Introduction to Lidar and Airborne Laser Scanning

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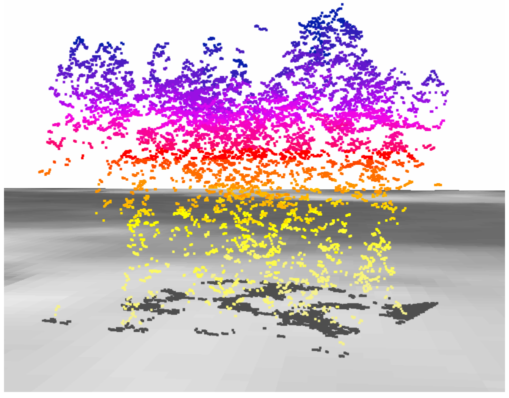


Terminology

- LIDAR: Light Detection and Ranging
- LASER : Light Amplification by Stimulated Emission of Radiation
- ALS: Airborne Laser Scanning
- Terms are used quite interchangeably
- Most systems are pulsed Laser scanner systems

LIDAR platforms

- Spaceborne
  - E.g. Geoscience Laser Altimeter System (GLAS)
- Airborne
  - Prevailing platform
- Ground lidar
  - 360 degree horizontal field
  - (rangefinders)
- bathymetric vs. topographic systems

Theory

- LIDAR systems are based on a distance measurement between the sensor system and the target
- 1064 nm is the wavelength used by most airborne scanners (at this wavelength the atmospheric attenuation is low). Also blue-green ALS systems are available.
- There are two different methods in use to determine the distance, (I) Time Pulsed Method, based on the accurate measurement of TOF, and (II) Phase Comparison Method, based on the measurement of the phase difference between a continuous outgoing and incoming wave train

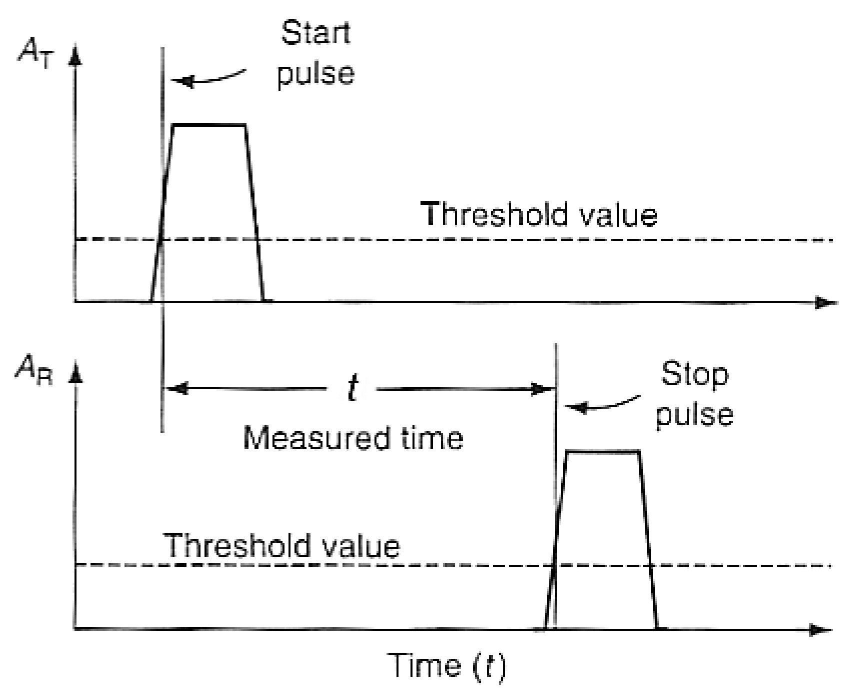
Timed Pulse Method

The laser ranging instrument measures the time interval that has elapsed between the pulse being emitted by the laser ranger located at point A and its return after reflection from an object located at point B:

$R = v*t/2$

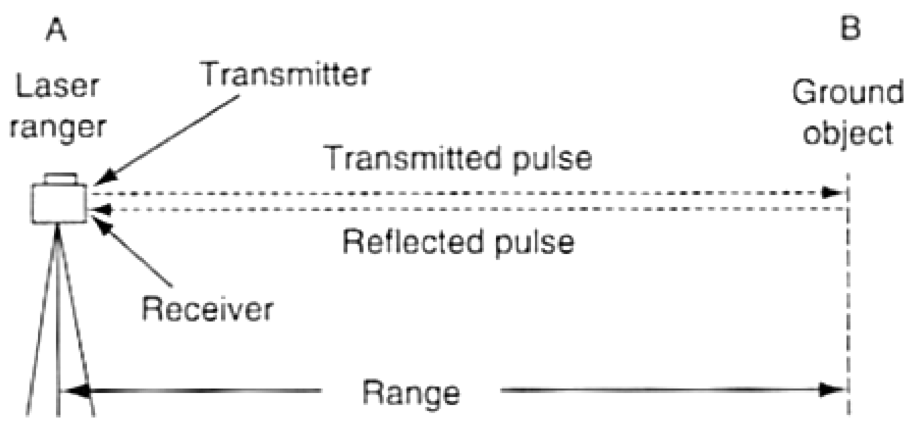
Where

R is the slant distance or range
v is the speed of EMR (known)
t is the measured time interval



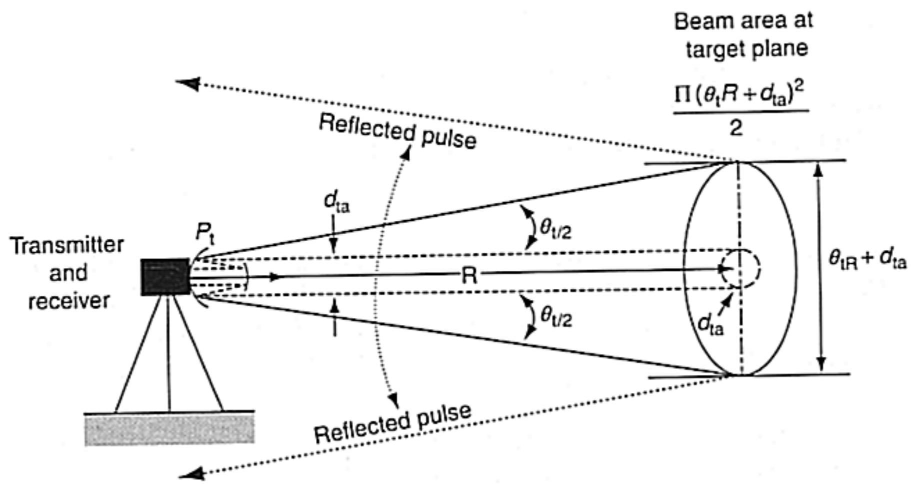
Timed Pulse Method

- Since the speed of light is very accurately known, in practice, the range precision is determined by the precision of the time measurement (not an issue in ALS)
- PRF may be a problem in long range applications (e.g. ALS) – multiple pulses in air simultaneously, etc.
- Most commonly used method for ranging applications



Beam divergence

- The beam divergence is an angular measure of the increase in beam diameter with distance from the aperture from which the electromagnetic beam emerges



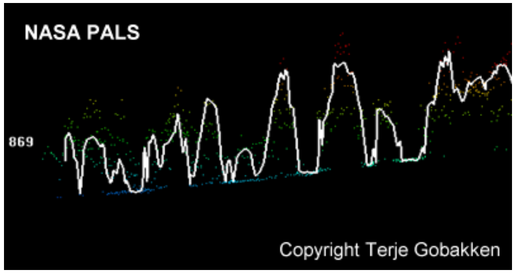
- Modern ALS instruments have a beam divergence in the range 0.3 – 0.5 mrad
- At a flying height of 1000 m the footprint (diameter of the beam circle at object distance) is about 30 and 50 cm for the beam divergences of 0.3 and 0.5 mrad, respectively

