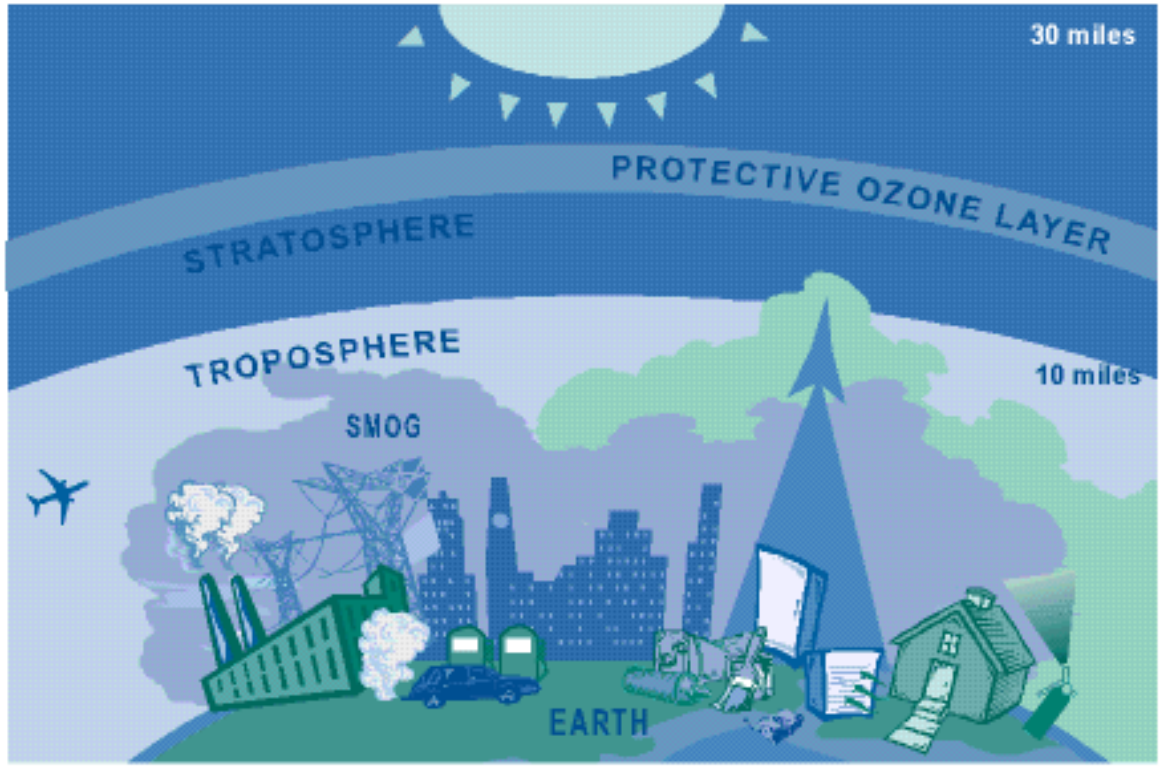
Ozone Layer Depletion

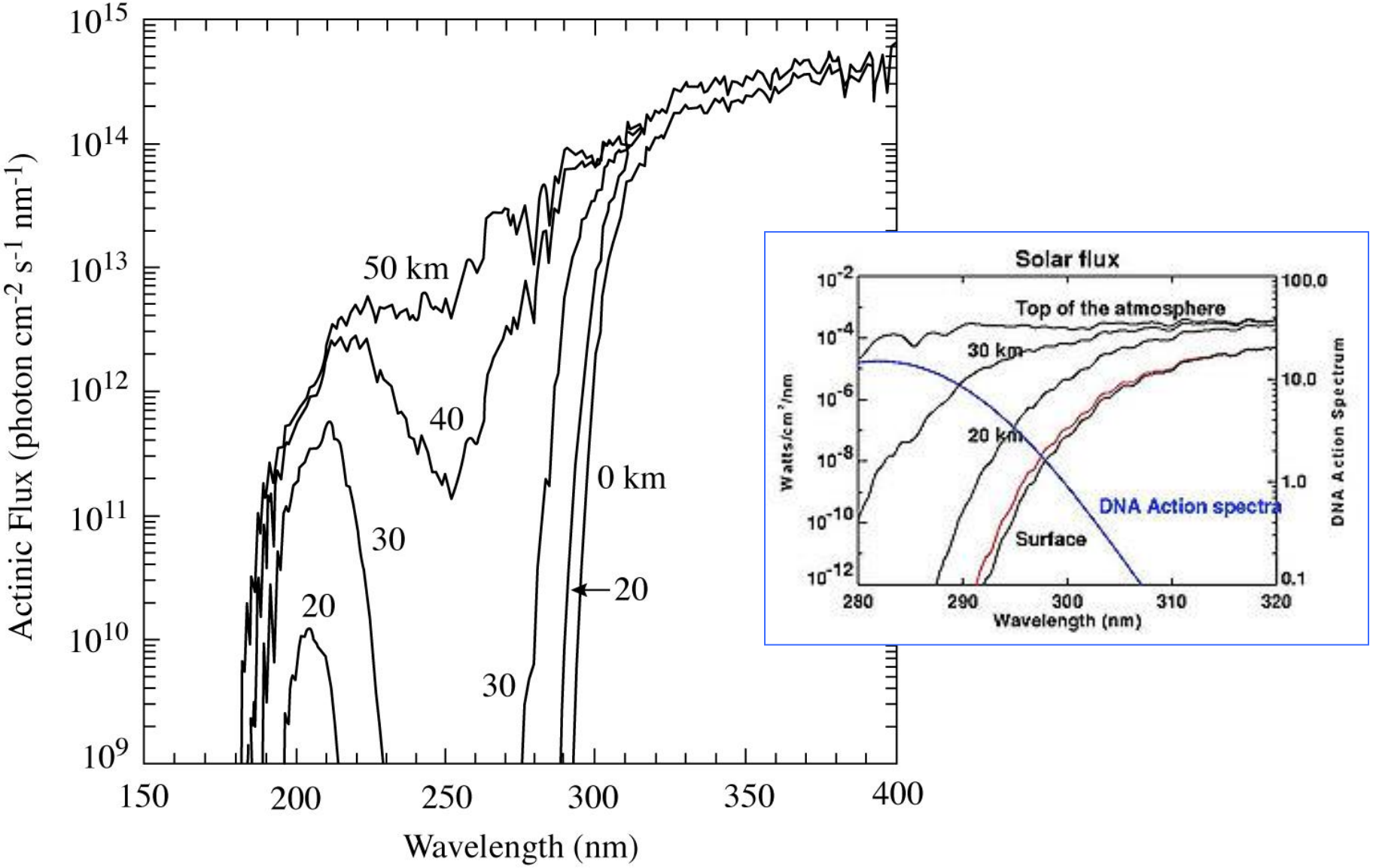
Stratospheric ozone and its importance

– The 'hole' story

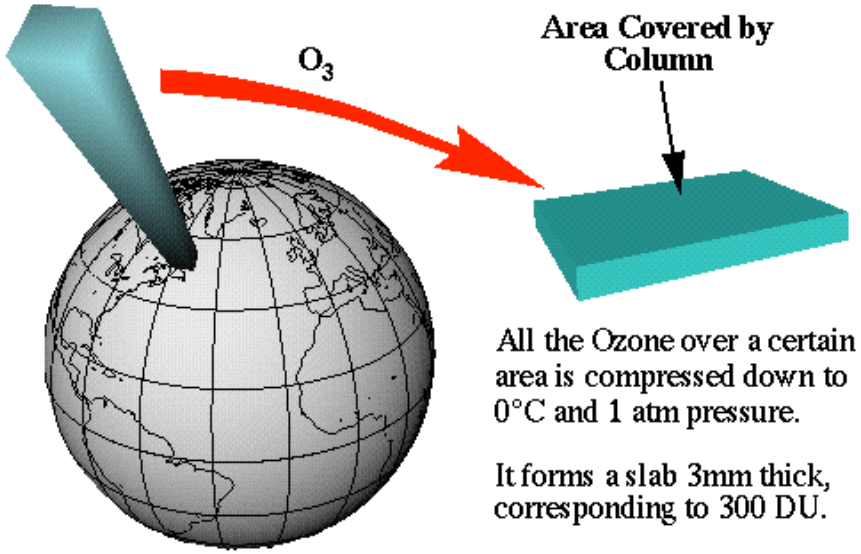


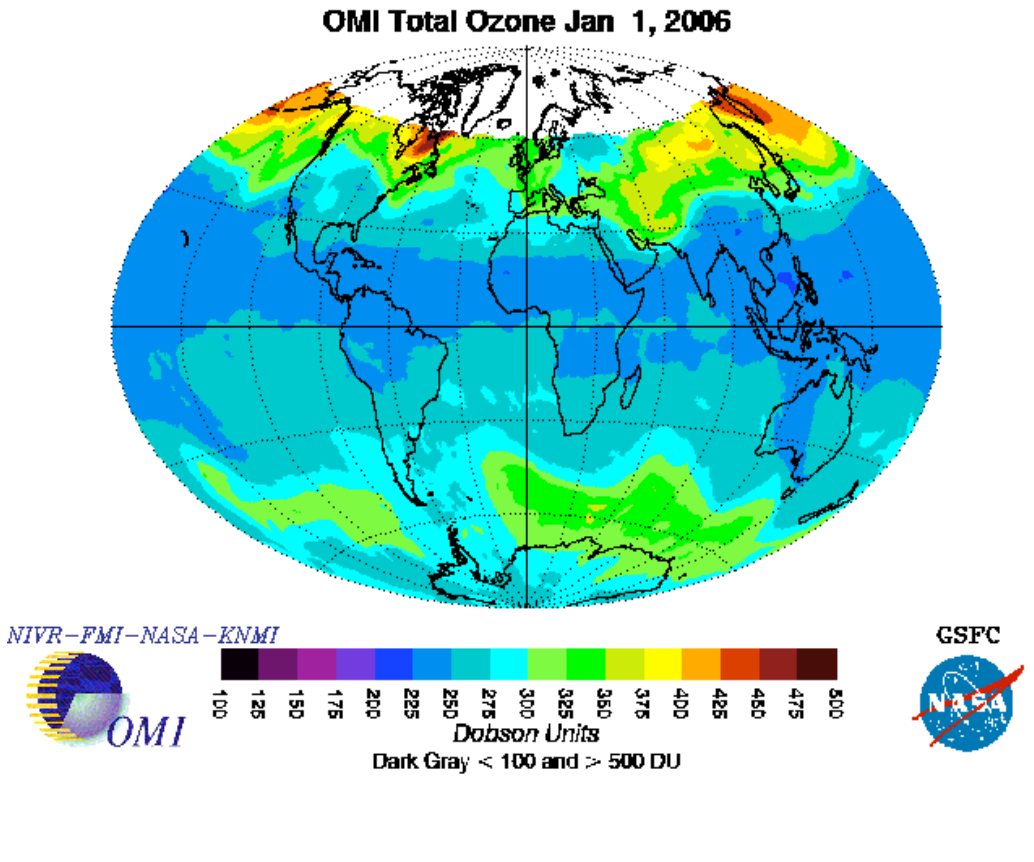
Atmospheric attenuation of SR

Solar UV radiation reaching the top of the atmosphere is absorbed by ozone



Dobson Unit





1 Dobson Unit (DU) is defined to be 0.01 mm thickness at stp; the ozone layer over Labrador is ~300 DU.

Mean ratio, column O_3: air = 5 x 10^{-7}

Ozone in Stratosphere:
Dobson Units (DU)

If 100 DU of ozone were brought to the Earth's surface, it would form a layer 1 millimeter thick. In the tropics, ozone levels are typically between 250 and 300 DU year-round. In temperate regions, seasonal variations can produce large swings in ozone levels. For instance, measurements in Leningrad have recorded ozone levels as high as 475 DU and as low as 300 DU.

