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12/5/16

Structure from Motion Photogrammetry for 3D Reconstruction of Crater Glacier on Mount St. Helens, Washington, USA

Abstract:

The Crater Glacier on Mount St. Helens is rare compared to most glaciers in the coterminous United States in that it is advancing – at a rate approximately 10 cm per day (USGS, 2013). The May 1980 eruption of Mount St. Helens created a deep, north facing crater and consequently provides a perfect environment for this glacier to grow. Yearly measurement and mapping campaigns of the terminus of Crater Glacier are carried out by the USGS (Walder et al, 2009). This study presents a flexible, cost-effective and accurate method for measuring crater glaciers growth as an alternative to aerial lidar or ground GPS surveys. A UAV-based photo acquisition and 3D image reconstruction methodology was used to create 3D models of the glacier terminus. On October 11th, 2016, 237 photos were acquired using a quadcopter platform and GoPro HERO 3 camera. Photos were processed using a Structure from Motion workflow with Pix4D software. An accuracy assessment of the models, using 11 GPS validation points, shows that the most accurate model yielded a RMSE of 0.37 meters at 0.1-meter pixel size. Furthermore, glacier and topographical change was analyzed by comparing the new DEMs to a lidar derived DEM from 2009. This change detection showed the glacier at its terminus has a max depth of 60 meters. In future studies an improved ground control methodology could be used to increase the accuracy and number of both control and test points. Additionally, a time series of 3D models could allow observation of topographic change of glacier movement between summer seasons.

STRUCTURE FROM MOTION PHOTOGRAMMETRY FOR 3D RECONSTRUCTION OF CRATER GLACIER ON MOUNT ST. HELENS, WASHINGTON, USA

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INTRODUCTION

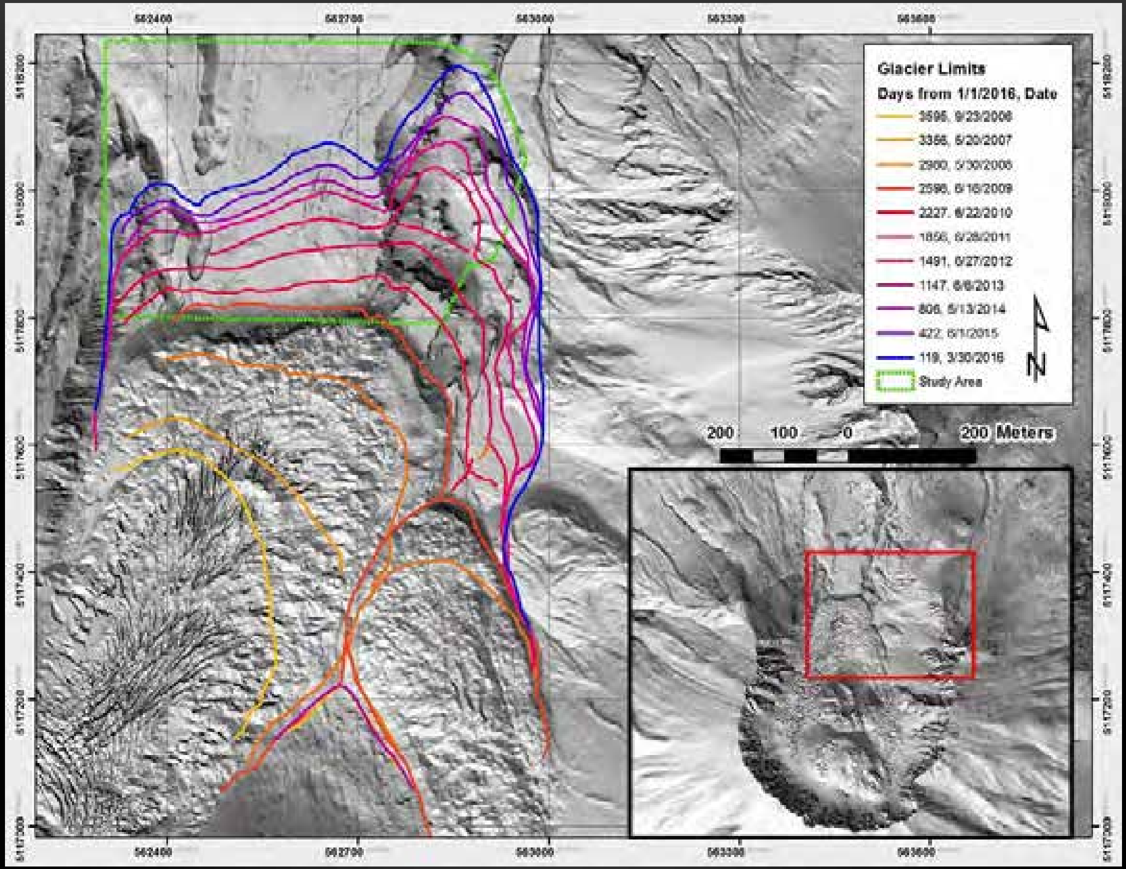
Why study and map glaciers?

