Introduction to the Ozone Layer
Why Do We Care About Atmospheric Ozone?

- Sun emits a broad spectrum of colors.
- Stratospheric ozone absorbs UV radiation < 300 nm, which is harmful to life.
- Anthropogenic influence decreases stratospheric ozone both globally and locally (ozone hole). The largest effect comes from CFCs (chlorofluorocarbons).

Malignant Melanoma from UV overexposure

![UV image of the Sun](image)

![Malignant Melanoma from UV overexposure](image)

**FIGURE 13.15** Normalized action spectra taking response = 1.0 at 300 nm (adapted from Madronich, 1992).
"Good Ozone": Stratospheric Ozone Layer

Concern: Massive disappearance of ozone over the South Pole during Antarctic Springs. Does it play a role in the global ozone budget?

Ozone Layer Benefit: Very little UV radiation with $\lambda<300$ nm reaches the Earth surface.
"Bad Ozone": Tropospheric Smog

LA smog in the forties

Plant damage

LA smog today

Health effects
Global Ozone Measurements from Space

Nimbus-4 satellite carried the first TOMS (Total Ozone Mapping Spectrometer) onboard
Until recently the Earth Probe TOMS (Total Ozone Mapping Spectrometer) was the only NASA spacecraft in orbit specializing in ozone retrieval. The Aura spacecraft launched in 2004 has a novel Ozone Monitoring Instrument (OMI) onboard. Just in time – TOMS died in 2006.
Earth Observing System (EOS) Aura is a NASA mission to study the Earth's ozone, air quality and climate. Aura Satellite Launched Successfully on July 15, 2004 from Vandenberg Air Force Base, CA.
Ozone and Air Quality Website

Global Ozone Maps Generated Daily!

EP/TOMS Total Ozone Nov 15, 2005

GSFC/613.3

dark gray for < 100 and > 500 DU
Ground Based Measurements of Ozone
TOMS Total Ozone Monthly Averages

South Pole Ozone Hole Evolution
Ozone Hole
North Pole: Ozone Hole Observed Only in the Coldest Years
Global Mean Stratospheric Ozone

Stratospheric ozone depletion is not limited to the polar regions; the effect is also detectable on a global scale!
CFCs Destroy Ozone Catalytically!

Chapman cycle:
\[ \text{O}_2 + \text{hv} \rightarrow 2\text{O} \]
\[ \text{O} + \text{O}_2 \rightarrow \text{O}_3 \]
\[ \text{O}_3 + \text{hv} \rightarrow \text{O} + \text{O}_2 \]

Perturbation by CFCs:
\[ \text{CF}_2\text{Cl}_2 + \text{hv} \rightarrow \text{Cl} + \text{CF}_2\text{Cl} \]
\[ \text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2 \]
\[ \text{ClO} + \text{O}_3 \rightarrow \text{Cl} + \text{O}_2 \]

![ER-2](image)

**FIGURE 1.8** Measured concentrations of the chlorine monoxide free radical (ClO) as well as O₃ outside and inside the polar vortex on August 23, 1987 (adapted from Anderson, 1989).
In the absence of industrial halocarbon production, the natural background for stratospheric chlorine (CH$_3$Cl production in surface ocean) would be ~ 500 pptv.

In their famous 1973 paper, Roland and Molina (UCI) pointed out that the photolysis of freons (CF$_2$Cl$_2$ – CFC-12 - and CFCl$_3$ - CFC-11) in the upper stratosphere is the major source of stratospheric chlorine. This process (photolysis in the stratosphere) is the only known loss mechanism for most of the fully halogenated alkanes.
CFC Control Strategies

CFC control agreements:

- **Montreal protocol** (1987): Reduce/freeze production of CFCs and halons* (not enough!)
- **London amendments** (1990): Completely eliminate CFCs, halons, CCl₄ by 2000; CH₃CCl₃ by 2005
- **Copenhagen amendments** (1992): Eliminate CFCs, halons, CCl₄, CH₃CCl₃ by 1996; freeze CH₃Br
- **Vienna amendments** (1995): Freeze HCFCs, and eliminate them in 2020; eliminate CH₃Br in 2010

* Halons are similar to CFCs but they contain bromine; HCFCs contain some remaining H atoms.