Climate change

Noctilucent clouds

Towering cumulonimbus (thunderstorm) clouds

Outline

1. A very brief tour of the atmosphere.
2. Albedo change.
3. Ozone depletion.
4. Global climate change.
5. Possible mechanisms for human-induced climate change.

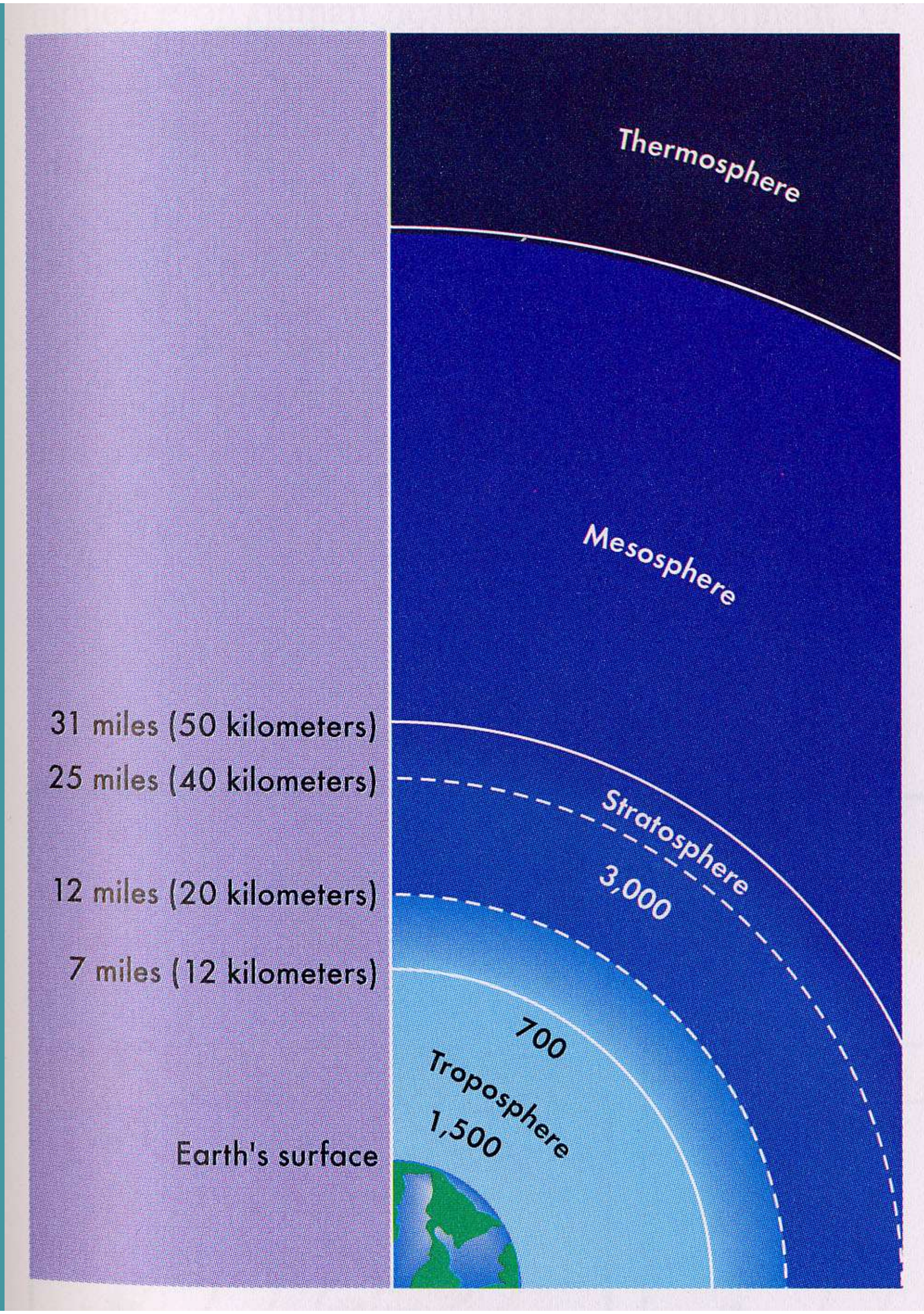
1. A very brief tour of the atmosphere

The Atmosphere

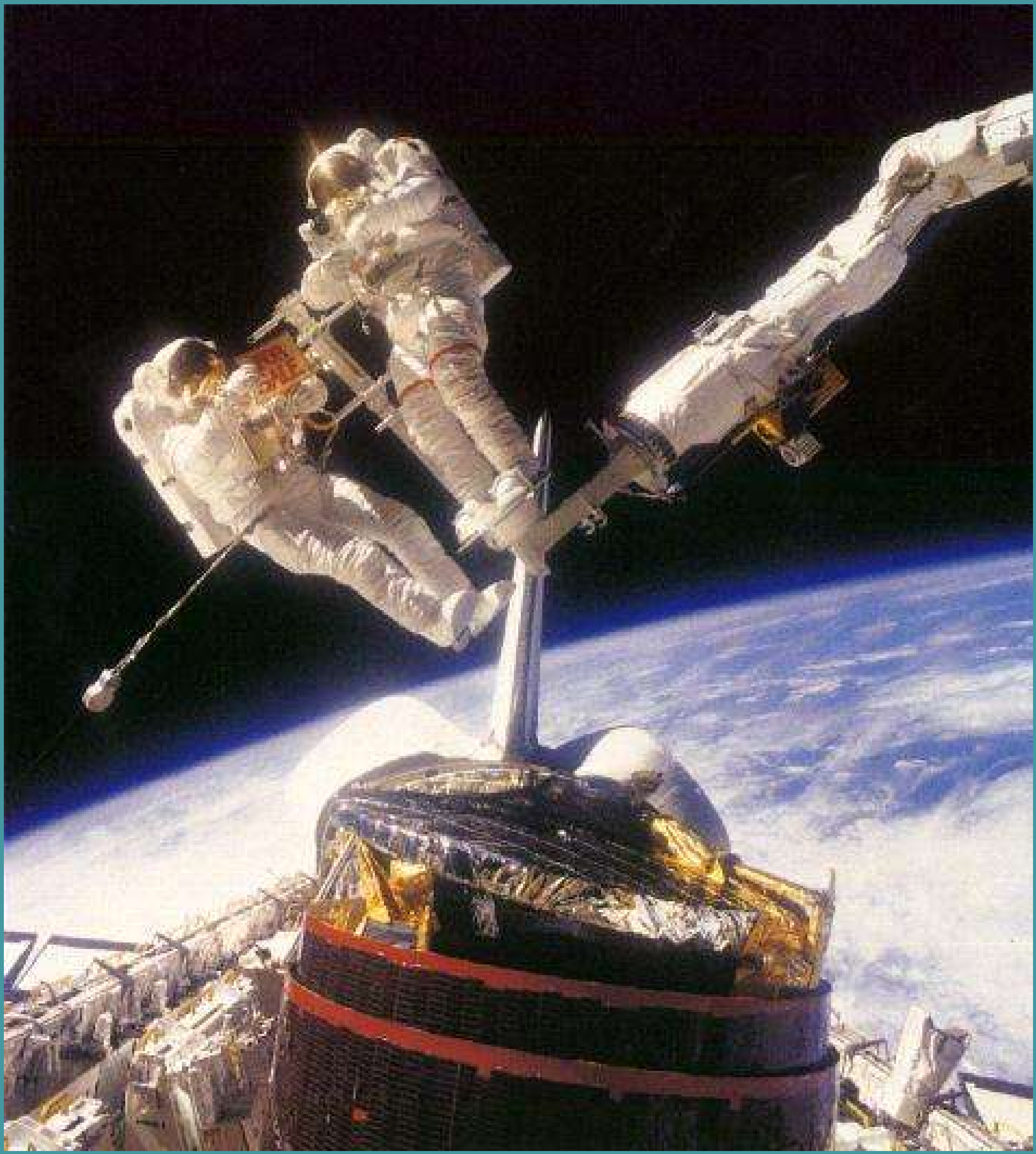
Is a thin layer of gases surrounding the earth.

Is essentially a series of ‘fluid rivers’ of air constantly moving around the earth.

Is the fastest way in which energy (heat) and substances (i.e. pollutants) are moved across the earth.



Structure of the atmosphere



The atmosphere as a thin layer of light blue along the horizon

Satellite retrieval, Nov. 14, 1984

Atmospheric gases

TABLE 2.1 Composition of the Atmosphere Near the Earth's Surface

PERMANENT GASES			VARIABLE GASES			
GAS	SYMBOL	PERCENT (BY VOLUME DRY AIR)	GAS (AND PARTICLES)	SYMBOL	PERCENT (BY VOLUME)	PARTS PER MILLION (ppm)
Nitrogen	N_2	78.08	Water vapor	H_2O	0 to 4	
Oxygen	O_2	20.95	Carbon dioxide	CO_2	0.035	350
Argon	Ar	0.93	Methane	CH_4	0.00017	1.7
Neon	Ne	0.0018	Nitrous oxide	N_2O	0.00003	0.3
Helium	He	0.0005	Ozone	O_3	0.000004	0.04
Hydrogen	H_2	0.00005	Particles (dust, soot, etc.)		0.000001	0.01
Xenon	Xe	0.000009	Chlorofluorocarbons (CFCs)		0.00000001	0.0001

Sun - Earth Relationship

Solar energy provides the energy which drives:

- the hydrological cycle.
- circulation of the atmosphere.
- powers winds and storms.

Thus, is responsible for climate and much of its temporal and spatial variability.

Wind

The horizontal and vertical movement of air relative to the earth's surface.

Is caused by variations in temperature and pressure, eg., air rises as it warms and a cool breeze moves in to take the place of the rising air.

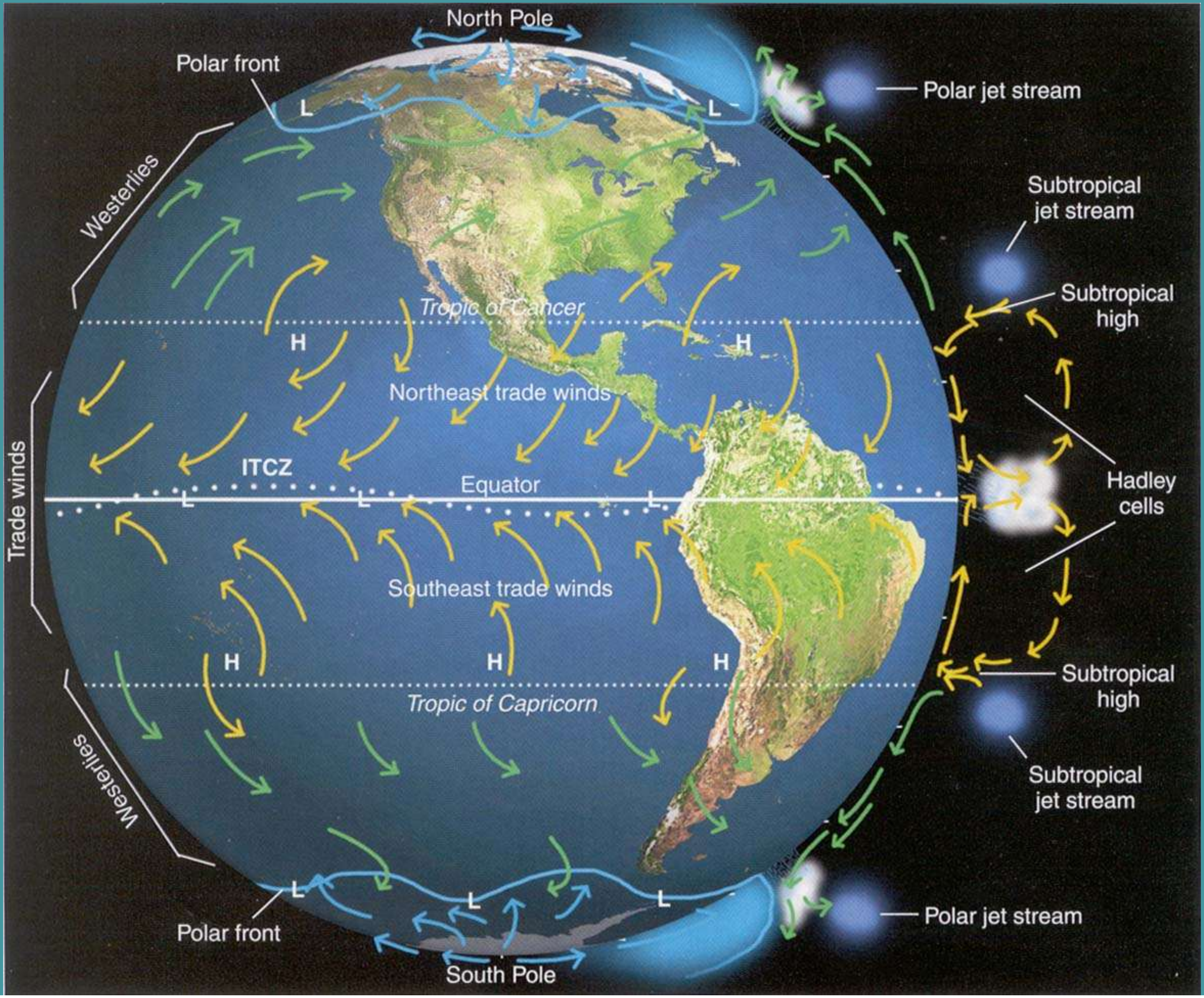
Global circulation patterns

The earth is divided into specific zones according to wide-scale movement of air.

