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# Comparison of Airborne and Mobile Terrestrial Lidar to Map Louisiana Levees

Cindy Thatcher[1], Jeffrey Danielson[2], Samsung Lim[3], Monica Palaseanu-Lovejoy[1], John Brock[4], and Dustin Kimbrow[5]

[1]U.S. Geological Survey, Eastern Geographic Science Center, Reston, VA [2]U.S. Geological Survey, EROS Center, Sioux Falls, SD [3]University of New South Wales, Sydney, NSW, Australia [4]U.S. Geological Survey, Coastal and Marine Geology Program, Reston, VA [5]U.S. Geological Survey, Alabama Water Science Center, Montgomery, AL

## Introduction

Flood protection in south Louisiana is largely dependent on earthen levees, and following Hurricane Katrina the State's levee system has received intense scrutiny. The USGS is working with the Louisiana Coastal Protection and Restoration Authority, Louisiana Sea Grant, and local levee districts in Lafourche and Terrebonne Parish to map and monitor non-federal levees using targeted airborne and terrestrial lidar surveys. Currently, comprehensive, elevation data of requisite vertical accuracy is lacking for most non-federal levees in south Louisiana because of high rates of subsidence and the difficulty of mapping long stretches of levees using a Global Positioning System or traditional surveying techniques. In early 2012, high resolution aerial lidar data was acquired following the centerline of each levee. In addition, a field survey was conducted along selected levee segments using a mobile lidar scanner mounted on a truck (Figure 1) to investigate improving the positional accuracy of the airborne lidar and to provide unique high resolution side-view profiles of selected levee sections. Although terrestrial lidar systems are capable of acquiring extremely dense point cloud data, a key disadvantage of terrestrial lidar is the occurrence of "shadows" of missing data, which is a phenomenon related to lidar's line-of-sight principle. The purpose of this study was to research a method to use airborne lidar to fill in the shadows and other data gaps in the terrestrial lidar data to provide a more comprehensive, three-dimensional view of landscape features than could be obtained using either type of data alone. We also examined the utility of using mobile terrestrial lidar point cloud data as ground control points to assess, and then potentially improve, the vertical accuracy of airborne lidar-derived digital elevation models.


**Figure 1.** Mobile terrestrial lidar system mounted on a vehicle.

## Lafourche Parish, Louisiana Lidar Surveys

Both airborne and terrestrial lidar data were acquired along levees in Lafourche Parish, Louisiana in early 2012 (Figure 2). High resolution airborne lidar was acquired in late January and early February of 2012 in a 100 m swath following the centerline of 340 linear km of levees in Lafourche Parish using an ALS60 lidar system (Digital Aerial Solutions, 2012). In April of 2012, a USGS field team collected terrestrial lidar data along 10 km of levee segments selected by the North Lafourche Levee District in Louisiana using a mobile lidar scanner (Optech ILRIS HD) mounted on a truck. The scanner is integrated with two Global Positioning System receivers and an inertial measurement unit (together known as a Position and Orientation System [POS]) to produce a point cloud georeferenced to the Universal Transverse Mercator coordinate system and the North American Vertical Datum of 1988. The earthen levees surveyed with terrestrial lidar have a typical height of 1 to 2 meters and are wide enough at minimum for a vehicle to drive on.

