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Remote Sensing Fundamentals – An Overview

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Presentation Outline

- Definition
- Fundamental Components
- Energy Path Concept
- Electromagnetic Radiation (EMR)
- Interactions of EMR and Surface Materials
- Effects of the Atmosphere
- Role of Remote Sensing in Studying the Earth
- Platforms and Sensors

Remote Sensing Defined

Remote Sensing is the science and art of obtaining information about objects or phenomena without being in contact with them. Remote sensing deals with the detection and measurement of objects with devices sensitive to electromagnetic energy such light, heat, and radio waves.

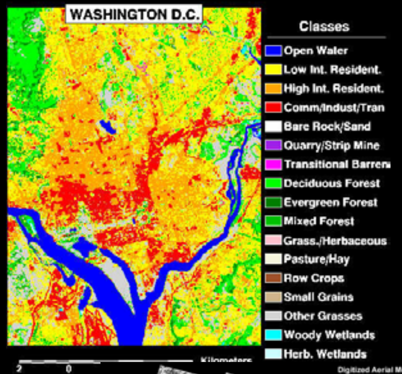
Courtesy of J.K. Lien

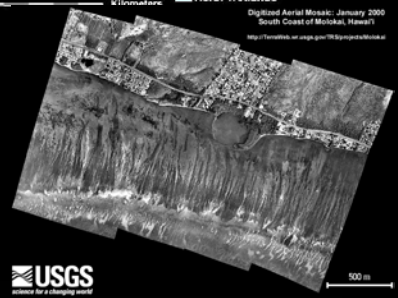
Definition (cont.)

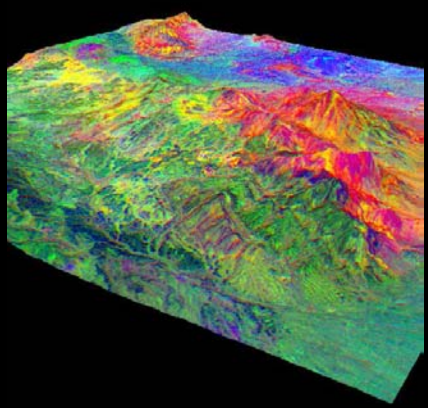
Land Remote Sensing deals with obtaining information about objects, resources, conditions, and processes that occur or operate on or near the land surface of the Earth…things like biologic conditions and resources, geologic and hydrologic processes and resources, topographic and geographic features, and human dynamics.

Some USGS Applications of Land Remotely Sensed Data

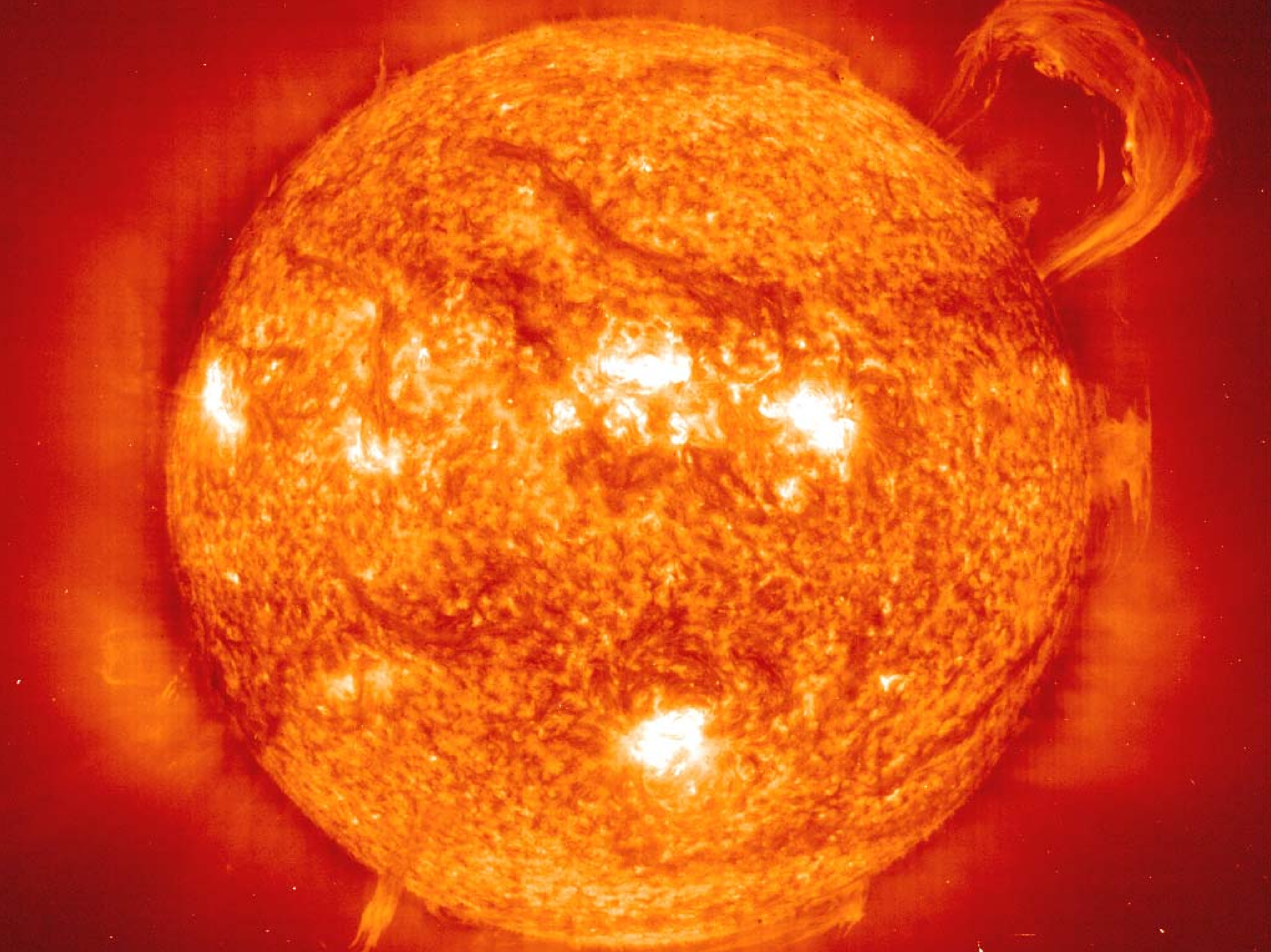
- Landsat 7 ETM+ Data
  - Land Cover Classification
  - Urban Impervious Cover Mapping
  - Vegetation Flow Resistance Mapping
  - Groundwater Discharge Modeling
  - Geologic Mapping
- Aerial Photography
  - Cooperative Vegetation Mapping Program
  - Monitoring Coral Reef Degradation
- Interferometric Radar
  - Earthquake-Related Ground Deformation
  - Volcanic Inflation Detection
- AVIRIS Data
  - Mineral Mapping
  - Crop Identification
- ASTER Data Geologic Studies

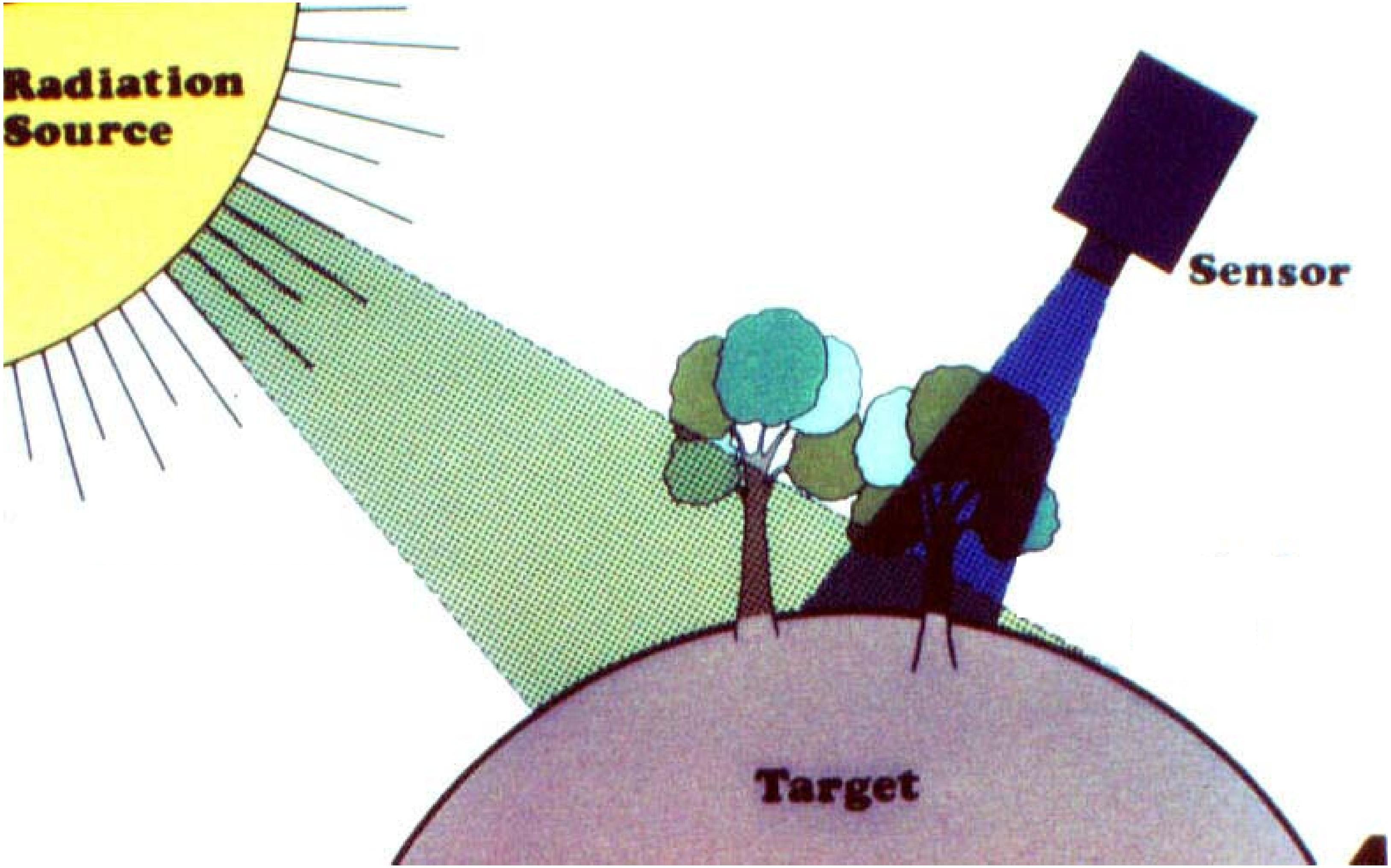






Fundamental Components
of
Land Remote Sensing



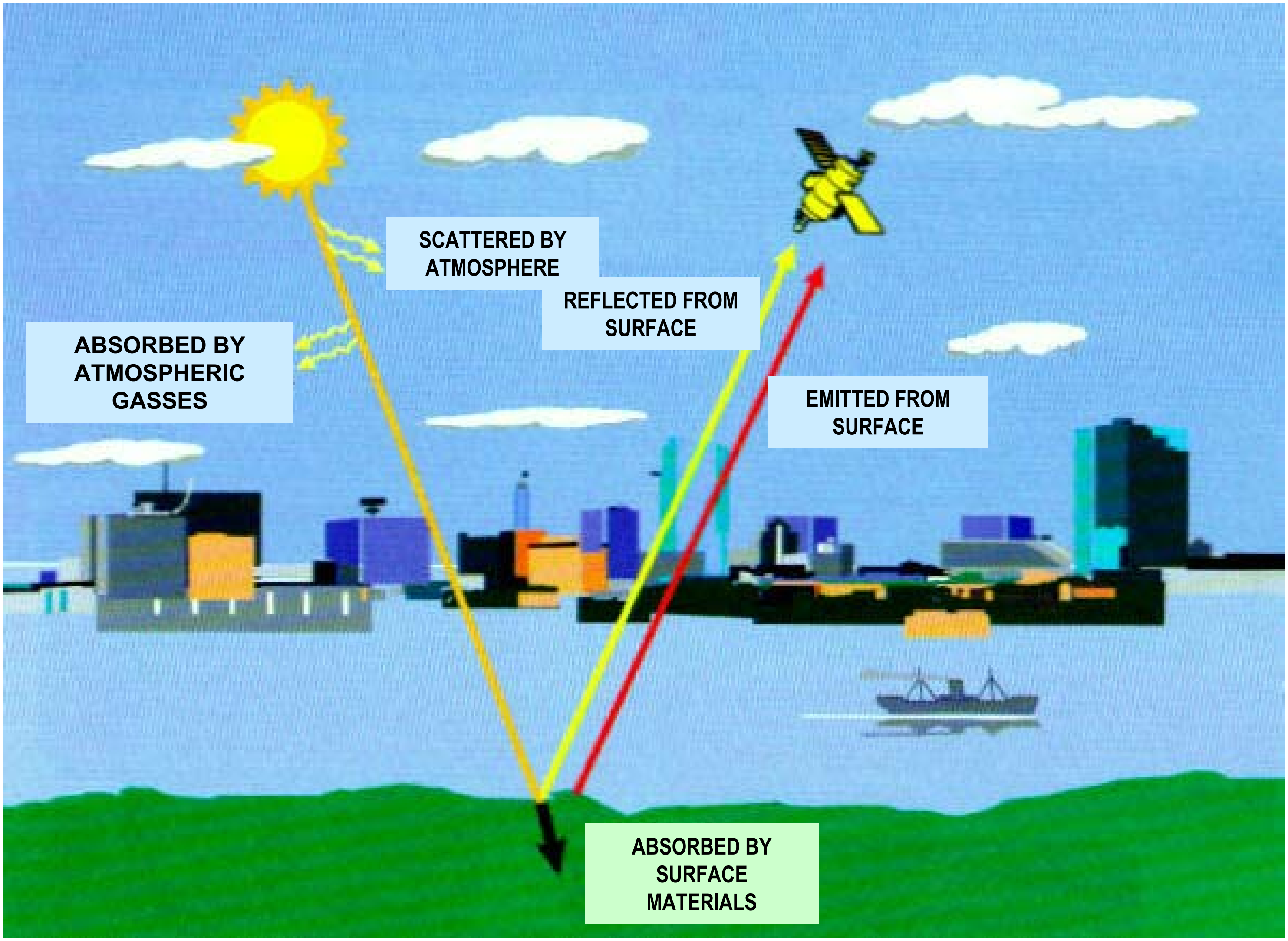


Remote Sensing's Primary Components: Source, Target, and Sensor

The Energy Path Concept

- Source of electromagnetic energy (usually the sun).
- Transmission of energy from the source to the Earth's surface.
- Reflection or re-emission of the energy from the surface.
- Transmission of energy from the surface to a sensor.
- Recording of the energy falling on the sensor's detectors.
- Processing the recorded data into information.

