Shiveluch volcano 2012-2019 photogrammetric dataset (http://doi.org/10.5880/GFZ.2.1.2021.002)

Shevchenko, A. V.[1,2], Dvigalo, V. N.[2], Zorn, E.U. [1], Vassileva, M.S. [1,3], Walter, T. R.[1], Svirid, I.Yu. [2] & Chirkov, S.A.[2]

1. *GFZ German Research Centre for Geosciences, Telegrafenberg, Potsdam, 14473, Germany*
2. *Institute of Volcanology and Seismology FEB RAS, 9 Piip boulevard, Petropavlovsk-Kamchatsky, 683006, Russia*
3. *Leibniz University Hannover, Welfengarten 1, Hannover, 30167, Germany*

1. Licence

2. Citation

When using the data please cite:

Shevchenko, A. V., Dvigalo, V. N., Zorn, E.U., Vassileva, M.S., Walter, T. R., Svirid, I.Yu. & Chirkov, S.A. (2021), Shiveluch volcano 2012-2019 photogrammetric dataset. GFZ Data Services. http://doi.org/10.5880/GFZ.2.1.2021.002

The data are supplementary material to:

Shevchenko, A. V., Dvigalo, V. N., Zorn, E.U., Vassileva, M.S., Massimetti, F., Walter, T. R., Svirid, I.Yu., Chirkov, S.A., Ozerov, A.Yu., Tsvetkov, V.A. & Borisov, I.A. (2021), Construction and destruction processes during the 2018-2019 eruption episode at Shiveluch volcano, Kamchatka, studied from satellite and aerial data. Front. Earth Sci. Submitted.

Table of contents

3. Data Description

Here we present a photogrammetric dataset on the 2018-2019 eruptive period at Shiveluch volcano, Kamchatka Peninsula, which is one of the most active volcanoes in the world. We collect and process high-resolution remote sensing data, comprising optical (aerial and satellite) and thermal aerial data. The photogrammetry aimed to extract the pre-eruption topography for 18 July 2018 and monitor the co-eruptive topography on 22 August 2019 and 22 October 2019. We also reprocessed the 12 July 2012 data described in (Shevchenko et al., 2015) with new techniques to gain better resolution. The collected data were processed using Erdas Imagine, Agisoft Metashape, and Thermoviewer software. Here we publish four high-resolution point clouds in LAS format, for optical and two infrared orthophotos in TIFF format referenced to the WGS84 (UTM zone 57N). To better understand the relationship between construction and destruction events, and to shed some light on the structural architecture of the volcano, we investigated the 2018-2019 activity, revealing an interesting and complex relationship between different intrusive, extrusive, explosive, and thermal characteristics of the evolving lava dome, details of which were further described in Shevchenko et al. (2021 in review).

3.1. Sampling method and analytical procedure

The optical satellite images are tri-stereo panchromatic 1-m resolution imagery acquired on 18 July 2018 with Pléiades satellite PHR1B sensor.

The optical aerial data are nadir and oblique images collected during helicopter overflights on 12 July 2012 with Canon EOS 20D conventional digital camera (focal length - 14.183 mm, resolution - 3,504×2,336 px), and on 22 August 2019 and 22 October 2019 with PhaseOne IXA 160 digital aerial camera (focal length - 28 mm, resolution - 8,984×6,732 px). The average flying height was 4,000 m a.s.l. for the nadir survey and 3,200 m a.s.l. for the oblique survey.

The thermal infrared images were recorded from a helicopter together with the optical survey (see above) before and after the 29 August 2019 eruption. On the first flight, we used a FLIR Tau 2 camera with a 9 mm lens and a TEAX ThermalCapture frame grabber set to a sampling rate of 8 Hz. The resulting images had a resolution of 640×512 px and provided radiometric temperature data. For the second flight, we used a ThermaCAM P640 camera at a resolution of 640×480 px, exported and processed with FLIR Tools (v.5.13), assuming the same environmental parameters as before.

