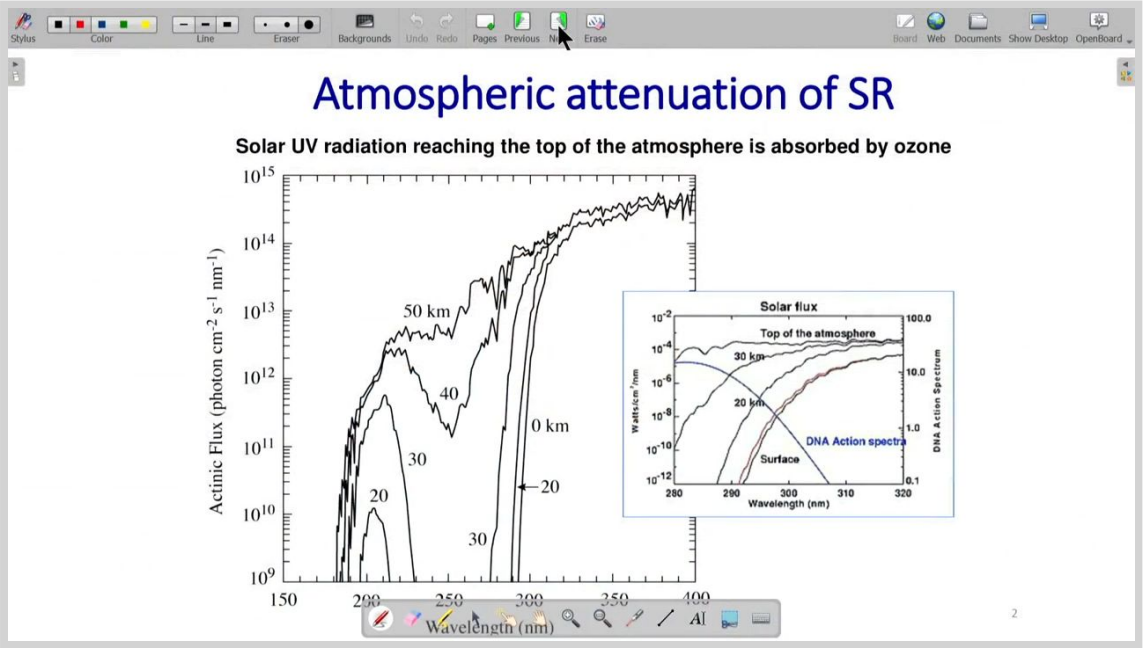
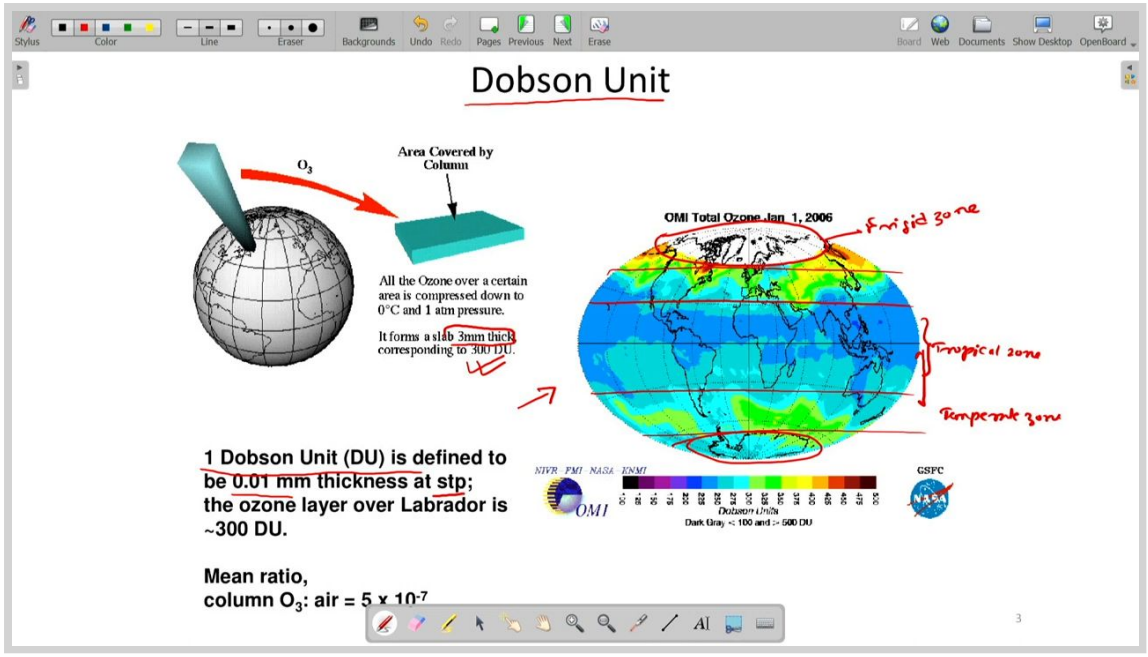
←

