Topic # 18
OZONE DEPLETION IN THE STRATOSPHERE
Part 1

AND LINKS TO OTHER GLOBAL CHANGE TOPICS THIS SEMESTER

(see pp 135- 139 in Class Notes Packet)

The real answer:

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)

Bullet 1, p 139

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

The THEORY that the ozone layer in the stratosphere might be damaged or depleted by human intervention (supersonic jets, CFC's, etc) . . . .

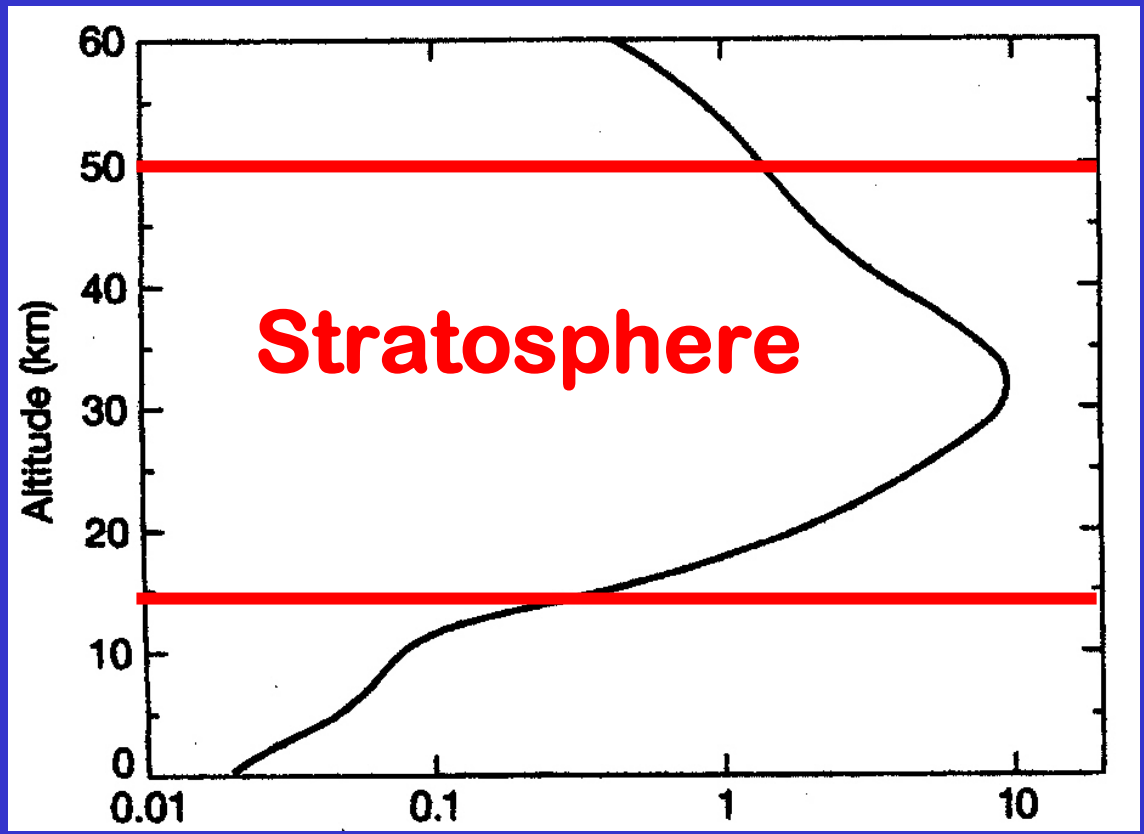
. . . preceded the actual OBSERVATION of the ozone hole.

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

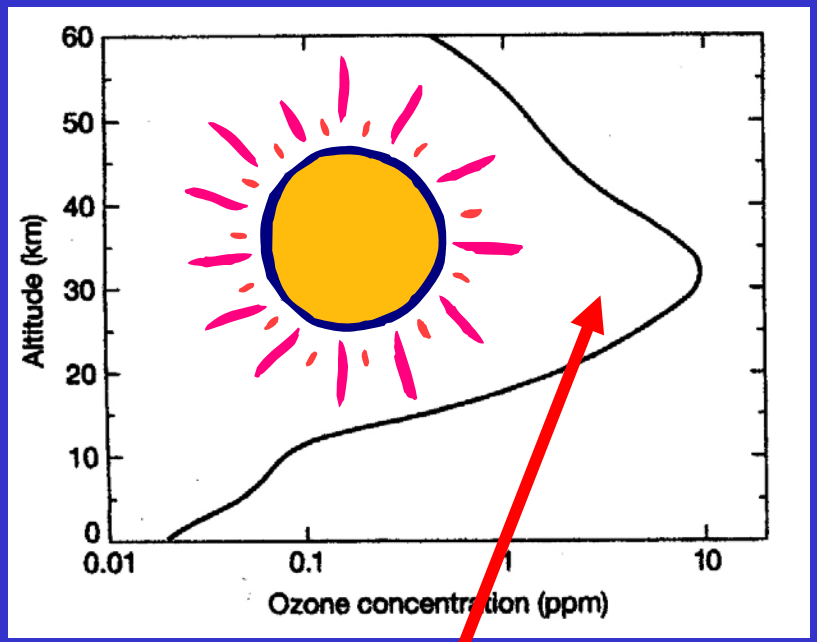
But let's begin with the stratospheric ozone layer itself . . . . . .

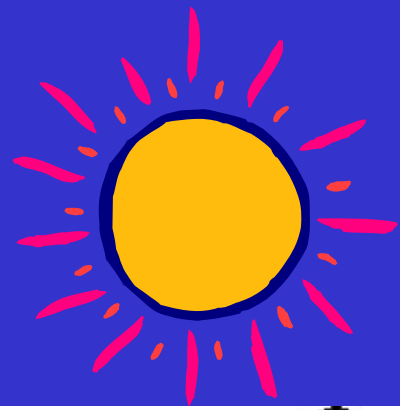
WHERE IS THE OZONE LAYER?

IGC
Fig. 3-11



OZONE: Sources





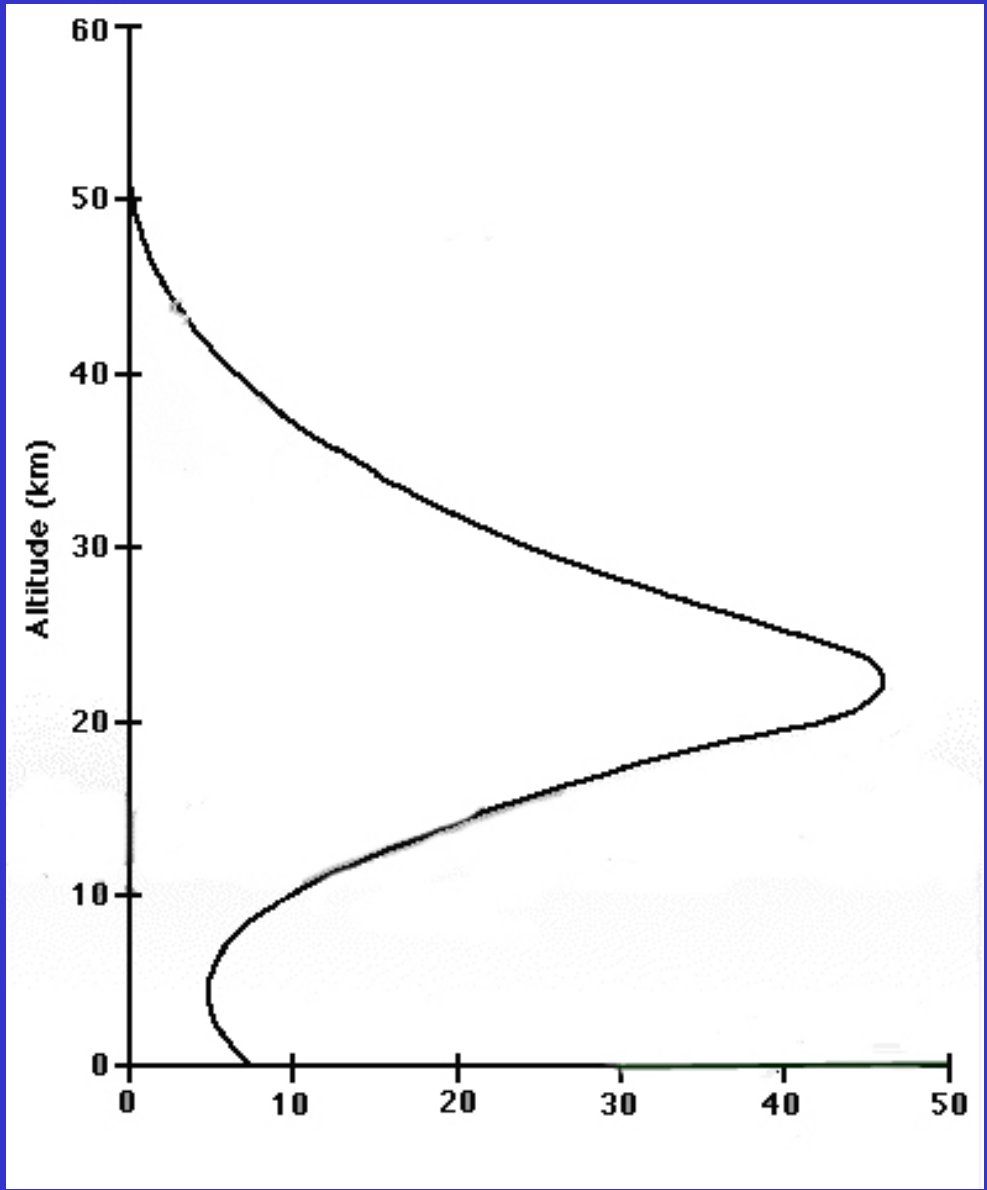
Produced naturally in photochemical reactions in stratospheric ozone layer - -"good ozone"

