GEO 827 – Digital Image Processing and Analysis DIPA

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Lecture: T & Th: 5:20 – 6:10pm; RM. GEO 201

Lab: T & Th: 7:00–8:50pm; RM GEO 201

Assistants

- Class introduction
- Name, Program/Major

Class Objectives

- To learn technical skills and analytical methods
- To be able to apply these skills and methods in your research
- To find and download EOS data (e.g. Landsat, MODIS products, etc)
- Data processing chains
- Value-added products (Surface reflectance, vegetation indices, classified images, cloud screening of long term data records (ltdr), etc.)

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- **Grading Policy:**

• Lab Exercises	50
• Midterm Exam	20
• Final Exam	30
Total	100

A:90-100; **B**:80-89; **C**:70-79; **D**:60-69; **E**:50-59

Homeworks and labs

- Materials will be mailed
- Lab exercises – Word or pdf or other formats are acceptable
- Send homework via email

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- **Text Books and Reference Materials**
  - J. R. Jensen, “Introductory Digital Image Processing – A remote sensing perspective”, 4th ed. Prentice Hall, 2015, ISBN-10: 013405816X • ISBN-13: 9780134058160
  - Option to rent from Amazon for $56 (http://www.amazon.com/Introductory-Digital-Image-Processing-Perspective/dp/013405816X)
  - R. A. Schowengerdt, “Remote sensing – Models and Methods for Image Processing”, 3rd ed., Academic Press, 2006
- **Lab Materials**
  - Lab exercises will be based on course materials
- **On Reserve at the library**
  - J. R. Jensen, “Introductory Digital Image Processing – A remote sensing perspective”, 3th ed.,2005

Topics

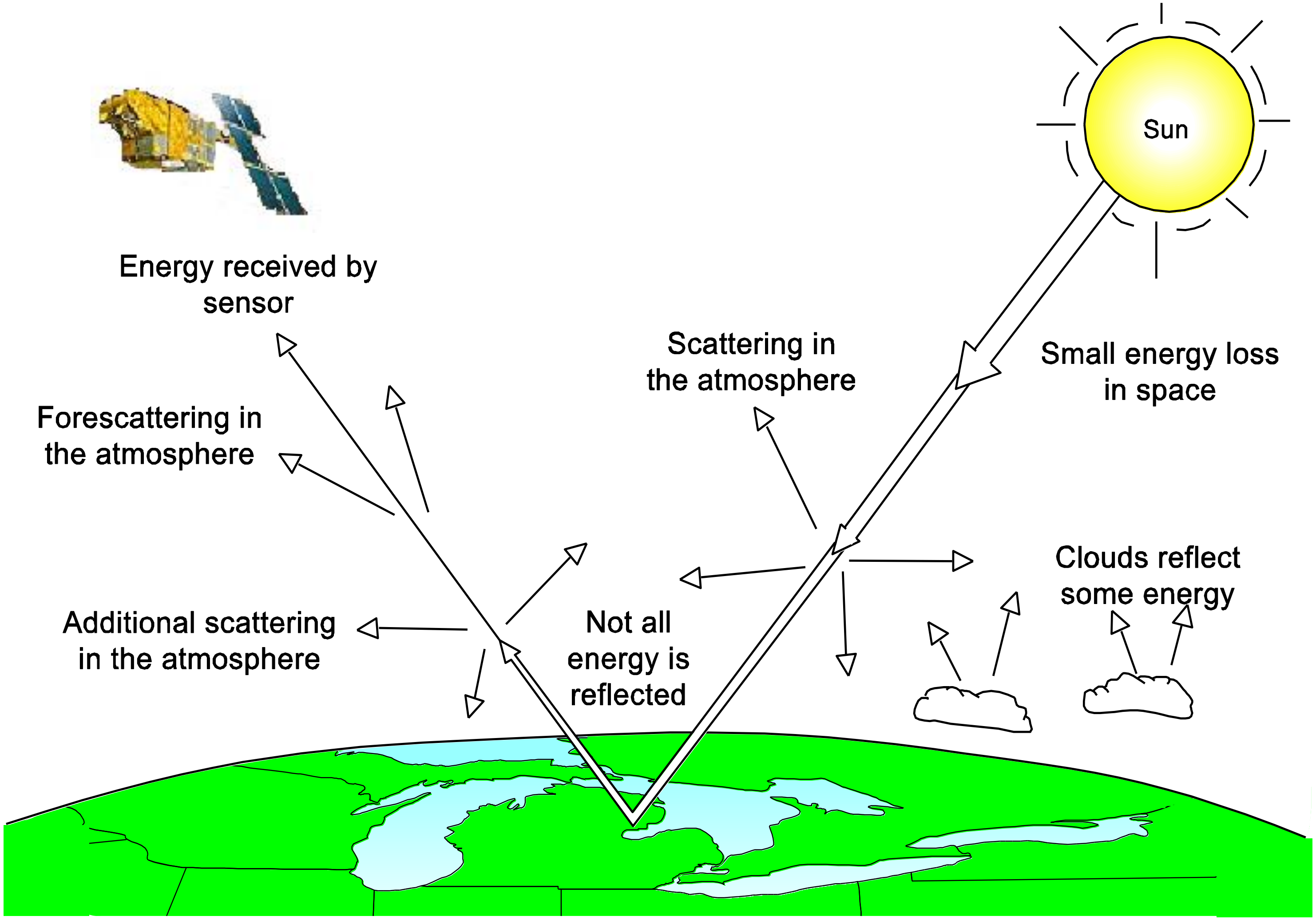
- Review of fundamentals of remote sensing
- Techniques required prior to analysis
  - Raw imagery → Physical units
  - Corrections required (geometric, atmospheric and sun-earth-sensor geometry)
- Methods of analysis
  - Transformation from data to products and information
- Applications

Physical Basis of Remote Sensing

- Remote sensing devices record radiant energy reflected or emitted from surfaces.
- Passive remote sensing imagers record
  1) sunlight reflected from surfaces, or
  2) heat energy radiated from surfaces.
- Active remote sensing imagers irradiate ("illuminate") the landscape and record the amount of this energy that is reflected or scattered from surfaces.

