Mar. 10

- 12 passenger van reserved
- will leave at 2 pm
- where?
  - Parking lot at Cook Field?

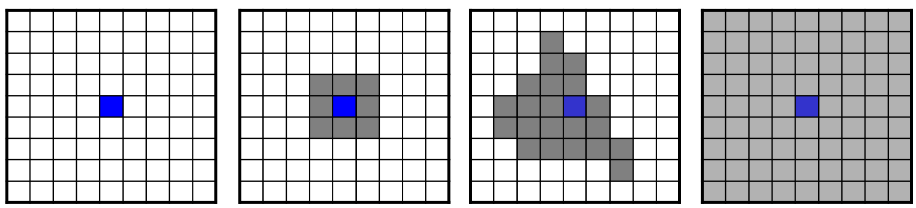
Sq. Mi to Sq. Km

Contents Preview Description

STATE_ABBR	POP2000	POP2005	POP00_SQMI	POP05_SQMI	WHITE	BLACK	AMERI_ES	ASIAN	HAWN_PI
HI	1211537	1277055	189.9	200	294102	22003	3535	503868	113539
WA	5894121	6319255	87.5	93.9	4821823	190267	93301	322335	23953
MT	902195	929880	6	6.2	817229	2692	56068	4691	470
ME	1274923	1317758	39.6	41	1236014	6760	7098	9111	382
ND	642200	637399	9	9	593181	3916	31329	3606	230
SD	754844	783954	9.8	10.1	669404	4685	62283	4378	261
WY	493782	510057	5	5.2	454670	3722	11133	2771	302
WI	5363675	5600519	95.5	99.9	4769857	304460	47228	88763	1630
ID	1293953	1428234	15.5	17.1	1177304	5456	17645	11889	1308
VT	608827	622817	63.3	64.9	589208	3063	2420	5217	141
MN	4919479	5257496	58.2	62.2	4400282	171731	54967	141968	1979
OR	3421399	3657282	35.2	37.7	2961623	55662	45211	101350	7976
NH	1235786	1317967	133.5	142.3	1186851	9035	2964	15931	371
IA	2926324	2967823	52	52.7	2748640	61853	8989	36635	1009
MA	6349097	6474034	776.7	792.1	5367286	343454	15015	238124	2489
NE	1711263	1768255	22.1	22.8	1533261	68541	14896	21931	836
NY	18976457	19411913	390.8	399.6	12893689	3014385	82461	1044976	8818
PA	12281054	12480851	270.6	275.1	10484203	1224612	18348	219813	3417
CT	3405565	3510998	684.2	705.3	2780355	309843	9639	82313	1366
RI	1048319	1074684	1003.2	1028.4	891191	46908	5121	23665	567

Map Algebra Operations

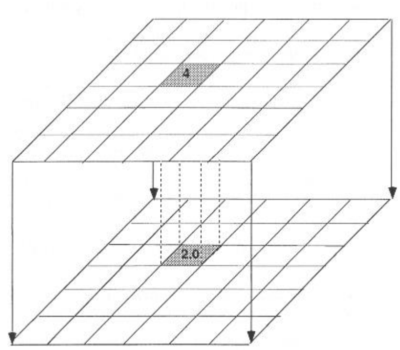
- Tomlin (1990) defines and organizes operations as ***local***, ***focal***, ***zonal,*** and ***global*** according to the ***spatial scope*** of the operations
  - *Geographic Information System and Cartographic Modeling*, Englewood Cliffs: Prentice Hall, 1990.



Local Focal Zonal Global

Local Operations

- Compute a new raster layer.
- The value for each cell on the output layer is a function of one or more cell values at the ***same location*** on the input layer(s).



Local Operations

- Arithmetic operations

  +, -, *, /, Abs, …
- Relational operators

  >, <, …
- Statistic operations

  Min, Max, Mean, Majority, …
- Trigonometric operations

  Sine, Cosine, Tan, Arcsine, Arccosine, …
- Exponential and logarithmic operations

