Remote Sensing: Fundamentals and Applications

HYDAP Kick-Off Meeting
Part One

evropský sociální fond v ČR
EVROPSKÁ UNIE
MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY
OP Vzdělávání pro konkurenceschopnost
INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Remote Sensing Overview

- Part One
  - Definitions
  - EM radiation
  - Interaction w/ atmosphere
  - Interaction w/ surfaces
  - Emissions by surfaces
- Part Two
  - Sensor types
  - Platforms

Remote Sensing Overview

- Part Three
  - Satellite RS datasets
  - Processing and analysis
  - Data archives, access policies
  - Applications

What is Remote Sensing?

- Remote Sensing (RS) is the process of getting information about something without coming into physical contact with it
- RS is an very diverse technological and scientific field
- The focus of this presentation is remote sensing of the geophysical and biological characteristics of the Earth

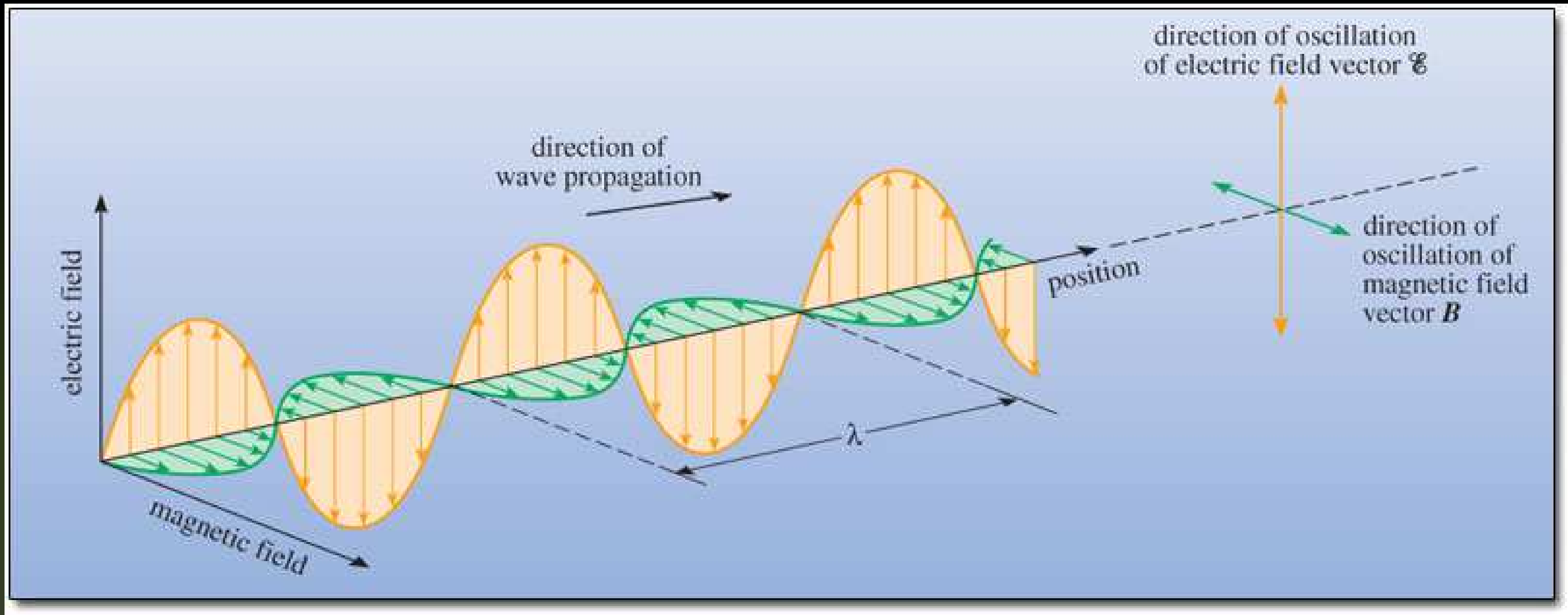
Steps in Remote Sensing

- Energy Source
- Interaction with the Atmosphere
- Interaction with the Target
- Recording of Energy by the Sensor
- Transmission, Reception, and Processing
- Interpretation and Analysis
- Application

Earth Remote Sensing

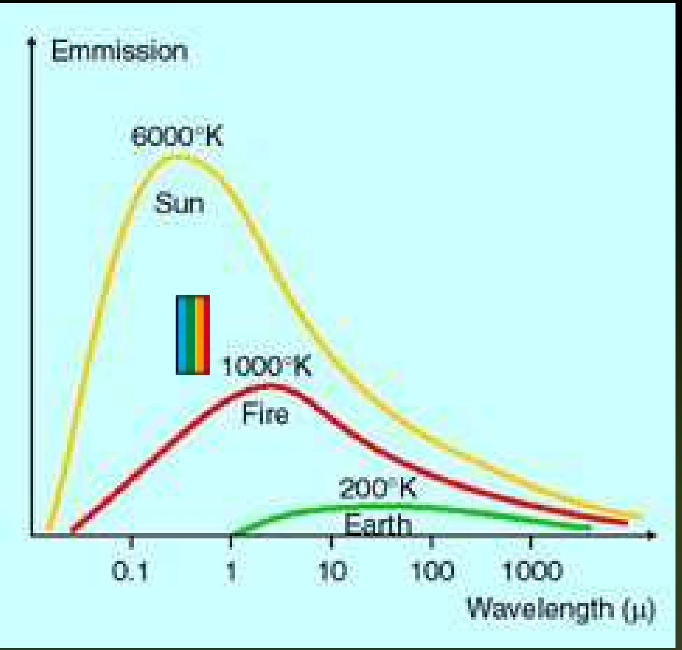
- Earth remote sensing involves measuring and interpreting the electromagnetic radiation (EMR) received at the sensor from the earth-atmosphere system.
- There are 3 possible sources for this radiation:
  - reflected solar radiation
  - emitted thermal radiation
  - radiation directed at the earth from a platform and reflected back

Electromagnetic Radiation

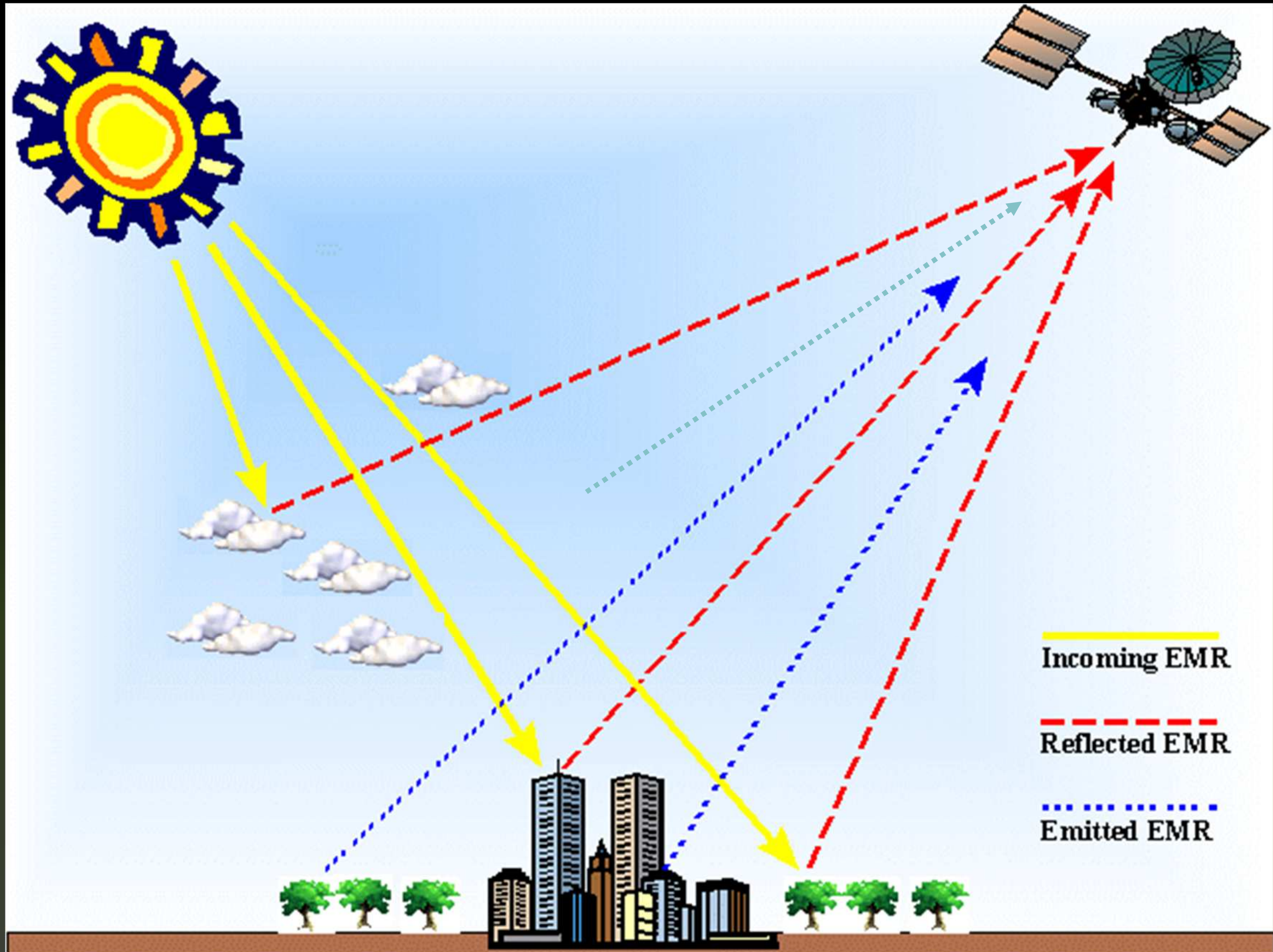


Sunlight

- All matter at a temperature above absolute zero emits radiation
  - this radiation is characteristic of the temperature of that matter
- The sun emits radiation that is centered in the *visible* portion of the EM spectrum



A *Blackbody* is a perfect emitter (and absorber) of radiation. The amount and distribution of wavelengths (spectrum) of the radiation it gives off depend only on its temperature.


Incoming EMR
Reflected EMR
Emitted EMR

What does the satellite see?
What information do the photons contain?

1) Backscattered photons which never reach the surface.

