Information Technologies for the Analyzing of Kamchatka and the Kuril Islands Volcanoes Activity in 2019-2020

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Abstract

The work is devoted to the activity analysis of Kamchatka and the Kuril Islands volcanoes in 2019-2020.The activity of the volcanoes was estimated based on the processing of data from daily satellite monitoring carried out using the information system “Remote monitoring of Kamchatkan and the Kuriles volcanoes activity (VolSatView)”.The activity of the Kamchatka and the Kuril Islands volcanoes considered based on the analysis of their thermal anomalies. Analysis of the characteristics of thermal anomalies over volcanoes was carried out in KVERT IS. Analysis of the temperature of thermal anomalies of volcanoes in the Kuril-Kamchatka region in 2019-2020 shows a significantly higher activity of the Kamchatka volcanoes in comparison with the Kuril volcanoes.

Keywords 1

IS VolSatView, satellite data, thermal anomaly, volcano, eruption, activity, Kamchatka, Kuril Islands

1. Introduction

Explosive volcanic eruptions are the most dangerous for the population and aviation due to the high energetics of the volcanic process and their poor predictability. There are 68 active volcanoes in Kamchatka and the Kuril Islands, there are annually explosive, effusive and extrusive eruptions of 4-6 volcanoes, during which tons of volcanogenic products in the form of lava, pyroclastics, volcanic gases and aerosols come to the Earth's surface. In 2011-2014, scientists of the KVERT (Kamchatkan Volcanic Eruption Response Team) of the Institute of Volcanology and Seismology (IVS) Far East Branch (FEB) Russian Academy of Sciences (RAS), the Institute of Space Research (ISR) RAS, the Computing Center (CC) FEB RAS and the Far East Center of the Scientific Research Center “Planeta” created and continues to develop the information system (IS) “Remote monitoring of Kamchatkan and the Kuriles volcanoes activity (VolSatView)”, intended for a comprehensive operational and retrospective analysis of volcanic activity using satellite and video data [1, 2, 3, 4, 5]. In 2014-2015, together with KVERT IVS and CC FEB RAS scientists, a subsystem was created using the PUFF model, NOAA meteorological data and the developed software as part of the automated IS (AIS) "Signal", which simulates the propagation of ash clouds and plumes during volcanic eruptions [1, 3, 6, 7].

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2. IS VolSatView

Focused on freely distributed non-commercial satellite products, VolSatView is capable of automated collection of various satellite data of low, medium and high resolution with the maximum frequency of their entry into the system and remote (distributed) work with them [1, 2, 3, 5, 6]. VolSatView implements a wide range of tools for working with satellite and cartographic information, for example, directly in the system web interface, tools are available for highlighting and determining parameters: thermal anomalies in volcano areas; ash clouds and plumes at any distance from volcanoes, etc., which significantly increases the efficiency of monitoring volcanoes. VolSatView makes it possible to perform joint analysis of satellite and other instrumental scientific data (meteo-, video, results of mathematical modeling, etc.) coming from other ISs, in particular: KVERT and VOKKIA (Volcanoes of Kurile-Kamchatka Island Arc) IVS FEB RAS, AIS "Signal" CC FEB RAS [1, 7]. For example, directly in VolSatView, you can visualize on satellite images with ash plumes the results of numerical modeling of the propagation of these plumes from volcanoes.

To monitor volcanoes, VolSatView has operatively updated data of the average resolution of the following satellite systems: NOAA-18/19 (AVHRR - Advanced Very-High-Resolution Radiometer), Terra and Aqua (MODIS - Moderate Resolution Imaging Spectroradiometer), Suomi NPP (National Polar -orbiting Partnership) and JPSS-1 (Joint Polar Satellite System) (VIIRS - Visible Infrared Imaging Radiometer Suite), Sentinel 3A and 3B (SLSTR - Sea and Land Surface Temperature Radiometer) [1]. Since March 15, 2016, the IS receives data from the Himawari-8 geostationary satellite (AHI instrument - Advanced Himawari Imager), updated every 10 minutes [8]. Currently, within the framework of volcanoes monitoring, about 200 satellite images per day are available for analysis. A detailed study of events and eruptions products in VolSatView is possible using satellites Landsat-7 (ETM + - Enhanced Thematic Mapper Plus), Landsat-8 (OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor)), Kanopus-V (MSS (multi-spectral imaging system), PSS (panchromatic imaging system)), Resurs – 1/2 (Geoton; KShMSA-VR and KShMSA-SR - wide-coverage multi-spectral equipment of high and medium resolution), EO-1 (Earth Observing One Mission) (Hyperion), Sentinel 2B (MSI - MultiSpectral Instrument) [1].

