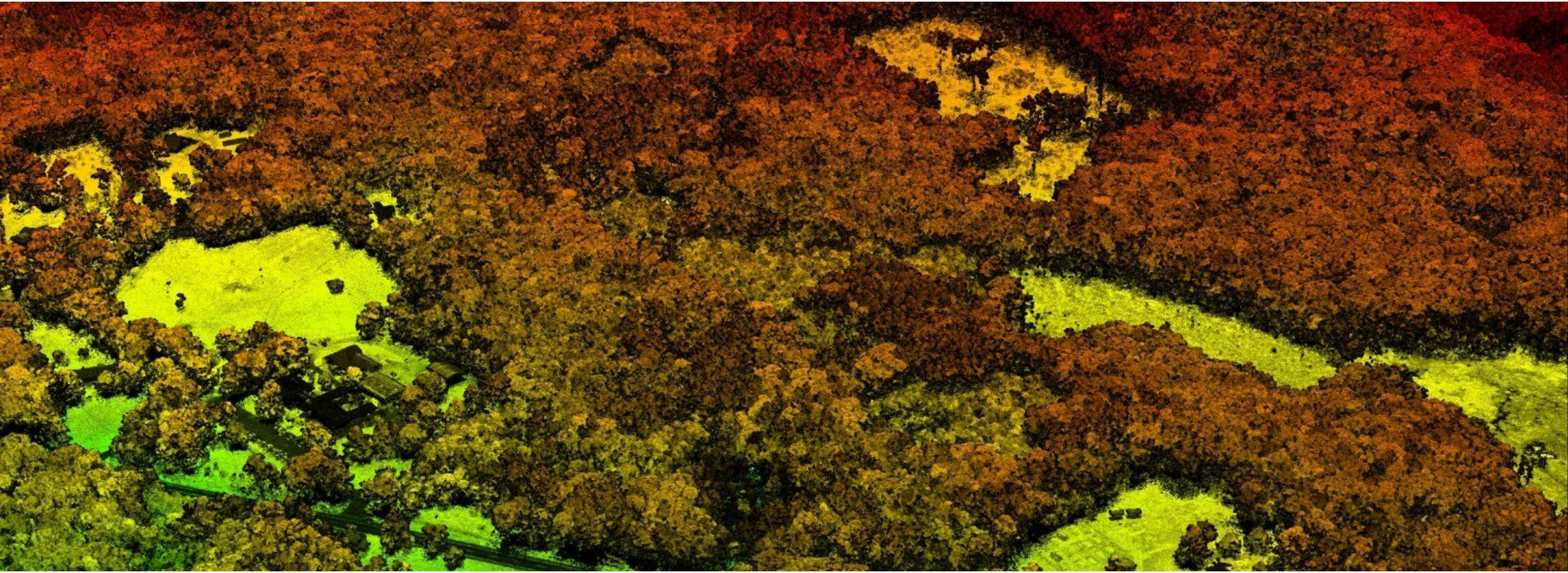
EDS 223: Geospatial Analysis & Remote Sensing
Week 10

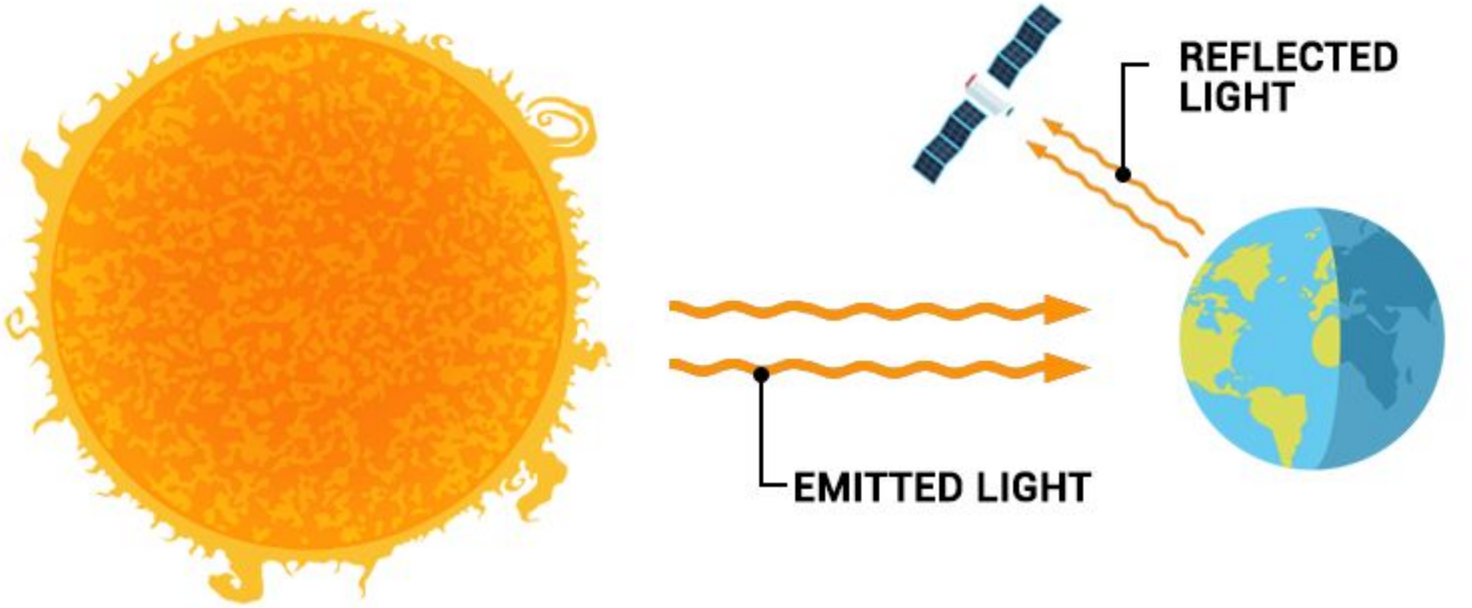


NEON

Welcome!

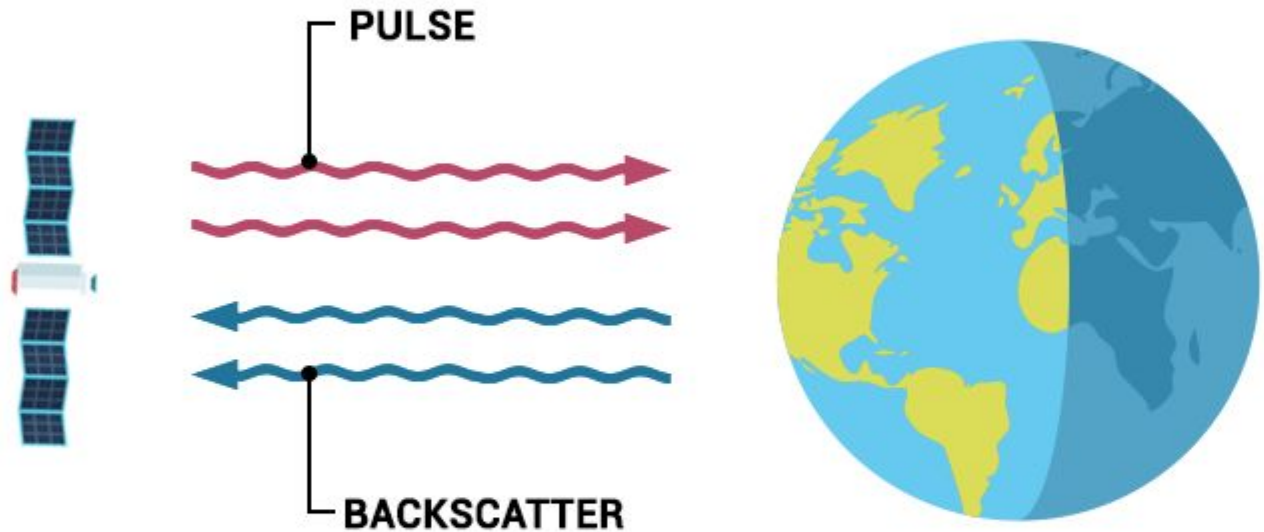
- **LAST DAY OF CLASS!**
- **Assignments**
  - Assignment 4 due December 9
    - Sorry for the typos! Revised copy distributed on Slack
  - Portfolio due December 15
    - Come to office hours for help/guidance this week!
- **Today**
  - Active remote sensing
    - Lidar + Lab
    - Radar
    - Trivia!

Passive remote sensing



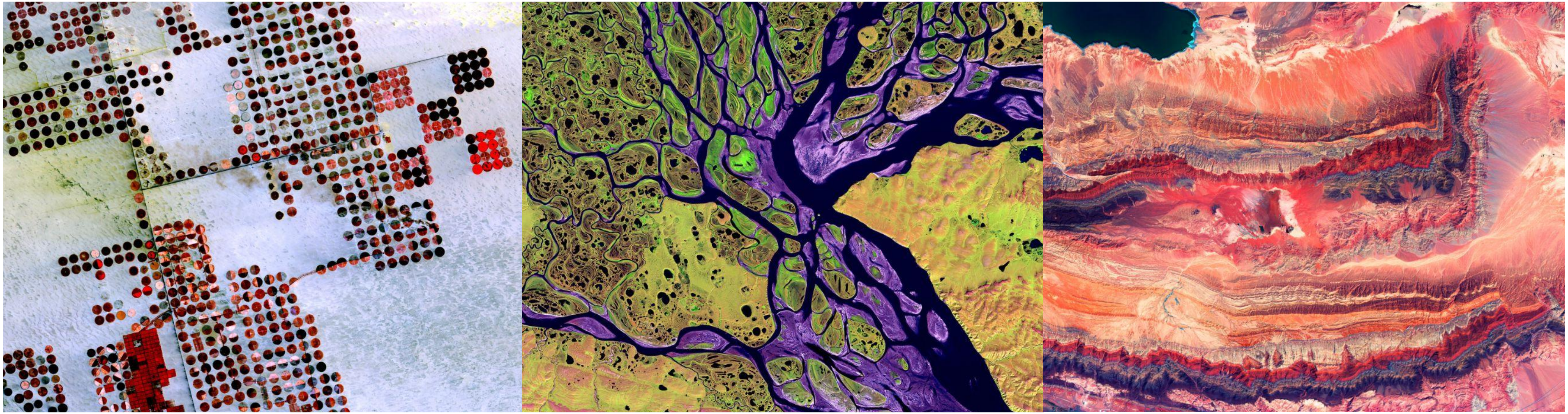
Source: GIS Geography

Active remote sensing



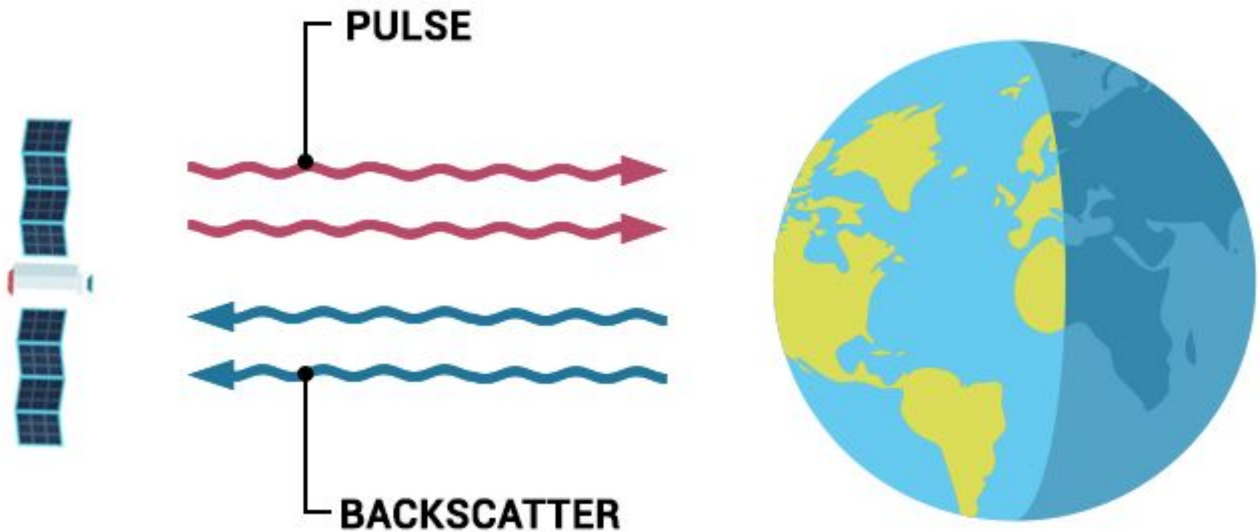
Source: GIS Geography

Passive remote sensing



USGS via Unsplash

Active remote sensing

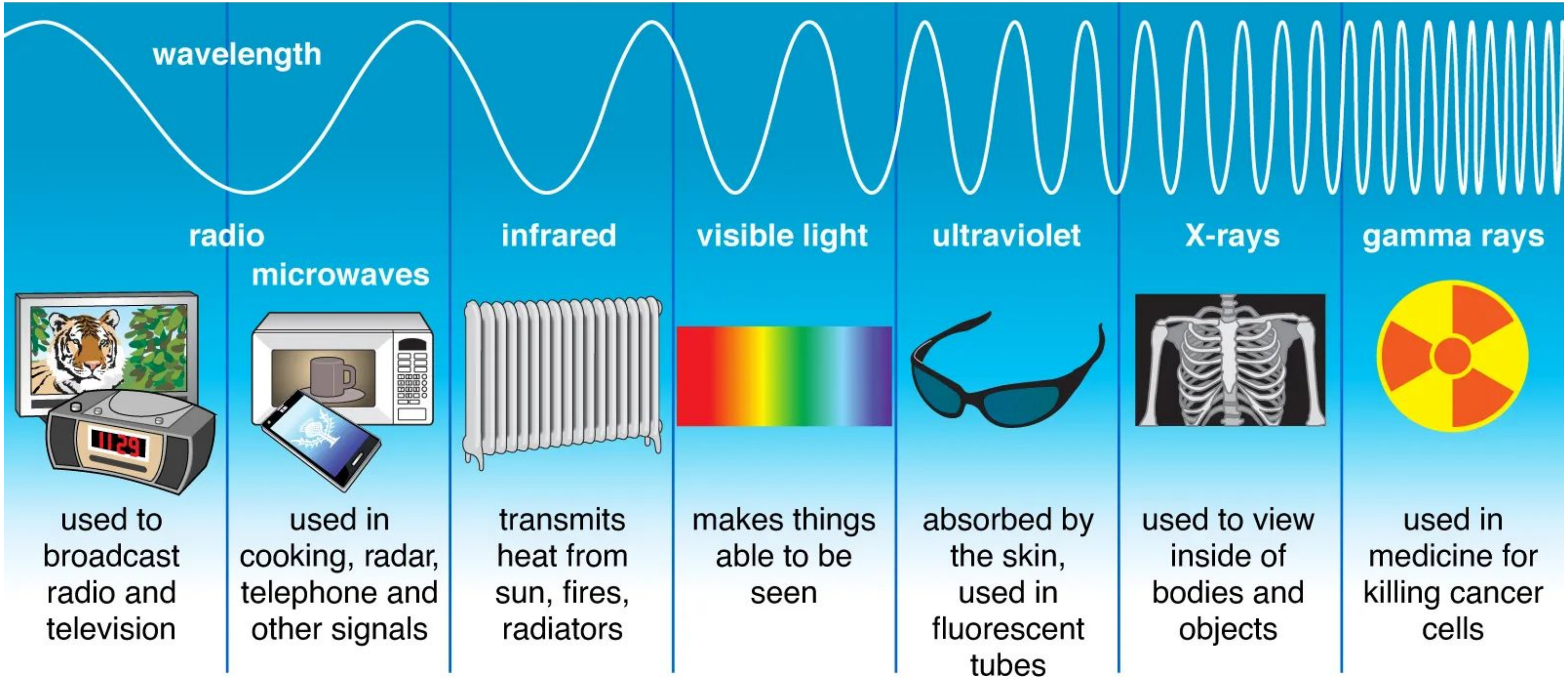


Source: GIS Geography

What is remote sensing?

"the **art, science, and technology** of obtaining reliable information about physical objects and the environment, through the process of recording, measuring, and interpreting imagery and digital representations of **energy** patterns derived from **non-contact sensor systems**."
(Colwell, 1997)

Electromagnetic spectrum

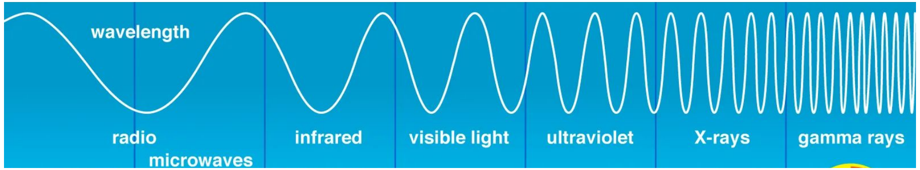


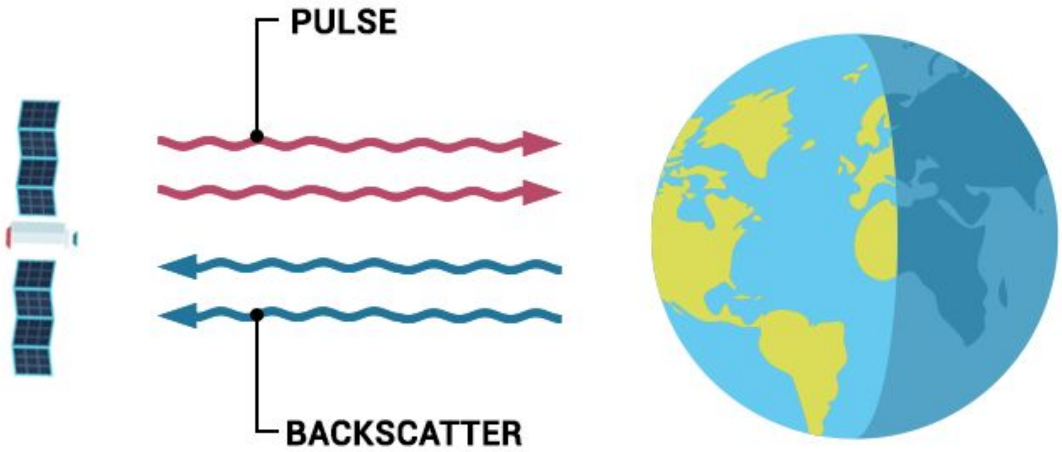
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection and Ranging

