Structure and Chemistry of the Atmosphere

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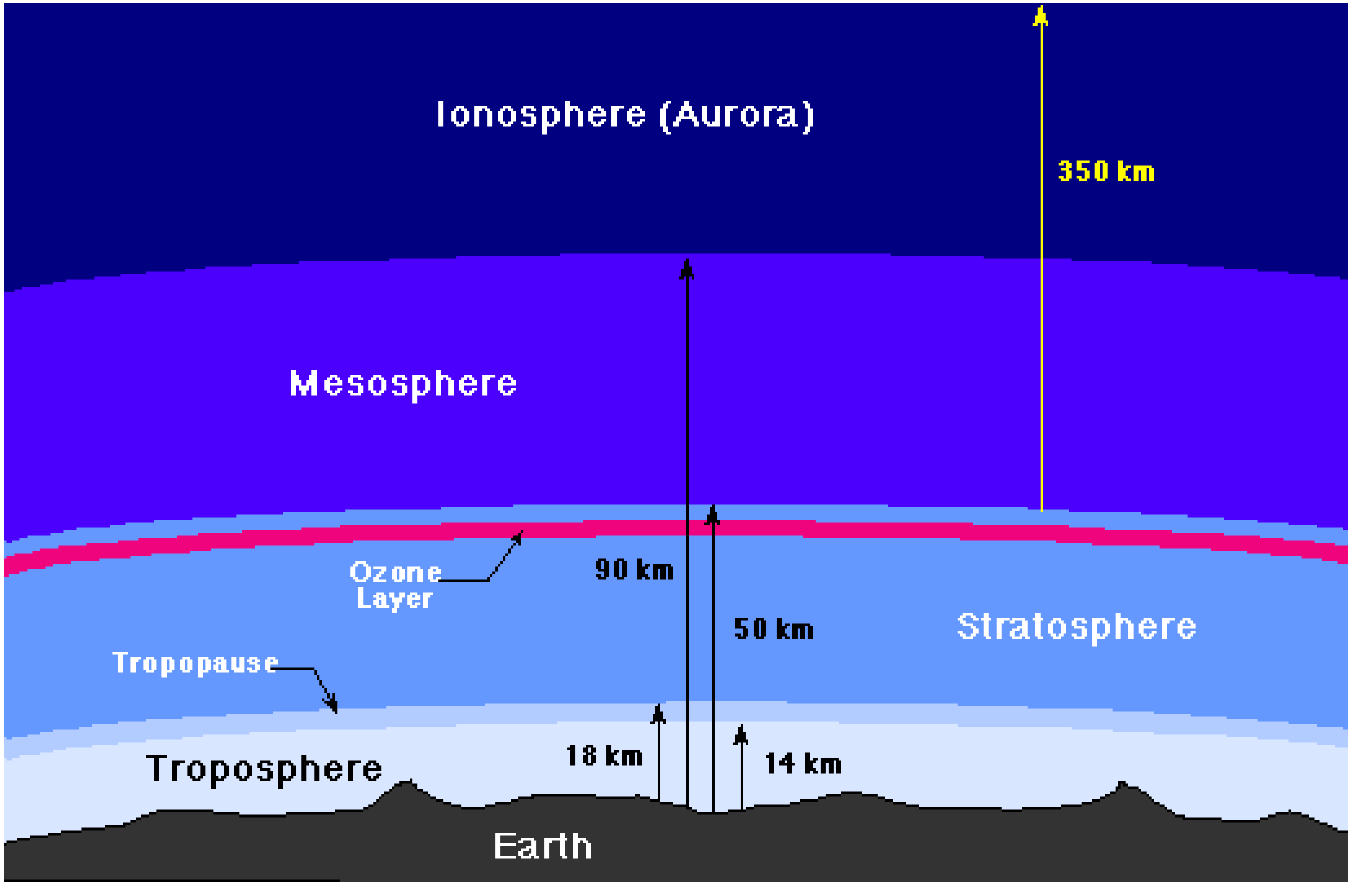
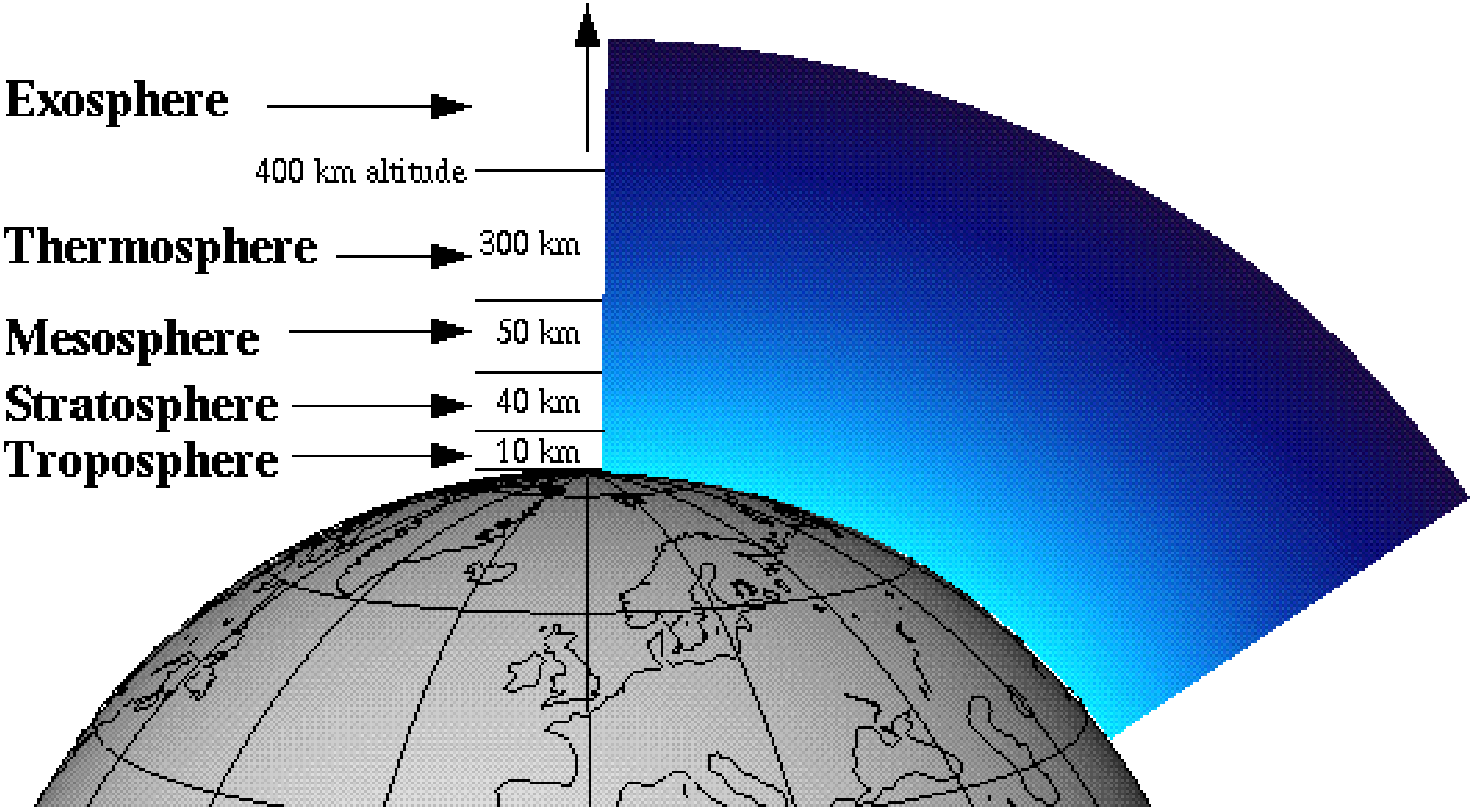
Department of Chemistry
Bowdoin College

The Structure of the Atmosphere



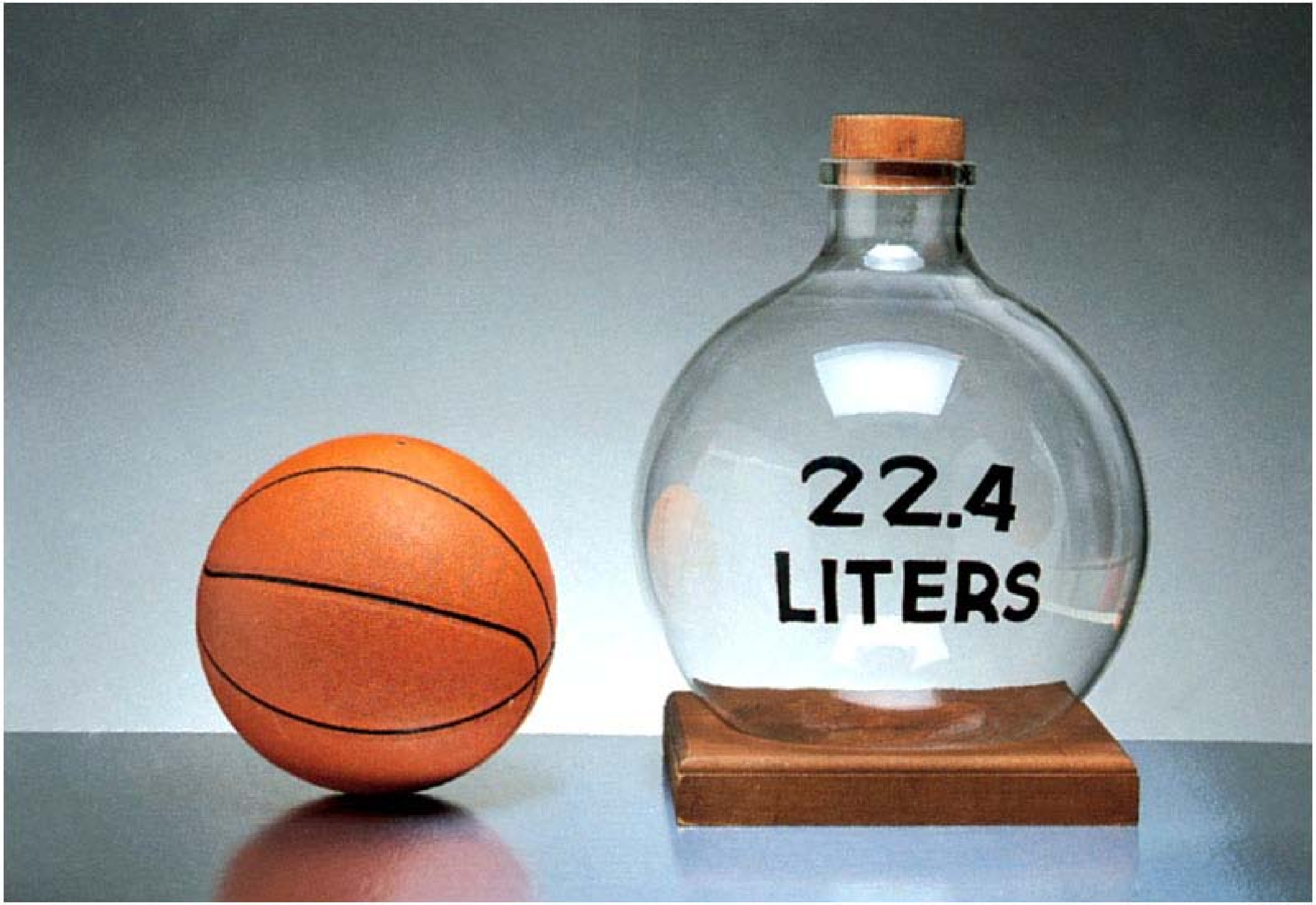
http://www.cartage.org.lb/en/themes/sciences/astronomy/Solarsystem/TheSolarsystem/theearth/TheEarth'sAtmosphere/TheEarth'sAtmosphere.htm

The Atmosphere: 1.8×10^{20} mole gas



http://www.chs.k12.nf.ca/science/b3201/WebCT-Copy/images/lesson-images/lesson01/atmosphere.gif

A Mole of Gas:
6.023×10^{23} atoms/molecules



Source: *Chemistry* by Cheng

Composition of Atmosphere

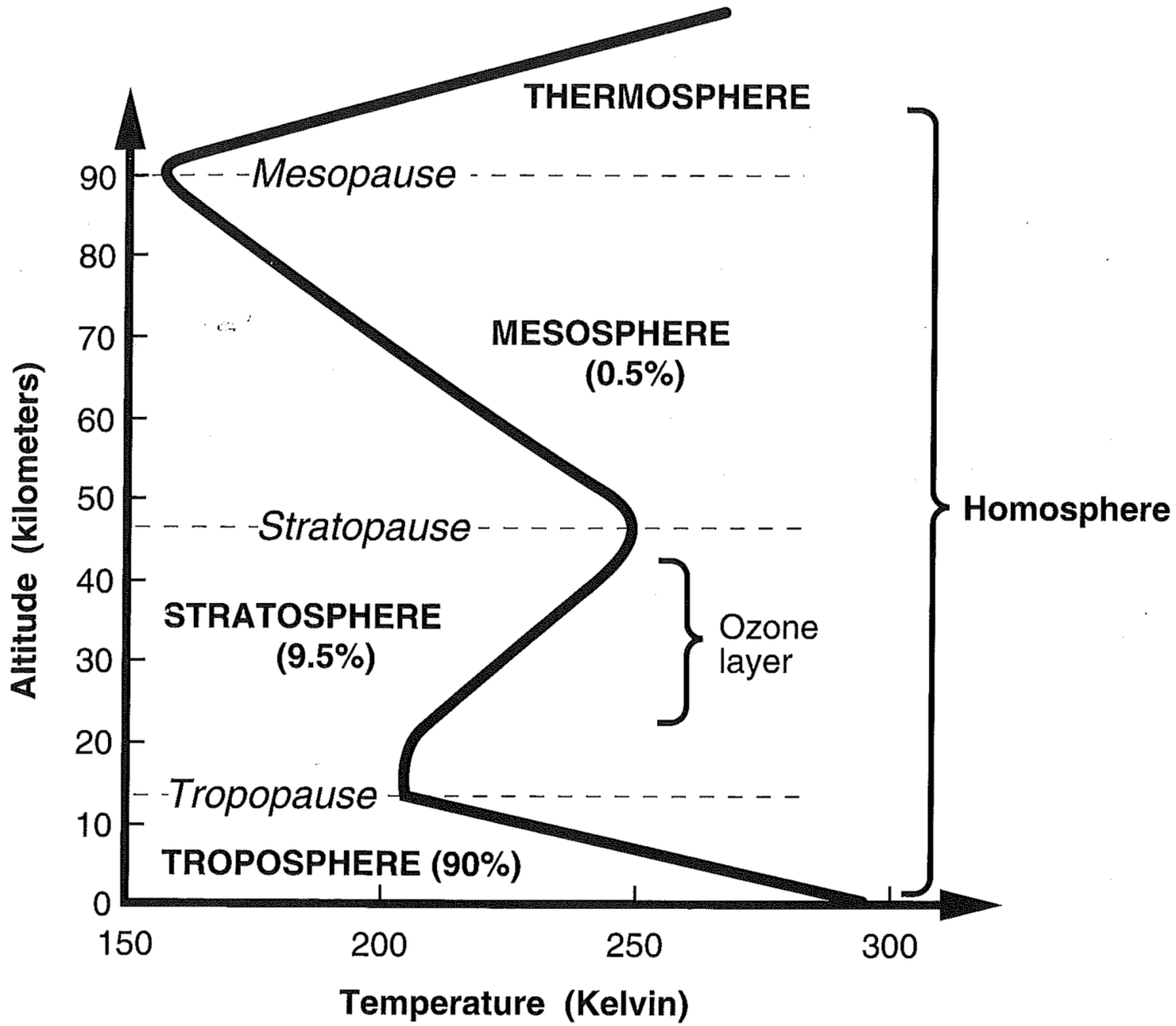
Composition of Dry Air at Sea Level

Gas	Composition (% by Volume)
N_2	78.03
O_2	20.99
Ar	0.94
CO_2	0.039204*
Ne	0.0015
He	0.000524
Kr	0.00014
Xe	0.000006

