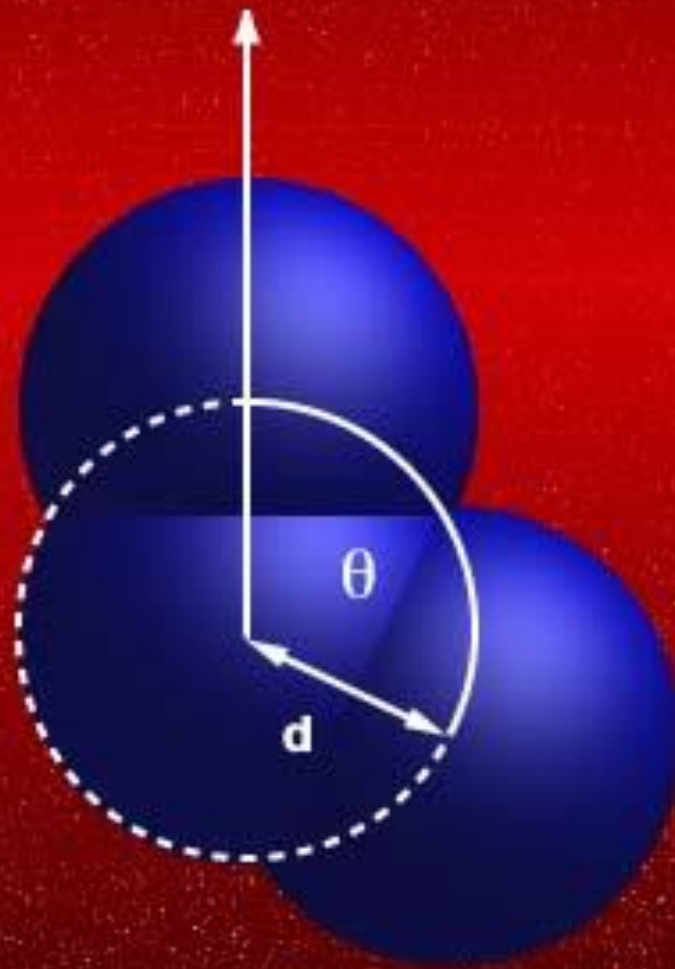


Stratosphere and Ozone

Ozone (Greek, ozein, to smell)



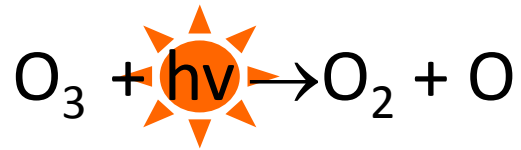
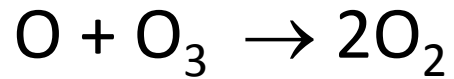
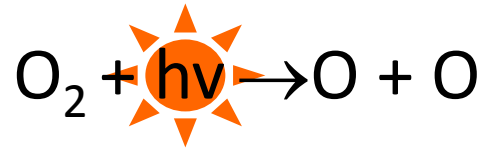
Ozone Molecule



$$\theta = 116.5^\circ$$

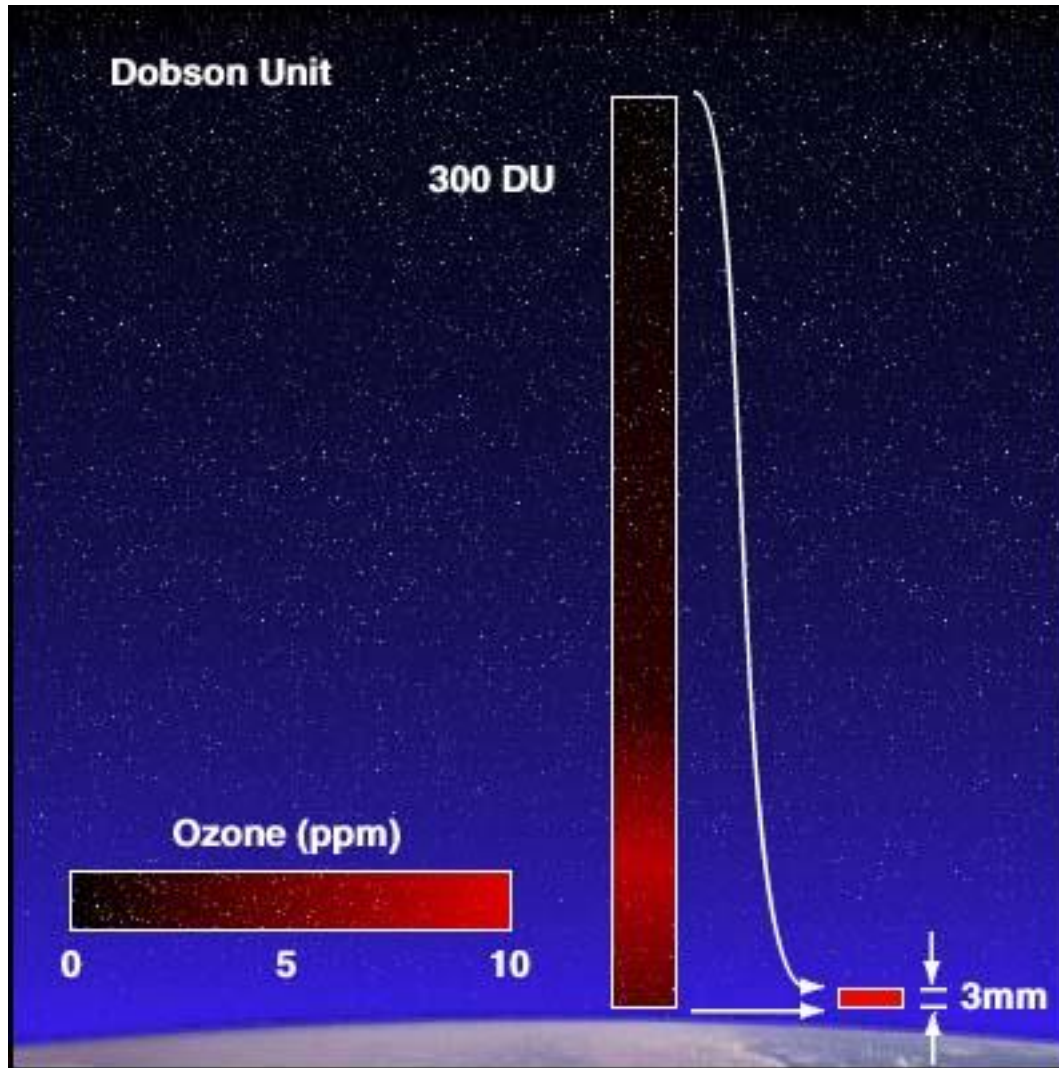
$$d = 1.28 \text{ \AA}$$

Chapman Mechanism



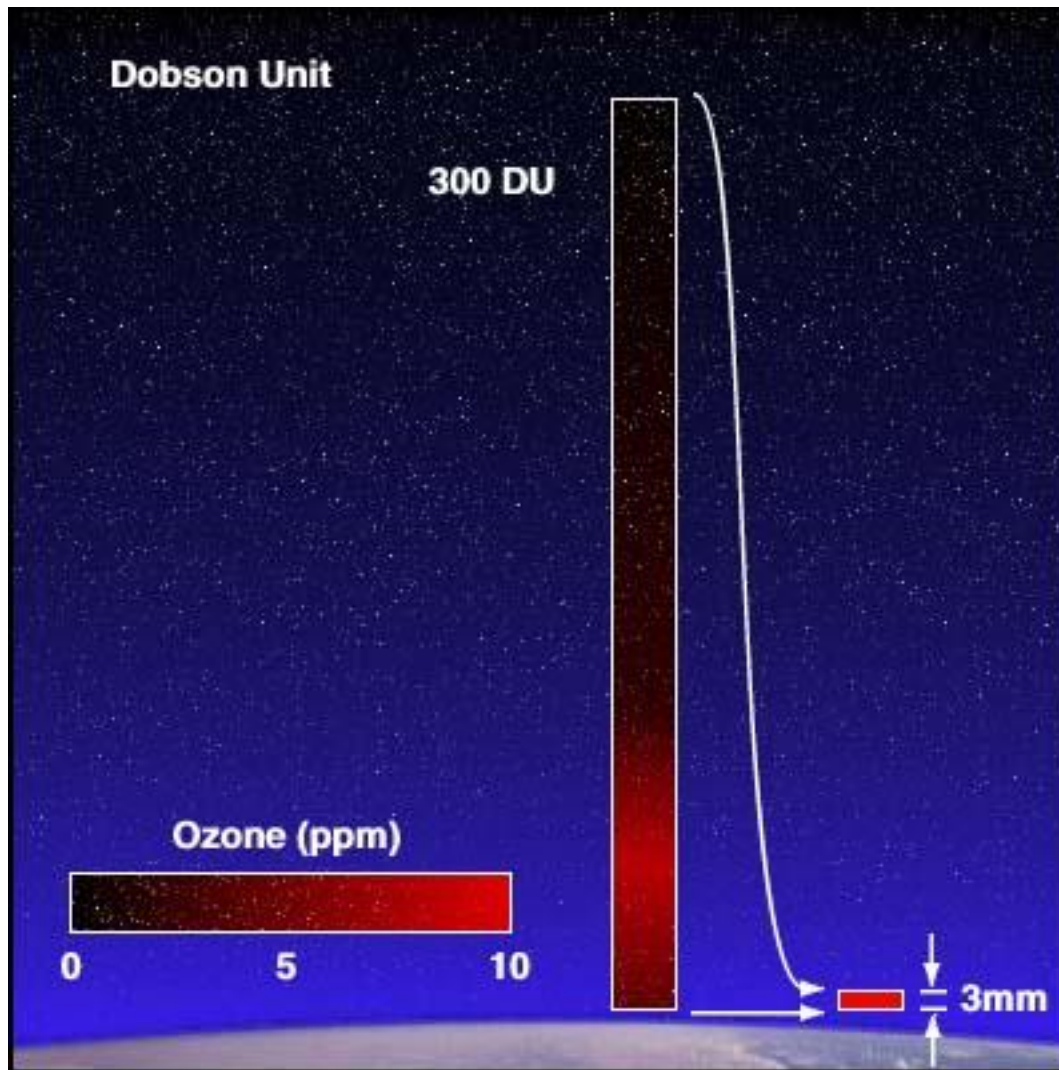
↑
‘third-body’ anything





What units are used to report the amount of the ozone?

