SNAMP Spatial Team Workshop 2009: LiDAR analysis in the context of forest adaptive management.
June 3 2009: Oakhurst CA

SNAMP Spatial Team Workshop 2009: LiDAR analysis in the context of forest adaptive management.
June 4 2009: Foresthill CA

SNAMP Spatial Team Workshop Agenda

Welcome and introductions

Meeting goals

PART 1
- Introduction to LiDAR
  - Laser Sensors
  - Types
  - Applications

SNAMP
- SNAMP LiDAR specs
- SNAMP Science Models
- SNAMP LiDAR products
- SNAMP LiDAR products
  - DEM (Water, Wildlife & Fire)
  - Canopy cover (Water, Wildlife & Fire)
  - Tree height (Water, Wildlife & Fire)
  - Canopy bulk density (Fire)
  - Canopy fuel (Fire)
  - Canopy base height (Fire)
  - Understory
  - Other research
  - Questions and Data Show-and-Tell

PART 2
- Other Imagery
  - NEXIS, NEXTMAP, TM, others
- Data Sharing Server
  - How and from where to download the data
  - SNAMP website

PART 3
- Other research
- Questions and Data Show-and-Tell

Meeting Goals and Desired Outcomes

Goals:
- To inform stakeholders about SNAMP spatial team people and research, with concentration on LiDAR data.

Desired Outcomes:
- Increased knowledge of how spatial data are integrated into SNAMP.
- Open communication between SNAMP spatial team and stakeholders.
- Participate in the SNAMP adaptive management outreach process.

Sierra Nevada Adaptive Management Project

SNAMP was formed to develop, implement and test Adaptive Management processes through testing the efficacy of Strategically Placed Landscape Treatments (SPLATs) across four response variables, including:

- Public participation
- Wildlife
  - Pacific Fisher
  - California Spotted Owl
- Water
- Fire/forest health

- Each of these groups has an associated research team, and all are supported by a spatial team.

How did SNAMP begin?

Why SNAMP?

Controversy over USFS management

Consensus that forests are at risk from fire

Uncertainty on how best to reduce risk

An acknowledged need to learn more
SNAMP Goals
Provide independent third-party research on effects of USFS fuels treatment.
Help develop and evaluate an adaptive management program with strong public participation.

Adaptive Management (AM) is:
Learning through deliberate experimentation
(Walters and Green, 1997)
The UCST is committed to a participatory AM process that engages scientists, public stakeholders and the resource agency(s) throughout the entire process.

Adaptive management cycle
1. Determine management goals
2. Gather & synthesize
3. Design and implement
4. Monitor & evaluate
5. Incorporate knowledge
6. Adjust management

SNAMP Spatial Team
Principal Investigators:
Qinghua Guo, UC Merced
Maggi Kelly, UC Berkeley
Graduate Students:
Marek Jakubowski, UCB
Wenkai Li, UCM
Staff:
Hong Yu, UCM
Visitors:
Alessandro Montaghi, UCB
Celia Garcia, UCB
Shasta Ferranto, UCB

Spatial Team Goals
- Developed to assist in the GIS and remote sensing technology that all teams require.
- Members of the spatial team have the responsibility for supporting all other teams’ GIS, remote sensing and spatial analysis needs.
- Conduct applied research in application of spatial technology to forest science and management

Spatial Team Activities
- LIDAR data acquisition and analysis
- Field campaign
- SNAMP team support

SNAMP Study Areas
These sites were chosen because: 1) Active USFS management plans in place; 2) Met a range of scientific criteria (including providing habitat for wildlife species and the potential for recruiting large tree structures); and 3) the sites were representative of typical Sierran landscapes.

Why do outreach?
Essential components of the SNAMP process
- Outreach
- Comprehensive and sustained process
- Effective facilitation
- Transparent decision making
Will increase participation, which should:
- Allow for shared learning
- Improved research and implementation outcomes

Why do outreach?
Essential components of the SNAMP process
- Outreach
- Comprehensive and sustained process
- Effective facilitation
- Transparent decision making
Will increase participation, which should:
- Allow for shared learning
- Improved research and implementation outcomes
Introduction to Lidar

Lidar = Light Detection and Ranging

Lidar Data:
1. Range: The measurement of the speed which a pulse of light returns to a sensor is converted to elevation above sea level.
   \[ R = \frac{1}{2} ct \]
   - \( R \): range
   - \( t \): time
   - \( c \): speed of light

2. Intensity: The recorded maximum return from all the returns.

Lidar Components
- Laser & receiver
  - Nd:YAG laser is target
  - Laser wavelength can differ (e.g., 1064 nm)
- IMU
  - Gyroscopes and accelerometers
    - Records roll, pitch, yaw of aircraft
- GPS
  - Differentially corrected
    - Provides cm accuracy of aircraft
    - Allows cm accuracy of laser pulse
- On-board computer
  - Receives data, stores information (intensity, XYZ info, GPS info)
  - Converts into XYZ
  - On-board display
- Scanning mechanism
  - Oscillating mirror

