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The Alaska Volcano Observatory is a cooperative program of the U.S. Geological Survey, University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological & Geophysical Surveys. The Alaska Volcano Observatory is funded by the U.S. Geological Survey Volcano Hazards Program and the State of Alaska.

2013 Volcanic Activity in Alaska: Summary of Events and Response of the Alaska Volcano Observatory

Scientific Investigations Report 2015–5110

U.S. Department of the Interior
U.S. Geological Survey

Cover: Aerial view of the eruption at Veniaminof's intracaldera cone, August 18, 2013, from an overflight co-sponsored by the National Geographic Society. This cone rises about 1,000 feet above the surrounding icefield. It has been intermittently erupting lava, ash, and steam since June 13, 2013. This photograph shows the incandescent, orange stream of molten lava emerging from the active cone. Steam billows from the pit at the base of the cone where the lava encounters and melts ice and snow. A small, ash-rich plume rises just above the vent producing a diffuse ash cloud that drifts downwind. In the foreground, round patches probably represent ballistic impact craters. Photograph by Game McGimsey, AVO/USGS. AVO database image at URL: http://www.avo.alaska.edu/images/image.php?id=56211.

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By James P. Dixon, Cheryl Cameron, Robert G. McGimsey, Christina A. Neal, and Chris Waythomas

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Scientific Investigations Report 2015–5110

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Geological Survey, Reston, Virginia: 2015

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Conversion Factors

Inch/Pound to International System of Units

Multiply	By	To obtain
acre	4,047	square meter (m^2)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
foot (ft)	0.000305	kilometer (km)
foot (ft)	0.3048	meter (m)
inch (in)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
mile (mi)	1.609	kilometer (km)
tons	0.9072	metric tons

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as

$$°C = (°F - 32) / 1.8.$$

International System of Units to Inch/Pound

Multiply	By	To obtain
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	3,281	foot (ft)
meter (m)	3.281	foot (ft)
metric ton	1.1022	tons
millimeter (mm)	0.03937	inch (in.)
nanometer per second (nm/s)	3.94 E-8	inch per second (in/s)
square meter (m^2)	0.0002471	acre
cubic meter (m^3)	35.31	cubic foot (ft^3)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F = (1.8 \times °C) + 32.$$

Datum

Altitude and elevation as used in this report refer to distance above sea level, unless otherwise noted.

Locations in latitude and longitude are presented in degrees and minutes rounded to the nearest minute referenced to the World Geodetic System of 1984 (WGS 84) datum.

2013 Volcanic Activity in Alaska: Summary of Events and Response of the Alaska Volcano Observatory

By James P. Dixon[1], Cheryl Cameron[2], Robert G. McGimsey[3], Christina A. Neal[3], and Chris Waythomas[3]

Abstract

The Alaska Volcano Observatory (AVO) responded to eruptions, volcanic unrest or suspected unrest, and seismic events at 18 volcanic centers in Alaska during 2013. Beginning with the 2013 AVO Summary of Events, the annual description of the AVO seismograph network and activity, once a stand-alone publication, is now part of this report. Because of this change, the annual summary now contains an expanded description of seismic activity at Alaskan volcanoes. Eruptions occurred at three volcanic centers in 2013: Pavlof Volcano in May and June, Mount Veniaminof Volcano in June through December, and Cleveland Volcano throughout the year. None of these three eruptive events resulted in 24-hour staffing at AVO facilities in Anchorage or Fairbanks.

Introduction

The Alaska Volcano Observatory (AVO) is responsible for monitoring the volcanoes of Alaska, warning those at risk, and conducting research to better understand how volcanoes work. As of December 31, 2012, 29 Alaskan volcanoes were instrumented with networks of seismometers sufficiently reliable in their operation to detect and track earthquake activity (fig. 1; table 1). Seismic data from these networks are reviewed daily. Seismic stations were installed at two additional volcanoes in 2005 (Little Sitkin and Semisopochnoi; fig. 1); however, telemetry links have remained intermittently operational and AVO does not consider these volcanoes to be seismically monitored. Wrangell's monitoring network suffered outages of such sufficient length that it was removed from the monitored list at the end of the year.

The Alaska Volcano Observatory (AVO) monitors, studies, and warns of volcanic unrest at Alaskan volcanoes. This report summarizes notable volcanic activity and volcano seismicity in Alaska during 2013 (fig. 1; tables 1 and 2) and briefly describes AVO's response. We include information on all volcanoes at an elevated Aviation Color Code (**YELLOW, ORANGE**, or **RED**) or Volcano Alert Level (**ADVISORY, WARNING**, or **WATCH**) and those that prompted increased attention by AVO staff, even if no formal public notification ensued. We also include observations, images, and data that are difficult to publish elsewhere.

As of December 31, 2013, 29 of the 52 historically active volcanoes in Alaska are instrumented with a network of seismometers sufficiently reliable in their operation to detect and track earthquake activity (table 3). Seismic stations were installed at two additional volcanoes in 2005 (Little Sitkin and Semisopochnoi; fig. 1); however, telemetry links have remained intermittently operational and AVO does not consider these volcanoes to be seismically monitored. The network at Ugashik-Peulik and Ukinrek Maars was briefly unoperational in 2013 as these volcanoes were removed from the seismically monitored list in March and added back to the monitored list in May. Seismograph station outages such as those experienced at Ugashik-Peulik are not unusual in the harsh environments of remote Alaska. In recent years, AVO has started removing volcanoes from the monitored list when a prolonged seismograph network outage has occurred.

AVO's volcano monitoring program (tables 4a and 4b), which began in 1988, currently (2013) includes daily analysis of satellite imagery, Web camera images, and seismicity, occasional overflights, airborne-gas measurements, compilation of pilot reports (PIREPS), and observations of local residents and mariners. AVO also receives real-time deformation data from permanent Global Positioning System (GPS) stations at four Alaskan volcanoes (Okmok, Augustine, Akutan, and Spurr). Periodic analysis of Interferometric Synthetic Aperture Radar (InSAR) imagery also is used to detect deformation at volcanoes in Alaska (for example, Lu, 2007). AVO also is increasing the use of infrasound to detect explosions throughout the Aleutian arc (for example, Fee and others, 2010).

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Figure 1. Map showing 52 historically active volcanoes in Alaska along with place names used in this report. Following the established criteria and review of Cameron and others (2008), historically active volcanoes are considered those that have had an eruption or period of intense deformation, seismic or fumarolic activity that is inferred to reflect the presence of magma at shallow levels beneath the volcano. The "historical" period in Alaska is considered post-1700 when written records of volcanic activity began.

Table 1. Summary of 2013 volcanic activity in Alaska, including eruptions, possible eruptions, and unusual increases in seismicity or fumarolic activity.

[With the merging of the annual earthquake catalog, the number of volcanoes reported in this table and subsequent summaries show an increased number of volcanoes with reported activity. Cross-referenced lists of volcanic activity by year and by volcano for this and all previous Alaska Volcano Observatory annual activity reports are presented in tables 4a and 4b. Location of volcanoes shown in figure 1. **Abbreviation:** SVA, Suspect Volcanic Activity]

Volcano	Date of activity	Type of activity
Wrangell Volcano	August 2 Throughout the year	SVA: Redistributed ash Observation of fumarolic activity
Redoubt Volcano	Throughout the year	Degassing, robust fumarolic plumes
Iliamna Volcano	February 2, August 25, September 20 July 24	Avalanches SVA: Increased steaming
Fourpeaked Volcano	April, May May 19	Increased seismicity Observation of steaming
Ugashik-Peulik	June 18, August 12	Observations of steaming, sulfur odor
Aniakchak Volcano	Intermittent throughout year	Short seismic swarms
Mount Veniaminof Volcano	June–December	Effusive eruption
Pavlof Volcano	May–August	Strombolian eruption
Shishaldin Volcano	January May 13	Increased seismicity Observation of steaming
Akutan Volcano	January Intermittent throughout year	Triggered seismicity Possible tremor
Makushin Volcano	Intermittent throughout year	Observation of steaming, possible tremor, earthquake swarms
Okmok Volcano	March 7, September 28, October 9 May–December Intermittent throughout the year	Earthquake swarms Episode of rapid inflation Possible tremor
Cleveland Volcano	Intermittent throughout year	Lava extrusion, explosions, small ash clouds
Korovin Volcano	March–April Throughout the year	Earthquake swarms Possible tremor
Great Sitkin Volcano	July, August	Earthquake swarms
Mount Gareloi	July–August July 30	Felt earthquakes Observation of steaming

As part of AVO's longstanding close cooperation with Russian volcano monitoring (KVERT, Kamchatkan Volcanic Eruption Response Team) and reporting groups in the Russian Far East (SVERT, Sakhalin Volcanic Eruption Response Team) (Neal and others, 2009a), earlier versions in this report series included summaries of activity in Kamchatka and the Kurile Islands (table 5). Beginning with the 2011 report (McGimsey and others, 2014), AVO no longer includes this information and refers interested readers to the Web sites of the Kamchatka and Sakhalin Volcanic Eruption Response Teams (http://www.kscnet.ru/ivs/kvert/index_eng.php and http://www.imgg.ru/?id_d=659, accessed January 1, 2015) and to the Global Volcanism Project (GVP).

Beginning with the 2013 AVO Summary of Events, the annual description of the AVO seismograph network and activity, once a stand-alone publication (for example, Dixon and others, 2013), is now part of this report. Because of this change, the annual summary now contains an expanded description of seismic activity at Alaskan volcanoes. All hypocentral locations of earthquakes in the AVO seismic catalog are available as part of the Advanced National Seismic System (ANSS) catalog (http://quake.geo.berkeley.edu/cnss/, accessed January 1, 2015) and currently are being added on a daily basis. Continuous waveform data for most AVO seismograph stations are archived and available through the

Incorporated Research Institutions for Seismology (IRIS) Web site at www.iris.edu (accessed January 1, 2015). A metadata file in the form of a dataless SEED file (Incorporated Research Institutions for Seismology, 2010) for the AVO seismograph network also is available from IRIS at www.iris.edu/pub/RESPONSES/DATALESS_SEEDS (accessed January 1, 2015).

Descriptions are presented in geographic order from northeast to southwest (from Wrangell Volcano to Little Sitkin Volcano). Each entry has a title block with the following information about the volcano—unique GVP-assigned identifier, latitude and longitude, summit elevation, and geographic region. Each event summary ends with a paragraph of background comments about the volcano in question. (Note we are including in this report both the GVP legacy volcano number and a new unique number assigned during the GVP database redesign in 2013.) Information is derived from published material as well as AVO daily status reports, weekly updates and special information releases, AVO email and online electronic logs, and the Smithsonian Institution Global Volcanism Network Bulletins that are available at http://www.volcano.si.edu/reports_bgvn.cfm (accessed January 1, 2015).

Measurements are presented in International System of Units (SI) with approximate conversions to English or Inch-Pound Units in parentheses for convenience. Altitudes and elevations reported are in meters above sea level (ASL) and feet ASL in parentheses. Time is reported as Coordinated Universal Time (UTC) with the local time, Alaska Standard Time (AKST) or Alaska Daylight Time (AKDT) in parentheses. Volcano locations in latitude and longitude (presented in degrees and minutes rounded to the nearest minute) and summit elevations are taken from the Alaska Volcano Observatory database (World Geodetic System of 1984 datum) and may differ slightly from previously published compilations.

What is an “historically active volcano”?

AVO defines an “active” volcano as a volcanic center that has had a recent eruption (see What is an :eruption”) or period of intense deformation, seismic or fumarolic activity that is inferred to reflect the presence of magma at shallow levels within the volcano. The “historical” period in Alaska is considered to be after about 1700, when written records of volcanic activity began. Based on a rigorous re-analysis of all accounts of volcanic activity in Alaska from many sources, Cameron and others (2008) conclude that 52 Alaskan volcanoes fit these criteria. This is a change from the often-cited 41 volcanoes of Miller and others (1998), and from previously published map compilations. As geologic understanding of Alaska’s volcanoes improves through additional fieldwork and modern radiometric-dating techniques, our list of “active” volcanoes will continue to evolve.

What is an “eruption”?

The specific use of the term ‘eruption’ varies from scientist to scientist and there is no universally agreed-upon definition. Here, we adopt the usage of the Smithsonian Institution’s Global Volcanism Program, which defines eruptions as “…events that involve the explosive ejection of fragmental material, the effusion of liquid lava, or both” (Siebert and others, 2010). The elements of this definition that we wish to emphasize are the verbs ‘eject’ and ‘effuse,’ which refer to dynamic surface processes that pose some level of hazard. The presence or absence of often ambiguous ‘juvenile material’ or fresh magma is not relevant to this use of the term eruption, particularly when communicating a potential hazard. This definition would not, however, include passive volcanic degassing or hydrothermal-fluid discharge.

Table 2. Alaskan volcanoes with Aviation Color Code and Volcano Alert Level changes at Alaskan volcanoes in 2013.

[Description of Aviation Color Codes is shown in appendix 1. Volcanoes that do not have a real-time seismic network are not assigned a color code **GREEN** because without seismic data, Alaska Volcano Observatory has no definitive information that the level of activity at the volcano is at background. For these volcanoes, AVO uses the designation **UNASSIGNED**. For a discussion of Color Code terms, see Gardner and Guffanti, 2006]

Color Code	Date of change
ILIAMNA	
YELLOW/ADVISORY	January 1 – January 9
GREEN/NORMAL	January 9 – December 31
UGASHIK-PEULIK	
GREEN/NORMAL	January 1 – March 29
UNASSIGNED	March 29 – May 22
GREEN/NORMAL	May 22 – December 31
VENIAMINOF	
UNASSIGNED	January 1 – June 7
YELLOW/ADVISORY	June 7 – June 13
ORANGE/WATCH	June 13 – September 20
YELLOW/ADVISORY	September 20 – October 6
ORANGE/WATCH	October 6 – October 17
YELLOW/ADVISORY	October 17 – December 31
PAVLOF	
YELLOW/ADVISORY	January 1 – May 13
ORANGE/WATCH	May 13 – May 28
YELLOW/ADVISORY	May 28 – June 4
ORANGE/WATCH	June 4 – July 2
YELLOW/ADVISORY	July 2 – August 8
GREEN/NORMAL	August 8 – December 31
CLEVELAND	
YELLOW/ADVISORY	January 1 – February 9
ORANGE/WATCH	February 9 – March 8
YELLOW/ADVISORY	March 8 – May 4
ORANGE/WATCH	May 4 – June 4
YELLOW/ADVISORY	June 4 – December 31

Table 3. History of seismic monitoring of Alaskan volcanoes from August 1971 through December 2013.

[History of seismic monitoring compiled by J. Dixon. "First station installed" refers to the date when Alaska Volcano Observatory (AVO) first received real-time data from a permanent station. This date can be many months following initial fieldwork at the volcano. AVO considers the seismic network "complete" following installation and data transmission from a minimum of four seismic stations. Typically, AVO seismologists monitor the seismicity at the volcanic center for at least 6 months to understand background rates of seismicity before formally declaring a volcano seismically monitored and adding it to the monitored list. We note here the first mention of the seismic status of each monitored volcano in the AVO weekly update. Regularly issued written information statements began during the Redoubt eruption in 1989–90 and were expanded to include all Cook Inlet volcanoes in April 1991. The magnitude of completeness is the lowest magnitude earthquake that can confidently be located for activity at the volcanic center with an operational seismograph network. For more information on specific seismic network histories, readers are referred to the series of annual seismic summaries prepared by AVO (for example, Dixon and others, 2013). A breakdown by type of event is shown in appendix 2]

Volcano	Approximate start date of seismic monitoring	Earthquakes located in 2013	Magnitude of completeness
Wrangell	First station installed – July 2000 Network complete – **August 2001** Added to monitored list in weekly update – November 2001 Removed from monitored list in weekly update – January 27, 2012	0	0.9
Spurr	First station installed – August 1971 Network complete – **August 1989** Added to monitored list in weekly update – April 1991	331	0.2
Redoubt	First station installed – August 1971 Network complete – **August 1988** Added to monitored list in weekly update – April 1991	189	0.3
Iliamna	First station installed – September 1987 Network complete (Min 4 stations) – **September 1994** Added to monitored list in weekly update – April 1991	444	0.2
Augustine	First station installed – October 1976 Network complete – **August 1978** Added to monitored list in weekly update – April 1991	101	0.0
Fourpeaked	First station installed – September 2006 Network complete (Min 4 stations) – **October 2006** Added to monitored list in weekly update – October 2006 Removed from monitored list in weekly update – November 2009	71	0.4
Katmai-North (Snowy)	First station installed – August 1988 Network complete – **October 199**8 Added to monitored list in weekly update – December 1998	116	0.8
Katmai-Central (Griggs, Katmai, Novarupta, Trident)	First station installed – August 1988 Network complete (Min 4 stations) – **July 1991** Added to monitored list in weekly update – November 1996	157	0.4
Katmai-South (Martin, Mageik)	First station installed – August 1988 Network complete – **July 1996** Added to monitored list in weekly update – November 1996	223	0.3
Ukinrek Maars/ Peulik	First station installed – March 2005 Network complete (Min 4 stations) – **March 2005** Added to monitored list in weekly update – April 2005	17	0.9
Aniakchak	First station installed – July 1997 Network complete – **July 1997** Added to monitored list in weekly update – November 1997 Removed from monitored list in weeily update – November 2009	48	1.4
Veniaminof	First station installed – February 2002 Network complete – **February 2002** Added to monitored list in weekly update – September 2002 Removed from monitored list in weekly update – November 2009	7	1.5

Table 3. History of seismic monitoring of Alaskan volcanoes from August 1971 through December 2013.—Continued

Volcano	Approximate start date of seismic monitoring	Earthquakes located in 2013	Magnitude of completeness
Pavlof	First station installed – July 1996 Network complete – **July 1996** Added to monitored list in weekly update – November 1996	9	1.0
Dutton	First station installed – July 1988 Network complete – **July 1996** Added to monitored list in weekly update – November 1996	11	1.0
Shishaldin (and Isantoski)	First station installed – July 1997 Network complete – **July 1997** Shishaldin added to list in weekly update – November 1997 Isantoski added to list in weekly update – December 1998	3	0.6
Westdahl (and Fisher)	First station installed – August 1998 Network complete – **October 1998** Added to monitored list in weekly update – December 1998	22	1.1
Akutan	First station installed – March 1996 Network complete – **July 1996** Added to monitored list in weekly update – November 1996	146	0.3
Makushin	First station installed – July 1996 Network complete – **July 1996** Added to monitored list in weekly update – November 1996	457	0.7
Okmok	First station installed – January 2003 Network complete – **January 2003** Added to monitored list in weekly update – January 2004	55	0.9
Korovin	First station installed – July 2004 Network complete – **July 2004** Added to monitored list in weekly update – December 2005 Removed from monitored list in weekly update – January 2004	189	1.2
Great Sitkin	First station installed – September 1999 Network complete – **September 1999** Added to monitored list in weekly update – December 1999	79	0.6
Kanaga	First station installed – September 1999 Network complete – **September 1999** Added to monitored list in weekly update – December 2000	147	1.2
Tanaga	First station installed – August 2003 Network complete – **August 2003** Added to monitored list in weekly update – June 2004	98	1.1
Gareloi	First station installed – August 2003 Network complete – **September 2003** Added to monitored list in weekly update – June 2004	10	1.2
Semisopochnoi (Cerberus)	First station installed – September 2005 Network complete – **September 2005** Not yet added to monitored list in weekly update	0	1.0
Little Sitkin	First station installed – September 2005 Network complete – **September 2005** Not yet added to monitored list in weekly update	3	0.0

Table 4a. Compilation by year of Alaskan volcanoes included in an Alaska Volcano Observatory Annual Summary, 1992–2013.

[Volcanoes are presented in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc]

Volcanoes mentioned	
Alaskan	**Russian**
1992	
Spurr/Crater Peak	
Iliamna	
Redoubt	
Mageik (Katmai Group)	
Westdahl	
Akutan	
Bogoslof	
Seguam	
1993	
Churchill	
Sanford	
Spurr/Crater Peak	
Veniaminof	
Shishaldin	
Makushin	
Seguam	
Kliuchef (Atka)	
Kanaga	
1994	
Sanford	
Iliamna	
Katmai Group (Martin, Mageik, Trident)	
Veniaminof	
Kupreanof	
Shishaldin	
Makushin	
Cleveland	
Kanaga	
1995	
Katmai Group (Martin)	Bezymianny
Veniaminof	Karymsky
Shishaldin	
Makushin	
Kliuchef (Atka)	
Kanaga	
1996	
Wrangell	Klyuchevskoy
Iliamna	Bezymianny
Katmai Group (Martin, Mageik, Trident, Katmai)	Karymsky
	Avachinsky
	Mutnovsky
Pavlof	Alaid (Kurile Islands)
Shishaldin	
Westdahl	
Akutan	
Amukta	
Korovin (Atka)	
Kanaga	
1997	
Wrangell	Sheveluch
Sanford	Klyuchevskoy
Shrub Mud	Bezymianny
Iliamna	Karymsky
Katmai Group (Martin, Mageik, Snowy, Kukak)	Alaid (Kurile Islands)
Chiginagak	
Pavlof	
Shishaldin	
Okmok	
Cleveland	
Amukta	
1998	
Shrub Mud	Sheveluch
Augustine	Klyuchevskoy
Becharof Lake	Bezymianny
Chiginagak	Karymsky
Shishaldin	
Akutan	
Korovin (Atka)	
1999	
Wrangell	Sheveluch
Shrub Mud	Klyuchevskoy
Iliamna	Bezymianny
Veniaminof	Karymsky
Pavlof	
Shishaldin	
Vsevidof	
2000	
Wrangell	Sheveluch
Katmai Group (Snowy)	Klyuchevskoy
Chiginagak	Bezymianny
Shishaldin	Karymsky
	Mutnovsky
2001	
Katmai Group (Snowy/Kukak)	Sheveluch
	Klyuchevskoy
Pavlof	Bezymianny
Frosty	Karymsky
Shishaldin	Avachinsky
Makushin	
Okmok	
Cleveland	
Great Sitkin	

Table 4a. Compilation by year of Alaskan volcanoes included in an Alaska Volcano Observatory Annual Summary, 1992–2013.—Continued

[Volcanoes are presented in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc]

Year	Volcanoes mentioned: Alaskan	Volcanoes mentioned: Russian
2002	Wrangell Katmai Group (Martin, Mageik) Veniaminof Mt. Hague (Emmons Lake Caldera) Shishaldin Great Sitkin	Sheveluch Klyuchevskoy Bezymianny Karymsky
2003	Wrangell Redoubt Iliamna Augustine Katmai Group (Mageik) Veniaminof Pavlof Hague (Emmons Lake Caldera) Shishaldin Akutan	Sheveluch Klyuchevskoy Bezymianny Karymsky Alaid Chikurachki
2004	Crillon (non-volcanic peak) Spurr Katmai Group (Martin) Veniaminof Shishaldin Westdahl	Sheveluch Klyuchevskoy Bezymianny Karymsky Chirinkotan (Kuriles)
2005	Spurr Iliamna Augustine Katmai Group (Martin, Mageik, Trident) Chiginagak Aniakchak Veniaminof Pavlof/Hague Shishaldin Cleveland Korovin Kasatochi Tanaga	Sheveluch Klyuchevskoy Bezymianny Karymsky Avachinsky Mutnovsky Ebeko Chikurachki
2006	Klawasi Spurr Augustine Fourpeaked Katmai Group (Martin, Mageik, Trident) Veniaminof Cleveland Korovin Kasatochi	Sheveluch Klyuchevskoy Bezymianny Karymsky Ebeko Severgin Berga
2007	Redoubt Augustine Fourpeaked Veniaminof Pavlof Akutan Cleveland Korovin	Sheveluch Klyuchevskoy Bezymianny Karymsky Gorely and Mutnovsky Chikurachki Berga
2008	Redoubt Aniakchak Veniaminof Shishaldin Okmok Cleveland Kasatochi	Sheveluch Klyuchevskoy Bezymianny Karymsky Koryaksky Gorely and Mutnovsky Chikurachki Tyatya
2009	Sanford Redoubt Fourpeaked Aniakchak Veniaminof Shishaldin Okmok Cleveland	Sheveluch Klyuchevskoy Bezymianny Kizimen Karymsky Koryaksky Gorely Ebeko Sarychev Raikoke
2010	Wrangell Sanford Redoubt Fourpeaked Katmai Group Becharof Lake Aniakchak Veniaminof Westdahl	Sheveluch Klyuchevskoy Bezymianny Kizimen Karymsky Gorely Ekarma

Table 4a. Compilation by year of Alaskan volcanoes included in an Alaska Volcano Observatory Annual Summary, 1992–2013.—Continued

[Volcanoes are presented in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc]

Volcanoes mentioned	
Alaskan	**Russian**
Makushin	
Cleveland	
Kasatochi	
2011	
Wrangell	
Sanford	
Redoubt	
Fourpeaked	
Aniakchak	
Veniaminof	
Makushin	
Westdahl	
Cleveland	
Kasatochi	
2012	
Wrangell	
Spurr	
Redoubt	
Iliamna	
Augustine	
Fourpeaked	
Katmai Group (Martin)	
Aniakchak	
Cleveland	
Kanaga	
Little Sitkin	

Volcanoes mentioned	
Alaskan	**Russian**
2013	
Wrangell	
Redoubt	
Iliamana	
Augustine	
Fourpeaked	
Peulik	
Aniakchak	
Veniaminof	
Pavlof	
Shishaldin	
Akutan	
Makushin	
Okmok	
Cleveland	
Atka (Korovin)	
Great Sitkin	
Gareloi	

Table 4b. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summary, 1992–2013.

