Topic # 8
ATMOSPHERIC STRUCTURE & CHEMICAL COMPOSITION

All about the GASES IN THE ATMOSPHERE, esp. GREENHOUSE GASES!

Class Notes pp 37- 41

also we'll be referring back to p 32-35 occasionally

Overheard: Sept 22
Tuesday, September 22, 2009

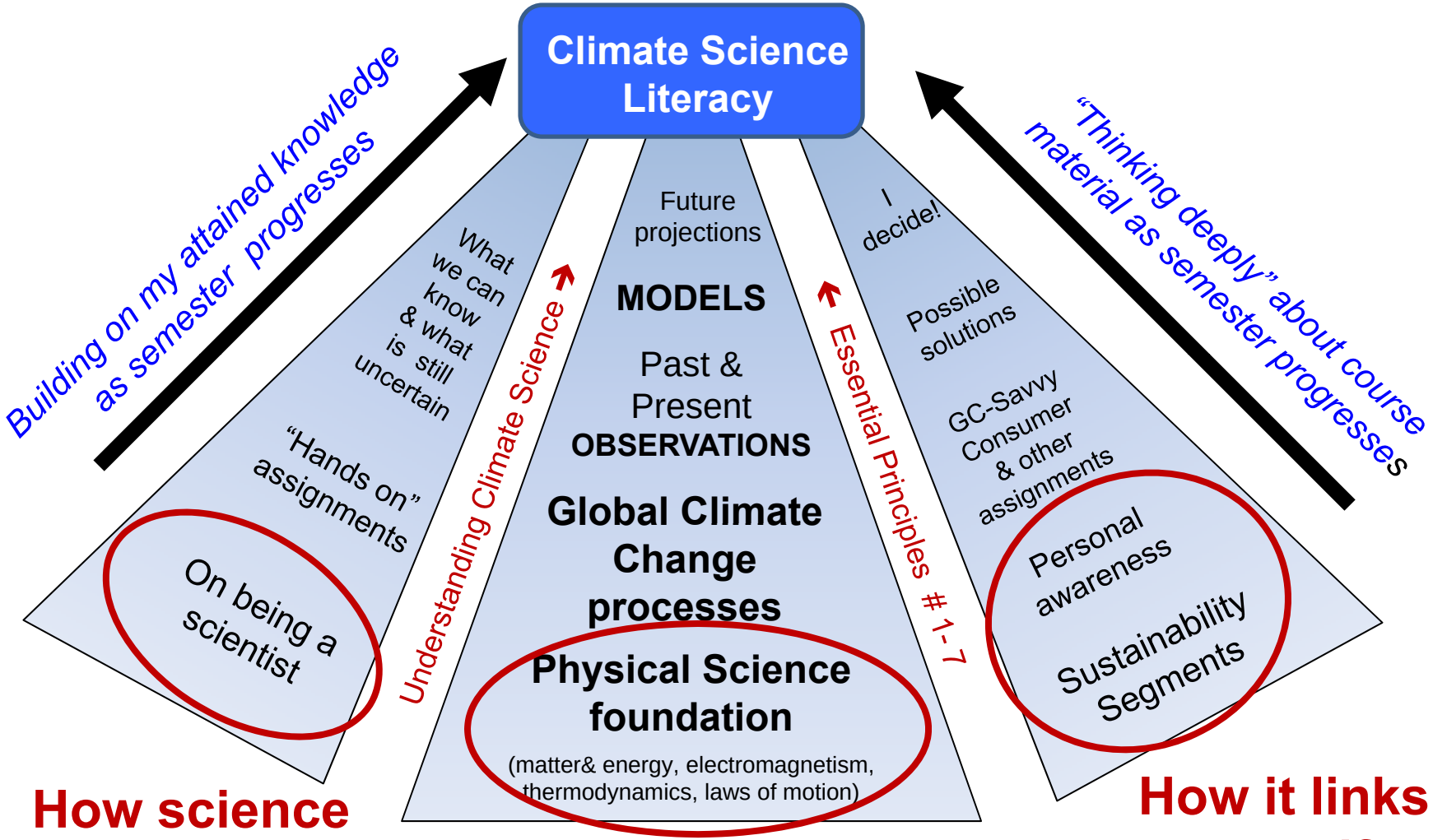
(Walking out of natural sciences 101: Intro to Global Change)

"Guy on phone: I don't get why she talks about global warming all the time. It's not even real."

— ILC

WHERE ARE WE HEADED & WHY?

GOAL: Enhanced Understanding Of Global Change Science, How It Operates, & What It Means To Me Personally



This figure is on p 7 of Class Notes

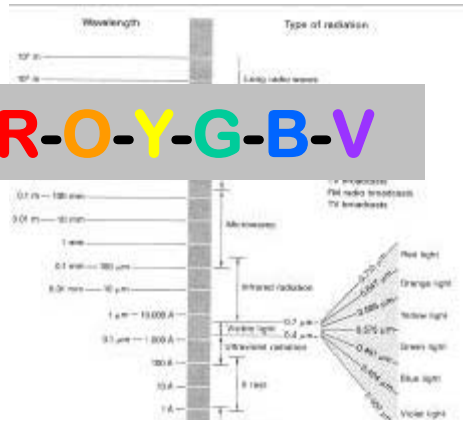
TODAY'S CLASS

KEY GLOBAL CHANGE ISSUES FOR TODAY'S CLASS:

1. Gases that contribute to the **GREENHOUSE EFFECT** & where they come from

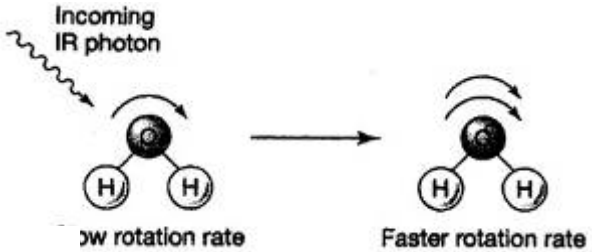
2. Intro to some aspects of **"OZONE"** (as a **Greenhouse Gas** & in relation to the "**Ozone Hole**" (Depletion of Stratospheric Ozone)

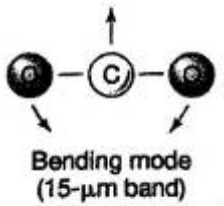
Things you've seen before that will all come together under this topic:

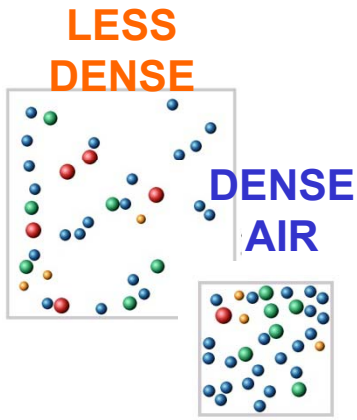


R-O-Y-G-B-V

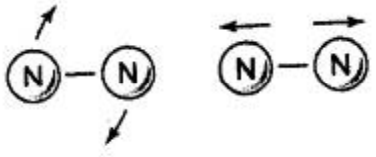
$$E = \sigma T^4$$

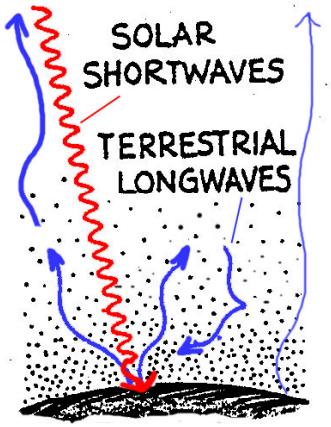


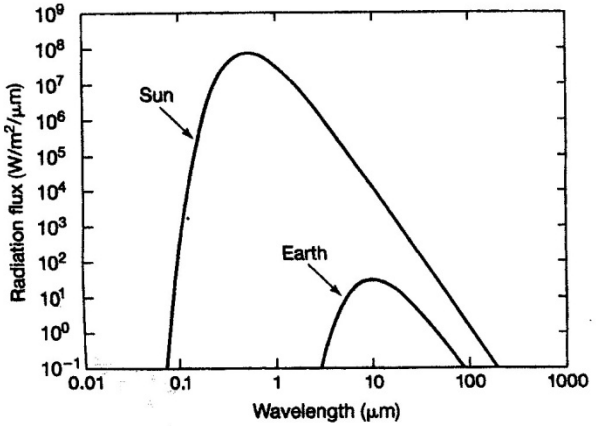


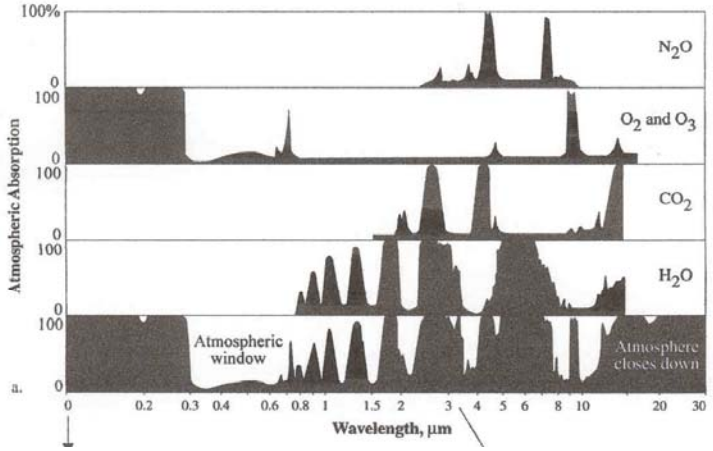


$$E = h\,c\,/\,\lambda$$









$$\lambda_m = a\,/\,T$$

OBJECTIVES:

To understand:

-- the VERTICALSTRUCTURE of the atmosphere & its relationship to temperature

-- which GASES are in the atmosphere

-- where they are concentrated, and

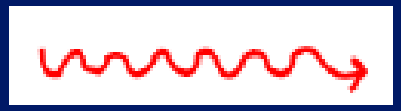
-- why gases at different levels are linked to the Greenhouse Effect & Ozone Depletion

We travel together, passengers in a little space-ship, dependent on its vulnerable supplies of air and soil.

~ Adlai Stevenson

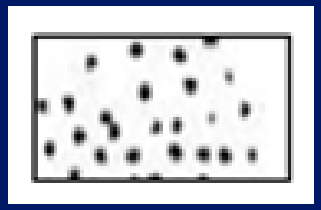
CLASS CONCEPTS SELF TEST

KEY:



= represents Solar shortwave (SW) radiation

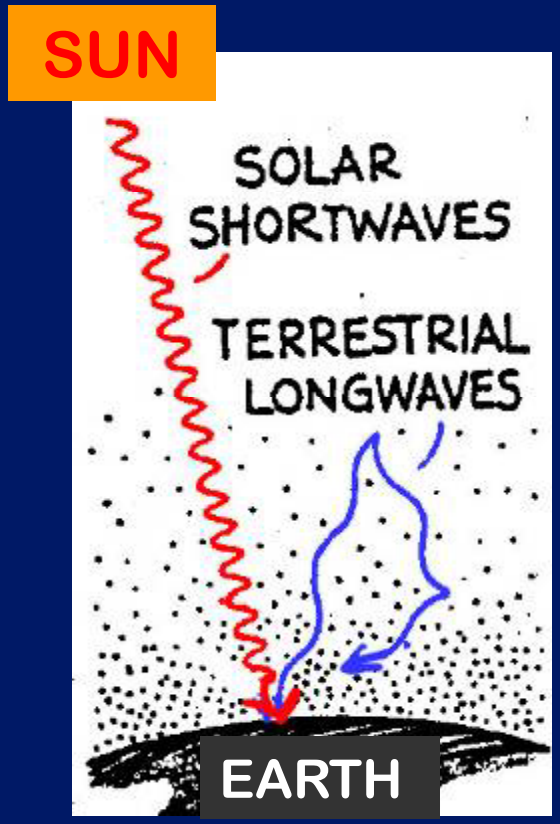
= represents Terrestrial longwave (LW) (infrared IR radiation)



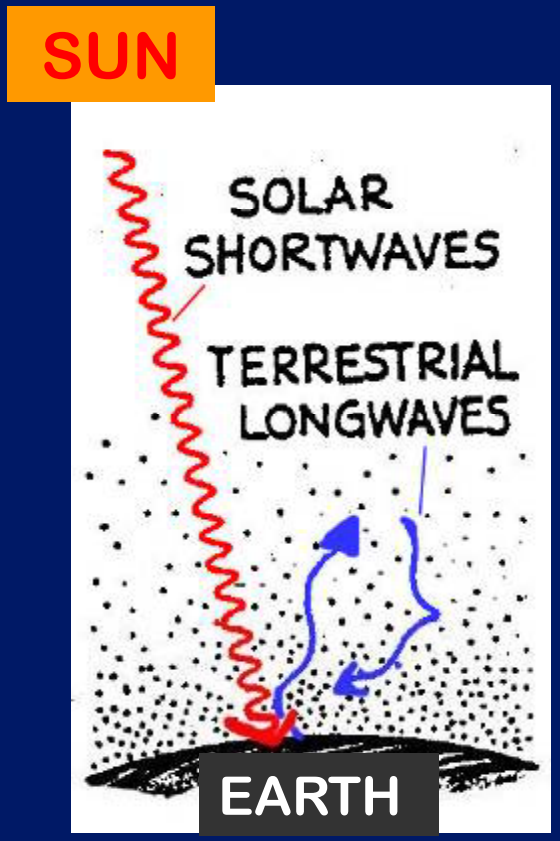
= represents the atmosphere and its gases

(Recall: these gases can absorb and emit certain kinds of radiation: Radiation Law #6)

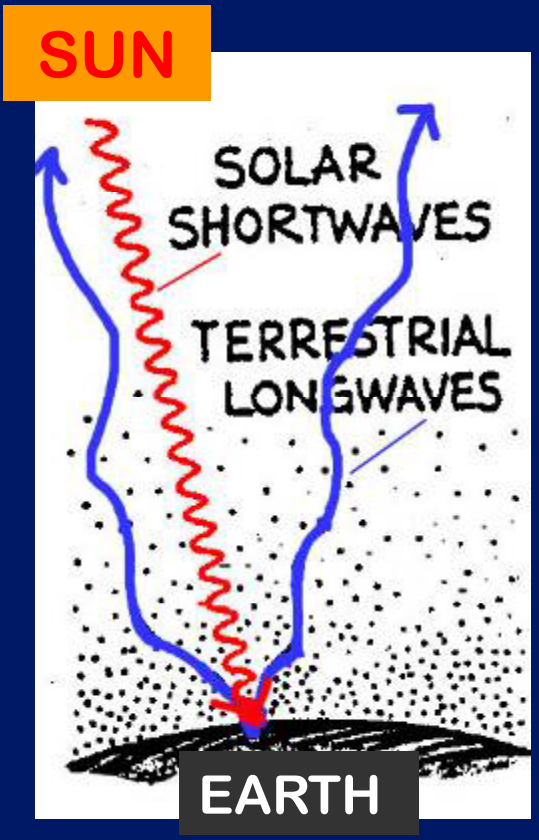
Q1. Which diagram shows shortwave (SW) solar radiation being reflected BACK to space?



A



B



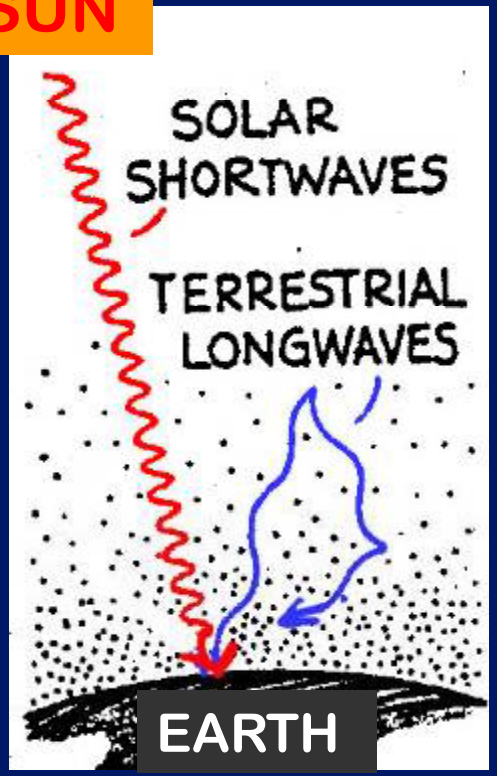
C

NONE OF THEM!!

SW reflection would look like this:

or

SUN



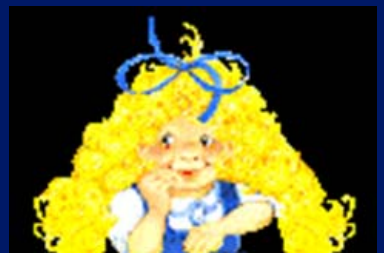
A

Q2. Diagram A shows LW radiation "bouncing off" the gases in the atmosphere

(i.e. being reflected back to the surface by the gases without being absorbed by them.)

Is this an accurate depiction of how the Greenhouse Effect works?

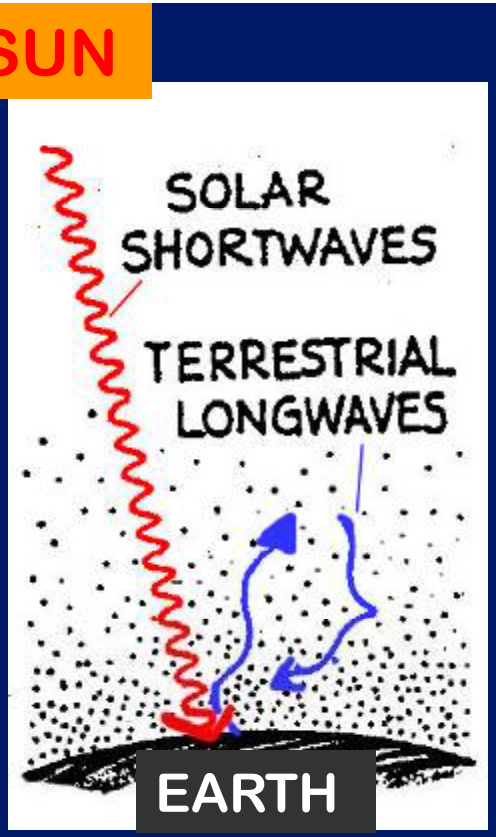
CHOICES: YES NO PARTLY



OH NO !!!