00:01

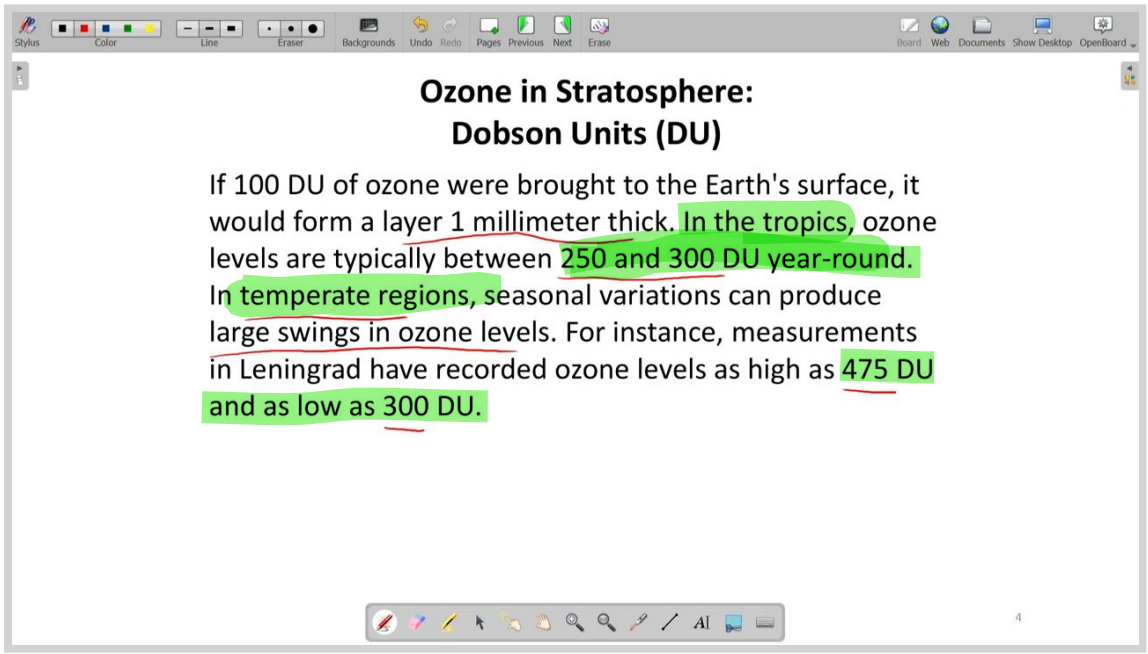
01:02



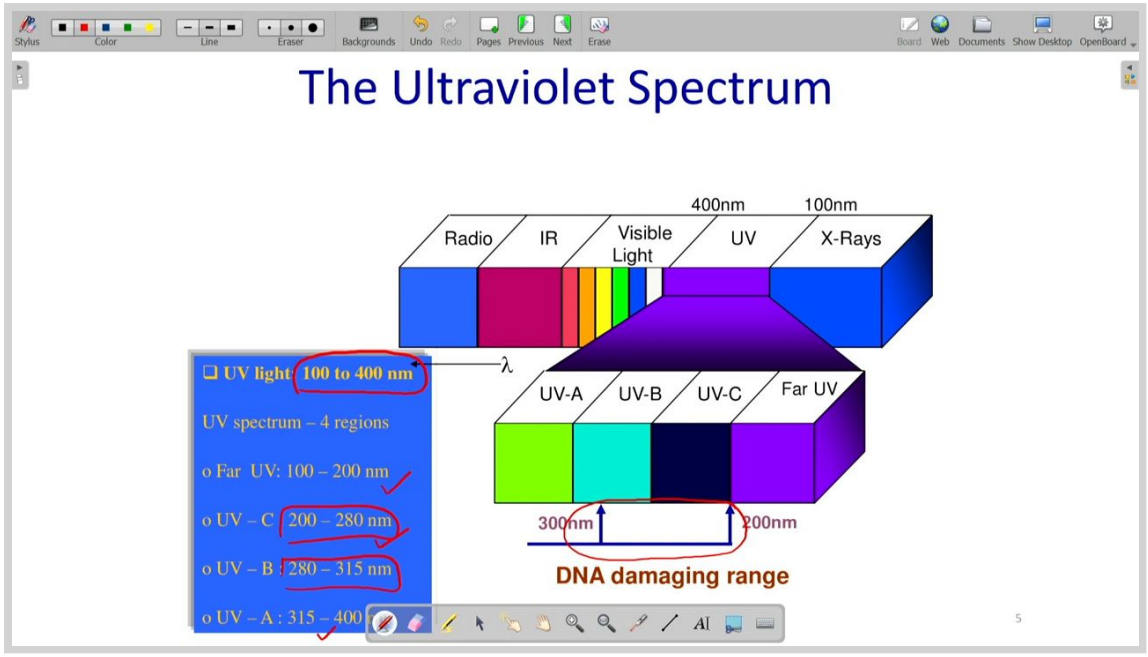
04:01


Dobson Unit
O_3
Area Covered by Column
All the Ozone over a certain area is compressed down to 0°C and 1 atm pressure.
It forms a slab 3mm thick corresponding to 300 DU.
OMI Total Ozone Jan 1, 2006
Frigid zone
Tropical zone
Temperate zone
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}
NIVR FMI NASA ENMI
OMI
GSFC
Dobson Units
Dark Gray = 100 and > 500 DU

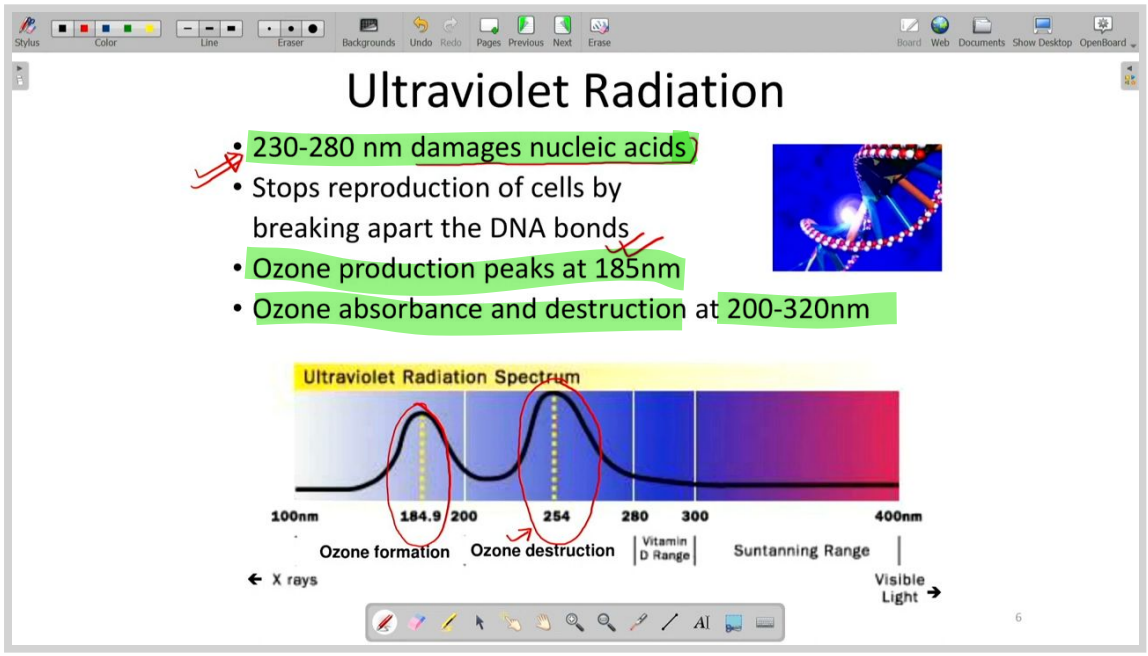
[04:39](#)


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.

