

High-resolution Digital Surface Model of the 2021 eruption deposit of Cumbre Vieja volcano, La Palma, Spain

Riccardo Civico¹, Tullio Ricci¹, Piergiorgio Scarlato¹, Jacopo Taddeucci¹, Daniele Andronico¹, Elisabetta Del Bello¹, Luca D'Auria^{2,3}, Pedro A. Hernández^{2,3}, Nemesio M. Pérez^{2,3}, María Asensio-Ramos², José Barrancos^{2,3}, David Calvo², David Martínez van Dorth^{2,3}, Eleazar Padrón^{2,3}, Antonio Álvarez², Carlo Doglioni¹

1 Istituto Nazionale di Geofisica e Vulcanologia, Italy

2 Instituto Volcanológico de Canarias - INVOLCAN, 38320 San Cristóbal de La Laguna, Tenerife, Canary Islands

3 Instituto Tecnológico y de Energías Renovables - ITER, 38600 Granadilla de Abona, Tenerife, Canary Islands

Digital surface model of the Cumbre Vieja new volcano edifice and lava flows (La Palma, Spain) produced from 9970 UAS derived aerial photographs using the Structure-from-Motion method.

The 2021 eruption of Cumbre Vieja volcano is the largest eruptive event in recorded history for La Palma Island (Canary Island, Spain). Over almost 3 months (September 19 - December 13, 2021), the volcano produced profound morphological changes in the landscape affecting both the natural and the anthropic environment over an area of tens of km².

Model shows numerous volcanic features including the new main edifice, lava flows, rafted material on lava flows, and tephra deposits. In addition, numerous fractures affecting the main edifice are evident.

For more details on this dataset, please see the citation:

Civico R., Ricci, T., Scarlato P., et al. (2022). High-resolution Digital Surface Model of the 2021 eruption deposit of Cumbre Vieja volcano, La Palma, Spain. *Sci Data* (submitted)

Project Name: 2021 Cumbre Vieja volcano eruption (La Palma, Spain) SfM DSM

Personnel

- PIs: Riccardo Civico, Tullio Ricci
- Contributors: Piergiorgio Scarlato, Jacopo Taddeucci, Daniele Andronico, Elisabetta Del Bello, Luca D’Auria, Pedro A. Hernández, Nemesio M. Pérez, María Asensio-Ramos, José Barrancos, David Calvo, David Martínez van Dorth, Eleazar Padrón, Antonio Álvarez, Carlo Doglioni

Dates of Collection: January 24-January 28, 2022

Site Information: Cumbre Vieja Volcano is part of a north-south trending rift zone located in the island of La Palma, Canarias, Spain. The area affected by the 2021 eruption is centered at 17.8972579°W, 28.6195191°N.

Site Conditions: Survey conditions varied during the fieldwork. The light varied between sunny and cloudy, depending upon the presence of clouds and showers in the western side of the island. The wind varied between light to strong breeze.

UAS Equipment and Data Collection Methods: We used a DJI Phantom 4 RTK to collect aerial photographs. We used the DJI GS RTK app to plan the flight missions using the “Photogrammetry” setting. We flew the UAS 50-200 m above ground level with both nadir and oblique camera angles. We collected aerial photographs on different days with varying light conditions.

Processing: We processed the photographs collected by the UAS into point cloud and DSM using Agisoft Metashape®. We set the processing parameters in Agisoft Metashape® to high for photo alignment accuracy and high quality and aggressive depth filtering for dense point cloud generation. We processed the Digital Surface Model (DSM) using the suggested resolution. The differing light conditions result in sharp gradients in color in portions of the point cloud.

