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

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Outline of Presentation

* Objectives
* Introduction
* Study Site
* Datasets
* Methodology
* Results
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* Questions

Objective

Evaluate and improve elevation accuracy within a

LiDAR-derived salt marsh Digital Elevation Model (DEM)

Introduction

* Produce $6.3 - $22.9 billion annually for CA
  * Commercial harvesting
  * Recreational fishing
* Protect
  * Humans
  * Animals
* Detoxification
* Purification
* Helps stabilize:

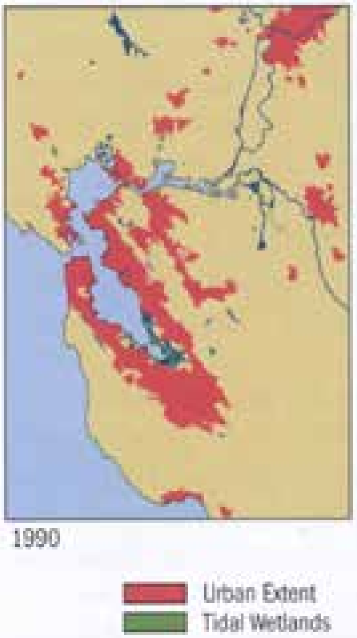
  N_2, SO_2, CO_2, CH_3

“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

* 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

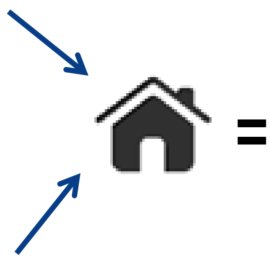
Map 5. San Francisco Bay-Delta wetlands and urbanization, 1850. (Redrawn from U.S. Geological Survey, no date.)

Map 6. San Francisco Bay-Delta wetlands and urbanization, 1940. (Redrawn from U.S. Geological Survey, no date.)



Map 7. San Francisco Bay-Delta wetlands and Urbanization, 1990. (Redrawn from U.S. Geological Survey, no date.)

