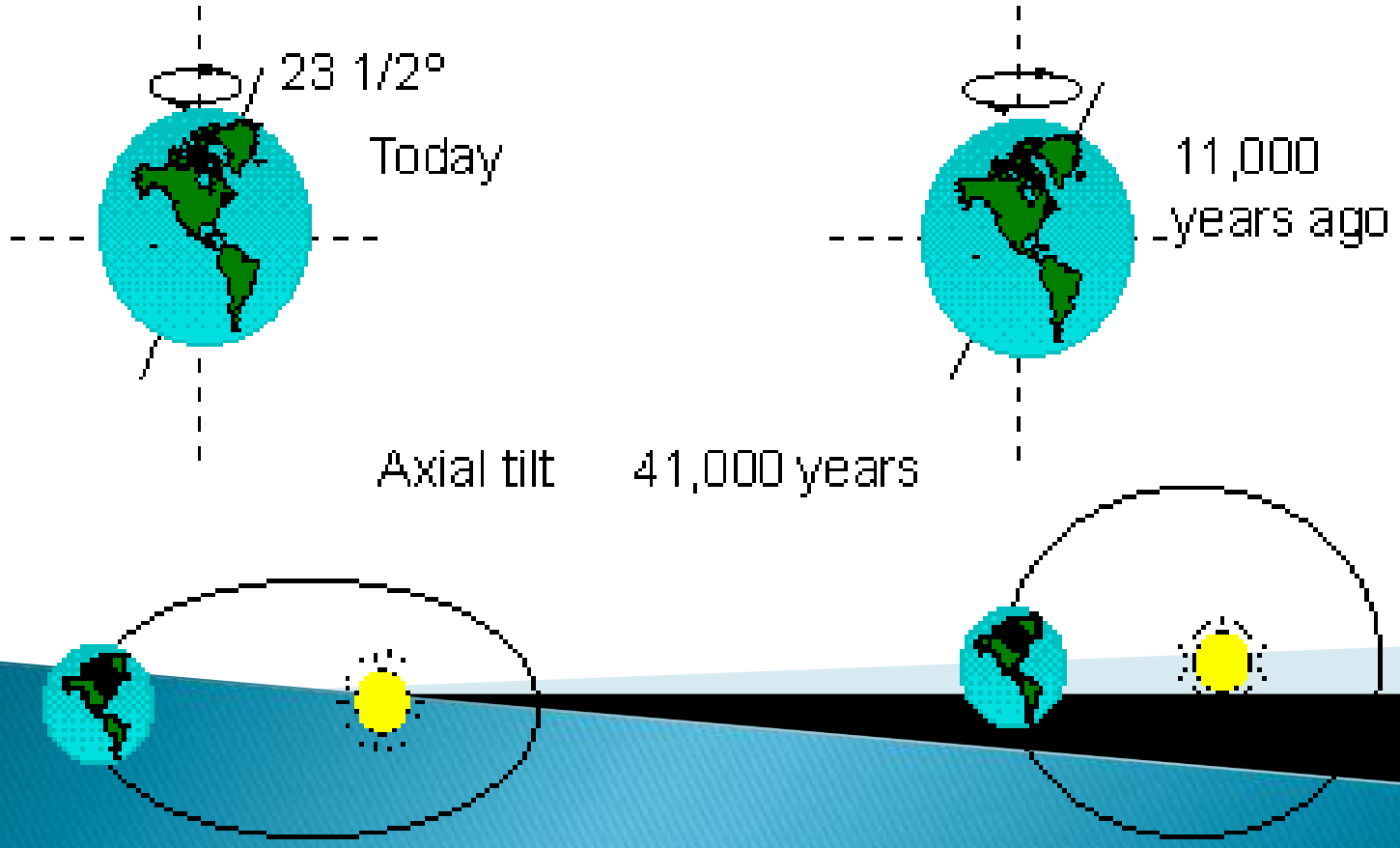
700 Myr,

300 Myr and

42 Myr

Milankovitch Cycles: Tilt and Obliquity

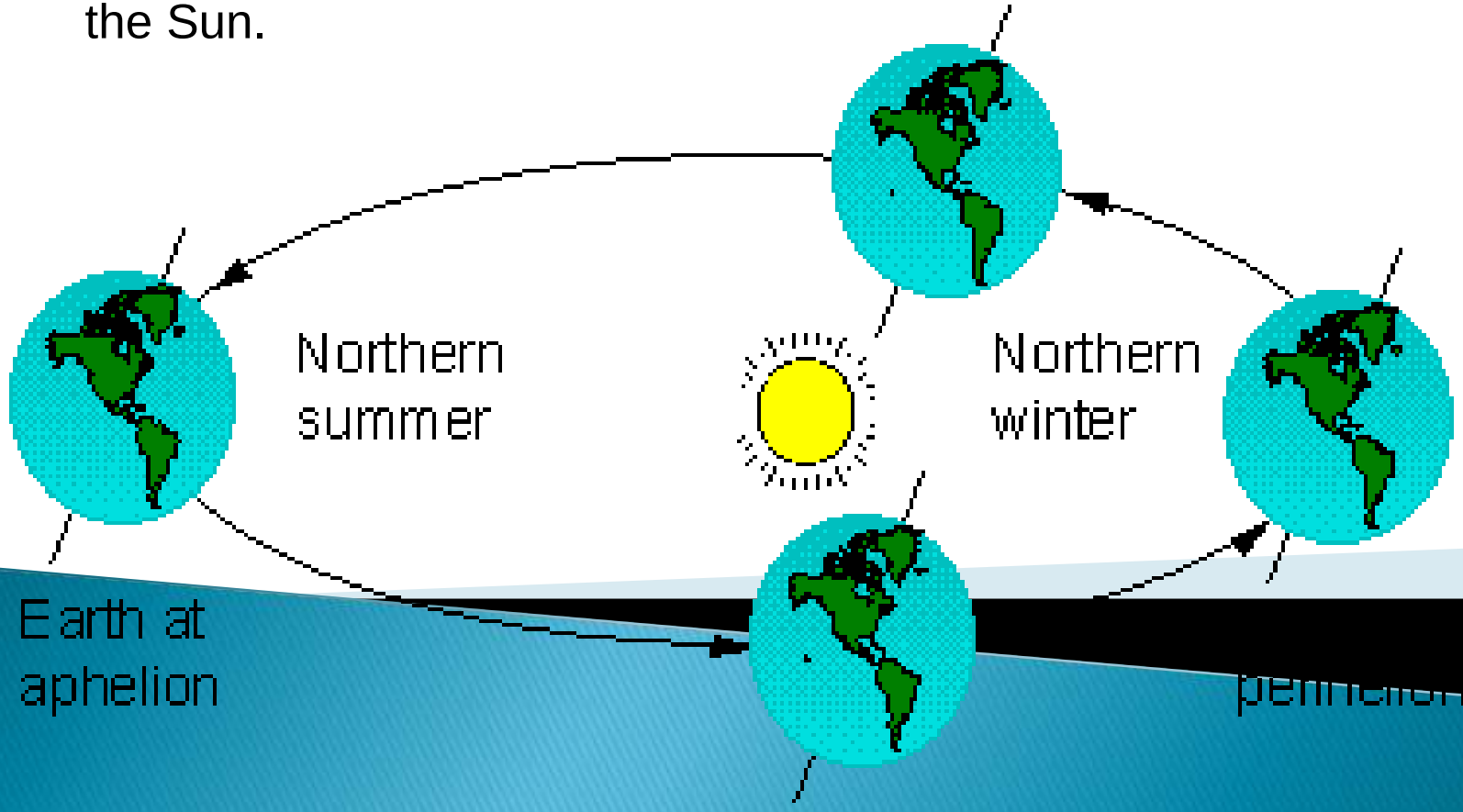
Milankovitch described changes in the amount of solar radiation received by the Earth in terms of astronomical properties: changes in the orientation of the Earth in space that regularly repeat.



Milankovitch Cycles: Precession

Precession is the ‘wobble’ of the Earth on its axis. Variation in precession changes the amount of energy received by the Sun.

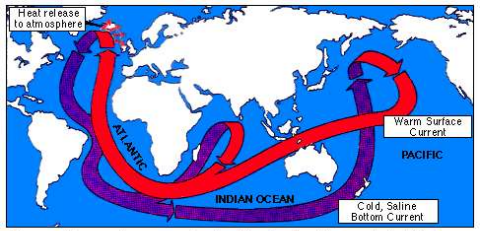
When the cycles of tilt, obliquity and precession align, we should expect periods of elevated or diminished global temperature.



Solar Output

It appears that our Sun does not transmit a constant intensity of radiation: observations indicate a variability of 0.1-0.2%. If solar output decreases for a period of time, it causes cooling on Earth.

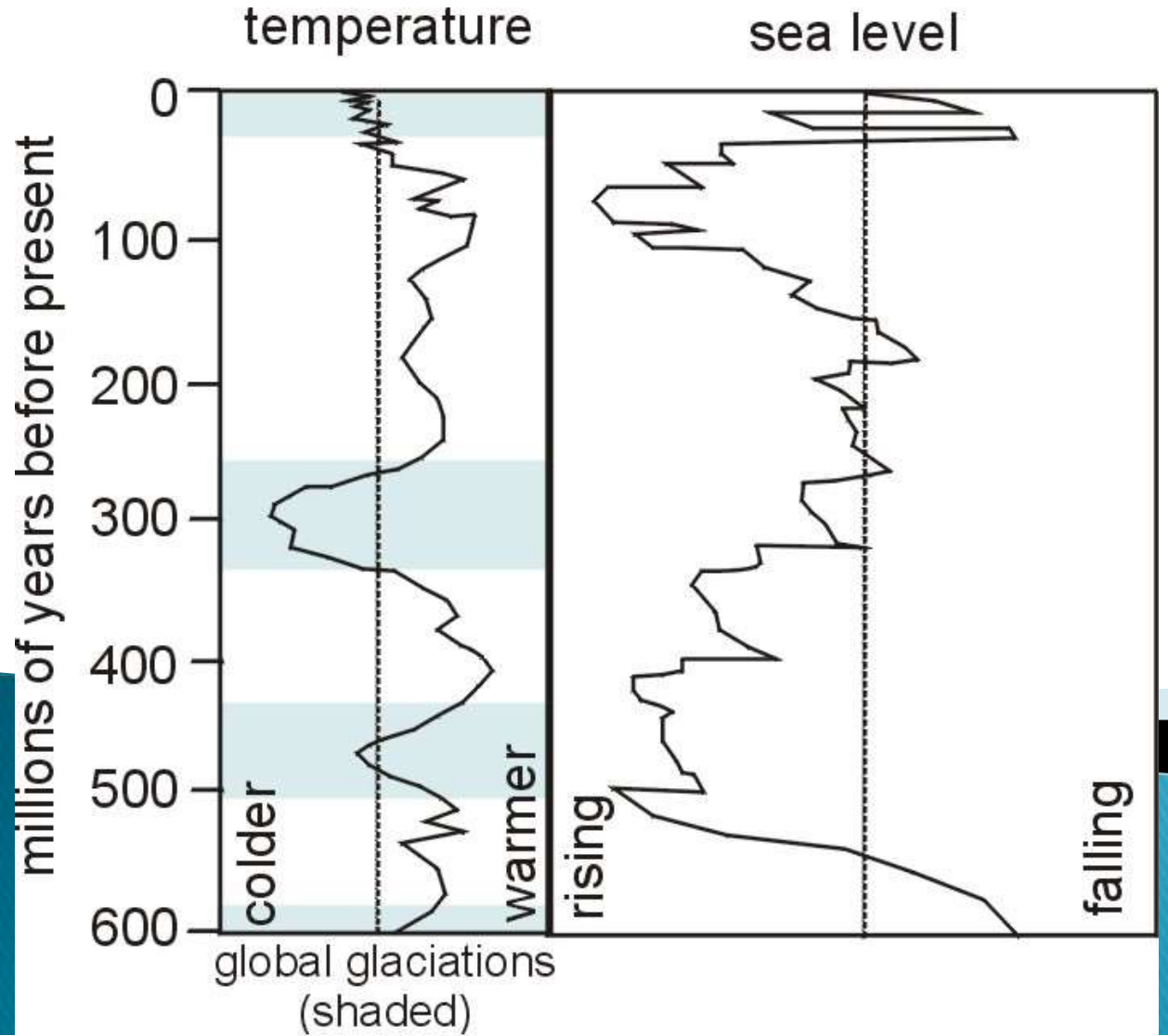
Although sunspot activity is cyclical (22 years), we do not currently have an accurate concept of how solar output has changed (and will change) on longer time scales.