Source: *Chemistry* by Chang

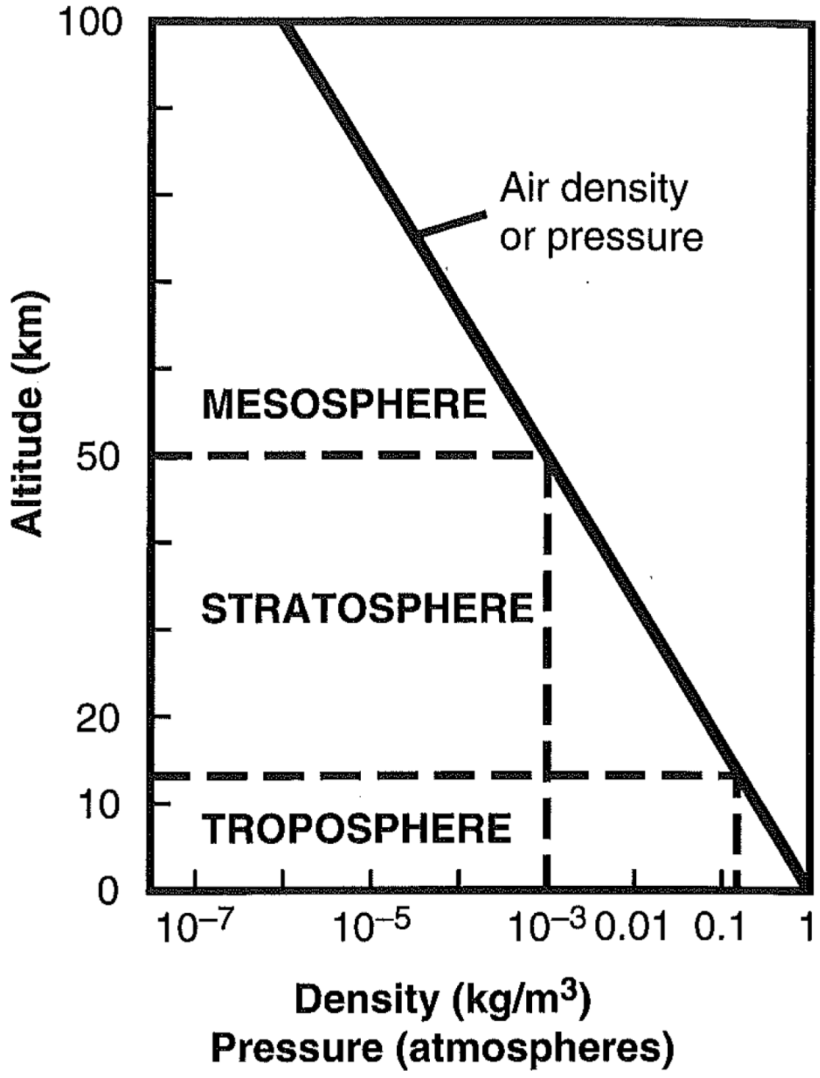
* ftp://ftpcmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt

Temperature versus Altitude



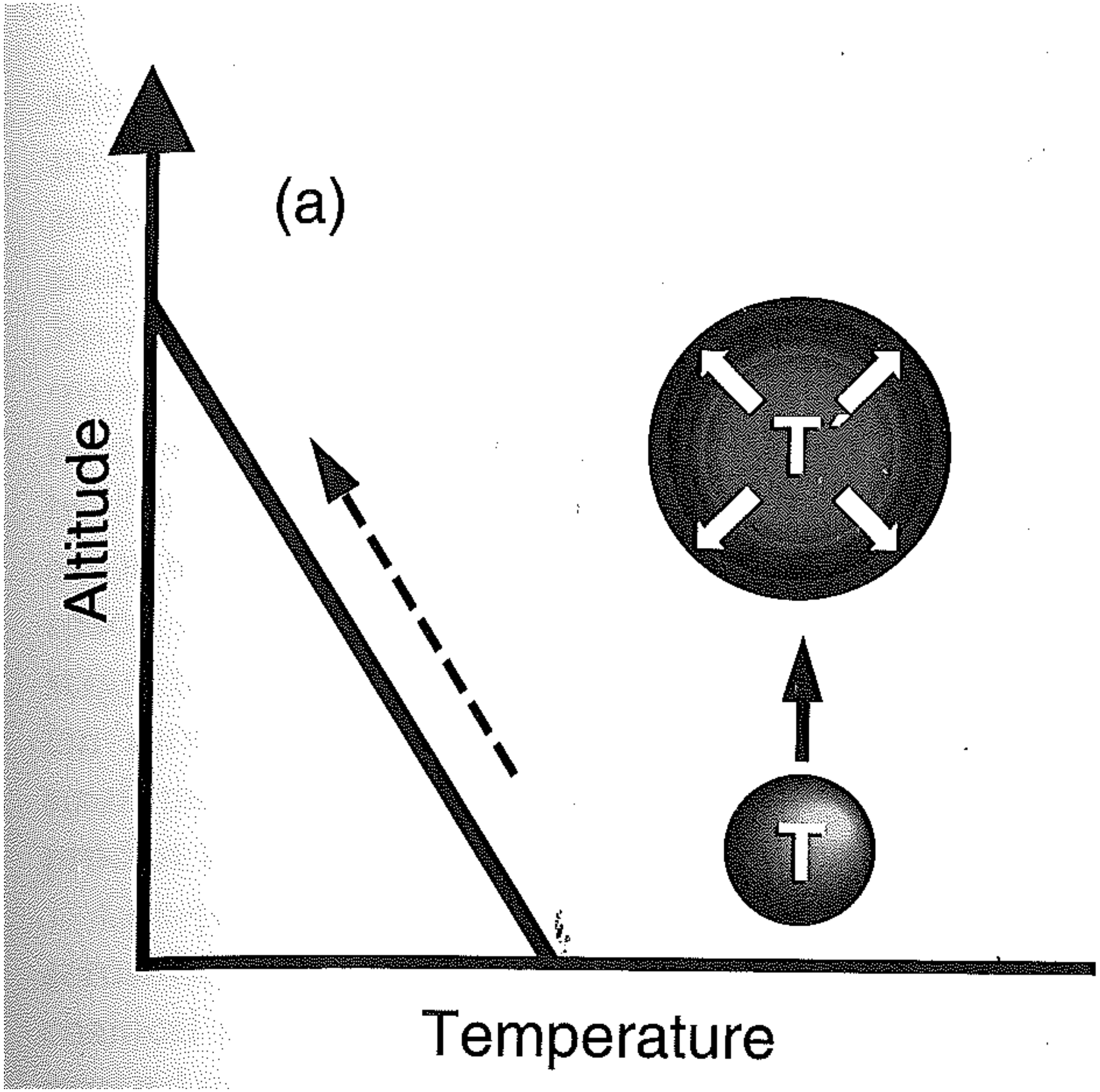
Source: *Earth Under Siege* by Turco

Pressure versus Altitude



Source: *Earth Under Siege* by Turco

Adiabatic Cooling



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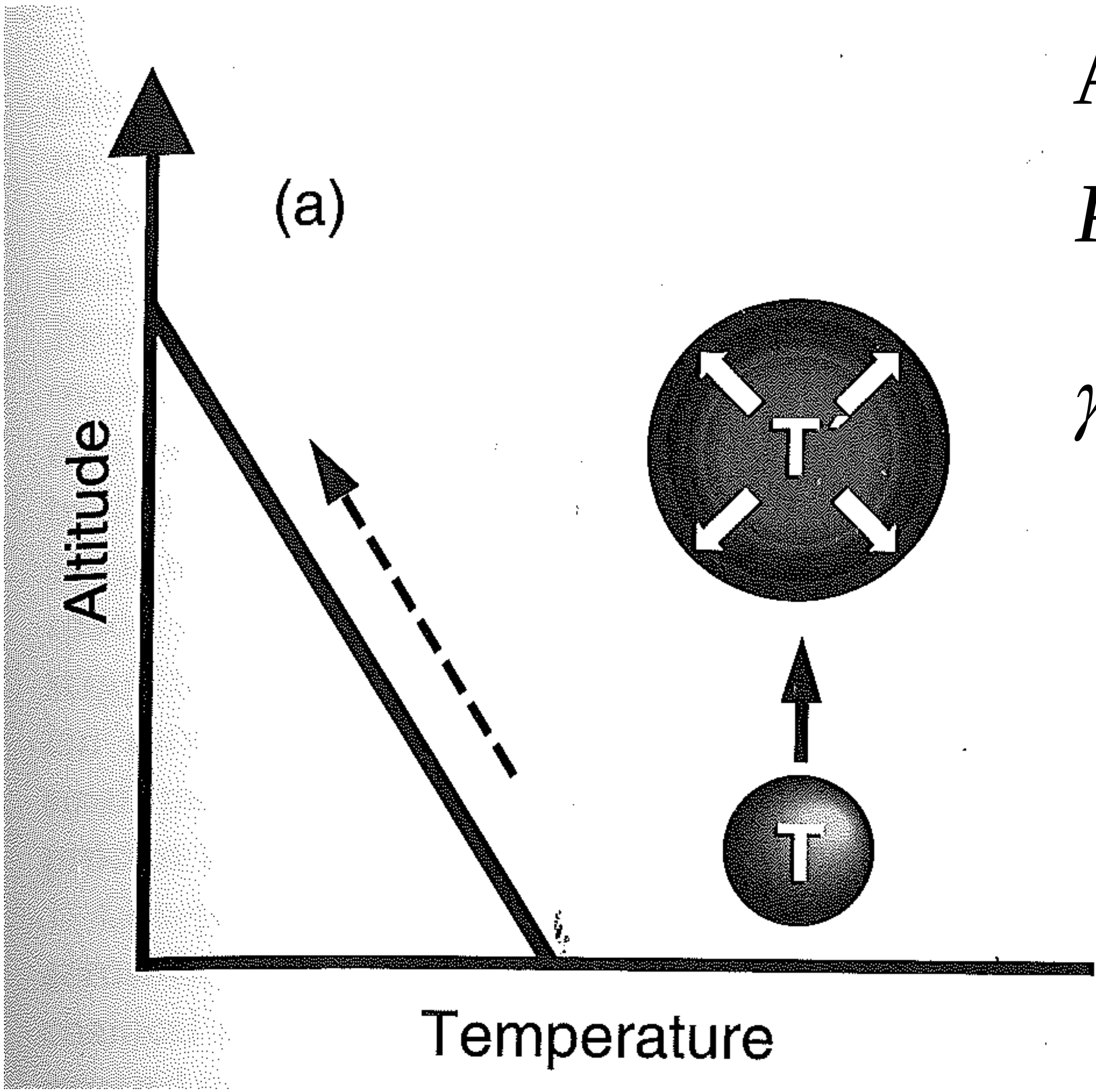
Adiabatic Cooling



Adiabatic Law:

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$\gamma = \frac{C_P}{C_V}$$

Source: ***Earth Under Siege*** **by Turco**

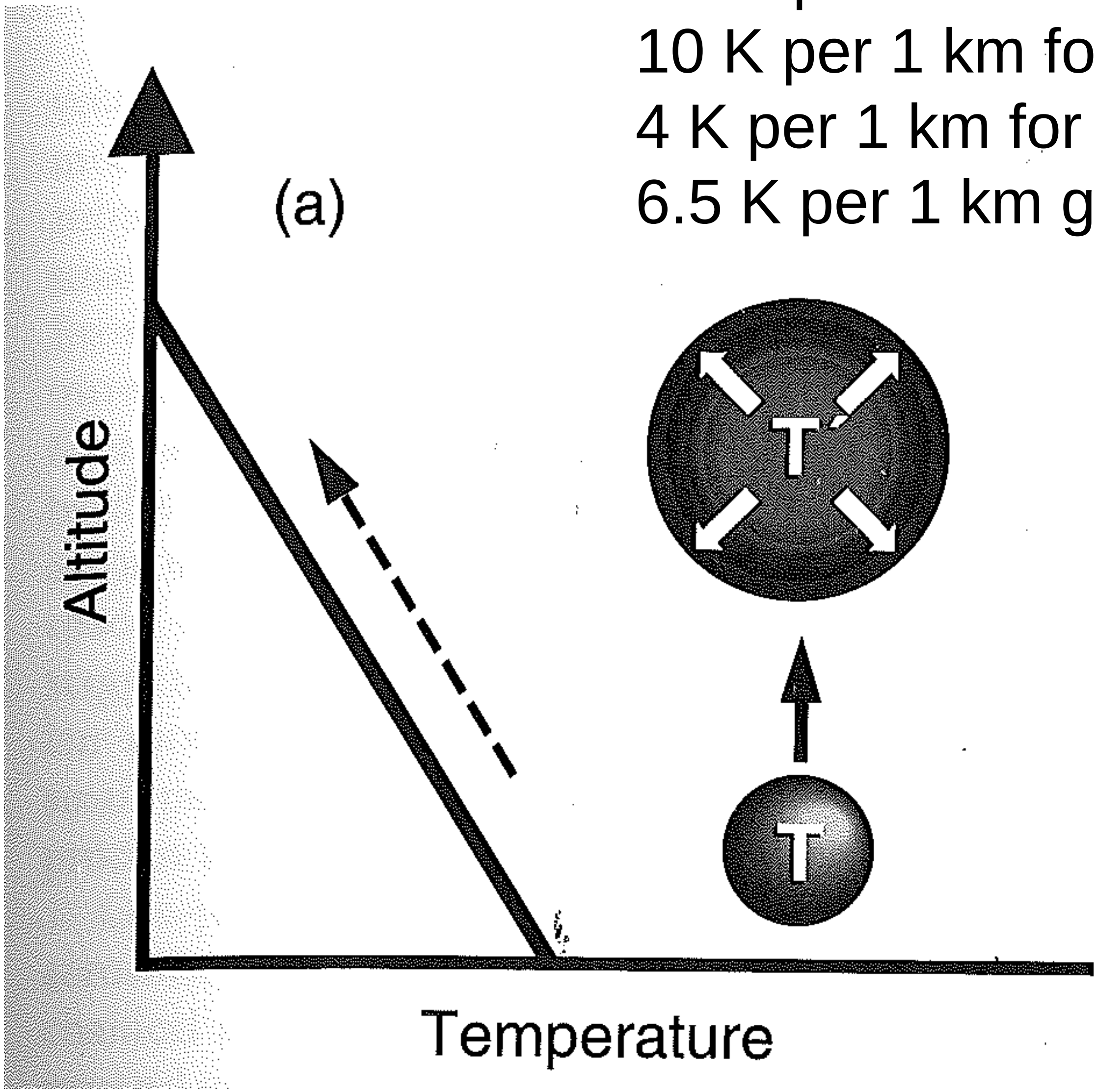
Adiabatic Cooling

Adiabatic Lapse Rate:

10 K per 1 km for dry air

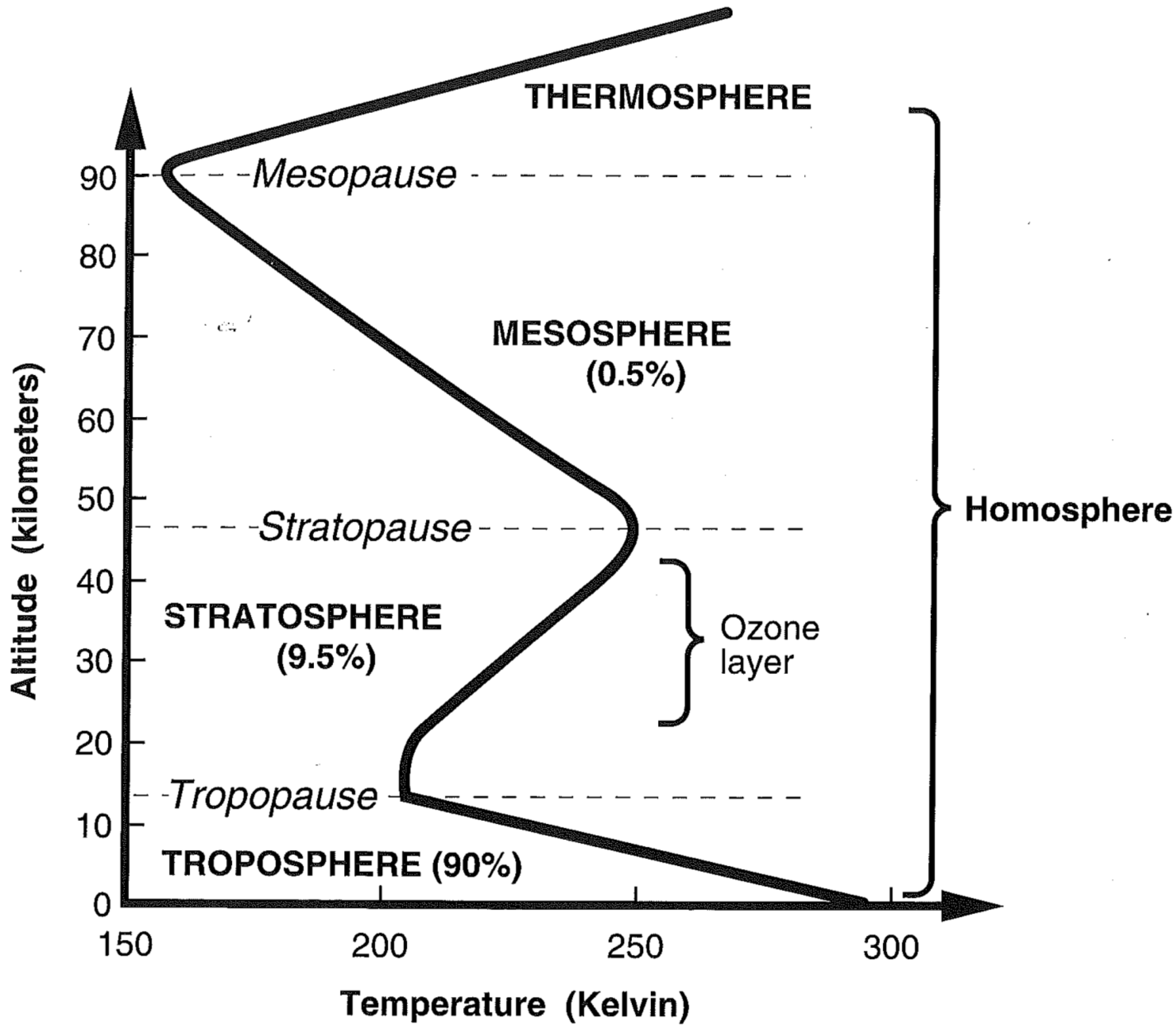
4 K per 1 km for air saturated with H_2O

