G-5 ACTIVITY ON VOLCANISM & CLIMATE

P.S. This is one of my favorite questions to ask on the FINAL EXAM!!!!

THE ANSWERS!

#1. List 4 reasons why Tambora in 1815 resulted in the largest GLOBAL cooling:

#1 Low latitude eruption → both hemispheres

#2 Large amount of eruptive material (50 sq km!)

#3 Aerosol cloud was HUGE and went into both hemispheres equally

#4 Sulfuric acid (H_2SO_4) content was very large

#2. Give at least two reasons why the eruption of Mt St. Helens was NOT a very climatically effective eruption:

#1 High latitude – could only affect part of Northern Hemisphere

#2 Low sulfur content

(also, low volume, didn't get to S. Hemisphere, etc.)

3 HOW did the temperature at the 3 levels respond to the Agung and Pinatubo eruptions?

#4 EXPLAIN WHY – referring to Radiation Balance?

Level A (Surface) – **Cooled**

Why? 

by sulfate aerosols in stratosphere and therefore less SW got into troposphere to be absorbed by Earth's surface

Level B (Lower Troposphere) – **Cooled**

Why? 

by stratospheric aerosols => less SW absorbed at surface and in troposphere,
ALSO: less 

radiated up into troposphere from the cooler Earth's surface

Level C (Lower Stratosphere) – **Warmed** immediately after both eruptions

Why? Sulfate aerosols in the stratosphere **absorbed** some wavelengths of incoming SW 

and heated up, they also absorbed some of the Earth's outgoing LW 

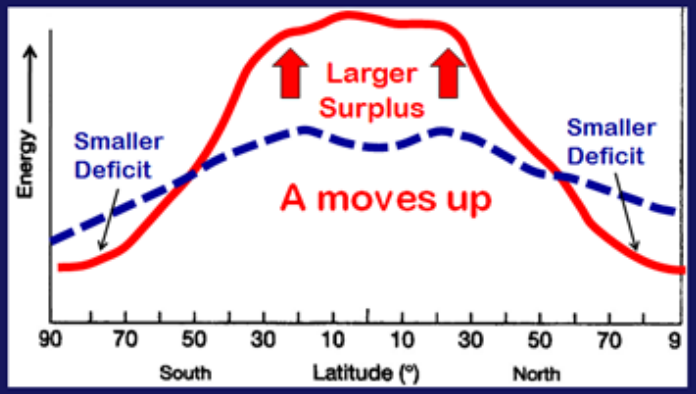
as it radiated up out of the troposphere

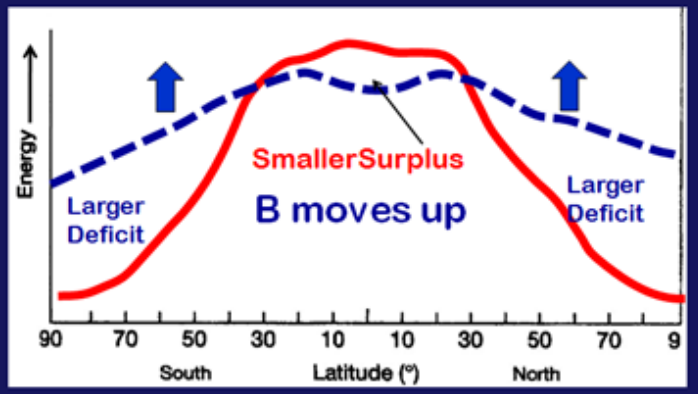
TO SUMMARIZE: 2 KEY POINTS

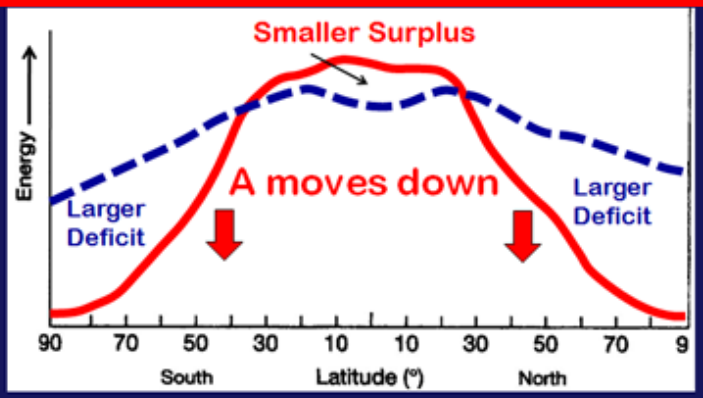
- Major eruptions with a long-lived sulfate aerosol veil REFLECT incoming solar radiation back to space BEFORE it enters the mid- & lower troposphere or gets to the Earth's surface, hence the troposphere & surface get COOLER after an eruption.

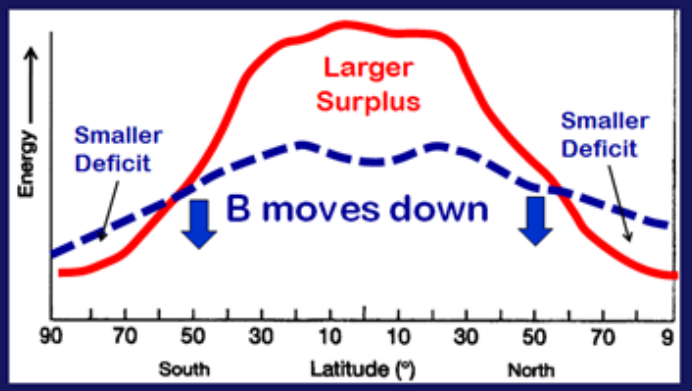
- The aerosols in the stratosphere can also ABSORB some wavelengths of incoming SW and outgoing LW, so that the stratosphere WARMS slightly after an eruption.

Show how the energy balance would change if a major volcanic eruption occurred:





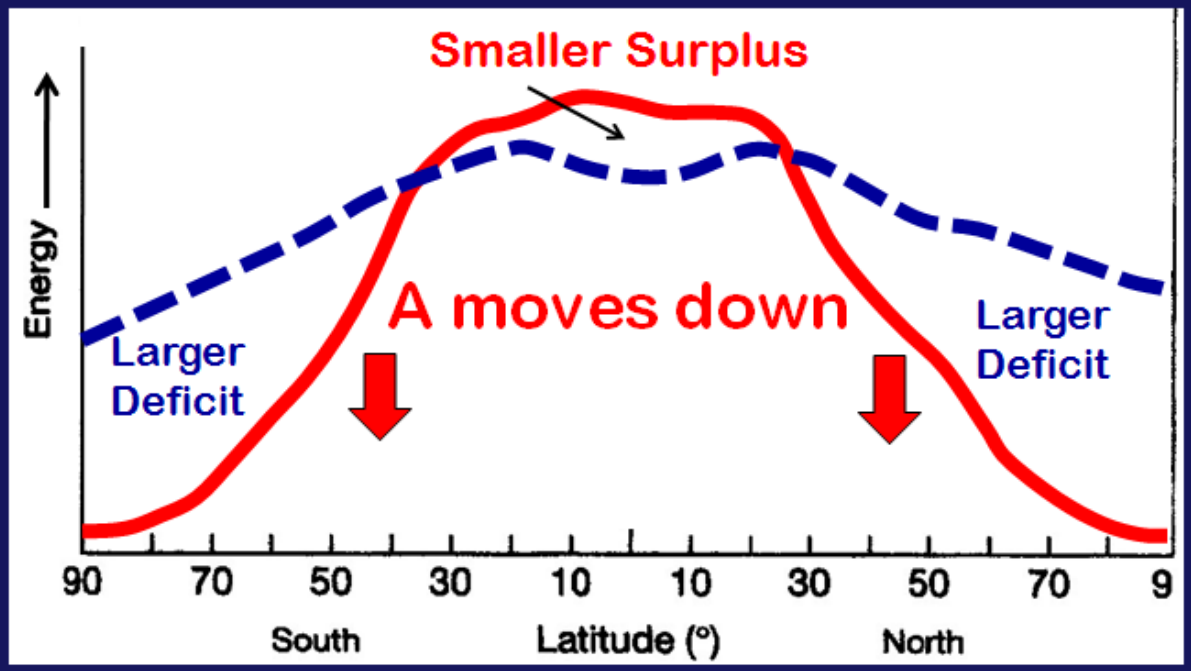




WHICH ONE IS RIGHT ?

Does the change affect CURVE A or CURVE B?

A moves down, and B stays the same . . . .



. . . but eventually B will also move down a bit due to cooler Earth temps and less outgoing LW

