Topic Series 03

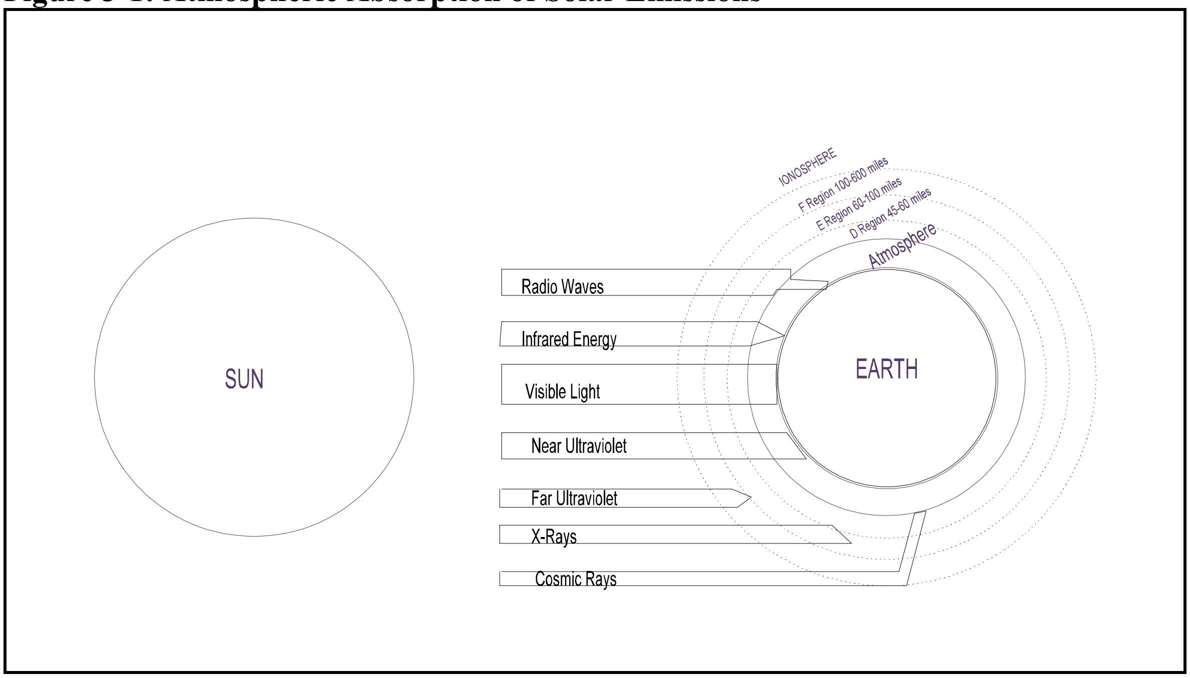
EMS, Interactions, and Remote Sensing Characteristics

I. Energy Relationships

Electromagnetic energy is a dynamic form of energy that is caused by the oscillation or acceleration of an electrical charge. All natural and synthetic substances, above zero, continuously produce and emit a electromagnetic energy in proportion to their temperatures.

The SUN is the source of all energy in-coming to the EARTH, and the basic source of this energy is THERMONUCLEAR reactions in the core of the SUN involving the synthesis of helium from hydrogen which proceeds with a loss of mass and a liberation of energy. The energy is transported outward by radiation, and in the process, a solar magnetic field (Mechanical Energy) is organized. In addition to the mechanical energy, the energy radiated from the SUN'S surface (PHOTOSPHERE) ranges from COSMIC RAYS to RADIO WAVES. Only visible light and near ultraviolet energy easily penetrates the Earth's atmosphere to reach the ground.

Figure 3-1: Atmospheric Absorption of Solar Emissions



II. Methods of Energy Transfer

Energy is the capacity to do work and takes forms such as:

mechanical,
chemical,
electrical, and
heat.

In the course of work being accomplished, the resulting energy must be transferred from one body to another or from one location to another locations. Energy transfers are accomplished by one of three methods:

1. Conduction is the direct transfer of energy from one body to another during physical contact; e.g. a metal spoon in a hot cup of coffee. It is of most importance in solids.