The Energy Path Concept



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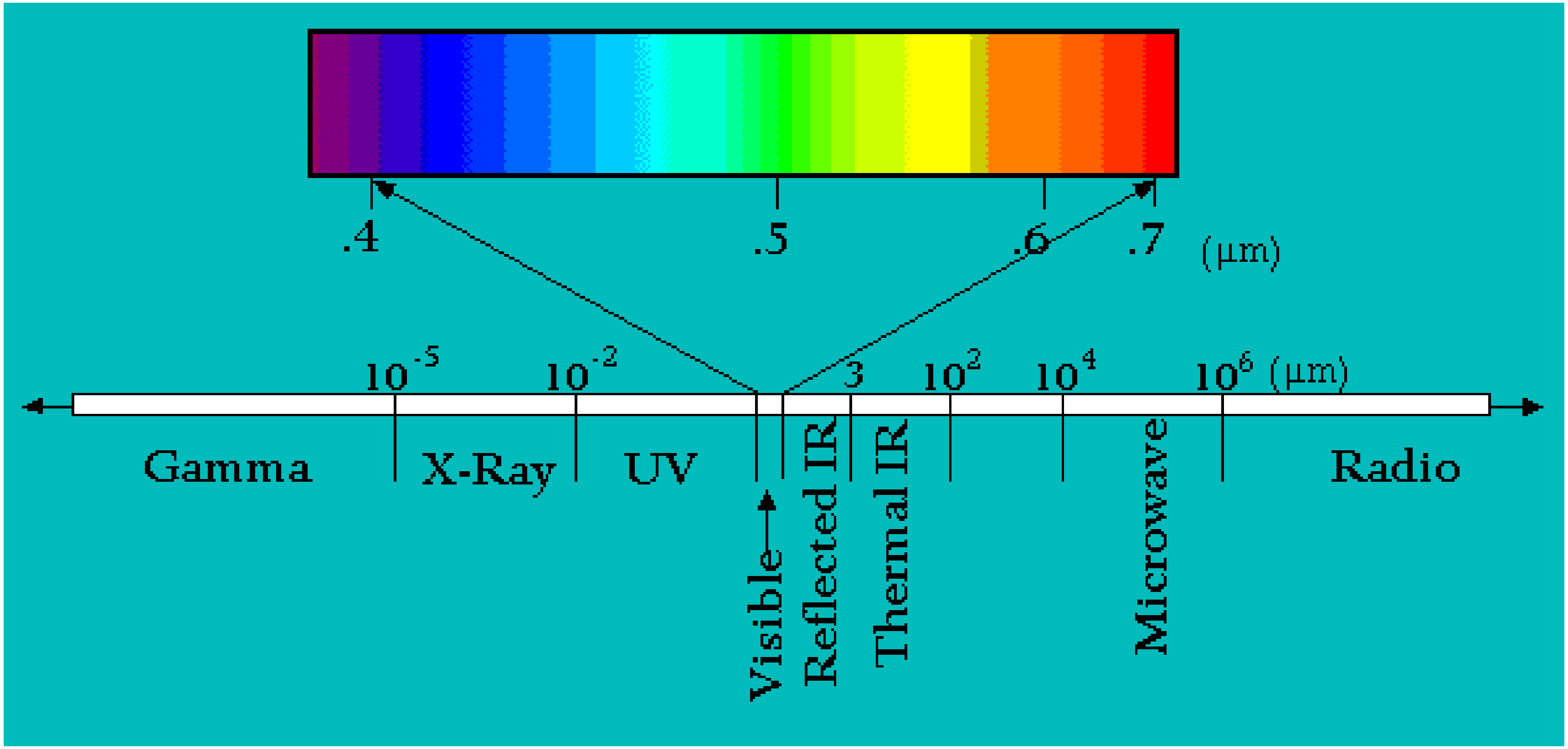
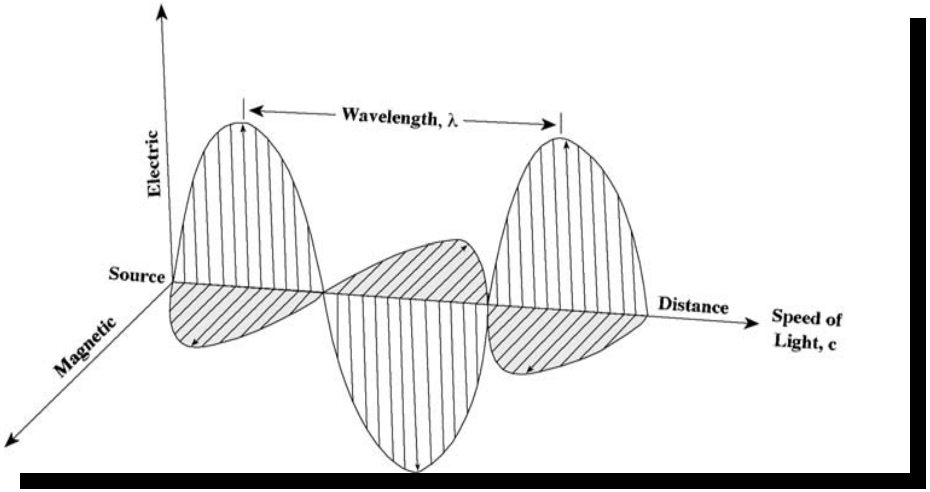
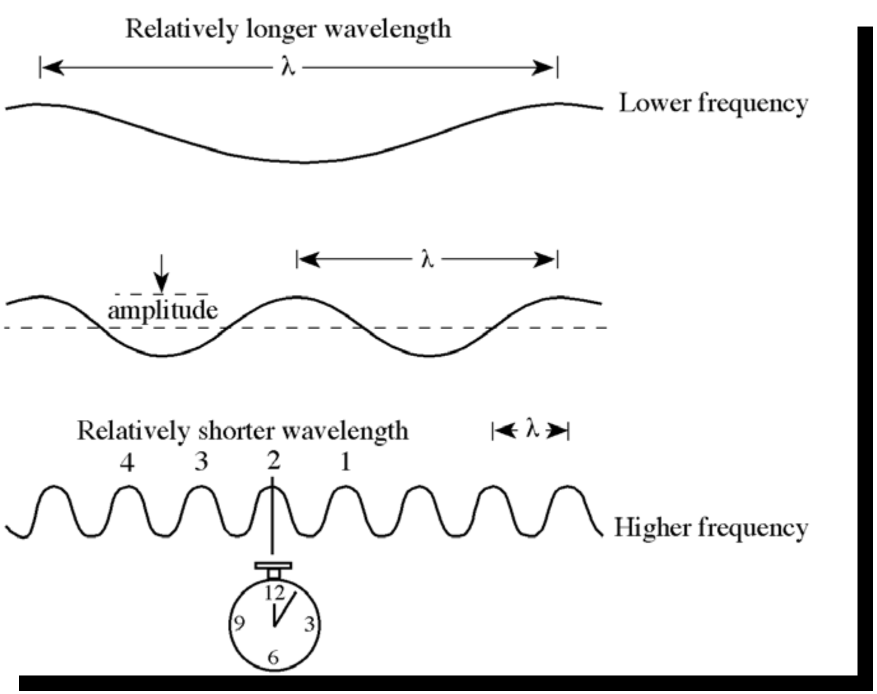
Electromagnetic Radiation (EMR)



What is EMR?

- Light is a wave
- Like all waves, it has:
  - speed (c = 2.99 x 10^8 m/s)
  - Wavelenth (λ), measured in
    - micrometer (10^{-6} m), or
    - nanometers (10^{-9} m)
  - frequency (f), measured in *Hertz*, or *cycles per second*
  - $c = \lambda f$
- Other wave properties
  - phase
  - polarization





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What is EMR?

- It's also a particle (called a photon)
- The energy of the photon is related to its frequency: $E = hf$ (*h* is called *Plancks' constant*)
- To avoid the embarrassment of admitting that no single theory describes both waves and particles, physicists adopted the term:

Wave/Particle Duality

Wave-Particle Duality

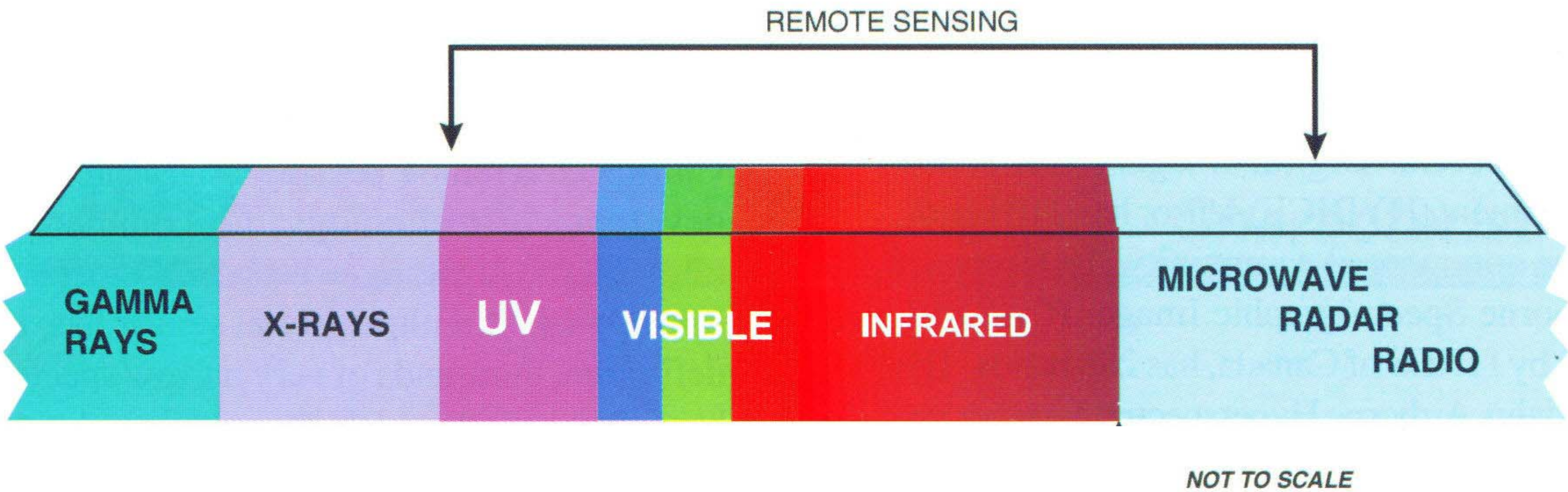
EMR behaves in two inseparable ways…..

