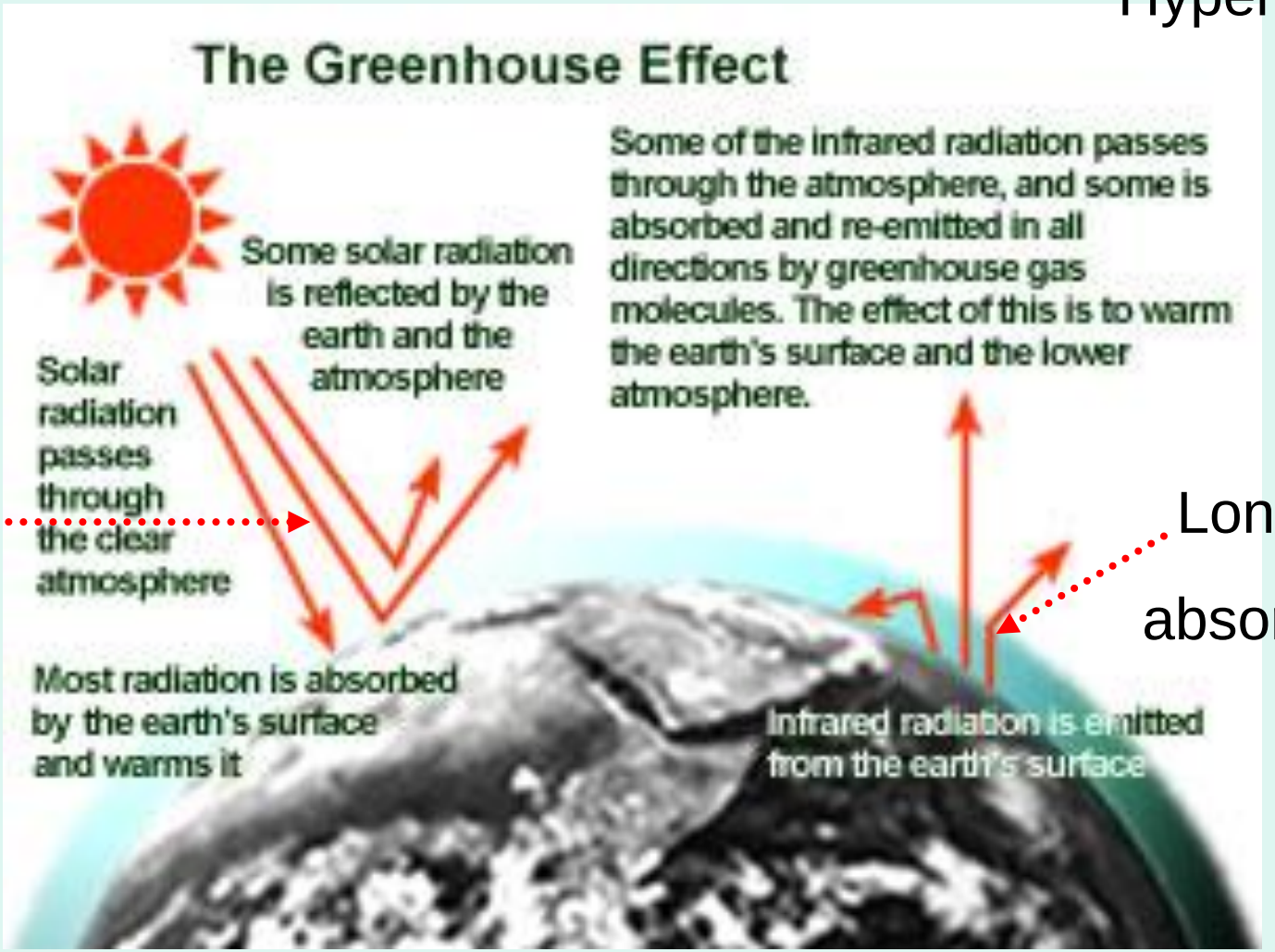
Greenhouse effect

Hyperlink



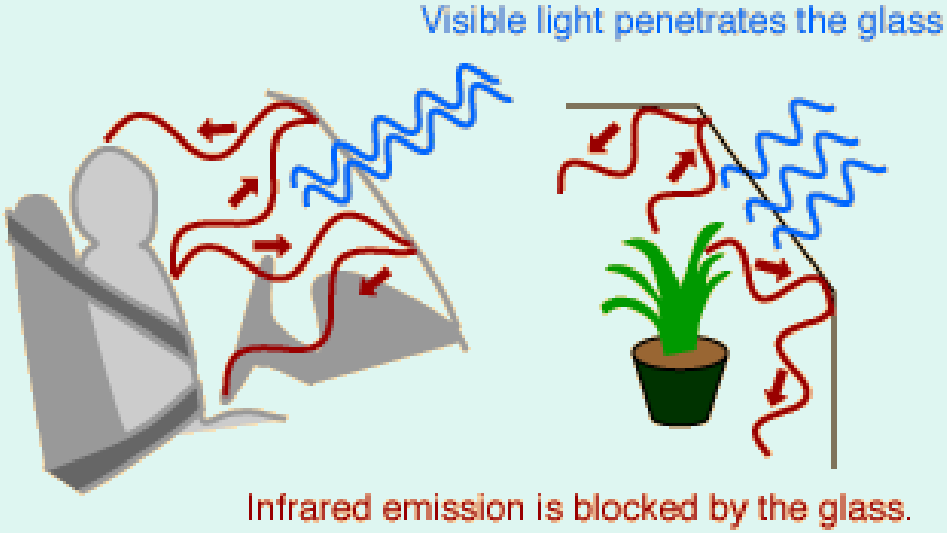
Short λ not absorbed

Long λ absorbed

Solar constant

- The sun radiates $3.9 \times 10^{26} W$
- The Earth is a distance of $1.5 \times 10^{11} m$ from the sun
- Calculate the power per m^2 reaching the Earth.

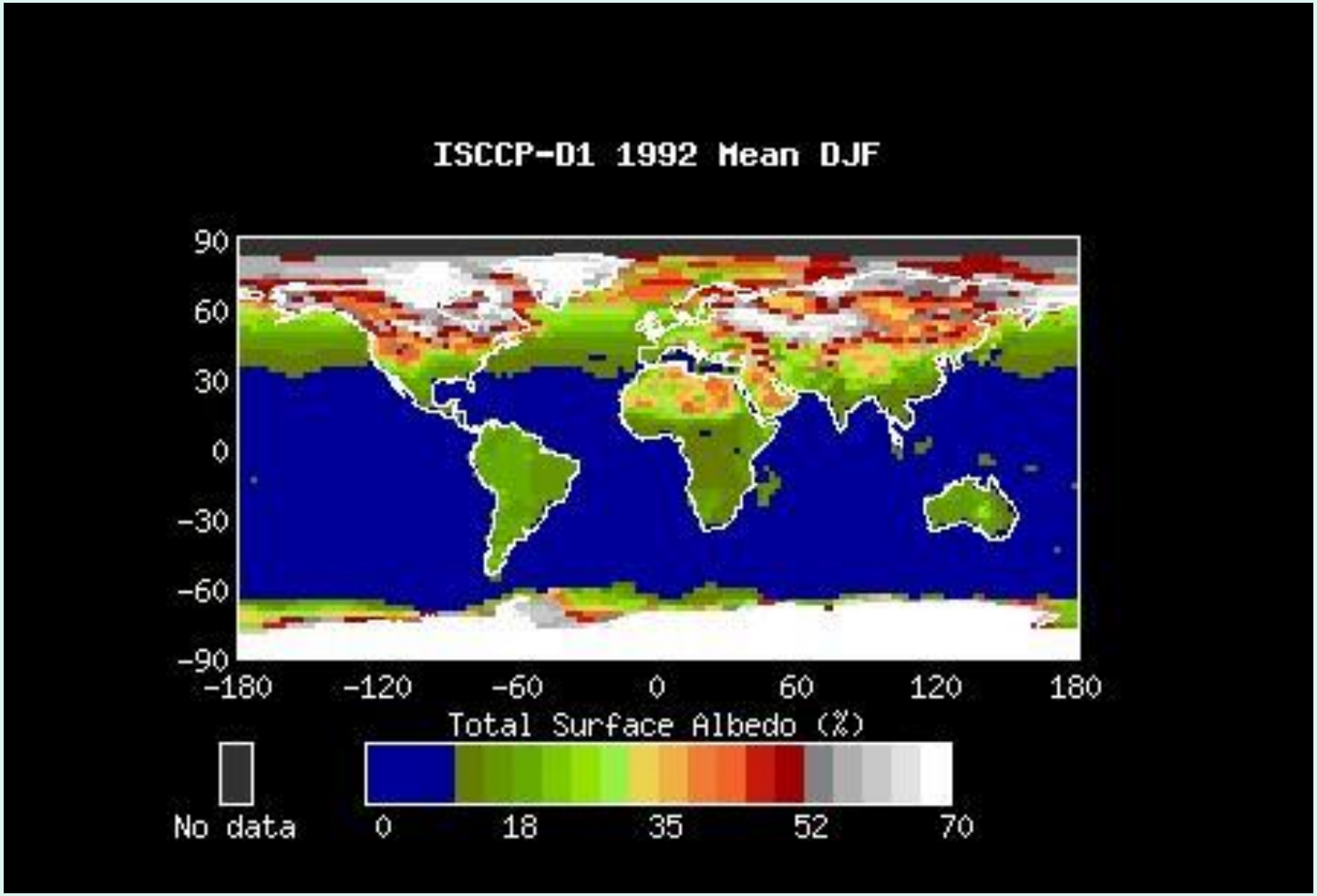
$$I = \frac{\text{power}}{A}$$



When the energy reaches the Earth, what happens to it?

