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LAND MANAGEMENT ENVIRONMENT & SOLID-WASTE

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LAND MANAGEMENT IN CENTRAL ASIA

12.- Sensors and Remote Sensing Platforms

Thermal and Microwave Sensors

LM-W12-V80

Why study thermal and microwave sensors?

These sensors reveal physical properties that are not visible in ordinary optical imagery.

Learning outcomes

Explain the basic principles of thermal and microwave remote sensing.

Differentiate thermal infrared, passive microwave, and active microwave systems.

Describe the main products derived from these sensor classes.

Recognize major applications, strengths, and limitations.

Select an appropriate sensor class for different monitoring tasks.

Key message

Thermal sensors focus on temperature-related properties.

Microwave sensors are powerful when weather or darkness limits optical imaging.

Examples

Heat islands, fire mapping, soil moisture, flood mapping, and surface deformation.

Sense
heat, emission, or backscatter

Interpret
temperature, moisture, roughness

Apply
hazards, water, agriculture, cities

What do thermal and microwave sensors measure?

Both classes operate beyond the visible region, but they sense different physical processes.

Thermal sensors

Measure emitted thermal radiation.

Closely related to surface temperature and emissivity.

Common outputs include brightness temperature and land-surface temperature.

Passive microwave sensors

Measure natural microwave emission from the surface or atmosphere.

Often used for moisture and temperature-related studies.

Examples include radiometers.

Active microwave sensors

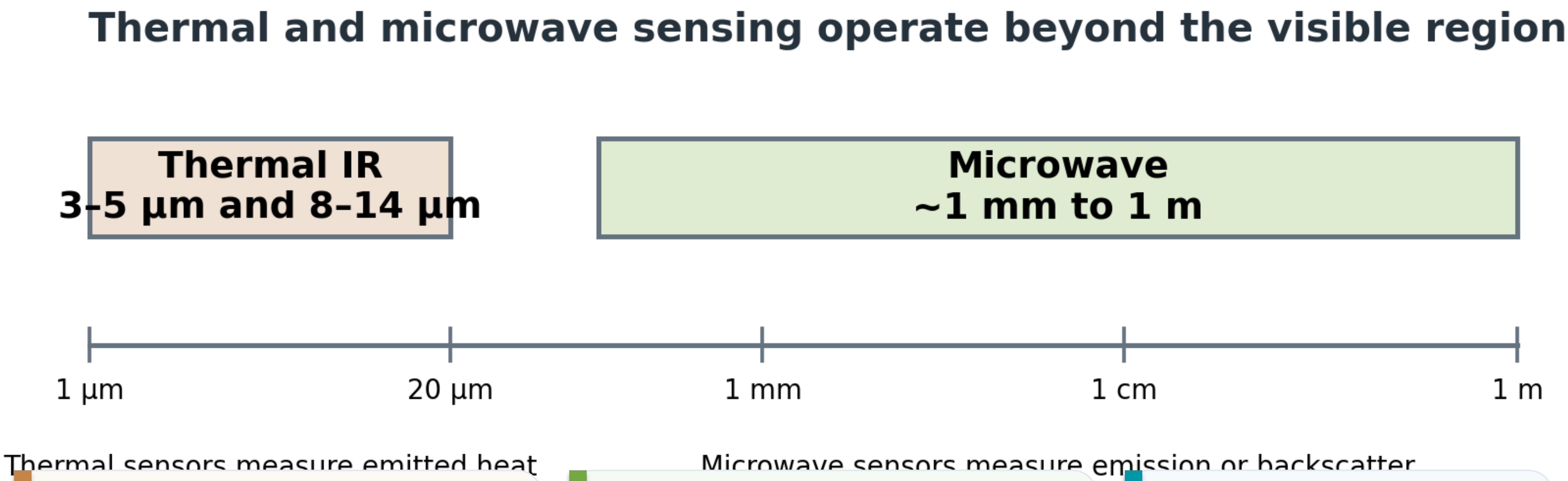
Transmit a microwave pulse and record the return.

