A LiDAR APPLICATION FOR TIN CONSTRUCTION AND ACCURATE LONGITUDINAL PROFILE OF THE MOHAWK RIVER, NEW YORK, U.S.A.

Antonios E. Marsellos[1]

[1]*Dept. of Geological Sciences, University of Florida, 241 Williamson Hall, PO Box 112120, Gainesville, FL 32611, U.S.A., marsellos@gmail.com*

UNIVERSITY of FLORIDA

INTRODUCTION

Figure 1: A satellite image of the Mohawk river (shown with a red line) where 44 bridges and lock stations (shown with white dots) divide the river into 45 river segments.Natural hazards such as ice jams or tropical storms have resulted to significant flooding along Mohawk river in an annual base (Johnston and Garver, 2001; Lederer and Garver, 2001; Sheller et al., 2002; Garver and Cockburn, 2009), and it is required to simulate similar events in order to evaluate or/and possibly predict future disasters (Marsellos et al. 2010a; 2010b; Foster et al., 2011; Marsellos & Garver, 2012; Foster & Marsellos, 2012). Flood simulations require high resolution digital elevation models (DEMs) that will provide a realistic digital representation of surface of less than a meter accuracy. Light Detection and Ranging (LiDAR) data successfully provide high-resolution topographic data, for simulation or damage evaluation, including digital reconstruction of paleo-geomorphological features such as abandon river channels that may reactivate during flooding (Marsellos & Garver, 2010; Marsellos & Tsakiri, 2010). Figure 2: LiDAR sensors receive multiple returns (echoes). Classification of LiDAR points and TIN will provide a bare-earth model (BEM) or a digital surface model (DSM).

The study area is the Mohawk river where LiDAR data cover approximately 164 km of its length (Fig. 1). LiDAR data may provide some times high-resolution digital elevation models (DEM) of decimeter accuracy. However, many pseudo-structures and artifacts may also be revealed. In urban areas, features like roads or buildings have an important effect on flooding and as such must be accounted for in the model set-up. In rural areas or in highly covered vegetated areas trees have been resolved by LiDAR DEMs as large-scale structures that may yield to false digital elevation models, and they require an extensive post-processing and filtering. An alternative digital elevation model could be the Shuttle Radar Topography Mission (SRTM) data which do not require substantial post-processing procedures but they provide low-detailed structures (Fig. 3). As far as topographic data collection is concerned, it is impossible to completely cover or map 100% of the geomorphological features in numerous scales depending the GIS spatial application, since the more that is known, the better. However, the accuracy of a model is not depending of the amount of data as there are cases in which more data may provide a very demanded post-processing to eliminate false information such as triangulation of LiDAR points from tree-trunks or brunches or wires.

1 Longitudinal Profile and TIN Construction

One way to examine a stream is to examine its longitudinal profile. Such a profile is simply a cross-sectional view of a stream from its source area (called the head) to its mouth, the point where it empties into another water body – in our case Mohawk river intersects with the Hudson river. A digitized central line along the river is required to be used to extract a topographic profile. The intersection of the line with quantitative topographic data such as the digital representation of a surface is a longitudinal river's profile. A common method is to use a triangulated irregular network (TIN). A TIN is a digital data structure used in geographic information system (GIS) for the representation of a surface. TIN utilizes LiDAR points at the river bank to create vectors and edges to digitally represent the physical land surface and create a digital surface model (DSM; Fig. 2). Three-dimensional (3D) visualizations are readily created by rendering of the triangular facets. TIN-construction of a combination of assigned points as ground and as canopy may yield to pseudo structures, especially using triangulated irregular networks in highly vegetated areas. This is because LiDAR points may yield to structures covering a larger area on the ground than just tree trunks. Fortunately, LiDAR points are classified into ground or above the ground points representing structures or trees. Utilizing only ground points to create a TIN will provide a bare earth model (BEM; Fig. 2). This digital elevation model (DEM) eliminates artifacts and pseudo-structures or steep triangular facets covering the river's surface derived from LiDAR points on trees or branches around the river bank. A series of TIN facets representing river's surface can be constructed.

RESULTS

LiDAR data have successfully provided a high-resolution river's longitudinal profile (Fig. 4) using triangulated irregular network (TIN) and utilizing only ground points. From the population of the ground points minimum values of elevation were found to be considered more reliable for construction of the river's surface and the associated river's longitudinal profile. Mohawk river extents along the LiDAR scanned area on 164 km and 45 segments constrained by lock stations or bridges. The river follows a longitudinal profile with an elevation drop of 120.8 m along 164 km, while there are segments where river elevation drops at about 27.2 m. The lower reaches of Mohawk river are approaching an elevation of 5.7 m where Mohawk river intersects with the Hudson river.