Albedo

$$\text{albedo} = \frac{\text{total scattered power}}{\text{total incident power}}$$



the fraction of the incident sunlight that is reflected

Variations in albedo

Sample albedos

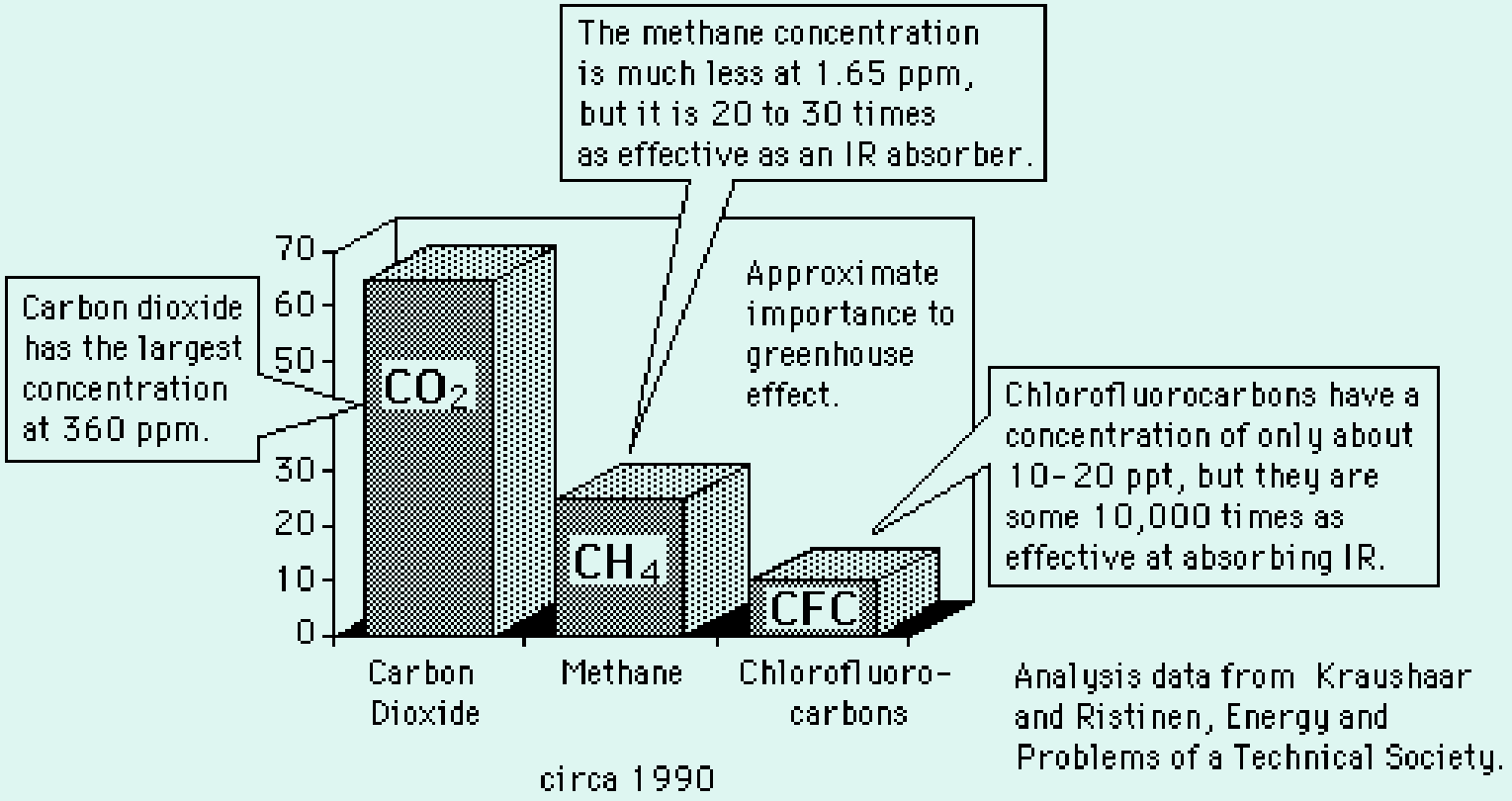
Surface	Typical Albedo
Fresh asphalt	0.04
Conifer forest (Summer)	0.08,0.09 to 0.15
Worn asphalt	0.12
Deciduous trees	0.15 to 0.18
Bare soil	0.17
Green grass	0.25
Desert sand	0.40
New concrete	0.55
Fresh snow	0.80–0.90

The albedo also varies with factors like season, latitude and cloud cover

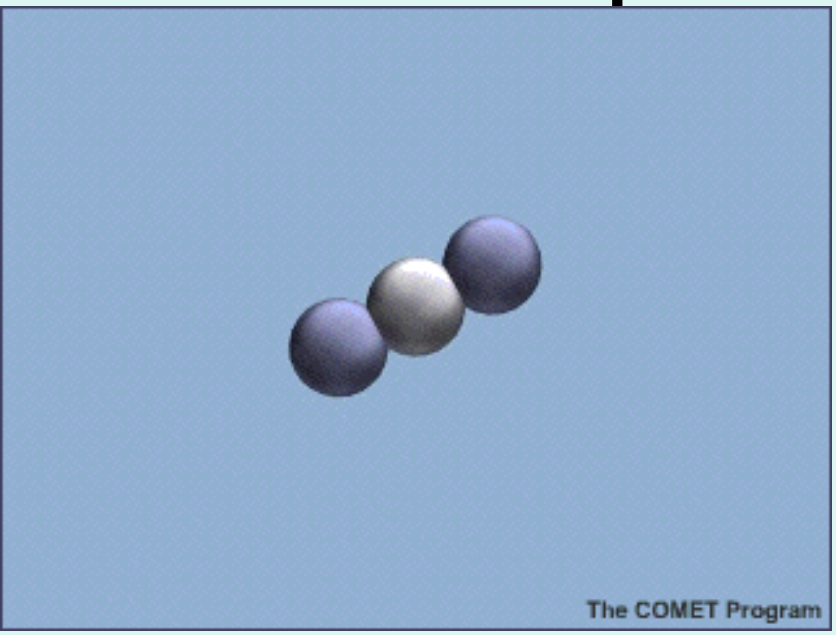
The average value on Earth is 0.3

Why does the reflected radiation not escape into space?

