




# Lidar 101: Intro to Lidar

Jason Stoker  
USGS EROS / SAIC





## Lidar

- Light Detection and Ranging
  - Laser altimetry
  - ALTM (Airborne laser terrain mapping)
  - Airborne laser scanning



## Lidar

- Laser
- IMU (INS)
- GPS
- Scanning Mirror
- On board computer

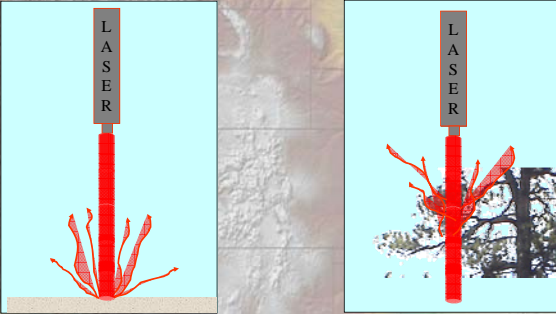




## Laser

- Pulse laser
- Records distance to target
  - $\text{Time} * c / 2$
- Laser wavelengths can differ
  - 1064 nm
- 100-150 kHz systems available today

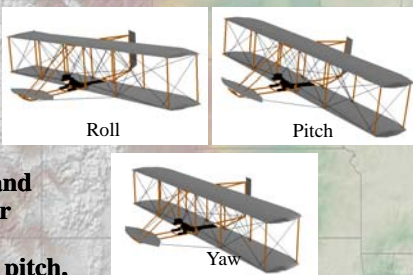




## Lidar Laser


## IMU

- Inertial Measurement Unit
- Gyroscopes and accelerometer
- Records roll, pitch, yaw of aircraft





## GPS

- Global positioning system
- Differentially corrected
- Provides cm accuracy of aircraft
- Allows cm accuracy of laser pulse



The diagram shows three GPS satellites in orbit above a yellow aircraft. Red lines represent the signal paths from the satellites to the aircraft. Below the aircraft, a red oval on the ground represents the ground station or receiver on the surface.



## Scanning Lidar




The image shows a 3D point cloud of a city area, with a yellow aircraft flying above it. The point cloud shows the buildings and terrain in a perspective view.

Courtesy of Dodson & Associates




## On-board Computer

- Records data
  - Photon detector (intensity)
  - Laser timing
  - IMU info
  - GPS info
  - Mirror scan angle
- Converts into XYZ
  - Millions of points
- On-board display




The photograph shows a ruggedized computer system with a monitor displaying a 3D point cloud, a keyboard, and a mouse, all housed in a protective case.




## Error Budget

- Detector Bias and gain
  - Diff b/w electrical and mechanical sensor origin
  - Fluctuations in pulse caused by atmosphere
  - Variance caused by SNR, variance of pulse length and variance of sampling frequency
- Pointing Jitter
  - Horizontal position dependent on stability of mirror (tan of terrain slope- high relief, higher error)
- INS (IMU) errors
  - Misalignment and time-dependent gyro-drift




## Error Budget (cont)

- GPS Errors
  - Orbit Errors
  - Ionospheric and tropospheric delays,
  - Phase ambiguities
  - Multipath returns
- Atmospheric influences
  - Propagation delays
  - Diffraction, absorption and scattering
  - Dependent on flying height, moisture

