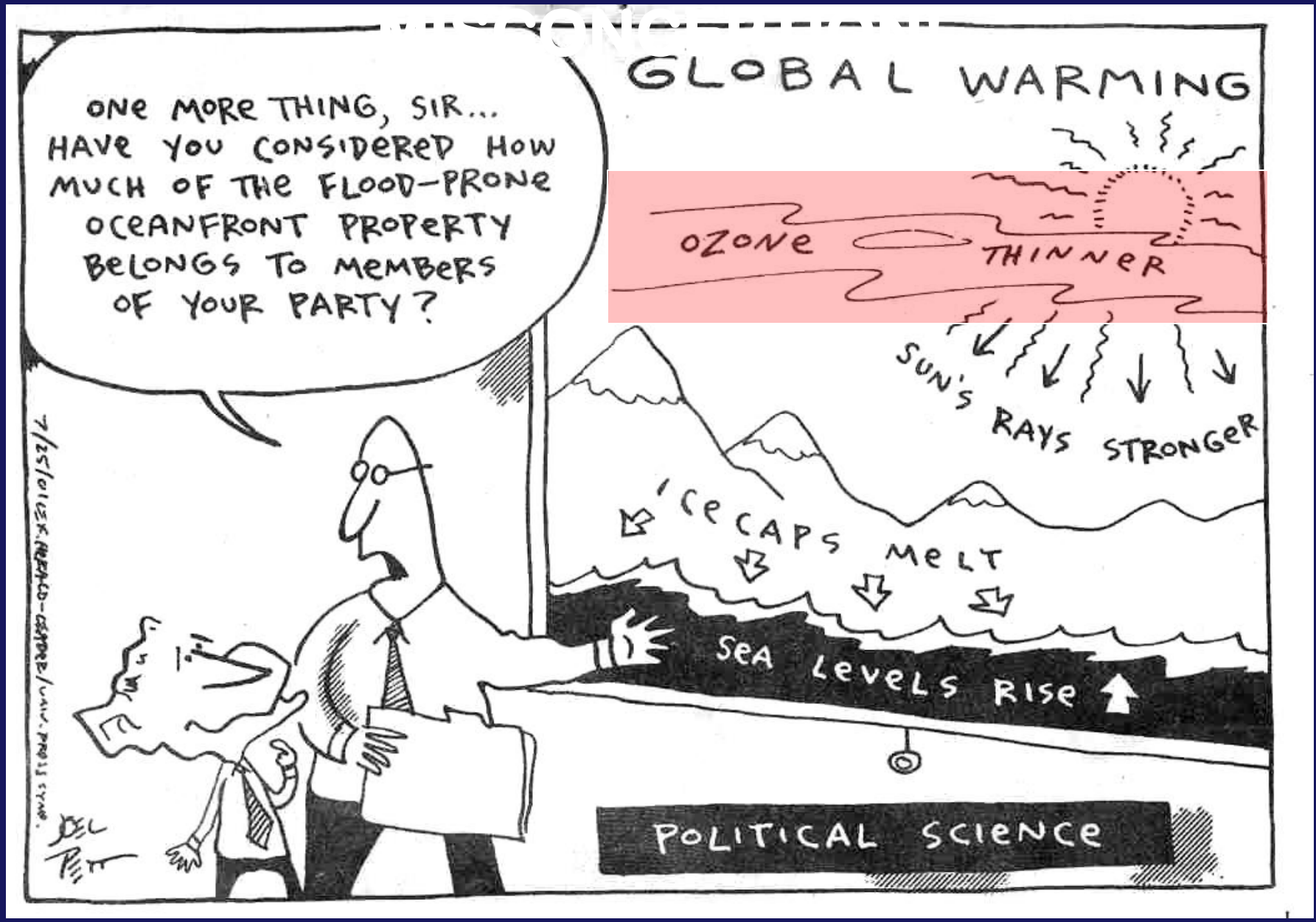
Topic # 14 – Part II

OZONE DEPLETION IN THE STRATOSPHERE

A Story of Anthropogenic Disruption of a Natural Steady State

p 85 in Class Notes

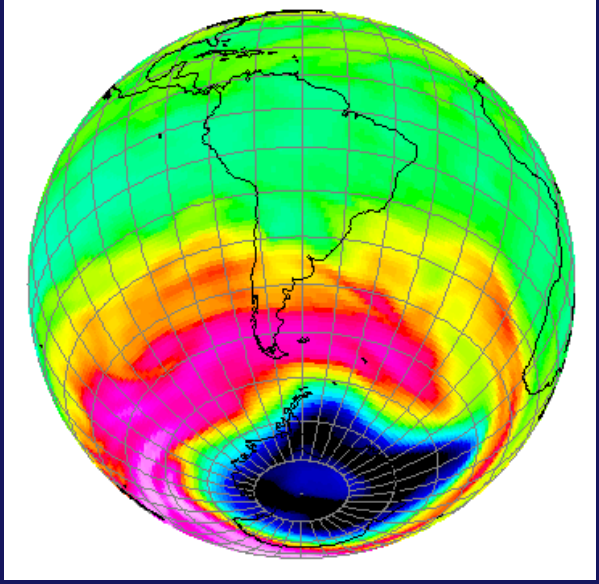
OZONE-RELATED CARTOON:



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

1 – YES
2 -- NO

THE DESTRUCTION OF STRATOSPHERIC OZONE



The ozone hole is:

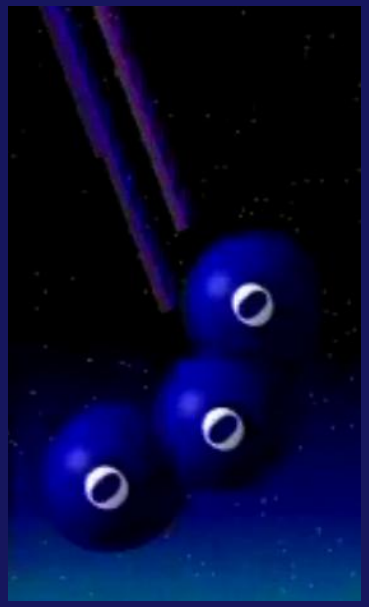
-- a depletion of ozone in the lower stratosphere

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

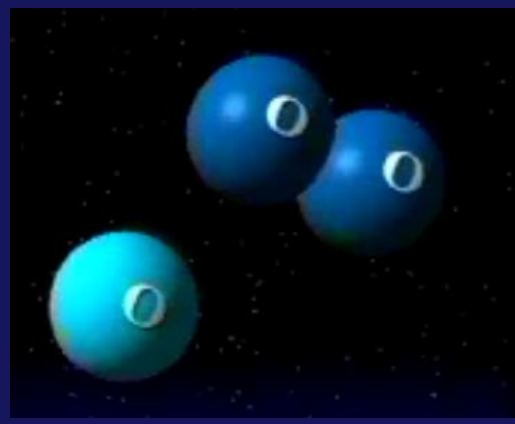
Box on p 85

The Natural Chapman Mechanism in the Stratosphere

Breaks down & re-forms ozone naturally in a steady state



High energy UV splits apart O_3



single O molecule bonds with O_2 to produce new O_3

FLOW DIAGRAM OF A STEADY STATE

Inflow

Ozone being formed via natural Chapman mechanism

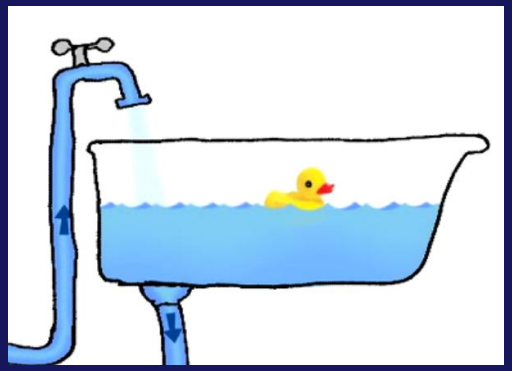
Reservoir of STRATOSPHERIC OZONE

Outflow

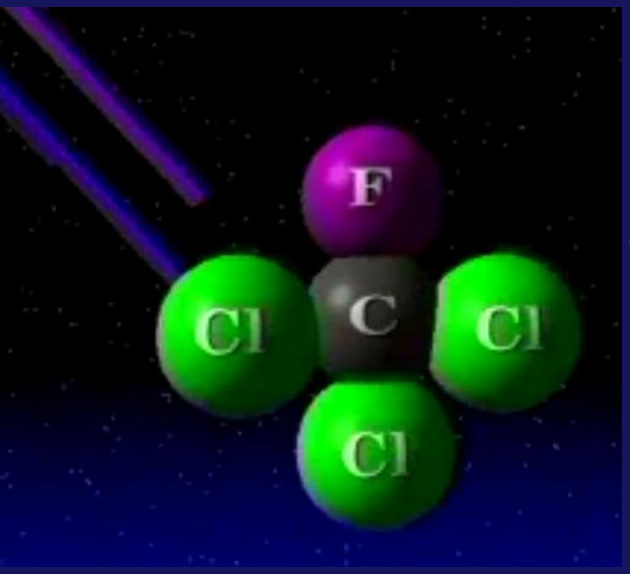
Ozone being destroyed via natural Chapman mechanism

Where have we seen something like this before?

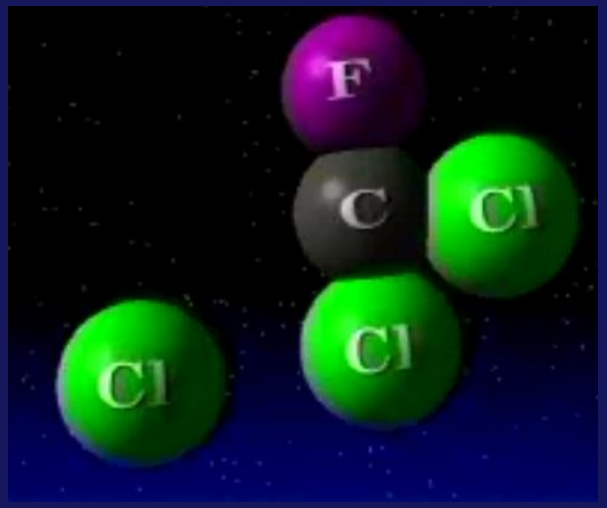
I-1 Lesson 1
Carbon Dioxide in the Atmosphere

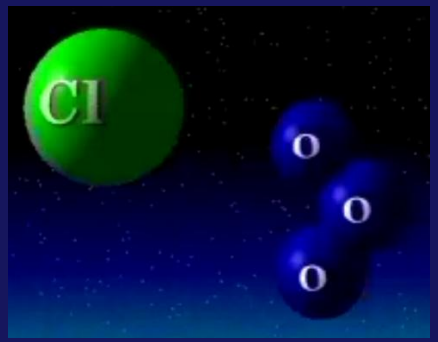


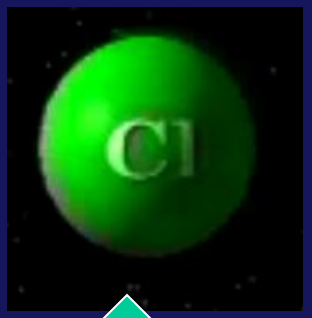
DESTRUCTION OF OZONE BY CFC's & CHLORINE CATALYST



A single Cl atom destroys 100,000s of O_3 but is not itself destroyed







Box on p 85

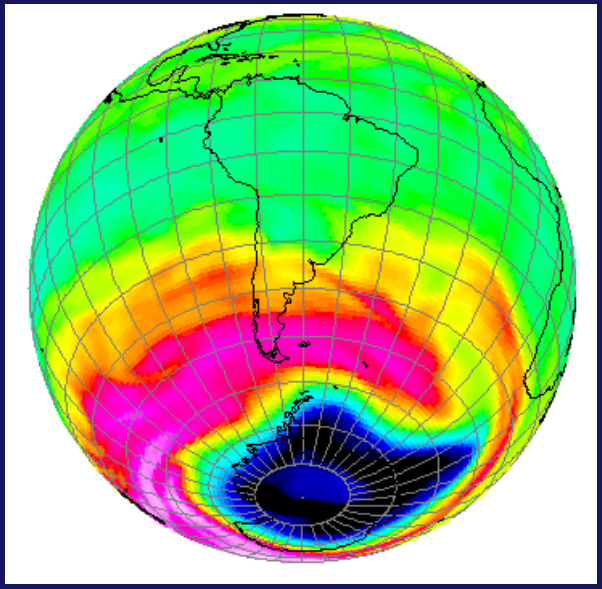
DESTRUCTION OF OZONE BY CFC's & CHLORINE CATALYST

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)

Then came . . .

