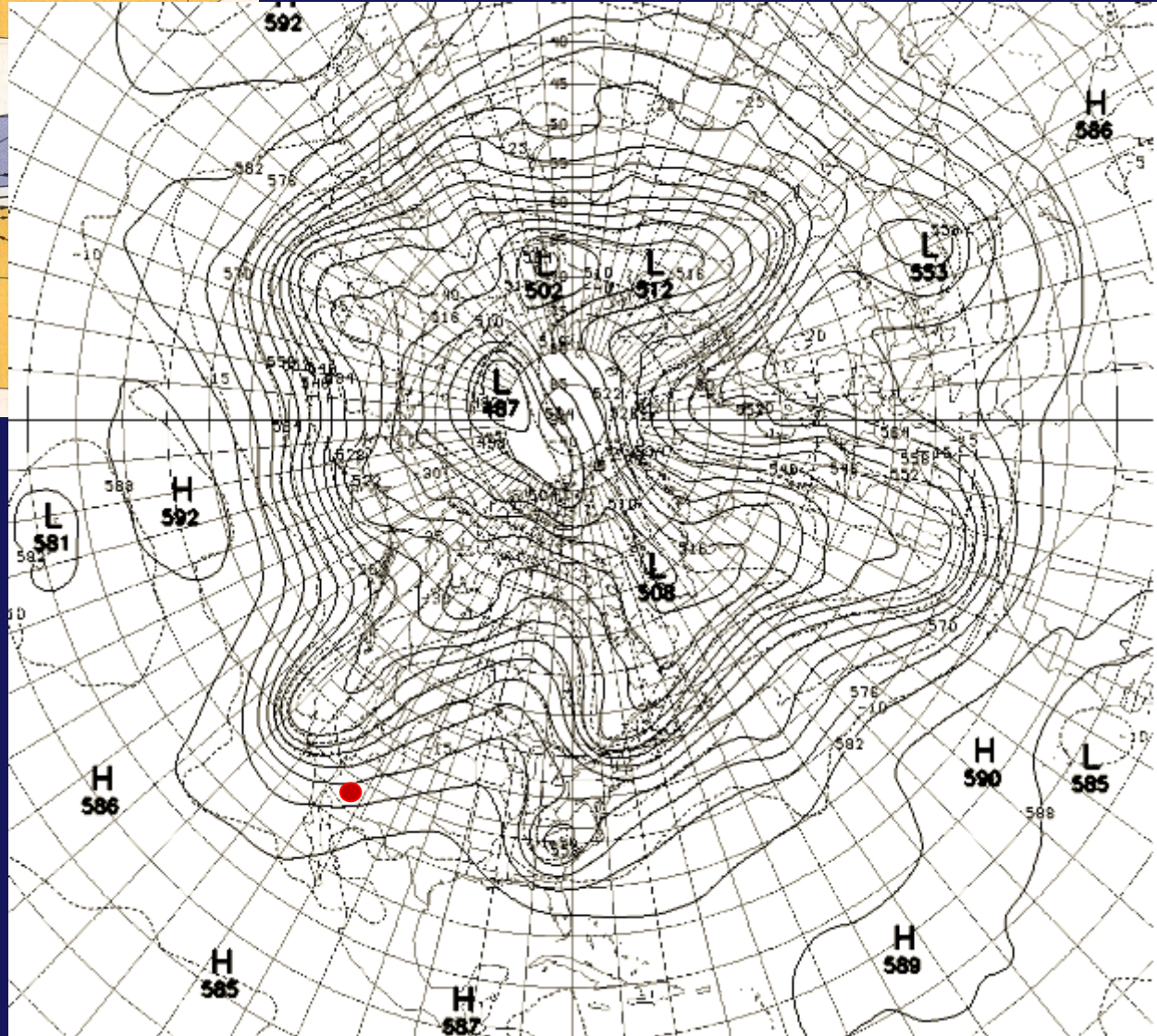
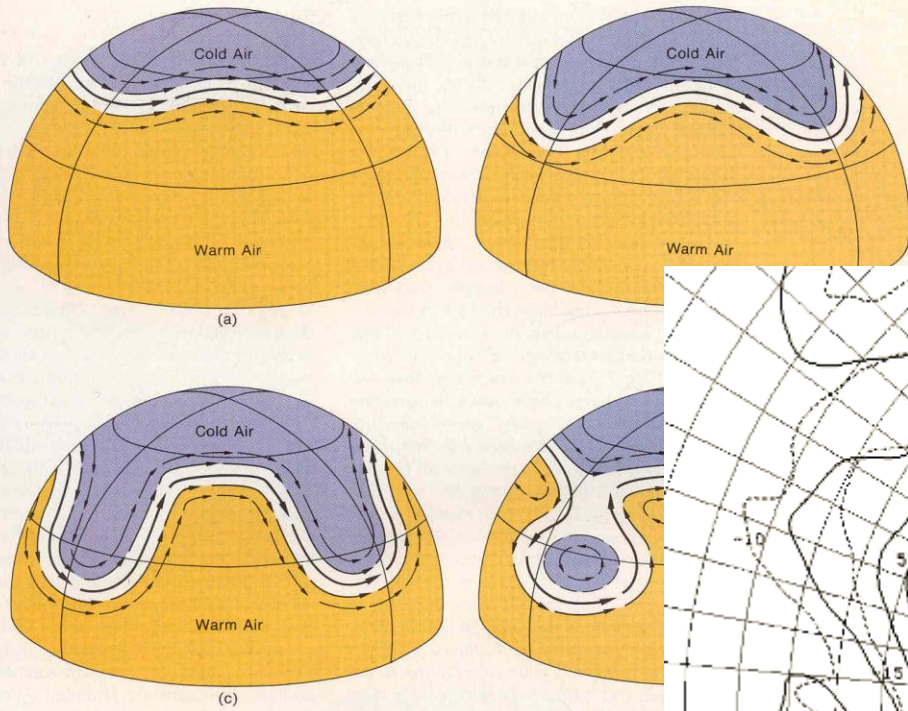


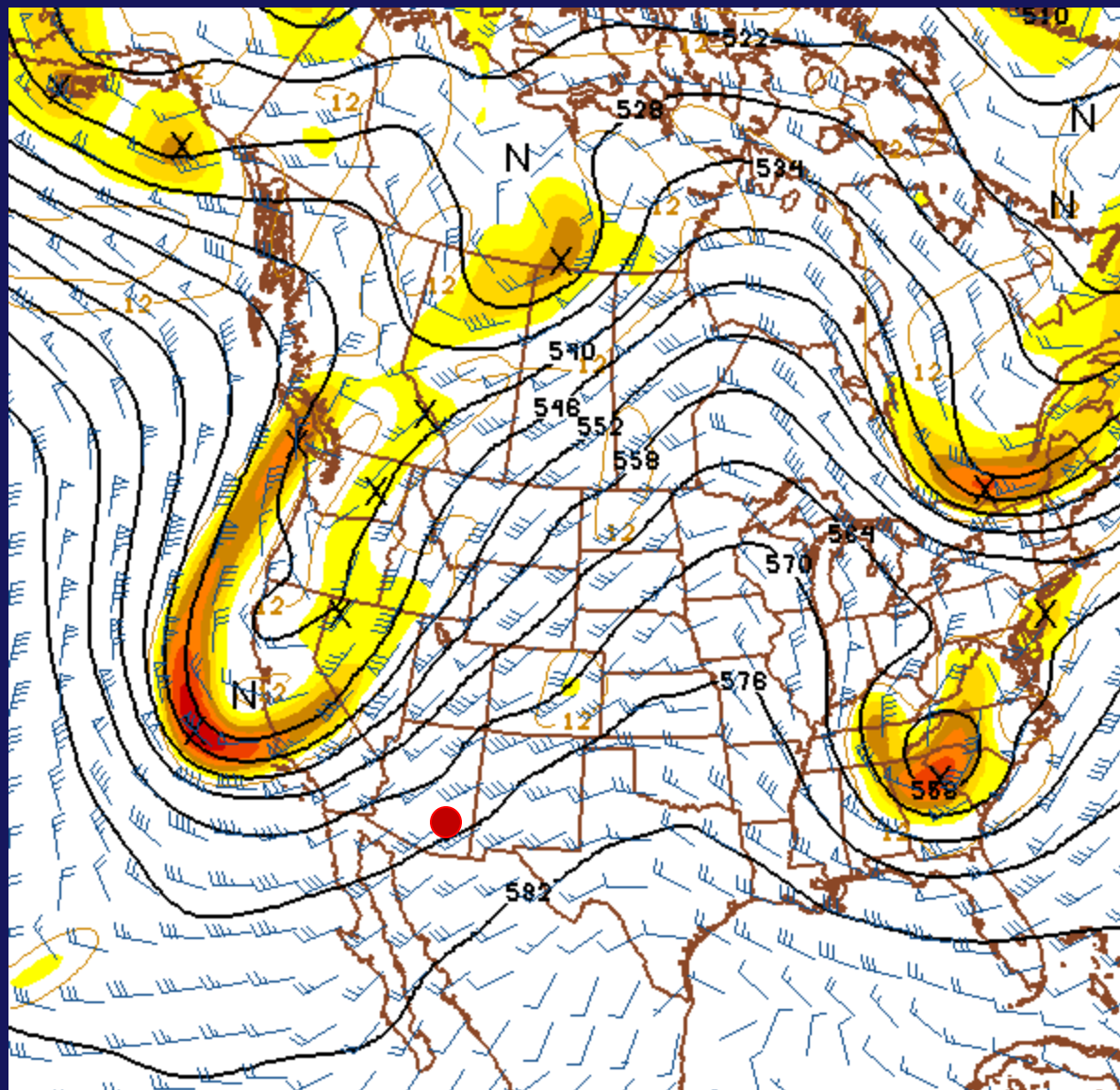
HOMECOMING WEATHER!



The Rossby
Wave pattern
today:
Friday Nov 4th
@ 5 am

Forecast says the wave of cool air will move over us!!

Dress warmly!



