Paper Code: GIS 03

Principles of Remote Sensing

Interaction of EM radiation with atmosphere including Atmospheric Scattering, Absorption and Emission

PG Diploma in RS & GIS

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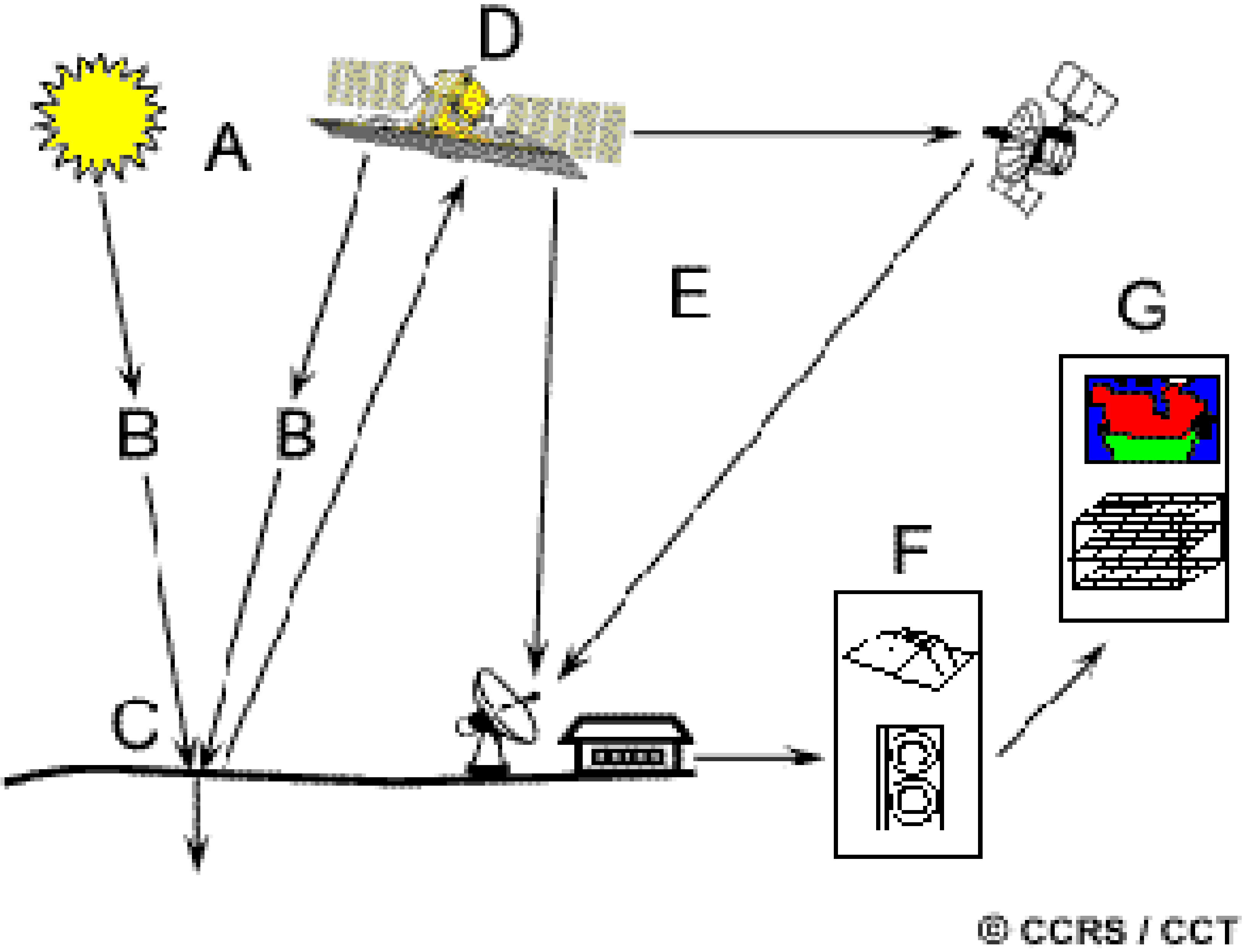
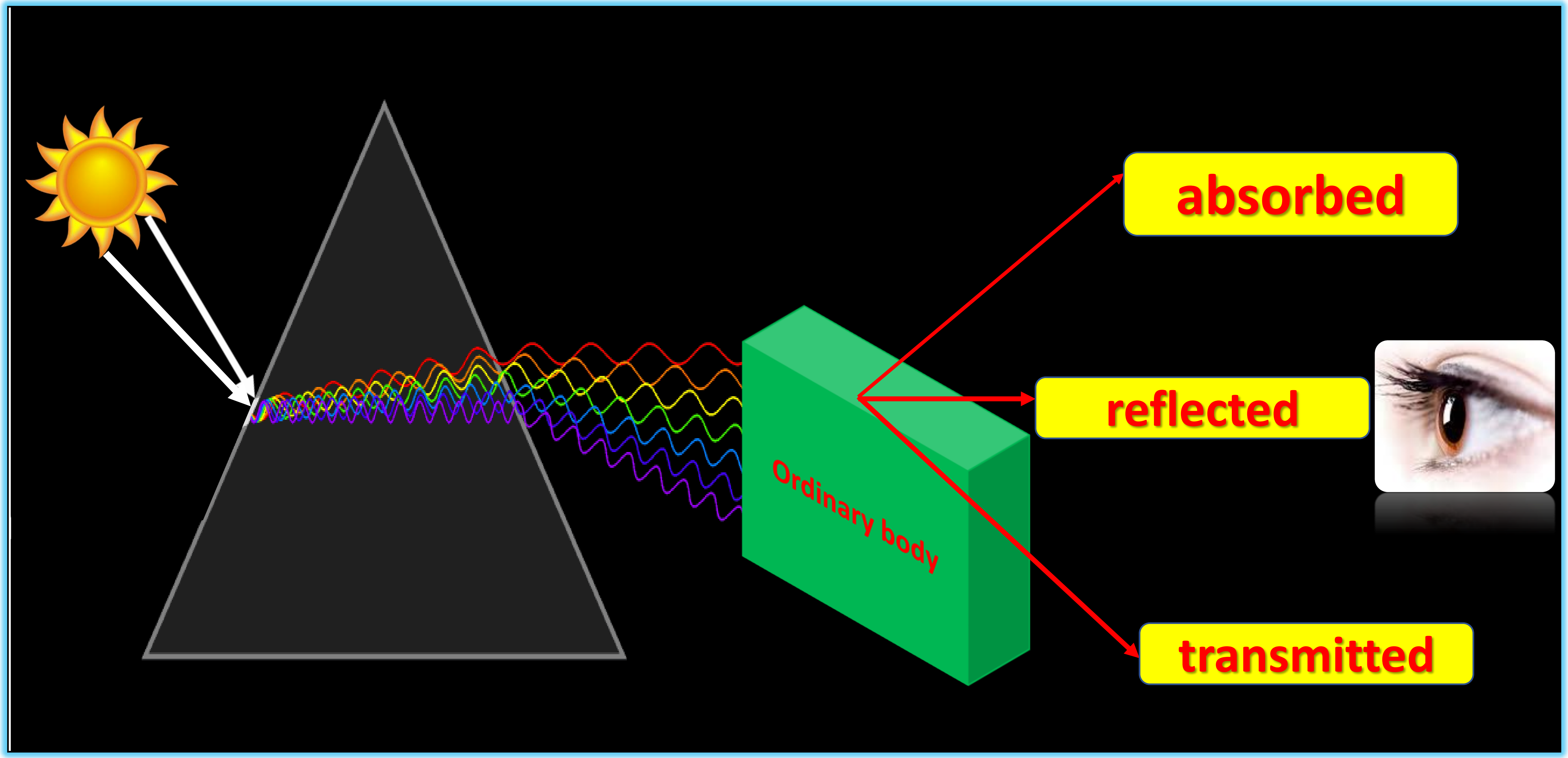
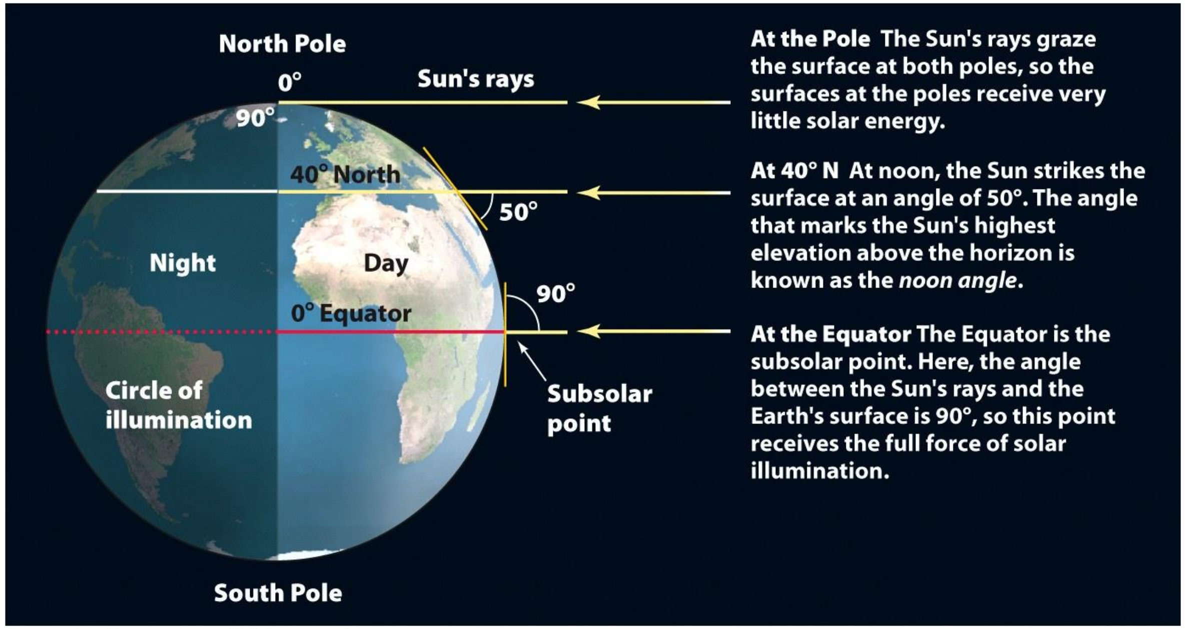
Process of Remote Sensing




