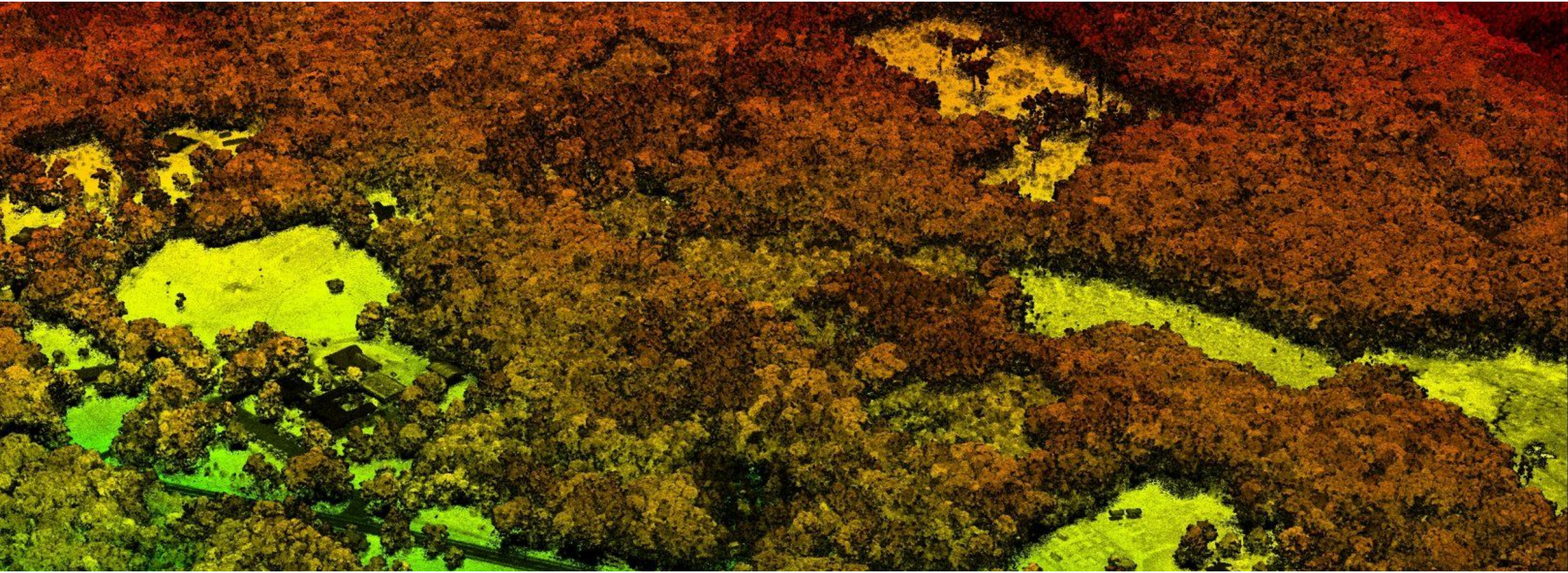
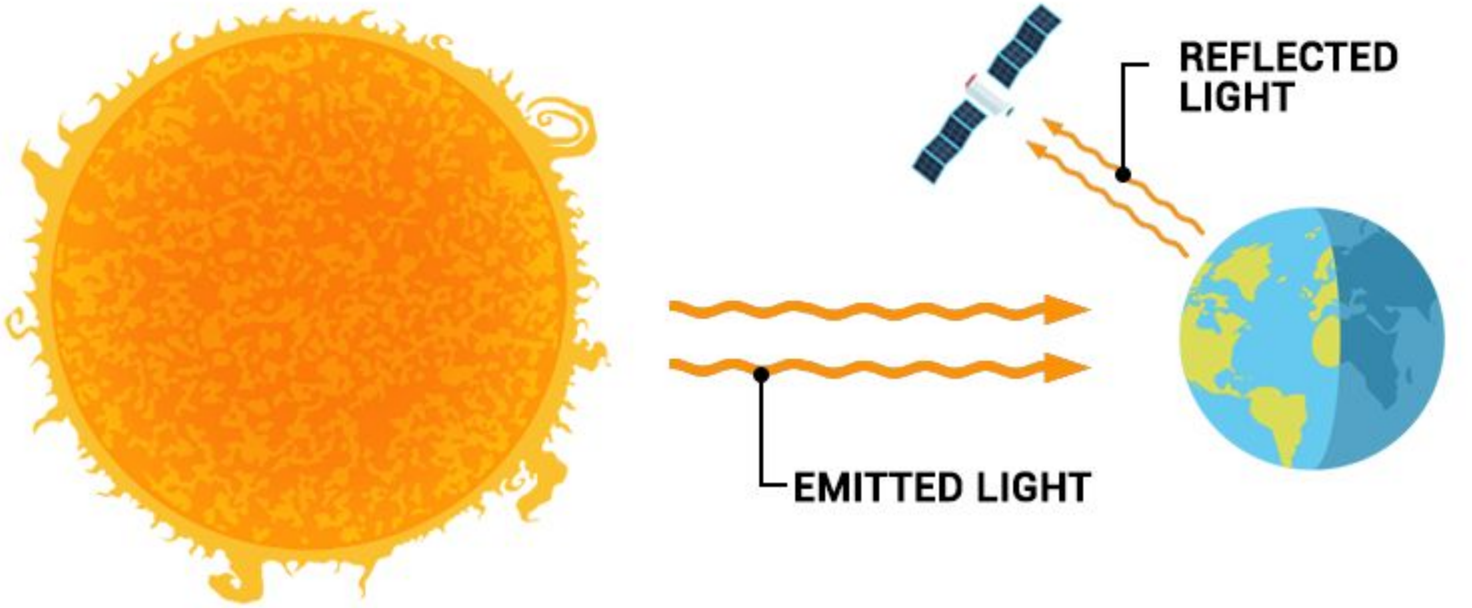
EDS 223: Geospatial Analysis & Remote Sensing
Week 10



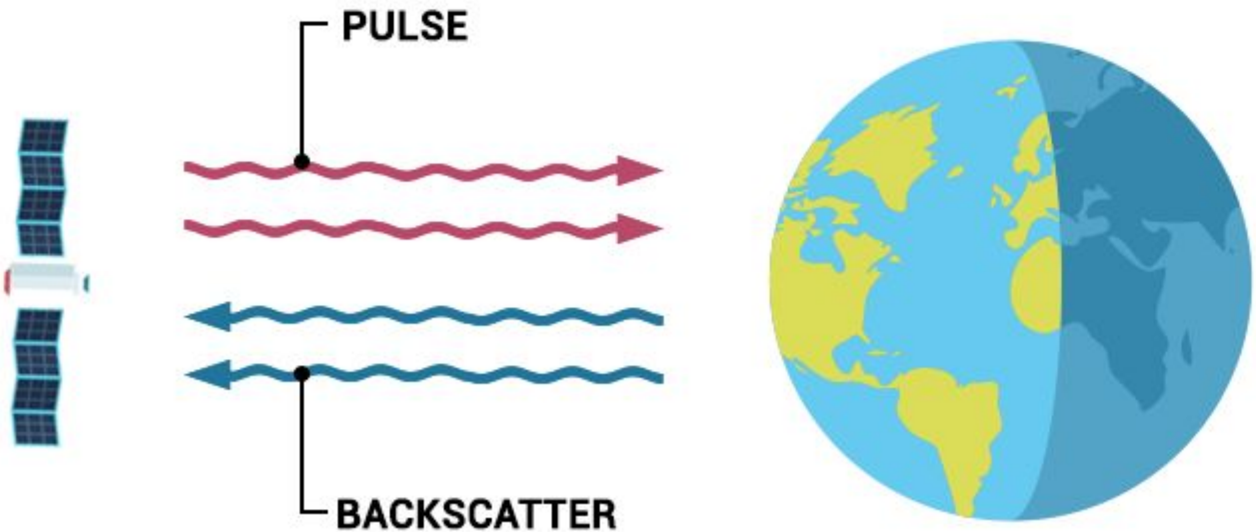
NEON

Passive remote sensing



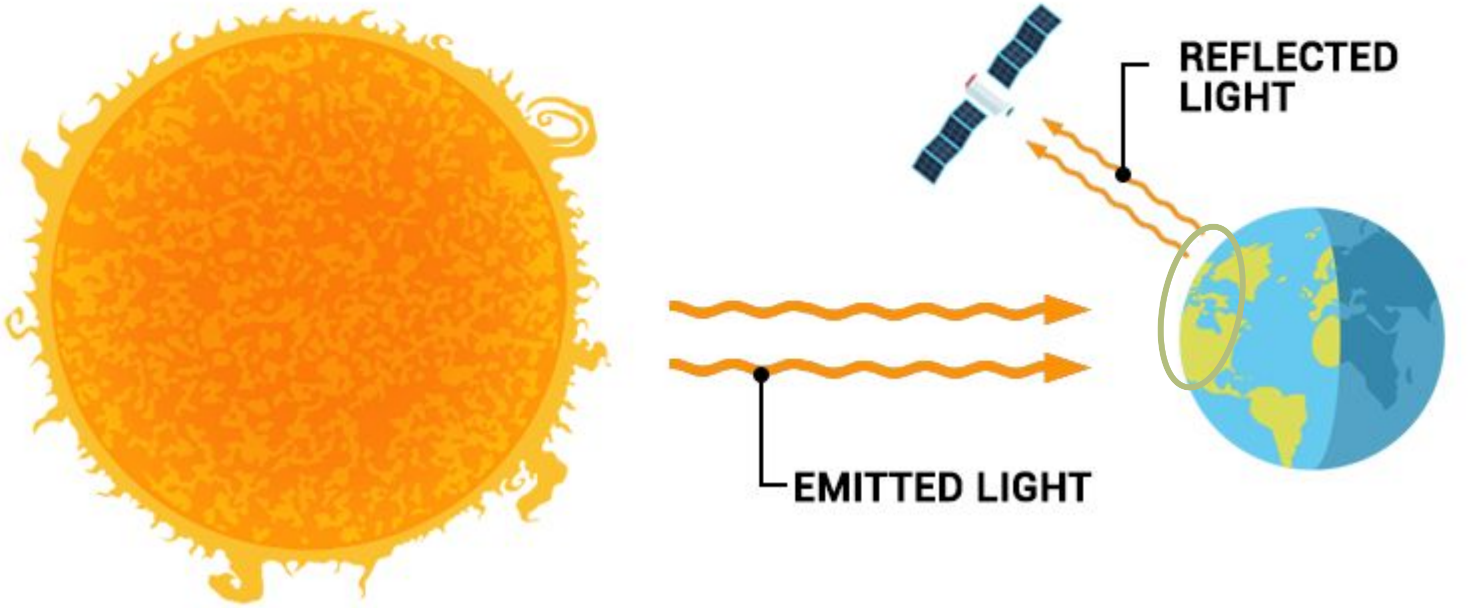
Source: GIS Geography

Active remote sensing



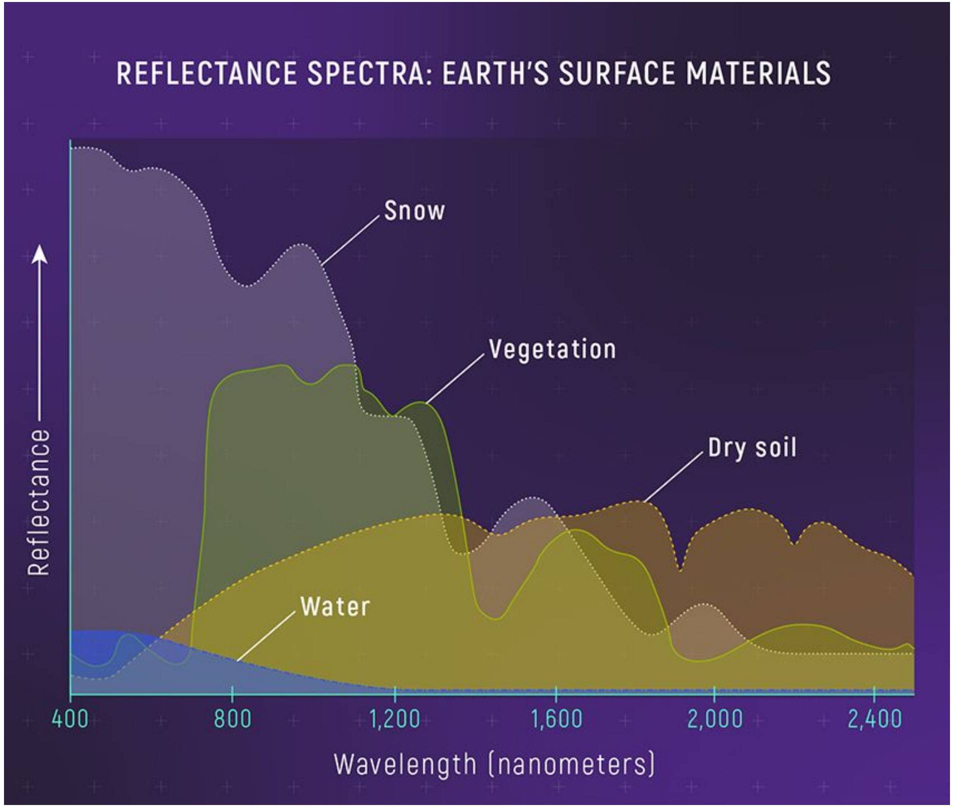
Source: GIS Geography

Passive remote sensing



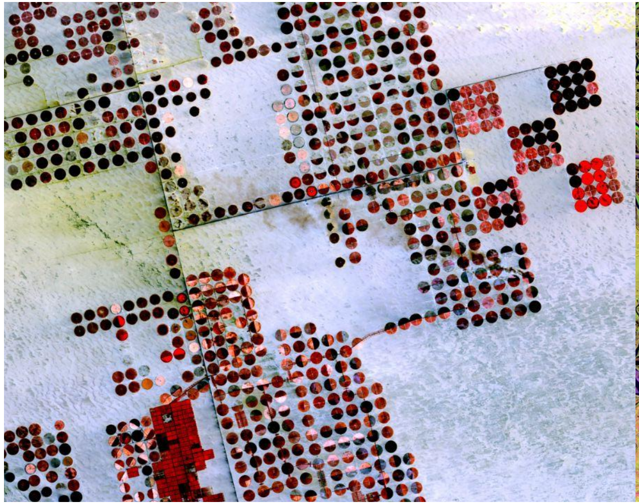
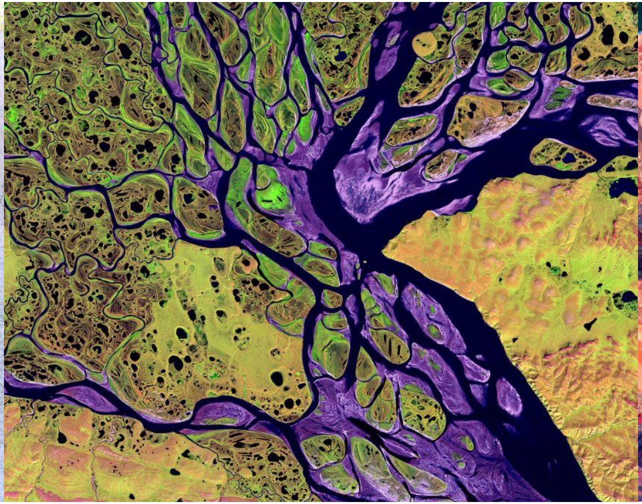
Source: GIS Geography

Reflectance spectra



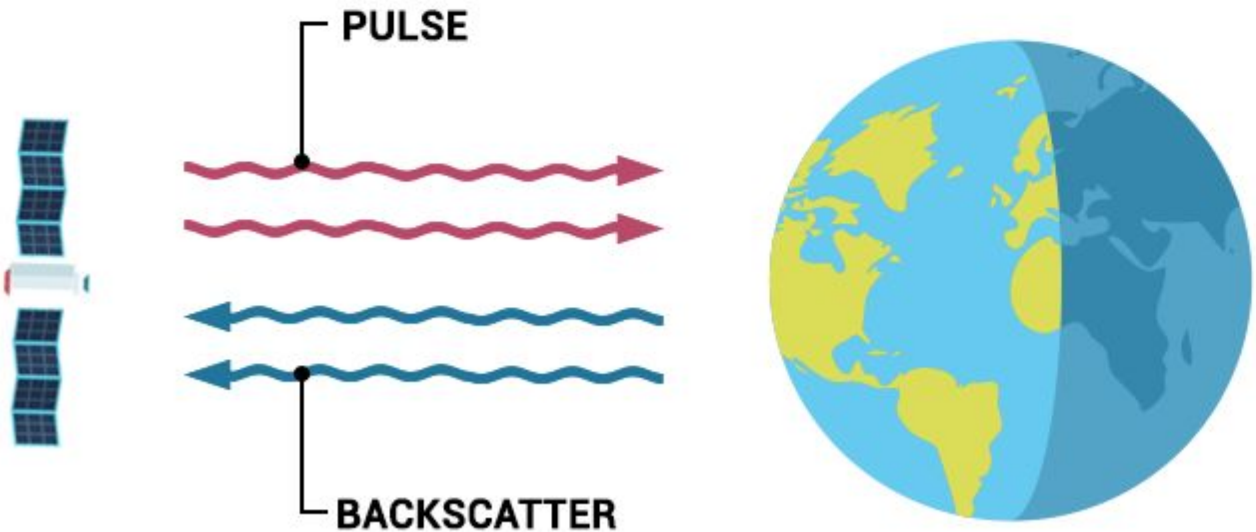
Source: NASA, Leah Hustak

Passive remote sensing


USGS via Unsplash

Active remote sensing

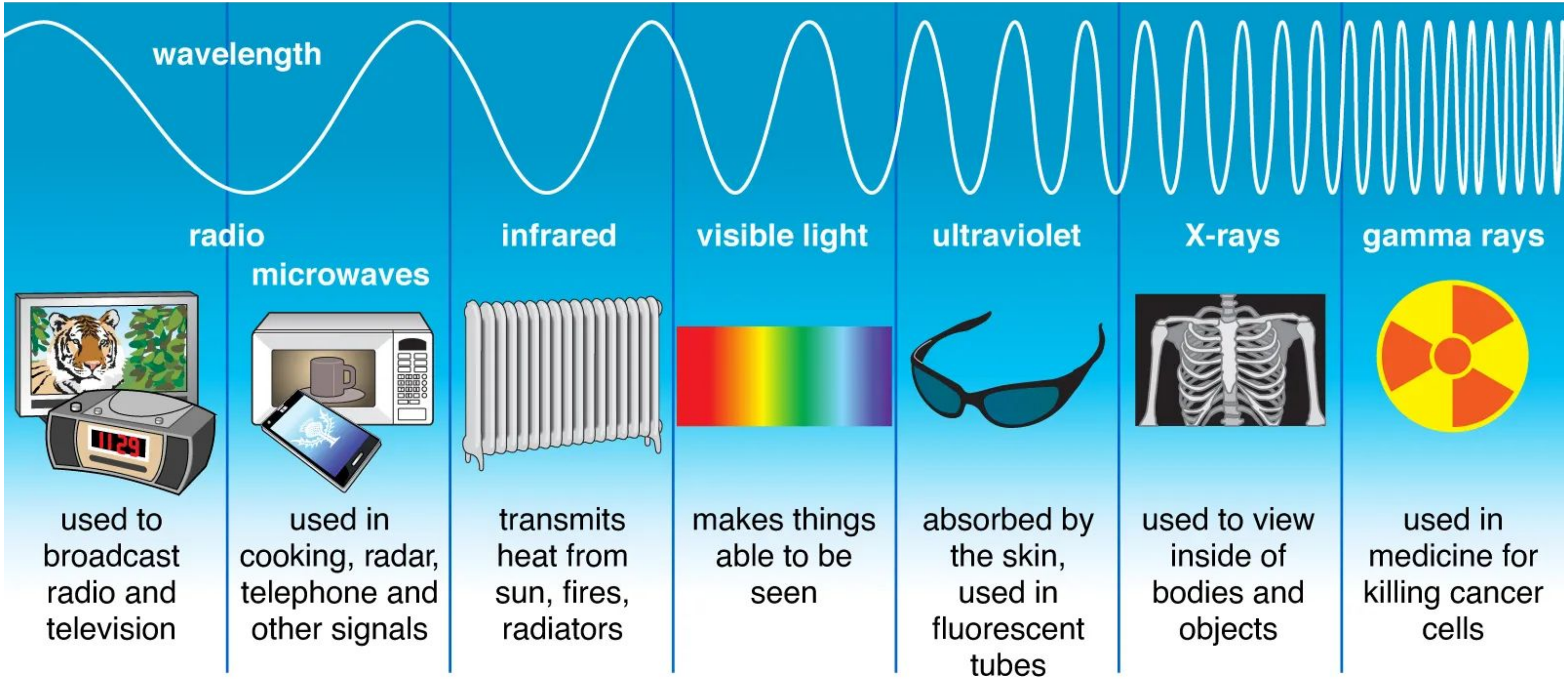


Source: GIS Geography

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

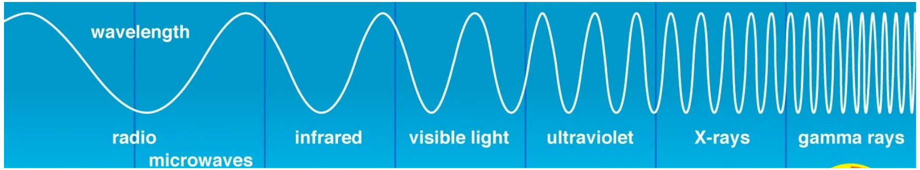


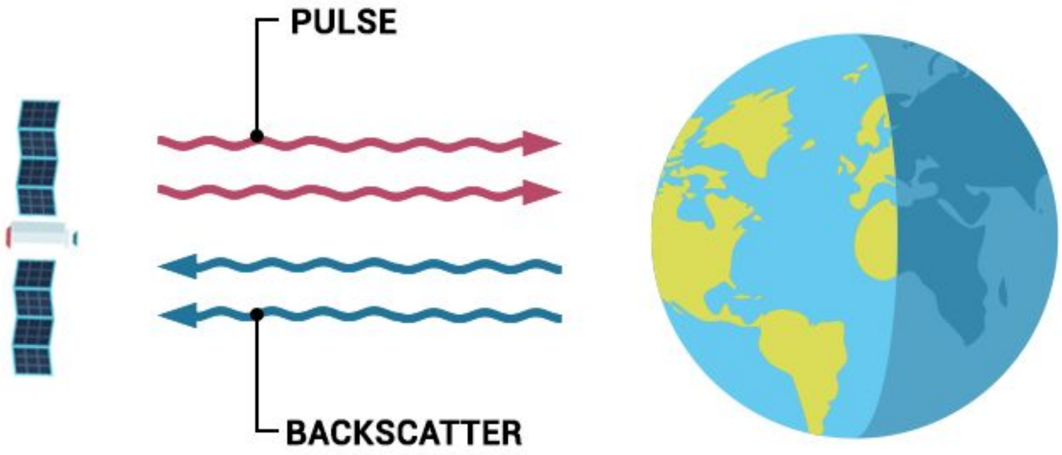
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection and Ranging

LiDAR
Light Detection and Ranging





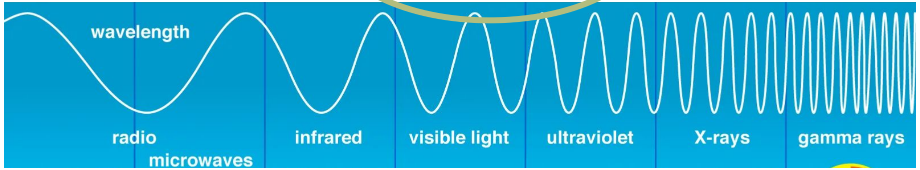
Source: GIS Geography

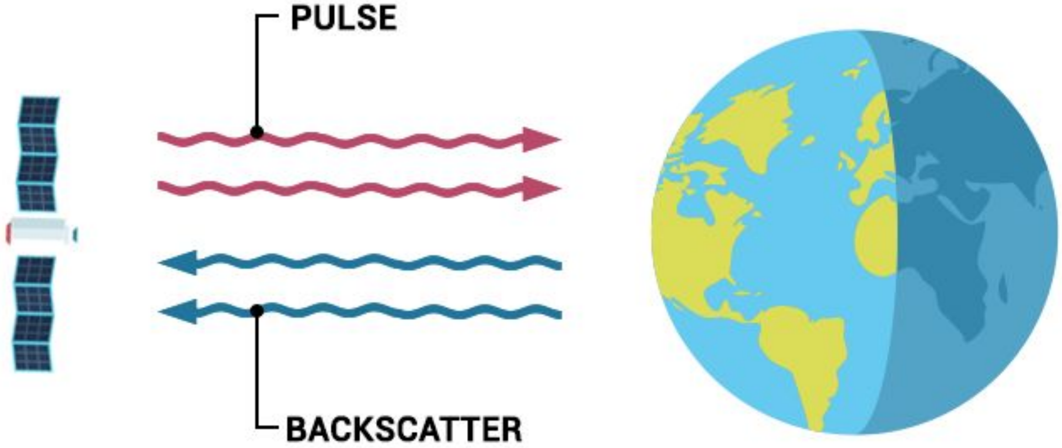
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

