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LESLIE
LAND MANAGEMENT ENVIRONMENT & SOLID-WASTE

Co-funded by the European Union

TIIAME

MICRO-CREDENTIAL

LAND MANAGEMENT IN CENTRAL ASIA

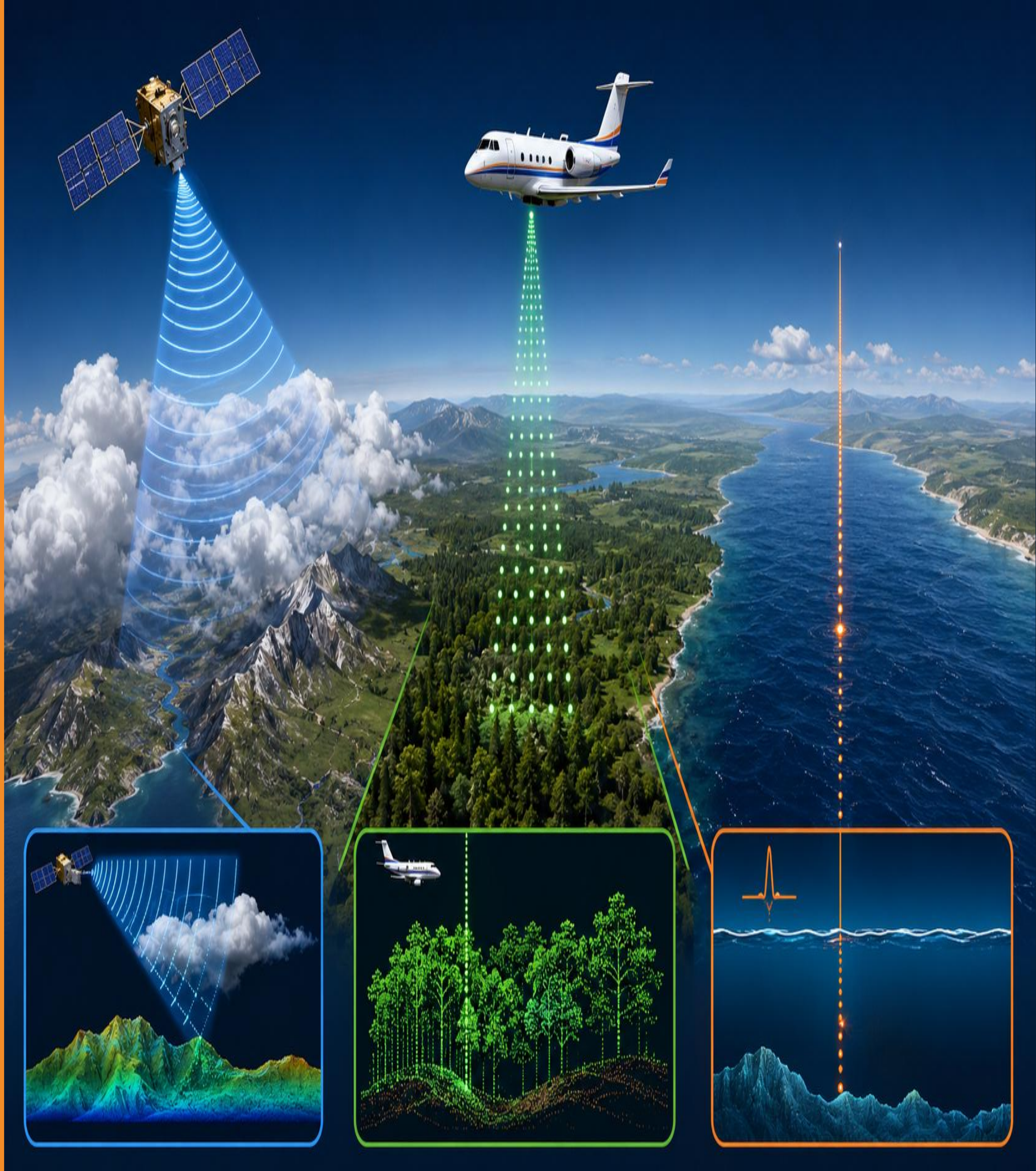
14.- Radar and Laser Remote Sensing

Advantages and Limitations of Radar and LiDAR

LM-W14-V97

Advantages and Limitations of Radar and LiDAR

Micro-credential: Remote Sensing for Land Management in Central Asia



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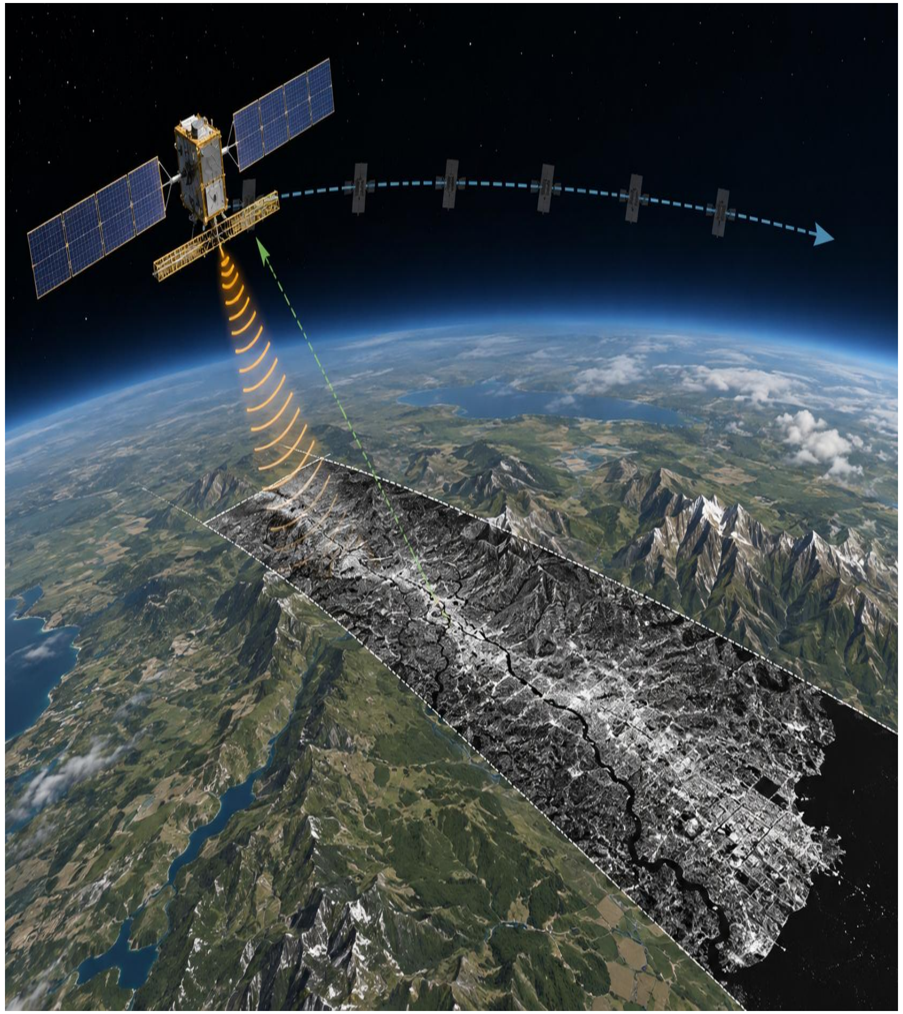