absorbed
reflected
transmitted
Ordinary body

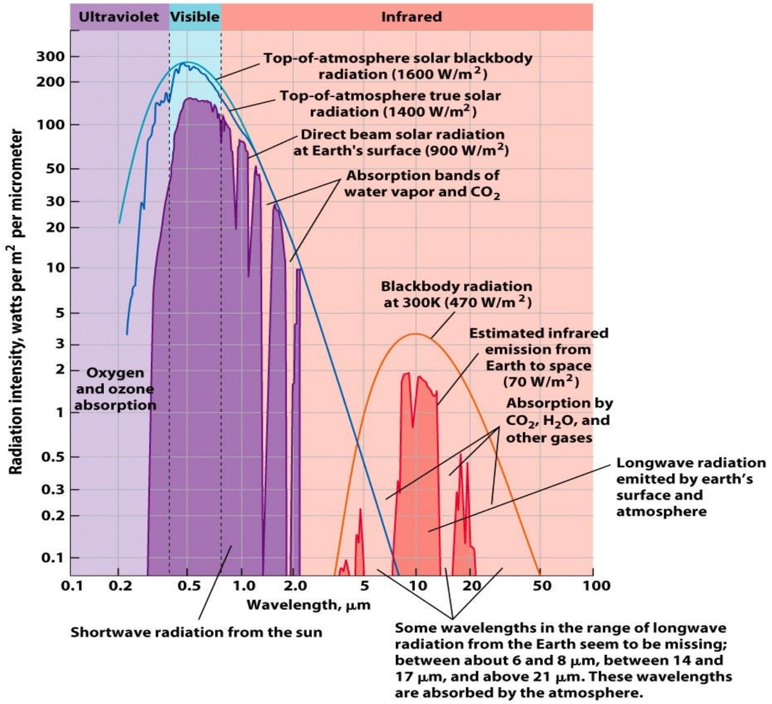
Insolation

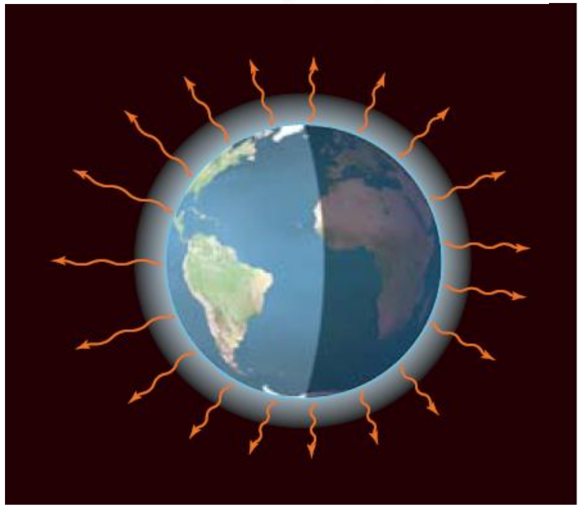
- Daily insolation – avg radiation total in 24 hours
  - Depends on :
    - Sun angle – higher sun angle → greater insolation
    - Length of day – higher latitudes get long summer days
- Annual insolation – avg radiation total for year
  - Also depends on sun angle and length of day
  - Both of these determined by latitude
  - So, latitude determines annual insolation

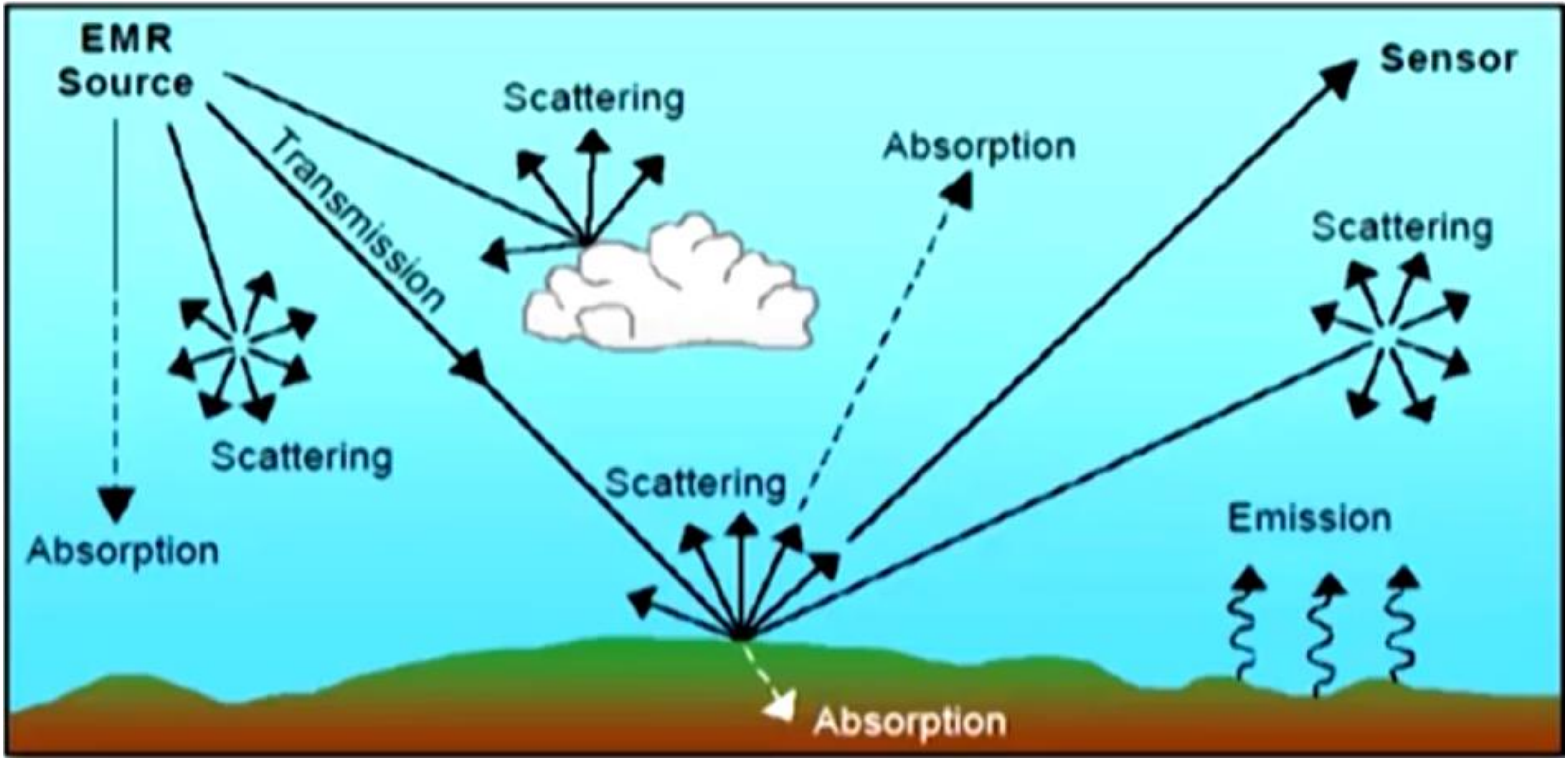


Longwave Radiation

- Energy emitted from Earth's surface
- 3-30 µm wavelength
- Strong absorption by CO_2 and H_2O↑
  - This absorption part of greenhouse effect
- Longwave radiation is emitted by Earth back to space.
- Thus, Earth's temp remains fairly constant.






EMR
Source
Scattering
Absorption
Sensor
Transmission
Scattering
Scattering
Scattering
Absorption
Emission
Absorption

Gases composition of Atmosphere

- ✓ Oxygen and Nitrogen are present in the ratio 1:4
- ✓ both together add to 99 percent of the total gaseous composition in the atmosphere
- ✓ Ozone is present in very small quantities and is mostly concentrated in the atmosphere between 19 and 23km.

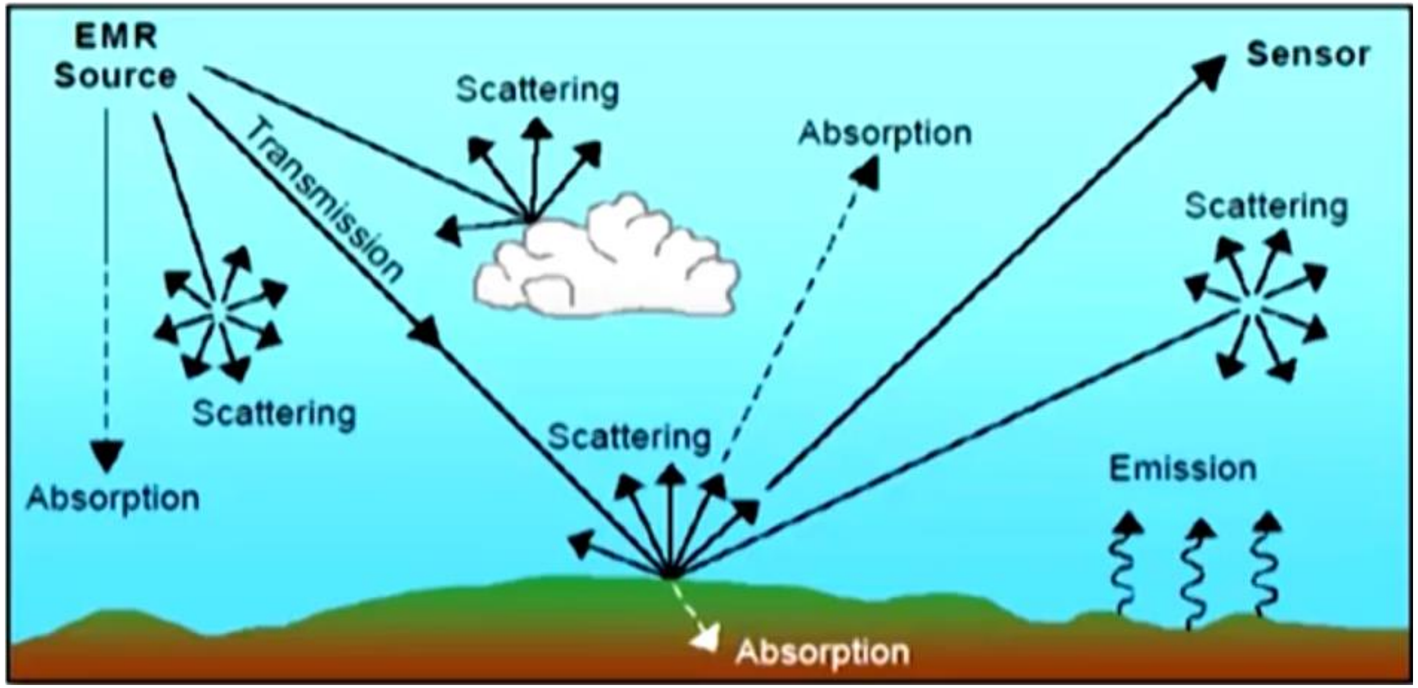
Gaseous composition of the Earth's atmosphere (from Gibbson, 2000)

Component	Percentage
Nitrogen (N2)	78.08
Oxygen (O2)	20.94
Argon	0.93
Carbon Dioxide(CO2)	0.0314
Ozone (O3)	0.00000004

- ✓ In addition to the above gases, the atmosphere also contains water vapor, methane, dust particles, pollen from vegetation, smoke particles etc.