1. As fluctuating electric and magnetic *waves*: Propagation of Energy

2. As packets of particles called *photons* or *quanta:* Quantify Energy

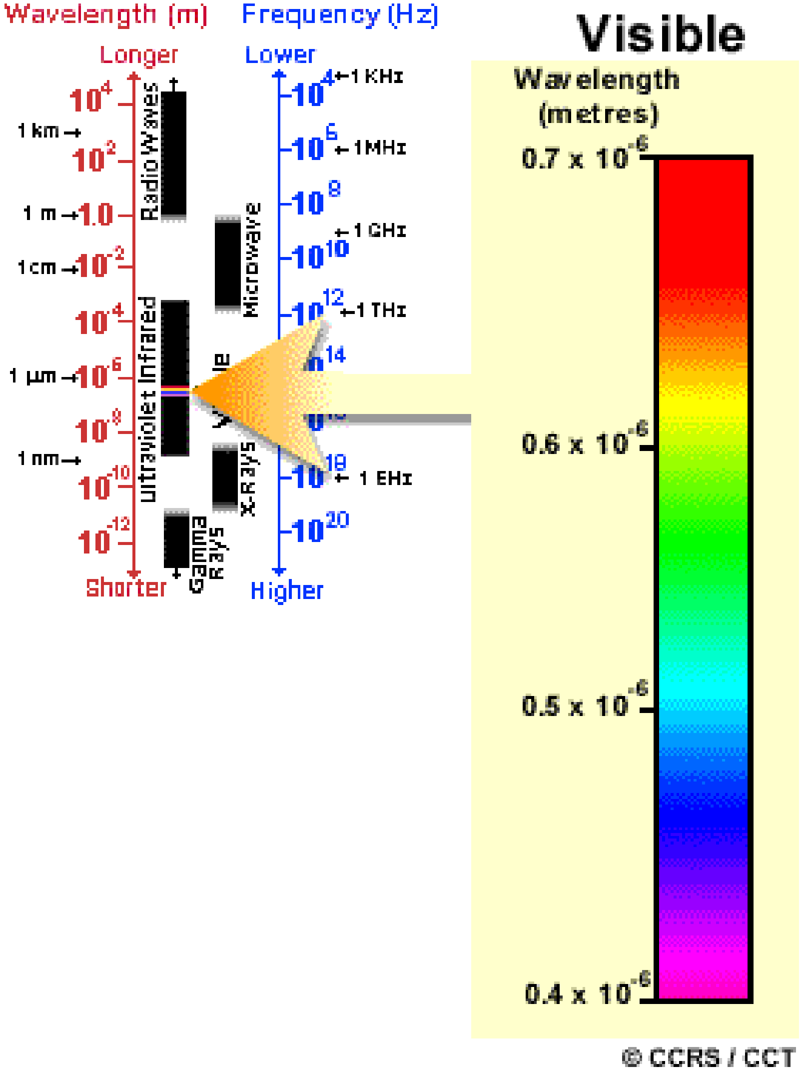
To address any given problem, only one of these descriptions can be applied.

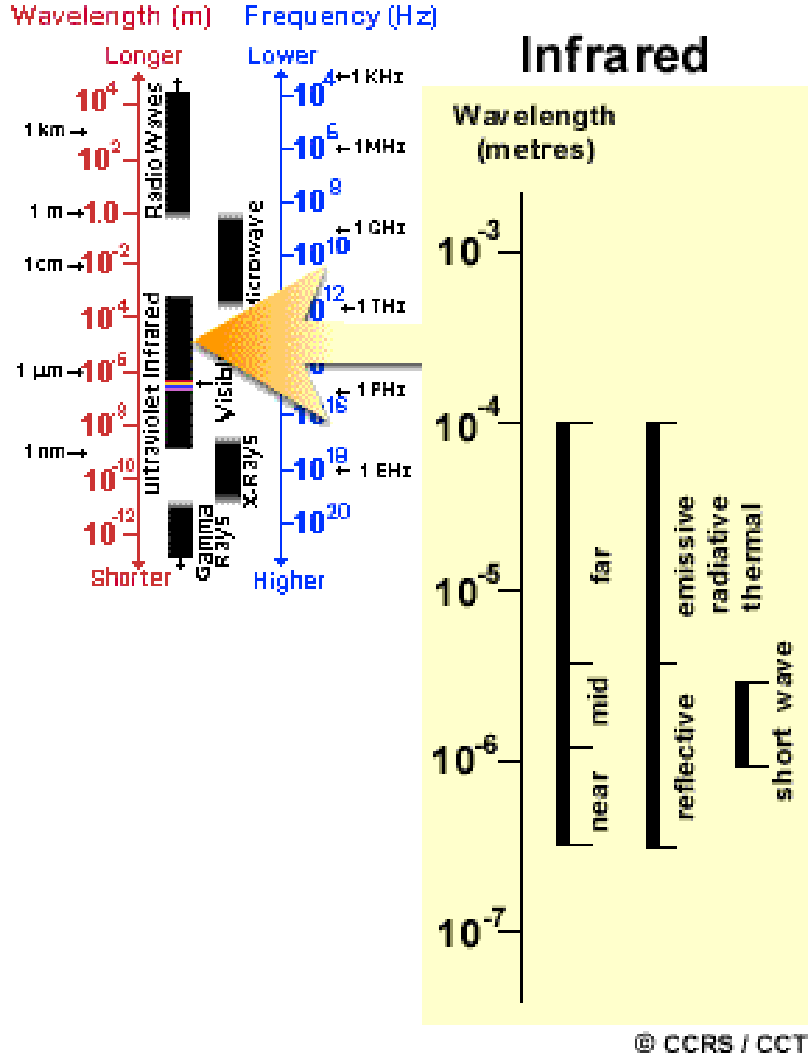
The Remote Sensing Portion of the Spectrum



Logicon Geodynamics

EMR Sensed by ASTER and MODIS





Interaction of EMR with Surface Materials

EMR/Matter Interactions

- A material object can reflect, transmit or absorb radiation that is incident upon it
  - reflectance – fraction of incident radiation reflected
  - transmittance – fraction of incident radiation transmitted
  - absorptance – fraction of incident radiation absorbed
- Energy conservation –

$$\mathbf{r + t + a = 1}$$

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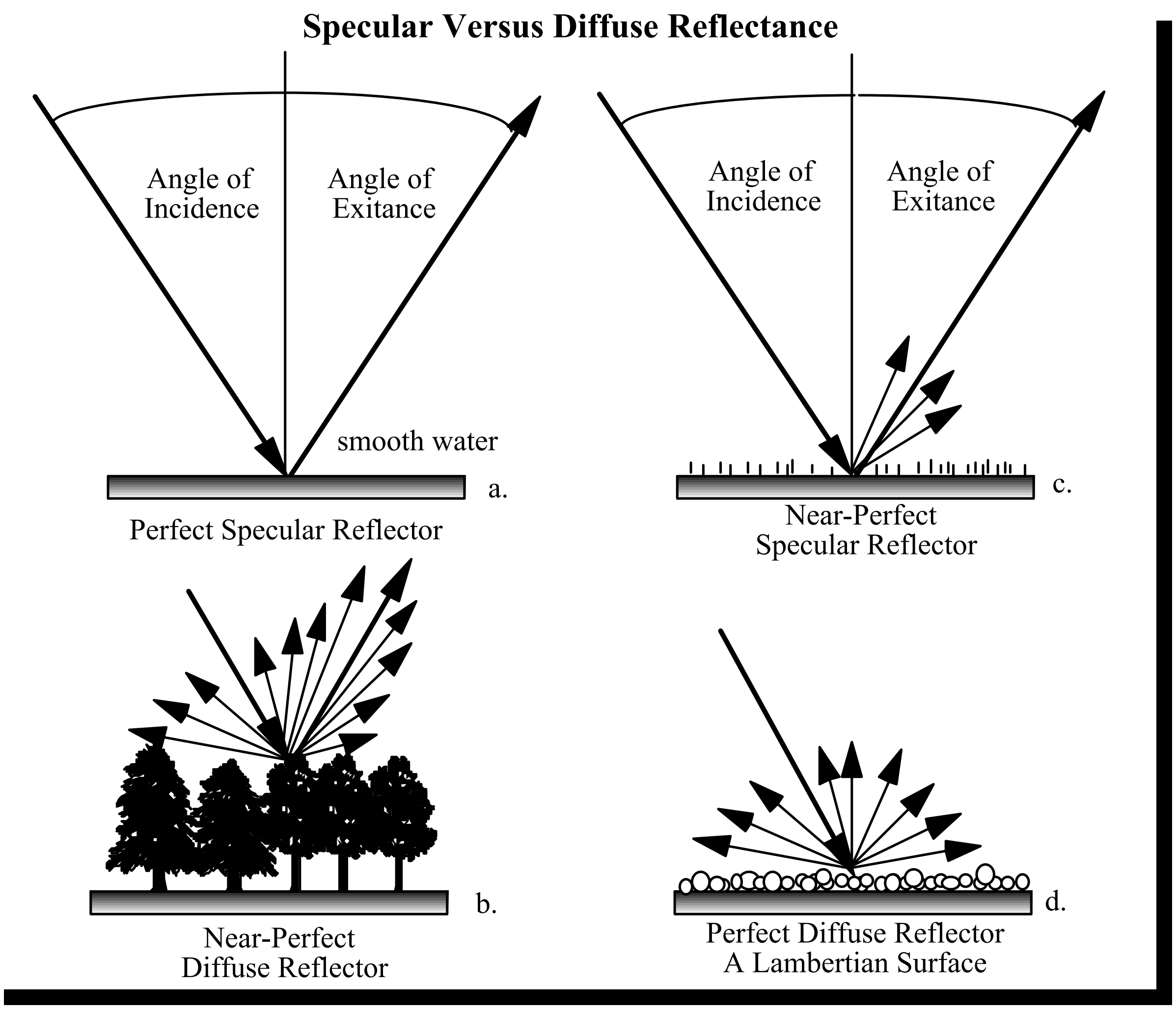
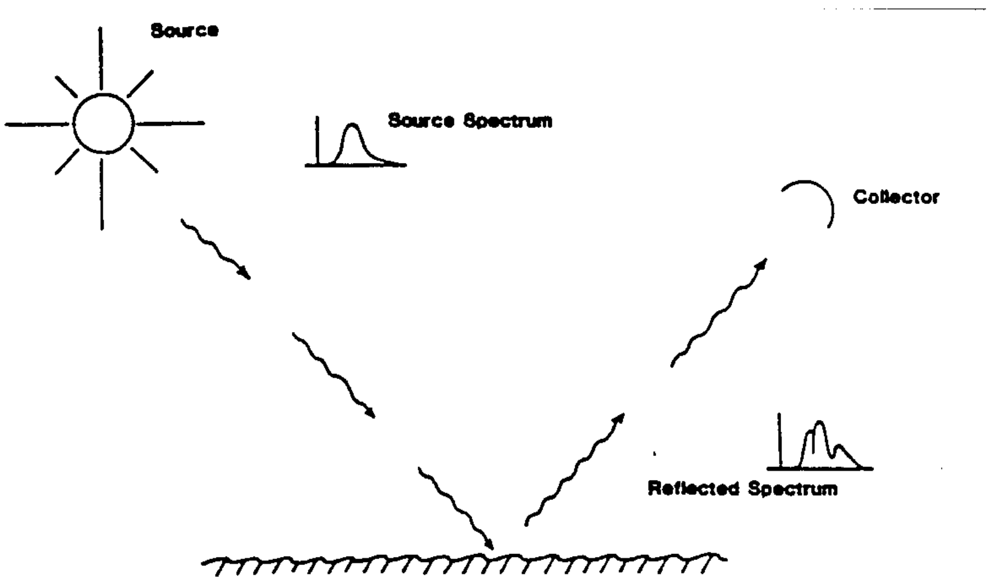
Types of Reflectance



Jenson, 2000

Surface Interactions



from Elachi, 1987

❖The surface imprints on the reflected wave a certain spectral signature, so we can measure the reflected wave and determine information about the surface.

Spectral Properties

- The ***spectral properties*** of an object describe how the object's reflectance, transmittance and absorptance properties change with wavelength.
- These changes are due to the chemical and physical properties of the object.
- Therefore, by remotely observing reflected or emitted ***spectra*** from the Earth's surface, we can infer material and structural properties of surface features.