Greenhouse gases



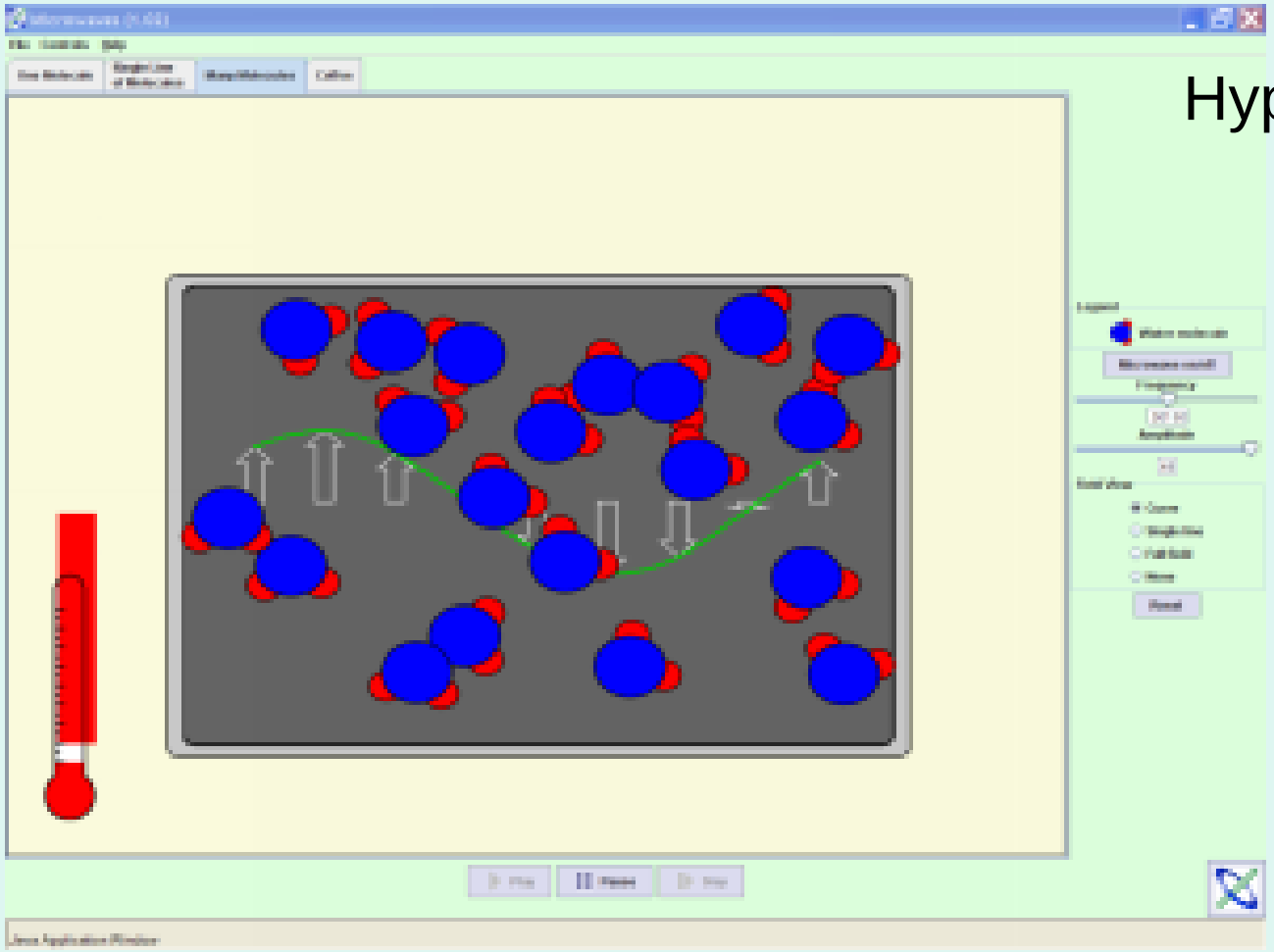
Absorption of IR radiation



The resonant frequency of greenhouse gases is in the IR region

Carbon dioxide, water vapour , methane , nitrous oxide , and a few other gases are greenhouse gases. They all are molecules composed of more than two component atoms, bound loosely enough together to be able to vibrate with the absorption of heat. The major components of the atmosphere N_2 and O_2 are two-atom molecules too tightly bound together to vibrate and thus they do not absorb heat and do not contribute to the greenhouse effect.

