Space Physics

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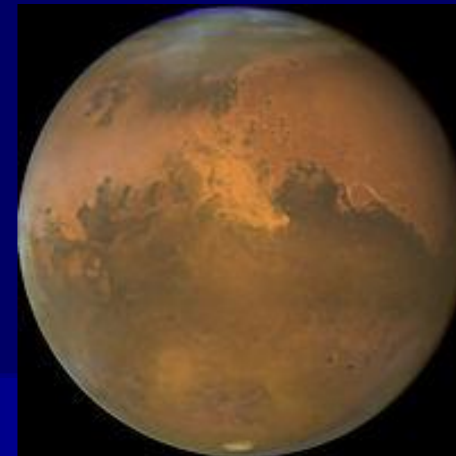
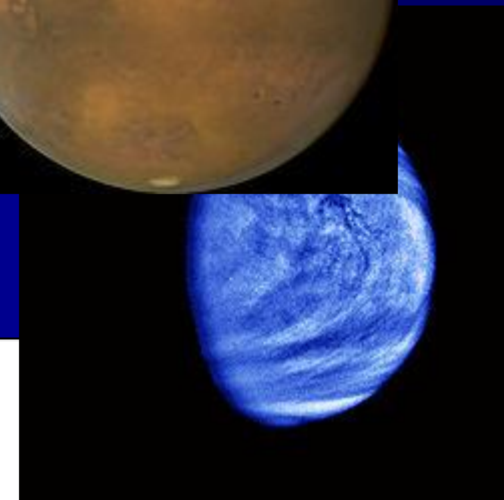
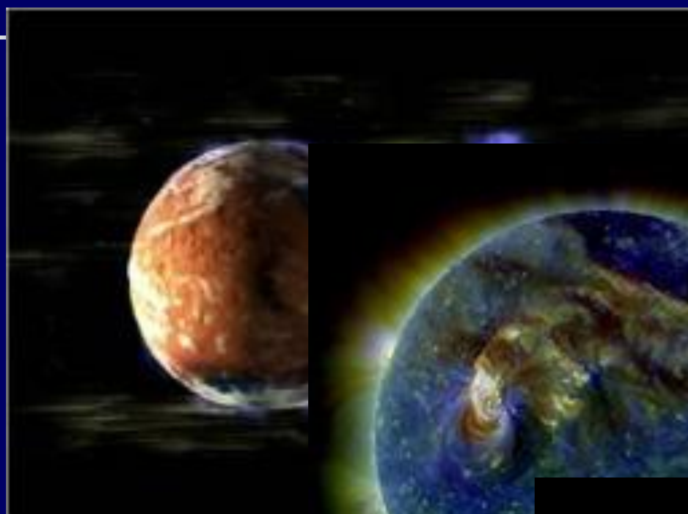
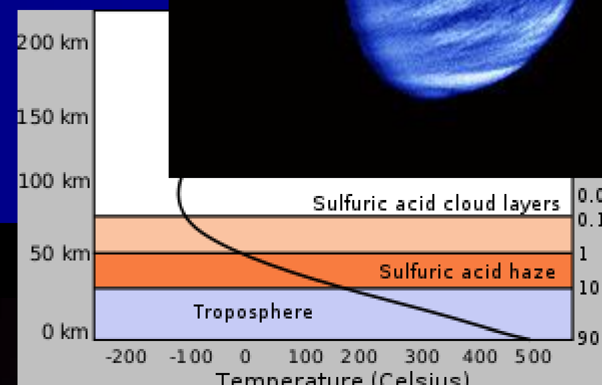
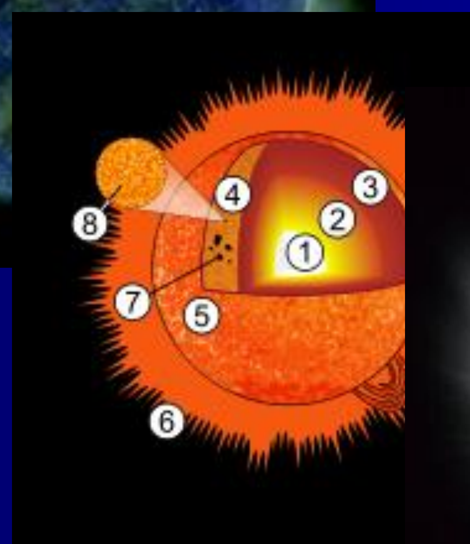
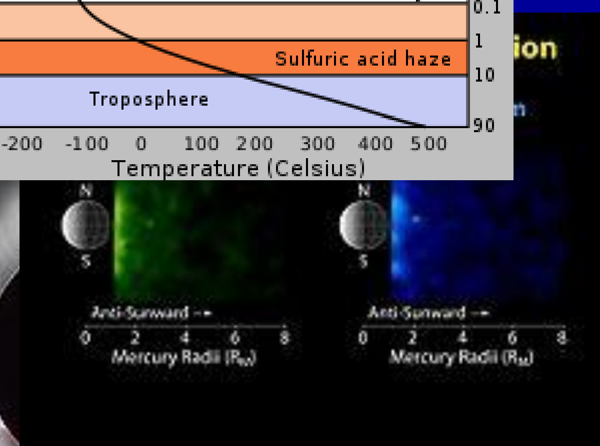












Lecture – 05

Temperature Profile of the Earth

Temperature Profile of the Earth

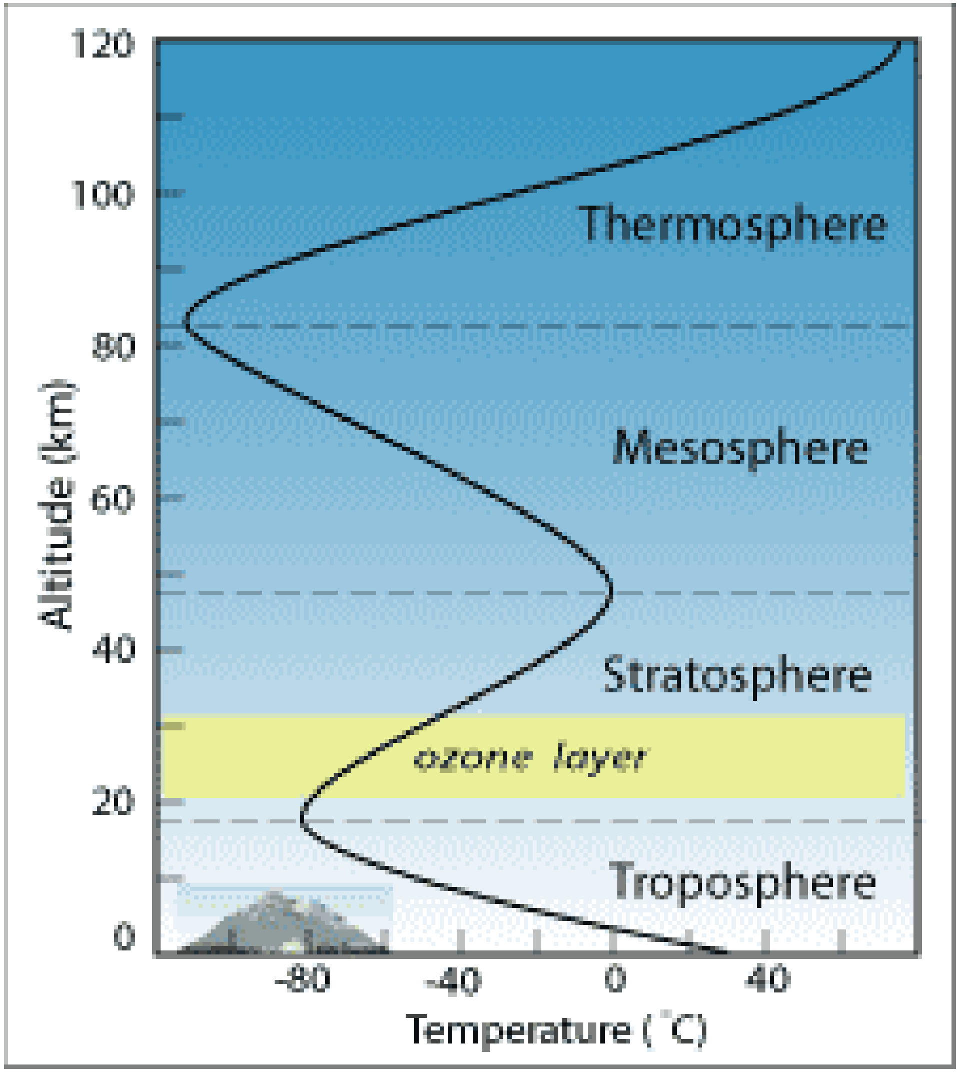
The temperature of the atmosphere of the Earth varies with the **distance from the equator** (latitude) and **height above the surface** (altitude). It also changes in **time**, **varying from season to season**, **from day to night** and **irregularly due to passing weather systems**. If these variations 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.