The Ultraviolet Spectrum

- **UV light: 100 to 400 nm**

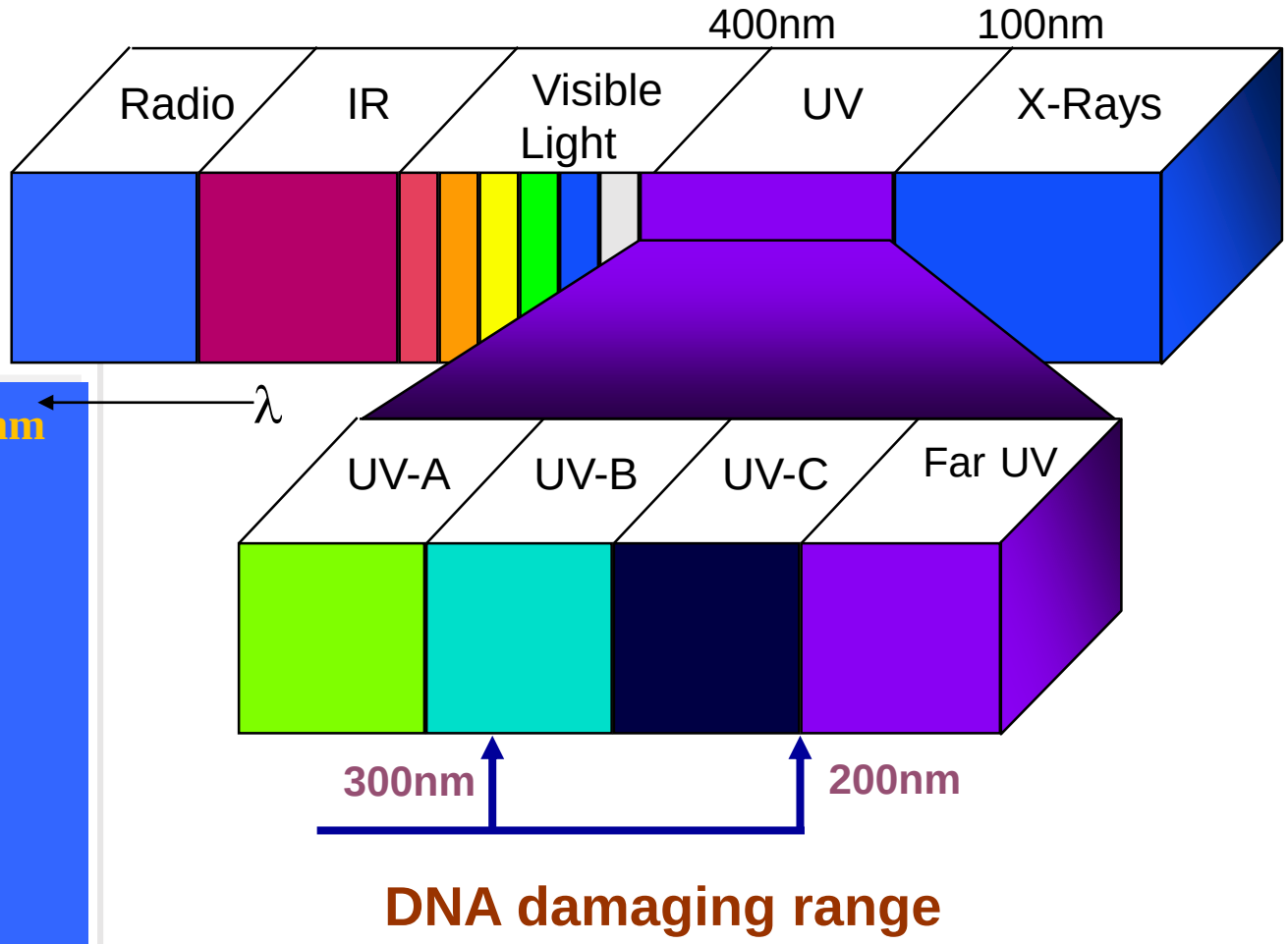
UV spectrum – 4 regions

o Far UV: 100 – 200 nm

o UV – C : 200 – 280 nm

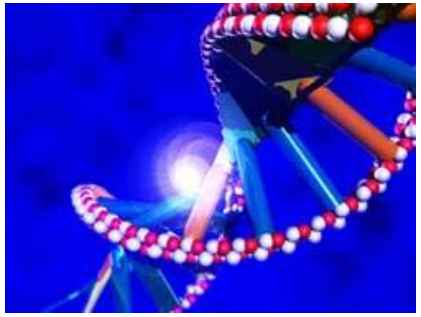
o UV – B : 280 – 315 nm

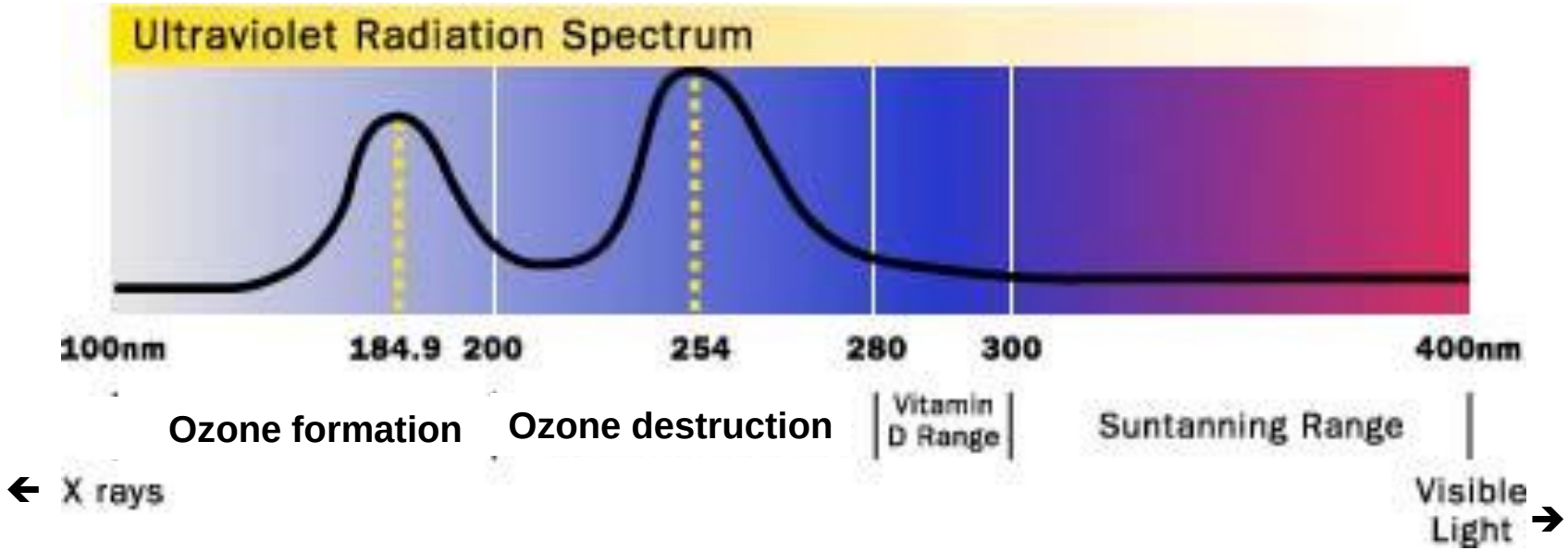
o UV – A : 315 – 400 nm



Ultraviolet Radiation

- 230-280 nm damages nucleic acids
- Stops reproduction of cells by breaking apart the DNA bonds
- Ozone production peaks at 185nm
- Ozone absorbance and destruction at 200-320nm





UV ozone generation and destruction: equilibrium

- $O_2 + h\upsilon_{185} \rightarrow 2O\cdot$
- $O\cdot + O_2 + M \rightarrow O_3 + M$
- $O_3 + h\upsilon_{254} \rightarrow O_2 + O\cdot$

