Topic # 7
ATMOSPHERIC STRUCTURE
&
CHEMICAL COMPOSITION

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

Class Notes pp 37- 41

OBJECTIVES:

To understand:

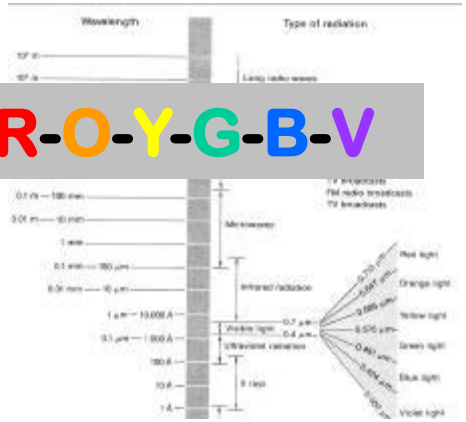
-- the VERTICALSTRUCTURE of the atmosphere & its relationship to temperature

-- which GASES are in the atmosphere

-- where they are concentrated, and

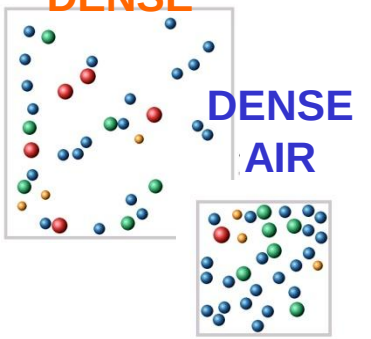
-- why gases at different levels are linked to the Greenhouse Effect & Ozone Depletion

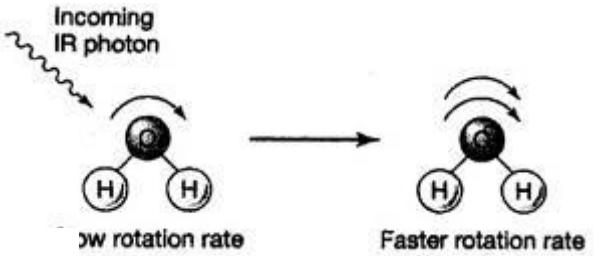
Things you've seen before that will all come together under this topic:

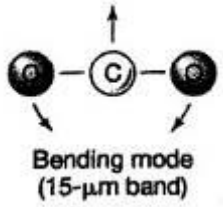


R-O-Y-G-B-V

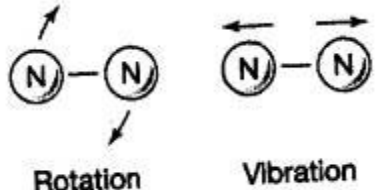
$$E = \sigma T^4$$

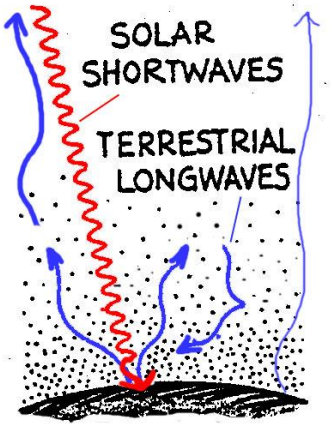


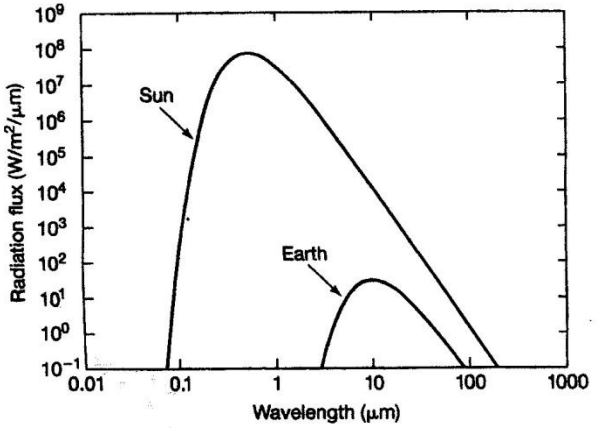


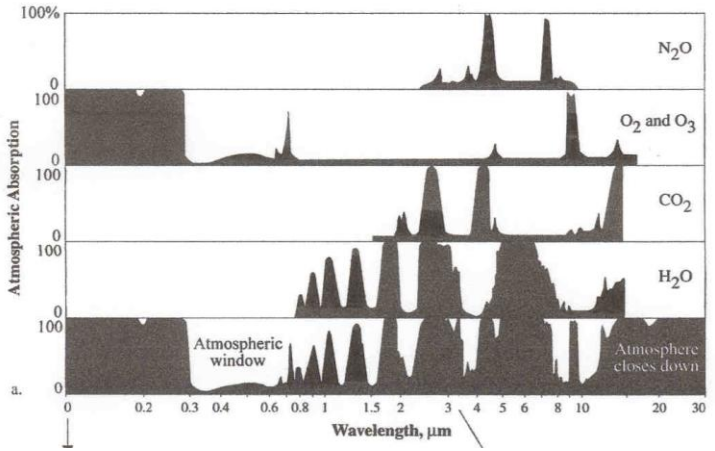


$$E = h\,c\,/\,\lambda$$









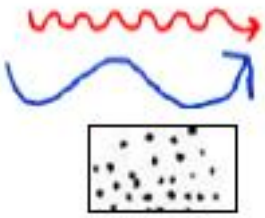
$$\lambda_m = a\,/\,T$$

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

~ Adlai Stevenson

SOLAR vs TERRESTRIAL RADIATION CLASS CONCEPTS SELF TEST

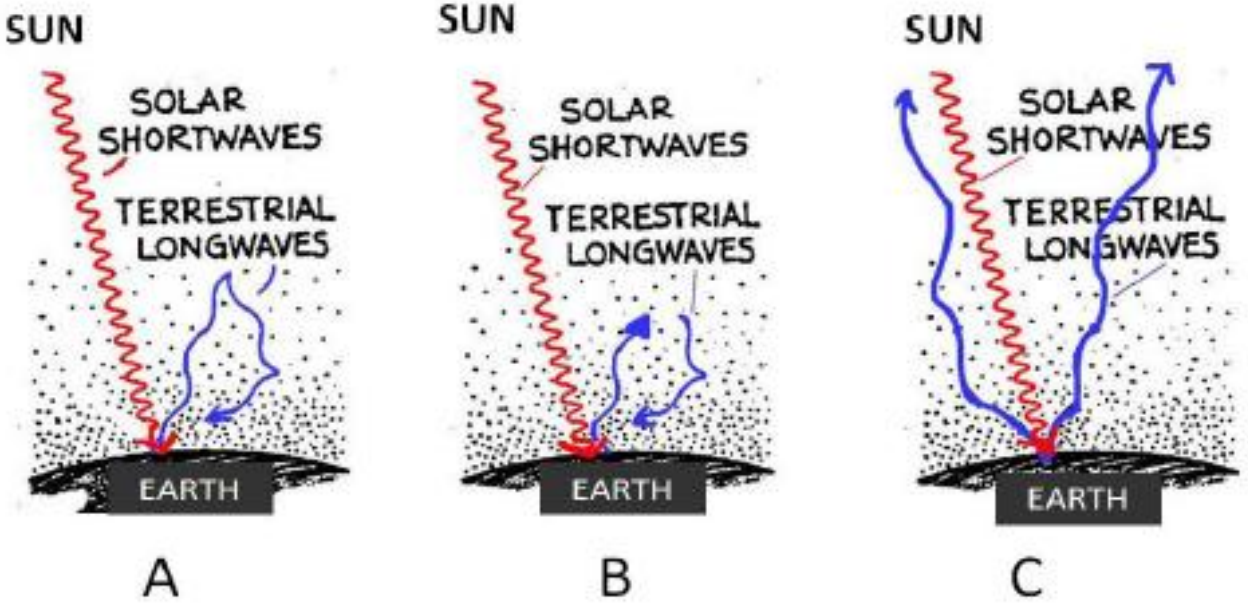
KEY:



= represents Solar shortwave (SW) radiation

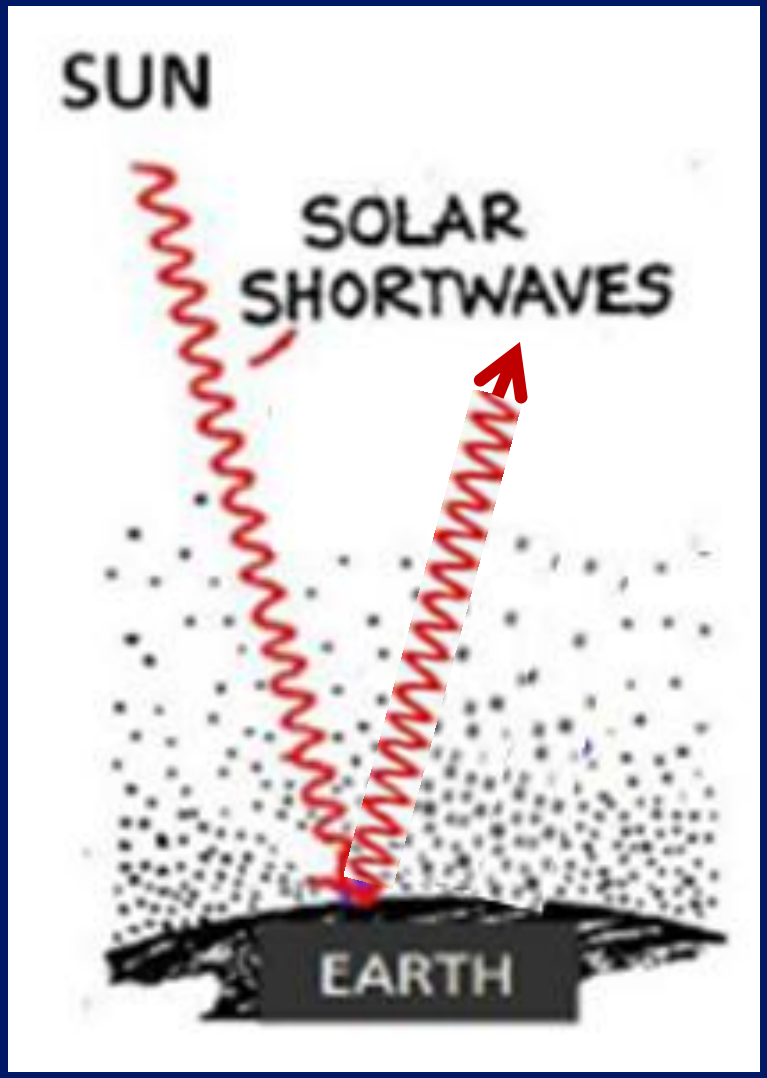
= represents Terrestrial longwave (LW) (infrared IR radiation)

= represents the atmosphere and its gases (which can absorb and emit certain kinds of radiation)

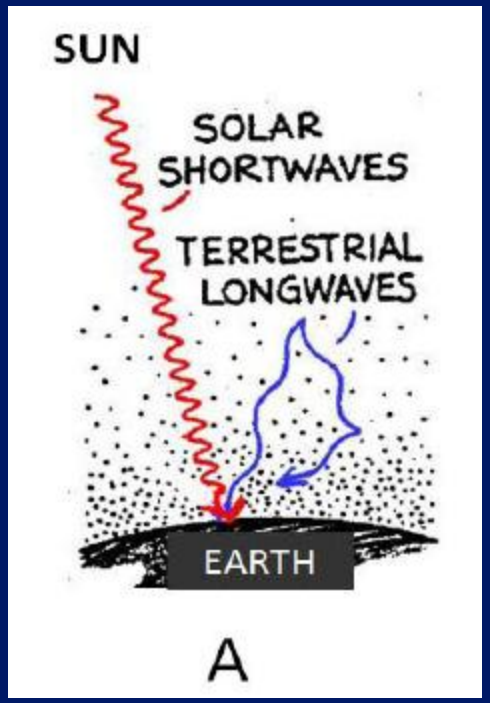


Q1. Which diagram above shows SW (solar radiation being reflected back to space?

A **B** **C** **None of them**



Here's the correct diagram to show **SW Solar** being **reflected** back to space!



Q2. Diagram A shows LW (IR) terrestrial radiation "bouncing off" (or reflecting) the gases in the atmosphere and being sent back to Earth's surface.

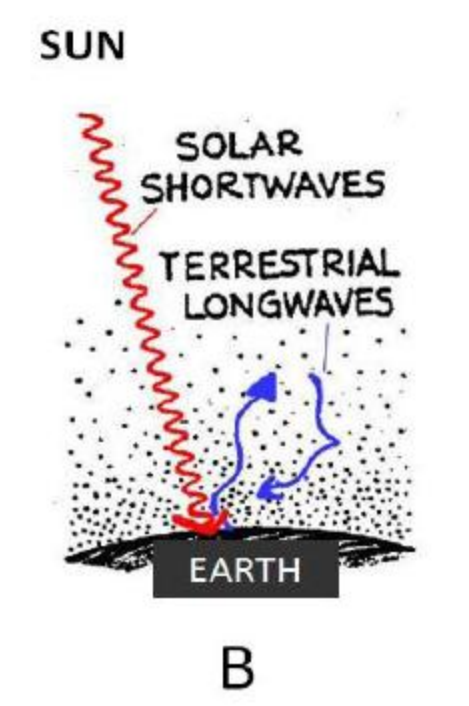
(i.e. being reflected back to the surface by the gases without being absorbed by them.)

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

Yes **No** Partly

DON'T USE "BOUNCING or "REFLECTING" to describe the Greenhouse Effect process

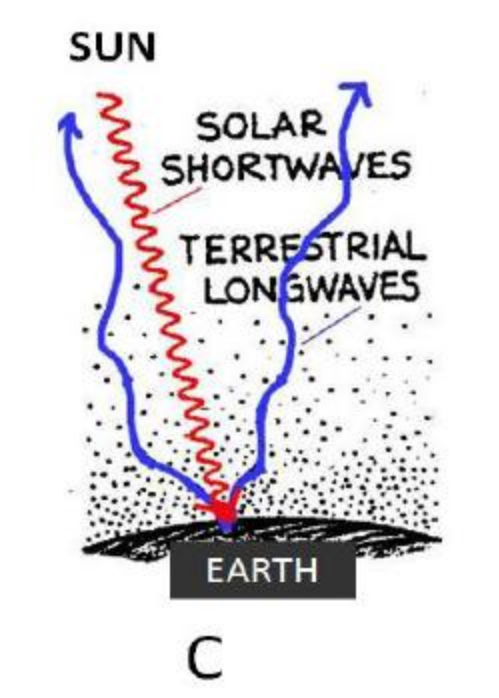
GH gases ABSORB & RE-RADIATE!



Q3. Diagram B shows LW (IR) terrestrial radiation being absorbed and then emitted back down by the gases in the atmosphere.

