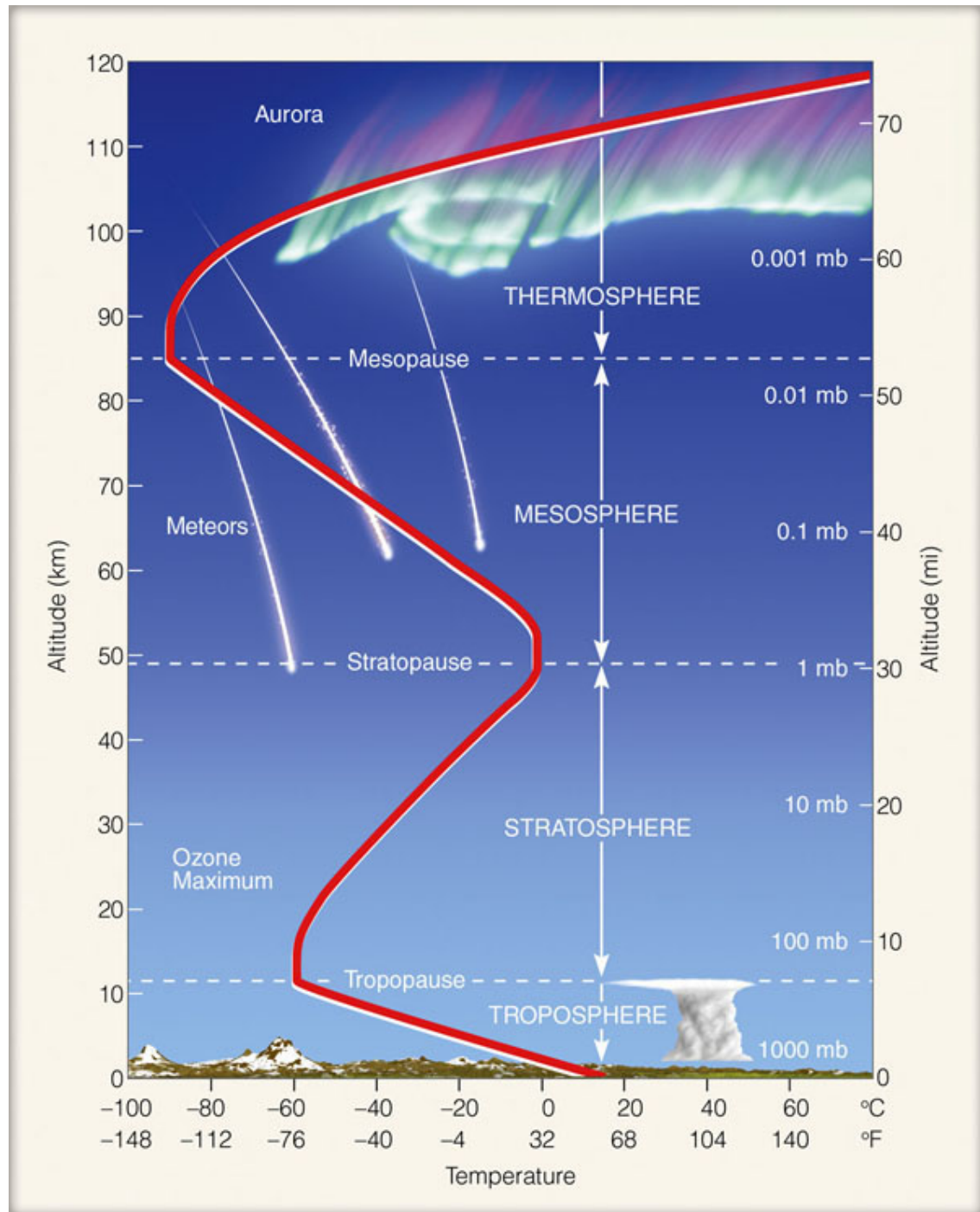


Antarctic Ozone Depletion

EVSC 1300

Spring 2017

Average vertical temperature structure of atmosphere



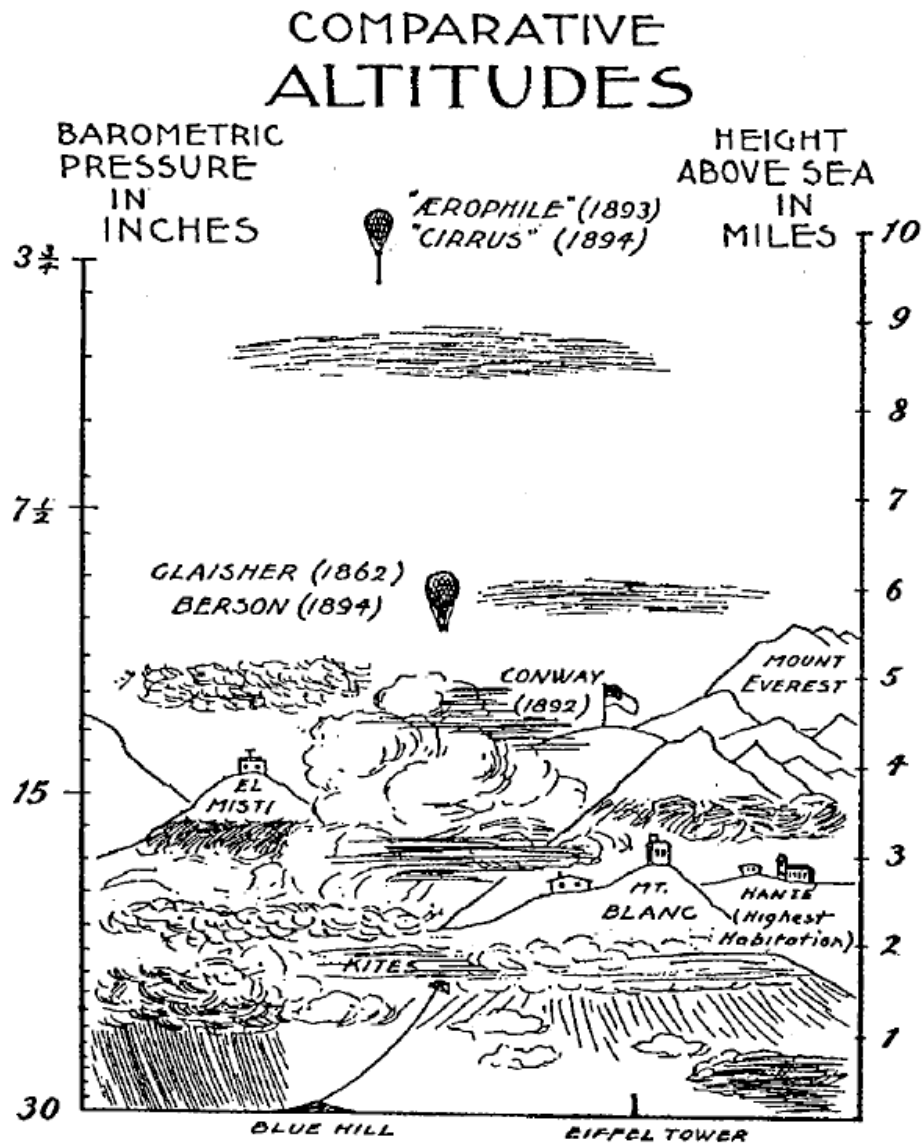


Fig. 3. Upper-air research at the end of the 19th century (taken from ROTCH 1896).

