

Biennial report for Permanent Supersite/Natural Laboratory

Kamchatka-Kuriles Supersite

History	https://geo-gsnl.org/supersites/permanent-supersites/kamchatka_kuriles_supersite/
Supersite Coordinator	Alina Shevchenko German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam Institute of Volcanology and Seismology, 9 Piip Boulevard, 683006 Petropavlovsk-Kamchatsky

1. Abstract

The permanent Kamchatka-Kuriles Supersite was established in 2020 to facilitate data access and promote research collaboration in studying active volcanoes on the Kamchatka Peninsula and Kurile Islands and to assess the potential volcanic hazards and their possible impact. Over the two years of activity, the supersite provided access to various in-situ and EO data. The in-situ archive and recent aerial photogrammetric and seismic data were provided for studying the past and ongoing activity of several volcanoes in the Kamchatka-Kuriles subduction zone, and about 50 Pleiades datasets, 50 TerraSAR-X datasets, and about 250 COSMO-SkyMed were obtained capturing edifices of more than 30 volcanic objects. In addition, the available data is complemented by other data source products of external partners worldwide, such as the thermal emission monitoring over many target sites in the region. The processing and analysis of the in-situ and acquired satellite data let the supersite members and other scientists in Italy, Germany, France, and elsewhere investigate potentially hazardous events. For instance, highlight examples are the lava spine formation at Shiveluch volcano and the development of fumarolic fields at Ebeko volcano. The EO data used in publications include mainly Pleiades images. Obtaining such a large data material we started to employ, develop, and compare new methods of processing and analysis. For example, processing the Pleiades images using different software (ERDAS Imagine and Agisoft Metashape) let to explore the advantages and limits of the different approaches regarding orientation, geo-referencing, and visualization of the images and DEMs. Overall, the data provided within the Kamchatka-Kuriles Supersite can be seen as highly useful and give a great opportunity to perform high-resolution observations of the remote and rapidly changing active volcanic region.

Scientists/science teams

Researcher/team	Name, affiliation, address, e-mail, website/personal page of team leader
Researcher 1	Alina Shevchenko, German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, alinash@gfz-potsdam.de , https://www.gfz-potsdam.de/staff/alina.shevchenko , Institute of Volcanology and Seismology, 9 Piip Boulevard, 683006 Petropavlovsk-Kamchatsky
Researcher 2	Thomas Walter, German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, twalter@gfz-potsdam.de , thomas.walter@gfz-potsdam.de , http://www.gfz-potsdam.de/en/section/physics-of-earthquakes-andvolcanoes/staff/profil/thomas-walter
Researcher 3	Alexey Ozerov, Institute of Volcanology and Seismology, 9 Piip Boulevard, 683006 Petropavlovsk-Kamchatsky, ozarov@kscnet.ru , http://www.ozarov.ru
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Scientists/science teams issues

No science team members were added. The researchers worked as one team on several projects, led by Thomas Walter and Alina Shevchenko.

Kamchatka belongs to Russia and currently, institutional collaborations are overshadowed by the political situation. However, on the personal and research scientist level, as well within the EU and beyond, teams continue to collaborate on this supersite data, as the available data streams further improve and allow key questions of research to be studied. Kamchatka-Kurile volcanic hazards are in the aviation transit path between Asia and North America, which is why the continued observations are highly relevant.

1. In situ data

Type of data	Data provider	How to access	Type of access
<i>e.g. seismic waveforms, GPS time series, gas measurements, etc.</i>	Link to data repository or description of procedure for data access	E.g. unregistered public, registered public, limited to GSNL scientists, etc.
Seismic	Kamchatka branch of the Geophysical Service of Russian Academy of Sciences	http://www.emsd.ru/~ssl/monitoring/ma_in.htm	unregistered public
Seismic	The GEOFON program, GFZ	https://geofon.gfz-potsdam.de/waveform/archive/network.php?ncode=D0&year=2015	unregistered public; for the restricted data a written permission from the

			<i>data producer is required</i>
Camera monitoring	<i>Institute of volcanology and seismology</i>	<i>http://geoportal.kscnet.ru/volcanoes/webcams.php</i>	<i>unregistered public</i>
Aerial DEMs	<i>Institute of volcanology and seismology</i>	<i>Contact supersite coordinator</i>	<i>limited to GSNL scientists</i>

In situ data issues

Due to the ongoing world health and political situations, the access to some of the initially indicated in-situ data dependent on the fieldwork was restricted. These data are not listed in the table above though were used in previous research described below. Further developments will be closely watched and evaluated. For now, institutional collaborations are limited, but collaborations on a personal and research level continued.