Physical Basis of Remote Sensing

- Typical Energy Flow for passive remote sensing



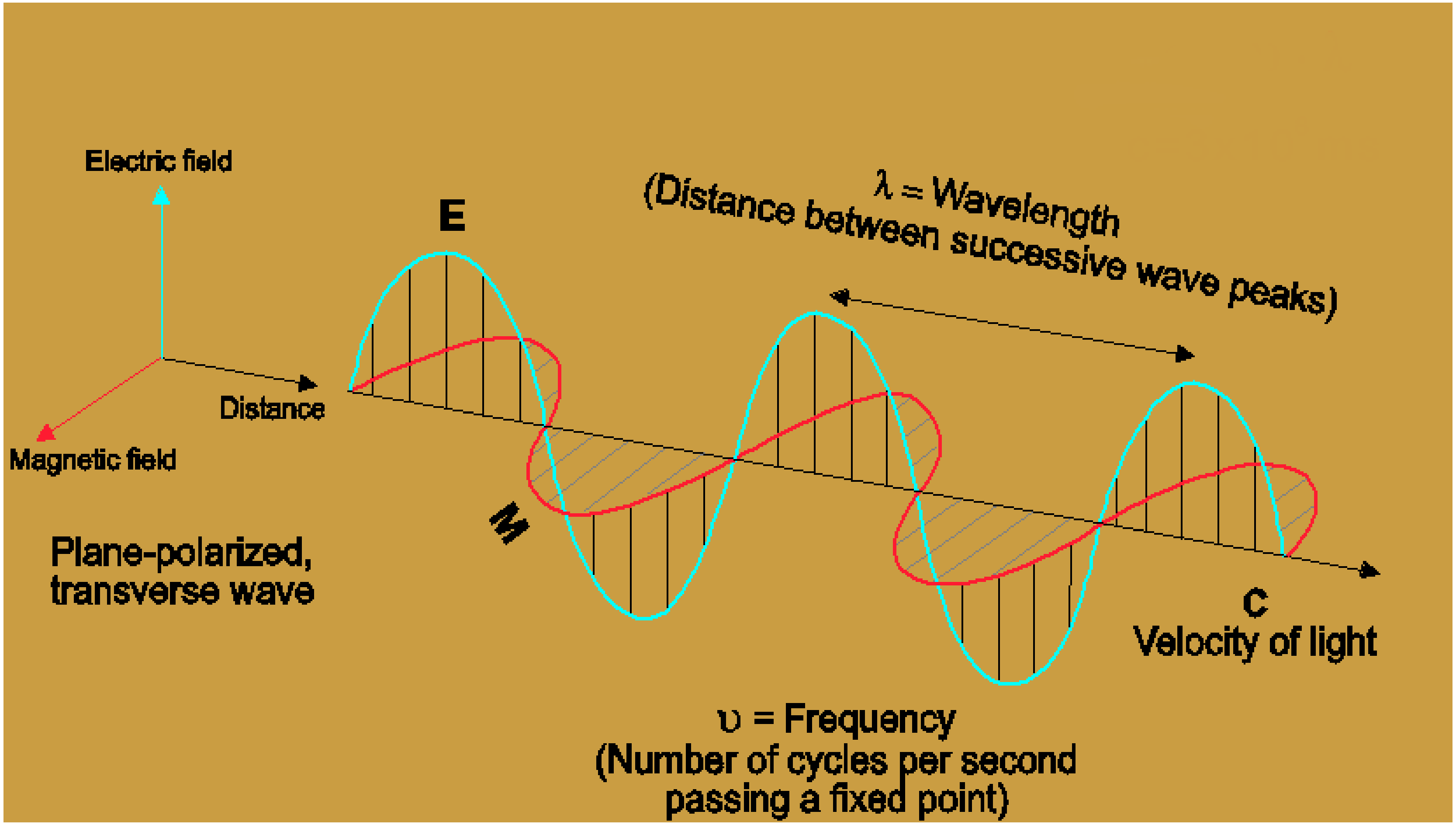
Physical Basis of Remote Sensing

- The radiant energy (electromagnetic radiation) recorded by remote sensing devices includes light (i.e. visible radiant energy), as well as invisible energy.
- Electromagnetic radiation (EMR) is a dynamic form of energy made manifest only by its interaction with matter.
- EMR radiates according to the wave theory.

