Photogrammetric Modeling of Built and Natural Environments Using Ground and Drone Images

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Introduction & Objectives

1

This study utilizes ground and drone imaging and photogrammetric (PG) modeling software (Agisoft Metashape) to investigate a variety of geologic and built environmental settings. We conducted guided summer research at diverse field sites and undertook follow-up practicum coursework (EES 392) to learn associated modeling and analytical techniques reported on here.

The objectives of this project were to:

1. Learn to collect (**Panel 2**) and process images to create 3D models (**Panel 3**).
2. Use and manipulate models, analyze and visualize trace fossils, geologic outcrops, and the built environment (**Panels 2-4**).
3. Create 3D printable files, height maps, change detection models, and perform geospatial analysis in ArcGIS (**Panels 5-7**).

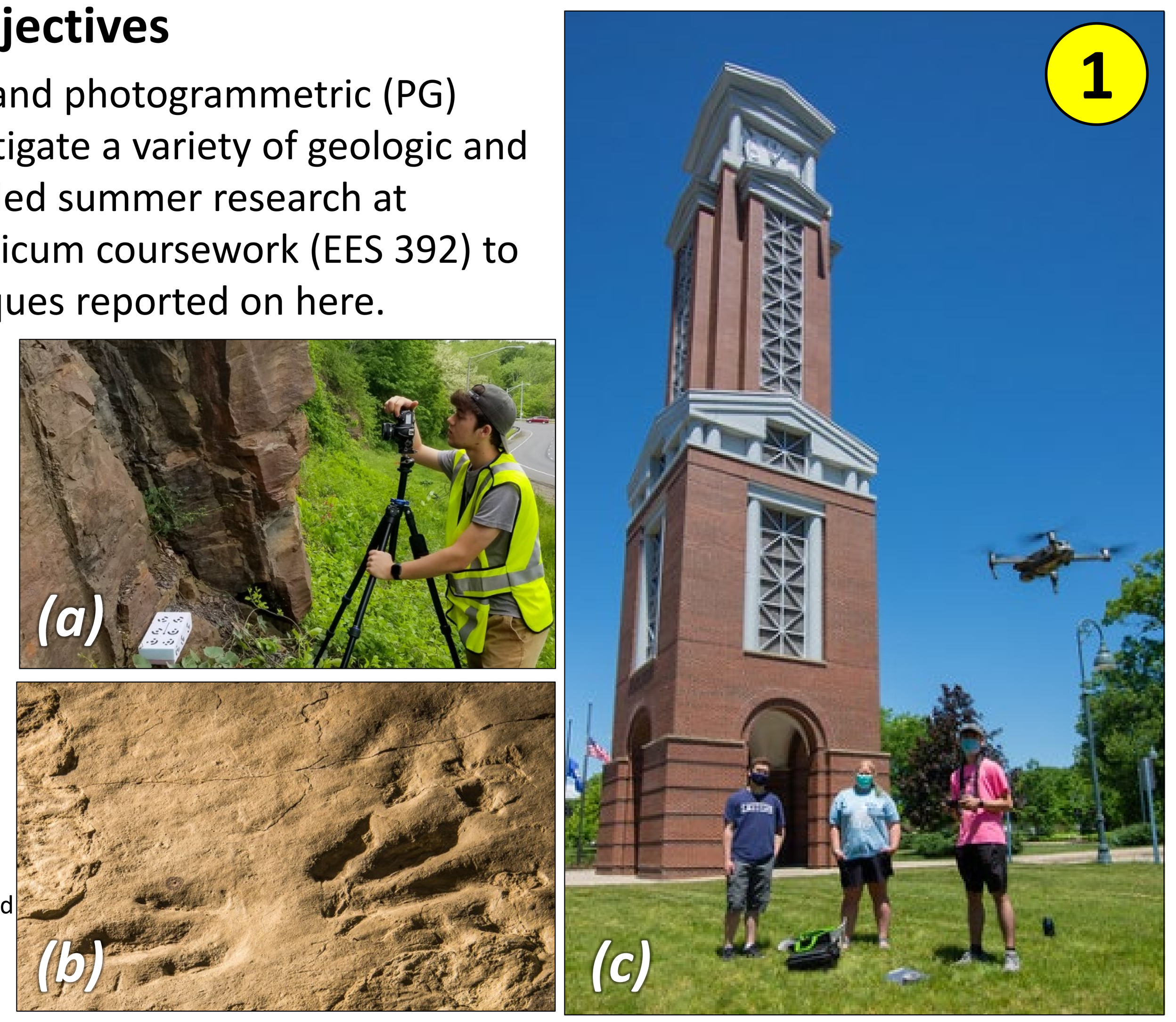


Figure 1. Photogrammetry is a science that uses many images taken at different positions to build a 3D model with high resolution that can be utilized to visualize and measure the modeled subject. We apply these techniques to areas of coastal change in RI (**Panel 2**), ***(a)*** Jurassic bedrock outcrops in CT, ***(b)*** related dinosaur tracks in CT, and ***(c)*** built environments on campus.

Field Sites in CT and RI:

2

Summer field work focused on imaging coastal change in Rhode Island, dinosaur tracks and related bedrock outcrops in CT and built environments on Eastern's Campus (**Fig. 2**). Each site has significant contextual background as summarized in figure captions.

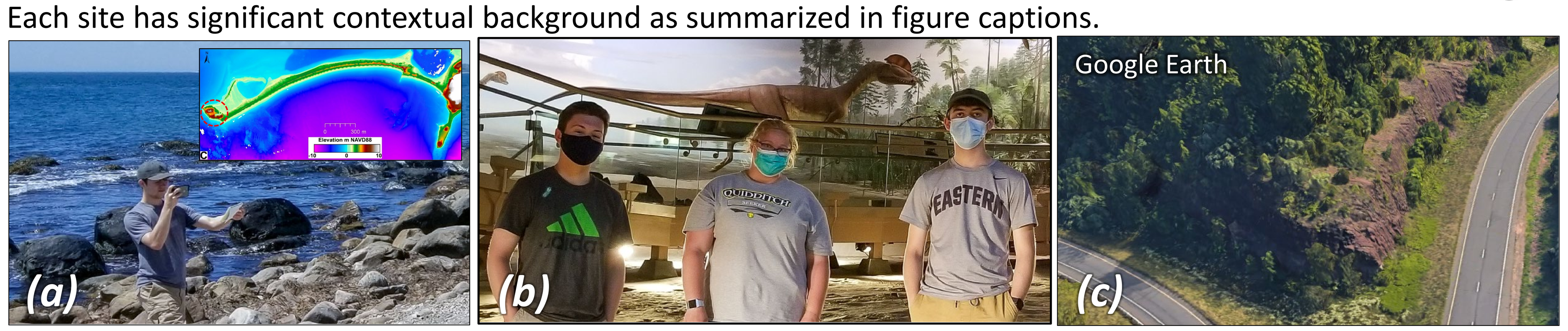