LiDAR
Light Detection and Ranging





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Active remote sensing

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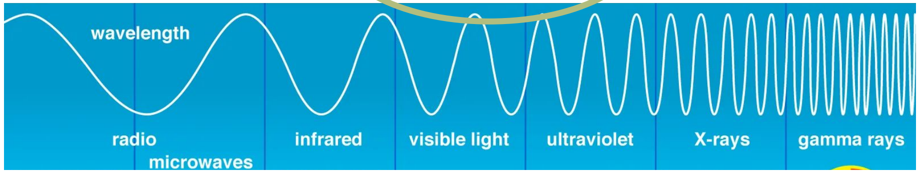
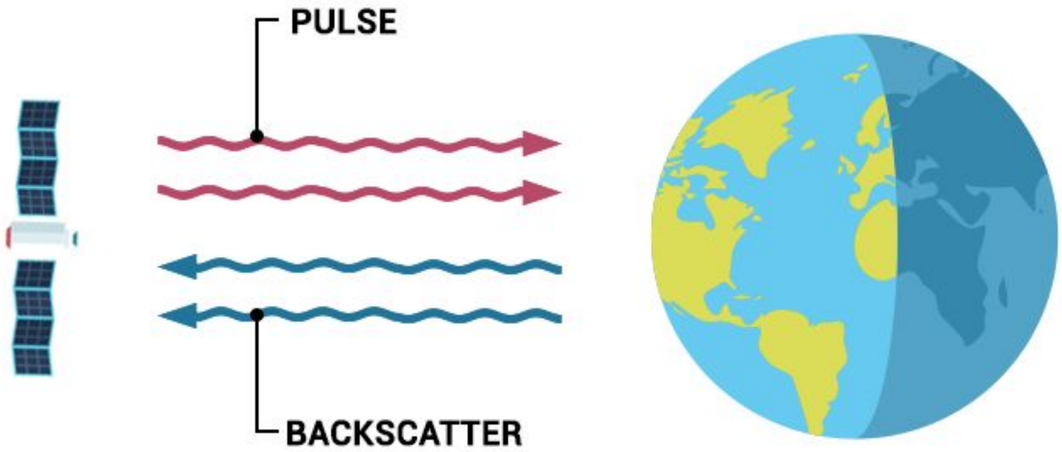
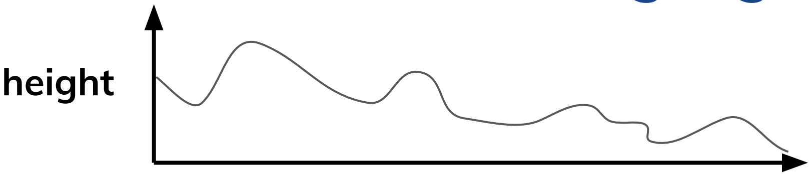
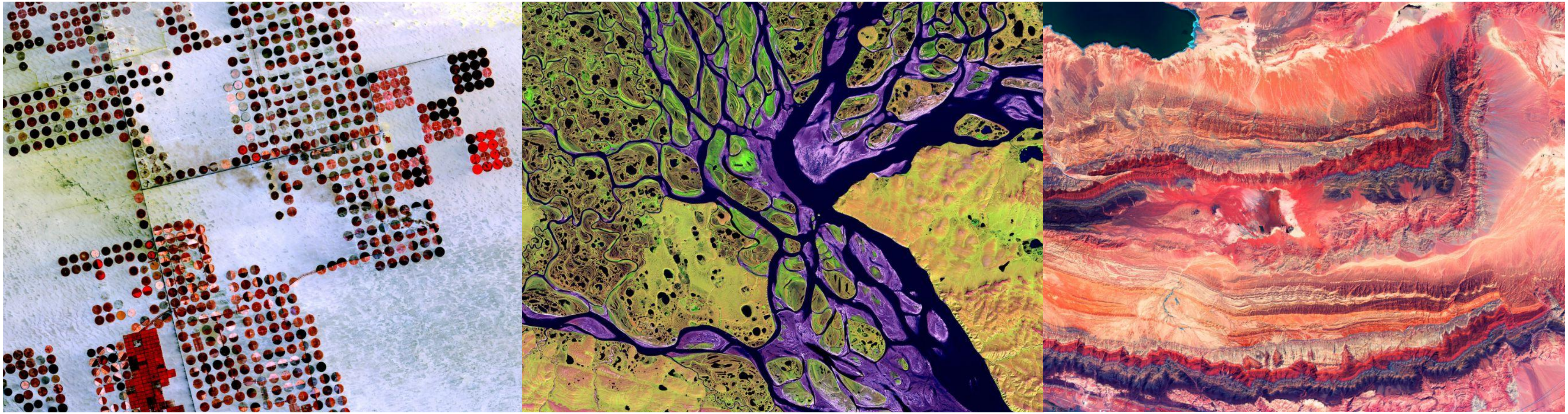




Source: GIS Geography

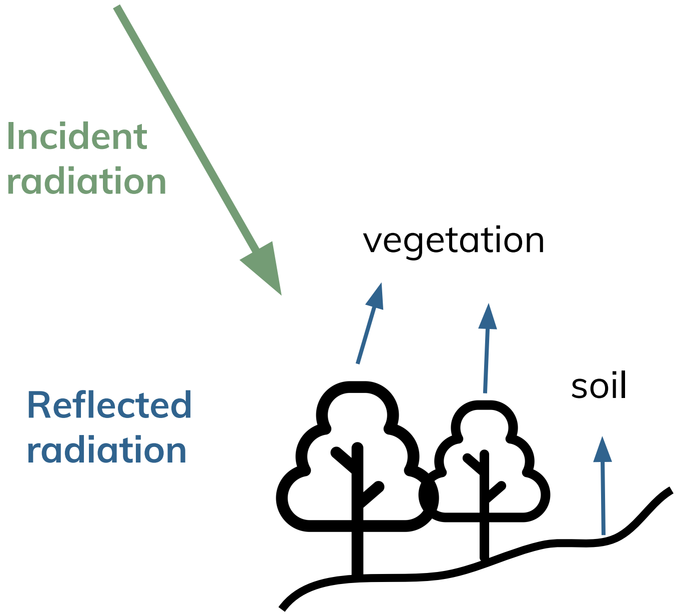
LiDAR: Light Detection and Ranging





USGS via Unsplash

Using light to measure height



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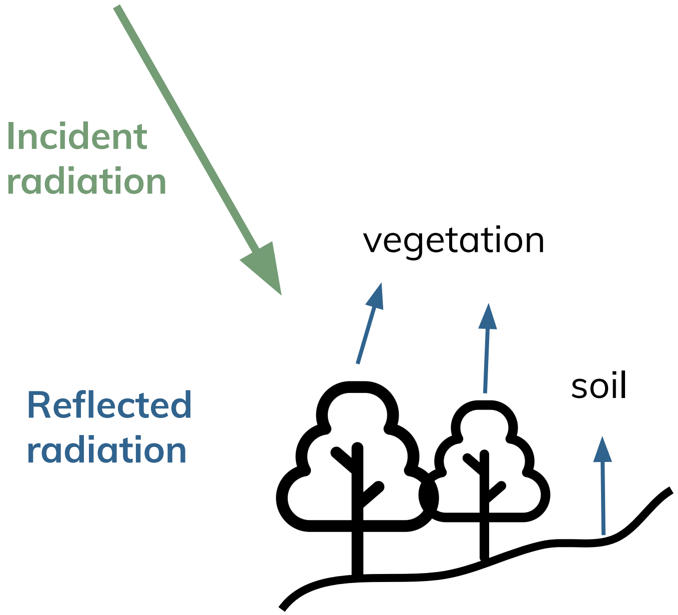

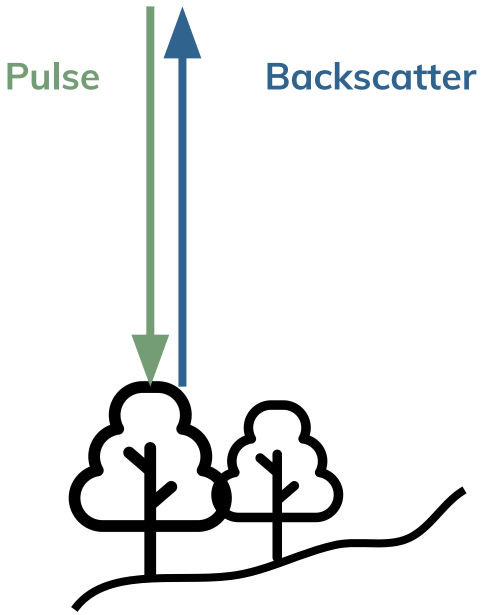

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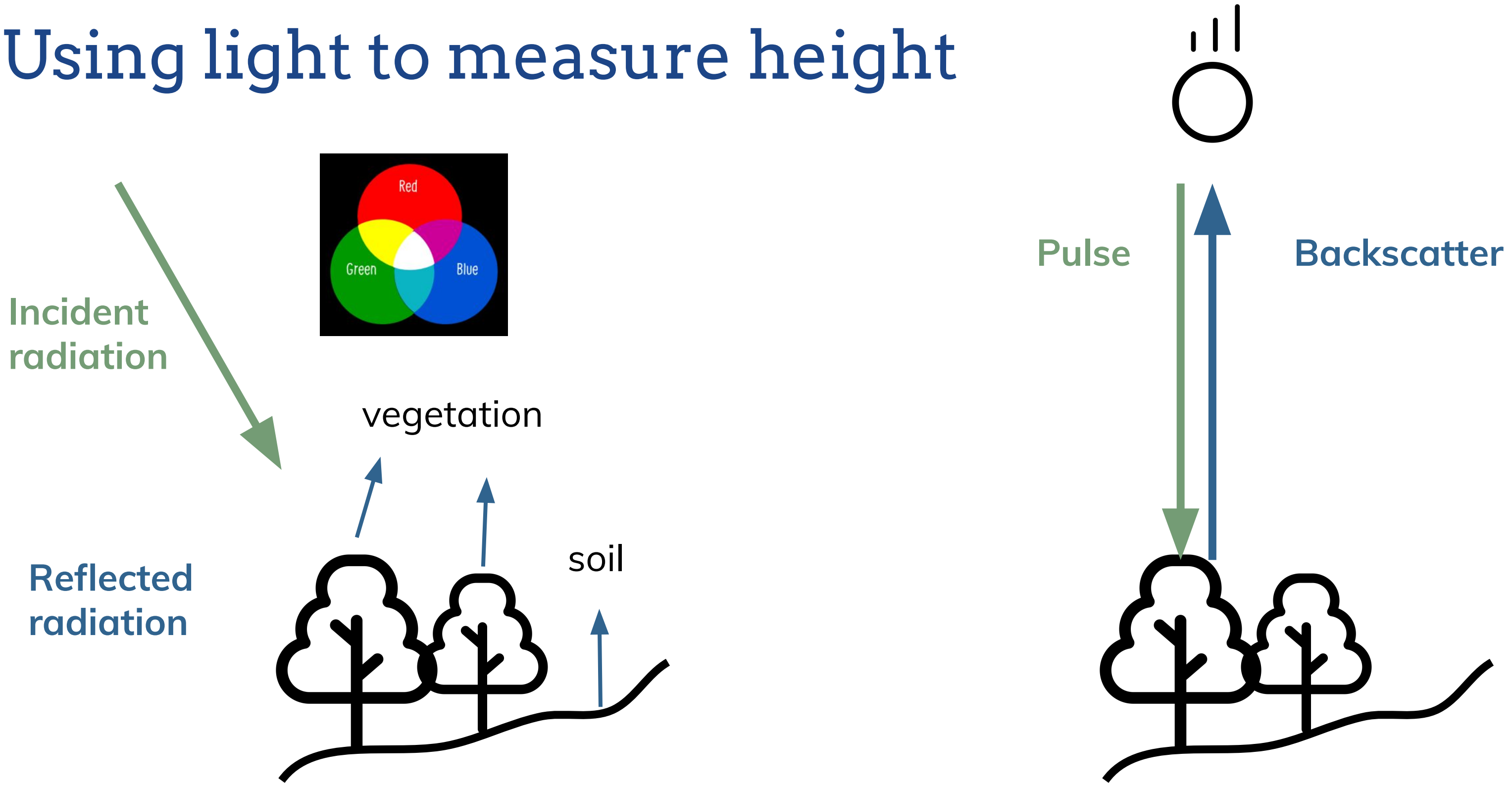

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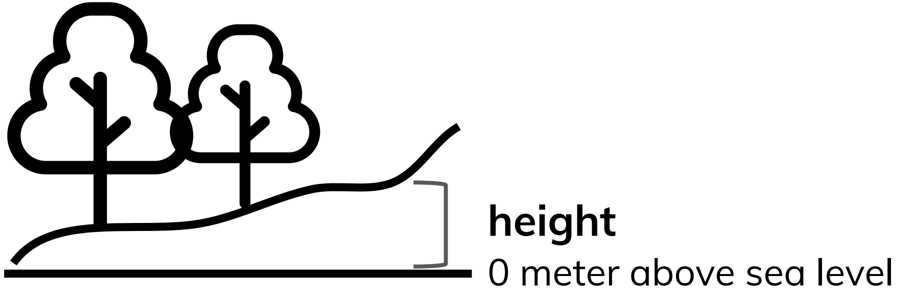

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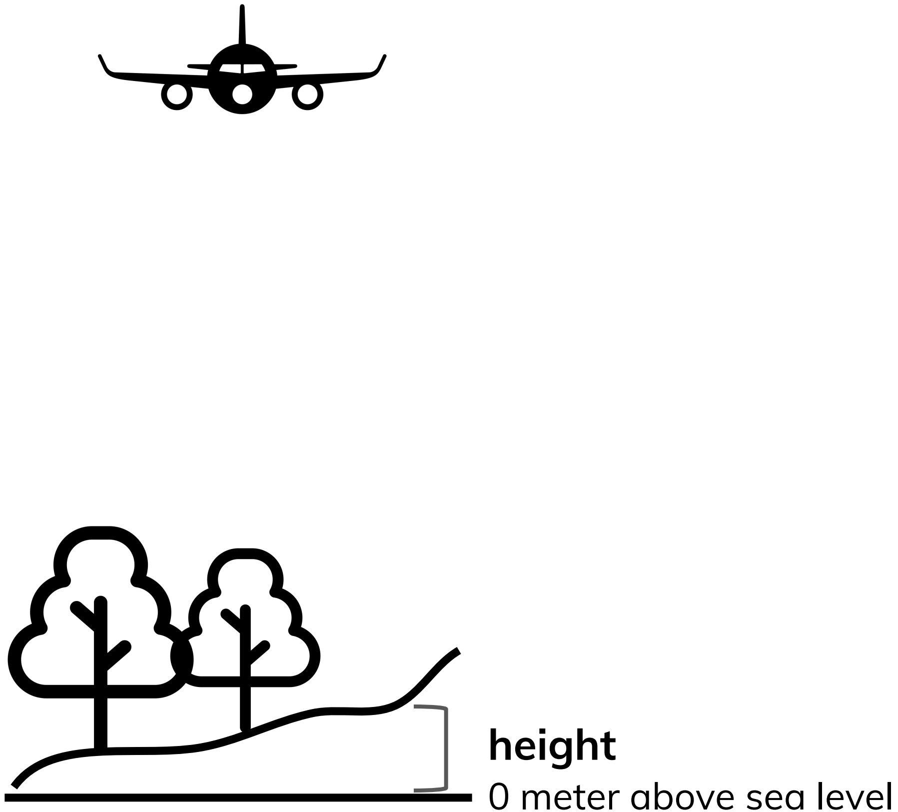

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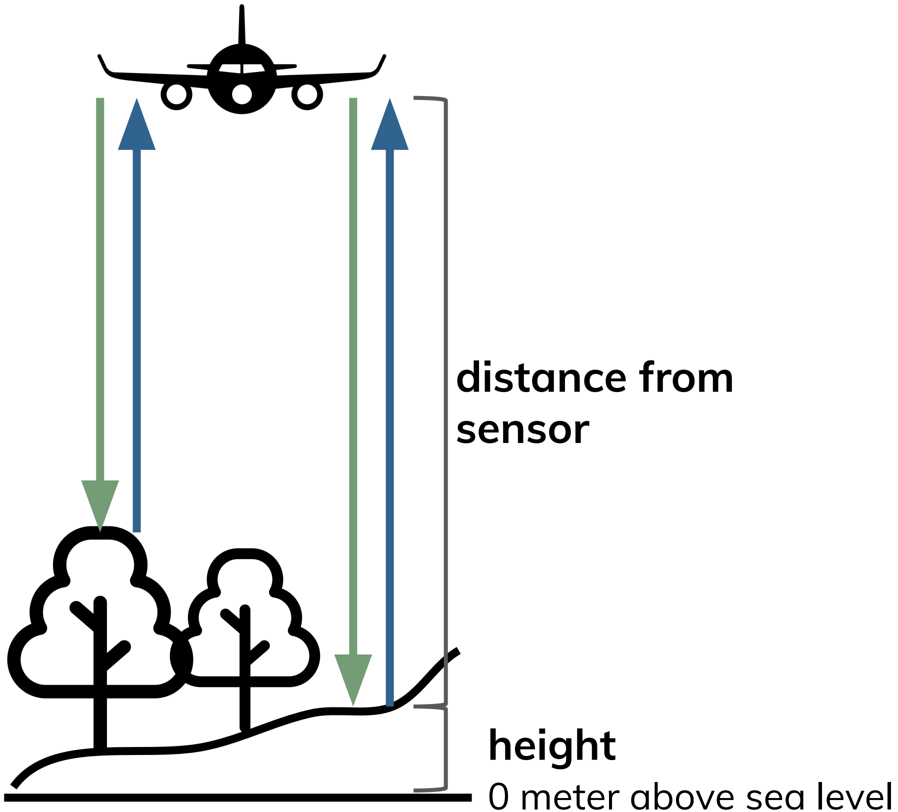
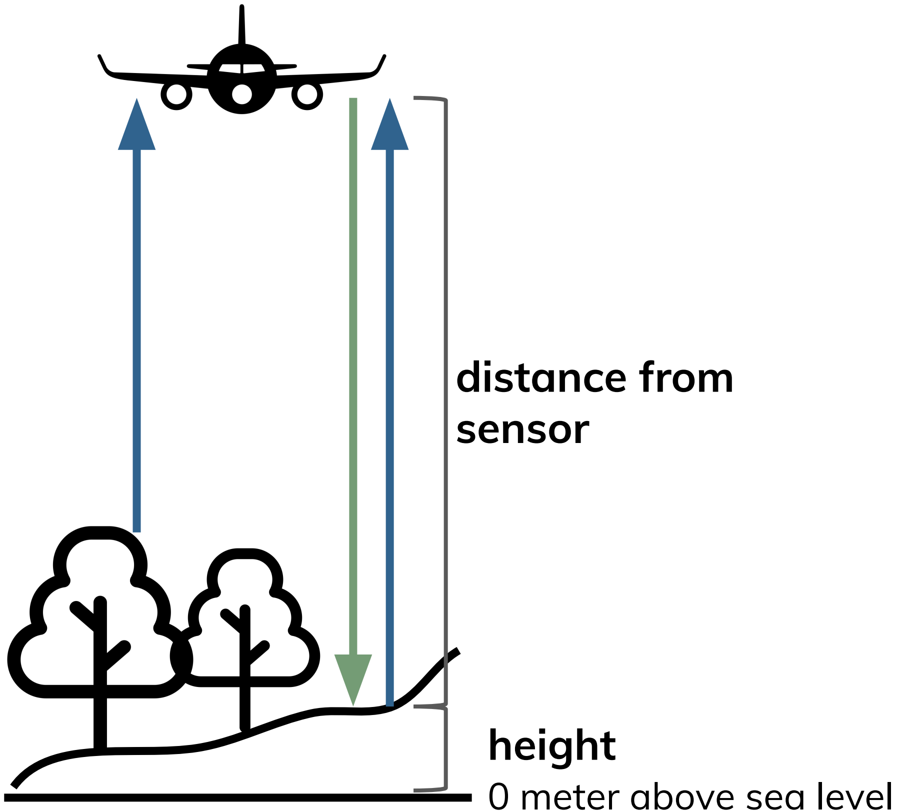


Using light to measure height

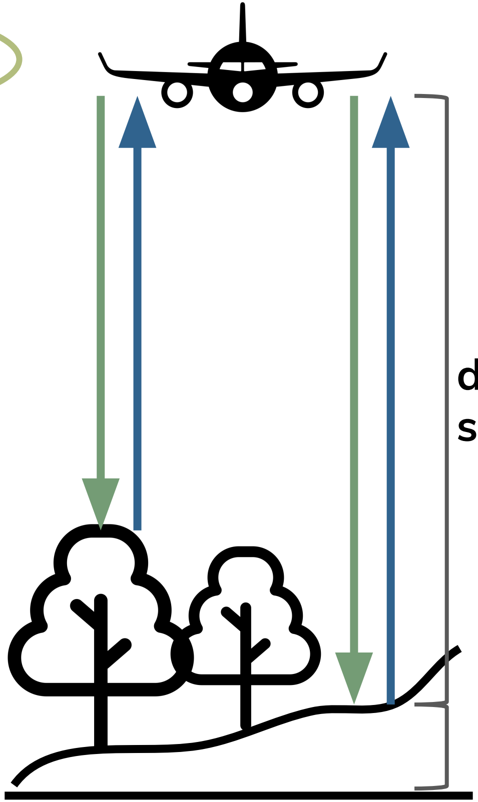
$$\text{Velocity} = \frac{\Delta x}{\Delta t} = \frac{\text{distance traveled}}{\text{duration}}$$



