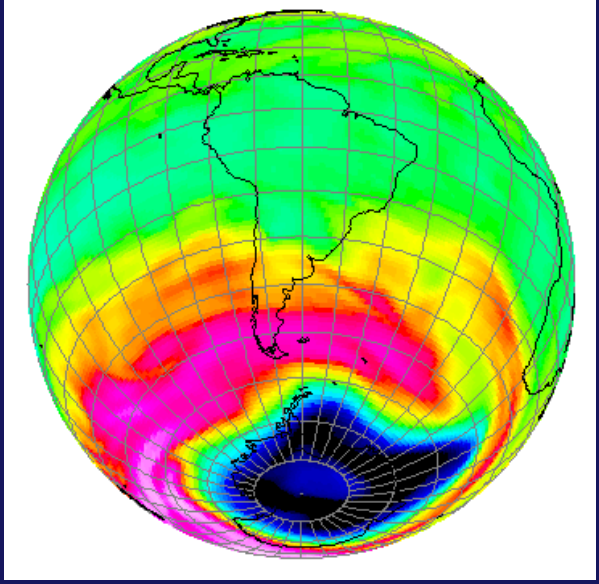
Topic # 13 (cont.)

OZONE DEPLETION IN THE STRATOSPHERE – Part II

A Story of Anthropogenic Disruption of a Natural Steady State

p 77-79 in Class Notes

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

Q1– Which of the following is NOT an "ingredient" of the Recipe for the Antarctic Ozone Hole

1 – A Catalyst
2 – Stratospheric Warming
3 – Polar stratospheric clouds
4 – Chlorine

Q1– Which of the following is NOT an "ingredient" of the Recipe for the Antarctic Ozone Hole

1 – A Catalyst

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3 – Polar stratospheric clouds

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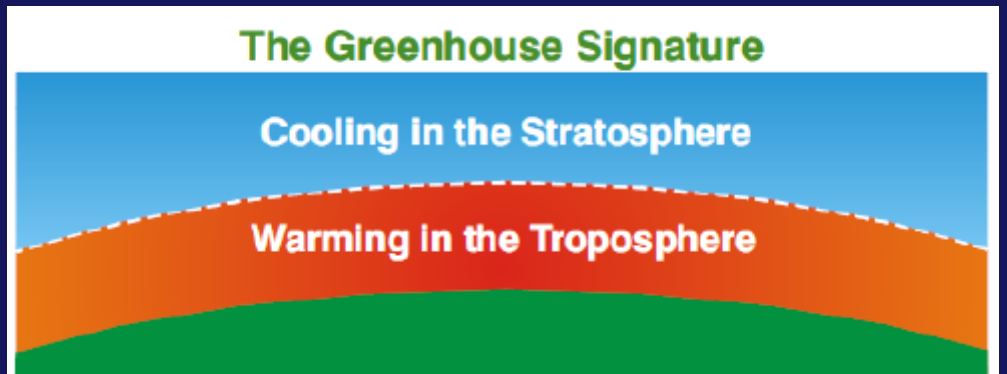


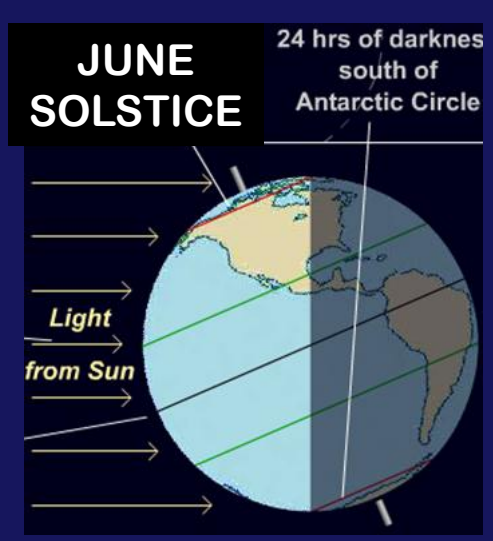
p 41 in Class Notes

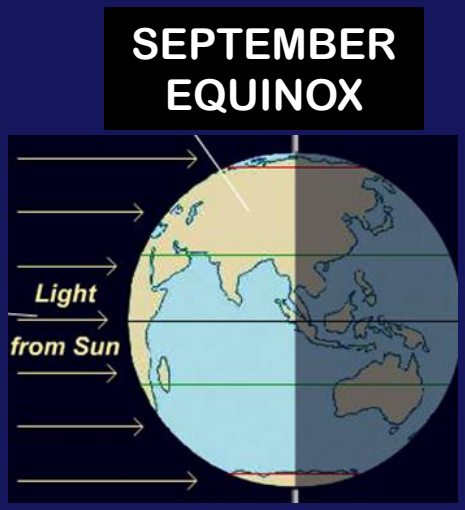
Q2– Which of the following is the ONE KEY ingredient NOT listed in the previous slide that is absolutely necessary!!!

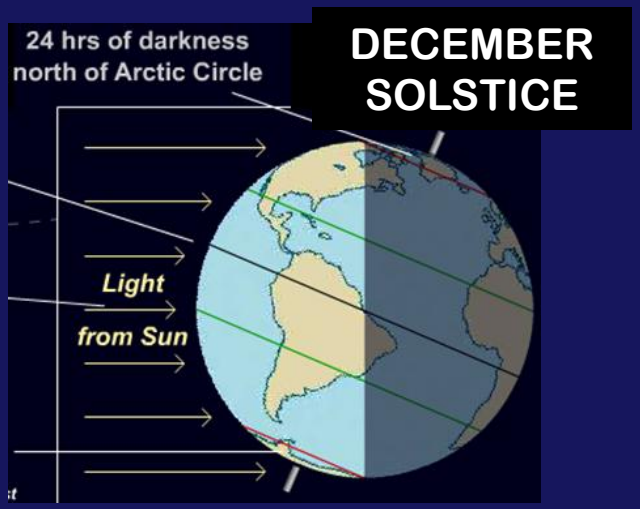
1 – IR radiation
2 – Water vapor
3 – A Catalyst
4 – Sunlight

Q2– Which of the following is the ONE KEY ingredient NOT listed in the previous slide that is absolutely necessary!!!

1 – IR radiation
2 – Water vapor
3 – A Catalyst
4 – Sunlight







The STORY OF THE DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

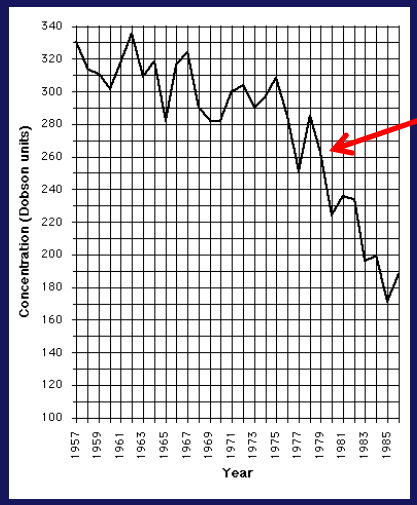
DISCOVERY OF THE OZONE HOLE:

"A Misadventure of Science?"

CHAPTER 1

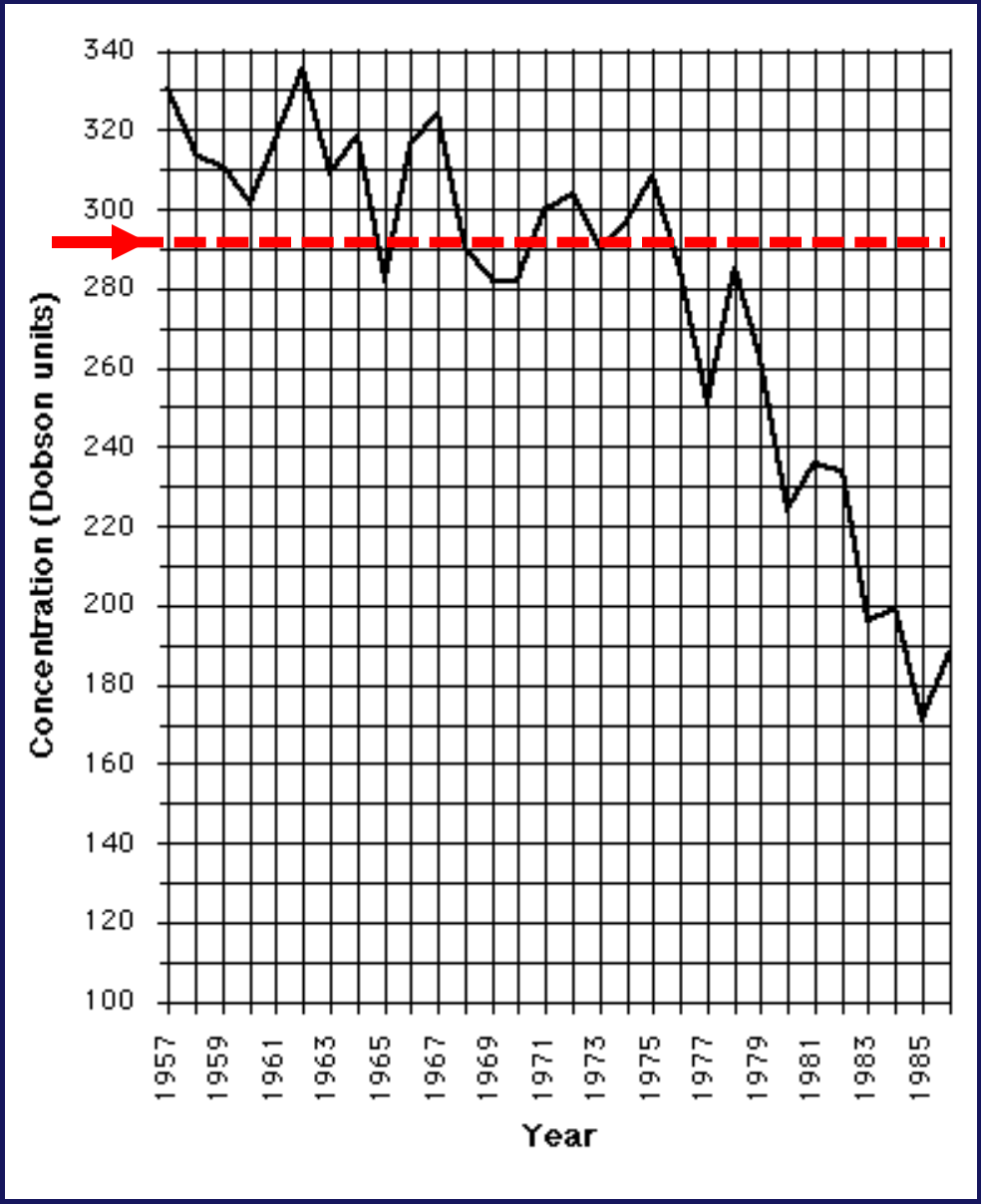
- **Ground-based** ozone measurements since **1956**. (British survey team)

- 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)

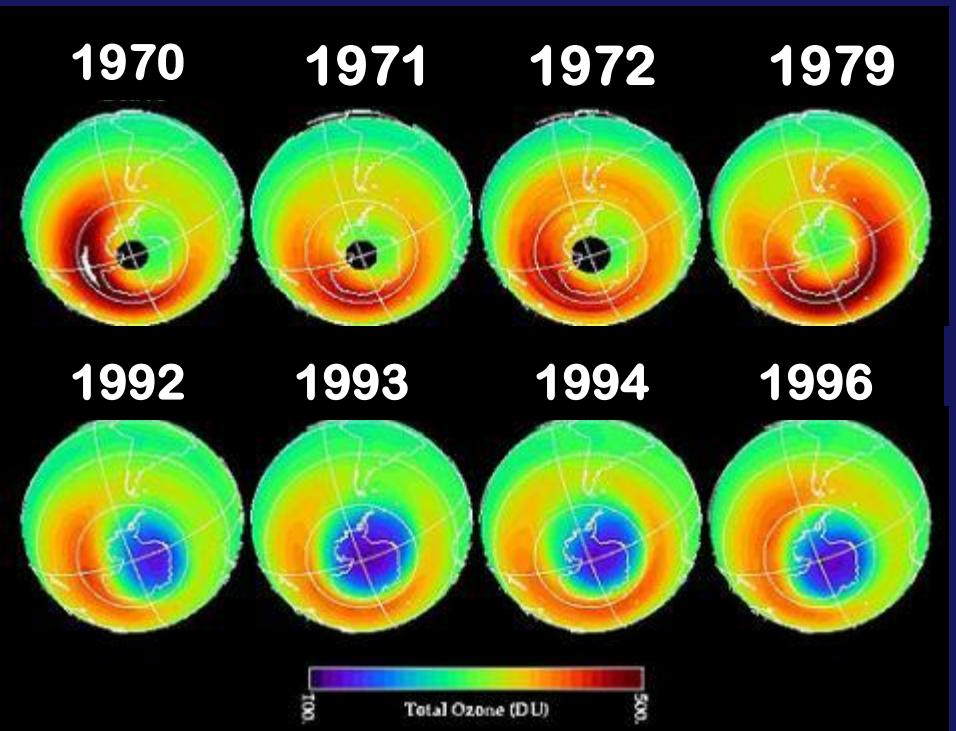
1957-1986

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 !!