- Glaciers serve as proxy for global climate change
  - Satellite imagery for monitoring retreat or growth
  - Extent and coverage for estimating glacier mass balance
  - Mass balance is the ratio of accumulation and ablation
- In many places, glaciers serve as fresh water storage
  - Volume estimation and snow water equivalent
- Glacier retreat can drive periglacial hazards, e.g. debris flows and outburst floods

STUDY AREA

PRIOR STUDIES

First video courtesy of USGS (2013); Second courtesy of USGS (2012)

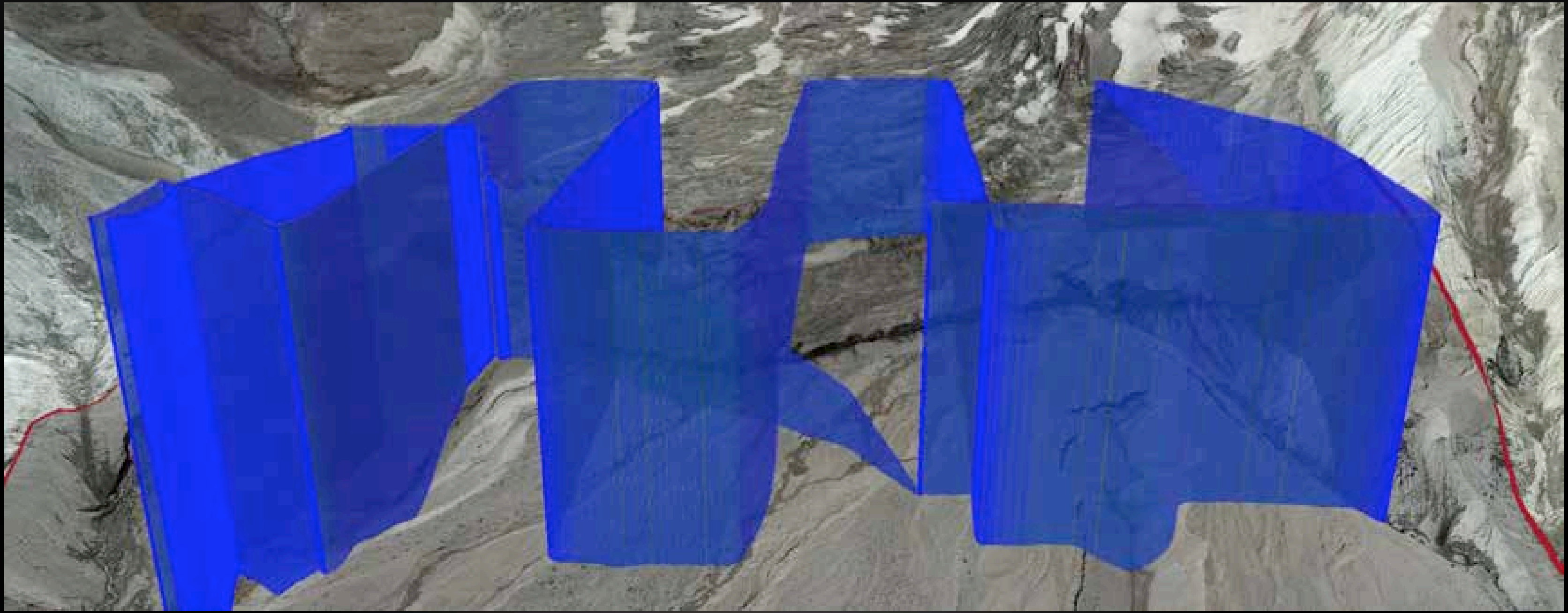


PRIOR STUDIES

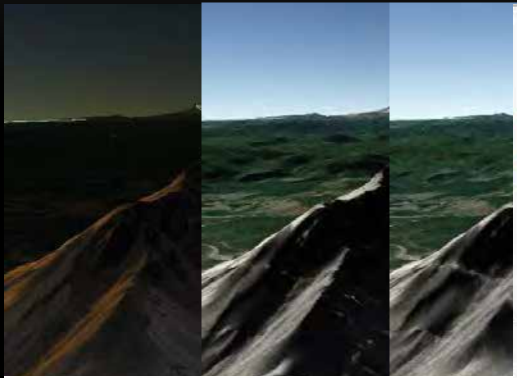
MISSION PLANNING

