

# **COURSE: SATELLITE IMAGE PROCESSING**

## **LECTURE 5 – Radiometric Resolution and Correction**

Lecturer: Dr. Tingneyuc Sekac, Ph.D. PNG University of Technology

# Radiometric Information and Resolution

Some remote sensing systems record the:

- reflected,
- emitted, or
- back-scattered

electromagnetic radiation with more precision than other sensing systems

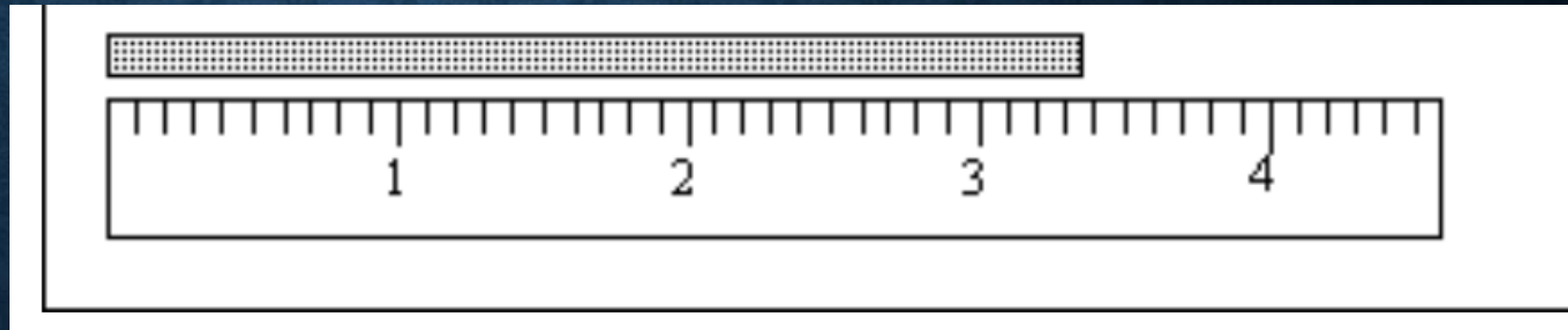
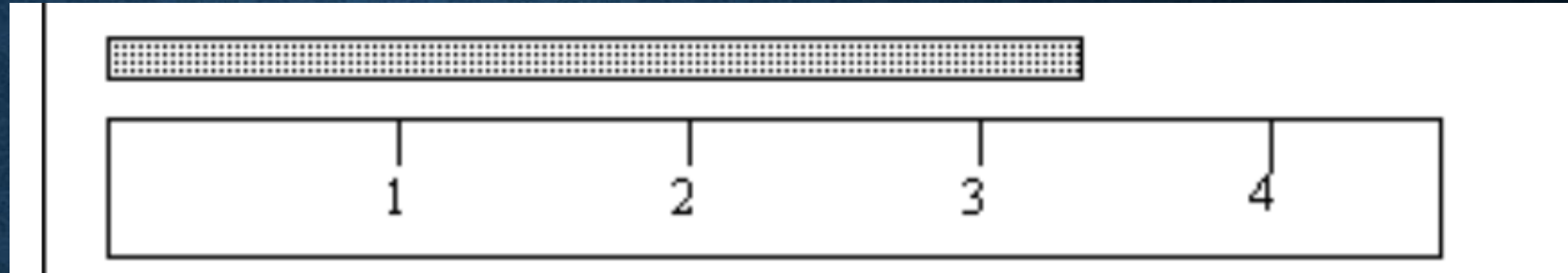
# Radiometric Information and Resolution

If you want precisely to measure the length of an object, would you rather use a ruler with 16 or 1,024 subdivisions on it

.....????.....

# Radiometric Information and Resolution

- ❑ On a ruler with a coarse scale, the rod is between 3 and 4 cm, and we estimate it to be about 3.3 cm.
- ❑ The instrument's least count is 1cm
- ❑ On a ruler with a fine scale, the rod is between 3.3 and 3.4 cm, and we estimate it to be about 3.38 cm.
- ❑ The instrument's least count is 0.1cm

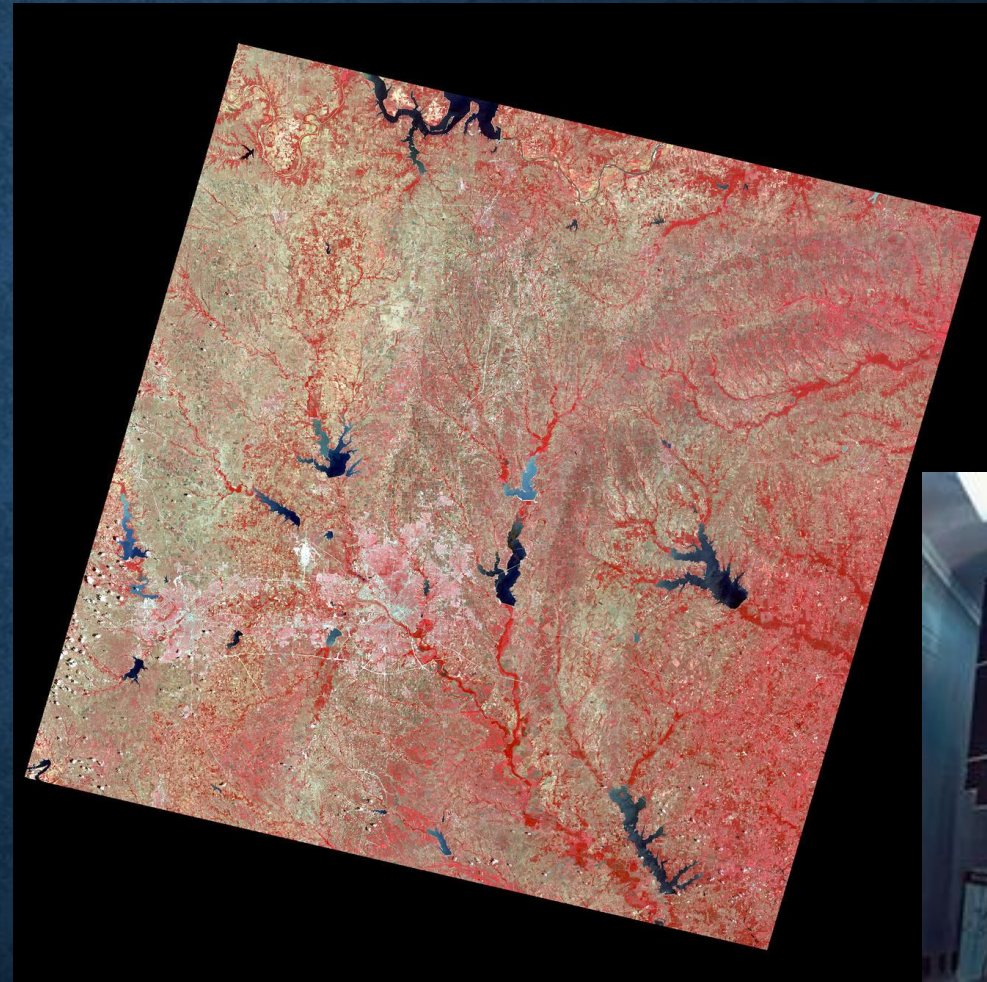


# Radiometric Information and Resolution

- Radiometric resolution is defined as the sensitivity of a remote sensing detector to differences in signal strength as it records the radiant flux;
  - reflected,
  - emitted, or
  - back-scattered from the terrain
  
- It defines the number of just discriminable signal levels.
  
