Space & Atmospheric Physics

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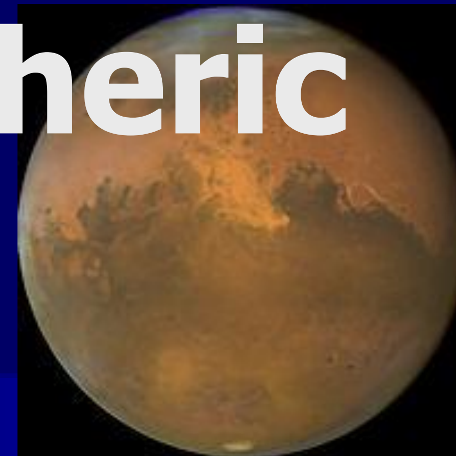
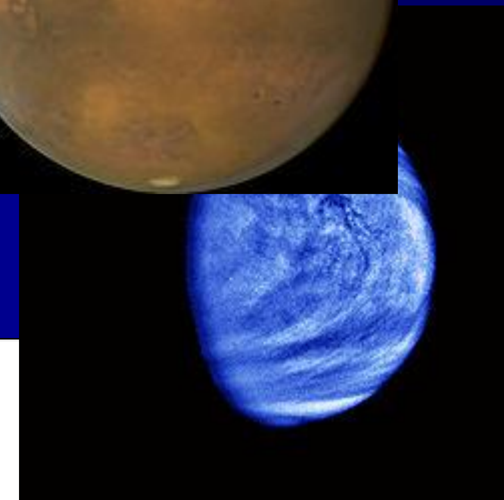
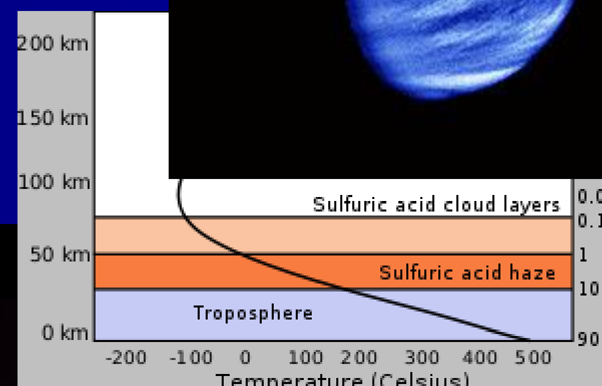
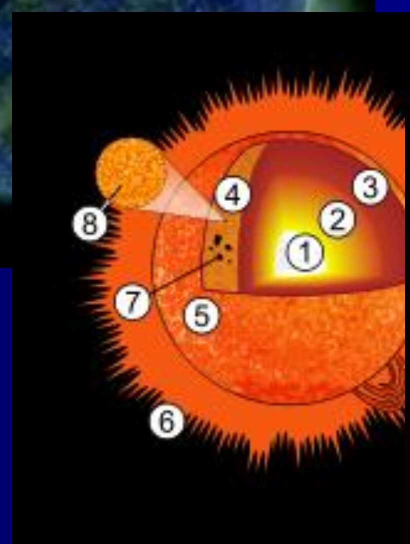
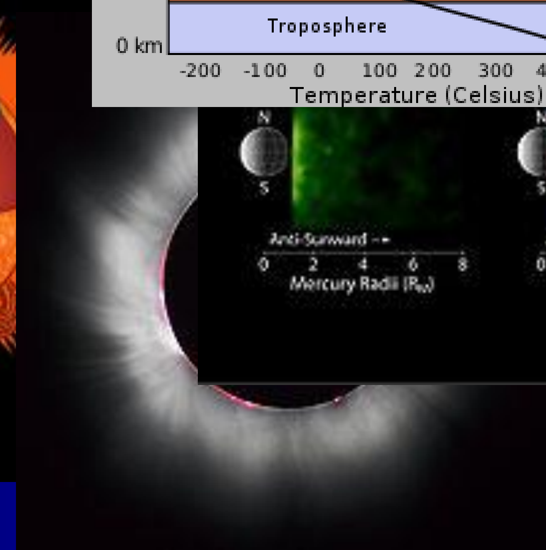
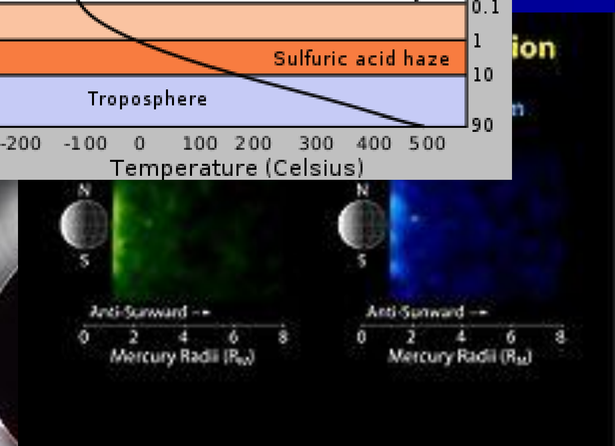












Lecture – 05

Earth Atmosphere

Retaining of Gases in the Earth
Major / Minor constituents
Barometric Equation
Scale Height
Atmospheric Regions
Temperature Profiles
Retaining of Gases
Number Density Profiles

Temperature Profile of the Earth

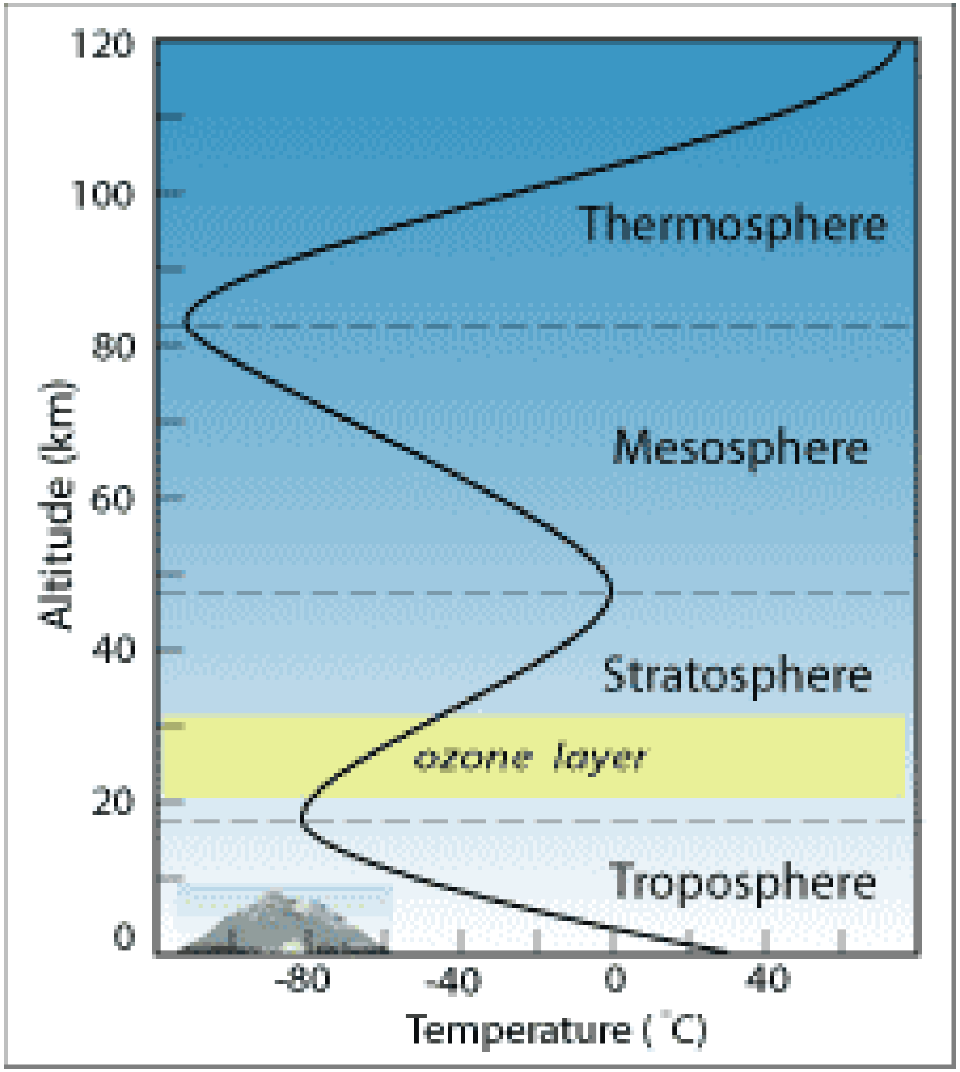
The temperature of the atmosphere of the Earth varies with the **distance from the equator** (latitude) and **height above the surface** (altitude). It also changes in **time**, **varying from season to season**, **from day to night** and **irregularly due to passing weather systems**. If these variations are averaged out on a global basis, a pattern of average temperatures emerges for the atmosphere.

The vertical temperature profile (the way temperature changes with height) divides the atmosphere into four layers:

The troposphere,
The stratosphere,
The mesosphere,
The thermosphere.

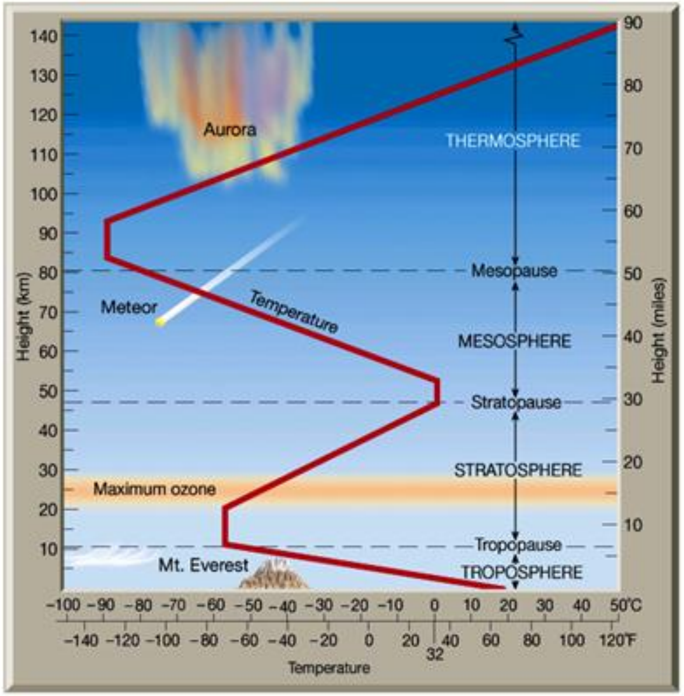
The boundaries between these regions / layers are called tropopause, stratopause and mesopause.

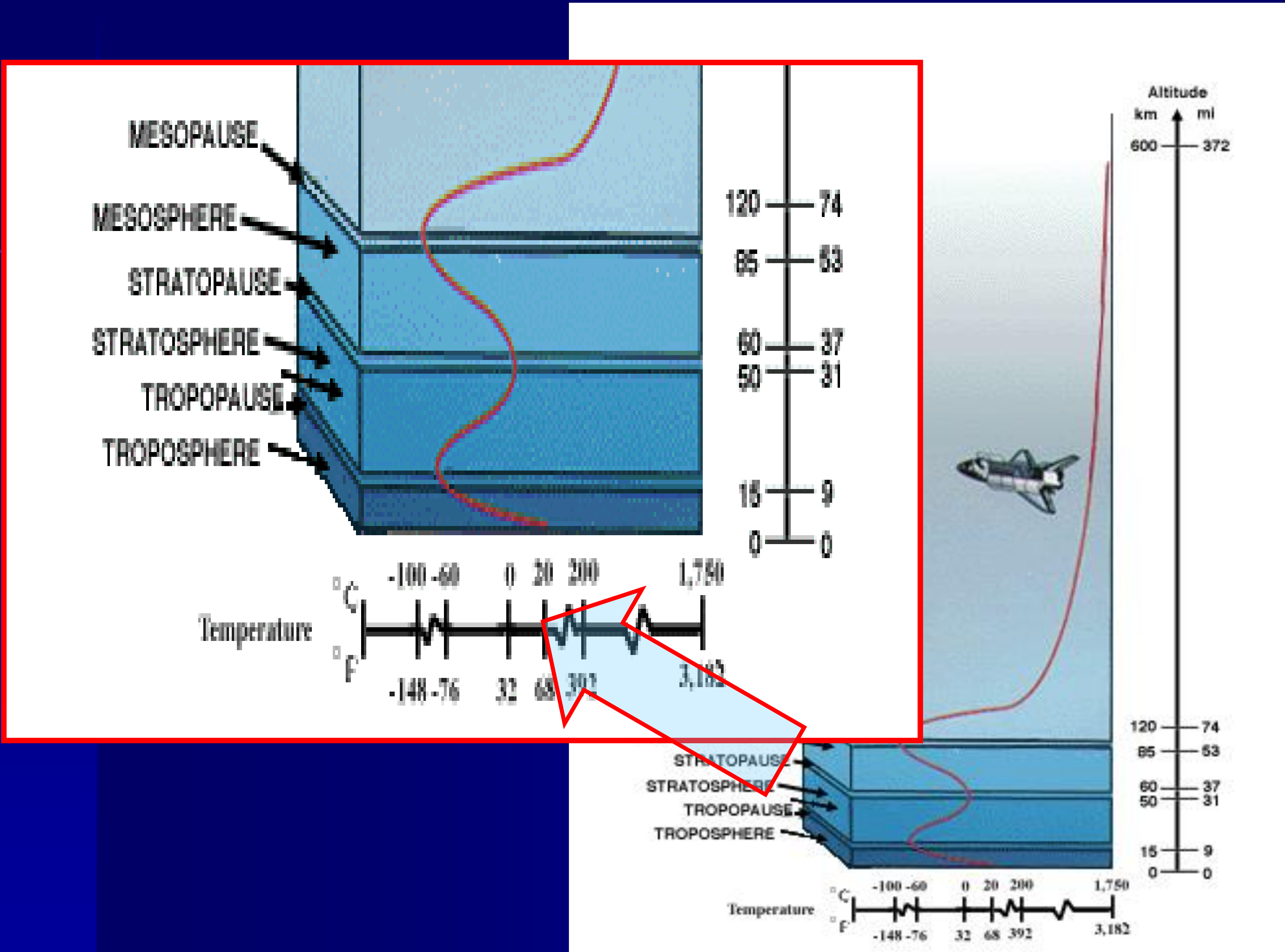
Temperature Profile



This graph shows how temperature varies with altitude in earth's atmosphere.