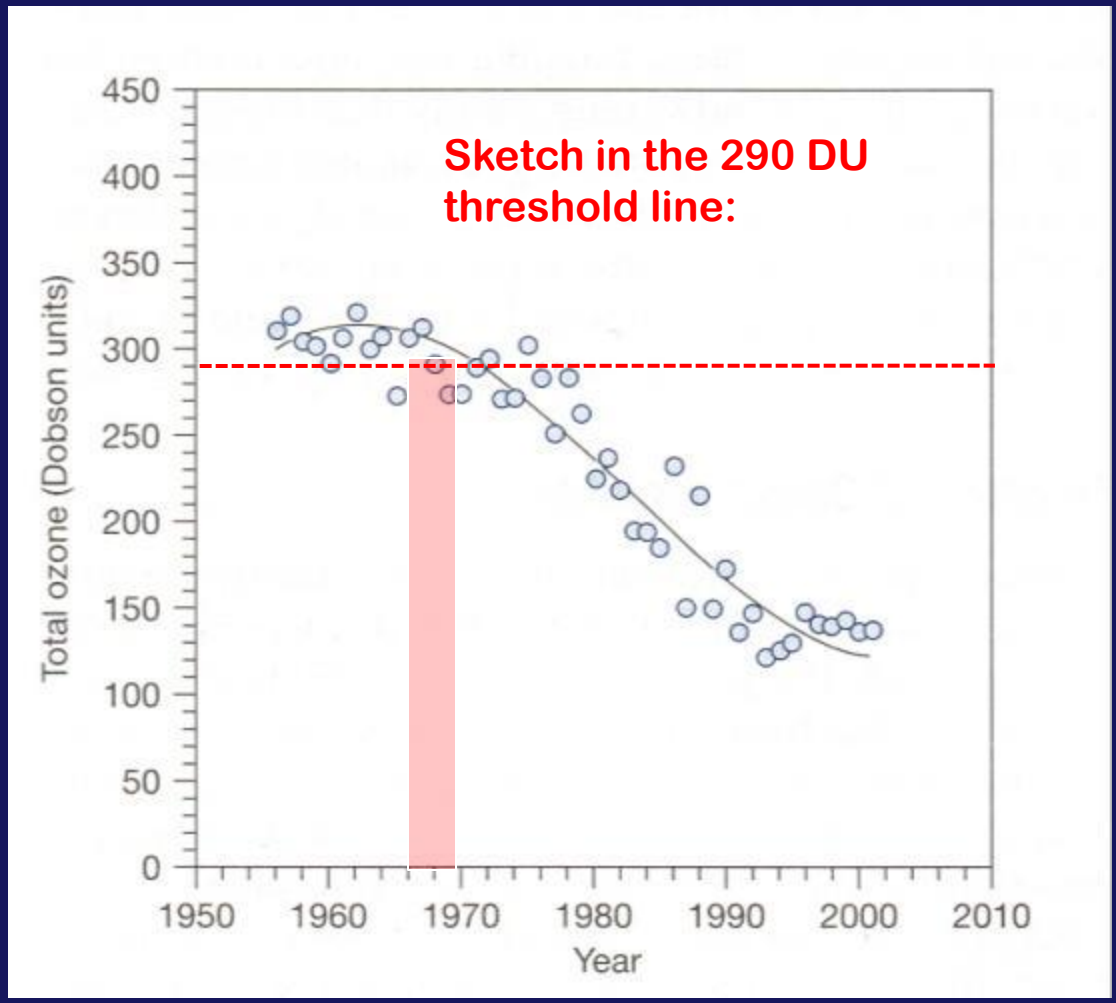
THE DISCOVERY OF THE OZONE HOLE!



When did the Hole begin forming?

OZONE is measured in DOBSON UNITS (DU)

Ozone Hole generally defined as < 290 DU



~ 1969 to 1970

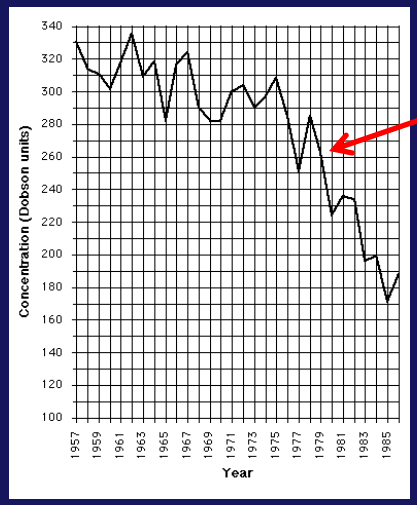
DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

CHAPTER 1

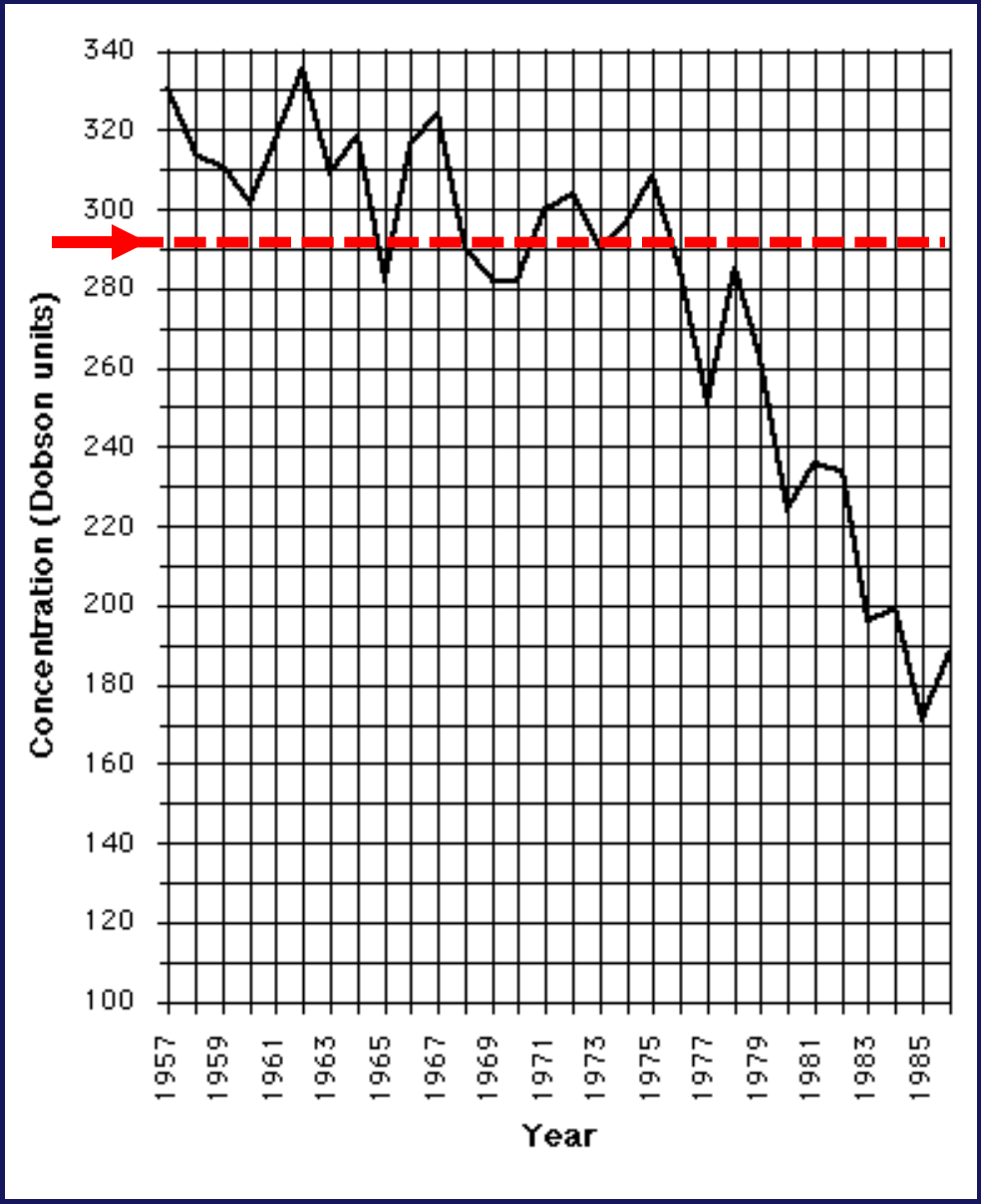
- **Ground-based** ozone measurements since **1956**. (British survey team)

- 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)

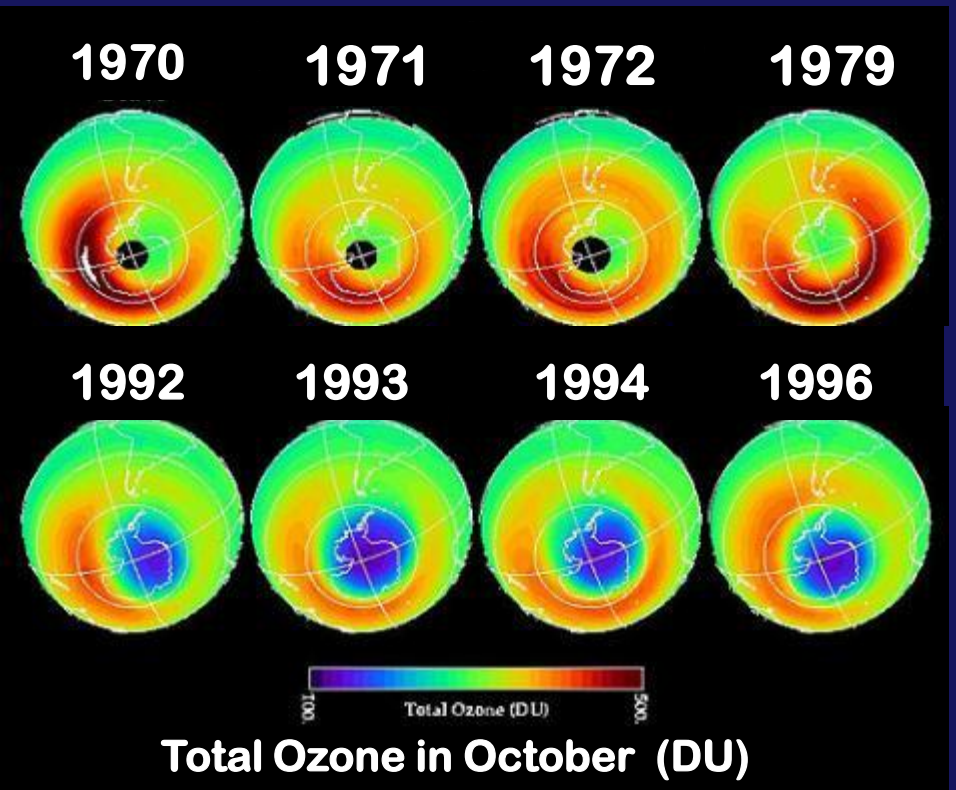
1957-1986

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.)

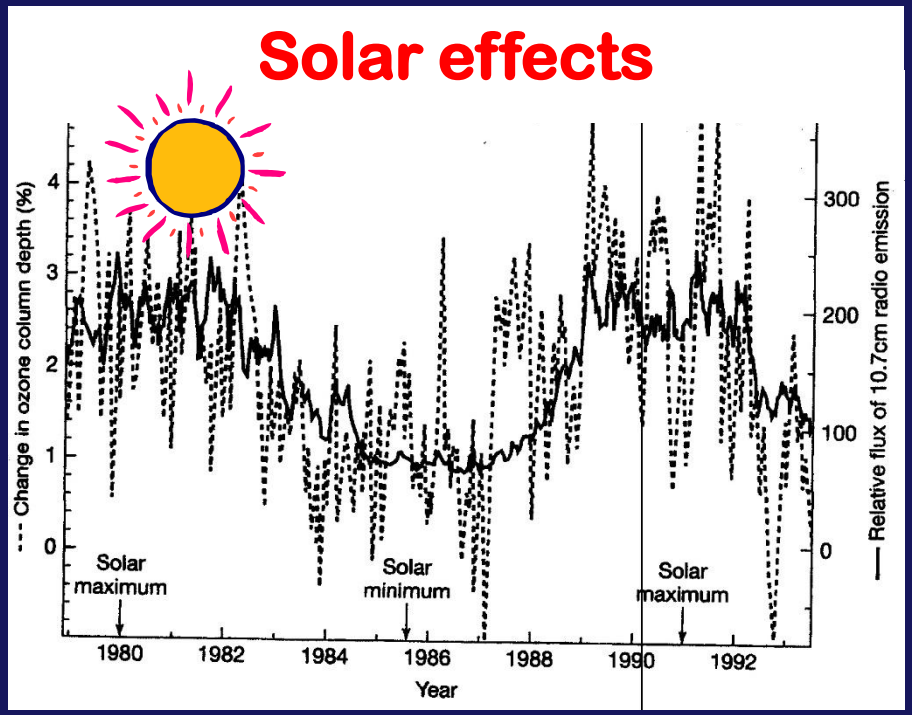
CHAPTER 3

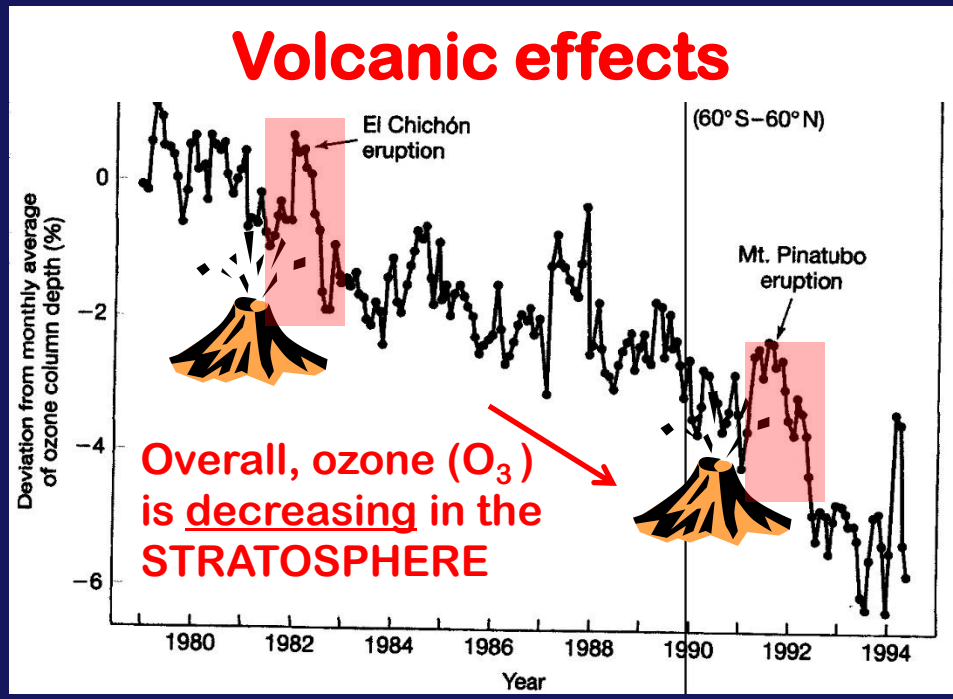
- In **1986** Dr. Susan Soloman's expedition to Antarctica ➔ identified chlorine increase