Dobson: named for G.M.B. Dobson who investigated atmospheric ozone ~ (1920-1960)

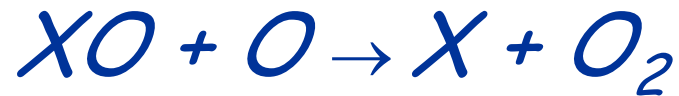
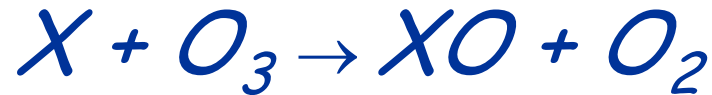


Dobson: compress all the ozone in a column down to 0°C and 1 atm and measure the thickness of the column.

0.01mm = 1 Dobson

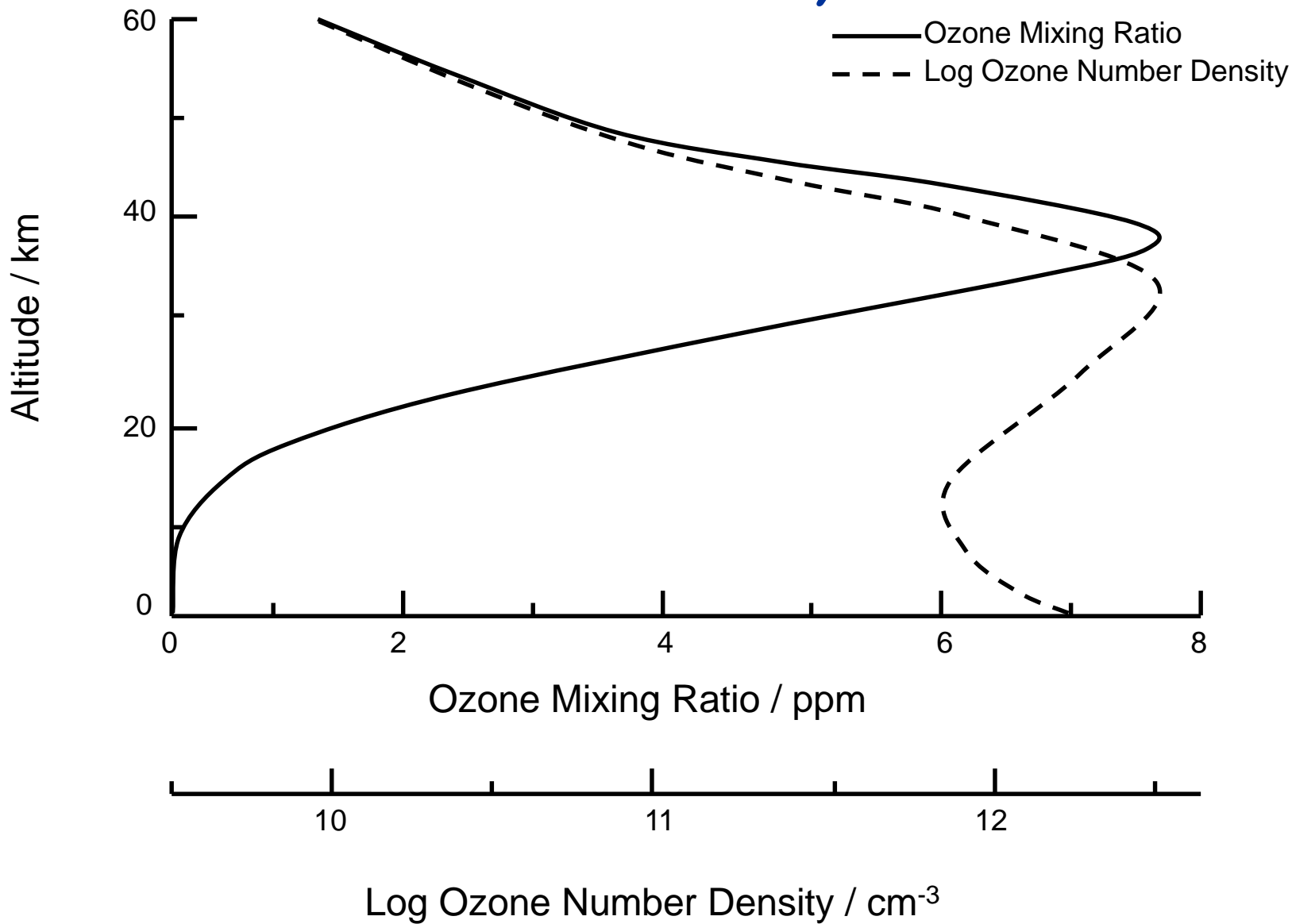


Catalytic Ozone Depletion Cycles

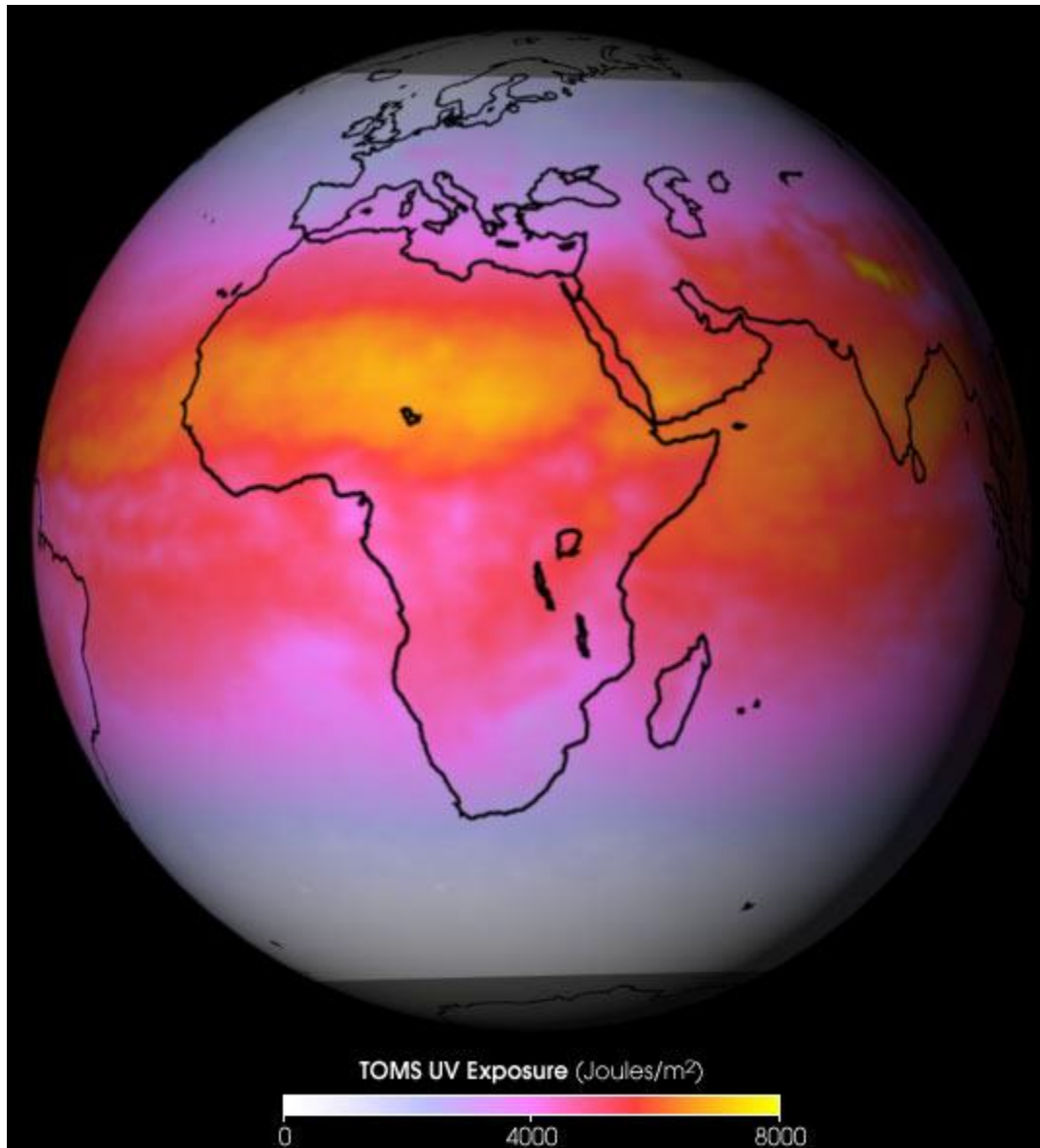


$X = H, OH, NO, Cl$

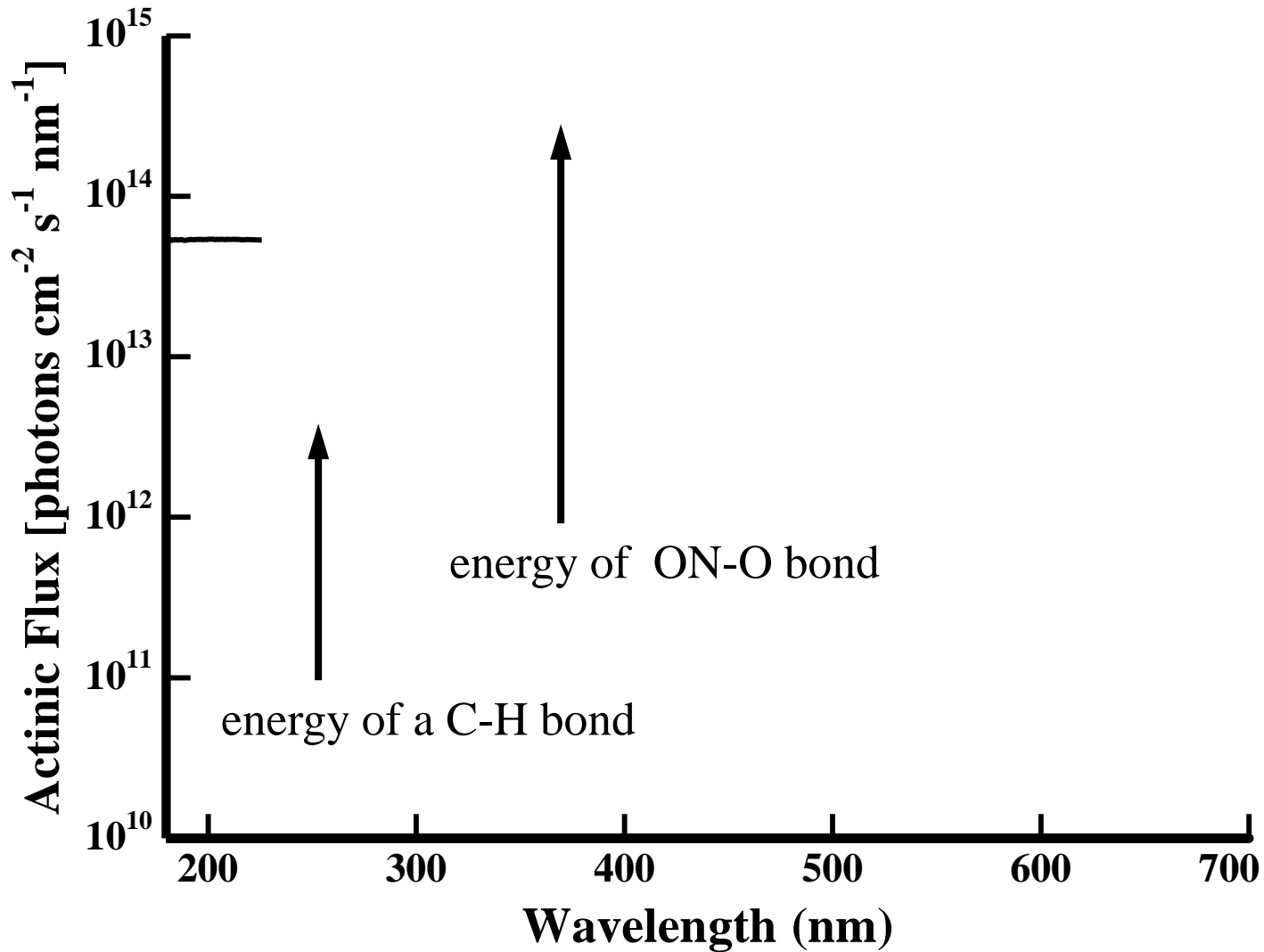