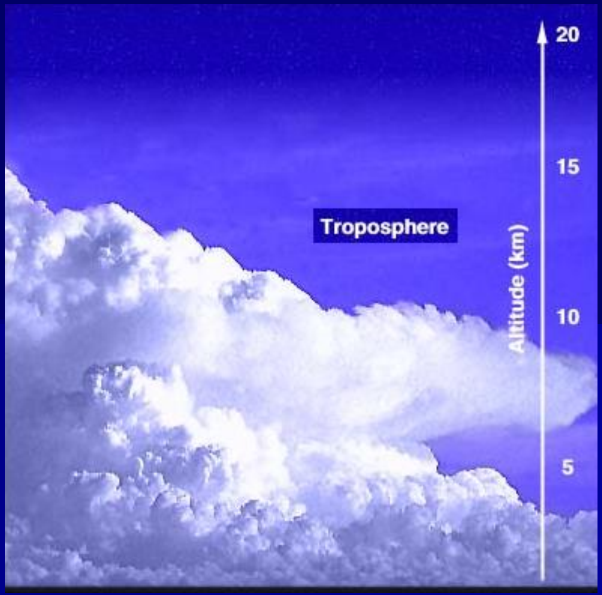
Vertical structure of the atmosphere




MESOPAUSE
MESOSPHERE
STRATOPAUSE
STRATOSPHERE
TROPOPAUSE
TROPOSPHERE
120 74
85 53
60 37
50 31
15 9
0 0
°C -100 -60 0 20 200 1,750
Temperature
°F -148 -76 32 68 392 3,182
Altitude
km mi
600 372
120 74
85 53
60 37
50 31
15 9
0 0
STRATOPAUSE
STRATOSPHERE
TROPOPAUSE
TROPOSPHERE
°C -100 -60 0 20 200 1,750
Temperature
°F -148 -76 32 68 392 3,182

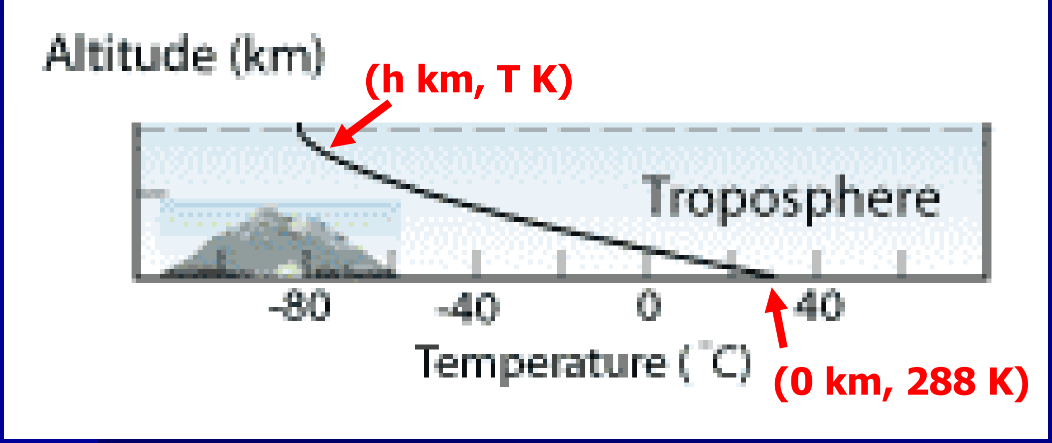
Troposphere

This is the lowest layer and extends from the ground to about 13 km. The **heat source for this region is the surface of the Earth**, at a temperature of 290 ± 20 K and, therefore, as we move away from the ground, the temperature decreases at a rate of reaching a minimum of 210 ± 20 K at the tropopause.



This level, is just above the cruising altitude of large commercial jet aircraft.

The drop of temperature with height is called the lapse rate, is nearly steady throughout the troposphere at 6.5°C/ km.



The drop of Temperature with height :

Lapse Rate : 6.5 °C / km

Space Physics Lec 05 Temp Pro Values.nb * - Wolfram Mathema...

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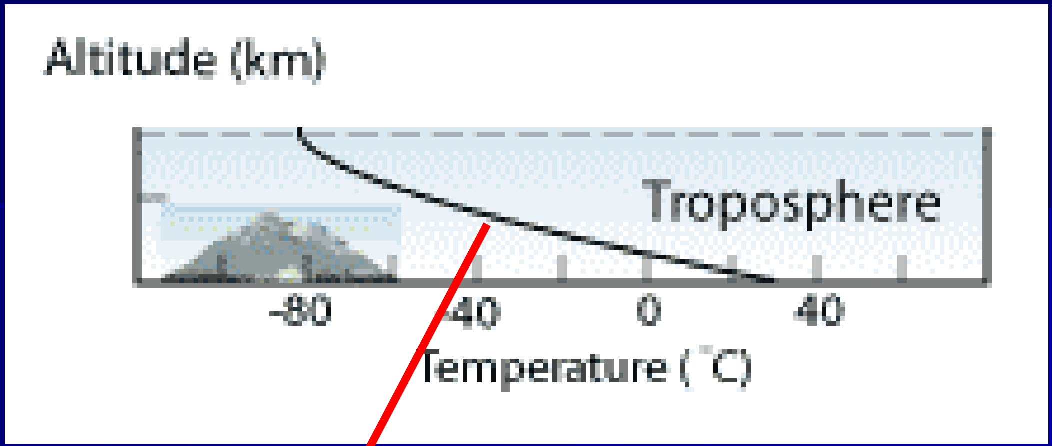
In[1]:=
```
h1 = 0;
h2 = h;
rate = -6.5;
thita1 = 15 + 273;
thita2 = T;
Solve[
 ((thita2 - thita1) / (h2 - h1)) ==
  rate, T]
```

Out[6]= $\left\{\left\{T \to \left(-6.5 + \frac{288.}{h}\right) h\right\}\right\}$

Troposphere

Altitude (km)	Temperature (K)
0	288
2	275
4	262
6	249
8	236
10	223
12	210



Lapse Rate : 6.5 °C / km

(km)

$$T(h) = -6.5\,h + 288$$

(K) (K)

1 °C = 1 K

Tropopause:

The upper boundary of the troposphere occurring at an altitude of 13 ± 5 km.

Pidurutalagala, or Mount Pedro in English, is an ultra prominent peak, and the tallest mountain in Sri Lanka, at **2,524 m**. **Find the temperature at the top of the mountain.**

Answer : 10.5 °C

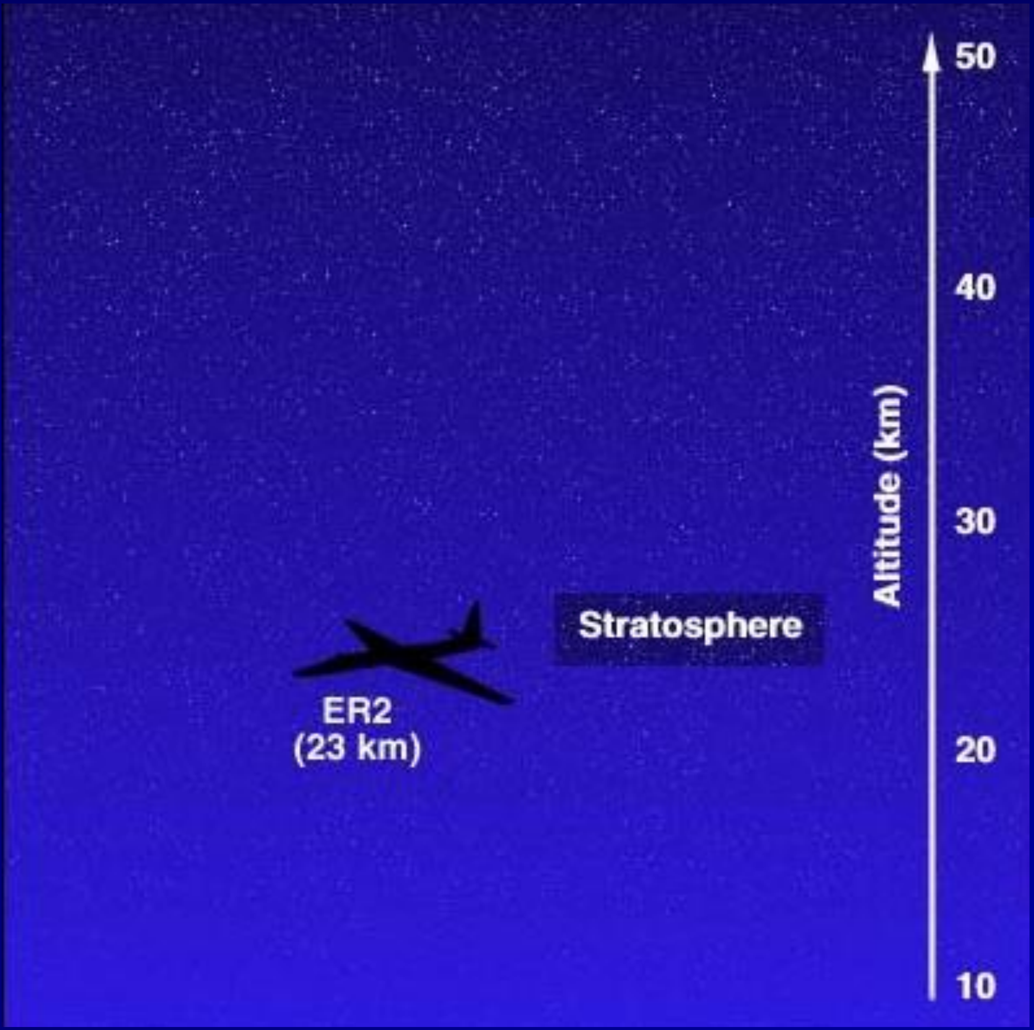
Mount Everest, is Earth's highest mountain. Its peak is **8,848 meters** above sea level. **Find the temperature at the top of the mountain**.

Answer : - 30.5 °C

Stratosphere:

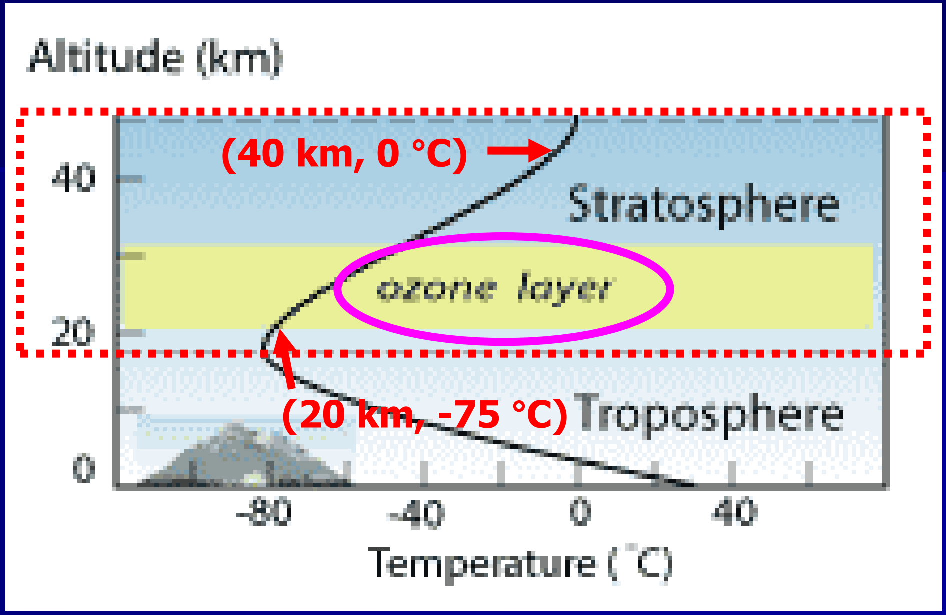
The stratosphere is situated directly above the troposphere and just below the mesosphere.

Atmospheric temperature is roughly constant over the next 20 km and then begins to rise with increasing altitude up to about 50 km. This region of increasing temperatures is the stratosphere. At the top of the layer, called the stratopause, temperatures are nearly as warm as the surface values.



Stratosphere:

The temperature beings to rise in this region reaching a maximum of 270 ± 20 K at the stratopause. **The heating of the stratosphere is due to the absorption of the ultraviolet radiation in the 2000 Å - 3000 Å range by the Ozone** in the **ozonosphere**.



The upper layers of the stratosphere are heated by the presence of an ozone layer that absorbs **ultraviolet (UV) radiation from the Sun radiation that would otherwise be harmful to living organisms on Earth**. The Ozone layer reaches a maximum concentration around 20 – 25 km.

Stratopause:

The upper boundary of the stratosphere occurring at an altitude of 50 ± 5 km.