Figure 2. ***(a)*** Napatree Point (NP) is a peninsular-shaped barrier that extends westward into the Block Island Sound. Photogrammetric fieldwork focused on the western headlands which are cored by glacial till. The site is a barrier during storms, dampening storm surge and protecting portions of Little Narragansett Bay (Oakley, 2021). NP has a varied habitat that is utilized by a variety of endangered avian species. See details in **Panel 6**.

(b) Dinosaur State Park (DSP) is a significant tracksite with ~2,000 tracks discovered in August 1966 and declared a State Park less than a month later. These tracks are preserved in gray sandstones, some of which are interpreted as having formed in an Early Jurassic lake shoreline environment ~200 million years ago (**Panel 6**).

(c) We also examine the Upper East Berlin Formation exposed in outcrop along Highway 9 in Berlin, CT. This site contains lakebeds and playa arkose, grey sandstone, and black shales (Early Jurassic) that correlates to footprint strata at DSP. The rocks also contain raindrop impressions, mudcracks, and cross bedding suggesting subaerial to shallow-water depositional environments that have paleoenvironmental importance and are interesting to 3D-model.

Making a 3D Model in Metashape:

3

Metashape software analyzes images captured from different angles with significant overlap to build detailed point cloud models. These models are useful for extracting detailed topographic data to analyze the subject and associated environments. Modeling begins by aligning images to locate camera positions and construct a cloud of tie points. This thin cloud is then used to construct a dense point cloud, a mesh that joins points, and a final textured model (**Fig. 3**).