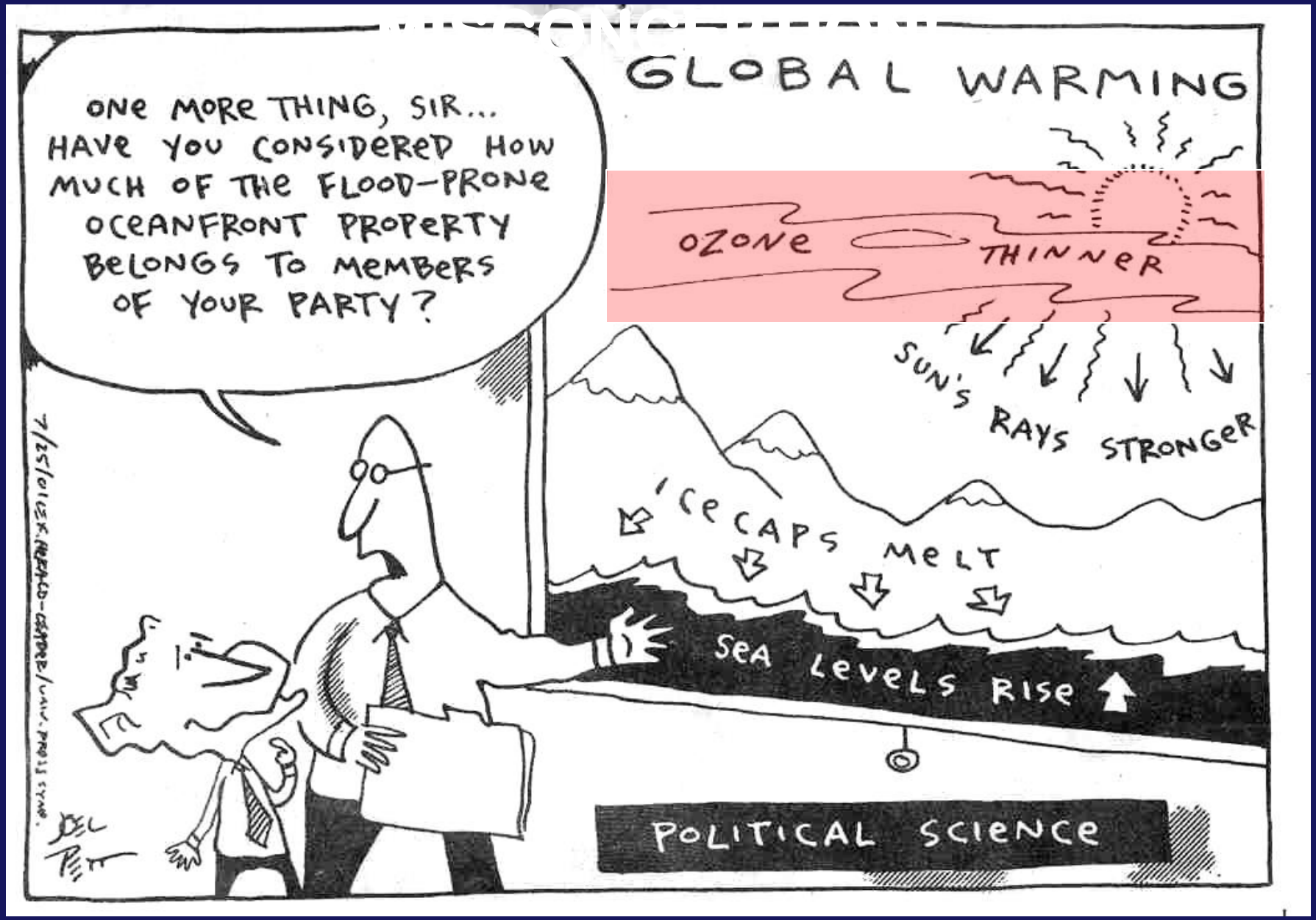
Topic # 14

OZONE DEPLETION IN THE STRATOSPHERE

A Story of Anthropogenic Disruption of a Natural Steady State

p 83 in Class Notes

AN OZONE-RELATED CARTOON:



Q1 – Is the depletion of STRATOSPHERIC OZONE (in the OZONE HOLE and elsewhere) an important cause of GLOBAL WARMING?

1 – YES
2 -- NO

“[The Ozone Treaty is] the first truly global treaty that offers protection to every single human being.”

~ Mostofa K. Tolba,
Director of the UN Environment Programme

OZONE STORY = A very interesting illustration of the scientific process!

The THEORY that the ozone layer in the stratosphere might be damaged by human intervention PRECEDED the actual OBSERVATION of the ozone hole.

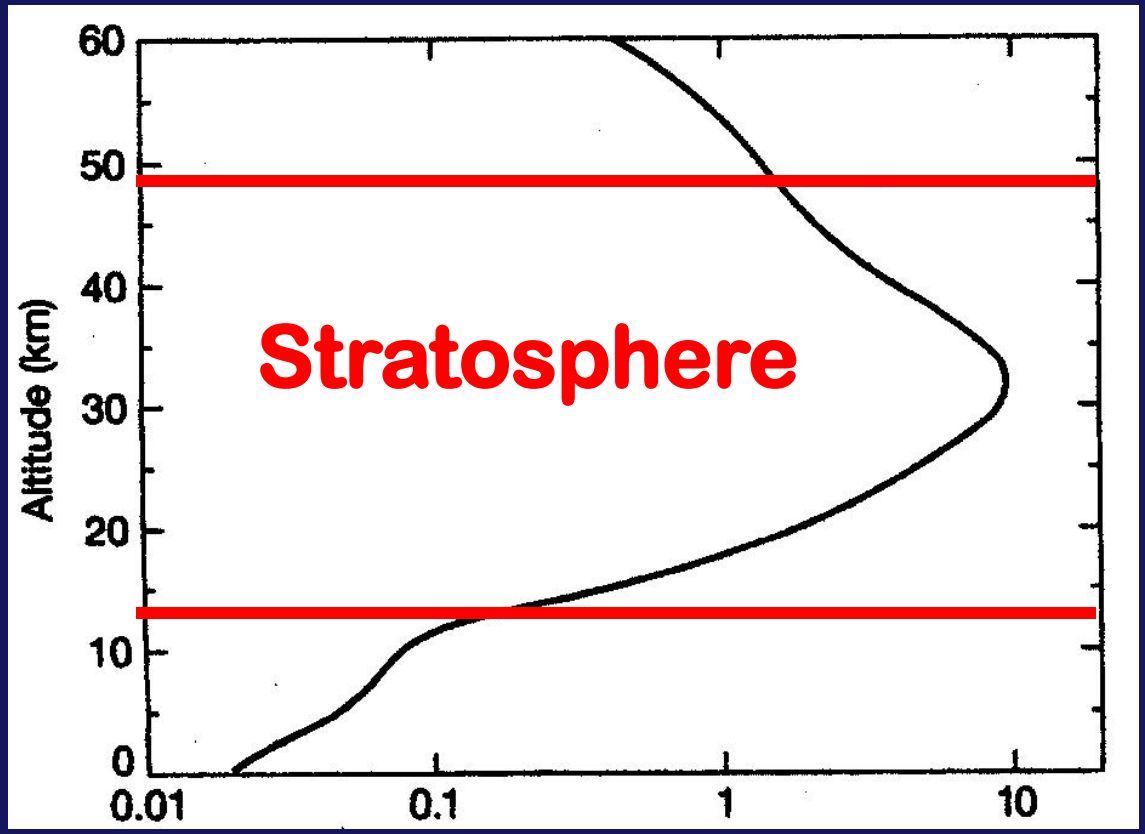
Yet, when the hole WAS observed (via satellite) it was almost "missed" because it wasn't expected . . .

But let's begin with the stratospheric ozone layer itself . . . . . .

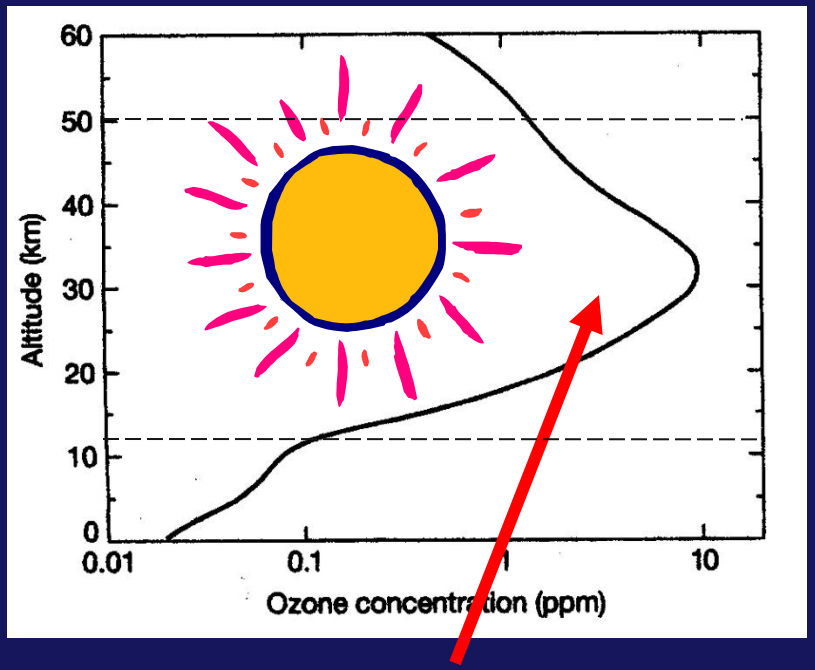
Key Concept

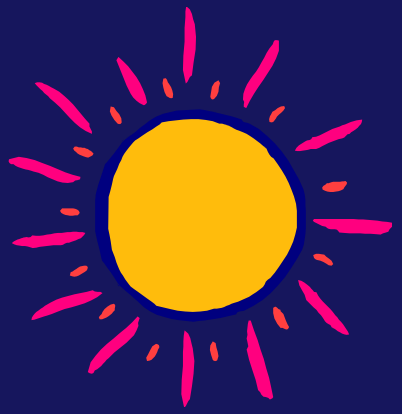
REVIEW: WHERE IS THE OZONE LAYER?