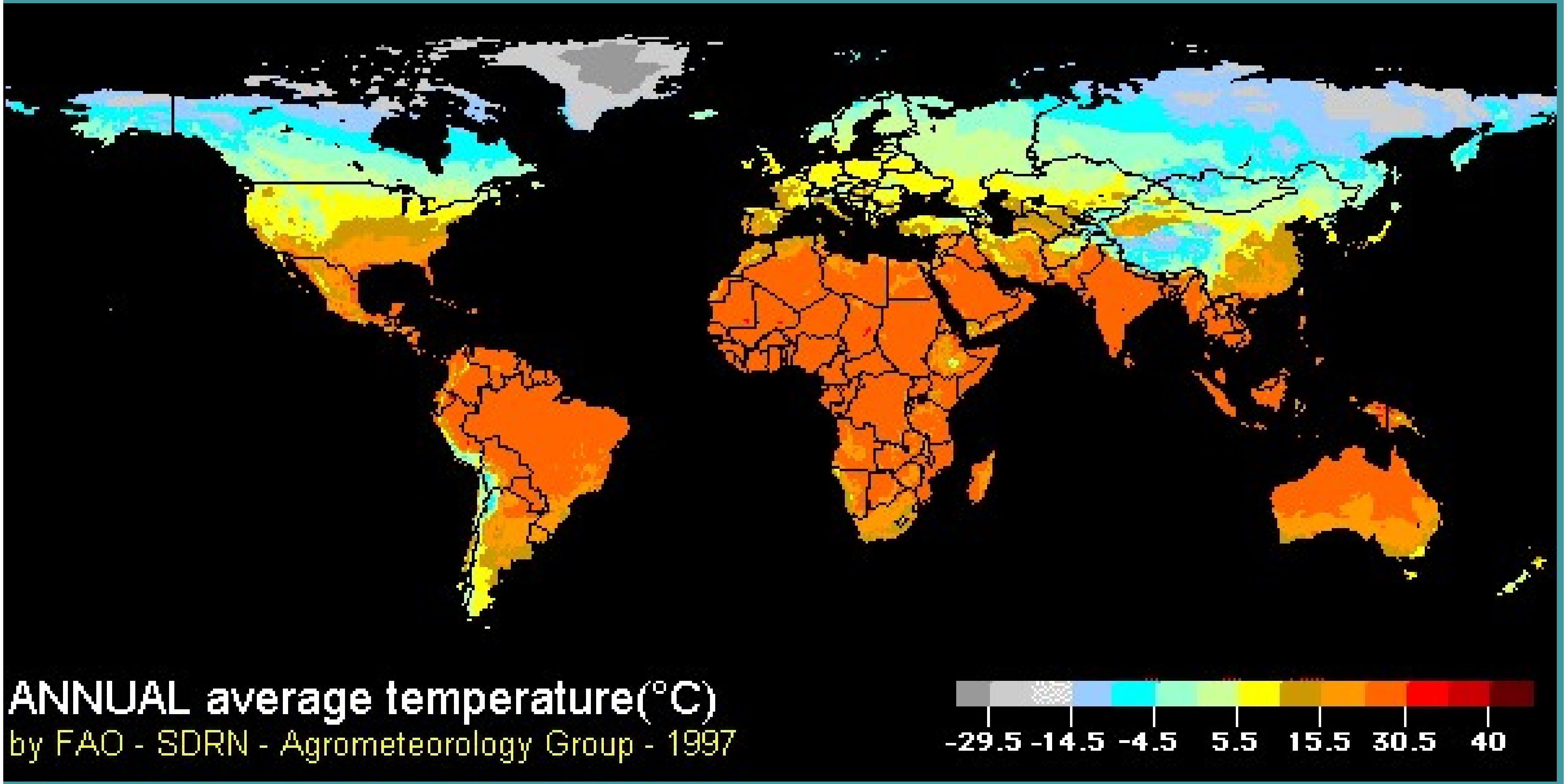
These global patterns are influenced by:

- rotation of the earth (the Coriolis Effect).
- incident angle of the sun.
- differential heating of the surface.

Global circulation patterns



Average global temperature



2. Albedo change

The proportion of insolation (incoming radiation) reflected from a surface, i.e. the reflectivity of a body.

Black body: albedo = 0

White body: albedo = 1

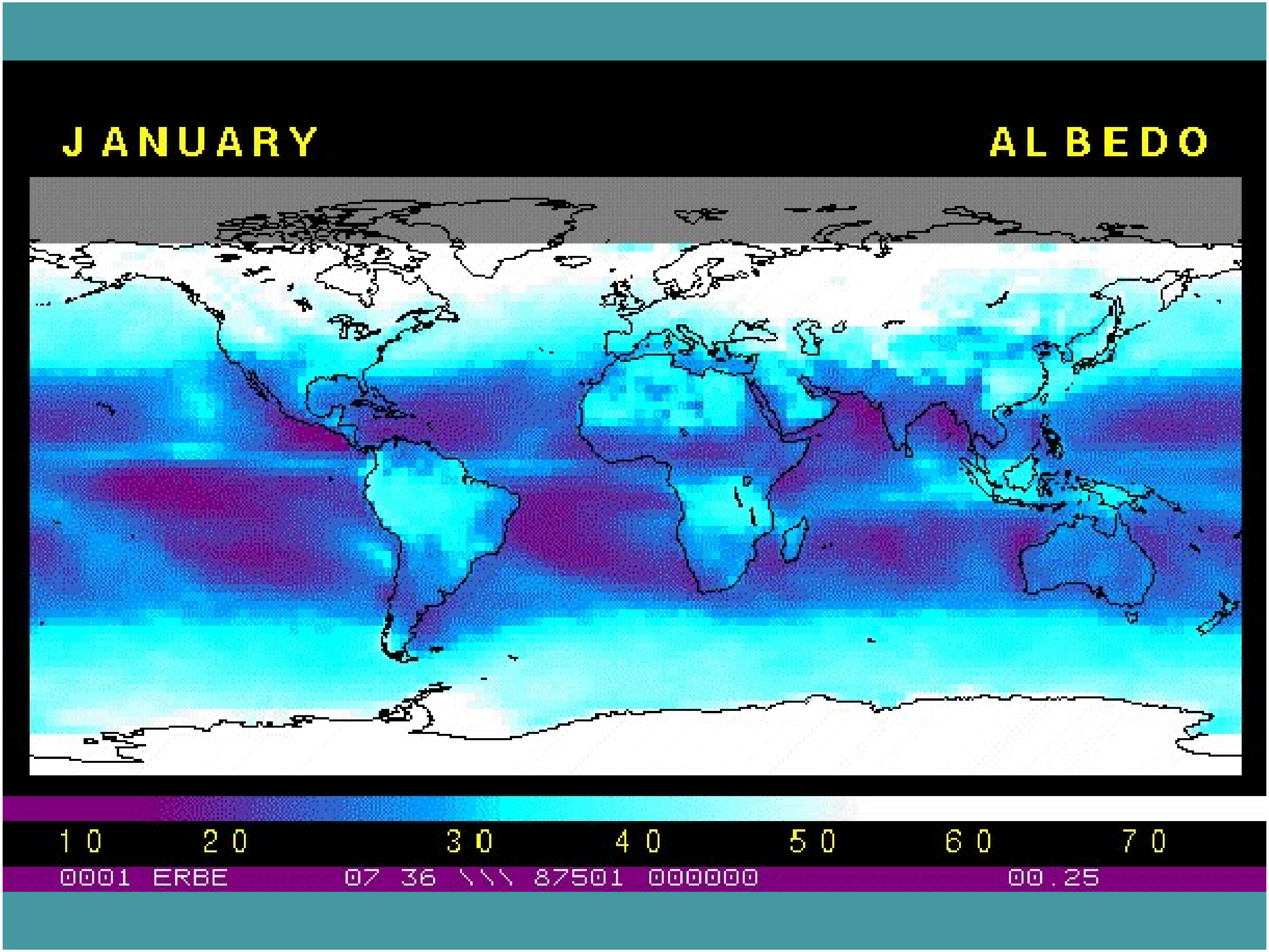
Albedo

Black body: albedo = 0
(0% reflectivity).

Low albedo surfaces:
- road surface (asphalt)
- exposed soil
- shingled roof

White body: albedo = 1
(100% reflectivity)