2. Satellite data

Type of data	Data provider	How to access	Type of access
TerraSAR X, COSMO-SkyMed, Radarsat 2, ALOS-1/2, etc.	DLR, ASI, CSA, JAXA, etc.	Link to data repository or description of procedure for data access	<i>E.g. unregistered public, registered public, limited to GSNL scientists, etc.</i>
Pleiades	CNES	POC requests access from CNES for individual users, data further accessible via GEP	GSNL scientists
Cosmo-SkyMed	ASI	POC requests access from ASI for individual users, data further accessible via GEP	GSNL scientists
TerraSAR-X	DLR	Available after acceptance of PI proposal by DLR, data further accessible via GEP	GSNL scientists

Satellite data issues

With the employment of the Geohazard Exploitation Platform, the data access will be simplified for the GSNL scientists.

Pleiades: Our orders fully covered the quota, but the obtained data didn't reach the quota limit only because some of the images were rejected due to the cloud coverage. Still, we obtained quite a large number of Pleiades images – about 135 (45 datasets of tri-stereo images), many of them have been already processed and many are currently under processing.

COSMO-SkyMed: Over the two years, we acquired 200 archive datasets within the 700 acquisition quota and about 50 new acquisitions within 200 (100 per year).

TerraSAR-X: We ordered about 50 datasets within the 300 images quota (150 per year).

We haven't ordered Radarsat-2 data yet.

The full number of quotas was not used for COSMO-SkyMed, TerraSAR-X, and Radarsat-2 data because of the following reasons:

- *Unstable employment position of the Supersite coordinator in 2020-2021. Due to the pandemic, it was not possible to return to Kamchatka, and the coordinator had to apply for new positions in Germany, which took a lot of time.*
- *Due to the ongoing political situation the new data ordering was suspended until the CEOS decision.*
- *The Supersite doesn't have enough members who specialize in radar data processing. We are going to improve this situation soon by inviting new members. For this, we plan presentations and dedicated discussion rounds at the forthcoming Cities on Volcanoes conference in Greece (2022), and at the IAVCEI General Assembly in New Zealand (2023).*

3. Research results

For the first two years of the Supersite activity, we were concentrating mainly on the activity of one of the most hazardous volcanoes in the Kamchatka-Kuriles region – Shiveluch. For the first research we used in-situ data – optical and infrared aerial images collected during fieldwork, and further – DEMs available after the image processing, as well as seismic data provided by the Kamchatka branch of the Geophysical Service. We analyzed the recent activity of Shiveluch characterized by repeated episodes of lava dome growth and destruction due to large explosions and collapses. We investigated the evolution of the 2018–2019 eruption episode and evaluated the morphological and structural changes that led to the August 29, 2019 explosive eruption and partial dome collapse. Our results showed in detail the morphodynamics of the dome with lava intrusion and extrusion, multiple crater formations, and pyroclastic depositions. Using the high-resolution photogrammetric data, we were able to calculate the precise volumetric changes at the dome, volumes and thicknesses of pyroclastic deposits, and other morphometric parameters. This research showed that the structural architecture at Shiveluch is dominated by an SW-NE lineament and that there is a complex interplay of volcano constructive and destructive processes. We developed a conceptual model emphasizing the relevance of structural trends, namely, 1) an SW-NE-oriented (possibly regional) structure and 2) the infilled amphitheater and its decollement surface, both of which are vital for understanding the directions of growth and collapse and for assessing the potential hazards at both Shiveluch and dome-building volcanoes elsewhere.