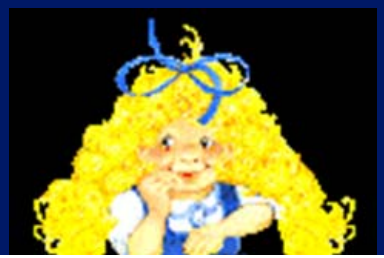
Q3. Diagram B shows LW radiation being absorbed and them emitted by the gases in the atmosphere.

Is this an accurate depiction of how the Greenhouse Effect works?



B

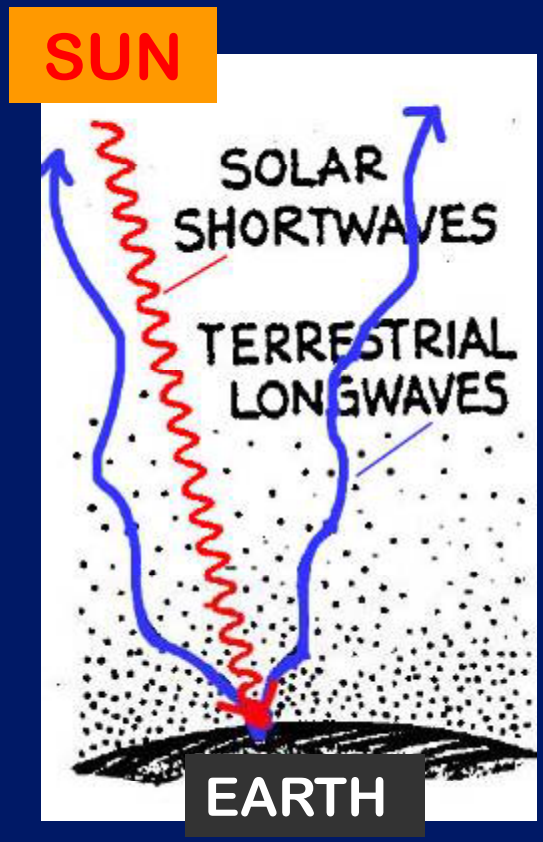
CHOICES: YES NO PARTLY



YES !

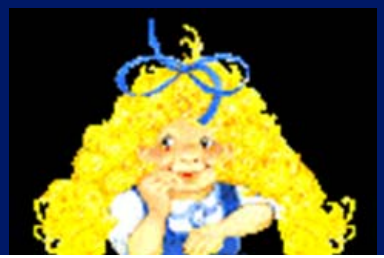
Q4. Diagram C shows LW radiation going right through the atmosphere out to space.

Is this an accurate depiction of how the Greenhouse Effect works?

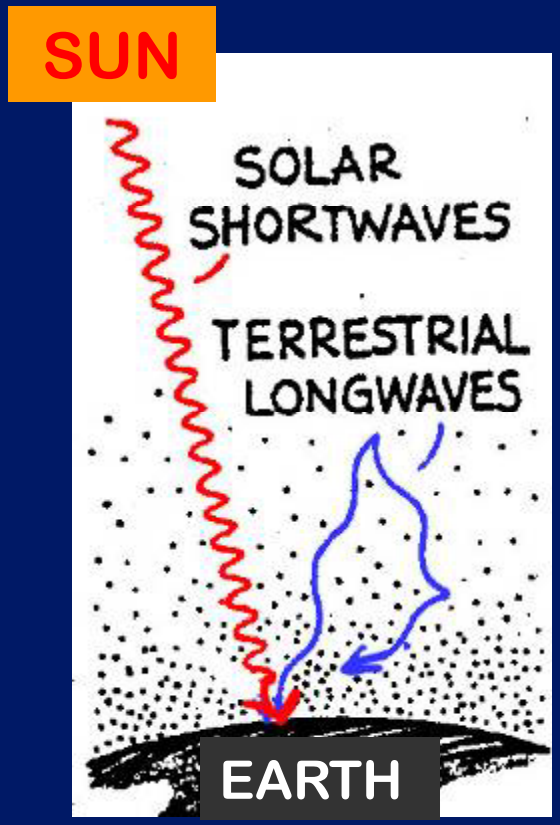


C

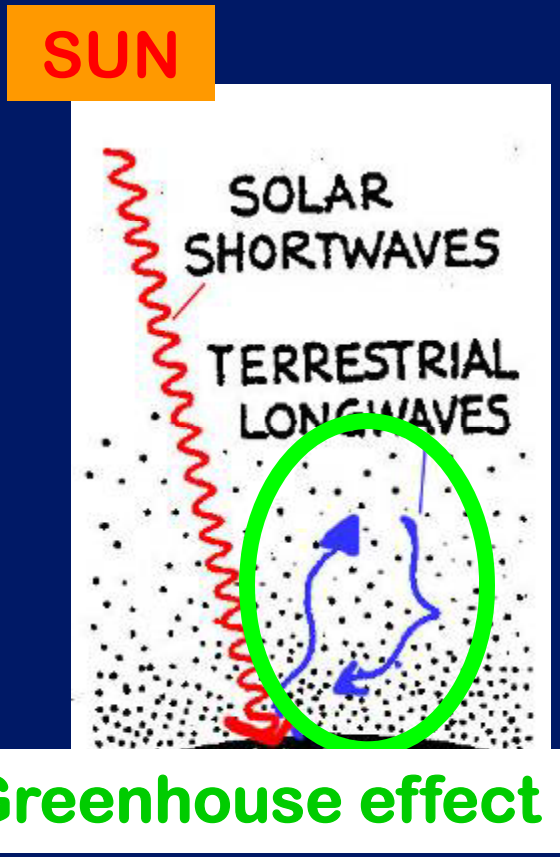
CHOICES: YES NO PARTLY



Q5. On the diagram that you think best depicts the processes involved in the **GREENHOUSE EFFECT**, circle the specific part of the diagram that represents the Greenhouse Effect.

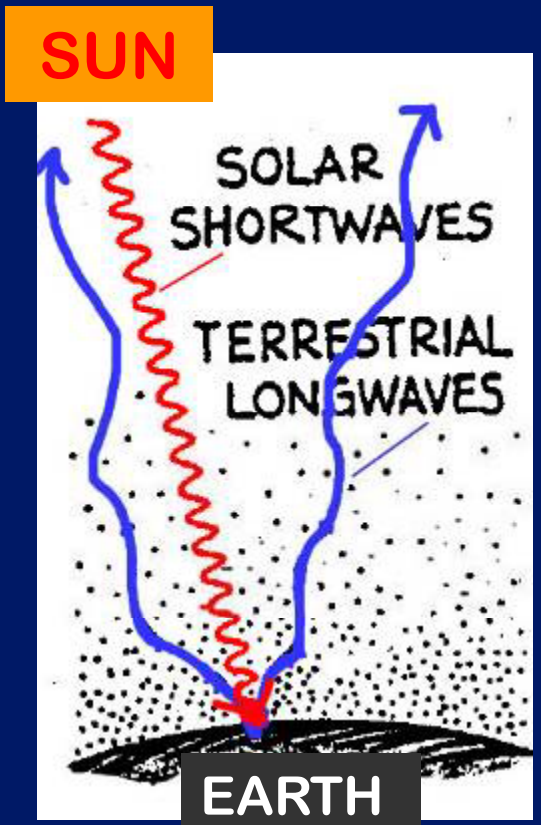


A



Greenhouse effect

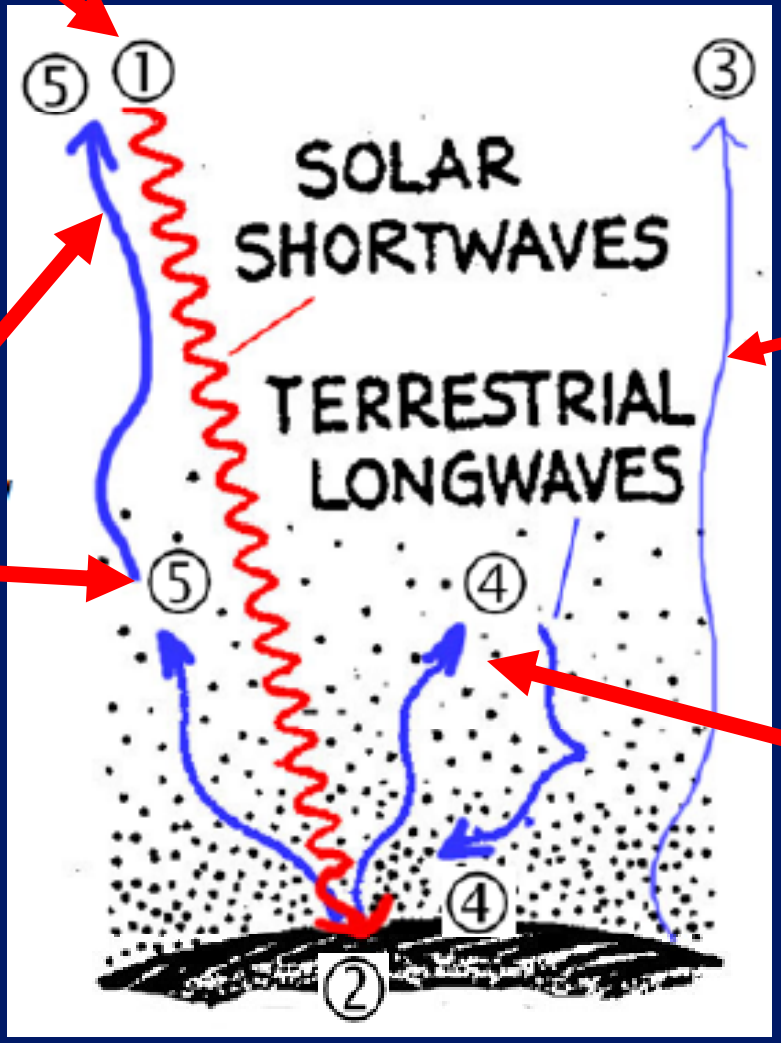
B



C

Modified Cartoon of Solar (SW) & Terrestrial (LW) wavelengths of radiation:

(1) Some Incoming SW radiation from the SUN goes right through the atmosphere to Earth (w/o being absorbed)



(3) Some IR radiation is emitted from the Earth's surface right out to space through "IR window"

(5) Some IR radiation is absorbed by GH gases in the atmosphere, but is emitted out to space (not back to Earth)

(4) Some IR radiation is absorbed by GH gases in the atmosphere and emitted back to Earth

(2) The Earth absorbs SW

Modified Cartoon of Solar (SW) & Terrestrial (LW) wavelengths of radiation:

(1) Some Incoming SW radiati… the SUN g… through th… atmosphe… (w/o being …

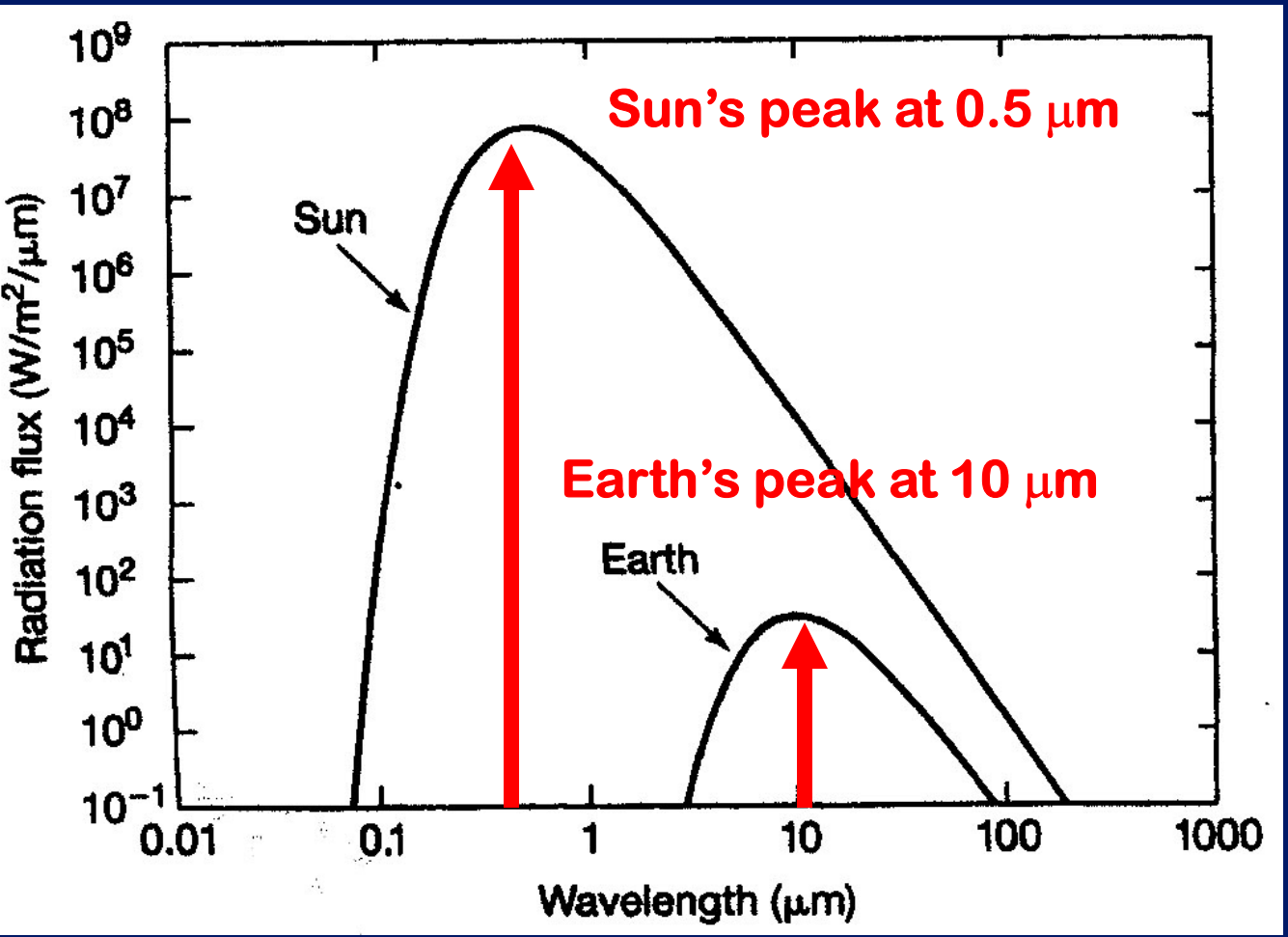
(3) Some IR radiation is …mitted from the …h's surface …t out to …ce through …window"

BUT WHAT ABOUT INCOMING SOLAR SW? IS IT DEPICTED CORRECTLY?

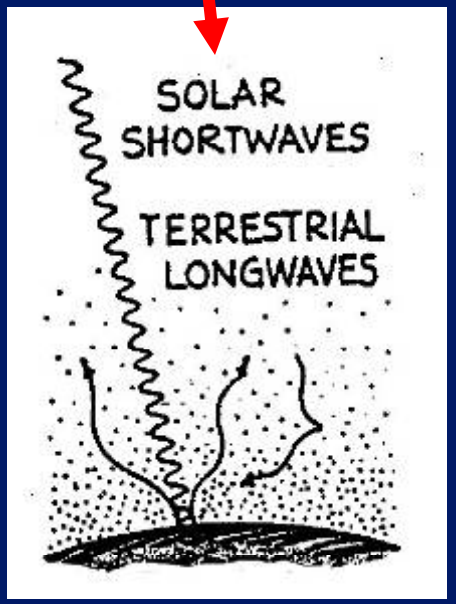
(5) Some… radiation… absorbe… gases in … atmosph… emitted … space (not back to Earth)

…ome IR …tion is …rbed by GH …s in the …sphere and …ted back to Earth

(2) The Earth absorbs SW



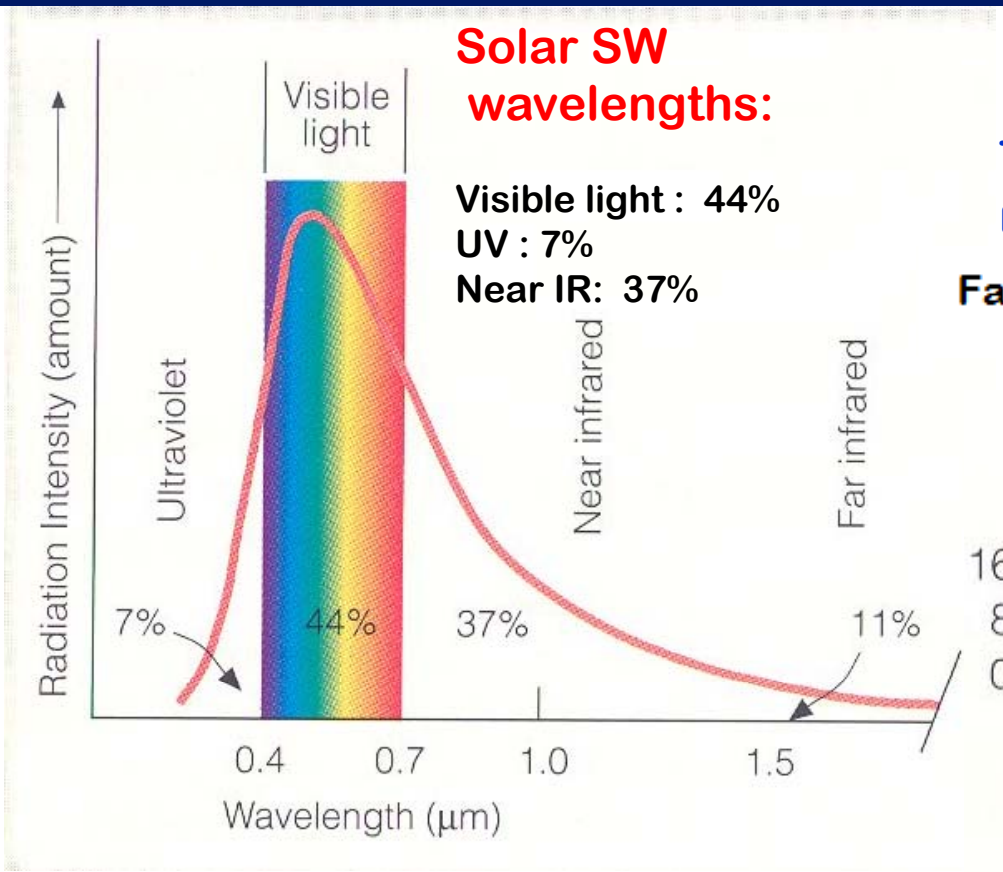
Wein's is the law behind this cartoon



Review p 32

Shortwave SOLAR radiation (SW) = UV + VIS + Near IR

TERRESTRIAL radiation (LW) = Far IR

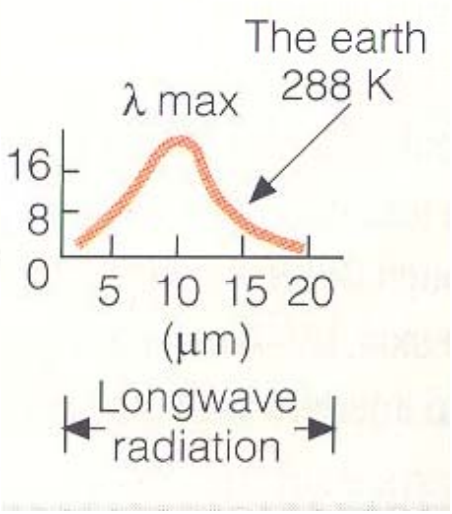


Solar SW wavelengths:

Visible light : 44%
UV : 7%
Near IR: 37%

Terrestrial (Earth) radiation wavelengths:

Far IR, with a maximum at ~ 10 μm

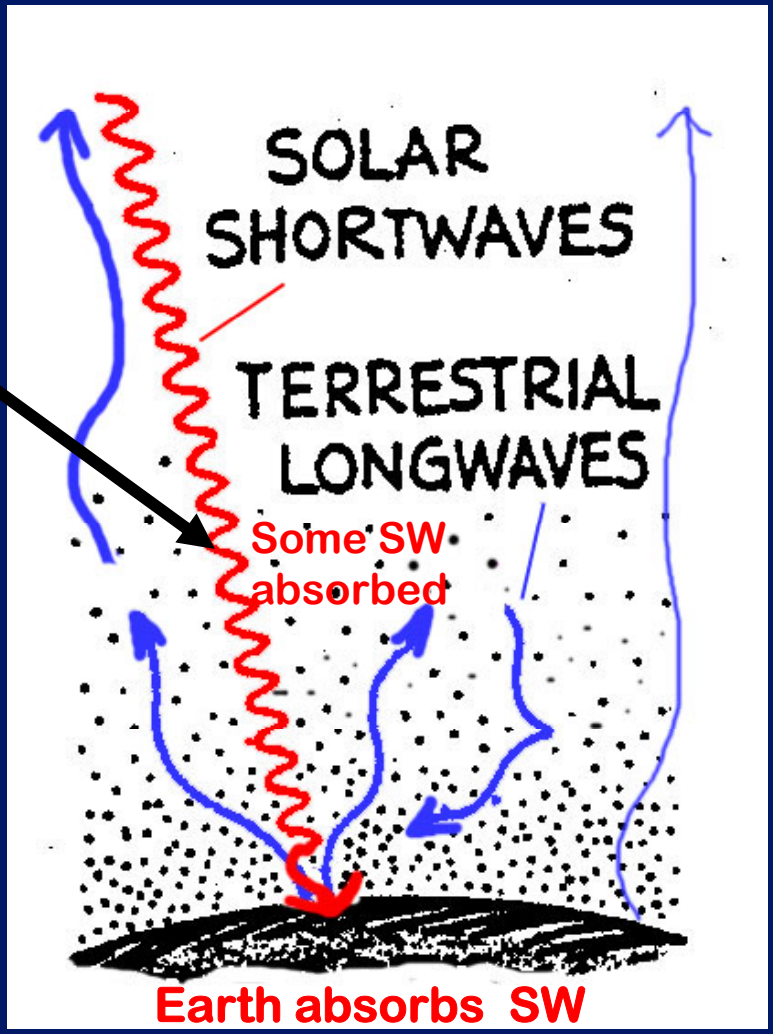


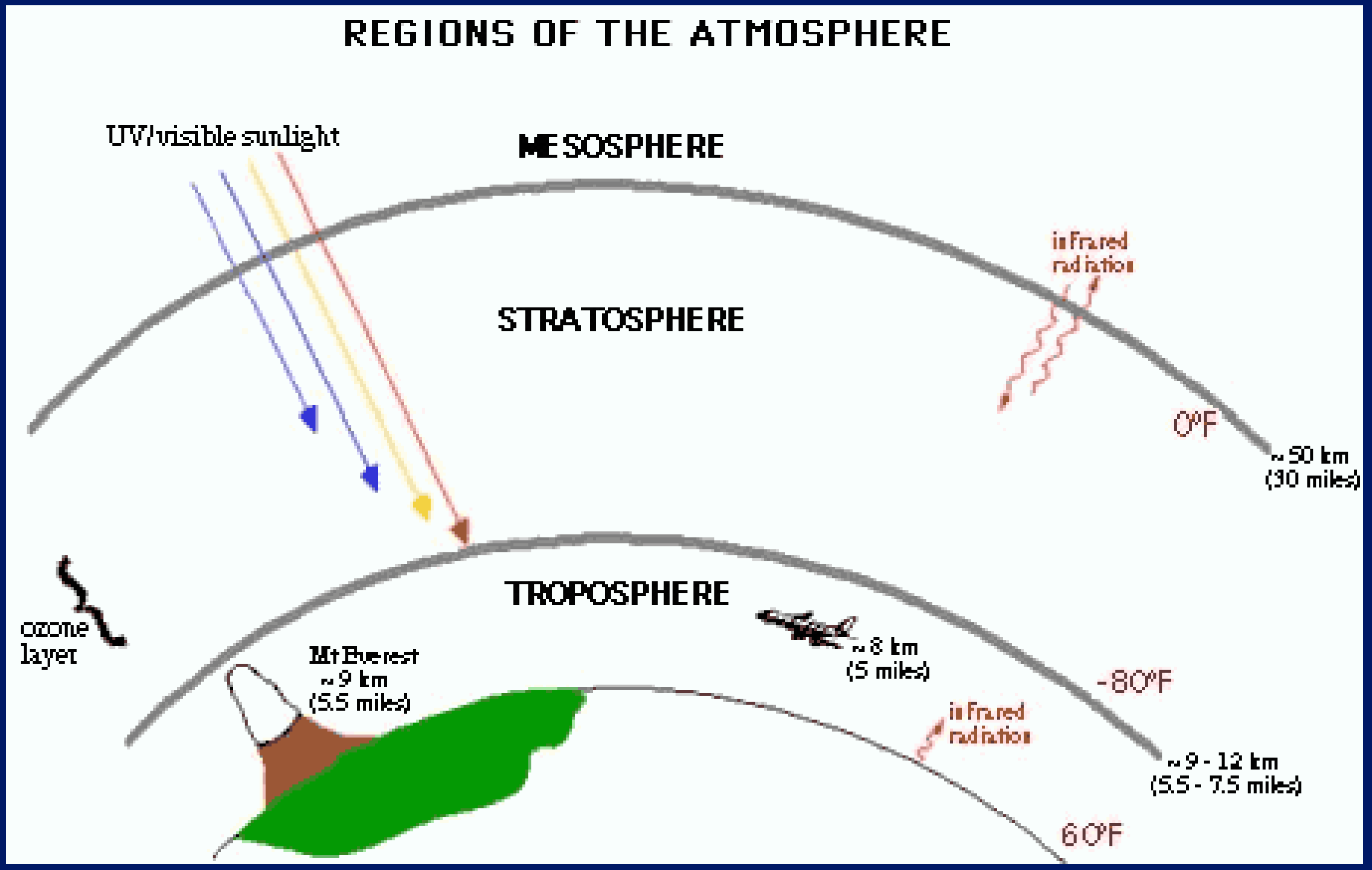
Review p 32

How do we correct the depiction of incoming SW?

Some SW gets absorbed on its way down to the surface!

(in addition to terrestrial LW (IR) radiation being absorbed in the GHE)



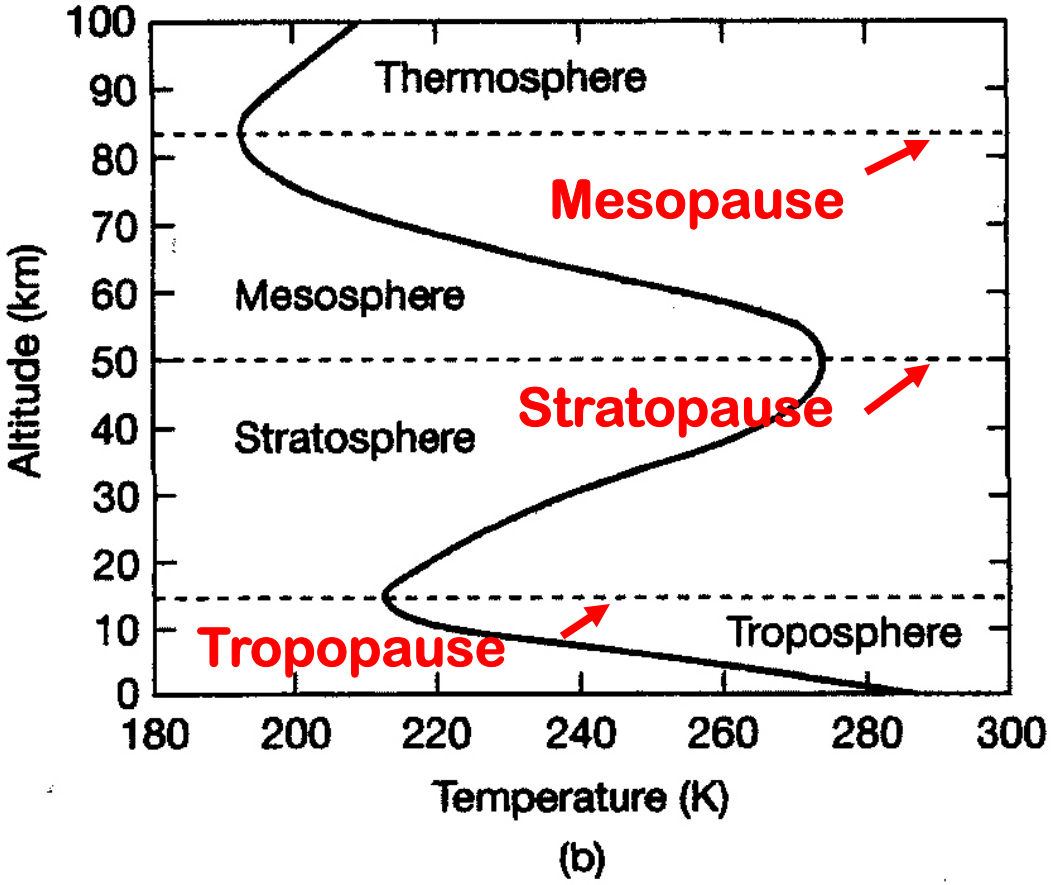


http://earthguide.ucsd.edu/earthguide/diagrams/atmosphere/index.html

The Vertical Structure of the Atmosphere

KEY CONCEPT:

The atmosphere's vertical structure is defined by CHANGES in the trend of TEMPERATURE with height.

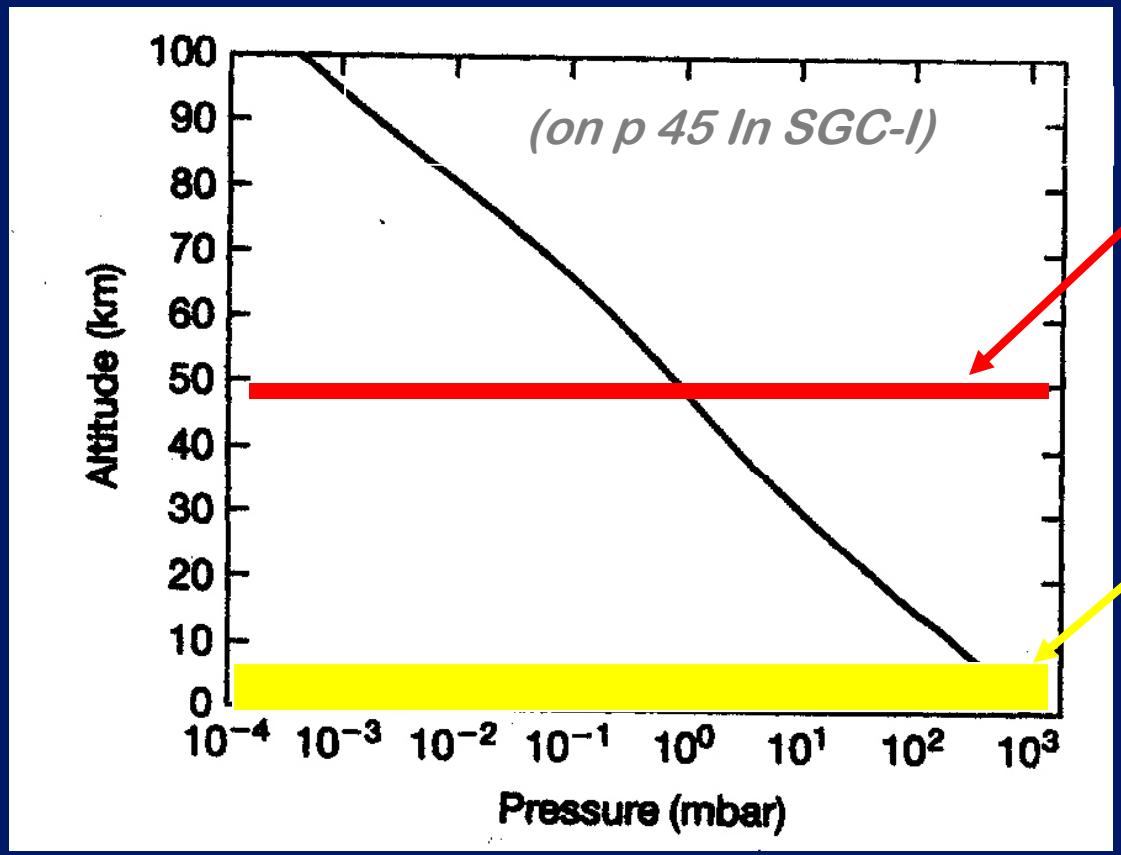


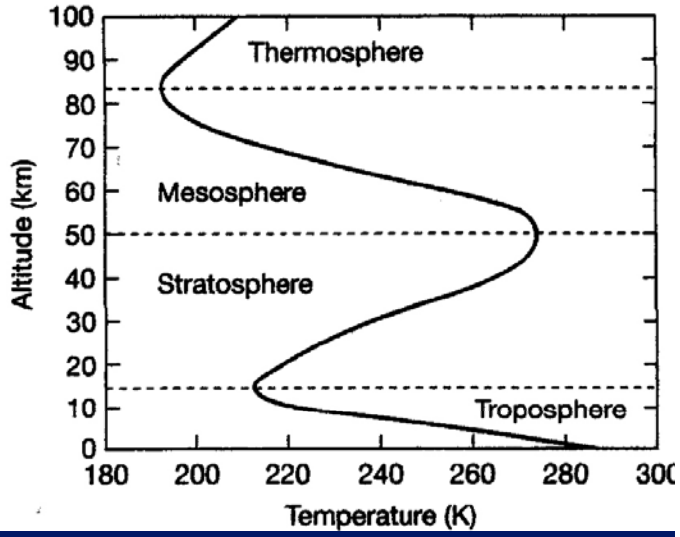
“TRy Sally’s Maroon THermals”

. . . or
think up
your own!