Interaction with Atmosphere

- ✓ Before radiation (used for remote sensing) reaches the earth's surface it has to travel through some distance of the earth's atmosphere.
- ✓ Particles and gases in the atmosphere can effect the incoming light
- ✓ These effects are caused by the mechanisms of scattering and absorption.



Layer of Atmosphere

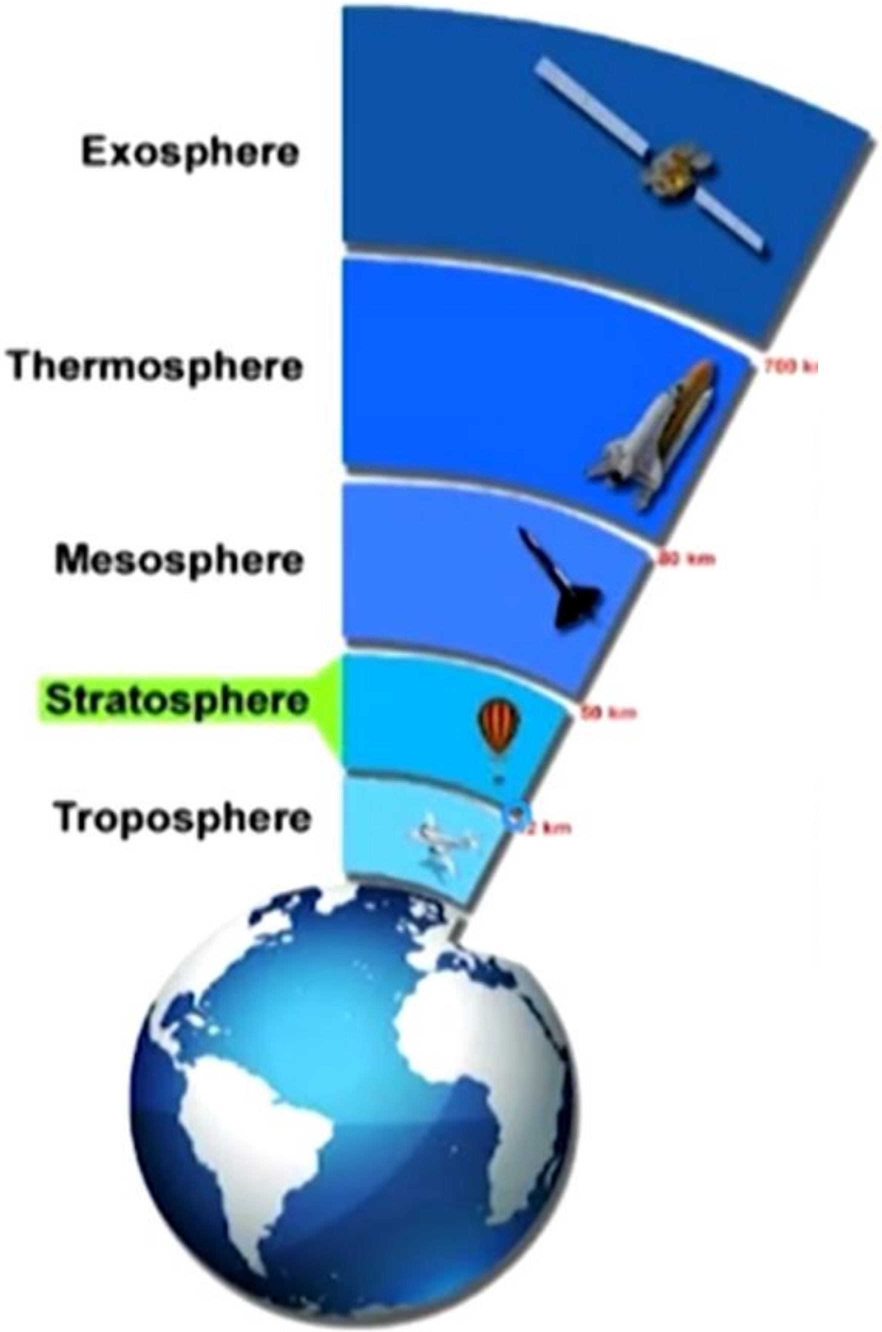
Exosphere:
- ✓ Outer most layer
- ✓ 700 to 10,000 Km
- ✓ Contains most of the satellite orbit of the earth surface.

Thermosphere:
- ✓ Second highest layer
- ✓ Contain the ionosphere
- ✓ Space shuttle orbit at this layer

Mesosphere:
- ✓ Third height layer
- ✓ 50 to 80 Km
- ✓ Mainly accessed by sounding rockets

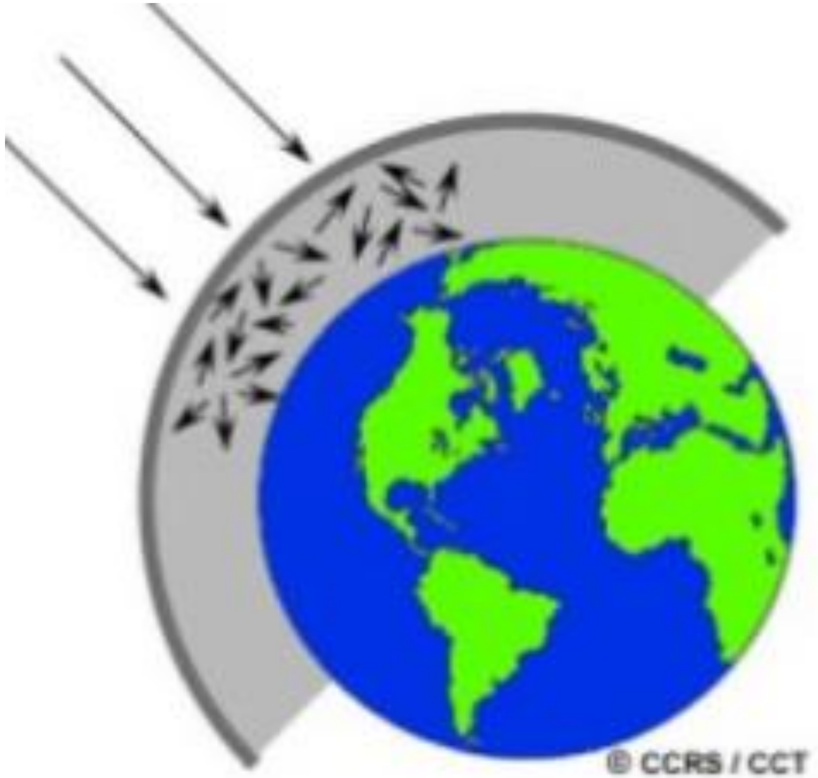
Stratosphere
- ✓ Ozone in the **stratosphere** filters out harmful ultraviolet radiation from reaching the earth.

Troposphere:
- ✓ Lower Layer +-12 Km
- ✓ Weather takes Place
- ✓ Accessed by propeller driven aircraft



Scattering

Interaction with Atmosphere



- ✓ **Scattering** occurs when particles or large gas molecular present in the atmosphere interacts with and causes the electromagnetic radiation to be redirected from its original path.

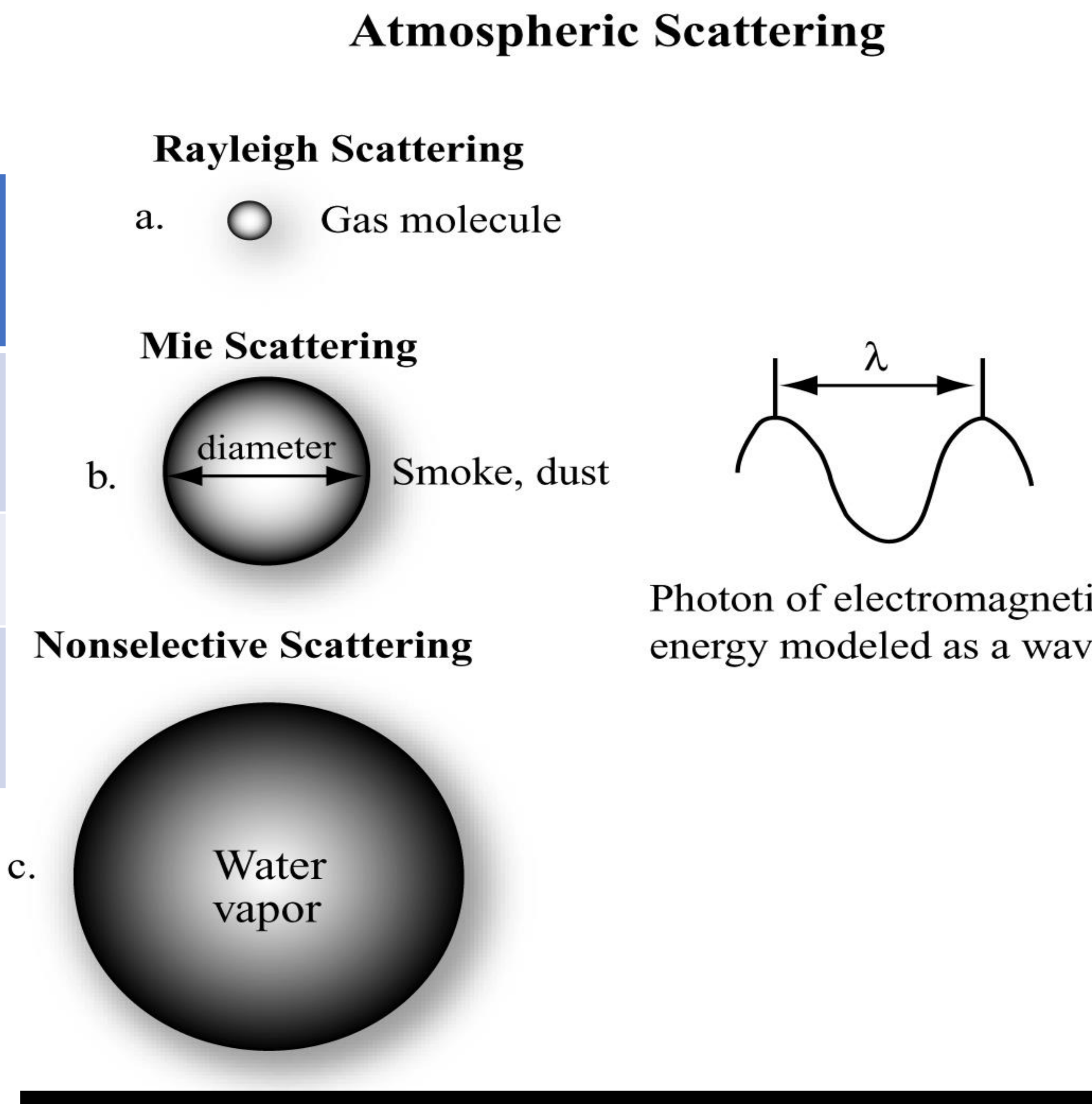
- ✓ How much scattering takes place depends on several factors including:

  - ➢ The wavelength of the radiation.(multispectral scanner in different wave band behaved differently)
  - ➢ The abundance of particles or gases (density of particles present in the atmosphere)
  - ➢ The distance the radiation travels through the atmosphere.(effects differently on vertical or oblique aliment of the sensor)

- ✓ There are three major types of scattering which takes place.

The various types of scattering of visible light

Types of Particle	Particle Diameter (Micrometers)	Type of Scattering	Phenomena
Air Molecular	0.0001 to 0.001	Rayleigh	Blue Sky, Red sunsets and sunrise
Aerosols (Pollutants)	0.01 to 1.0	Mie	Brownish sky, Smog, fog
Cloud Droplets	10 to 100	Geometric or Non selective	White Clouds



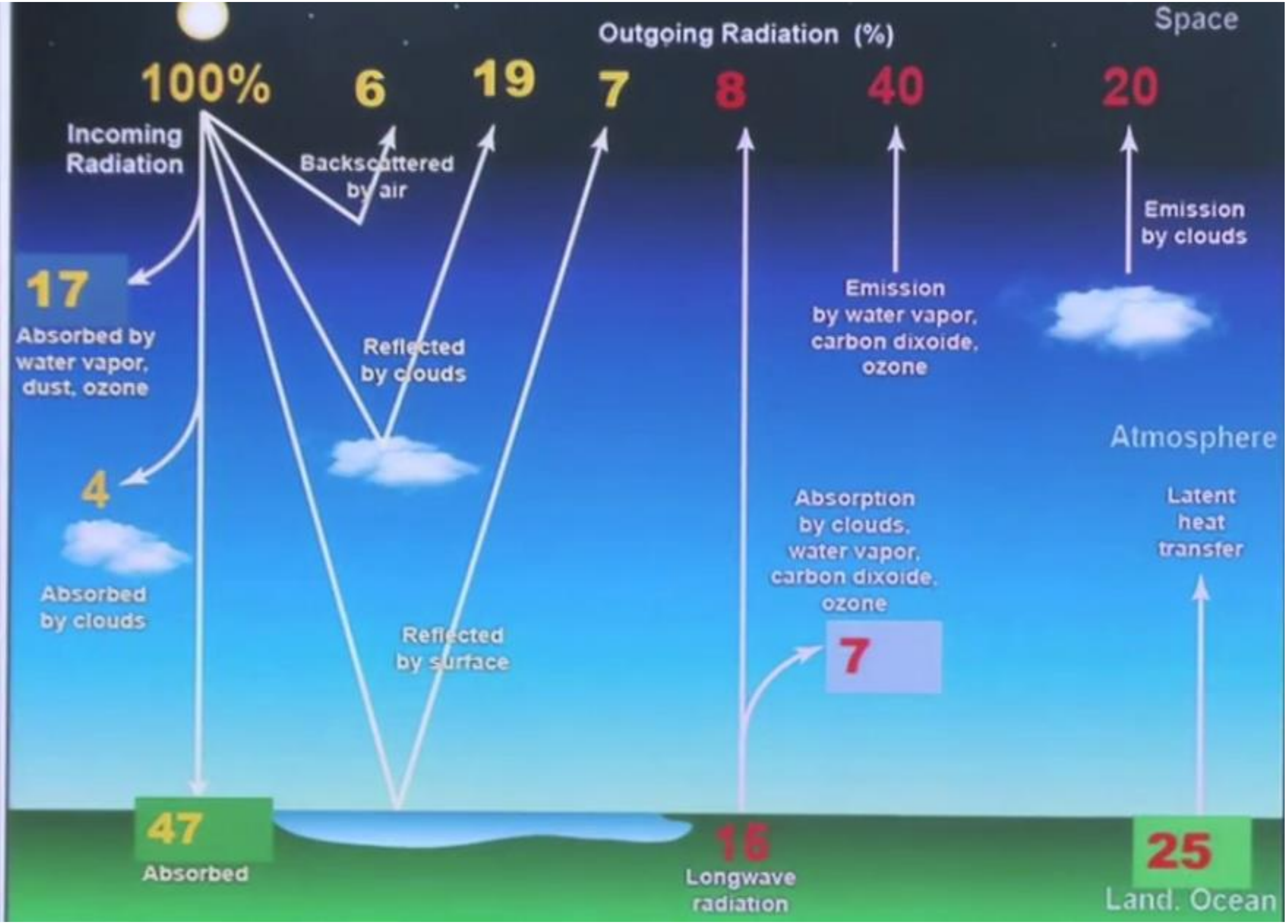
Scattering

- ✓ Once electromagnetic radiation is generated, it is propagated through the earth's atmosphere almost at the speed of light in a vacuum.

- ✓ As the radiation passes through the atmosphere, the gases and the particles in the atmosphere interact with them causing changes in the magnitude, wavelength, velocity, direction, and polarization

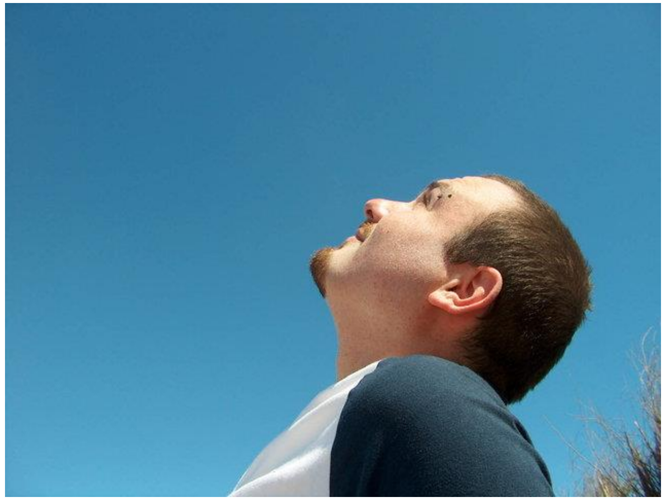
- ✓ Unlike a vacuum in which nothing happens, however, the atmosphere may affect not only the speed of radiation but also its wavelength, intensity, spectral distribution, and/or direction.
- ✓ *Scatter* differs from *reflection* in that the direction associated with scattering is ***un***predictable, whereas the direction of reflection is predictable. There are essentially three types of scattering:
    - Rayleigh,
    - Mie, and
    - Non-selective.

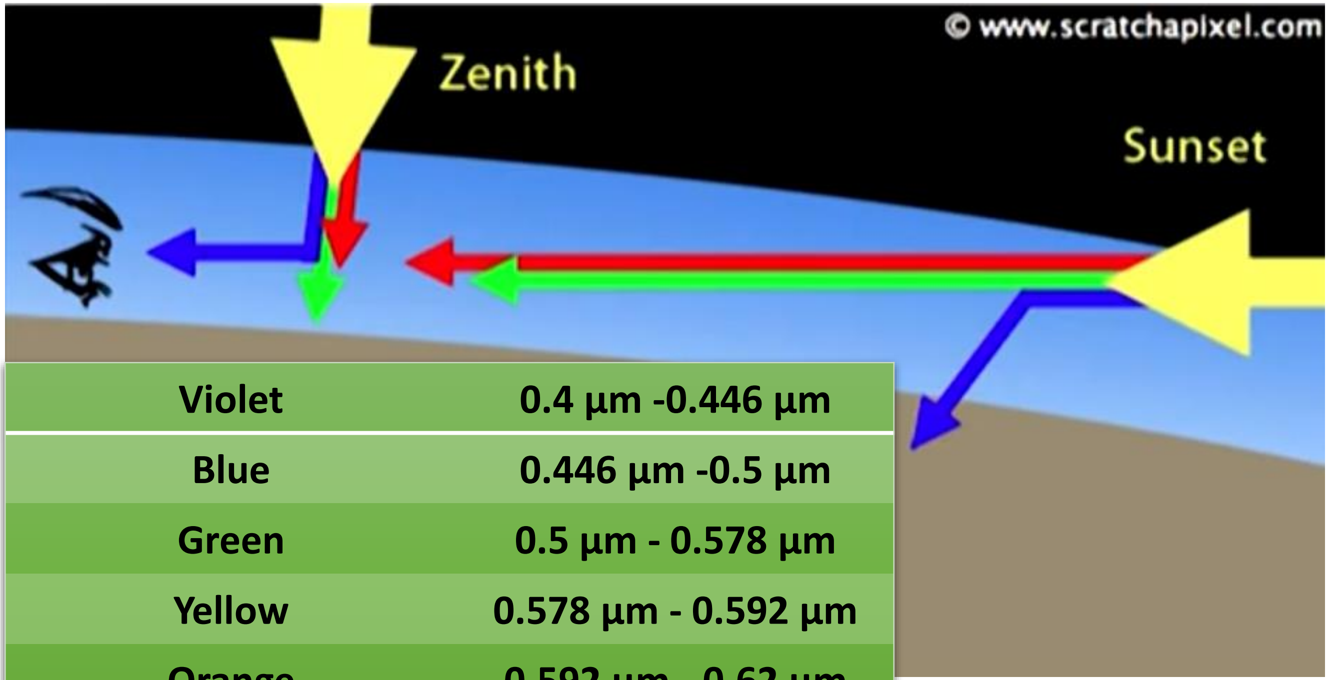
- ✓ *Rayleigh scattering is also known as selective scattering or molecular scattering.*
- ✓ *Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation.*
- ✓ *These could be particles such as small specks of dust or nitrogen or oxygen molecular.*
- ✓ *Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelength.*
- ✓ *Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere.*