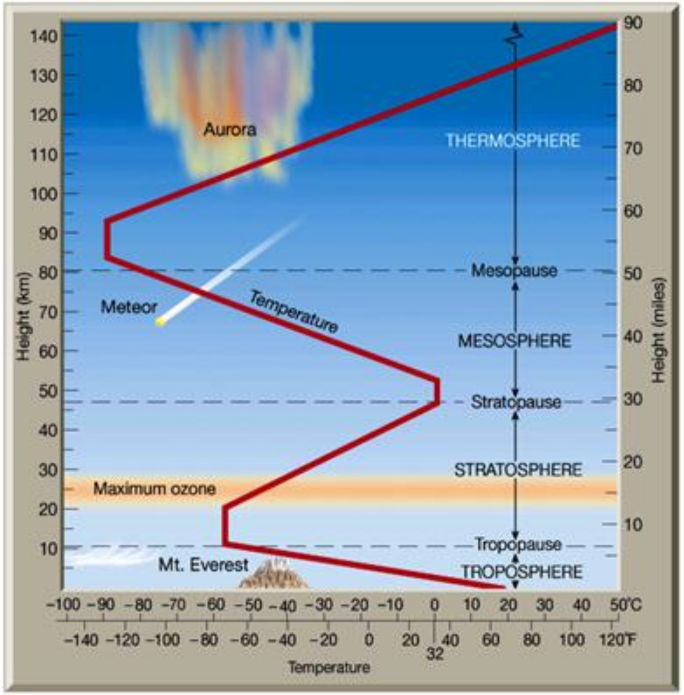
The boundaries between these regions / layers are called tropopause, stratopause and mesopause.

Temperature Profile



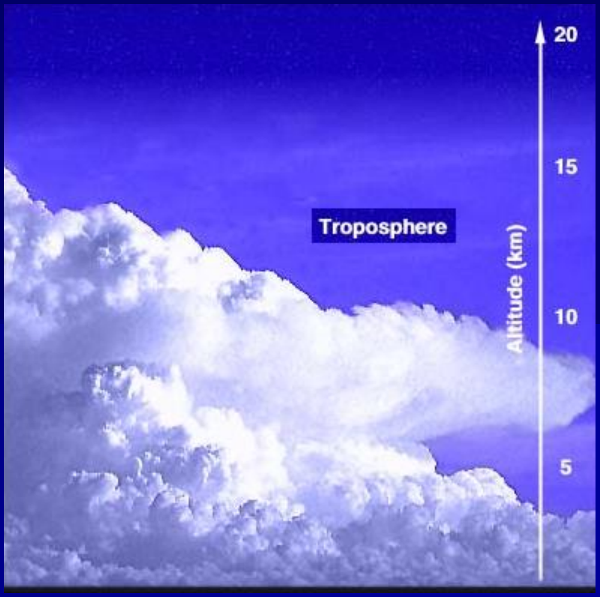
This graph shows how temperature varies with altitude in earth's atmosphere.

Vertical structure of the atmosphere



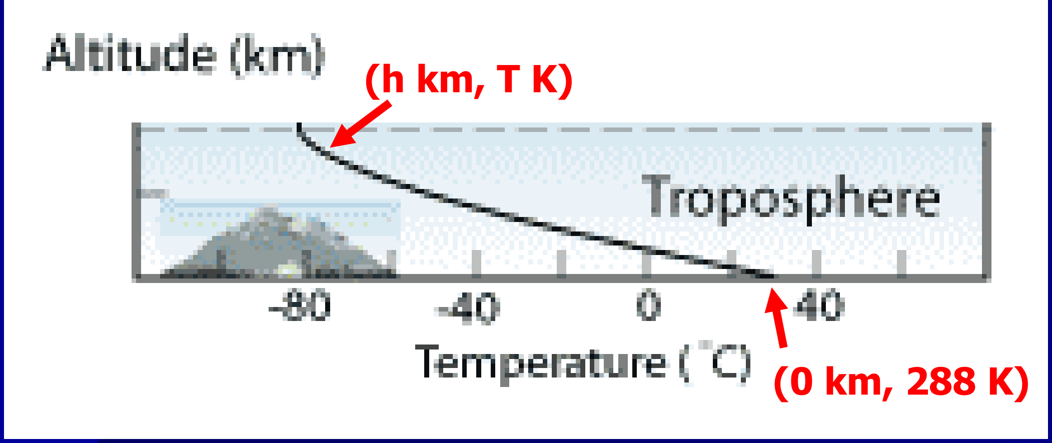
Troposphere

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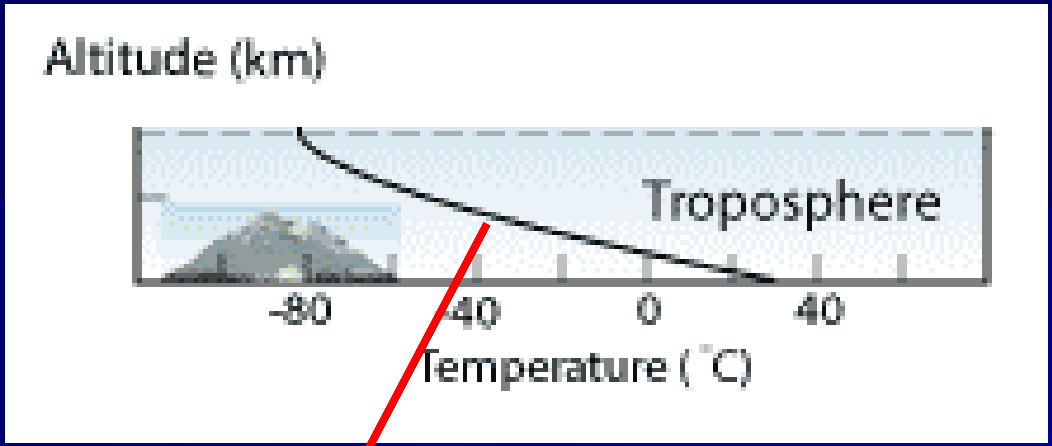
In[1]:=
```
h1 = 0;
h2 = h;
rate = -6.5;
thita1 = 15 + 273;
thita2 = T;
Solve[
 ((thita2 - thita1) / (h2 - h1)) ==
  rate, T]
```