6.5 K per 1 km global average

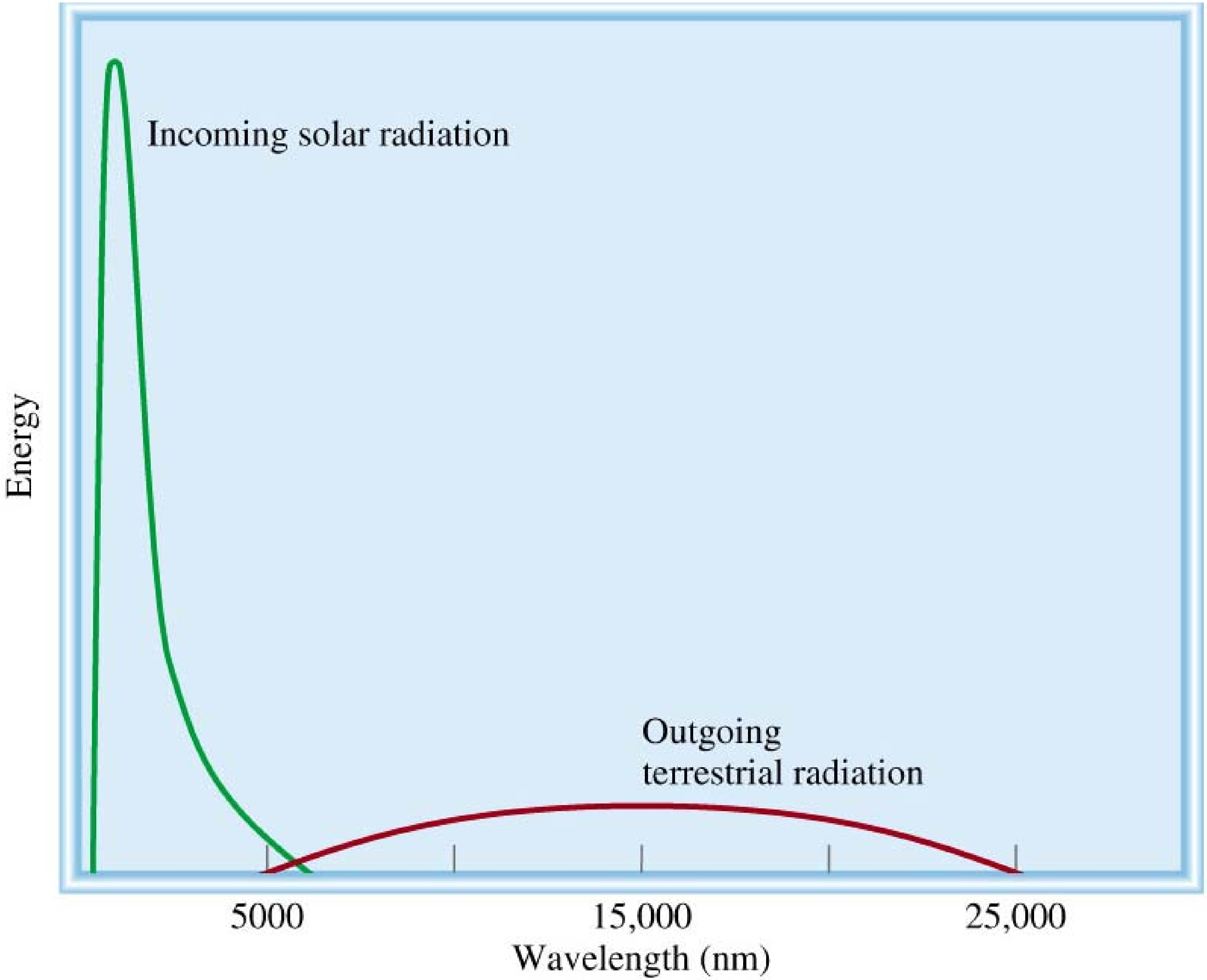


Source: ***Earth Under Siege*** **by Turco**

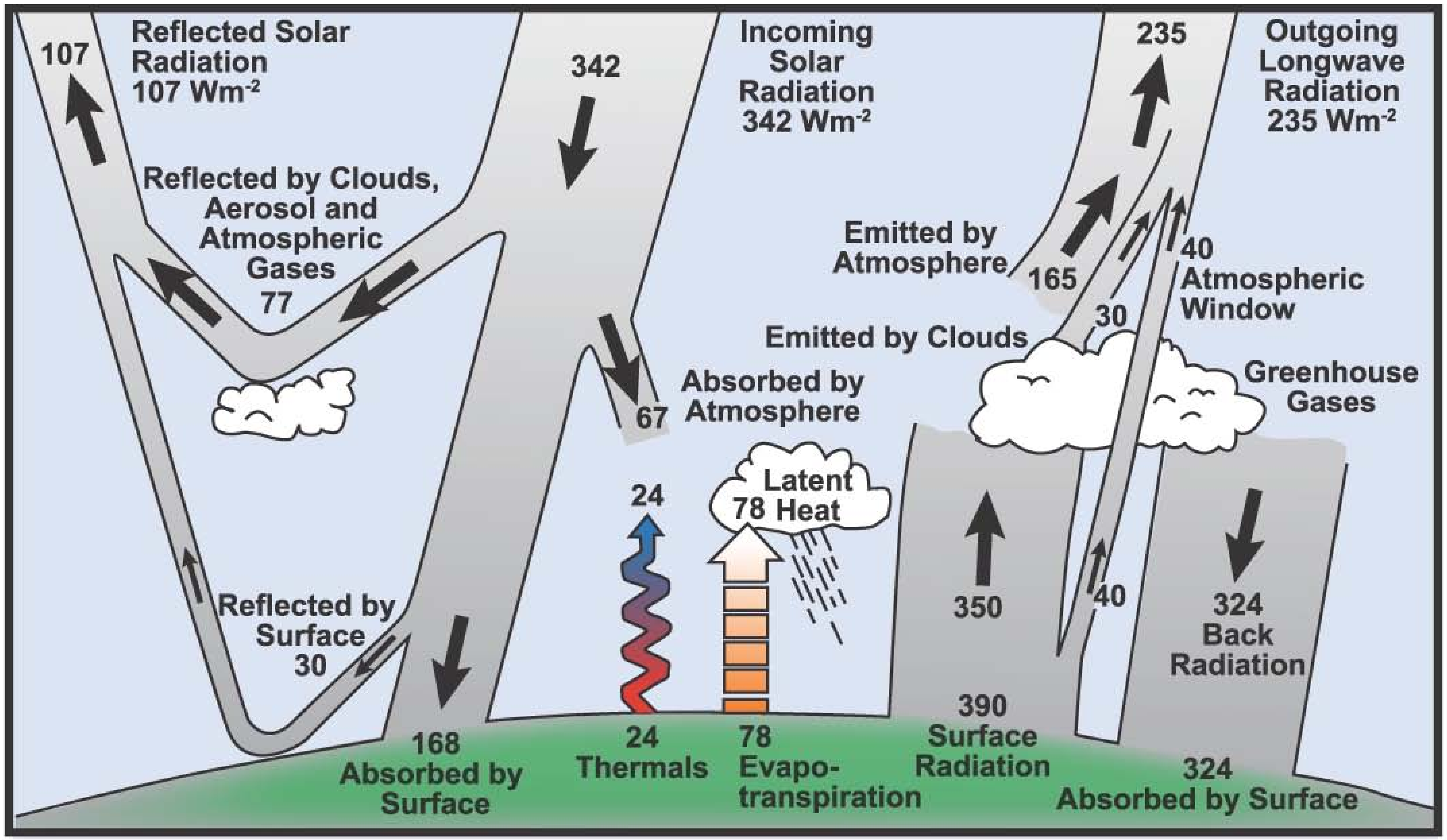
Temperature versus Altitude



Source: *Earth Under Siege* by Turco

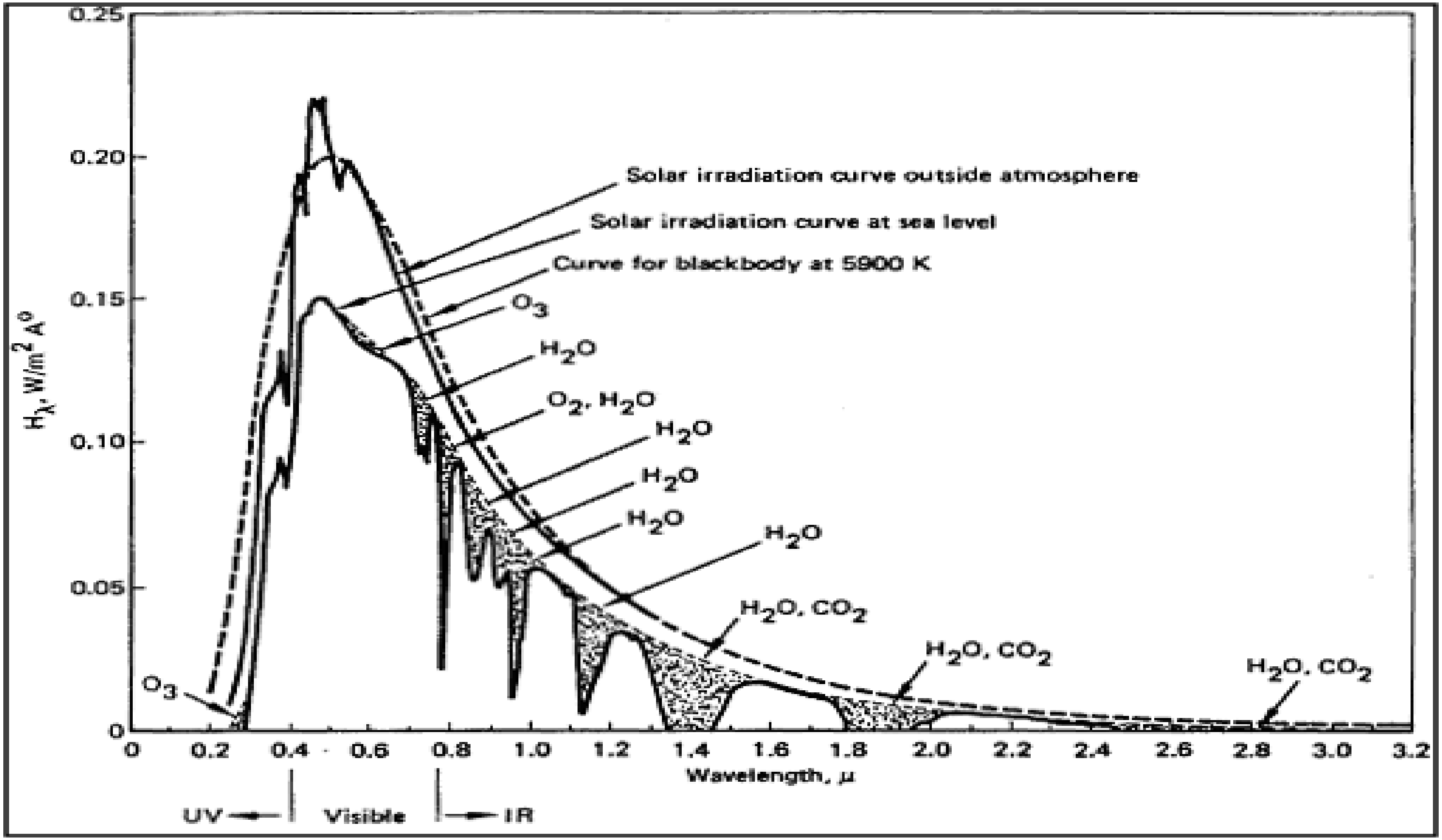


Source: ***Chemistry*** **by Chang**

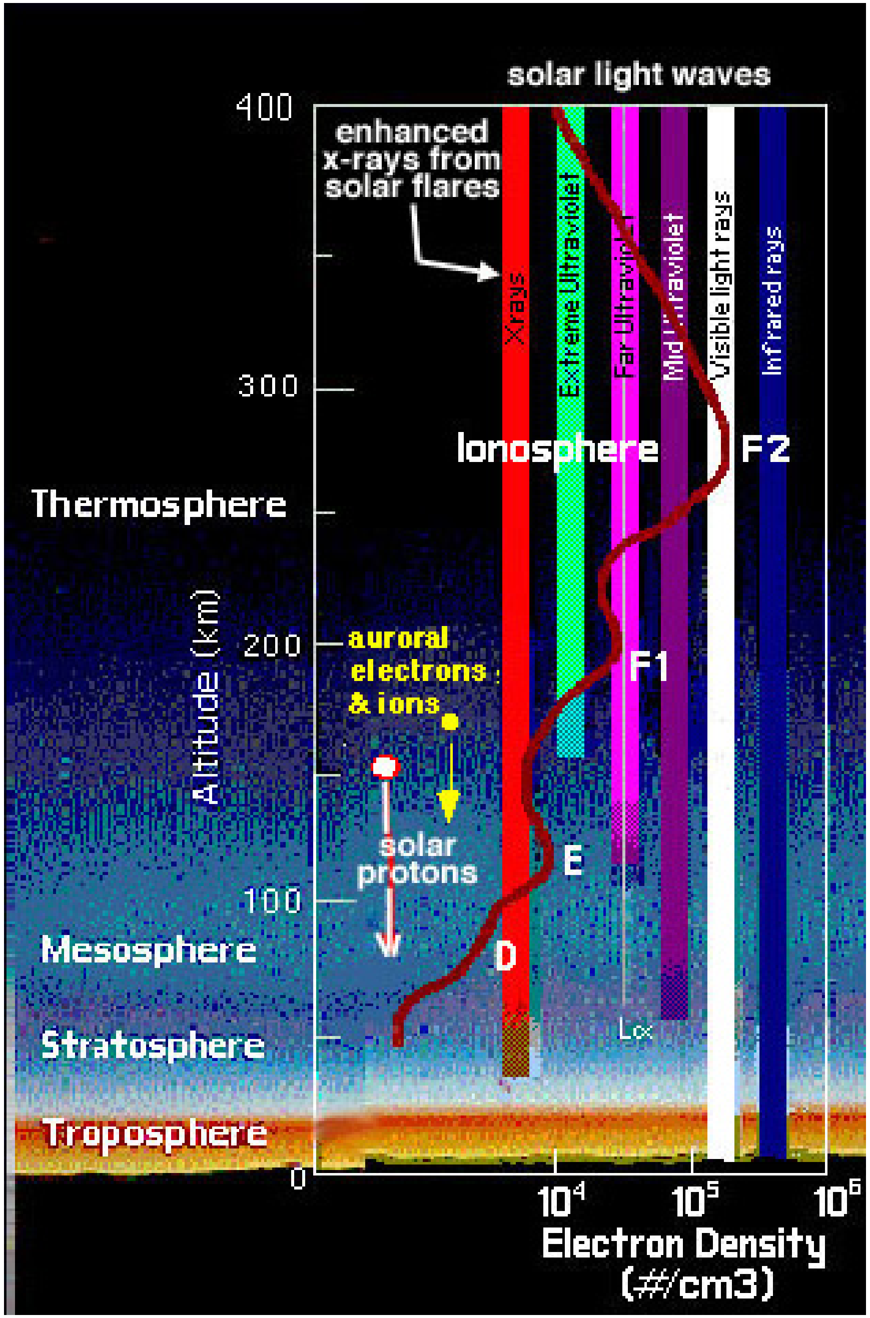


Source: IPCC AR4

Solar Radiation



http://msis.jsc.nasa.gov/sections/section05.htm



http://www.haystack.mit.edu/edu/pcr/Atmospheric/spaceweather/webpagetheionosphere.html

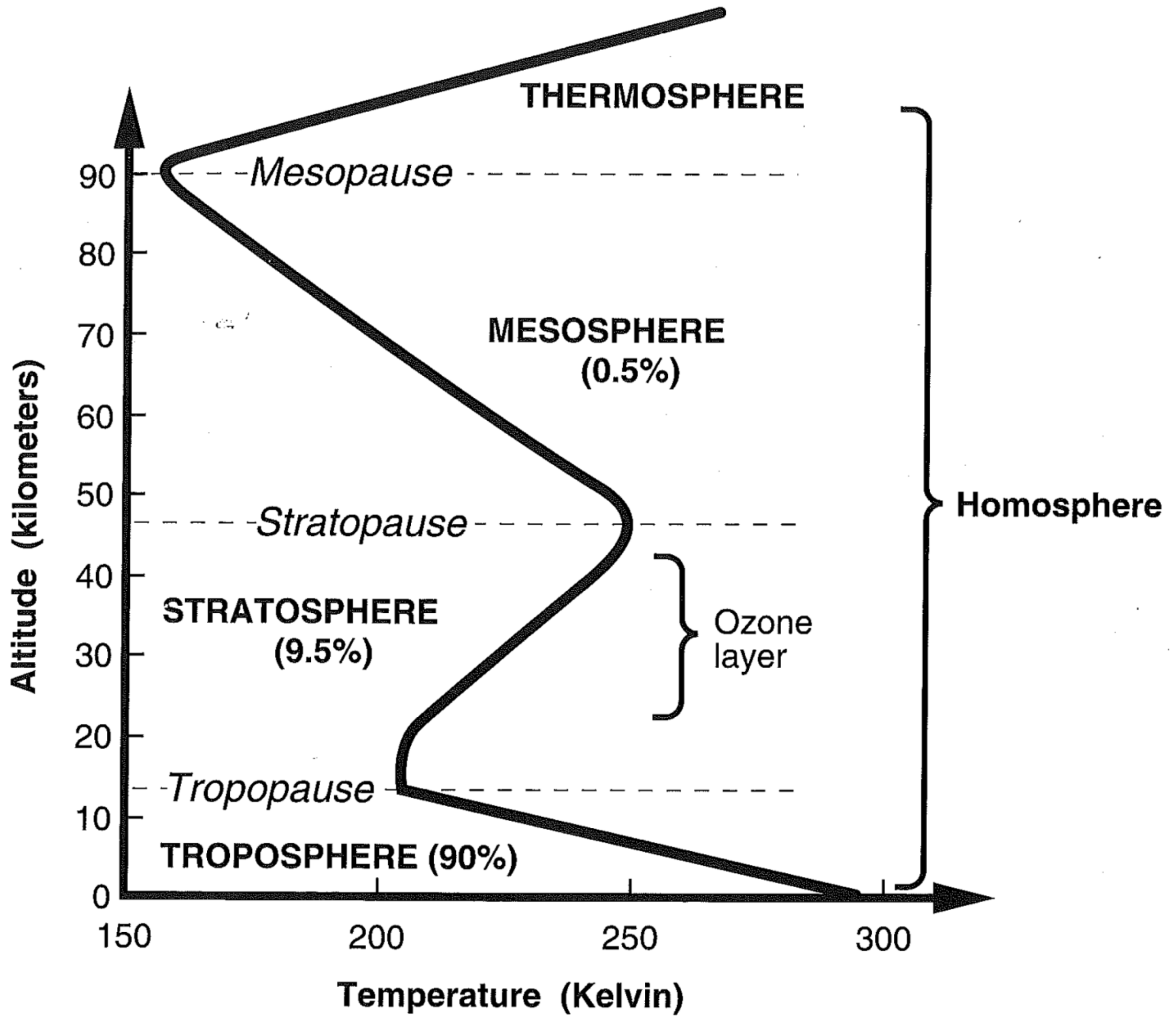
Photolytic Cleavage and Ionization

$$O_2 + h\nu\ (\lambda < 242\ \text{nm}) \rightarrow O^* + O^*$$

and

$$O^* + h\nu\ (\lambda < 92\ \text{nm}) \rightarrow O^+ + e^-$$

Temperature versus Altitude



Source: *Earth Under Siege* by Turco

Chapman Mechanisms

In the unperturbed stratosphere ozone is produced by

$O_2 + h\nu\ (\lambda < 242\ \text{nm}) \rightarrow O^* + O^*$ (I)

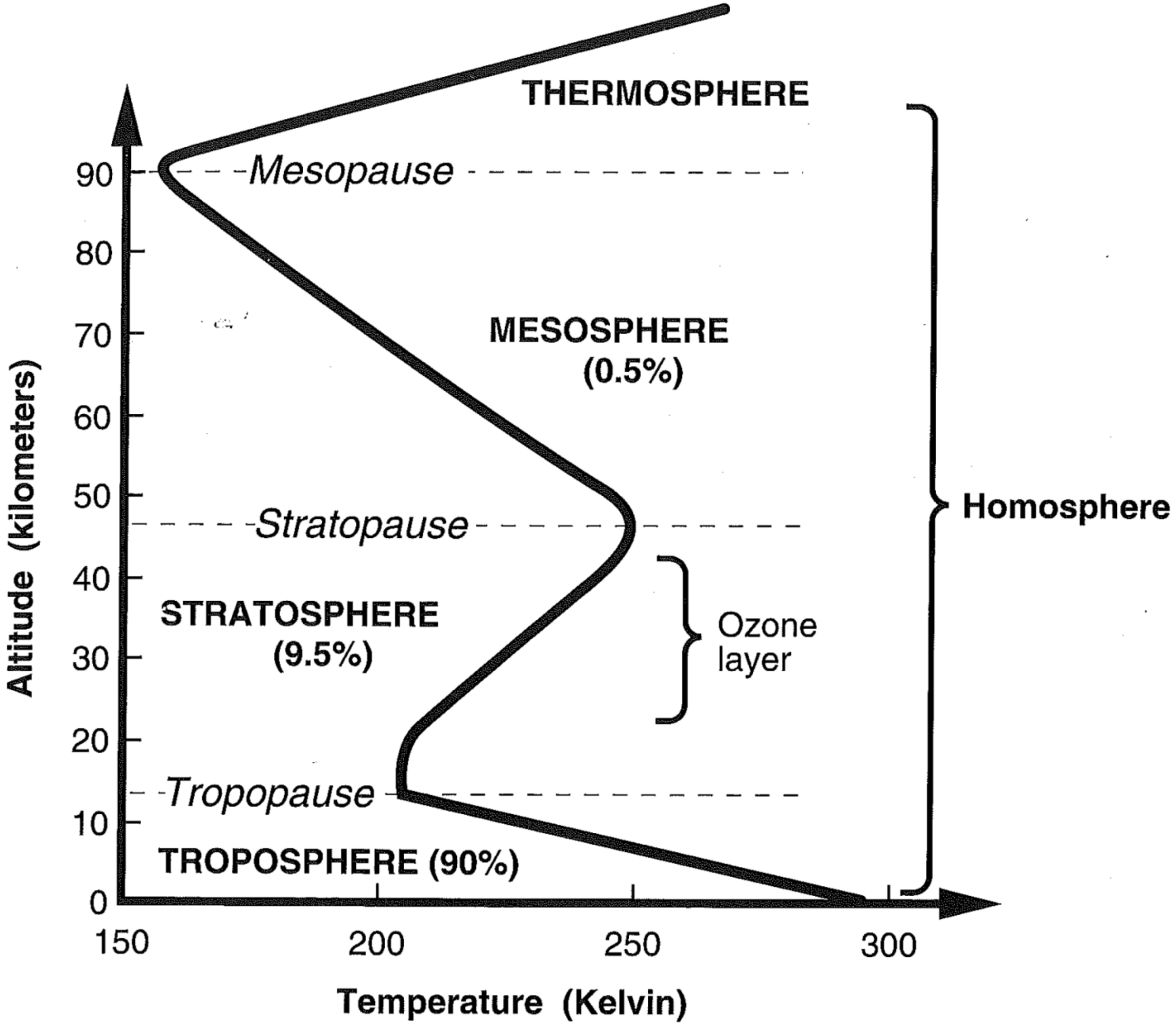
$O^* + M + O_2 \rightarrow O_3 + M + \text{energy}$ (II)

and then subsequently destroyed by

$O_3 + h\nu\ (200\ \text{nm} < \lambda < 300\ \text{nm}) \rightarrow O + O_2$ (III)

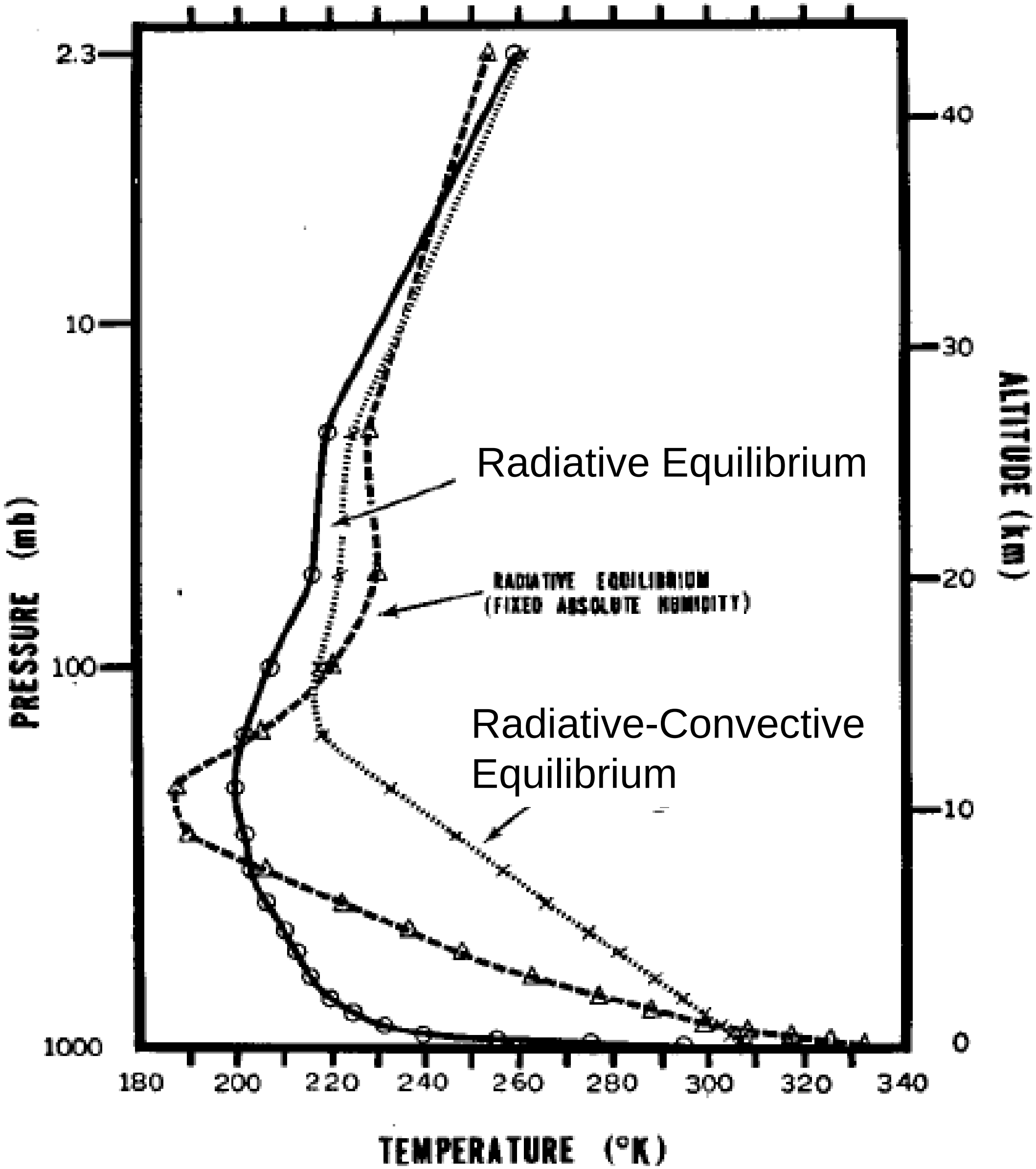
$O + O_3 \rightarrow O_2 + O_2 + \text{energy}$ (IV)