LOOP

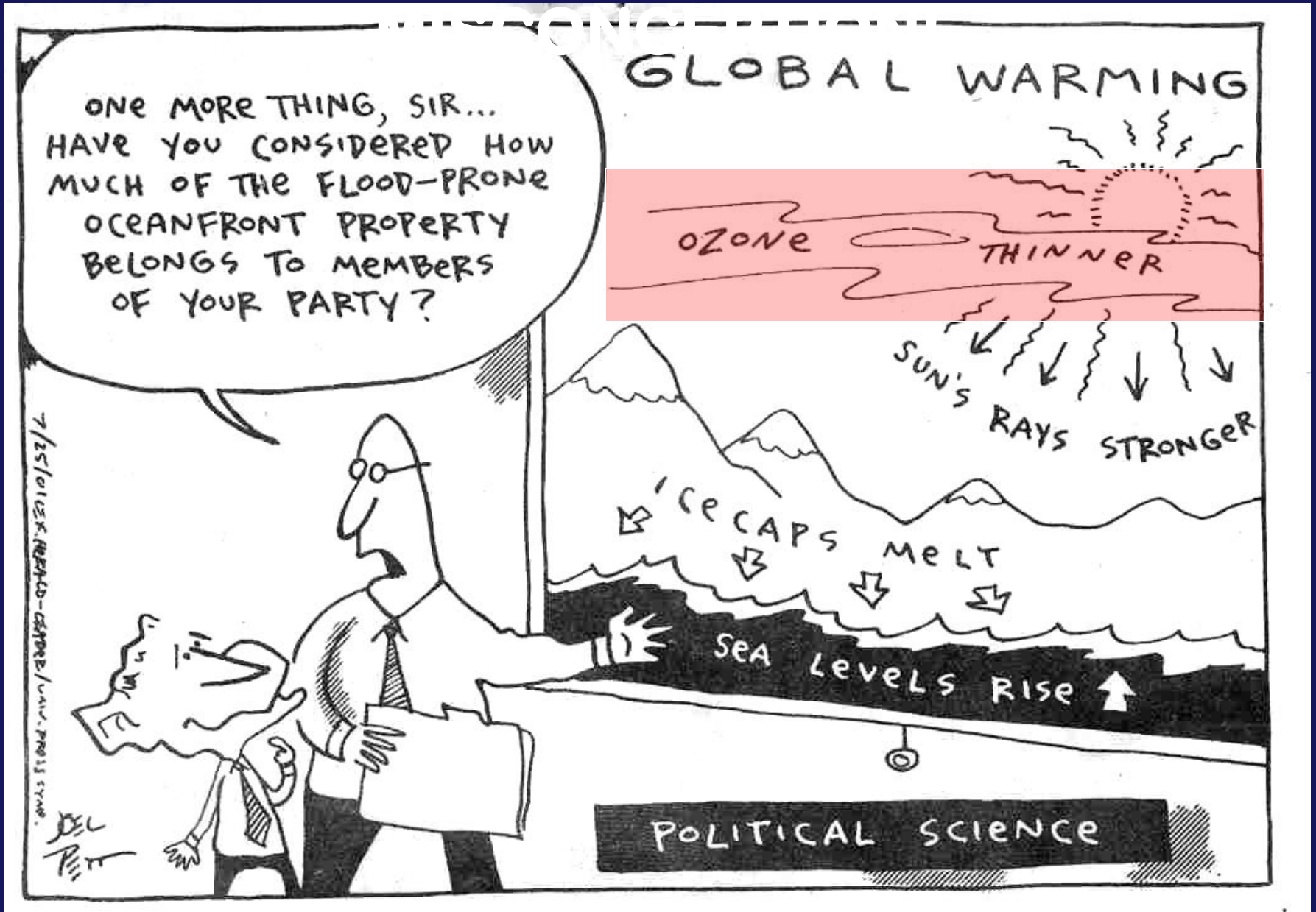
Topic # 13

OZONE DEPLETION IN THE STRATOSPHERE

A Story of Anthropogenic
Disruption of a Natural
Steady State

p 77 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

[Answer not revealed. . . This question will be asked again on MONDAY!]

“[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!

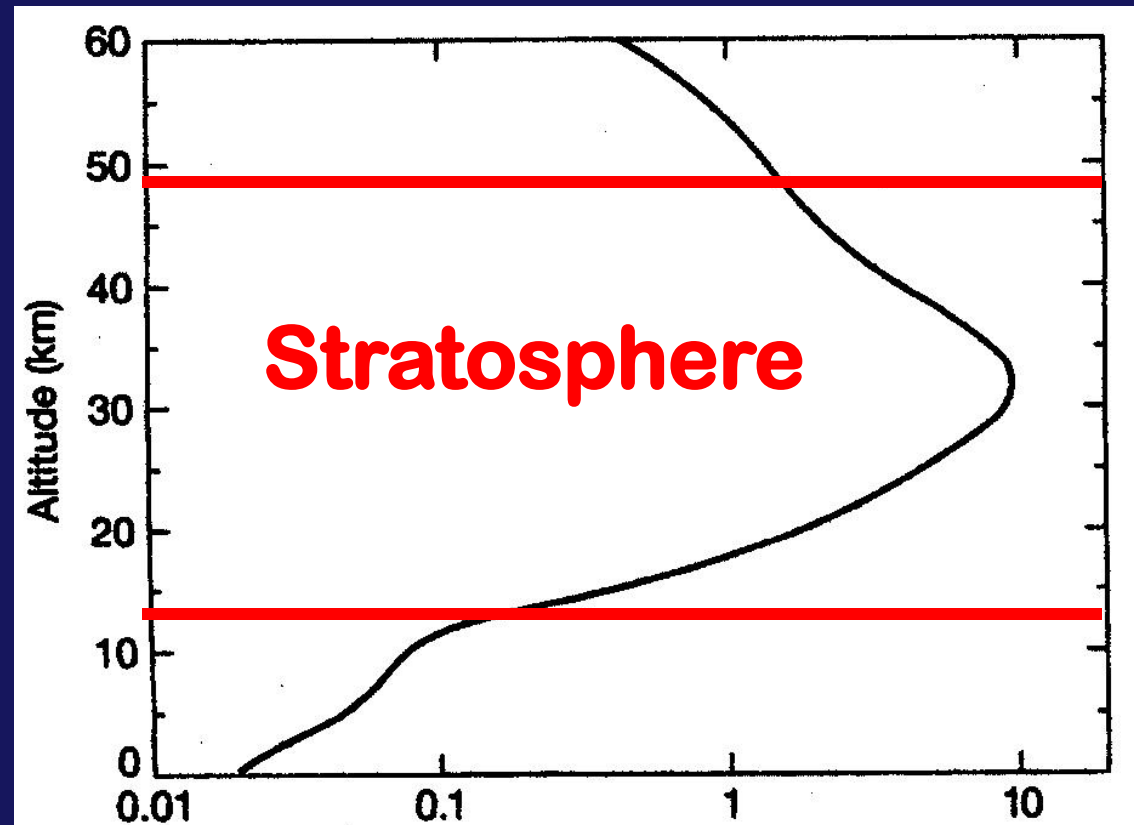
The THEORY that the ozone layer in the stratosphere might be damaged by human intervention PRECEDED the actual OBSERVATION of the ozone hole.

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

REVIEW: WHERE IS THE OZONE LAYER?

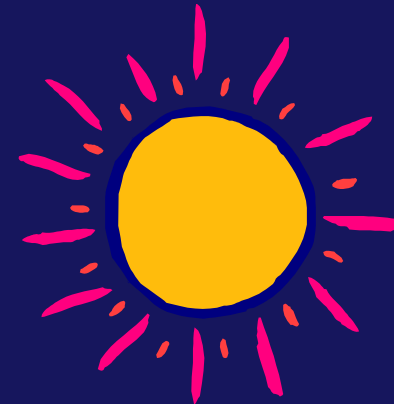
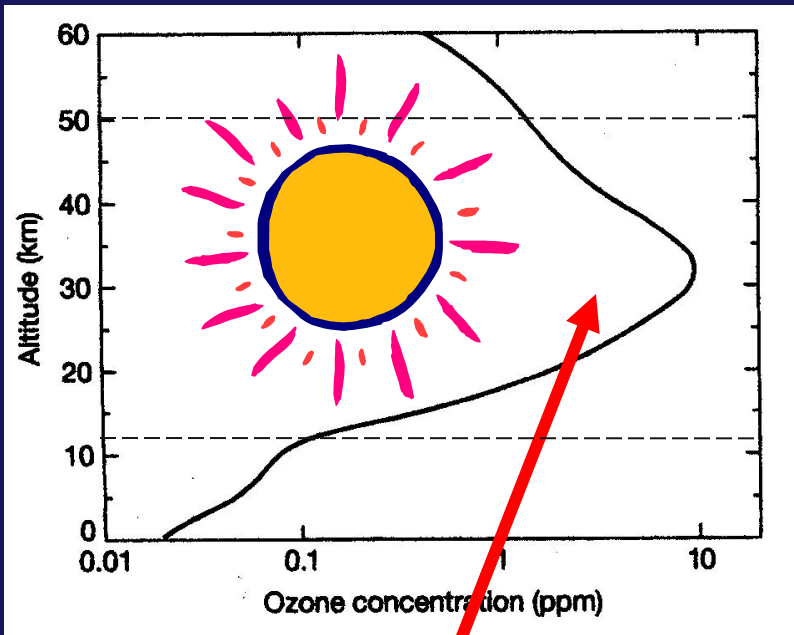
SGC
E-Text
Fig. 3-11



Ozone Concentration (ppm)



OZONE: Sources



Ozone is produced naturally in photochemical reactions in the stratospheric ozone layer --“good ozone” -- is decreasing!

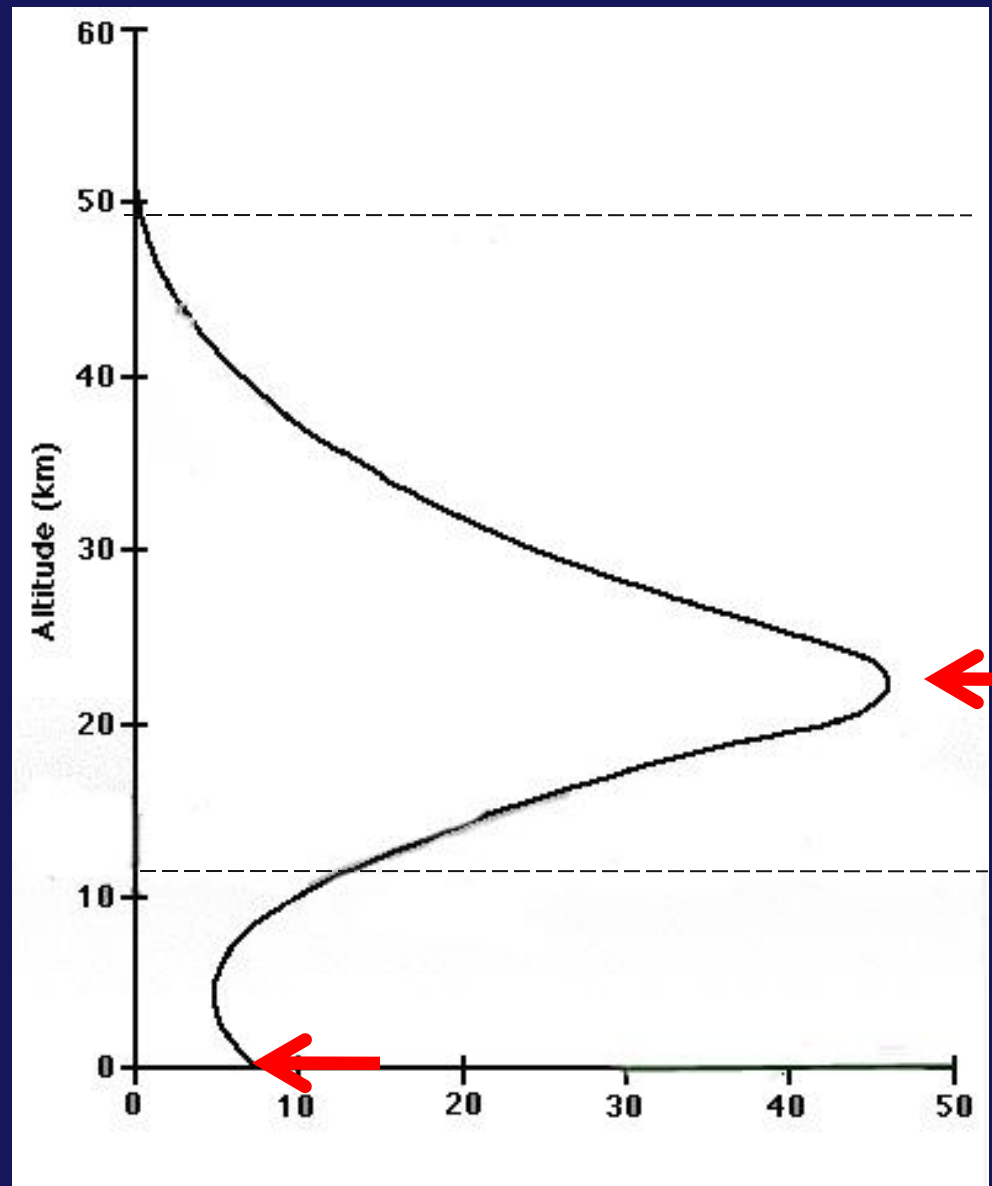


However, ozone has increased in troposphere due to photochemical smog reactions -- “bad ozone”