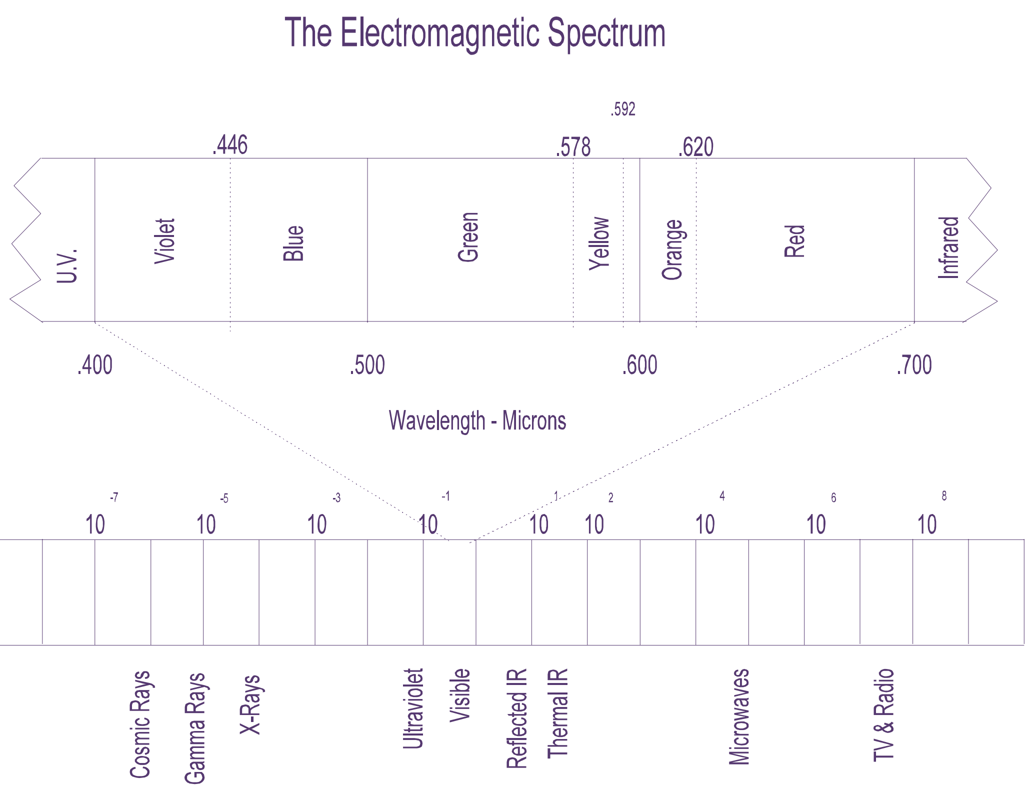
2. Convection is energy transfer by physical movement of some energized medium from one location to another. It is possible only in liquids and gasses.

3. Radiation is the transfer of energy form one body to another in the absence of an intervening material medium. Radiation is the only method by which solar energy can cross space and enter the earth's atmosphere.

III. Electromagnetic Spectrum (EMS)

The entire range of electromagnetic radiation (EMR)comprises the electromagnetic spectrum (EMS). The EMS is a continuum for EMR according to wavelength, frequency, and photon energy. The EMS is subdivided into named <u>spectral bands</u>:

Figure 3-2: The Electromagnetic (EMS) Spectrum



Gamma rays - biologically lethal, short wavelengths
X-Rays
Ultraviolet
Visible
Infrared
Microwave
Radio & TV

Each spectral band is composed of a defined group or bundle of continuous spectral lines, with each line representing a single wavelength or frequency. The bands that are used in remote sensing are ultraviolet (UV), visible, infrared (IR), and microwave.

The boundaries of the visible spectral band are defined by the wavelength limits of human vision. The retina of the human eye is most sensitive to the radiant energy in the very narrow visible band. The bulk of the sun's radiant energy reaches the top of the earth's atmosphere as white light, which is the evenly distributed wavelengths of the visible spectral band that have not been separated into their spectral components.

