

Rapid, Remote Assessment of Hurricane Matthew Impacts
Using 4D Structure-from-Motion Photogrammetry:
Supplemental Material

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SUPPLEMENTAL MATERIAL

This is supplemental material to accompany the manuscript titled “Rapid, Remote Assessment of Hurricane Matthew Impacts Using 4D Structure-from-Motion Photogrammetry” by Sherwood *et al.* The supplement provides information about the independent ground-truth points surveyed by the U.S. Geological Survey field crew on October 13 and 14, 2016. The team consisted of J. Bernier, B.J. Reynolds, and N. Zaremba. They identified twelve points on features that were likely to be visible in the aerial photos and that did not appear to have moved since the storm. The points included corners of asphalt and concrete slabs, the ends of exposed water pipes, the end of a wall, a dune scarp, a nearly-buried fire hydrant, and the trunk of a downed palm tree. The points were located by setting up a RTK GNSS (real-time kinematic global navigation satellite surveying system) consisting of a base station with an Ashtech Proflex 800 base station with Thales choke-ring antenna and an Ashtech Proflex 800 receiver with an Ashtech GNSS antenna that was placed on a tripod over the feature and collected observations for 5 minutes. These data were post-processed to provide positions with horizontal precision of ~1.5 cm and vertical precision of ~3.5 cm, based on the maximum standard deviations in the recorded time series, instrument precision, and distance (<1 km) from the base station to the survey point.

Table S1 lists the surveyed points and coordinates in the NAD83(2011), Geoid12a reference frame. Figure S1 contains photos of the features; additional photos were used to help locate the features in the oblique aerial images. Table S2 lists the coordinates of the ground-truth points in Universal Transverse Mercator (UTM) Northing and Easting (meters, zone 17 North) in the NAD83 reference frame (Geoid12a). Vertical coordinates were meters referenced to North American Vertical Datum of 1988 (NAVD88). The short descriptions in column two indicate whether the point has questionable horizontal positioning (h?), vertical positioning (v?), or both (h, v?). Table S2 also lists the estimated location of the features determined by locating them in the oblique images and extracting their coordinates according to the 4D SfM reconstruction, and the associated differences. The summary rows at the bottom of the table list the mean difference, standard deviation of the differences, root-mean-squared differences, and minimum and maximum absolute differences. Tables S3 and S4 contain the same information for subsets of the features: in Table S3, features with questionable vertical control have been removed, and in Table S4, features with questionable horizontal control have been removed. Vertical positioning was considered compromised when the feature was prominent relative to its immediate surroundings, and small errors in the horizontal position could have led to substantial vertical differences. Horizontal positioning was considered compromised if the feature was indistinct or difficult to locate precisely in the oblique photos.

ACKNOWLEDGMENT

This work was been supported by the U.S. Geological Survey, Coastal and Marine Geology Program.

DISCLAIMER

Use of firm and product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Table S1. List of the surveyed locations of the ground-truth points

Name	Description	Latitude	Longitude	Ellipsoid Ht. (m)	SD Horiz. (m)	SD Height (m)
M004	South edge of asphalt slab on east side of road (A1A)	29.6737216	-81.2152390	-26.739	0.008	0.010
MNTZ1	Slab of concrete on W side of road (A1A) , NE edge of slab	29.6726199	-81.2146417	-26.576	0.007	0.010
MNTZ2	Small concrete pad on beach by I-beam piles, NE corner	29.6722418	-81.2141249	-26.532	0.008	0.012
MNTZ3	E edge of scarp, just N of "Marineland" stone sign	29.6713116	-81.2137703	-24.129	0.008	0.012
MNTZ4	NW corner of "Marineland" sign	29.6709818	-81.2136885	-23.605	0.008	0.013
MNTZ5	Exposed benchmark on shoreface, adjacent to culvert/septic tank?	29.6720073	-81.2140318	-26.145	0.008	0.013
MNTZ6	On top of yellow fire hydrant partially buried by sand at S end of overwash area 2, beside power pole	29.6758396	-81.2157224	-26.217	0.008	0.014
MNTZ7	W end of exposed blue water pipe oriented perpendicular to the shoreline in overwash area 2	29.6759040	-81.2158351	-26.406	0.009	0.020
MNTZ8	NE corner of concrete slab, remnants of driveway through dunes adjacent to overwash area 2	29.6768547	-81.2160458	-26.294	0.010	0.027
MNTZ9	Dead palm on beach at the root/stem interface	29.6814579	-81.2176119	-26.511	0.008	0.019
MNTZ10	N end of white water line at the breach	29.6838388	-81.2186780	-27.426	0.007	0.015
MNTZ11	W end of blue water pipe in breach, probably covered at high tide. No setup photo. Tripod was setup on closest end to house in photo	29.6842682	-81.2188569	-28.793	0.007	0.014