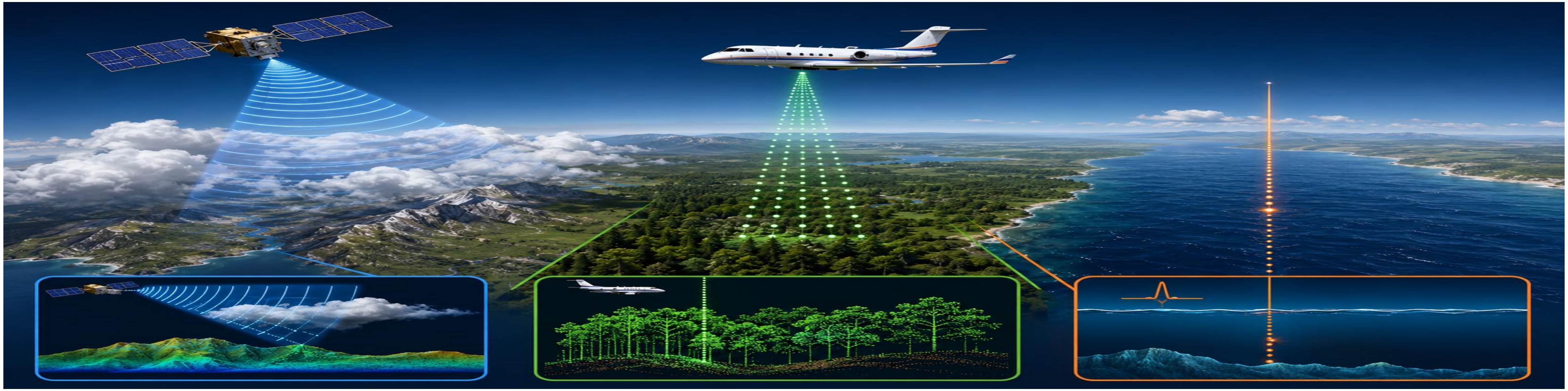
By the end of this lesson, students will be able to:

Compare radar and LiDAR as active remote sensing systems.
Explain the major technical advantages of each technology.
Identify key limitations that affect data interpretation and cost.
Select radar, LiDAR, or an integrated approach for land and water studies.
Relate sensor choice to Central Asian terrain, irrigation, and environmental monitoring needs.



