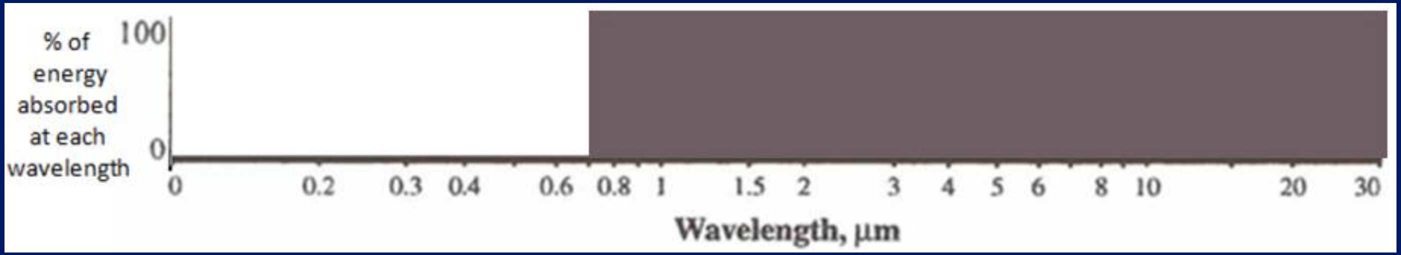
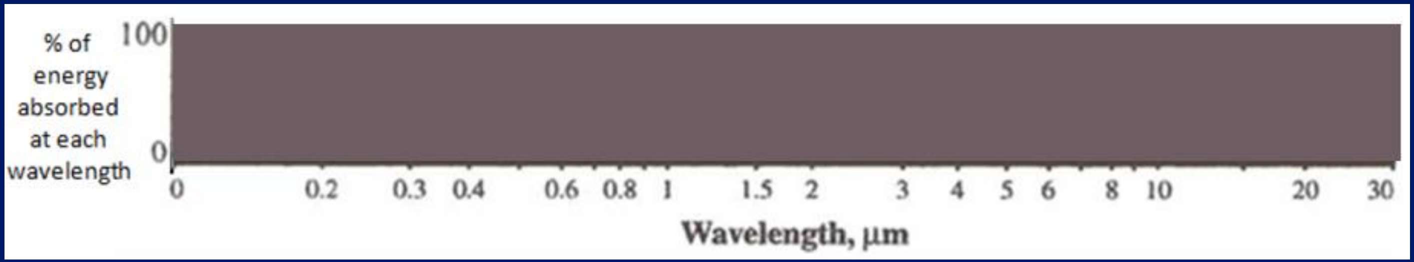
To start off, some clicker review questions from last week's classes . . . . .

Q-1 Which of the following absorption curves represents a <u>hypothetical</u> atmosphere that has a "perfect" greenhouse effect ?

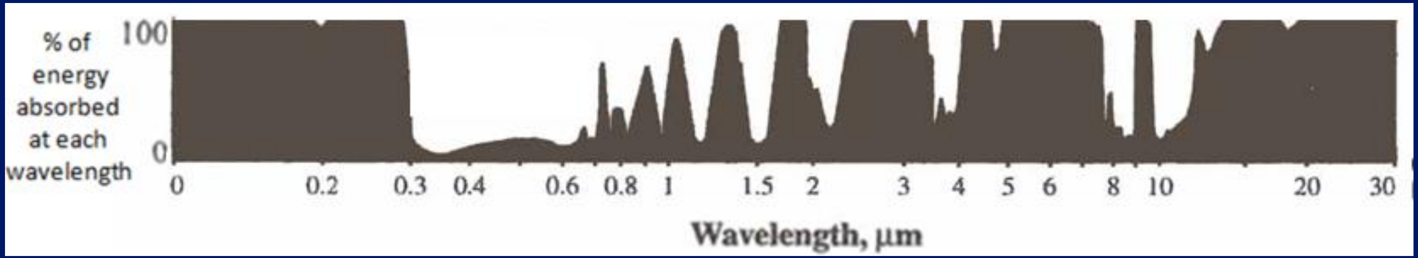
1.



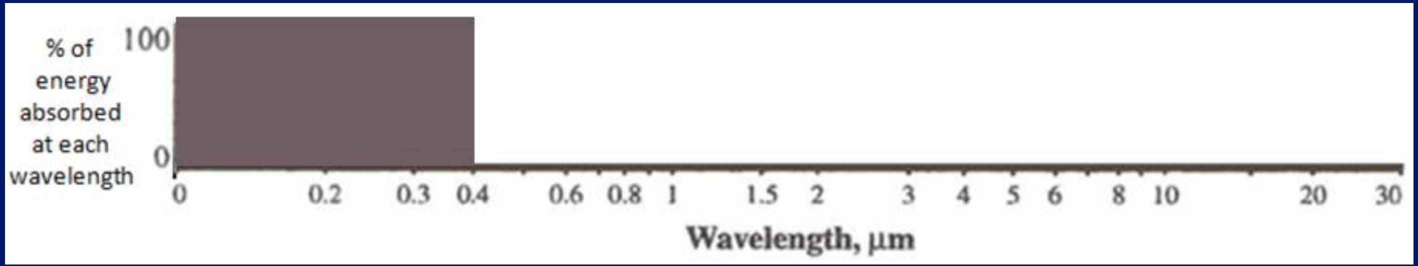
2.



3.



4.



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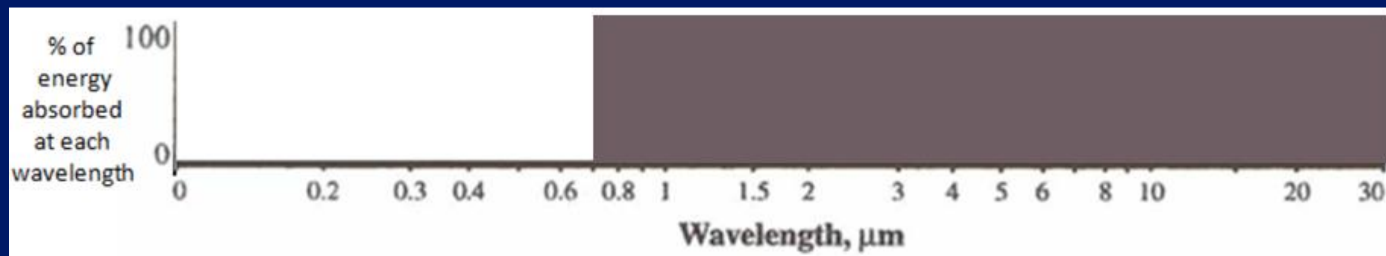
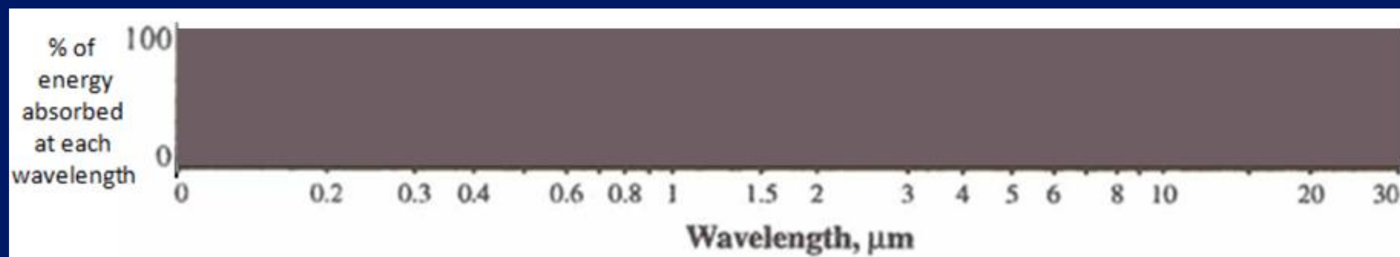
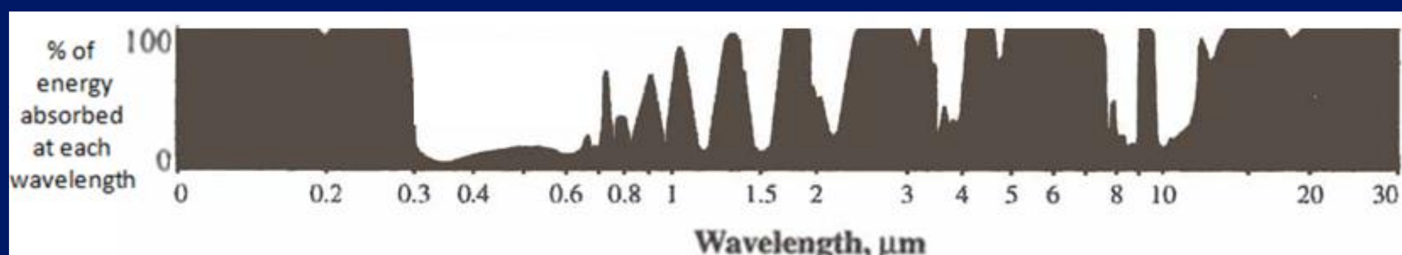


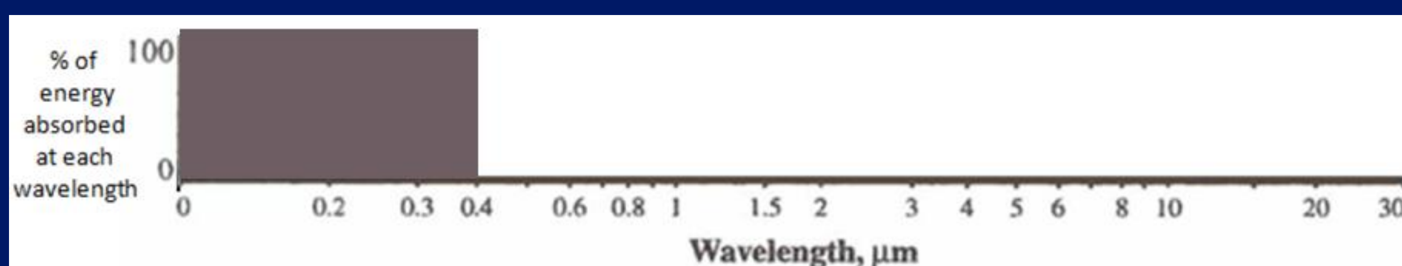
2.

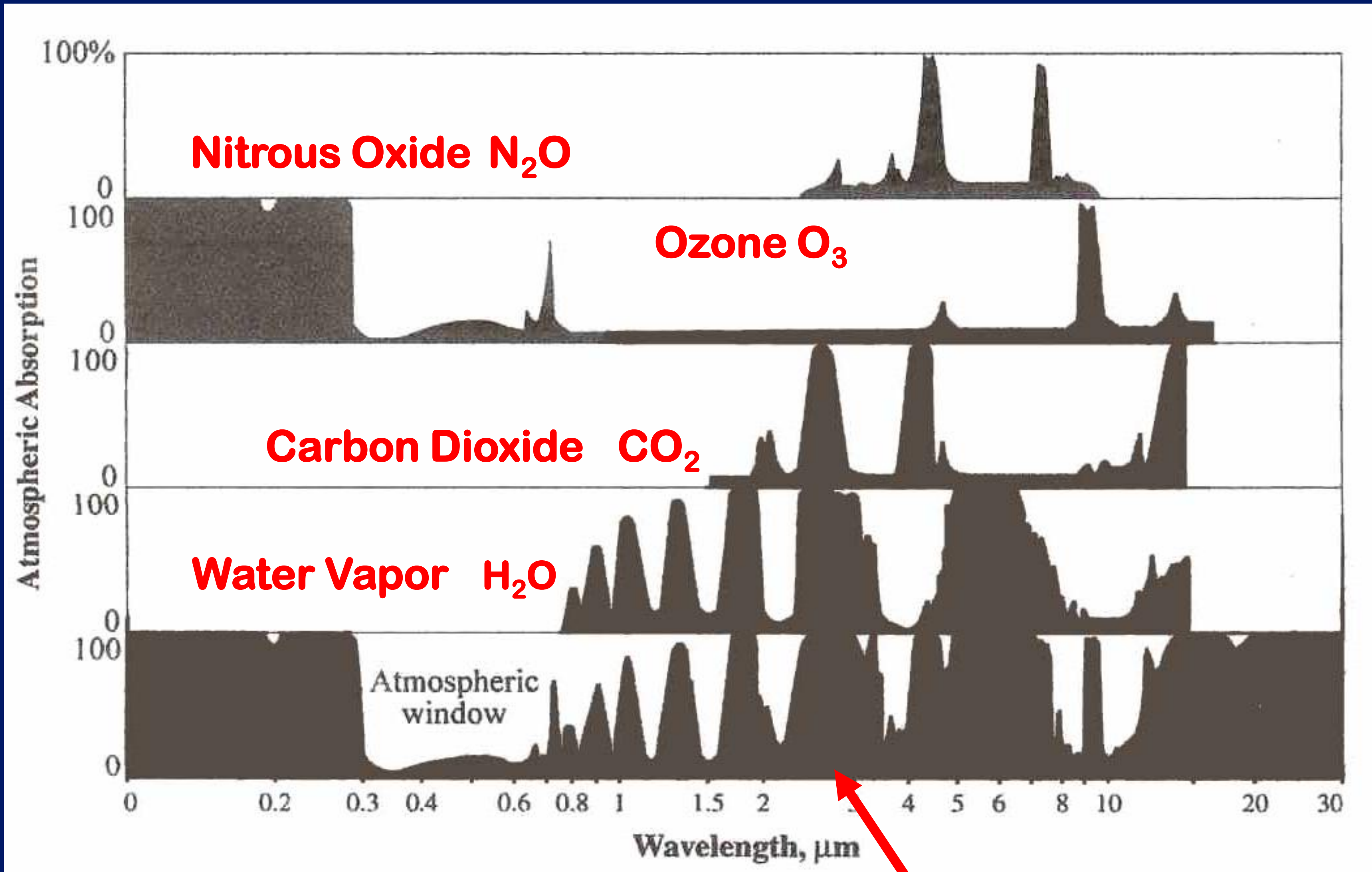


3.



4.

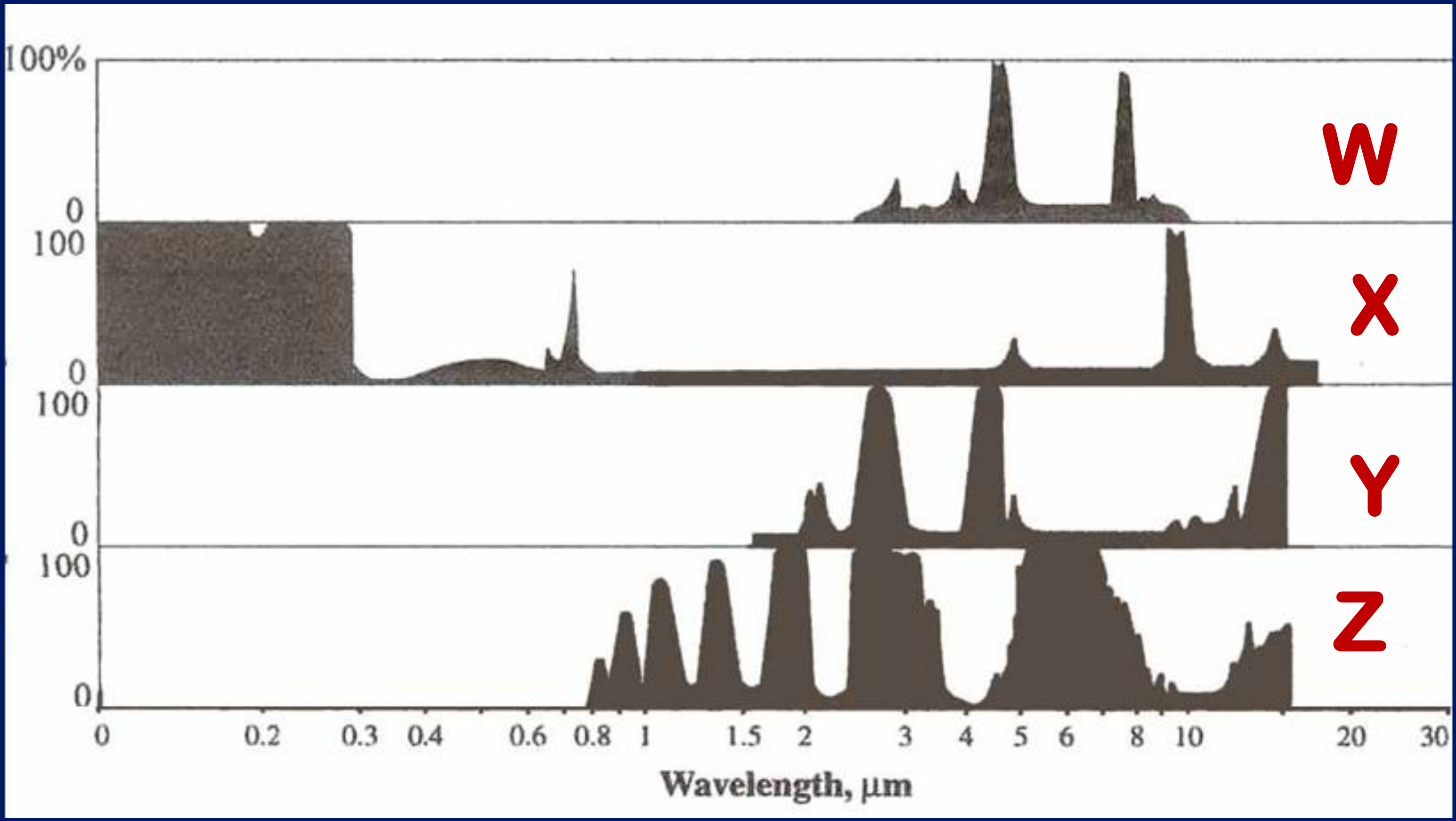




All gases in the atmosphere together!

Q2 – Which of the following absorption curves is for a GAS that is NOT a greenhouse gas!