Using light to measure height

$$\text{Velocity} = \frac{\Delta x}{\Delta t} = \frac{\text{distance traveled}}{\text{duration}}$$

distance traveled = velocity x duration



$$\textbf{distance from sensor} = \frac{\text{distance traveled}}{2}$$

height

0 meter above sea level

Using light to measure height

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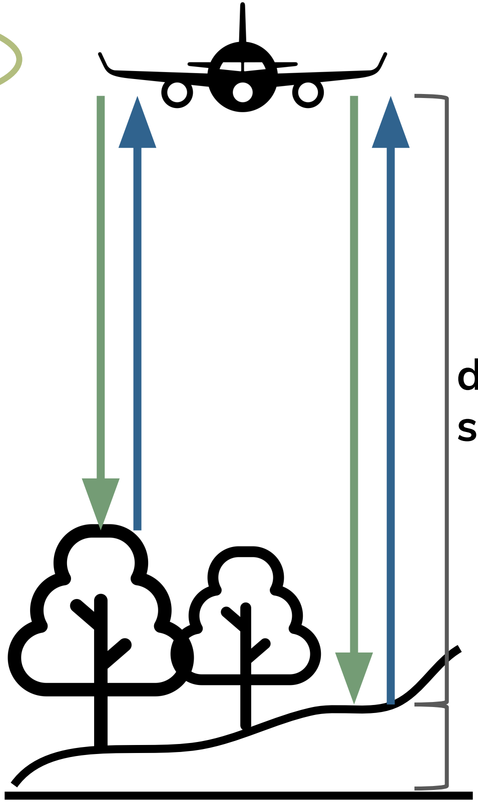

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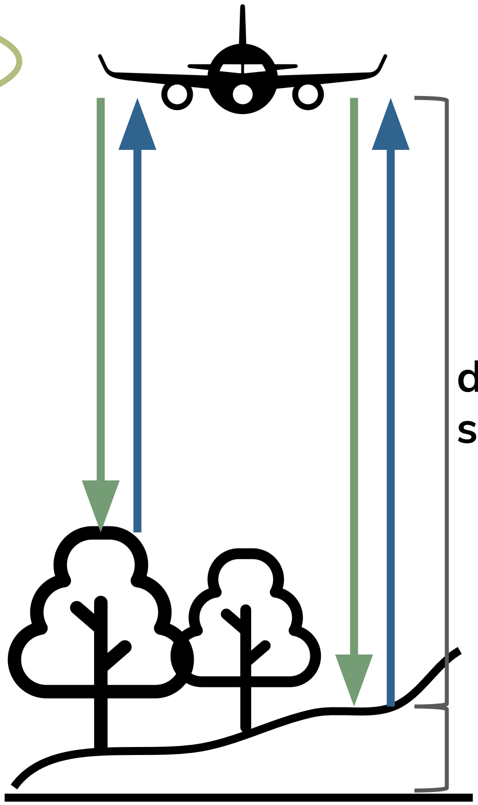

Speed of light
(always known!)

$$\textbf{distance from sensor} = \frac{\text{velocity x duration}}{2}$$

height

0 meter above sea level

Using light to measure height

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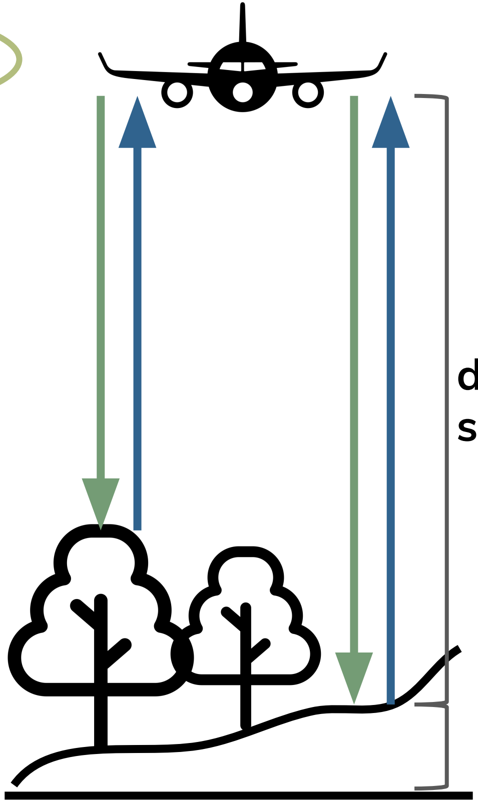

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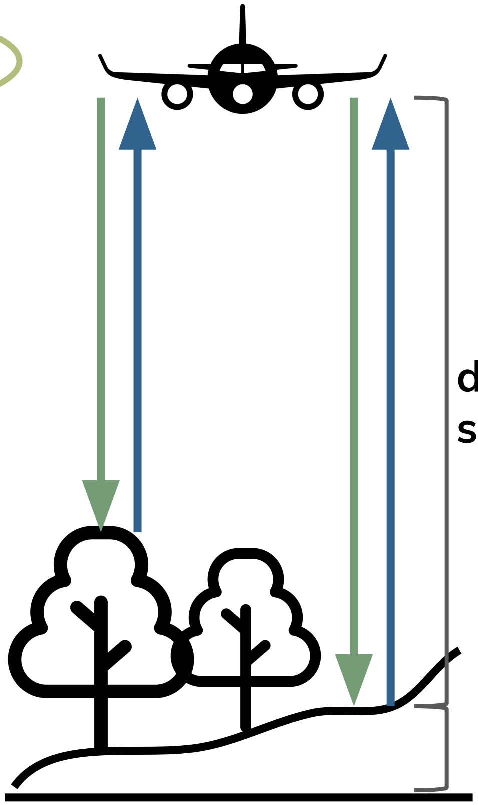

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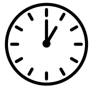
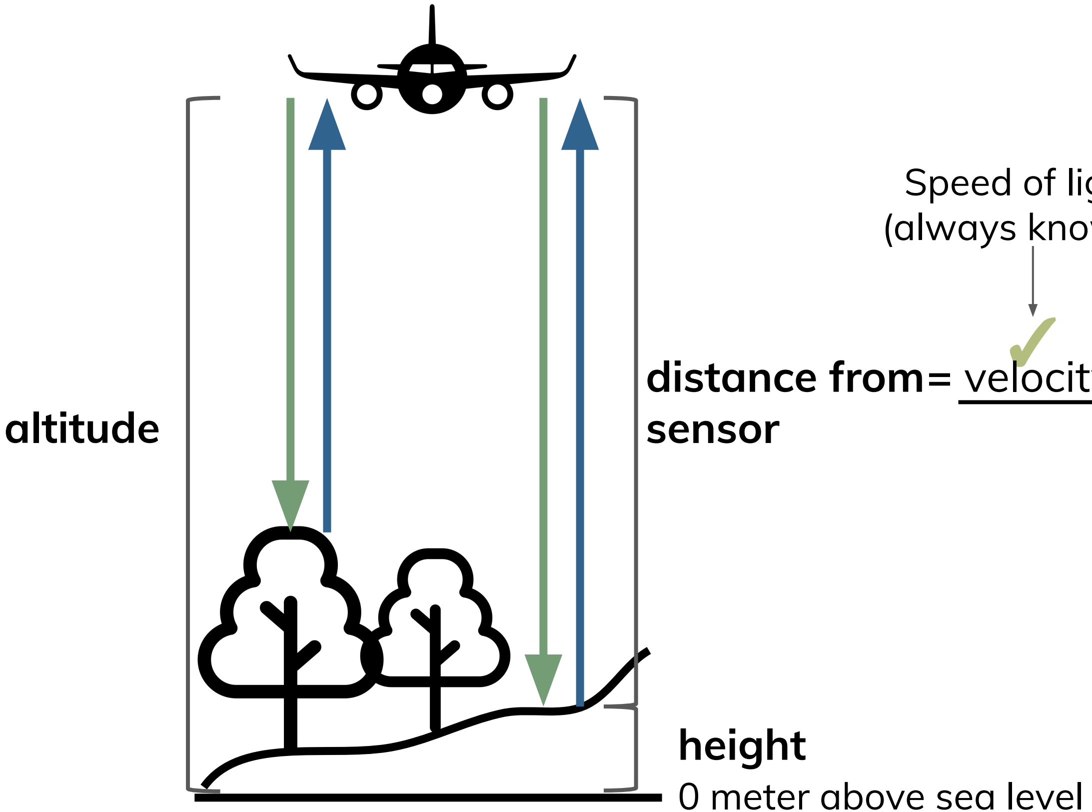


$$\textbf{distance from sensor} = \frac{\text{velocity x duration}}{2}$$

height?

0 meter above sea level

Using light to measure height



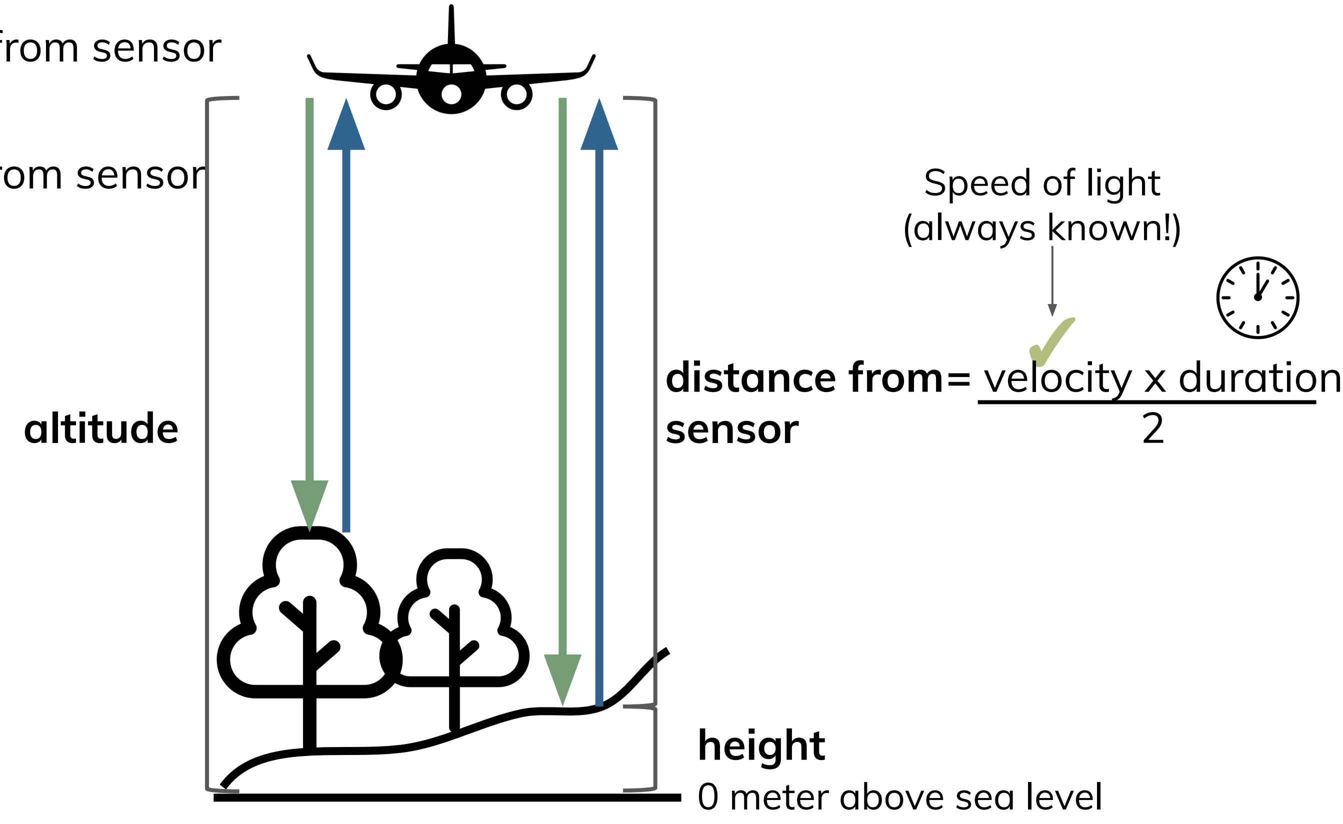
Speed of light
(always known!)

$$\text{distance from sensor} = \frac{\text{velocity} \times \text{duration}}{2}$$

Using light to measure height

altitude = height + distance from sensor

height = altitude - distance from sensor

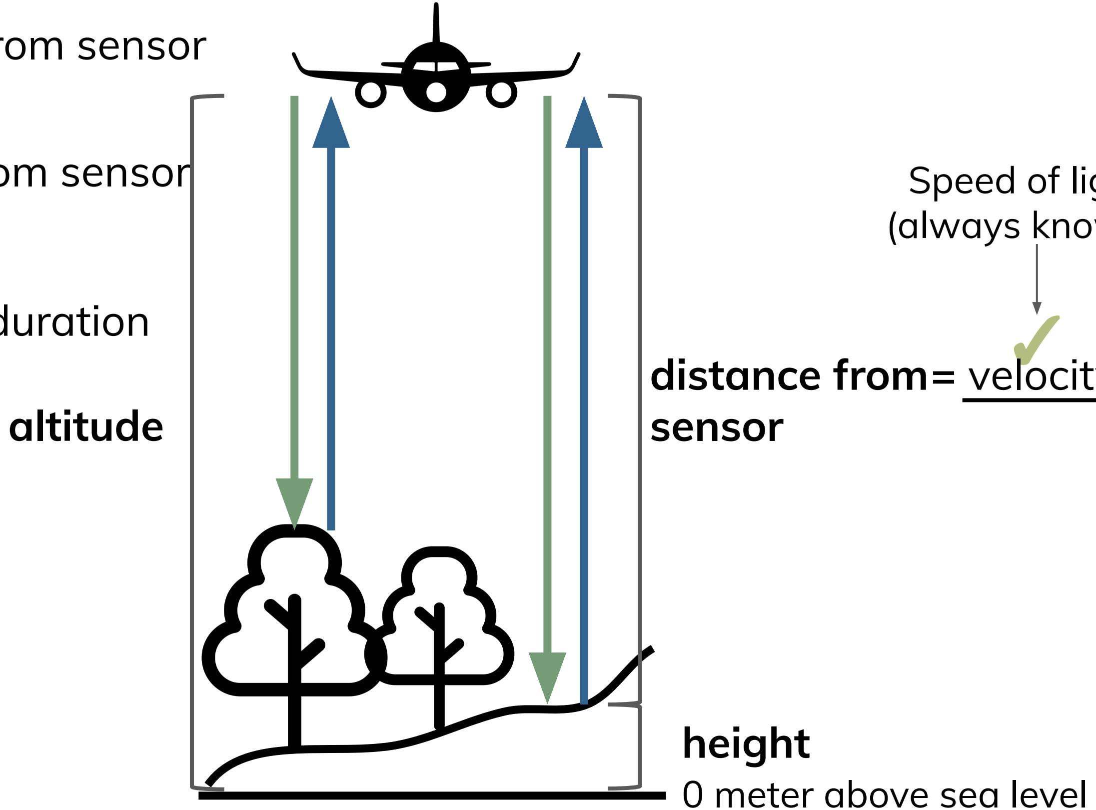


Using light to measure height

altitude = height + distance from sensor

height = altitude - distance from sensor

height is inversely related to duration



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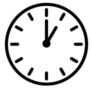
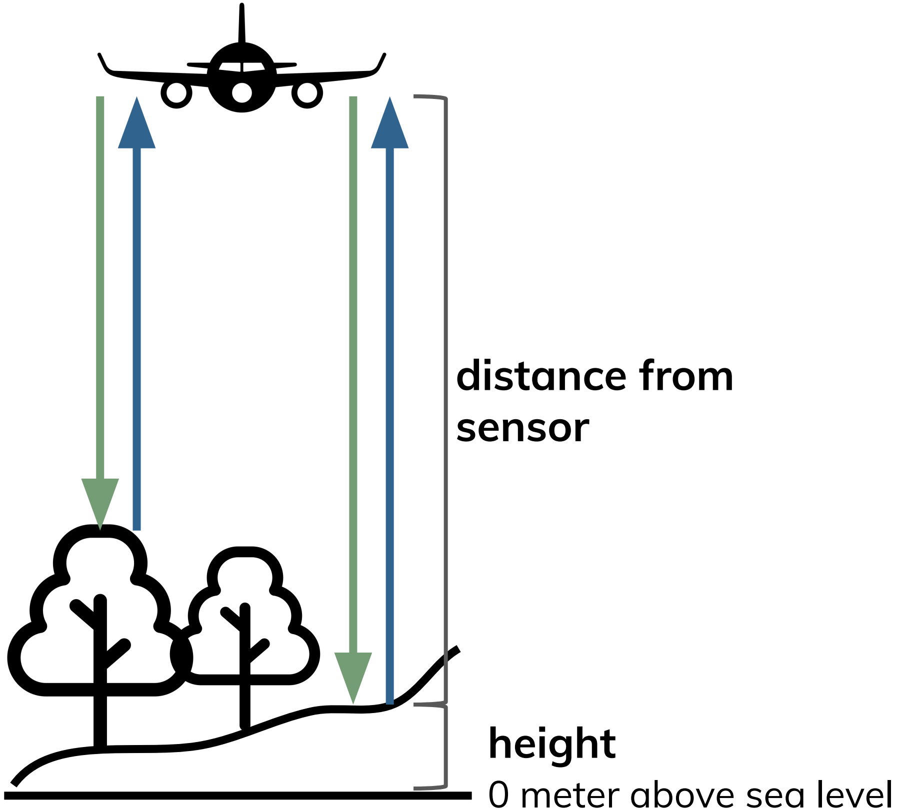


$$\textbf{distance from sensor} = \frac{\text{velocity} \times \text{duration}}{2}$$

Using light to measure height

What components to do we need?