  Sqr, sqrt, exp, exp2, …

Local Operation--Examples

9	9	7
9	8	5
6	3	0

+

0	0	2
0	0	1
0	0	0

=

9	9	9
9	8	6
6	3	0

9	9	7
9	8	5
6	3	0

/

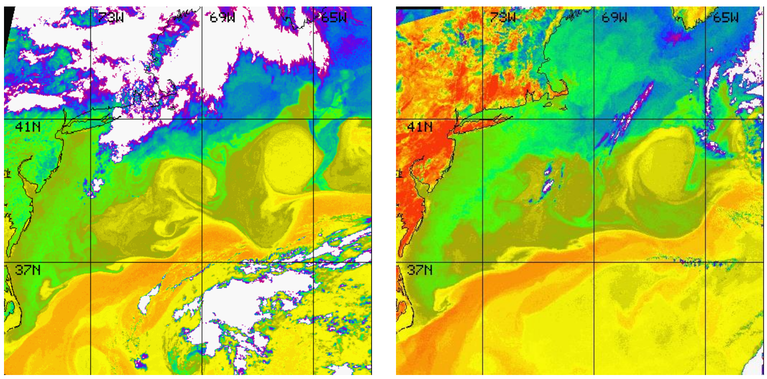
0	0	2
0	0	1
0	0	0

=

N	N	3.5
N	N	5
N	N	N

Removing Clouds Using a Local Operation

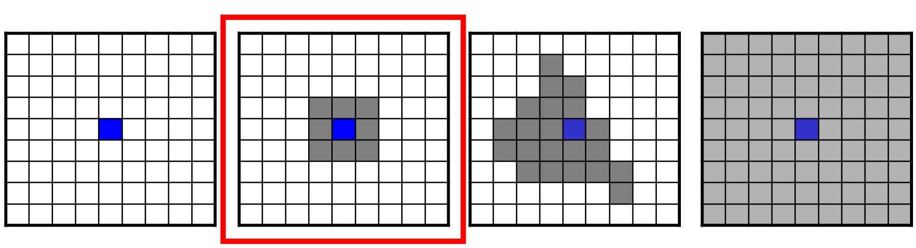
- Two consecutive ocean surface temperature raster layers for the same area (measured at a slightly different time).



Images are from: http://rs.gso.uri.edu/amy/avhrr.html

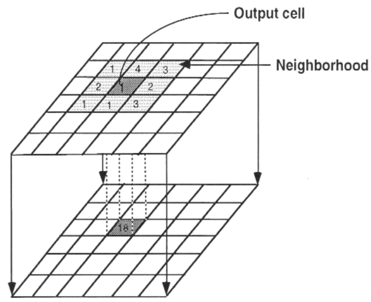
Map Algebra Operations

- Operations are grouped as *local*, ***focal***, *zonal*, and *global* according to the *spatial scope* of the operations.



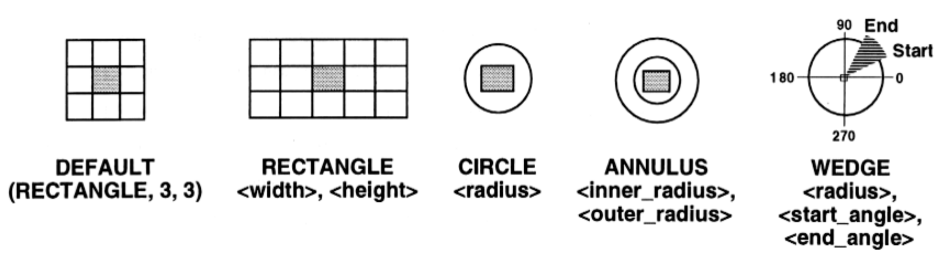
Focal Operations

- Compute an output value for each cell as a function of the cells that are within its neighborhood
- Widely used in image processing with different names
  - Convolution, filtering, kernel or moving window
- Focal operations are *spatial* in nature



Neighborhoods

- The simplest and most common neighborhood is a 3 by 3 rectangle window
- Other possible neighborhoods
  - a rectangle, a circle, an annulus (a donut) or a wedge

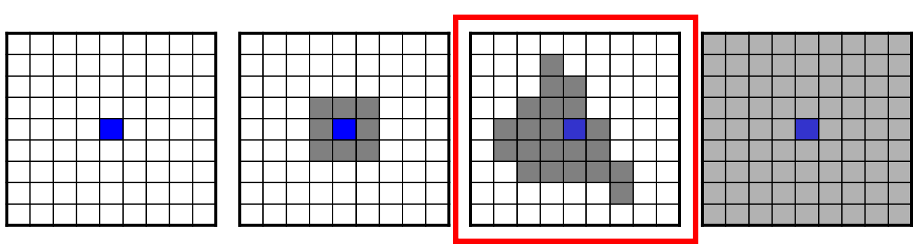


Focal Statistics

- Create a text file to convert to a grid
  - http://desktop.arcgis.com/en/arcmap/10.3/tools/spatial-analyst-toolbox/how-focal-statistics-works.htm

