Adjustment of a Lidar Digital Elevation Model in the Lower Pascagoula River Salt Marsh, Mississippi

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Abstract

Light detection and ranging (lidar) digital elevation models are widely used in modeling coastal marsh systems as well as many other natural resource management applications. However, topographic elevation errors in these models mischaracterizes the current state of the system which propagates inaccuracies when estimating future changes. For the Pascagoula, MS, region, the bias in the salt marsh lidar DEM can be characterized by comparing it to ground truth elevation observations. This technique can be replicated in other coastal regions with similar vegetation profiles. As the world becomes increasingly vulnerable to the effects of climate change and sea level rise, it is important to accurately characterize the current state of the system so that decision makers can effectively monitor the impacts of future changes such as marsh restoration and migration, natural and nature based protective infrastructure, and land use planning policies.

Background

Lidar utilizes remote sensing technology to measure elevations on Earth's surface. This method of using lasers to measure distances by illuminating the target and measuring the reflection of the light with a sensor. Lidar is commonly used for creating models that show elevations and topography of a particular region. It can be used for taking inventory of a large biomass, or for landslide investigations, or even for predicting spider distributions [1]. Lidar is classified by the way they collect data. Satellite lidar is the primary way to model sea level rise because the data is often public so it is relatively easy to access. It can also measure large areas quickly, which makes it a more efficient way to collect data across the Earth's oceans. However, collecting data using satellite lidar has some limitations. It is dependent on clear weather conditions as clouds can interfere with the clarity of the image. Additionally, since collecting data via a satellite is very expensive, scientists are dependent on outside agencies such as NOAA (National Oceanic and Atmospheric Administration), USIEI (United States Interagency Elevation Inventory), or NASA. Lidar data can be used to produce maps and models.

Digital elevation models are the digital representation of land surface elevation with respect to any reference datum. Each matrix point of an image has a value corresponding to its altitude above sea level [2]. It is the primary way in which topography is displayed because it is the simplest form of digital representation. They are used for hydrologic and geologic analyses, hazard monitoring, natural resources exploration, and even for agricultural management. DEM data will be used to identify marshes and wetlands [3].

When used for modelling marsh surface elevation, there is a high bias in the data obtained from bare earth lidar-derived digital elevation models. The bias is due to a number of factors. First, the laser is unable to penetrate dense grasses. Second, there is a "dead zone" which is the vegetation structure height that results in only one laser return per pulse. Third, the standing water that is often present on the marsh surface absorbs the laser pulse instead of reflecting it. Lastly, the heterogeneity of above-ground biomass density on small spatial scales can bias the results as well [4].

Figure 1: Satellite image of Pascagoula River. The wetlands displayed are Estuarine and Marine Wetlands (orange), and Freshwater Emergent Wetlands (purple) (National Wetlands Inventory, 2020).

Methodology

Pascagoula is a coastal community in Mississippi that is characterized by its relationship to water. Not only is the city located along the Gulf of Mexico, but it is also home to the longest free flowing waterway in the nation, the Pascagoula River. This research is important for this location because the coastal region surrounding the Pascagoula River has about 11,150 acres of marsh which can be seen in Figure 1 [5]. It is important for scientists and leaders in the area to have an accurate image of the salt marsh in their region to monitor sea level rise.

To make the DEM adjustment, lidar satellite imagery and a DEM image were created. To create the satellite images, ESA's Copernicus satellite 2A lidar data was used. The red, green, blue, and near infrared bands were extracted from those images and the tiles were merged to create a complete and cohesive image for each band. This lidar image was taken from data that contained 7.2% cloud cover. There is some cloud coverage that is visible. However, the cloud cover is mostly over the water so it should not interfere with the data in the coastal marsh area. Interestingly, it does not appear in the near-infrared image.