The present large-scale ocean current system determines climate to a great extent. The huge "conveyor belt" reacts extremely sensitively to global temperature changes accompanying each increase and decrease in the content of carbon dioxide in the atmosphere. - Broecker

Paleoclimate Cycles

Milankovitch Cycles and sunspots as we understand them affect climate on time scales too short to explain Ice Ages.

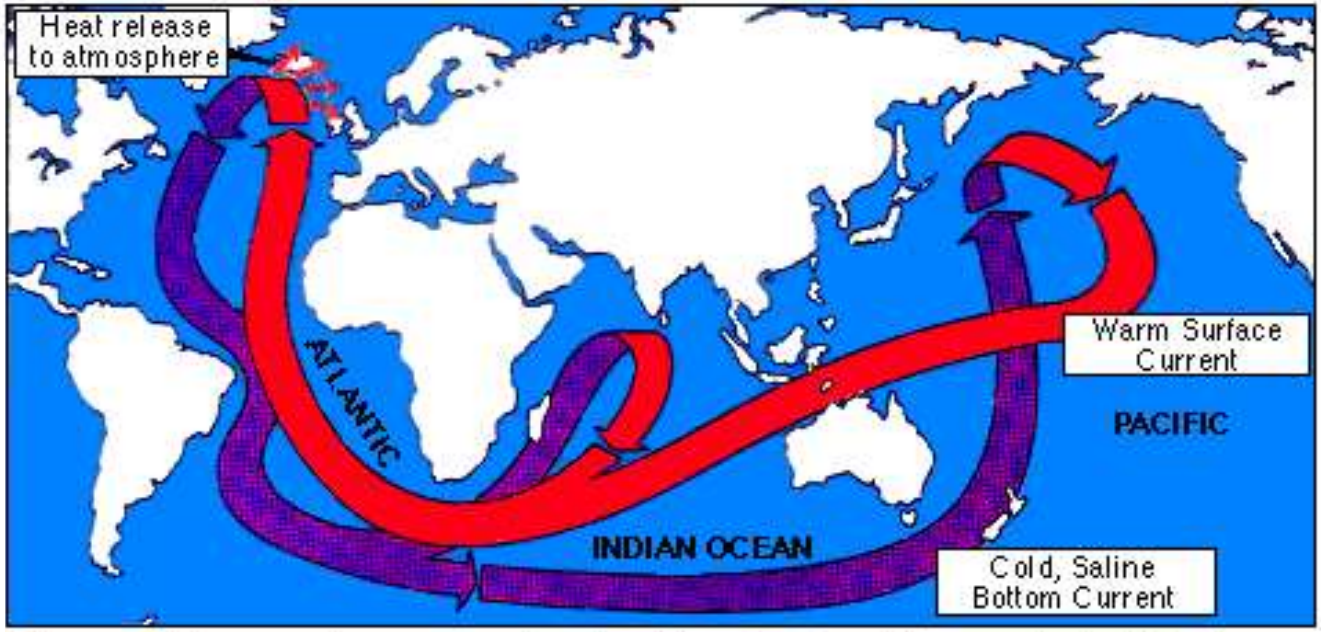


Coincidence of global cold periods with major tectonic events suggests important feedbacks between tectonics and climate.

Plate Tectonics and Climate

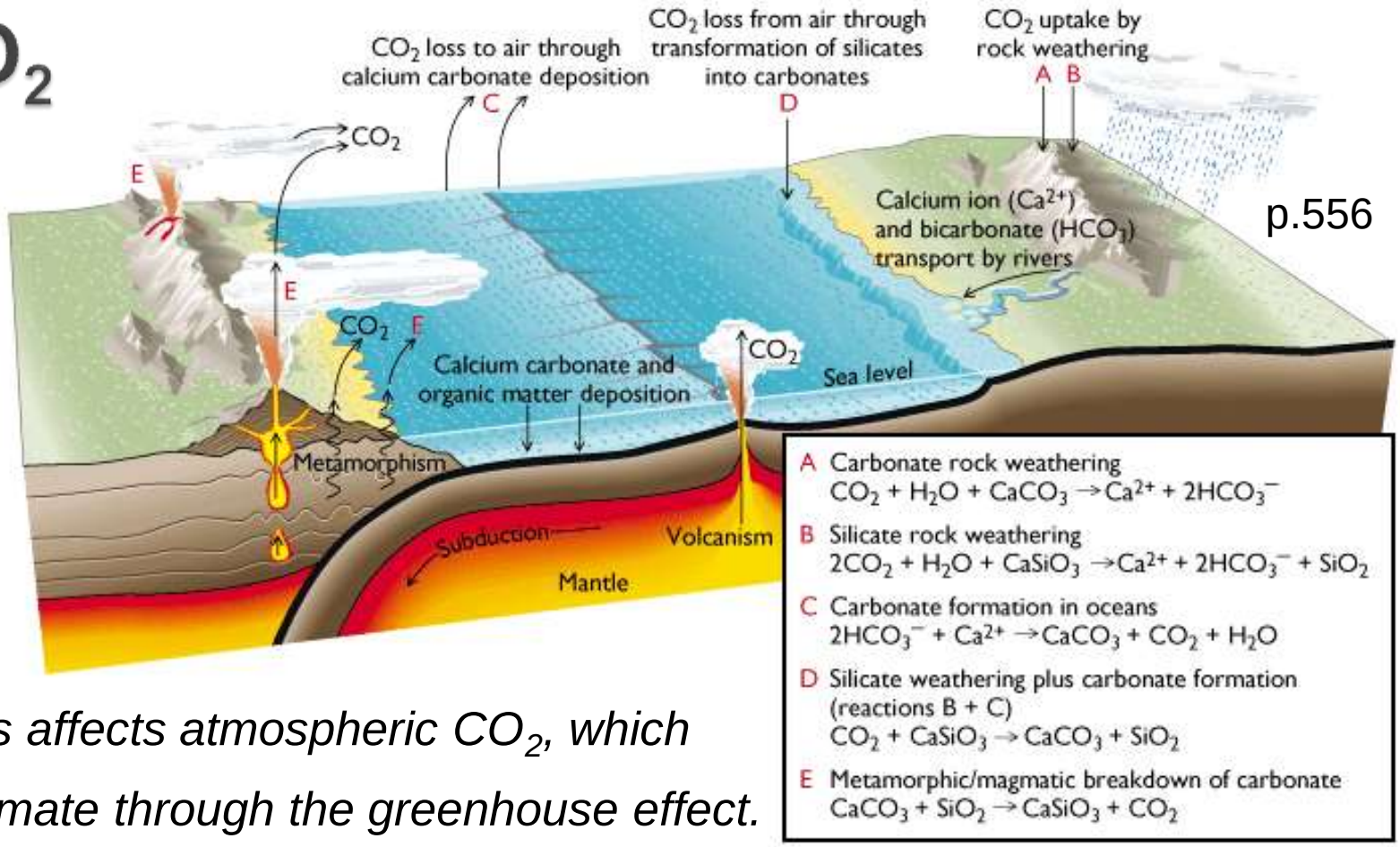
Plate tectonics can affect climate in a variety of ways. Since ocean and atmosphere circulation are linked, any process that changes one, forces the other, which affects climate.

Closing and opening seaways (e.g., Panama, SE Asia) is an obvious link between plate tectonics and climate.



The present large-scale ocean current system determines climate to a great extent. The huge "conveyor belt" reacts extremely sensitively to global temperature changes accompanying each increase and decrease in the content of carbon dioxide in the atmosphere. - Broecker

Plate Tectonics and CO_2



p.556

Plate tectonics affects atmospheric CO_2, which factors into climate through the greenhouse effect.

Volcanoes produce CO_2. If global volcanism slows, as would be the case when supercontinents stabilize, less atmospheric CO_2 would trigger global cooling. Increased volcanism puts more CO_2 in the atmosphere and results in more greenhouse warming.

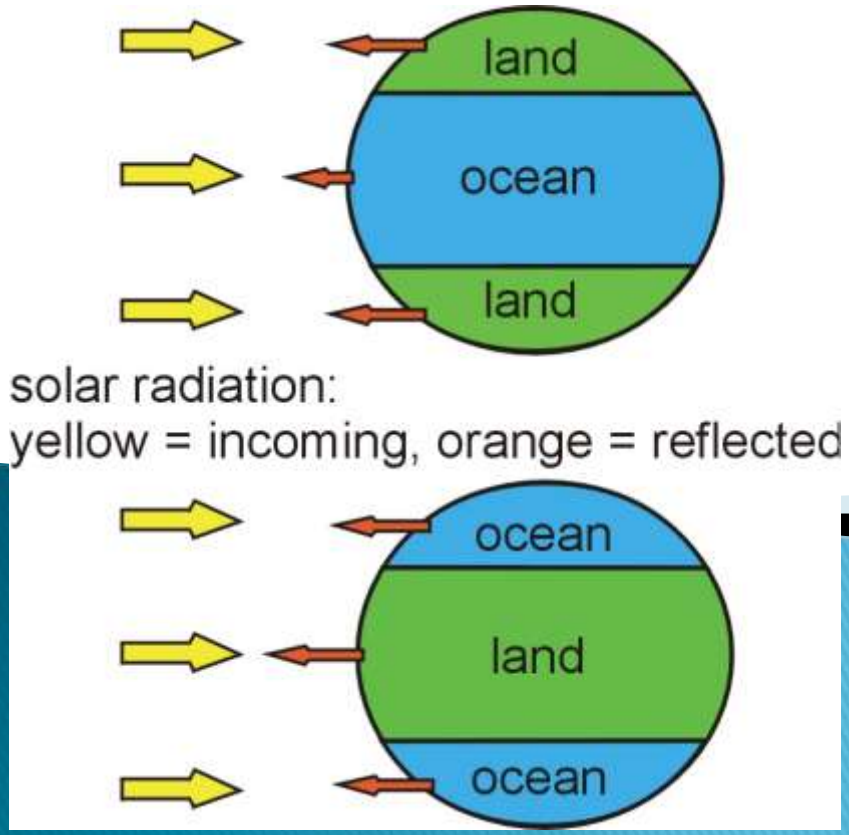
Albedo and Climate

Albedo is reflectivity: materials like ocean water have low albedo whereas land masses have moderate albedo. The highest albedo is snow and ice (very light in color). Hence, periods when polar ice becomes very extended will promote further cooling. This is a *positive feedback* mechanism.

Dust in the atmosphere has the same effect: it forms a high albedo veil around the Earth, so that much solar radiation is reflected before it reaches the surface. Dust can come from dry climate periods, volcanic eruptions or other means.

Land Mass Distribution and Climate

Materials absorb and reflect solar radiation to different extents. Ocean water is much more absorbent than land masses, so that continents reflect a lot more solar energy back into space than the oceans.



The Earth receives more solar radiation at low latitudes (near equator) than near the poles.