The Ozone Layer



The Ozone Layer and UV Radiation



Solar Flux: 5800 K Object



Beer's Law

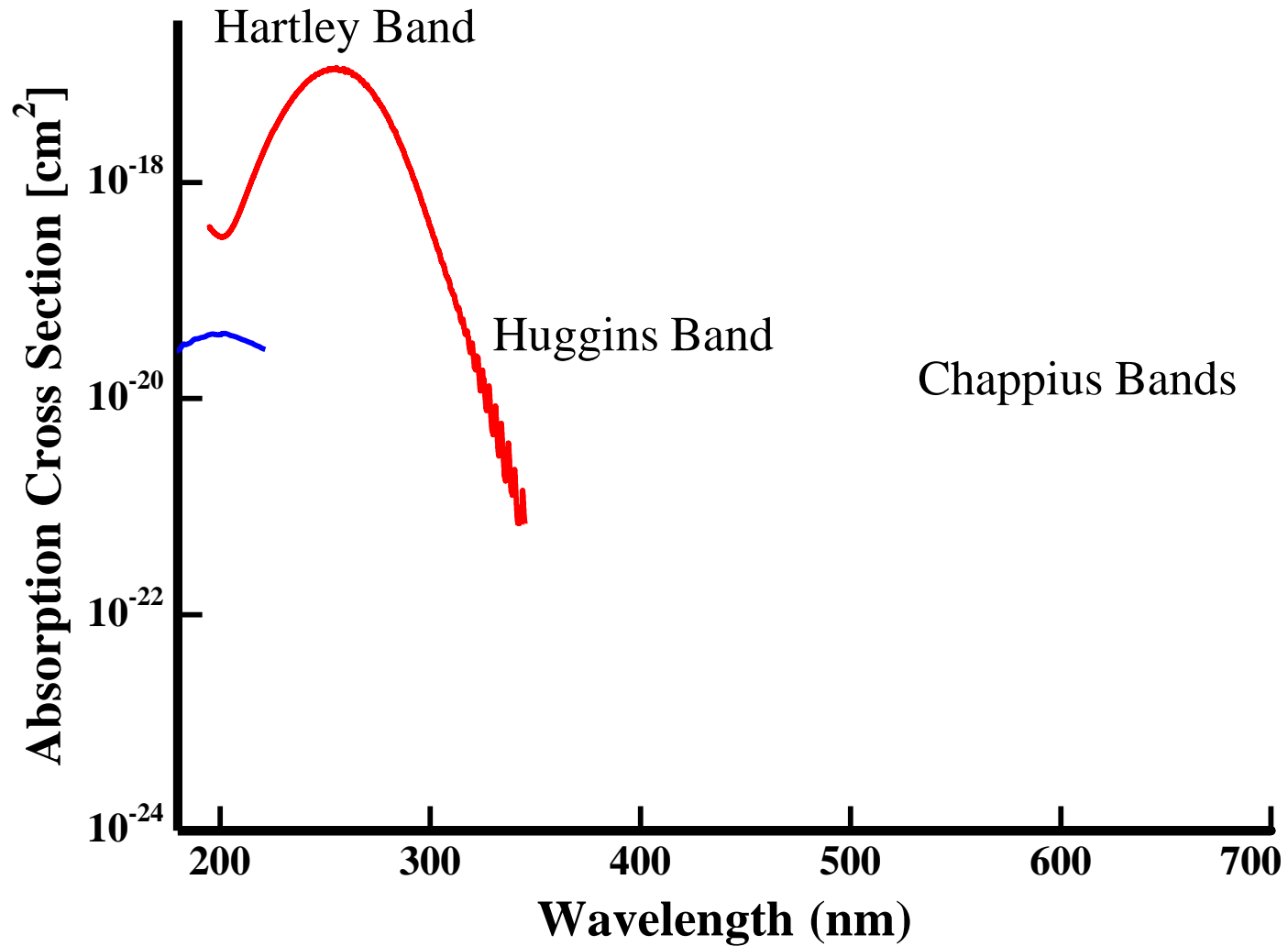
$$A = \varepsilon \times c \times l$$

ε : extinction coefficient

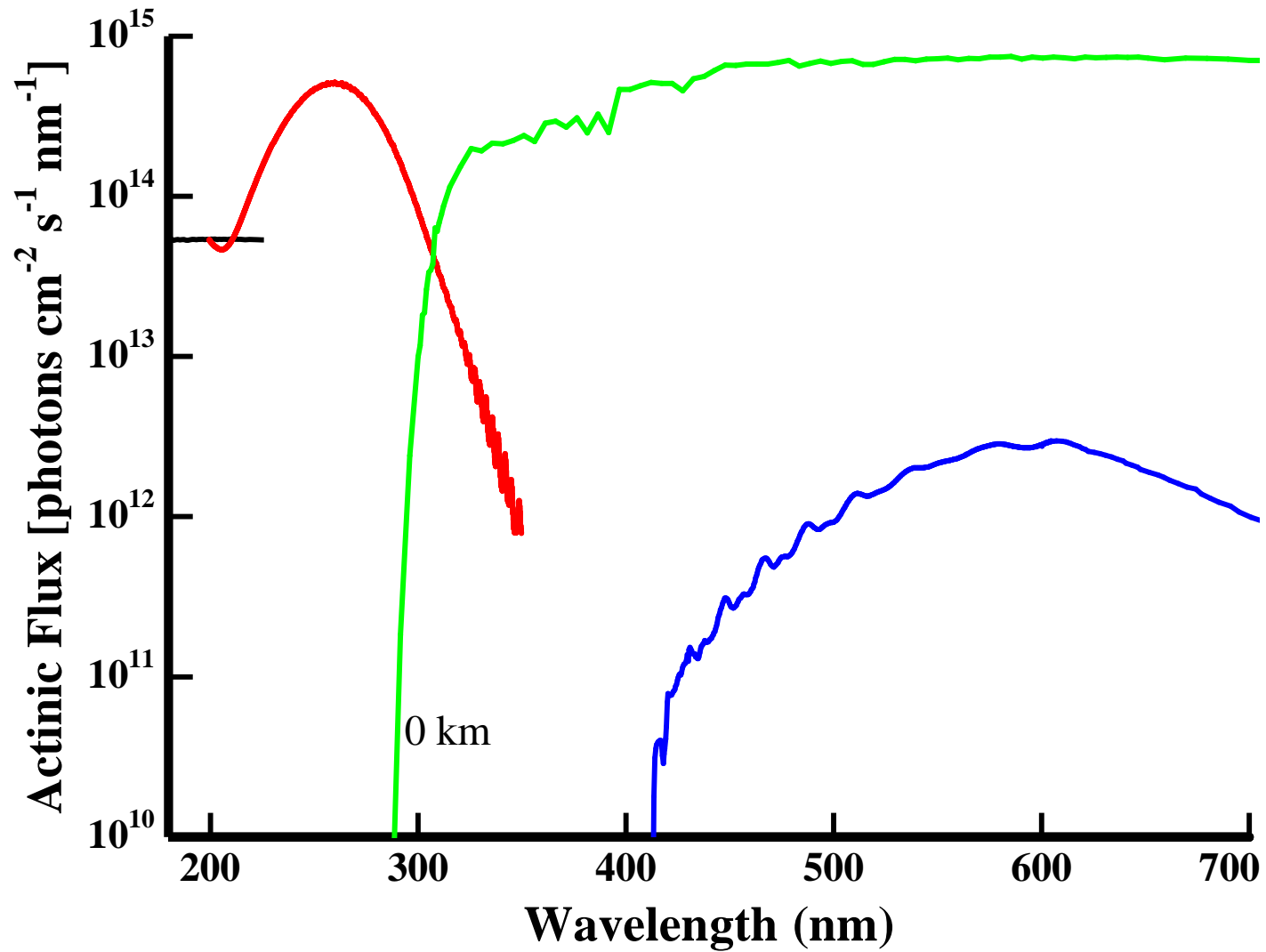
c : concentration

l : path length

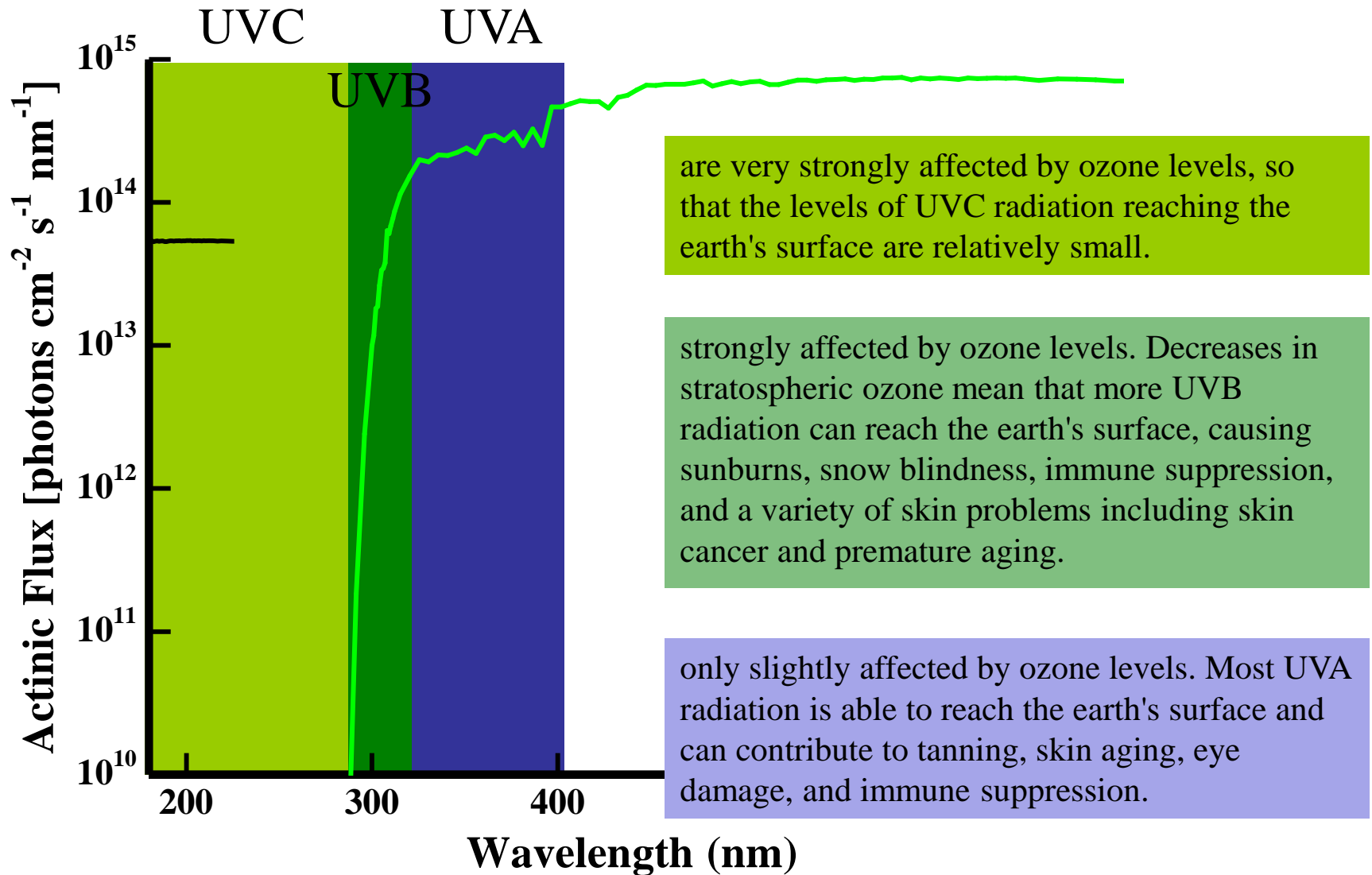
Ozone Absorption



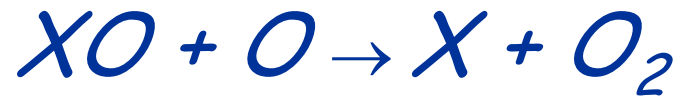
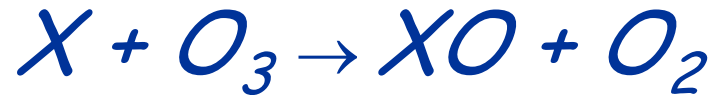
Solar Flux: 5800 K Object