3.2. Data processing

We processed the Pleiades satellite data in Erdas Imagine 2015 v15.1 similar to (Bagnardi et al., 2016; Shevchenko et al., 2020). For the relative orientation of the images, 37 tie points were calculated automatically with further manual correction, and for the interior and exterior orientation, Rational Polynomial Coefficients block adjustment, which is a transformation between pixels to latitude, longitude, and height information, was automatically employed. After the image orientation, we obtained a photogrammetric model with a total root mean square error (RMSE) of 0.2 m. By using the Enhanced Automatic Terrain Extraction module (eATE) with normalized cross-correlation algorithm as implemented in the Erdas Imagine software, we were able to extract a 2 m resolution point cloud (PC) referenced to the WGS84 coordinate system UTM57 zone. This PC was filtered with the CloudCompare v2.9.1 noise filter and then manually cleaned with the CloudCompare segmentation tool. As strong volcanic steam emissions caused a large gap in the PC at the NE part of the dome, we used a 5 m resolution DEM constructed from TanDEM-X data to fill the gap and obtain the missing topography.

The aerial optical data were processed in Agisoft Metashape 1.5.2. For interior orientation, we set the cameras' parameters (focal length and sensor size). Relative orientation was performed automatically by the image alignment and tie points calculation. For the exterior orientation and ground control points (GCPs) assignment, we used coordinates taken from stable topographic prominences identified in the 1979 photogrammetric model (Dvigalo, 1988), which is referenced to the USSR State Geodetic Network coordinate system (Chumachenko, 1966); the same technique was employed for geo-referencing the previous Shiveluch photogrammetric dataset (Shevchenko et al., 2015). The total RMSEs of the aerial models' orientation varies from 1.5 m to 2 m (Supplementary Table 1). As a result of processing, we obtained three aerial PCs with a 2 m average resolution, which were then filtered and cleaned in the same way described above. The gaps caused by the volcanic steam emissions and by the atmospheric clouds were closed by manual points collection using the anaglyph stereo mode of Photomod 5, which was performed by placing a floating mark on the visible surface and stores XYZ coordinates of each point similar to (Schilling et al., 2008; Shevchenko et al., 2020).

The aerial PCs had the same spatial scale as the Pleiades PC but were shifted in geo-position due to the different coordinate systems. To compare the PCs, we aligned the aerial PCs to the Pleiades PC with several points on the rim of the amphitheater using the CloudCompare alignment tool. The RMSEs of the alignment vary from 2.3 to 3.1 m. Thus, we obtained four stacked PCs in WGS84 UTM57 and were able to calculate differences between them.

The infrared aerial images were processed and exported using Thermoviewer (v3.0.4), assuming a constant emissivity of 0.95, a transmissivity of 0.7 as well as environmental and path temperatures of 10 C°, which are values comparable to similar studies (Stevenson and Varley, 2008).

4. File description

4.1. File inventory

The data include individual point clouds in LAS format, and optical and infrared orthophotos in TIF format from each date of aerial survey and satellite acquisitions, and a description of these data in PDF format.

File name	File format	File size	Content
2021_002_Shevchenko-at-al_Shiveluch-volcano_data-description.pdf	PDF	-	Description of data and methods
2021_002_Shevchenko-at-al_Shiveluch-volcano_12072012_point-cloud.las	LAS	65.64 MB	Point cloud
2021_002_Shevchenko-at-al_Shiveluch-volcano_18072018_point-cloud.las	LAS	521.32 MB	Point cloud
2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_point-cloud.las	LAS	139.82 MB	Point cloud
2021_002_Shevchenko-at-al_Shiveluch-volcano_22102019_point-cloud.las	LAS	387.46 MB	Point cloud