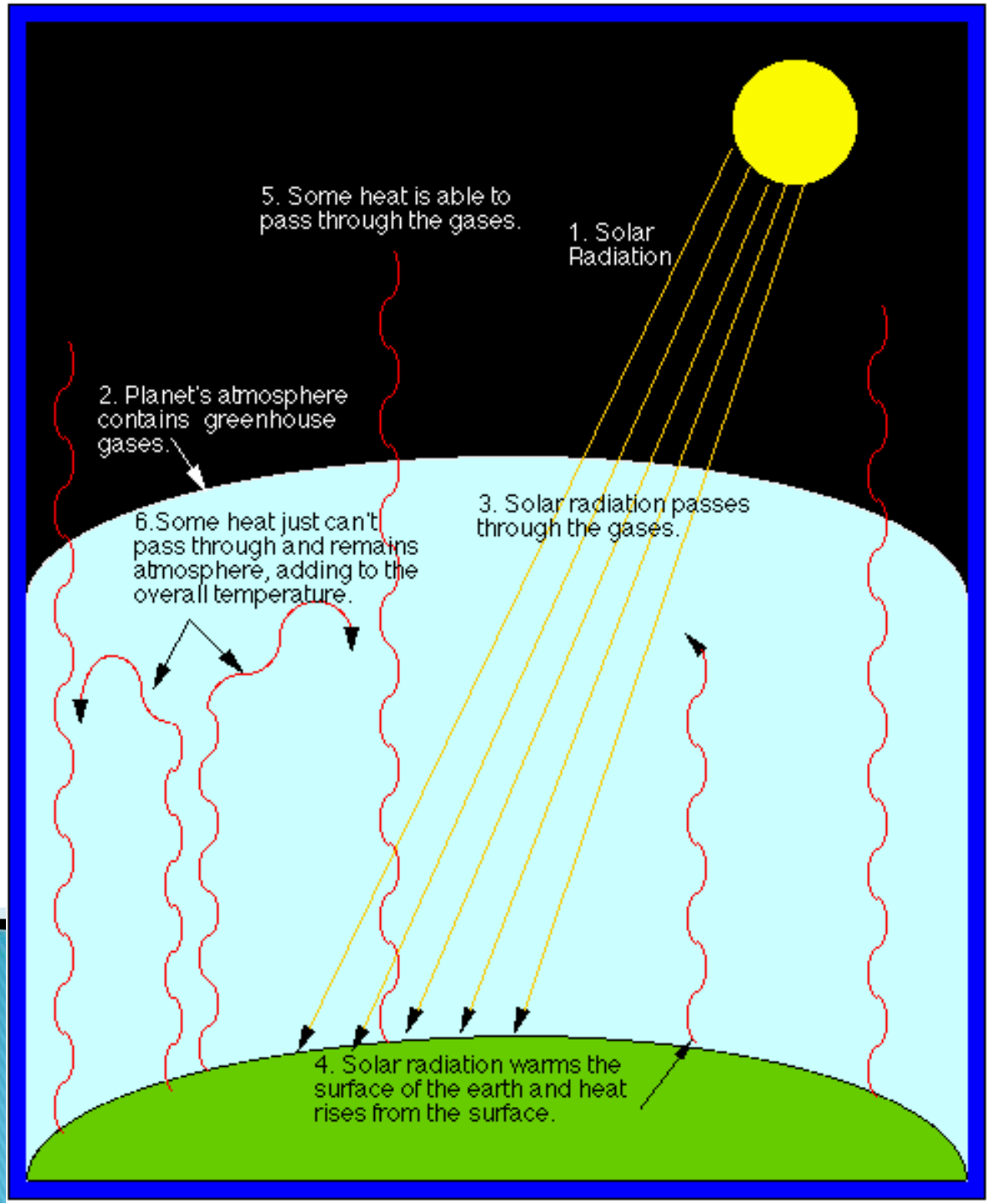
An Earth with land masses clustered at low latitudes would reflect more solar energy into space, [illegible] a cooler planet than one with more equatorial ocean area.

The Greenhouse Effect

The most important *greenhouse gases* are H_2O, CO_2 and CH_4 (methane).

Without this effect, the Earth would be cold and inhospitable.

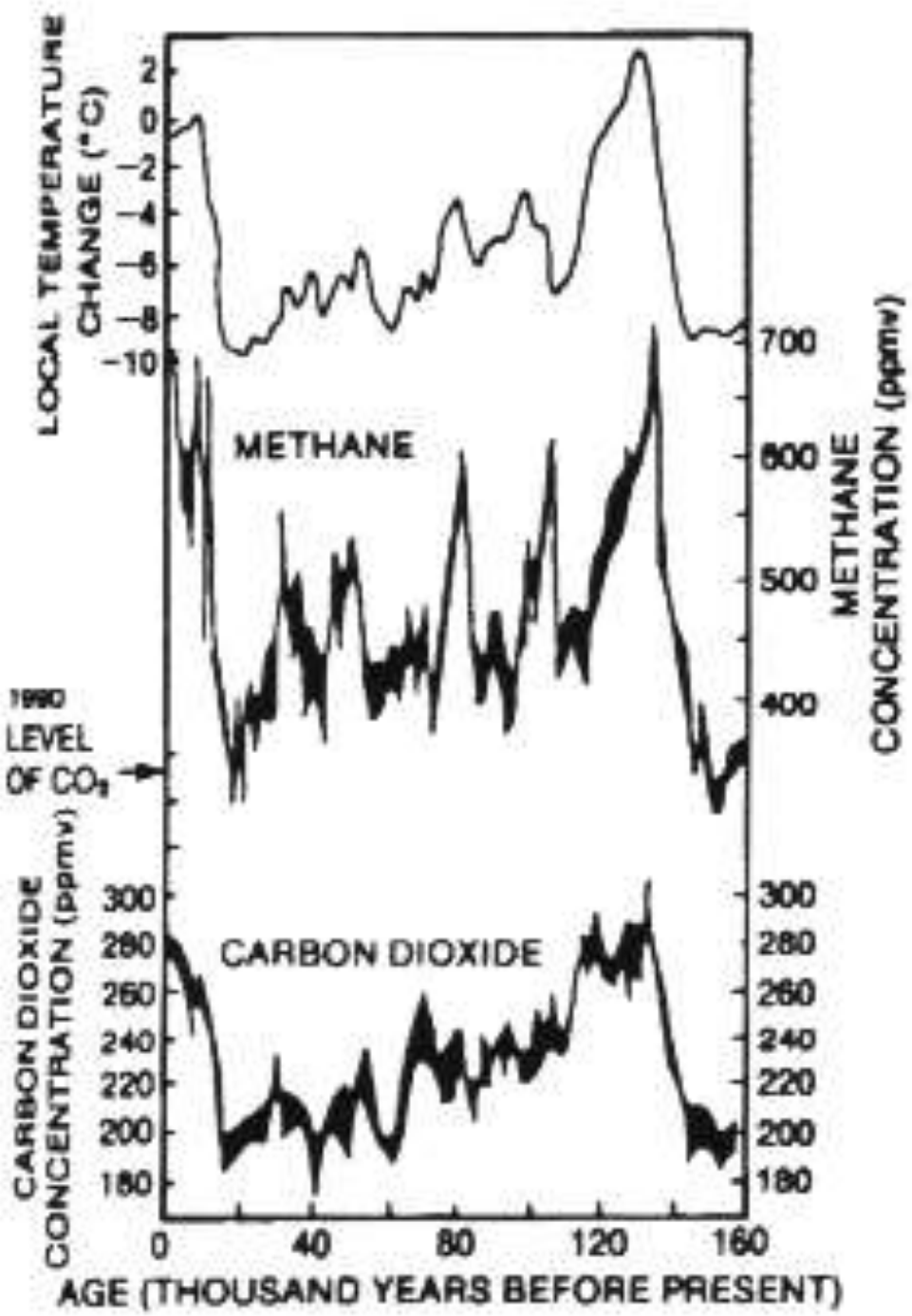
Taken too far to the other extreme, the Earth could evolve into a hothouse.



Greenhouse Gases and Global Temperature

There is no debate over the validity of the greenhouse effect.

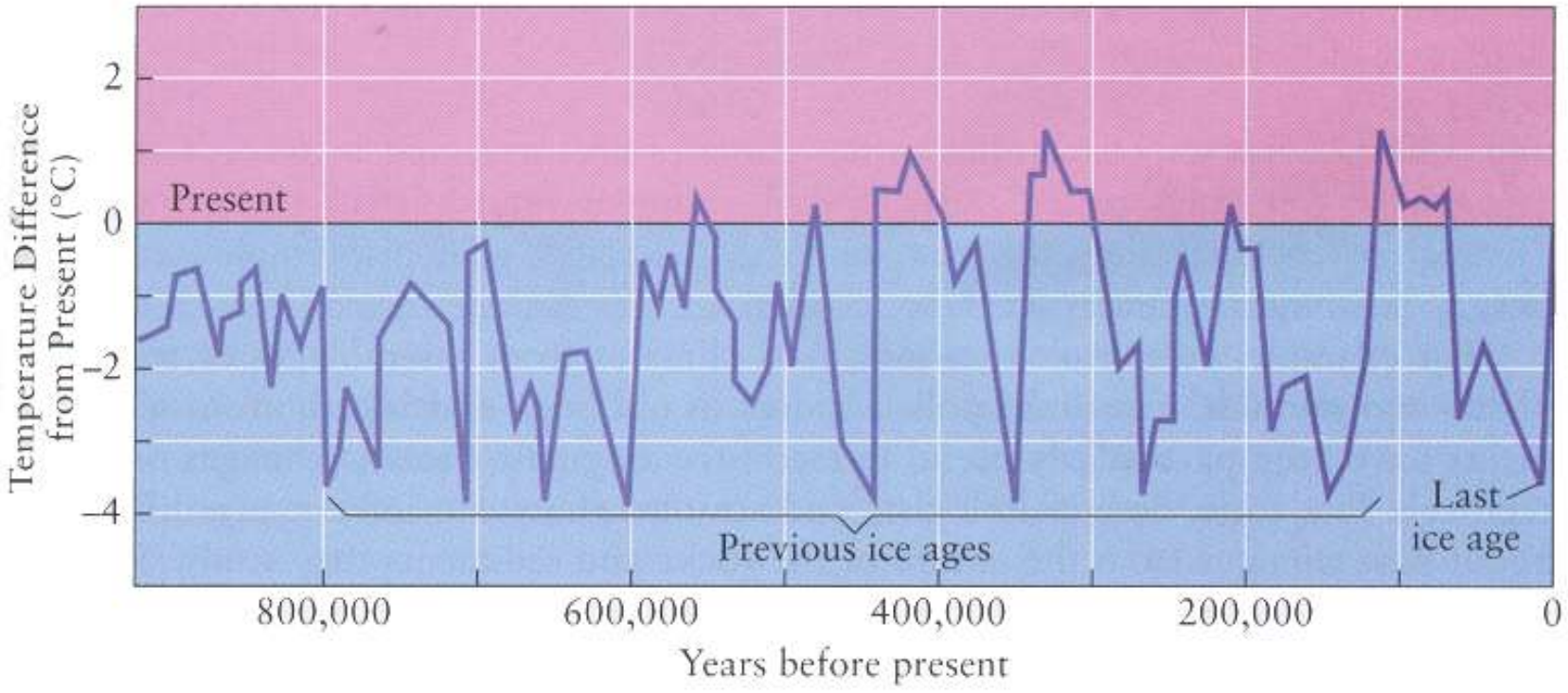
The question is whether the climate fluctuations of the last 160,000 yr were brought on by greenhouse gas variations or if global climate changed greenhouse gas abundances.



Climate of the Last Million Years

Although climate in the last million years has been dominantly colder than today, we are able to resolve rapid, short-term fluctuations from cold to warm.

Indeed, as we probe geological records of climate more closely, we see changes from interglacial (warm) periods to glacial periods that take < 400 years.



Working With Glacial Ice

Layering in the ice provides a time record, just like varved lake sediments.

Geologists examine the stable isotope compositions and trapped gas contents (CO_2 and CH_4) of ice cores.

Oxygen Isotopes in Ice Cores

How does glacial ice record tell air temperatures?

Oxygen has three isotopes, all of which are non-radioactive (stable). As precipitation forms in clouds, a certain proportion of each of the oxygen isotopes goes into the rain or snow.

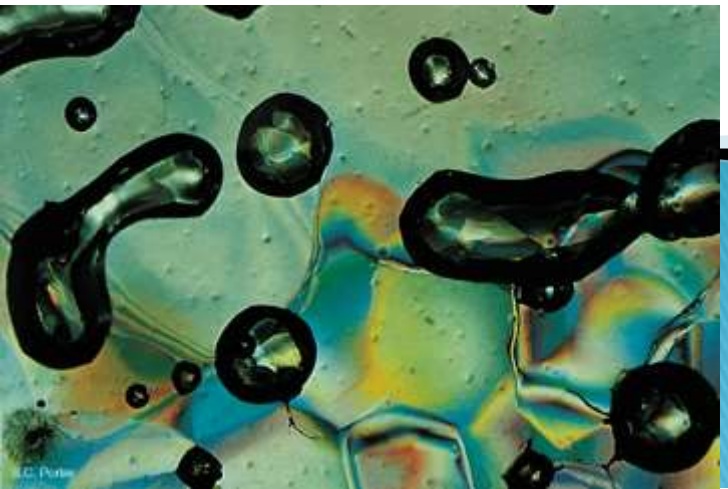
The exact proportion is *temperature dependent*.

As temperature drops, oxygen in precipitation incorporates a larger proportion of isotopically light ^{16}O relative to heavy ^{18}O.