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

Yes No Partly

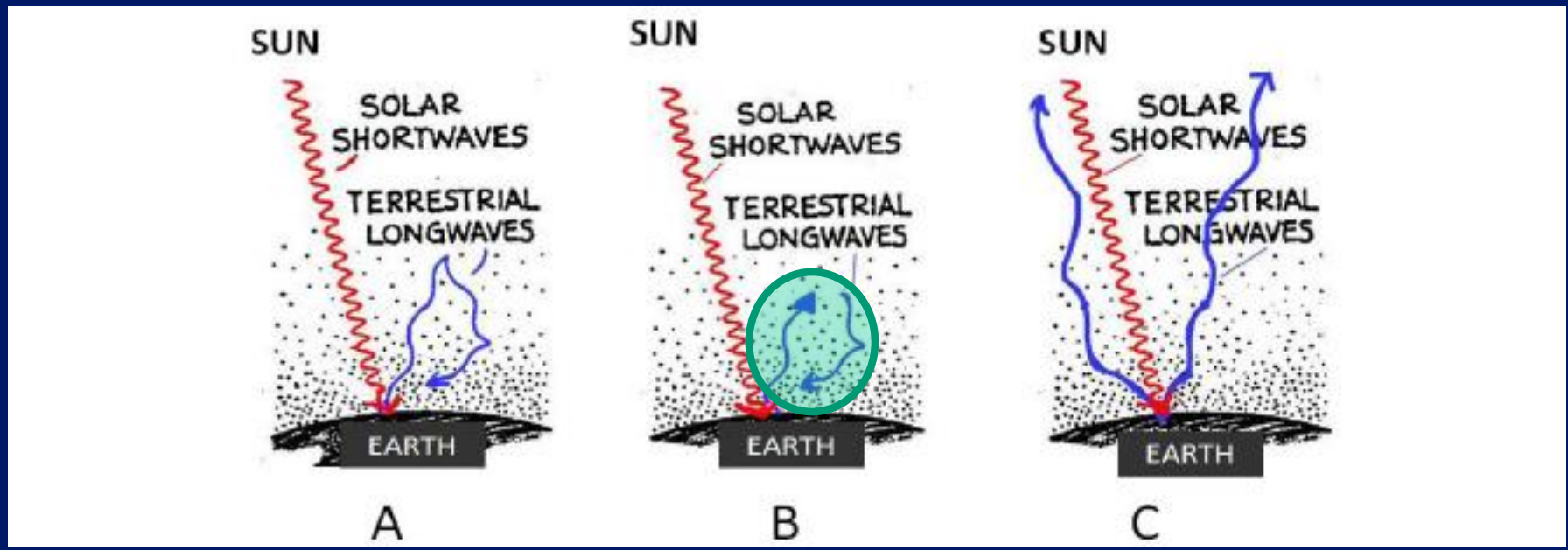


Q4. Diagram C shows LW (IR) terrestrial radiation going right through the atmosphere out to space.

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

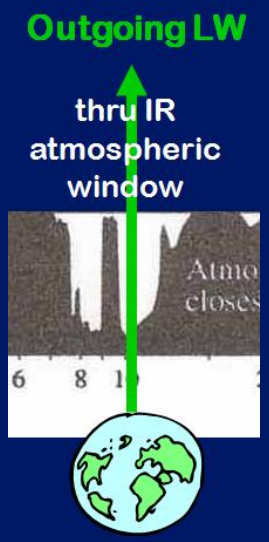
Yes **No** Partly

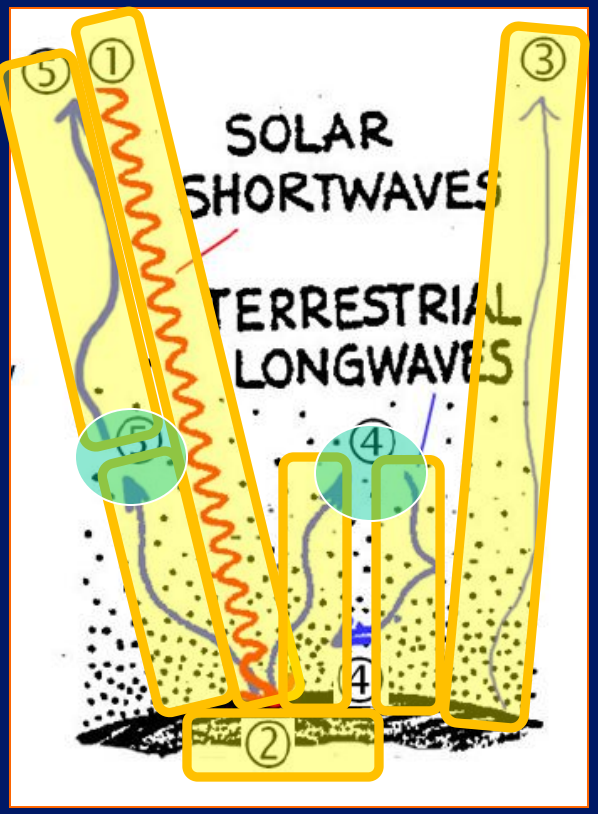
Q5. On the diagram that you think best depicts the processes involved in the GREENHOUSE EFFECT, CIRCLE the specific part of the diagram that represents the Greenhouse Effect:



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

③ Some IR radiation is emitted from the Earth's surface right <u>out</u> to space through "IR window"





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

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

Absorption & re-emission by GH gases

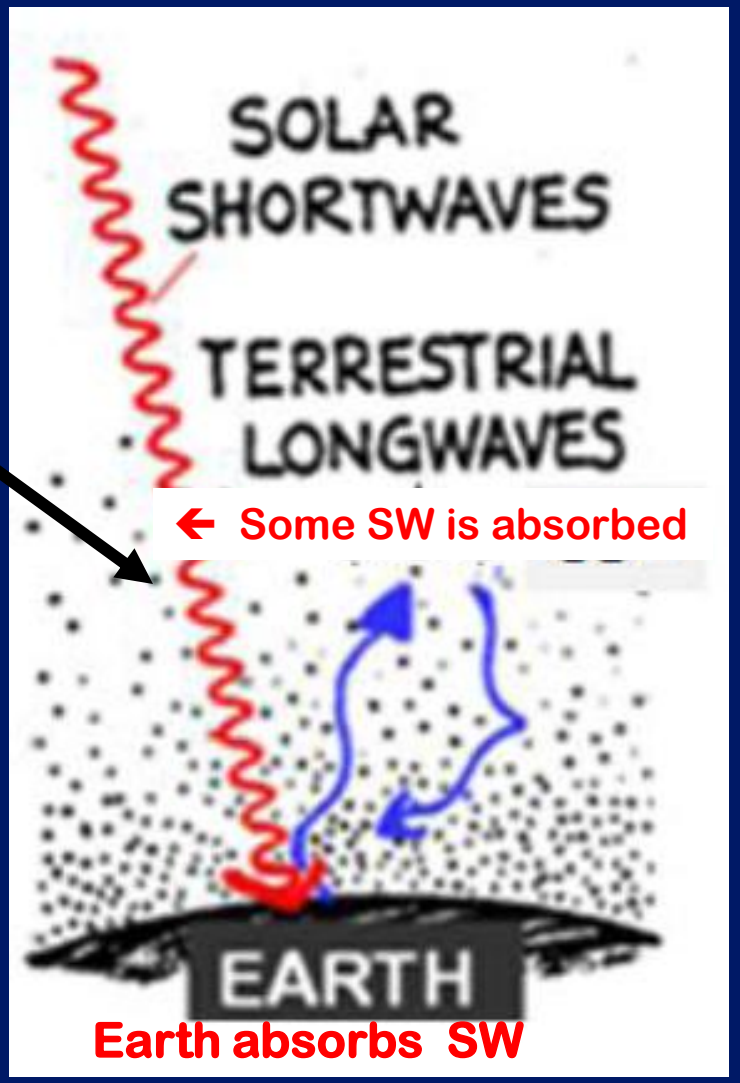
Absorption & re-emission by GH gases

② The Earth absorbs SW that reaches the surface

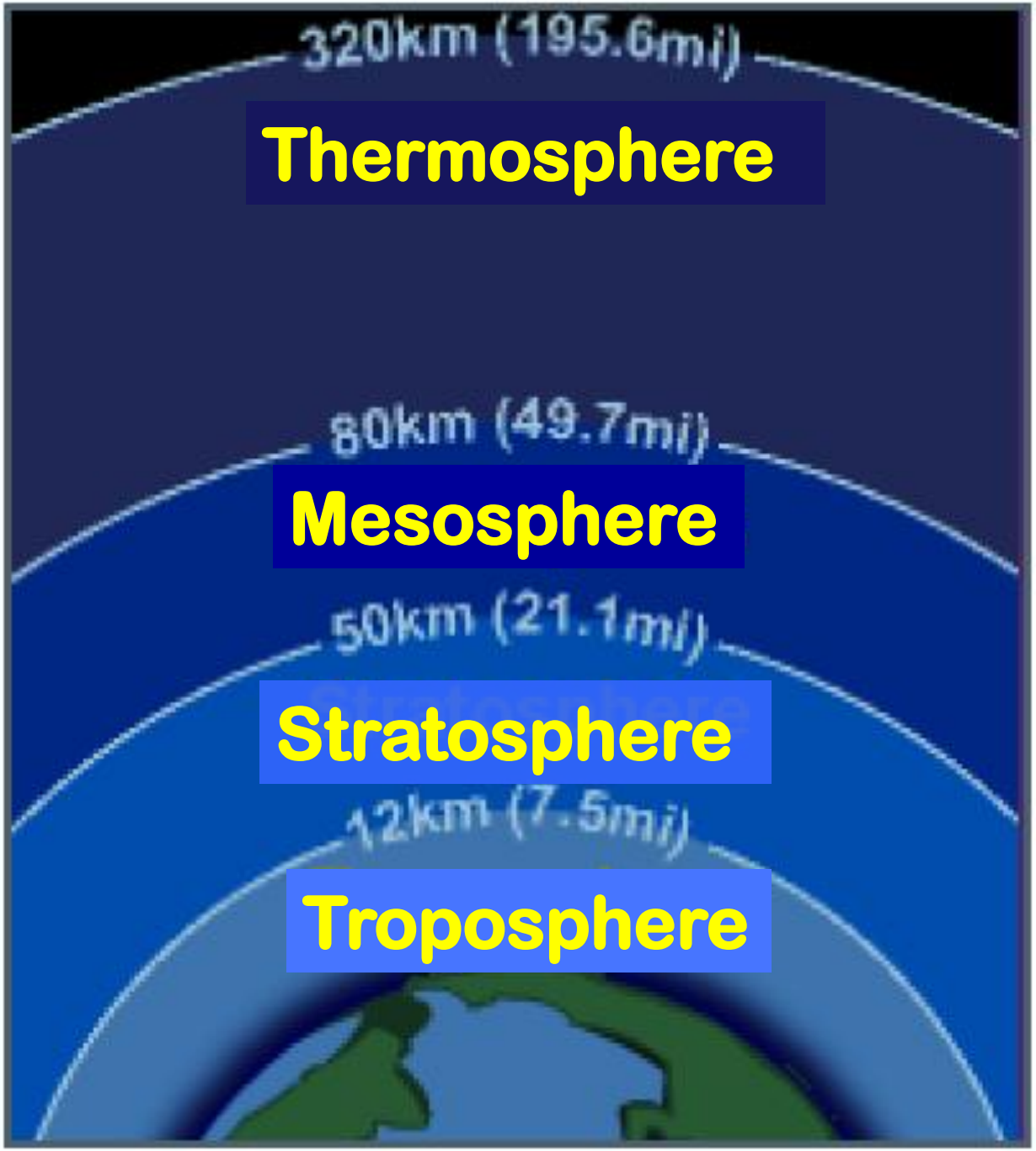
There's one more thing to correct in our the depiction of incoming Solar . . . .

<u>Some</u> SW radiation gets absorbed on its way down to the surface!

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



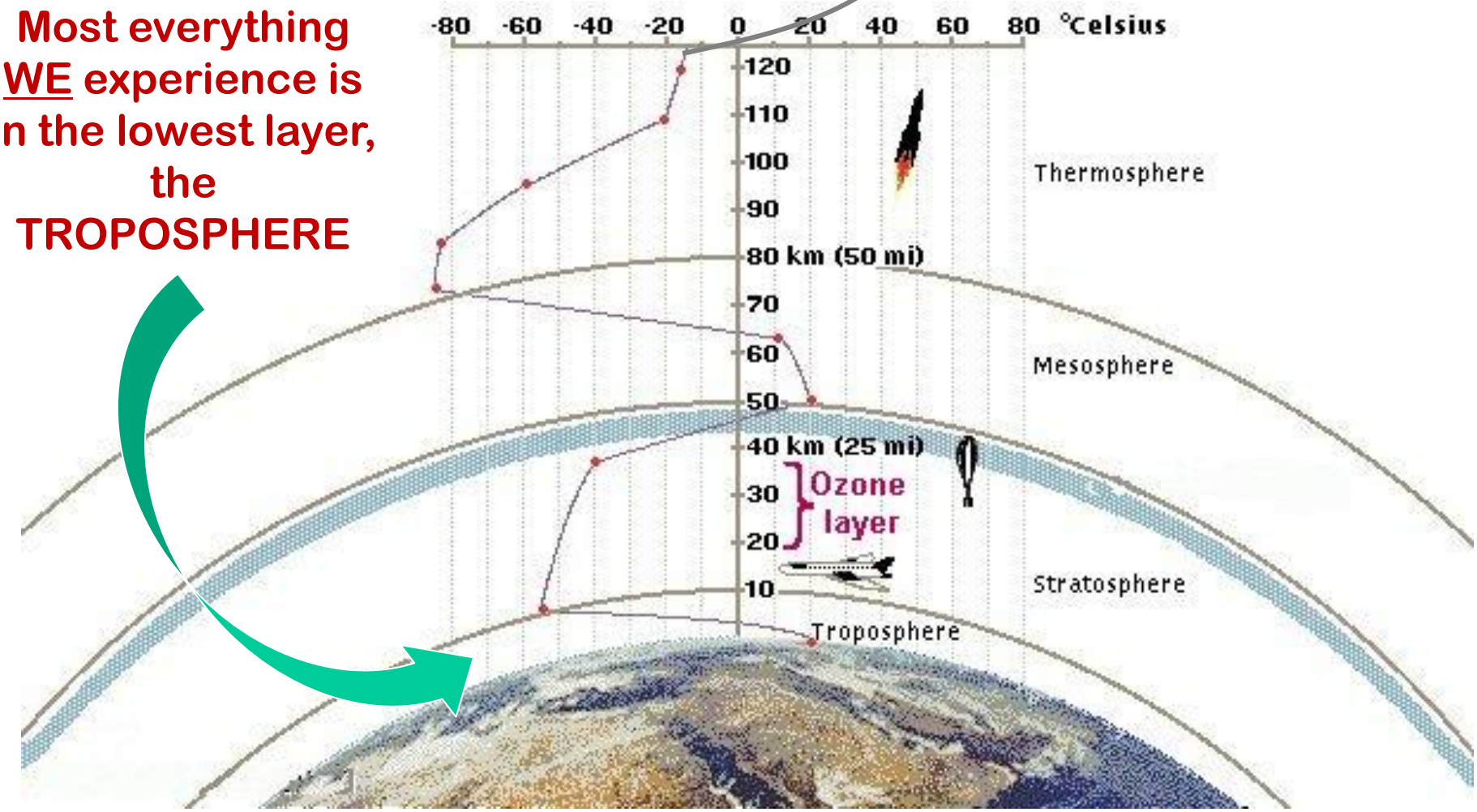
The atmosphere has a "structure" of different named layers :



These layers have different thicknesses and temperatures. . .

