

Topic # 15 Wrap-up
OZONE DEPLETION
IN THE
STRATOSPHERE
(cont.)

see pp 81-85 in Class Notes

What is significant
about the date
September 16th
with respect to the
topic of ozone?

International Day for the Preservation of the Ozone Layer

SEPTEMBER 16th

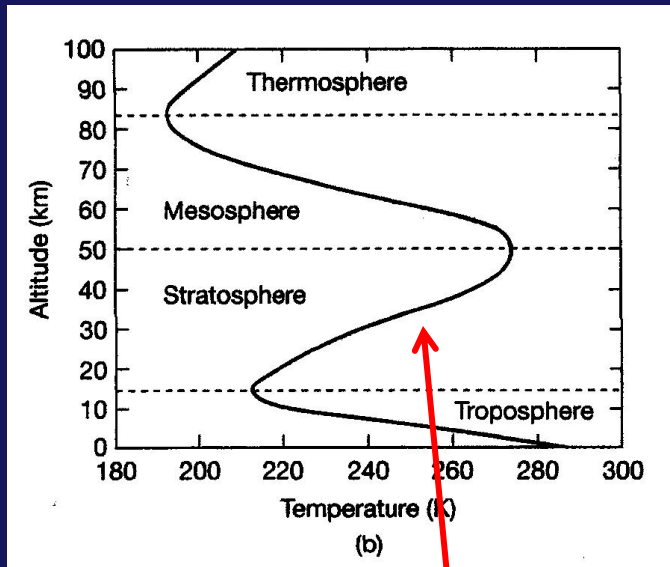
The United Nations' (UN) International Day for the Preservation of the Ozone Layer is celebrated on September 16 every year. This event commemorates the date of the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.



The earth's ozone layer plays an important role in protecting human health and the environment. ©iStockphoto.com/Stephen Strathdee

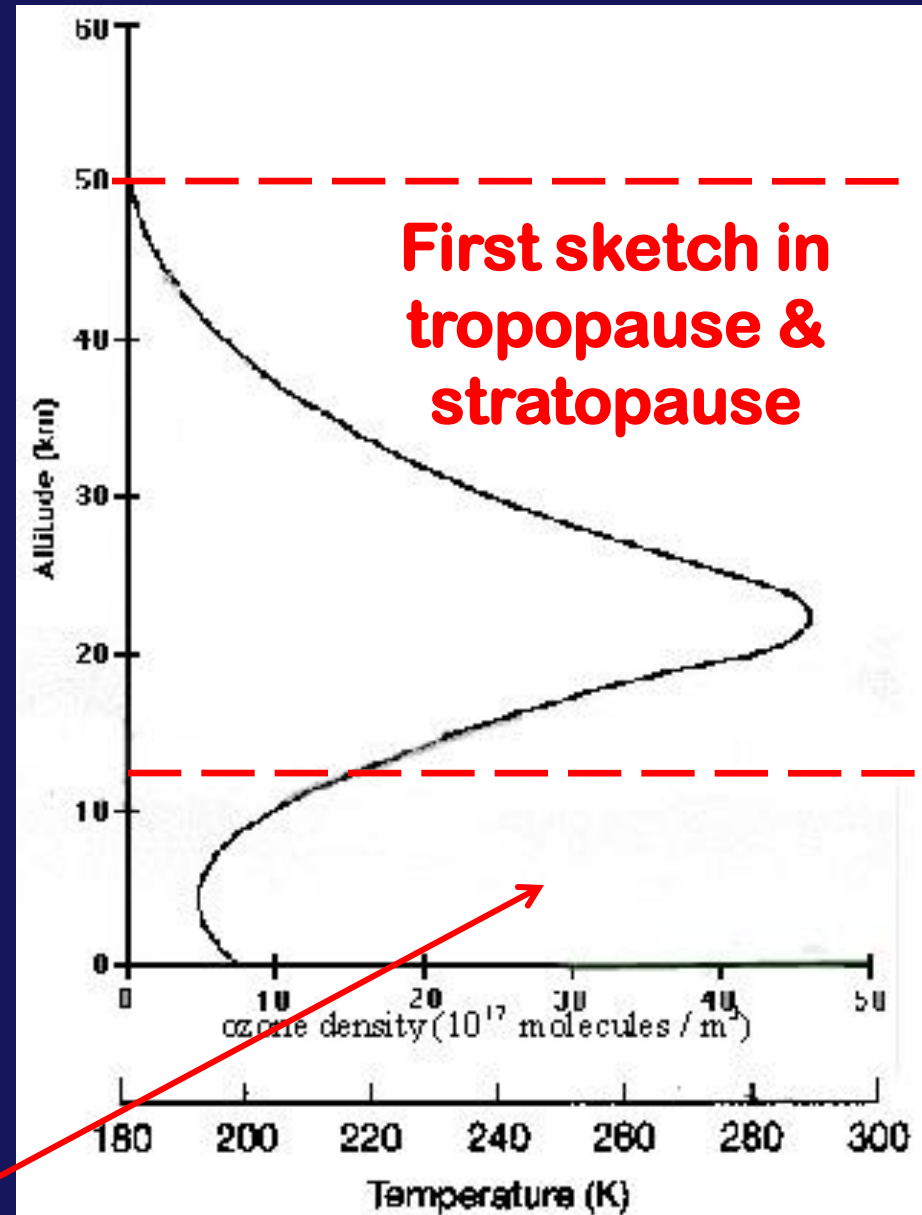
From p. 40 in
Class Notes:

Temperature graph



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

Ozone Density graph

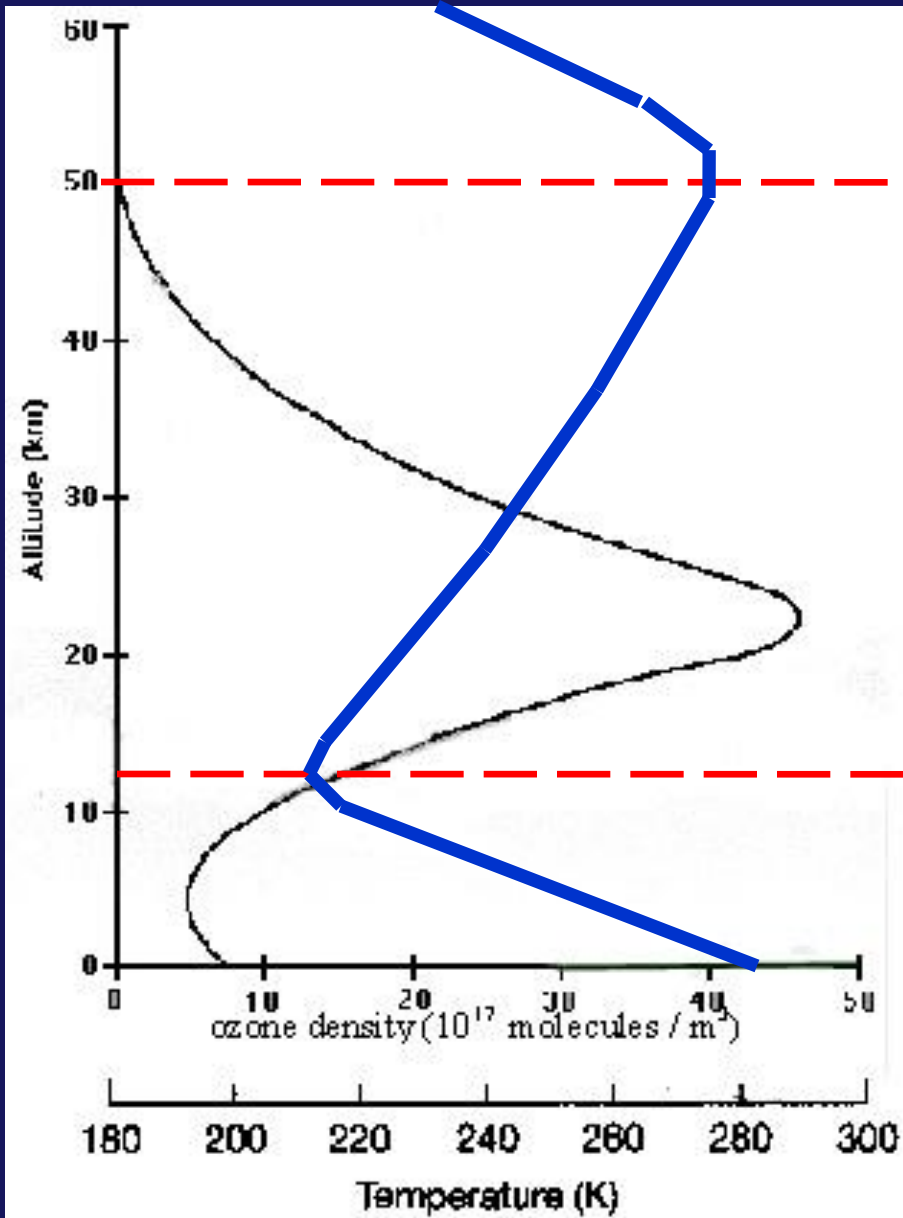


TEMPERATURE

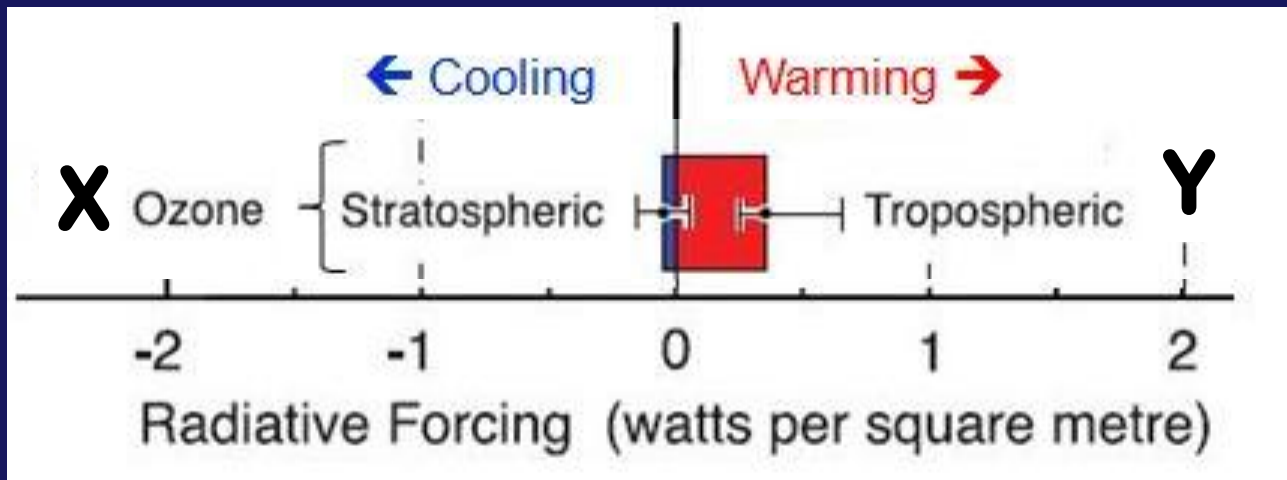
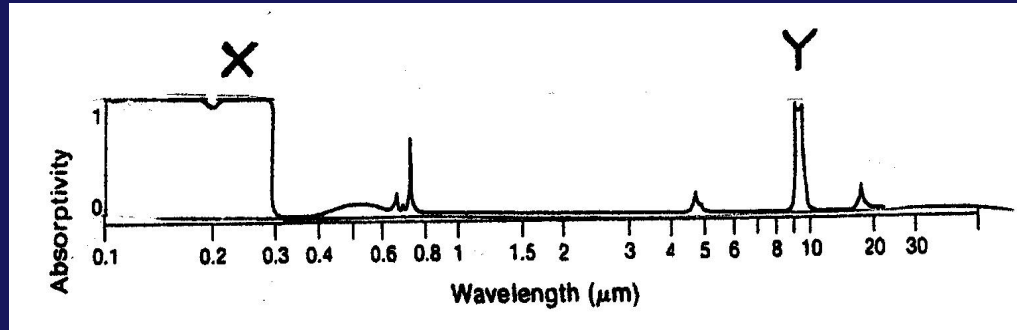
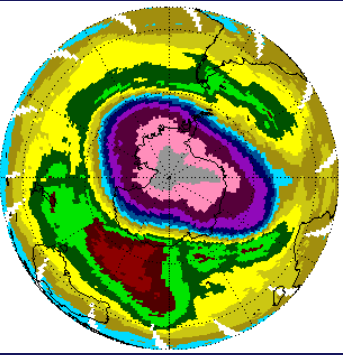
[increases / decreases]

with increasing altitude
in the stratosphere

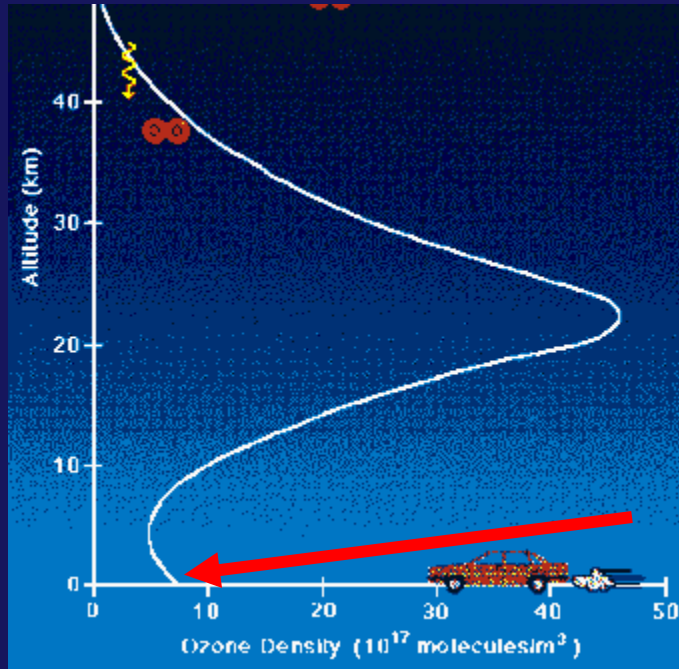
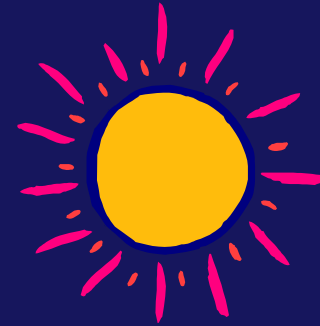
WHY???



