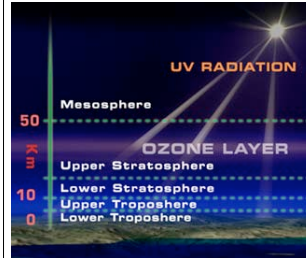


Atmospheric Problems

- | | |
|----------------------------|-------------|
| • Air Pollutants | Local |
| • Acid Rain | Regional |
| • Ozone Depletion | Hemispheric |
| • Warming & Climate Change | Global |

Ozone Depletion

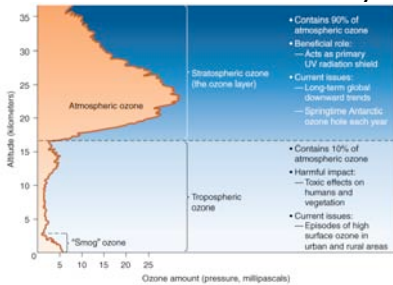
- Ozone depletion and the ozone hole are not in any way related to global warming



Stratospheric Ozone > Essential for Life

Tropospheric Ozone > Harmful

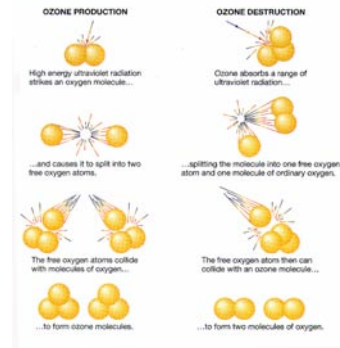
The Ozone Layer



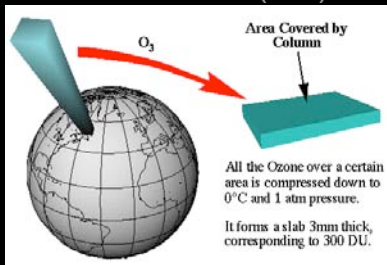
• 99% of UV is blocked by O₃

O₃ Production

- Long term: Net Production of O₃

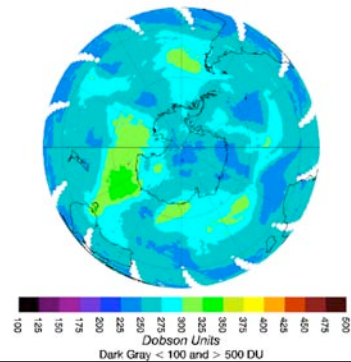


Dobson Unit (DU)



EP/TOMS Version 8 Total Ozone for Mar 5, 2005

Average values
300 +/- 50 DU



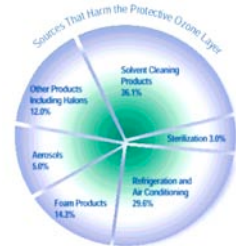
Chlorofluorocarbons (CFC's)

- Developed in the 1930's (Freon)
- Nontoxic and nonflammable and can be readily converted from a liquid to a gas and vice versa (unstable)
- Have been used extensively as aerosol-spray propellants (Freon-11), refrigerants (Freon-12), solvents, & foam-blowing agents



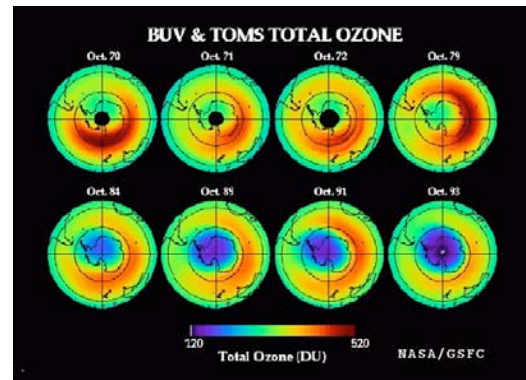
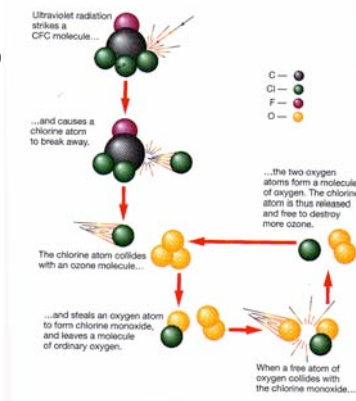
Ozone Depleting Chemicals