Sensor positioning

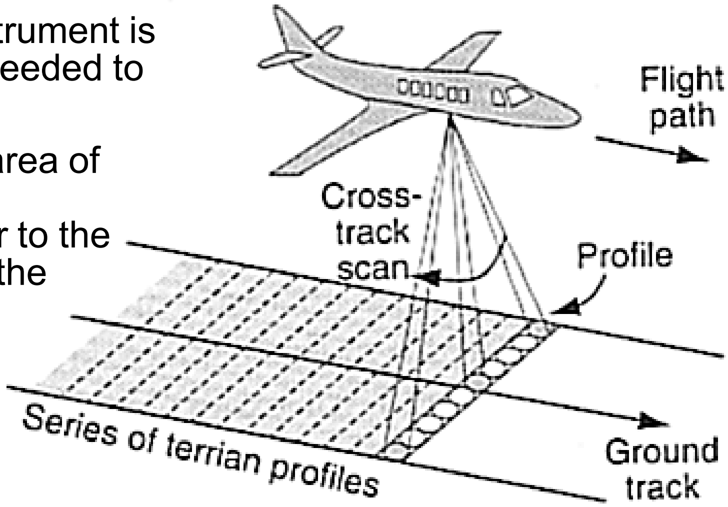
- Knowing the sensor position accurately is crucial
  - How to obtain the position of LIDAR device?
- The development of satellite positioning enabled the use of airborne LIDAR
- ALS relies on GPS/IMU
  - GPS = Global Positioning System
  - IMU = Inertial Measurement Unit
- In theory *in-situ* positioning
- In practice final pulse coordinates are produced during post processing
  - GPS/INS post-processing, strip adjustment, calibration…

Profilers and scanners

- Laser profiling
  - Terrestrial applications
  - Airborne applications
    - elevation profile
    - laser altimeter