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

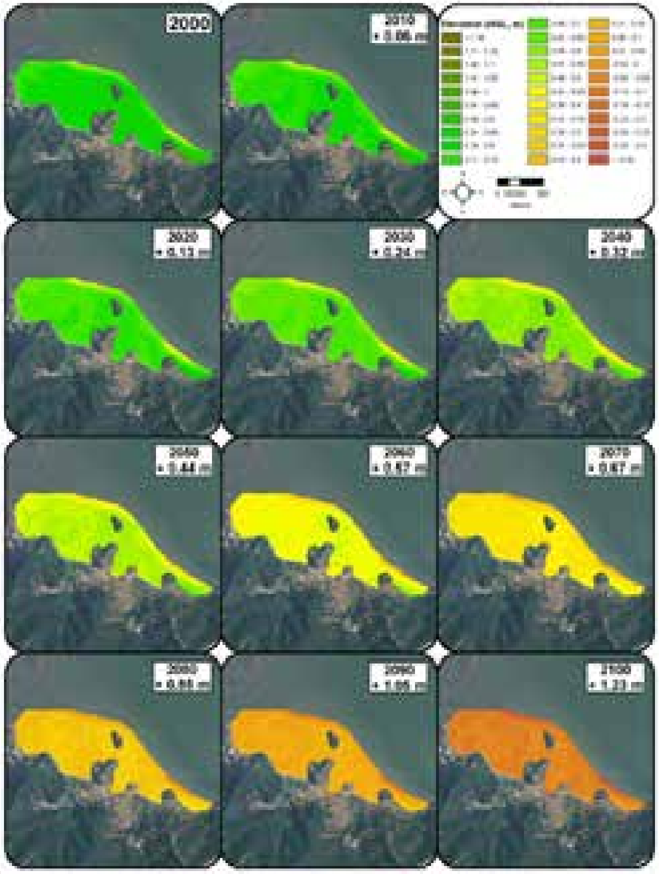
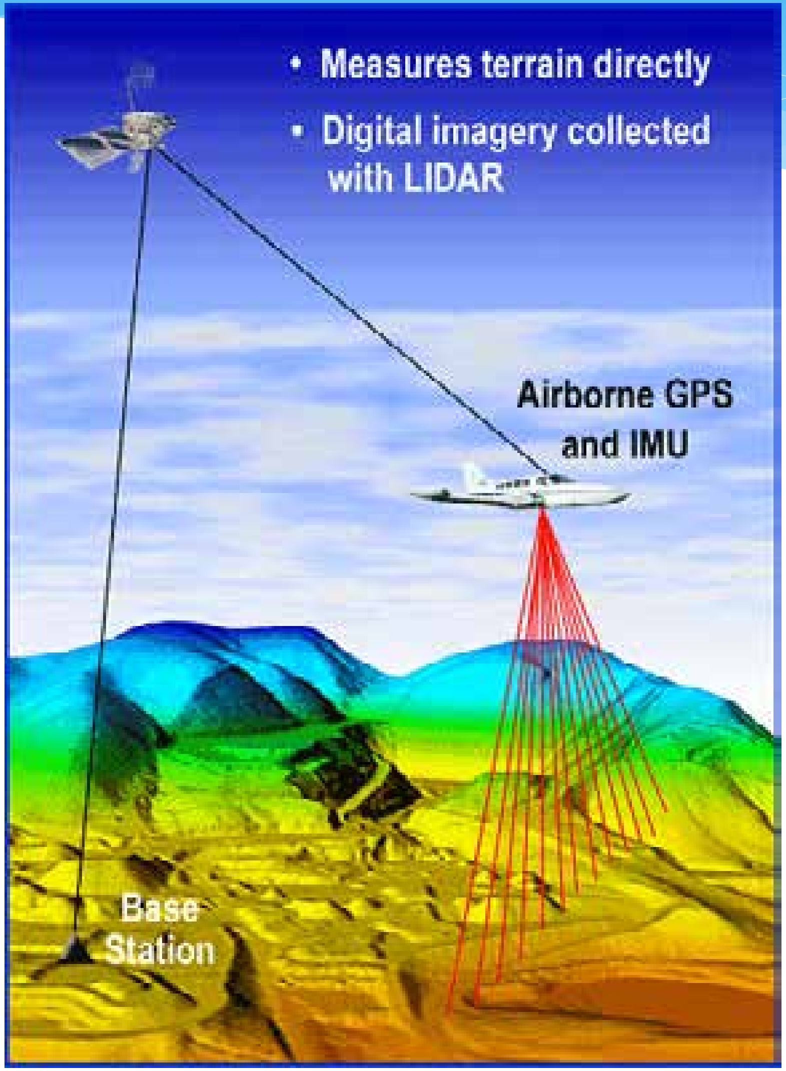


Figure C-6. WARMER results for China Camp. WARMER accounts for changes in relative sea-level, subsidence, inorganic sediment accumulation, above/below ground organic matter productivity, compaction, and decay. Non-linear sea-level rise projections for California were used (Cayan *et al.* 2009).

* 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

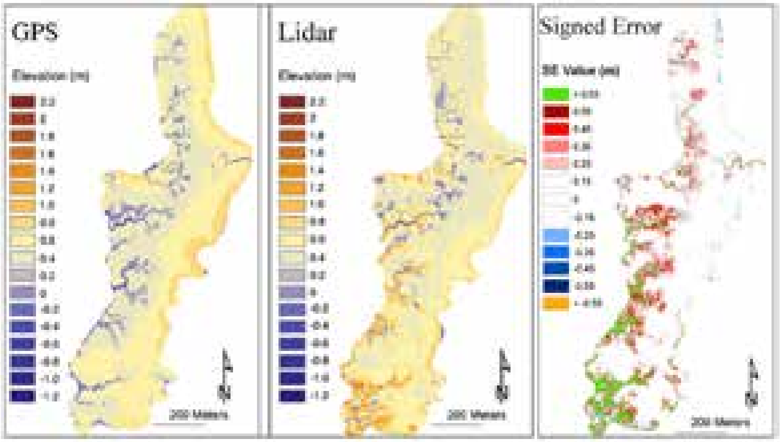


- Delivers high resolution point clouds
- Allows for generation of a Digital Elevation Model (DEM)
- Accuracy can be sub-meter

Previous Research

* Montane, J., and Torres, R. (2006)
  * Found LiDAR overestimation of ~7 cm
* Chassereau, J., Bell, J., and Torres, R. (2011)
  * 78% of LiDAR +/- 15 cm of GPS
* Hladik, C., and Alber, M. (2012)
  * 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