Atmospheric Pressure = weight of the air column above

Atmospheric Pressure & Mass Vary with Height





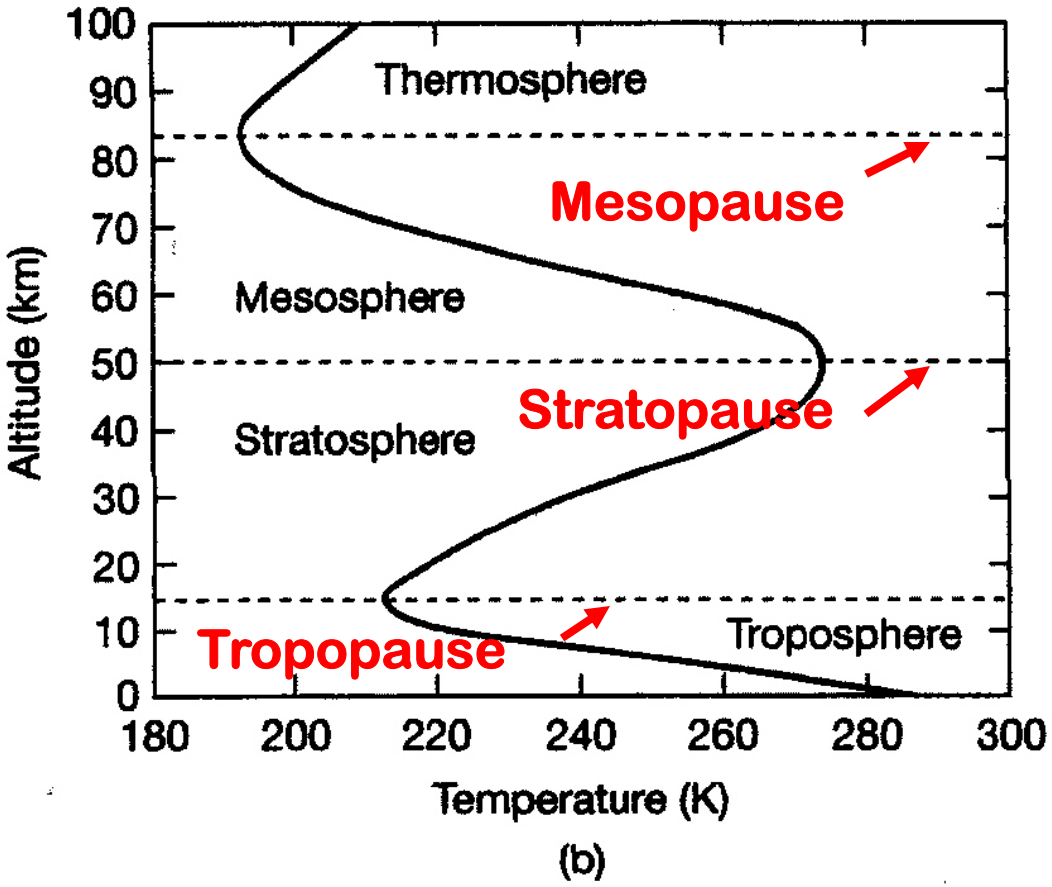
99% of mass lies below ~ 50 km (top of Stratosphere)

50% of mass lies below ~ 6 km (middle Troposphere)

The Vertical Structure of the Atmosphere

Why the zig-zags in the

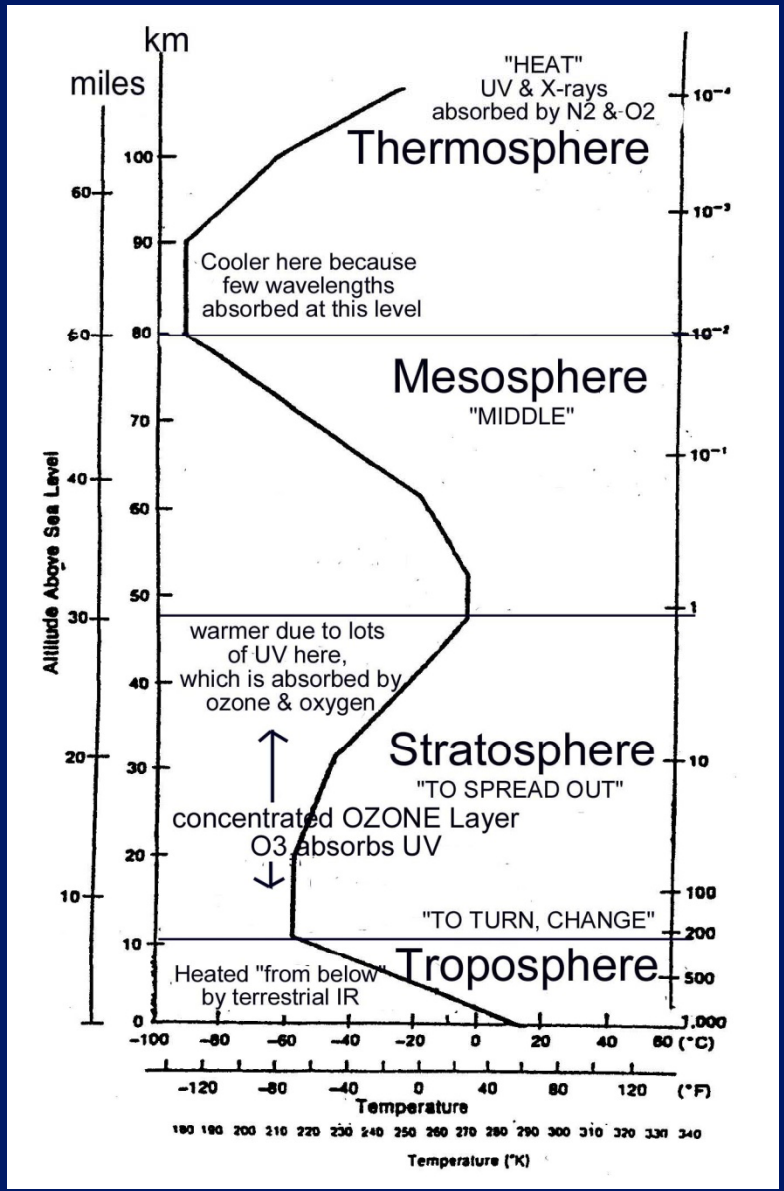
temperature / height graph?



The changes in temperature with height are the result of:

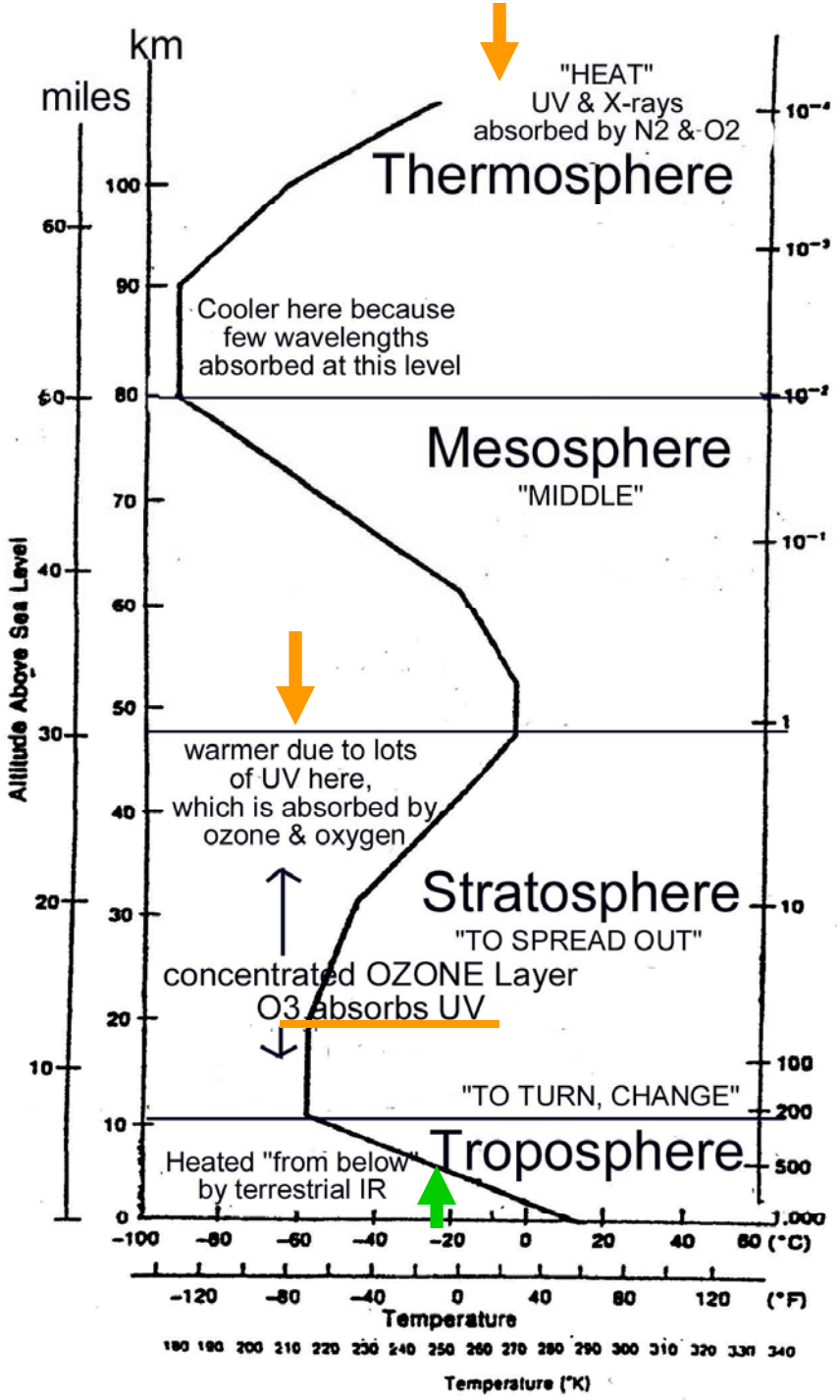
differential absorption of shortwave (SW) & longwave (LW) radiation

by atmospheric GASES concentrated at various altitudes.

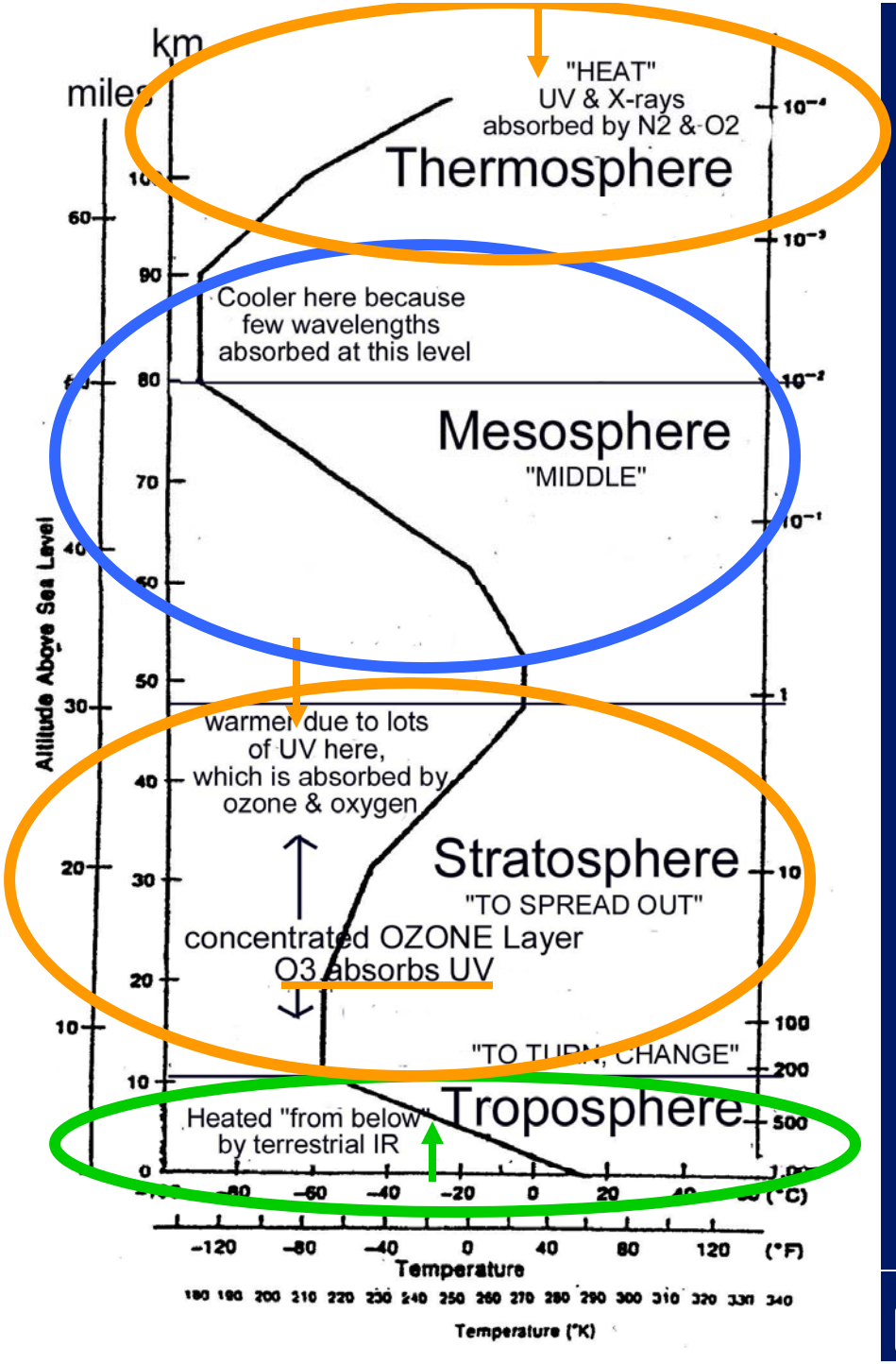


Incoming solar SW (mostly visible & near IR + UV)

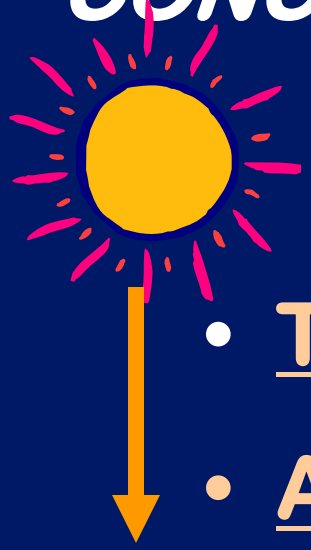
Outgoing terrestrial LW (Far IR) radiated from Earth's surface



Here's why these changes in **temperature** occur ➔



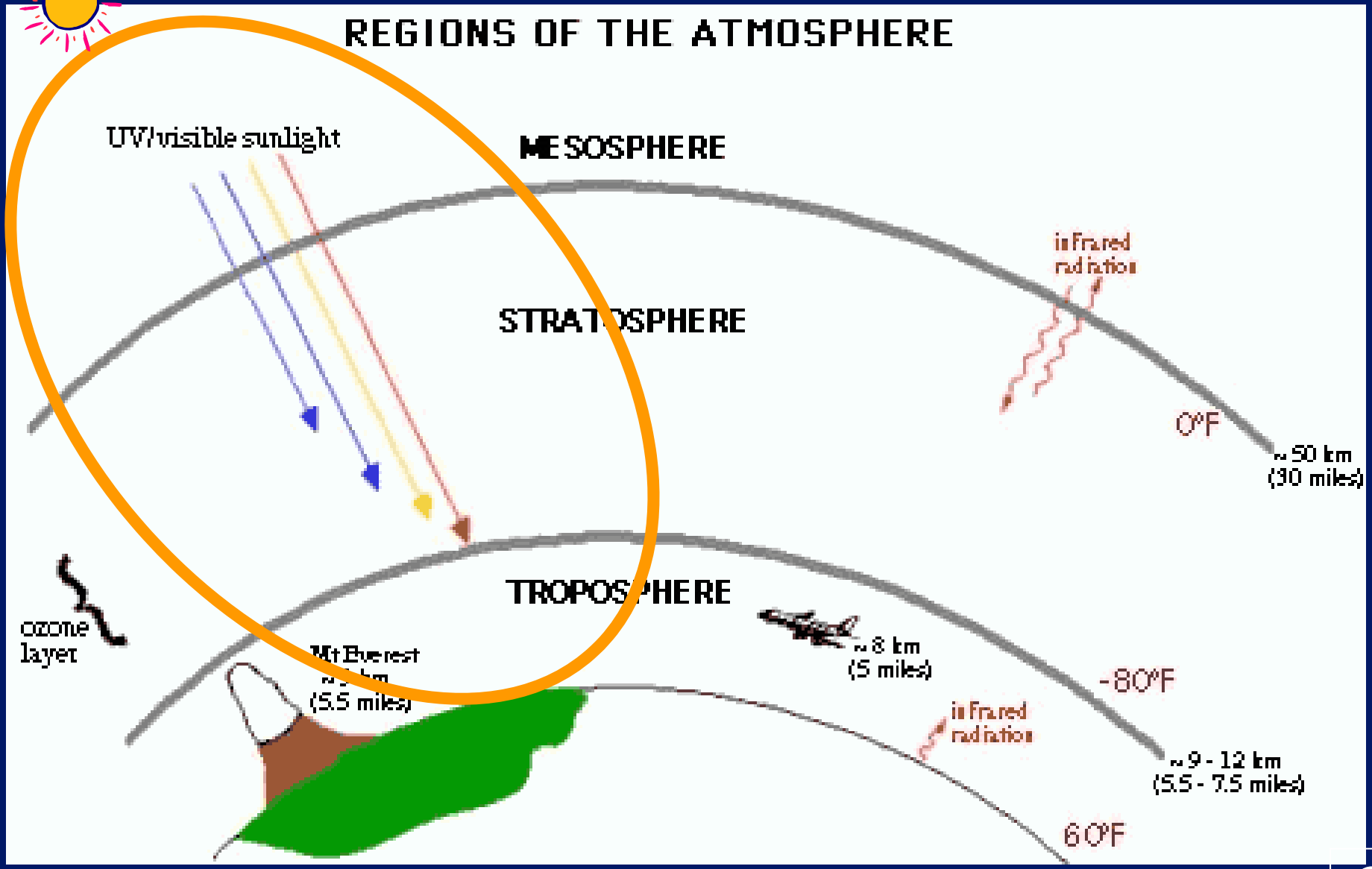
KEY CONCEPT: **On its way to the Earth's surface, several things can happen to incoming SOLAR RADIATION:**



- **TRANSMITTED (to Earth's surface)**
- **ABSORBED (by gases, dust, clouds)**
- **SCATTERED / REFLECTED**
  - **Reflected back to space**
  - **Scattered (and indirectly transmitted to Earth's surface)**