Space
Outgoing Radiation (%)
100%
6
19
7
8
40
20
Incoming Radiation
Backscattered by air
Emission by clouds
17
Absorbed by water vapor, dust, ozone
Reflected by clouds
Emission by water vapor, carbon dixoide, ozone
Atmosphere
4
Absorbed by clouds
Absorption by clouds, water vapor, carbon dixoide, ozone
Latent heat transfer
Reflected by surface
7
47
Absorbed
16
Longwave radiation
25
Land, Ocean

Interaction with Atmosphere:





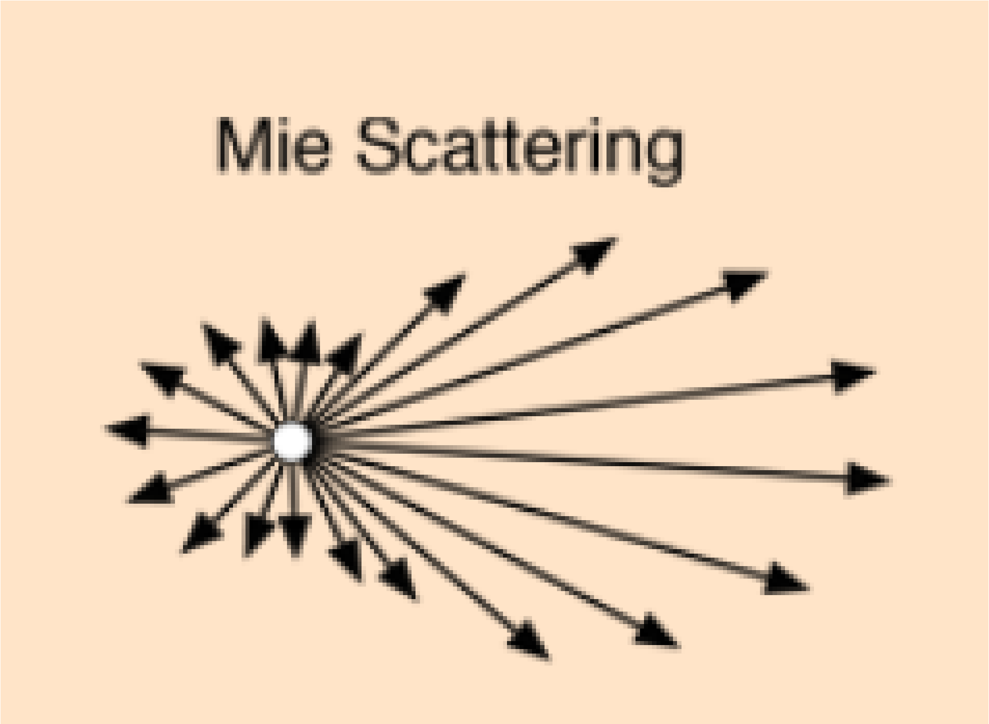
Violet	0.4 µm -0.446 µm
Blue	0.446 µm -0.5 µm
Green	0.5 µm - 0.578 µm
Yellow	0.578 µm - 0.592 µm
Orange	0.592 µm - 0.62 µm
Red	0.62 µm -0.7 µm

- ✓ The fact that the sky appears BLUE during the day is because of the following phenomenon.

- ✓ As sunlight passes through the atmosphere, the shorter wavelengths (i.e. blue) of the visible spectrum are **scattered** more than the other (longer) visible wavelengths.

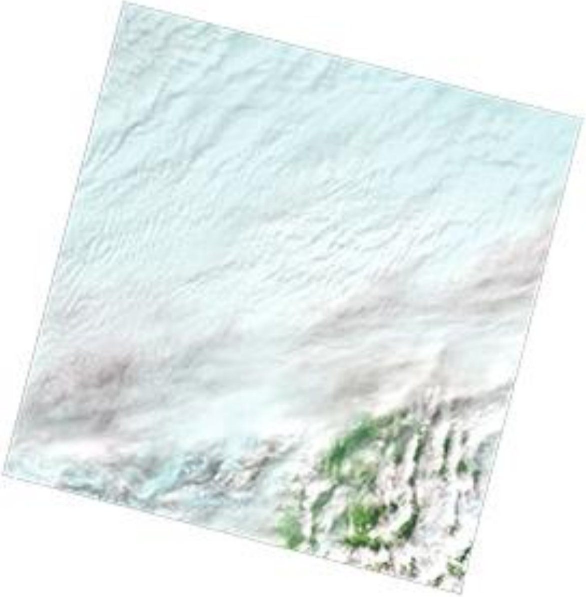
- ✓ At sunrise and sunset the light has to travel farther through the atmosphere than at midday and the **scattering of the shorter wavelength is more complete**, this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.

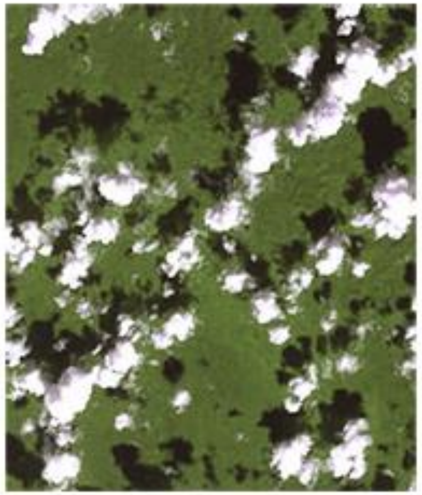
Mie Scattering



- ✓ *Mie scattering occurs when the particles are just about the same size as the wavelength of the radiation.*
- ✓ *Dust pollen, smoke and water vapor are common causes of mie scattering which tends to affect longer wavelengths than those affected by **Rayleigh scattering.***
- ✓ *Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant and dominates when cloud conditions are overcast.*

Nonselective Scattering





- ✓ *The final scattering mechanism of importance is called* ***nonselective or geometric scattering.***
- ✓ *This occurs when the particles are much larger than the wavelength of the radiation.*
- ✓ *Water droplets and large dust particles can cause this type of scattering.*
- ✓ ***Nonselective scattering*** *gets its name from the fact that all wavelengths are scattered about equally.*
- ✓ *This type of scattering causes fog and clouds to appear white (blue+green+red = white light) to our eyes.*