File name	File format	File size	Content
2021_002_Shevchenko-at-al_Shiveluch-volcano_12072012_orthophoto.tif	TIF	610.07 MB	Optical orthophoto
2021_002_Shevchenko-at-al_Shiveluch-volcano_18072018_orthophoto.tif	TIF	262.12 MB	Optical orthophoto
2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_FLIR-orthophoto.tif	TIF	14.90 MB	Infrared orthophoto
2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_orthophoto.tif	TIF	322.57 MB	Optical orthophoto
2021_002_Shevchenko-at-al_Shiveluch-volcano_22102019_FLIR-orthophoto.tif	TIF	4.150 MB	Infrared orthophoto
2021_002_Shevchenko-at-al_Shiveluch-volcano_22102019_orthophoto.tif	TIF	322.57 MB	Optical orthophoto

4.2. Description of data tables

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_12072012_point-cloud.las** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6479, 161.3344	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6088, 161.3320	
	North-west	56.6488, 161.2840	
	South-west	56.6099, 161.2816	
Measurement XY	3,105x4,328		Value of XY in meters
Resolution	2		Average distance between points in meters
Acquisition date	2012-07-12		Date of aerial survey (yyyy-mm-dd)
Sensor	Canon EOS 20D		Digital camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_18072018_point-cloud.las** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6479, 161.3344	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6088, 161.3320	
	North-west	56.6488, 161.2840	
	South-west	56.6099, 161.2816	
Measurement XY	3,105x4,328		Value of XY in meters
Resolution	2		Average distance between points in meters
Acquisition date	2018-07-18		Date of survey (yyyy-mm-dd)
Sensor	Pleiades-1B and TanDEM-X		Satellites

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_point-cloud.las** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6479, 161.3344	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6088, 161.3320	
	North-west	56.6488, 161.2840	
	South-west	56.6099, 161.2816	
Measurement XY	3,105x4,328		Value of XY in meters
Resolution	2		Average distance between points in meters
Acquisition date	2019-08-22		Date of aerial survey (yyyy-mm-dd)
Sensor	PhaseOne IXA 160		Digital aerial camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_22102019_point-cloud.las** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6479, 161.3344	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6088, 161.3320	
	North-west	56.6488, 161.2840	
	South-west	56.6099, 161.2816	
Measurement XY	3,105x4,328		Value of XY in meters
Resolution	2		Average distance between points in meters
Acquisition date	2021-10-22		Date of aerial survey (yyyy-mm-dd)
Sensor	PhaseOne IXA 160		Digital aerial camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_12072012_orthophoto.tif** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6532, 161.3698	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.5751, 161.3648	
	North-west	56.6560, 161.2201	
	South-west	56.5778, 161.2155	
Measurement XY	8,726x9,172		Value of XY in meters
Resolution	1.5		Ground size of a pixel in meters
Acquisition date	2012-07-12		Date of aerial survey (yyyy-mm-dd)
Sensor	Canon EOS 20D		Digital camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_18072018_orthophoto.tif** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6532, 161.3698	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.5751, 161.3648	
	North-west	56.6560, 161.2201	
	South-west	56.5778, 161.2155	
Measurement XY	8,726x9,172		Value of XY in meters
Resolution	2.2		Average distance between points in meters
Acquisition date	2018-07-18		Date of aerial survey (yyyy-mm-dd)
Sensor	Pleiades-1B and TanDEM-X		Optical and radar satellites