The main tasks of operational satellite monitoring of volcanoes are as follows:

- detection of ash clouds and plumes, determination of their parameters (length, area and azimuth of propagation);
- detection of thermal anomalies in the areas of volcanoes, determination of their parameters (size, temperature of the anomaly and background);
- analysis of the dynamics of the activity of volcanoes, on which thermal anomalies were detected, during the effusive or intereruptive phase of activity.

In this paper, we will consider the activity of the Kamchatka and the Kuril Islands volcanoes based on the analysis of their thermal anomalies, has interactive detected on data by AVHRR, MODIS, VIIRS, and Sentinel.

3. Thermal anomalies in the volcanoes area

Instruments for analyzing temperature fields are available directly in the VolSatView IS web interface, allowing you to instantly view the temperature values (in degrees Celsius or Kelvin) at each point of the satellite image, which significantly reduces the time for analyzing thermal anomalies in areas of active volcanoes. KVERT scientists interactively process satellite images in the VolSatView IS, and enter the characteristics of thermal anomalies into the KVERT IS database [9].To analyze data on thermal anomalies in volcanoes areas, online tools for their graphical visualization was created in the KVERT IS (Figure 1).

Thermal anomalies in the volcanoes area have a different nature associated with their activity. During volcanic eruptions (emissions of hot volcanic products into the atmosphere during explosive activity; formation of pyroclastic flows; effusing of lava flows; squeezing of extrusions, etc.) the brightness temperature of anomalies reaches maximum values (close to the measurement limit of sensors); during the intereruptive phase of volcanic activity (gas-steam emissions from fumaroles),

thermal anomalies are either not recorded, or their brightness temperatures are close to background temperatures.