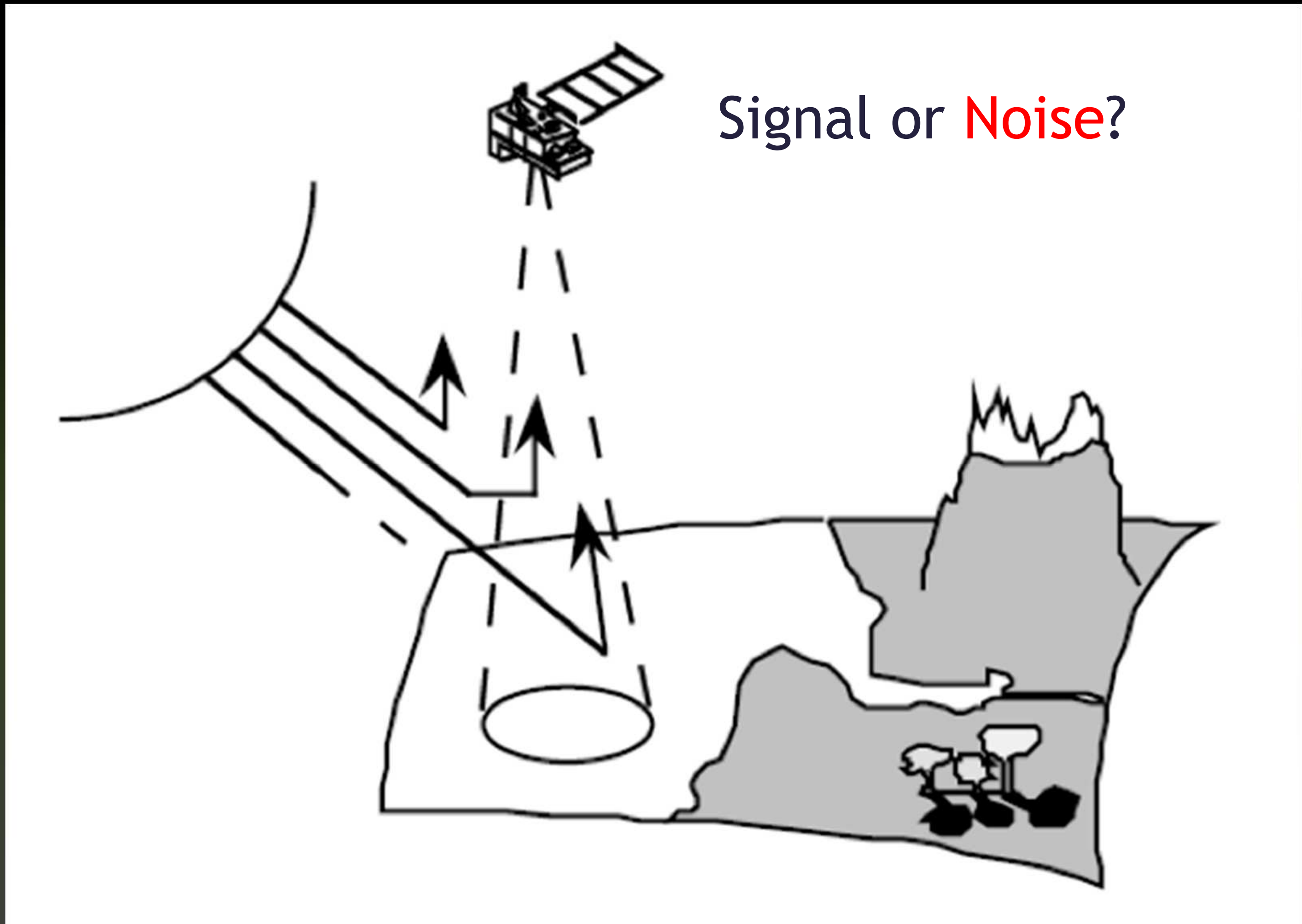
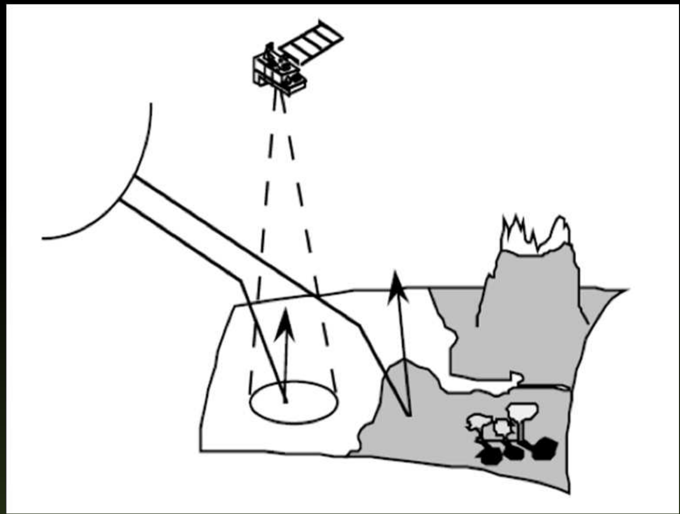


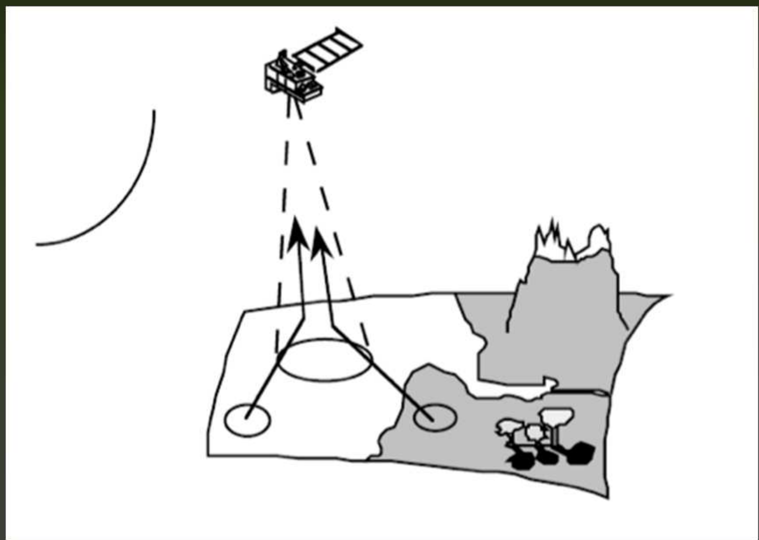
Diagram from E. Vermote et. al, 6S manual

Diffuse solar radiation.

2) Scattered photons that illuminate the ground.



Signal or Noise?



3) Photons reflected by the surface and then scattered by the atmosphere.

Diagram from E. Vermote et. al, 6S manual

Multiple scattering events

This is usually ignored after one or two interactions.

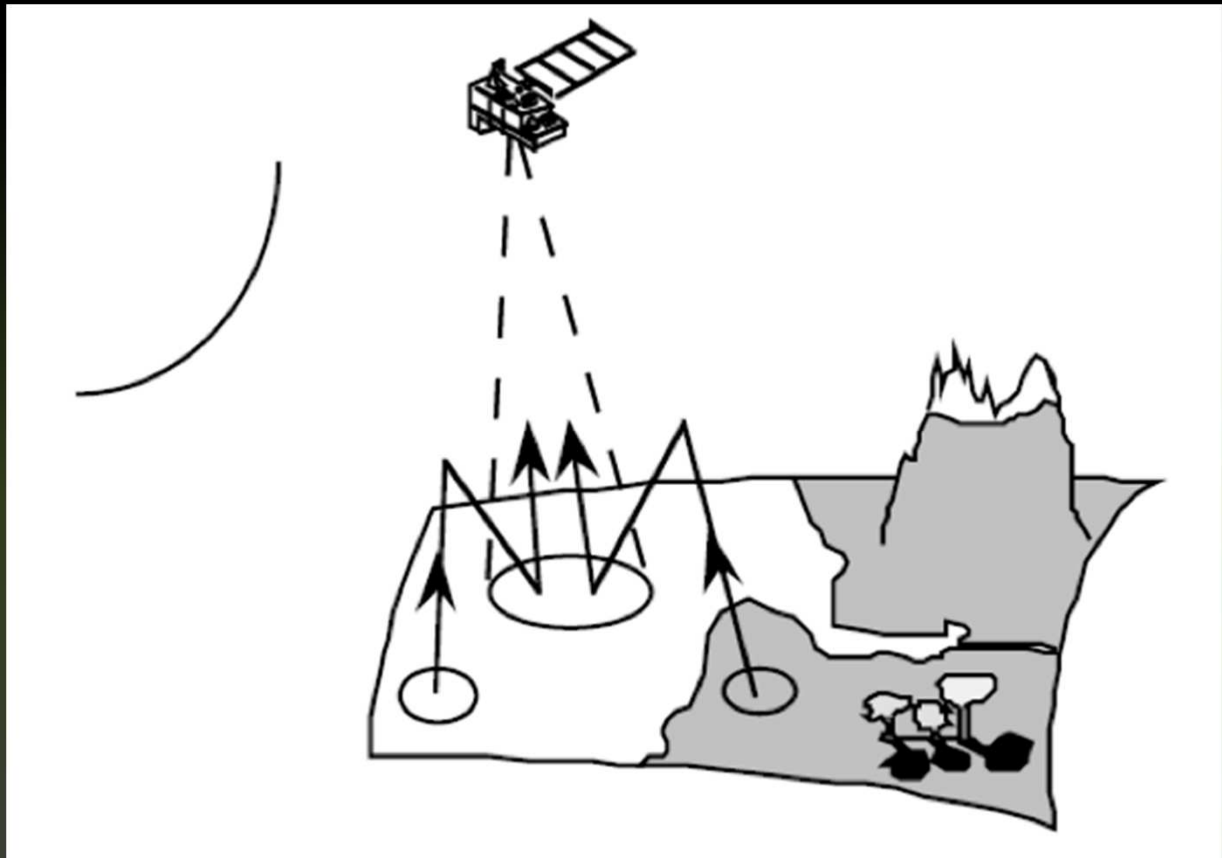


Diagram from E. Vermote et. al, 6S manual

The real atmosphere complicates the signal. Only a fraction of the photons reach the sensor so that the target seems less reflecting.

