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# MICRO-CREDENTIAL

# LAND MANAGEMENT IN CENTRAL ASIA

## 14.- Radar and Laser Remote Sensing

*Active Remote Sensing Systems*

*LM-W14-V93*

# Active Remote Sensing Systems

Radar, LiDAR, altimetry and active Earth observation for land management

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# Learning objectives

This lesson introduces active sensing systems and how they support land monitoring.

1. Define active remote sensing and explain how it differs from passive sensing.

2. Identify the main families of active systems: radar, LiDAR, altimeters and scatterometers.

3. Explain the transmit–return measurement principle in simple terms.

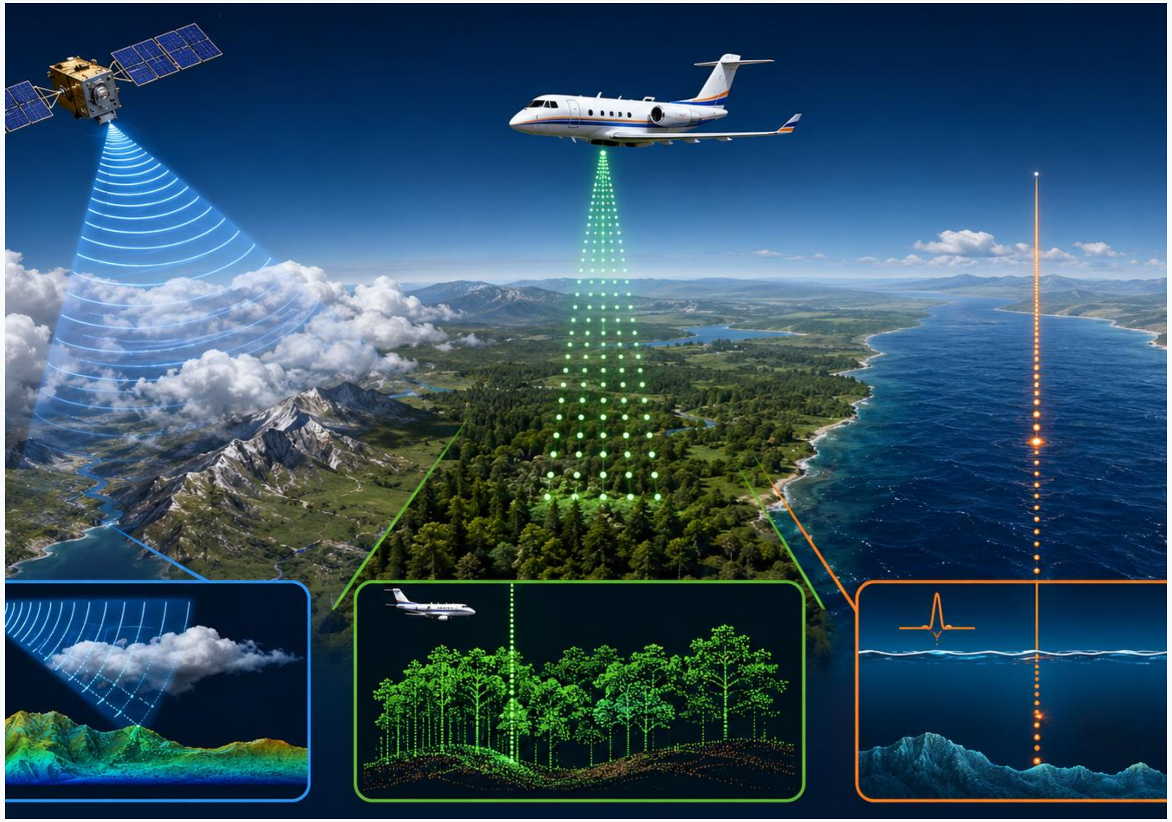
4. Recognize the strengths and limitations of active sensing for land management.