Physical Basis of Remote Sensing

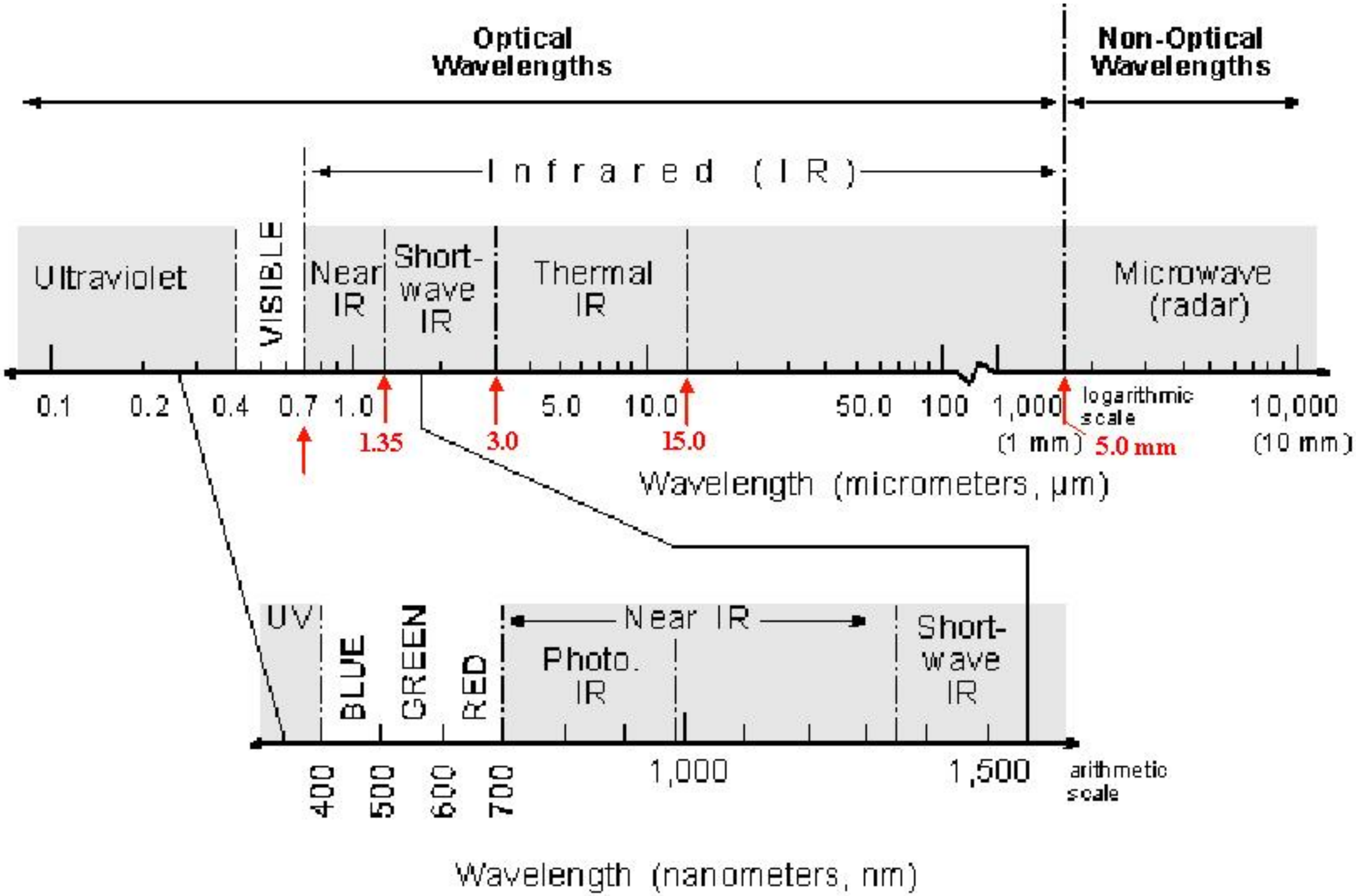
- Maxwell's Wave theory **c = n * l**

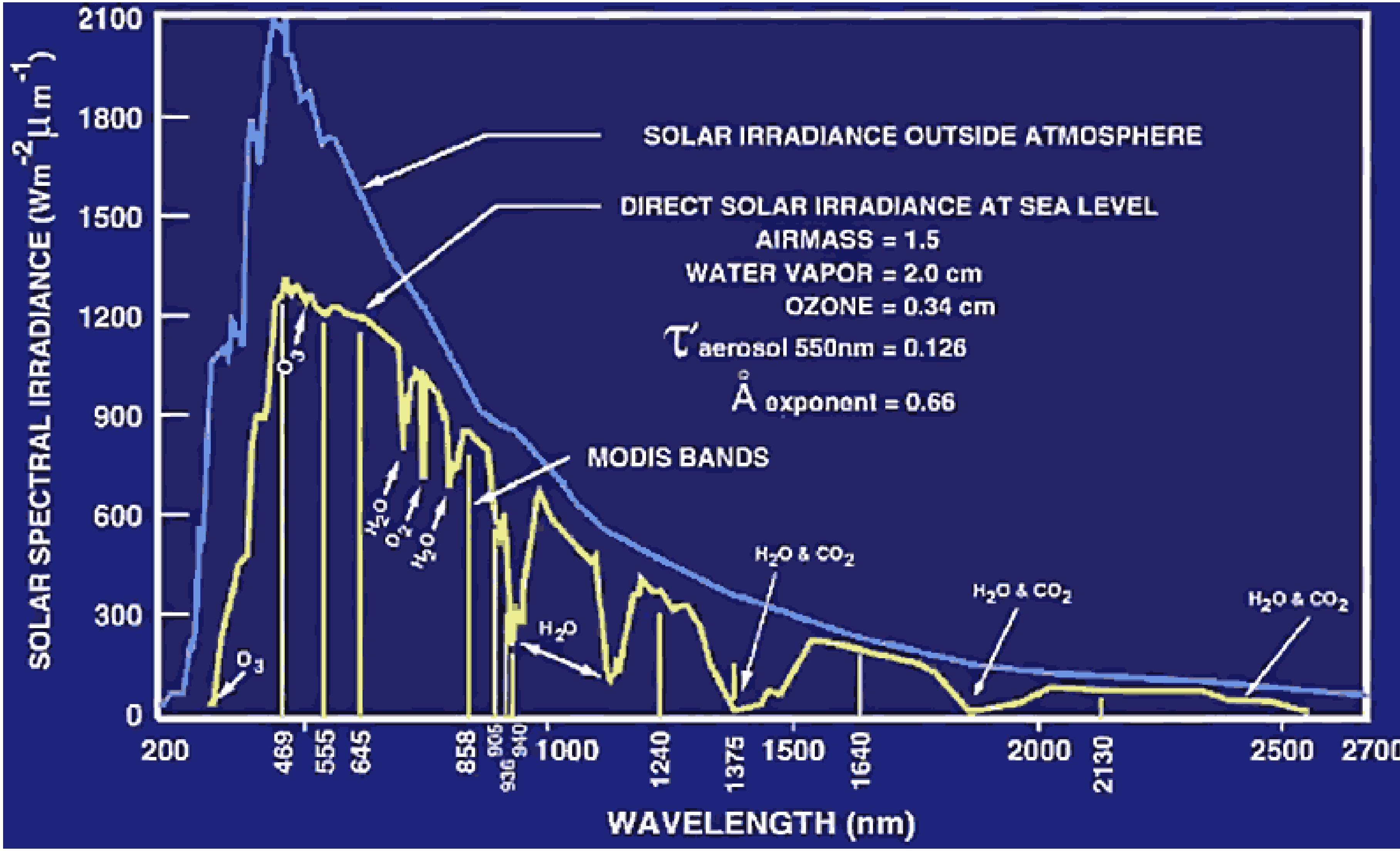
$c = 3 \times 10^{8}$ m s^{-1}



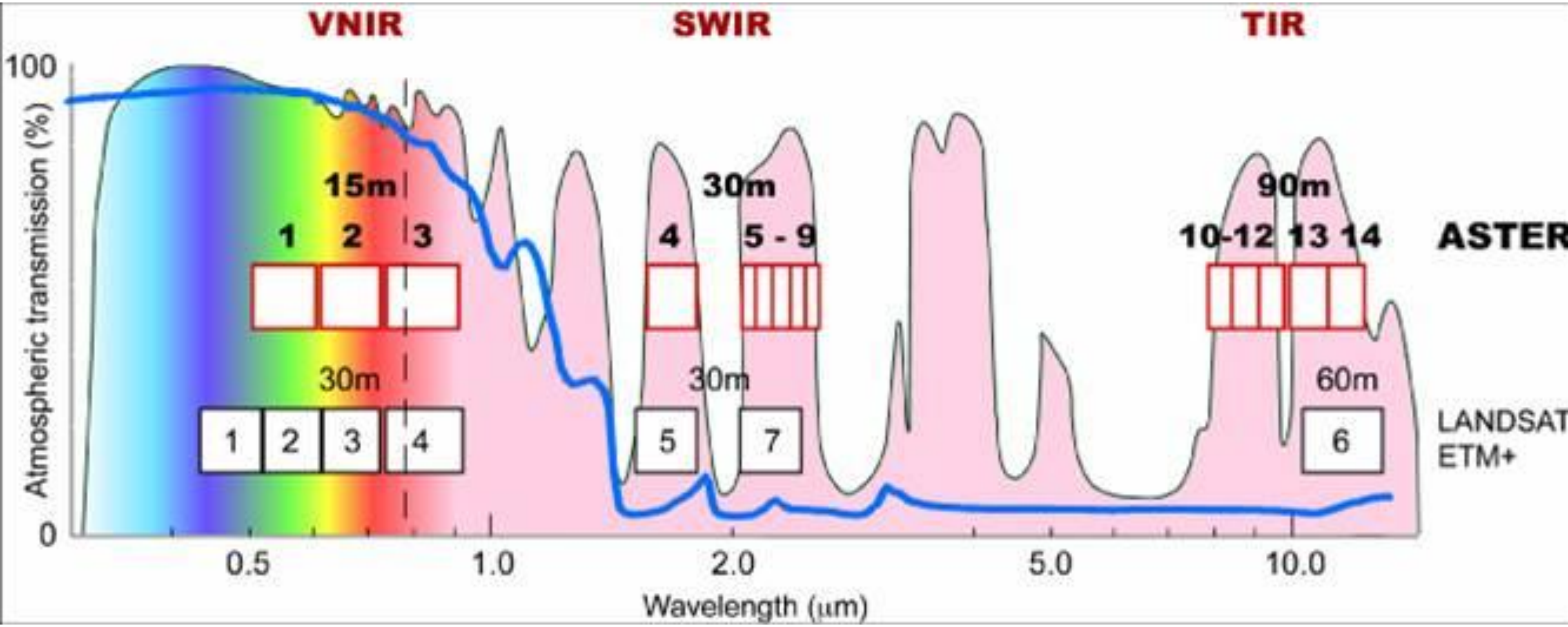
Physical Basis of Remote Sensing

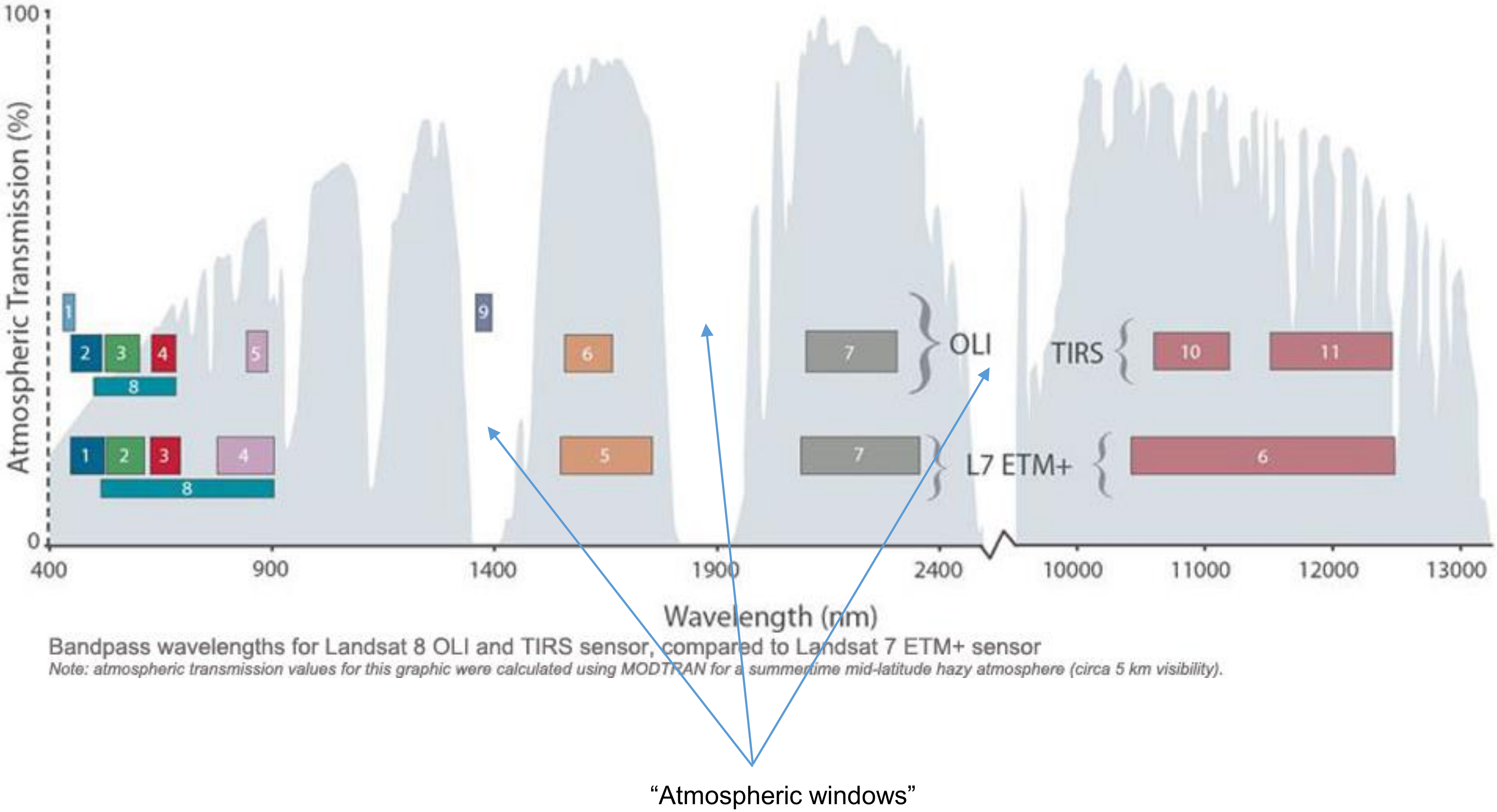
- Electromagnetic spectrum



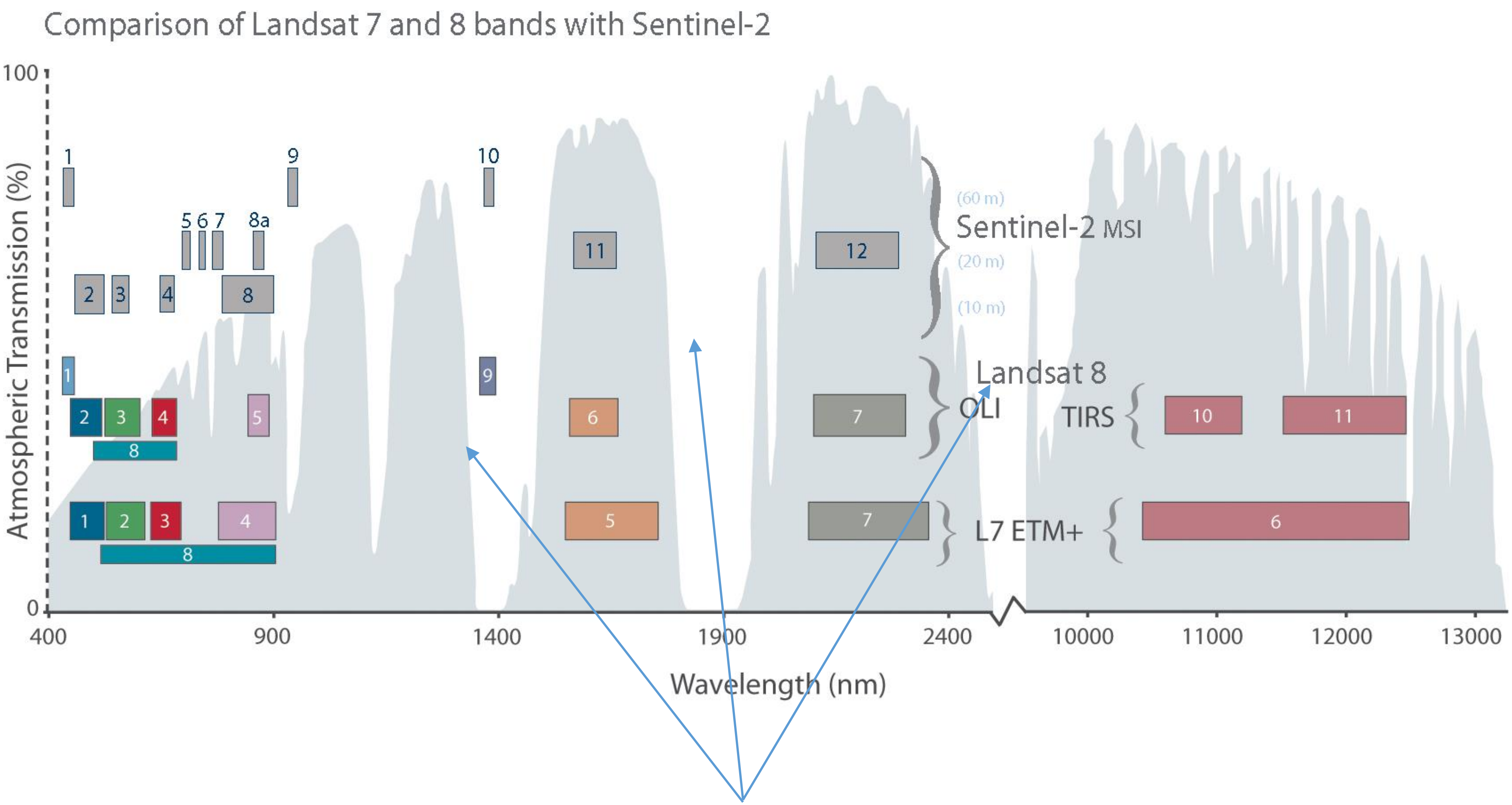


SOLAR SPECTRAL IRRADIANCE (Wm-2 µm-1)
2100
1800
1500
1200
900
600
300
0
SOLAR IRRADIANCE OUTSIDE ATMOSPHERE
DIRECT SOLAR IRRADIANCE AT SEA LEVEL
AIRMASS = 1.5
WATER VAPOR = 2.0 cm
OZONE = 0.34 cm
τ′aerosol 550nm = 0.126
Å exponent = 0.66
MODIS BANDS
O3
O3
H2O
O2
H2O
H2O
H2O & CO2
H2O & CO2
H2O & CO2
200
469
555
645
858
906
936
940
1000
1240
1375
1500
1640
2000
2130
2500
2700
WAVELENGTH (nm)


VNIR
SWIR
TIR
100
0
Atmospheric transmission (%)
15m
30m
90m
1
2
3
4
5 - 9
10-12
13
14
ASTER
30m
30m
60m
1
2
3
4
5
7
6
LANDSAT
ETM+
0.5
1.0
2.0
5.0
10.0
Wavelength (μm)



https://landsat.usgs.gov/ldcm_vs_previous.php



“Atmospheric windows”

http://landsat.gsfc.nasa.gov/wp-content/uploads/2015/06/Landsat.v.Sentinel-2.png

Exercise (in your own time)
Spectral Characteristics Viewer
"What are the best spectral bands to use for my study?"

https://landsat.usgs.gov/tools_spectralViewer.php

The spatial resolution most interesting aspect of a satellite image, but less appreciated is how irradiative energy reflected by surface materials are used to identify features.

The Spectral Characteristics Viewer allows viewers to visualize how the bands of various satellite sensors measure the intensity of the wavelengths (colors) of light; this is called the Relative Spectral Response (RSR).