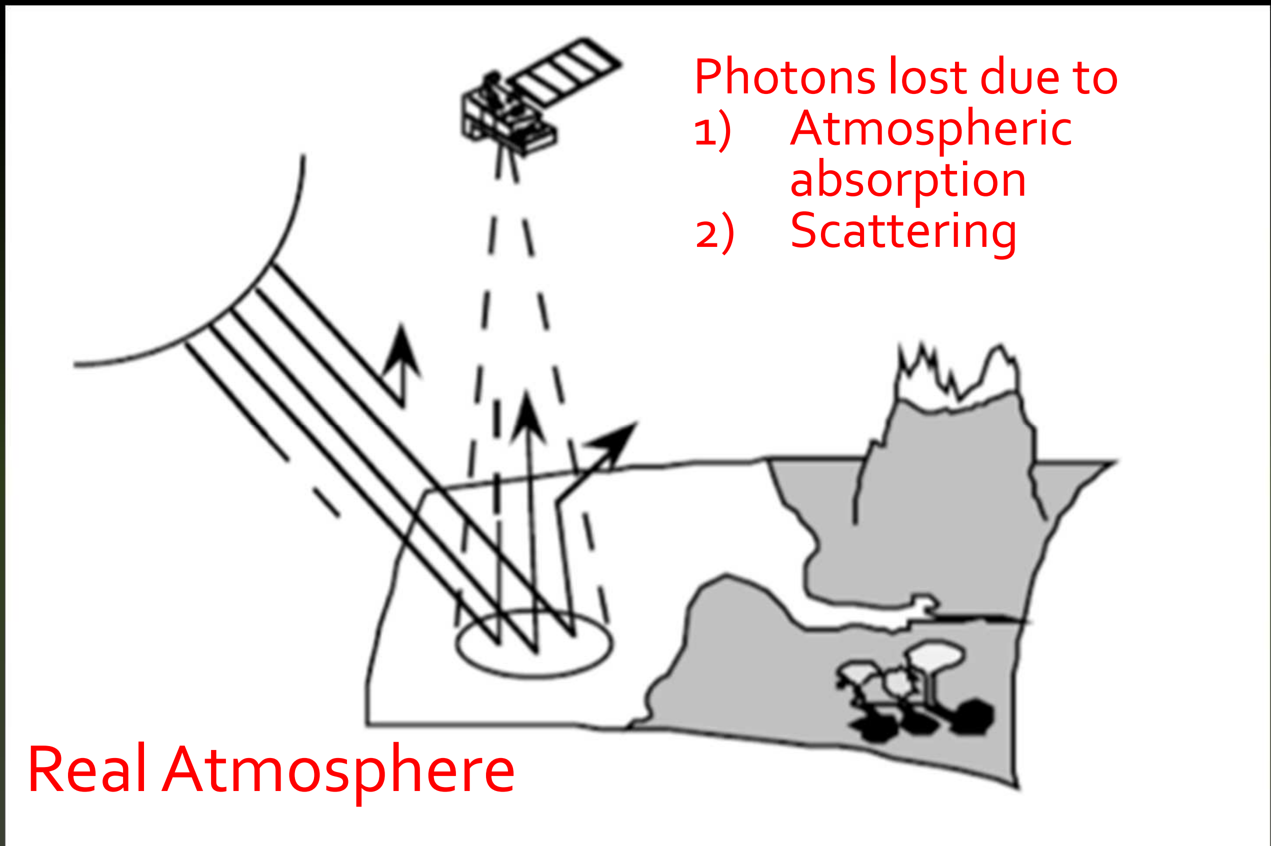
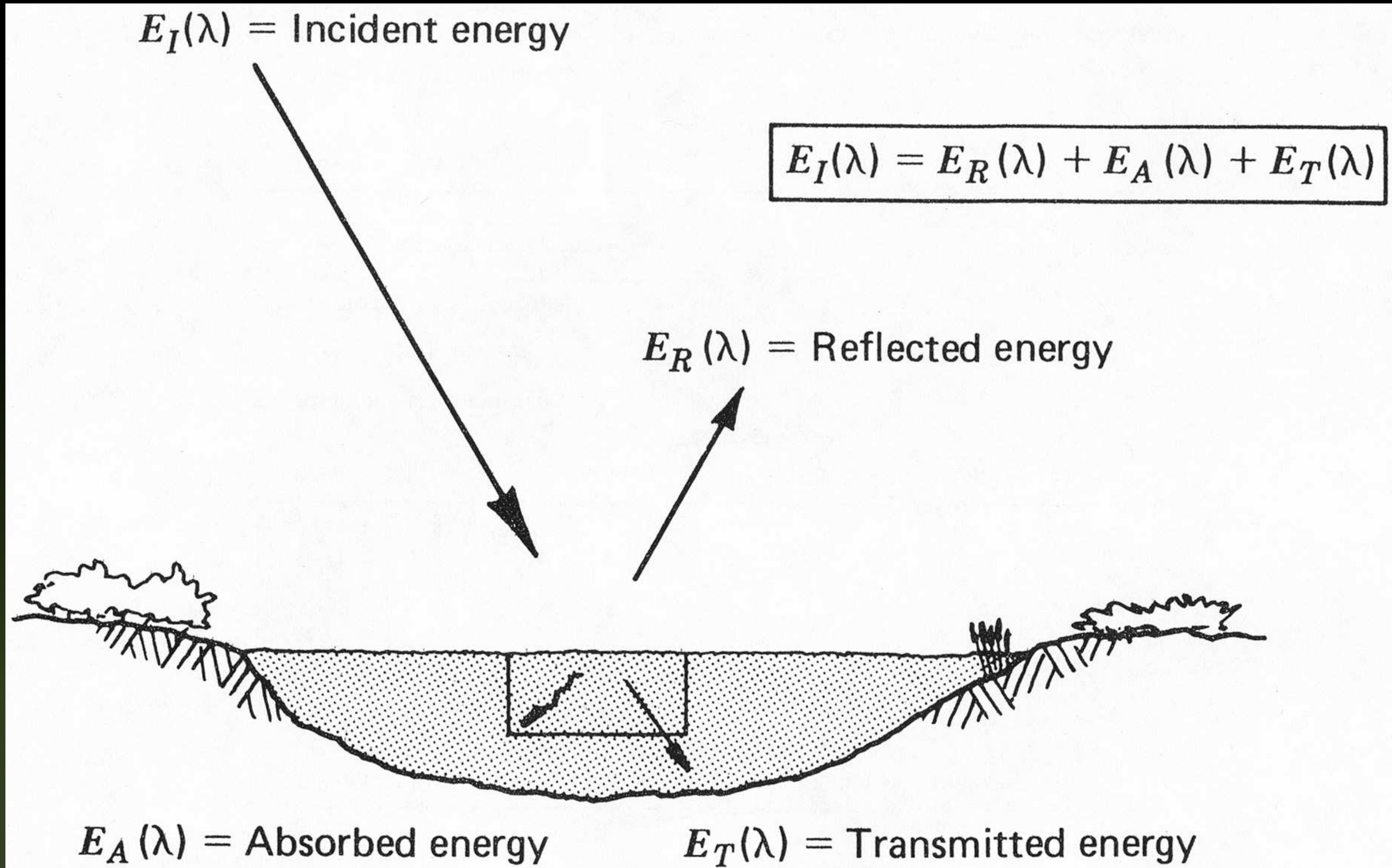


Diagram from E. Vermote et. al, 6S manual

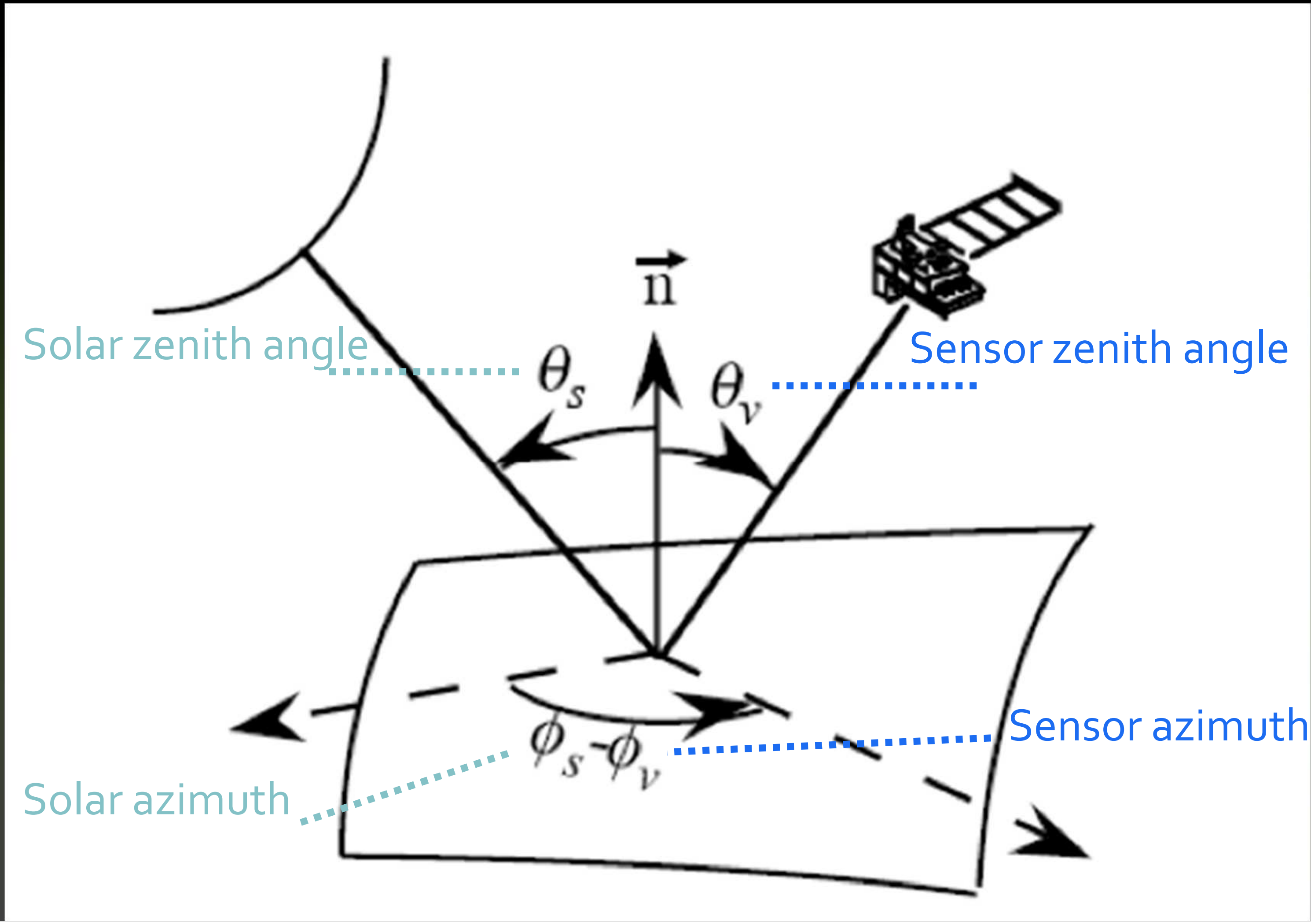
Fate of EM Radiation



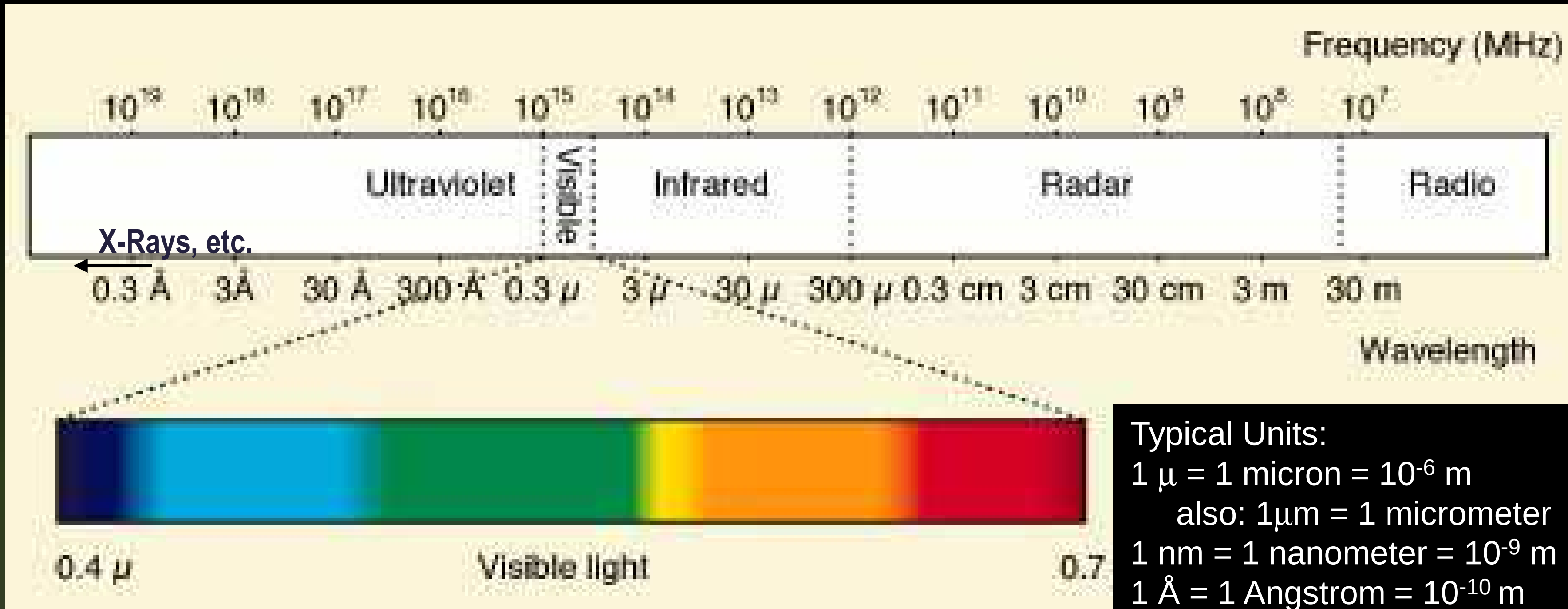
Incident solar energy can either be reflected, transmitted or absorbed