Solar Flux: 5800 K Object



Catalytic Ozone Depletion Cycles

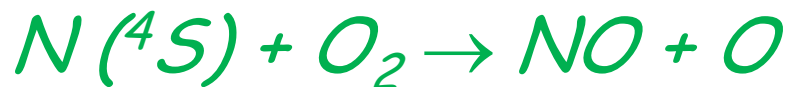


$X = H, OH, NO, Cl$

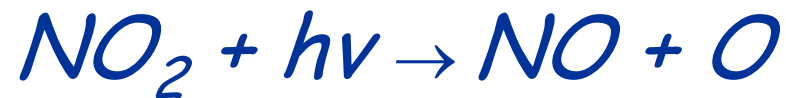
HO_x Cycle



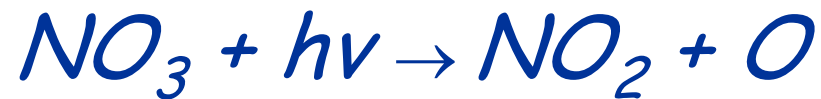
NO_x Cycle



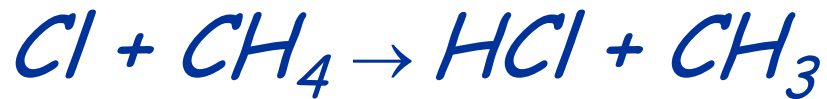
Null Cycles



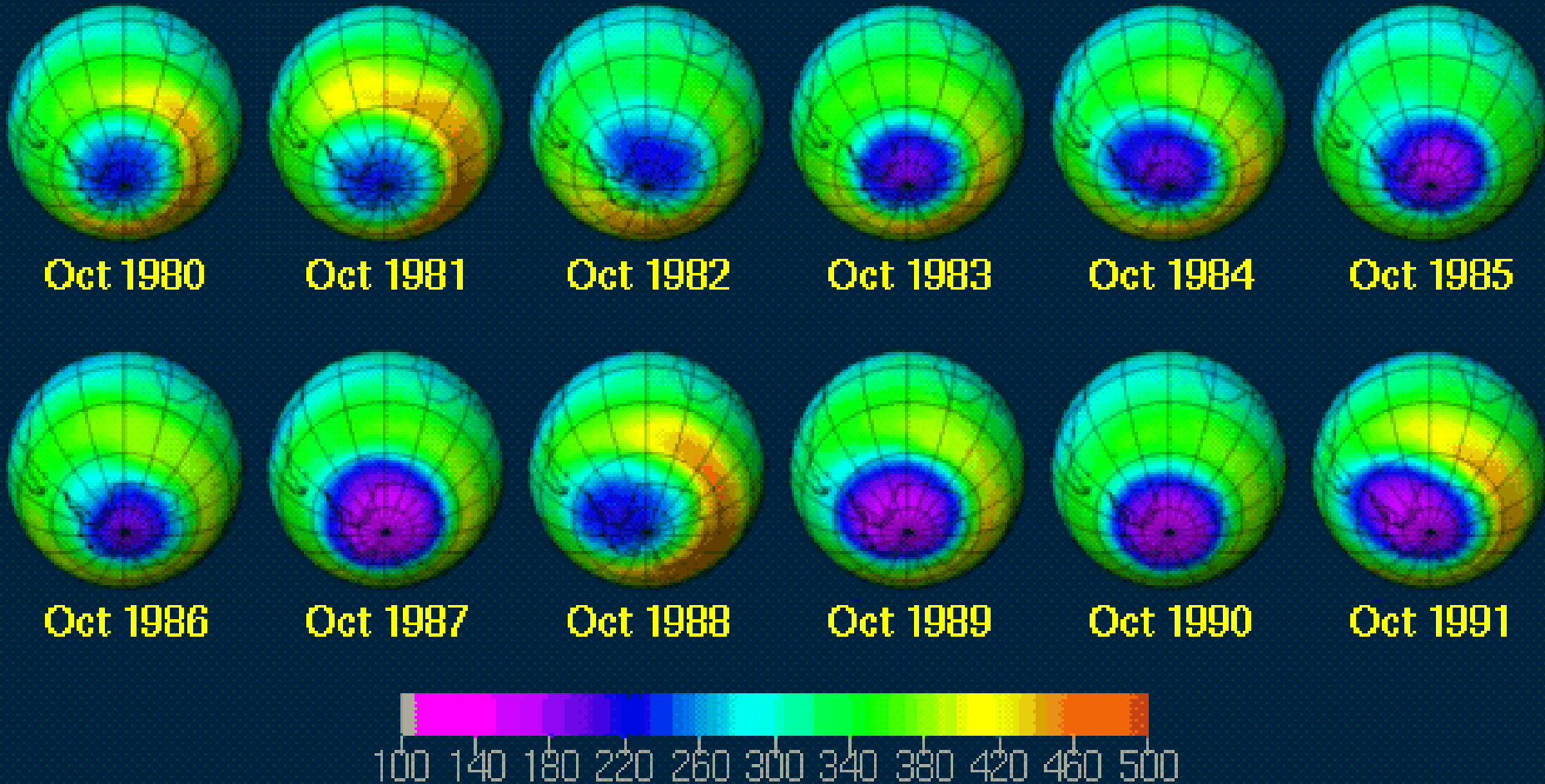
Null Cycles



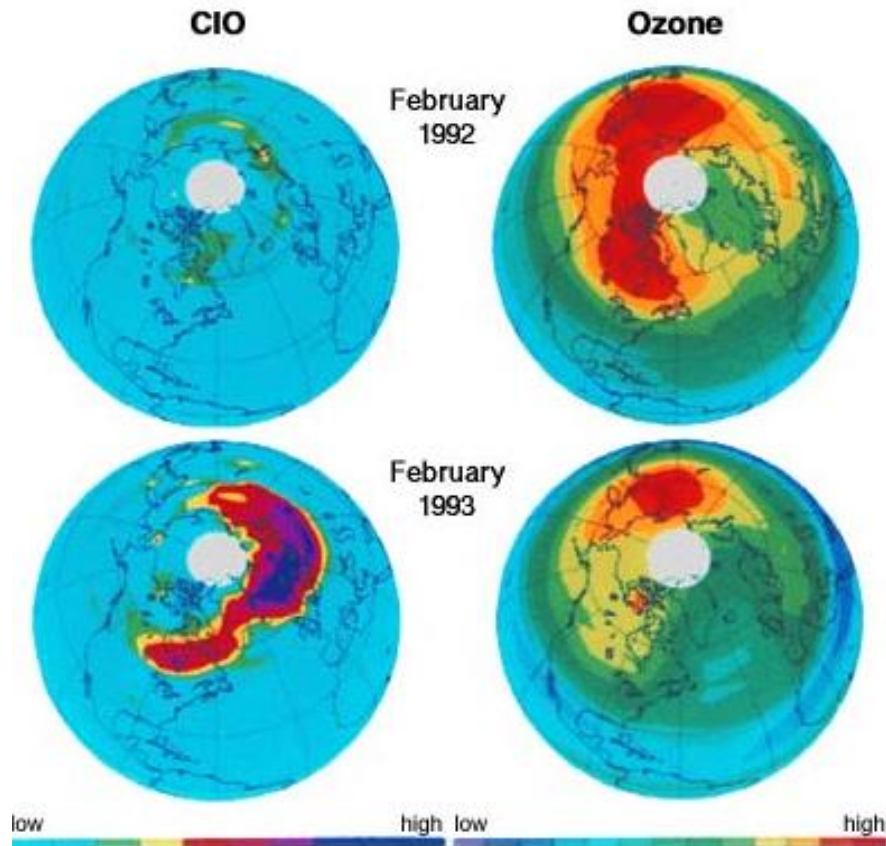