Temperature versus Altitude

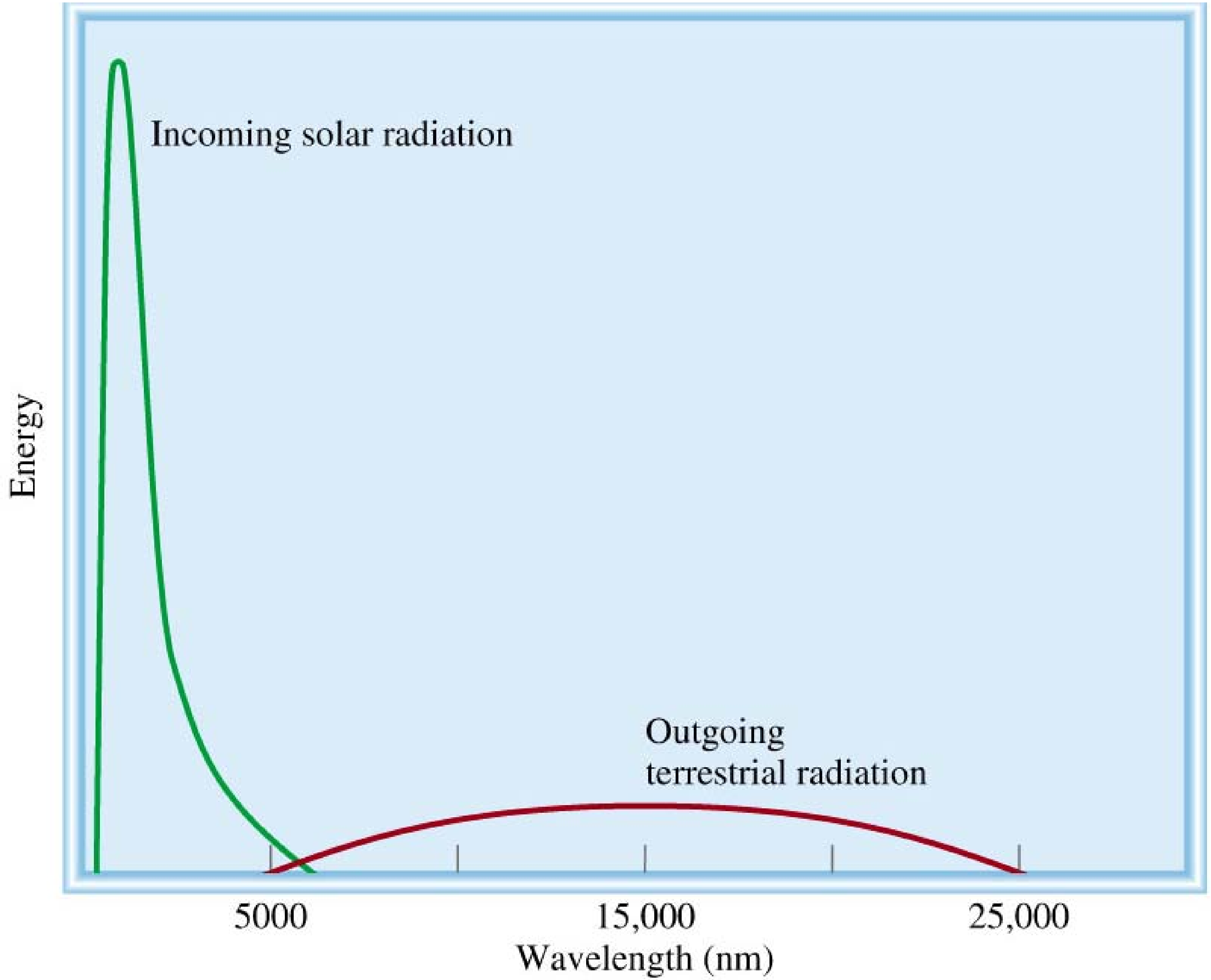


Source: *Earth Under Siege* by Turco

1D Radiative Convective Model

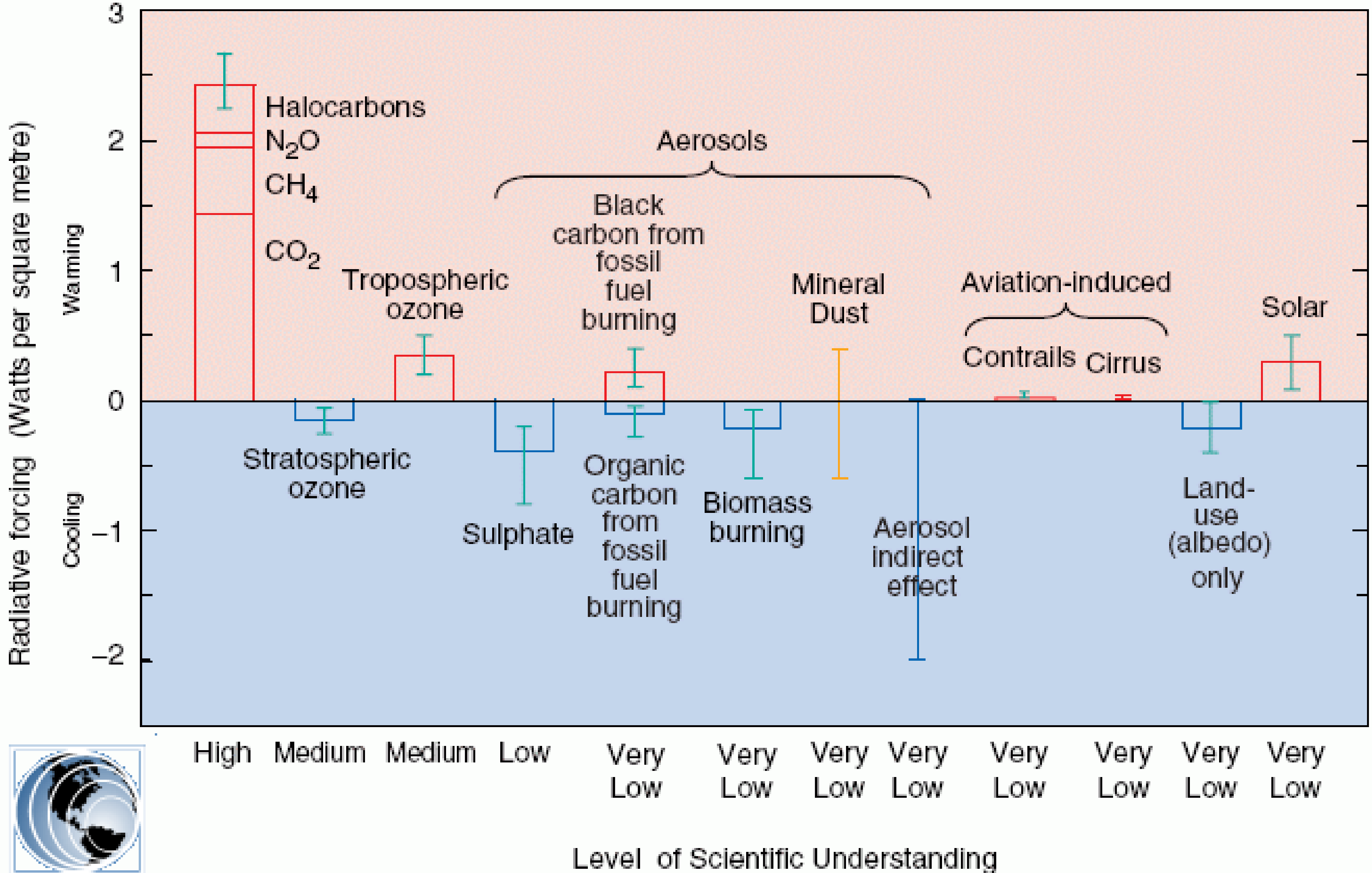


Manabe
& Wetherald 1967



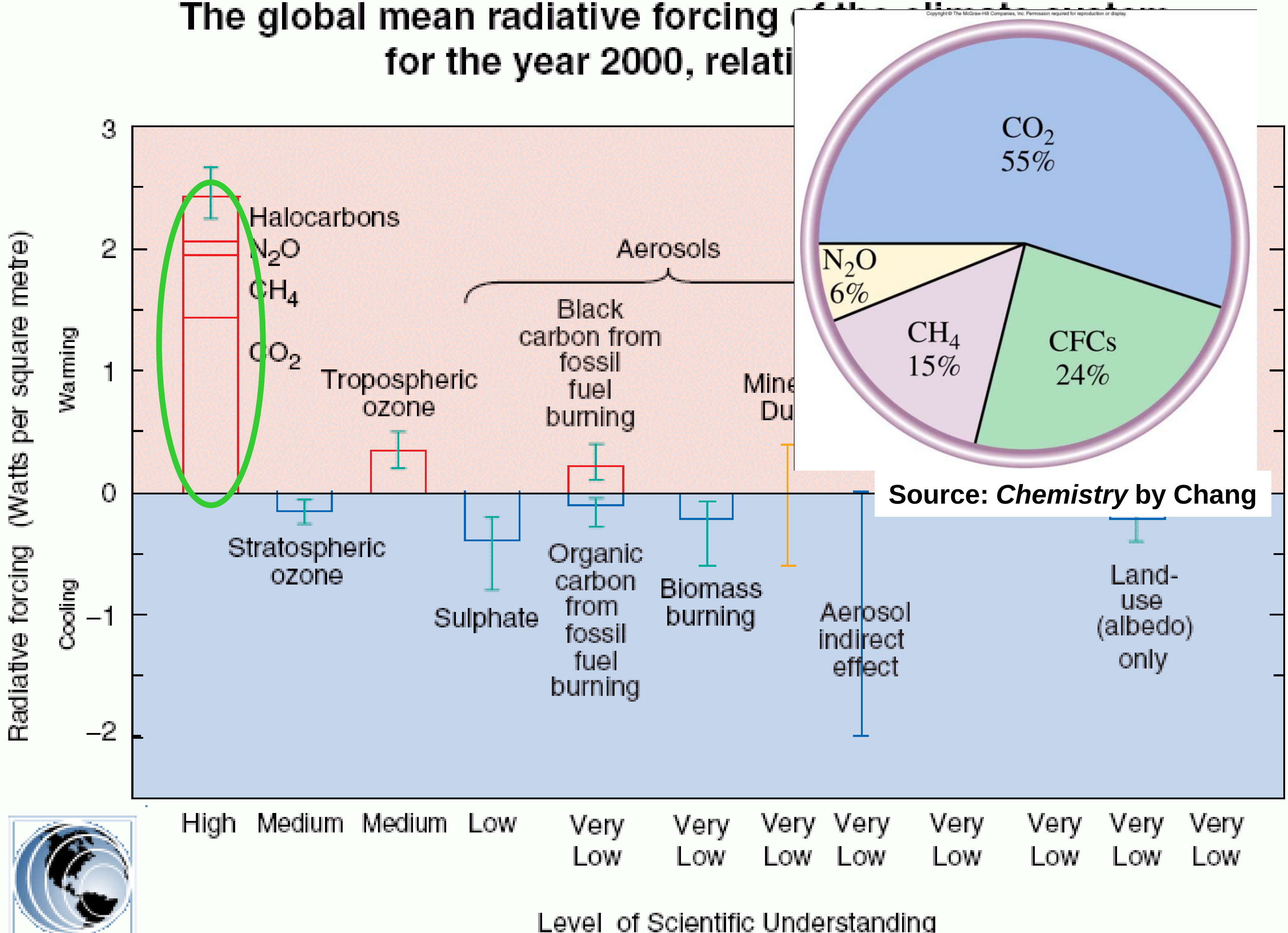
Source: ***Chemistry*** **by Chang**

The global mean radiative forcing of the climate system for the year 2000, relative to 1750



Source: IPCC TAR

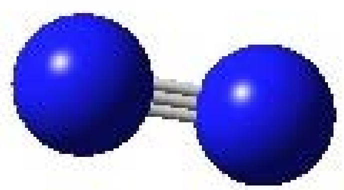
The global mean radiative forcing [of the climate system]
for the year 2000, relati[ve ...]