By overlaying the spectral curves from different spectra (features), the user can determine which bands of the selected sensor(s) will work for the application.

Relative Spectral Responses (RSR) for Landsat sensors can be found on http://landsat.usgs.gov/instructions.php.

Physical Basis of Remote Sensing

- **Radiant energy** - **Q** *units: joules (J)*
  - Energy traveling in the form of electromagnetic waves.
- **Radiant flux** - **Φ** *units: watts*

  (W [joules/second])
  - The rate at which radiant energy is transferred from a point or a surface to another surface; a measure of radiant power.

$$\boldsymbol{\Phi} = \delta \mathbf{Q} / \delta \mathbf{t}$$

[Φ = Phi]

Physical Basis of Remote Sensing

- **Radiant flux density - E^{-} or M**

units: watts per sq. meter, W m^{-2}

- The radiant flux at a surface divided by the area of the surface. When referring to the radiant flux *incident on* a surface, we call it:

  Irradiance - $\mathbf{E}^{-}$ = d**F** / d**A** [W m^{-2}]

- When referring to the radiant flux *emitted from* a surface, we call it:

  Radiant exitance - **M** = d**F** / d**A** [W m^{-2}]

Physical Basis of Remote Sensing

- **Radiant flux density - E^{-}** or **M**
  - Notice that the units and defining equations for both ***radiant exitance*** and ***irradiance*** are identical.
  - The only difference between these two radiometric terms is that ***irradiance*** refers to radiation ***arriving*** *at* a surface, where as ***radiant exitance*** refers to radiation ***leaving*** a surface.