The various types of scattering of visible light

Types of Particle	Particle Diameter (Micrometers)	Type of Scattering	Phenomena
Air Molecular	0.0001 to 0.001	Rayleigh	Blue Sky, Red sunsets and sunrise
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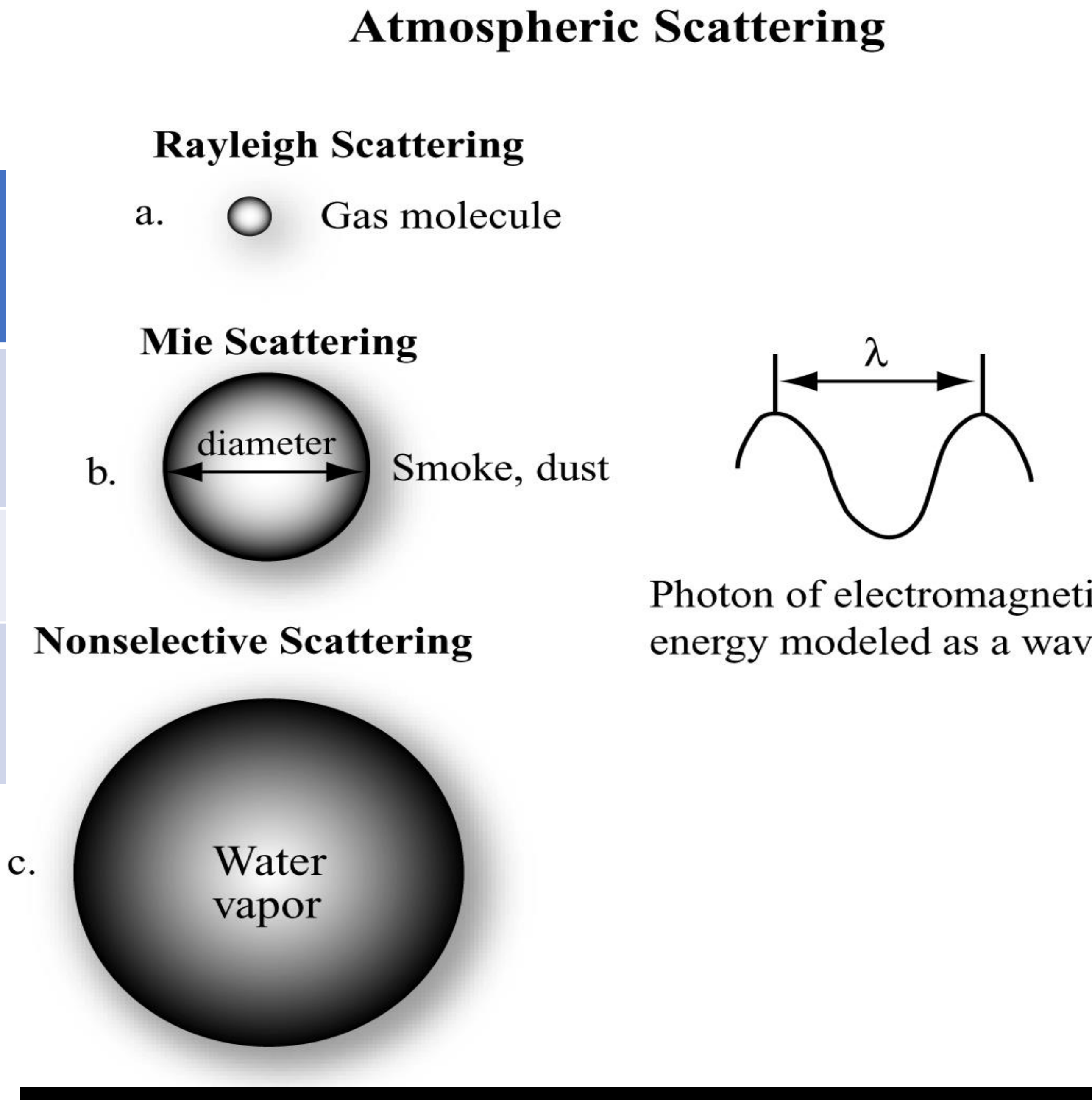
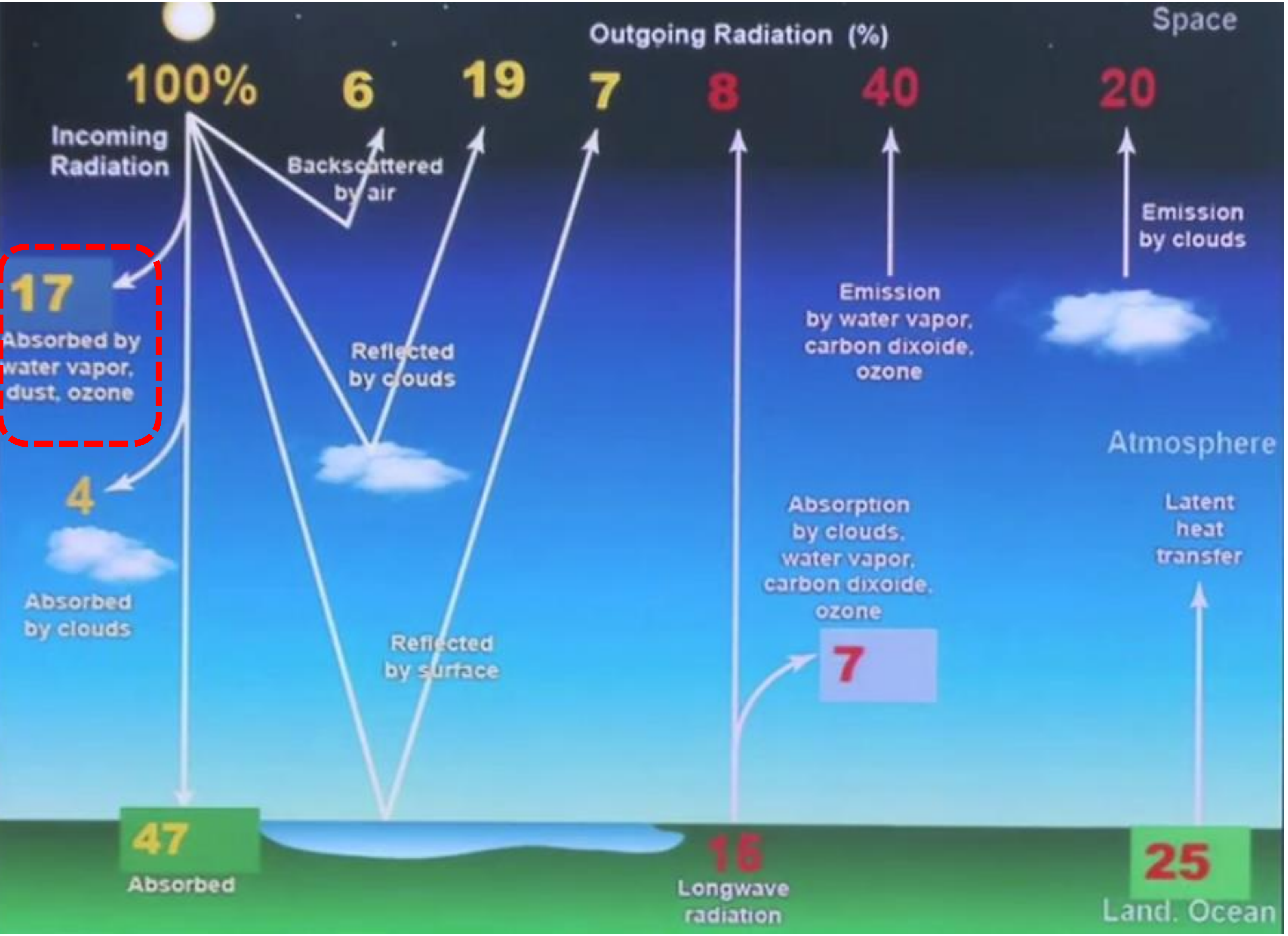
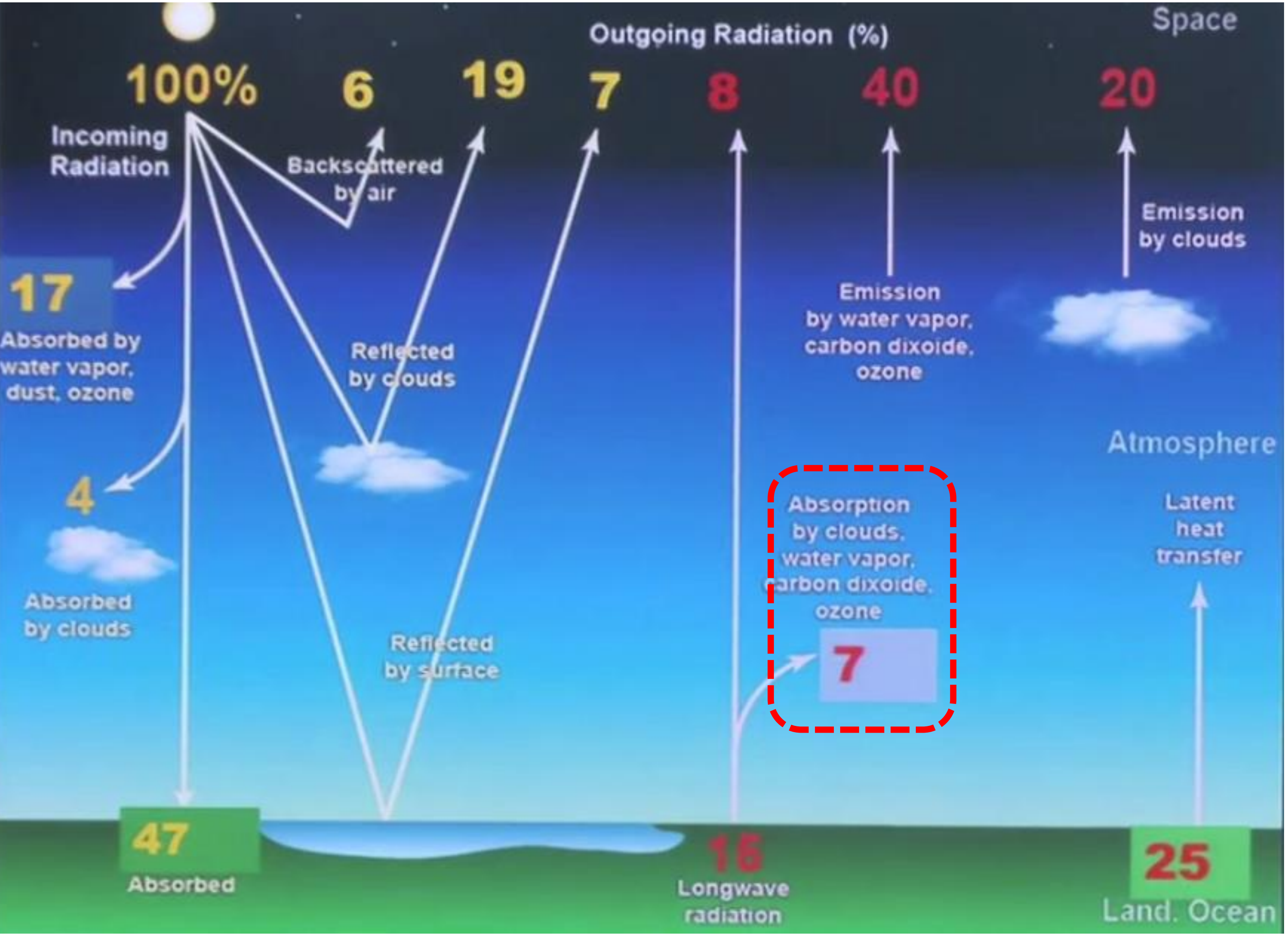


