CZO | Critical Zone Observatories
U.S. NSF National Program

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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 (CZOs) provide important platforms for studying the processes occurring in the Critical Zone (see 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 snowpack 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^2). 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.

Vegetation

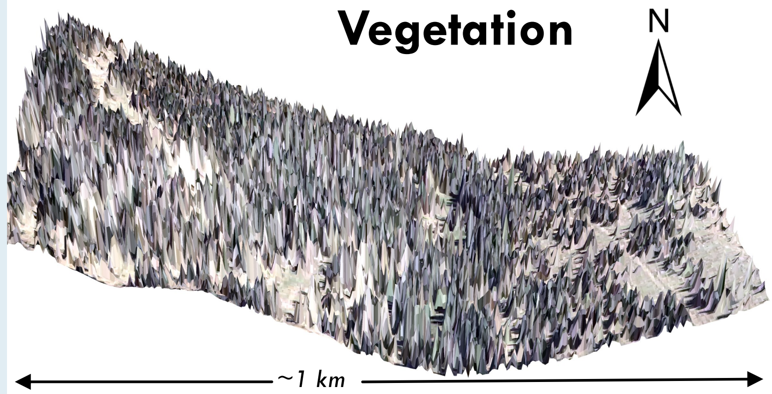

Figure 1. *Vegetation heights estimated using LiDAR at the Jemez River CZO in New Mexico. The colors are from a high-resolution ortho-photo and show trees, meadows, and an old logging road (right side).*

Topography

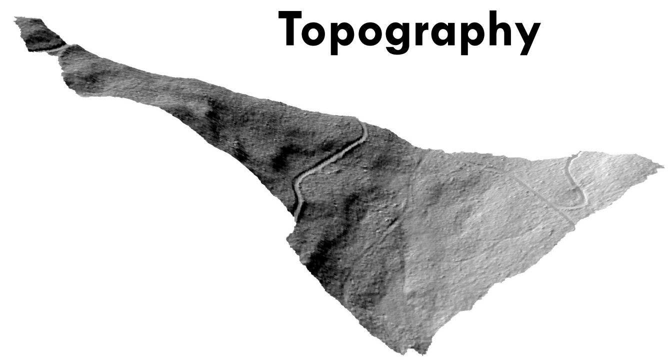

Figure 2. *Hillshade of the 'bare-ground' topography estimated with LiDAR. LiDAR data can help identify topographical features, like the logging road visible in Fig. 1 and others hidden under forest canopy.*

Snowpack

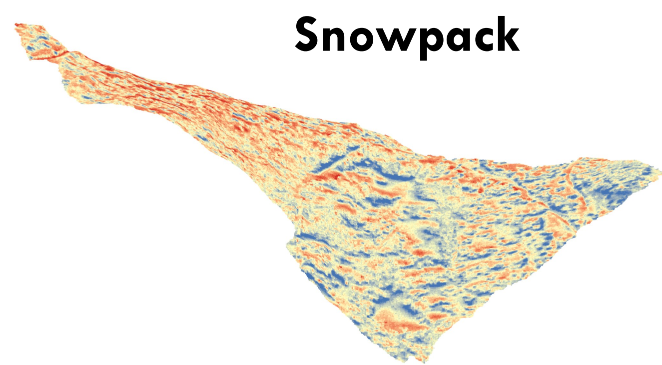

Figure 3. *Snow depth derived from LiDAR datasets. Snow depths near zero (red) occur under dense trees, while deeper depths near 1.5 m (blue) occur in shady-areas on the north-facing edges of meadows.*

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
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/
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
2. Tutorial #1: 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.

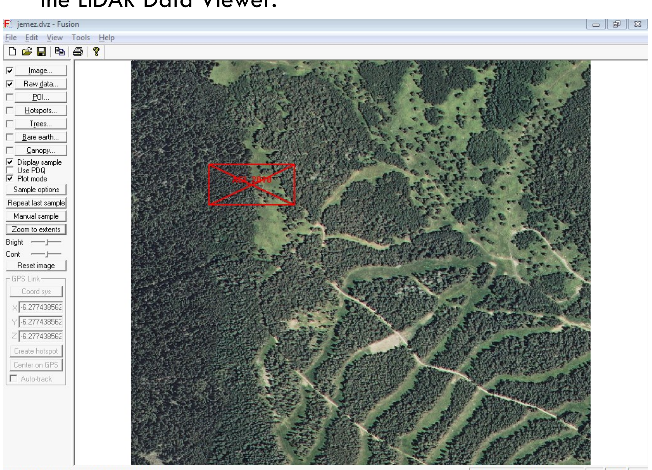

Figure 4. *FUSION viewer after photo.bmp and AGI_2010.las have been loaded into 'Images…' and 'Raw data…', respectively.*

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

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.

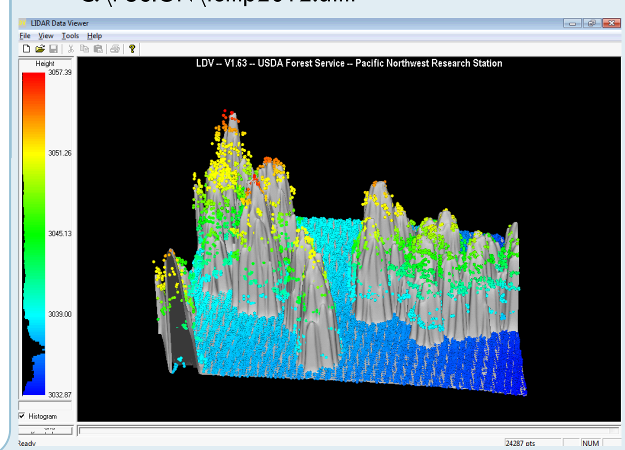

Figure 5. *The LDV Viewer showing the 2010 (pre-fire) point cloud on the 2012 (post-fire) canopy model. Comparison of the two LiDAR datasets provides an estimate of the distribution and severity of the Las Conchas forest fire.*