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

review

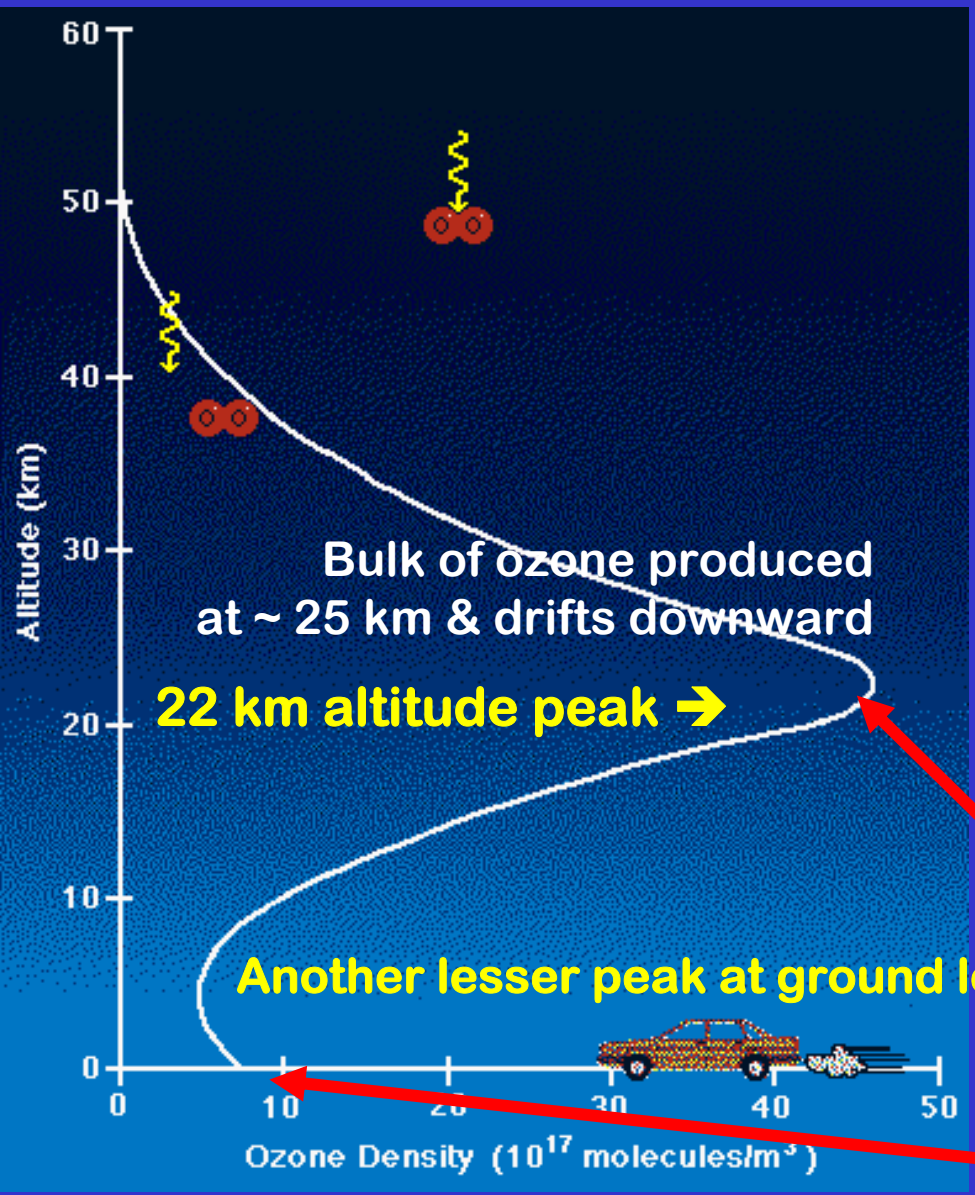
Here's a different version of the figure →

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 / $m^{3)}$



Now let's focus on the "GOOD" ozone located in the STRATOSPHERE (the ozone that is being depleted leading to an ozone "hole")

"Good" ozone
&
"Bad" ozone

☺

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

Due to: the natural "Chapman Mechanism"

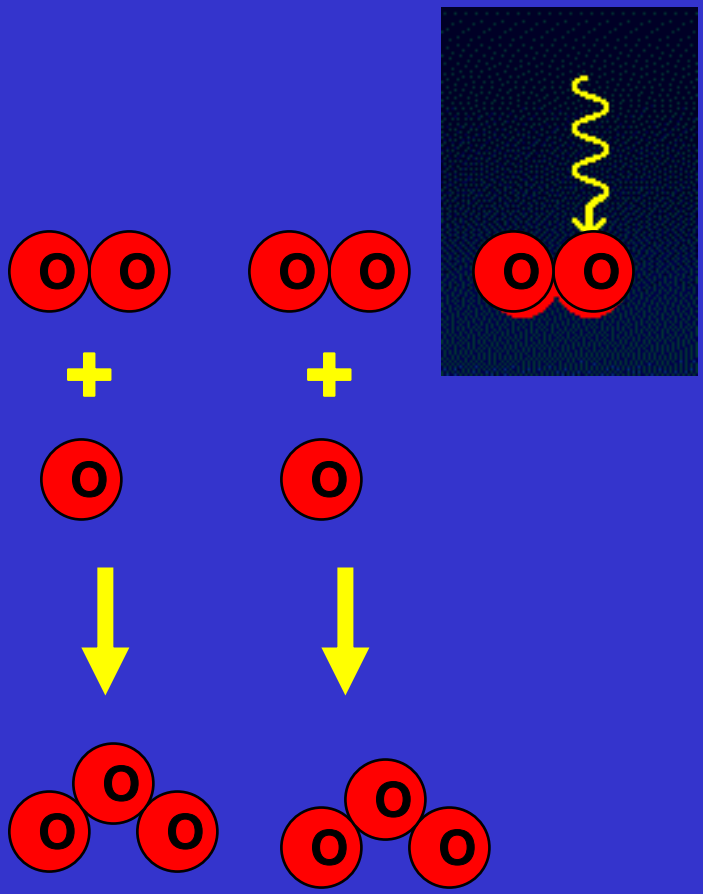
(a series of photochemical reactions)

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).