Geometric issues of the illumination and the measurement

Very important for surface and atmospheric signal

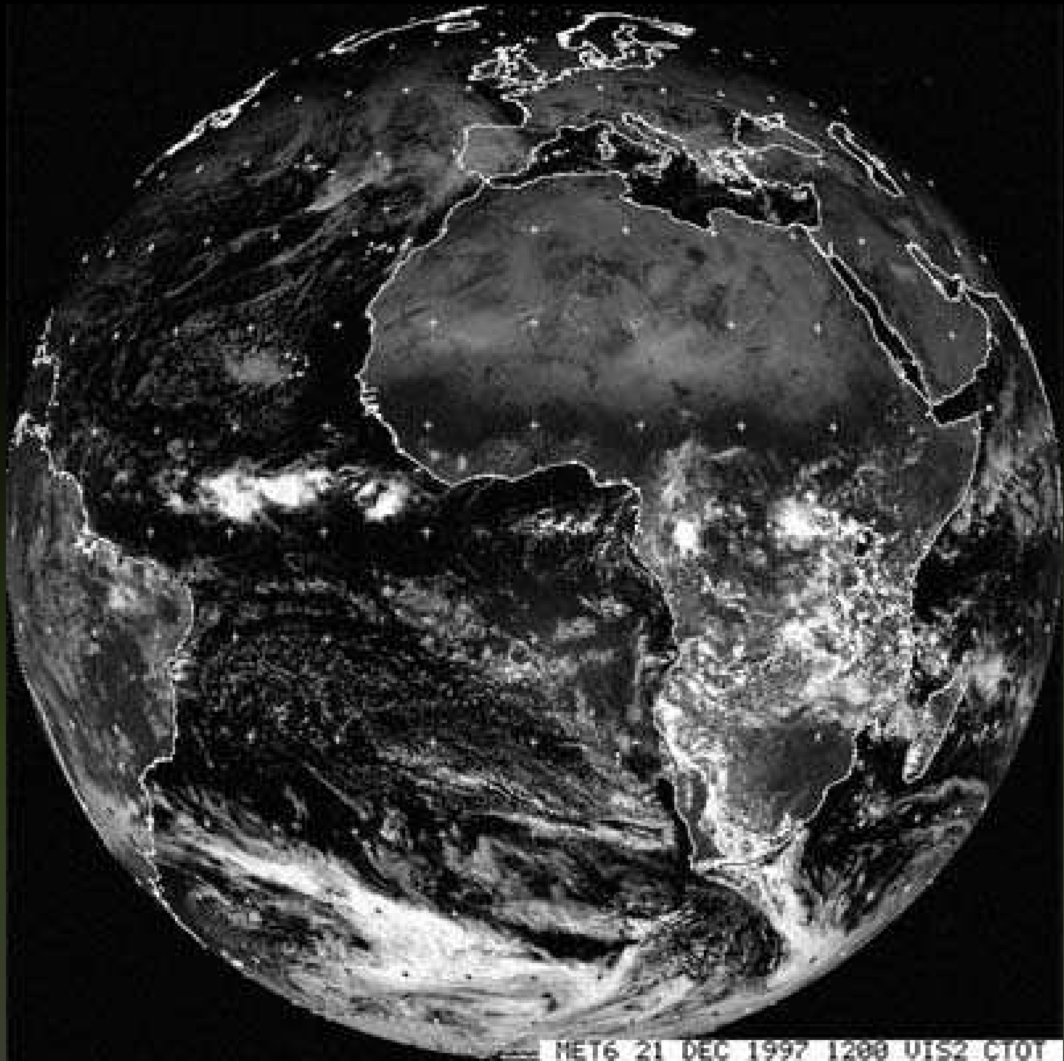


The Electromagnetic Spectrum

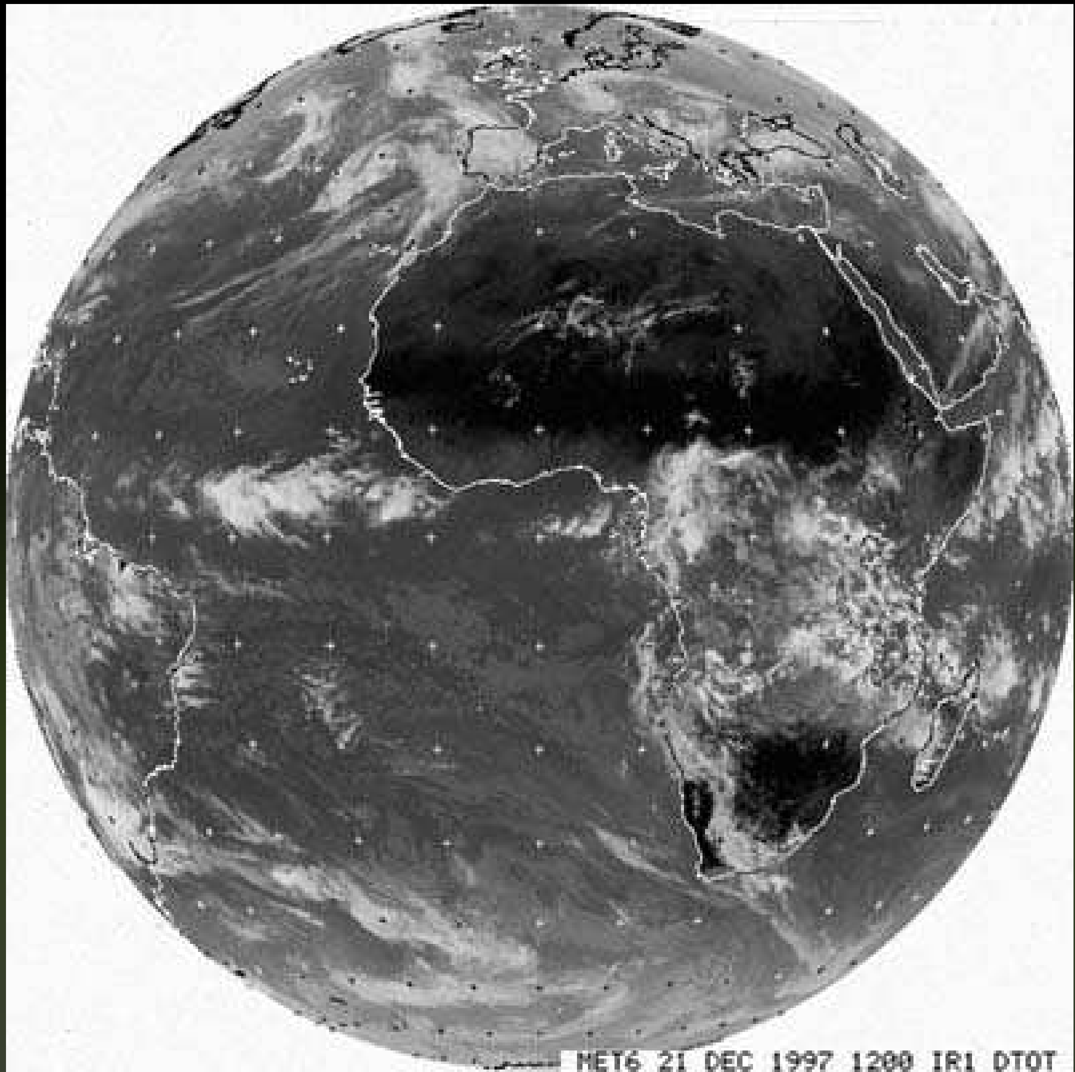


Typical Units:
1 μ = 1 micron = 10^{-6} m
also: 1μm = 1 micrometer
1 nm = 1 nanometer = 10^{-9} m
1 Å = 1 Angstrom = 10^{-10} m

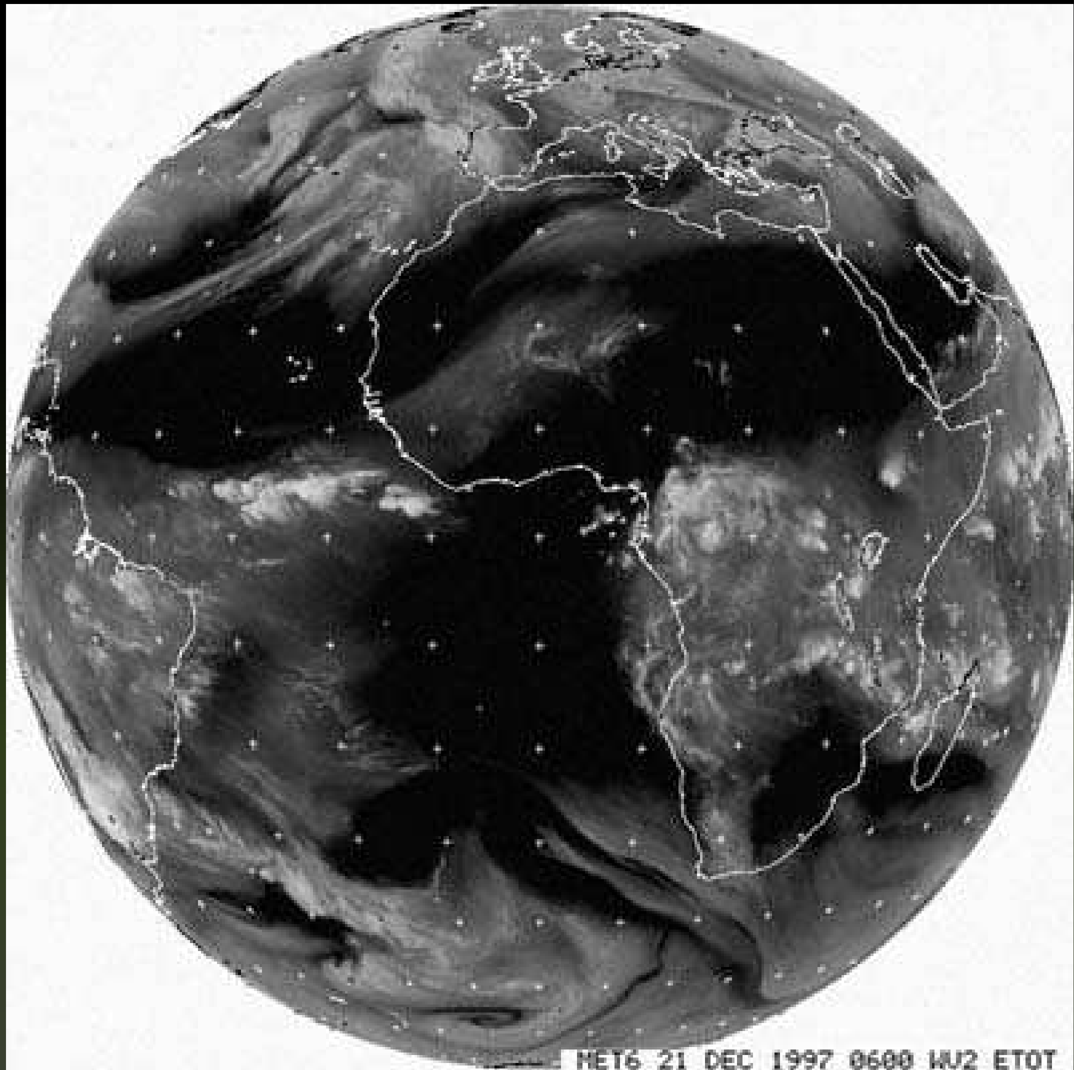
The EM spectrum is a continuum extending well past the range of this figure. Electromagnetic radiation is characterized by its frequency (or wavelength) and its polarization.