Equilibrium between production and destruction

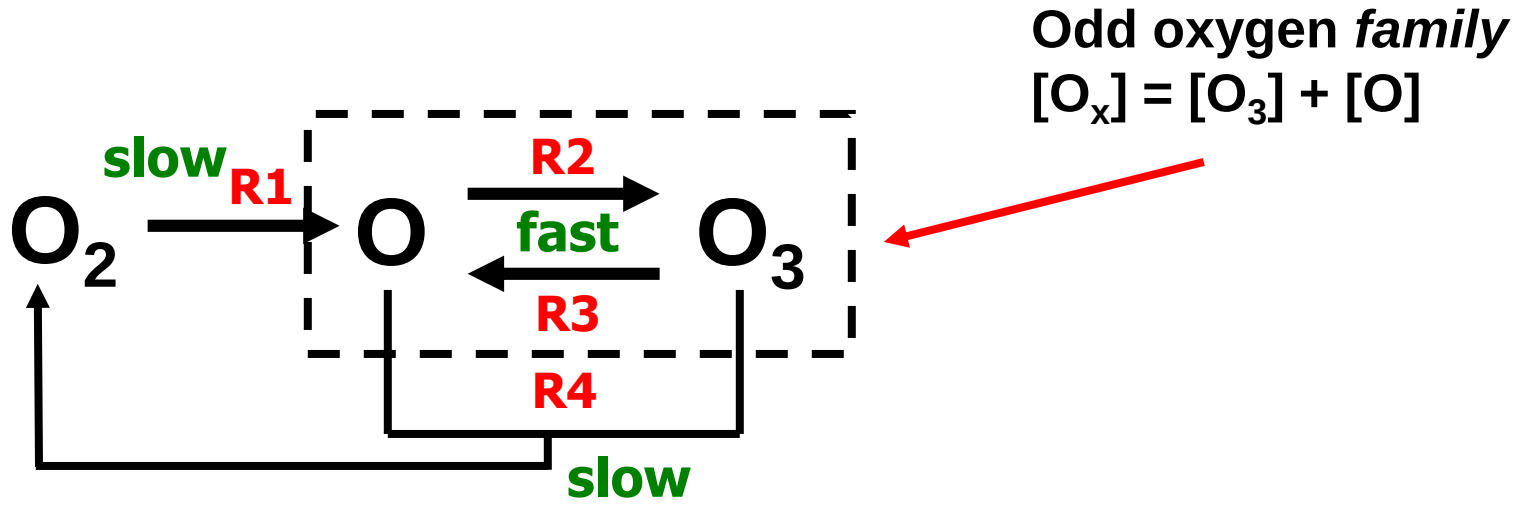
Chapman Mechanism

(R1) $O_2 + h\nu \rightarrow O + O \quad (\lambda < 240\ \text{nm})$

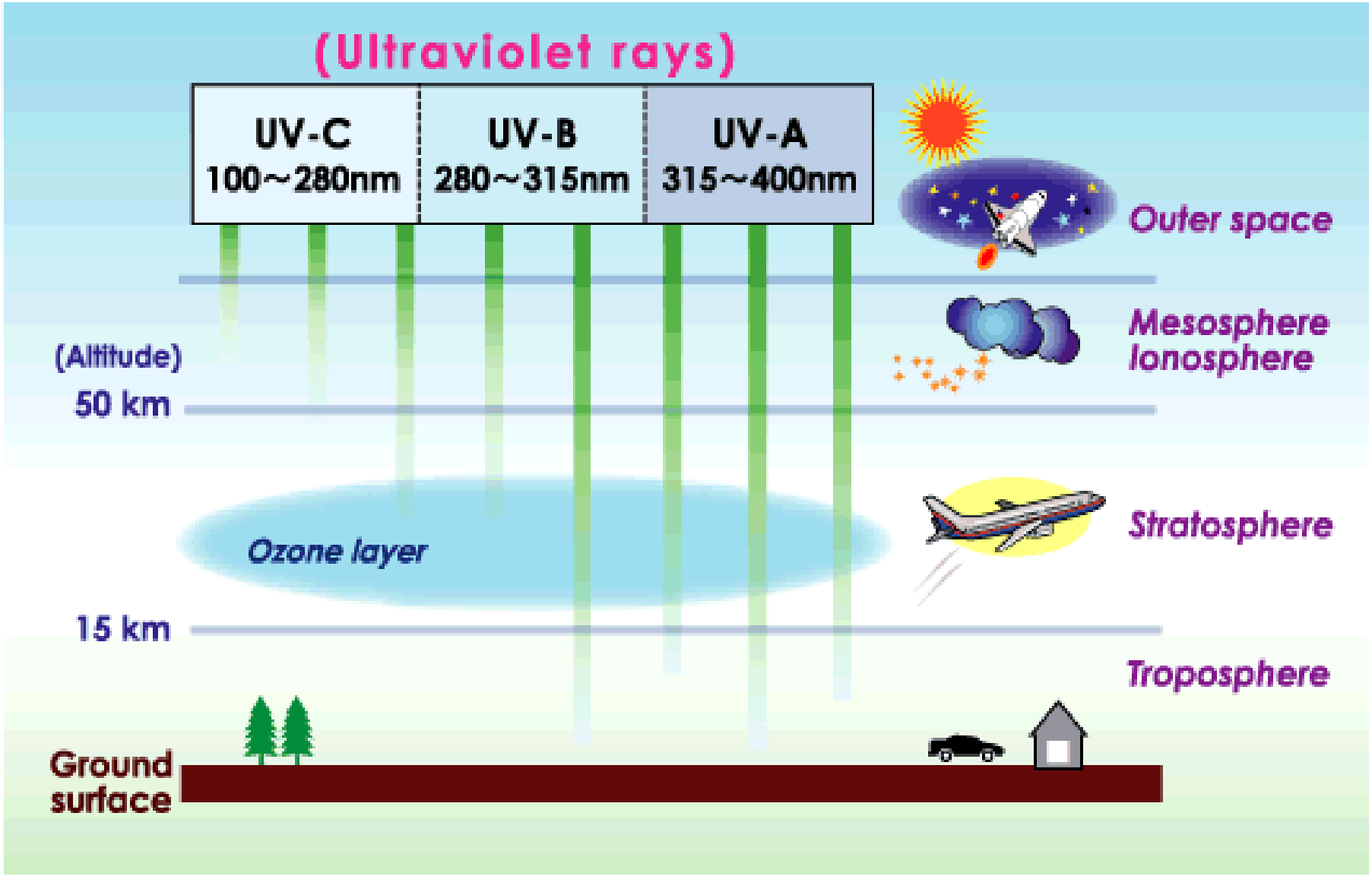
(R2) $O + O_2 + M \rightarrow O_3 + M$

(R3) $O_3 + h\nu \rightarrow O_2 + O \quad (\lambda < 320\ \text{nm})$

(R4) $O_3 + O \rightarrow 2O_2$



Atmospheric Layers

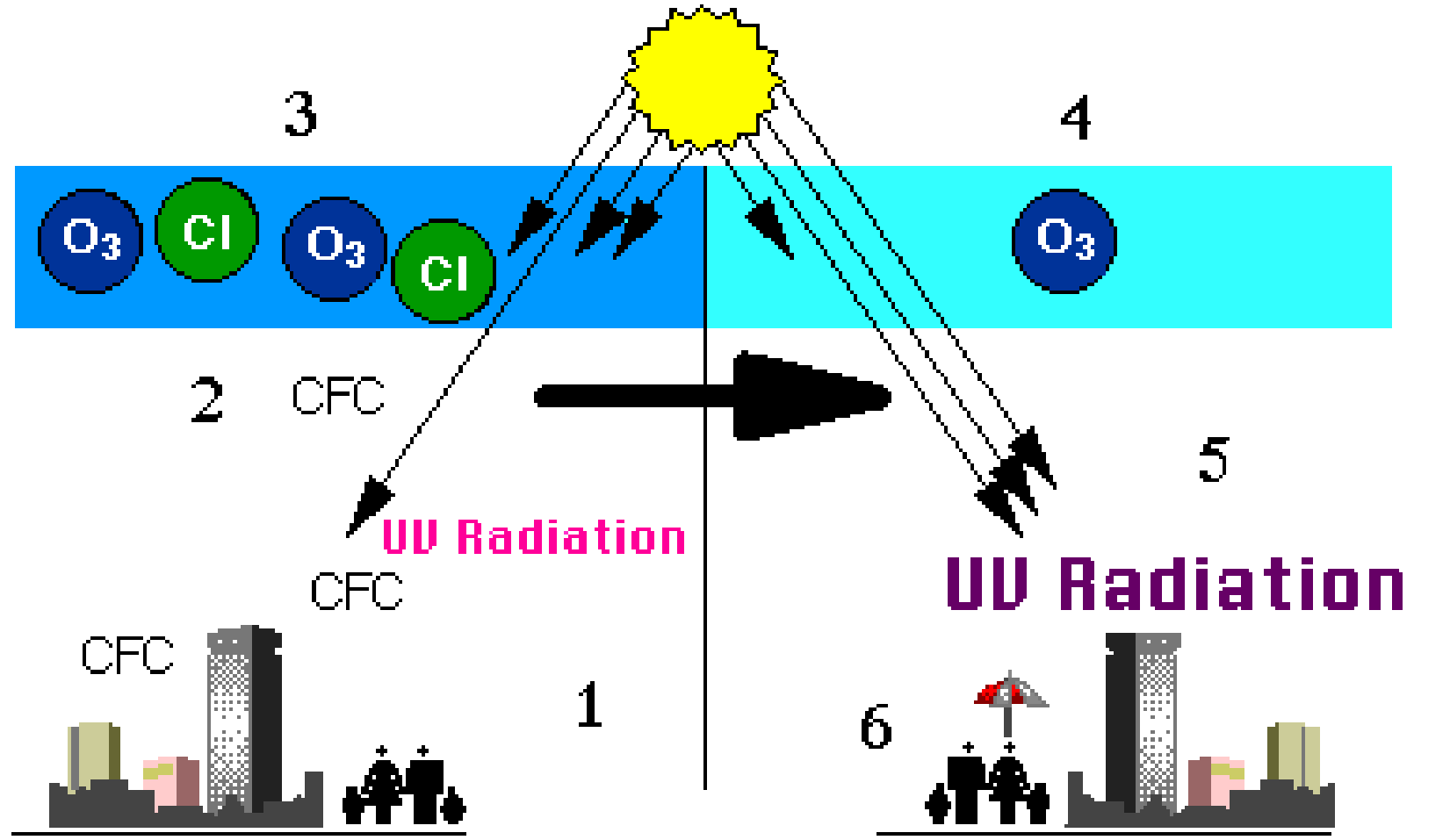


The catalyzed cycle of stratospheric ozone production and destruction

1. $h\upsilon + O_2 \rightarrow 2O\cdot$
2. $O\cdot + O_2 \rightarrow O_3$
3. $O_3 + X \rightarrow O_2 + OX$
4. $OX + O\cdot \rightarrow O_2 + X$

