

# Topic # 13 (cont.)

## **OZONE DEPLETION IN THE STRATOSPHERE – Part III**

A Story of Anthropogenic  
Disruption of a Natural  
Steady State

p 77-79 in Class Notes

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

**“A Misadventure of Science?”**

# DISCOVERY OF THE OZONE HOLE:

## CHAPTER 1

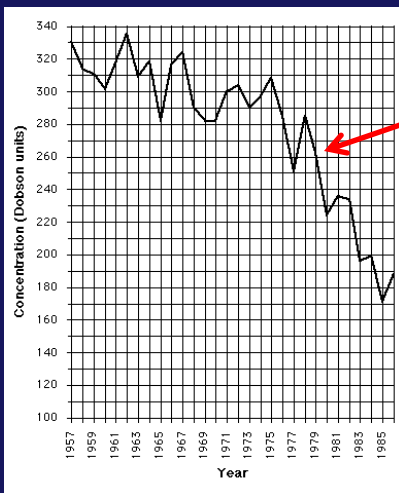


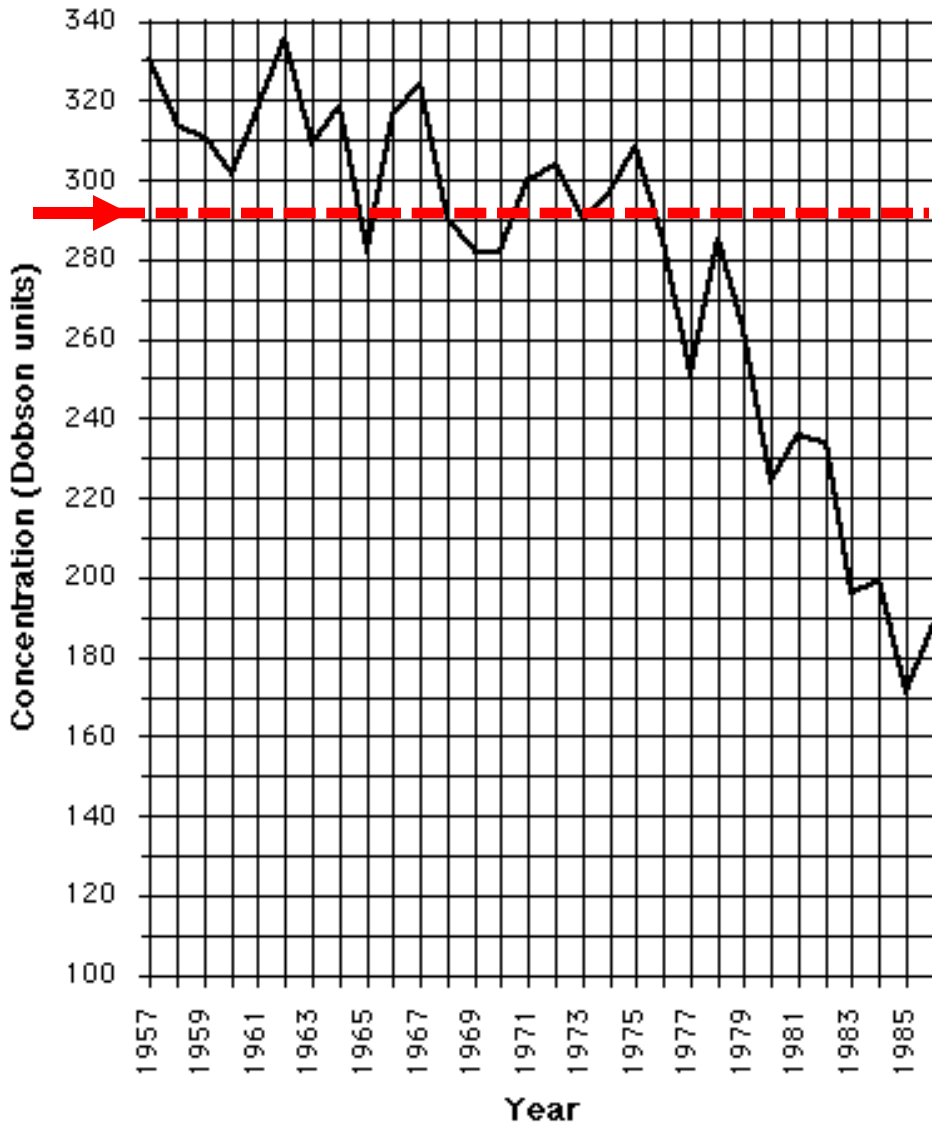
- Ground-based ozone measurements since **1956**. (British survey team)

- 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**

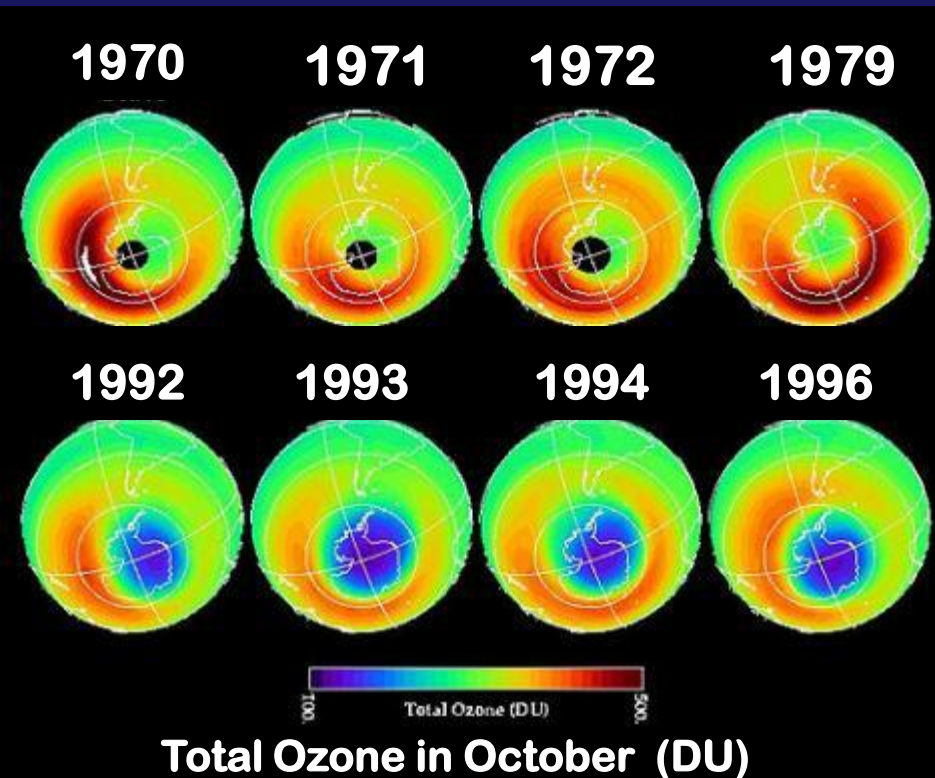
Early data from ground measurements of British survey team



# DISCOVERY OF THE OZONE HOLE :

## CHAPTER 2

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



- 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:

## 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**

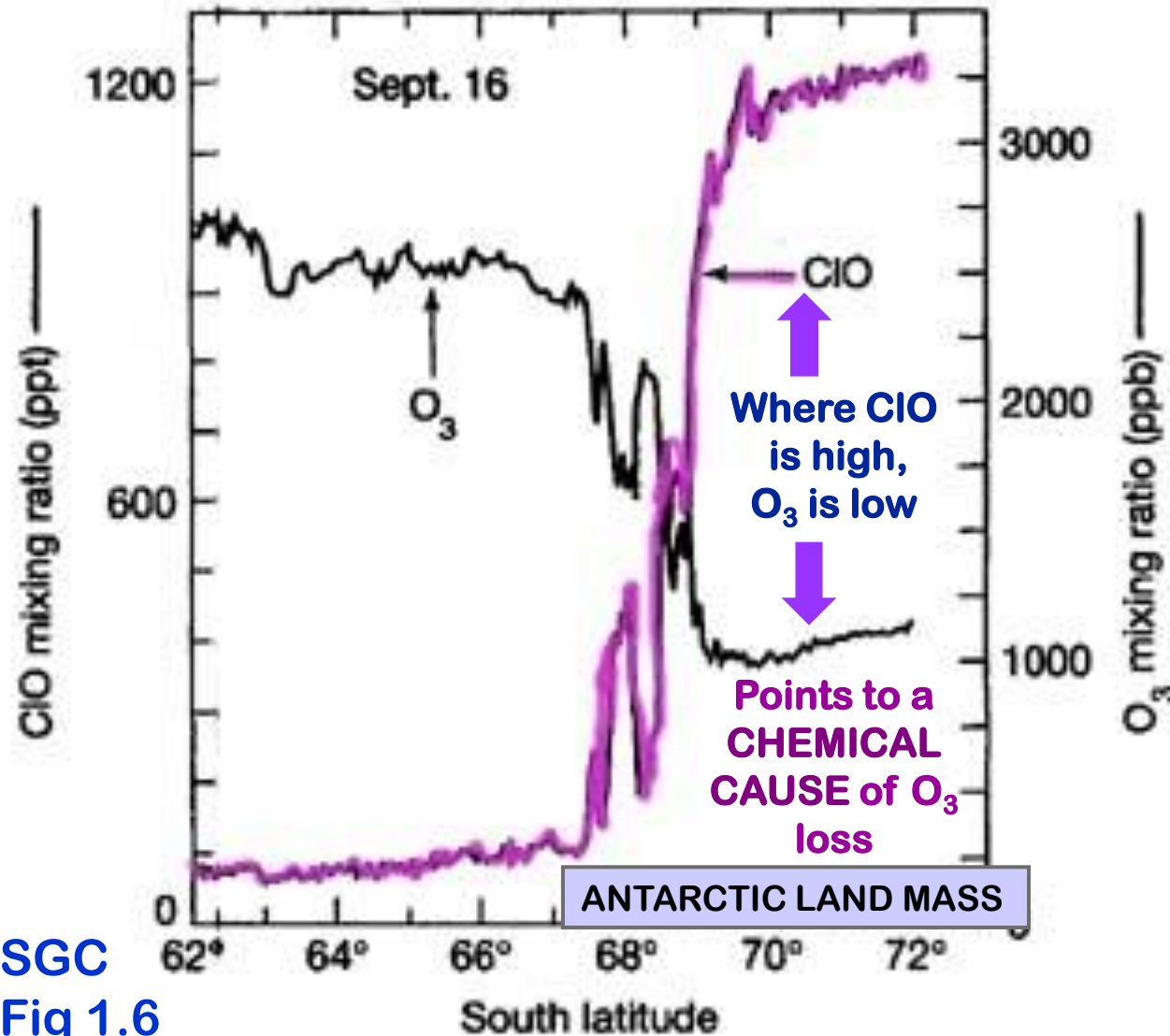


# CONCLUSION:

**ClO** (chlorine monoxide) in hole region was

**THE Evidence !**

... showed that **chemical reactions** occurred in hole during time of greatest  $O_3$  depletion



SGC  
Fig 1.6

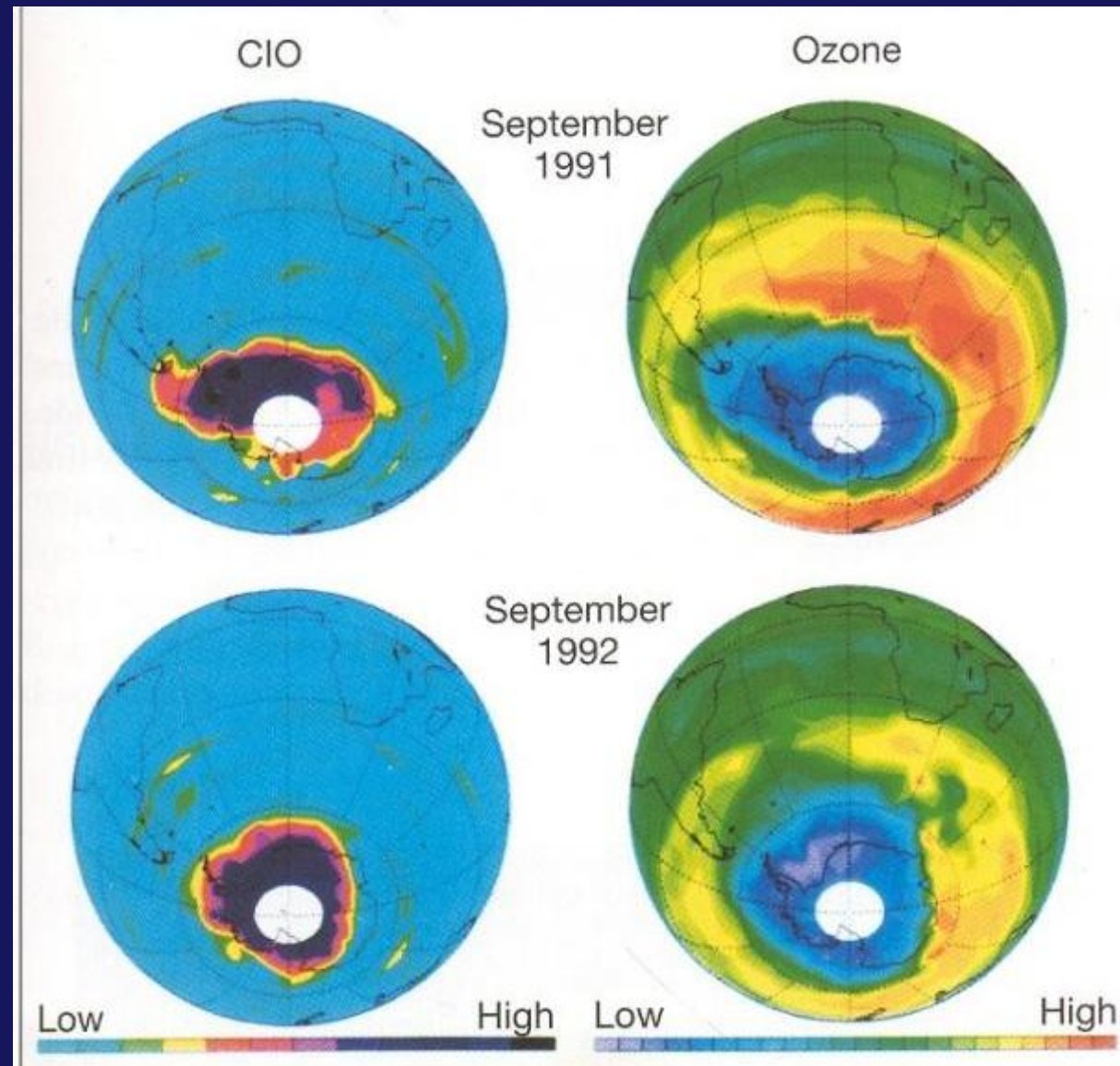
→ To the South Pole



# The EVIDENCE that SOLVED THE MYSTERY !

Simultaneous  
measurements  
of ozone (O<sub>3</sub>)  
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.**

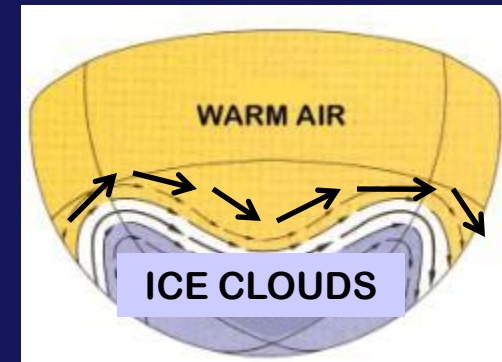
# WHY ANTARCTICA?

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**

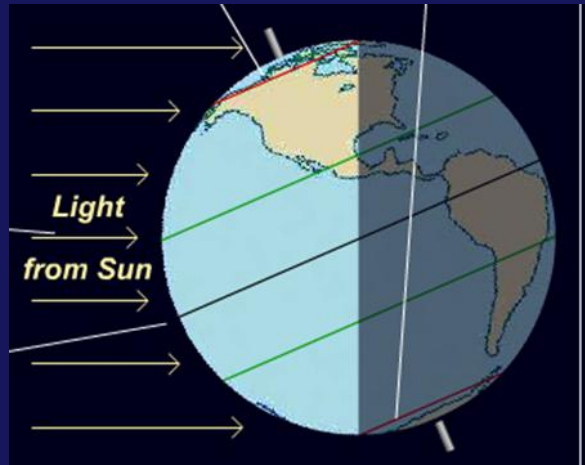
[\[Go to movie clip\]](#)



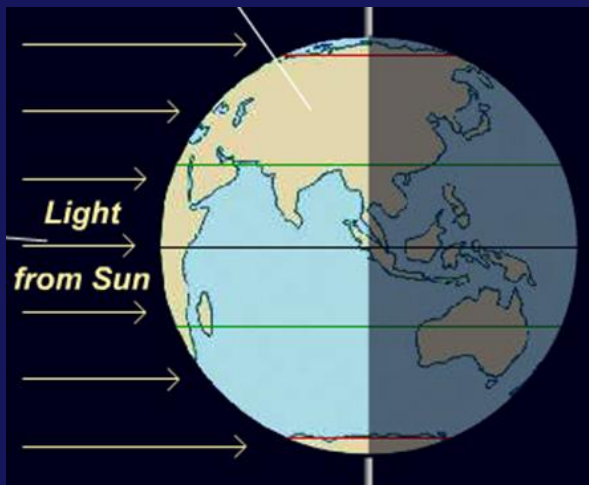
# LAST INGREDIENT:

## SUNLIGHT + UV PHOTONS

June



Sept



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

Key Concept

# HOW DEEP DOES THE HOLE GET?

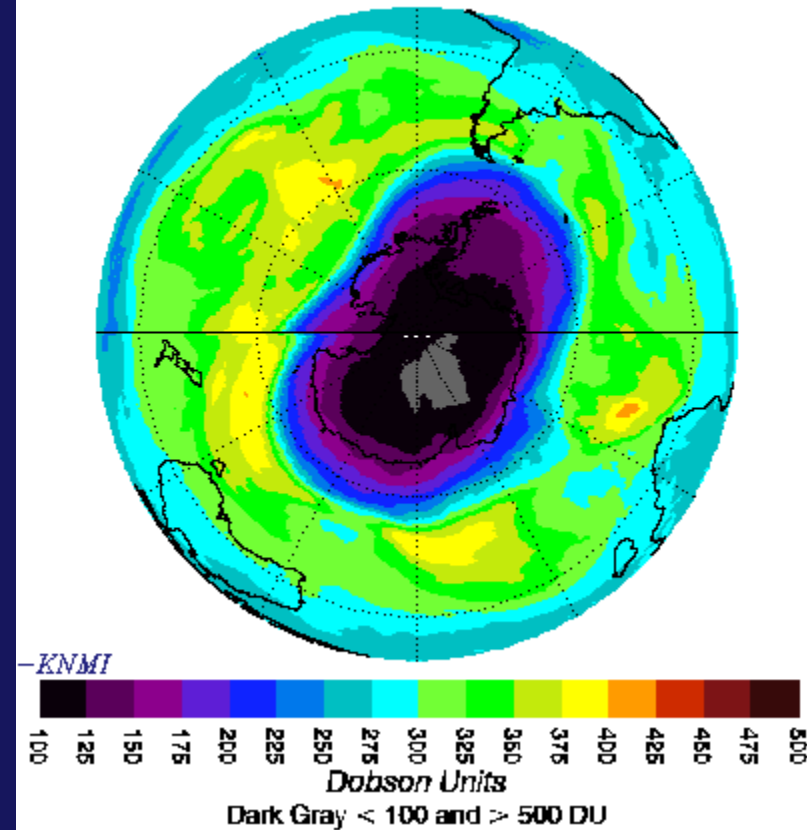
The intensity of ozone depletion varies from year to year.