- CFC's
- HCFC's
- Halons (bromide) used in fire extinguishers
- Methyl Bromide (pesticide)
- Although used in smaller quantities, bromides are more effective in destroying O_3



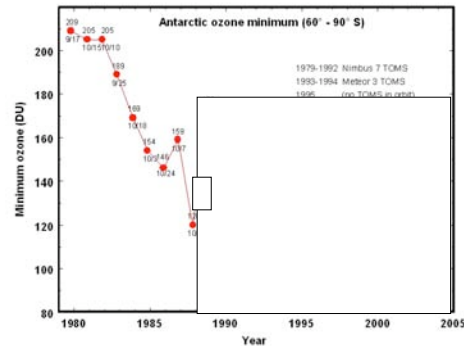
Ozone Destruction

- For this to occur, CL needs a surface for reaction

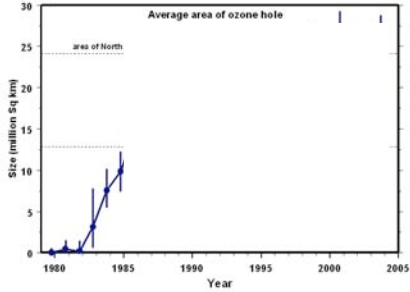


The Ozone Hole

- Beginning in the early 80's satellites began observing a significant drop in ozone levels every:
- Sept/Oct over Antarctica (Spring)
- March/April over the Arctic (Spring)
- Levels much more diminished over Antarctica



- Hole is defined as < 220 DU



Questions

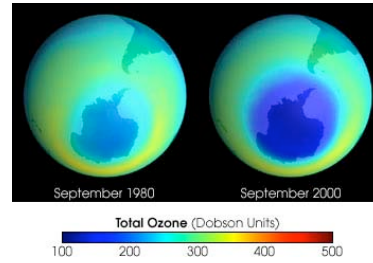
- What was the cause?
- Why in the polar regions?
- Why in the spring months?
- Why more depletion in the S. Hemi.?
- Why was the depletion getting more severe each year?
- Could we stop the depletion?

- 1987 Researchers find CL in the Antarctic stratosphere
- 1994 Researchers find HF in the Antarctic stratosphere
- There is no natural sources of atmospheric FI
- Only one possible source of Cl & FI > human-made CFC's

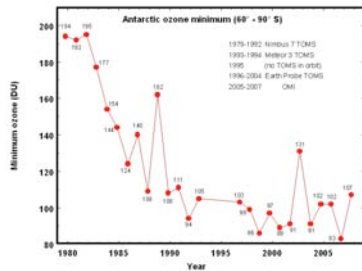
Science once again proves Rush is an idiot!



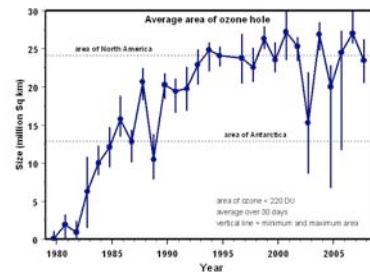
Ozone Hole 1980 to 2000



Ozone minimum



Ozone hole size



Polar Stratospheric Clouds

- Clouds do not normally form in the stratosphere due to its extreme dryness.
- During winter at high latitudes, however, stratospheric temperature sometimes becomes low enough (-80°C) to promote formation of clouds.

Polar Stratospheric Clouds

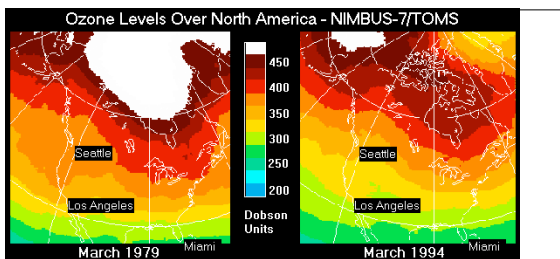
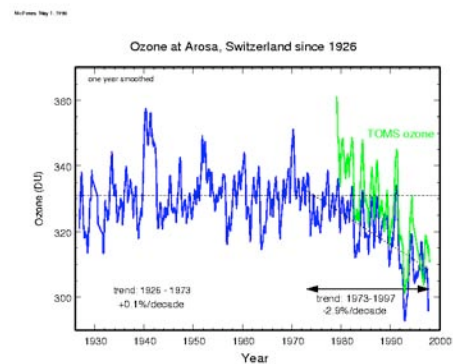
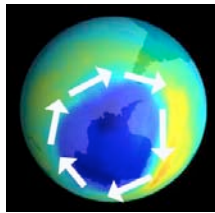
- Provide a surface which converts benign forms of chlorine into reactive, ozone-destroying forms
- During the winter months, polar regions receive no sunlight, becomes cold enough to form Polar Strat. Clouds.
- During spring sunlight hits the polar stratosphere, the UV radiation is the energy source for the ozone destruction reactions.