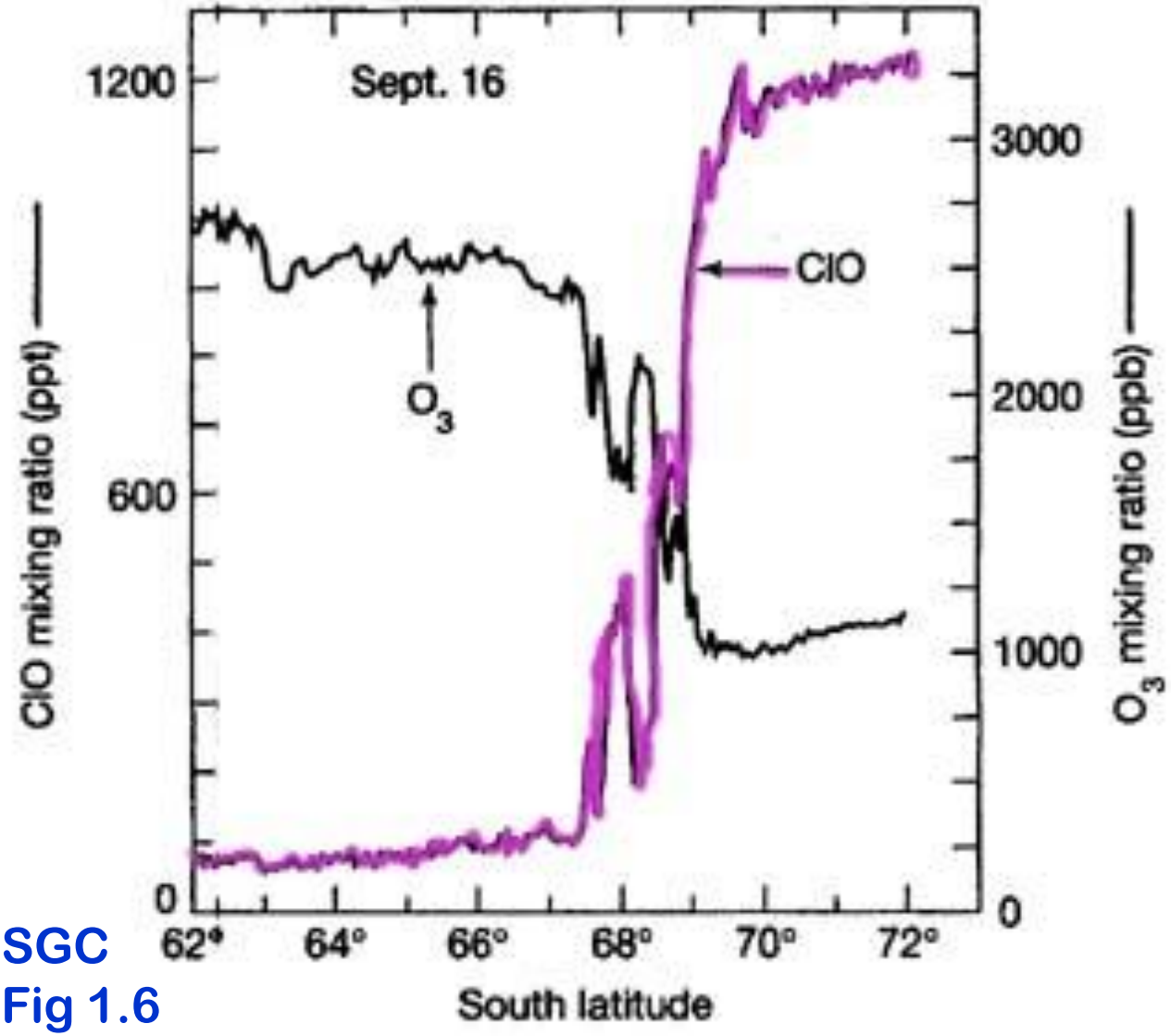
DISCOVERY OF THE OZONE HOLE

(cont.)

CHAPTER 3

- In 1986 Dr. Susan Soloman'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

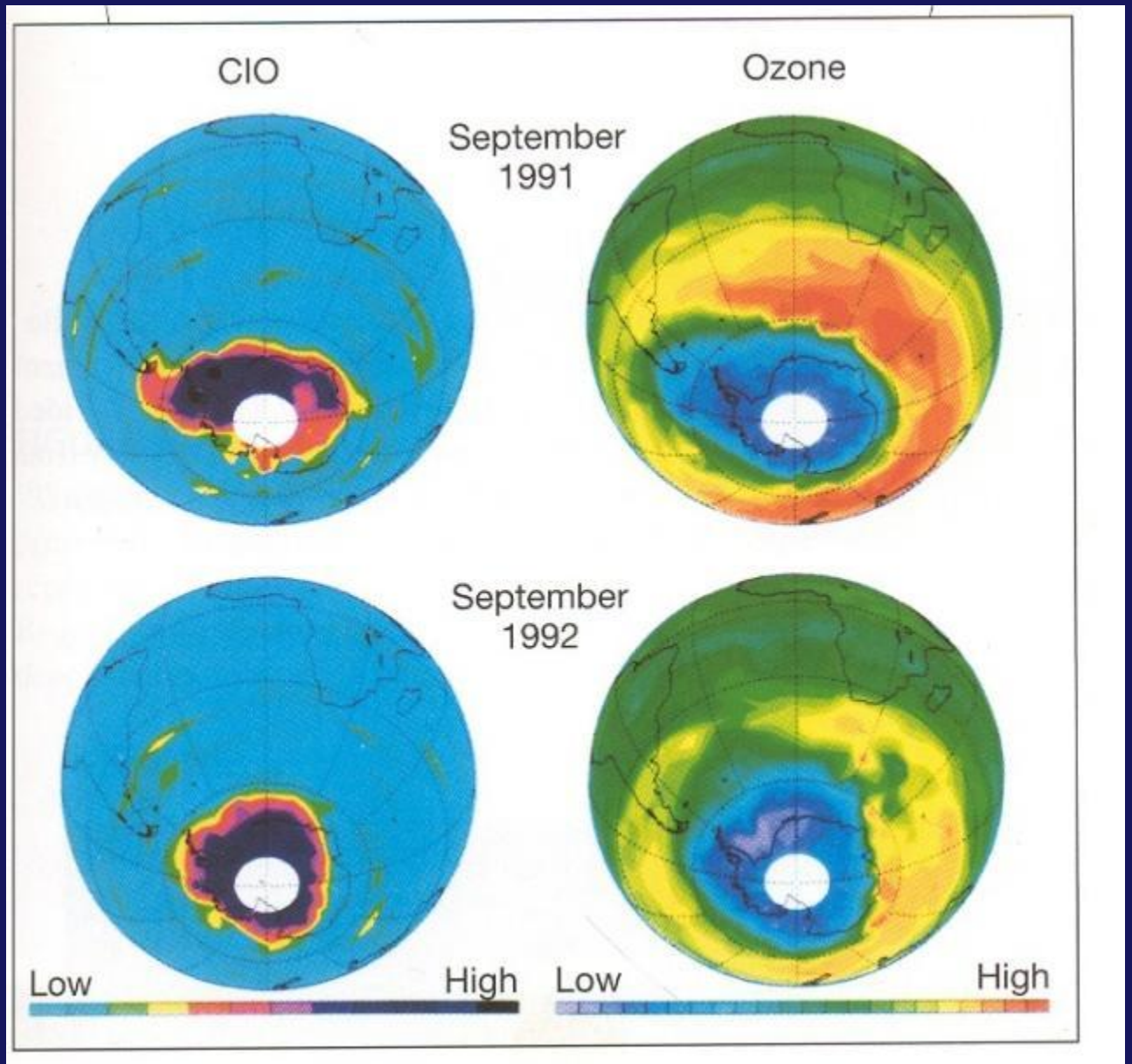
ClO (chlorine monoxide) from the chlorine catalytic cycle = **THE evidence of chemical reactions** occurring in hole region during time of greatest O_3 depletion (in September, spring in Southern Hemisphere)

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 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?

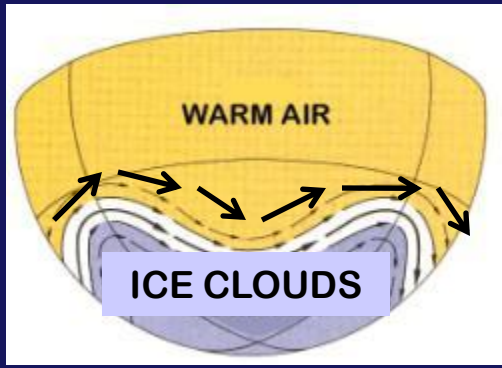
The ozone "hole(s)" have a unique REGIONALITY and SEASONALITY :

> 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.

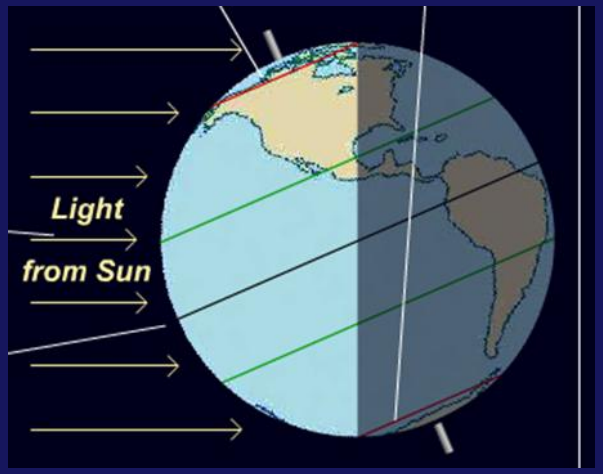
POLAR STRATOSPHERIC CLOUDS OVER ANTARCTICA

[Go to movie clip]

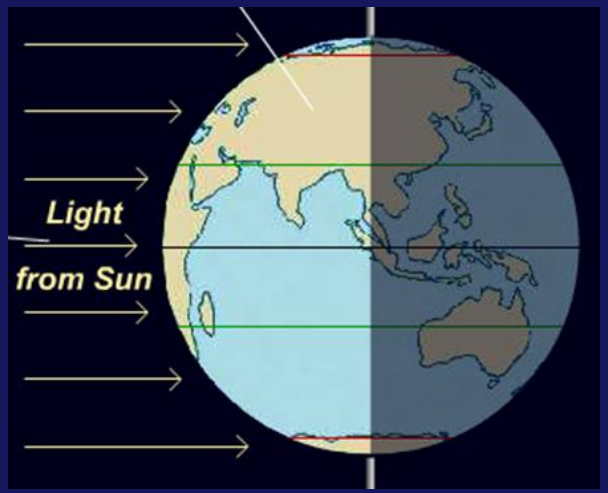
LAST INGREDIENT:

SUNLIGHT + UV PHOTONS

June

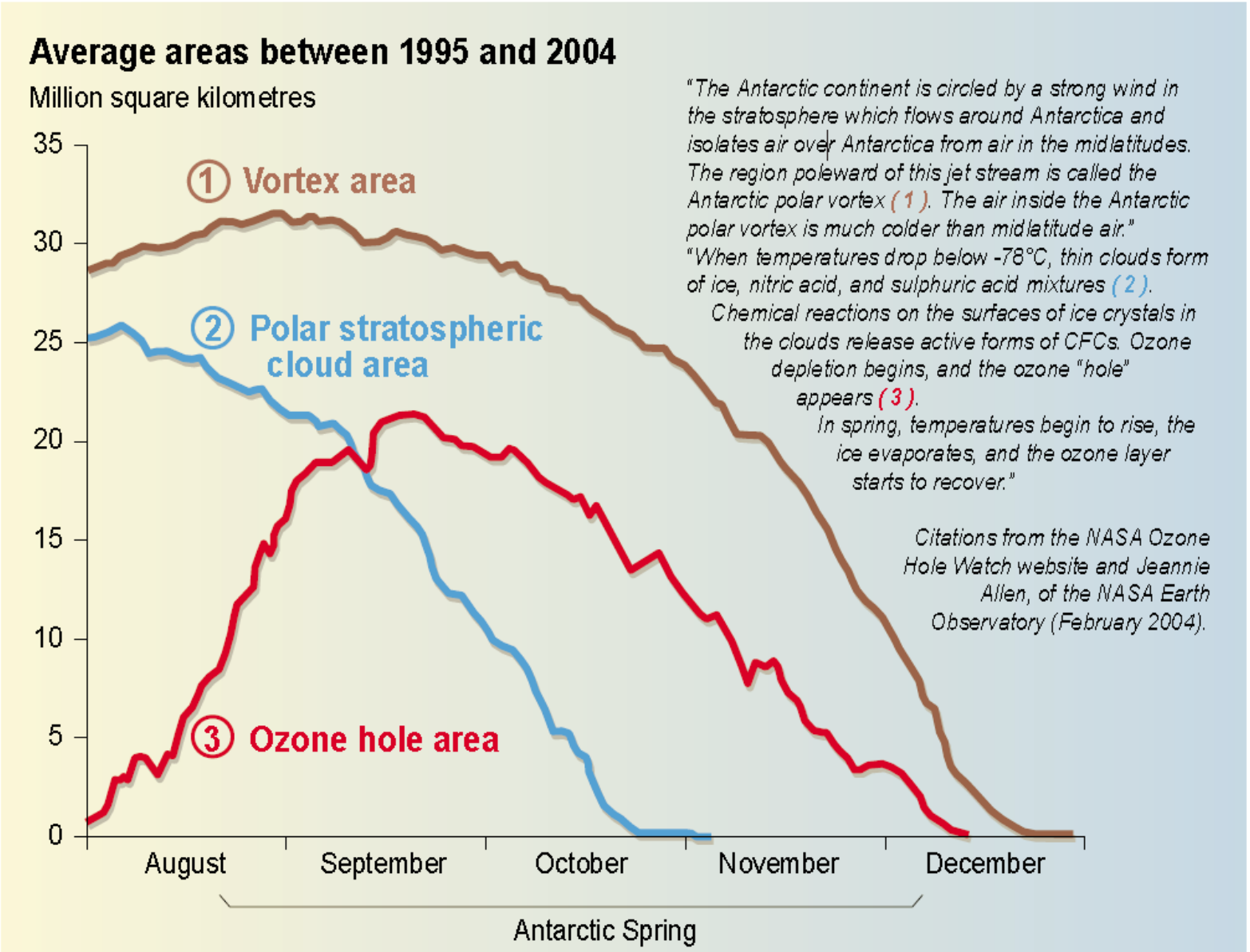


Sept



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

THE "HOLE": A RESULT OF SPECIAL WEATHER CONDITIONS OVER THE POLE REPEATED EVERY SPRING

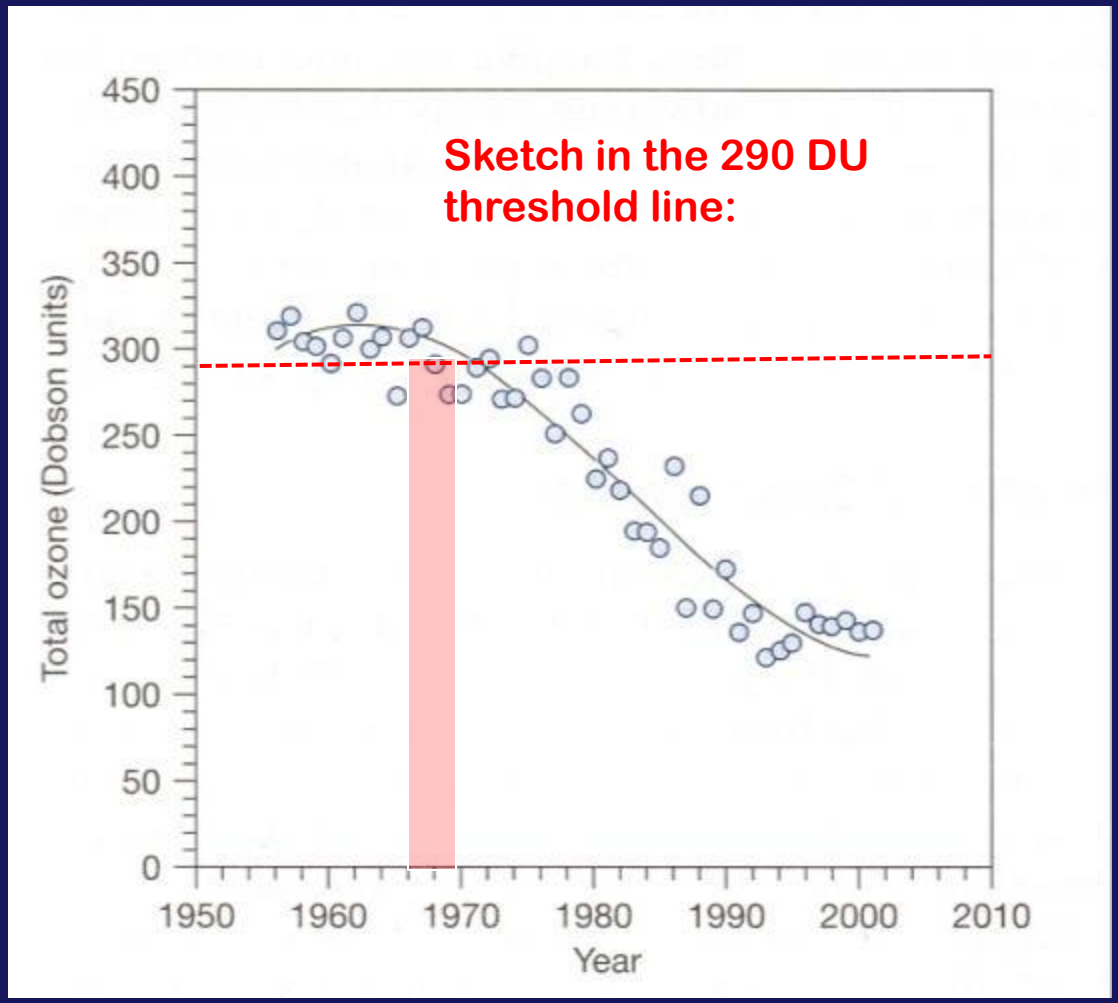


RATE OF OZONE DEPLETION

in DOBSON UNITS (DU)

When did the Hole begin forming?

Hole generally defined as < 290 DU

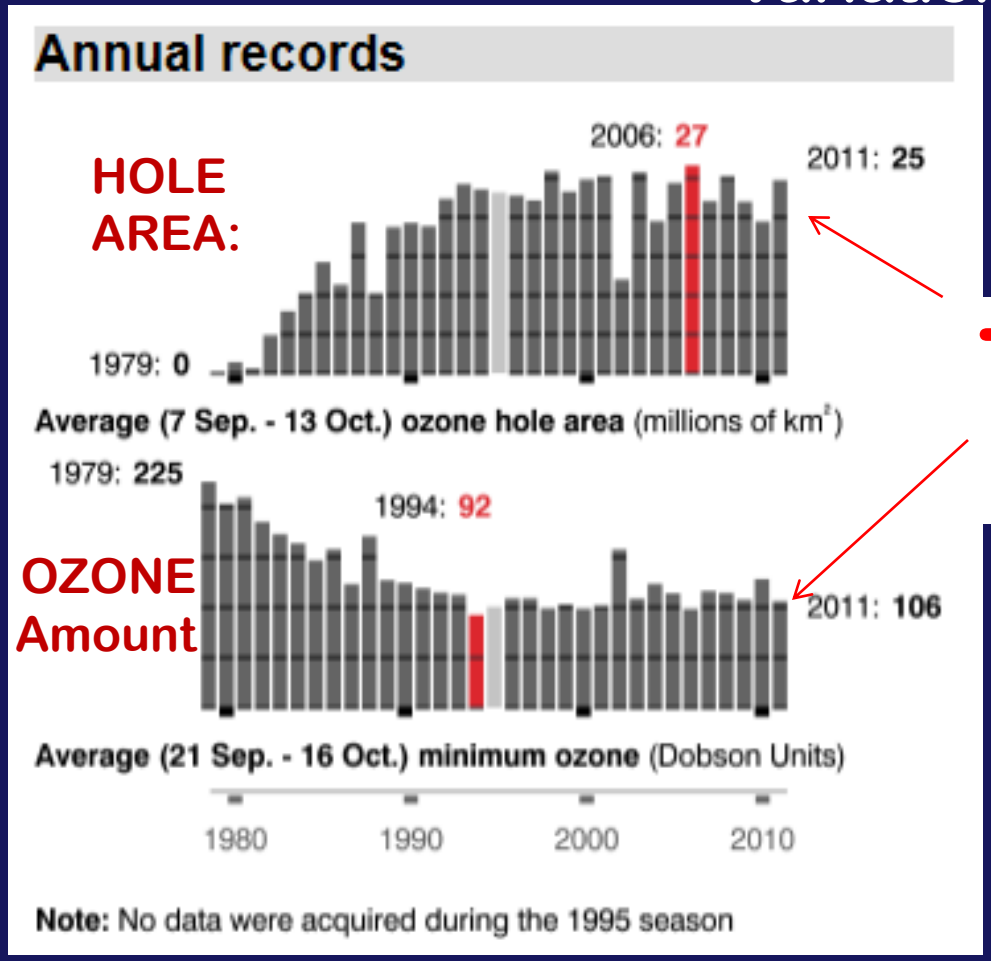


~ 1969 to 1970

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

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

Annual Ozone Hole Variations (since 1979)

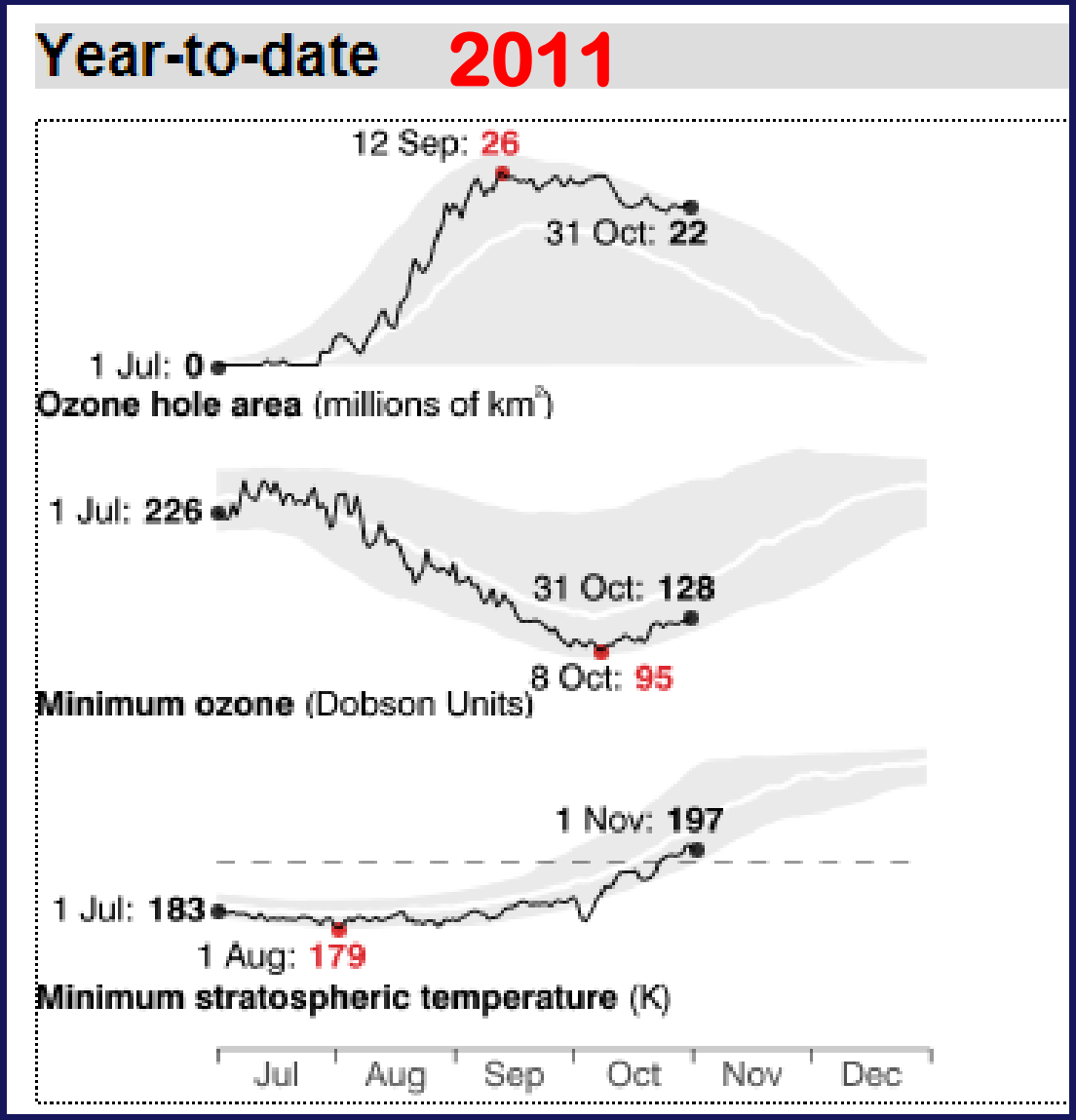


This year: 2011

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

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

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



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

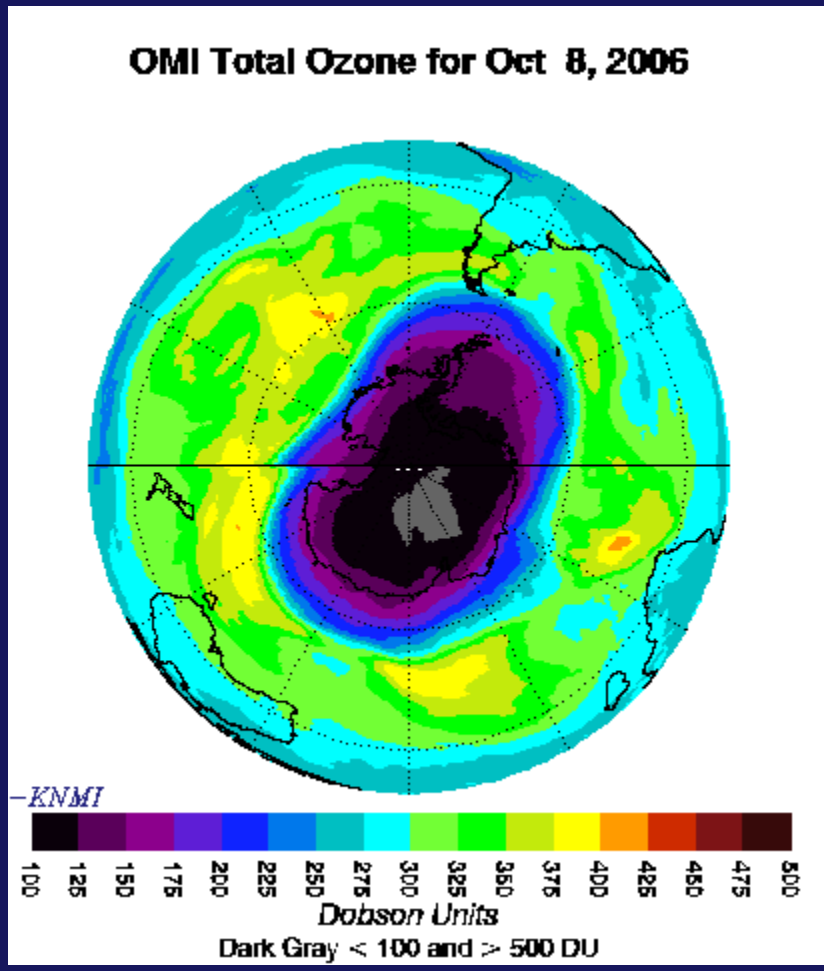
HOW DEEP DOES THE HOLE GET?