SGC E-Text Fig. 3-11



OZONE: Sources



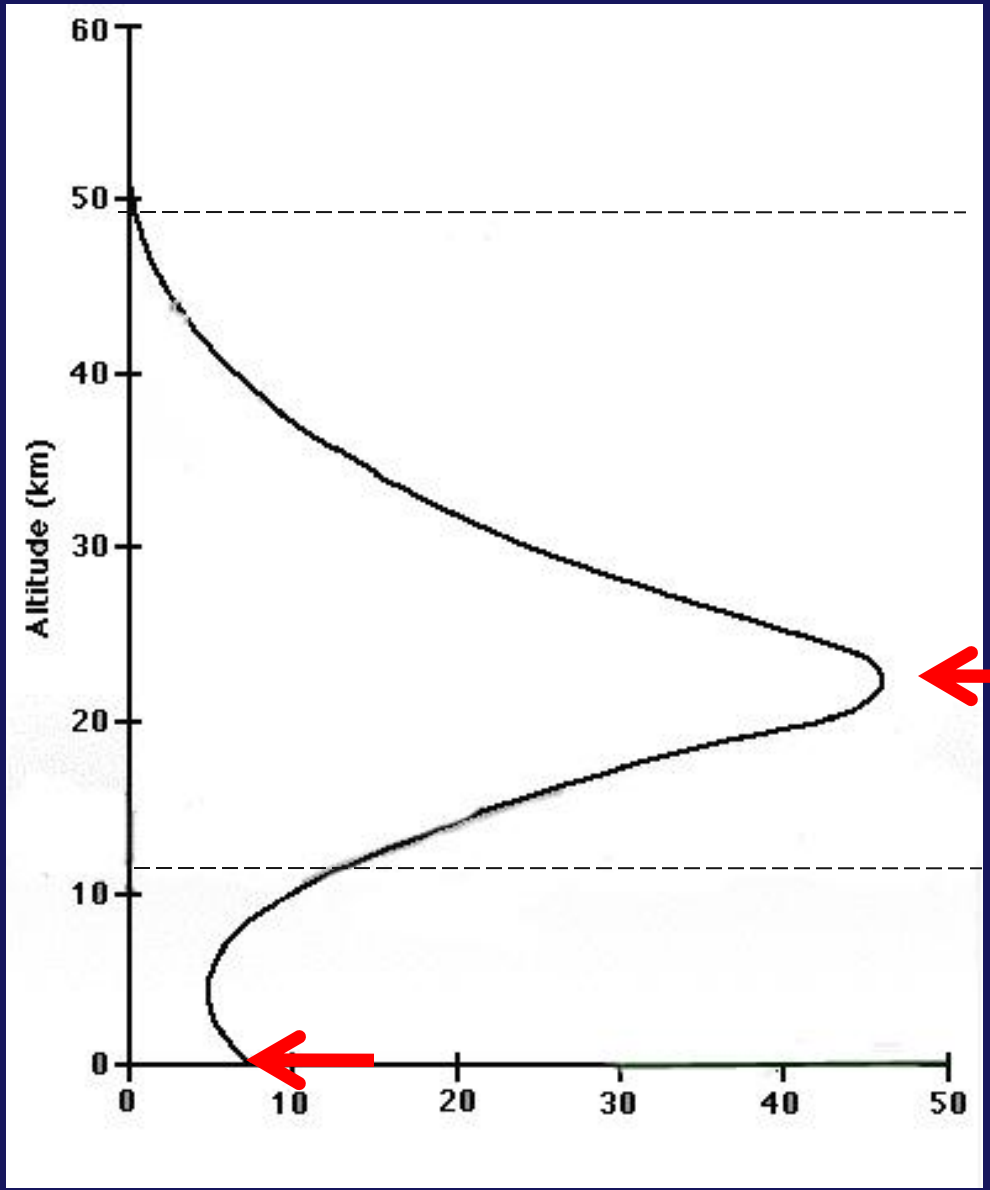


Ozone is produced naturally in photochemical reactions in the stratospheric ozone layer --"good ozone" -- is <u>decreasing</u>!

However, ozone has <u>*increased*</u> in troposphere due to photochemical smog reactions -- "bad ozone"

Here's a different version of the figure ➔

Shows 2 peaks, a major peak in O_3 density in the **stratosphere**, a smaller secondary peak in the **lower troposphere**



Ozone Density

(10^{17} molecules / m^{3})

THE OZONE LAYER IN THE STRATOSPHERE -- WHY IT'S THERE

Due to: the natural "Chapman Mechanism"

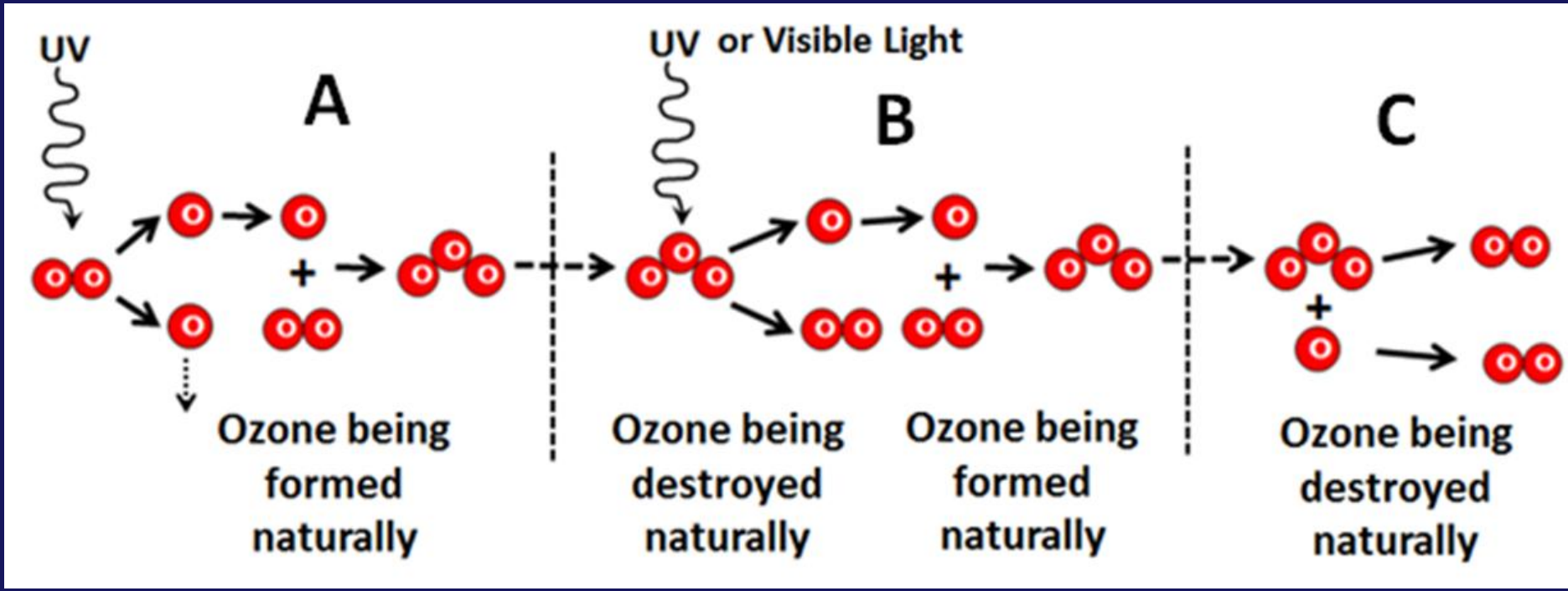
(a series of photochemical reactions)

THE CHAPMAN MECHANISM

(first proposed in 1930s)

- ozone is continuously produced and destroyed
- through **PHOTOCHEMICAL REACTIONS** in the stratosphere
- involves oxygen (O_2), molecular oxygen (O), photons of UV radiation, and OZONE (O_3).

The Chapman Mechanism



(See explanation in box on top of p 83)

[Go to movie clip]

In theory:

- **a balance of ozone is established over time**

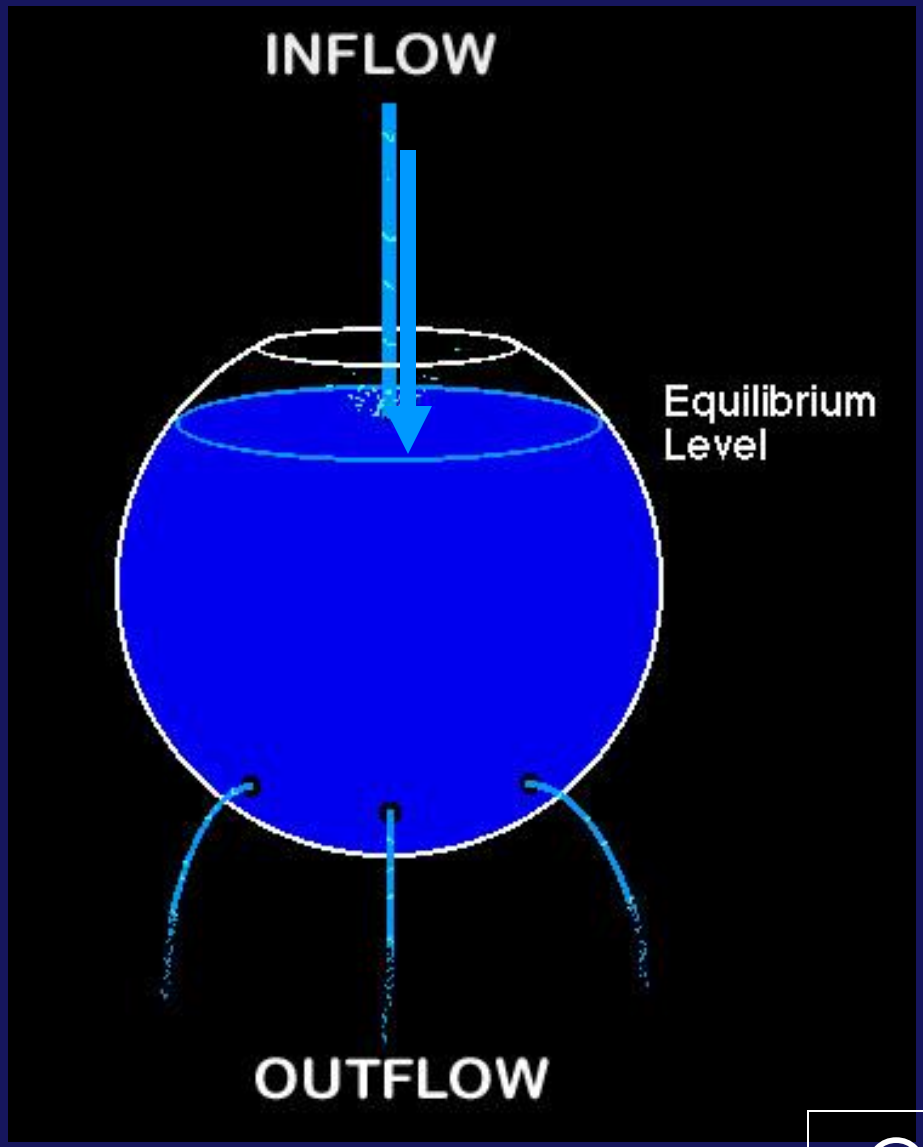
- **prevents much of the harmful UV radiation from reaching the earth's surface.**

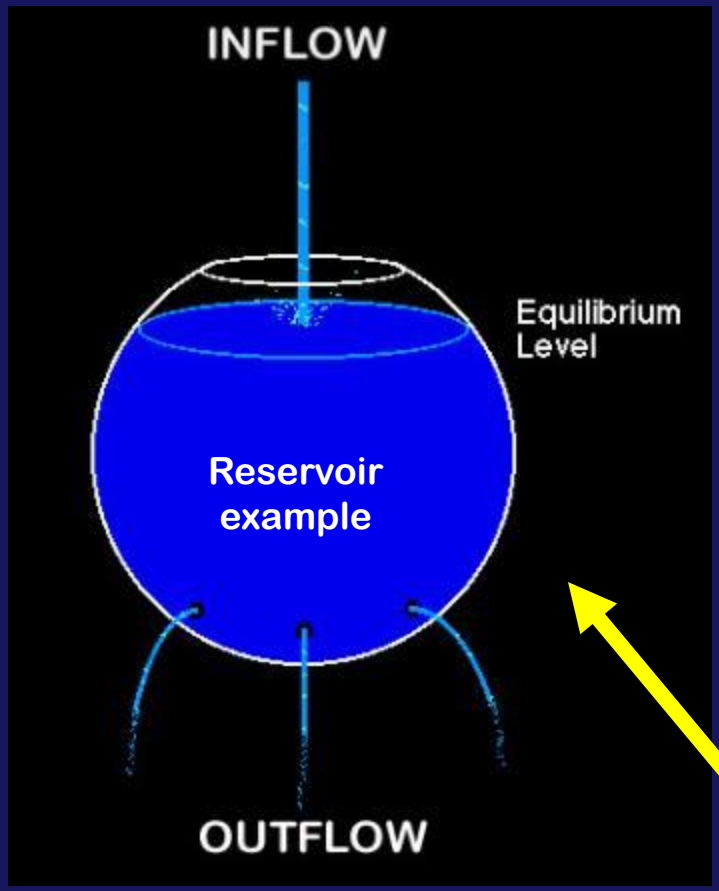
Leads to an "Equilibrium" or "Steady State"

STEADY STATE =

a condition in which the STATE of a system component (e.g. reservoir)

is CONSTANT over time.