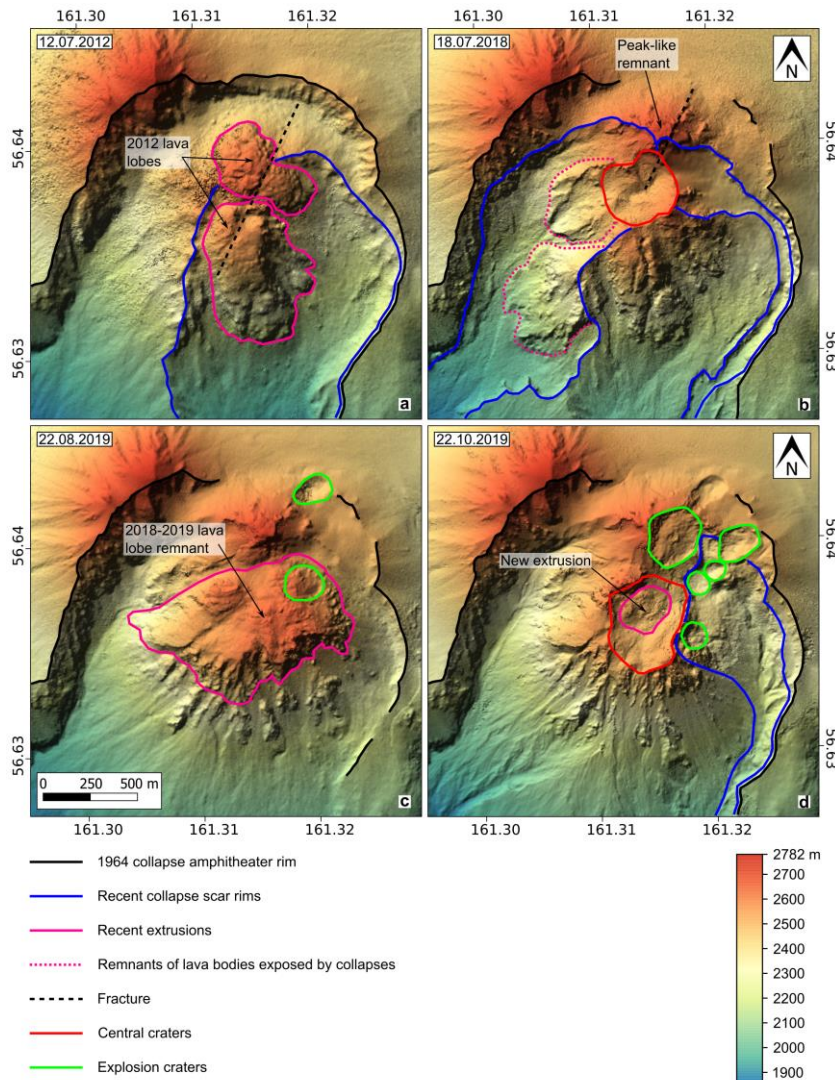


Figure 1 Hillshade maps of the Shiveluch dome for the 2012 base map and three acquisitions covering the 2018–2019 construction-destruction period. Note the formation of new central craters (red circles) and short-lived explosion craters (green circles). The DEMs were derived from the in-situ aerial photogrammetric data (a, c, d) and from Pleiades satellite data locally complemented by TDX data (b).

Further, we continued our study of Shiveluch using in-situ and EO data provided via GSNL. This allowed us to combine remote sensing observations with both analog and numerical experiments to describe the extrusion of a spine at the Shiveluch that started in 2020. We used two Pleiades datasets acquired at a two-week interval; thus, we were able to reveal minor changes in the spine development, such as partial collapse and fracturing, and calculate the extrusion velocities. The pre-eruption aerial in-situ data showed that the spine growth was preceded by bulging of the dome surface, followed by extrusion in an asymmetric manner. The spine then elongated along an identified in the previous research SW-NE lineament and bends toward the north. Further numerical modeling highlighted that the spine could be inclined to the north due to the topography and hidden architecture of the subsurface. We suggest that such complexities are rather common, where mechanical heterogeneities in the conduit material, mechanical erosion of the hidden spine buried by the co-evolving dome, as well as the pre-existing topography control directionality the spine growth and spine instability. The results of this research are relevant for understanding the growth and collapse hazards of spines and provide unique insights into the hidden magma-conduit architecture.