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

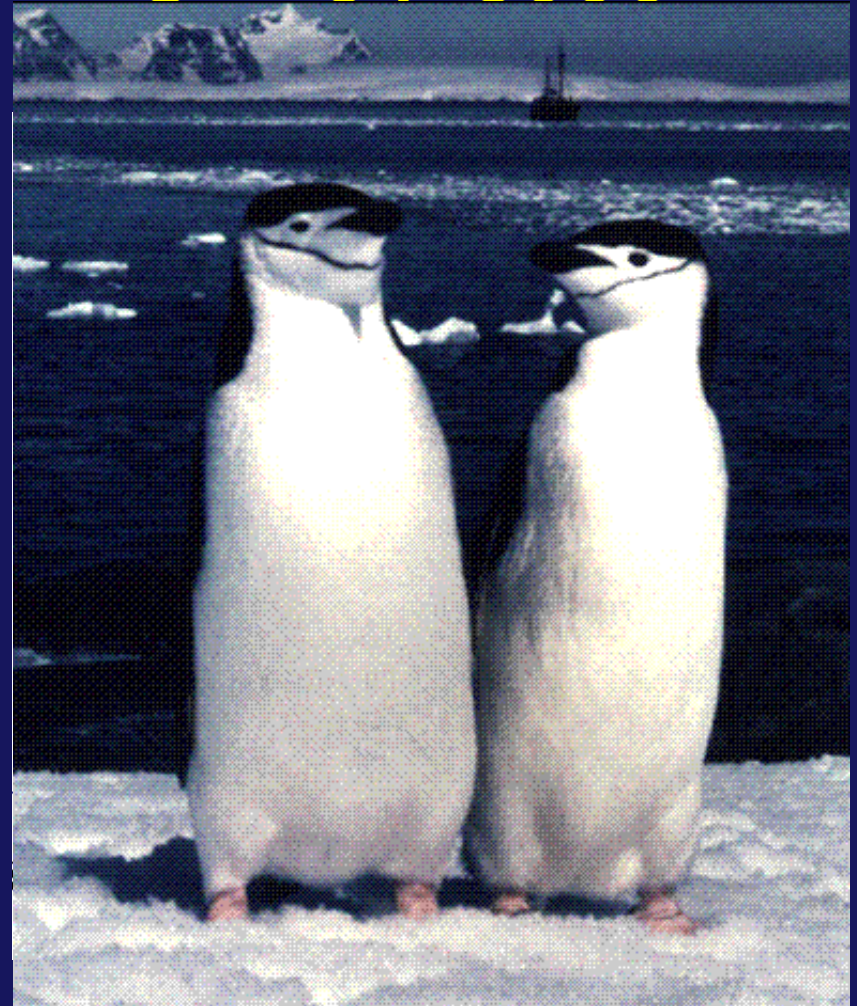
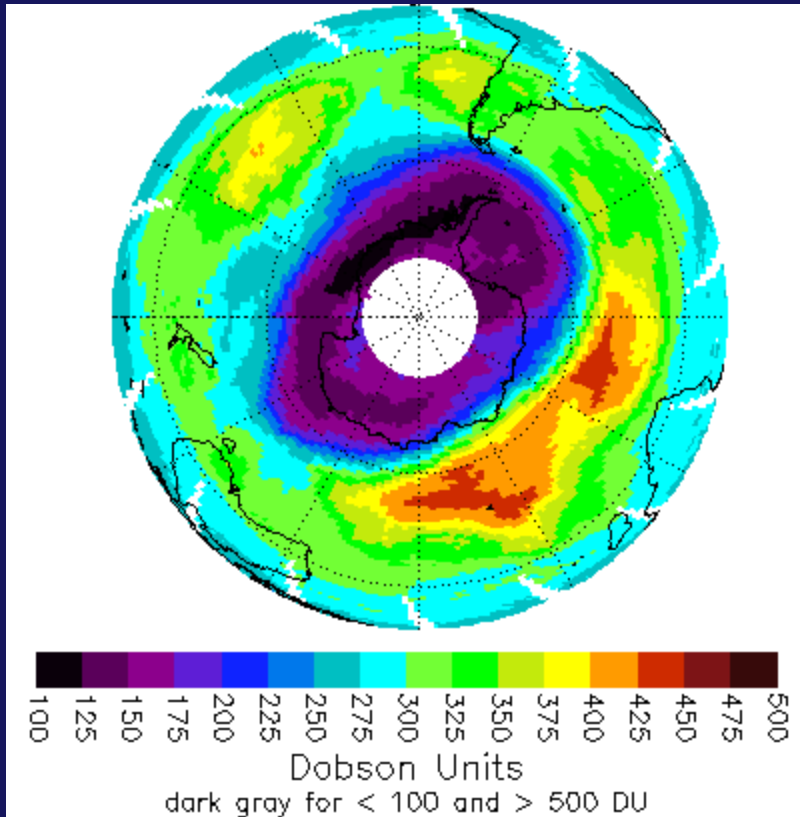


**2006** also saw the second **LARGEST** sustained ozone hole.





Sep 9, 2000



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



**Sep  
2000**

# **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. . . .**

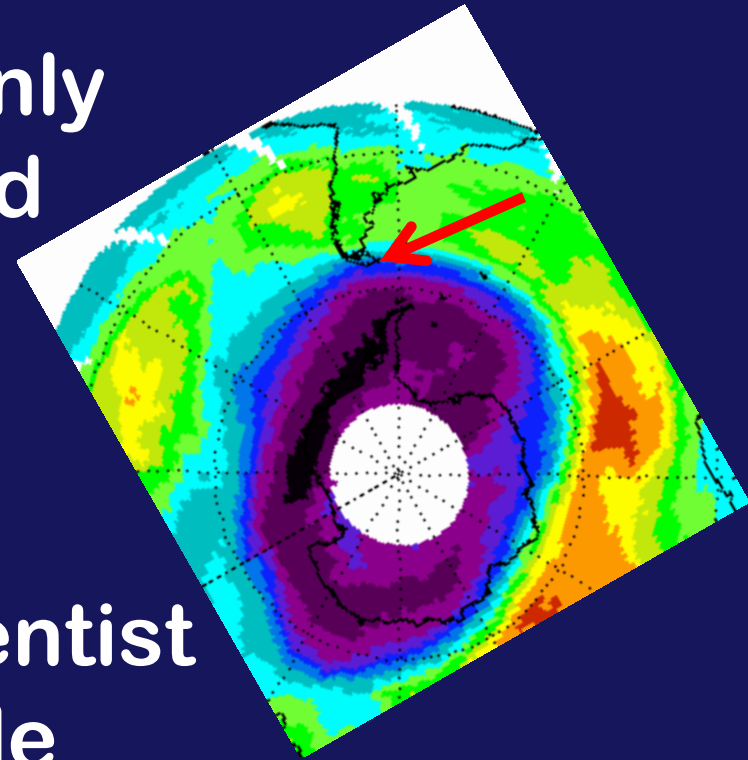


**In an Upside-Down World, Sunshine Is Shunned  
(New York Times 12-27-2002)**



“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.**”