Steady state can be achieved in a reservoir:

a) if there are no inflows or outflows, *or*

b) if the rate of inflow = the rate of outflow.

Any imbalance in these rates leads to a change in the level of the reservoir.

FLOW DIAGRAM OF A STEADY STATE

Inflow

Ozone being formed via natural Chapman mechanism

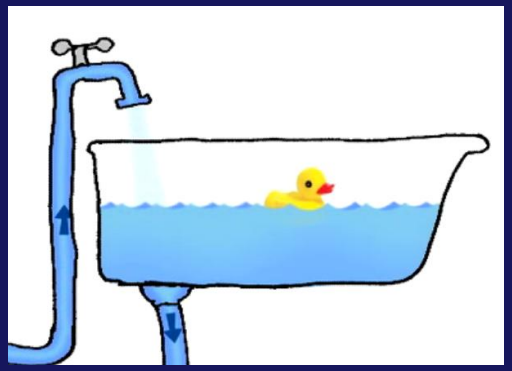
Reservoir of STRATOSPHERIC OZONE

Outflow

Ozone being destroyed via natural Chapman mechanism

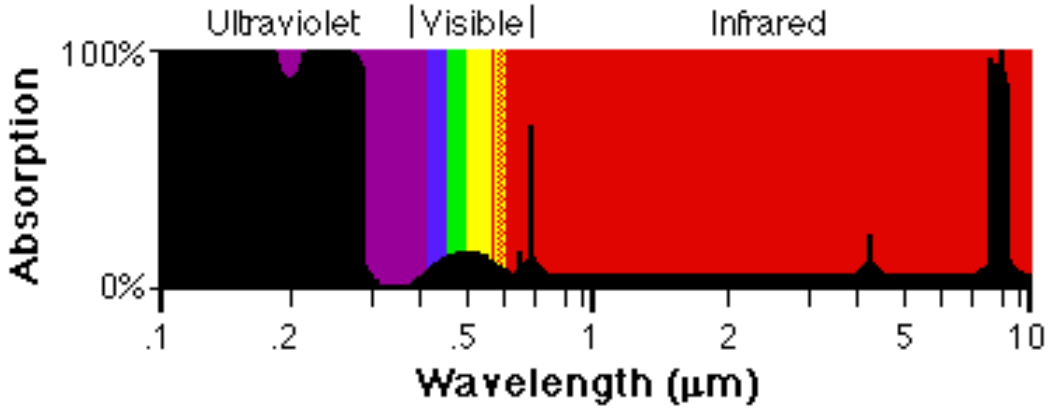
Where have we seen something like this before?

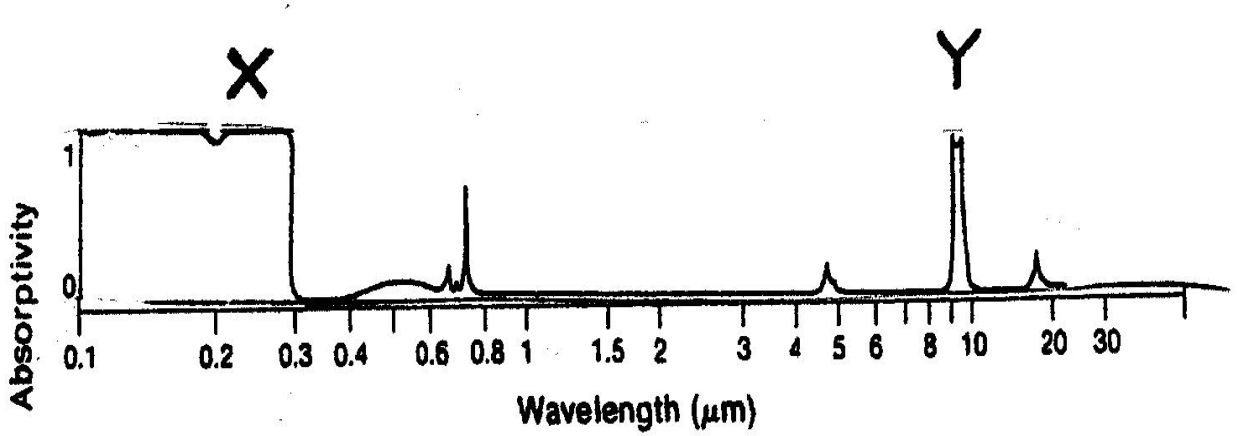
I-1 Lesson 1
Carbon Dioxide in the Atmosphere



Review: Why stratospheric ozone is "Good":

Black areas = radiation absorbed

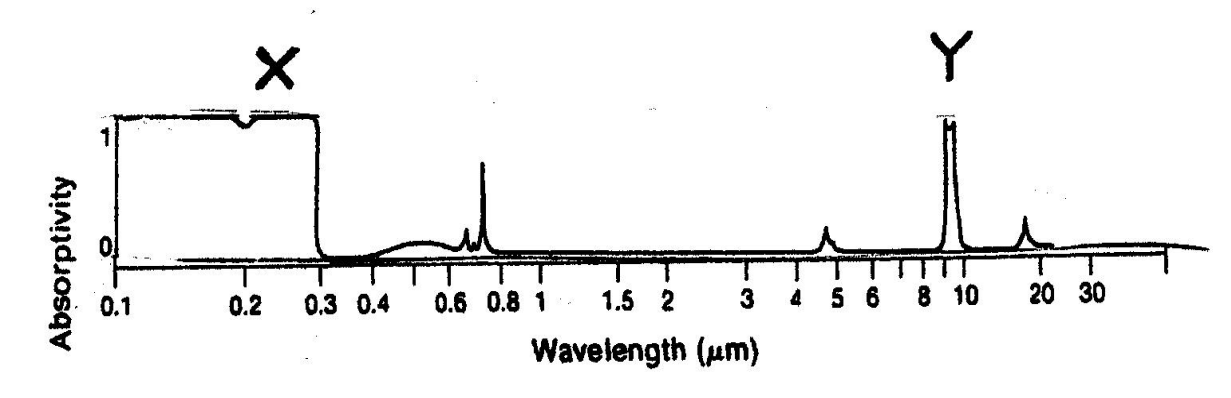




Ozone has the property of being a very strong absorber of ultraviolet radiation → **nearly total absorption of wavelengths less than 0.3 μm**

←remember this absorption curve?

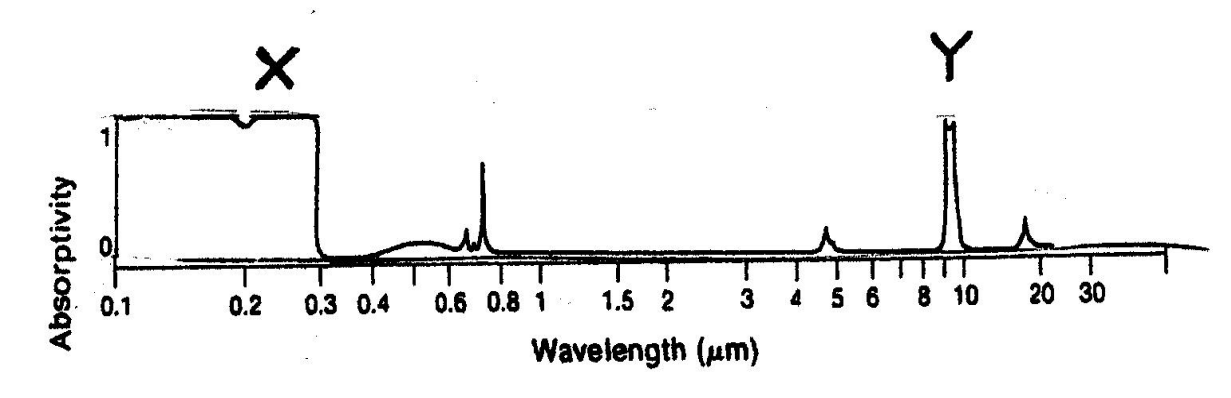
←CLICKER Q coming up!



Q2 – What is the CORRECT completion to this sentence:

The global change issue usually referred to as **Stratospheric Ozone Depletion** is related to the part of the absorption curve that is labeled ____.

(1) **X** or (2) **Y**



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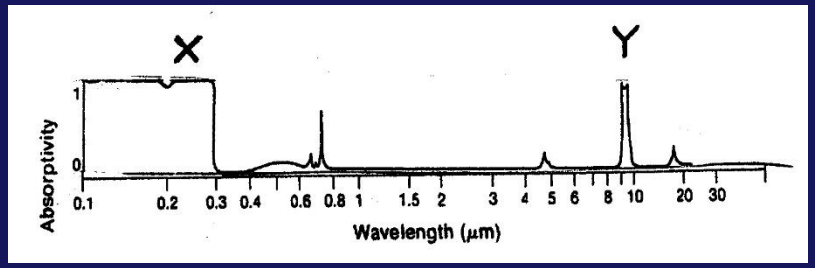
Q3. Ok, X is right, but Why?

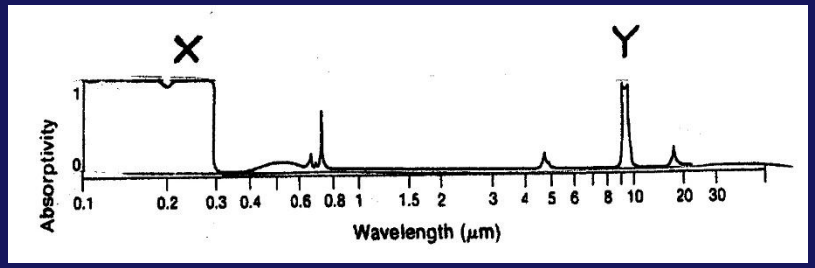


1. . . . because X represents UV radiation being absorbed -- hence if ozone is depleted, MORE ultraviolet radiation will reach the Earth's surface.

