

## The Critical Zone: Where Rock Meets Life

The Critical Zone (CZ) is defined as the zone at Earth's land surface extending from the top of the vegetation canopy through soil to subsurface depths at which fresh groundwater freely circulates, the zone in which most terrestrial life including humanity relies. Critical Zone Observatories (CZO) provide important platforms for studying the processes occurring in the Critical Zone (see [criticalzone.org](http://criticalzone.org)). The goal of the CZOs is to build a network

to advance interdisciplinary studies of Earth surface processes, in part to enable a predictive capability for recognizing potential variations in CZ processes in response to ongoing human-induced land-use and climate change. The eight CZOs work together on cross-site activities to enhance the broader impact of work at individual CZOs and for the CZO program as a whole. One such cross-site activity is a Light Detection and Ranging (LiDAR) dataset.

### What is LiDAR?

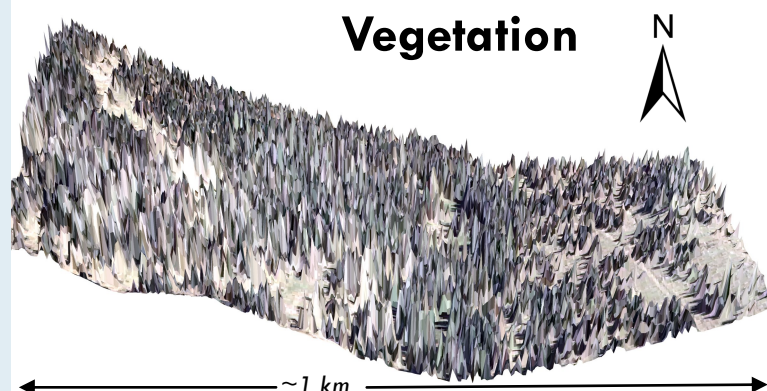
LiDAR, which stands for *Light Detection and Ranging*, is a remote sensing method that uses light in the form of a pulsed laser to measure distances to Earth. LiDAR is the light equivalent of sonar. These light pulses generate precise, three-dimensional information about Earth surface characteristics. The CZO data was collected using a laser mounted on an airplane. A sensor records this reflected light to measure a range (or distance). When laser ranges are combined with position and orientation data

generated from linked GPS and inertial measurement unit systems and scan angles, the result is a dense, detail-rich group of elevation points, called a "point cloud". Each point in the point cloud has three-dimensional spatial coordinates (latitude, longitude, and height) that correspond to a particular point on Earth's surface. The point clouds are used to generate other geospatial products, such as vegetation canopy models (Fig. 1), topography information (Fig. 2), and snow-pack measurements (Fig. 3).

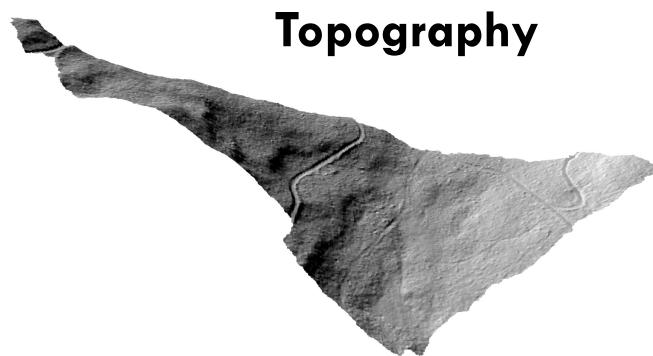
### Exploring the Critical Zone with LiDAR

LiDAR offers a unique means to explore the Critical Zone at very fine scales (~1 m) over very large areas (>100 km<sup>2</sup>). It therefore allows CZ scientists a way to understand how detailed measurements fit into the larger landscape. For example, because individual trees can be identified with LiDAR (Fig. 1 and 5), CZ scientists can use LiDAR to "scale up" measurements of transpiration made on single trees to the entire forest. The difference between 'snow-on' and 'snow-off' LiDAR elevations can be used to produce distributed snowpack measurements (Fig. 3) to predict snowmelt and water availability. In addition, LiDAR is being used to estimate the impacts of forest fire on vegetation