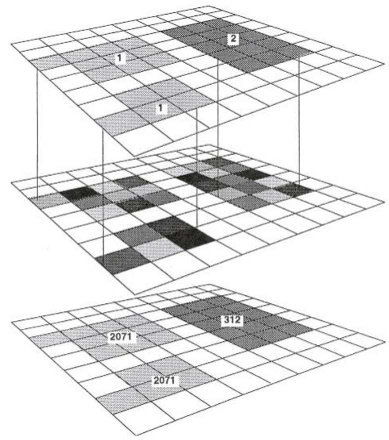
Map Algebra Operations

- Operations are grouped as *local, focal,* ***zonal,*** and *global* according to the *spatial scope* of the operations.



Zonal Operations

- Compute a new value for each cell as a function of the cell values within a zone containing the cell
- Zone layer
  - defines zones
- Value layer
  - contains input cell values



Zonal Statistical Operations

- Calculate statistics for each cell by using all the cell values within a zone
- Zonal statistical operations:
  - ZonalMean, ZonalMedian, ZonalSum, ZonalMinimum, ZonalMaximum, ZonalRange, ZonalMajority, ZonalVariety, ….
- http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/h-how-zonal-statistics-works.htm

Zonal Statistical Operation Example

1	1	4	3	3
1	1	4	3	3
2	2	2	3	4
2	1	2	3	4
1	1	4	4	4

Zone Layer

1	2	3	4	5
6	7	8	9	1
2	3	4	5	6
7	8	9	1	2
3	4	5	6	7

Value Layer

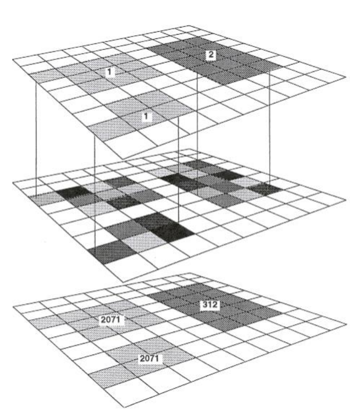
ZonalMax

Output Layer

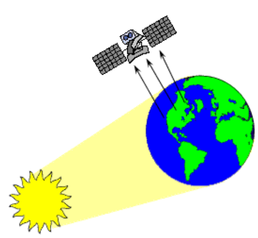
8	8	8	9	9
8	8	8	9	9
9	9	9	9	8
9	8	9	9	8
8	8	8	8	8

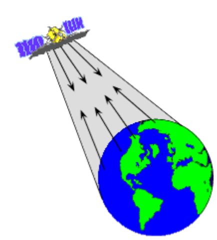
Outputs of Zonal Operations

- Raster layer
  - All the cells within a zone have the same value on the output raster layer
- Table
  - Each row in the table contains the statistics for a zone.
  - The first column is the value (or ID) of each zone.
  - The table can be joined back to the zone layer.



Passive and Active Sensors





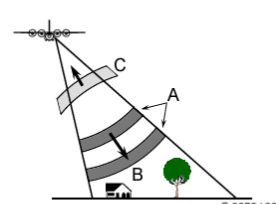
- *Passive*
  : detect energy when the naturally occurring energy is available
  : visible, near-infrared and thermal imaging sensors
- *Active*
  : provide their own energy source for illumination
  : microwave (Radar) sensors

Widely Used Active RS Systems

- **RADAR**: *RA*dio *D*etection *A*nd *R*anging
  - ✓ Long-wavelength microwaves (1 – 100 cm)
- **LIDAR**: *LI*ght Detection *A*nd *R*anging
  - ✓ Short-wavelength laser light (UV, visible, near IR)
- **SONAR**: *SO*und *N*avigation *A*nd *R*anging: (very long wave, low Hz)
  - ✓ Earth and water absorb acoustic energy far less than EMR energy
  - ✓ Seismic survey use small explosions, record the reflected sound
  - ✓ Sound waves are extremely slow (300 m/s in air, 1,530 m/s in sea-water)
  - ✓ Bathymetric sonar (measure water depths and changes in bottom topography)