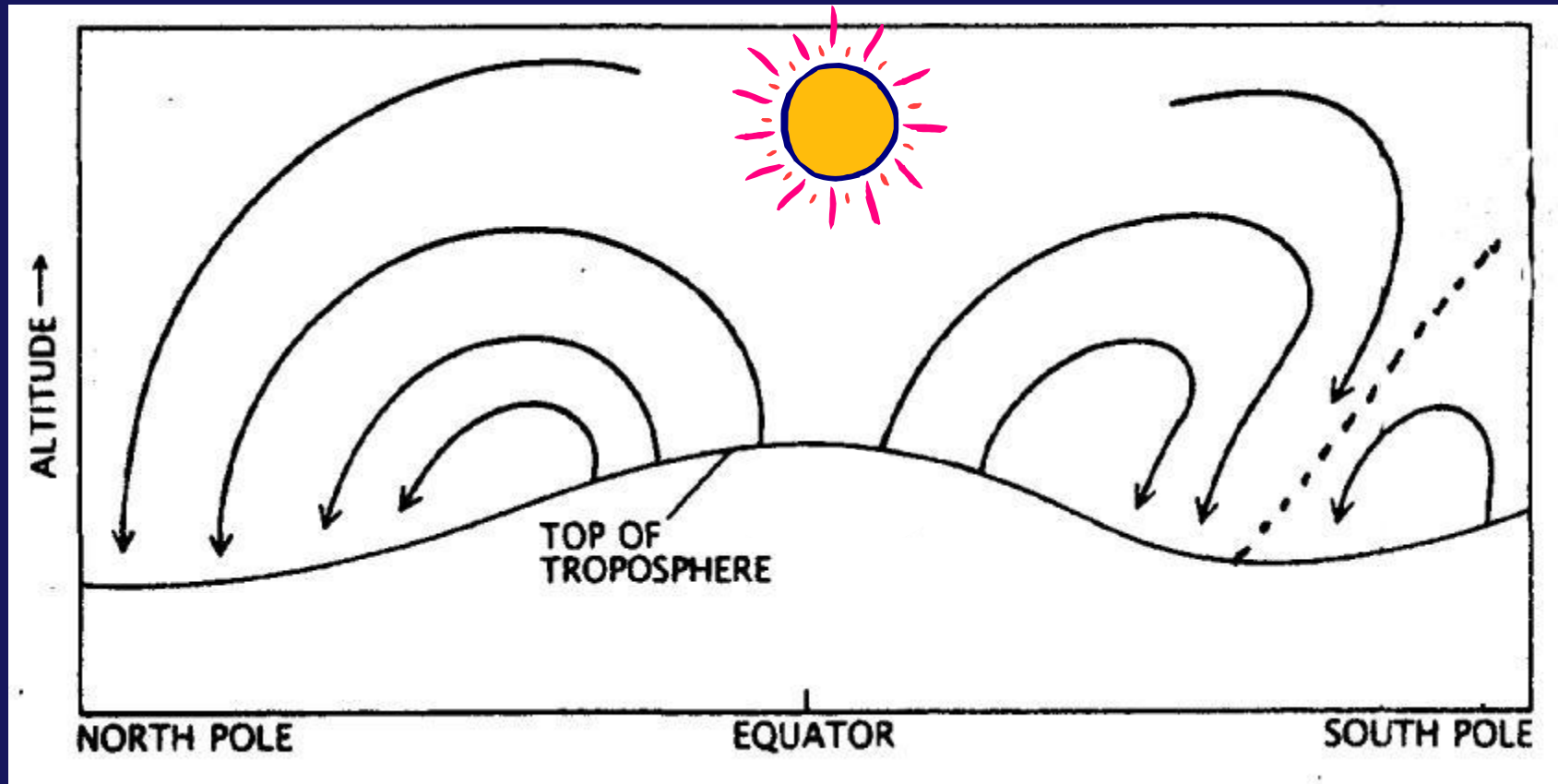
# What about other parts of the globe?

- > 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 is highest in TROPICS  
but stratospheric circulation  
distributes it poleward



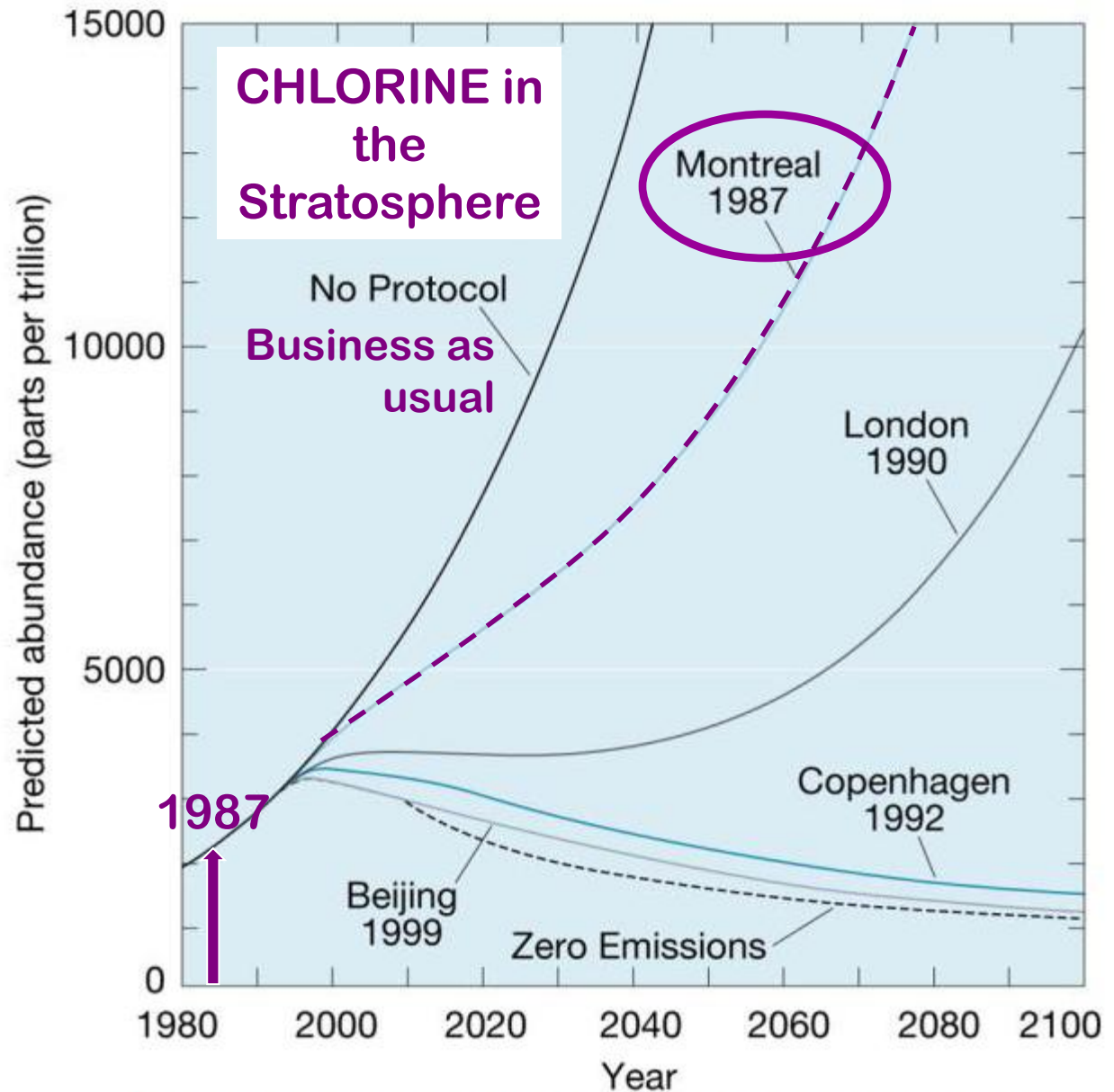


**Why do you think ozone production  
in the stratosphere is highest over  
the TROPICS?**

**Hint: Chapman Mechanism**

# WHEN WILL THE HOLE HEAL?

When chlorine  
concentrations  
drop!



Projected atmospheric chlorine concentrations under the various international agreements

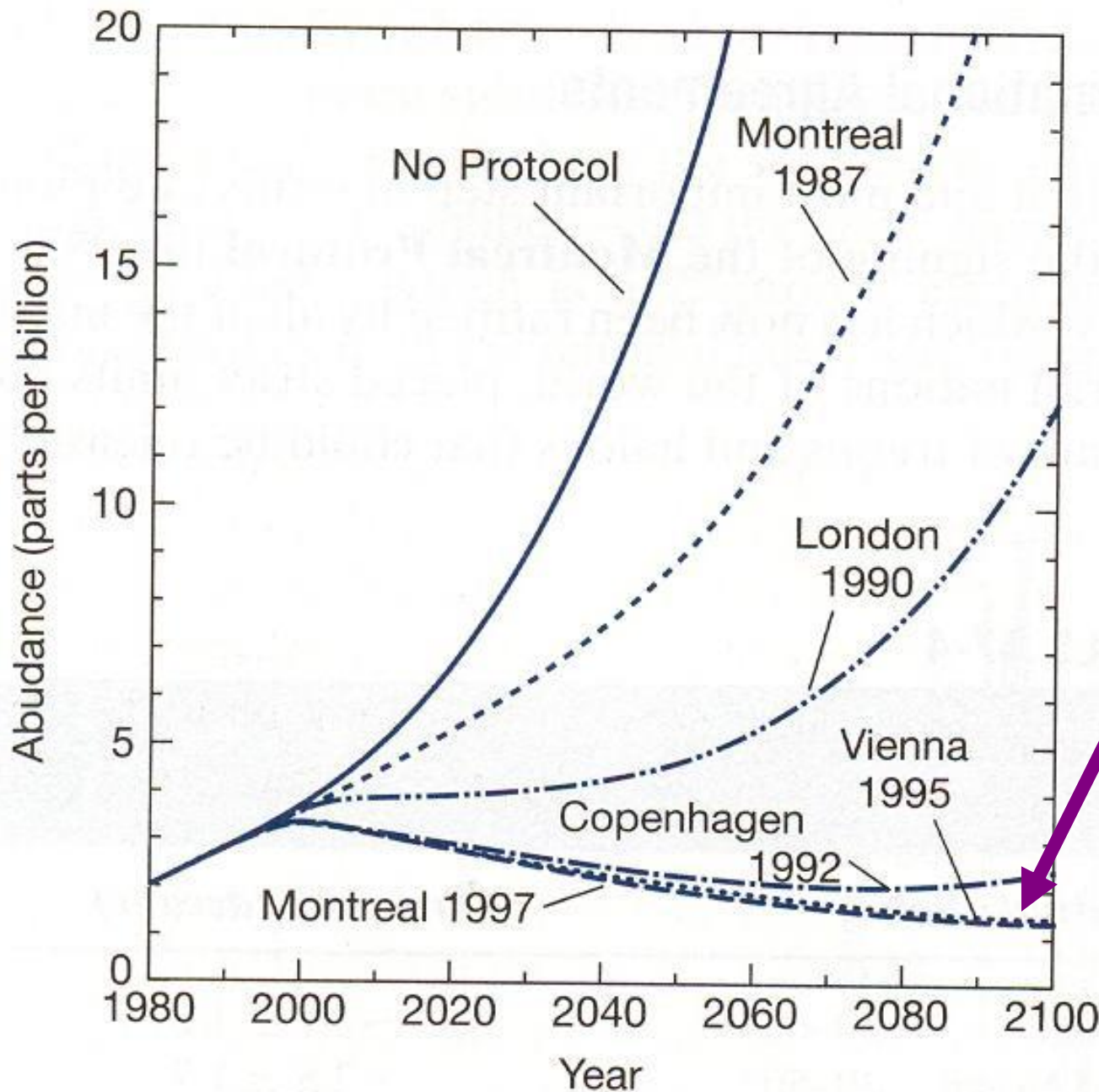
# International Day for the Preservation of the Ozone Layer