Spectral Region	Percent of Total Energy
Ultraviolet	7.27
Visible	43.50
Near IR	36.80
Middle IR	12.00
Total	99.57

The visible spectrum is composed of the spectral colors:

...........VISIBLE SPECTRUM...............

Ultraviolet	**Violet**	**Blue**	**Green**	**Yellow**	**Orange**	**Red**	Infrared
	.400	.446	.500	.578	.592	.620	.700

The additive primary colors, a color that cannot be made from any other color, are blue, yellow, and red. All colors perceived by the human eye can be produced by combining portions of the primary colors.

We poor humans can see only a very narrow window within the entire range of the ELECTROMAGNETIC SPECTRUM. We see only that reflected energy in the 0.4 to 0.7 MICRON (10 X -6 meter) range - (1 mm = 1/1000 meter, 1 micron = 1/1,000,000 meter). If I marked the lefthand side of these three boards as GAMMA rays, then VISIBLE REFLECTED ENERGY is just a small band, with CIR, MID-IR, THERMAL IR JUST ABOVE, then the RADAR, and MICROWAVE wavelengths way out here at the far right side of the board.

IV. EMR Interactions with Matter

The strongest source of incident EMR is the sun, called insolation, a shortening of incoming solar radiation. When EMR strikes matter in the earths atmosphere, it may be:

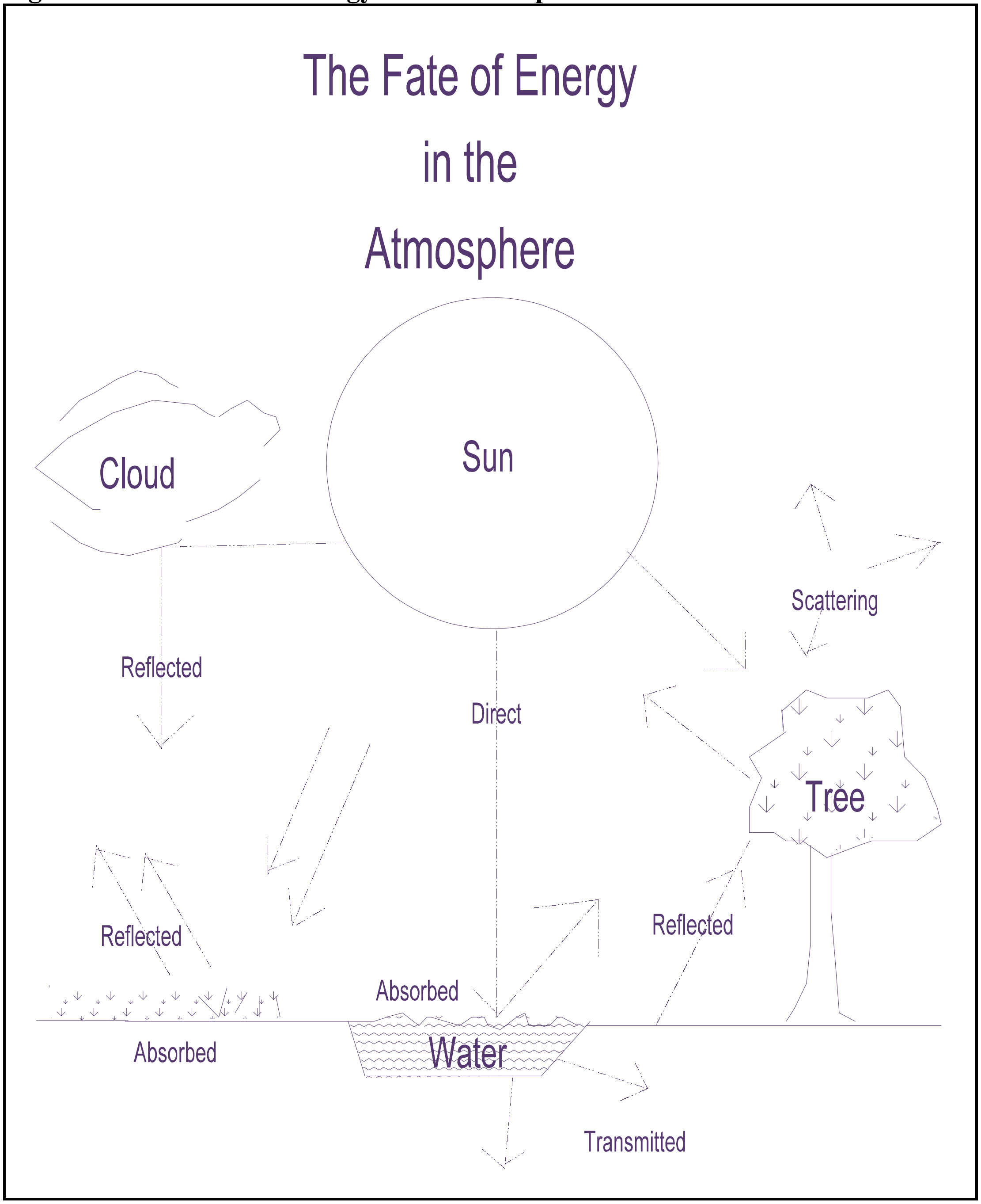
Transmitted - process by which incident radiation passes through matter with measurable attenuation.