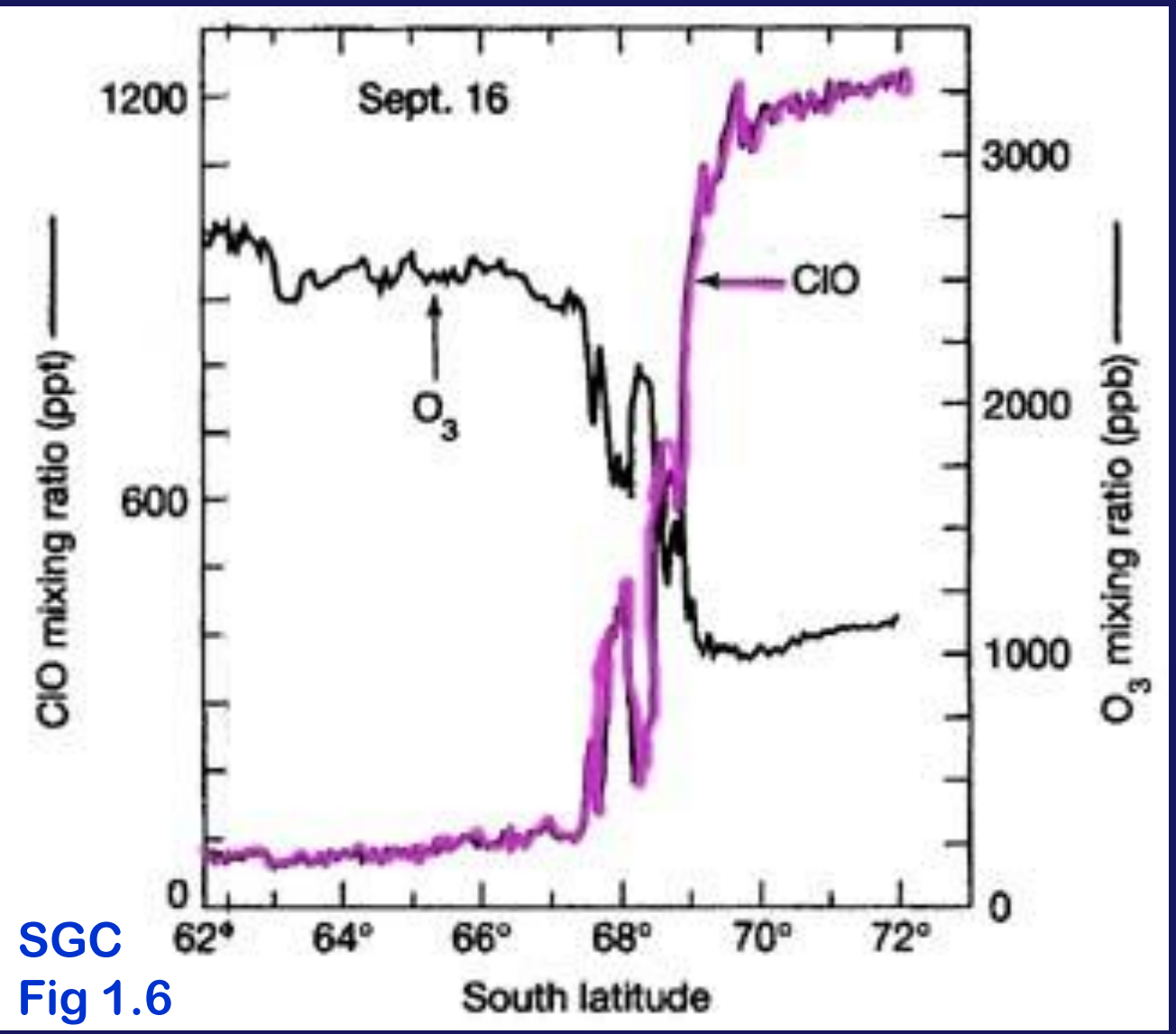
- She devised the theory that correctly explained the destruction of ozone by chlorine compounds

Other hypotheses & theories to explain the hole have included:

- **solar variability** (sunspot cycle ➔ Chapman variations)
- **dynamical air motion** (atmo circulation moves around O_3)
- **volcanic eruptions** (chemical reactions destroy O_3)







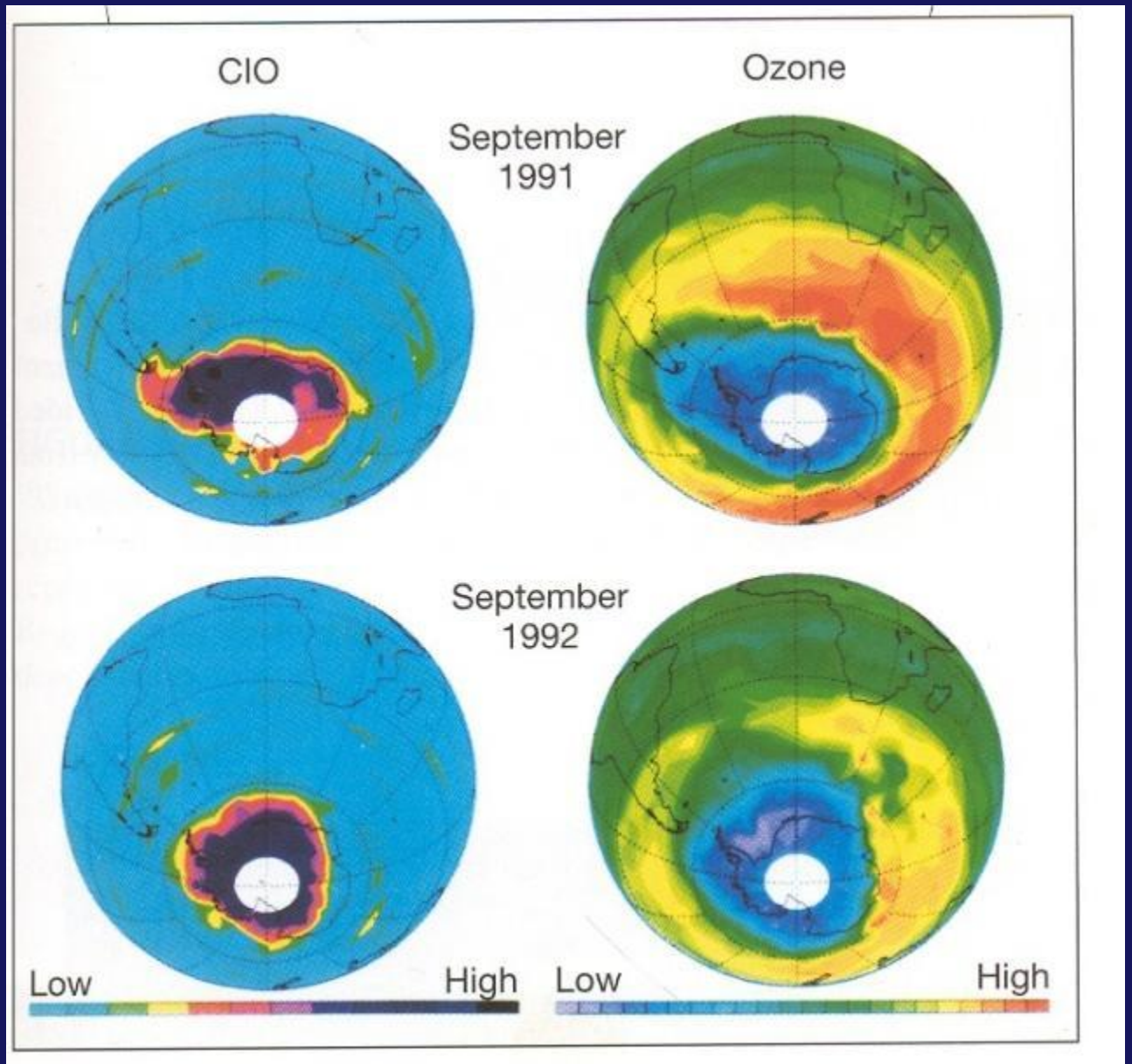
SGC
Fig 1.6

ClO (chlorine monoxide) from the chlorine catalytic cycle = THE evidence of chemical reactions occurring in hole region during time of greatest O_3 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 accepted as conclusive at present.

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

SO HOW DOES THE DESTRUCTIONHAPPEN

– and why over Antarctica??

WHY ANTARCTICA?

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

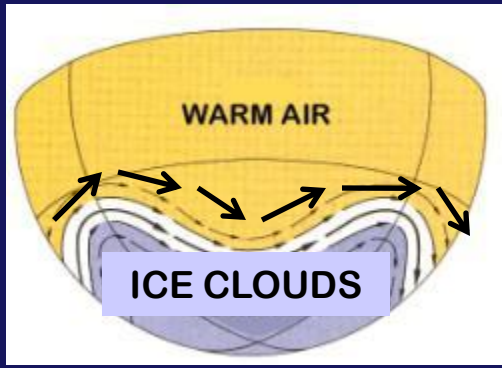
> it is most severe over Antarctica in S.H. spring (Sep, Oct);

> a less severe depletion (not a true hole) occurs over the Arctic in N.H. spring (Feb, Mar)

Box on p 85

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.

Box on p 85

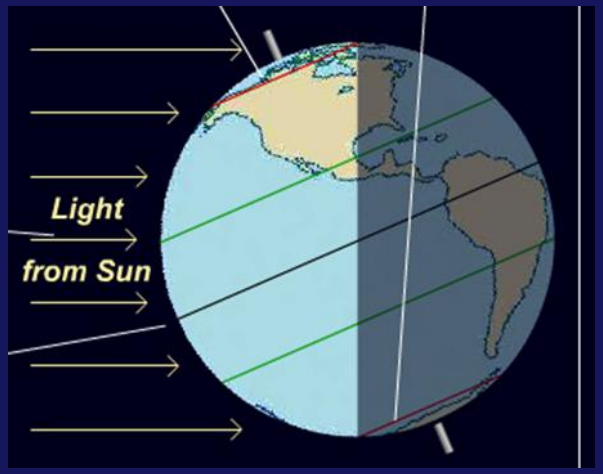
POLAR STRATOSPHERIC CLOUDS OVER ANTARCTICA

[Go to movie clip]

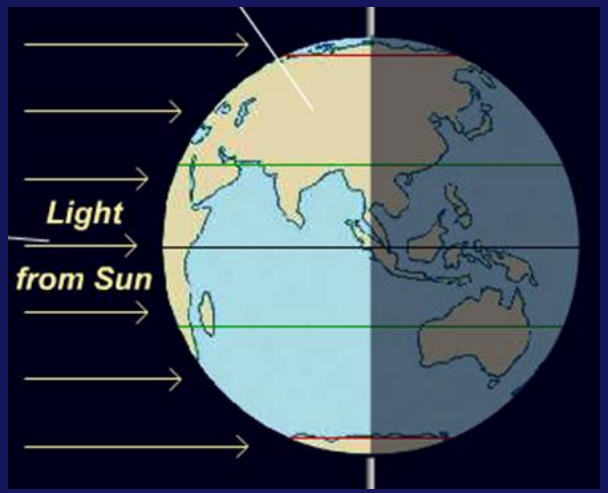
LAST INGREDIENT:

SUNLIGHT + UV PHOTONS

June



Sept

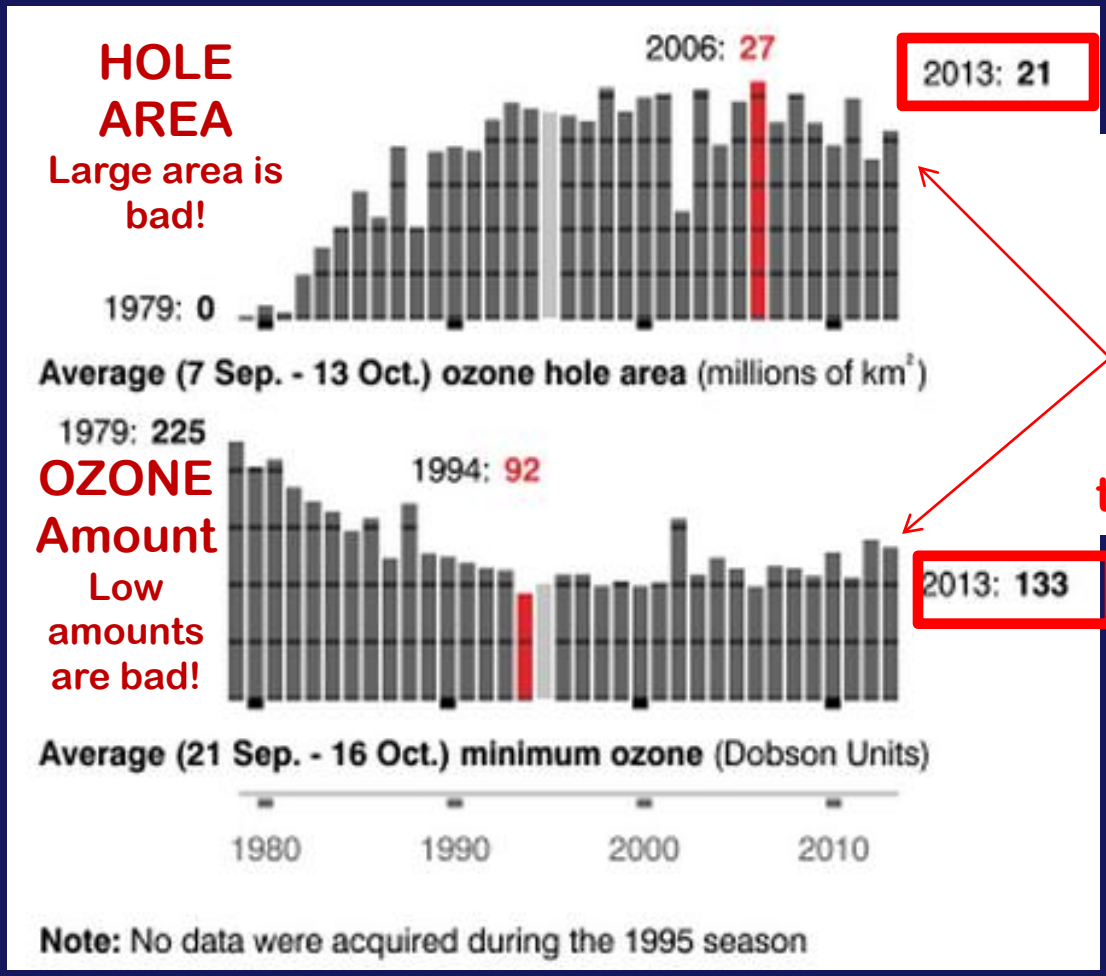


Only after well after the June Solstice and esp. the September Equinox, does the South Pole & Antarctic Circle receive sufficient sunlight!

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

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

Annual Ozone Hole Variations (since 1979)



This year: 2013

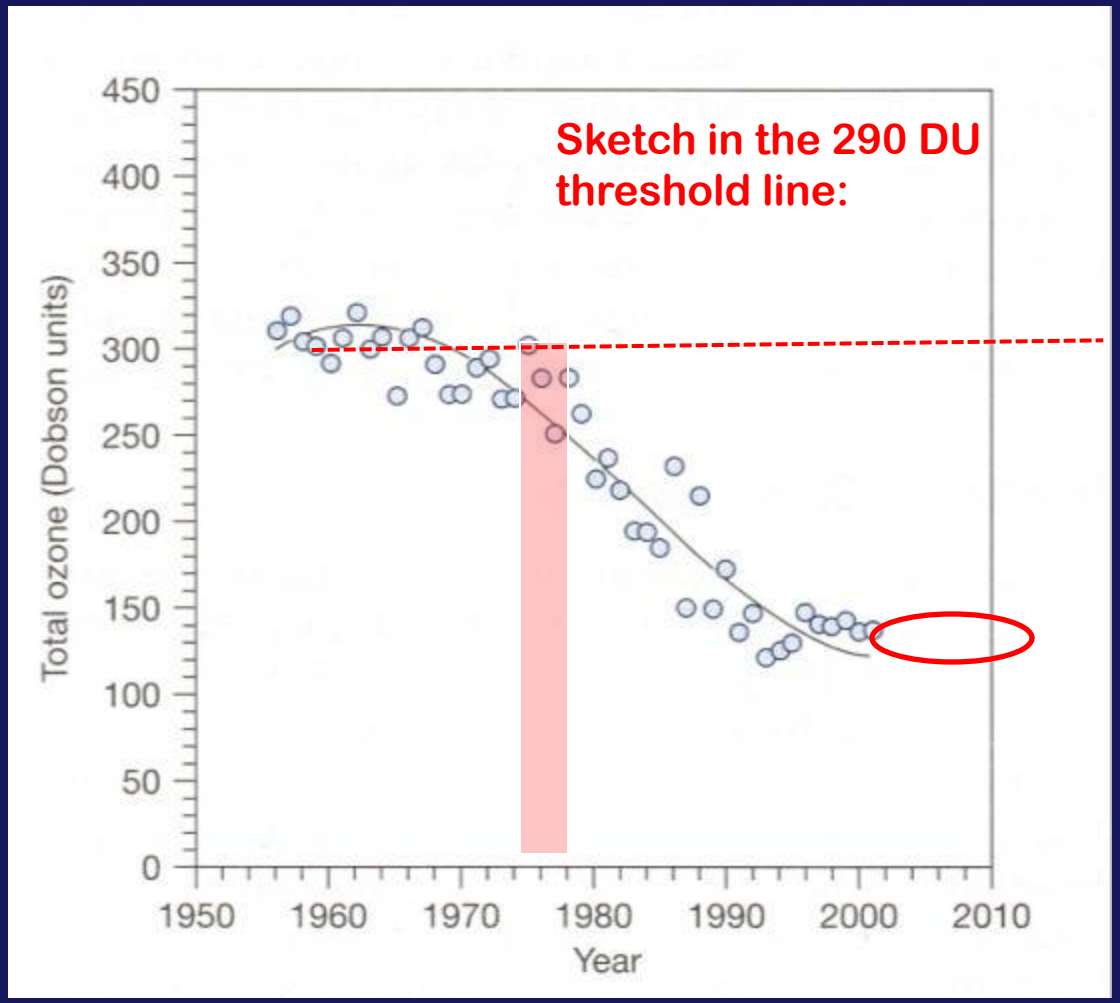
(a little worse than last year but better than a few years ago!)

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

Review of Ozone Concentration Time series

Hole generally defined as < 290 DU

2012 = 139 DU
2013 = 133 DU



~ 1969 to 1970

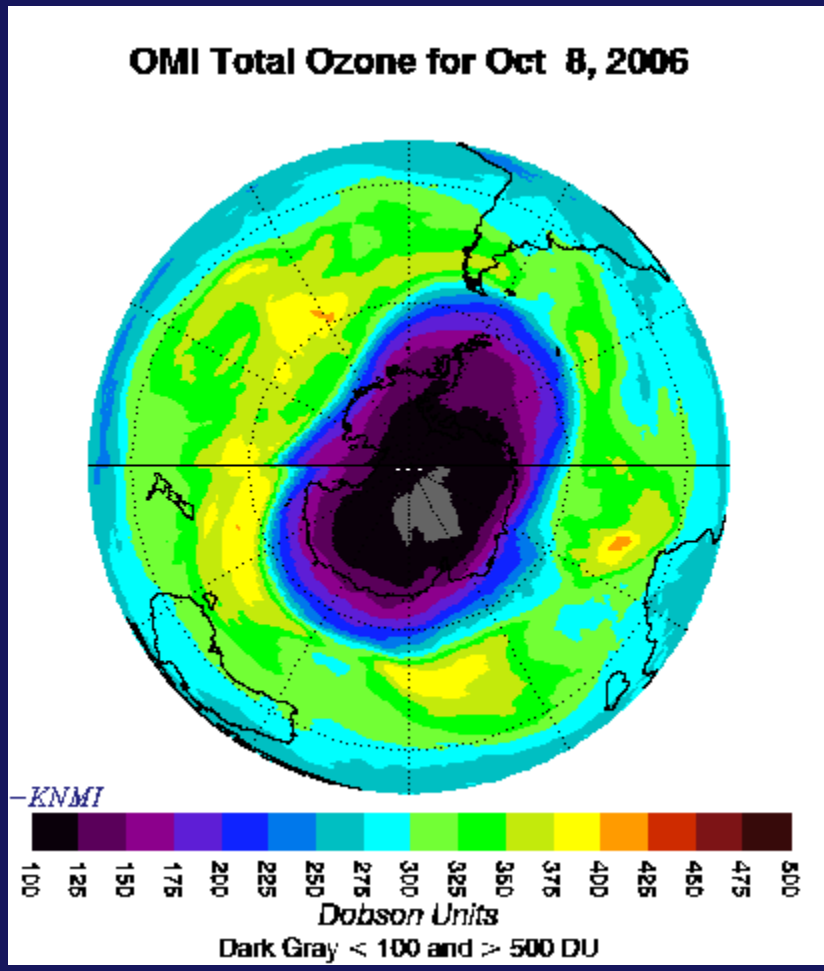
HOW DEEP DOES THE HOLE GET?

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!

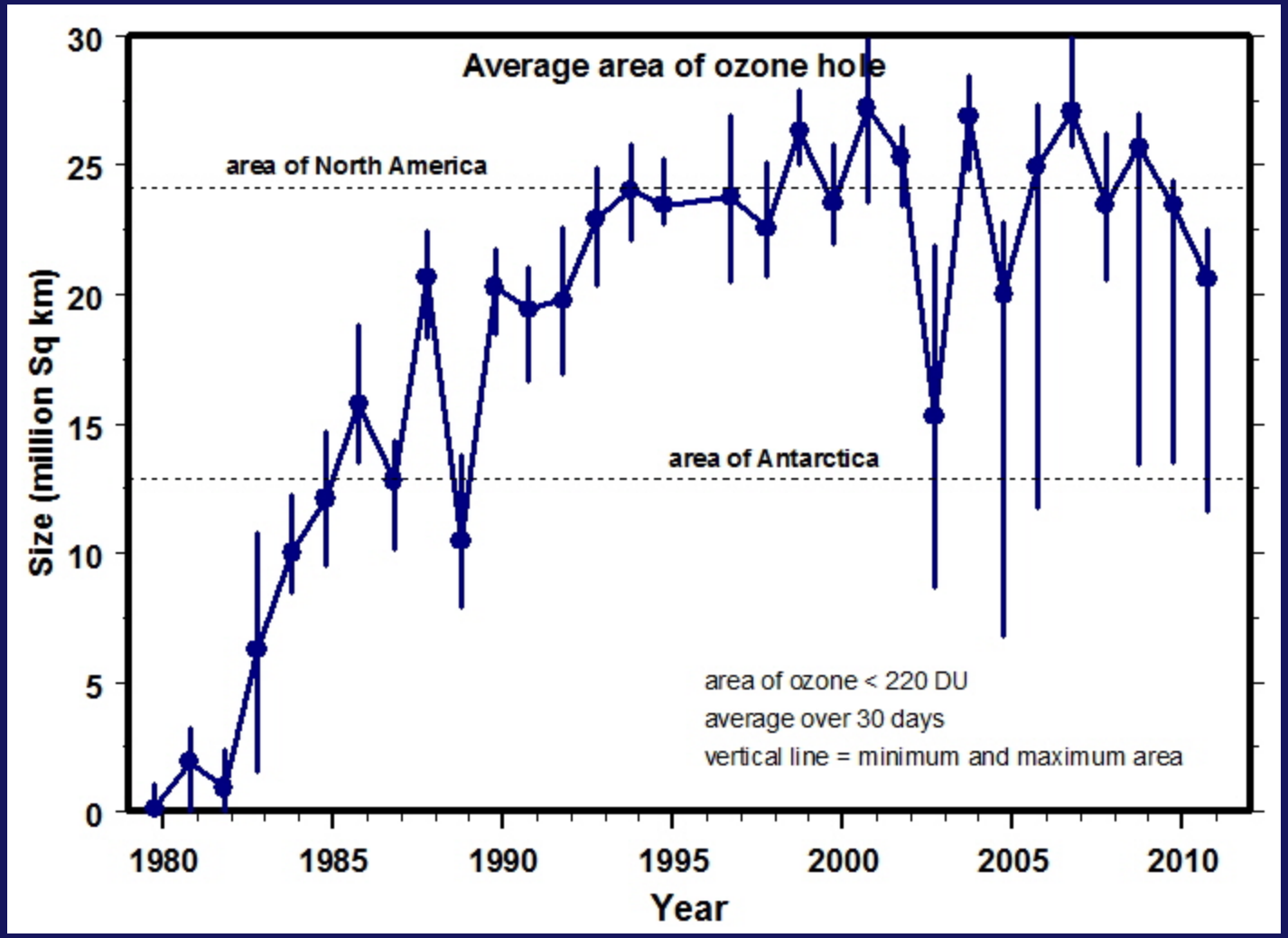
In this critical layer, the instrument measured a record low of only 1.2 DU!