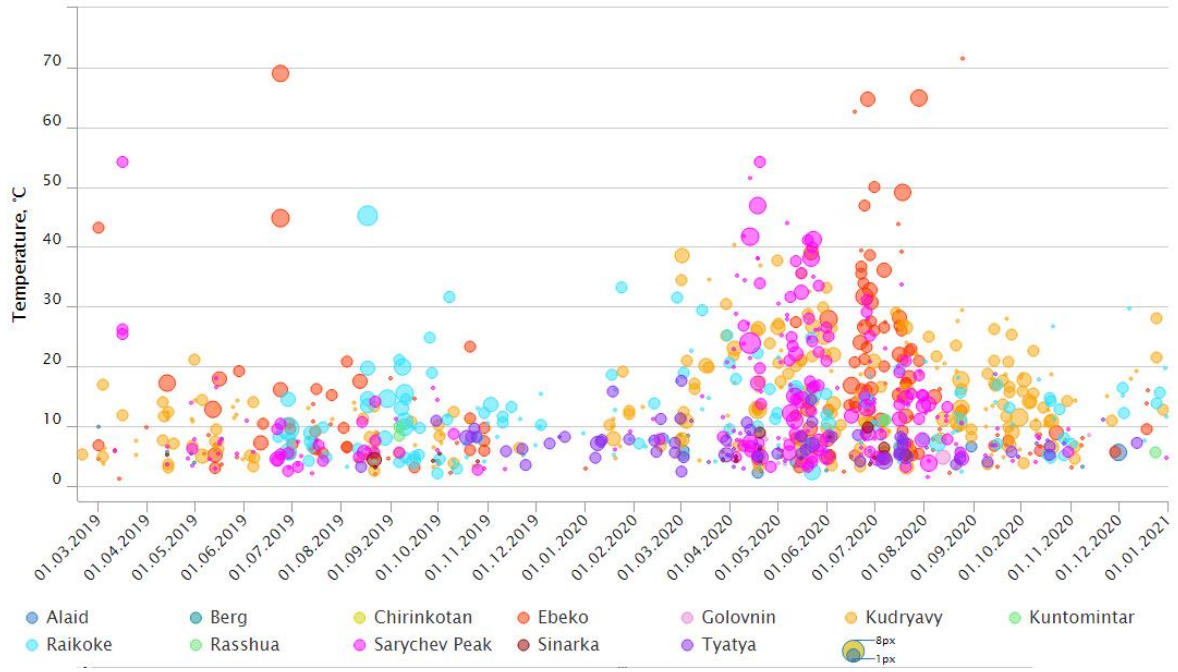

Figure 1: Diagram shows the value of a difference of the average daily temperature between the thermal anomalies and the background, and the size of thermal anomalies over the Kuril Islands active volcanoes according to satellite data of medium resolution in VolSatView IS. Statistical analysis of data for the period2019-2020was carried out in KVERT IS.

4. Activity of Kamchatka and Kuril Islands volcanoes in 2019-2020

In 2019-2020 six volcanoes of Kamchatka and the Kuril Islands erupted. The volcanoes Sheveluch, Klyuchevskoy, Bezymianny, and Karymsky erupted at Kamchatka, and the volcanoes Ebeko, and Raikoke – at the Kuril Islands [10, 11, 12].

The eruptive activity of Sheveluch volcano began since 1980, and it is continuing at present. A growth of the lava dome continued all years, a strong fumarolic activity, and an incandescence of the lava dome and hot avalanches accompanied this process. In 2019, strong explosions sent ash up to 10-11.5 km above sea level (a.s.l.) on 09 March, 10 April, 29 August, 02 and 06 October, 03 and 11 November [10]. In 2020, strong explosions sent ash up to 7-10 km a.s.l. on 08 April, and 22 and 29 December [11]. Satellite data showed a thermal anomaly over the volcano all years (Figure 2).

In 2019-2020, two moderate terminal explosive-effusive eruptions of Klyuchevskoy volcano occurred: first from 01 November, 2019, till 03 July, 2020 [13], and second from 30 September, 2020, till 08 February, 2021 [11, 12]. Explosive activity of Strombolian type and effusing the lava flows along Apakhonchichsky and Kozyrevsky chutes were responsible for the high temperature of the thermal anomaly over Klyuchevskoy volcano during both eruptions (Figure 2).

Two strong explosive eruptions occurred on Bezymianny volcano in 2019 [10, 14], and one in 2020 [15]. 20 January, 2019, explosions sent ash up to 10-12 km a.s.l., 15 March, 2019, – up to 15 km a.s.l., and on 21 October, 2020,– up to 11 km a.s.l. The maximum temperature of the thermal anomaly over the volcano was during the explosive eruption on March 15, 2019 (Figure 2).Thanks to monitoring the state of the thermal anomaly, scientists of KVERT predicted the eruption of 15 March, 2019, by for 6.5 hours before strong explosive event [14].

Eruptive activity of Karymsky volcano was uneven in 2019-2020 [10, 11]. Strong explosions rose ash up to 6, and 8 km a.s.l. on 21 August, 2019, and 08 November, 2020, respectively. The thermal anomaly over the volcano was recorded on satellite images mainly during explosive events (Figure 2).

Moderate explosive eruption of Ebeko volcano began on October, 2016, and it is continuing at present. In 2019, daily occurred from one till eight-nine (27 April and 27 May) explosions [10]; in 2020, monthly its were from 12 (February) till 117 (June) [11]. Ash rose up to 4.5 km a.s.l. A thermal anomaly over the volcano was noted on satellite images not always (Figure 3).