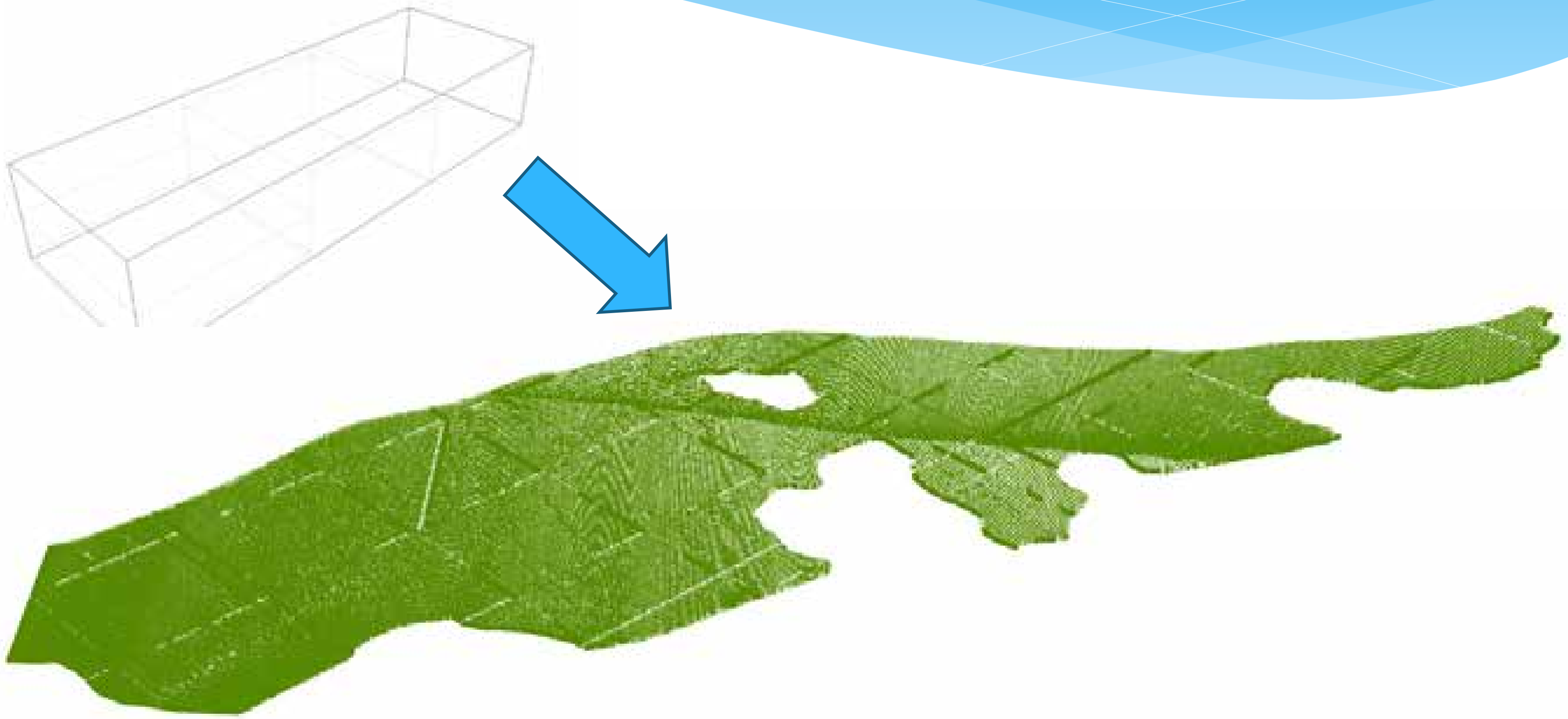
Study Site


CHINA CAMP
STATE PARK
China Camp State Park
A California State Park,
Operated by
Friends Of China Camp