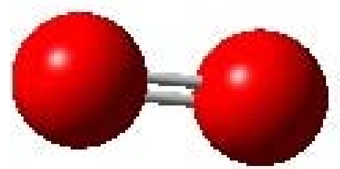
Source: *Chemistry* by Chang

Source: IPCC TAR

Composition of Atmosphere



N_2



O_2

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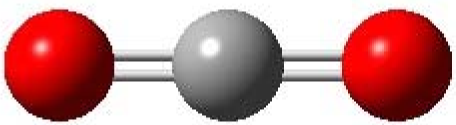
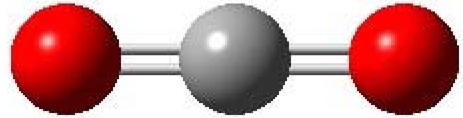
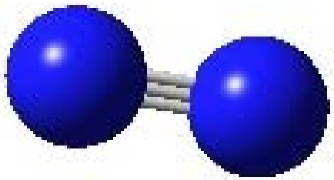


CO_2

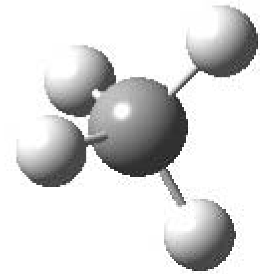
Source: *Chemistry* by Chang



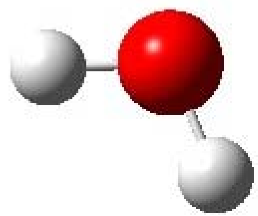
CO_2



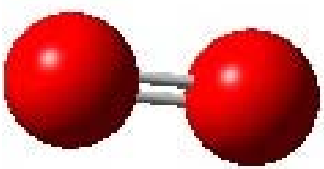
N_2



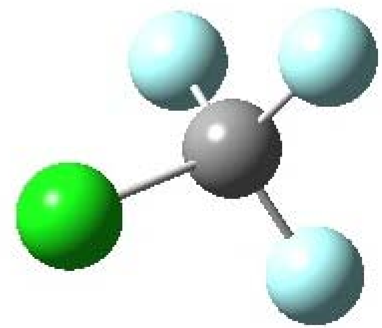
CH_4



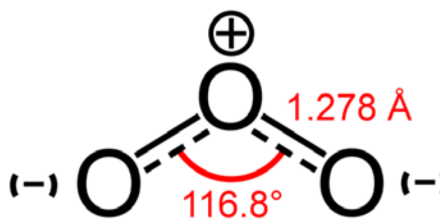
H_2O



O_2

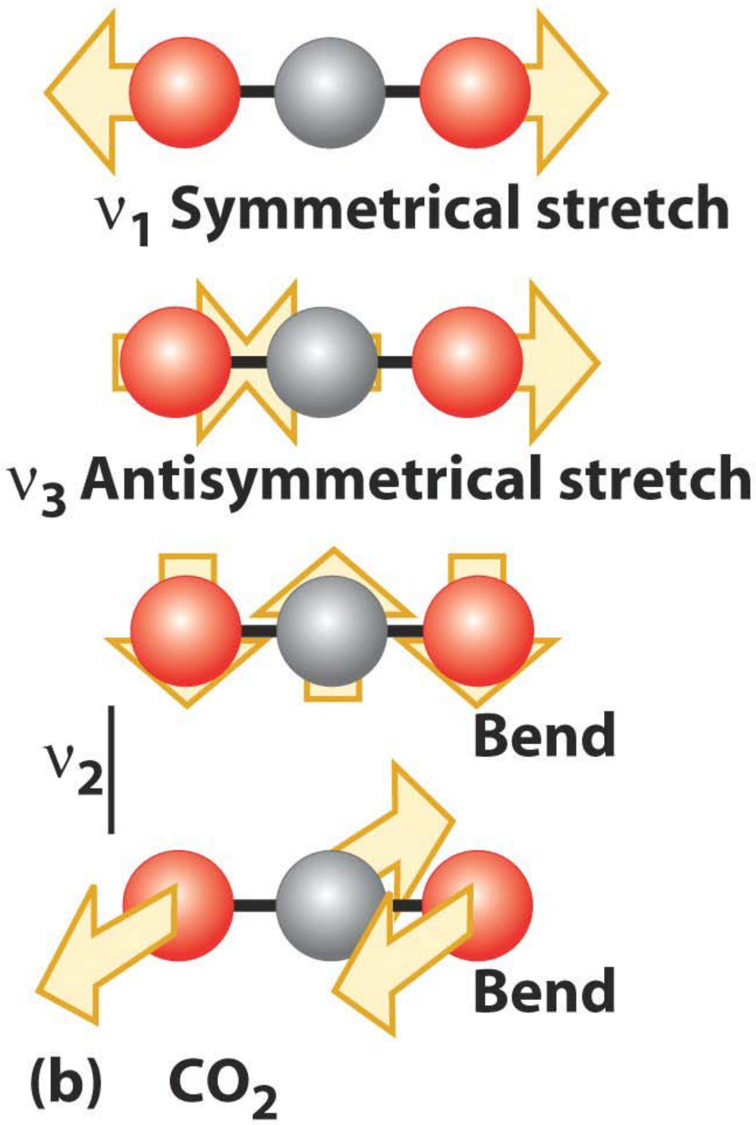


CF_3Cl

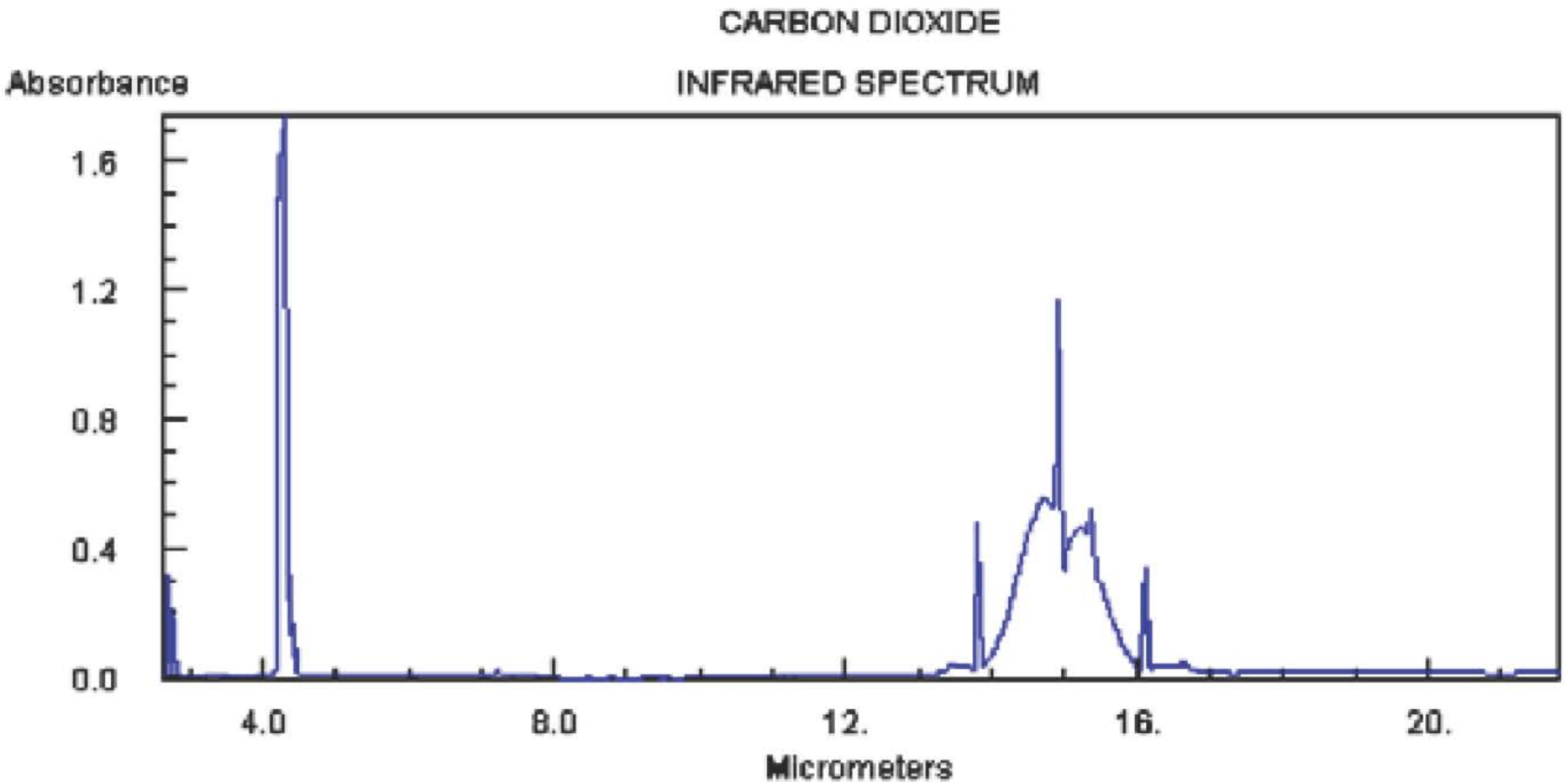


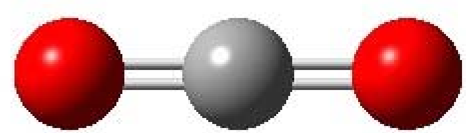
O_3

Vibrational Modes



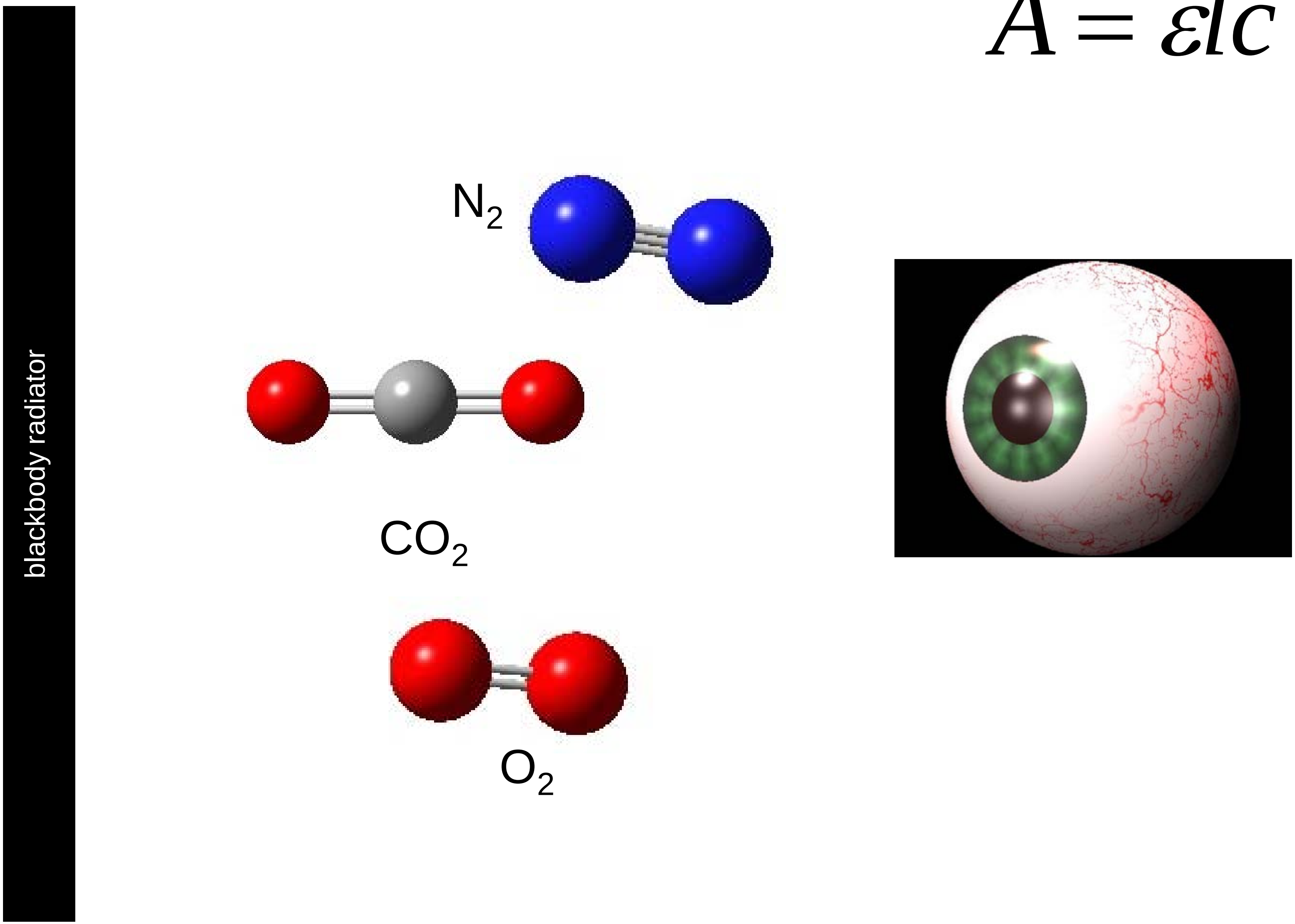
Source: *Chemical Principles* by Atkins and Jones


CARBON DIOXIDE
INFRARED SPECTRUM
Absorbance
1.6
1.2
0.8
0.4
0.0
4.0
8.0
12.
16.
20.
Micrometers