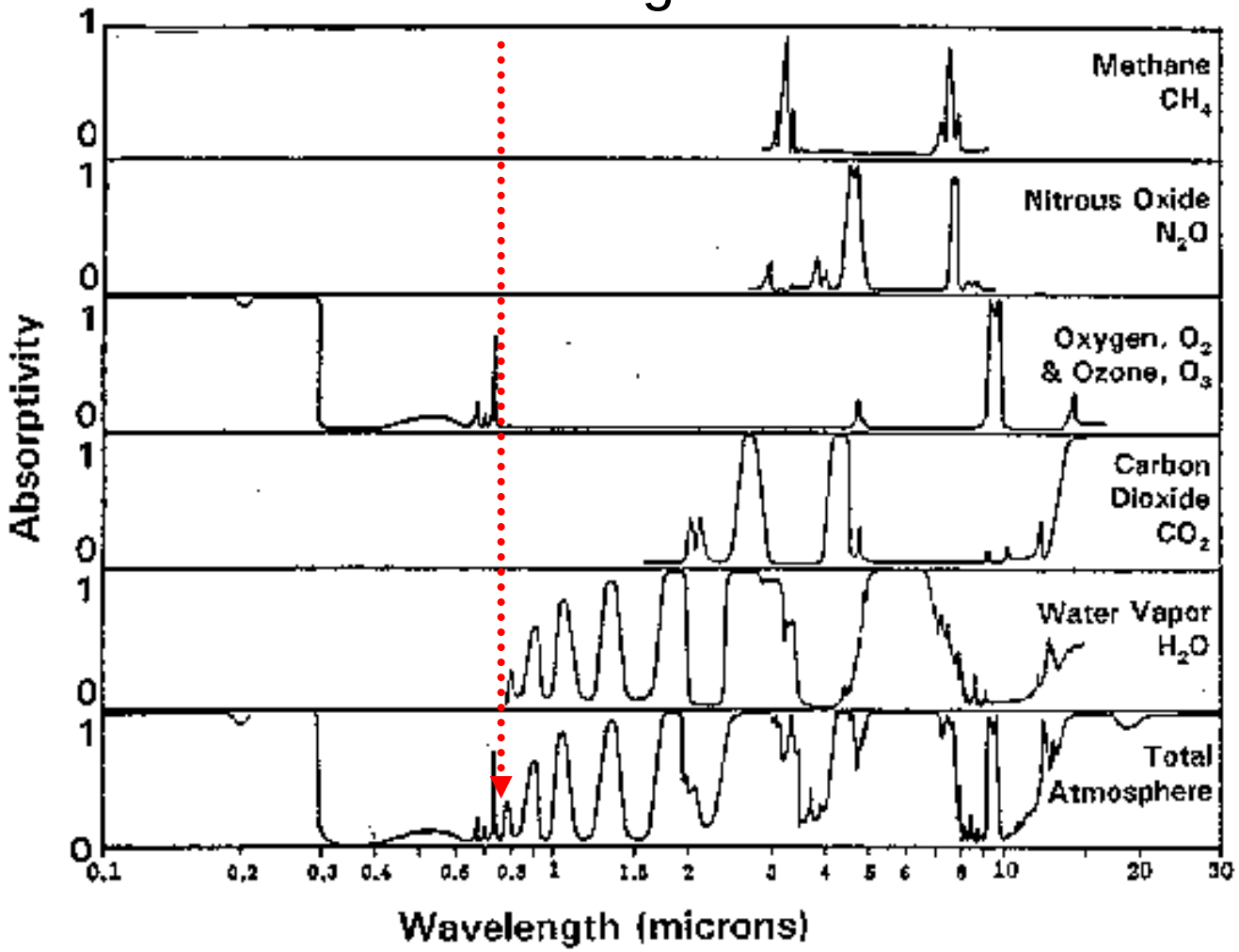
Microwave simulation



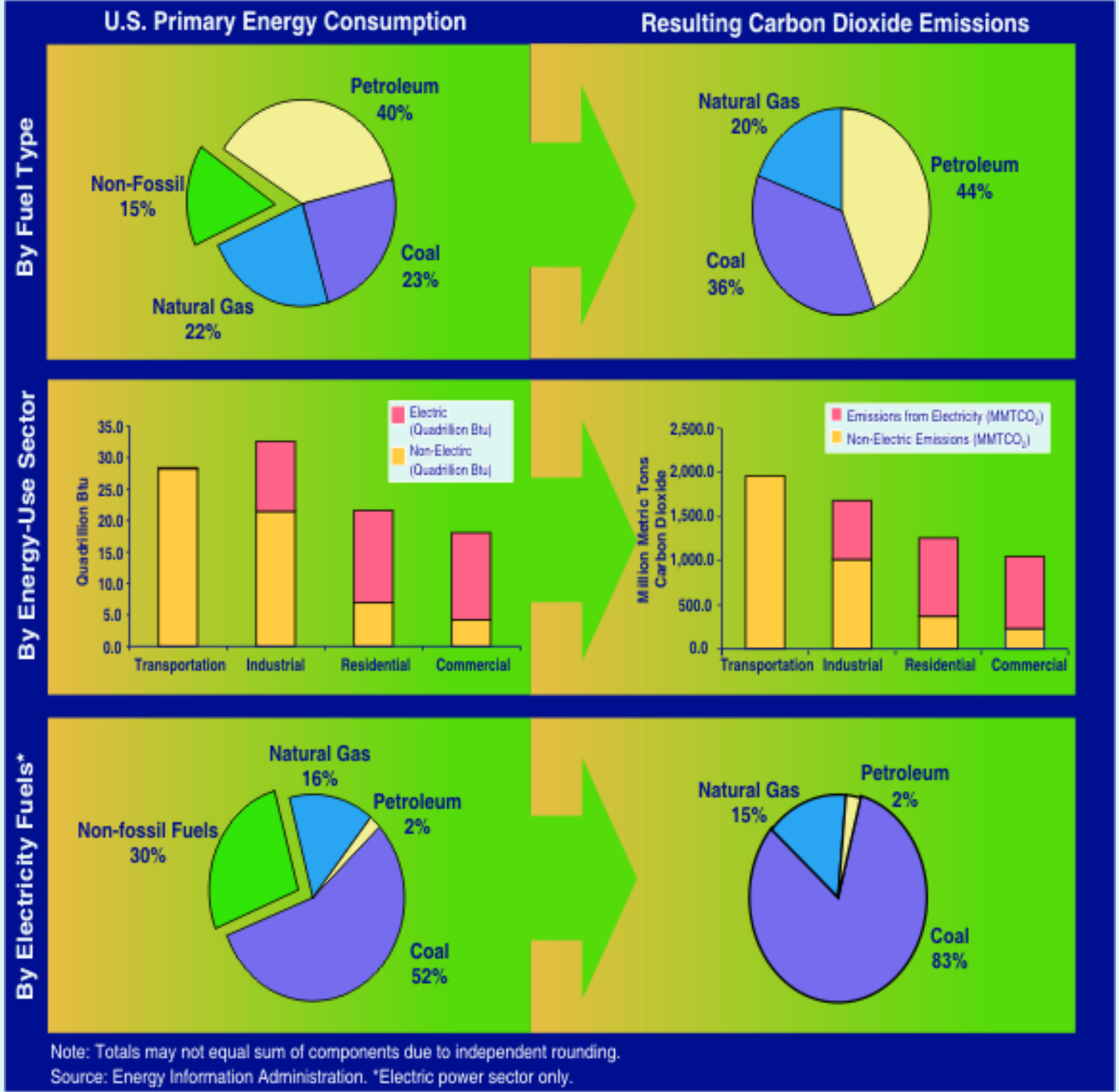
Hyperlink

ABSORPTION SPECTRA FOR MAJOR NATURAL GREENHOUSE GASES IN THE EARTH'S ATMOSPHERE

Start of IR region 0.7 nm



[After J. N. Howard, 1959: *Proc. I.R.E. 47*, 1459; and R. M. Goody and G. D. Robinson, 1951: *Quart. J. Roy. Meteorol. Soc. 77*, 153]



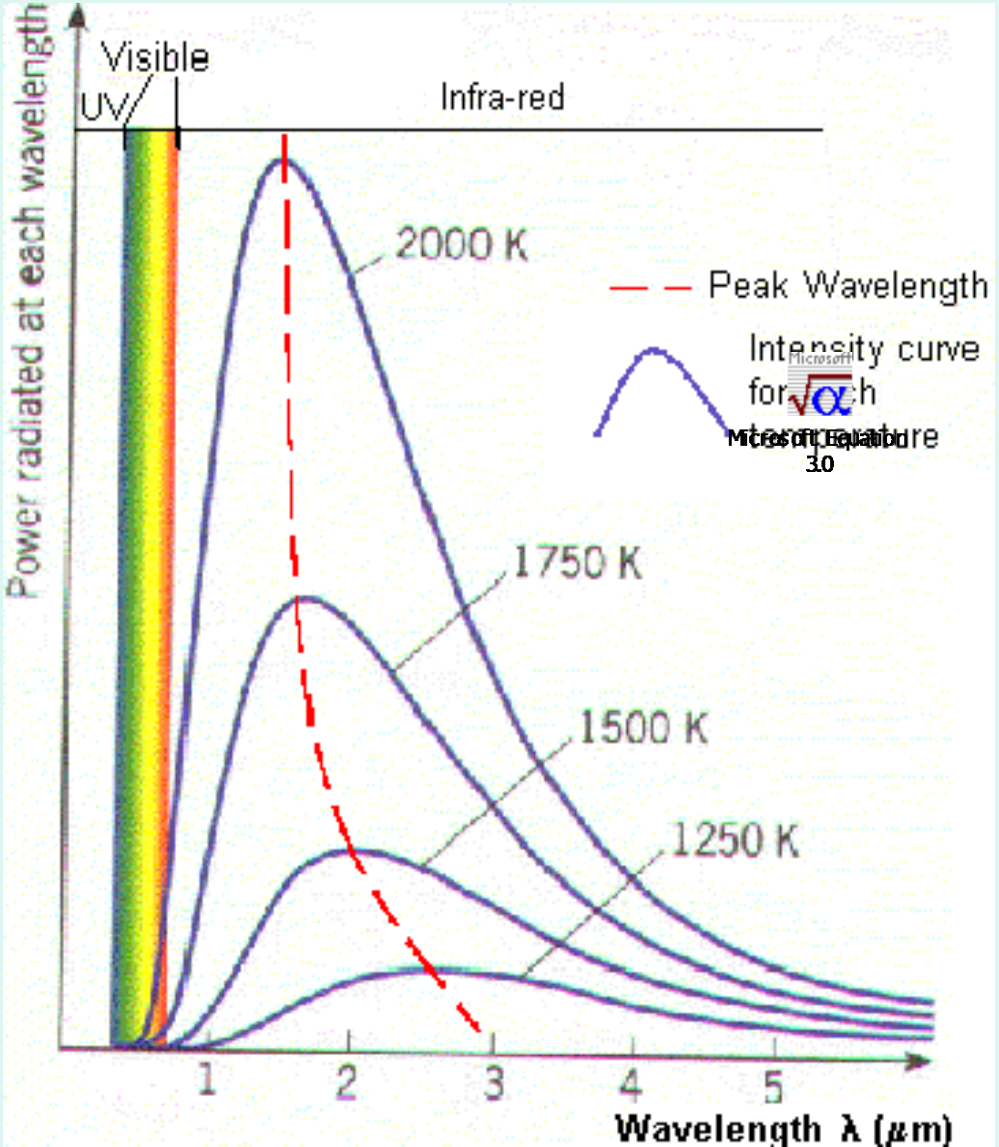
Note: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration. *Electric power sector only.

Sources of greenhouse gases

- Burning of fossil fuels and deforestation leading to higher carbon dioxide concentrations
- Livestock CO_2 and CH_4
- Fertilisers N_2O
- CFC's in refrigeration and fire extinguishers
- When these gases are ranked by their contribution to the greenhouse effect, the most important are:
- water vapour, which contributes 36–70%
- carbon dioxide, which contributes 9–26%
- methane, which contributes 4–9%
- ozone, which contributes 3–7%

How much heat does the Earth radiate?

The nature of black-body radiation.