Georeferencing: The data on camera position were collected using GNSS-RTK information embedded in the image metadata by means of a DJI D-RTK 2 Mobile Station. In addition, 40 ground control points (GCPs) were distributed along the



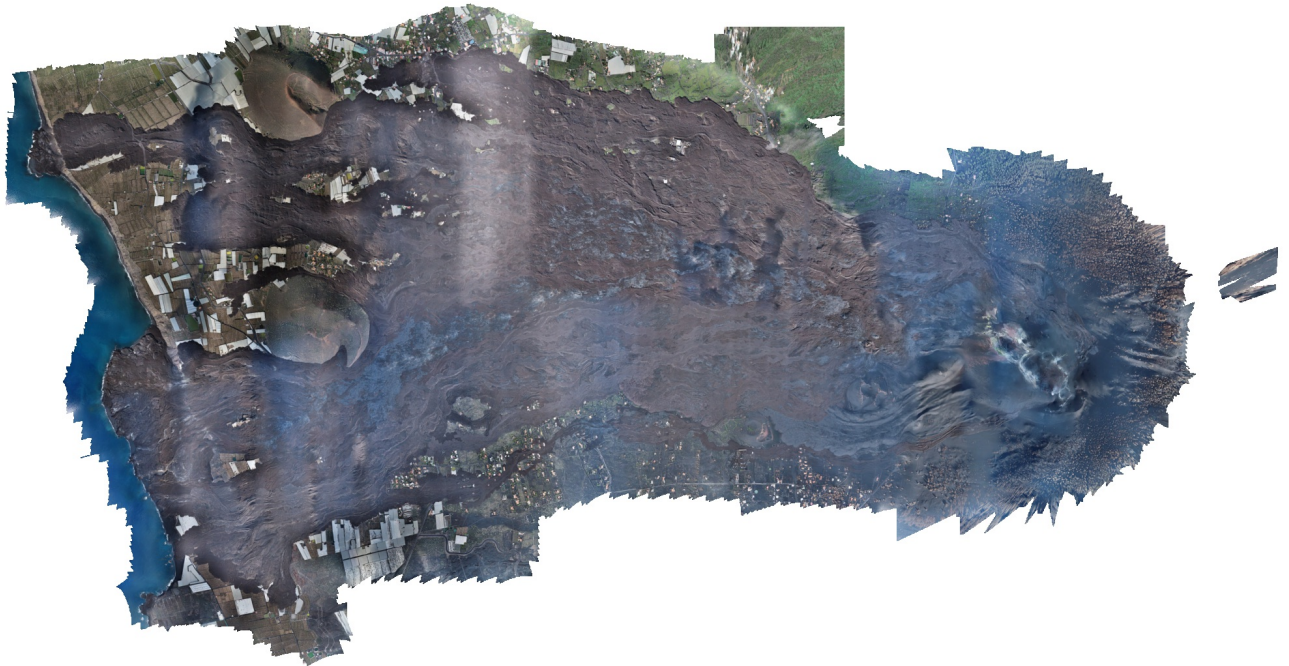
outer boundary of the lava flow and in the cone area to establish survey control. GCPs were measured with a GNSS survey in real-time kinematic (RTK) mode, with differential corrections sent in real-time by the Instituto Geográfico Nacional differential positioning service available at <https://www.ign.es/web/ign/portal/gds-gnss-tiempo-real>. The surveyed GCPs have an accuracy of 1-2 cm in horizontal coordinates and 2-4 cm in elevation.

Products: We generated a 0.2 m/pixel DSM covering an area of about 17 km². The dataset was processed and exported in the REGCAN95/UTM zone 28N [EPSG:4083] Coordinate System. The transformation from ellipsoidal to orthometric heights has been performed using the Geoid model EGM08-REDNAP (<https://datos-geodesia.ign.es/geoid/>). According to the Agisoft Metashape[®] survey report the ground control points (GCPs) and check points error estimates are as follows: the total GCPs RMSE is 6.18 cm and the total Check points RMSE is 14.59 cm.

2021 Cumbre Vieja volcano eruption (La Palma, Spain) SfM DSM

Digital surface model of the Cumbre Vieja new volcano edifice and lava flows (La Palma, Spain) produced from 9970 UAS derived aerial photographs using the Structure-from-Motion method.