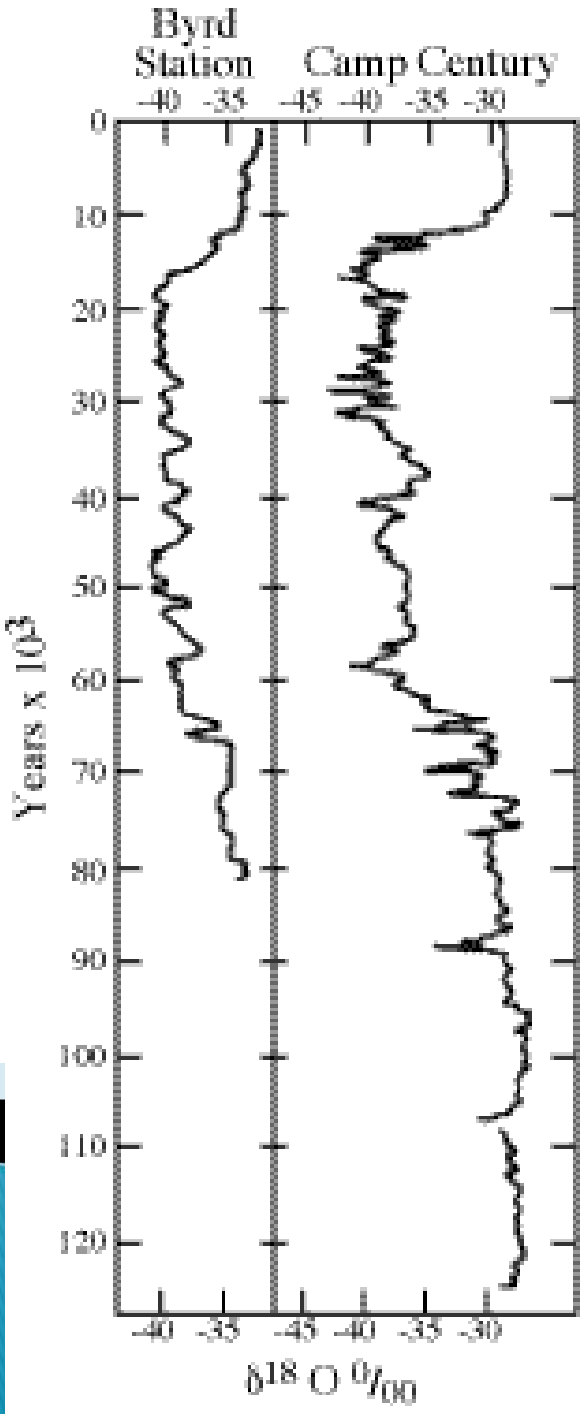
Thus, oxygen in glacial ice acts as a thermometer of past air temperature.

Global Oxygen Isotope Correlations

Oxygen isotope temperature data from different Greenland ice cores demonstrate the same trends.



CO_2 contents of ice cores mimic the changes in temperature from oxygen isotopes.



Oxygen Isotopes in Ocean Sediments

Glacial ice gets us back <1 Myr ago:

how do we construct geologically extensive climate records?

Since sea surface temperature is linked to atmospheric temperature, we can use organisms that live in the oceans. Again, these organisms take in oxygen and the oceanic oxygen budget is isotopically proportional to temperature, due to differences in the oxygen that evaporates. More light oxygen is lost to evaporation in cold times, so low temperature sea water has high ratios of $^{18}O/^{16}O$.

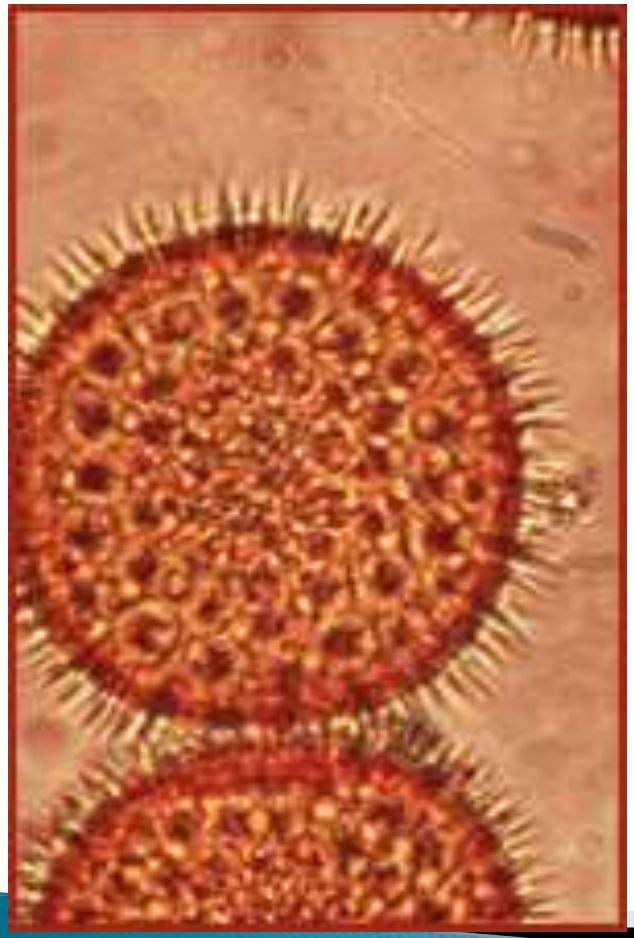
Organisms growing in these waters take on the ambient oxygen isotope composition.

from Coral Reefs

Corals grow in shallow marine environments and are sensitive to changes in ocean temperature, and are indicators of *past sea level*.

Corals also can be precisely dated, so with them we can construct detailed records of how ocean temperature+sea level have changed over the last several million years.

Pollen and Climate Change

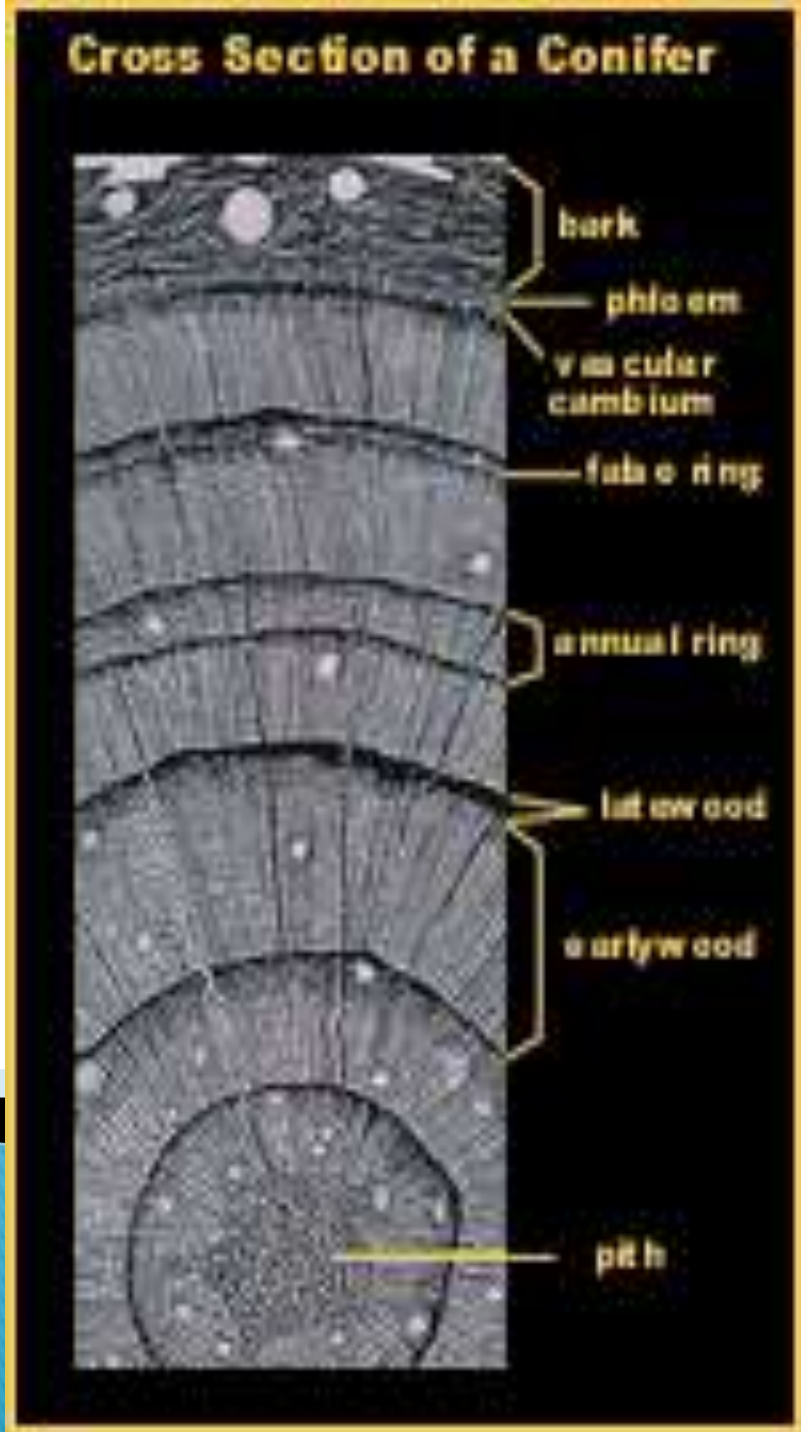


Pollen grains in sediment give an estimate of types of vegetation prevailing in an area, which is linked to climate.

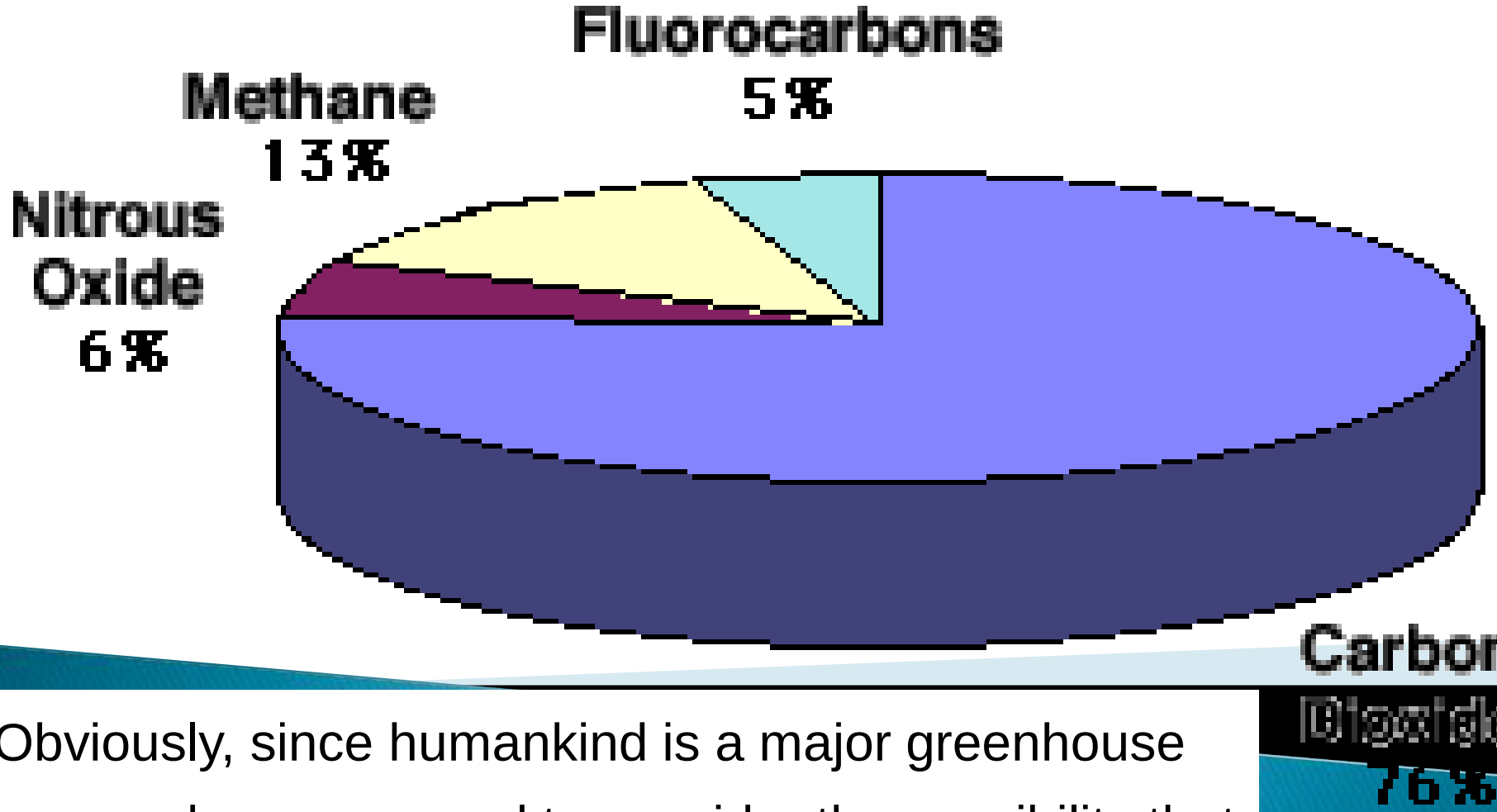
Tree Rings and Climate Change

Structure of tree rings give another estimate of relative moisture and temperature conditions.

By selecting specific types of trees, we can examine stresses of extended cold or warm periods with very high resolution back to several thousand years.