Most everything WE experience is in the lowest layer, the TROPOSPHERE

This zig-zag line is showing changes in temperature with altitude



The Vertical Structure of the Atmosphere

KEY CONCEPT:

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

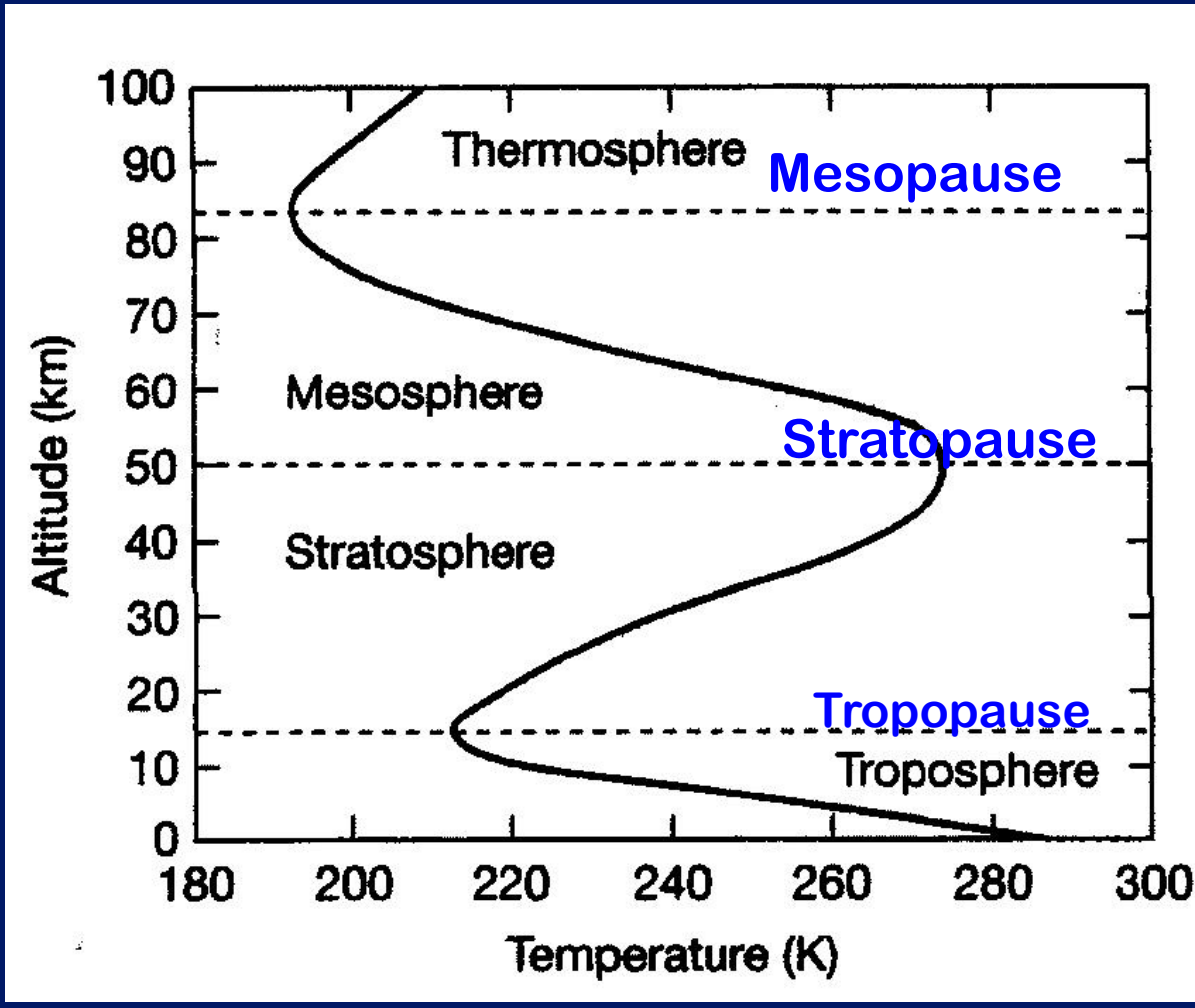
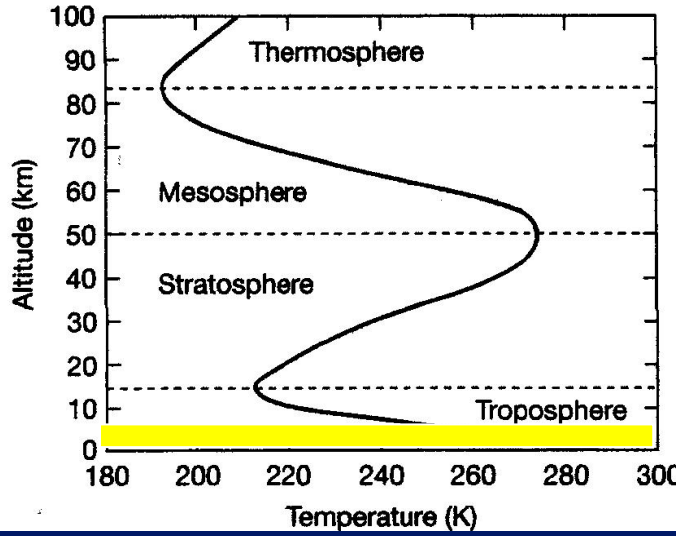
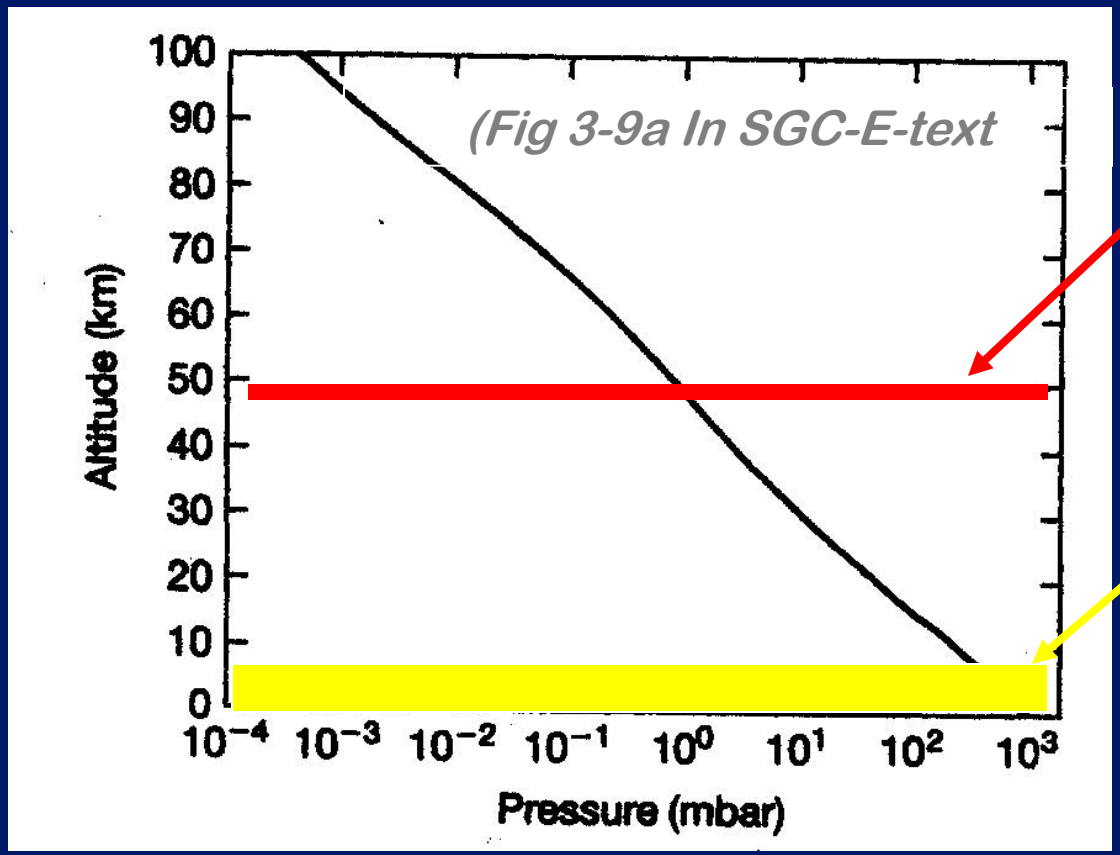


Figure 3-9b in SGC E-text

Atmospheric Pressure = weight of the air column above

Atmospheric Pressure & Mass Vary with Height





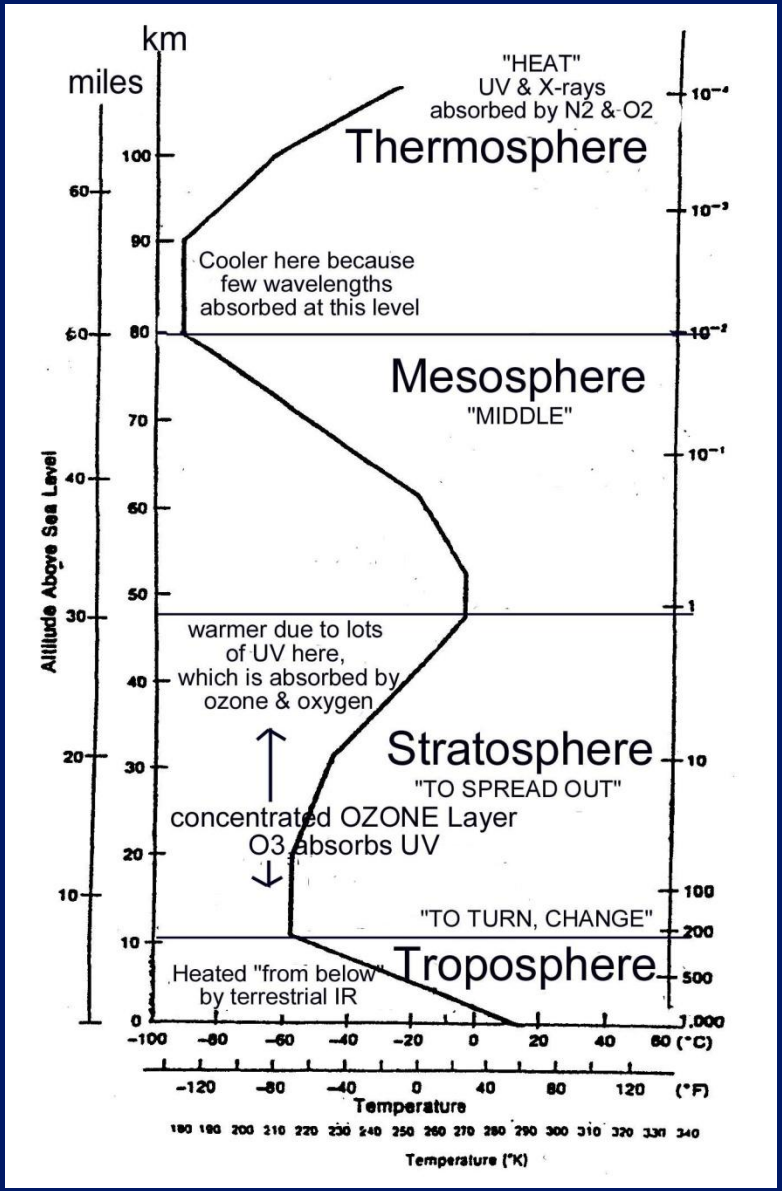
99% of mass lies below ~ 50 km (top of Stratosphere)

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

The changes in temperature with height are the result of:

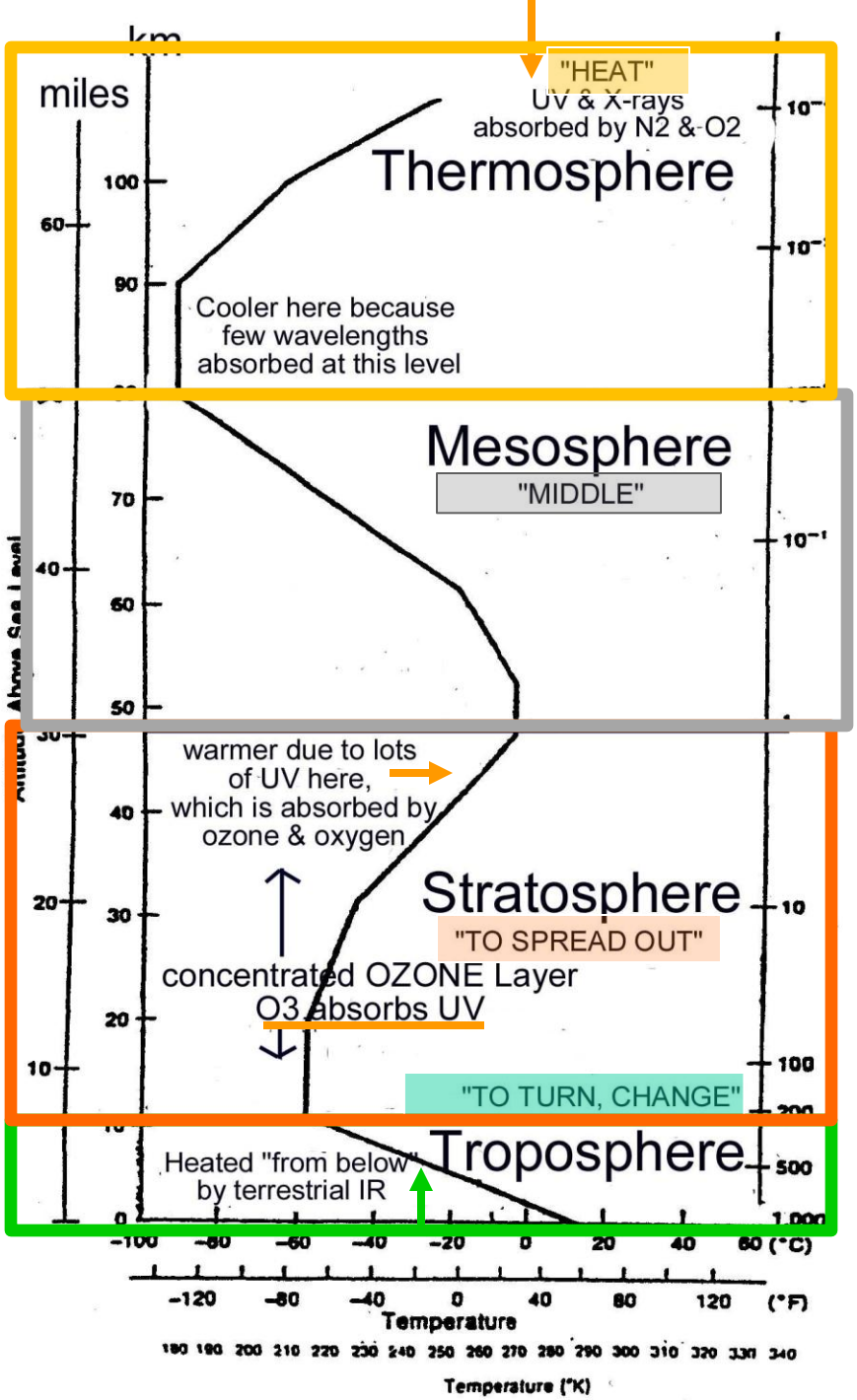
differential absorption of shortwave (SW) & longwave (LW) radiation

by atmospheric GASES concentrated at various altitudes.