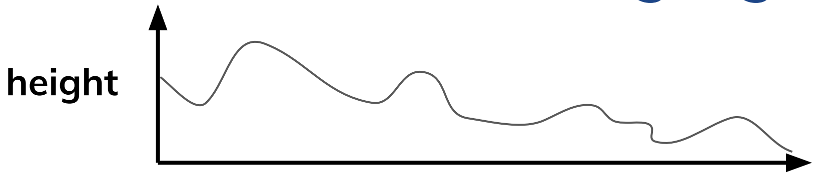
LiDAR
Light Detection
and Ranging

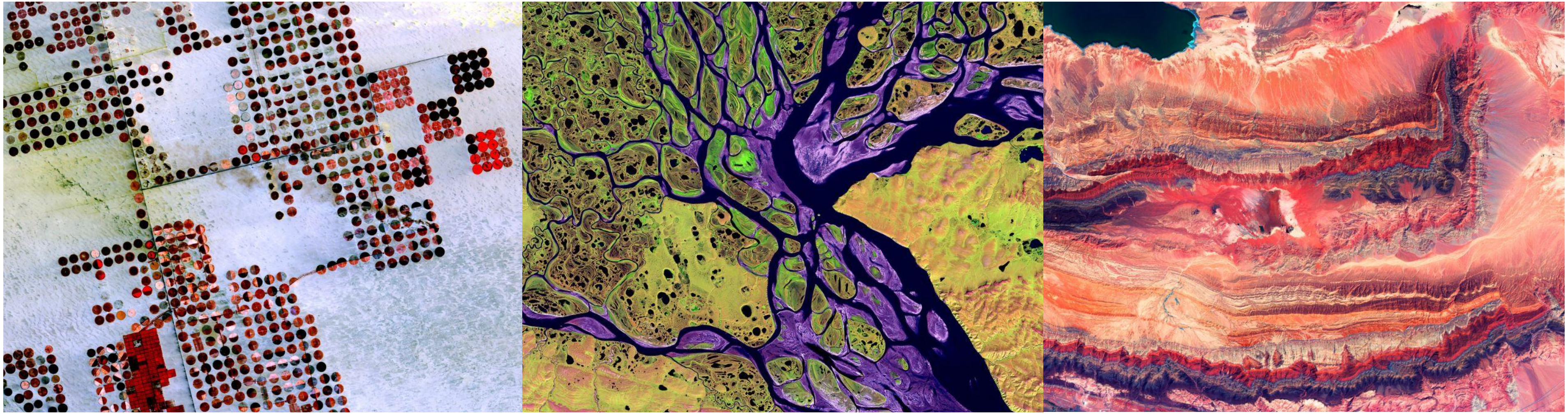




Source: GIS Geography

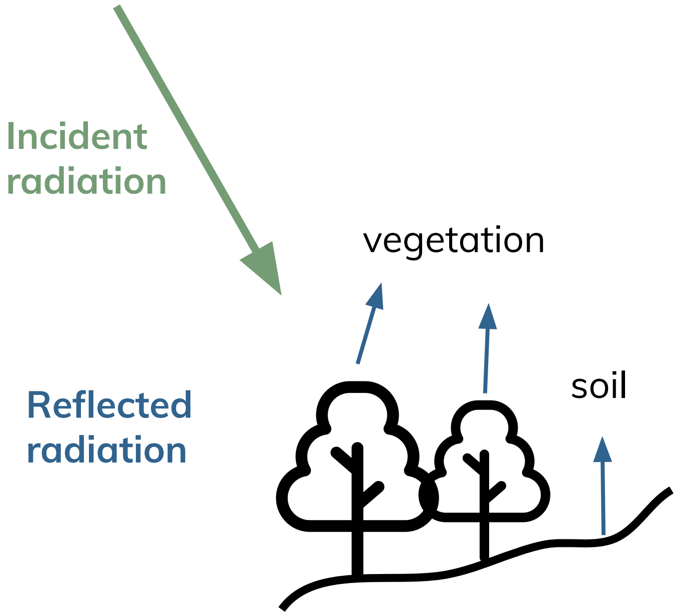
LiDAR: Light Detection and Ranging



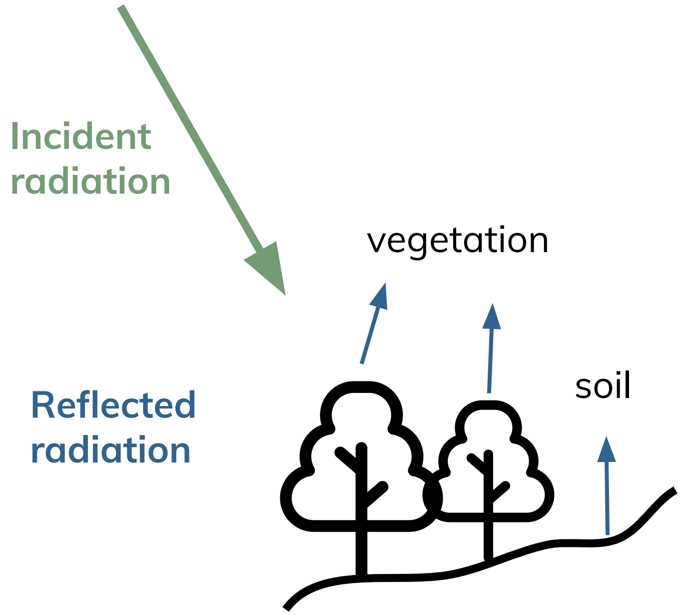


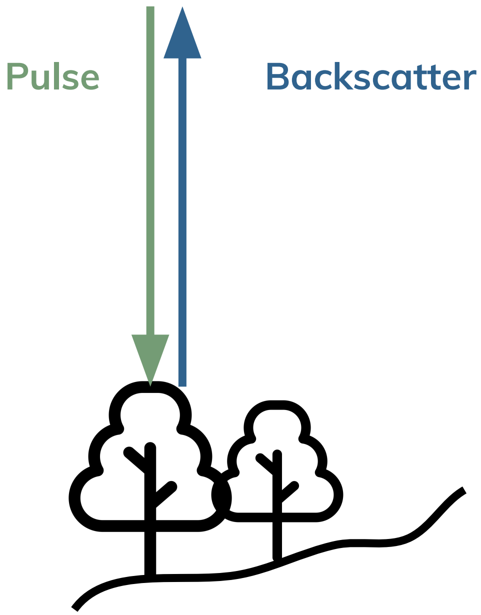
USGS via Unsplash

Using light to measure height

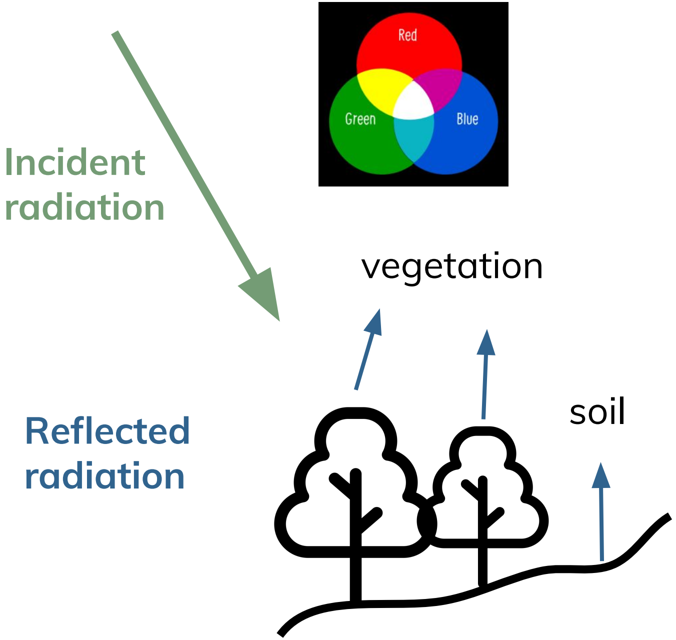


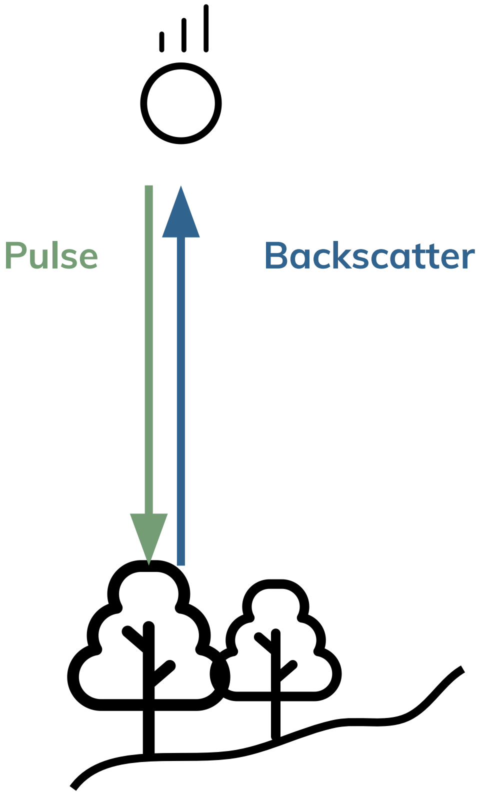
Using light to measure height



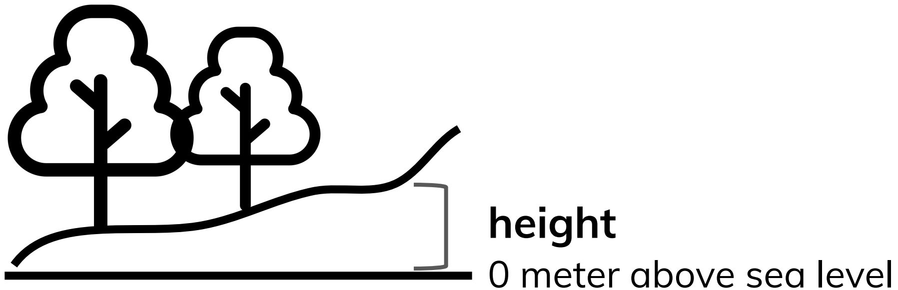


Using light to measure height

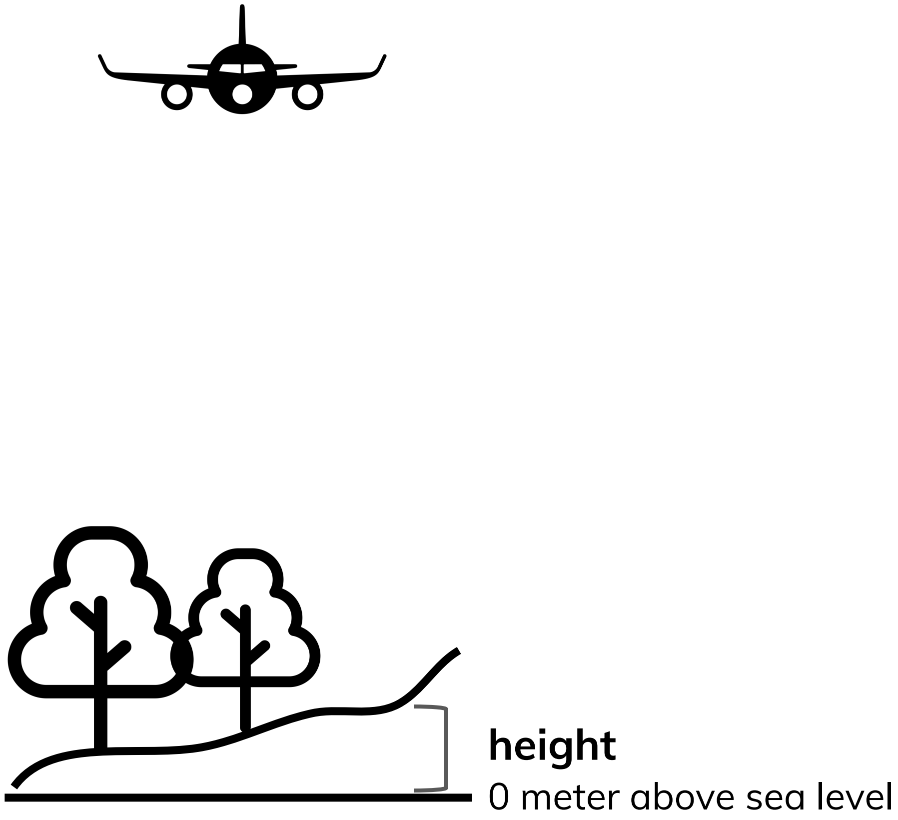




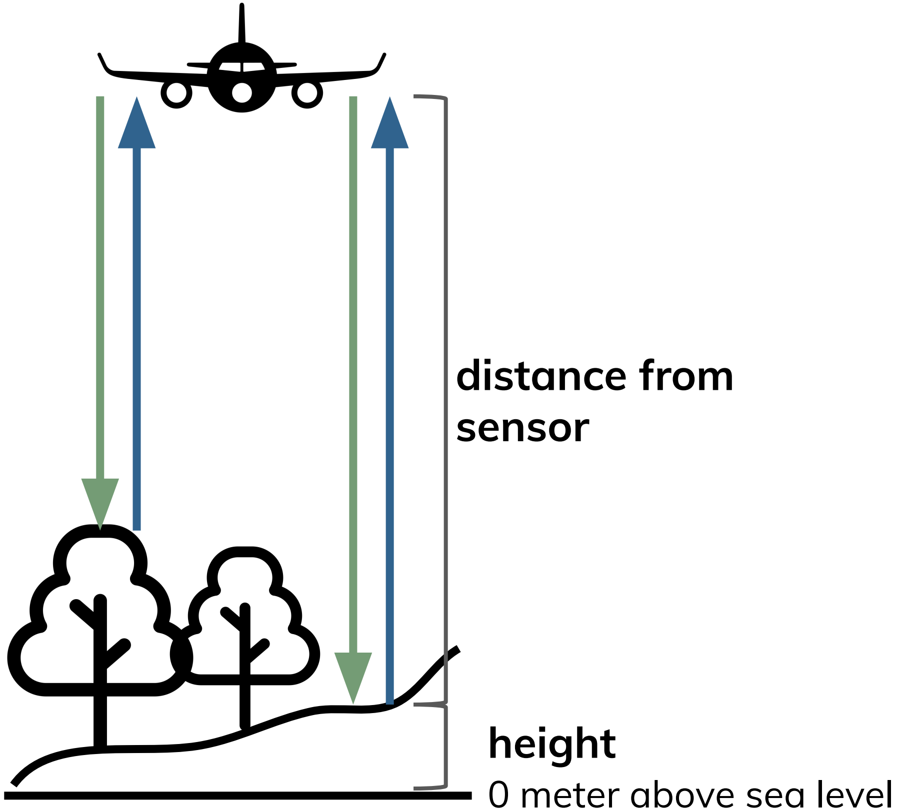
Using light to measure height



Using light to measure height

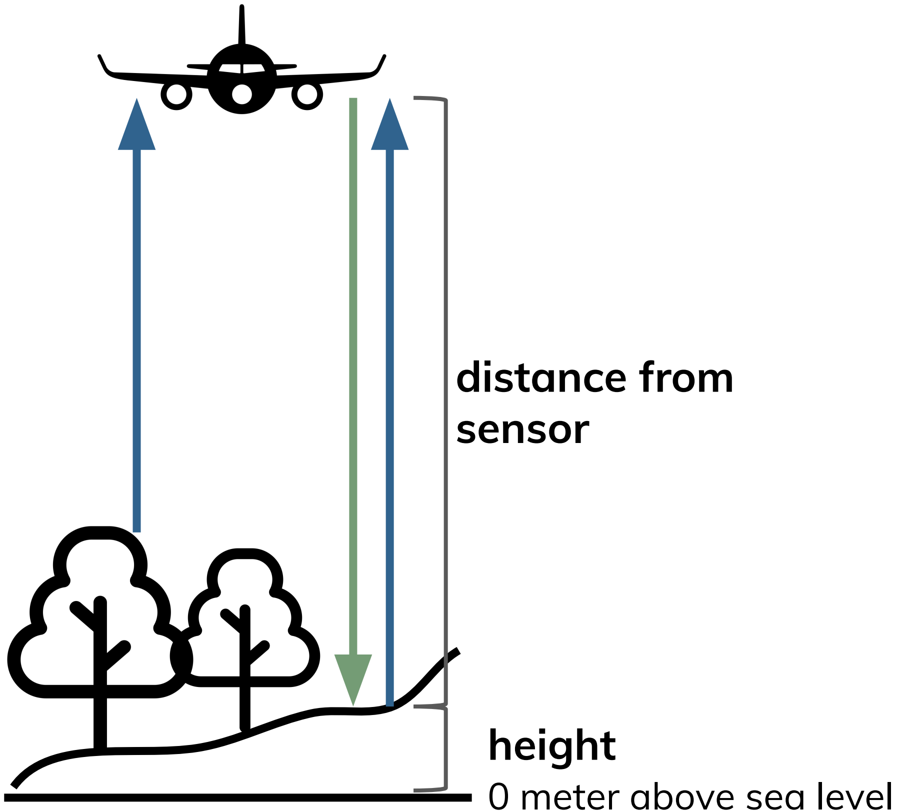


Using light to measure height



Using light to measure height

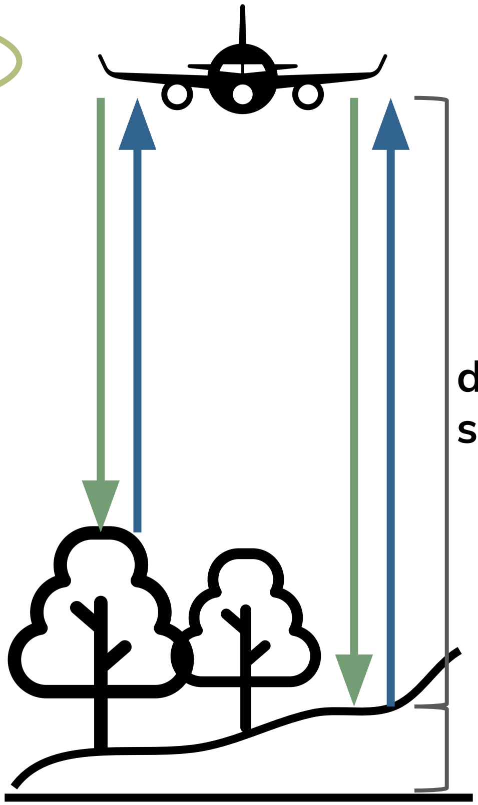
$$\text{Velocity} = \frac{\Delta x}{\Delta t} = \frac{\text{distance traveled}}{\text{duration}}$$



Using light to measure height

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

$$\text{distance traveled} = \text{velocity x duration}$$



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

height

0 meter above sea level

Using light to measure height

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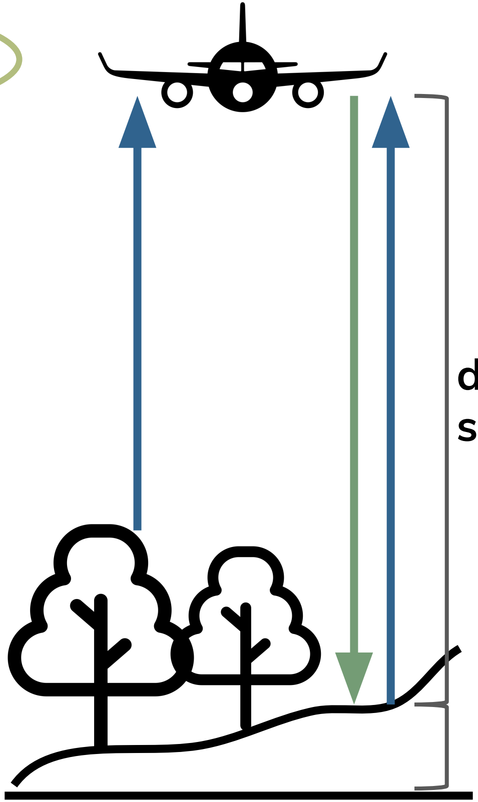
$$\text{distance traveled} = \text{velocity x duration}$$



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Using light to measure height

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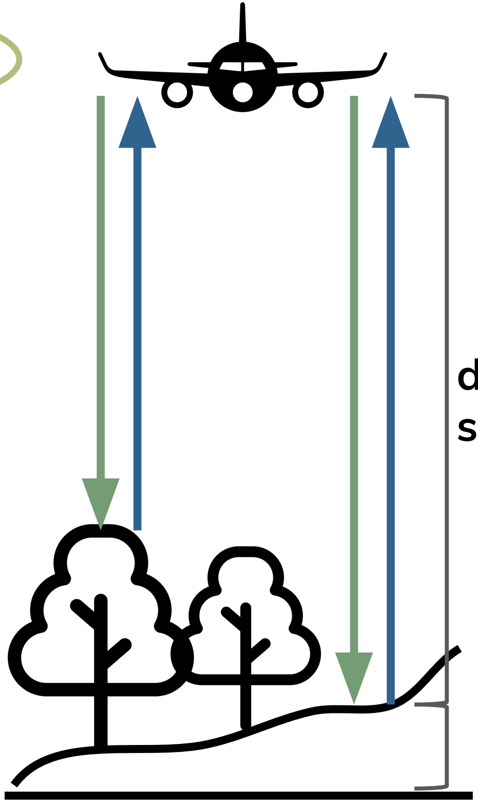
distance traveled = velocity x duration



Speed of light
(always known!)

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

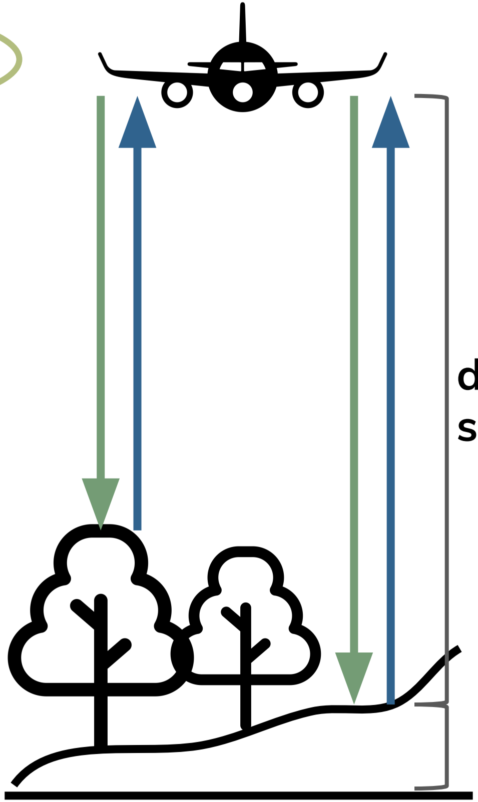
height

0 meter above sea level

Using light to measure height

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

$$\text{distance traveled} = \text{velocity} \times \text{duration}$$



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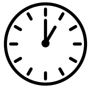


$$\textbf{distance from sensor} = \frac{\text{velocity} \times \text{duration}}{2}$$

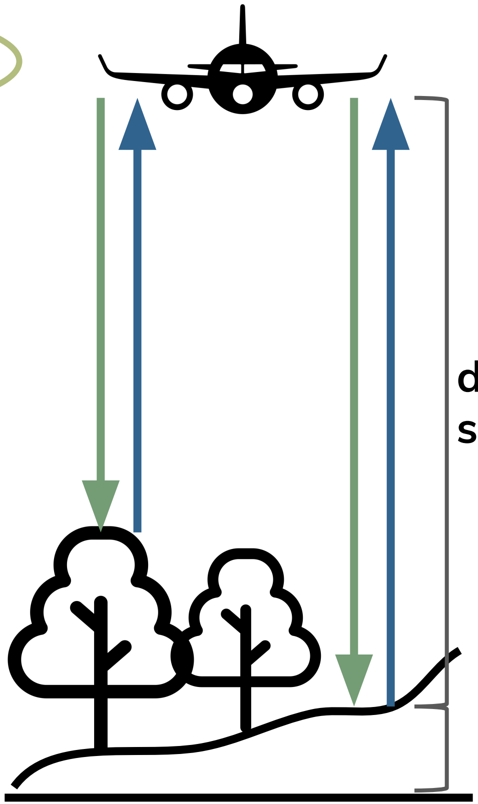
height

0 meter above sea level

Using light to measure height

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

$$\text{distance traveled} = \text{velocity x duration}$$



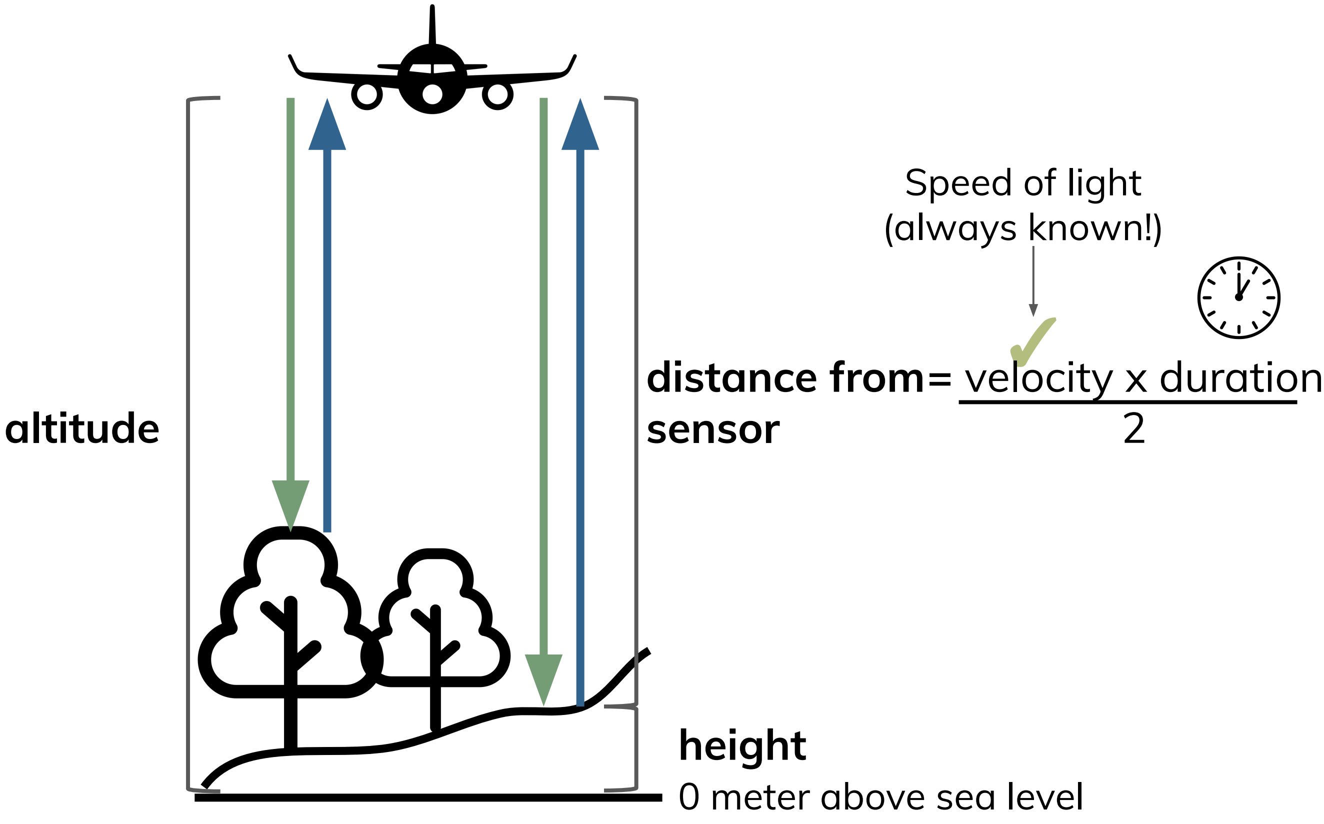
Speed of light
(always known!)