2006 also saw the second LARGEST sustained ozone hole.

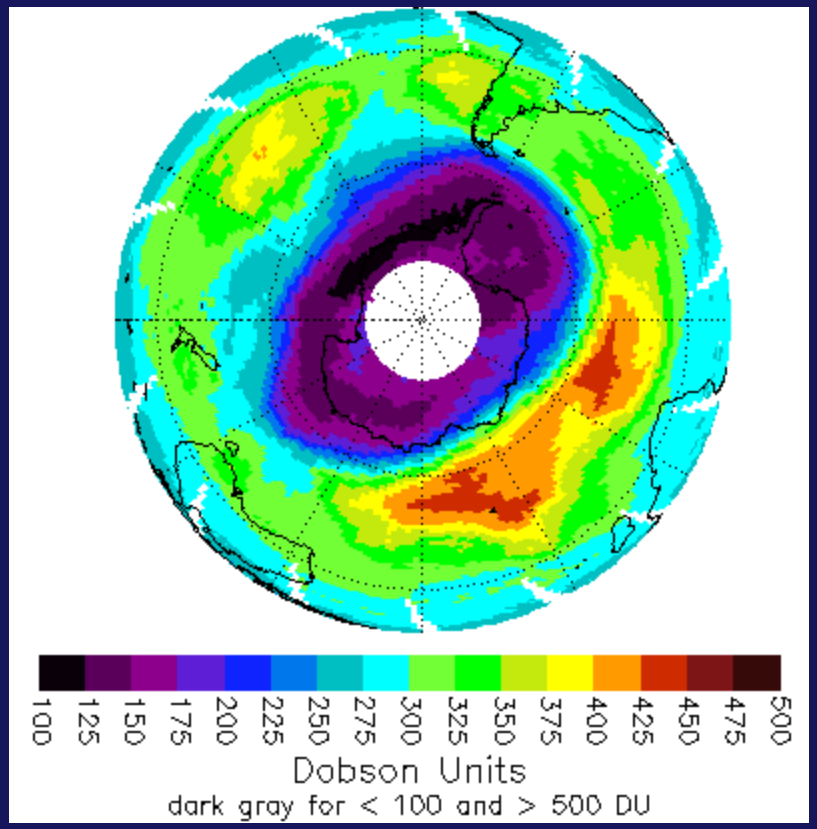
http://www.sciencedaily.com/releases/2006/10/061019162053.htm

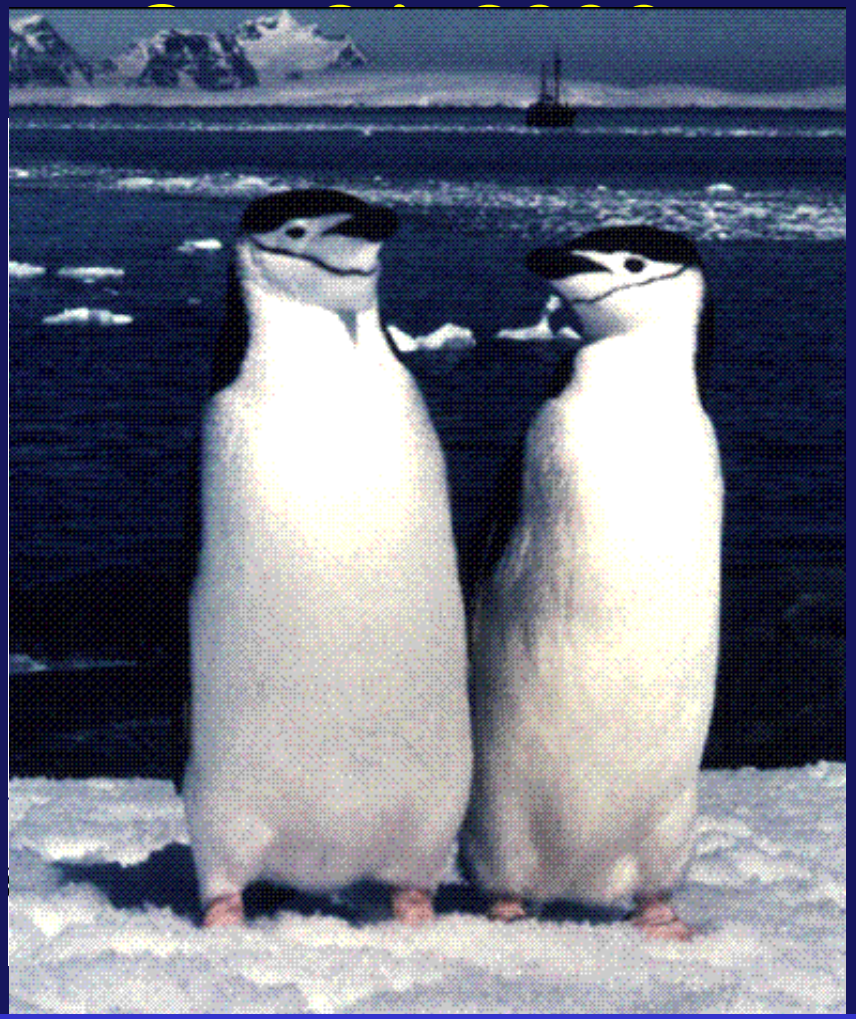
The AVERAGE SIZE OF THE HOLE has varied:



http://toms.gsfc.nasa.gov/eptoms/dataqual/oz_hole_avg_area_v8.jpg

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

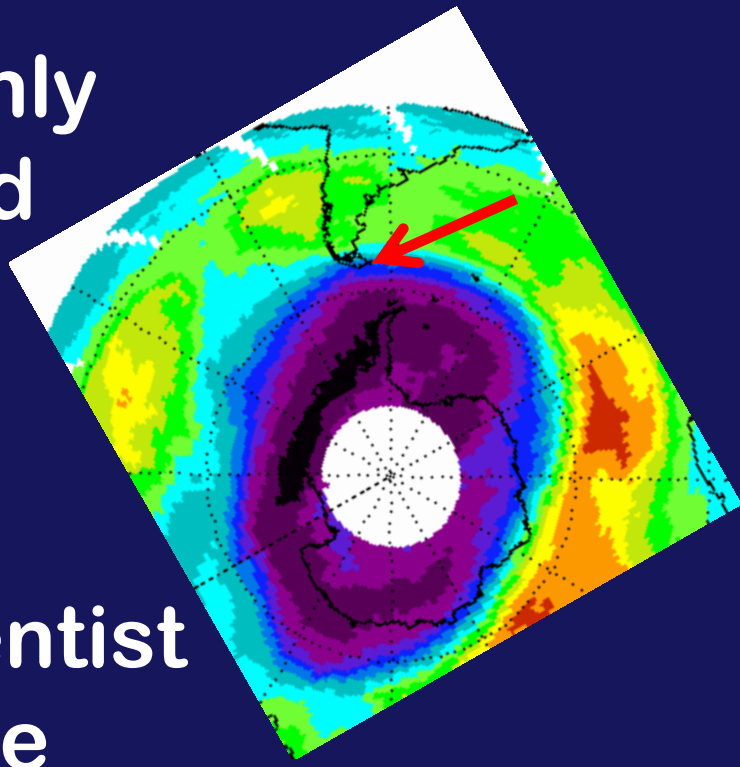
WELLINGTON, New Zealand –

"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."

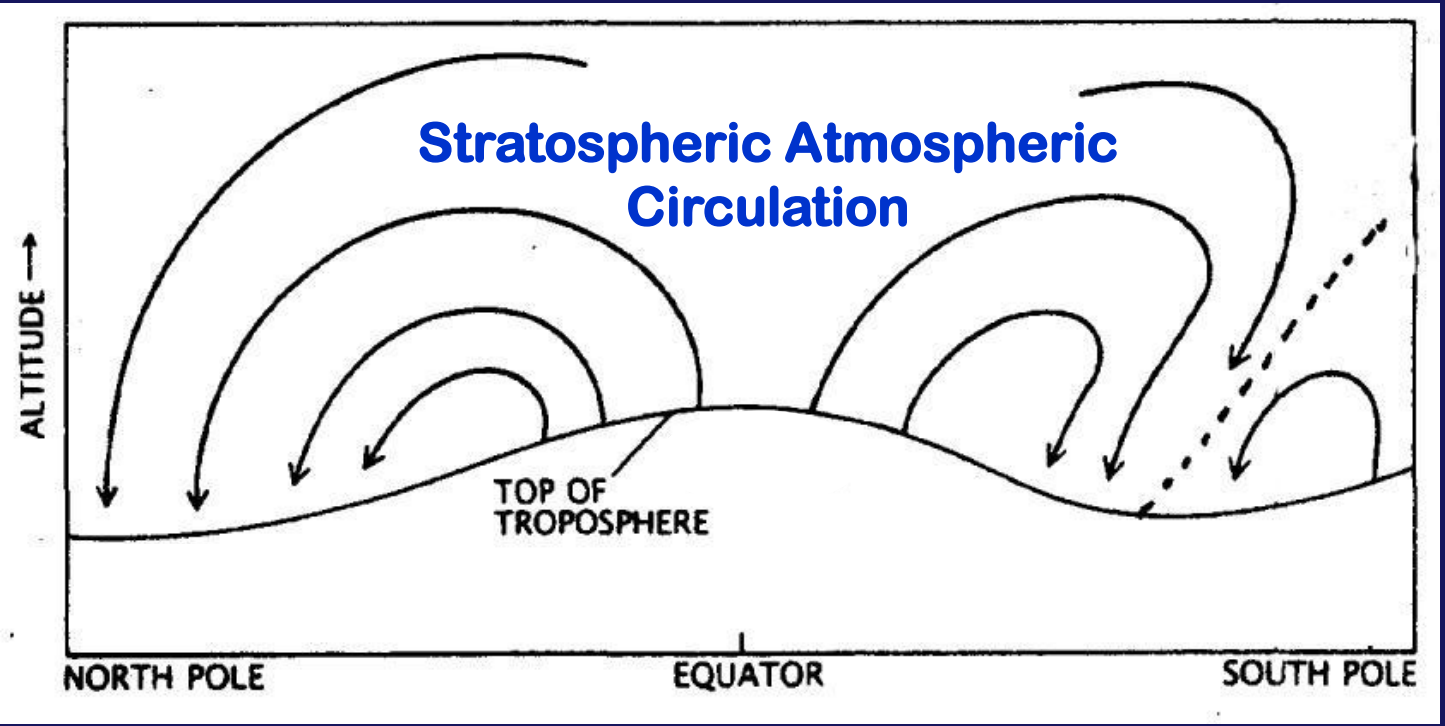
What about other parts of the globe?

> 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

Ozone production is highest in TROPICS - - WHY? (think Chapman mechanism)



. . . but stratospheric circulation distributes it poleward

Arctic ozone depletion also takes place!

There are concerns that an "Arctic Ozone Hole" may develop that is similar to the severe Antarctic Hole

"An Arctic Ozone Hole, if similar in size to the Antarctic Ozone Hole, could expose over 700+ million people, wildlife and plants to dangerous UV ray levels.

The likely hood of this happening seems inevitable based on the deterioration of ozone layer caused by the effects of global warming on the upper atmosphere."

