Geography 403
Lecture 4
Electromagnetic Radiation and Interactions

Needs: Lect_403_4.ppt and Yosemite image set as Band examples

Key Terms and Concepts
Electromagnetic Radiation (EMR): Basics, Spectrum, Transfer
Polarization and Coherence
Radiant Flux Density and Inverse Square Law
Radiation Laws: Planck's, Wien's and Stephan-Boltzman
Emissivity
Radiation Interactions (reflection, transmission, absorption) and types (specular and diffuse)
Use of Multiple Bands for Surface ID (Water, Vegetation, Ice)

A. Basics of EMR
PP1 1. EMR is the primary medium for remote sensing
PP2 a. Propagates as "wave-particle" packets of energy
2. Properties
PP3 a. Wavelength (crest to crest, μm), λ
b. Wave velocity, 3×10^8 m/s in vacuum, c
c. Frequency, how many waves pass a point per second, f or Hz
PP4&5 d. $\lambda f = c$, example. $(4 \times 10^{-7}$ m$)(7.5 \times 10^{14}$ hz$) = 3 \times 10^8$ m/s
PP6 e. Polarization--waves can be horizontally or vertically oriented, filters can be used to view only one component, many surfaces selectively reflect one component, basis of "polarized" sunglasses, also useful in SLAR applications (note: natural radiation occurs in **all** rotational positions)
f. Coherence--put all waves "in phase"--LASER light, some radars--strengthens propagation of EMR

B. EM spectrum *(multi-concept, show different Yosemite bands in IDRISI)*
PP7-9 1. Most wave-like--radio waves with λ of 1-10,000 m
2. Microwaves--absorbed by water, reflected by metal, have a λ of .1cm to 1 m--used in radar and passive microwave analysis
3. Infrared--48% of sun's energy .7 μm to 1000 μm
a. 0.7 to 1.5 μm--near IR
b. 1.5 to 5.5 μm–middle IR
c. 5.5 to 14μm--far IR or thermal IR (longer blocked by H_20 absorption)
4. Visible .4-.7 μm (violet to red)
5. Ultraviolet (2.5 nm to .4 μm)
6. X-rays and Gamma-rays even shorter wavelengths--behave like particles

C. EMR transfer

P10 1. Radiant energy measured in energy units such as the joule

2. Radiant Flux--flow of energy per unit time
   - a. j/s (watt), how EMR is transferred from target to sensor

3. Radiant Flux density--Radiant flux per unit area, such as w/m^2

PP11
   - a. Radiance--RFD from a specific direction (3-D solid angle, steradian)
   - b. Irradiance--RFD from all directions

PP12
   - c. "inverse square law"--intensity diminishes proportional to the square of the distance (solid angle covers progressively larger areas), ex. Camera flash effectiveness

4. Applications
   - a. Visible and NIR--for individual wavelengths or bands, try to maximize contrast in spectral radiance between target objects and their background
   - b. Thermal IR--radiances can be related to actual temperatures
   - c. SLAR--topographic differences affect reflection of EMR

D. Radiation Laws *(pages 254-257 [and other places] in Jensen)*

PP13 1. Basics--temperature is a measure of speed of molecular motion
   - a. High temps, fast movement, charged particles--make EMR
   - b. Characteristic λs depend on temperature of emitter
   - c. If warm enough, "color" indicates level of emission
   - d. In nature all energy is not emitted at the same λ, rather emitted over a wide range with a characteristic shape

PP14 2. Planck's Law of Black Body Radiation—"shape" of emission
   - a. Curve defined by a formula for each absolute temperature (°K), higher temperatures equal more total energy, and smaller λs, shows how much for each λ
   - b. Black body is an ideal substance that conforms to this curve and is a perfect absorber and emitter of EMR, the sun is close, but many terrestrial objects are quite different

PP15 3. Wien's displacement law--exact wavelength of maximum emission
   - a. $\lambda max = \alpha / T$ (°K), where : $\alpha = 2897.8$ µm°K
   - b. 6000°K λmax = .48 µm, sun--95% between .25 and 2.5 µm
   - c. 285°K λmax = 10.17 µm, earth--95% between 2.5 and 25 µm
   - d. Important to know source of energy you are using--fortunately very little overlap between solar and terrestrial sources
   - e. In R.S., we are usually interested in "bands" of EMR, as instruments and target responses are seldom monochromatic

PP16 4. Stefan-Boltzmann Law--total EMR energy emitted, area under Planck curve
   - a. $E = \varepsilon\sigma T^4$ (emissivity, $\varepsilon = 1$ for a black body)
     where: $\sigma = 5.67 \times 10^{-8}$ w/m^2K^4
   - b. 6000°K = 7.35×10^7 w/m^2
   - c. 285°K = 374 w/m^2

d. Can measure area under the curve in a selected band to determine the amount of energy available to “illuminate” a target

5. Emissivity (close to BB for solar, but highly variable for terrestrial objects--need detailed descriptions for targets

a. Most terr. surface have ε of .85-.95 for long wave energy

b. Consider Kirchoff's Law ($a\lambda = \varepsilon\lambda$) for interactions

c. Thermal sensors may see polished metal at the same temperature as snow as colder due to its low ε

E. Radiation Interactions

PP17-18 1. Reflection = outgoing / incoming energy (r)

a. Specular = glass-like

b. Diffuse = all directions

2. Transmission = throughput / incoming energy (t)

PP19 3. Absorption = into / incoming energy (a)

4. r+t+a=1 or r+a=1 if no t (opaque objects)

5. Examples

PP20 a. Absorption of long wave in atmospheric “windows” affects band choices, allows selection of “depth” viewed in atmosphere for remotely sensed thermal profiles

b. Scattering--particles in atmosphere act as diffuse reflectors--can reduce energy reaching sensor, or confuse target with background (reduce contrast) highly dependent on wavelength of EMR (radar vrs. blue light)

c. Emission by the atmosphere can cause “thermal fog” in thermal IR imaging of a surface viewed from above

F. Reflection considerations *(multi-band concept, show band combinations)*

PP21 Basic Cover types: Bare Ground, Vegetation, Water, Ice-snow

PP22 1. Specular versus Diffuse (most surface are diffuse)

a. Depends on wavelength of EMR compared to “roughness” of surface (fine sand rough in visible, forest rough for radar)

b. Viewing angle changes reflection low angle “rougher” than high angles

c. Scattering much greater for blue light than green, red and NIR bands

PP23 2. Soil types--can appear different in visible imagery

a. Soil moisture--maximum r when completely dry, and changes little as moisture is added until it reaches a “critical level”, when r drops rapidly (depends of soil texture)

b. Soil components--chemicals, humus, salt

c. Soil structure and viewing angle may be important (plowed furrows in small scale images for example)

3. Water surfaces (considerable λ variations)

a. NIR, high a, little r

b. Green and Blue visible, little a, higher t and r, blue can be used to look at water quality, and underwater structure

c. Turbid water appears much lighter in green and red bands

4. Vegetation
   a. Living vegetation has a pronounced spectral reflectance curve (mod. green, low red, extremely high NIR)
   b. Different species show distinct responses--grasses higher r in all bands than forests (easy to distinguish on CIR)
   c. r changes with growth stage (NIR reduces as plant matures, curve “flattens” out when plant dies)
   d. r also affected by health of plant (trees under disease or insect stress may be detectable) from healthy members
5. Ice–high reflection in visible and NIR, low reflection in mid-IR