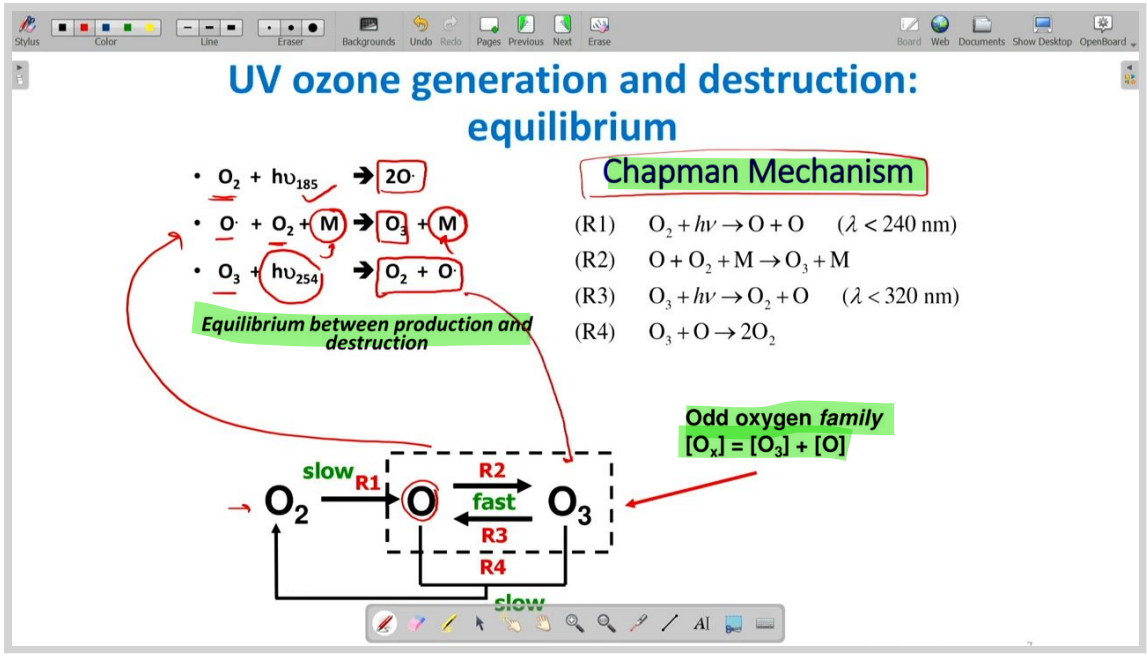
[05:50](#)


The Ultraviolet Spectrum
400nm
100nm
Radio
IR
Visible Light
UV
X-Rays
λ
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
UV-A
UV-B
UV-C
Far UV
300nm
200nm
DNA damaging range

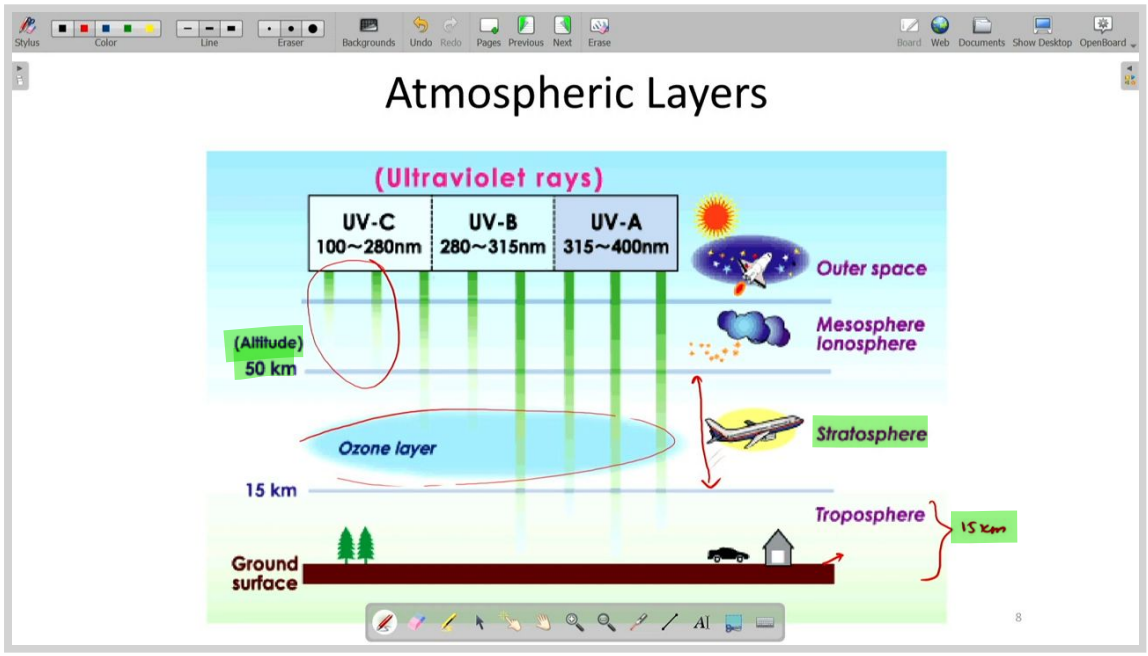
[06:55](#)


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
Ultraviolet Radiation Spectrum
100nm
184.9
200
254
280
300
400nm
Ozone formation
Ozone destruction
Vitamin D Range
Suntanning Range
X rays
Visible Light

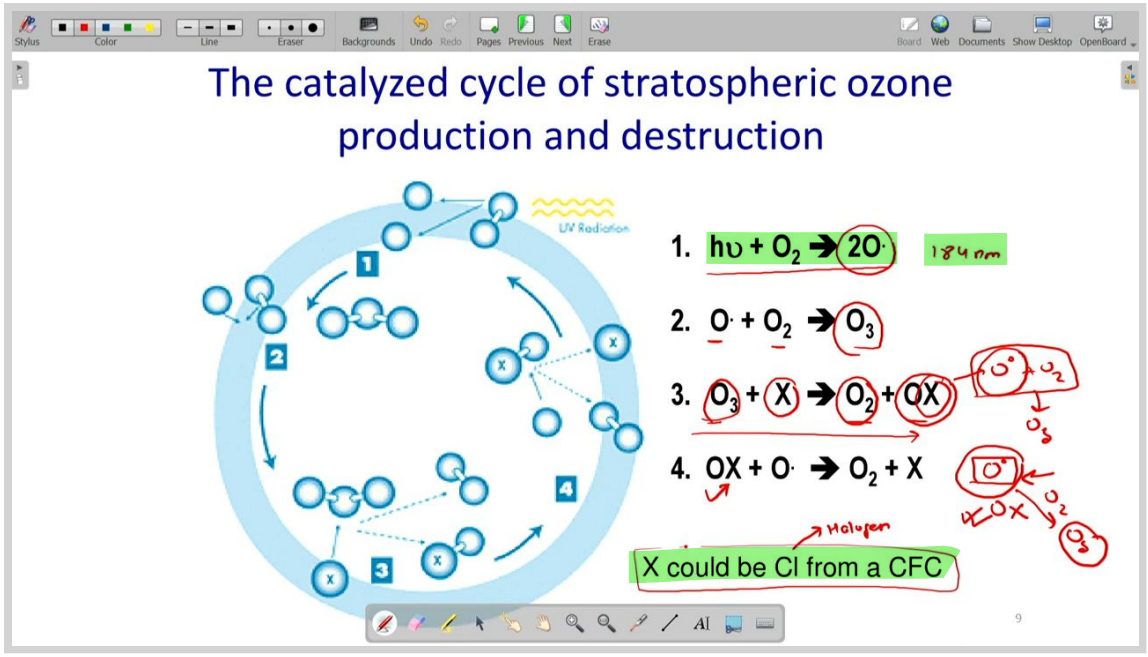
[08:56](#)