X could be Cl from a CFC

Ozone Depletion Process

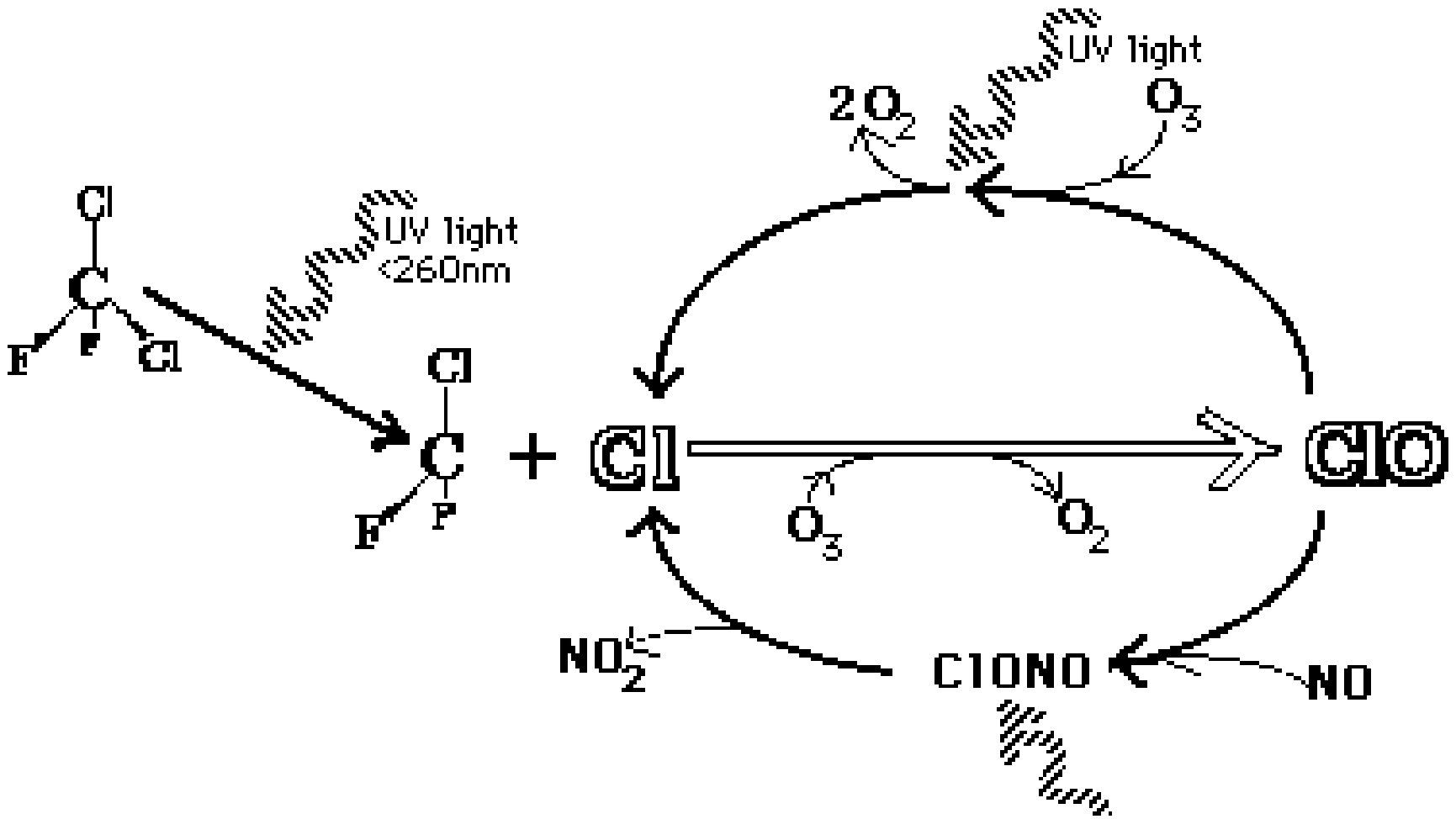


1 - CFCs released
2 - CFCs rise into ozone layer
3 - UV releases Cl from CFCs

4 - Cl destroys ozone
5 - Depleted ozone -> more UV
6 - More UV -> more skin cancer

Halogen catalysis of ozone destruction

ozone:



Halogen removal from atmosphere

- $Cl + CH_4 \rightarrow HCl + CH_3\cdot$
- $ClO + NO_2 \rightarrow ClONO_2$

  Both HCl and $ClONO_2$ inactive: rain out
- $Br + O_3 \rightarrow BrO + O_2$
- $Br + CH_4 \rightarrow HBr + CH_3\cdot$

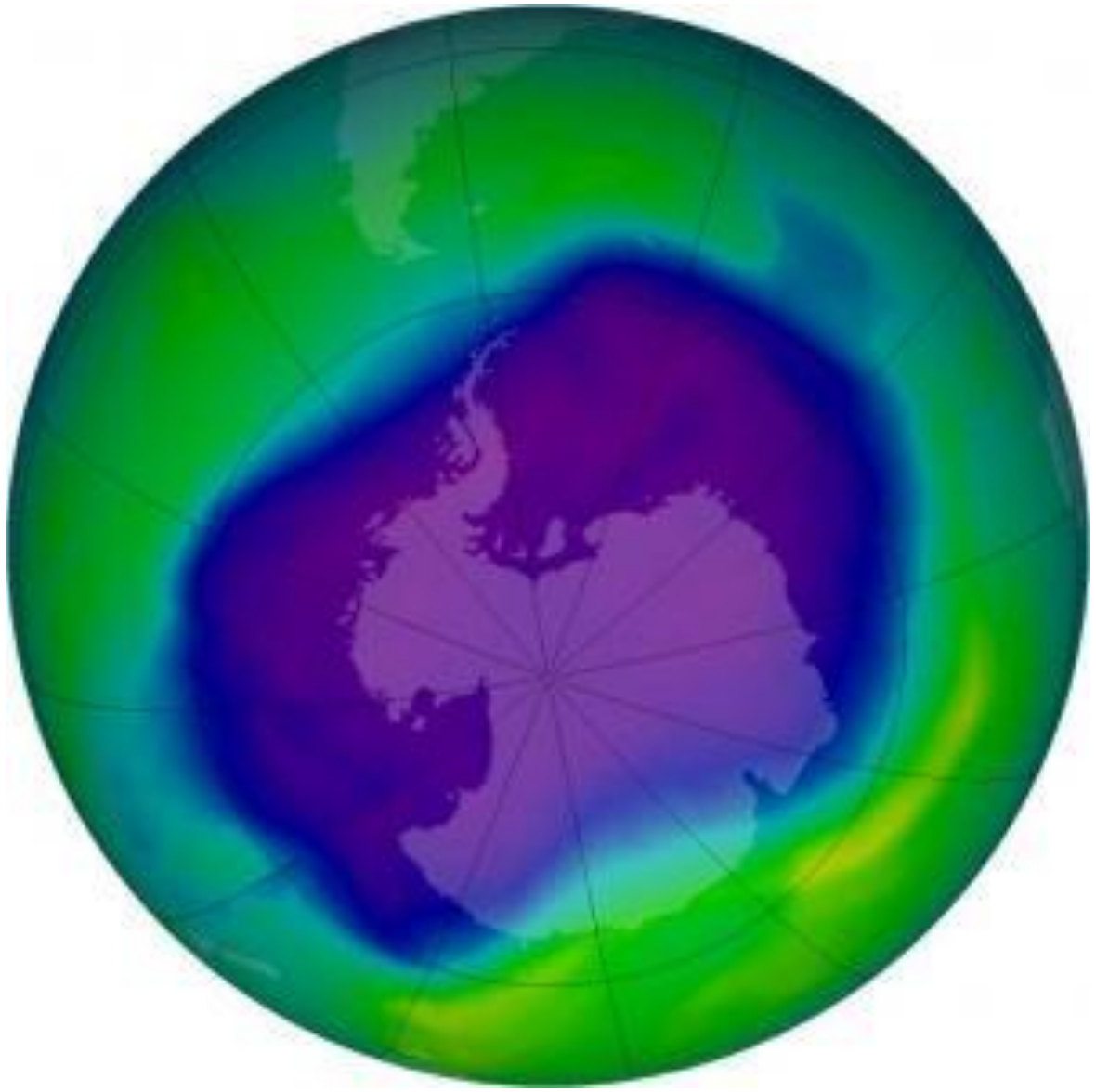
  HBr can photolytically provide Br again