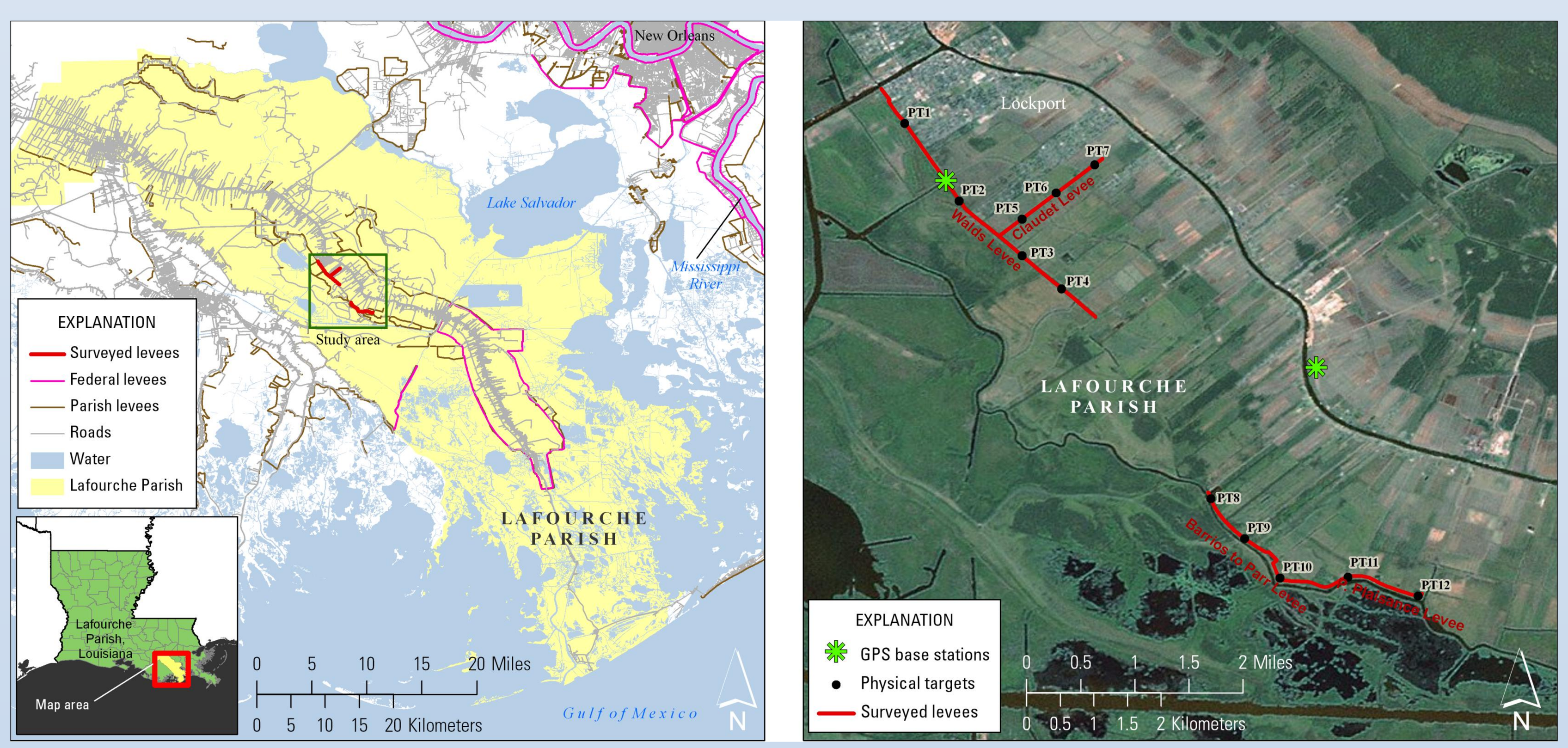


**Figure 2.** The extensive levee system in Lafourche Parish, Louisiana. The levee segments shown in red were surveyed using both aerial and terrestrial lidar.

To evaluate the accuracy of the terrestrial lidar data, independent elevation data were collected by conducting a GPS survey to establish the x,y,z coordinates of 20 targets (placed flat on the ground or mounted on tripods) placed on the levees during the terrestrial lidar survey (Figure 3). A GPS base station was established over a nearby benchmark for the duration of the study for differential GPS correction of both the POS and the GPS target survey data.