Lidar for Data Capture
- Advantages
  - Collect large data sets quickly and economically
  - 100 sq mi - 1,000+ sq miles
  - Sensor can be flown at night
  - Acquisition in all seasons leaf-on and leaf-off
  - Can be collected during cloudy conditions if clouds are above aircraft
  - Very accurate
- Disadvantages
  - Cannot sense through rain, thick clouds, haze, wind (dust), or smoke
  - Limited in thick forest or dense vegetation
  - Surface materials may absorb laser
  - Large data file sizes
  - Small project areas not economical

Lidar Differences
- Airborne or ground
- Type of scanning mechanism
  - Single, multiple, or waveform returns
- Footprint size
- Posting density
- Application: atmospheric / terrestrial / bathymetric

Scanning Lidar
The integration of a device such as an oscillating mirror allows for the development of scanning Lidar.
**Ground-based Lidar**

Ground-based lidar systems are hemispherical scanning laser range finders that fire millions of laser pulses and records detailed structural information at a range of up to 200 m. Data can be used to derive:

- canopy height
- basal area and stem density
- vertical foliage distribution
- leaf area index


**Lidar Returns**

- Discrete return
  - Single
  - Multiple
- Waveform return

Discrete-return lidar devices major peaks that represent discrete objects in the path of the laser illumination. Waveform-recording systems capture the entire signal trace for later processing.

**Lidar Specifications**

- Flying altitude (500–1500m AGL)
- Laser pulse:
  - Pulse rate frequency, measured in KHz (as high as 107,000 points per second)
  - Laser is coherent light, but does spread
  - Beam divergence, measured in milliradians
- Scan:
  1. Scan angle, measured in degrees
  2. Scan frequency, measured in Hz

**Footprint Size & Density**

The laser footprint is approximately circular on the ground.

- Footprint size is a function of:
  - Beam divergence
  - Flying altitude
  - Scan angle
  - Pointing density is a function of:
    - Flying altitude
    - Scan angle
    - Scanning frequency
    - Pulse repetition

**Terrestrial Lidar**

Lasers for terrestrial applications generally have wavelengths in the range of 900–1064 nanometers, where vegetation reflectance is high. One drawback of working in this range of wavelengths is absorption by clouds, which impedes the use of these devices during overcast conditions.

**Bathymetric Lidar**

Bathymetric Lidar systems typically use a blue-green laser centered on 532 nm and a raster scanning mechanism to acquire lidar data to measure bathymetry.

Source: NASA Experimental Advanced Airborne Research Lidar (EAARL)
Lidar Data Products

- **DEM** – Digital Elevation Model
  - elevation points over a contiguous area
- **DTM** – Digital Terrain Model
  - elevation information about bare-earth surface without the influence of vegetation or man-made features
- **DSM** – Digital Surface Model
  - elevation information about surfaces in the landscape, including vegetation, buildings and other structures
- **CHM** – Canopy Height Model
  - height information about vegetation features with elevation removed

Lidar Data

- Mass points: x, y, z, intensity

**Topographic Analysis**

Methods are similar to customary 3-D analysis, but resolution and timing make analysis more meaningful.

**Vegetation Analysis**

There are many ways to analyze Lidar data for vegetation information, in general, we can divide these methods into two types:

1. Analyzing canopy height model (i.e. the last return data);
2. Analyzing the height profile through the full range of Lidar returns.

**Lidar Intensity**

Lidar light has very small bandwidth (2-5 nm); most multispectral imaging remote sensing bandwidths are often quite wide: 50-100nm. The intensity value is not directly comparable to the reflectance from the same object in optical remote sensing due to scattering and other factors. There are no guidelines on the interpretation of Lidar intensity images.

But intensity still can be useful for analysis.
Lidar Applications

From Leffky et al. 2002:

Only a few application areas have been rigorously evaluated, and many other applications are feasible.

Developments in lidar remote sensing are occurring so rapidly that it is difficult to predict which applications will be dominant in 5 years.

Currently ecological applications of lidar remote sensing:

- ground topography,
- 3D structure and function of vegetation canopies,
- forest stand structure attributes.

Lidar Applications: Topography

Photogrammetric techniques have long been used to collect topographic information from stereo imagery.

From Dietrich and Herrera, 2006. The recent use of a topographic signature of life. Nature: The influence of life on topography is a topic that has remained largely unexplored. Erosion laws that explicitly include biotic effects are needed to expand the intrinsic small-scale processes can influence the form of entire landscapes, and to determine whether these processes create a distinctive topography.

Dietrich et al. are using lidar and radar to compare topographic landscapes on Earth and mars.

Lidar Applications: Vegetation Canopies


Lidar can provide fine-grained information about the 3D structure of ecosystems across broad spatial extents.

This data can be used to investigate:

- Animal-habitat relationships,
- Fire behavior,
- Carbon and energy balance,
- Infiltration, canopy capture and sublimation.

Lidar Applications: Forest Structure

From Lucas et al. 2009. Retrieving forest biomass through integration of CASI and Lidar data. IJRS.

Lucas et al. 2009 used CASI and lidar data to map biomass in a complex Australian forest.