Radar Basics

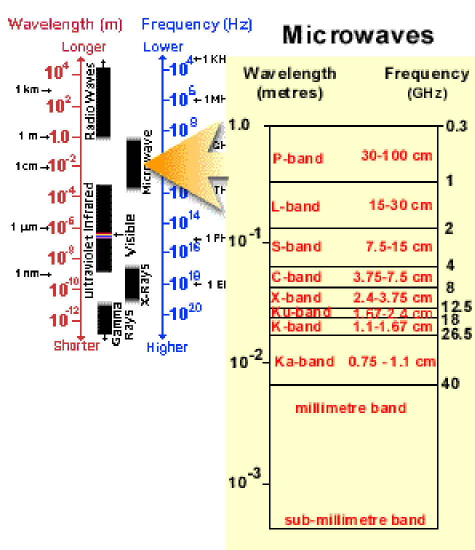
- It consists fundamentally of a transmitter, a receiver, an antenna, and an electronics system to process and record the data.
  - ✓ The transmitter generates successive short bursts (or **pulses** of microwave (A) at regular intervals which are focused by the antenna into a beam (B).
  - ✓ The radar beam illuminates the surface obliquely at a right angle to the motion of the platform.
  - ✓ The antenna receives a portion of the transmitted energy reflected (or **backscattered**) from various objects within the illuminated beam (C).



Commonly Used Bands

- Ka, K, and Ku bands: very short wavelengths used in early airborne radar systems but uncommon today
- X-band: used extensively on airborne systems for military reconnaissance and terrain mapping
- C-band: common on many airborne research systems (CCRS Convair-580 and NASA AirSAR) and spaceborne systems (including ERS-1 and 2 and RADARSAT).
- S-band: used on board the Russian ALMAZ satellite.
- L-band: used onboard American SEASAT and Japanese JERS-1 satellites and NASA airborne system.
- P-band: longest radar wavelengths, used on NASA experimental airborne research system.

Commonly Used Bands



Two Imaging Radar Systems

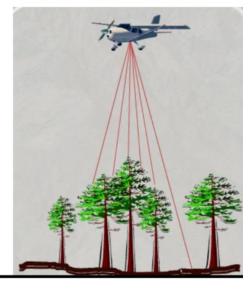
- In World War II, ground based radar was used to detect incoming planes and ships (non-imaging radar)
- Imaging RADAR was not developed until the 1950s (after World War II). Since then, side-looking airborne radar (*SLAR*) has been used to get detailed images of enemy sites along the edge of the flight field. SLAR is usually *a real aperture radar*. The longer the antenna (but there is limitation), the better the spatial resolution.

RAR vs. SAR

- Real aperture radar (RAR)
  - ✓ aperture means antenna
  - ✓ a fixed length (for example: 1 - 15m)
- Synthetic aperture radar (SAR)
  - ✓ 1m (11m) antenna can be synthesized electronically into a 600m (15 km) synthetic length
  - ✓ most (air-, space-borne) radar systems now use SAR

LiDAR

- ***Li**ght **D**etection **A**nd **R**anging*
  - ✓ measures **distance**
    - ➢ by sending thousands of laser light pulses every second which then strike and reflect from the surfaces on the earth
    - ➢ then measures the time of the pulse returns
    - ➢ the measured times are converted to distance-from-sensor data
    - ➢ the distance-from-sensor data can be converted into accurately geo-referenced data in near real time
- Similar to or different from Radar?



Resources to Watch

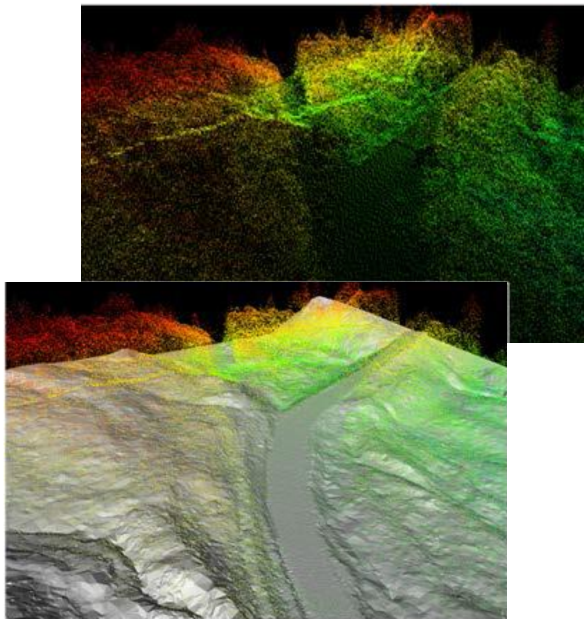
- Lidar: Light Detection and Ranging
  - ✓ The American Society for Photogrammetry and Remote Sensing
  - ✓ https://www.youtube.com/watch?v=hxiRkTtBQp8
- LiDAR - Introduction to Light Detection and Ranging
  - ✓ The Science of Measuring Ecosystems: NEON Education
  - ✓ https://www.youtube.com/watch?v=m7SXoFv6Sdc