OZONE'S DUAL PERSONALITY!



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.**



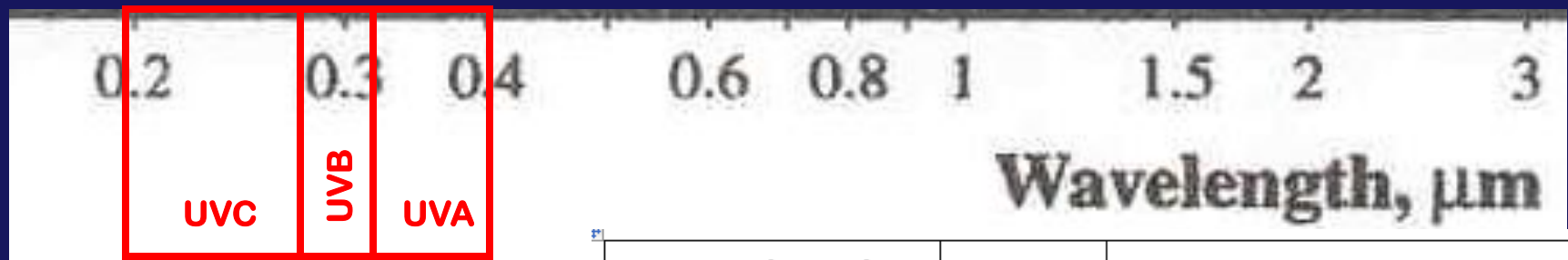
→ When inhaled, even at very low levels, ozone can:

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



**ANOTHER LINK TO
EVERYDAY LIFE:**

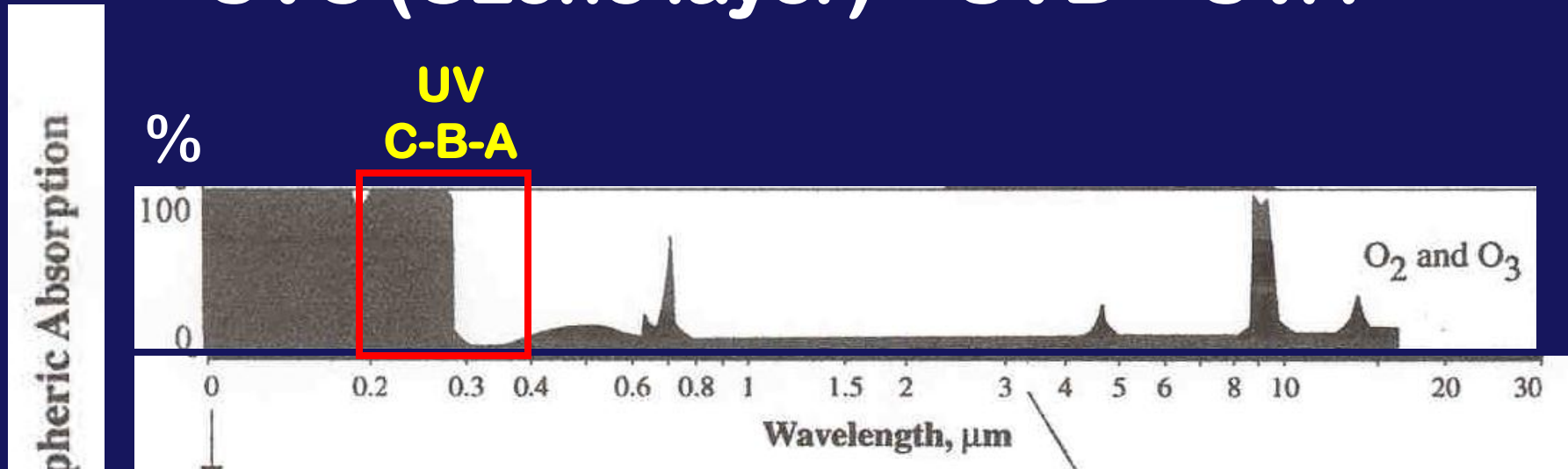
SUN SAFETY!



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

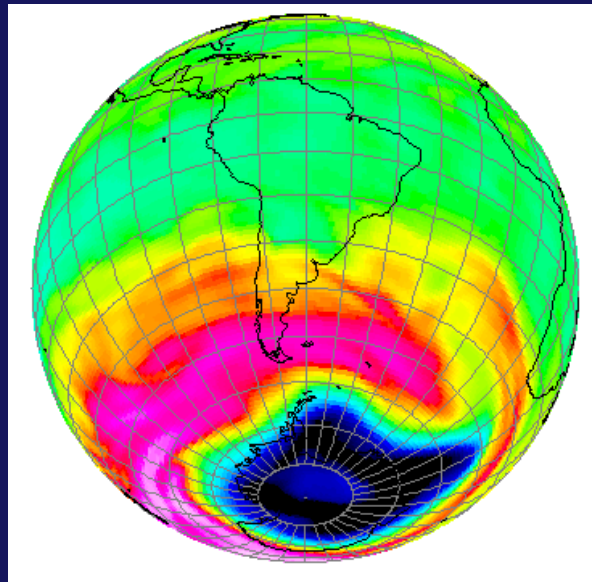
FULL SPECTRUM PROTECTION NEEDED!!

UVC (Ozone layer) + UVB + UVA



OZONE / Oxygen
Absorption Curve

THE DESTRUCTION OF STRATOSPHERIC OZONE



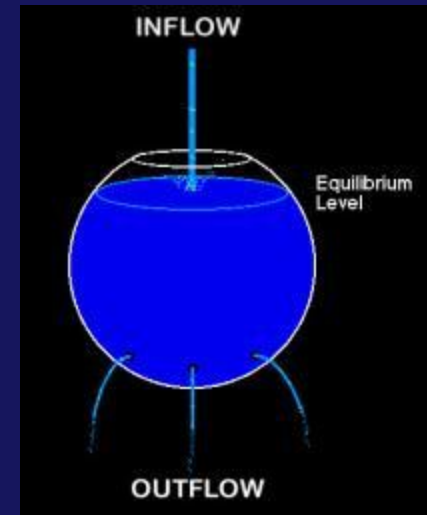
The ozone hole is:

-- a depletion of ozone in the lower stratosphere

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

NOTE: the “Key Concepts”
are all provided on p 85

The Chapman Mechanism steady state “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:

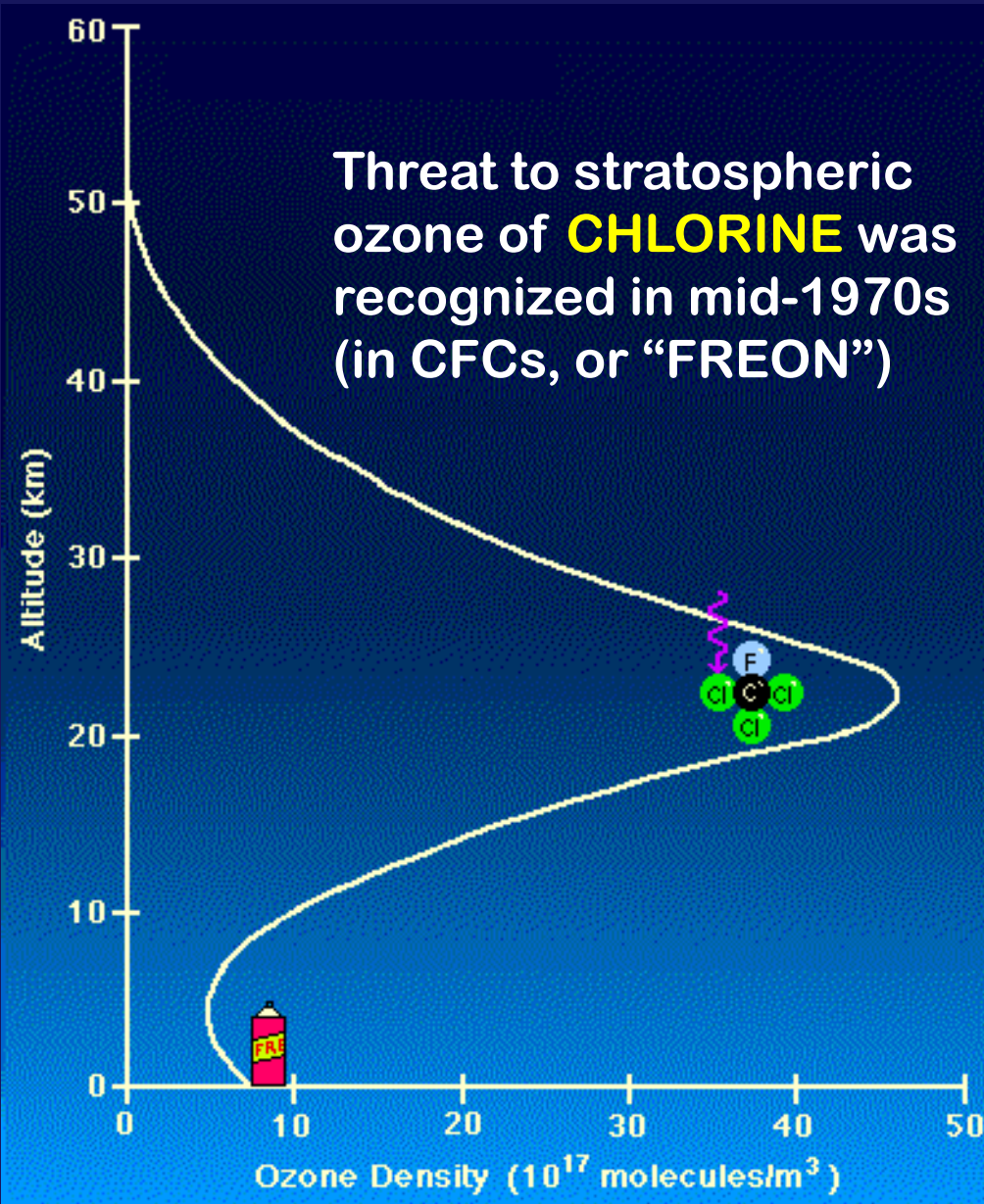
- the chlorine removes ozone from the stratosphere
- and also frees more chlorine atoms to begin the process all over again