Lasers

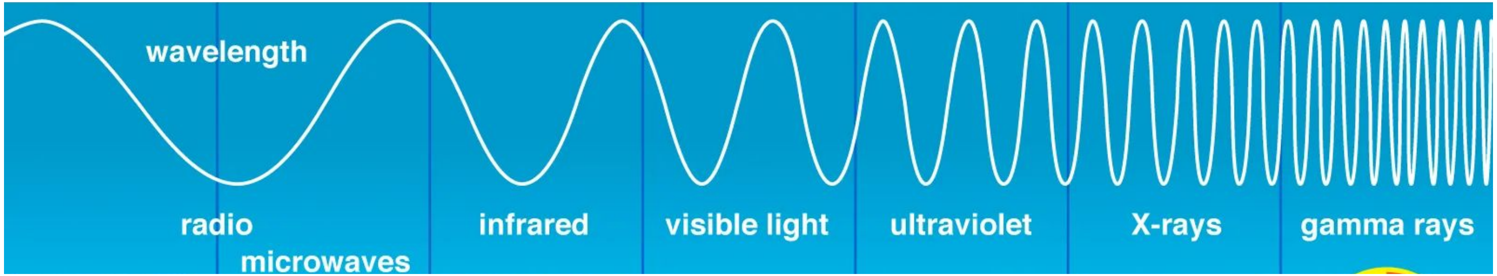
Source: Google Image search for “laser cats”

Lasers

near
infrared
1064 nm

green
532 nm

LiDAR
Light Detection
and Ranging



Lasers

LiDAR
Light Detection
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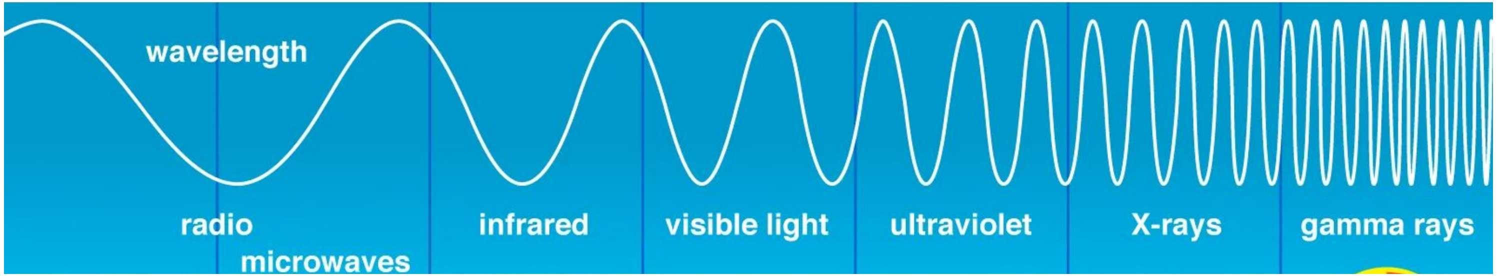
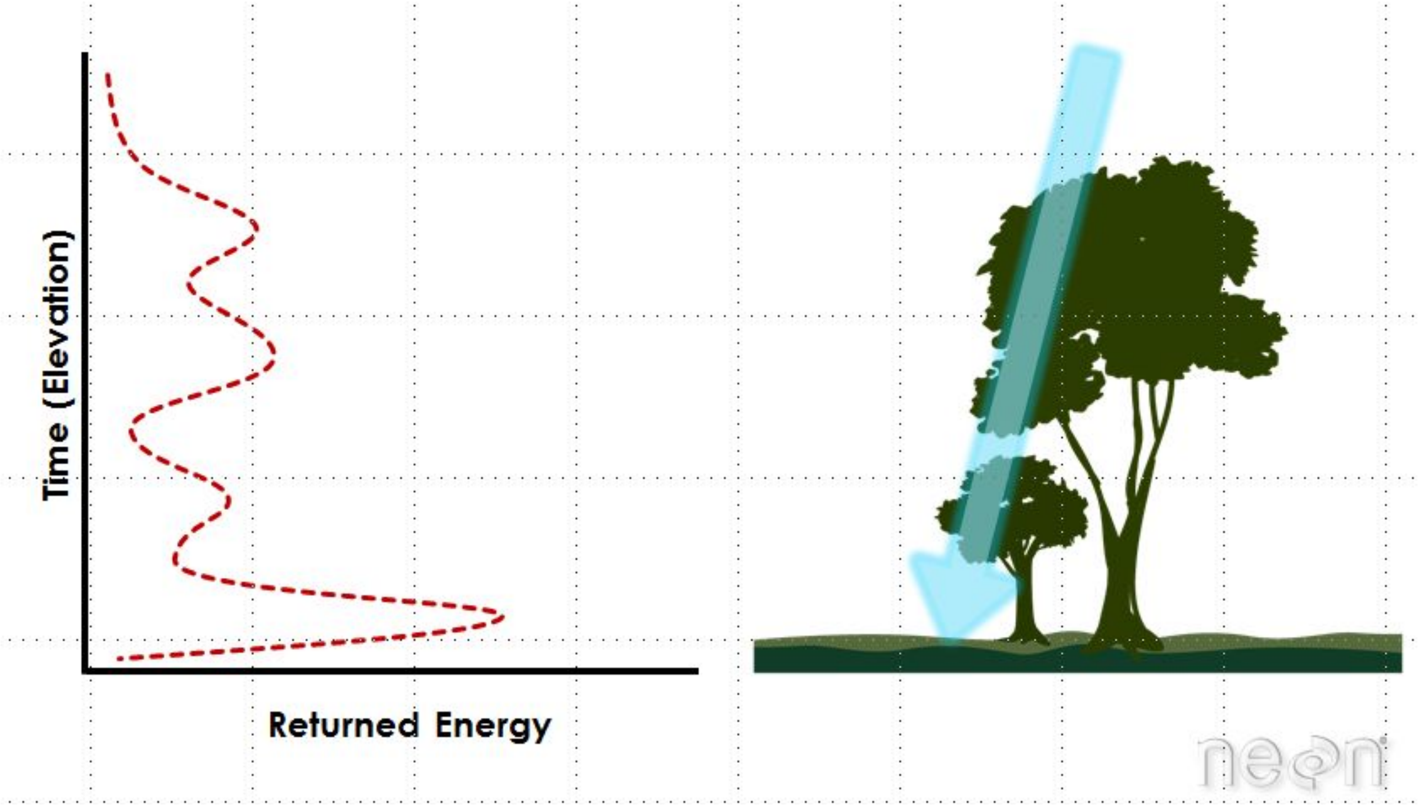


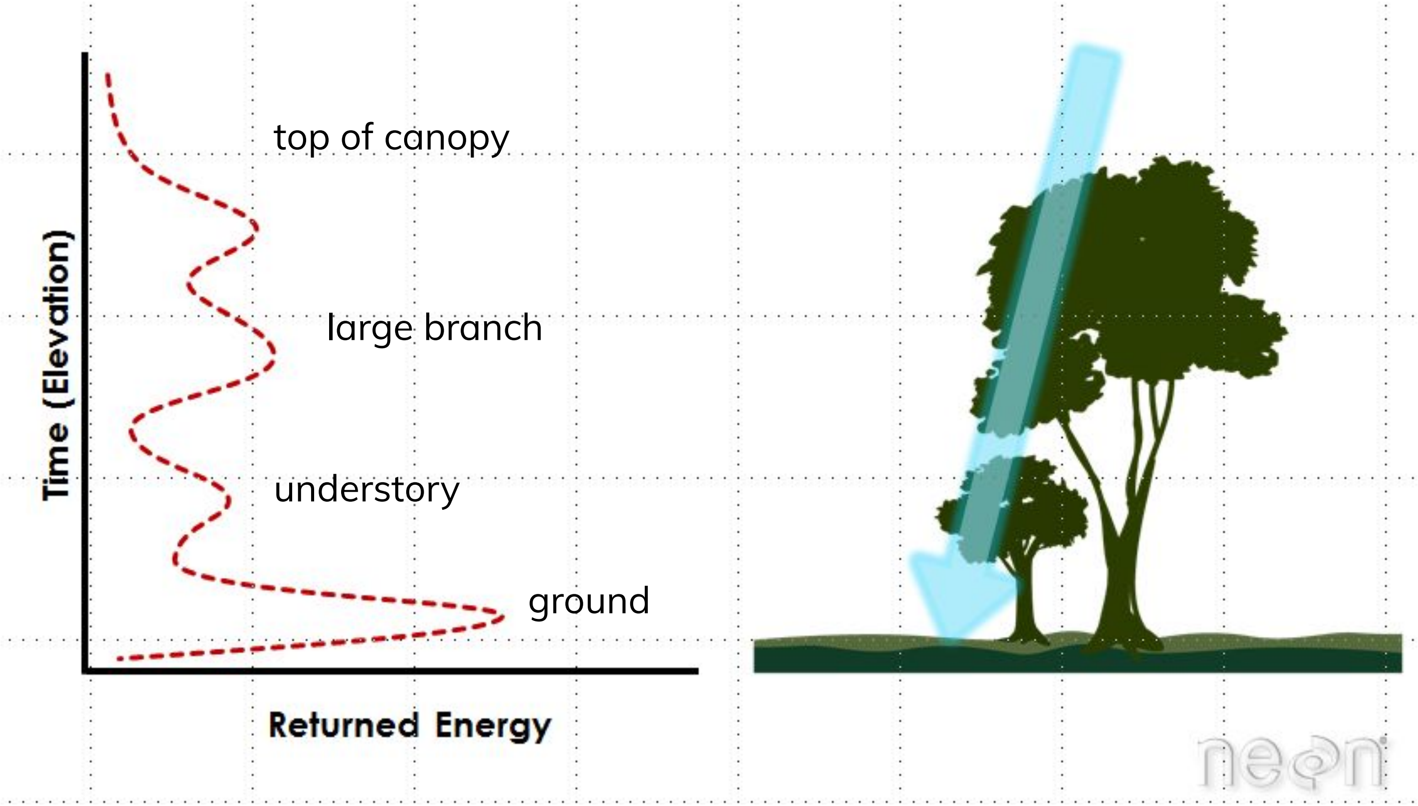
- Highly reflected off of vegetation
- Monochromatic
    - spectrally narrow - know what to expect from its interactions
    - spatially narrow - stays concentrated over long distances

LiDAR energy returns



Source: NEON

LiDAR energy returns



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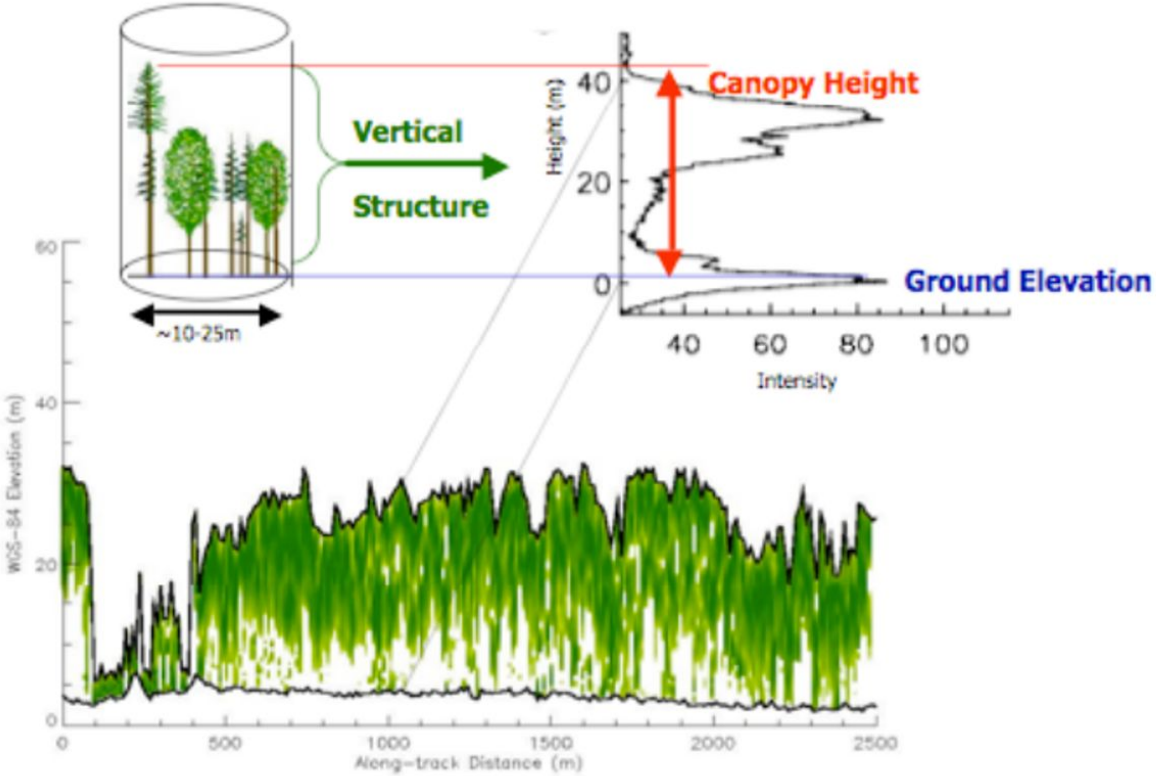
LiDAR energy returns



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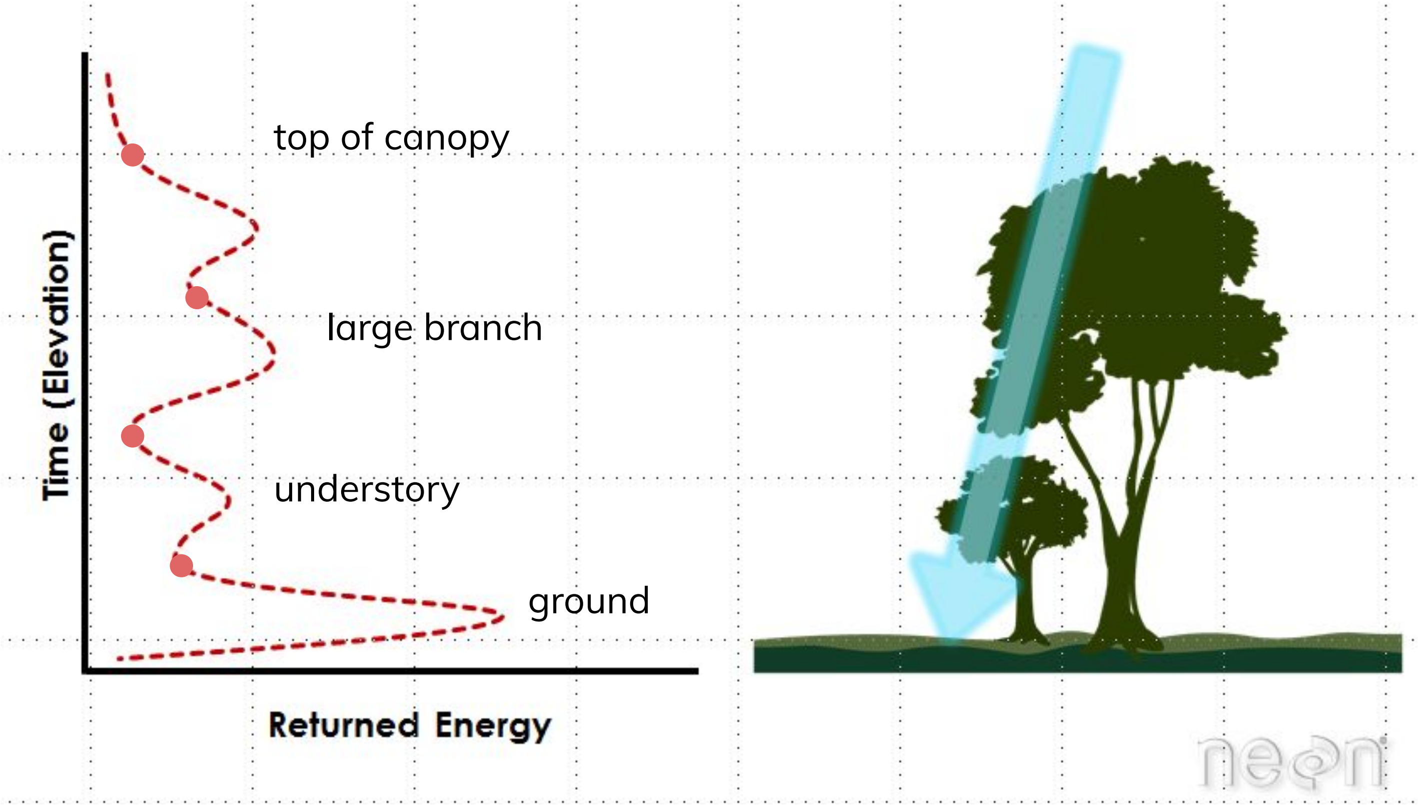
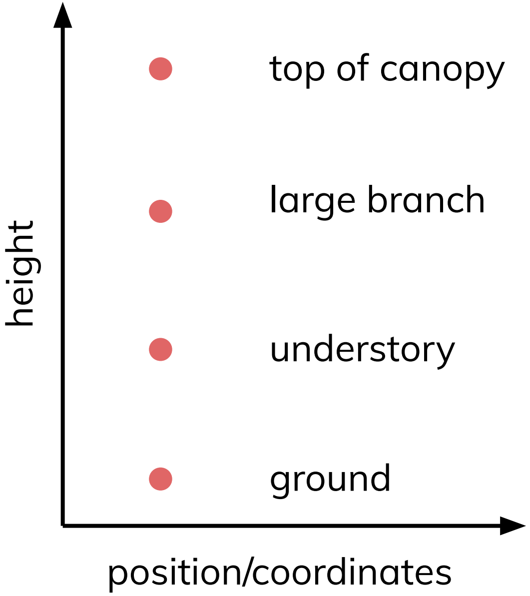
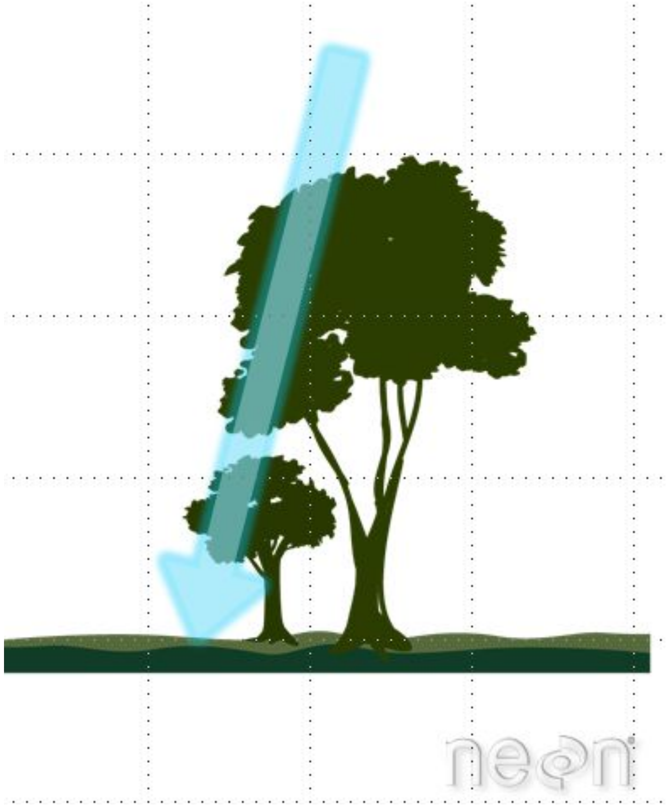


Source: NEON

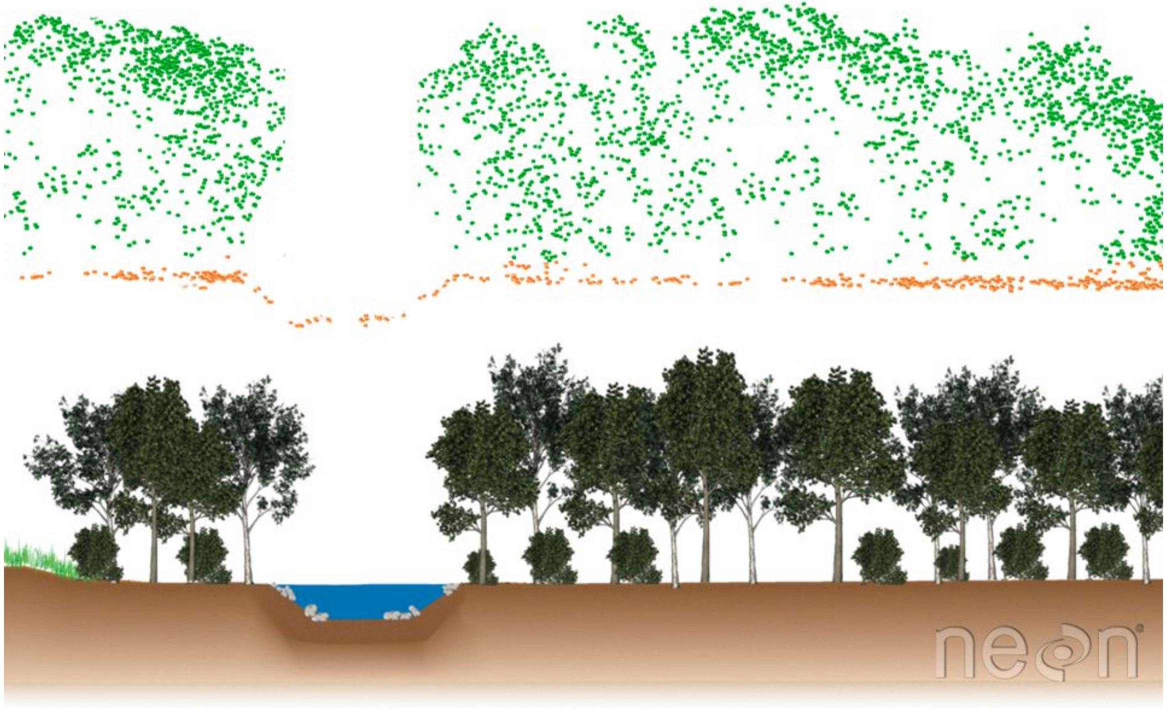
LiDAR energy returns





Source: NEON

LiDAR energy returns



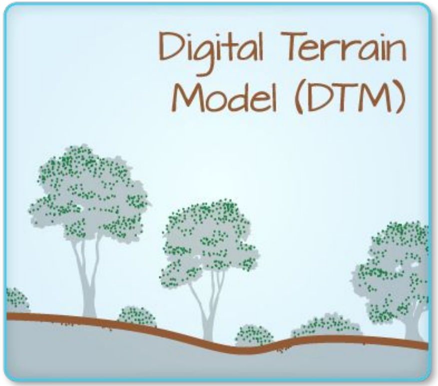
Source: NEON

https://www.youtube.com/watch?v=mi0w3OhpswM&t=3s&ab_channel=LiDARit

Point clouds to surface models

Source: NEON

Point clouds to surface models



Source: NEON

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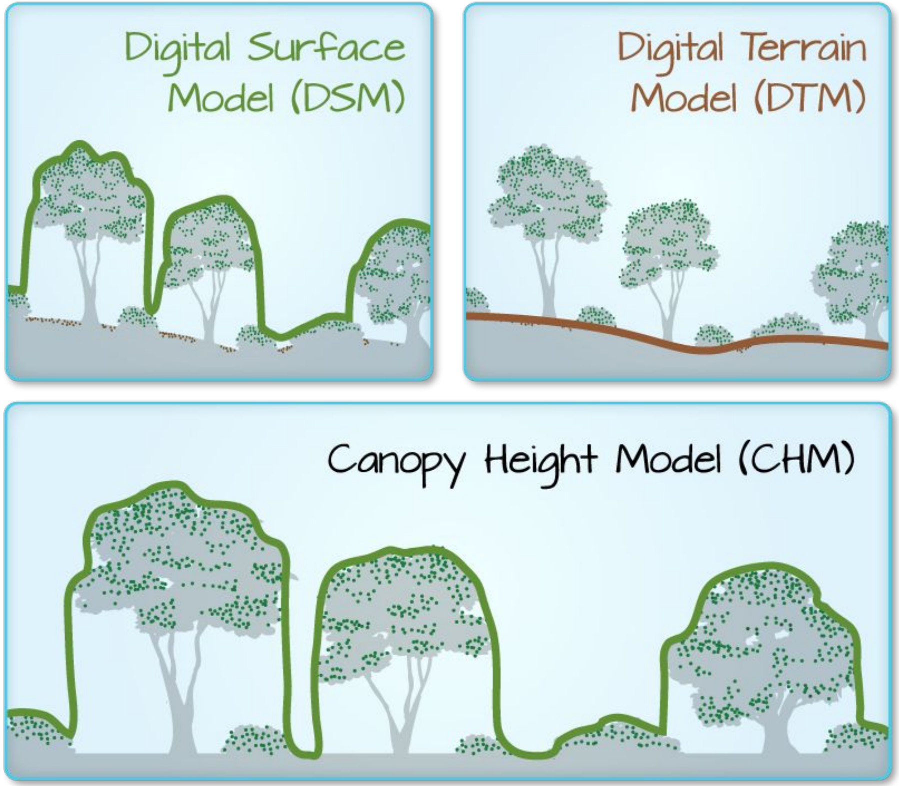