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

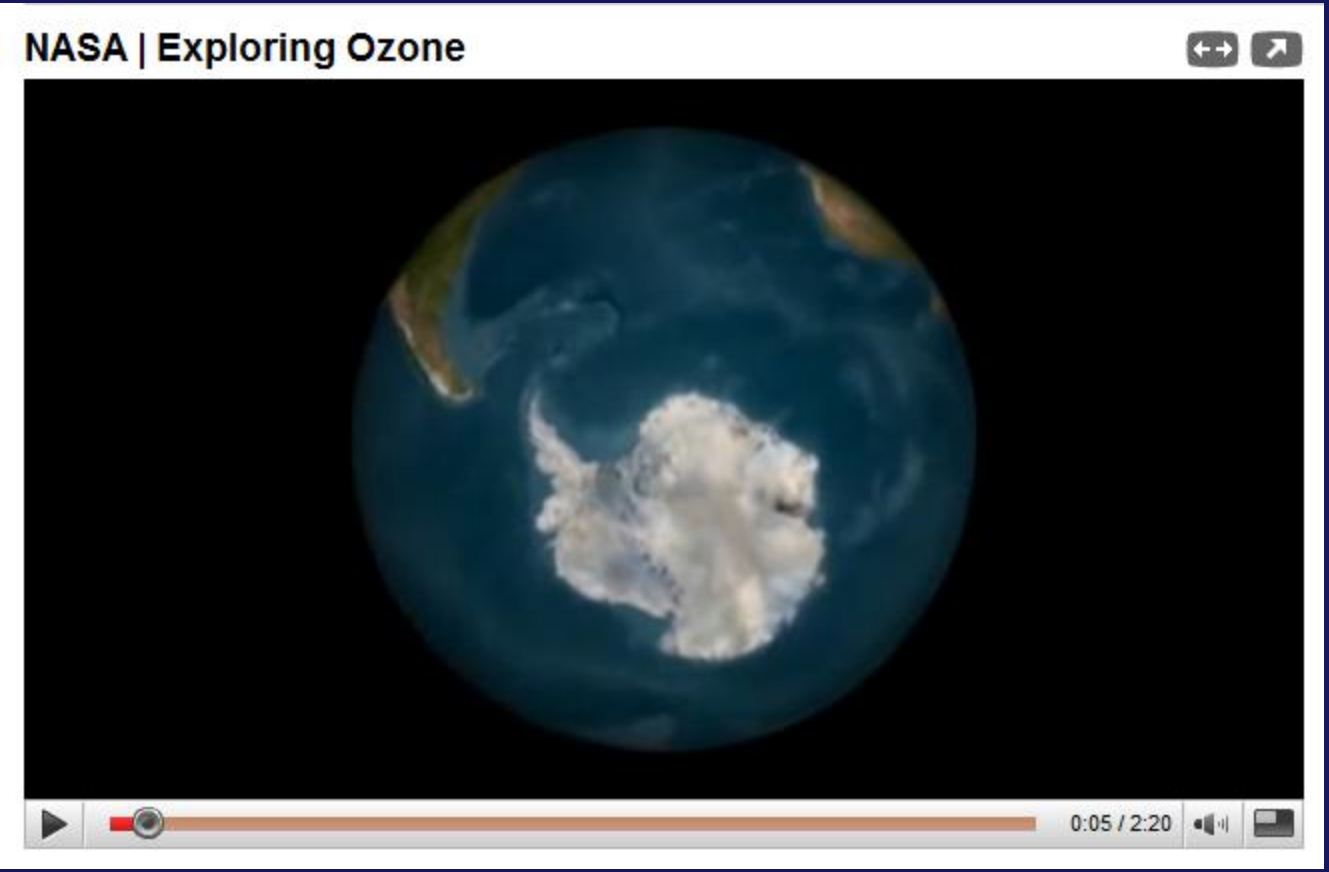
Why can't we just ship the "bad ozone" in the troposphere up to the stratosphere to 'fill the hole'?

> Ozone is *increasing* in the troposphere due to car exhaust, etc ("bad ozone"), but only at the rate of about 1% per year,

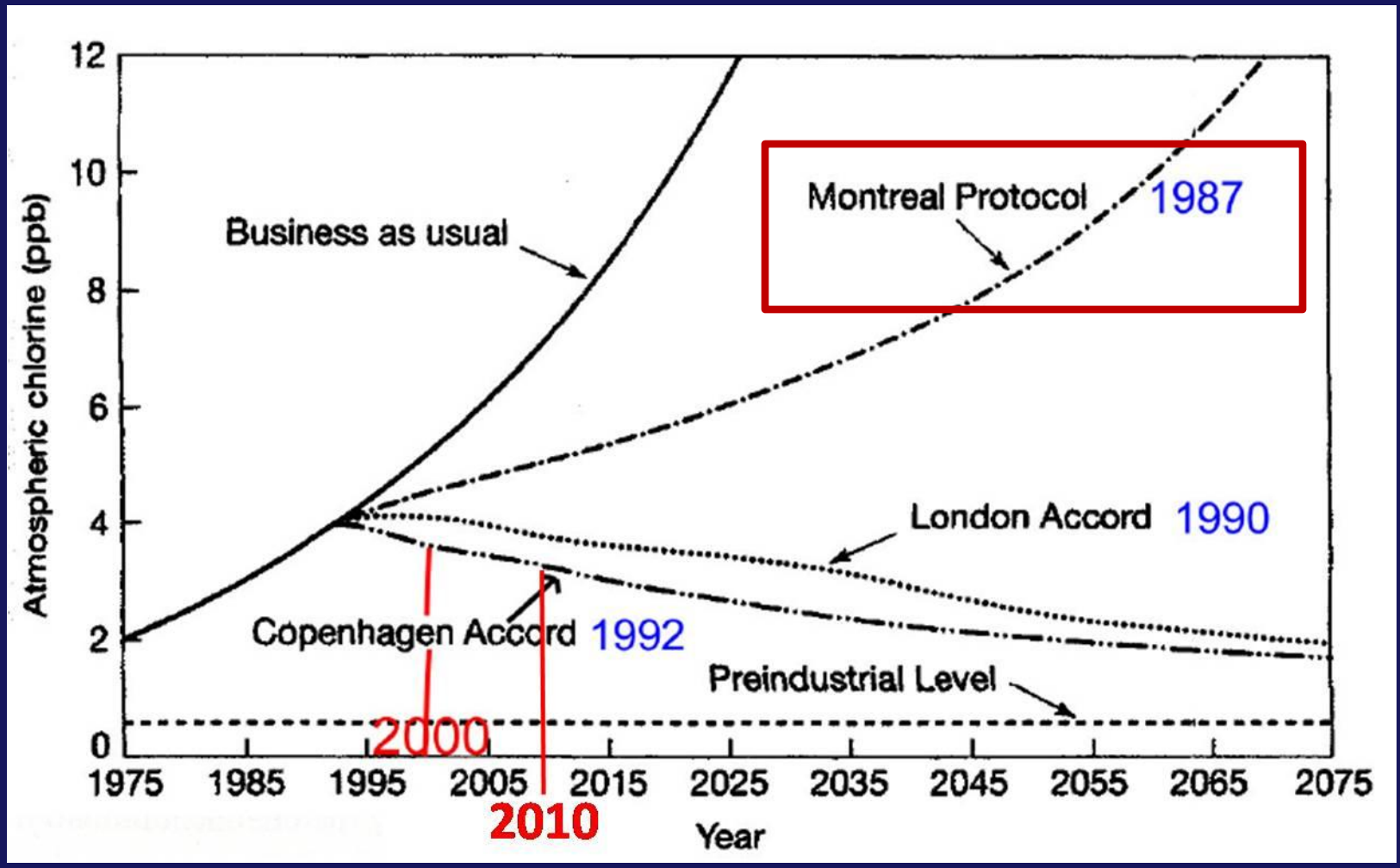
> hence stratospheric levels of "good ozone" are going down at a rate faster than ozone is being added in the troposphere.

Box on p 85

Recap:



http://www.youtube.com/watch?v=qUfVMogIdr8&feature=player_embedded



Very long residence time of CFCs!

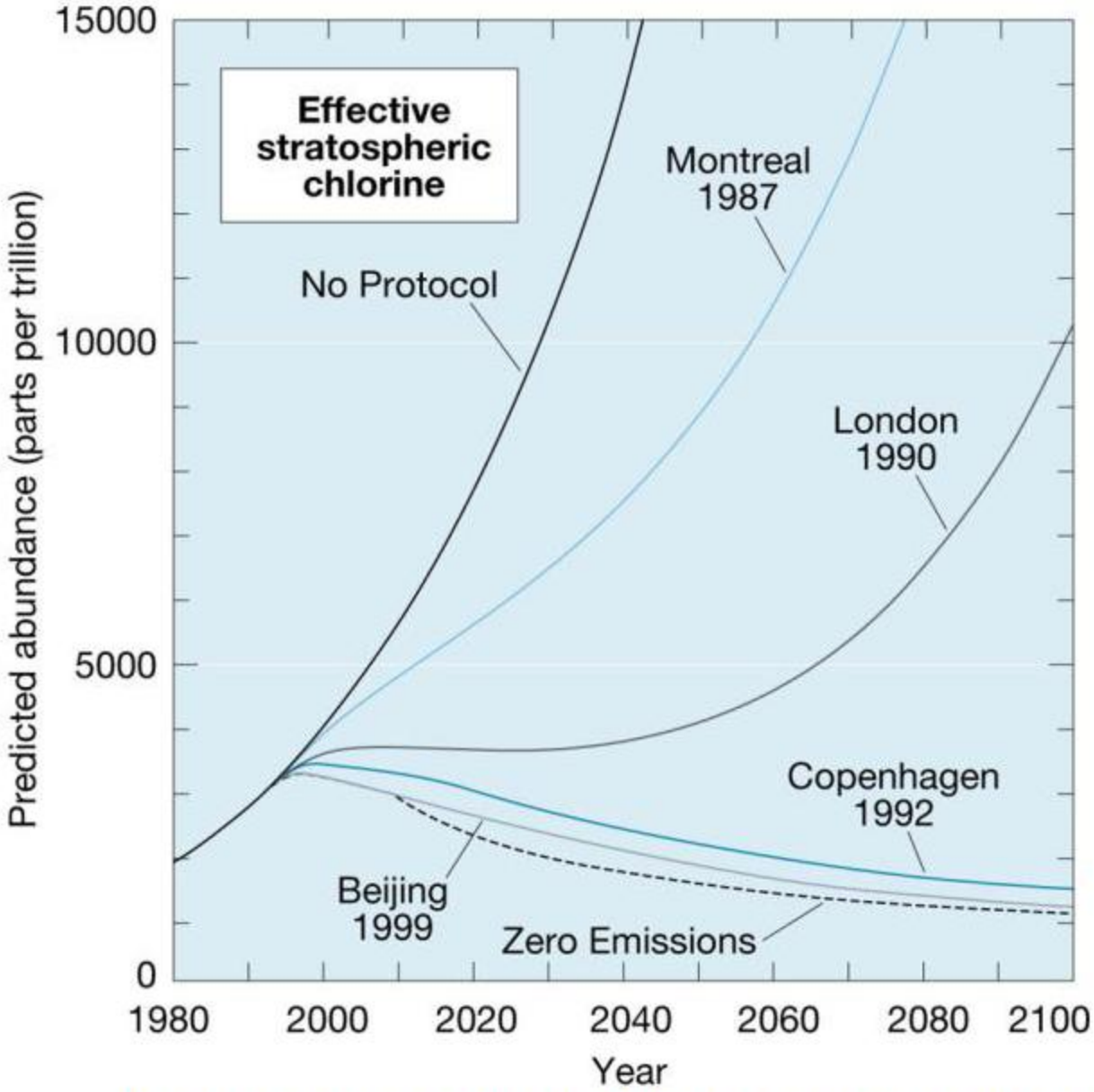
International Day for the Preservation of the Ozone Layer

SEPTEMBER 16th

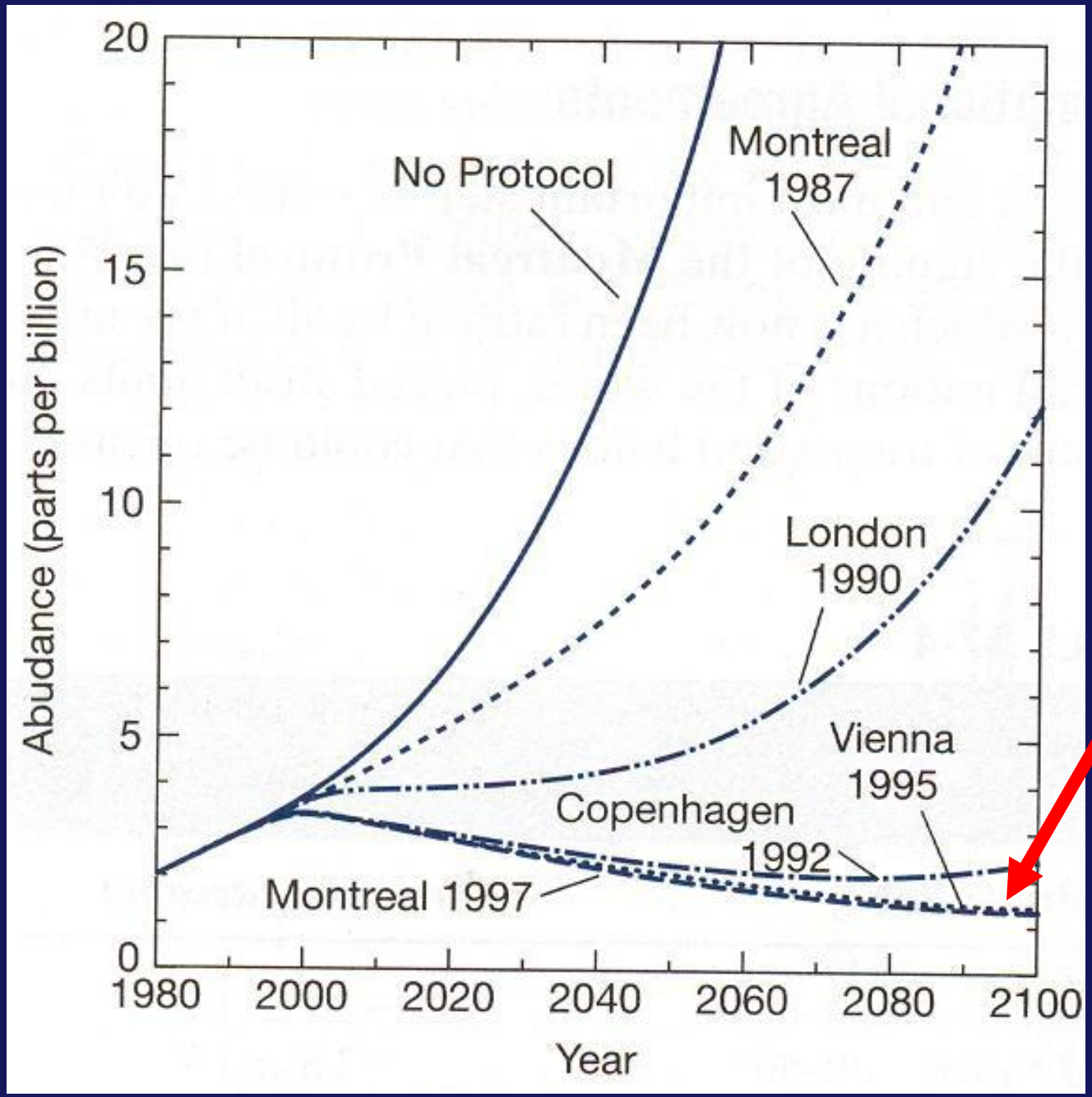
The United Nations' (UN) International Day for the Preservation of the Ozone Layer is celebrated on September 16 every year. This event commemorates the date of the signing of the Montreal Protocol on Substances that Deplete the Ozone Layer in 1987.