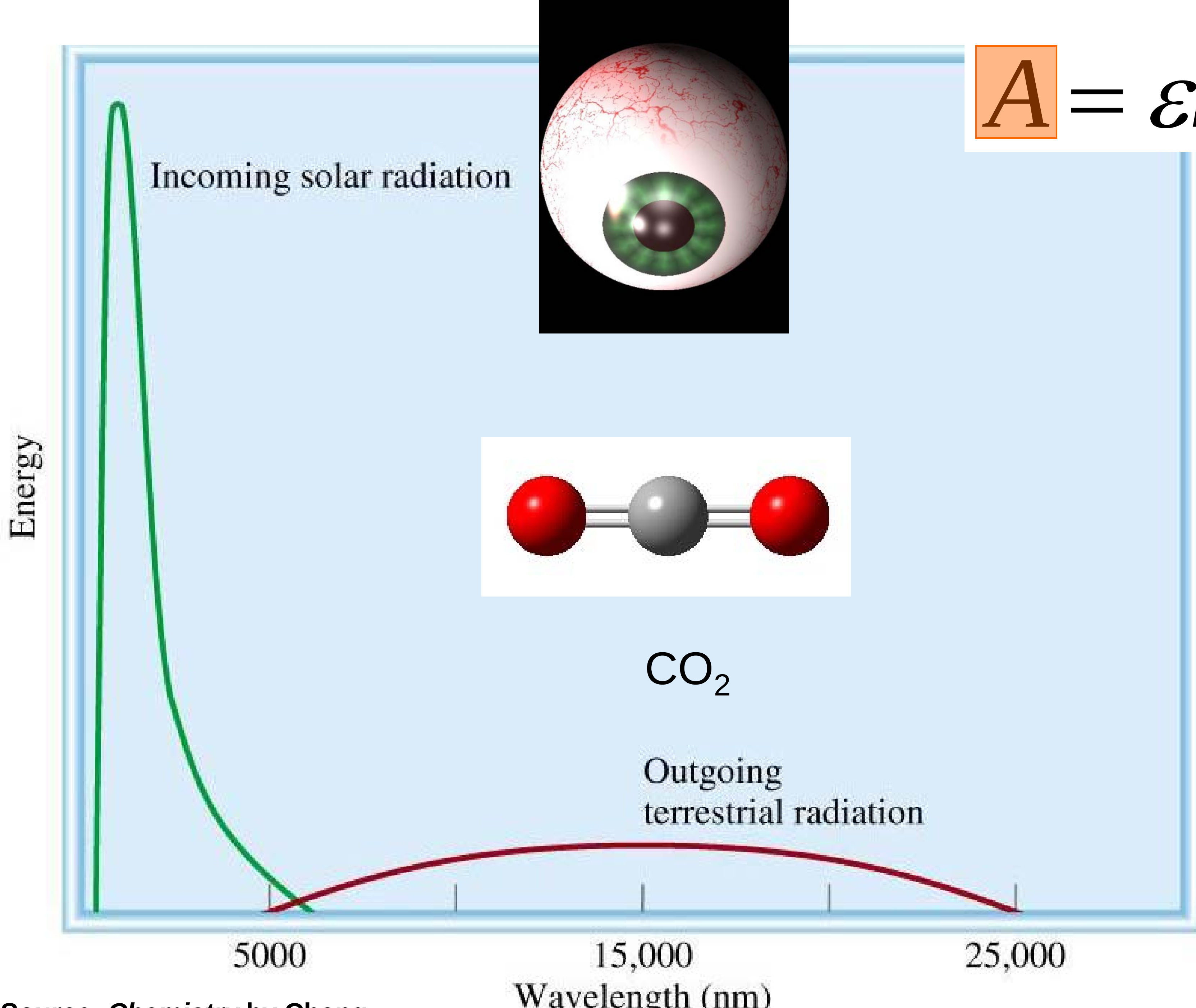


CO_2

$$A = \varepsilon l c$$

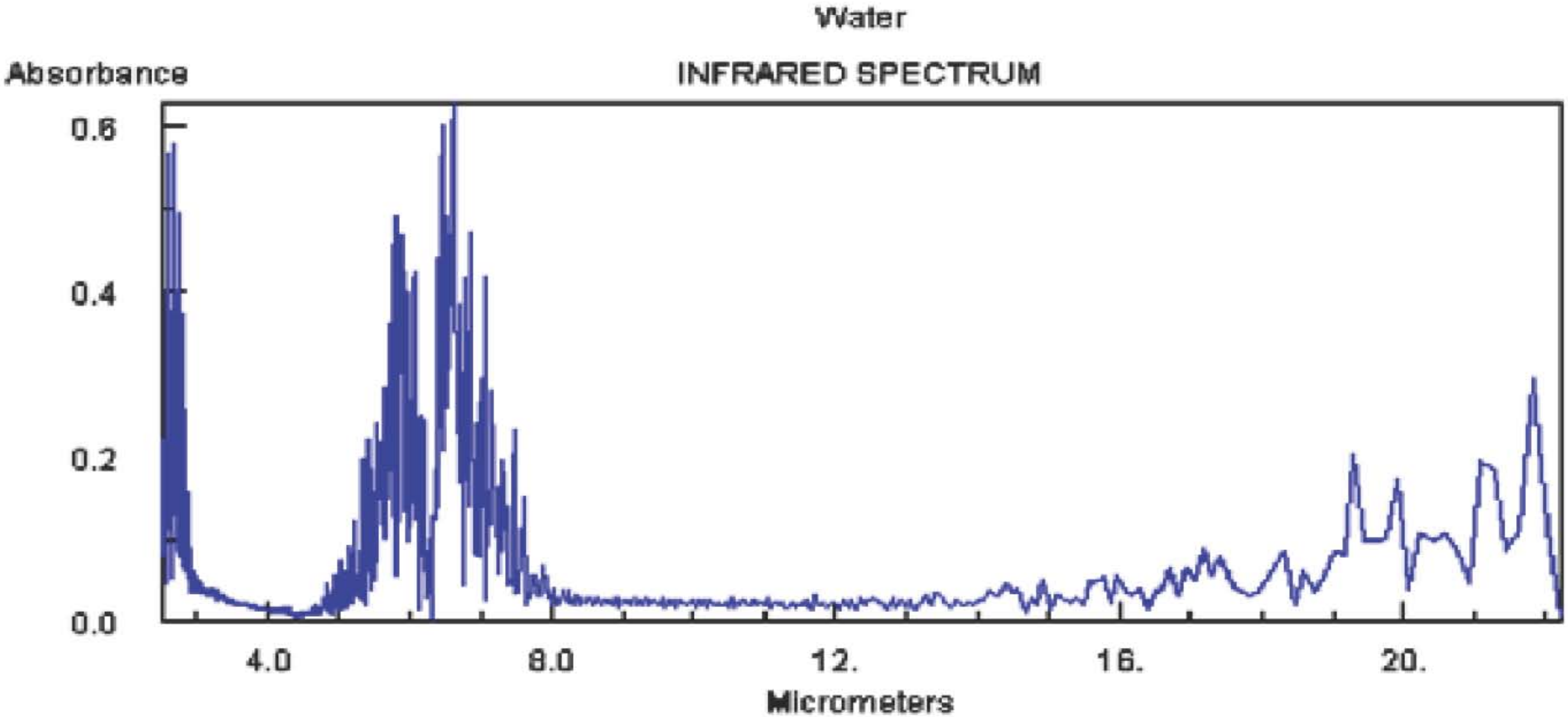


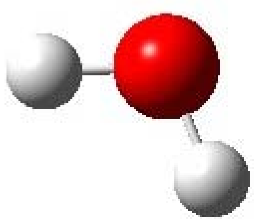
$$A = \varepsilon l c$$



CO_2

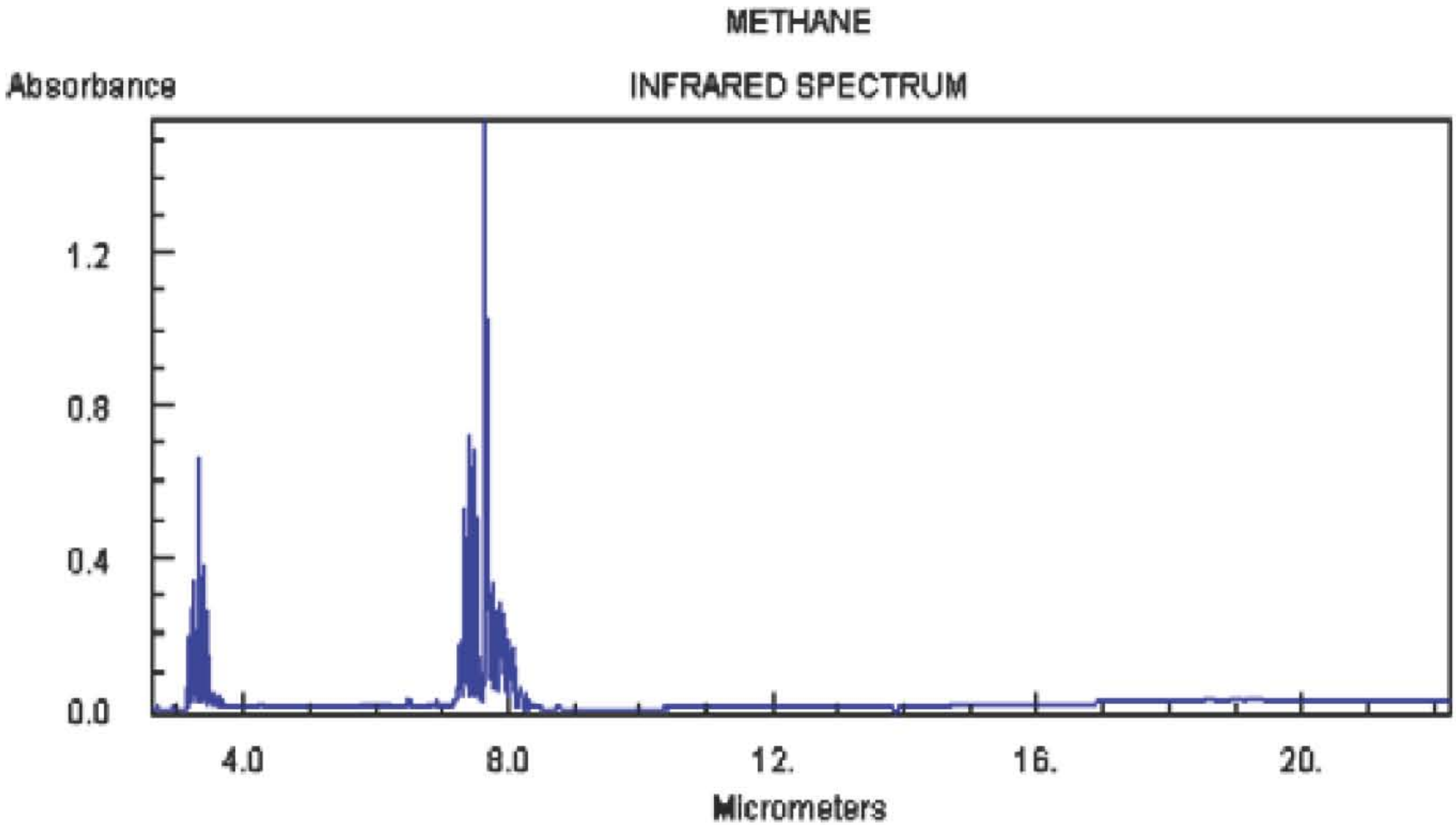
Source: *Chemistry* by Chang

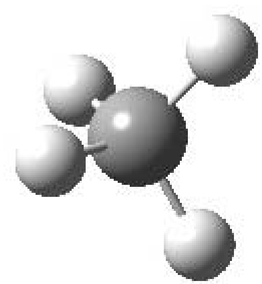




H_2O

http://webbook.nist.gov/





CH_4

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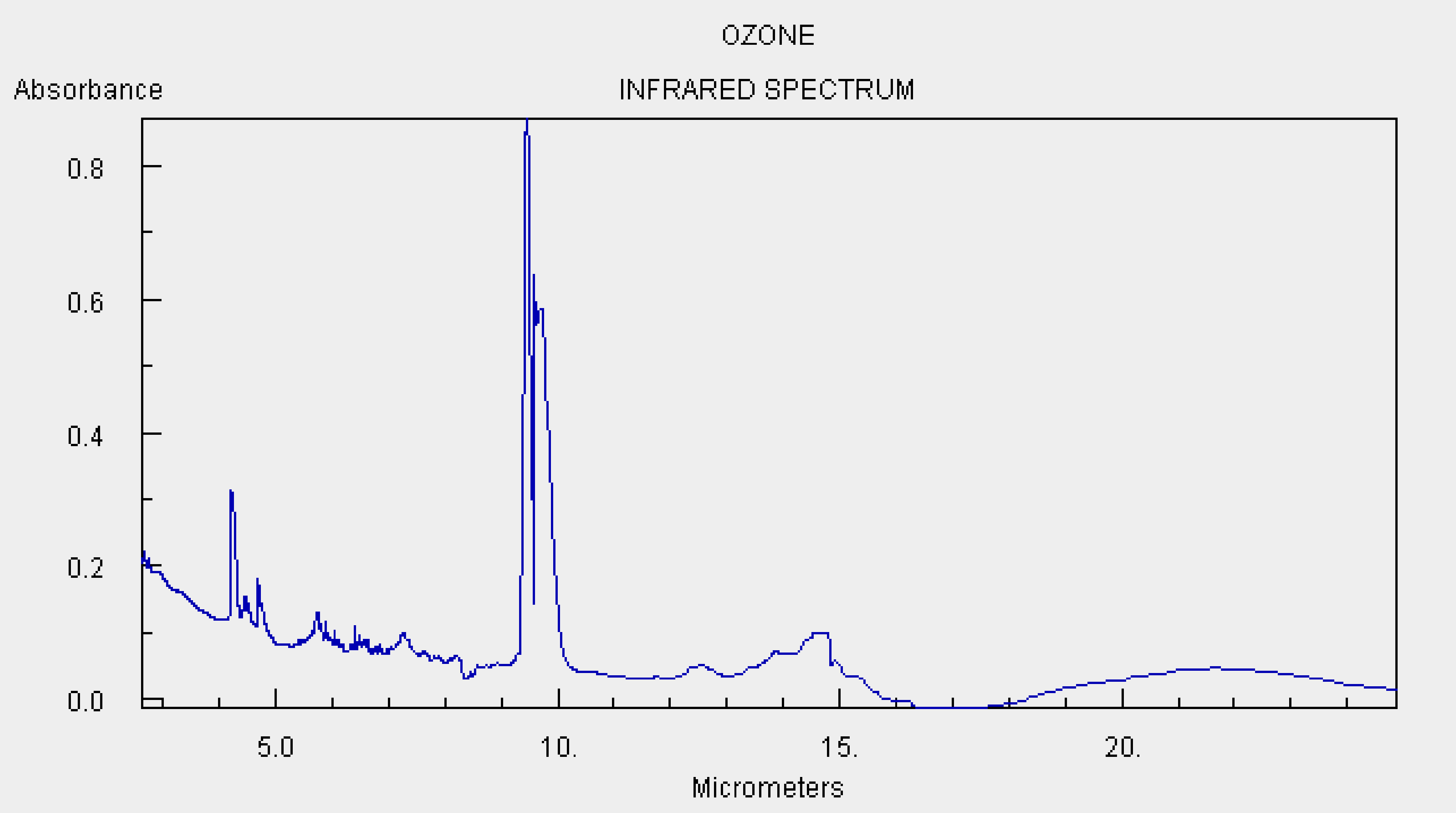