[Volcanic centers are listed from east to west. Suspect Volcanic Activity (SVA) is defined as a report of eruption or possible eruption that is normal fumarolic activity or non-volcanic phenomena, such as weather related. PIREP, pilot weather report; CO_2, carbon dioxide]

Volcano	Yearmentioned	Type of activity
Churchill	1993	SVA, anomalous seismicity
Wrangell	1996	SVA, steam plume
	1997	SVA, steam plume
	1999	SVA, steaming and phreatic ash emission
	2000	SVA, steam plumes
	2002	SVA, suspicious clouds, redistributed ash
	2003	SVA, anomalous clouds
	2007	Triggered seismicity, vapor clouds, wind-blown ash
	2010	Anomalous clouds
	2012	Anomalous clouds
	2013	SVA, redistributed ash, fumarolic activity
Sanford	1993	SVA, reported steam plume likely from avalanche
	1994	SVA, reported steam plume likely from avalanche
	1997	SVA, large steam cloud from southwest face
	2009	Persistent anomalous clouds
	2010	Anomalous cloud from southwest face
Shrub Mud	1997	Eruption; energetic ejection of saline mud and CO_2
	1998	Eruption continues; ejection of saline mud and CO_2
	1999	Eruption continues; ejection of saline mud and CO_2
Klawasi Mud	2006	Possible new mud vent
Spurr	1992	Subplinian eruptions; ash, pyroclastic flows, lahars
	1993	SVA, glacial outburst produces seismicity
	2004	Heat flux to summit; lahars; cauldron develops
	2005	Continued heat to summit; cauldron evolves
	2006	Continued heat to summit; cauldron evolves
	2012	Glacial outburst flood
Redoubt	1992	SVA, steam plume from still-cooling dome
	2003	SVA, anomalous weather cloud
	2007	Possible steaming and increased thermal flux
	2008	Pre-eruption increase in gas emissions and thermal flux from summit crater
	2009	Major magmatic eruption, domes, lahars, ash fall
	2010	Vapor and gas clouds; brief uptick in seismicity
	2012	Degassing, robust fumarolic plume
	2013	Degassing, fumarolic plume
Iliamna	1992	SVA, PIREP of large steam plume, media frenzy
	1994	SVA, vigorous steam plume, avalanche
	1996	Intense seismicity related to magmatic intrusion
	1997	SVA; anomalous seismic swarm; avalanche
	1999	SVA, avalanche
	2003	SVA, avalanche
	2005	SVA, rock avalanche
	2012	Fumarolic plume, seismic swarms, avalanches
	2013	SVA, increased steaming, avalanches
Augustine	1998	1986 dome spine partially collapses, generates mudflow
	2005	Precursory activity prior to eruption in early 2006
	2006	Explosive and effusive eruption
	2007	Strong seismicity and steam plumes
	2012	Fumarolic plumes, sulfur odor, seismicity

Table 4b. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summary, 1992–2013.—Continued

[Volcanic centers are listed from east to west. Suspect Volcanic Activity (SVA) is defined as a report of eruption or possible eruption that is normal fumarolic activity or non-volcanic phenomena, such as weather related. PIREP, pilot weather report; CO_2, carbon dioxide]

Volcano	Yearmentioned	Type of activity
Fourpeaked	2006	Phreatic eruption
	2007	Ongoing fumarolic emissions, seismicity
	2009	Continued decline in gas emissions
	2010	Decreasing fumarolic emissions, sporadic earthquake swarms
	2012	Increased seismicity
	2013	Increased seismicity, anomalous plume
Katmai Group		
Mageik	1992	SVA, anomalous cloud
Martin/Mageik/Trident	1994	SVA, plume-like cloud
Martin	1995	SVA, large steam plume
Martin/Mageik/Trident/Katmai	1996	SVA, anomalous seismicity
Martin/Mageik/Snowy/Kukak	1997	SVA, PIREPS of ash and steam plumes
Snowy	2000	SVA, steaming hole in glacier
Snowy/Kukak	2001	SVA, steaming hole in glacier
Martin/Mageik	2002	SVA, steam plume
Mageik	2003	SVA, steaming, large cloud of re-suspended ash
Martin	2004	SVA, large steam plume
Martin/Mageik/Trident	2005	SVA, steam cloud, re-suspended ash
Martin	2006	Earthquake swarm
Martin	2010	Re-suspended ash
Martin	2012	Elevated seismicity, fumarolic plumes
Becharof Lake	1998	SVA, intense seismic swarm and inflationary episode
	2010	Earthquake swarm
Ugashik-Peulik	2013	SVA, reported steaming, sulfur odors
Chiginagak	1997	Minor eruptive activity, new fumarole field
	1998	SVA, continuation of increased fumarolic activity
	2000	SVA, steam emissions from fumarole field
	2005	Heat to summit; acidic flood; cauldron develops
Aniakchak	2005	SVA, anomalous seismicity, thermal anomaly
	2008	Weather related noise on seismic stations
	2009	Anomalous seismicity
	2010	Low frequency earthquake swarm
	2011	Anomalous seismicity
	2012	Increased seismicity, possible tremor
	2013	Short seismic swarms
Veniaminof	1993	Low-level eruption and lava flows
	1994	Strombolian eruption and lava flows
	1995	Strombolian eruptions
	1999	SVA, extreme discharge and turbid river
	2002	Low-level phreatic eruptions
	2003	Low-level phreatic eruptions
	2004	Weak phreatic and Strombolian eruption
	2005	Intermittent phreatic and Strombolian eruption
	2006	Intermittent phreatic and Strombolian eruption
	2007	Decline in vapor plumes
	2008	Weak phreatic emissions and vapor plumes
	2009	Minor phreatic eruptions, sporadic
	2010	Sporadic seismicity, vapor plumes
Kupreanof	1994	SVA, PIREP of unusual steam plume

Table 4b. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summary, 1992–2013.—Continued

[Volcanic centers are listed from east to west. Suspect Volcanic Activity (SVA) is defined as a report of eruption or possible eruption that is normal fumarolic activity or non-volcanic phenomena, such as weather related. PIREP, pilot weather report; CO_2, carbon dioxide]

Volcano	Yearmentioned	Type of activity
Pavlof	1996	Strombolian eruption
	1997	Strombolian eruption concludes
	1999	SVA, summit snow melt, ash dustings, steam plumes
	2001	SVA, steaming, possible ash, sulfur smell
	2005	SVA, mis-located steam plume
	2007	Strombolian eruption, lava flows, lahars
	2012	Tremor burst, fumarolic plume
	2013	Strombolian eruption
Hague (Emmons Lake Caldera)	2002	SVA, increase in fumarolic activity in summit crater
	2003	SVA, crater lake drains, refills, drains
	2005	SVA, steam plume
Frosty	2001	SVA, rock fall avalanches
Shishaldin	1993	Minor phreatic
	1994	SVA, PIREP of minor steam/ash
	1995	Minor eruptive activity, steam/ash
	1996	Eruption; steam/ash and thermal anomaly
	1997	Minor eruptive activity, steam/ash
	1998	Minor eruptive activity, steam/ash
	1999	Strombolian eruption
	2000	Minor eruptive activity, steam/ash
	2001	Minor unrest, seismicity increase, steam clouds
	2002	SVA, shallow seismicity; PIREP of possible eruption
	2003	SVA, steam plumes
	2004	Small steam and ash plumes
	2005	SVA, increased seismicity, steam plumes prompt PIREPS
	2008	Minor phreatic (?) ash emission and vigorous vapor plumes
	2009	Increased seismicity, small steam plumes, thermal anomalies
	2013	Seismicity, small steam plume
Westdahl	1992	Fissure eruption, lava fountains, ash clouds, lava flow
	1996	SVA, suspicious weather cloud on satellite image
	2004	SVA, seismic swarm
	2010	Increase in lower crustal seismicity
Akutan	1992	SVA, steam/ash emissions
	1996	Intensive seismicity, ground cracking
	1998	SVA, tremor-like seismicity
	2003	SVA, anomalous steam plume
	2007	Triggered seismicity; inflation; anomalous steaming
	2013	Triggered seismicity, intermittent tremor
Makushin	1993	Minor phreatic
	1994	SVA, PIREP of minor steam/ash
	1995	SVA, steam plume
	2001	SVA, increase in seismicity
	2008	Discolored seawater in Unalaska Bay
	2010	Seismicity, anomalous clouds reported
	2013	Tremor, small steam plume
Bogoslof	1992	Dome extrusion, ash and steam emissions
Okmok	1997	Strombolian eruption
	2001	SVA, seismic swarm
	2008	Major Phreatomagmatic eruption
	2009	Caldera floor uplift, tremor bursts, inflation
	2011	Inflation
	2013	Sporatic tremor, earthquake swarm, inflation

Table 4b. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summary, 1992–2013.—Continued

[Volcanic centers are listed from east to west. Suspect Volcanic Activity (SVA) is defined as a report of eruption or possible eruption that is normal fumarolic activity or non-volcanic phenomena, such as weather related. PIREP, pilot weather report; CO_2, carbon dioxide]

Volcano	Yearmentioned	Type of activity
Vsevidof	1999	SVA, sighting of ash after regional earthquake
Cleveland	1994	SVA, possible steam/ash emission
	1997	Minor eruption, steam/ash
	2001	Eruption; gas/ash, lava/debris flows
	2005	Intermittent explosions
	2006	Intermittent explosions
	2007	Intermittent explosions, small ash clouds, ballistics
	2008	Intermittent explosions; small ash clouds
	2009	Thermal anomalies, minor ash and gas emissions, flowage and ballistics deposits
	2010	Explosions, small ash clouds, vapor plumes, thermal anomalies
	2011	Intermittent explosions, small ash clouds
	2012	Thermal anomalies, intermittent explosions, small ash clouds
	2013	Lave extrusion, explosions, small ash clouds
Amukta	1996	Small eruption; ash emission
	1997	SVA, PIREP of small ash eruption
Seguam/Pyre Peak	1992	Minor eruptive activity, steam/ash emissions
	1993	Fissure eruption produces lava flow and ash cloud
Atka		
Kliuchef	1993	SVA, audible rumbling, strong sulfur odor
Kliuchef	1995	SVA, large steam plume, strong sulfur odor
Korovin	1996	SVA, PIREP of ash cloud, suspicious cloud on satellite image
Korovin	1998	Eruption; explosions and ash fall
Korovin	2005	Minor eruption, steam and ash
Korovin	2006	Seismic swarms, uplift, increased fumarolic activity
Korovin	2007	Seismic swarms; fumarolic activity
Korovin	2013	Earthquake swarms, intermittent tremor
Kasatochi	2005	SVA, unusual bubbling; floating scum on crater lake
	2006	Continued bubbling in intracaldera lake
	2008	Major explosive eruption
	2009	Summit lake level rise
	2010	Fumarolic emission, diffuse degassing, coastal erosion
Great Sitkin	2001	SVA, anomalous seismicity
	2002	SVA, seismic swarm, tremor
	2013	Earthquake swarms
Kanaga	1993	SVA, increased steaming
	1994	Eruption; steam/ash and lava flow
	1995	Minor eruptive activity, steam/ash and lava
	1996	Possible eruption and ash emission
	2012	Phreatic (?) explosion, limited ash fall, new summit fissure
Gareloi	2013	SVA reported steaming, felt earthquakes, anomalous seismicity, including a period of tremor
Tanaga	2005	SVA, anomalous seismicity, including a period of tremor
Little Sitkin	2012	Seismic swarms, likely magmatic intrusion

Table 5. Citations for Alaska Volcano Observatory Annual Summary reports, 1992–2012.

Year	Citation	URL
1992	McGimsey, R.G., Neal, C.A., and Doukas, M.P., 1995, Volcanic activity in Alaska: Summary of events and response of the Alaska Volcano Observatory, 1992: U.S. Geological Survey Open-File Report 95-83, 26 p.	http://pubs.er.usgs.gov/publication/ofr9583/
1993	Neal, C.A., McGimsey, R.G., and Doukas, M.P., 1996, Volcanic activity in Alaska: Summary of events and response of the Alaska Volcano Observatory, 1993: U.S. Geological Survey Open-File Report 96-24, 21 p.	http://pubs.usgs.gov/of/1996/0024/
1994	Neal, C.A., Doukas, M.P., and McGimsey, R.G., 1995, 1994 Volcanic activity in Alaska: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 95-271, 20 p.	http://pubs.usgs.gov/of/1995/0271/
1995	McGimsey, R.G., and Neal, C.A., 1996, 1995 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 96-738, 22 p.	http://pubs.usgs.gov/of/1996/0738/
1996	Neal, C.A., and McGimsey, R.G., 1997, 1996 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 97-433, 34 p.	http://pubs.usgs.gov/of/1997/0433/
1997	McGimsey, R.G., and Wallace, K.L., 1999, 1997 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 99-448, 42 p.	http://pubs.usgs.gov/of/1999/0448/
1998	McGimsey, R.G., Neal, C.A., and Girina, Olga, 2004, 1998 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 03-423, 35 p.	http://pubs.usgs.gov/of/2003/of03-423/
1999	McGimsey, R. G., Neal, C. A., and Girina, Olga, 2004a, 1999 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2004-1033, 49 p.	http://pubs.usgs.gov/of/2004/1033/
2000	Neal, C.A., McGimsey, R.G., and Chubarova, Olga, 2004, 2000 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2004-1034, 37 p.	http://pubs.usgs.gov/of/2004/1034/
2001	McGimsey, R.G., Neal, C.A., and Girina, Olga, 2004b, 2001 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2004-1453, 57 p.	http://pubs.usgs.gov/of/2004/1453/
2002	Neal, C.A., McGimsey, R.G., and Girina, Olga, 2005, 2002 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2004-1058, 55 p.	http://pubs.usgs.gov/of/2004/1058/
2003	McGimsey, R.G., Neal, C.A., and Girina, Olga, 2005, 2003 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2005-1310, 62 p.	http://pubs.usgs.gov/of/2005/1310/
2004	Neal, C.A., McGimsey, R.G., Dixon, J.P., and Melnikov, Dmitry, 2005, 2004 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 2005-1308, 71 p.	http://pubs.usgs.gov/of/2005/1308/

Table 5. Citations for Alaska Volcano Observatory Annual Summary reports, 1992–2012.—Continued

Year	Citation	URL
2005	McGimsey, R.G., Neal, C.A., Dixon, J.P., Ushakov, Sergey, 2007, 2005 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2007-5269, 94 p.	http://pubs.usgs.gov/sir/2007/5269/
2006	Neal, C.A., McGimsey, R.G., Dixon, J.P., Manevich, Alexander, and Rybin, Alexander, 2009, 2006 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2008-5214, 102 p.	http://pubs.usgs.gov/sir/2008/5214/
2007	McGimsey, R.G., Neal, C.A., Dixon, J.P., Malik, Nataliya, and Chibisova, Marina, 2011, 2007 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2010–5242, 110 p.	http://pubs.usgs.gov/sir/2010/5242/
2008	Neal, C.A., McGimsey, R.G., Dixon, J.P., Cameron, C.E., Nuzhdaev, A.E., and Chibisova, M., 2011, 2008 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2010–5243, 87 p.	http://pubs.usgs.gov/sir/2010/5243/
2009	McGimsey, R.G., Neal, C.A., Girina, O.A., Chibisova, Marina, and Rybin, Alexander, 2013, 2009 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2013–5213, 125 p.	http://pubs.usgs.gov/sir/2013/5213/
2010	Neal, C.A., Herrick, J., Girina, O., Chibisova, M., Rybin, A., McGimsey, R., and Dixon, J., 2013, 2010 Volcanic activity in Alaska, Kamchatka, and the Kurile Islands: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2013-5034, 76 p.	http://pubs.usgs.gov/sir/2014/5034/
2011	McGimsey, R.G., Maharrey, J. Z., and Neal, C.A., 2014, 2011 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2014–5159, 50 p.	http://pubs.usgs.gov/sir/2014/5159/
2012	Herrick, J.A., Neal, C.A., Cameron, Dixon, and McGimsey, R.G., 2014, 2012 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2014–5160, 82 p.	http://pubs.usgs.gov/sir/2014/5160/

Volcanic Activity in Alaska, East to West from Wrangell to Little Sitkin

Wrangell Volcano

GVP New # 315020

CAVW# 1105-02-

62°00'N 144°01'W
4,317 m (14,163 ft)

Copper River Basin

FUMAROLIC ACTIVITY, LIKELY REDISTRIBUTED ASH

No eruptive activity or significant unrest is known to have occurred at Wrangell Volcano in 2013. As in previous years, AVO received a report of likely fumarolic activity high on the flanks of Wrangell. The seismograph network continued to be nonoperational for all of 2013 because of the extreme elevation of the seismograph stations and the resultant difficulty in maintaining a seismograph network above 2,000 m (6,500 ft). Wrangell retained the Aviation Color Code and Volcano Alert Level **UNASSIGNED** throughout 2013.

A resident of Kenny Lake described seeing an "ash puff "or "ash spray" from Wrangell that deposited a layer of ash on the snow sometime before August 2. Although the ash appears to be remobilized from previous eruptions (for example, forming elongated debris slides or flows), it is possible that it was originally deposited during a phreatic emission of ash, similar to descriptions of activity beginning in the late 1700s through the present (AVO Web site: https://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Wrangell; accessed January 1, 2015) In response to this report, internal discussions within AVO concluded that no volcanic process of significance was involved and no formal information releases was issued.

Wrangell is a massive, glacier-covered volcano in the Wrangell-St. Elias National Park and Preserve in eastern Alaska (Richter and others, 1995). Three geothermally active craters occur on the eastern and western rims of the ice-filled 4 × 6 km (2.5 × 3.7 mi) summit crater, historically the source of nearly constant fumarolic emission (Benson and others, 2007). Resultant steam plumes can be quite vigorous and sometimes reach hundreds of meters (thousands of feet) above ground level, occasionally entraining fine fragmental debris and producing localized deposits of dark material on the ice. This, in addition to wind redistribution of debris from the summit area, is often mistaken for eruptive activity. A four-station seismic network was installed in 2000 and 2001, but has not been recording data since February 2011. AVO relies on local observers, Web cameras, pilots, and satellite imagery to detect activity at the volcano. Except for occasional vigorous steam and phreatic ash emission, no historical magmatic eruptions are known to have occurred (Richter and others, 1995).

Redoubt Volcano

GVP New # 313030

CAVW# 1103-03-

60°29'N 152°45'W
3,108 m (10,197 ft)

Cook Inlet

WEB CAMERA VIEWS OF VAPOR PLUME

Activity related to cooling and continued degassing of the 2009 lava dome on Redoubt Volcano prompted attention on clear days. Web camera views of Redoubt during April and May frequently showed a white vapor plume (fig. 2). During a flight on April 18 to investigate the plume at Redoubt, the crew determined that the concentration of gas species in the plume remained unchanged from 2012 measurements (C. Werner, U.S. Geological Survey, written commun., 2013). During 2013, the Aviation Color Code and Volcano Alert Level at Redoubt remained at **GREEN/NORMAL**.

Heavily ice-mantled Redoubt Volcano is located on the western side of Cook Inlet, 170 km (106 mi) southwest of Anchorage and 82 km (51 mi) west of Kenai, within Lake Clark National Park and Preserve. Recent eruptions occurred in 1902, 1966–68, 1989–90, and 2009 (Waythomas and others, 1997; Schaefer, 2011; McGimsey and others, 2014). The 1989–90 and 2009 eruptions produced mudflows, or lahars, that traveled down the Drift River and partially flooded the Drift River Oil Terminal facility. The 1966–68 eruption also produced lahars down the Drift River. Ash clouds produced by the 1989–90 and 2009 eruptions seriously affected air traffic and resulted in minor or trace amounts of ash on communities in south-central Alaska (Miller and Chouet, 1994; Schaefer, 2011).

Figure 2. Web camera view of the Redoubt summit from "Juergen's Hut", an AVO instrumentation trailer on the ridge just north of the volcano, at 17:56 UTC (09:56 AKDT), May 17, 2013.

Iliamna Volcano

GVP New # 313020

CAVW# 1103-02-

60°02'N 153°04'W
3,053 m (10,016 ft)

Cook Inlet

AVALANCHE ACTIVITY

Activity at Iliamna Volcano in 2013 was highlighted by the observation of three significant rock/snow/ice avalanches, which often are seen on Iliamna. Monitoring highlights included a flight to measure gas emissions in April and substantial upgrades to AVO's geophysical monitoring network in August and September. Iliamna began 2013 at Aviation Color Code and Volcano Alert Level **YELLOW/ ADVISORY**, based on seismicity interpreted to be caused by a magmatic intrusion (Neal and others, 2012). On January 9, 2013, citing decreasing seismicity, AVO downgraded the Aviation Color Code and Volcano Alert Level to **GREEN/ NORMAL**, and Iliamna remained at this level throughout the rest of 2013.

On February 2, 2013, seismic signals indicated that a substantial avalanche had occurred on the eastern flank of Iliamna on the Red Glacier (fig. 3) at 13:58 UTC (4:58 a.m. AKST). This slide was preceded by 3 days of elevated seismicity with more than 40 earthquakes, several as large as ML=3. An hour before the avalanche, small, repeating earthquakes occurred, gradually increasing in rate to merge into a continuous signal. After about 5 minutes of sustained broad-frequency signal, the sequence abruptly ended, signaling the end of the avalanche. This avalanche also produced a signal seen on the infrasound array at Dillingham, Alaska (fig. 1), approximately 320 km (200 mi) southwest of Iliamna. Poor weather obscured views of the volcano, and prevented immediate visual confirmation of the avalanche. AVO mentioned the avalanche in the February 8, 2013 weekly update, noting that avalanches are common at Iliamna, and are not indicative of volcanic unrest. Later in February, AVO received visual confirmation of the avalanches when a local resident sent photographs from early February, showing the avalanche deposits on the Red Glacier (fig. 4).

On April 18, AVO scientists conducted a gas-measurement flight to Iliamna. During this flight, they detected emissions slightly greater than Iliamna's long-term background values (C. Werner, U.S. Geological Survey, written commun., 2013). Iliamna's typical fumaroles were visible and documented by AVO observers on the gas-measurement flight.

On July 24, a citizen observer used the "Is Ash Falling?" notification system (http://www.avo.alaska.edu/ashfall/ashreport.php, accessed January 1, 2015) on AVO's Web site to report "increased" steaming without ash on Iliamna's eastern flank during the evenings of the week of July 15. AVO noted no anomalous seismicity or evidence of increased steaming in satellite data. When Iliamna is backlit in the evening hours, as viewed from the Kenai Peninsula, its normal fumarolic plume often appears more prominent.

During August and September, AVO improved and upgraded geophysical equipment at Iliamna. Two new broadband seismometers were installed at pre-existing station sites ILW and IVE with a Web camera at site IVE.

Satellite data from August 25 showed two modest avalanches down the northern-northeastern flank of Iliamna. On September 20, AVO received photographs of a new, significant, eastern flank avalanche at Iliamna (fig. 5). AVO had incomplete seismic data through September and AVO was not able to find evidence of the event in the existing seismic data. As determined in satellite imagery, the avalanche had a headwall scarp measuring 300 m (980 ft) wide by 40 m (130 ft) tall; source-to-terminus, the feature was about 1,200 m (3,940 ft) long.

A photograph taken by a local resident on November 5 clearly depicts a flow feature on the eastern flank of Iliamna (fig. 6). A review of seismic records revealed a landslide at 16:32 UTC (7:32 AKST) on November 5. Careful analysis of seismic data on November 5 and 6 suggests two additional smaller avalanches after the larger one, although we do not have further photographic confirmation.

Iliamna Volcano is a glacier-carved stratovolcano located approximately 215 km (134 mi) southwest of Anchorage on the western side of the lower Cook Inlet. Although no historical eruptions are known, geologic studies document late Holocene explosive activity as well as repeated, significant mass wasting of the steep, hydrothermally altered edifice (Waythomas and Miller, 1999). Fumaroles located at about 2,740 m (8,990 ft) elevation on the eastern flank produce nearly constant plumes of steam condensate and volcanic gas (Werner and others, 2011). In the past two decades, seismic activity suggests at least two magmatic intrusions have occurred (Roman and others, 2004; Prejean and others, 2012).