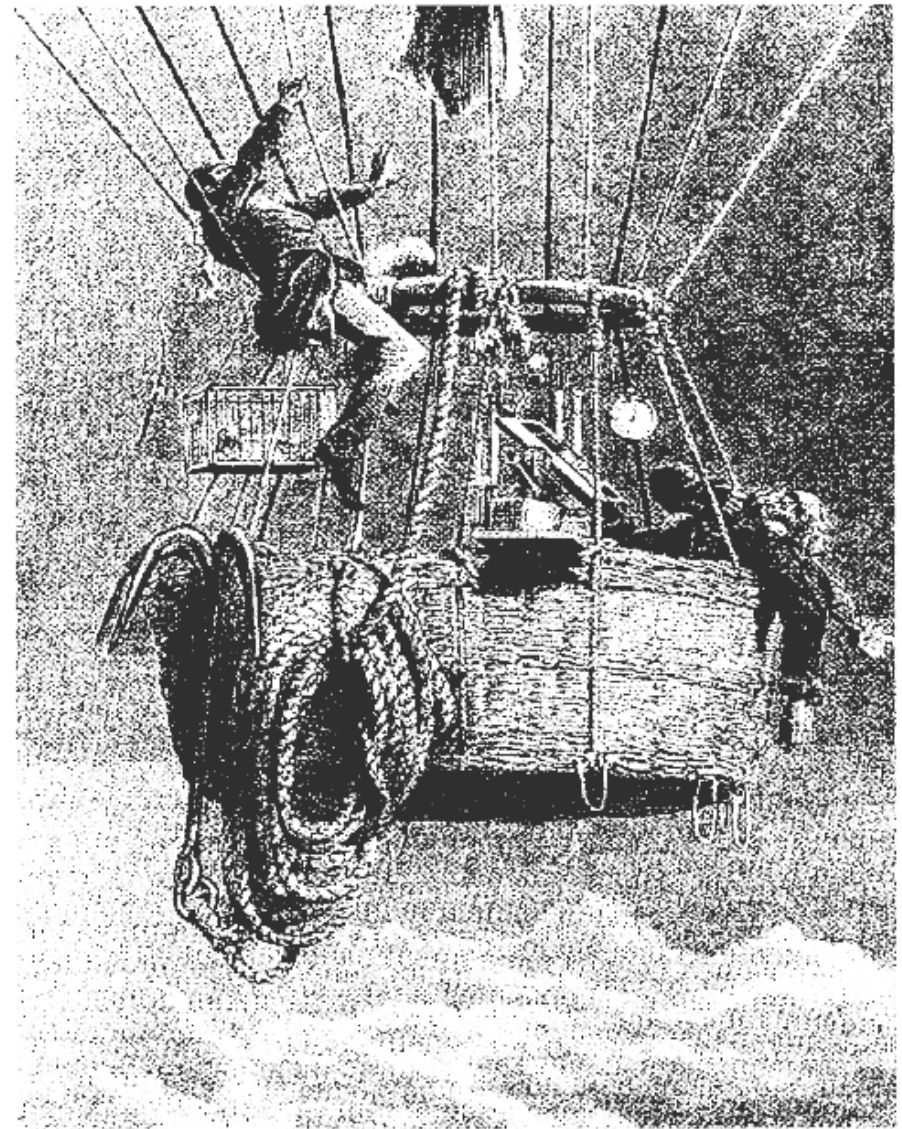
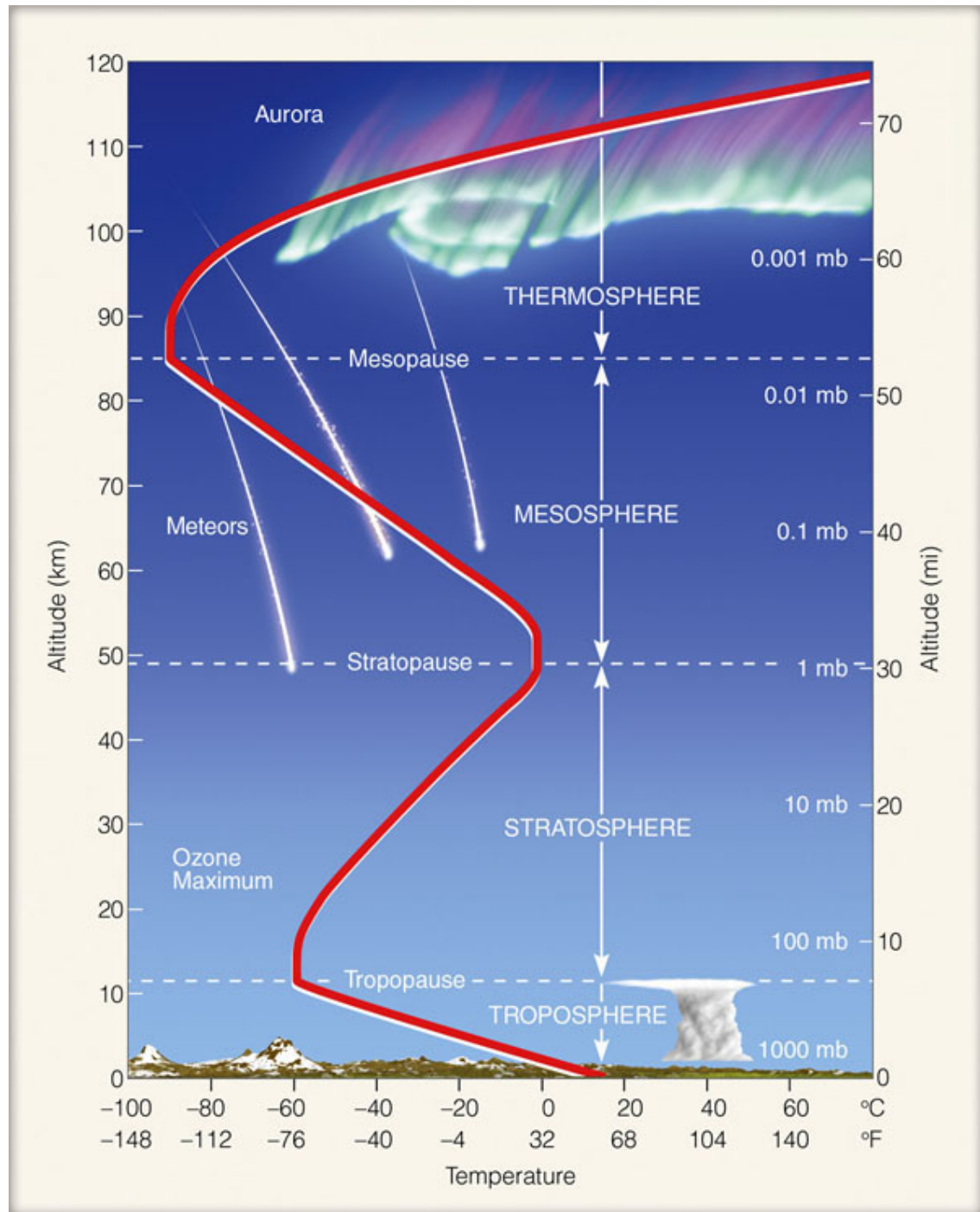
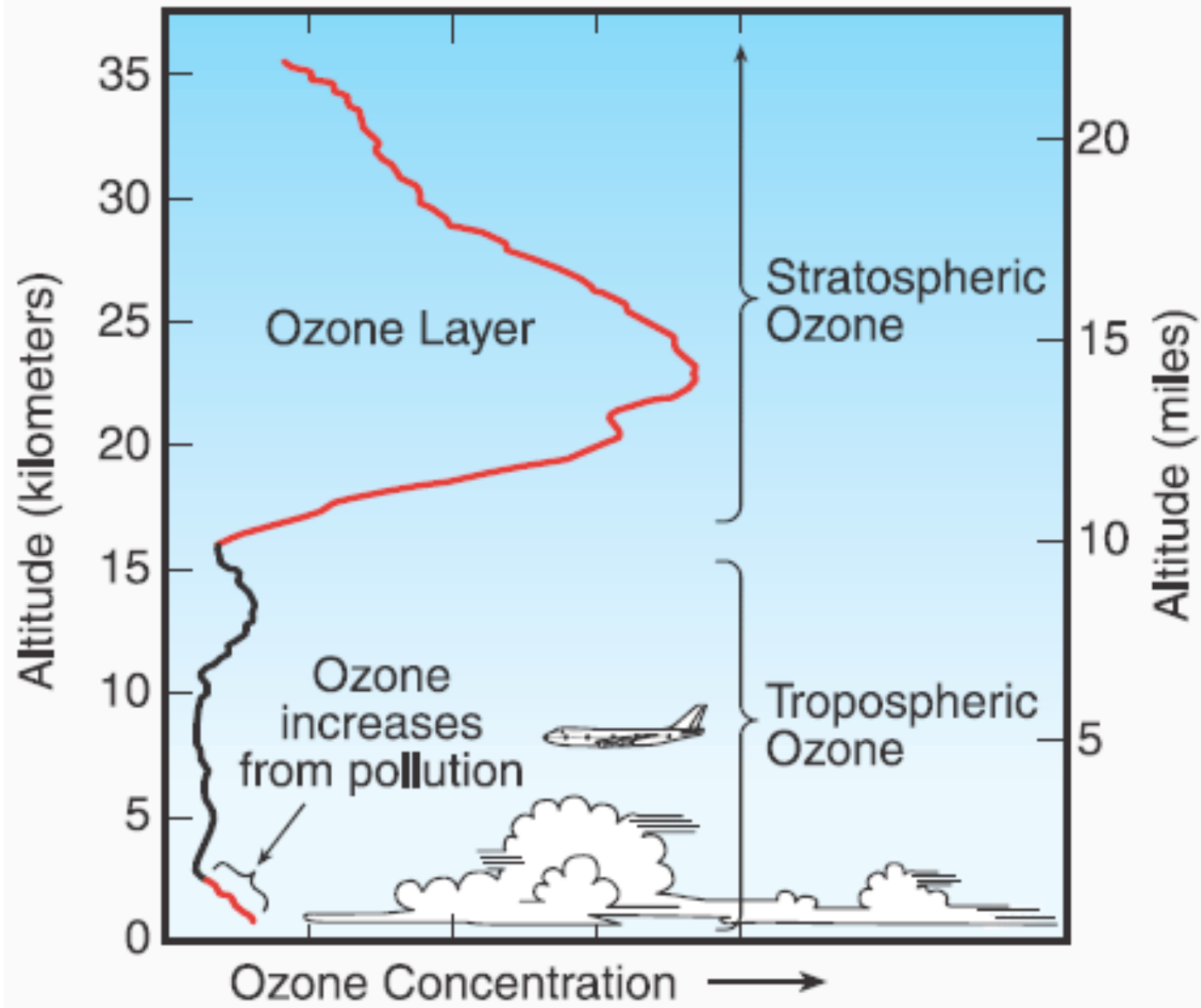


Fig. 1. Contemporary sketch of the dramatic situation when Coxwell and Glaisher became unconscious during their flight in an aerostat in 1862 (taken from FLAMMARION 1885).

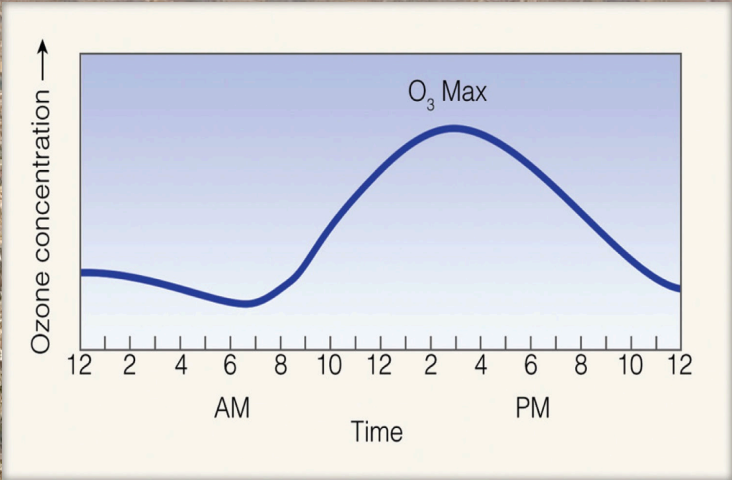
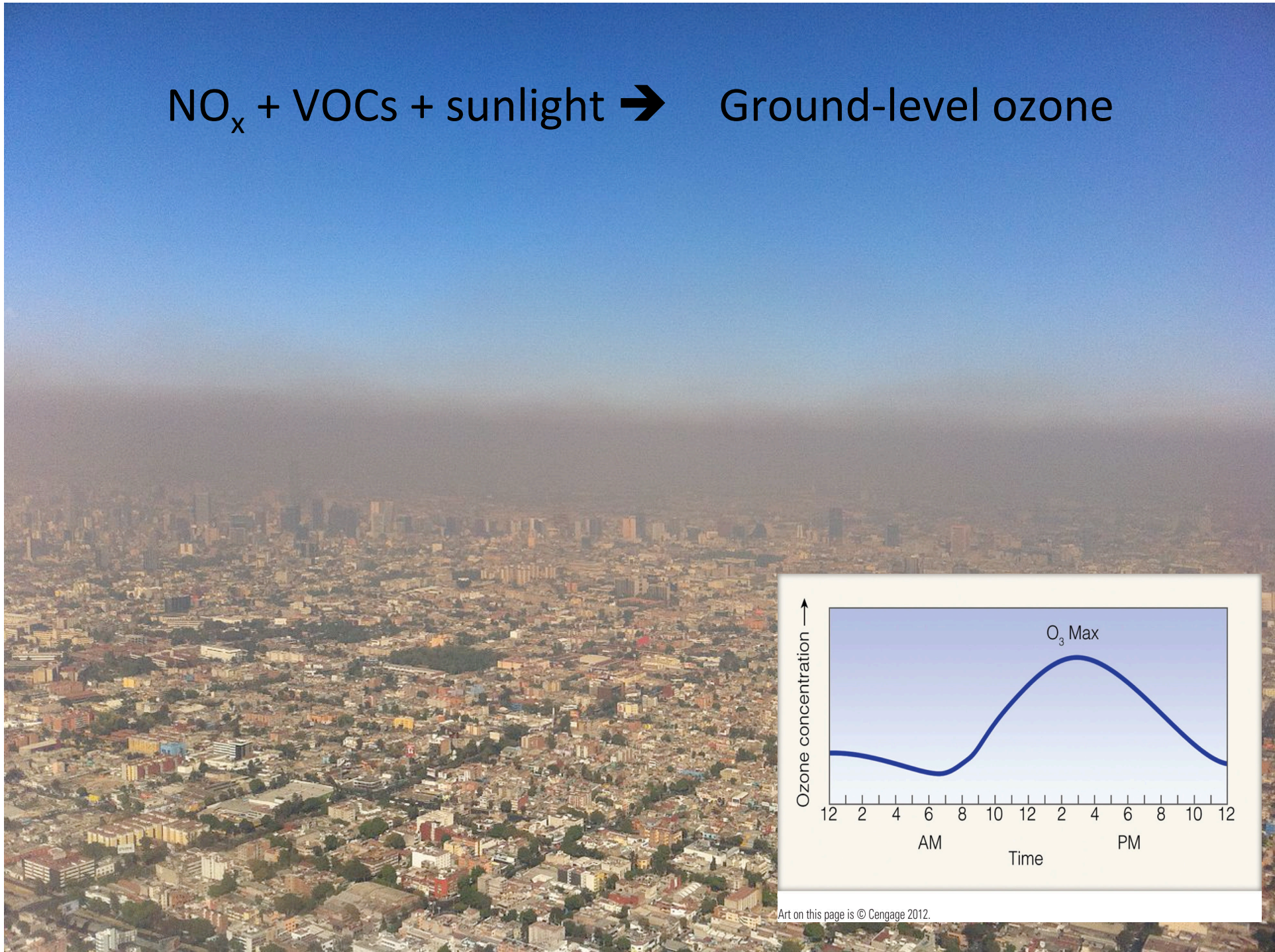
Average vertical temperature structure of atmosphere