Reservoirs



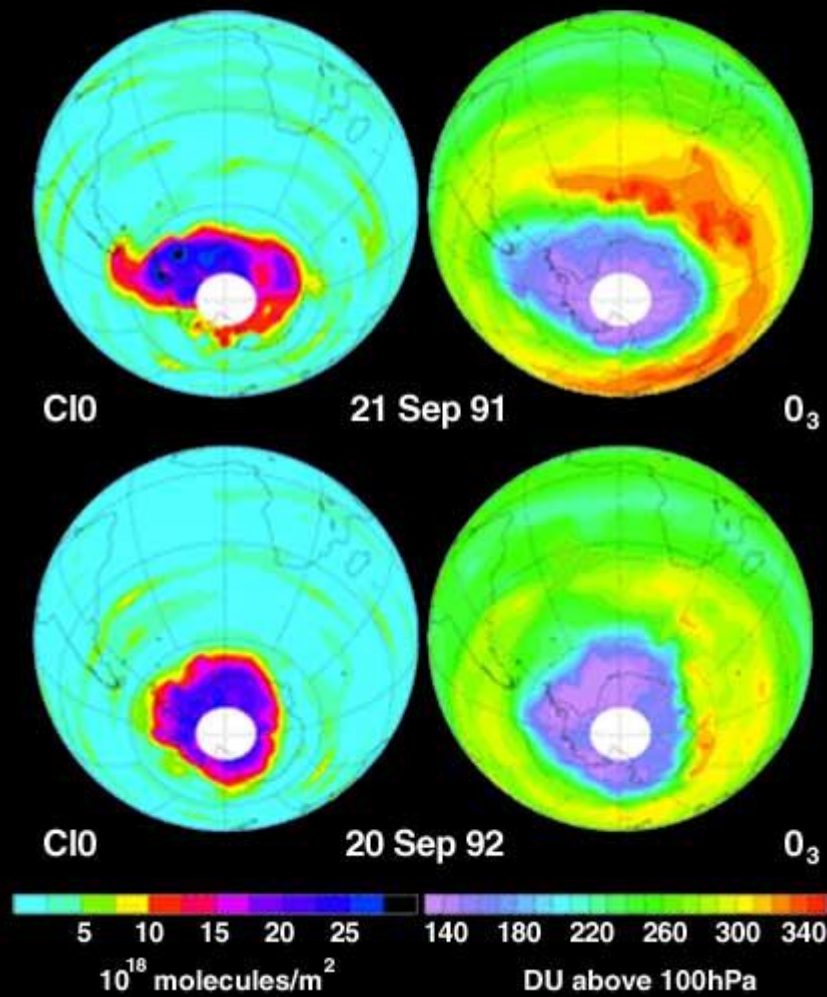
Antarctic Ozone Hole



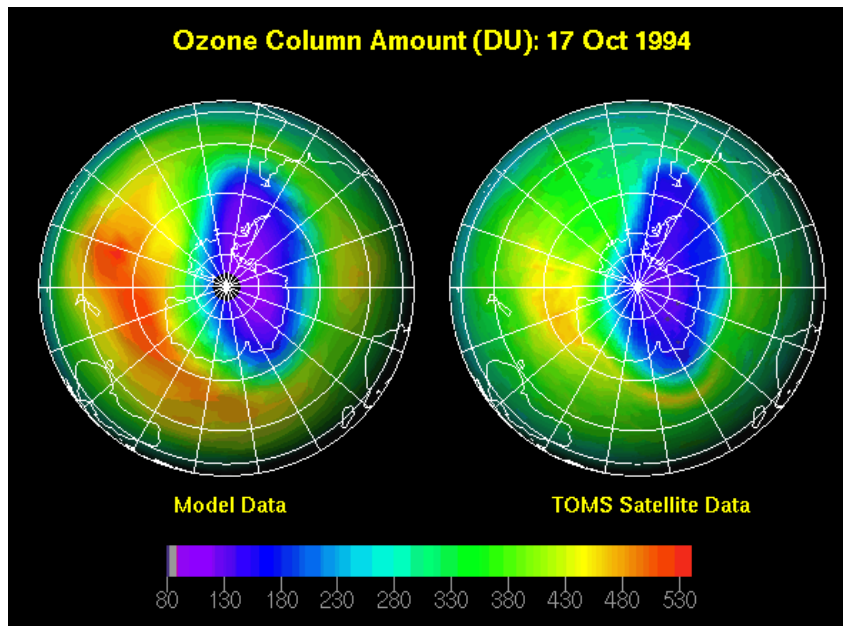
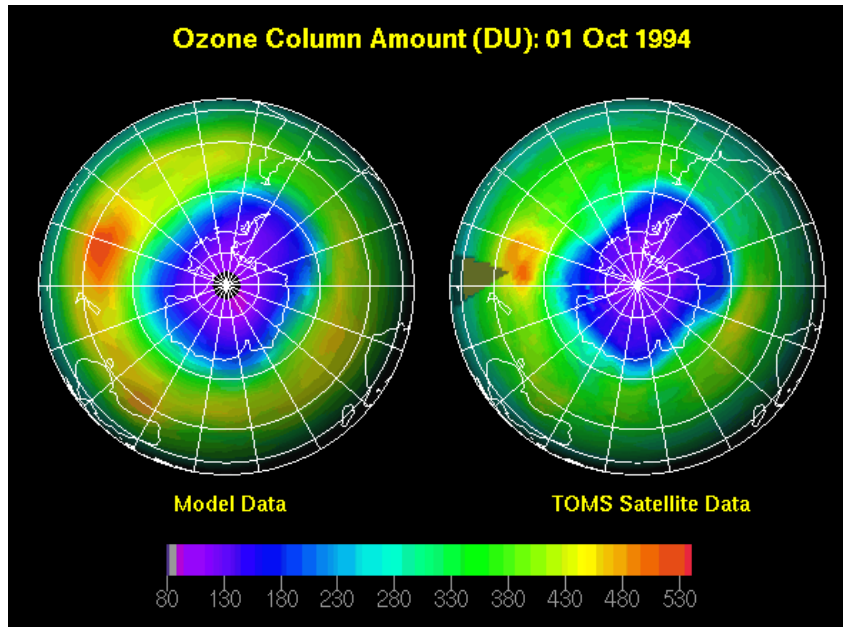
Correlation Between CIO and O₃



Chlorine Monoxide and the Ozone Hole: 1991 and 1992
measured by UARS MLS; from *Waters et al., Nature, 123, 597 (1993)*

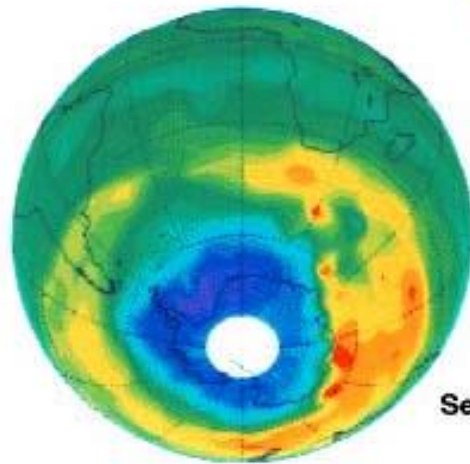
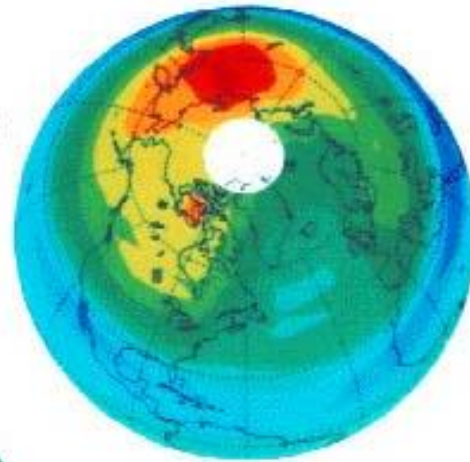