Bullet 3, p 139



The Chapman Mechanism

Ozone exists in the upper atmosphere as a consequence of photochemical reactions between molecular oxygen and sunlight:

$$O_2 + O_2 + O_2 + \text{sunlight}$$

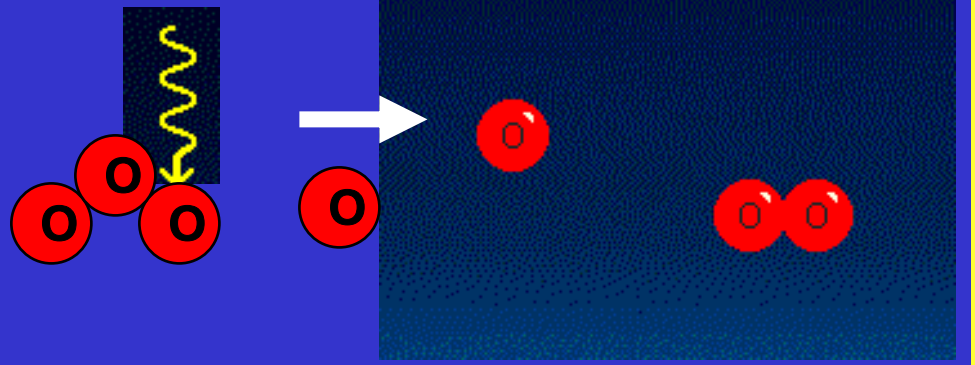
$$\rightarrow O_2 + O + O + O_2$$

$$\rightarrow O_3 + O_3$$

HOW the CHAPMAN MECHANISM Works

- ozone is continuously produced and destroyed
- through **PHOTOCHEMICAL REACTIONS** in the stratosphere
- involves oxygen, molecular oxygen, UV radiation, and ozone.

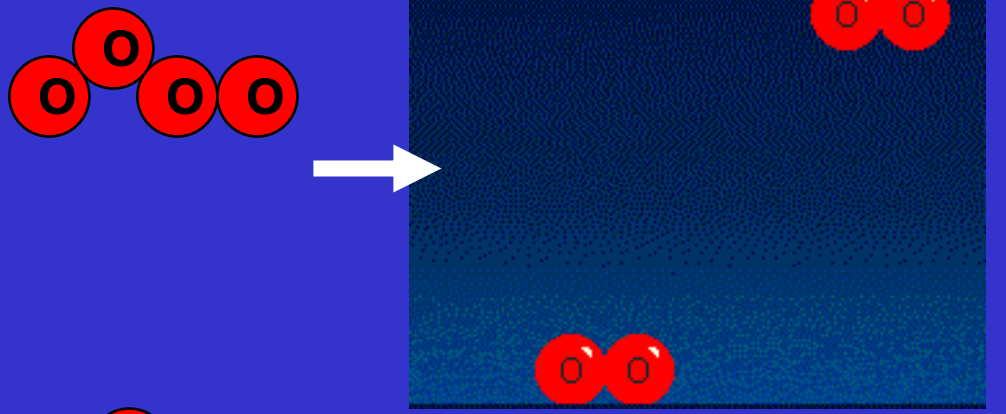
Bullet 3, p 139



Ozone is destroyed naturally by reaction with ultraviolet radiation:

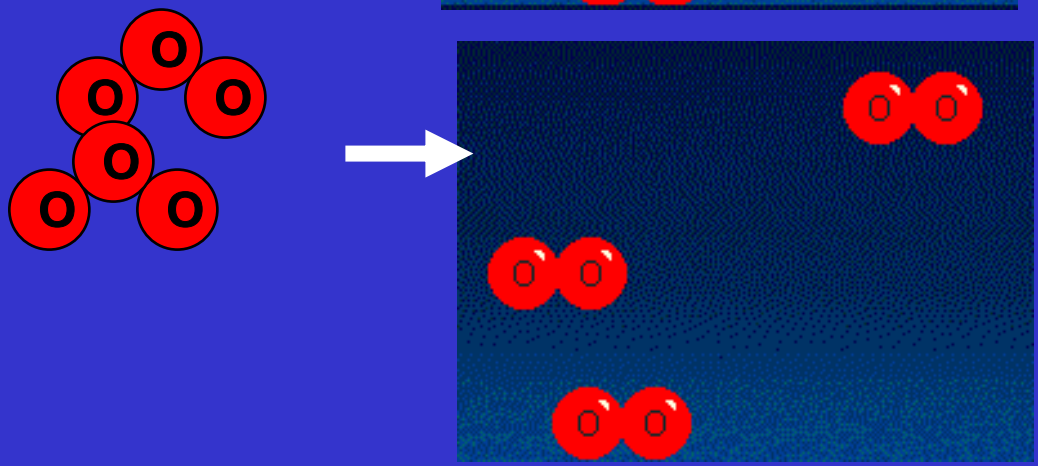
$$O_3 + UV \rightarrow O_2 + O$$

This is part of how the ozone layer protects the earth's surface from ultraviolet radiation.



Ozone is also destroyed naturally by reactions promoted by collisions with atomic oxygen:

$$O_3 + O \rightarrow 2\,O_2$$

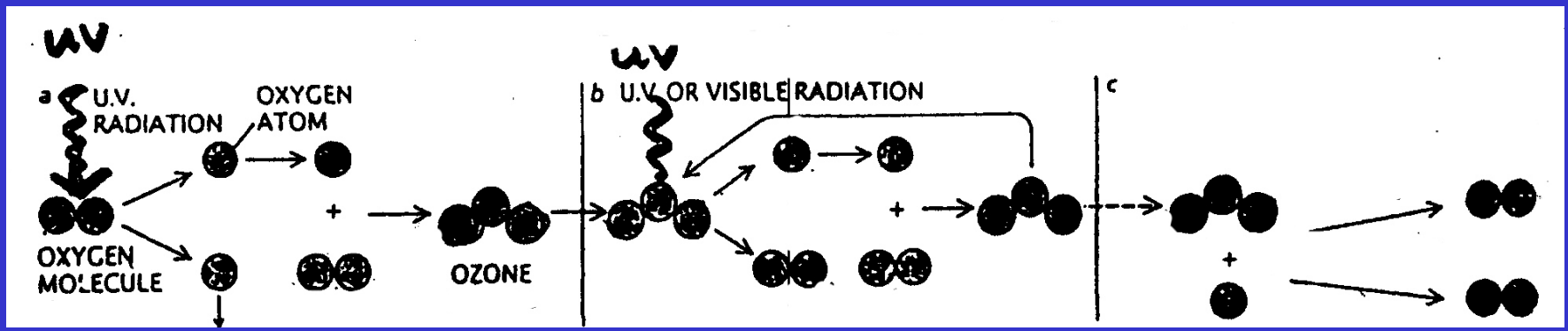


As well as being destroyed by collisions with itself:

$$O_3 + O_3 \rightarrow 3\,O_2$$

The Chapman Mechanism

(another view)



Ozone being formed naturally

Ozone being destroyed naturally

Ozone being formed naturally

Ozone being destroyed naturally

[Go to movie clip]

In theory:

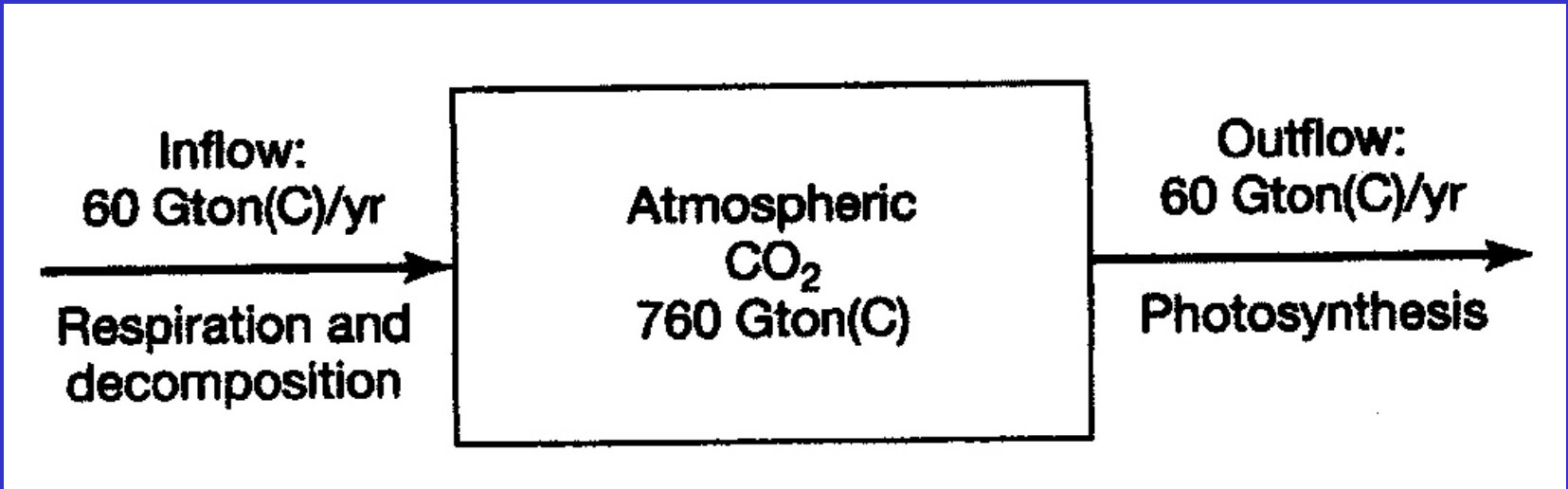
> a balance of ozone is established over time