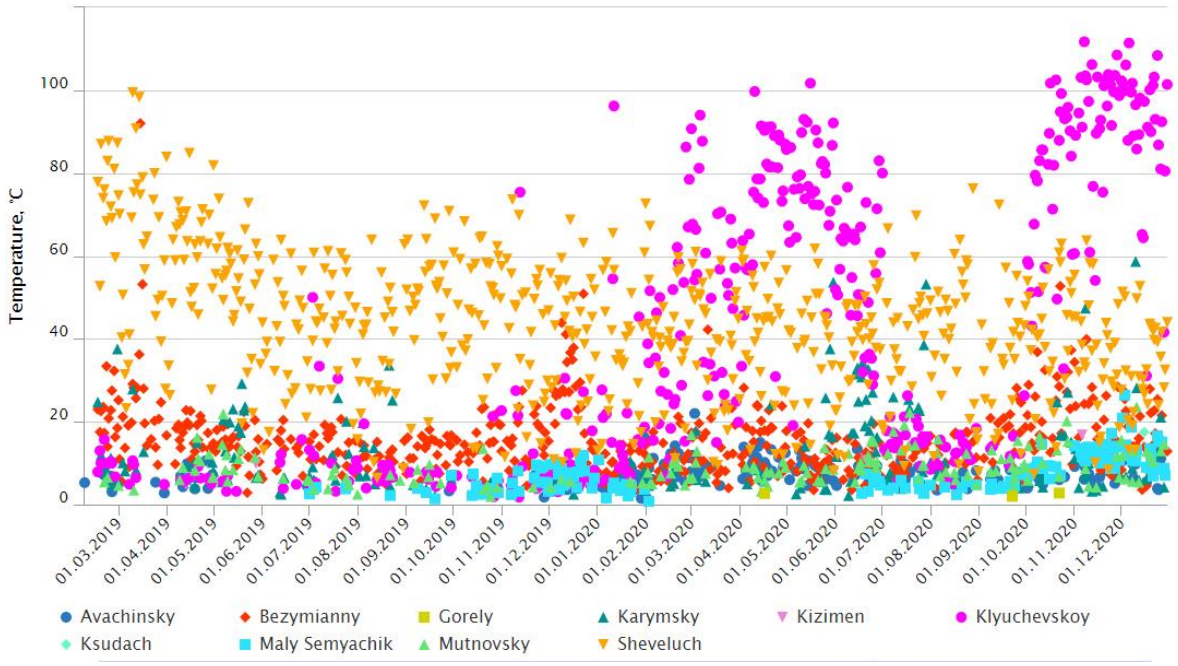

Figure 2: Data on the Kamchatkan active volcanoes during 2019-2020.The value of a difference of the average daily temperature between the thermal anomaly and the background according to satellite data of medium resolution in VolSatView IS. Statistical analysis of data was carried out in KVERT IS.

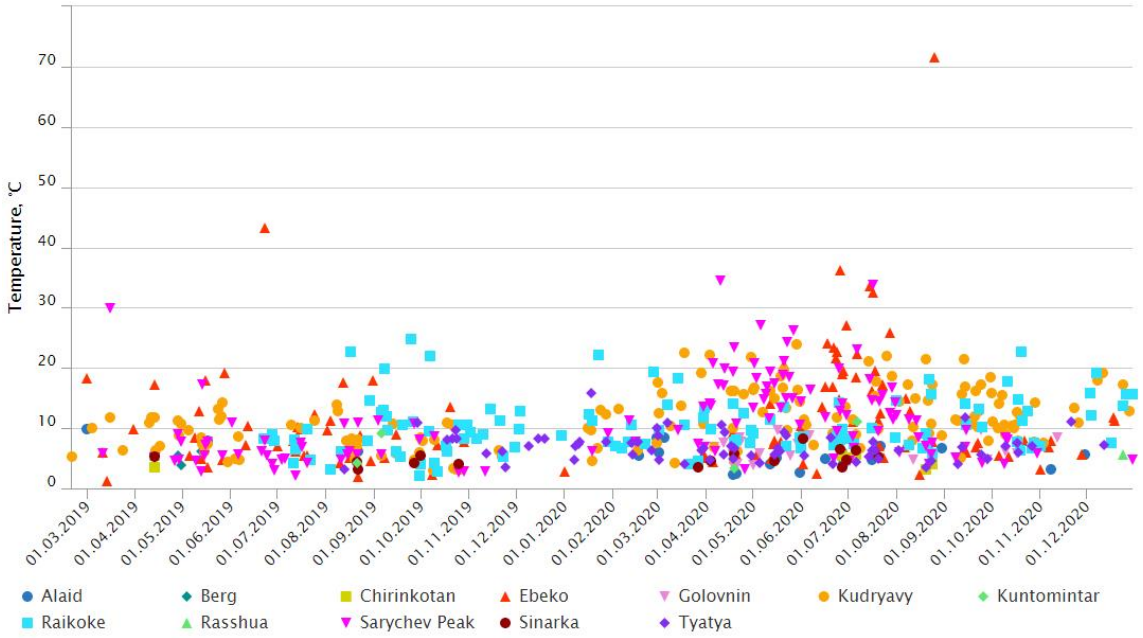

Figure 3: Data on the Kuril Islands active volcanoes during 2019-2020.The value of a difference of the average daily temperature between the thermal anomaly and the background according to satellite data of medium resolution in VolSatView IS. Statistical analysis of data was carried out in KVERT IS.