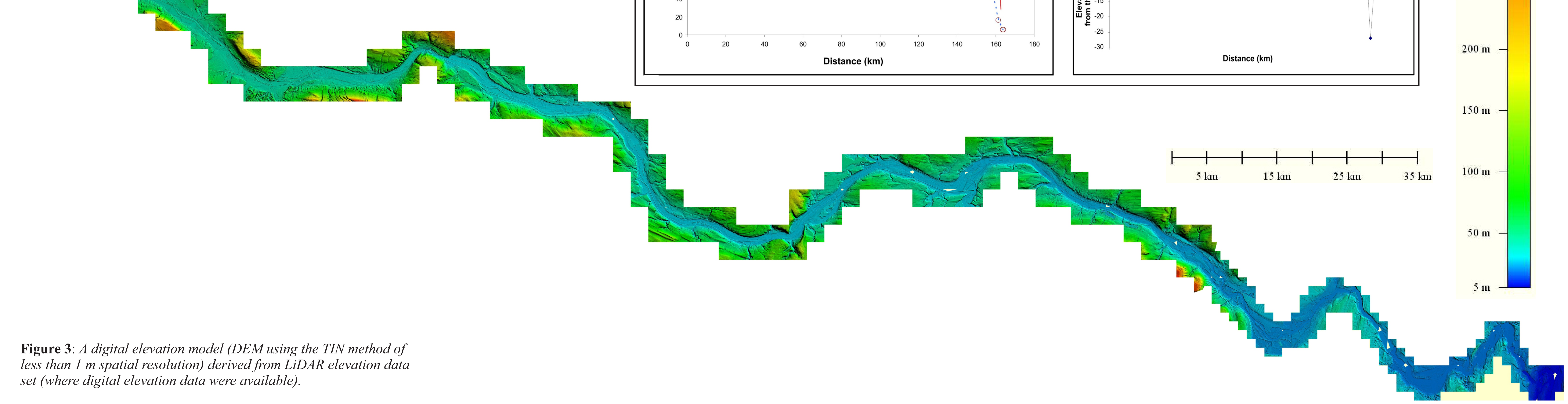
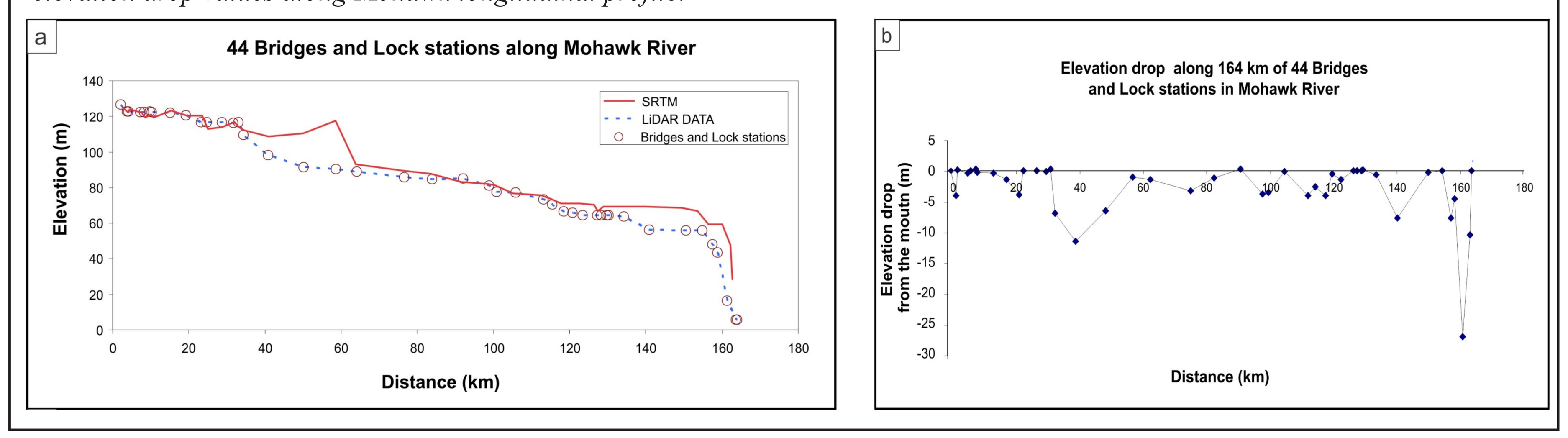


Figure 3: *A digital elevation model (DEM using the TIN method of less than 1 m spatial resolution) derived from LiDAR elevation data set (where digital elevation data were available).*