1: W 2: X 3: Y 4: Z 5: NONE of THEM



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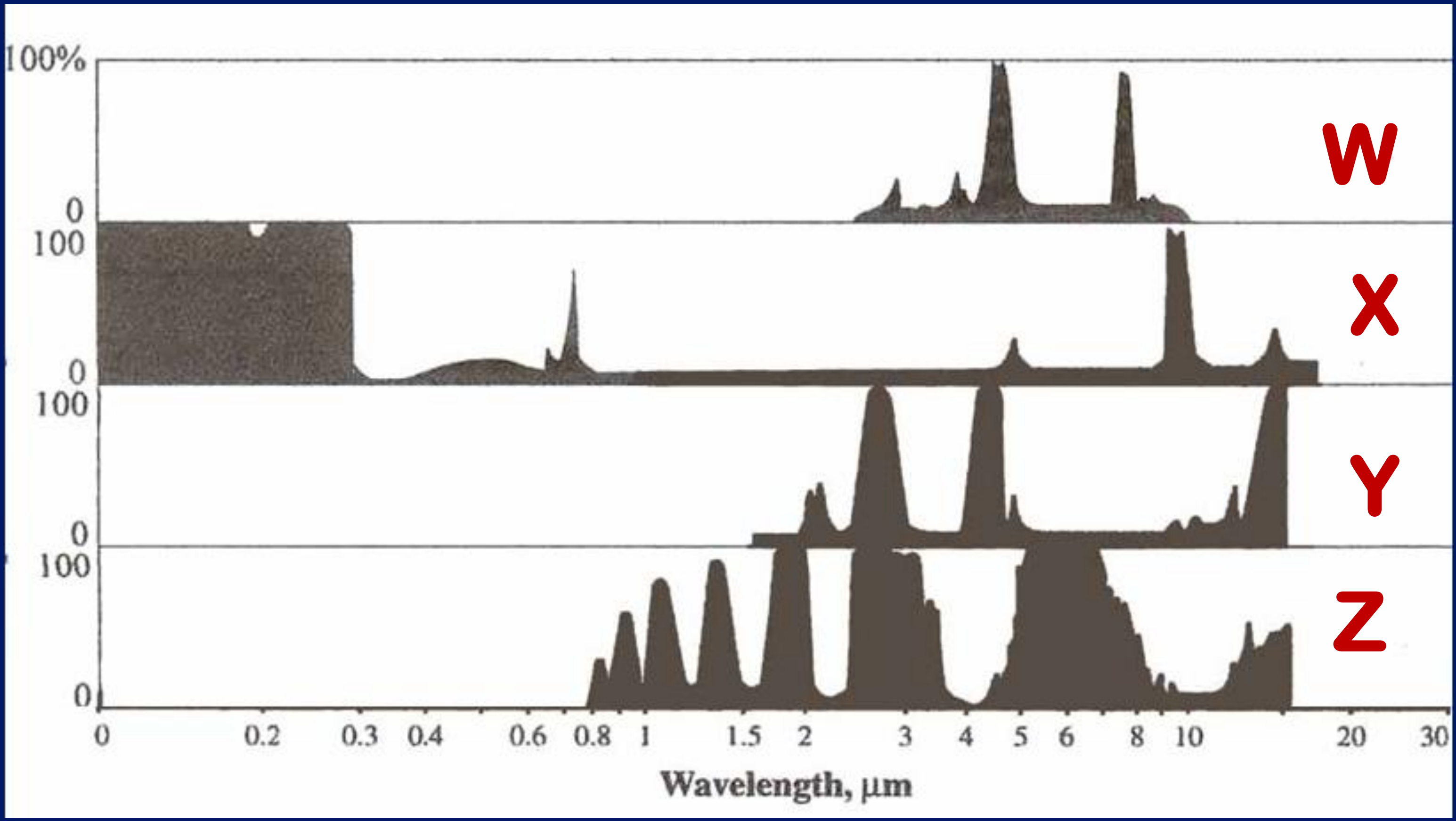
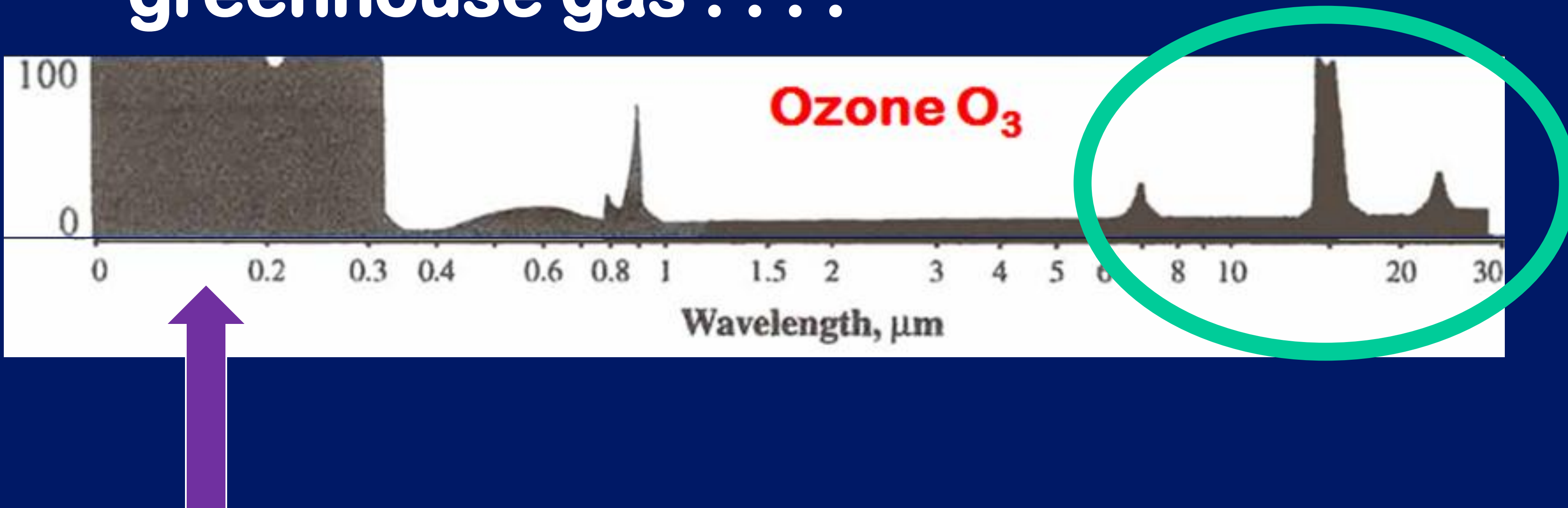


Absorption in this part of the absorption curve (IR wavelengths) indicates that OZONE is a greenhouse gas . . . .



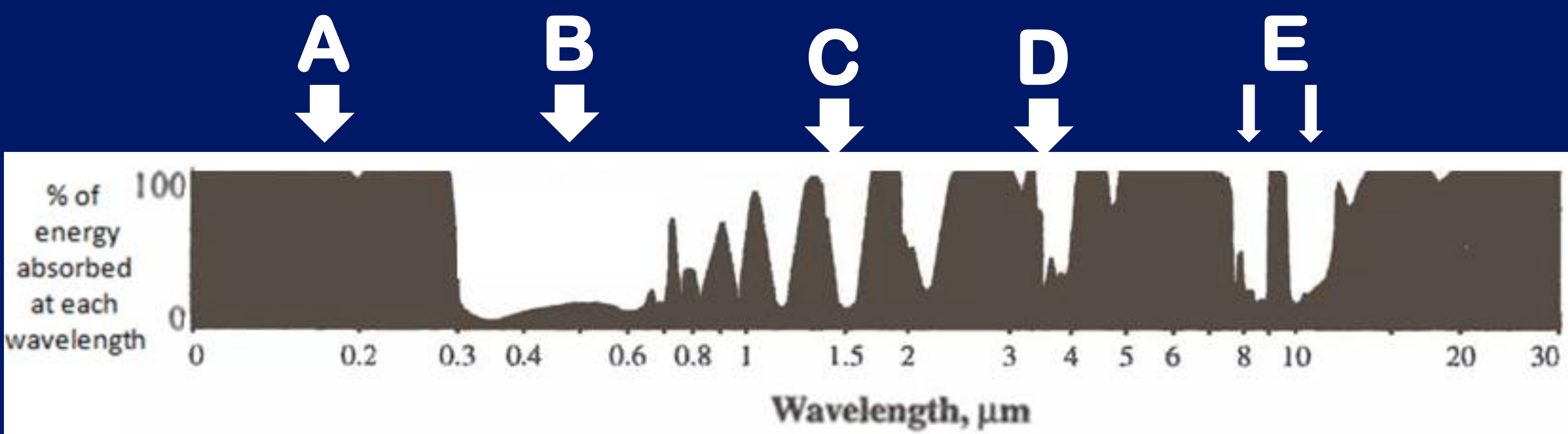
. . . even though OZONE also absorbs radiation in the UV part of the spectrum!

Q3 - Here's the absorption curve for ALL the gases in the atmosphere put together, i.e. curve for the **"Whole Atmosphere"**

Last week we talked about two **"windows"** in the curve that indicate at what wavelengths radiation easily comes **IN** to the surface of the Earth or escapes **OUT** to Space.

Where are these two windows?

1: A + B **2:** B + E **3:** C & D **4:** D + E



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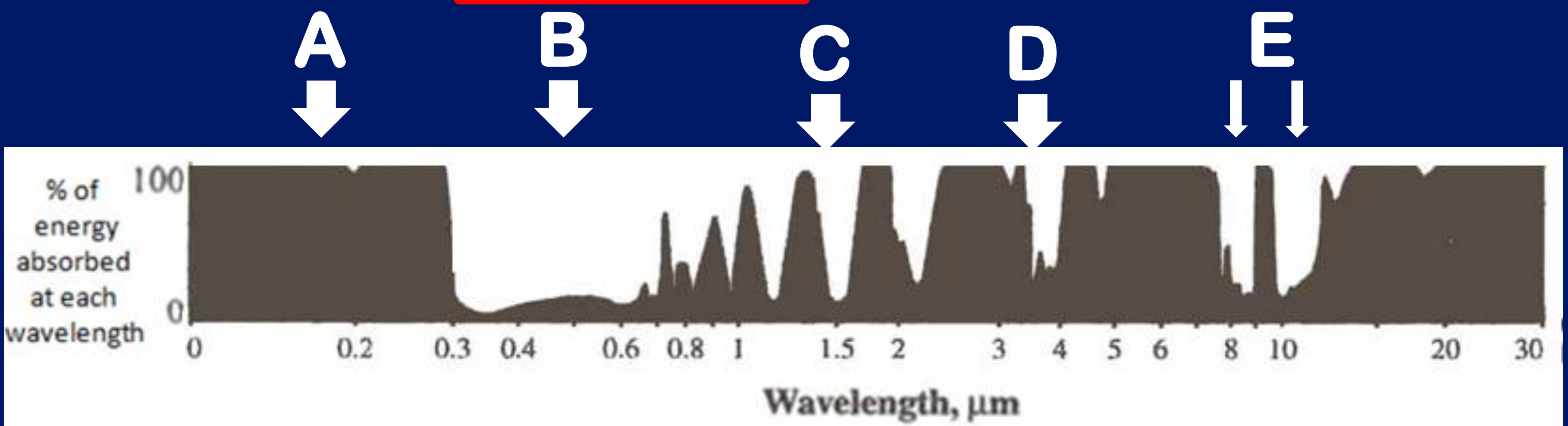
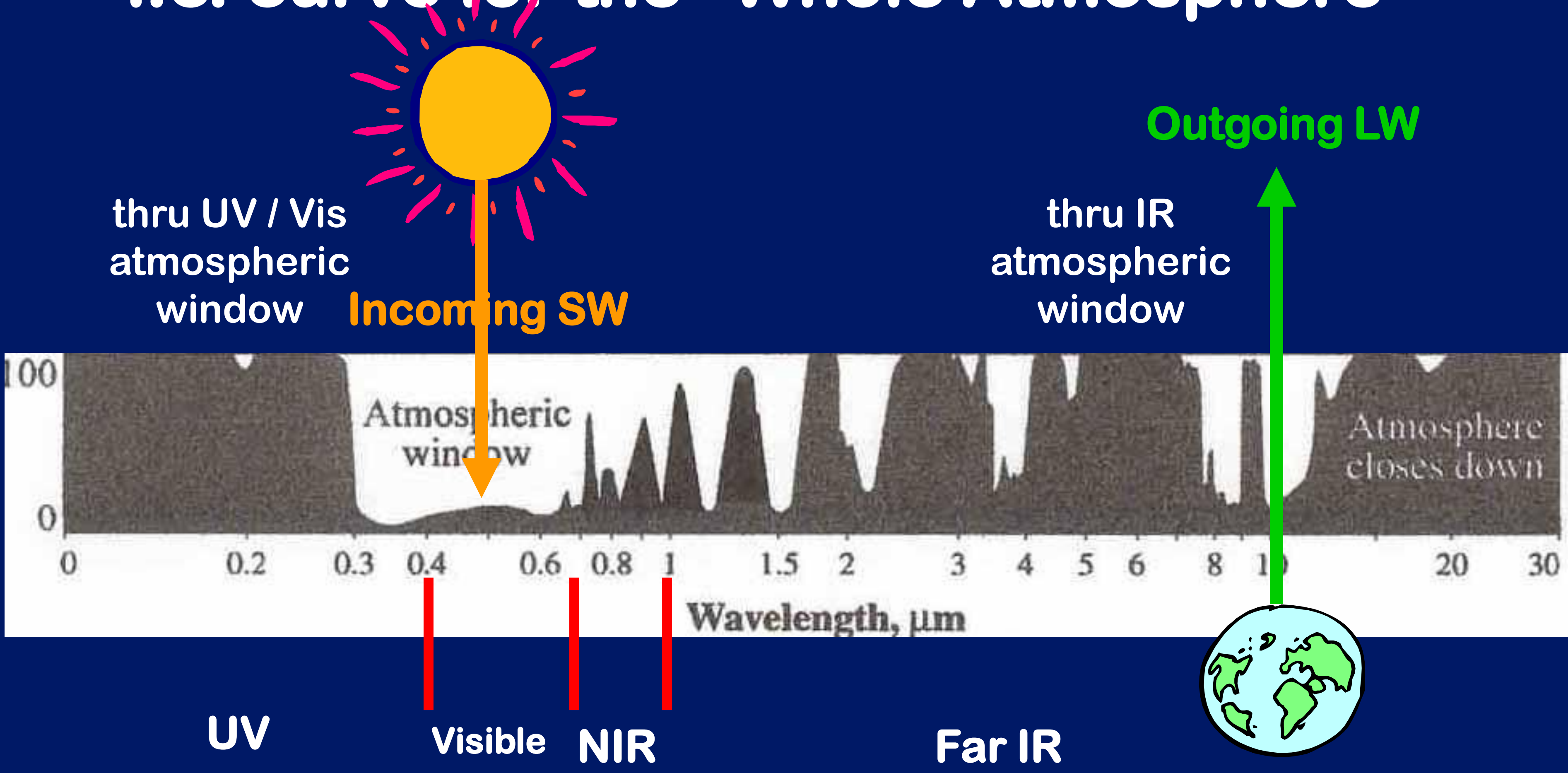


Absorption by ALL the gases in the atmosphere put together –

i.e. curve for the "Whole Atmosphere"



Bottom row p 38

KEY CONCEPTS TO GET OUT OF ALL OF THIS:

1. Solar radiation is mostly in shortwave (SW) form (visible and UV).

Most visible & UV wavelengths are TRANSMITTED through the atmosphere but some (esp. harmful UV) are absorbed on their way to Earth's surface by O_2 and O_3.

☺

2. Most of the incoming solar energy absorbed by the Earth and the atmosphere is absorbed ***at the EARTH'S SURFACE*** which then radiates IR outward to heat up the atmosphere.

Hence, the **ATMOSPHERE is HEATED** primarily from **BELOW**
(i.e. from terrestrial radiation)

☺

3. Terrestrial radiation is mostly in **longwave (LW) form (IR).**

Much of the outgoing terrestrial radiation is **ABSORBED by H_2O and CO_2 (and other GH gases)** before it escapes to space, and it is re-**radiated back to the Earth's surface**

This is the
"Greenhouse Effect".

4. The re-radiation of LW (IR) energy to the Earth's surface by GH gases is what keeps the Earth in the **"just right" temperature range** for water to be present in all 3 phases and just right for US too!

Without the "Greenhouse Effect," the Earth would be too COLD for life as we know it!

Topic # 8
ATMOSPHERIC STRUCTURE & CHEMICAL COMPOSITION

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

Class Notes pp 39- 43

OBJECTIVES:

To understand:

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

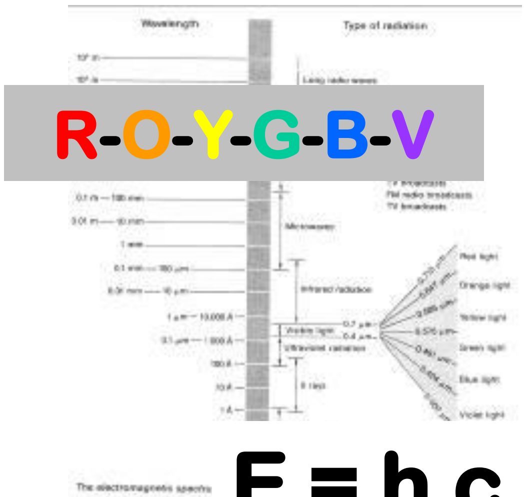
-- which **GASES** are in the atmosphere

-- **where** they are concentrated, and

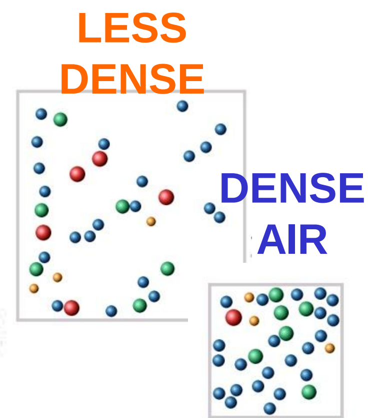
-- why gases at different levels are linked to the **Greenhouse Effect** & **Ozone Depletion**

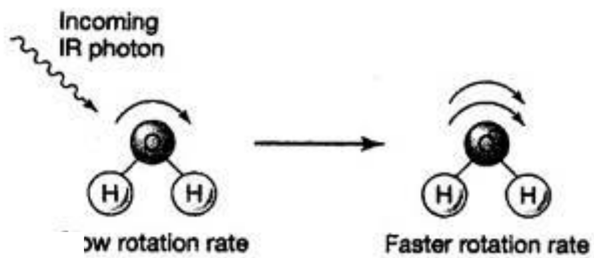
☺

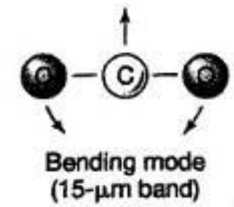
Things you've seen before that will all come together under this topic:



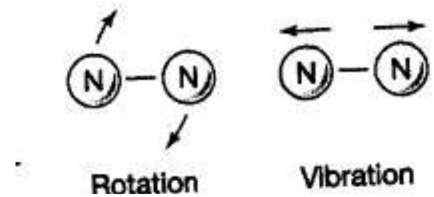
$$E = \sigma T^4$$

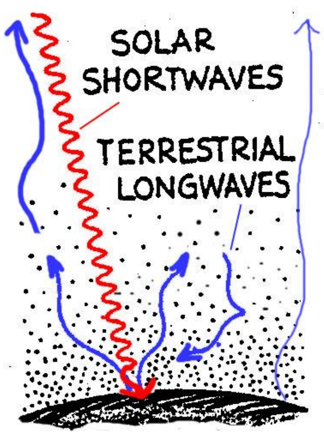


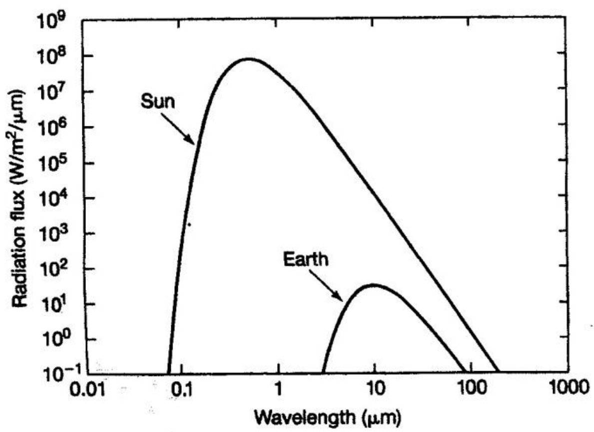


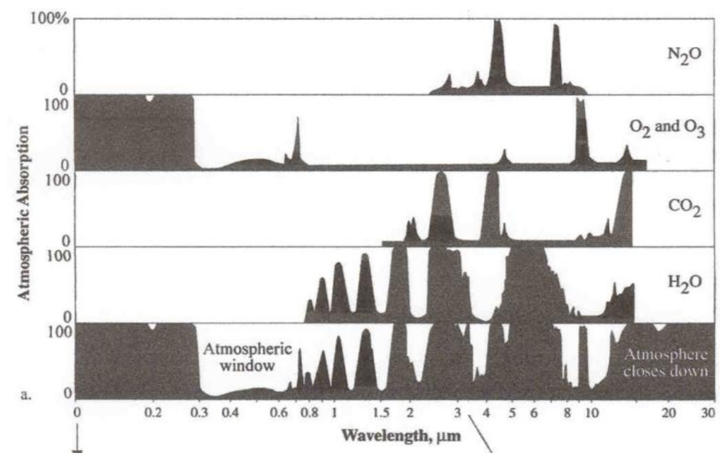


$$E = h\,c\,/\,\lambda$$









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

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

~ Adlai Stevenson

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

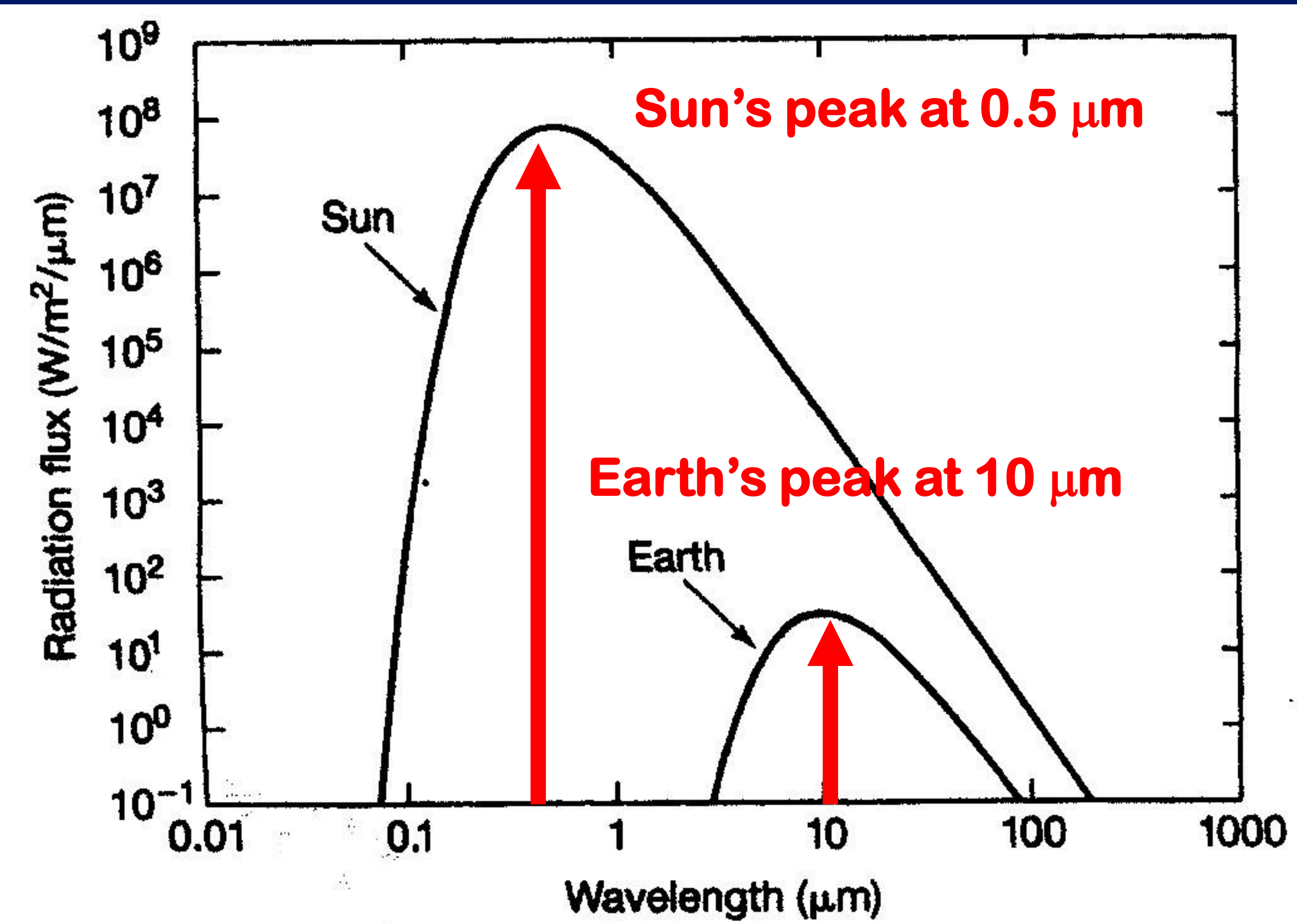
(1) Some Incoming SW radiation from the SUN goes right through the atmosphere to Earth

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

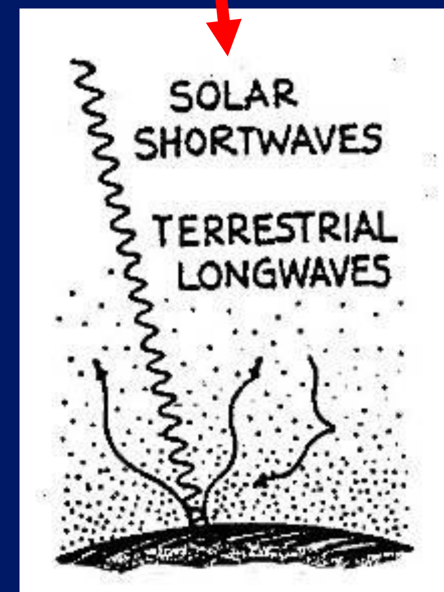
BUT WHAT ABOUT INCOMING SOLAR SW? IS IT DEPICTED CORRECTLY?

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

review



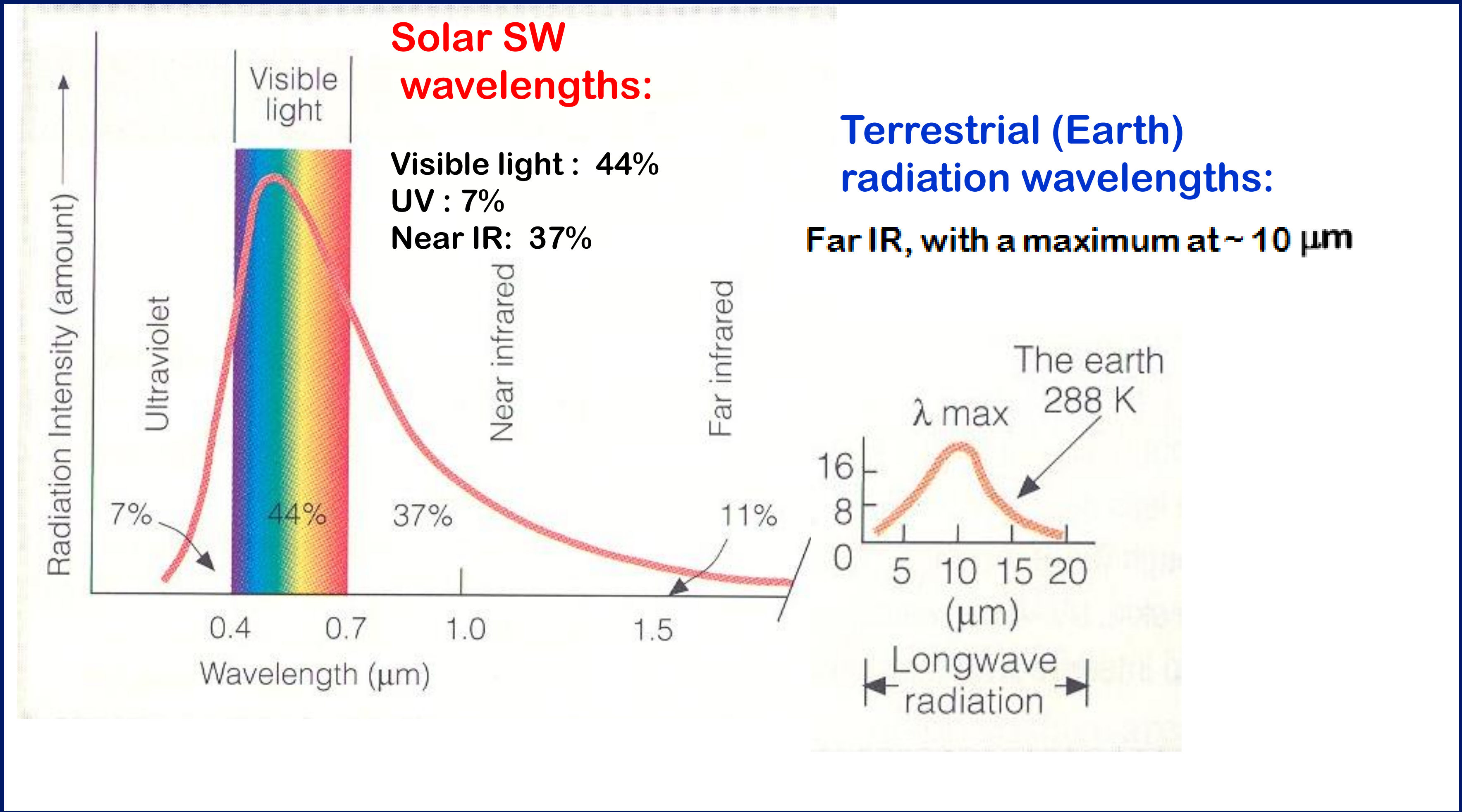
Wein's is the law behind this cartoon



Review p 36

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

TERRESTRIAL radiation (LW) = Far IR

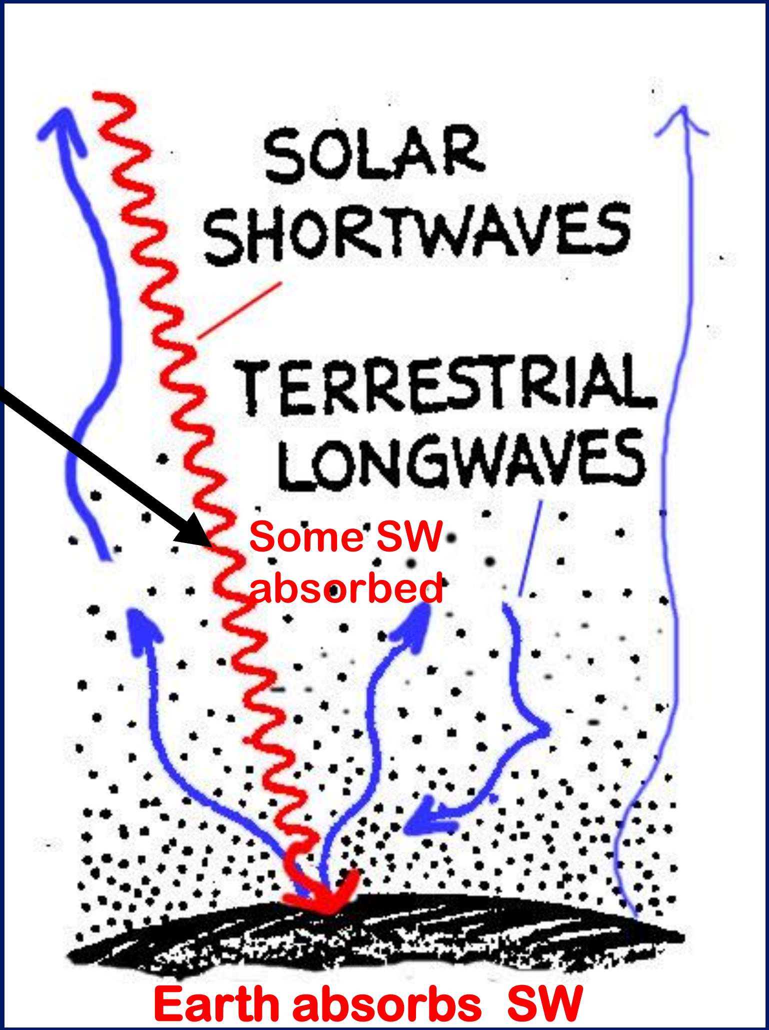


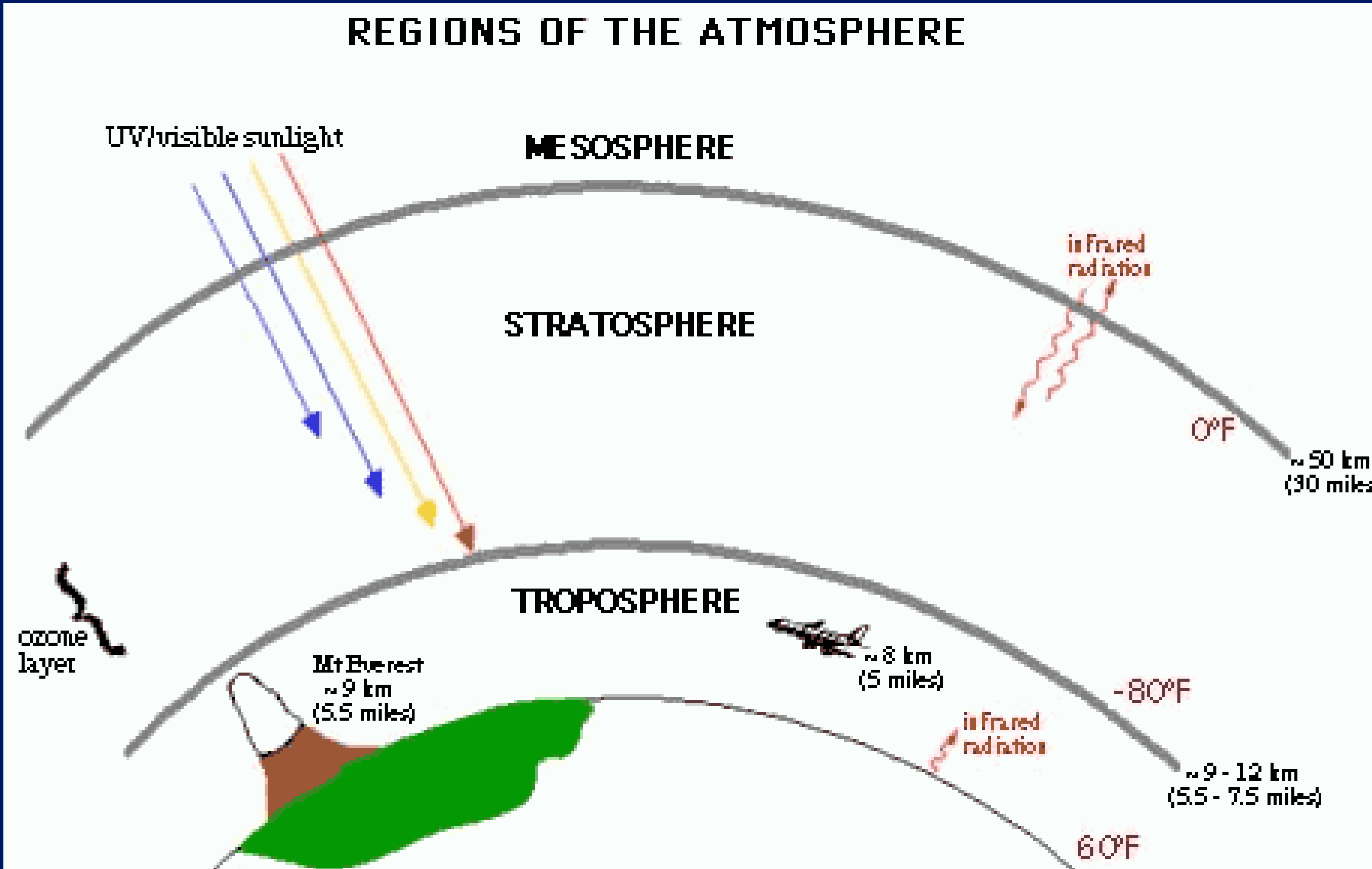
Review p 36

How do we correct the depiction of incoming SW?

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

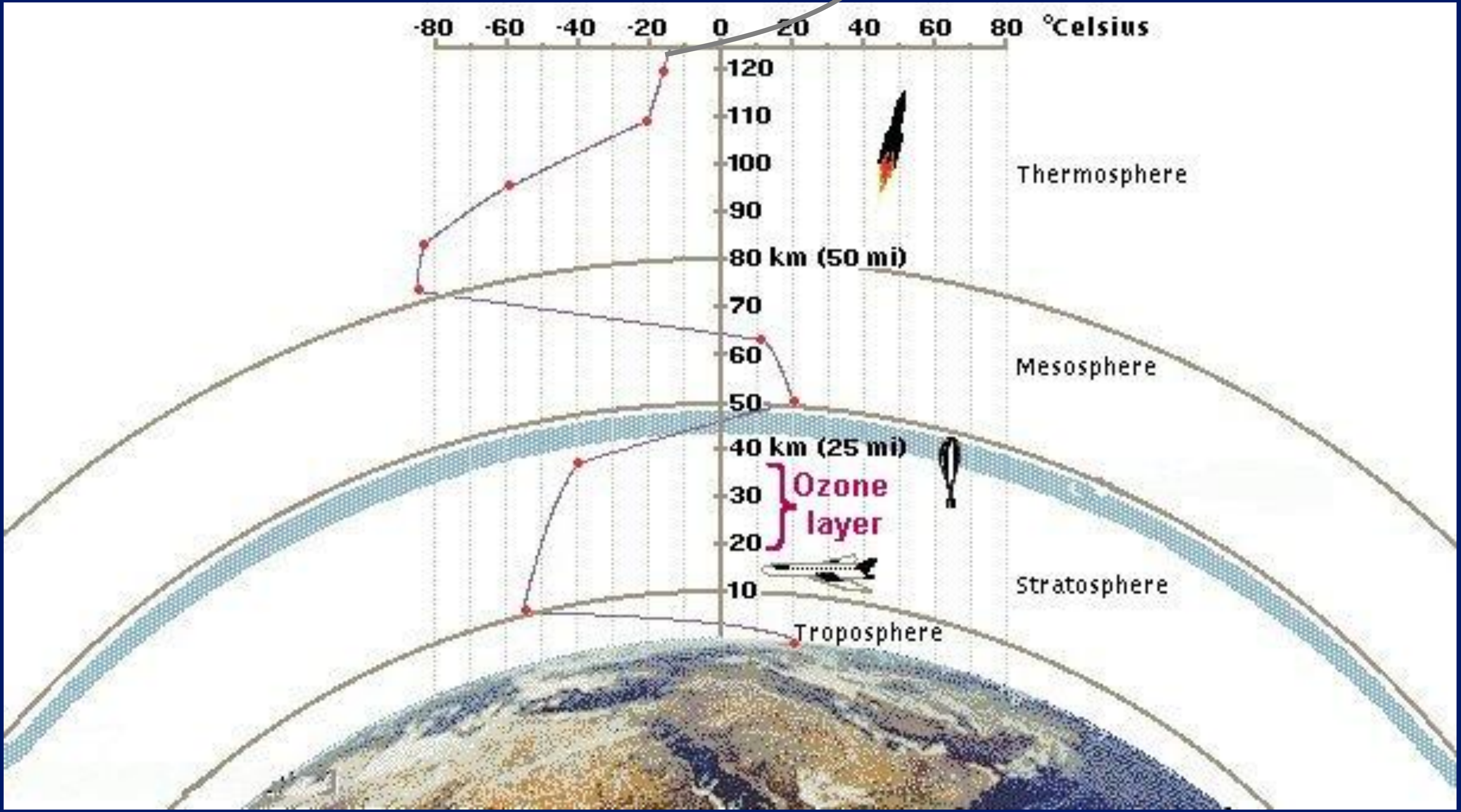
(in addition to terrestrial LW (IR) radiation being absorbed in the GHE)





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

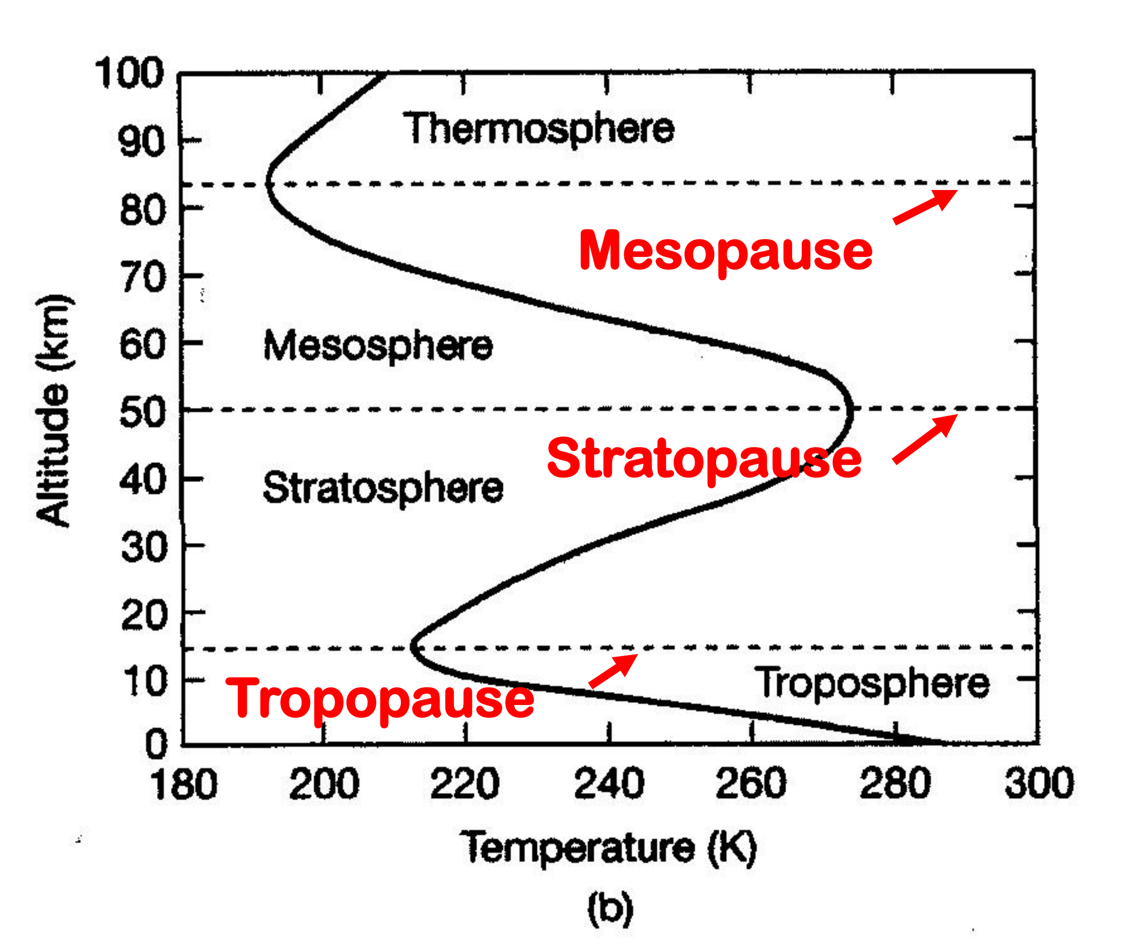
~1700 C at 600 km (~370 mi)