High albedo surfaces:
- snow, glaciers
- deserts
- tin roof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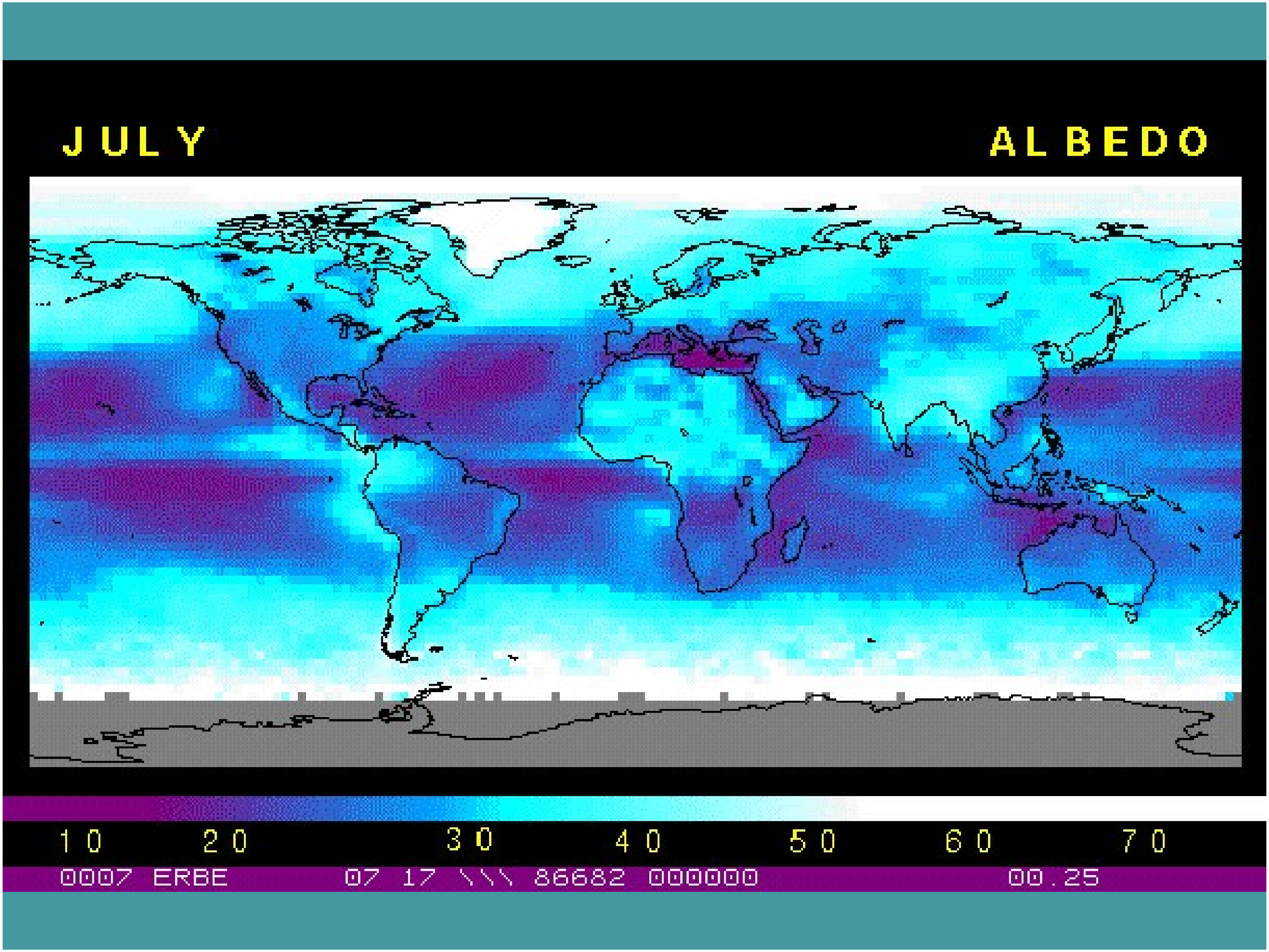
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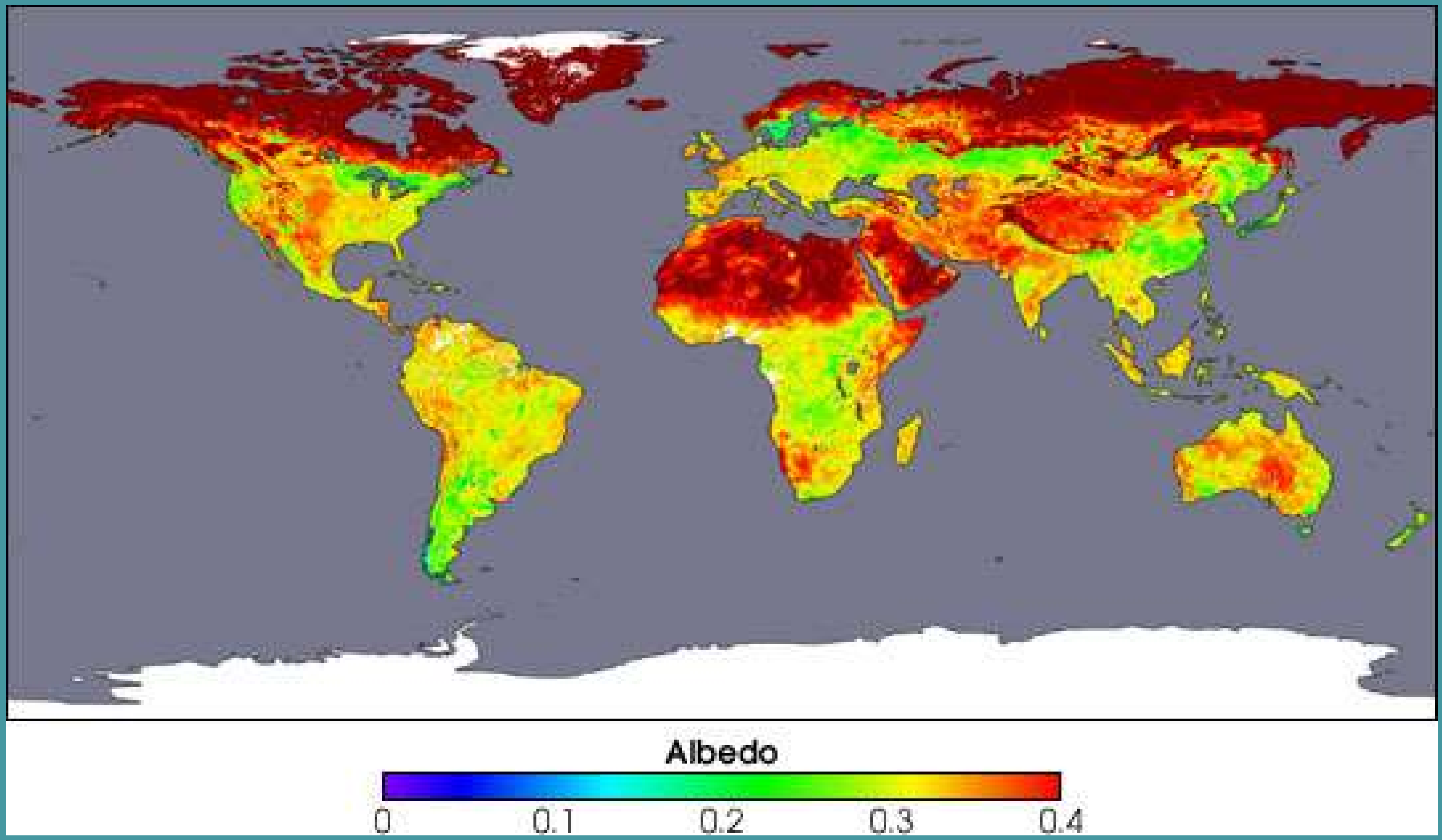
Mean global albedo



Albedo change

Is the alteration of landscapes such that the radiation energy budget is altered on a local to regional scale.

Is most often achieved through either agricultural activities or deforestation.

Potential effects of removal of tropical rain forests

Deforestation

↓

Increased surface albedo

↓

Reduced surface absorption of solar energy

↓

Surface cooling

↓

Reduced evaporation and sensible heat flux from the surface

↓

Reduced convective activity and rainfall

↓

Reduced release of latent heat, weakened Hadley circulation and cooling in the mid and upper troposphere

↓

Increased tropical lapse rates

↓

Increased precipitation in the latitude bands 5–25°N and 5–25°S, and a decrease in the equator–pole temperature gradient

↓

Reduced meridional transport of heat and moisture out of equatorial regions

↓

Global cooling and a decrease in precipitation between 45–85°N and 40–60°S

Cconsequences of anthropogenic land cover change on ecosystems at regional and global scales

- Depends on type of land cover conversion.
- Large regional disparities.
- Temperate ecosystem conversion: increase in NPP (net primary productivity), surface cooling.
- Tropical conversion: decrease in Net Primary Productivity; surface warming.
- Global averages mask regional differences.

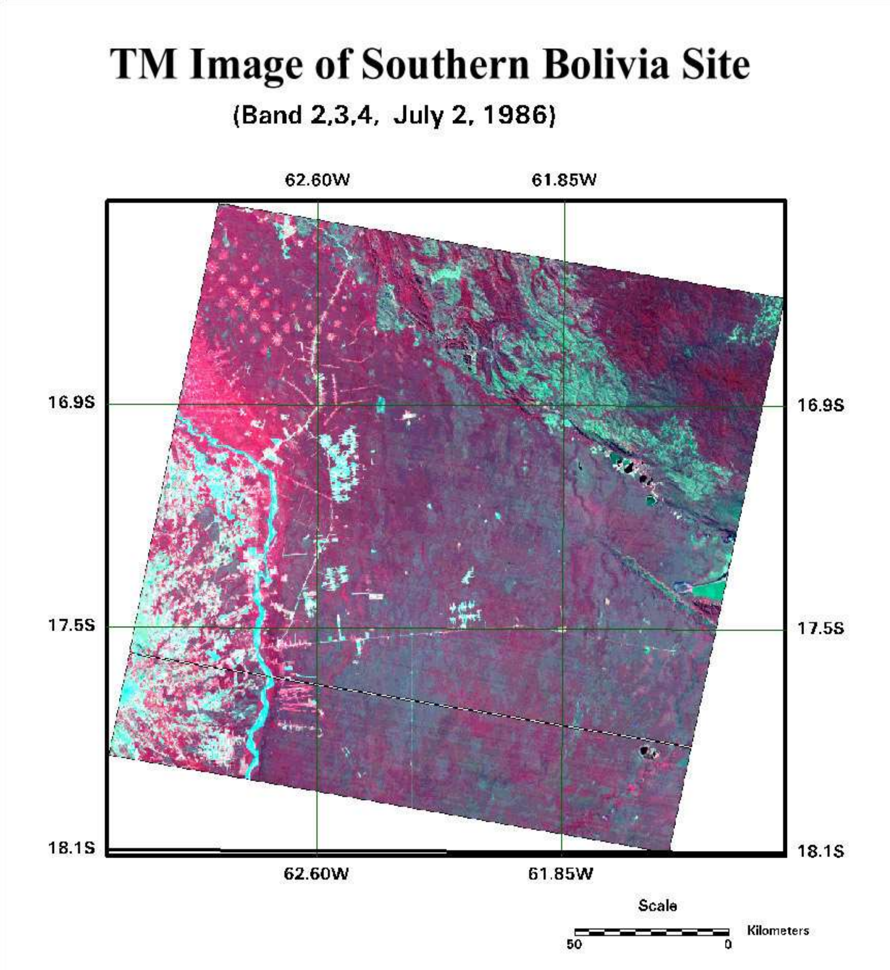
Differences between future and past land cover changes

Past conversions predominantly in temperate regions for mechanized agriculture.

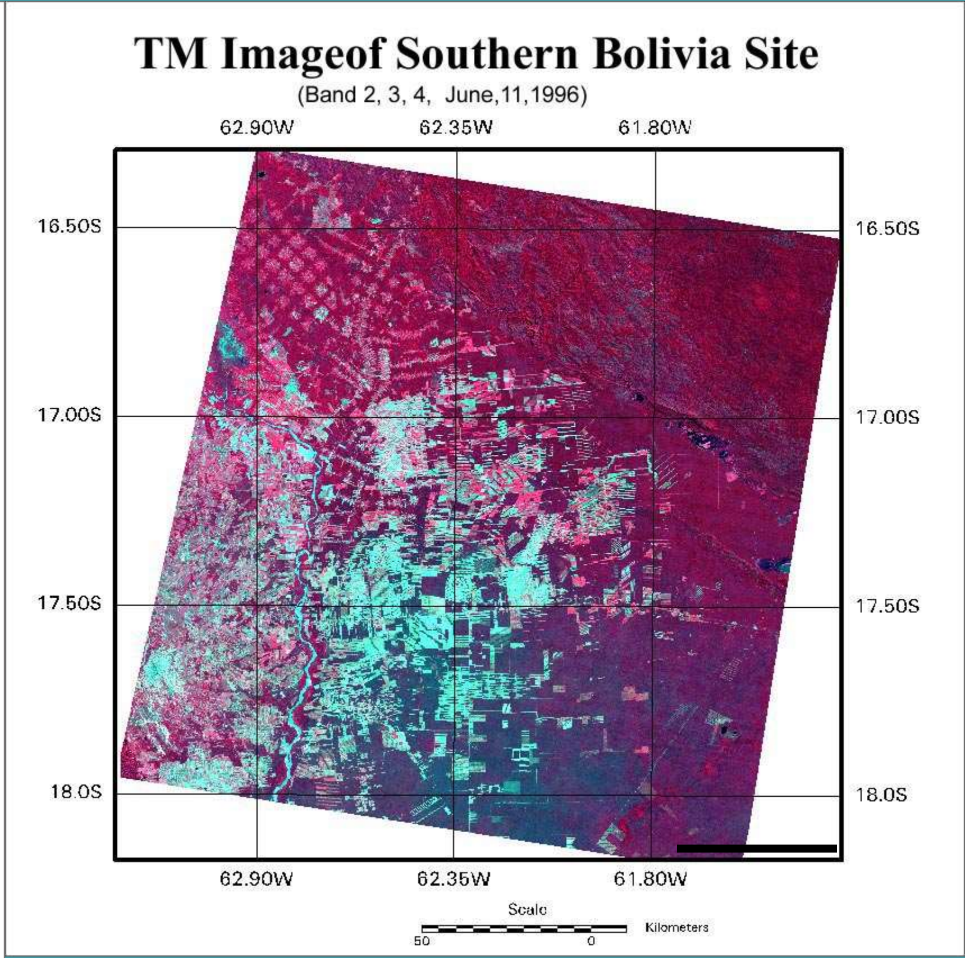
Future conversion likely to be predominant in tropics.

The past may not compare to the future

1986



1996



Deforestation in Southern Bolivia

3. Ozone depletion

Ozone is an atmospheric trace gas.

The ozone molecule contains three oxygen atoms ($O_{3)}$.

How is ozone produced?

- It is formed when oxygen absorbs solar radiation.
- Ozone reacts with various other chemicals, and thus is highly reactive.
- Ozone also absorbs incoming UV radiation.

Why is the ozone layer important?

Ozone acts as the Earth's protective shield against the Sun's harmful ultraviolet radiation (UV radiation).