2. . . . because X represents terrestrial longwave radiation being absorbed -- and hence serves as a catalyst in the Chapman mechanism.

3. . . .because X represents easy transmission of wavelengths of terrestrial longwave radiation out to space which then disappear through the "atmospheric window" also known as the ozone hole.

Q3. Ok, X is right, but Why?



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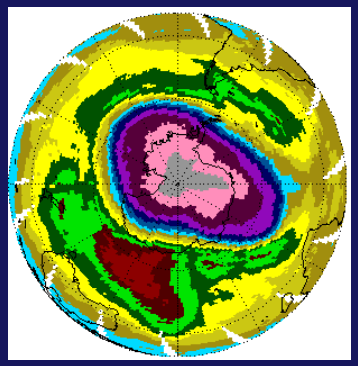
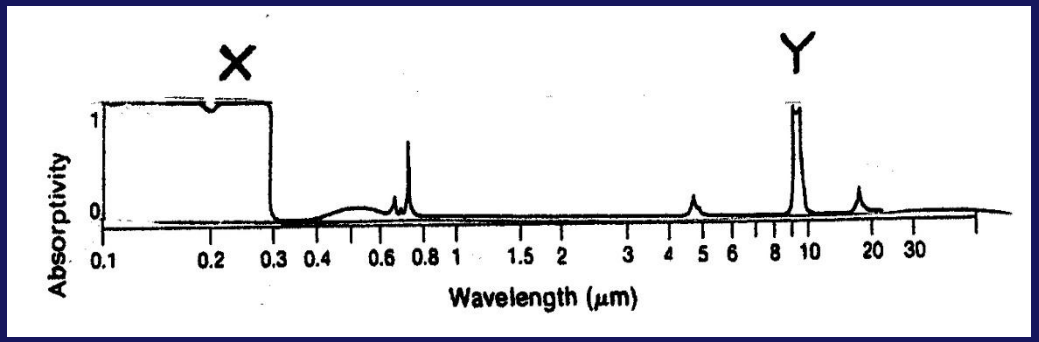
OZONE'S DUAL PERSONALITY!



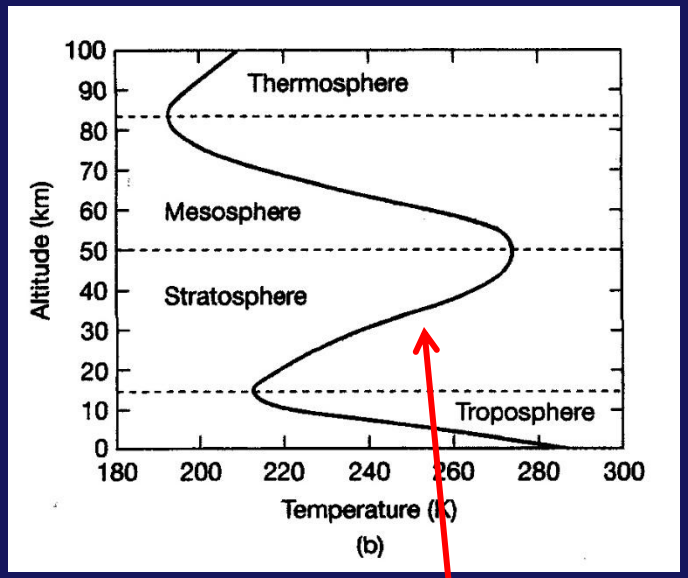


Important as an absorber of harmful UV in the **STRATOSPHERE**

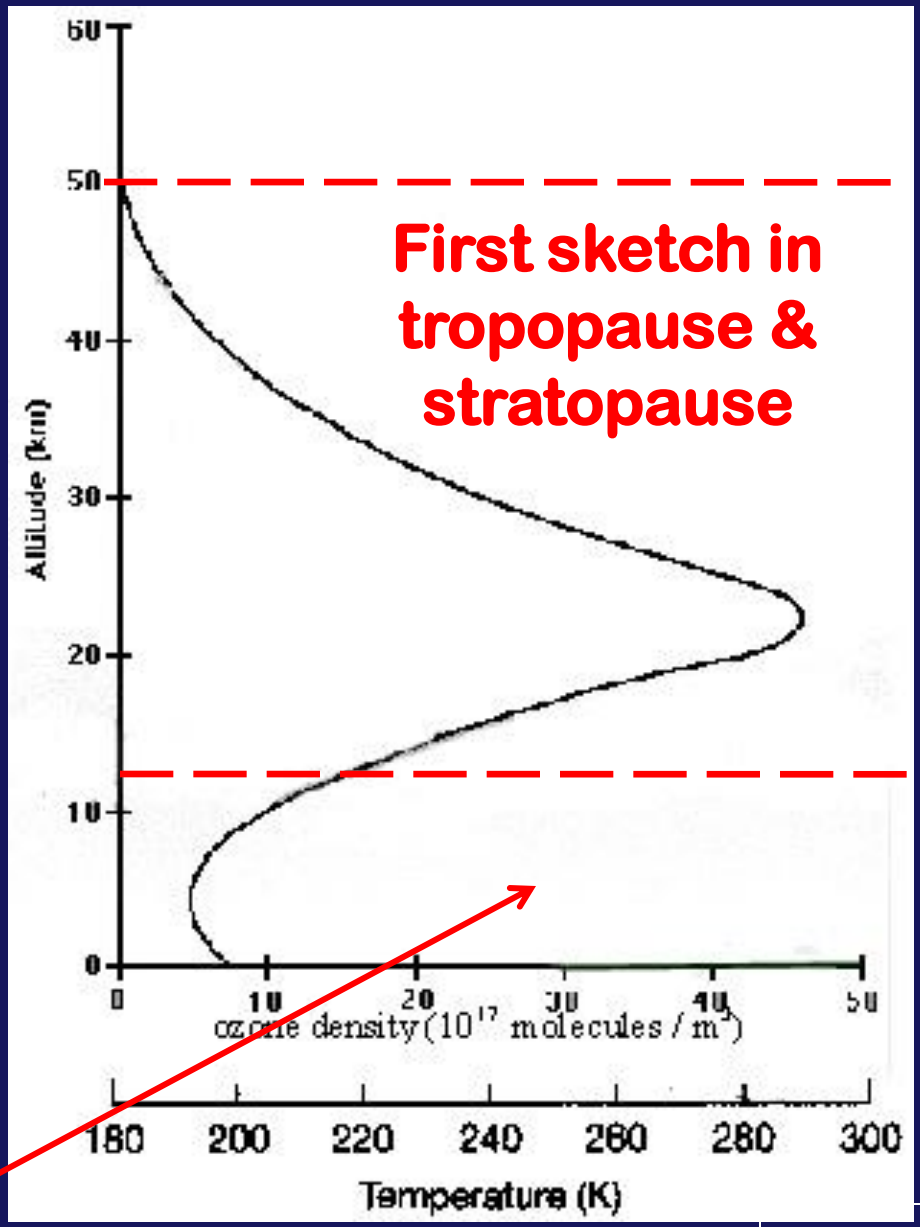
Important as a GH Gas = absorber of IR in the **TROPOSPHERE**

Hands on – sketch this in on p 84:

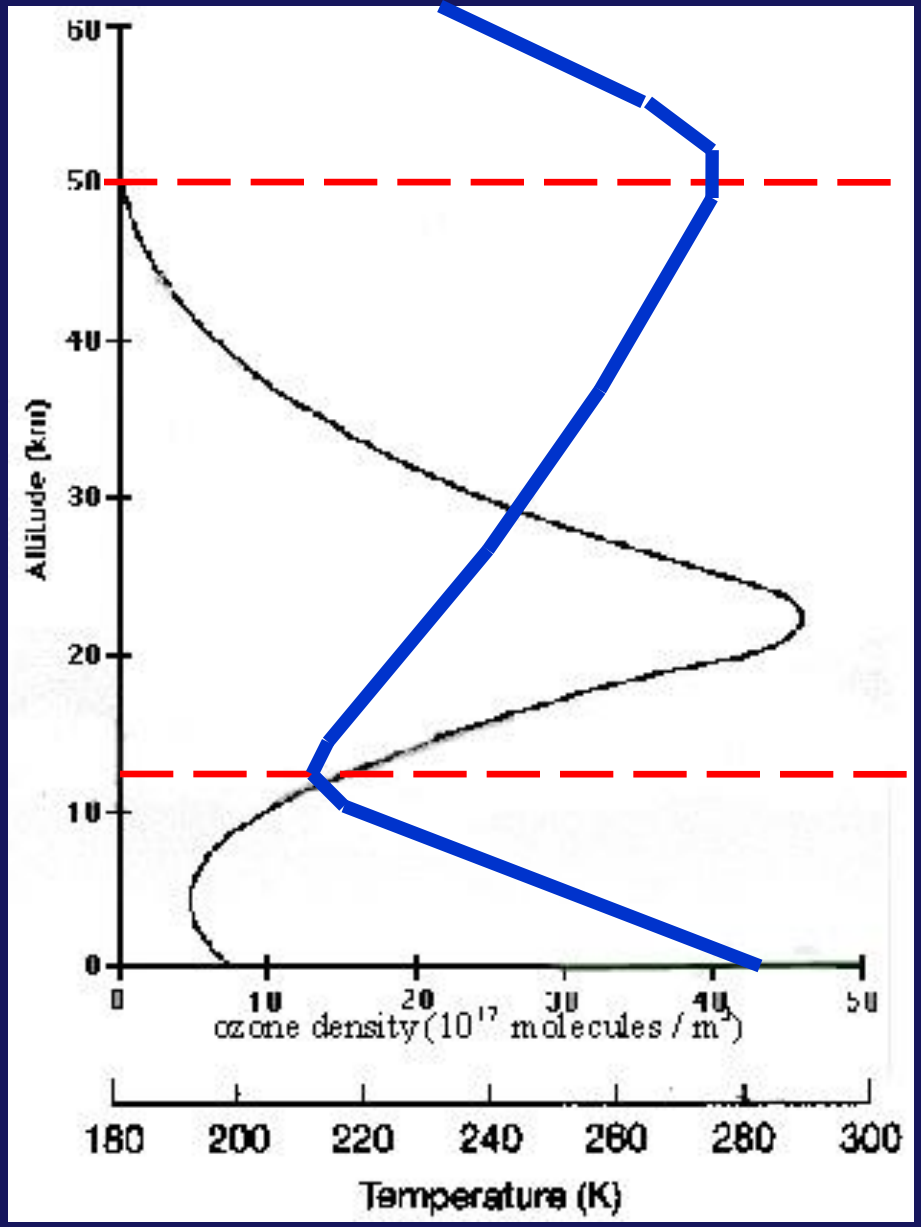
Temperature graph



Ozone Density graph



Now roughly sketch the <u>temperature</u> line from this graph onto the ozone graph



Fill in the Q on p 84:

Q. Does the temperature of the atmosphere **INCREASE** or **DECREASE** with increasing altitude in t the Stratosphere?

TEMPERATURE

[increases / decreases]

with increasing altitude in the stratosphere

WHY???

p 84

Q4. Why is there an increase in temperature with altitude in the STRATOSPHERE?