The Vertical Structure of the Atmosphere

KEY CONCEPT:

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



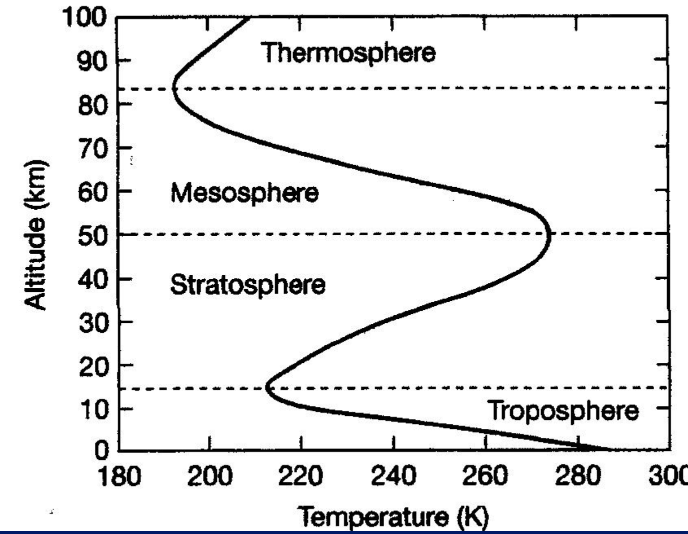
p 40 top

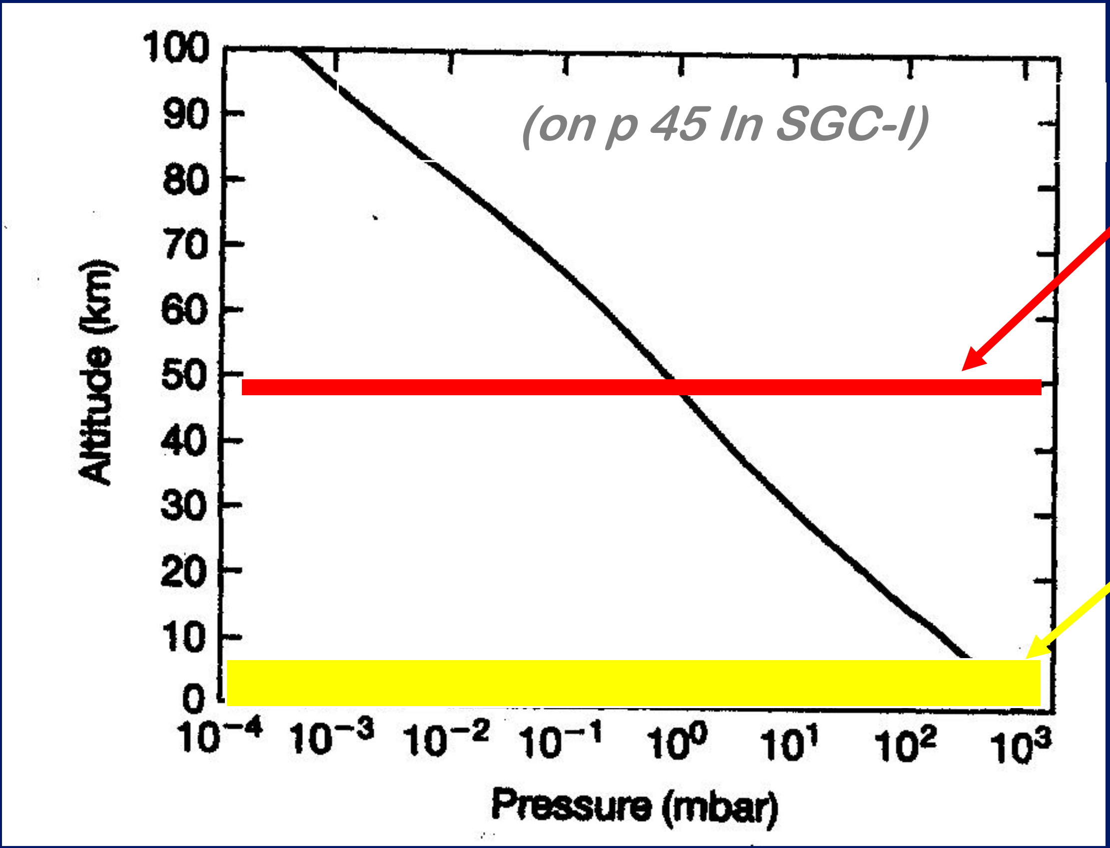
"TRy Sally's Maroon THermals"

. . . or
think up
your own!

Atmospheric Pressure = weight of the air column above

Atmospheric Pressure & Mass Vary with Height





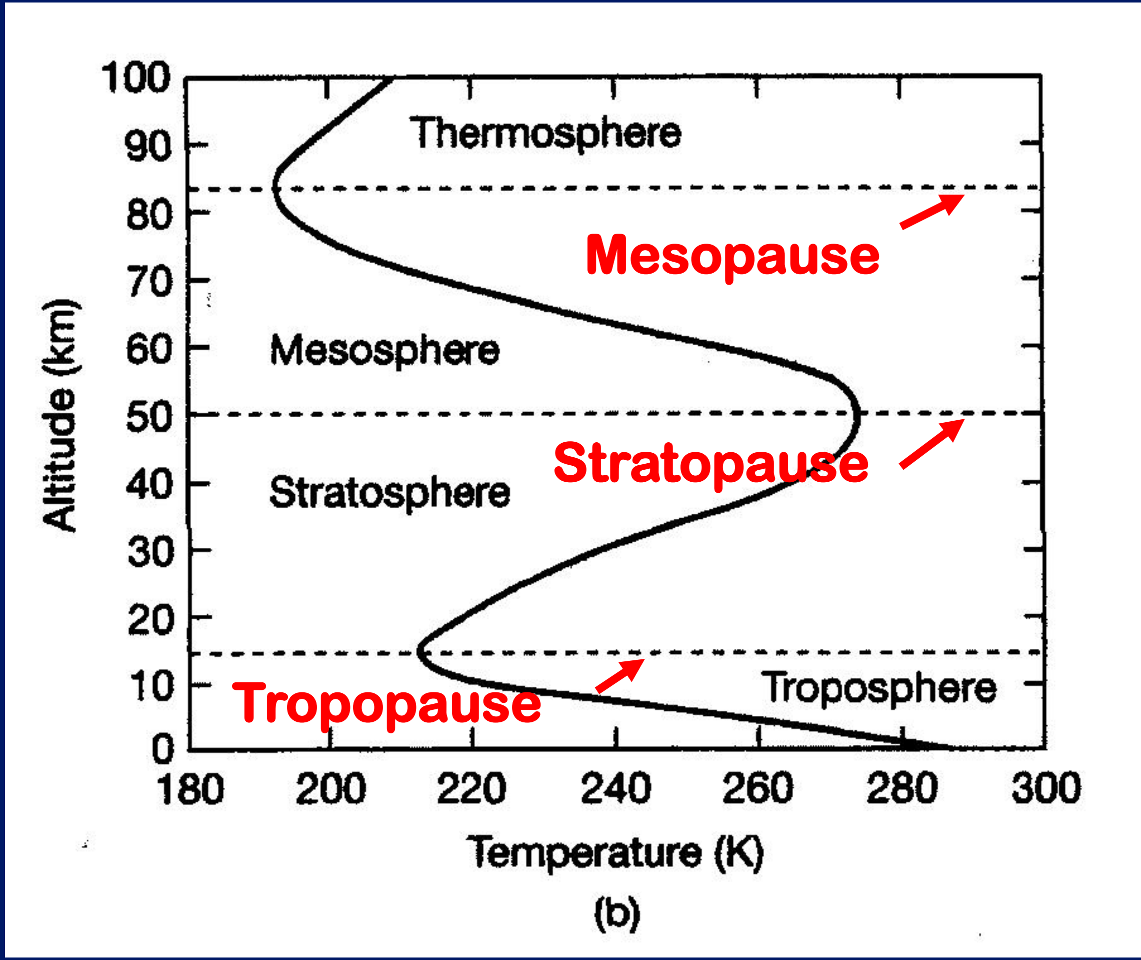
99% of mass lies below ~ 50 km (top of Stratosphere)

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

☺

The Vertical Structure of the Atmosphere

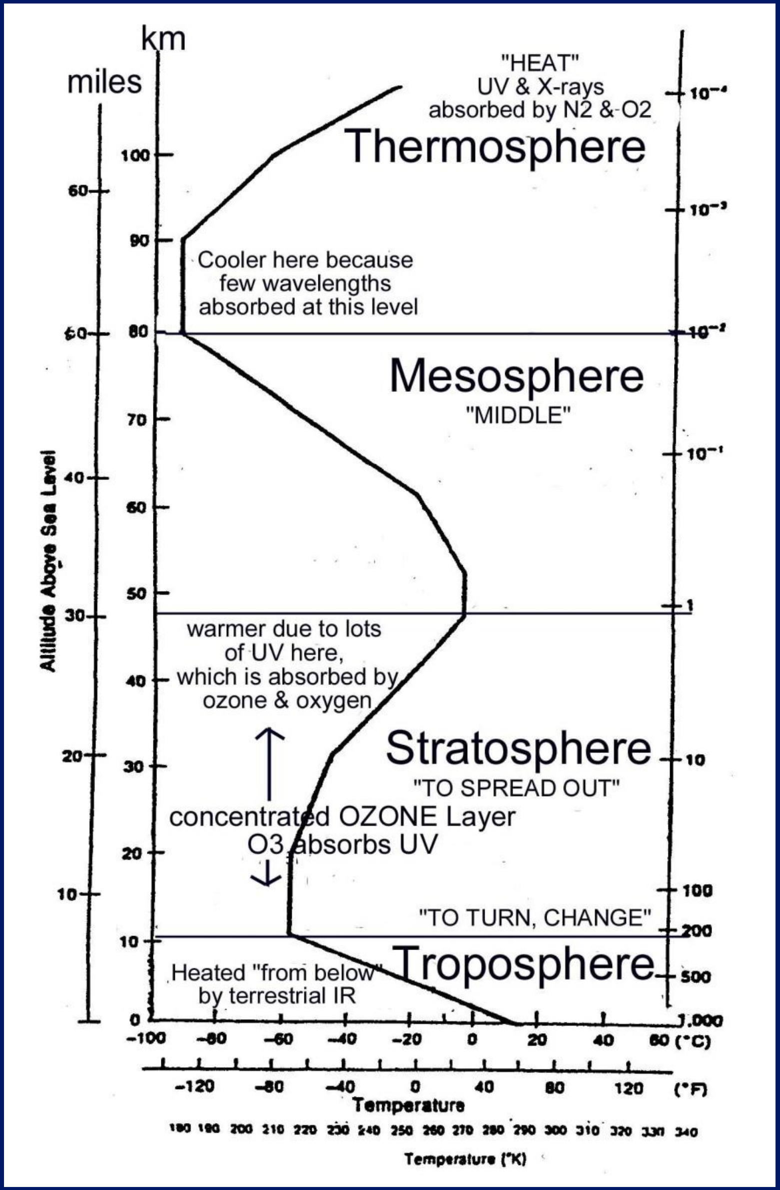
Why the zig-zags in the temperature / height graph?



The changes in temperature with height are the result of:

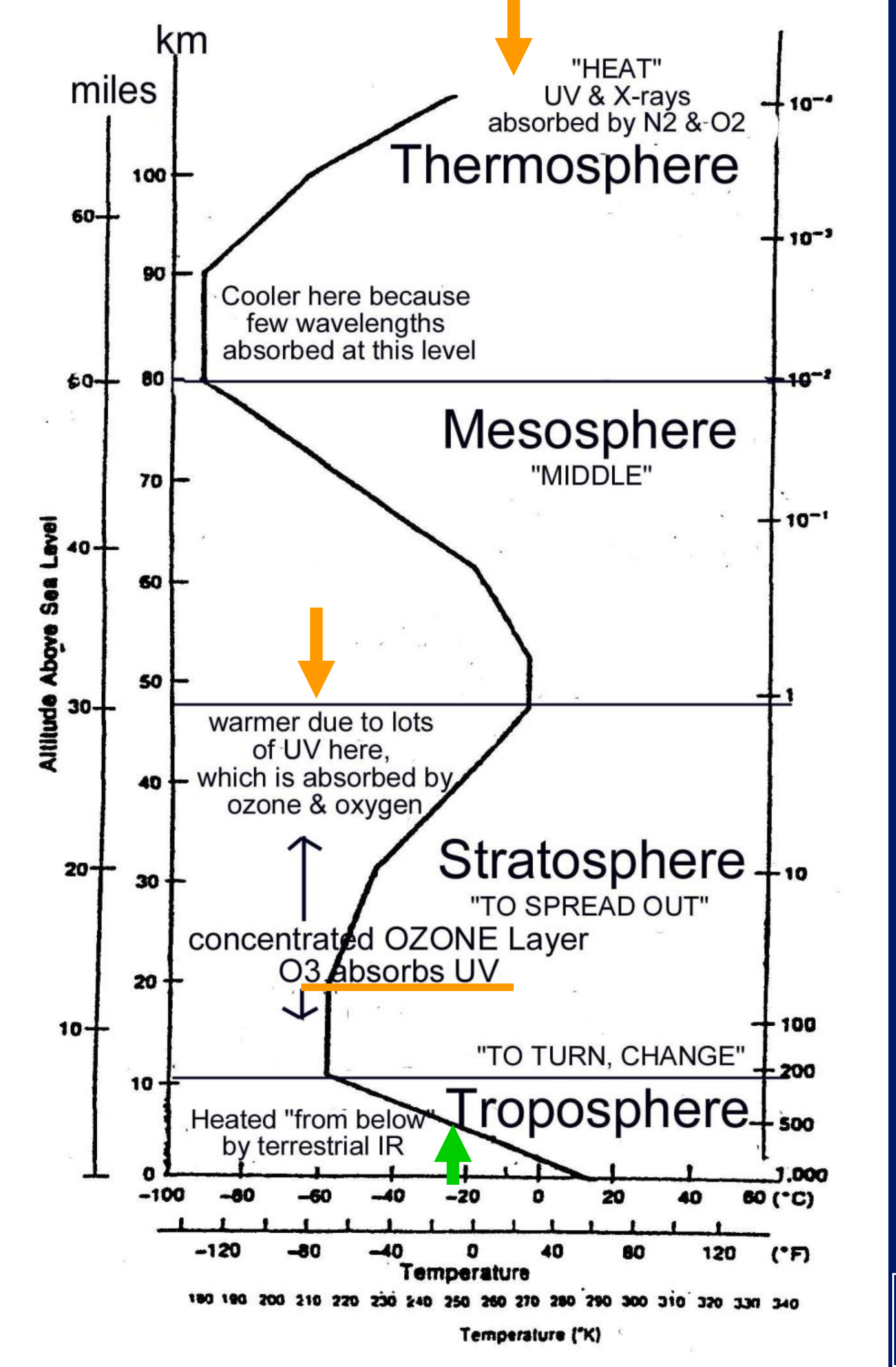
differential absorption of shortwave (SW) & longwave (LW) radiation

by atmospheric GASES concentrated at various altitudes.

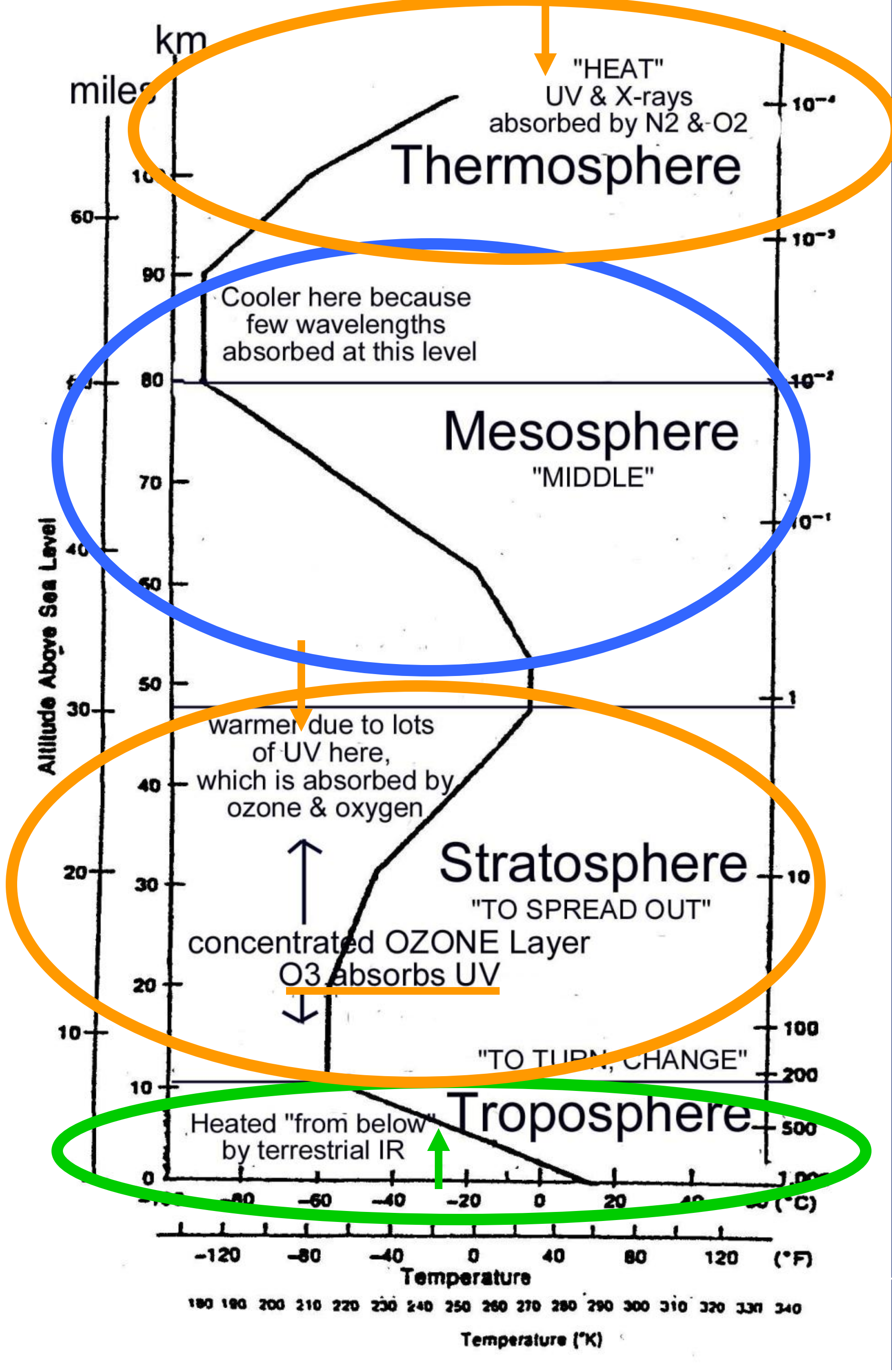


Incoming solar SW (mostly visible & near IR + UV)