Greenhouse Gas Production Today (global)



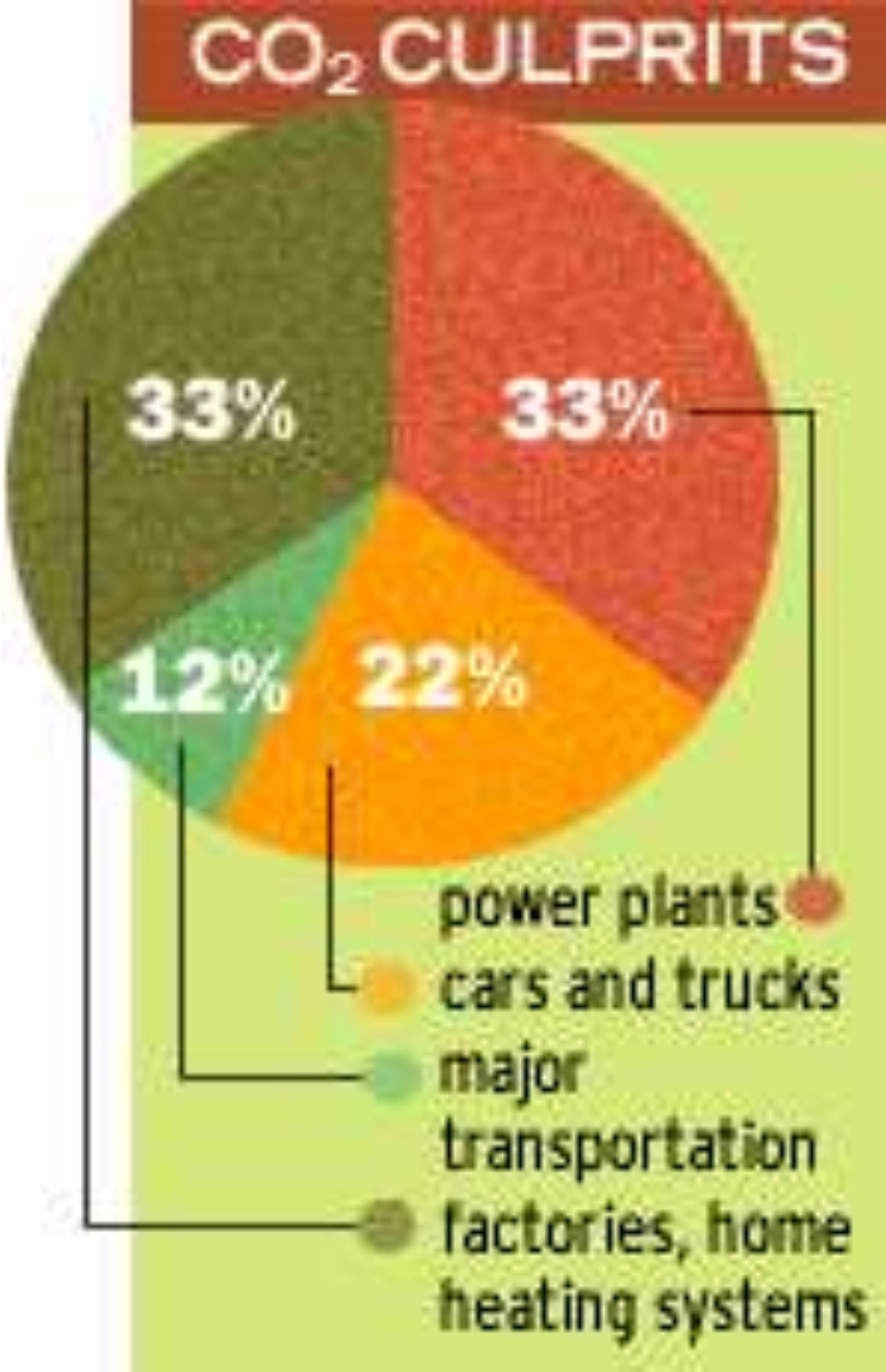
Obviously, since humankind is a major greenhouse gas producer, we need to consider the possibility that our activities affect global climate.

CO_2 Emissions in the U.S.

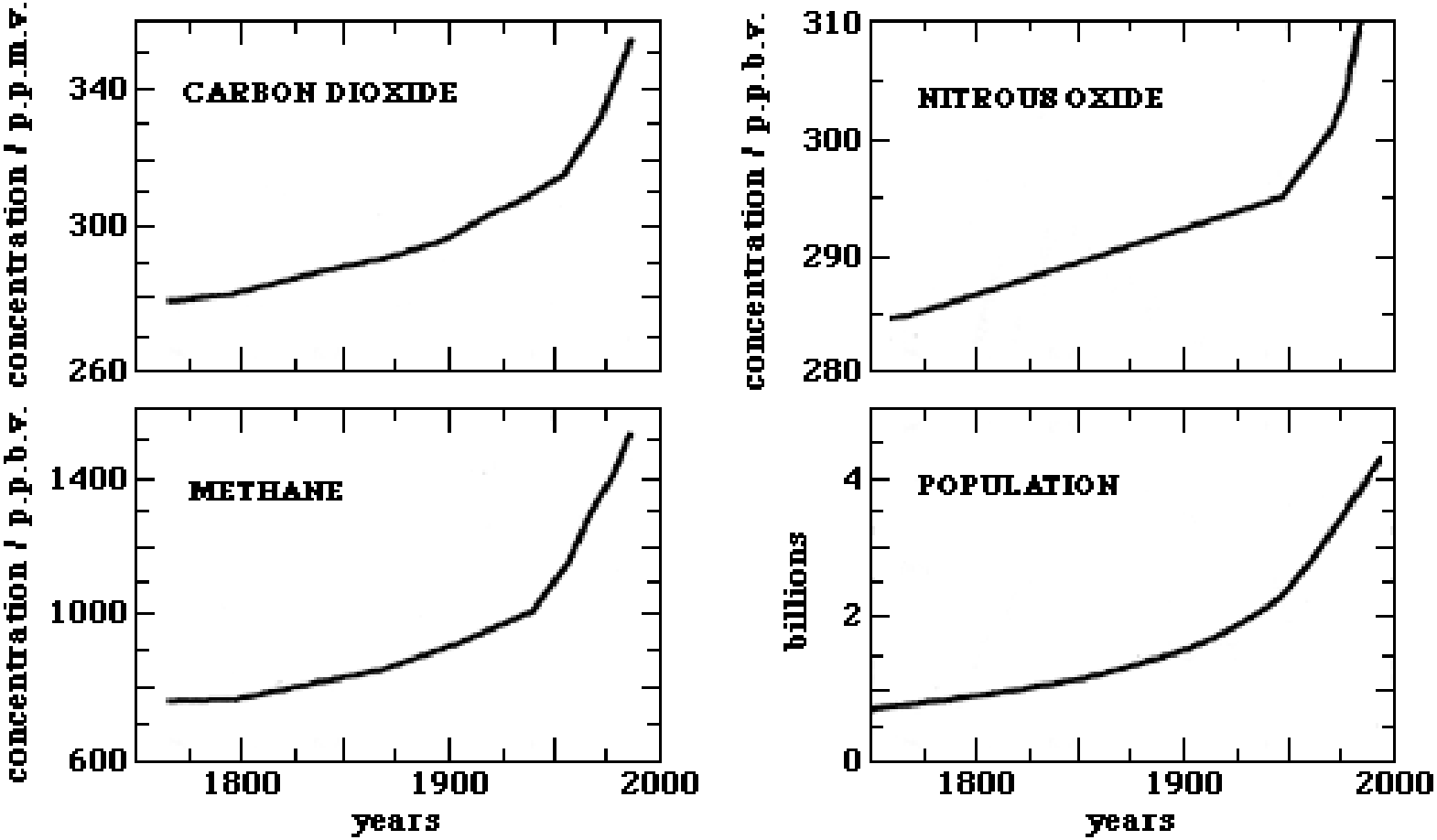
A large amount of CO_2 is produced in generating electricity (most power plants burn carbon-based fuels).

What can you do to reduce CO_2 emission?

- drive fuel efficient vehicle
- use public transportation
- use energy efficient appliances



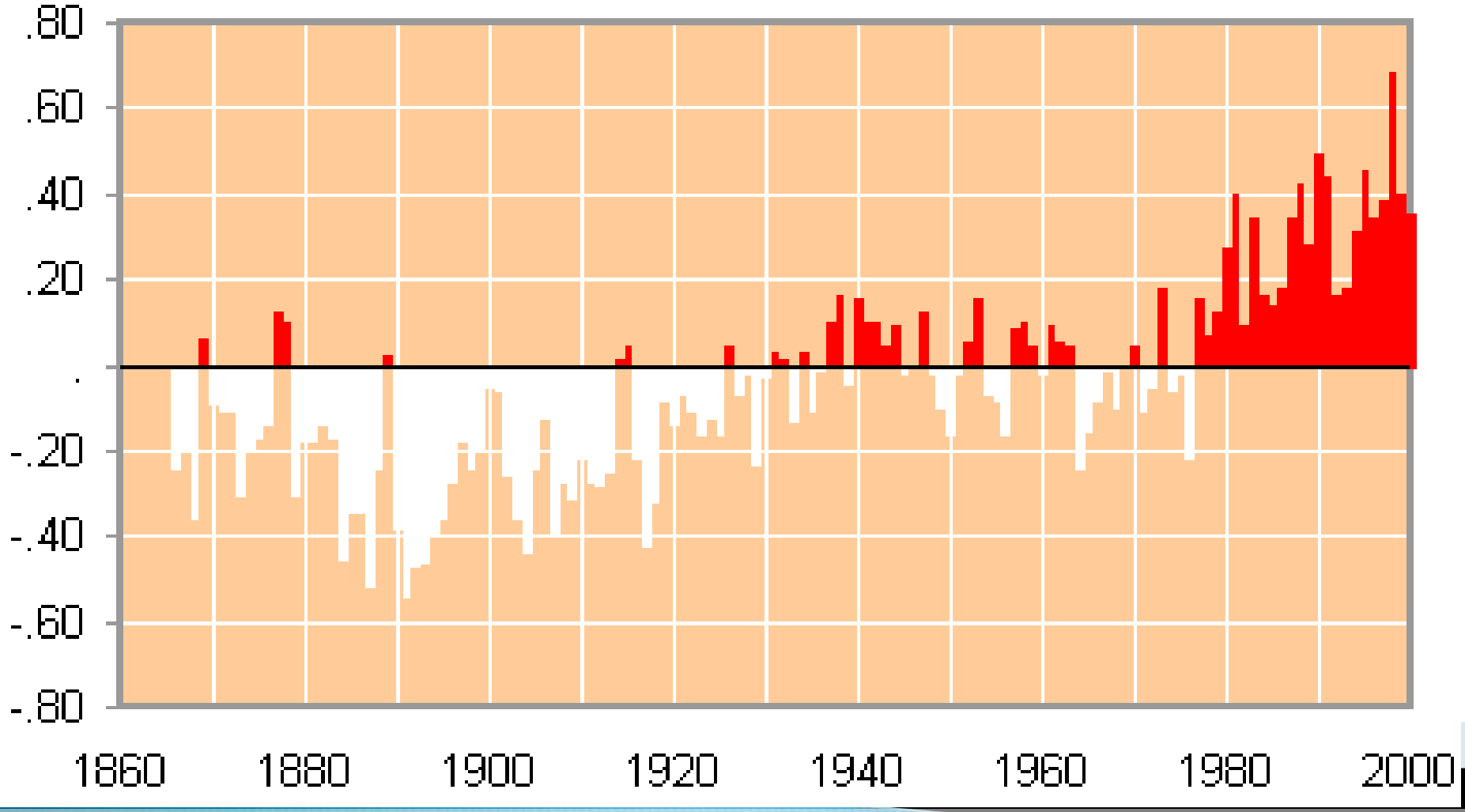
Increases



Increase of greenhouse gas concentrations over the last 200 years from antarctic ice cores. CO_2 (from Oeschger & Siegenthaler 1988), CH_4 (from Pearman et al. 1986), N_2O (from Khalil & Rasmussen 1988). The population growth is included for comparison.

Adapted from: Lorius, Claude, Jean Jouzel, and Dominique Raynaud (1992) The ice core record: past archive of the climate and signpost to the future. In: *Antarctica and Environmental Change*, (ed. D.J. Drewry, R.M. Laws, and J.A. Pyle) pp. 27-34, New York: Oxford University Press.