Physical Basis of Remote Sensing

- **Radiance – L (E)**

  units: watts per sq. meter per steradian, $W \cdot m^{-2} \cdot sr^{-1}$

  - Radiant flux propagated in a given direction, per unit solid angle about that direction and per unit area projected normal to the direction (dA cos Q). The angle Q is measured between the direction and a perpendicular to the unit area. Radiance is a geometric radiation quantity that describes the *spatial distribution* of radiant flux density.

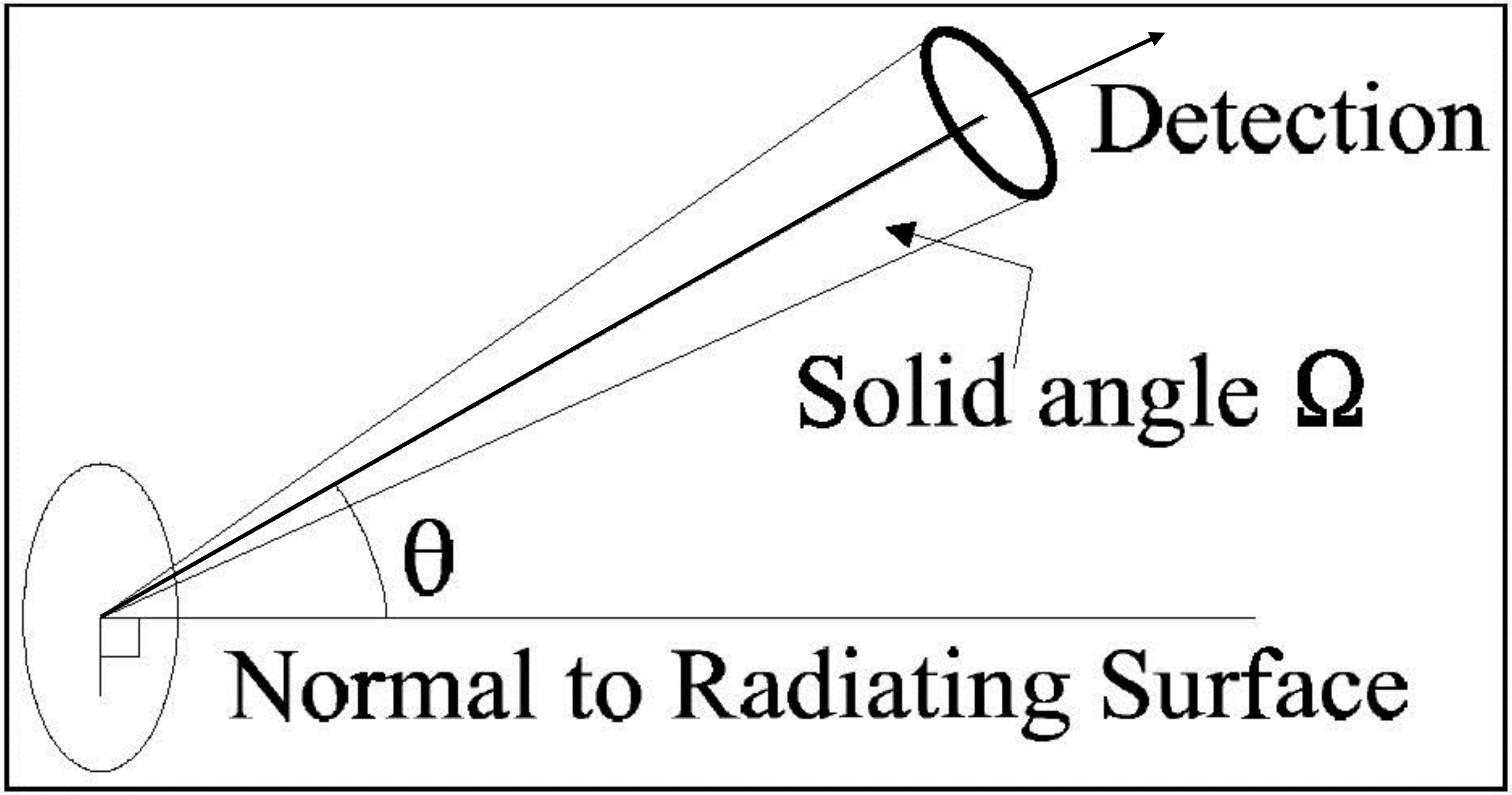
$$L = d\mathbf{F} \,/\, d\mathbf{W} \cdot d\mathbf{A} \cdot \cos \mathbf{Q}$$

Physical Basis of Remote Sensing

- **Radiance** – **L (E)**

  units: watts per sq. meter per steradian, $W \cdot m^{-2} \cdot sr^{-1}$

  L = d**F** / d**W** · d**A** · cos **Q**



Physical Basis of Remote Sensing

- **Reflectance – r** *unitless or expressed as a %*
  - E / E^{-}
  - $(E / E^{-}) * 100$ *[percent reflectance]*

Physical Basis of Remote Sensing

- When radiant energy, or any related quantity, is measured in terms of its monochromatic components (i.e. narrow wavelength range) it becomes a function of wavelength.

- Therefore, the designations for these quantities must be preceded by the adjective “spectral”, as in ”spectral irradiance.”

- The symbol for each quantity, is followed by the symbol for wavelength (**l**).

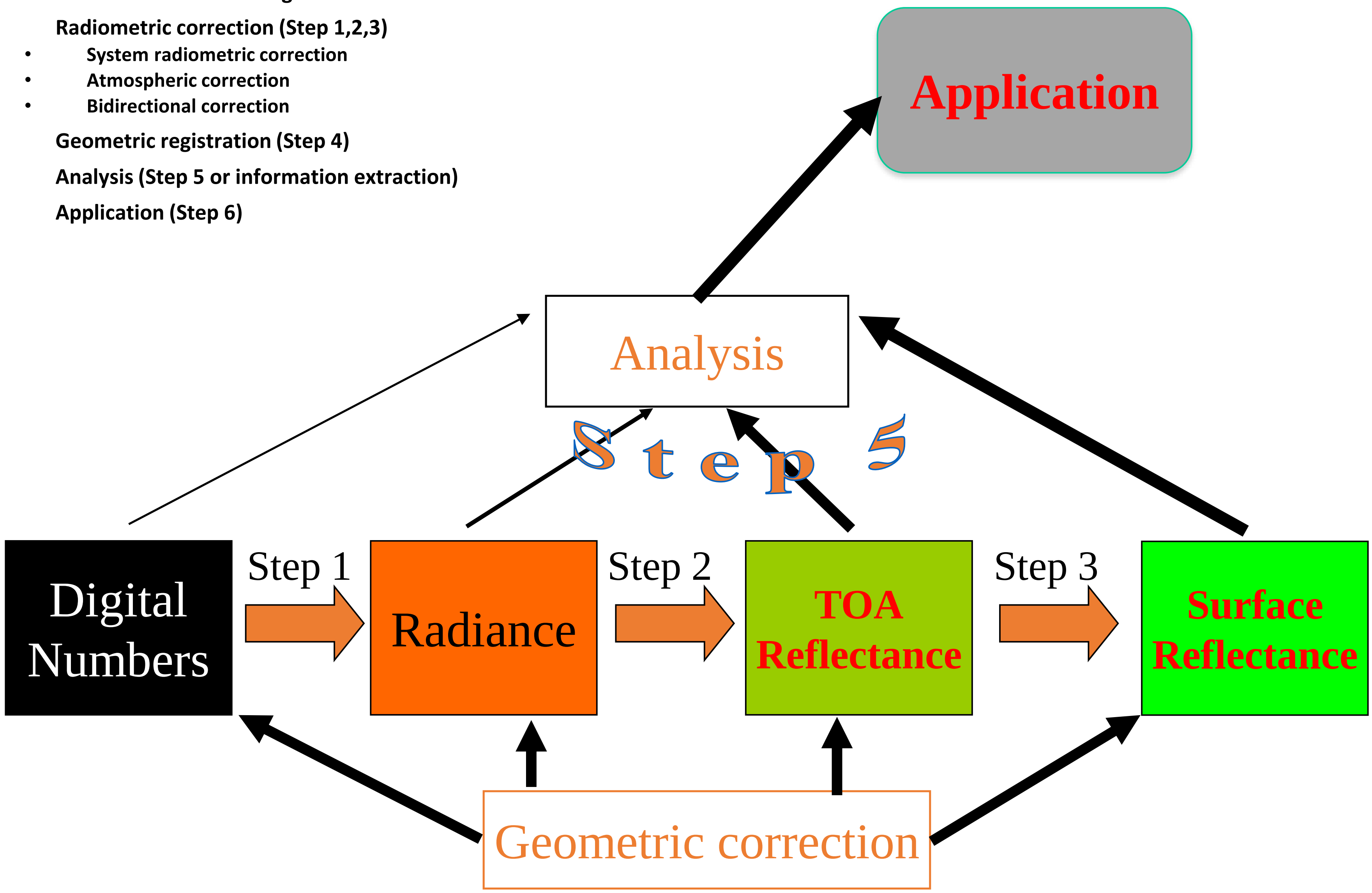
  - For example, spectral irradiance has the symbol $E^{-}_{(\mathbf{l})}$