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)

(K) **T(h) = - 6.5 h + 288** (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

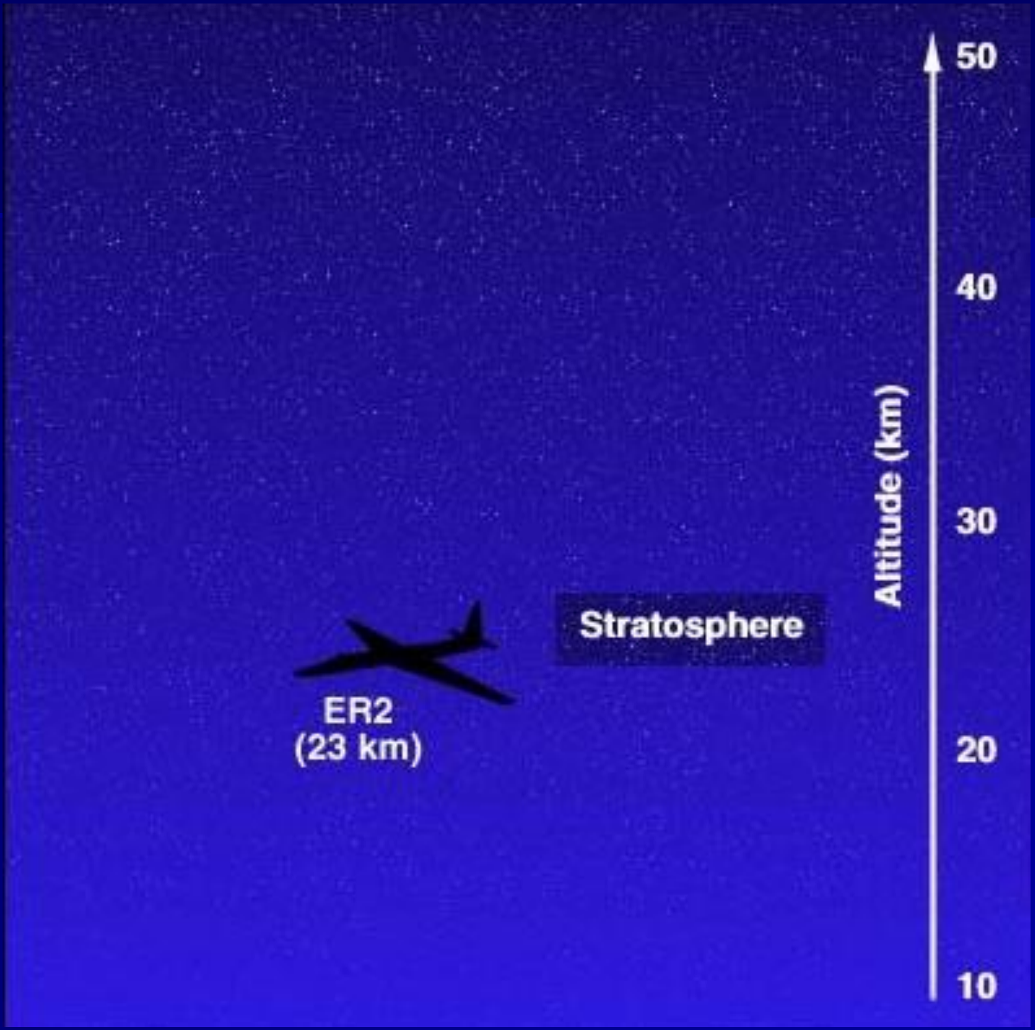
Mount Everest, is Earth's highest mountain. Its peak is **8,848 meters** above sea level. **Find the temperature at the top of the mountain**.

Answer : - 30.5 °C

Stratosphere:

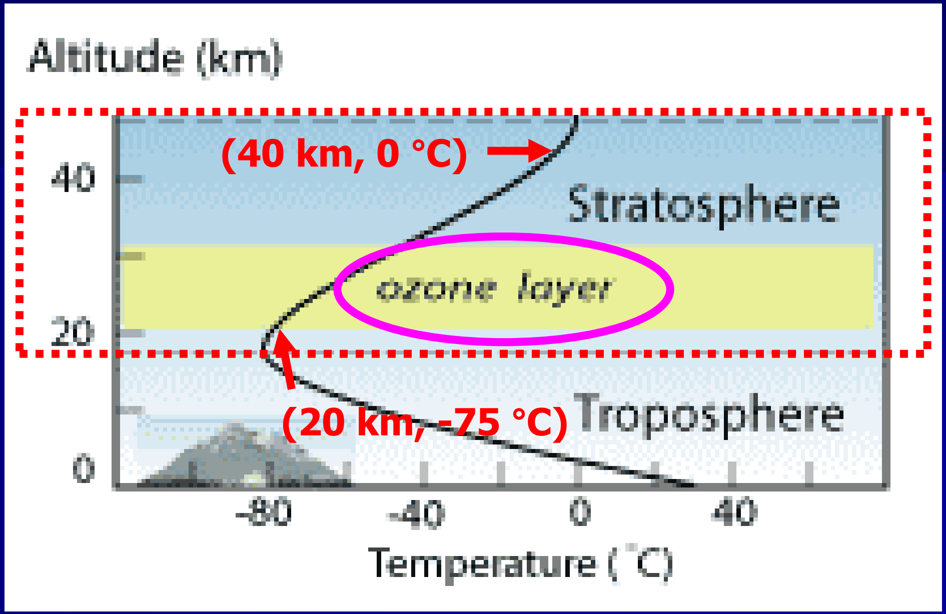
The stratosphere is situated directly above the troposphere and just below the mesosphere.