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

Leads to an “Equilibrium” or “Steady State”

Bullet 3, p 139

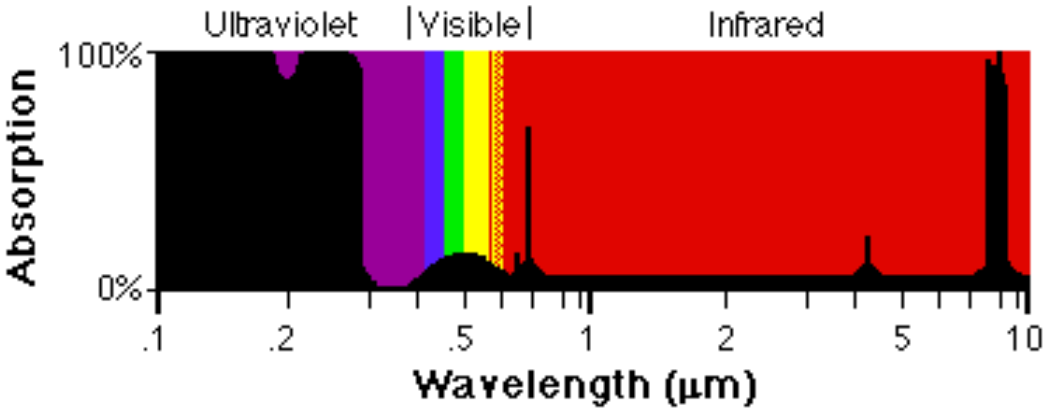
Where else have we seen A STEADY STATE?

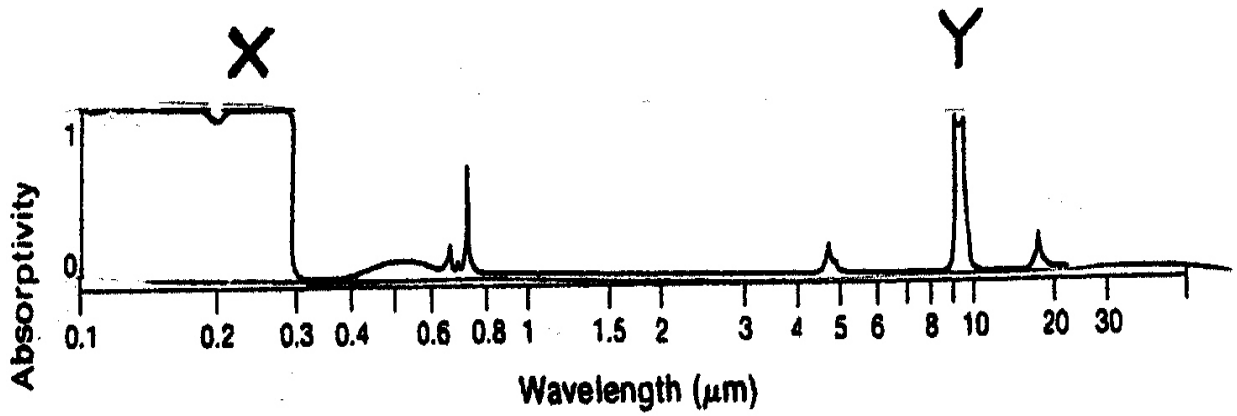


review

Why stratospheric ozone is "Good":

Black areas = radiation absorbed



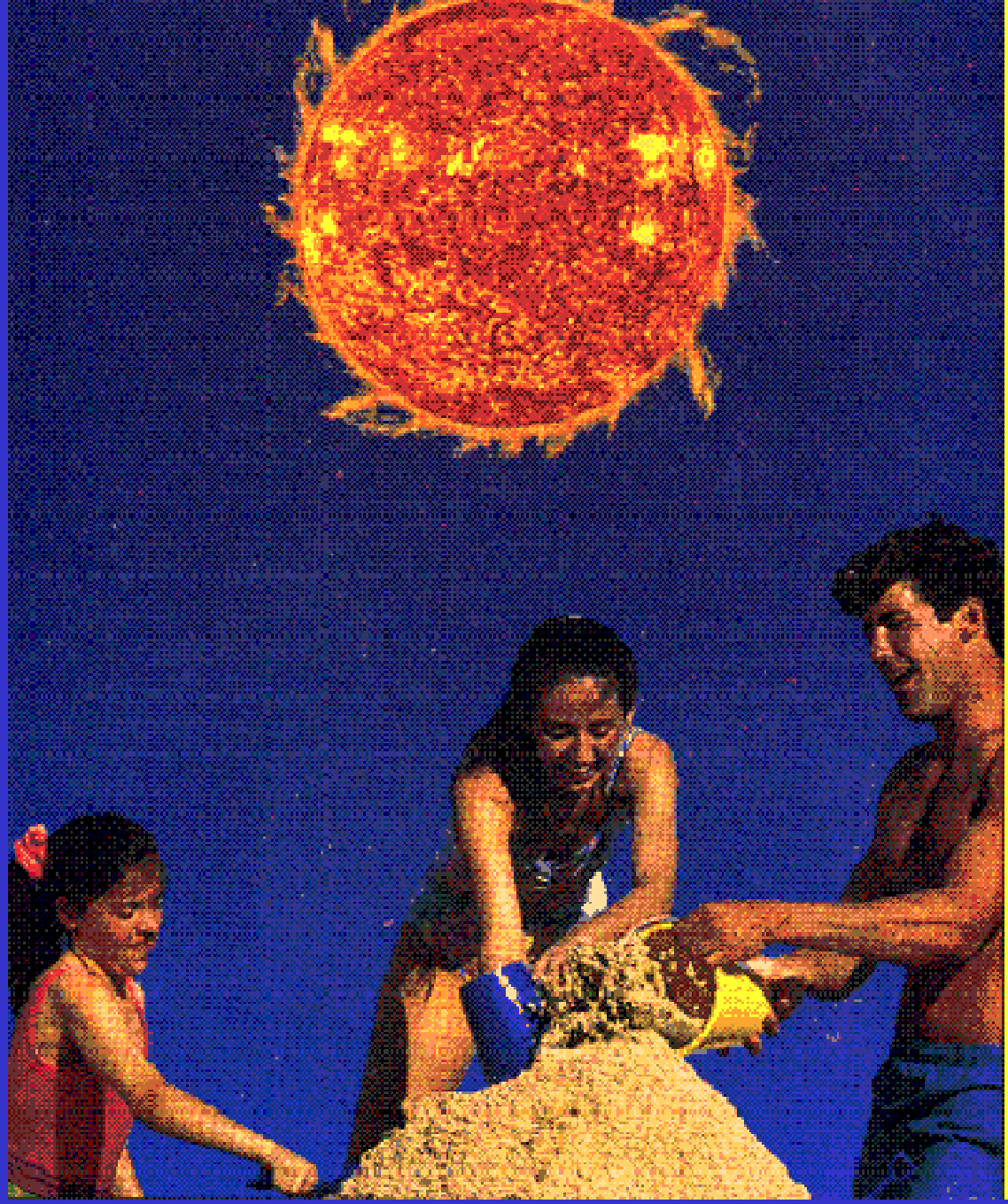


Ozone has the property of being a very strong absorber of ultraviolet radiation → nearly total absorption of wavelengths less than 0.3 μm

What is the wavelength range of visible light?