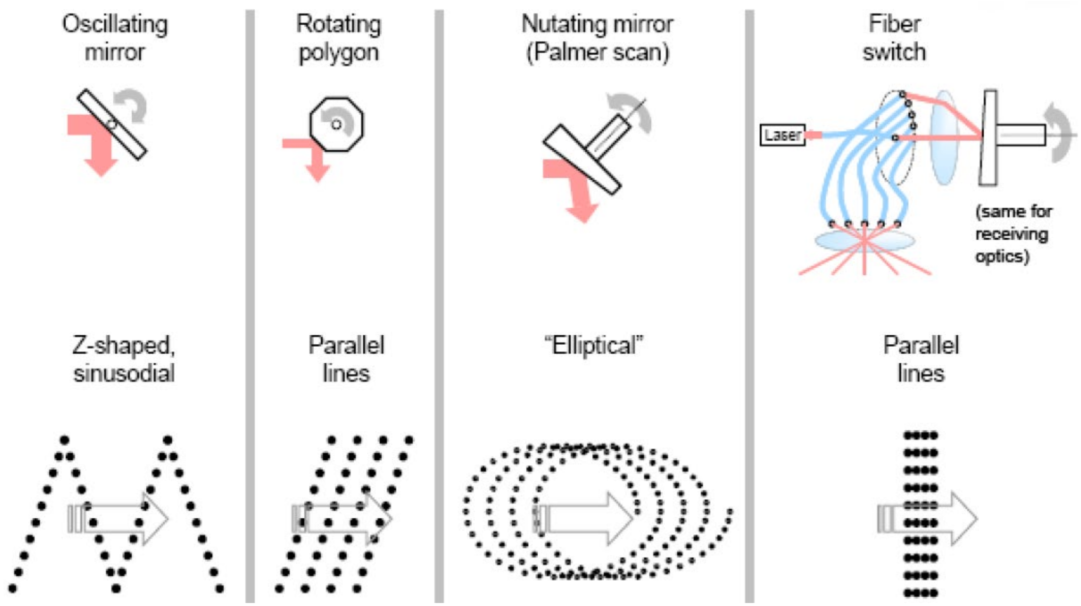


- Laser scanning
  - With the addition of scanning mechanism the laser ranging instrument is upgraded from being a profiler to becoming a scanner
  - In terrestrial scanners the position of the instrument is fixed; therefore, motion in two directions is needed to scan an area
  - In airborne or speceborne instruments the area of scanning is achieved by a series of profile measurements in the direction perpendicular to the flight line while the forward motion provides the second dimension



Scanning mechanisms

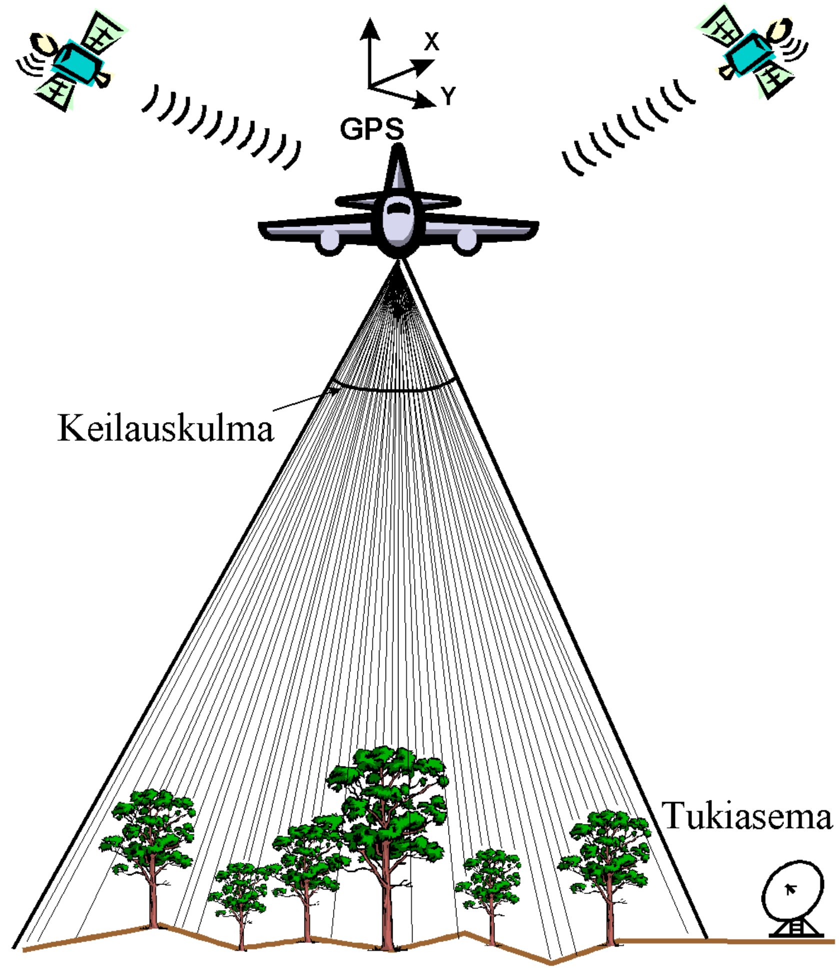
- Different scanning mechanisms produce different ground patterns