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]
```

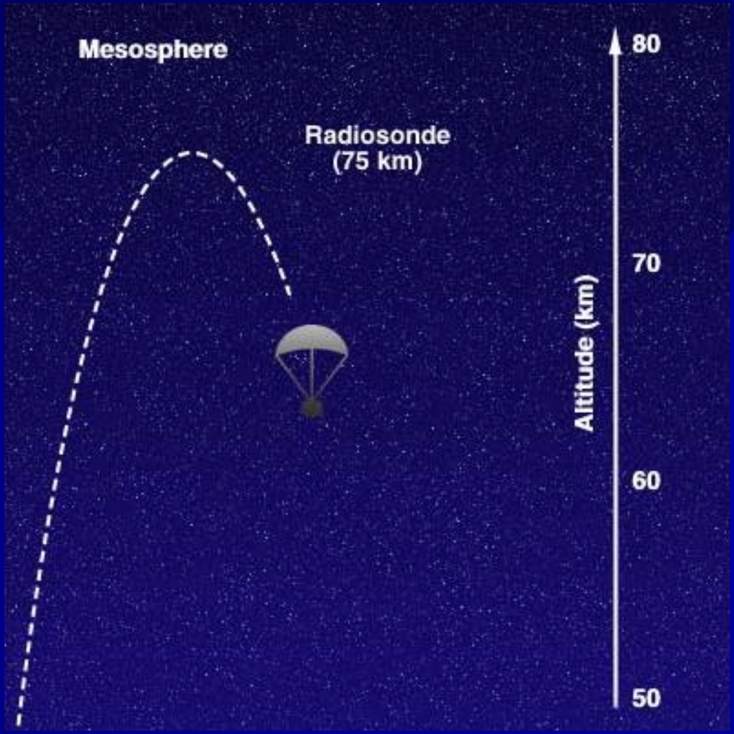
Out[66]= $\left\{\left\{T \to \frac{3}{4}\,(164 + 5\,h)\right\}\right\}$

Mesosphere:

It is sandwiched between the stratosphere and the thermosphere.

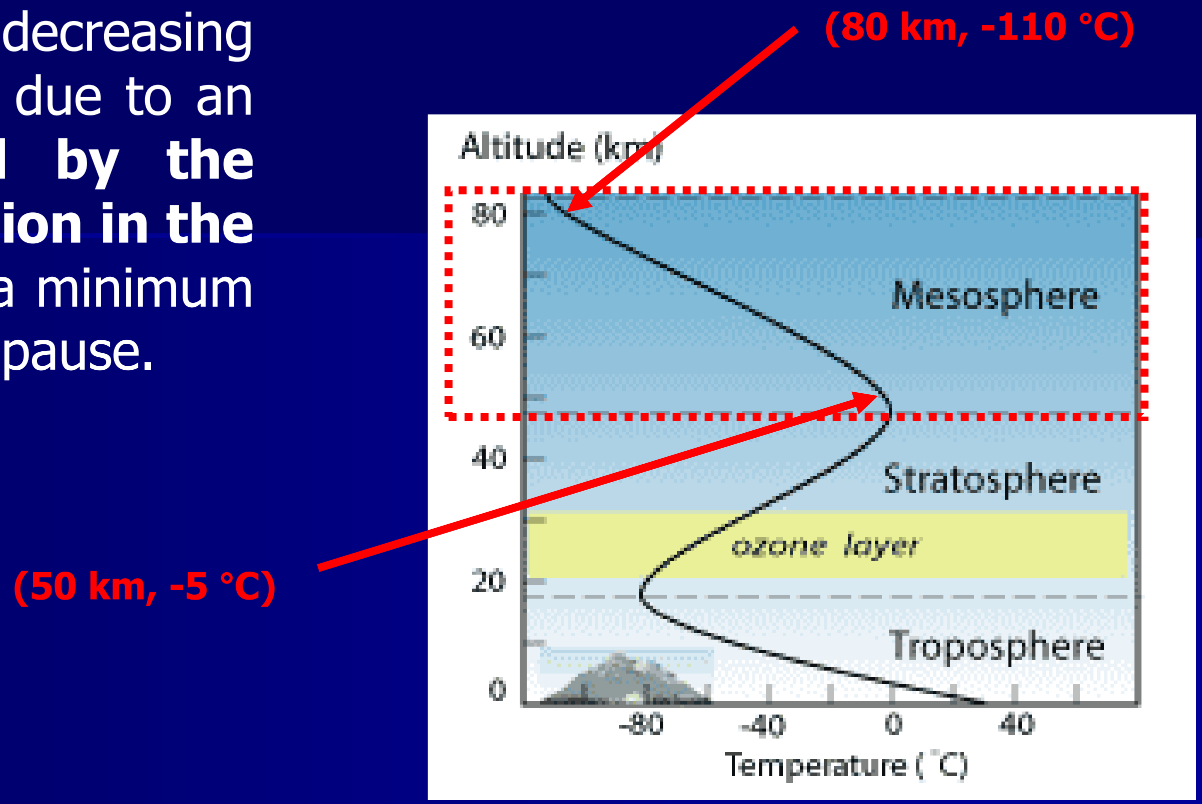
Between about 50–80 km lies the mesosphere, where atmospheric temperature resumes its drop with altitude and reaches a very cold minimum of 180K (−93°C) at the top of the layer (the mesopause), around 80 km.

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 CO_2 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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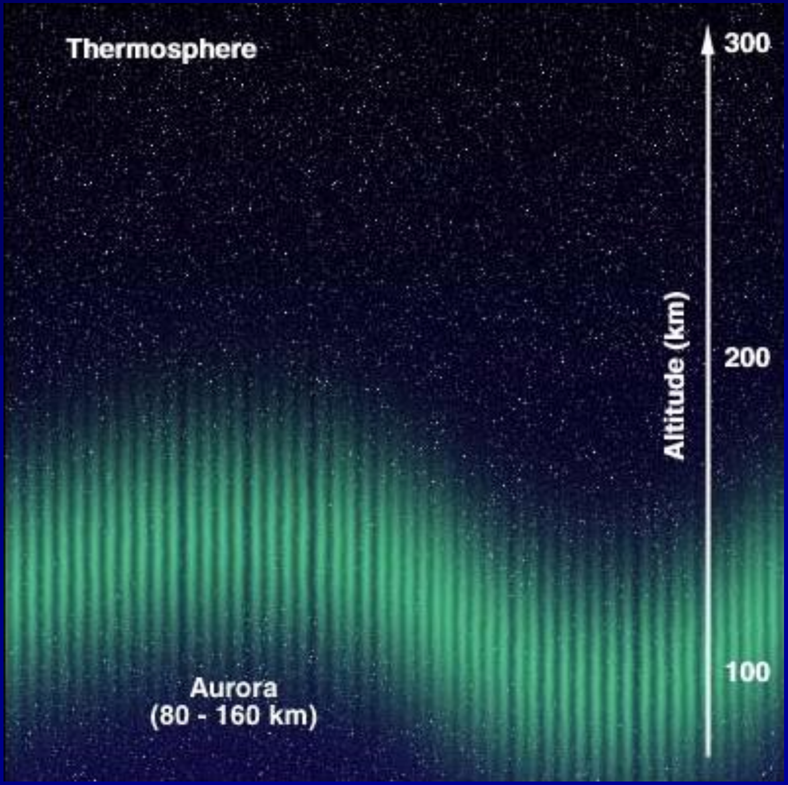
In[57]:=
```
h1 = 50;
h2 = 80;
thita1 = -5 + 273;
thita2 = -110 + 273;