  Halons and CH_3Br provide Br

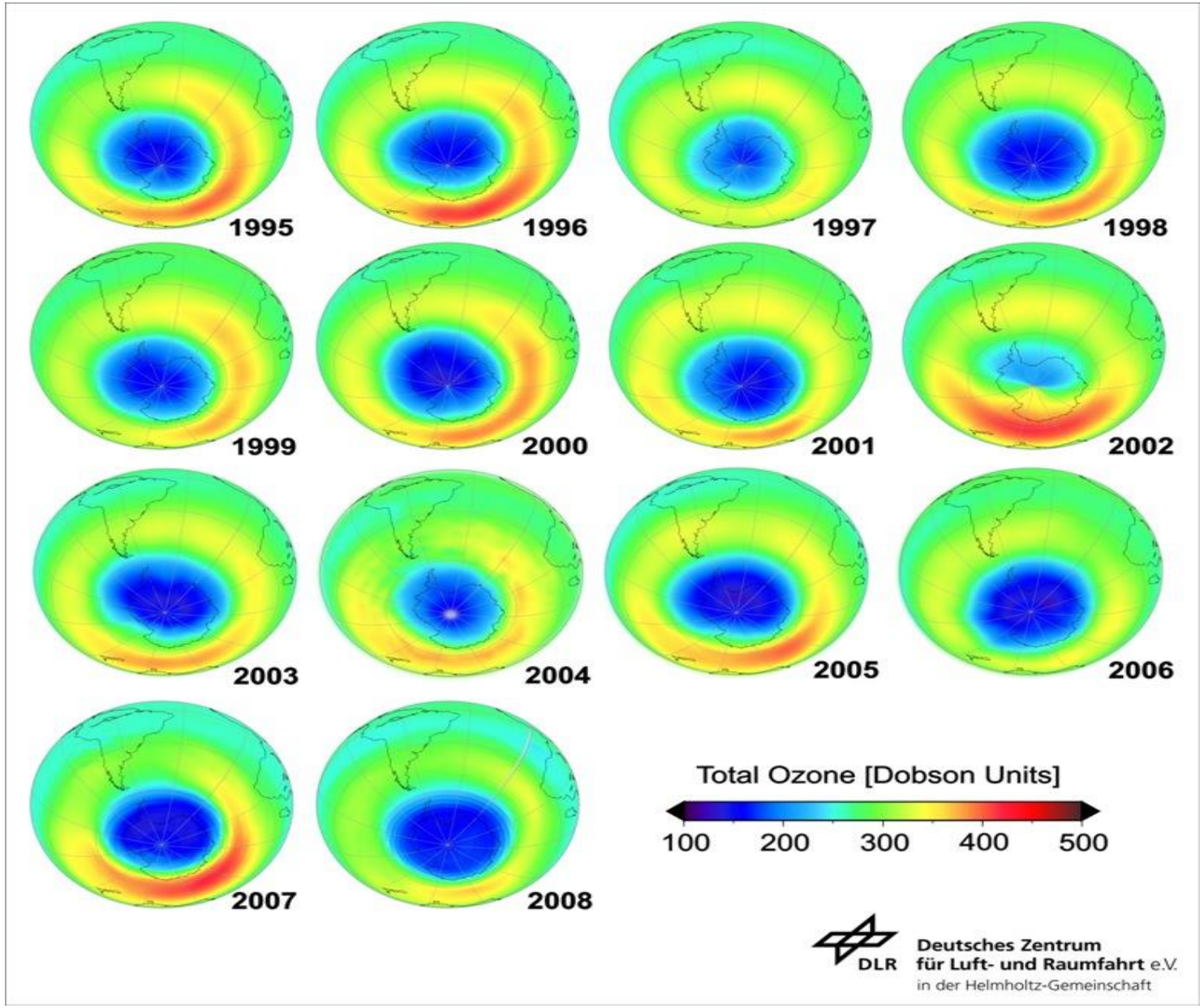
Ozone Depleting Substances

List of ozone depleting substances http://www.epa.gov/ozone/ods.html

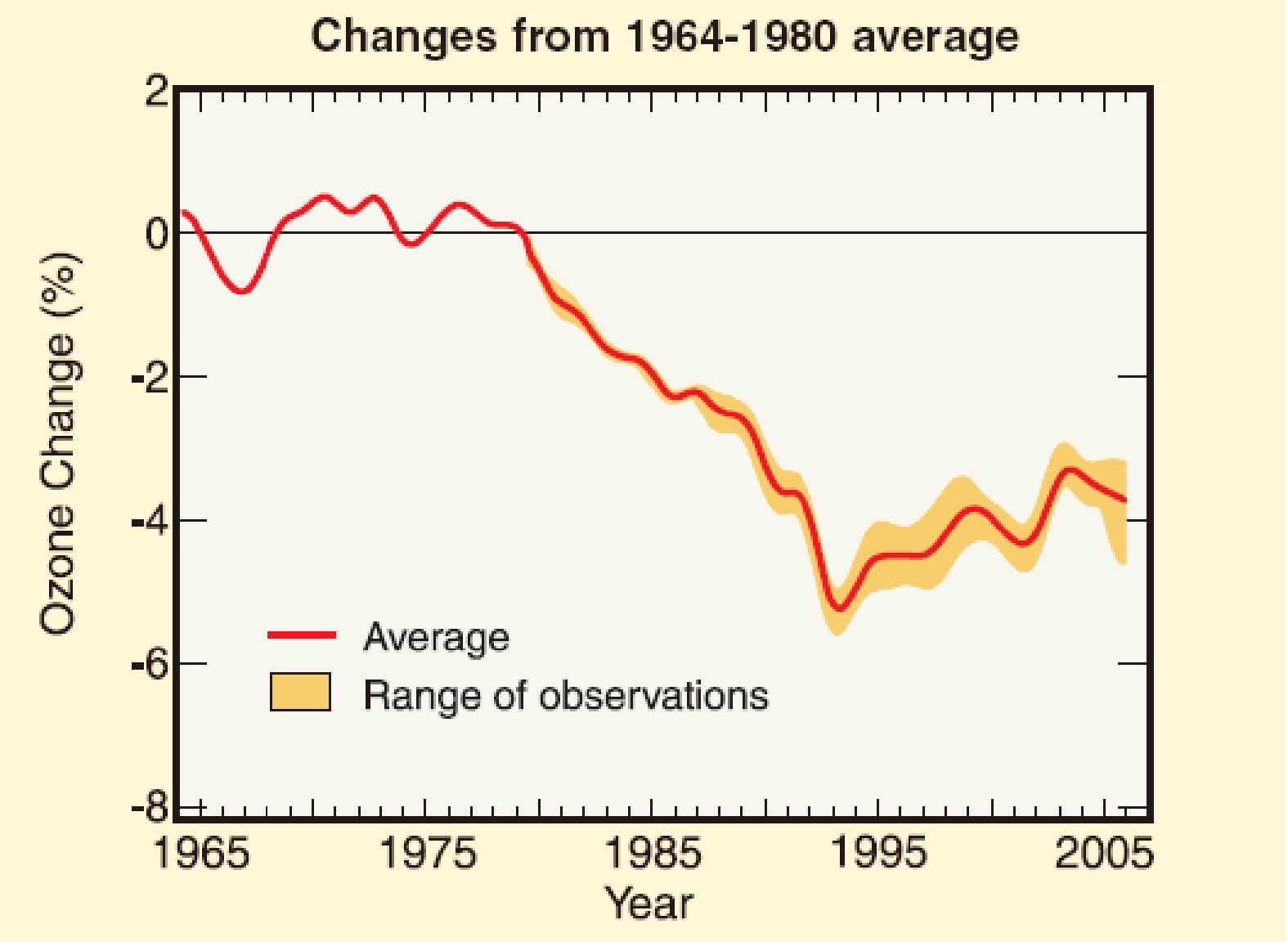
Record ozone hole, 2006



Evolution of ozone hole



Global total ozone change



Noble for Ozone hole explanation

The Nobel Prize in Chemistry 1995

Paul J. Crutzen

The Netherlands