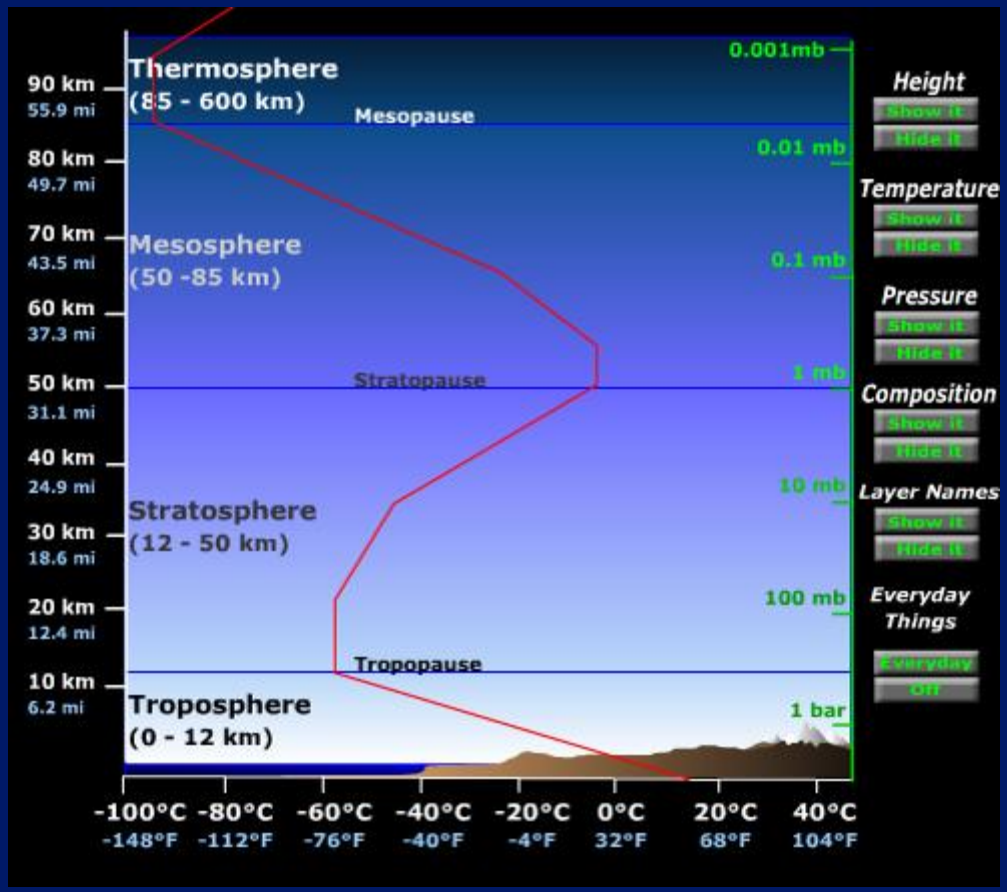
Here's why these changes in **temperature** occur :

Let's start at the SURFACE ➔



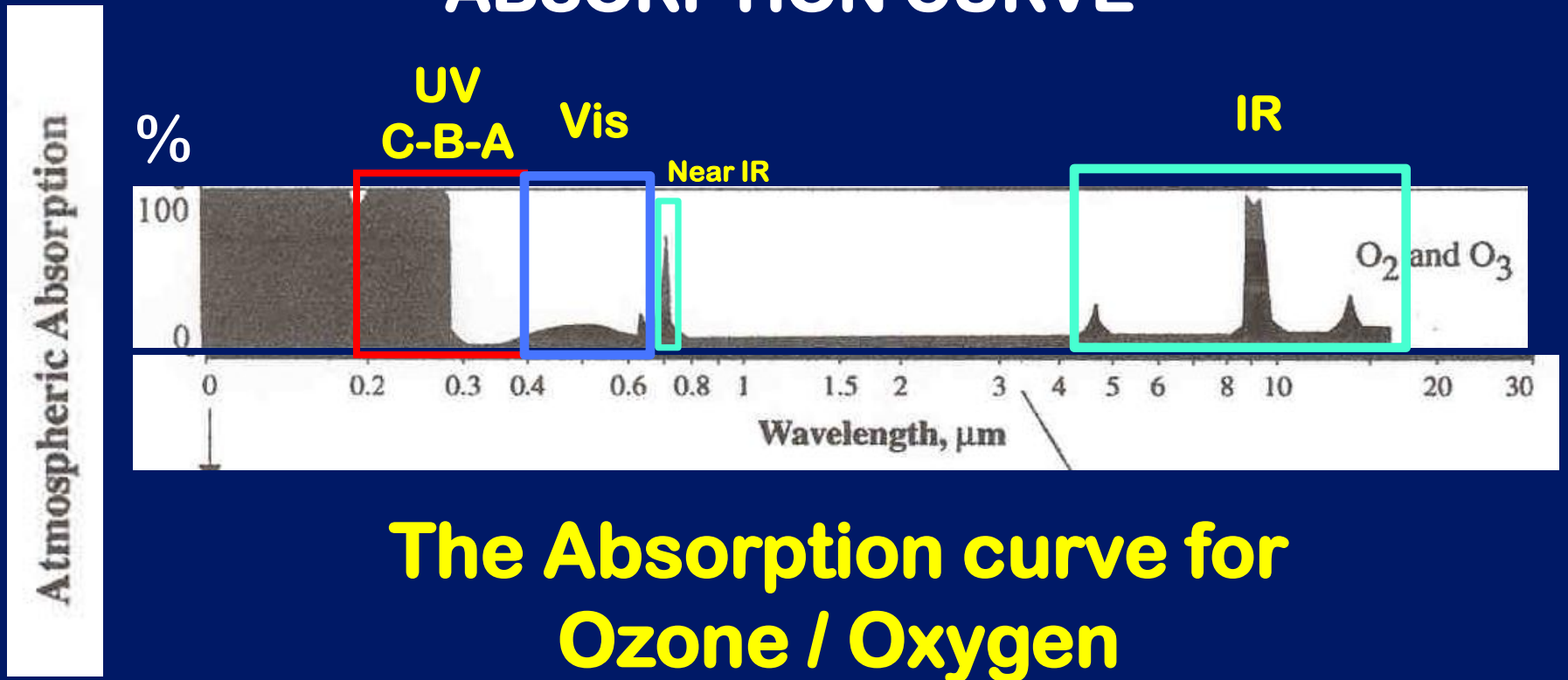
A nice online review . . .

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



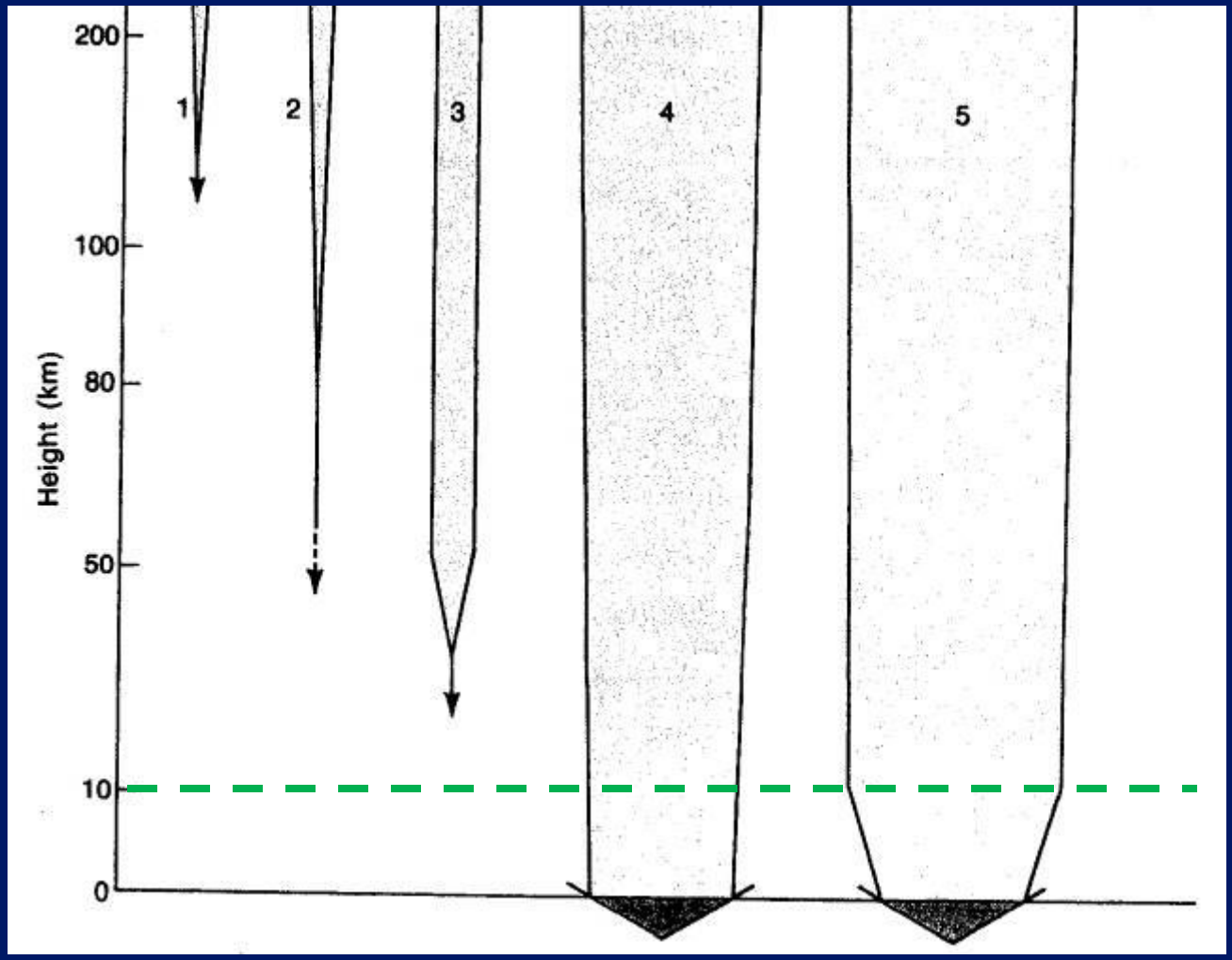
REVIEW: The pattern of electromagnetic wavelengths that are **absorbed** & **emitted** by a particular atom (or combination of atoms)

is called its ABSORPTION SPECTRUM or its ABSORPTION CURVE



The Absorption curve for Ozone / Oxygen

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



GROUP WORK:
Study this box of info & answer Q1, Q2, & Q3

1. UV, $\lambda < 0.12$ µm, absorbed by N_2 and O_2 in upper atmosphere
2. UV, $0.12\ \mu m \leq \lambda < 0.18$ µm absorbed by O_2
3. UV, $0.18\ \mu m \leq \lambda < 0.34$, µm absorbed by O_3 in ozone layer
4. Near UV and visible, $0.34\ \mu m \leq \lambda < 0.7$ µm transmitted nearly undiminished except for scattering
5. Near IR, $0.7\ \mu m \leq \lambda < 3.0$ µm , absorbed slightly by O_2 and in troposphere by H_2O

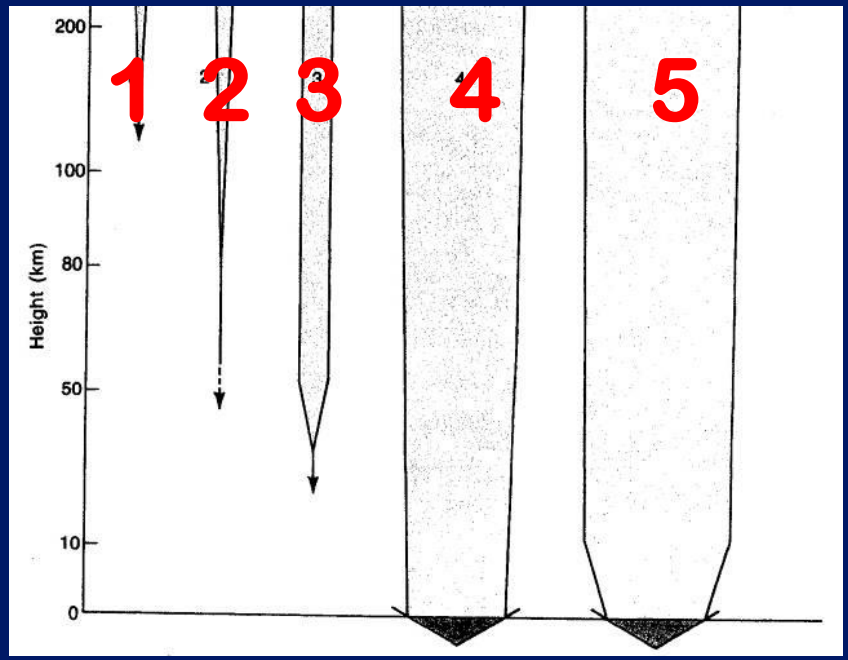
Reminder: ***Ultraviolet radiation:*** *UVC = 0.20 - 0.29 UVB = 0.29 - 0.32 UVA = 0.32 - 0.40* µm

AFTER YOU'VE WORKED ON page 38 in YOUR GROUP . . .

CLICKER your answers in!

Q 1. The GREATEST amount of incoming solar energy (represented by the width of the arrows) is transferred to Earth via **which wavelengths** of electromagnetic radiation?

1. UV < 0.12 μm
2. UV 0.12 – 0.18 μm
3. UVC + UVB
4. BOTH arrow s
   4 + 5



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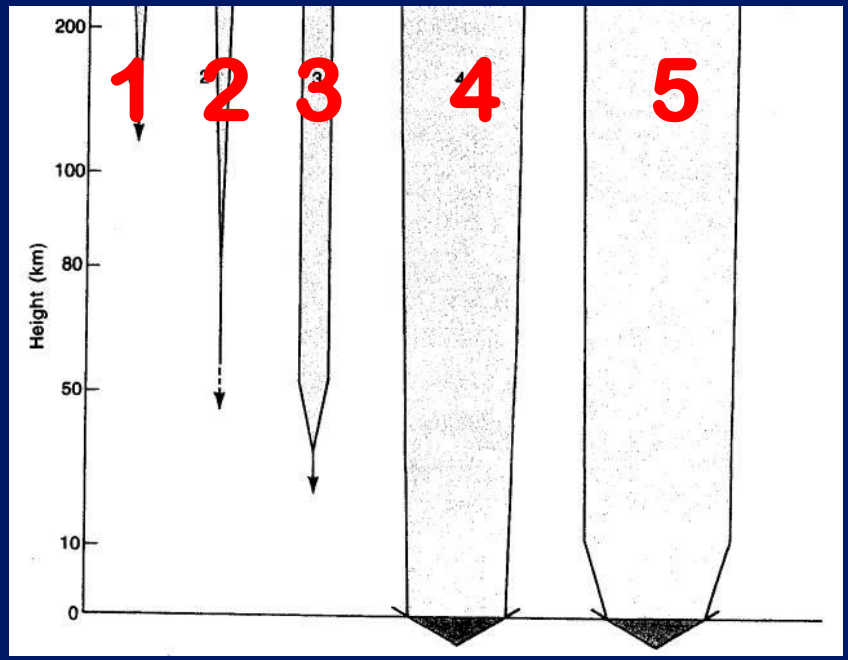

Q 2. Why does ARROW #3's radiation get attenuated below 50 km?