Reflectance Spectra

- Reflectance spectra infer absorptance ($r + a = 1$, assuming $t = 0$)
- Causes of absorption features:
  - electronic transition – photons of specific energies excite electrons from their "ground state" (<1 micron, higher energies)
  - vibrational transitions – molecules "vibrate" at characteristic frequencies based on their bond structure (1 – 3 microns, middle energies)
  - rotational – molecules "rotate" at characteristic frequencies (>2 microns, lower energies)

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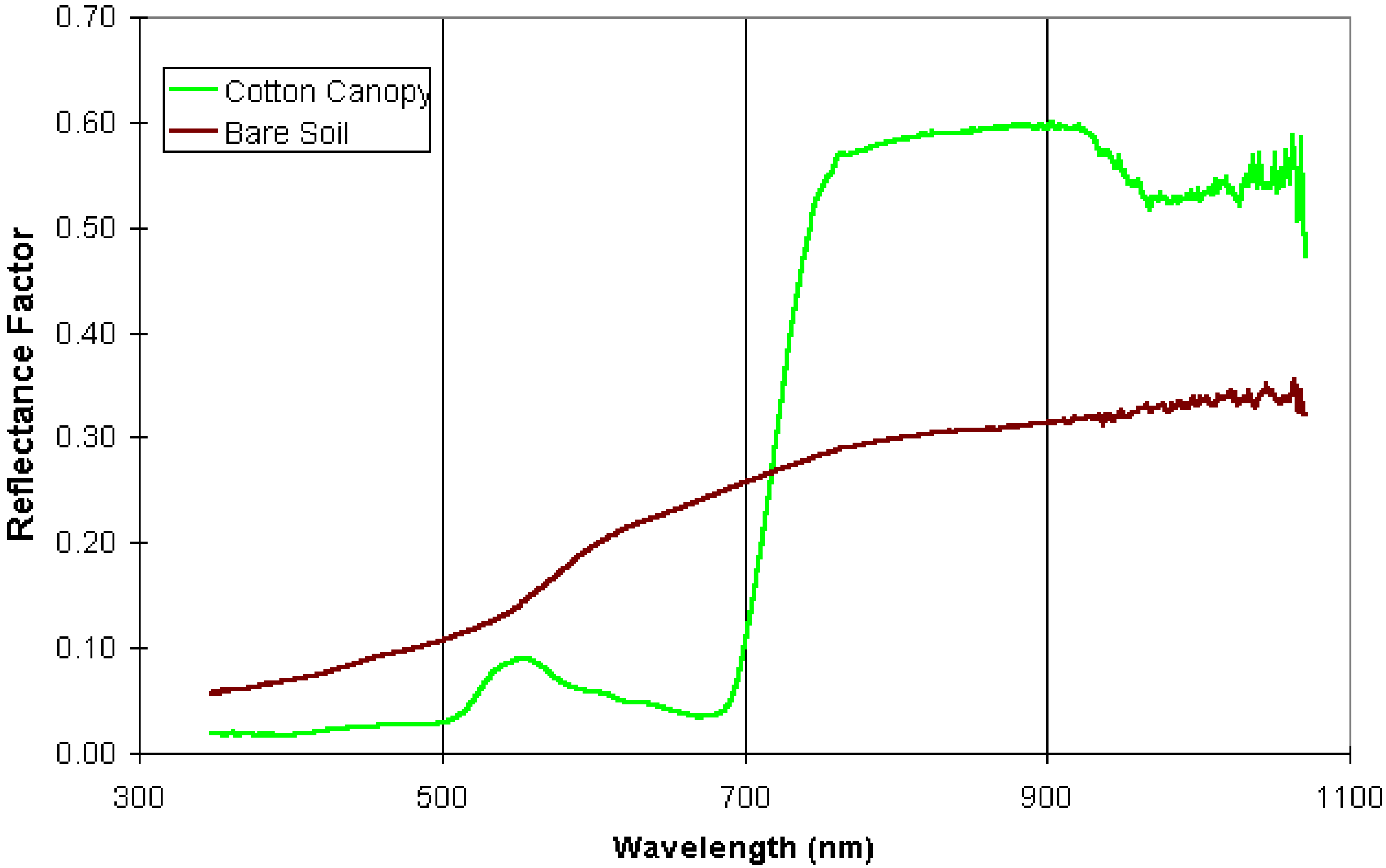
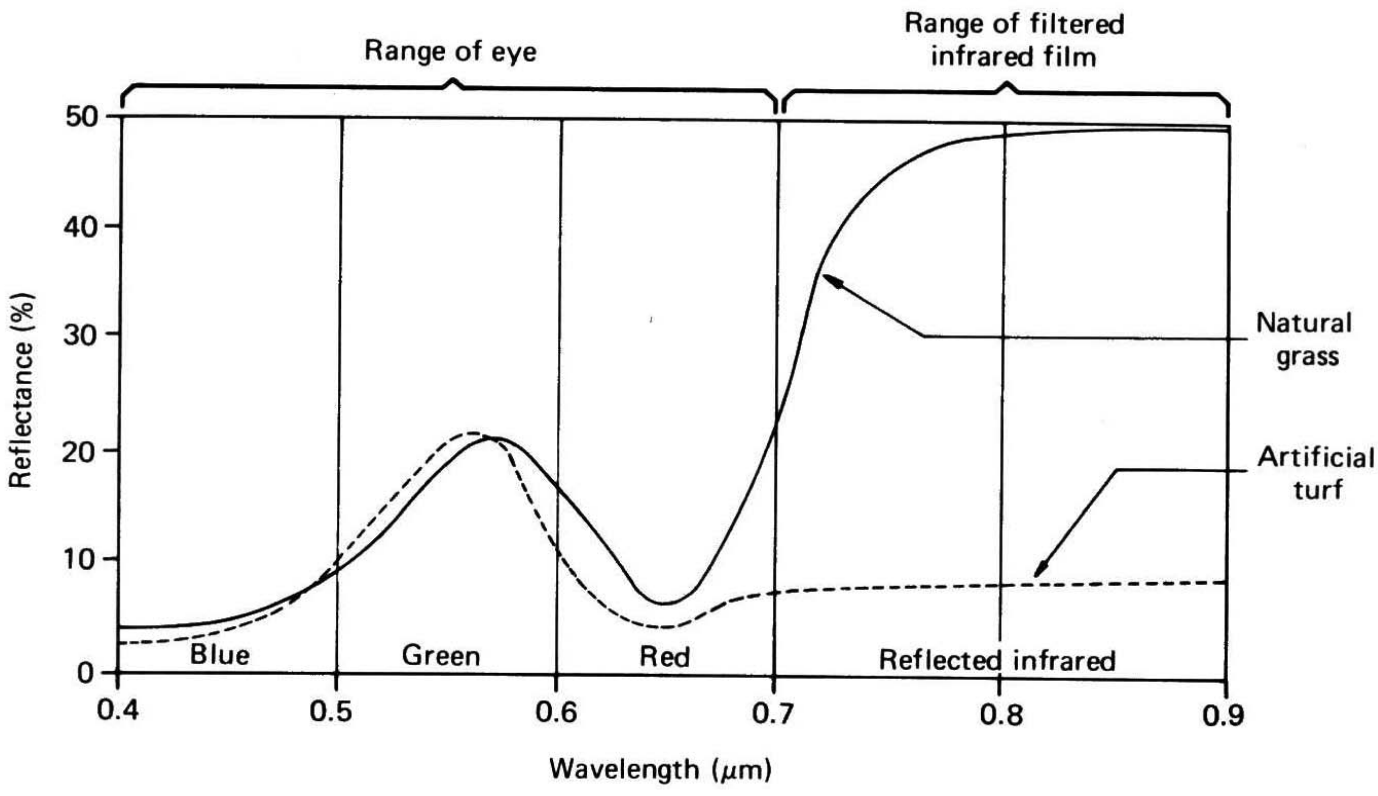
Typical Crop and Soil Reflectance Spectra

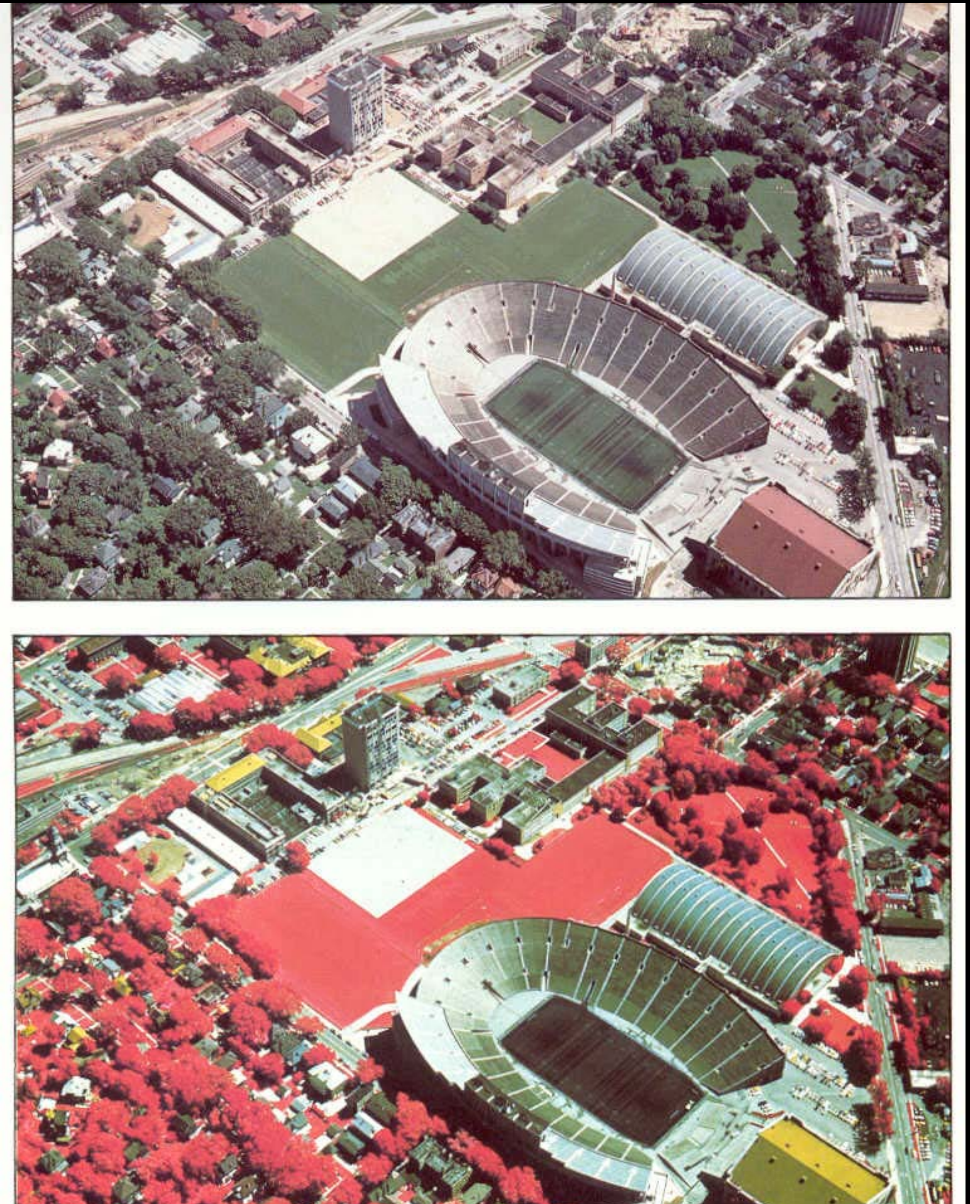


All That's Green Is Not Grass

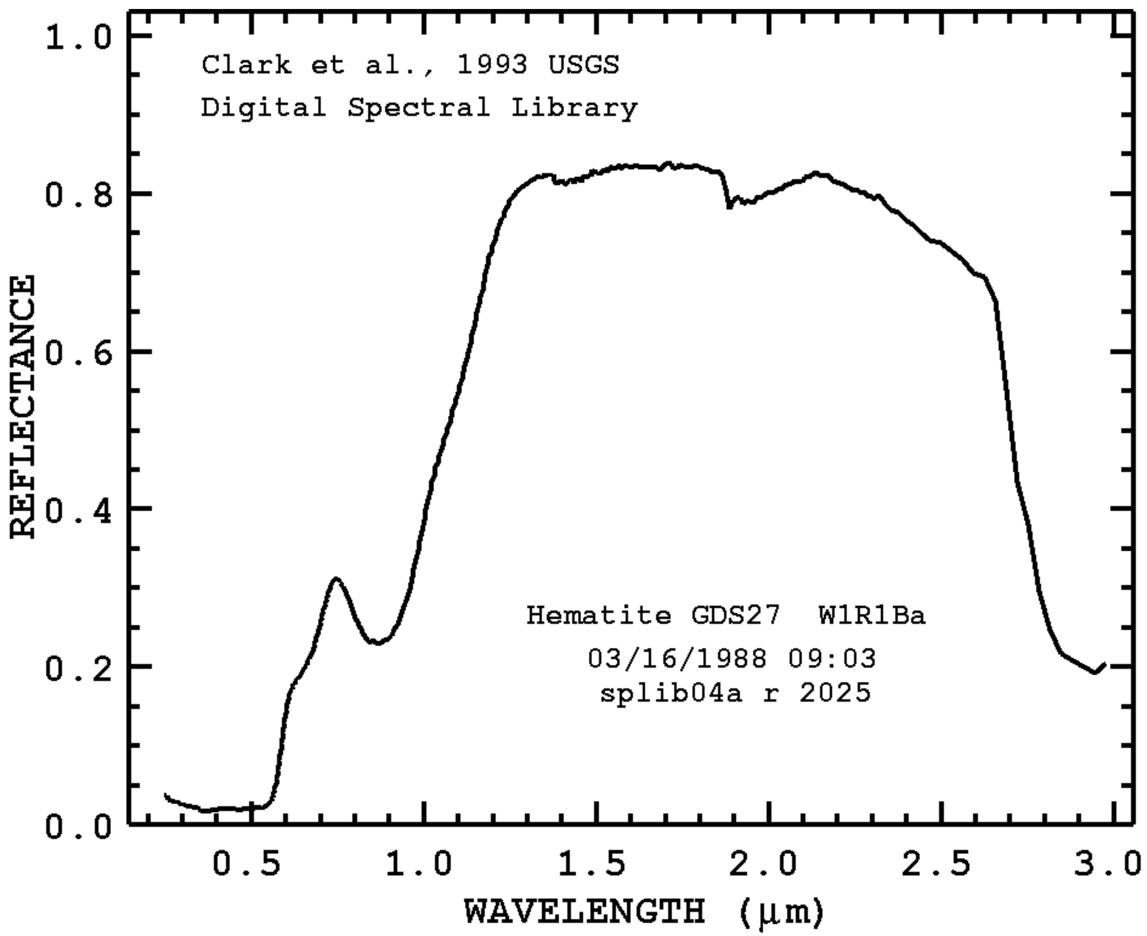


Or Is It?!

