Error Reduction Techniques on a LiDAR Salt Marsh DEM Using RTK GPS

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Adam McClure
Graduate Student
Geography Department
San Francisco State University
Outline of Presentation

- Objectives
- Introduction
- Study Site
- Datasets
- Methodology
- Results
- Discussion
- Questions
Evaluate and improve elevation accuracy within a LiDAR-derived salt marsh Digital Elevation Model (DEM)
Produce $6.3 - $22.9 billion annually for CA
* Commercial harvesting
* Recreational fishing

Protect
* Humans
* Animals

Detoxification

Purification

Helps stabilize:
\[ N_2, S0_2, C0_2, CH_3 \]
Historical wetlands loss
- California has lost 95% of wetlands habitat
- In Sf Bay, wetlands have diminished by 90% since the mid 1800’s

Gold Rush!
- Filling, Diking, Draining, Agriculture

“The Lord giveth, and the Lord taketh away, but He is no longer the only one to do so.”
Aldo Leopold, The Sand County Almanac
Home is where the salt marsh is

Endangered Species @ China Camp:
Salt Marsh Harvest Mouse, CA Clapper Rail and CA Black Rail (not pictured)
SLR and Salt Marshes

- Animal and plant species undergo environmental stresses
- Vegetation can convert to mudflats or open water
- Elevation differences less than 10 cm can determine species distribution
- Change in erosion and accretion rates
What is LiDAR?

- **Light Detection And Ranging**
- Scanning system that rapidly collects large amounts of 3D data \((x,y,z)\)
- Used to model ground and above-ground objects
- Delivers high resolution point clouds
- Allows for generation of a Digital Elevation Model (DEM)
- Accuracy can be sub-meter
Previous Research

  - Found LiDAR overestimation of ~7 cm

- Chassereau, J., Bell, J., and Torres, R. (2011)
  - 78% of LiDAR +/- 15 cm of GPS

  - Mean signed error (SE) went from 10 cm to 1 cm
West Coast v. East Coast

- Salt Marsh Similarities
  - Topography
  - Geomorphology
  - Environments (tides and seasons)
  - Threats

- Salt Marsh Differences
  - Size
  - Vegetation Diversity
  - Research
Study Goal

Provide a comprehensive methodology to evaluate and improve elevation accuracy within a LiDAR-derived salt marsh DEM by combining the density of LiDAR and the high accuracy of RTK GPS with local vegetation conditions.
LIDAR point cloud

A little over 900 points here, each one representing 3500 actual data points
Statistics generated for each vegetation class and the overall DEM include:

- Signed Error (SE)
- Standard Deviation (SD)
- Root Mean Square Error (RMSE)
- Fundamental Vertical Accuracy (FVA)
- 95th percentile

\[
SE_i = z_{\text{LiDAR}_i} - z_{\text{RTK}_i}
\]

\[
RMSE = \sqrt{\frac{\sum (z_{\text{LiDAR}_i} - z_{\text{RTK}_i})^2}{n}}
\]
Flowchart of Methods

- **Vegetation**
- **Original LiDAR-derived DEM**
- **Clip**
  - **Individual Species DEM (5)**
  - **RTK GPS Points (75%) (6)**
  - **Elevation Extraction @ Point**
    - **Vertical Accuracy Assessment (6)**
      - **Unvegetated Correction Factors**
      - **Vegetated Correction Factors (5)**
    - **Unvegetated Modified DEM**
    - **Vegetated Modified DEM (5)**
      - **RTK GPS Points (25%) (6)**
      - **Mosaic**
        - **Modified DEM**
          - **Elevation Extraction @ Point**
            - **Vertical Accuracy Assessment (6)**
## Results