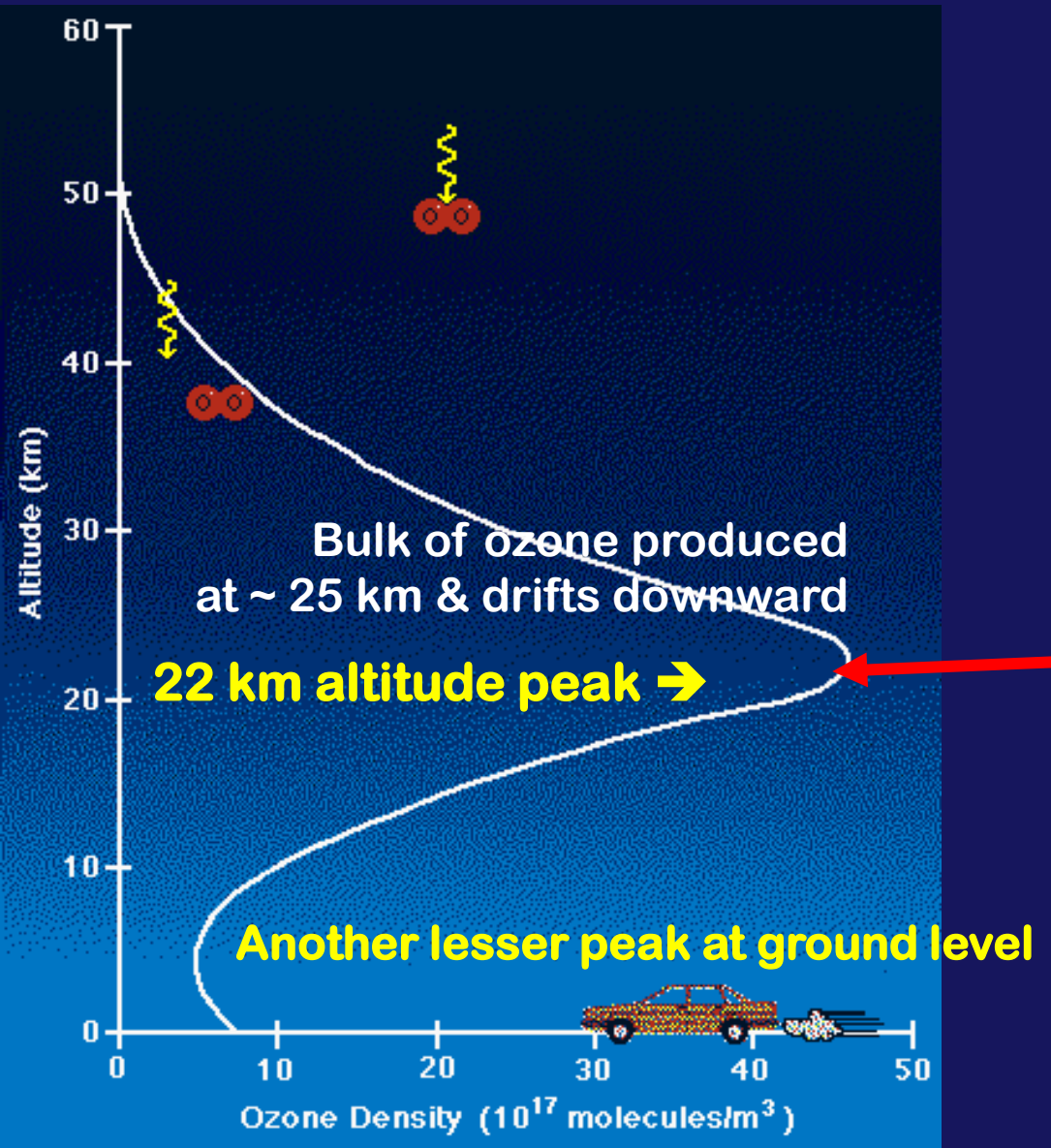
review

Here's a different version of the figure →

Shows 2 peaks, a major peak in O₃ density in the **stratosphere**, a smaller secondary peak in the **lower troposphere**



Ozone Density
(10^{17} molecules / m³)



First we'll focus on the "GOOD" ozone located in the STRATOSPHERE (the ozone that is being depleted leading to an ozone "hole")



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

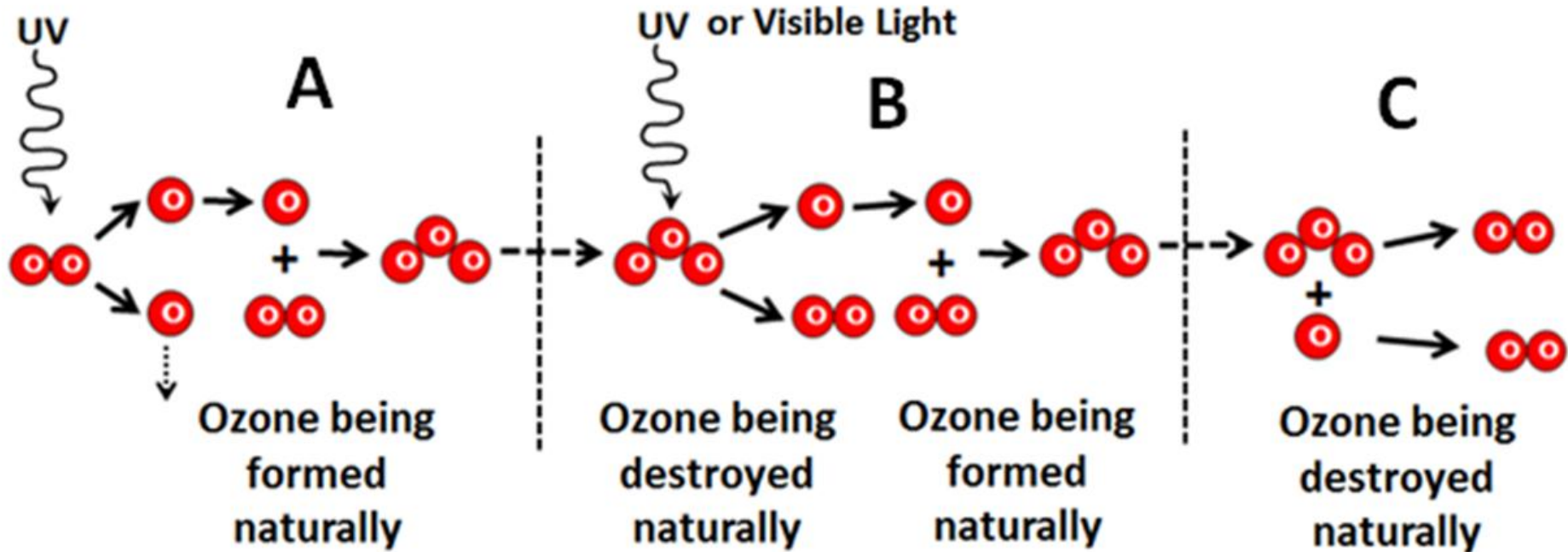
Due to: the natural
“Chapman Mechanism”
(a series of photochemical reactions)

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 77)

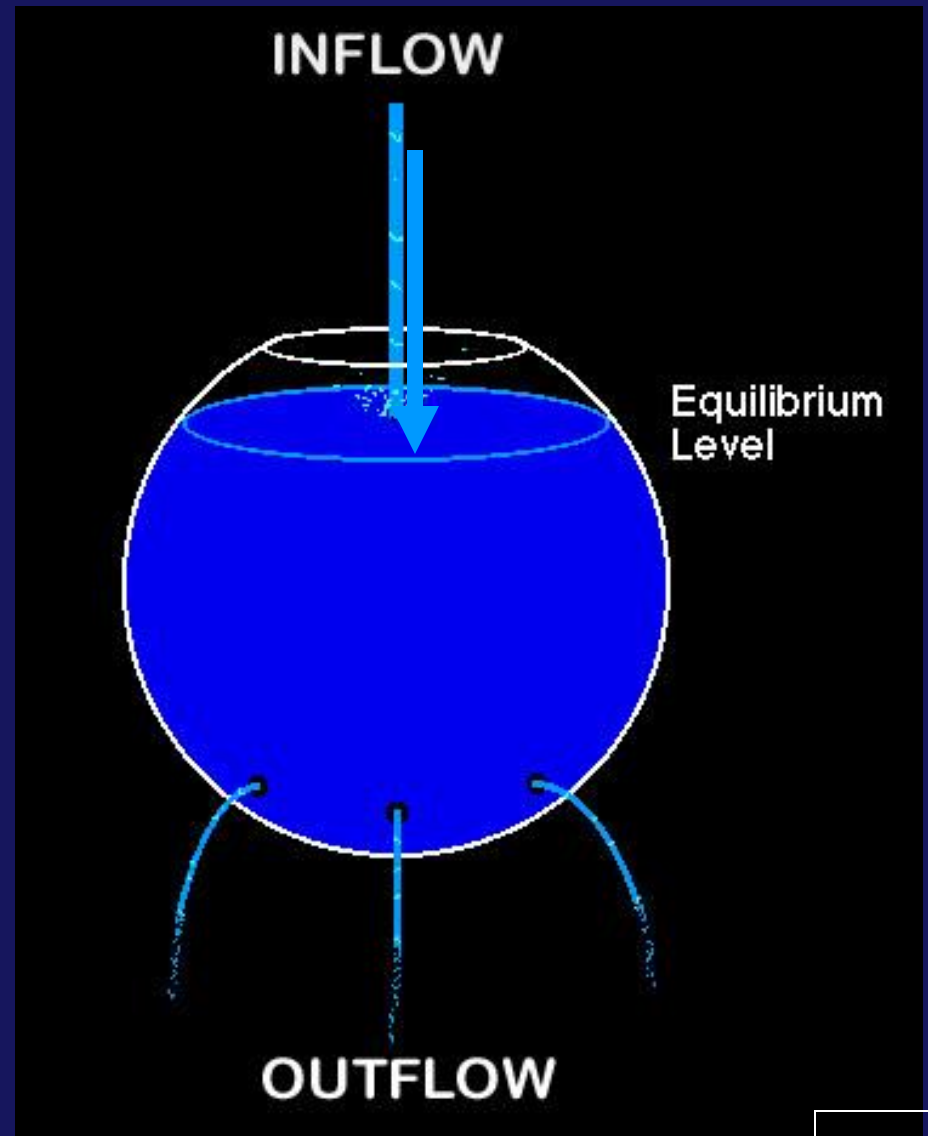
[Go to movie clip]

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.