- Therefore, radiometric resolution can have a significant impact on our ability to measure the properties of scene objects.

# Radiometric Information and Resolution

- ❑ The Landsat 1 Multispectral Scanner launched in 1972 recorded reflected energy with a precision of 6-bits (values ranging from 0 to 63).
- ❑ Landsat 4 and 5 Thematic Mapper sensors launched in 1982 and 1984, respectively, recorded data in 8-bits (values from 0 to 255).



Landsat 1 image



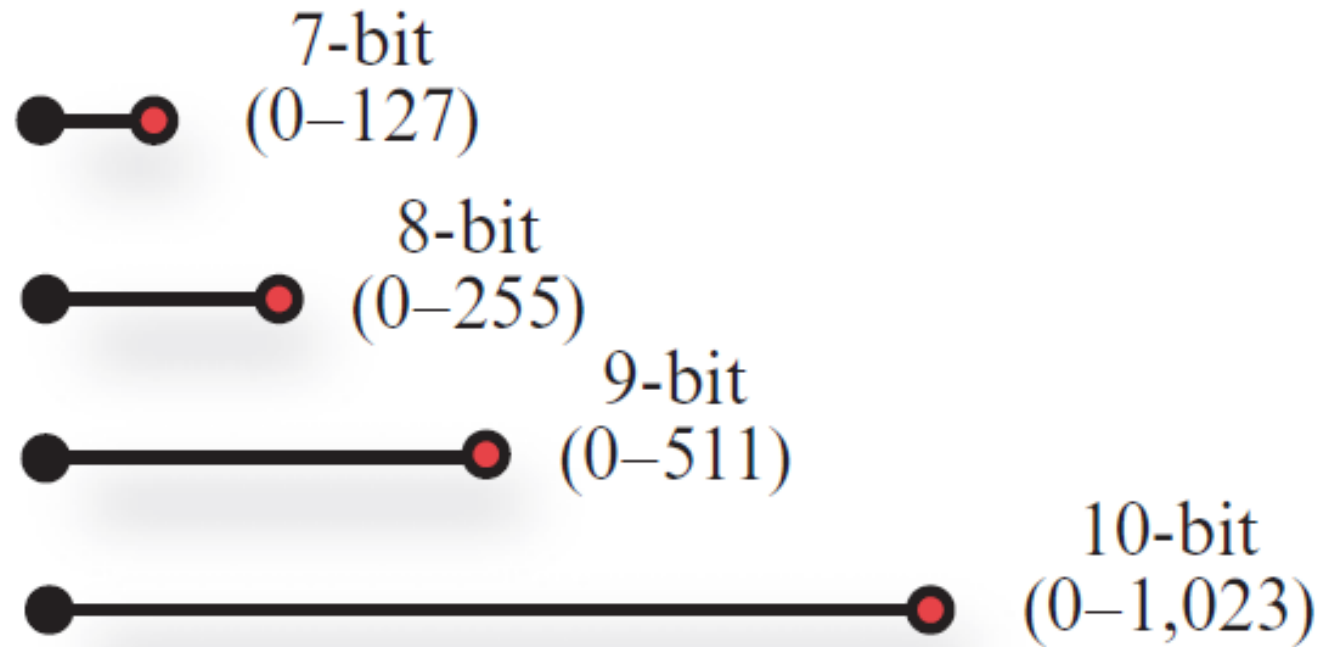
Landsat 1 Satellite

# Radiometric Information and Resolution

- ❑ GeoEye-1 and WorldView-2 sensors record information in 11-bits (values from 0 to 2,047).
- ❑ Several new sensor systems have 12-bit radiometric resolution (values ranging from 0 to 4,095).
- ❑ Radiometric resolution is sometimes referred to as the **level of quantization**.
- ❑ High radiometric resolution generally increases the probability that phenomena will be remotely sensed more accurately.

# Radiometric Information and Resolution

## Radiometric Resolution



# Radiometric Correction

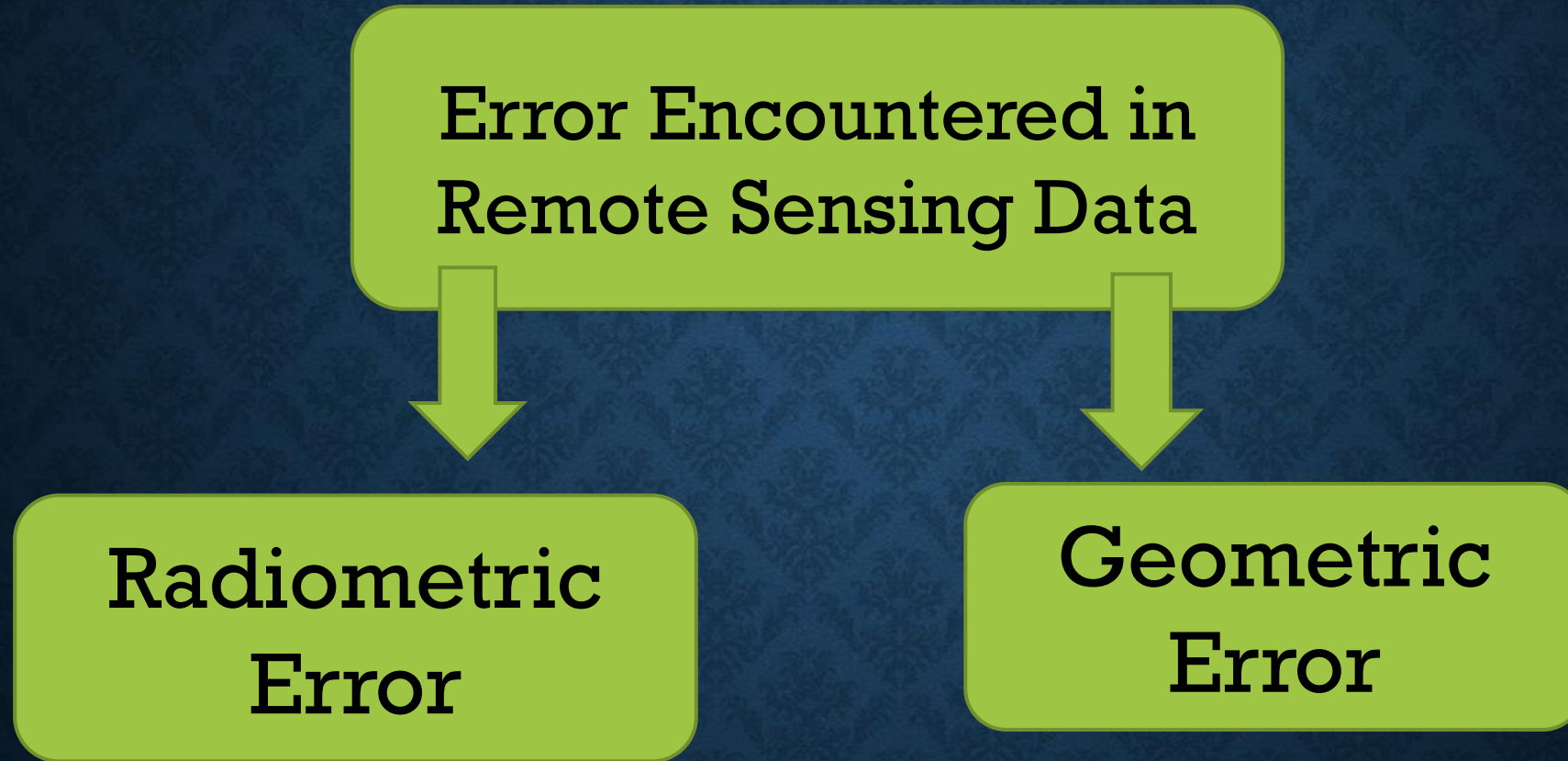


❑ Landsat-7 ETM+ scene

❑ The top right image is the atmospherically corrected scene employing a haze removal over land and water.