Examples include radar and SAR.

Outputs are strongly influenced by roughness, moisture, and geometry.

Spectral regions used by these sensors

Thermal and microwave windows are chosen because they allow useful signals to reach the sensor.



Thermal windows

Commonly 3–5 µm and 8–14 µm.

Microwave wavelengths

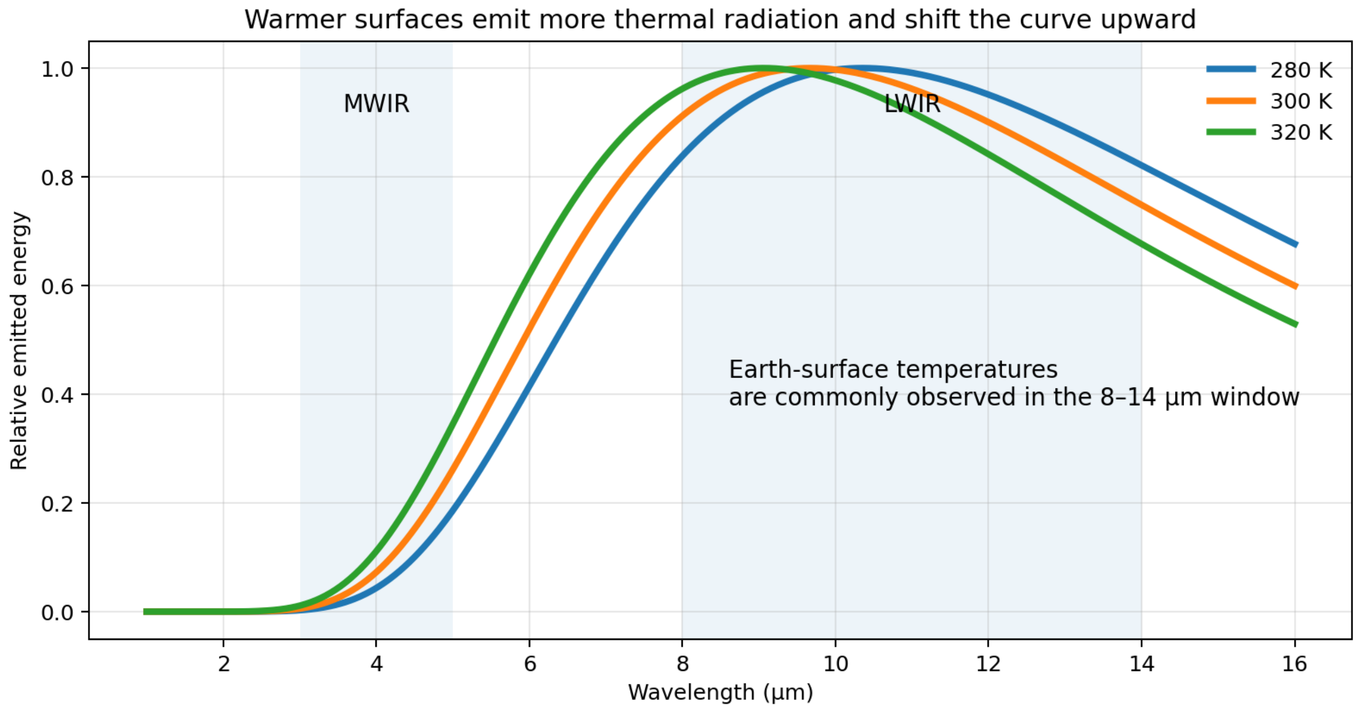
Range from millimeters to centimeters and beyond.

Operational value

Good for day/night and, in many cases, all-weather sensing.

Thermal sensing principle

All objects above absolute zero emit thermal radiation.



Interpretation guide

Warmer objects emit more energy.