Leica, Optech | Riegl based systems | TopEye | TopoSys

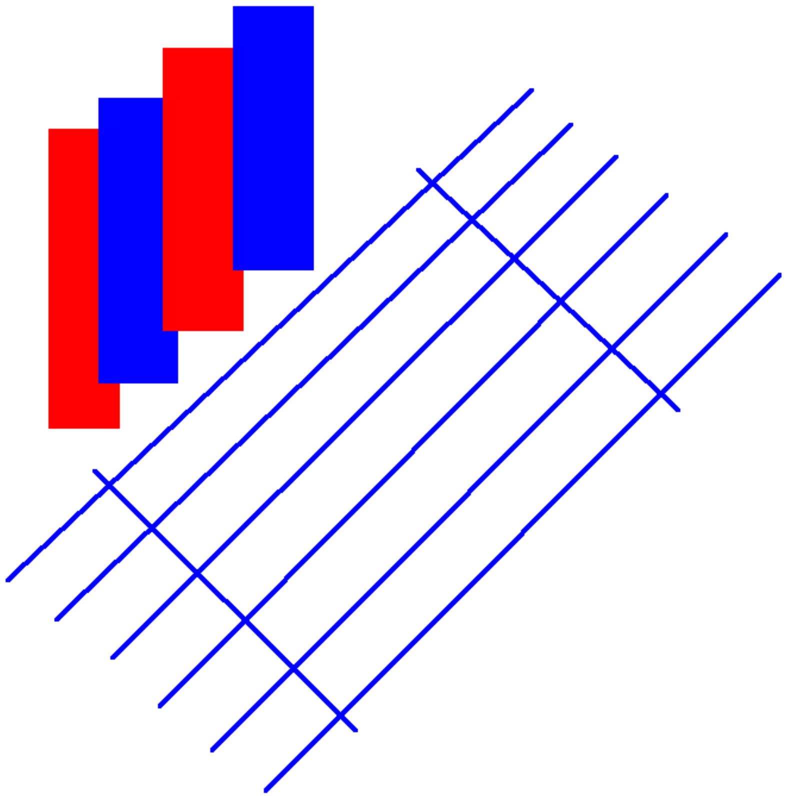
Airborne Laser Scanning

- The x spacing of the laser hits on the ground depends on the viewing angle, pulse repetition rate and flight altitude
- The y spacing is a function of the flight speed and pulse repetition rate