1. It is the **closest layer to the sun,** hence it is closest to the solar "heat source."

2. It receives **large amounts of UV radiation** from the sun PLUS it has a **high concentration of ozone** to absorb this UV.

3. It is the layer which **contains most of the GH gases that absorb IR radiation** emitted by the Earth's surface.

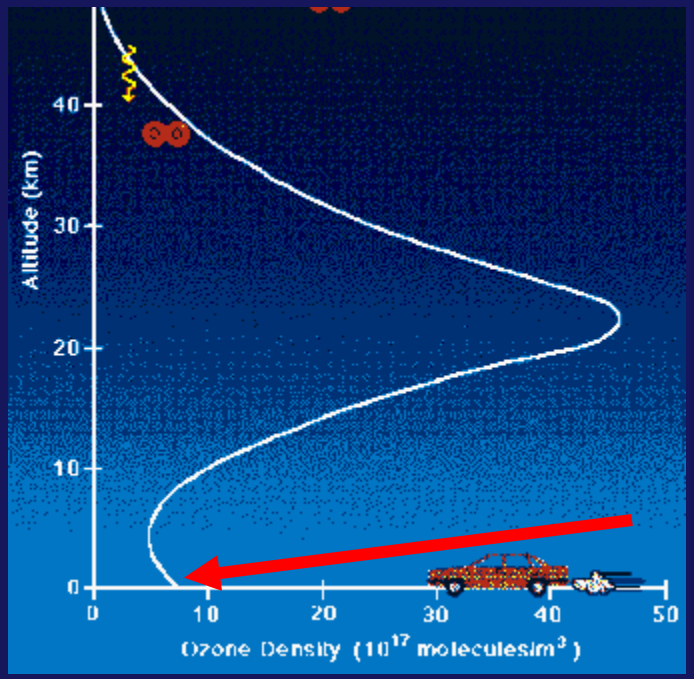
Q4. Why is there an increase in temperature with altitude in the STRATOSPHERE?

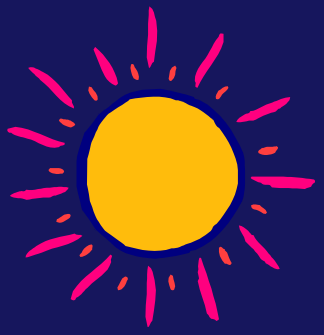
1. It is the **closest layer to the sun,** hence it is closest to the solar "heat source."

2. It receives **large amounts of UV radiation** from the sun PLUS it has a **high concentration of ozone** to absorb this UV.

3. It is the layer which **contains most of the GH gases that absorb IR radiation** emitted by the Earth's surface.

What about the "BAD" ozone located in the troposphere?





Ozone has *increased* in troposphere due to photochemical smog reactions ➔ "bad ozone"

HEALTH AND ENVIRONMENTAL EFFECTS OF GROUND-LEVEL OZONE

Why are We Concerned about Ground-Level Ozone?

➔ **Ozone is the prime ingredient of smog in our cities and other areas of the country.**

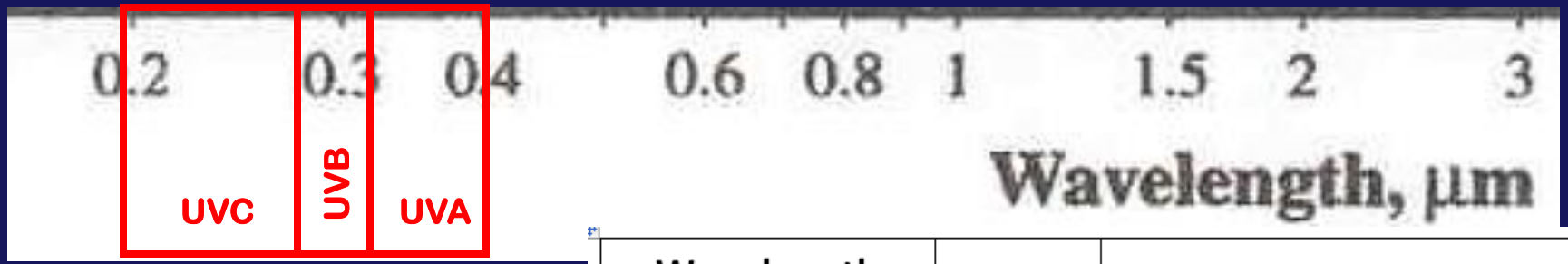
Phoenix smog➔

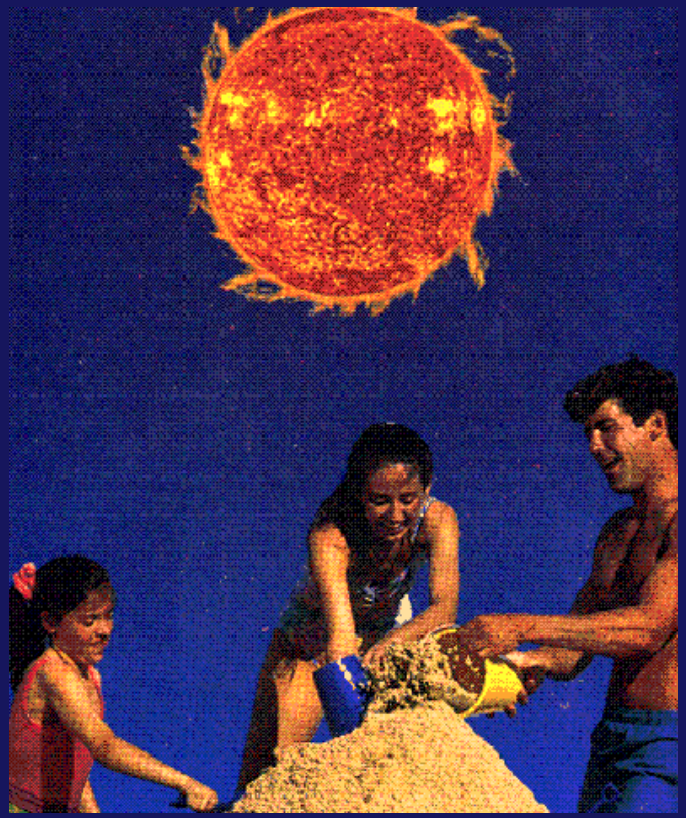
➔ When inhaled, even at very low levels, ozone can:

- cause acute respiratory problems
- aggravate asthma
- cause significant temporary decreases in lung capacity
- cause inflammation of lung tissue
- lead to hospital admissions & emergency room visits
- impair the body's immune system defenses

ANOTHER LINK TO EVERYDAY LIFE:

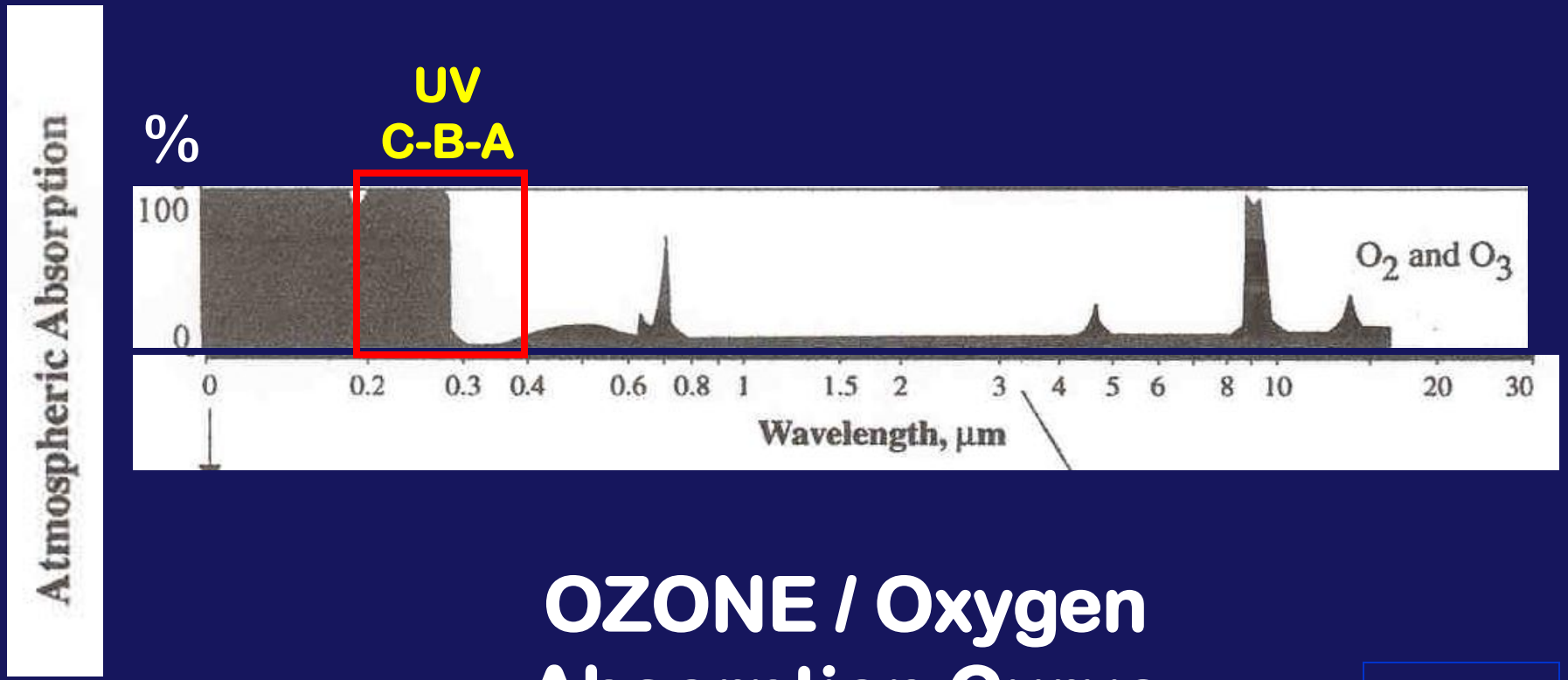
SUN SAFETY!