Figure 4: *(a) Longitudinal profile after LiDAR DEM (of less than 1 m spatial resolution) of a cross-section along the length of Mohawk river. Steeper gradient occurs near the intersection with the Hudson river. Longitudinal profile after SRTM DEM provides erroneous steeper gradient due to low spatial resolution (30 m / pixel); (b) graph shows the elevation drop values along Mohawk longitudinal profile.*



METHODS

LiDAR data were processed in a GIS software (ArcGIS; ESRI) to construct a bare-earth digital elevation model. The study area of Mohawk river has been divided into 45 river segments constrained by 44 lock stations or bridges. The 44 stations (Figure 1; white dots) were used to clip the polygon (buffer-polyline) and obtain the 45 river segments for further elevation stats. Along those segments, digital elevation surfaces were constructed, and a profile section along a digitized central buffered line of 1 meter width (Figure 1; red line) at the Mohawk river was made. Longitudinal profile was created by tracing the intersection of the digitized river and the constructed LiDAR-DEM and applying the elevation stats on the 45 polyline features. Mean, mode, minimum, maximum elevation values, and elevation drops have been calculated. Mean elevation values were considered not accurate as they are biased by higher elevation ground points not belonging to the river bank. Only minimum elevation values were considered for the longitudinal profile of the river to avoid any possible TIN facet deviated from the water surface. Minimum elevation values have been plotted (Fig. 4). For the TIN construction, LiDAR raw data (.LAS) were used in tiles of approximately ~ 1.25 to 1.6 million points, and each tile was integrated in an ArcGIS geodatabase after conversion into shapefile. Approximately 460 tiles were used and almost 0.5 billion points were processed. A geodatabase was used and all the shapefiles were imported to facilitate faster data processing (larger than 60,000 megabytes). LiDAR points were queried and 325,000 (ground) points were utilized.

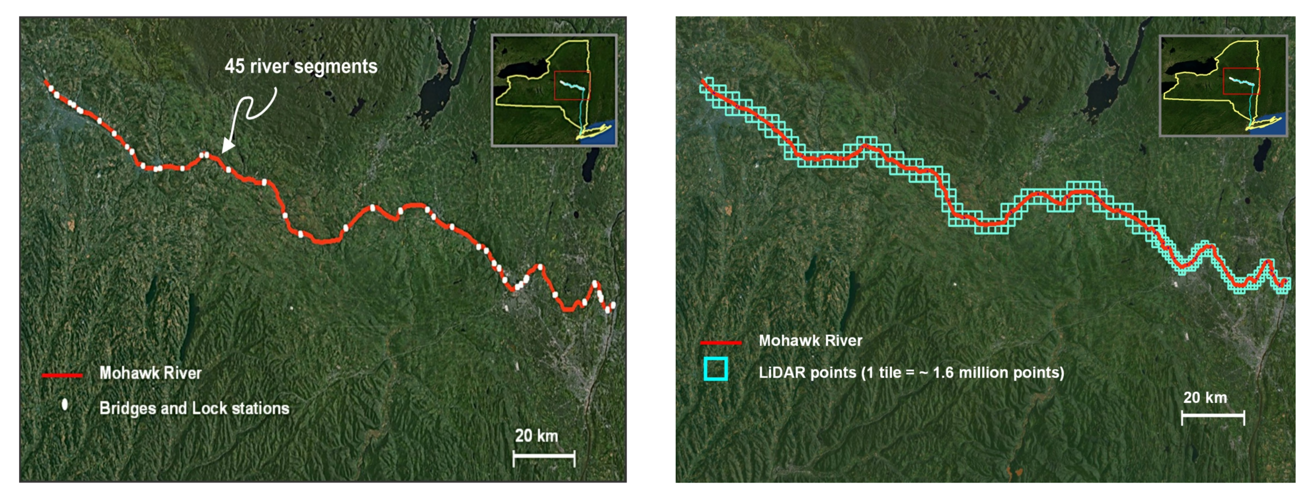
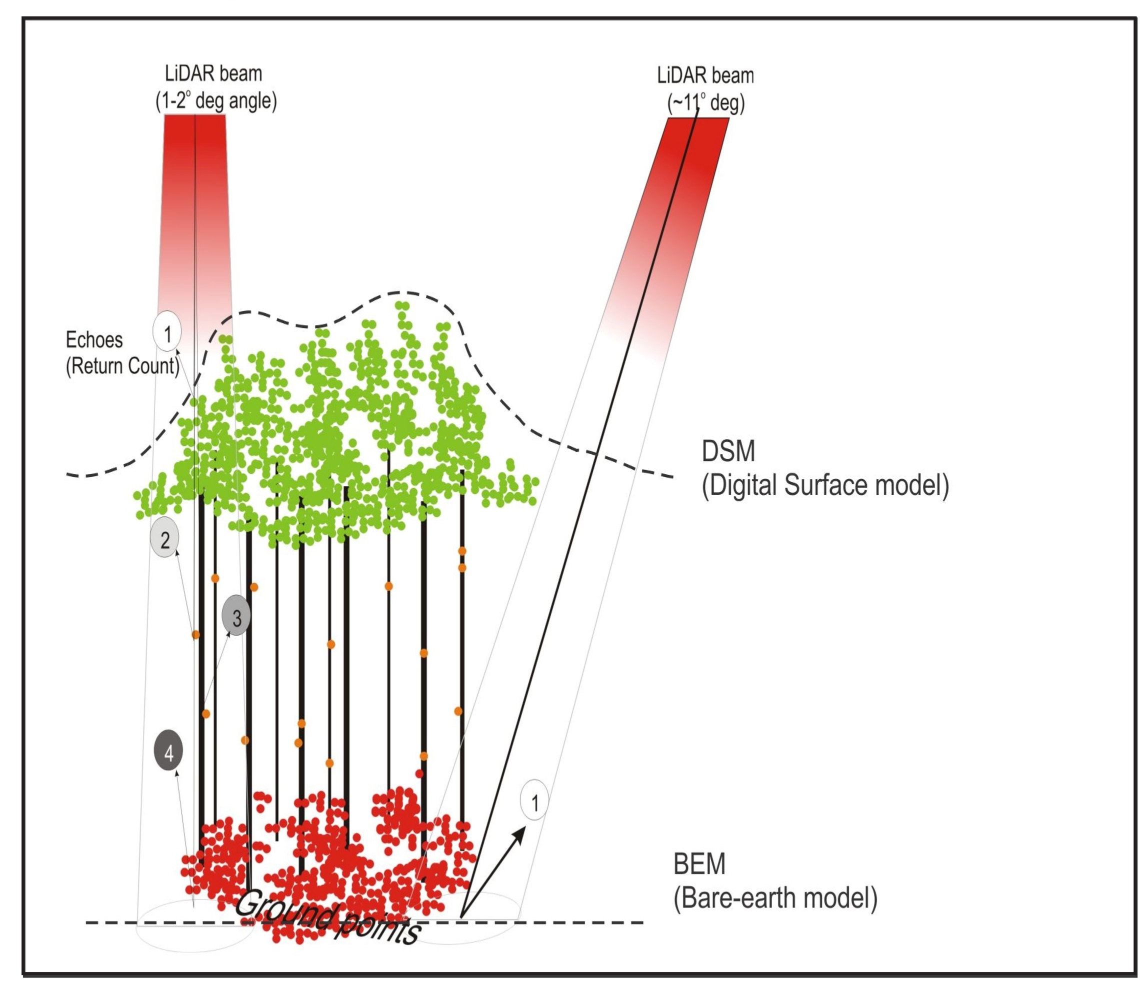