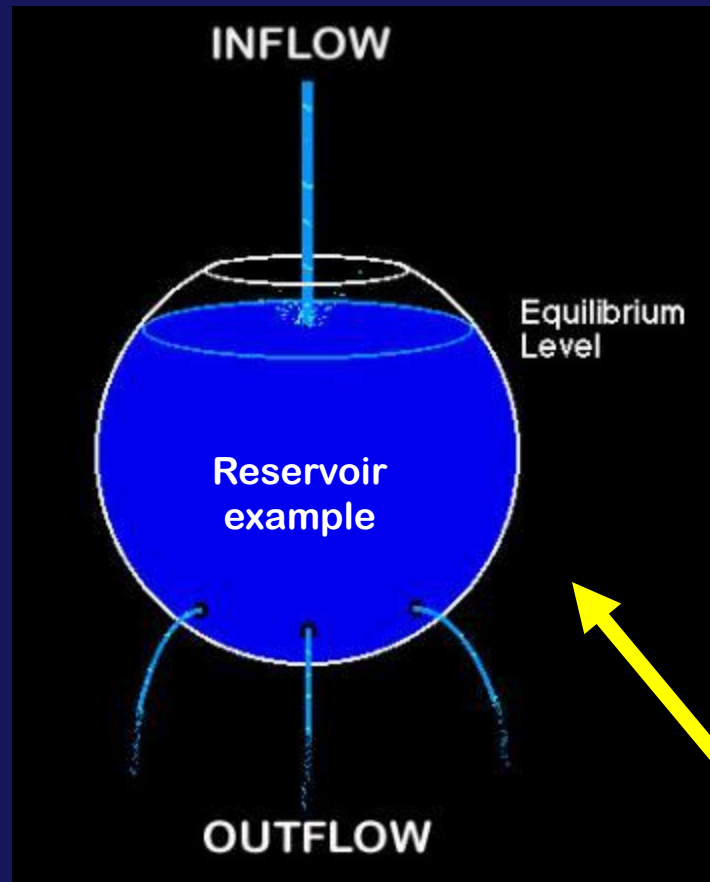


Steady state can be achieved in a reservoir:

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.

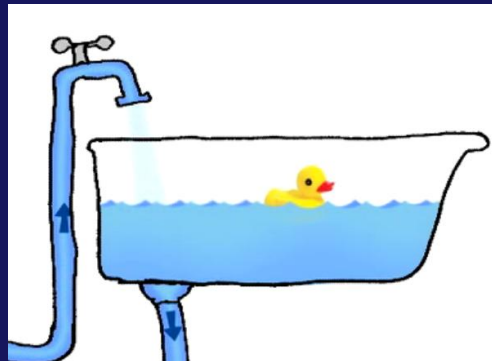


FLOW DIAGRAM OF A STEADY STATE



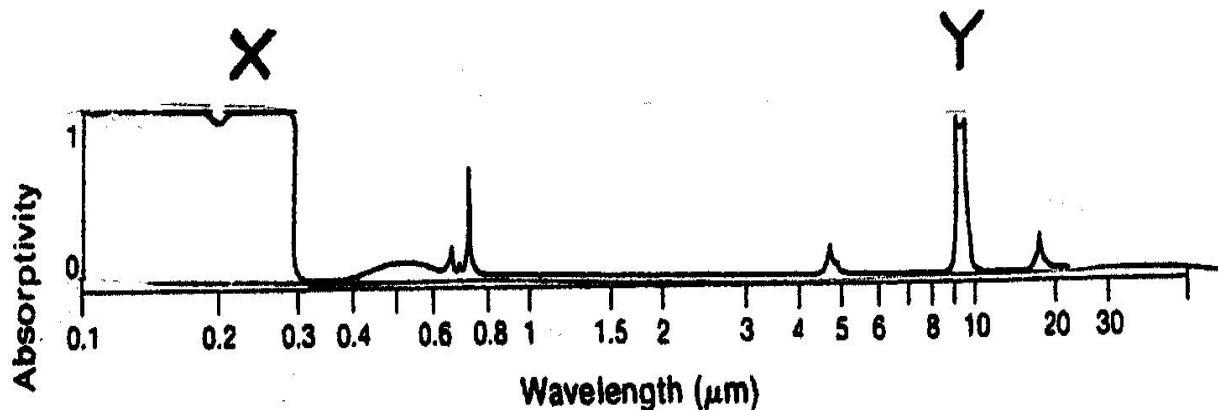
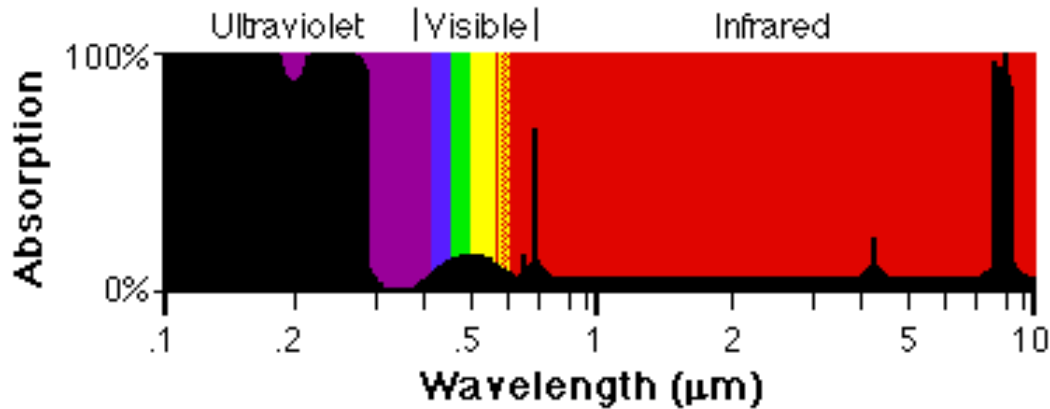
Where have we seen something like this before?

Lesson 1
Carbon Dioxide in
the Atmosphere



Review: Why stratospheric ozone is “Good”:

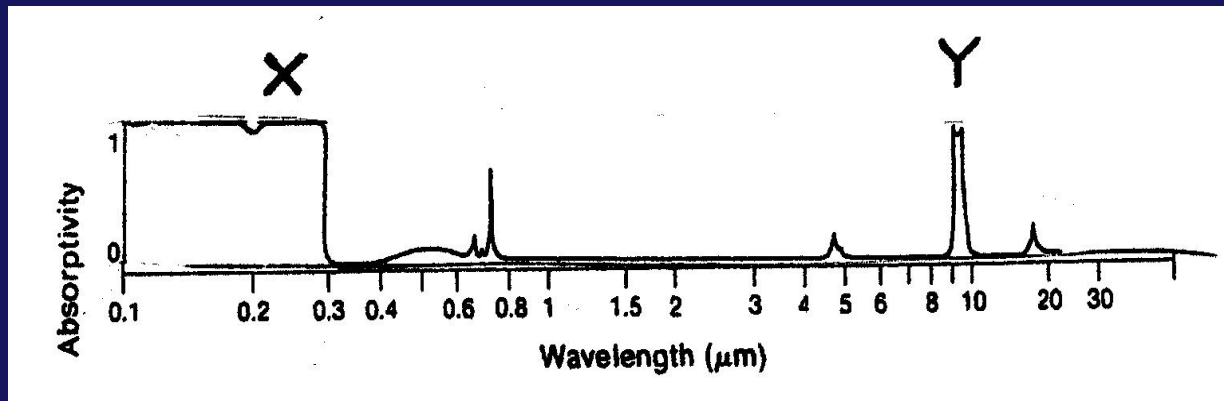
Black areas = radiation absorbed



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?

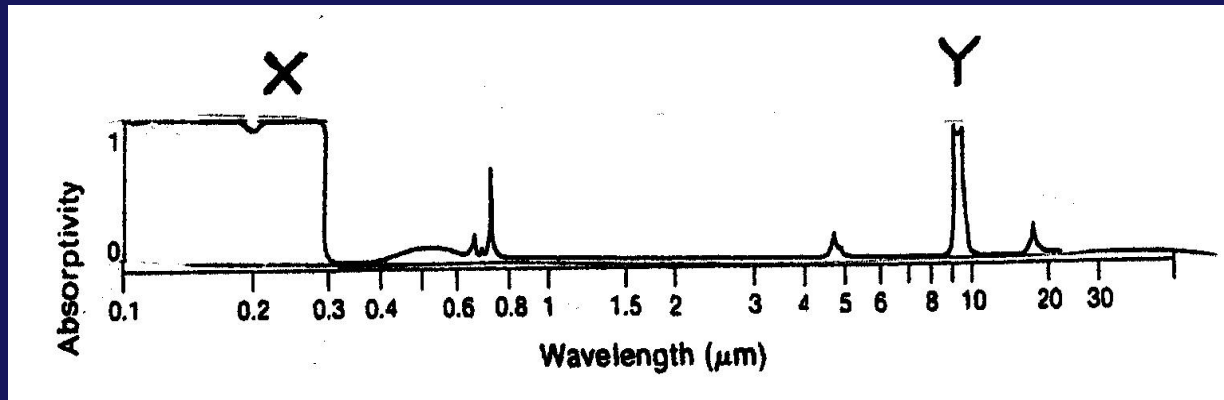
←**CLICKER Q** coming up!



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**

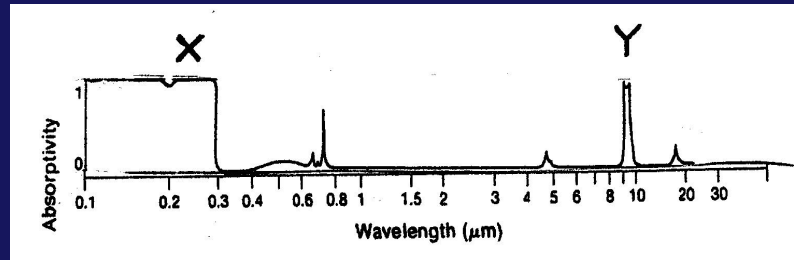


Q2 – What is the **CORRECT** completion to this sentence:

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

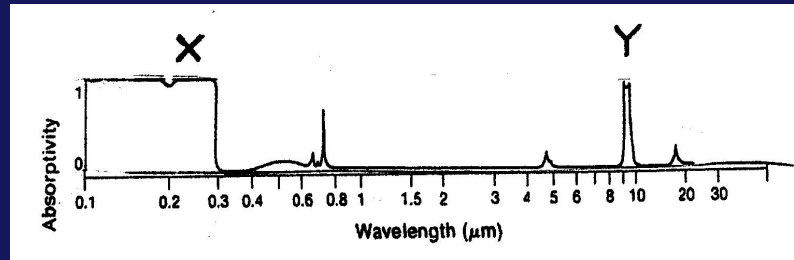
(1) **X** or (2) **Y**

Q3. Ok, X is right, but Why?