Temp Pro Values.nb * - Wolfram Mathematica 12.1

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```
In[62]:= h1 = 20;
         h2 = 40;
         thita1 = -75 + 273;
         thita2 = 0 + 273;
         Solve[((T - thita1) / (h - h1)) ==
           ((thita2 - thita1) / (h2 - h1)),
          T]
```

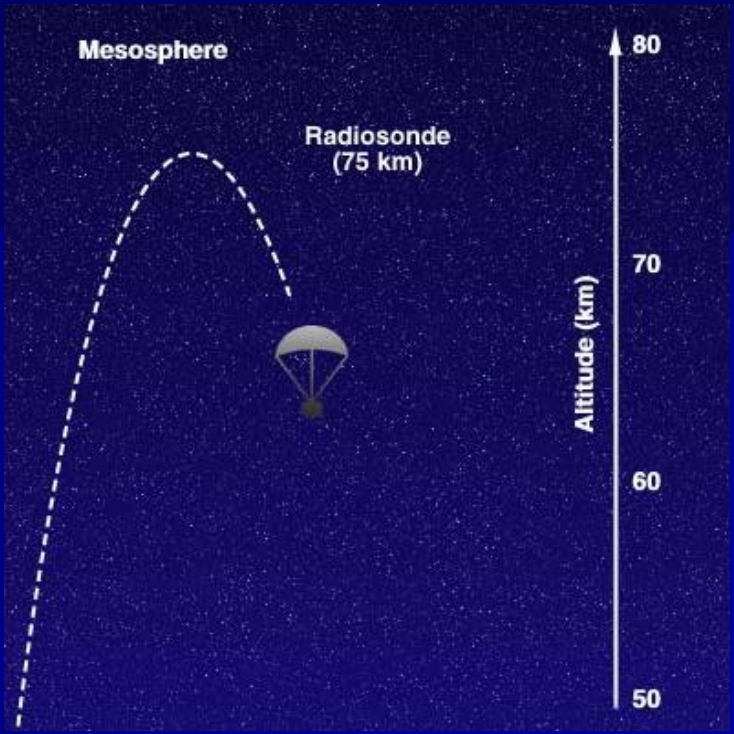
$$\text{Out[66]=}\ \left\{\left\{T \to \frac{3}{4}\,(164 + 5\,h)\right\}\right\}$$

Mesosphere:

It is sandwiched between the stratosphere and the thermosphere.

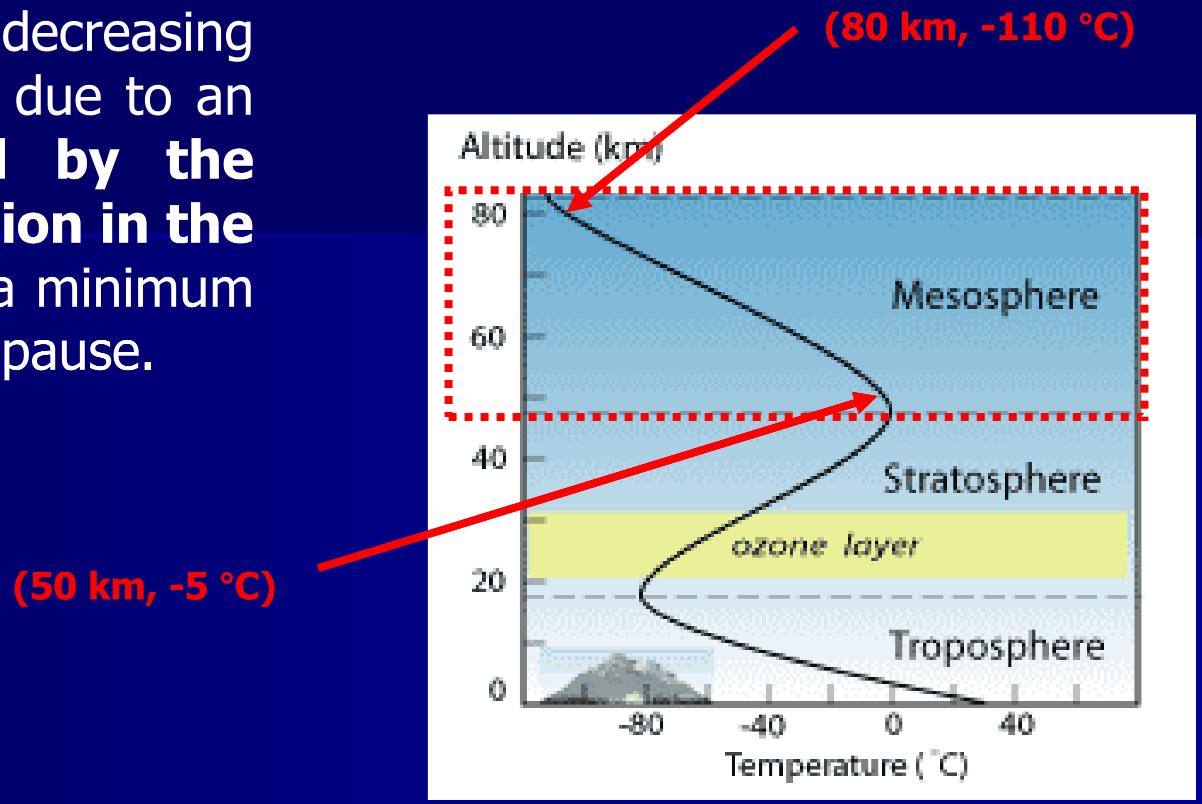
Between about 50–80 km lies the mesosphere, where atmospheric temperature resumes its drop with altitude and reaches a very cold minimum of 180K (−93°C) at the top of the layer (the mesopause), around 80 km.

Millions of meteors burn up daily in the mesosphere, as a result of collisions with the gas particles contained there, leading to a high concentration of iron and other metal atoms.



Mesosphere:

The temperature starts decreasing with height in the region due to an **energy sink provided by the CO2 and Oxygen emission in the far infrared**. It reaches a minimum of 180 ± 20 K at the mesopause.



Mesopause:

The upper boundary of the mesosphere occurring at an altitude of 85 ± 5 km.

Temp Pro Values.nb * - Wolfram Mathematica 12.1

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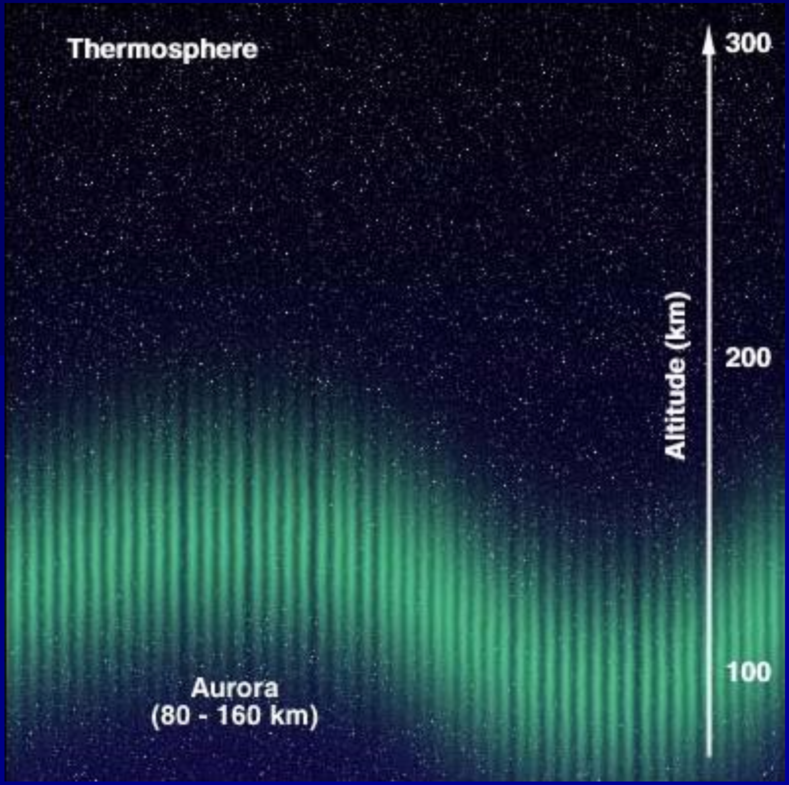
```
In[57]:= h1 = 50;
         h2 = 80;
         thita1 = -5 + 273;
         thita2 = -110 + 273;
         Solve[((T - thita1) / (h - h1)) ==
           ((thita2 - thita1) / (h2 - h1)),
          T]
```

Out[61]= $\left\{\left\{T \to \frac{1}{2}\,(886 - 7\,h)\right\}\right\}$

Thermosphere:

Above the mesopause is the thermosphere, which as its name implies is a zone of high gas temperatures. In the very high thermosphere (about 500 km above Earth's surface) gas temperatures can reach from 500 K – 2,000K (227°C – 1,727°C), depending on how active the sun is.



However, **these figures are somewhat misleading**. Temperature is a measure of the energy of the gas molecules' motion. Although they have high energies, the molecules in the thermosphere are present in very low numbers, less than one millionth of the amount present on average at Earth's surface. If a person were in the thermosphere, it would feel to them much more like the icy cold of space because such a small number of energetic gas molecules would be unable to transfer much of their heat energy.

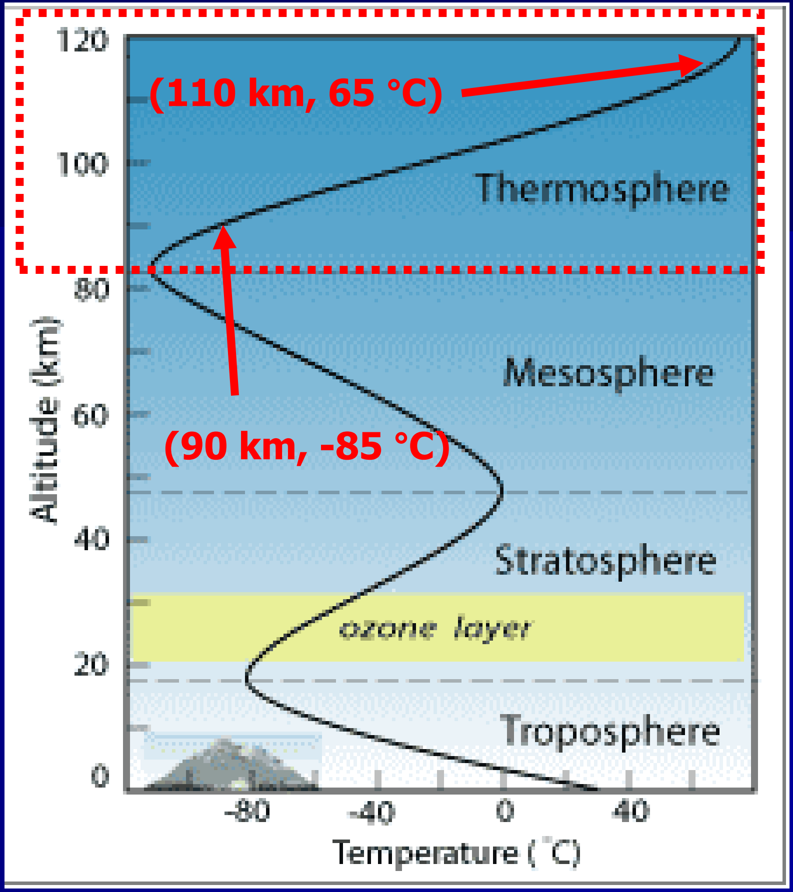
Thermosphere:

The aurora (the Southern and Northern Lights) primarily occur in the thermosphere. Charged particles (electrons, protons, and other ions) from space collide with atoms and molecules in the thermosphere at high latitudes, exciting them into higher energy states. Those atoms and molecules shed this excess energy by emitting photons of light, which we see as colorful auroral displays.

The aurora : the aurora is formed when protons and electrons from the Sun travel along the Earth's magnetic field lines. The lights of the aurora come in different colours. **Oxygen atoms** give off green light and sometimes red. **Nitrogen** molecules glow red, blue, and purple.

Thermosphere:

The temperature increases steeply with height in this region reaching its peak value of 1500 ± 500 K at the thermopause. The very effective **heating source of this layer is the far ultra-violet (100 Å – 2000 Å) radiation from the Sun which is absorbed in this region causing the photodissociation and photoionization of the atmospheric constituents**. Solar particles and meteors also make a small contribution to the heating process.



Temp Pro Values.nb * - Wolfram Mathematica 12.1

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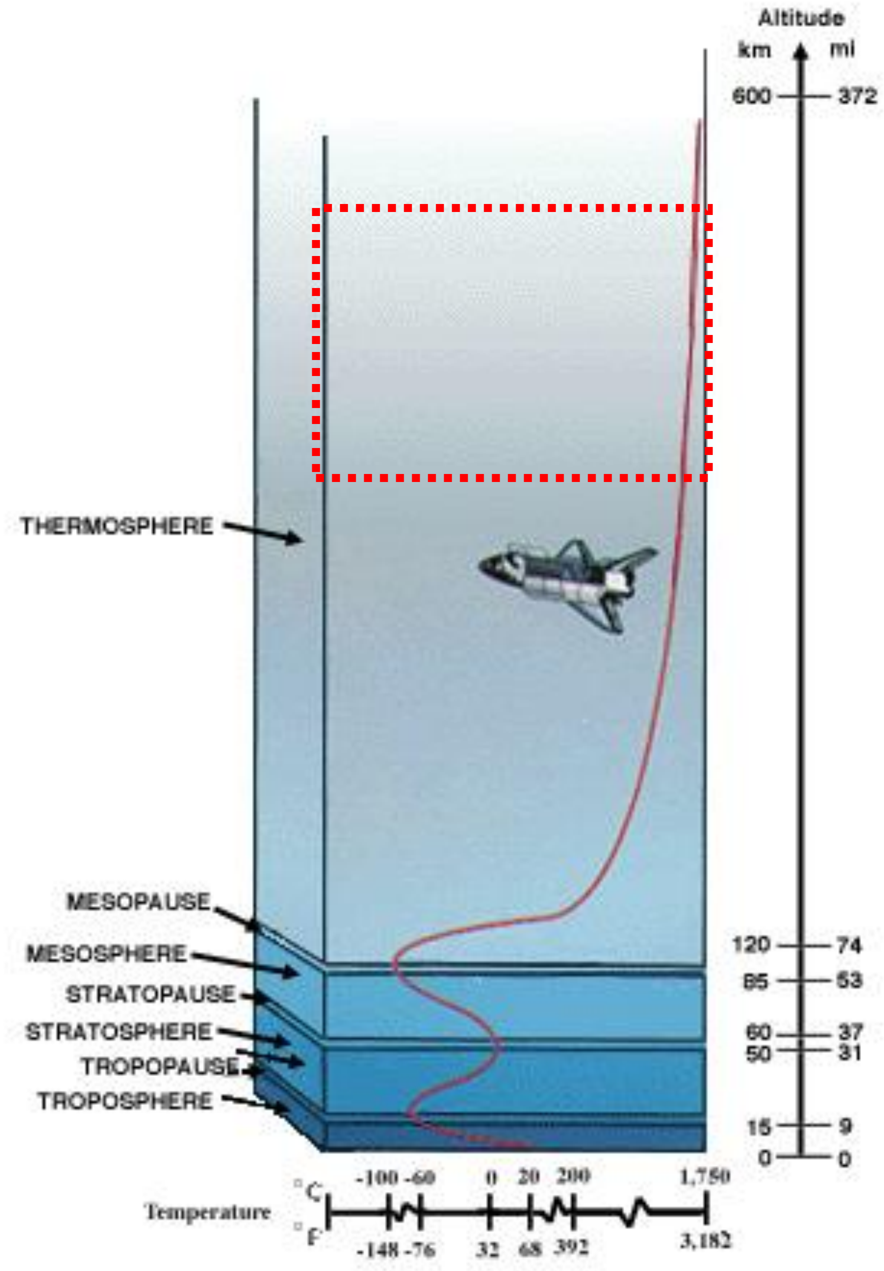
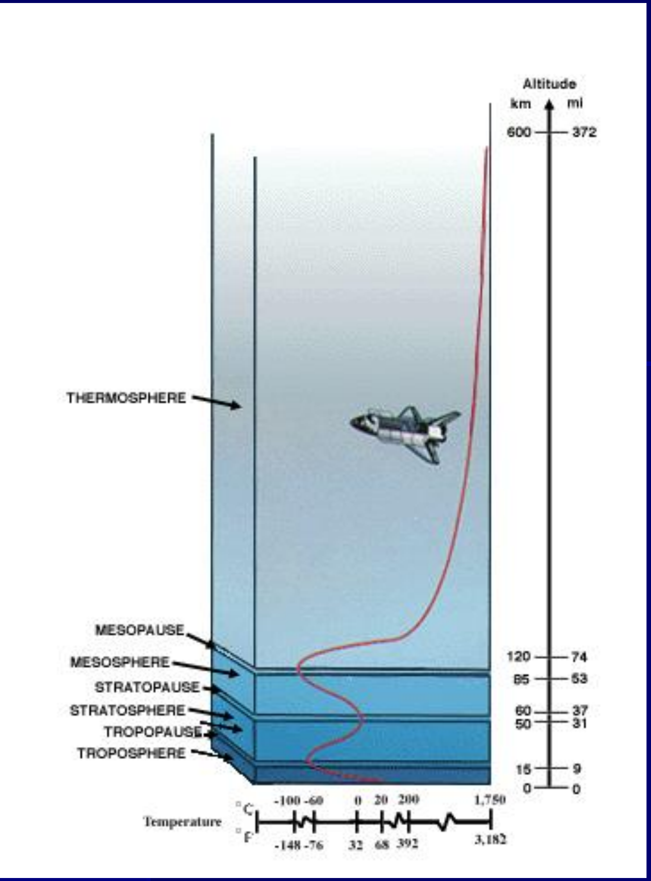
```
In[75]:= h1 = 90;
         h2 = 110;
         thita1 = -85 + 273;
         thita2 = 65 + 273;
         Solve[((T - thita1) / (h - h1)) ==
           ((thita2 - thita1) / (h2 - h1)),
          T]
```

Out[79]= $\left\{\left\{T \to \frac{1}{2}\,(-974 + 15\,h)\right\}\right\}$

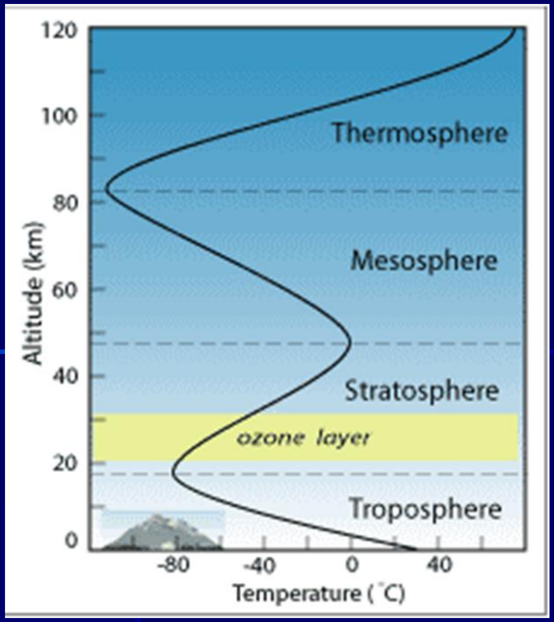
Thermopause:

The upper boundary of the thermosphere occurring at an altitude of 350 ± 100 km. Above this height the atmosphere, due to its high thermal conductivity, maintains the same high temperature which it first reached at the thermopause.





$$
T(h) = \begin{cases} -6.5\,h + 288 & ;\ 0 \le h < 20 \text{ km} \\ 3.75\,h + 123 & ;\ 20 \le h < 40 \text{ km} \\ -3.5\,h + 443 & ;\ 50 \le h < 80 \text{ km} \\ 7.5\,h - 487 & ;\ 90 \le h < 110 \text{ km} \end{cases}
$$



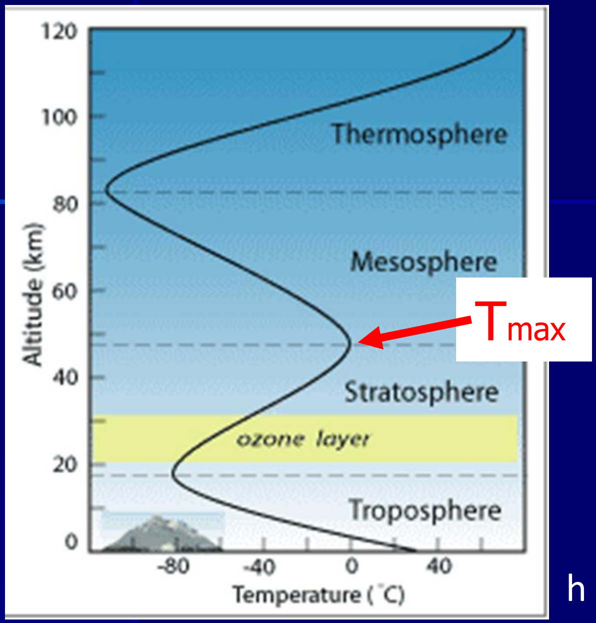
Ozone Layer :

The variation of the middle of the graph is due to the Ozone Layer. Because the UV (ultra violet) radiation from the Sun is absorbed by the Ozone Layer. As a result the UV reacts with the atoms of the O_3 layer increases.

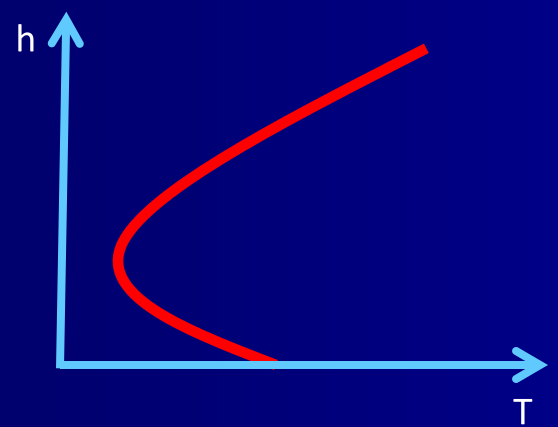
In a planet, the temperature decreases as the distance surface of the planet increases. But after certain distance, due to the effect of the Sun, the temperature increases again.

But the Earth behaves slightly different from the normal planet. That is when the distance from the surface of the Earth increases, initially the temperature decreases, then the temperature increases, again after a certain distance the temperature decreases and finally the temperature increases continuously !

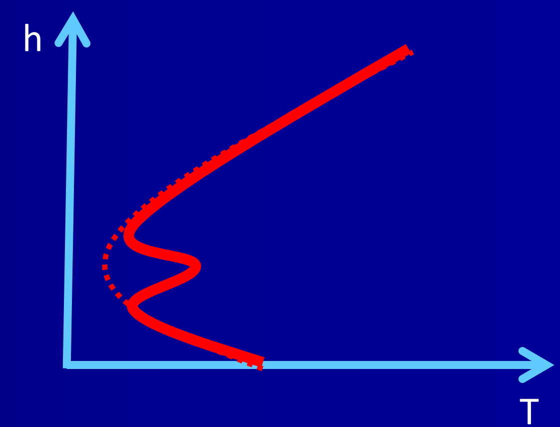
Ozone Layer :



This T_{max} of the middle of the graph, is **depend on the number of O_3 exist in the Ozone Layer**. If we study the graph of Height vs Temperature of any planet, we can get an idea whether it has an Ozone Layer or Not !



The Graph of h vs T of a planet which does not consist an Ozone Layer

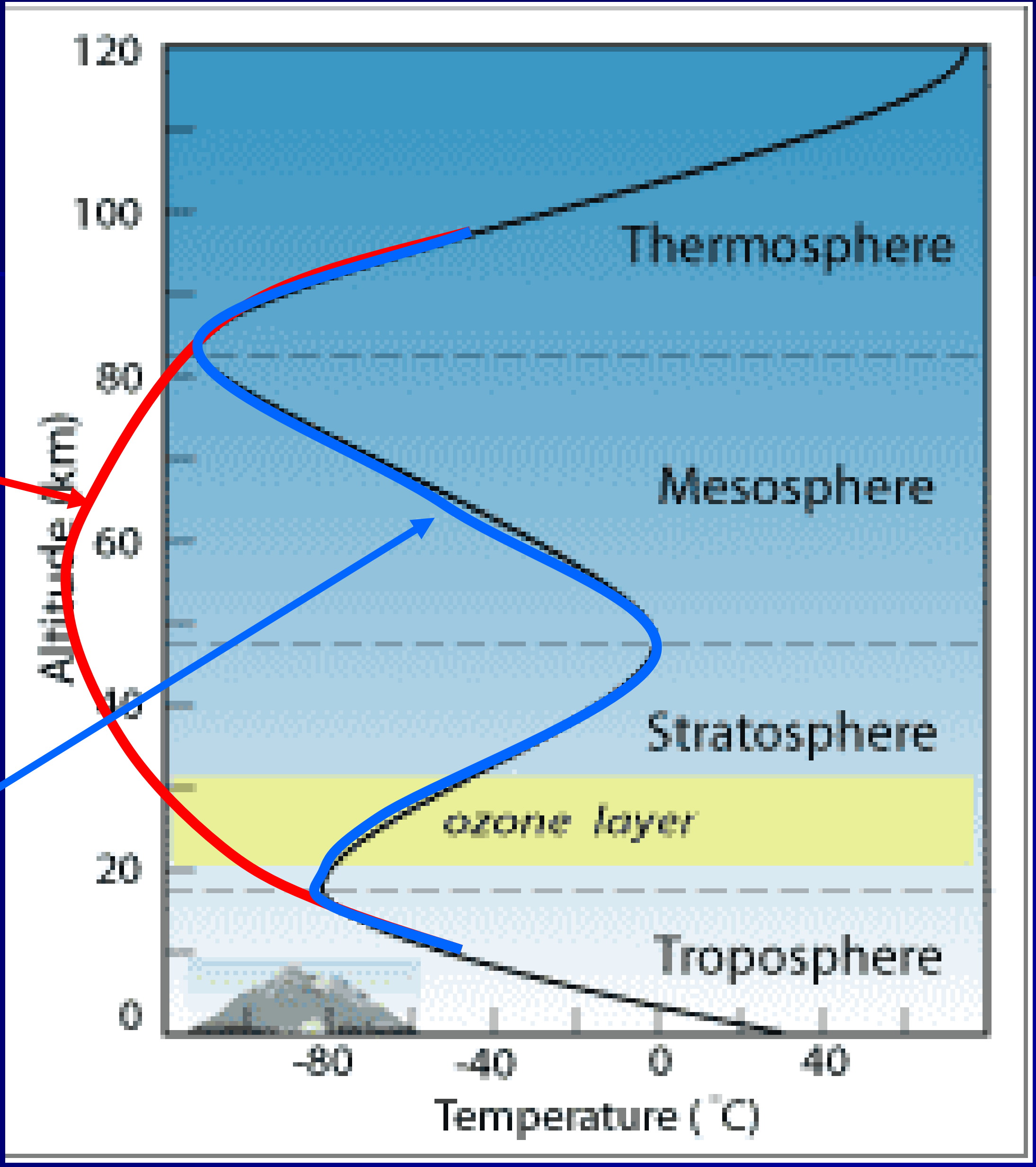


The Graph of h vs T of a planet which consist an Ozone Layer

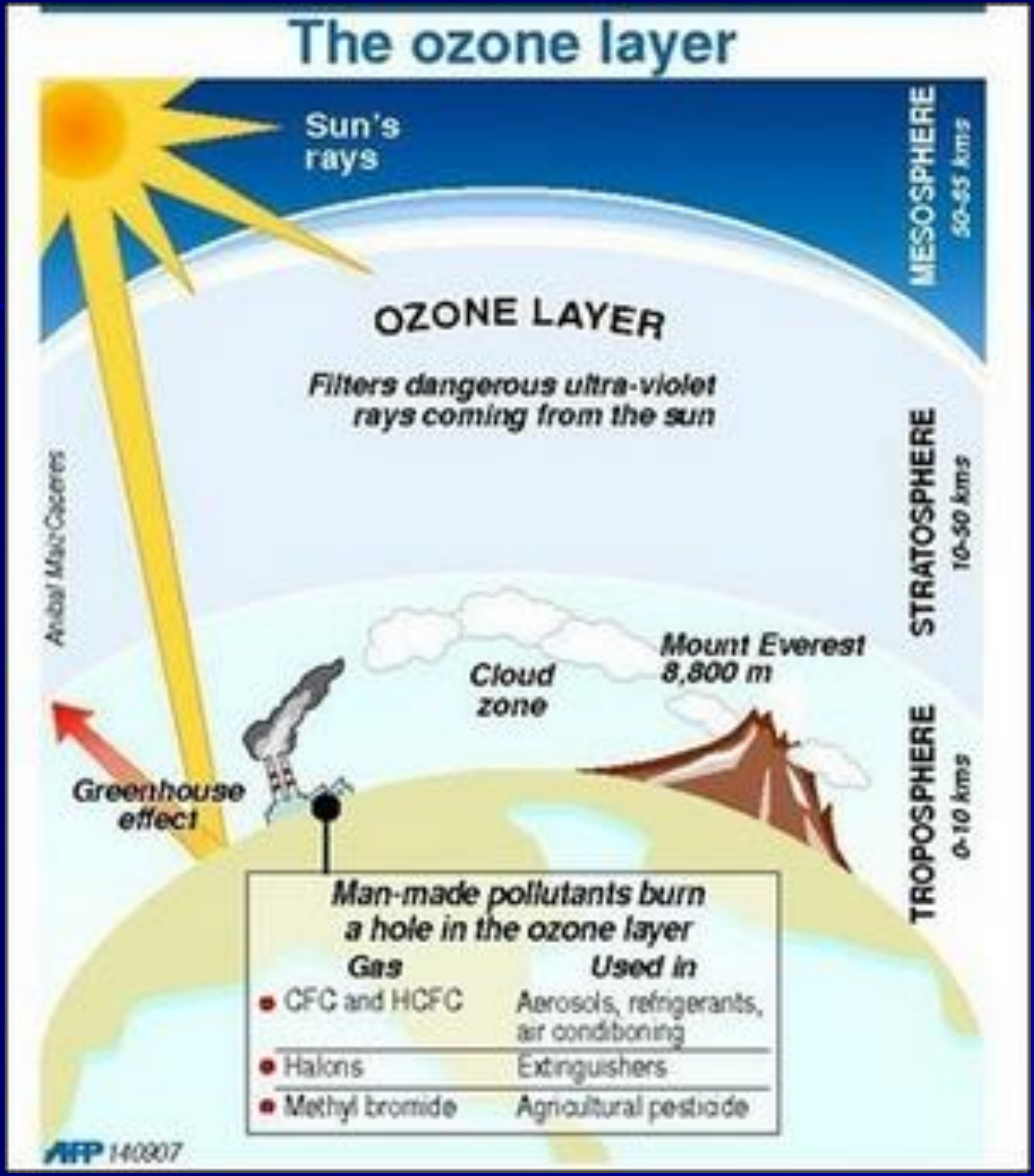
Altitude vs Temperature Graph of a Planet :

A planet which does not consist an Ozone Layer

A planet which consists an Ozone Layer



OZONE LAYER


The ozone layer
Sun's rays
MESOSPHERE 50-65 kms
OZONE LAYER
Filters dangerous ultra-violet rays coming from the sun
STRATOSPHERE 10-50 kms
Mount Everest 8,800 m
Cloud zone
Greenhouse effect
TROPOSPHERE 0-10 kms
Man-made pollutants burn a hole in the ozone layer
Gas
Used in
CFC and HCFC
Aerosols, refrigerants, air conditioning
Halons
Extinguishers
Methyl bromide
Agricultural pesticide
AFP 140907

Ozone layer

The **ozone layer** is a layer in **Earth's Atmosphere which contains relatively high concentrations of ozone** (O_3).