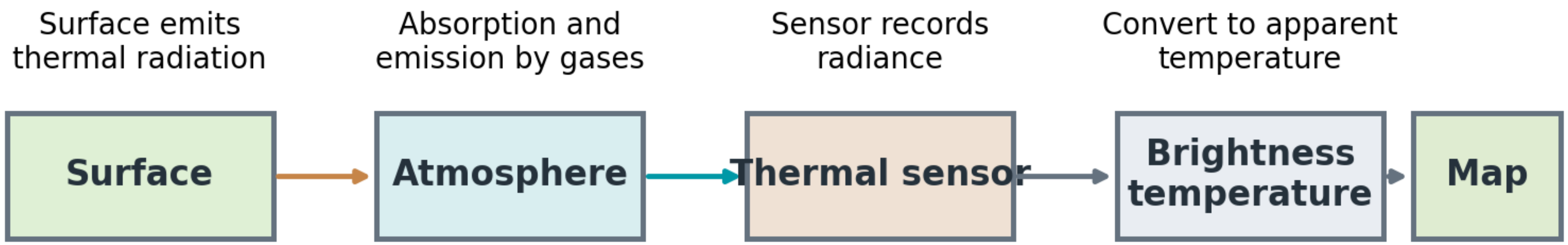
A sensor first measures radiance, not temperature directly.

Emissivity matters because different materials do not emit equally.

The atmosphere can weaken or distort the thermal signal.

From emitted energy to thermal products

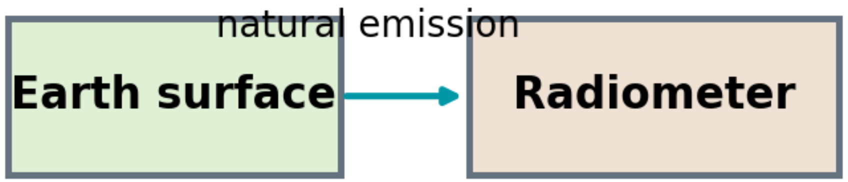
A thermal image is the result of several physical and processing steps.



Useful thermal products

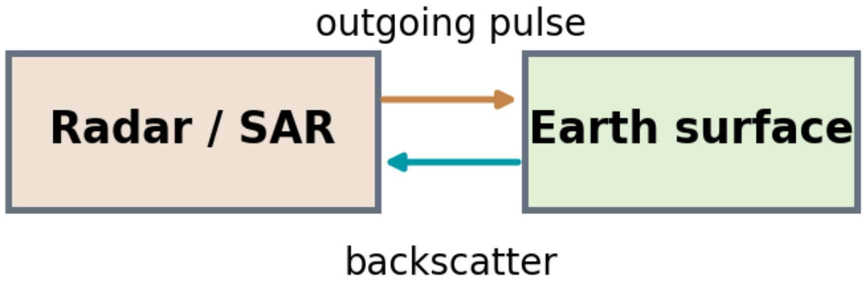
Brightness temperature, land-surface temperature, hotspot detection, and thermal anomaly maps.