5. Connect active data products to agriculture, water, terrain and disaster monitoring.

# What makes a system “active”?

An active sensor provides its own energy source instead of relying only on sunlight or naturally emitted energy.

The sensor emits a controlled pulse or beam toward the target.
The target modifies the signal through reflection, scattering or absorption.
The sensor records the returned signal and timing information.
The data can be transformed into images, elevation profiles, point clouds or geophysical measurements.



Simple definition: active remote sensing is measuring the returned response from energy that the sensor itself has emitted.

# Active and passive systems compared

Both approaches are important, but they answer different observation needs.

| Feature | Passive remote sensing | Active remote sensing |
|---|---|---|
| Energy source | Sunlight or natural emission | Sensor emits its own energy |
| Typical examples | Optical, thermal, multispectral | Radar, LiDAR, radar altimetry |
| Best strength | Spectral colour and vegetation information | Day/night operation, range and structure |
| Typical limitation | Clouds, shadows and sunlight dependence | Speckle/noise, geometry effects, larger data complexity |
| Useful for | Land cover, indices, surface temperature | Terrain, deformation, floods, biomass, moisture, elevation |

In practice, strong land monitoring often combines both: optical data for spectral information and active data for structure, moisture, elevation and all-weather observation.

# The active sensing measurement loop

The core logic is similar across radar, LiDAR and altimetry systems.

**Emit pulse** → **Travel to target** → **Interact with surface** → **Return echo** → **Convert to data**

### Time-of-flight

Measures distance by using the travel time of the pulse and the known speed of electromagnetic energy.

### Signal strength

Measures how much energy returns. This supports interpretation of surface, structure and material properties.

Important: active data are not automatically “easier” than optical images. They require understanding of geometry, wavelength and surface interaction.

# Main families of active remote sensing systems

Different active systems use different signals and produce different data products.

### Imaging radar / SAR

Microwave pulses create 2D images of surface backscatter.

### LiDAR

Laser pulses produce accurate elevation and 3D point clouds.

### Radar / laser altimetry

Near-nadir pulses measure height profiles and surface elevation.