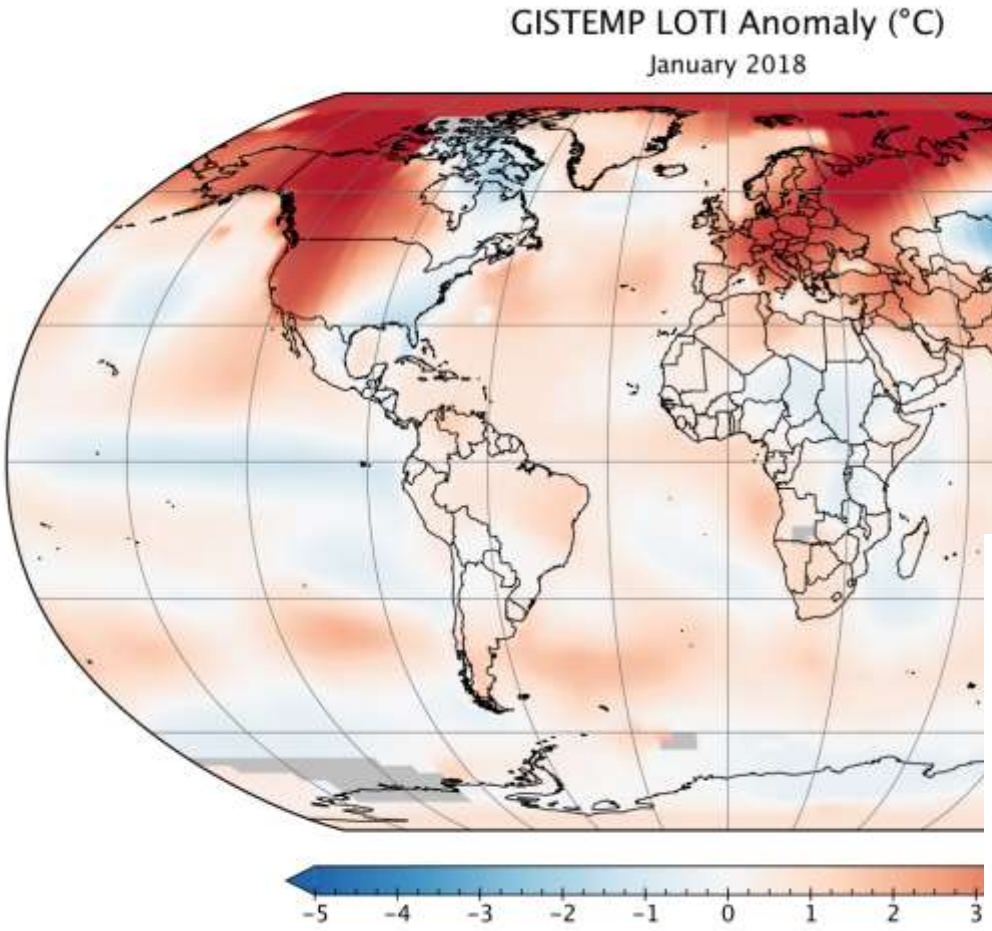
Temperature



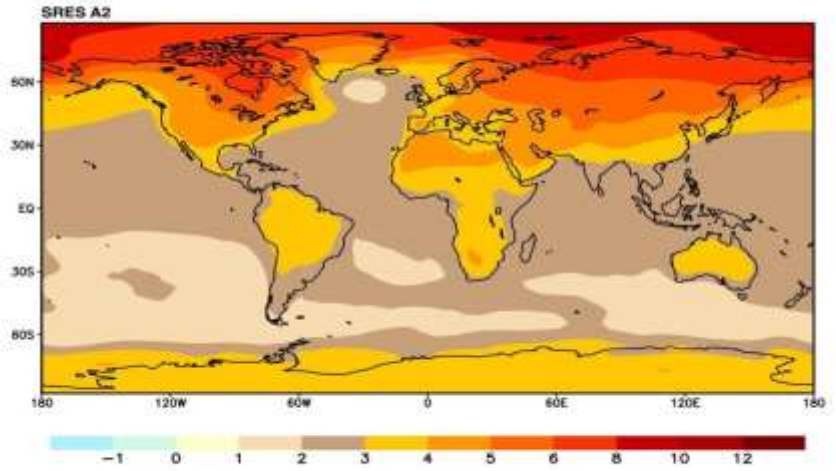
The question remains: is this global climate change all our fault?

If so, consider that the IPCC suggests a global increase of **1.4 to 5.8ºC** by **2100** given current greenhouse gas emissions.

Twentieth Century Temperature



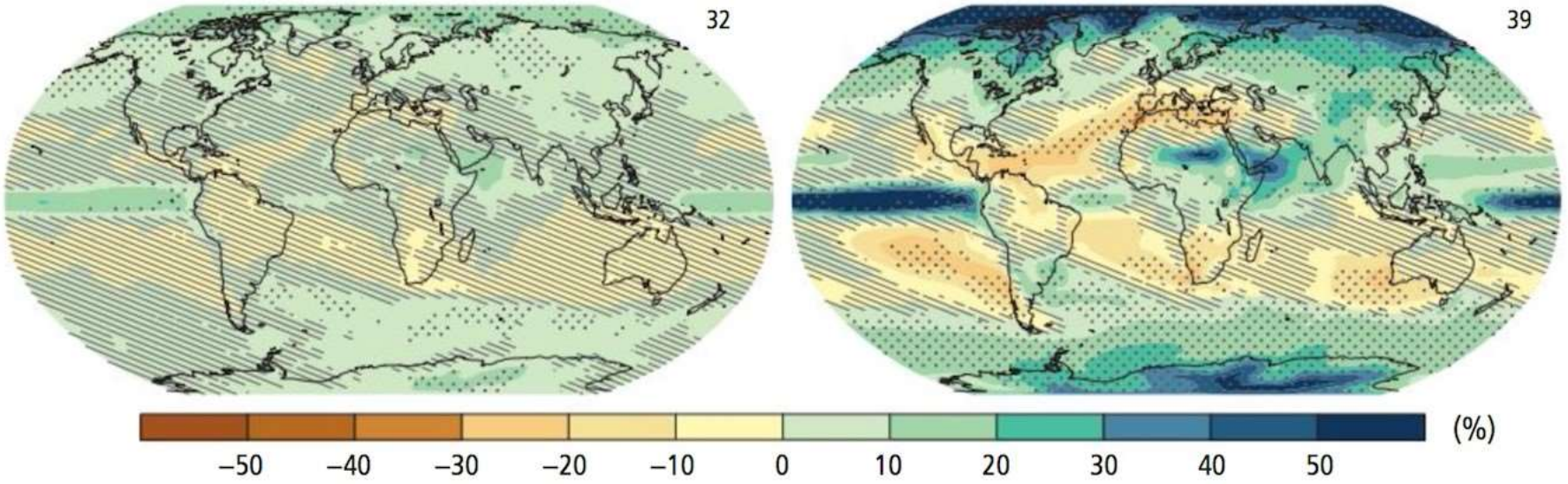
LAND AREAS ARE PROJECTED TO WARM MORE THAN THE OCEANS WITH THE GREATEST WARMING AT HIGH LATITUDES



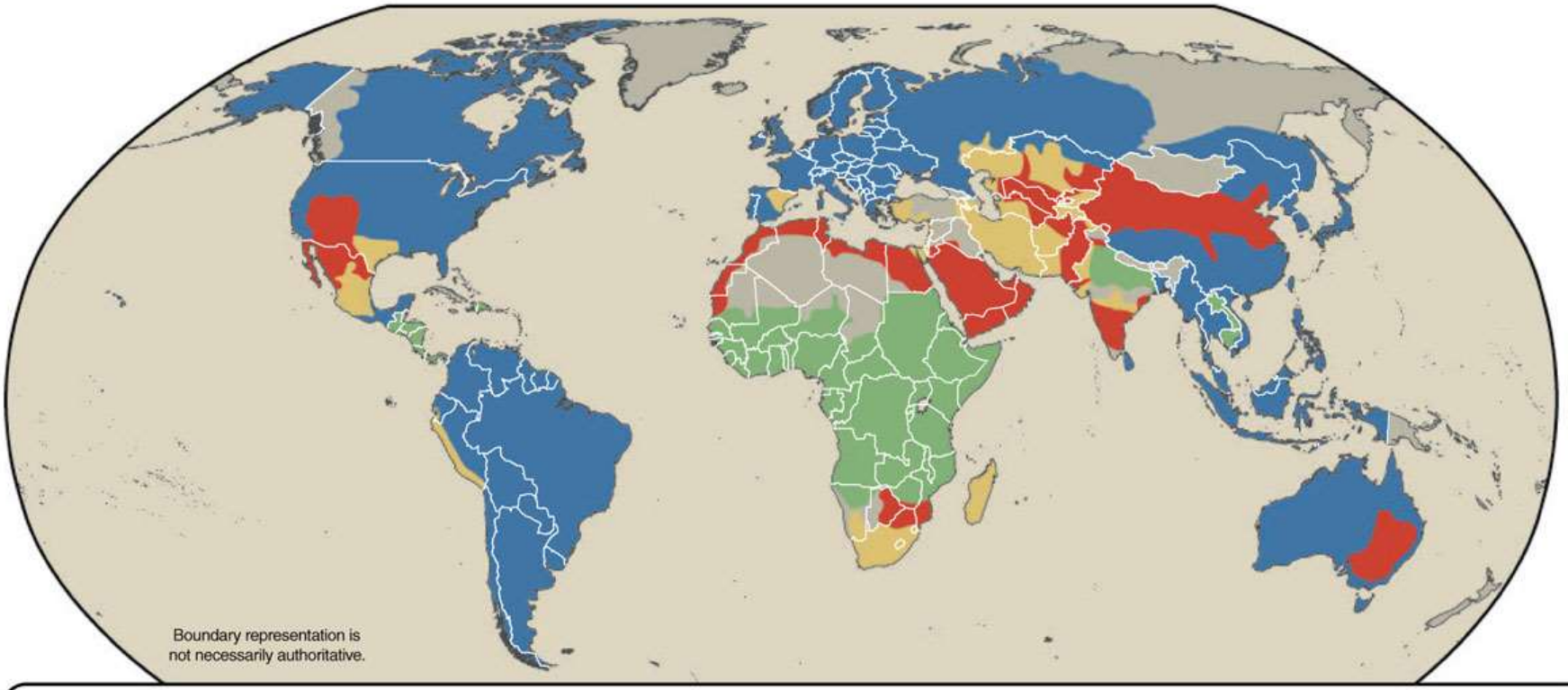
Annual mean temperature change, 2071 to 2100 relative to 1990: Global Average in 2085 = 3.1°C

PRECIPITATION RATES ARE CHANGING

Change in average precipitation (1986–2005 to 2081–2100)



Projected Global Water Scarcity, 2025



Physical water scarcity: More than 75% of river flows are allocated to agriculture, industries, or domestic purposes. This definition of scarcity — relating water availability to water demand — implies that dry areas are not necessarily water-scarce.

Approaching physical water scarcity: More than 60% of river flows are allocated. These basins will experience physical water scarcity in the near future.