Modeling the Antarctic 'ozone hole'



Polar Ozone

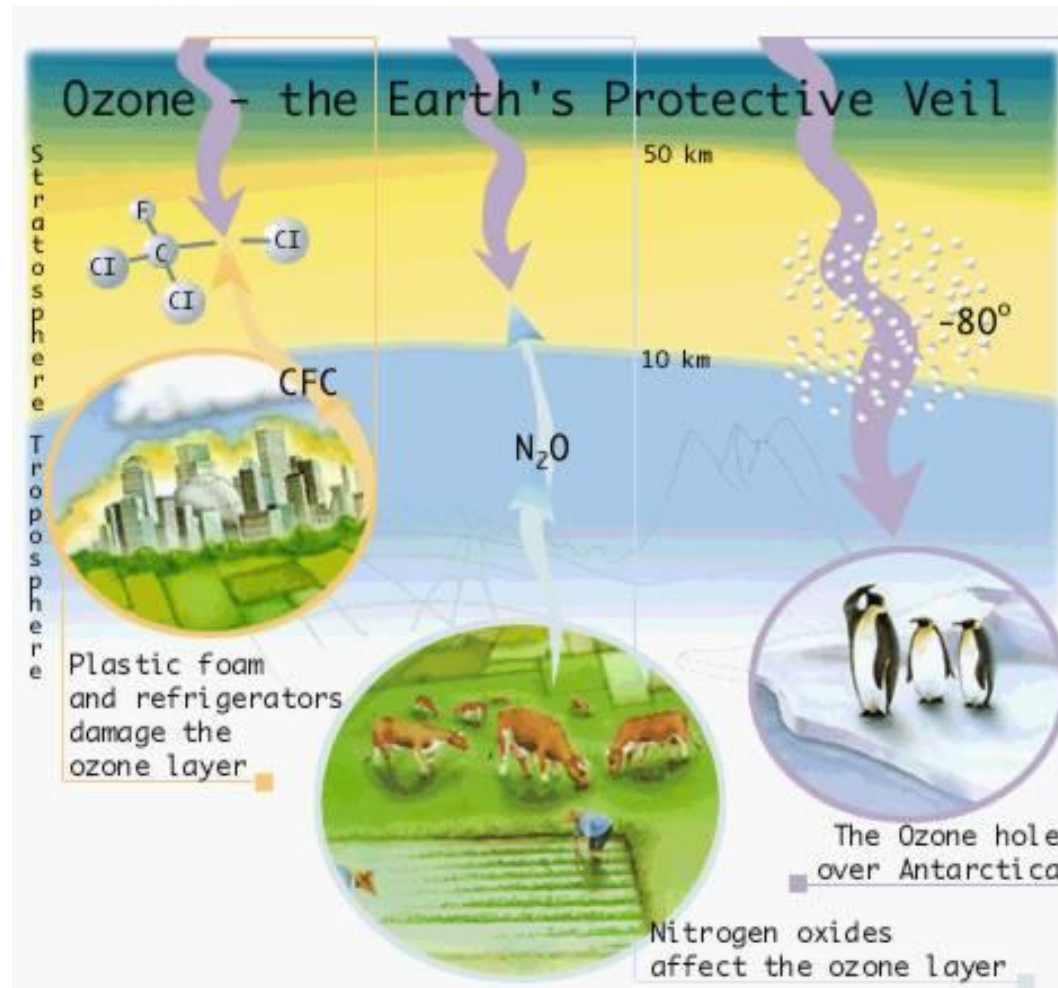
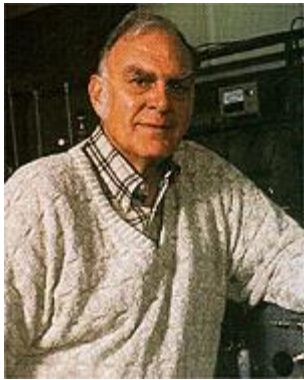
February 1993



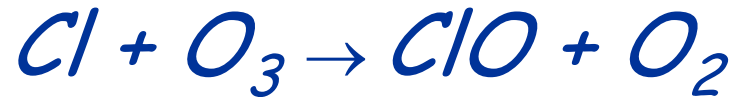
September 1992

low Total Column Ozone (DU) high

Nobel Prize in Chemistry



ClO_x Cycles

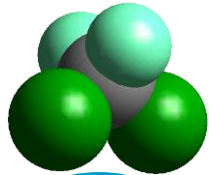


Mixing Times and Transport

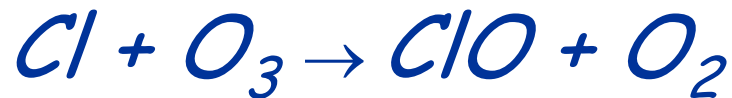
- *Vertical Mixing within Troposphere: weeks*
- *Mixing within Hemispheres: months*
- *Mixing between Hemispheres: ~1 year*
- *Mixing between Stratosphere and Troposphere: years*

Ozone Depletion by CFC's

CFC-12



chlorofluorocarbons



Nomenclature for CFC's

CFC-xyz

x: number of carbon atoms - 1

y: number of hydrogen atoms + 1

z: number of F atoms

CFC-12



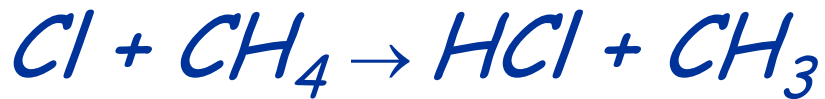
CFC-115



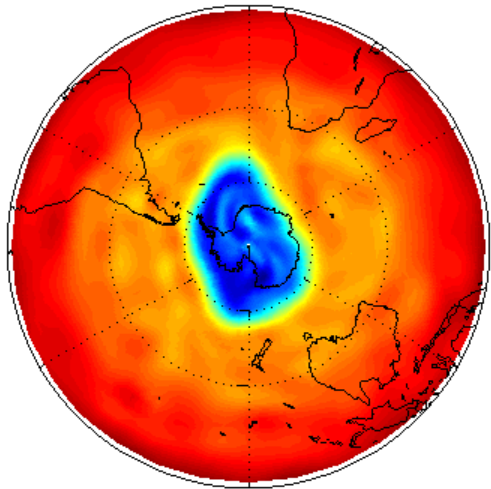
Lifetimes of CFC's in the Atmosphere

<i>Halocarbon</i>	<i>Atmospheric Lifetime (yr)</i>
$CFCl_3$	60
CF_2Cl_2	105
$CF_2ClCFCl_2$	101
CF_2ClCF_2Cl	236
CF_2ClCF_3	522