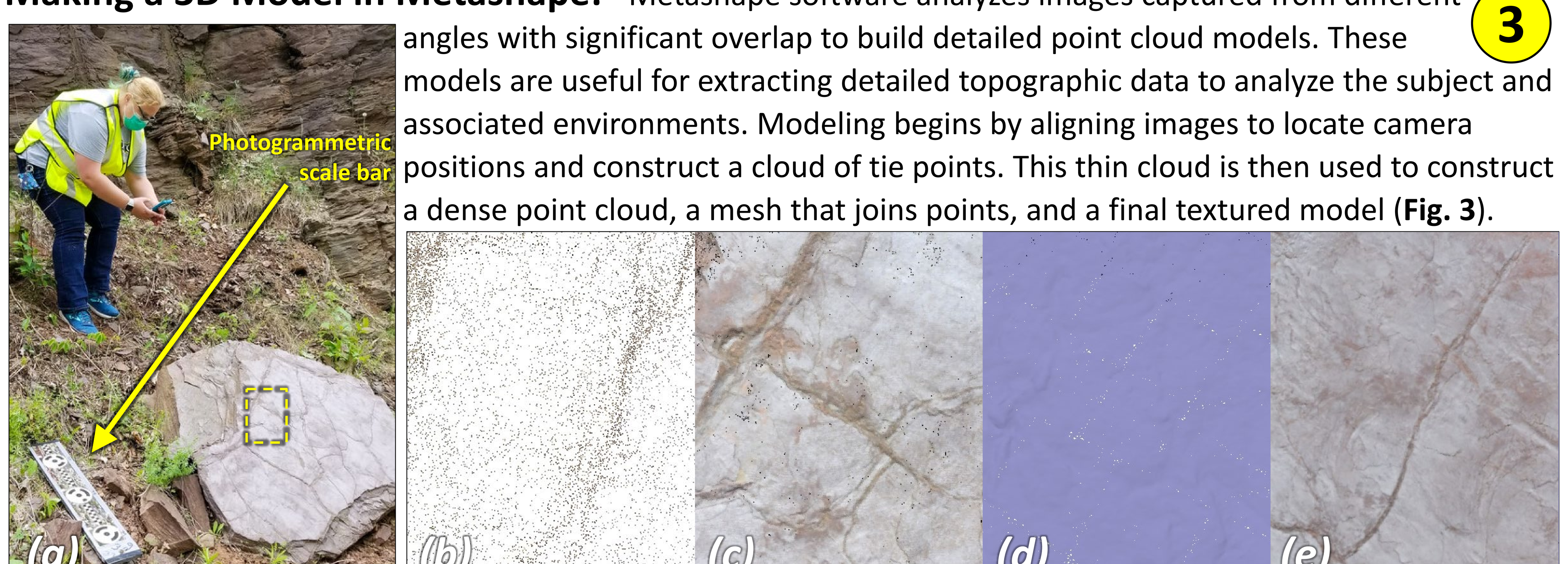


Figure 3. Building a Metashape model for desiccation-cracked mudstone with a sample ***(a)*** that had broken off the CT-Highway 9 outcrop. The tie point model ***(b)*** is improved by filtering and removing poor quality points, which improves accuracy assessments and reduces software processing time. The dense cloud ***(c)*** is then generated and consists of more than 32.1 million X-Y-Z points. The dense cloud is next used to construct a wireframe mesh ***(d)*** which consists of many triangles,each connecting the closest three tie points in the point cloud. Finally, the model is texturized ***(e)*** by using RGB color data derived from the original images using a high accuracy setting.

Digital Outcrop Models, 3D Building Models, Height Maps

4

Detailed point cloud models are often used to examine bedrock outcrops through the construction of digital outcrop models (**Fig. 4a**). As well paleontologists often construct detailed topographic visualizations called height maps of trace fossils like dinosaur tracks, and new digital twin databases for built environments can incorporate detailed models of the building structures. We used our PG techniques to explore these types of models.

Digital Outcrop Models: Several PG models were constructed for Jurassic sedimentary rocks exposed on Highway 9 (**Panel 2**). This includes mudcracked shale (**Panel 3**) and an outcrop displaying lakebed cycling (**Fig. 4a**).