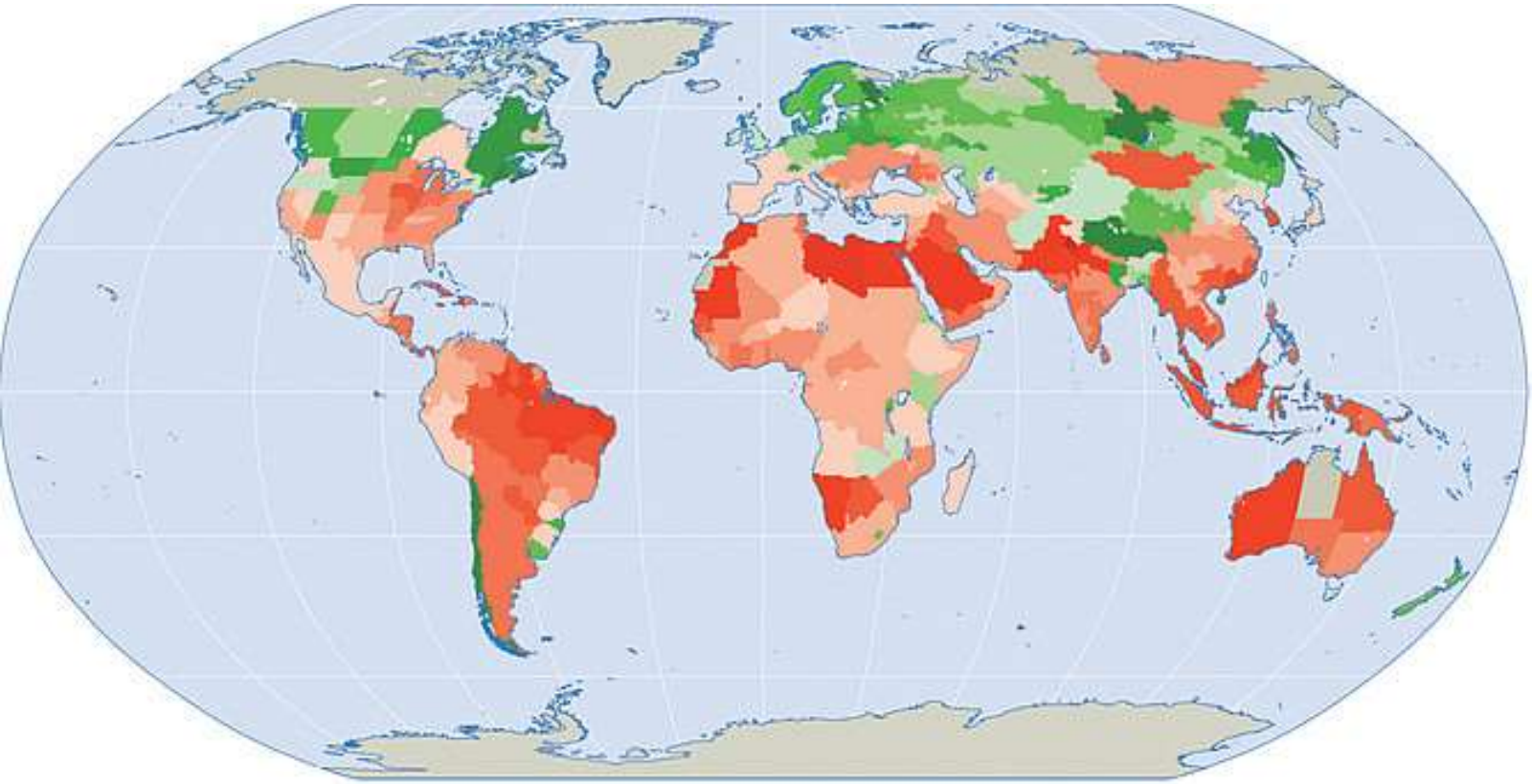
Economic water scarcity: Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

Little or no water scarcity: Abundant water resources relative to use. Less than 25% of water from rivers is withdrawn for human purposes.

Not estimated

Source: International Water Management Institute.

Percentage Change in yields



Percentage change in yields between 2010 and 2050

-50 -20 0 +20 +50 +100

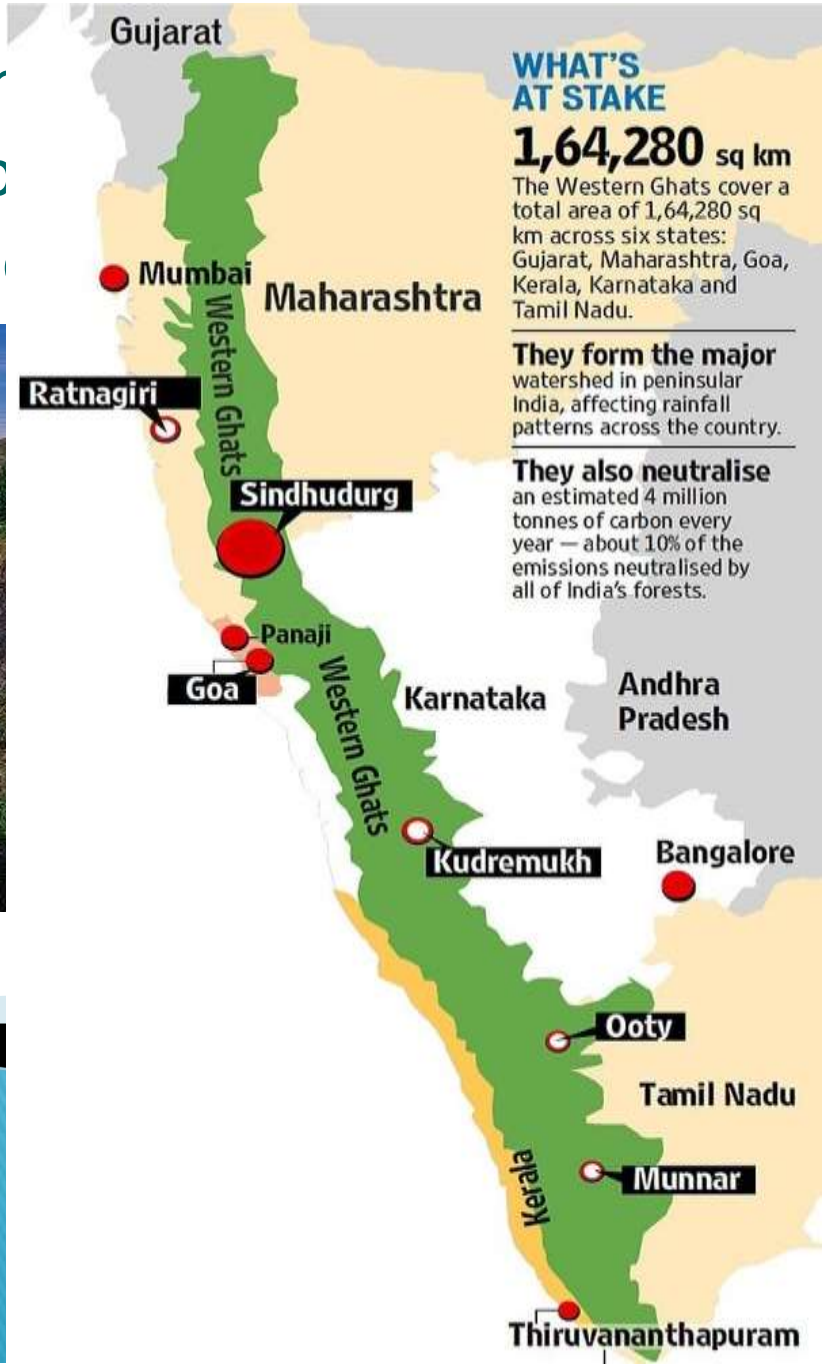
No data

Source: World Bank (2010)

The Western Ghats

Over 5,000 different **plants** occur ir
the **Western Ghats**. Around **1,700** c
these are **found nowhere** else in th
world .

- Savanna Grassland
- Heterogenous Flora



CLIMATE-VEGETATION EQUILIBRIUM

- The Rainforest here occurs in the mist laden humid environment receiving 7-8 months of rainfall.
- Strengthened Summer Monsoon and Winter Monsoon
- The highlands (1500m altitude) obstructs the clouds resulting into heavy rainfall during SWM.
- The retreat of monsoon again showers rain in this region.
- The windward side towards the coast receives most of the rainfall and thereby, the occurrence of Rainforest
- Most of pollen from this region is transported to coastal /marine wetlands where they get preserved
- Therefore, the coastal sediments and Marine sediments serve as potential archive for monitoring climate through palynology.

Adverse Climate: Low Rainfall (During Cold & Arid Conditions- Glacial periods)

- Vegetation shrinks to Pockets in areas retaining soil moisture around water body, Crevices or shady area where evaporation is minimum.

- Plant takes refuge in pockets

Western Ghats – Drivers

Humans would have inhabited 15,000 years BP, but farming may be less than 10,000 years

Middle Stone Age (Mesolithic: 12,000 – 5000 BP) witnessed hunter gatherers to food growers

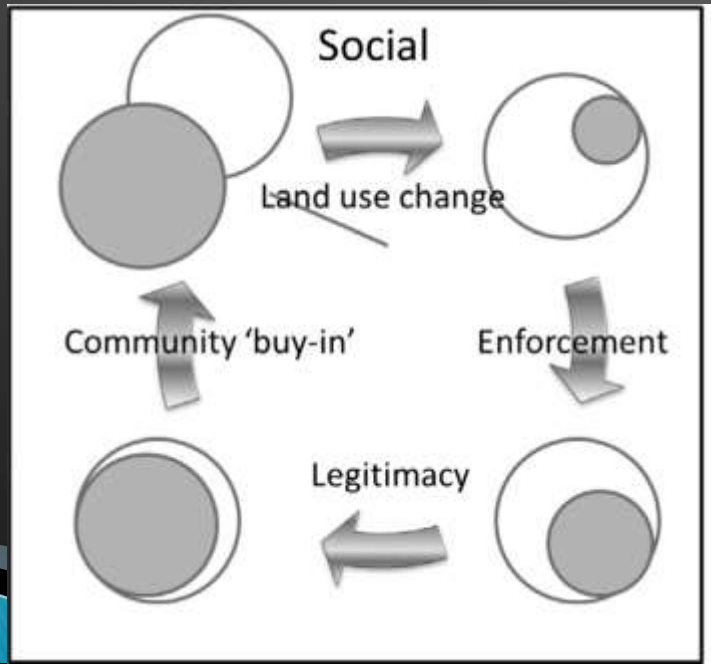
During New Stone Age (Neolithic: 5000 – 3000 BP) primitive agriculture and pastrolism was prevalent

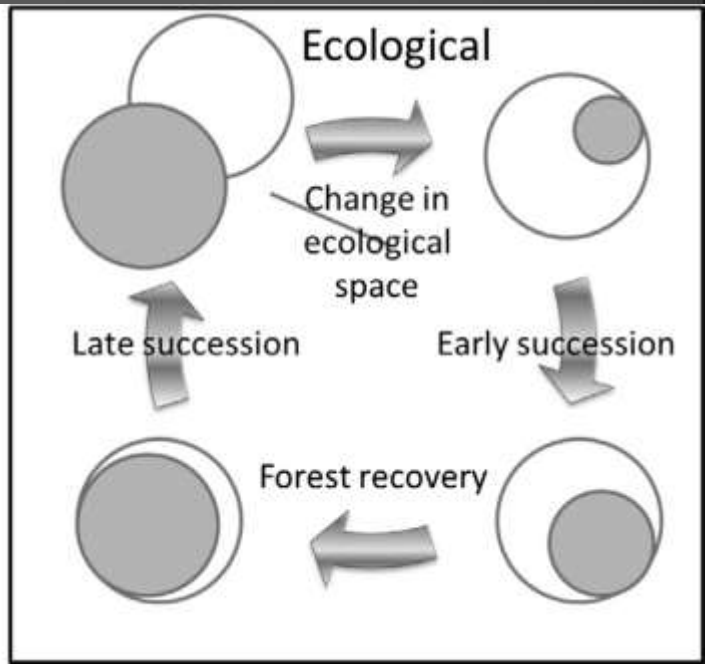
During Neolithic period (3000 – 2000 BP) iron was widely used and during this period widespread forest clearance had happened

Cultural Drivers Bhagwat et al. 2014

In Sacred Grooves: Throughout the 1000-year sequence, the prevalent trend is that of increasing tree cover and decreasing grass cover.

In non-sacred parts: **G**radual decline in forest cover took place over the last 1000 years





Commercial Exploitation of the land in western Ghats

Loss in Plant Diversity

- Climate Change
- Enhanced by Anthropogenic activity

Palynological study from south-western ghats – Anjum Farooqui et al

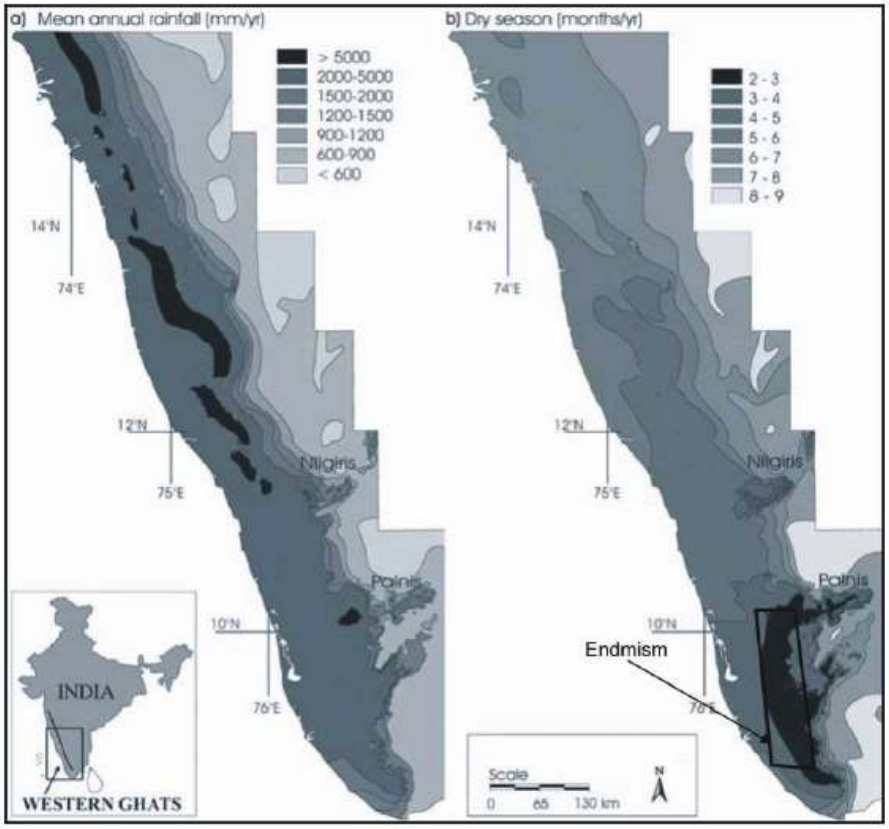


Figure 4. Map showing relative to mean annual rainfall and the length of the dry season in the Western Ghats, South India (after Pascal 1982; Barboni *et al*. 2003).