Physical Basis of Remote Sensing

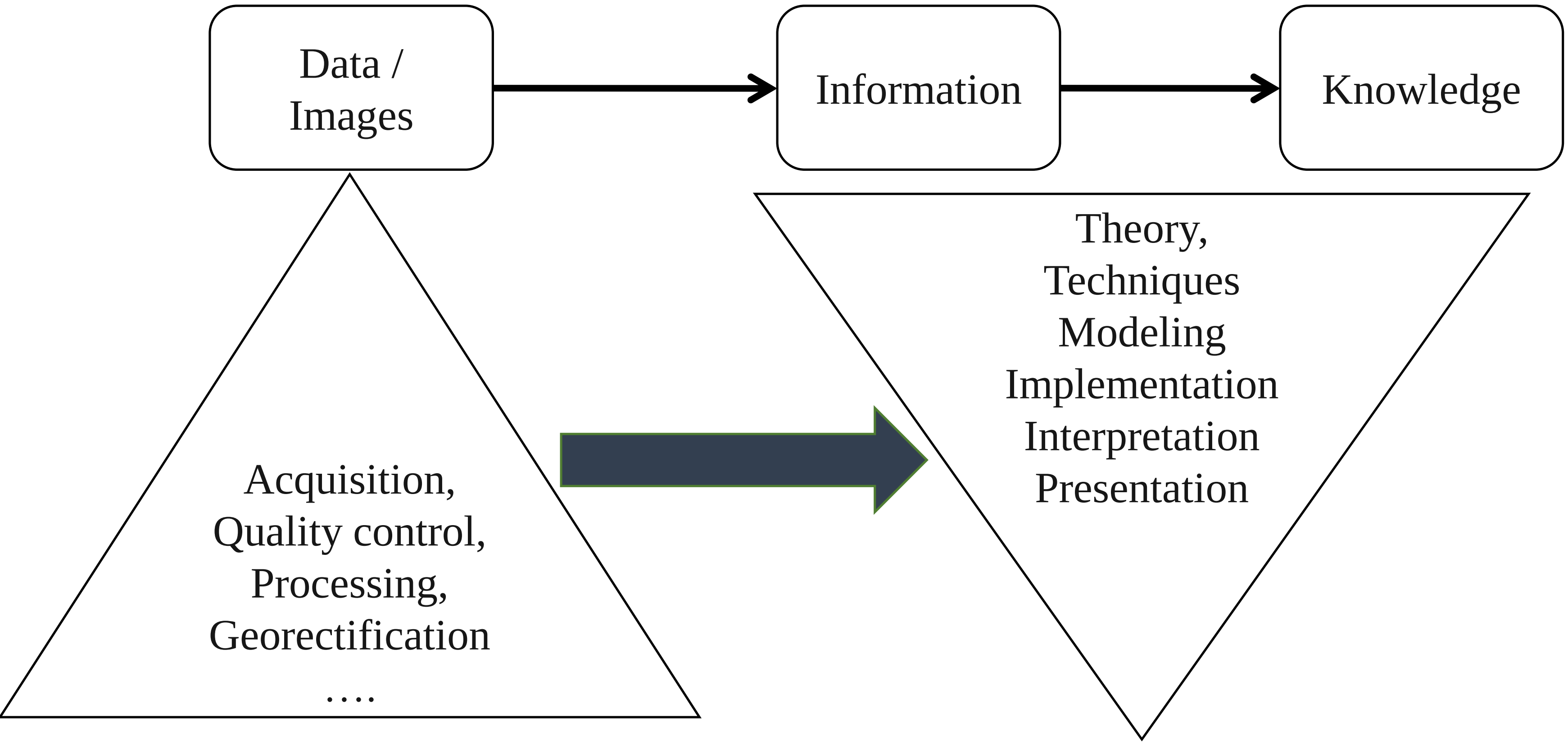
- Interaction of Sunlight ($E\downarrow$) with earth features
  - Reflected (ρ = reflectance)
  - Transmitted (τ = transmittance)
  - Absorbed (α = absorptance)
  - $E_{(\lambda)}\downarrow = E\rho_{(\lambda)} + E\boldsymbol{\tau}_{(\lambda)} + E\boldsymbol{\alpha}_{(\boldsymbol{\lambda})}$
  - $\mathbf{E\rho_{(\lambda)}} = E\downarrow_{(\lambda)} - [\, E\tau_{(\lambda)} + E\alpha_{(\lambda)}]$

DIPA Flowchart – All you need to know

0. **Overview of Remote Sensing**
1. **Radiometric correction (Step 1,2,3)**
   - **System radiometric correction**
   - **Atmospheric correction**
   - **Bidirectional correction**
2. **Geometric registration (Step 4)**
3. **Analysis (Step 5 or information extraction)**
4. **Application (Step 6)**



DIPA Flowchart – All you need to know



Terms and Functions in DIPA

- **Important Terms**
  - ***Spatial Resolution***
  - ***Radiometric Resolution***
  - ***Temporal Resolution***
  - ***Spectral Resolution***
- **Processing**
  - ***Radiometric Correction***
  - ***Geometric Correction***
  - ***Display & Enhancement***
  - ***Information Extraction***