Max-Planck-Institute
for Chemistry Mainz, Germany

1933 -

Mario J. Molina

USA

MIT, USA
Cambridge, MA

1943 -

F. Sherwood Rowland

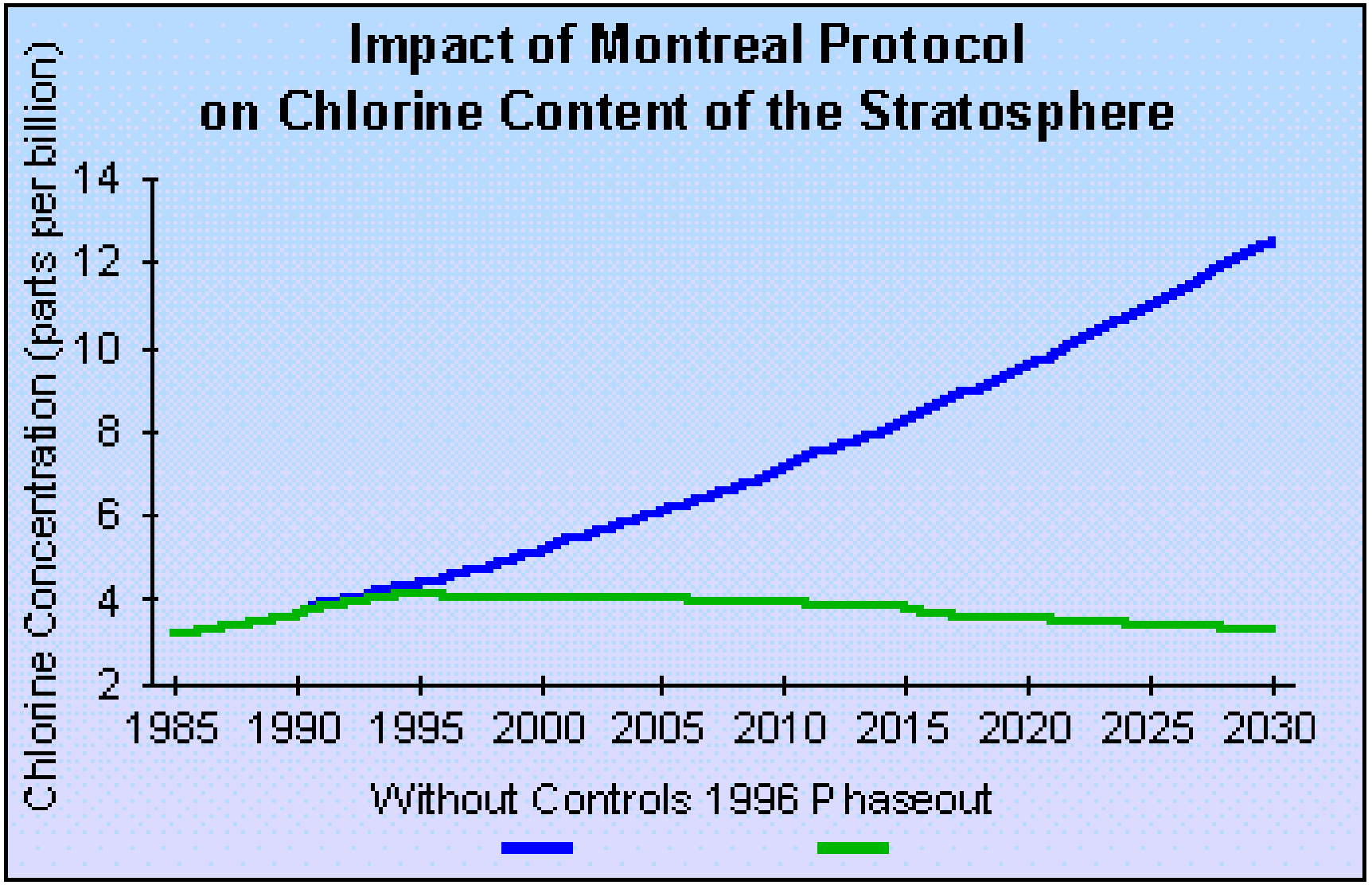
USA

Department of Chemistry,
University of California
Irvine, CA, USA

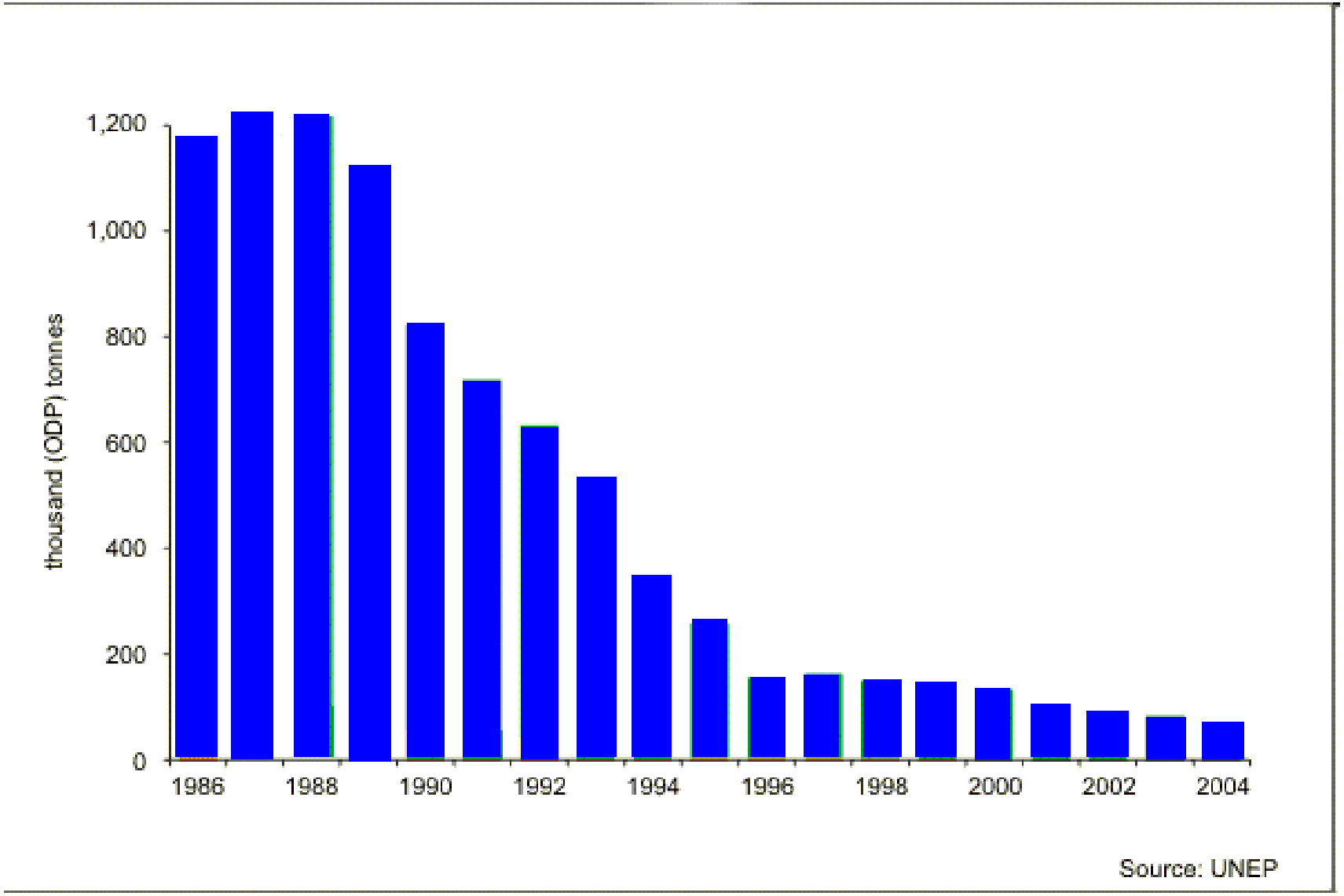
1927 -

"for their work in atmospheric chemistry, particularly concerning the formation and decomposition of ozone"