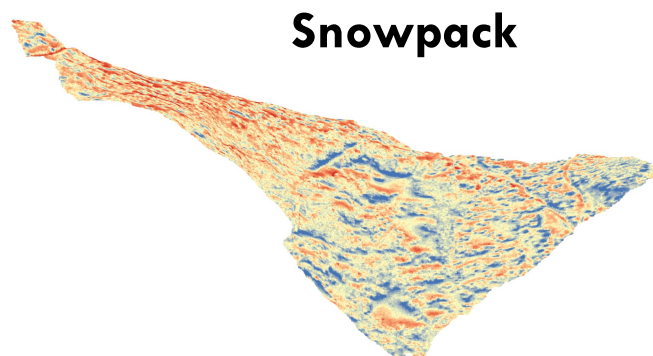
and erosion. The exercise on the back of this handout allows high-school students the opportunity to explore LiDAR datasets from the Jemez River Basin CZO in New Mexico. Students will be able to visualize how the forest changed following the massive Las Conchas forest fire in 2011. LiDAR flights were collected near the Parajito Ski Resort in 2010 (Fig. 4) before the fire and 2012 following the fire. The dramatic changes in the forest can be visualized and measured using LiDAR. This new technology offers the possibility to better understand how fires and other disturbances affect the CZ, which we rely on for water and other natural resources.



**Figure 1.** Vegetation heights estimated using LiDAR at the Jemez River CZO in New Mexico. The colors are from a high-resolution ortho-photo and show trees, meadows, and an old logging road (right side).



**Figure 2.** Hillshade of the 'bare-ground' topography estimated with LiDAR. LiDAR data can help identify topographical features, like the logging road visible in Fig. 1 and others hidden under forest canopy.



**Figure 3.** Snow depth derived from LiDAR datasets. Snow depths near zero (red) occur under dense trees, while deeper depths near 1.5 m (blue) occur in shady-areas on the north-facing edges of meadows.

# Exercises Using LiDAR to Explore the Critical Zone

## Goals of Class Exercises

1. Expose students to LiDAR technology
2. Let students explore a LiDAR point cloud
3. Learn how to extract information from LiDAR

### COMPUTER REQUIREMENTS!

**Window PC:** Windows XP, Windows Vista, or Windows 7 or newer

**Fast computer:** 2 MB RAM (or more), 1 GHZ processor (or faster)

**Enough memory:** 100 MB free memory (or more)

**Fast internet connection:** download 1 MB/min

## Teacher Preparation

### WEBSITE WITH HANDOUT AND TEACHER RESOURCES:

1. <http://criticalzone.org/national/publications/pub/harpold-agi-lidar-handout>

### DOWNLOAD FUSION LDV:

1. Download the .exe file at: [http://forsys.cfr.washington.edu/fusion/FUSION\\_Install.exe](http://forsys.cfr.washington.edu/fusion/FUSION_Install.exe)
2. Run .exe file and install the program at C:/FUSION (you need administrator status)

### DOWNLOAD DATASETS:

1. Visit: [ftp://snowserver.colorado.edu/pub/WesternCZO\\_LiDAR\\_data/AGI\\_exercise/](ftp://snowserver.colorado.edu/pub/WesternCZO_LiDAR_data/AGI_exercise/)
2. Right click and save AGI\_exercise.zip or save each file separately
3. Extract the zip file contents to C:/FUSION

### PRACTICE THE EXERCISES:

1. Should take 5 to 10 minutes.

## Online Resources

### LiDAR TEACHING RESOURCES:

1. Open topography: <http://www.opentopography.org/index.php/resources/education>
2. Teachers domain: <http://www.teachersdomain.org/resource/npe11.sci.phys.energy.lidarmap/>
3. A neat video: <http://www.youtube.com/watch?v=WJoaksSKaOo>

### HELP RESOURCES FOR FUSION:

1. Manual: [http://forsys.cfr.washington.edu/fusion/FUSION\\_manual.pdf](http://forsys.cfr.washington.edu/fusion/FUSION_manual.pdf)
2. Tutorial #1: [https://cloud.sdsc.edu/v1/AUTH\\_opentopography/www/shortcourses/09SCEC\\_course/09SCEC\\_Exercise1\\_Fusion.pdf](https://cloud.sdsc.edu/v1/AUTH_opentopography/www/shortcourses/09SCEC_course/09SCEC_Exercise1_Fusion.pdf)
3. Tutorial #2: <http://www.fs.fed.us/eng/rsac/fusion/pdfs/Exer02GettingStarted.pdf>