$\lambda_{max} \times T$ = Wien's constant

Stefan–Boltzmann law

$$P = \sigma A T^4$$

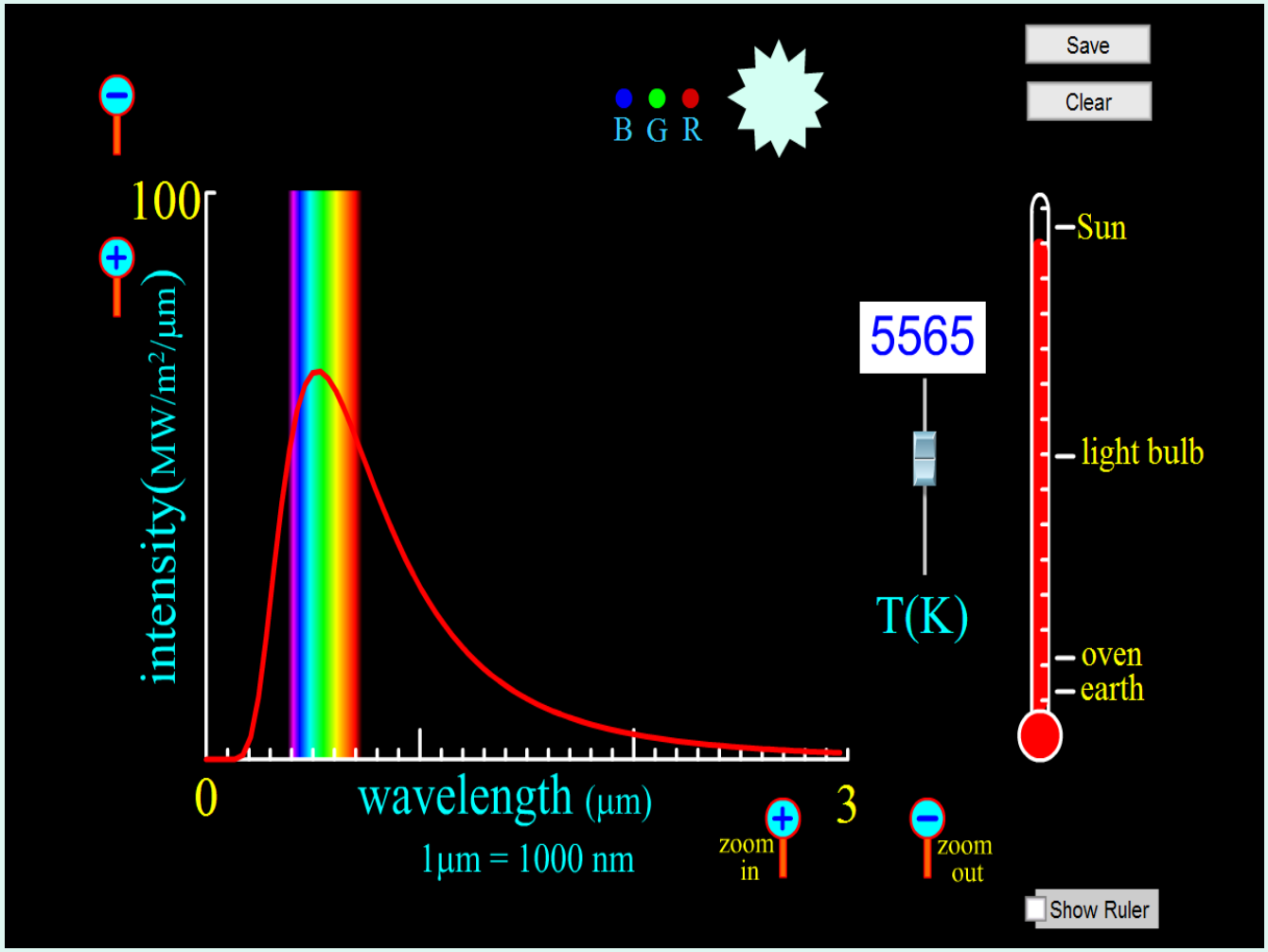
P = Power output

σ = Stefan–Boltzmann constant

A = Surface area of emitting body

T = Temperature of the emitter

Black body simulation



Emissivity

- The Earth is not a perfect Black Body radiator
- The emissivity is defined as

$$\frac{power - radiated - by - object}{Power - from - black - body - at - same - temp}$$

Therefore the Earth is not a perfect absorber or emitter of heat. Black objects have a high emissivity, white low.

$$\text{power} = e\sigma AT^4$$

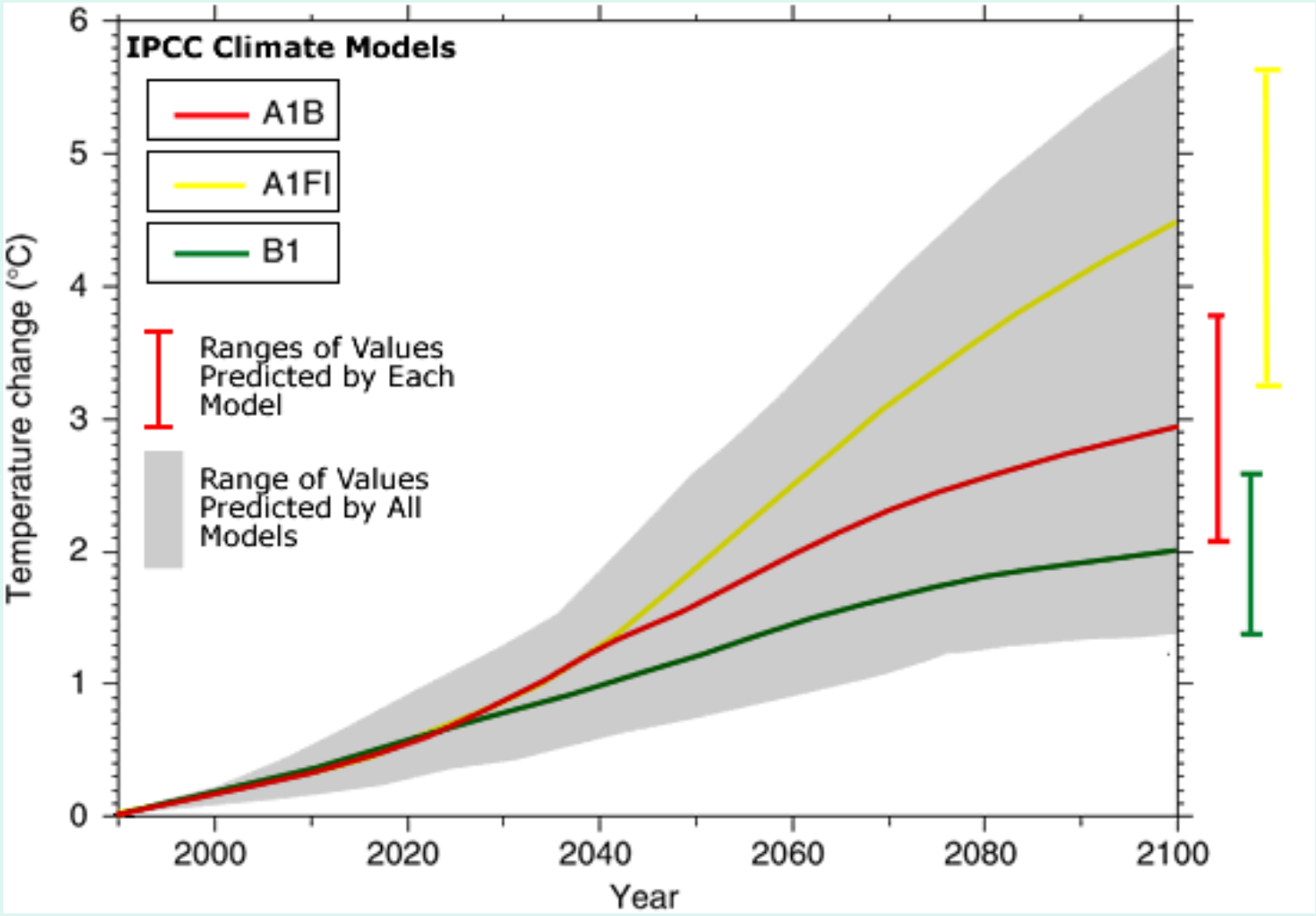
Values of emissivity

Aluminium: anodised	0.77
Aluminium: polished	0.05
Asbestos: board	0.96
Asbestos: fabric	0.78
Asbestos: paper	0.93
Asbestos: slate	0.96
Brass: highly polished	0.03
Brass: oxidized	0.61
Brick: common	.81-.86
Brick: common, red	0.93
Brick: facing, red	0.92
Brick: fireclay	0.75
Brick: masonry	0.94
Brick: red	0.90
Carbon: candle soot	0.95
Carbon: graphite, filed surface	0.98

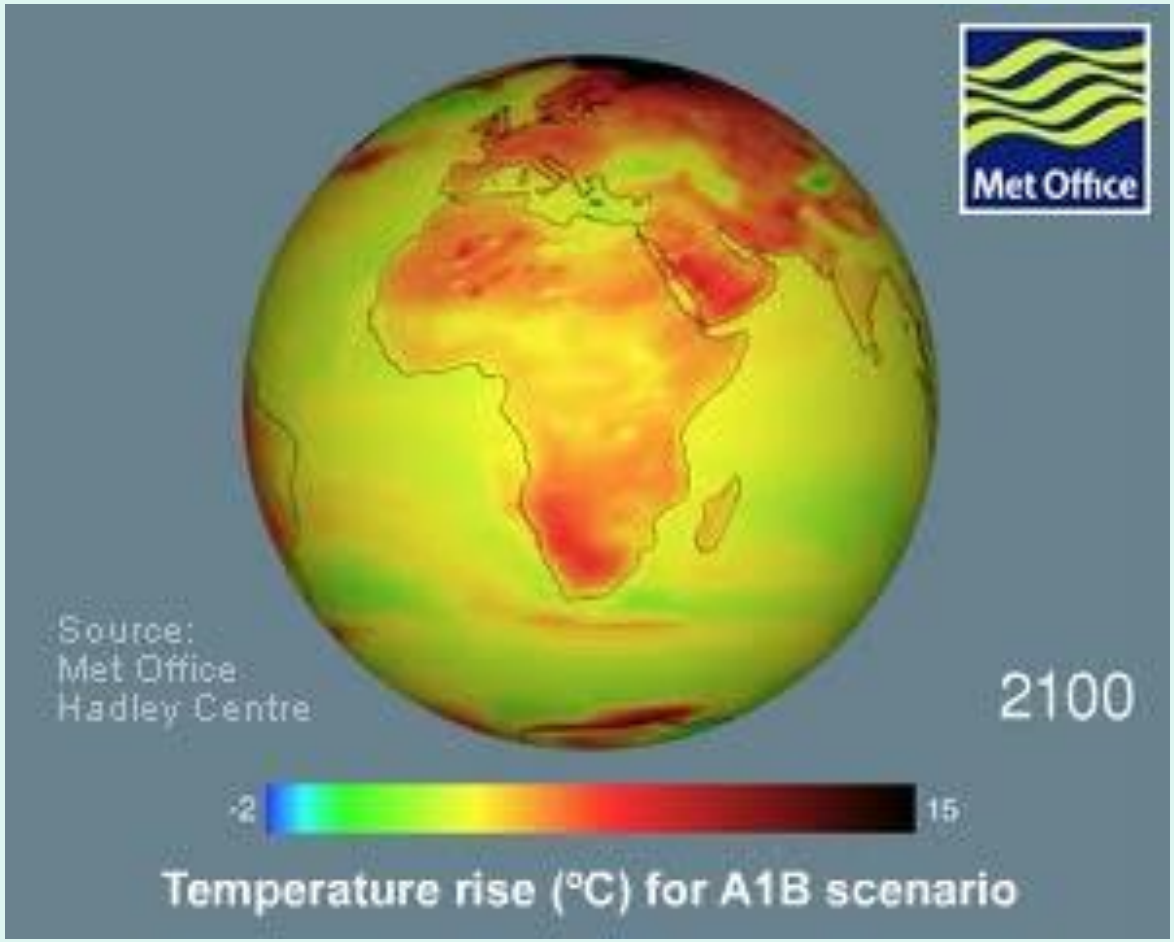
What is the effect of the absorbed radiation on the temperature of the Earth?