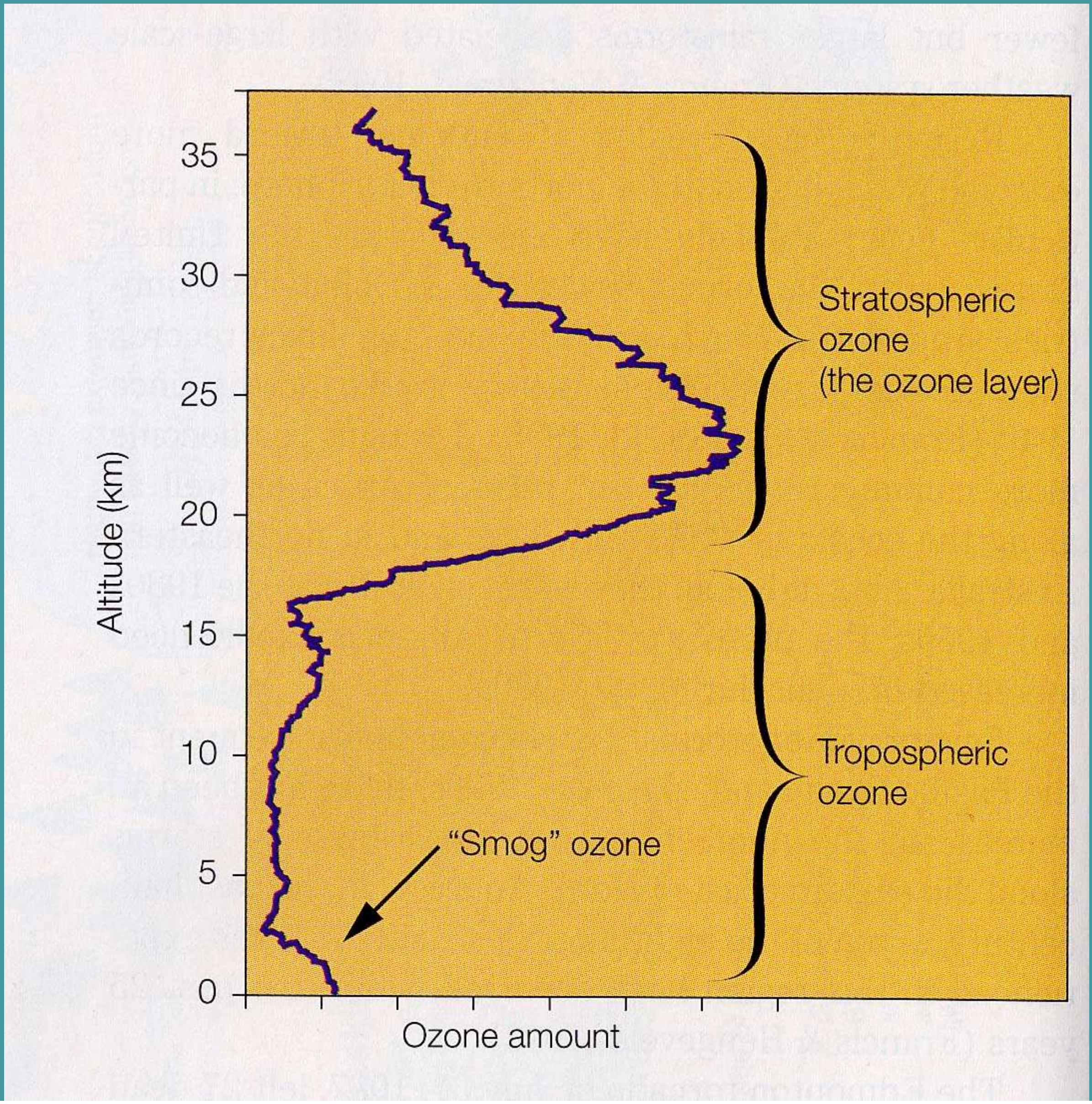
Without the ozone layer, life would not exist on Earth.

The natural development of the ozone layer permitted life to evolve above water.

Why is the ozone layer important?

- Human activity has impact on the chemistry of the upper atmosphere - ozone depletion by CFCs.
- Changes in the chemistry of the upper atmosphere have real impacts in the troposphere (i.e., where we live):
  - skin cancer rates
  - effects on global food cycle.

Ozone in the atmosphere



Is present at all levels but mainly in two layers.

Types of ozone

Good ozone: thick layer which filters UV radiation, protecting organisms on the earth's surface.

Bad ozone: produced by automobile pollution and is harmful to human health (photochemical smog).

Tropospheric ozone is not concentrated enough to filter UV radiation.

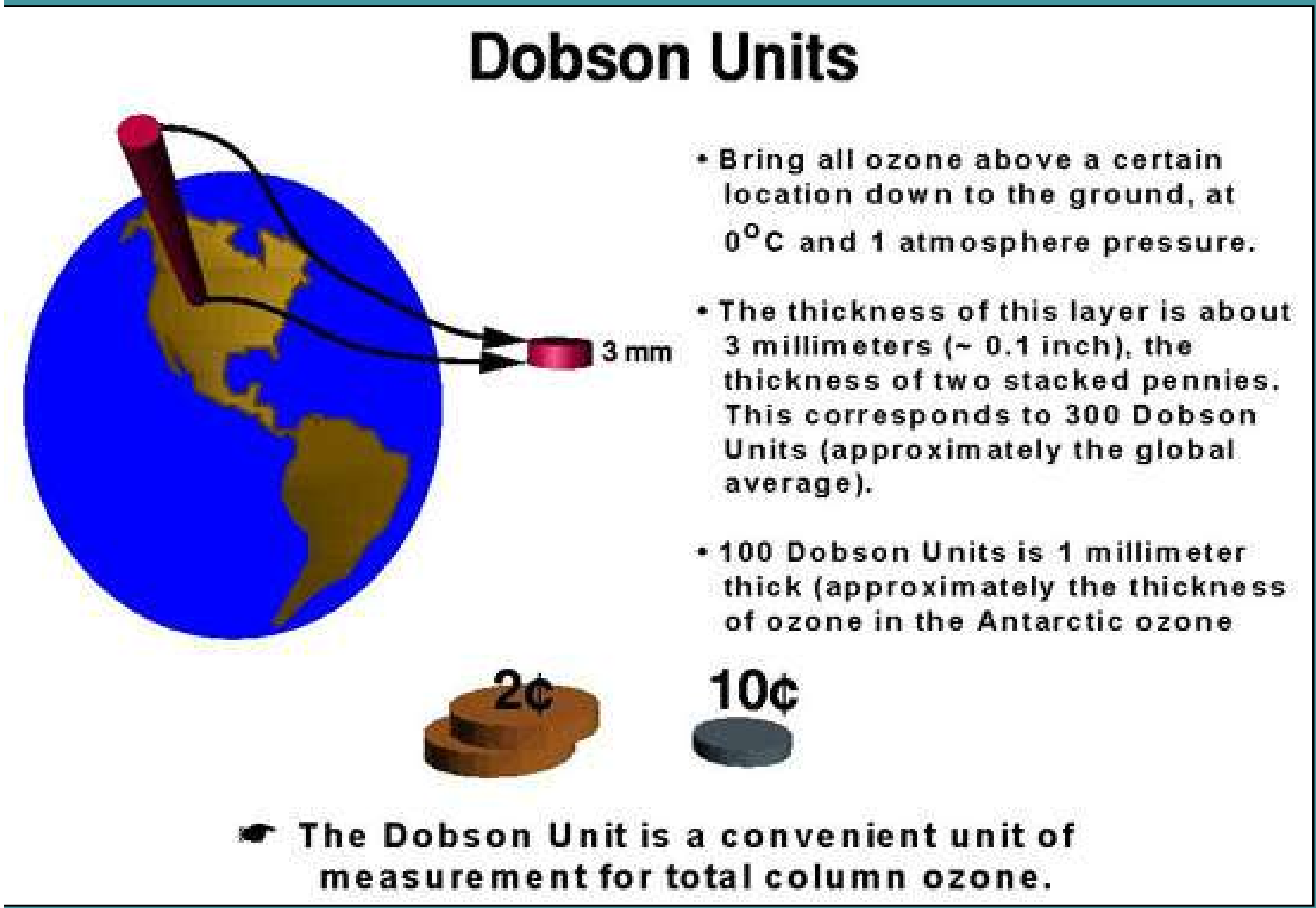
Ozone in the atmosphere

Ozone is mainly produced in the tropics because of the higher amounts of solar radiation.

Ozone is mainly destroyed at middle and higher latitudes by chemical processes.

Thus, ozone naturally has large variations in space and time.

Measuring ozone

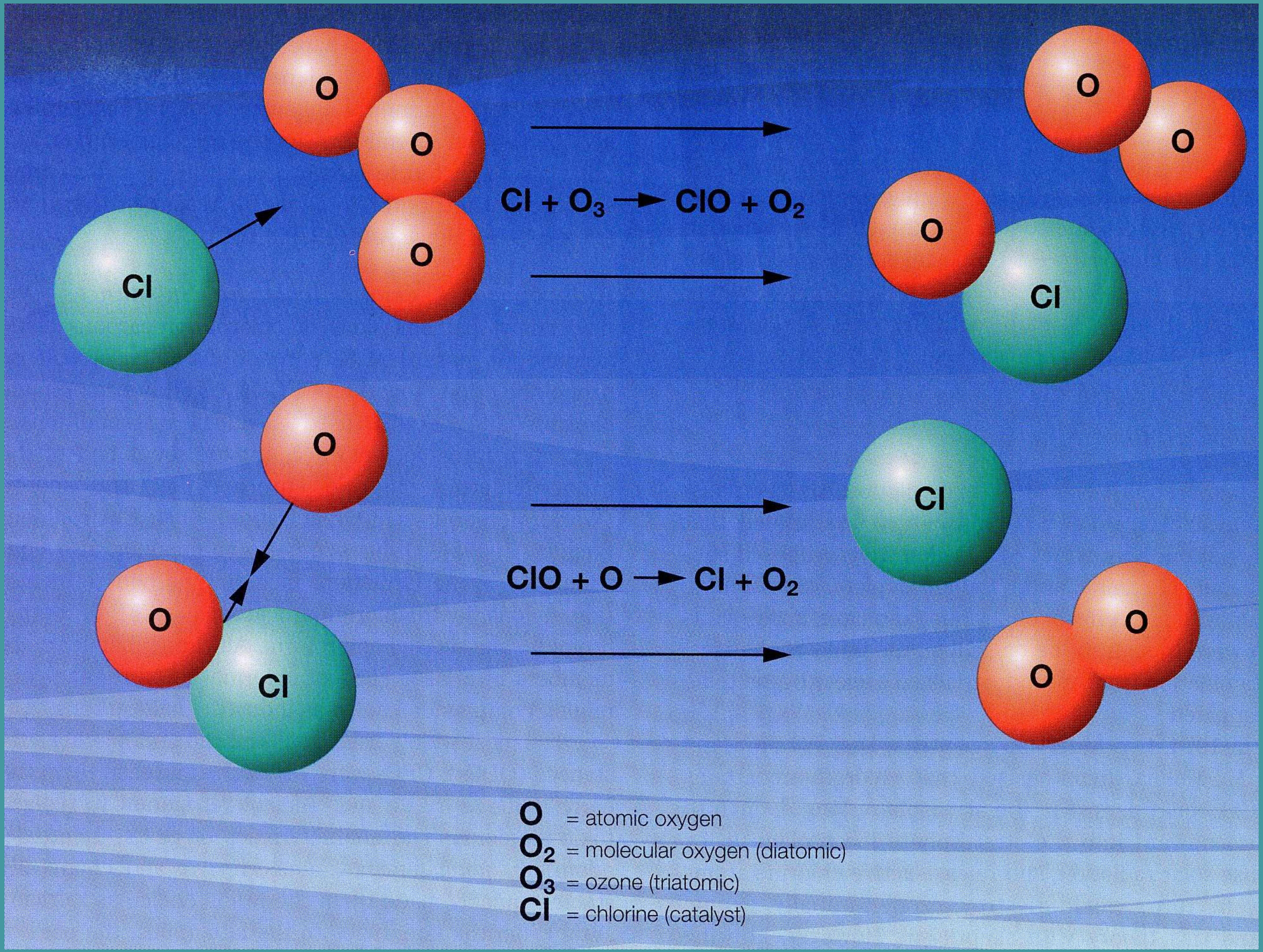


Ozone hole: region where the layer thins to < 220 DU.

Ozone history

- CFCs developed in 40's and 50's for use in refrigerants, propellants, fire retardants.
- 1970's CFCs detected in atmosphere. Many of these have long atmospheric lifetimes (10's to 100's of years).
- 1974 researchers proposed that CFC's can destroy ozone in the stratosphere. CFCs broken apart by UV radiation forming chlorine which can destroy ozone quickly.

Ozone depletion process



Ozone history

1978: CFCs used in aerosols banned.