Solve[((T - thita1) / (h - h1)) ==
   ((thita2 - thita1) / (h2 - h1)),
  T]
```

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.

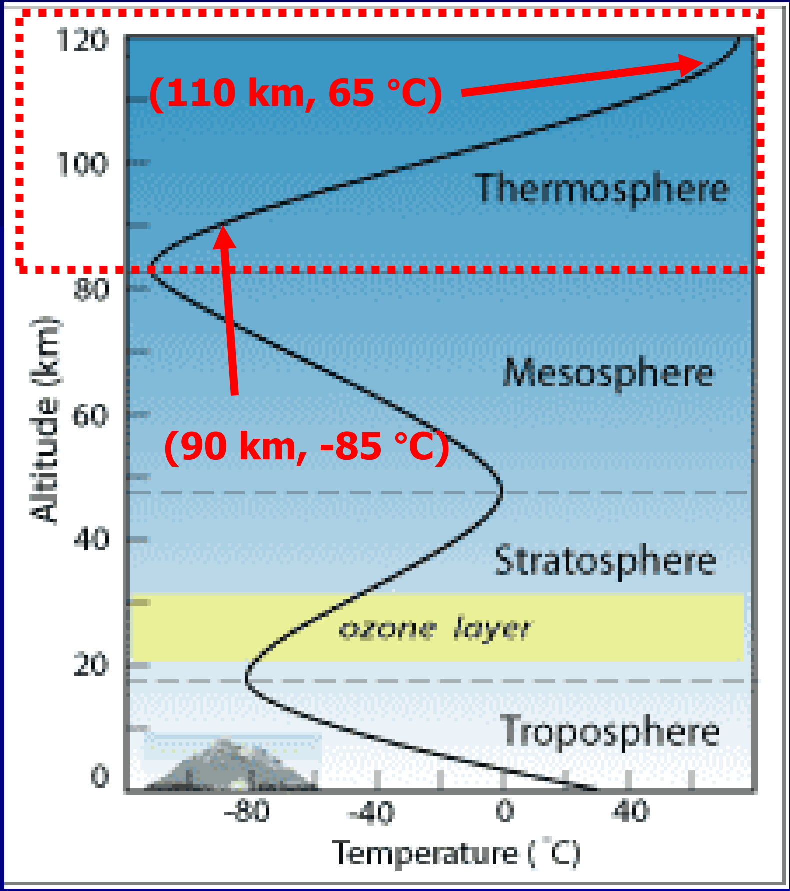
Thermosphere:

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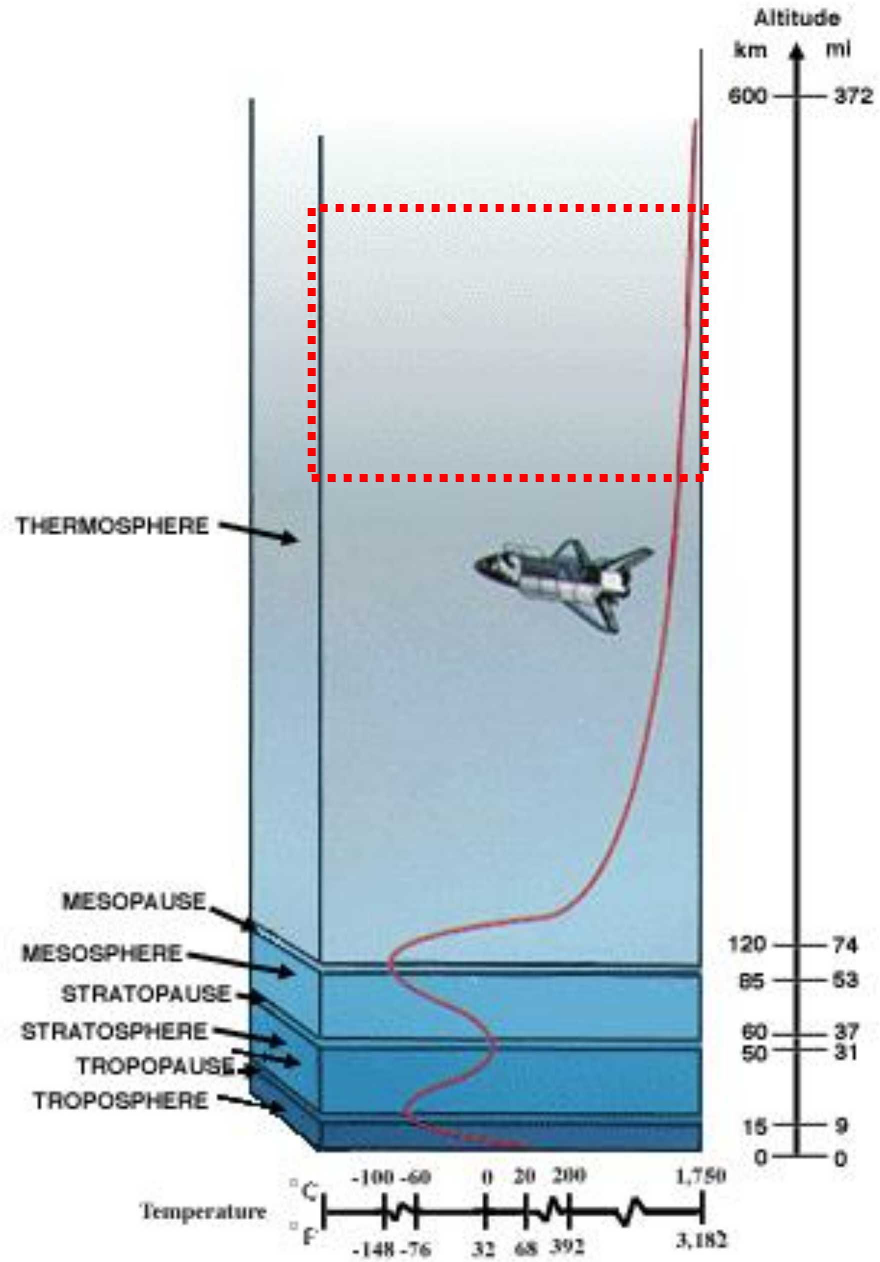
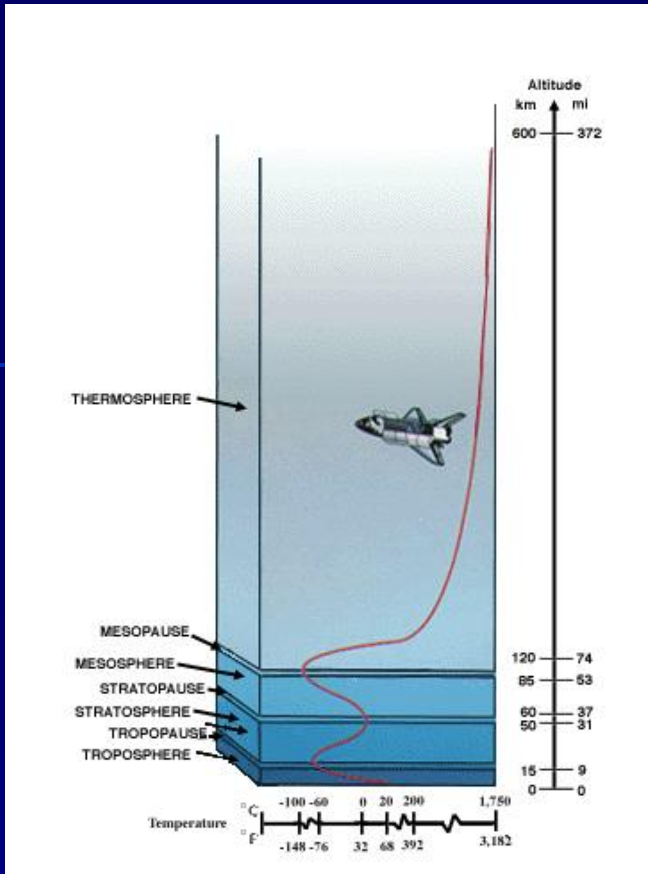
```
In[75]:= h1 = 90;
         h2 = 110;
         thita1 = -85 + 273;
         thita2 = 65 + 273;
         Solve[((T - thita1) / (h - h1)) ==
           ((thita2 - thita1) / (h2 - h1)),
          T]
```

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.

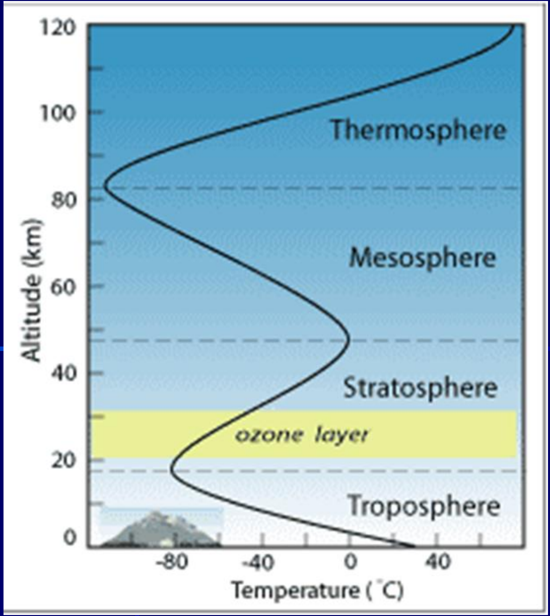




$$T(h) = \begin{cases} -6.5\,h + 288 & ;\ 0 \le h < 20 \text{ km} \\ 3.75\,h + 123 & ;\ 20 \le h < 40 \text{ km} \\ -3.5\,h + 443 & ;\ 50 \le h < 80 \text{ km} \\ 7.5\,h - 487 & ;\ 90 \le h < 110 \text{ km} \end{cases}$$