❑ The haze removal over water is one of the new features of the 2011 release.

# Radiometric and Geometric Error



# Radiometric and Geometric Correction

- Radiometric correction is concerned with improving the accuracy of surface spectral reflectance, emittance, or back-scattered measurements obtained using a remote sensing system

Source: (Johannsen and Daughtry, 2009; San and Suzen, 2010).

# Radiometric and Geometric Correction

- Geometric correction is concerned with placing the reflected, emitted, or back-scattered measurements or derivative products in their proper planimetric (map) location.

# Radiometric Correction Concept

Radiometric Correction

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graph TD; A[Radiometric Correction] --> B[Electromagnetic Radiation Principles]; B --> C[Atmospheric]; B --> D[Topography/Slope/Aspect]; C --> E[Reflectance Characteristics of the Scene]; D --> E;
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Electromagnetic Radiation Principles

Atmospheric

Topography/Slope/Aspect

Reflectance Characteristics of the Scene

# Electromagnetic Radiation Principles

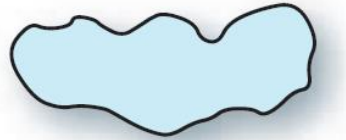
## Energy Transfer

### Conduction



a.

### Convection



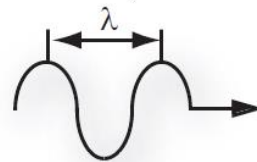
Pulse of warm air

Terrain

b.

Pan in contact with burner

### Radiation



Electromagnetic wave



Earth (not to scale)

c.

Sun (not to scale)



Energy may be transferred in three ways :

- ✓ conduction,
- ✓ convection ,
- ✓ radiation .

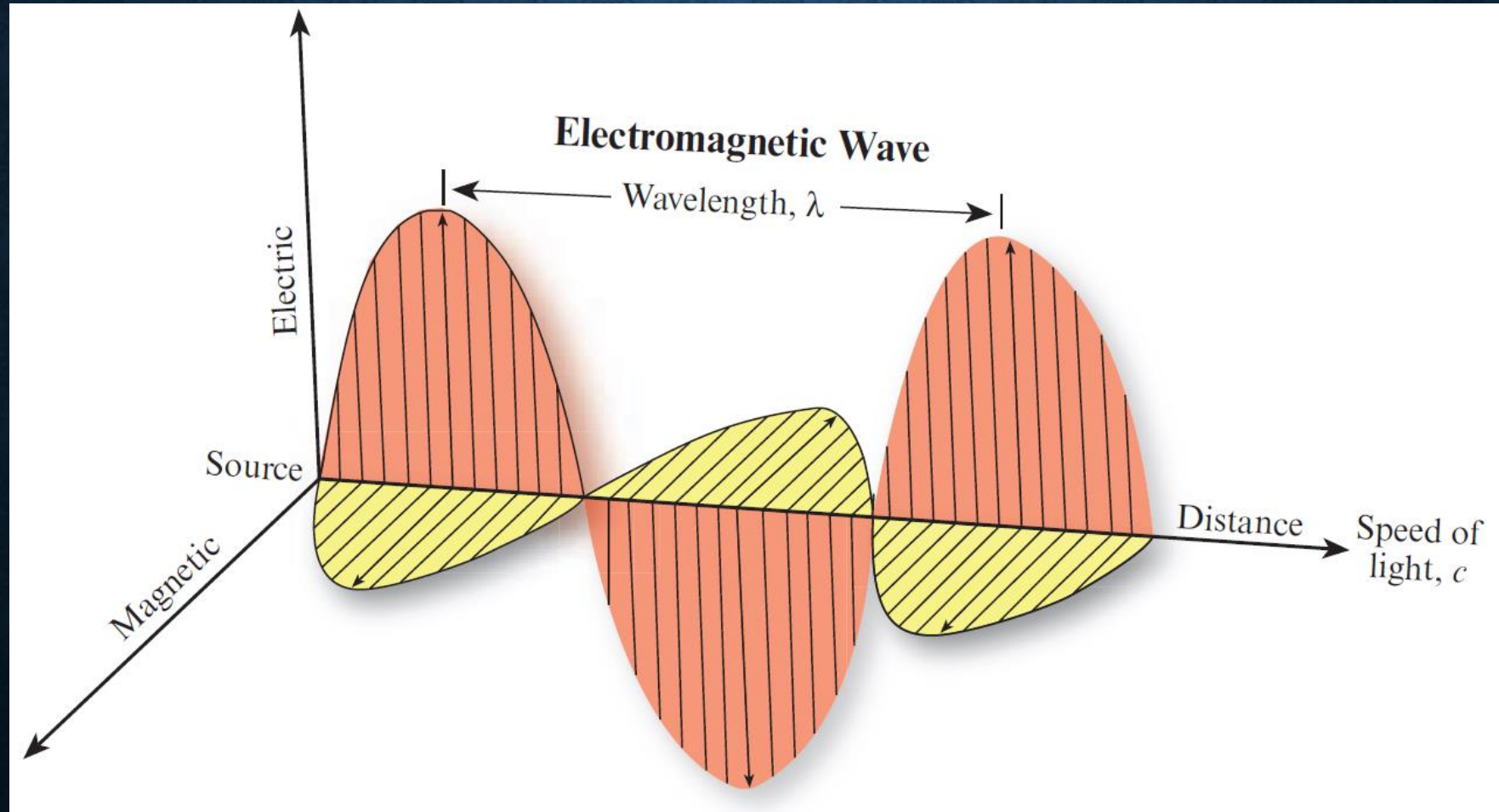
# Electromagnetic Radiation Principles

For example, if the energy being remotely sensed comes from the Sun, the energy:

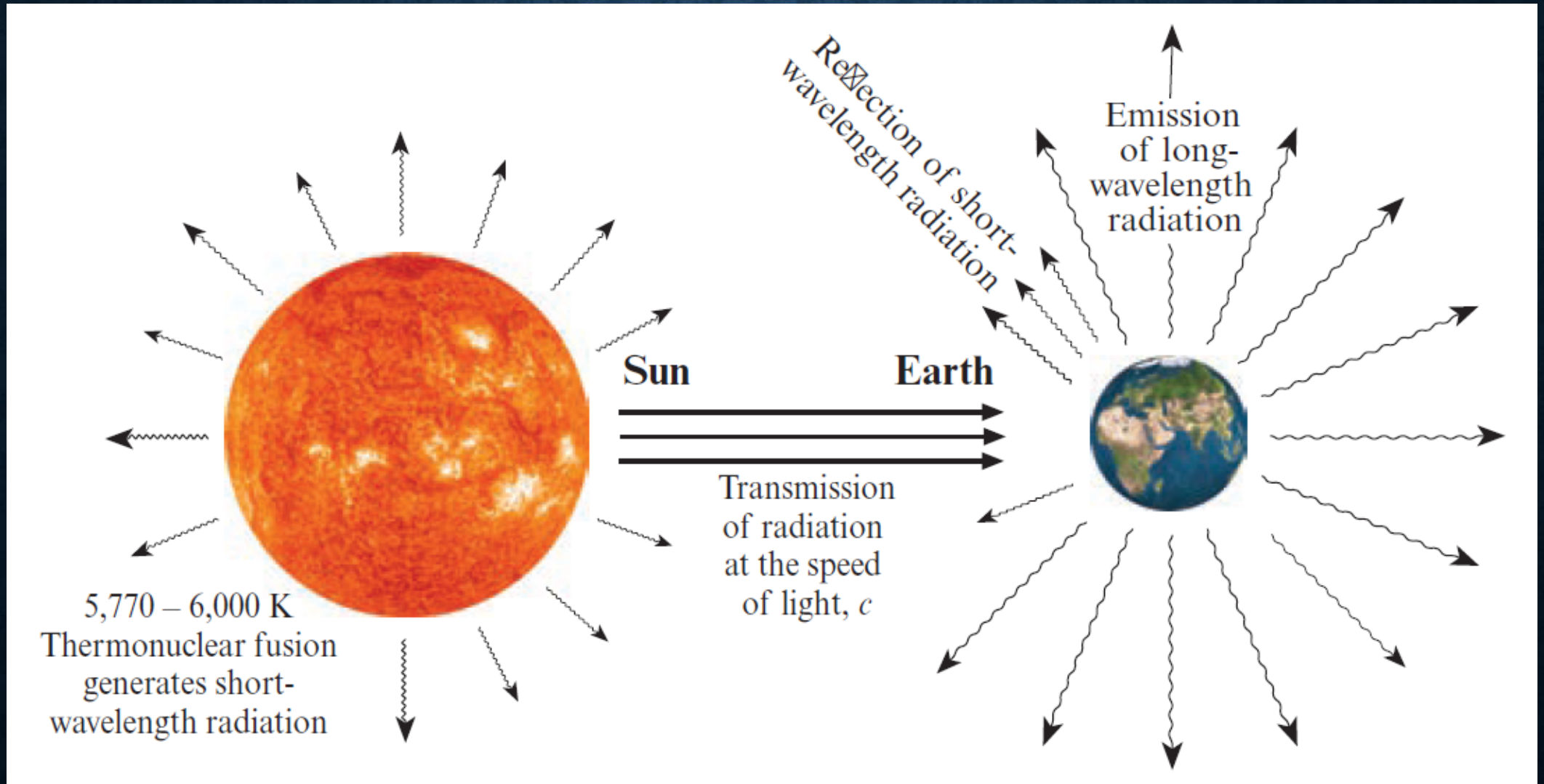
- is radiated by atomic particles at the source (the Sun),
- travels through the vacuum of space at the speed of light,
- interacts with the Earth's atmosphere,
- interacts with the Earth's surface,
- interacts with the Earth's atmosphere once again, and
- finally reaches the remote sensing system, where it interacts with various optics, filters, film emulsions, or detectors.

# Electromagnetic Radiation Principles

For example, if the energy being remotely sensed comes from the Sun, the energy:



# Electromagnetic Radiation Principles



## Wien's displacement law

In principle, the Stefan-Boltzman Law means that the hotter a body the higher the radiant existence from a body.

The spectral (wavelength) peak of maximum existence also changes as a function of temperature and is given by **Wien's displacement law**:

Where  $A$  is a constant of proportionality, called Wien's displacement constant and equals  $2.897\ 768 \times 10^{-3} \text{ m K} = 2.897768 \times 10^6 \text{ nm K} = 2898 \text{ }\mu\text{mK}$ .

$$\lambda_m = \frac{A}{T}$$

**Key point:** the temperature of a body is a major control on the amount of radiance emitted from a surface.

# Wavelength Determination

$$0.483 \mu\text{m} = \frac{2,898 \mu\text{m K}}{6,000 \text{ K}} .$$

$$9.66 \mu\text{m} = \frac{2,898 \mu\text{m K}}{300 \text{ K}} .$$

# Atmospheric Energy – Matter Interactions

1. Refraction

2. Scattering

3. Absorption

4. Reflectance

# Atmospheric Energy – Matter Interactions

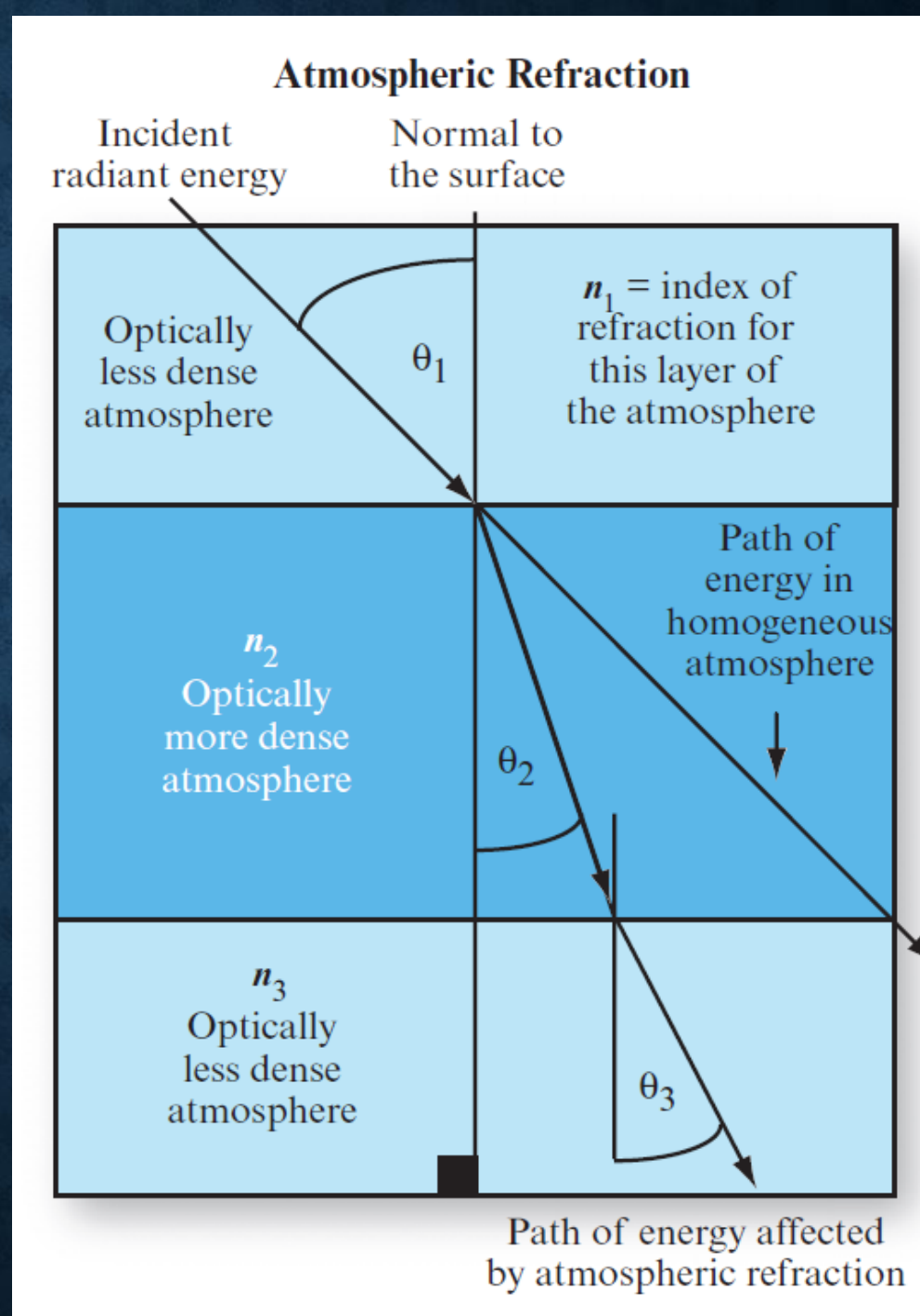
Once electromagnetic radiation is generated, it is propagated through the Earth's atmosphere almost at the speed of light in a vacuum.