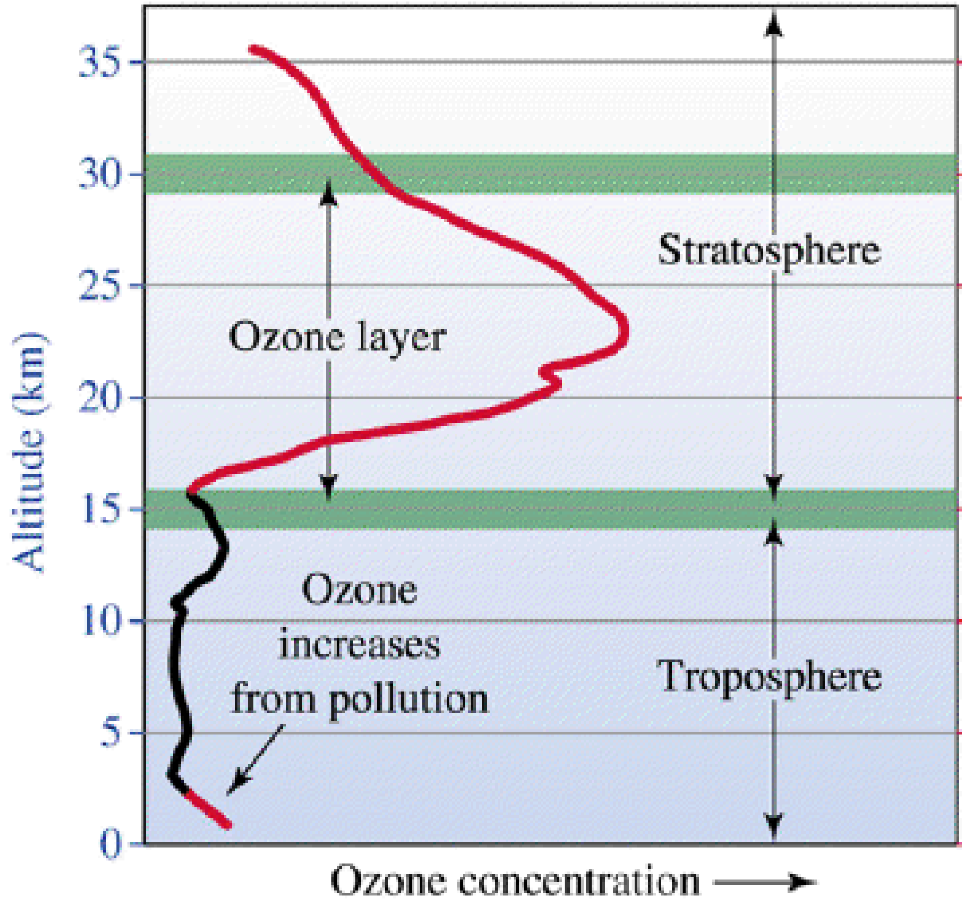
This layer absorbs 97–99% of the Sun's high frequency ultraviolet light, which is damaging to life on Earth. It is mainly located in the lower portion of the stratosphere from approximately **13 to 40 kilometres above Earth**, though the **thickness varies seasonally and geographically**.

The ozone layer was discovered in **1913 by the French physicists Charles Fabry and Henri Buisson**.

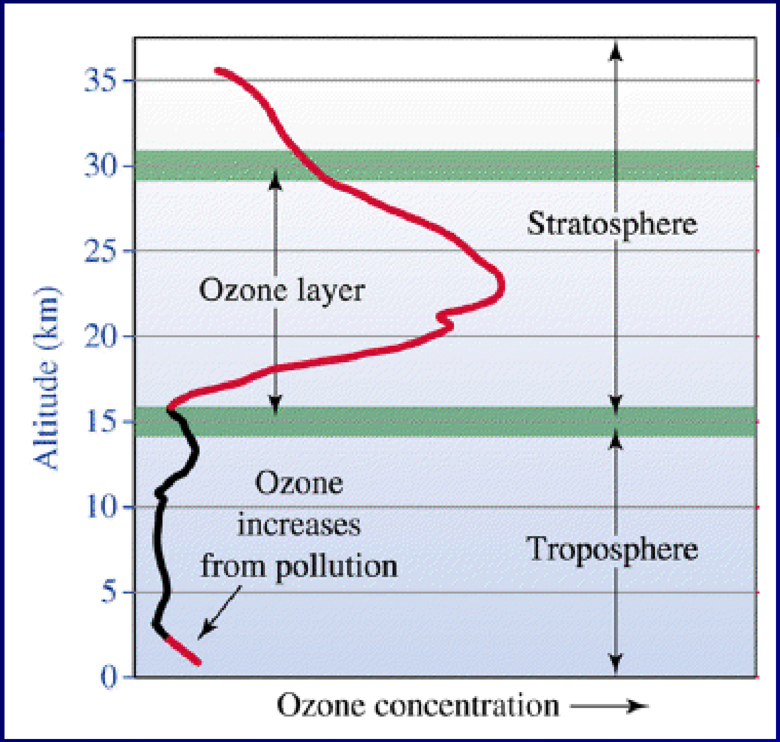
Ozone layer

Its properties were explored in detail by the British meteorologist G. M. B. Dobson, who developed a simple spectrophotometer (the Dobson meter) that could be used to measure stratospheric ozone from the ground. Between 1928 and 1958 Dobson established a worldwide network of ozone monitoring stations, which continue to operate to this day. The "**Dobson Unit**", a convenient measure of the **columnar density of ozone overhead**, is named in his honour.

The Ozone Layer



What is the maximum concentration of ozone in the ozone layer?



- Maximum of absolute conc about 23 km (up to 10^{13} molecules/mL)
- Maximum of relative conc about 35 km (up to 10 ppm)

Origin of ozone

The photochemical mechanisms that give rise to the ozone layer were discovered by the British physicist Sidney Chapman in 1930.

Ozone in the Earth's stratosphere is created by ultraviolet light striking oxygen molecules containing two oxygen atoms (O_2), splitting them into individual oxygen atoms (atomic oxygen); the atomic oxygen then combines with unbroken O_2 to create ozone, O_3.

$$O_2 + E_{\text{From Sun}} \text{----}\rightarrow O + O$$

$$O_2 + O \text{----}\rightarrow O_3$$

Origin of ozone

The ozone molecule is also unstable (although, in the stratosphere, long-lived) and when ultraviolet light hits ozone it splits into a molecule of O_2 and an atom of atomic oxygen, a continuing process called the ozone oxygen cycle, thus creating an ozone layer in the stratosphere, the region from about 10 to 50 kilometres above Earth's surface.

$$O_3 + E_{UV} \longrightarrow O_2 + O + \text{Heat}$$

$\lambda < 3100$ Å

For this reaction, wave length of the UV radiation should be less than 3100 Å

Origin of ozone

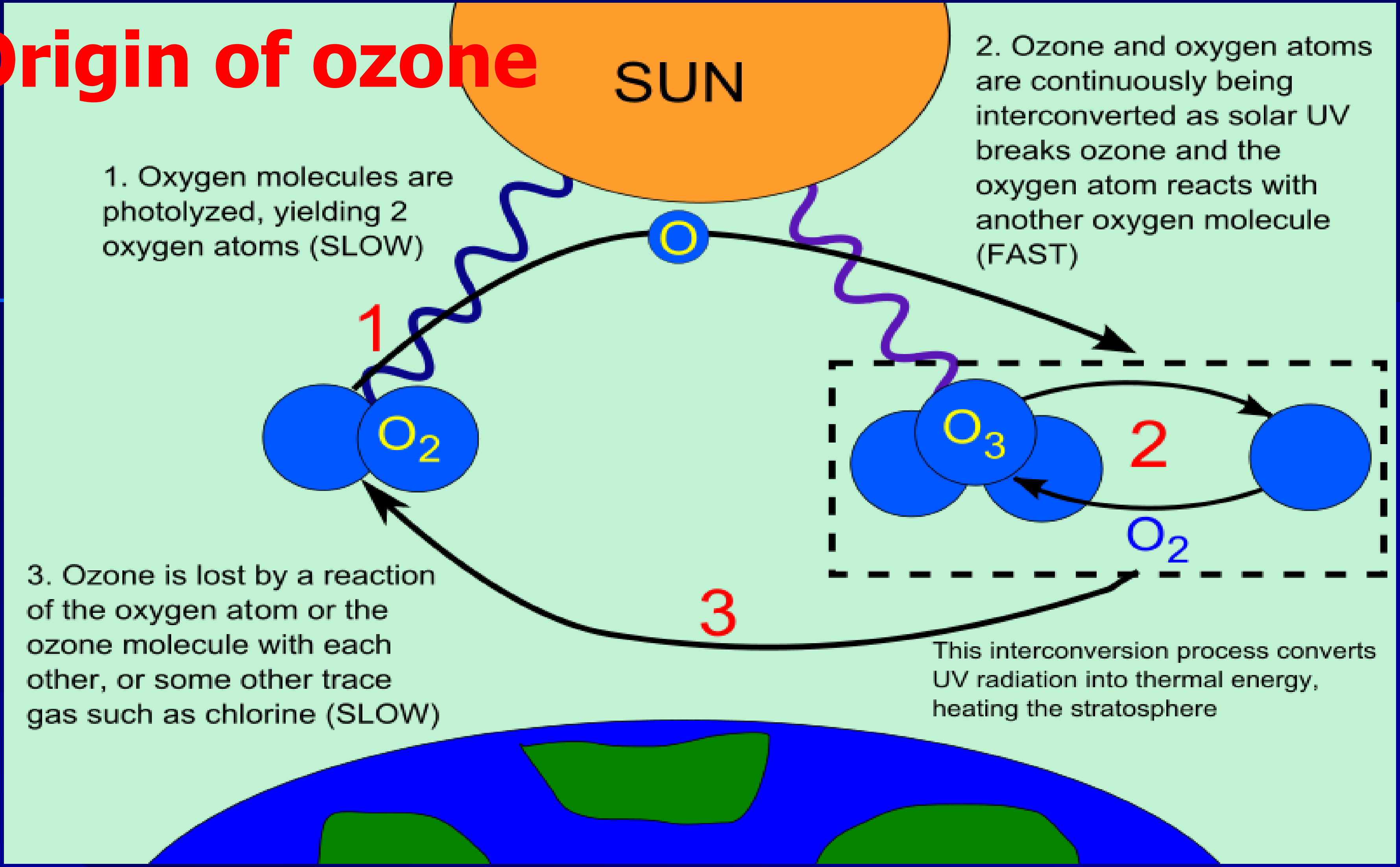
$$O_3 + E_{UV} \dashrightarrow O_2 + O + \text{Heat}$$

10^6 O_2 molecules are required to absorb the same amount of radiation that is absorbed by a single O_3 molecule. This is the importance of O_3!

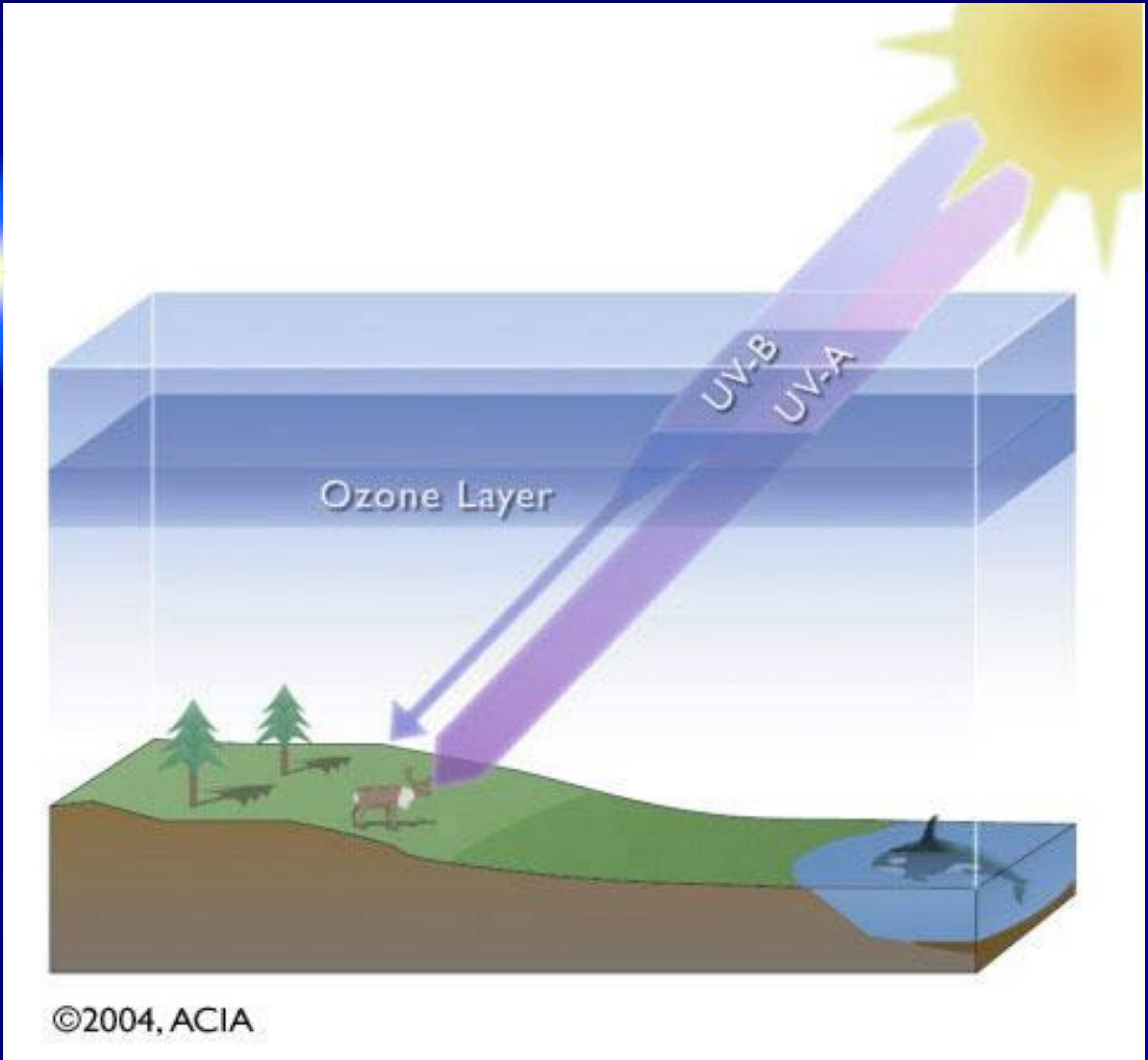
After O_3 reacting with UV radiation from the Sun, it produces O_2 and O irons and energy and again O_2 and O irons recombine naturally in the Ozone layer to reproduce O_3.

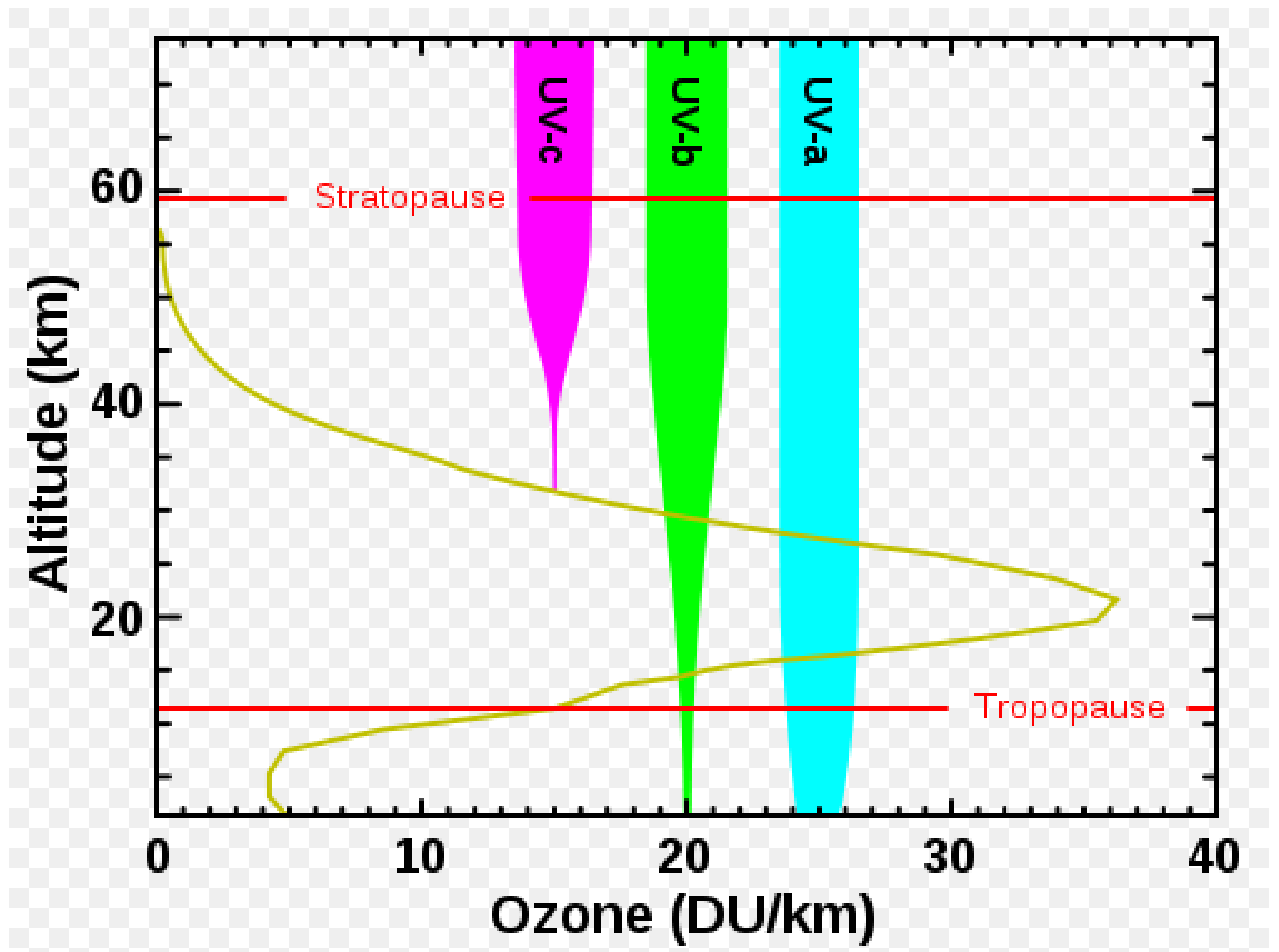
About 90% of the ozone in our atmosphere is contained in the stratosphere. Ozone concentrations are greatest between about 20 and 40 kilometres, where they range from about 2 to 8 parts per million. If all of the ozone were compressed to the pressure of the air at sea level, it would be only a few mili-meters thick.

Origin of ozone



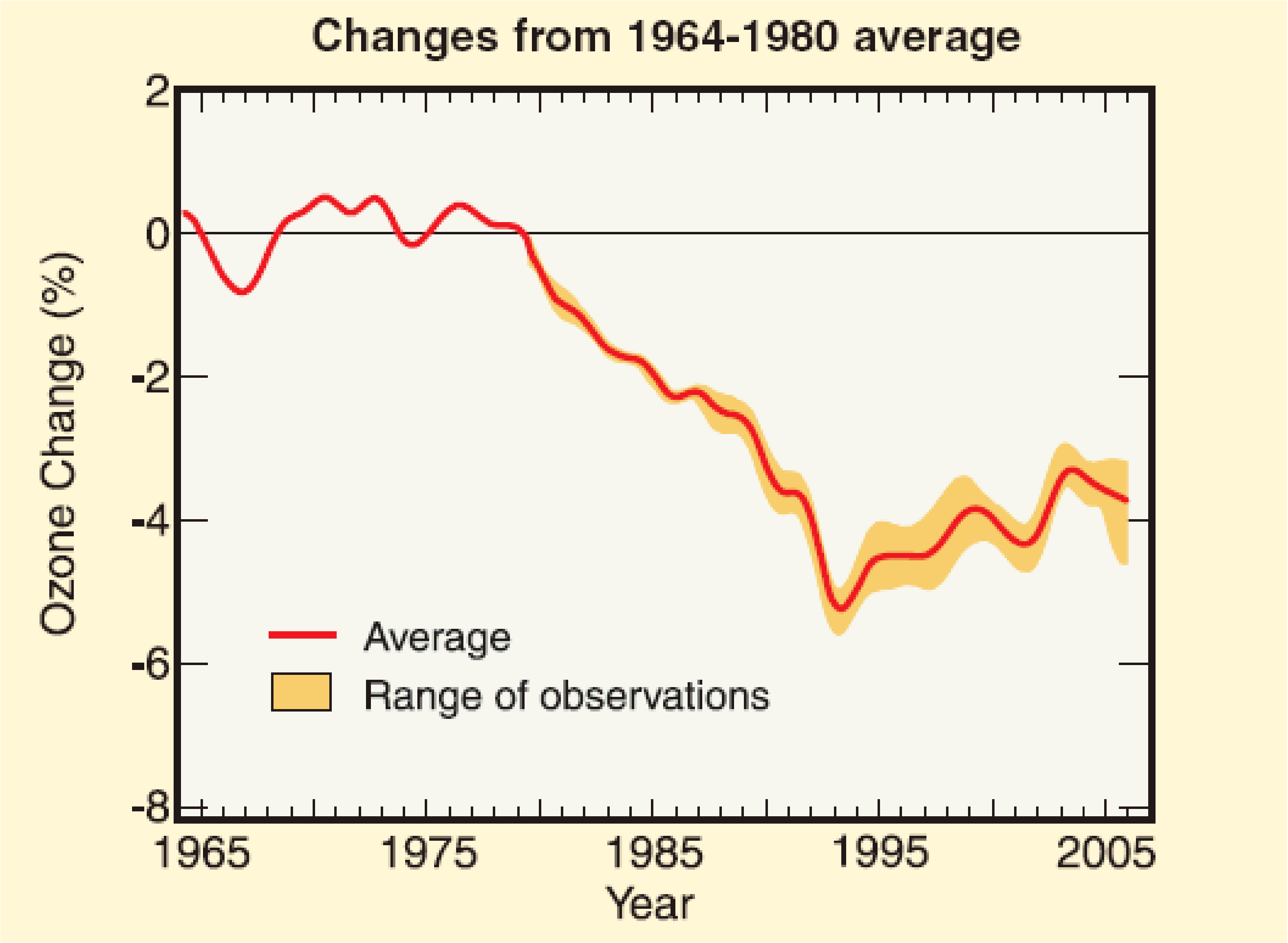
About 90% of the ozone in our atmosphere is contained in the stratosphere. Ozone concentrations are greatest between about 20 and 40 kilometres, where they range from about 2 to 8 parts per million. If all of the ozone were compressed to the pressure of the air at sea level, it would be only a few milimeters thick.