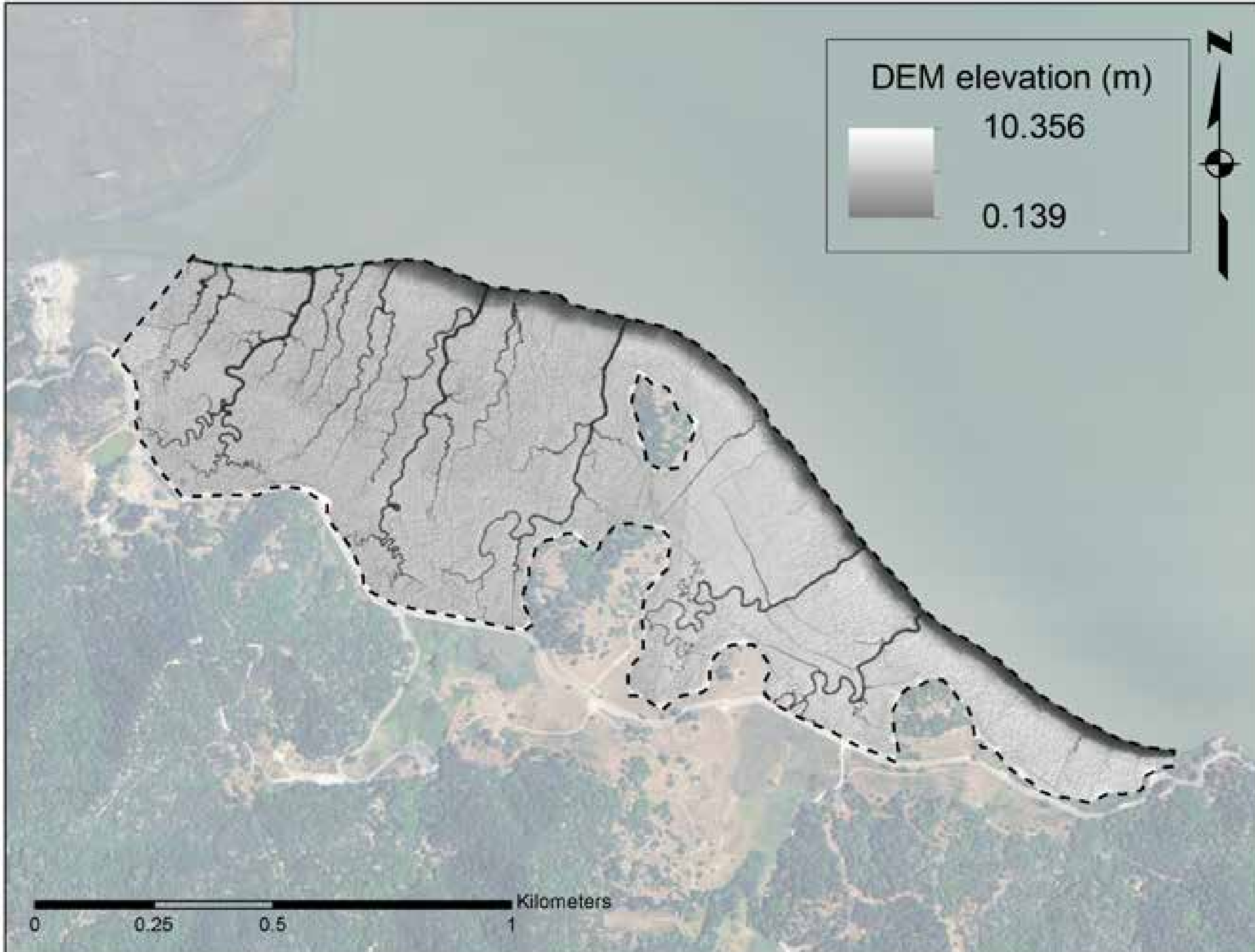

0
5,000
10,000
Meters


0
400
800
Meters

LIDAR point cloud