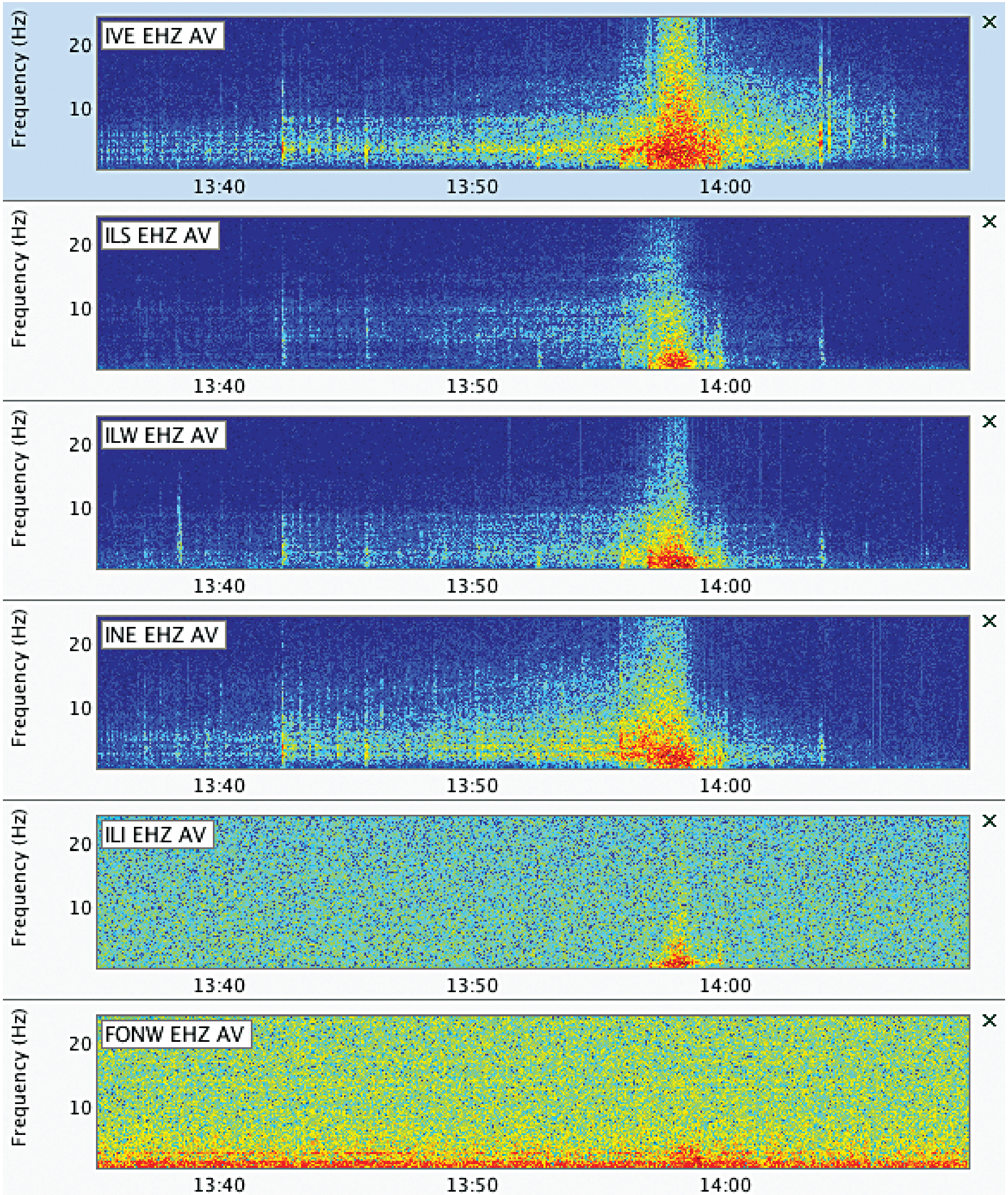

Figure 3. Spectrogram of the avalanche on Iliamna Volcano, 13:58 UTC (4:58 a.m. AKST), February 2, 2013.

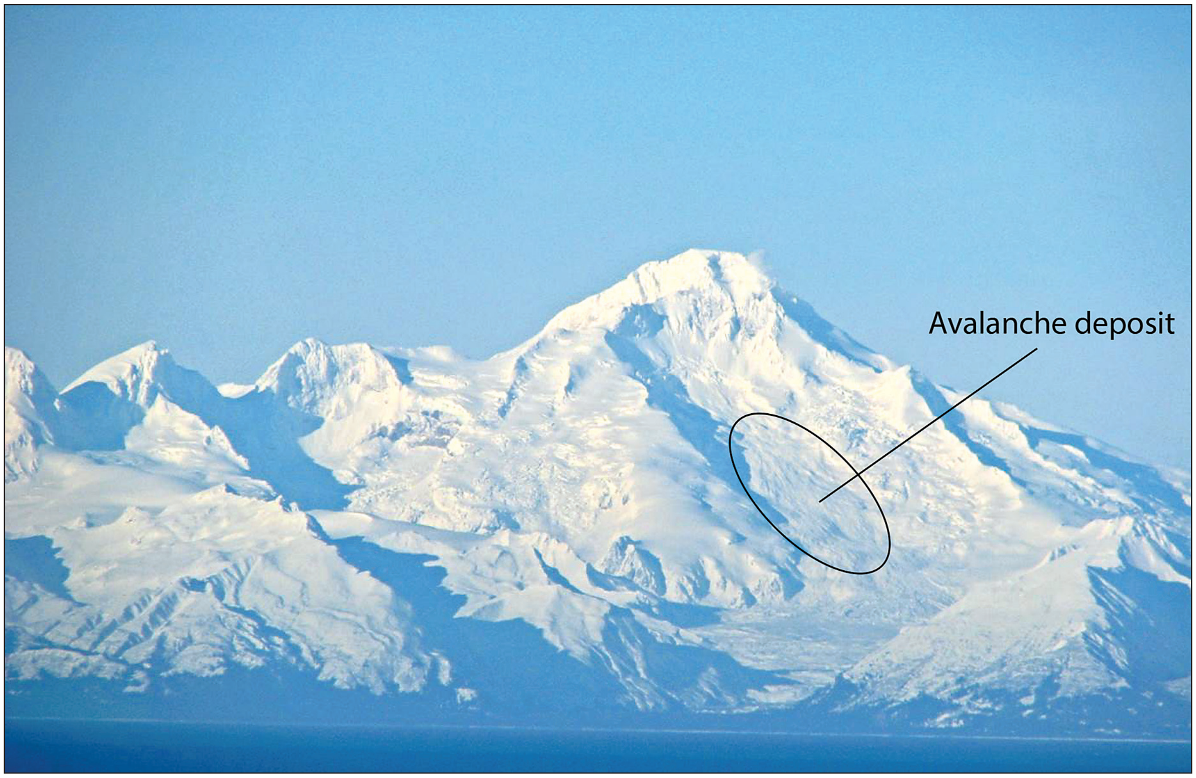

Figure 4. View of eastern flank of Iliamna Volcano from the Kenai Peninsula, February 11, 2013. The location of the February 2 avalanche is shown by the arrow. Photograph by Dennis Anderson, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=47331.

Figure 5. Aerial view of avalanche on eastern flank of Iliamna Volcano, September 20, 2013. Photograph by Stephen Hunter, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=56654.

Figure 6. View of eastern flank of Iliamna Volcano from Kenai Peninsula and the November 5, 2013 avalanche deposit. Photograph by Dennis Anderson, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=57111.

Fourpeaked Volcano

GVP New # 312260

CAVW# 1102-26-

58°46'N 153°40'W
2,104 m (6,903 ft)

Cook Inlet/Alaska Peninsula

SEISMICITY, OBSERVATIONS OF STEAMING

A minor increase in seismicity at Fourpeaked Volcano in April and May prompted additional analysis of monitoring data by AVO. AVO also received a report in May of steaming near Mount Douglas and Fourpeaked. During 2013, the Aviation Color Code and Volcano Alert Level for Fourpeaked remained at **GREEN/NORMAL**.

A ML=4.5 earthquake occurred just west of Fourpeaked at 06:34 UTC (22:34 AKDT) on May 12. The Alaska Earthquake Information Center (AEIC) located this earthquake 15 km (9 mi) west of Fourpeaked and 25 km (16 mi) west-southwest of Mount Douglas at 15 km (9 mi) depth. This earthquake was immediately preceded by two foreshocks. A dozen small earthquakes occurred in this region in the 3 days before the ML=4.5. Another ML=4.5 earthquake occurred near Fourpeaked at 02:33 UTC (18:33 AKDT) on May 14, about 40 hours after the first earthquake. Comparison of the initial waveforms of the earthquake on seismograph station KABU suggests that both earthquakes had the same location and similar focal mechanisms. AVO analysts located 28 earthquakes in the 2 weeks following the second mainshock. It is unknown if this series of earthquakes are volcanic, but no observations of increased volcanic activity were received.

On May 19, a crew of Alaska Department of Fish and Game biologists reported steaming near Mount Douglas and Fourpeaked. AVO followed up on this report, noting that the lake at Mount Douglas froze over in previous years but did not freeze in 2013, which is likely the cause of the isolated report.

Foupeaked is a little known, deeply glaciated stratocone that experienced a phreatic eruption in 2006 (Neal and others, 2009b). AVO is aware of one report of possible increased fumarolic output in the summer of 1965. Although the range of sizes and styles of past eruptions are not well constrained, past eruptions of andesite and dacite indicate that eruptions at Fourpeaked can be explosive, possibly producing plumes that reach in excess of 10 km (33,000 ft) ASL (J. Fierstein, U.S. Geological Survey, oral commun., 2006). Fourpeaked lies within the northeastern corner of Katmai National Park and Preserve on the Alaska Peninsula, 12 km (7.5 mi) southwest of Mount Douglas.

Ugashik-Mount Peulik

GVP New # 312130

CAVW# 1102-13-

57°45'N 156°22'W
1,474 m (4,836 ft)

Alaska Peninsula

SULFUR EMISSION REPORT, NETWORK OUTAGES

AVO received a report of "smoke" or steaming from Mount Peulik in June and August. Network outages that existed at the beginning of the year continued through March. On March 29, the Aviation Color Code and Volcano Alert Level were changed from **GREEN/NORMAL** to **UNASSIGNED**. The network returned to operation as a result of increased solar input during the summer months, and the Aviation and Volcano Alert Level returned to **GREEN/NORMAL** on May 22.

On June 18, AVO received a pilot report of "smoke or steaming emerging from Mount Peulik," but no anomalous activity was noted at the time of the report. On August 12, AVO received a second observation of unusual activity from a long-time guide in the area, reporting "sulfur smell and lack of fish." No similar reports were received and AVO did not investigate further.

Mount Peulik, a small stratovolcano about 10 km (6.2 mi) in diameter at the base, is located just south of Becharof Lake on the Alaska Peninsula, approximately 540 km (325 mi) southwest of Anchorage and 115 km (70 mi) south of King Salmon (fig. 7). The volcano partially covers the northern margin of Ugashik caldera, an older circular structure about 5 km (3.1 mi) in diameter (Miller, 2004). Peulik's summit crater—about 1.5 km (1 mi) in diameter—is breached on the western side.

Figure 7. View of Mount Peulik from Lower Ugashik inlet, January 13, 2006. Photograph by Robert Dreeszen, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php? id=9865.

Aniakchak Volcano

GVP New # 312090

CAVW# 1102-09-

56°54'N 158°13'W
1,341 m (4,400 ft)

Alaska Peninsula

SHORT SEISMIC SWARMS

Sequences of low-frequency events lasting approximately 10 minutes were detected at least 10 times during 2013 at Aniakchak Volcano—January 3, February 4, February 26, March 21, March 26, April 13, April 20, May 3, June 3, and July 4 (fig. 8). These short series of up to a dozen earthquakes compose the majority of events observed beneath the Aniakchak caldera in 2013 and short swarms are commonly seen. On August 3, the AEIC recorded an M 4.7 earthquake 32 km (20 mi) west-northwest of Yantarni volcano and 38 km (23 mi) northeast of Aniakchak. At least 30 aftershocks were detected with magnitudes between 1.7 and 4.3. Although this was considered non-volcanic seismicity, AVO considered the potential for regional seismicity to precede eruptive activity, and decided that this seismicity was not generating signs of volcanic unrest. The Aviation Color Code and Volcano Alert Level for Aniakchak was **GREEN/NORMAL** for all of 2013, although it was downgraded to **UNASSIGNED** in early 2014.

Aniakchak is a circular caldera 10 km (6.2 mi) in diameter and as deep as 1 km (3,280 ft) from the rim to the caldera floor (fig. 9). The caldera formed during a catastrophic eruption of some 75 km^3 (18 mi^3) of material about 3,400 years ago (Miller and Smith, 1987; Dreher and others, 2005; Bacon and others, 2014). Numerous lava domes, lava flows, and scoria cones occupy the interior of the caldera (Neal and others, 2000); the largest intracaldera cone is Vent Mountain, 2.5 km (1.5 mi) in diameter and rising 430 m (1,410 ft) above the floor of the caldera. The only historical eruption of Aniakchak, a powerful explosive event that covered a large part of the eastern Alaska Peninsula with ash, occurred in 1931 (Nicholson and others, 2011). Aniakchak also is notorious for anomalous seismic signals during the adverse weather and icing conditions common during the Alaska Peninsula winters (Neal and others, 2000).

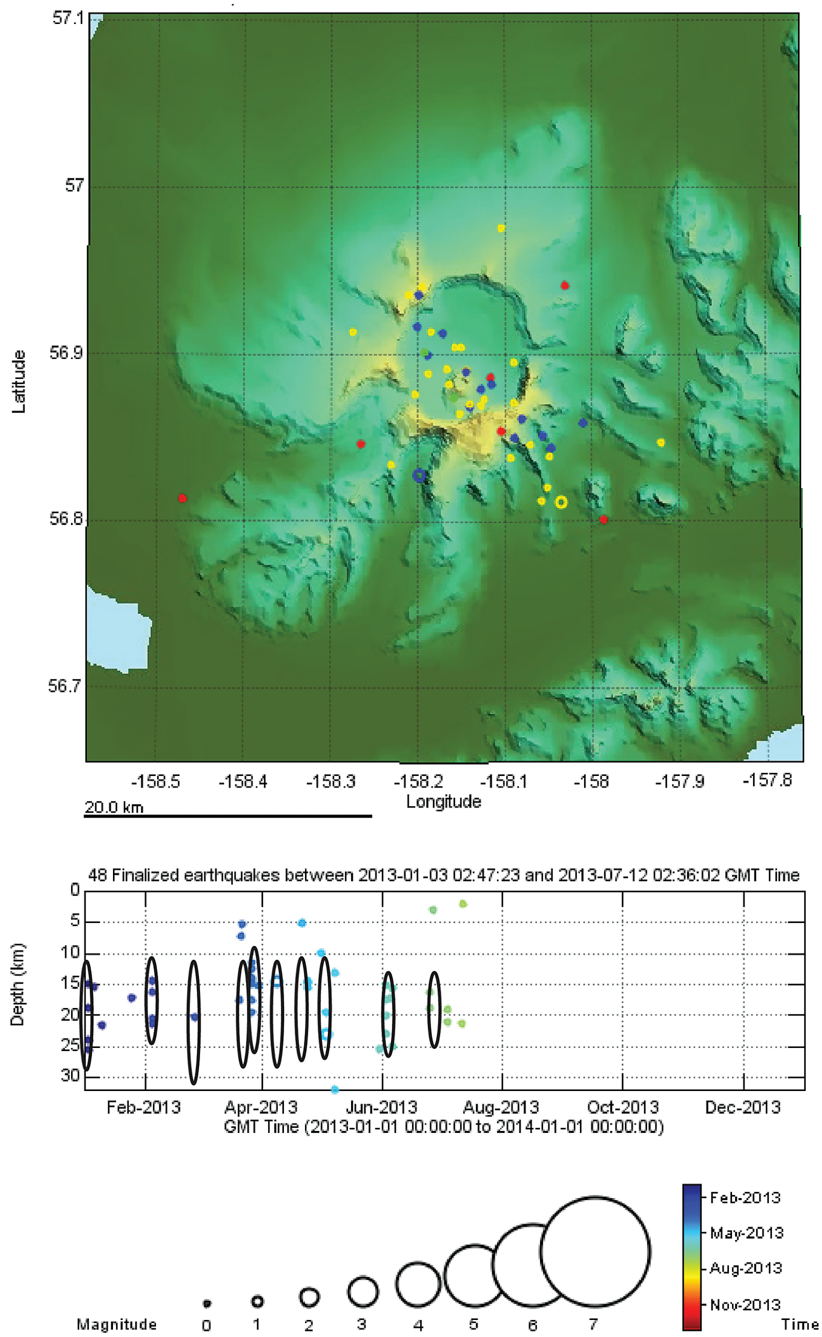

Figure 8. Seismicity at Aniakchak Volcano in 2013. The elongated ellipses show the occurrences of short swarms of deep, low-frequency earthquakes. Earthquake symbols increase in size with increasing earthquake magnitude and the color of the symbols varies with time of the year. Increasing station outages in the last one-half of the year resulted in no swarms reported in internal logs following July 2013.

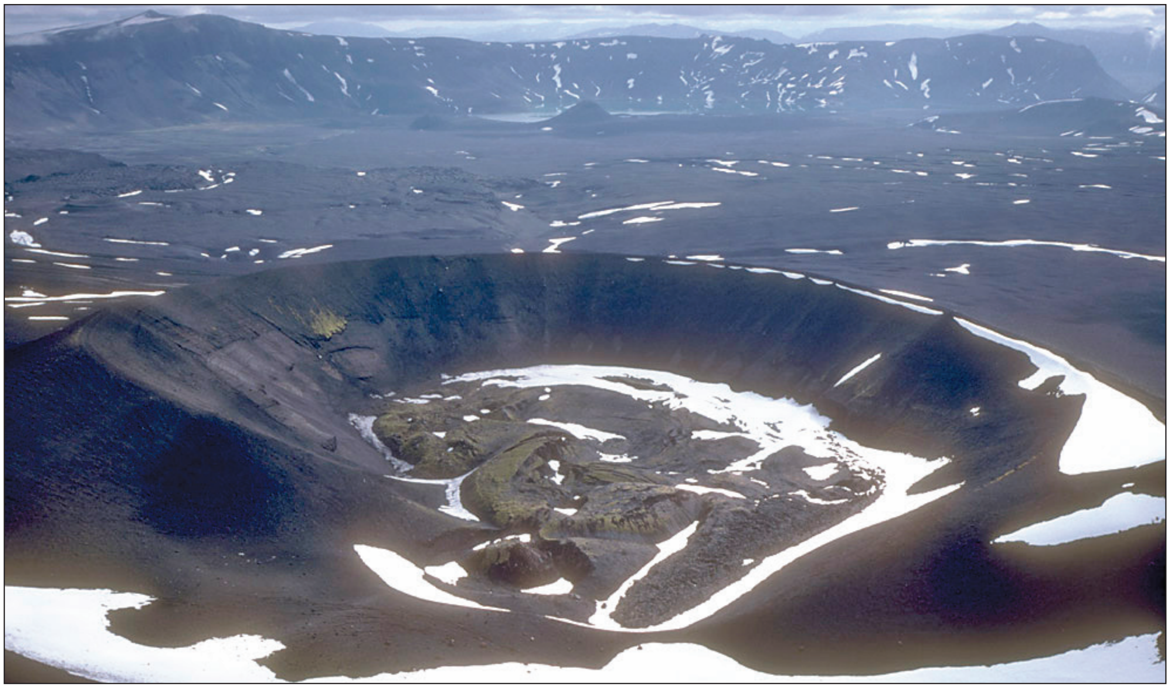

Figure 9. View looking northeast from the Aniakchak Caldera rim on June 30, 1992. This crater, about 600 m (1,970 ft) across, was the site of intermittent explosions of pumice-lithic tephra over the course of several weeks in May and June 1931. During the final phases of the eruption, a small lava flow and spatter field formed in the bottom of the crater. Photograph by Game McGimsey, USGS/AVO. AVO database image URL: http://www.avo.alaska.edu/images/image.php? id=450.

Mount Veniaminof Volcano

GVP New # 312070

CAVW# 1102-07-

56°12'N 159°23'W
2,507 m (8,225 ft)

Alaska Peninsula

EFFUSIVE ERUPTION

Mount Veniaminof Volcano is a frequently active volcano on the Alaska Peninsula (fig. 1). From 2002 through 2010, nearly continuous low-level eruptive activity waxed and waned, producing wispy plumes that were reported by pilots, recorded on satellite images, and observed in images from the Federal Aviation Administration (FAA) Web camera in Perryville, 35 km (22 mi) east of the volcano. Activity ceased during the first one-half of 2013. In early June 2013, a several-day period of abrupt and gradually increasing levels of seismic tremor heralded the onset of a largely effusive eruption from the intracaldera cinder cone (table 6). Over the next 5 months, ash emissions and Strombolian explosions accompanied by five lava flows poured down the flanks of the active cone and advanced onto the surrounding ice-filled caldera. This eruption constructed a new spatter cone within the summit crater of the main active cone (Waythomas, 2013).

On June 7, 2013, gradually increasing, low-frequency tremor was recorded on two seismograph stations (VNWF and VNHG) as satellite images recorded elevated surface temperatures at the summit of the intracaldera cinder cone (fig. 10). The following day, June 8, in response to the continuing increase in seismic tremor, AVO upgraded the Aviation Color Code and Volcano Alert Level from **GREEN/NORMAL** to **YELLOW/ADVISORY**. Over the next several days, seismic tremor steadily increased. On June 13, seismicity levels and elevated surface temperatures at the summit of the cinder cone, as observed in satellite images indicated an eruption was likely underway. AVO issued a Volcanic Activity Notice (VAN) upgrading the Aviation Color Code and Volcano Alert Level from **YELLOW/ADVISORY** to **ORANGE/WATCH**. On June 14, ash deposits on the ice/snow-covered caldera floor were visible in satellite images, and the presence of lava on the cone was observed.

Clear weather provided good views from the FAA Web camera, located in nearby Perryville, as the eruptive activity increased and produced minor ash clouds (fig. 11). Satellite views on June 18 confirmed the Strombolian eruption and effusion of a 100 m (330 ft) wide lava flow (Flow 1; flow numbers refer to those identified in figure 12 down the southwestern flank of the main cinder cone). Interaction of the lava with the caldera snow and ice field at the base of the main cone generated water-rich, ashy plumes (fig. 13). Clear satellite views the following day showed active flow lobes advancing over the ice at the base of the cone (fig. 14).

For the next couple of weeks, the activity continued with the southern flank flows (Flows 1 and 2) advancing and widening, with minor accumulations of ash on the caldera floor (figs. 15 and 25); Flow 2 descended east and adjacent to Flow 1, and Flow 3 advanced between and over the margins of Flows 1 and 2. The Strombolian eruption was visible in infrared satellite imagery, from the FAA Web camera in Perryville, and from several local lodges and remote camps (figs. 16 and 17).

On July 16, AVO geologist Chris Waythomas visited the caldera by helicopter, making observations and taking the first close-up photographs documenting the lava flows and ice cauldron formation (figs. 18 and 19). These close-up images of the vent area showed a new cone of accumulated spatter nested within the summit crater of the main cone.

By late July, the activity appeared to be waning as seismicity decreased, and reached a low level by August 2. In clear satellite views over this period, elevated surface temperatures were consistent with the still cooling, but no longer advancing, lava flow. On August 11, seismic tremor increased abruptly, and very high surface temperatures were observed in satellite images, suggesting that eruptive activity had resumed and lava again was flowing from the summit vent. Nighttime satellite images on August 12 confirmed lava erupting from the cone, and a clear morning view from the Perryville Web camera showed a minor ash column and cloud over the summit cone.

On August 18, AVO geologist Game McGimsey accompanied Ben Edwards, Dickinson University, on a National Geographic Society-sponsored visit to the caldera to document the ongoing activity, particularly the interaction of lava flows and the surrounding ice field. The southern flank lava flows had coalesced and largely melted into the ice, enlarging the ice cauldrons documented in July by Chris Waythomas, USGS/AVO (fig. 20). Steam rose from the margins where the hottest parts of the flows were still in contact with ice and water.

Table 6. Summary of activity and observations at Mount Veniaminof Volcano in 2013.