Why more depletion over Antarctica?

- 1) Antarctic colder
- 2) Stronger, longer lasting

Polar Vortex

- Strong (> 150 mph) band of winds circulating the poles.
- Does not allow mixing of O_3 depleted air with other air for months.



- 1 % decrease in $\text{O}_3 \gg$
- 2% increase in UV \gg
- 4% increase in skin cancer rates
- UV also causes cataracts, harms the immune system.

UV Rays

- UVA - Most reaches Earth's surface $>$ tanning, skin aging
- UVB - Controlled by O_3 concentrations $>$ sunburns, skin cancers and damage

Effects

- Terrestrial Ecosystems - UV reduces plant growth and crop yields.
- Aquatic Ecosystems- UV harms phytoplankton at the base of the food chain.
- Human Health - immune system, cataracts

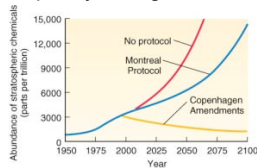
United States

- > 1/2 of all new cancer is skin cancer
- > one half million cases per year - 100,000 cases are melanoma
- Cases of melanoma have tripled since 1980
- One person dies of melanoma each hour
- One in four Americans will develop skin cancer

What was Done? Montreal Protocol

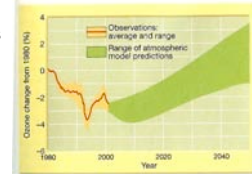
- 1978 - Freon-11 banned as spray can aerosol, Freon-12 the coolant, refrigerant & blowing agent not affected.
- 1980's - additional scientific evidence & observations indicated growing damage to the ozone layer
- 1987 - 24 countries sign the Montreal Protocol. Agree to cut CFC's 50% by 2000 and immediately stop production of halons.
- Problem - slowed, not stopped the rate of destruction.
- 1988 - Ozone loss reaches record rate. Two weeks later DuPont, the leading producer of CFC's calls for a global ban on CFC production

- 1990 - Montreal Protocol amended so developed countries stop CFC production by 2000, developing by 2010. Also will begin phase out of HCFC's and methyl bromide. Signed by 93 nations.
- 1992 - 2000 changed to 1996
- One of our greatest success stories, scientific knowledge was used to avert a potential global disaster. Showed how quickly changes can be made.

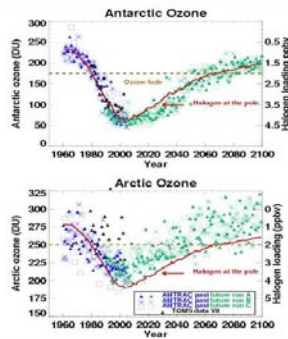


Problems

- CL can reside for 100 years in stratosphere
- Millions of tons of CFC's reside in the stratosphere
- Some O₃ destroying chemicals will not be phased out for decades.
- Some countries still producing/smuggling CFC's
- CFC's exist in old equipment
- Global population growth is driving more halocarbon production
- Has slowed O₃ destruction, not stopped it. Ozone layer will continue to thin for decades.



- Minimum O₃ between 2000 - 2010
- Antarctic ozone recovers ~2065
- Arctic ozone recovery is slower and more uncertain



Summary - Ozone

- How is chlorine so destructive to ozone?
- What proof is there that Cl in the stratosphere came from anthropogenic sources?
- Why does an ozone "hole" appear in the poles? In the Spring?
- What factors lead to a "hole" over Antarctica but not the Arctic?
- What are the trends in the Northern Hemi? Why is this important?
- What was the Montreal Protocol, what were its successes? weaknesses?
- What problems exist that is slowing ozone recovery?