0.4 to 0.7 μm

← remember this figure?



The "B" component of ultraviolet light, which ranges from .29 to .32 µm, has been linked to two types of skin cancer: basal cell carcinoma and squamous cell carcinoma. Currently, there are 300,000 to 400,000 cases of basal cell carcinoma and 100,000 cases of squamous cell carcinoma reported each year in the United States.

UVA = .32 to .4 µm

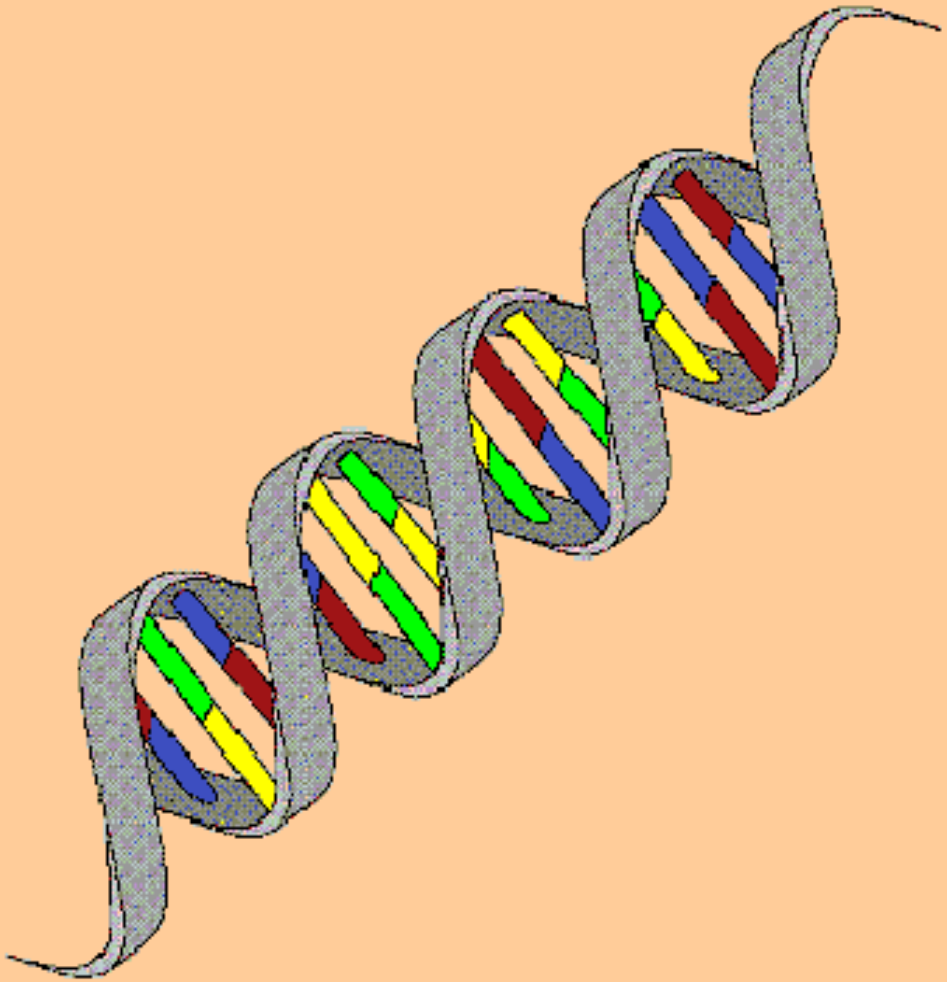
(once thought to be relatively harmless, BUT causes wrinkles, premature aging and associated sun-related skin damage; new research indicates possible skin cancer link)

UVB = .29 to .32 µm

(harmful, sunburn, skin cancer)

UVC = .20 to .29 µm

(extremely harmful, damages DNA)



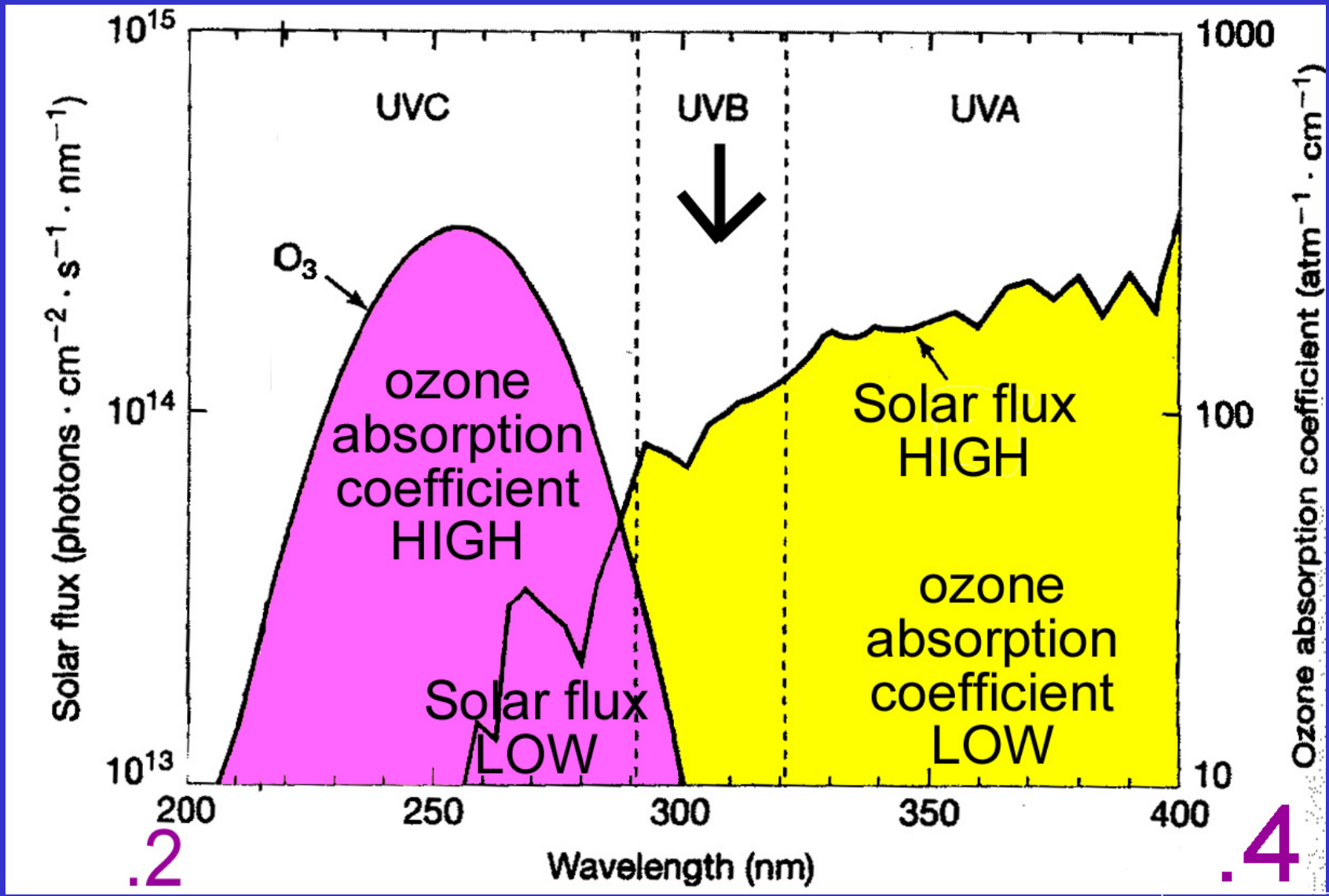
Segment of a DNA Molecule

Ultraviolet-B appears to prevent normal responses of human immune systems, and may adversely affect the survivial of various animal and plant species, including crops. A third type of skin cancer, melanoma, shows only a minor linkage to ultraviolet light.