Unlike a vacuum in which nothing happens, however, the atmosphere affect:

- speed of radiation
- wavelength,
- intensity,
- spectral distribution.

# Atmospheric Energy – Matter Interactions: Refraction

- ❑ The speed of light ( $c$ ) in a vacuum is  $3 \times 10^8$  m/s.
- ❑ Refraction takes place when EMR encounters substances of different density, like air and water.
- ❑ The index of refraction ( $n$ ) is a measure of the optical density of a substance.
- ❑ This index is the ratio of the speed of light in a vacuum,  $c$ , to the speed of light in a substance such as the atmosphere or water,  $cn$ :



# Atmospheric Energy – Matter Interactions: Refraction

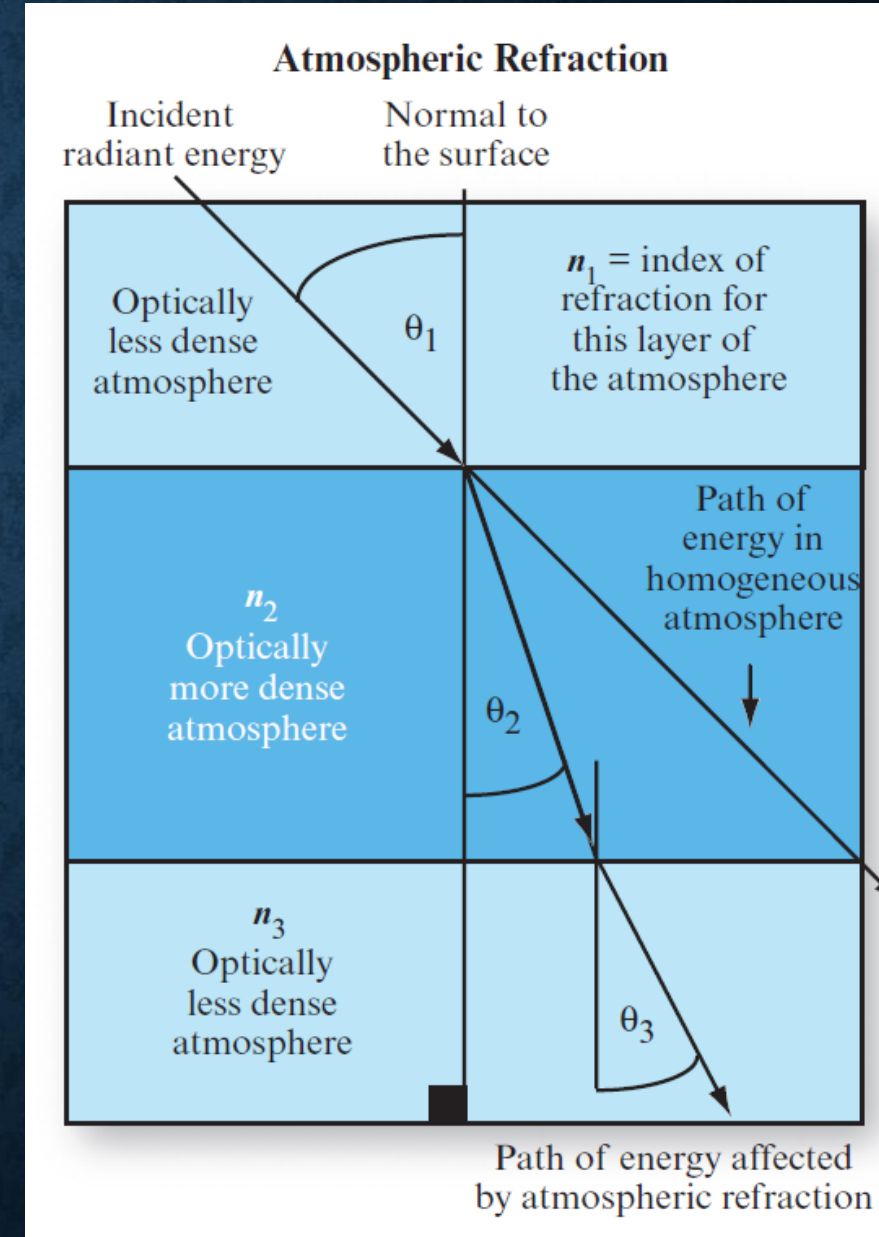
- The speed of light in a substance can never reach the speed of light in a vacuum. Therefore, its index of refraction must always be greater than 1.

$$n = \frac{c}{c_n}$$

- Ex: Index of refraction for the atmosphere is 1.0 and 1.33 for water.
- Light travels more slowly through water because of water's higher density.