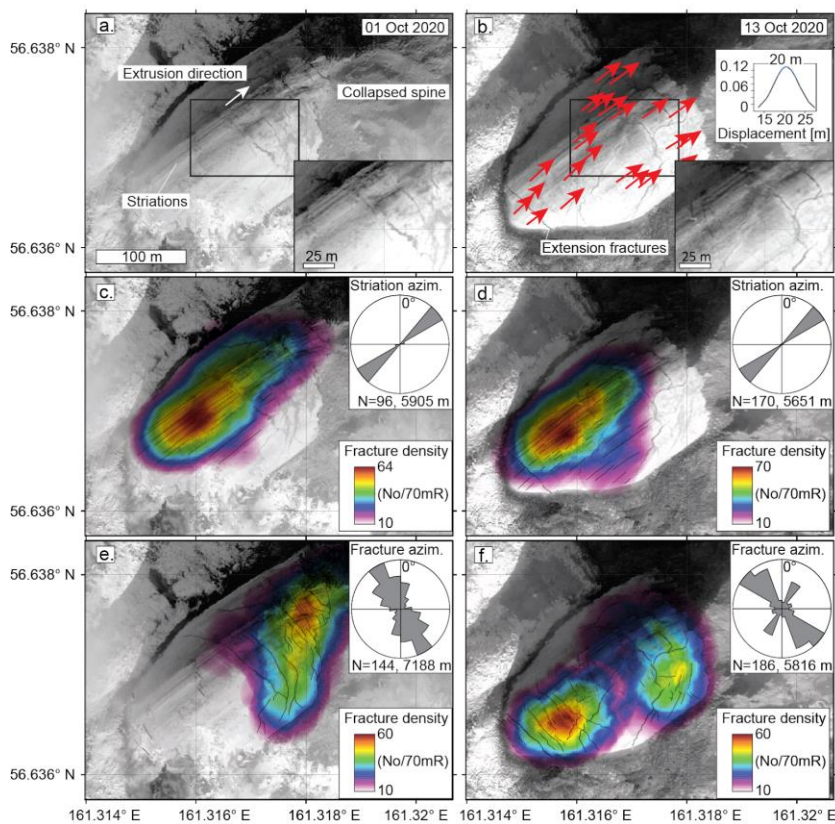


Figure 2 Displacement and fracture analysis. The 2020 Shiveluch spine, shown for two Pleiades orthophotos (October 1 and 13, 2020). **a.** Striations have developed in a NE-SE direction. Fractures show opening perpendicular to the elongation axis. **b.** The following satellite data reveals similar striations, but fractures have been displaced to the NE. **c. and d.** Striation density analysis reveals clustering at the lower SE flank of the spine, with orientation NE-SW. **e. and f.** Fracture density concentrates near the spine collapse region at higher elevations. Statistics and rose plots show the 72 features weighted by length to 1649 elements, the mean directions at 132° with an angular deviation of 59.6° .

Publications

Peer reviewed journal articles

- Walter T.R., Zorn E.U., Harnett C.E., Shevchenko A.V., Belousov A.B., Belousova M.G., Vassileva M.S. 2022. Tracking magma spine extrusion from space: Implications for conduit and topography complexity at Shiveluch volcano, Kamchatka. *Nature Commun. Earth Environ.* Under review.
- 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. Constructive and Destructive Processes During the 2018–2019 Eruption Episode at Shiveluch Volcano, Kamchatka, Studied From Satellite and Aerial Data. *Frontiers in Earth Science*. V. 9. <https://doi.org/10.3389/feart.2021.680051>
- Coppola D., Laiolo M., Massimetti F., Hainzl S., Shevchenko A.V., Mania R., Shapiro N.M., Walter T.R. 2021. Thermal remote sensing reveals communication between volcanoes of the Klyuchevskoy Volcanic Group. *Sci Rep* 11, 13090. <https://doi.org/10.1038/s41598-021-92542-z>
- Mania R., Cesca S., Walter T., Koulakov I., Senyukov S.L. 2021. Inflating Shallow Plumbing System of Bezymianny Volcano, Kamchatka, Studied by InSAR and Seismicity Data Prior to the 20 December 2017 Eruption. *Frontiers in Earth Science*, 9, 765668. <https://doi.org/10.3389/feart.2021.765668>
- Koulakov I., Plechov P., Mania R., Walter T., Smirnov S.Z., Abkadyrov I., Jakovlev A., Davydova V., Senyukov S., Bushenkova N., Novgorodova A., Stupina T., Droznina S.Y. 2021. Anatomy of the Bezymianny volcano merely before an explosive eruption on 20.12.2017. *Scientific Reports*, 11, 1758. <https://doi.org/10.1038/s41598-021-81498-9>
- Belousov A., Belousova M., Auer A., Walter T., Kotenko T. 2021. Mechanism of the historical and the ongoing Vulcanian eruptions of Ebeko volcano, Northern Kuriles. *Bulletin of Volcanology*, 83, 4. <https://doi.org/10.1007/s00445-020-01426-z>