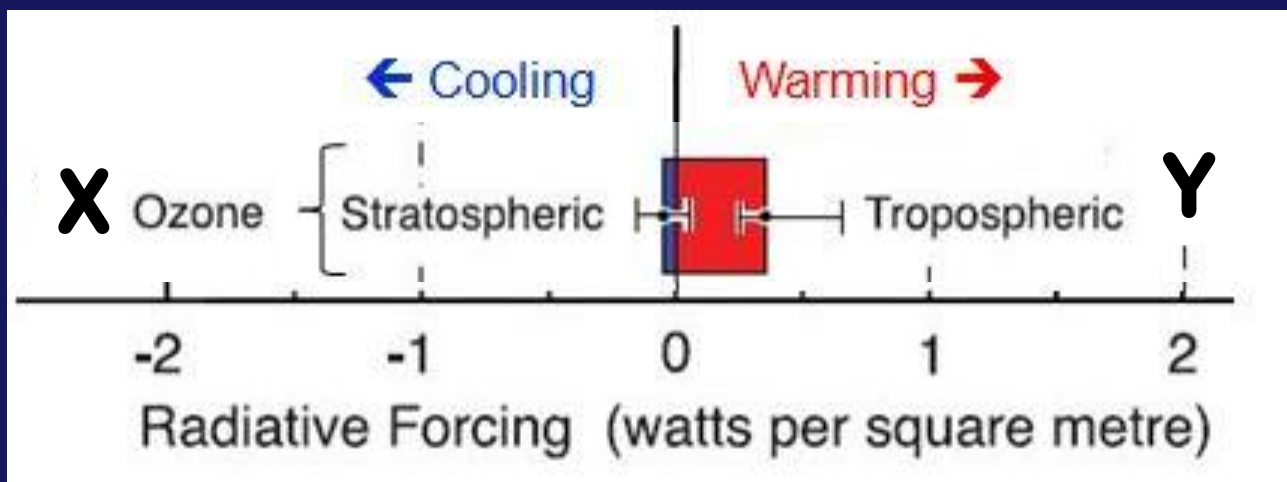
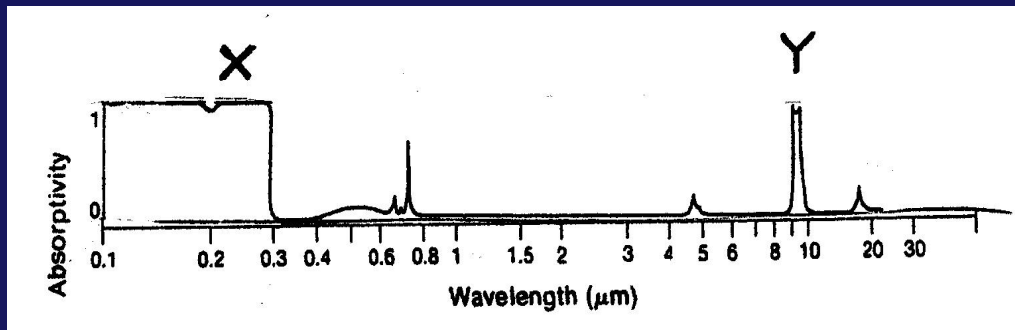
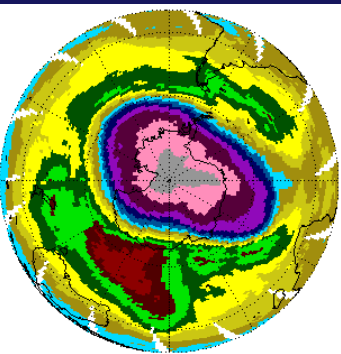
1. . . . because X represents **UV** radiation being absorbed -- hence **if ozone is depleted, MORE ultraviolet** radiation will **reach the Earth's surface**.
2. . . . because X represents **terrestrial longwave** radiation being absorbed -- and hence serves as a catalyst in the Chapman mechanism.
3. . . . 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?



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.

OZONE'S DUAL PERSONALITY!

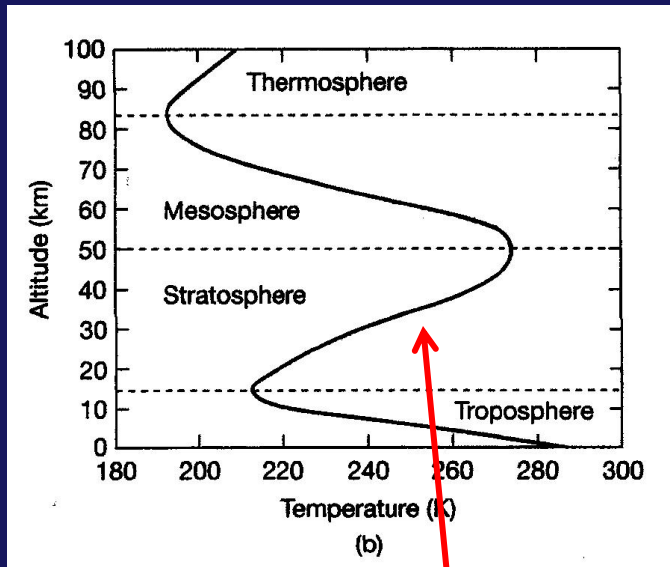


Important as an absorber of harmful UV in the **STRATOSPHERE**

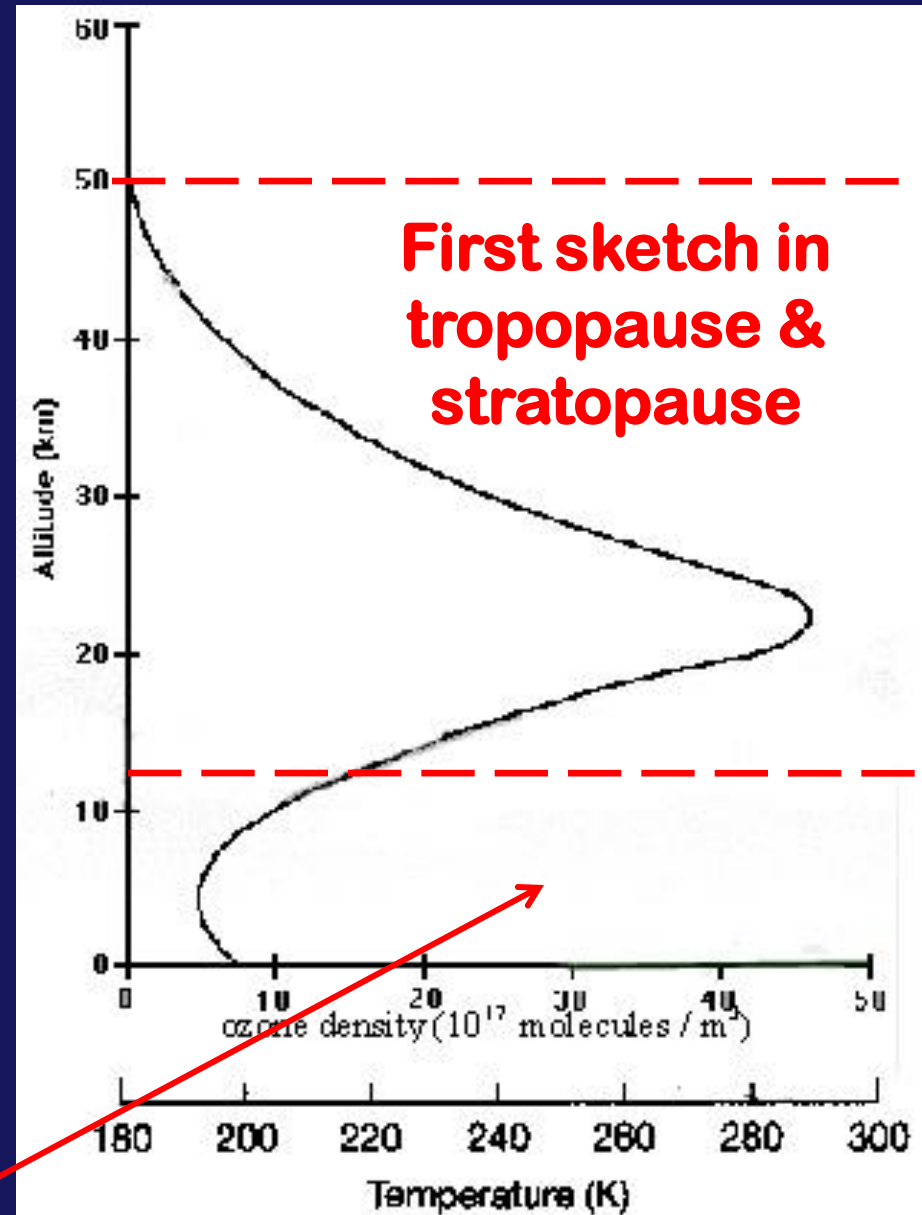
Important as an absorber of IR as a GH Gas in the **TROPOSPHERE**