Lastly for the biological effects of UV radiation, at ultraviolet wavelengths of about .26 µm, the acids on the DNA molecule (responsible for transmitting genetic information from one generation to the next) are destroyed.

UV-C wavelengths are the most harmful

"GOOD" Stratospheric
OZONE absorbs harmful UVC & most harmful UVB



Wavelength Range	Name	Biological Effect
.32 to .4 µm (320-400 nm)	**UVA** **(SPF doesn't rate UVA protection!)**	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** **(see SPF for protection)**	harmful, causes sunburn, skin cancer, and other disorders
.20 to .29 µm (200 - 290 nm)	**UVC** **(almost completely absorbed by O3)**	extremely harmful, damages DNA -- but almost completely absorbed by ozone

p 135

WAVELENGTH PROTECTION FOR DIFFERENT SUNSCREEN INGREDIENTS:

UV WAVELENGTH BANDS	UVC	UVB	UVA
wavelength band range in nanometers	200-290	290-320	320-400
Padimate O, 290-315 nanometers		**(X)**	
Benzophenones, 250-350 nanometers	**(X)**	**X**	**(X)**
Octyl methoxycinnamate, 290-320 nanometers		**X**	
Avobenzone, 320-400 nanometers			**X**
Oxybenzone 270 to 350 nanometers	**(X)**	**X**	**(X)**
Titanium dioxide, 290-700 nanometers		**X**	**X**
Zinc oxide, 290-700 nanometers		**X**	**X**

X = over the entire band **(X) = protects over part of the band**

X = protects over the longer wavelength UVA band, now known to be harmful

Check the active ingredients:

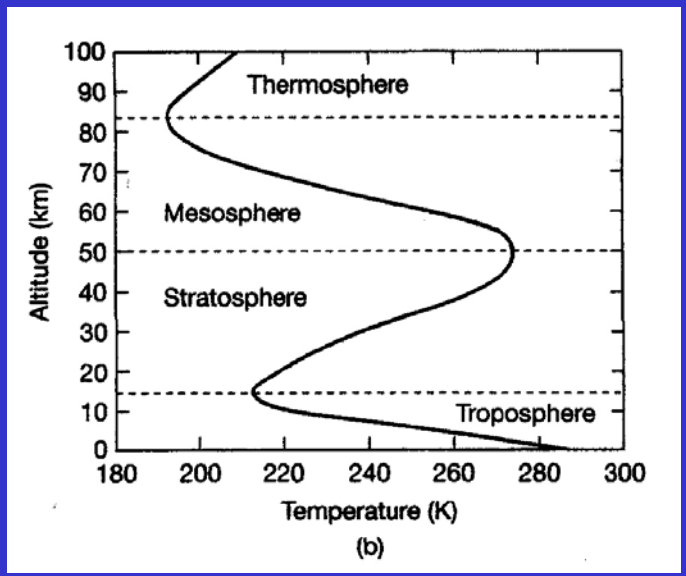
- **titanium dioxide**
- **zinc oxide**
- **avobenzone** (also called butyl methoxydibenzoylmethane)

are the ONLY ingredients authorized for use in U.S. products that protect you from the entire UVA spectrum.

Therefore, if one of those isn't listed as an active ingredient on the label, the product should not be used for sun protection by anyone!

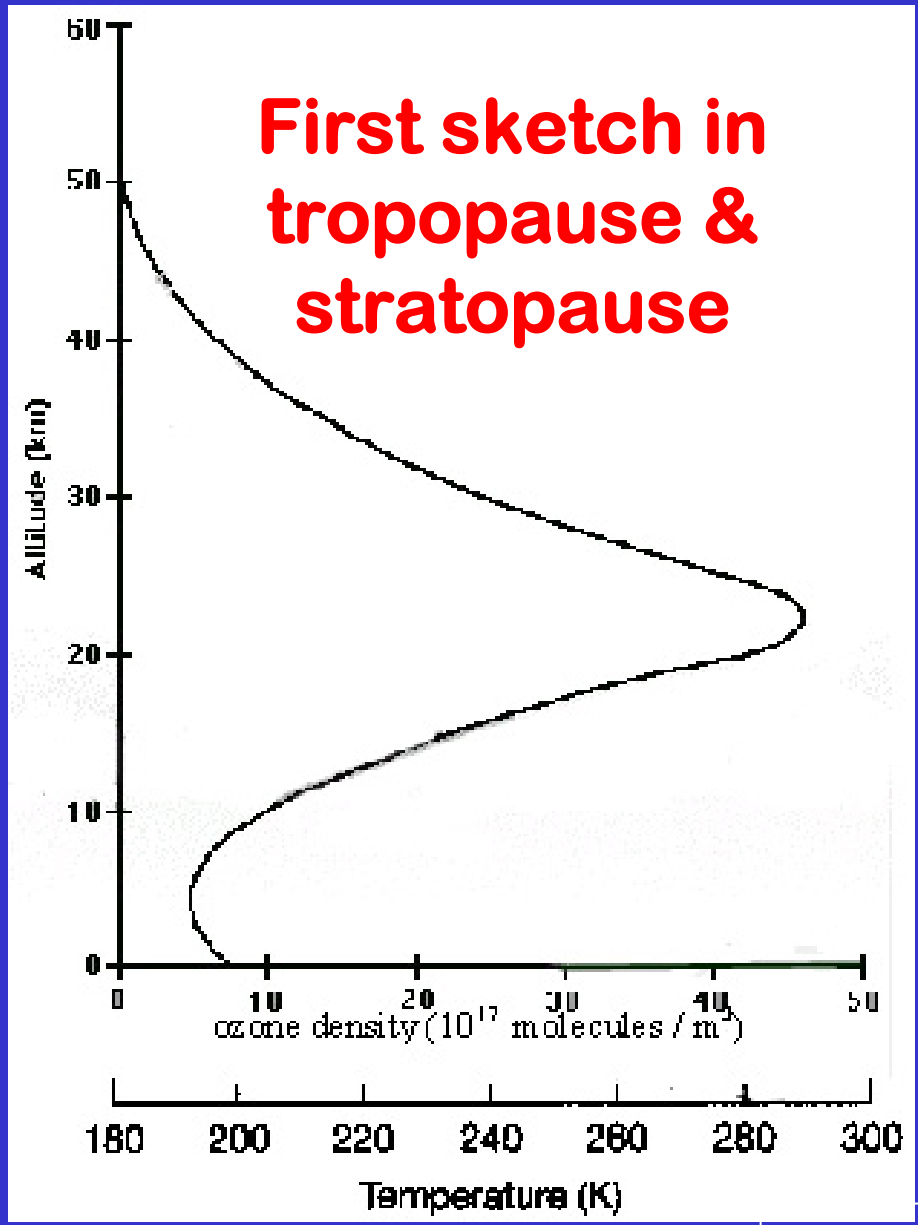
P. 136 in Class Notes:

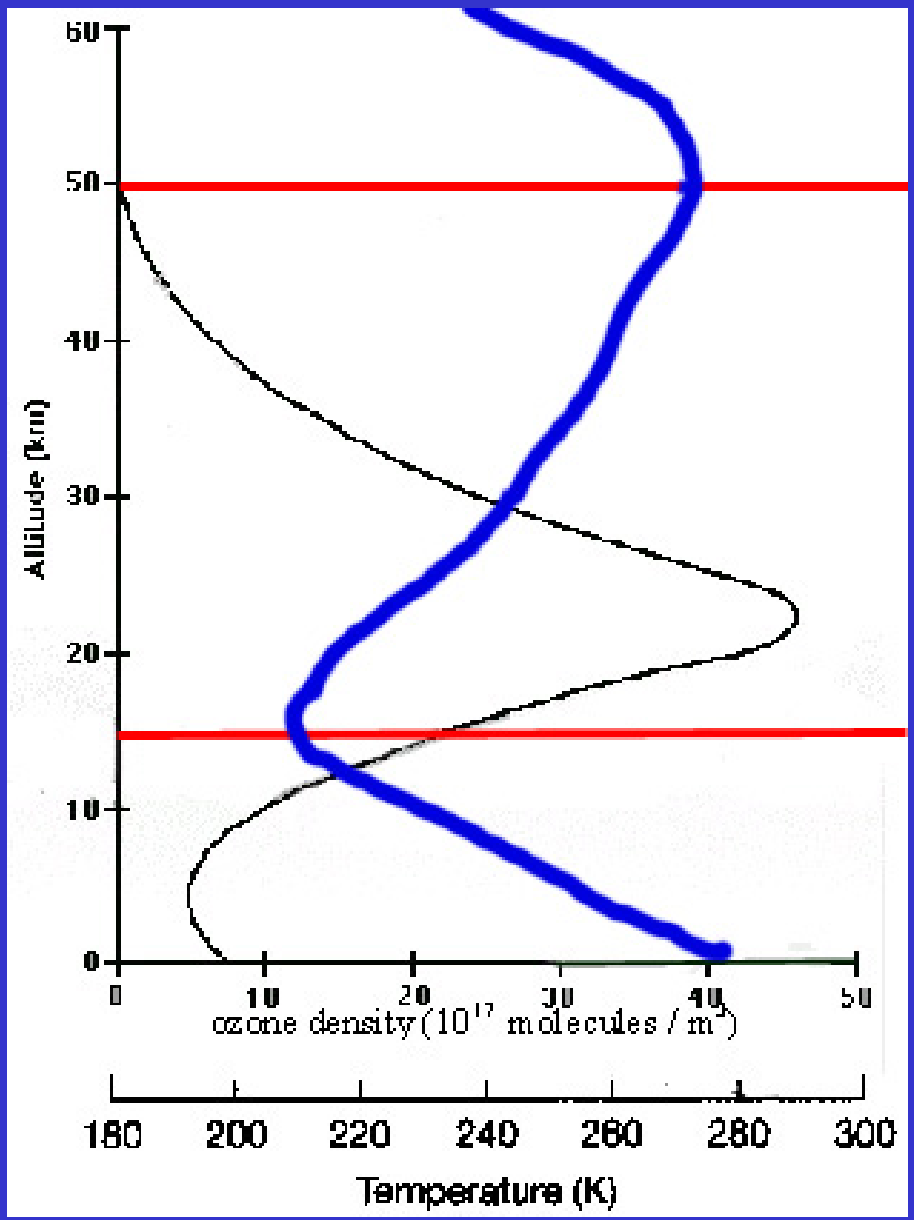
Temperature graph



Roughly sketch temperature line on ozone graph

Ozone Density graph





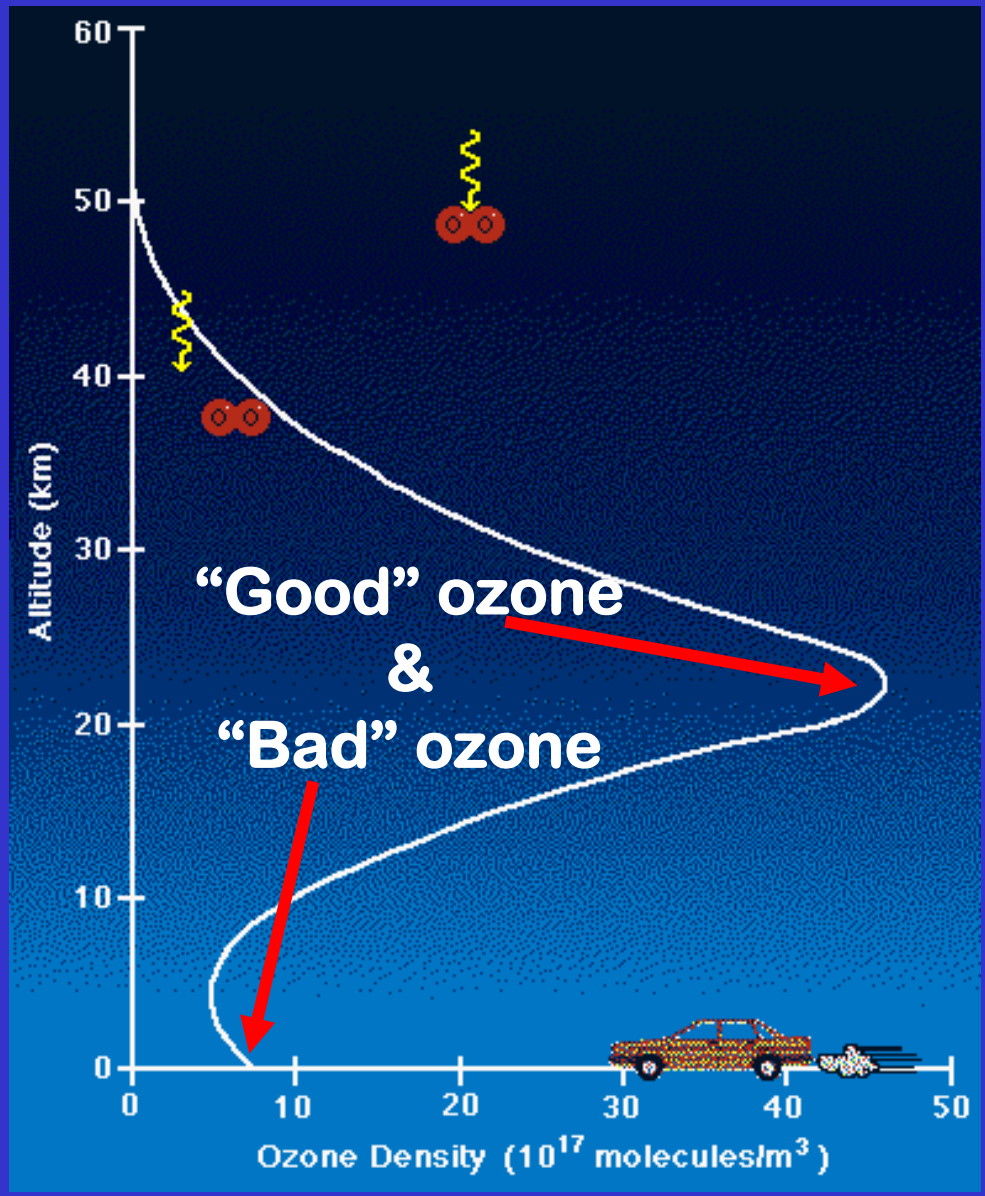
Temperature

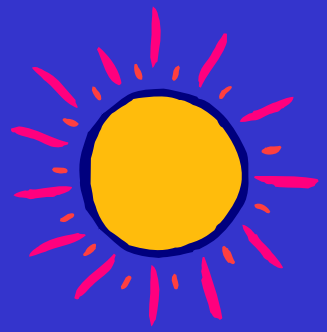
[increases / decreases]

with increasing altitude in the stratosphere

WHY???

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.

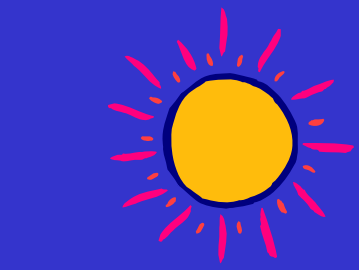
➔ When inhaled, even at very low levels, ozone can:

- cause acute respiratory problems
- aggravate asthma
- cause significant temporary decreases in lung capacity of 15 to over 20 percent in some healthy adults
- cause inflammation of lung tissue
- lead to hospital admissions and emergency room visits
- impair the body's immune system defenses