UV ozone generation and destruction: equilibrium
Chapman Mechanism
(R1) $O_2 + h\nu \rightarrow O + O$ ($\lambda < 240$ nm)
(R2) $O + O_2 + M \rightarrow O_3 + M$
(R3) $O_3 + h\nu \rightarrow O_2 + O$ ($\lambda < 320$ nm)
(R4) $O_3 + O \rightarrow 2O_2$
Equilibrium between production and destruction
Odd oxygen family
$[O_x] = [O_3] + [O]$
slow
R1
R2
fast
R3
R4
slow

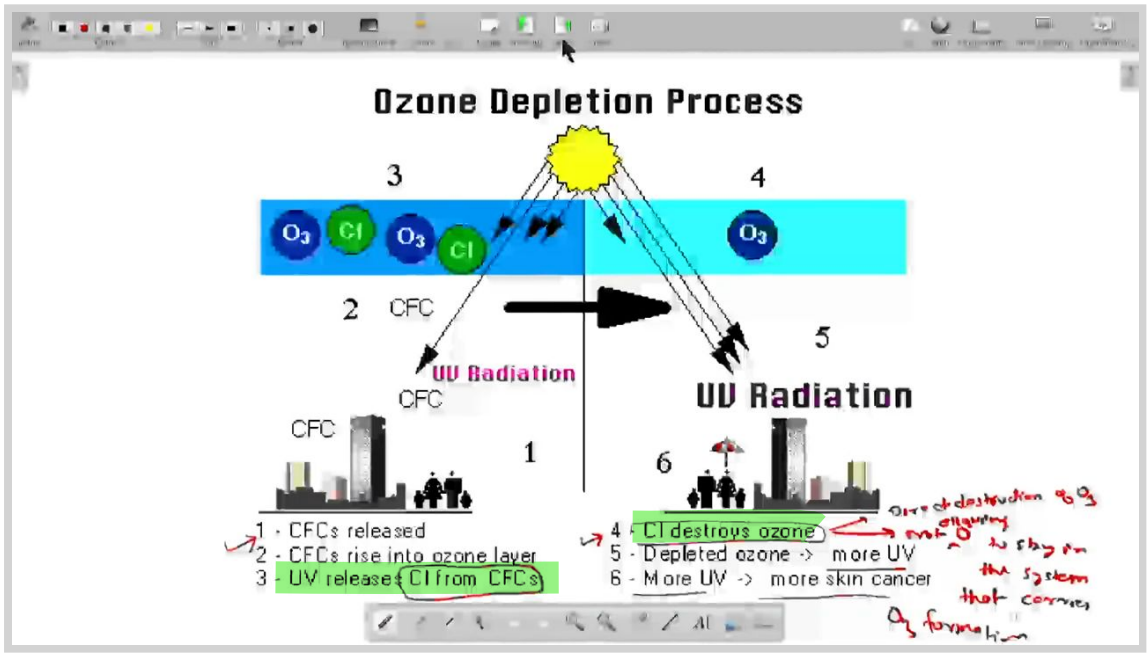
09:48


Atmospheric Layers
(Ultraviolet rays)
UV-C 100~280nm
UV-B 280~315nm
UV-A 315~400nm
Outer space
Mesosphere Ionosphere
(Altitude) 50 km
Ozone layer
Stratosphere
15 km
Troposphere
15 km
Ground surface

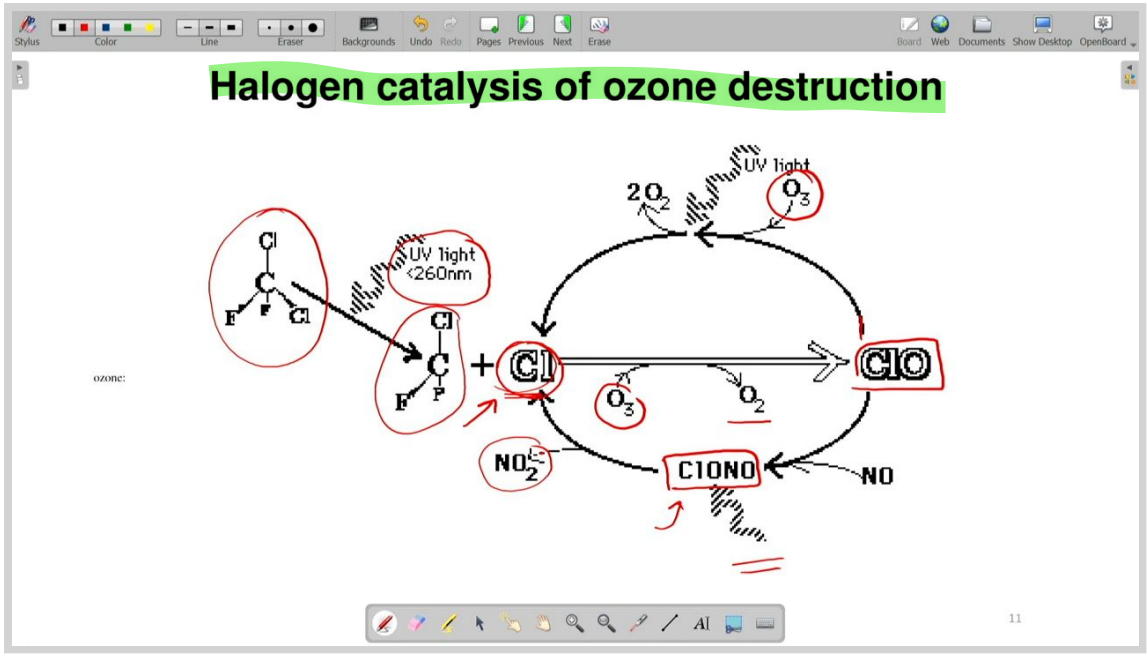
13:24


The catalyzed cycle of stratospheric ozone production and destruction
UV Radiation
1. hυ + O2 → 2O· 184 nm
2. O· + O2 → O3
3. O3 + X → O2 + OX
4. OX + O· → O2 + X
X could be Cl from a CFC