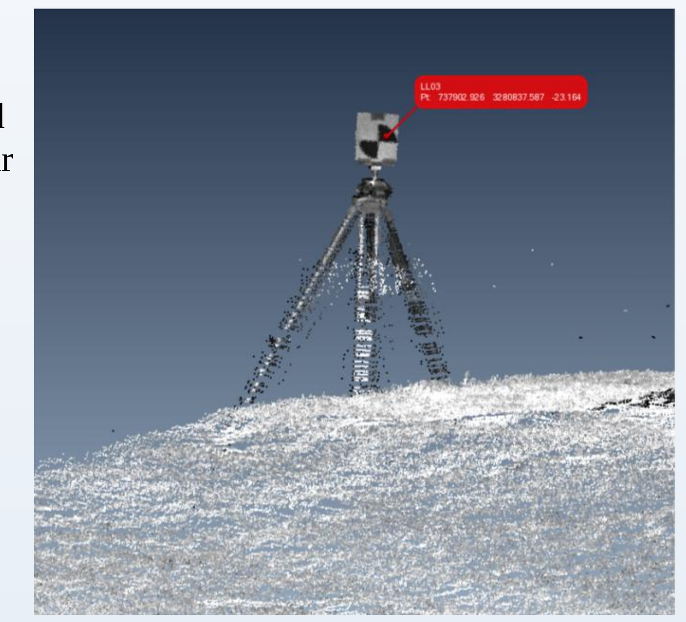

**Figure 3.** Lidar point cloud of a target established to measure horizontal and vertical positional accuracy of the lidar data. The points are shaded using intensity values and the location of the target center established with precision GPS is shown in red.

## Results

The point density as well as the horizontal and vertical accuracy of the terrestrial lidar was much higher than that of the aerial lidar (Table 1). Raster digital elevation models (DEMs) derived from the bare earth points were extracted from the point clouds at 0.2 m resolution for the terrestrial lidar and 0.5 m resolution for the aerial lidar.

Several scans were required to map the crest and sides of the levees with the mobile terrestrial lidar scanner. The lower edge of the levee sides in some areas was covered with dense, tall wetland vegetation (Figure 4) that was impossible to traverse with a truck or an all-terrain vehicle. Therefore, the levee sides in some areas could not be completely mapped with the terrestrial lidar scanner.

**Figure 4.** Dense wetland vegetation on the side of a levee.

The vertical agreement between the bare earth point clouds was good, although the aerial lidar data exhibited a negative vertical bias of approximately 0.05 m relative to the terrestrial lidar. Because neither the aerial or terrestrial lidar point clouds exhibited a vertical bias relative to the ground control points, this vertical difference may be related to errors in the identification of bare earth points in the terrestrial lidar on grass-covered levees. More analysis is needed to determine if applying more aggressive bare earth filtering parameters to the terrestrial lidar point cloud could reduce this vertical difference.

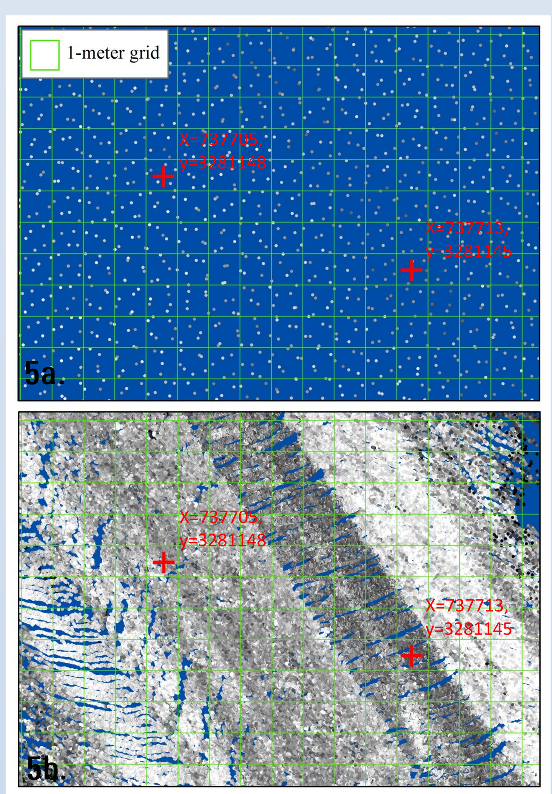


**Figure 5a-b.** Aerial lidar (a) and terrestrial lidar (b) point density at the same location on the crown of a levee. The points are shaded by intensity values.

| | Airborne lidar | Mobile terrestrial lidar |
|---|---|---|
| Mean point density (per m²) | 3.5 | 866 |
| DEM resolution | 0.5 m | 0.2 m |
| Field of view | nadir (30°) | side-looking |
| Swath width | 600 m | 7.5 m |
| Point cloud file format | .LAS | .LAS |
| Coordinate system | UTM, NAVD88 | UTM, NAVD88 |
| Vertical accuracy (RMSE) | 0.05 m | 0.023 m |
| Horizontal accuracy (RMSE) | 0.10 to 0.20 m (estimated) | 0.034 m |