An early and familiar example of satellite remote sensing is the weather satellite.
Here we see an image made from the visible band of a *geostationary* satellite. Clouds are bright, as are sand. Ocean and vegetation are darker.



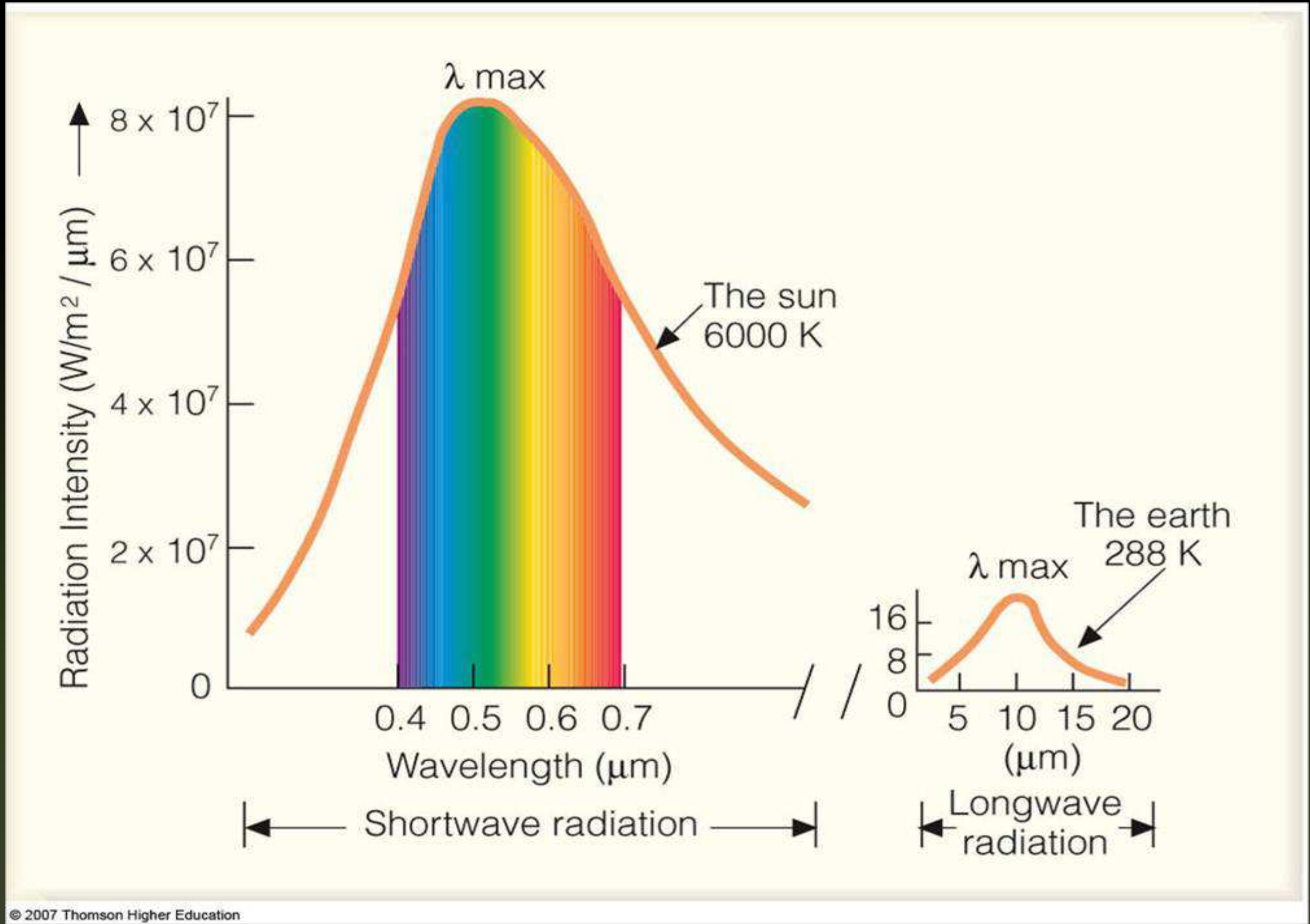
This image comes from the thermal IR sensors on the same satellite. The grayscale is inverted so that warm surfaces are dark and cool surfaces are light. Thus, high clouds are white and hot sand is dark. The ocean is in between. Clouds closer to the surface are less bright, but can still be distinguished from the ocean.



In the previous two images the sensors were broadband. Here is an image of the outgoing radiation at one particular wavelength corresponding to the emissions from water vapor molecules in the atmosphere. Deep tropical convection and midlatitude synoptic systems are visible.

Combining measurements at multiple wavelengths in the visible portion of the spectrum allow the creation of “true color” images like this. Unlike the previous images this is a composite from many individual acquisitions made from a polar orbiting satellite.

Shortwave and Longwave Radiation



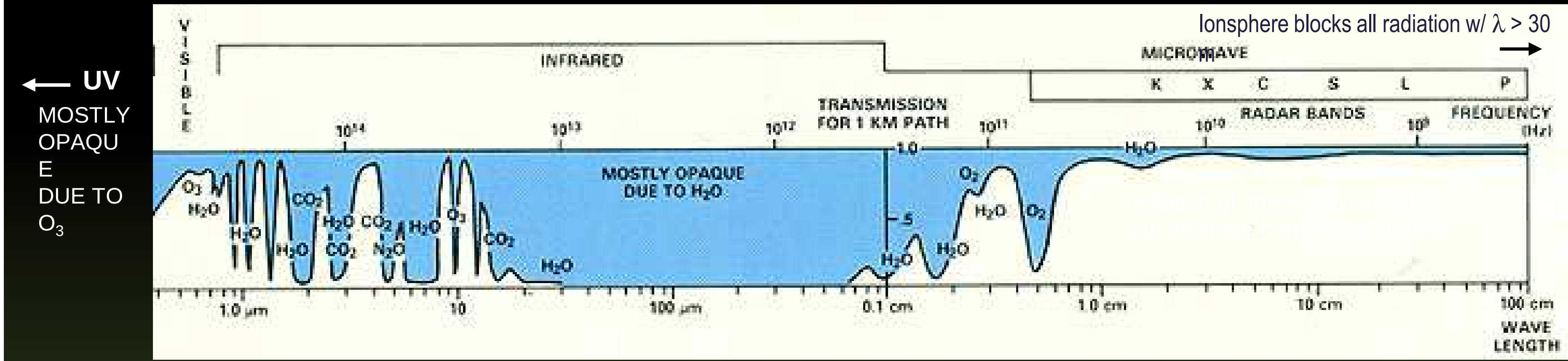
- Shortwave radiation from the sun is reflected from earth atmosphere that is seen by satellite (< 4 micron)

- Longwave radiation is earth emitted radiation (> 4 um)

The Atmosphere

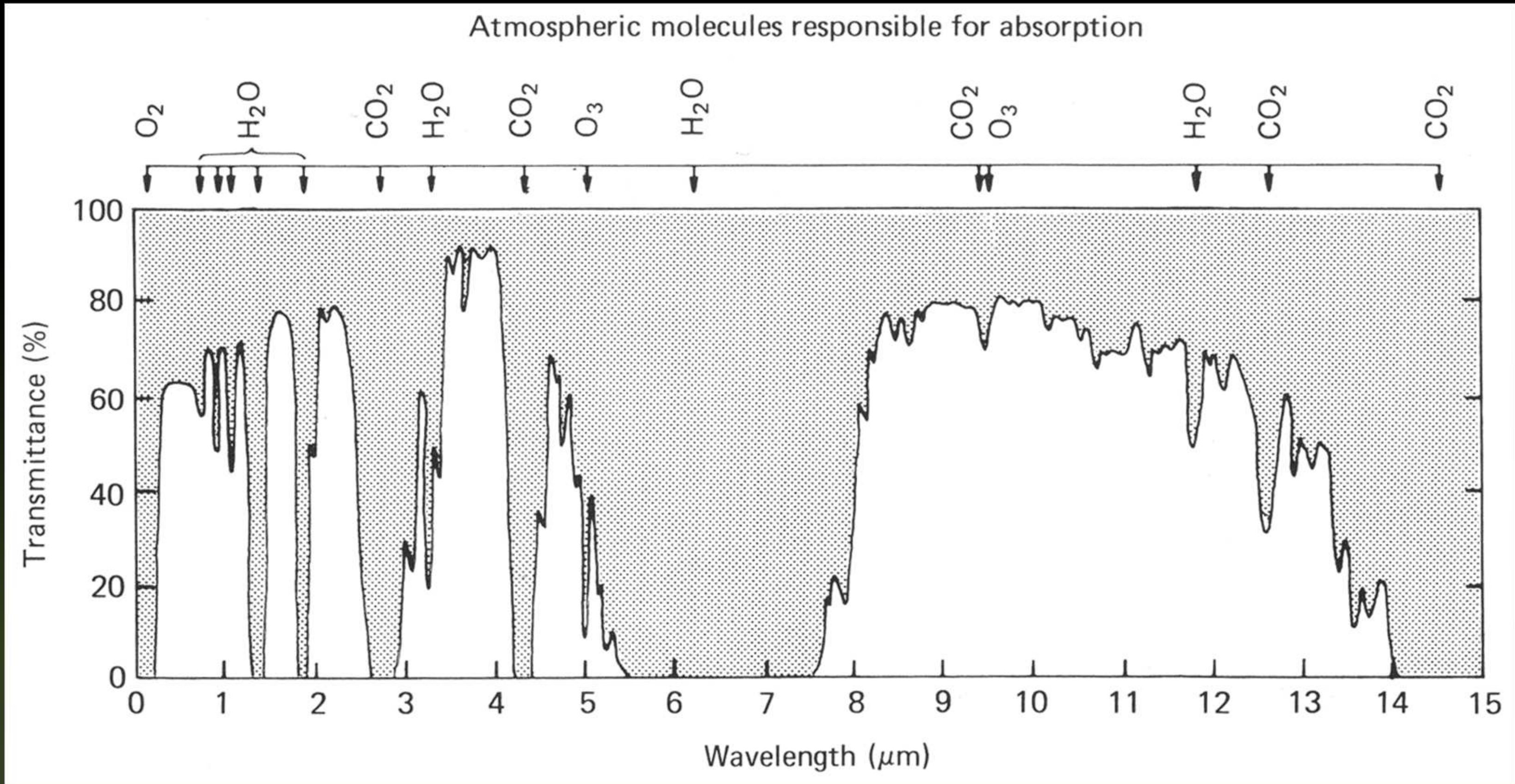
- Measuring things on the Earth's surface would be much easier if there were no atmosphere
- Clouds are an obvious problem
- But a "clear" atmosphere also interacts with EMR, altering both the incoming solar and the outgoing surface reflected or emitted radiation
- The atmosphere both subtracts (through absorption and scattering) and adds (emission, backscatter, diffusion) to the signal received by the sensor