[**Note:** An important reporting change occurred in May 2013 when AVO analysts stopped reporting the number of pixels with elevated temperatures seen in satellite images. Through May 2013, as a measure of elevated surface temperatures, "number of pixels" reported in parentheses are from an internal Alaska Volcano Observatory (AVO) database of daily satellite observations; this number is a very rough proxy for the intensity of elevated surface temperatures. After May 2013, the presence of elevated surface temperatures are noted with the phrase "Elevated temperatures." Absence of elevated temperature entries may simply mean clouds obscure the ground. **Abbreviations:** ASL, above sea level; ft, foot; km, kilometer; m, meter]

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
06-07-13	GREEN/NORMAL		Elevated temperatures	Increased steam plume, vent slightly hotter than previous month.	Low frequency tremor has begun.
06-08-13	YELLOW/ADVISORY				Gradually increasing seismic tremor.
06-09-13	YELLOW/ADVISORY				Tremor continuing.
06-10-13	YELLOW/ADVISORY			Steam plume from cinder cone.	Tremor amplitude slowly increasing.
06-11-13	YELLOW/ADVISORY				Tremor amplitude slowly increasing.
06-12-13	YELLOW/ADVISORY				Tremor amplitude no longer increasing but remains high.
06-13-13	ORANGE/WATCH	Effusive activity an small explosions.	Elevated temperatures	Dark ash cloud visible from Port Moller, rising 5,000 to 12,000 ft ASL.	Tremor character is indicative of low-level effusive activity and small explosions.
06-14-13	ORANGE/WATCH		Elevated temperatures	Lava observed at the vent with an ash plume as high as 12,000 ft ASL.	Repeating tremor bursts.
06-15-13	ORANGE/WATCH		Elevated temperatures		
06-16-13	ORANGE/WATCH		Elevated temperatures		
06-17-13	ORANGE/Watch		Elevated temperatures	The most intense activity is at the northernmost vent in the intracaldera cone.	
06-18-13	ORANGE/WATCH	Explosions.	Elevated temperatures	Ash clouds were sporadic and reached up to 12,000 ft ASL. The lava flow grew in size, and now extends 500 m (1,600 ft).	
06-19-13	ORANGE/WATCH		Elevated temperatures	Ash plume to 1,000 to 1,500 above peak, moving to the west and changing to a easterly direction when the plume reached 11,000 to 12,000 ft ASL.	Veniaminof network went out.
06-20-13	ORANGE/WATCH		Elevated temperatures		Veniaminof network restored.
06-21-13	ORANGE/WATCH		Elevated temperatures		Discrete tremor events continue.
06-22-13	ORANGE/WATCH		Elevated temperatures		
06-23-13	ORANGE/WATCH		Elevated temperatures		
06-24-13	ORANGE/WATCH		Elevated temperatures	Plume visible on FAA web camera in Perryville from interaction of lava with snow and ice.	
06-25-13	ORANGE/WATCH		Elevated temperatures	Several new lava flows covering the southern flank of the active intracaldera cone. FAA Web camera in Perryville shows whitish plumes rising to just above the rim of the caldera.	

Table 6. Summary of activity and observations at Mount Veniaminof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
06-26-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures	There are three distinct lava flow lobes all extending down the cone from the active vent toward the south-southwest. Incandescence seen in FAA Web camera.	A sequence of infrasonic tremor was recorded in Dillingham.
06-27-13	**ORANGE/WATCH**		Elevated temperatures		
06-28-13	**ORANGE/WATCH**		Elevated temperatures		
06-29-13	**ORANGE/WATCH**		Elevated temperatures		
06-30-13	**ORANGE/WATCH**		Elevated temperatures	Loud rumbling noise heard at Chignak Lake. It is the loudest reported since the start of the eruption.	Seismicity shows tremor with distinct events.
07-01-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures	Lava flows continue, extending about 750 m (2,400 ft) from the vent.	
07-02-13	**ORANGE/WATCH**		Elevated temperatures	First time loud rumbling has been heard in Perryville.	
07-03-13	**ORANGE/WATCH**			Lava is now accumulating on the most recent flow. Incandescence seen from Perryville.	
07-04-13	**ORANGE/WATCH**		Elevated temperatures	Satellite images shows active lava flow on the southern flank of the intracaldera cone.	
07-05-13	**ORANGE/WATCH**		Elevated temperatures		
07-06-13	**ORANGE/WATCH**		Elevated temperatures		
07-08-13	**ORANGE/WATCH**		Elevated temperatures	FAA Web camera showed incandescence from cone in early morning hours. Minor plumes observed.	
07-09-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures	FAA Web camera shows very weak emission of vapor and possibly minor ash. Plume appears contained within caldera. Reports of rumbling from Perryville are loudest to date.	Infrasound has picked up and consists of semi-continuous impulses, consistent with continuous shock waves emitted from the vent.
07-10-13	**ORANGE/WATCH**	Lava in crater.	Elevated temperatures	Steady vapor and weak ash plumes largely within caldera and incandescence in multiple Web camera images.	
07-11-13	**ORANGE/WATCH**	Lava effusion.		Incandescence from intracaldera cone in Web camera overnight.	
07-12-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures	Continued eruption of lava and probably minor ash from summit intracaldera cone.	

Table 6. Summary of activity and observations at Mount Veniaminof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
07-13-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures	Continued eruption of lava and minor ash from intracaldera cone. An extensive, ash-poor plume was observed in mid-IR and visible images extending towards the northwest at an estimated height of 10,000 ft ASL.	
07-14-13	**ORANGE/WATCH**	Lava effusion.	Elevated temperatures		
07-15-13	**ORANGE/WATCH**	Lava effusion.		Active lava effusion continues at the summit and flows down the southern flank of the active cone. Crevasses and cauldrons in the ice field continue to grow in size at the flow termini. A low, small plume appears to contain some ash.	
07-16-13	**ORANGE/WATCH**	Strombolian activity.	Elevated temperatures	A new cone has been constructed by accumulations of splatter within the larger summit crater of the main cone.	
07-17-13	**ORANGE/WATCH**		Elevated temperatures		
07-19-13	**ORANGE/WATCH**		Elevated temperatures		
07-20-13	**ORANGE/WATCH**		Elevated temperatures		
07-21-13	**ORANGE/WATCH**		Elevated temperatures		
07-22-13	**ORANGE/WATCH**		Elevated temperatures		
07-23-13	**ORANGE/WATCH**		Elevated temperatures	Incandescence observed in evening Web camera views from Perryville and daytime images show low-level plume of ash and steam rising to just above the rim of the caldera.	
07-24-13	**ORANGE/WATCH**	New lava flows.		A second spatter vent formed east of the vent that has effused most of the lava to date. This new vent is the source of a lava flow that extends down the northeastern flank of the active cone.	
07-25-13	**ORANGE/WATCH**		Elevated temperatures	Incandescence observed in evening Web camera views from Perryville. Daytime images show low-level plume of ash and steam rising to just above the rim of the caldera that were slightly more robust than usual.	
07-26-13	**ORANGE/WATCH**		Elevated temperatures		
07-27-13	**ORANGE/WATCH**		Elevated temperatures	Report of ash emissions at Veniaminof about 2,000 ft above the cone.	
07-28-13	**ORANGE/WATCH**		Elevated temperatures		Seismicity is decreasing.

Table 6. Summary of activity and observations at Mount Veniaminof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
07-29-13	**ORANGE/WATCH**		Elevated temperatures	Plumes observed below 15,000 ft ASL without any ash signature.	
07-30-13	**ORANGE/WATCH**		Elevated temperatures	No evidence of steam or ash plumes.	
08-02-13	**ORANGE/WATCH**				Tremor that declined over the last few days has begun to pick up again.
08-11-13	**ORANGE/WATCH**	Eruption and lava effusion.		Low-level plume coming from the intracaldera cone seen in Web camera. Renewed lava extrusion.	Seismic tremor has increased on local subnet. Infrasonic signals were recorded on the Dillingham array.
08-12-13	**ORANGE/WATCH**	Lava effusion.		Ash cloud viewed in FAA Web camera.	The tremor bursts are back and occasionally they are relatively strong.
08-13-13	**ORANGE/WATCH**		Elevated temperatures		
08-18-13	**ORANGE/WATCH**	Strombolian activity.		Observed low-level Strombolian activity, and low-level ash emission. Lava stream flowing.	
08-19-13	**ORANGE/WATCH**			Reports of ‘feeling explosions and tremors’ were received.	
08-20-13	**ORANGE/WATCH**			Web camera views show a slightly more robust ash plume.	
08-27-13	**ORANGE/WATCH**			Web camera images from Perryville show a slightly more robust plume, up to 12,000 ft ASL, heading toward the east beyond the caldera rim.	
08-29-13	**ORANGE/WATCH**			Ice pits at the toe of the eastern flows continue to deepen and widen.	
08-30-13	**ORANGE/WATCH**	Strombolian activity.		Lava fountaining, and ash emissions to 15,000 to 20,000 ft ASL. Ash fell on Perryville.	Intense seismicity recorded.
09-01-13	**ORANGE/WATCH**	Strombolian activity.		Ash fall in Chignak Lake, volcano continues to erupt with plumes up to 15,000 ft ASL.	
09-02-13	**ORANGE/WATCH**			Ash cloud to 12,000 ft ASL.	Eruption signals seen on seismic channels.
09-03-13	**ORANGE/WATCH**				Eruption signals seen on seismic channels.
09-04-13	**ORANGE/WATCH**				Eruption signals seen on seismic channels.
09-06-13	**ORANGE/WATCH**			Further development of northeastern lava flow with new flow advancing down the southeastern flank onto the ice field.	

Table 6. Summary of activity and observations at Mount Veniaminof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
09-07-13	ORANGE/WATCH	New lava flows.		Clear views show two plumes, one to the west associated with low-level ash emission and one to the east that is steam rising off to the east.	
09-11-13	ORANGE/WATCH			New satellite views show a narrow southeastern lava flow extended beyond the wide terminus seen last week.	
09-19-13	ORANGE/WATCH			No change in lava flow area or ice deformation compared to the previous week.	
09-20-13	YELLOW/ADVISORY			No evidence of eruptive activity observed in satellite and Web camera imagery over the past week.	Based on a decline in seismic activity.
10-01-13	YELLOW/ADVISORY			Photographs show cone and new lava plows partially covered by snow. Minor steam emissions from the summit event.	
10-04-13	YELLOW/ADVISORY				Low levels of seismicity continue.
10-06-13	ORANGE/WATCH	Eruption resumed.		The eruption of Veniaminof resumed this morning. Highly elevated surface temperatures were observed in satellite images this morning.	Seismic tremor increased with resumption of the eruption.
10-07-13	ORANGE/WATCH		Elevated temperatures		
10-09-13	ORANGE/WATCH			Citizen in Kujulik Bay, 100 km northeast of Veniaminof, could hear and feel the eruption.	
10-10-13	ORANGE/WATCH				Some signals are clearly correlated with reports of rumbling.
10-11-13	ORANGE/WATCH		Elevated temperatures	The volcano has been sputtering and booming for the last 3 days with ash at Chignik Lake.	
10-14-13	ORANGE/WATCH			MIR data show the lava effusion has paused.	
10-17-13	YELLOW/ADVISORY			Satellite observations shows the eruption has paused.	Seismic activity has decreased over the past week.

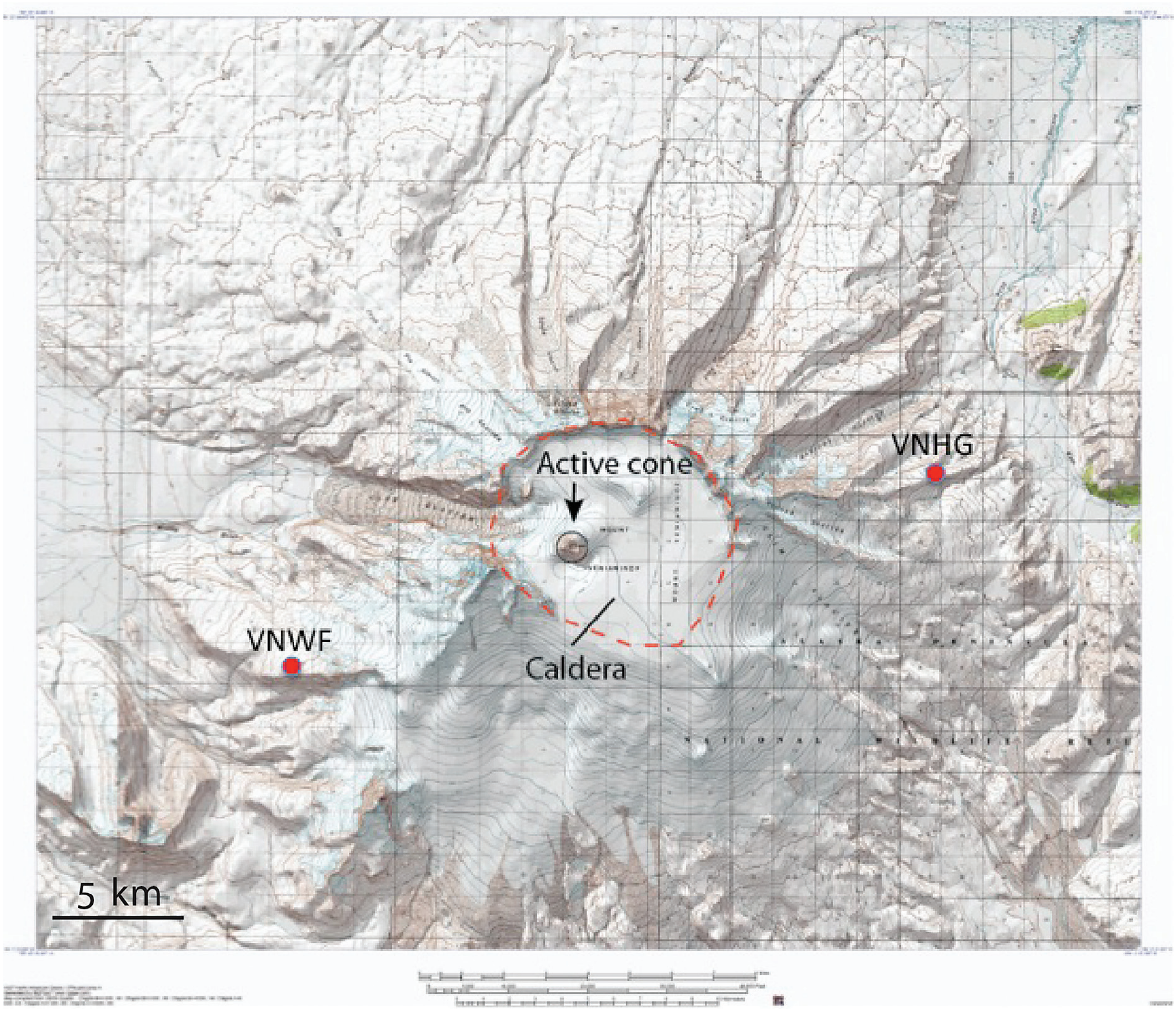

Figure 10. Topographic map of Mount Veniaminof Volcano showing margin of the caldera (red dashed line) and the active cone within the caldera (black circle). Seismic stations VNWF and VNHG were the most fully operable of the network in June 2013. The eruption that began in early June produced a small lava flow (less than 0.8 km (0.5 mi) long as of June 18) down the southwestern flank of the active intracaldera cinder cone. Veniaminof caldera is 10 km (6 mi) in diameter. Image courtesy of AVO/UAFGI, June 19, 2013. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=50831 nu=0.

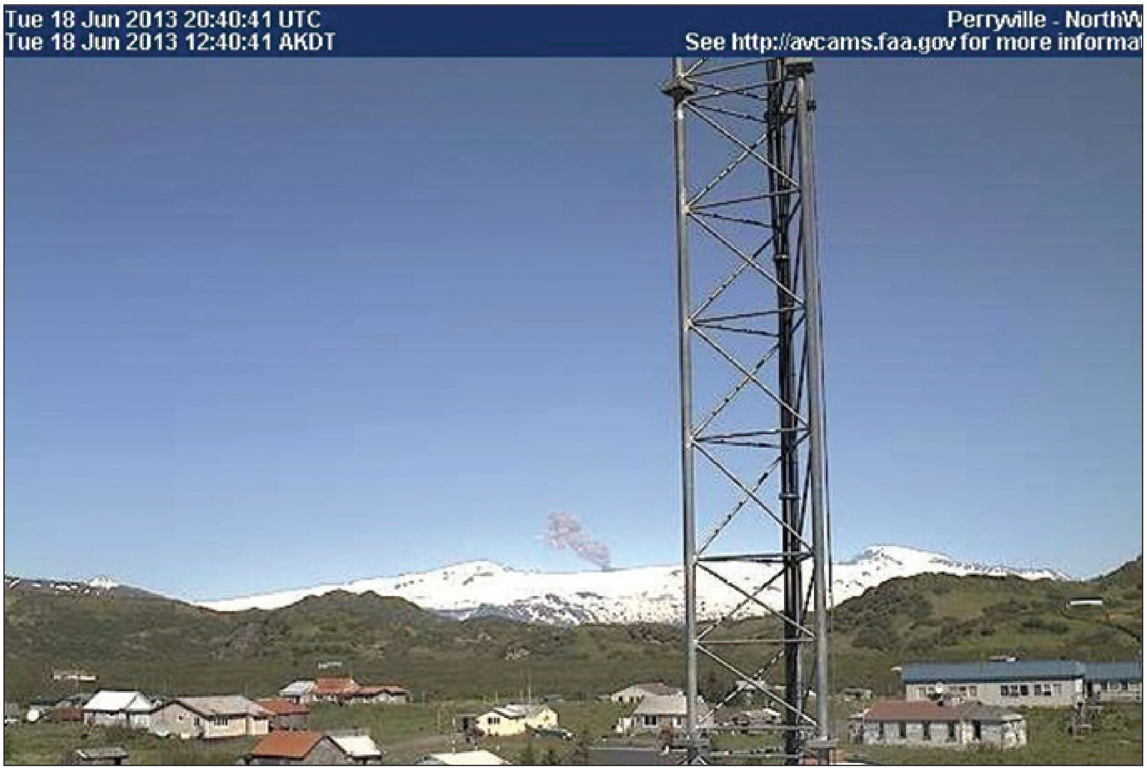

Figure 11. Web camera image of ash emission from active cone of Mount Veniaminof Volcano, as seen from the FAA Perryville northwest Web camera, June 18, 2013. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=50801.

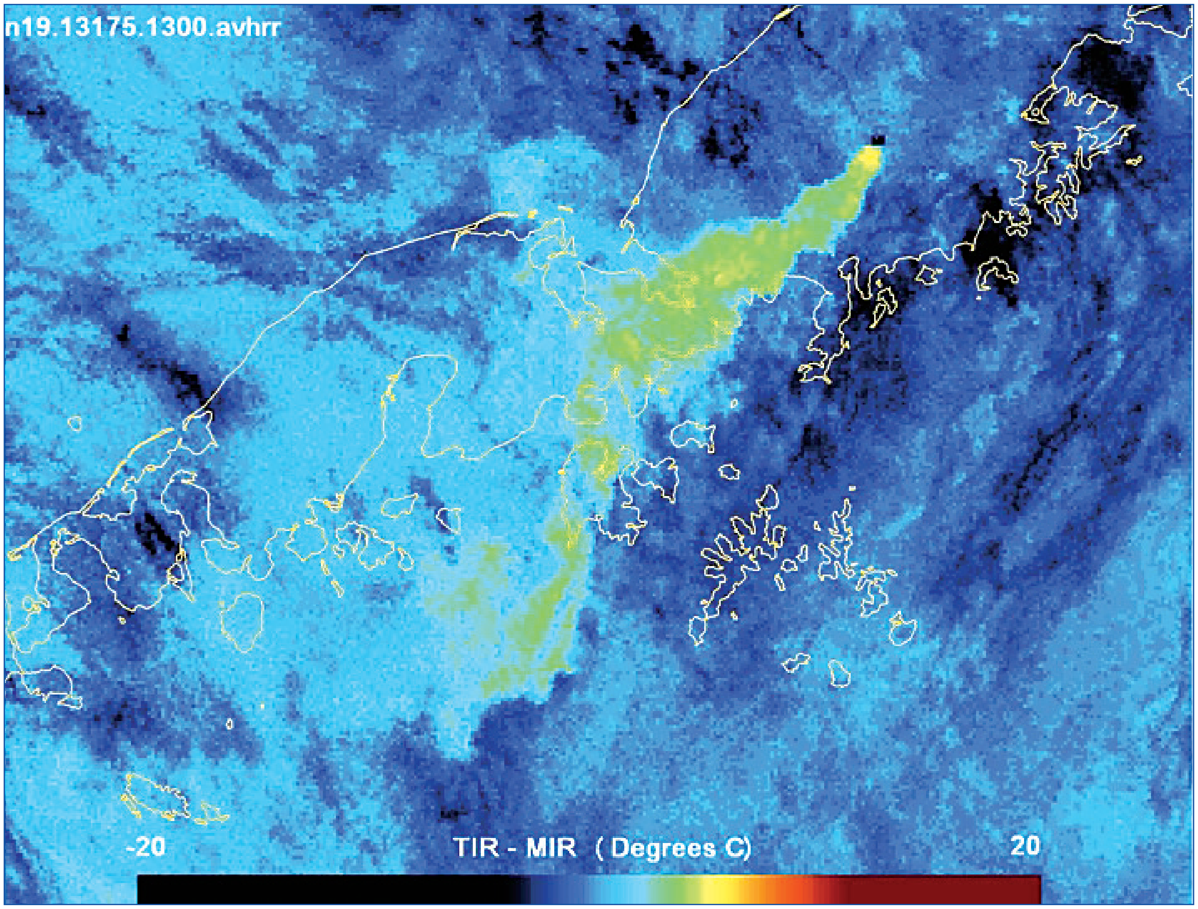

Figure 12. Nighttime AVHRR thermal-IR minus mid-IR enhancement image showing an extensive, water-rich plume emanating from the intracaldera cinder cone of Mount Veniaminof Volcano at 13:00 UTC (05:00 AKDT) on June 24, 2013. The plume likely results from lava interacting with snow and ice and is mainly steam, but may have contained minor ash. Image courtesy Dave Schneider, USGS/AVO. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=66601.

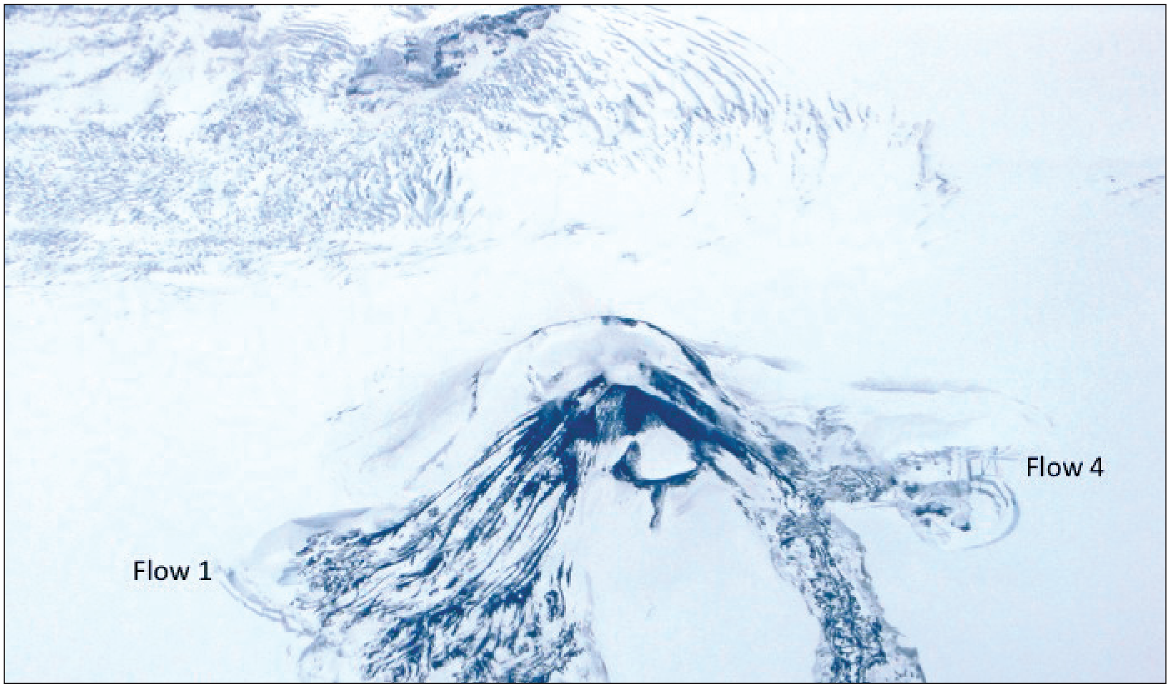

Figure 13. Aerial view of active cone of Mount Veiaminof Volcano, October 1, 2013. The new lava flows are partially covered by snow. Flows are numbered 1 to 5 in order of when they formed. Photograph courtesy of Ryan Hazen and Todd Mueller, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=57057.