Greenhouse simulation

Predictions



Met office prediction



GLOBAL WARMING

Describe some possible models of global warming.

Students must be aware that a range of models has been suggested to explain global warming, including changes in the composition of greenhouse gases in the atmosphere, increased solar flare activity, cyclical changes in the Earth's orbit and volcanic activity.

State what is meant by the enhanced greenhouse effect.

It is sufficient for students to be aware that enhancement of the greenhouse effect is caused by human activities.

Identify the increased combustion of fossil fuels as the likely major cause of the enhanced greenhouse effect

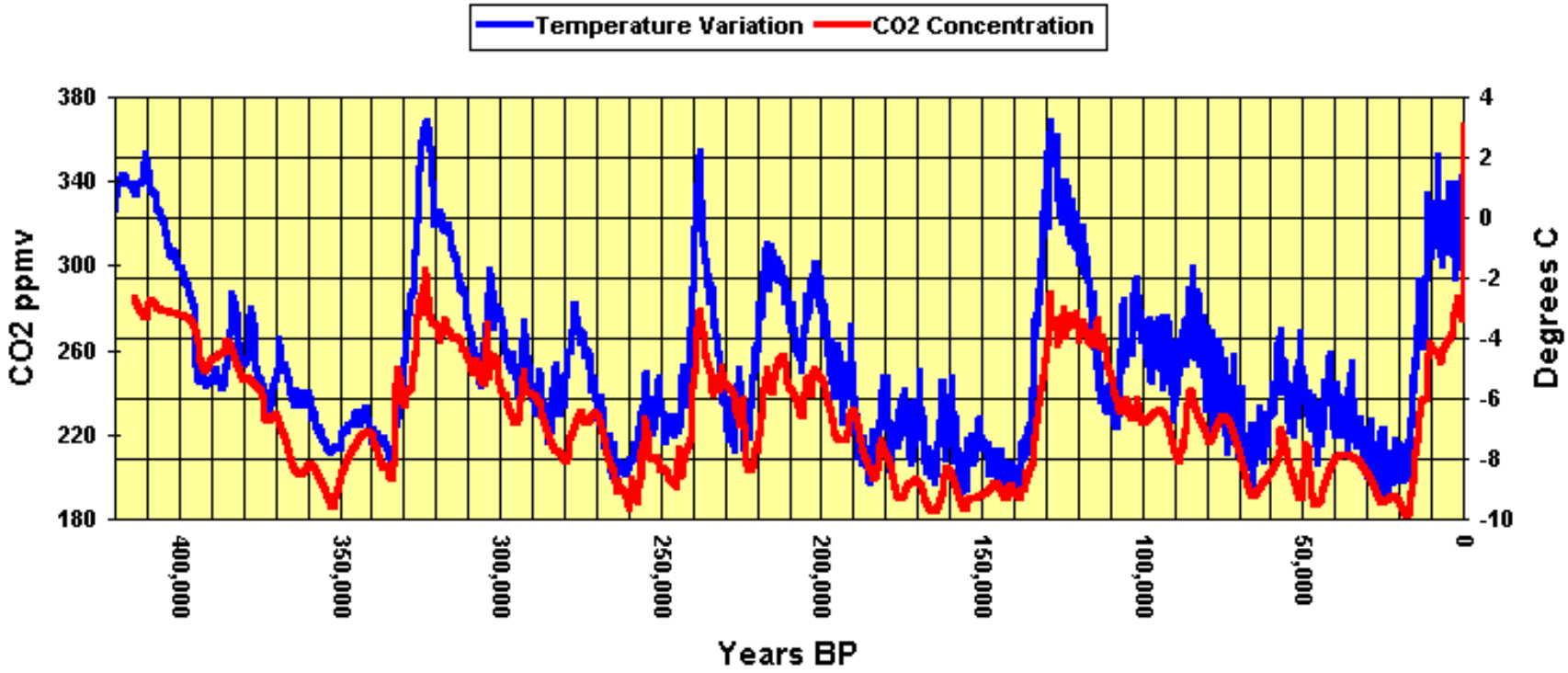
Students should be aware that, although debatable, the generally accepted view of most scientists is that human activities, mainly related to burning of fossil fuels, have released extra carbon dioxide into the atmosphere.

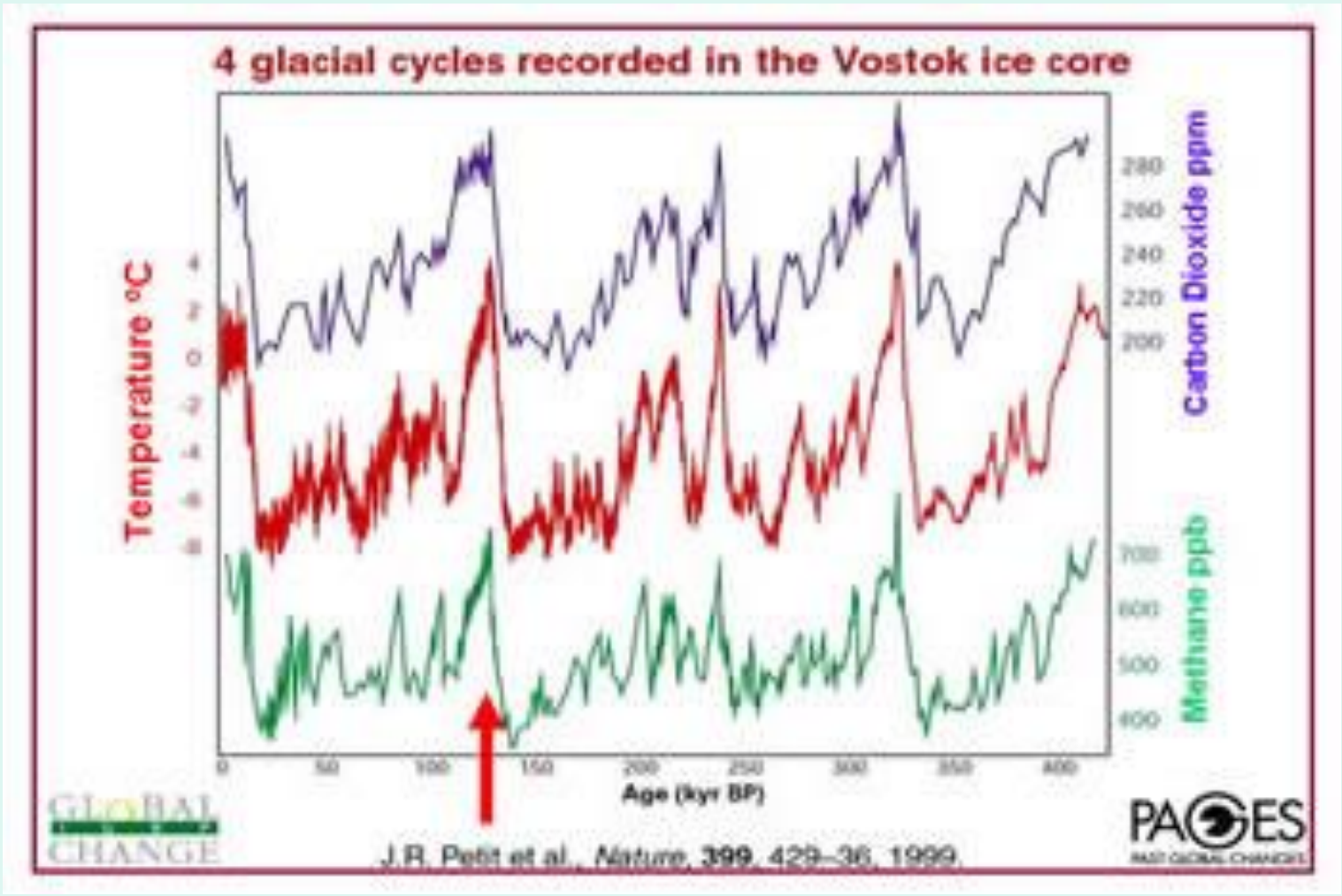
Describe the evidence that links global warming to increased levels of greenhouse gases.

