OZONE DEPLETION IN THE STRATOSPHERE – Part III

A Story of Anthropogenic Disruption of a Natural Steady State

p 77-79 in Class Notes
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
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!!
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.
CONCLUSION:

ClO (chlorine monoxide) in hole region was

THE Evidence!

... showed that chemical reactions occurred in hole during time of greatest O₃ depletion
The EVIDENCE that SOLVED THE MYSTERY!

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

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**!

2006 also saw the second LARGEST sustained ozone hole.

http://www.sciencedaily.com/releases/2006/10/061019162053.htm
Here are some inhabitants with strong cause for concern about the Ozone Hole!
But what about the rest of us?
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
“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.
“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.

“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.

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

A woman and her child are bundled up against the sun
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** 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!
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 . . .
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.

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

Sketch in the 290 DU threshold line:

Estimate for when hole formation began: ~1969 -1970 ??
This year: 2012
(better than last year; was 2nd smallest in 20 years!)

Annual Ozone Hole Variations (since 1979)

HOLE AREA
Large area is bad!

OZONE Amount
Low amounts are bad!

see also:  http://macuv.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.”

http://www.theozonehole.com/arcticozone.htm
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 14th!