23 March 2022



Survey Data

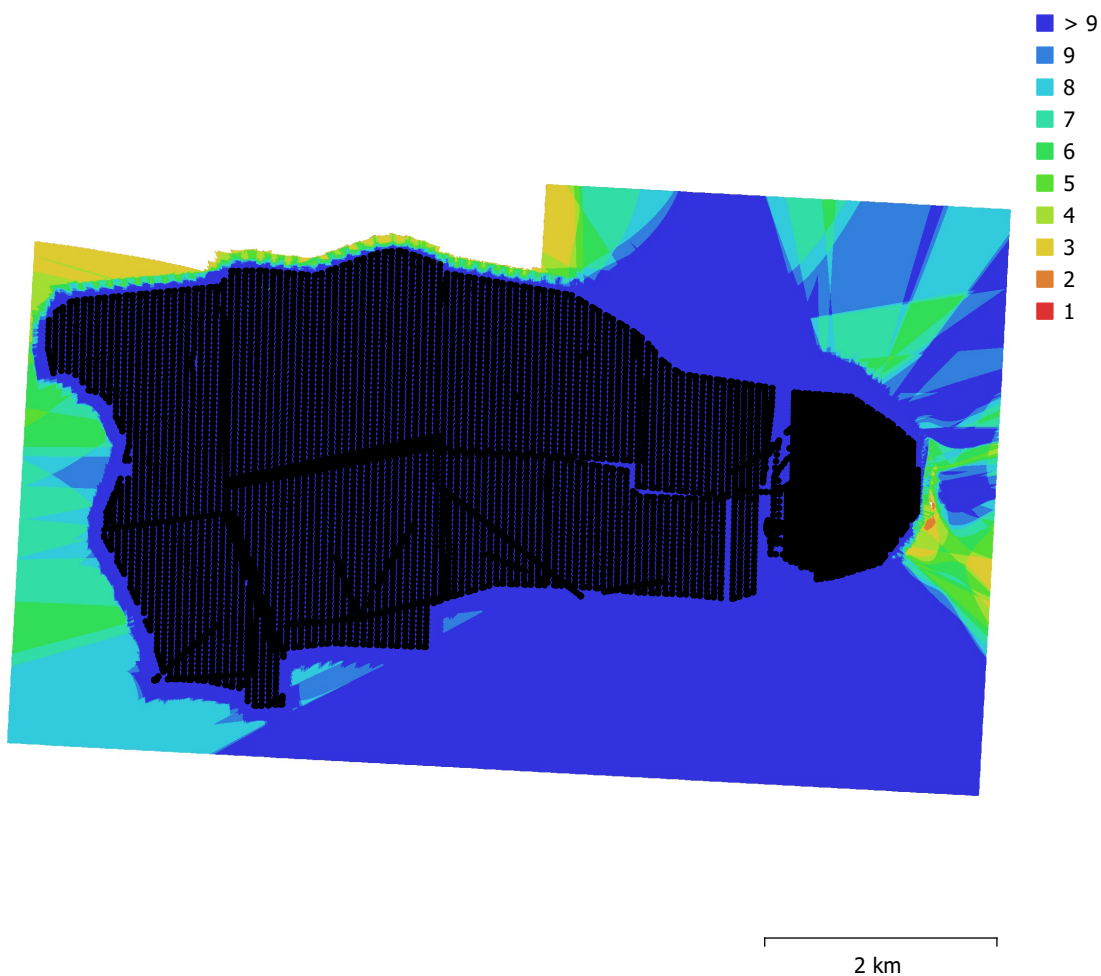


Fig. 1. Camera locations and image overlap.

Number of images:	10,437	Camera stations:	9,970
Flying altitude:	187 m	Tie points:	2,751,497
Ground resolution:	4.46 cm/pix	Projections:	17,509,917
Coverage area:	39.2 km ²	Reprojection error:	0.642 pix

Camera Model	Resolution	Focal Length	Pixel Size	Precalibrated
FC6310R (8.8mm)	5472 x 3648	8.8 mm	2.41 x 2.41 μ m	Yes

Table 1. Cameras.