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

http://www.timeanddate.com/holidays/un/international-ozone-layer-preservation-day



Projected atmospheric chlorine concentrations under the various international agreements



Newer model results based on more recent agreements:

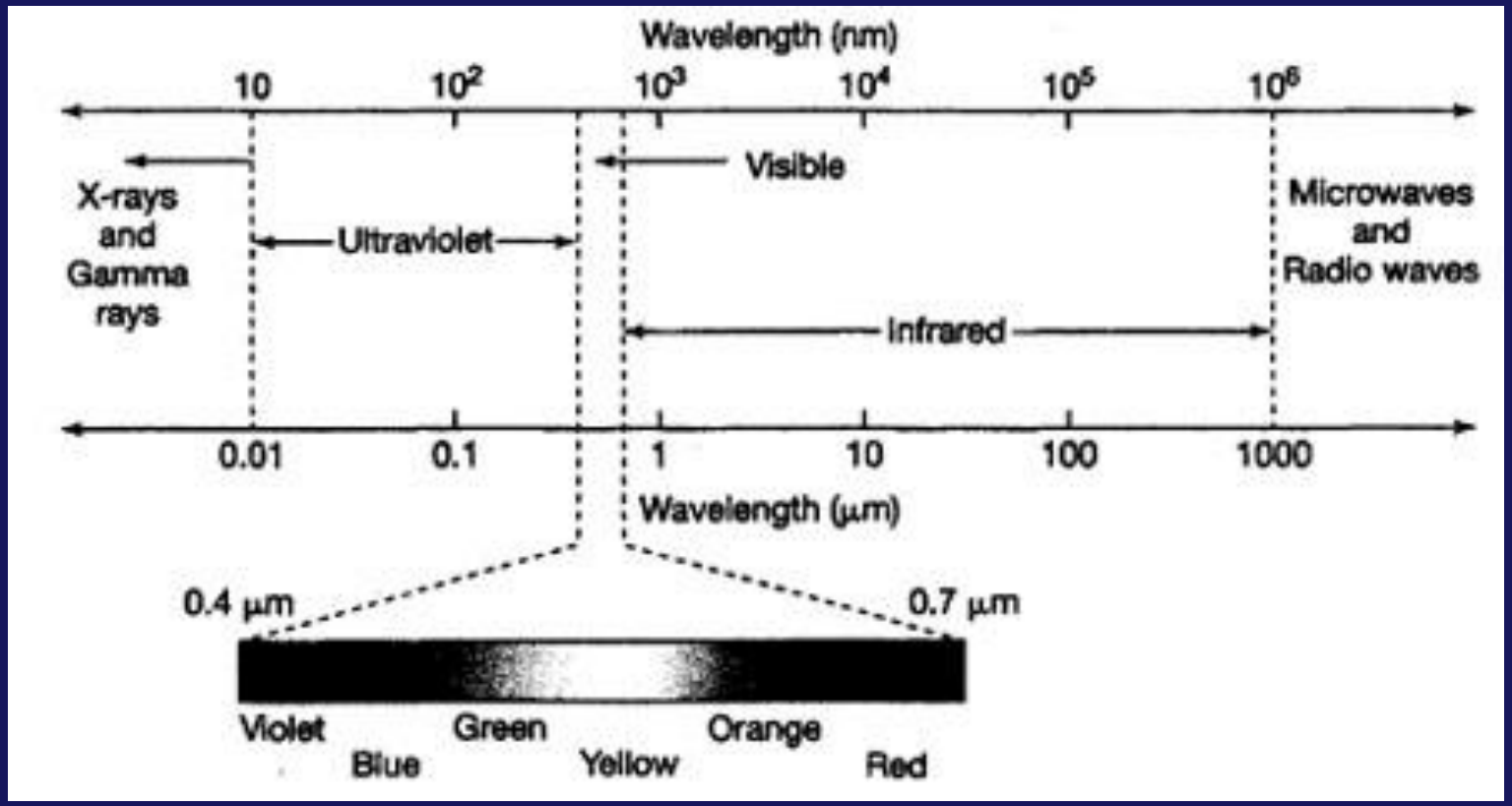
Vienna 1995
&
Montreal 1997

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

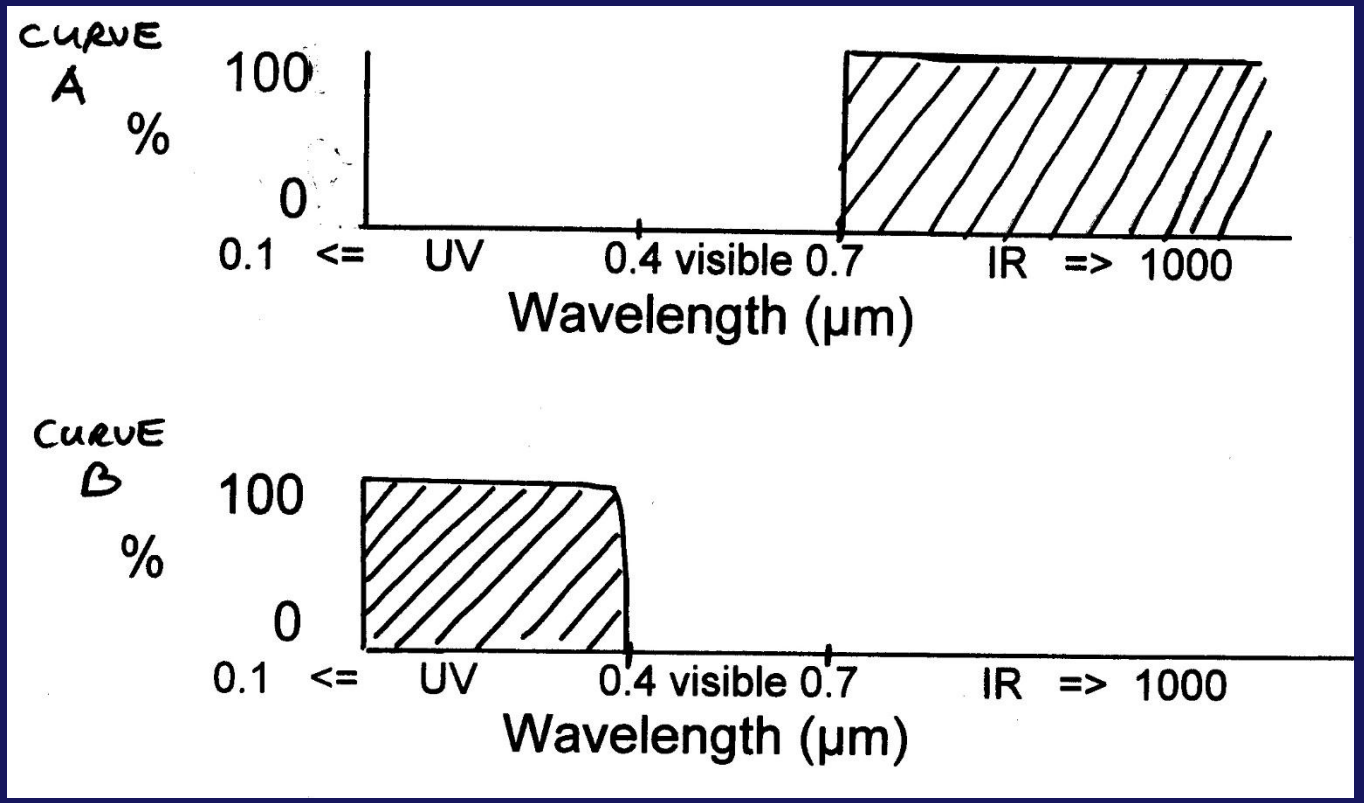
THE OZONE DEPLETION STORY TIES TOGETHER MANY OF THE CONCEPTS YOU'VE LEARNED IN THE COURSE THUS FAR:

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

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

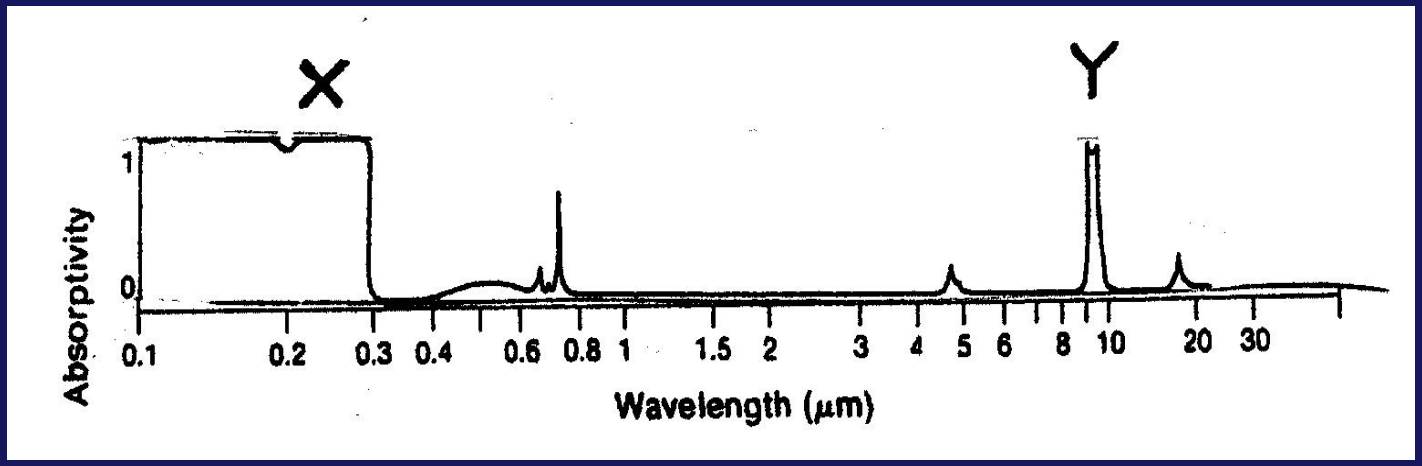


> absorption curves, especially the absorption curve for ozone

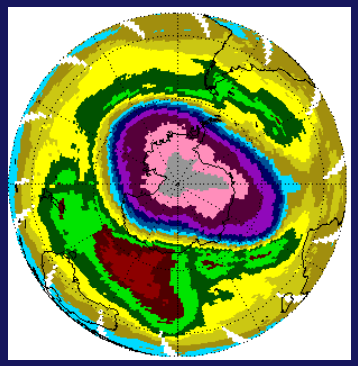


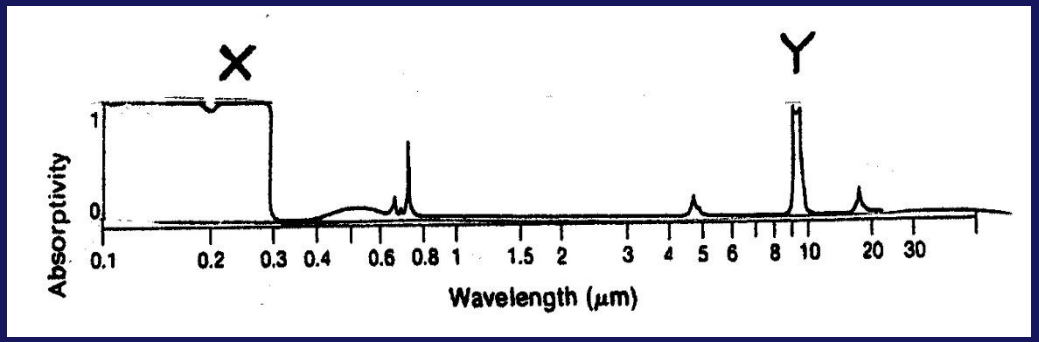
> Effect of clouds -- in this case the importance of Polar Stratospheric Clouds (PSCs)

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



OZONE'S DUAL PERSONALITY!