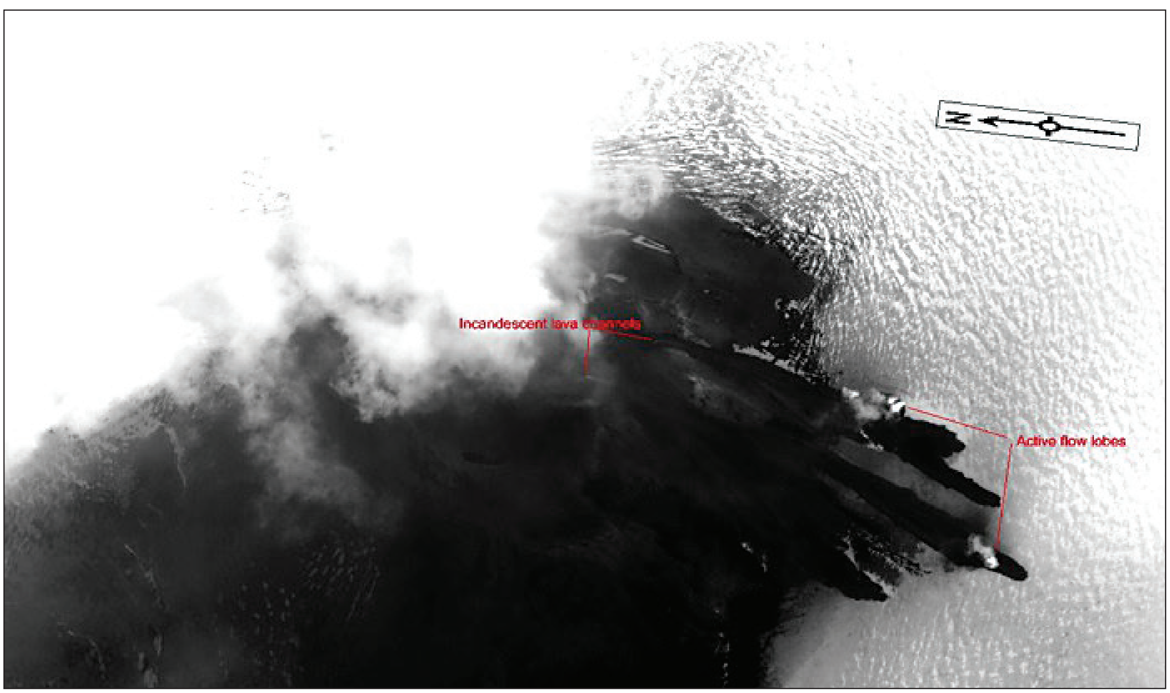

Figure 14. High-resolution satellite view (Digital Globe™ WorldView 1) showing several new lava flow-lobes extending down the southern flank of the active intracaldera cone in Veniaminof caldera, June 25, 2013. The longest flow-lobe in this view is about 750 meters (2,460 feet) from the incandescent summit to the toe of the flow on the ice field. Dark ash covers much of the northwestern flank of the cone and the ice field. Image courtesy Rick Wessels, USGS/AVO, and Digital Globe, Inc.™. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=51071.

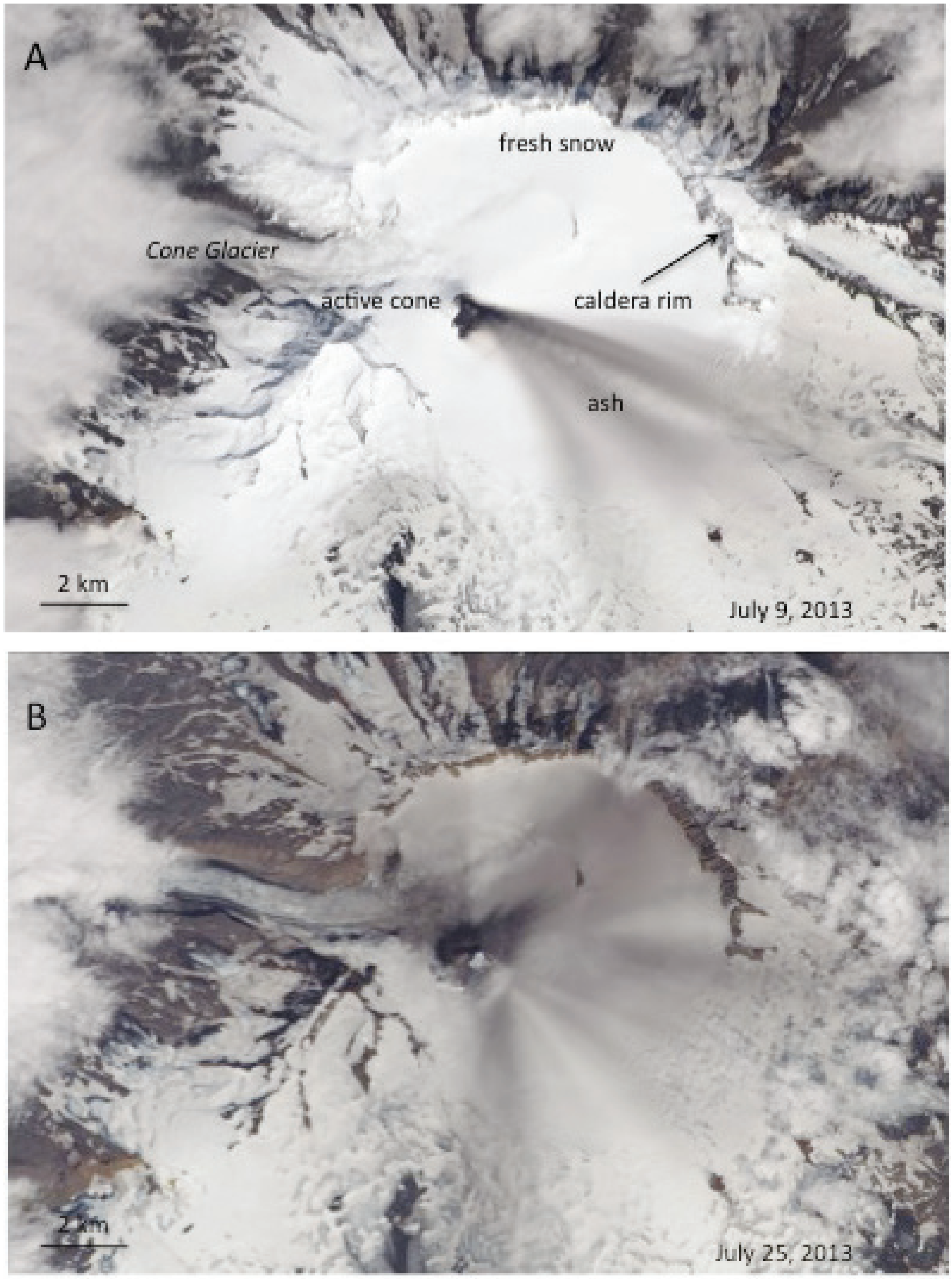

Figure 15. Natural color Landsat 8 data from the USGS Earth Explorer satellite. Image A was acquired on July 9, 2013. Image B was acquired on July 25, 2013. Both images show radial pattern of ash deposition from emissions at the active cone. Images courtesy Dave Schneider, USGS/AVO.

Figure 16. Telephoto view of erupting Mount Veniaminof Volcano, July 9, 2013. Photograph was taken from the Sandy River about 20 miles west of the volcano. Bright orange incandescence indicates a burst of lava (lava fountaining) from the vent hidden from view within a crater atop the cinder cone. The burst produces a small cloud of ash and lapilli, which typically falls out within a few kilometers of the vent. At times, the eruption has been characterized by closely spaced bursts that produce 'puffs' of ash. During the daytime, the incandescence is more difficult to see (bright orange glow). Photograph by William Jasper, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=56303.

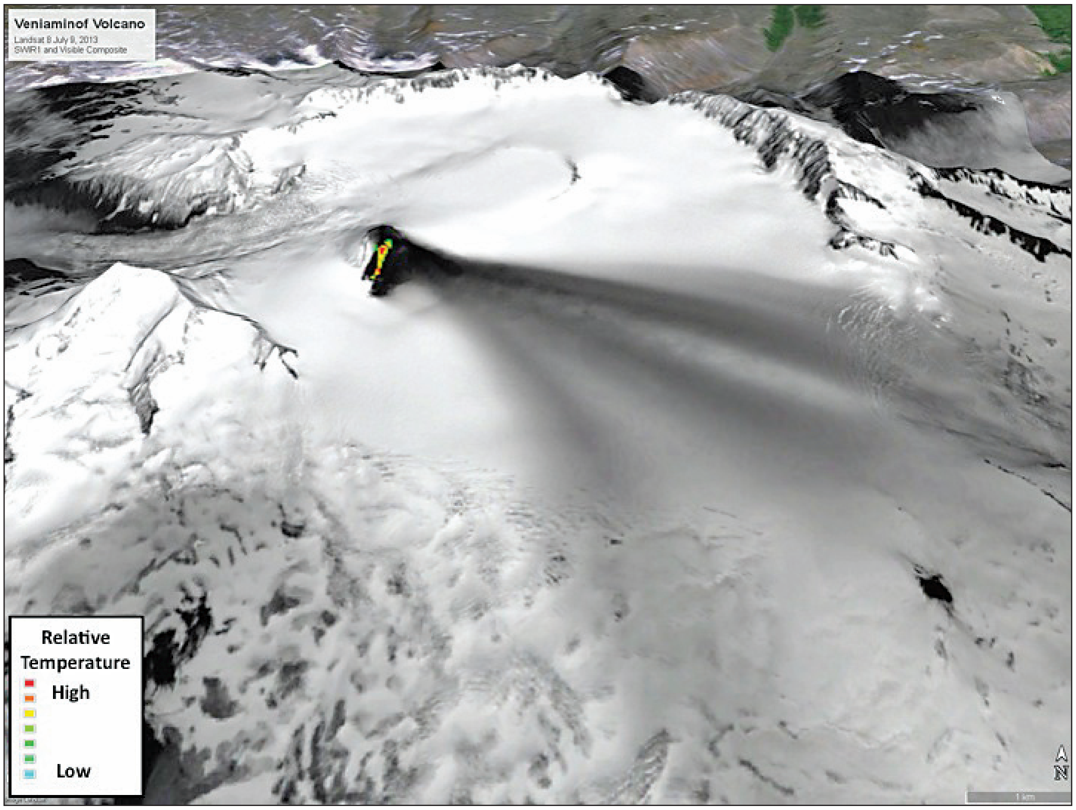

Figure 17. Composite Landsat 8 satellite image of Mount Veniaminof Volcano collected on July 9, 2013. This image is a composite of the short-wave infrared data (to show thermal emissions from the active lava flow) overlain onto an oblique visible wavelength image. The active lava flow is shown in shades of yellow and orange, and extends southward from the vent. Thin deposits of volcanic ash are seen on the snow and ice as radial spokes that form when ash is emitted under changing wind direction. Image courtesy Dave Schneider, USGS/AVO.

Figure 18. Photograph of low-level explosive burst of ash and spatter at the new cone within the summit crater of the main intracaldera cone of Mount Veniaminof Volcano, July 16, 2013. View is toward the southeast. Photograph by Chris Waythomas, USGS/AVO, July 16, 2013. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=51291.

Figure 19. Photograph of southwestern flank of the intracaldera cone at Mount Veniaminof Volcano showing lava flows emplaced during eruptive activity in June–July 2013. View is toward the east. These flows appear similar to the lava flows produced during the 1993 eruption. Photograph by Chris Waythomas, AVO/USGS, July 16, 2013. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=51301.

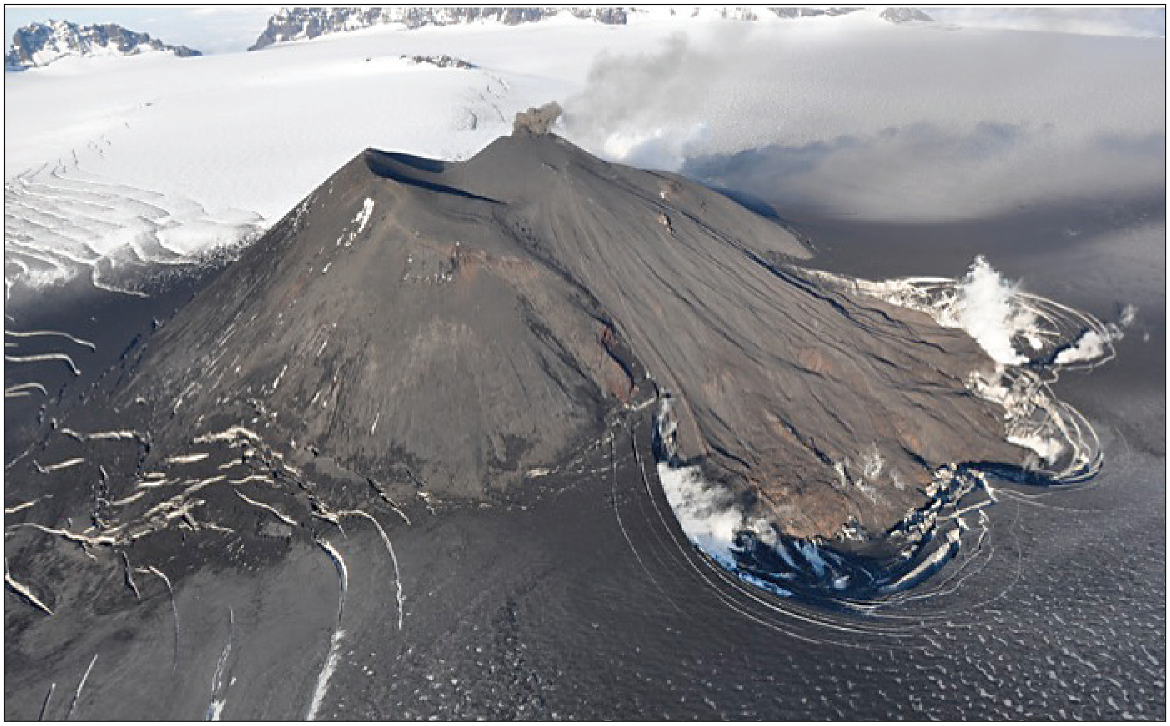

Figure 20. A small puff of ash emerges from the active cone inside Mount Veniaminof Volcano caldera on August 18, 2013. A fan of lava flows active earlier in the summer descends the southern flank of the cone onto glacial ice, producing white steam clouds and depressions where melting has occurred. The surrounding glacier is darkened by recent ash fall. Photograph by Game McGimsey, USGS/AVO. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=55761.

Strombolian explosions of incandescent lava and minor ash emissions were observed at the central active vent on August 18 (fig. 21). Two new lava flows issued either from tubes emerging from accumulations of spatter near the vent rim on the northeastern flank of the new cone, or from vents through the base of that cone. The flows descended to the ice field below, coalescing and forming another ice cauldron (fig. 22); forming Flow 4 (Waythomas, 2013). Voluminous steam generated by interactions of lava and ice/water obscured views into the cauldron. Forward Looking Infrared Radiometer (FLIR) images delineated the lava flows and hot spatter on the cone (fig. 22). As measured by the FLIR, maximum temperatures reached 700° to 800 °C.

Elongated lobes of sediment extended from the southern side of the ice cauldron, forerunners to the fifth and final lava flow of the eruption (figs. 23 and 24). Eruptive activity continued unabated for the next 12 days, and on August 30, AVO issued a VAN to report the intense seismicity, lava fountaining, and ash emissions as high as 15,000–20,000 ft (4,570–6,100 m) ASL. This marked the strongest unrest and eruptive activity since the eruption began in June. Satellite images on September 6 indicated further development of the lava flows on the northeastern flank (Flow 4), expansion of the main ice cauldron at its base, and creation of a second ice cauldron. A new lobe of the lava flow (Flow 5) also appeared in the satellite images, advancing southward from the main cauldron of Flow 4. The flow was captured in aerial photographs the following day (fig. 24). This flow continued to advance for possibly another week, but, by September 19, no evidence of active lava flows was observed in satellite images. Seismicity had begun to decrease during the week and the eruption appeared to be waning.

In response to the decrease in seismicity, and no evidence of eruptive activity in satellite and Web camera images, AVO issued a VAN on September 20 to downgrade the Aviation Color Code and Volcano Alert Level from **ORANGE/WATCH** to **YELLOW/ADVISORY**. An October 1 aerial image shows all five lava flows, partially snow covered, and only minor steam emissions from the summit vent (fig. 13).

Figure 21. Images of eruptive activity at the intracaldera cinder cone of Mount Veniaminof Volcano on August 18, 2013. Strombolian explosions hurl lava bombs, spatter, and ash skyward as lava pours from an upper northeastern-flank vent, feeding a flow that descends to the ice-covered caldera floor; the lava flow in image D either is venting from a tube within spatter, or is flowing through at the contact of the new spatter cone and older-cone summit crater. All photographs by Game McGimsey, USGS/AVO. AVO database image URLs: A, http://www.avo.alaska.edu/images/image.php?id=66501; B, http://www.avo.alaska.edu/images/image.php?id=66511: C, http://www.avo.alaska.edu/images/image.php?id=66521; and D, http://www.avo.alaska.edu/images/image.php?id=66531.

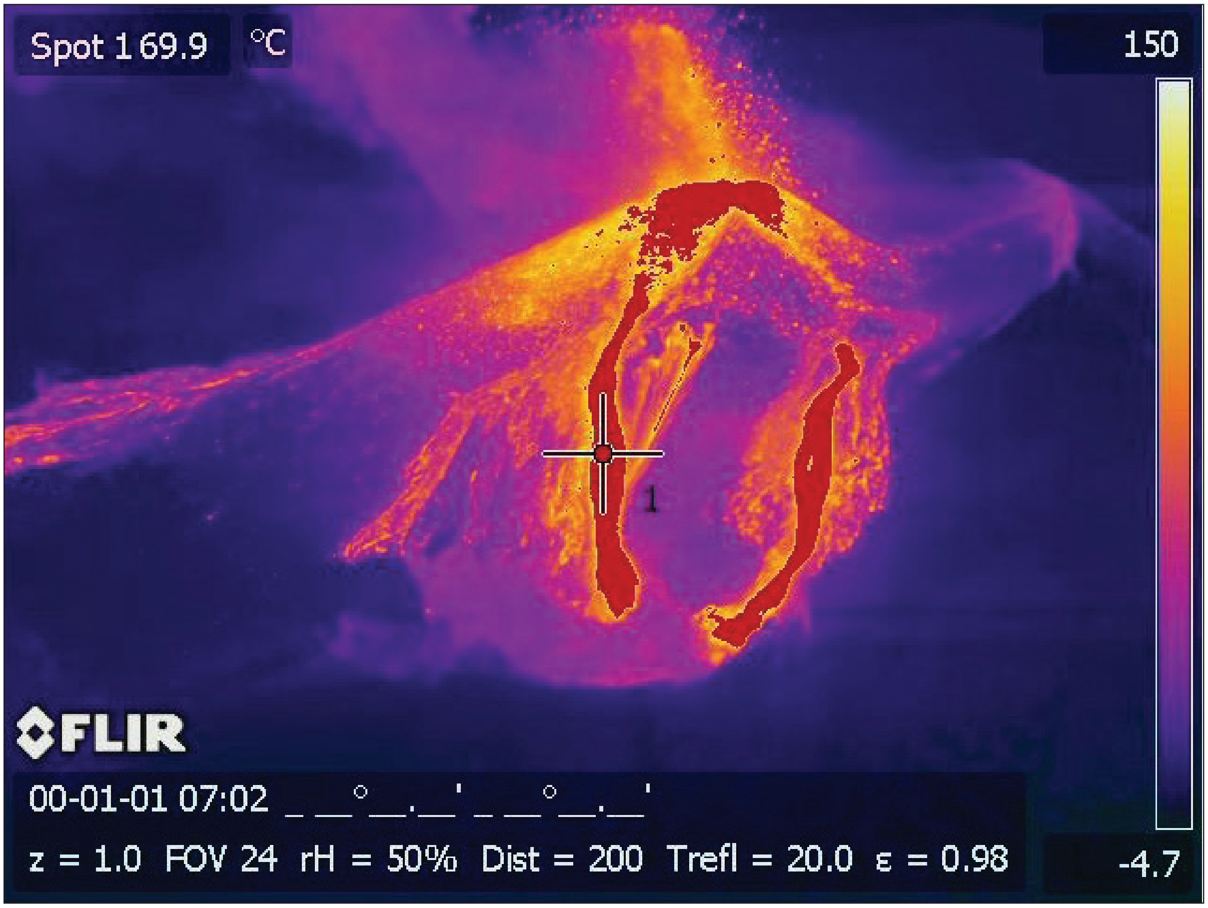

Figure 22. Forward Looking Infrared Radiometer (FLIR) image of the erupting intracaldera cone of Mount Veniaminof Volcano on August 18, 2013. In this oversaturated image (due to low thermal imagery setting), the active lava flows (hottest) are red and the lava fountaining at the summit is easily visible. These lava flows are on the northeastern flank of the cone. FLIR image by Game McGimsey, USGS/AVO. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=57831.

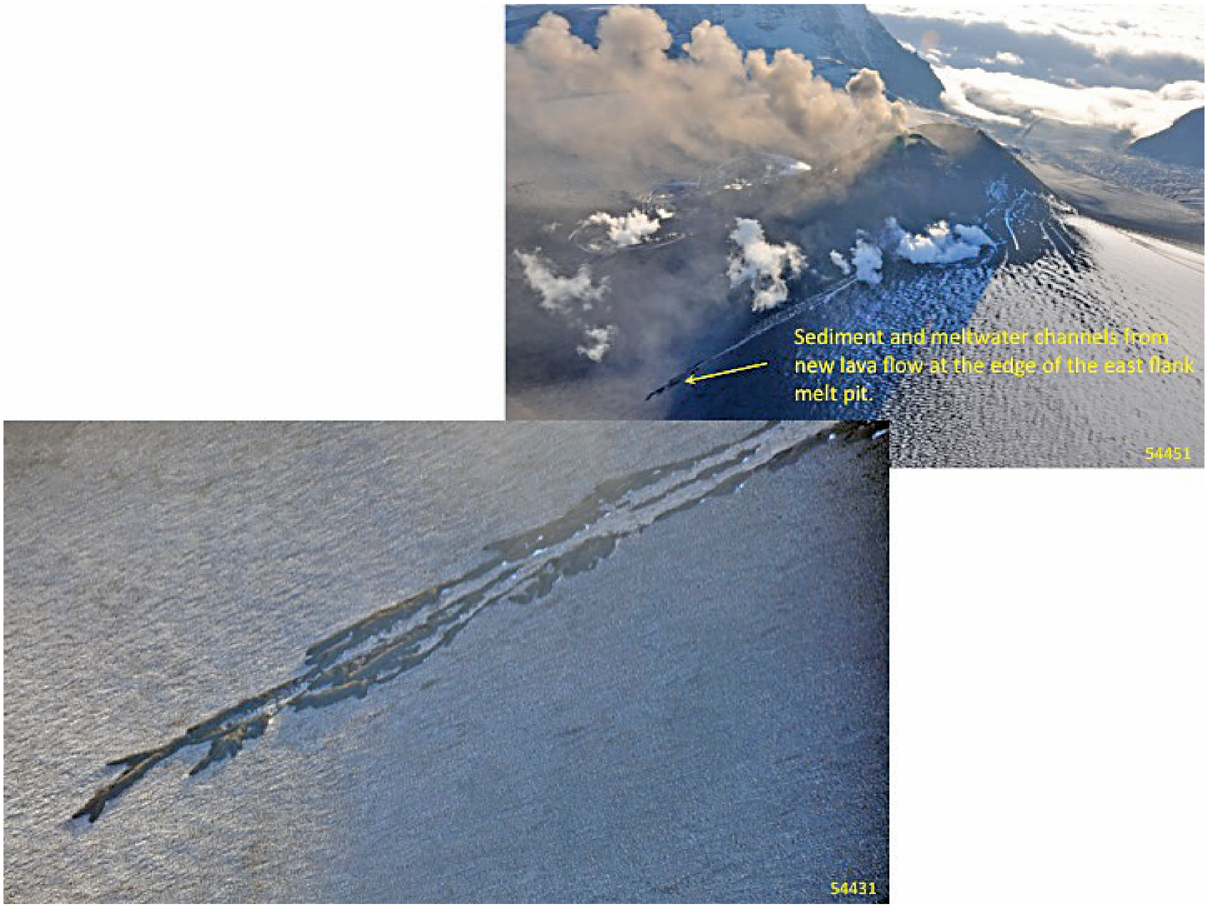

Figure 23. Photographs of sediment lobes advancing from the southern side of the ice cauldron on the northeastern flank of the Mount Veniaminof Volcano, August 18, 2013. Bottom image is zoomed-in view of the distal end of sediment and melt-water channels produced by the new lava flow at the southern edge of the melt pit shown in upper image. These channels and sediment deposits were not “hot” in Forward Looking Infrared Radiometer (FLIR) images; however, these are the forerunners of the third and final lava flow to form from this eruption. Photographs by Game McGimsey, USGS/AVO. AVO database image URLs: Top image, http://www.avo.alaska.edu/images/image.php?id=54451; bottom image, http://www.avo.alaska.edu/images/image.php?id=54431.

Figure 24. Aerial view of Mount Veniaminof Volcano erupting on September 7, 2013. Note the white water vapor clouds indicating that hot lava is interacting with snow and ice. A gray-brown ash column rises from the active vent. The advancing flows in foreground are on the southeastern flank of the cone and were the last flows emplaced in the 2013 eruption. The summit ice field is darkened with recent ash fall. Photograph by Joyce Alto, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=56424.

