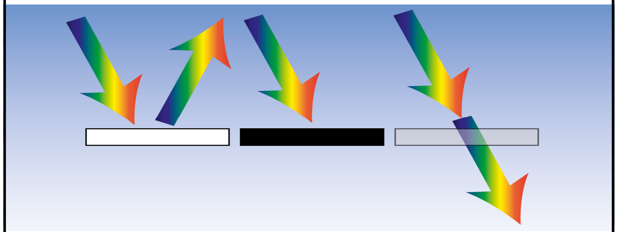
Lecture 2 – How does Light Interact with the Environment?



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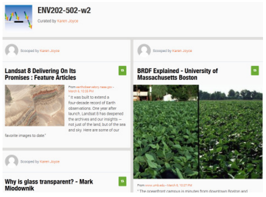
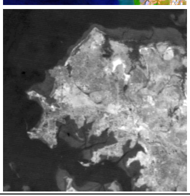
Bldg Purple 12.3.09

Treasure Hunt

- Find and scan all 11 QR codes
- Choose one to watch / read in detail
- Post the key points as a 'reaction' to http://www.scoop.it/t/env202-502-w2 (need to sign in first)



EMR and Remote Sensing



EMR Principles and Properties

- Understanding how EMR interacts with the feature you are interested in is the basis for interpreting remotely sensed data
- This also enables you to select appropriate remotely sensed data
- Leads to visual & quantitative interpretation of images and other data sets to IDENTIFY features and MEASURE biophysical properties of interest

EMR Wave and Particle Theories

- Any material with molecular motion (T > 0K) emits radiant energy
- Can earth surface features be differentiated based on the amount of EMR they emit?
- EMR radiates according to wave theory

$c = \nu\lambda$

As c remains constant, if v increases, λ must decrease (and vice versa)

where

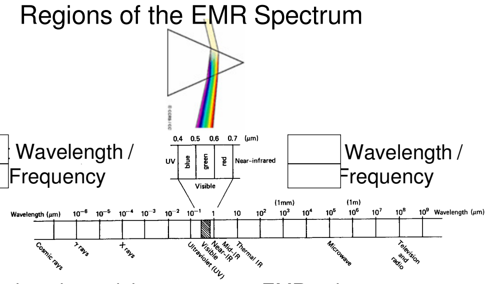
c = speed of light (3×10^8 m.sec^{-1})

λ = wavelength of EMR (µm = micro-m = 10^{-6}m)

ν = frequency of EMR (sec^{-1})

Regions of the EMR Spectrum

Wavelength / Frequency



Wavelength / Frequency

- Wavelengths and the spectrum - EMR units
- Frequencies (instead of wavelengths as units?)
- Energy levels

Particle Theory

- EMR is composed of discrete units (photons or quanta)
- Determines energy level of EMR
- Planck' s equation for the EMR emitted at a specific wavelength and frequency:

$Q = h\nu$

where

Q = radiant energy of quanta (joules)

h = Planck's constant (6.626×10^{-34} joules.sec)

ν = frequency of EMR (sec^{-1})

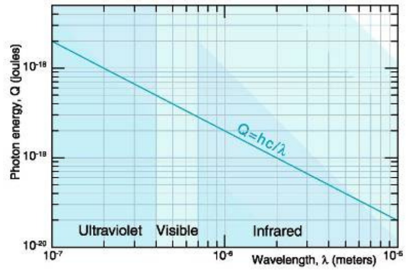
Remember: $c = \nu\lambda$ or: $\nu = c/\lambda$

$Q = h\,c/\lambda$

As h & c are constants, energy is inversely proportional to wavelength

Energy, Wavelength & Frequency

- Wavelength (inverse) and frequency (direct) relationships with EMR energy levels

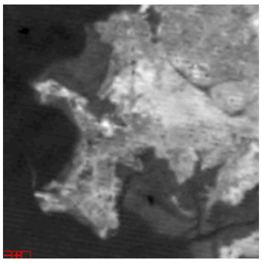


(Diagram source: The Light Measurement handbook http://www.intl-light.com/handbook/)

Energy & Wavelength

- Why is the Thermal Infrared image more blurry than the Mid Infrared image?