CFC compounds

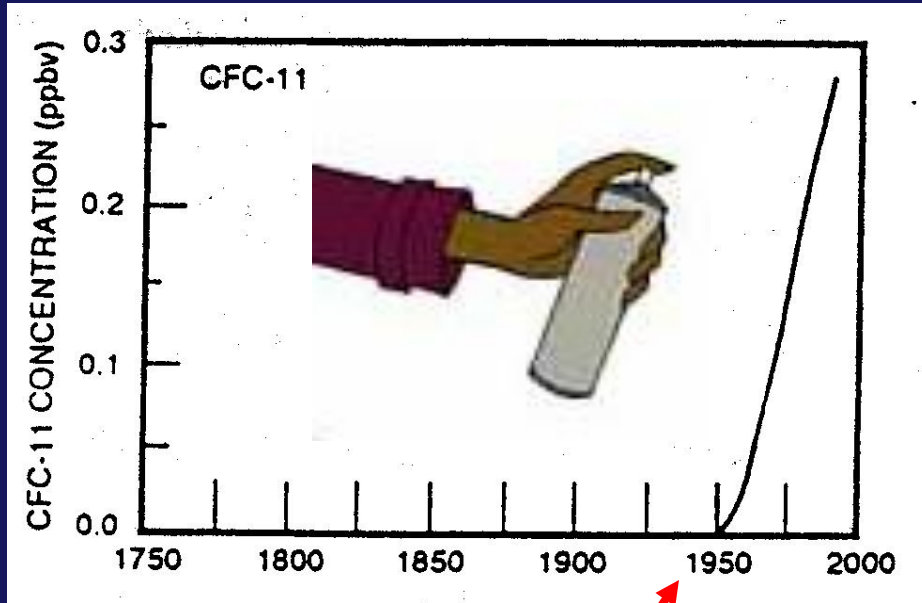
Chlorofluorocarbons

are unreactive at Earth's surface,

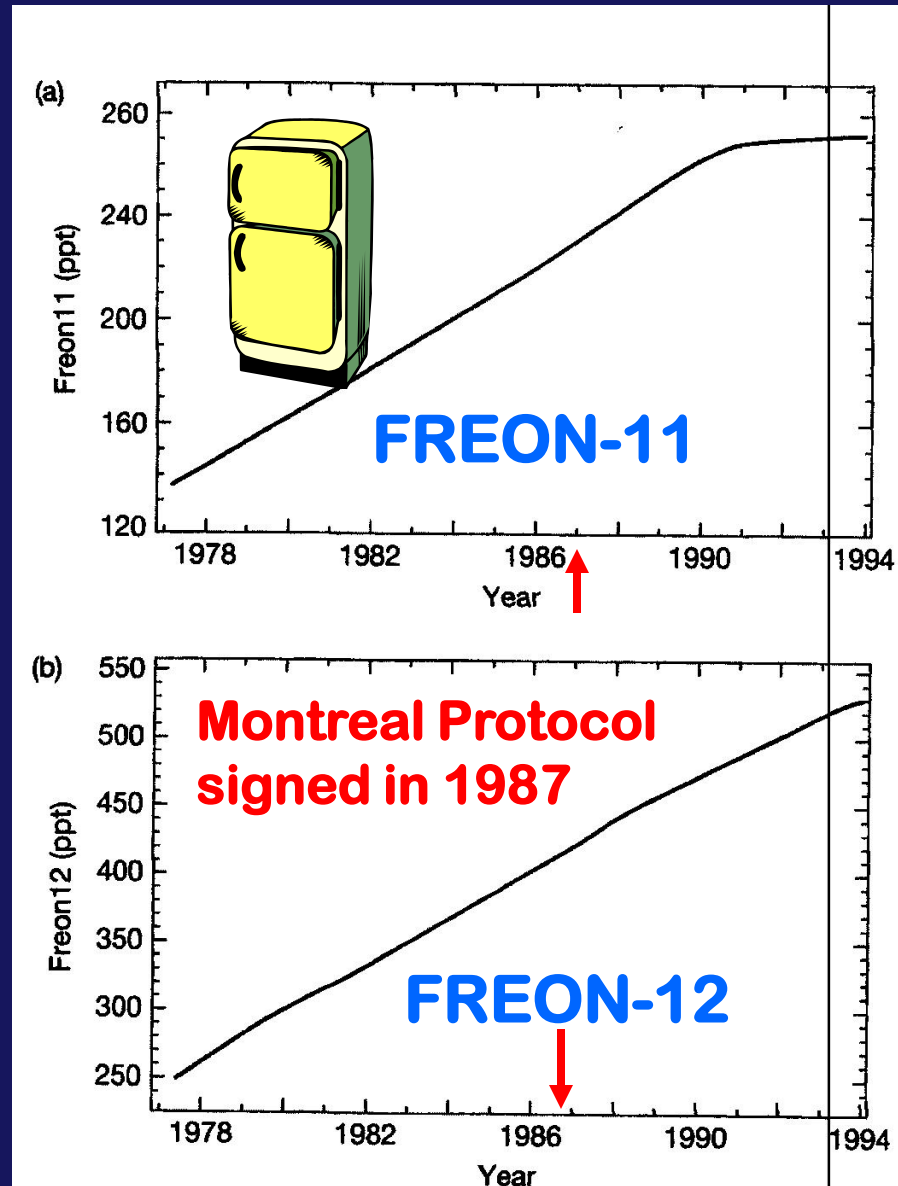
but if they get into the stratosphere, they can be broken down by high energy UV radiation → leads to release of highly reactive **CHLORINE atoms (Cl)**



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)

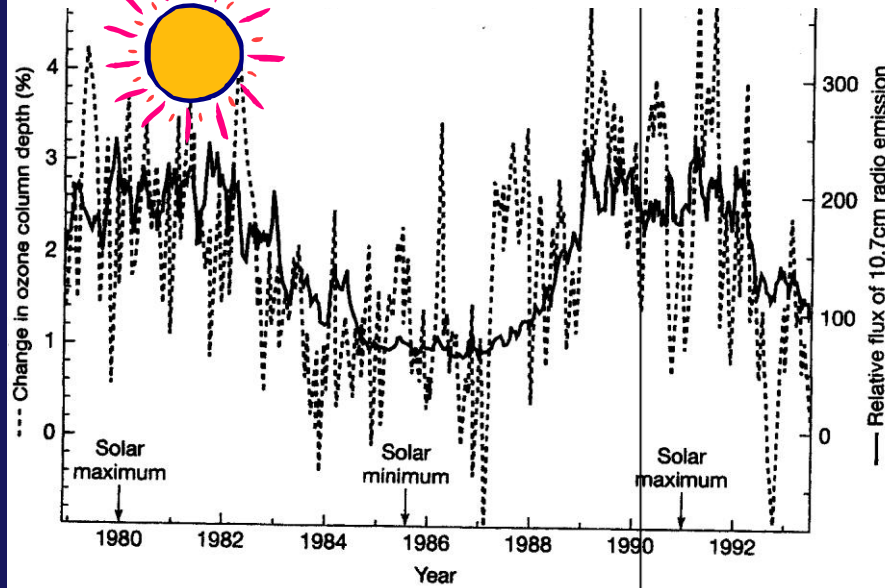
Key Concept

Other theories to explain the hole have included:

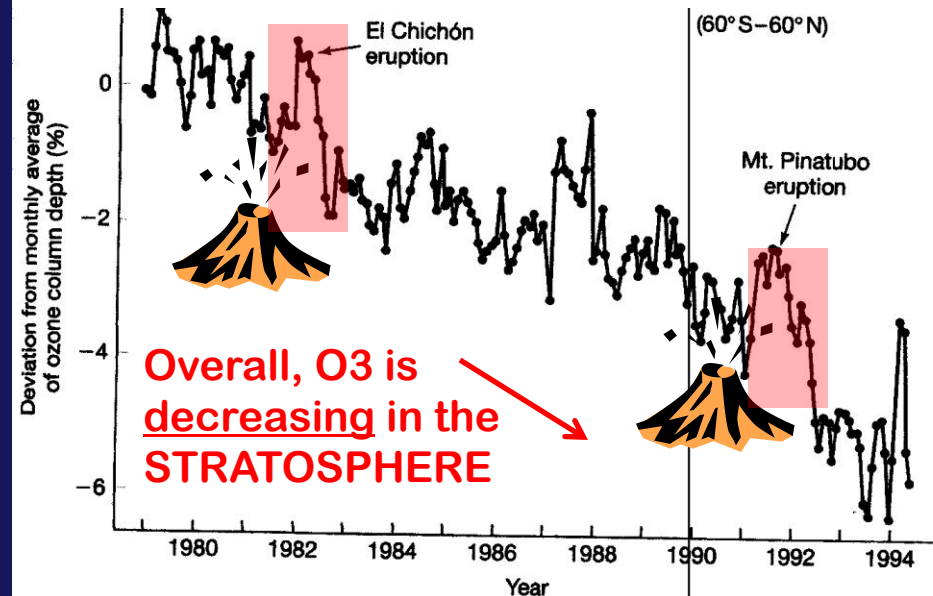
- solar variability (sunspot cycle)
- dynamical air motion
- volcanic eruptions

Key Concept

Solar effects



Volcanic effects



The STORY OF THE DISCOVERY OF THE OZONE HOLE:

“A Misadventure of Science?”

DISCOVERY OF THE OZONE HOLE:

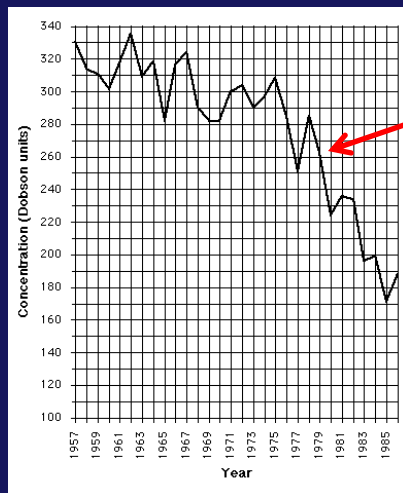
“A Misadventure of Science?”

CHAPTER 1



- Ground-based ozone measurements since **1956**. (British survey team)

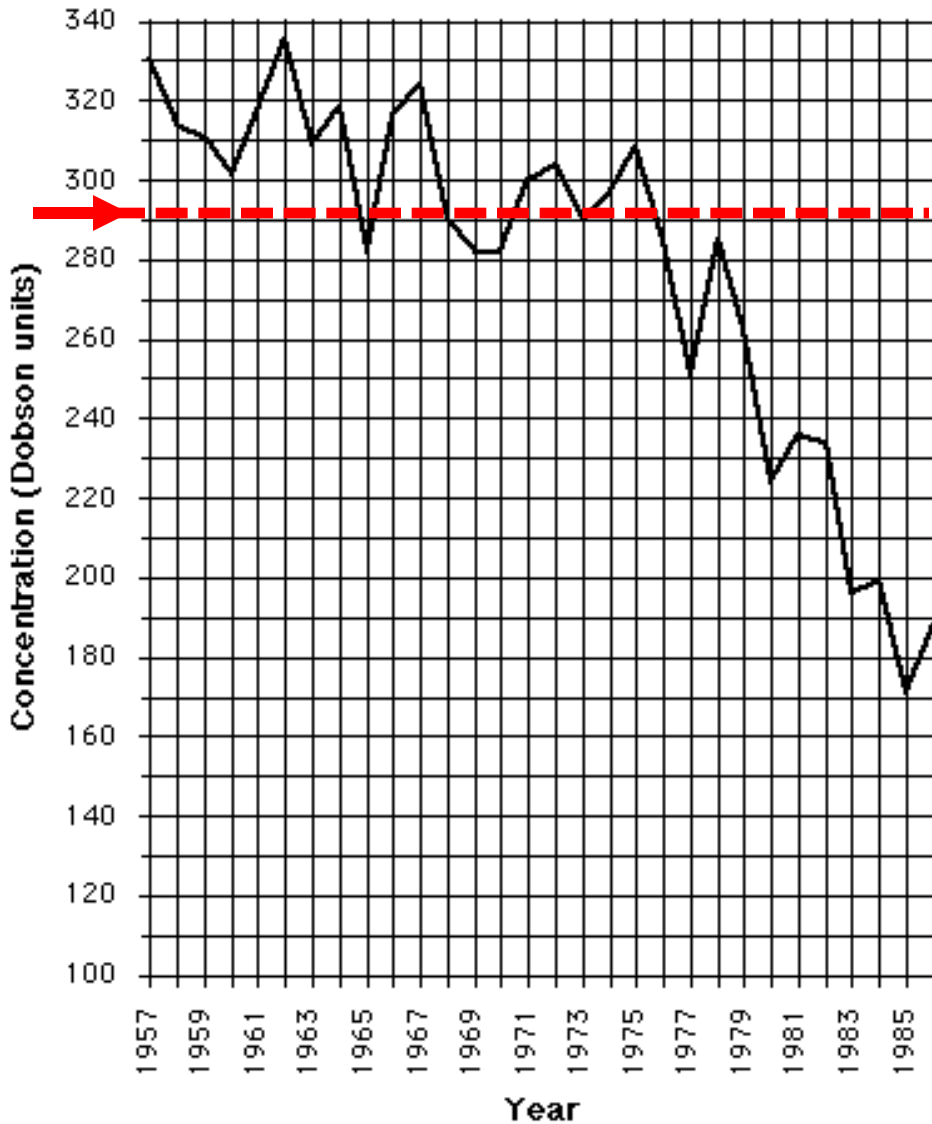
- They observed a new trend of decreasing ozone concentrations beginning in **1977**



- Didn't believe their measurements & delayed publication for several years while rechecking data & instruments.

Finally published in **1985**;
greeted with skepticism!