# Atmospheric Energy – Matter Interactions: Refraction

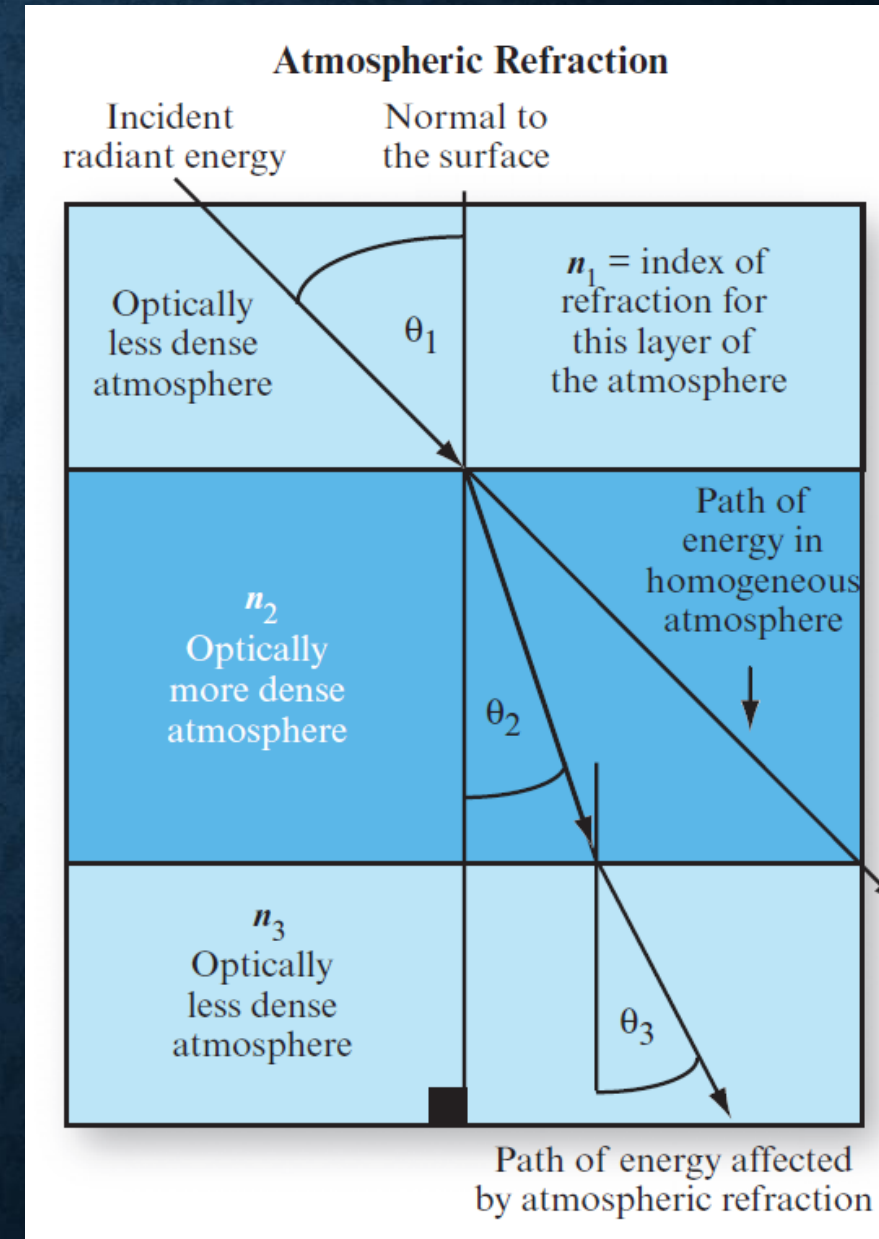
- ❑ Refraction in three non-turbulent atmospheric layers
- ❑ Snell's law can be used to predict how much bending will take place, based on a knowledge of the:
  1. Angle of Incidence ( $\theta$ ) and
  2. the index of refraction at each atmospheric layer ( $n_1, n_2, n_3$ )



# Atmospheric Energy – Matter Interactions: Refraction

The amount of refraction is a function of the;

- angle made with the vertical ( $\theta$ ),
- the distance involved
- and the density of the air involved