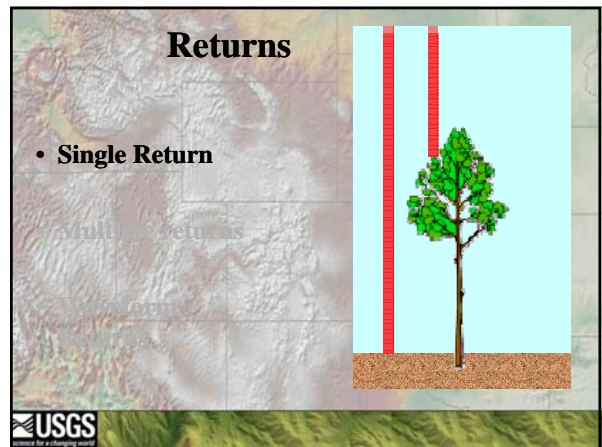
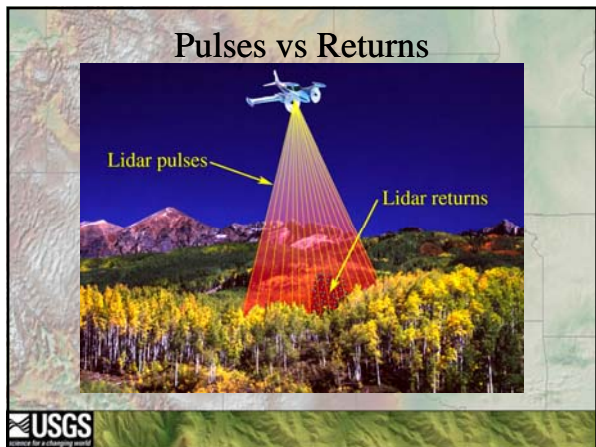
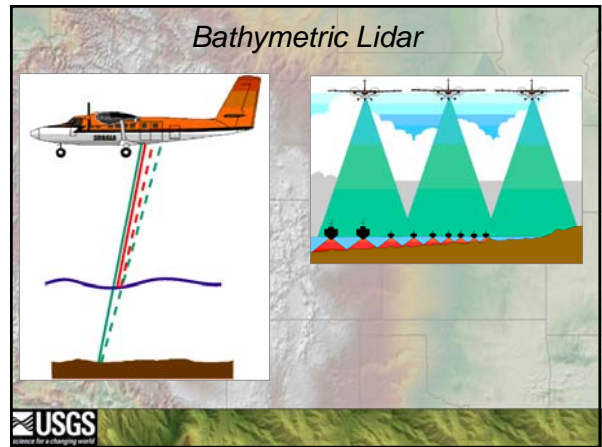
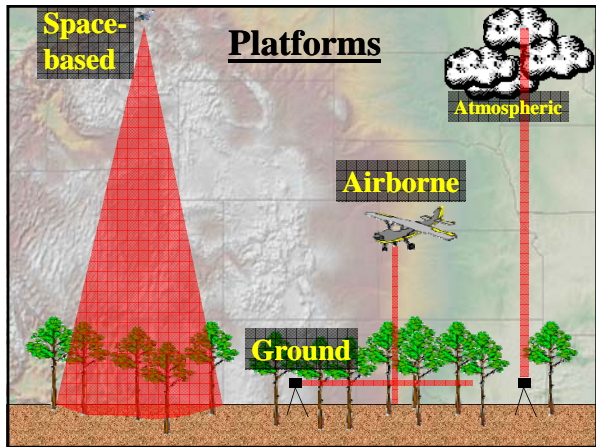
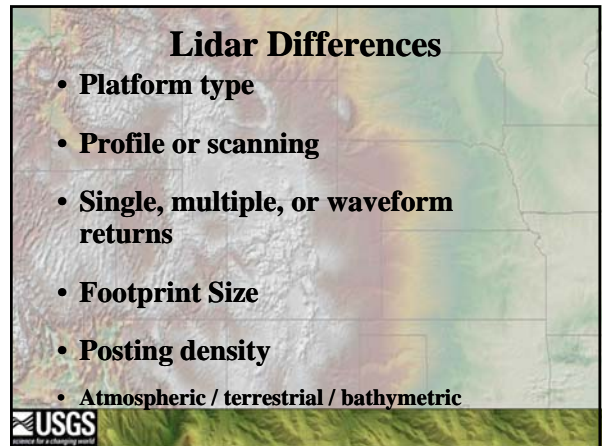
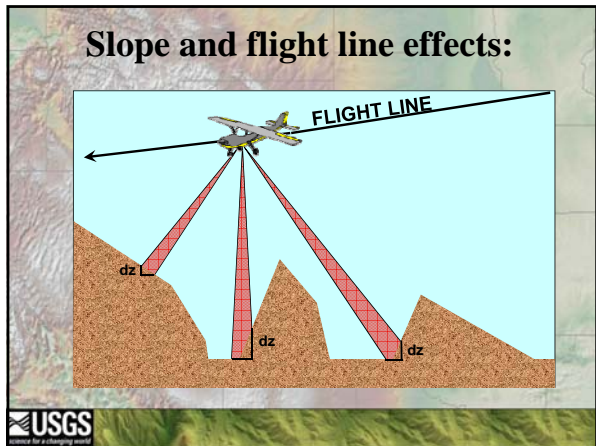