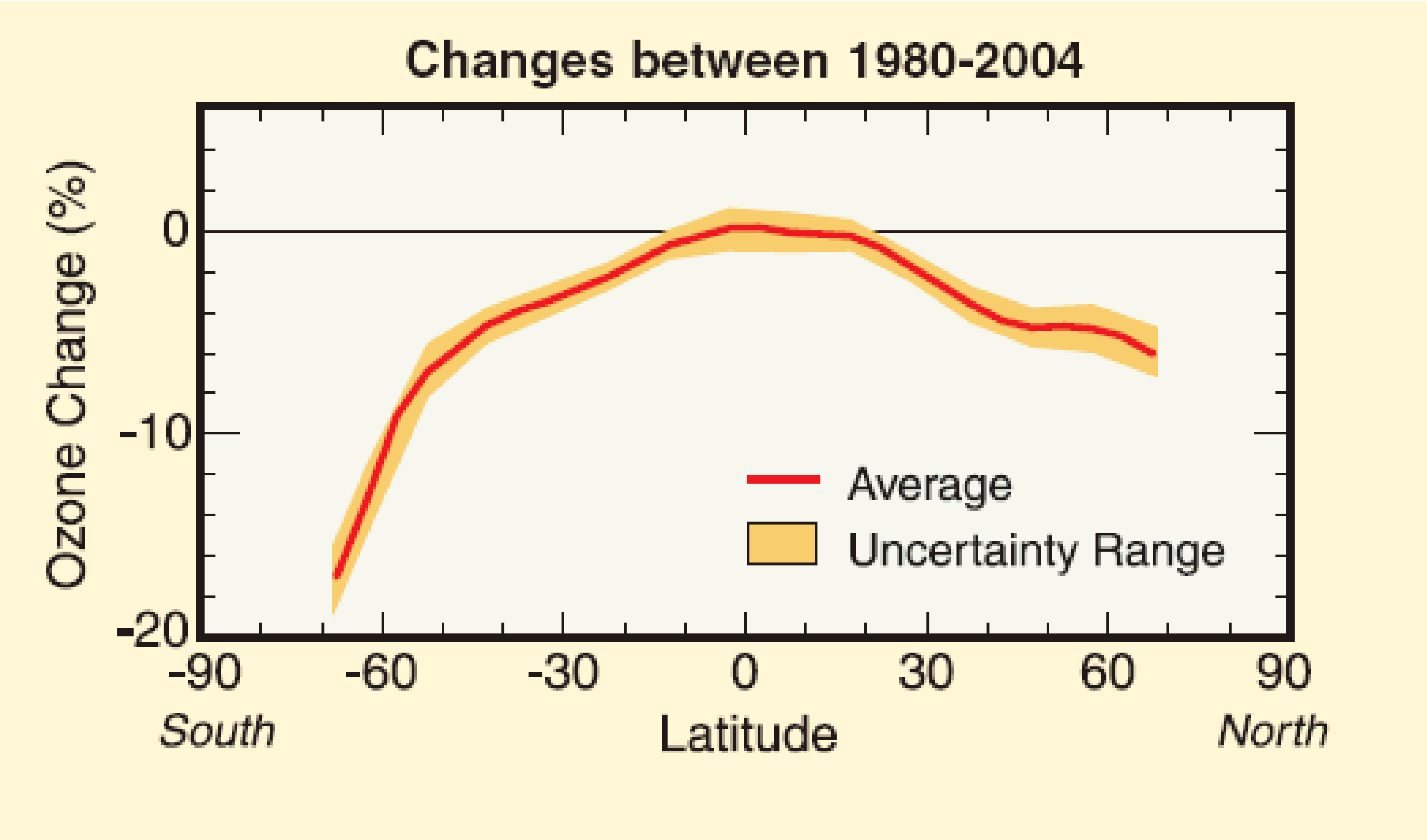

UV-B
UV-A
Ozone Layer
©2004, ACIA



UV-c
UV-b
UV-a
Stratopause
Tropopause
60
40
20
Altitude (km)
0
10
20
30
40
Ozone (DU/km)

Global Total Ozone Change




Changes between 1980-2004
Ozone Change (%)
0
-10
-20
-90
-60
-30
0
30
60
90
South
Latitude
North
Average
Uncertainty Range

Ozone depletion

The ozone layer can be depleted by **free radical catalysts, including nitric oxide** (NO), **nitrous oxide** (N_2O), **hydroxyl** (OH), **atomic chlorine** (Cl), and **atomic bromine** (Br).

While there are natural sources for all of these species, the concentrations of chlorine and bromine have increased markedly in recent years due to the release of large quantities of man-made **organohalogen compounds**, especially **chlorofluorocarbons** (CFCs) and **bromofluorocarbons**.

O3 + CFC ----→ O2 + O + CFC

X X

Ozone depletion

$O3 + CFC \dashrightarrow O2 + O + CFC$

CFC (**chlorofluorocarbons**) molecules reacts with O_3 and it produces O_2 and O irons and again CFC. This released CFC again break O_3 and this process repeated continuously. As a result a small number of CFC molecules can break a large number of O_3 molecules to O_2 and O irons. The Cl in CFC molecules is the main cause to break O_3 molecules.

Because of this reason usage of an electrical items which contain CFC was prohibited !

Ozone depletion

$$O_3 + CFC \longrightarrow O_2 + O + CFC$$

Because of this reason usage of an electrical items which contain CFC was prohibited !

As mentioned earlier, from the graph of h vs T of a planet, we can conclude whether the planet contains an Ozone Layer or not. If a planet contains Ozone Layer, there is a high possibility for the Living Organisms to exist in the planet !

In our planetary system, if we analyze the graph of h vs T of the planets and other natural satellites (moons), in any of these an Ozone Layer does not exist except the Earth !

Form the above statement we can conclude that any living organisms can not exist in any planets than the Earth !

Using this logic argument we can interpret whether a living organism can exist in another planetary system. The closest planetary system is situated 4.2 light years (Alpha-Centauri) far away from our planetary system.

Form the above statement we can conclude that any living organisms can not exist in any planets than the Earth !

We can not 100% confirm conclude whether there exist any living organism, by using the another planetary system, by using the above interpretation. But this is the way which is usually done in Science

5 PRODUCTS THAT CAUSE OZONE DEPLETION

1. Inhalers

2. Fire extinguishers

3. Aerosol hairsprays

4. Wasp (දෙබරා) and hornets (බඹරා) sprays

5. Foam insulation product

Ozone depletion

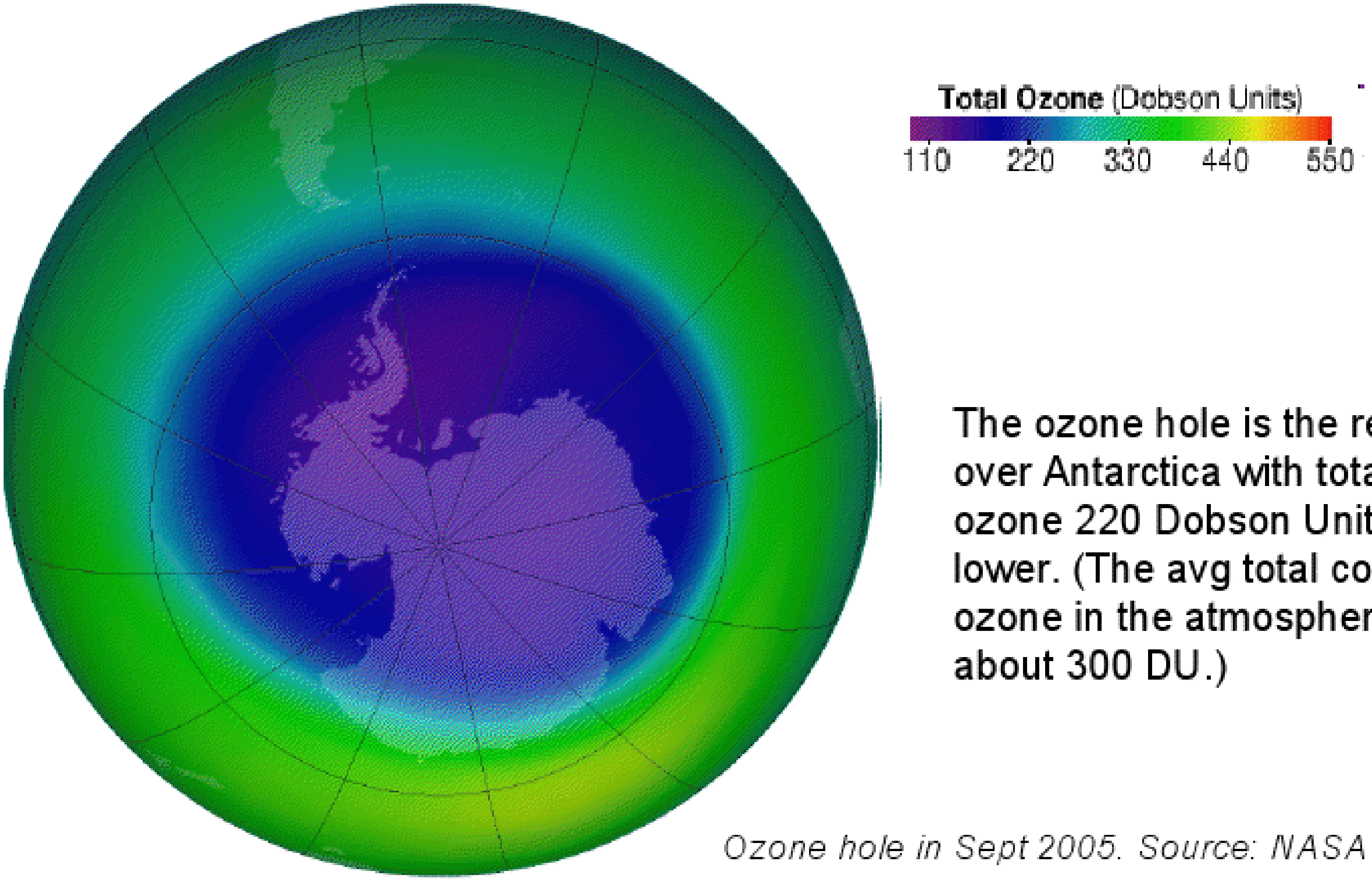
These highly stable compounds are capable of surviving the rise to the stratosphere, where Cl and Br radicals are liberated by the action of ultraviolet light. Each radical is then free to initiate and catalyze a chain reaction capable of breaking down over 100,000 ozone molecules. The breakdown of ozone in the stratosphere results in the ozone molecules being unable to absorb ultraviolet radiation. Consequently, unabsorbed and dangerous ultraviolet-B radiation is able to reach the Earth's surface.