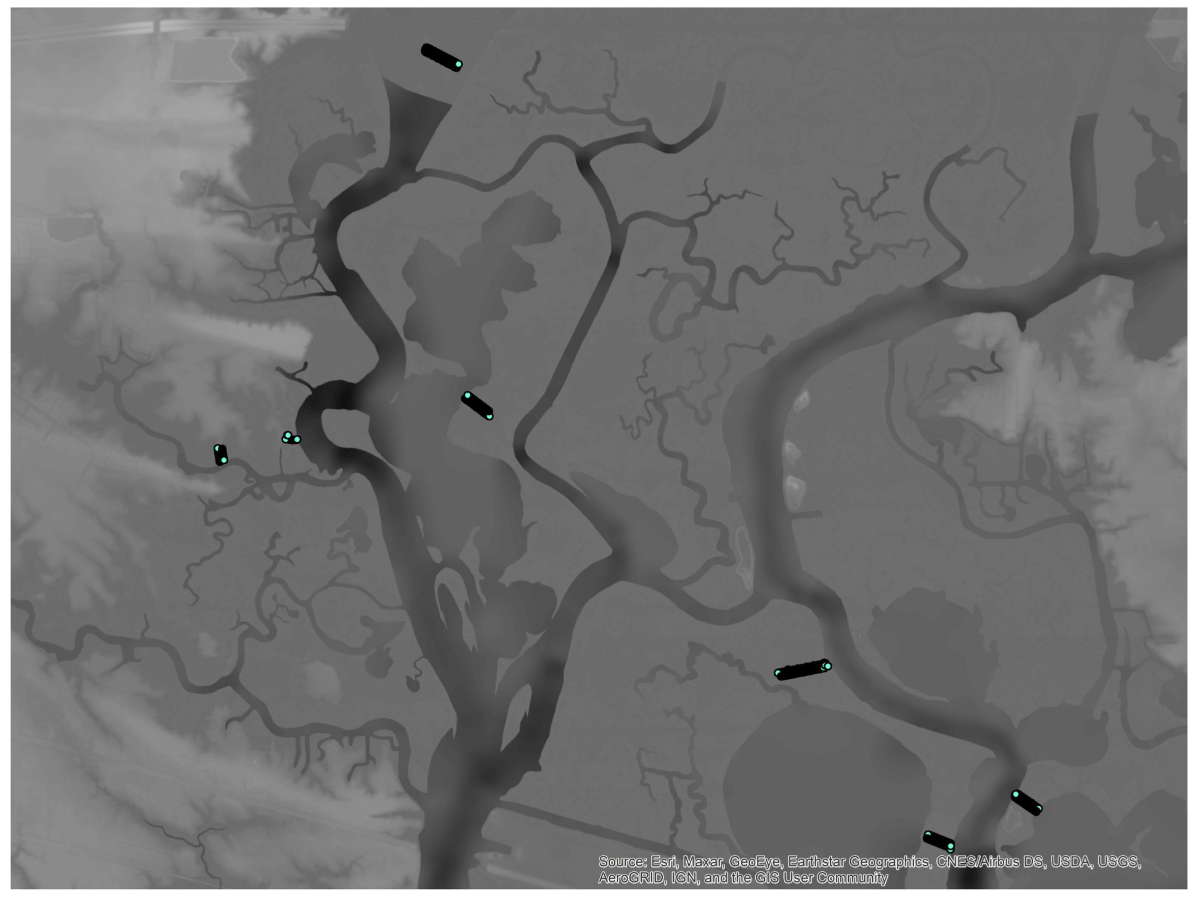
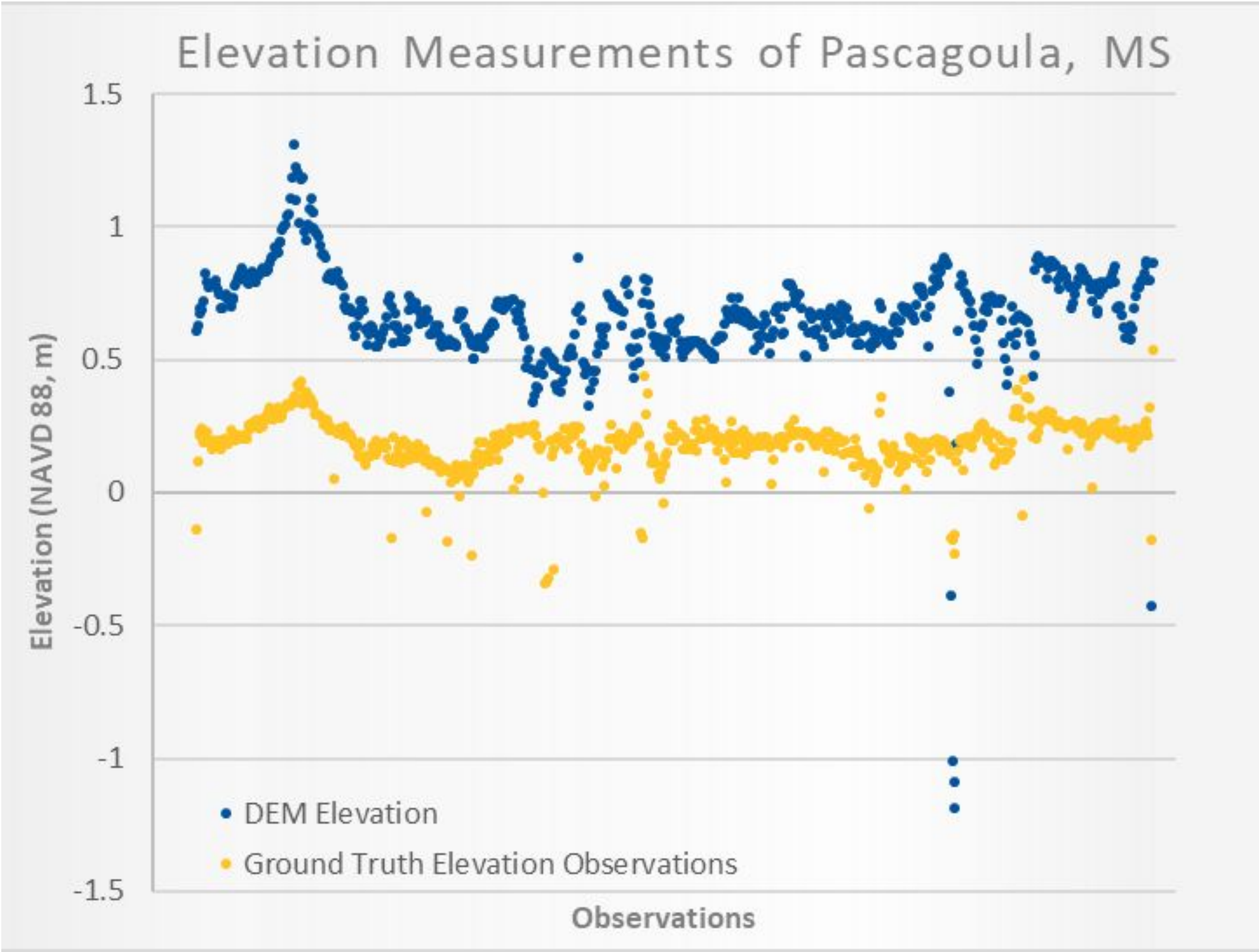
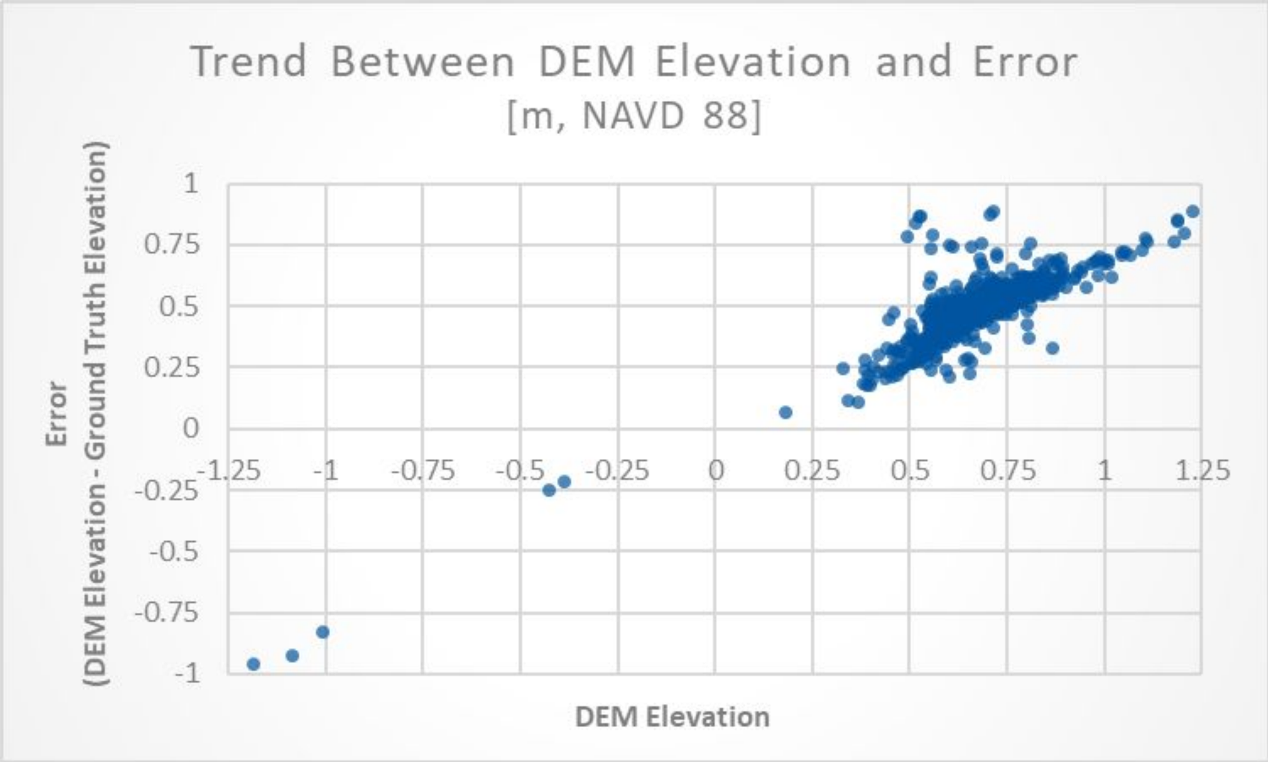


Figure 2: Lidar derived Digital Elevation Model for Pascagoula Mississippi with ground truth points.



Data Analysis

Data for the lidar derived DEM image was collected by a 2014 USGS survey. The error between the lidar derived DEM elevations and the ground truth observations were found by subtracting the latter from the former. The table below illustrates the comparison between the DEM elevations and the calculated error. According to this data, the more extreme elevations tend to have a greater error. As DEM elevation increases, error also increases. The identity line represents a hypothetical scenario in which the error increases proportionally with respect to elevation. The difference between the identity line and the plots illustrates that the error starts to increase more slowly as elevation increases.



Conclusions

The lidar derived DEM tended to report higher elevations compared to the ground truth measurements. This could be due to the dense vegetation and the presence of water in the salt marsh. Salt marshes are critical to the resiliency of a community, but they are vulnerable to permanent inundation as a result of sea level rise. The northern Gulf of Mexico is home to about 40 percent of the coastal wetlands in the US (NOAA, 2017). Therefore, this work can and should be replicated for other cities in the region, so that they can accurately characterize the current state of the system to effectively monitor future changes that will inevitably occur.
Further research will be conducted to apply the adjustment to the DEM. Additionally, this will be replicated for the Apalachicola River, Big Bend region.

References

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