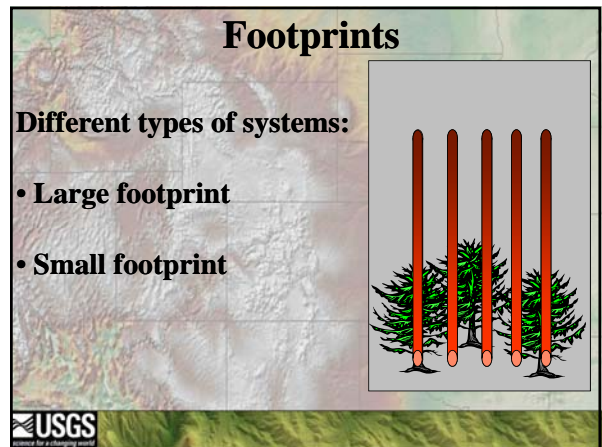
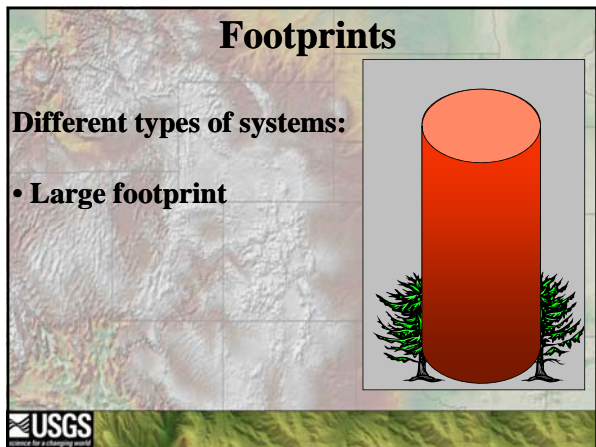
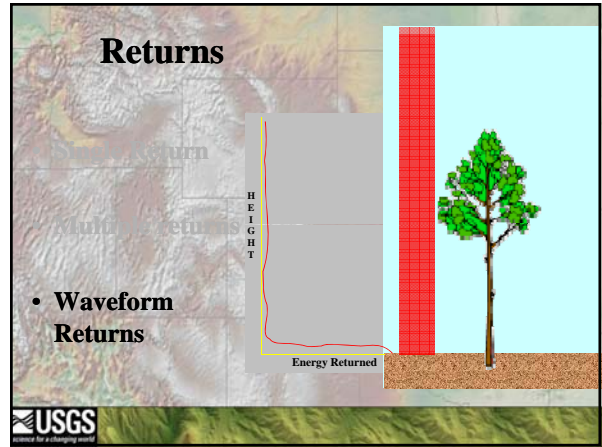
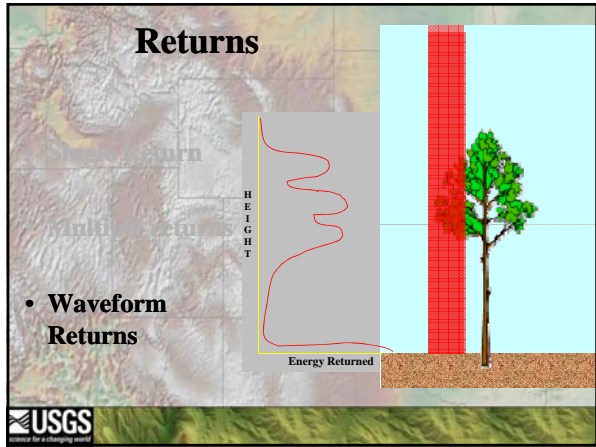
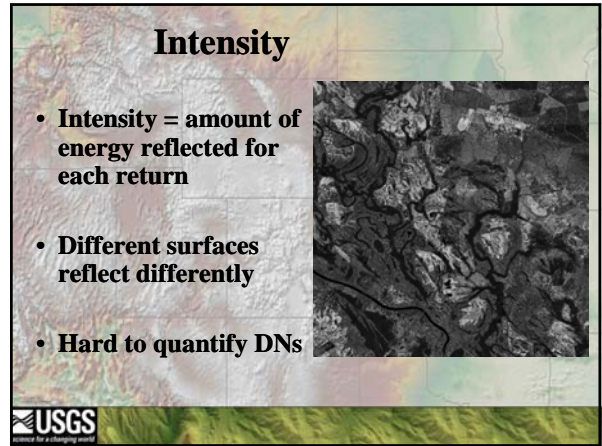
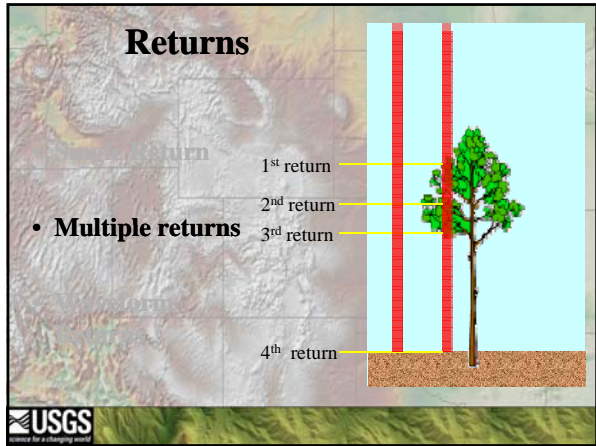
## Error Budget (cont)

- Reflectivity of target
  - Influences SNR and consequently point precision
- GPS and INS integration
  - When use the same clock, errors are minimal
  - When don't, asynchronization in the clocks cause positioning errors in the order of the velocity of the aircraft time the sync error















### Beam Divergence

- Light tends to spread out
- Laser is coherent light, but spreads too
- Beam divergence
- Measured in milliradians
- Higher up, the larger the footprint will be



### Beam Divergence

- Light tends to spread out
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### Posting Density


- Returns called "postings"
- Function of:
  - Laser pulse rate
    - Hz or kHz
  - Flying ht/speed
  - Scan angle
  - Not regular interval

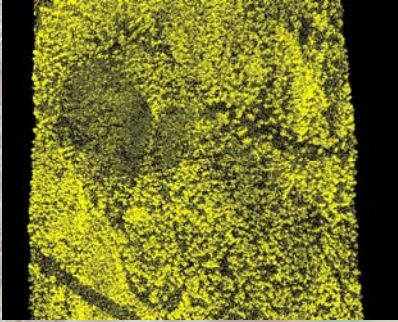

### Introduction

Most commercial systems today are:

- Small footprint
- Multiple return
- Collecting imagery simultaneously
- Large footprint continuous waveform operated by NASA
  - Some systems sample in the waveform