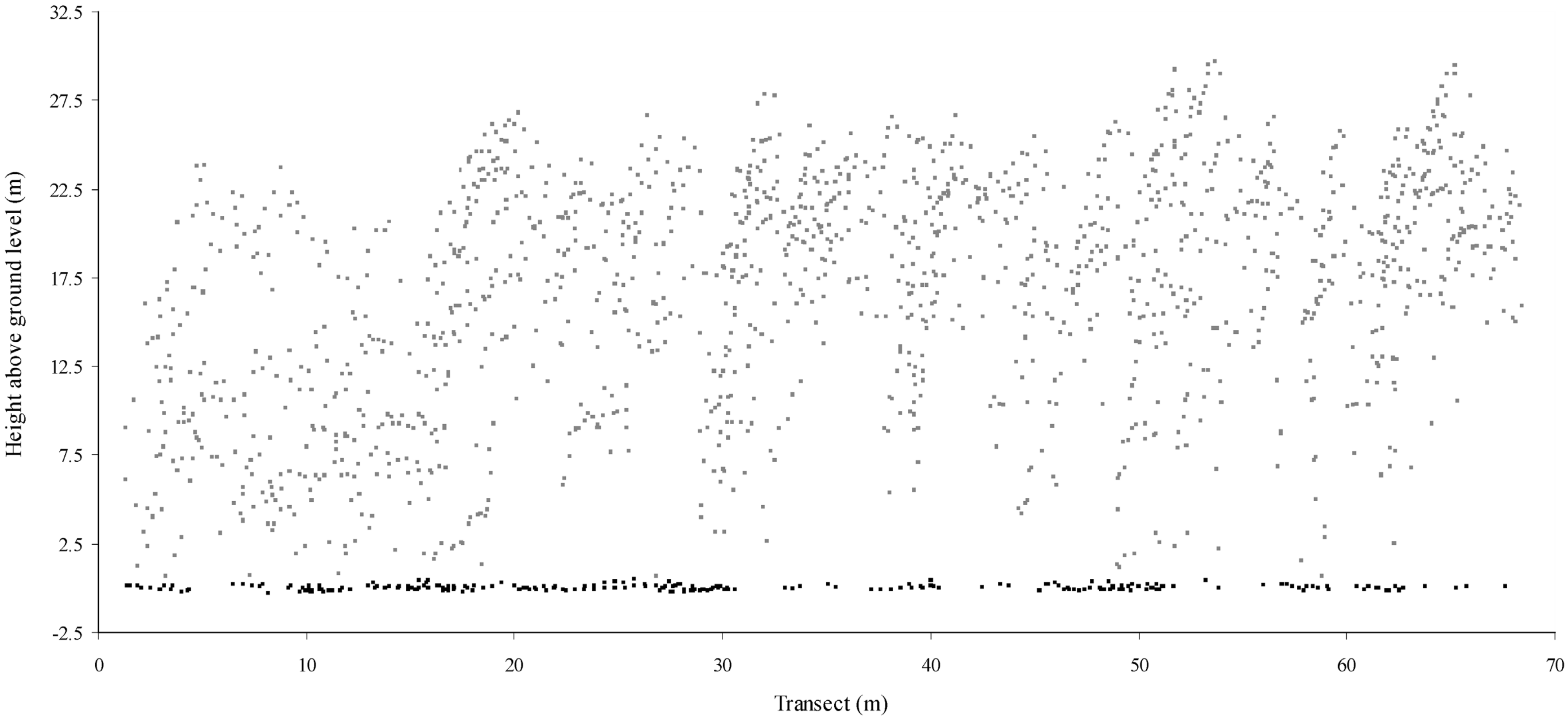


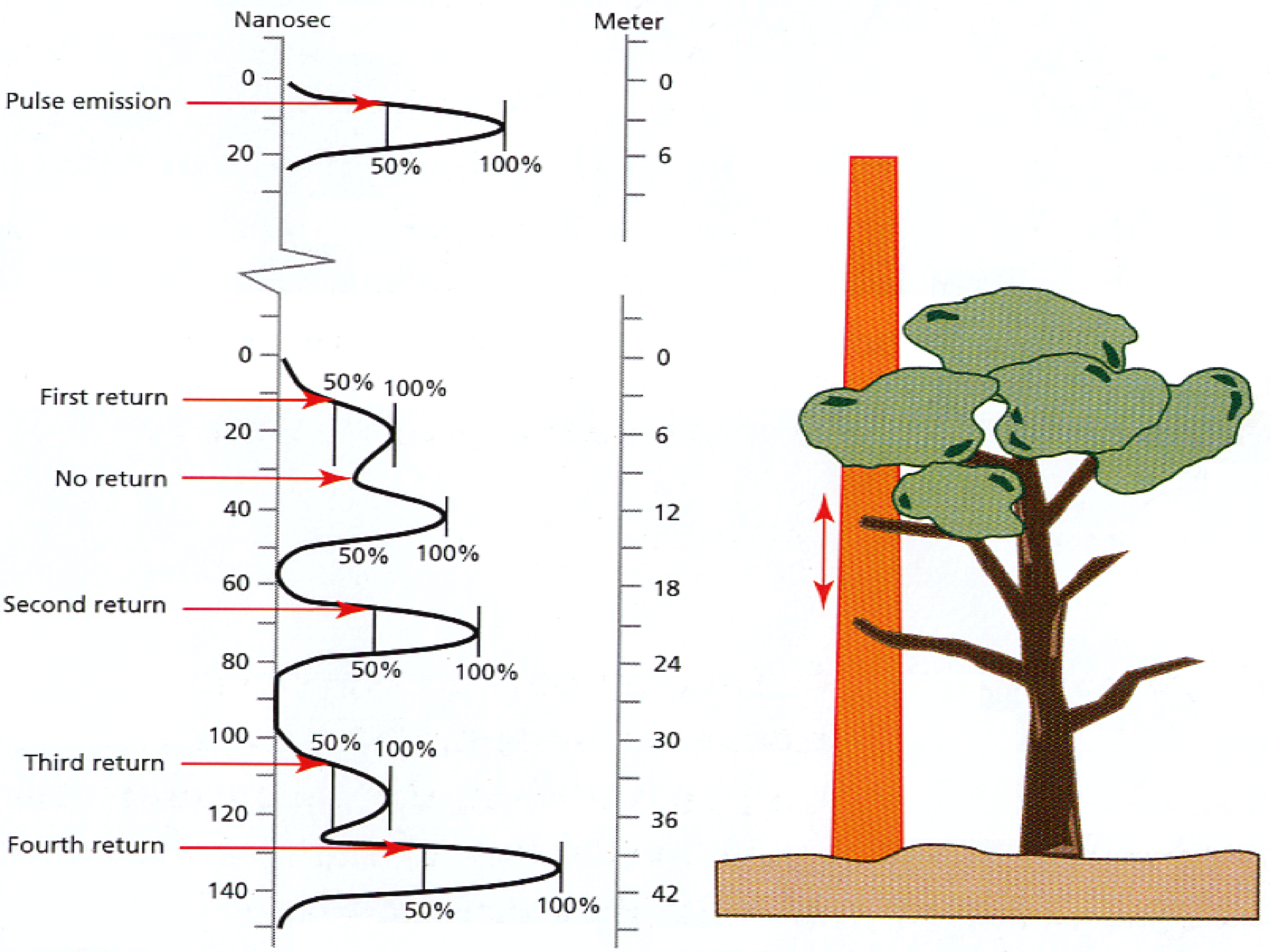
Airborne Laser Scanning

- Airborne LIDAR instrument is usually carried by fixed wind airplane
- Flight altitude and scanning angle define swath width on ground
- Adjacent flight lines are captured with an overlap of approximately 20-40% in order to obtain full area coverage