Source: NEON

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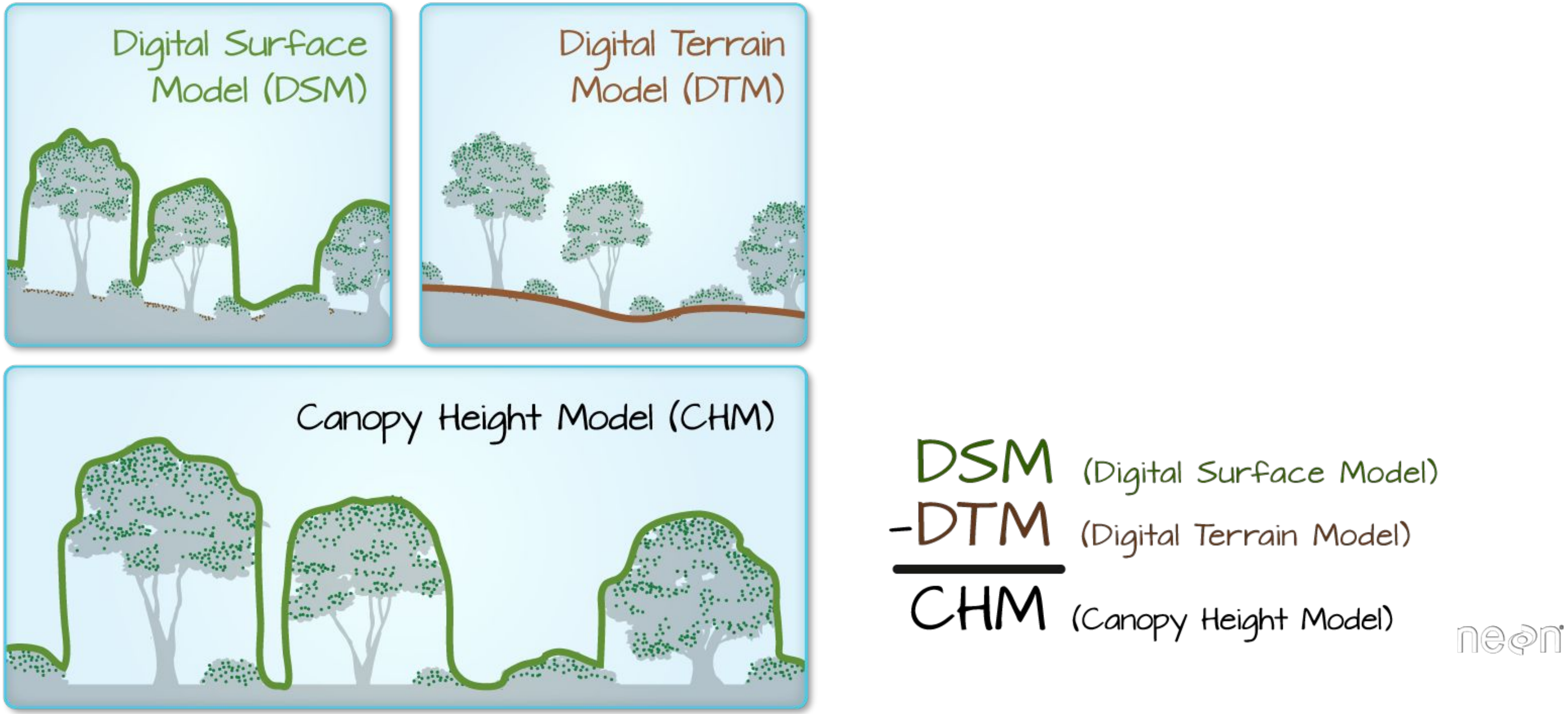
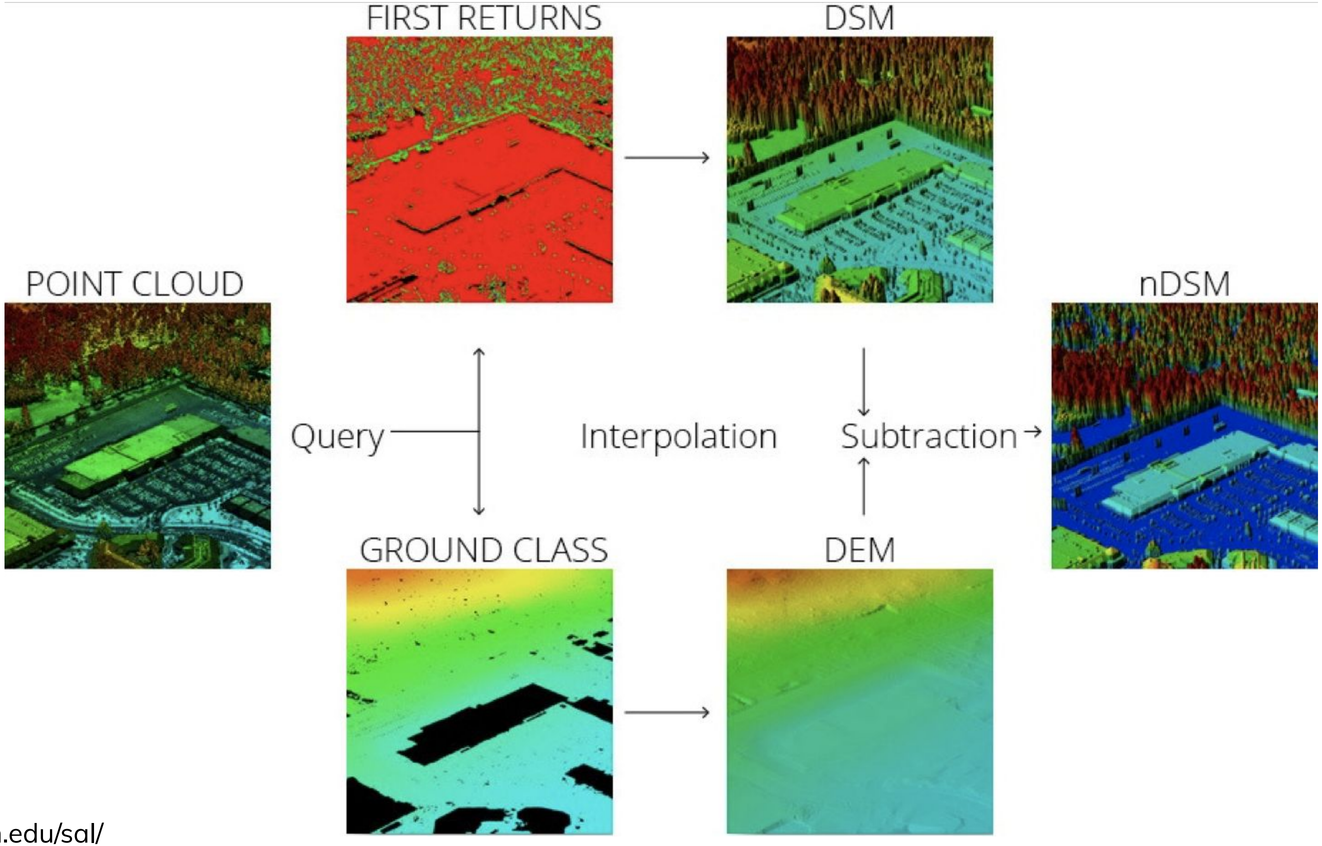


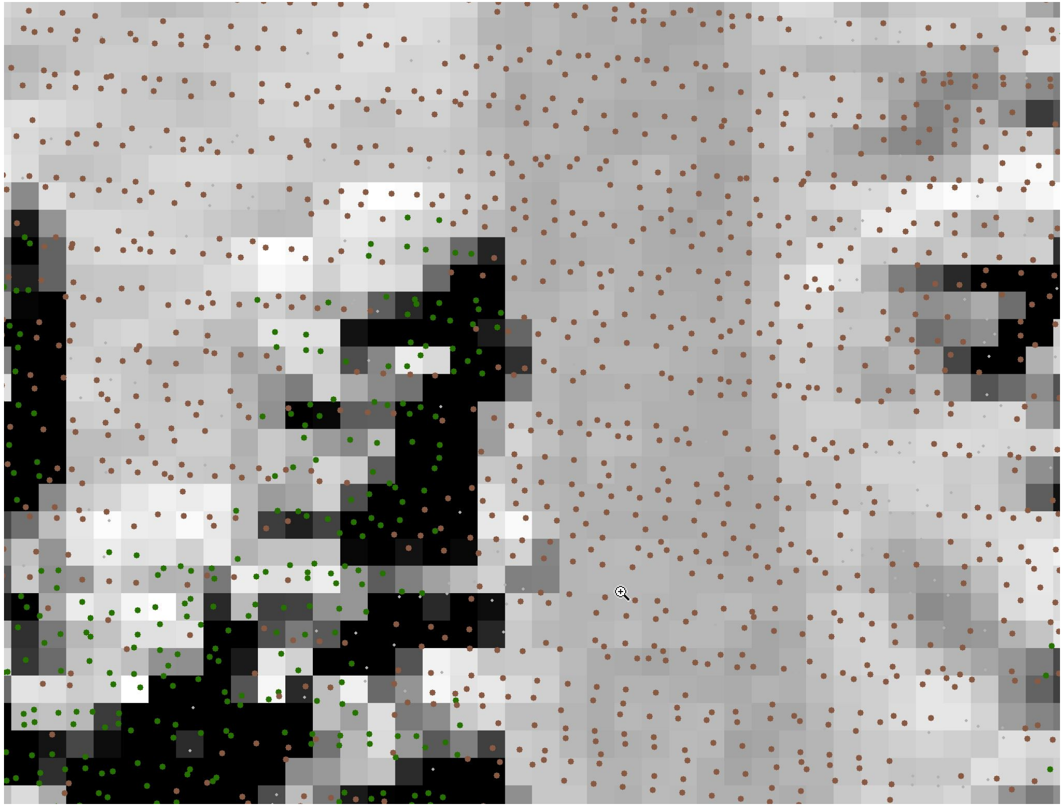
Source: NEON

Point clouds to surface models

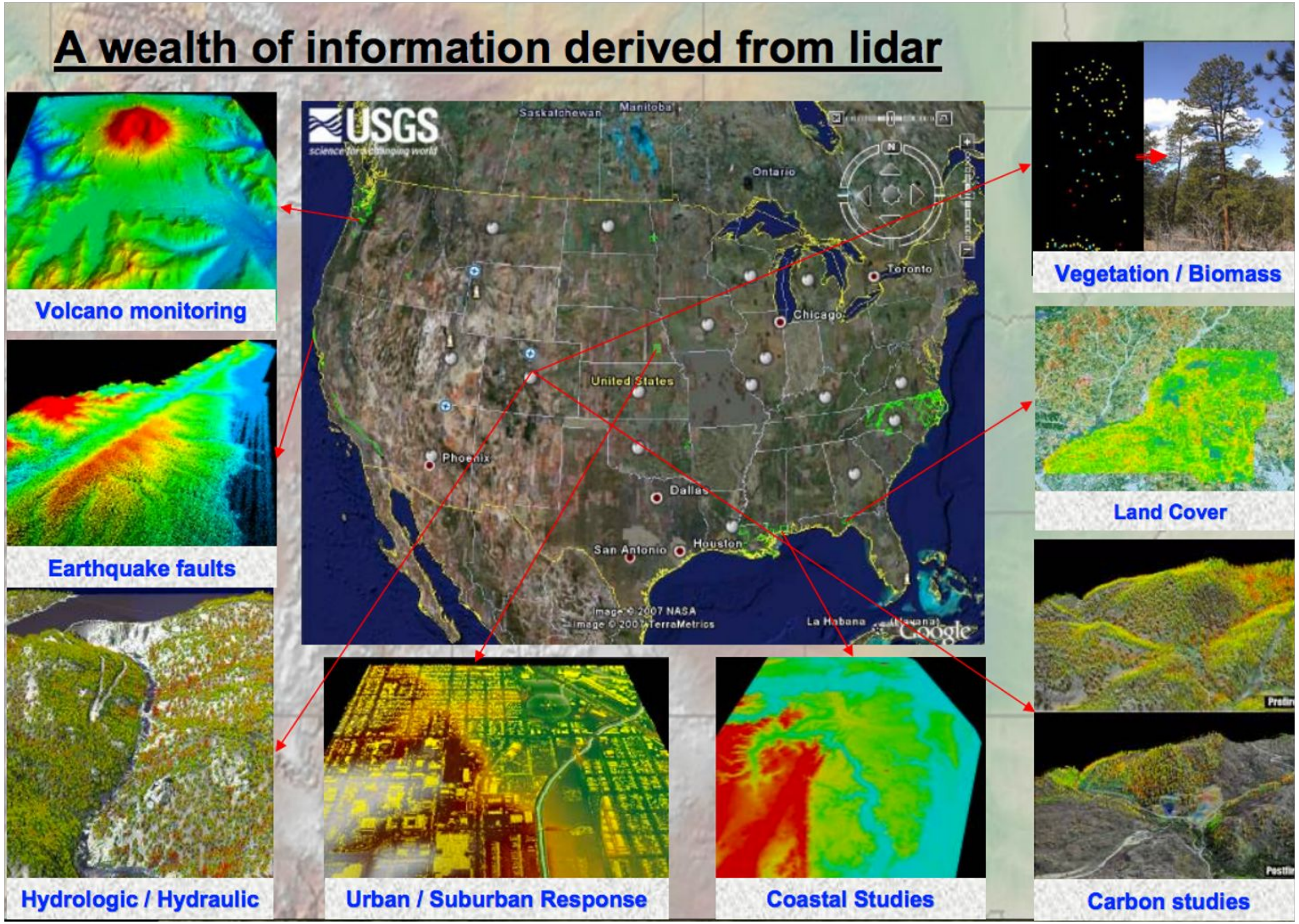


Source: https://site.uvm.edu/sal/

Point clouds to raster

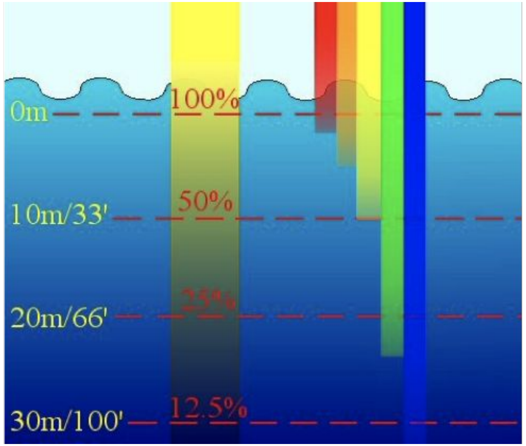


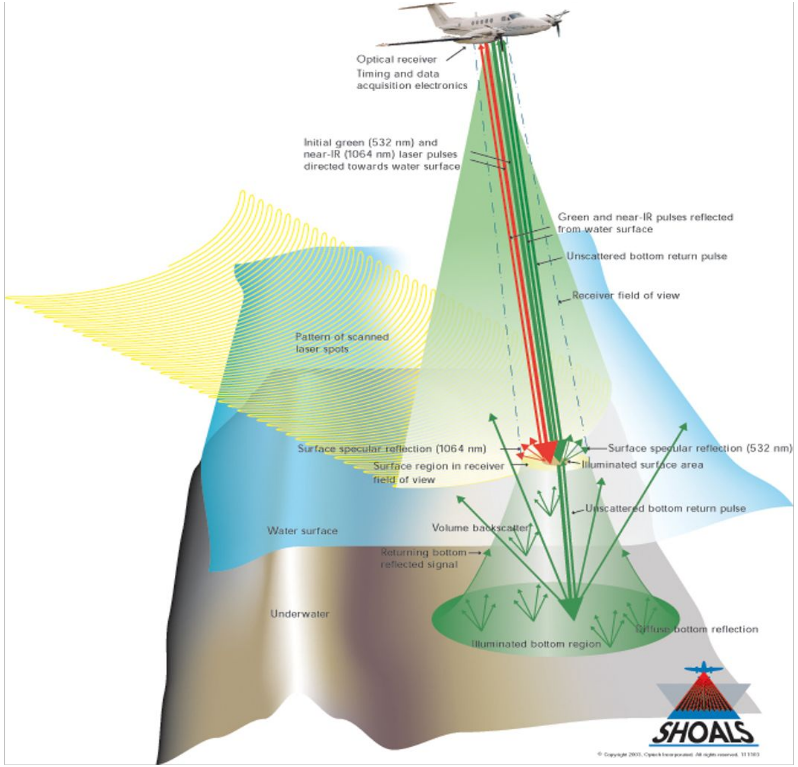
Source: Earth Lab


A wealth of information derived from lidar
USGS
Saskatchewan
Manitoba
Ontario
Toronto
Chicago
United States
Phoenix
Dallas
San Antonio
Houston
La Habana
Image © 2007 NASA
Image © 2007 TerraMetrics
Google
Volcano monitoring
Earthquake faults
Hydrologic / Hydraulic
Urban / Suburban Response
Coastal Studies
Vegetation / Biomass
Land Cover
Carbon studies

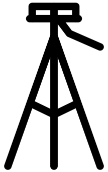
Source: USGS

Aquatic LiDAR

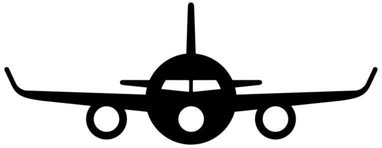




LiDAR systems



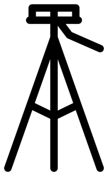
terrestrial



air-borne

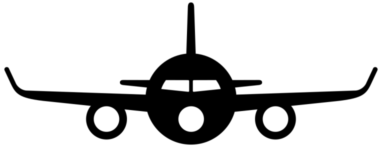
space-borne

LiDAR systems



terrestrial

- Best resolution
- Worst coverage



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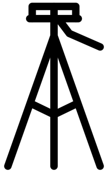

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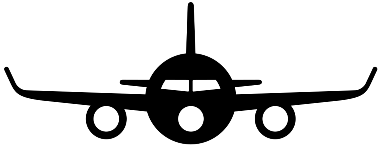


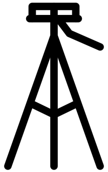
air-borne

- Most common
- Still rare!