Declining OZONE CONCENTRATIONS (in Dobson units)

(over Antarctica)

1957-1986

Early data from ground measurements of British survey team

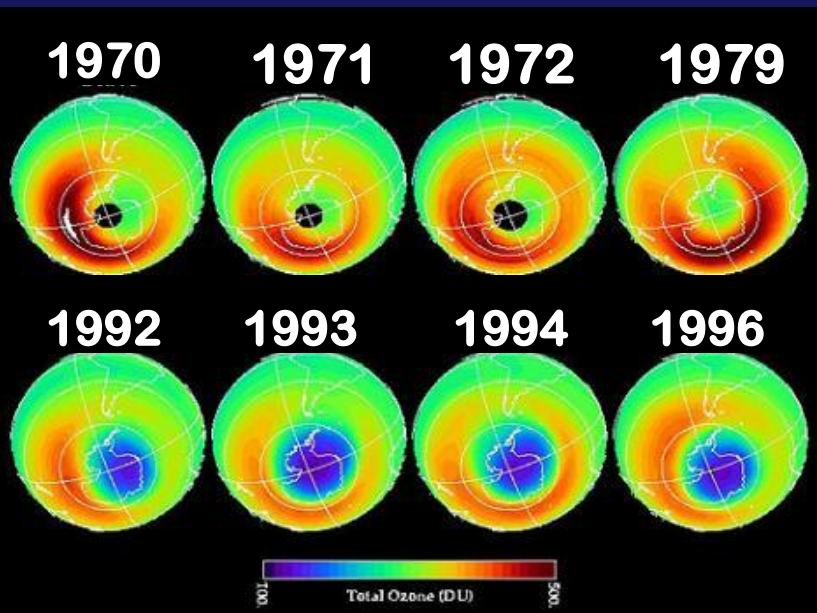


DISCOVERY OF THE OZONE HOLE (cont.)



CHAPTER 2

- Meanwhile, satellites had been launched to observe ozone from above via the **TOMS** instrument on the satellite



Total Ozone in October (DU)

- TOMS detected the developing hole, but the anomalously low readings were rejected as “noise” by the computer program set up to process the data !!



DISCOVERY OF THE OZONE HOLE

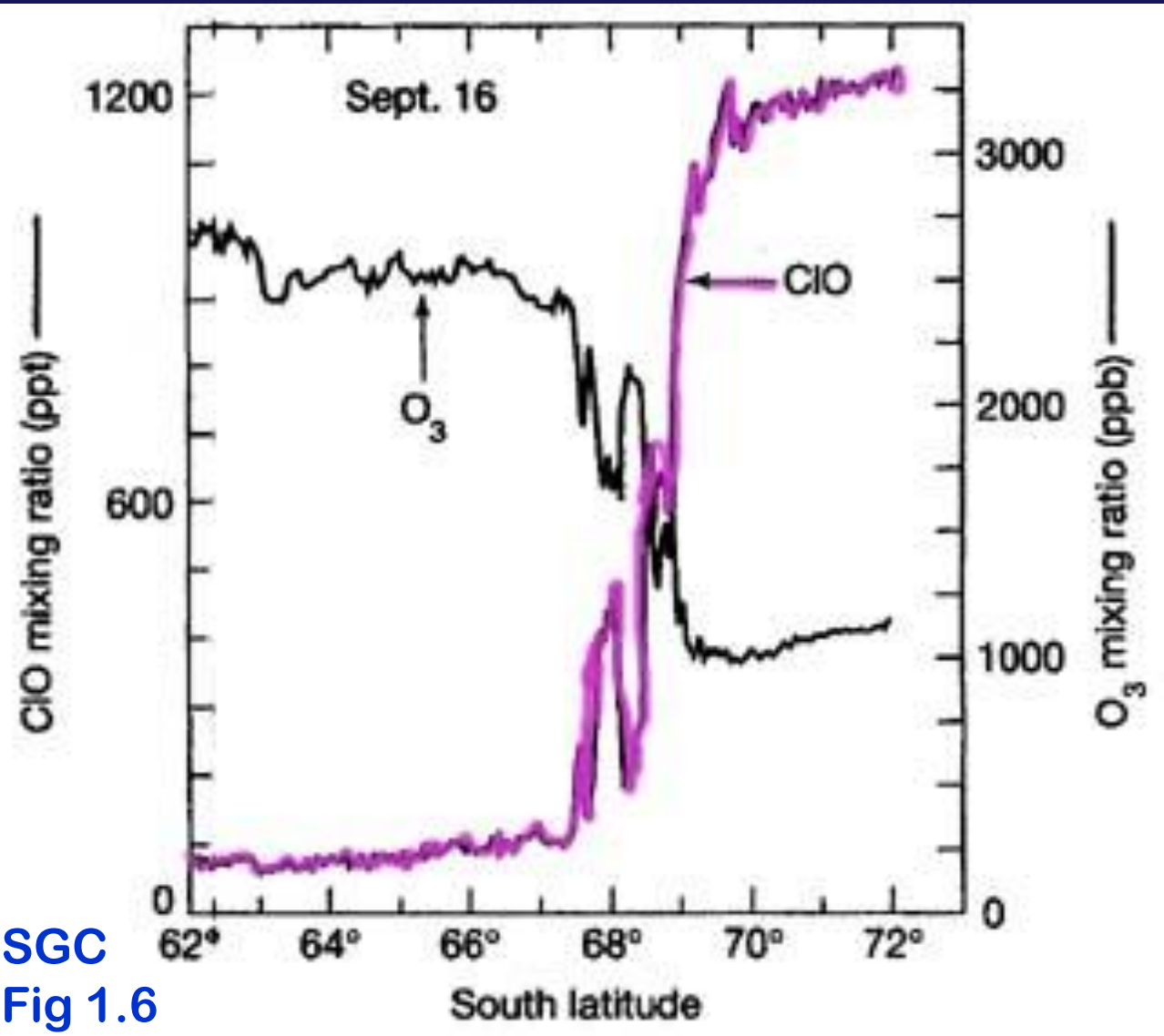
(cont.)

CHAPTER 3



- In **1986** Dr. Susan Solomon's expedition to Antarctica → identified chlorine increase
- She devised the **theory** that correctly explained the destruction of ozone by chlorine compounds





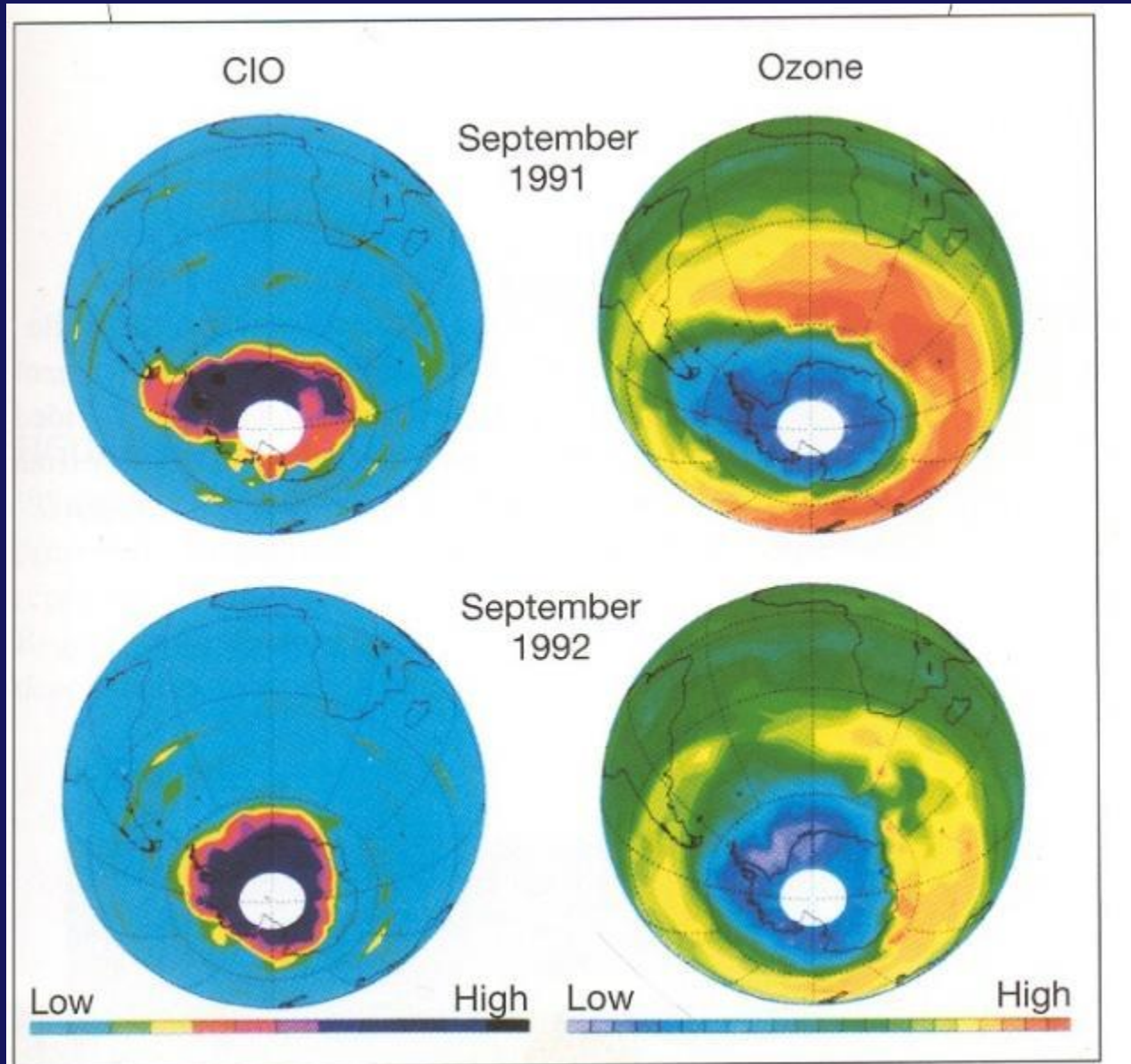
SGC
Fig 1.6

ClO (chlorine monoxide) from the chlorine catalytic cycle = **THE evidence of chemical reactions** occurring in hole region during time of greatest O₃ depletion (in September, spring in Southern Hemisphere)

ANTARCTIC LAND MASS

—————→ To the South Pole

Simultaneous measurements of ozone (O₃) and chlorine monoxide (ClO)



Color version of SGC Fig 1.6



The chemical reaction theory – **catalyzed by chlorine from CFCs** -- is almost universally accepted as conclusive at present.

The prominent scientists involved in developing the chemical reaction theory were awarded the **Nobel Prize for Physics in 1995.**

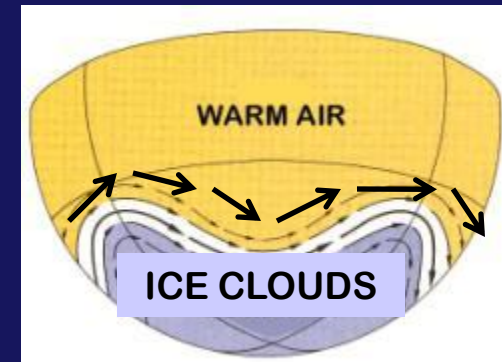
WHY ANTARCTICA?

The ozone "hole(s)" have a unique **REGIONALITY** and **SEASONALITY** :

- > it is most severe over Antarctica in S.H. spring (Sep, Oct);
- > a less severe depletion (not a true hole) occurs over the Arctic in N.H. spring (Feb, Mar)

The special conditions that make ozone depletion most severe over polar regions (esp. Antarctica) are:

(1) the unique **CIRCUMPOLAR CIRCULATION PATTERN** over Antarctica in winter which isolates the stratosphere inside a vortex and acts like a "containment vessel" in which chemical reactions may occur in near isolation;



(2) The presence of **POLAR STRATOSPHERIC ICE CLOUDS** -- on the surfaces of these extremely cold cloud particles certain chemical reactions are more efficient and faster.

Key Concept



**POLAR
STRATOSPHERIC
CLOUDS OVER
ANTARCTICA**

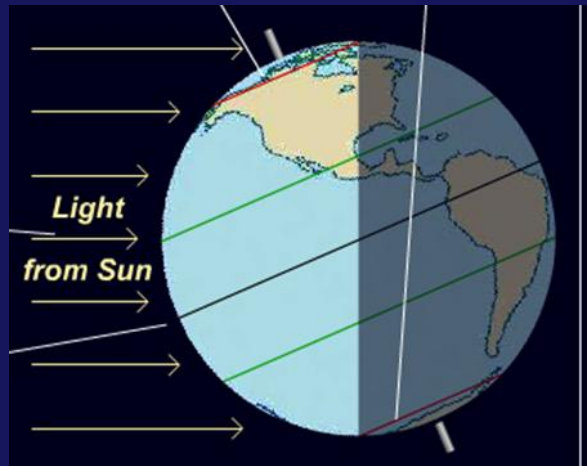
[\[Go to movie clip\]](#)



LAST INGREDIENT:

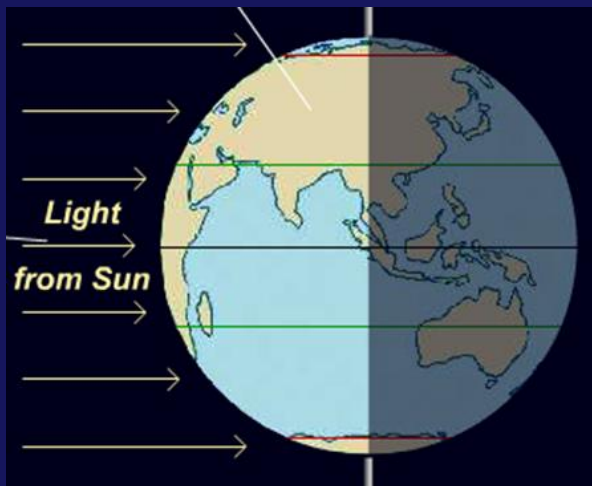
SUNLIGHT + UV PHOTONS

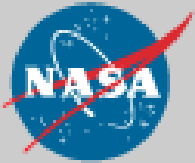
June



Only AFTER the June Solstice and closer to the **SEPTEMBER EQUINOX** (which is **Southern Hemisphere Spring**), does the South Pole & Antarctic Circle receive sufficient sunlight!