Figure 1 (left): *A satellite image of the Mohawk river (shown with a red line) where 44 bridges and lock stations (shown with white dots) divide the river into 45 river segments. LiDAR DEM was constructed after using 460 tiles of ~ 1.25-1.6 million elevation points each.*

Figure 2 (below): *LiDAR sensors receive multiple returns (echoes). Classification of LiDAR points and TIN will provide a bare-earth model (BEM) or a digital surface model (DSM).*



2 Bare-earth Model

LiDAR is capable to provide high-quality digital topographic data and map very small topographic changes. LiDAR sensors utilize a laser pulse (typically 0.5 and 1 meter in diameter) and a pulse length (a short tie of the laser pulse). LiDAR sensors are capable of receiving multiple returns, commonly up to five returns per pulse. Thousands of returns per second can be recorded classifying targets according to the number of return. When a laser pulse hits a soft target (e.g., a forest canopy), the first return represents the top of that feature assigning elevation and geographic coordinates. However, a portion of the laser light beam likely continues downwards below the soft target and hit a tree branch or the ground below a tree. This would provide a second return or echo. Theoretically, the last return represents the bare earth terrain. Areas nearby water bodies such as very saturated soil return very low-intensity laser light that may allow to delineate abandon channels (Marsellos & Garver, 2010; Marsellos & Tsakiri, 2010). Surface water (lake or river) does not return laser light or returns a low-intensity signal representing a saturated soil and therefore a low-intensity value LiDAR point or no point such as a void is created that shows the outline of a current river channel or lakes. For this reason, it is prerequisite to utilize minimum-elevation value points located around the river bank area to yield a triangulated irregular network of LiDAR ground points that it approaches the current river's water elevation.

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Aknowledgements

Special thanks to Professor John Garver for providing me LiDAR data, the opportunity to participate in Mohawk Water Symposium 2013, and inspiration to work on natural hazards in Mohawk watershed.