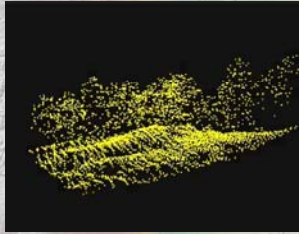



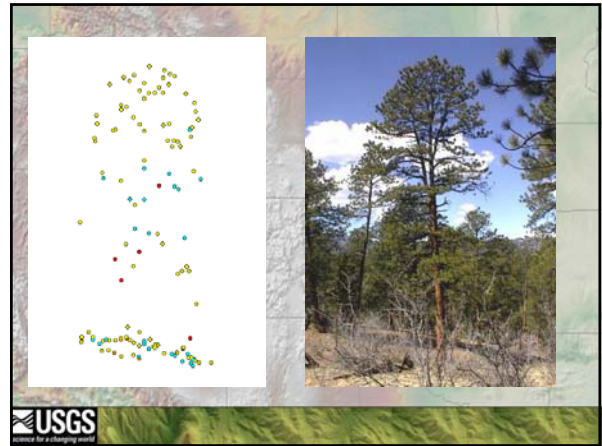
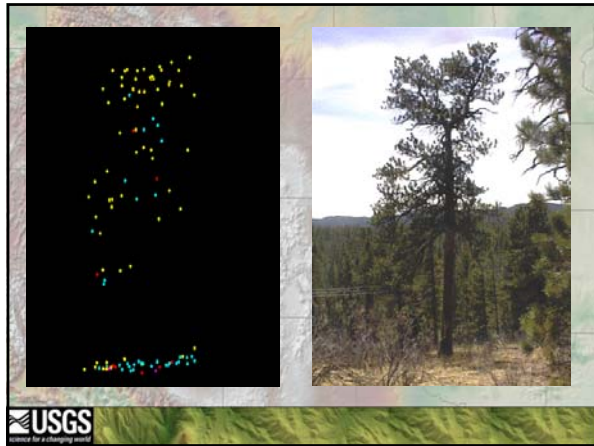
### Raw lidar returns

### Current Lidar Representations of 3D data

- Point Cloud



**Current Lidar Representations of 3D data**

- **Triangulated Irregular Network (TIN)**

**Converting Points to TIN**

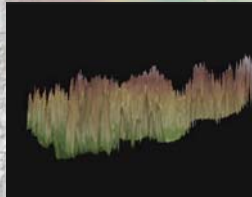

**TIN Without Breaklines Not Hydro-Enforced**

**TIN With Breaklines—Hydro-Enforced**

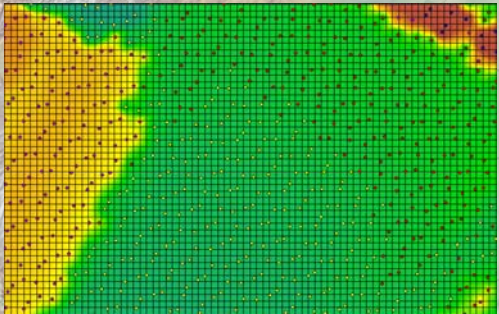



## Current Lidar Representations of 3D data

- Point Cloud
- Triangulated Irregular Network (TIN)
- Raster (Grid)