Active sensing: one principle, two different signals



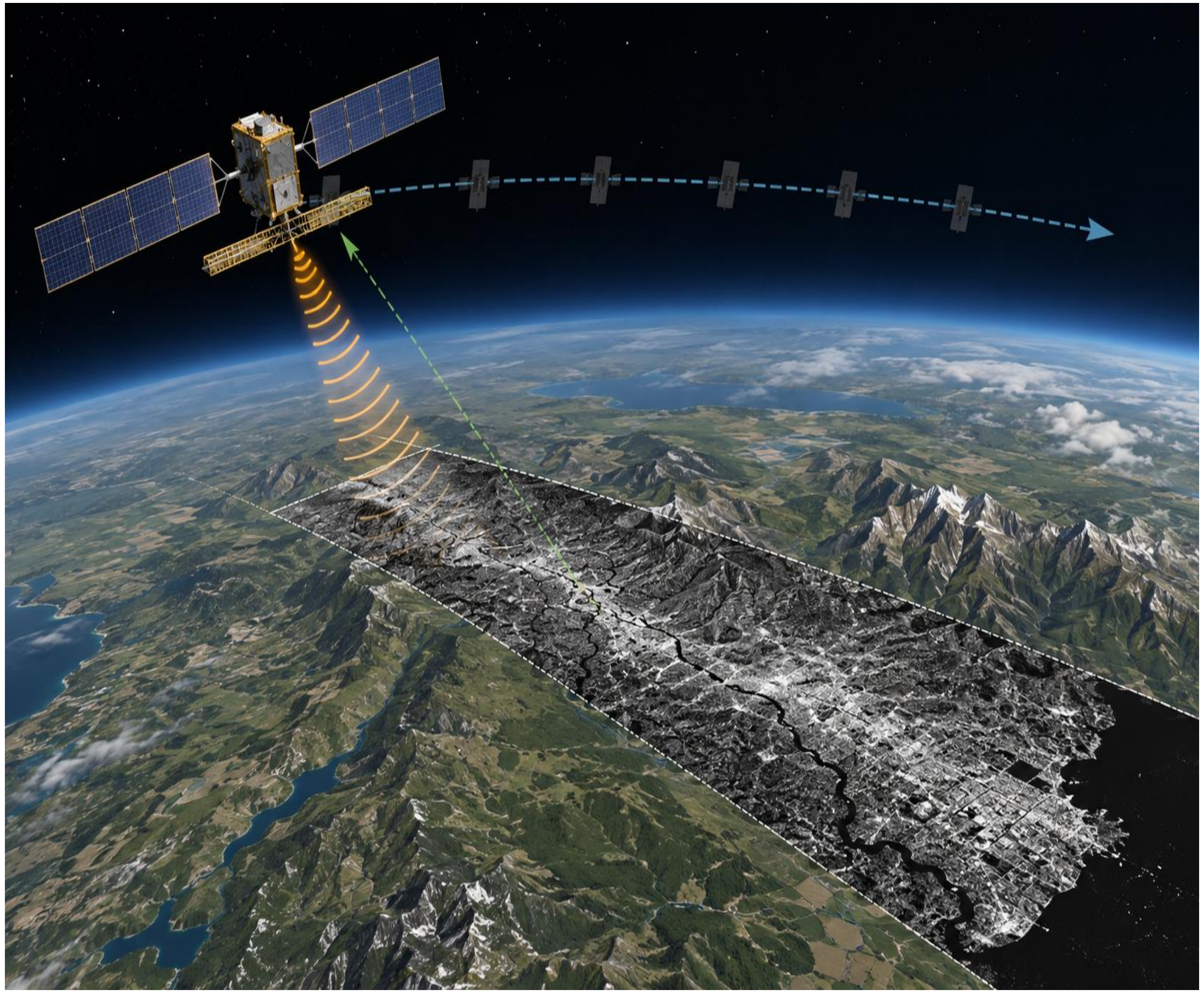
Radar

Uses microwave energy. Strong for all-weather mapping, water/soil moisture sensitivity, and repeated large-area monitoring.

LiDAR

Uses laser pulses. Strong for precise 3D measurement of terrain, vegetation structure, buildings, canals, and micro-topography.

Radar advantages: monitoring when optical imagery fails



Main strengths

Operates day and night because it provides its own signal.
Microwave wavelengths can work through cloud cover and haze.
Sensitive to surface roughness, structure, and dielectric properties such as liquid water.
Useful for flood mapping, wetland change, deformation, and agricultural monitoring.

Best when regular monitoring is needed under clouds, at night, or across large territories.

Radar limitations: powerful data, but not always intuitive

Speckle

Radar images often have a grainy appearance. Filtering can reduce noise, but too much filtering may remove useful spatial detail.