Ozone in the Atmosphere

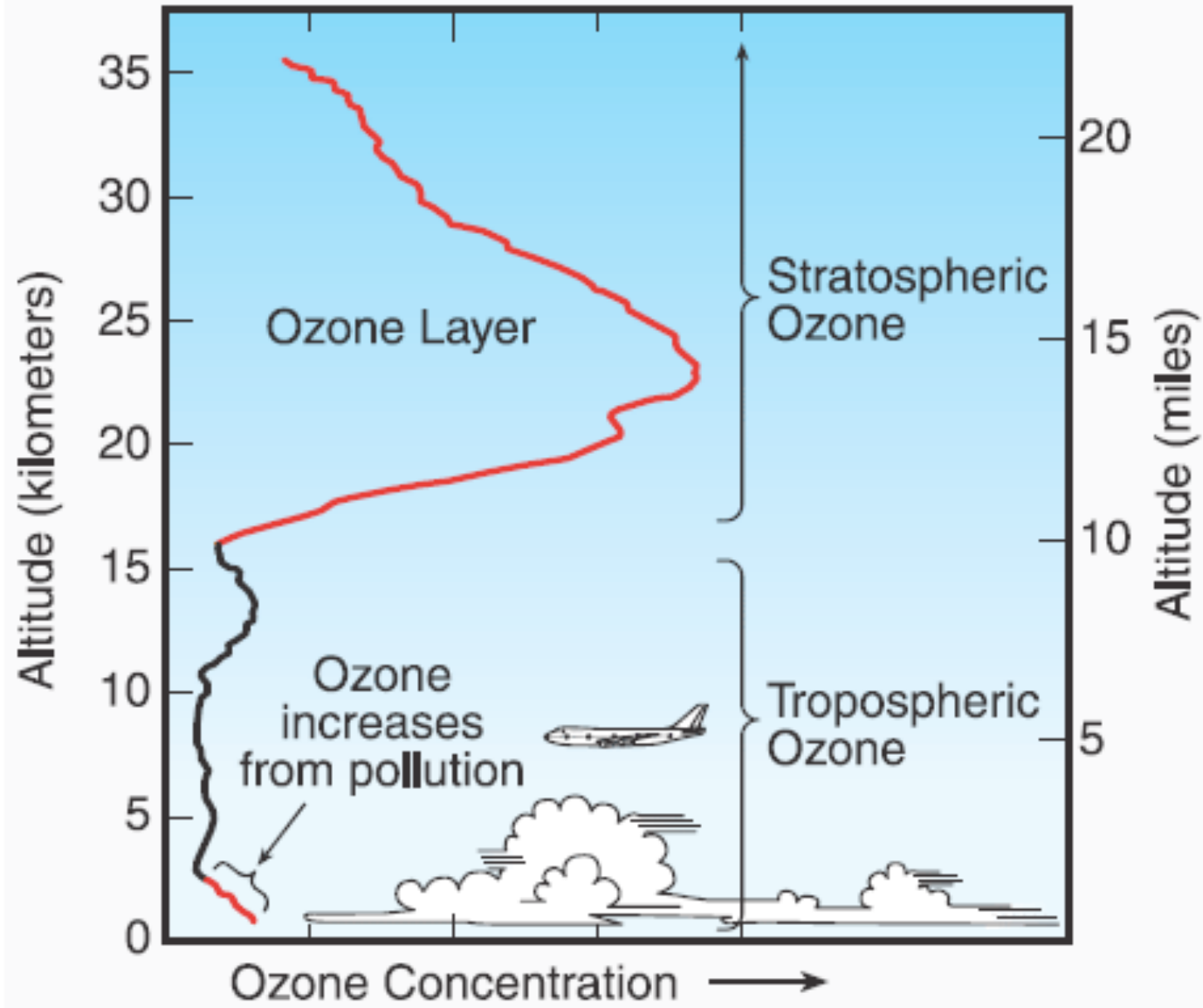


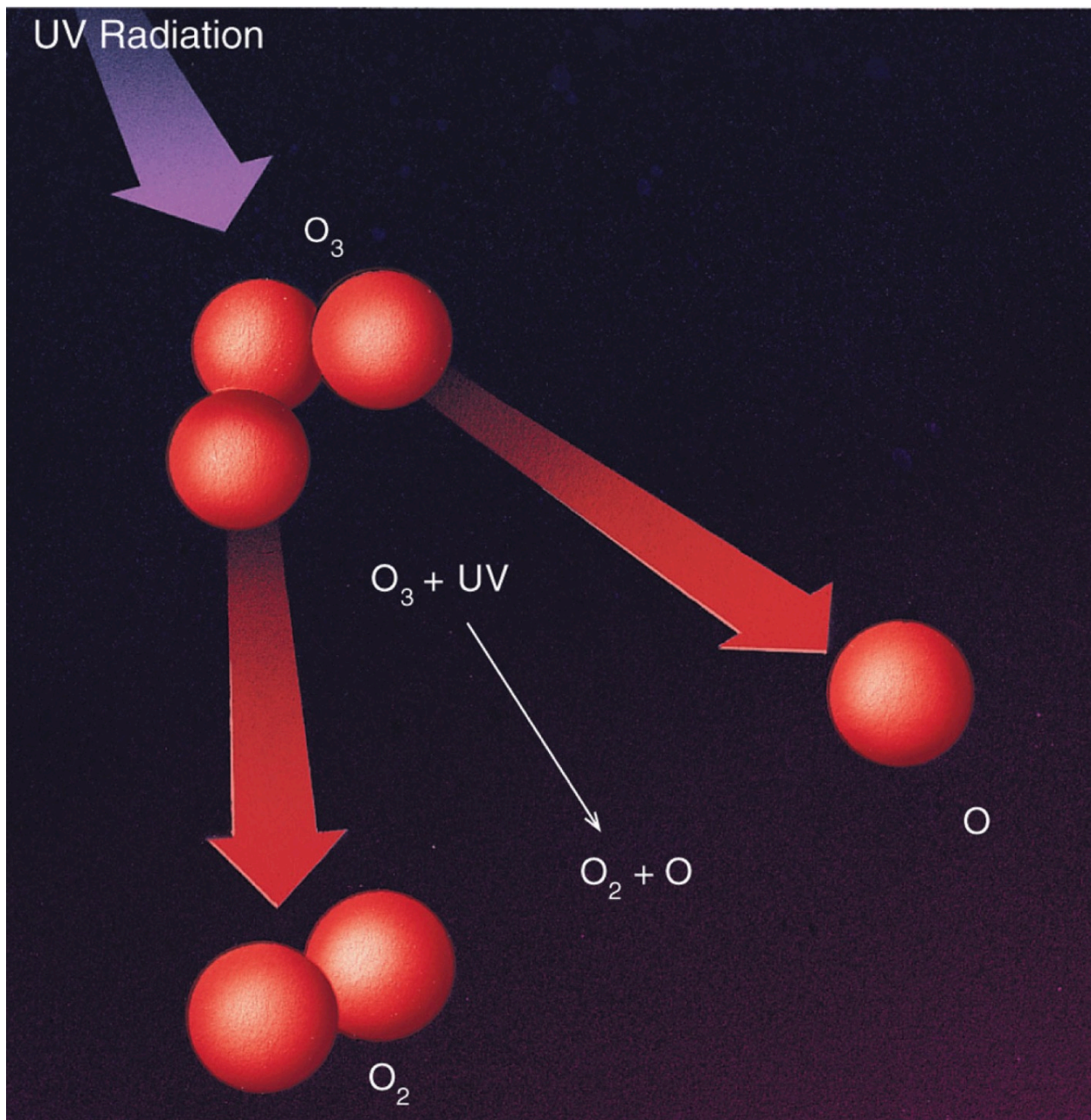
$\text{NO}_x + \text{VOCs} + \text{sunlight} \rightarrow \text{Ground-level ozone}$



Art on this page is © Cengage 2012.

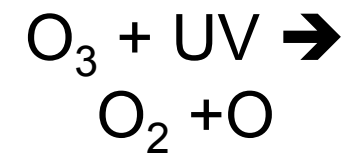
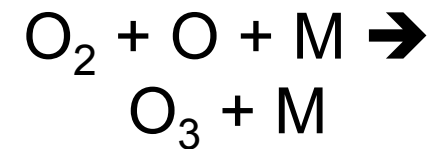
Ozone in the Atmosphere





© Cengage 2012

Ozone is naturally occurring in the stratosphere.