## Interpolating a Raster- IDW

## Research and Applications

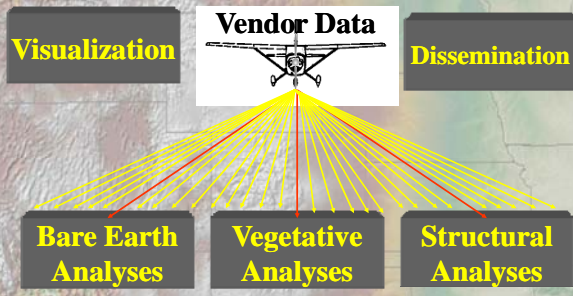



## Lidar Applications

Vendor Data


Visualization      Dissemination

Bare Earth Analyses      Vegetative Analyses      Structural Analyses

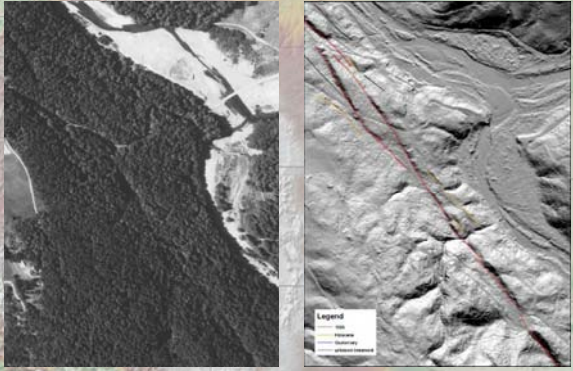




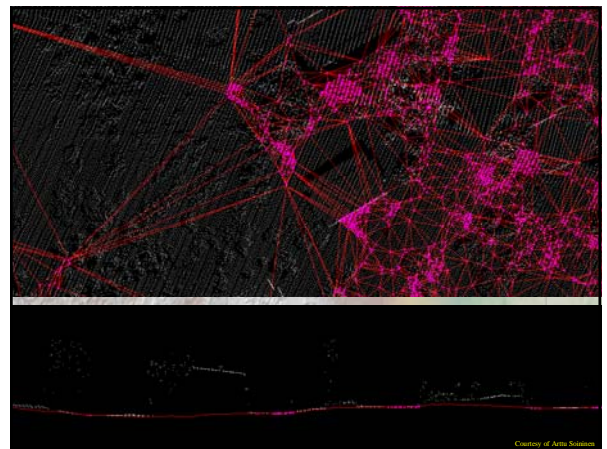
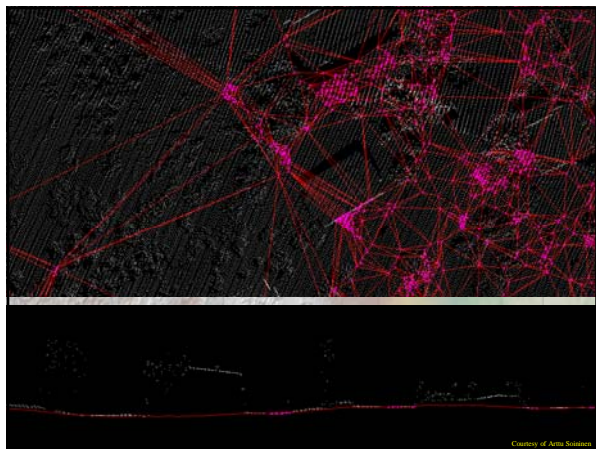
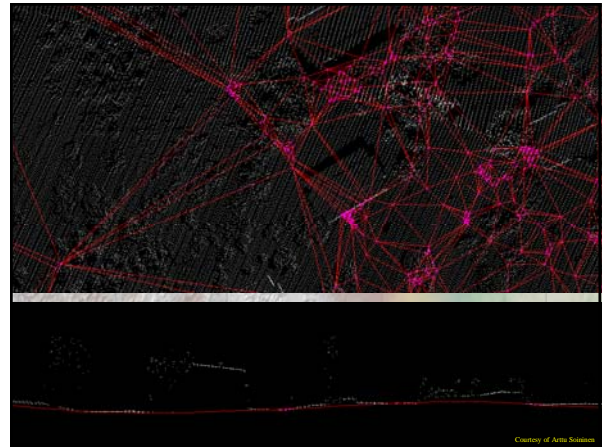
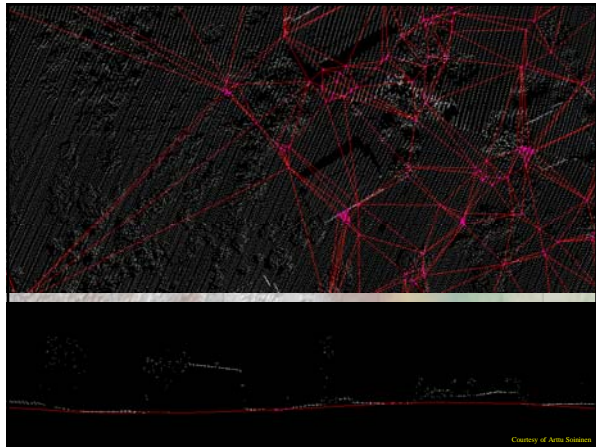
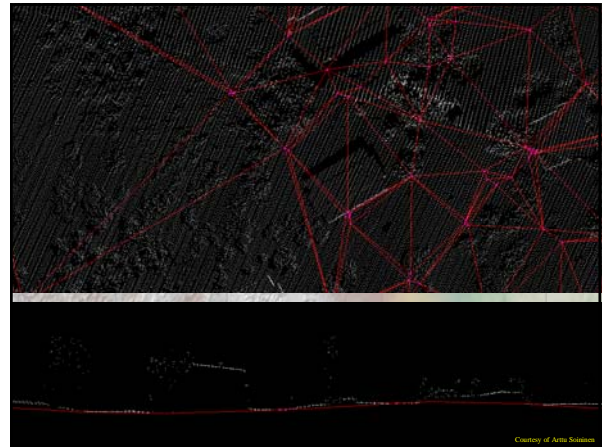
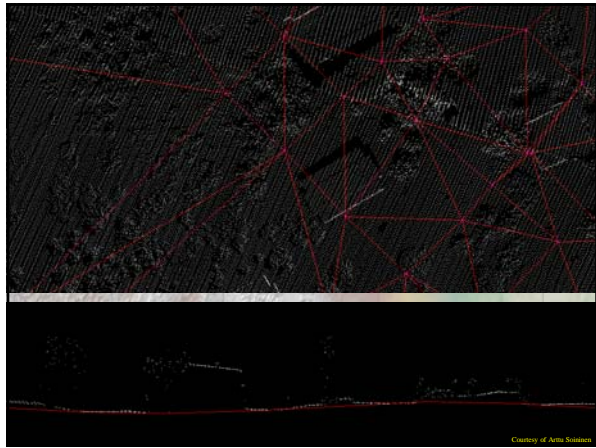
## Bare Earth Analysis

- Primary focus of commercial sector
  - \$\$\$\$\$
- Technology is become widely accepted
- More cost effective / accurate than photogrammetry