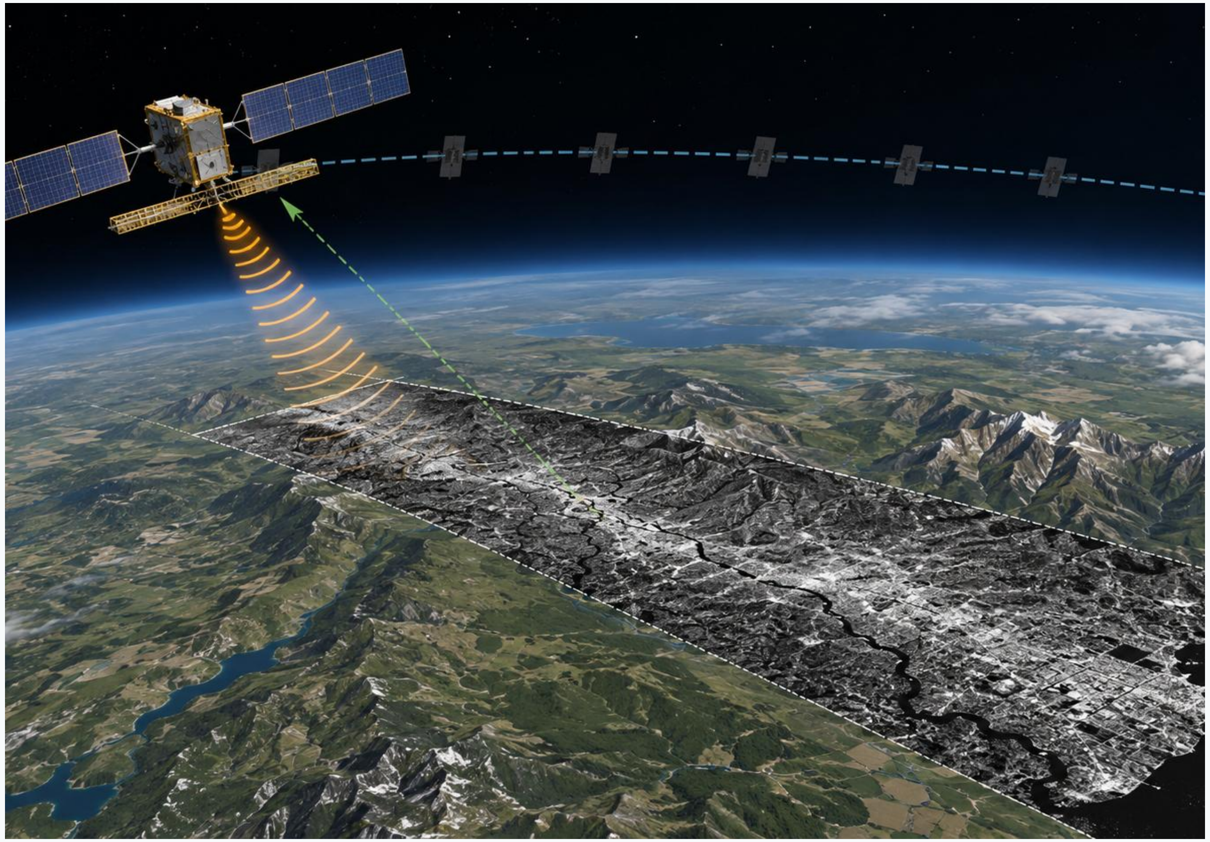
### Scatterometers

Wide-area radar backscatter measurements support wind, soil moisture and surface monitoring.

# Imaging radar and SAR

Synthetic Aperture Radar is the most widely used active imaging system for land observation.

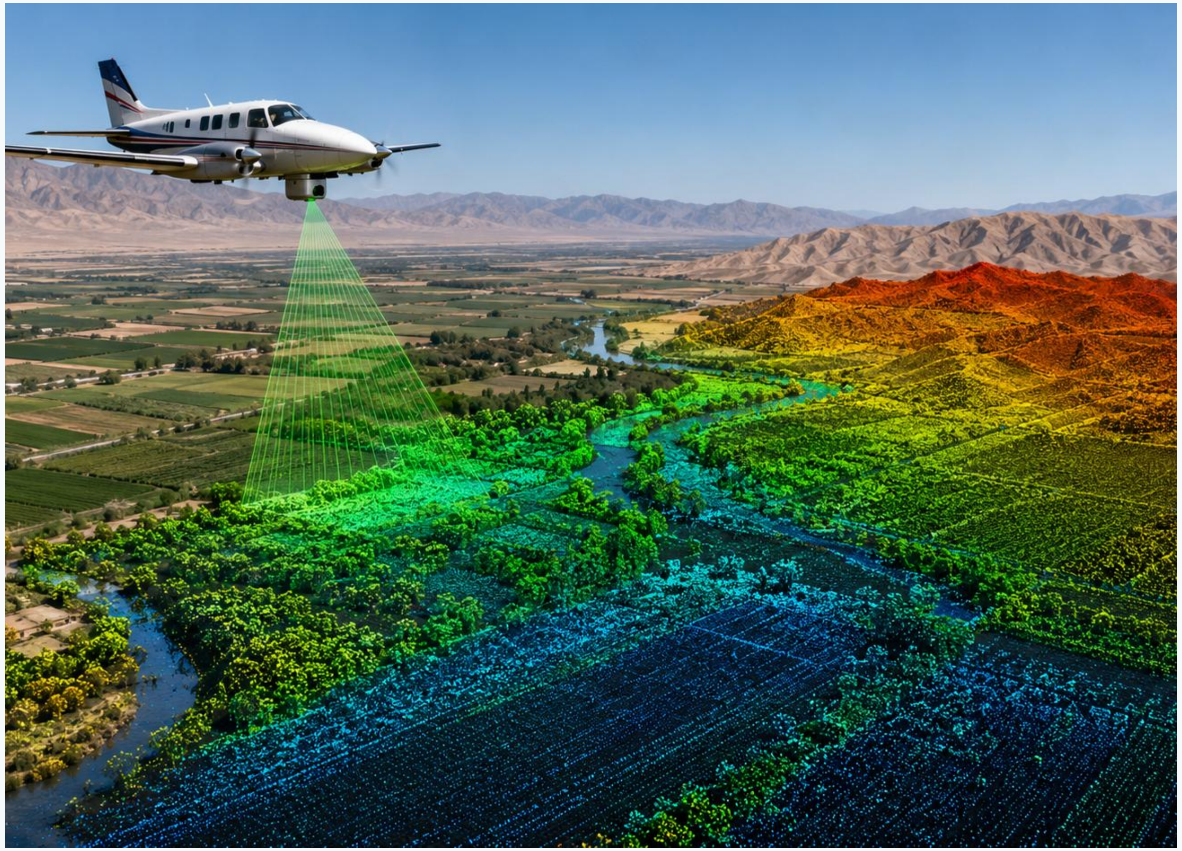
SAR observes the surface with microwave pulses from a moving platform.
It can create high-resolution images in darkness and through many cloud conditions.
SAR image brightness depends on roughness, moisture, structure and viewing angle.
Common applications include flood mapping, crop monitoring, deformation and land-cover analysis.