Earth Atmosphere

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



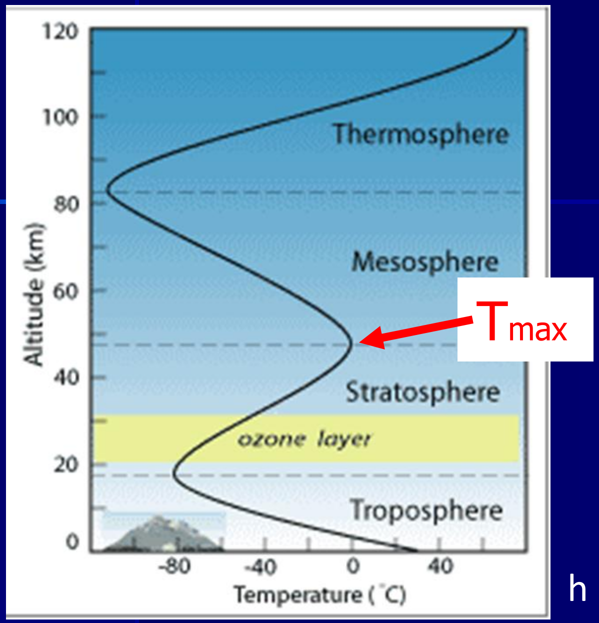
Ozone Layer :

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.

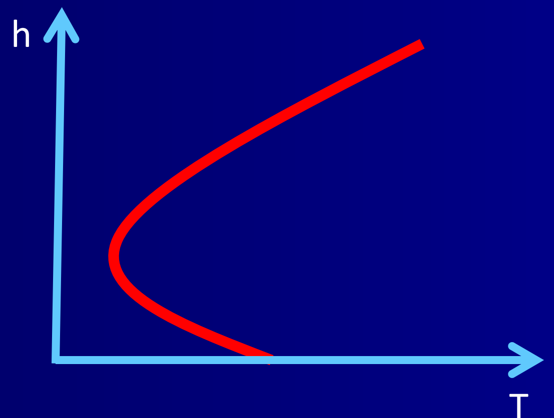
In a planet, the temperature decreases as the distance surface of the planet increases. But after certain distance, due to the effect of the Sun, the temperature increases again.

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 !

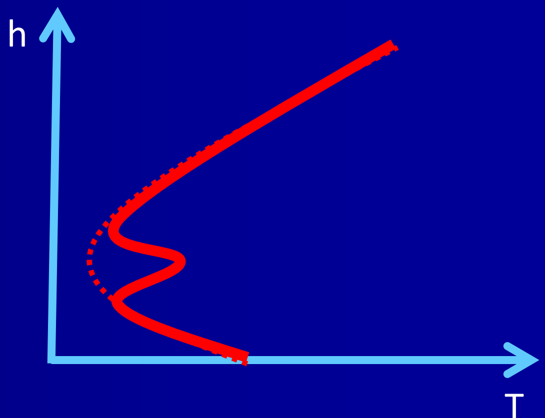
Ozone Layer :



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

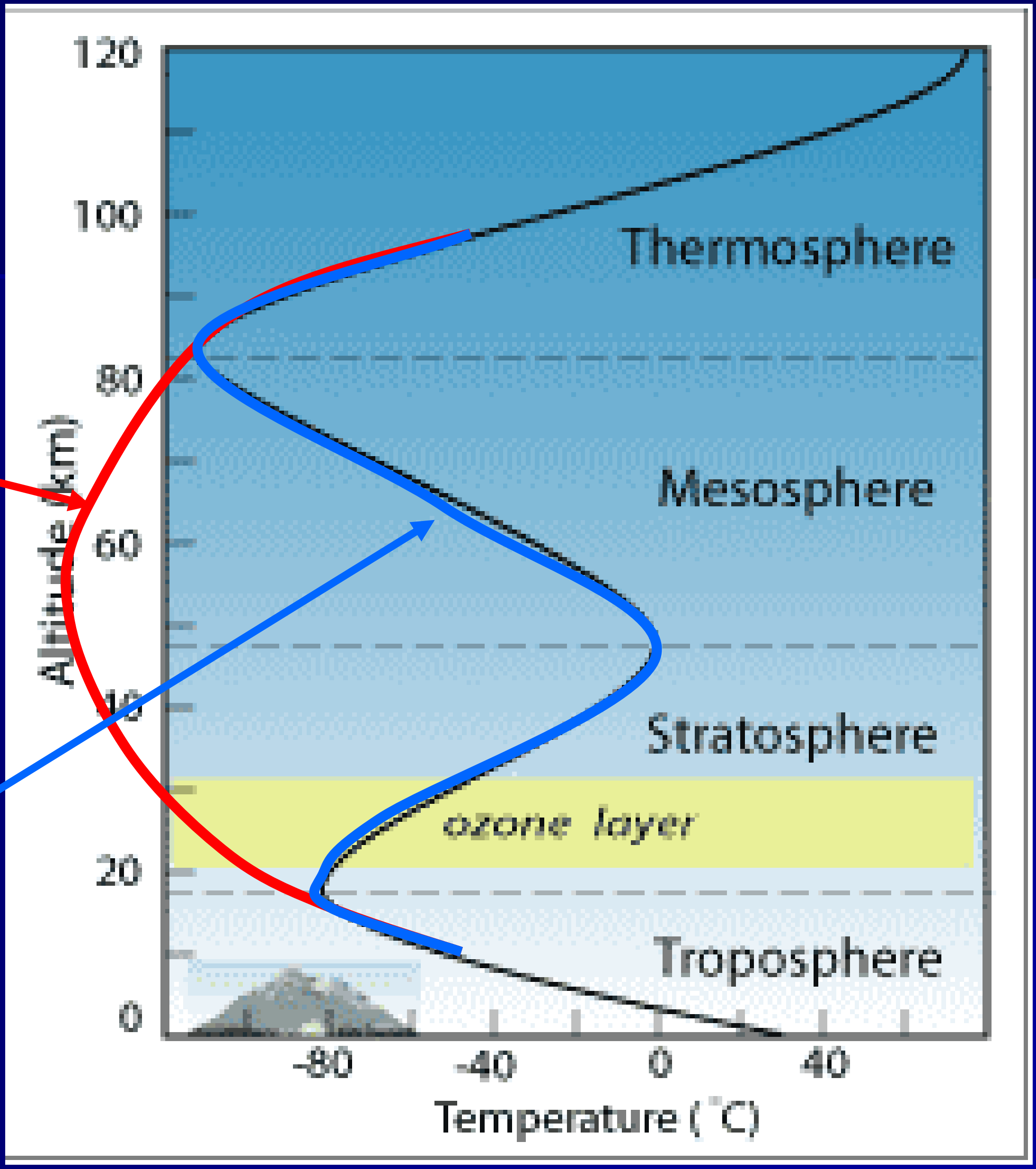


The Graph of h vs T of a planet which consist an Ozone Layer