Reflected - process by which incident radiation bounces off the surface of a substance in a predictable direction.

Scattered - process by which incident radiation is dispersed or spread out unpredictably in may directions.

Absorbed - process by which incident radiation is taken in by the medium. A portion of the radiation is converted into internal heat energy and emitted or reradiated at longer thermal infrared wavelengths.

Figure 3-3 The Fate of Energy in the Atmosphere



V. Atmospheric Scattering and Absorption

Little of the energy produced by the SUN is lost in SPACE, however, when energy reaches the LOWER IONOSPHERE (45 - 60 miles above EARTH), interactions begin - the last 45 miles is, however, tough because of scattering and absorption.

ATMOSPHERIC SCATTERING is the unpredictable diffusion of radiation by particulate matter in the atmosphere. There are multiple interactions among energy waves and the molecules and particles in the atmosphere. There are two major processes:

SELECTIVE SCATTERING - so-called because SHORTER wavelengths of energy are SELECTIVELY scattered.

- Raleigh Scattering
- Mie or nonmolecular

NON-SELECTIVE SCATTERING

RAYLEIGH scattering is caused by gas molecules and other tiny particles that are much smaller in diameter than the wavelength of the interacting radiation. The cause of HAZE.

The selective RAYLEIGH scattering of Violet & Blue energy creates the BLUE color of the SKY; Why is the sun RED/ORANGE at sunrise and sunset and white at Noon? The energy from the sun at noon has the shortest path to travel, and all wavelengths are equally scattered, but with the long pathway at sunrise, the scattering and absorption of short wavelengths is so complete we only see the orange and red.

Selective scattering is also known as **SKYLIGHTING** - shadows are never BLACK because of the scattered illumination. One of the striking aspects of the photos by the Apollo astronauts on the MOON is the complete lack of detail in the shadows - BLACK shadows. WHY? (answer: lack of atmosphere for scattering...)

MIE scattering exists when atmospheric particle diameters are equal to or greater than the energy wavelengths. Important Mie scattering agents are water vapor, smoke, fumes, haze.

NON-SELECTIVE - dust, fog, clouds with particle diameters much larger than the wavelengths; non-selectively scatters, in the visible, equal quantities of blue,green, red- making fog and clouds appear WHITE.

ABSORPTION - in contrast to scattering, absorption results in the effective energy loss to the atmospheric materials. The most efficient absorbers of solar radiation are water vapor, CO_2,and ozone; each absorbing energy in a different waveband -thus, when we design a sensor, we look for ATMOSPHERIC WINDOWS