Absorption

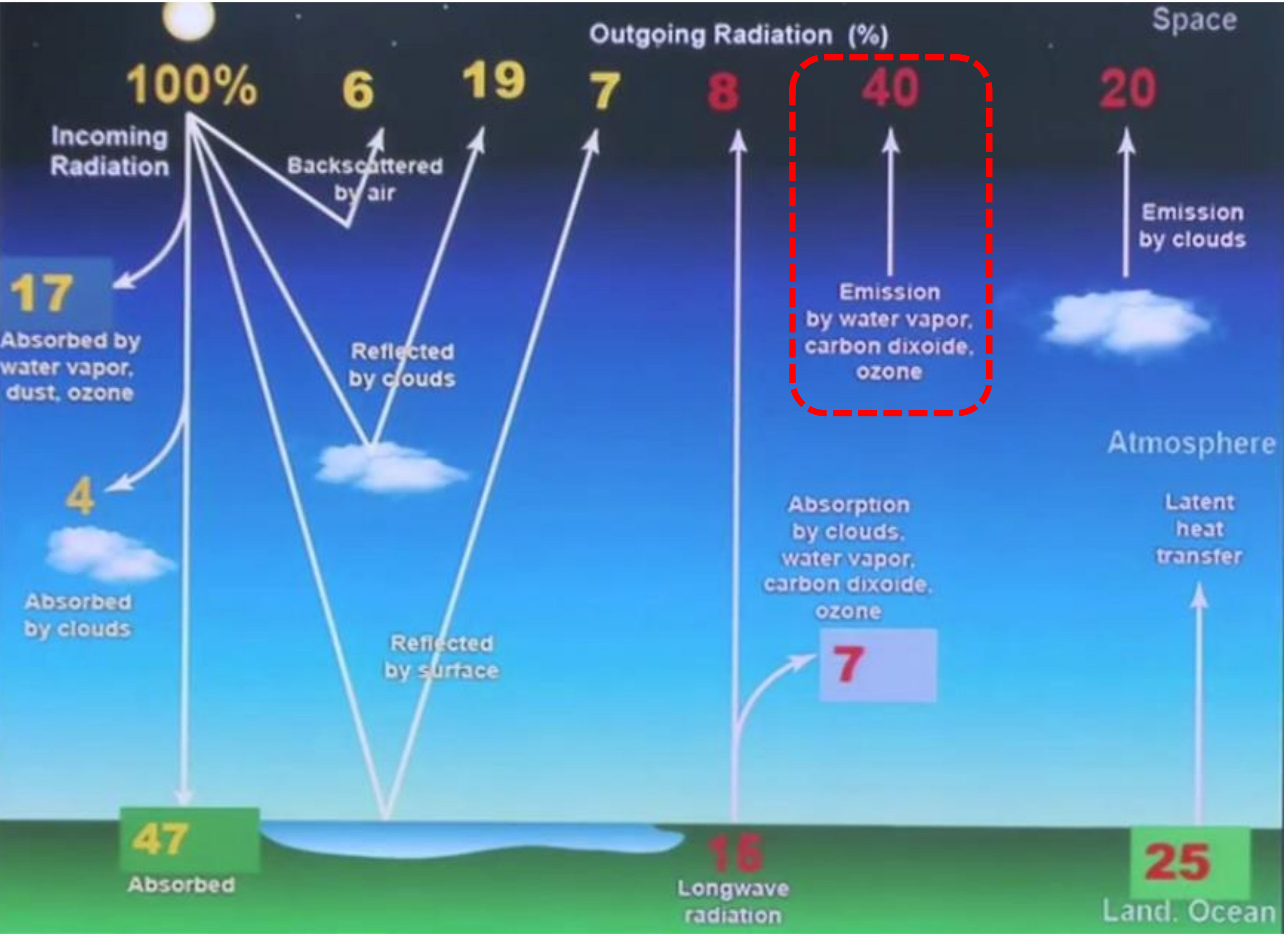
Absorption



- ✓ Absorption is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere.
- ✓ In contrast to scattering, this phenomenon causes molecular in the atmosphere to absorb energy at various wavelengths.
- ✓ **Ozone, carbon dioxide and water vapor** are the three main atmospheric constituents which absorb radiation.
- ✓ Ozone serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. without this protective layer in the atmosphere our skin would burn when exposed to sun light.

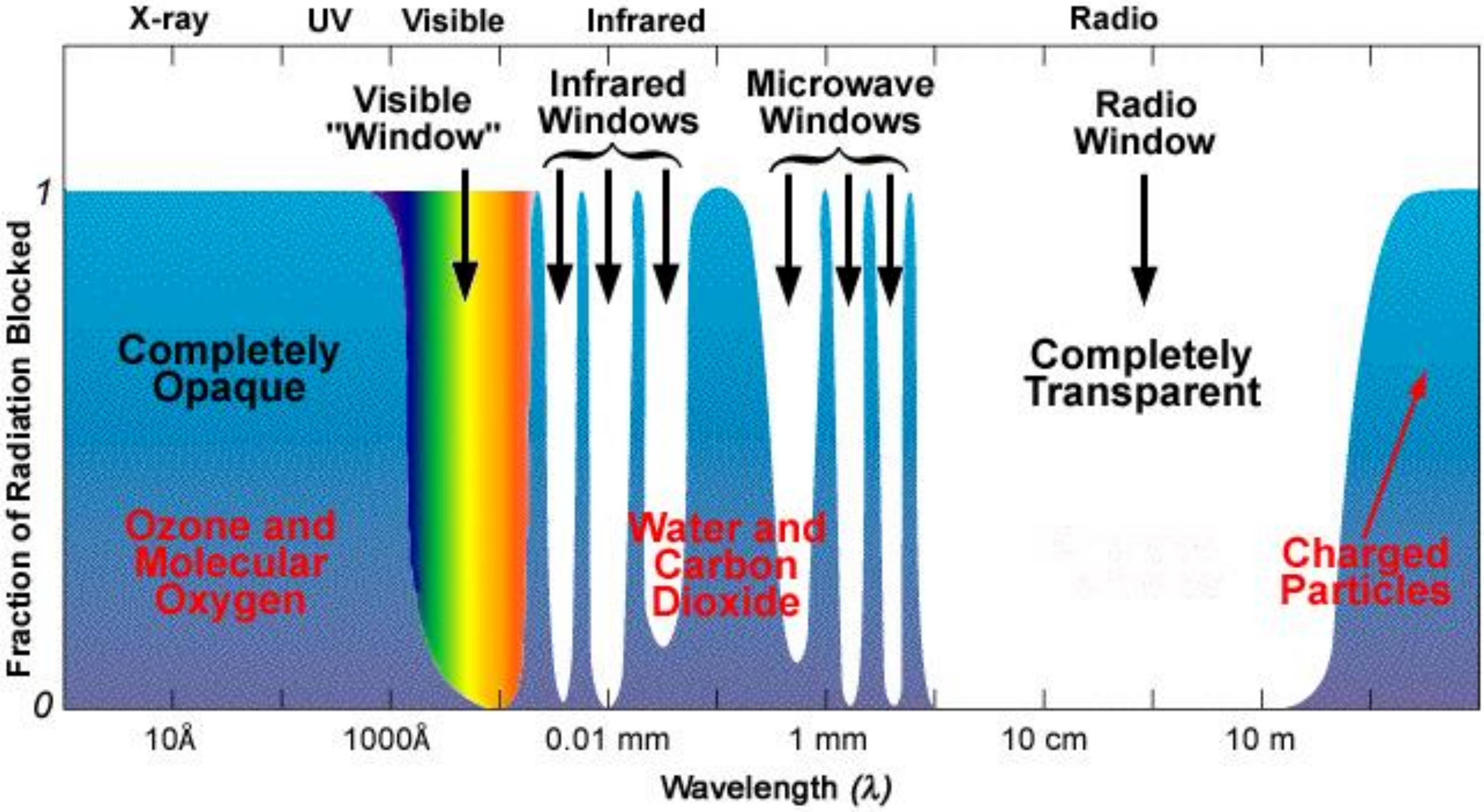


- ✓ Carbon dioxide referred to as a **greenhouse gas**.
- ✓ This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum that area associated with thermal heating which serves to trap this heat inside the atmosphere.

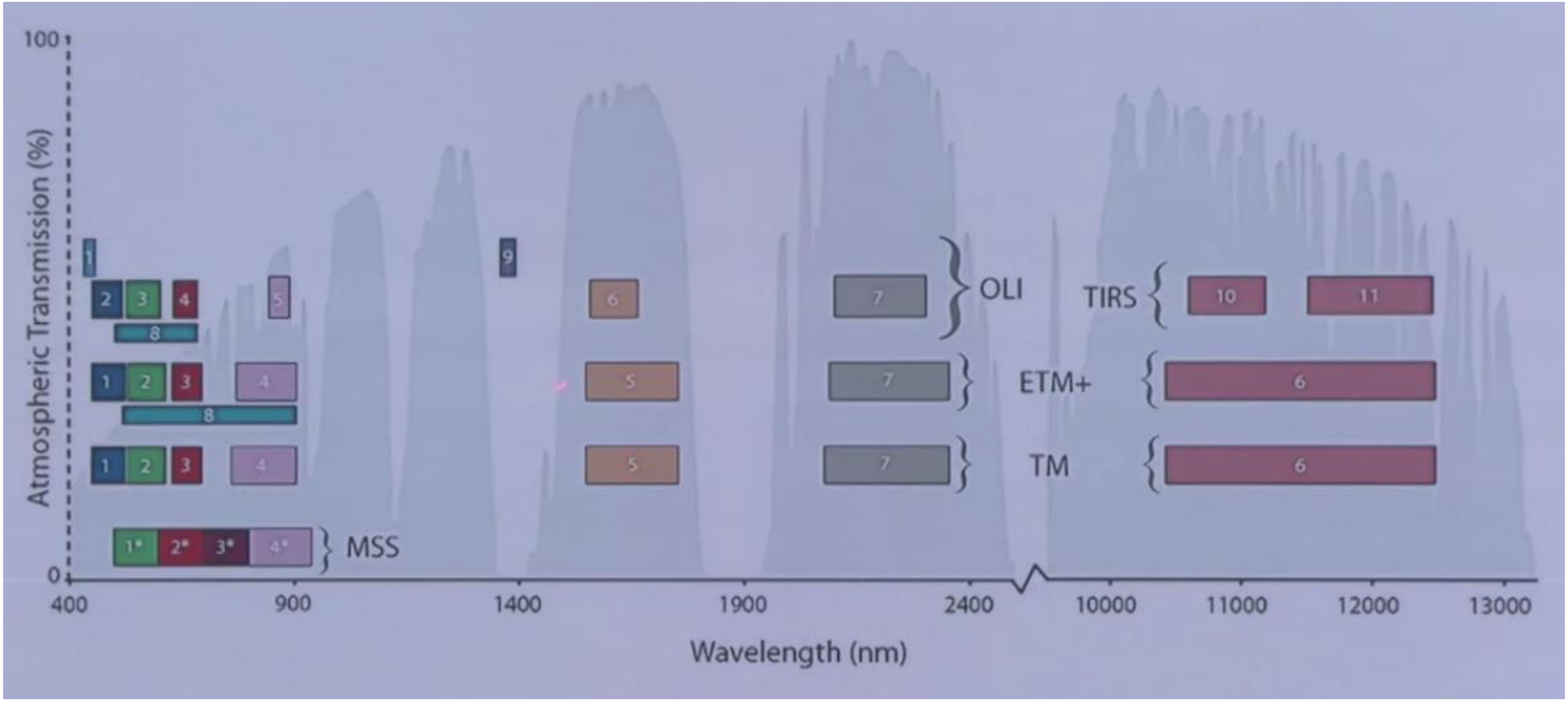


- ✓ Water vapor in the atmosphere absorbs much of the incoming and outgoing shortwave infrared and longwave microwave radiation (between 22 micrometer and 1 meter)
- ✓ The presence of water vapor in the lower atmosphere varies greatly from location to location and at different times of the year.
- ✓ For example, the air mass above a desert would have very light water vapor to absorb energy, while the tropics would have high concentrations of water vapor (i.e. high humidity).
- ✓ Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can look for remote sensing.