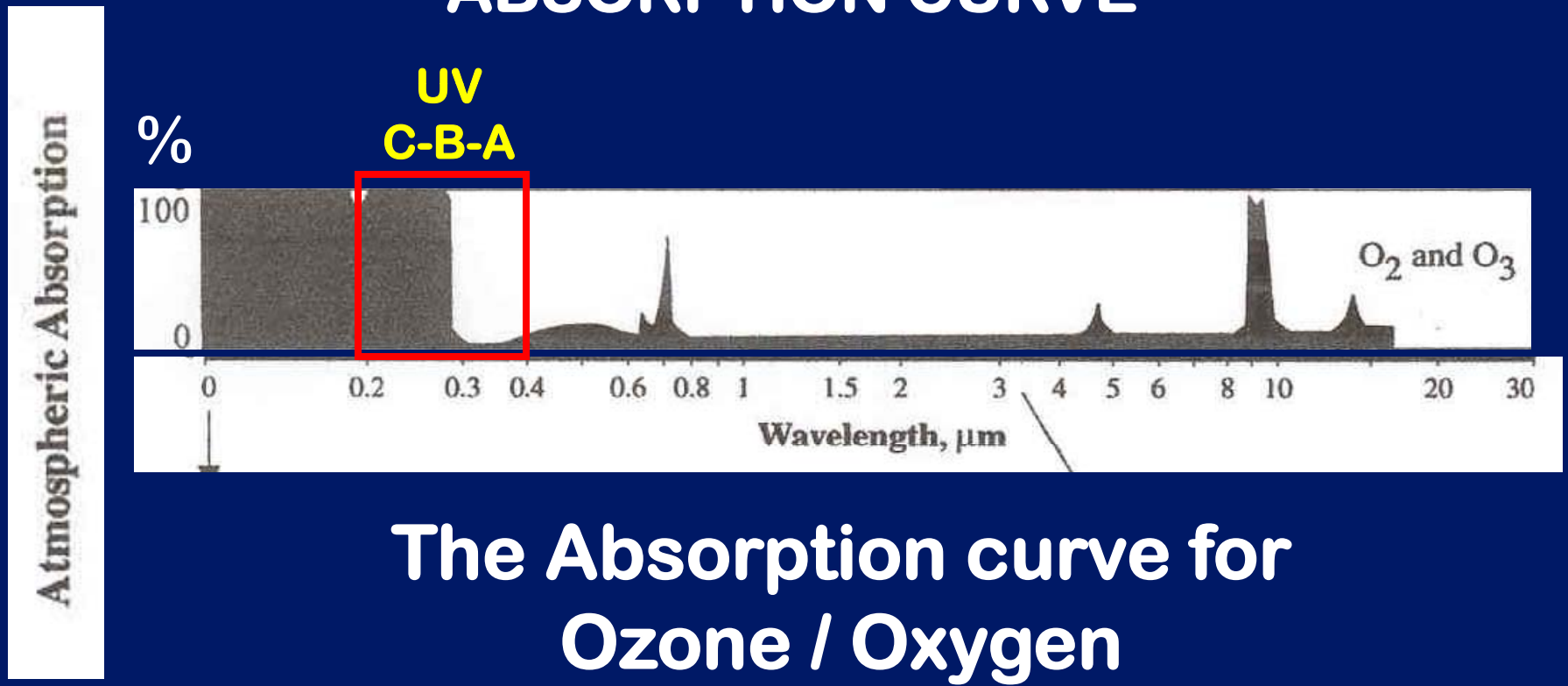
Take notes

Let's look closer at the incoming shortwave (SW) radiation (UV, Visible & "near IR")



REVIEW: The pattern of electromagnetic wavelengths that are **absorbed** & **emitted** by a particular atom (or combination of atoms)

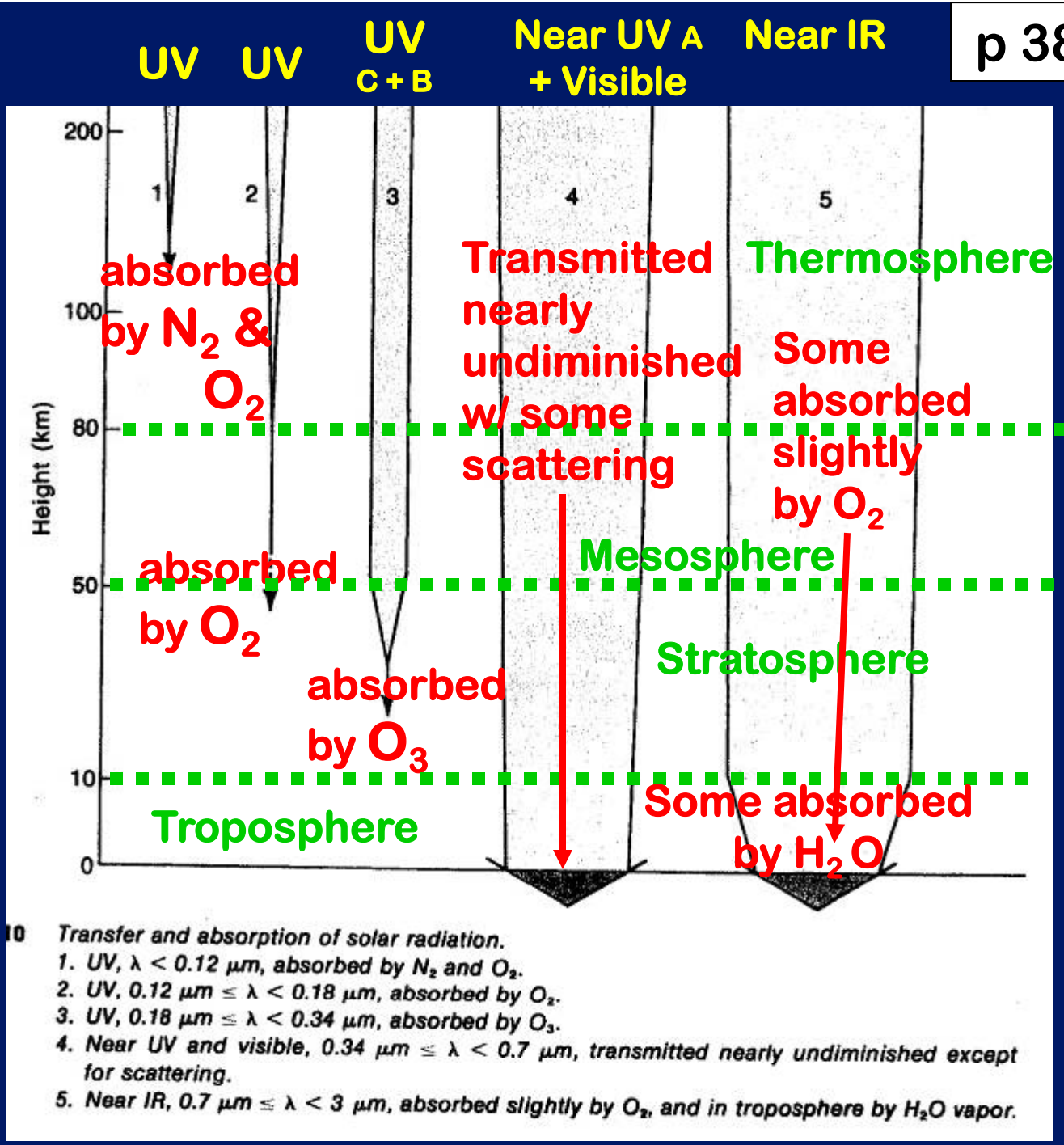
is called its ABSORPTION SPECTRUM or its ABSORPTION CURVE



The Absorption curve for Ozone / Oxygen

UV rays < .32 μm very harmful to life on Earth arrows 1, 2 + 3

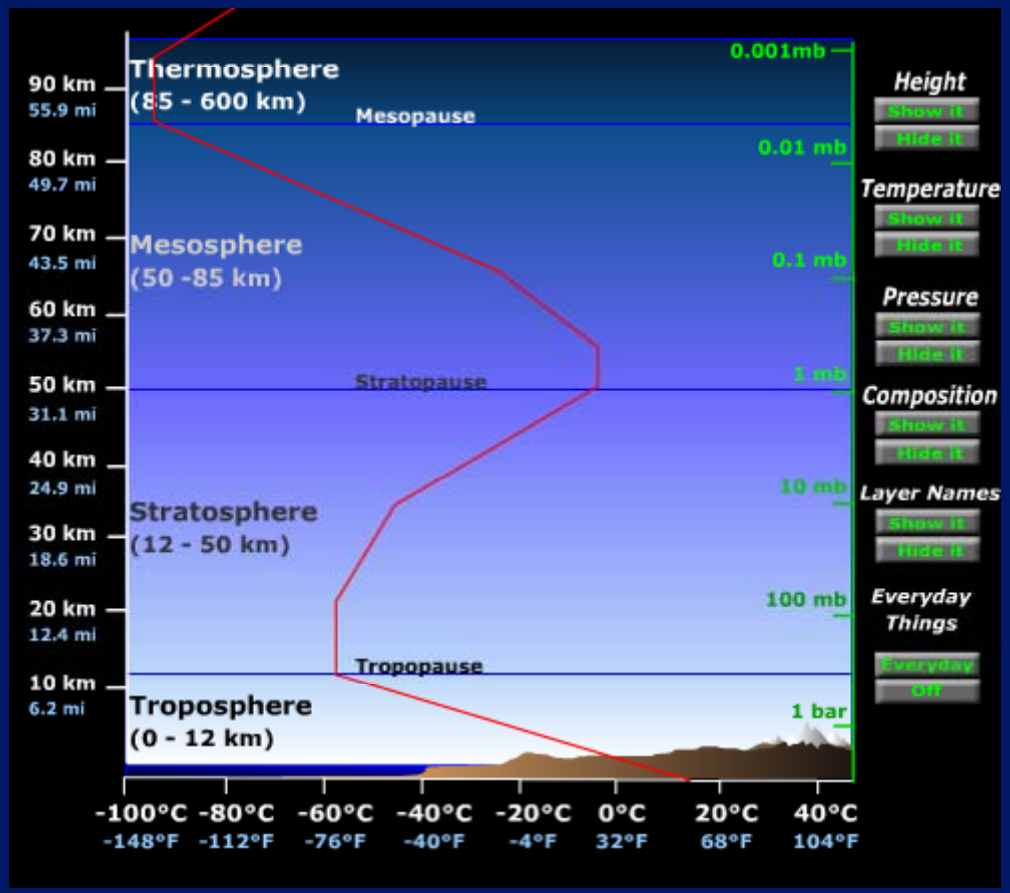
How incoming SOLAR radiation of different wavelengths gets TRANSMITTED or ABSORBED by different gases on its way to the Earth's surface



10 *Transfer and absorption of solar radiation.*
1. *UV, $\lambda < 0.12$ μm, absorbed by N_2 and O_2.*
2. *UV, $0.12\ \mu m \leq \lambda < 0.18\ \mu m$, absorbed by O_2.*
3. *UV, $0.18\ \mu m \leq \lambda < 0.34\ \mu m$, absorbed by O_3.*
4. *Near UV and visible, $0.34\ \mu m \leq \lambda < 0.7\ \mu m$, transmitted nearly undiminished except for scattering.*
5. *Near IR, $0.7\ \mu m \leq \lambda < 3\ \mu m$, absorbed slightly by O_2, and in troposphere by H_2O vapor.*

REVIEW . . .

http://earthguide.ucsd.edu/earthguide/diagrams/atmosphere/index.html



IN-CLASS "SELF CHECK" TIME !!

Q 1 - The atmospheric layer of the troposphere is important to global climate change because:

1. it is the layer closest to the sun, which is the source of the Earth's energy

2. it is the layer in which temperature INCREASES with altitude in the atmosphere and where most of the atmosphere's ozone occurs

3. it is the layer in which most of our weather, heat transfer, & greenhouse gases occur

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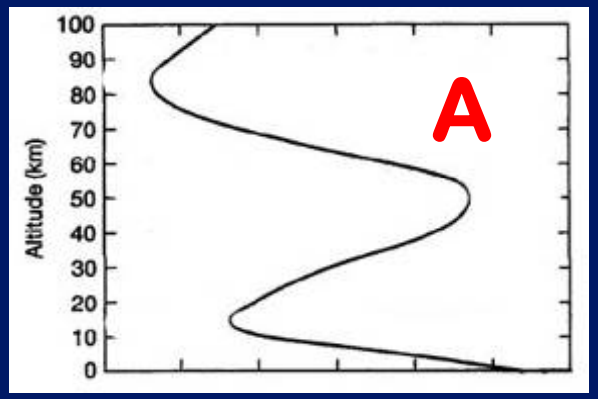
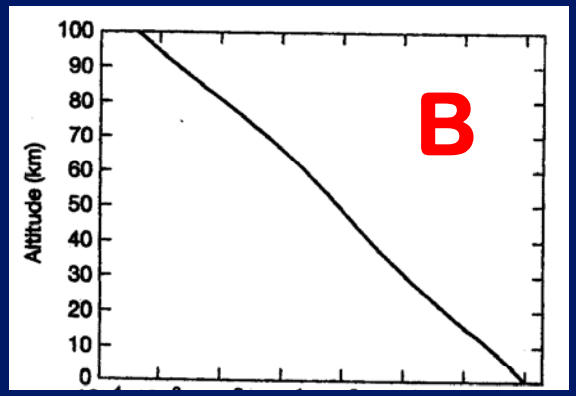
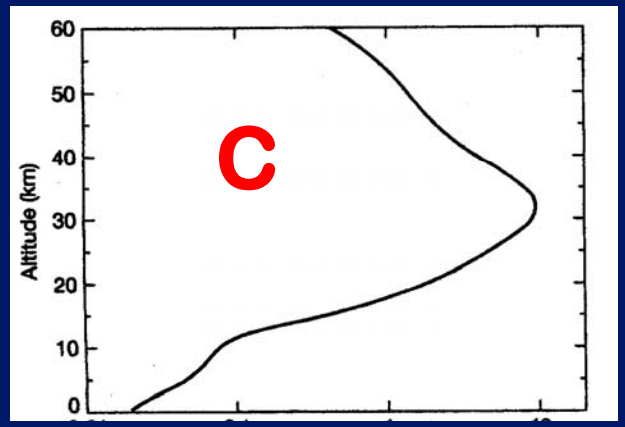
3. it is the layer in which most of our weather, heat transfer, & greenhouse gases occur

Q2 – Here are 3 graphs showing "something" varying with altitude in the atmosphere. Which is which?





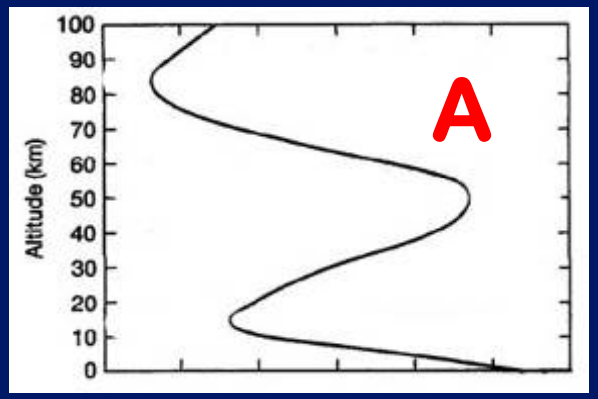


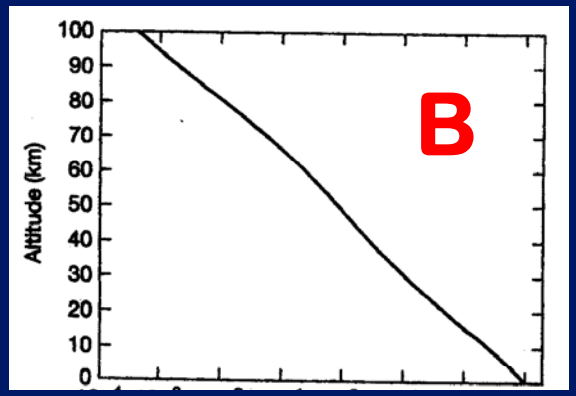
1. A = water vapor
   B = pressure
   C = temperature

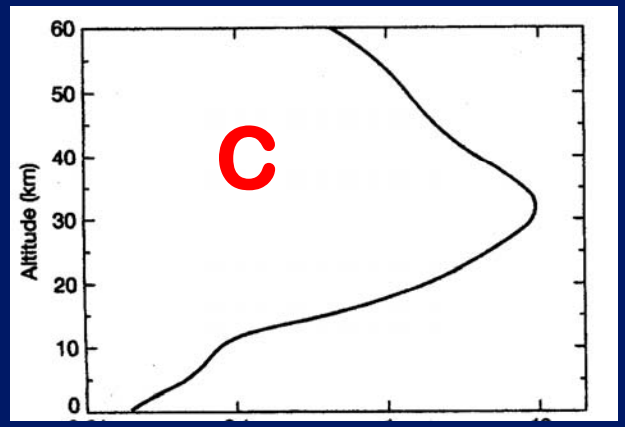
2. A = temperature
   B = pressure
   C = ozone concentration

3. A = ozone concentration
   B = temperature in the troposphere
   C =temperature in the stratosphere

Q2 – Here are 3 graphs showing "something" varying with altitude in the atmosphere. Which is which?