Opacity of Atmosphere to EMR



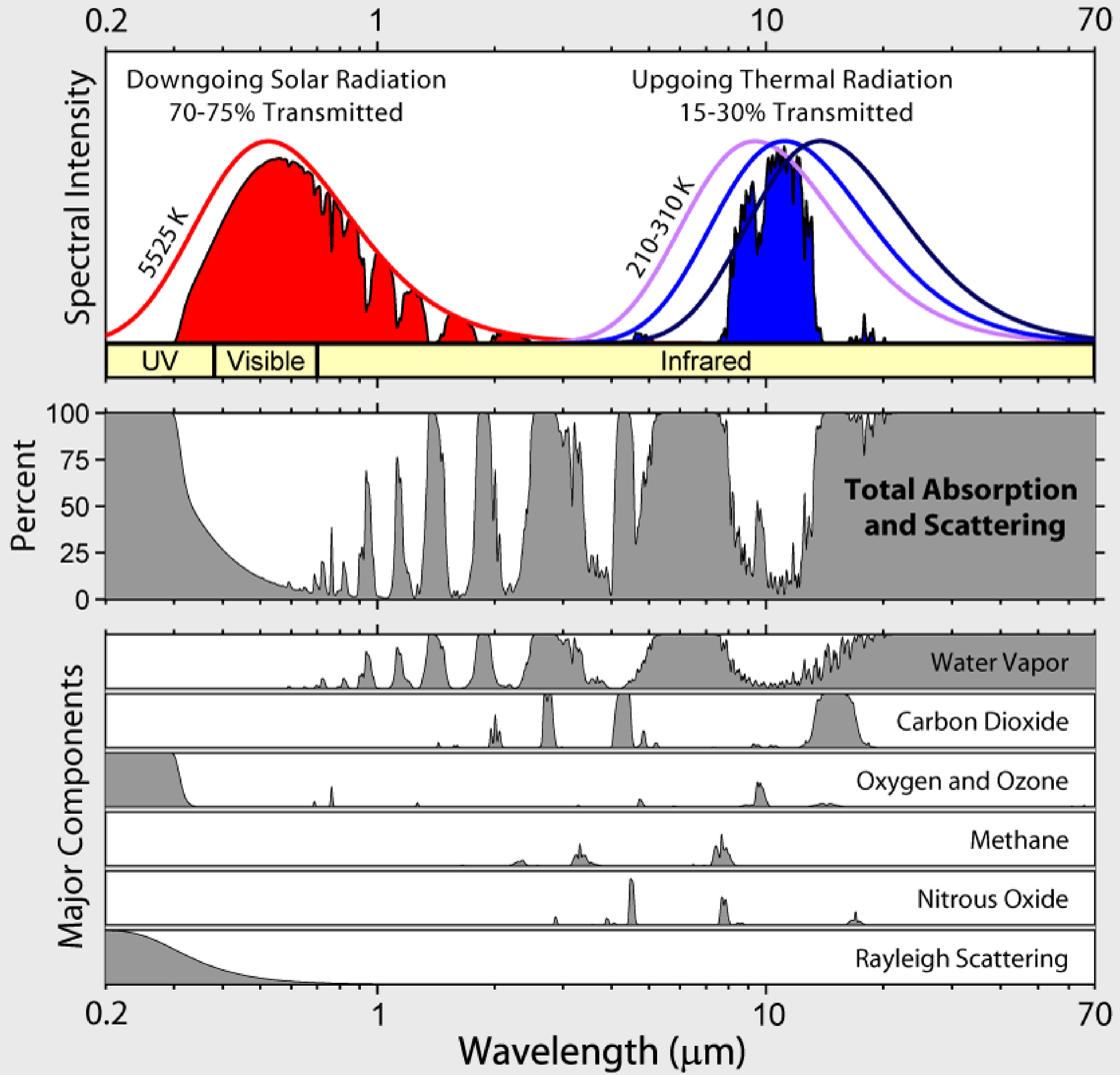
- Most satellite remote sensing instruments operate in regions of the EM spectrum where the atmosphere allows the radiation to pass relatively unhindered
  – These are called atmospheric *windows*
- Atmospheric *sounders* measure on the *shoulders* of molecular absorption bands allowing them to detect radiation from different layers of the atmosphere

Atmospheric Windows



The molecular absorption lines of different gases are responsbile for the opacity of the atmosphere at certain wavelengths

Radiation Transmitted by the Atmosphere



Analysis of Received Radiation

- Radiation received by a sensor is a combination of EMR emitted or reflected by the surface and the EMR added or subtracted by the intervening atmosphere.
  - the wavelength, intensity and polarization of the radiation is used to detect something about its origin
- The top-of-the-atmosphere *radiance* is the energy received by the satellite sensor and includes all of these effects.
- The objective in surface remote sensing is to remove all extraneous effects (atmosphere, illumination and viewing geometry)

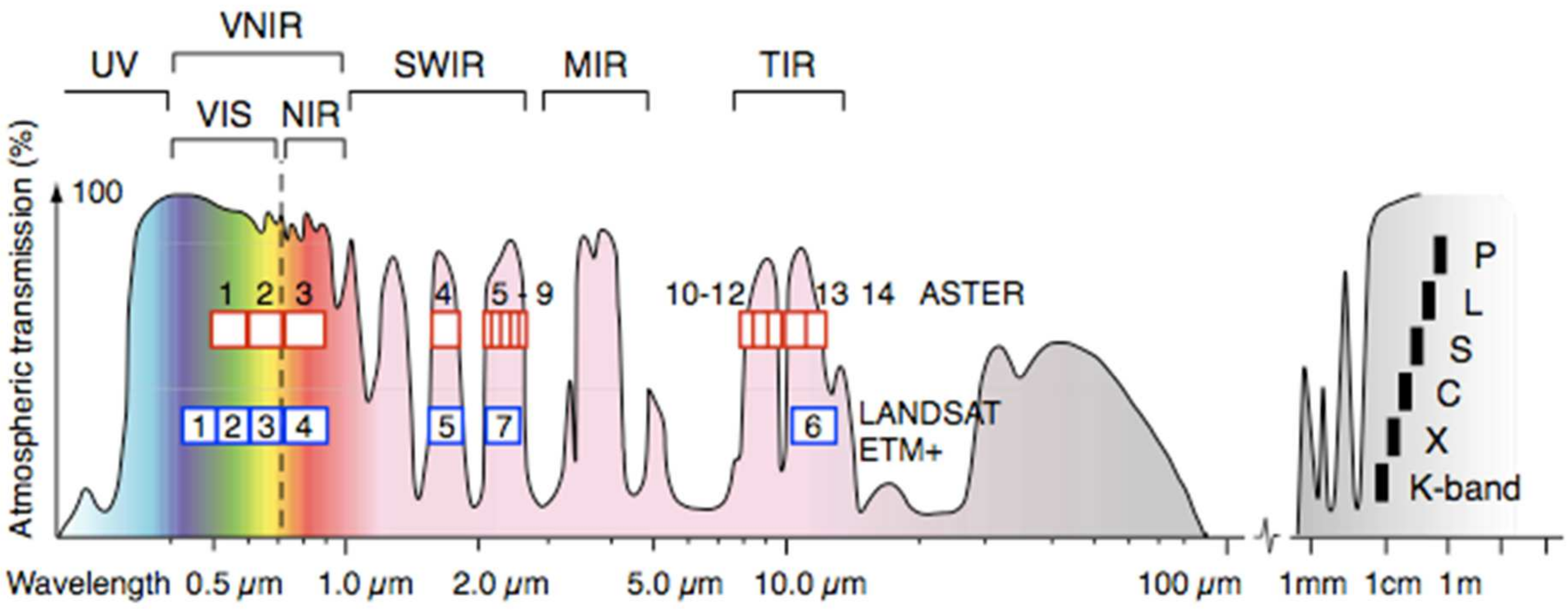


Fig. 5-1 Atmospheric transmission, sections of the optical and microwave spectrum, and spectral range of Landsat ETM+ and ASTER bands. UV: ultraviolet; VIS: visible; NIR: near infrared; SWIR: short-wave infrared; MIR: middle infrared; TIR: thermal infrared.

Some Common Terminology

- VNIR = Visible and Near Infrared
- SWIR = Shortwave Infrared
- TIR = Thermal Infrared

Typical magnitudes:

Visible Light ~ 0.6 μm = 600 nm = 6000 Å

Reflected Solar Infrared (NIR) ~ 3 – 5 μm

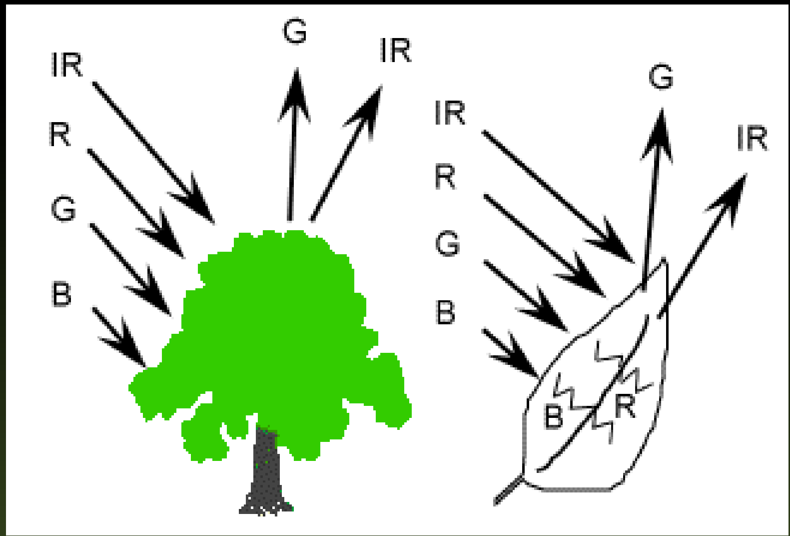
Reflectance

- For instruments measuring in the solar portion of the spectrum the objective is to deduce how much radiation was impingent on the surface and how much was reflected back.
- *Spectral reflectance* is the amount of EMR reflected from a surface divided by the amount of EMR incident on a surface, at a specific wavelength.
- *Spectral Reflectance Curve* - a graph of spectral reflectance of an object as a function of wavelength.
  - This determines the "color" of the object
  - Can be used to distinguish vegetation, rock type, snow cover, ocean chlorophyll, etc.