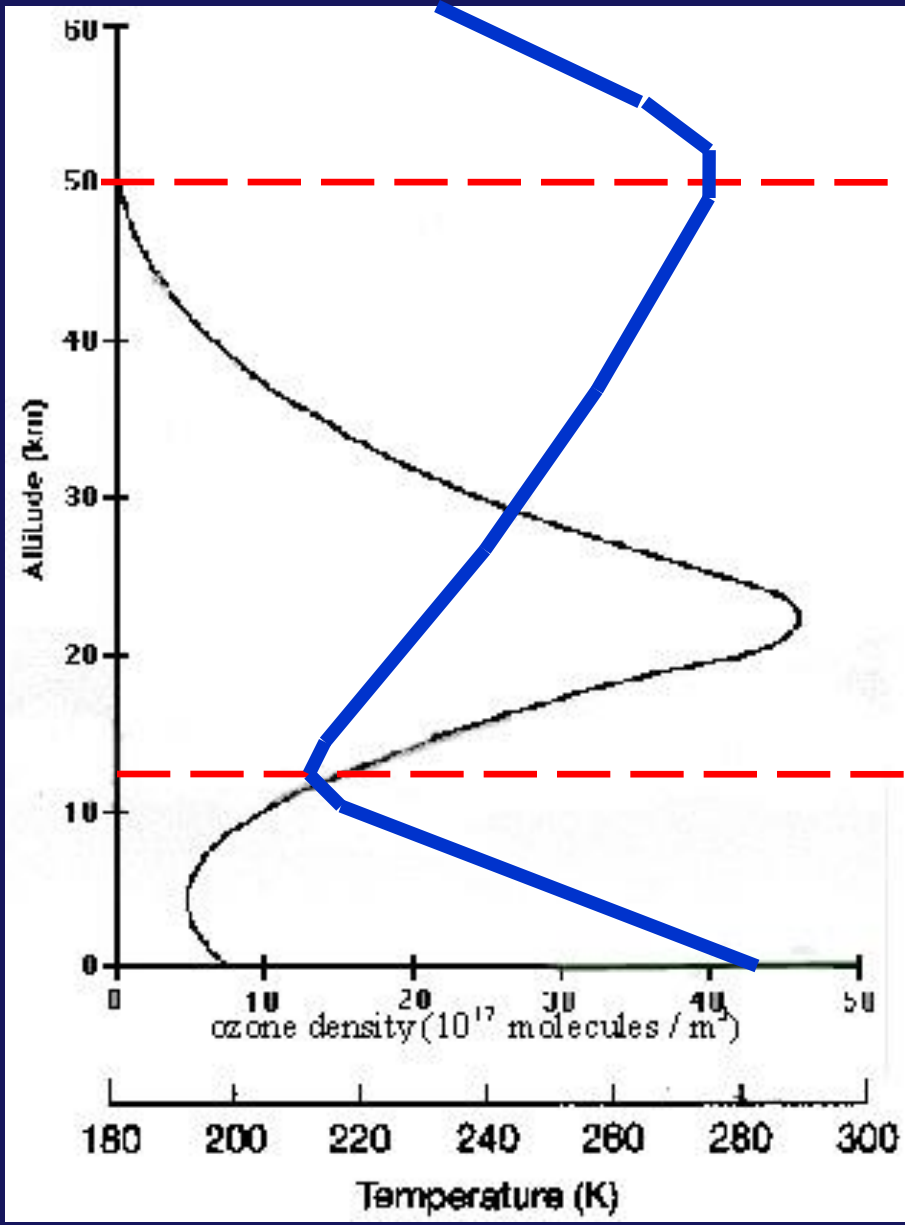
Ozone Density graph

Temperature graph



Now roughly sketch the temperature line from this graph onto the ozone graph





TEMPERATURE

[increases / decreases]

with increasing altitude
in the stratosphere

WHY???

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

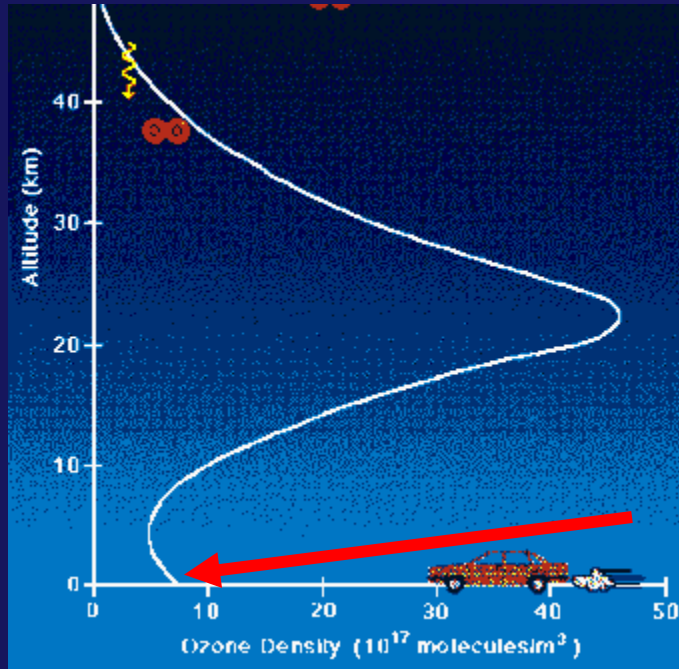
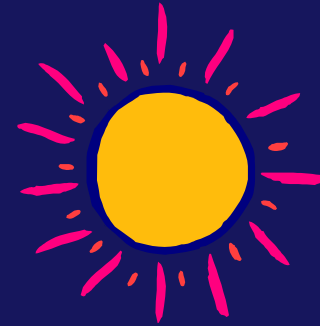


1. It is the **closest layer to the sun**, hence it is **closest to the solar “heat source.”**
2. It receives **large amounts of UV radiation** from the sun PLUS it has a **high concentration of ozone** to absorb this UV.
3. It is the layer which **contains most of the GH gases** that absorb IR radiation 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 →



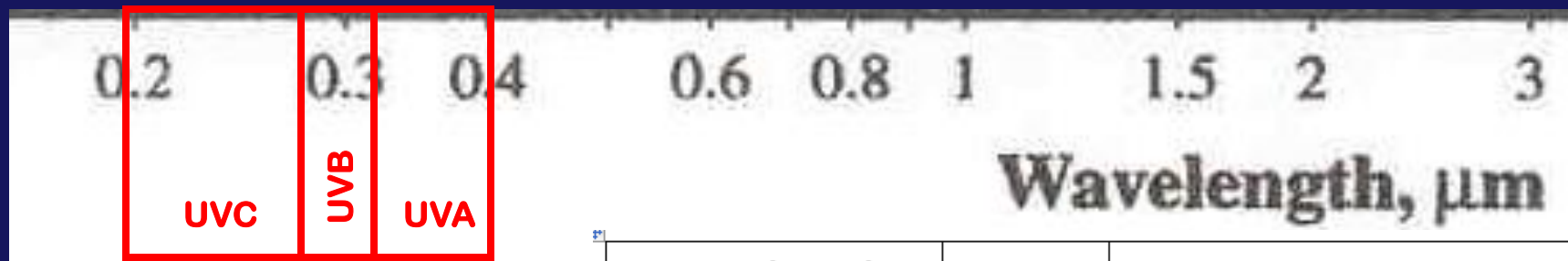
→ When inhaled, even at very low levels, ozone can:

- 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



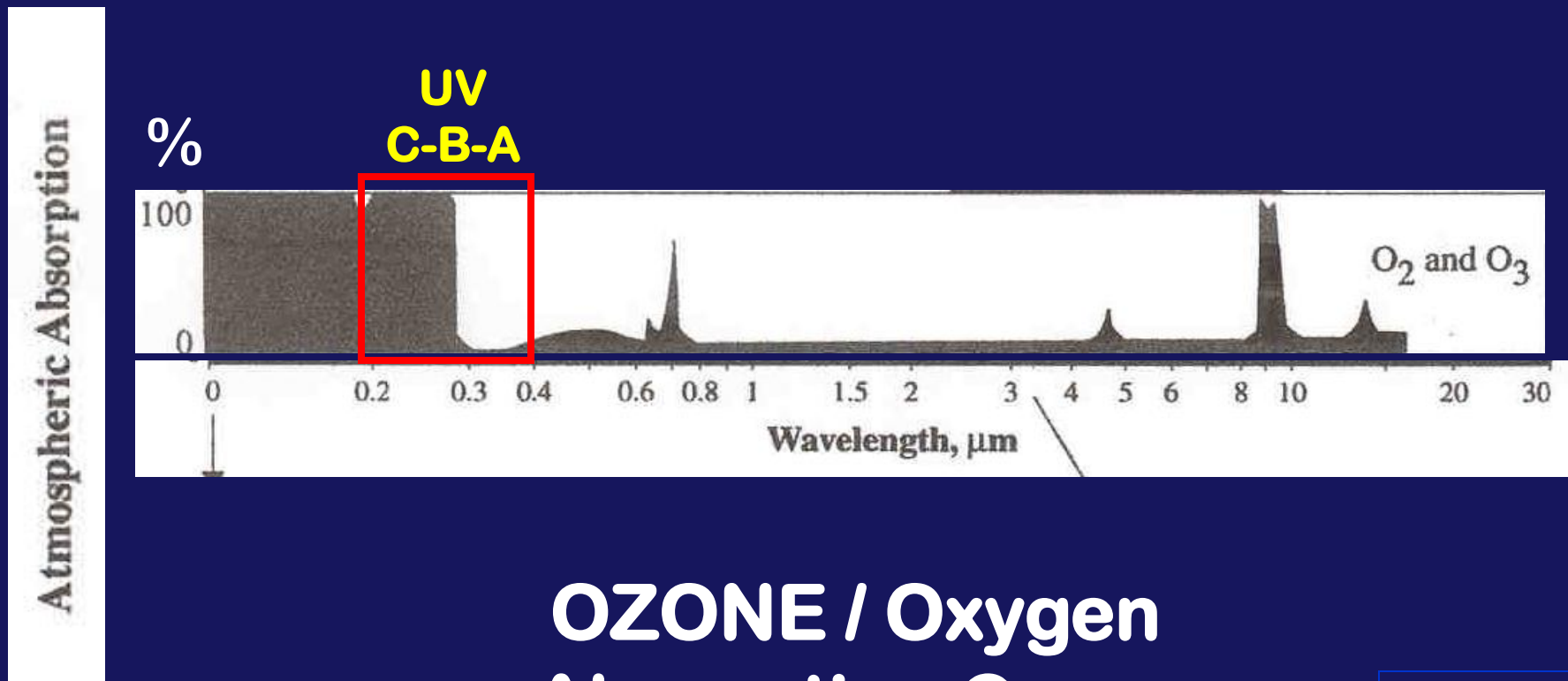
**ANOTHER LINK TO
EVERYDAY LIFE:**

SUN SAFETY!



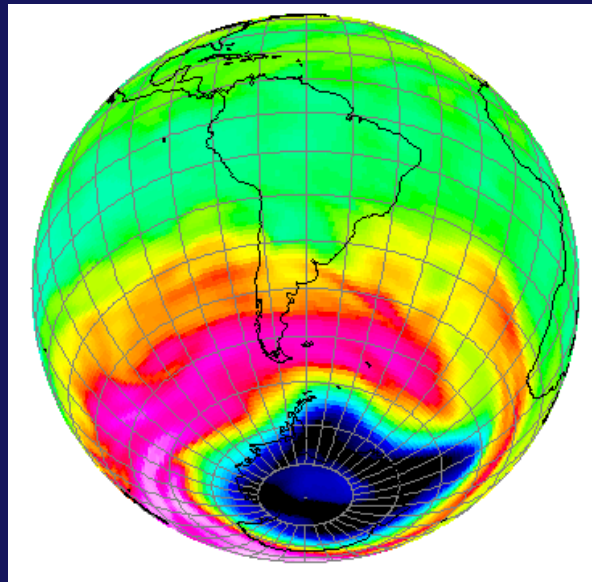
Wavelength Range	Name	Biological Effect
.32 to .4 μm (320-400 nm)	UVA	once thought to be relatively harmless, BUT causes wrinkles, premature aging and associated sun-related skin damage; new research indicates possible skin cancer link
29 to .32 μm (290-320 nm)	UVB	harmful , causes sunburn, skin cancer, 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

THE DESTRUCTION OF STRATOSPHERIC OZONE



The ozone hole is:

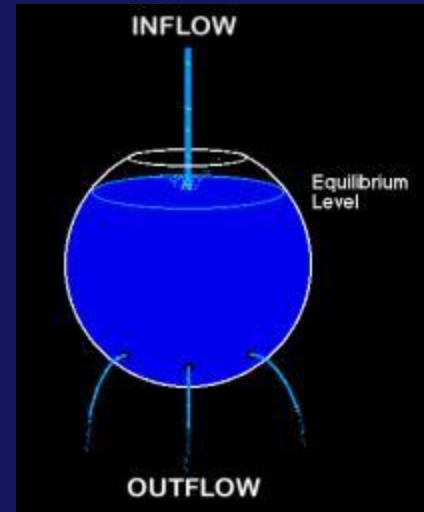
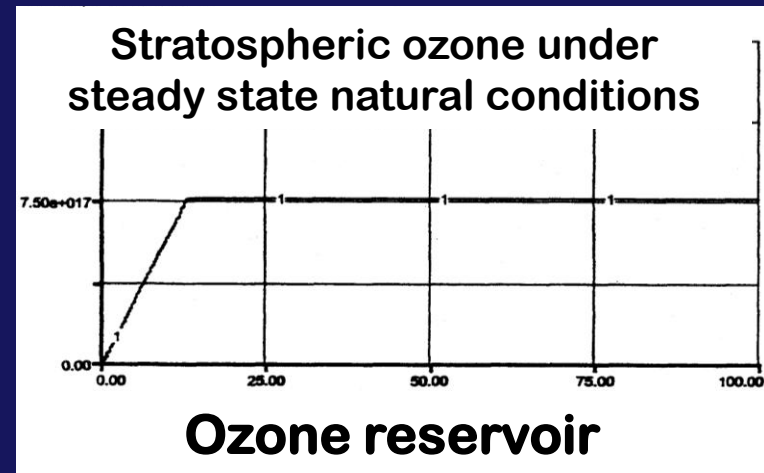
-- a depletion of ozone in the lower stratosphere

-- 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 79

The Chapman Mechanism “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:

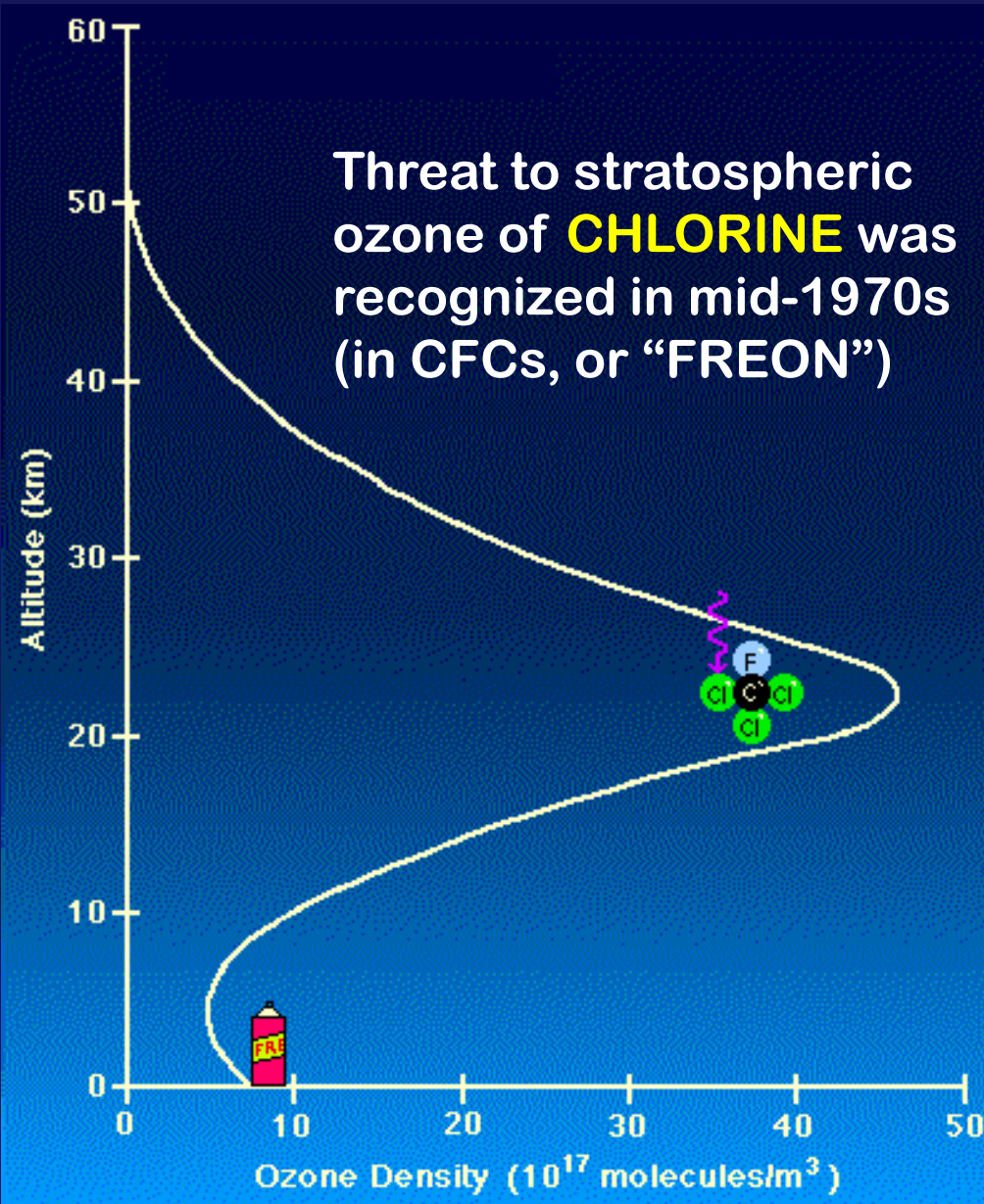
- **the chlorine removes ozone from the stratosphere**
- **and also frees more chlorine atoms to begin the process all over again**

CFC compounds

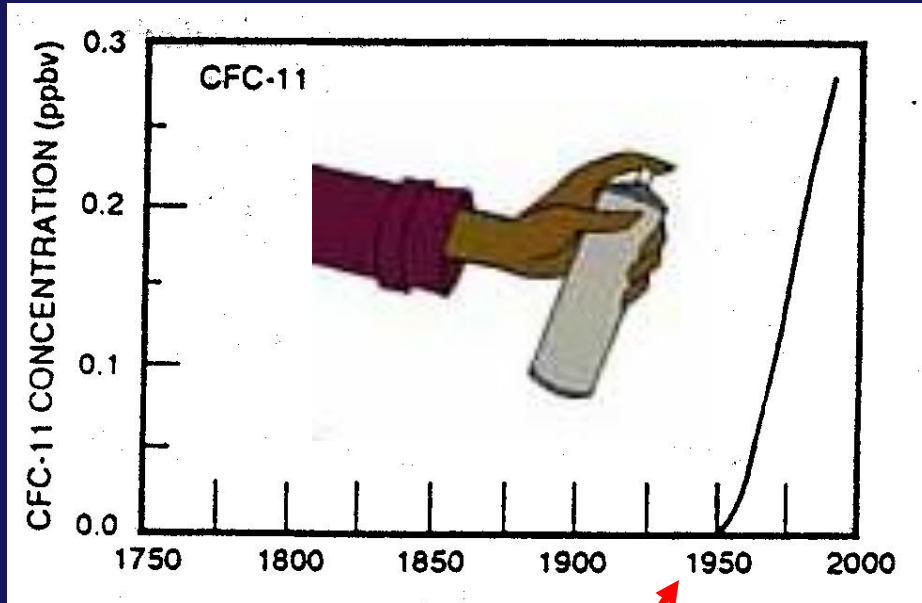
Chlorofluorocarbons

are unreactive at Earth's surface,

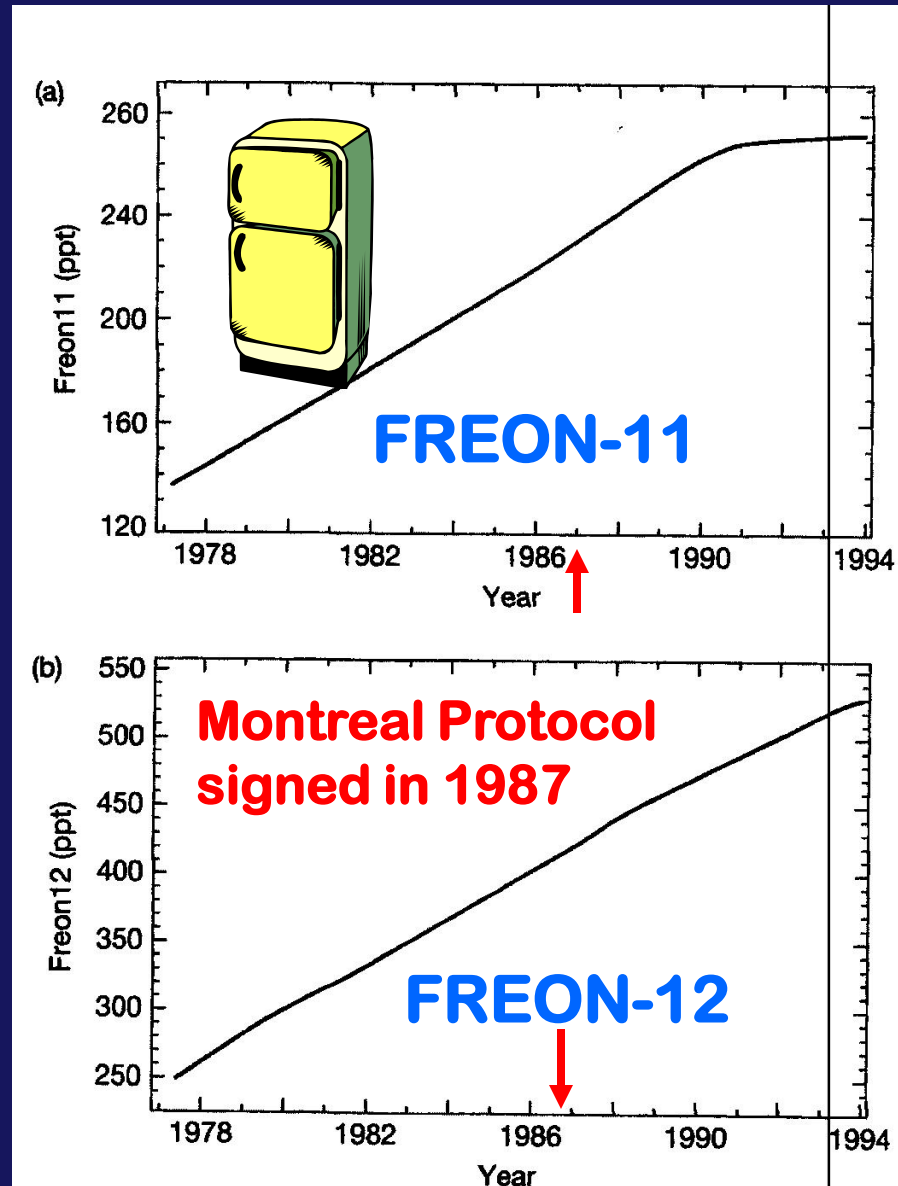
but if they get into the stratosphere, they can be broken down by high energy UV radiation → leads to release of highly reactive **CHLORINE atoms (Cl)**