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_FLIR-orthophoto.tif** contains results of infrared aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6439, 161.3567	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6121, 161.3125	
	North-west	56.6611, 161.3149	
	South-west	56.6285, 161.2711	
Measurement XY	3,208x4,460		Value of XY in meters
Resolution	2.1		Average distance between points in meters
Acquisition date	2019-08-22		Date of aerial survey (yyyy-mm-dd)
Sensor	FLIR Tau 2		Infrared camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_22082019_orthophoto.tif** contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6532, 161.3698	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.5751, 161.3648	
	North-west	56.6560, 161.2201	
	South-west	56.5778, 161.2155	
Measurement XY	8,726x9,172		Value of XY in meters
Resolution	2		Average distance between points in meters
Acquisition date	2019-08-22		Date of aerial survey (yyyy-mm-dd)
Sensor	PhaseOne IXA 160		Digital aerial camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_22102019_FLIR-orthophoto.tif** contains results of infrared aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6458, 161.3210	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.6288, 161.3283	
	North-west	56.6441, 161.3089	
	South-west	56.6299, 161.3096	
Measurement XY	866x1,911		Value of XY in meters
Resolution	1		Distance between points in meters
Acquisition date	2019-10-22		Dates of survey (yyyy-mm-dd)
Sensors	ThermaCAM P640		Infrared camera

File **2021_002_Shevchenko-at-al_Shiveluch-volcano_**22102019_orthophoto.tif contains results of aerial data photogrammetric processing.

Column header	Unit		Description
Edge of boundary	North-east	56.6532, 161.3698	Latitude and longitude in WGS84 in decimal degrees
	South-east	56.5751, 161.3648	
	North-west	56.6560, 161.2201	
	South-west	56.5778, 161.2155	
Measurement XY	8,726x9,172		Value of XY in meters
Resolution	2		Distance between points in meters
Acquisition date	2019-10-22		Dates of survey (yyyy-mm-dd)
Sensors	ThermaCAM P640 Pleiades-1B and DJI Mavic Pro		Infrared camera Satellite and UAV

5. Acknowledgements

These data were obtained and processed within the framework of VOLCAPSE and EPOS projects, which have been funded by the European Research Council under the European Union's H2020 Programme, grant numbers [ERC-CoG 646858] and [676564], respectively. We thank GFZ and IViS DVO RAN for financial support during fieldwork, and Alexey Yu. Ozerov, Valery A. Tsvetkov, and Ilya A. Borisov for the fieldwork contribution.

6. References

Bagnardi, M., González, P. J., and Hooper, A. (2016). High-resolution digital elevation model from tri-stereo Pleiades-1 satellite imagery for lava flow volume estimates at Fogo Volcano. Geophys. Res. Lett. 43, 6267–6275. https://doi.org/10.1002/2016GL069457

Chumachenko, Z. N. (1966). Instructions on the Construction of the State Geodetic Network of the USSR. Moscow: Nedra, pp. 343 (In Russian).

Dvigalo, V. N. (1988). Growth of a dome in the crater of Shiveluch volcano in 1980–1981 from photogrammetry data. Volcanol. Seism. 6, 307–316.

Schilling, S. P., Thompson, R. A., Messerich, J. A., and Iwatsubo, E. Y. (2008). Use of digital aerophotogrammetry to determine rates of lava dome growth, Mount St. Helens, Washington, 2004-2005. Professional Paper 1750-8, 145–167. https://doi.org/10.3133/pp17508

Shevchenko, A. V., Dvigalo, V. N., and Svirid, I. Y. (2015). Airborne photogrammetry and geomorphological analysis of the 2001-2012 exogenous dome growth at Molodoy Shiveluch Volcano, Kamchatka. J. Volcanol. Geotherm. Res. 304, 94–107. https://doi.org/10.1016/j.jvolgeores.2015.08.013

Shevchenko, A. V, Dvigalo, V. N., Walter, T. R., Mania, R., Maccaferri, F., Svirid, I. Y., et al. (2020). The rebirth and evolution of Bezymianny volcano, Kamchatka after the 1956 sector collapse. Commun. Earth Environ. 1, 15. https://doi.org/10.1038/s43247-020-00014-5

Stevenson, J. A., and Varley, N. (2008). Fumarole monitoring with a handheld infrared camera: Volcán de Colima, Mexico, 2006–2007. J. Volcanol. Geotherm. Res. 177, 911–924. https://doi.org/10.1016/j.jvolgeores.2008.07.003