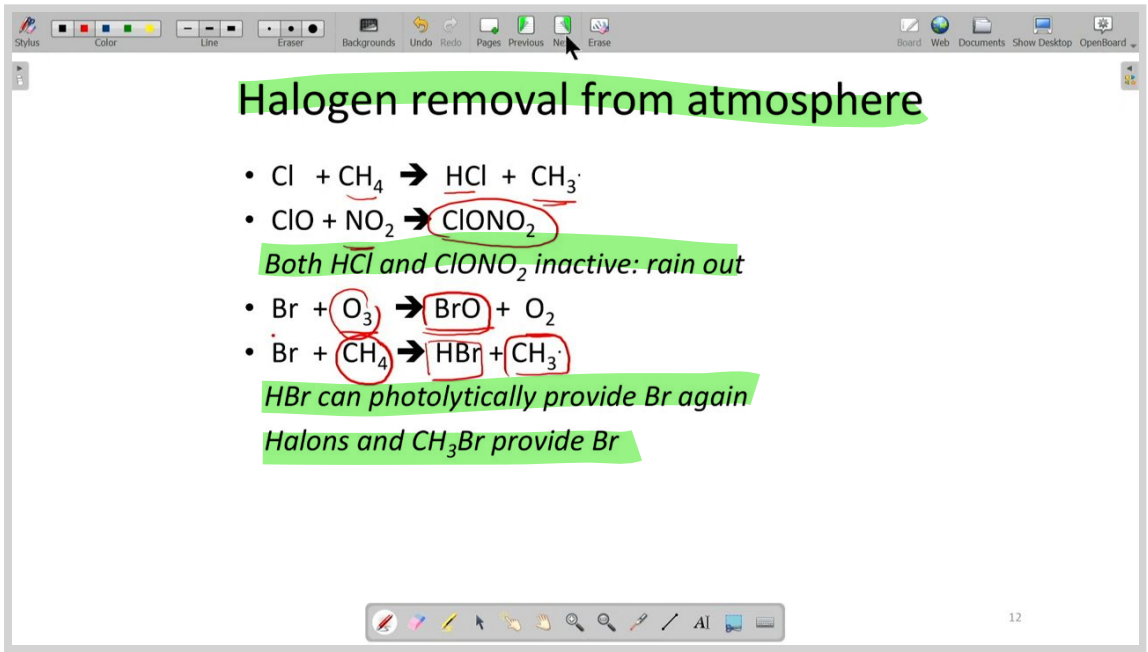
[15:08]


Ozone Depletion Process
3
4
2 CFC
5
UV Radiation
CFC
CFC
1
6
UV Radiation
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

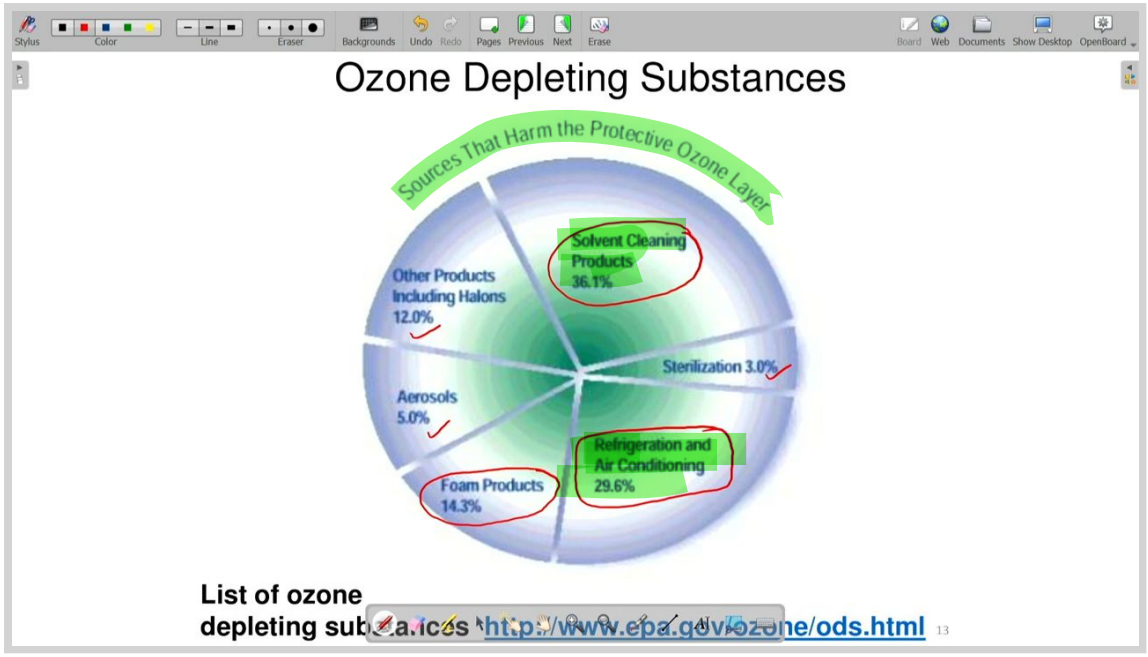
[16:44]


Halogen catalysis of ozone destruction
UV light
$2O_2$
O_3
UV light
<260nm
Cl
F
F
Cl
Cl
F
F
Cl
+
ClO
O_3
O_2
NO_2
ClONO
NO
ozone:
11

