





3. Key concepts and physical principles of remote sensing methods: electromagnetic energy, its properties, spectral behaviour and interaction with the environment

Principle of Remote Sensing

Detection and discrimination of objects or surface features = detecting and recording of electromagnetic radiation reflected or emitted by objects or surface material



Different objects return different amount and kind of energy in different bands of the EMG spectrum.

Remote Sensing Sensors



- Dependent on a natural source (e.g. Sun, Earth) to provide energy
- The satellite sensor records primarily the radiation that is reflected from the target



- Use an artificial source for energy
- The satellite itself can send a pulse of energy which can interact with the target
- Can be carried out during day and night and in all weather conditions

Source: https://www.earthdata.nasa.gov/learn/backgrounders/passive-sensors, https://www.earthdata.nasa.gov/learn/backgrounders/passive-sensors

Properties of Electromagnetic radiation

Electromagnetic radiation has properties of <u>waves</u> but also can be thought of as a <u>stream of particles (quantum).</u>





Electromagnetic wave

According to Maxwell's EM wave theory, light waves are related to changing electric fields and magnetic fields. The change within the electrical and magnetic field leads to the propagation of electromagnetic waves or light waves (c = 299 792 458 m.s⁻¹)



- Wavelength and frequency have an inverse relationship, as indicated by the equation. If wavelength increases, then frequency decreases and vice versa.
- Wavelength is the distance between identical points (adjacent crests) in the adjacent cycles of a waveform signal propagated in space or along a wire.
- The amplitude of an electromagnetic wave is the height of the wave crest above the undisturbed position. This frequency is measured in cycles per second, or hertz



Inverse Relationship between Wavelength and Frequency

Blackbody radiation

- Object or system which absorbs all radiation incident upon it and reradiates energy
- All matter with a temperature above absolute zero (k) radiates energy in the form of EM waves of various wavelenghts
- By measuring the blackbody emission curves at different temperatures, it was able to construct two phenomenological Laws: Stefan-Boltzmann's Law and Wien's Displacement Law



Blackbody radiation

Energy of a photon

We can measure the energy of a photon using Einstein's equation:

$$E = hf = \frac{hc}{\lambda}$$

h = 6.63 x 10⁻³⁴ Js \rightarrow Planck constant

f = frequency of photon/electromagnetic radiation

 $c = 3 \times 10^8 \text{ m/s} \rightarrow \text{speed of light in a vacuum}$

 λ = wavelength of photon/electromagnetic radiation

Stefan-Boltzmann law

We can measure the energy of a photon using Einstein's equation:

 $I = \sigma T^4$

I is the intensity of emitted em radiation in W/m^2

 σ (lower case sigma) is the Stefan-Boltzmann constant 5.67 \times 10 $^{-8}$ W m $^{-2}$ K $^{-4}$

T is the temperature in kelvin, K



Source:http://lifeng.lamost.org/courses/astrotoday/CHAISSON/AT304/HTML/AT3040 2.HTMBAk

Blackbody radiation



$$\Delta Q = Q_m - Q_n = h.\gamma \qquad \gamma - frequency(ni)$$

Planck constant h=6,625.10⁻³⁴J.s

Source: Jensen (2005)

Electromagnetic bands used in Remote Sensing





- The Sun produces a continuous spectrum of energy from gamma rays to radio waves that continually bathe the Earth in energy.
- The portion of the spectrum may be measured using wavelength, frequency or electron volts (eV). All units are interchangeable.

Source: https://www.researchgate.net/publication/326025281_Review_on_Material_Processing_Through_Microwave_Energy, https://www.iasnotes.in/2022/10/insolation-and-heat-budget-vision-ias-notes-upsc-classnotes.html

Electromagnetic bands used in Remote Sensing





Source: https://ltb.itc.utwente.nl/498/concept/81525, https://rpubs.com/GeospatialEcologist/RS, https://www.mdpi.com/2226-4310/9/4/213

Electromagnetic bands used in Remote Sensing



Interaction of EMR with atmosphere

- Energy recorded by RS systems undergoes fundamental interactions that should be understood to properly interpret the remotely sensed data. For example, if the energy comes from the Sun, the energy:
- propagates through the vacuum of space at the speed of light
- interacts with the Earth's atmosphere
- interacts with the Earth's surface
- <u>interacts with the Earth's atmosphere once</u> <u>again</u>
- finally reaches the remote sensor where it interacts with various optical systems, etc.



Source:https://atmos.eoc.dlr.de/projects/scops/sciamachy_book/sciamachy_book _figures_springer/chapter_7/fig_7_1.jpg

For	mor	e informa	ation.	see	the	tut	orial:
3.	Key	concepts	of	remote	sens	ing	<u>data</u>
proc	essing	,converting	DN	values	to rad	iance	and
reflectance, using SNAP software							

Interaction of EMR with atmosphere

• Upon interaction with matter, EMR can undergo transmission, reflection, refraction, diffraction, adsorption and scattering



Source: Robinson and Dean, 2017, https://socratic.org/questions/how-can-refraction-make-a-rainbow-1

- There are essentially three types of scattering:
 - Rayleigh
 - Mie
 - Non-selective
- Type of scattering is a function of:
 - 1) the wavelength of the incident radiant energy, and
 - the size of the gas molecule, dust particle, and/or water vapor droplet encountered





- The Rayleigh scattering effect in the atmosphere causes greater reflection of shorter wavelengths (blue color) – blue color of clear sky
- Involves particles smaller than the wavelength of incident light

Source: http://hyperphysics.phttps://www.researchgate.net/figure/Rayleigh-scattering-causes-us-to-perceive-a-blue-sky-during-daytime-and-a-red-sky-at_fig15_233793398, hy-astr.gsu.edu/hbase/atmos/blusky.html, https://fineartamerica.com/featured/red-sunset-jasna-buncic.html, https://theconversation.com/explainer-why-is-the-sky-blue-10821,

Rayleigh scattering



Before Rayleigh correction

After Rayleigh correction

Source: https://forum.step.esa.int/t/still-a-strong-rayleigh-signal-after-rayleigh-correction/7006/8:

Mie scattering

$\emptyset \approx \lambda$

Clearer effect at longer λ

- Predominates for particle sizes equal or larger than a wavelength (0.1 10 times the wavelength)
- Occurs below 4.5 km in the atmosphere more spherical particles with diameters approx. equal to the size of the wavelength of the incident energy (aerosols, pollution, dust particles, etc.)
- Produces almost white glare around the sun when a lot of particulate material is present in the air
- White light from mist and fog
- Contributes to the reddish sunsets

Source: http://www.china.org.cn/travel/2017-07/06/content_41165327.htm, https://medium.com/@elif_erkk/the-color-of-clouds-and-the-color-of-the-sky-a-dance-of-light-and-scattering-acbf2e66fe22



Non-selective scattering

 $\emptyset > \lambda$

Similar at different λ : clouds.

- Takes place in the lower parts of the atmosphere where the particles are larger than 10 times the wavelength of the incident radiation
- Here, any wavelength can be scattered equally effectively, hence the clouds appear white, for example













Thank you for the attention

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