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!

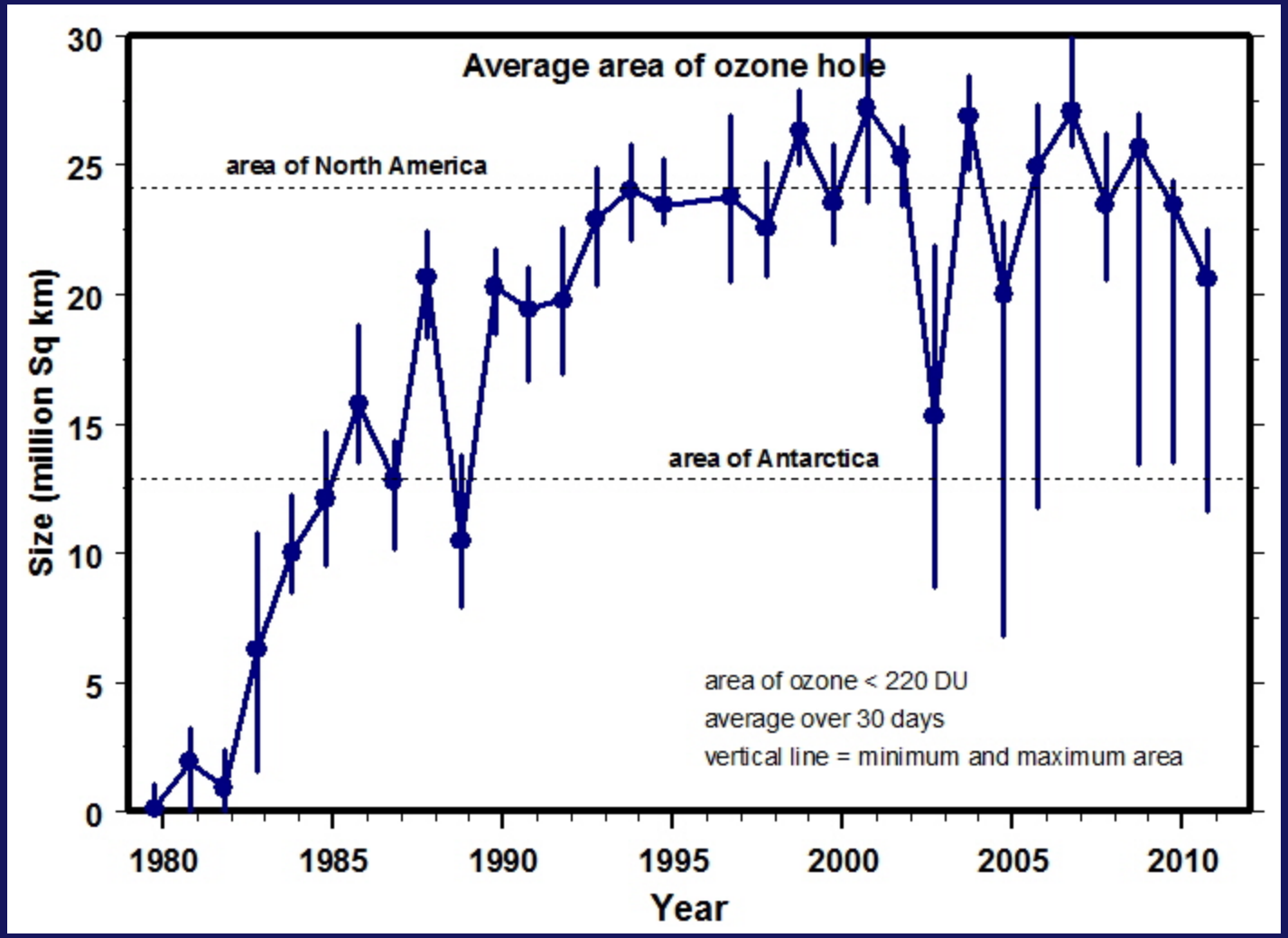
In this critical layer, the instrument measured a record low of only 1.2 DU!



2006 also saw the second LARGEST sustained ozone hole.

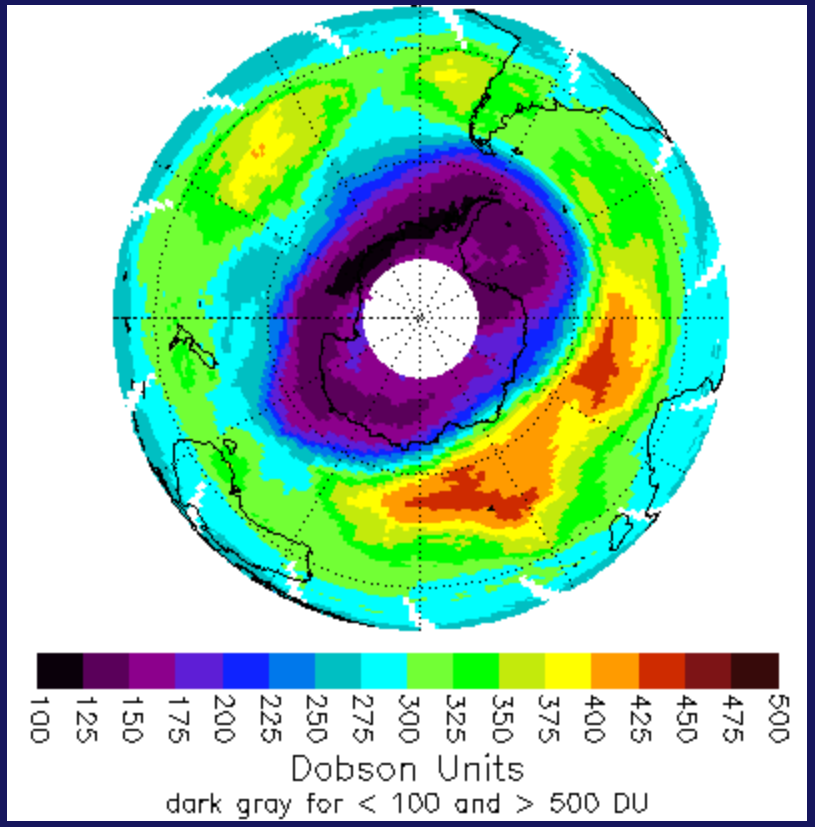
http://www.sciencedaily.com/releases/2006/10/061019162053.htm

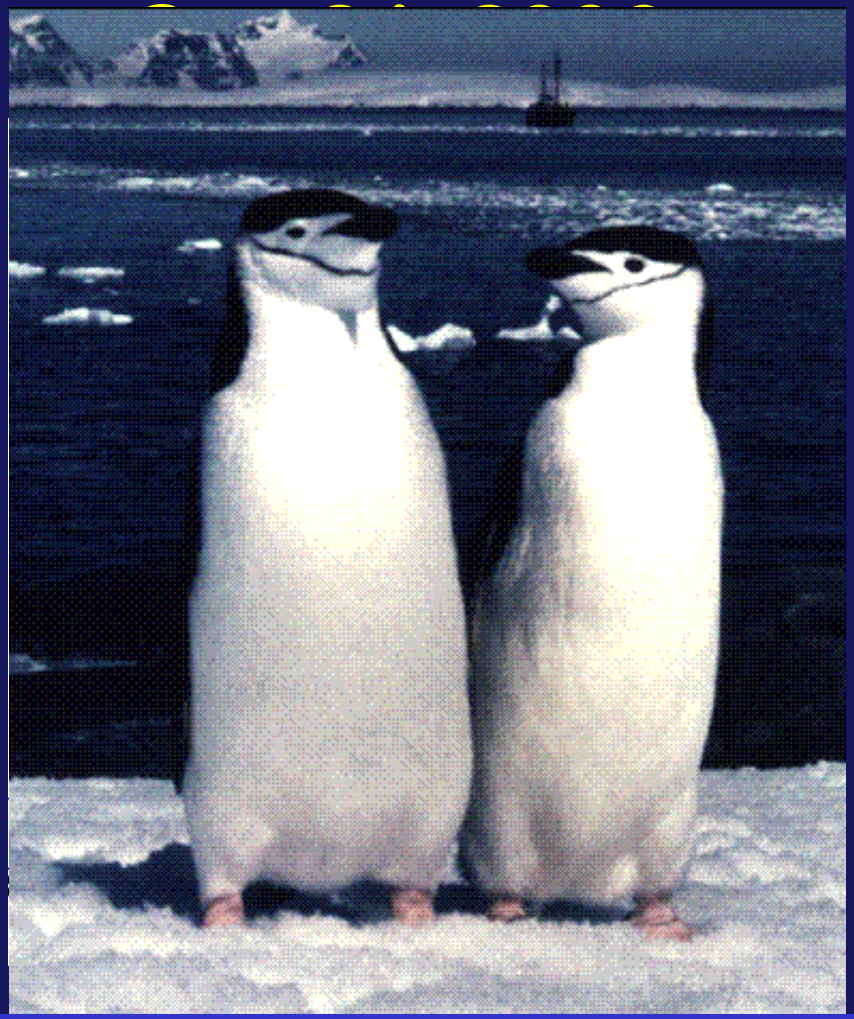
The AVERAGE SIZE OF THE HOLE has varied:



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 in 2000

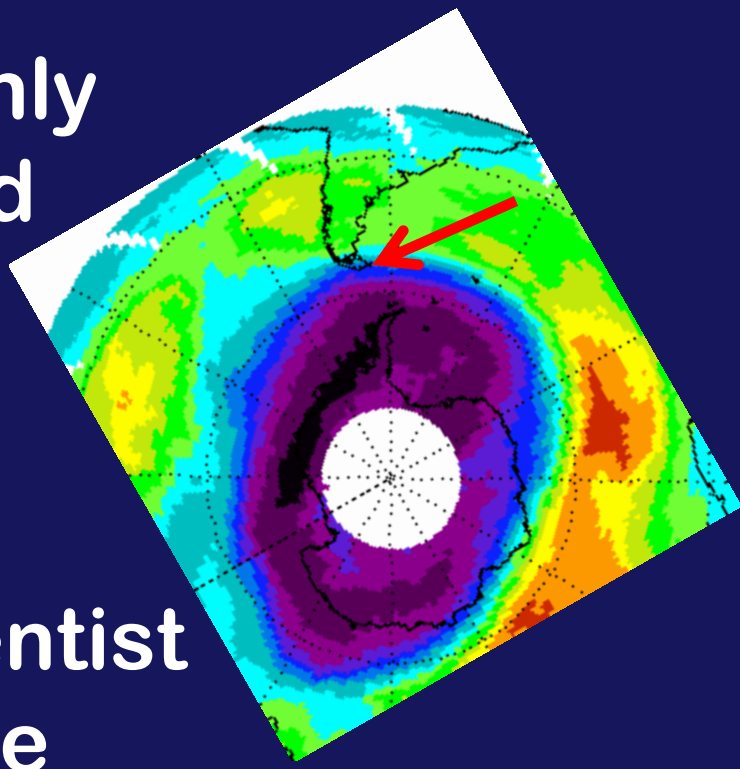
THE ASSOCIATED PRESS 10-6-00

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

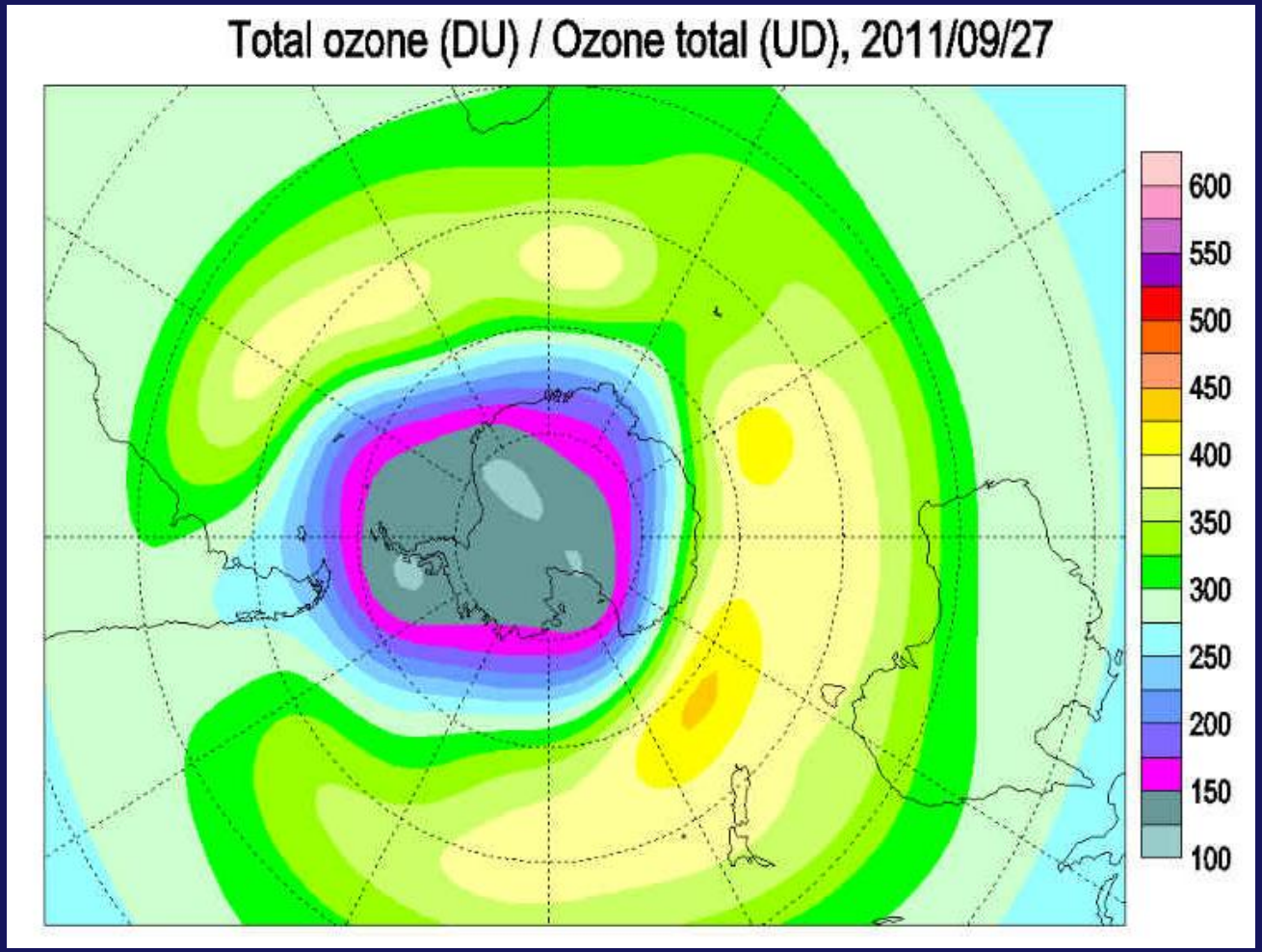
"For those two days, the hole extended over Punta Arenas, a southern Chilean city of about 120,000 people, exposing residents to very high levels of ultraviolet radiation.

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

This continues to happen!!!

The Ozone hole reached land and population areas in Argentina, Chile and The Falkland Islands on September 25-28 and October 16-19, 2011.

http://www.theozonehole.com/sa2011.htm



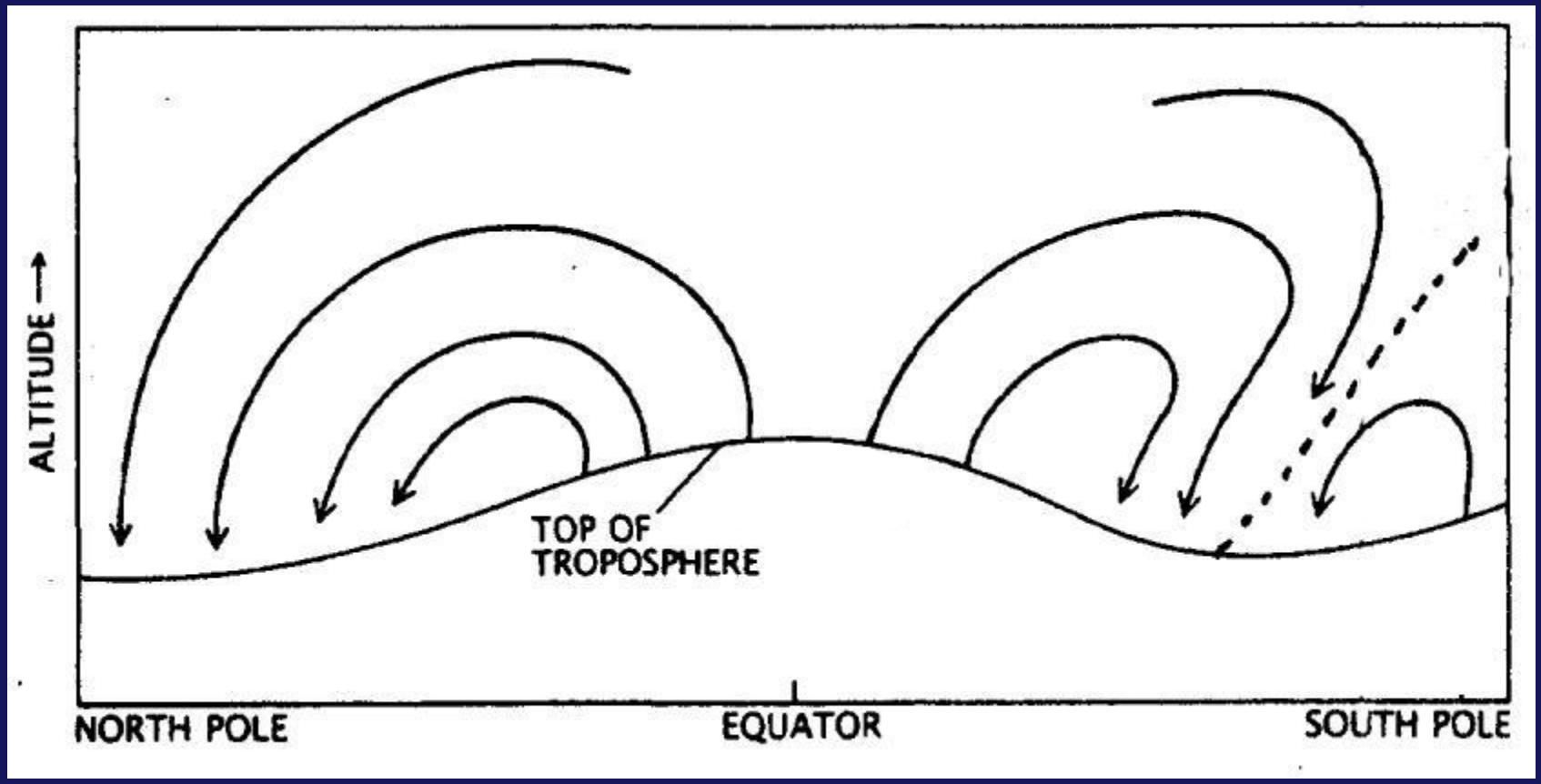
What about other parts of the globe?

> 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

Q3. Why do you think ozone production in the stratosphere is highest over the TROPICS?

1. Because of all the CFC's being produced there

2. Because of all the solar radiation received there

3. Because the tropics are far away from Antarctica

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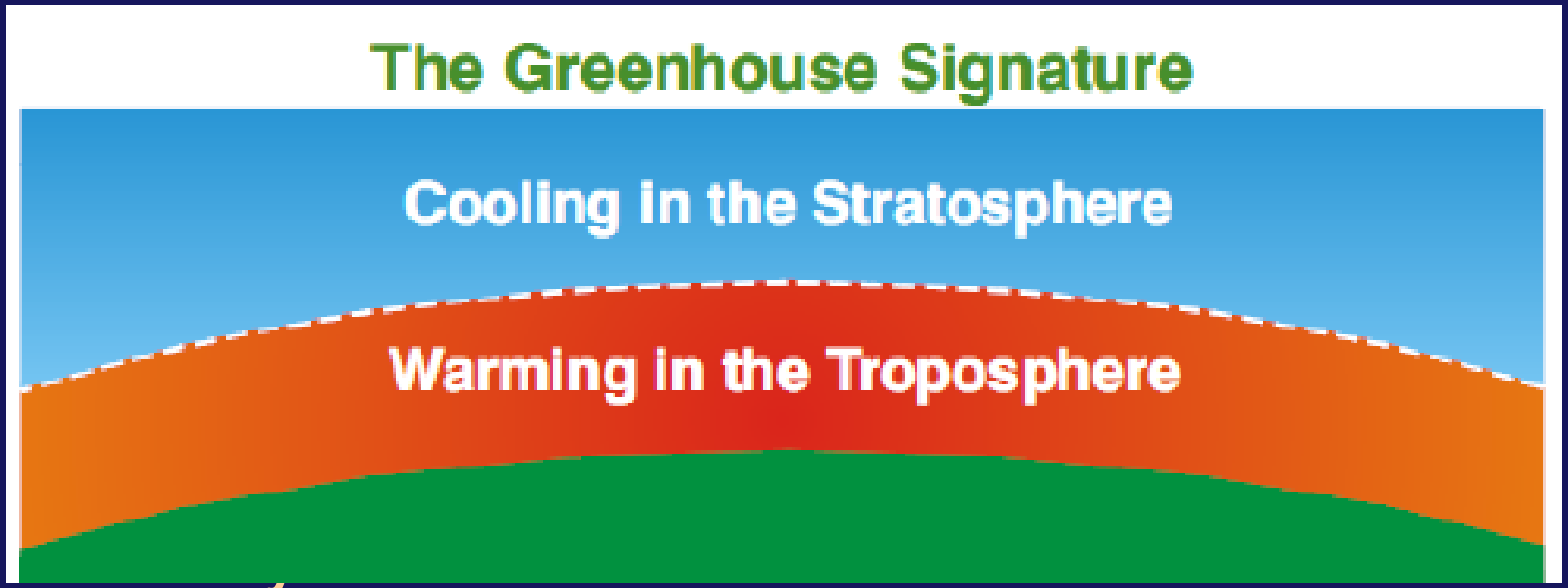
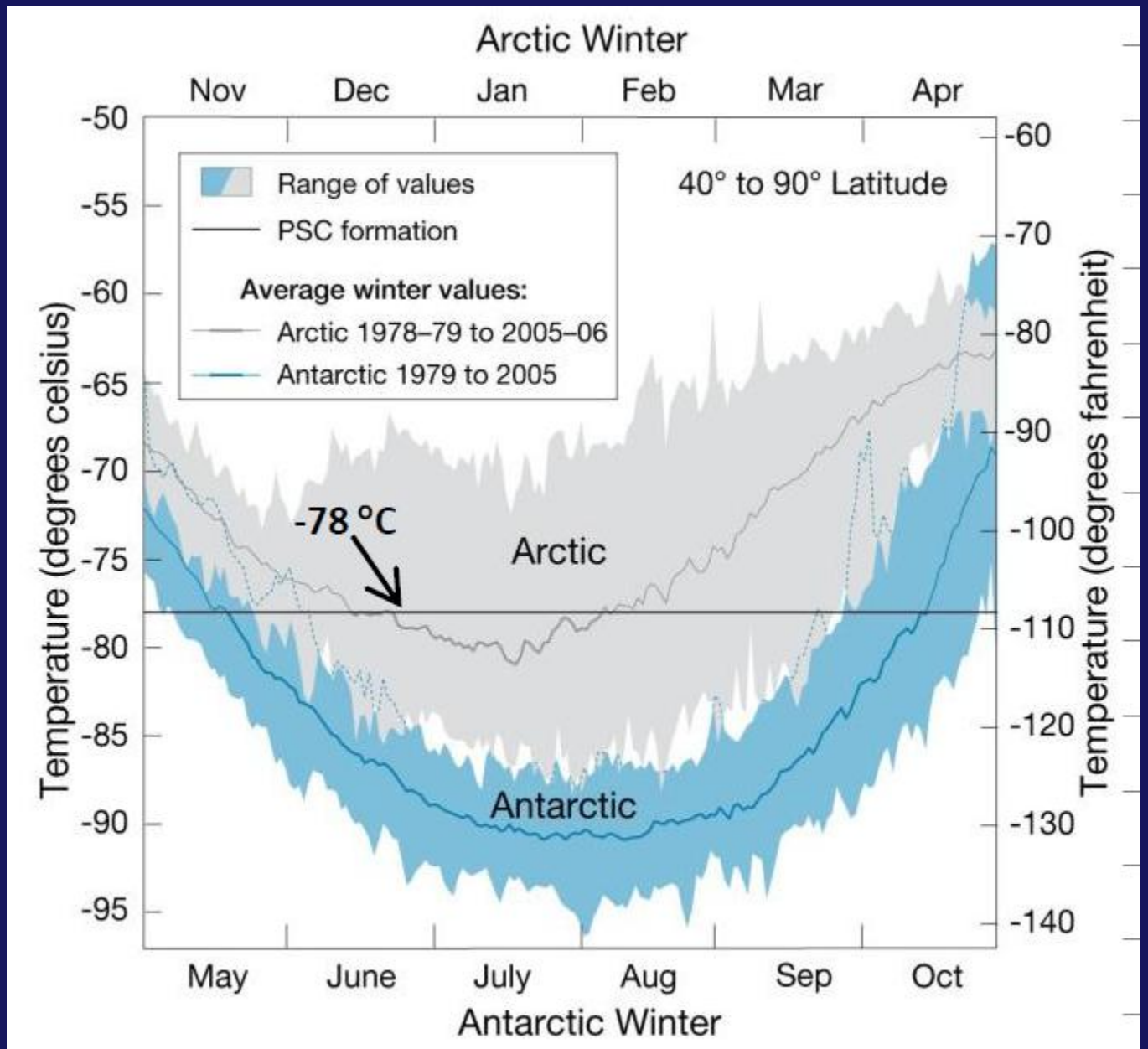
1. Because of all the CFC's being produced there
2. Because of all the solar radiation received there
3. Because the tropics are far away from Antarctica

Arctic ozone depletion also takes place!