1. Because this is the area of the mesosphere and there is very little absorption of radiation in this layer
2. Because nitrogen (N_2) and oxygen (O_2) are abundant at 50 km and act as GHG's to absorb the UVC + UVB rays
3. Because this is the area of the stratosphere where ozone (O_3) is concentrated and absorbs harmful UVC + UVB rays

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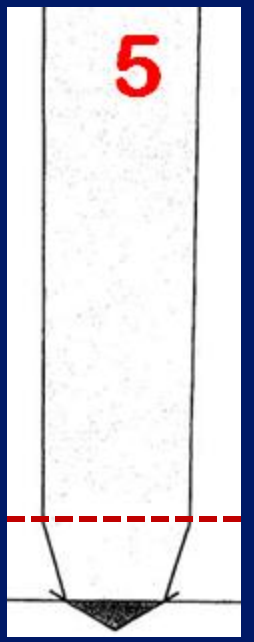
Q 3. Why does ARROW #5's radiation get attenuated (thinner) below 10 km?



1. Because ozone (O_3) is abundant below 10 km and absorbs large amounts of incoming IR
2. Because this is the area of the troposphere where water vapor (H_2O) is abundant and (as a GHG) it absorbs IR
3. Because clouds in the troposphere block out some of the incoming visible light rays

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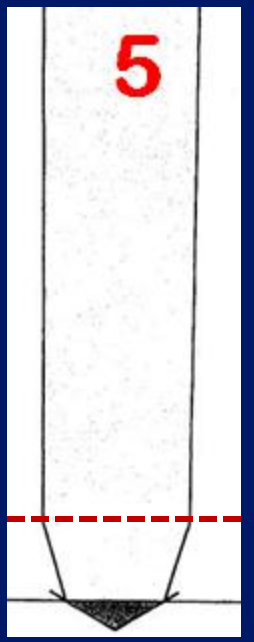

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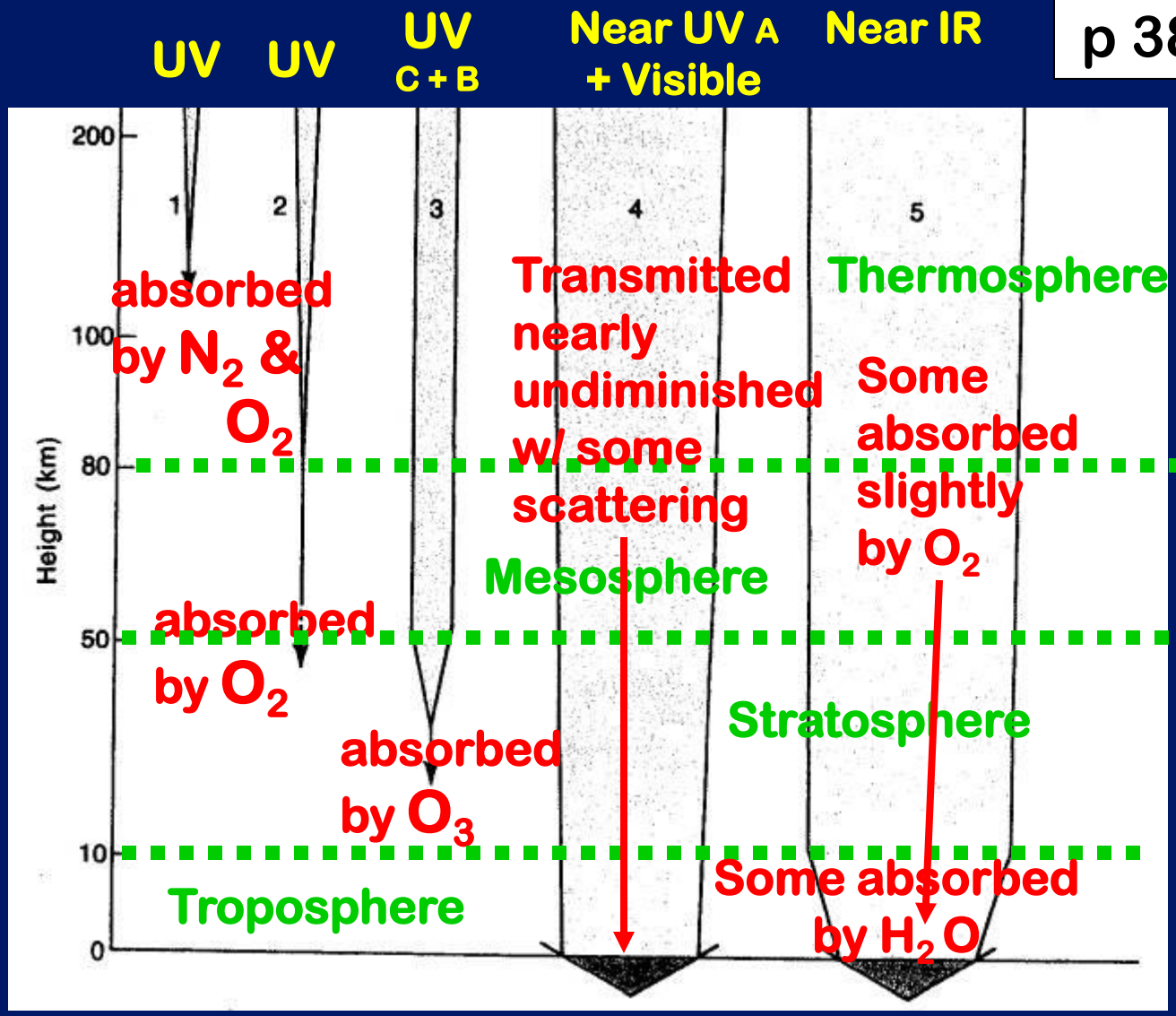
UV rays < .32 µm very harmful to life on Earth arrows 1, 2 + 3

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



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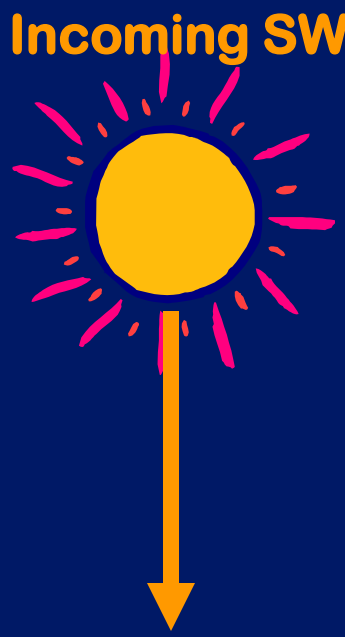
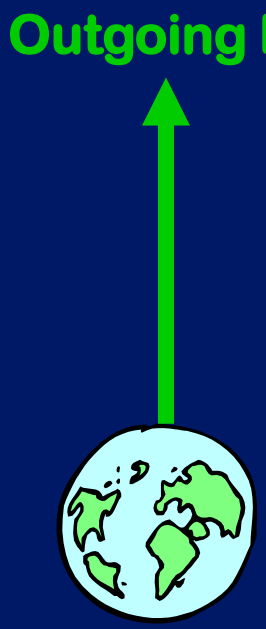
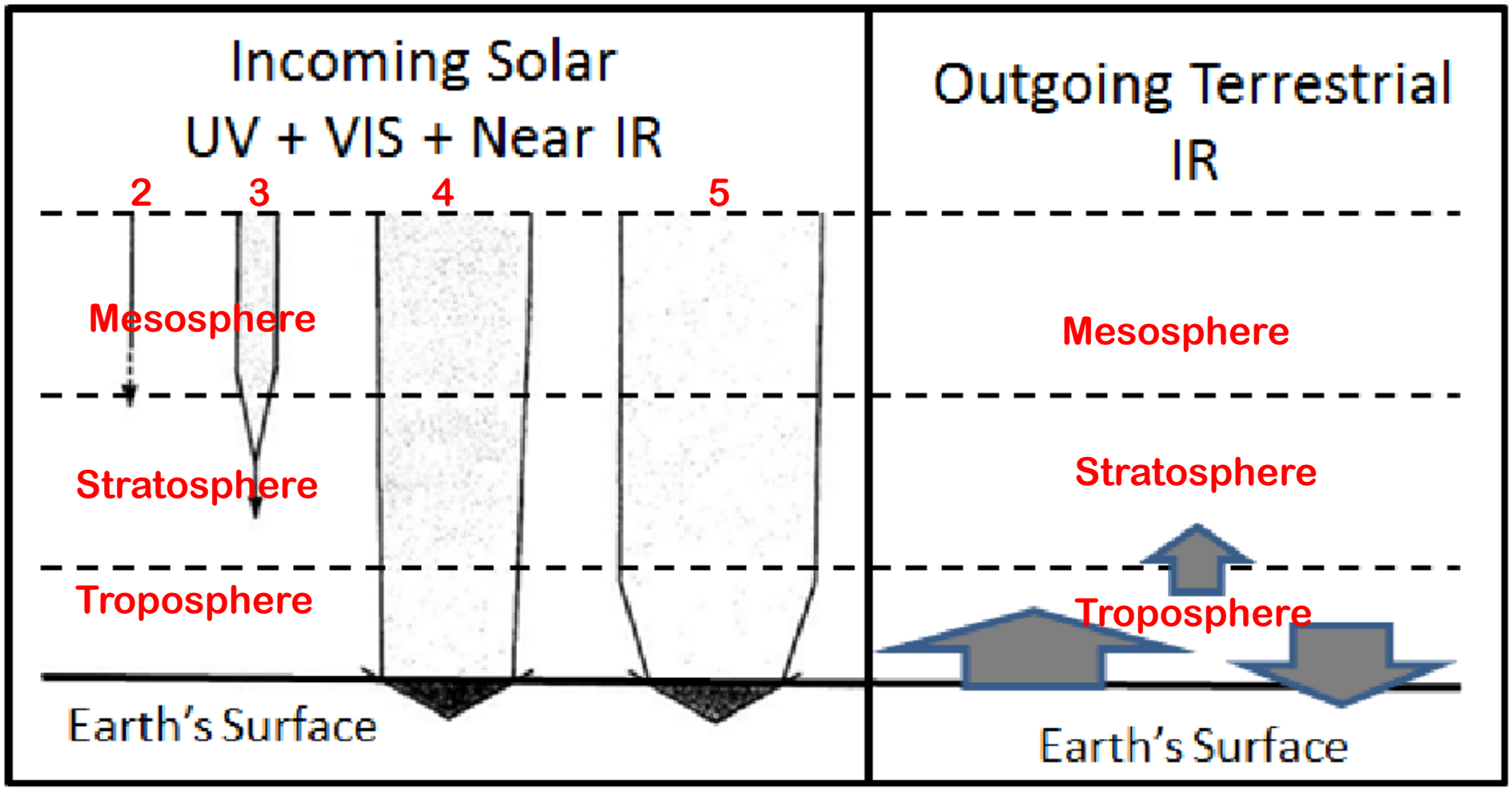


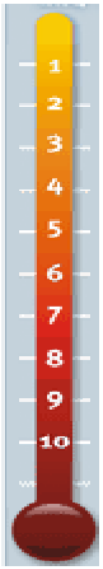
OK – so that explains what happens in different layers of the atmosphere to the **INCOMING SOLAR Shortwave (SW)** on its way down to the Earth's surface . . . .



. . . But what happens to the **OUTGOING TERRESTRIAL Longwave (IR)** radiation when it radiates from the Earth's surface upwards??

Write in the names of the layers:





INDICATOR INTERLUDE . . .

The Greenhouse Warming Signature:
"Increasing CO2 warms the Troposphere and cools the Stratosphere"

The Greenhouse Signature

What would a <u>SOLAR</u> Warming Signature look like?

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?

ATMOSPHERIC COMPOSITION

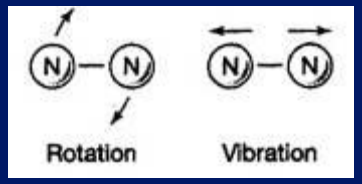
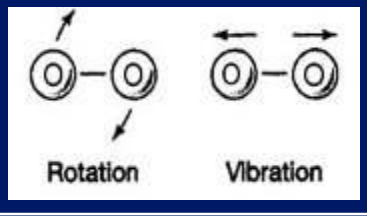
* = Greenhouse Gas (GHG) RF = Radiative Forcing of GHG's in Wm^{-1}

Gas	Symbol	Percent Concentration (by volume dry air)	Concentration in Parts per Million (ppm)	*RF W/m^2
Nitrogen	N_2	78.08	780,800	
Oxygen	O_2	20.95	209,500	
Argon	Ar	0.93	9,300	
* **Water Vapor**	H_2O	0.00001 *(South Pole)* – 4 *(Tropics)*	0.1 *(South Pole)* – 40,000 *(Tropics)*	*varies*
* **Carbon Dioxide**	CO_2	0.0390+ (*2009*) http://co2now.org/	390+ (*2010*) http://co2now.org/	1.66
* **Methane**	CH_4	0.0001774 *(in 2005)*	1.774	0.48
* **Nitrous Oxide**	N_2O	0.0000319	0.319	0.16
* **Ozone**	O_3	0.0000004 *(in 70s)*	0.01 *(at the surface)*	*varies*
* **CFCs** (e.g. Freon-12) (Chlorofluorocarbons)	CCl_2F_2	0.0000000538	0.000538 *RF for all CFC Totals:*	0.170 0.268
* **HCFCs** (e.g., HCFC-22) (Hydrochlorofluorocarbons)	$CHClF_2$	0.0000000169	0.000169 *RF for all HCFC Totals:*	0.033 0.039
Neon, Helium, Hydrogen, Krypton, Xenon	Ne, He, H, Kr, Xe	0.0018 – 0.000009	18 – 0.09	
Particles (dust, soot)	--	0.000001	0.0001	

For more on GHG concentrations see: http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-chapter2.pdf Table 2.1

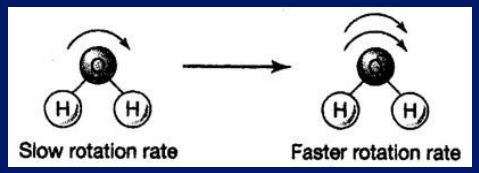
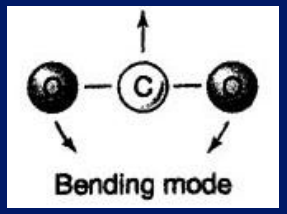
Top of p 39