Reservoirs



01-Sep-1996



Polar Vortex

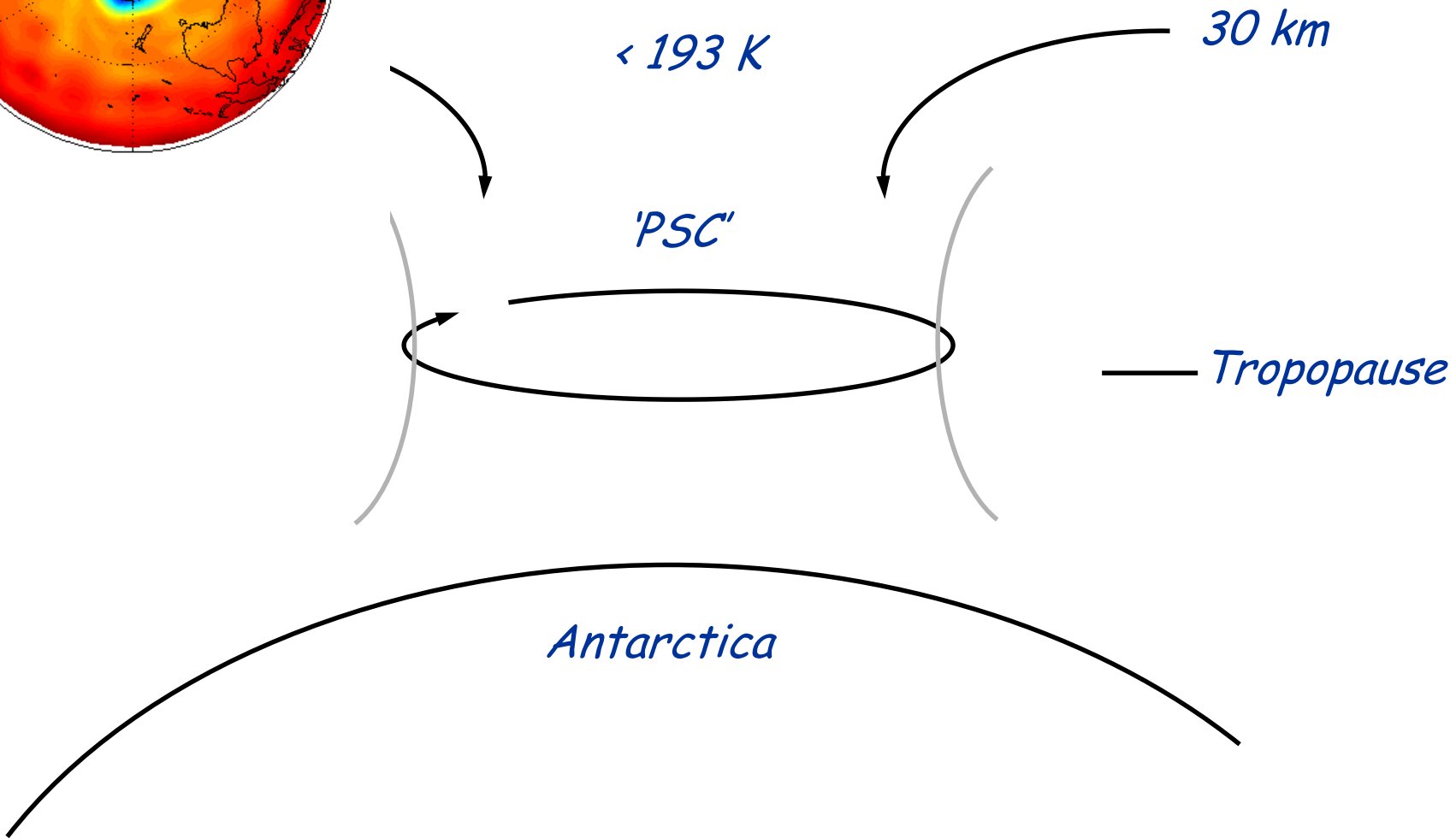
< 193 K

30 km

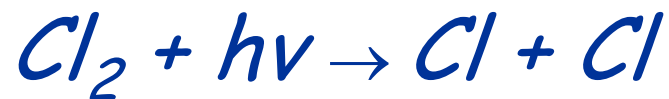
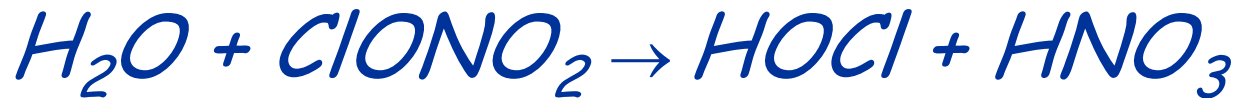
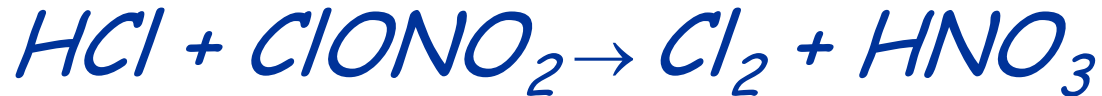
'PSC'

— Tropopause

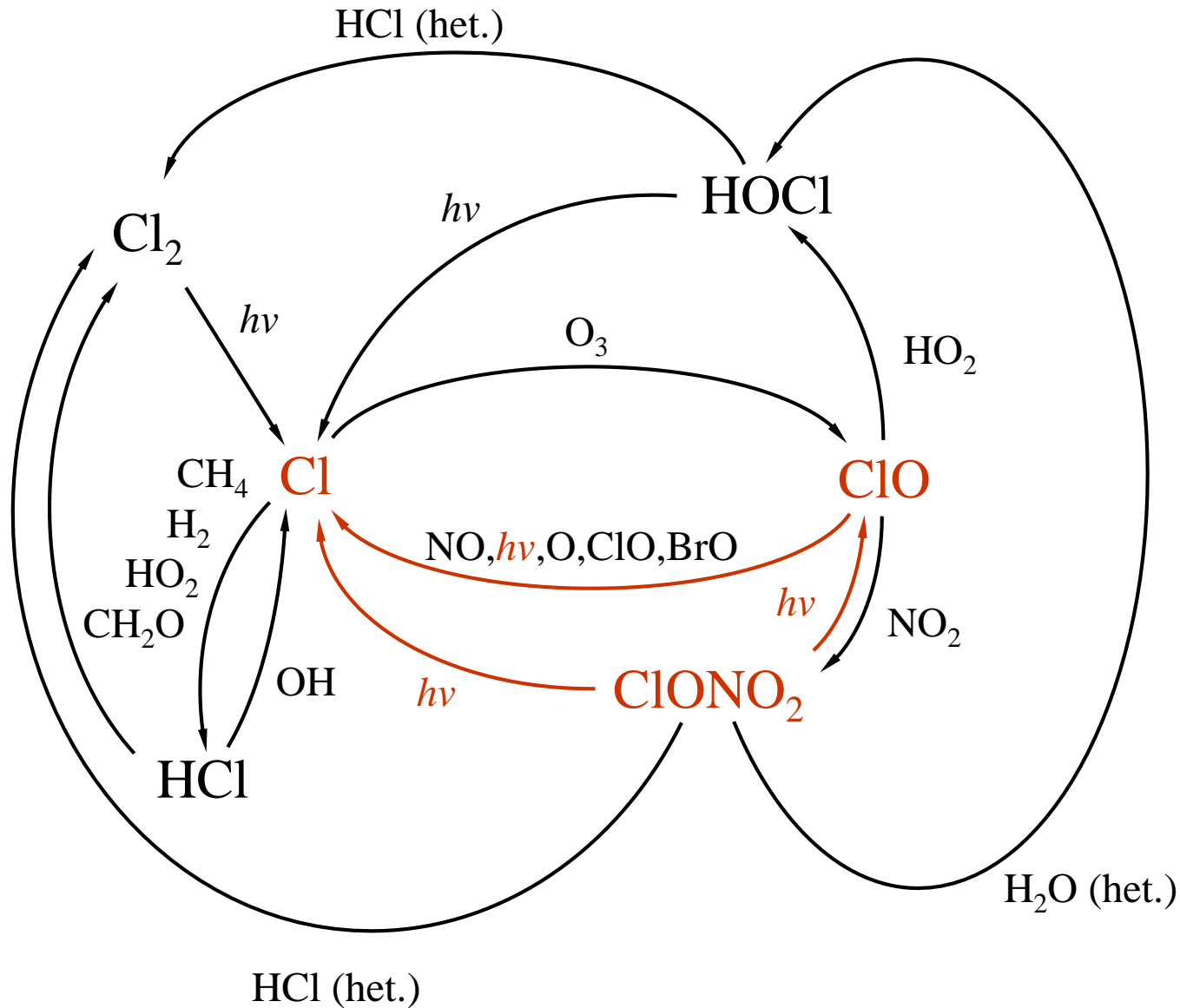
Antarctica



Role of PSCs



Atmospheric Chlorine Cycles

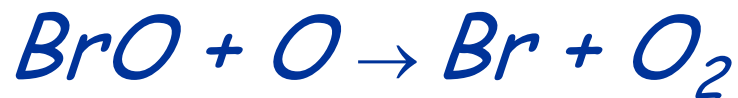
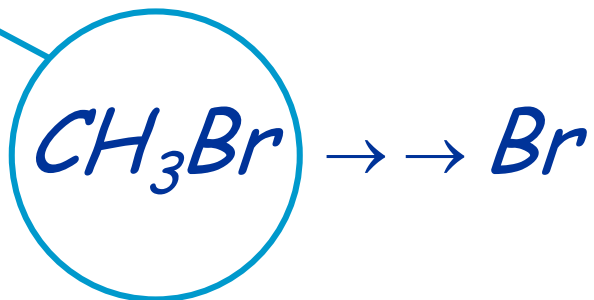


Mixing Times and Transport

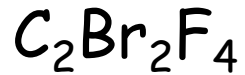
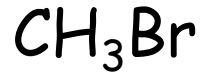
- *Vertical Mixing within Troposphere: weeks*
- *Mixing within Hemispheres: months*
- *Mixing between Hemispheres: ~1 year*
- *Mixing between Stratosphere and Troposphere: years*

Ozone Depletion by Methyl Bromide

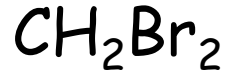
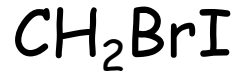
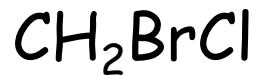
Pesticide, 20-60 kilotons/yr due to agriculture



Sources of Atmospheric Bromine

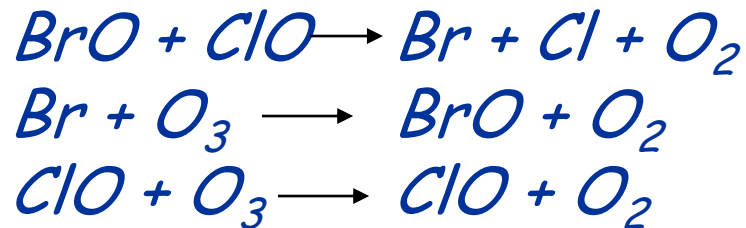
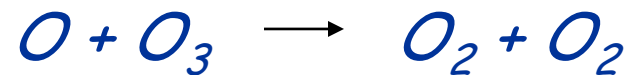
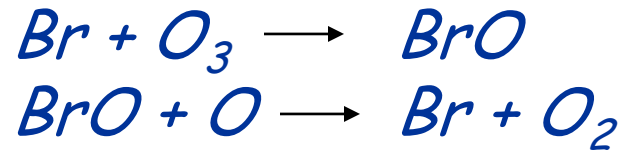


'halons', anthropogenic sources



natural sources,
phytoplankton and
microalgae

Coupling of Br and Cl Cycles



The Montreal Protocol

"Perhaps the single most successful international agreement to date has been the Montreal Protocol." -Kofi Annan, Secretary General of the United Nations

Ozone Depleting Substances

Chlorofluorocarbons (CFCs)

Halons

Carbon tetrachloride

Methyl chloroform

Hydrochlorofluorocarbons (HCFCs)

Hydrobromofluorocarbons (HBFCs)