Figure S1. Representative images of the ground-truth features



Table S2. Ground-Truth Points

Name	Description	Easting (m)	Northing (m)	Elevation (m)	SfM Est. Northing (m)	SfM Est. Easting (m)	SfM Est. Elev. (m)	Horiz. Diff. (m)	Total Diff. (m)	Easting Diff. (m)	Northing Diff. (m)	Elev. Diff. (m)
M004	slab (h?)	479173.10	3282651.32	2.05	479173.48	3282650.85	1.87	0.61	0.63	0.38	-0.47	-0.18
MNTZ1	slab	479230.67	3282529.14	2.21	479230.63	3282528.28	2.03	0.87	0.88	-0.03	-0.87	-0.18
MNTZ2	slab	479280.60	3282487.16	2.26	479280.66	3282486.35	2.22	0.81	0.82	0.07	-0.81	-0.03
MNTZ3	scarp (h, v?)	479314.72	3282384.02	4.66	479314.46	3282383.77	4.44	0.36	0.42	-0.26	-0.25	-0.22
MNTZ4	wall (v?)	479322.57	3282347.46	2.64	479321.66	3282347.05	4.04	1.00	1.72	-0.91	-0.41	1.40
MNTZ5	bm (h?)	479289.56	3282461.16	2.64	479289.97	3282460.32	2.58	0.94	0.94	0.41	-0.84	-0.06
MNTZ6	hydr (h, v?)	479126.76	3282886.10	2.57	479127.17	3282885.95	2.24	0.43	0.54	0.40	-0.14	-0.33
MNTZ7	pipe (v?)	479115.87	3282893.24	2.38	479115.93	3282892.28	2.08	0.97	1.02	0.07	-0.97	-0.30
MNTZ8	slab	479095.68	3282998.62	2.50	479095.70	3282997.67	2.52	0.95	0.95	0.02	-0.95	0.02
MNTZ9	palm (h, v?)	478945.10	3283508.96	2.28	478944.06	3283508.24	1.92	1.27	1.32	-1.04	-0.72	-0.36
MNTZ10	pipe (v?)	478842.46	3283772.96	1.37	478842.66	3283772.57	1.70	0.44	0.56	0.21	-0.39	0.34
MNTZ11	blue pipe (moved)	478825.24	3283820.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Mean Difference								0.79	0.89	-0.06	-0.62	0.01
RMS Difference								0.83	0.96	0.48	0.68	0.48
Std. Dev. Difference								0.27	0.36	0.47	0.28	0.48
Min. Abs. Difference								0.36	0.42	0.02	0.14	0.01
Max. Abs. Difference								1.27	1.72	1.04	0.97	1.40

Table S3. Ground-Truth Points; Features with Questionable Vertical Control Removed

Name	Description	Easting (m)	Northing (m)	Elevation (m)	SfM Est. Northing (m)	SfM Est. Easting (m)	SfM Est. Elev. (m)	Horiz. Diff. (m)	Total Diff. (m)	Easting Diff. (m)	Northing Diff. (m)	Elev. Diff. (m)
M004	slab (h?)	479173.10	3282651.32	2.05	479173.48	3282650.85	1.87	0.61	0.63	0.38	-0.47	-0.18
MNTZ2	slab	479280.60	3282487.16	2.26	479280.66	3282486.35	2.22	0.81	0.82	0.07	-0.81	-0.03
MNTZ1	slab	479230.67	3282529.14	2.21	479230.63	3282528.28	2.03	0.87	0.88	-0.03	-0.87	-0.18
MNTZ5	bm (h?)	479289.56	3282461.16	2.64	479289.97	3282460.32	2.58	0.94	0.94	0.41	-0.84	-0.06
MNTZ8	slab	479095.68	3282998.62	2.50	479095.70	3282997.67	2.52	0.95	0.95	0.02	-0.95	0.02
Mean Difference								0.83	0.84	0.17	-0.79	-0.09
RMS Difference								0.84	0.85	0.25	0.81	0.12
Std. Dev. Difference								0.12	0.12	0.19	0.16	0.08
Min. Abs. Difference								0.61	0.63	0.02	0.47	0.02
Max. Abs. Difference								0.95	0.95	0.41	0.95	0.18

Table S4. Ground-Truth Points; Features with Questionable Horizontal Control Removed

Name	Description	Easting (m)	Northing (m)	Elevation (m)	SfM Est. Northing (m)	SfM Est. Easting (m)	SfM Est. Elev. (m)	Horiz. Diff. (m)	Total Diff. (m)	Easting Diff. (m)	Northing Diff. (m)	Elev. Diff. (m)
MNTZ1	slab	479230.67	3282529.14	2.21	479230.63	3282528.28	2.03	0.87	0.88	-0.03	-0.87	-0.18
MNTZ2	slab	479280.60	3282487.16	2.26	479280.66	3282486.35	2.22	0.81	0.82	0.07	-0.81	-0.03
MNTZ7	pipe (v?)	479115.87	3282893.24	2.38	479115.93	3282892.28	2.08	0.97	1.02	0.07	-0.97	-0.30
MNTZ8	slab	479095.68	3282998.62	2.50	479095.70	3282997.67	2.52	0.95	0.95	0.02	-0.95	0.02
MNTZ10	pipe (v?)	478842.46	3283772.96	1.37	478842.66	3283772.57	1.70	0.44	0.56	0.21	-0.39	0.34
Mean Difference								0.81	0.84	0.07	-0.80	-0.03
RMS Difference								0.83	0.86	0.10	0.82	0.22
Std. Dev. Difference								0.19	0.16	0.08	0.21	0.22
Min. Abs. Difference								0.44	0.56	-0.03	-0.97	-0.30
Max. Abs. Difference								0.97	1.02	0.21	-0.39	0.34