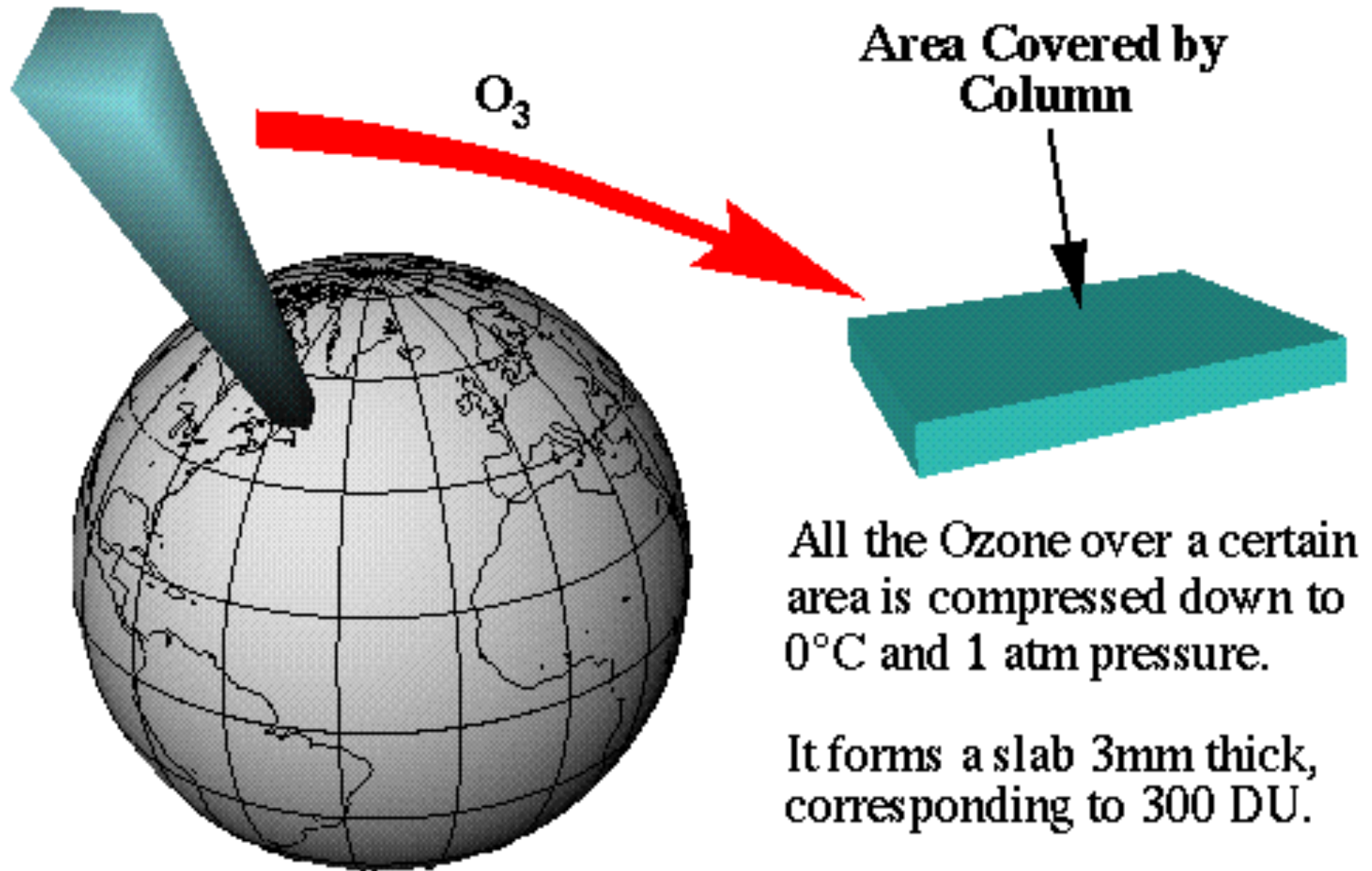


Ozone blocks harmful UV radiation!

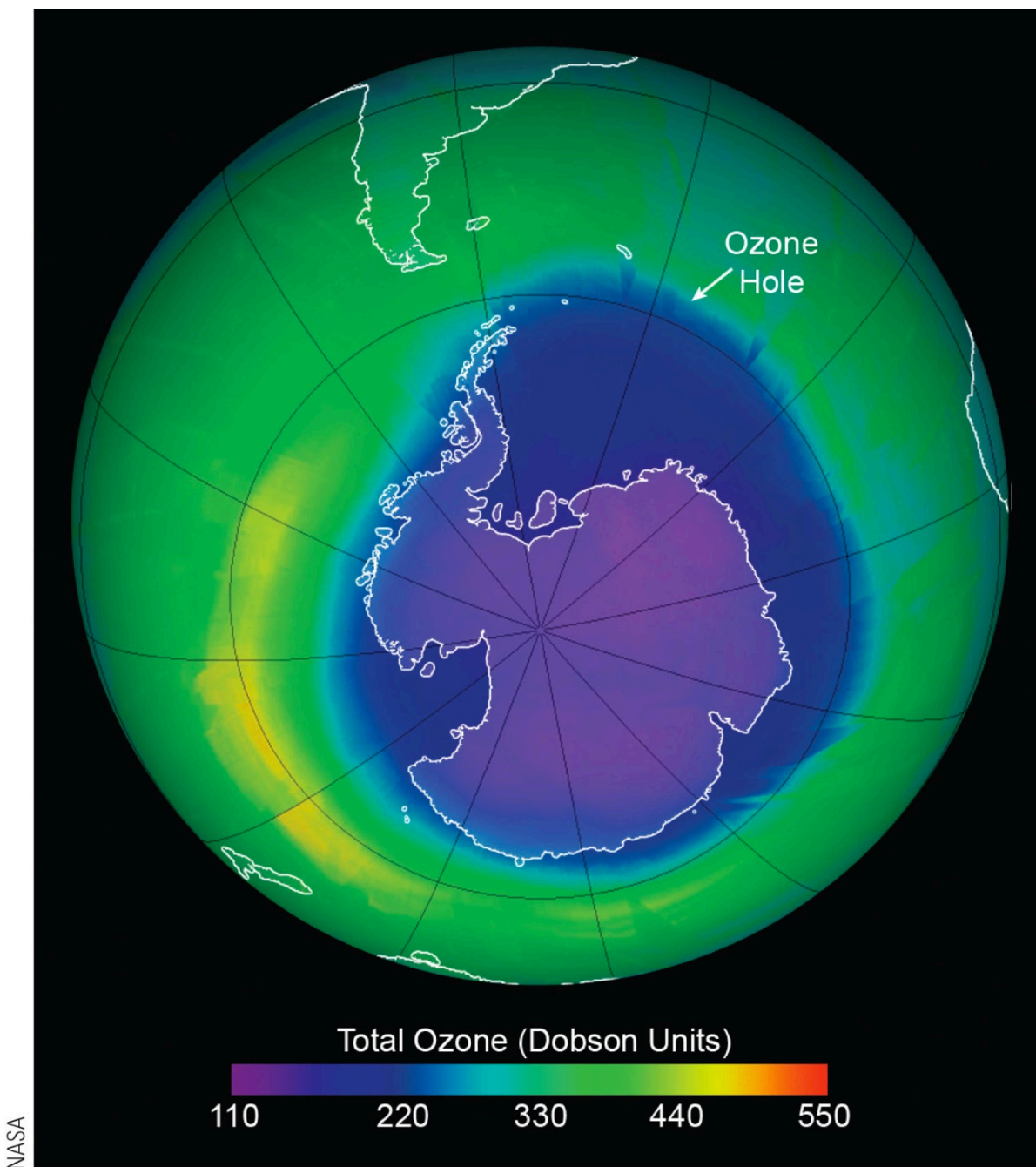
Figure18-9 p528

How is ozone measured?

Ozone Measurement in Dobson Units (DUs)



Antarctic Ozone Hole



http://ozonewatch.gsfc.nasa.gov/ozone_maps/movies/OZONE_D2006-07-01%25P1D_G%5E720X486.LSH.mp4