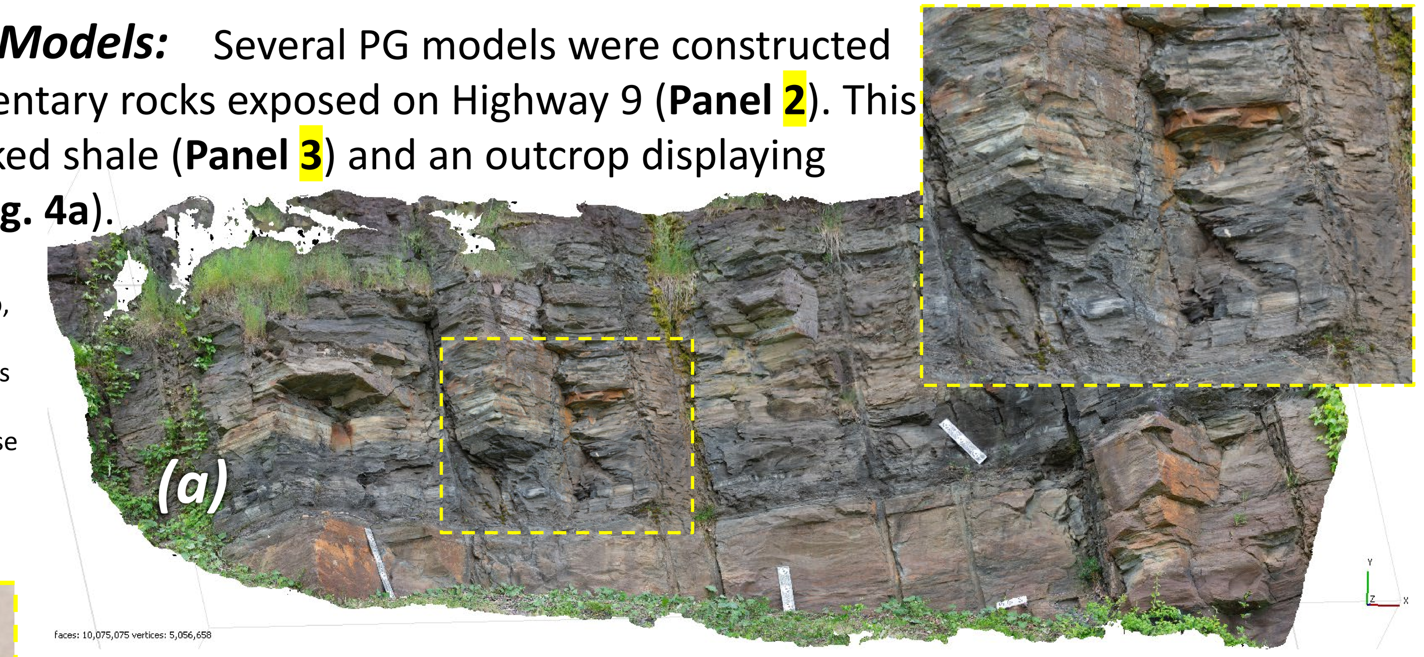
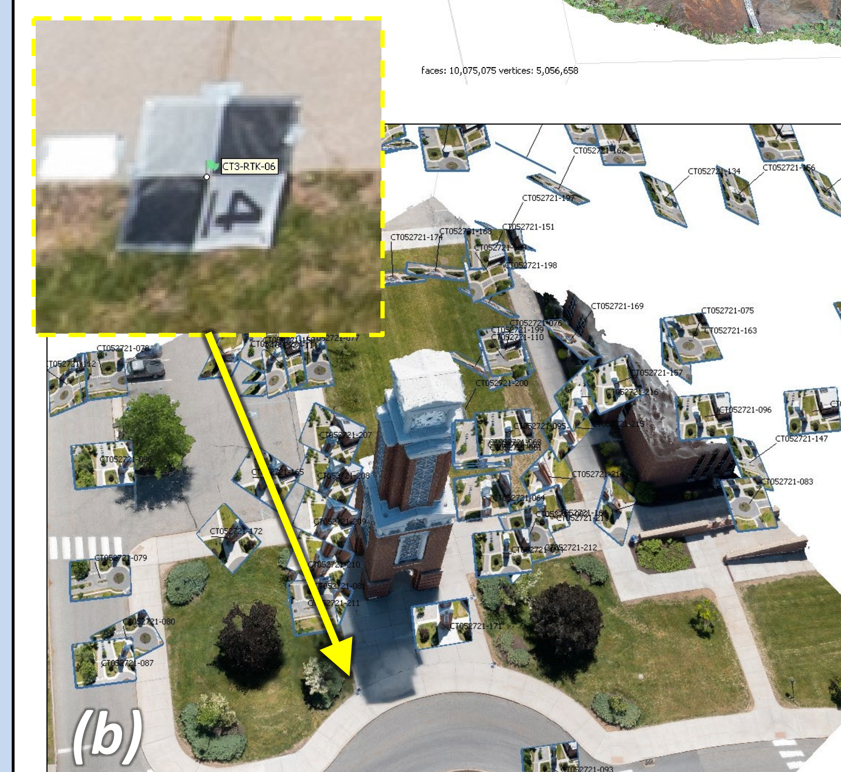