## 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.



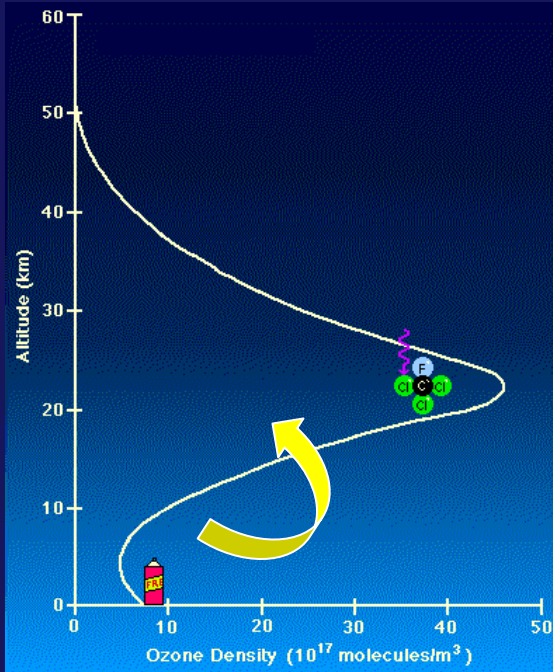
*The earth's ozone layer plays an important role in protecting human health and the environment. ©iStockphoto.com/Stephen Strathdee*



**Most recent agreements:**

**Vienna 1995  
&  
Montreal 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'?

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



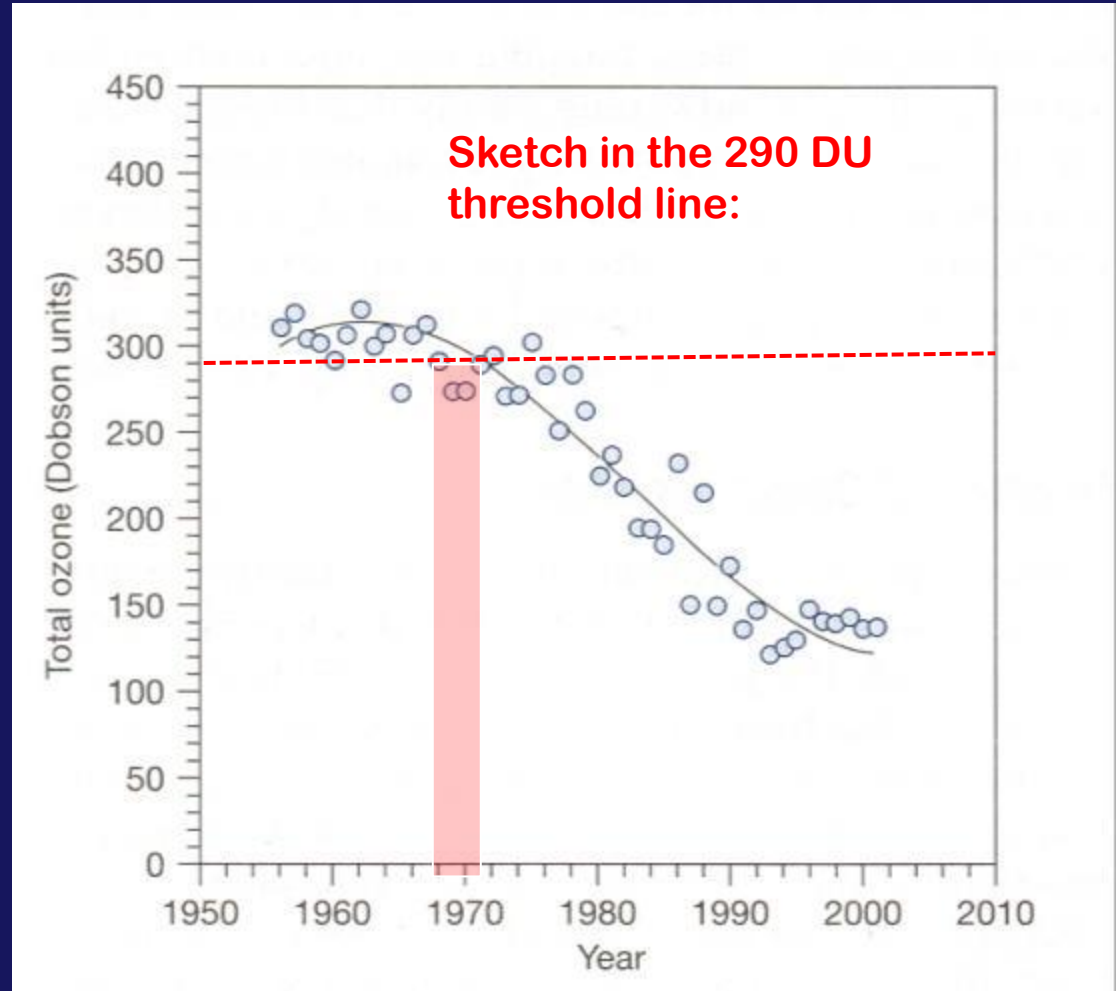


# WHAT'S THE CHANGE OVER TIME IN OZONE DEPLETION?

Need to know  
**WHEN** the  
Antarctic Hole  
began forming . . .

Hole is generally  
defined as  
**< 290 DU**

**DU = DOBSON UNITS**



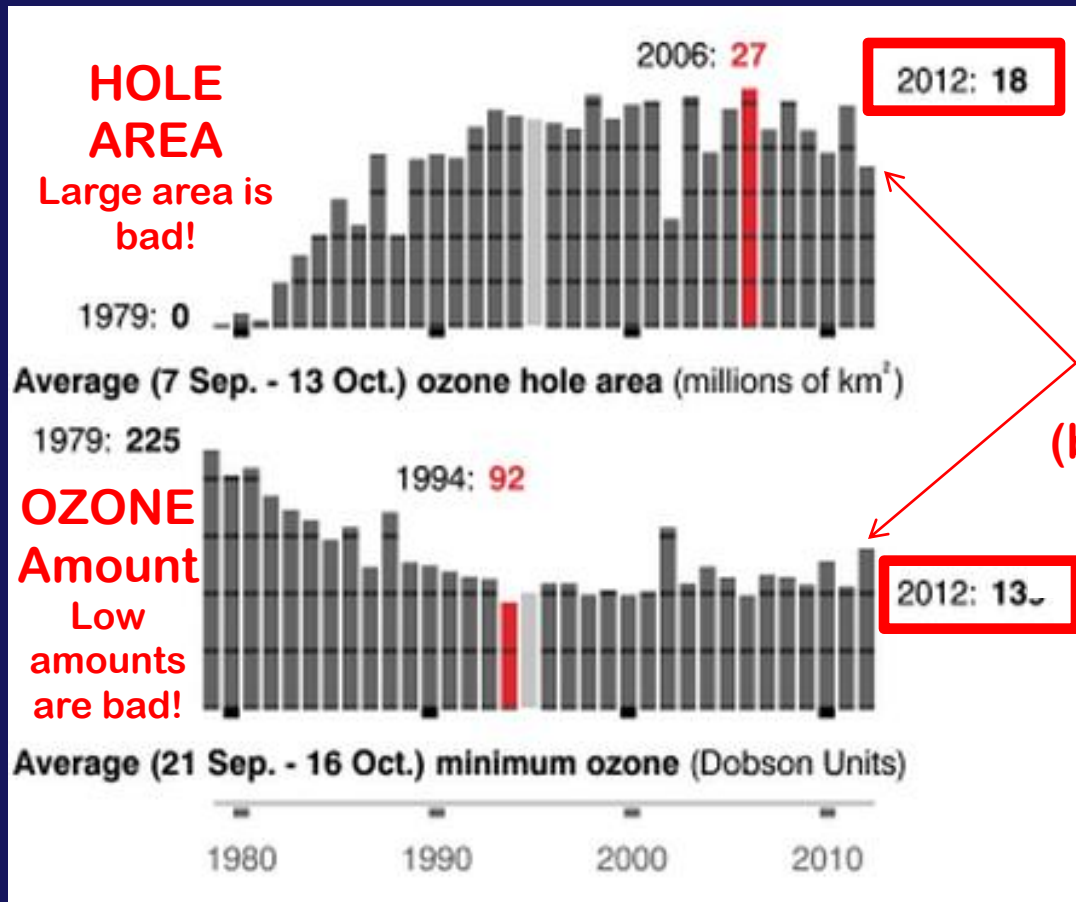
Estimate for when  
hole formation began: ~1969 -1970 ??