Sept



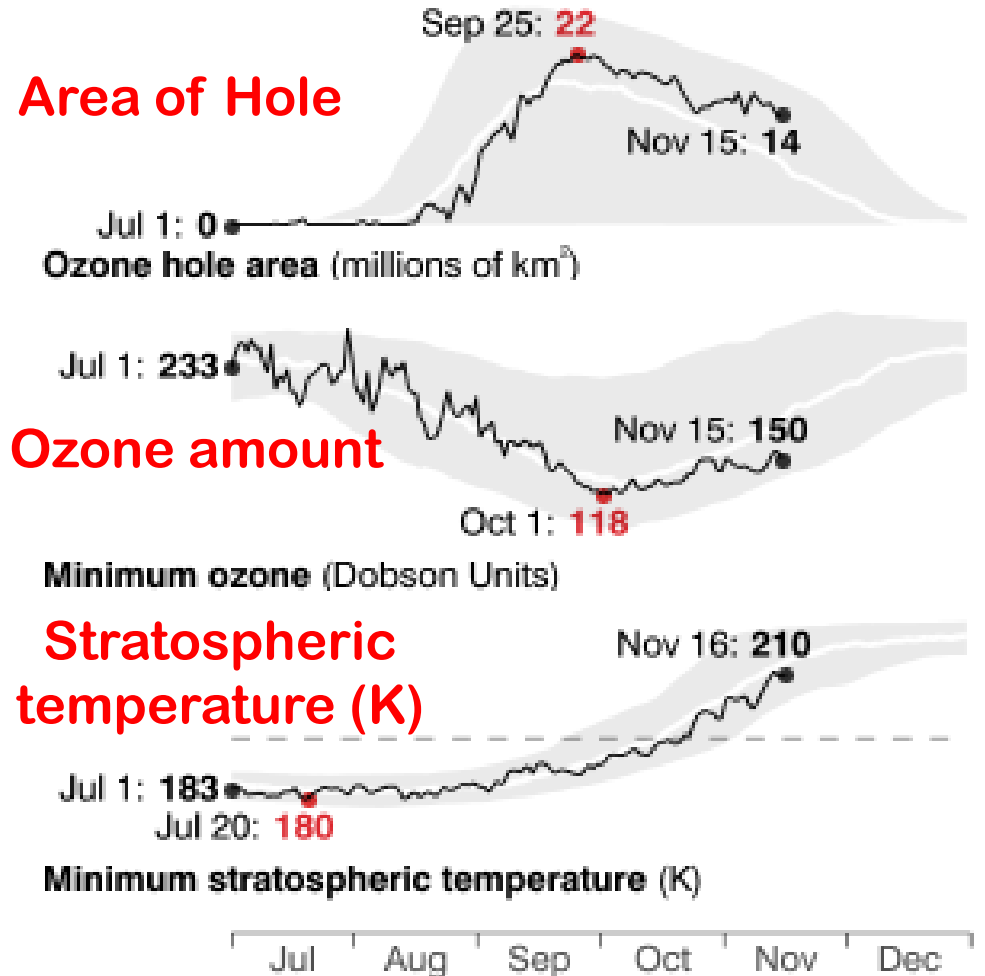


OZONE HOLE WATCH

images, data, and information; updated daily

2010 data

<http://ozonewatch.gsfc.nasa.gov/>

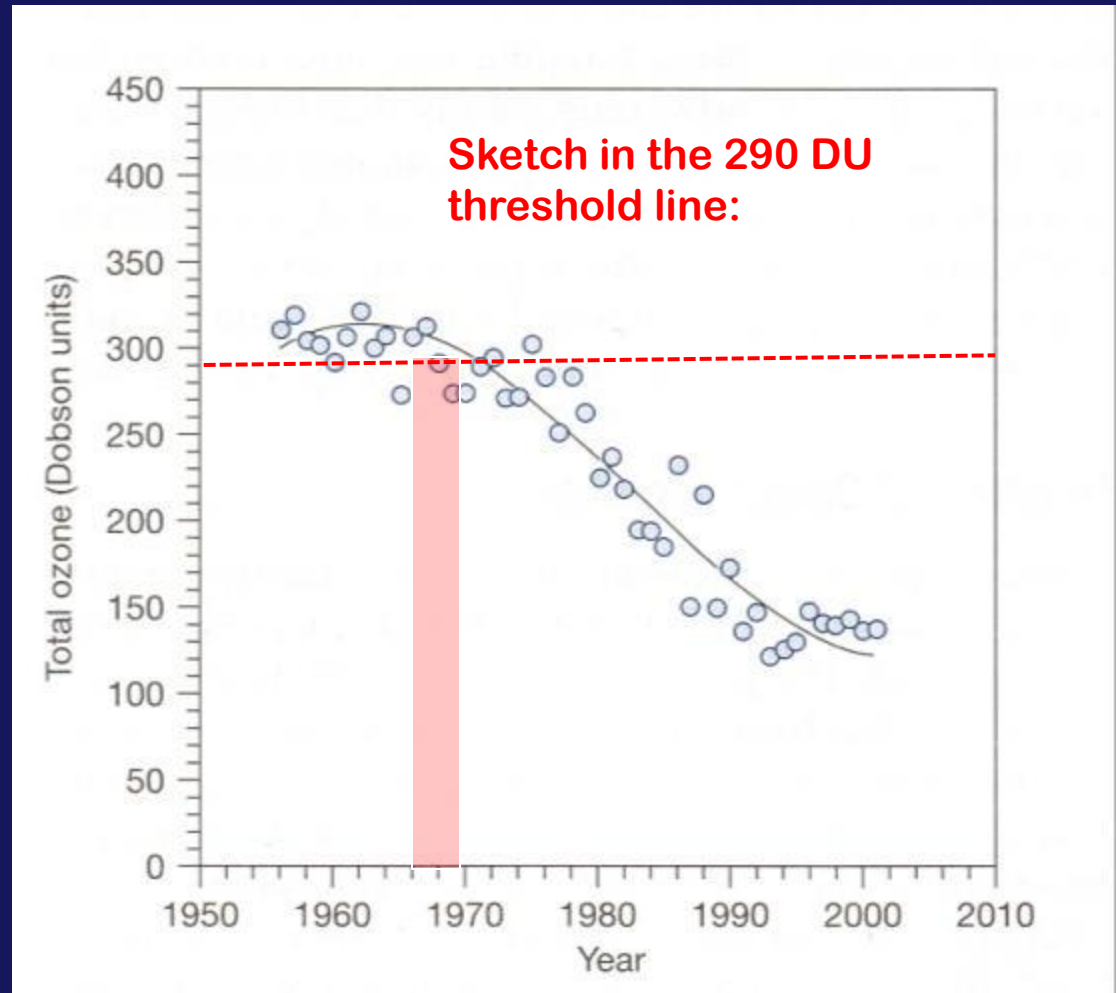


RATE OF OZONE DEPLETION

in DOBSON UNITS (DU)

When did the Hole
begin forming?

Hole generally
defined as
< 290 DU

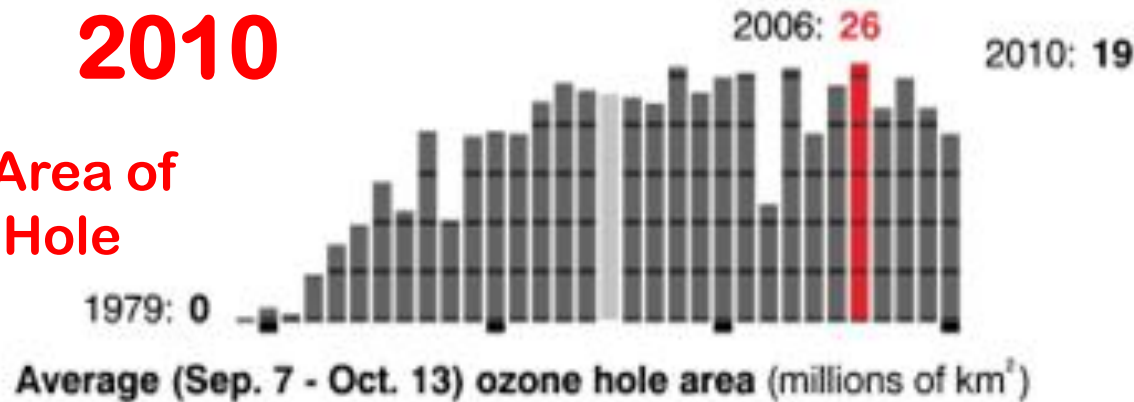


~ 1969 to 1970

<http://ozonewatch.gsfc.nasa.gov/>

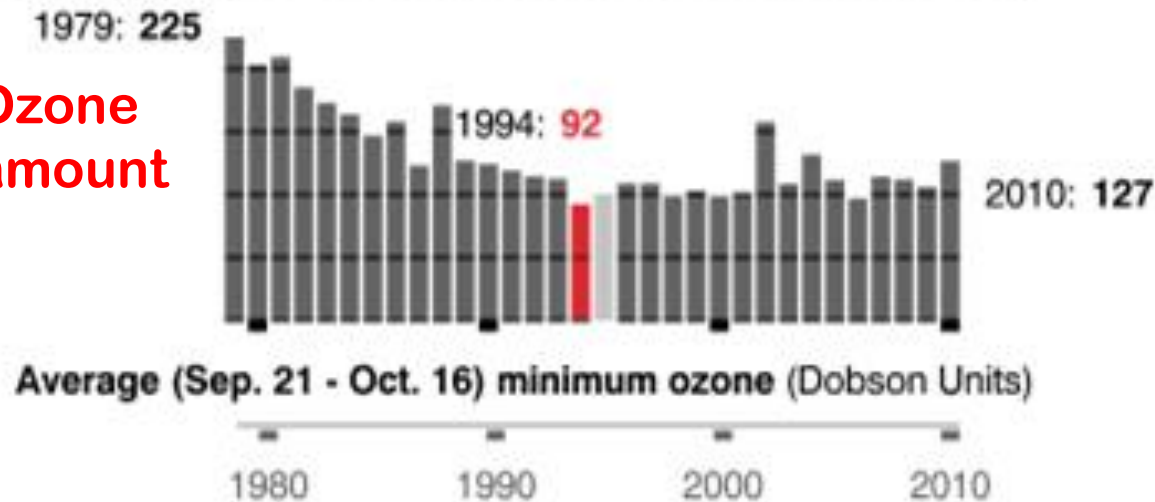
2010

Area of Hole



Average (Sep. 7 - Oct. 13) ozone hole area (millions of km²)

Ozone amount



Average (Sep. 21 - Oct. 16) minimum ozone (Dobson Units)

Note: No data were acquired during the 1995 season

UPDATE OF
graph on
your p 83

see also: <http://macuv.gsfc.nasa.gov/>

HOW DEEP DOES THE HOLE GET?