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

height?

0 meter above sea level

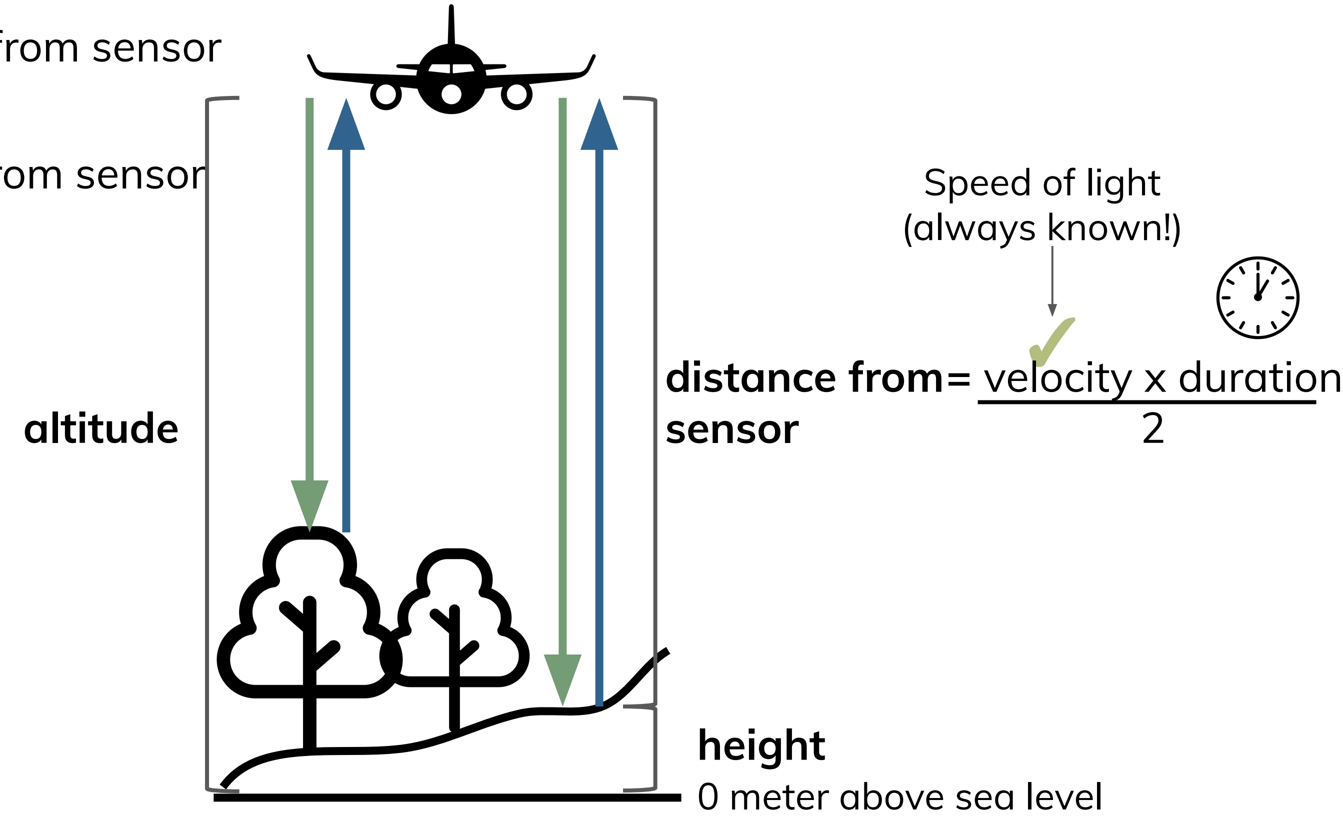
Using light to measure height



Using light to measure height

altitude = height + distance from sensor

height = altitude - distance from sensor



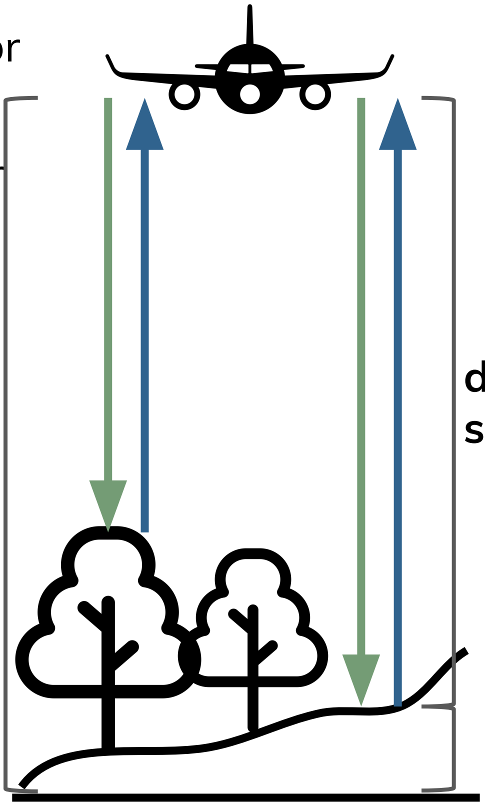
Using light to measure height

altitude = height + distance from sensor

height = altitude - distance from sensor

height is inversely related to duration

altitude



Speed of light (always known!)

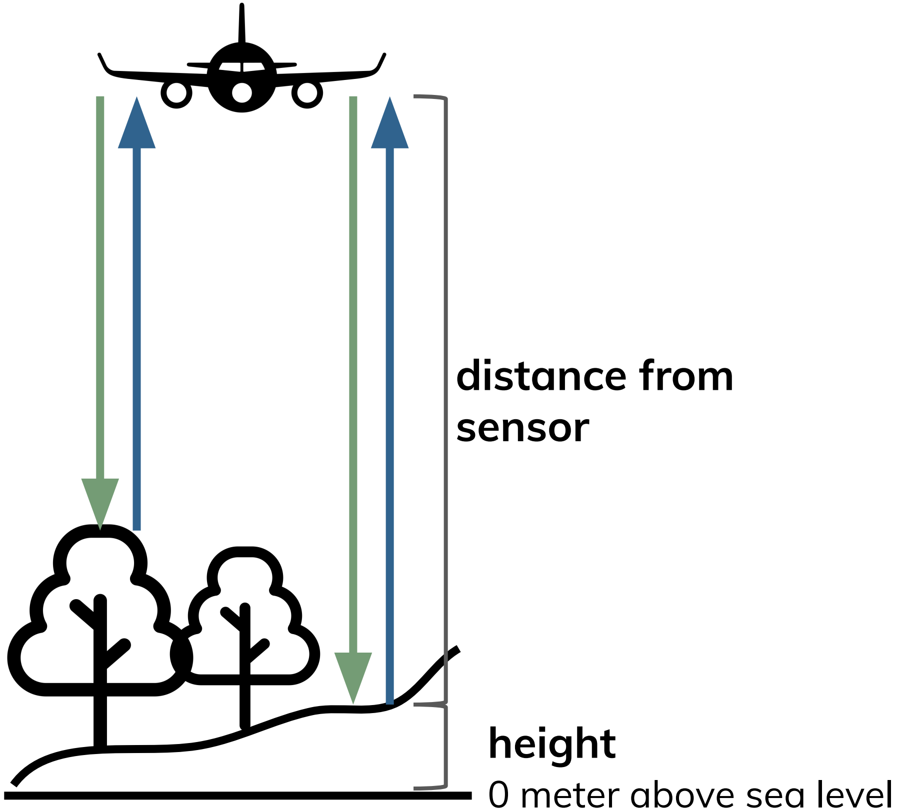
distance from sensor $= \dfrac{\text{velocity x duration}}{2}$

height

0 meter above sea level

Using light to measure height

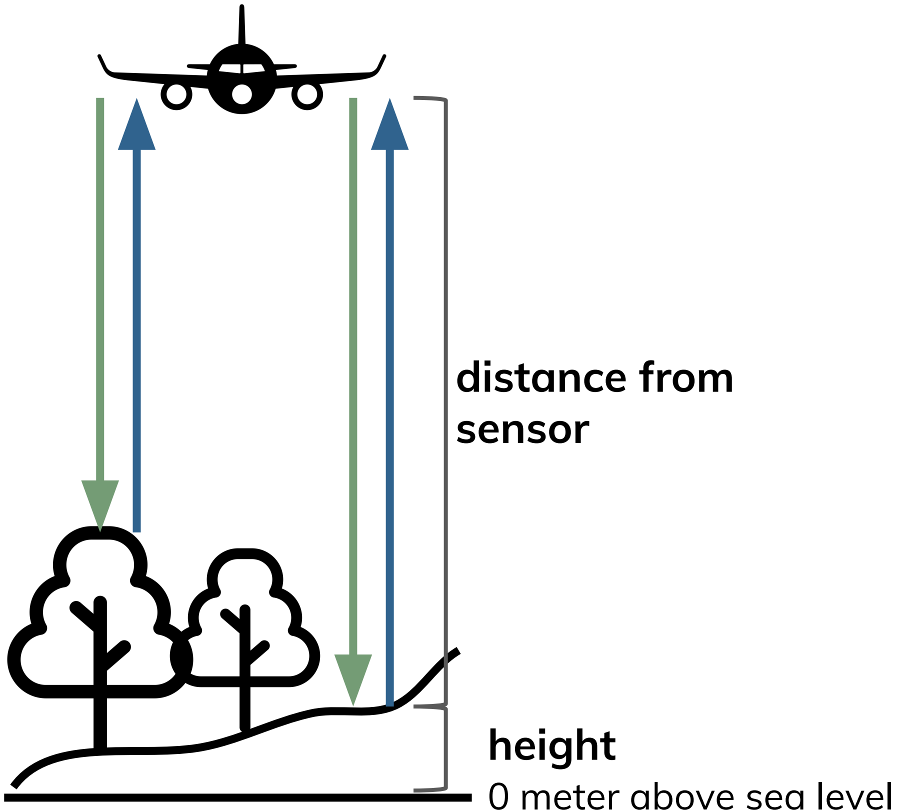
What components to do we need?



Using light to measure height

What components to do we need?

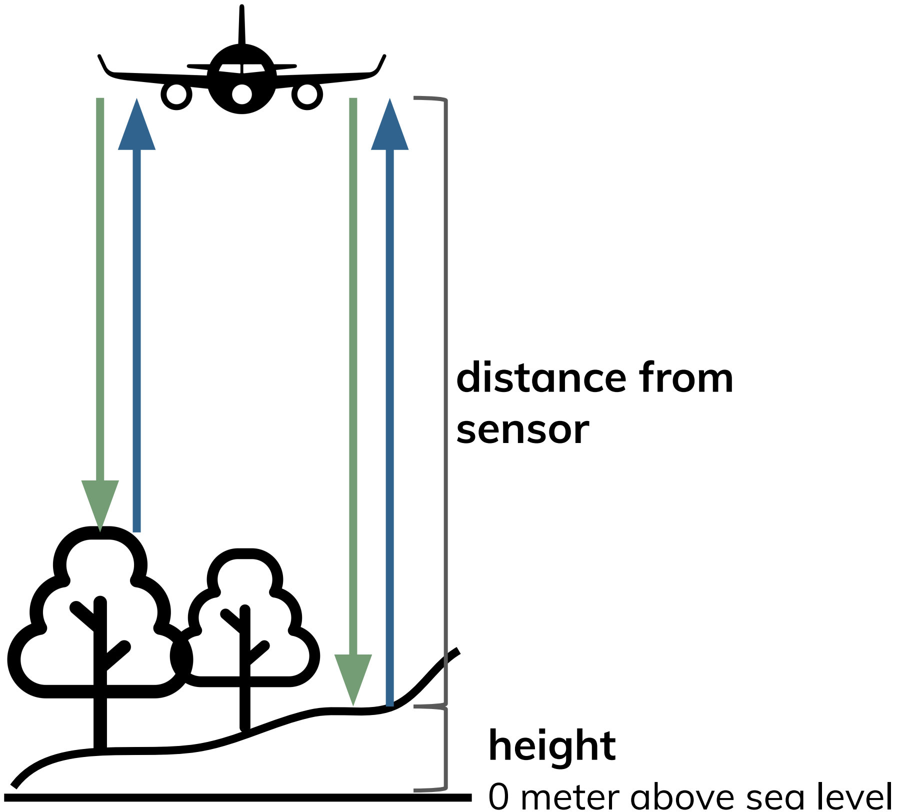
- emit/receive radiation
- know location
- know orientation
- keep track of everything



Using light to measure height

What components to do we need?

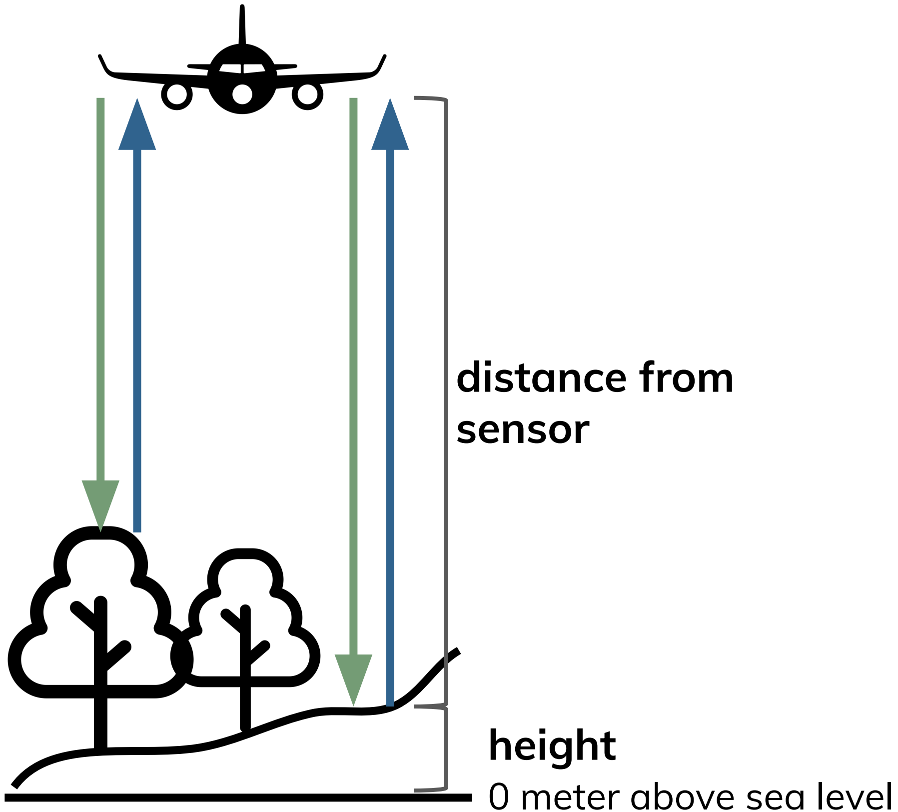
- **emit/receive radiation**
- know location
- know orientation
- keep track of everything



Using light to measure height

What components to do we need?

- **emit/receive radiation**
  - Laser
- know location
- know orientation
- keep track of everything



Lasers

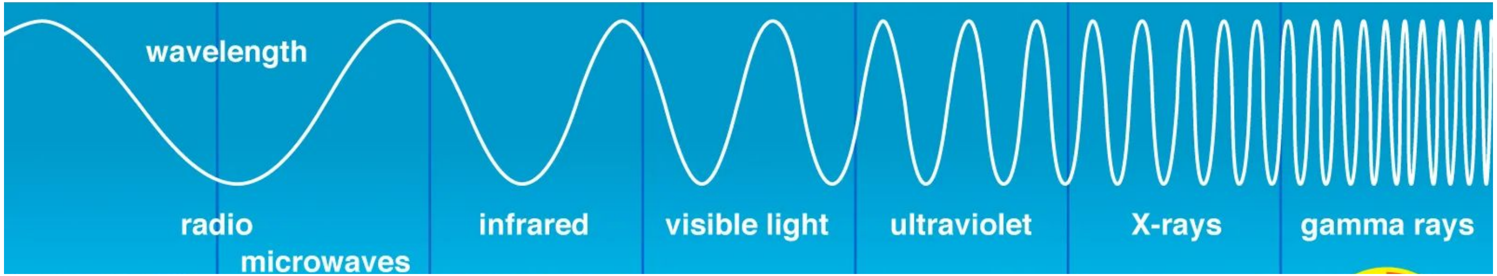
Source: Google Image search for “laser cats”

Lasers

LiDAR
Light Detection
and Ranging

near
infrared
1064 nm

green
532 nm



Lasers

LiDAR
Light Detection
and Ranging

near infrared
1064 nm

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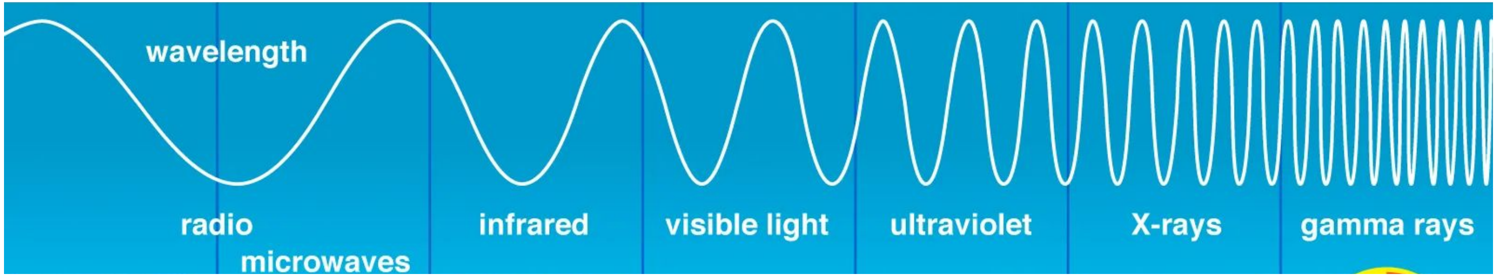
532 nm

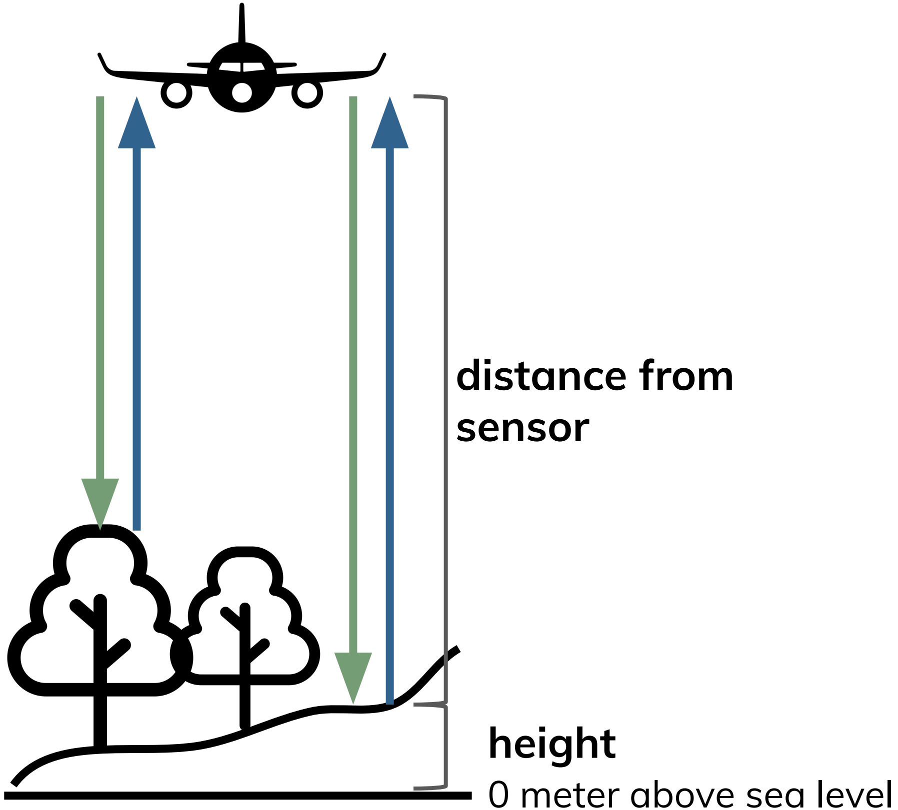


- Highly reflected off of vegetation
- Monochromatic
  - spectrally narrow - know what to expect from its interactions
  - spatially narrow - stays concentrated over long distances

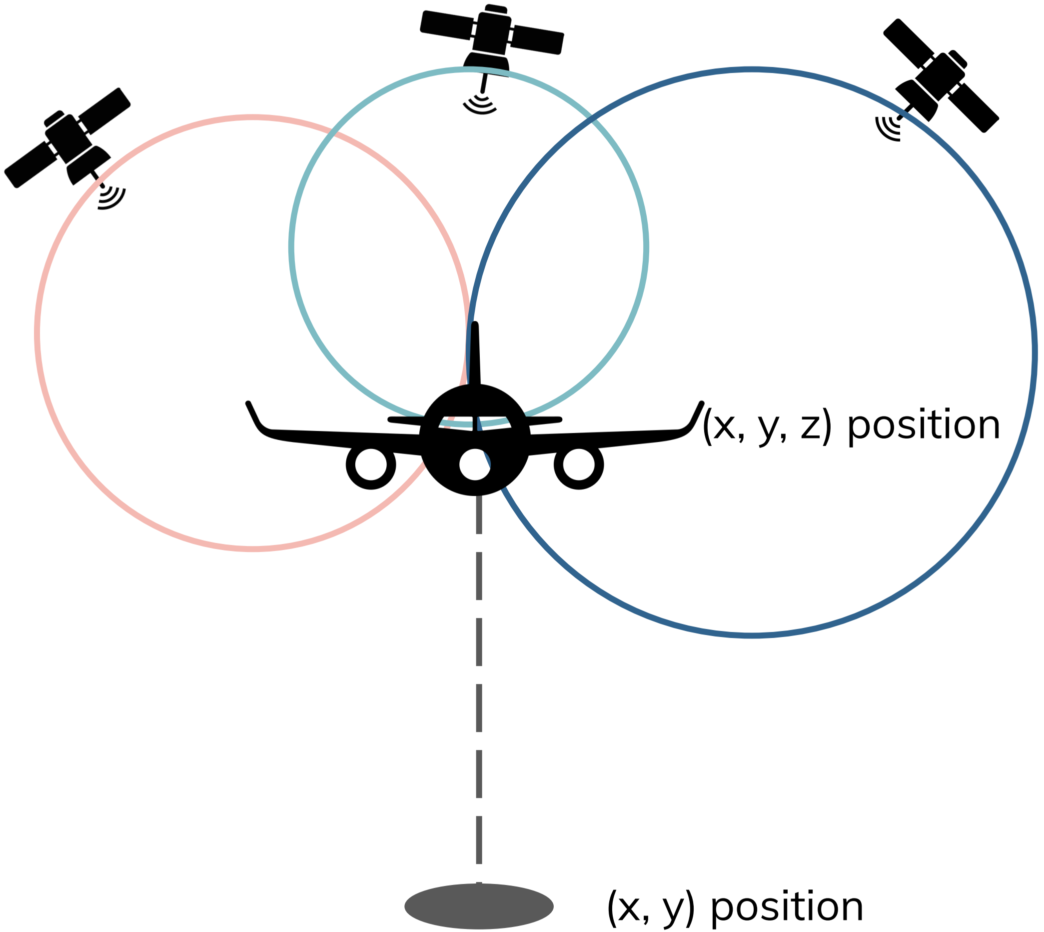
Using energy to measure height

What components to do we need?

