ERASMUS-EDU-2023-CBHE
Project number: 101129032

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LAND MANAGEMENT ENVIRONMENT & SOLID-WASTE

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11.- Electromagnetic Radiation and Energy Interaction

Nature of Electromagnetic Radiation

LM-W11-V71

Why Electromagnetic Radiation Matters

Core idea

Remote sensing works because energy travels from a source, interacts with Earth materials, and then reaches a sensor.

Why students study it

The physics of radiation explains why vegetation, water, soil, and urban surfaces appear different in images.

Practical value

It supports image interpretation, sensor selection, atmospheric correction, and data analysis.

Energy source — Atmosphere — Surface target — Sensor — Information

In every remote sensing system, energy is the starting point. If we understand the nature of radiation, we can better understand what images mean.

What Is Electromagnetic Radiation?

Definition
Electromagnetic radiation is energy that travels through space as coupled electric and magnetic fields. It does not need a material medium.

In remote sensing
Sensors measure reflected solar radiation, emitted thermal radiation, or energy returned by active systems such as radar.

Radiation can be described as:

- a wave
- a stream of photons
- a measurable signal

Wave Model and Photon Model

Wave model

Useful for describing wavelength, frequency, propagation, reflection, refraction, and interference.

Key question: How does the signal travel and interact?

Photon model

Useful for describing discrete packets of energy.

Higher-frequency radiation carries more energy per photon. This helps explain detection limits and energy differences across the spectrum.

Both models are important: the wave model explains geometry and behavior, while the photon model explains energy at the microscopic level.

Wavelength, Frequency, and Energy

Speed relation

$c = \lambda f$

The speed of light equals wavelength multiplied by frequency.

Photon energy

$E = hf$

Energy increases when frequency increases.

Linked idea

Shorter wavelength means higher frequency and higher photon energy.

Long λ **→ frequency ↑** **Short λ**

Remote sensing often compares wavelengths in nanometers (nm) or micrometers (µm).

The Electromagnetic Spectrum

Remote sensing mainly uses UV, visible, near infrared, shortwave infrared, thermal infrared, and microwave regions.

Gamma / X-ray	UV	Visible	NIR	SWIR	Thermal IR	Microwave

Visible bands support human-like image interpretation.

Near infrared is especially useful for vegetation analysis.

Thermal infrared records emitted energy related to temperature.

Microwave is used in radar because it can operate day or night and often through clouds.

Atmospheric Effects and Atmospheric Windows

Main processes

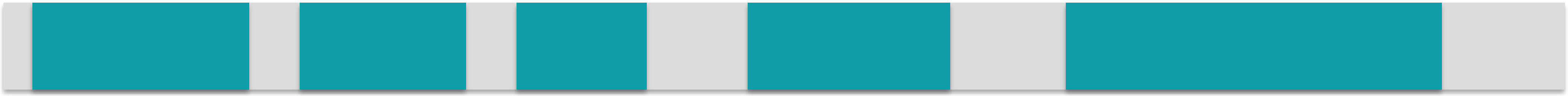
Absorption removes part of the signal.
Scattering changes direction and reduces clarity.
Both processes modify what the sensor receives.

Important absorbers

Water vapor, ozone, carbon dioxide, and other gases absorb energy in specific wavelength regions.

Atmospheric windows

These are wavelength ranges where transmission is relatively high and sensing is easier.



Sensors are designed to observe in windows where the atmosphere transmits energy more effectively.

Source–Target–Sensor Framework

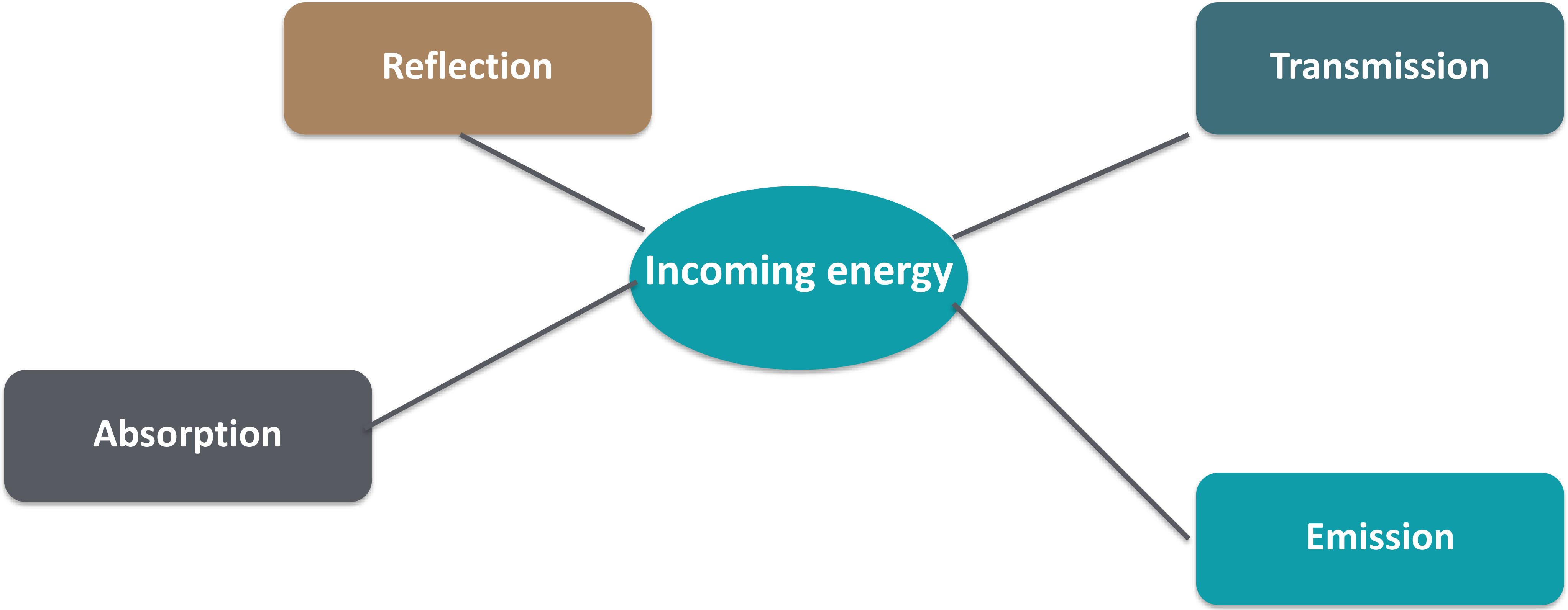
Source: usually the Sun for passive systems, or the instrument itself for active systems.