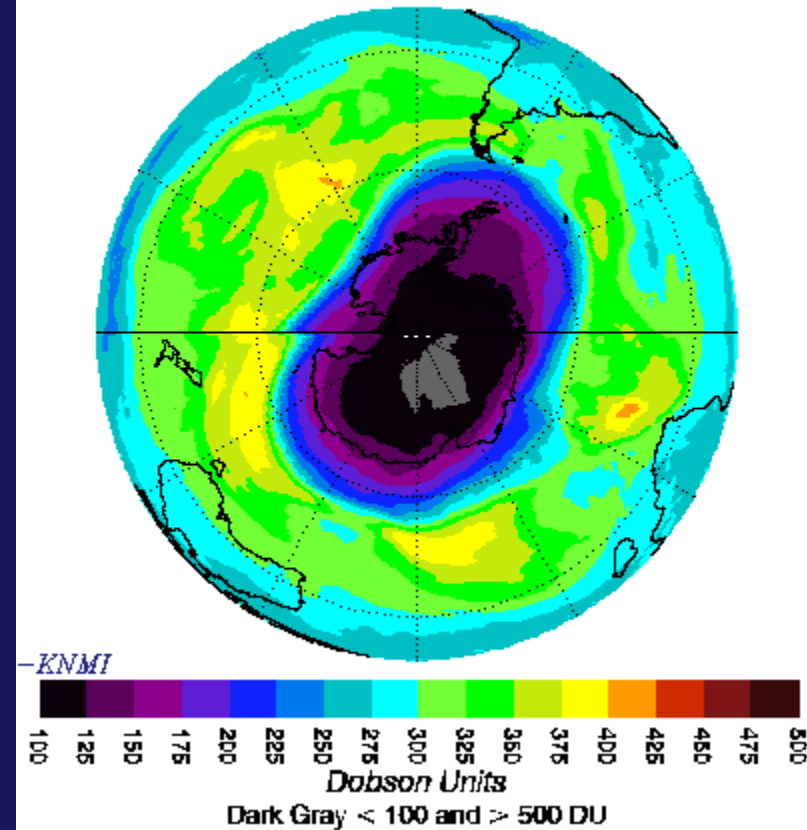
The intensity of ozone depletion varies from year to year.

The value of **85 Dobson Units** on **October 8, 2006** was the **second lowest ever recorded** by satellite measurements.

Nearly ALL of the ozone in the layer 8-13 miles above the Earth's surface was destroyed!

In this critical layer, the instrument measured a record low of only **1.2 DU!**

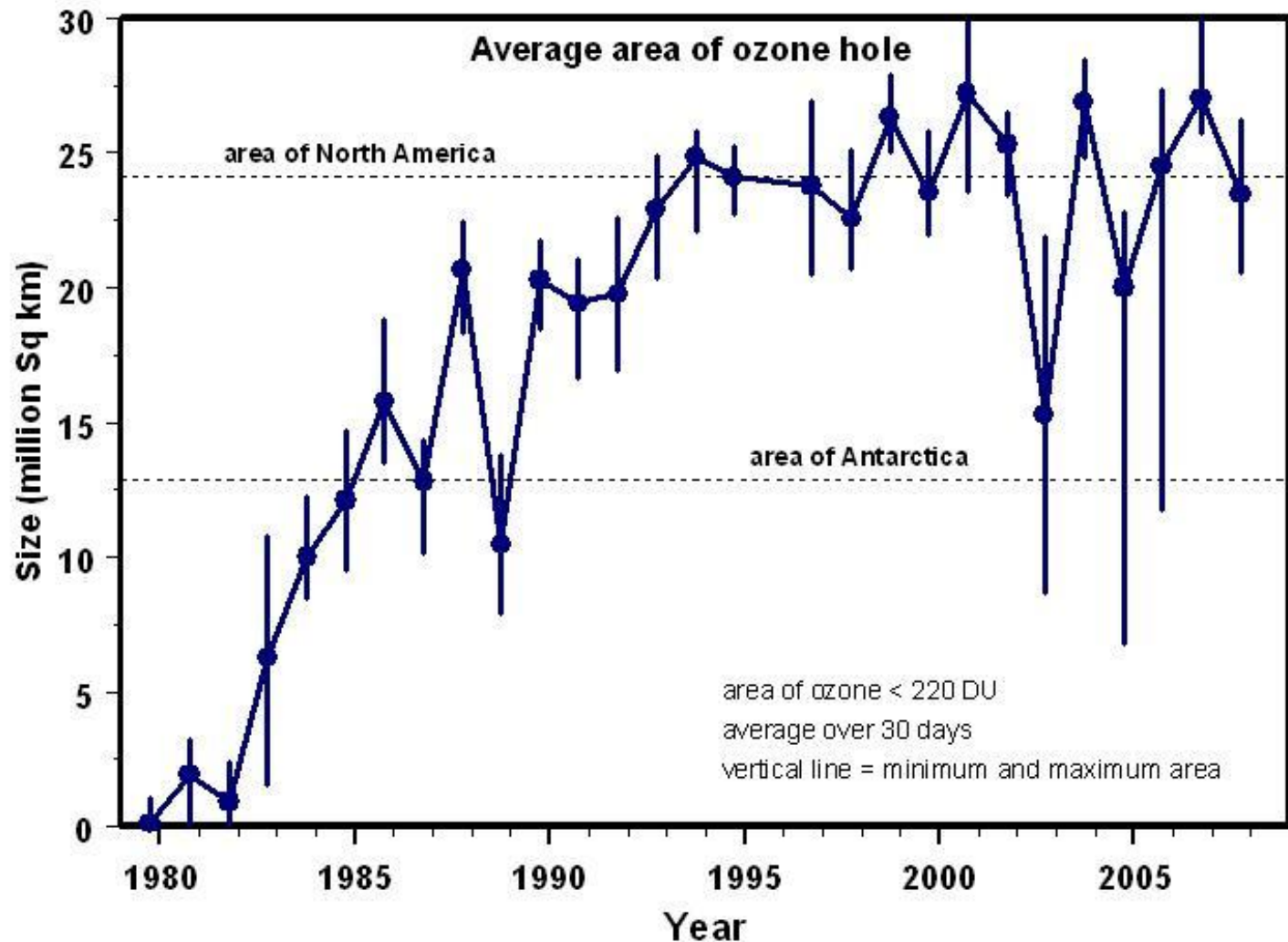
OMI Total Ozone for Oct 8, 2006



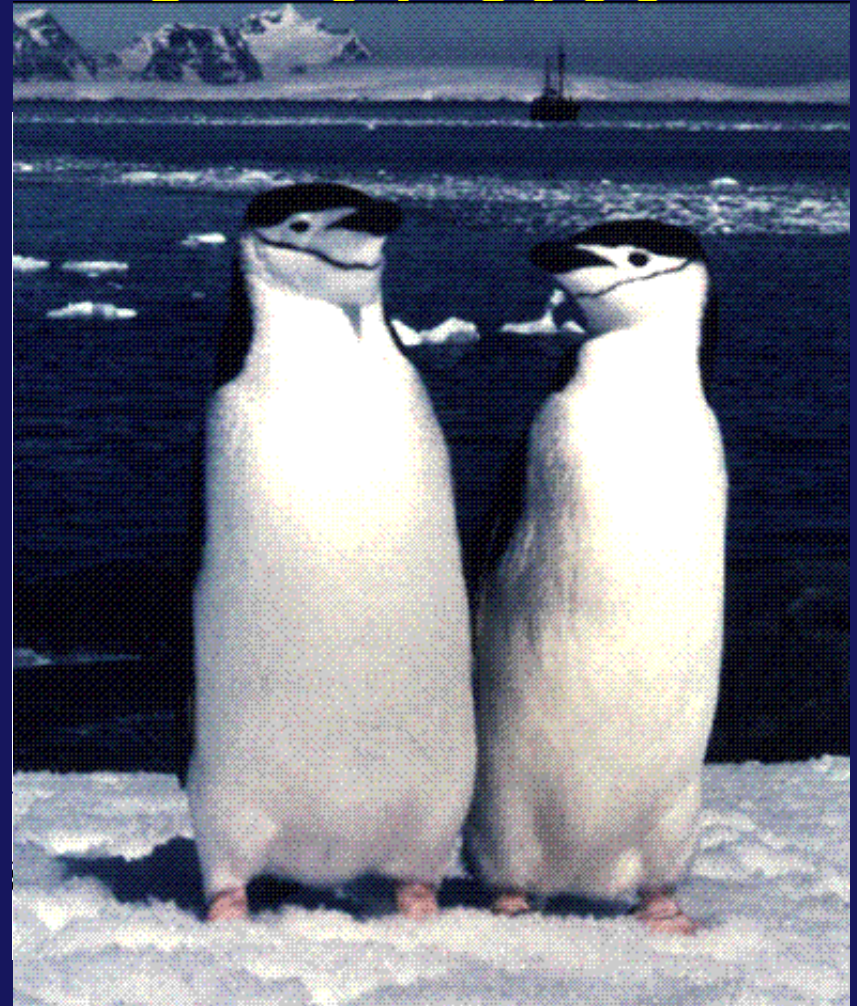
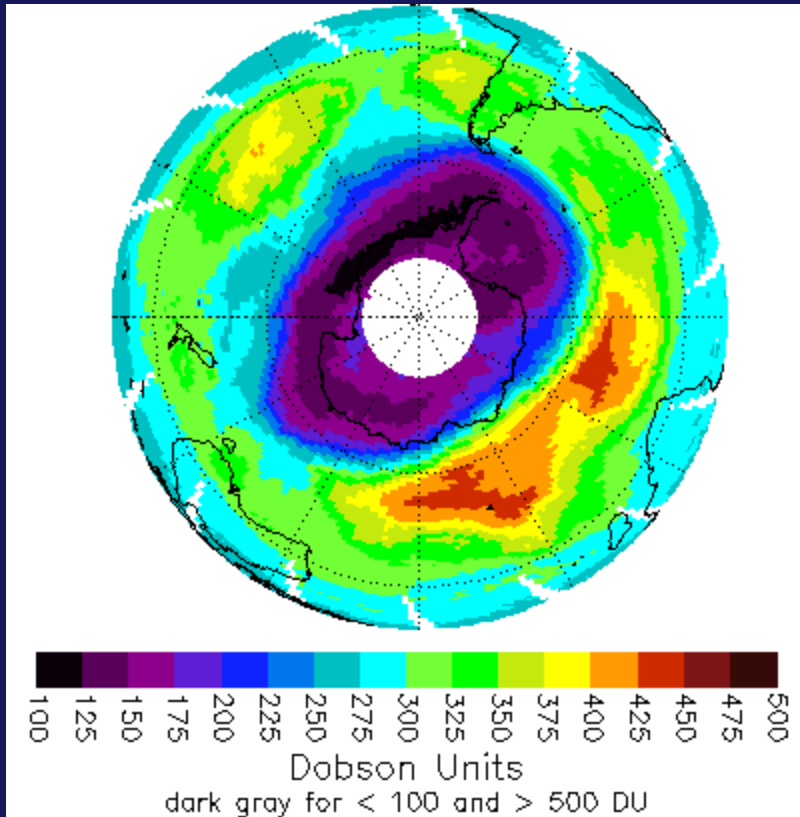
2006 also saw the second **LARGEST** sustained ozone hole.



Over time, the **AVERAGE SIZE OF THE HOLE** has gotten **LARGER**:



Sep 9, 2000



Here are some inhabitants with strong cause for concern about the Ozone Hole!
But what about the rest of us?



HOLE IN OZONE LAYER EXPOSED A CITY

THE ASSOCIATED PRESS 10-6-00

WELLINGTON, New Zealand –

“The hole in the ozone layer over Antarctica stretched over a Chilean city when it ballooned to a record size last month, the first time it has reached a population center, scientists said yesterday. . . .

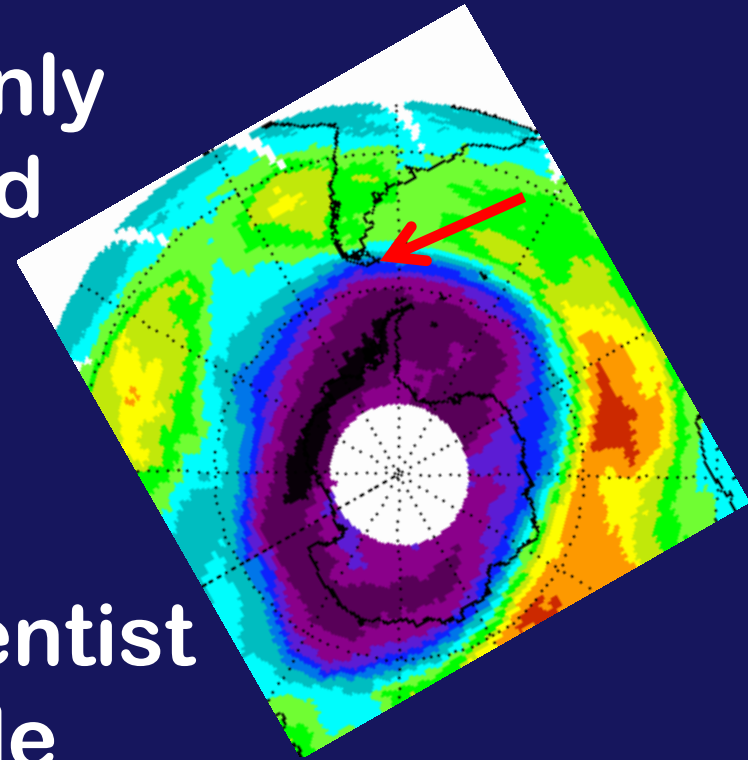


In an Upside-Down World, Sunshine Is Shunned
(New York Times 12-27-2002)



“Previously, the hole had only opened over Antarctica and the surrounding ocean.