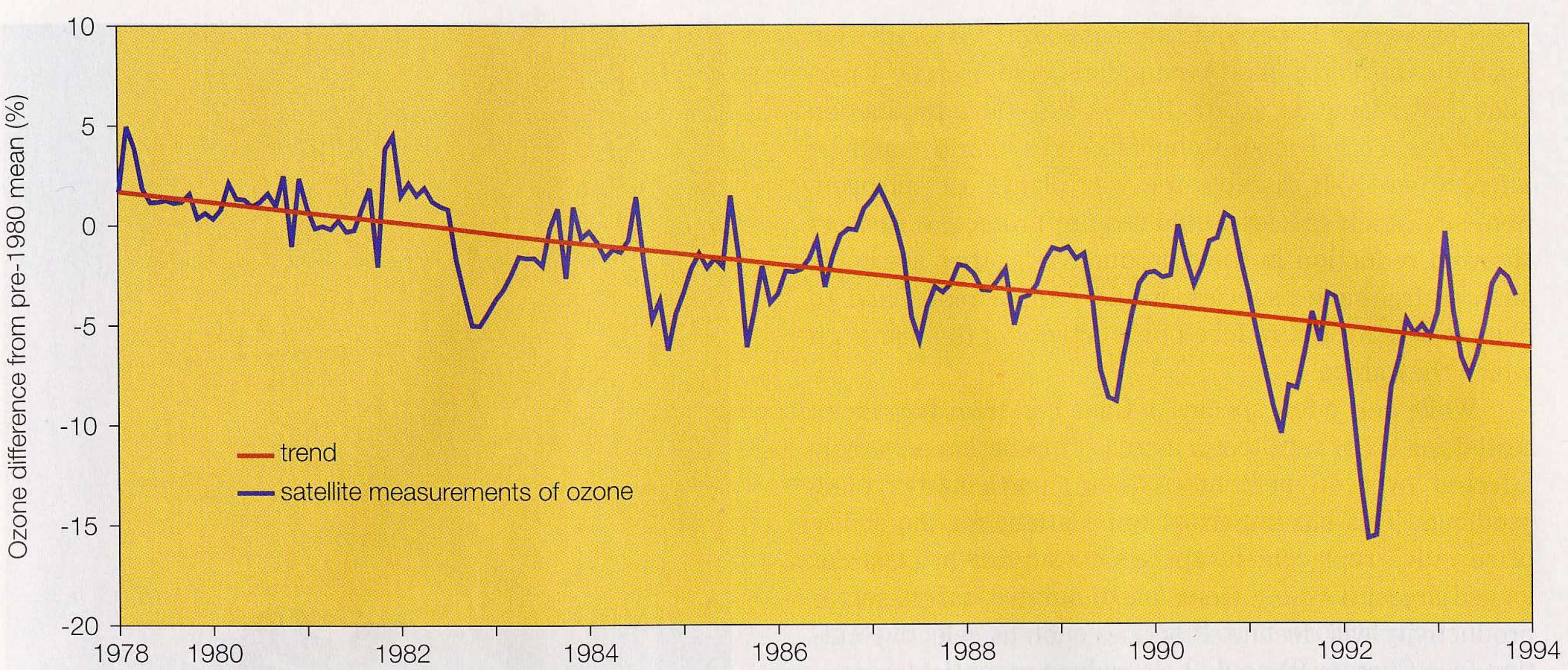
1985: British Antarctic Survey reports 40% loss of ozone over Antarctica during spring. (NASA confirms)

1987: Signing of the Montreal Protocol

- International agreement to reduce CFC use.
- Later agreements agreed to completely phase out CFC and halons.

1996 Complete ban on industrial production of CFCs went into effect.

Ozone depletion



O_3 depletion in the northern hemisphere

Ozone hole - Antarctic

First discovered in 1985: observations from Antarctica extend back into 1950's.

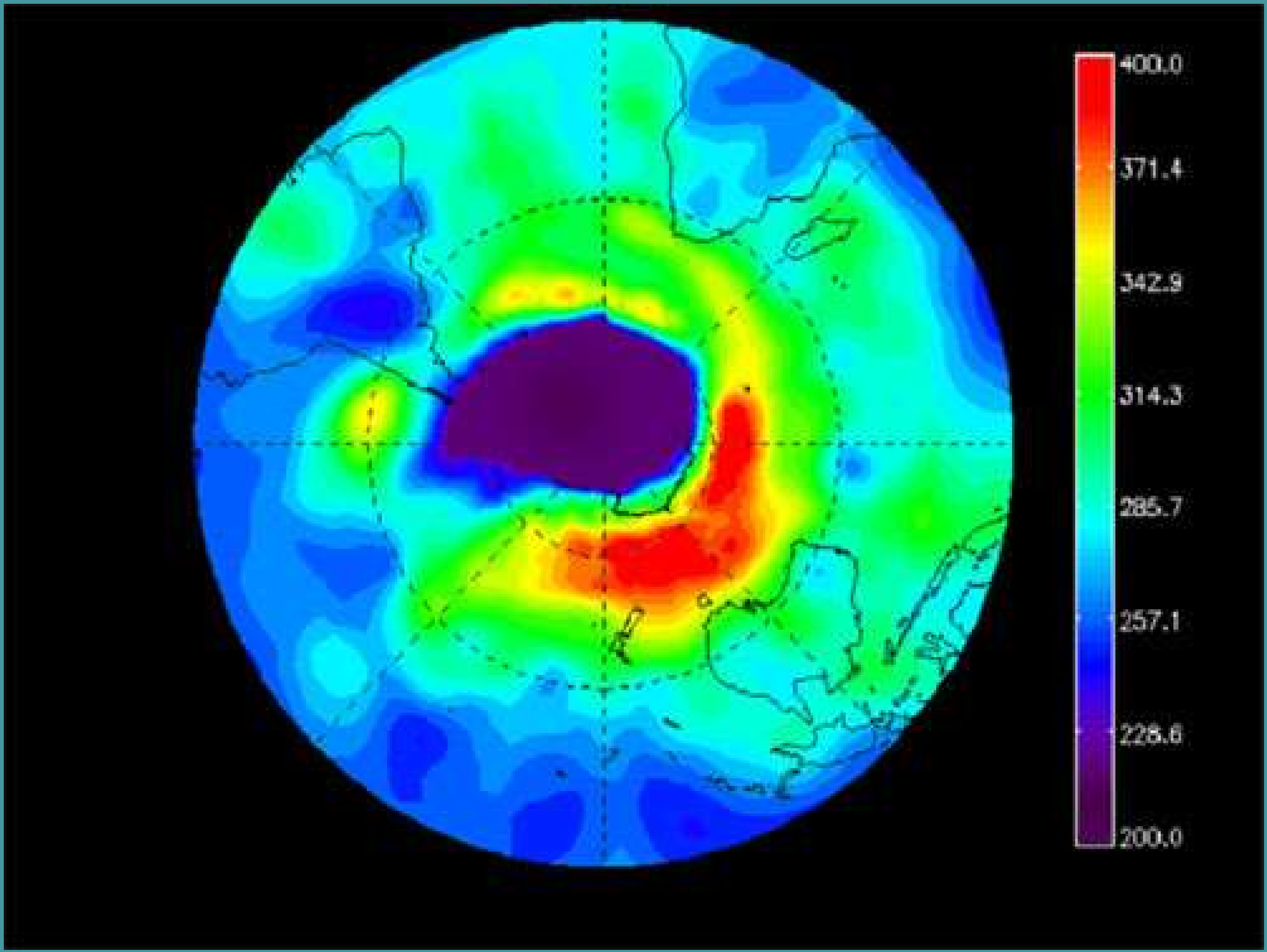
Characterized as a rapid depletion of ozone over Antarctica during spring.

- Ozone hole season, Spring (August – October)
- Ozone hole located over mainly over Antarctica
- Ozone hole recovers by late December

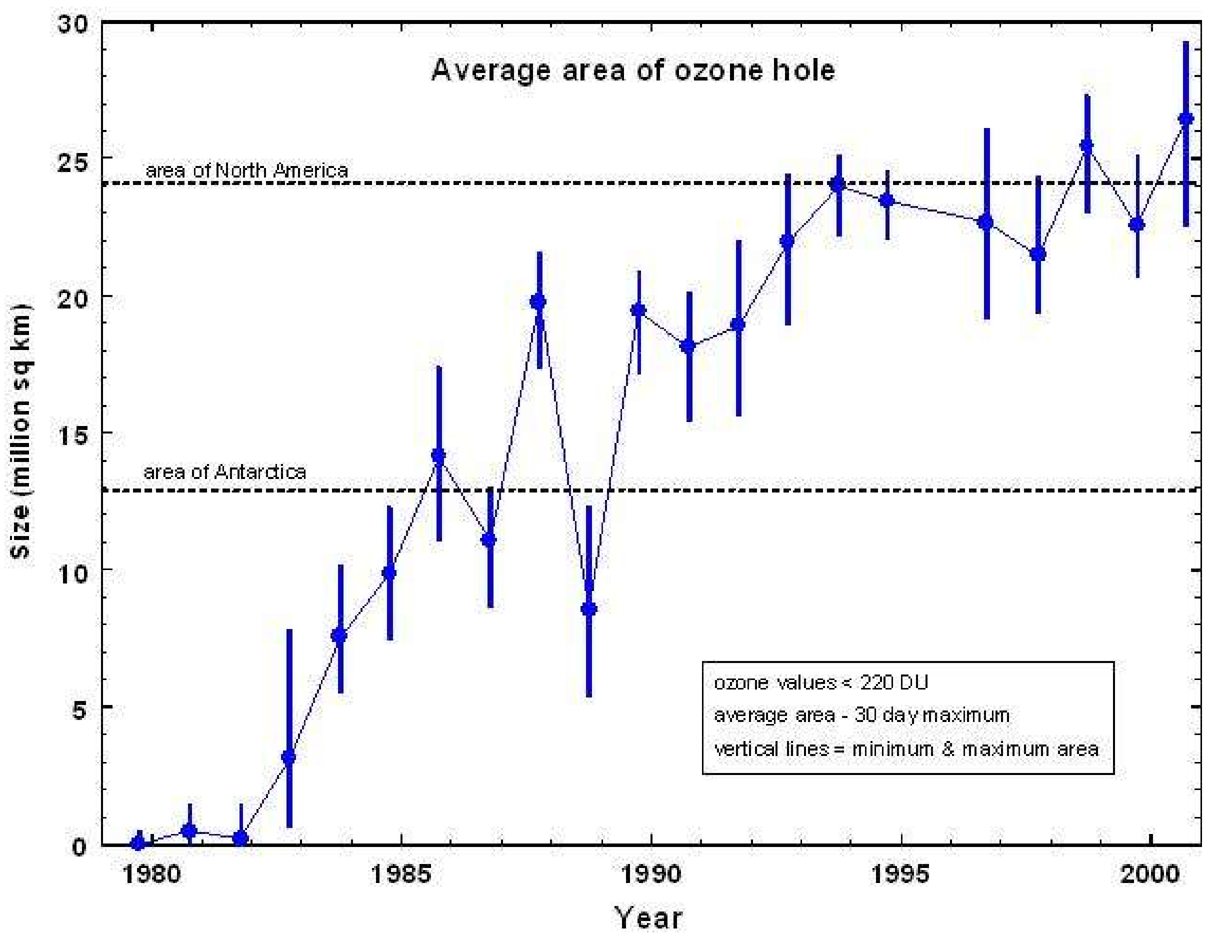
Ozone hole caused by human chemicals (CFC's).

Ozone hole not present in early 1970's.

Ozone levels: Oct. 14, 1997



Is the ozone hole getting bigger?



- large increase in 1980's
- relatively stable in 1990's

Why should we care about O_3?

With ozone depletion, there will be higher rates of UV radiation.

More UV radiation rates mean:

- Higher rates of skin cancer
- Higher amounts of cataracts
- Possible danger to plant and animal life

Without the ozone layer, life on the Earth’s surface would not exist.

The future of the ozone layer

Montreal Protocol (1988): international agreement to phase out ozone depleting chemicals.

Further amendments accelerated the phase out.

Developed countries have switched to HCFC's (more ozone friendly) instead of CFC's.

Developing countries have until 2010 to phase out CFC's.

The future of the ozone layer

Observations indicate that chlorine is beginning to decline in the atmosphere (which is good).

Still large uncertainties about illegal trade/use of CFC's (not so good).

Future:

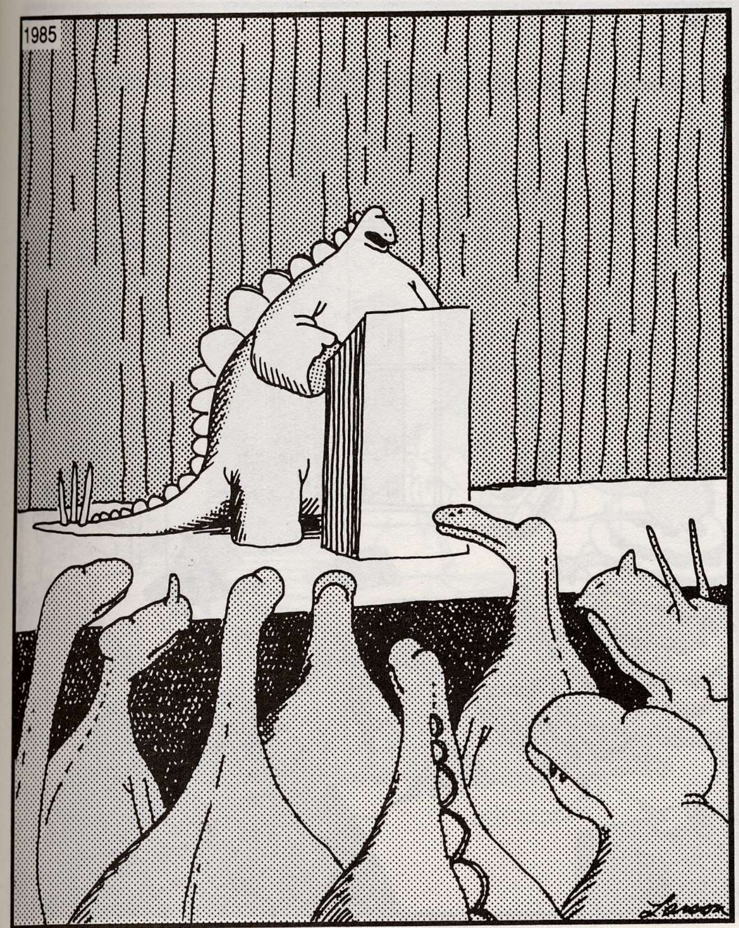
Atmospheric models suggest that atmospheric chlorine will return to pre-80's in next 50 to 100 years. A slow ozone recovery will follow decreasing chlorine concentrations.