On October 6, an abrupt increase in seismic tremor and the observation of highly elevated surface temperature indicated a resumption of lava effusion, and AVO responded by upgrading the Aviation Color Code and Volcano Alert Level to **ORANGE/WARNING**. No ash emissions were observed, and within a few days, seismicity began decreasing in what would be a downward trend coincident with the final end of eruptive activity in 2013. The Aviation Color Code and Volcano Alert Level were downgraded on October 17 to **YELLOW/ADVISORY**. Throughout the remainder of 2013, occasional elevated surface temperatures were observed in satellite images consistent with the cooling lava flows, and steam emission from the summit vent was visible on clear days in Web camera images.

The 2013 eruption of Veniaminof produced about 5 × 105 m^3 of erupted lava, comparable in size to the 1983 eruption (Waythomas, 2013). A real-time seismic amplitude (RSAM) time series (Endo and Murray, 1991) from seismic station VNWF (fig. 11) is shown in figure 25 for the 5-month-long eruption, including significant eruptive events and color code changes (Waythomas, 2013). Before- and after-eruption views of the intracaldera cinder cone and geomorphic changes produced by the 2013 eruption are shown in figures 26 and 27.

Veniaminof, an ice-clad, about 350-km^3 (about 84-mi^3) andesitic stratovolcano, is one of the largest and most active volcanoes of the Aleutian Arc (Miller and others, 1998; Bacon and others, 2007). Located 775 km (482 mi) southwest of Anchorage and 35 km (22 mi) north of Perryville (fig. 1), the summit comprises an ice-filled, 10-km (6.2-mi) diameter caldera. Two Holocene caldera-forming eruptions are recorded in extensive pyroclastic-flow deposits around the volcano (Miller and Smith, 1987). Veniaminof has had at least 14 eruptions in the past 200 years, all from the approximately 300-m-high (984-ft-high) intracaldera cone. The last significant magmatic eruption prior to 2013 occurred during 1993–95 (Neal and others, 1995; McGimsey and Neal, 1996; Neal and others, 1996). This eruption was characterized by intermittent, low-level emissions of steam and ash, and production of a small lava flow that melted a pit at the base of the cone in the caldera-ice field, similar to the prior effusive eruption of 1983 (Yount and others, 1985). During some of the significant historical eruptions, such as during 1983–84, ash plumes reached about 7,600 m (about 25,000 ft) ASL and produced ash fallout within about 40 km (about 25 mi) of the volcano.

Recent eruptions of Veniaminof Volcano are characterized by brief bursts of ash emission, small explosions, and occasional lava emissions. Ash plumes associated with this type of activity typically are diffuse and generally do not reach more than 20,000 ft ASL. Ash fallout typically is limited to the flanks of the volcano. Minor emissions of steam and ash may persist for weeks to months. The last episode of more energetic activity occurred during 1993–95, when an ash plume rose to about 18,000 ft ASL and small lava flows poured onto glacier ice around the intracaldera cone.

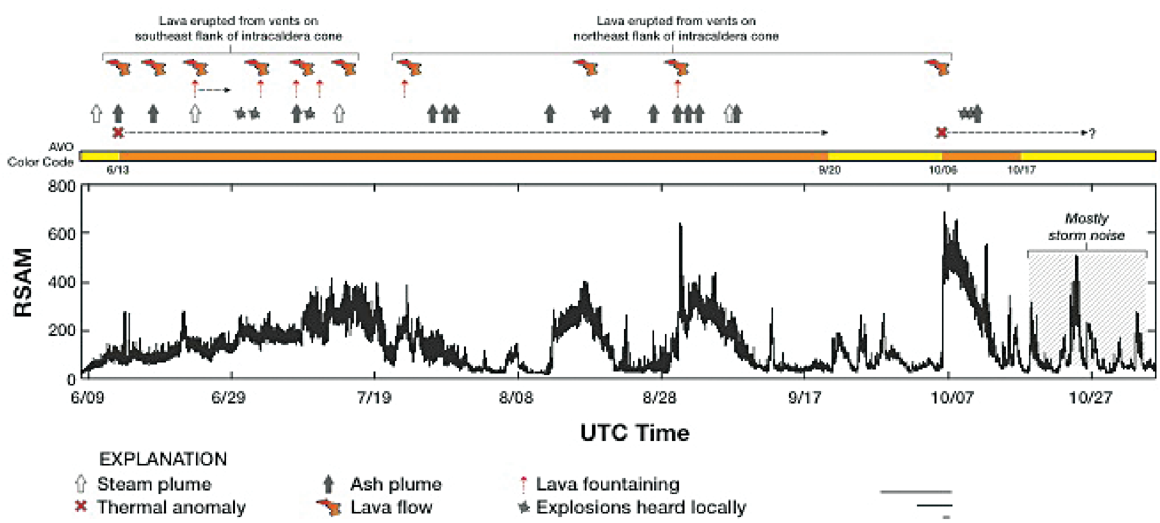

Figure 25. Real-time seismic amplitude (RSAM) time series from seismic station VNWF (located on the lower southwestern flank of Mount Veniaminof Volcano; see fig. 11), and significant eruptive events from June 13 to October 17, 2013. The AVO Aviation Color Code during the eruption also is shown (Gardner and Guffanti, 2006).

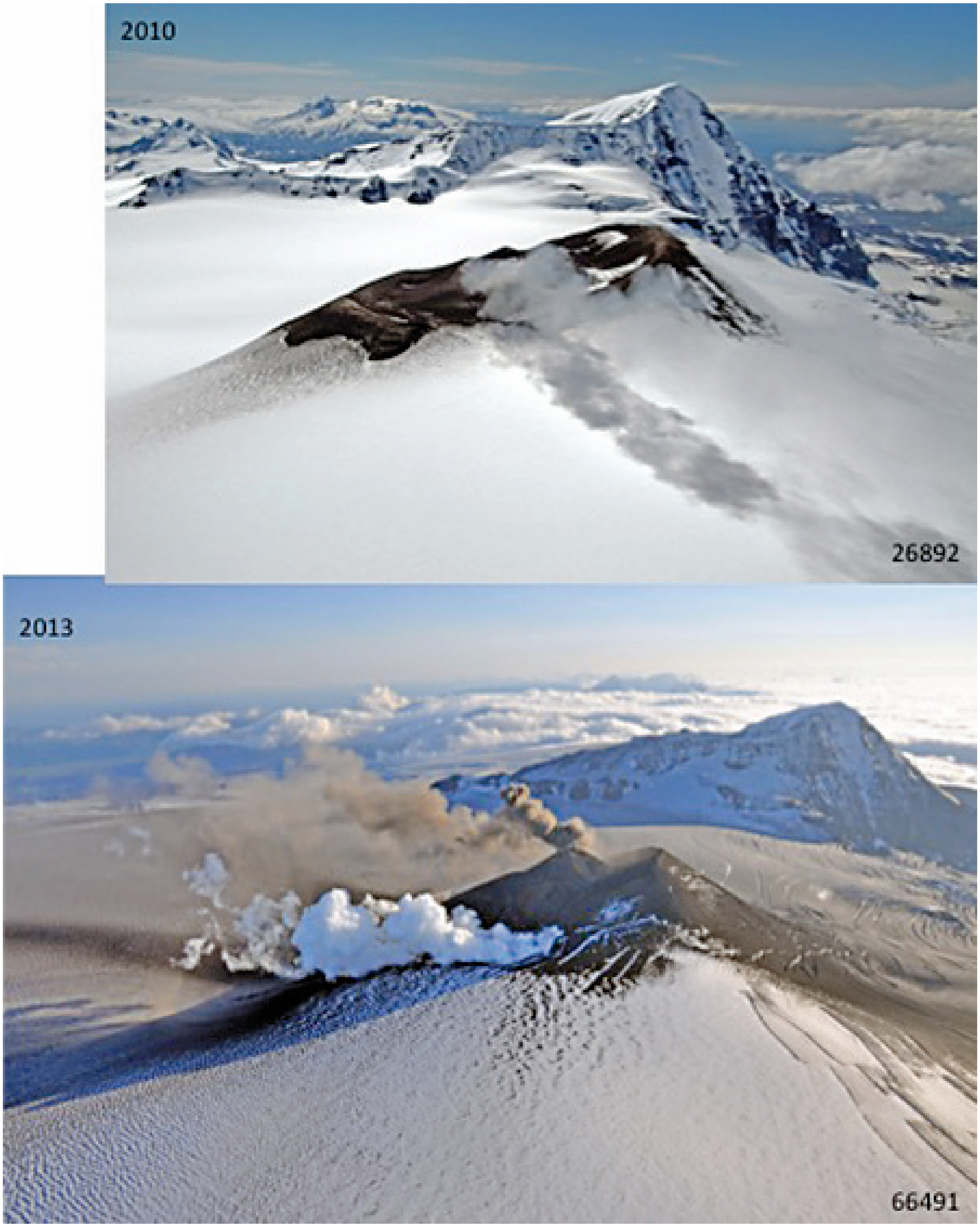

Figure 26. Image comparison of the Mount Veniaminof Volcano intracaldera cinder cone in showing the geomorphic changes that occurred during the 2013 eruption. Aerial views from the north of intracaldera cinder cone on July 15, 2010 (top image), and during the recent eruption on August 18, 2013 (bottom image). Parasitic growth of a new cinder cone is occurring within the older cone. Top photograph by Cyrus Read, USGS/AVO; AVO database image URL, http://www.avo.alaska.edu/images/image.php?id=26892. Bottom photograph by Game McGimsey, USGS/AVO; AVO database image URL, http://www.avo.alaska.edu/images/image.php?id=66491.

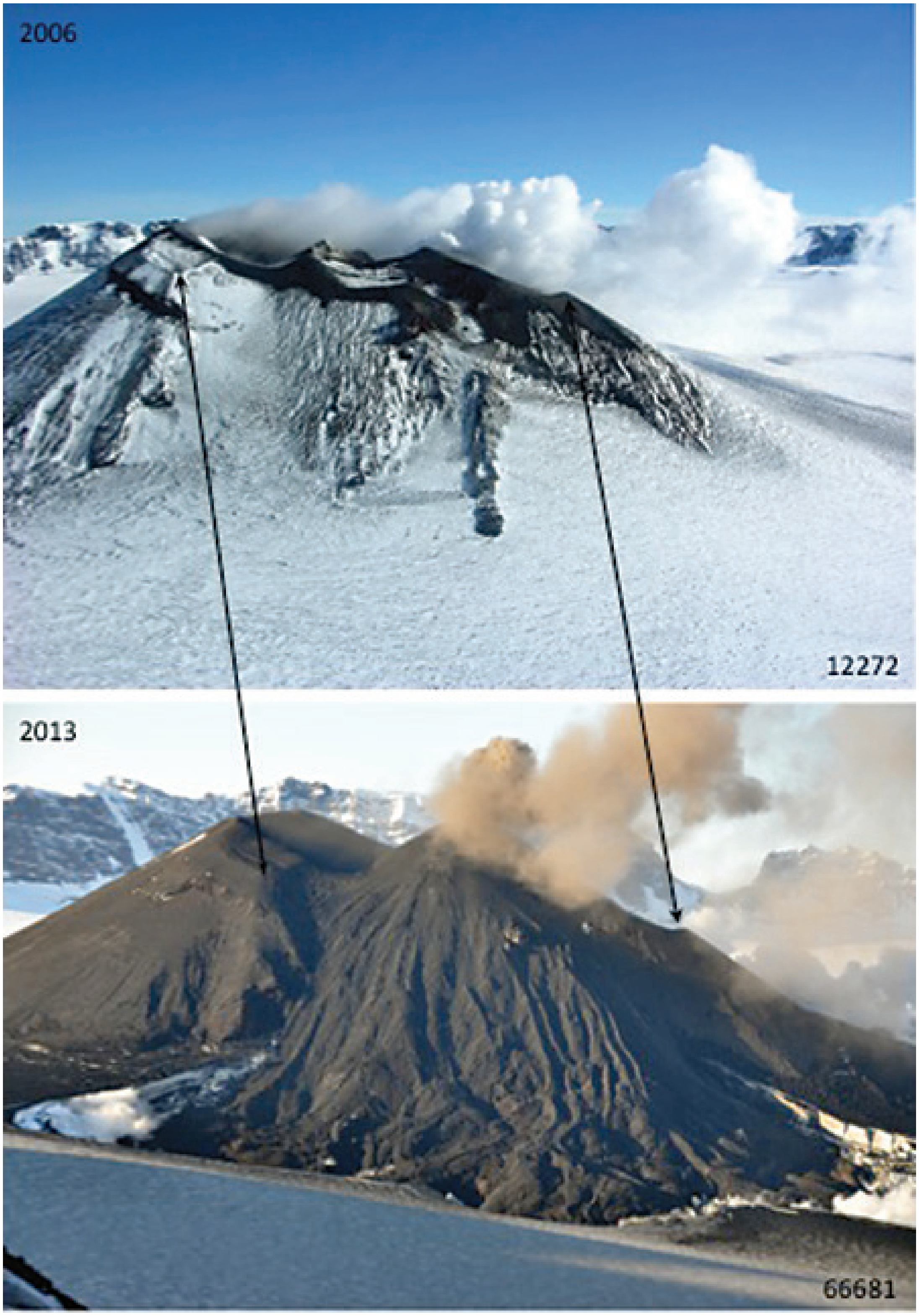

Figure 27. Image comparison of the Mount Veniaminof Volcano intracaldera cinder cone in 2006 (top) with the changes that occurred during the 2013 eruption (bottom). View is of the southwestern flank and arrows indicate identical points in each image. The 2013 image shows the development of the nested cone that grew inside the summit crater of the older cone, and the fan of coalesced lava flows on the southwestern flank. Top photograph by Tim Plucinski, USGS/AVO, July 26, 2006; AVO database image URL, http://www.avo.alaska.edu/images/image.php?id=12272. Bottom photograph by Game McGimsey, USGS/AVO, August 18, 2013; AVO database image URL http://www.avo.alaska.edu/images/image.php?id=66681.

Pavlof Volcano

GVP New # 312030

CAVW# 1102-03-

55°25'N 161°54'W
2,518 m (8,261 ft)

Alaska Peninsula

STROMBOLIAN ERUPTION

Pavlof Volcano erupted in May 2013 and was characterized by Strombolian explosions and periods of continuous tremor. Eruption plumes deposited trace amounts of ash in nearby communities during the first 2 weeks of the eruption and again in early June. Activity and observations are summarized in table 7. Pavlof was upgraded from the Aviation Color Code and Volcano Alert Level of **GREEN/NORMA**L to **ORANGE/WARNING** on May 13, remaining at **ORANGE/WARNING** for 17 days during the 3-week-long eruption, with remainder of the time at **YELLOW/ADVISORY**. On August 8, the Aviation Color Code and Volcano Alert Level were downgraded to **GREEN/NORMAL**, where it remained for the rest of the year.

The 2013 eruption of Pavlof Volcano began on the morning of May 13, 2013, following a 6-year period of repose. Eruption onset was characterized by subtle, low-level seismicity beginning about 16:00 UTC (08:00 AKDT) and continuing for the first 24–48 hours of the eruption. A strong, persistent thermal signal from the Pavlof summit area was first observed in mid-infrared AVHRR satellite imagery at 15:17 UTC (07:17 AKDT) on May 13, and AVO upgraded the Aviation Color Code and Volcano Alert Level to **ORANGE/WATCH**, stating that an eruption was likely to progress. A pilot report at 03:00 UTC on May 13 (19:00 AKDT, May 14) confirmed the eruption, with numerous dark streaks on the upper northern flank of the volcano that appeared to be a lava flow and lahars initiated by melting of snow and ice in the summit area (fig. 28). Similar flows also were observed farther down the northern flank and that were initiated by the ejection of hot debris onto snow and ice. Residents of Sand Point, 85 km (53 mi) east of the volcano, reported seeing a distinctive glow at the summit of Pavlof during the evening of May 13, indicating likely lava fountaining. By the next day, satellite observations showed that a lava flow extending down the northern flank well beyond the summit vent. The flow was estimated to be about 600 m (2,000 ft) long and 30 m (100 ft) wide, and originated from a vent within a small crater just north of the summit.

AVO received numerous observations on May 14 confirming eruptive activity underway at Pavlof Volcano. Pilot reports and Web camera views of the volcano indicated that ash emissions as high as about 4 km (13,000 ft) ASL were occurring intermittently. Views of Pavlof, such as that in figure 29, indicated several light-colored plumes rising off the lower northern flank, suggesting flowage of hot debris over ice and snow. Throughout the day on May 14, numerous strong bursts of tremor coincided with similar observations of large steam plumes rising off the northern flank of the volcano. Light-colored plumes from some of these events reached as high as 6 km (20,000 ft) ASL. Incandescence associated with strong lava fountaining at the summit also was observed throughout the evening of May 14. The lava fountaining was robust enough that relatively continuous infrasonic tremor was produced and recorded on infrasound arrays on Akutan Island (290 km [180 mi] southwest of Pavlof) and Okmok (460 km [285 mi] southwest of Pavlof) Volcanoes and at Dillingham (455 km [283 mi] northeast of Pavlof).

Noticeable fallout of fine ash occurred as far as 80 km (50 mi) downwind of the volcano on May 14, 15, and 18, and was reported to AVO. During May 15–20, sulfur dioxide (SO_2) from Pavlof was detected in OMI satellite data; the estimated SO_2 mass during May 15–16 was 1,000–2,000 metric tons and at least 4,000 metric tons on May 18–20 (Simon Carn, written commun., 2013). Sulfur dioxide also was detected on multiple days by the GOME-2 (Global Ozone Monitoring Experiment-2) and IASI (Infrared Atmospheric Sounding Interferometer) instruments

From May 15 to 21, the eruption was characterized by nearly continuous tremor and explosions. A relatively continuous ash plume was apparent in AVHRR and MODIS satellite images and also was observed by pilots. Ash emissions during this period reached as high as 7 km (23,000 ft) ASL and extended about 400–500 km (250–310 mi) southeast of the volcano on May 18 (fig. 30). On May 19, trace amounts of ash fall occurred on the communities of Sand Point and Nelson Lagoon, 90 km (56 mi) southwest and northeast of Pavlof, respectively. AVO scientists examined an ash sample collected in Sand Point that consisted almost entirely of dark angular glass shards. A single electron microprobe analysis of the glass indicated that it is compositionally andesite (58 percent silicon dioxide, SiO_2) and similar to ash deposits associated with previous historical eruptions (K. Wallace, USGS-AVO unpub. data; microprobe analyses by L. Hayden, USGS).

Table 7. Summary of activity and observations at Pavlof Volcano in 2013.

[**Note:** An important reporting change occurred in May 2013 when AVO analysts stopped reporting the number of pixels with elevated temperatures seen in satellite images. Through May 2013, as a measure of elevated surface temperatures, "number of pixels" reported in parentheses are from an internal Alaska Volcano Observatory (AVO) database of daily satellite observations; this number is a very rough proxy for the intensity of elevated surface temperatures. After May 2013, the presence of elevated surface temperatures are noted with the phrase "Elevated temperatures." Absence of elevated temperature entries may simply mean clouds obscure the ground. **Abbreviations:** ASL, above sea level; ft, foot; GOME-2, Global Ozone Monitoring Experiment-2; km, kilometer; RSAM, Real-time Seismic Amplitude Measurement]

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
05-13-13	**ORANGE/WATCH**	Active lava effusion.	Elevated temperatures	Residents in Sand Point observed a lava flow on Pavlof. Pilot reported a steam plume rising about 1,000 ft above the summit of Pavlof.	Seismic tremor observed.
05-14-13	**ORANGE/WATCH**	Active lava effusion.	Elevated temperatures	A new lava flow extending due north from the summit was observed. Pilots reported ash plumes from 9,000 to 15,000 ft ASL. Another pilot reported flowage deposits downslope of the lava flow terminus.	Tremor picked up today. The Okmok infrasound array has detected fairly continuous infrasonic tremor.
05-15-13	**ORANGE/WATCH**	Explosions and lava effusion.	Elevated temperatures	Satellite view shows a narrow lava channel diverging into two or more channels that extend at least 3 km downslope. Explosions with plumes to 20,000 ft ASL.	Explosion signals with a strong low frequency component seen clearly on nearby stations.
05-16-13	**ORANGE/WATCH**	Pyroclastic flows.	Elevated temperatures	Plume height 15,00–20,000 ft ASL with ash cloud extending 125 km southeast.	
05-17-13	**ORANGE/WATCH**		Elevated temperatures	Plume height 15,000–20,000 ft ASL, ash fall on Sand Point.	The RSAM has reached the highest levels we have seen in the past 72 hours; continuous infrasound tremor on Okmok array.
05-18-13	**ORANGE/WATCH**		Elevated temperatures	Plume with SO_2 signature extending up to 300 km towards the southeast. Plume height: 16,000–23,000 ft ASL, ash fall on Sand Point.	
05-19-13	**ORANGE/WATCH**	Active lava effusion.	Elevated temperatures	Incandescence seen in night-time Web camera view. Ash cloud to be around 15,000 ft ASL. Lava flow length is 5 km, trace ash at Nelson Lagoon Village.	
05-20-13	**ORANGE/WATCH**		Elevated temperatures	A SO_2 plume from Pavlof was detected by the GOME-2 satellite.	Infrasonic tremor was nearly constant at the Dillingham array. Seismic amplitude levels seem similar to earlier in the eruption.
05-21-13	**ORANGE/WATCH**		Elevated temperatures		Dramatic decrease in the RSAM values as tremor is replaced by discrete events.

Table 7. Summary of activity and observations at Pavlof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
05-22-13	ORANGE/WATCH		Elevated temperatures	Deep vent crater north of the summit observed.	Numerous small transient events were recorded on the Okmok infrasound array.
05-27-13	ORANGE/WATCH		Elevated temperatures	No major changes since 4 days previous.	
05-28-13	YELLOW/ADVISORY		Elevated temperatures	Observed plume height: 15,000 ft ASL.	Seismic tremor and small discrete explosions are no longer detected in seismic and pressure sensor data.
06-04-13	YELLOW/ADVISORY			Resumption of eruption, ash plume height: 19,000 ft ASL.	Seismic temor is confirmation of resumed activity at Pavlof. Occasional infrasound signals from Pavlof have been recorded in Dillingham.
06-05-13	ORANGE/WATCH		Elevated temperatures	Plume height: 15,000–16,000 ft ASL. Ash plume extending approximately 40 km to the west.	Eruption activity characterized by narrow band tremor with occasional discrete explosion events.
06-06-13	ORANGE/WATCH		Elevated temperatures	Small patches of ash at 16,000–18,000 ft ASL moving 25 mi to the north-northwest.	
06-07-13	ORANGE/WATCH		Elevated temperatures	Plume height: 16,500 ft ASL.	Continued narrow band tremor accompanied by occasional explosion signals.
06-08-13	ORANGE/WATCH			Pavlof Ash height: 17,400 ft ASL.	
06-09-13	ORANGE/WATCH		Elevated temperatures	Plume height: 12,000 ft ASL.	Tremor continues with occasional explosion signals.
06-12-13	ORANGE/WATCH		Elevated temperatures	Minor eruptive activity observed. Plume to 12,000 ft ASL moving to the northeast.	
06-13-13	ORANGE/WATCH				Seismic tremor and explosion signals continue.
06-14-13	ORANGE/WATCH		Elevated temperatures	Minor eruptive activity with ash puffs up to 11,000 ft ASL.	
06-18-13	ORANGE/WATCH	Active lava effusion.	Elevated temperatures	Eruption continuing to produce a small ash plume with lava continuing to issue from the summit vent. Ash plume moving southwest at 13,000 ft ASL.	
06-19-13	ORANGE/WATCH		Elevated temperatures	Weak ash cloud.	
06-24-13	ORANGE/WATCH		Elevated temperatures		

Table 7. Summary of activity and observations at Pavlof Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
06-25-13	**ORANGE/WATCH**	Strombolian activity.		Plume heights up to 28,000 ft ASL with ash fall on King Cove.	Seismic data indicate that the eruption has escalated. The level of seismicity now is comparable to the strongest seismic activity detected during the earlier part of the 2013 eruption on May 16–17. The seismicity is characterized by continuous intense tremor and frequent small explosions that are likely associated with lava fountaining and unknown amounts of ash production.
06-26-13	**ORANGE/WATCH**		Elevated temperatures	Light plume to about 300 ft above summit. Plumes visible from the volcano extending west-northwest over Cold Bay.	Decreased activity; tremor is now discontinuous with RSAM values falling. Some explosions with air waves.
06-27-13	**ORANGE/WATCH**	Strombolian activity		Fresh pyroclastic deposits with some lava fountaining and ash emission. The volcano is much less restless than it was earlier in the week.	The level of seismicity over the past 24 hours has continued to decrease and now consists primarily of low-level continuous tremor.
06-28-13	**ORANGE/WATCH**		Elevated temperatures	Possible plumes evident in satellite data a distance of about 100 km northwest of the volcano.	Relatively continuous low-level tremor and occasional small explosions have characterized the seismicity for the past several days.
07-02-13	**YELLOW/ADVISORY**				Seismic tremor and small discrete explosions are no longer detected in seismic and pressure sensor data.
07-05-13	**YELLOW/ADVISORY**			Satellite observations are consistent with the cooling of the previously erupted lava.	Seismic activity remains very low.
07-08-13	**YELLOW/ADVISORY**				Occasional tremor correlated across multiple stations.
07-09-13	**YELLOW/ADVISORY**			A comparison between images now and a week ago, show that the lava flow has not changed.	
07-17-13	**YELLOW/ADVISORY**			Three new lava flows on the north-northwest flank of Pavlof.	Interaction with cooling lava flow and snow and ice are causing flowage signals to be seen on seismographic stations on Pavlof. Lots of buried snow/ice up there and the lava flows are still quite hot.
08-08-13	**GREEN/NORMAL**			Satellite images and Web camera views of the volcano show no evidence of continuing lava or ash emission.	Seismicity is now at background levels.