Figure 1-6 p9

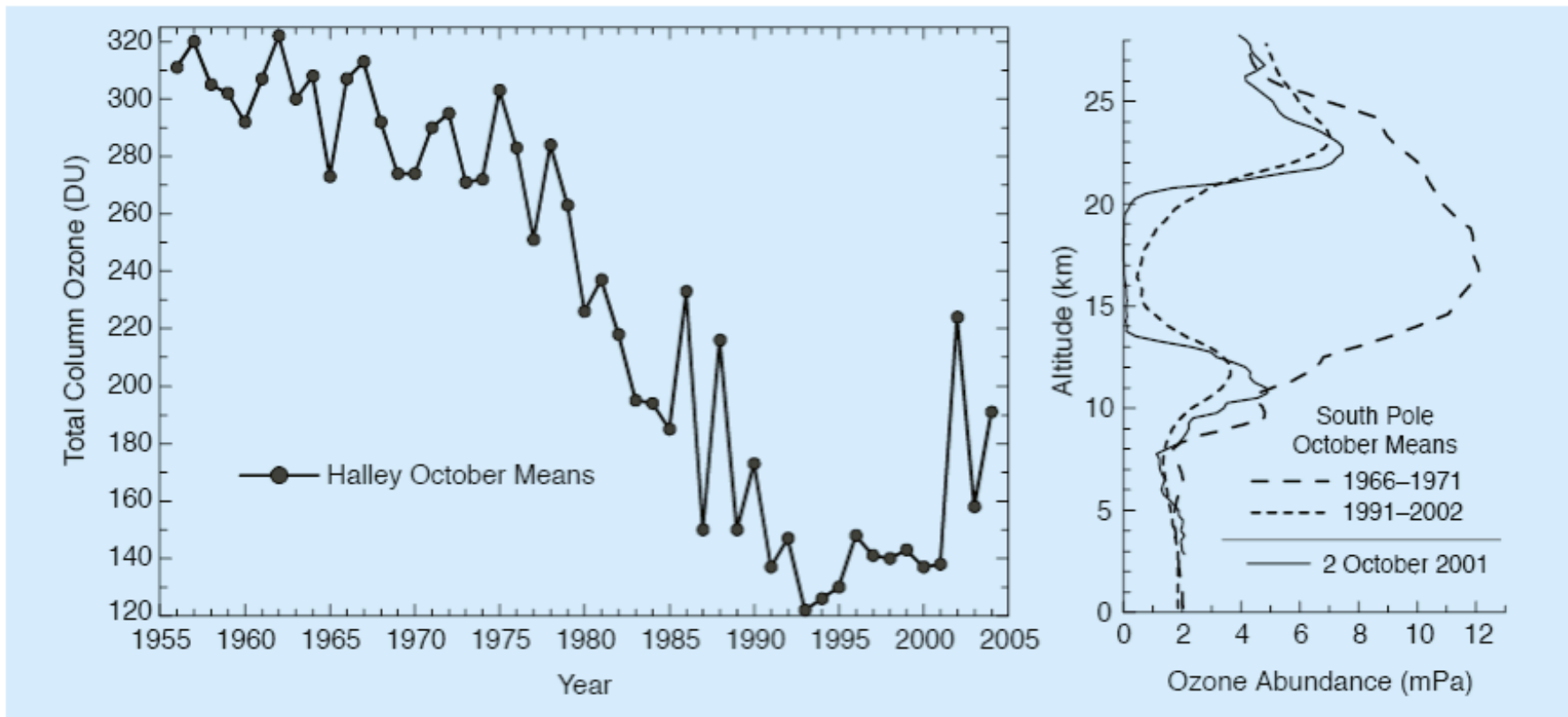
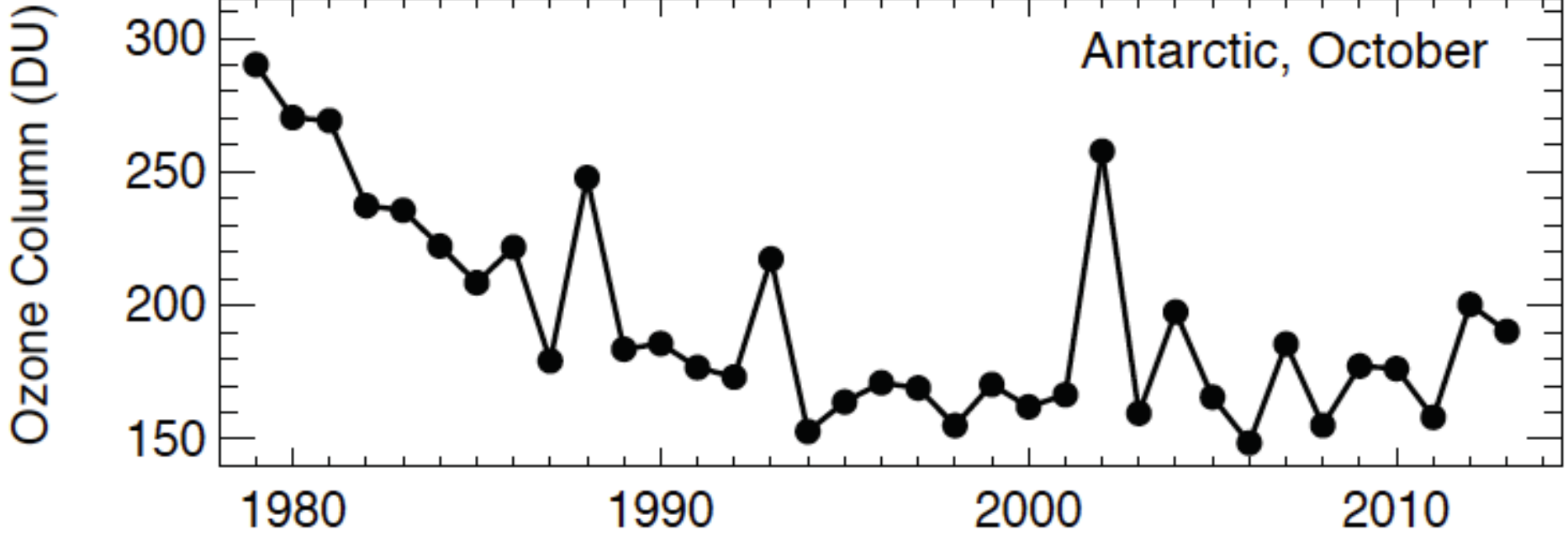
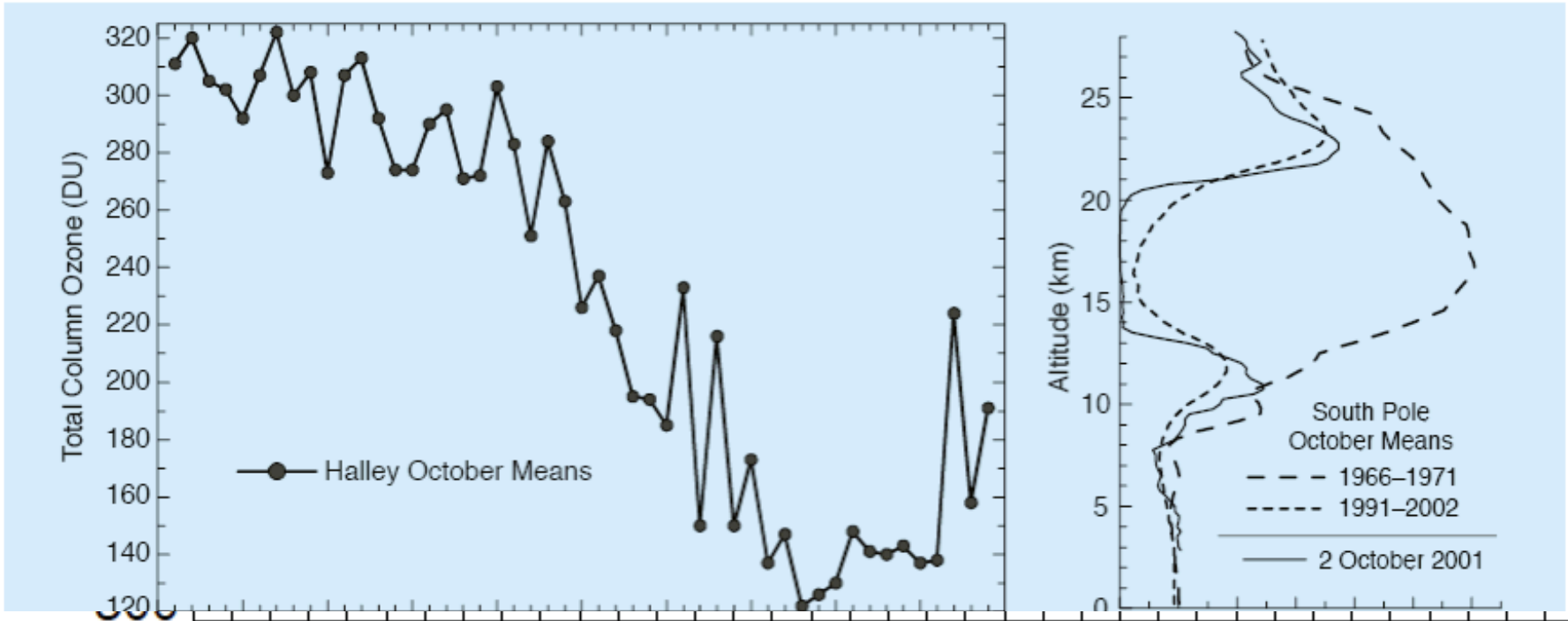
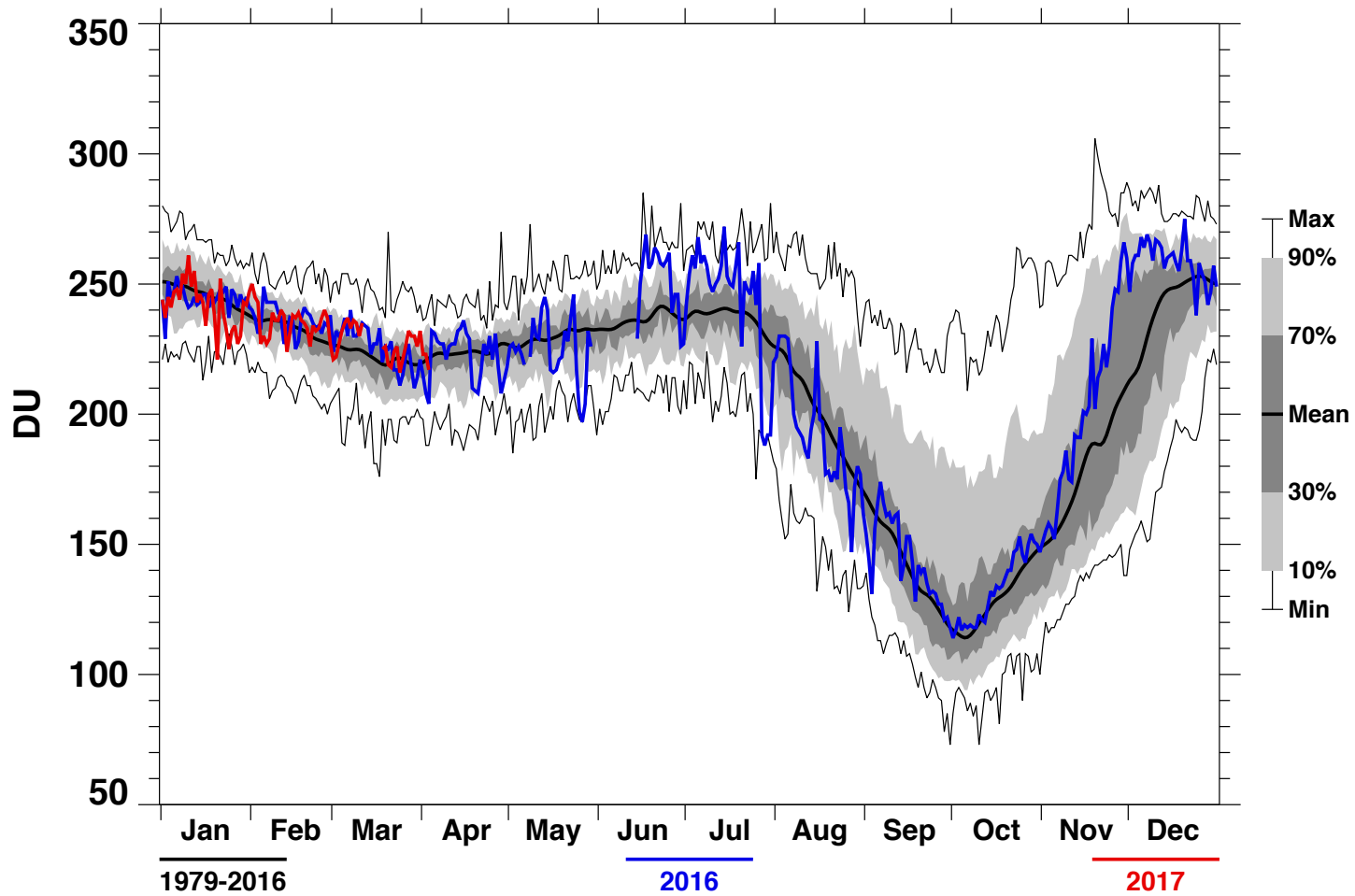


Figure 1.5. Left panel: October mean total column ozone measurements from the Dobson spectrophotometer at Halley, Antarctica (73.5°S , 26.7°W). Right panel: Vertical ozone profiles measured by ozonesondes at South Pole station, Antarctica (90°S). These data are from the WOUDC (World Ozone and UV Data Centre) and NDSC (Network for Detection of Stratospheric Change) databases. The 1966–1971 October mean profile is shown using a long-dashed line, the 1991–2002 October mean profile as a short-dashed line, and the single ozonesonde flight on 2 October 2001 as a solid line.