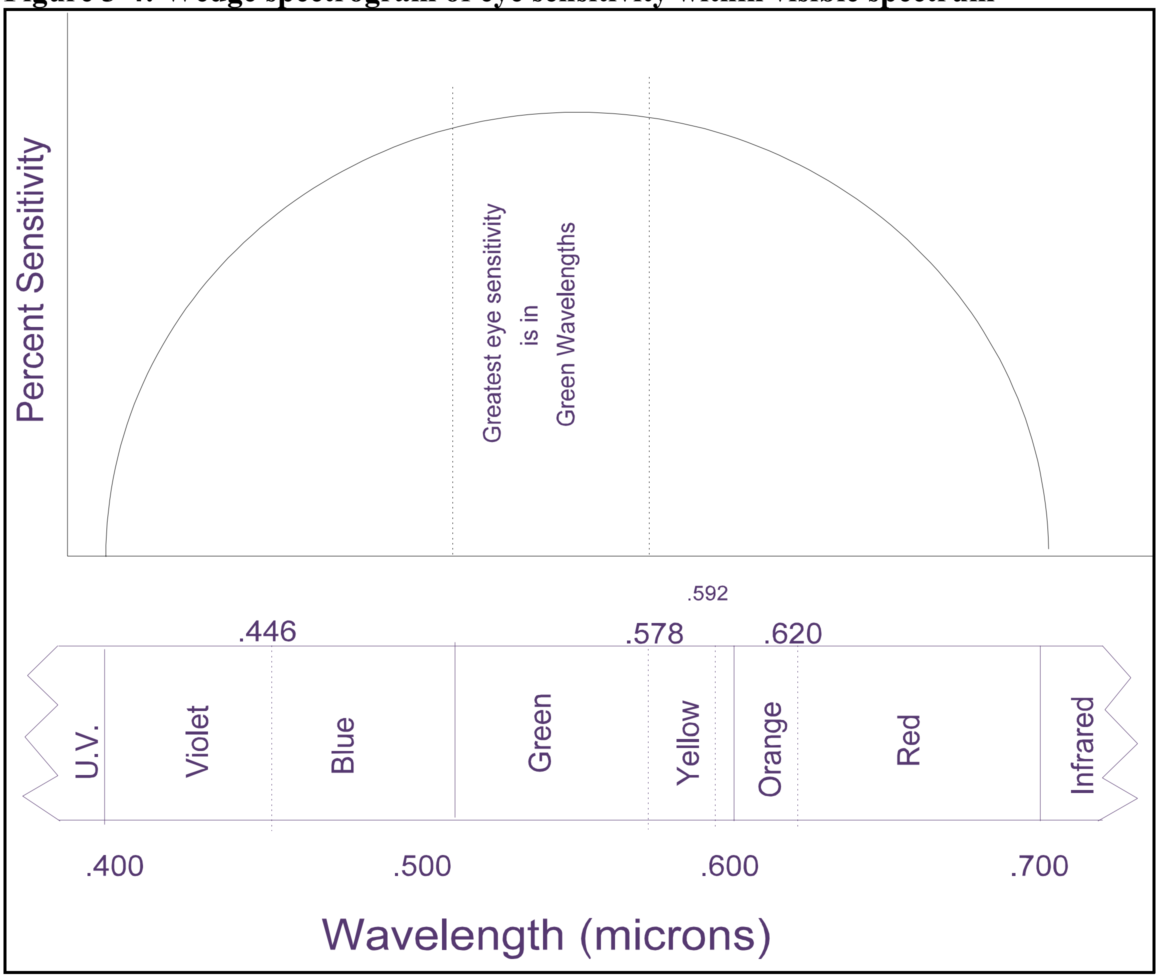
VI. Reflectance Patterns

Wedge Spectrogram

The appearance of an object depends upon the relative amounts of the different portions of the spectrum reflected by it, as well as the amount of illumination it receives. Each substance has its own wavelength reflection ratio on the spectro-photometric curve and each light sensitive material (film, eye, etc.) has it own "**wedge spectrogram**" or wavelength sensitivity ratio.

The human eye is sensitive to the visible spectrum ranging in wavelengths from .400 to .700 microns, but is most sensitive to the green wavelengths because the most chemical reaction (change) occurs on the retina (rods and cones).