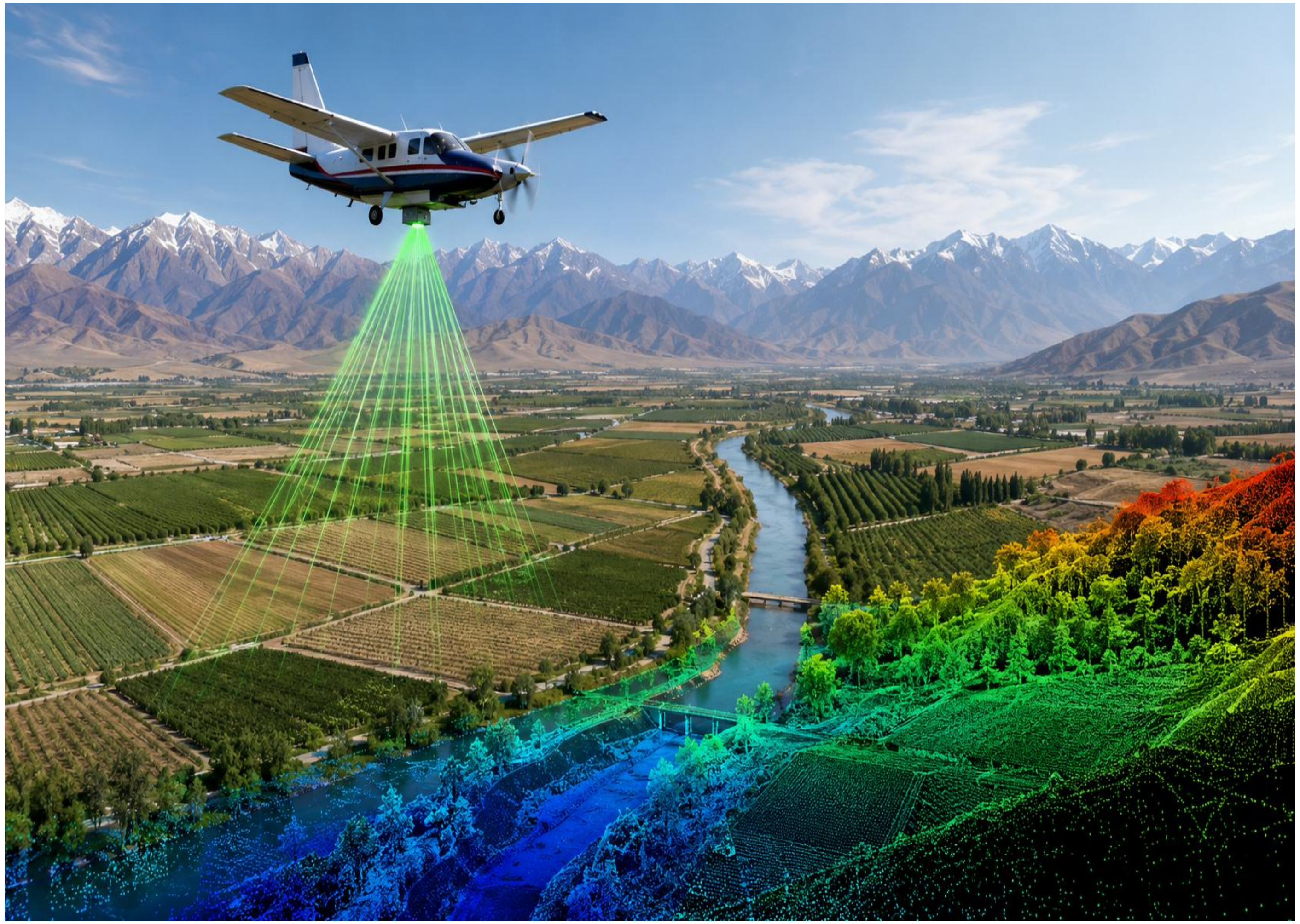
Geometry

Foreshortening, layover, and shadow occur especially in mountains and steep slopes. This matters in Central Asian terrain.

Interpretation

Radar brightness is not a natural colour image. It depends on wavelength, polarization, angle, moisture, and surface structure.

LiDAR advantages: precise 3D structure and terrain detail



Main strengths

Produces dense 3D point clouds with accurate x, y, and z coordinates.
Can separate ground, vegetation, buildings, and infrastructure layers.
Supports bare-earth DEMs, DSMs, contours, slope and drainage analysis.
Very useful for canals, floodplains, landslides, forestry, and urban mapping.

Best when centimetre-to-decimetre 3D detail is more important than broad regional coverage.