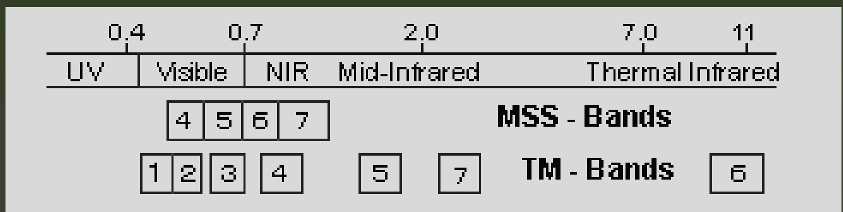
Spectral Reflectance

Outgoing

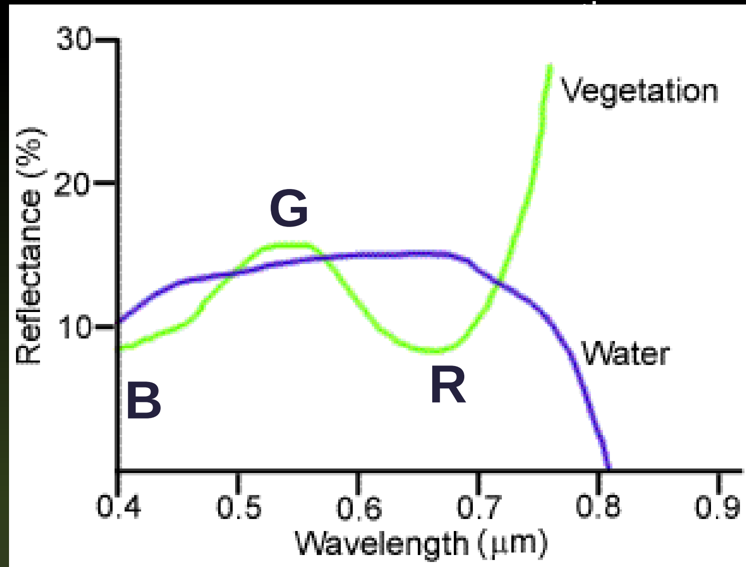
Incoming



Reflection can be *specular* (mirror-like) or diffuse (all directions)



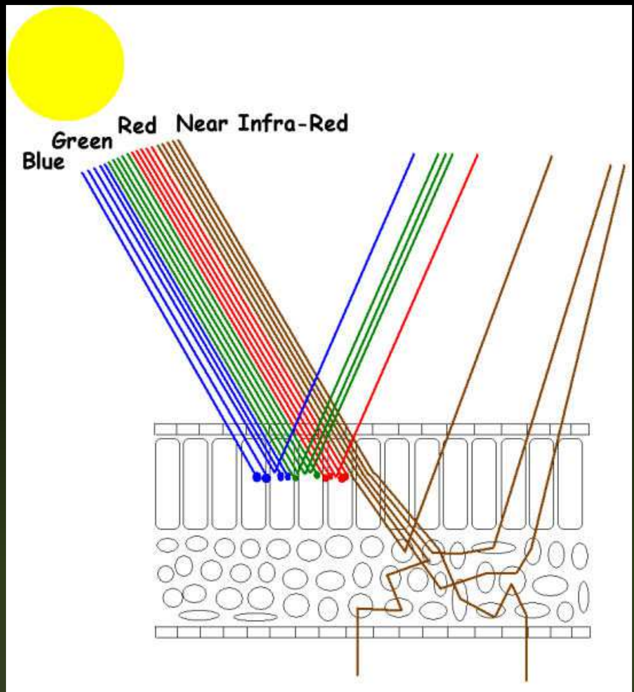
Highly reflective in IR to avoid excess heating &

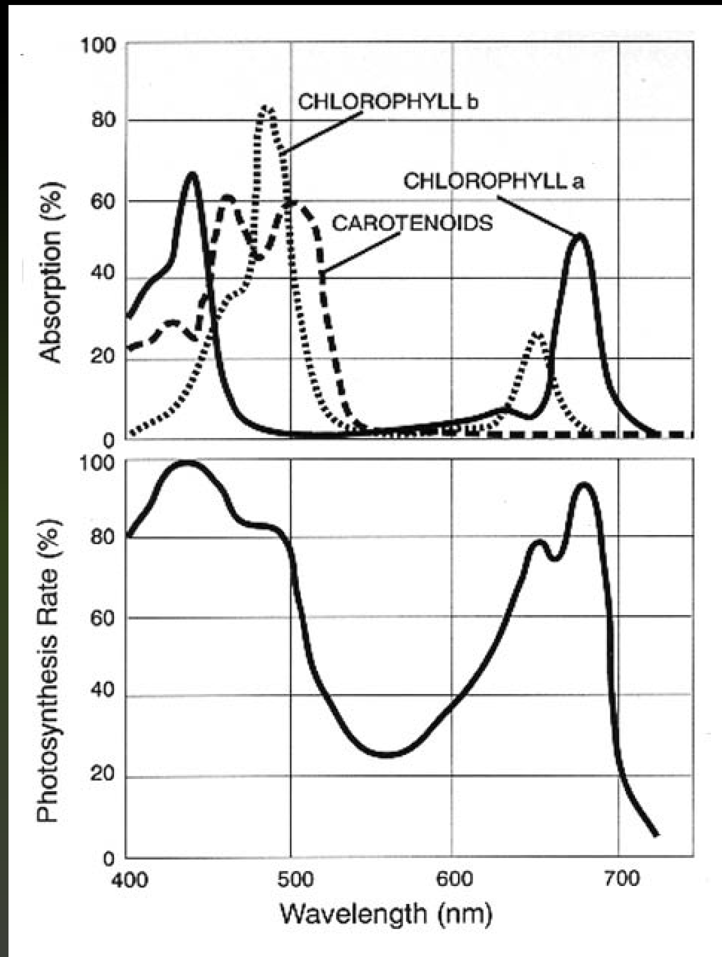


$$\text{NDVI} = \frac{\text{NIR - red}}{\text{NIR + red}}$$

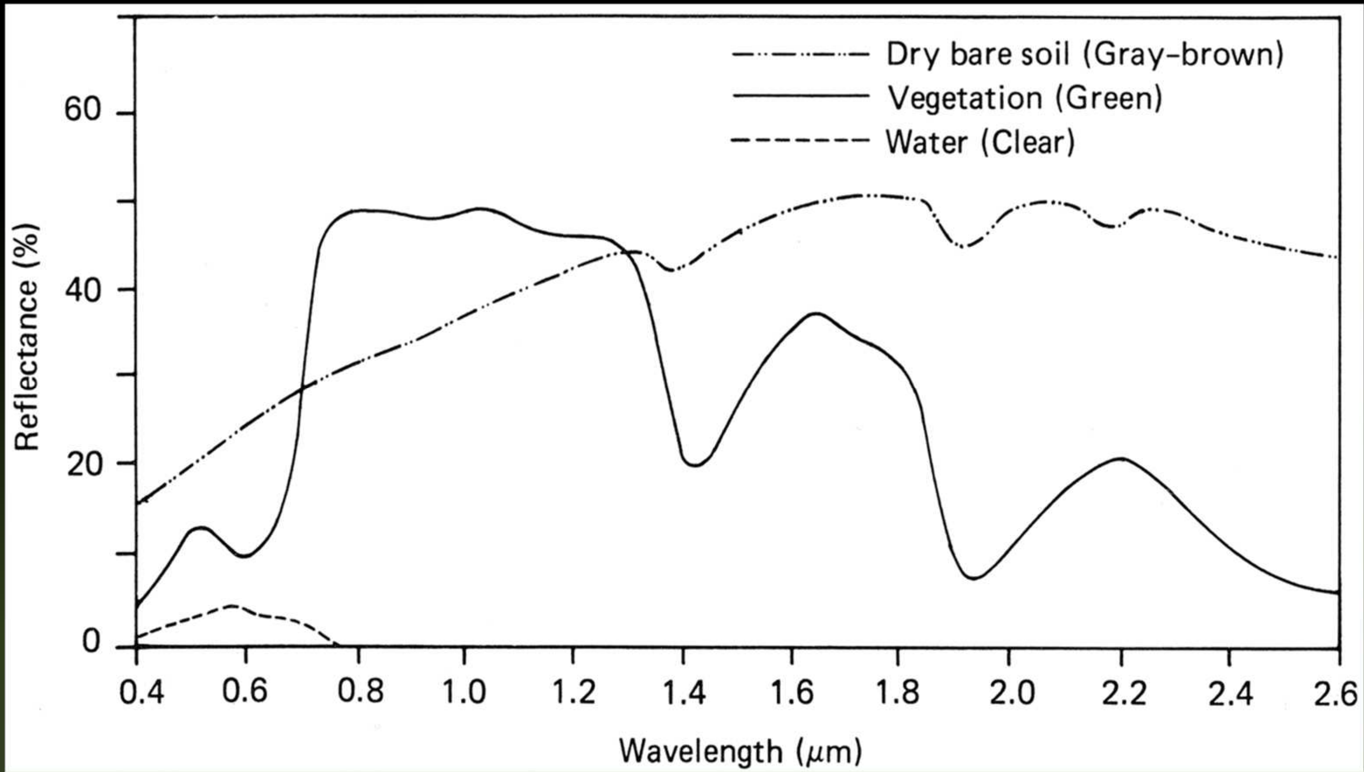
Larger values mean more vegetation in pixel.

Sunlight and Plants



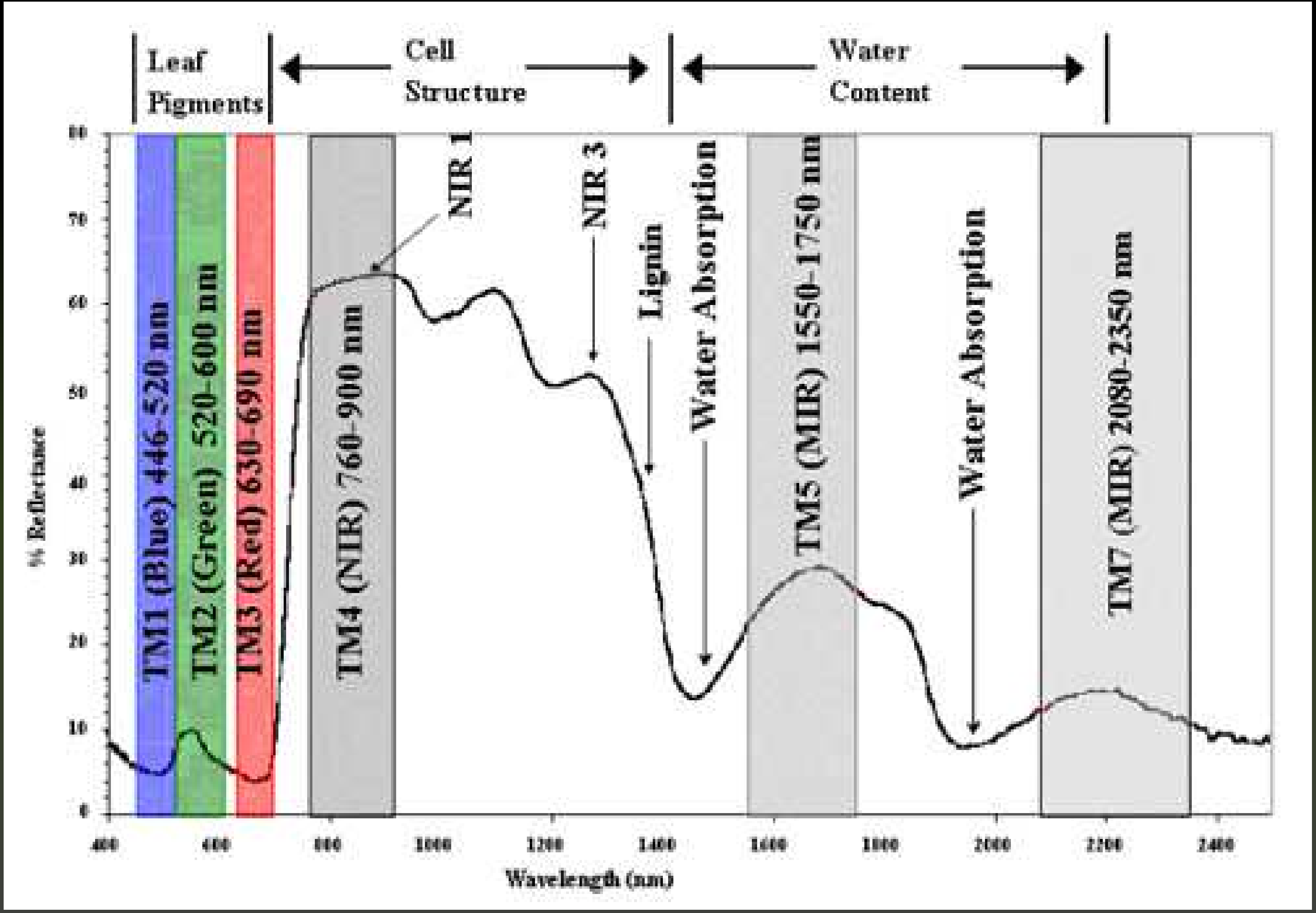


Spectral Signatures



The unique signature of various classes (e.g. Vegetation, Water, bare Soil) in the example above allows multi-spectral satellite imagery for identification