Indeed Not!

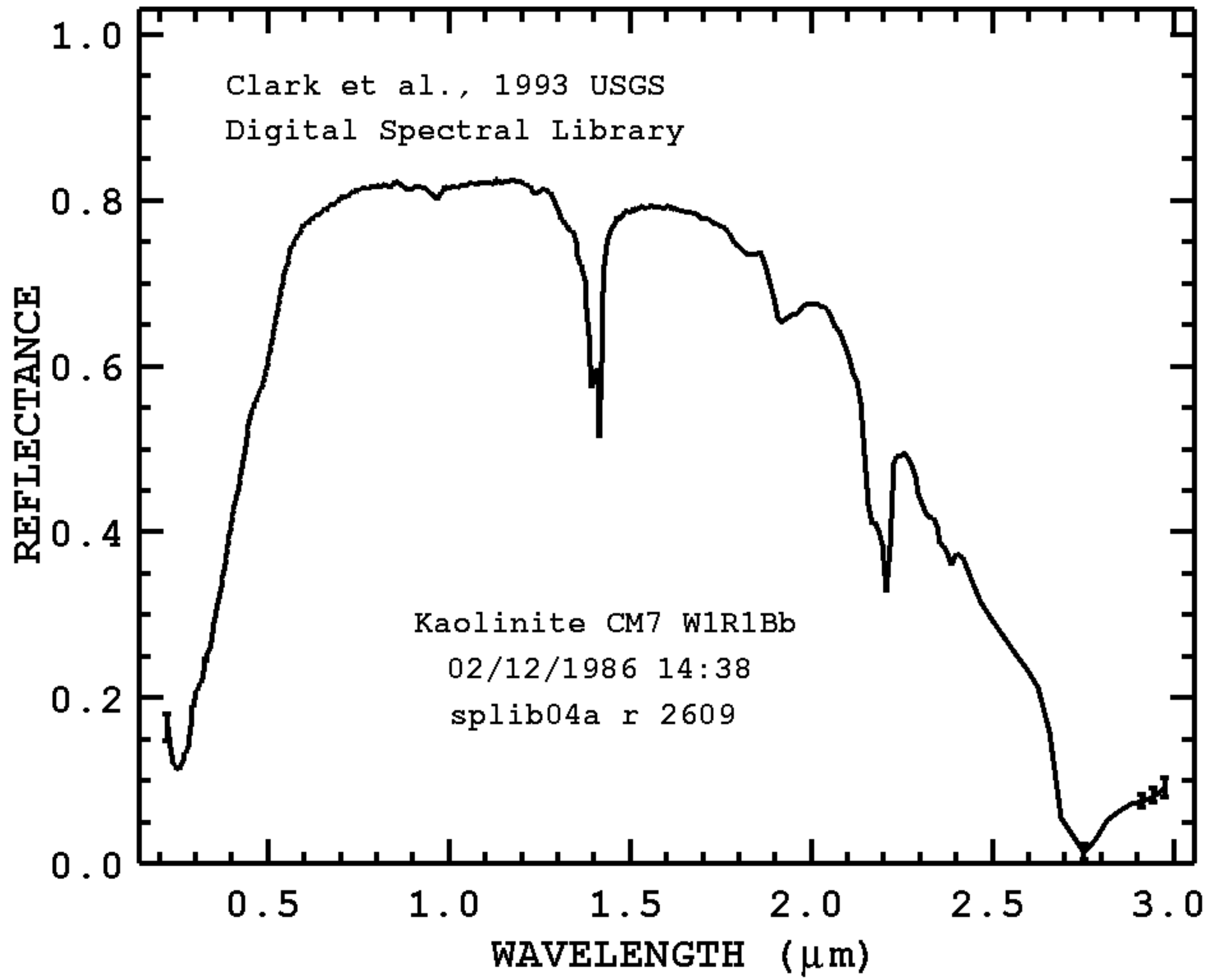


Typical Hematite Spectra

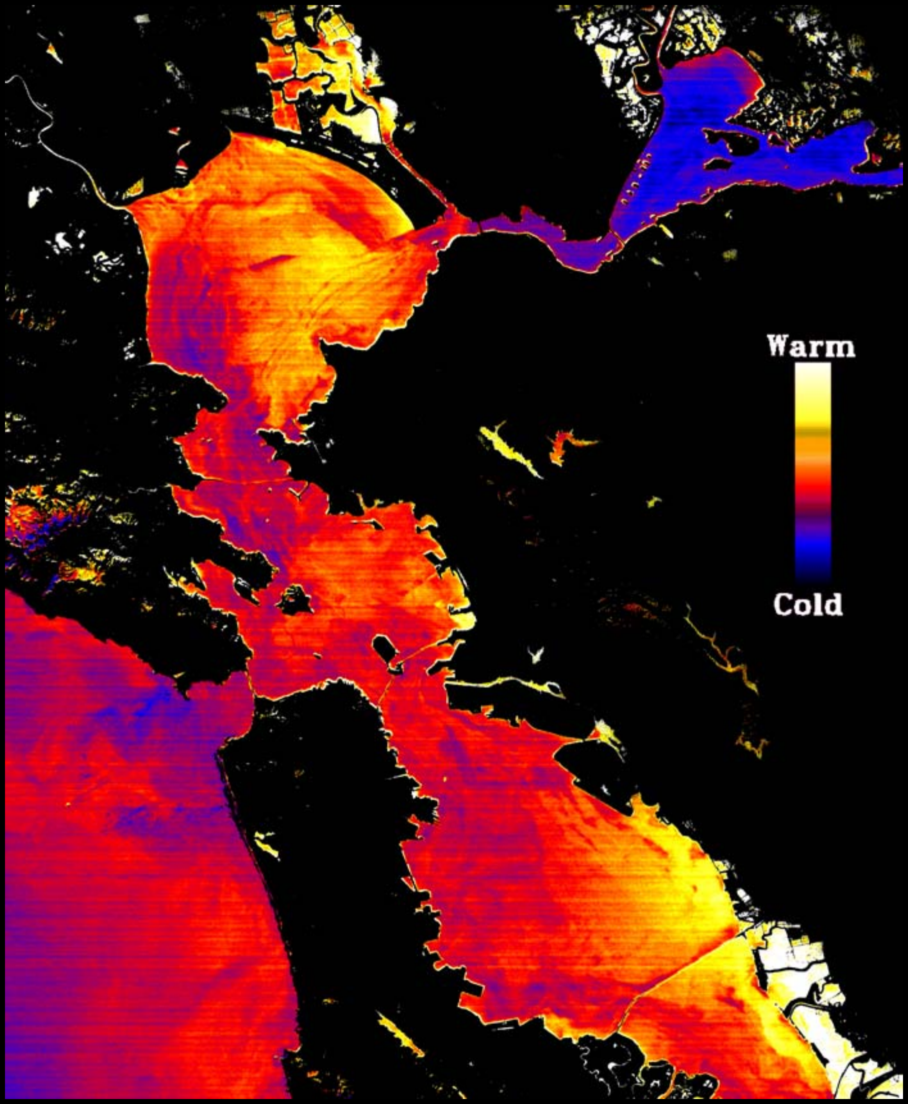


Hematite (Fe_2O_3)

Typical Kaolinite Spectra



A Little Bit on Thermal Remote Sensing



Concepts Important in Thermal Remote Sensing

- Planck's Law

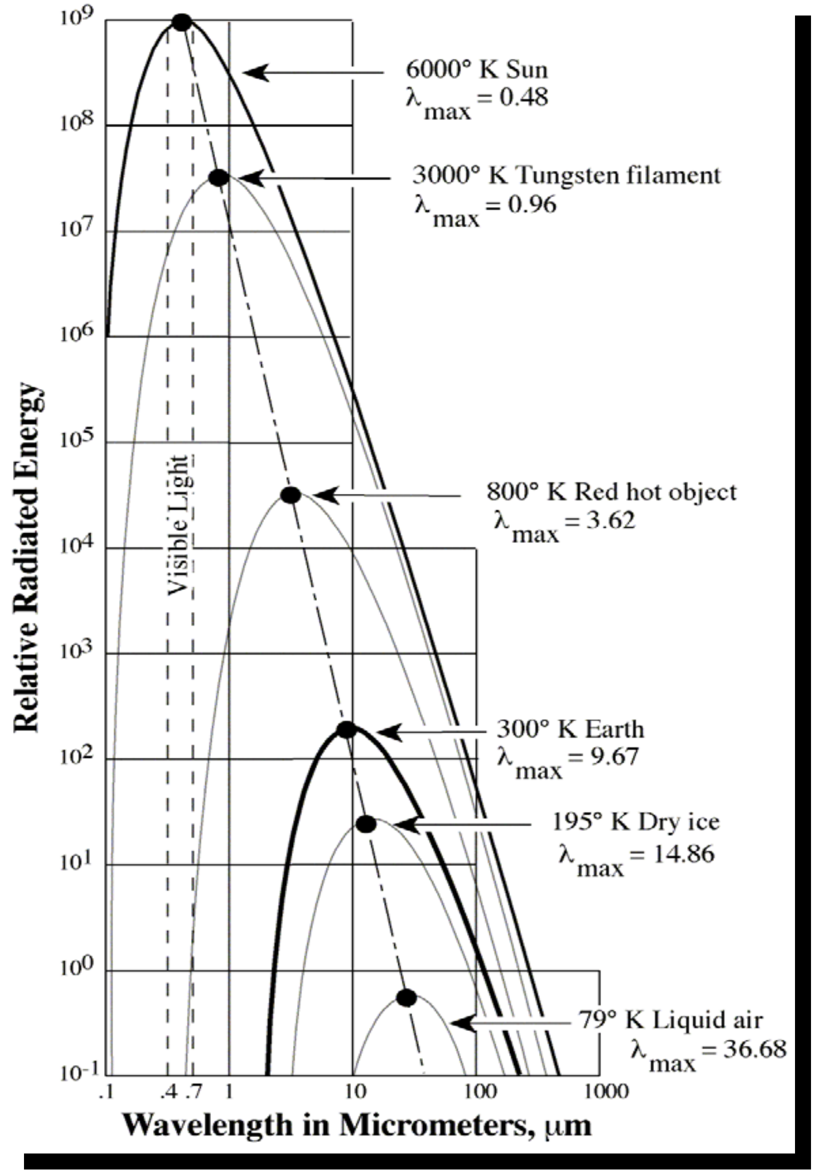
  All objects emit radiation based on their temperature.
- Stefan-Boltzmann's Law

  Objects with higher temperatures emit at greater rates than objects with lower temperatures.
- Wien's Displacement Law

  Objects with higher temperatures have shorter wavelengths of maximum emission than objects with cooler temperatures.
- Kirchhoff's Law

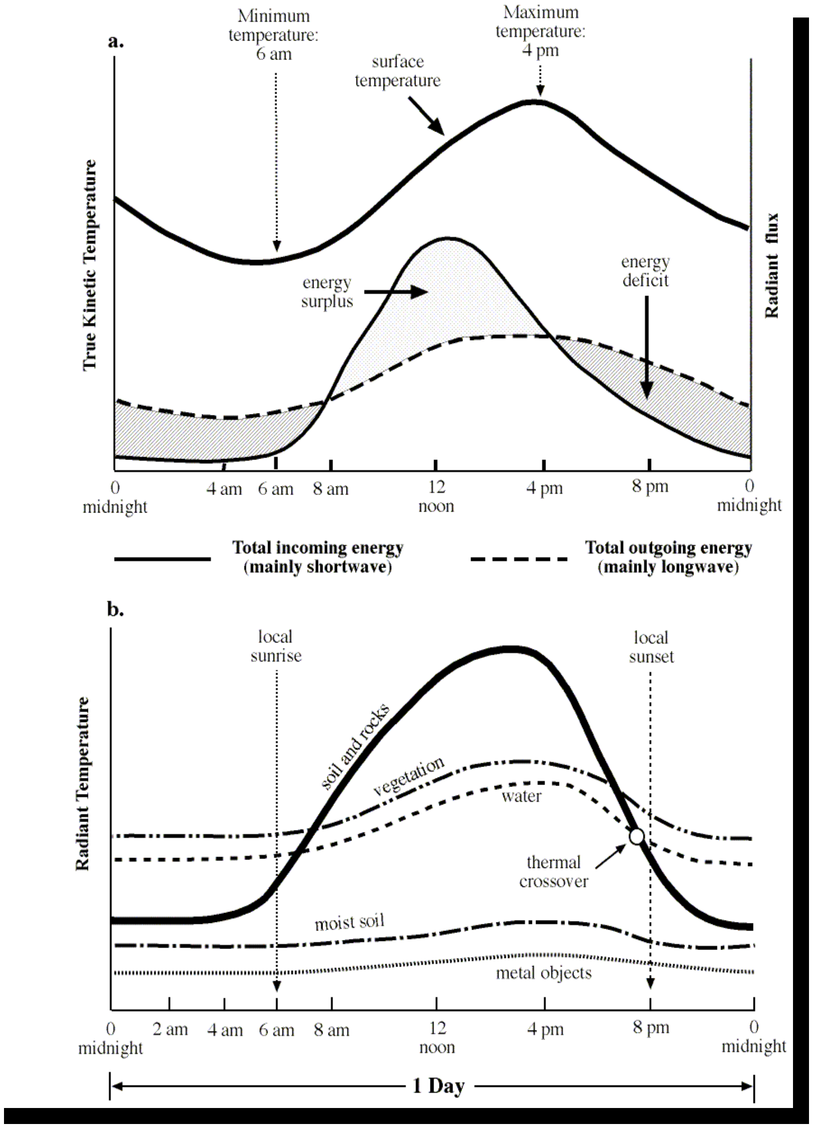
  Good absorbers are good emitters.