**Table 1.** Specifications of the aerial and terrestrial lidar collected along levees in Lafourche Parish, LA in 2012.

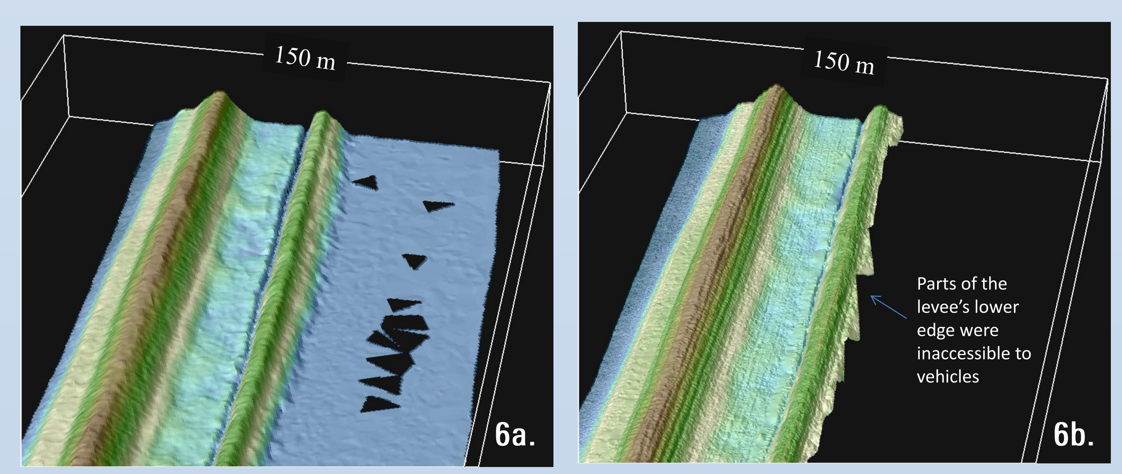


**Figure 6.** Example Digital Elevation Models (DEMs) derived from aerial lidar, gridded at 0.5 m (a), and terrestrial lidar, gridded at 0.2 m resolution (b).

## Conclusions

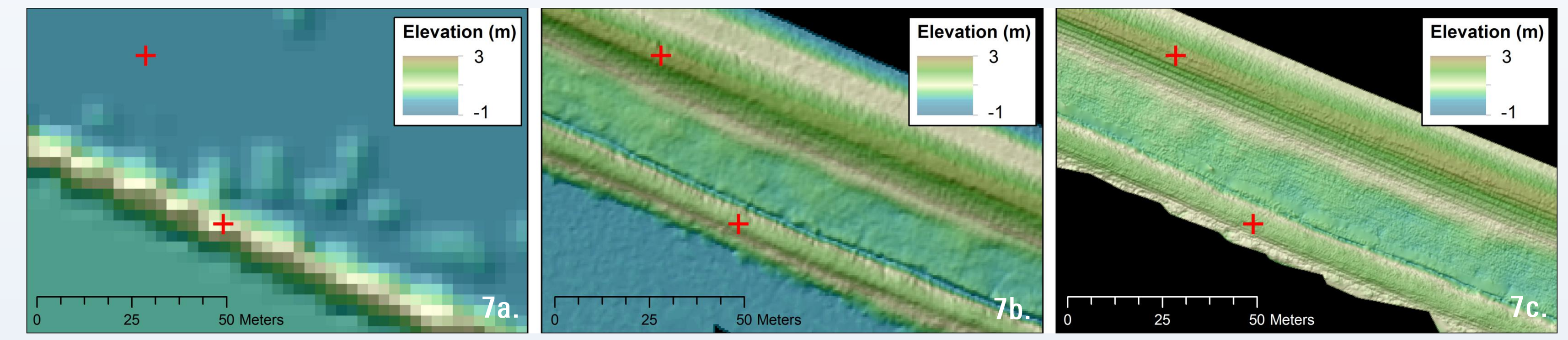


**Figure 7.** 3 m resolution Digital Elevation Model (DEM) derived from 2002 aerial lidar (a), 0.5 m resolution DEM derived from 2012 airborne lidar (b), and 0.2 m resolution DEM derived from 2012 terrestrial lidar (c). A new, larger levee constructed parallel to the existing levee is visible in the 2012 lidar data.