Methyl bromide

Developed Countries

Phased out end of 1995

Phased out end of 1993

Phased out end of 1995

Phased out end of 1995

Freeze from 1996

35% reduction by 2004

65% reduction by 2010

90% reduction by 2015

Total phase out by 2020

Phased out end of 1995

Freeze in 1995 at 1991 level

Developing Countries

Total phase out by 2010

Total phase out by 2010

Total phase out by 2010

Total phase out by 2015

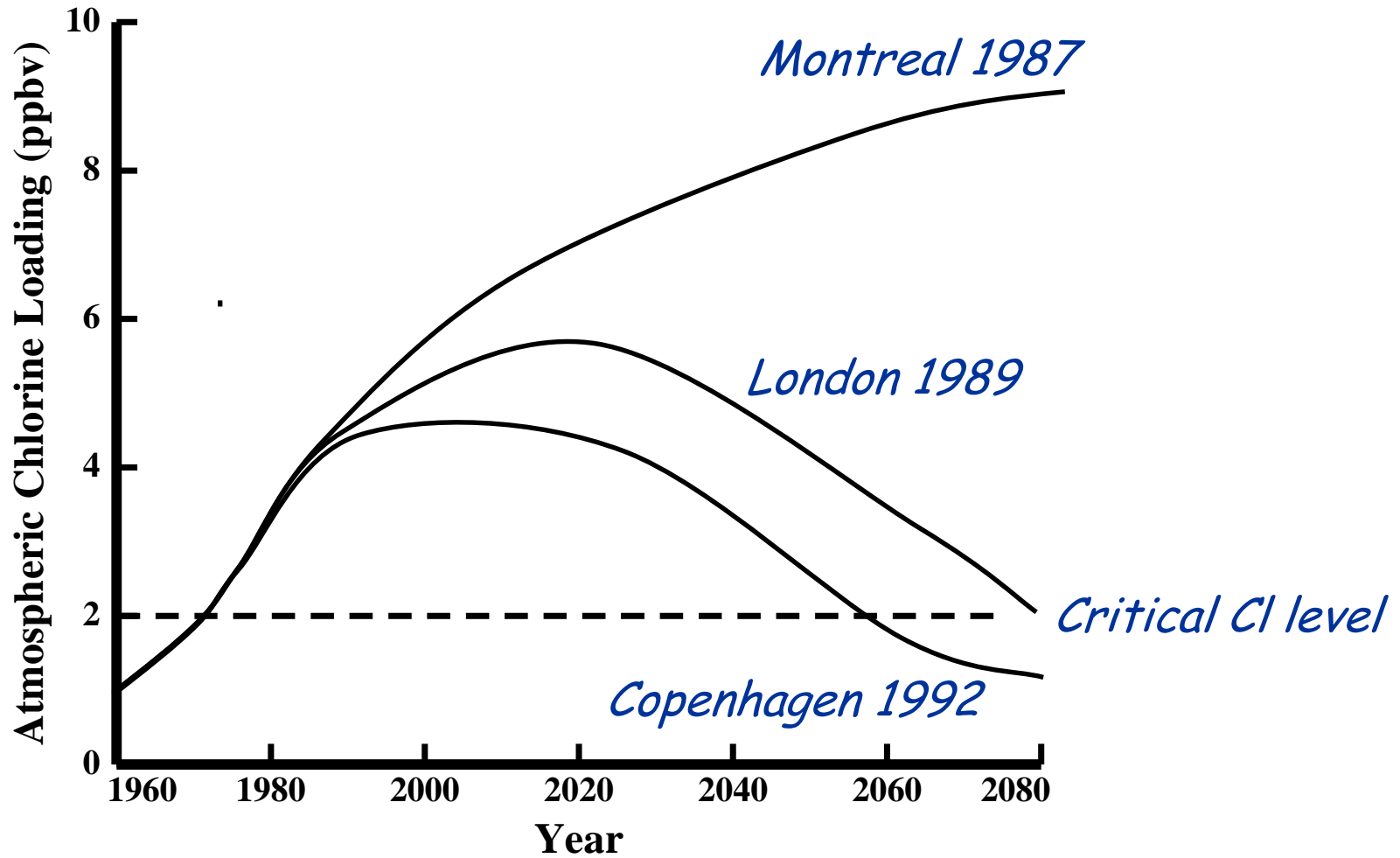
Freeze in 2016

Total phase out by 2040

Phased out end of 1995

Freeze in 2002

Atmospheric Chlorine Loading



Lifetimes of HCFC's in the Atmosphere

<i>HCFC</i>	<i>Atmospheric Lifetime (yr)</i>	<i>ODP</i>
<i>HCFC-123</i>	<i>1.6</i>	<i>0.02</i>
<i>HCFC-124</i>	<i>6.7</i>	<i>0.022</i>
<i>HCFC-141b</i>	<i>12</i>	<i>0.11</i>
<i>HCFC-142b</i>	<i>23</i>	<i>0.065</i>
<i>HCFC-225ca</i>	<i>3</i>	<i>0.025</i>

ODP (Ozone Depletion Potential): Relative to CFC-11

Ozone Depletion is Good for You:

The Montreal Protocol was adopted with no consideration whatsoever of the benefits of UV exposure. For most land vertebrates including man, the only source of vitamin D-required for the metabolism of calcium into bone-is derived from the action of UV on the oils in the skin, fur, or feathers. (Furred and feathered creatures get their vitamin D by self-grooming). A shortage of vitamin D during the period of formation of the skeleton leads to rickets in the young and to osteoporosis in the old. Among the estimated 25 million people in the U.S. suffering osteoporosis today, there are approximately twice as many bone fractures per year, typically of the femur, as there are new cases of skin cancer. Theoretically, increased UV flux, as from decreases in the thickness of the ozone layer, would alleviate this condition in future generations.

Ellsaesser, Hugh W., "With Respect to the Ozone Hole-Gore is Part of the Problem" in John A Baden, editor, *Environmental Gore: A Constructive Response to Earth in the Balance*, Pacific Research Institute for Public Policy, 1994.



Do volcanoes,
which release large
quantities of HCl
into the
atmosphere,
contribute more to
stratospheric ozone
depletion than
anthropogenic
sources?





Although volcanic eruptions release significant quantities of HCl, few are strong enough to reach the stratosphere. In addition, the amount of water released is 1,000 times greater and most HCl is rained out.



Ozone Hole Blamed for Frog Decline

By MARLA CONE
TIMES ENVIRONMENT WRITER

In research that for the first time suggests that the thinning of the Earth's ozone layer directly harms wild animals, scientists reported Monday that frog eggs are being killed by ultraviolet radiation in the Pacific Northwest.

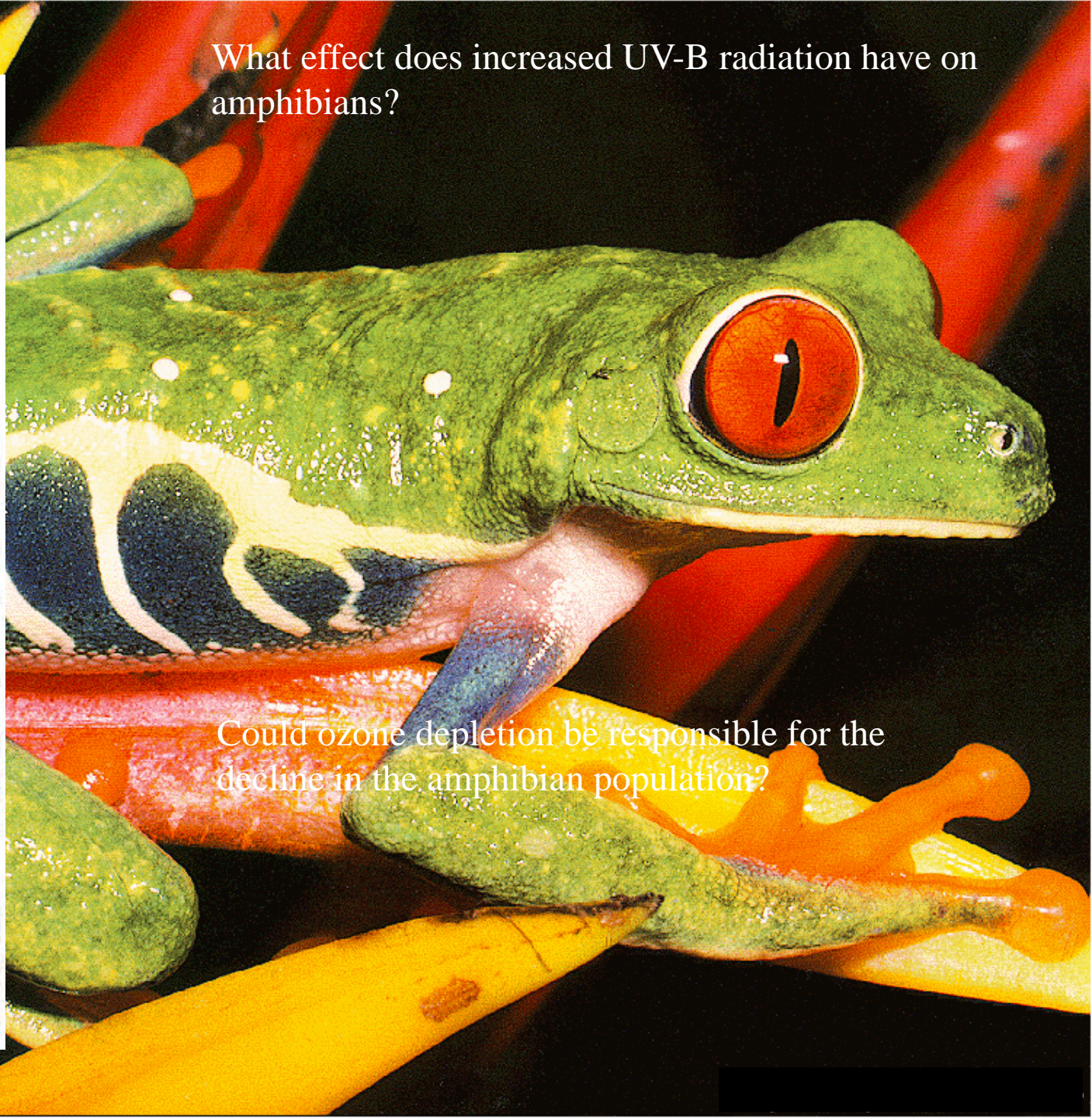
Oregon State University's study of frogs in the Cascade Mountains could help solve the mystery of why many of the world's frogs and toads seem to be vanishing, especially at high altitudes.

The most alarming aspect of the research, some scientists say, is that it indicates UV radiation is damaging wildlife in heav-

Please see FROGS, A20

What effect does increased UV-B radiation have on amphibians?

Could ozone depletion be responsible for the decline in the amphibian population?





UV-B radiation has been shown to affect the proportion of eggs which hatch in certain species. However, the amphibian decline is worldwide and areas of significant UV-B increase is restricted.





"Well, I'm addicted. ... Have you tried Carol's sheep dip?"

Is the increased UV-B radiation caused by ozone depletion blinding Sheep in Chile?

"temporary cataracts" were reported to be affecting sheep grazing at high altitudes in the spring





Johns Hopkins researchers has discovered that the blindness was the result of 'pink-eye'