Blackbody Radiation Curves



Jenson, 2000

Diurnal Energy and Temperature Variation



Jensen, 2000

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The Role of Emissivity

- Different substances *at the same temperature* can emit different amounts of radiation because of their different emissivities!
- The emissivity of an object is influenced by its color, composition, surface roughness, moisture content, compaction, and various other factors.

$$F_b = \sigma T^4_{kin}$$

$$\varepsilon = \frac{F_r}{F_b}$$

$$F_r = \varepsilon \sigma T^4_{kin}$$

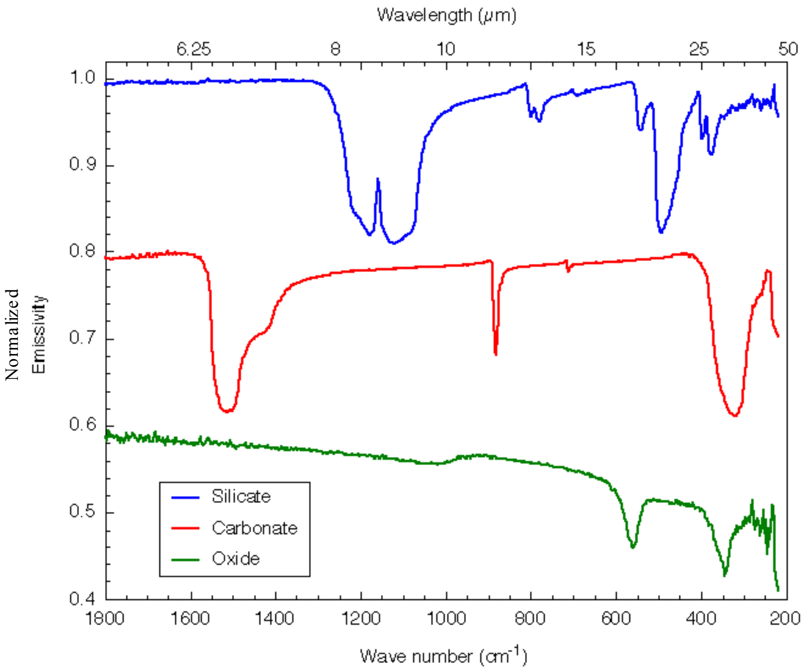
$$T_{rad} = \varepsilon^{1/4}\, T_{kin}$$

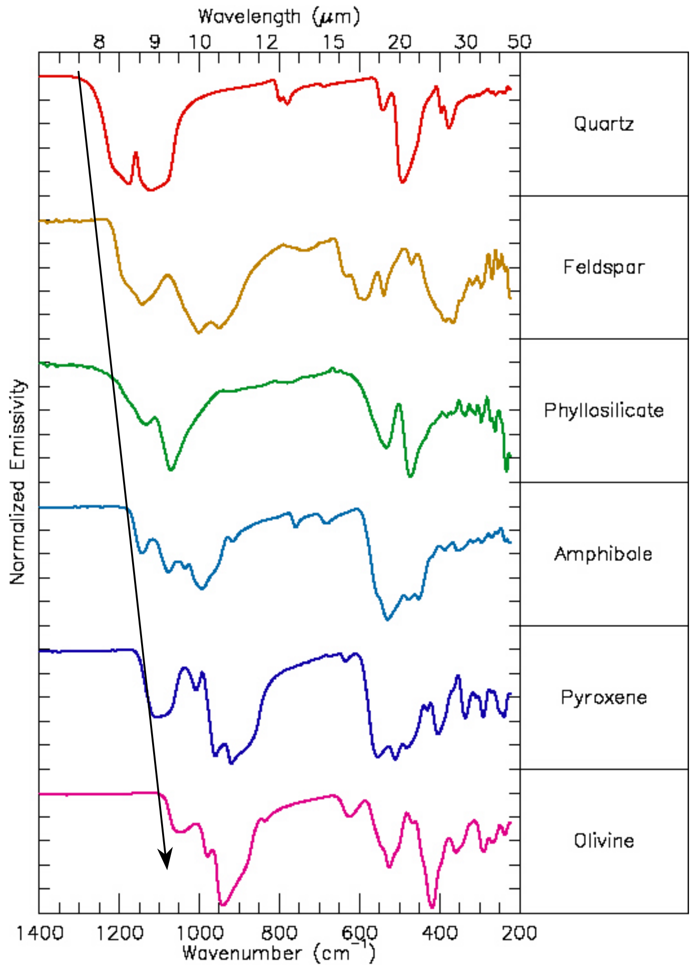
Kirchoff's Radiation Law

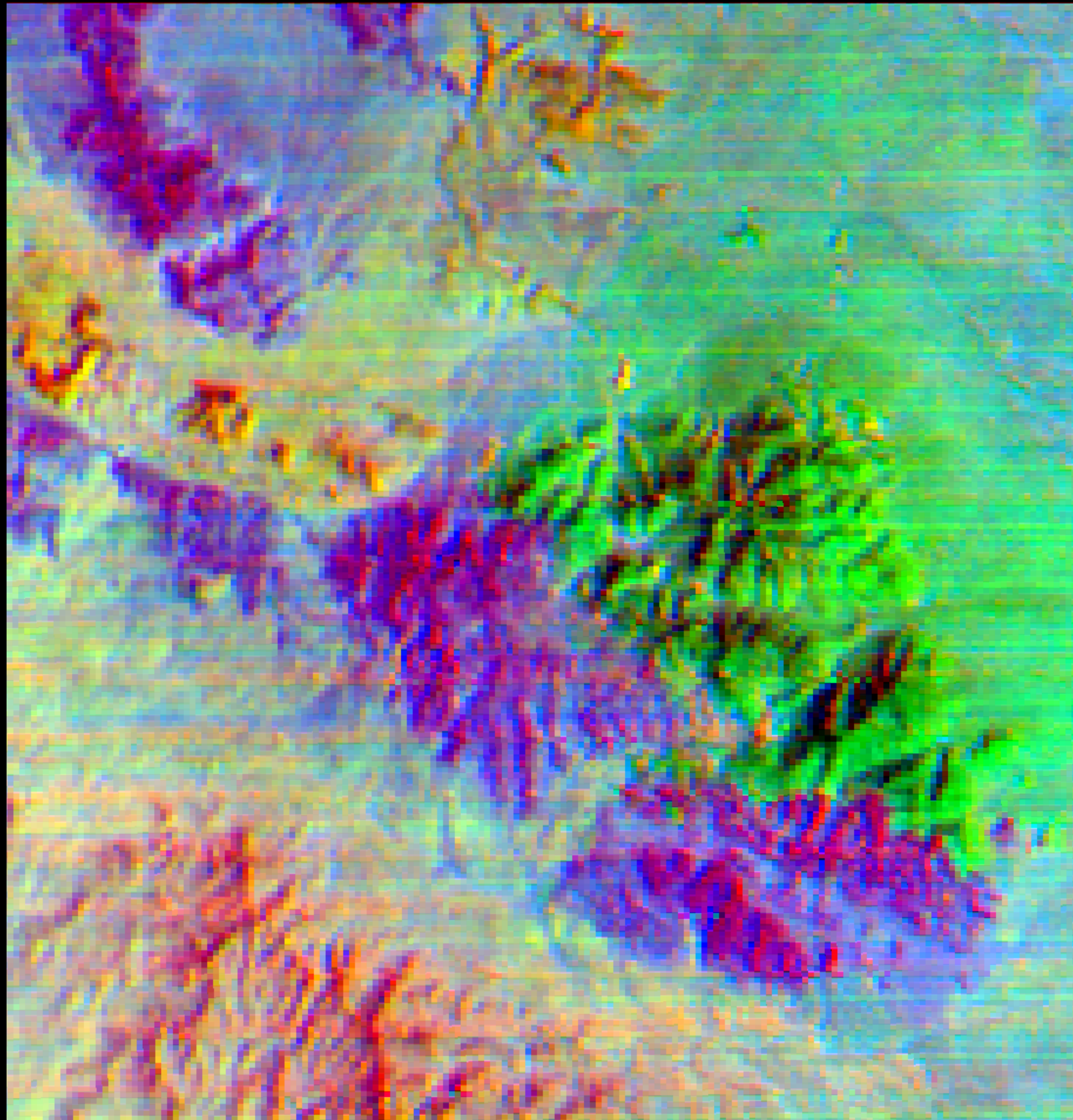
Example Emissivities (8-14 μm)

Material	Emissivity
Asphalt Paving	0.96
Grass	0.97
Pure Water	0.99
Concrete Sidewalk	0.97
Typical Granite	0.82
Dolomite (rough)	0.96
Glass Mirror	0.02

Emissivity Spectra of Some Rock Forming Minerals







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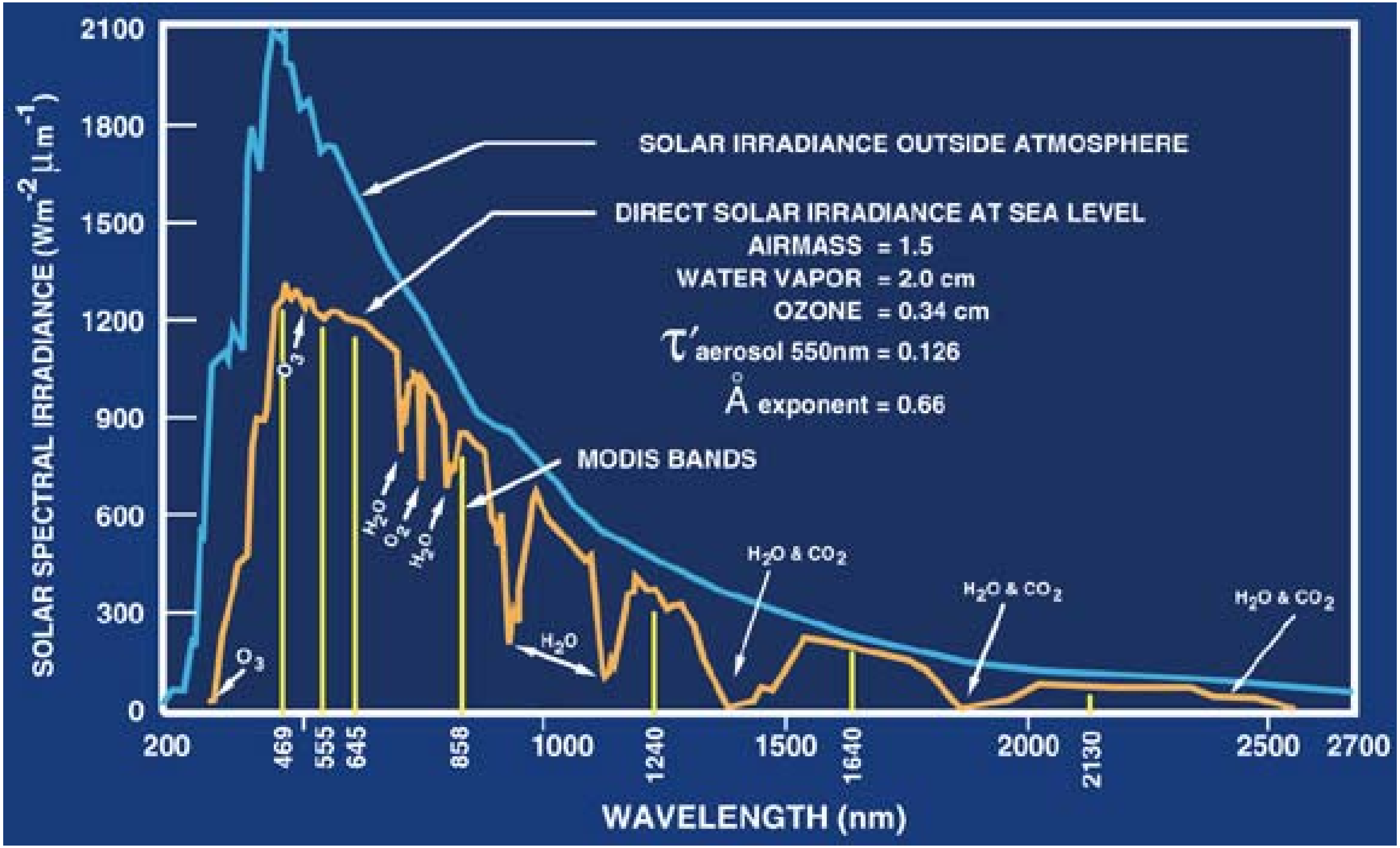
Effects of the Atmosphere