Impact of Montreal Protocol

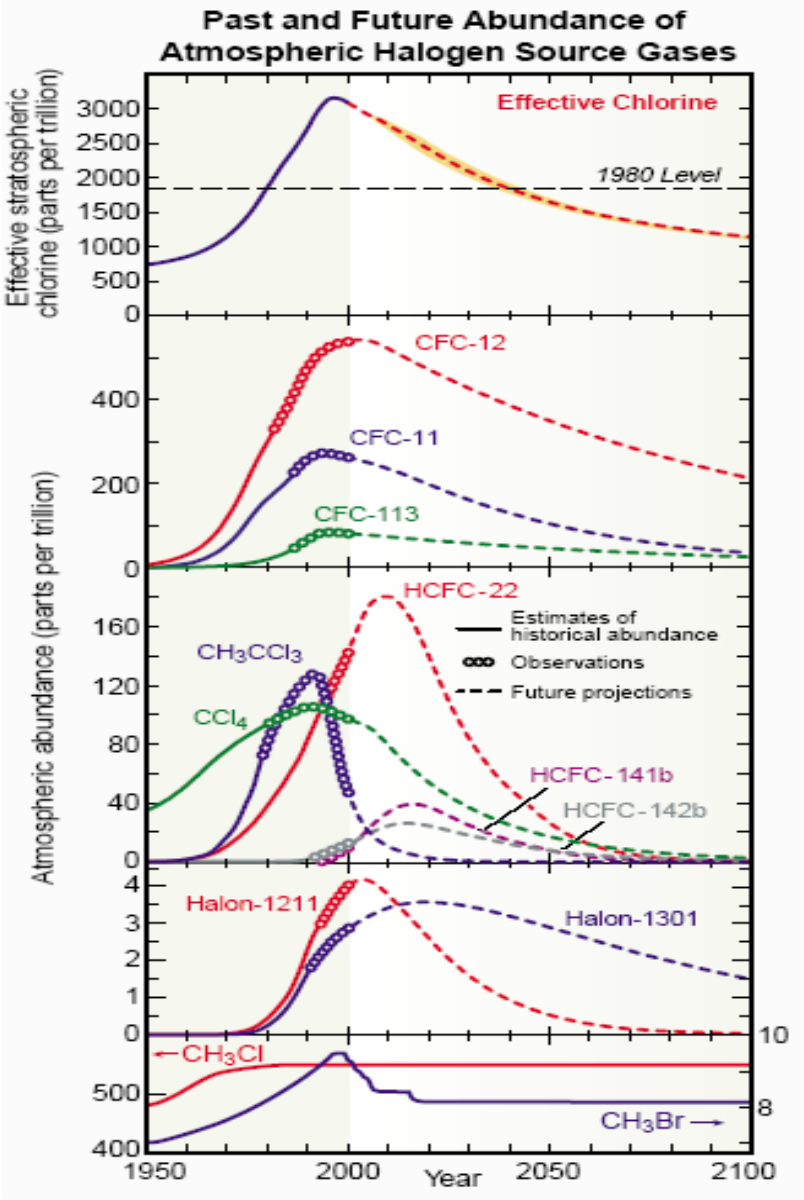


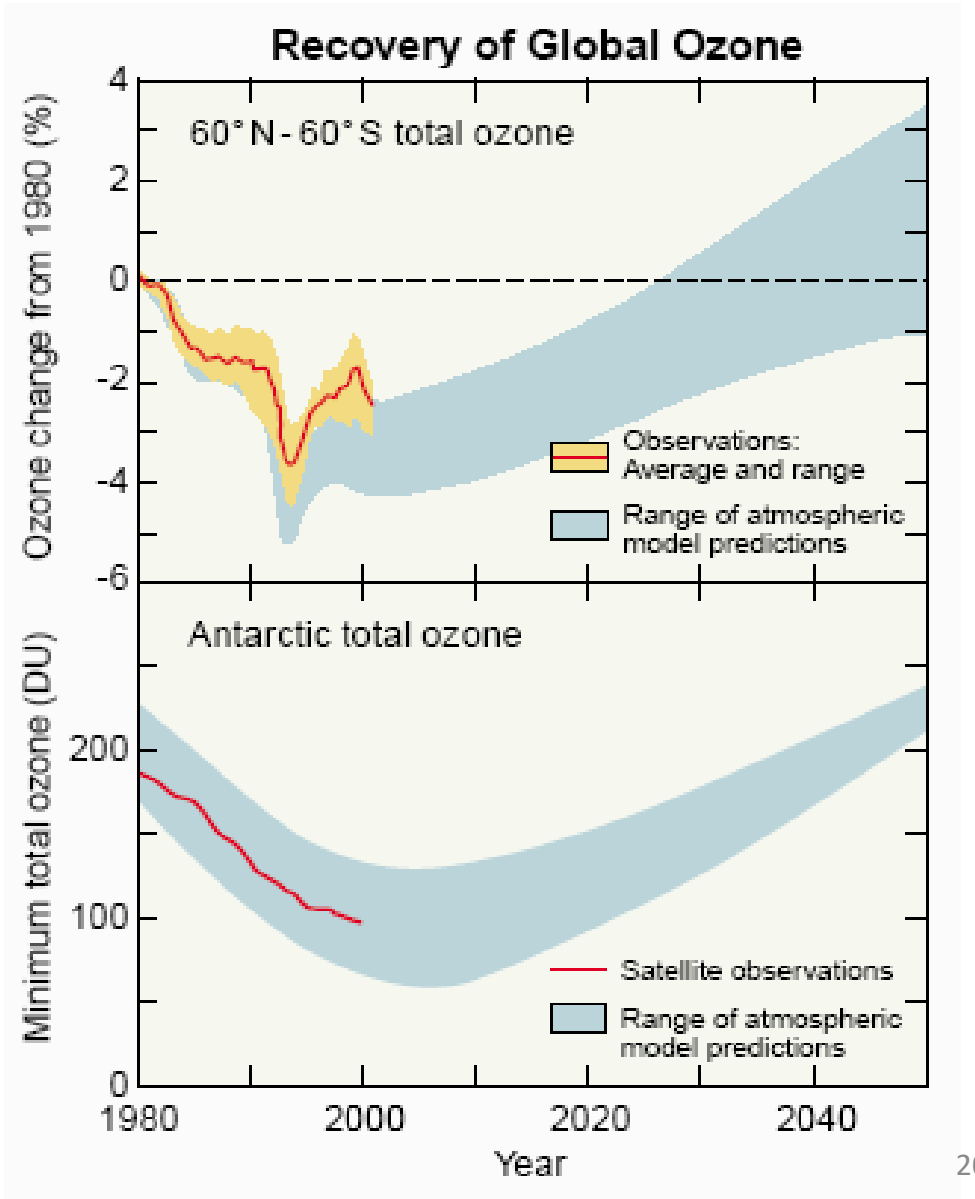
Impact of Montreal Protocol



World Production of CFCs

Impact of Montreal Protocol





Ozone layer recovery