Figure 3-4: Wedge spectrogram of eye sensitivity within visible spectrum



Remember from the previous lectures, the colors of the visible spectrum. Each color is heterochromatic (i.e. contains more than one wavelength), but the hue characteristics can be divided into the following sets:

Violet	0.400 - 0.446 microns
Blue	0.446 - 0.500
Green	0.500 - 0.578
Yellow	0.578 - 0.592
Orange	0.592 - 0.620
Red	0.620 - 0.700

Solar radiation is greatest in intensity about 0.540 microns, which is about the same wavelength

a. to which the human eye is most sensitive, and
b. that which chlorophyll reflects the most,

resulting in the characteristic green color in sunlight.

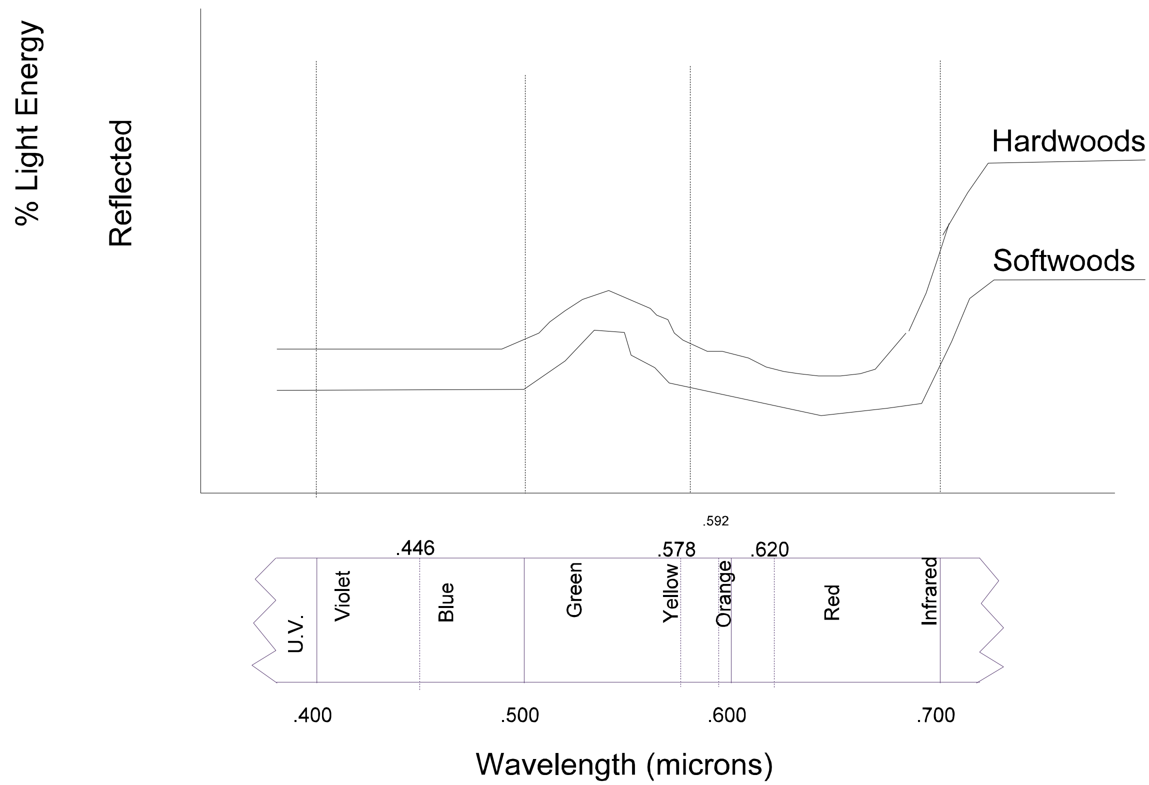
VII. Spectro-Photometric Reflectance

Spectral curves developed from green foliage vary little in shape, but do vary in intensity. Conifers, in general, exhibit lower reflectance than do broad-leaved trees, both in green and in the infrared.

Conifers - low reflectance - less light to film (i.e. lighter on negative) = darker on positive

Hardwoods - hight reflectance - more light to film (i.e. darker on negative) = lighter on positive

Figure 3-5: Typical spectro-photometric curves for hardwoods vs. softwoods.



White light represents all the light in the visible spectrum. Surface absorption determines the object color (i.e. tone) because the reflected light. The bands of individual species curves tend to overlap in all wavelengths except the green band. The green is being reflected the greatest.