Ozone levels, over the northern hemisphere, have been dropping by 4% per decade. Over approximately 5% of the Earth's surface, around the north and south poles, much larger (but seasonal) declines have been seen; these are the ozone holes.

In 2009, nitrous oxide (N_2O) was the largest ozone-depleting substance emitted through human activities.

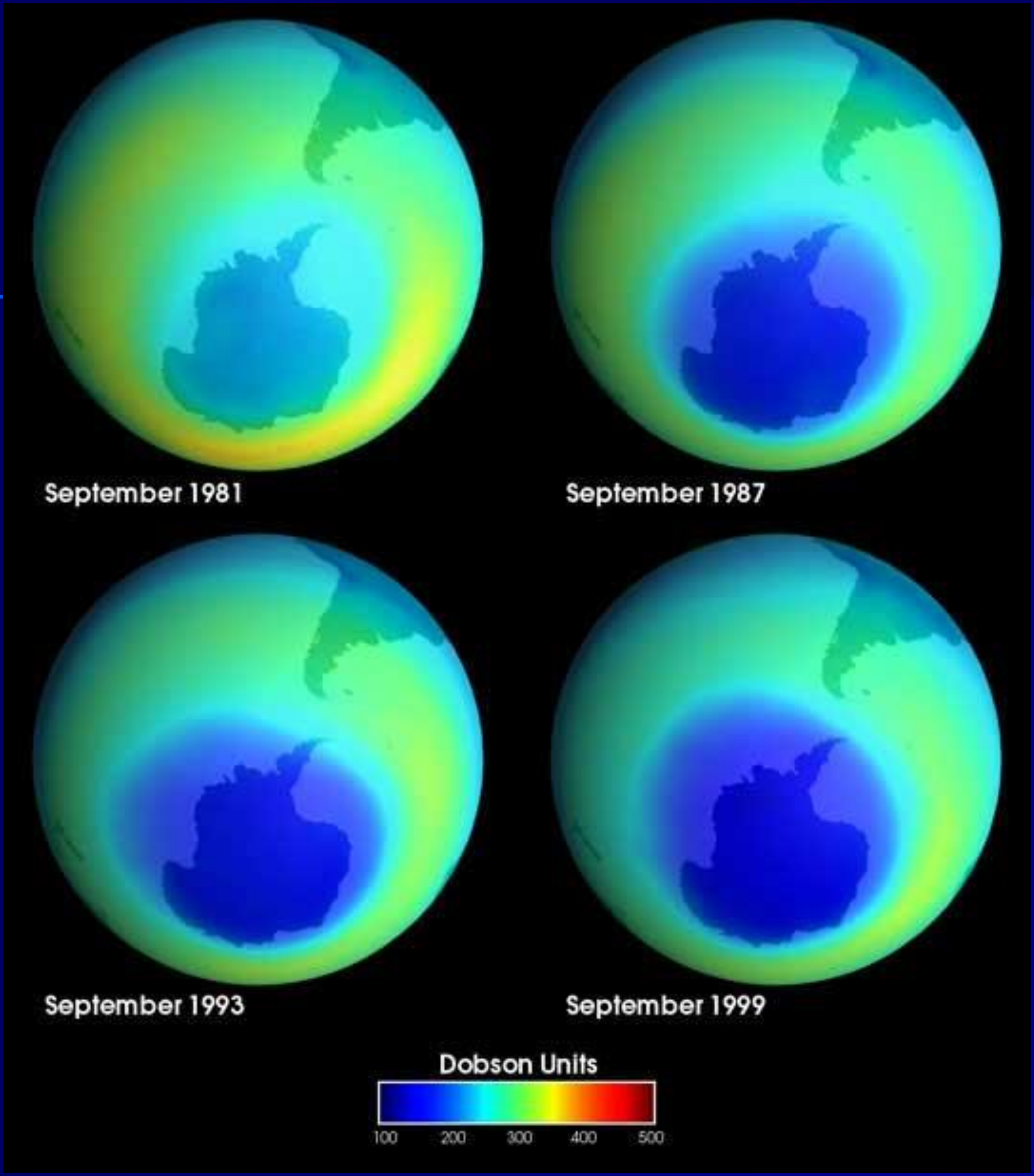
The "Ozone Hole"

– What is the "ozone hole?" When did it first appear? How does it form?



The ozone hole is the region over Antarctica with total ozone 220 Dobson Units or lower. (The avg total column ozone in the atmosphere is about 300 DU.)

Ozone hole in Sept 2005. Source: NASA


September 1981
September 1987
September 1993
September 1999
Dobson Units
100
200
300
400
500

Regulation

In 1978, the United States, Canada and Norway enacted bans on CFC-containing aerosol sprays that are thought to damage the ozone layer. The European Community rejected an analogous proposal to do the same.

In the U.S., chlorofluorocarbons continued to be used in other applications, such as refrigeration and industrial cleaning, **until after the discovery of the** Antarctic **ozone hole in 1985**.

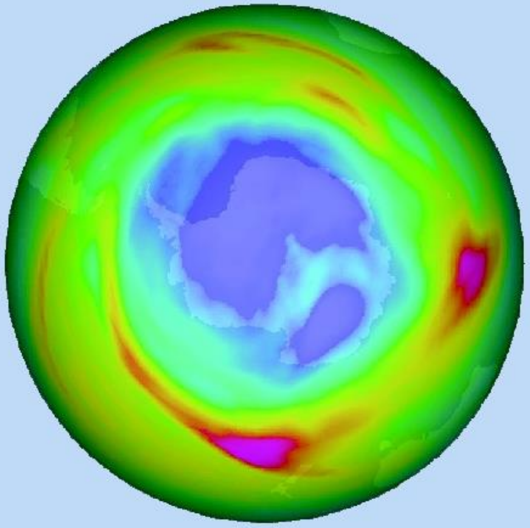
After negotiation of an international **treaty** (**the Montreal Protocol**), CFC production was sharply limited beginning in 1987 and phased out completely by 1996.

Since that time, the **treaty** has been amended to ban CFC production **after 1995 in the developed countries, and later in developing. Today, over 160 countries have signed the treaty**.

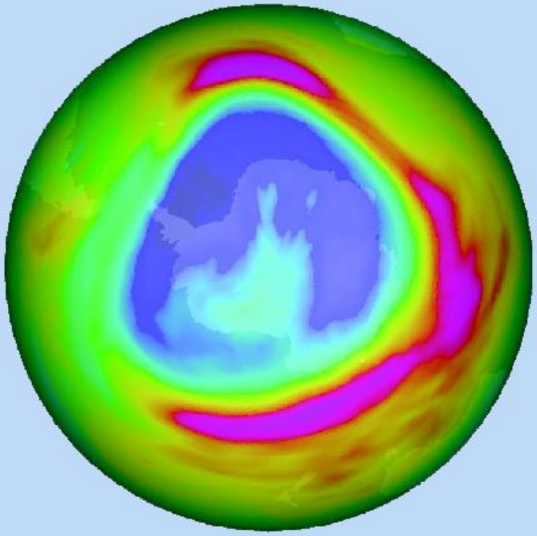
NASA Observations Confirm Expected Ozone Layer Recovery

NASA satellite observations have provided the first evidence the rate of ozone depletion in the Earth's upper atmosphere is decreasing. This may indicate the first stage of ozone layer recovery.

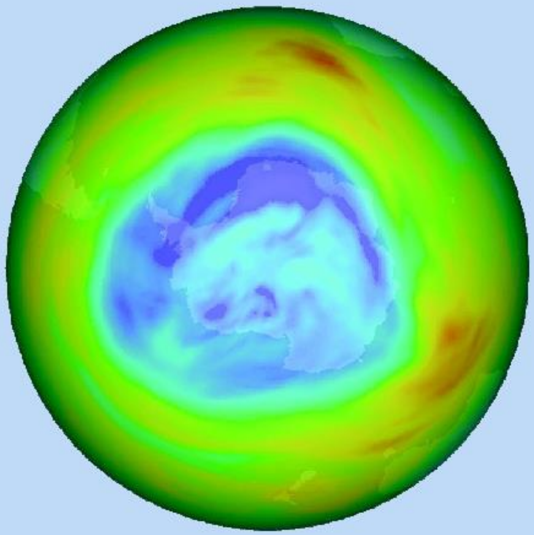
9 September 2006



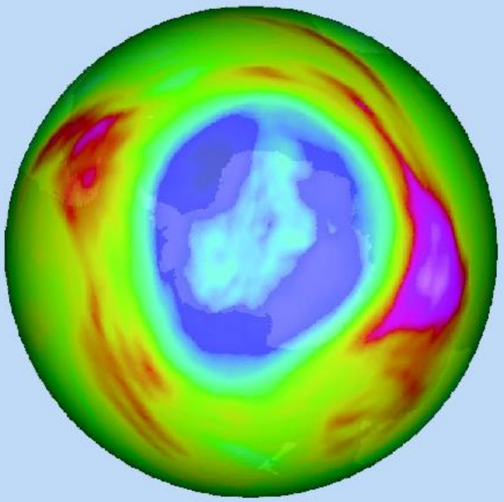
9 September 2007



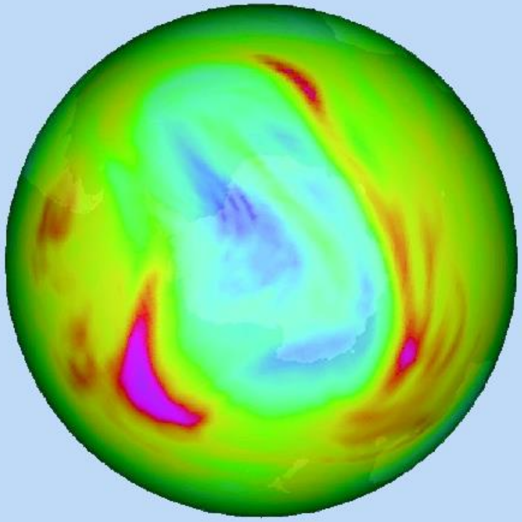
9 September 2008

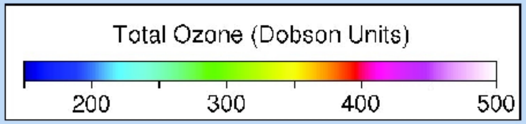


9 September 2009



9 September 2010





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Global Warming

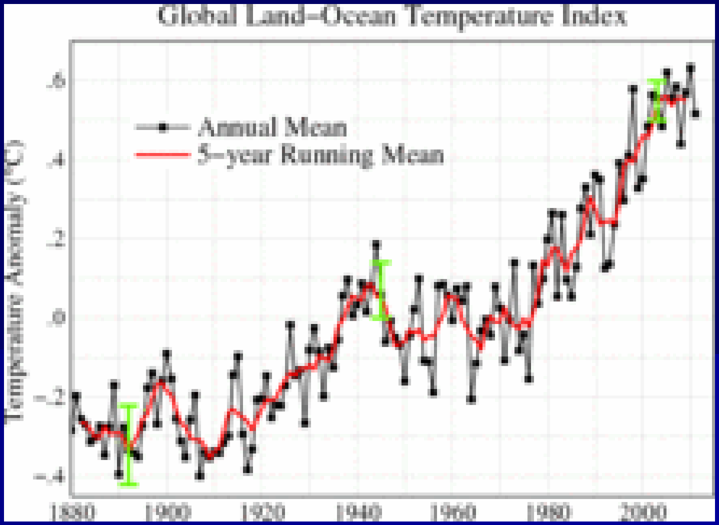
Global Warming

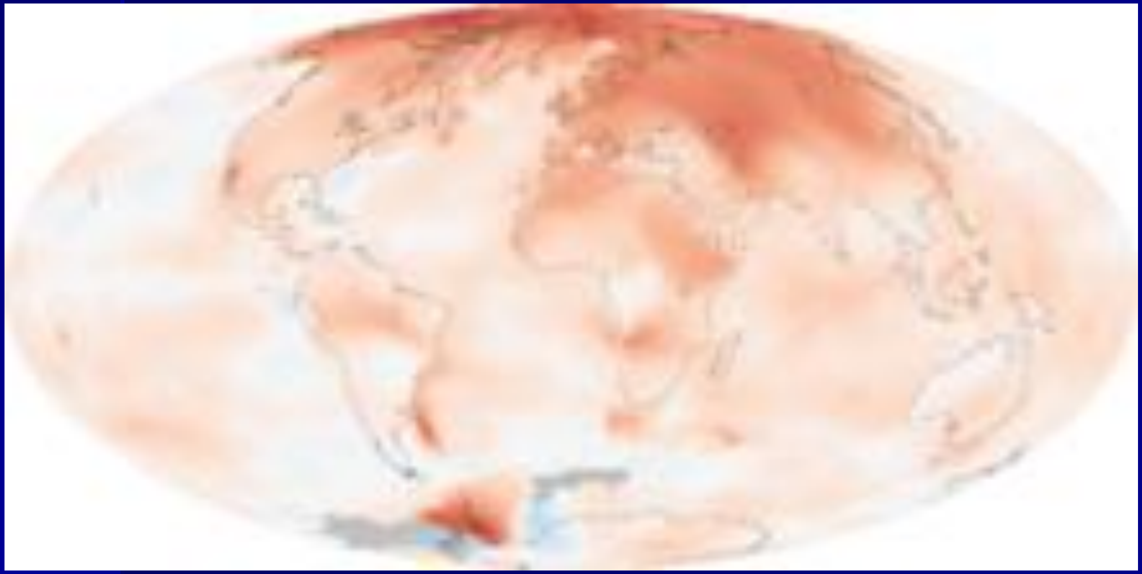
Global warming is the rise in the average temperature of Earth's atmosphere and oceans since the late 19th century and its projected continuation.

Since the early 20th century, Earth's mean surface temperature has increased by about 0.8 °C, with about two-thirds of the increase occurring since 1980.

Global Warming

Global mean land-ocean temperature change from 1880–2011, relative to the 1951–1980 mean. The black line is the annual mean and the red line is the 5-year running mean. The green bars show uncertainty estimates. (Source: NASA GISS)





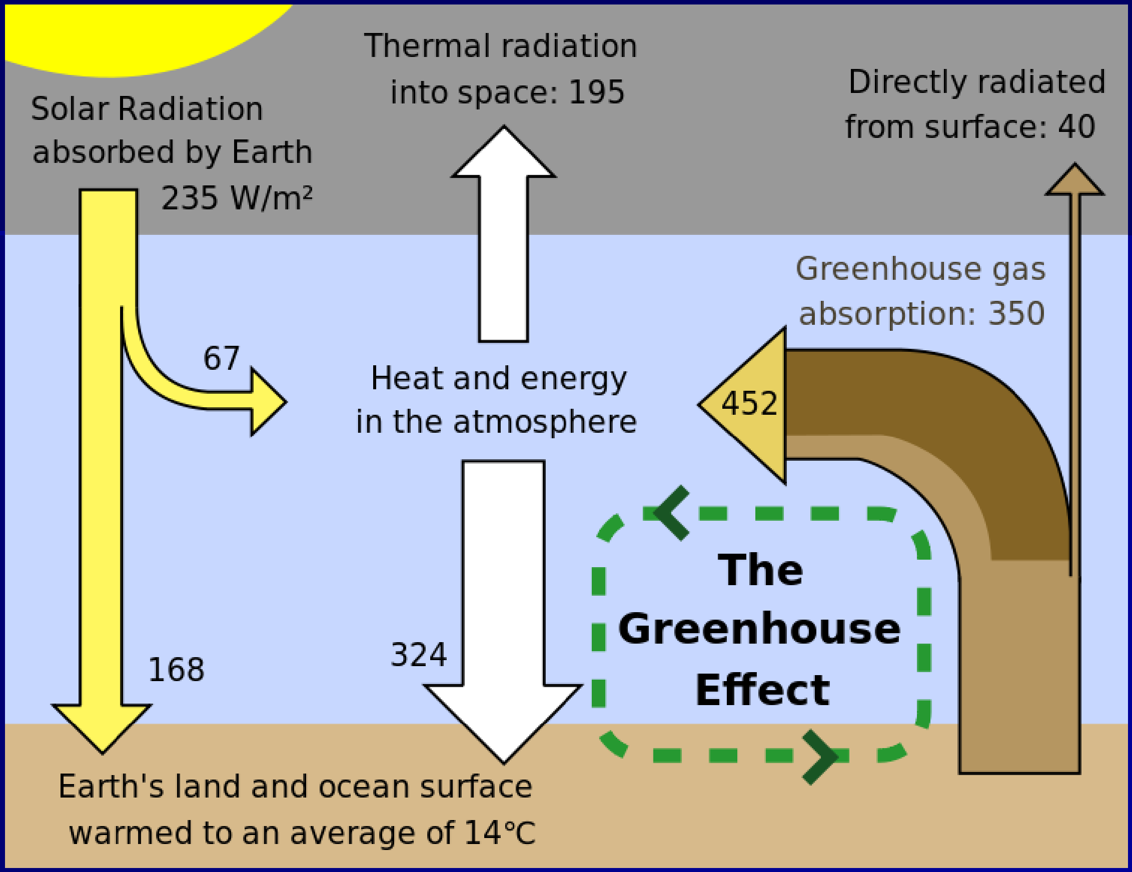
The map shows the 10-year average (2000–2009) global mean **temperature anomaly** relative to the 1951–1980 mean.

The largest **temperature increases** are in the Arctic and the Antarctic Peninsula. Source: **NASA Earth Observatory**