- **emit/receive radiation**
  - Laser
- **know location**
  - GPS
- know orientation
- keep track of everything



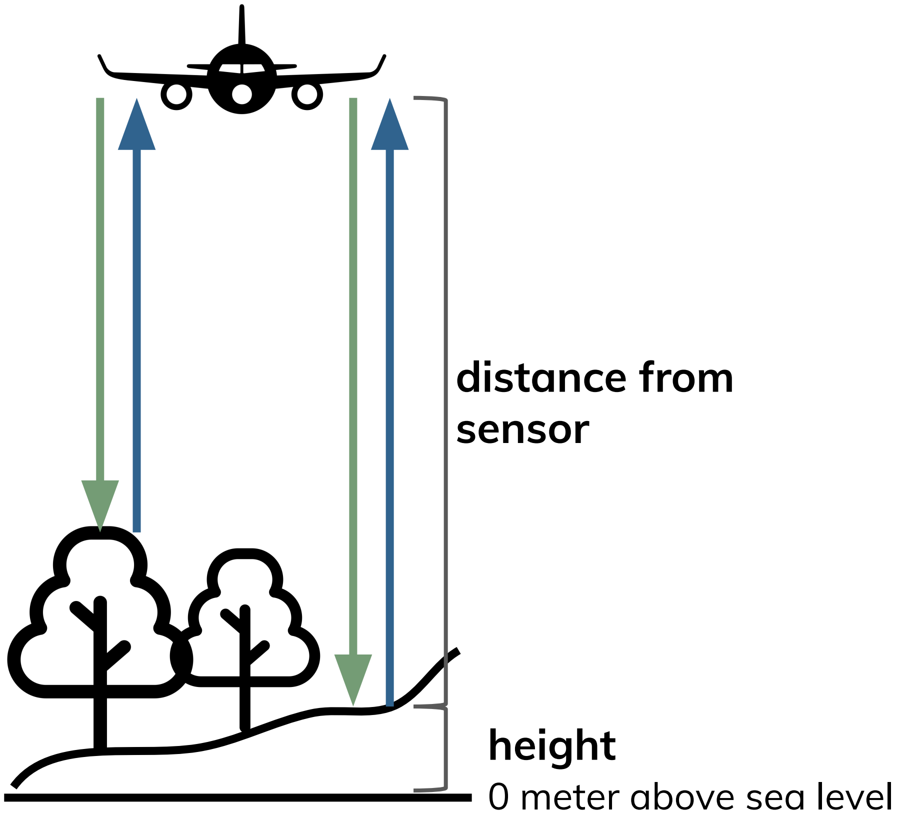
Positioning



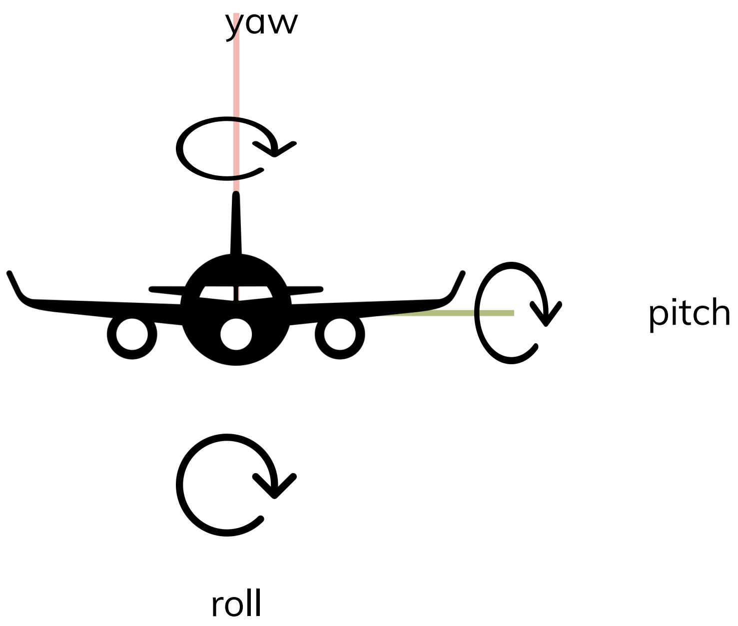
Using energy to measure height

What components to do we need?

- **emit/receive radiation**
    - Laser
- **know location**
    - GPS
- **know orientation**
    - Inertial Measurement Unit
- keep track of everything



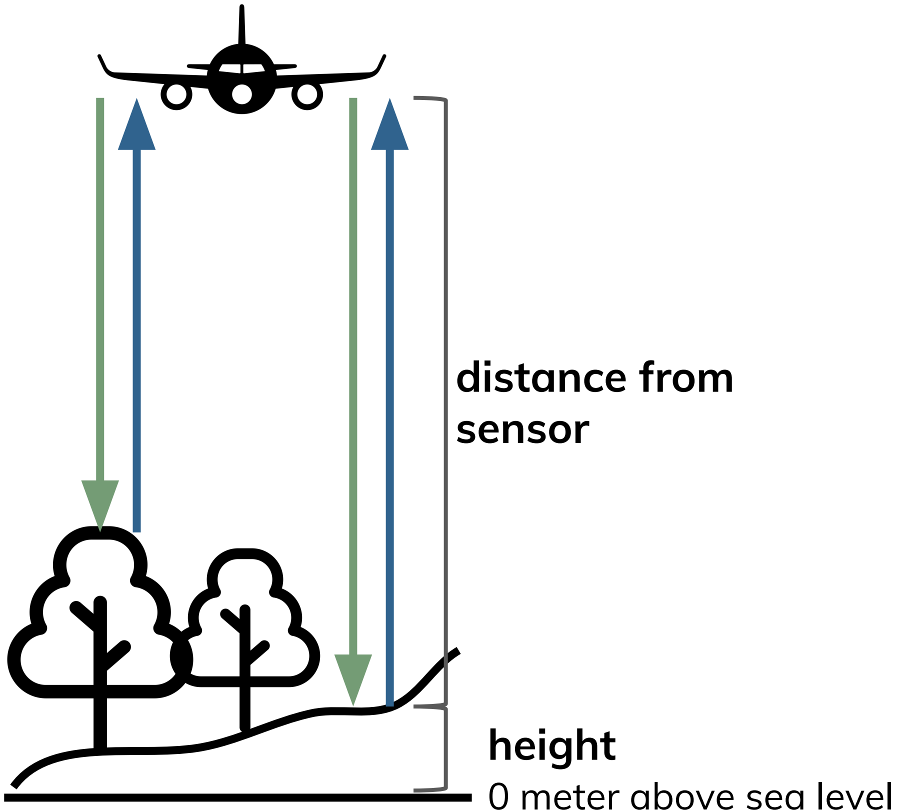
Orientation



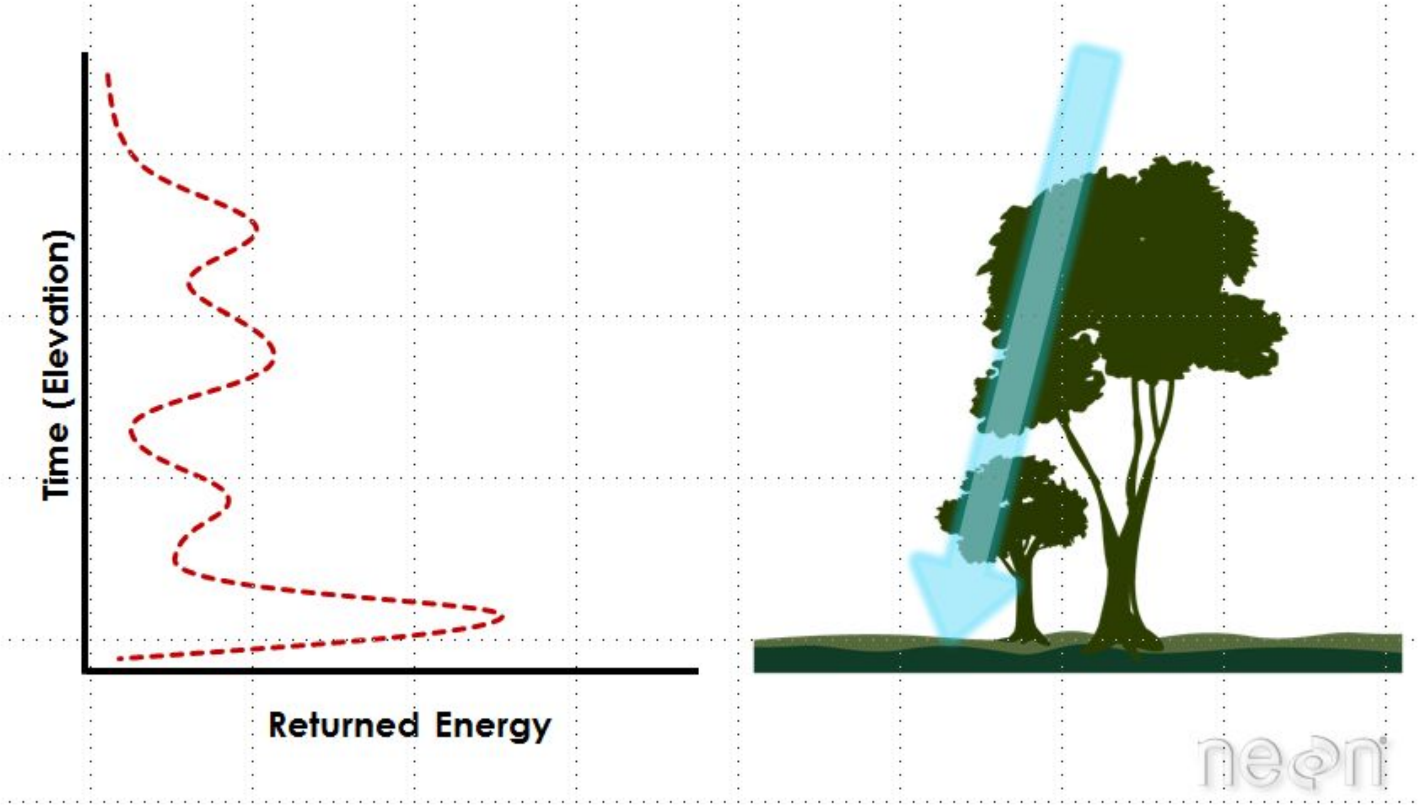
Using energy to measure height

What components to do we need?

- **emit/receive radiation**
  - Laser
- **know location**
  - GPS
- **know orientation**
  - Inertial Measurement Unit
- **keep track of everything**
  - On-board computer

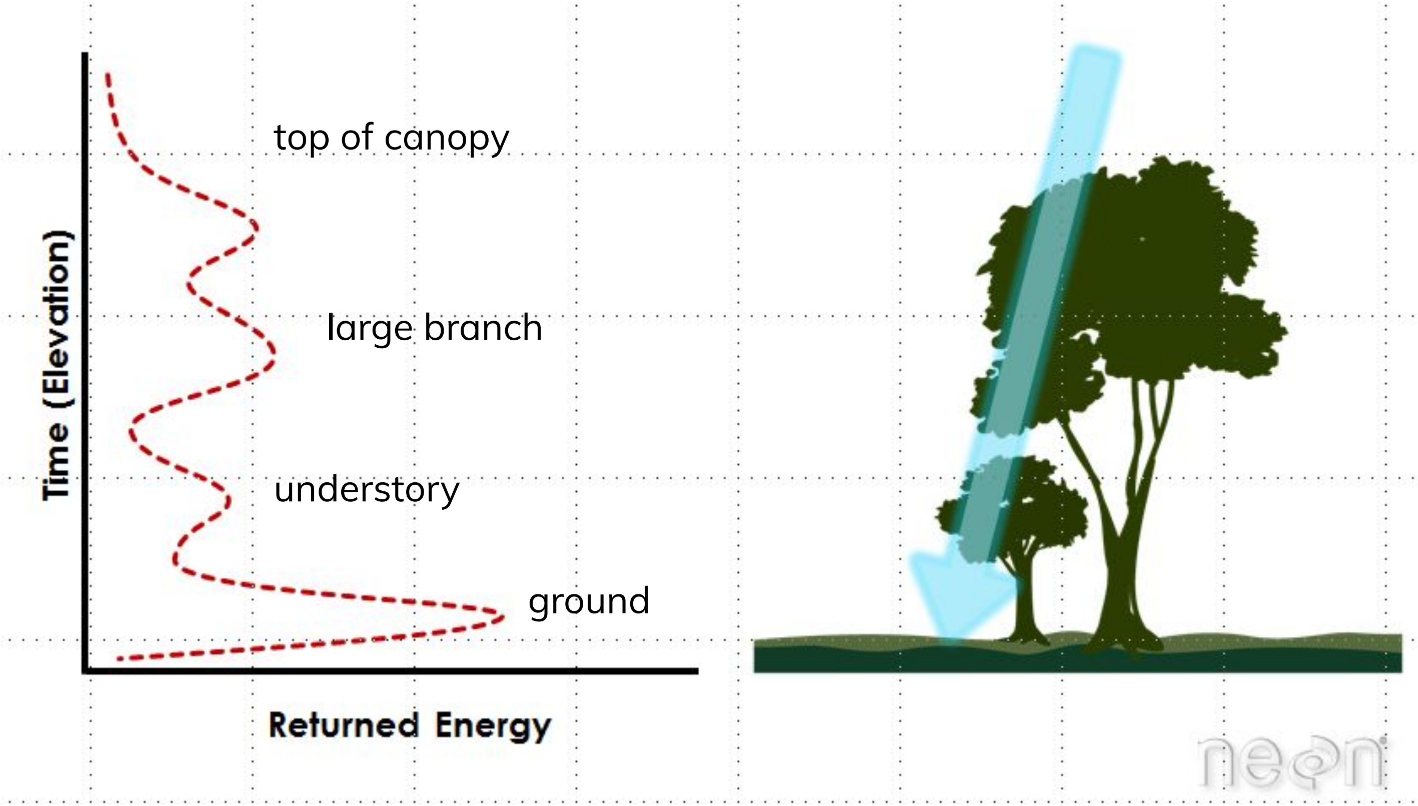


LiDAR energy returns



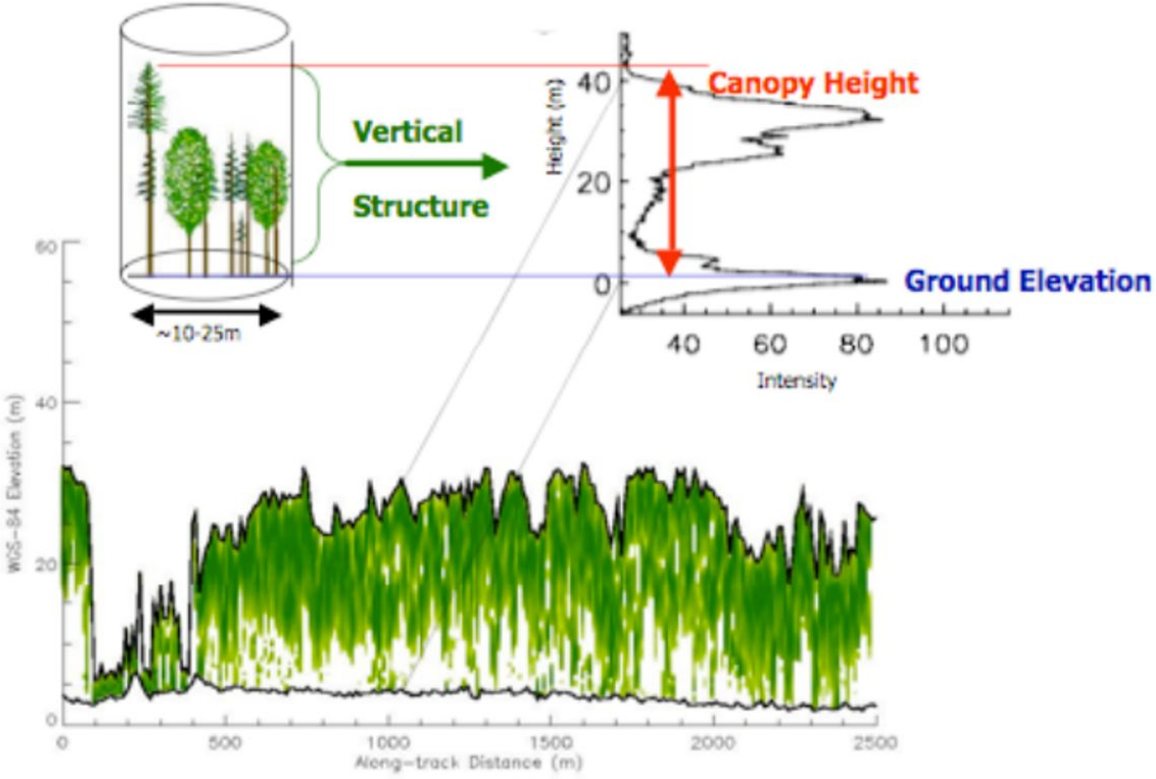
Source: NEON

LiDAR energy returns



Source: NEON

LiDAR energy returns



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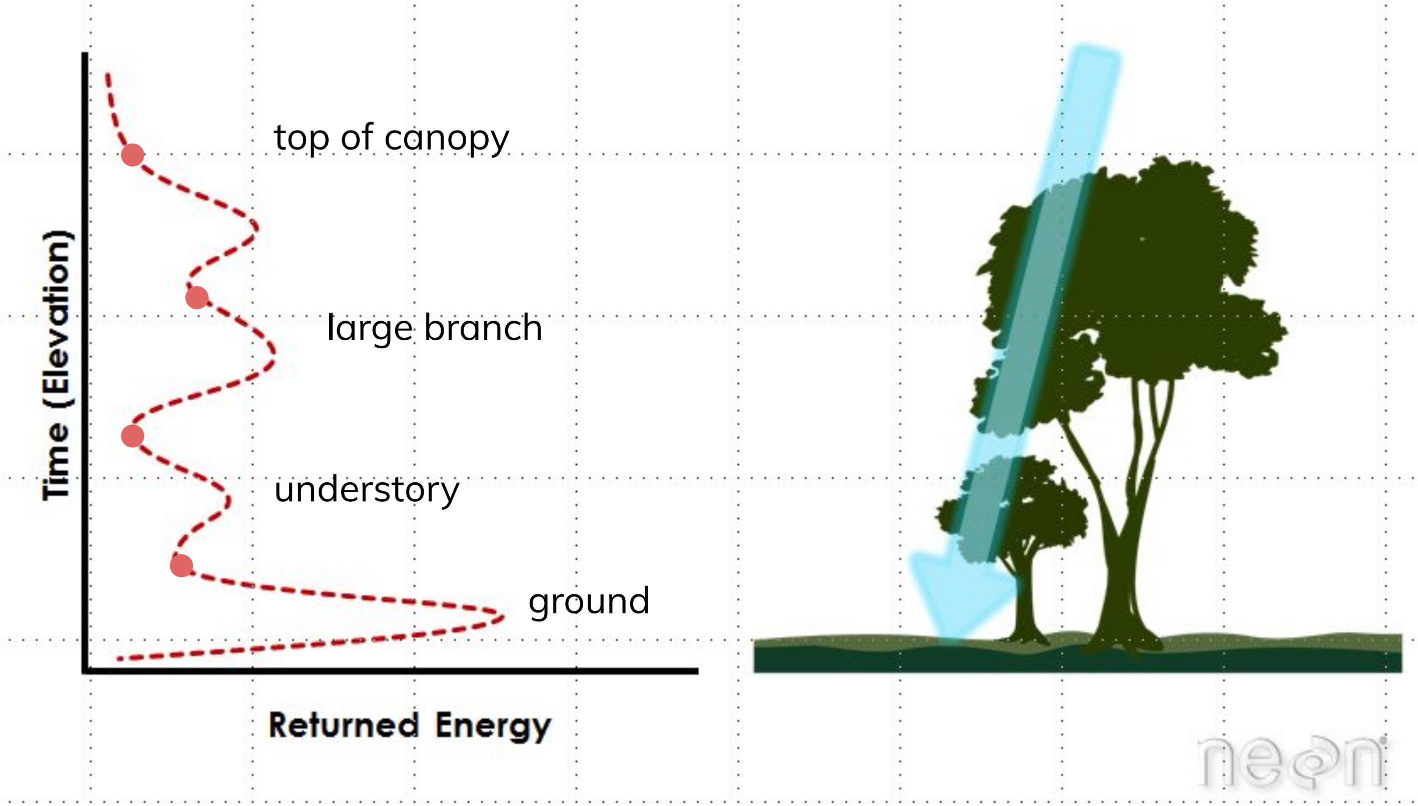

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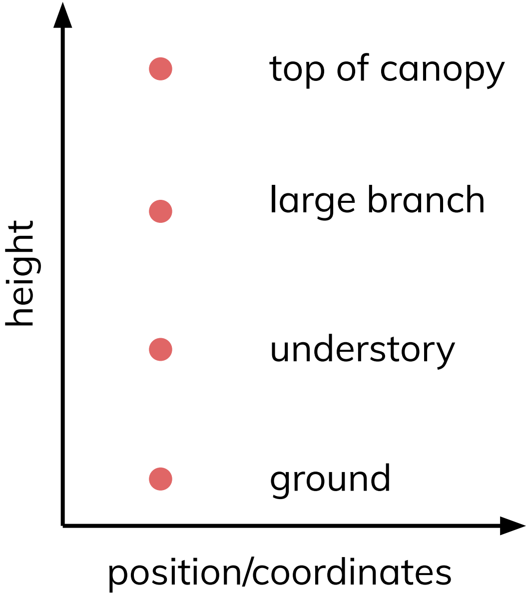
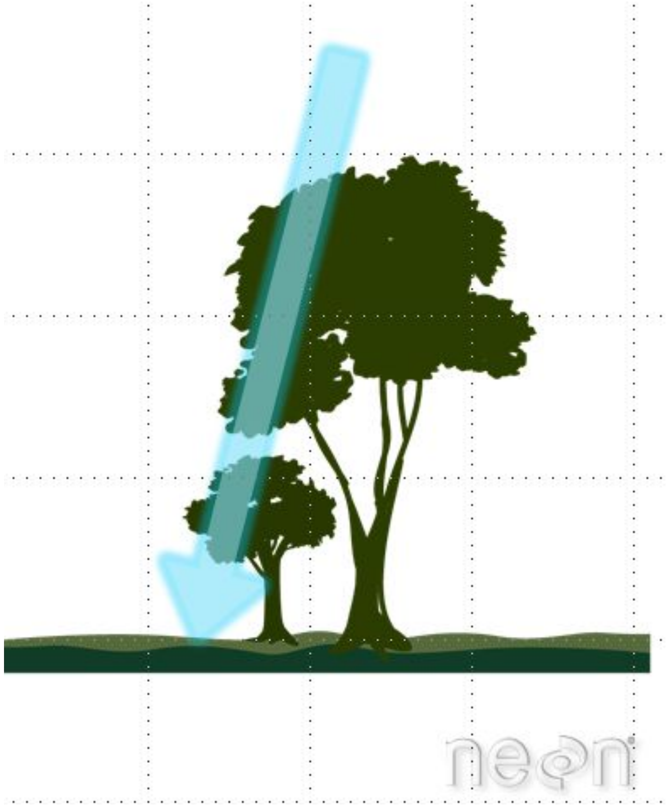
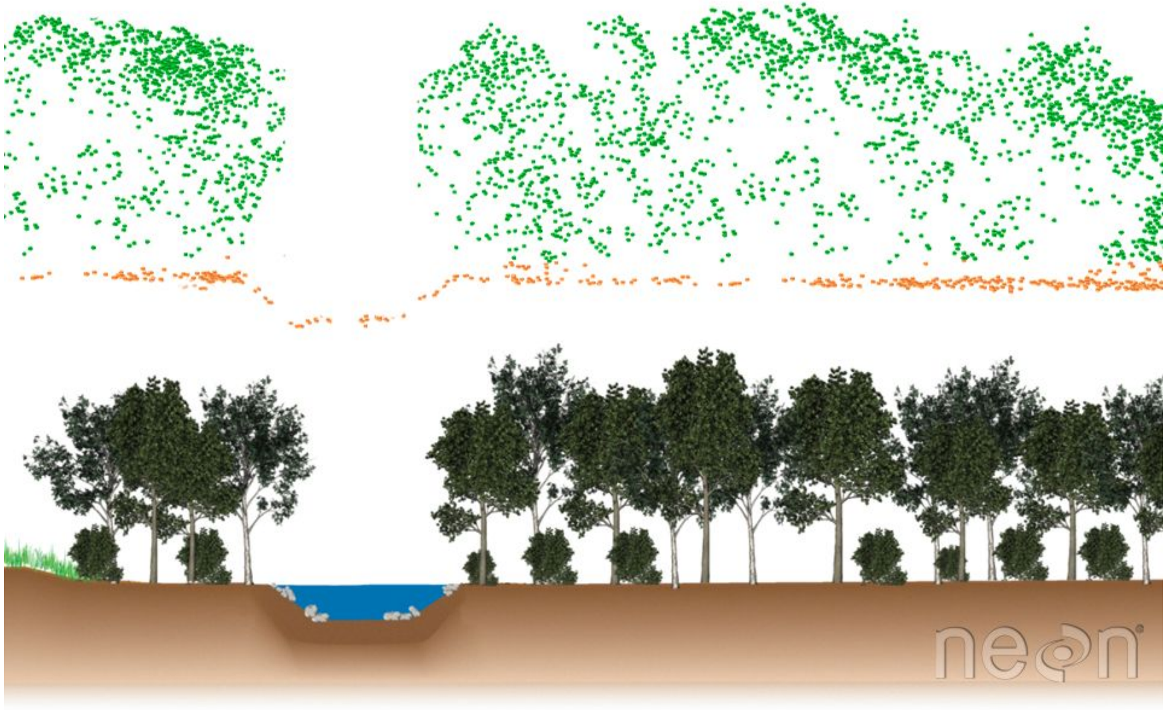
LiDAR energy returns