Altitude vs Temperature Graph of a Planet :

A planet which does not consist an Ozone Layer

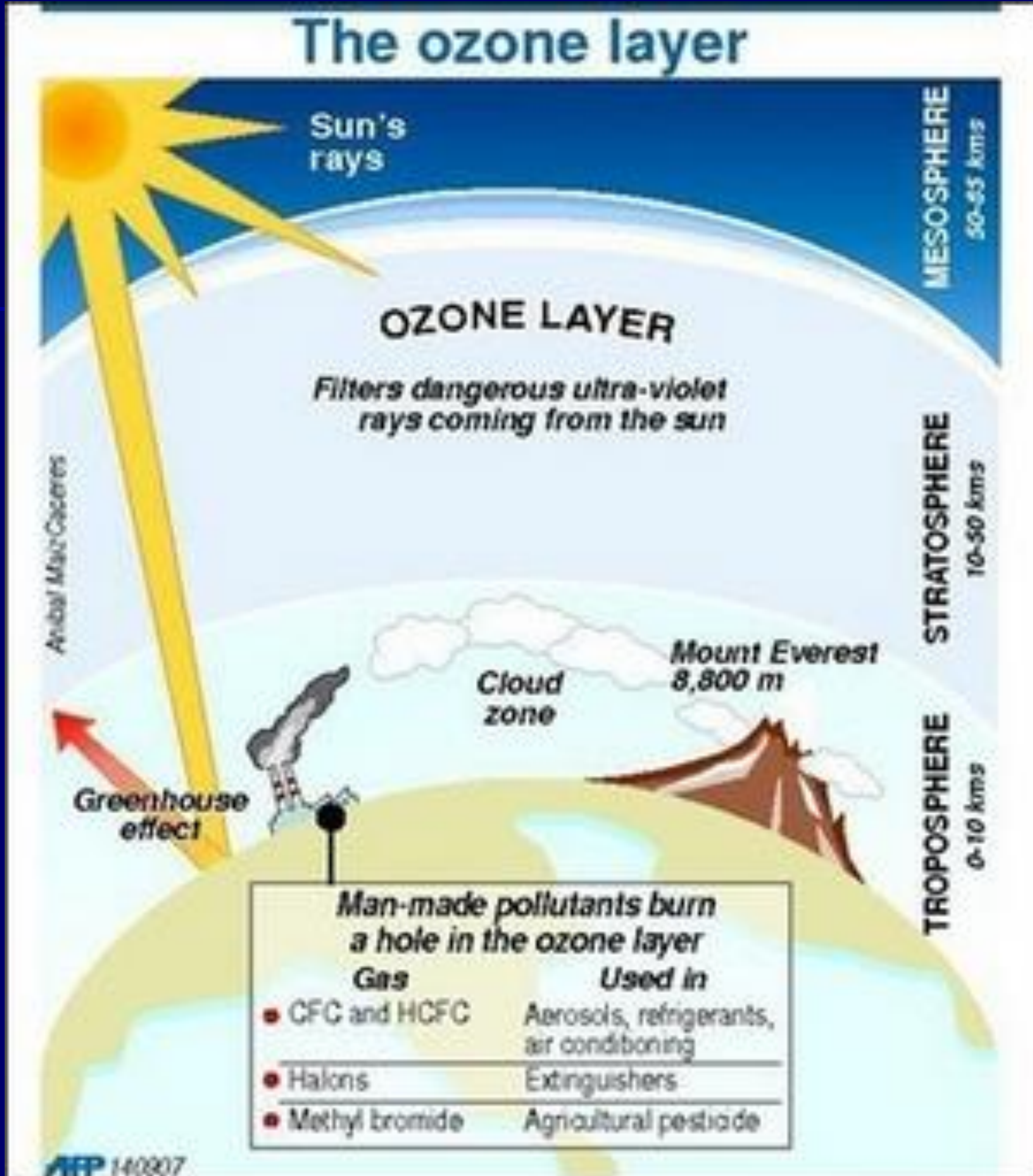
A planet which consists an Ozone Layer



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

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
Cloud zone
Mount Everest 8,800 m
TROPOSPHERE
0-10 kms
Greenhouse effect
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).

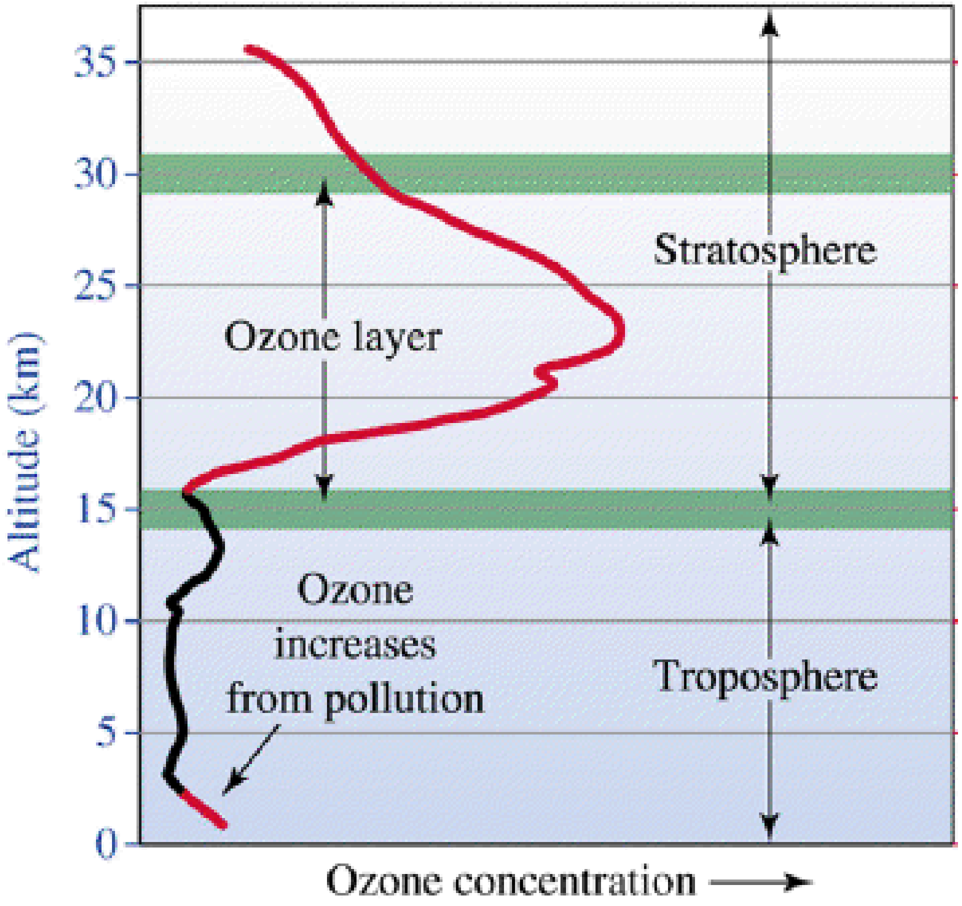
This layer absorbs 97–99% of the Sun's high frequency ultraviolet light, which is damaging to life on Earth. It is mainly located in the lower portion of the stratosphere from approximately **13 to 40 kilometres above Earth**, though the **thickness varies seasonally and geographically**.

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