Conference presentations/proceedings

Shevchenko A.V., Walter T.R., Vassileva M.S., Zorn E.U. 40 years of lava dome growth at Shiveluch volcano, Kamchatka, studied from aerial and satellite data. 11th Cities on Volcanoes conference, Heraklion, Greece, 12-17 June 2022.

Vassileva M.S., Zorn E.U., Shevchenko A.V., Motagh M., Walter T.R. High-resolution satellite radar shadow analysis for pyroclastic flows thickness estimation: Shiveluch 2018-2019 dome growth and collapse case study. 11th Cities on Volcanoes conference, Heraklion, Greece, 12-17 June 2022.

Research products

Type of product	Product provider	How to access	Type of access
Digital elevation models and orthophotos of Shiveluch volcano	Shevchenko A.V., Walter T.R., and others	http://dx.doi.org/10.5880/GFZ.2.1.2021.002	Public
Digital elevation models and orthophotos of various Kamchatka-Kurile volcanoes	Shevchenko A.V.	By request to the Supersite coordinator	limited to GSNL scientists

Research product issues

As we generated several high-resolution DEMs from the Pleiades data that can be further used for hazard assessments we need to increase the involvement of other GSNL scientists in collaborative research on the Kamchatka-Kurile volcanoes.

4. Dissemination and outreach

The Supersite members and their colleagues in GFZ made several announcements about the Supersite during their conference presentations dedicated to Kamchatkan volcanoes.

5. Funding

There is no dedicated funding for the Kamchatka-Kuriles Supersite. However, the in-situ data collection was funded by VOLCAPSE, an ERC project within the H2020 Program, and by internal funds of IVS and GFZ.

6. Stakeholders interaction and societal benefits

The stakeholder that benefited from the Kamchatka-Kuriles Supersite over the reference period is the Volcanological Station of Kamchatka. The extraction of the precise topographies of volcanoes from the Pleiades data and recording of the morphodynamics from the high-temporal-resolution radar data made it possible to perform detailed analysis of the volcano morphologies using various techniques. On the base of the extracted during the two years

period high-resolution topographies, the employees of the Station will analyze potential hazards from the Northern group of Kamchatkan volcanoes. The interaction with other Stakeholders was complicated due to pandemics and, further, due to political situation.

7. Conclusive remarks and suggestions for improvement

The first two-year activity of the Supersite was complicated due to the pandemic and further due to the political situation, which prevented the required collaborations between the scientific community and stakeholders, and dissemination and outreach. Nonetheless, we were able to achieve some notable scientific results using the in-situ and EO data:

- We revealed the main structural trend at Shiveluch volcano that affects the directions of all recent partial lava dome collapses.*
- We identified the main precursor of the preparing hazardous events at Shiveluch – swelling of the dome flanks.*
- We developed a conceptual model of the Shiveluch lava dome development through the interaction of constructive and destructive processes.*
- We described in detail and analyzed the first whaleback spine ever observed at Shiveluch.*
- We generated high-resolution DEMs for most of the active volcanoes of Kamchatka and Kuriles.*

However, there are several issues that could prevent further development of the Supersite:

- The collection of the new in-situ data is currently problematic because of the IVS-GFZ joint fieldwork inability.*
- The scientific collaboration between IVS and GFZ (and many other European institutions) is now restricted.*

We hope that the above-listed issues will be solved otherwise it will be difficult to continue the Supersite activity. Yet, we will try to develop the Supersite with the involvement of new members and increase collaboration between GSNL scientists. Over the next two-year period, we will use the whole amount of the provided quotas as there will be more scientists to process them.