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)

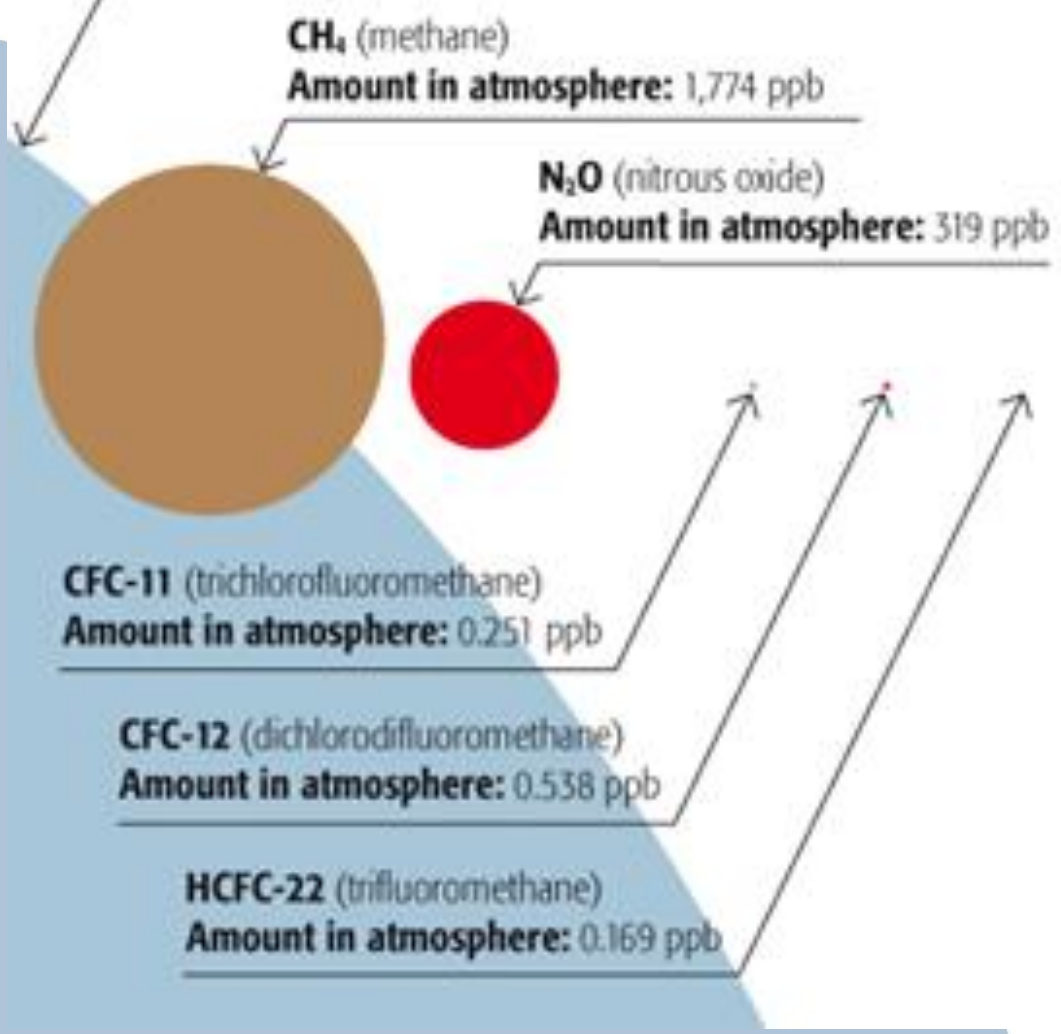
Greenhouse Gases !

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!

CO_2



Amount in Atmosphere = 390,000+ ppb

(From: DP text p 29 where it says 386,000 ppb!)

With your Group . . .
STUDY THE TABLE ON
Page 40
to familiarize yourself with
each of the GHG's

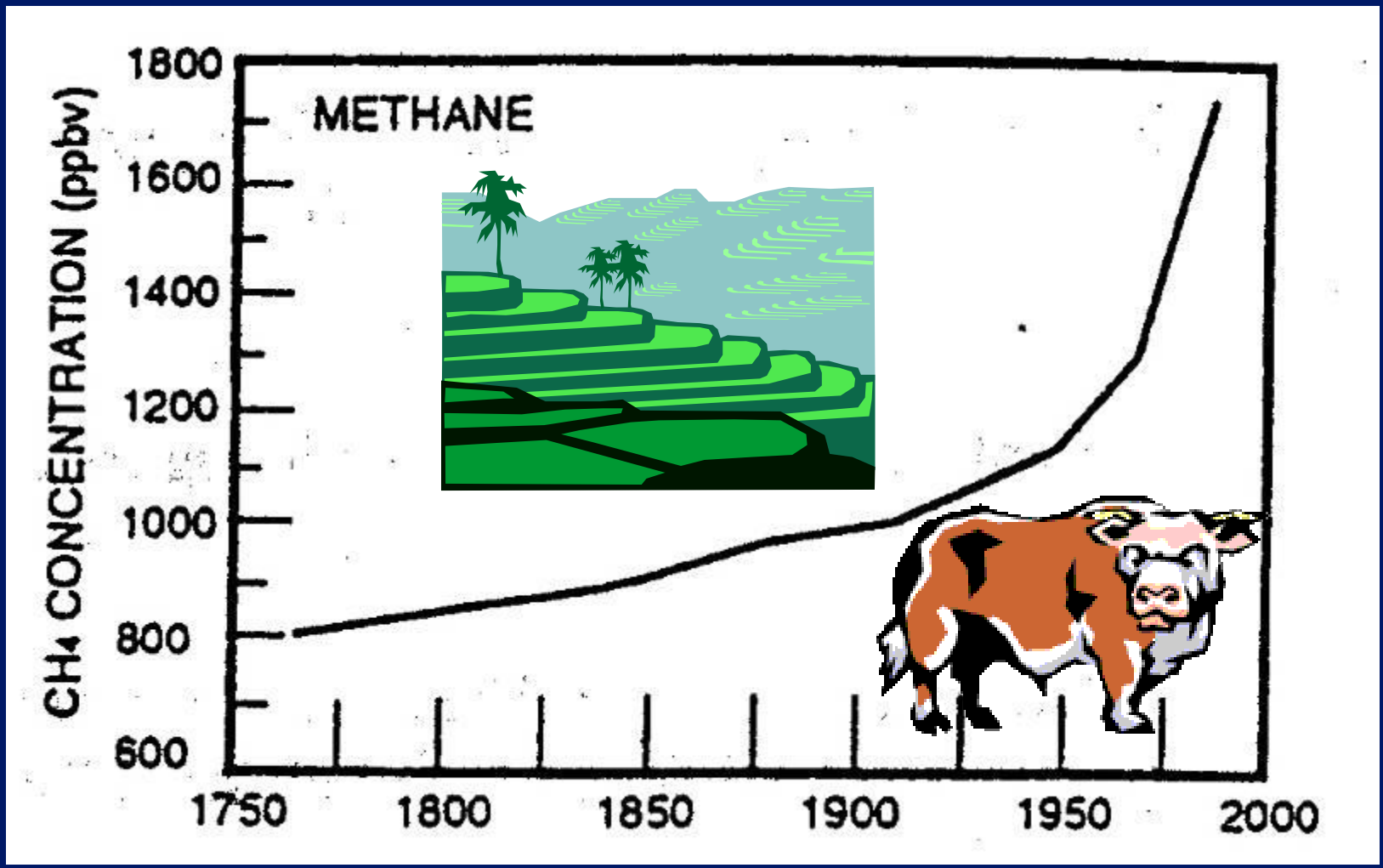
Then get ready for the
"NAME THAT GAS!"
Group competition

GROUPS: # 1 #10 #17

Name that GAS!!!

MYSTERY GHG # 1

METHANE: Trends



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)

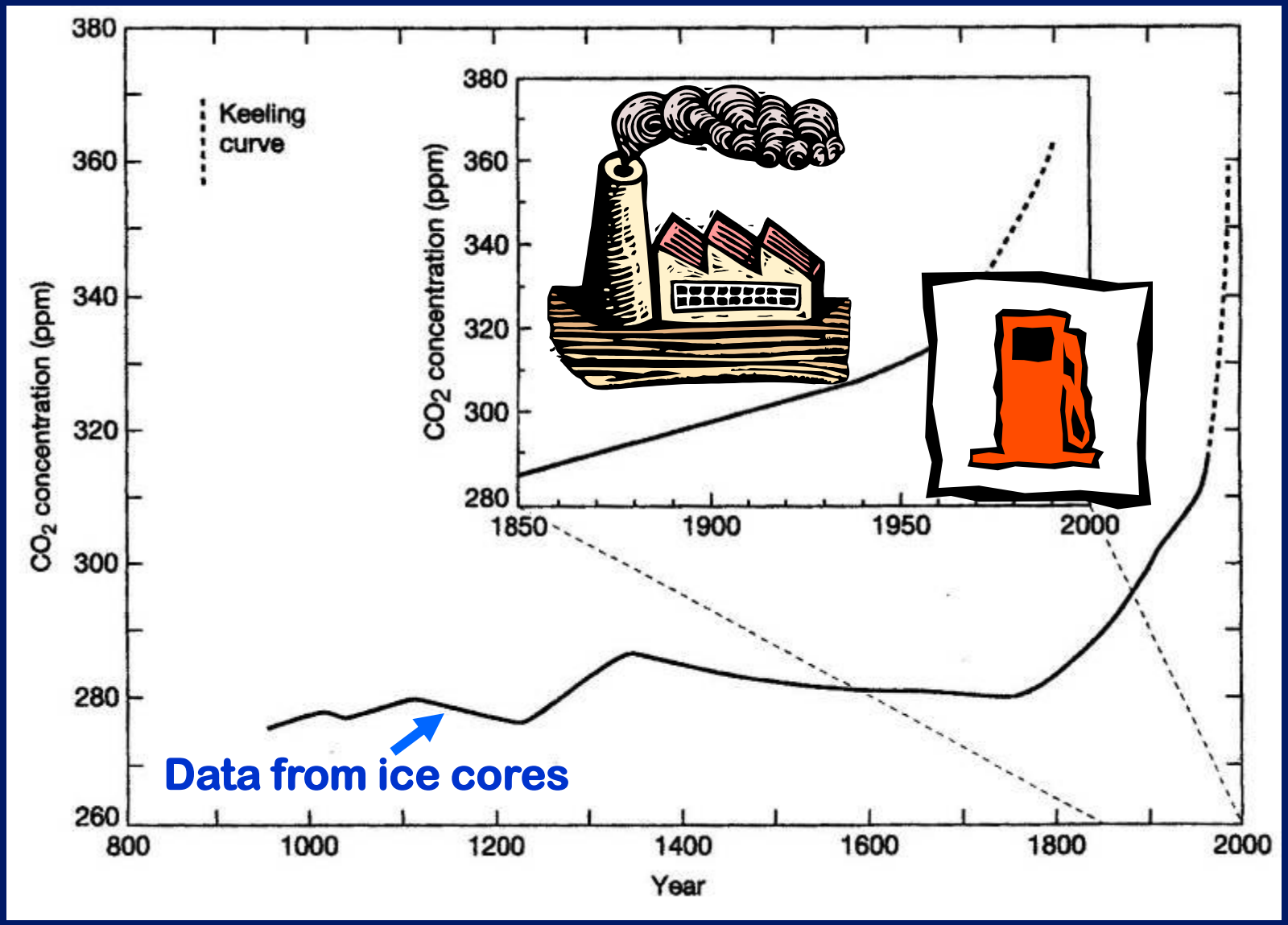
☺ Table on p 40

GROUPS: # 2 #8 #16

Name that GAS!!!

MYSTERY GHG #2

CARBON DIOXIDE: Trends



CARBON DIOXIDE :

* Arrives in atmosphere naturally through the natural carbon cycle

* Has increased dramatically since the 1800s due to:

FOSSIL FUEL COMBUSTION:

oil, coal, gas (automobiles) . . .
But especially **COAL**

☺ Table on p 40

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!

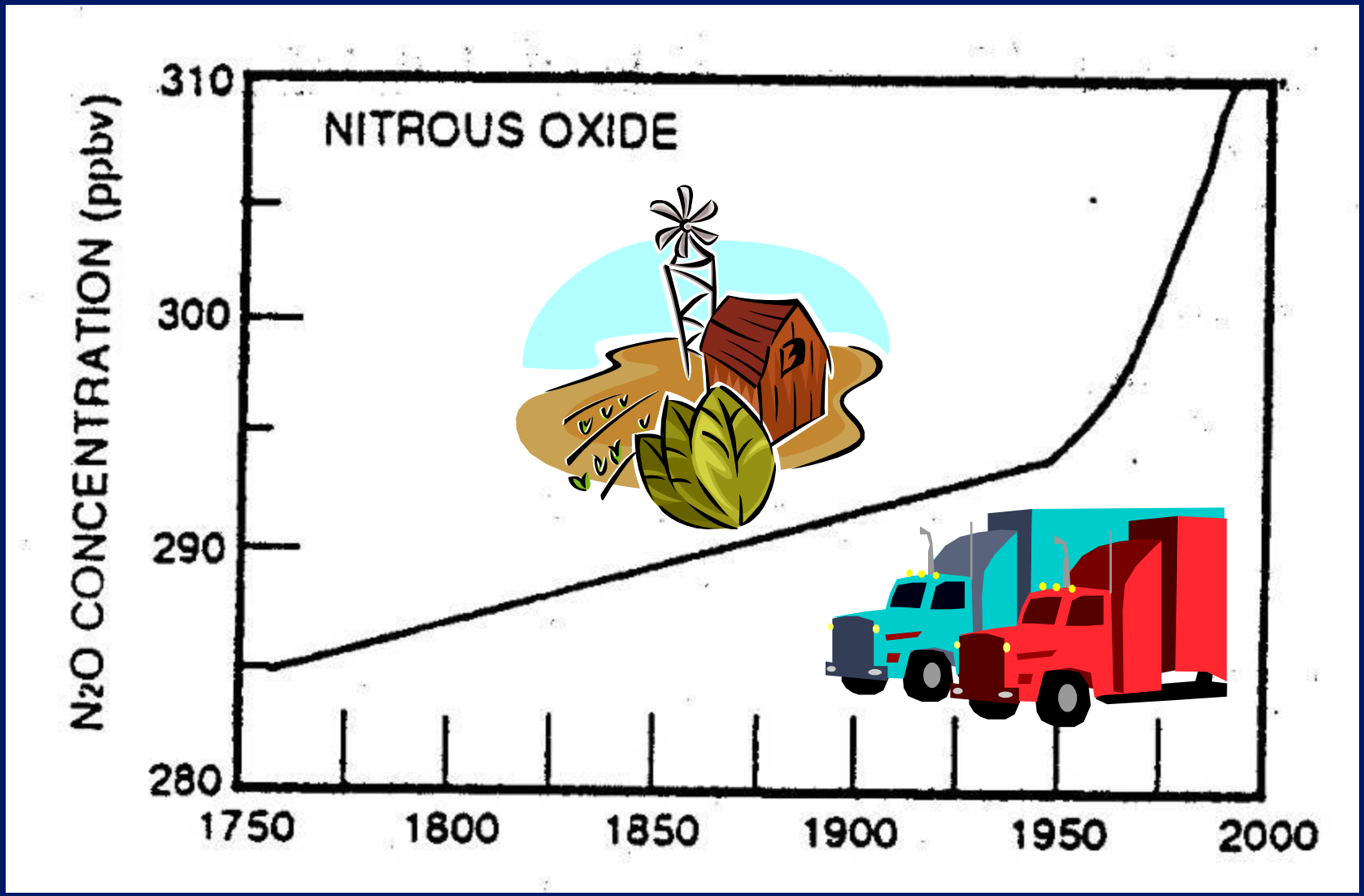
☺ Table on p 40

GROUPS: # 20 #12 #5

Name that GAS!!!