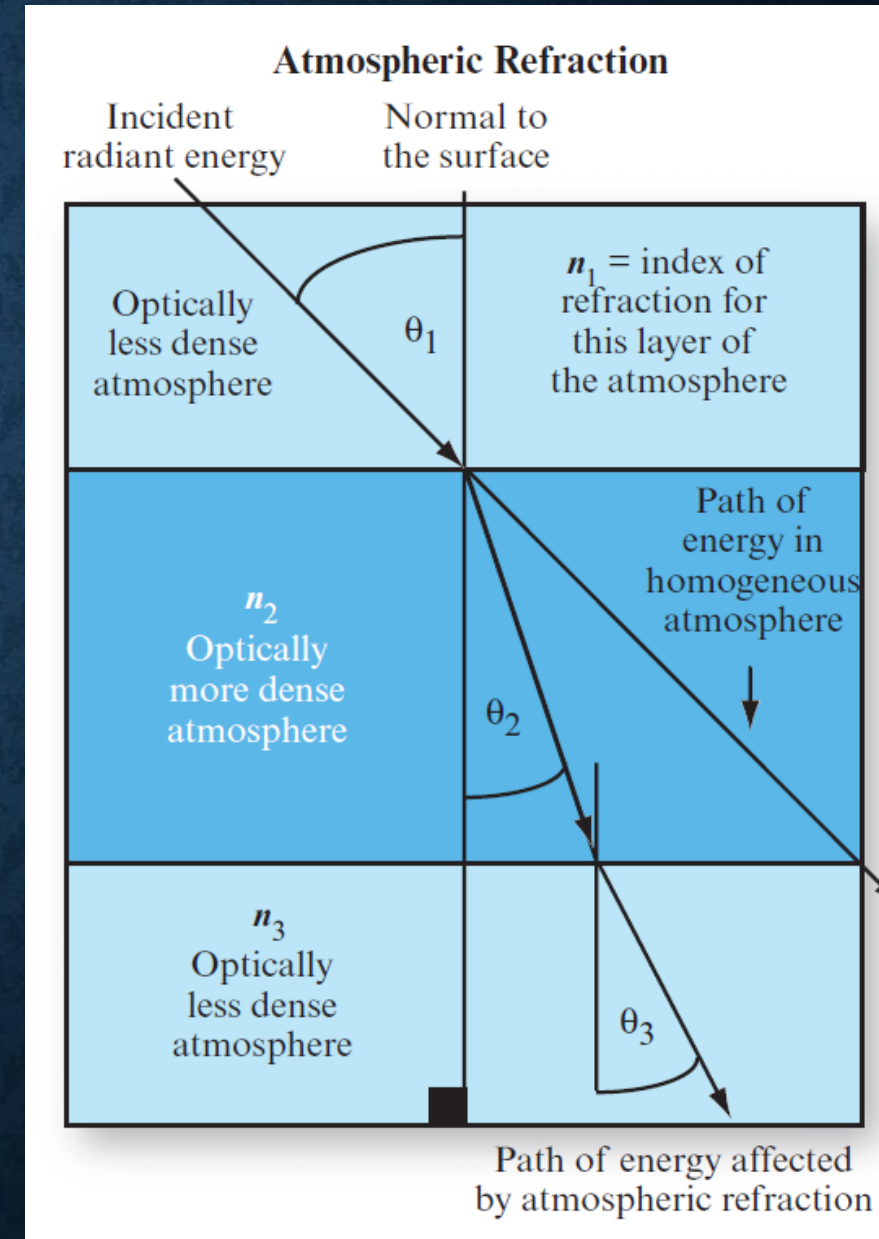


# Atmospheric Energy – Matter Interactions: Errors

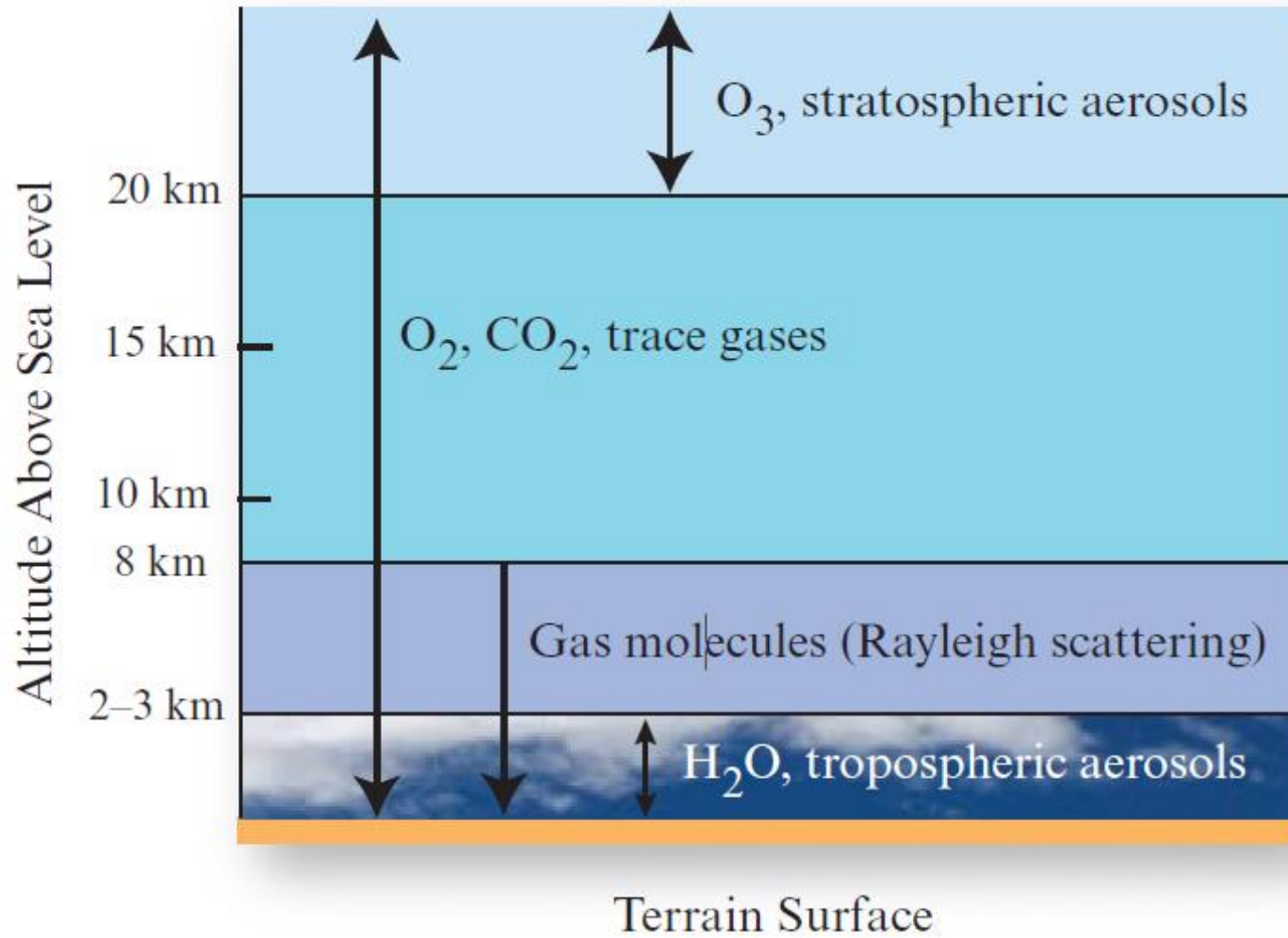
- ❑ Serious errors in location due to refraction can occur in images formed from energy detected at high altitudes or acute angles.
- ❑ However, these location errors are predictable by Snell's law and thus can be removed:

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

Knowing the index of refraction and angle of incidence – possible to Predict amount of refraction ( $\sin \theta_2$ ) that will take place.



# Atmospheric Layers and Constituents



Major subdivision of the atmosphere and the types of molecules and aerosols found in each layer


# Atmospheric Scattering

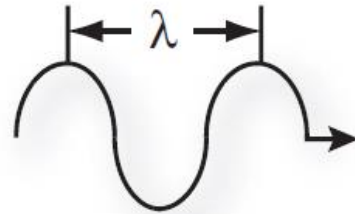
## Atmospheric Scattering

### Rayleigh Scattering

a.  Gas molecule


### Mie Scattering

b.  Smoke, dust



Photon of electromagnetic energy modeled as a wave

### Nonselective Scattering

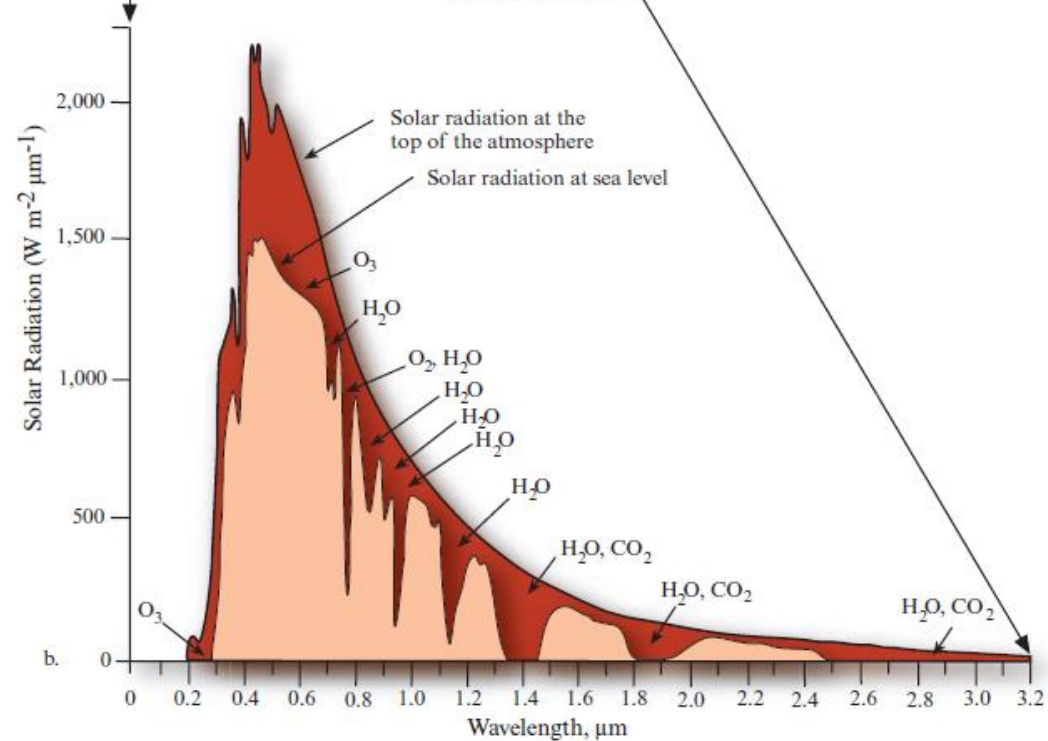
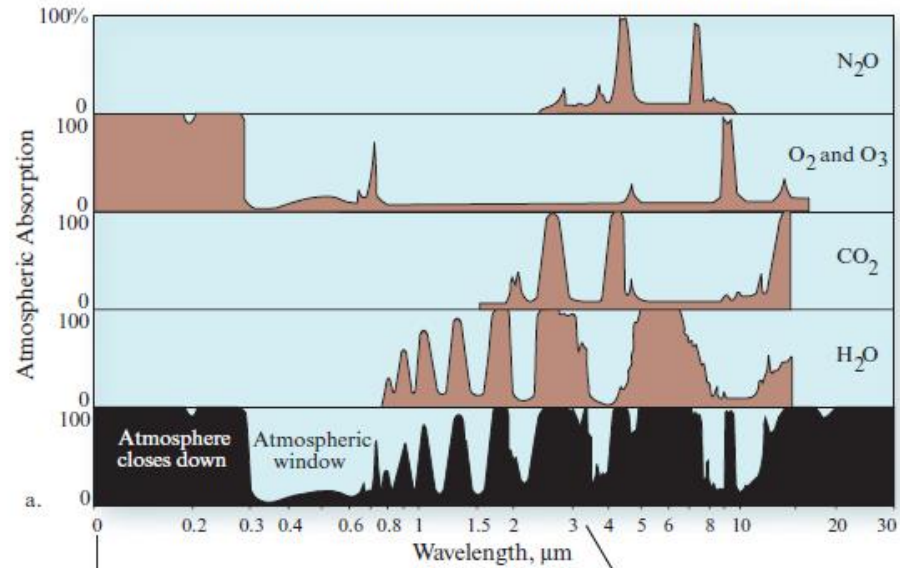
c.  Water vapor