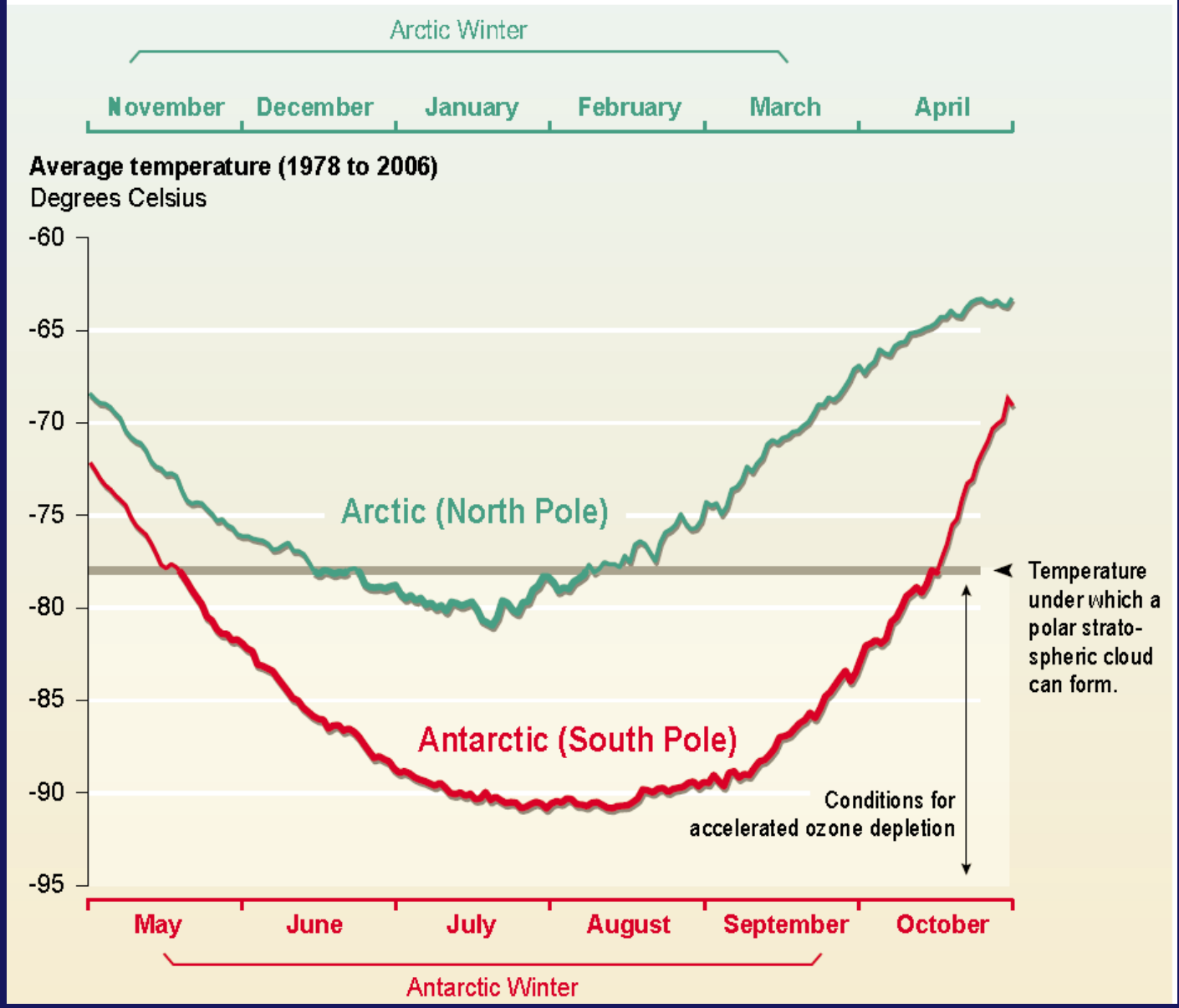
The likelihood of this happening seems inevitable based on the deterioration of ozone layer caused by the effects of global warming on the upper atmosphere."

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

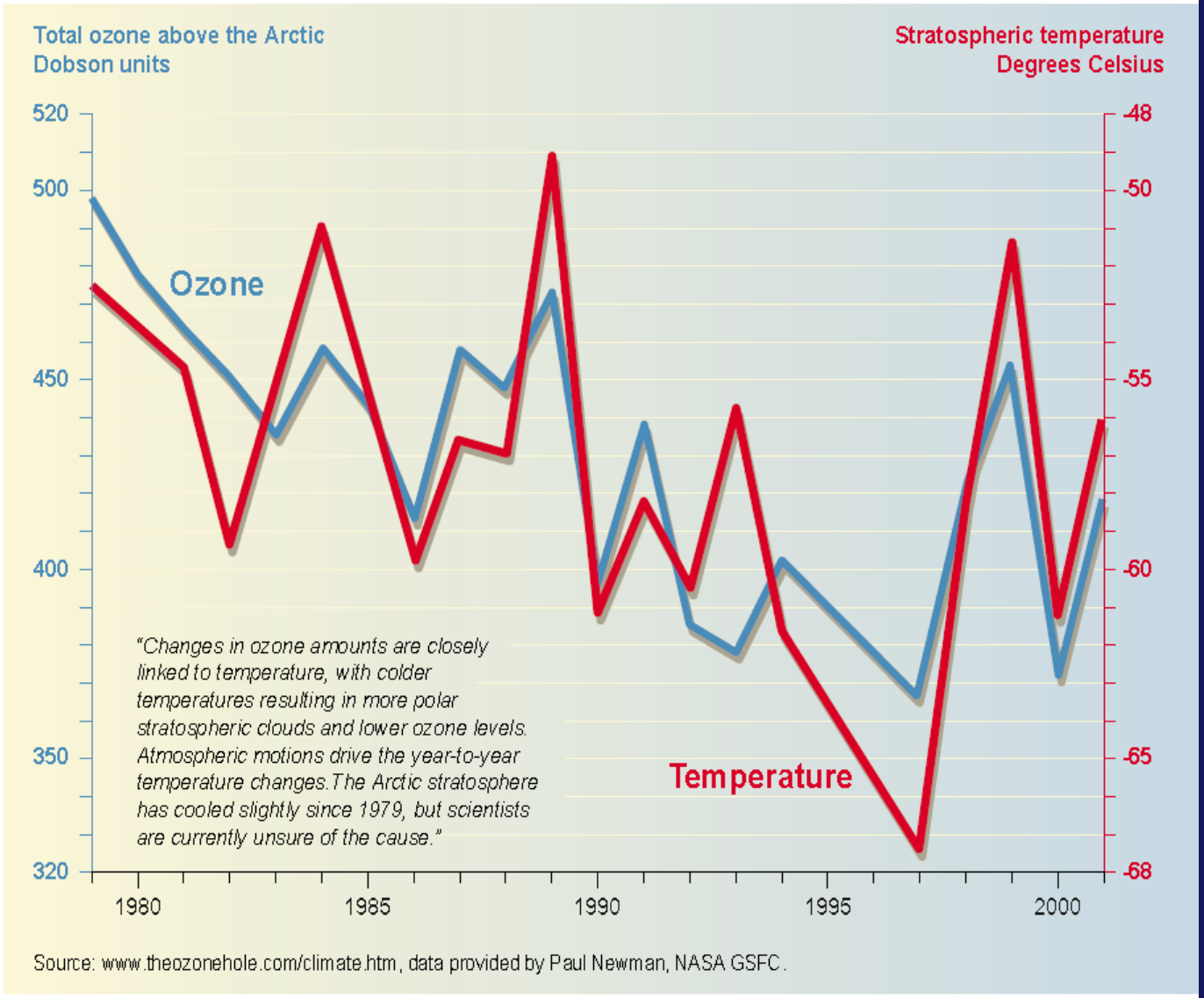


Minimum air temperature in the polar stratosphere over the Arctic (top) and Antarctic (bottom)

THE COLDER ANTARCTIC WINTER DRIVES FORMATION OF THE HOLE IN THE SOUTH

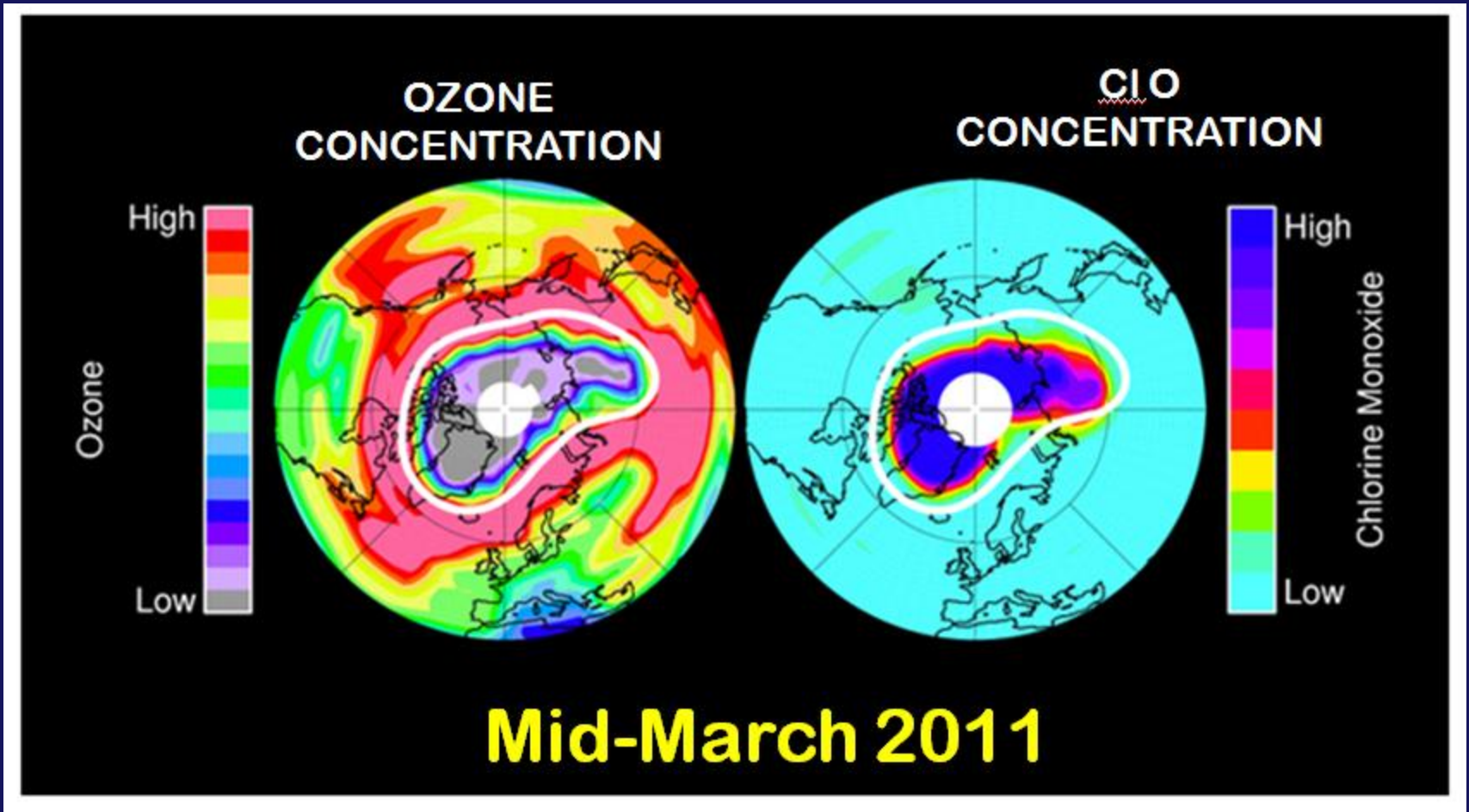


ARCTIC OZONE DEPLETION AND STRATOSPHERIC TEMPERATURE



This graph shows total ozone and stratospheric temperatures over the Arctic since 1979. Changes in ozone amounts closely follow temperature, with colder temperatures resulting in more polar stratospheric clouds that intensify ozone destruction. See also www.

2011: UNPRECEDENTED ARCTIC OZONE LOSS!



“ . . . comparable to that seen in some years in the Antarctic . . . .”

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.