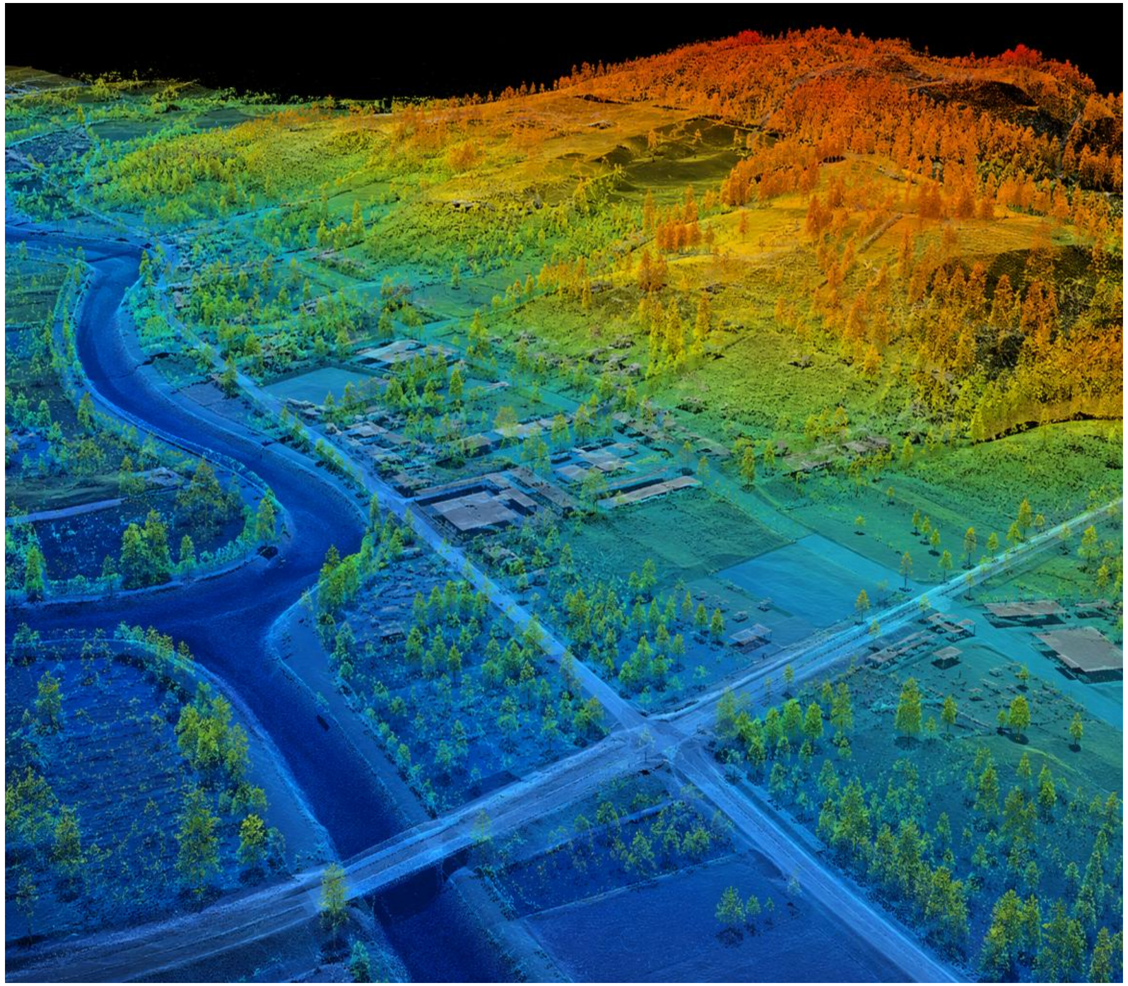
LiDAR limitations: high precision requires careful conditions

Weather and atmosphere
Laser pulses are limited by clouds, heavy rain, dust, smoke, and dense haze.

Cost and logistics
Aircraft or UAV campaigns require planning, equipment, pilots, permissions, and processing capacity.

Coverage and data volume
LiDAR gives high detail, but datasets can be very large and campaign areas are often smaller than satellite radar scenes.

Water and reflectance
Near-infrared LiDAR usually performs poorly over water; bathymetric LiDAR needs green wavelengths and clear water.