Source: NEON

LiDAR energy returns



Source: NEON

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

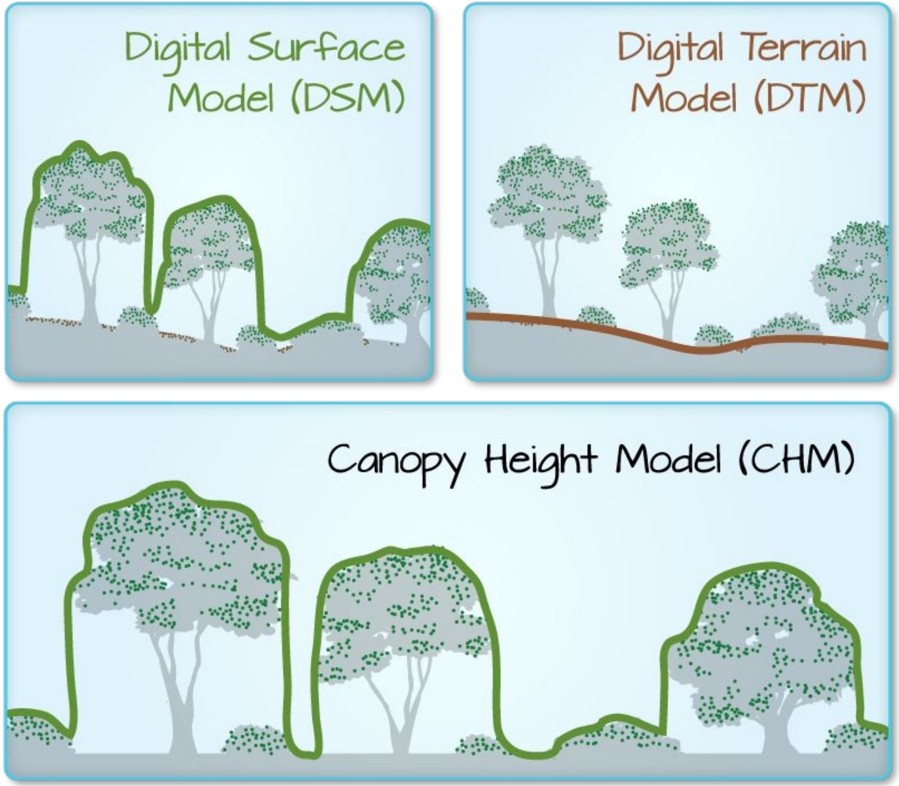
Point clouds to surface models

Source: NEON

Point clouds to surface models

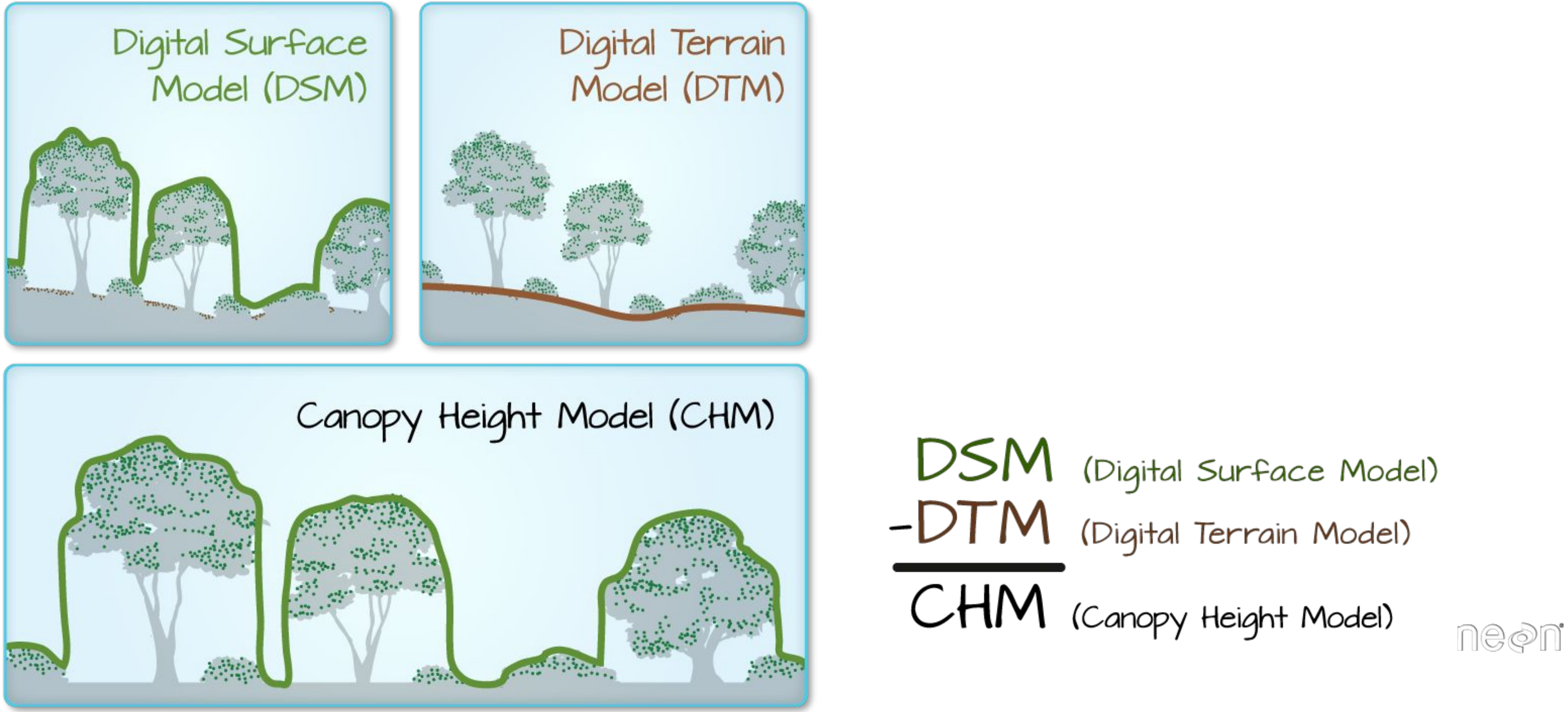
Source: NEON

Point clouds to surface models



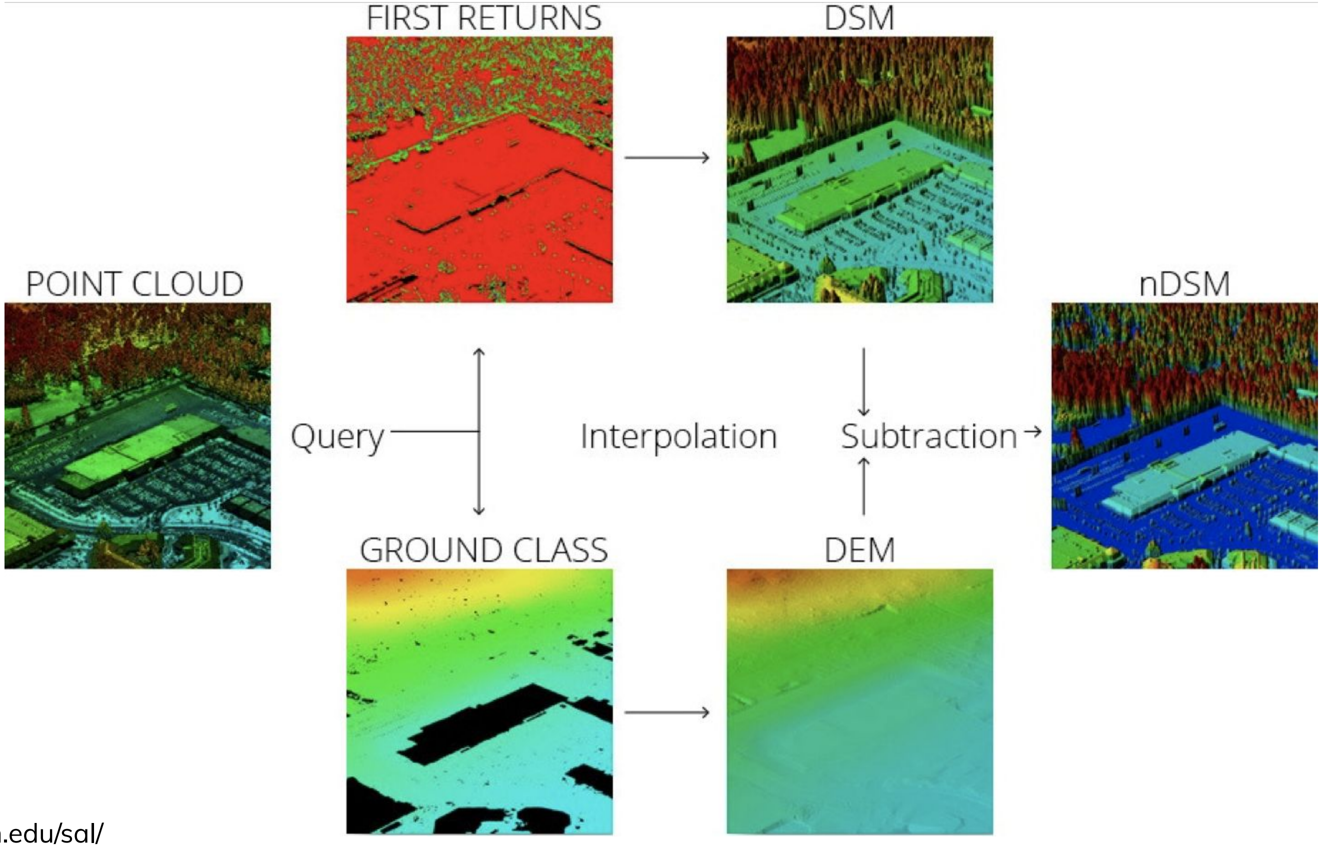
Source: NEON

Point clouds to surface models



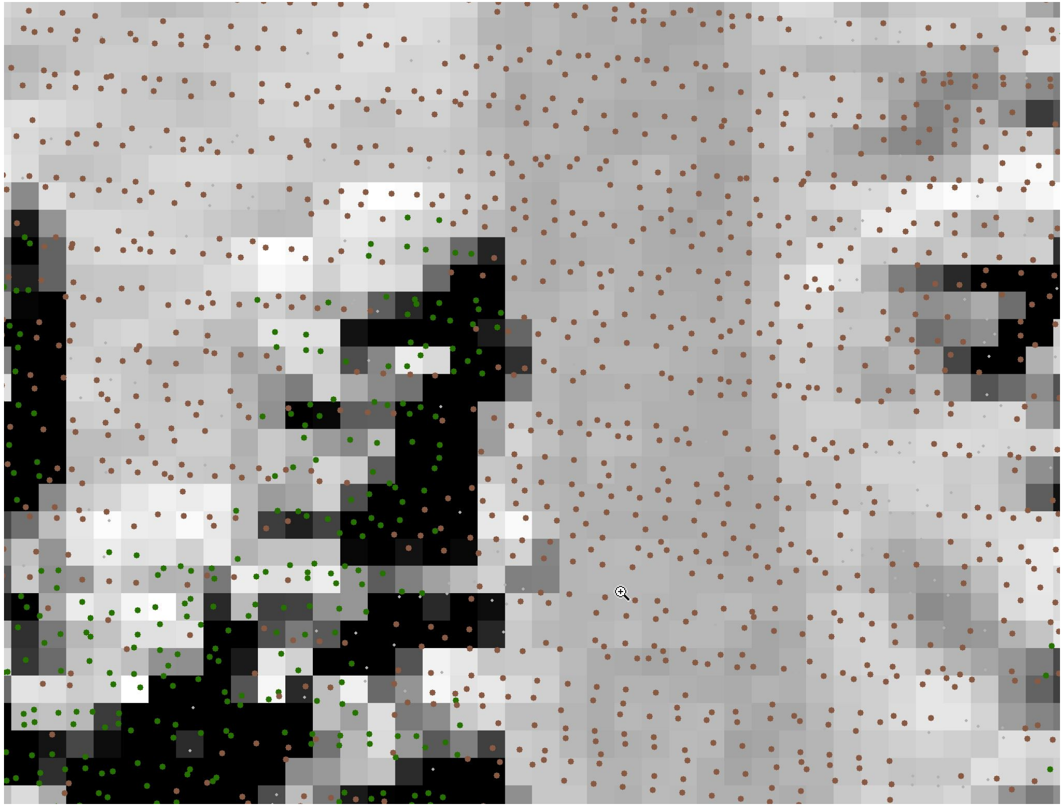
Source: NEON

Point clouds to surface models

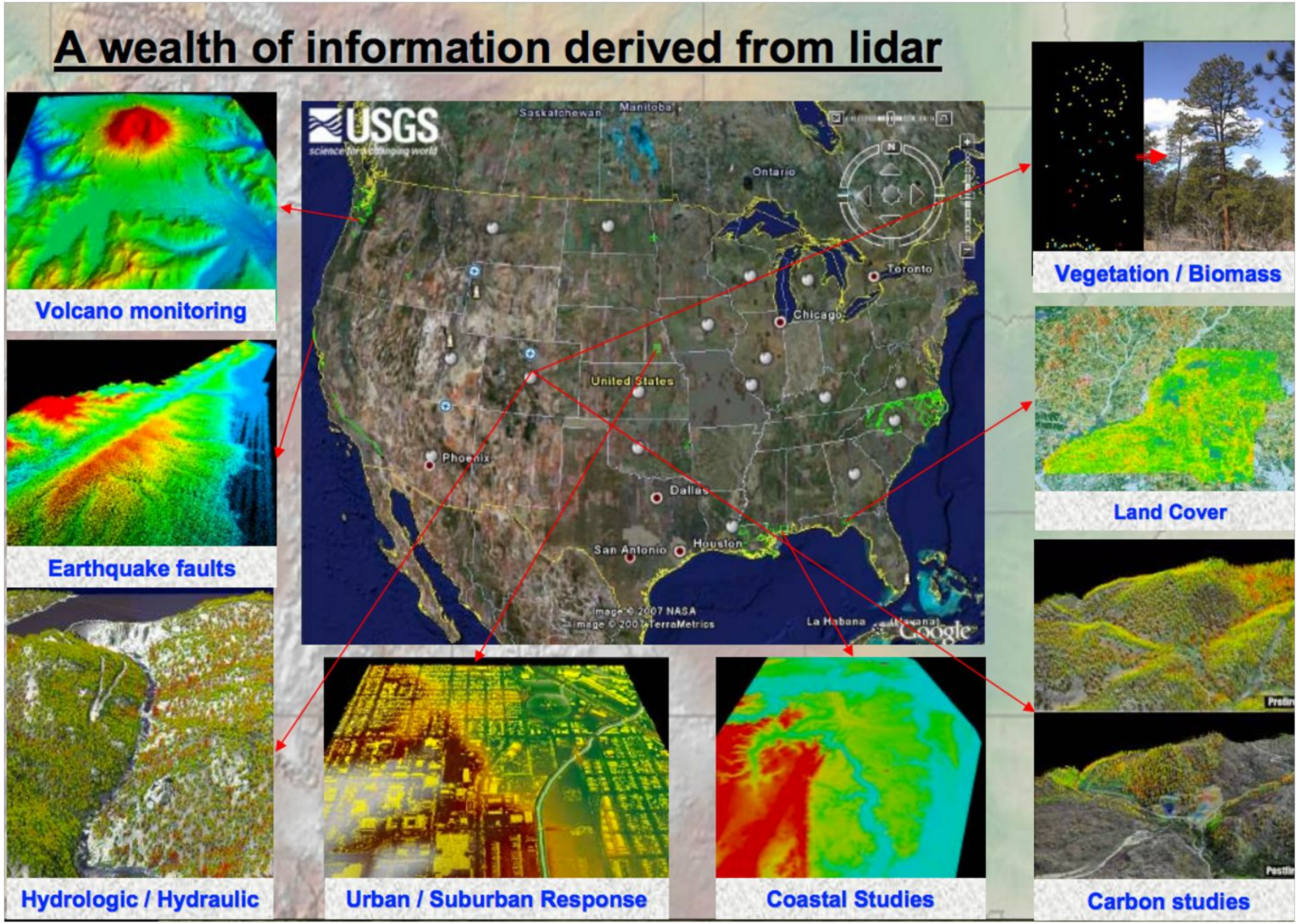


Source: https://site.uvm.edu/sal/

Point clouds to raster

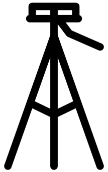


Source: Earth Lab

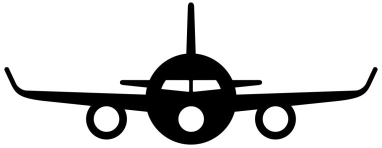

A wealth of information derived from lidar
USGS
Saskatchewan
Manitoba
Ontario
Toronto
Chicago
United States
Phoenix
Dallas
San Antonio
Houston
La Habana
Image © 2007 NASA
Image © 2007 TerraMetrics
Google
Volcano monitoring
Earthquake faults
Hydrologic / Hydraulic
Urban / Suburban Response
Coastal Studies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

Source: USGS

LiDAR systems



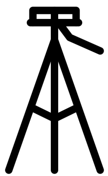
terrestrial



air-borne

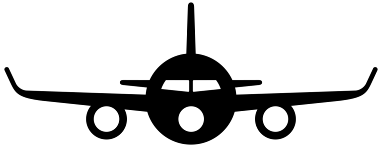
space-borne

LiDAR systems

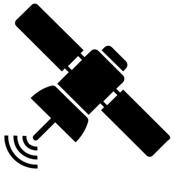


terrestrial

- Best resolution
- Worst coverage



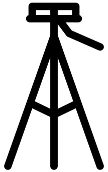
air-borne



space-borne

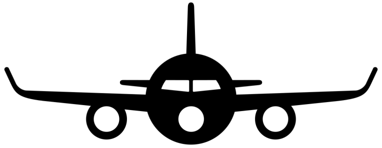
- Worst resolution
- Best coverage

LiDAR systems



terrestrial

- Best resolution
- Worst coverage



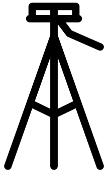
air-borne

- Most common
- Still rare!

space-borne

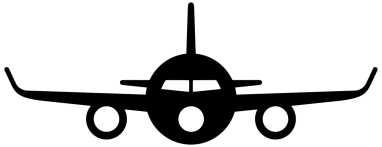
- Worst resolution
- Best coverage

LiDAR systems



terrestrial

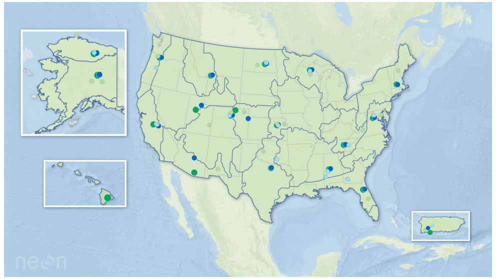
- Best resolution
- Worst coverage



air-borne

- Most common
- Still rare!

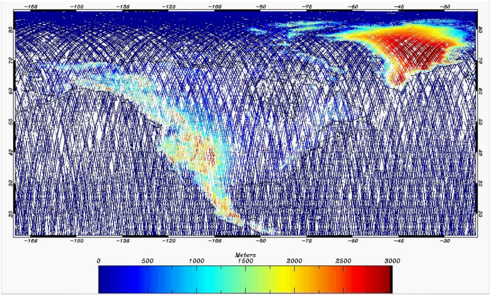
NEON
National Ecological Observatory Network



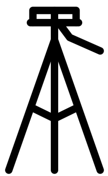
space-borne

- Worst resolution
- Best coverage

ICESat
Ice, Cloud, and land Elevation Satellite

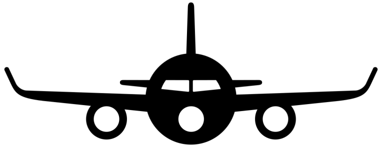


LiDAR systems



terrestrial

- Best resolution
- Worst coverage



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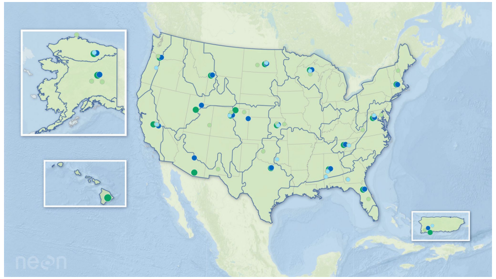
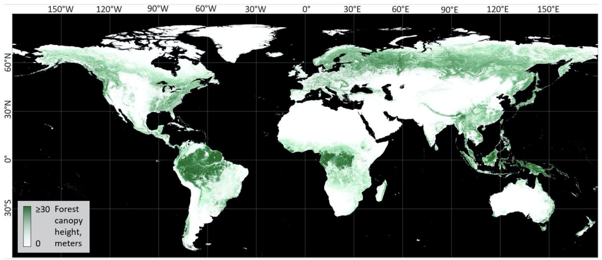
National Ecological Observatory Network



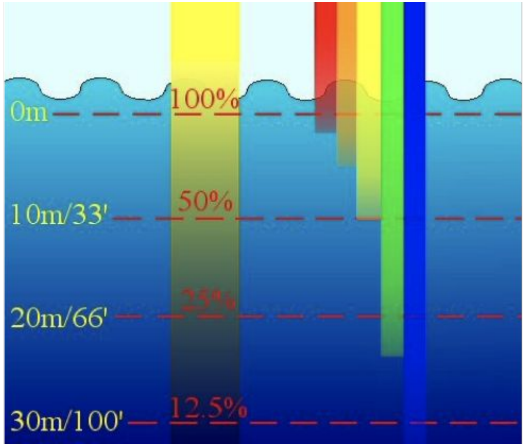
space-borne

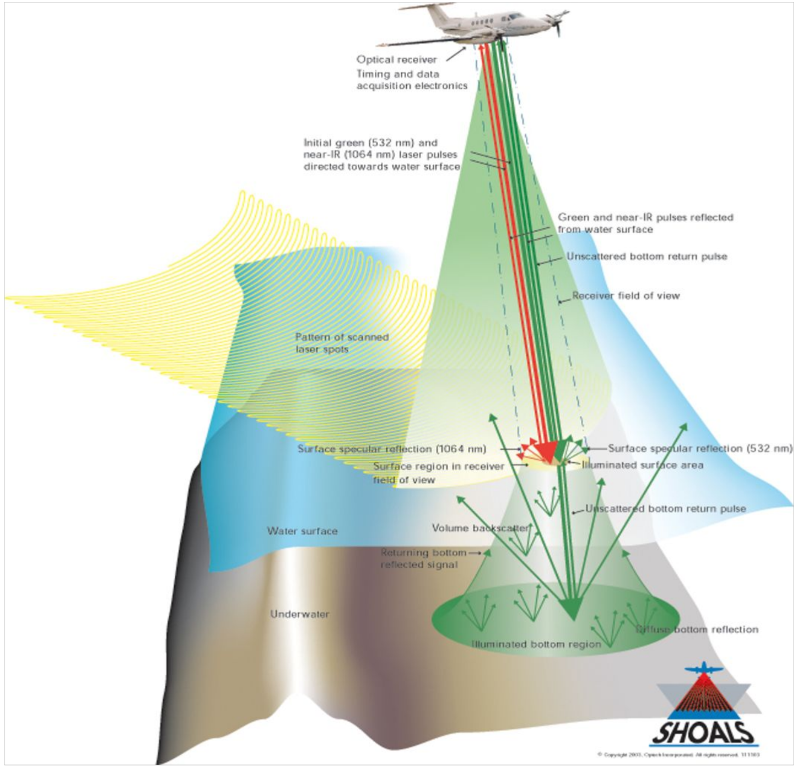
- Worst resolution
- Best coverage

GEDI
Global Ecosystem Dynamics Investigation



Aquatic LiDAR



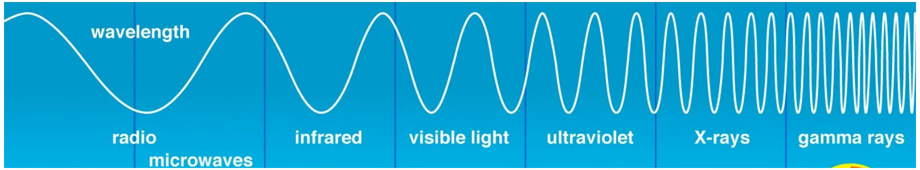


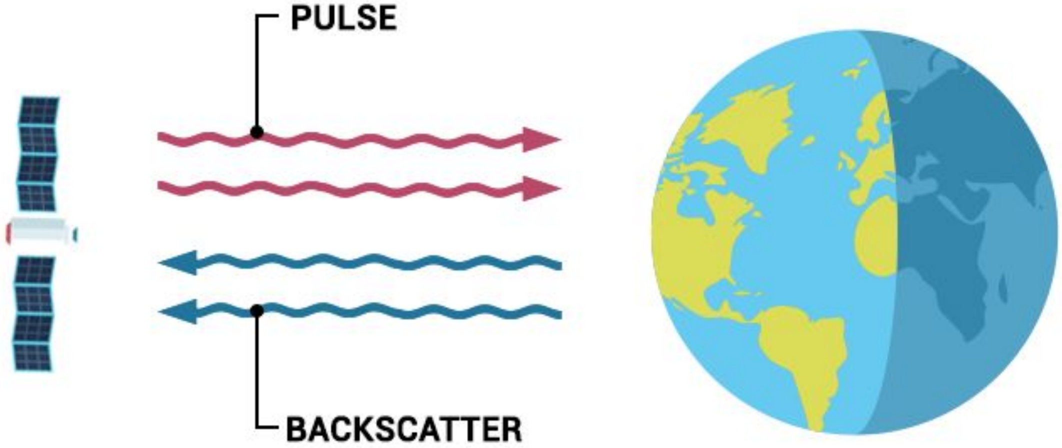
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