- Four separate flights (~10 minutes) and only fourth flight was successful (~20 minutes)
- 70% sidelap
- 70% overlap
- Flight height was ~395 feet AGL
- Photo time interval was 1 second
- Camera GoPro HERO4 Silver

MISSION PLANNING



WEATHER AND DAY LIGHT



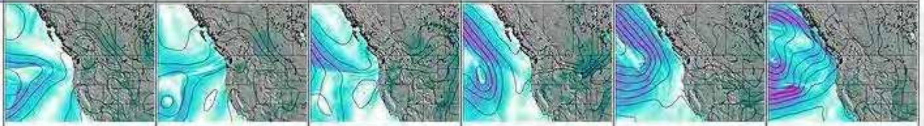
Astronomy

Oct. 11, 2016	Rise
Actual Time	7:24 AM PDT
Civil Twilight	6:53 AM PDT
Nautical Twilight	6:18 AM PDT
Astronomical Twilight	5:43 AM PDT

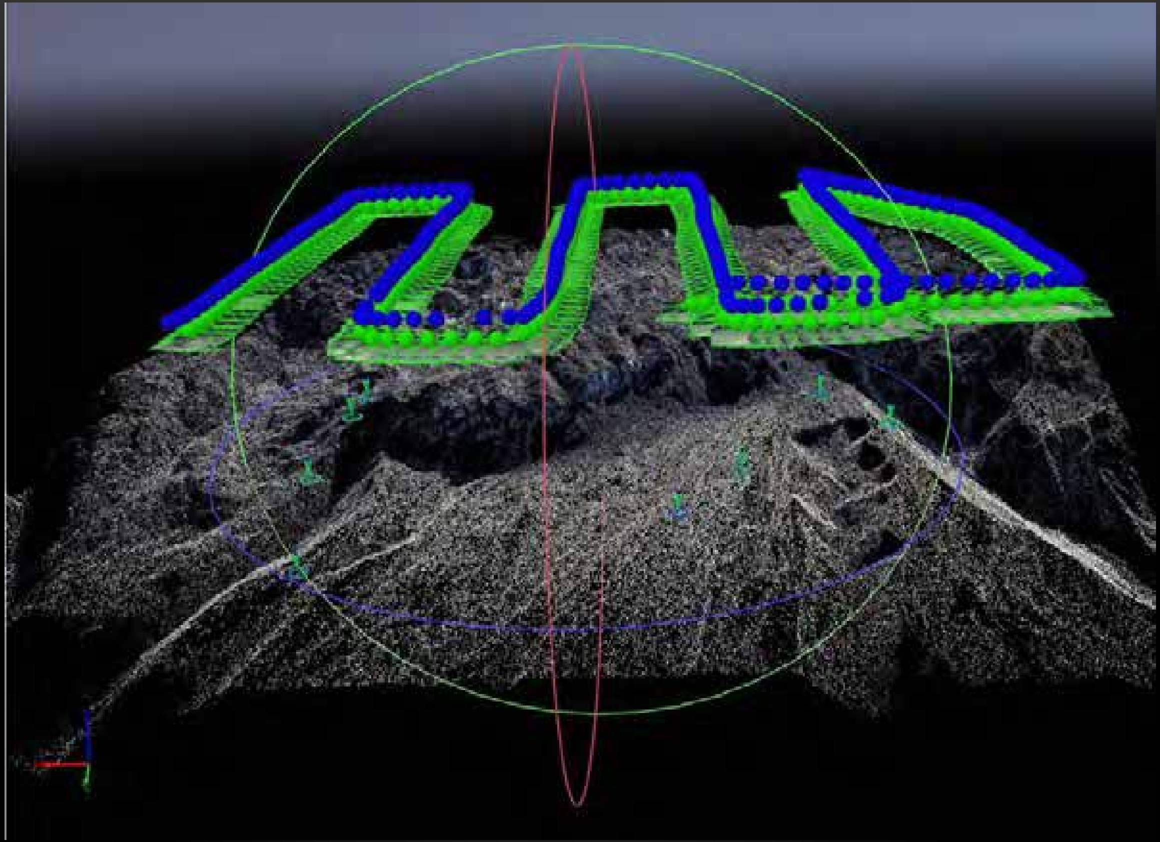
heaviest on Sun night. Mild temperatures (max 43°F on Fri night, min 34°F on Fri morning). Winds decreasing (near gales from the WSW on Sat night, moderate winds from the NW by Sun night).