Figure 4. ***(a)*** View of the modeled Highway 9 outcrop, with an inset showing high detail. There were 89 images used to build the model, resulting in 50,375,569 dense cloud points.



Modeling the Built Environment:

Modeling buildings is best accomplished using drone imagery and a combination of vertical and oblique views. We used a DJI Mavic Pro 2 drone to capture aerial images of the Science Building (**Panel 5**) and the Clock Tower (**Fig. 4b**).

Figure 4. ***(b)*** Drone imagery shown in Metashape with visible photographs of the clock tower that were used to build the model. Inset shows the targets that were measured to determine ground control coordinates using real-time kinematic Global Positioning System equipment.

Paleontological Height Maps:

Height maps are commonly used for detailed topographic representations of trace maps like those we built for *Eubrontes* tracks imaged at DSP. This required us to import Metashape .ply data files into Cloud Compare software. The model was shifted to a 0,0,0 point origin and the difference in height with reference to a fit-plane were calculated to represent elevation (**Fig. 4c**).

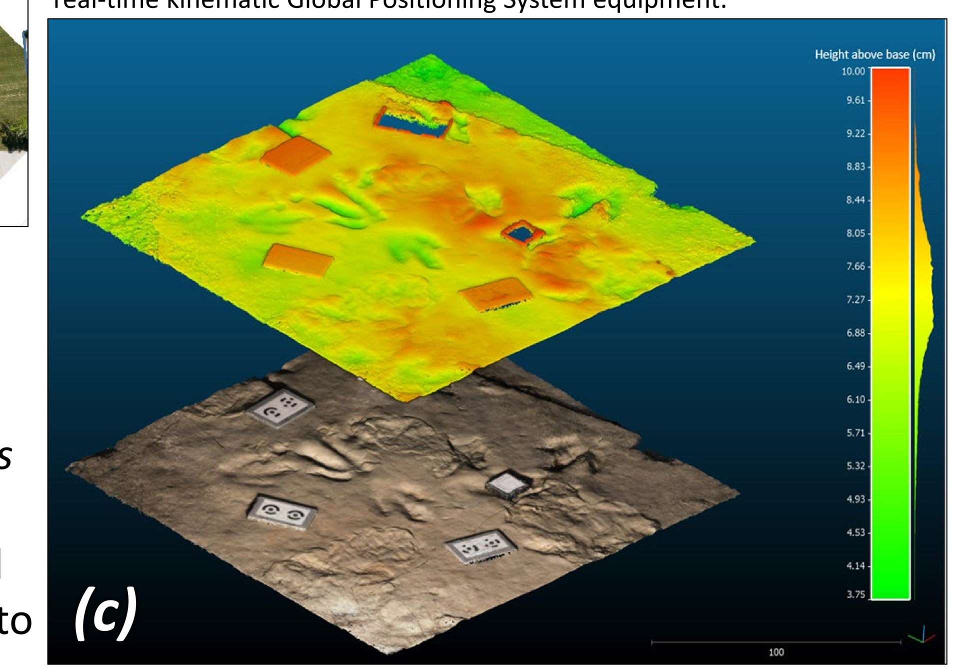


Figure 4. ***(c)*** View of the dinosaur track heightmap above the textured model. The heightmap represents color coded topography by taking the difference of the model from a fit-plane generated to a height of 0 as ground level. A color scale bar was then imported to display height differences.