MYSTERY GHG # 3

NITROUS OXIDE: Trends



NITROUS OXIDE (N_2O): Sources

* Produced naturally in soils

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

* Has long atmospheric residence time (~ 150 years)

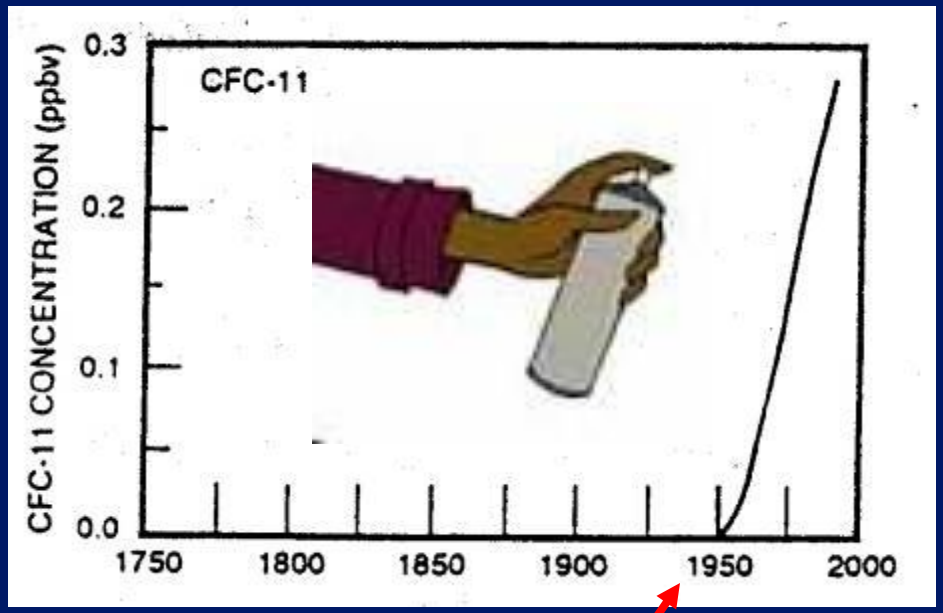
☺ Table on p 40

GROUPS: # 4 #11 #15

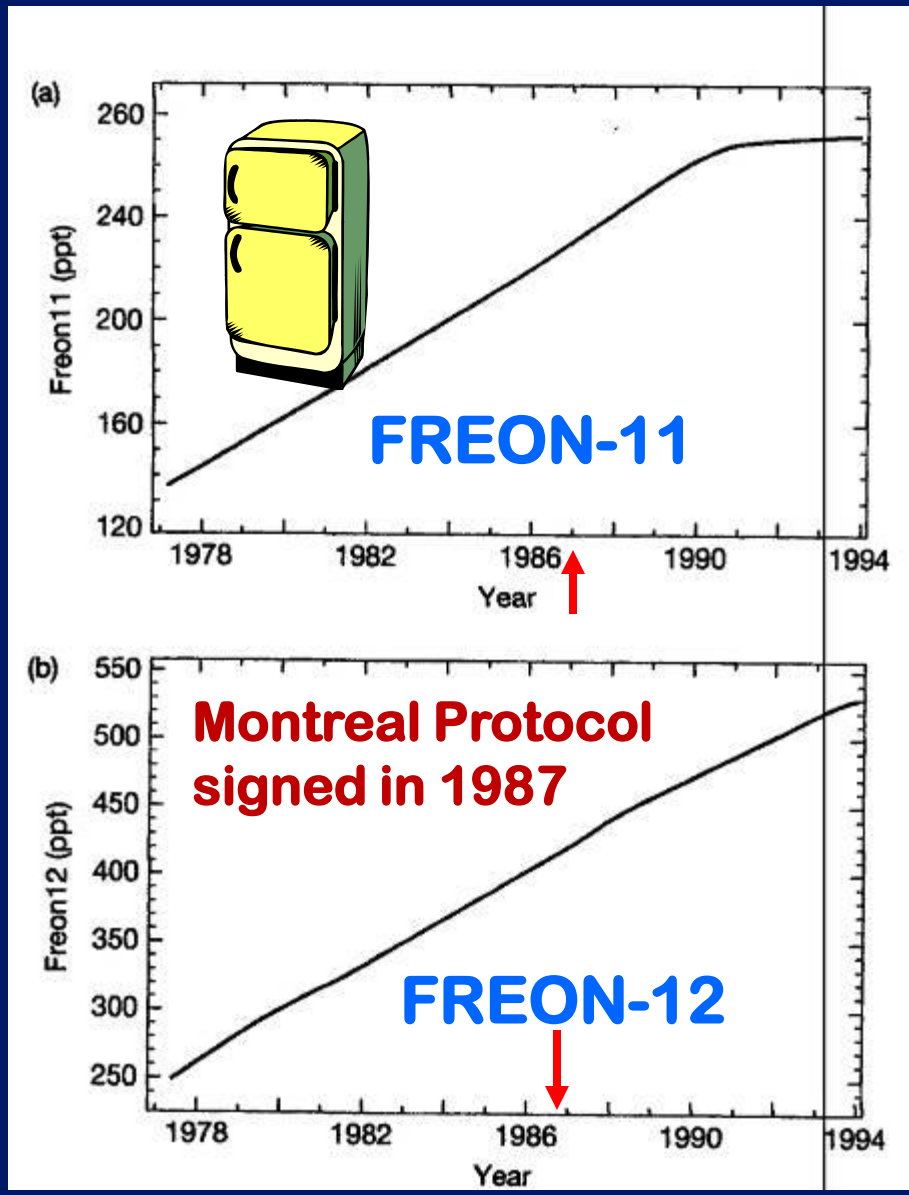
Name that GAS!!!

MYSTERY GHG # 4

CFCs: Trends



Human-made -- didn't exist before 1950!



CFCs (Freon-11 & Freon-12)

* Human-made CFCs (didn't exist in atmosphere prior to 1950s)

* Have increased at rates faster than any other greenhouse gas; used in refrigerants, fire retardants, some aerosol propellants & foam blowing agents

* Absorb at different wavelengths than H_2O and CO_2 (in 8 –12 μm "WINDOW" part of spectrum), hence a single molecule can have great effect

MONTREAL (and subsequent) PROTOCOLS have reduced CFCs!

☺ Table on p 40

Q – Why do you think the concentration of CFC's didn't begin dropping immediately after the Montreal Protocol in 1987?

1. Because it was an international "agreement only" and the nations of the world never followed through.

2. Because it called for only a 50% reduction of CFC's over 10 years and had to be followed by more stringent protocols later.

3. Because CFC's are very stable molecules and don't break down easily once they are in the atmosphere.

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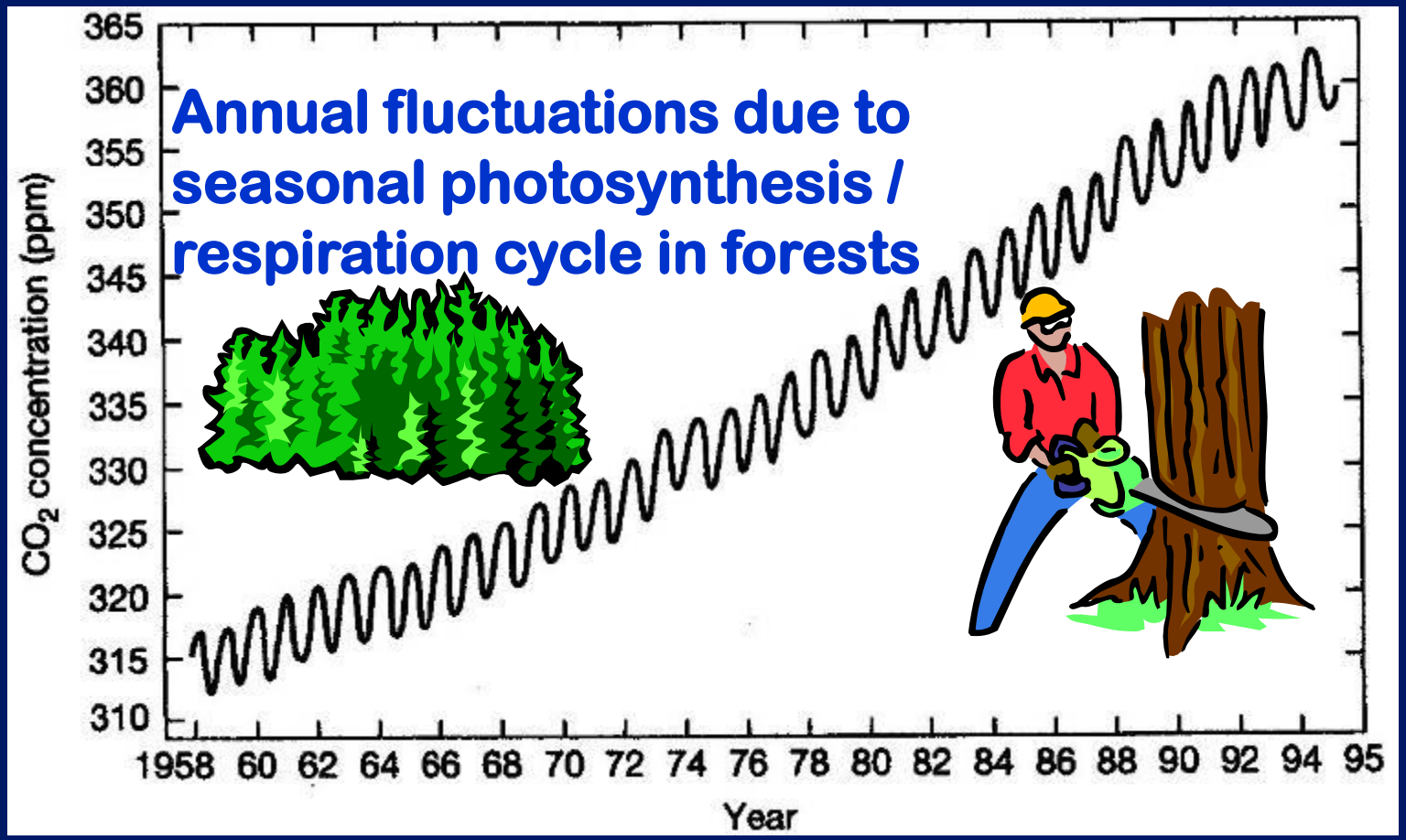
3. Because CFC's are very stable molecules and don't break down easily once they are in the atmosphere.

GROUPS: # 18 #13 #7

Name that GAS!!!

MYSTERY GHG #5

CARBON DIOXIDE --- Trends:



The Keeling Curve

CARBON DIOXIDE (cont.):

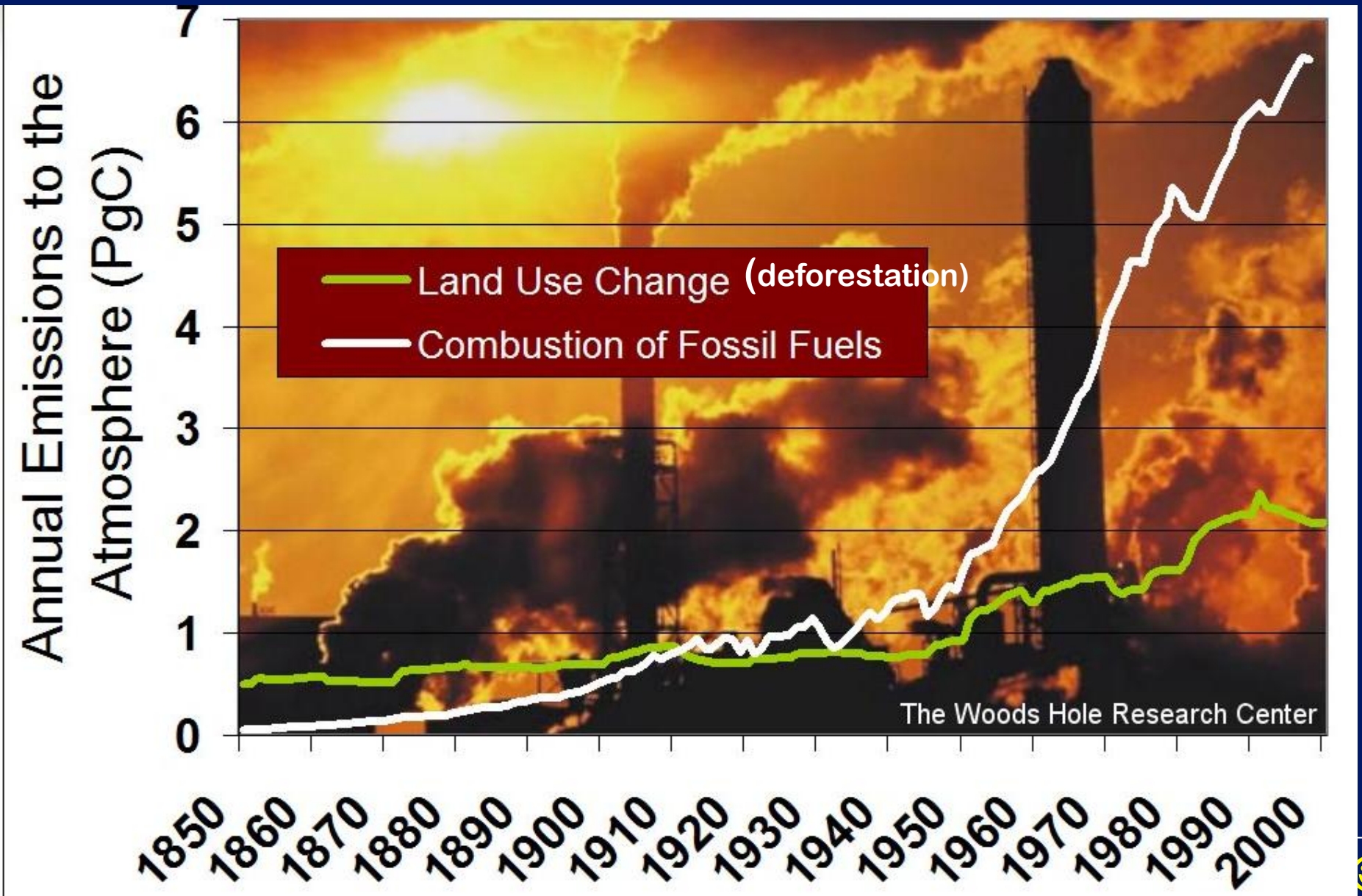
* **Has increased dramatically since the 1800s due to:**

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.)