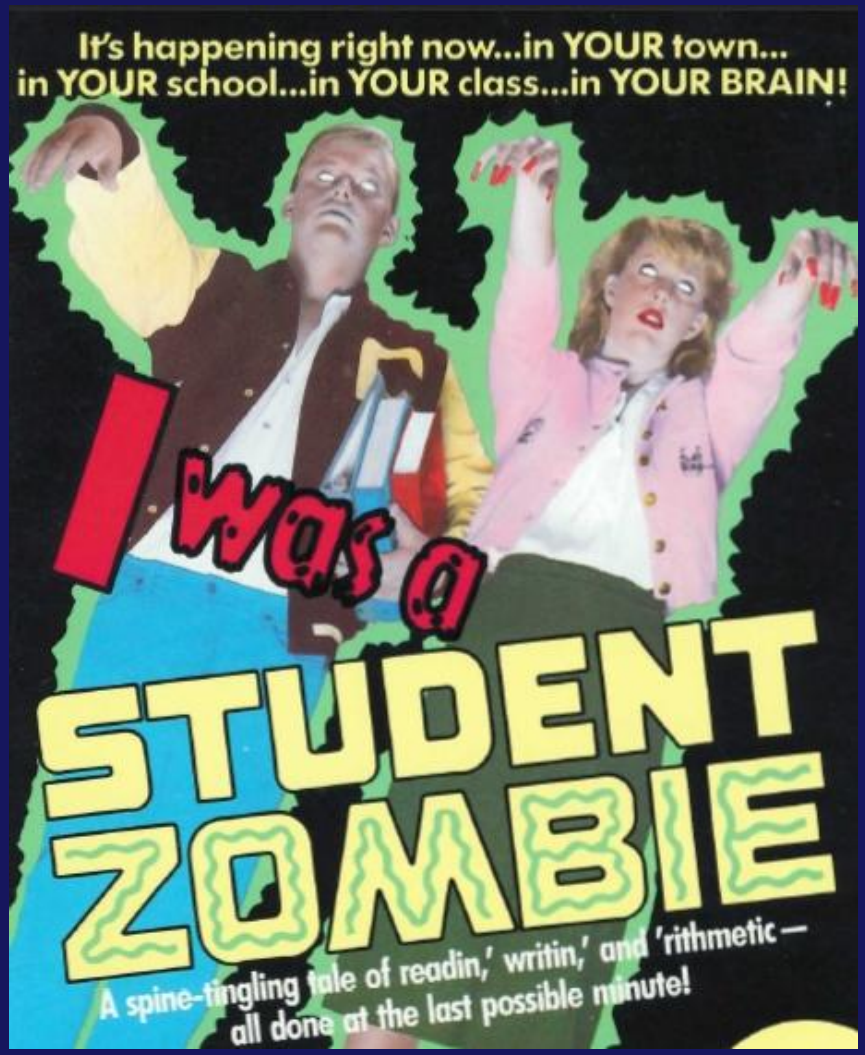


Wavelength Range	Name	Biological Effect
.32 to .4 µm (320-400 nm)	UVA	once thought to be relatively harmless, **BUT causes wrinkles, premature aging** and associated sun-related skin damage; **new research indicates possible skin cancer link**
29 to .32 µm (290-320 nm)	UVB	**harmful**, causes sunburn, skin cancer, and other disorders
.20 to .29 µm (200 - 290 nm)	UVC	**extremely harmful, damages DNA** -- but almost completely absorbed by ozone

FULL SPECTRUM PROTECTION NEEDED!!

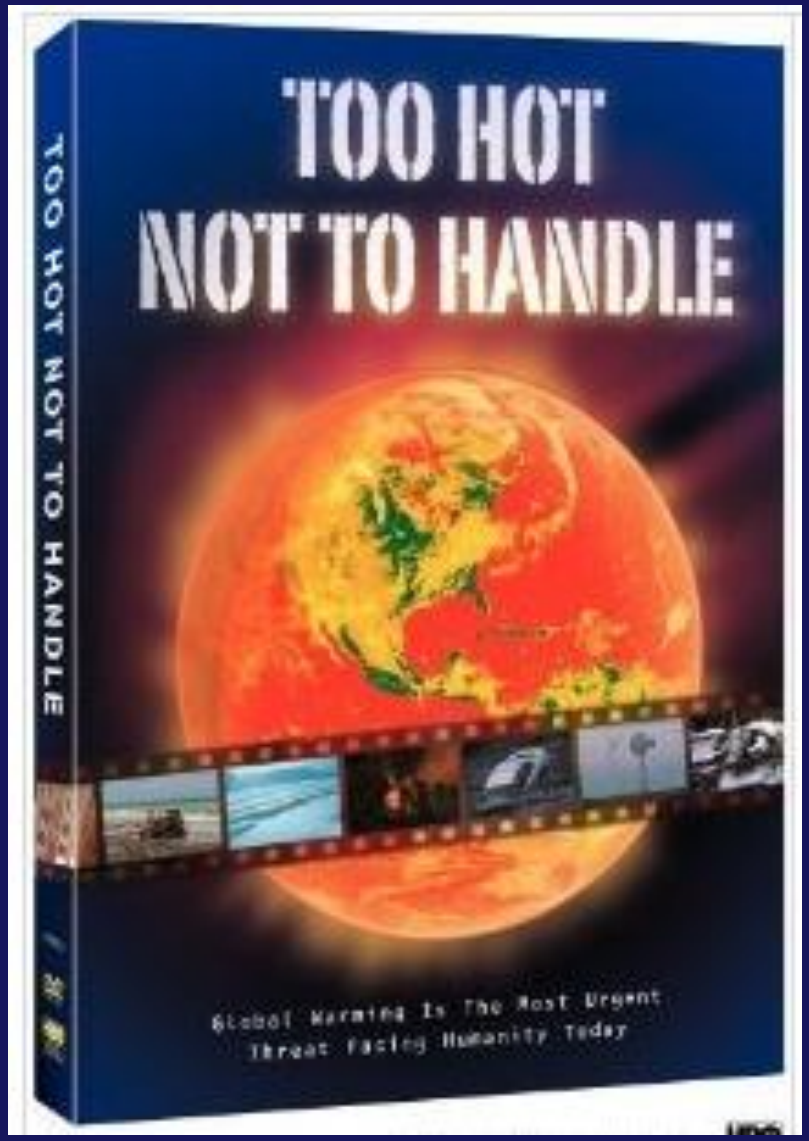


OZONE / Oxygen Absorption Curve

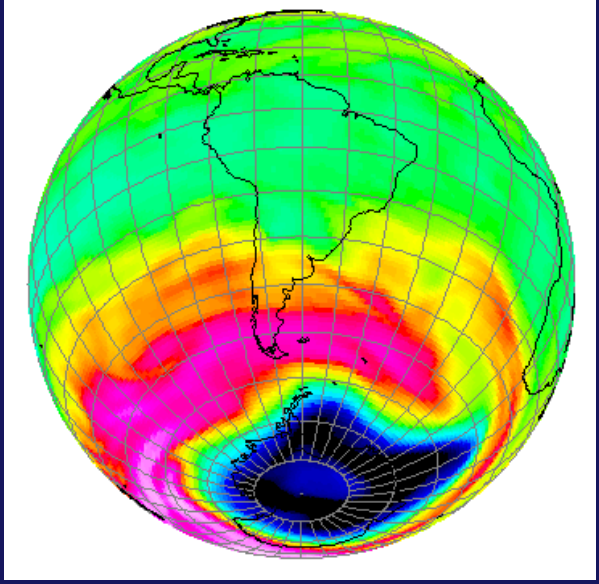


ZOMBIE BREAK !

MORE SOLUTIONS!!!!



THE DESTRUCTION OF STRATOSPHERIC OZONE



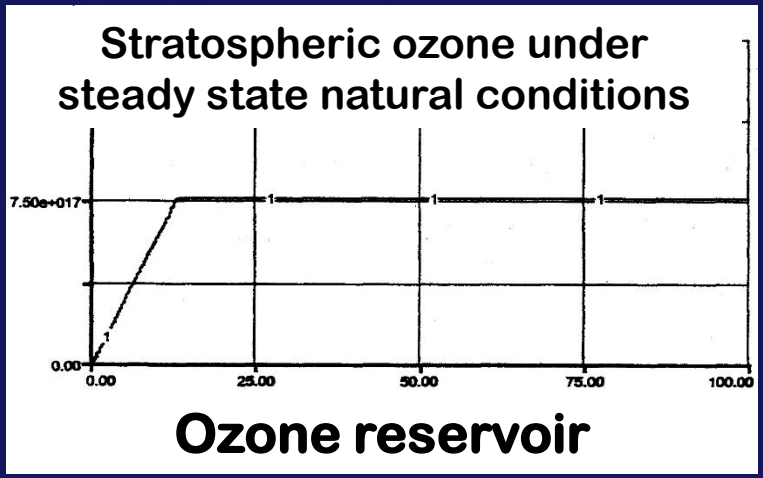
The ozone hole is:

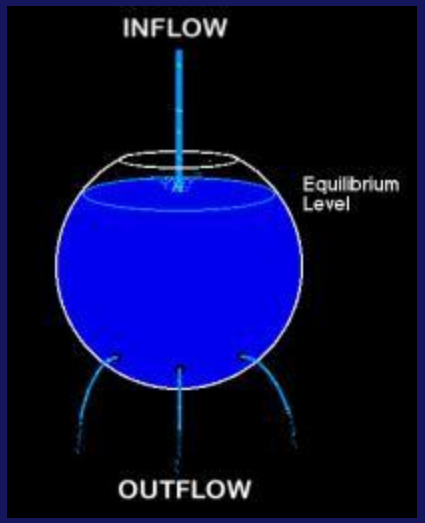
-- a depletion of ozone in the lower stratosphere