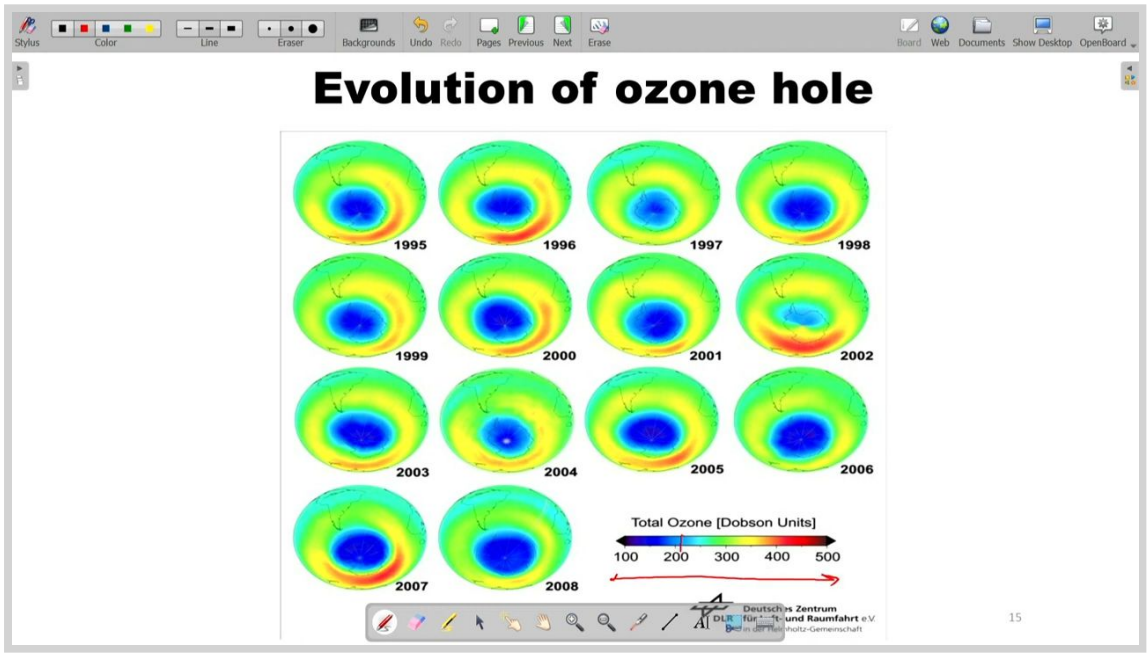
[17:39](#)


Halogen removal from atmosphere
• Cl + CH_4 → HCl + CH_3·
• ClO + NO_2 → $ClONO_2$
Both HCl and $ClONO_2$ inactive: rain out
• Br + O_3 → BrO + O_2
• Br + CH_4 → HBr + CH_3·
HBr can photolytically provide Br again
Halons and CH_3Br provide Br
12

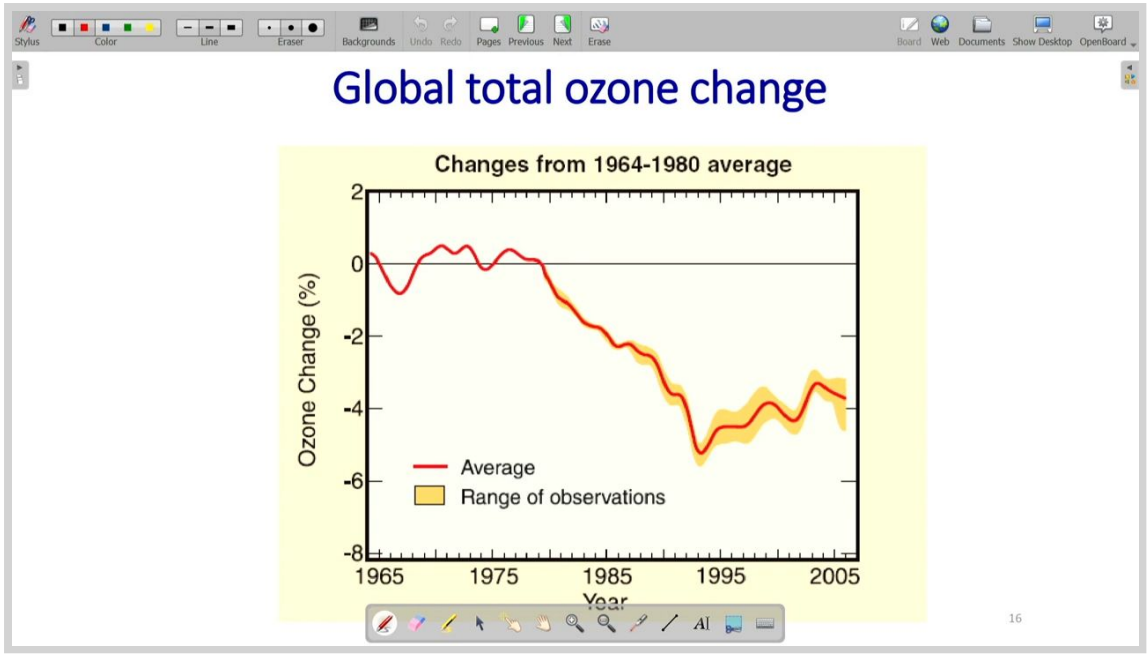
[18:18](#)


Ozone Depleting Substances
Sources That Harm the Protective Ozone Layer
Solvent Cleaning Products 36.1%
Other Products Including Halons 12.0%
Sterilization 3.0%
Aerosols 5.0%
Refrigeration and Air Conditioning 29.6%
Foam Products 14.3%
List of ozone depleting substances
http://www.epa.gov/ozone/ods.html