☺ Table on p 40

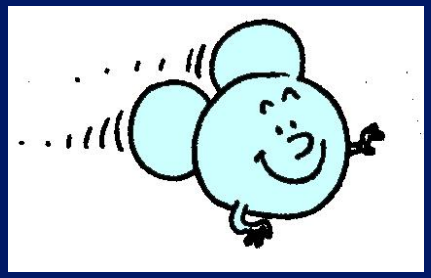
CARBON emissions into the atmosphere are increasing:



GROUPS: # 9 #19 #6

Name that GAS!!!

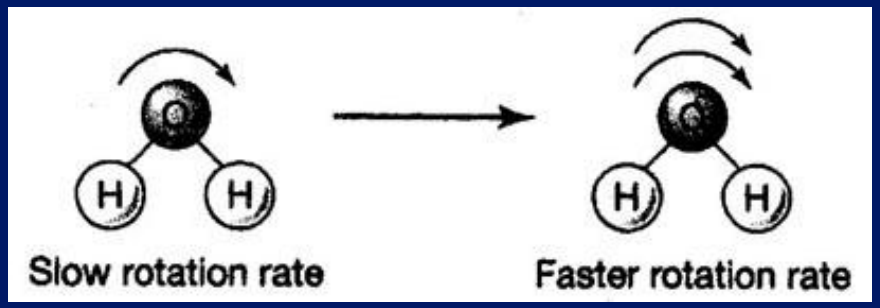
MYSTERY
GHG # 6



WATER VAPOR

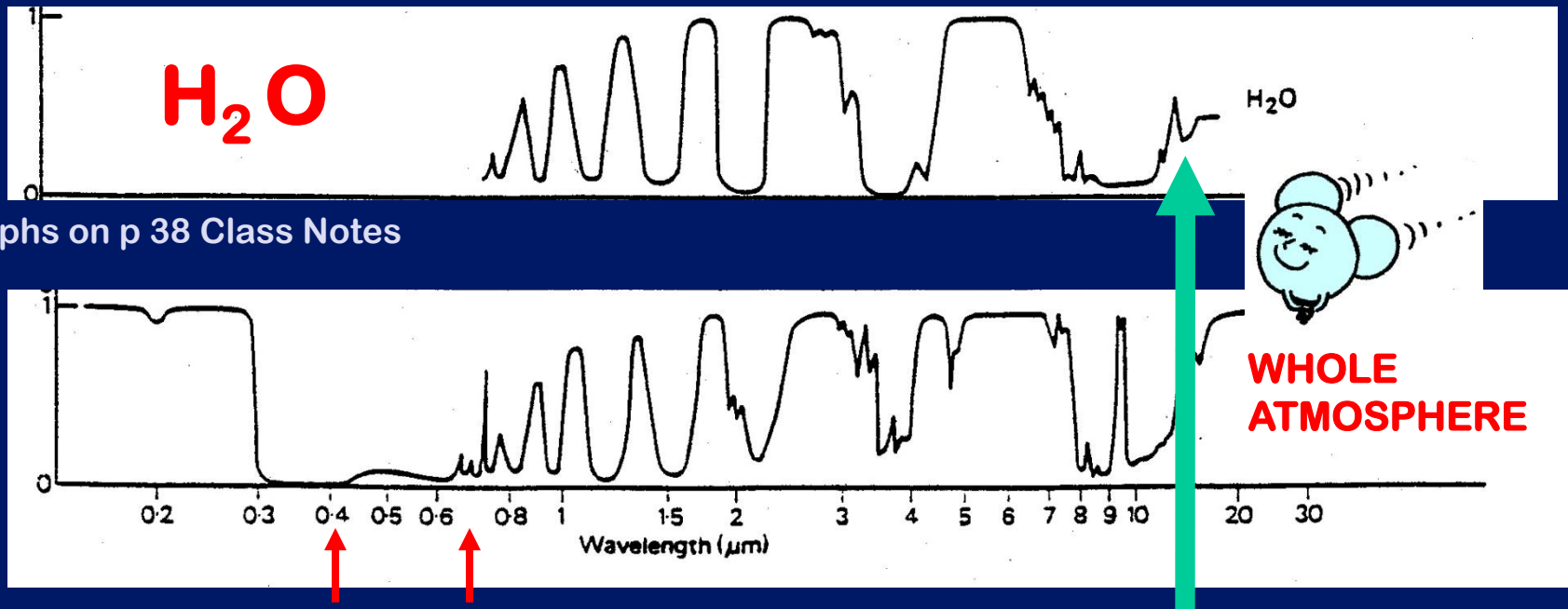
* Arrives in atmosphere naturally through evaporation & transpiration

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



GASTable on p 40

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



IR at 12 µm absorbed

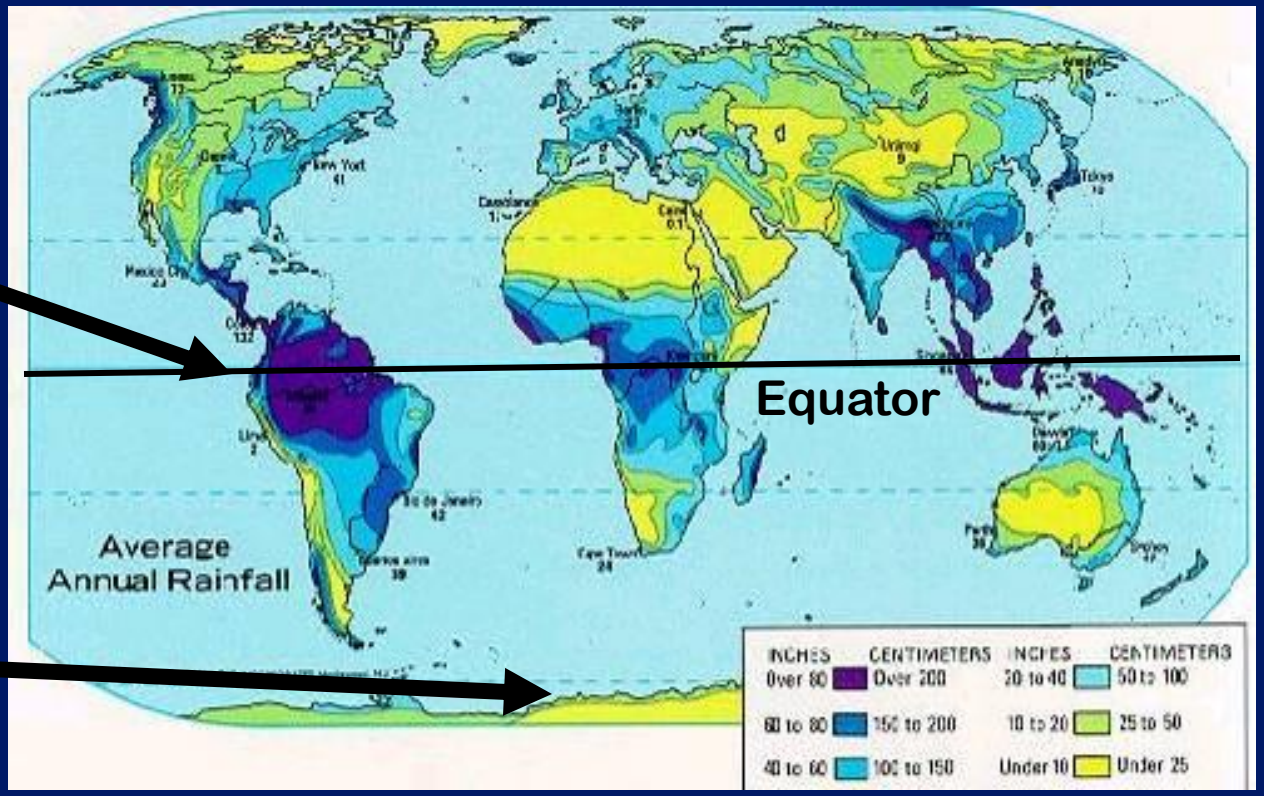
(12 µm close to the radiation wavelength of 10 µm, at which most of Earth's terrestrial radiation is emitted.)

WATER VAPOR (cont):

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

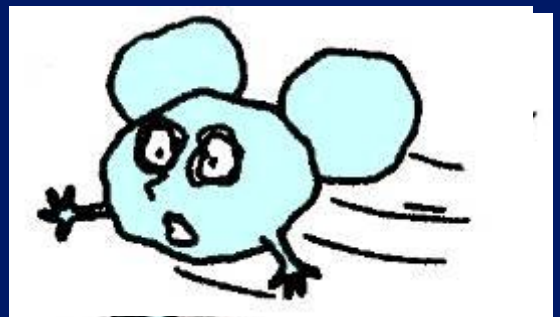
Blue = wettest climates, lots of humidity & water vapor

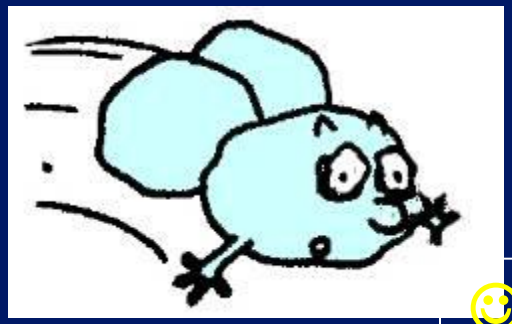
Yellow = driest climates, less atmospheric water vapor



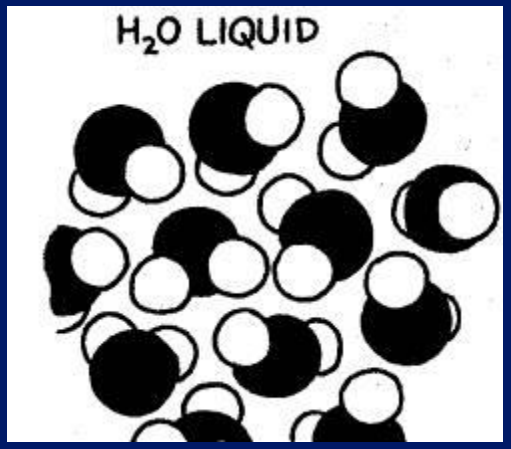
At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.

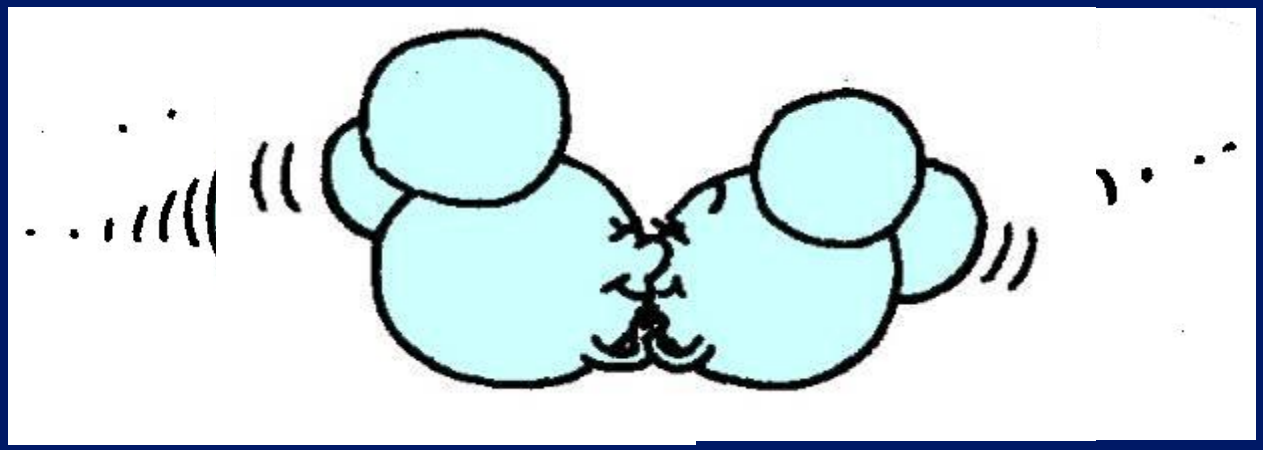
Hence hot climates can hold more water vapor in the air





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!

GROUPS: # 21 #14 #3

Name that GAS!!!

MYSTERY
GHG # 7

OZONE: Sources

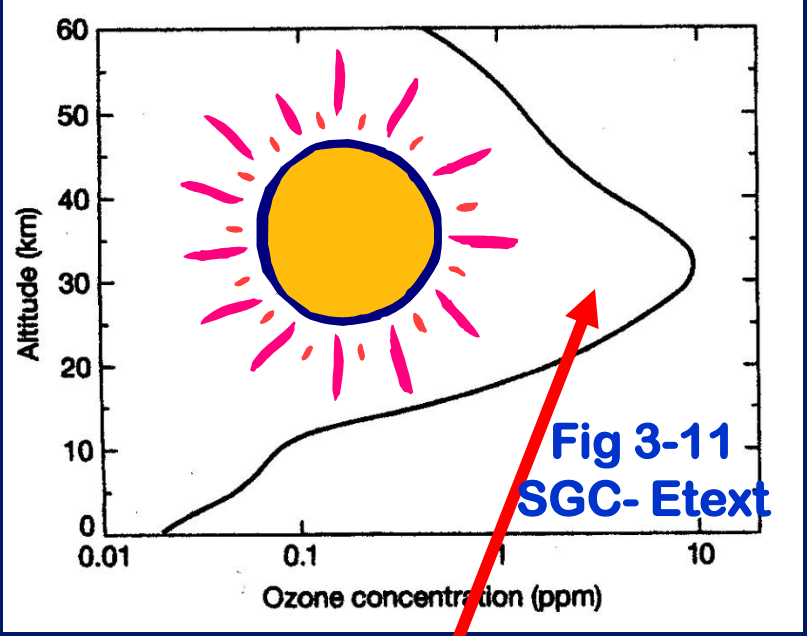
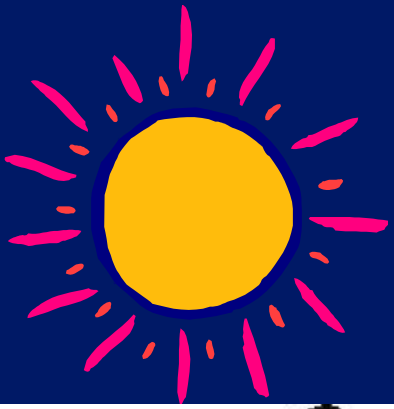


Fig 3-11
SGC- Etext



Produced naturally in photochemical reactions in STRATOSPHERIC ozone layer --"good ozone"

Has *increased* in TROPOSPHERE due to photochemical smog reactions -- "bad ozone"

☺ Table on p 40

We'll finish up
OZONE
next week

GO CATS!
Beat the Huskies