



## Background

- @ Where is the ozone "layer"?
- @ What is its purpose?
- @ What do scientists say is happening to it?
  - Supporting evidence:
    - 1979→1994, 4% ozone loss globally
- @ Why care?

|   |  |   |   |
|---|--|---|---|
| CFCs and other chlorine-containing compounds and halons | Chlorine and bromine atoms in stratosphere | Ozone depletion with severe seasonal depletion at poles | More UV reaches earth   |
| Model 1   | Model 2                                    | Model 3   |   |
|   |  |   | Serious health effects<br>Lower crop yields<br>More smog<br>Possible changes in climate |

## Causes of Ozone Depletion

- @ Primary cause?
  - Discovered?
  - A.k.a.?
  - Benefits?
  - Uses?
  - Can be released by burning?

## How do CFCs deplete ozone?

- CFCs stable, move from troposphere to stratosphere
- UV breaks off chlorine molecule (Cl) from CFC
- Cl acts as a catalyst to break down ozone (O<sub>3</sub>)
  - catalyst - promotes a chemical reaction without itself being used up in the reaction
  - shifts equilibrium of oxygen / ozone reaction:

$$O_2 \rightleftharpoons O_3$$

Ultraviolet light hits a chlorofluorocarbon (CFC) molecule, such as CFC<sub>2</sub>, breaking off a chlorine atom and leaving CFC<sub>2</sub>.

Once free, the chlorine atom is off to attack another ozone molecule and begin the cycle again.

The chlorine atom attacks an ozone (O<sub>3</sub>) molecule, pulling an oxygen atom off it and leaving an oxygen molecule (O<sub>2</sub>).

A free oxygen atom pulls the oxygen atom off the chlorine monoxide molecule to form O<sub>2</sub>.

The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule (ClO).

The chlorine monoxide molecule reacts with another ozone molecule, pulling an oxygen atom off it and leaving an oxygen molecule (O<sub>2</sub>).

The chlorine atom and the oxygen atom join to form a chlorine monoxide molecule (ClO).

Summary of Reactions:  
 $CCl_2F + UV \rightarrow Cl + CCl_2F$   
 $Cl + O_3 \rightarrow ClO + O_2$  (repeated many times)  
 $Cl + O - Cl + O_2$

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### STRATOSPHERIC OZONE FORMATION AND DESTRUCTION

Enhanced chlorine cycle: O<sub>3</sub> loss

O<sub>3</sub> Transport

High-Latitude Ozone Loss

N. Polar Stratospheric Clouds

North Pole

60° N

Tropopause

Stratosphere

Troposphere

Equator

Equator

60° S

South Pole

Cl Reservoirs

Polar Stratospheric Clouds

Enhanced chlorine cycle: O<sub>3</sub> loss is accelerated, "hole" results

Ultraviolet radiation from the Sun

O<sub>3</sub> Production

CFCs

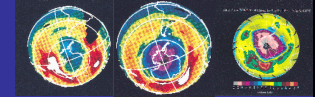
CFCs react with UV and release chlorine, which can react with ozone to produce chlorine monoxide (ClO). This results in midlatitude ozone loss. Other atmospheric gases react with chlorine and chlorine monoxide to form Cl reservoirs, which are usually inert.

## Other O.D.C.s

| Br Compounds | Cl Compounds |
|--------------|--------------|
|              |              |

## Antarctic Seasonal Thinning

- @Not conventional wisdom
- @40-50% loss of ozone over Antarctica during their spring and early summer (Sept. – Dec)
- @The process?



1. Winter – polar vortex forms
  - Winds blow circularly around pole
  - Isolated from rest of atmosphere
2. Water forms ice crystals in vortex
3. Crystals collect CFCs on surface
  - Also speeds up release of Cl & ClO
4. ClOs combine → Cl<sub>2</sub>O<sub>2</sub>
  - Not reactive ... no sun
5. Accumulates in vortex
6. In spring, more sunlight... breaks up stored Cl<sub>2</sub>O<sub>2</sub> releasing lots of Cl atoms
7. Cl atoms deplete the ozone!

## Other side effects...

Vortex breaks up in spring

Ozone depleted air flows northward

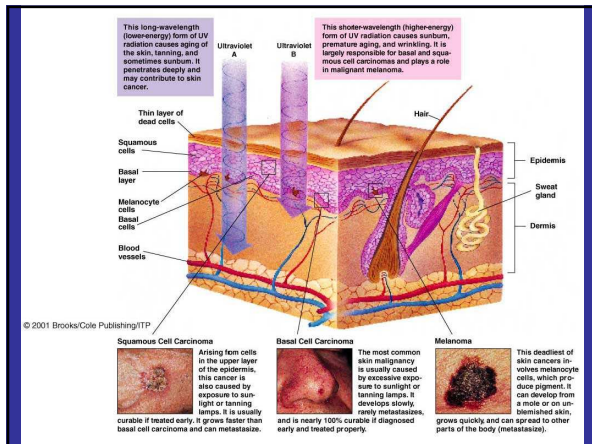
Lingers over Australia, New Zealand, S. America, S. Africa

Heightened risk of sun/UV damage

## U.V. Exposure Issues

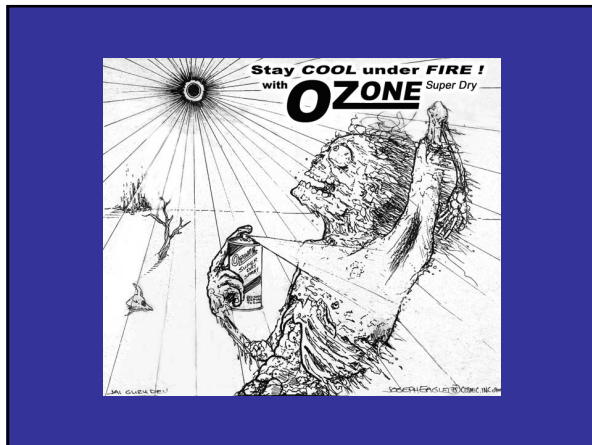


1. Skin Cancer
2. Immune system suppression
3. ↑ smog & acid deposition
4. ↓ crop yields
5. ↓ forest productivity (trees UV-B sensitive)
6. ↑ materials deterioration
7. ↓ phytoplankton productivity
8. General ecosystem damage



# Solutions

- @ CFC substitutes (p. 525)
- @ **Montreal Protocol**
  - 1987
  - 36 nation treaty
  - Cut CFC emissions 35% by 2000
  - Continued to meet ('90,'92,'97) to discuss other ODCs
  - Hopeful, but not all nations enforced



<http://www.epa.gov/ozone/>