Holocene and Pre LGM record

Shola Forest in western ghats

Nilgiri Hills ~35-15 ka Shola forest invaded grassland (40 ka record)

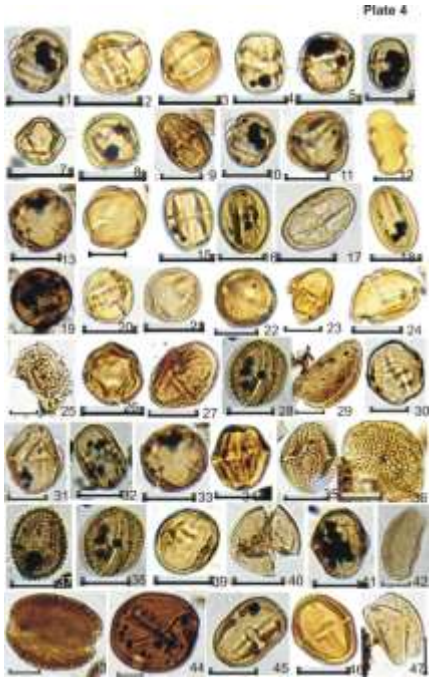
(

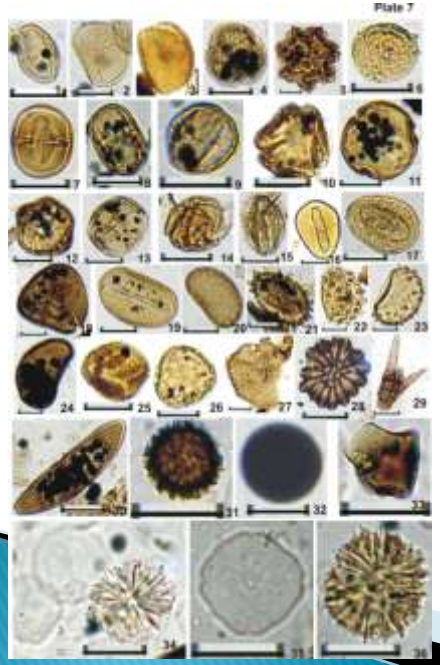
Palni Hills ~12ka- invasion of shola forest (50 ka record)

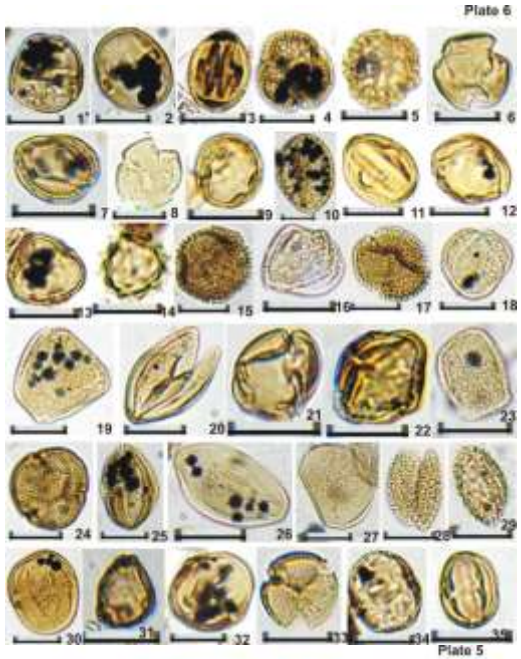
Late Quaternary Record

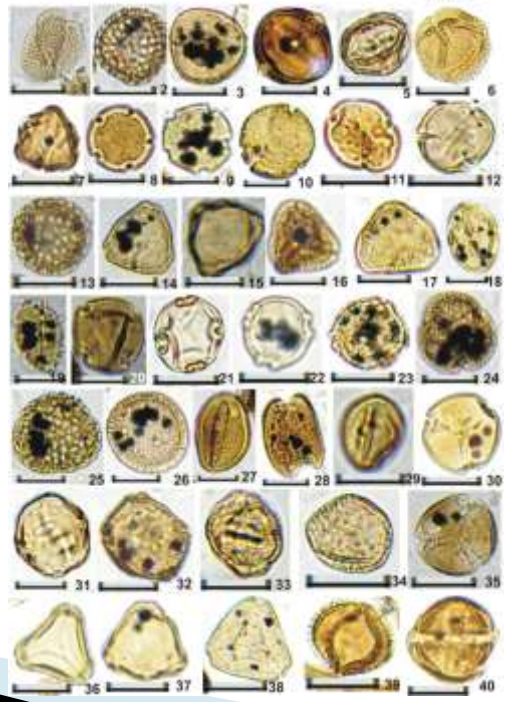
Chaganachery Well Section Kerala:

Pollen grains of about 80 taxa of rain forest and mangroves along with the Dinoflagellate cysts were recorded along with the YTT – Glass Shards (MIS 5.1).

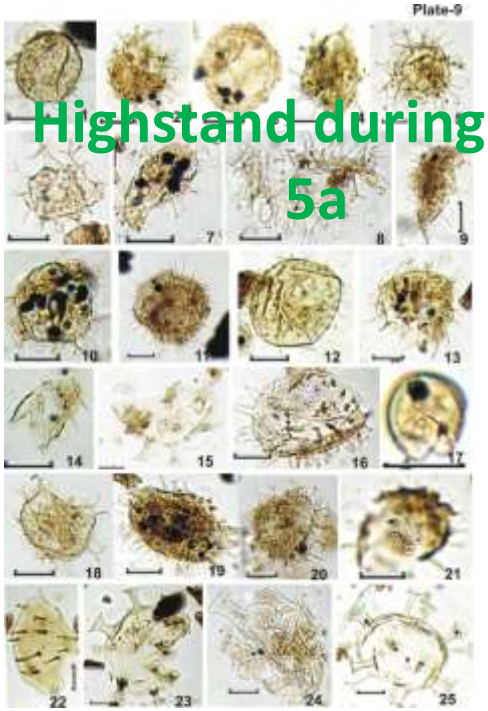








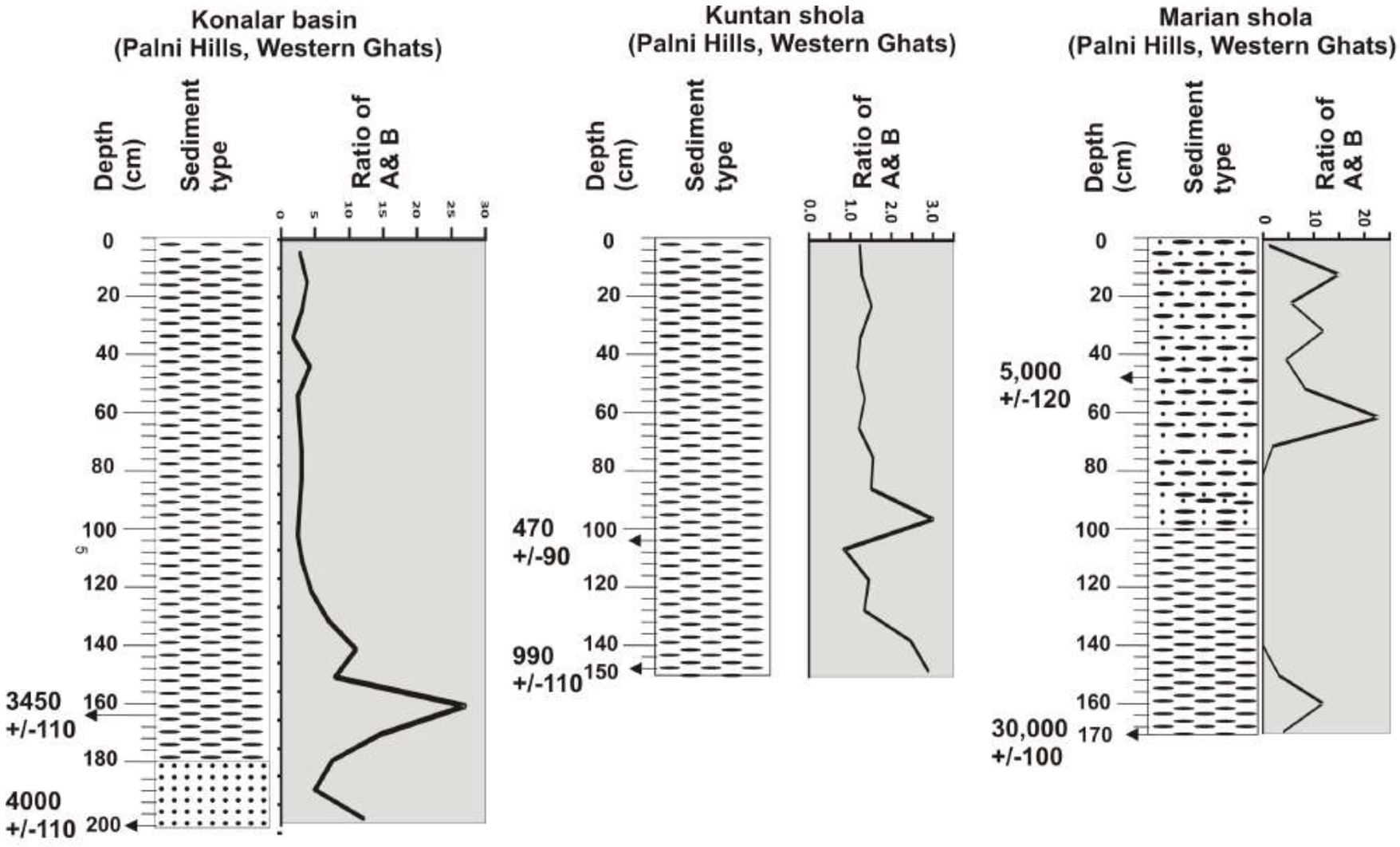
Pollen grains during MIS 5a from Chaganachery Kerala



Highstand during MIS 5a

Farooqui et al., 2010

Palynological Study in sediment cores from Palni Hills, South-western Ghats



S.K. Bera, A.Farooqui and H.P. Gupta (BSIP)

Highlights of palynological study in Sediment core from south-eastern Arabian Sea

- 140 ka pollen record of western ghat rainforest from Arabian sea, India.
- Sea level highstand during MIS-6,5 & Holocene supported by high terrestrial clasts.
- *Ongoeckia gore* relates to Gondwana lineage of rainforest flora in southern India.
- Similar monsoon circulation over South India since the Middle Miocene Climate Optimum.
- Drastic decline in rainforest diversity post LGM

Environmental Policy In India

- The Policy Statement for Abatement of Pollution and the National Conservation Strategy and Policy Statement on Environment and Development were brought out by the MoEF in 1992.
- The EAP (Environmental Action Programme) was formulated in 1993 with the objective of improving environmental services and integrating environmental considerations into development programmes.

Environmental Policy In India

National Environment Policy, 2006

- **It the first initiative in strategy-formulation for environmental protection in a comprehensive manner.**
- **It undertakes a diagnosis of the causative factors of land degradation with a view to flagging the remedial measures required in this direction.**
- **It recognizes that the relevant fiscal, tariffs and sectoral policies need to take explicit account of their unintentional impacts on land degradation.**

Environmental Policy In India

National Environment Policy, 2006 (contd.)

- **The solutions offered to tackle the problem comprise adoption of both, science-based and traditional land-use practices, pilot-scale demonstrations, large scale dissemination, adoption of Multi-stakeholder partnerships, promotion of agro-forestry, organic farming, environmentally sustainable cropping patterns and adoption of efficient irrigation techniques.**

Constitutional Framework

- **Article 21 - Fundamental Rights**
- **Article 48A - Directive Principles of State Policy**
- **Article 51A(g) - Fundamental Duties**

National Environment Policy, 2006

Enhancing and Conserving Environmental Resources

Land Degradation

National Environment Policy, 2006

Enhancing and Conserving Environmental Resources

Forests and Wildlife