Solar Radiation Available



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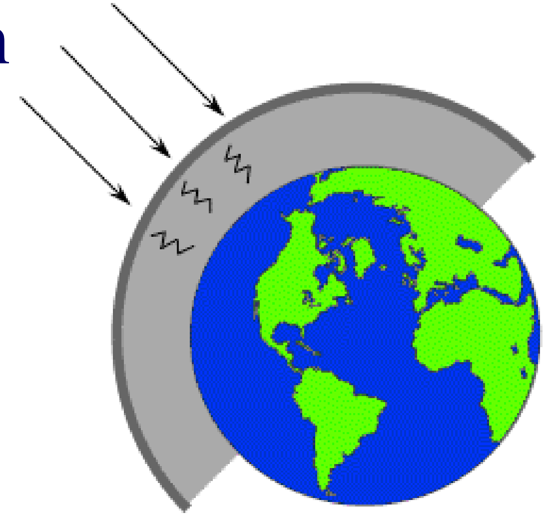
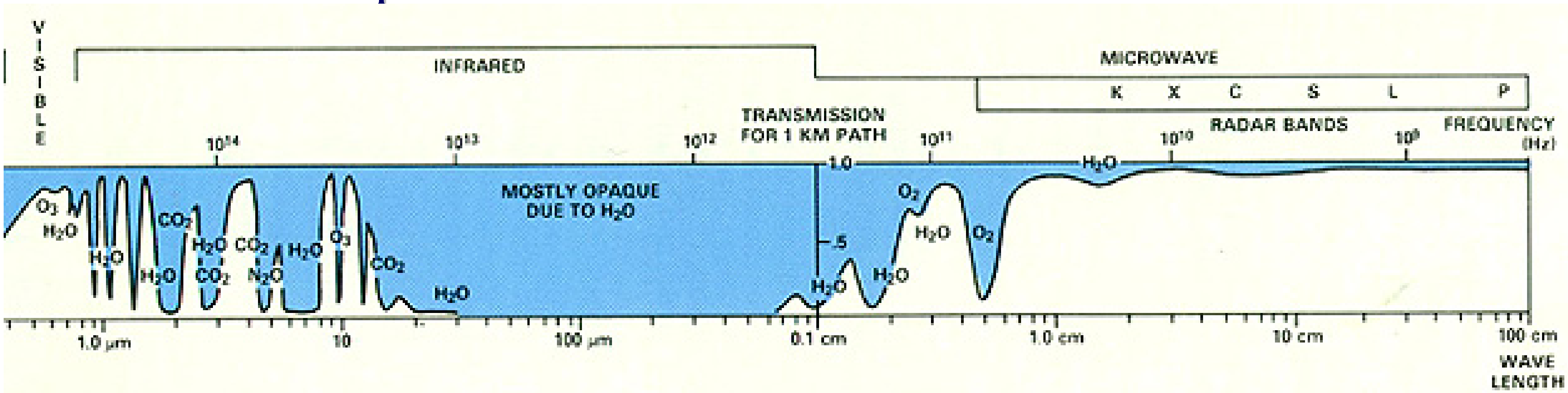
Atmospheric Absorption

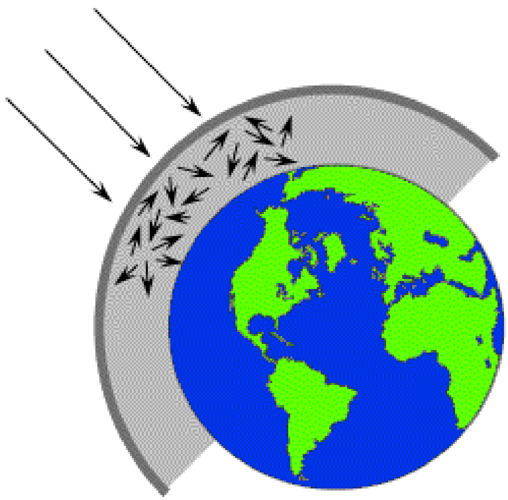
- Parts of the electromagnetic spectrum pass through the atmosphere, while others are attenuated or blocked.
- Most absorption is caused by three atmospheric gases:
  - Ozone
  - Carbon Dioxide
  - Water Vapor





Atmospheric Scattering

- Scattering is the redirection, in any direction, of EMR by particles suspended in the atmosphere, or by large molecules of atmospheric gasses.



- Three Types of Scattering:
  - **Rayleigh**, mostly in the upper atmosphere; sometimes called clear atmosphere scattering. Caused by tiny particles and molecules smaller than λ.
  - **Mie**, mostly in the lower atmosphere (0-5km); caused by dust, pollen, smoke and water droplets. Its effects also are wavelength dependent and affect EMR mostly in the visible part of the spectrum.
  - **Non-selective**, mostly in the lower atmosphere by H_2O vapor and particles much larger than the incident radiation.

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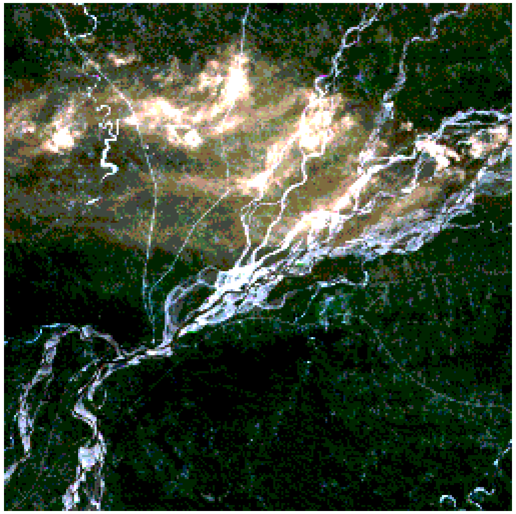
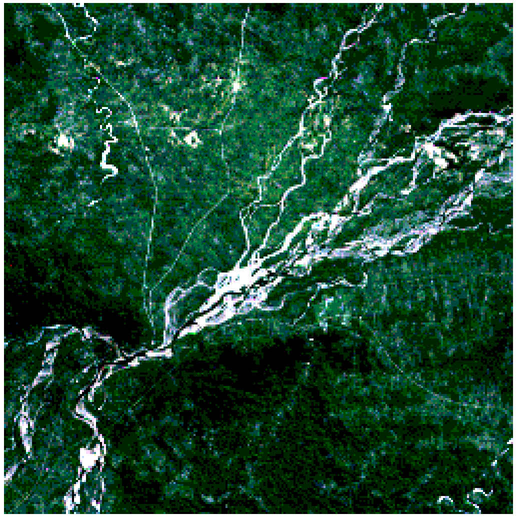
Correcting for Atmospheric Effects





- Remove effects of atmospheric scattering and to a lesser extent, atmospheric absorption.
  - Measure or estimate atmospheric parameters
  - Apply values from a radiative transfer code or LUT
  - Retrieve surface radiance or surface reflectance

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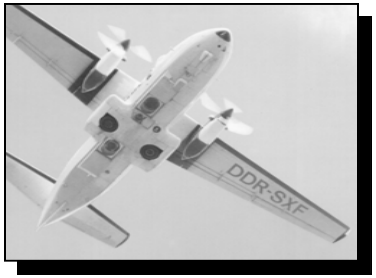
Role of Remote Sensing in Studying the Earth

- By-and-large, remotely sensed data are merely ***sources of information*** from which geophysical parameters can be derived and meaningful interpretations made.
- Meaningful interpretations about -
  - Biologic conditions and resources
  - Geologic and hydrologic processes and resources
  - Topographic and geographic features
  - Human dynamics
- Remotely sensed data are most effective when they are used in combination with other data and tools.

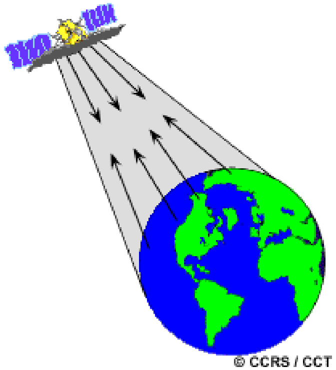
Platforms and Sensors

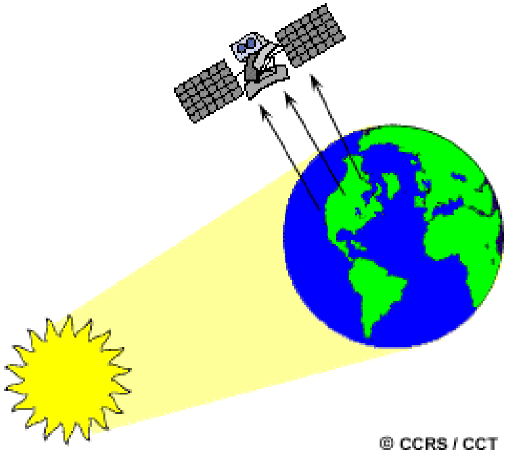
Basic Types of Land Remote Sensing Systems

- Airborne vs. Spaceborne



- Active vs. Passive





- Film vs. Electro-Optical vs. Non-Imaging

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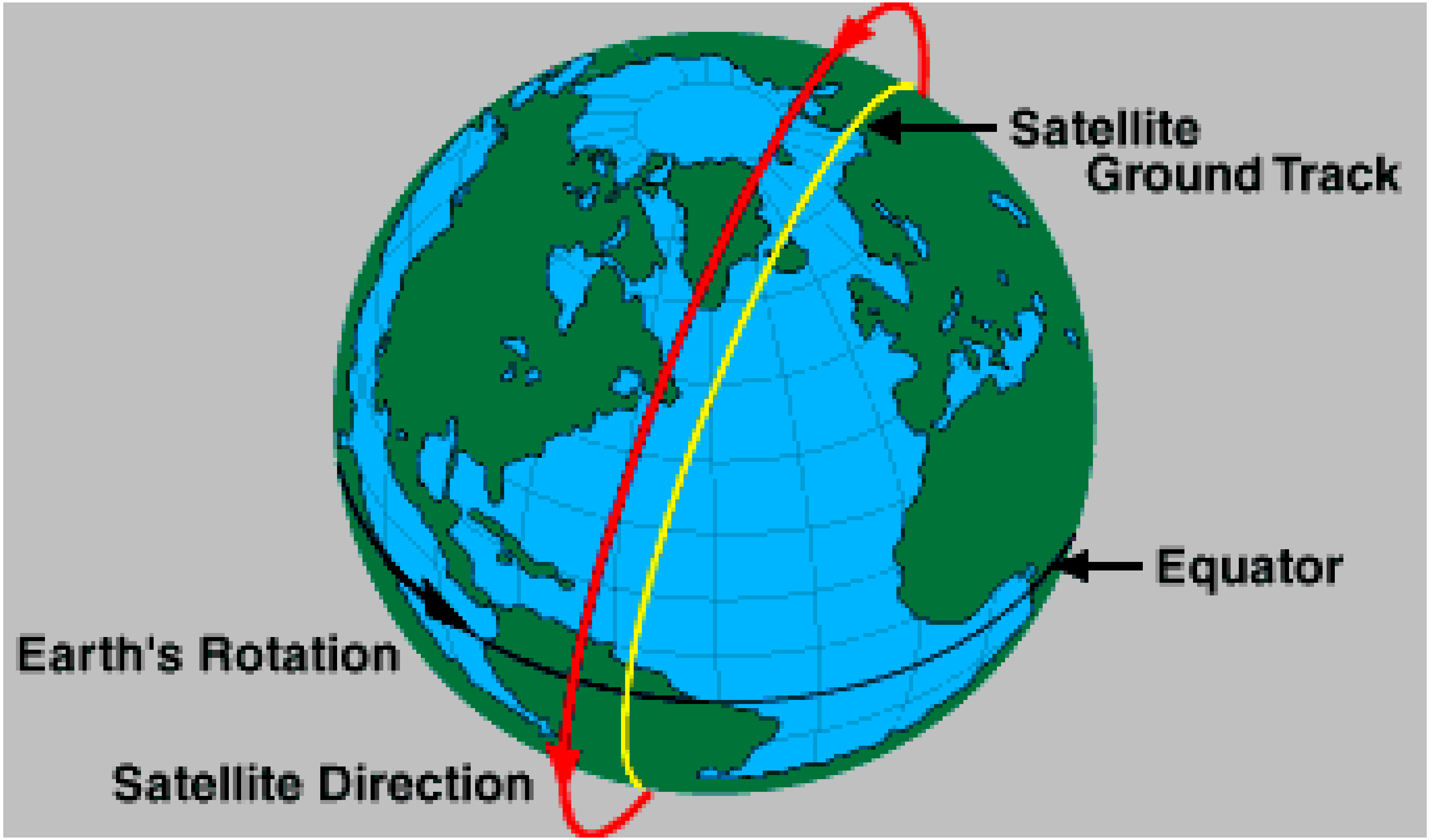
Prominent Satellite Land Remote Sensing Systems