Camera Calibration

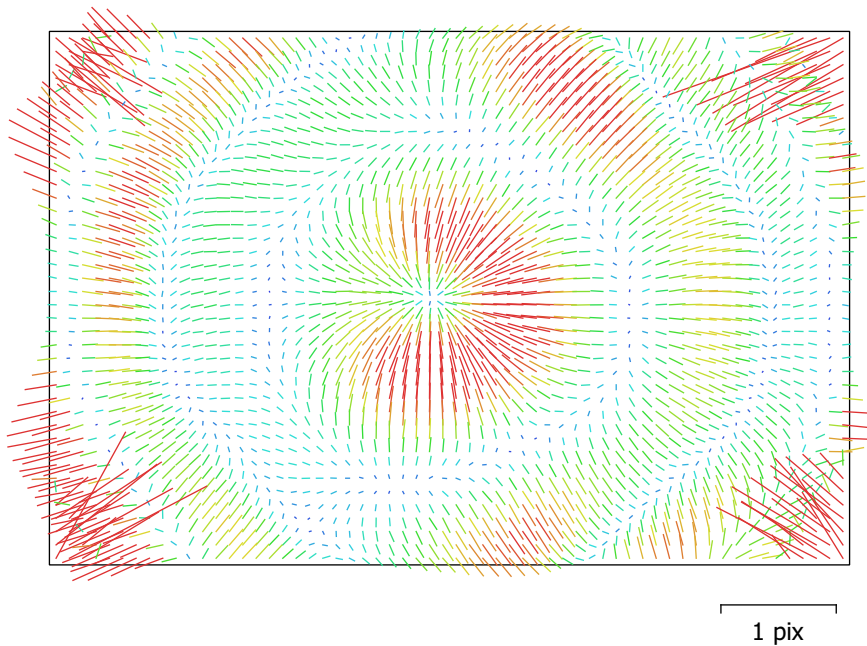


Fig. 2. Image residuals for FC6310R (8.8mm).

FC6310R (8.8mm)

10437 images, precalibrated

Type	Resolution	Focal Length	Pixel Size
Frame	5472 x 3648	8.8 mm	2.41 x 2.41 μm
F:	3693.51		
Cx:	-3.19488	B1:	0
Cy:	-13.5957	B2:	0
K1:	-0.281769	P1:	-0.000458649
K2:	0.122018	P2:	-4.9546e-06
K3:	-0.0331482	P3:	0
K4:	0	P4:	0