Passive microwave



Measures microwave emission related to temperature and moisture

Active microwave



Measures returned energy related to roughness, moisture, geometry, and structure

Passive microwave

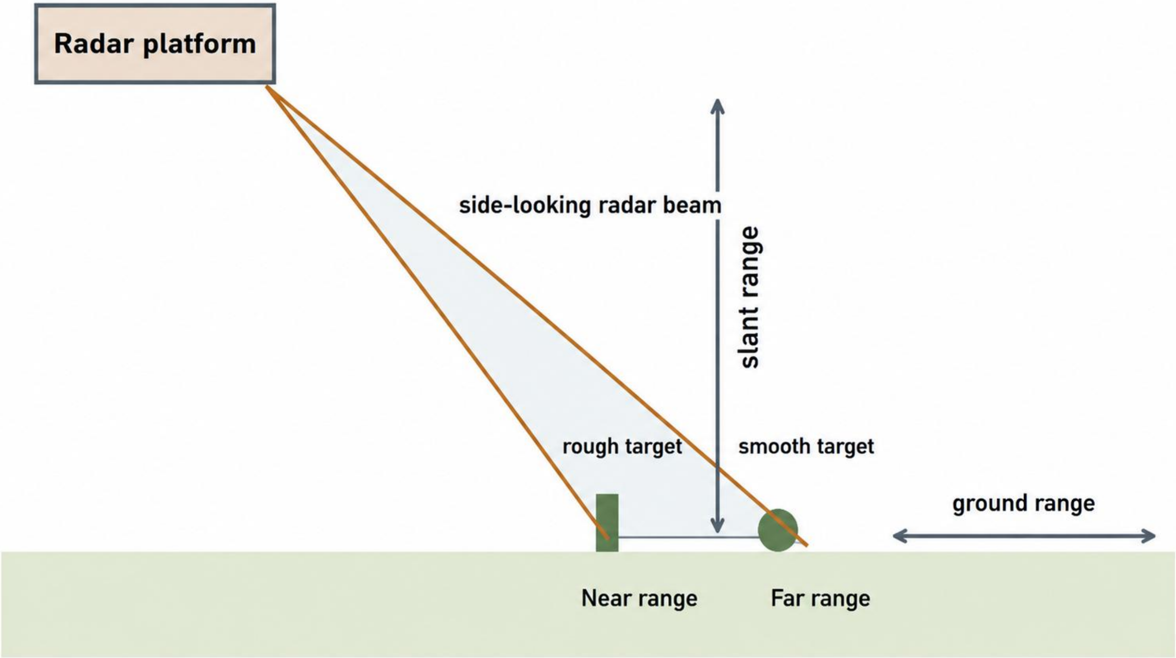
Often used for broad-scale moisture, snow, and atmospheric studies.

Active microwave

Often used for flood mapping, crop structure, sea ice, and land deformation.

Radar and SAR viewing geometry

Radar is side-looking, so geometry and surface orientation strongly influence the return signal.



Backscatter depends on moisture, surface roughness, geometry, and wavelength.

Important terms

Slant range, ground range, incidence angle, layover, shadow, and speckle are key concepts in radar interpretation.

Comparing thermal and microwave sensors

The table below summarizes the main differences.

Criterion	Thermal sensors	Microwave sensors
Main signal	emitted thermal radiation	microwave emission or radar backscatter
Typical operation	mainly passive	passive or active
Strength	surface temperature patterns	all-weather and day/night capability
Sensitive to	temperature and emissivity	moisture, roughness, geometry, structure
Common uses	heat islands, fires, stress	floods, soil moisture, deformation, ice

Take-away

Thermal data is excellent for heat-related analysis, while microwave data is especially valuable when clouds, darkness, or structure/moisture information are important.

Key applications

These sensor classes are widely used in environmental monitoring and decision support.

Agriculture

Thermal: crop water stress

Microwave: soil moisture and crop structure

Supports irrigation decisions

Water and floods

Thermal: warm/cool water contrasts

Microwave: flood extent under clouds

Useful in emergency response

Urban and energy

Thermal: heat islands and energy loss

Microwave: urban structure and surface texture

Hazards and cryosphere

Thermal: active fires and volcanic heat

Microwave: snow, ice, and deformation monitoring

Each class has strong advantages, but also practical constraints.

Thermal strengths

- day and night temperature mapping
- strong for fires and heat stress
- good for urban heat analysis

Thermal limits

- emissivity and atmosphere matter
- coarser spatial detail is common
- not ideal under thick clouds

Microwave strengths

- works through clouds in many cases
- day/night capability
- sensitive to moisture and structure

Microwave limits

- interpretation can be less intuitive
- speckle and geometric effects
- specialized processing is often needed

In many professional workflows, thermal and microwave data are used together with optical data to balance interpretability and physical sensitivity.

Examples of common thermal and microwave missions

You do not need to memorize every mission, but the classes are worth recognizing.