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

## Annual Ozone Hole Variations (since 1979)



**This year:  
2012**

(better than last year;  
was 2<sup>nd</sup> smallest  
in 20 years!)



OZONE HOLE WATCH

images, data, and information; updated daily

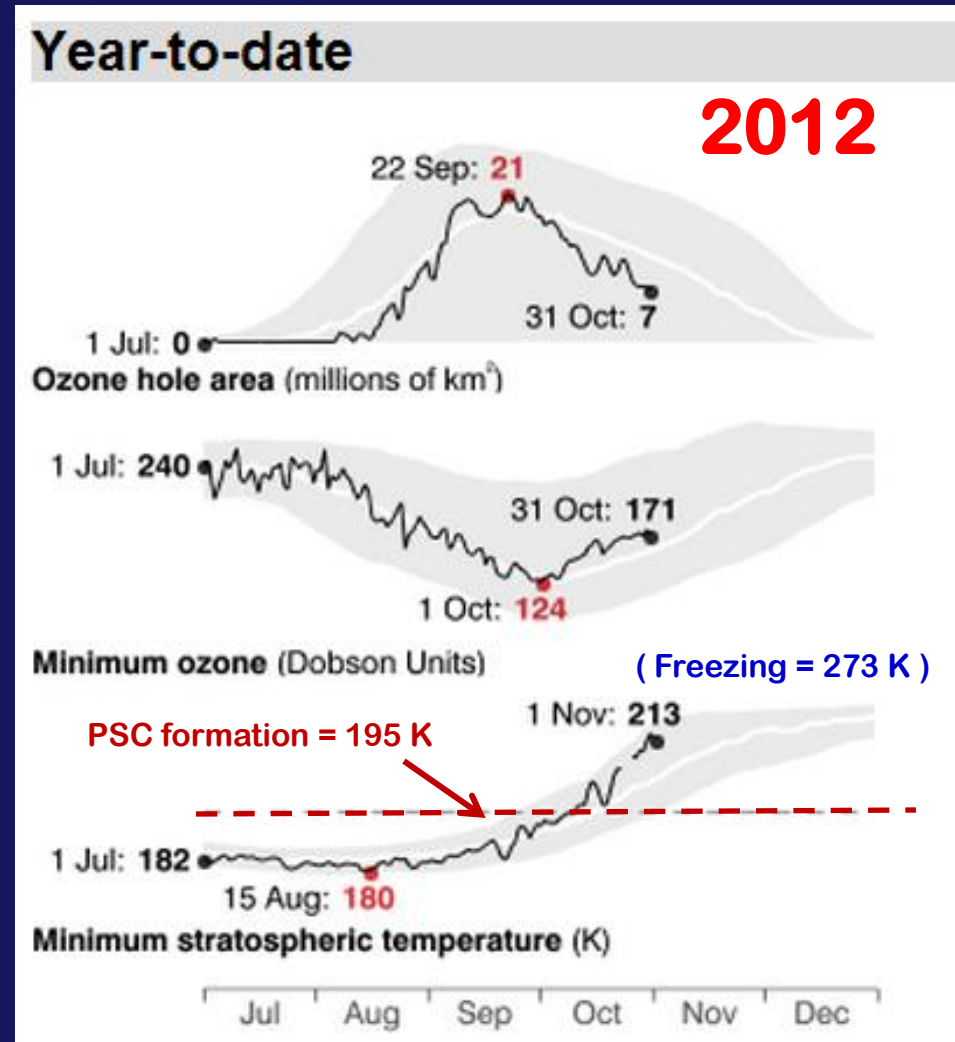
<http://ozonewatch.gsfc.nasa.gov>

## DAILY VALUES OF THE 2012 HOLE:

Size of Hole:

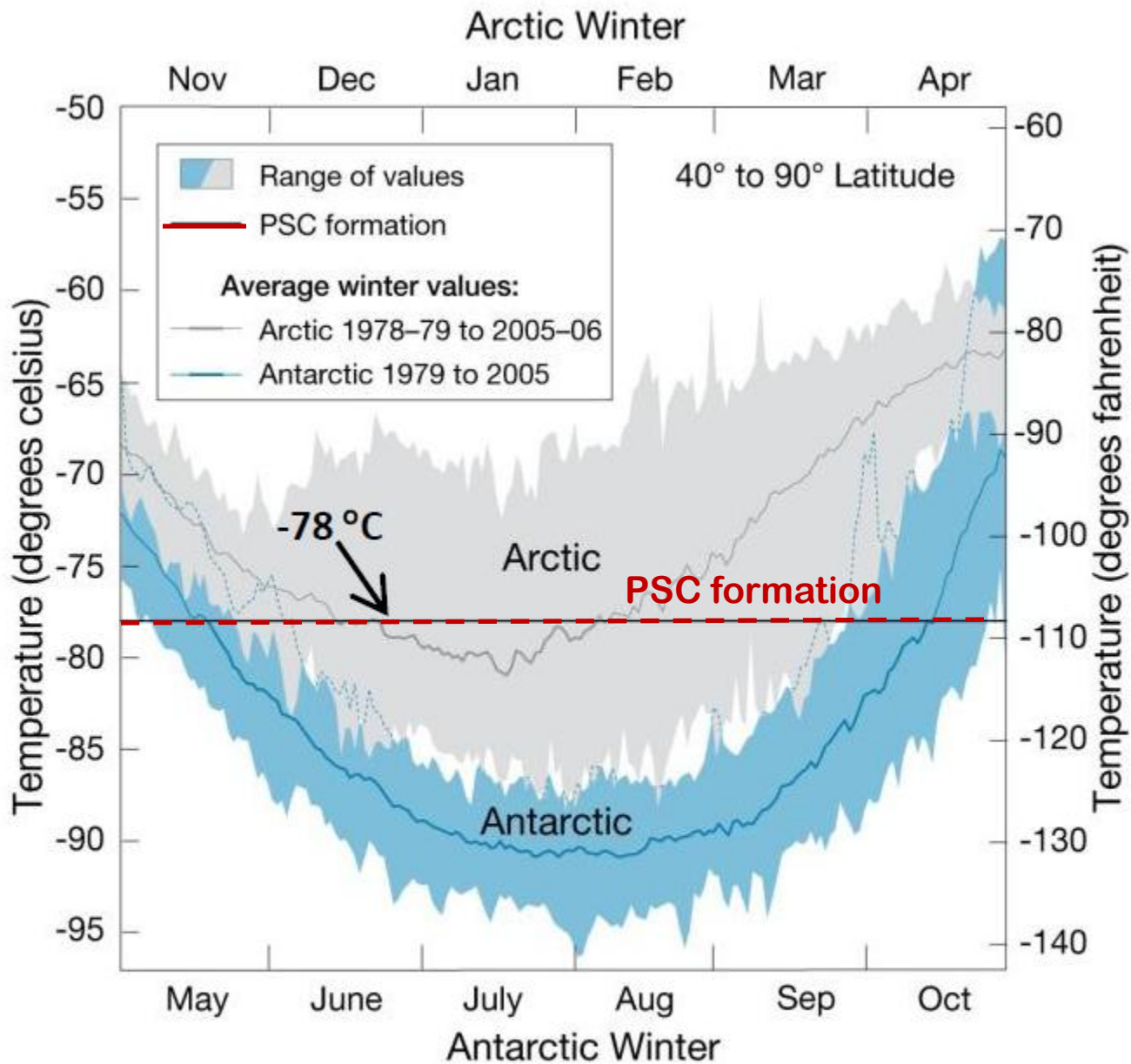
Dobson Units:

Stratospheric Temperature:

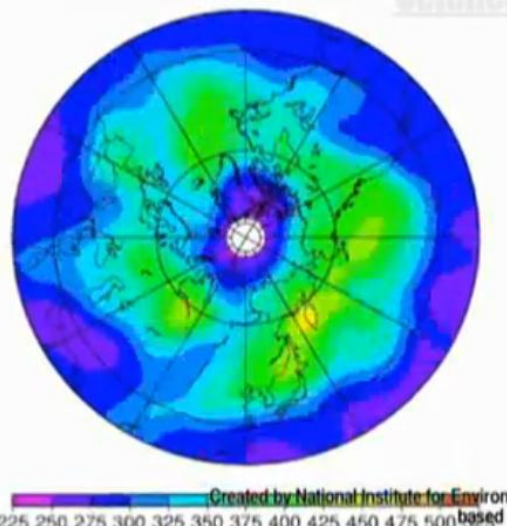


see also: <http://macuv.gsfc.nasa.gov/>





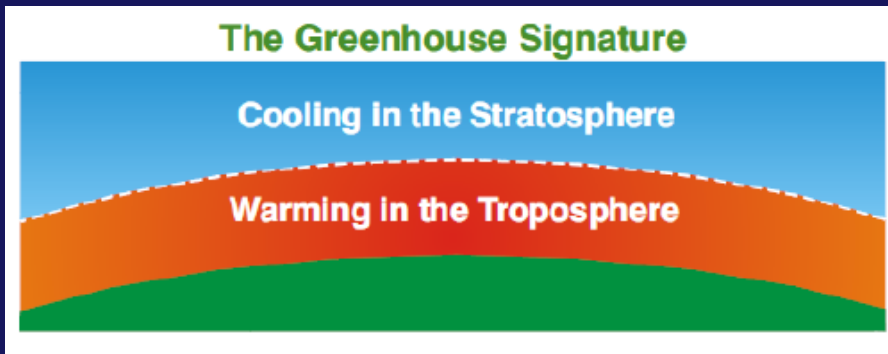
**Minimum air temperature in the polar stratosphere over the Arctic (top) and Antarctic (bottom)**