Q4. What is important about the date SEPTEMBER 16th?

1- It's the date of the **SEPTEMBER EQUINOX**

2 – It's the date when scientists first discovered the **OZONE HOLE** (even though they didn't realize it!)

3 – It's an International Day in honor of the **OZONE LAYER**

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

Q5. The Antarctic Ozone Hole is predicted to keep getting larger for the next several years, then it should start decreasing in size. In what year is the hole expected to be back to 1980 levels?

1- 2018

2 - 2025

3 - 2050

4 - 2070

5 - 2090

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1- 2018

2 - 2025

3 - 2050

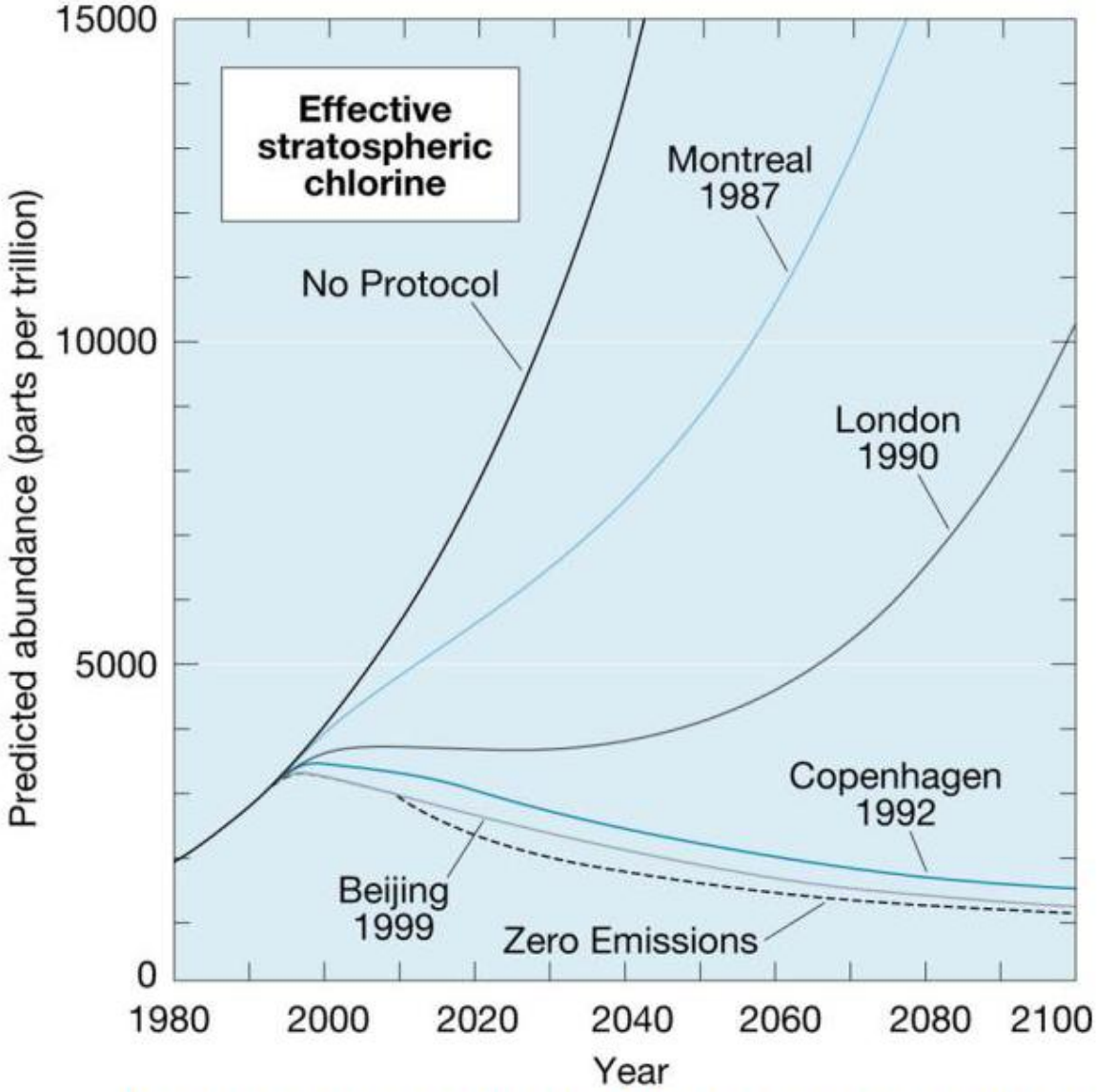
4 - 2070

5 - 2090

Why such a long recovery time??

Very long residence time of CFCs!

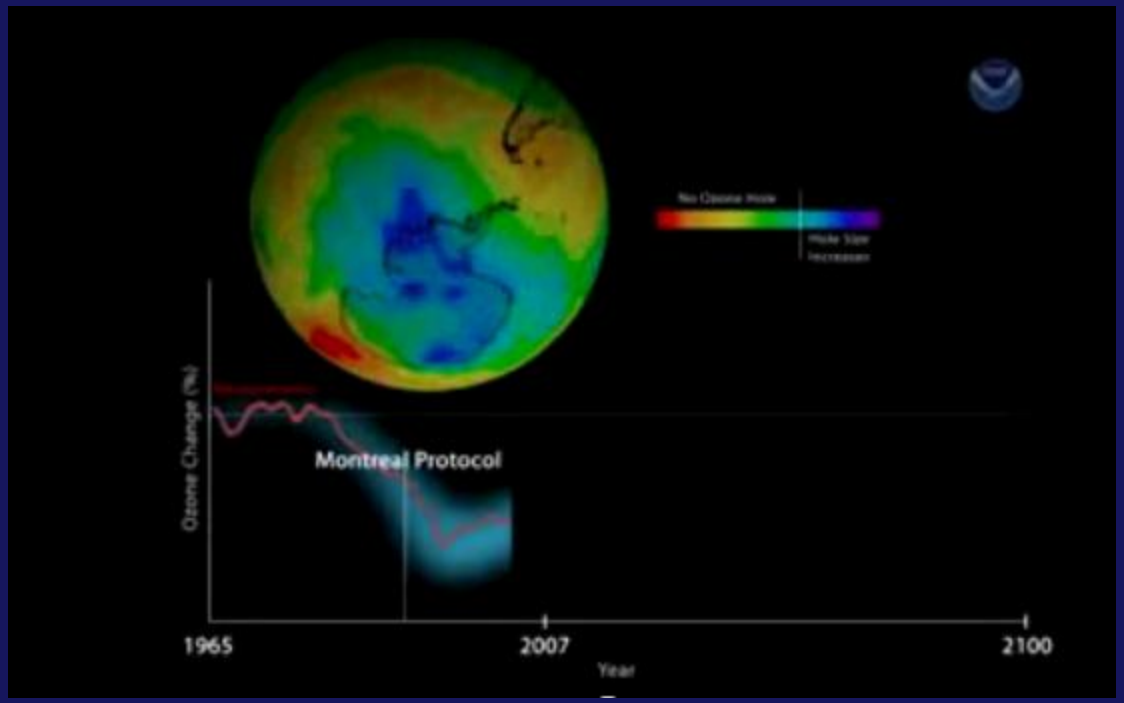
The world is "making do" with freon substitutes, but some concern over long-term effects of substitutes remains . . .



Projected atmospheric chlorine concentrations under the various international agreements

http://www.youtube.com/watch?v=Dn3KvZ_Xyqs&eurl=http://www.theozonehole.com/discoverer.htm

OZONE &
THE MONTREAL PROTOCOL

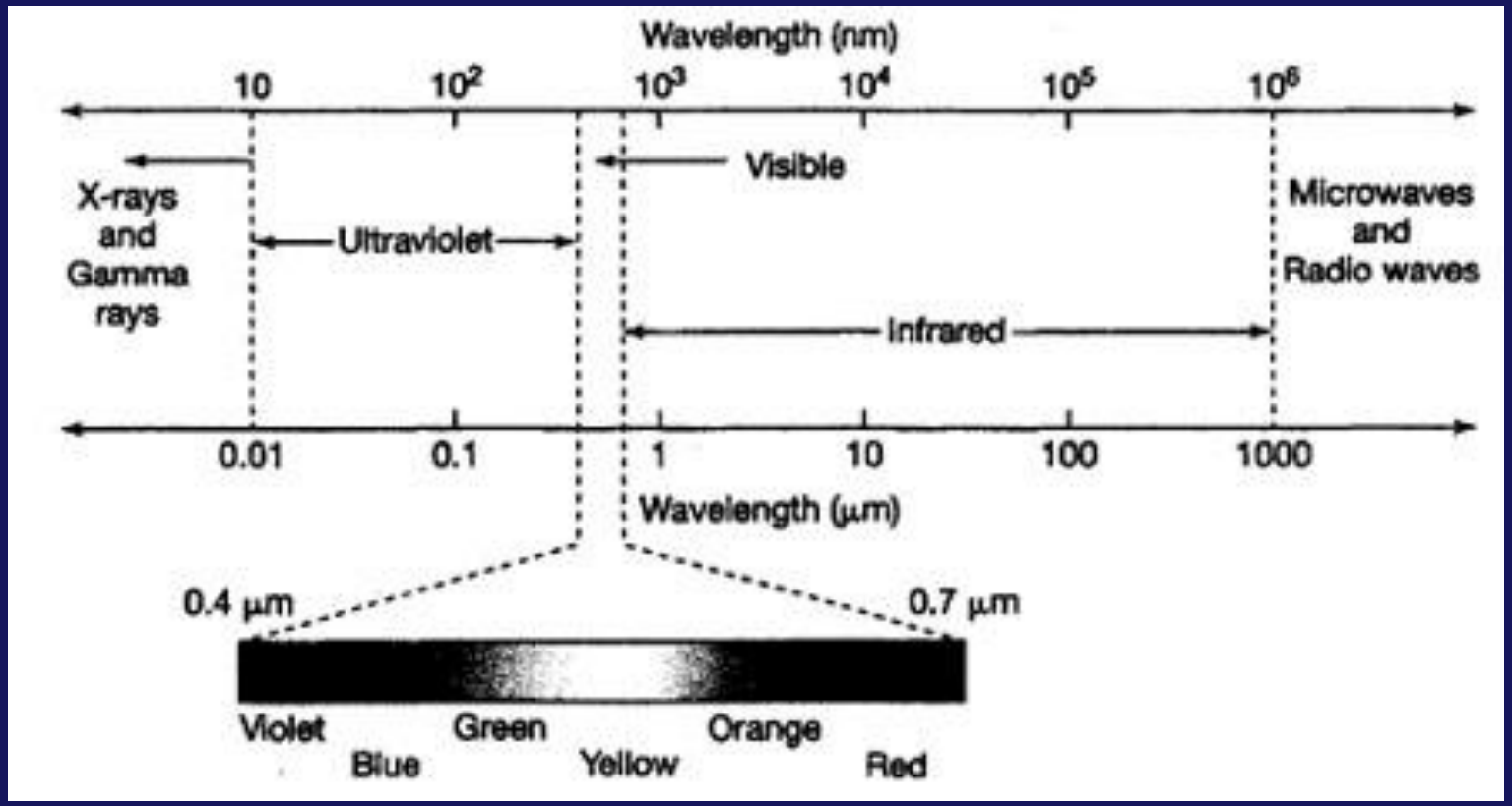


http://www.youtube.com/watch?v=Dn3KvZ_Xyqs&eurl=http://www.theozonehole.com/discoverer.htm

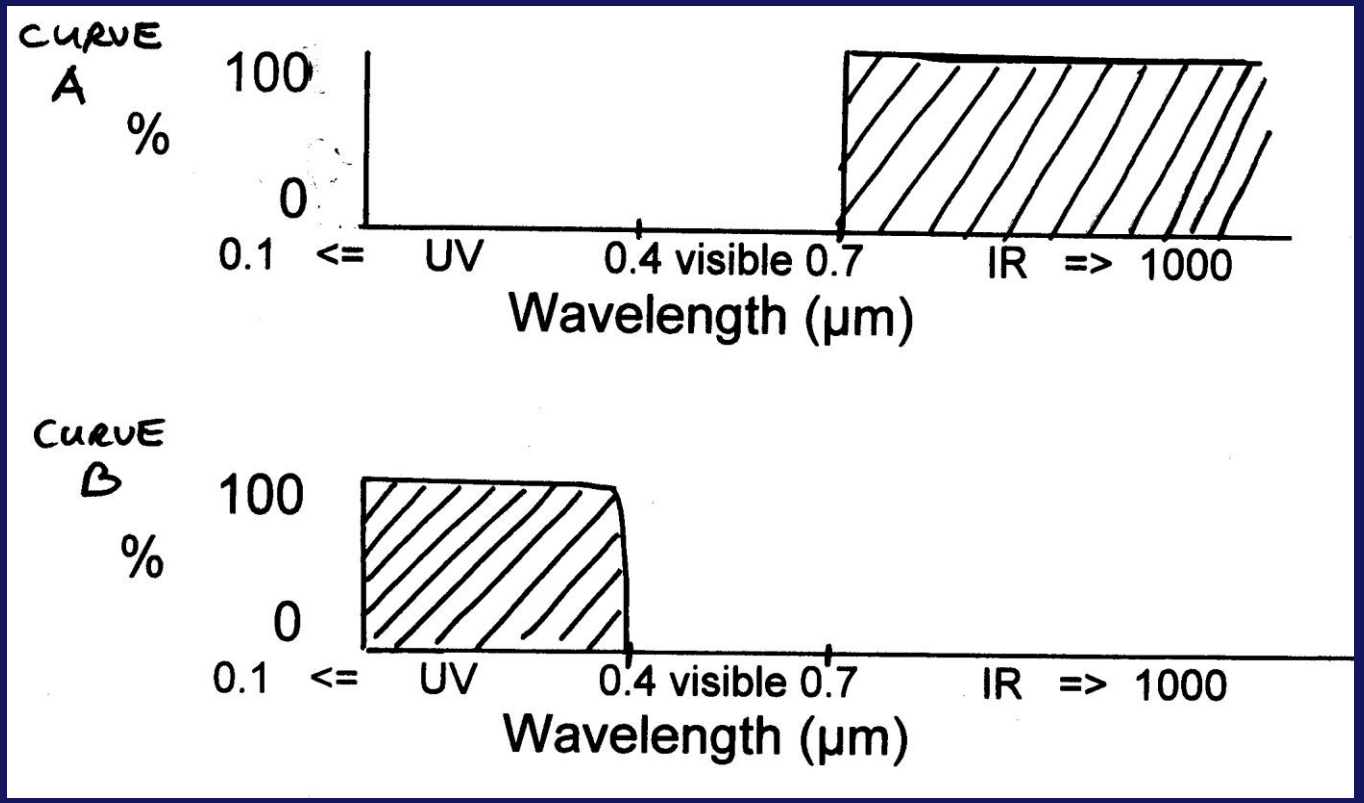
THE OZONE DEPLETION STORY TIES TOGETHER MANY OF THE CONCEPTS YOU'VE LEARNED IN THE COURSE THUS FAR:

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

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

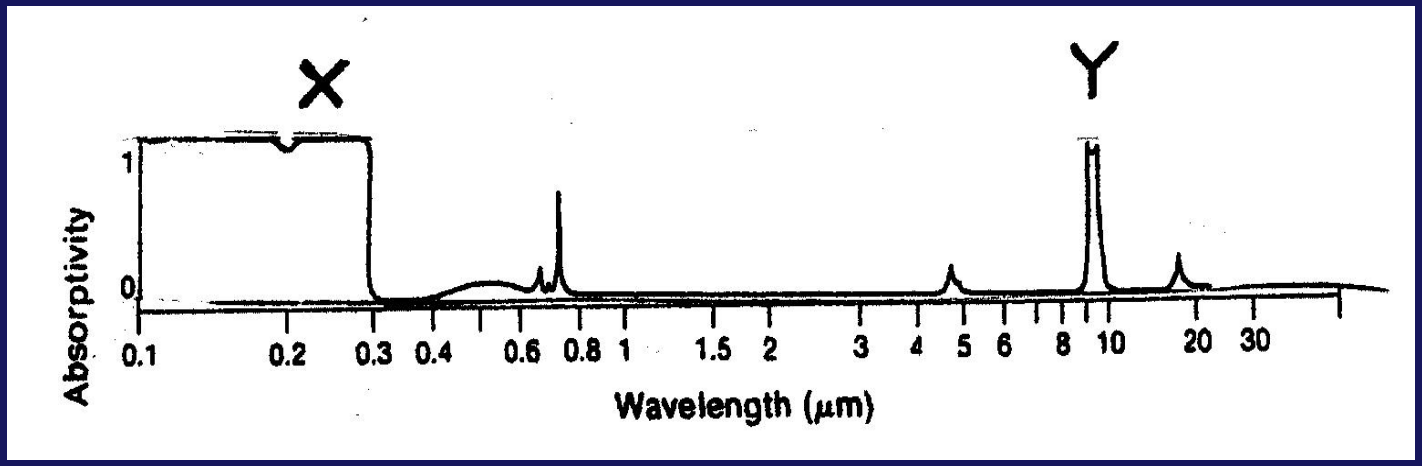


> absorption curves, especially the absorption curve for ozone

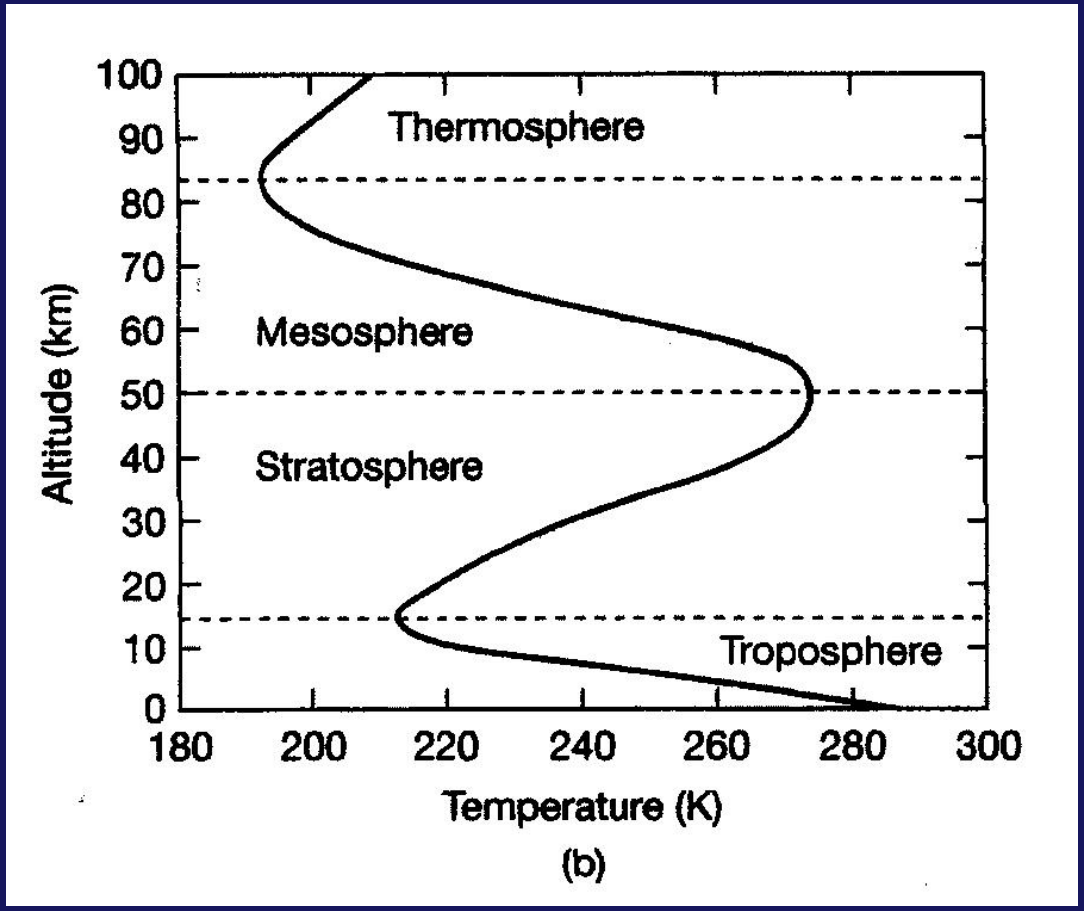


> Effect of clouds -- in this case the importance of Polar Stratospheric Clouds (PSCs)

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



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



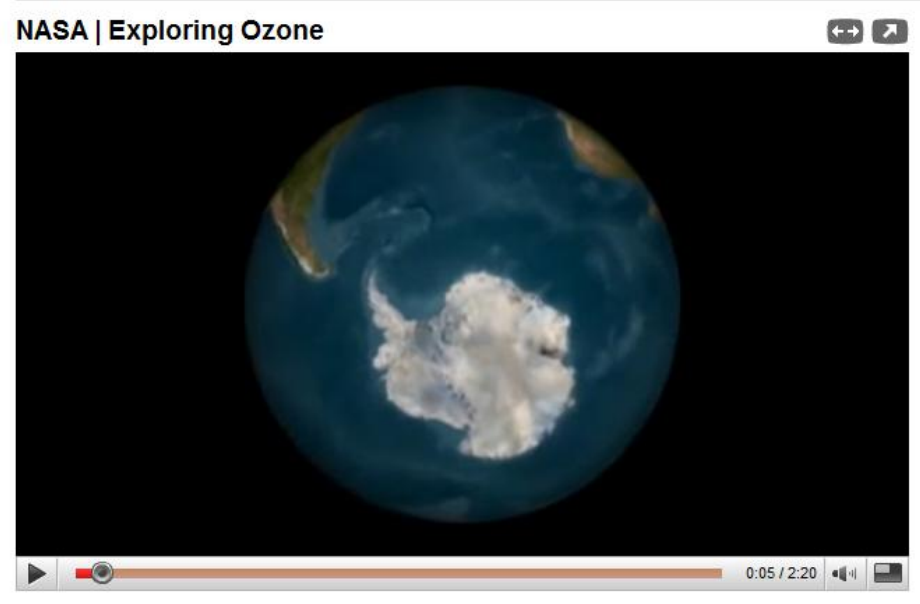
> the ever-changing nature of science; early theory right for wrong reason

> Preconceived ideas influencing one's observations

. . . and the surprise of discovery!

The Antarctic Ozone Hole -- From Discovery to Recovery, a Scientific Journey

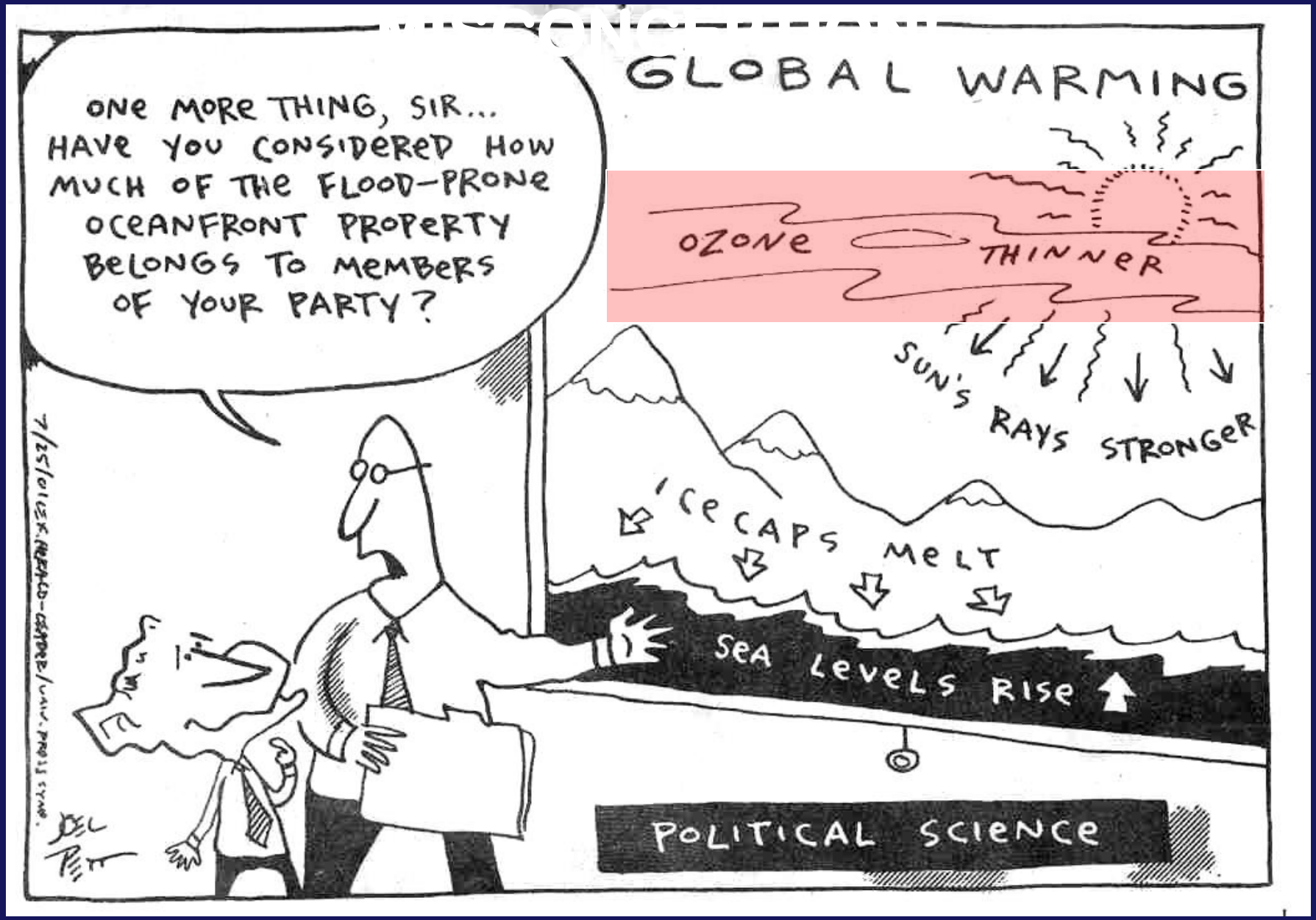
http://www.youtube.com/watch?v=AU0eNa4GrgU&feature=player_embedded#!



Ingredients Recap:

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

AN OZONE-RELATED CARTOON:



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

1 – YES
2 -- NO