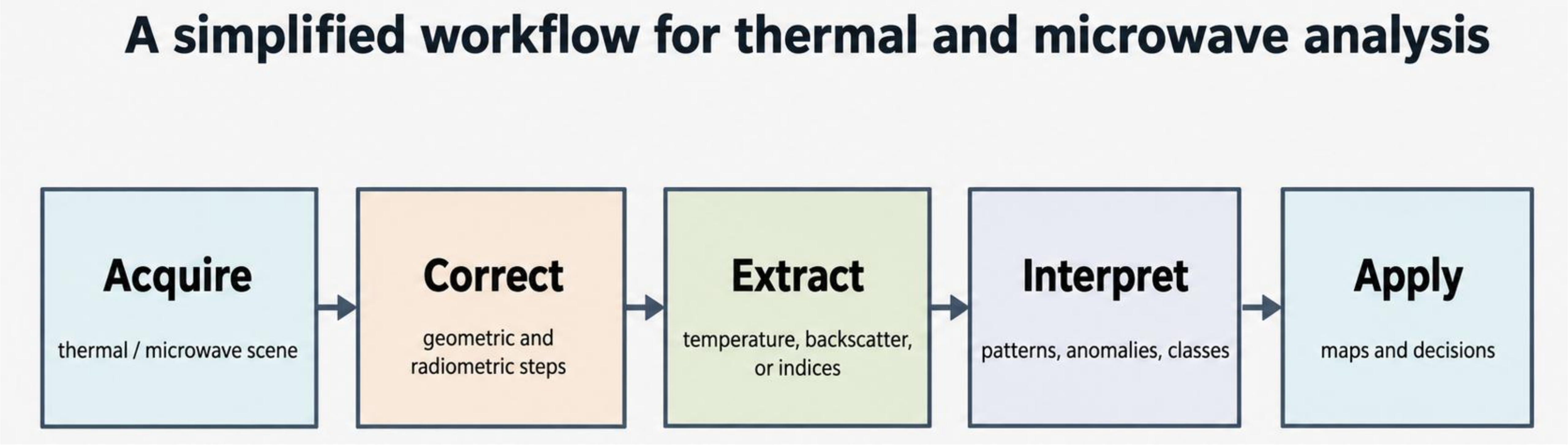
Mission / sensor	Class	Mode	Typical strength	Typical applications
Landsat TIRS	Thermal	Passive	surface temperature	heat islands, fires, water temperature patterns
MODIS thermal bands	Thermal	Passive	frequent large-area coverage	fires, drought, regional monitoring
SMAP radiometer	Microwave	Passive	soil-moisture sensitivity	soil moisture and freeze-thaw studies
Sentinel-1 SAR	Microwave	Active	cloud-penetrating radar	floods, deformation, crop monitoring
RADARSAT / ALOS SAR	Microwave	Active	structural and surface sensitivit	hazards, forests, ice, land monitoring

Note

Exact band ranges and technical specifications vary, but these examples show the major categories students should know.

A simplified analysis workflow

Both thermal and microwave data require careful preprocessing and interpretation.



Important processing needs

Thermal workflows often require emissivity and atmospheric consideration. Radar workflows often require speckle filtering, calibration, and terrain correction.

Key ideas to remember

Thermal sensors

Measure emitted radiation related to surface temperature.

Strong for heat islands, fire mapping, and stress detection.

Affected by emissivity and atmosphere.

Microwave sensors

Measure microwave emission or radar backscatter.

Strong for all-weather day/night monitoring and moisture-related analysis.

Interpretation is less intuitive and often requires more specialized processing.

References

Selected introductory and authoritative sources

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

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

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

NASA Earthdata and NASA Earth Observatory. Introductory materials on thermal remote sensing and radar basics.

USGS Landsat Missions. Thermal Infrared Sensor (TIRS) overviews and educational resources.

ESA Sentinel Online. Introductory materials on Sentinel-1 SAR and Earth observation missions.

FAO and USGS educational resources on Earth observation, thermal sensing, and environmental monitoring.

Independent study suggestion

Students are encouraged to compare an optical image, a thermal image, and a SAR image of the same area to see how each sensor class highlights different physical properties.

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