The strong explosive eruption of Raikoke volcano occurred on 21-26 June, 2019 [10, 16]. Paroxysmal phase of the eruption continued for 15 hours. Explosions send ash up to 13.5 km a.s.l. A thermal anomaly over the volcano was registering from 21 June, 2019, till end of 2020 (Figure 3).

5. Analysis of Kamchatka and Kuril Islands volcanic activity in 2019-2020

In addition to the four volcanoes described above, in 2019-2020, the thermal anomalies were constantly or from time to time recorded in the six Kamchatkan volcanoes area: Avachinsky, Gorely, Kizimen, Ksudach, Maly Semyachik, and Mutnovsky (Figure 2). If the maximum value of a difference of the average daily temperature between the thermal anomaly and the background for Klyuchevskoy volcano explosive-effusive eruption was 111.7 °C, and for Bezymianny volcano explosive eruption was 92 °C, that for Avachinsky volcano it was 22 °C, Kizimen 16.8 °C, Maly Semyachik 26.4 °C, Mutnovsky 23.6 °C, Ksudach 17.5 °C (Figure 2). That is, the value of a difference in the average daily temperature between the thermal anomaly and the background for the non-erupting volcanoes of Kamchatka was less than 30 °C. It should be said that crater lakes exist in the craters of Maly Semyachik and Mutnovsky volcanoes. Although the lake of Maly Semyachik volcano is much larger, the temperatures of thermal anomalies of these two volcanoes are close.

In 2019-2020, on the Kuril Islands, in addition to Ebeko and Raikoke, the thermal anomalies were noted on ten volcanoes: Alaid, Berg, Chirinkotan, Golovnin, Kudryavy, Kustomintar, Rasshua, Sarychev Peak, Sinarka, and Tyatya (Figure 3). Thermal anomalies were constantly noted on the volcanoes Sarychev Peak, Kudryavy, and Raikoke. The maximum value of a difference of the average daily temperature between the thermal anomaly and the background for Ebeko explosive eruption was 71.5 °C, for volcanoes Alaid, Berg, Chirinkotan, Golovnin, Kustomintar, Rasshua, and Sinarka it was less than 10 °C, but for Tyatya volcano – less than 16 °C, and for Kudryavy volcano – less than 25 °C. The crater lake appeared into Raikoke volcano after the eruption on June 21, 2019, and its maximum value of a difference of the average daily temperature between the thermal anomaly and the background was 24.8°C – very close with Mutnovsky volcano crater lake [17]. From 30 March, 2020, a rather rapid increase in the temperature of the thermal anomaly of Sarychev Peak volcano was noted (Figure 3). The maximum value of a difference of the average daily temperature between the thermal anomaly and the background was noted on 10 April, 2020 (34.4°C), then the temperature of the anomaly gradually decreased to the usual fumarole activity of the volcano. Probably, there was an ascent of fresh magmatic substance along the volcano's vent, but it did not reach the edge of the crater [12].

Analysis of the temperature of thermal anomalies of volcanoes in the Kuril-Kamchatka region in 2019-2020 shows a significantly higher activity of the Kamchatka volcanoes in comparison with the Kuril volcanoes (Figure 2, 3). Four volcanoes erupted at Kamchatka (one constantly), and two volcanoes at the Kuril Islands. Fresh magmatic matter was constantly flowing to the earth surface in the Kamchatka region, as evidenced by the high temperatures of the thermal anomalies of the volcanoes. The value of a difference in the average daily temperature between the thermal anomaly and the background for the non-erupting volcanoes of Kamchatka was less than 30 °C, and for Kuril Islands volcanoes it was less than 10 °C.

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