LiDAR
Light Detection
and Ranging





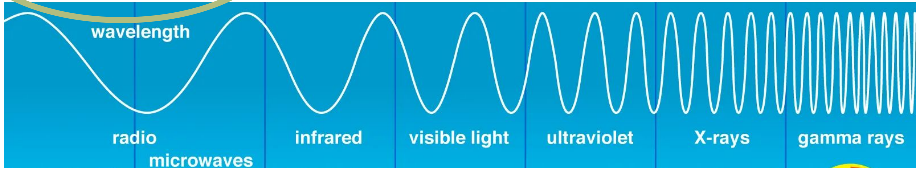
Source: GIS Geography

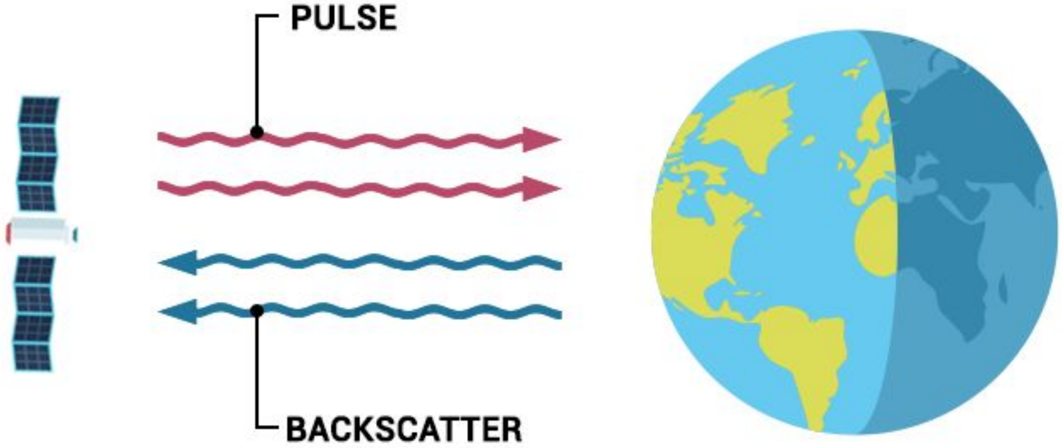
Active remote sensing

What type of energy are we working with?

RADAR
Radio Detection and Ranging

LiDAR
Light Detection and Ranging

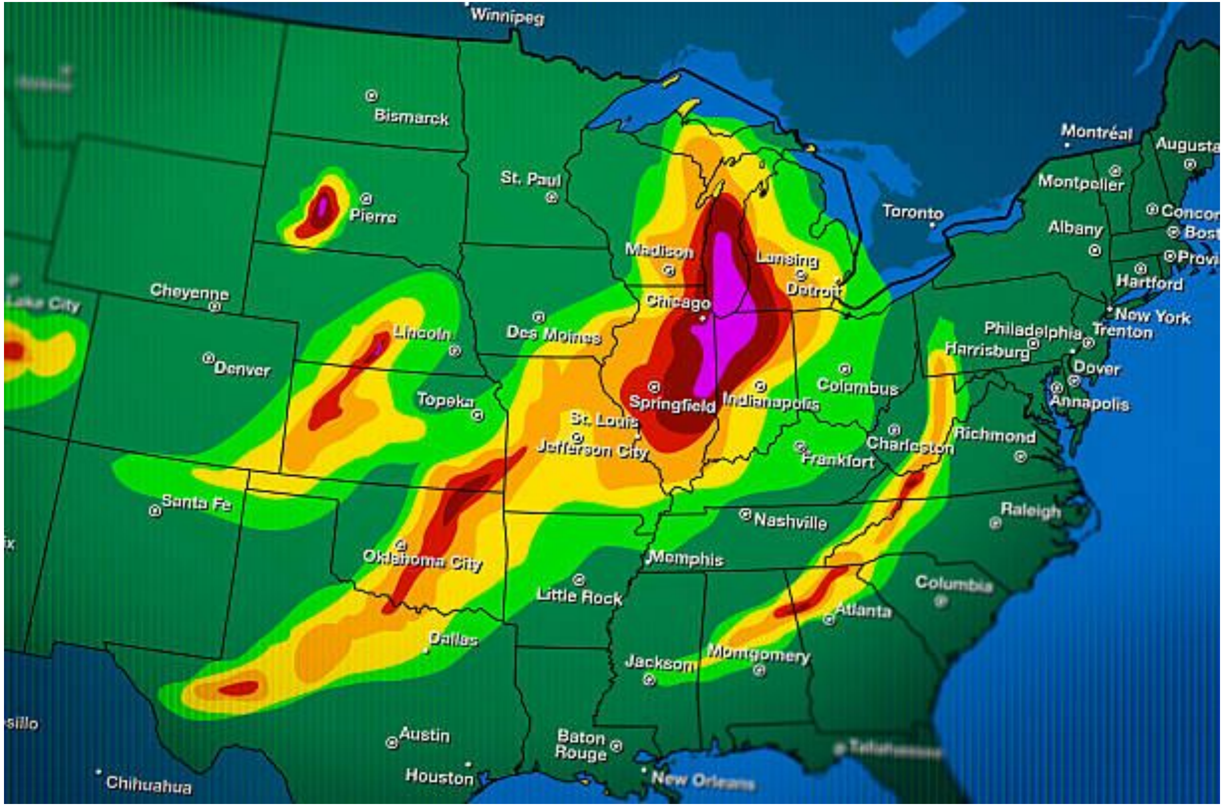




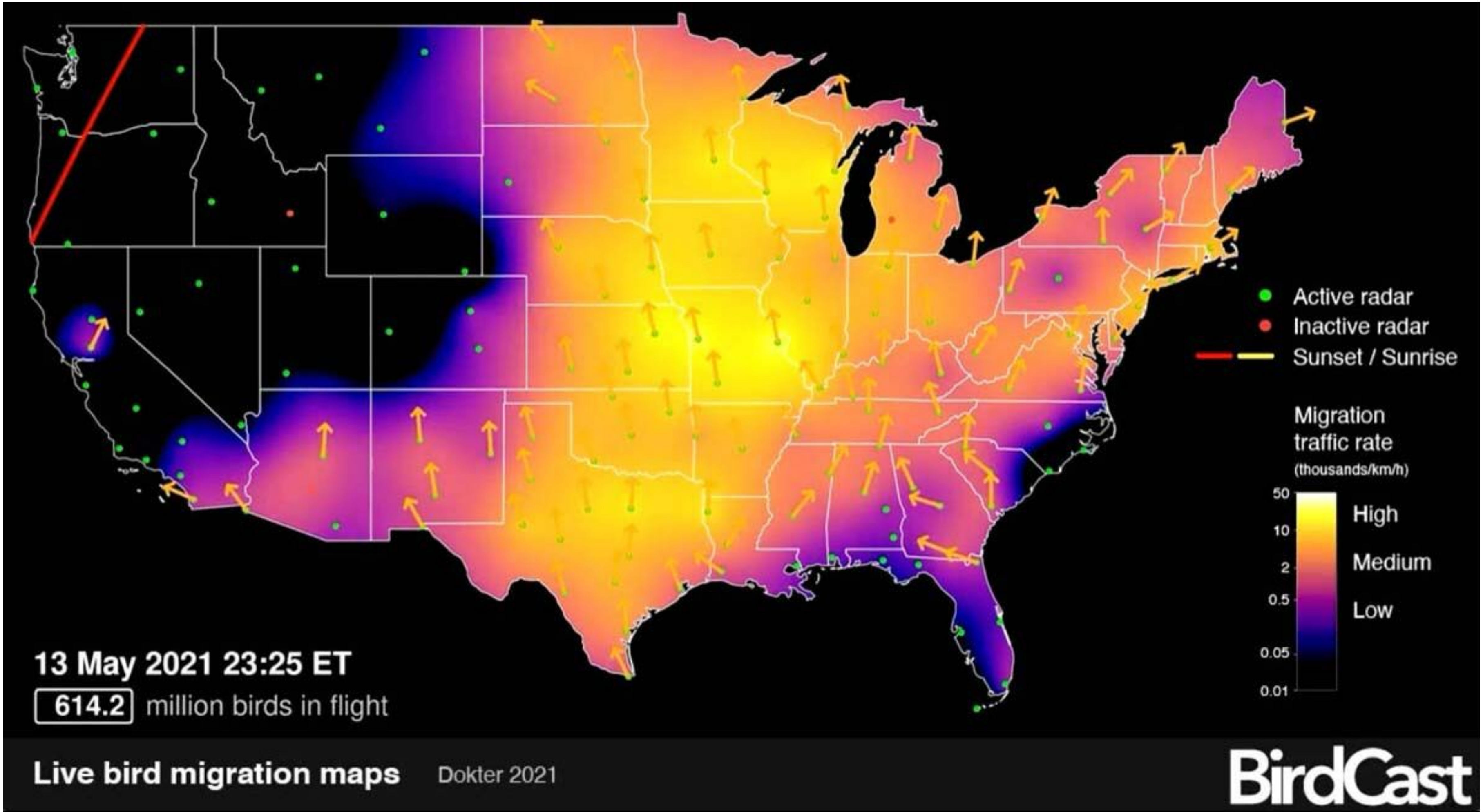
Source: GIS Geography

A note on context…

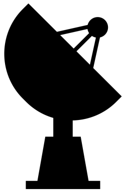
https://www.youtube.com/watch?v=xpIRqdxqDyY&ab_channel=CanadaAviationandSpaceMuseum



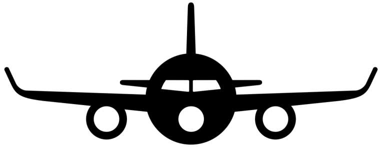
Winnipeg
Bismarck
St. Paul
Pierre
Madison
Lansing
Detroit
Chicago
Cheyenne
Lincoln
Des Moines
Denver
Topeka
Springfield
Indianapolis
Columbus
St. Louis
Jefferson City
Frankfort
Charleston
Richmond
Santa Fe
Nashville
Raleigh
Oklahoma City
Memphis
Little Rock
Columbia
Atlanta
Dallas
Jackson
Montgomery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


Active radar
Inactive radar
Sunset / Sunrise
Migration traffic rate
(thousands/km/h)
50
10
2
0.5
0.05
0.01
High
Medium
Low
13 May 2021 23:25 ET
614.2 million birds in flight
Live bird migration maps
Dokter 2021
BirdCast

RADAR systems



terrestrial



air-borne

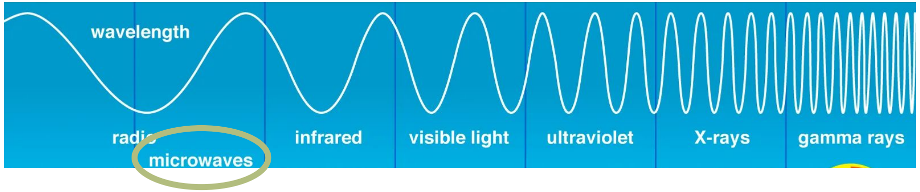
space-borne

"remote sensing"

RADAR electromagnetic

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

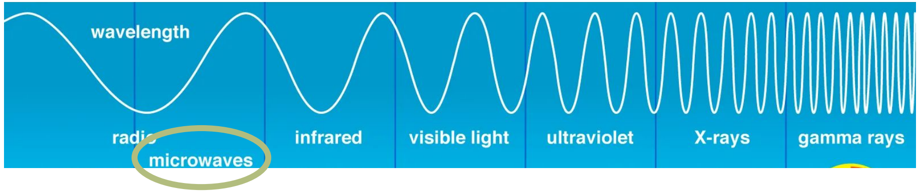


Source: GIS Geography

RADAR electromagnetic wavelengths

What type of energy are we working with?

RADAR
Radio Detection
and Ranging

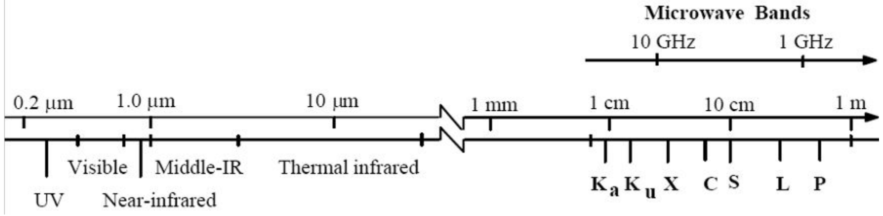


Source: GIS Geography

RADAR electromagnetic wavelengths

longer wavelengths

Band Designations (common wavelengths shown in parentheses)	*Wavelength (λ) in cm*	*Frequency (ν) in GHz*
K	1.18 - 1.67	26.5 to 18.0
K_a (0.86 cm)	0.75 - 1.18	40.0 to 26.5
K_u	1.67 - 2.4	18.0 to 12.5
X (3.0 and 3.2 cm)	2.4 - 3.8	12.5 - 8.0
C (7.5, 6.0 cm)	3.8 - 7.5	8.0 - 4.0
S (8.0, 9.6, 12.6 cm)	7.5 - 15.0	4.0 - 2.0
L (23.5, 24.0, 25.0 cm)	15.0 - 30.0	2.0 - 1.0
P (68.0 cm)	30.0 - 100	1.0 - 0.3



Source: Jensen 2007

RADAR electromagnetic wavelengths

longer wavelengths

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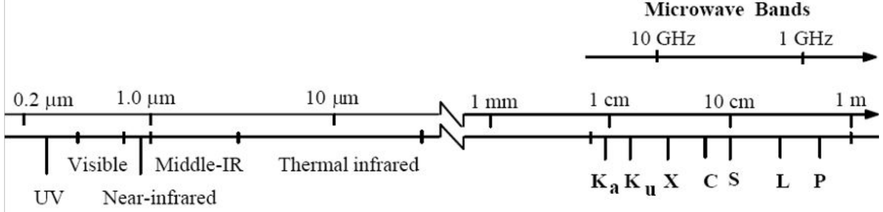

feature size

clouds/precipitation

ice

geology

Source: Jensen 2007

RADAR electromagnetic wavelengths

longer wavelengths

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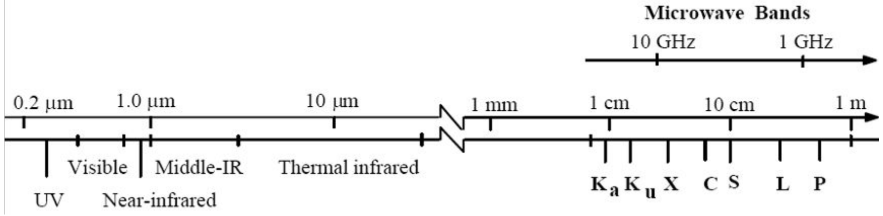


feature size

clouds/precipitation

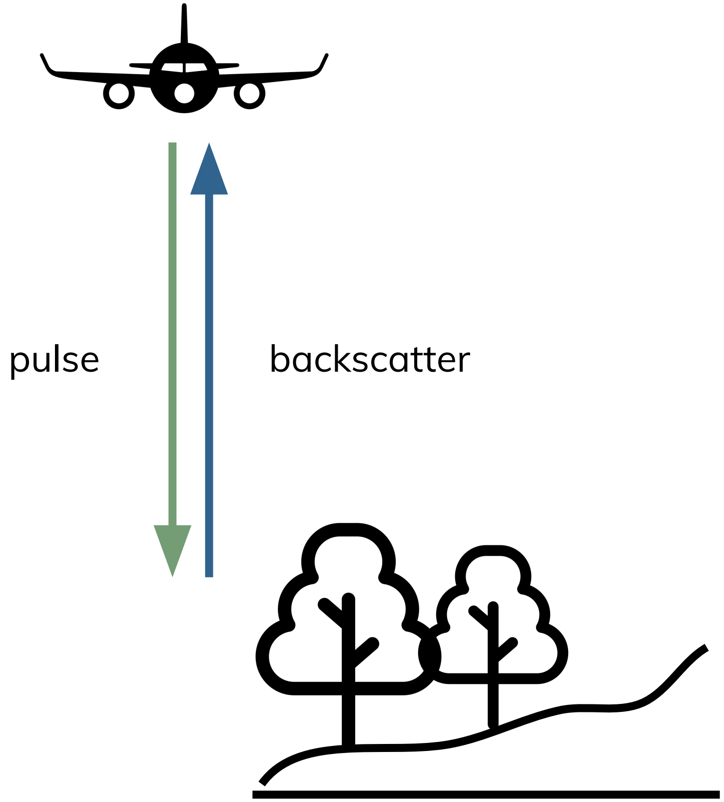
ice

geology

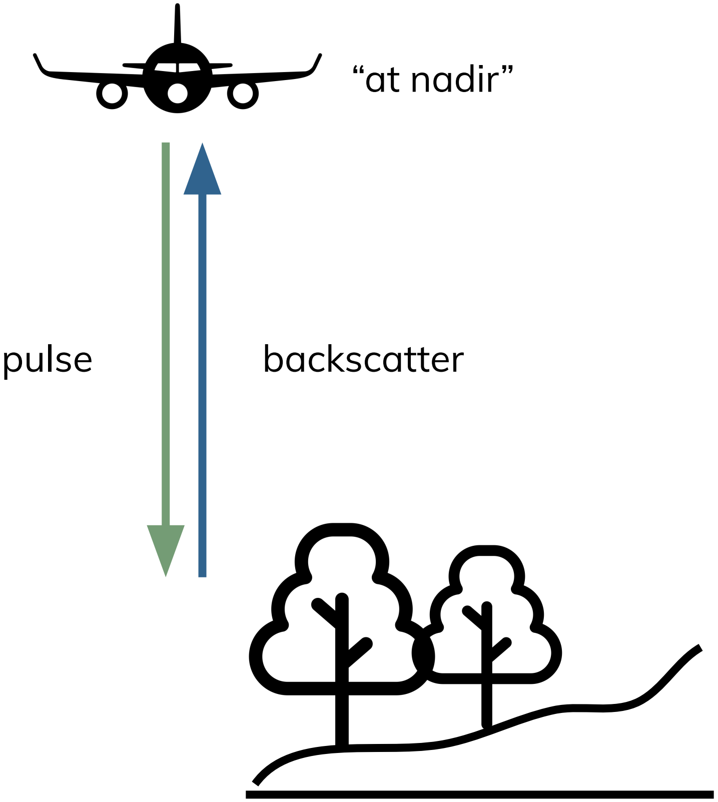
makes it through clouds!