Ground Control Points

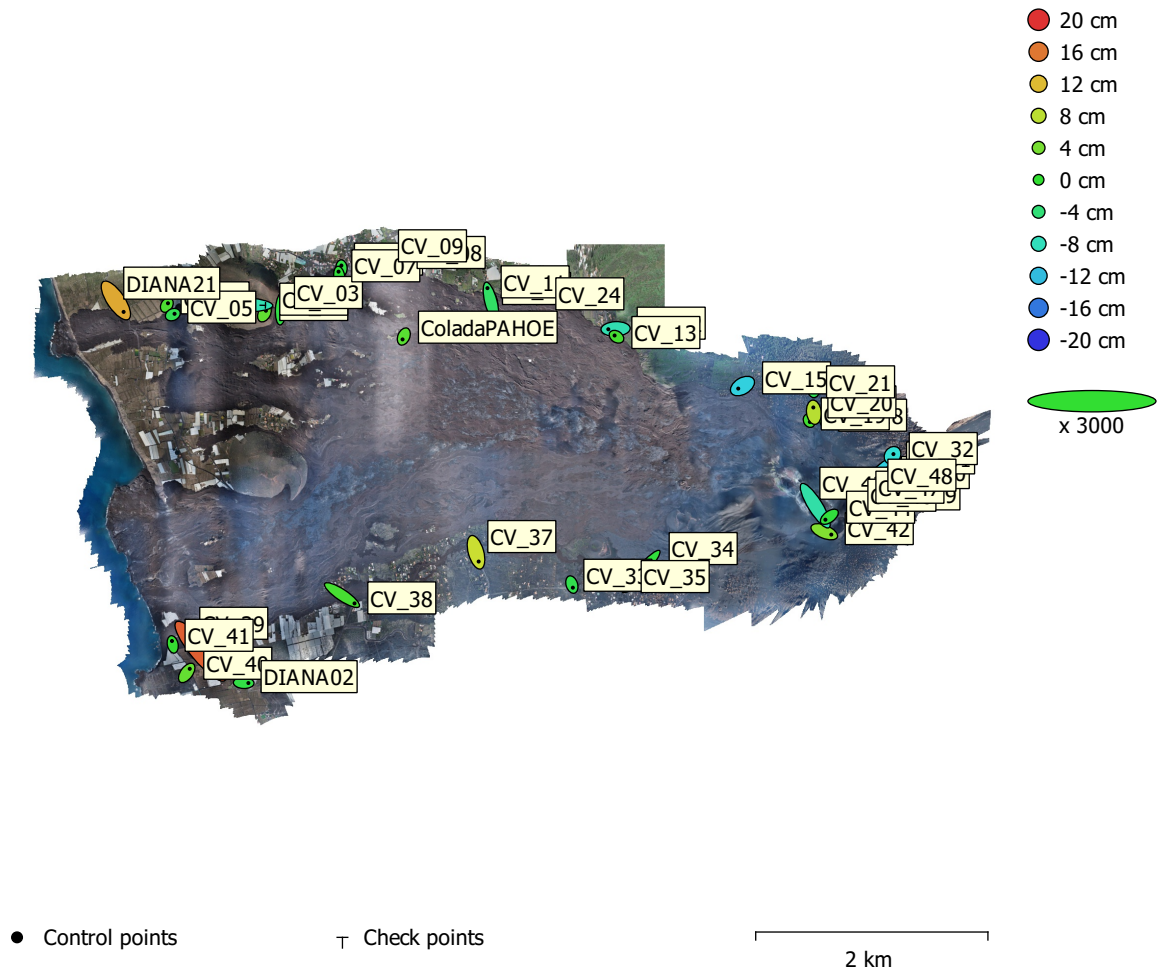


Fig. 3. GCP locations and error estimates.

Z error is represented by ellipse color. X,Y errors are represented by ellipse shape.

Estimated GCP locations are marked with a dot or crossing.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
33	2.22233	2.93895	4.9619	3.68459	6.18035

Table 2. Control points RMSE.

X - Easting, Y - Northing, Z - Altitude.

Count	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (cm)
7	8.40241	7.77961	9.0432	11.4509	14.5912

Table 3. Check points RMSE.

X - Easting, Y - Northing, Z - Altitude.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
CV_01	0.846826	1.54212	2.70496	3.22677	1.761 (6)
CV_03	0.447659	6.13528	-1.14212	6.25672	2.656 (11)
CV_04	0.655831	1.02091	1.56172	1.97771	0.891 (13)
CV_05	0.999252	0.46582	-1.91699	2.21141	1.369 (11)
CV_06	-0.0773117	1.48659	-1.16765	1.89191	0.764 (14)
CV_07	-0.407864	2.63412	-0.384271	2.69307	2.361 (5)
CV_08	-1.97499	1.0871	-4.82325	5.32411	1.224 (15)
CV_10	-1.04034	3.49818	-2.57706	4.46775	1.267 (11)
CV_11	-2.01853	7.87562	-2.97531	8.6575	2.180 (14)
CV_12	-4.1906	-0.194875	-7.39976	8.5062	2.815 (9)
CV_13	-1.08776	0.70135	1.17235	1.74629	1.425 (7)
CV_15	-2.43437	-1.44895	-10.8052	11.1704	3.803 (6)
CV_18	0.245854	-0.408544	1.51902	1.5921	1.103 (13)
CV_19	0.391649	-0.710919	0.910013	1.21939	1.210 (20)
CV_20	-0.330204	2.72912	7.72155	8.19631	7.197 (5)
CV_21	-0.0192323	-0.959584	-2.07273	2.28416	1.908 (15)
CV_24	-3.32543	0.842222	-1.04225	3.58526	1.524 (12)
CV_29	-0.967158	1.94351	-2.73679	3.49323	1.598 (6)
CV_30	0.334433	4.6825	-11.3363	12.2699	1.297 (13)
CV_32	0.516325	0.68601	-9.37302	9.41227	1.640 (10)
CV_33	0.572249	-1.77545	-1.60578	2.46135	1.693 (5)
CV_35	-0.609359	-1.19329	-0.184393	1.3525	1.267 (12)
CV_37	1.52905	-5.32332	8.86144	10.4499	3.425 (14)
CV_38	7.20029	-4.78051	1.20973	8.72702	2.823 (17)
CV_40	1.73674	2.36484	2.87171	4.10554	1.027 (16)
CV_41	-0.420389	1.95631	0.220197	2.01305	1.387 (6)
CV_42	4.02375	-1.63892	4.66327	6.3736	1.779 (17)
CV_44	-2.27078	-1.67936	-0.642358	2.89643	1.814 (14)
CV_47	-0.0245087	-1.29712	-0.364428	1.34756	1.513 (8)
CV_48	-2.66983	-1.51411	0.751422	3.15993	7.822 (4)
DIANA21	4.44532	-6.57221	13.1396	15.3494	2.279 (8)
DIANA02	2.68693	-0.102701	-1.15769	2.92752	1.963 (10)