The point of all this?

The point of reviewing the composition of the atmosphere, the role of albedo and the importance of ozone depletion is that the atmosphere is:

- a dynamic system.
- highly variable.
- incredibly complex.

4. Global climate change



"The picture's pretty bleak, gentlemen.... The world's climates are changing, the mammals are taking over, and we all have a brain about the size of a walnut."

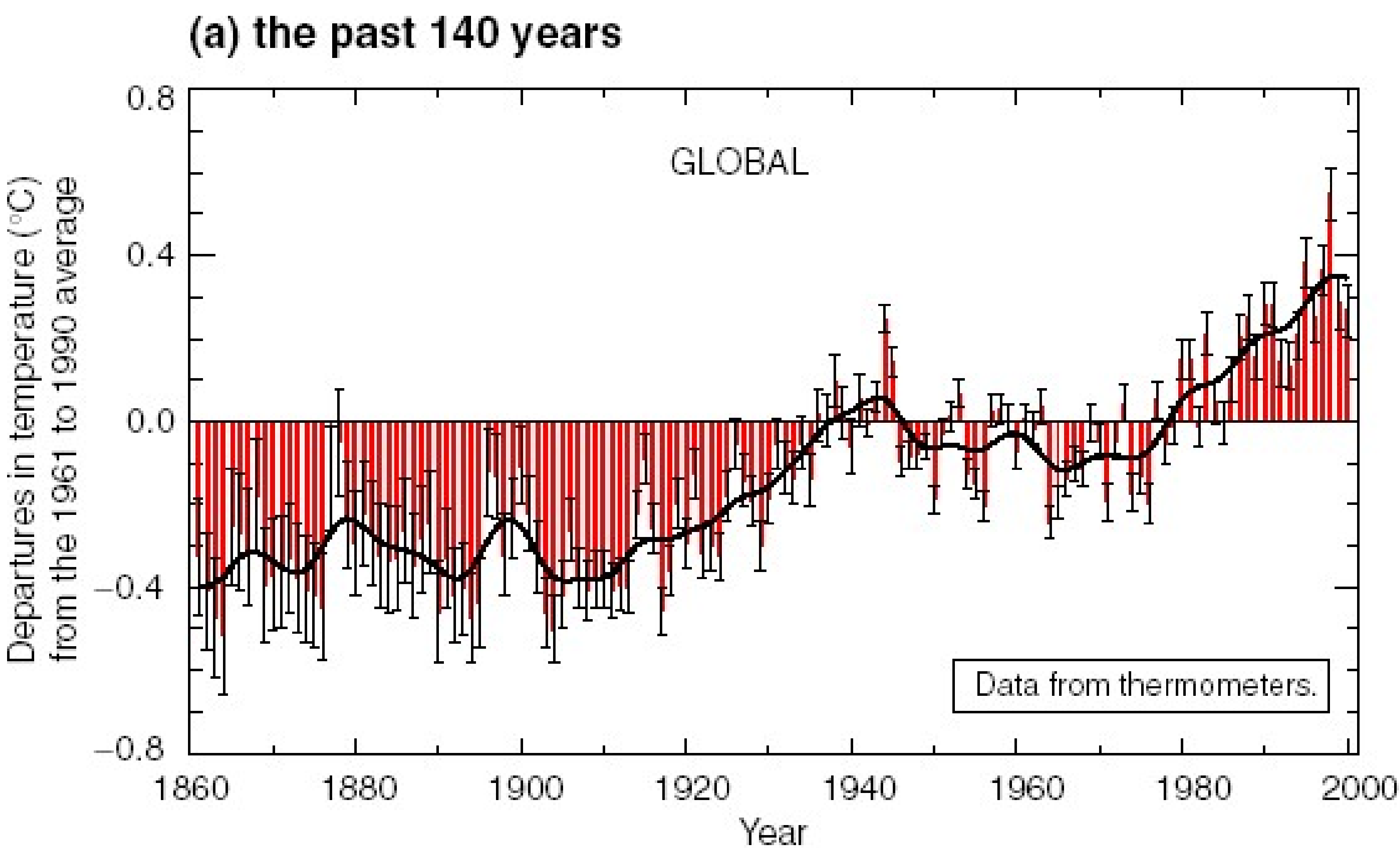
Global climate change

There is little doubt that human activity has significantly increased the concentration of several gases in the atmosphere over the past century.

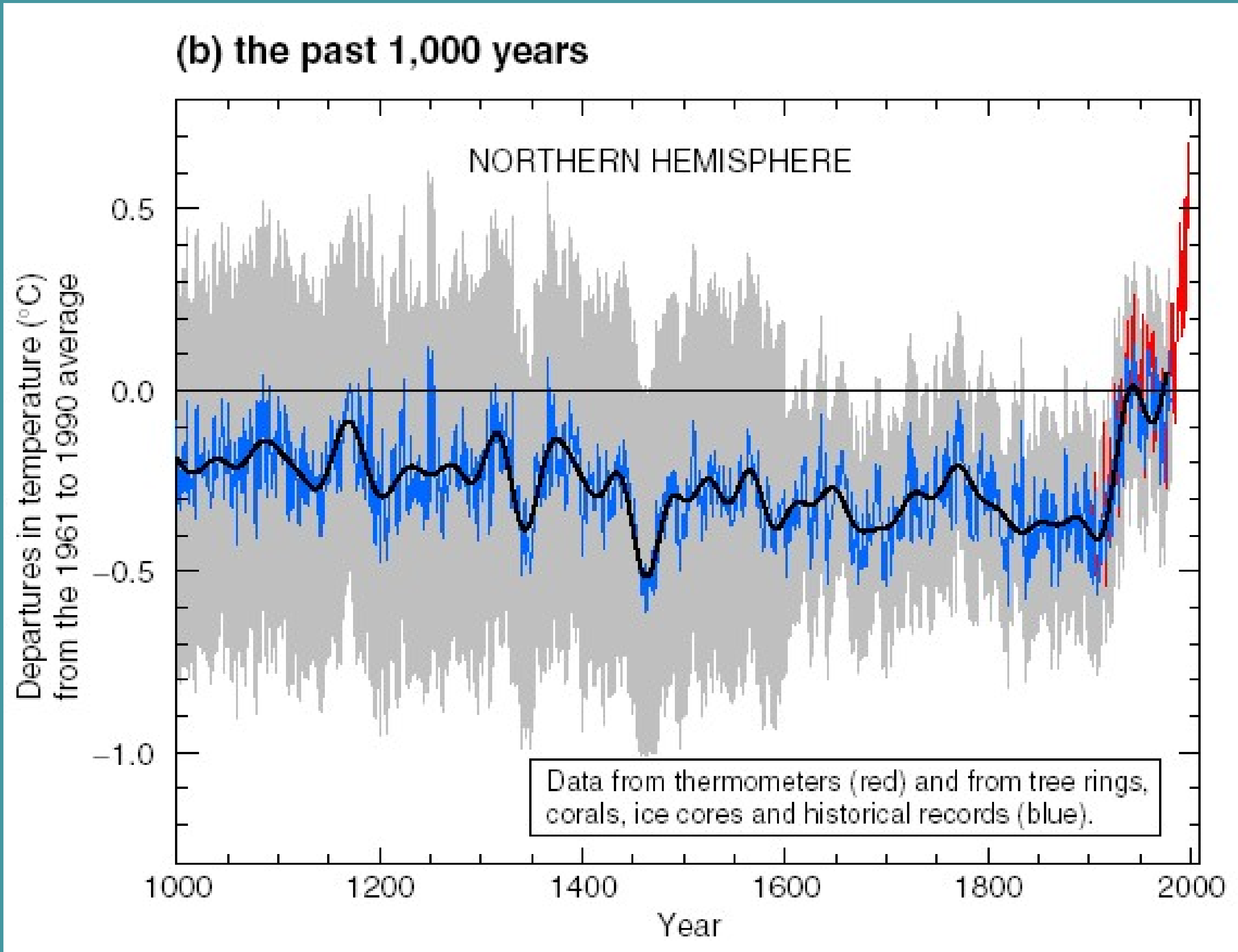
"An increasing body of observations gives a collective picture of a warming world and other changes in the climate system."

Source: Intergovernmental Panel on Climate Cchange
Third Assessment Report. 2001

Variations of the Earth's surface temperature for:



Source: IPCC TAR. 2001



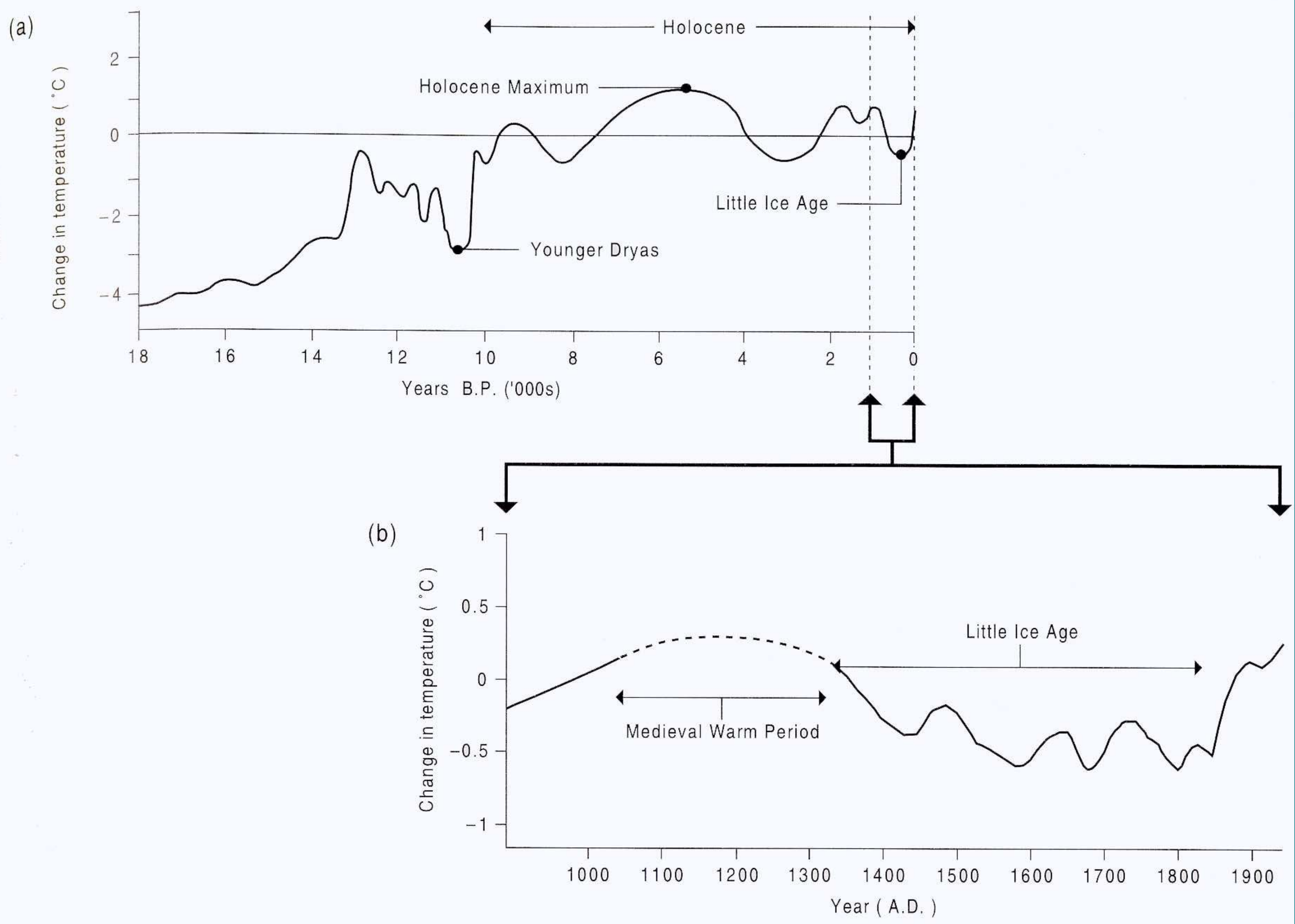
Source: IPCC TAR. 2001

Global climate change

“our poor knowledge and understanding of the workings of the global heat balance make the current and future situation [of the atmosphere] uncertain.”