Model Manipulation and 3D Printing

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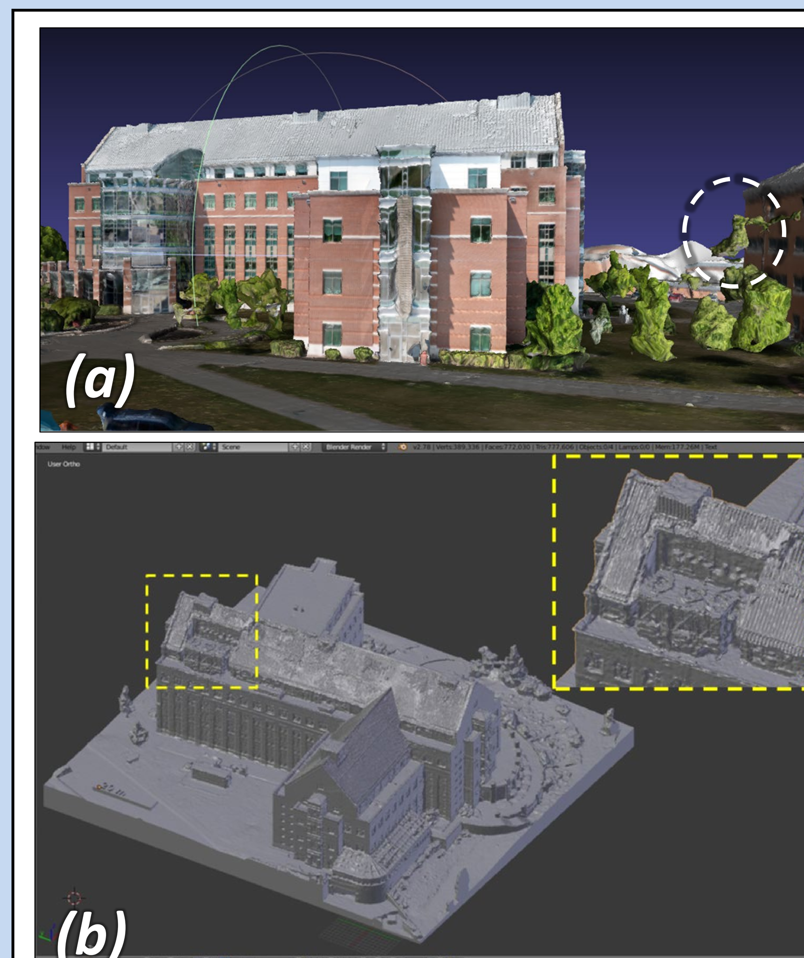


The MeshLab software was used to modify models, using segmentation tools to delete unnecessary sections prior to 3D printing (**Fig. 5a**). A Drone Deploy model of the ECSU Science Building was imported from Metashape (as an .obj file) and segmented and exported as a .stl file. Blender software was used to convert and refine Meshlab file for 3D printing. In Blender, this involved using an imported mesh to carve a new cubic mesh that was resized to fit the model well. A Boolean modifier was used to carve the mesh cube with the model and create a solid volume with a rectangular base that could be 3D printed (**Fig. 5b**). In the final model, it was noted that the roof of the Science Building was poorly rendered due to its highly reflective appearance which did not model well in Metashape (**Fig. 5b** inset). Once completed a new .stl file was generated and printed using a MakerBot additive printer (**Fig. 5c**).

Figure 5. ***(a)*** The unedited MeshLab model of the Science Building showing floating trees (white circle) that were removed prior to 3D printing. ***(b)*** Blender view with inset illustrating imperfections in the model for the HVAC unit on the Science Building. These modelling errors arise due to reflectivity of the roof and incomplete imaging due to the confined space. ***(c)*** The printed model as viewed in front of the Science Building.

Change Detection Estimation, Napatree Point, RI.