-- that has occurred with increasing severity each spring (since measurements begin in 1970s)

NOTE: this and other "bullet" items from today's lecture are in the box on p 85

The Chapman Mechansim "balance" is being disrupted by the introduction of CFC's and other similar gases into the stratosphere:





> CFCs are photo-dissociated into **FREE CHLORINE ATOMS (Cl)** and other molecular fragments by UV rays

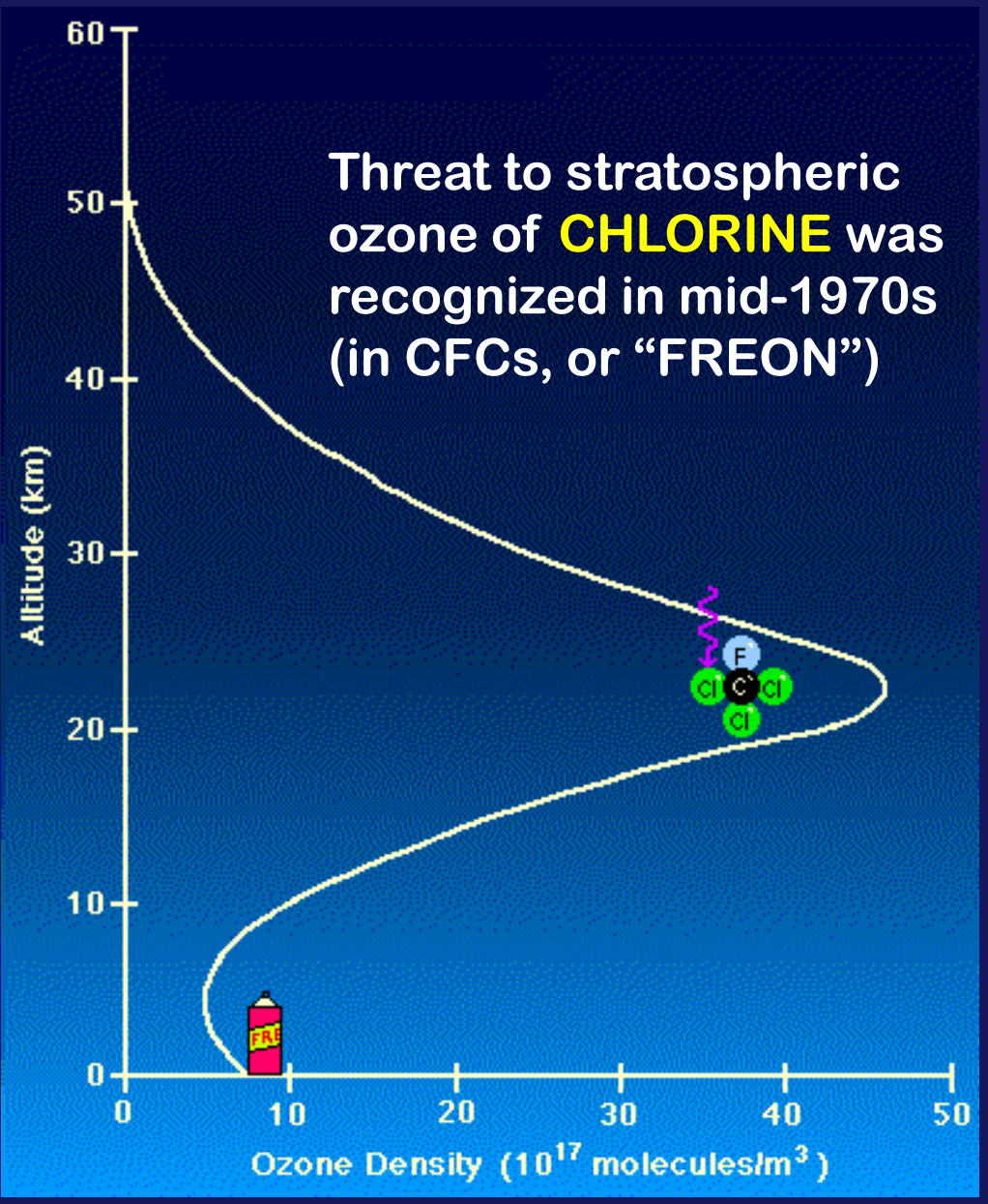
> **Chlorine** (and other gases such as Nitric oxide, NO) act as **catalysts** in ozone loss reactions

CATALYST =

A compound that increases the rate of a chemical reaction and is itself unchanged by the reaction

Through chemical reactions:

- **the chlorine removes ozone from the stratosphere**
- **and also frees more chlorine atoms to begin the process all over again**



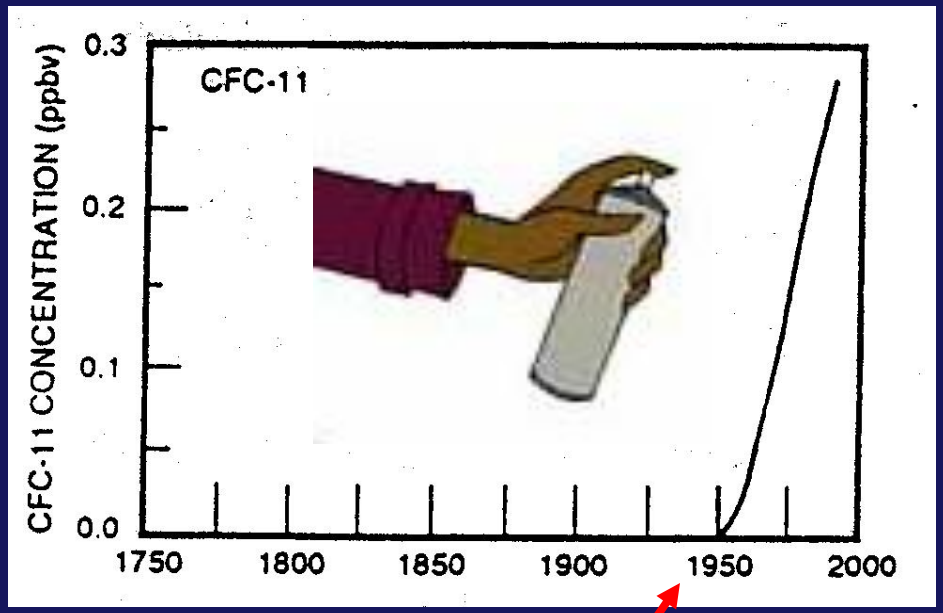
CFC compounds

Chlorofluorocarbons

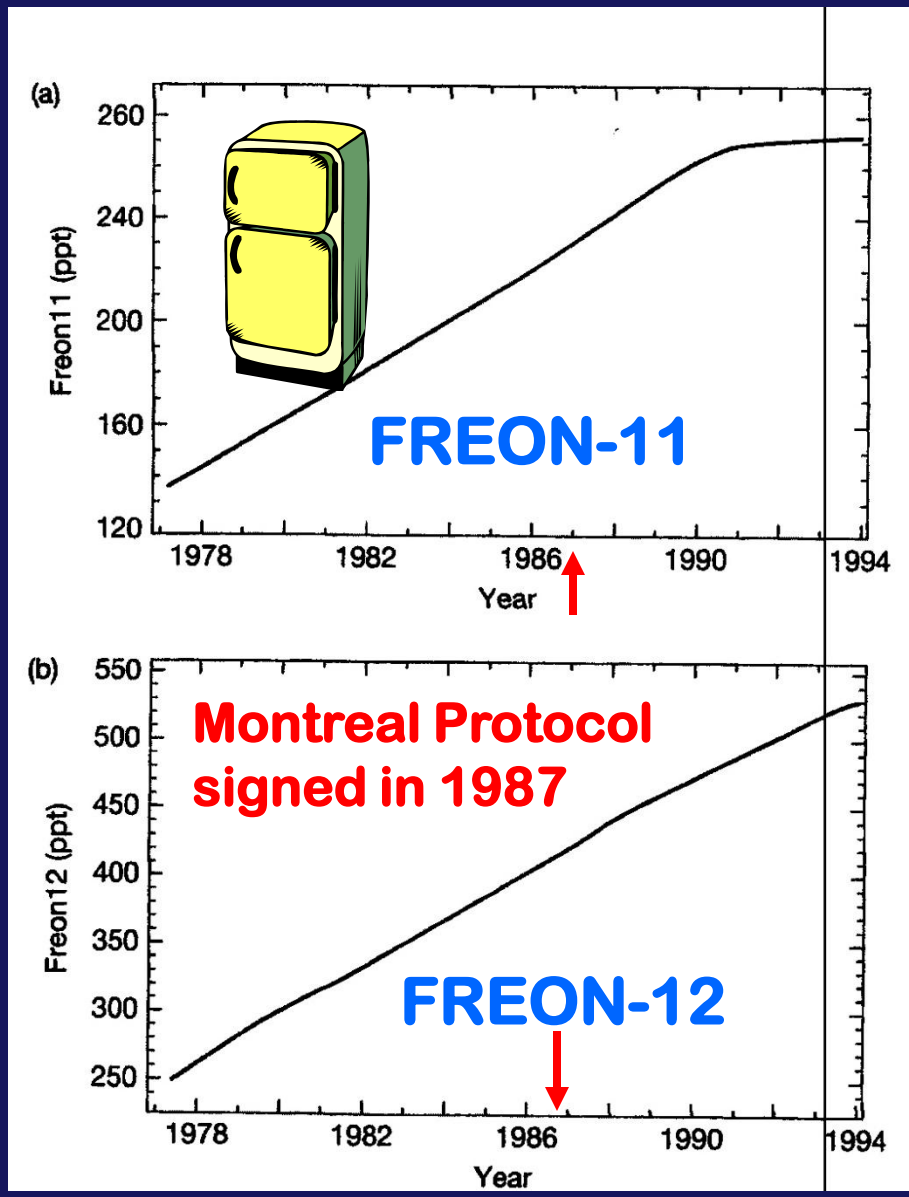
are unreactive at Earth's surface,

but if they get into the stratosphere, they can be broken down by high energy UV radiation → leads to release of highly reactive **CHLORINE atoms (Cl)**

CFCs: Trends



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



review

CFC's & the CHLORINE CATALYST

A single chlorine atom may destroy hundreds of thousands of ozone molecules during its residence in the stratosphere!

[Go to movie clip]

To be continued . . . . .