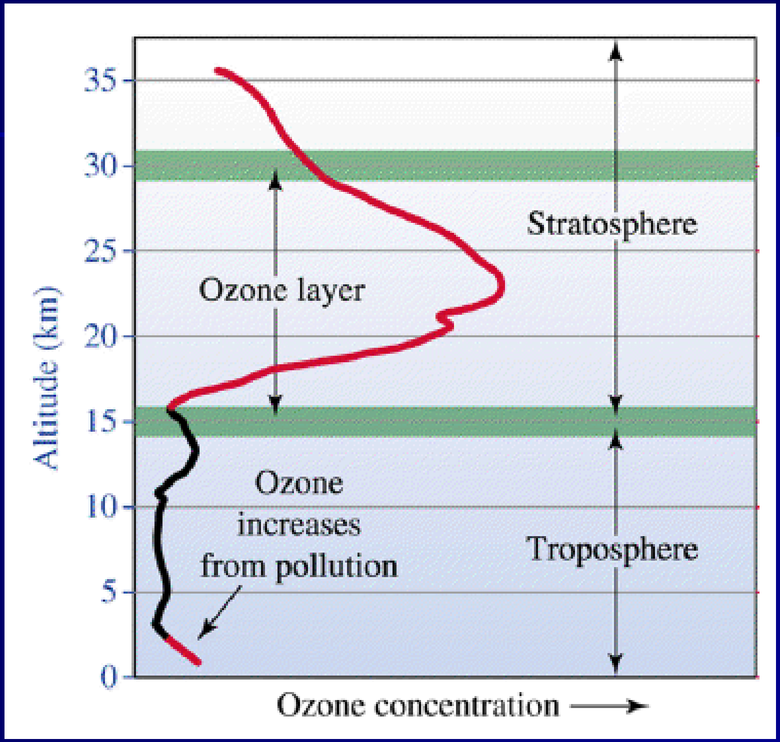
Ozone layer

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.

$$O_2 + E_{\text{From Sun}} \longrightarrow O + O$$

$$O_2 + O \longrightarrow O_3$$

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.

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

λ < 3100 Å

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

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 mili-meters thick.

Origin of ozone

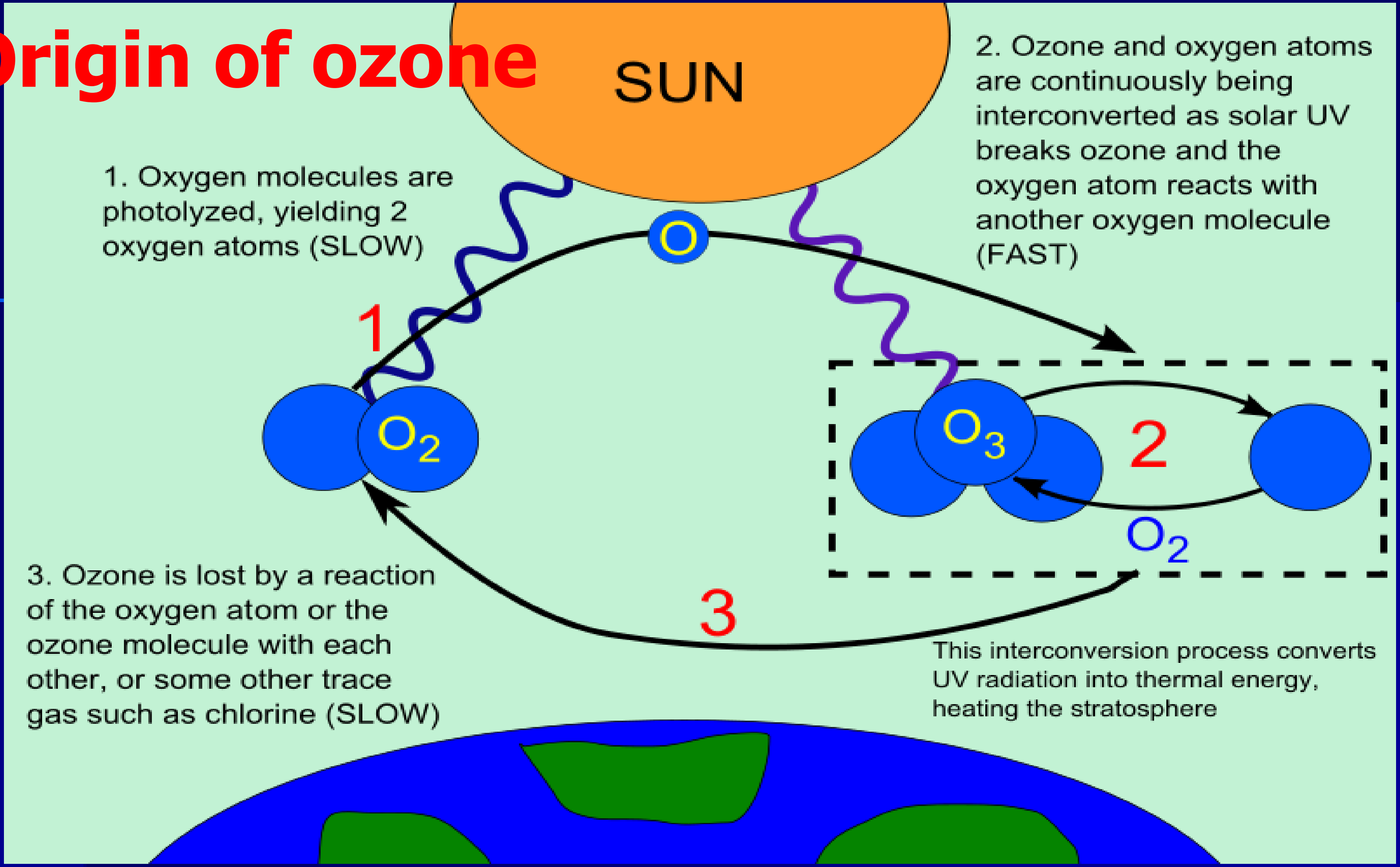
$$O_3 + E_{UV} \longrightarrow O_2 + O + \text{Heat}$$

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 milimeters thick.

Origin of ozone



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Thank You !
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