CFCs: Trends



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



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]

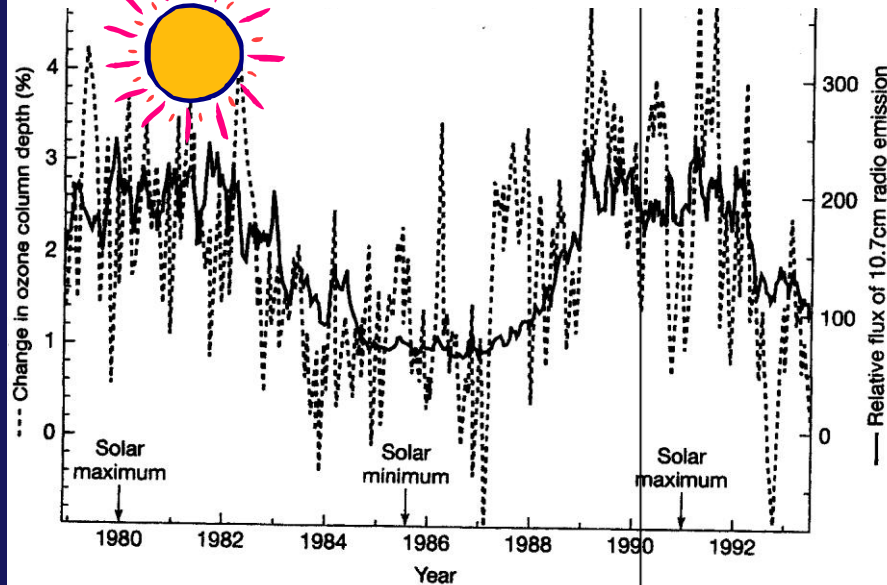
**This chemical theory of ozone destruction by
CFC's was first proposed in 1974 – but no
observations existed!**

**(Atmospheric chemists Crutzen, Molina, Rowland
were later given Nobel prize for this theory)**

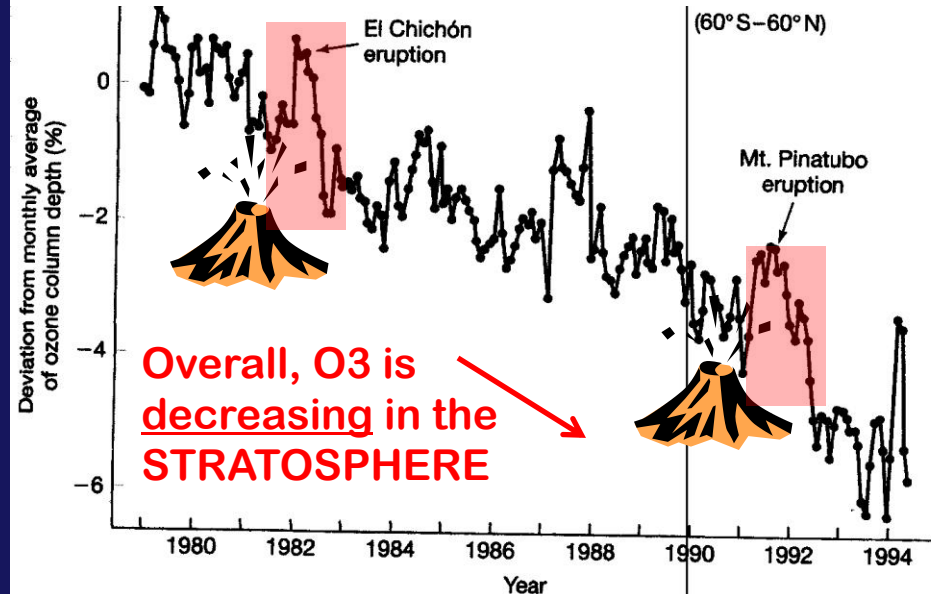
Other theories to explain the hole have included:

- solar variability (sunspot cycle)
- dynamical air motion
- volcanic eruptions

Solar effects



Volcanic effects

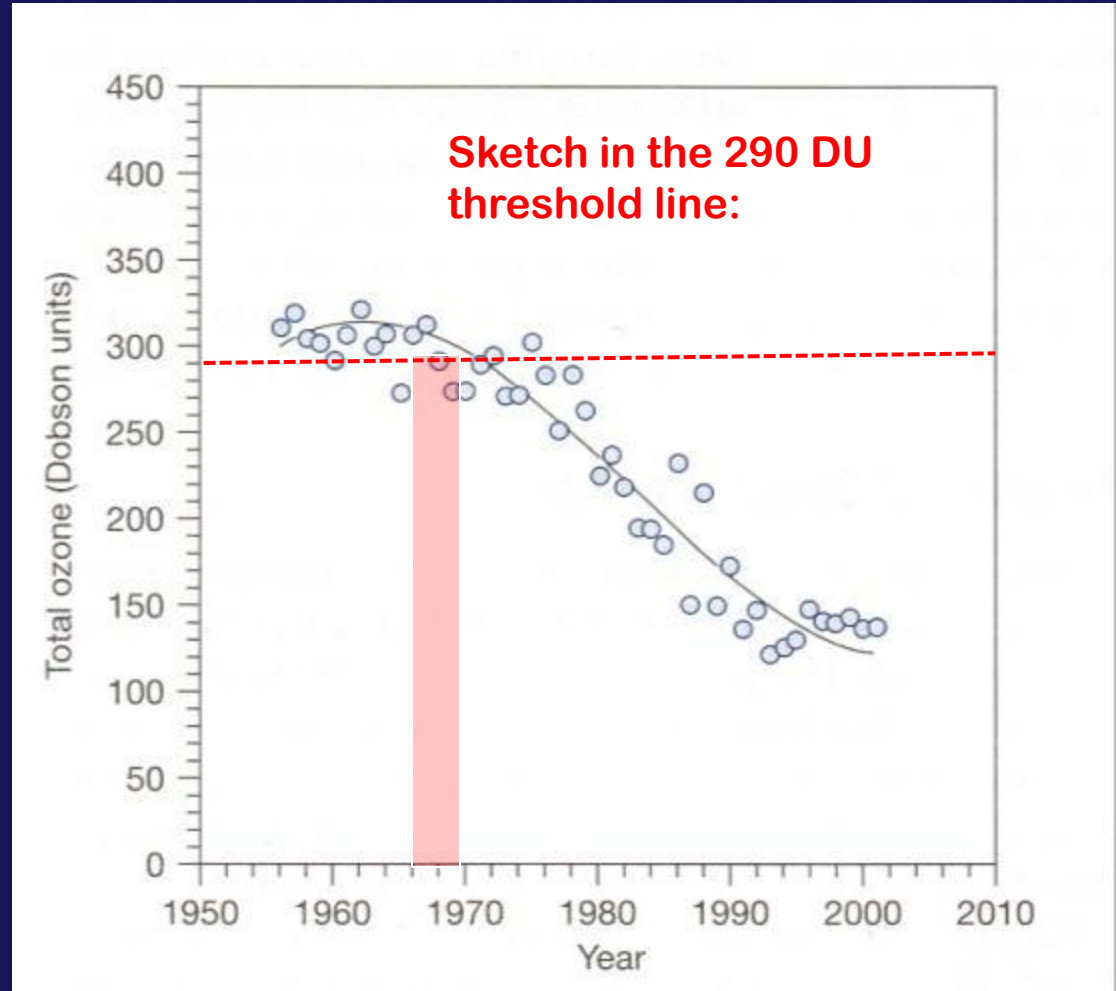


RATE OF OZONE DEPLETION

in DOBSON UNITS (DU)

When did the Hole
begin forming?

Hole generally
defined as
< 290 DU

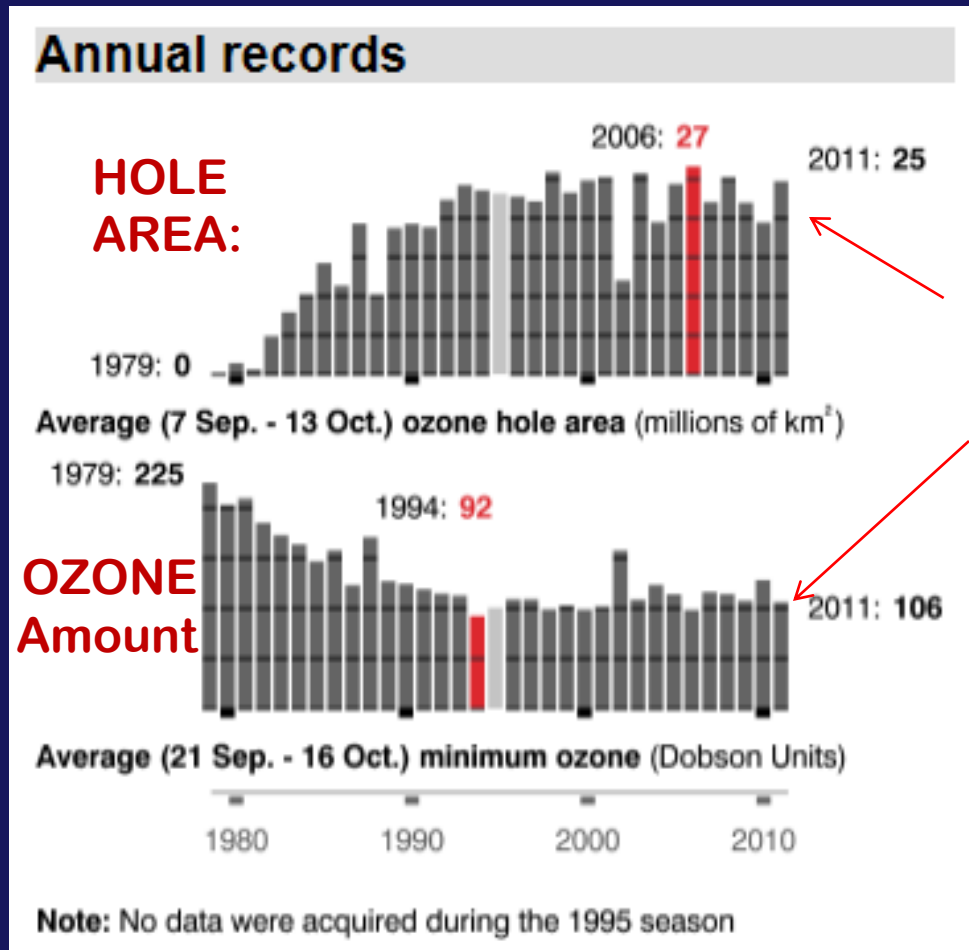


~ 1969 to 1970



OZONE HOLE WATCH
images, data, and information; updated daily

Annual Ozone Hole Variations (since 1979)



**This year:
2011**

RECIPE FOR THE OZONE HOLE

<http://www.youtube.com/watch?v=qUfVMogldr8>

NEXT:

**The STORY OF THE DISCOVERY
OF
THE OZONE HOLE:**

“A Misadventure of Science?”

HAPPY HOMECOMING!!



GO CATS!