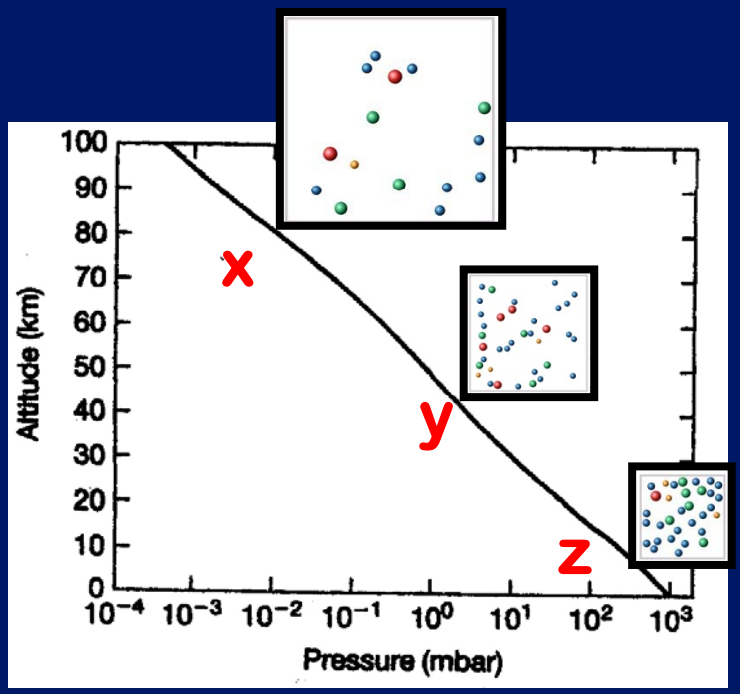


1. A = water vapor
   B = pressure
   C = temperature

2. A = temperature
   B = pressure
   C = ozone concentration

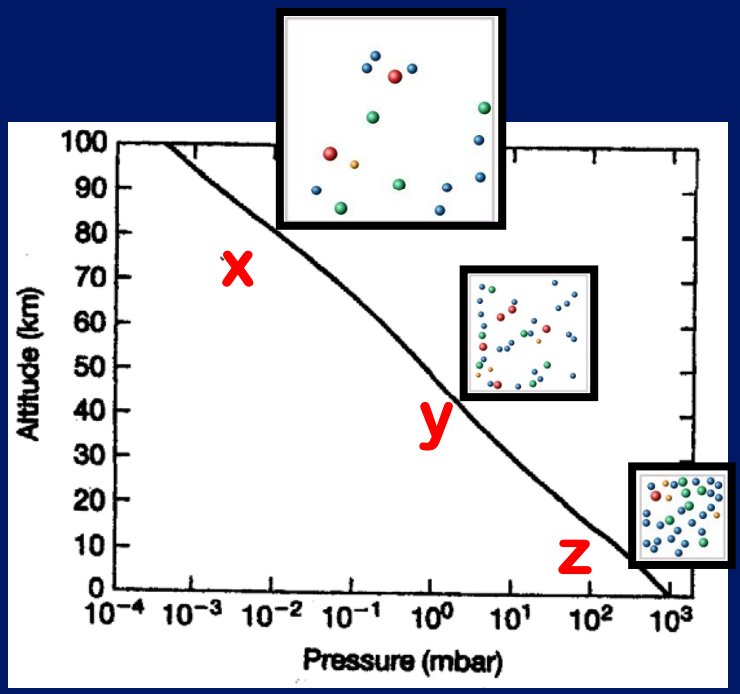
3. A = ozone concentration
   B = temperature in the troposphere
   C =temperature in the stratosphere

Q3 – Here is the graph of atmospheric pressure vs. altitude, with "parcels of air" shown to depict the density of the atmosphere's gases at 3 different altitudes. **If the air in Parcel X is forced to subside (sink) to the altitude of Parcel Z, what will happen to the air in Parcel X?**



1. it will get more dense and get cooler
2. it will get more dense and warm up
3. it will get more dense, and no change in temperature will occur

Q3 – Here is the graph of atmospheric pressure vs. altitude, with "parcels of air" shown to depict the density of the atmosphere's gases at 3 different altitudes. **If the air in Parcel X is forced to subside (sink) to the altitude of Parcel Z, what will happen to the air in Parcel X?**



1. it will get more dense and get cooler
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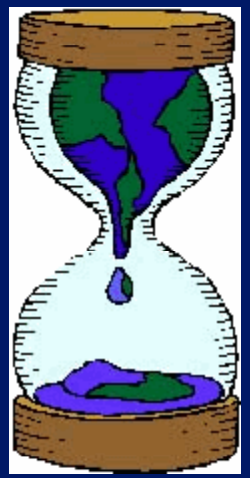
THE SUSTAINABILITY SEGMENT



Short video on:

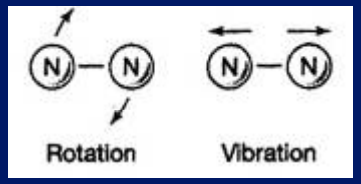
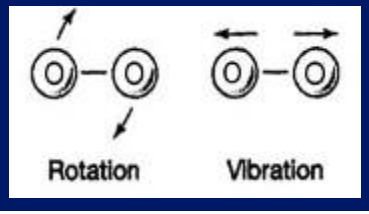
Photographic artist
Chris Jordan

ATMOSPHERIC COMPOSITION

Which gases?
What concentration?
Which ones are
Greenhouse Gases (GHG)?
Where do the GHG's come from?

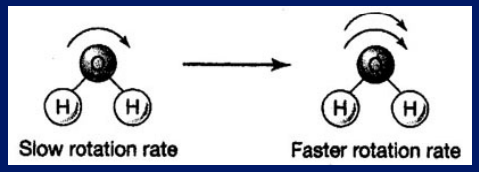
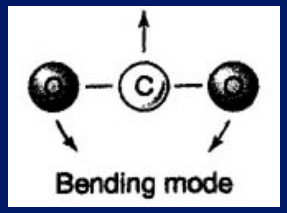
Which GHG's are changing in concentration due to HUMAN ACTIVITIES?

Most Abundant Gases in the Atmosphere

GAS	Symbol	% by volume	% in ppm
Nitrogen 	N_2	78.08	780,000
Oxygen 	O_2	20.95	209,500
Argon	Ar	0.93	9,300

Total = 99.96%

Next Most Abundant Gases:

GAS	Symbol	% by volume	% in ppm
Water Vapor 	H_2O	0.00001 (South Pole) to 4.0 (Tropics)	0.1 - 40,000
Carbon Dioxide 	CO_2	0.0390 (and rising!)	360 (in 1997) **390 !** (in May 2009)

Greenhouse Gases !

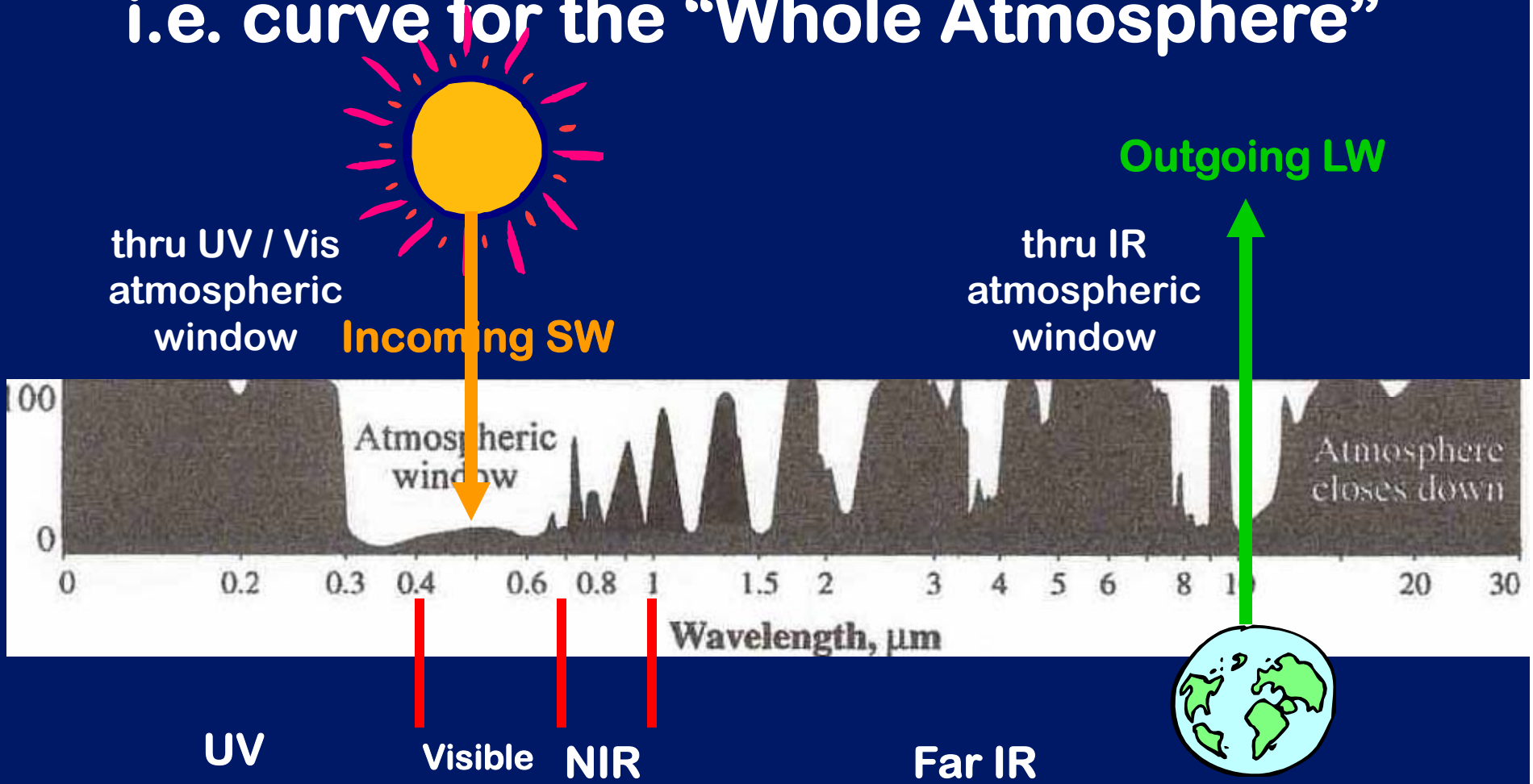
Other Important Greenhouse Gases:

GAS	Symbol	% by volume	% in ppm
Methane	CH_4	0.00017	1.7
Nitrous Oxide	N_2O	0.00003	0.3
Ozone	O_3	0.0000004	0.01
CFCs (Freon-11)	CCl_3F	0.000000026	0.00026
CFCs (Freon-12)	CCl_2F_2	0.000000047	0.00047

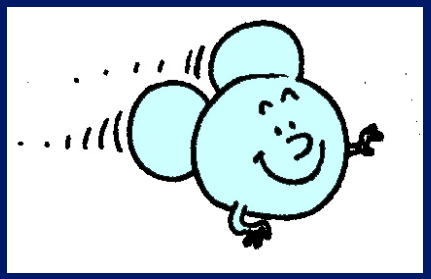
Greenhouse Gases!

Absorption by ALL the gases in the atmosphere put together –

i.e. curve for the "Whole Atmosphere"



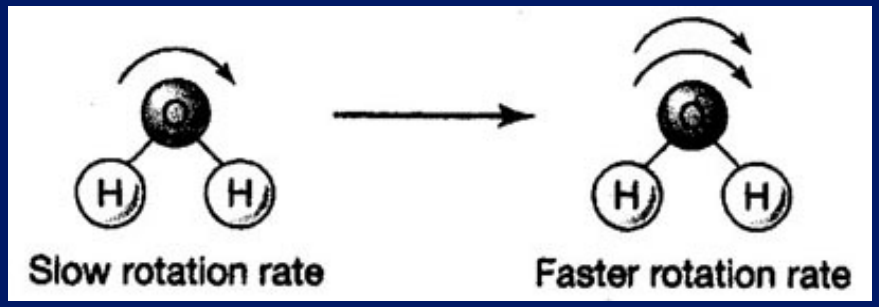
Review bottom of p 384



WATER VAPOR

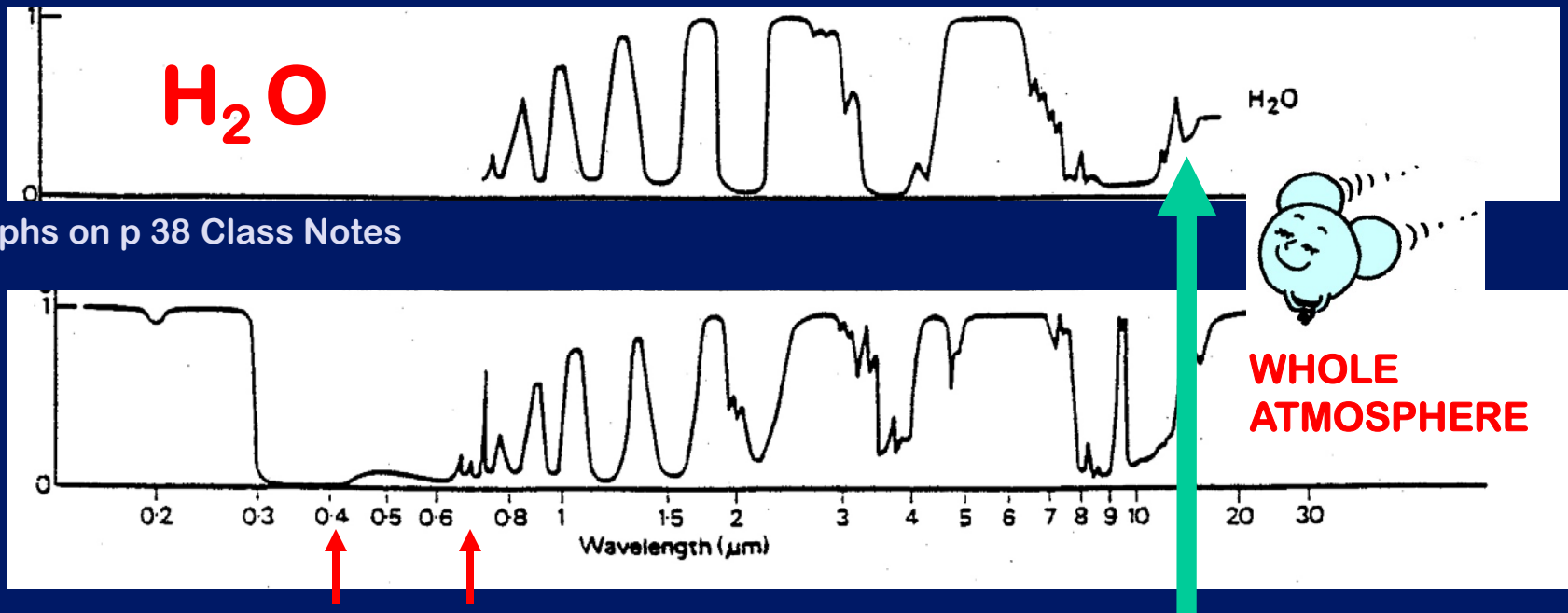
* Arrives in atmosphere naturally through evaporation & transpiration

* Due to unique quantum rotation frequency, H_2O molecules are excellent absorbers of IR wavelengths of **12 µm and longer**;



Just listen!
This info is in
Table on p 39

Virtually 100% of IR longer than 12 µm is absorbed by H_2O vapor and CO_2



Graphs on p 38 Class Notes

WHOLE ATMOSPHERE

IR at 12 µm absorbed

(12 µm close to the radiation wavelength of 10 µm, at which most of Earth's terrestrial radiation is emitted.)

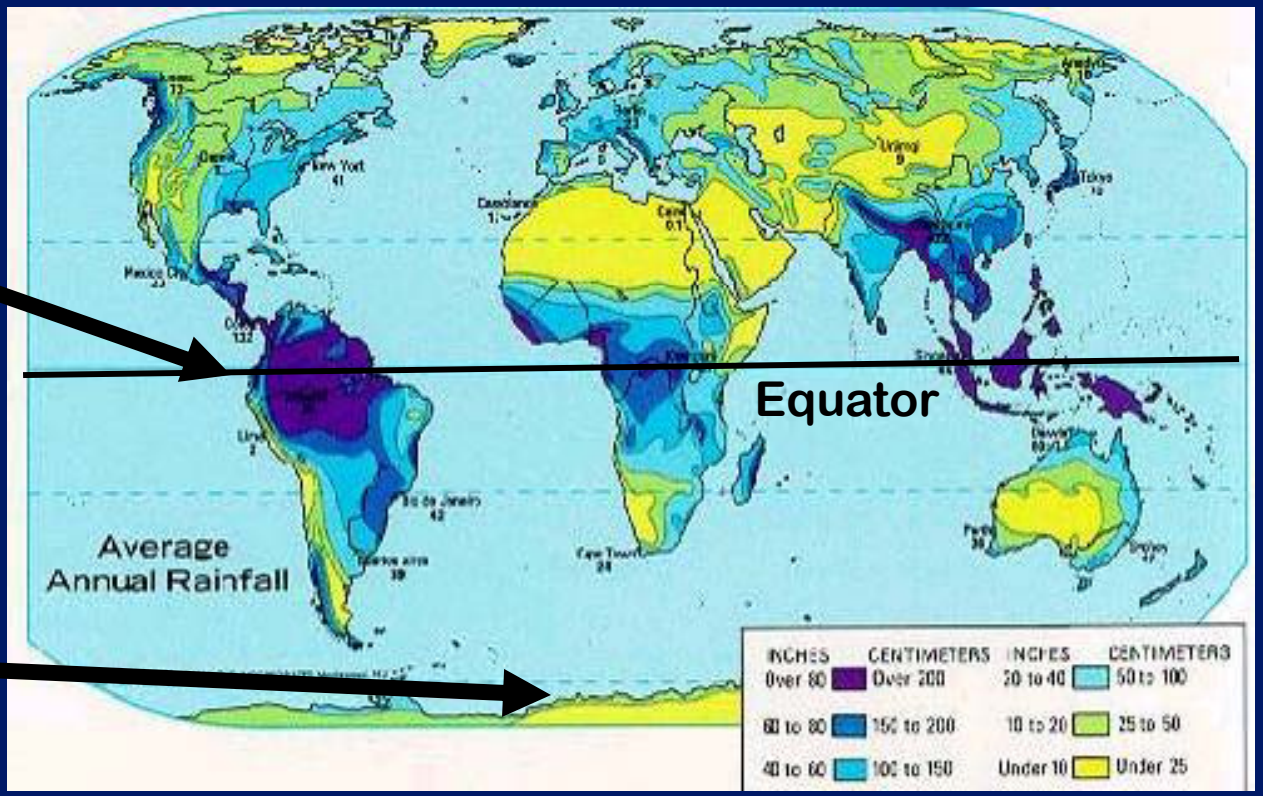
Just listen!

WATER VAPOR (cont):

* H_2O has variable concentration and residence time in the atmosphere depending on location and atmospheric circulation

Blue = wettest climates, lots of humidity & water vapor

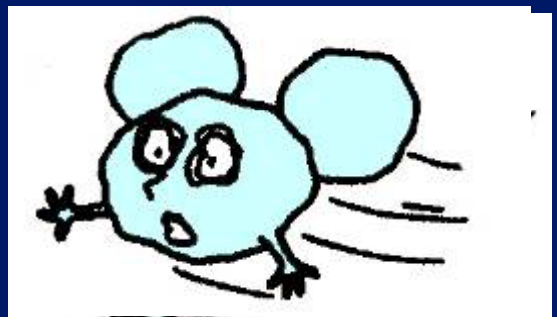
Yellow = driest climates, less atmospheric water vapor

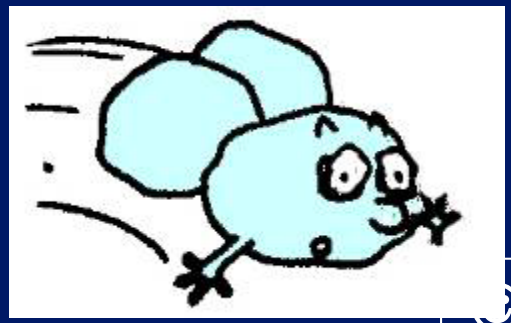


Just listen!