## Arctic ozone depletion also occurs!

“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 likelihood of this happening seems inevitable based on the deterioration of ozone layer caused by the effects of global warming on the upper atmosphere.”**



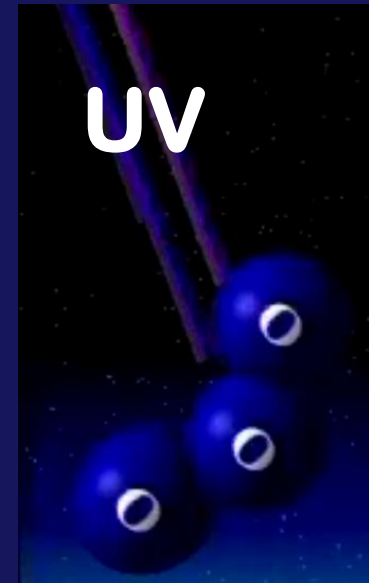
Colder stratosphere = more PSC's!



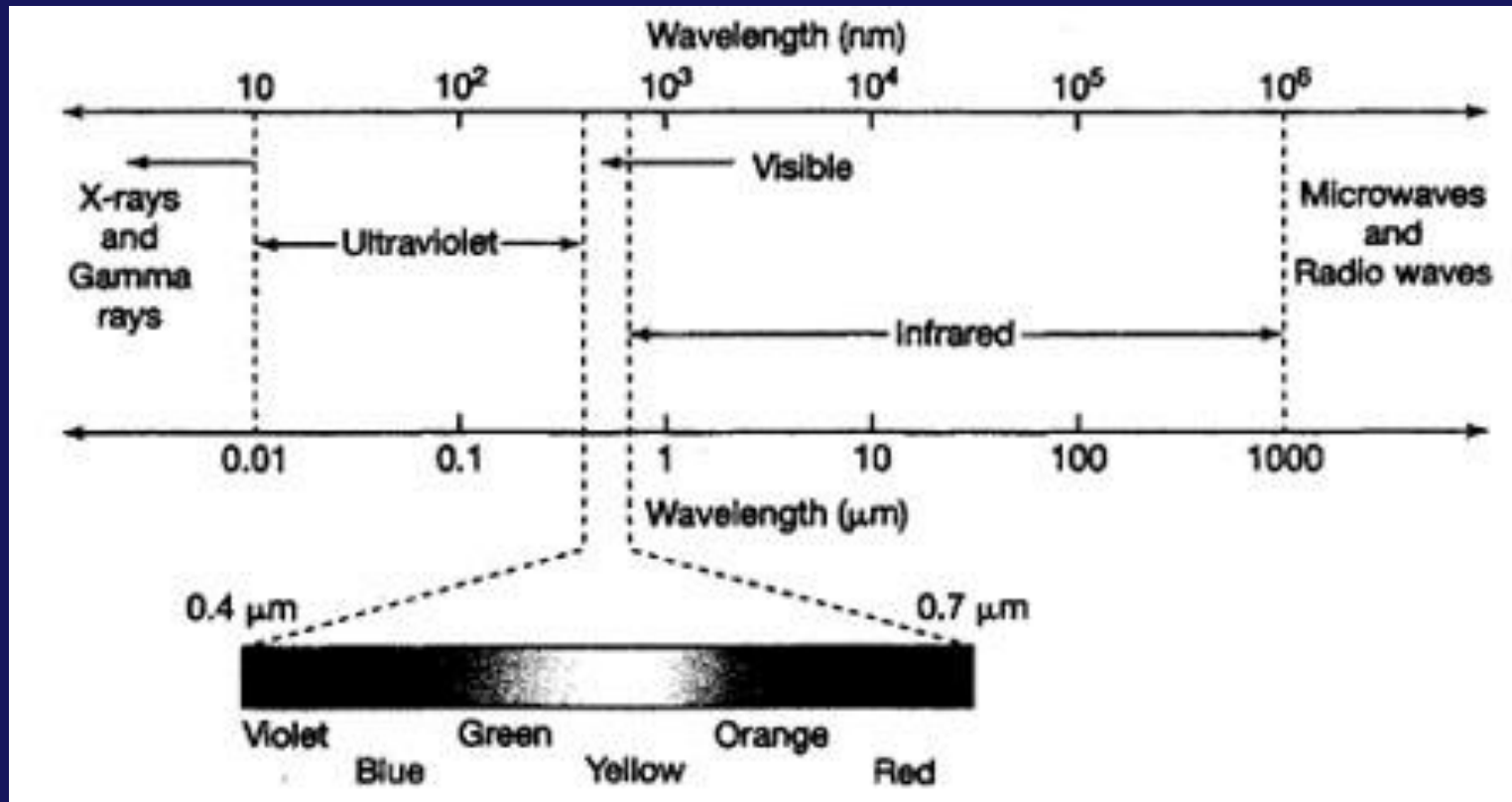
# EPILOGUE

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

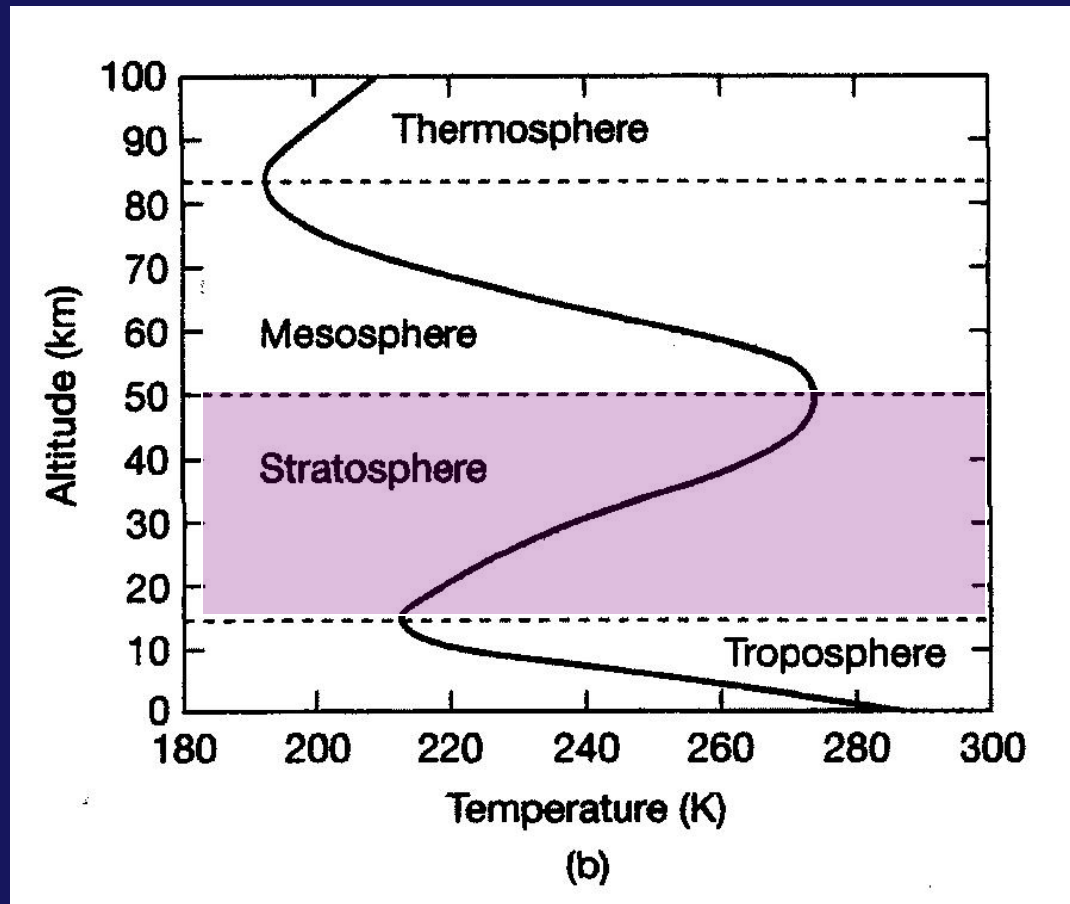


# > the electromagnetic spectrum --especially the wavelengths of UV radiation

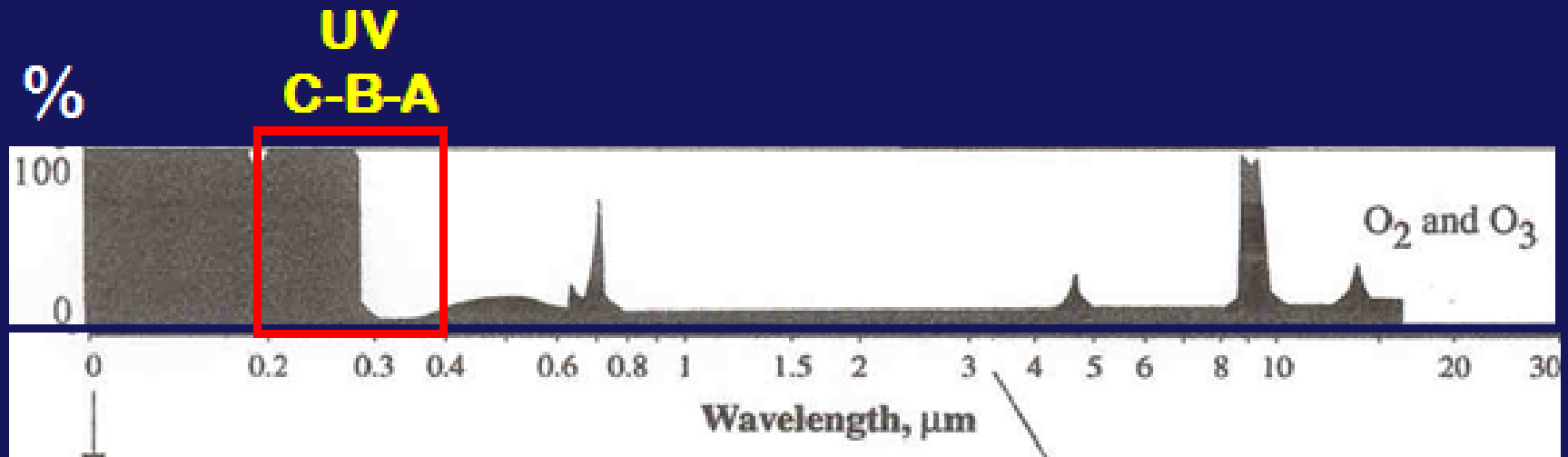




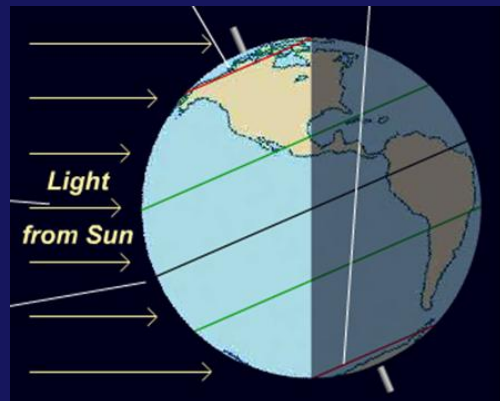
# > the vertical structure of the atmosphere (troposphere, stratosphere)



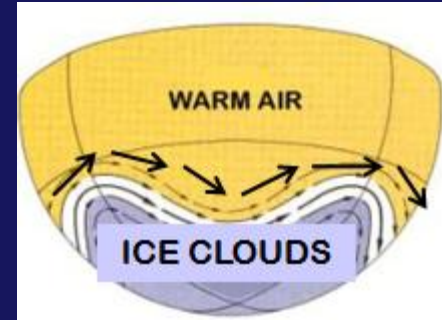