A key advantage to the terrestrial lidar system is the ability to generate relatively low cost time-series data sets to monitor topographic change over time (Perroy et al., 2010). In addition, the very high accuracy in both the vertical and the horizontal planes provides the capability of measuring fine-scale changes that might be difficult to detect with an airborne lidar system. However, topographic shadowing and physical access limitations caused by water features, tall vegetation, rough terrain, and the need to obtain permission to enter private land can be significant obstacles to developing a comprehensive elevation model of landscape features using terrestrial lidar. The side-looking orientation of the terrestrial lidar system can present challenges to mapping topographic features completely, but collecting data from both the horizontal and vertical view angles and conducting multiple scans with a large amount of overlap can help minimize problems such as shadows of missing data.

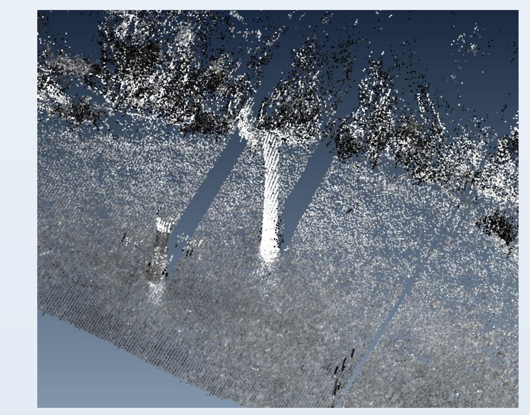

**Figure 8.** A lidar point cloud from a single terrestrial lidar scan with shadows of missing data, caused by objects blocking the laser scanner's line-of-sight.

The acquisition of levee metrics such as crest height presently relies heavily on ground surveys. For example, cross sections of levees are typically acquired at half-mile or longer intervals using ground surveying techniques. The airborne and terrestrial lidar levee data acquisitions are useful in augmenting traditional ground-based survey information for monitoring levee conditions while offering a unique 3-dimensional perspective of levees. With continuous elevation information provided by the airborne lidar survey for the entire parish levee system, levee cross sections, crest heights, and other metrics can be calculated at up to 0.5 m intervals for a much more comprehensive assessment of levee geometry. The resulting improved lidar levee elevation data can be used for coastal elevation, hydrologic, and storm surge modeling and will also be used to update USGS National Elevation Dataset for coastal Louisiana.

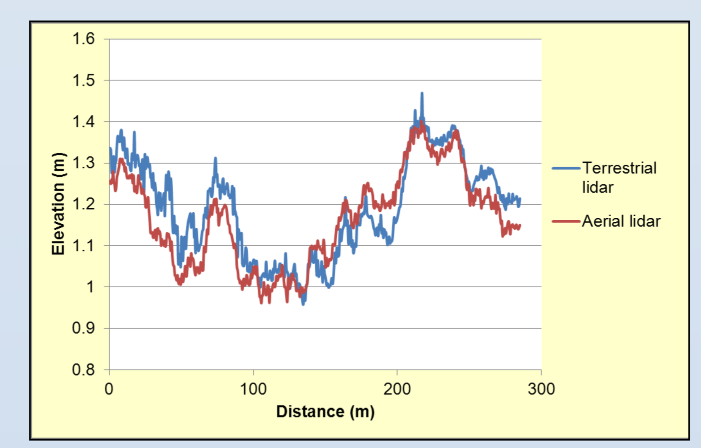


**Figure 9.** Elevation profile of a 300 m segment of levee crest based on terrestrial and airborne lidar. There is an offset of approximately 5 cm between the two datasets.

Parish levees are often relatively narrow and have a relatively low height (i.e., 1-2 meters; Figure 8) compared to Federally-maintained levees. However, these small local levees often have a major impact on hydrologic flow because there is so little topographic relief in south Louisiana. High-accuracy elevation data are therefore critical to local levee district managers as well as scientists and government officials involved in Louisiana coastal monitoring and restoration. The terrestrial lidar survey of Lafourche Parish levees demonstrates the use of a relatively new technology for mapping features such as levees at a high level of detail or for repeat surveys to measure localized geomorphic changes.

**Figure 10.** A parish-maintained levee in Lafourche Parish, LA.

### Acknowledgements

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### References

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