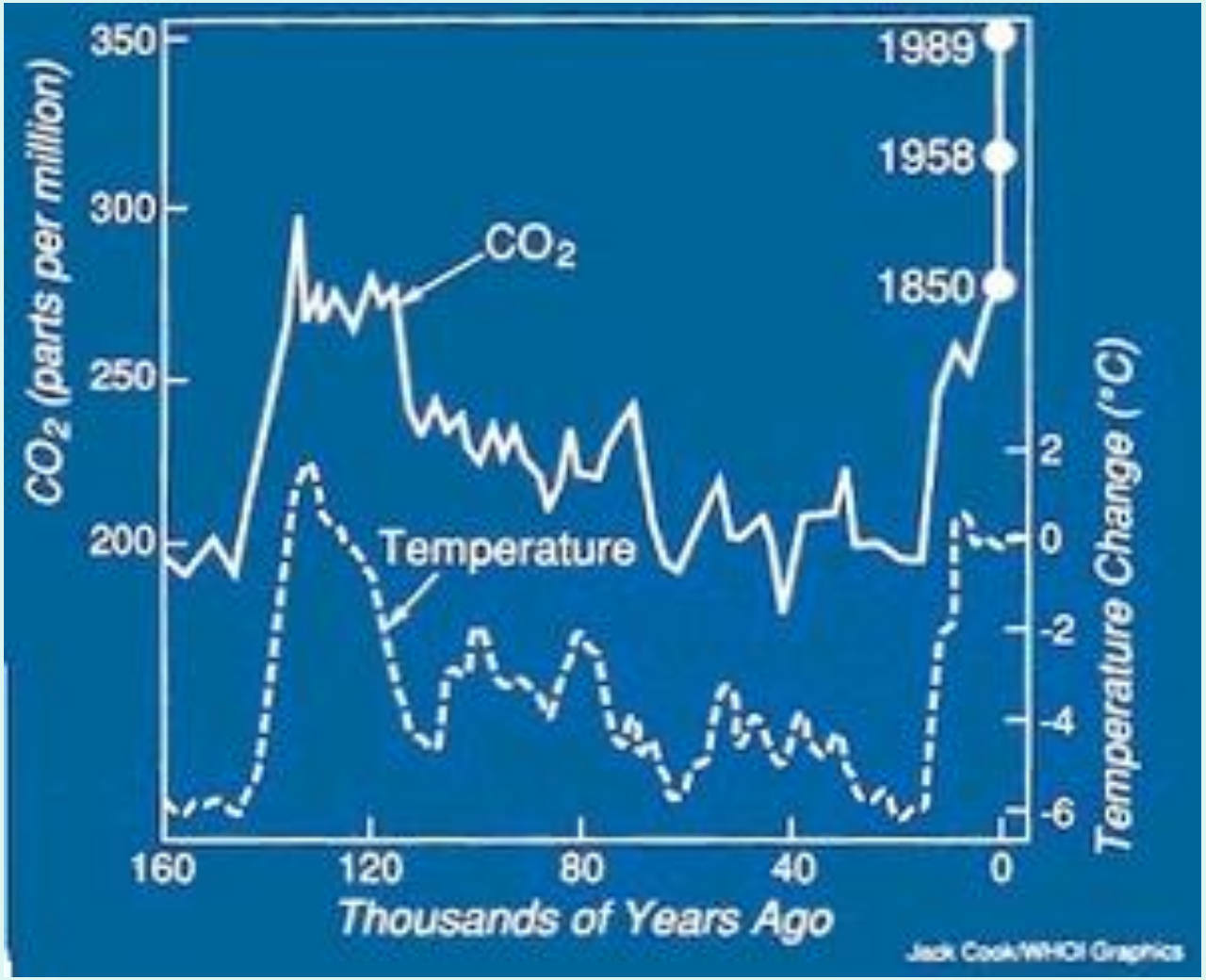
- For example, international ice core research produces evidence of atmospheric composition and mean global temperatures over thousands

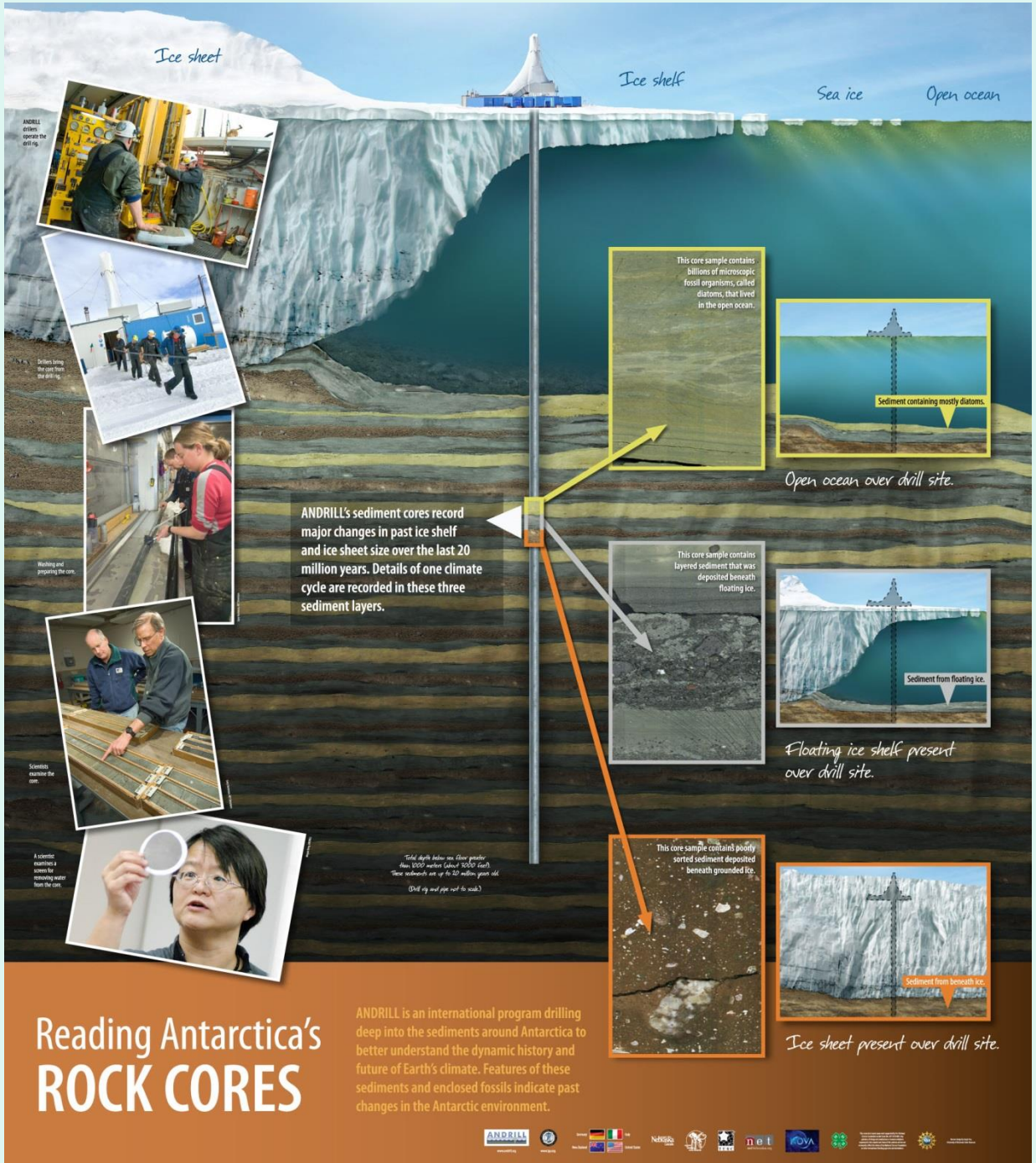
  of years (ice cores up to 420,000 years have been drilled in the Russian Antarctic base, Vostok).