MIR



TIR

EMR Units

- Airborne and satellite imaging systems record the amount of EMR being reflected or emitted from a target
- Amount of EMR reaching a sensor is in one of the following units:

TERM	UNIT	DESCRIPTION
radiant energy (Q)	joule	energy per quanta
radiant flux (ϕ)	watt (joule.second^{-1})	energy per unit time
Radiant flux density		
irradiance (E,Q)	watt.m^{-2}	incident flux per unit area over all angles
radiance (L)	watt.m^{-2}.sr^{-1}	incident flux per unit area at specific solid/3-D angle
spectral radiance (L)	watt.m^{-2}.sr^{-1}.μm^{-1}	incident flux per unit area at specific angle over a set range of wavelengths

Source: S. Phinn

EMR Units

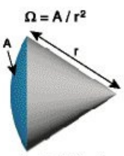


Fig. 7.2 Solid angle

Fig. 7.1

Note: sr = Steradian, refers to a unit solid angle (a 3D angle) that relates to a camera or sensor's field of view

(Diagram source: The Light Measurement handbook http://www.intl-light.com/handbook/)

Stefan Boltzman Law

- Provides a basis for distinguishing objects based on measurements of emitted energy
- Temperature controls the amount of emitted energy from an object
- The amount of energy a blackbody radiates (M) is a function of its temperature (T)

$M = \sigma T^4$

Emitted energy increases very quickly with increases in Temp

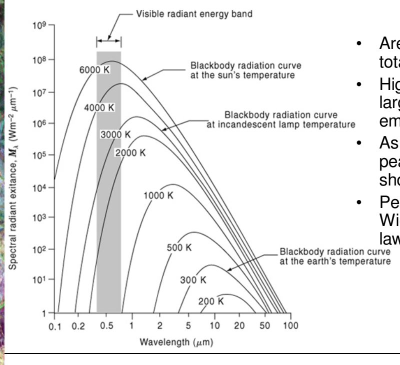
where, M = total spectral radiant exitance (watts.m^{-2})

σ = Stefan-Boltzman constant (5.6697×10^{-8} watts.m^{-2} K^{-4})

T = temperature in K

- Note the threshold for reflection/emission is around 3μm, i.e. most EMR beyond this emitted, while EMR at < 3μm is reflected sunlight

Radiant energy



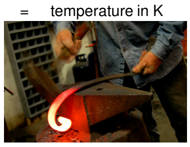
- Area under curves = total radiant energy
- High temperature = large total amount of emitted radiation
- As temp increases, peak emission shifts to shorter wavelengths
- Peak determined by Wien's displacement law

Wien's Displacement Law

- Use to select optimum wavelength of EMR to record for monitoring specific targets
- Wavelength of maximum emitted energy depends on an object's temperature
- The wavelength (λ) of maximum spectral radiant exitance (M) is inversely related to its temperature (T):

$\lambda_{max} = A / T$ Higher temp = Shorter wavelength

where, λ_{max} = wavelength of maximum spectral radiant exitance (μm)
A = 2898 μm.K
T = temperature in K



Color Scale of Temperature

color	Temperature °C	Temperature K
incipient red heat	500 - 550	770 - 820
dark red heat	650 - 750	920 - 1020
bright red heat	850 - 950	1120 - 1220
yellowish red heat	1050 - 1150	1320 - 1420
incipient white heat	1250 - 1350	1520 - 1620
white heat	1450 - 1550	1720 - 1820

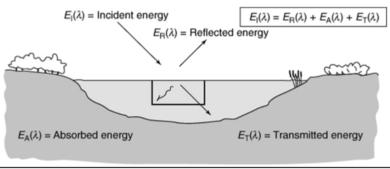
Sources: Process Associates of America & Handbook of Chemistry & Physics, 1924

Recap

- As wavelengths decrease,
  - frequency increases (wave theory),
  - energy increases
- Emitted energy increases very quickly with increases in temperature (Stefan Boltzman Law)
- As temperatures increase, wavelength of maximum emitted energy decreases (Wien's Displacement Law)

Conservation of Energy

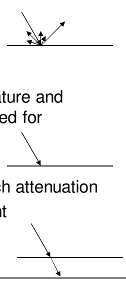
- Need to understand this to interpret image data sets and measure processes responsible for absorption, reflection and transmission of EMR
- Controls on elements of image formation
- For any wavelength of EMR and incident amount of EMR (E) interacting with a surface:



E = Reflected + Transmitted + Absorbed

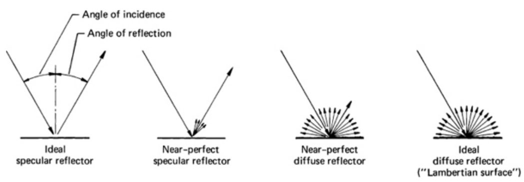
EMR Interactions

- Reflection
  - Re-direction of light striking non-transparent surface
  - Strength of reflection – type of surface
  - Diffuse – smooth
  - Specular (Lambertian) – rough
- Absorption
  - Energy of the photon is taken up by the feature and converted to other forms of energy (e.g. used for photosynthesis)
- Transmission
  - Light passing through material without much attenuation
  - Water most affected by transmission of light
  - Plant leaves