Source: N. Middleton “The global casino”.

Variations in average global temperature



Direct Atmospheric inputs

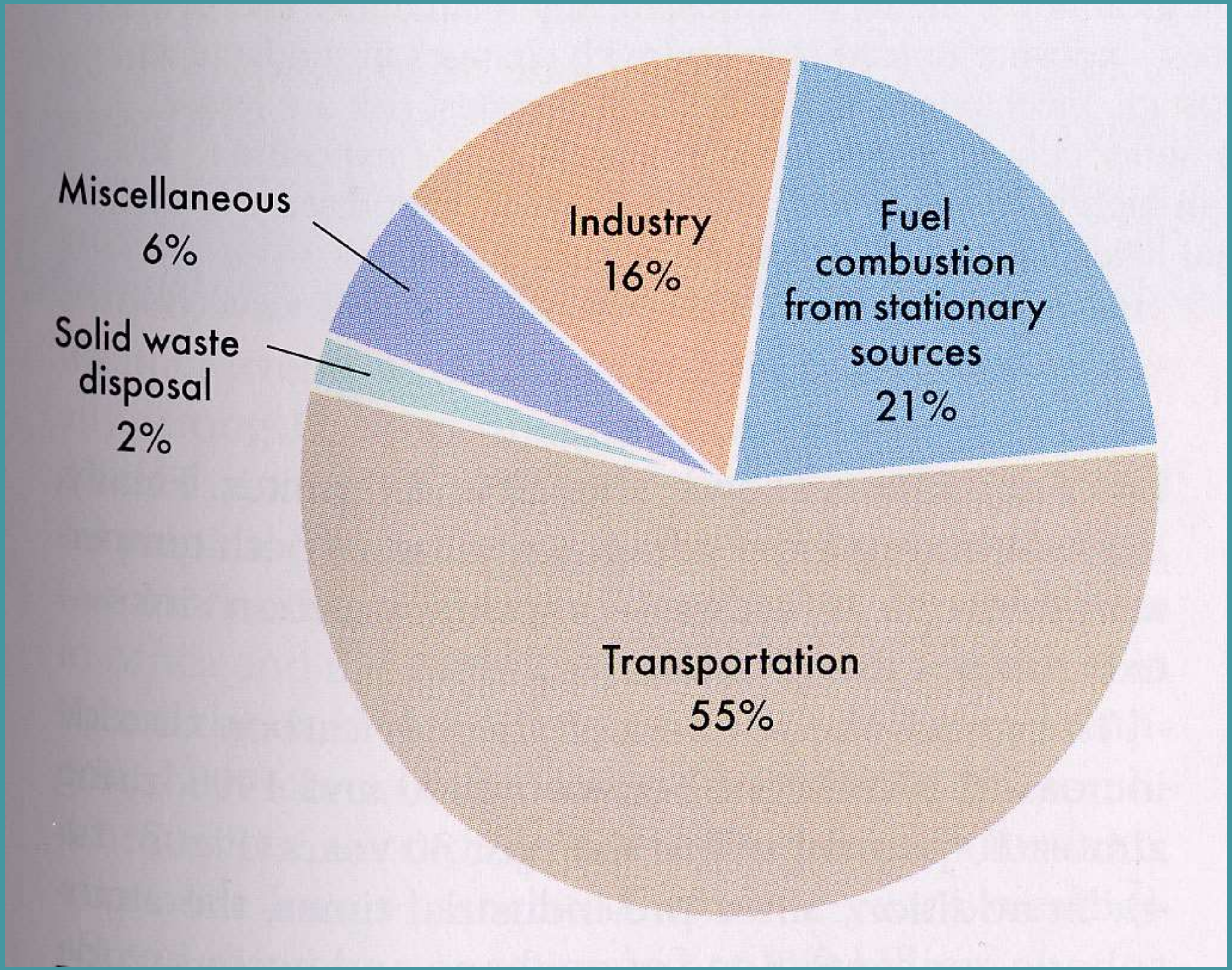
Methods through which human activity can directly alter atmospheric energy budget:

- gas emissions (CO_2, CH_4, CFC's)
- aerosol generation
- thermal pollution

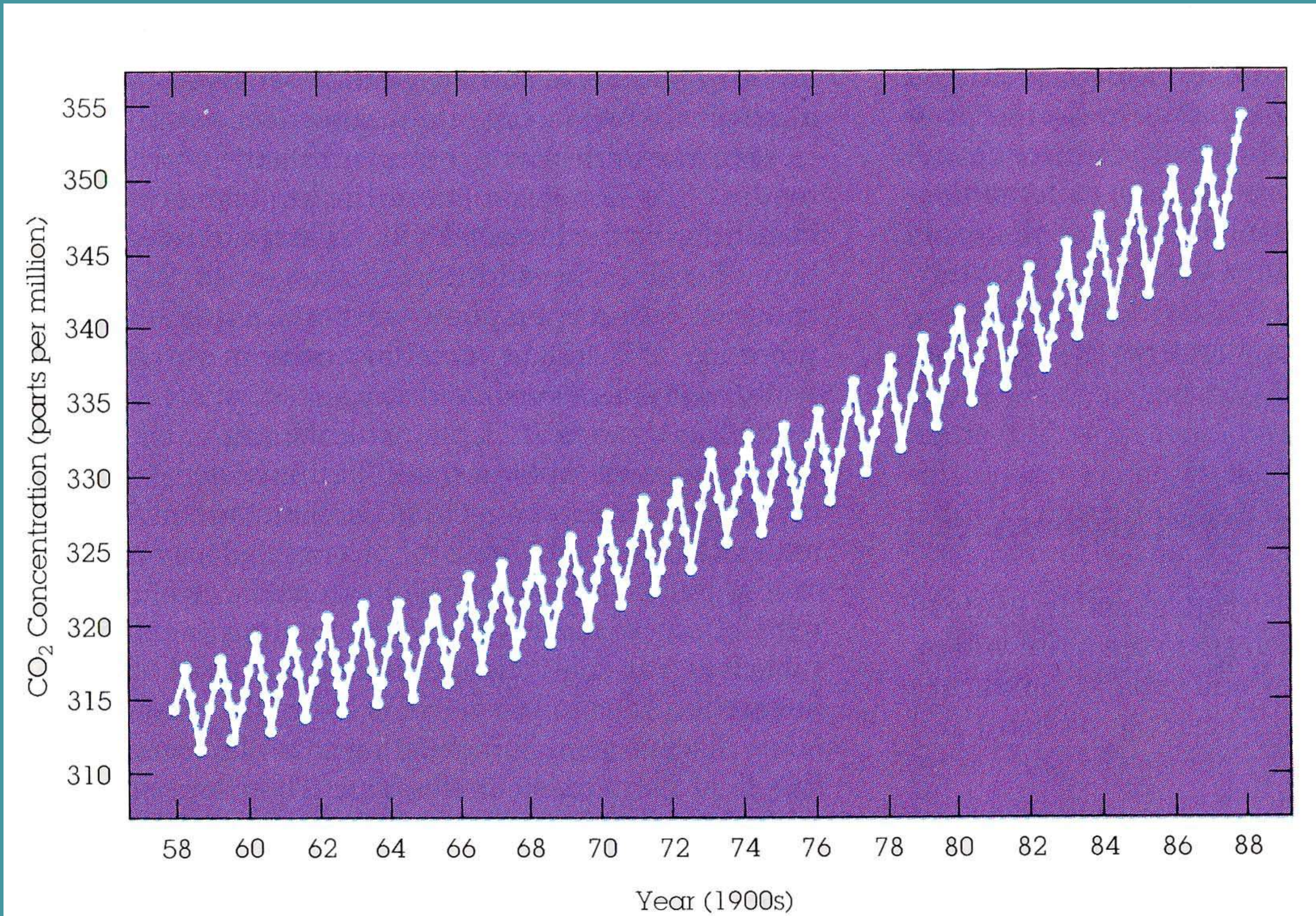
Atmospheric trace gases significant to global warming

	Carbon Dioxide	Methane	CFC's
Natural Source	Nature	wetlands	none
Anthropegenic source	Fossil fuels; deforestation	Rice crops; fossil fuels; cattle; biomass burning	Refrigerants; aerosols; industrial process.
Atmospheric lifetime	50-200 years	10 years	60-100 years
Annual rate of increase	0.5%	0.9%	4.0%
Global warming potential	1	11	3400-7100
Contribution to greenhouse effect	60%	15%	12%