Classroom caution: bright SAR pixels do not always mean “high reflectance.” They mean strong radar backscatter under a specific viewing geometry.

# LiDAR: active laser scanning

LiDAR measures distance using laser pulses, often producing dense 3D point clouds.



### What it measures

Precise ranges from the sensor to surfaces such as ground, buildings, tree canopy or infrastructure.

### Typical products

Digital terrain models, digital surface models, canopy height, building height and 3D point clouds.

### Land management value

Supports flood modelling, drainage planning, erosion analysis, forest structure and detailed topography.

# Altimetry and scatterometry

Not all active systems produce map-like images; some create profiles or broad geophysical measurements.

## Radar altimetry

Measures surface height along satellite tracks. Widely used for oceans, ice, lakes, rivers and topographic studies.

## Laser altimetry

Uses laser pulses to measure elevation and vertical structure. Examples include airborne LiDAR and spaceborne laser altimeters.

## Scatterometry

Measures normalized radar backscatter over broad areas. Often used for surface wind over oceans and land surface parameters.

## Why it matters

These systems are less familiar to students than images, but they provide essential quantitative measurements for environmental monitoring.

**ACTIVE DATA = IMAGE + PROFILE + POINT CLOUD + GEOPHYSICAL MEASUREMENT**

# From raw signal to useful information

Active remote sensing requires careful processing before interpretation.

**Acquire** → **Calibrate** → **Geocode** → **Filter / correct** → **Classify / model** → **Validate**

For SAR, common processing includes radiometric calibration, terrain correction, speckle filtering and conversion into useful backscatter layers.

For LiDAR, common processing includes point classification, ground filtering, point cloud quality checks and generation of elevation models.

Validation with field observations, cadastral data, UAV data or high-resolution imagery is essential for trustworthy results.

# Typical products from active systems

The product depends on the sensor type, acquisition geometry and processing level.

| System | Main product | What students can analyze |
|---|---|---|
| SAR | Backscatter image, coherence, interferogram | Floods, crop patterns, urban structure, deformation |
| LiDAR | Point cloud, DTM, DSM, canopy height | Terrain, drainage, trees, buildings, erosion risk |
| Radar altimetry | Elevation / water level profile | Lakes, reservoirs, rivers, ice and sea surface height |
| Scatterometer | Backscatter-derived variables | Wind fields, surface state, soil moisture indicators |

# Applications for land management

Active sensing is useful when structure, moisture, elevation or repeated monitoring is important.