“Citing data from NASA, atmospheric research scientist Stephen Wood said the hole covered **11.4 million square miles** - an area more than three times the size of the United States - on Sept. 9 and 10.





A "solar stoplight" in Punta Arenas announces an orange alert, the second highest of four levels, and warns people to limit their exposure to the sun between noon and 3 p.m. to a maximum of 21 minutes.



a woman and her child are bundled up against the sun

“For those two days, the hole extended over Punta Arenas, a southern Chilean city of about 120,000 people, exposing residents to very high levels of ultraviolet radiation.

“ . . . findings showed a city being exposed to the ozone hole for the first time.”

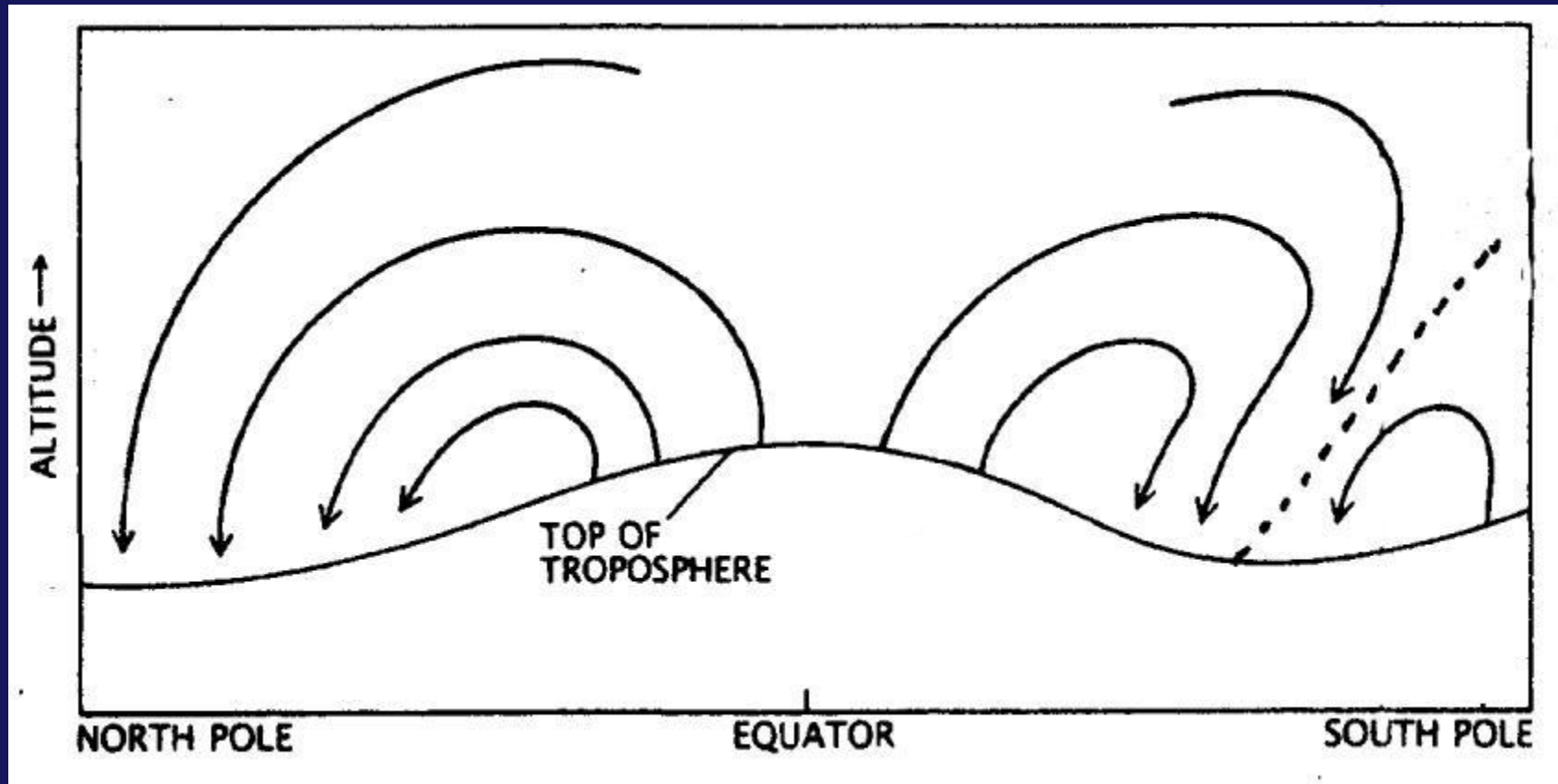


What about other parts of the globe?

- > Decreases have been observed in nearly all latitude zones:
(1.1 - 9% in S.H. & 1.1 - 3.7% in N.H.)
- > Mid-latitude ozone has been decreasing by ~ 4% per decade in both hemispheres, whereas tropical ozone has remained more or less constant.

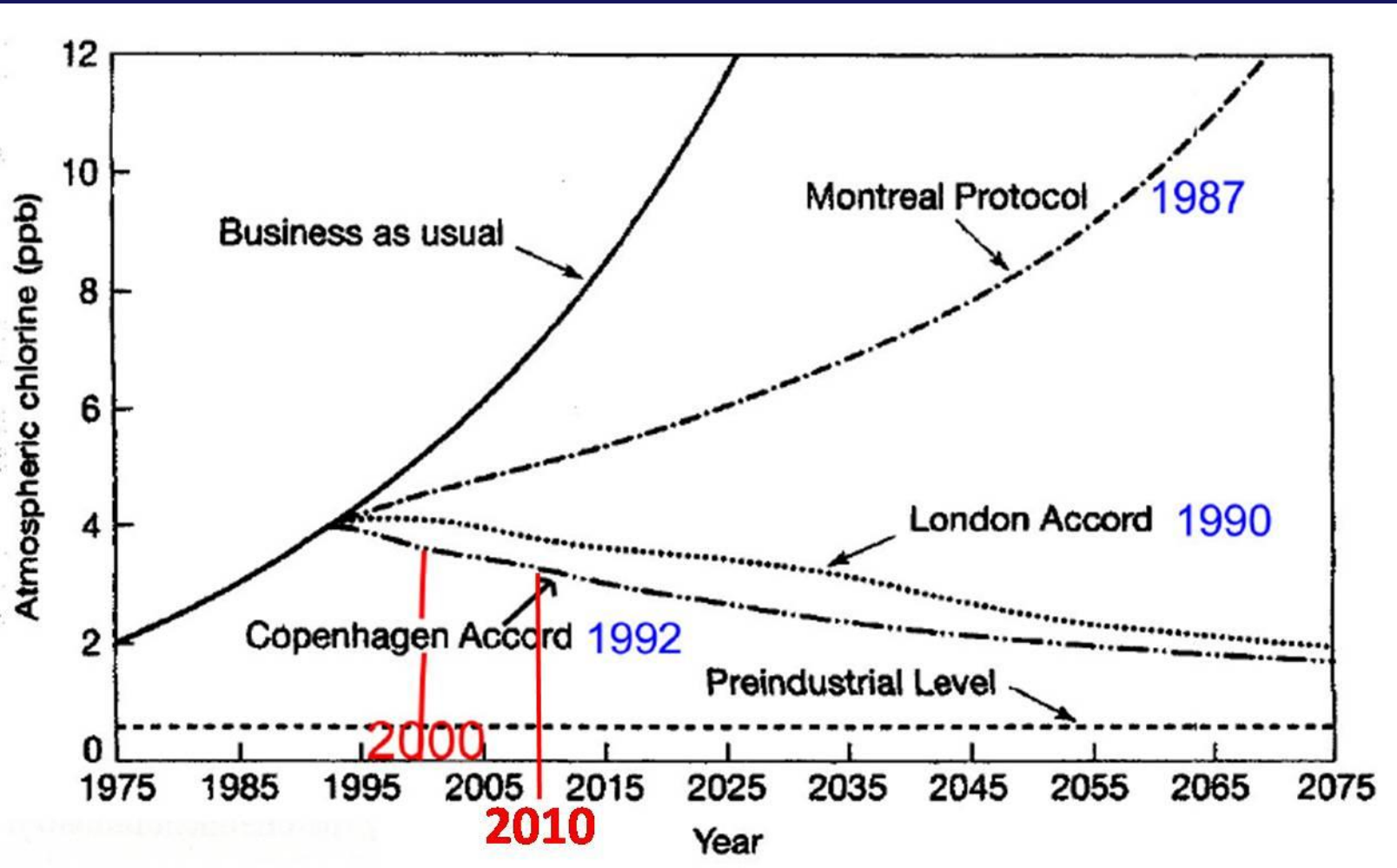
<http://www.theozonehole.com/arcticozone.htm>

Stratospheric Atmospheric Circulation Determines this Distribution

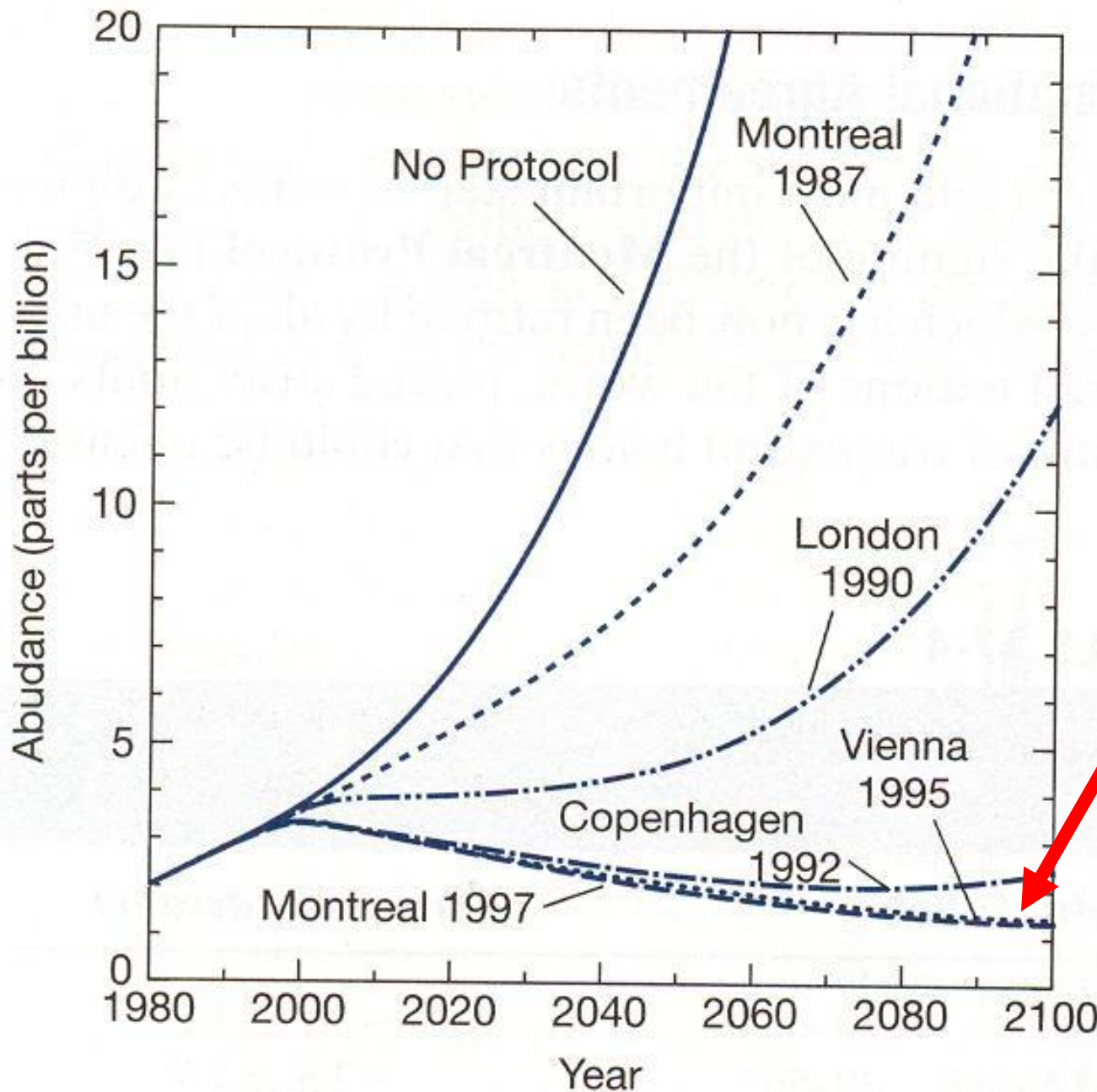


**Ozone production highest in tropics but
stratospheric circulation
distributes it poleward**





Very long residence time of CFCs!



Model results based on more recent agreements:

Vienna 1995 & Montreal (again) 1997

The world is “making do” with freon substitutes, but some concern over long-term effects of substitutes remains . . .

Why can't we just ship the “bad ozone” in the troposphere up to the stratosphere to ‘fill the hole’?