space-borne

- Worst resolution
- Best coverage

LiDAR systems



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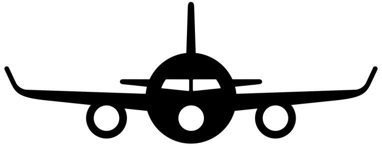

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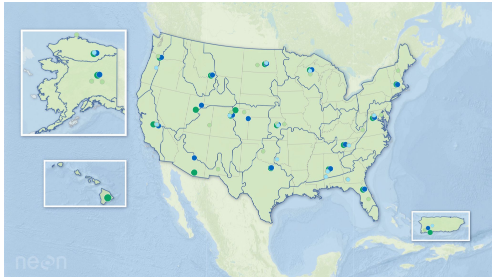
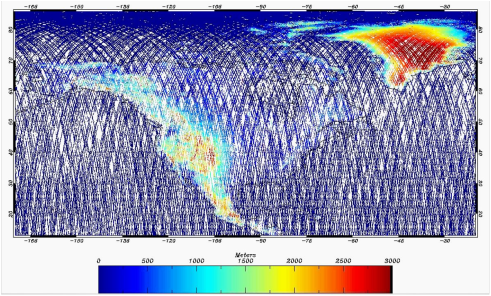
NEON
National Ecological Observatory Network



space-borne

- Worst resolution
- Best coverage

ICESat
Ice, Cloud, and land Elevation Satellite



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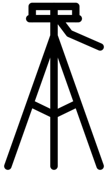

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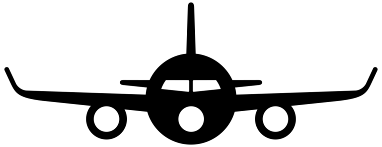

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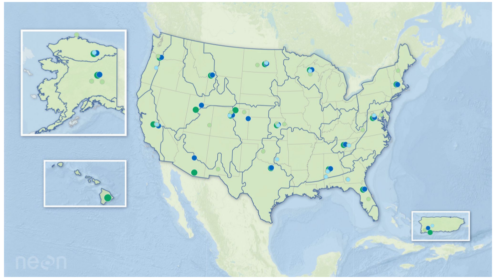

space-borne

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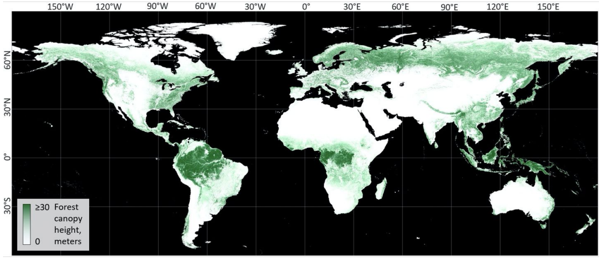
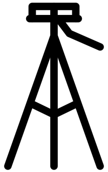
GEDI
Global Ecosystem Dynamics Investigation

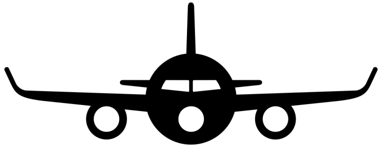


LiDAR systems



terrestrial

- Best resolution
- Worst coverage

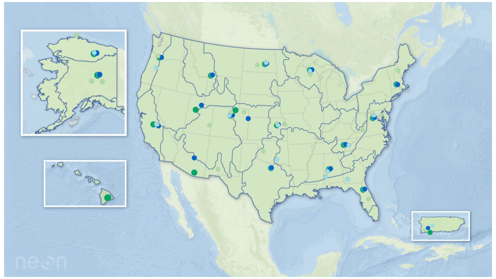


air-borne

- Most common
- Still rare!

NEON

National Ecological Observatory Network

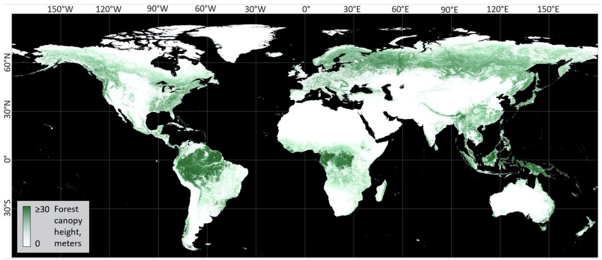


space-borne

- Worst resolution
- Best coverage

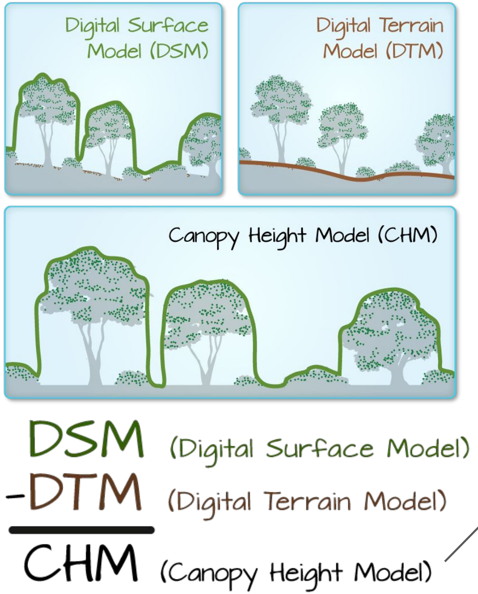
GEDI

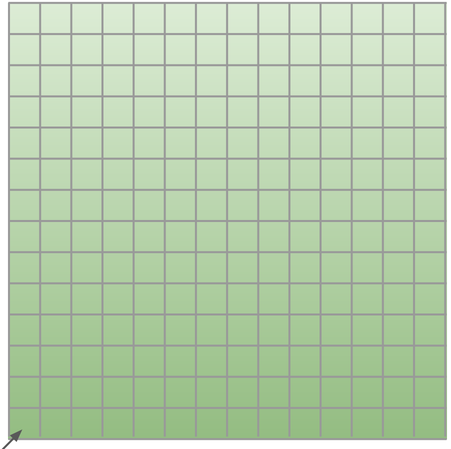
Global Ecosystem Dynamics Investigation



Using LiDAR data to measure tree height:
San Joaquin Experimental Range

Using LiDAR data to measure tree height:
San Joaquin Experimental Range

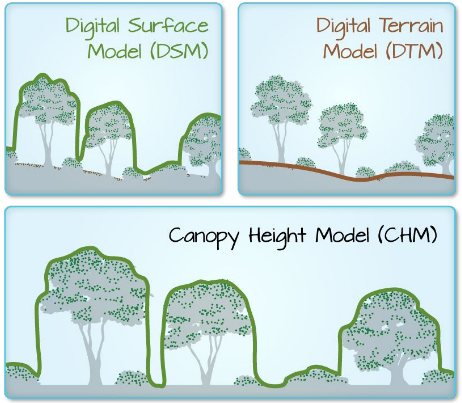




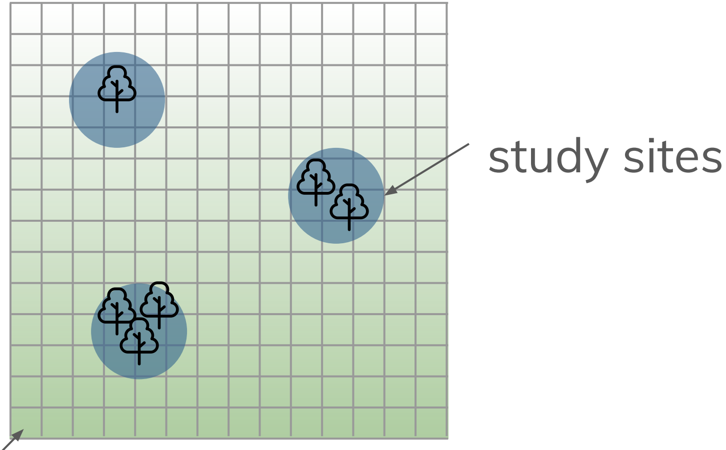
Source: NEON

Using LiDAR data to measure tree height:

San Joaquin Experimental Range

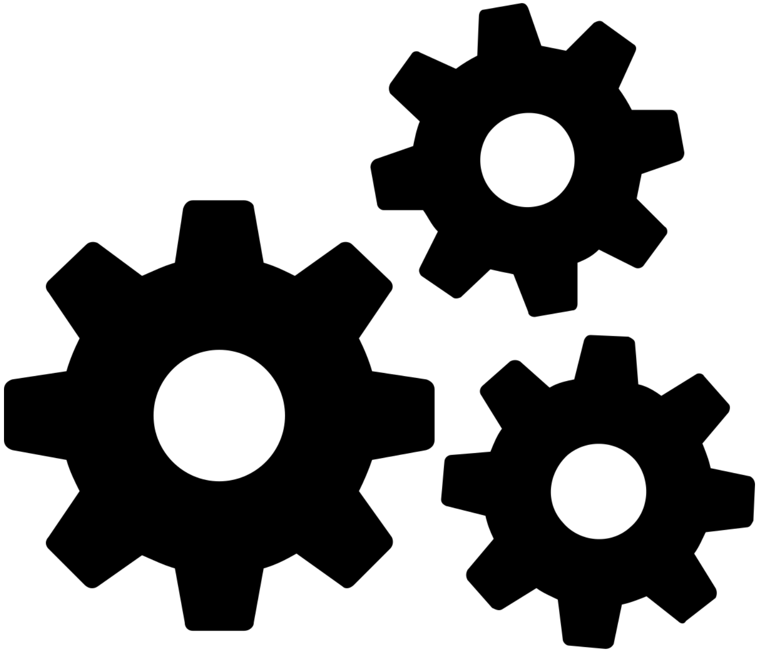


DSM (Digital Surface Model)
-DTM (Digital Terrain Model)
CHM (Canopy Height Model)



Source: NEON

Switching gears…

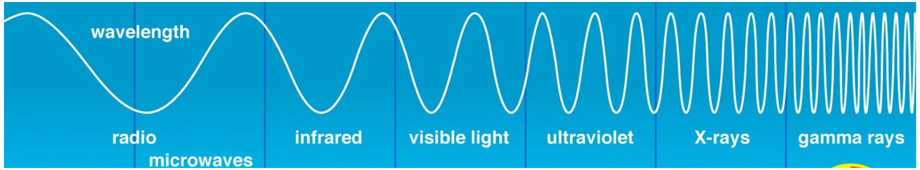


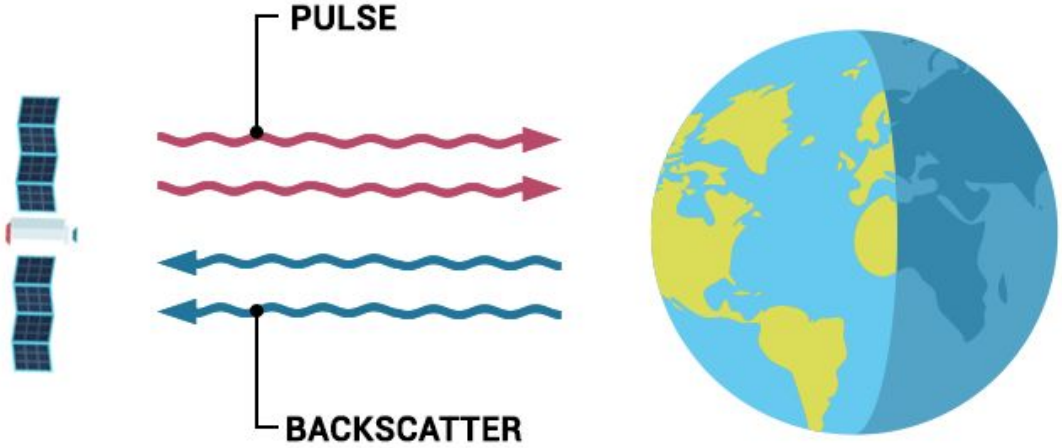
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

LiDAR
Light Detection
and Ranging





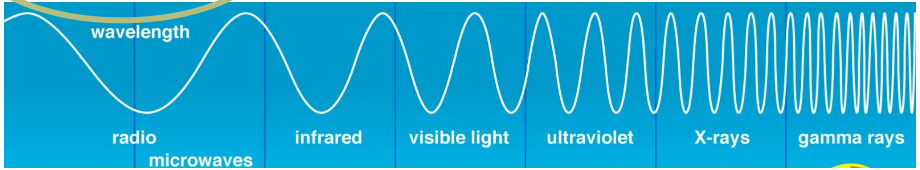
Source: GIS Geography

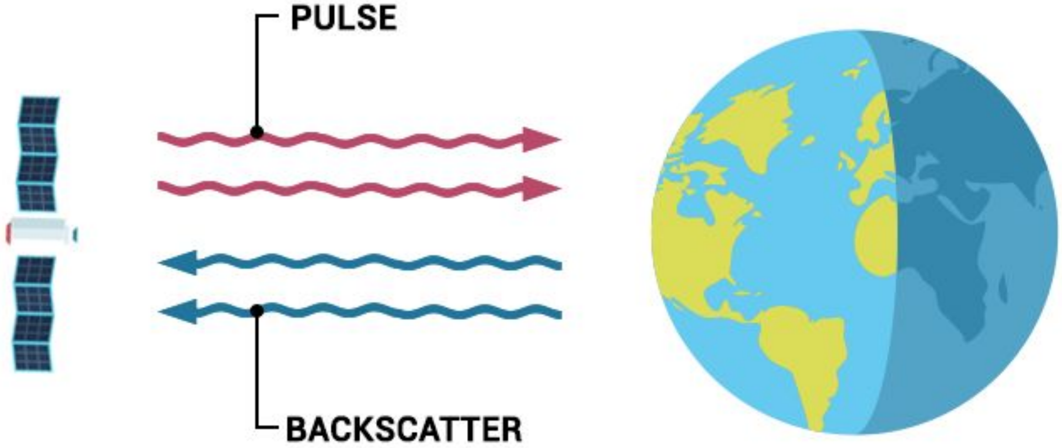
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

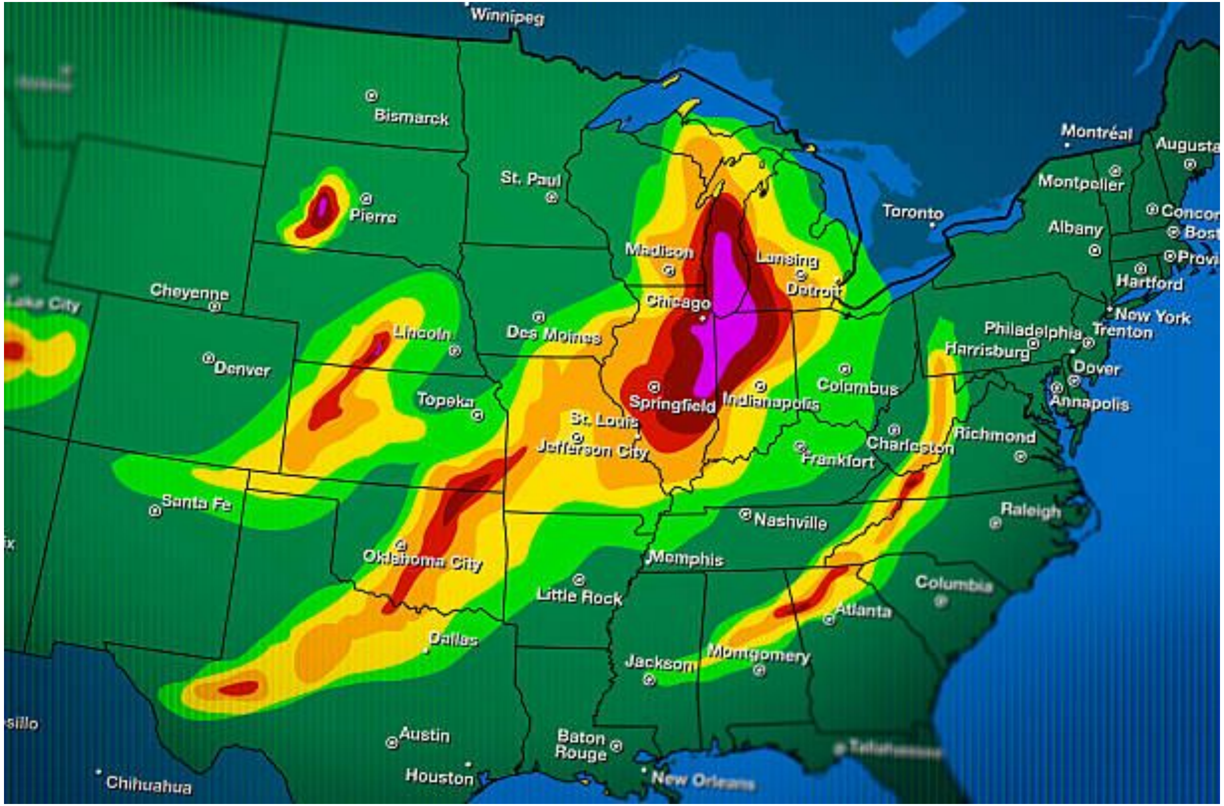
LiDAR
Light Detection
and Ranging





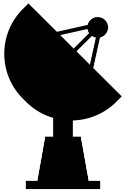
Source: GIS Geography

A note on context…

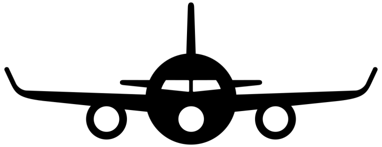


Winnipeg
Bismarck
Pierre
St. Paul
Madison
Lansing
Detroit
Chicago
Toronto
Montréal
Montpelier
Albany
Hartford
New York
Trenton
Philadelphia
Harrisburg
Dover
Annapolis
Cheyenne
Lincoln
Des Moines
Denver
Topeka
Springfield
Indianapolis
Columbus
St. Louis
Jefferson City
Charleston
Richmond
Frankfort
Santa Fe
Nashville
Raleigh
Oklahoma City
Memphis
Little Rock
Columbia
Atlanta
Dallas
Jackson
Montgomery
Austin
Baton Rouge
Houston
Chihuahua
New Orleans

RADAR systems



terrestrial

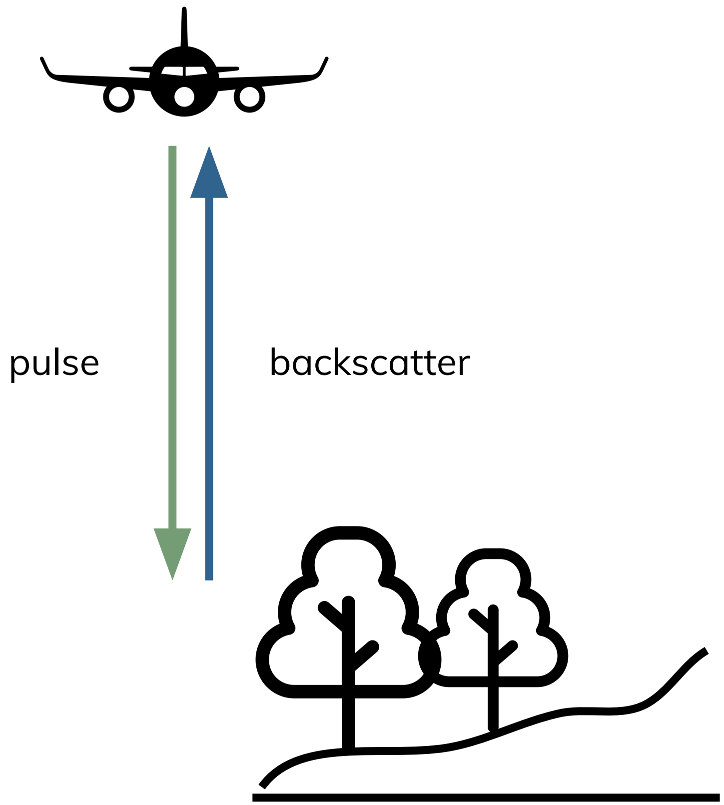


air-borne

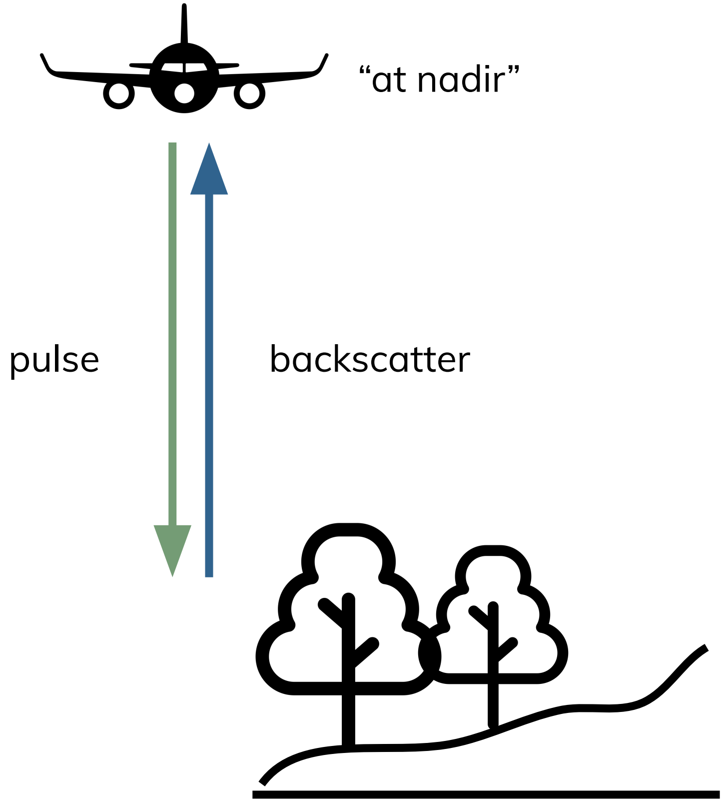
space-borne

“remote sensing”