6

Cloud Compare software was used to calculate change detection between 2016 and 2021 mesh models of the Napatree bluff. Calculating topographic change requires measuring the distance between two neighbor mesh models, one "compare" mesh to one "reference" mesh. To calculate change detection between the Napatree 2016 and 2021 bluff, the mesh models were imported into Cloud Compare, segmented, and trimmed. The calculation was set up as the 2021 mesh subtracted by the 2016 mesh using 'cloud to cloud distances' to compute the differences in elevation. Lastly, a color scale was imported and adjusted to display erosion as red and deposition as blue (**Fig. 6**). Calculating change between the 2016 and 2021 mesh models depict the amount the bluff retreated or advanced over a 5-year period.

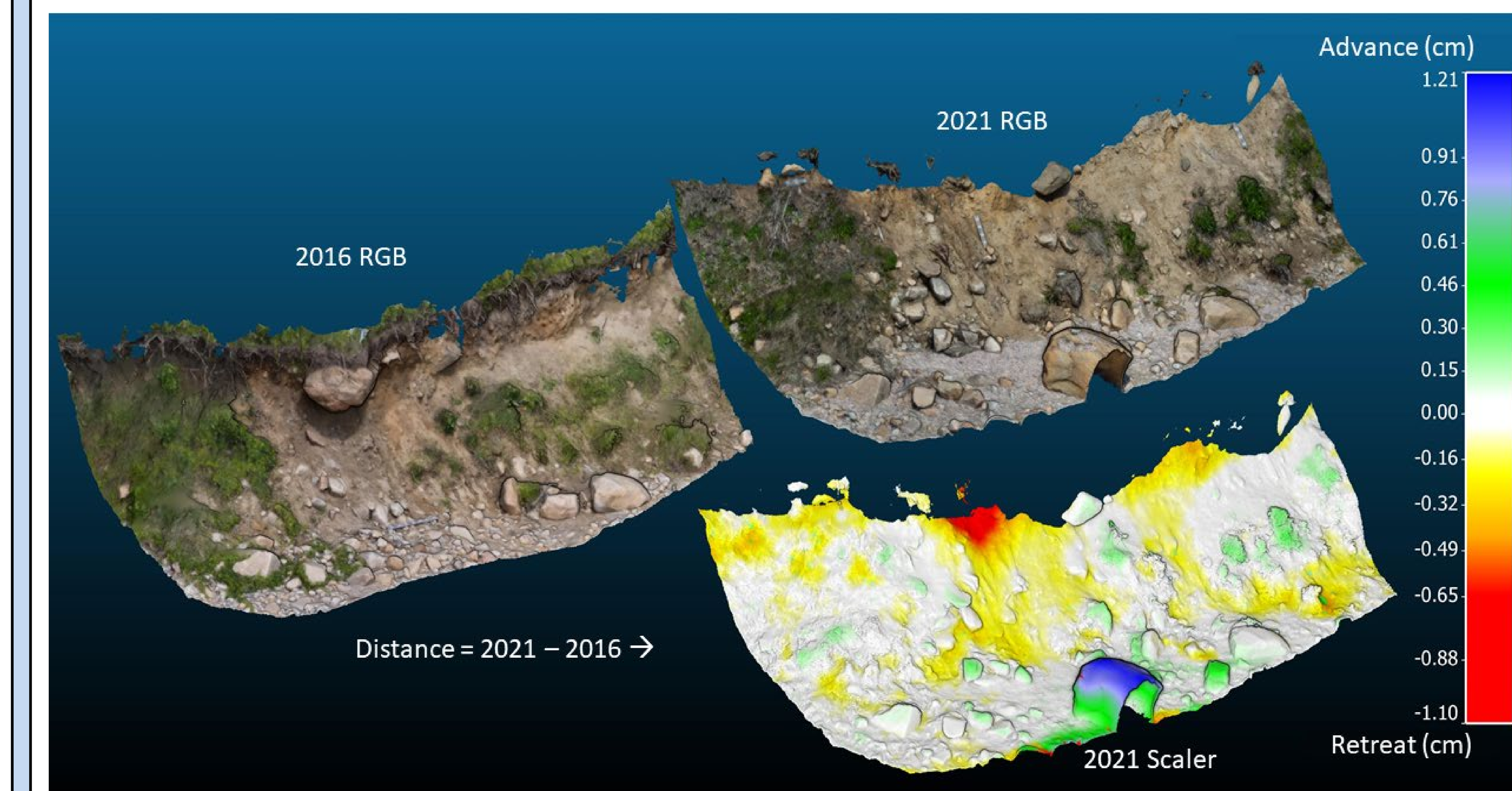
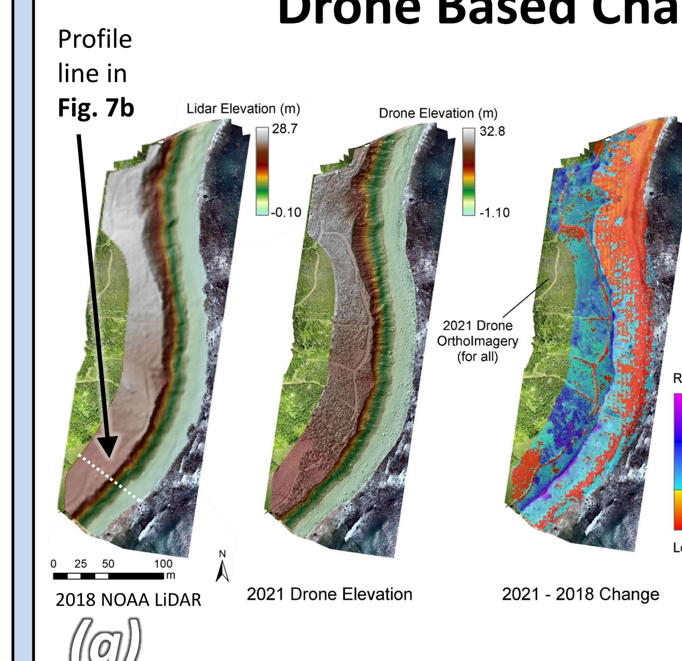