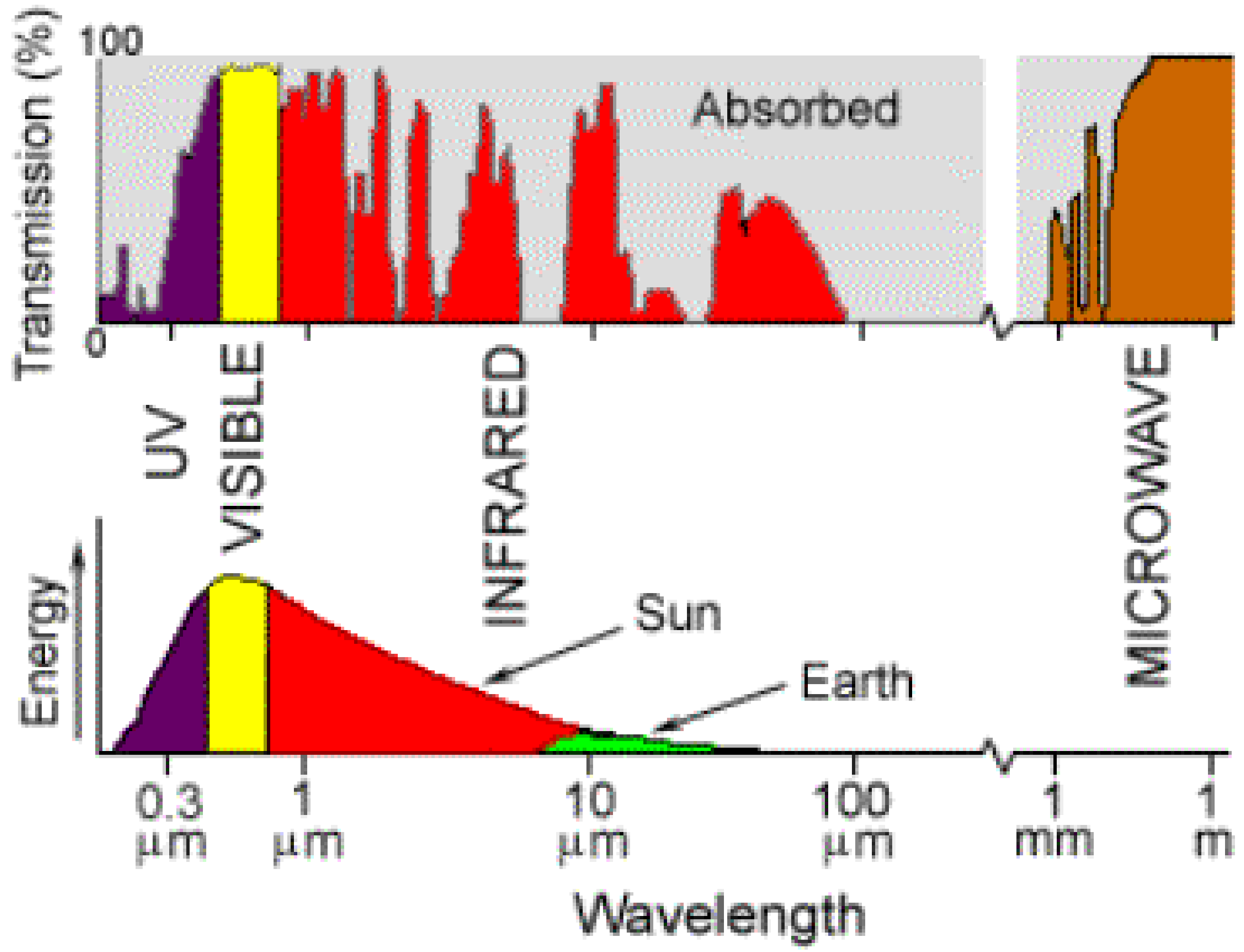
Atmospheric Window



Comparison of Landsat MSS, TM, ETM+ and L8 OLI TIRS Bands



Atmospheric Window

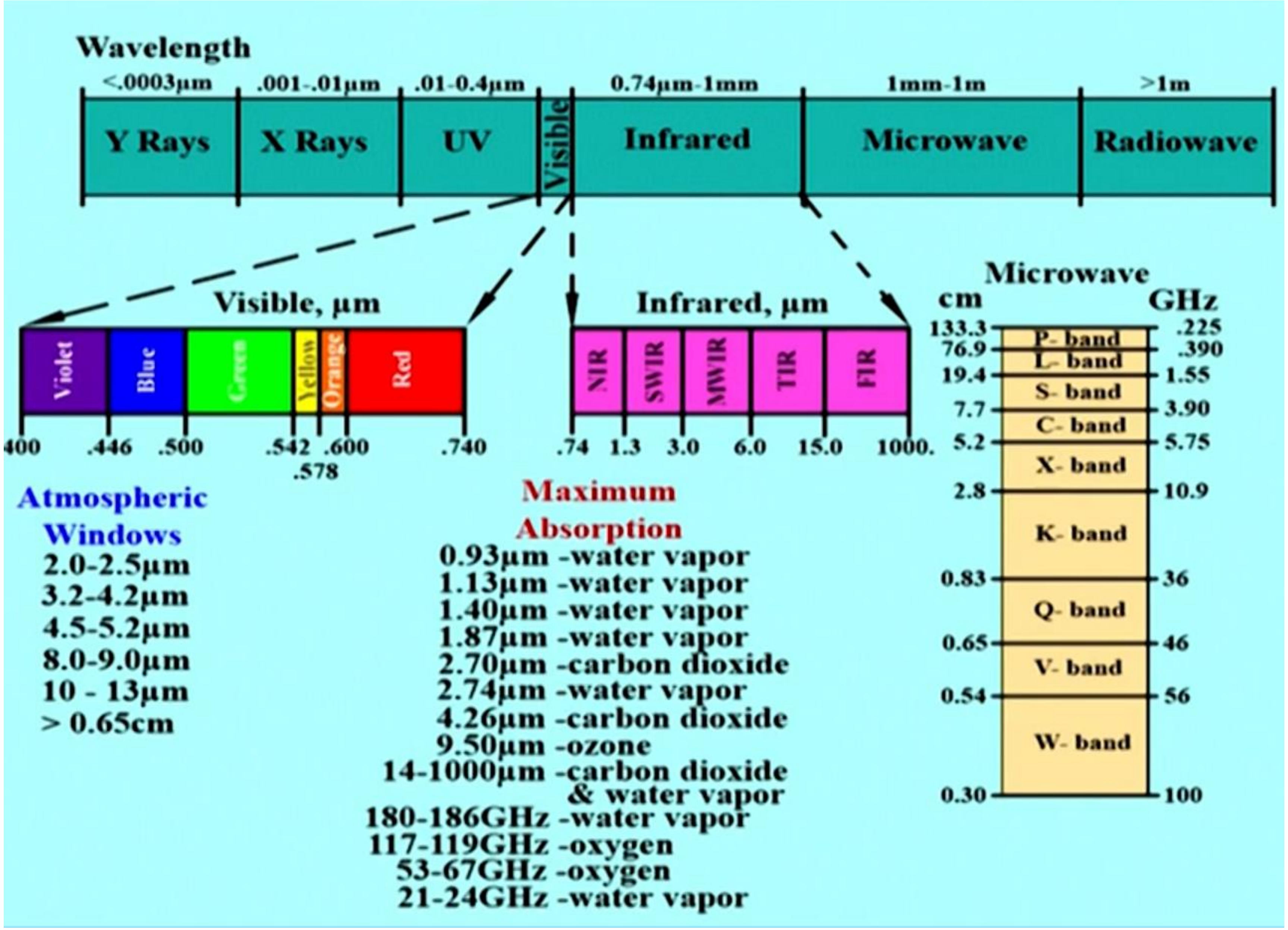


- ✓ Parts of the spectrum which are not severely influenced by atmospheric absorption are useful to remote sensors, are called atmospheric window.

- ✓ The visible portion of the spectrum to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun.

- ✓ Energy emitted by the earth corresponds to a window around 10 micrometer in the thermal IR portion of the spectrum.

- ✓ The large window at wavelength beyond 1 mm is associated with the microwave region.



Wavelength
<.0003µm
.001-.01µm
.01-0.4µm
0.74µm-1mm
1mm-1m
>1m
Y Rays
X Rays
UV
Visible
Infrared
Microwave
Radiowave
Visible, µm
Violet
Blue
Green
Yellow
Orange
Red
400
.446
.500
.542
.578
.600
.740
Infrared, µm
NIR
SWIR
MWIR
TIR
FIR
.74
1.3
3.0
6.0
15.0
1000.
Microwave
cm
GHz
133.3
.225
P- band
76.9
.390
L- band
19.4
1.55
S- band
7.7
3.90
C- band
5.2
5.75
X- band
2.8
10.9
K- band
0.83
36
Q- band
0.65
46
V- band
0.54
56
W- band
0.30
100
Atmospheric Windows
2.0-2.5µm
3.2-4.2µm
4.5-5.2µm
8.0-9.0µm
10 - 13µm
> 0.65cm
Maximum Absorption
0.93µm -water vapor
1.13µm -water vapor
1.40µm -water vapor
1.87µm -water vapor
2.70µm -carbon dioxide
2.74µm -water vapor
4.26µm -carbon dioxide
9.50µm -ozone
14-1000µm -carbon dioxide & water vapor
180-186GHz -water vapor
117-119GHz -oxygen
53-67GHz -oxygen
21-24GHz -water vapor