- Perpendicular flight lines are used for calibration purposes

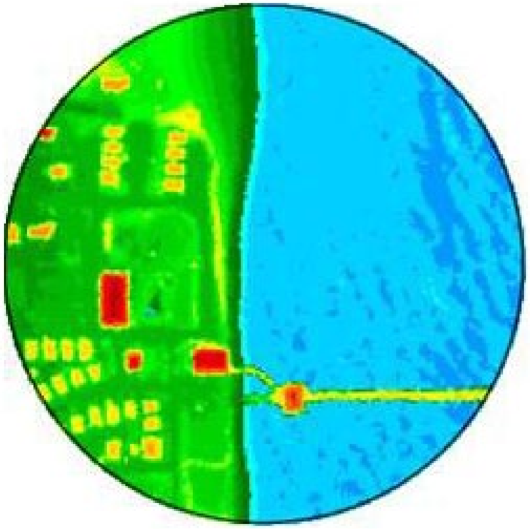


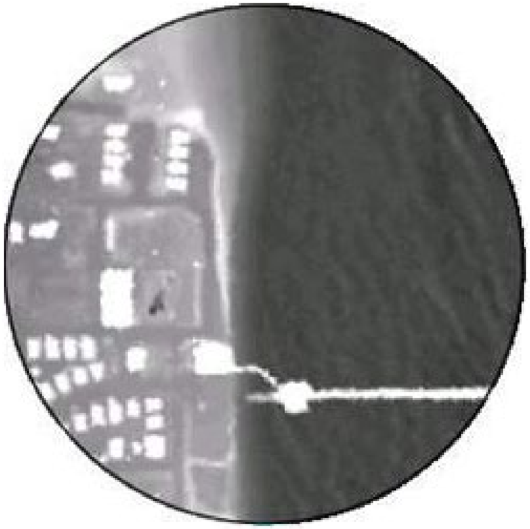
Airborne Laser Scanning




Nanosec
Meter
Pulse emission
0
20
50%
100%
0
6
First return
No return
Second return
Third return
Fourth return
0
20
40
60
80
100
120
140
50%
100%
0
6
12
18
24
30
36
42