Figure 6. View of 2016 and 2021 textured models with the change detection model showing red as erosion and blue as deposition.

Drone Based Change-Detection, Block Island, RI.

7

PG data may also be helpful in mapping coastal erosive change. We compared June-2021 drone PG models of Clay Head at Block Island, with similar LiDAR (laser-based) measurements in ArcGIS (**Fig. 7a**). Cross-sections reveal that drone models are strongly influenced by vegetation inland from the bluff which complicates interpretation (**Fig. 7b**).



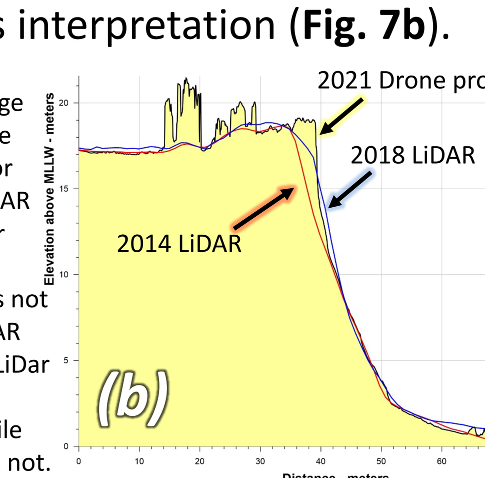


Figure 7. ***(a)*** Left to right views of 2018 LiDAR, 2021 drone, and change expressed raising or lowering of the land. ***(b)*** A corresponding profile for the dashed line in *(a)* depicting LiDAR and Drone elevations. The irregular profile (drone data; yellow) is not present in LiDAR lines because LiDar data strips vegetation while drone PG does not.

Summary

This research experience introduced photogrammetric modeling from ground and airborne imagery. These new techniques enable detailed visualization and measurement of topographic data for built and natural environments. This is also useful for measuring change through time at a variety of sites.

Citations

Oakley, Bryan A. 2021. Storm Driven Migration of the Napatree Barrier, Rhode Island, USA. Geosciences 11: 330.

Olsen, P., Whiteside, J., LeTourneau, P., Huber, P. 2005. Jurassic Cyclostratigraphy and Paleontology of the Hartford Basin. In: Guidebook for Field Trips in Connecticut, Skinner B. J., and Phillpotts, A.R. Editors. CT Geological and Natural History Survey Booklet. 305 pp.