Antarctic Ice Core Data 1

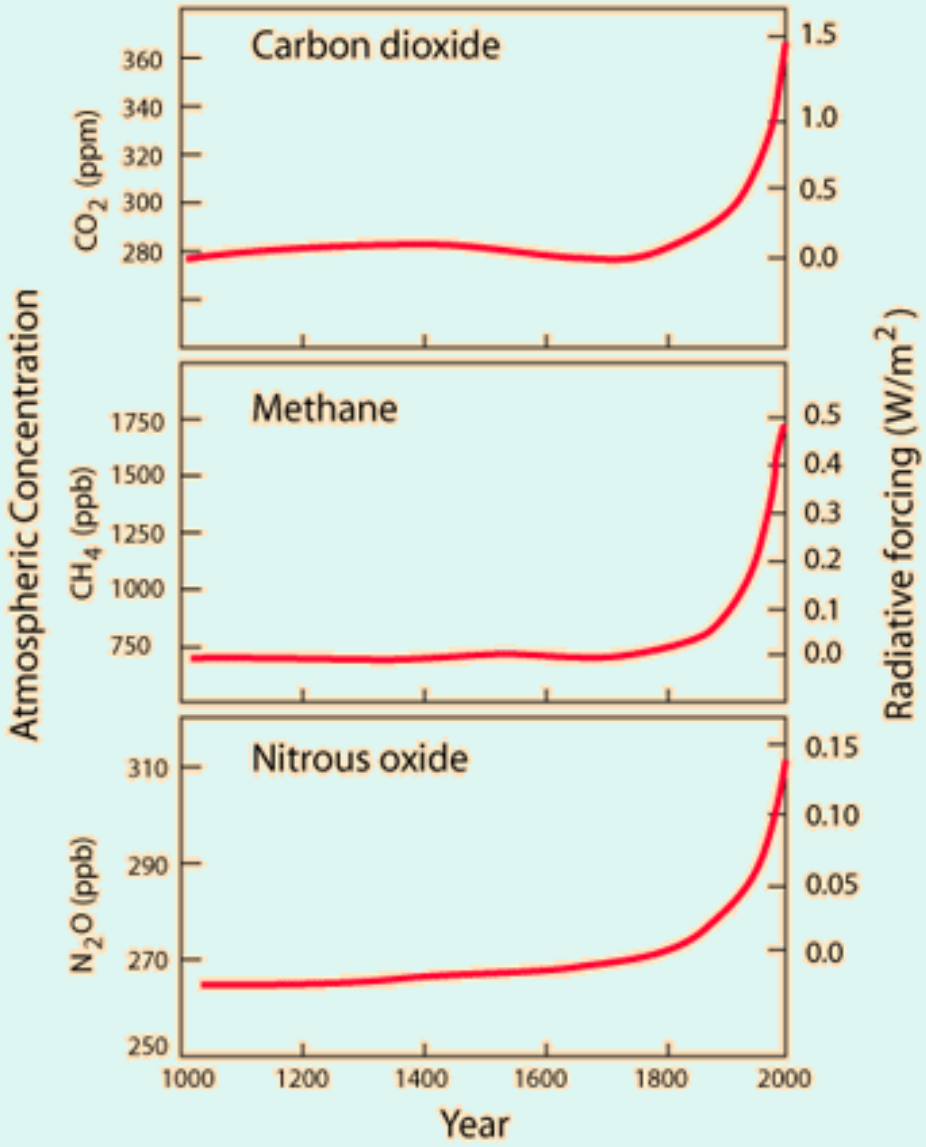



4 glacial cycles recorded in the Vostok ice core
Temperature °C
Carbon Dioxide ppm
Methane ppb
Age (kyr BP)
J.R. Petit et al., Nature, 399, 429–36, 1999
GLOBAL CHANGE
PAGES

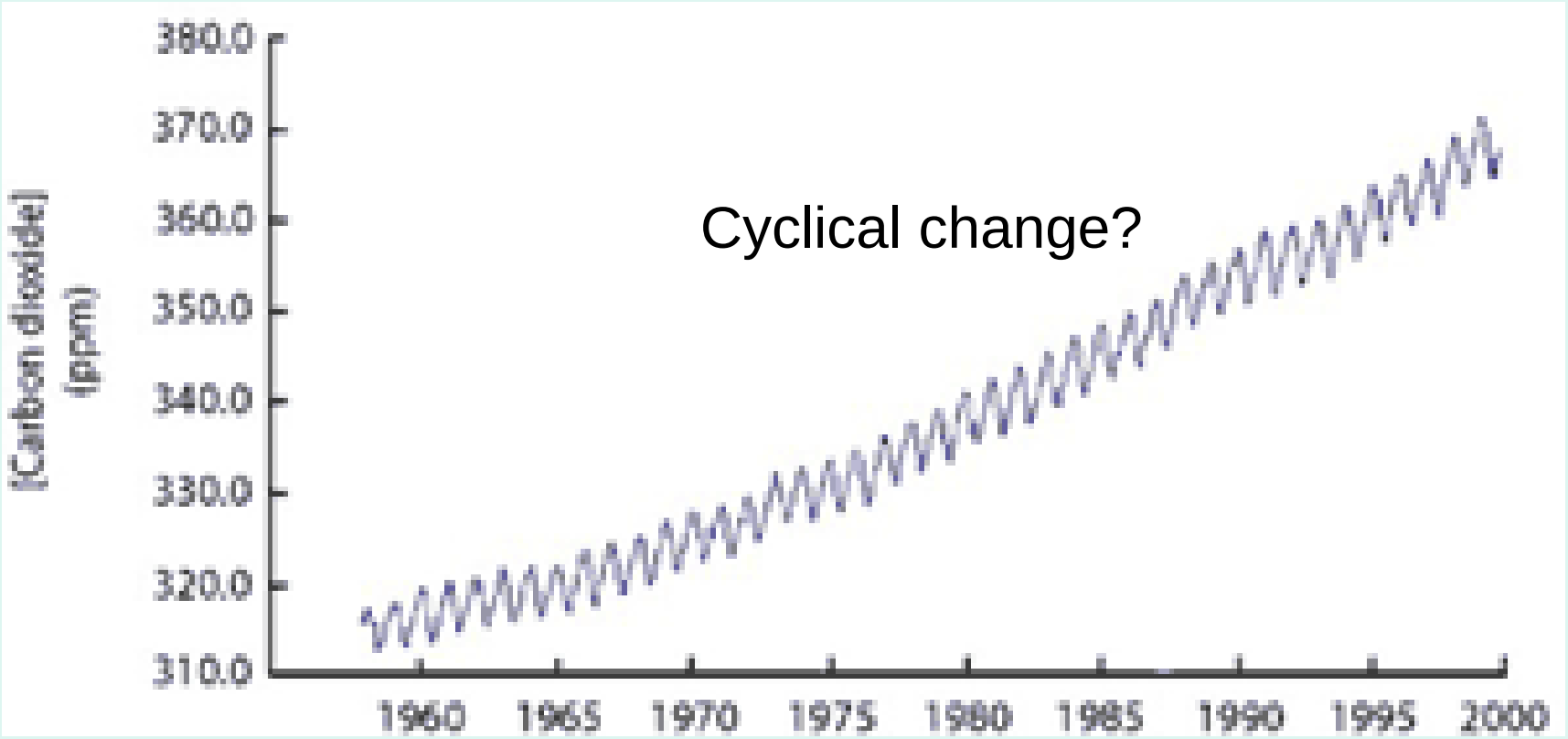

350
300
250
200
CO_2 (parts per million)
1989
1958
1850
CO_2
Temperature
2
0
-2
-4
-6
Temperature Change (°C)
160
120
80
40
0
Thousands of Years Ago
Jack Cook/WHOI Graphics


Ice sheet
Ice shelf
Sea ice
Open ocean
ANDRILL drillers operate the drill rig.
Drillers bring the core from the drill rig.
Washing and preparing the core.
Scientists examine the core.
A scientist examines a screen for removing water from the core.
ANDRILL's sediment cores record major changes in past ice shelf and ice sheet size over the last 20 million years. Details of one climate cycle are recorded in these three sediment layers.
Total depth below sea floor greater than 1000 meters (about 3000 feet).
These sediments are up to 20 million years old.
(Drill rig and pipe not to scale.)
This core sample contains billions of microscopic fossil organisms, called diatoms, that lived in the open ocean.
Sediment containing mostly diatoms.
Open ocean over drill site.
This core sample contains layered sediment that was deposited beneath floating ice.
Sediment from floating ice.
Floating ice shelf present over drill site.
This core sample contains poorly sorted sediment deposited beneath grounded ice.
Sediment from beneath ice.
Ice sheet present over drill site.
Reading Antarctica's
ROCK CORES
ANDRILL is an international program drilling deep into the sediments around Antarctica to better understand the dynamic history and future of Earth's climate. Features of these sediments and enclosed fossils indicate past changes in the Antarctic environment.

Evidence of Global warming



The concentration of carbon dioxide measured at Mauna Loa Observatory in Hawaii



Outline some of the mechanisms that may increase the rate of global warming.

Students should know that:

- global warming reduces ice/snow cover, which in turn changes the albedo, to increase rate of heat absorption
- temperature increase reduces the solubility of CO_2 in the sea and increases atmospheric concentrations
- deforestation reduces carbon fixation.