### Agriculture

crop structure, field moisture, irrigation effects, seasonal monitoring

### Water and floods

flood extent, wetland change, reservoir/water level support

### Soil and degradation

erosion-prone terrain, salinity risk context, surface roughness

### Urban / infrastructure

building height, subsidence, roads, drainage corridors

Central Asia context: active systems are especially useful in irrigated and semi-arid landscapes where clouds, water stress, drainage and land degradation require frequent monitoring.

# Which active system should be chosen?

Sensor selection should follow the land-management question, not only data availability.

| Question | Best active data option | Why |
|---|---|---|
| Where is flooding after heavy rain? | SAR | Cloud-tolerant and day/night monitoring |
| What is the exact terrain form? | LiDAR / laser altimetry | High vertical accuracy and dense elevation data |
| Is land surface moving or subsiding? | Repeat-pass SAR / InSAR | Sensitive to small surface displacement |
| What is forest or tree structure? | LiDAR + L-band SAR | Captures vertical and structural information |
| How can drainage planning improve? | LiDAR DTM + SAR wetness indicators | Combines topography with surface moisture patterns |

Practical recommendation: combine active data with field observations, cadastre boundaries and optical satellite imagery for stronger evidence.

# Strengths, limitations and interpretation risks

Active systems are powerful, but they require careful technical understanding.

## Strengths

- own energy source
- day/night capability
- useful under clouds
- structure and elevation information
- repeated monitoring potential

## Limitations

- speckle and noise
- geometric distortion
- processing complexity
- data volume
- interpretation depends on wavelength, angle and polarization

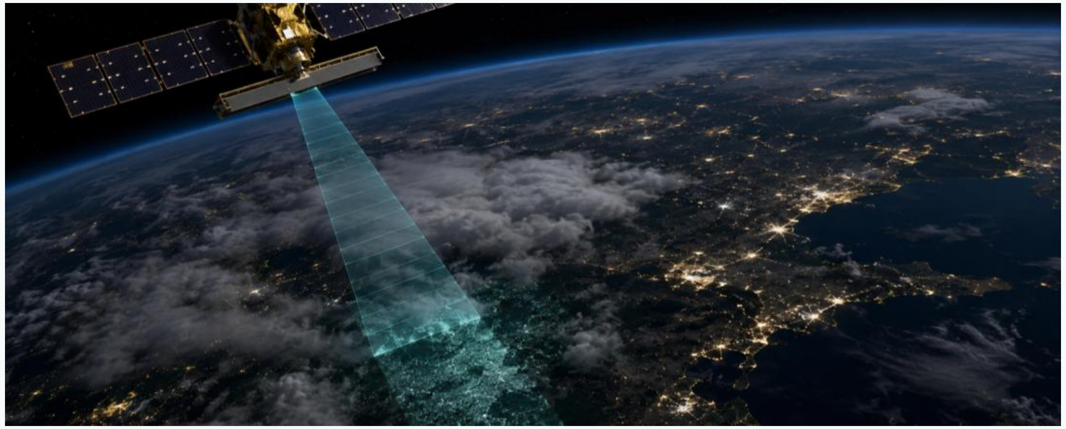
## Good practice

- use metadata
- check acquisition geometry
- compare multiple dates
- validate with field data
- combine radar/LiDAR with GIS and optical imagery

Key message for students: active sensing gives information that optical imagery cannot easily provide, but results must be interpreted with method and evidence.

# Summary and references

Active remote sensing expands land monitoring beyond optical imagery.



Active systems emit their own energy and measure the returned response.
Radar/SAR, LiDAR, altimetry and scatterometry produce different data products.
Interpretation depends on wavelength, geometry, polarization, surface structure and moisture.
For land management, active data are strongest when combined with GIS, field data and optical imagery.

## Selected references


NASA Earthdata. Active Instruments; Synthetic Aperture Radar (SAR); GEDI Lidar; NISAR mission pages.
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LESLIE project course materials and micro-credential template.

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