Active RS

- since lidar is an active sensor
  - ✓ data can be acquired day or night as long as the atmosphere is clear
- Lidar generates very large datasets
  - ✓ to collect 300-500 thousand positions (or more) per second
  - ✓ despite their size, the data can be post-processed to provide highly accurate and detailed DEMs, topographic maps, vegetation heights, structure and densities, and more
- The three-dimensional coordinates (e.g., x,y,z or latitude, longitude, and elevation) of the target objects are computed from
  - ✓ the time difference between the laser pulse being emitted and returned
  - ✓ the angle at which the pulse was "fired"
  - ✓ the absolute location of the sensor on or above the surface of the Earth

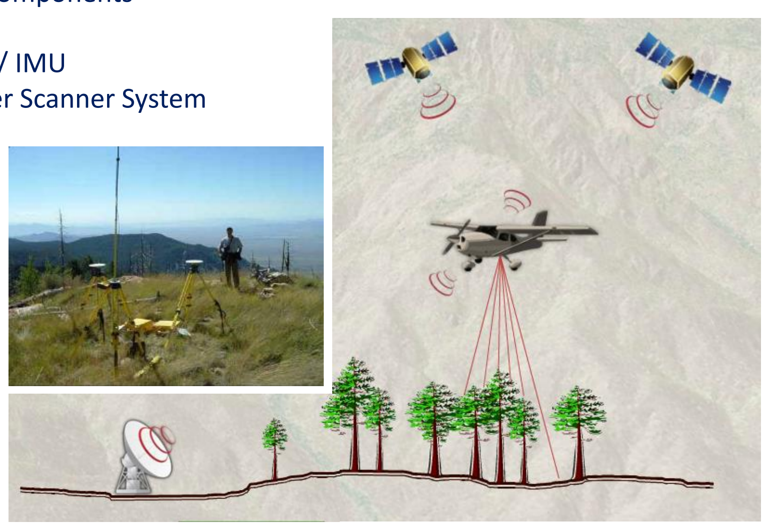
Rapid & Accurate Measurement

- Lidar instruments can rapidly measure the Earth's surface, at sampling rates greater than 150 kilohertz (i.e., 150,000 pulses per second).
- The resulting product is a densely spaced network of highly accurate georeferenced elevation points - often called a point cloud - that can be used to generate three-dimensional representations of the Earth's surface and its features.
- Typically, lidar-derived elevations have absolute accuracies of about 6 to 12 inches (15 to 30 centimeters) for older data and 4 to 8 inches (10 to 20 centimeters) for more recent data.



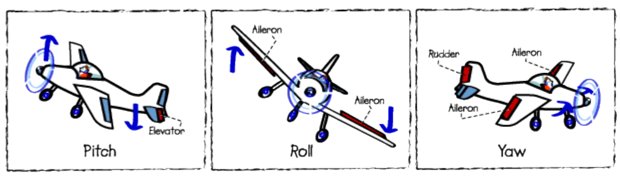
How LiDAR Works

- Major Components
  - ✓ GPS
  - ✓ INS / IMU
  - ✓ Laser Scanner System



INS & Laser Scanner System

- Onboard the aircraft
- INS / IMU
  - ✓ Internal Navigation System / Internal Measurement Unit
  - ✓ records the pitch, roll & yaw of the aircraft (i.e., the angle that the body of the lidar sensor is pointing)



- Laser Scanner System
  - ✓ The heart of the lidar system
    : laser source, laser detector, scanning mechanism, timing electronics, computing power