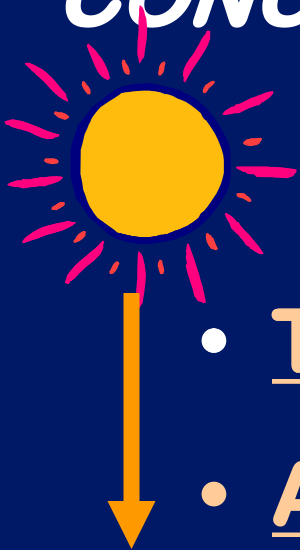
Outgoing terrestrial LW (Far IR) radiated from Earth's surface



Here's why these changes in temperature occur →

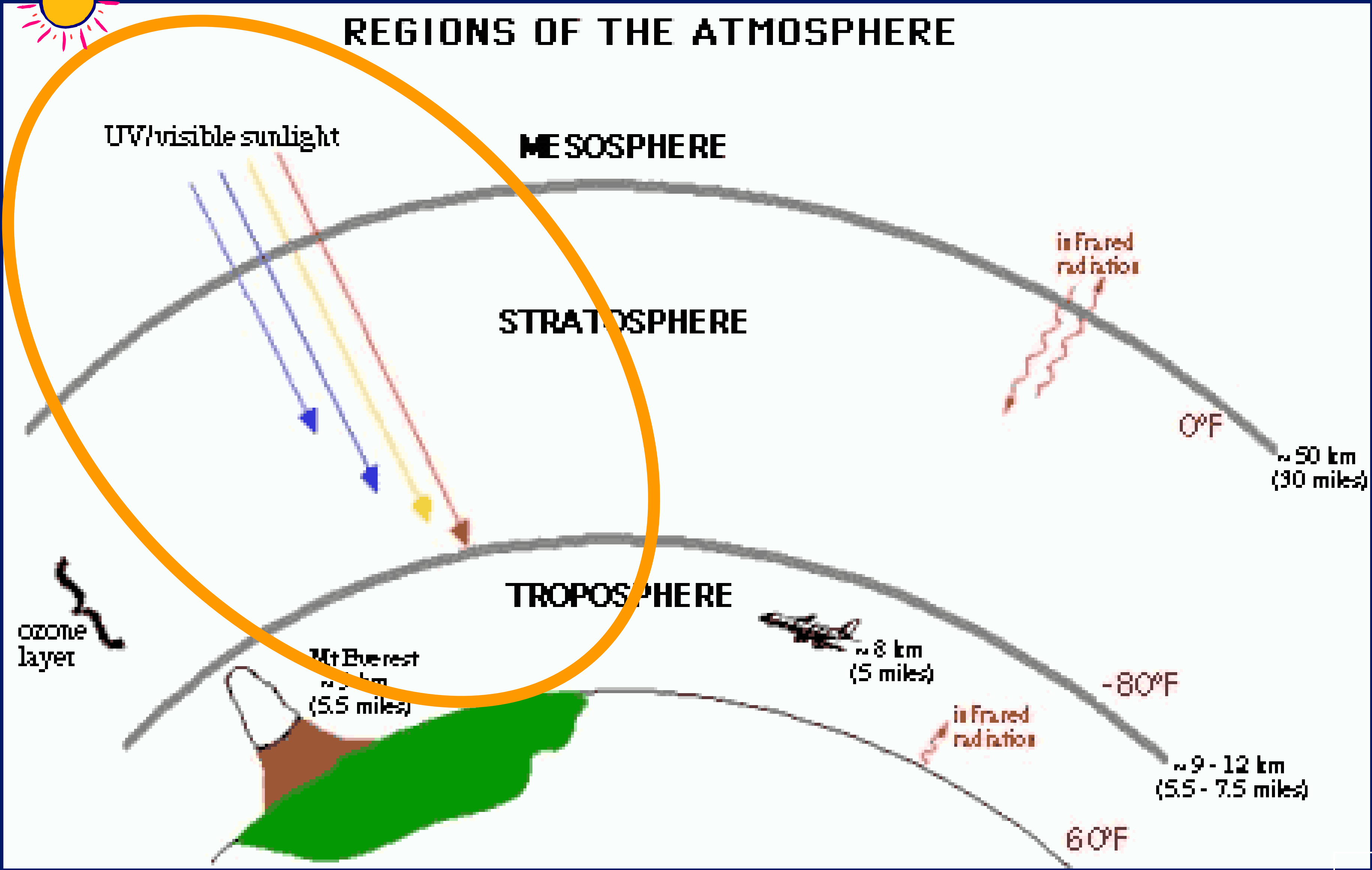


KEY CONCEPT: **On its way to the Earth's surface, several things can happen to incoming <u>SOLAR RADIATION</u>:**



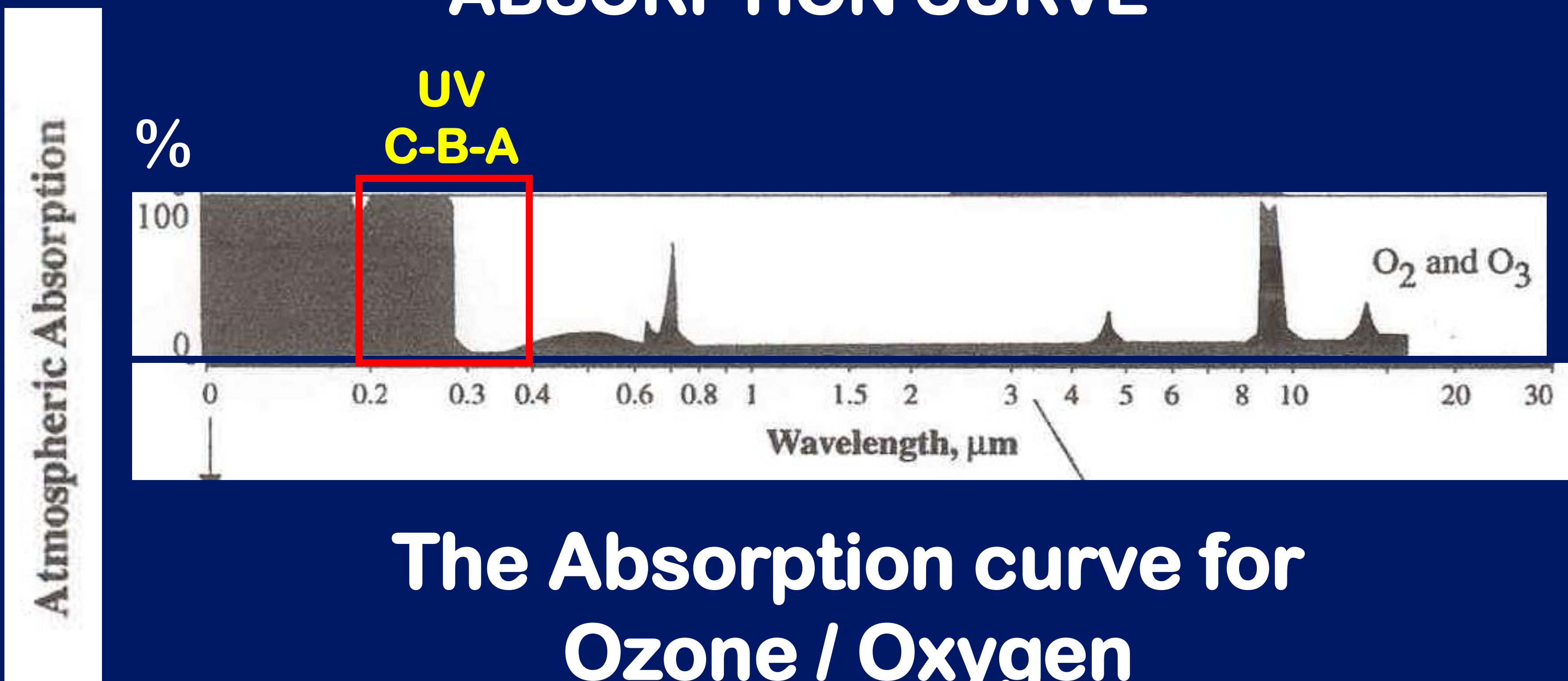
- **<u>TRANSMITTED</u> (to Earth's surface)**
- **<u>ABSORBED</u> (by gases, dust, clouds)**
- **<u>SCATTERED / REFLECTED</u>**
    - **<u>Reflected</u> back to space**
    - **<u>Scattered</u> (and indirectly transmitted to Earth's surface)**

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

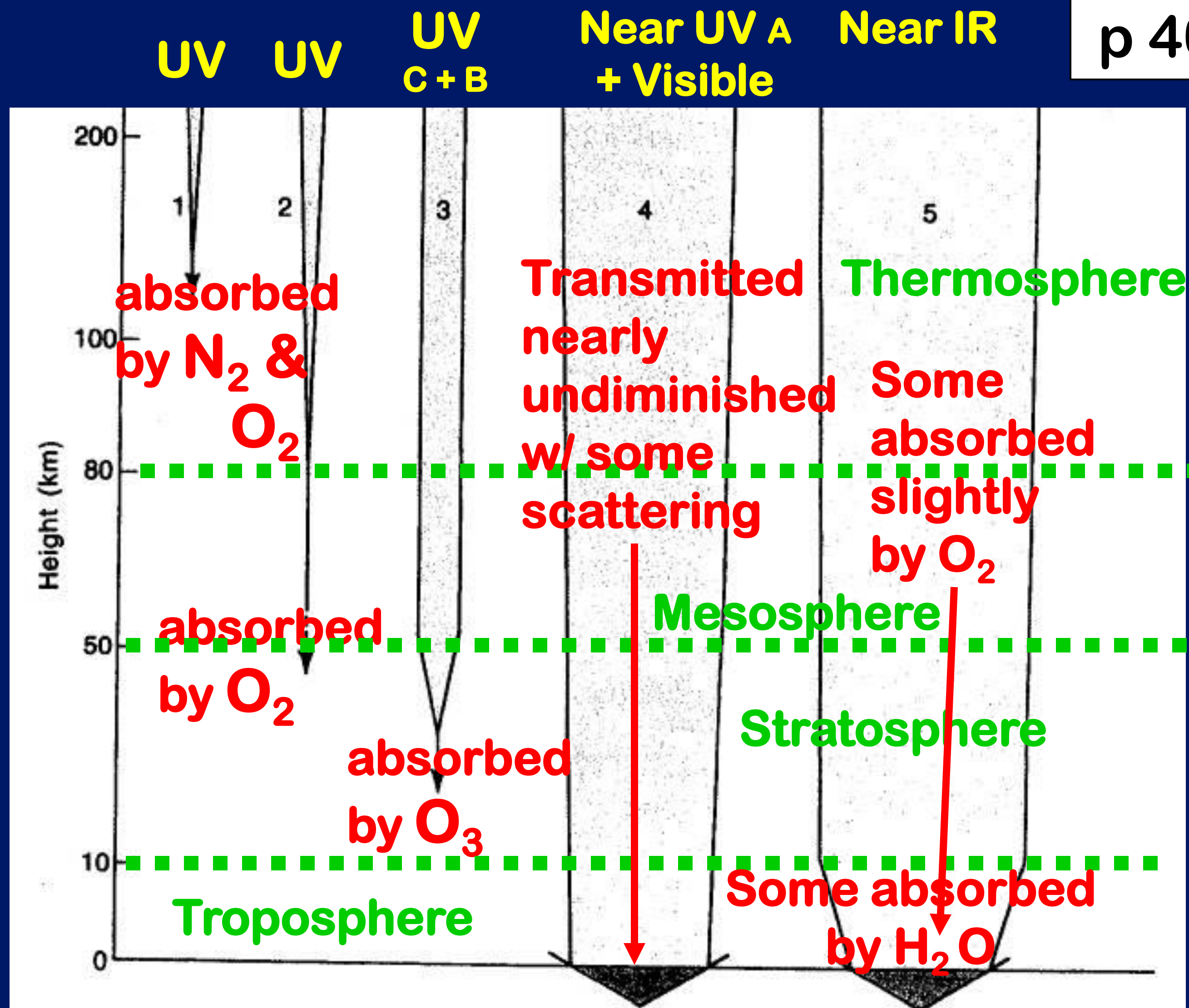


The Absorption curve for Ozone / Oxygen

☺

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 μm $\le \lambda < 0.18$ μm, absorbed by O_2.*
3. *UV, 0.18 μm $\le \lambda < 0.34$ μm, absorbed by O_3.*
4. *Near UV and visible, 0.34 μm $\le \lambda < 0.7$ μm, transmitted nearly undiminished except for scattering.*
5. *Near IR, 0.7 μm $\le \lambda < 3$ μm, absorbed slightly by O_2, and in troposphere by H_2O vapor.*

Q 4. **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. UVA + Visible
5. Near IR
6. BOTH 4 + 5

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Q 5. Why does ARROW #5's radiation get attenuated 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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Q 5. 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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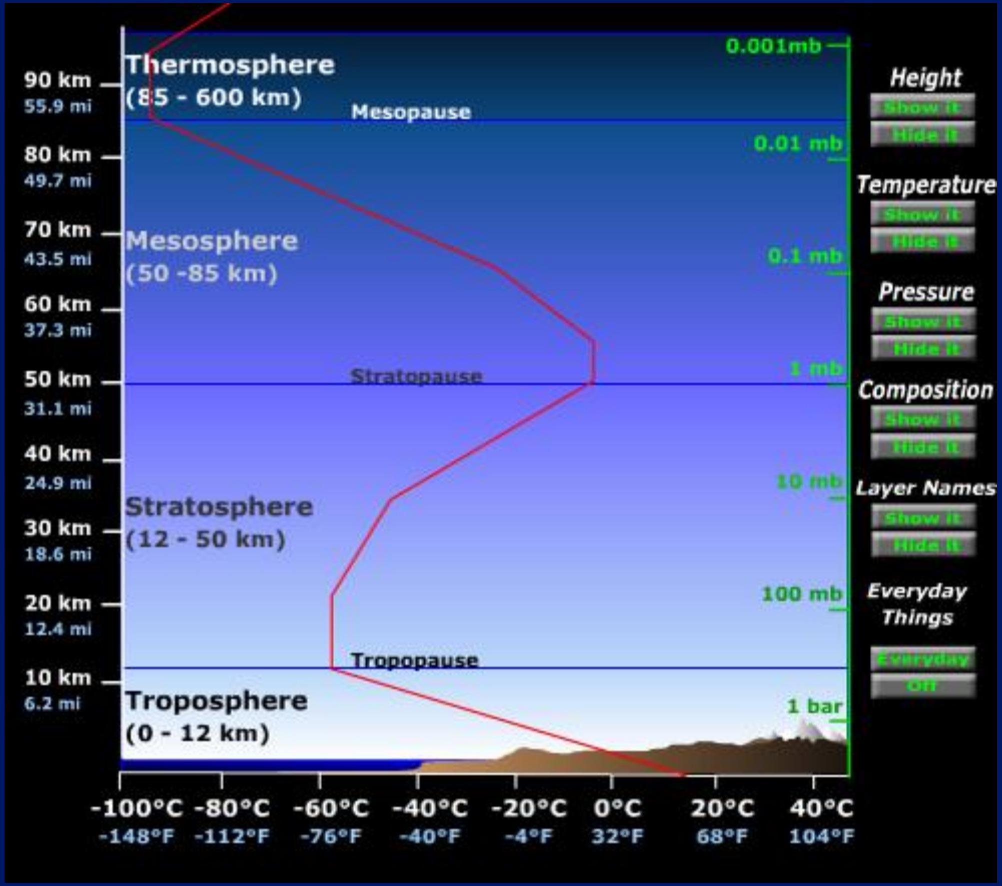
REVIEW . . .

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



Q 7 - 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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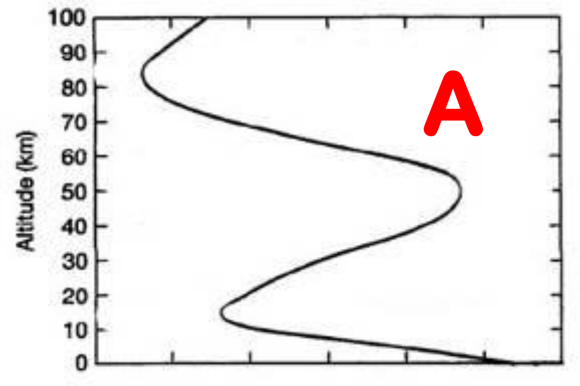
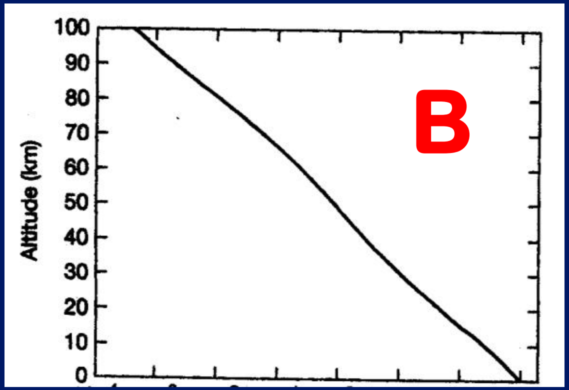
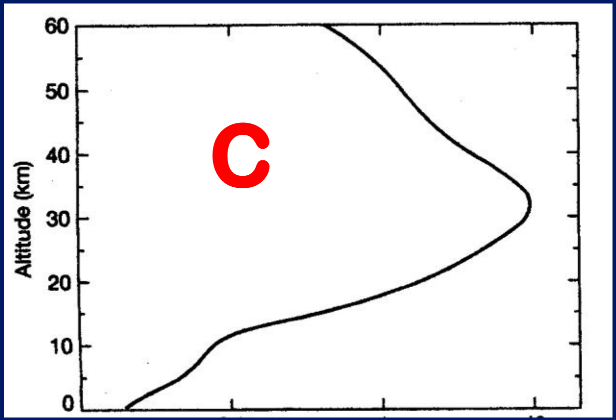
Q8 – Here are 3 graphs showing "something" varying with altitude in the atmosphere. Which is which?