> absorption curves, especially the absorption curve for ozone



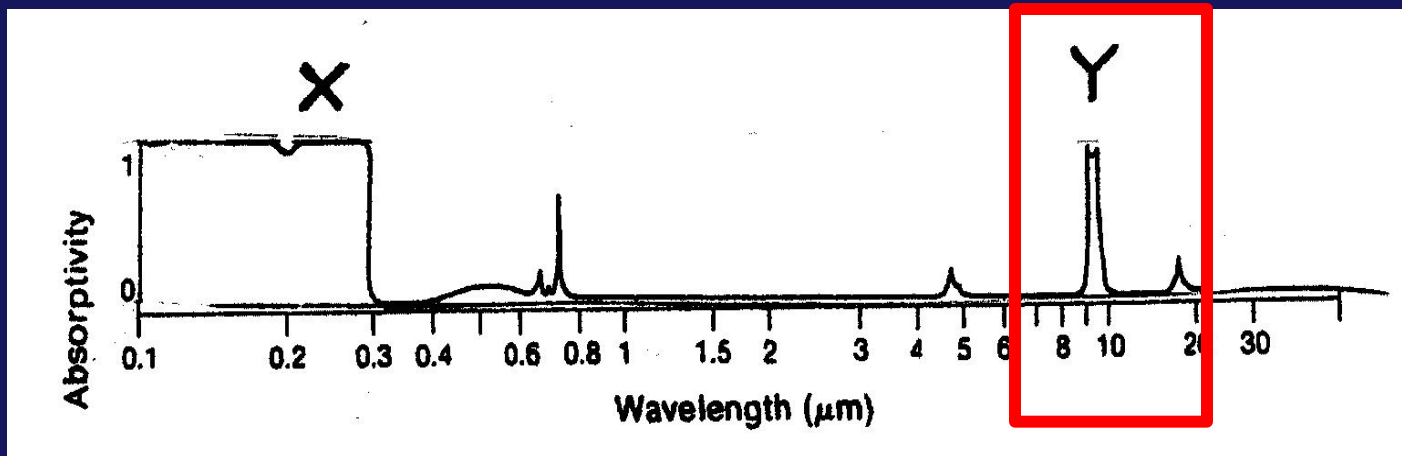
> Earth-Sun relationships



> atmospheric circulation & importance of Polar Stratospheric Clouds (PSCs)



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



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



> Preconceived ideas influencing one's observations

... and the surprise of discovery!

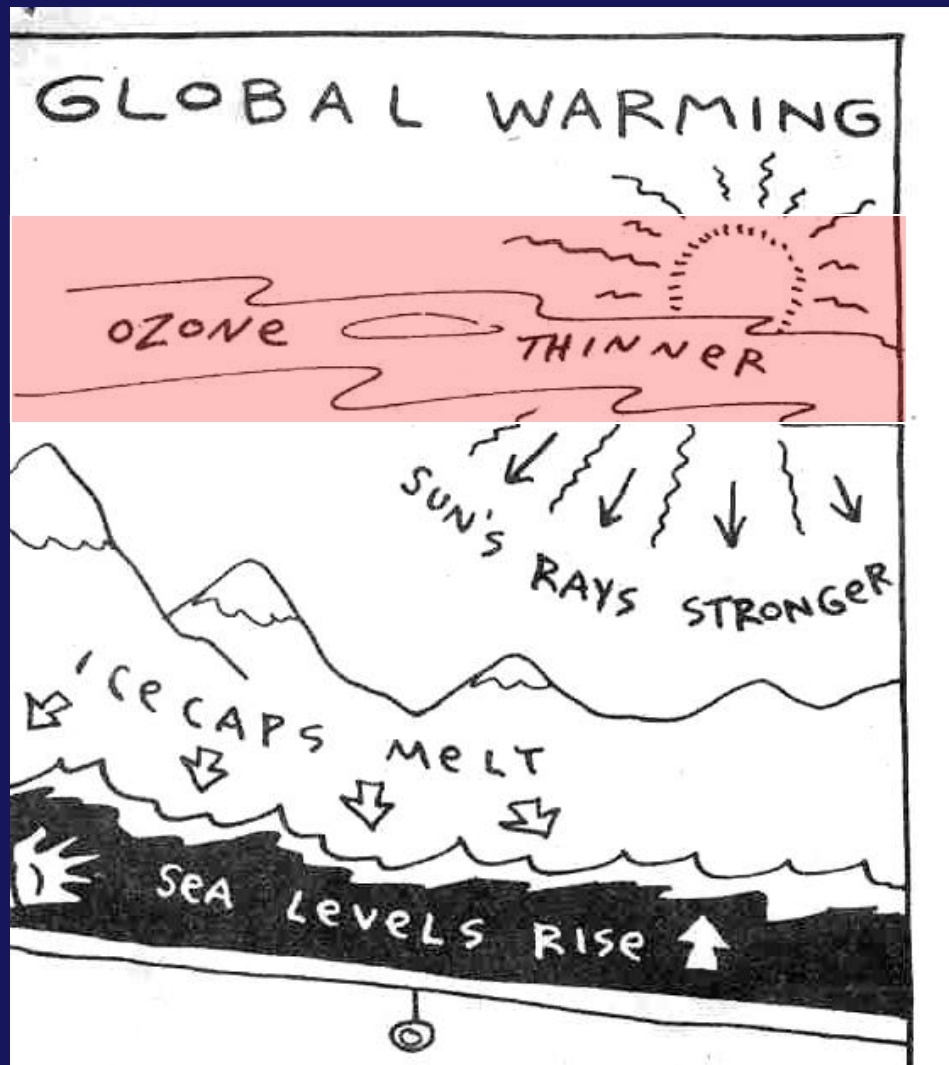








# AN OZONE-RELATED CARTOON: MISCONCEPTION!



**Q – Is the depletion of STRATOSPHERIC OZONE (in the OZONE HOLE and elsewhere) an IMPORTANT CAUSE of GLOBAL WARMING?**

**1 – YES**

**2 -- NO**

HAPPY HOMECOMING!!



GO CATS!

Don't Forget RQ-8 due  
before our next class on  
Wednesday Nov 14<sup>th</sup>!