GPS

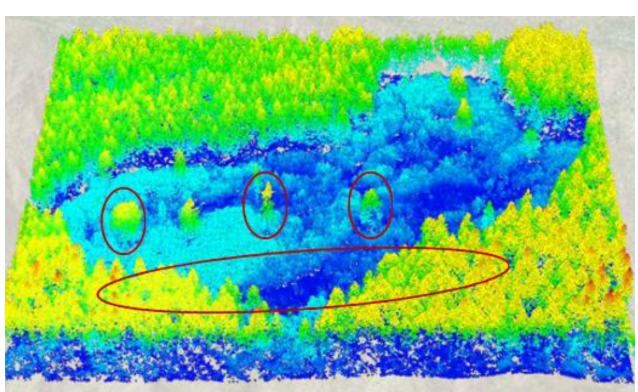
- LiDAR requires precise real-time positioning
  - ✓ well-surveyed GPS base station
  - ✓ the ground station should be located within 60 miles of the project site to ensure that the aircraft records the same set of GPS satellite signals as the ground station
  - ✓ co-initialized airborne GPS with the ground station
  - ✓ the position of the airborne GPS antenna is calculated at an interval of 0.5 seconds
  - ✓ after each mission, the data are downloaded and post processed
  - ✓ GPS data from the aircraft and the ground station(s) are processed together

Operating Wavelengths

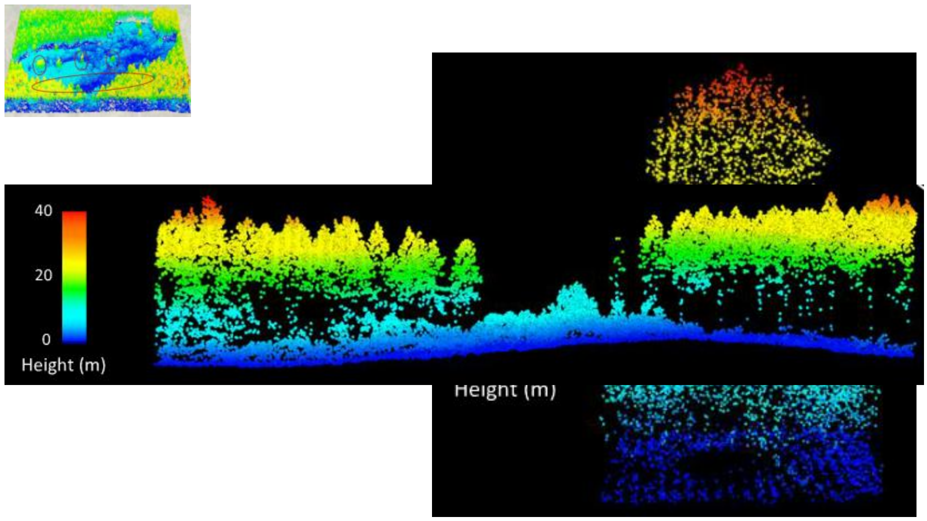
- In theory, any light source can be used to create a lidar instrument
- Near -Infrared wavelength
  - ✓ used by most airborne terrestrial lidar systems
  - ✓ the most common laser is the solid-state Nd:YAG laser which produces radiation at an IR wavelength of 1064 nm
  - ✓ easily absorbed at the water surface (unreliable water surface reflections)
- Green wavelength
  - ✓ used by all airborne bathymetric and topo-bathy systems
  - ✓ Nd:YAG IR laser output is frequency doubled to produce output at 532 nm at 532 nm
  - ✓ can penetrate water

LiDAR Data Viewing

- 10 acres (40, 469 sq. meters) of forest
  - ✓ more than 300, 000 points
  - ✓ the points are colored by height with the lower elevations being cool colors and the higher elevations being warm colors



LiDAR Tree Canopy



Can LiDAR "see" through trees??

- Reality
  - ✓ lidar can "see" through gaps in canopy- forming trees
- Rule of thumb
  - ✓ On a bright sunny day, if you can see sunlight on the ground, lidar will map it.
- Most of the larger scale elevation data sets have been generated using remote sensing technologies that cannot penetrate vegetation. Lidar is no exception; however, there are typically enough individual "points" that, even if only a small percentage of them reach the ground through the trees, there are usually enough to provide adequate coverage in forested areas.
  - ✓ In effect, lidar is able to see through holes in the canopy or vegetation.
  - ✓ Dense forests or areas with complete coverage (as in a rain forest), however, often have few "openings" and so have poor ground representation (i.e., all the points fall on trees and mid-canopy vegetation).

More Resources to Watch

- NASA | Intro to LIDAR - 2D Version
  - ✓ https://www.youtube.com/watch?v=Y4rrx4D7gcU

- The magic of lidar 3d mapping
  - ✓ New Forest National Park Authority
  - ✓ https://www.youtube.com/watch?v=0XdqGNu9bhk