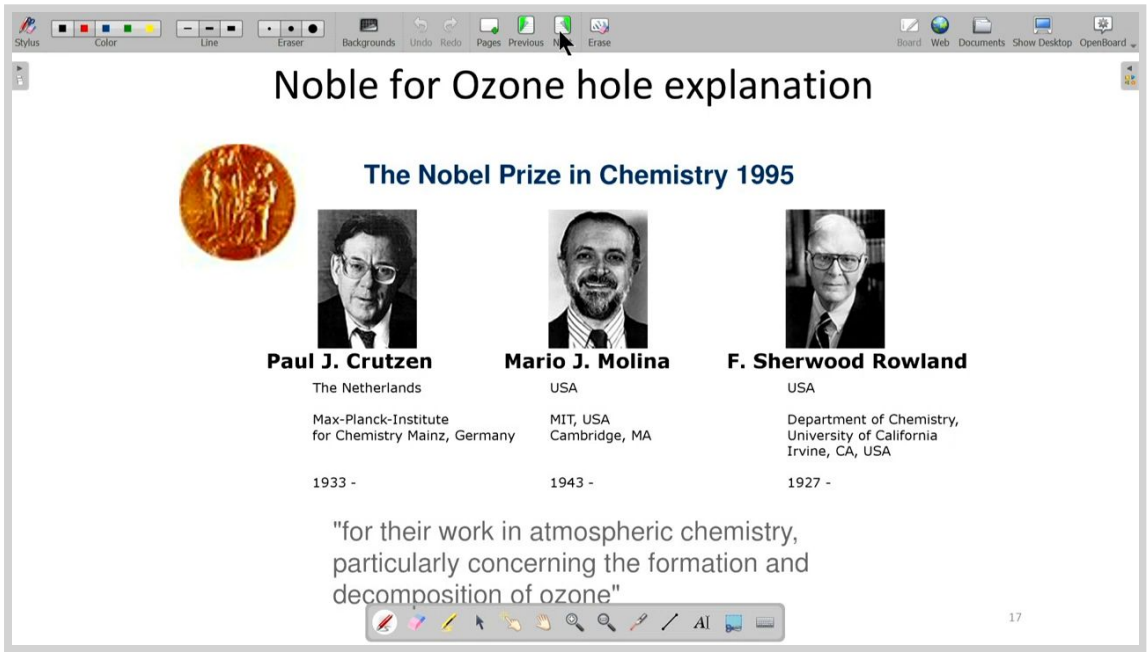
[18:50]


Evolution of ozone hole
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
Total Ozone [Dobson Units]
100 200 300 400 500

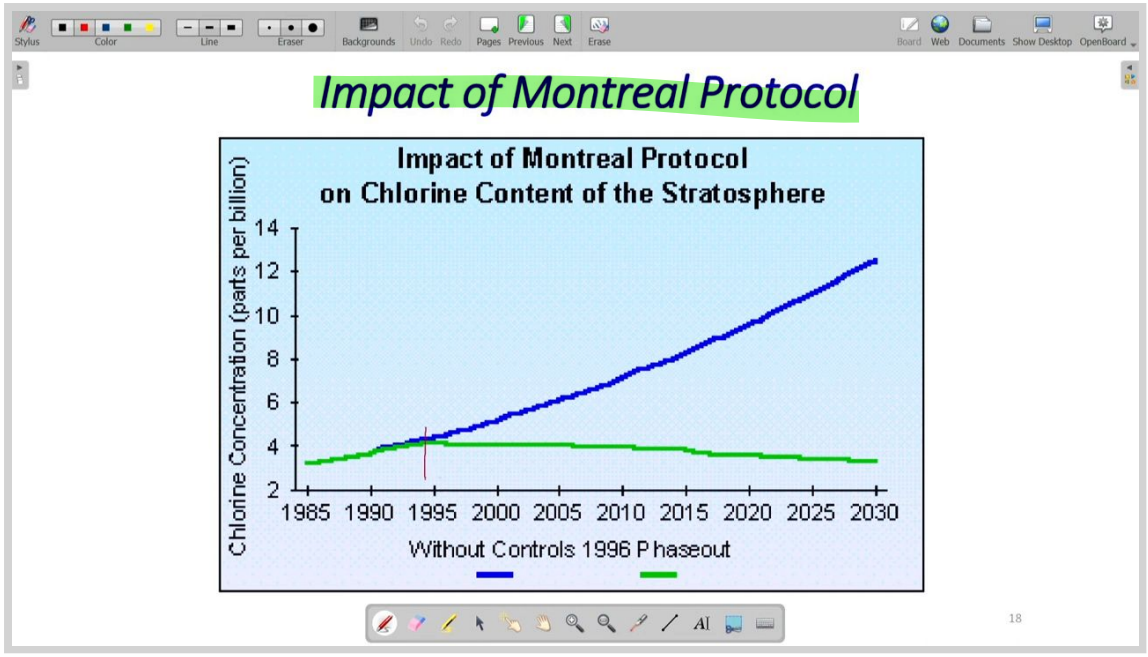
[20:33]


Global total ozone change
Changes from 1964-1980 average
Ozone Change (%)
2
0
-2
-4
-6
-8
1965
1975
1985
1995
2005
Year
Average
Range of observations
16

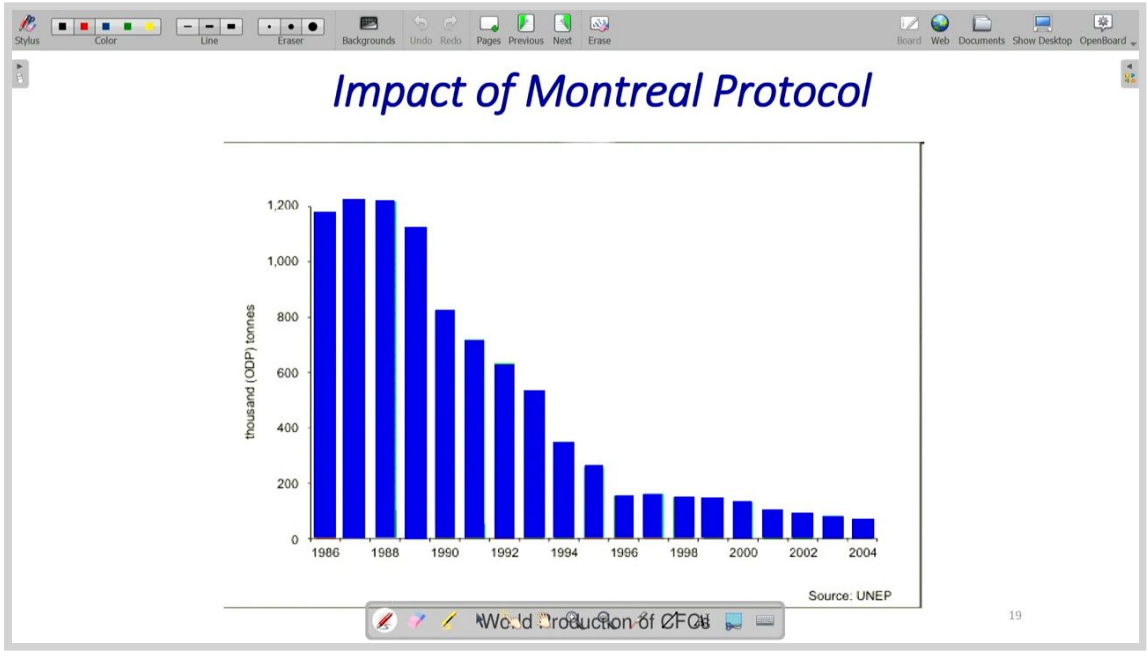
[21:04]