Direct comparison: what each technology measures best

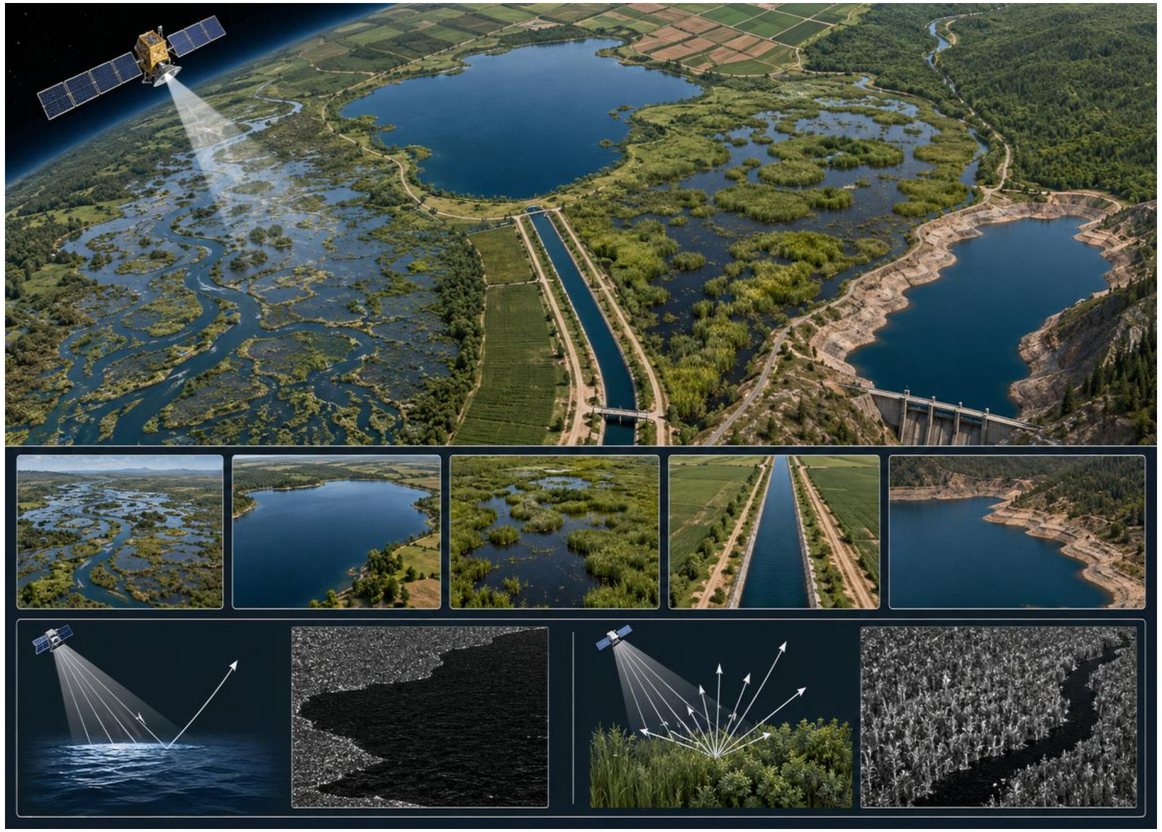
Criterion	Radar	LiDAR	Best use	Caution
Signal	Microwave	Laser light	Radar: cloud/night; LiDAR: 3D detail	Different physics
Main product	Backscatter, phase, coherence	Point cloud, DEM, DSM	Choose by output need	Not interchangeable
Weather	Often all-weather	Fair-weather preferred	Radar for clouds	LiDAR blocked by haze
Terrain detail	Moderate; geometry sensitive	High precision 3D	LiDAR for micro-relief	Cost and data size
Water mapping	Strong contrast for smooth water	Limited over water except green bathymetric	Radar for floods	Wind affects radar
Vegetation	Structure/moisture sensitivity	Height and canopy profile	Use both for biomass	Calibration needed

The better technology is the one that fits the question, landscape, budget, and required output.

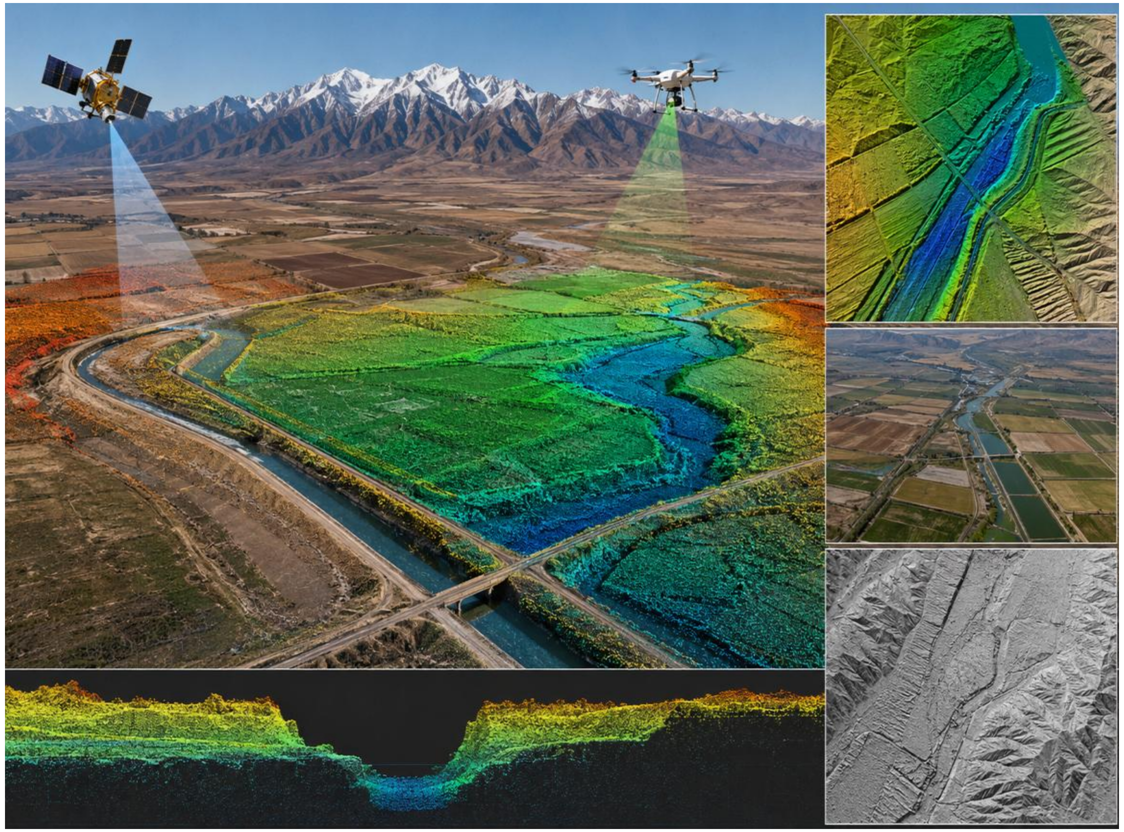
Decision matrix for land and water studies