Source: http://www.epa.gov/ttn/oarpg/naaqsfin/o3health.html

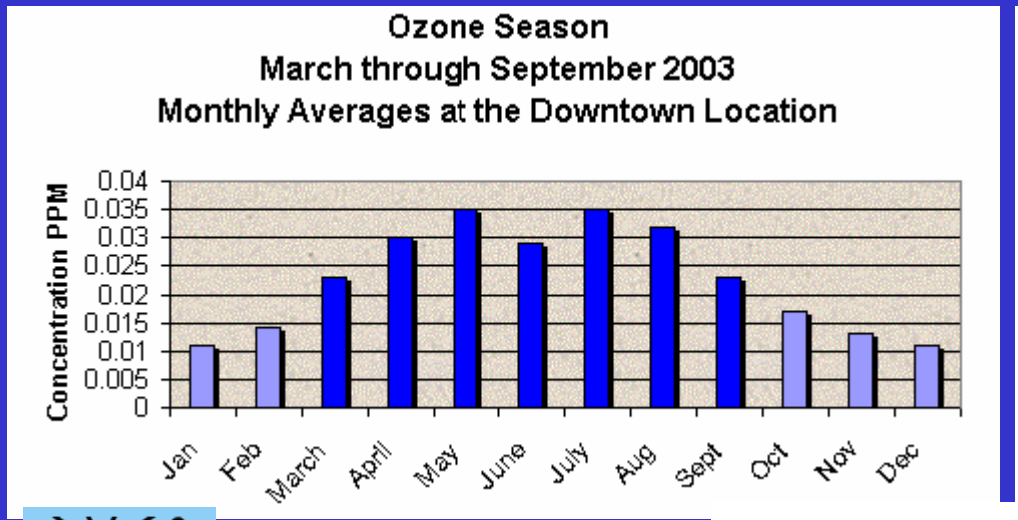
"BAD" OZONE

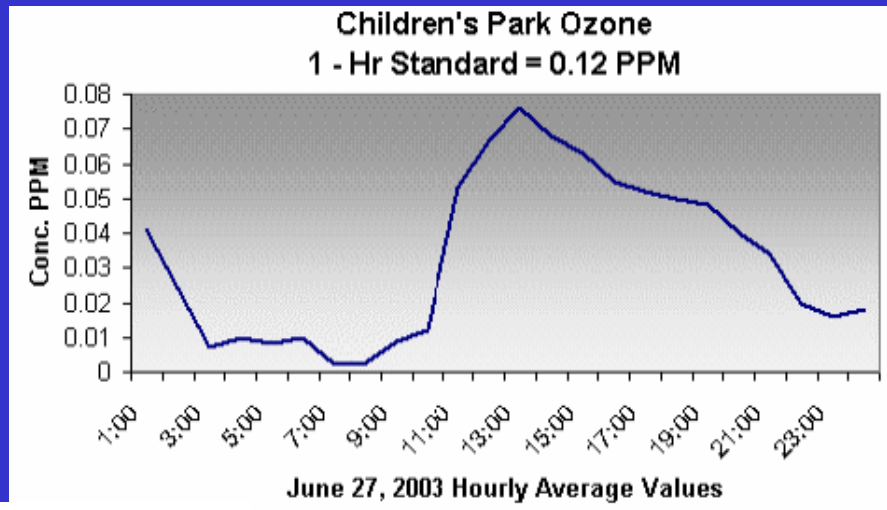
Ground-level ozone is a form of pollution created when:



nitrogen oxides in auto emissions
+ **hydrocarbons** from plant matter
+ **solvents** and **gasoline fumes**

. . . . mix and bake in stagnant heat and sunlight!





Tucson data

AIR INFO NOW

http://www.airinfonow.org/html/ozoneMC.html

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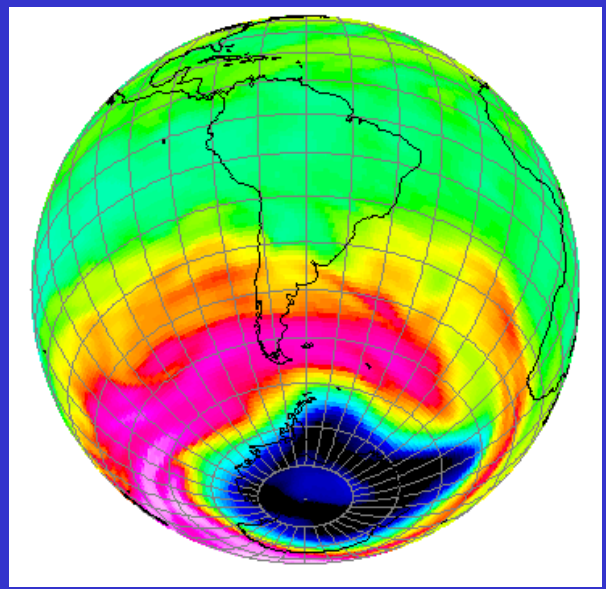
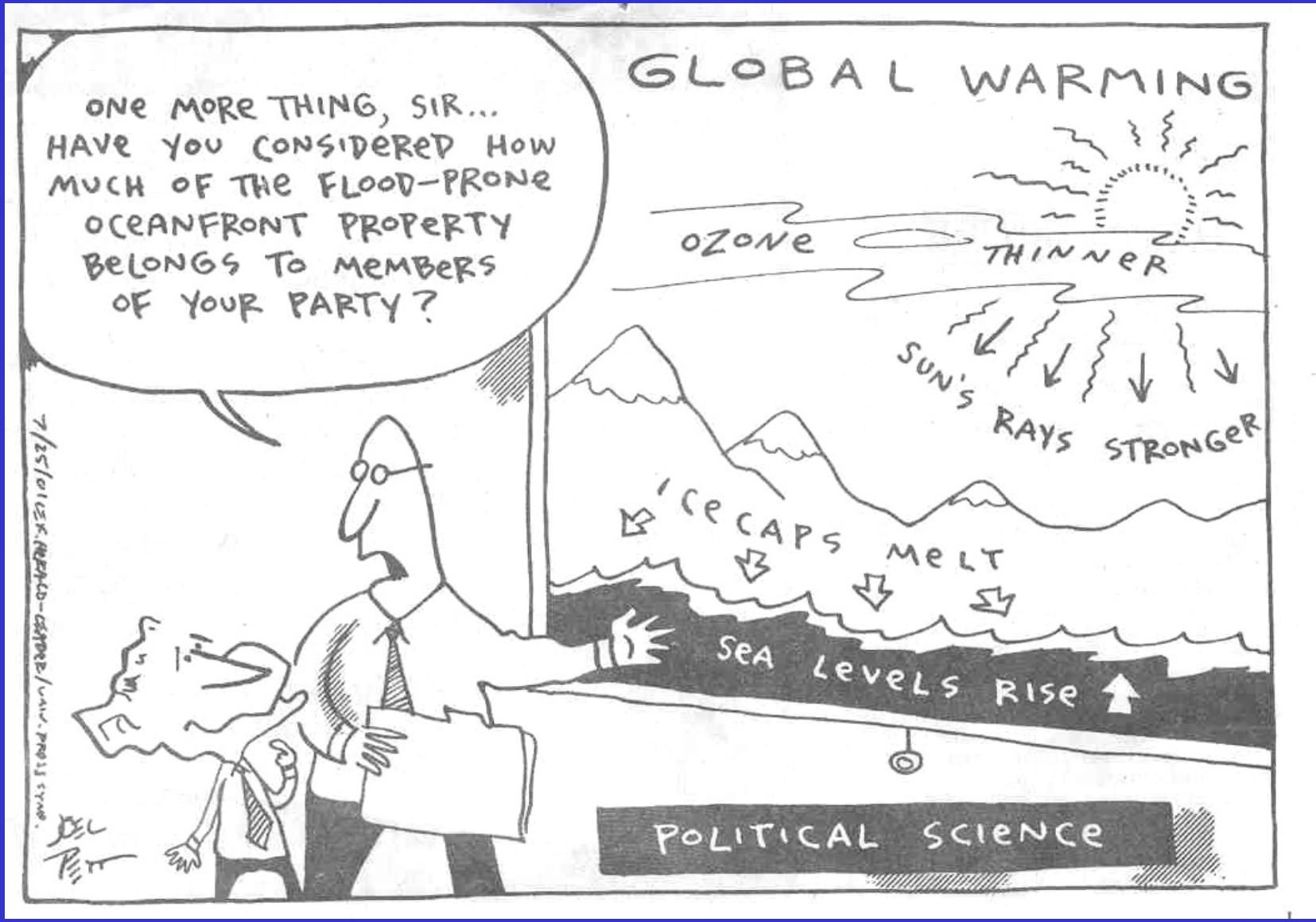
NEXT:

THE DESTRUCTION OF STRATOSPHERIC OZONE





What – if anything -- is scientifically inaccurate in this cartoon?

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To be continued after the Thanksgiving Break!