## Exercise 1: Setting up FUSION and viewing the LiDAR point cloud

### There are 5 steps to get the data ready to view:

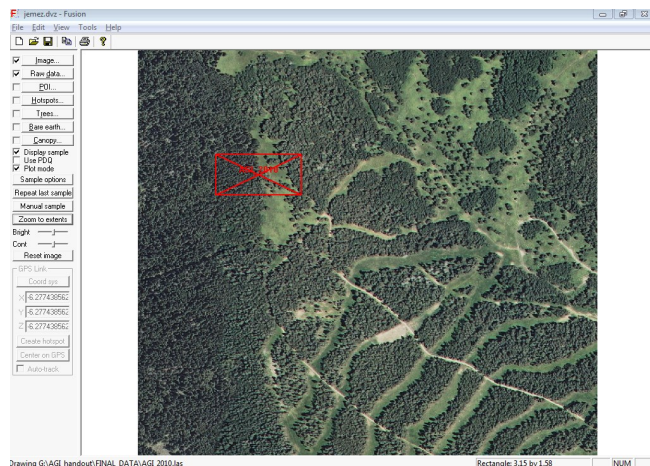
1. Open FUSION program to Start menu> Programs > FUSION (remember it must already be installed!).
2. Load the image file C:\FUSION\photo.bmp by clicking the 'Image...' button in the top left corner and press the check mark.
3. Press the 'Raw data...' button and check mark and select AGI\_2010.las. Your screen should look like Fig 4.
4. Save this FUSION file to C:\FUSION\jemez.dvz
5. Press the 'Manual sample' button and use: lower left: X:373125, Y:3973650 and upper right: X:373175, Y:3973700. This should open a 50X50 m area in the LiDAR Data Viewer.

### Explore the point cloud and create a canopy model:

1. Use the mouse and keyboard to navigate the point cloud (see box on the right for tips!).
2. Can you see the individual trees? Zoom in to look closer. Why are there black areas under the trees? (answer:: these areas were blocked from the laser by branches and leaves).
3. Go to Tools>Create canopy surface model... Save the file as C:\FUSION\temp2010.dtm
4. Choose 0.5 m for the surface model cell size and press Create Model. How does the canopy model look compared to Fig. 5?

### Continue to explore:

1. You can resample other areas of the point cloud (red box in Fig. 1) to view. Select smaller areas if the LDV Viewer is slow to load.



**Figure 4.** FUSION viewer after photo.bmp and AGI\_2010.las have been loaded into 'Image...' and 'Raw data...', respectively.

## Tips for Navigating in LDV

### ROTATE AND PAN:

- Hold left mouse button and move mouse OR
- Press Shift & right, left, up, and down.

### Zoom IN AND OUT:

- Hold left mouse button AND Ctrl button and move mouse

### OPEN MENU BAR:

- Right-click mouse

### CHANGE SYMBOL SIZE:

- Press Ctrl & + or - to make the symbols bigger and smaller.

### MAKE THE SURFACE PLATE TRANSPARENT:

- Press + or - to make more or less transparent

### ADD A SURFACE FILE:

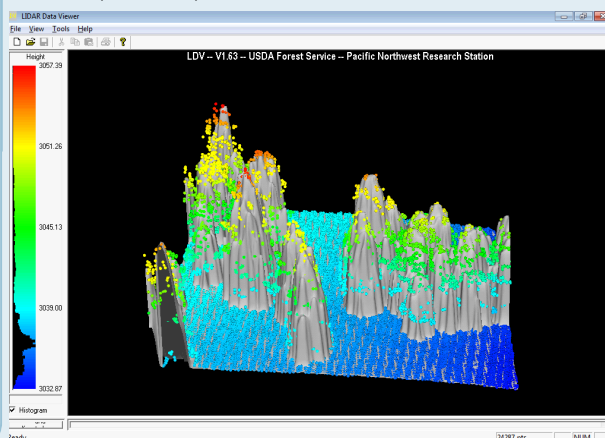
- Press Alt & J OR
- Right-click mouse and choose 'Surface file'

## Exercise 2: Exploring post-fire effects on forests using LiDAR

### Load the 2012 (post-fire) point cloud and create a canopy model:

1. Open your file from Exercise 1 C:\FUSION\jemez.dvz and press the 'Raw data...' button. Choose 'Delete all' then 'Add file...' and choose C:\FUSION\AGI\_2012.las
2. Choose 'Repeat last sample' or choose 'Manual sample' and re-enter coordinates.
3. Repeat steps 3 and 4 from earlier to create a canopy with the name: C:\FUSION\temp2012.dtm

4. Now change the 'Raw data..' back to AGI\_2010.las by repeating step 1.
5. Press 'Repeat last sample'
6. Now load the 2012 canopy model by pressing (Alt & J) and choosing the file C:\FUSION\temp2012.dtm
7. Your viewer should match Fig. 5 and show difference between the pre- and post- fire LiDAR. Were these trees burned? Do some trees look worse?
8. Choose other areas from FUSION viewer and repeat.



**Figure 5.** The LDV Viewer showing the 2010 (pre-fire) point cloud on the 2012 (post-fire) canopy model. Comparison of the two LiDAR datasets provides an estimate of the distribution and severity of the Las Conchas forest fire.