Flood extent under cloud cover	Radar	detects smooth water surfaces and works during storms
Canal embankment micro-topography	LiDAR	needs high-resolution elevation and slope detail
Ground subsidence monitoring	Radar / InSAR	phase changes can reveal deformation over time
Forest height and canopy layers	LiDAR	multiple returns describe vertical structure
Regional wetland monitoring	Radar + optical	moisture sensitivity and repeated satellite coverage
Urban 3D mapping	LiDAR	dense point clouds capture buildings and streets

Central Asian examples: where the trade-offs matter



Radar: water and moisture monitoring



LiDAR: terrain and infrastructure detail

In arid and irrigated landscapes, radar can support repeated observation of water extent, wet soils, and crop structure, while LiDAR can support elevation models for canals, drainage, flood routing, landslide mapping, and urban expansion control.

Advantages are strongest when linked to a clear workflow

1. Define problem

Flood, subsidence, erosion, biomass, canal condition

2. Select sensor

Radar, LiDAR, or both based on physics and scale

3. Process data

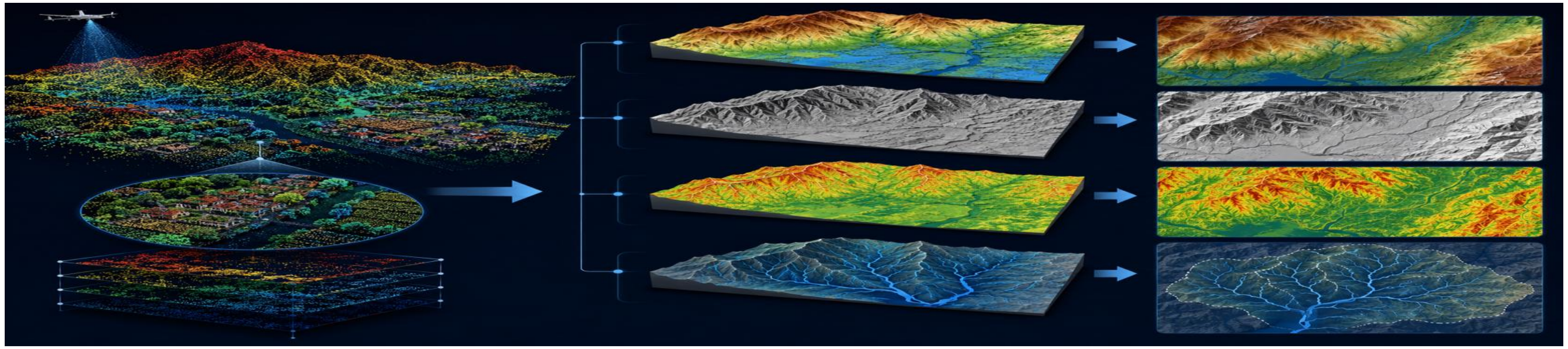
Calibration, georeferencing, filtering, classification

4. Validate

Field checks, GPS, existing maps, local knowledge

5. Apply

Planning, risk mapping, monitoring, reporting



Sensor advantages become useful only after preprocessing, validation, and interpretation are done carefully.

Common interpretation errors to avoid

Radar

Treating bright pixels as “high vegetation” without checking moisture, roughness, angle, and polarization.