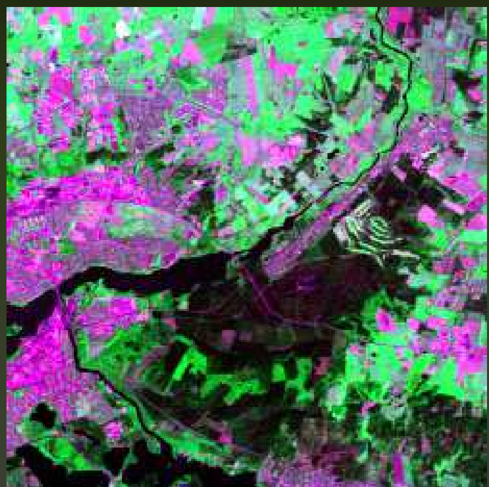
Landsat was designed to assess land cover



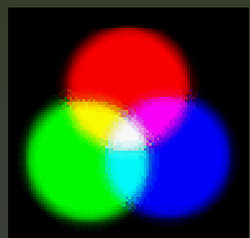
Landsat Ch. 2 (Green)
0.52 – 0.60 μm

Landsat Ch. 3 (Red)
0.63 – 0.69 μm

Landsat Ch. 4 (NIR)
0.76 – 0.90 μm



"False Color" composite created by assigning reflectance in channels 3, 4 and 2 to red, green and blue, respectively. Can be used to distinguish water, residential areas, crops, hardwood and softwood forests.



High Ch. 2 (Green) +
High Ch. 3 (Red) +
Low Ch. 4 (NIR) =
blue + red = magenta

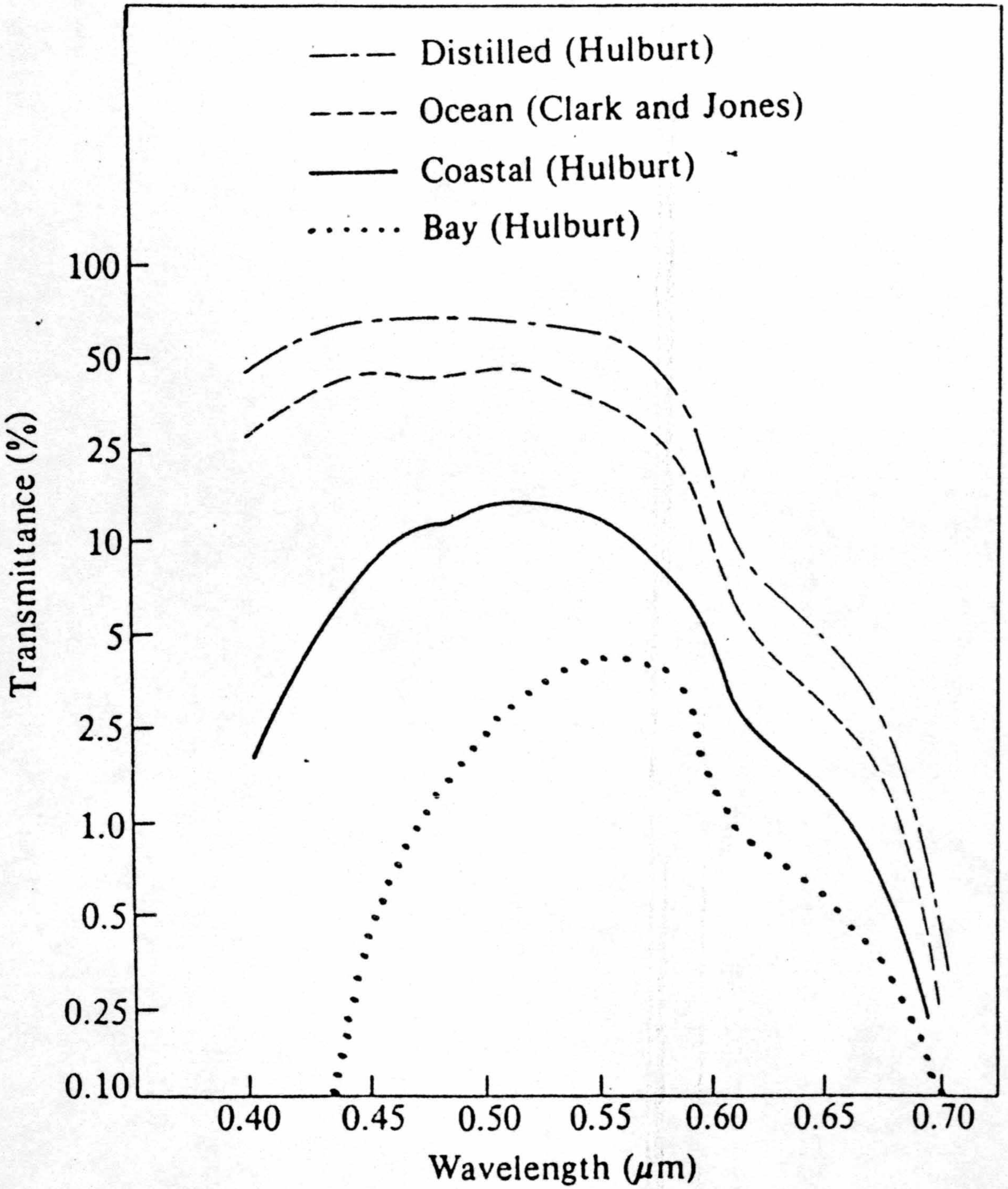


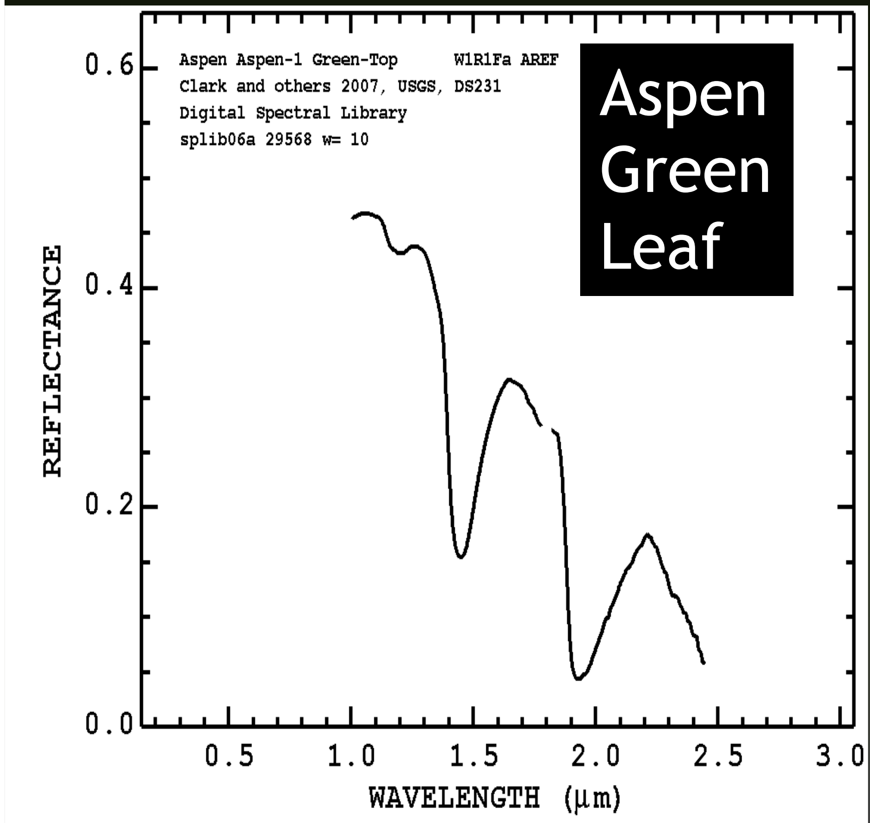
Figure 5-23 Spectral transmittance through ten meters of water of various types (*After Specht et a*
© copyright 1973, American Society of Photogrammetry. Used with permission.)

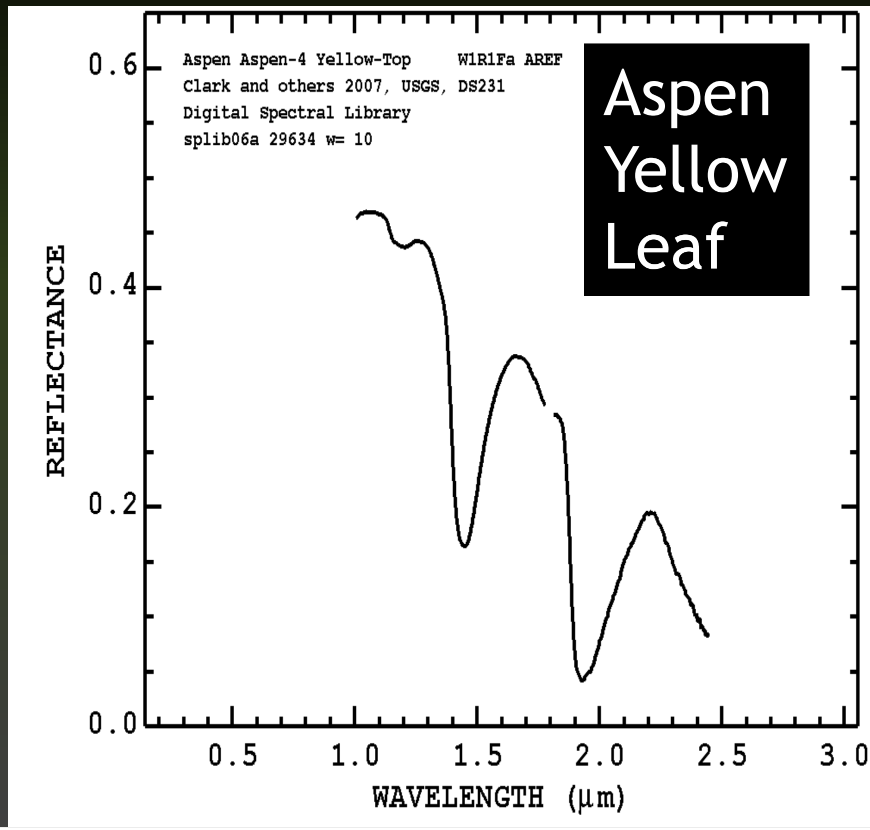
The signal reaching any space borne sensor is a complex mixture of surface and atmospheric components.

One of the advantages of MODIS is its broad spectral range. The wider the spectral range the more information content we have when we observe the Earth - Atmosphere system.

Let's begin simply by examining some sample spectra of different surfaces.

Aspen Leaves - very uniform





Remote Sensing of Radiation

Hyperspectral imaging spectrometers produce 3-D images or hyperspectral cubes of x*y*wavelength images using sensor arrays measuring at hundreds or thousands of wavelengths.

Hyperspectral cube generated from the NASA Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) airborne sensor.