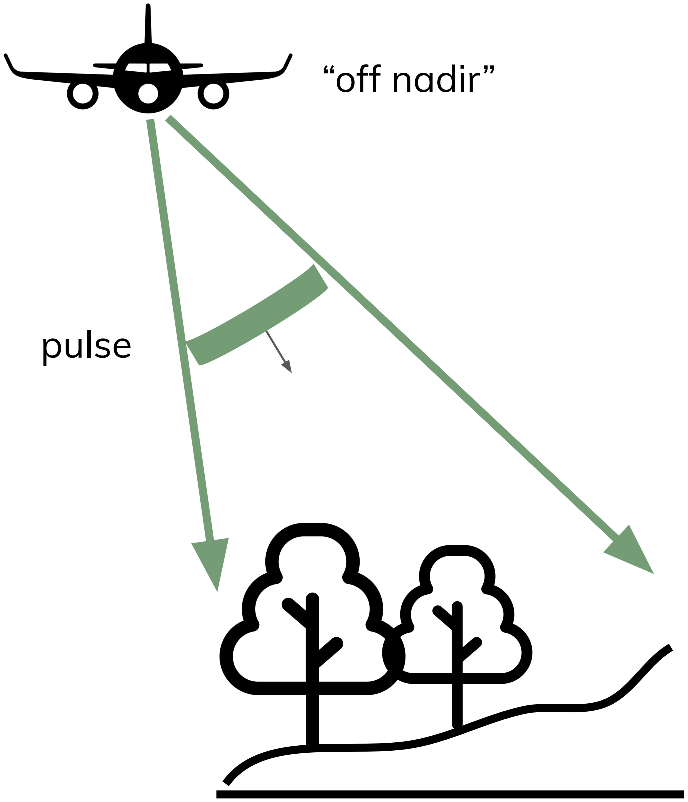
RADAR viewing geometry



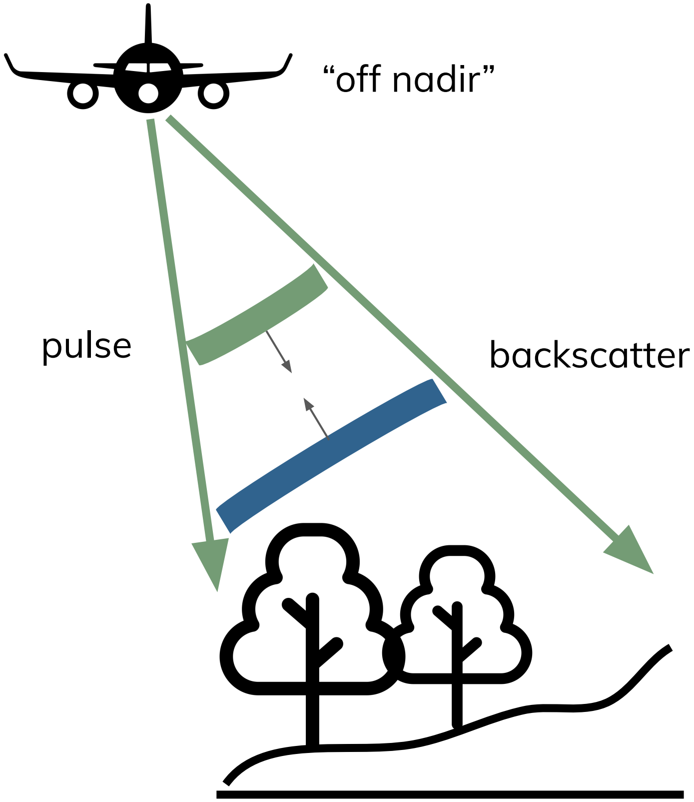
RADAR viewing geometry



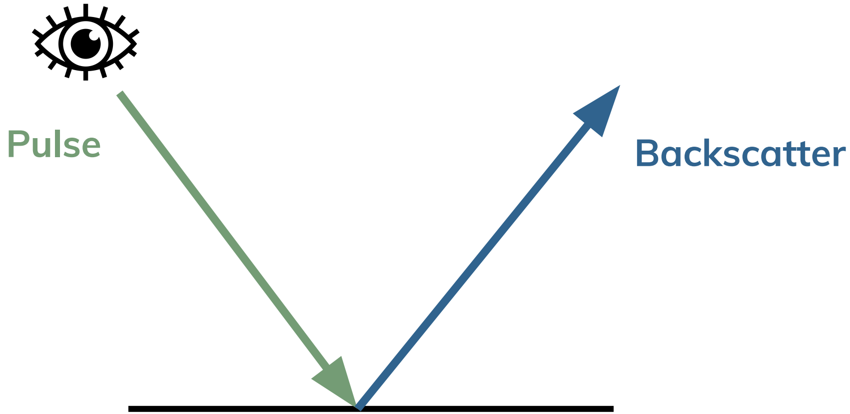
RADAR viewing geometry



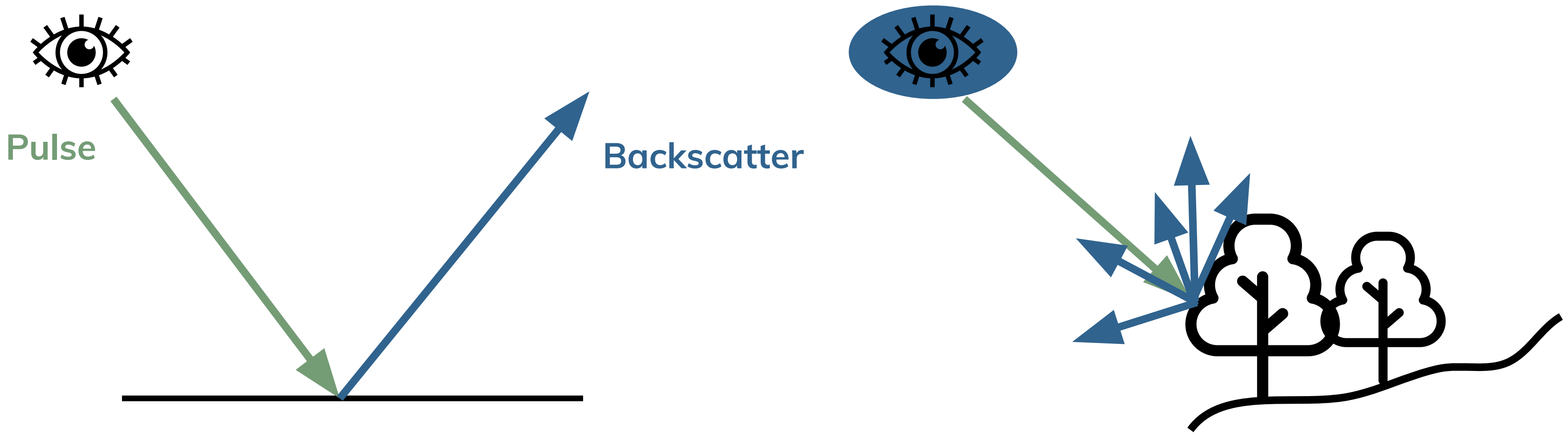
RADAR viewing geometry



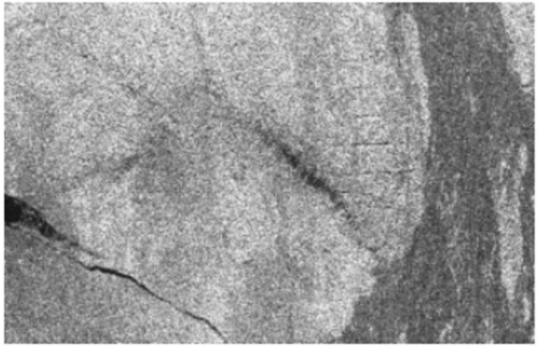
Microwave interactions with matter



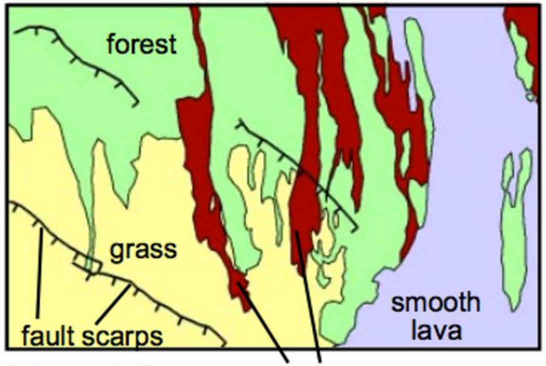
Microwave interactions with matter



Microwave interactions with matter



C-Band VV (wavelength = 6 cm)



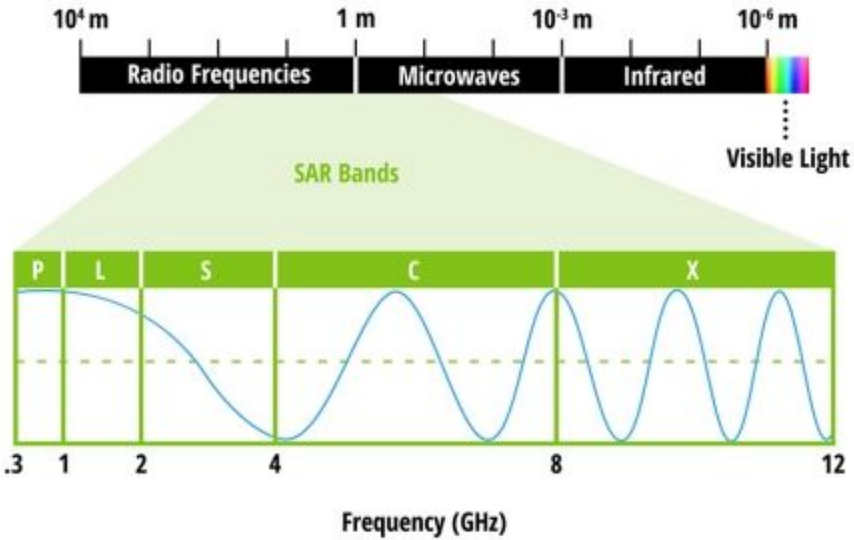
Interpretation

↑ surface roughness → ↑ backscatter

↑ brightness

Source: MicroImages

RADAR wavelengths



Source: NASA

RADAR wavelengths

longer wavelengths

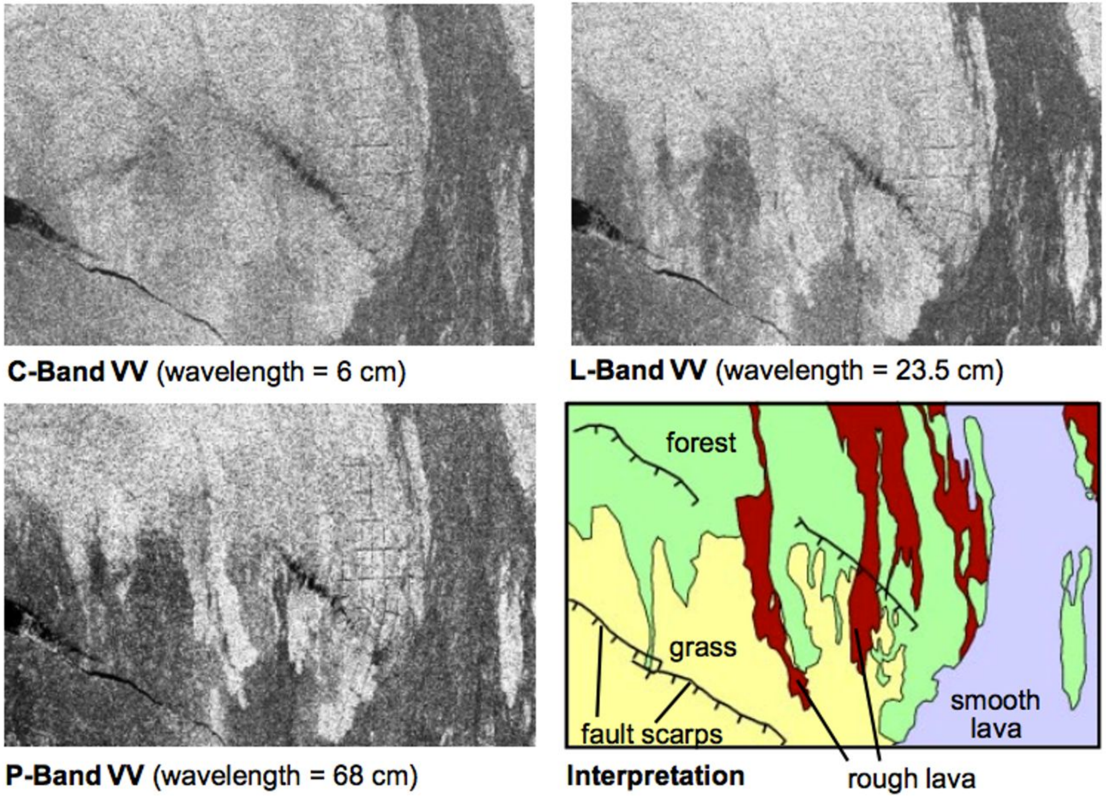
Band	Frequency	Wavelength	Typical Application
Ka	27–40 GHz	1.1–0.8 cm	Rarely used for SAR (airport surveillance)
K	18–27 GHz	1.7–1.1 cm	rarely used (H_2O absorption)
Ku	12–18 GHz	2.4–1.7 cm	rarely used for SAR (satellite altimetry)
X	8–12 GHz	3.8–2.4 cm	High resolution SAR (urban monitoring,; ice and snow, little penetration into vegetation cover; fast coherence decay in vegetated areas)
C	4–8 GHz	7.5–3.8 cm	SAR Workhorse (global mapping; change detection; monitoring of areas with low to moderate penetration; higher coherence); ice, ocean maritime navigation
S	2–4 GHz	15–7.5 cm	Little but increasing use for SAR-based Earth observation; agriculture monitoring (NISAR will carry an S-band channel; expends C-band applications to higher vegetation density)
L	1–2 GHz	30–15 cm	Medium resolution SAR (geophysical monitoring; biomass and vegetation mapping; high penetration, InSAR)
P	0.3–1 GHz	100–30 cm	Biomass. First p-band spaceborne SAR will be launched ~2020; vegetation mapping and assessment. Experimental SAR.