morning). Winds increasing (calm on Mon night, strong winds from the SSW by Wed night).

Metric / Imperial	Friday 7			Saturday 8			Sunday 9			Monday 10			Tuesday 11			Wednesday 12		
	AM	PM	night	AM	PM	night	AM	PM	night	AM	PM	night	AM	PM	night	AM	PM	night
See all weather maps																		
		Light		Heavy	Light		Heavy	Heavy										
Wind (mph)	25	15	30	25	25	35	25	20	15	5	5	5	10	5	10	15	20	20
Summary	light snow	light rain	heavy rain	heavy rain	light rain	rain shwrs	heavy rain	heavy rain	snow shwrs	clear	clear	clear	clear	clear	rain shwrs	some clouds	some clouds	rain shwrs
Snow (in)	0.8	-	-	-	-	-	-	-	5.9	-	-	-	-	-	-	-	-	-
Rain (in)	-	0.0	0.7	0.8	0.1	0.2	0.8	2.1	1.0	-	-	-	-	-	0.1	-	-	2.1
High °F	36	37	43	43	43	43	41	41	37	36	37	39	39	43	45	43	41	39
Low °F	34	36	37	43	43	43	41	41	34	36	37	39	39	41	43	41	41	36
Chill °F	23	28	32	34	34	32	30	30	27	28	32	39	34	39	39	36	32	28
Freezing level (ft)	7900	8700	10300	10000	10500	10300	9800	9500	7900	7900	8900	9400	10300	10200	10300	9200	8900	8200



FIELD DAY



PROCESSING

PROCESSING

- 237 photos used
- 2 different extents – first with DEM2 and then second with DEM3 and DEM4
- 2 different geotag time offsets – first with no offset on DEM2 and DEM3 and then 0.095 second offset with DEM4
- 7 cm pixel size for DEM2 (resampled to 10 cm) and 10 cm pixel sixe for DEM3 and DEM4
- Processing time was about ~12 hours

FINAL MODEL

RESULTS

Table 1. Evaluation of the residuals for the 9 GCPs used for georeferencing of the 3D models.

	Error X [m]	RMSE X [m]	Error Y [m]	RMSE Y [m]	Error Z [m]	RMSE Z[m]
DEM2	-0.0071	0.0491	-0.0051	0.0528	0.0043	0.0523
DEM3	-0.0071	0.0491	-0.0051	0.0528	0.0043	0.0523
DEM4	-0.0087	0.0503	-0.0068	0.0532	0.0043	0.0524

Table 2. Evaluation of the geometric accuracy of the 3D models using 11 validation points.