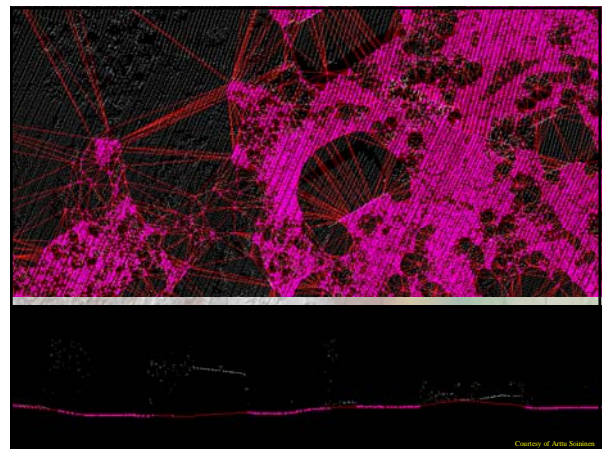
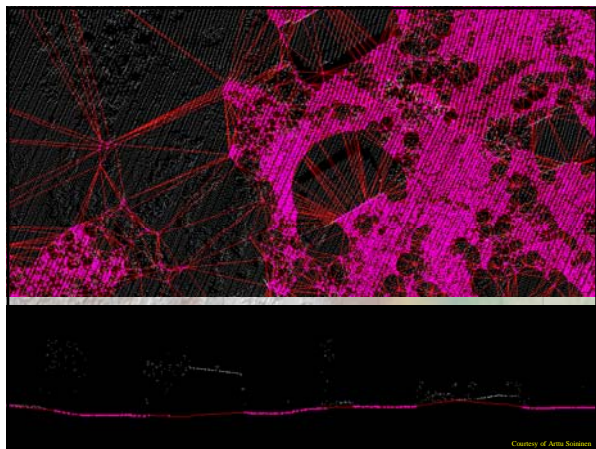
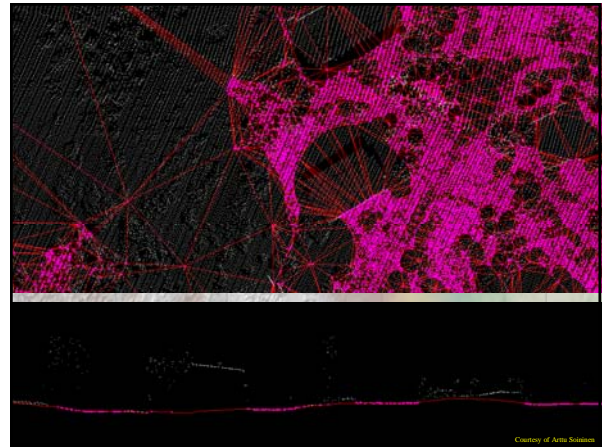
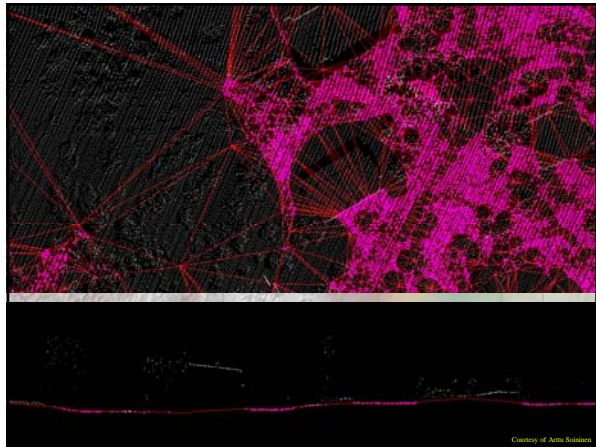
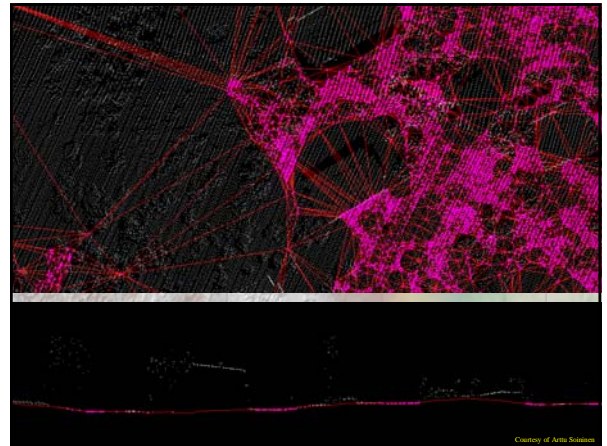
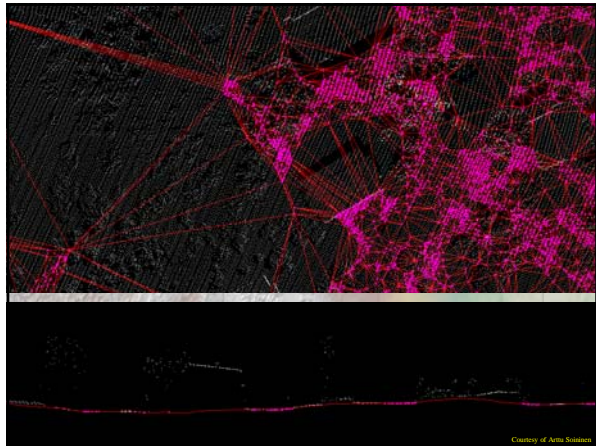