### Statistics comparing RTK GPS points to unmodified LiDAR DEM

<table>
<thead>
<tr>
<th>Cover Class</th>
<th>n</th>
<th>Mean SE (m)</th>
<th>Standard Deviation (m)</th>
<th>RMSE (m)</th>
<th>FVA (m)</th>
<th>95th Percentile (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alkali-bulrush (Bolboschoenus maritimus)*</td>
<td>14</td>
<td>0.255</td>
<td>0.176</td>
<td>0.310</td>
<td>0.608</td>
<td>0.437</td>
</tr>
<tr>
<td>Pacific cordgrass (Spartina pacifica)*</td>
<td>12</td>
<td>0.215</td>
<td>0.073</td>
<td>0.226</td>
<td>0.443</td>
<td>0.314</td>
</tr>
<tr>
<td>gumplant (Grindelia stricta)*</td>
<td>16</td>
<td>0.103</td>
<td>0.202</td>
<td>0.215</td>
<td>0.421</td>
<td>0.260</td>
</tr>
<tr>
<td>pickleweed (Sarcocornia pacifica)</td>
<td>480</td>
<td>0.170</td>
<td>0.104</td>
<td>0.199</td>
<td>0.390</td>
<td>0.292</td>
</tr>
<tr>
<td>saltgrass (Distichlis spicata)*</td>
<td>19</td>
<td>0.148</td>
<td>0.109</td>
<td>0.184</td>
<td>0.361</td>
<td>0.258</td>
</tr>
<tr>
<td>Unmodified DEM</td>
<td>564</td>
<td>0.160</td>
<td>0.139</td>
<td>0.212</td>
<td>0.416</td>
<td>0.301</td>
</tr>
</tbody>
</table>

### Statistics comparing RTK GPS points to modified LiDAR DEM

<table>
<thead>
<tr>
<th>Cover Class</th>
<th>n</th>
<th>Mean SE (m)</th>
<th>Standard Deviation (m)</th>
<th>RMSE (m)</th>
<th>FVA (m)</th>
<th>95th Percentile (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>alkali-bulrush (Bolboschoenus maritimus)*</td>
<td>9</td>
<td>-0.018</td>
<td>0.181</td>
<td>0.202</td>
<td>0.395</td>
<td>0.136</td>
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<tr>
<td>Pacific cordgrass (Spartina pacifica)*</td>
<td>4</td>
<td>0.002</td>
<td>0.067</td>
<td>0.073</td>
<td>0.142</td>
<td>0.068</td>
</tr>
<tr>
<td>gumplant (Grindelia stricta)*</td>
<td>6</td>
<td>0.004</td>
<td>0.189</td>
<td>0.200</td>
<td>0.391</td>
<td>0.140</td>
</tr>
<tr>
<td>pickleweed (Sarcocornia pacifica)</td>
<td>159</td>
<td>0.002</td>
<td>0.106</td>
<td>0.106</td>
<td>0.207</td>
<td>0.142</td>
</tr>
<tr>
<td>saltgrass (Distichlis spicata)*</td>
<td>6</td>
<td>0.011</td>
<td>0.087</td>
<td>0.087</td>
<td>0.170</td>
<td>0.102</td>
</tr>
<tr>
<td>Modified Mosaicked DEM</td>
<td>189</td>
<td>-0.004</td>
<td>0.098</td>
<td>0.098</td>
<td>0.191</td>
<td>0.137</td>
</tr>
</tbody>
</table>

* = average based on n value randomly resampled 30 times
Difference Map
**Case Study Takeaways**

**Vertical Error**
- Average DEM RMSE = 21 cm
- GGLP LiDAR RMSE ≤ 9.25 cm

- Vertical error consists of:
  - ~50% LiDAR projection area
  - ~50% laser penetration/filtering error
  - Interpolation error ~ 0 cm in relatively flat terrain

**Conclusions**
- Mean SE was reduced from 16 cm to 0 cm
- RMSE and 95th percentile values were also reduced
- Transferable methodology was developed to evaluate and improve elevation accuracy within a LiDAR-derived salt marsh DEM
Discussion/Future Research

- RTK GPS point collection and vegetation height
- Classification techniques – hyperspectral v. aerial photographs
- LiDAR data acquisition timing – seasons and tides
- Remote sensing techniques for modeling a salt marsh
Thank you!

Advising Committee:
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