Intensity





ALS height theme on the left and corresponding intensity image on the right

ALS applications

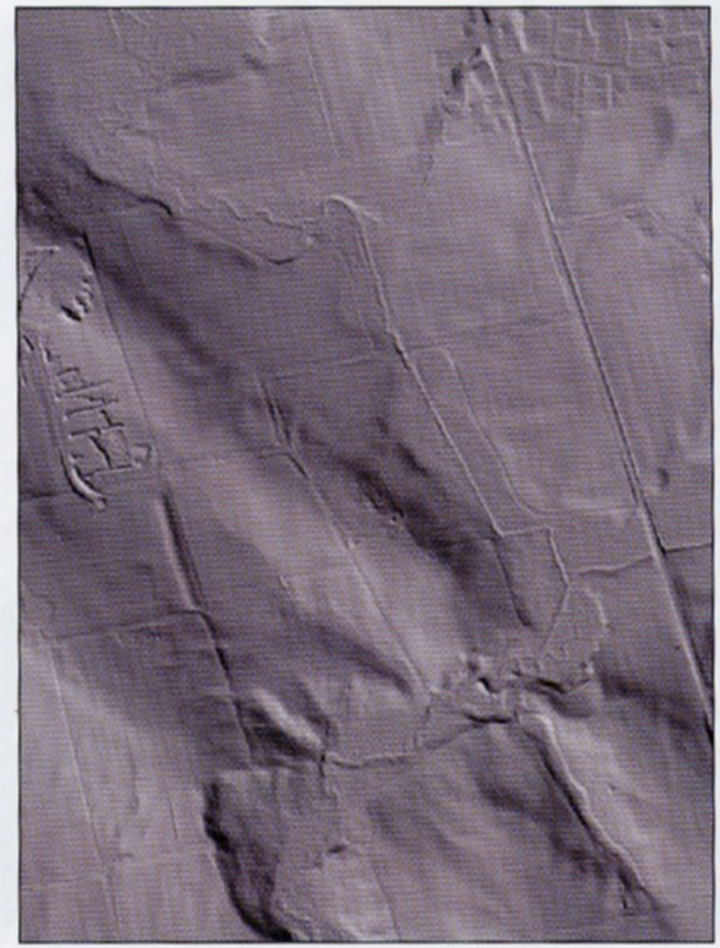
- Terrain modelling
- 3D-citymodels
- Archeology
- Military applications
- Geology
- Agriculture
- Forestry (mainly forest inventory)
- …

Height at above ground level

- ALS data suits very well for the generation of DTM
- ALS can map also the vegetation surface (DSM)
- In many applications, such as in forest inventory, the primary interest is in vegetation at a.g.l.
- Vegetation at a.g.l = DSM – DTM
- It is important to build accurate DTM, which is not always an easy task under canopy cover

ALS based DEMs

All last pulses



Filtered DTM based on last pulses

ALS specs in 2011

- The typical flight altitude is 300-3000 metres a.g.l.
- The footprint diameter is usually 0.1-1 m
- Vertical accuracy of about ± 5-50 cm depending on the surface characteristics and sub-metre horizontal accuracy
- The pulse density on the ground is usually something like 0.1-10 measurements per m^2
- Pulse repetition rates are now in the range 30–200 kHz, Multiple Pulses in Air Technology has been a disappointment

Practical issues about ALS

- ALS is becoming a mainstream technology and increasing amount of data is collected each year
- Increasing pulse repetition rate and increasing flight elevation
- Decreasing costs, however, platform costs do not decrease. Difficult to estimate future expenses.
- Data availability may be an issue – humidity, clouds etc. are problem
- Sensors are individuals