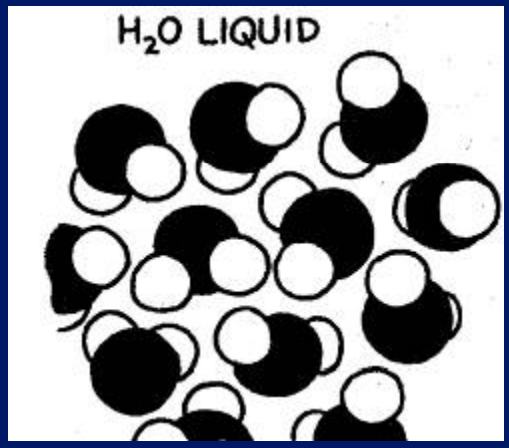
At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.

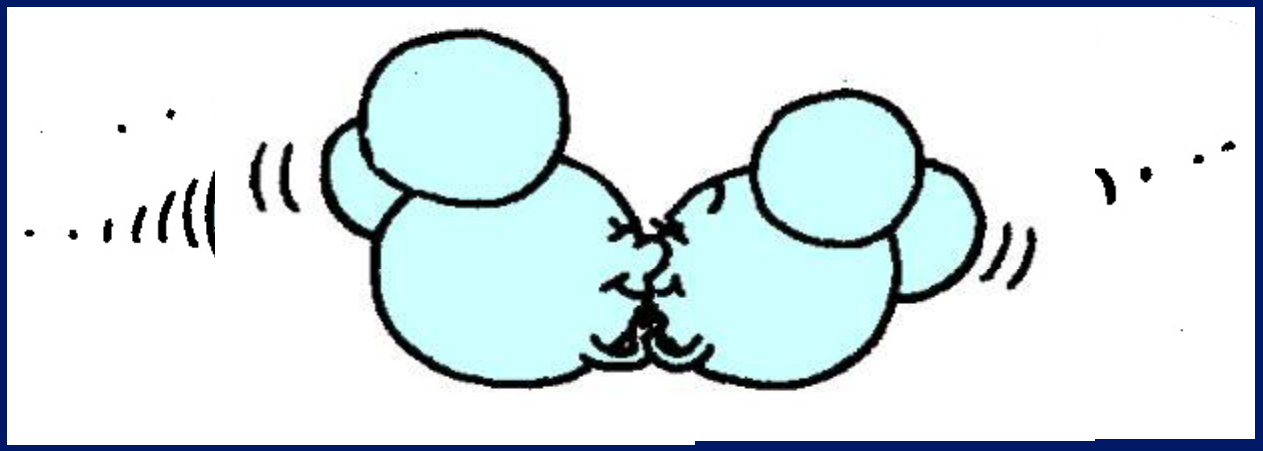
Hence hot climates can hold more water vapor in the air





At lower air temperatures as air gets more dense, H_2O molecules are more likely to bond so that a phase change to liquid water or even solid ice can occur.





Hence in cooler climates, more of the available H_2O is likely to be in the liquid or solid state on the Earth's surface

WATER VAPOR (cont):

* H_2O is NOT globally increasing in direct response to human-induced factors, but if global temperatures get warmer, H_2O vapor in the atmosphere *will increase . . . .*

Why???

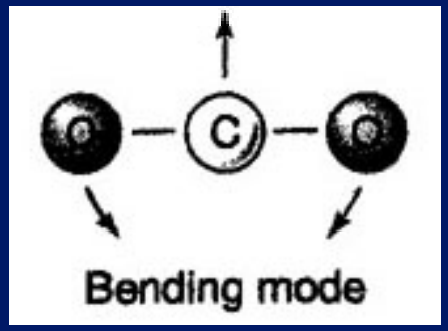
. . . due to more evaporation in the warmer climate!

THINK ABOUT THIS!

CARBON DIOXIDE:

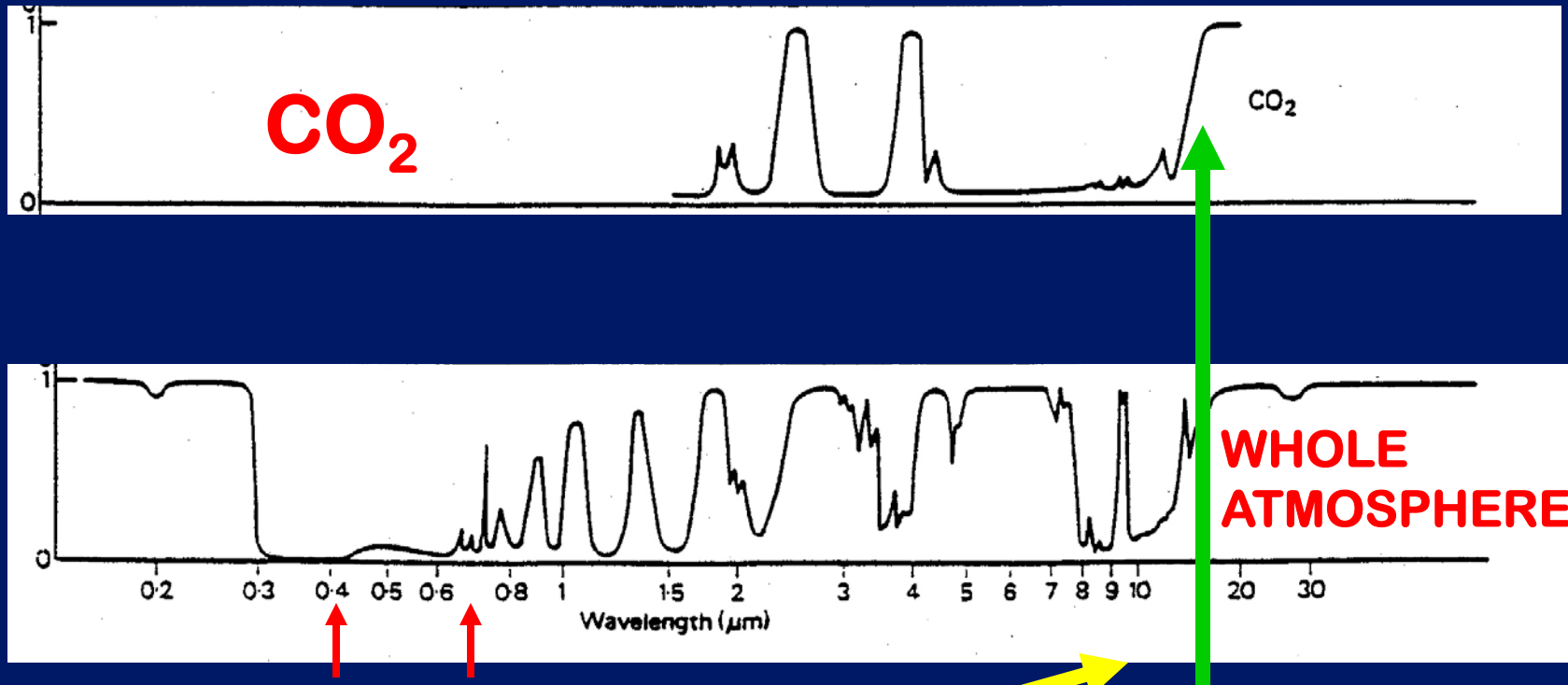
* Arrives in atmosphere naturally through the natural carbon cycle

* Due to unique quantum bending mode vibration behavior, CO_2 molecules are excellent absorbers of electromagnetic radiation of about 15 µm



Just listen!
This info is in
Table on p 39

CO_2 is excellent absorber of radiation of about 15 µm



(15 µm close to the radiation wavelength of 10 µm, at which most of Earth's terrestrial radiation is emitted.)

IR at 15 µm absorbed

See figure on p 34

CARBON DIOXIDE (cont.):

* **Has increased dramatically since the 1800s due to:**

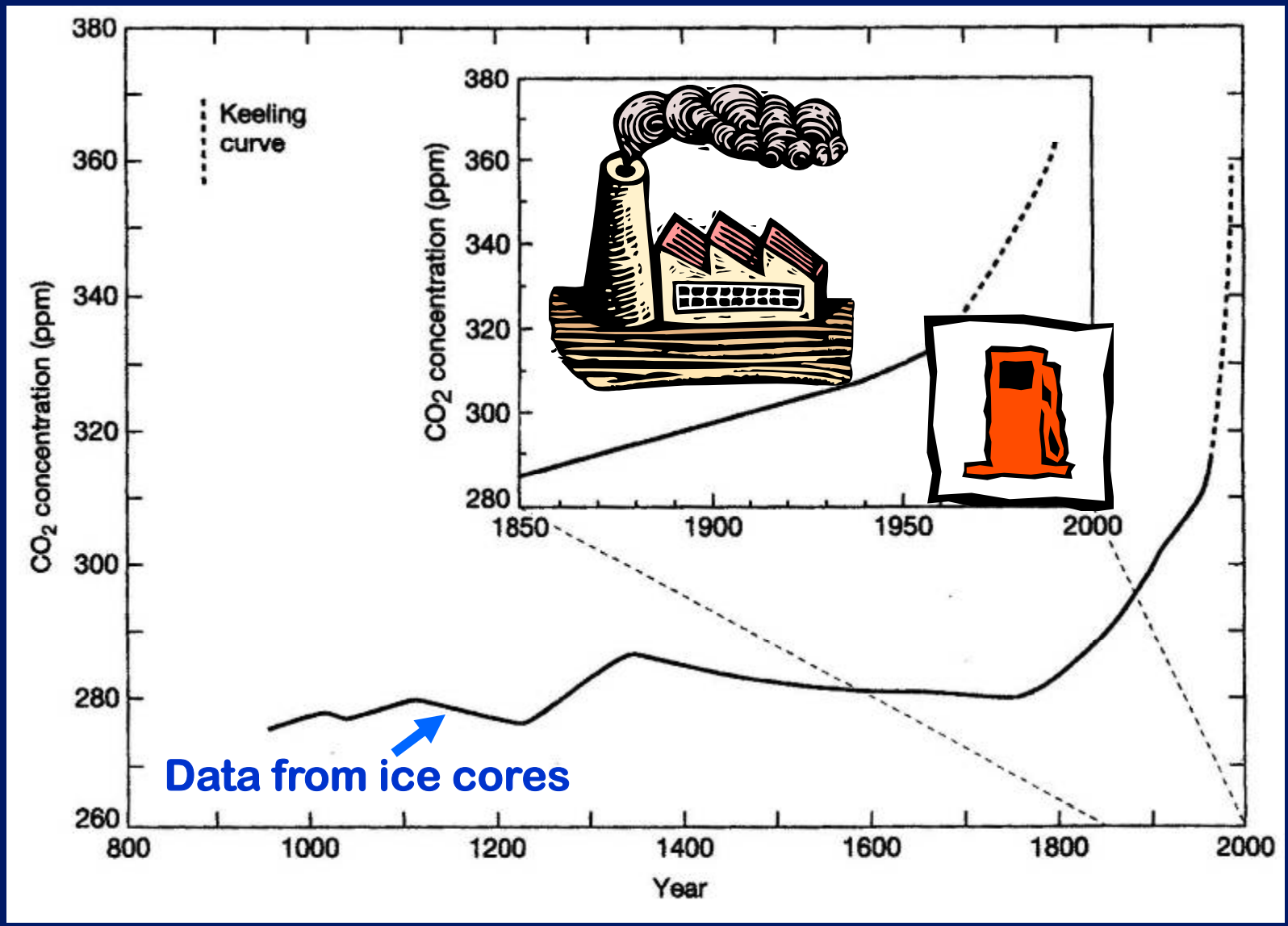
(1) **fossil fuel combustion**: oil, coal, gas -- especially coal, and

(2) **deforestation** -- which has the effect of increasing the amount of carbon in the atmospheric "reservoir" by reducing the photosynthesis outflow and increasing the respiration inflow.

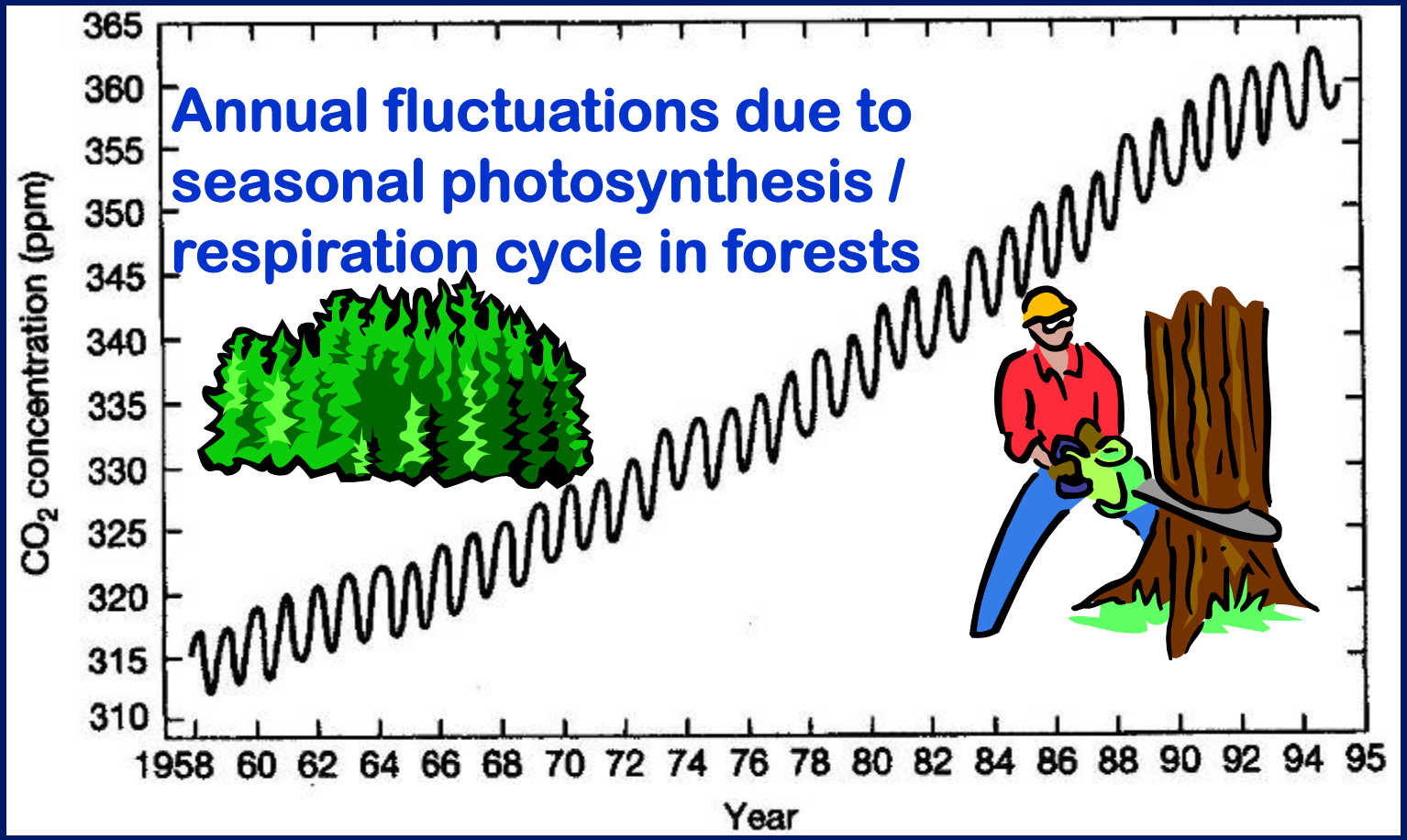
(Deforestation also accelerates forest decomposition, burning, etc. adding to the overall respiration inflow.)