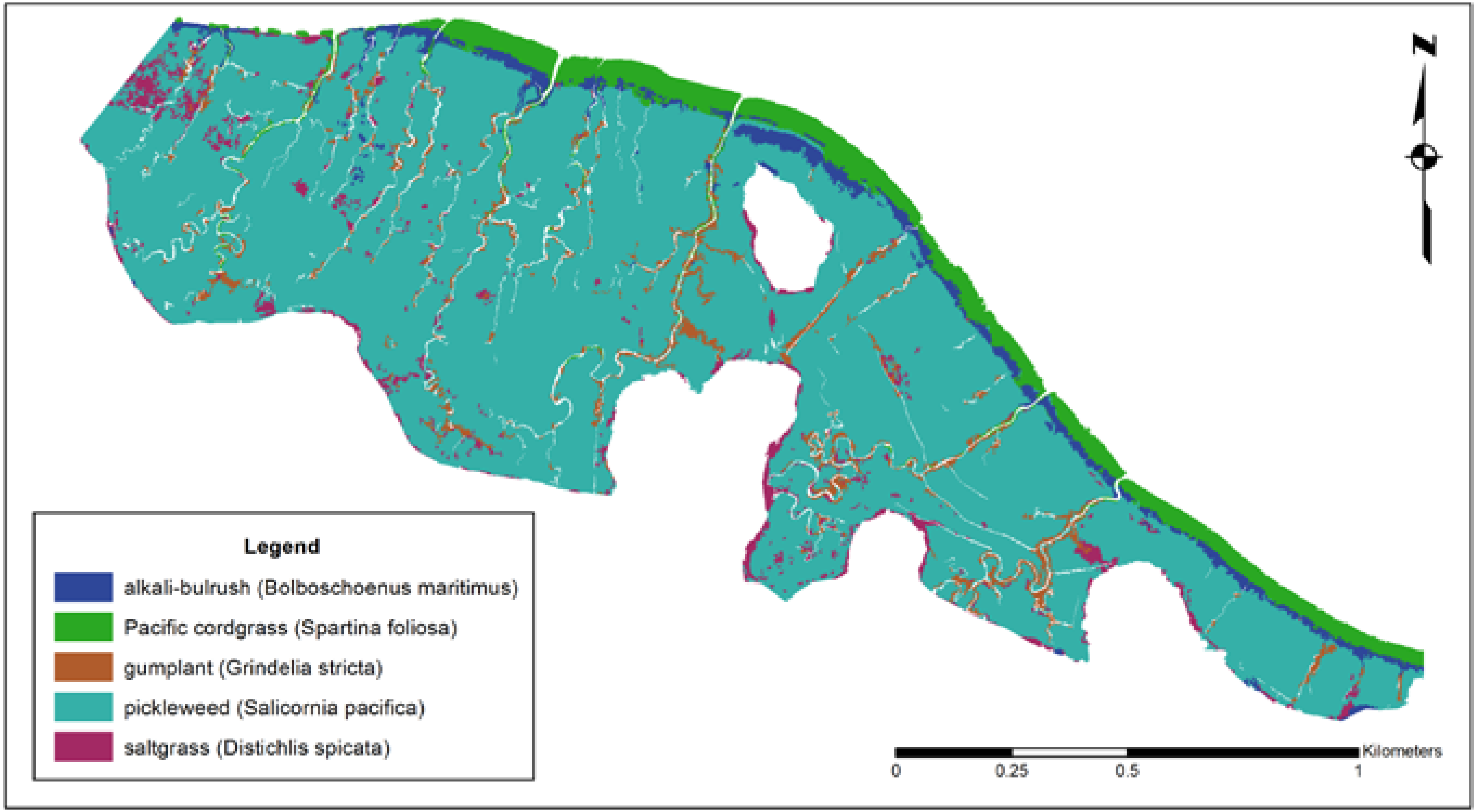
A little over 900 points here, each one representing 3500 actual data points