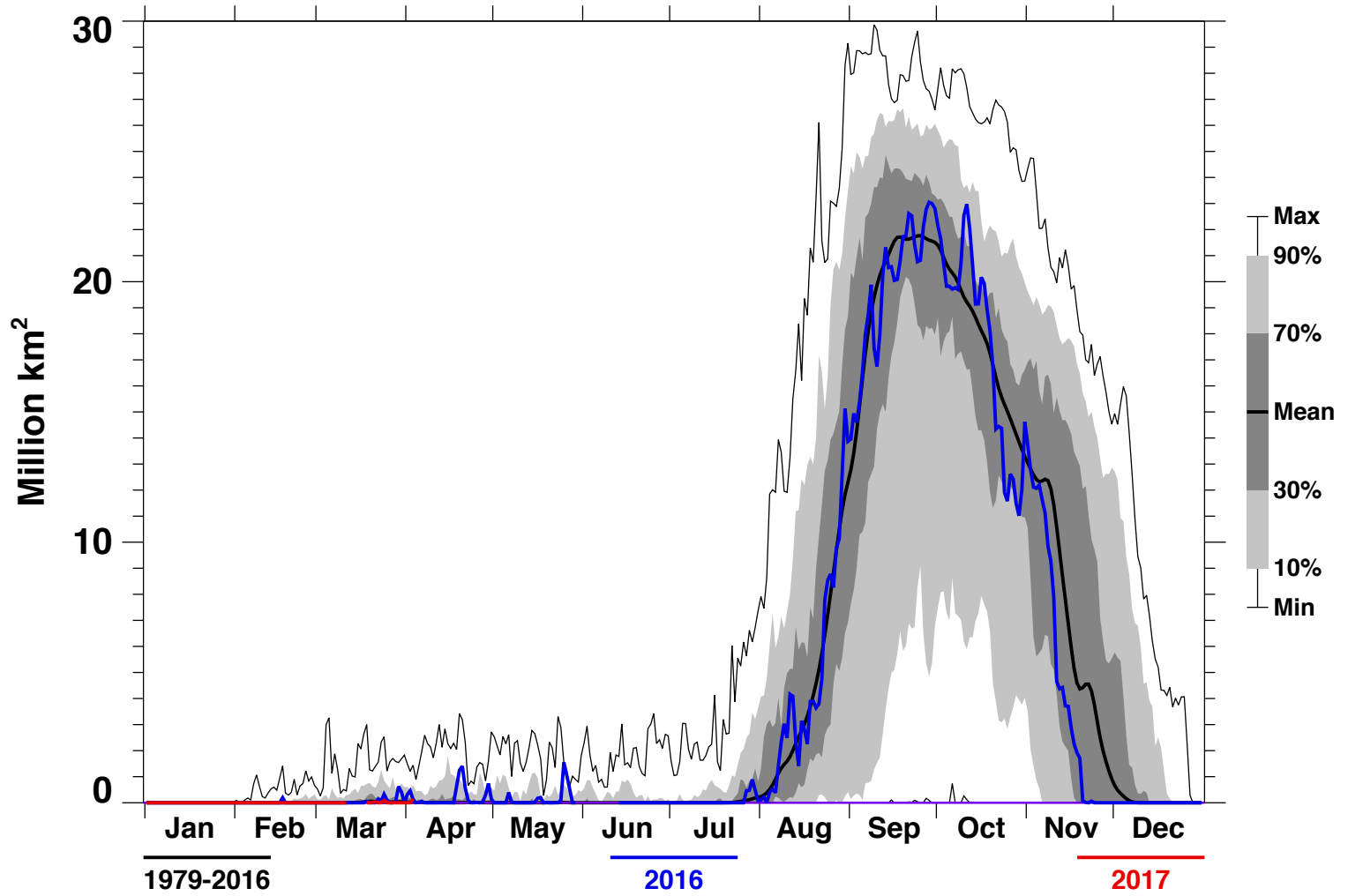
SH Minimum Ozone OMI+MERRA



P. Newman (NASA), E. Nash (SSAI), R. McPeters (NASA), S. Pawson (NASA)

2017-04-05T19:47:17Z

Ozone Hole Area OMI+MERRA



P. Newman (NASA), E. Nash (SSAI), R. McPeters (NASA), S. Pawson (NASA)

2017-04-05T18:44:00Z

Why does the ozone hole
form?

Antarctic Ozone Hole: Recipe



**Chlorofluorocarbons
(CFCs)**

40-150 year lifetimes



**Polar Stratospheric
Clouds**

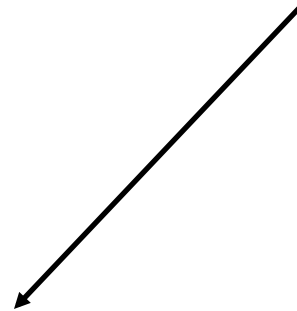
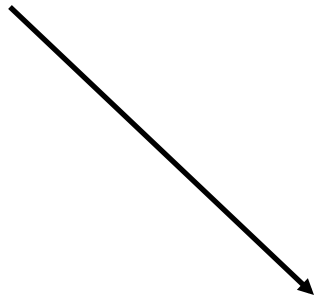
Temperatures < 200 K



Sunlight

**Heterogeneous Chlorine
Chemistry**

Ozone Depletion in Springtime Antarctic Stratosphere

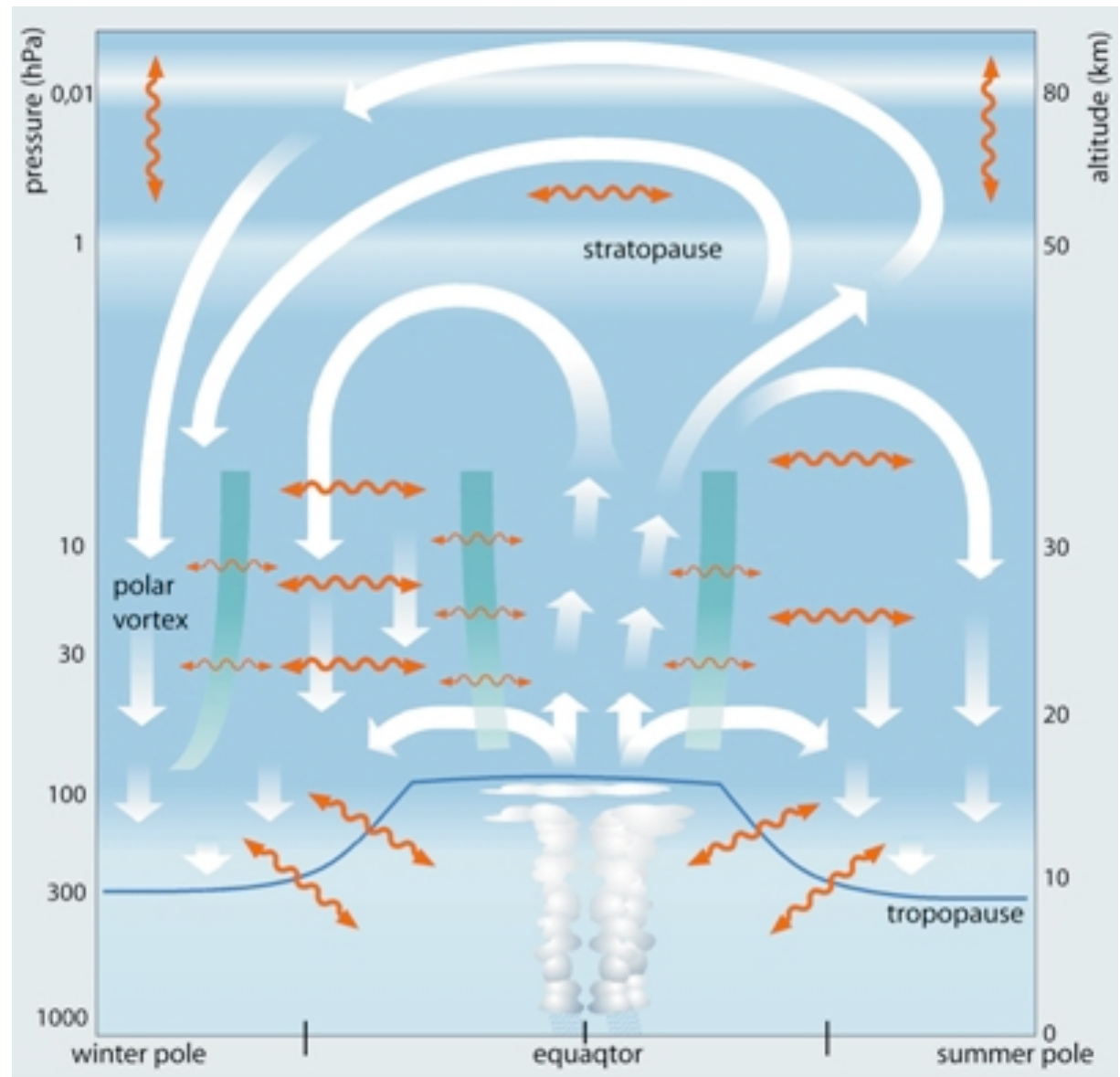


Chlorofluorocarbons (CFCs) (~200 parts per trillion)

- Manmade, chemically inert, nontoxic
 - Examples: CF_2Cl_2 , CFCl_3
- Sources:
 - Propellants in aerosol cans
 - Refrigerants
 - Blowing of plastic foam insulation
 - Cleaning solvents for electronics

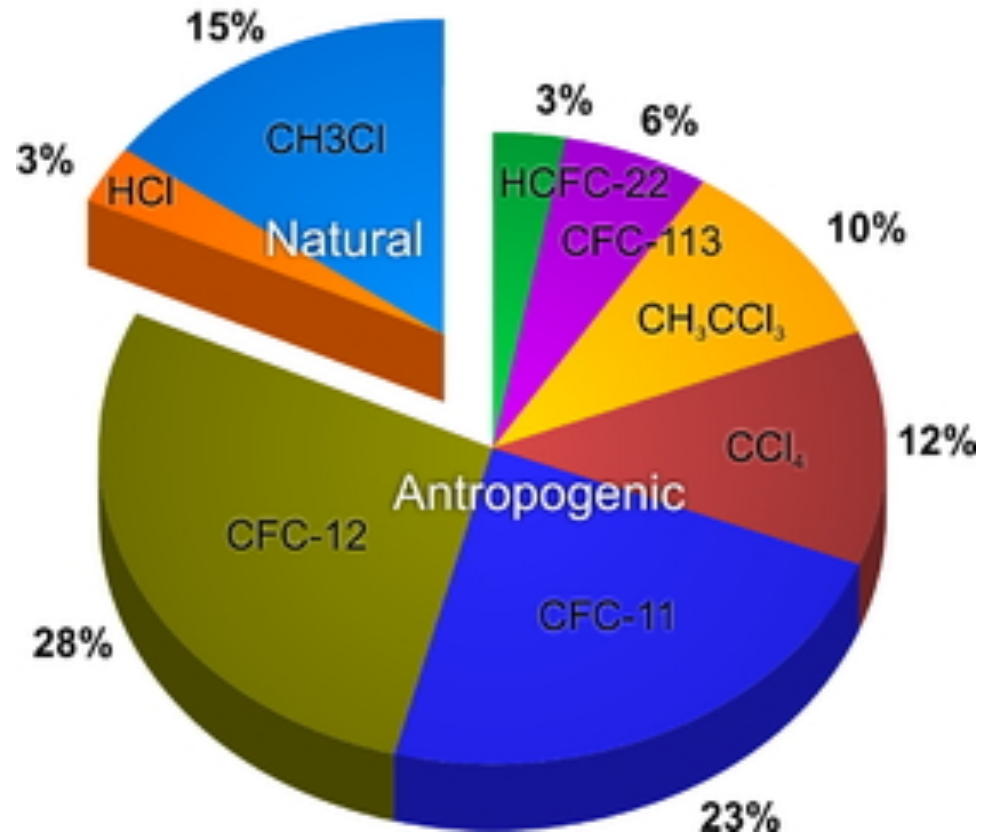
CFCs are transported into the stratosphere where they are broken down into their constituent atoms.

The chlorine atoms are key for the depletion of stratospheric ozone.