This info is in Table on p 39

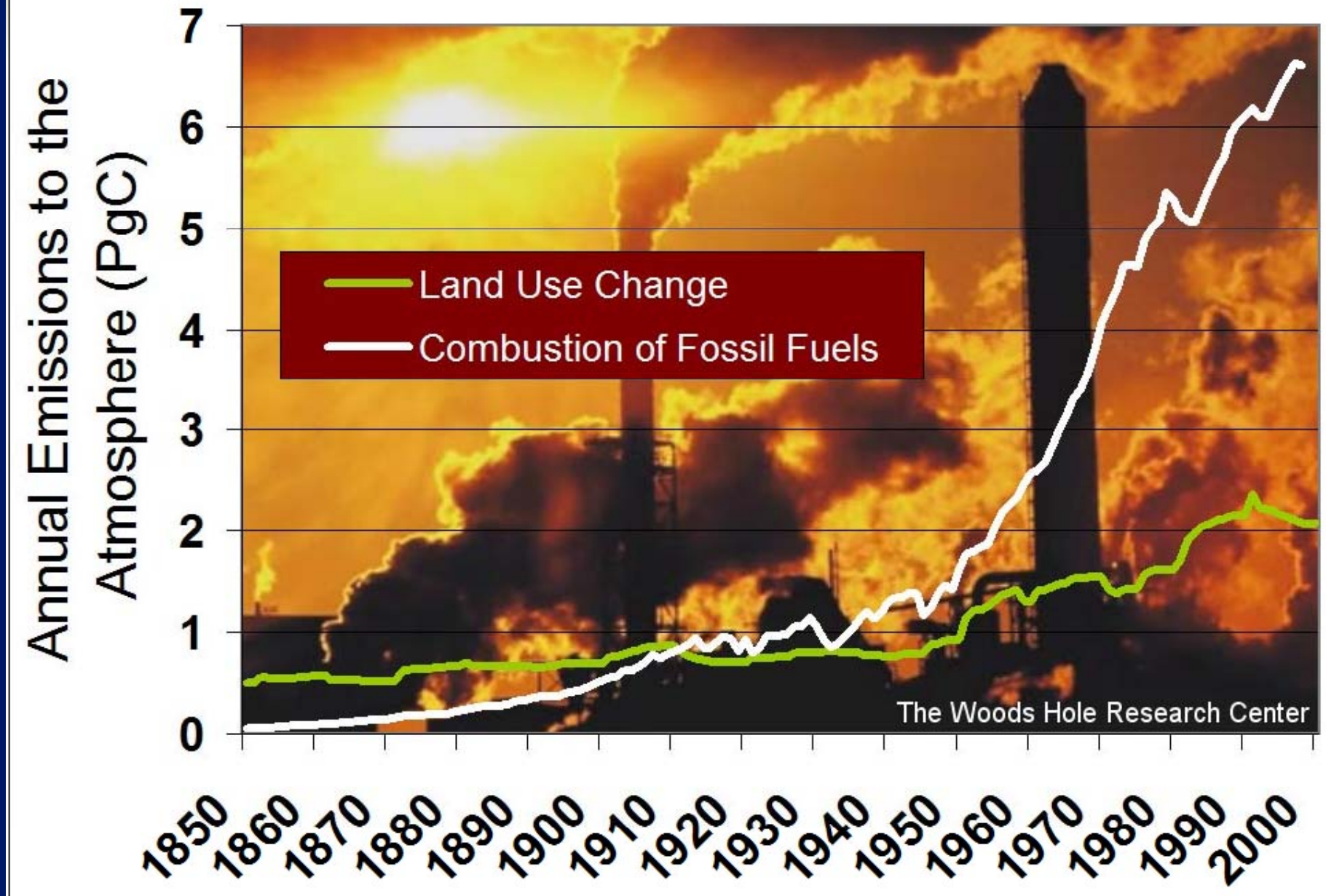
CARBON DIOXIDE: Trends



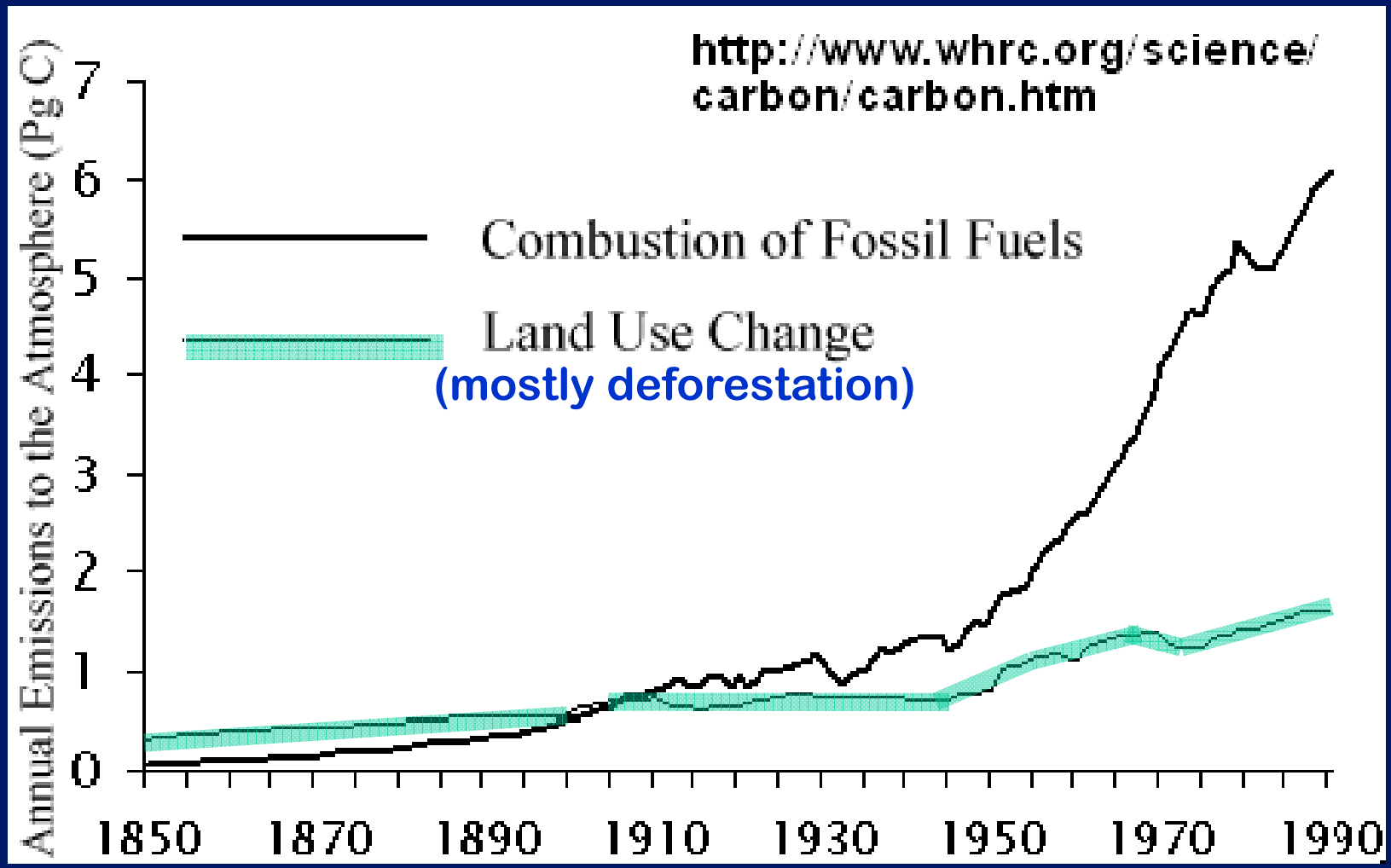
CARBON DIOXIDE --- Trends:



The Keeling Curve


Annual Emissions to the Atmosphere (PgC)
7
6
5
4
3
2
1
0
Land Use Change
Combustion of Fossil Fuels
The Woods Hole Research Center
1850
1860
1870
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000

CARBON emissions into the atmosphere are increasing:



CARBON DIOXIDE (cont.):

* **RESIDENCE TIME** in the atmosphere of CARBON ATOMS in the carbon cycle = ~ 12.7 years;

but residence time of CO_2 GAS MOLECULES is estimated at about 100 years

Plus it takes 50 to 100 years for atmospheric CO_2 to adjust to changes in sources or sinks.

If we make changes now, it will still be many, many years before the effect will be felt!

This info is in Table on p 39

METHANE (CH_4): Sources

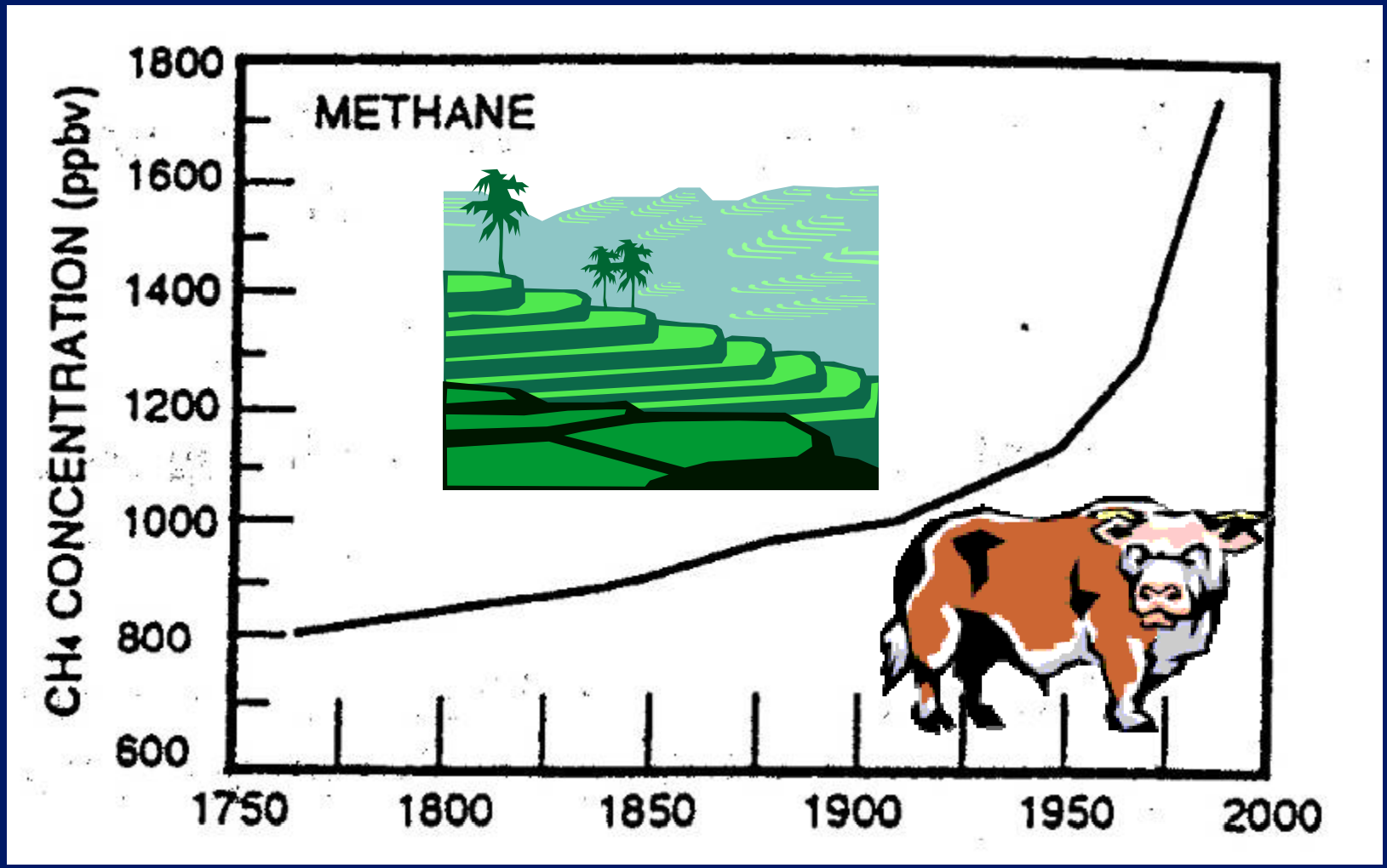
* Produced naturally in anaerobic processes (e.g., decomposition of plant material in swamps & bogs)

* **Has increased** due to the following activities: **raising cattle / livestock, rice production, landfill decomposition, pipeline leaks**

* **Has relatively short atmospheric residence time** because it reacts with OH (~10 years)

This info is in Table on p 39

METHANE: Trends



NITROUS OXIDE (N_2O): Sources

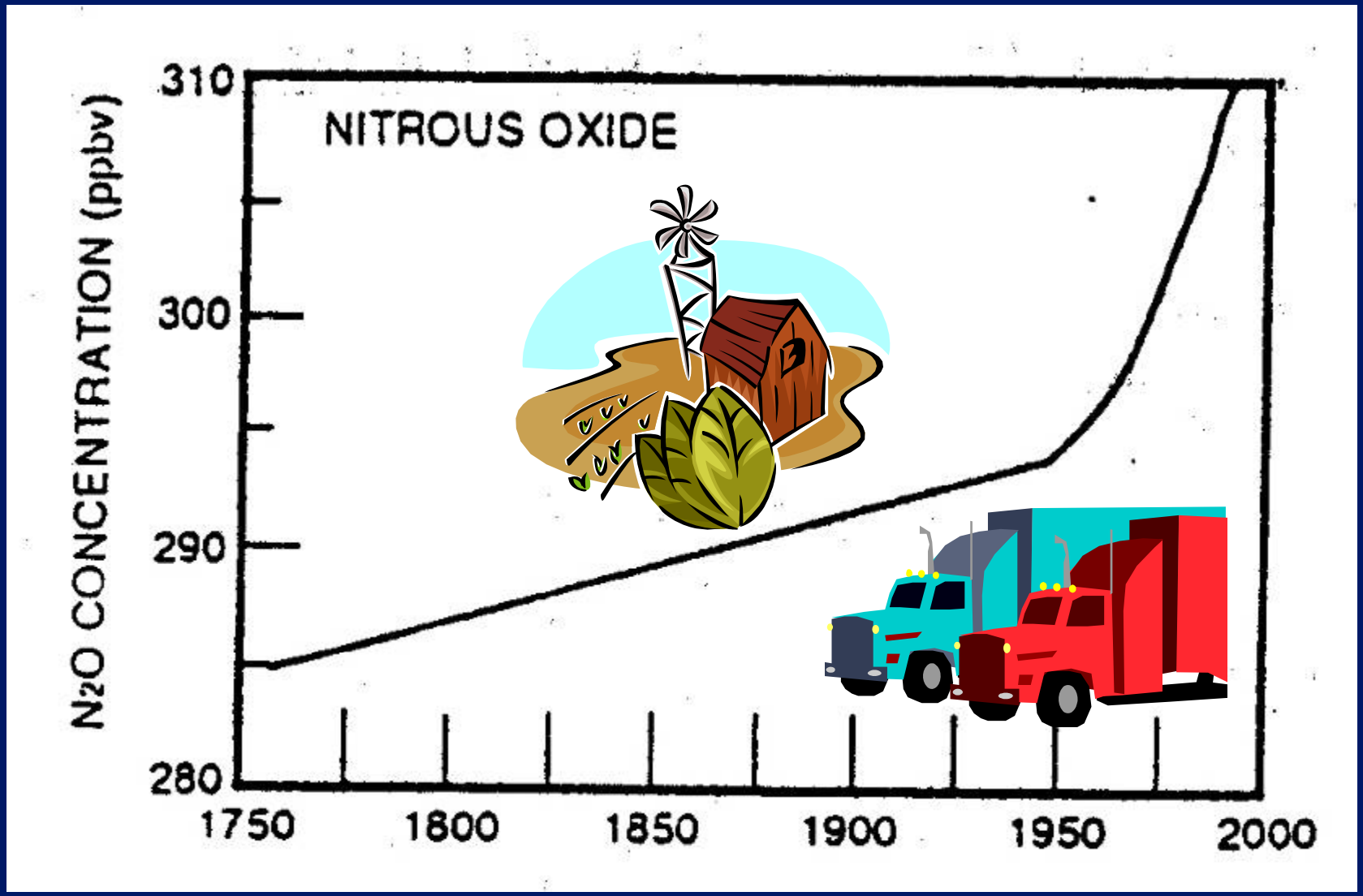
* Produced naturally in soils

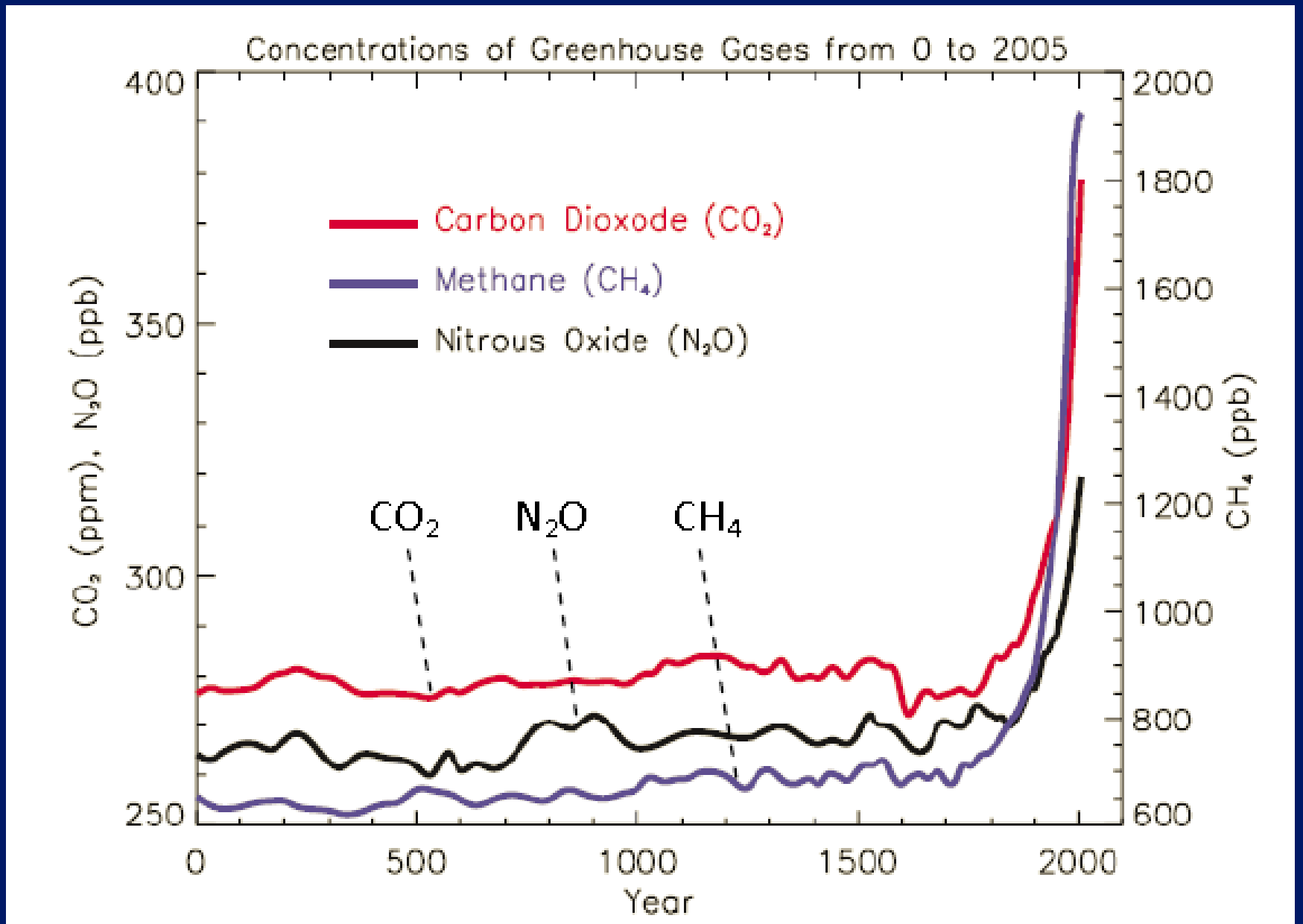
* Has increased due to fossil fuel combustion (esp. diesel), forest burning, use of nitrogen fertilizers

* Has long atmospheric residence time (~ 150 years)

This info is in Table on p 39

NITROUS OXIDE: Trends




Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO_2)
Methane (CH_4)
Nitrous Oxide (N_2O)
CO_2
N_2O
CH_4
CO_2 (ppm), N_2O (ppb)
CH_4 (ppb)
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000
Year

TO BE CONTINUED . . . .