Radar

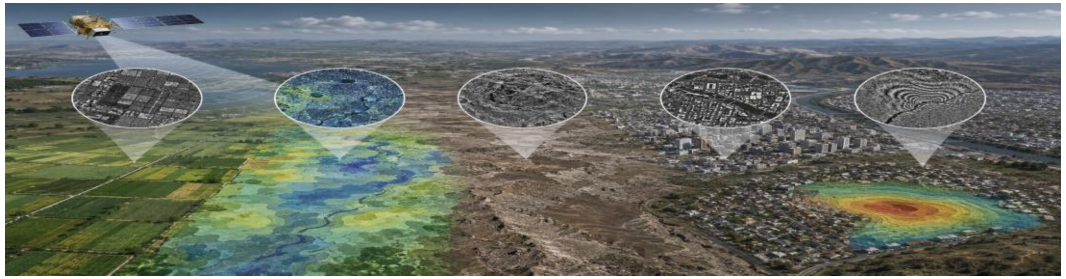
Ignoring terrain distortion in mountain valleys and steep irrigated foothills.

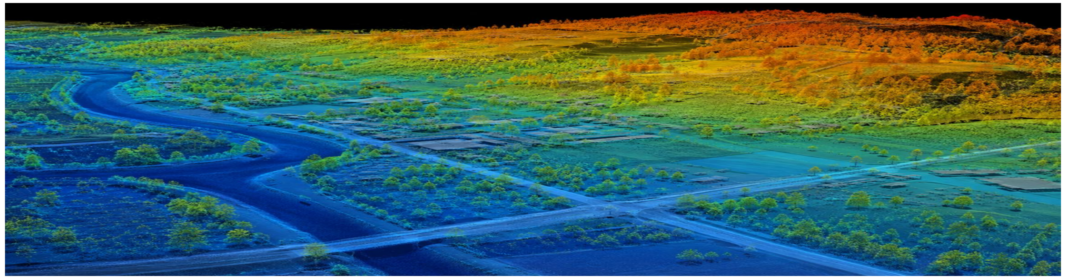
LiDAR

Using a point cloud without checking point density, classification quality, vertical datum, and acquisition date.

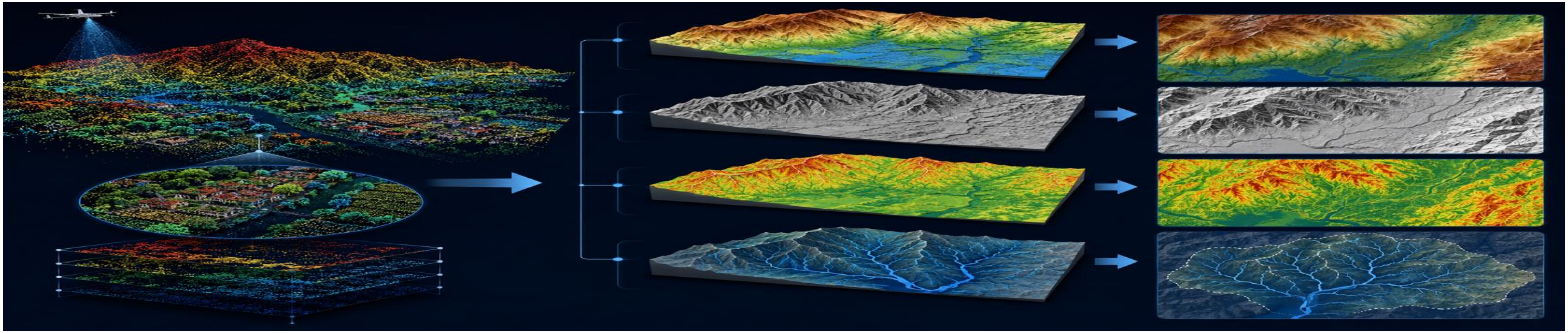
LiDAR

Assuming all LiDAR products are bare-earth DEMs; DSM, DTM, and point clouds answer different questions.





Integrated use: radar + LiDAR + GIS



Radar layer

Water extent, soil moisture signal, surface roughness, deformation

LiDAR layer

Bare-earth DEM, canal geometry, slope, building/vegetation height

GIS layer

Parcels, land use, roads, irrigation networks, field observations

Decision product

Risk maps, restoration priorities, engineering design, monitoring reports

Key takeaways

Radar is robust

It is strong for regular monitoring, cloudy regions, night-time acquisitions, water-related studies, and deformation analysis.

LiDAR is precise

It is strong for high-resolution 3D terrain, vegetation, urban, canal, and infrastructure mapping.

Both have limits

Radar requires careful interpretation; LiDAR requires fair-weather acquisition, high data handling capacity, and budget.

Selection is strategic

The best choice depends on the research question, landscape, scale, budget, and required final product.

Reflection question: For monitoring irrigated land in Uzbekistan, which technology would you choose first, and what limitation would you need to manage?

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Note: This educational presentation uses simplified explanations for bachelor-level learning. For operational projects, check sensor metadata, acquisition conditions, processing level, coordinate reference system, and validation data.

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