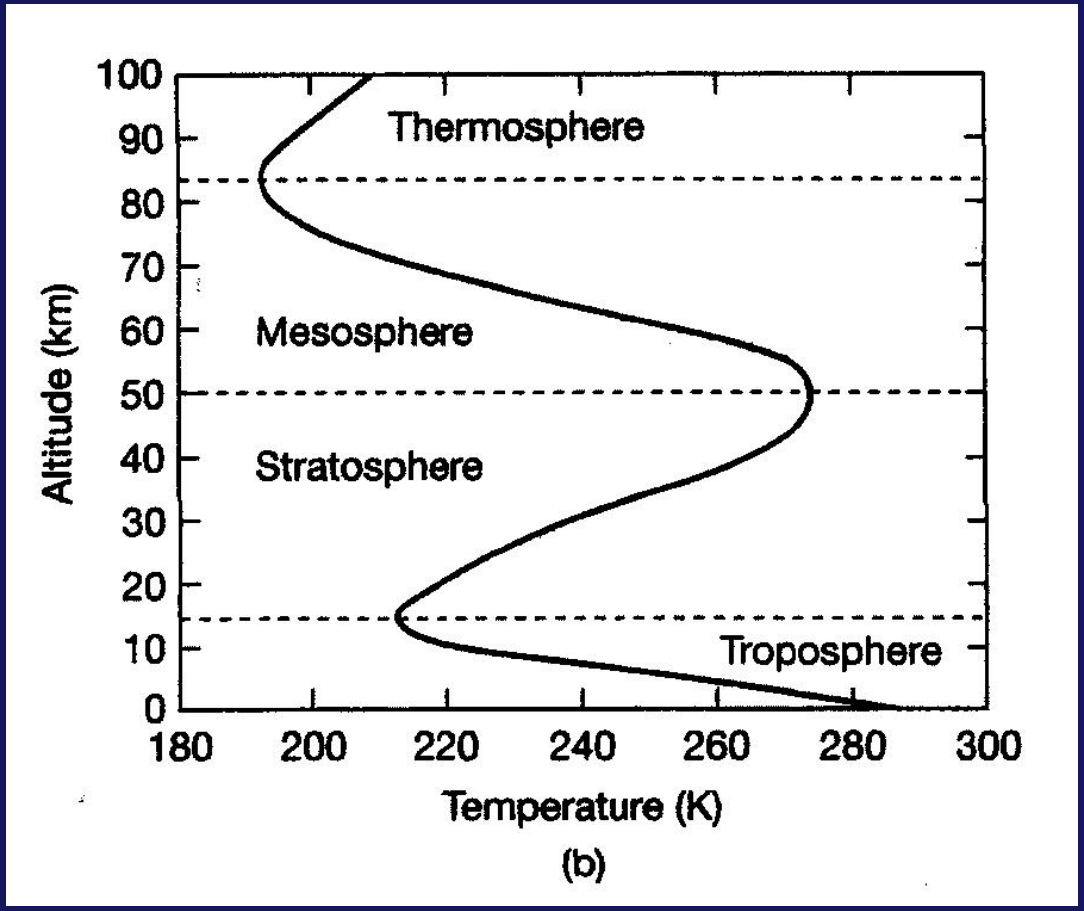




Important as an absorber of harmful UV in the **STRATOSPHERE**

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

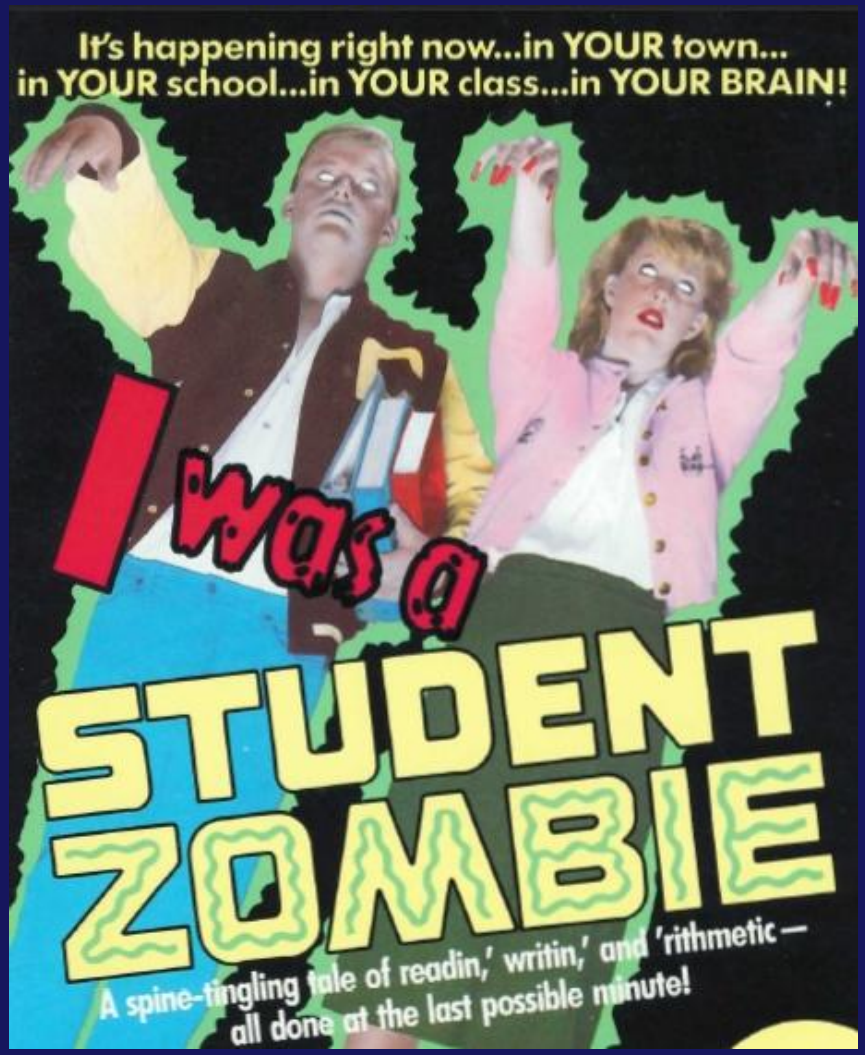
> the vertical structure of the atmosphere (troposphere, stratosphere)



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

> Preconceived ideas influencing one's observations

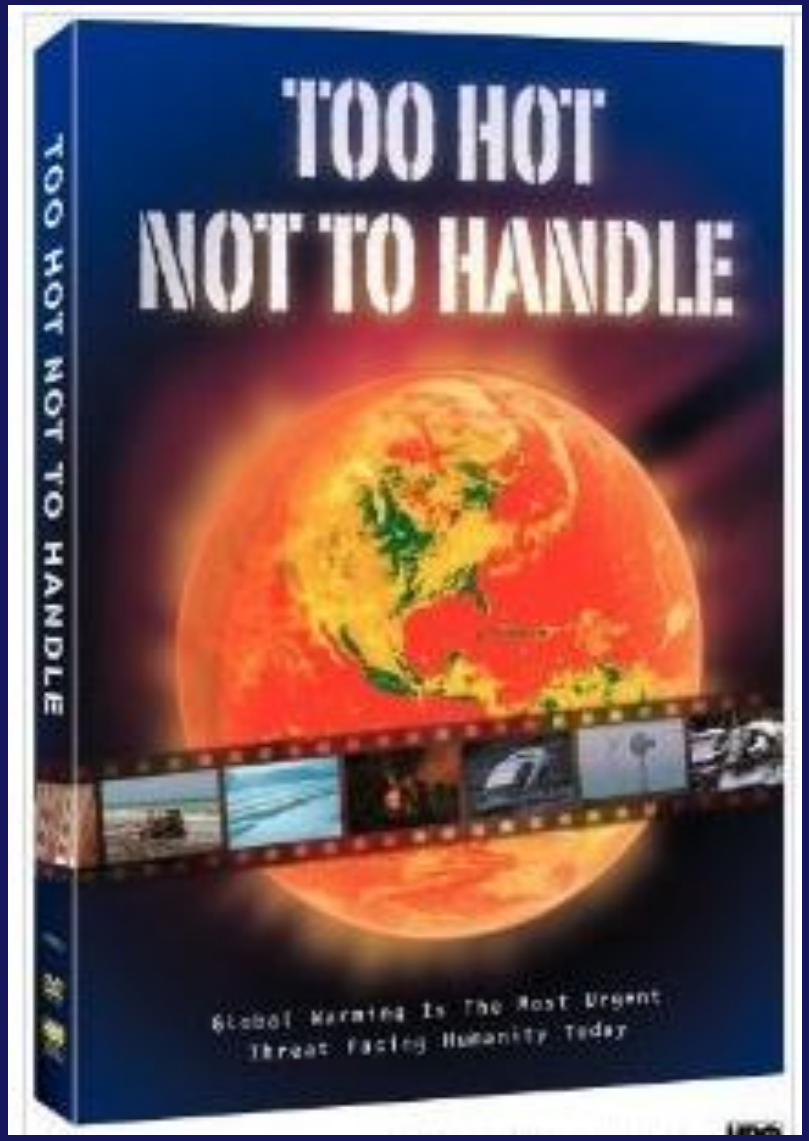
. . . and the surprise of discovery!



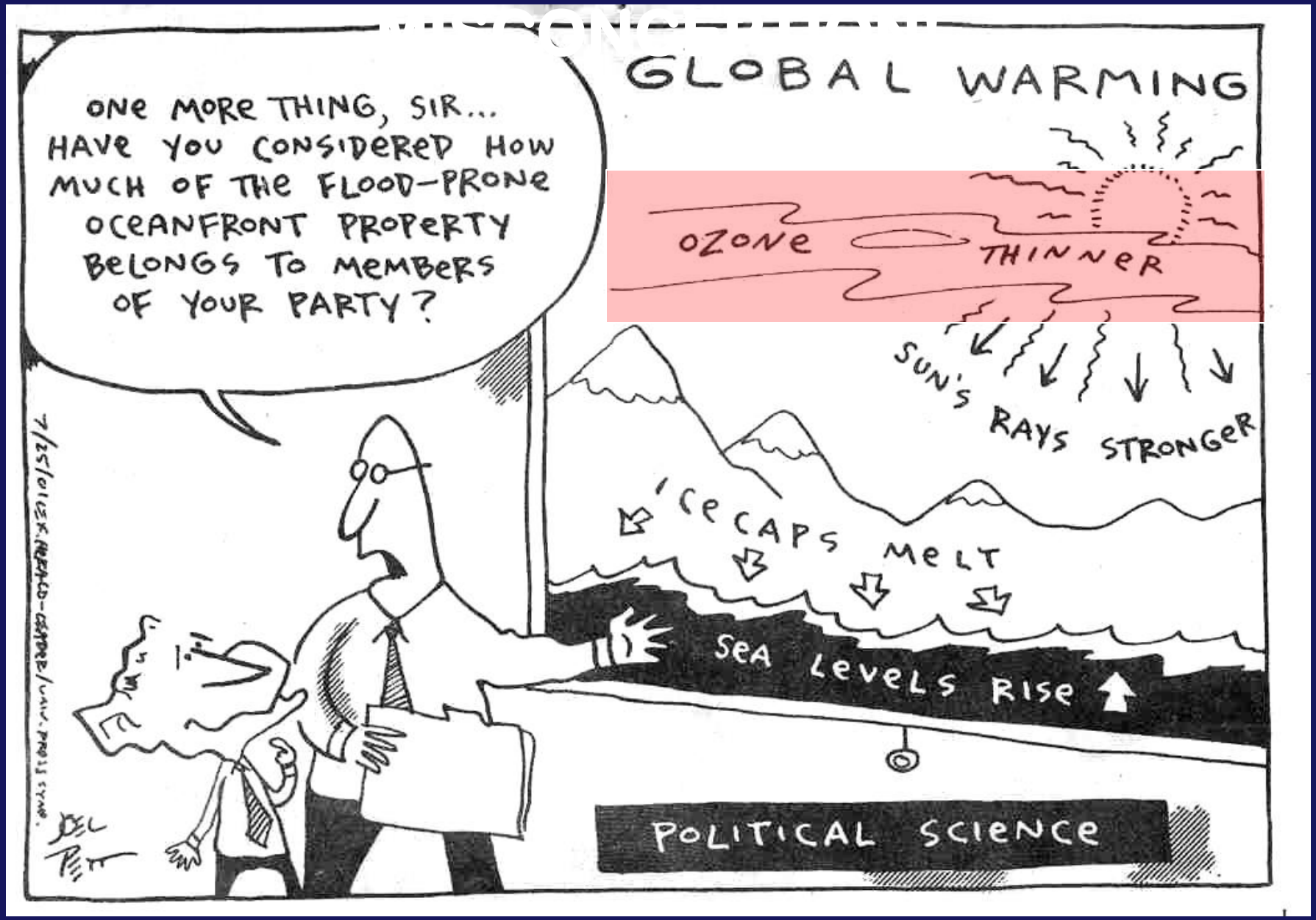
ZOMBIE BREAK !

The FINAL SEGMENT –

And 2 questions afterward . . .



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

Have a Good Weekend & get your LTL Part C done!

Don't forget I-3 either – due Sunday night!

GO CATS!