- The Landsat Satellites
  - First launched in 1972
  - 30+ years of ***continuous*** global coverage
  - Incredibly successful
- AVHRR
- SPOT
- Commercial Systems (Ikonos, Quickbird, Orbview)
- Terra – Centerpiece of the U.S. Global Change Research Program

The Near-Polar, Sun-Synchronous Orbit



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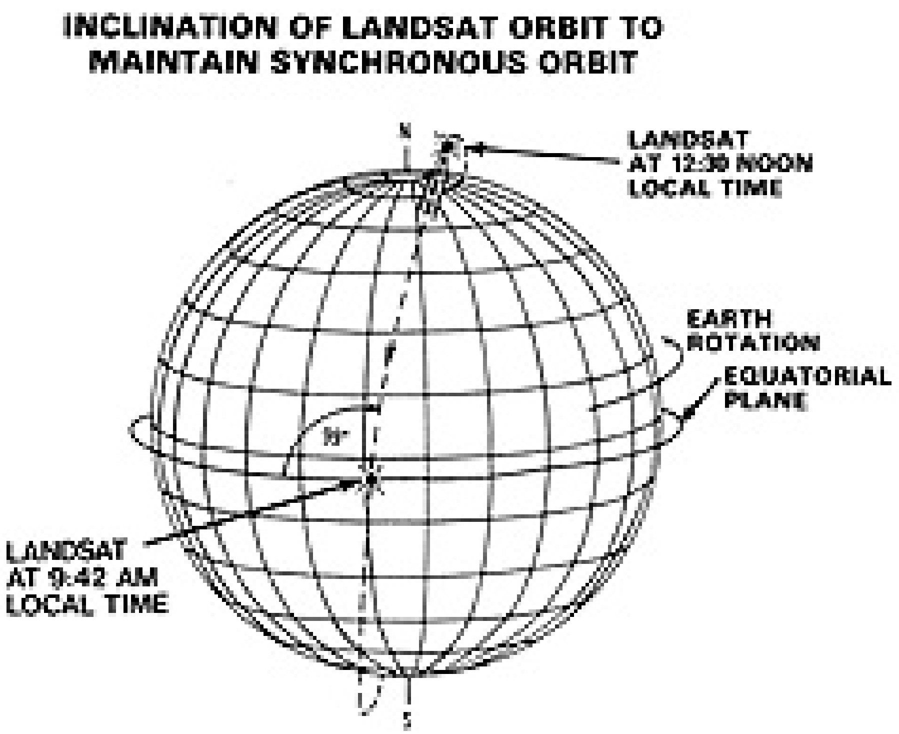

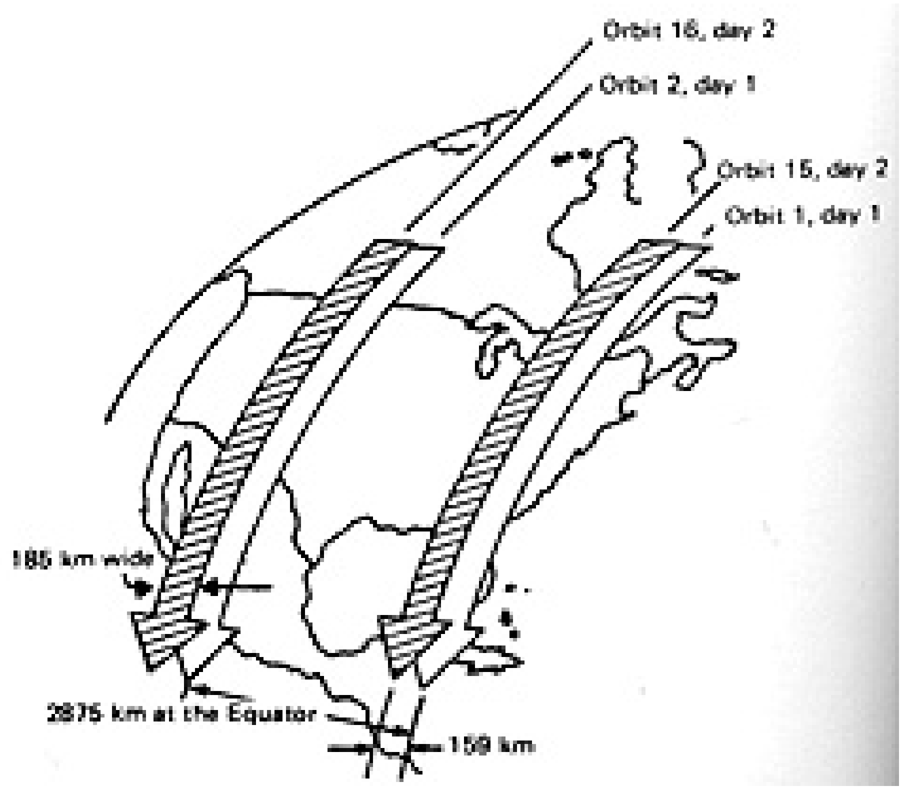

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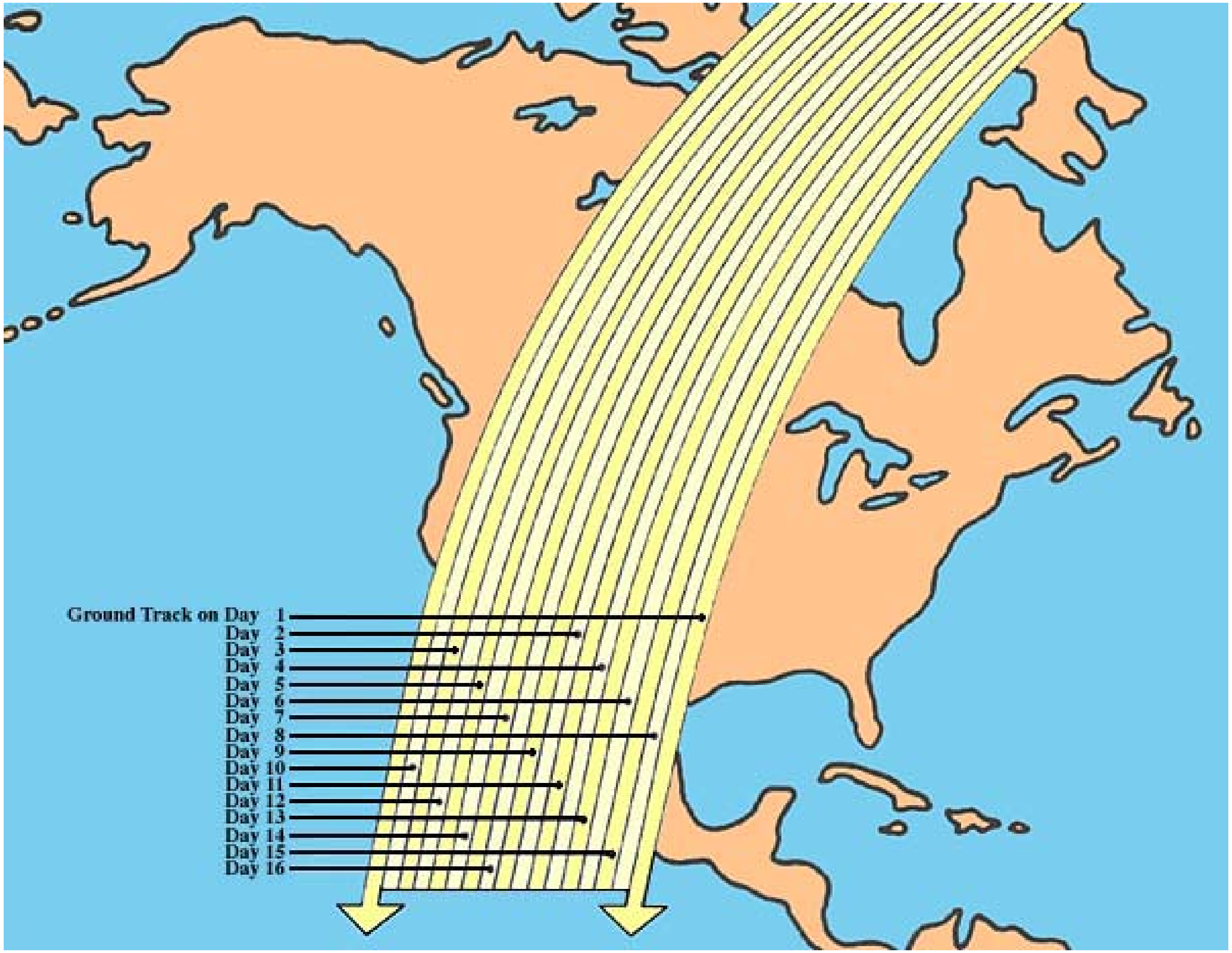

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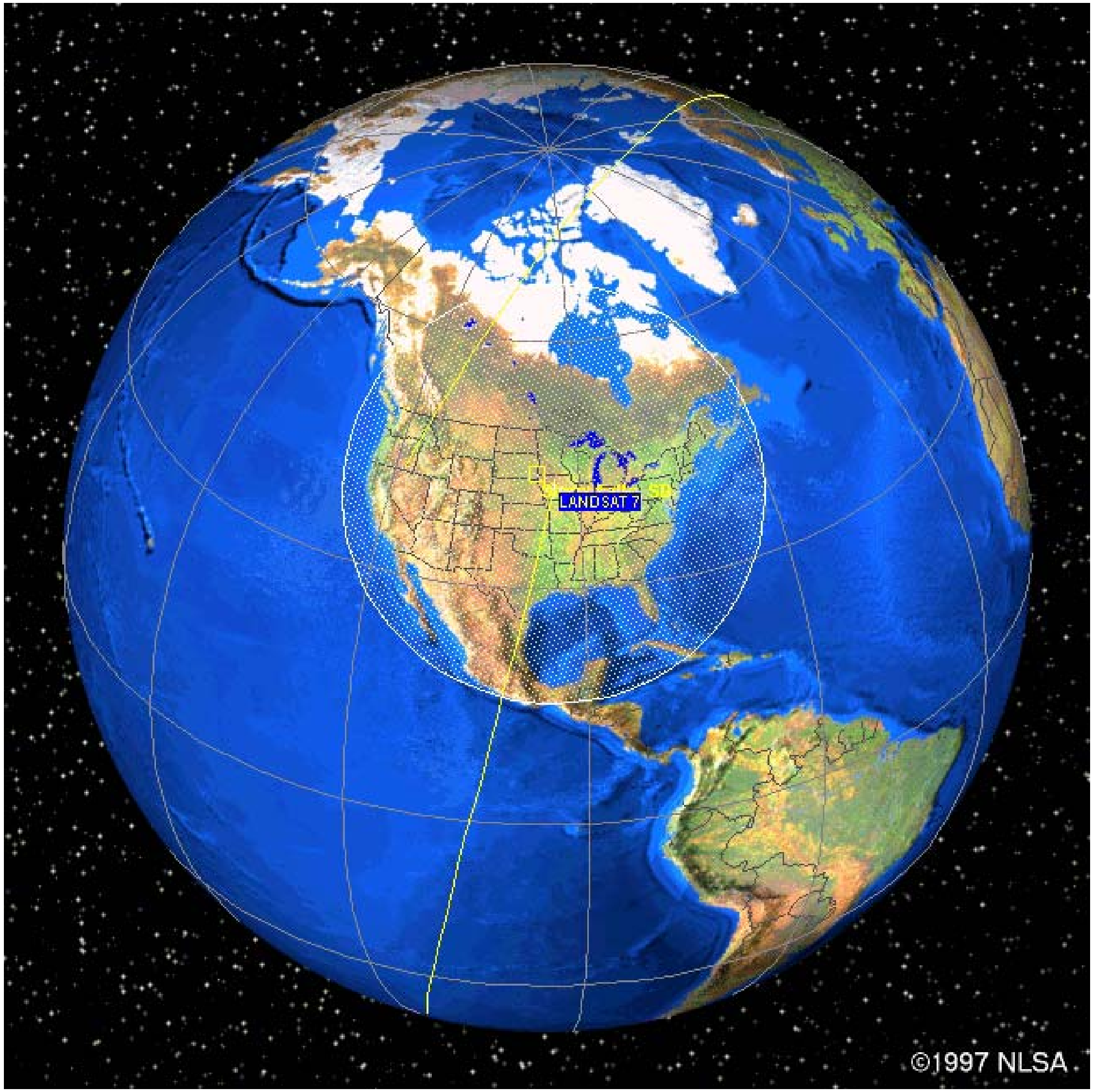

Questions?