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"
17

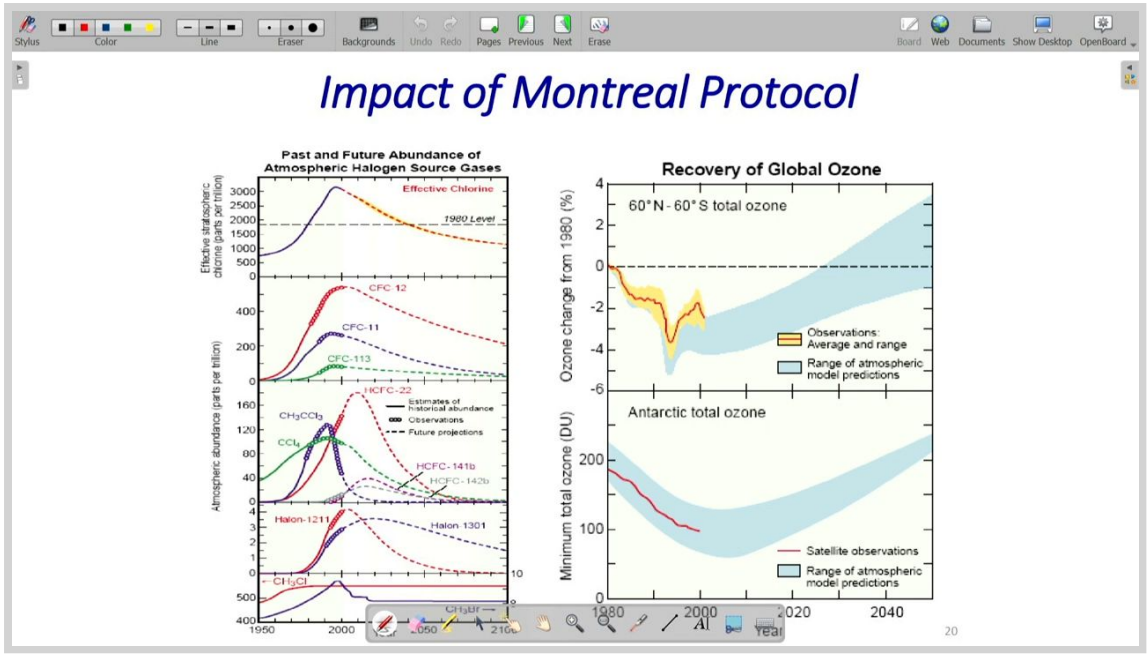
[21:38]


Impact of Montreal Protocol
Impact of Montreal Protocol
on Chlorine Content of the Stratosphere
Chlorine Concentration (parts per billion)
14
12
10
8
6
4
2
1985 1990 1995 2000 2005 2010 2015 2020 2025 2030
Without Controls 1996 Phaseout
18

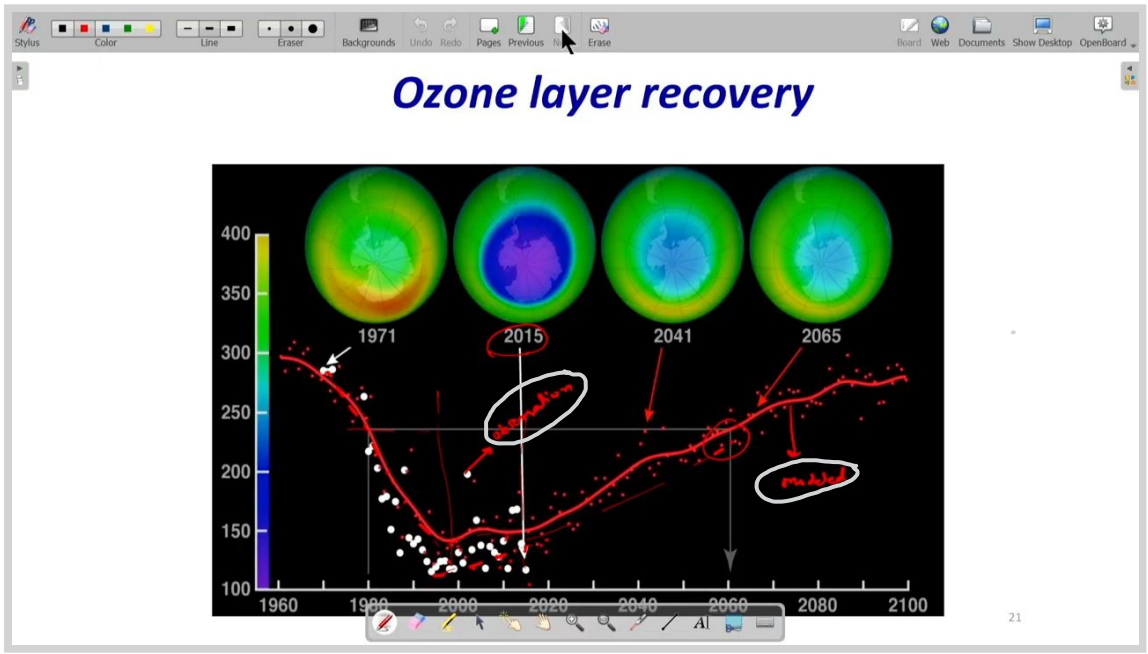
22:09


Impact of Montreal Protocol
thousand (ODP) tonnes
1,200
1,000
800
600
400
200
0
1986 1988 1990 1992 1994 1996 1998 2000 2002 2004
Source: UNEP
19

22:23


Impact of Montreal Protocol
Past and Future Abundance of Atmospheric Halogen Source Gases
Effective Chlorine
1980 Level
CFC-12
CFC-11
CFC-113
HCFC-22
Estimates of historical abundance
Observations
Future projections
HCFC-141b
HCFC-142b
Halon-1211
Halon-1301
Recovery of Global Ozone
60°N-60°S total ozone
Observations: Average and range
Range of atmospheric model predictions
Antarctic total ozone
Satellite observations
Range of atmospheric model predictions
Ozone change from 1980 (%)
Minimum total ozone (DU)

[24:00](#)


Ozone layer recovery
1971
2015
2041
2065
1960
2080
2100

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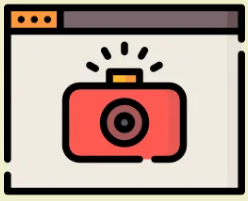
Pricing



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