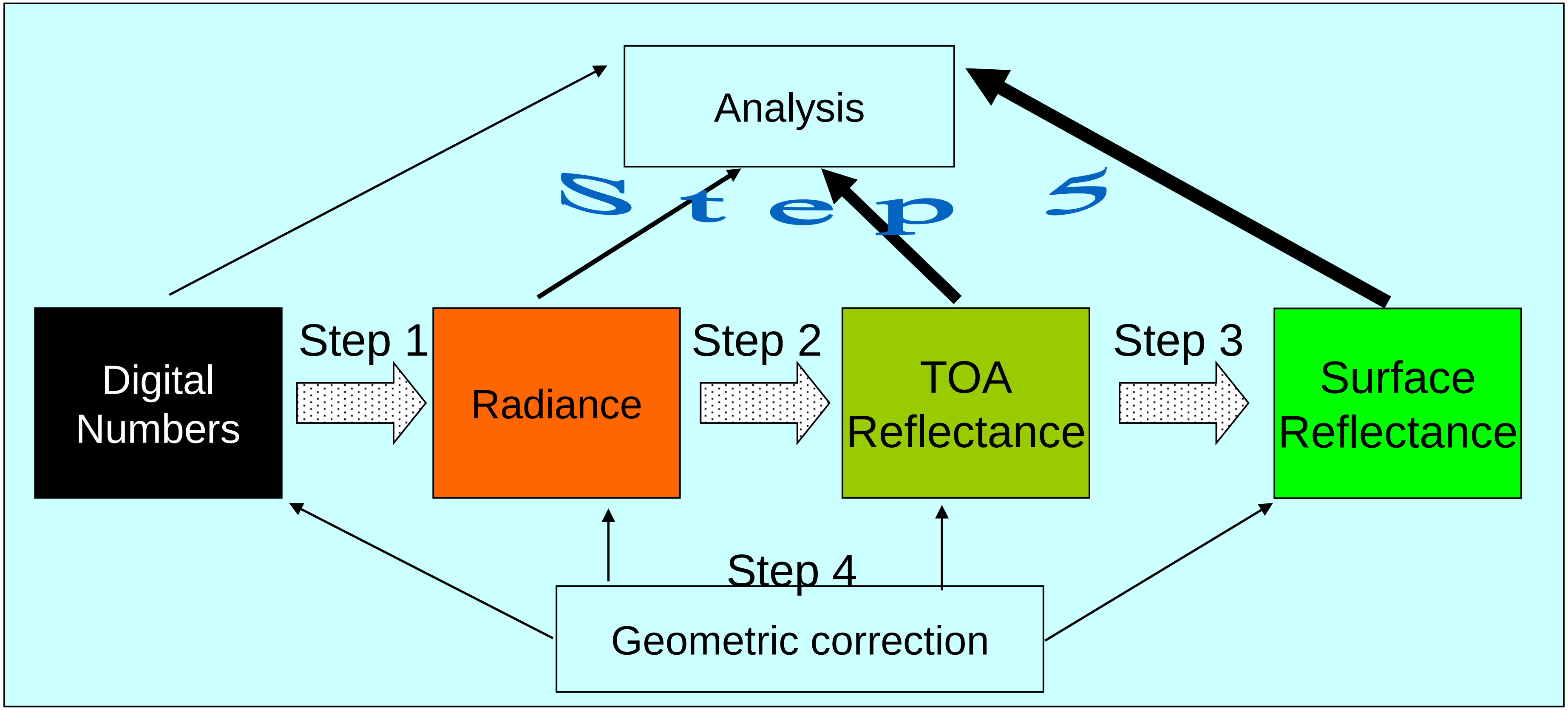
Corrections
1. Radiometric Correction

1.1 System Radiometric Correction

DIPA Flowchart

1. **Radiometric correction (Step 1,2,3)**
   - **System radiometric correction**
   - **Atmospheric correction**
   - **Bidirectional correction**
2. **Geometric registration (Step 4)**
3. **Analysis (Step 5 or information extraction)**

How to do this? Take Landsat as an example



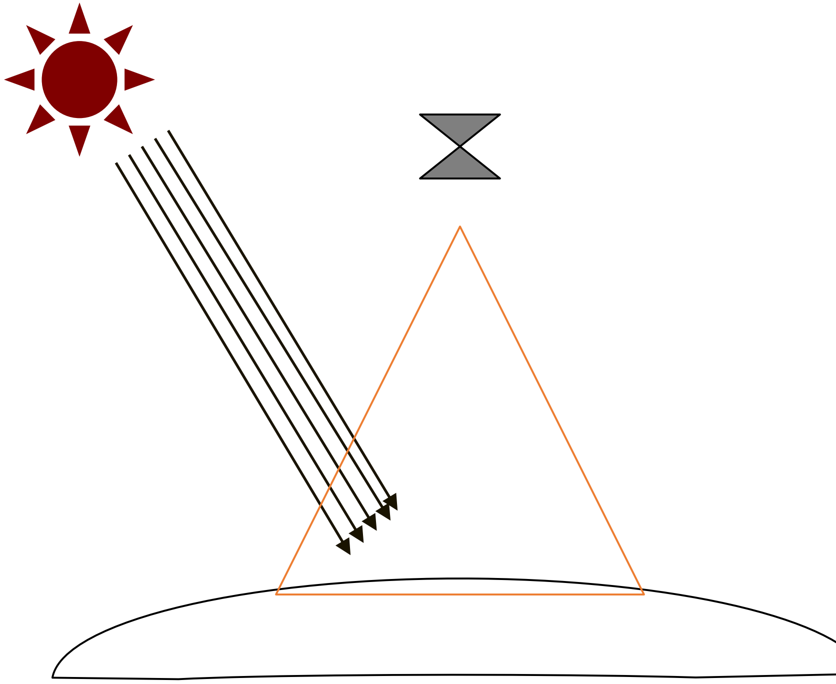
Sun

- Solar irradiance can be computed in theory
- Solar constant as suggested by Frohlich (1977):

  1373 ± 20 W/m^2,

  and by Forgan (1977):

  1375 ± 21 W/m^2



Exercise 03: What is the solar irradiance within the spectral regions of Enhanced Landsat Thematic Mapper Plus (or ETM+) Sensor?

Find them out and list them in a table in either XLS or WORD or pdf format. Send it via email on Angel system

Sun

- Solar irradiance at the top of atmosphere – Exo-atmosphere irradiance (Eo)
- Irradiance is attenuated by atmosphere when the Eo reaches to the earth surface
- To account for atmospheric effect, then, we need to know the properties of atmosphere
  - Transmission and absorption

Key Concepts

- BRDF – Bidirectional Reflectance Distribution Function

The fundamental and intrinsic property governing the reflectance behavior of a scene element is its bidirectional reflectance distribution function , or BRDF. The integration of this quantity over finite solid angles of incidence and exitance yields the “reflectance factor” that is actually estimated in most field measurements. However, multidirectional (omnidirectional) field radiance measurements of sufficient angular density can also provide useful estimates of the BRDF

Key Concepts

- Reflectance Factor:

  Reflectance factor is defined as the ratio of the radiant flux actually reflected by a sample surface to that which would be reflected into the same reflected-beam geometry by an ideal (lossless, that is, 100% reflectivity) perfectly diffuse (Lambertian) standard surface irradiated in exactly the same way as the sample.

Key Concepts

- **Conical Reflectance Factor:** is defined as the ratio of conical reflected flux to that of hemispherical incident radiant flux.
- **Bidirectional Reflectance Factor**, sometimes simply called reflectance factor, is defined as the target surface radiance divided by the radiance of a level reference surface standard irradiated by the sun. For small fields of view (angle of acceptance, < 20^o), this term is appropriate – with one direction being associated with the viewing angle and the other direction being associated with the solar zenith and azimuth angles. The “bidirectional reflectance” is frequently used rather loosely to refer to the bidirectional reflectance factor(s) measured over targets from one or more nadir and off-nadir viewing angles.

Key Concepts

- **Albedo** is defined as the ratio of the total solar flux reflected in all directions to the incident solar flux. It is an integral value over all wavelengths.

- Integration of bidirectional reflectance factors over all angles will yield albedo.