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

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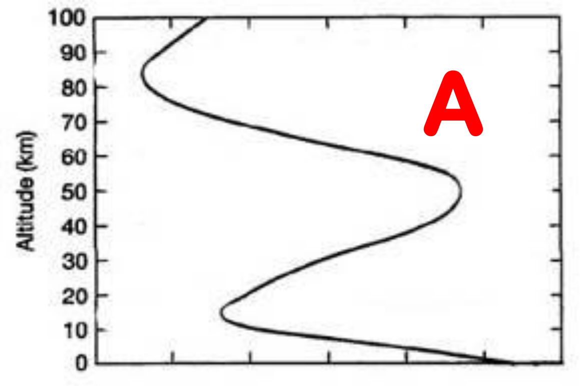

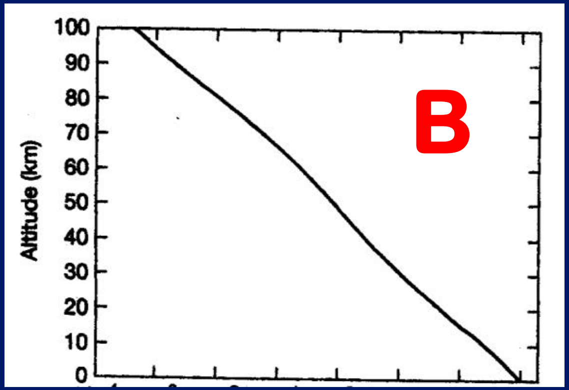

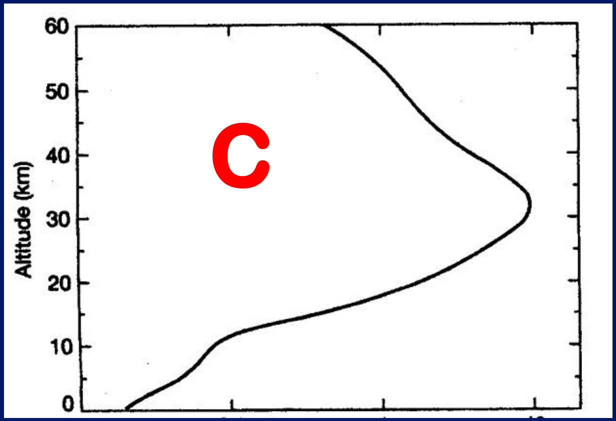

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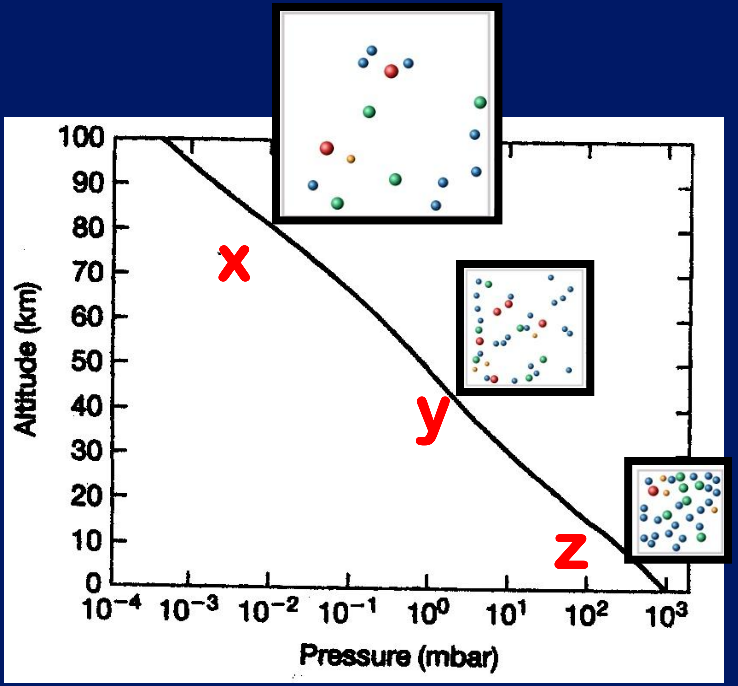
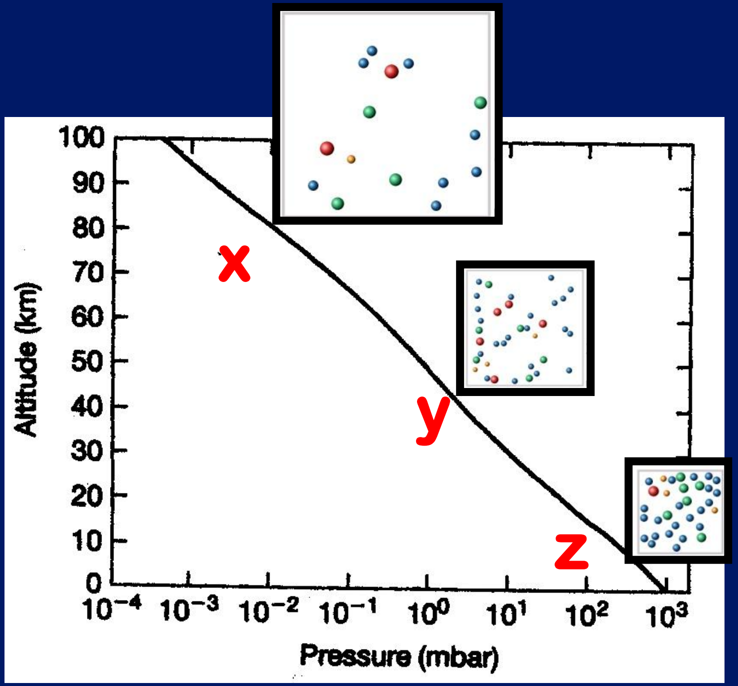
Q9 – Here is the graph of atmospheric pressure vs. altitude, with "parcels of air" shown to depict the density of the atmosphere's gases at 3 different altitudes. If the air in Parcel X is forced to subside (sink) to the altitude of Parcel Z, what will happen to the air in Parcel X?

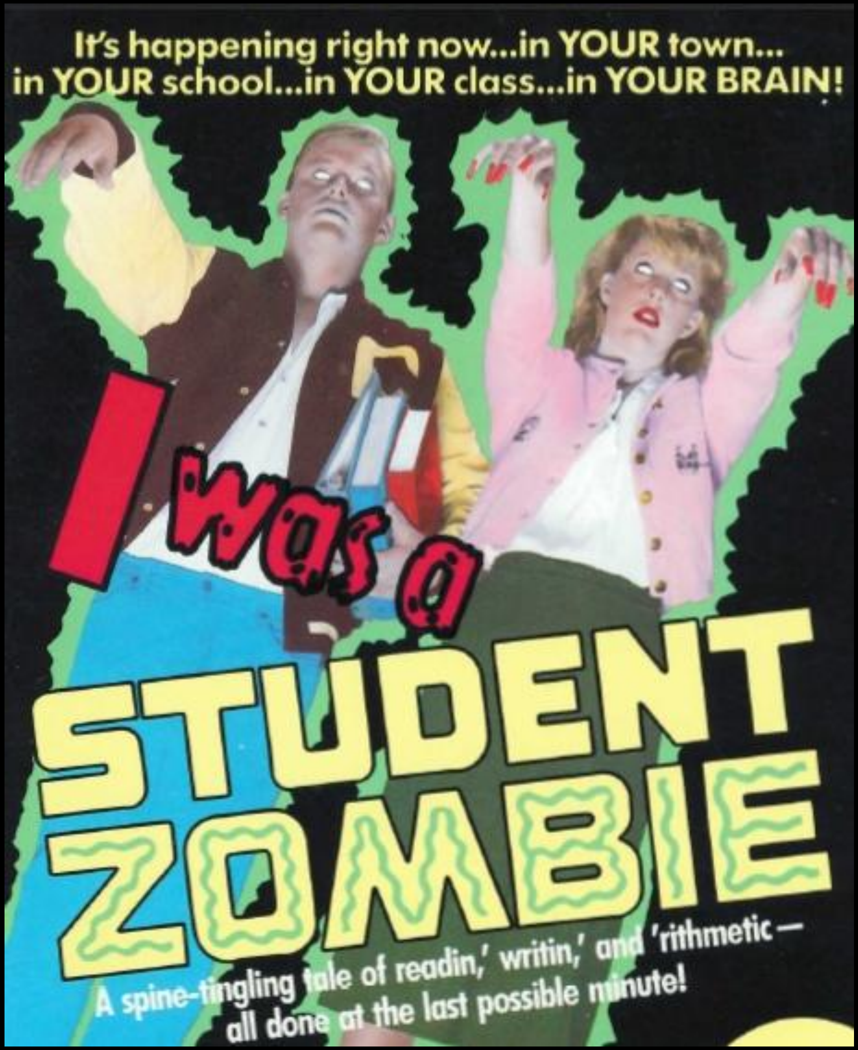


1. it will get more dense and get cooler
2. it will get more dense and warm up
3. it will get more dense, and no change in temperature will occur

Q9 – 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



ZOMBIE
BREAK !

The last segment of:

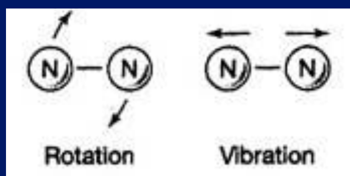
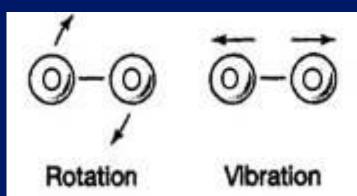
http://www.pbs.org/wgbh/nova/solar/

ATMOSPHERIC COMPOSITION

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

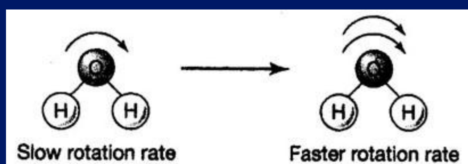
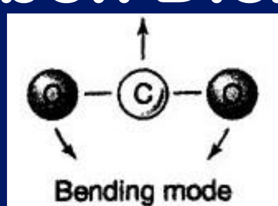
Which GHG's are changing in concentration due to HUMAN ACTIVITIES?

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	Sym bol	% 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 !

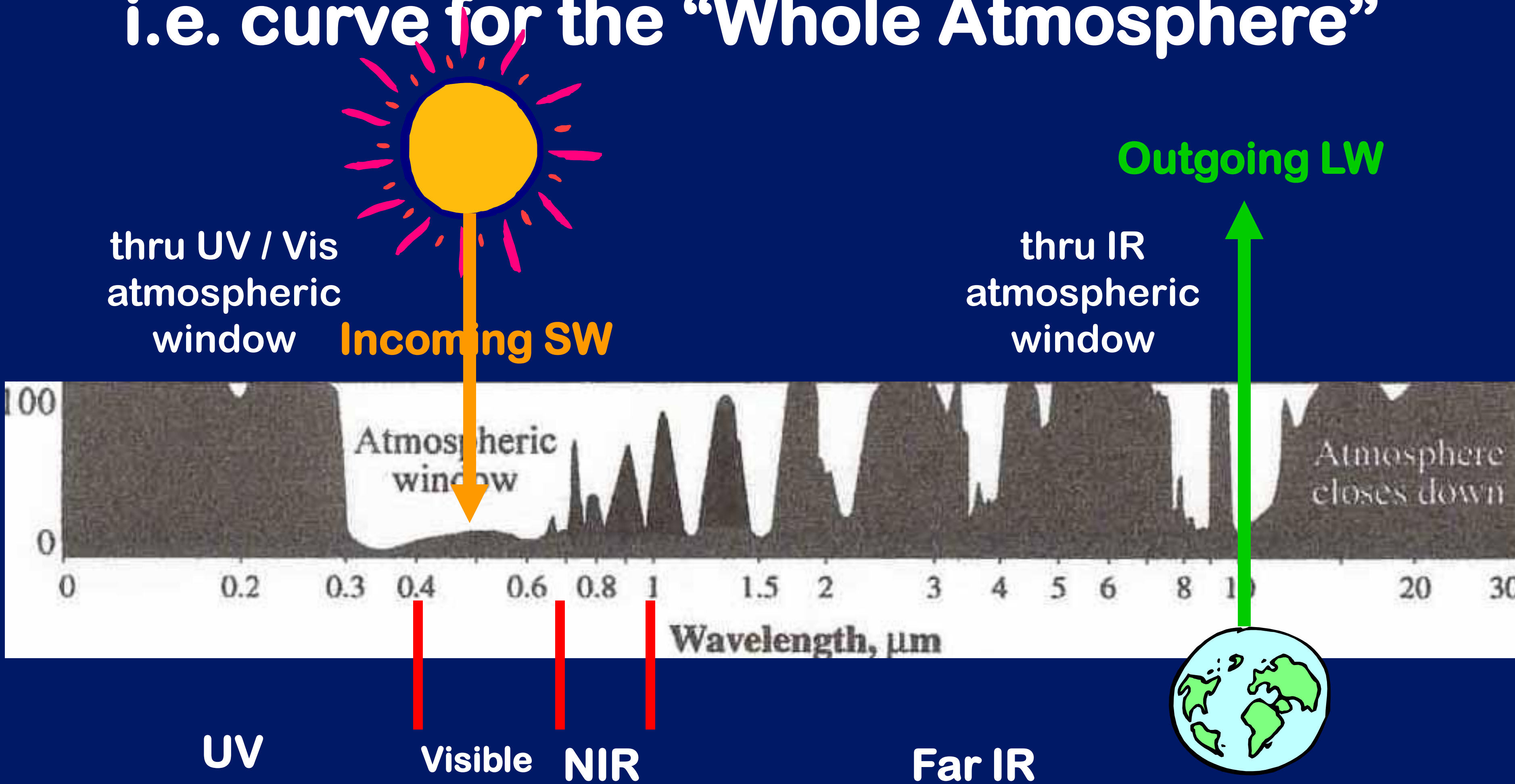
Other Important Greenhouse Gases:

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

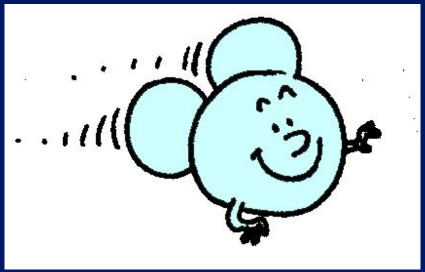
Greenhouse Gases!

Absorption by ALL the gases in the atmosphere put together –

i.e. curve for the "Whole Atmosphere"



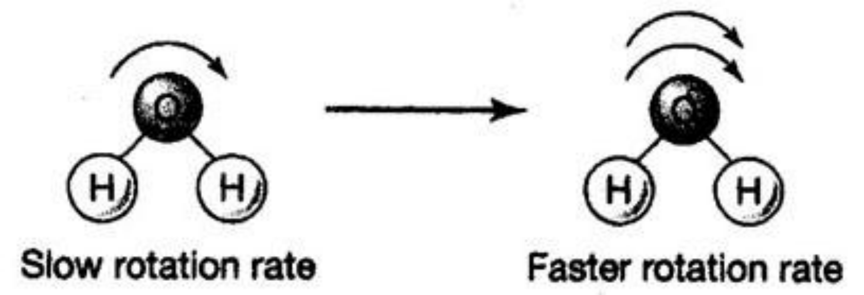
Review bottom of p 38



WATER VAPOR

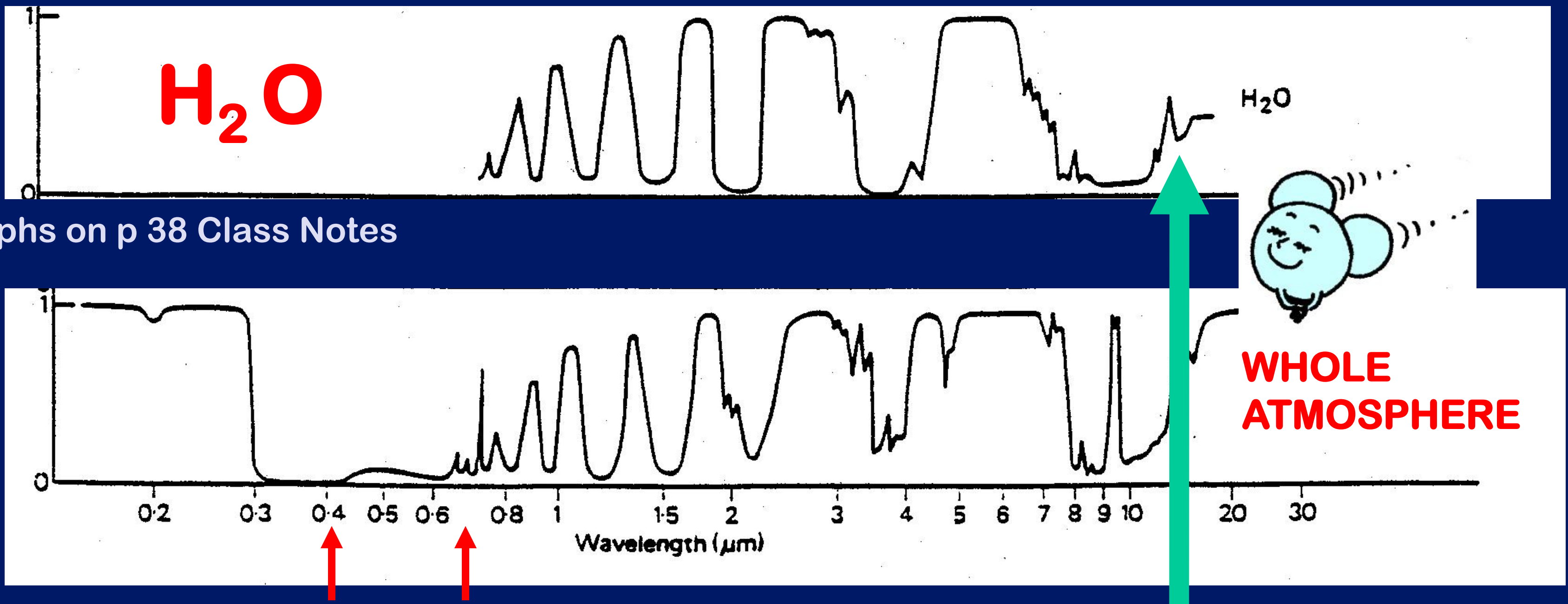
* Arrives in atmosphere naturally through evaporation & transpiration

* 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 41

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



Graphs on p 38 Class Notes

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!

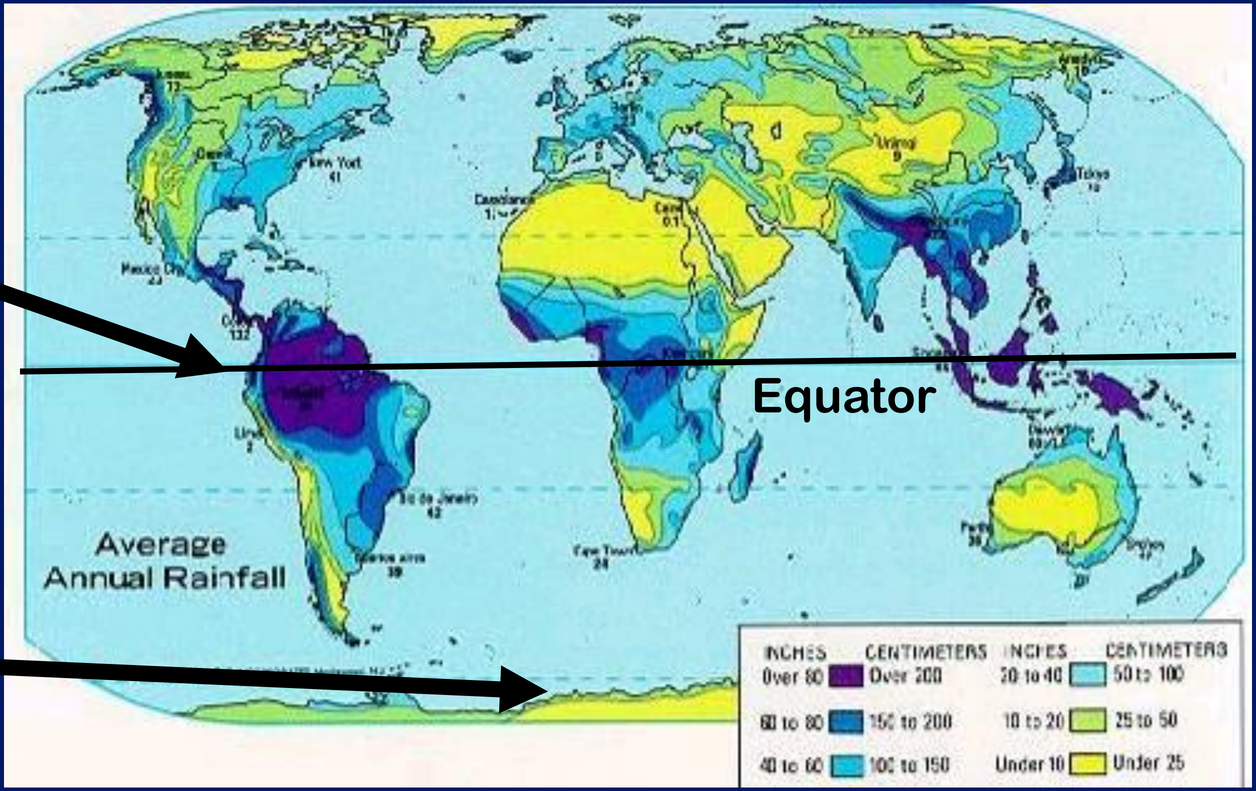
☺

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

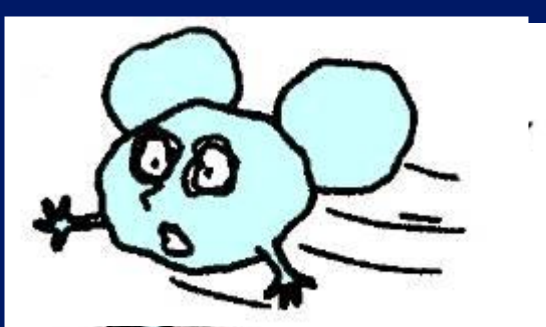


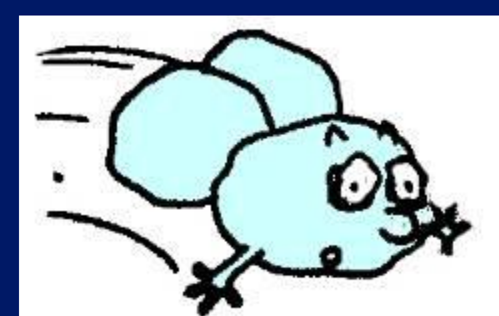
Just listen!