Figure 28. Photograph of steam with fresh lava flow on northern flank of Pavlof Volcano, confirming the start of the 2013 eruption. Photograph by Brandon Wilson, taken at 03:07 UTC, May 14, 2013 (19:07 AKDT, May 13, 2013), used with permission. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=48921.

Figure 29. View of Pavlof Volcano from Cold Bay Alaska, showing incandescent lava fountaining at the summit and a large steam plume rising off the northern flank, May 14, 2013. Hot avalanches of rock debris that flow rapidly downslope, incorporating and melting ice and snow, can generate these types of steam plumes. Photograph by Rachael Kremer, used with permission. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=49581.

Figure 30. Pavlof Volcano eruption on May 18, 2013. Photograph by Brandon Wilson, used with permission. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=50141.

From May 22 to June 4, the volcano was relatively quiet, and the seismicity during this period was characterized by episodic, discrete bursts of tremor lasting from 30 seconds to approximately 1 minute. During May 22–23, the lower Pavlof seismic network detected distinct ground-coupled airwaves. Infrasonic arrays at Dillingham and Okmok Volcano also recorded these probable explosion signals as impulsive infrasonic waves.

From May 27 to June 4, seismic tremor and small discrete explosions were no longer detected in seismic and infrasound data. Satellite observations during this period showed no evidence of elevated surface temperatures, volcanic gas (SO_2) or ash emissions. During periods of clear weather, no visual observations of ash emissions and Web camera views of the volcano were noted, indicating eruptive activity had paused. These observations prompted AVO to upgrade the Aviation Color Code and Volcano Alert Level to **YELLOW/ ADVISORY** at 20:50 UTC (12:50 AKDT) on May 27.

On June 4, 2013, AVHRR, MODIS, and GOES satellite data detected ash emission from Pavlof; passing pilots reported ash plumes as high as 5.7 km (18,700 ft) ASL. Slightly elevated levels of seismic tremor also were observed by midday (local) on June 4, roughly coincident with the observations of ash emissions, prompting a downgrade to **ORANGE/WATCH** at 12:15 UTC (20:15 AKDT). From June 14 to 19, seismic activity was characterized by periods of intermittent volcanic tremor and slightly more robust and more frequent explosions compared to the character of the seismicity from May 13 to 24. During this period, ash plumes generally were smaller and did not extend more than about 50 km (30 mi) downwind of the volcano. The maximum plume height reported by pilots was approximately 6 km (29,000 ft) ASL on June 10. Residents of Cold Bay reported barely perceptible trace ash fall during June 6–7.

From June 20 to 24, the Pavlof seismic network recorded moderate levels of relatively continuous tremor and small explosions. Several low-level ash plumes (generally less than 3.5 km or 11,500 ft) ASL were generated, although cloud cover occasionally inhibited observations.

Beginning around 07:00 UTC on June 25 (23:00 AKDT on June 24), tremor amplitudes at the volcano increased significantly and were characterized by high levels of continuous tremor and frequent explosions associated with robust episodes of lava fountaining and ash emission. The level of seismicity on June 25 was the strongest detected during the entire eruption. Observers in Sand Point reported incandescence and ash plumes as high as 6 km (20,000 ft) ASL on the morning of June 25, and around midnight on June 25, ash fall was reported in King Cove 50 km (30 mi) southwest of the volcano. Analysis of satellite images and pilot reports confirmed ash plumes as high as 7–8 km (23,000–26,000 ft) ASL. Sulfur dioxide emissions from Pavlof were detected by the Joint Polar Satellite System Ozone Monitoring Profiler Suite from 01:00 to 23:10 UTC on June 25. Automated analysis of this data indicated a mass of SO_2 of 6,000–7,000 metric tons near the volcano.

Between June 25 and 27, intermittent ash plumes rose to 6 km (20,000 ft) ASL. After June 27, the seismicity became less energetic, and occasional low-frequency events and low levels of increasing discontinuous tremor characterized the seismicity. Pilot reports on June 28 indicated no activity at the volcano, and over the next several days, seismic tremor and small discrete explosions were no longer detected in seismic and infrasound data. Satellite observations after July 1 showed no evidence of elevated surface temperatures, volcanic gas, or ash emissions. On July 2, AVO downgraded the Aviation Color Code and Volcano Alert Level to **YELLOW/ADVISORY**, where it remained until August 8 when the volcano returned to its normal background state and the Aviation Color Code and Volcano Alert Level were downgraded to **GREEN/ NORMAL**.

The lahars and ash plumes generated during the eruption did not pose any serious hazards for the area. However, numerous local airline flights were cancelled or rerouted, and trace amounts of ash fall occurred at all local communities surrounding the volcano, including Cold Bay, Nelson Lagoon, Sand Point, and King Cove. Observations by AVO scientists during July 16–17 indicated that only the upper part of the Cathedral River drainage (fig. 31) had been inundated by lahars. However, a fountain-fed lava flow, about 5.8 km (3.6 mi) in length, covering an area of about 730,000 m^2 (180 acres) on the northern flank of the volcano was observed (fig. 32). It was only possible to collect a few samples of the lava. These samples have not yet been analyzed, but appeared similar to other andesitic lava flows produced by historical eruptions of Pavlof.

Pavlof Volcano is a strikingly conical and symmetrical stratovolcano located on the southwestern end of the Alaska Peninsula about 950 km (590 mi) southwest of Anchorage (fig. 33). The community of Cold Bay is located 60 km (37 mi) to the southwest of Pavlof. Based on the historical record, it is the perhaps the most active volcano in the Aleutian arc (Miller and others, 1998). Eruptive activity typically is Strombolian lava fountaining over several weeks or months. The last eruption of Pavlof occurred in 2007 (McGimsey and others, 2014).

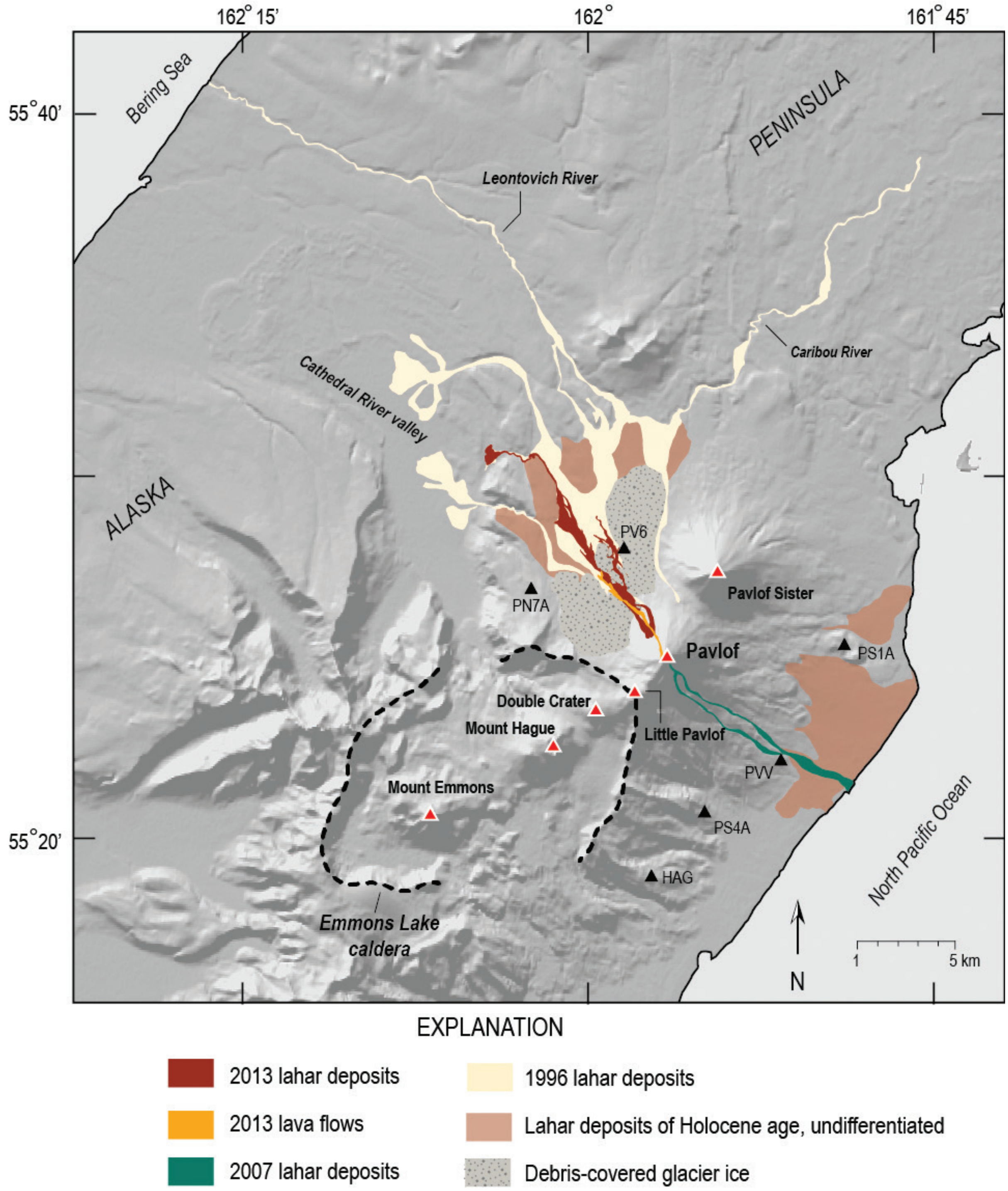

Figure 31. Shaded relief map of Pavlof Volcano and the Emmons Lake volcanic center showing the extent of lahar deposits associated with recent historical eruptions as well as the 2013 lava flow.

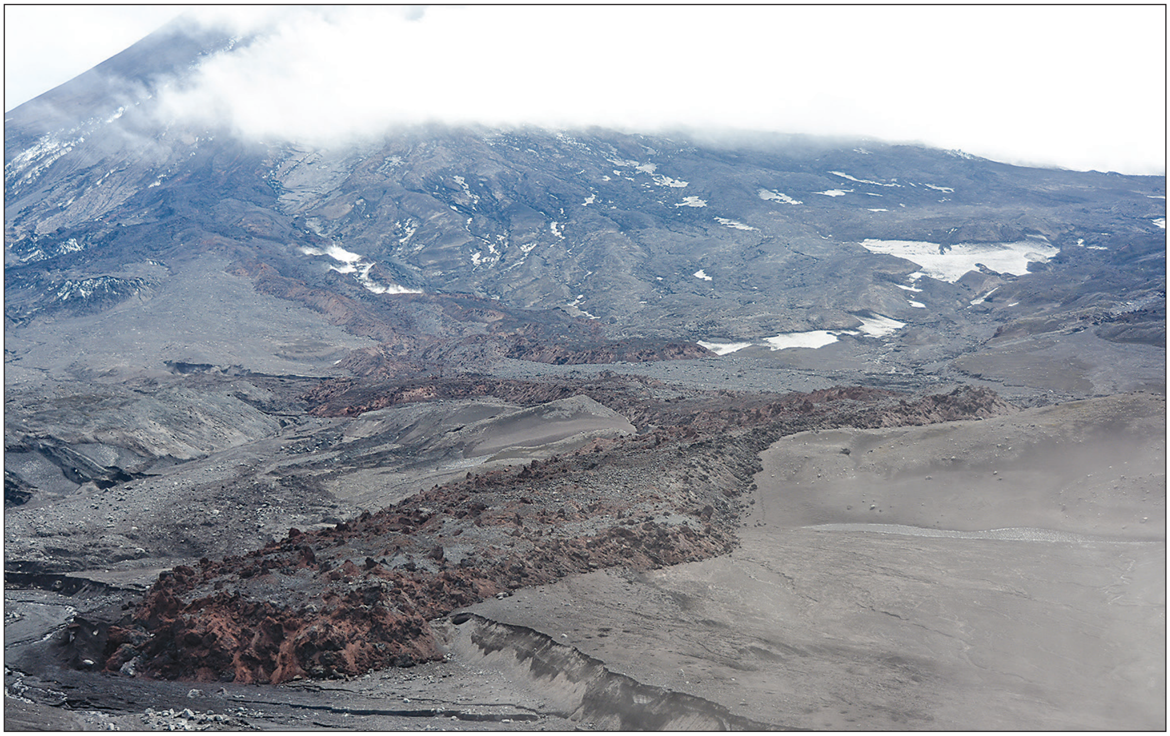

Figure 32. Photograph of lava flow produced during the 2013 eruption on the northern flank of Pavlof Volcano. This lava flow originated from a vent near the summit (obscured by clouds) and is about 6 kilometers long and covers an area of about 730,000 square meters. The relief of the lava flow terminus in the foreground of the photograph is about 20 meters. Photograph by Chris Waythomas, USGS/AVO, July 15, 2013.

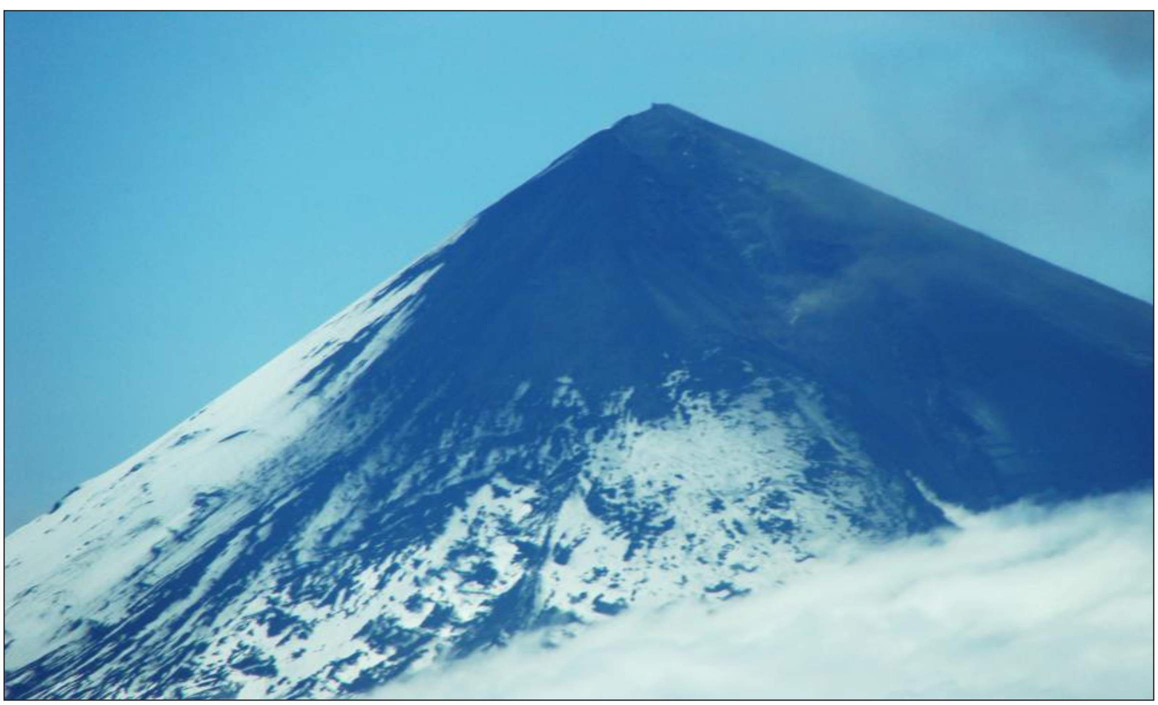

Figure 33. Photograph of Pavlof Volcano on the Alaska Peninsula, June 7, 2013. Photograph by Theo Chesley, used with permission. AVO database image URL: http://www.avo.alaska.edu/images/image.php? id=50641.

Shishaldin Volcano

GVP New # 31360

CAVW# 1101-26-

54°45'N 163°58'W
2,857 m (9,373 ft)

Fox Islands, Aleutian Islands

SEISMICITY, WEBCAM PLUME

In the first 2 months of 2013, persistent long-period earthquakes, occurring in pairs, continued at Shishaldin Volcano from activity that started in 2012 (fig. 34). This persistent seismicity, commonly seen on seismograph stations SSLN and SSBA, is similar to events seen by Caplan-Auerbach in 2003 (Caplan-Auerbach and Petersen, 2005) and is thought to be caused by fluid flow in a conduit. The initial signs of a failing network were seen in March, and by the end of the year, the lone broadband seismograph station in the Shishaldin network was the only reliable station for monitoring, preventing a full description of the seismicity in 2013. The long-period events that have been commonplace on the Shishaldin seismograph network since the 1999 eruption continued throughout the year. In 2013, one report of steaming from the Shishaldin summit was documented on clear Web camera views. Such clear views of Shishaldin are unusual, and the noted activity is typical of persistent degassing from Shishaldin that is not often seen because of poor visibility. The Aviation Color Code and Volcano Alert Level remained at **GREEN/NORMAL** throughout the year.

Shishaldin Volcano, located near the center of Unimak Island in the eastern Aleutian Islands, is a symmetric cone with a base diameter of approximately 10 mi (16 km). A small summit crater typically emits a noticeable steam plume with occasional small amounts of ash. Shishaldin is one of the most active volcanoes in the Aleutian volcanic arc, with at least 54 episodes of unrest including at least 25 confirmed eruptions since 1775 (https://www.avo.alaska.edu/volcanoes/volcact.php?volcname=Shishaldin, accessed January 1, 2015). Most of the eruptions of Shishaldin have consisted of small ash and steam plumes, although an eruption during April–May 1999 produced an ash column that reached a height of 13.7 km (45,000 ft) ASL (Nye and others, 2002).

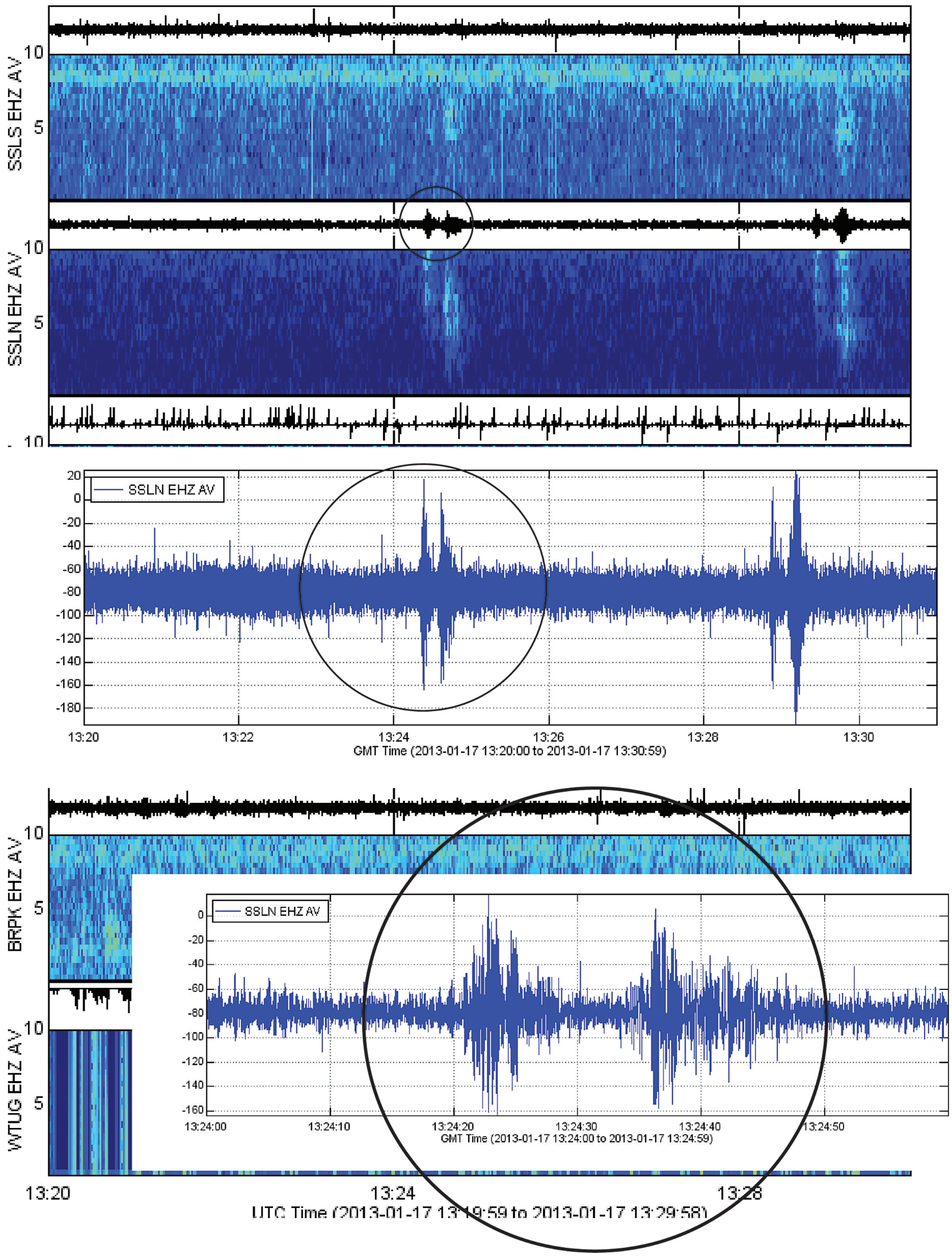

Figure 34. Double events recorded at seismograph stations surrounding Shishaldin Volcano in the first 2 months of 2013. The double event shown inside the circle occurred at 13:24 UTC (04:24 AKST) on January 17, 2013.

Akutan Volcano

GVP New # 311320

CAVW# 1101-32-

54°08'N 165°59'W
1,303 m (4,275 ft)

Fox Islands, Aleutian Islands

TRIGGERED SEISMICITY, TREMOR

Following the M=7.5 Queen Charlotte earthquake in southeast Alaska on January 5, 2013, the seismograph network on Akutan Volcano recorded episodes of phase modulated tectonic tremor. Other possible earthquake-triggered seismicity was noted at nearby Westdahl and within the Katmai volcanic cluster. AVO internal log entries periodically noted tremor at Akutan, with tectonic tremor as the most probable origin. Short sequences of low-frequency earthquakes were located on February 8, May 29, and September 13, with a small swarm of volcanic-tectonic events reported on July 12. The Aviation Color Code and Volcano Alert Level remained at **GREEN/ NORMAL** throughout the year.

Akutan Volcano is a composite stratovolcano with a circular summit caldera about 2 km (1.2 mi) across and 60–365 m (200–1,200 ft) deep (Byers and Barth, 1953; Motyka and others, 1981; Romick and others, 1990) and an active intracaldera cinder cone (Miller and others, 1998). The caldera rim reaches a maximum altitude of 1,303 m (4,275 ft) at Akutan Peak, the remnant of a pre-caldera cone now filled with a lava plug. The caldera is breached to the north. Caldera subsidence accompanied or followed eruptions from a series of rim vents. The vestige of a larger caldera, of probable late Pleistocene age and at least in part older than the cone of Akutan Peak, extends 1.5 km (0.9 mi) southwest of Akutan Peak and is terminated to the north by the younger caldera. Small glaciers fill the older crater and lie within the southwestern and southeastern margins of the younger caldera.

Makushin Volcano

GVP New # 311310

CAVW# 1101-31-

53°53'N 166°56'W
1,800 m (5,906 ft)

Fox Islands, Aleutian Islands

REPORTS OF PLUMES, SPORADIC TREMOR AND OTHER SEISMICITY

No eruptive activity occurred at Makushin Volcano in 2013, but increases in seismicity and reports of possible ash plumes prompted increased AVO attention. The Makushin seismograph network periodically recorded tremor episode during 2013, likely unrelated to volcanism. Short swarms of earthquakes are common near Makushin. Four such swarms were noted in the last one-half of the year on August 28, September 24, October 29, and December 25 (fig. 35). A single observation of a small steam plume was noted in a clear Web camera image of Makushin on March 24 (fig. 36). The Aviation Color Code and Volcano Alert Level remained GREEN/NORMAL throughout the year.

Makushin Volcano is located on the eastern Aleutian island of Unalaska about 25 km (15.5 mi) west of the city of Unalaska/Dutch Harbor, an active seafood port. The volcano is a broad, truncated, and deeply glaciated stratovolcano with a 3-km (1.9-mi) -wide summit caldera. Over the years as ice cover has retreated, a small intracaldera cinder cone that hosts a turquoise-colored lake and abundant fumaroles has become a prominent feature. The summit region is capped by a 40 km^2 (about 15 mi^2) icefield. Makushin is credited with 18 historical eruptions, the latest of which occurred on January 30, 1995, and consisted of a small summit explosion and ash plume that rose as high as 10,000 ft (3,000 m) ASL (McGimsey and Neal, 1996; McConnell and others, 1998; Begét and others, 2000).

