Ozone Depletion and the Ozone Hole Preview:

- Stratospheric sunscreen, tropospheric pollutant
- 60's & 70's theories suggested depletion mechanisms
- 1985 discovery of ozone was a big surprise
- Lead to increased research effort
- Chlorine and PSC hypothesized as cause
- Lead to international restrictions and bans
- 80's & 90's ozone hole continued to expand and mid-latitude loss continues
- Present: growth slowed although 2003 was big
- Chlorine concentrations stabilizing, CFC's eliminated
Ozone as natural sunscreen
Average TOMS Ozone 1978 – 1993

Average Ozone Column 1978-1993
Stratospheric Ozone: Brief Historical Perspective

- 1881: Hartley first hypothesized the presence of ozone (lab)
- 1924: Dobson invented spectrophotometer of measure ozone
- 1929: Gotz using Dobson's instrument found that ozone was in the stratosphere (~25 km)
- 1930: Chapman developed theory of stratospheric ozone origin
- 1949: Brewer, role of circulation in controlling ozone layer
- Catalytic cycles: Hydrogen (Hunt, 1966); NOx from tropospheric N2O (Crutzen, 1970); NOx from aircraft (Johnston, 1971); CFCs (Molina & Rowland, 1974)
- 1985: Farman discovers the ozone hole over Antarctica
- 1986: Solomon/McElroy unravel the role of polar stratospheric clouds and halogen catalysis

Jeagle, 2004
Measurements made by balloon ozonesondes before and after intense depletion.
October average ozone concentrations

70, 71, 72, 79 Avg.

92, 93, 94, 95 Avg.

Percent difference

Total DU

% Diff.
Polar Stratospheric Cloud Surface Reaction

1. HCl and CINO\textsubscript{2} collect on PSC

2. HCl and CINO\textsubscript{2} react on PSC to form Cl\textsubscript{2} and HNO\textsubscript{3}

3. Cl\textsubscript{2} comes off PSC, while HNO\textsubscript{3} remains on PSC to settle out of stratosphere.

3. Cl\textsubscript{2} is photolyzed by visible wavelengths, and begins catalytic reaction.

\[ \text{Cl}_2 + \text{HNO}_3 \rightarrow \text{Cl}_2 \text{HNO}_3 \]
Polar Stratospheric Clouds

Type I PSC:
- Nitric acid trihydrate (HNO₃ - 3•H₂O)
- Ternary solution (H₂O, H₂SO₄, HNO₃)
- Formation Temp: 195 K
- Particle diameter: 1μm
- Altitudes: 10-24 km
- Settling rates: 1km/30 days

Type II PSC:
- Water Ice
- Formation Temp: 188 K
- Particle diameter: > 10 μm
- Altitudes: 10-24 km
- Settling rates: > 1.5 km/day

Type II PSC cloud

Heterogeneous reactions take place on PSCs, releasing chlorine from HCl and ClONO₂ into reactive forms (ClO) that can rapidly destroy ozone.

PSC over Norway, January 1989, taken from the NASA DC-8
“wonder gas” CFCs were invented in 1928

1928 CFCs

1. non-toxic, non-corrosive, non-flammable, versatile, long life wonder gases!

Use of CFCs increases rapidly

1974 CFC Use (970 Million Kg)

- Refrigerants: 18%
- Cleaning Agents: 6%
- Blowing Agents: 5%
- Other: 2%
- Propellants: 69%
1970-1994: rapid increase in CFC-11 atmospheric levels

CFC-11 production rate


1994-today: CFC-11 is decreasing
Simultaneous observations of ClO and HCl inside polar vortex (Arctic 1993) → ClO increases and HCl decrease inside the polar vortex.

Ozone Hole Observations

• Begins to develop in August, fully developed by early October, broken up in early December.

• First began to appear in the early 1980’s.

• Compared to 1970’s, 60% reduction of ozone over Antarctica in early October.

• 100% loss of ozone in the 12–20 km region over Antarctica, some ozone remains both above 20 and below 12 km.

• Ozone hole covers approximately 22 million km² (slightly less than the surface area of the N. American continent).

• Ozone hole associated with cold Antarctic stratospheric temperatures.
Regulations on the production of CFCs

- **Vienna convention (1985):** Convention for the Protection of the ozone layer. Signed by 20 nations (research, future protocols)
- **London Amendment (1990):** Phaseout of production by 2000 for developed nations and by 2010 for developing nations
- **Copenhagen Agreement (1992):** Phaseout for developed nations by 1996.
The Montreal Protocol is Working!

Without the Montreal Protocol, ozone depletion in 2050 would be at least 50% at midlatitudes in the Northern Hemisphere and 70% at midlatitudes in the Southern Hemisphere, about 10 times larger than today.

Surface UV-B radiation in 2050 would at least double at midlatitudes in the Northern Hemisphere and quadruple at midlatitudes in the Southern Hemisphere compared with an unperturbed atmosphere. This compares to the current increases of 5% and 8% in the Northern and Southern Hemispheres, respectively, since 1980.

WMO 1998 Scientific Assessment of Ozone Depletion