8. Dissemination material for CEOS (discretionary)

In addition to the results shown in Section 3, we present below some of the DEMs generated from the Pleiades data:

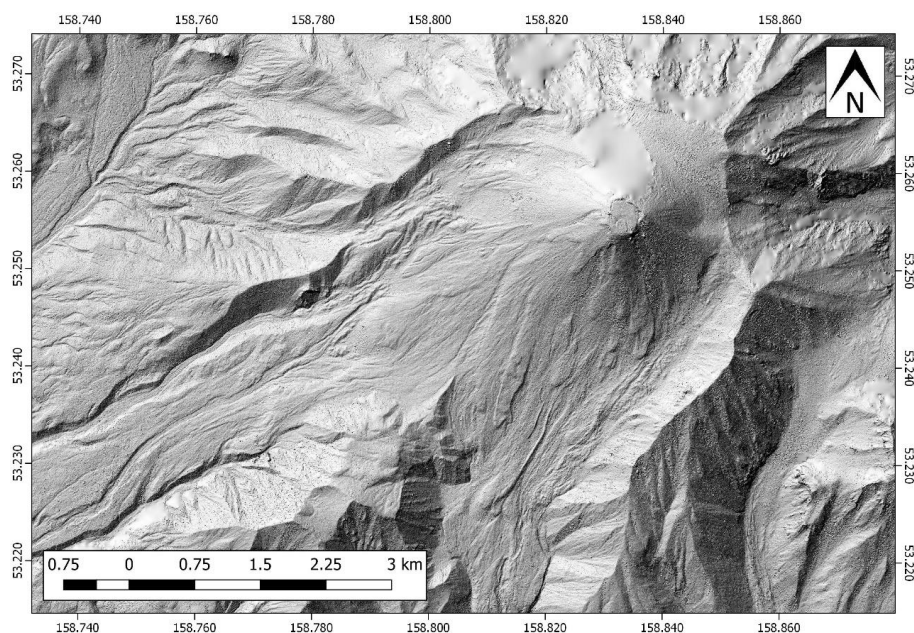


Figure 3 Hillshade visualisation of DEM of Avachinsky volcano in 2020 built from the Pleiades data.

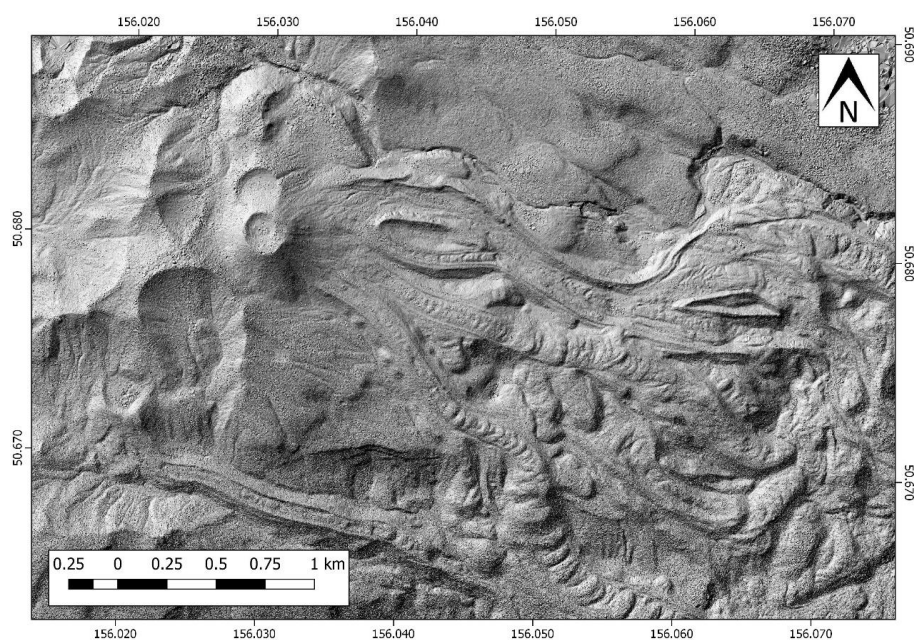


Figure 4 Hillshade visualisation of DEM of Ebeko volcano in 2020 built from the Pleiades data.