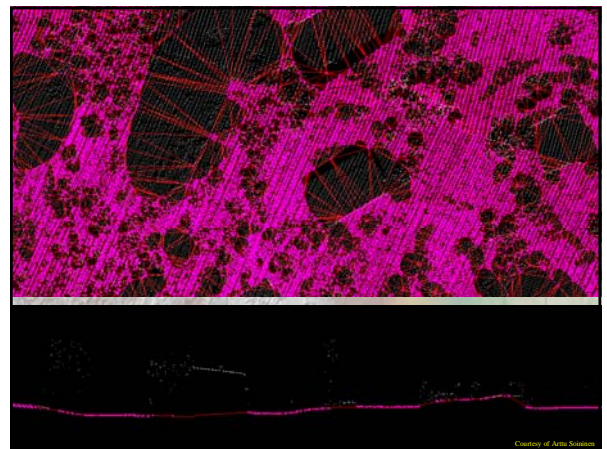
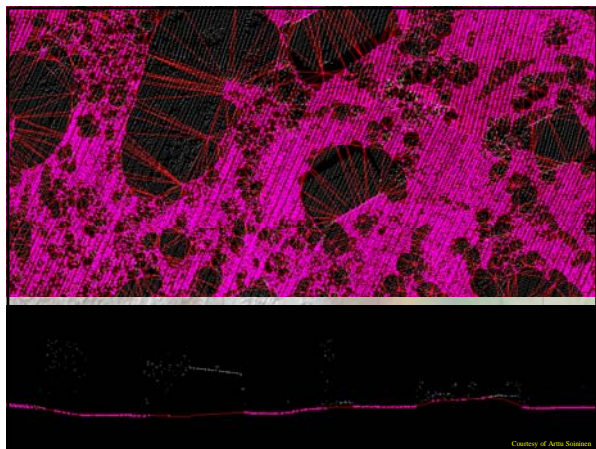
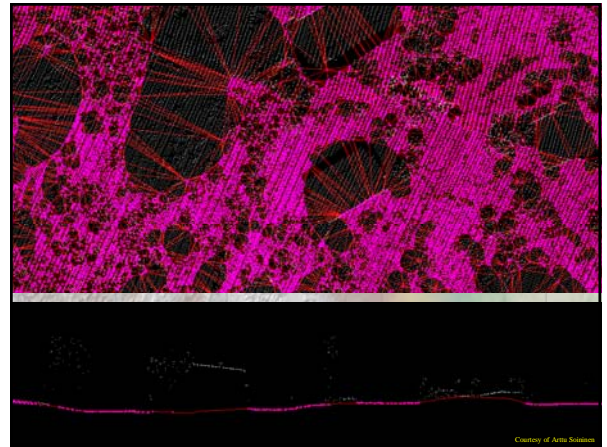
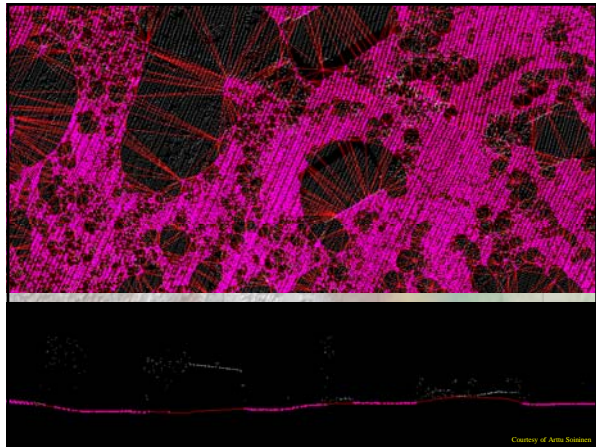
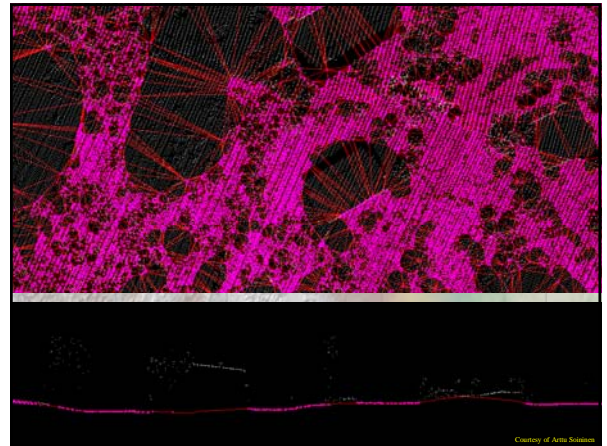
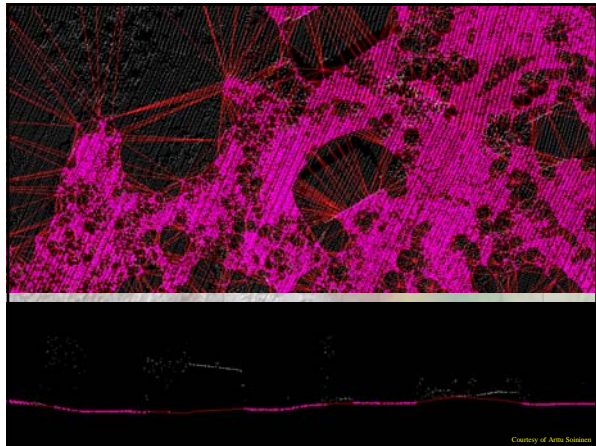
## Northern San Andreas LIDAR: fault geomorphology