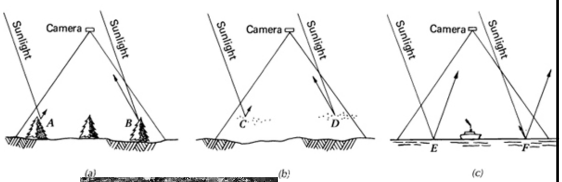
Reflectance

- **Diffuse reflectance** - uniform in all directions (Contains information on the characteristics of a target, by the nature of its interactions with EMR)
- **Specular reflectance** - mirror like / directional with no information on the characteristics of a target
- Accounts for amount of incoming radiation



Reflectance and Geometry

- Reflected EMR depends on angles of incident light and camera position

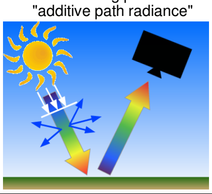


EMR Interactions in the Atmosphere

- How does the atmosphere alter the "quality" of satellite/ airborne images and aerial photographs?
- Identification of EMR interactions affecting an airborne or satellite image
- The effect of the atmosphere on the transmission of EMR to and from the earth's surface by scattering and absorption processes is a function of
  - Path length
  - EMR wavelength
  - Atmospheric conditions

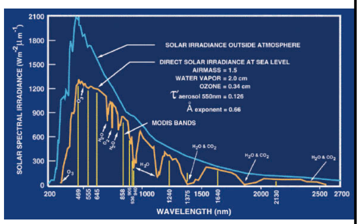
Scattering

- Rayleigh
  - particles smaller in diameter than the EMR wavelength
  - inversely proportional to 4th power of wavelength
  - air molecules scatters short wavelengths (blue sky)
- Mie
  - Particles equal in size to wavelength
  - Inversely proportional to 0.6-2nd power of wavelength
  - Water vapour, dust (haze), causes sky to take on reddish appearance
- Non-selective
  - Particles have greater dimensions than wavelength
  - Scatters all wavelengths
  - Water Droplets and ice (fog and clouds), causes white appearance
- All scattering produces "additive path radiance"



Absorption

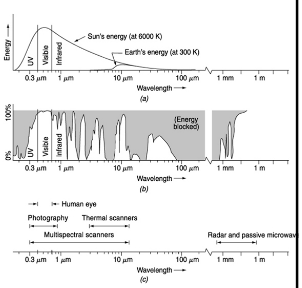
- Reduces the amount of incident solar radiation and reflected or emitted radiation traveling to the sensor
- Loss of EMR energy to atmospheric constituents
- Major absorbers:
  - H_2O, CO_2, O_3, O_2, N_2, O, N
- Minor absorbers:
  - NO, N_2O, CO, CH_4



Source: http://modarch.gsfc.nasa.gov/MODIS/ATM/solar.html

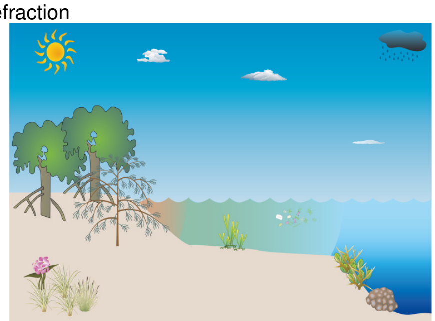
Atmospheric Windows

- Regions of the EMR spectrum where there is limited absorption of EMR by atmospheric constituents.
- EMR reflected or transmitted through the atmosphere measured by sensors in these spectral regions.



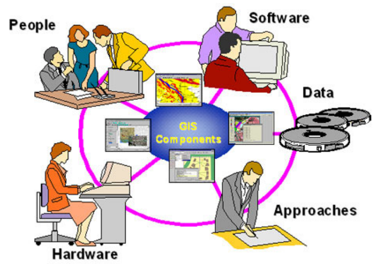
Your Job

- Annotate this image with arrows to indicate areas of reflection, absorption, transmission, scattering, and refraction



Student Choice: GIS vs. Remote Sensing

- Go to http://padlet.com/wall/env202-502-rsgis and post what comes to mind



http://www.polkcitymaps.org/GIS_Components.jpg