Sources of Stratospheric Chlorine

About 80% anthropogenic
About 20% natural
(but some natural HCl from
human-induced biomass
burning)



Based on early 1990s estimates (UNEP/WMO)

Antarctic Ozone Hole: Recipe



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Ozone Depletion in Springtime Antarctic Stratosphere

Polar Stratospheric Clouds



Antarctic Ozone Hole: Recipe



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**Polar Stratospheric
Clouds**

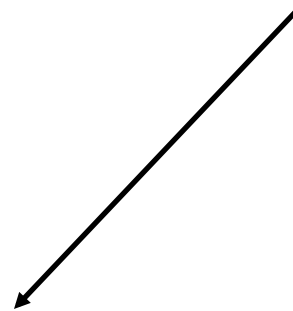
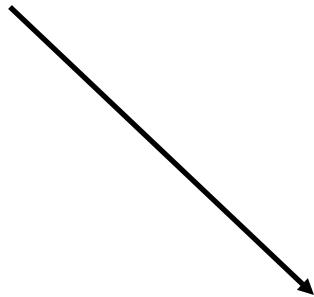
Temperatures < 200 K



Sunlight

**Heterogeneous Chlorine
Chemistry**

Ozone Depletion in Springtime Antarctic Stratosphere

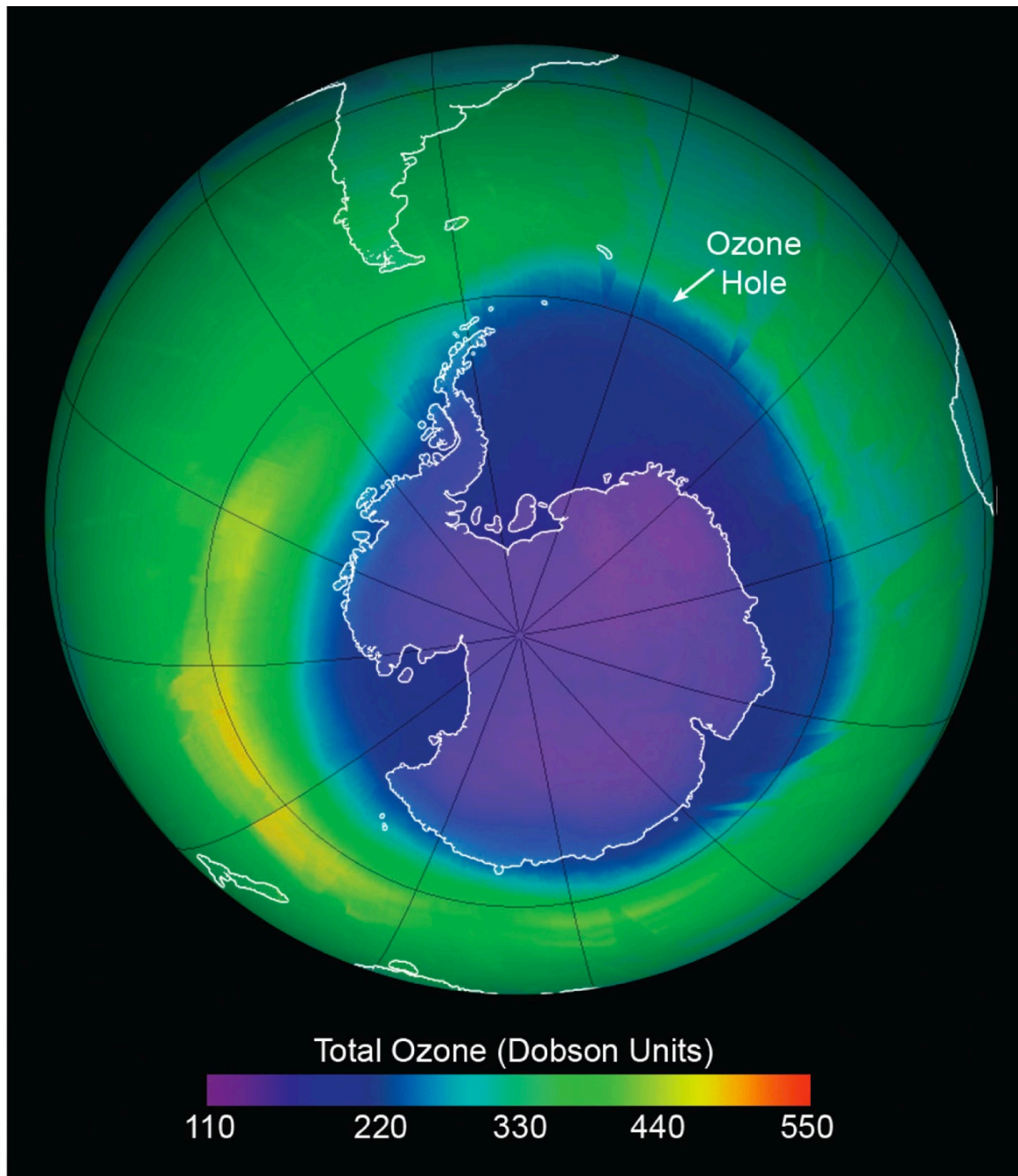


CFCs can upset balance between ozone production and destruction.

Ozone Hole:

Rapid depletion of stratospheric ozone layer with presence of CFCs, cold temperatures, and sunlight.

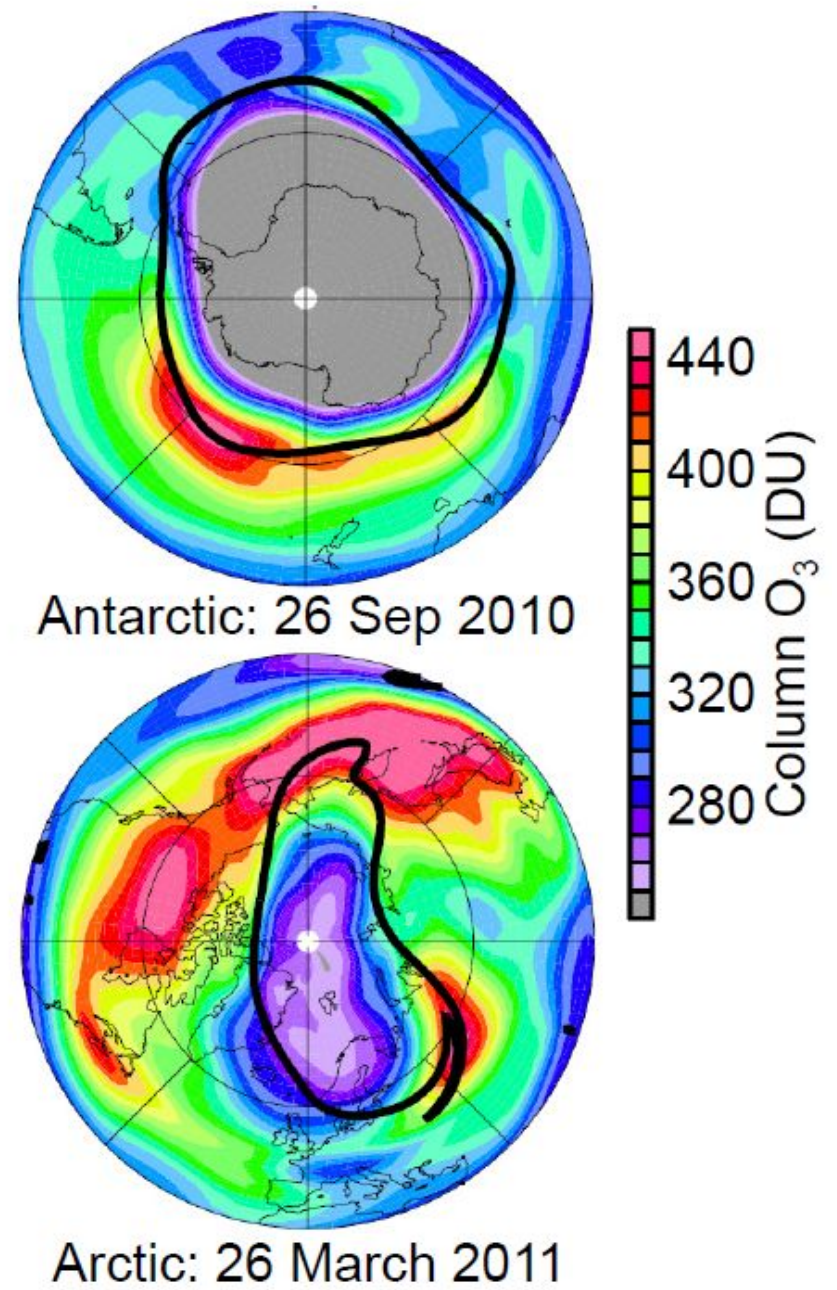
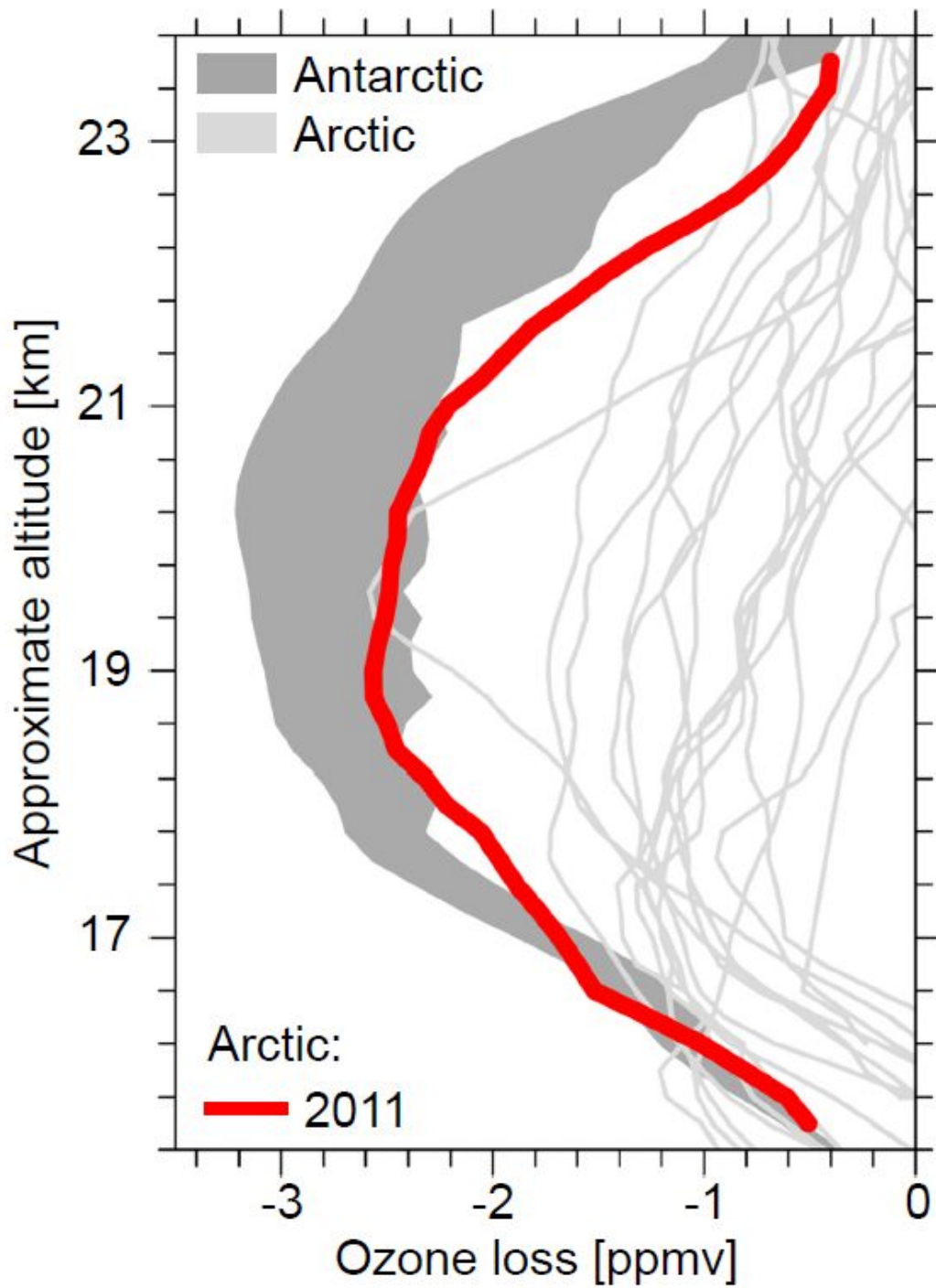
NASA



http://ozonewatch.gsfc.nasa.gov/ozone_maps/movies/OZONE_D2006-07-01%25P1D_G%5E720X486.LSH.mp4

Figure 1-6 p9

Why isn't there an ozone hole
in the Arctic?