DEM elevation (m)
10.356
0.139
N
0
0.25
0.5
1
Kilometers


0
150
300
Meters

China Camp Vegetation



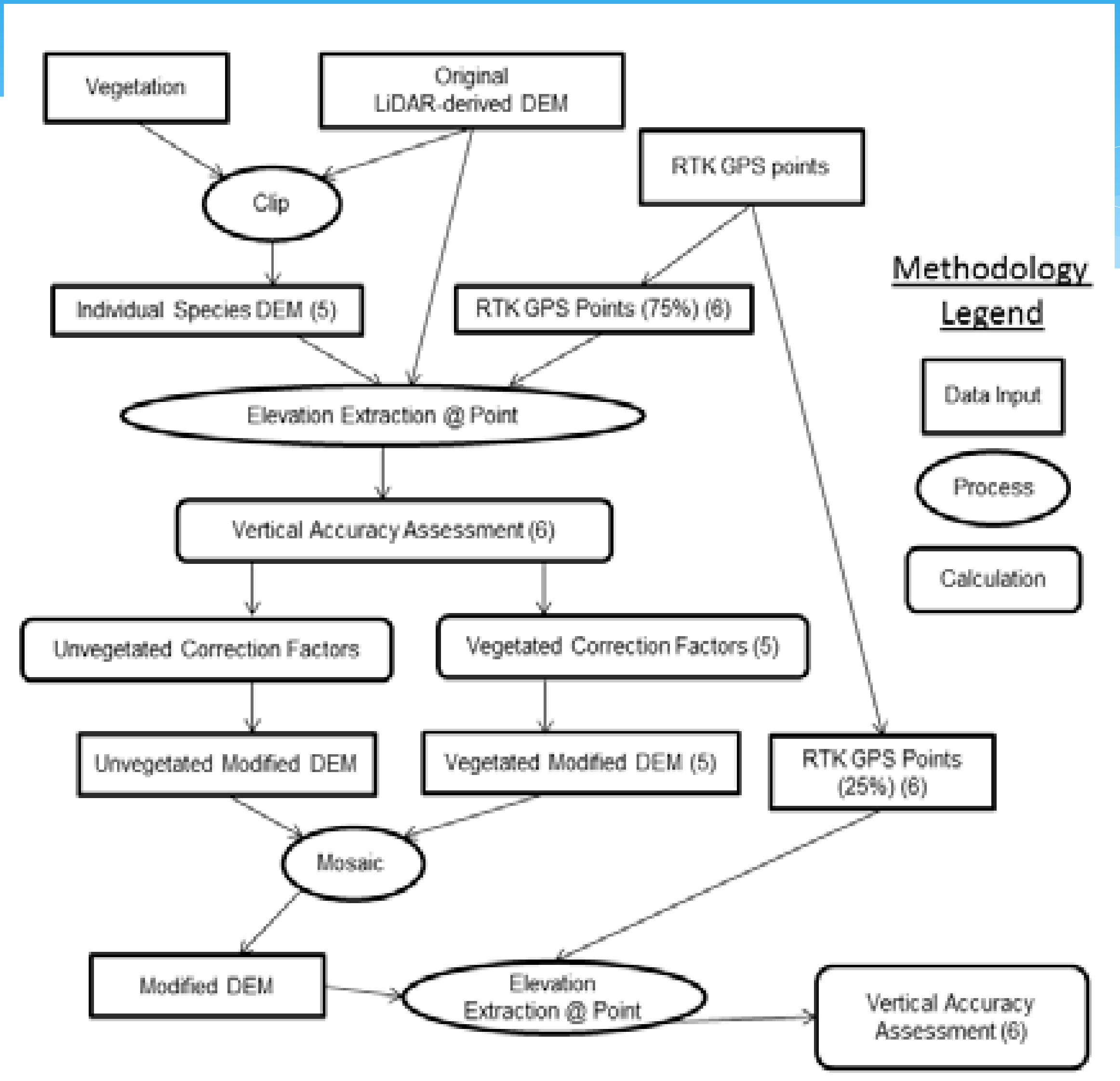
Methods – Accuracy Assessment

* 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

$$SE_i = z_{LiDAR_i} - z_{RTK_i}$$

$$RMSE = sqrt[\sum (z_{LiDAR_i} - z_{RTK_i})^2 / n]$$

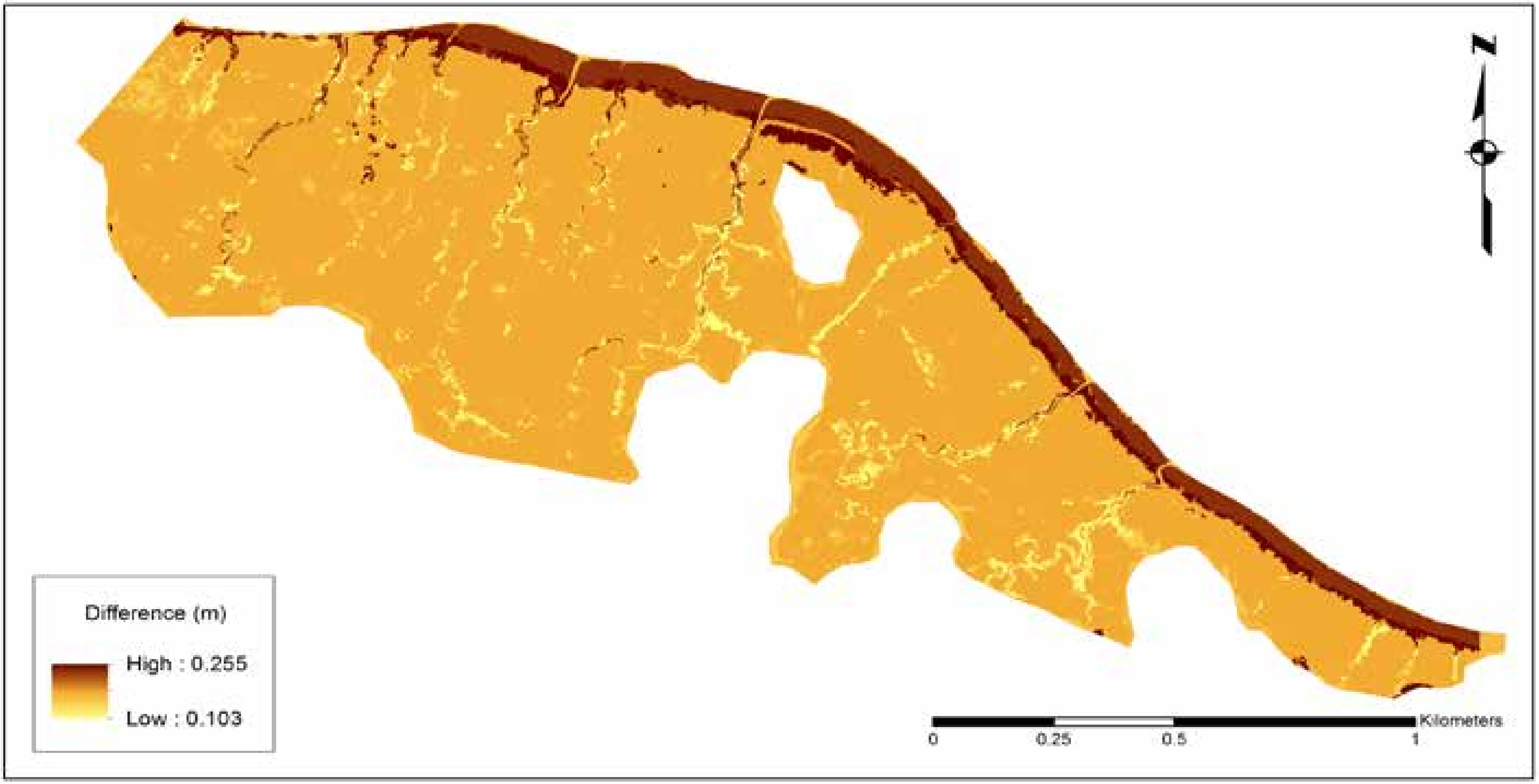
Flowchart of Methods



Results

Statistics comparing RTK GPS points to unmodified LiDAR DEM						
Cover Class	n	Mean SE (m)	Standard Deviation (m)	RMSE (m)	FVA (m)	95th Percentile (m)
alkali-bulrush *(Bolboschoenus maritimus)**	14	0.255	0.176	0.310	0.608	0.437
Pacific cordgrass *(Spartina pacifica)**	12	0.215	0.073	0.226	0.443	0.314
gumplant *(Grindelia stricta)**	16	0.103	0.202	0.215	0.421	0.260
pickleweed *(Sarcocornia pacifica)*	480	0.170	0.104	0.199	0.390	0.292
saltgrass *(Distichlis spicata)**	19	0.148	0.109	0.184	0.361	0.258
Unmodified DEM	564	0.160	0.139	0.212	0.416	0.301
Statistics comparing RTK GPS points to modified LiDAR DEM						
Cover Class	n	Mean SE (m)	Standard Deviation (m)	RMSE (m)	FVA (m)	95th Percentile (m)
alkali-bulrush *(Bolboschoenus maritimus)**	9	-0.018	0.181	0.202	0.395	0.136
Pacific cordgrass *(Spartina pacifica)**	4	0.002	0.067	0.073	0.142	0.068
gumplant *(Grindelia stricta)**	6	0.004	0.189	0.200	0.391	0.140
pickleweed *(Sarcocornia pacifica)*	159	0.002	0.106	0.106	0.207	0.142
saltgrass *(Distichlis spicata)**	6	0.011	0.087	0.087	0.170	0.102
Modified Mosaicked DEM	189	-0.004	0.098	0.098	0.191	0.137
** = 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 project 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!
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