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
ColadaPAHOE	-0.712391	-1.6545	2.20243	2.84527	1.791 (11)
Total	2.22233	2.93895	4.9619	6.18035	2.200

Table 4. Control points.
X - Easting, Y - Northing, Z - Altitude.

Label	X error (cm)	Y error (cm)	Z error (cm)	Total (cm)	Image (pix)
CV_02	14.6391	-0.399421	-7.43292	16.4229	0.318 (14)
CV_09	-1.31437	3.74463	-5.76175	6.99625	0.224 (8)
CV_31	8.13963	8.62848	-10.943	16.1386	0.498 (19)
CV_34	-8.51217	-9.64694	-0.592342	12.8791	0.391 (5)
CV_39	10.3391	-12.3907	17.3722	23.7112	0.824 (7)
CV_43	5.70584	-9.14729	-6.78252	12.737	0.361 (11)
CV_46	0.0892605	-2.18139	4.01437	4.56964	0.625 (7)
Total	8.40241	7.77961	9.0432	14.5912	0.478

Table 5. Check points.
X - Easting, Y - Northing, Z - Altitude.

Digital Elevation Model

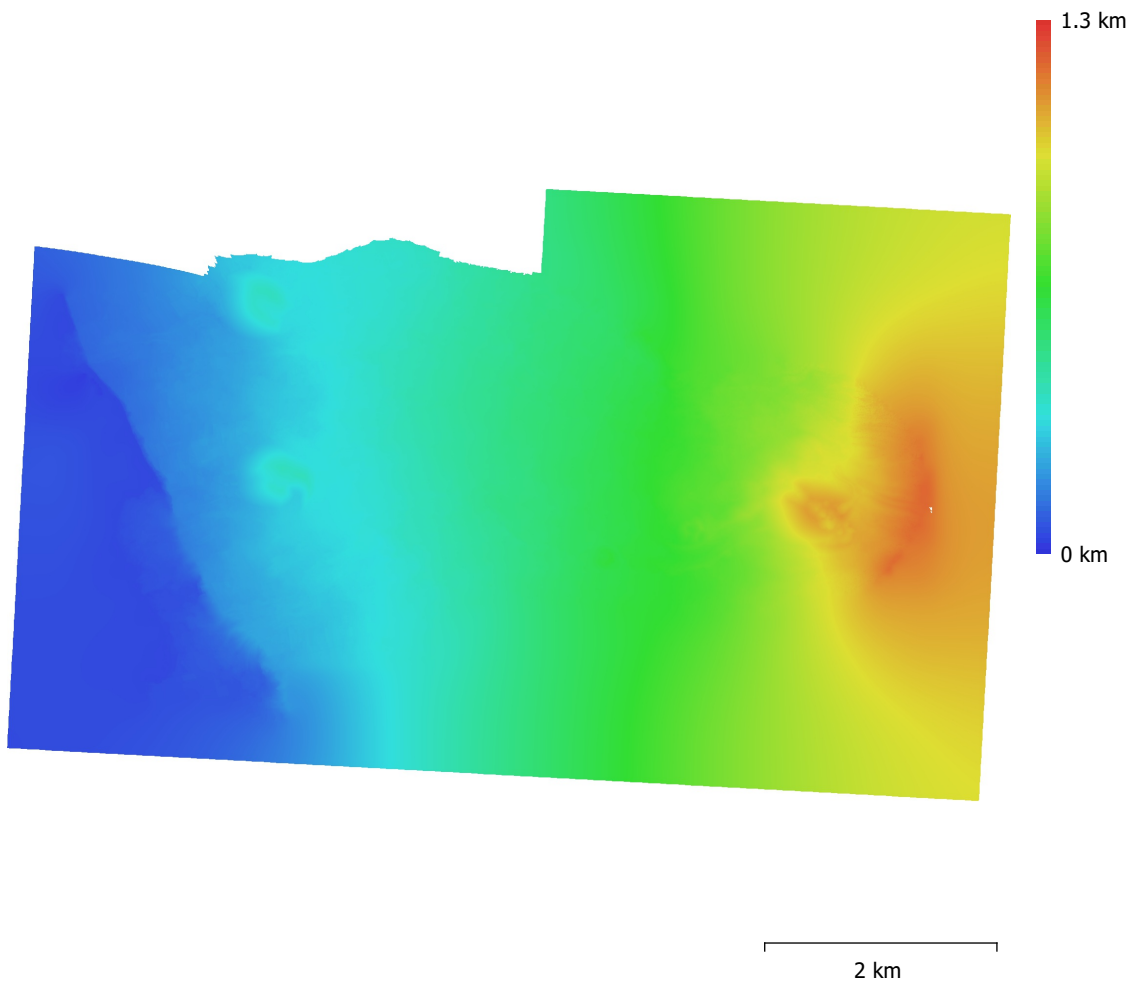


Fig. 4. Reconstructed digital elevation model.

Resolution: 8.91 cm/pix
Point density: 126 points/m²

Processing Parameters

General

Cameras	10437
Aligned cameras	9970
Markers	43

Shapes

Polygons	56117
Coordinate system	REGCAN95 / UTM zone 28N (EPSG::4083)
Rotation angles	Yaw, Pitch, Roll

Point Cloud

Points	2,751,497 of 3,395,342
RMS reprojection error	0.202692 (0.641846 pix)
Max reprojection error	1.56945 (11.5103 pix)
Mean key point size	3.02275 pix
Point colors	3 bands, uint8
Key points	No
Average tie point multiplicity	7.03354

Alignment parameters

Accuracy	High
Generic preselection	Yes
Reference preselection	Source
Key point limit	60,000
Tie point limit	2,000
Filter points by mask	Yes