When will the ozone hole
recover?

Montreal Protocol (1987)



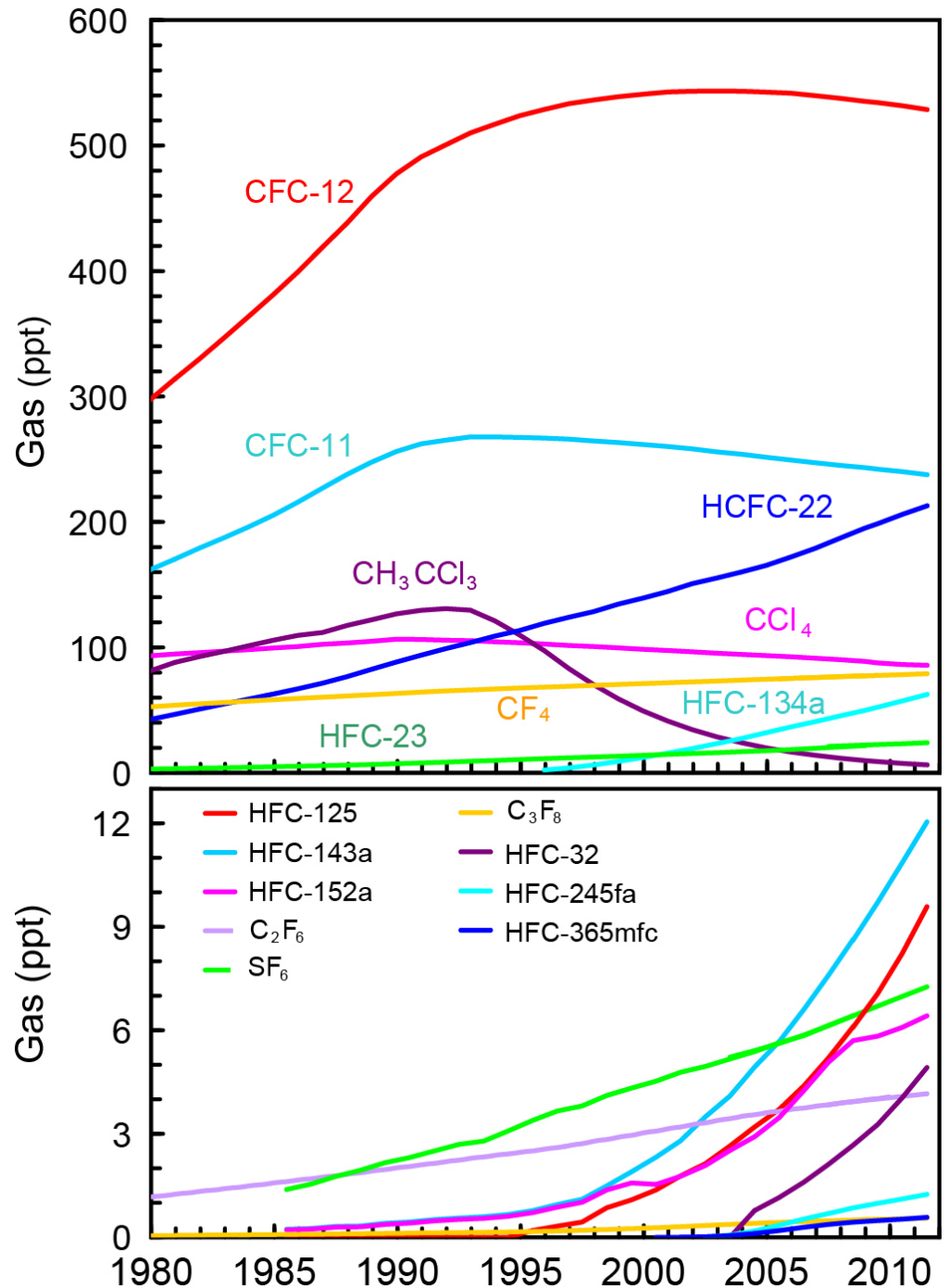
"Perhaps the single most successful international agreement to date has been the Montreal Protocol." -Kofi Annan, former Secretary General of the United Nations

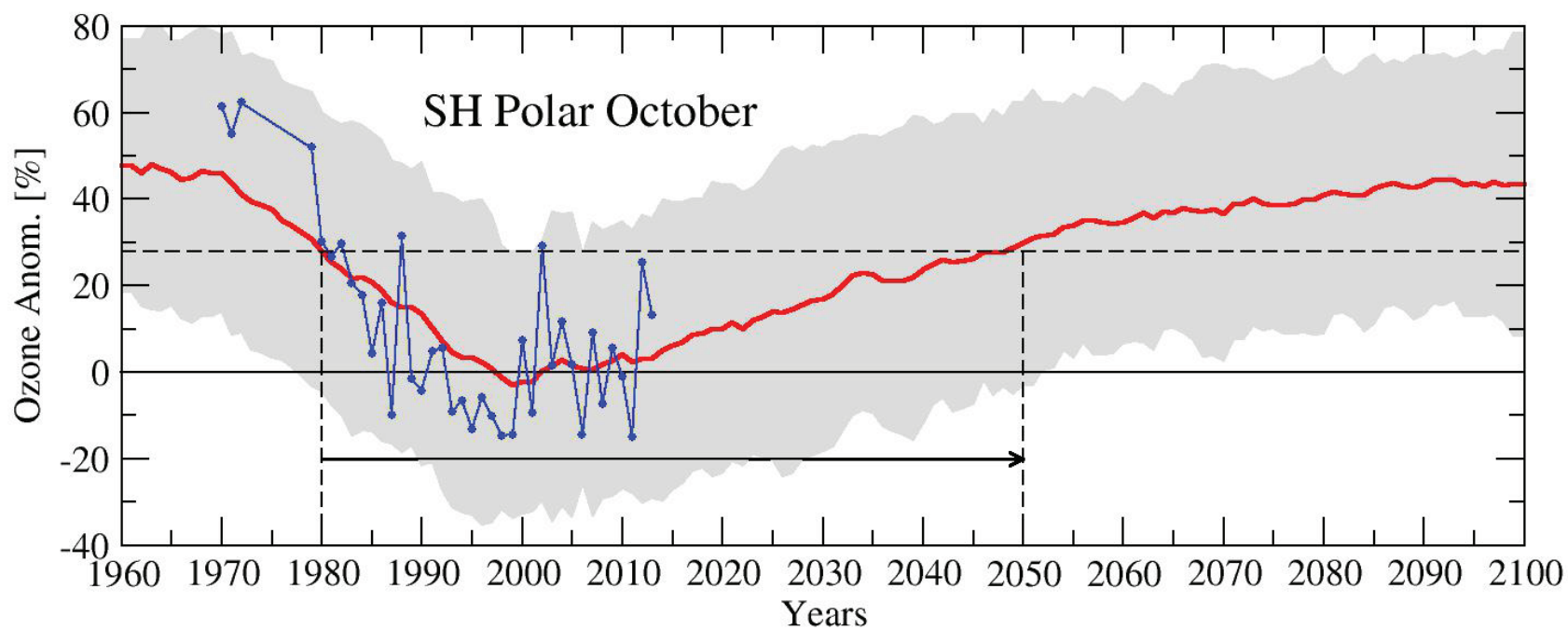
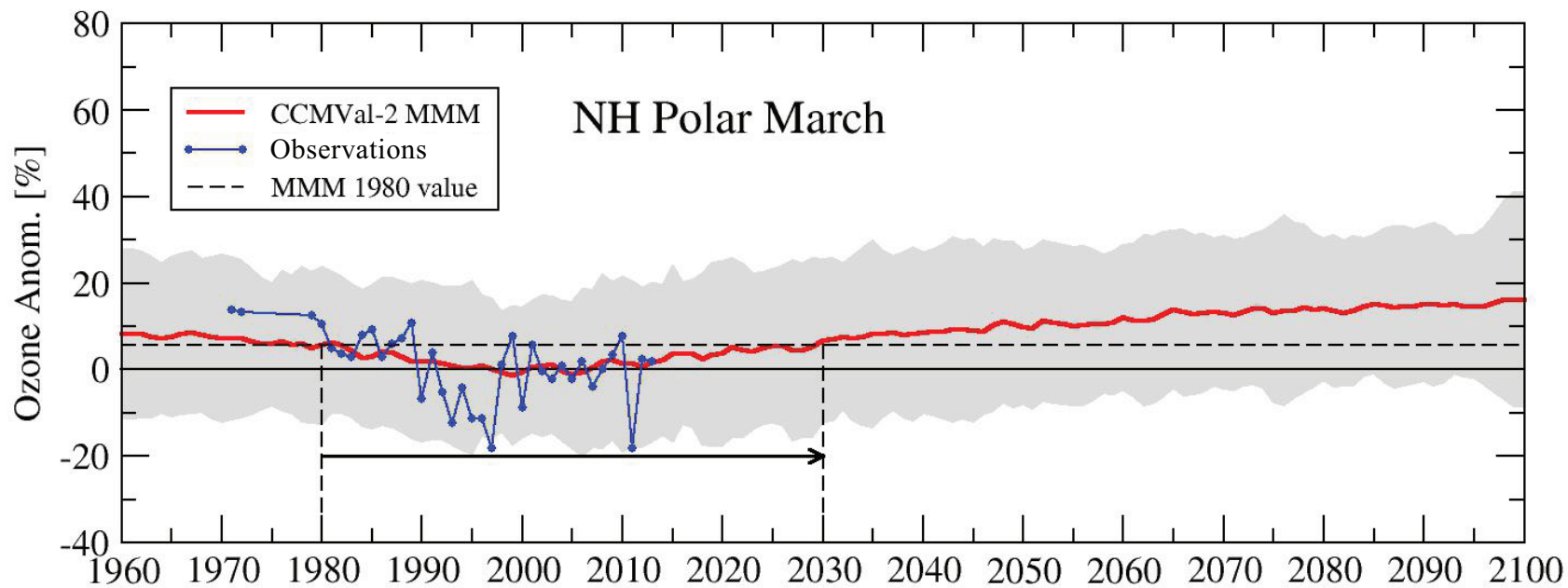


Chlorofluorocarbons (CFCs)

Regulated by Montreal
Protocol (1987)

Lifetimes of 40-150 years





Montreal Protocol

<https://www.youtube.com/watch?v=6ezl0ky45CQ>