☺

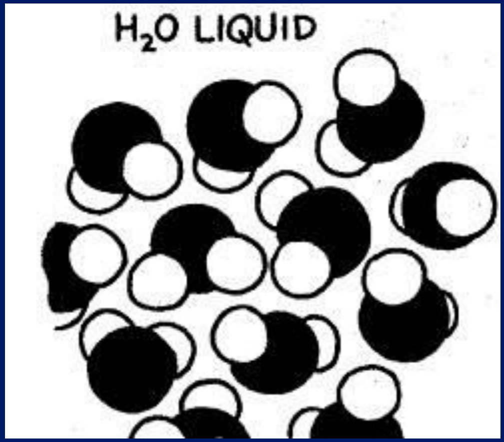
At higher air temperatures, H_2O molecules collide & rebound more frequently, leading to expansion of the air & the water vapor in the air.

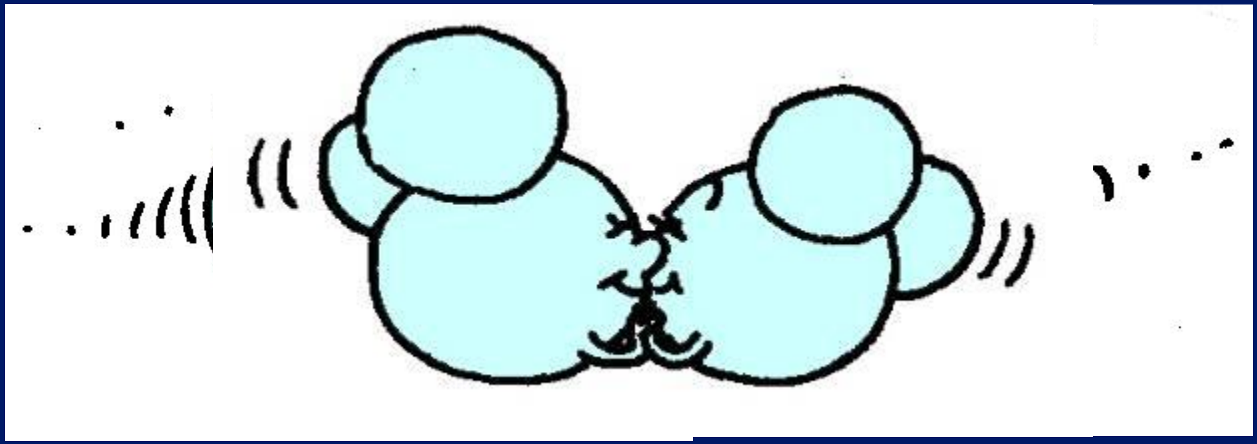
Hence hot climates can hold more water vapor in the air





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 <u>direct</u> response to human-induced factors, but if global temperatures get warmer, H_2O vapor in the atmosphere ***will* increase . . . .**

Why???

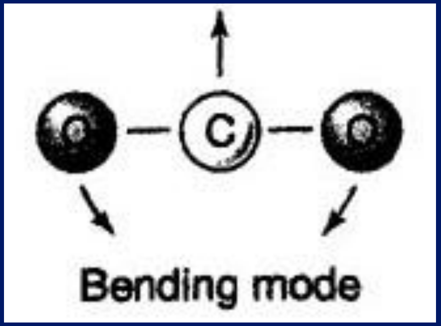
. . . due to more evaporation in the warmer climate!

THINK ABOUT THIS!

CARBON DIOXIDE:

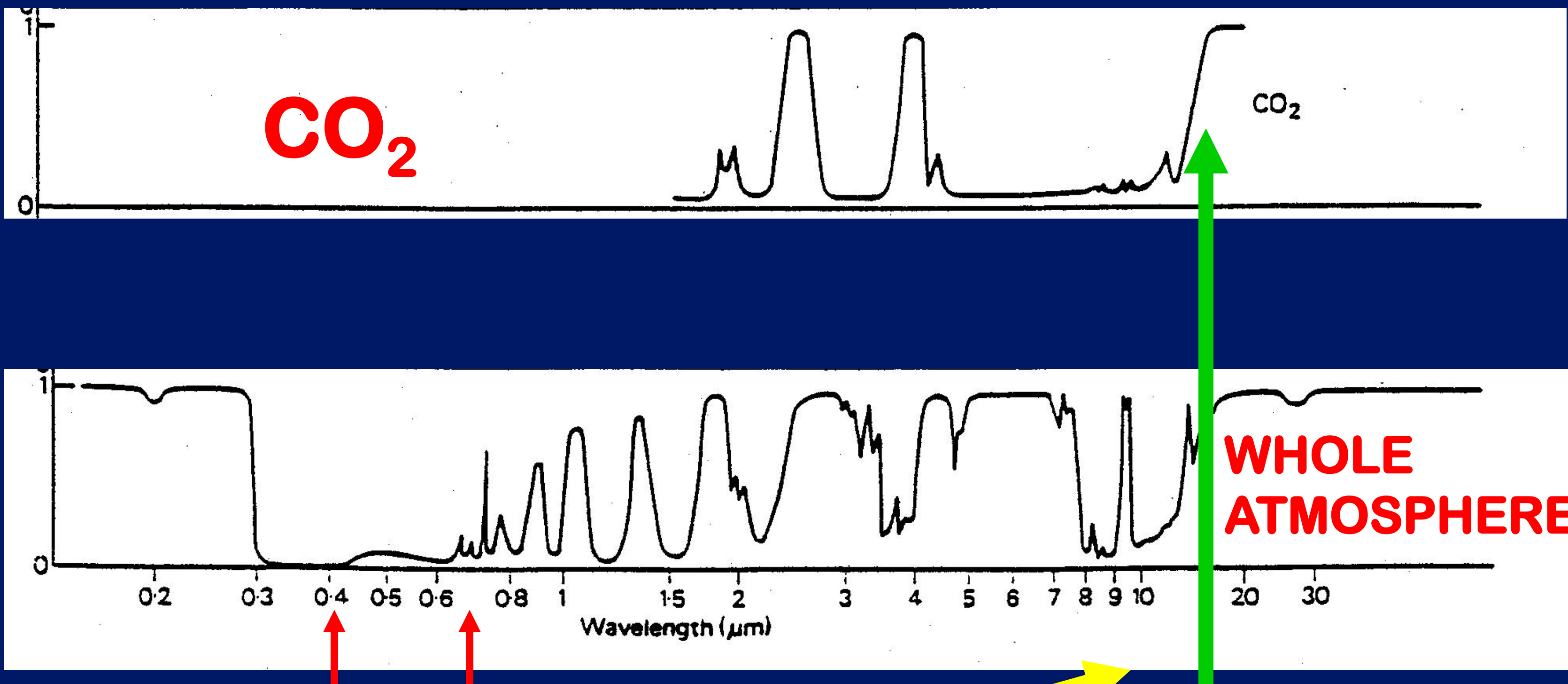
* Arrives in atmosphere naturally through the natural carbon cycle

* 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 41

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 38

CARBON DIOXIDE (cont.):

* Has increased dramatically since the 1800s due to:

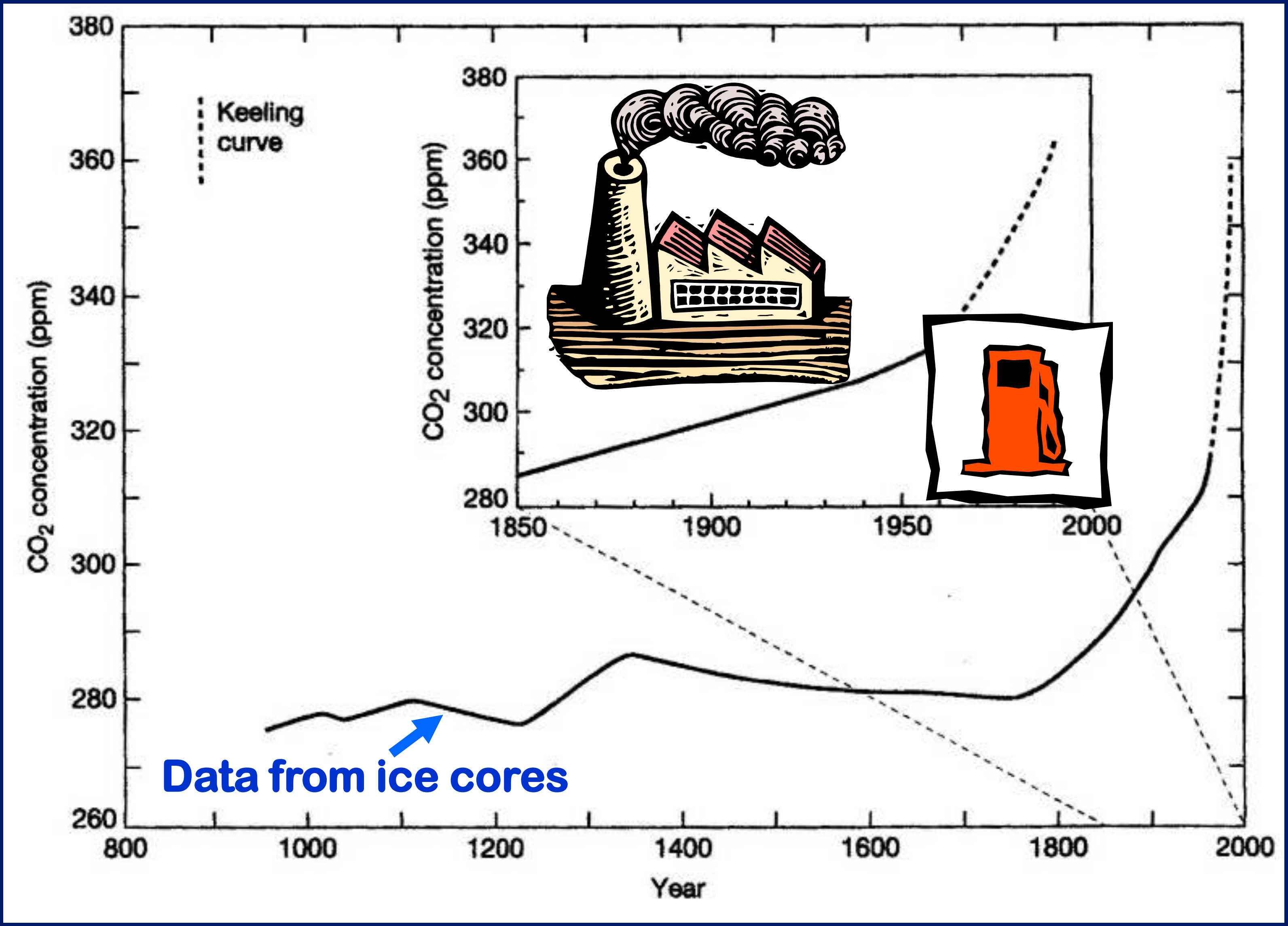
(1) fossil fuel combustion: oil, coal, gas -- especially coal, and

(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.

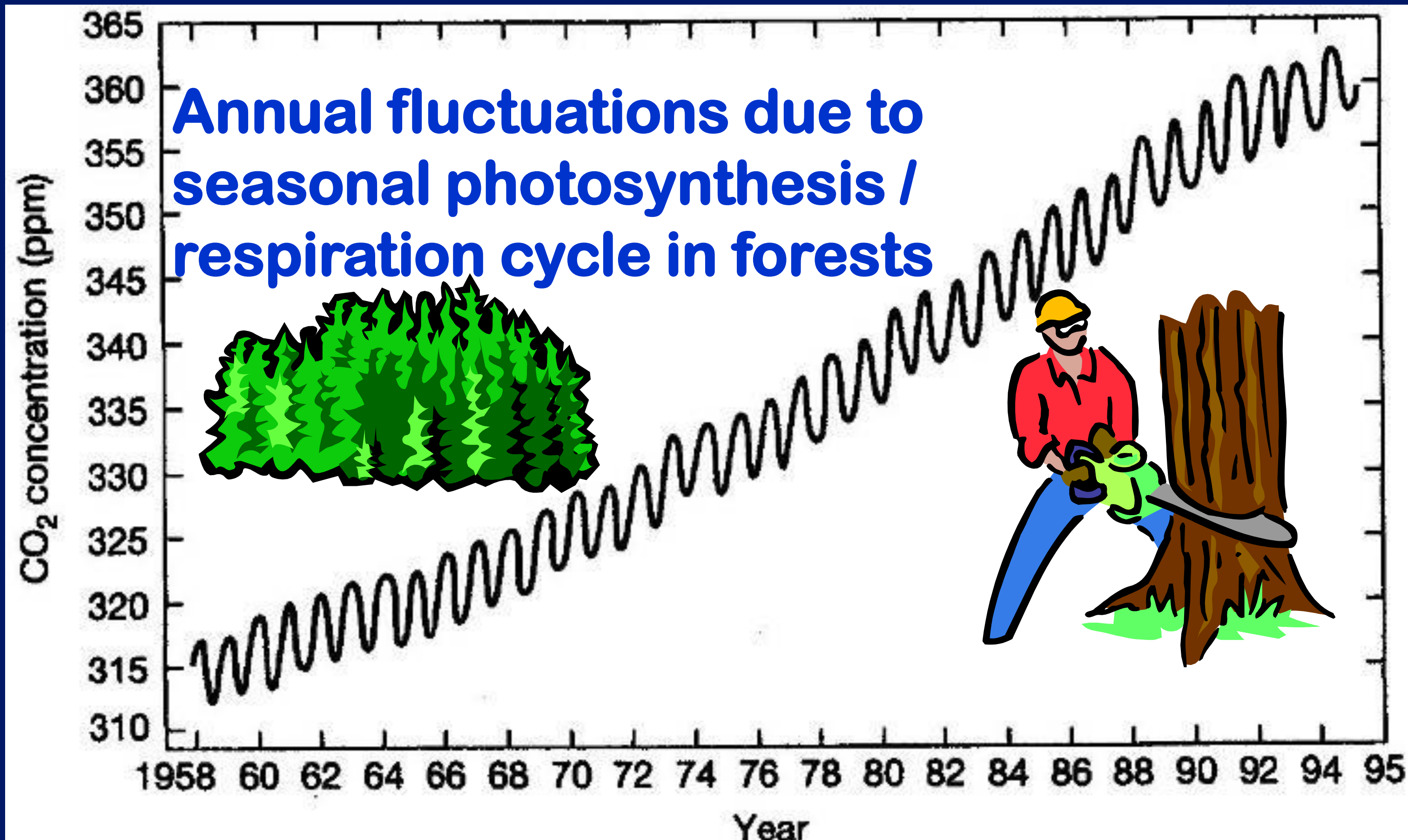
(Deforestation also accelerates forest decomposition, burning, etc. adding to the overall respiration inflow.)

This info is in Table on p 41

CARBON DIOXIDE: Trends

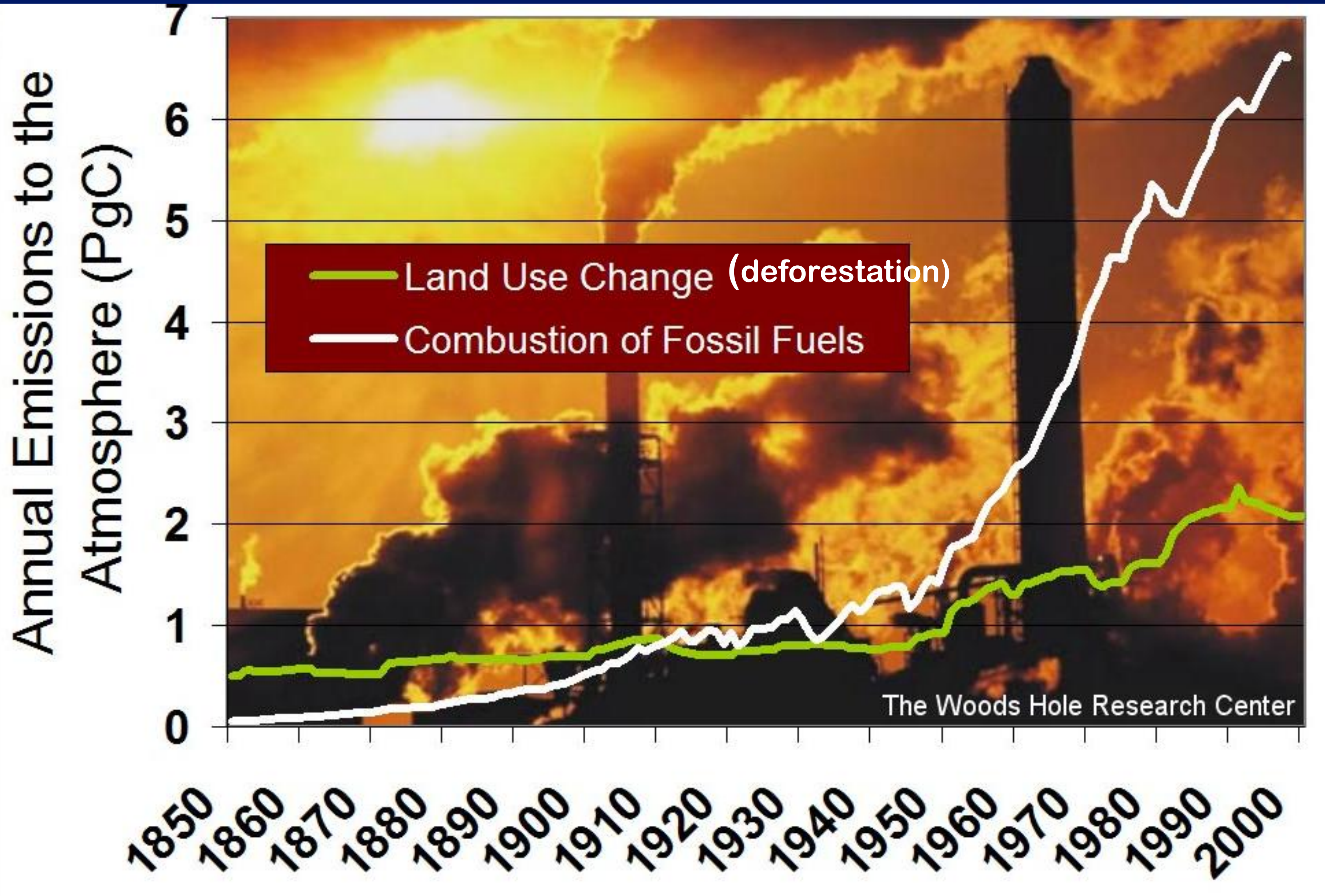


CARBON DIOXIDE --- Trends:



The Keeling Curve

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 <u>100 years</u>**

Plus **it takes 50 to 100 years for atmospheric CO_2 <u>to adjust</u> 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 41