Initial causes of temperature changes

Greenhouse gases :

The greenhouse effect is the process by which absorption and emission of infrared radiation by gases in the atmosphere warm a planet's lower atmosphere and surface.



Naturally occurring amounts of greenhouse gases have a mean warming effect of about 33 °C (59 °F). The major greenhouse gases are **water vapor, which causes about 36–70% of the greenhouse effect; carbon dioxide (CO2), which causes 9–26%; methane (CH4), which causes 4–9%; and ozone (O3), which causes 3–7%. Clouds also affect the radiation balance through cloud forcing similar to greenhouse gases.**

Initial causes of temperature changes

Particulates (අංශු) and soot (දැලි)

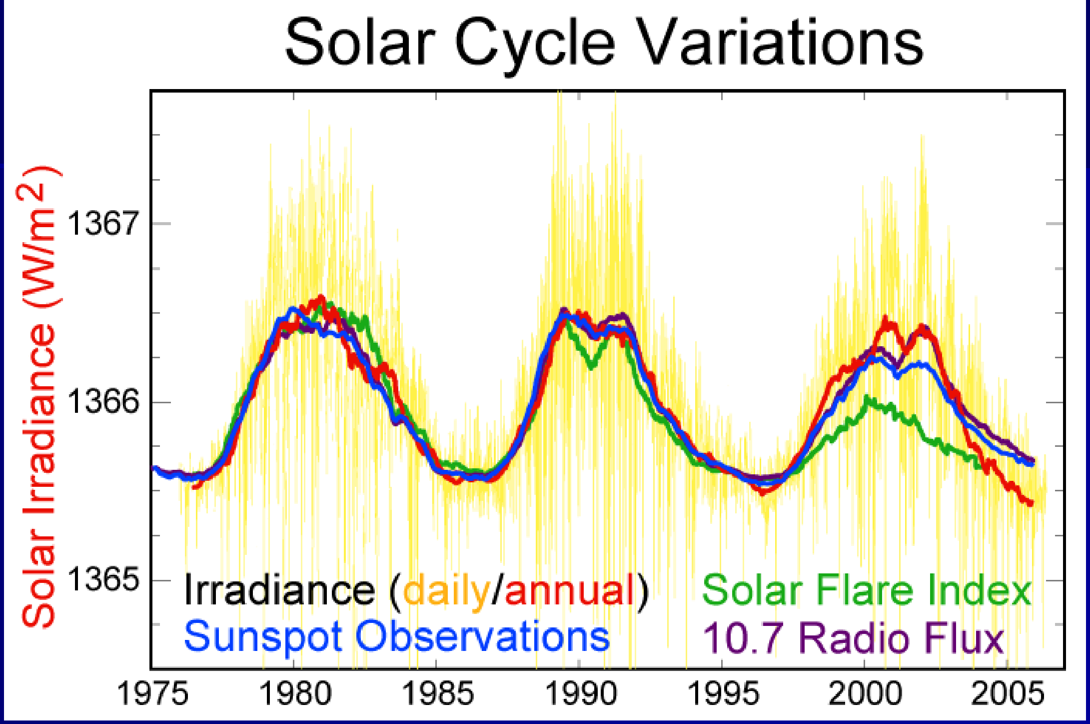
Global dimming, a gradual reduction in the amount of global direct irradiance at the Earth's surface, was observed from 1961 until at least 1990. The main cause of this dimming is particulates (අංශු) produced by volcanoes and human made pollutants, which exerts a cooling effect by increasing the reflection of incoming sunlight.

Soot (දැලි) may cool or warm the surface, depending on whether it is airborne or deposited. Atmospheric soot directly absorb solar radiation, which heats the atmosphere and cools the surface. In isolated areas with high soot production, such as rural India, as much as 50% of surface warming due to greenhouse gases may be masked by atmospheric brown cloud.

Initial causes of temperature changes

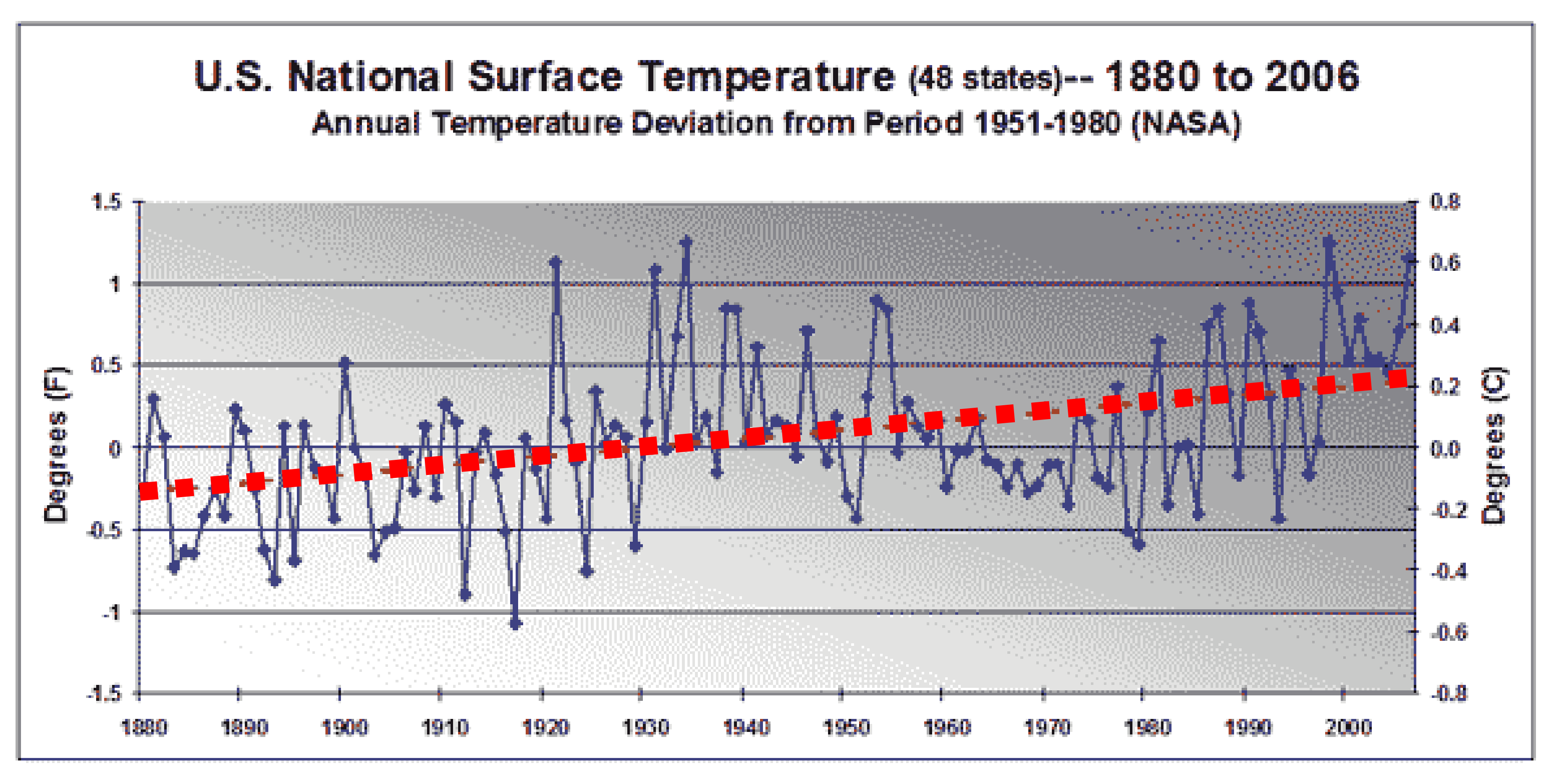
Solar activity

Solar variations causing changes in solar radiation energy reaching the Earth have been the cause of past climate changes. The effect of changes in solar forcing in recent decades is uncertain, but small, with some studies showing a slight cooling effect, while others studies suggest a slight warming effect.



Studies in 2011 have indicated that solar activity may be slowing, and that the next solar cycle could be delayed. To what extent is not yet clear; Solar Cycle 25 is due to start in 2020, but may be delayed to 2022 or even longer.

Global Warming



- There is a future threat of melting the glaciers in the polar regions of the Earth as a consequence of global warming. Ecologists have predicted that before the end of year 2050, the glaciers in the Polar Regions will melt entirely. The following table depicts the variation of the temperature and the prevailed carbon dioxide percentage of the environment with time for the last 27 years in the Arctic region of the earth. Values given here are the annual averages of daily records.

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Year	1983	1984	1985	1986	1987	1988	1989	1990	1991
Average Temperature (°C)	-40.0	-38.1	-38.0	-37.0	-36.4	-35.7	-35.2	-34.3	-33.9
Environment CO_2 percentage	0.5	1.0	1.9	2.0	3.0	3.9	4.2	5.0	5.2

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000
Average Temperature (°C)	-33.0	-32.2	-31.0	-29.7	-30.5	-30.1	-28.6	-28.0	-27.8
Environment CO_2 percentage	6.0	7.1	7.9	8.9	9.1	10.1	11.3	11.1	12.0

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009
Average Temperature (°C)	-27.0	-26.1	-25.6	-24.9	-24.0	-23.6	-22.9	-22.0	-21.5
Environment CO_2 percentage	12.9	13.1	14.1	15.2	15.3	16.5	16.9	18.0	18.9


Thank You !
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