feature size

Source: NASA

Microwave interactions with matter - wavelength

Microwave interactions with matter - wavelength



↑ wavelength

↓

↑ materials appear smooth

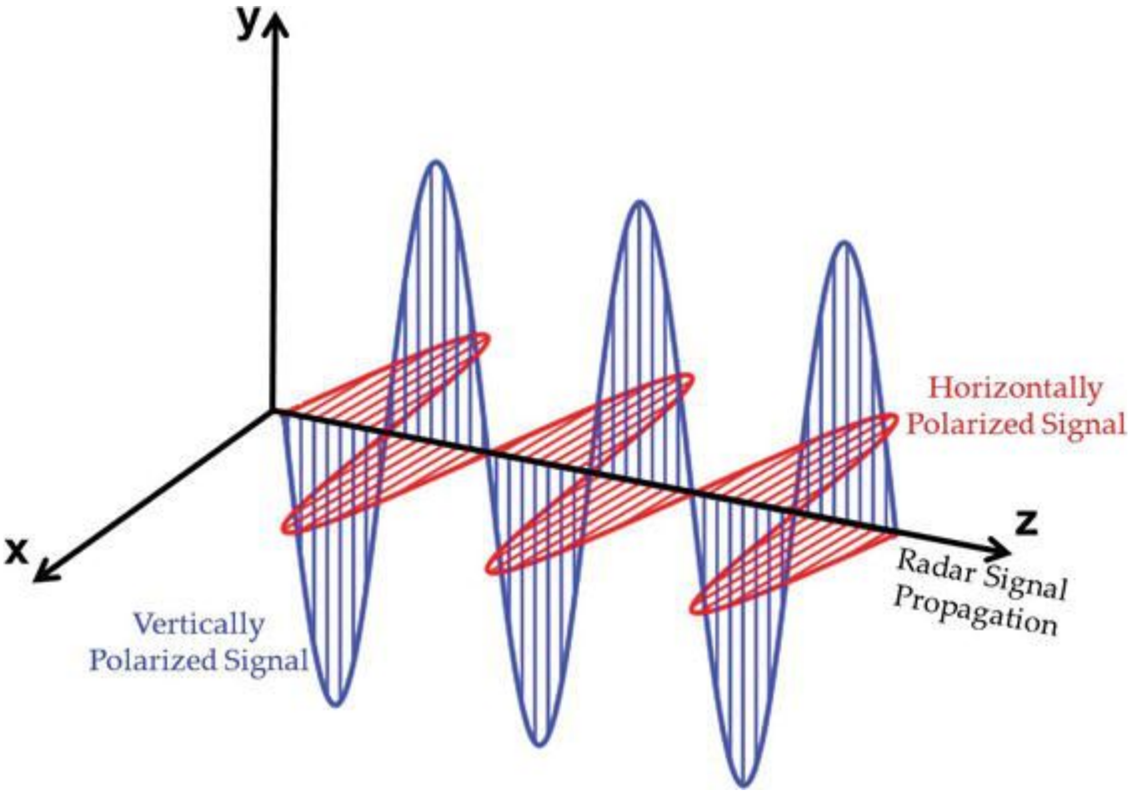
↓

↓ backscatter

↓ brightness

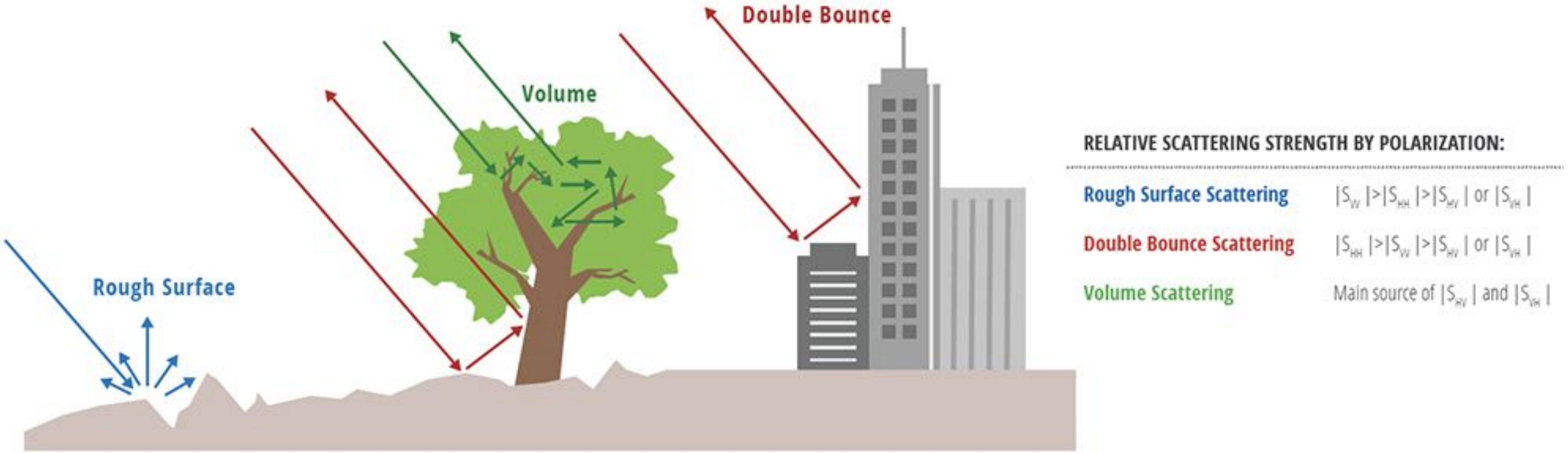
Source: MicroImages

Microwave interactions with matter - polarization



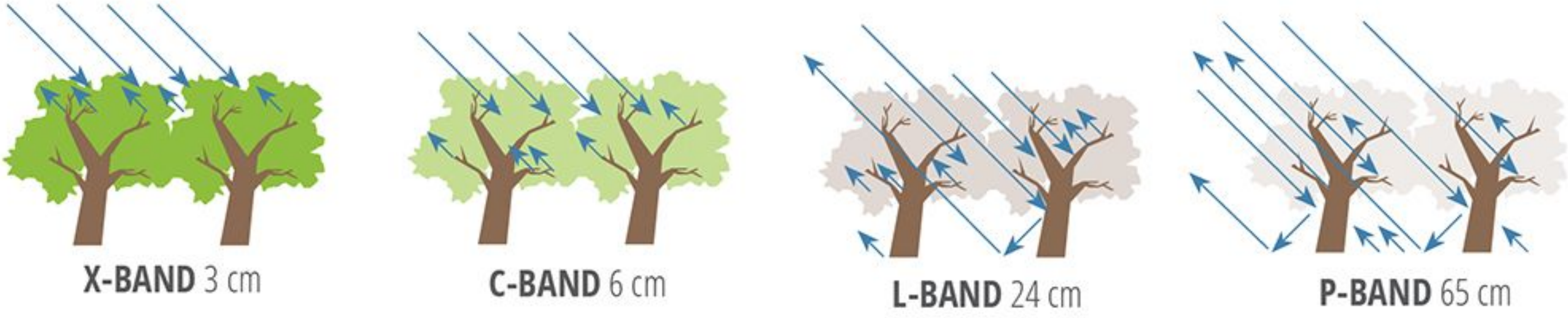
Source: Dabboor and Brisco 2018

Microwave interactions with matter - polarization



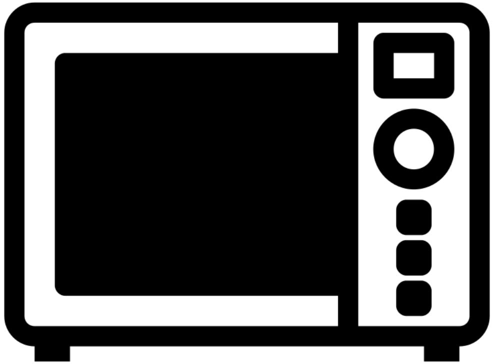
Source: NASA

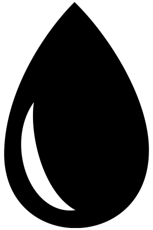
Microwave interactions with matter



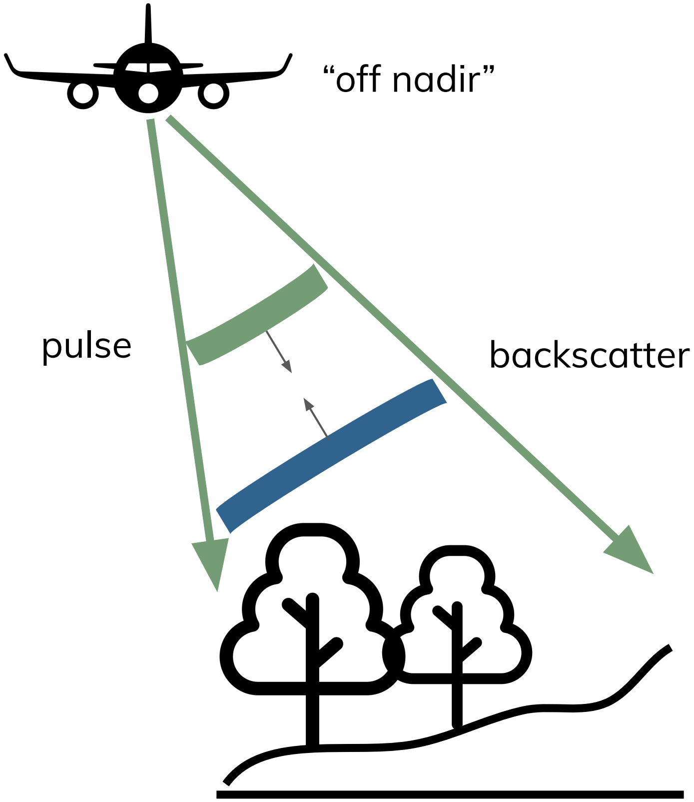
Source: NASA

Microwave interactions with matter

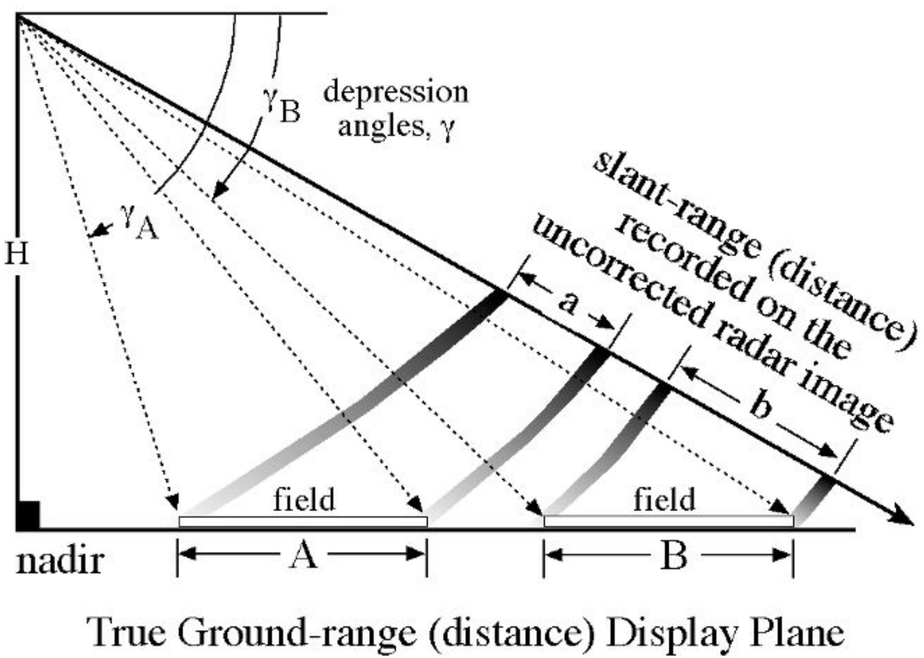




RADAR viewing geometry



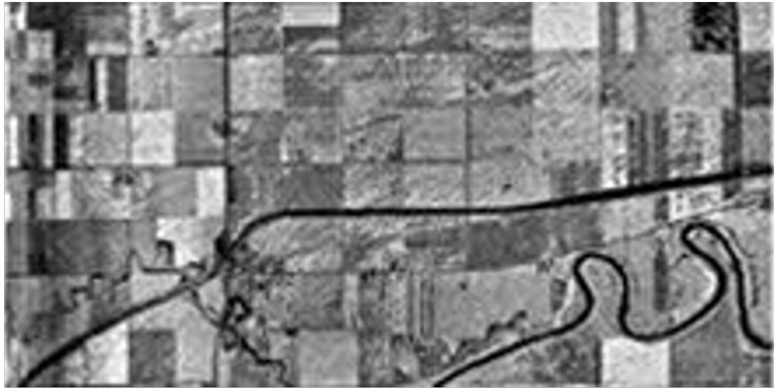
RADAR viewing geometry



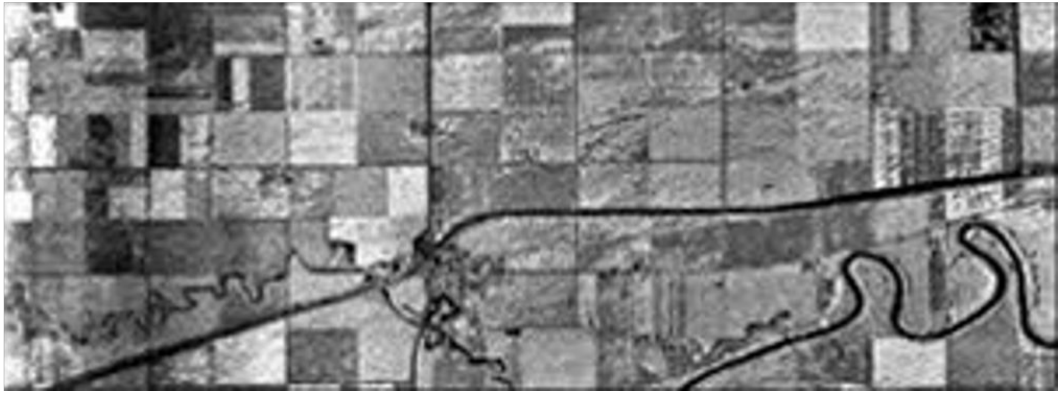
Source: Jensen 2007

Terrain distortions

uncorrected
slant-range geometry

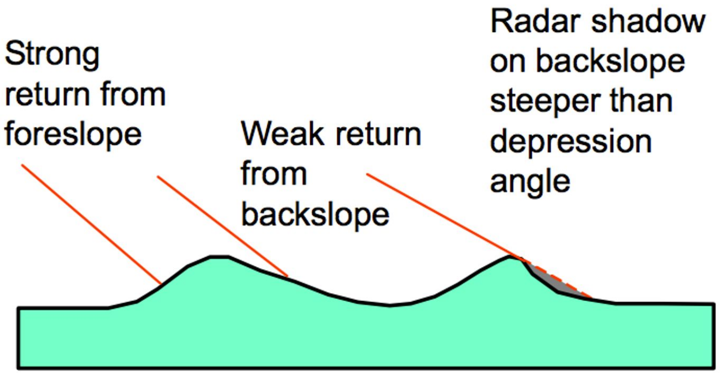


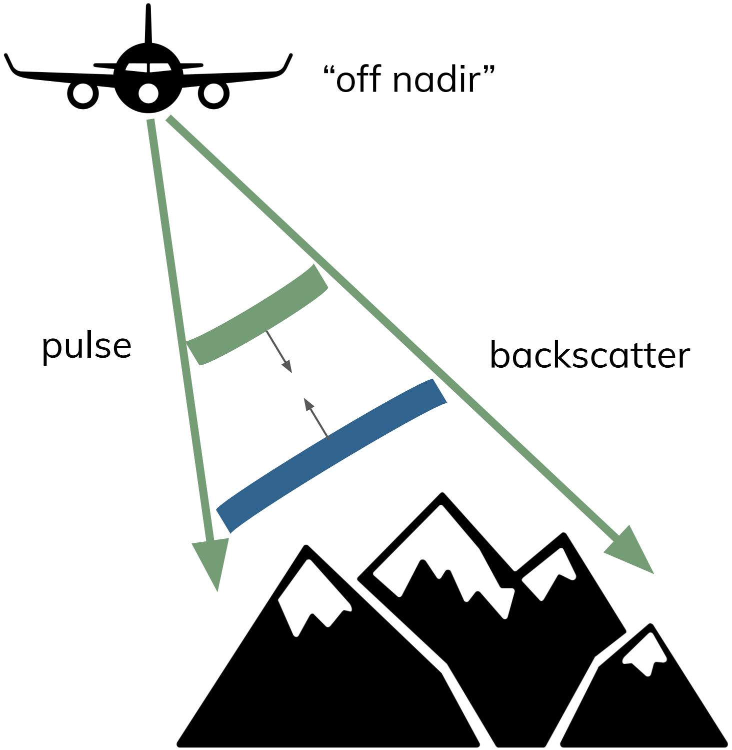
corrected
ground-range geometry



Source: MicroImages

Terrain distortions





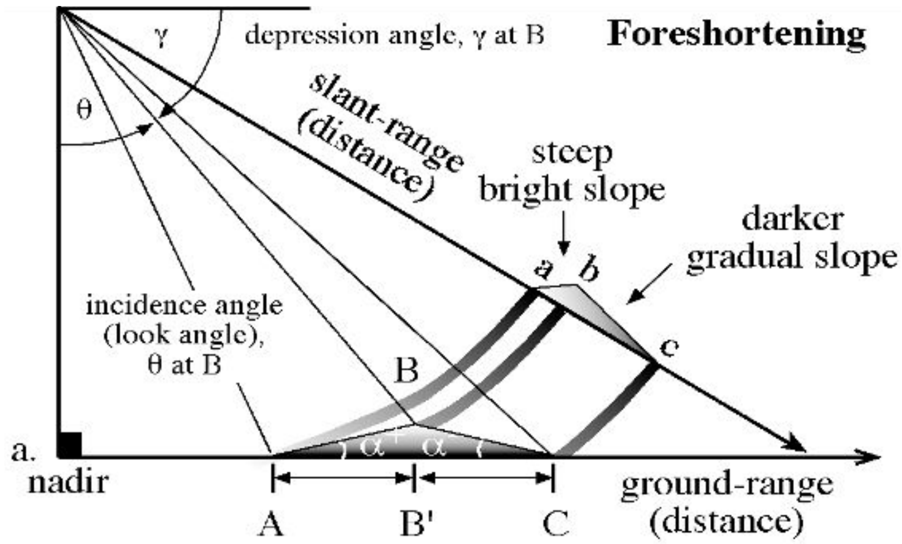
Source: MicroImages

Terrain distortions

“radar shadow”

Source: MicroImages

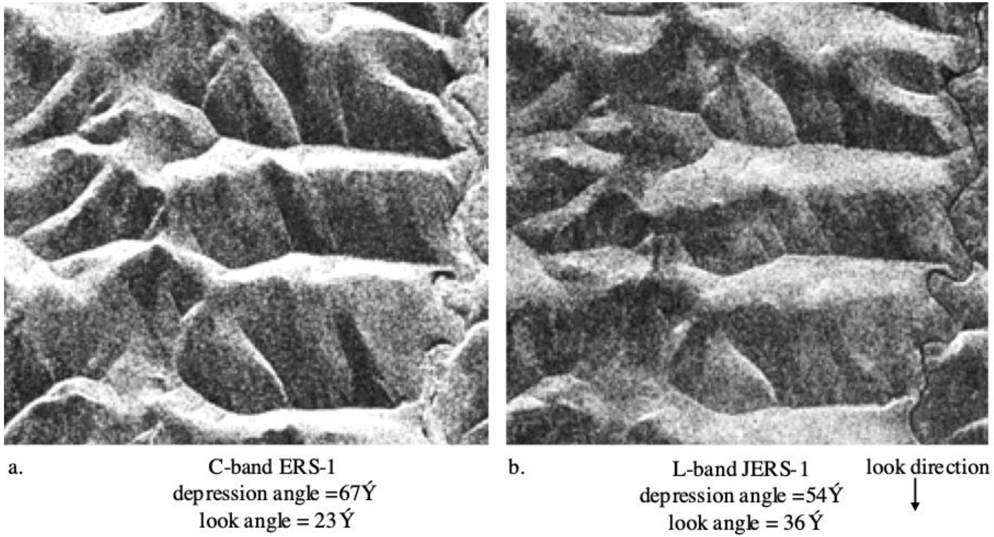
Terrain distortions



front of slope imaged faster than back of slope → front of slope appears compressed

Source: Jensen 2007

Terrain distortions



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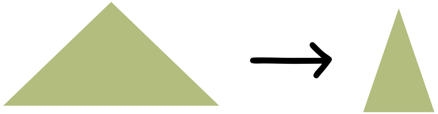
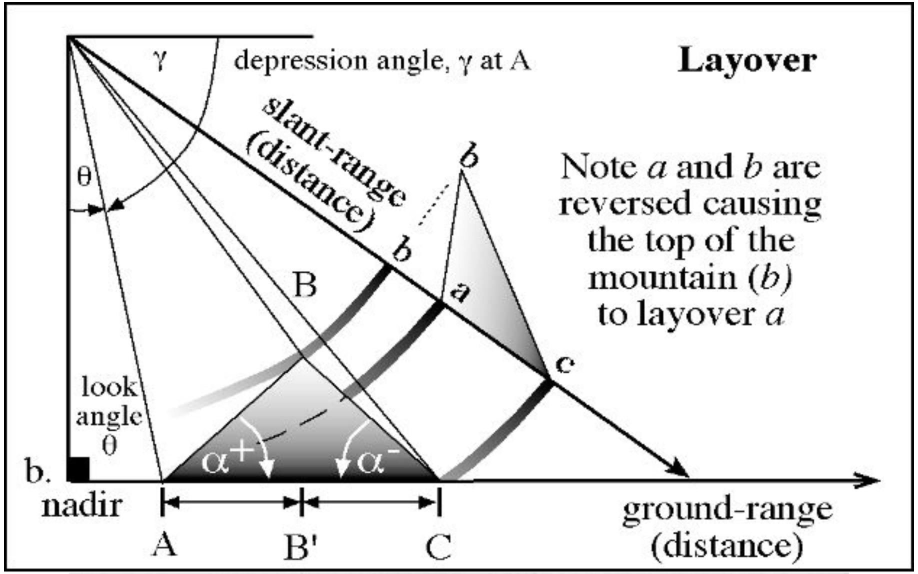
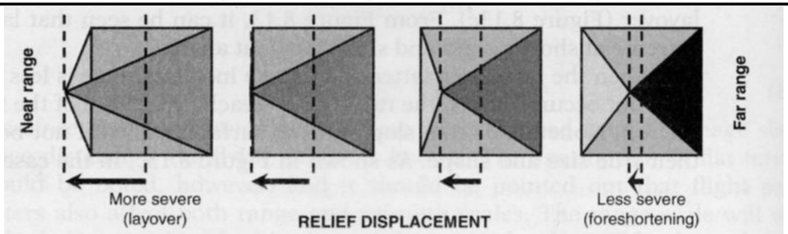
Source: MicroImages

Terrain distortions

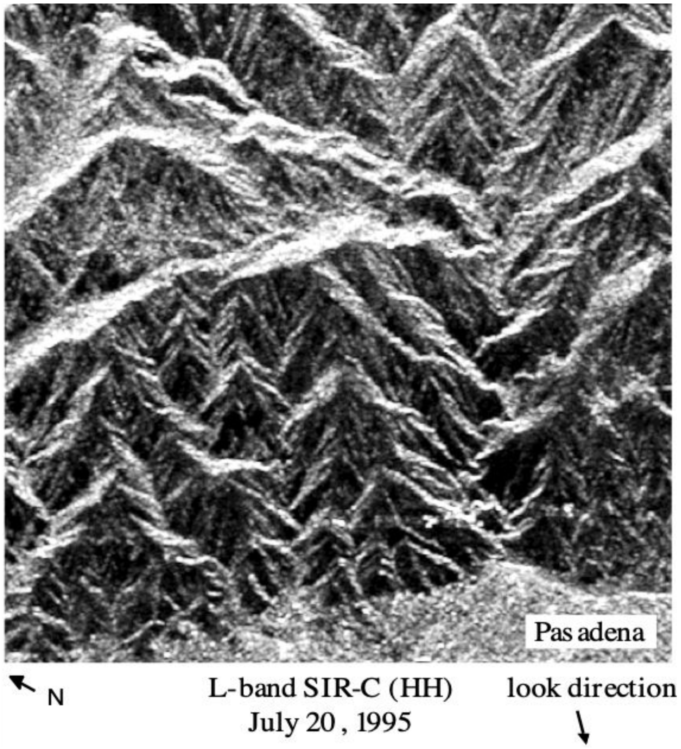






Source: Jensen 2007

Terrain distortions



Source: MicroImages

Advantages of RADAR

- **Works in all weather**
- **Works at night**
- **Provides information outside of the visible and infrared**
  - E.g. surface roughness, dielectric properties, moisture content
- **Can look beneath materials**
  - E.g. vegetation, sand, surface layers of snow