METHANE (CH_4):
Sources

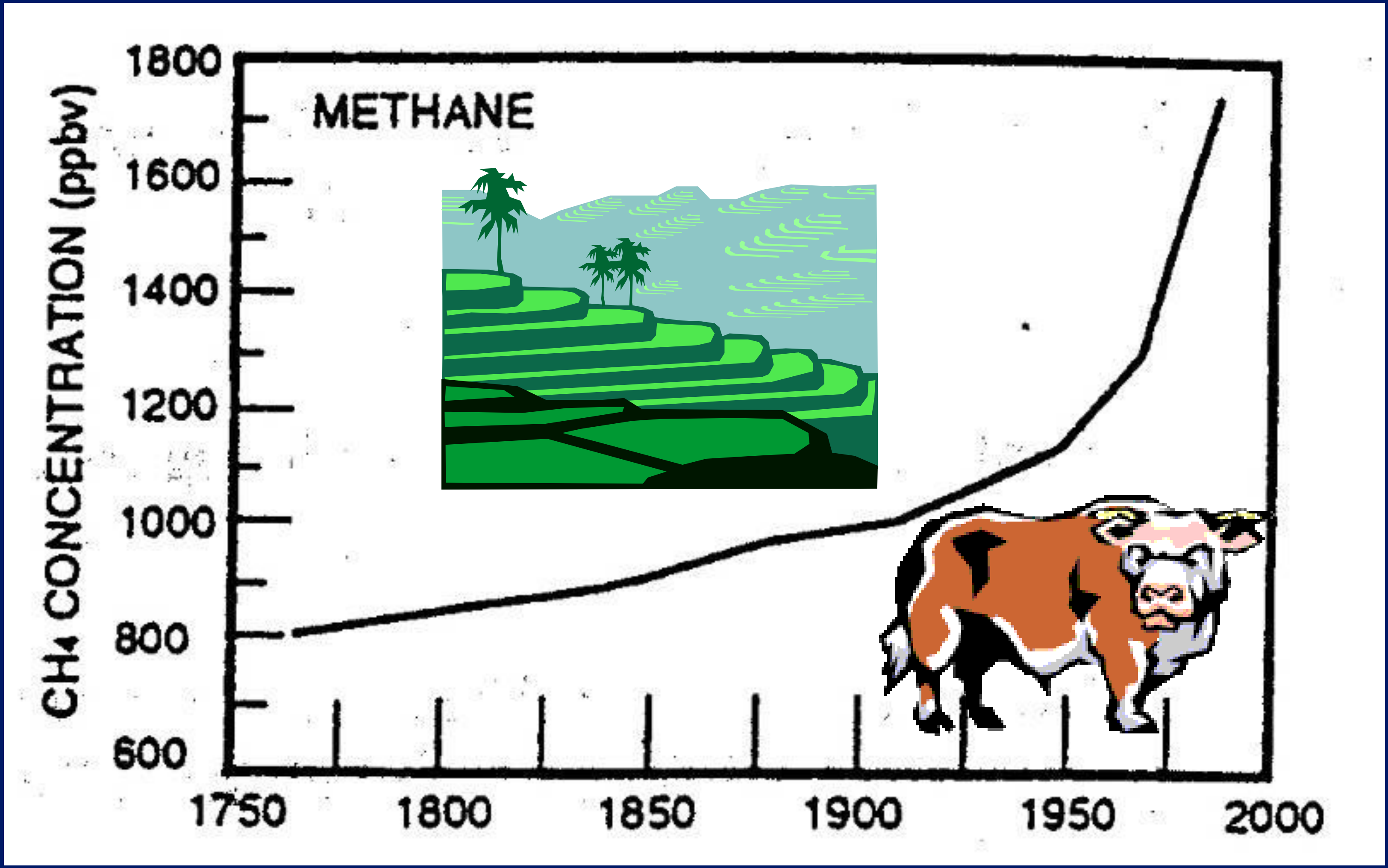
* Produced naturally in anaerobic processes (e.g., decomposition of plant material in swamps & bogs)

* 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 41

METHANE: Trends



NITROUS OXIDE (N_2O): Sources

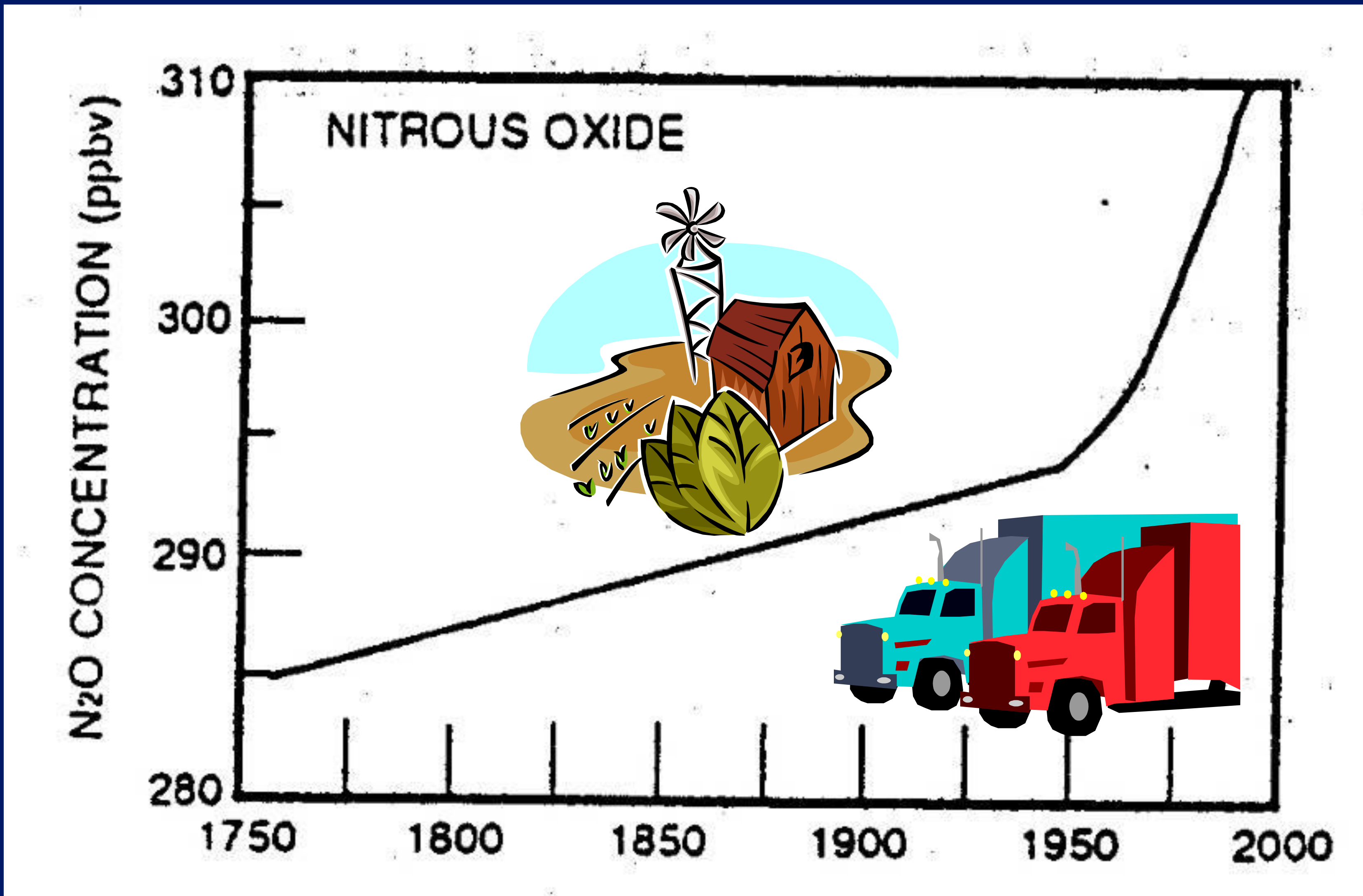
* Produced naturally in soils

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

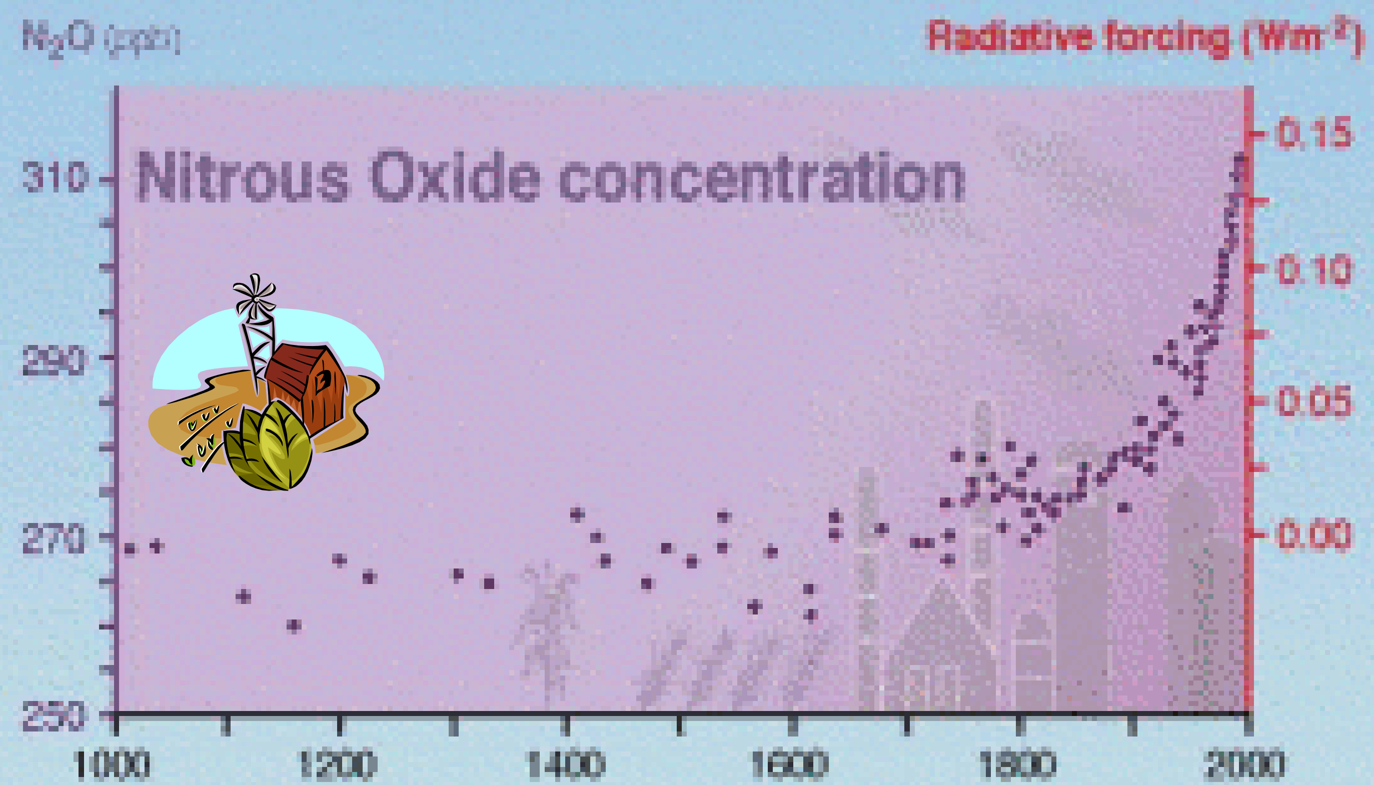
* Has long atmospheric residence time (~ 150 years)

This info is in Table on p 41

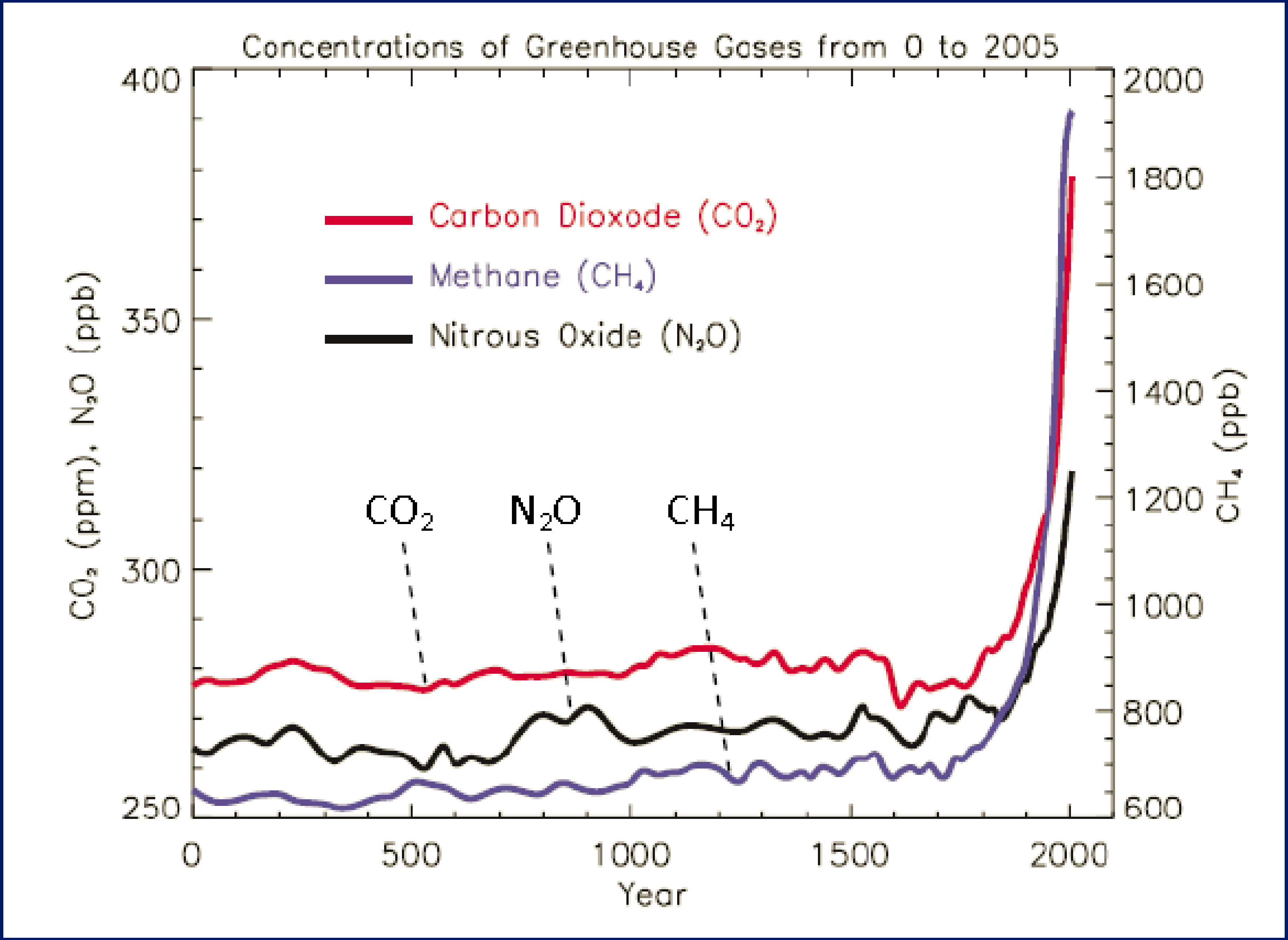
NITROUS OXIDE: Trends

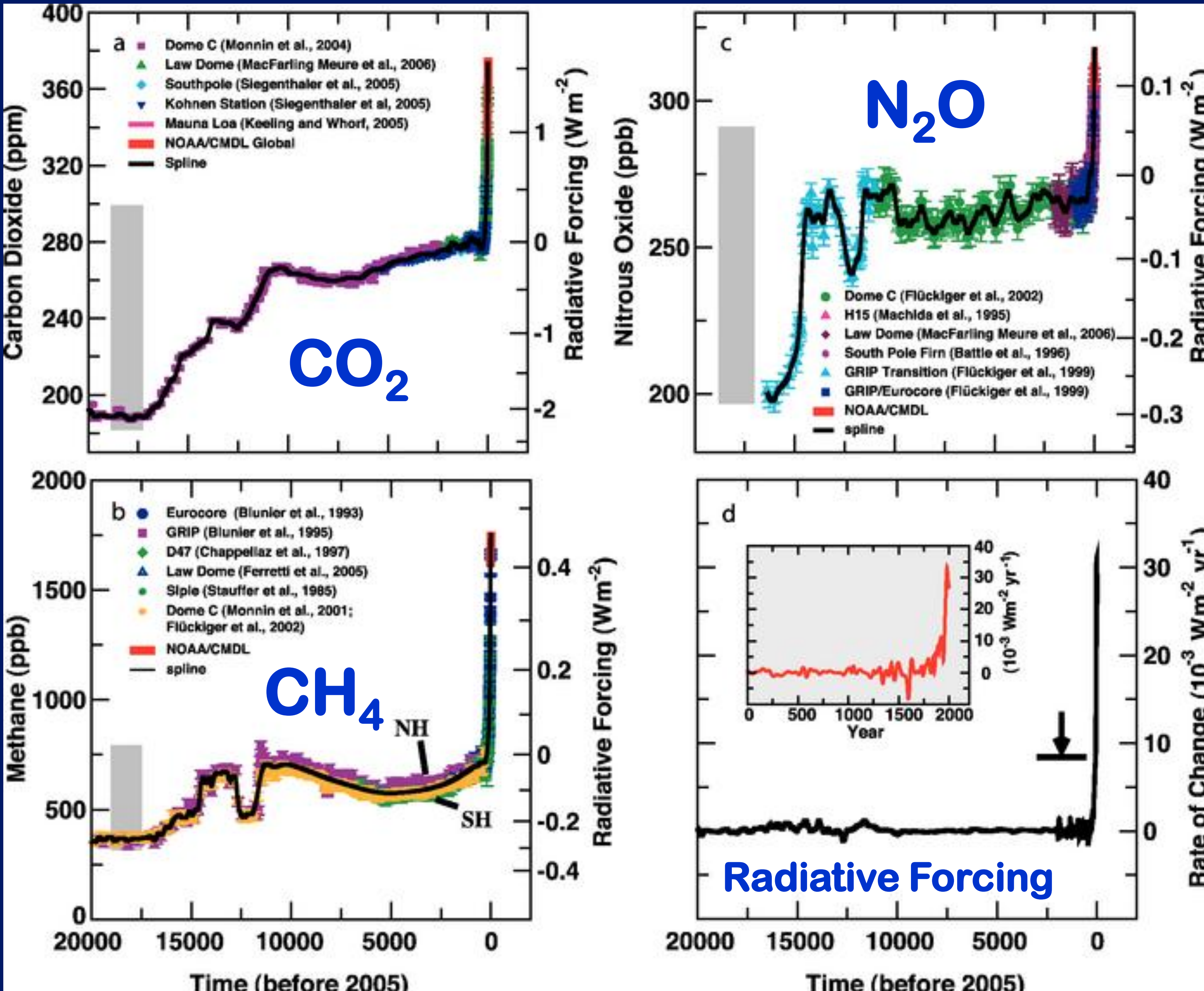


NITROUS OXIDE: Trends



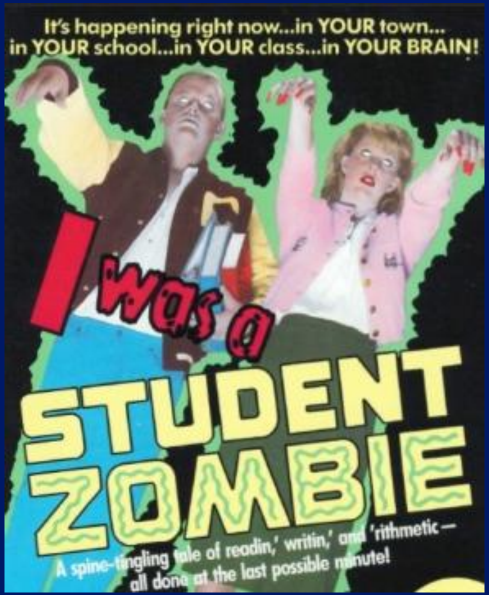
www.ipcc.ch


Concentrations of Greenhouse Gases from 0 to 2005
Carbon Dioxode (CO2)
Methane (CH4)
Nitrous Oxide (N2O)
CO2
N2O
CH4
CO2 (ppm), N2O (ppb)
CH4 (ppb)
Year
400
350
300
250
2000
1800
1600
1400
1200
1000
800
600
0
500
1000
1500
2000



The grey bars show the reconstructed ranges of natural variability for the past 650 kyr

INSTEAD OF ZOMBIE BREAK #2



WE ENDED CLASS EARLY!!!