Mask tie points	No
Guided image matching	No
Adaptive camera model fitting	Yes
Matching time	11 hours 15 minutes
Matching memory usage	13.98 GB
Alignment time	1 hours 59 minutes
Alignment memory usage	4.80 GB

Optimization parameters

Parameters	f, cx, cy, k1-k3, p1, p2
Adaptive camera model fitting	No
Optimization time	9 minutes 1 seconds
Software version	1.7.6.13779

Depth Maps

Count	9669
-------	------

Depth maps generation parameters

Quality	High
Filtering mode	Aggressive
Processing time	1 days 6 hours
Software version	1.6.3.10732

Dense Point Cloud

Points	2,747,646,924
Point colors	3 bands, uint8

Depth maps generation parameters

Quality	High
Filtering mode	Aggressive
Processing time	1 days 6 hours

Dense cloud generation parameters

Processing time	22 hours 52 minutes
-----------------	---------------------

Software version	1.6.3.10732
DEM	
Size	98,090 x 61,801
Coordinate system	REGCAN95 / UTM zone 28N (EPSG::4083)
Reconstruction parameters	
Source data	Dense cloud
Interpolation	Enabled
Processing time	57 minutes 41 seconds
Software version	1.6.3.10732
Orthomosaic	
Size	107,971 x 65,829
Coordinate system	REGCAN95 / UTM zone 28N (EPSG::4083)
Colors	3 bands, uint8
Reconstruction parameters	
Blending mode	Mosaic
Surface	DEM
Enable hole filling	Yes
Processing time	2 hours 17 minutes
Software version	1.6.3.10732
System	
Software name	Agisoft Metashape Professional
Software version	1.6.3 build 10732
OS	Windows 64 bit
RAM	63.83 GB
CPU	Intel(R) Core(TM) i9-9900K CPU @ 3.60GHz
GPU(s)	NVIDIA GeForce RTX 2080 SUPER