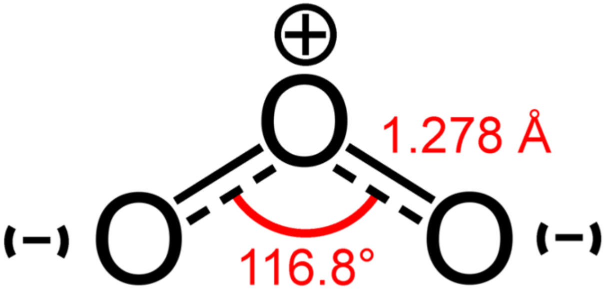

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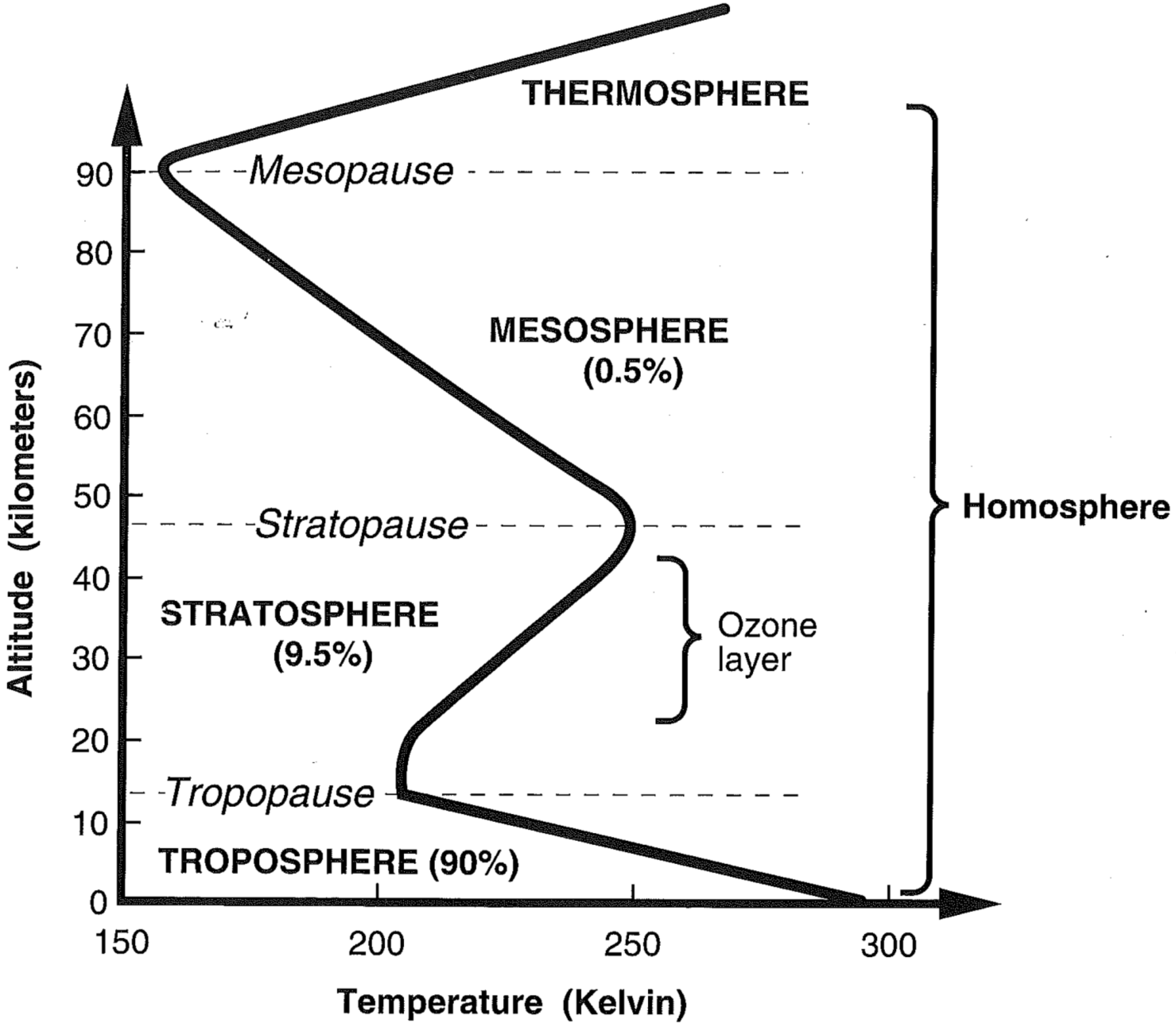
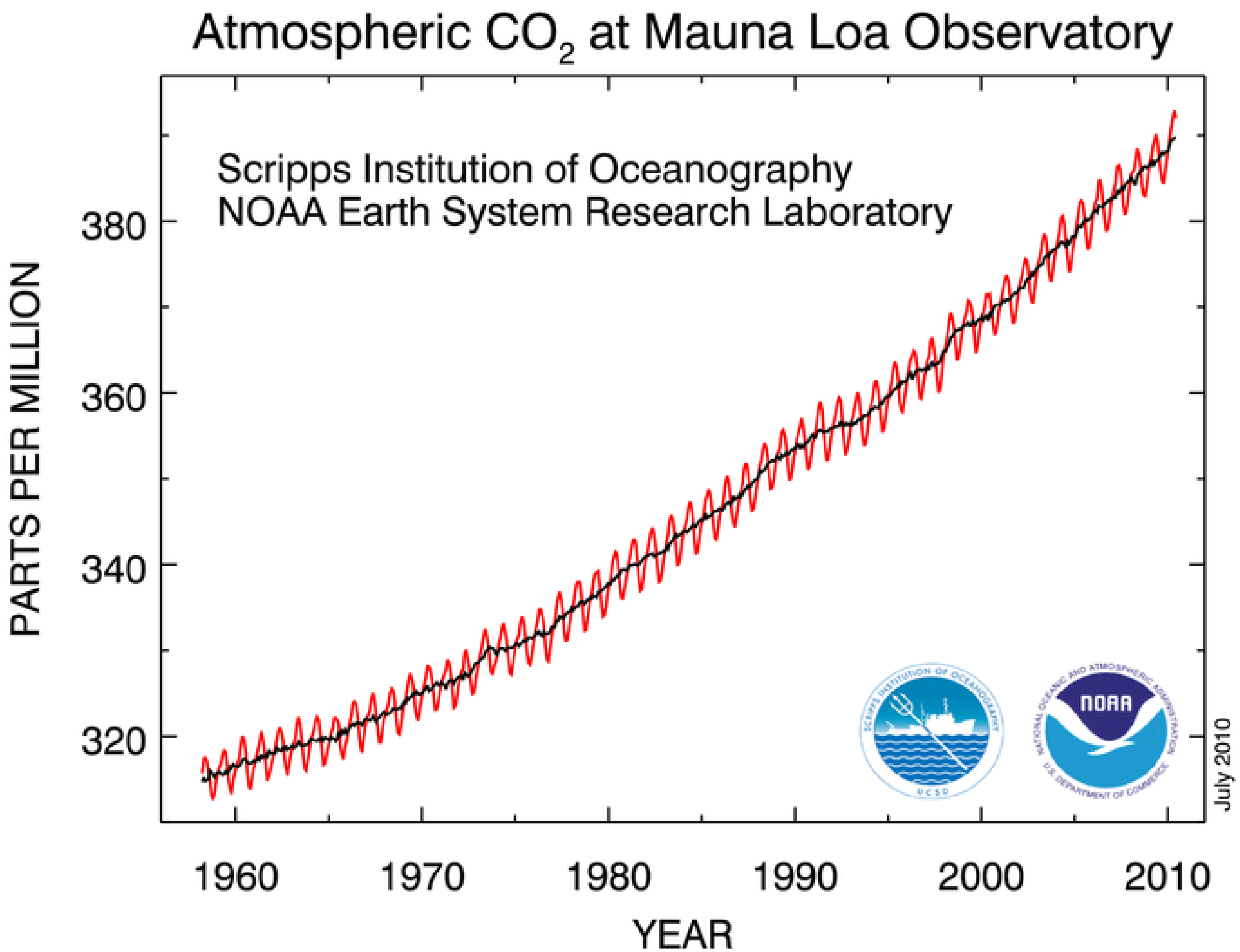
Temperature versus Altitude



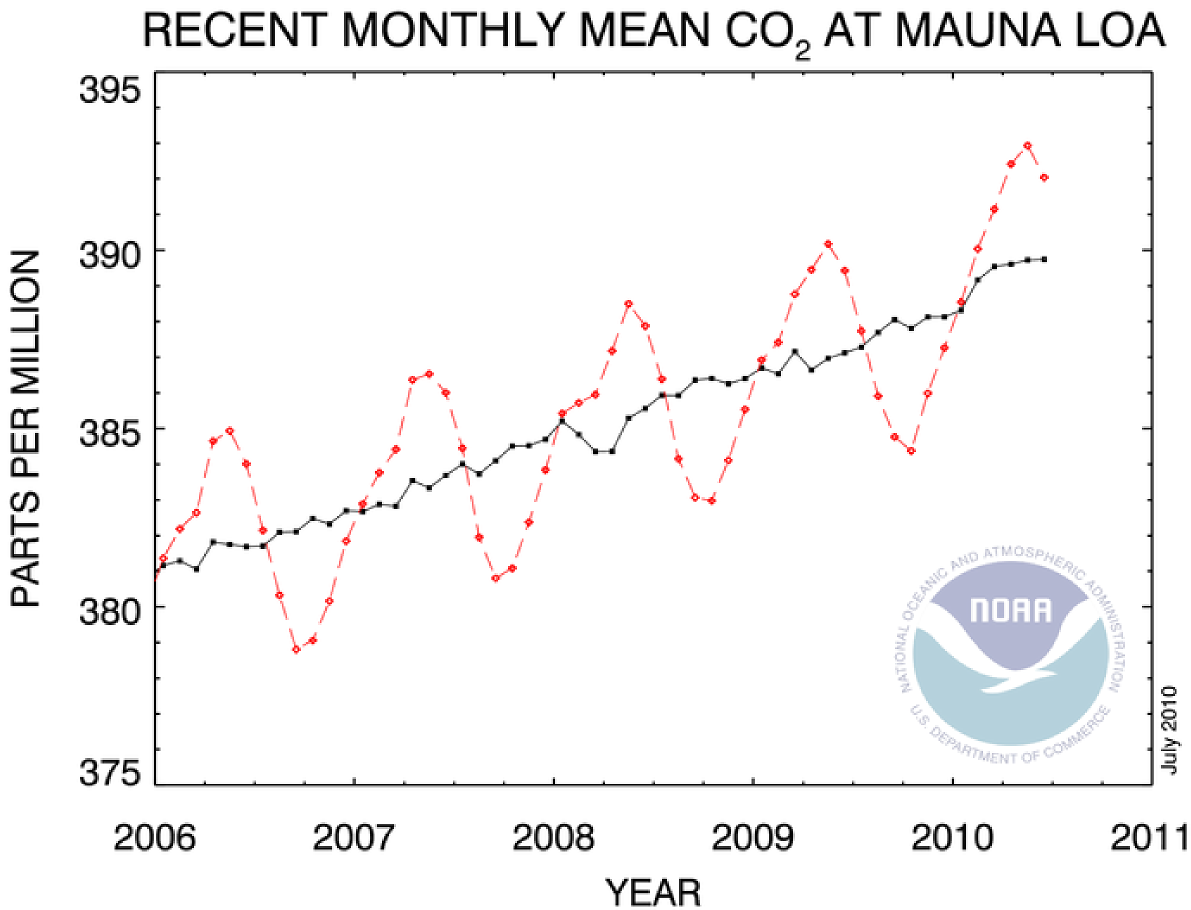
Source: *Earth Under Siege* by Turco

Trends in CO_2



http://www.esrl.noaa.gov/gmd/ccgg/trends/#mlo

Trends in CO_2



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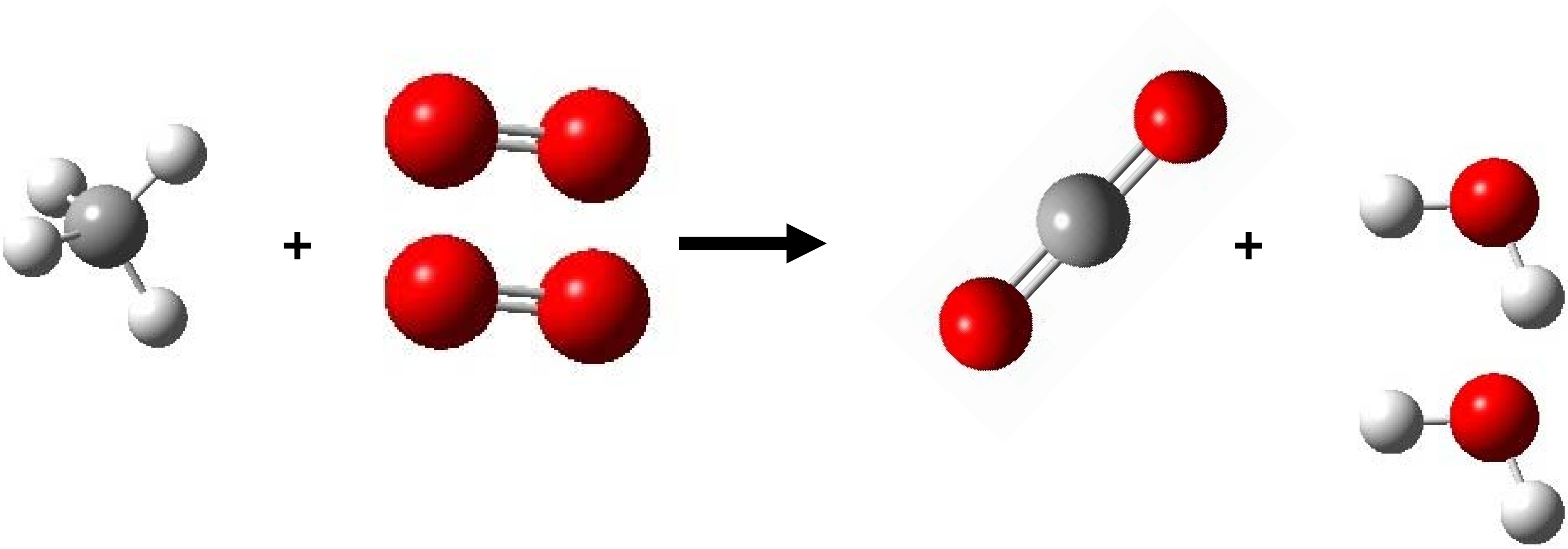
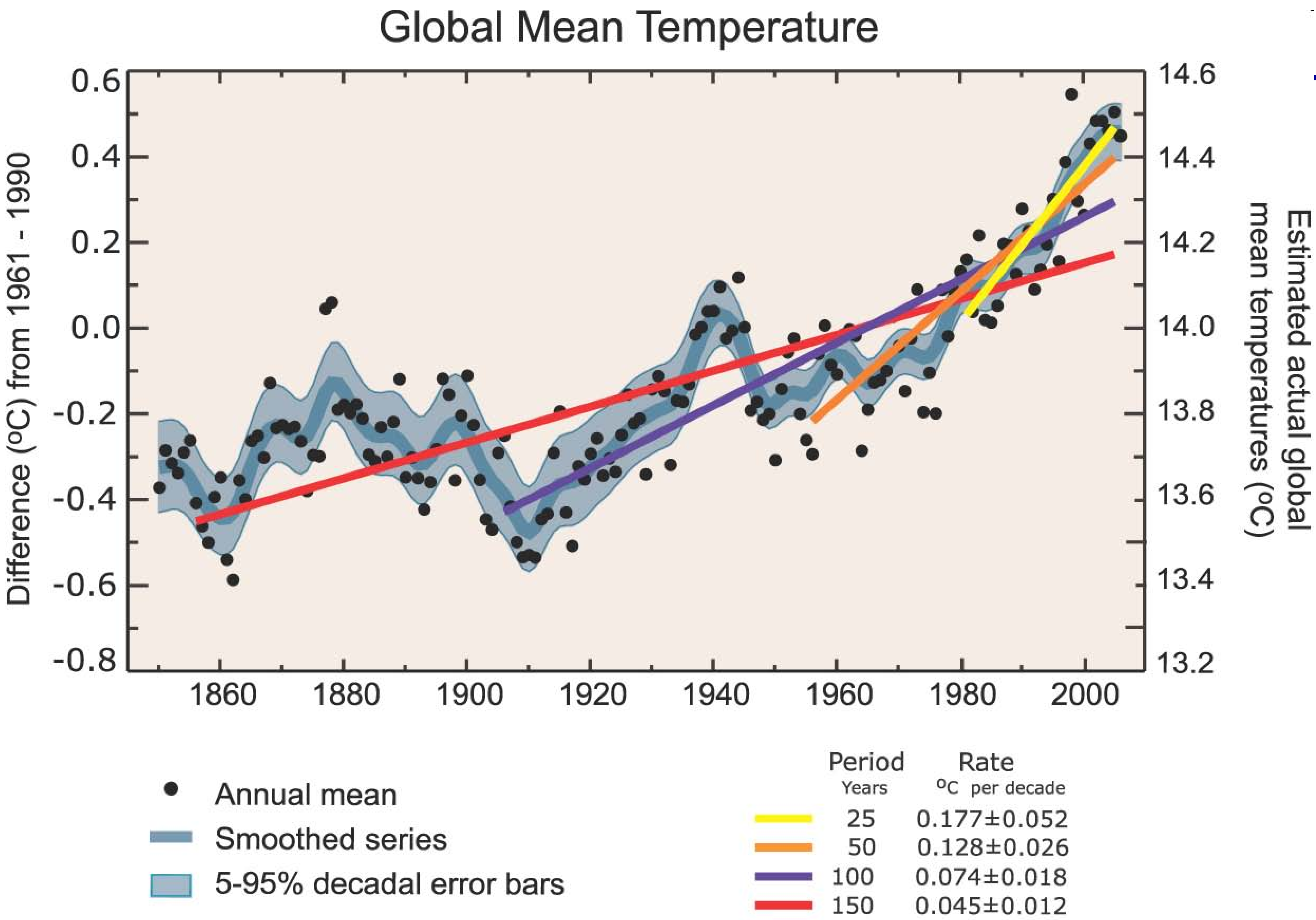


$$CH_4 + 2\,O_2 \longrightarrow CO_2 + 2\,H_2O$$



Source: IPCC AR4