Cultural sources of air pollutants in the USA

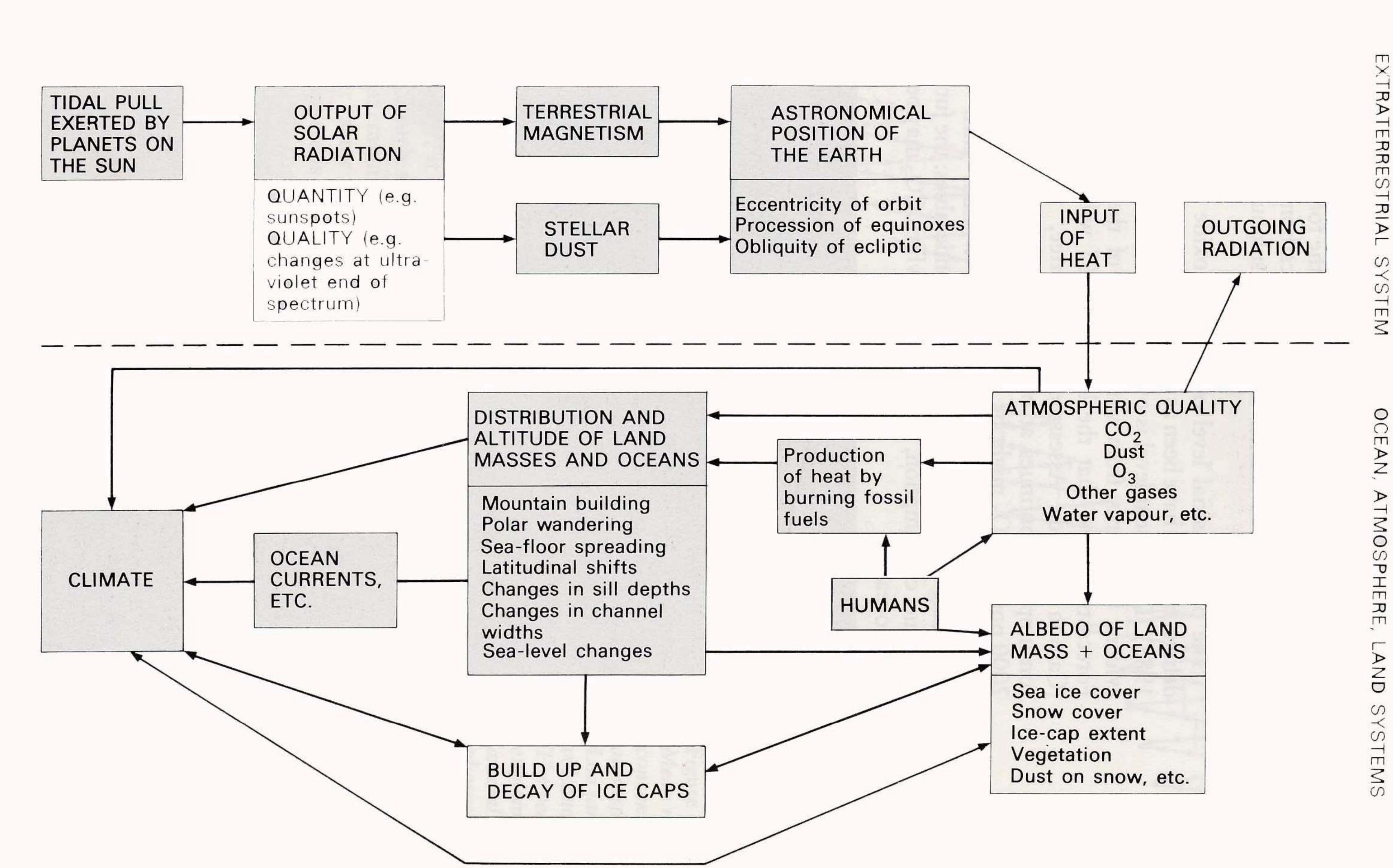


CO_2 in the atmosphere



Data from the Mauna Loa Observatory, Hawaii

Possible influences causing climate change

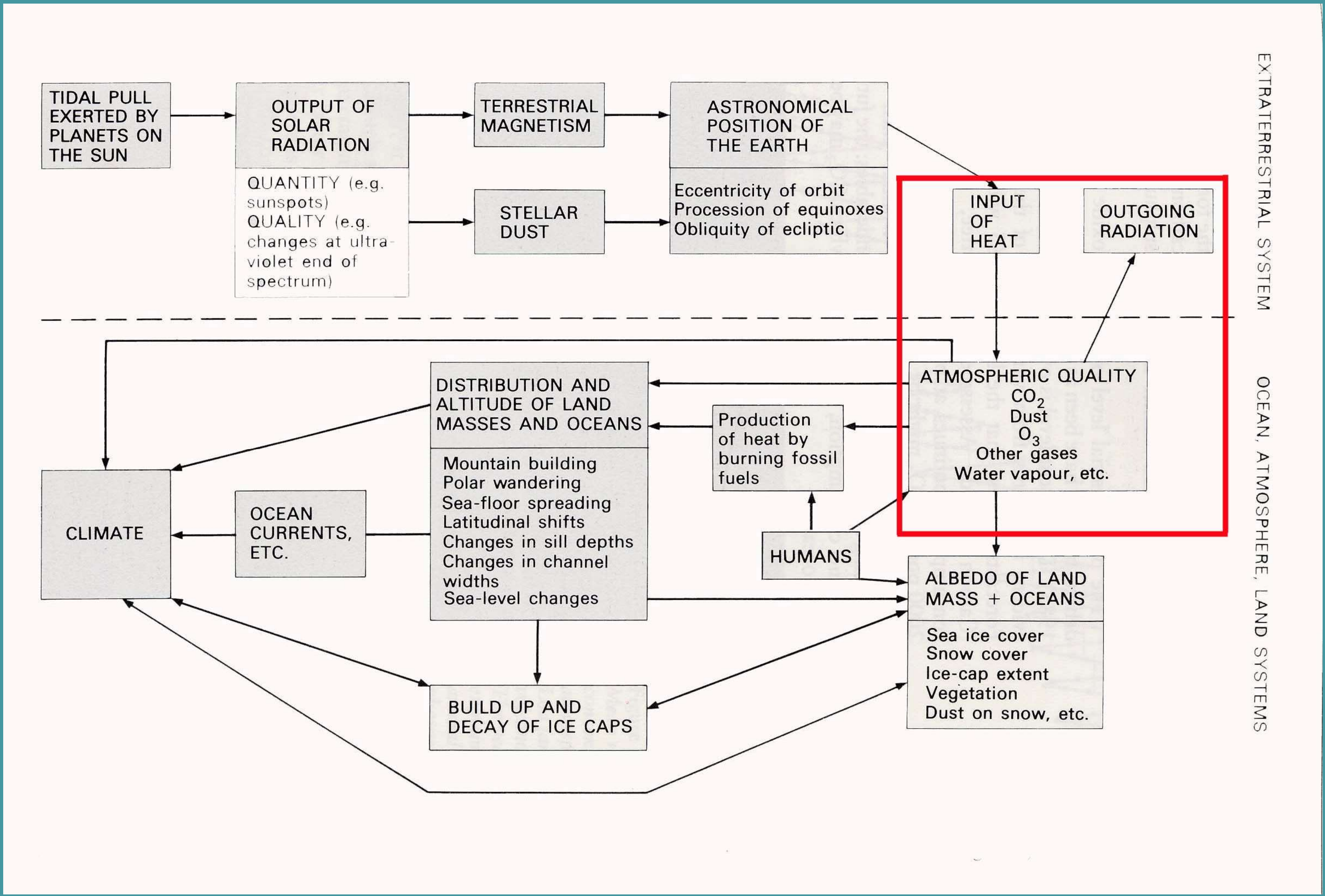


How does climate change occur?

Anthropogenic climate change can best be explained in terms of the energy balance of the atmosphere.

Position of the global energy budget within all possible influences illustrated on next slide.

Global energy budget position



Global energy balance

Is the energy state of the earth at any one time.

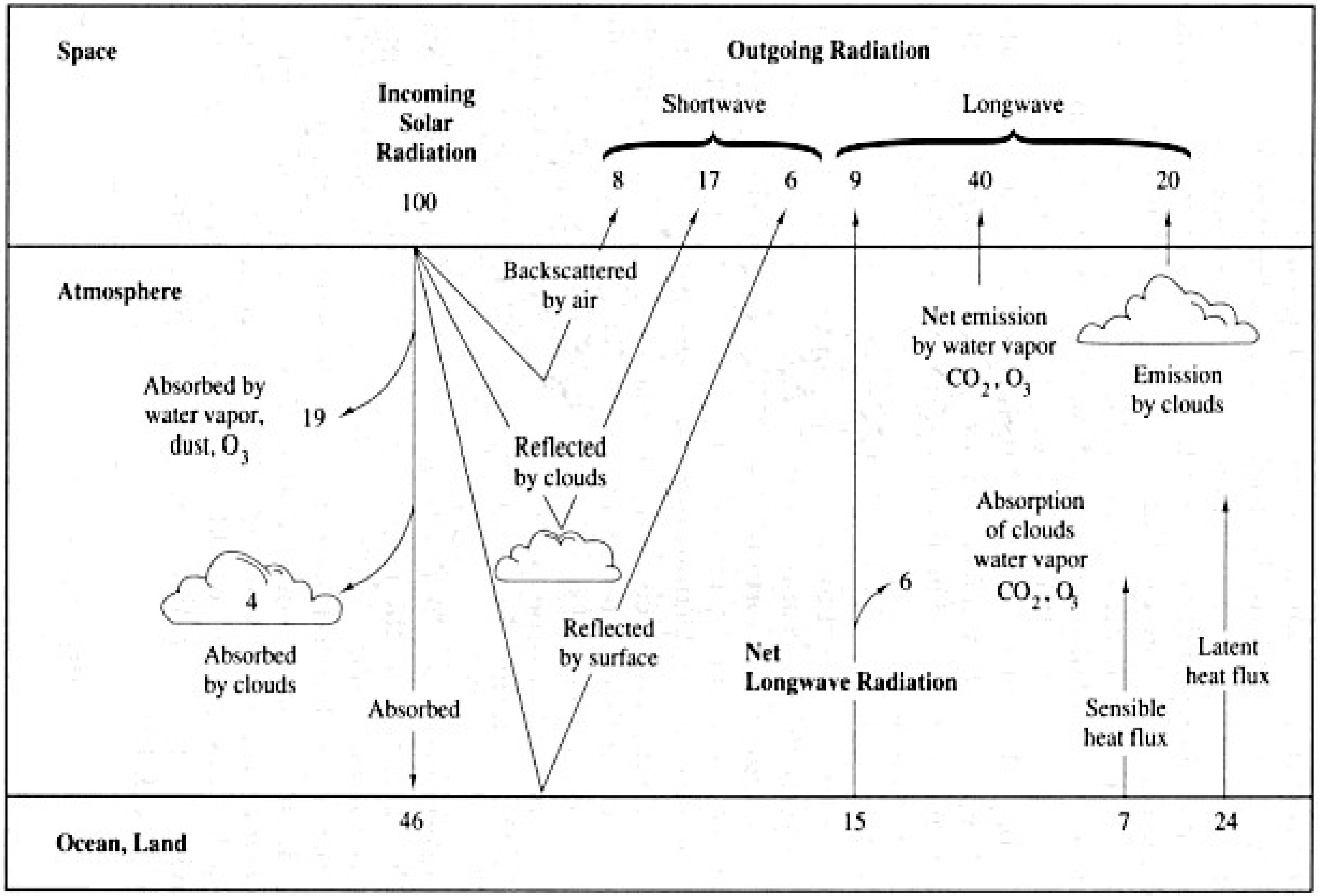
Is the difference between energy received and energy lost.

Shortwave radiation: absorbed from the sun.

Longwave radiation: emitted by the earth.

Net radiation = total radiation in – total radiation out.

Mean global energy budget



What is climate change?

It is simply a slight imbalance in the global atmospheric energy budget:

inputs > outputs

or

inputs < outputs

Anthropogenic discharges of trace gases beyond natural levels result in the retention of heat energy which would normally be emitted to space.

What is global warming?

Occurs when inputs exceed outputs, i.e. more heat is retained than lost.

The result?

Some basic effects of a warmer global climate

- Alteration of global air circulation patterns.
- Alteration of global ocean circulation patterns.
- Changes to marine water salinity.
- Changes to global heat distribution patterns.
- Alteration of regional climates.
- Increased frequency of severe storms.
- Changes in sea levels.

5. Possible mechanisms for human-induced climate change

1 - Direct Atmospheric inputs

- gas emissions (CO_2, CH_4, CFC’s)
- aerosol generation
- thermal pollution

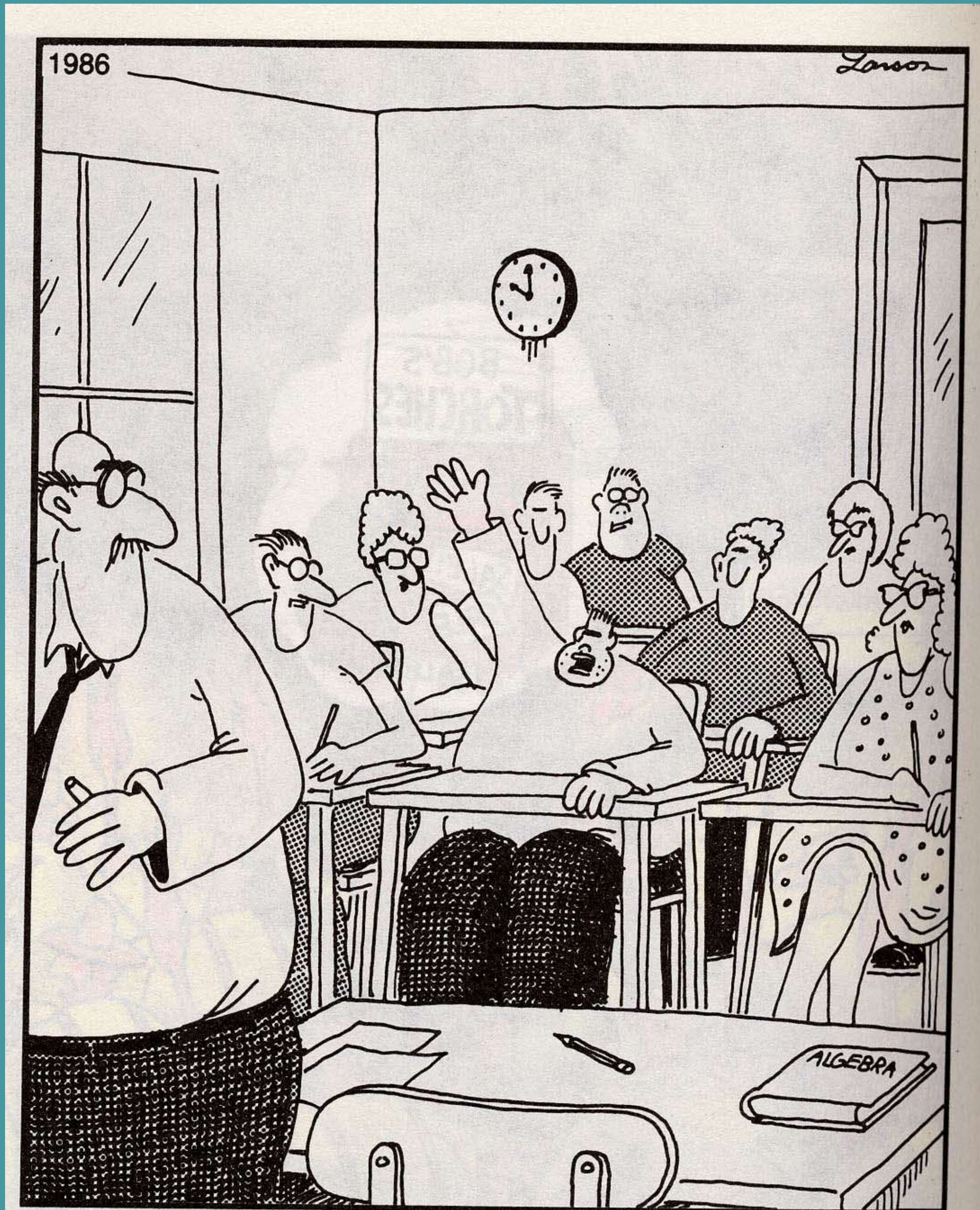
Possible mechanisms for human-induced climate change

2 - Changes to land surface

- albedo change
- roughness change
- extension of irrigation

3 - Alteration to the oceans

- current alterations
- diversion of fresh waters



Professor Legris, may I be excused? My brain is full.”

Next Class

Invasive Species