Type of scattering is a function of;

1. The wavelength of the incident radiant energy
2. The size of the gas molecule, dust particle, and/or
3. Water vapor droplet encountered.

# Absorption Bands

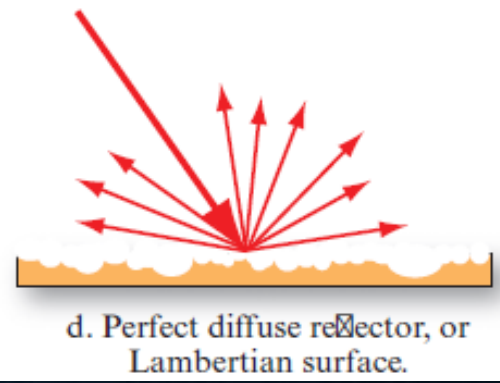
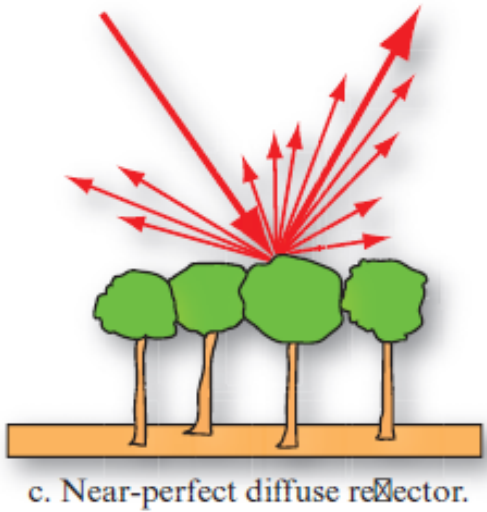
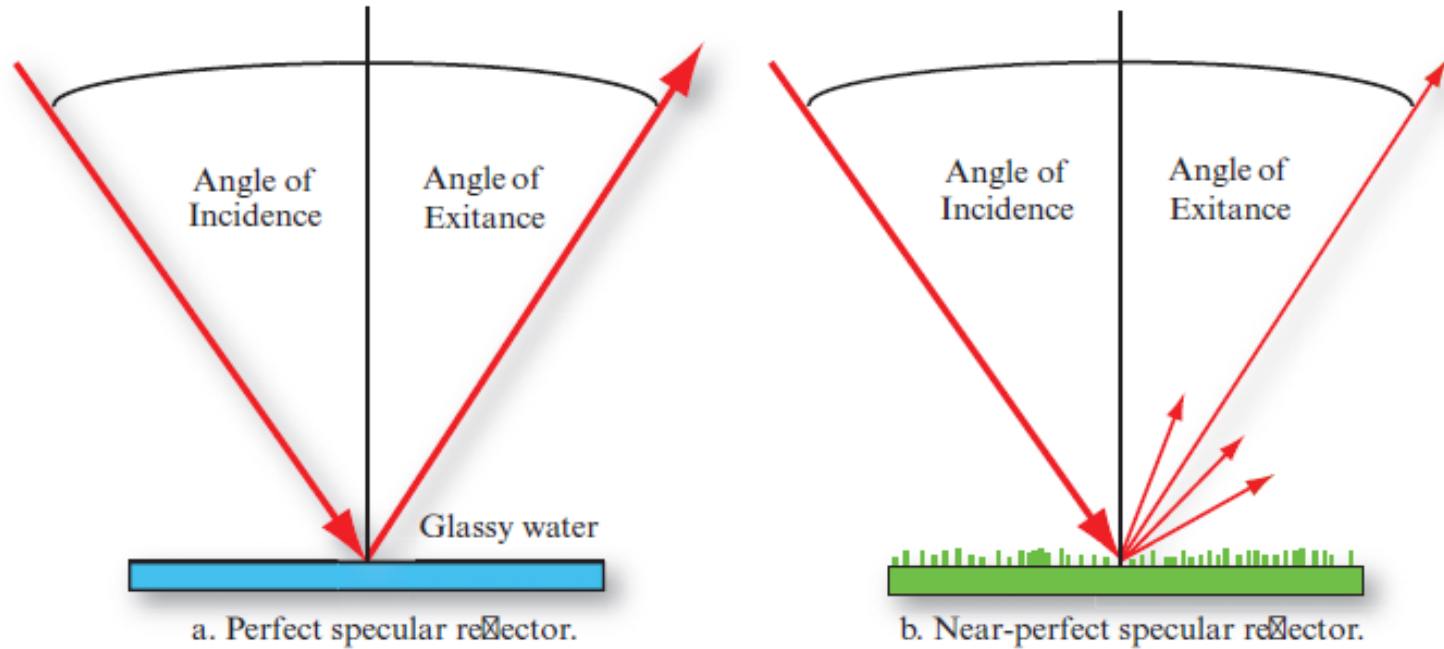
Absorption of the Sun's Incident Electromagnetic Energy in the Region from 0.1 to 30  $\mu\text{m}$  by Various Atmospheric Gases



# Radiation Reflectance

The nature of specular and diffuse reflectance

## Specular versus Diffuse Reflectance



# References:

R.Richter and D.Schlapfer, (2012), Atmospheric/Topographic Correction for Satellite Imagery (ATCOR-2/3UserGuide, Version8.2BETA. Retrieve: [https://www.dlr.de/eoc/en/Portaldata/60/Resources/dokumente/5\\_tech\\_mod/atcor3\\_manual\\_2012.pdf](https://www.dlr.de/eoc/en/Portaldata/60/Resources/dokumente/5_tech_mod/atcor3_manual_2012.pdf)

Jensen, John R., 2015- Introductory digital image processing : a remote sensing perspective / John R. Jensen, University of South Carolina. pages cm. -- (Pearson series in geographic information science) 4<sup>th</sup> ed.