Source: Jensen 2007

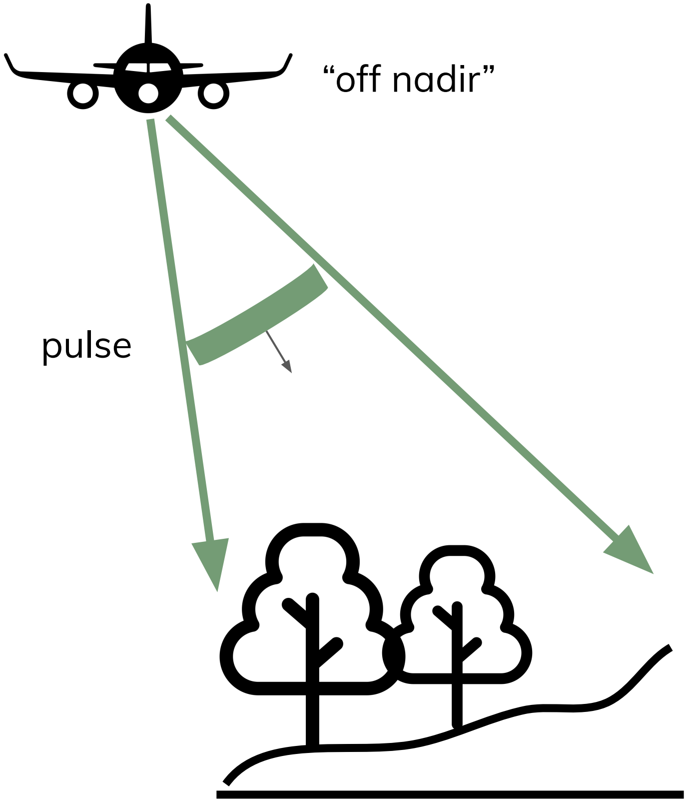
RADAR viewing geometry



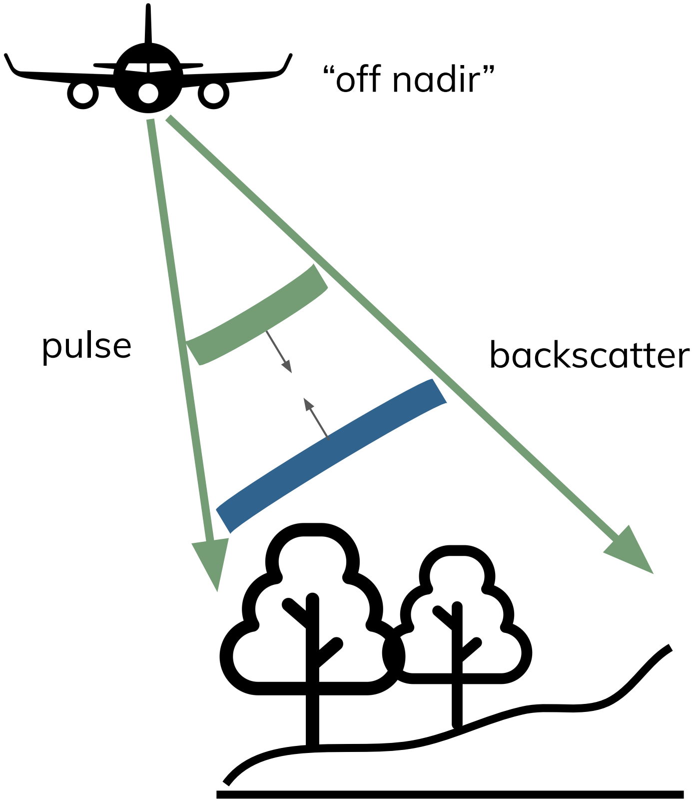
RADAR viewing geometry



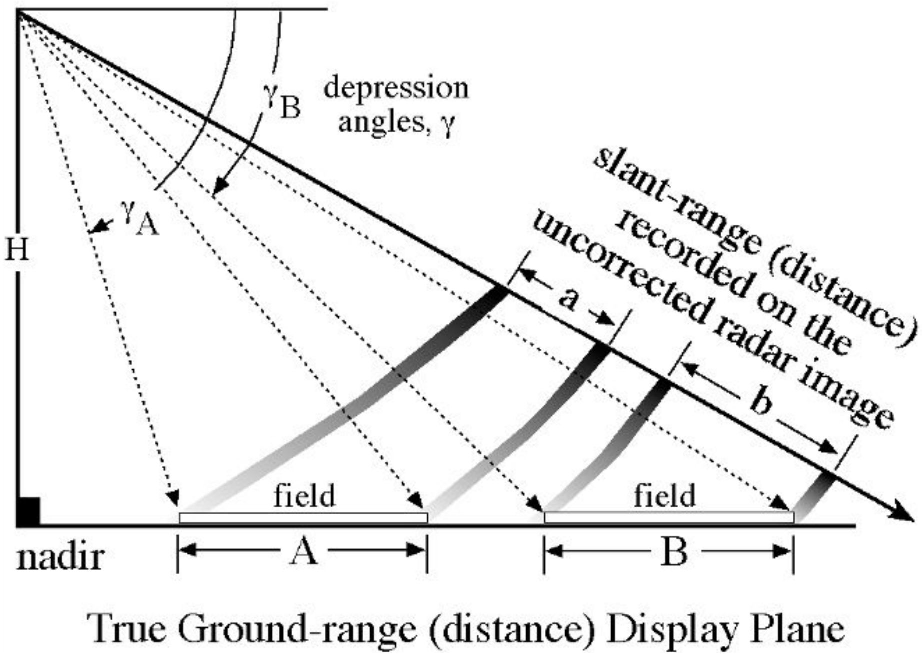
RADAR viewing geometry



RADAR viewing geometry



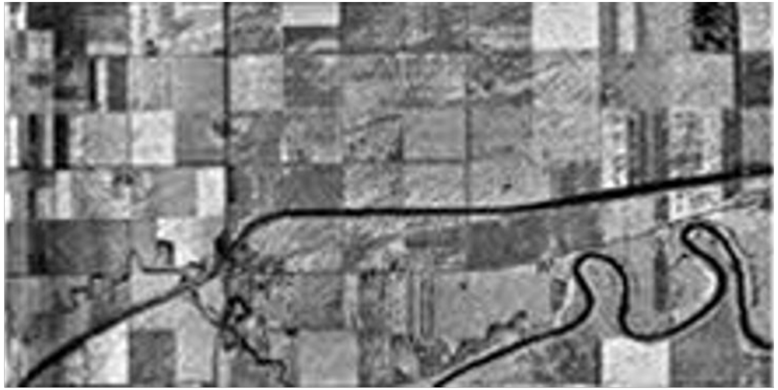
RADAR viewing geometry



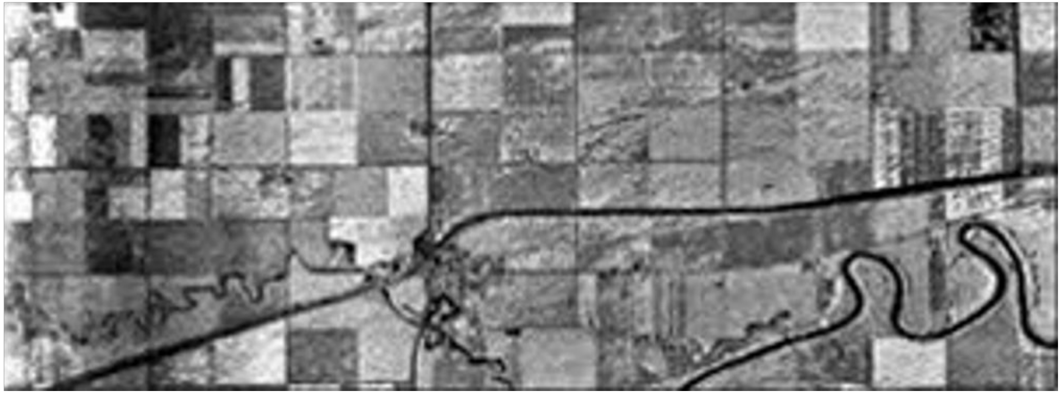
Source: Jensen 2007

RADAR viewing geometry

uncorrected
slant-range geometry



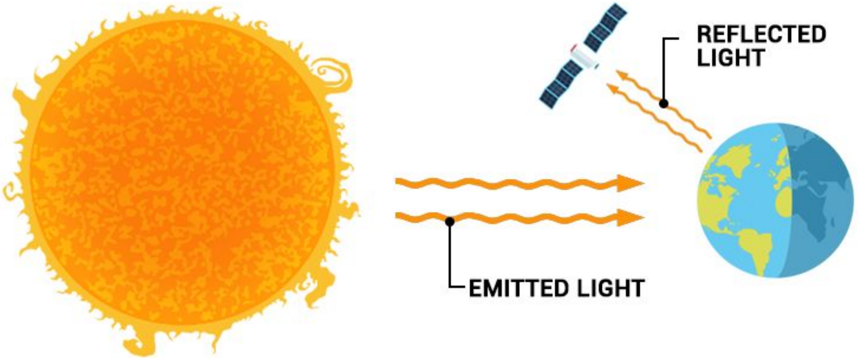
corrected
ground-range geometry



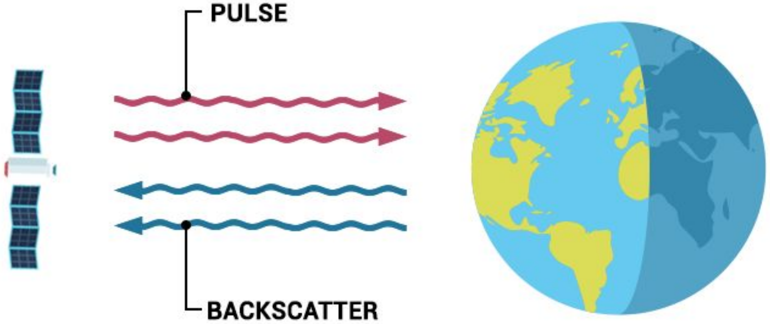
Source: MicroImages

Microwave interactions with matter

Passive systems:



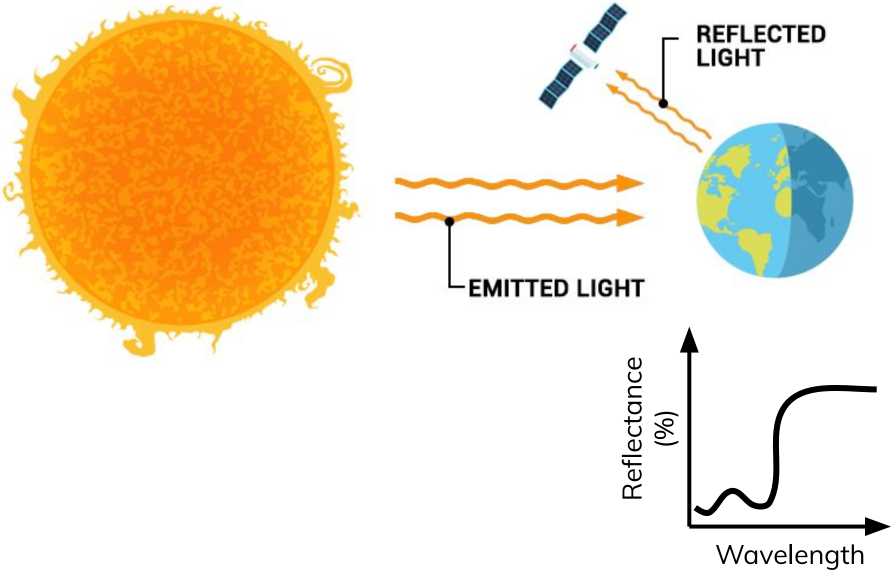
Active systems:



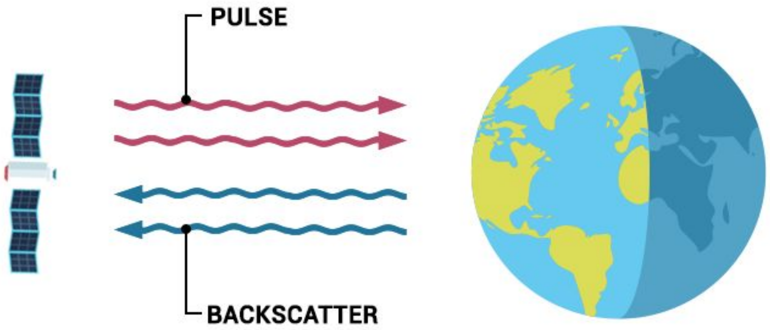
Source: GIS Geography

Microwave interactions with matter

Passive systems:



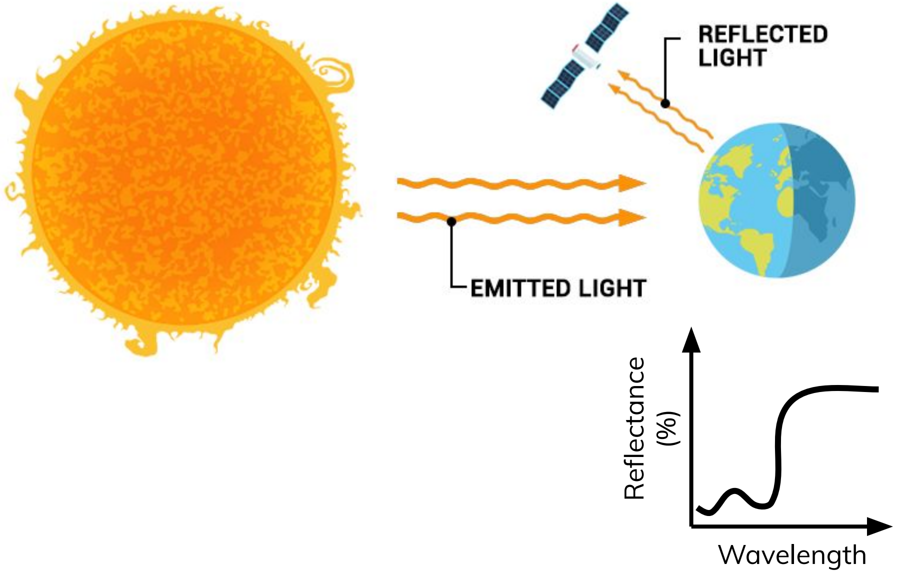
Active systems:



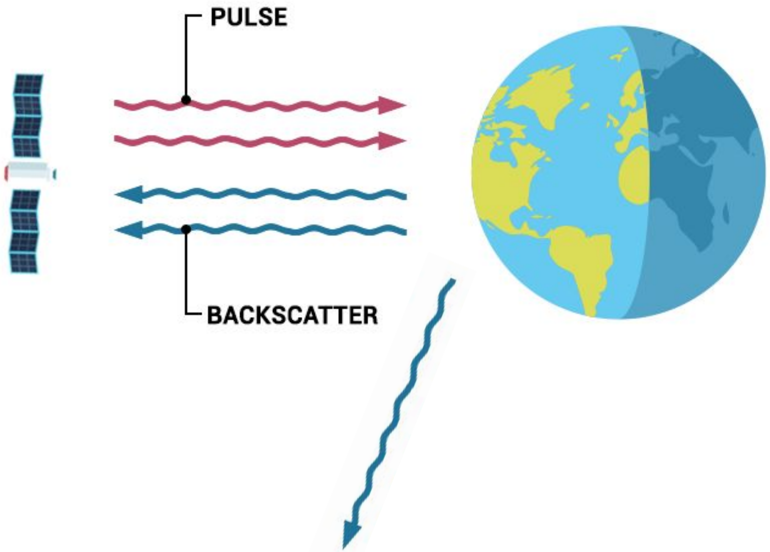
Source: GIS Geography

Microwave interactions with matter

Passive systems:



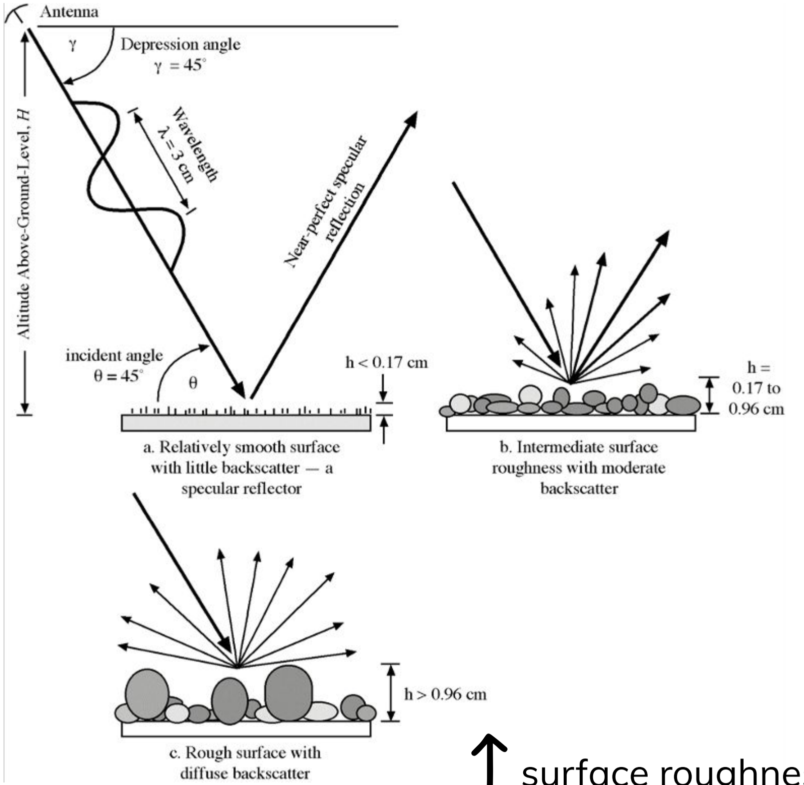
Active systems:



won’t be seen by sensor!

Source: GIS Geography

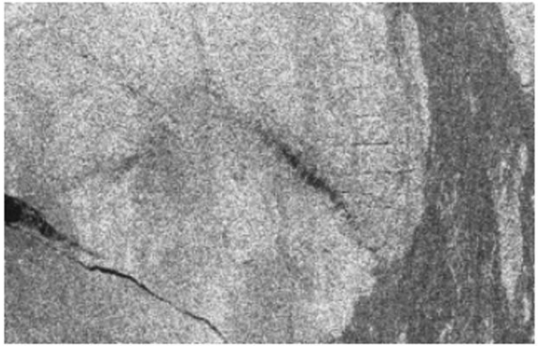
Microwave interactions with matter



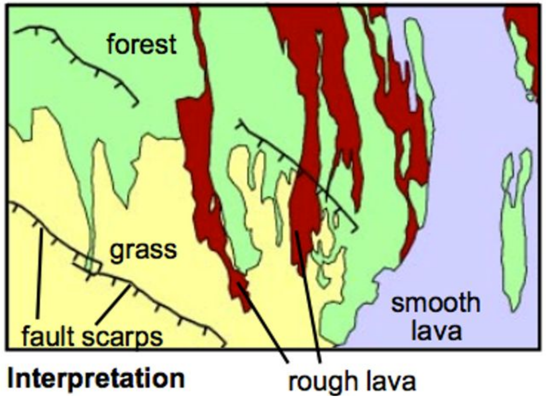
↑ surface roughness ⟶ ↑ backscatter

Source: Jensen 2007

Microwave interactions with matter



C-Band VV (wavelength = 6 cm)



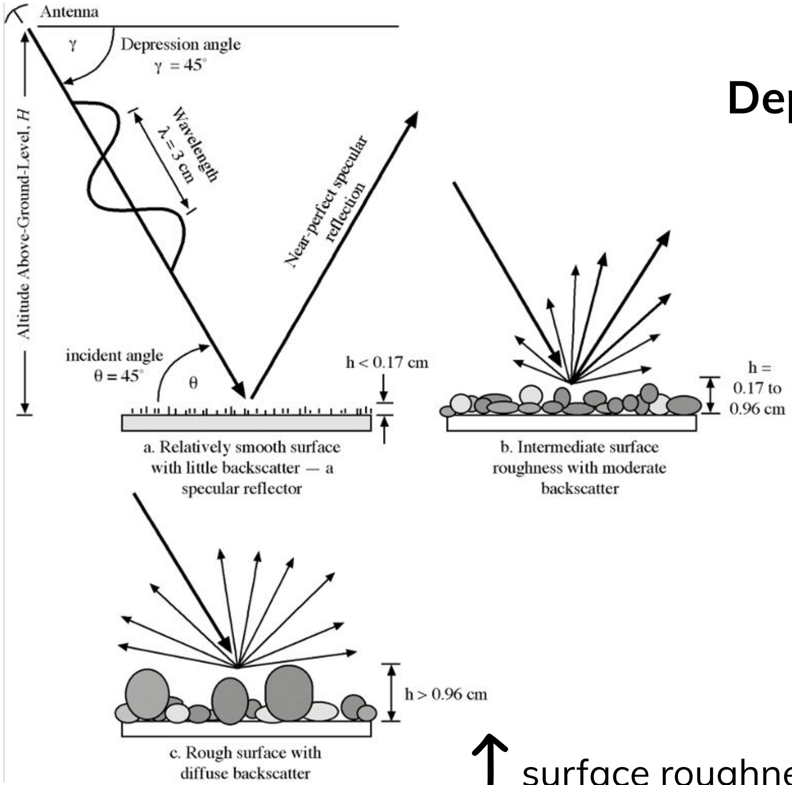
Interpretation

↑ surface roughness ⟶ ↑ backscatter

↑ brightness

Source: MicroImages

Microwave interactions with matter



Depends on wavelength!!

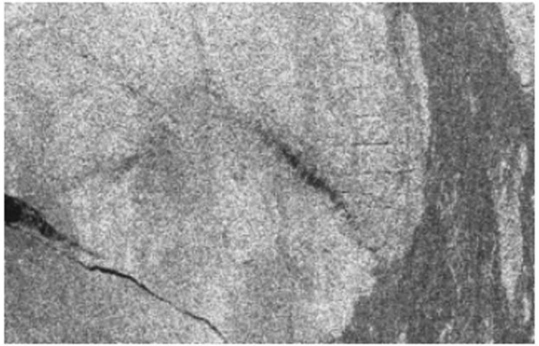
↑ surface roughness ⟶ ↑ backscatter

Source: Jensen 2007

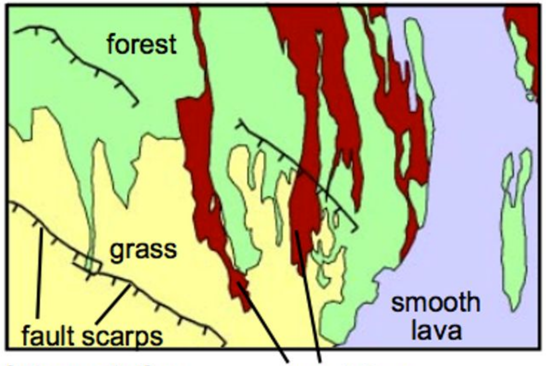
Microwave interactions with matter

Microwave interactions with matter

Microwave interactions with matter



C-Band VV (wavelength = 6 cm)



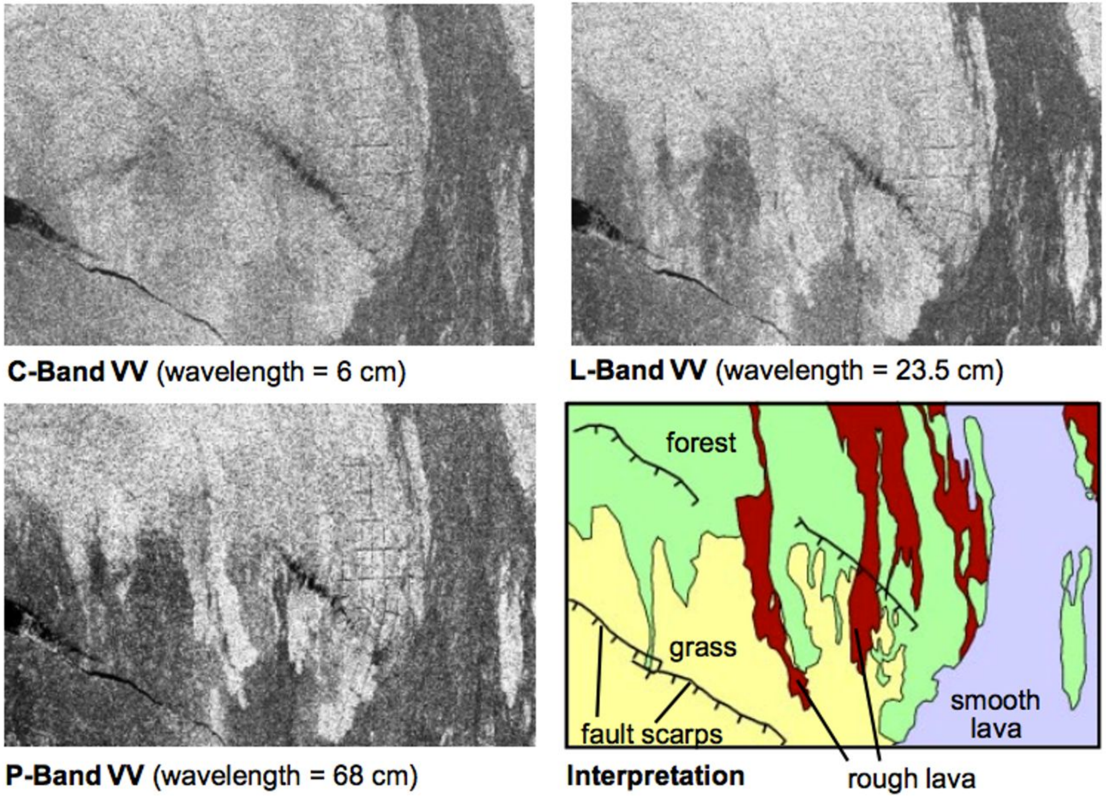
Interpretation

↑ surface roughness → ↑ backscatter

↑ brightness

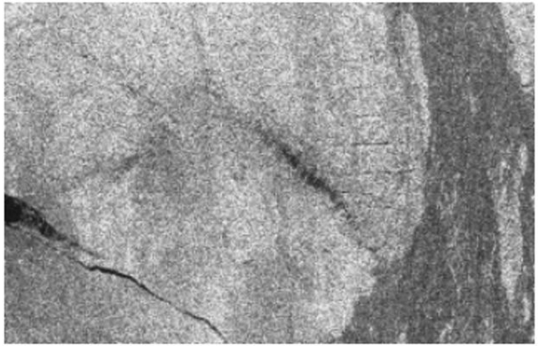
Source: MicroImages

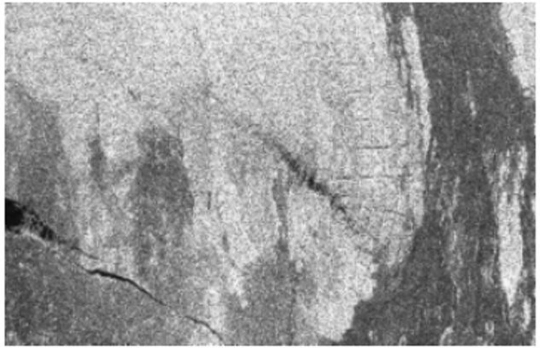
Microwave interactions with matter



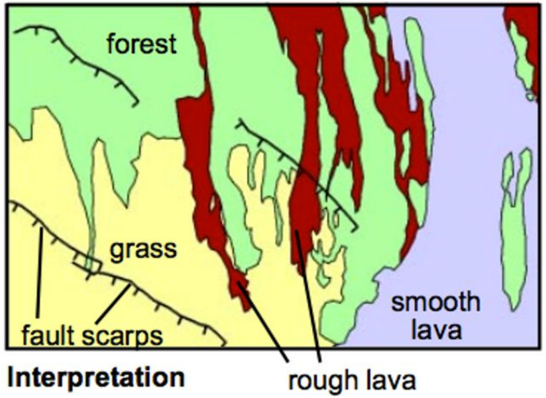
Source: MicroImages

Microwave interactions with matter


C-Band VV (wavelength = 6 cm)


L-Band VV (wavelength = 23.5 cm)


P-Band VV (wavelength = 68 cm)



Interpretation

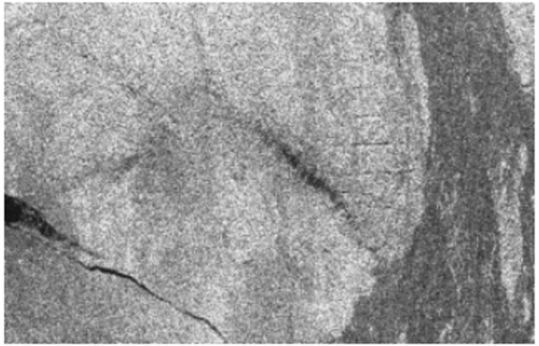
↑ wavelength

↓

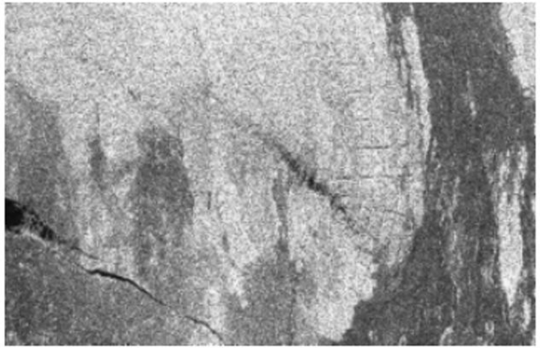
↑ materials appear smooth

Source: MicroImages

Microwave interactions with matter

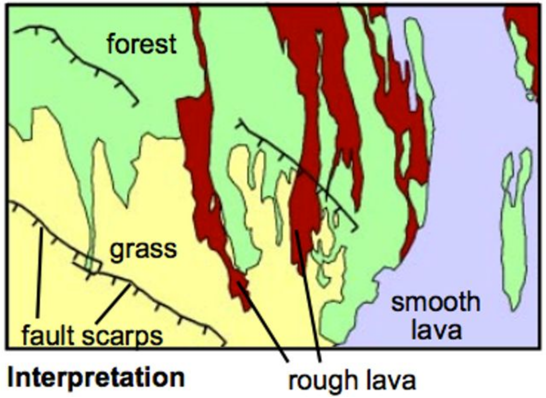


C-Band VV (wavelength = 6 cm)