- > Ozone is *increasing* in the troposphere due to car exhaust, etc (“bad ozone”), but only at the rate of about 1% per year,
- > hence stratospheric levels of “good ozone” are going down at a rate faster than ozone is being added in the troposphere.

Recap:



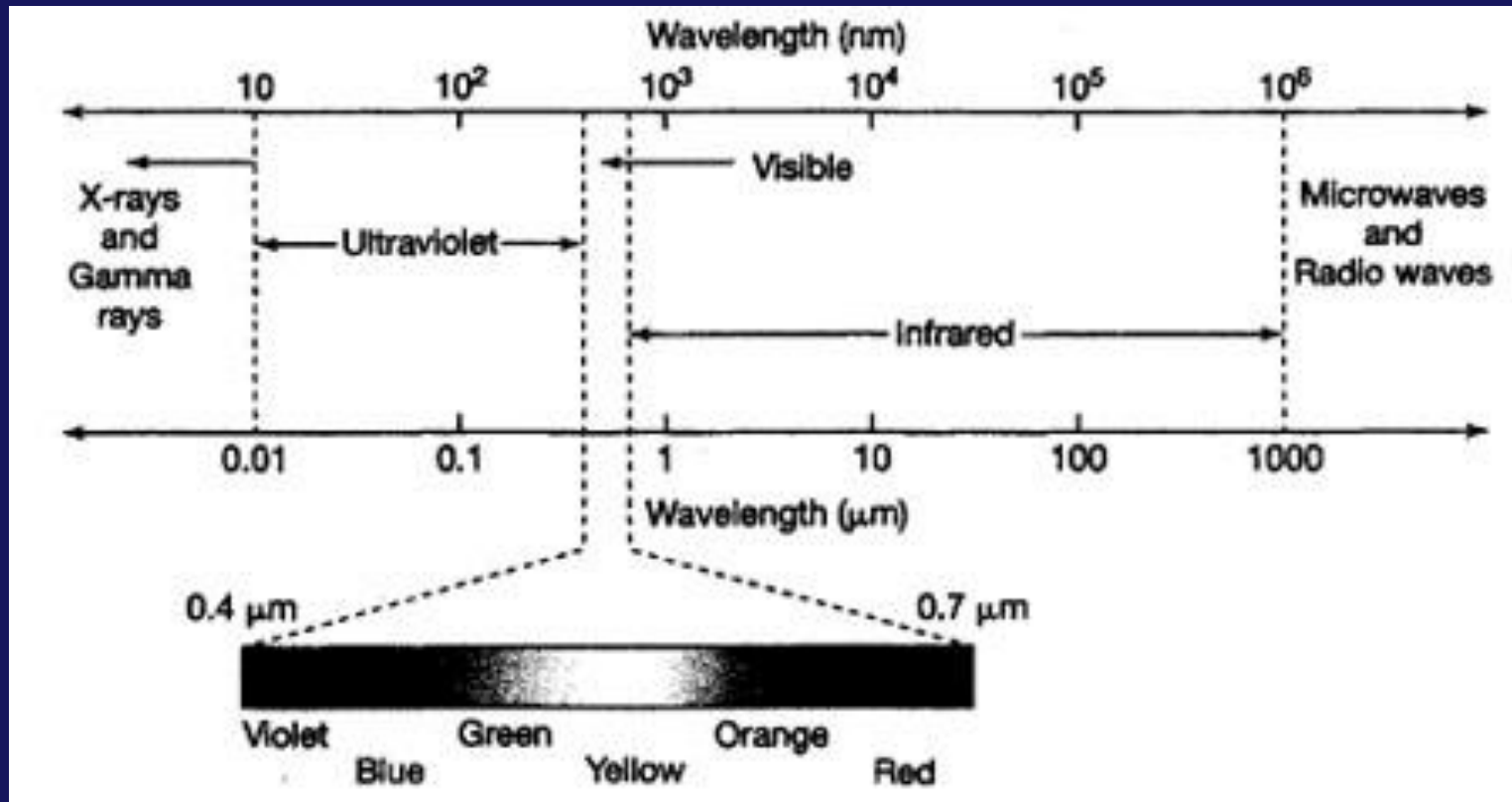
http://www.youtube.com/watch?v=qUfVMogldr8&feature=player_embedded

**THE OZONE DEPLETION STORY
TIES TOGETHER MANY OF THE
CONCEPTS YOU'VE LEARNED IN
THE COURSE THUS FAR:**

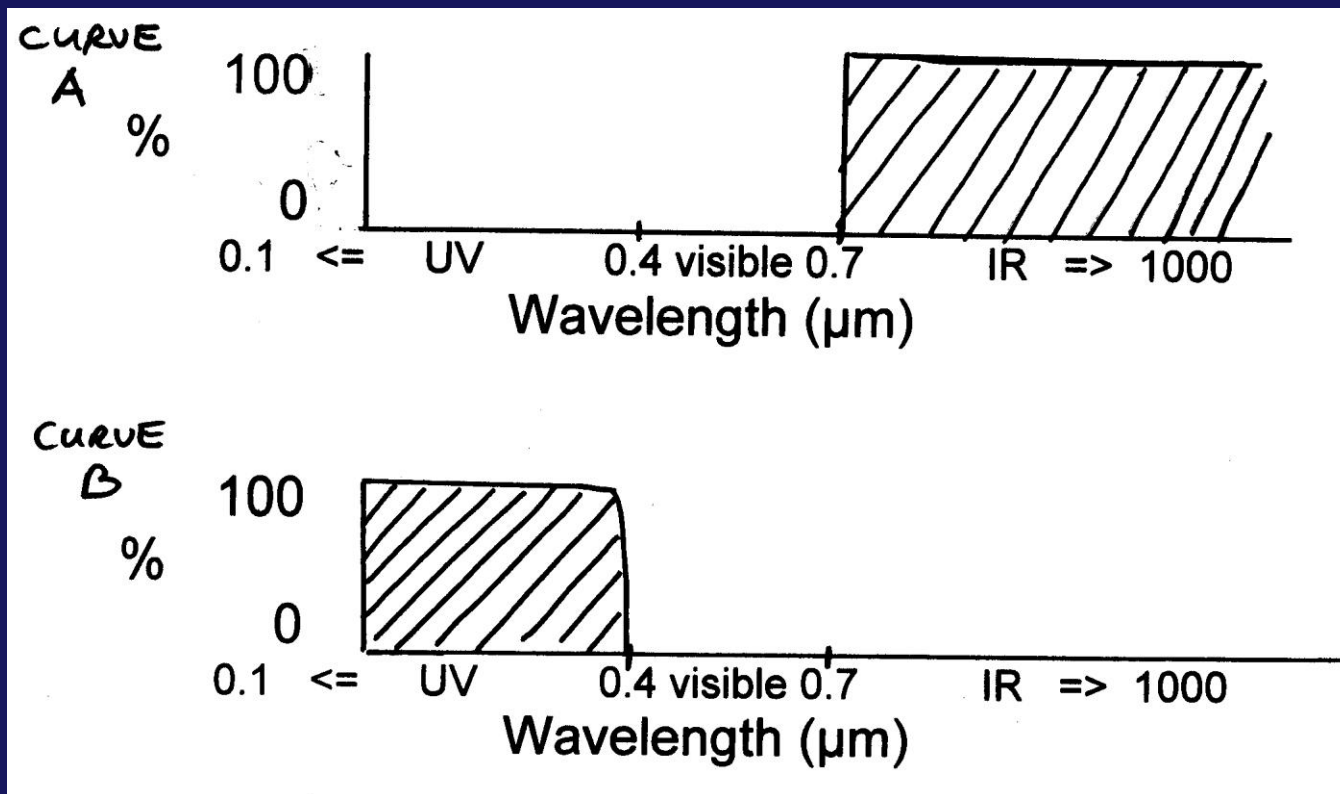
**> the nature of matter, e.g.,
chemical reactions and photon
interaction with atoms**



> the electromagnetic spectrum --especially the wavelengths of UV radiation

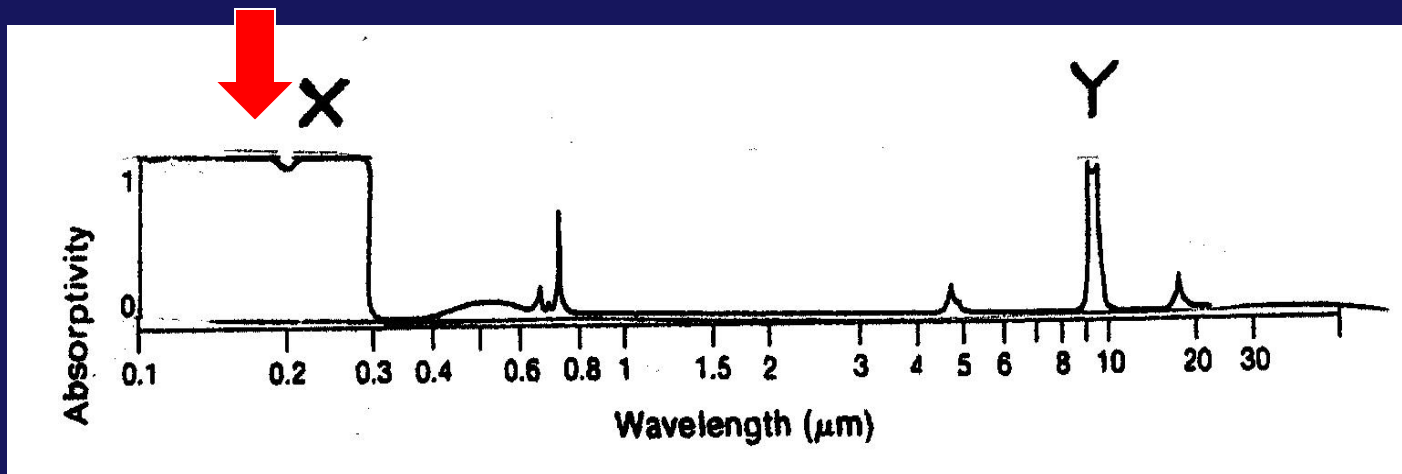


> absorption curves, especially the absorption curve for ozone

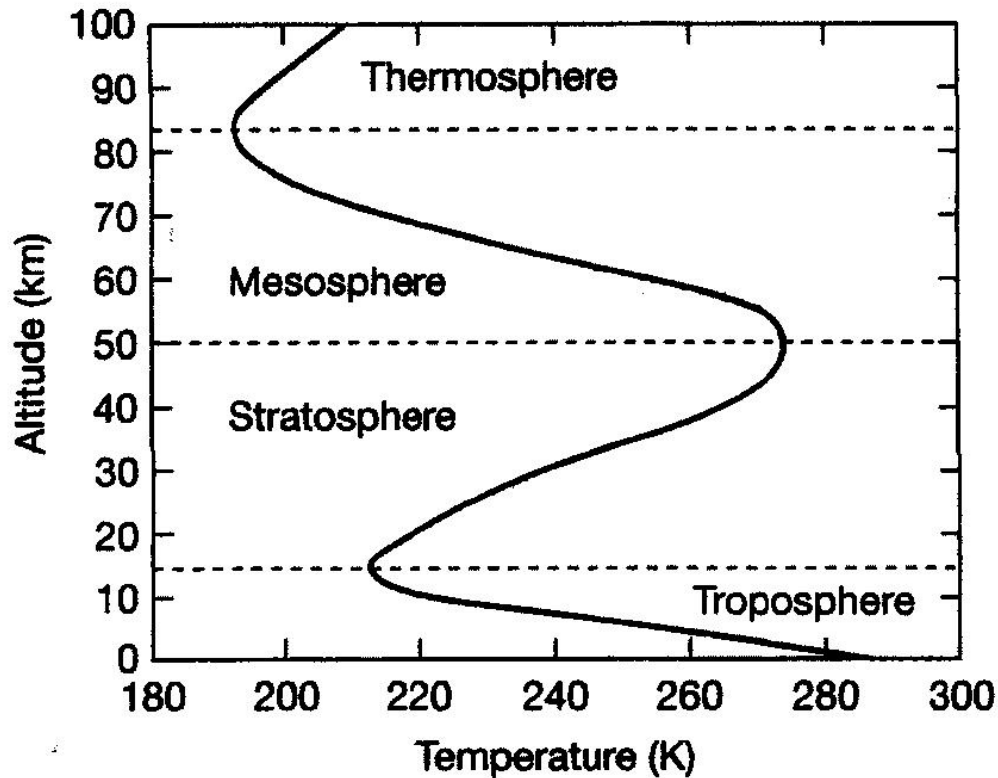


> Effect of clouds -- in this case the importance of Polar Stratospheric Clouds (PSCs)

> Greenhouse gases (ozone is also a greenhouse gas but this affects IR radiation, not UV radiation)



> the vertical structure of the atmosphere (troposphere, stratosphere)



(b)



> the ever-changing nature of science; early theory right for wrong reason



> Preconceived ideas influencing one's observations

... and the surprise of discovery!