Radiometry

- The Inverse Square Law
  - The inverse square law defines the relationship between the irradiance from a point source and distance. It states that the intensity per unit area varies in inverse proportion to the square of the distance.

$$\mathbf{E = I / d^2}$$

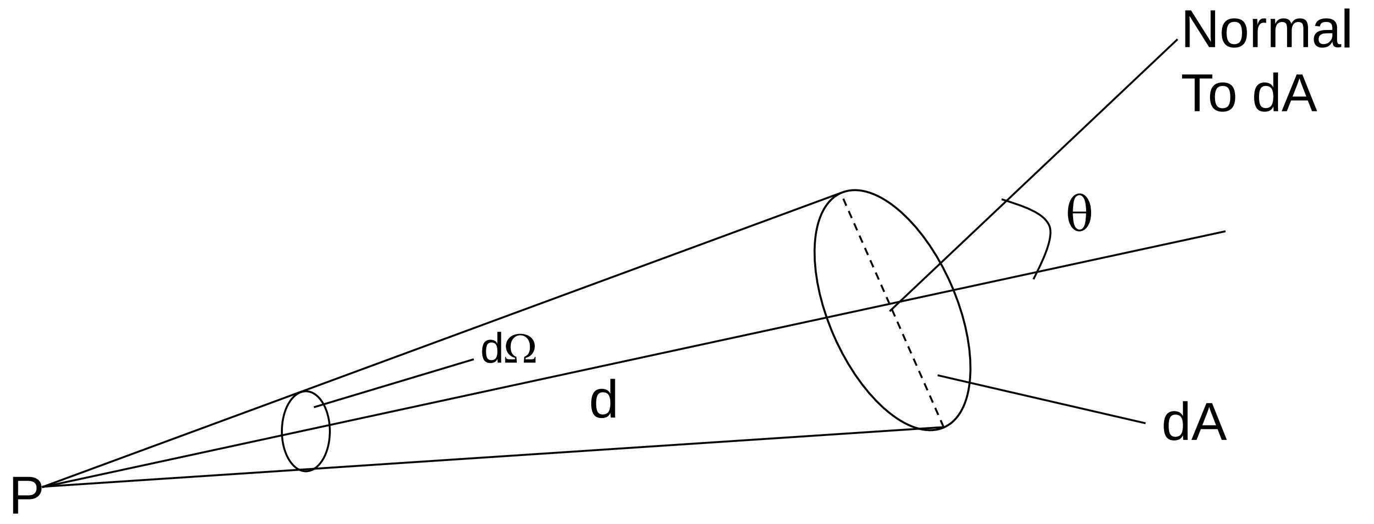
  - If you measure 16 W cm^{-2} at 1 meter, you will measure 4 W cm^{-2} at 2 meters.

Radiometry

- The Inverse Square Law
  - An alternative form is often more convenient:

$$E_1 \bullet d_1^{\,2} = E_2 \bullet d_2^{\,2}$$

  - Distance is measured to the first luminating surface

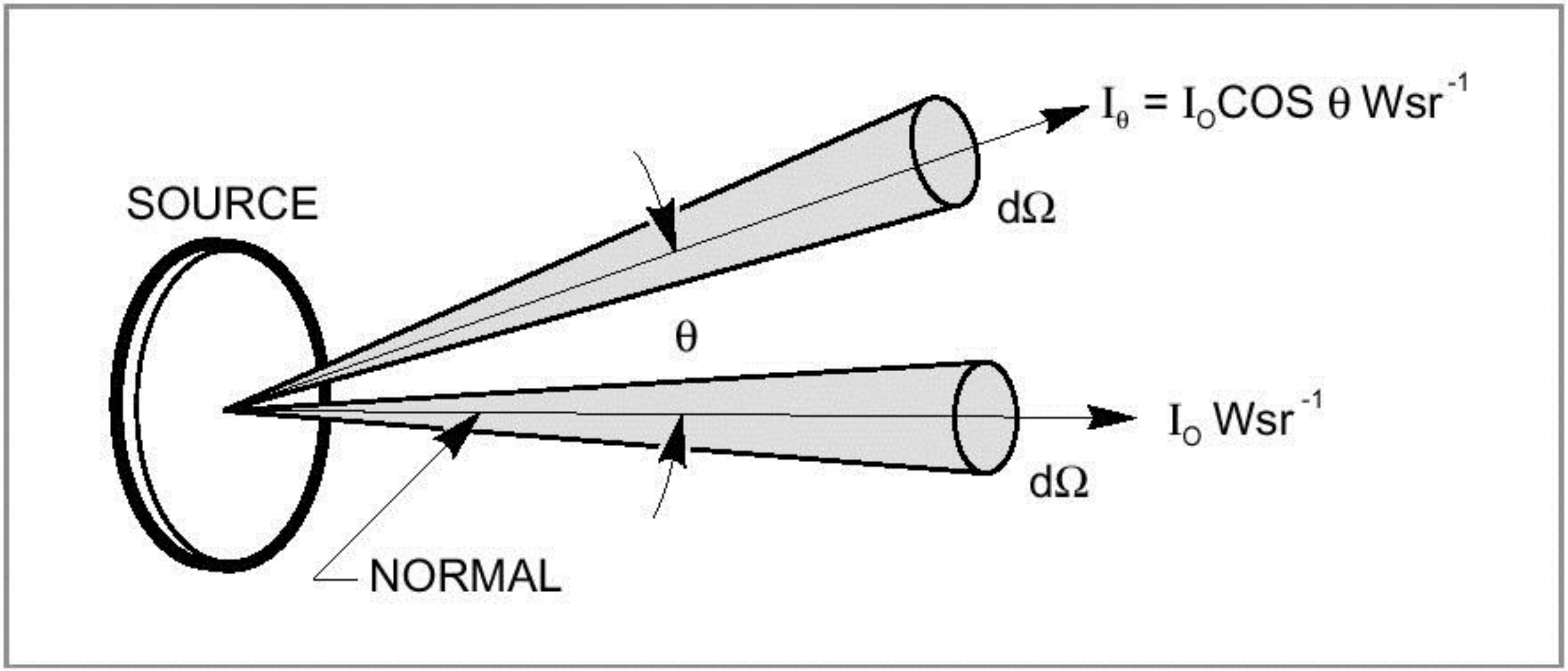


Radiometry

- Lambert's Cosine Law
  - The irradiance falling on any surface varies as a function of the cosine of the incident angle, θ.
  - The perceived measurement area orthogonal to the incident flux is reduced at oblique angles, causing light to spread out over a wider area than it would if perpendicular to the measurement plane.

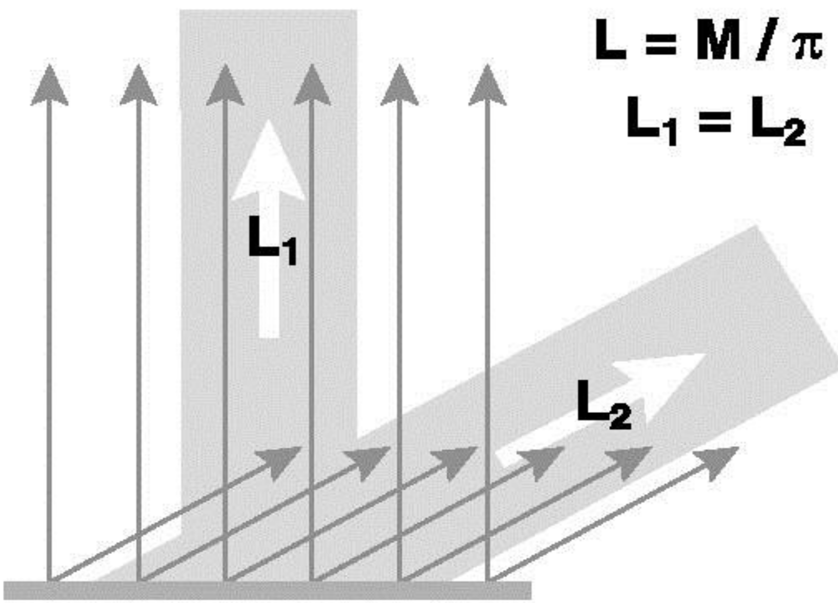
Radiometry

- Lambert's Cosine Law



Radiometry

- Lambertian Surface
  - A Lambertian surface provides uniform diffusion of the incident radiation such that its radiance is the same in all directions from which it can be measured.



A surface radiating equally at 0° and at 60°.

Since, by the cosine law, a radiance detector sees twice as much surface area in the same solid angle for the 60° case, the average radiance must be half the magnitude of the radiance in the 0° case.

Data sources

- Register and create username/psswrd @
  https://urs.earthdata.nasa.gov/
- NASA REVERB ECHO:
  http://reverb.echo.nasa.gov

Most MODIS data products and other EOS

https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table

Landsat and terrestrial data

- USGS Earth explorer:
  http://earthexplorer.usgs.gov/
- USGS GLOVIS:
  http://glovis.usgs.gov/