L-Band VV (wavelength = 23.5 cm)

P-Band VV (wavelength = 68 cm)



Interpretation

↑ wavelength

↓

↑ materials appear smooth

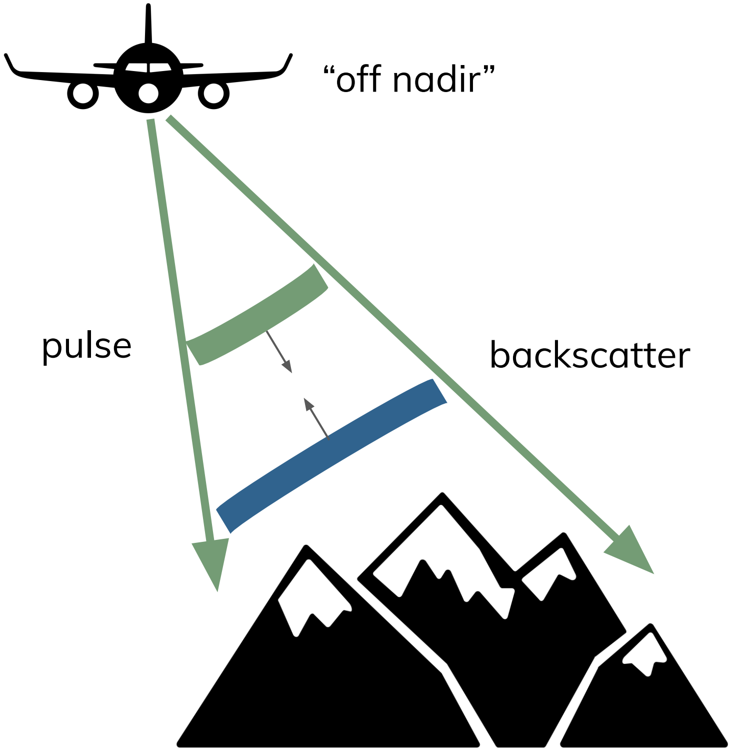
↓

↓ backscatter

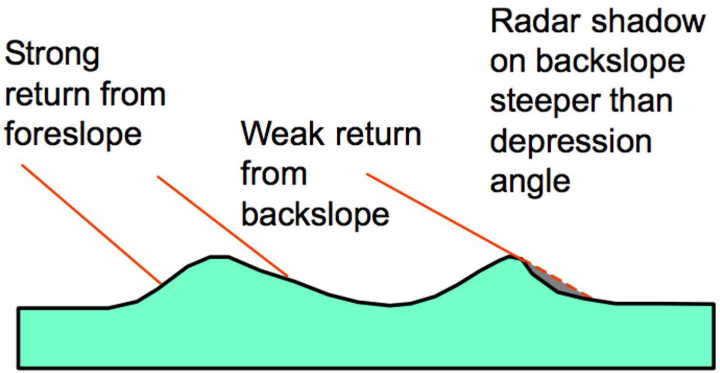
↓ brightness

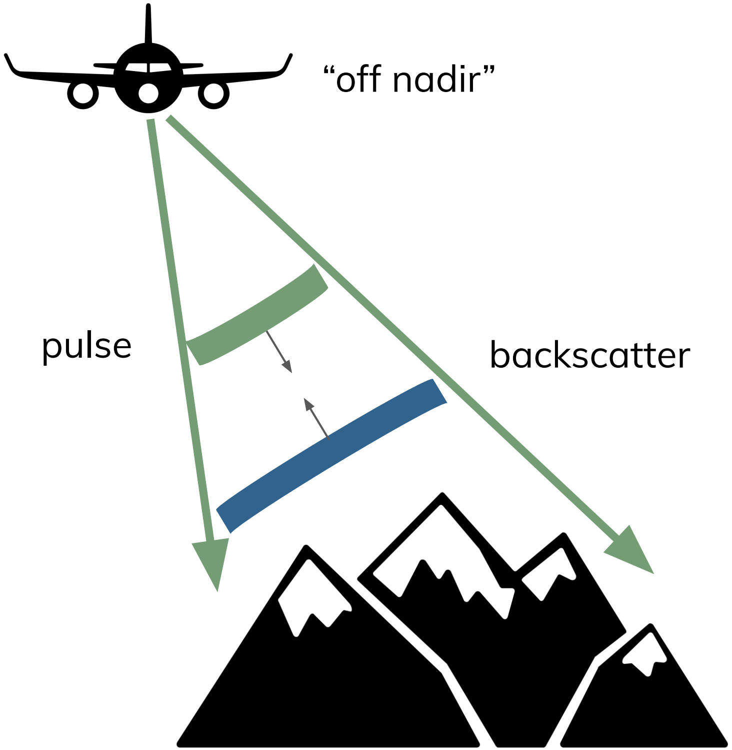
Source: MicroImages

Microwave interactions with matter



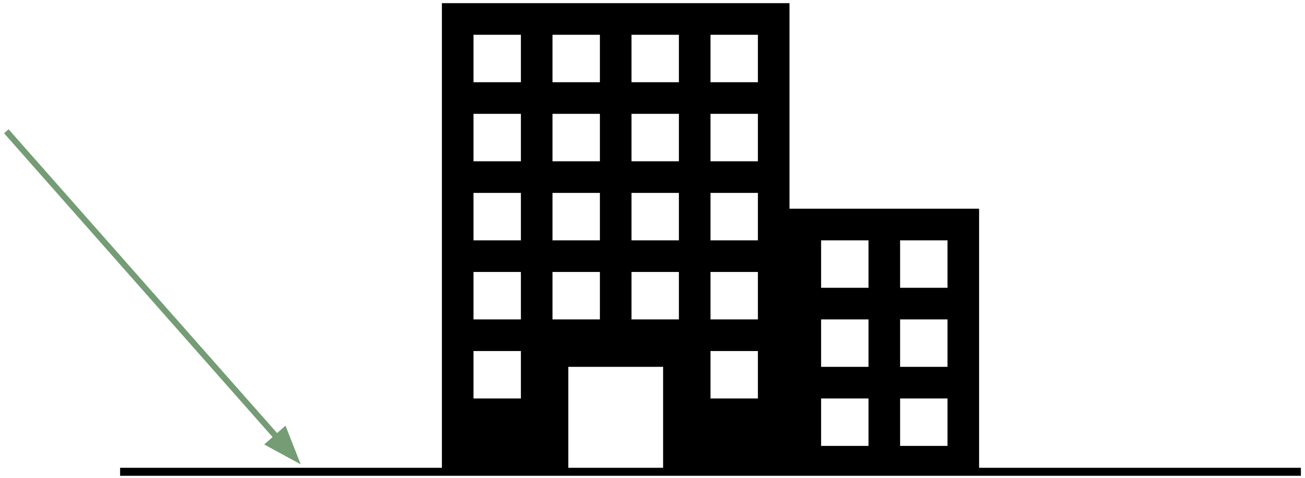
Microwave interactions with matter



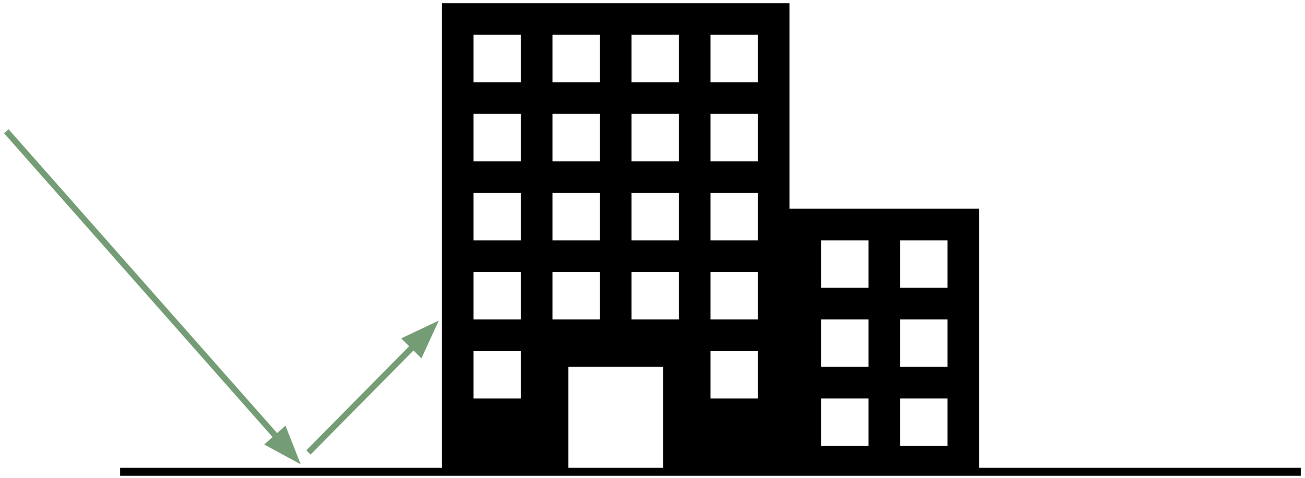


Source: MicroImages

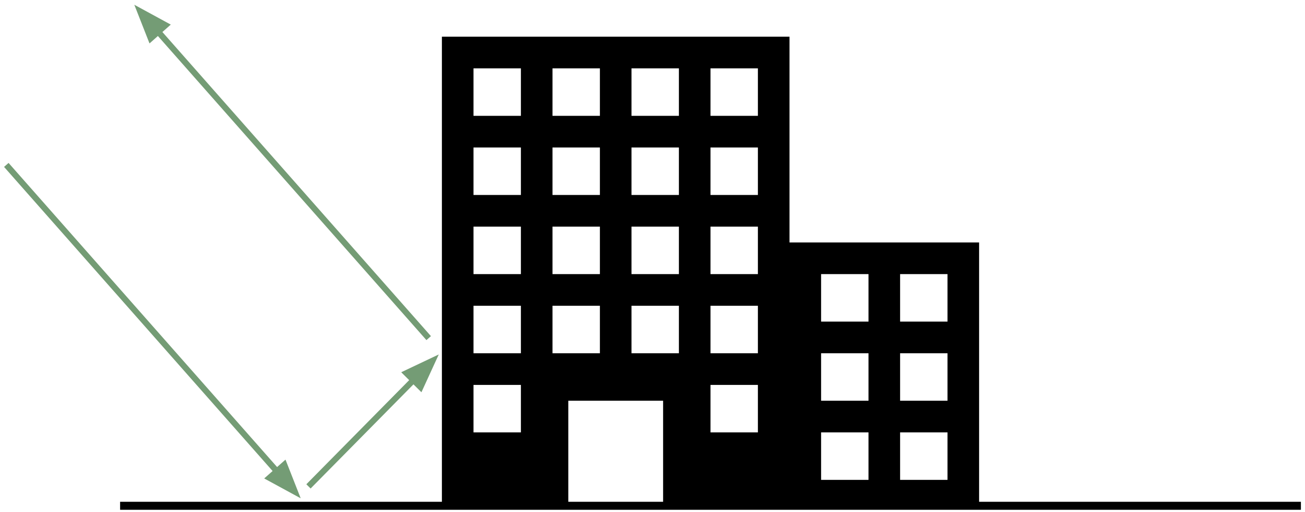
Microwave interactions with terrain



Microwave interactions with terrain

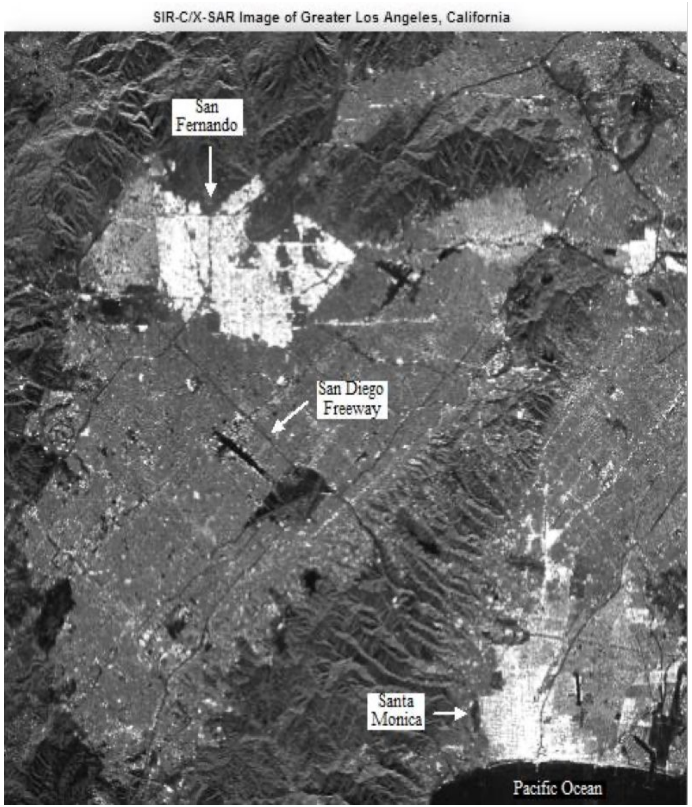


Microwave interactions with terrain



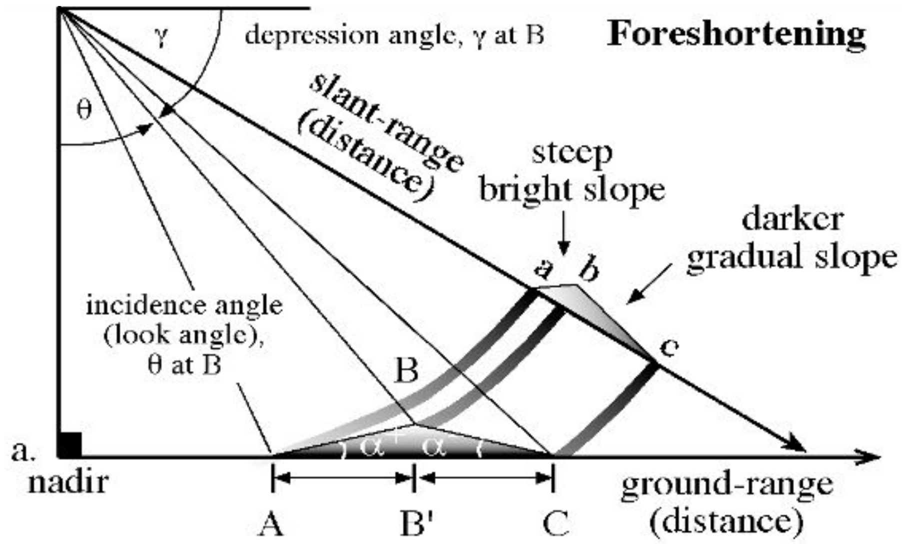
Microwave interactions with terrain

“corner reflector”



Source: MicroImages

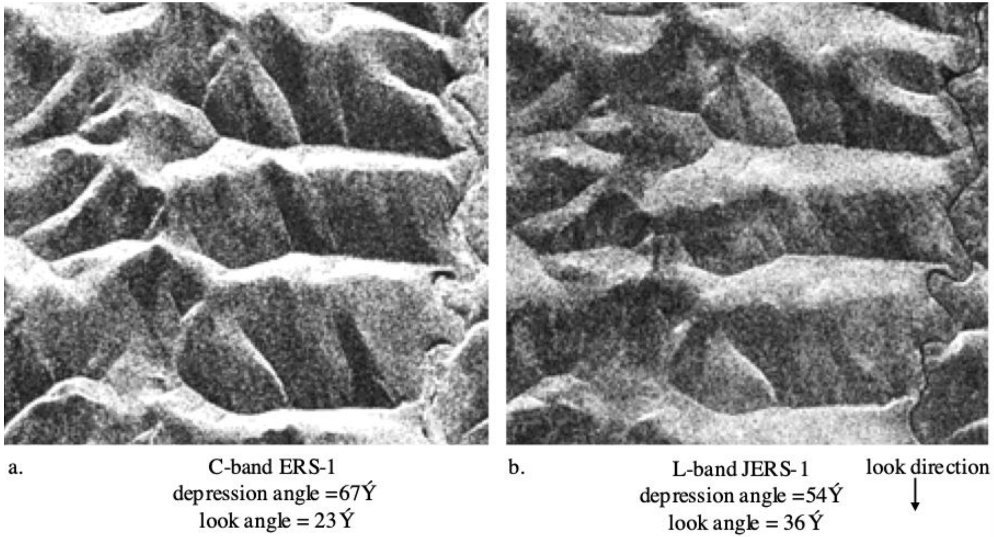
Microwave interactions with terrain



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

Source: Jensen 2007

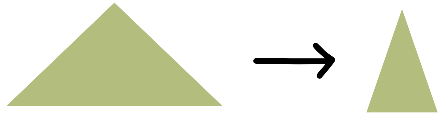
Microwave interactions with terrain

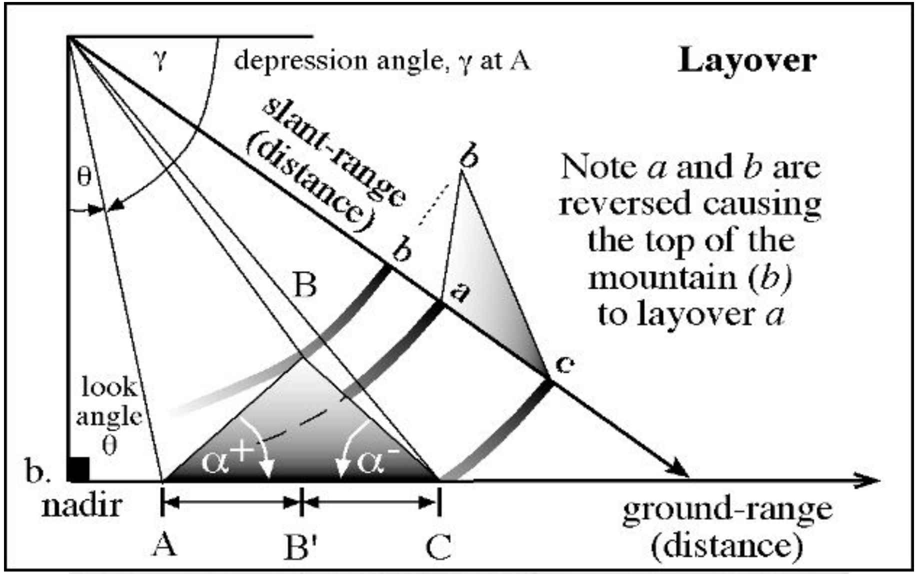


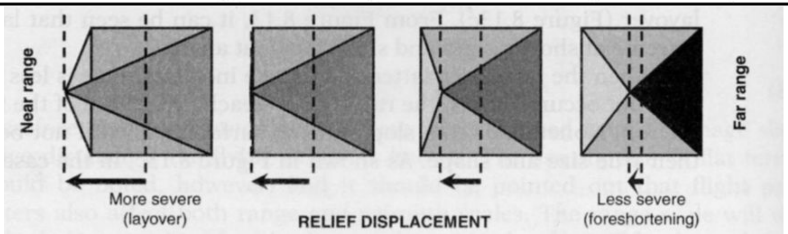
front of slope imaged faster than back of slope → front of slope appears compressed

Source: MicroImages

Microwave interactions with terrain

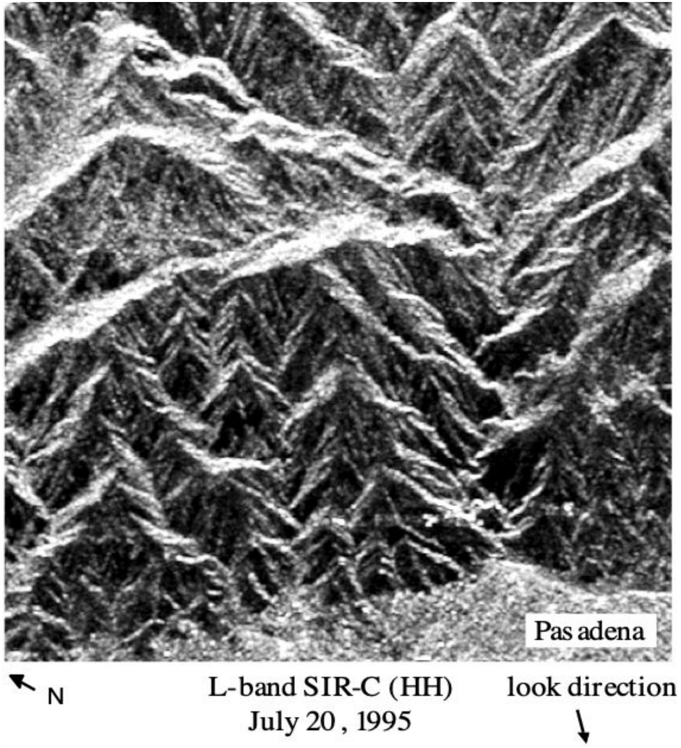






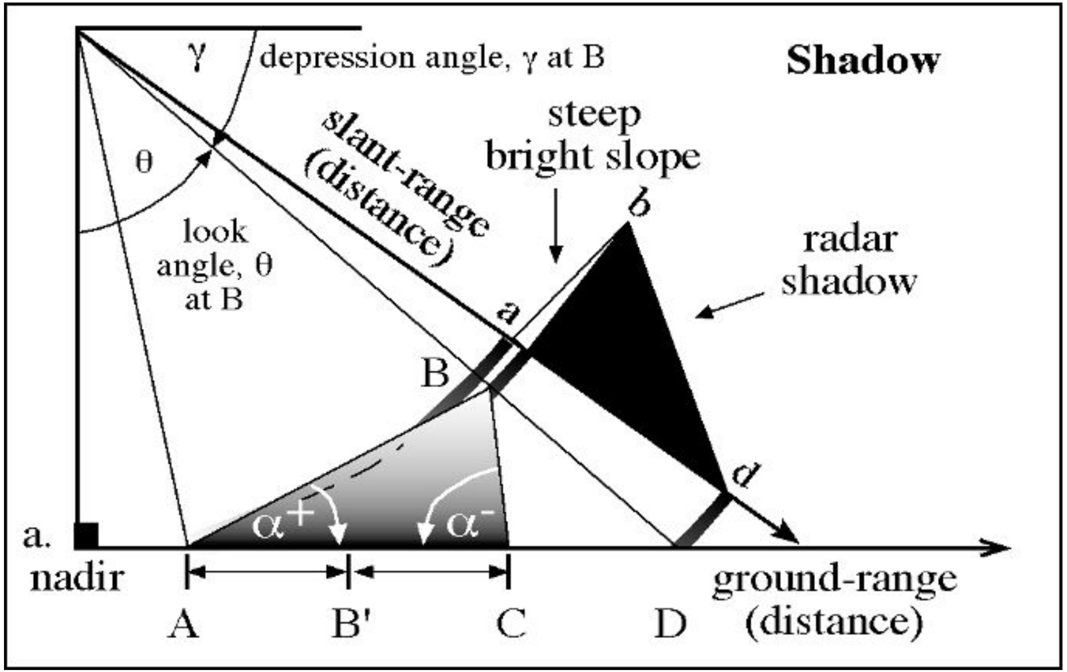
Source: Jensen 2007

Microwave interactions with terrain



Source: MicroImages

Microwave interactions with terrain



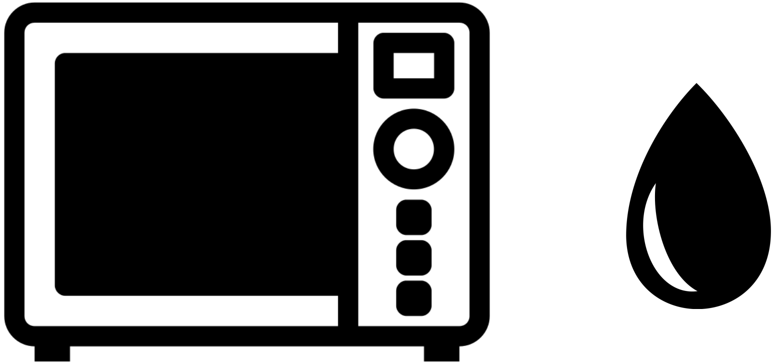
Source: Jensen 2007

Microwave interactions with terrain

“radar shadow”

Source: MicroImages

Microwave interactions with matter



Interpreting RADAR images

tone	terrain feature	cause of signature
bright	steep slopes facing antenna	lots of energy reflected back
very dark	steep slopes facing away	no energy reaches terrain, no return
very dark	calm water, dark pavement	smooth surfaces reflect energy away
very bright	man-made structure	intersecting surfaces reflect strongly
medium	vegetation	scatter in many directions

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 penetrate certain objects**
    - E.g. vegetation, sand, surface layers of snow
- **Spatial resolution independent of distance to object**