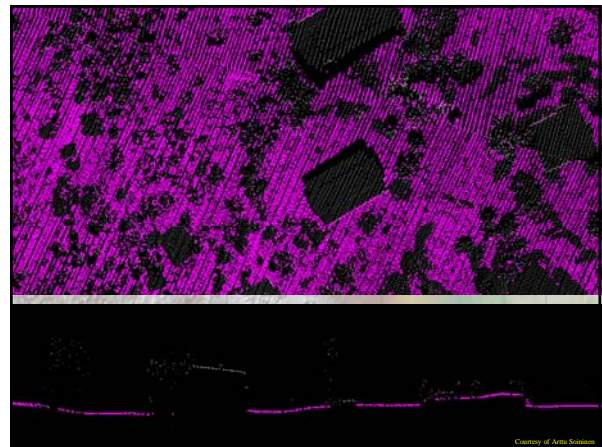
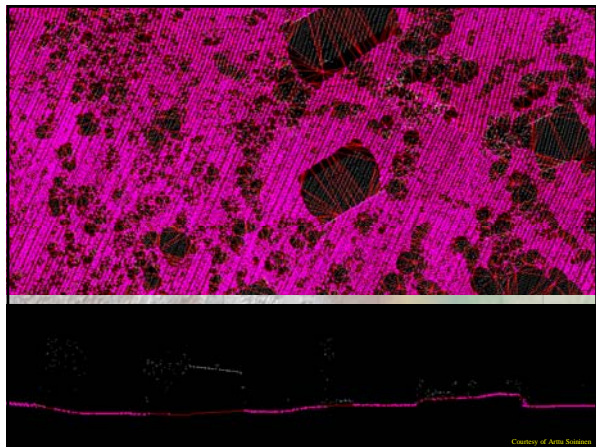
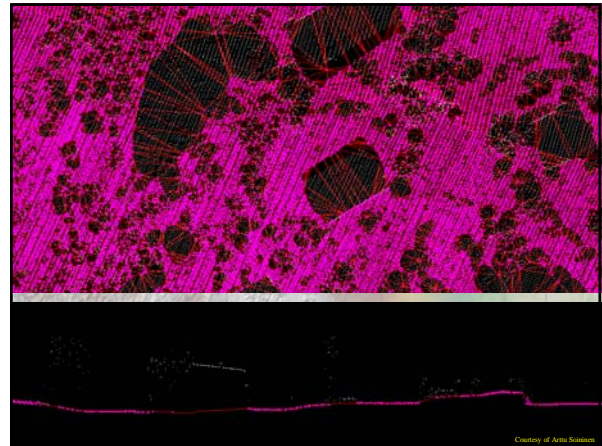
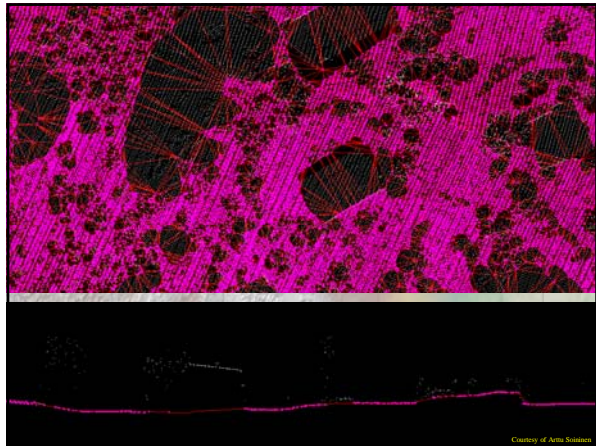












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[National Elevation Dataset](#) [Background](#) [Data](#) [Applications](#) [Research](#) [Publications](#) [FAQs](#) [Contact Us](#)

The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous US and 1:65,360-scale DEM data for Alaska. The dataset provides seamless coverage of the United States, HI, AK, and the island territories. NED has a consistent projection (Geographic), resolution (1 arc second), and elevation units (meters). The horizontal datum is NAD83, except for AK, which is NAD07. The vertical datum is NAVD83, except for AK, which is NAVD09. NED is a living dataset that is updated bimonthly to incorporate the "best available" DEM data. As more 1/3 arc-second (10m) data covers the US, then this will also be a seamless dataset.

The Seamless Data Distribution System (SDDS) offers seamless data for a user-defined area, in a variety of formats, for online download or media delivery.

U.S. Department of the Interior | U.S. Geological Survey