Target: vegetation, water, soil, rock, snow, or built surfaces.

Sensor: records how the target has reflected, emitted, or backscattered energy.

Source — illumination — Target — measured signal — Sensor

How Materials Interact with Radiation



Remote sensing signatures are different because materials partition energy differently. The balance between reflection, absorption, transmission, and emission creates measurable contrast.

Solar Radiation and Terrestrial Radiation

Solar radiation

The Sun is the main energy source for optical remote sensing.

Most solar energy used in remote sensing is measured in visible, near infrared, and shortwave infrared wavelengths after reflection from Earth surfaces.

Terrestrial radiation

The Earth also emits energy because it has temperature.

This emitted radiation is strongest in the thermal infrared region and is used to estimate surface temperature and heat patterns.

Simple Examples of Spectral Behavior

Vegetation

Absorbs strongly in blue and red because of pigments.
Reflects strongly in near infrared because of leaf structure.
This is why healthy vegetation often appears bright in NIR.

Water

Usually reflects less energy than land, especially in near infrared and shortwave infrared.
This makes water bodies easier to distinguish from vegetation and soil.

Dry soil / built surfaces

Their reflectance often changes more gradually with wavelength.
Moisture, texture, mineral content, and material type strongly influence the signal.

Passive and Active Sensing

Passive sensing

Uses natural energy, mainly sunlight or Earth-emitted thermal radiation.

Examples: photography, multispectral scanners, thermal sensors.

Best for: rich spectral information and broad land-cover analysis.

Active sensing

Sends out its own energy and measures the returned signal.

Examples: radar and LiDAR.

Best for: day-and-night operation and observations when sunlight is not available.

The main difference is the energy source. Understanding radiation makes this difference easy to remember.

Useful terms

Wavelength: nanometers (nm) or micrometers (µm)

Frequency: hertz (Hz)

Photon energy: joules (J)

Radiance: energy measured by the sensor from a direction

Reflectance: ratio describing how much incident energy is reflected

Key study point

In practice, remote sensing students often work with radiance and reflectance more directly than with raw photon counts.

Why it matters

Units help connect physical theory to image values, calibration, and interpretation.

Review Summary

Electromagnetic radiation is the energy foundation of remote sensing.

It can be described using both wave and photon models.

Wavelength, frequency, and energy are mathematically related.

Atmospheric windows determine which wavelengths are useful for sensing.

Different materials produce different signals because they interact with energy differently.

Passive and active systems differ mainly in where the energy comes from.

What energy is being measured?

How did the target interact with it?

Why can the sensor detect contrast?

References and Suggested Reading

Selected sources suitable for undergraduate remote sensing study

Lillesand, T., Kiefer, R. W., & Chipman, J. (2015). Remote Sensing and Image Interpretation (7th ed.). Wiley.

Jensen, J. R. (2016). Introductory Digital Image Processing: A Remote Sensing Perspective (4th ed.). Pearson.

Campbell, J. B., & Wynne, R. H. (2011). Introduction to Remote Sensing (5th ed.). Guilford Press.

Schowengerdt, R. A. (2007). Remote Sensing: Models and Methods for Image Processing (3rd ed.). Academic Press.

NASA ARSET Training Materials and Earth Observatory educational resources.

USGS Landsat Science educational resources and spectral information pages.

European Space Agency (ESA) Earth Observation educational resources.

ITC, University of Twente. Principles of Remote Sensing educational materials.

Prepared as an editable Office 2019-compatible presentation.

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