	Mean Error [m]	Absolute Error [m]	RMSE [m]	R2
DEM 2	-0.244802333	0.266644167	0.37489154	0.9991
DEM 3	-0.257520667	0.2779685	0.383512494	0.9991
DEM 4	-0.257520667	0.2779685	0.383512494	0.9991

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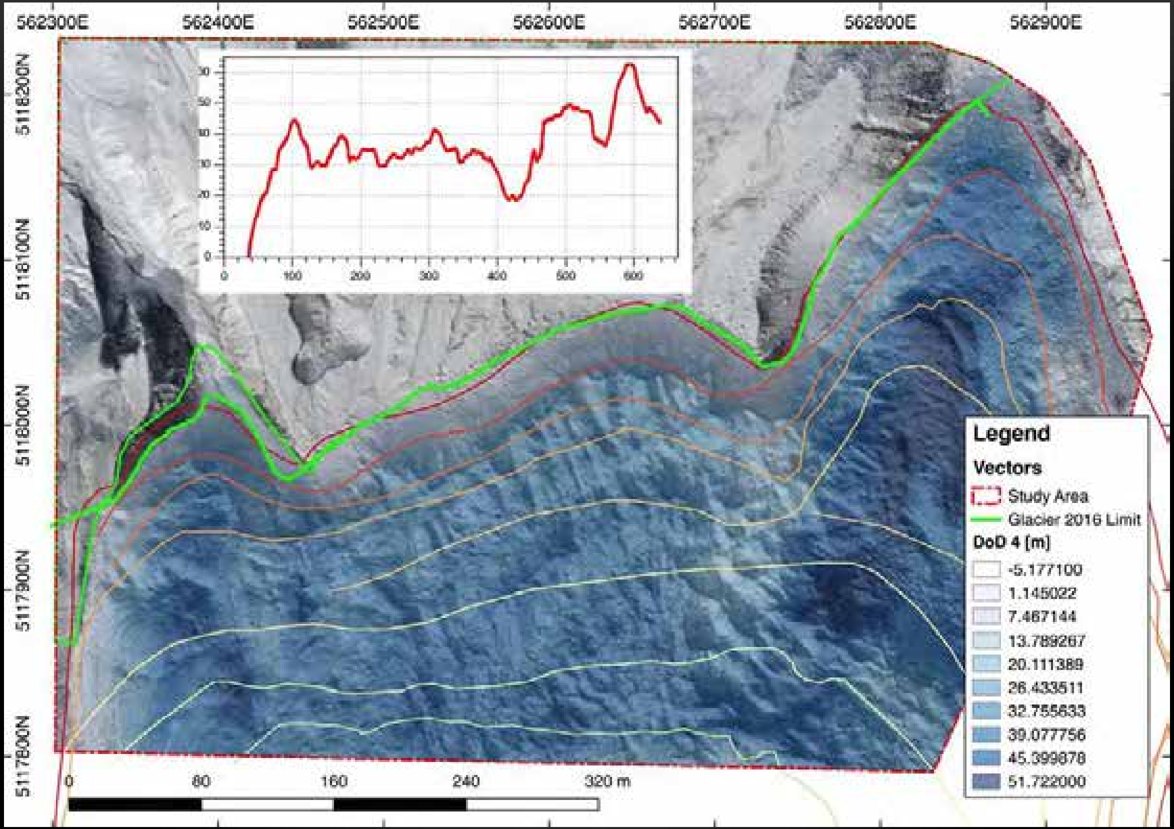
562300E
562400E
562500E
562600E
562700E
562800E
562900E
5118200N
5118100N
5118000N
5117900N
5117800N
0
80
160
240
320 m
Legend
Vectors
Study Area
Glacier 2016 Limit
DoD 4 [m]
-5.177100
1.145022
7.467144
13.789267
20.111389
26.433511
32.755633
39.077756
45.399878
51.722000

RESULTS

DISCUSSION

- In the future…
  - Improved sensor (camera)
  - Time series across multiple summer seasons
  - Larger survey area
  - Better ground control and validation data set

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