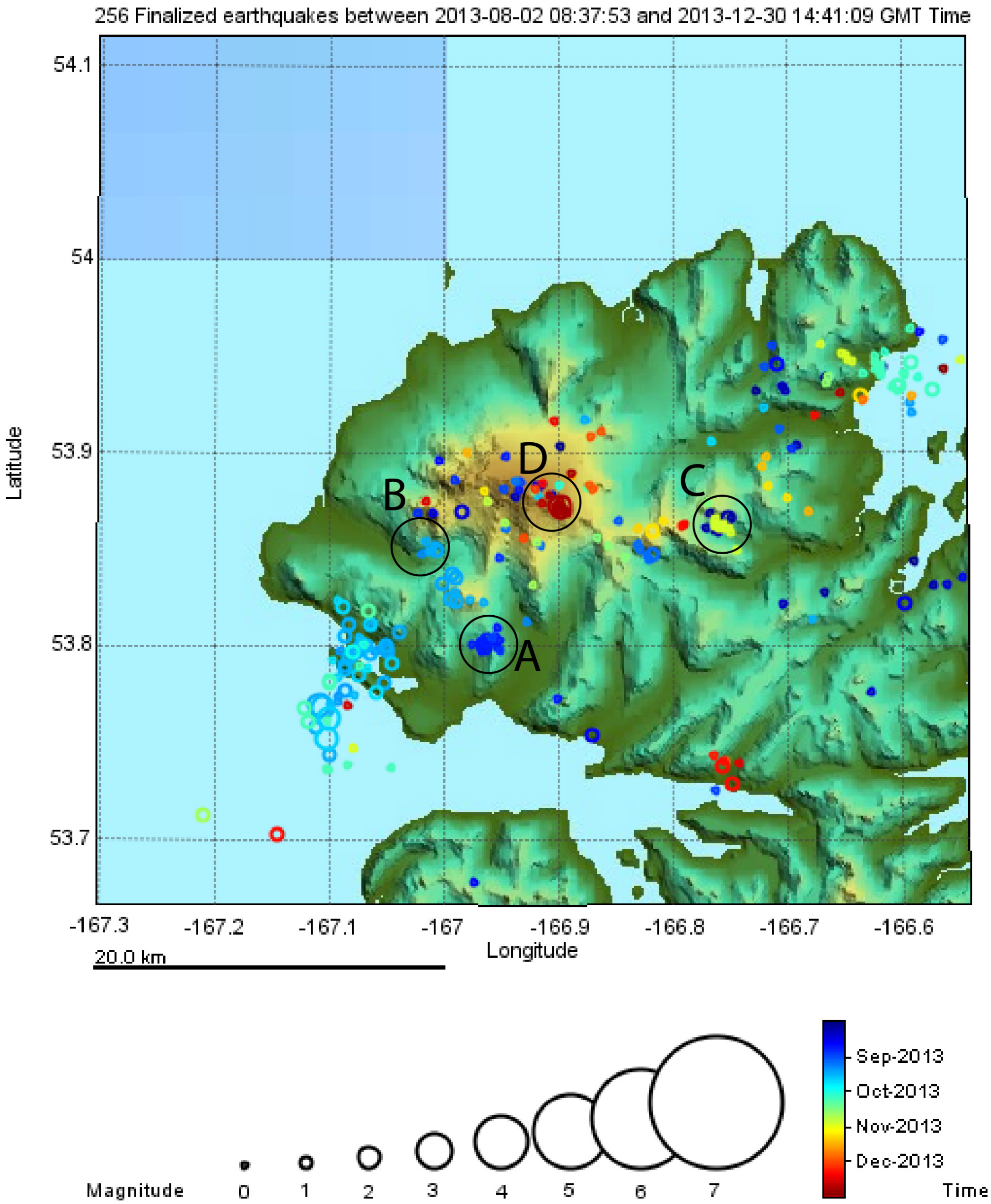

Figure 35. Seismicity surrounding Makushin Volcano. The four swarms are indicated by A: August 28, B: September 24, C: October 29, and D: December 25.

Figure 36. Web camera image of a small steam plume from the summit of Makushin Volcano on March 24, 2013.

Okmok Volcano

GVP New # 311290

CAVW# 1101-29-

53°25'N 168°08'W
1,073 m (3,520 ft)

Fox Islands, Aleutian Islands

SPORADIC TREMOR, EARTHQUAKE SWARM, RAPID INFLATION OF THE CALDERA

No eruptive activity was reported at Okmok Volcano, but seismic and geodetic observations of note were made in 2013. Sporadic tremor episodes and three swarms of earthquakes caught the attention of duty personnel in 2013. Geodetic instruments within the Okmok caldera detected a mid-year pulse of inflation. The Aviation Color Code and Volcano Alert Level remained at **GREEN/NORMAL** throughout the year.

On March 7, a 36-hour long swarm of over 1,000 low-frequency earthquakes was recorded on seismograph station OKTU, a station on Mount Tulik just outside the caldera (fig. 37). These earthquakes were too small to be recorded on adjacent stations and could not be located. The earthquakes formed two groups of earthquakes with similar waveforms (or earthquake families) that began at the same time, with the first earthquake family continuing for the duration of the swarm and the second family lasting for about the first 6 hours (fig. 38). Family 2 (short-duration family) contained larger events than family 1. After the family 2 (short-duration family) events ceased, the events in family 1 became larger and more infrequent than events earlier in the same earthquake family. Towards the end of the swarm, the event interval became more erratic, and the swarm ended abruptly.

Beginning in May 2013, the geodetic network at Okmok detected a pulse of rapid inflation, one of the steepest rises at Okmok since the 2008 eruption (fig. 39). The spatial pattern of the deformation is similar to past inflation events at Okmok, and points to an inflation source beneath the center of the caldera. In a study of ambient noise correlations between the Okmok stations OKNC and OKCE, evidence was found of 0.2-percent decrease in seismic velocity during late August and September within the caldera, indicating a change in composition of the crust sampled by the ray paths (Matt Haney, USGS/AVO, written commun., 2013). The geodetic and seismic evidence suggests an infusion of fluid or gas and, although it is certain that this was a change, it is not clear whether this change was magmatic or hydrologic.

A swarm of earthquakes began at 01:55 UTC on September 28 (17:55 AKDT on September 27) southwest of Okmok and northeast of Mount Recheshnoi in an active geothermal area. A second swarm occurred at Geyser Bight on October 9, forming a continuous zone of seismicity that extends from Recheshnoi towards Okmok (fig. 40). Neither swarm has led to eruptive activity and has continued to occur into 2014.

Okmok Volcano is a 10-km-wide (6.2-mi-wide) caldera that occupies most of the eastern end of Umnak Island, located 120 km (75 mi) southwest of the important fishing and transportation hub of Unalaska/Dutch Harbor in the eastern Aleutian Islands. The volcano, built on a base of Tertiary volcanic rocks, consists of three rock series: (1) older flows and pyroclastic beds of a pre-caldera shield complex, (2) pyroclastic deposits of two major caldera-forming eruptions, and (3) a post-caldera field of small cones and lava flows that includes historically active vents within the caldera (Byers, 1959; Larsen and others, 2007)). Okmok has had several eruptions in historical time, typically consisting of ash emissions occasionally higher than 9 km (30,000 ft) ASL, but generally much lower; lava flows crossed the caldera floor in 1945, 1958, and 1997 (Begét and others, 2005). The most recent eruption was a dramatic phreatomagmatic eruption over a 5-week period during the summer of 2008 (Neal and others, 2011). Thermal springs and fumaroles occur both within the Okmok caldera and at Hot Springs Cove, 20 km (12 mi) to the southwest.

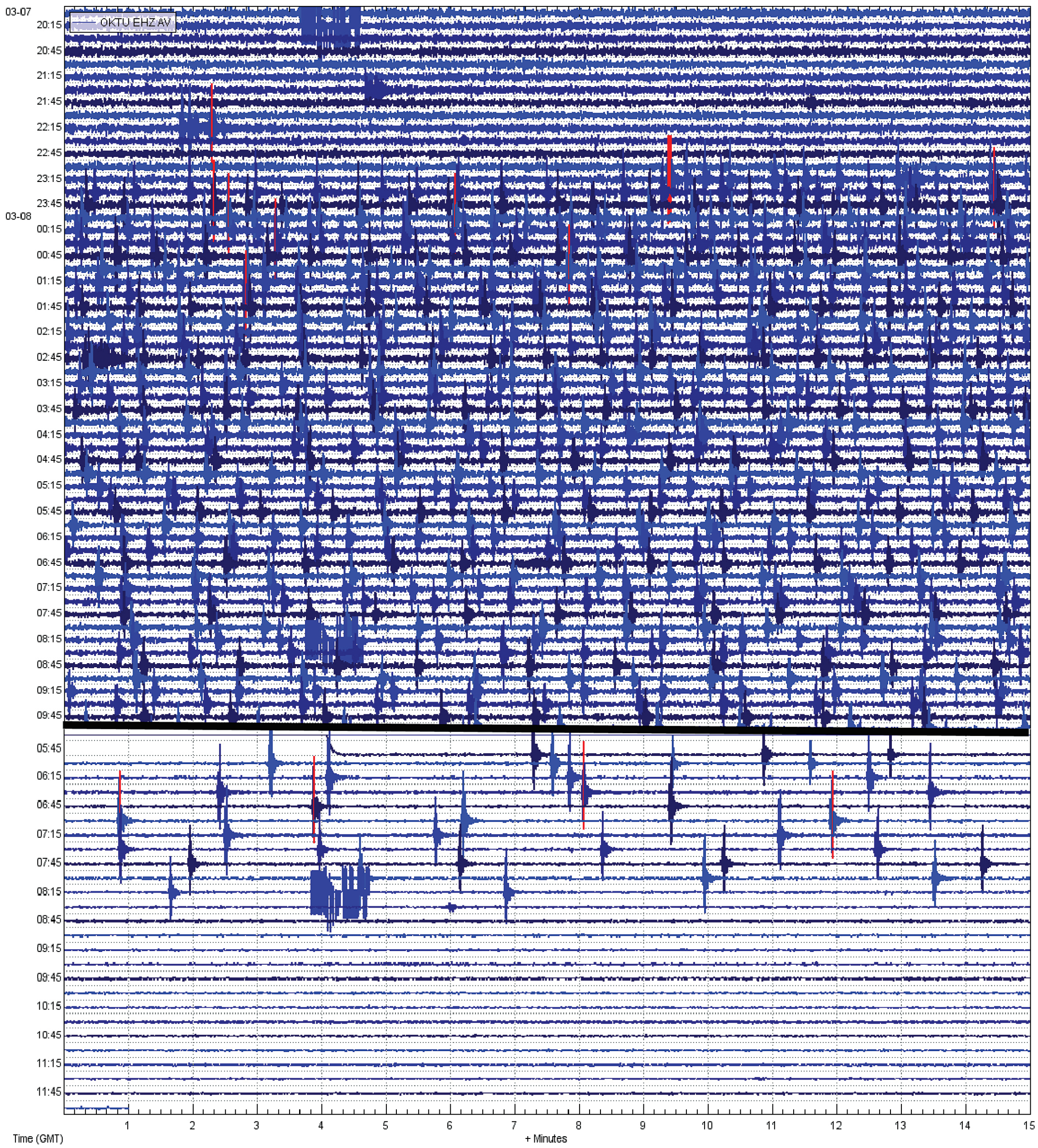

Figure 37. Webicorder of the earthquakes at seismograph station OKTU, Mount Tulik, Alaska, March 7–9, 2013. The date range from 10:00 UTC (01:00 AKST) on March 8 through 05:30 UTC on March 9 (20:00 AKST on March 8) is not shown. The seismicity in this section decreased steadily.

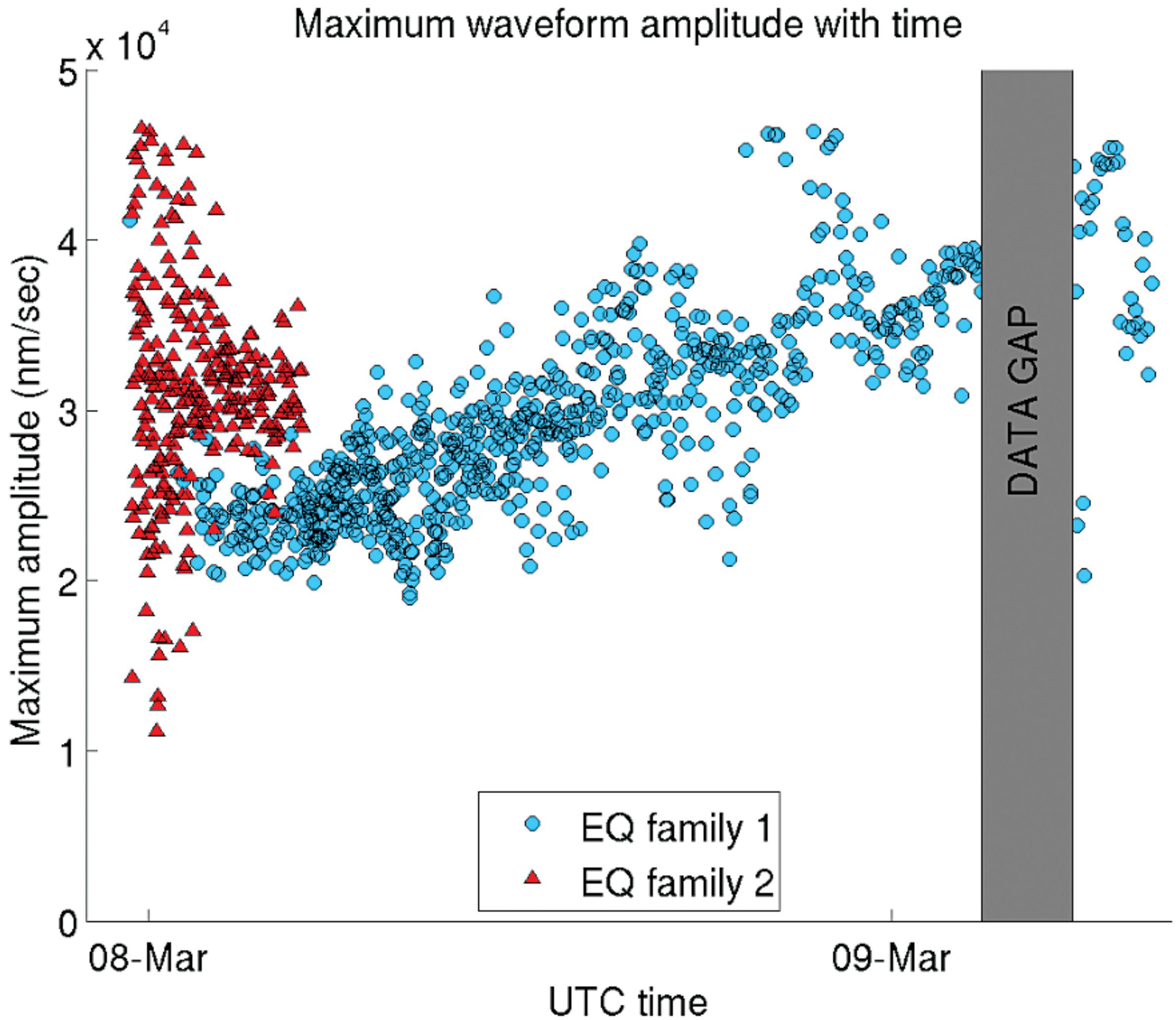

Figure 38. Plot of maximum waveform amplitude versus time for the low frequency earthquakes recorded at seismograph station OKTU, Mount Tulik, Alaska, March 7–9, 2013. Figure courtesy of H. Buurman, UAFGI/AVO.

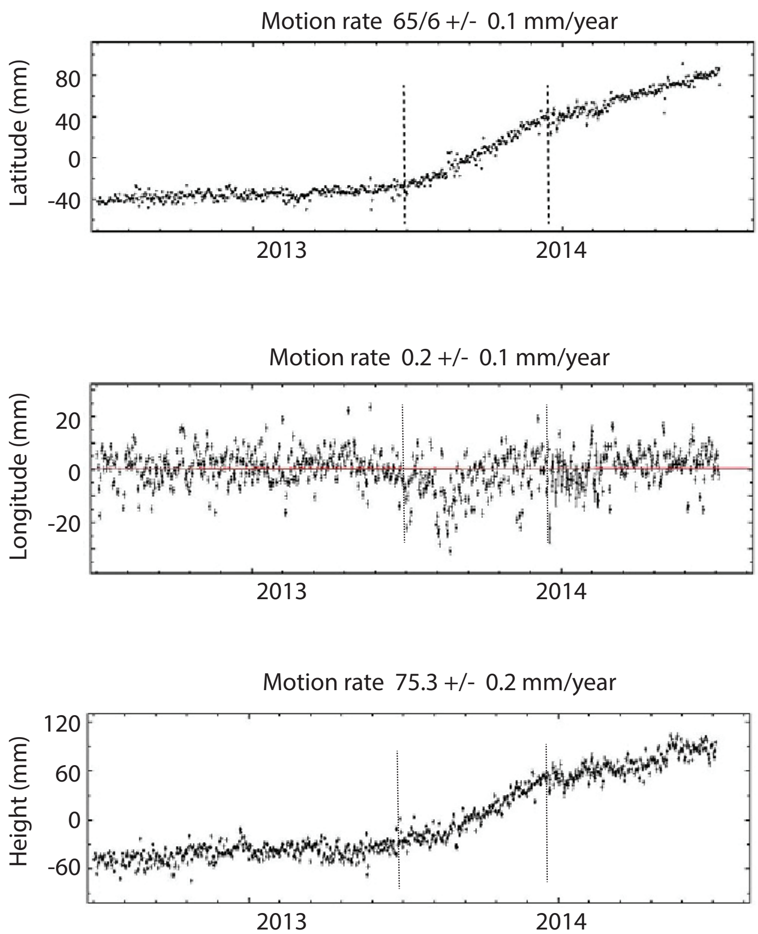

Figure 39. Geodetic plot showing increased rate of inflation at Okmok Volcano, May–December 2013 (bracketed by dashed lines).

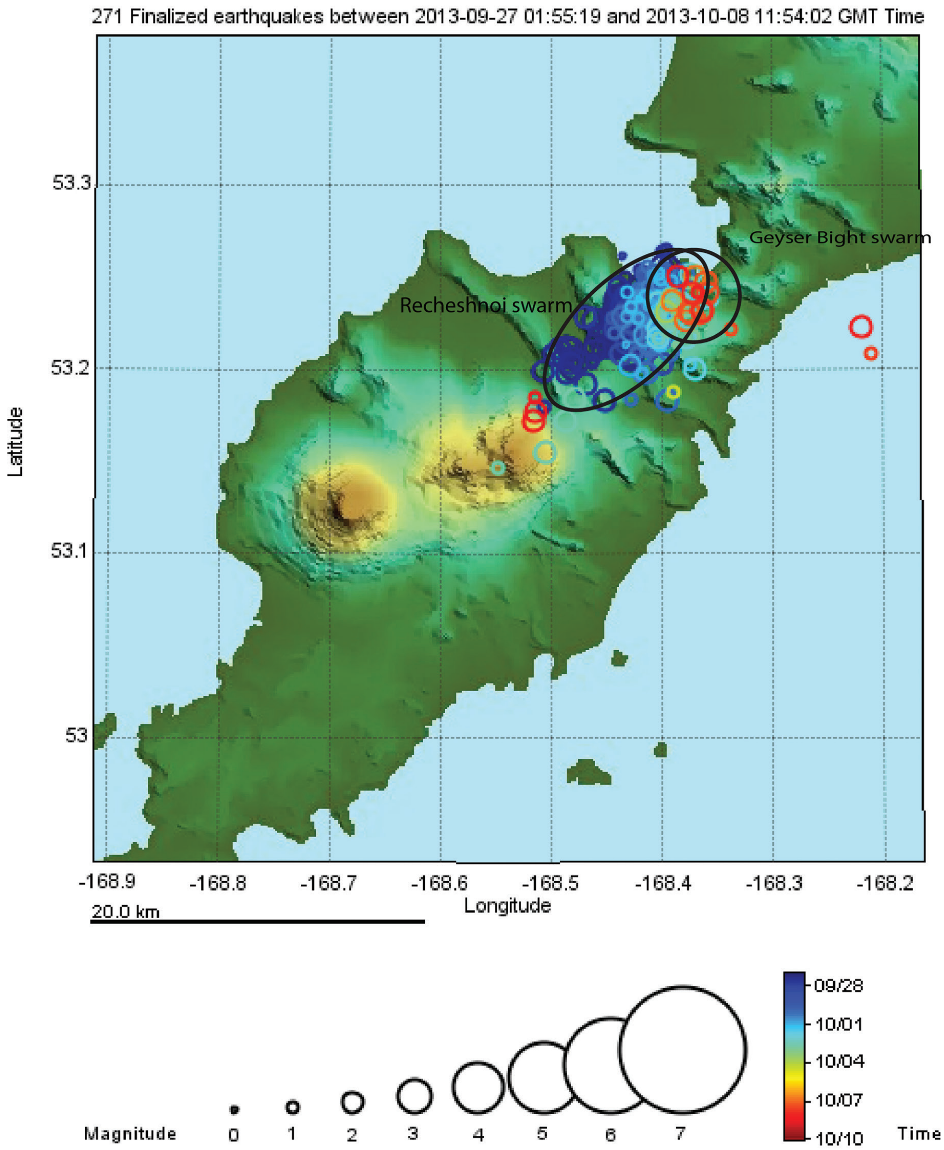

Figure 40. Map of earthquakes in the Recheshnoi (symbols in dark blue to light blue) and Geyser Bight (symbols in orange and red) earthquake swarms, eastern Aleutian Islands, September–October 2013.

Cleveland Volcano

GVP New # 311240

CAVW# 1101-24-

52°49'N 169°57'W
1,730 m (5,676 ft)

Chuginadak Island, Fox Islands, Aleutian Islands

LAVA EXTRUSION IN SUMMIT CRATER, EXPLOSIONS, SMALL ASH CLOUDS

Cleveland Volcano continued intermittent eruptive activity throughout 2013, producing and then destroying small lava flows in its summit crater and on the upper flanks, and generating small ash clouds, localized ejecta fields, debris flows and pyroclastic avalanches down the flank, and an occasionally visible vapor and gas plume from the summit. Elevated surface temperatures associated with the summit crater and recent eruptive deposits were frequently detected in satellite data. Several explosions, associated strong thermal anomalies, and small ash clouds were noted in May and at the end of December. Activity and observations are summarized in tables 8 and 9. Cleveland started the year with the Aviation Color Code and Volcano Alert Level at **YELLOW/ADVISORY**, and was upgraded to **ORANGE/WATCH** for a month-long period starting in May 2013.

Cleveland began 2013 at Aviation Color Code and Volcano Alert Level **YELLOW/ADVISORY**; no activity other than elevated temperatures in the summit area had been detected since the explosion on November 10, 2012 (Herrick and others, 2014, table 5). Early in 2013, a faint white steam cloud emanating from the summit crater was occasionally seen in satellite images. On January 30, 2013, after more than a week of consistently elevated temperatures in AVHRR images, satellite observations indicated a new lava flow inside the summit crater (table 8). Extrusion began sometime after January 7, when clear satellite images showed no lava in the crater, and before the January 30 satellite image showing a new lava flow. The round dome-like feature was about 100 m across. Significantly elevated temperatures continued in satellite images, visible even in fairly cloudy conditions. By February 9, a second lava extrusion 25 m (82 ft) across was perched across the late January dome. After learning of the existence of new lava in the summit crater, AVO upgraded the Aviation Color Code and Volcano Alert Level on February 6 to **ORANGE/WATCH**. AVO downgraded to **YELLOW/ADVISORY** on March 8 after no further escalation of activity.

AVO continued to observe persistently elevated surface temperatures in satellite data (weather permitting) throughout the spring. At 12:59 UTC (04:49 AKDT) on May 4, the Okmok infrasound and seismic networks recorded an explosion from Cleveland. In response, AVO raised the Aviation Color Code and Volcano Alert Level to **ORANGE/WATCH**. A small ash cloud was first visible in satellite imagery at 13:48 UTC (06:48 AKDT). Over the next 3 hours, a small, detached cloud moved east and then southeast from the volcano and was last discernable about 200 km (125 mi) downwind. The explosion was followed by a period of infrasonic tremor interpreted as continuous low-level emissions (gas and [or] ash) from the vent. May 5 satellite images, including an unusual elevated temperature signal in AVHRR data, showed a small patch of ash at the Cleveland summit (fig. 41). Residents of Nikolski, 74 km (46 mi) away, reported a booming noise about 8:00 p.m. local time on the same day; however, no correlative explosion was detected with infrasound or other techniques.

On May 6, infrasound sensors and analysis of airwave signals detected three explosions from Cleveland (table 8). Satellite observations that day showed that the Cleveland summit crater filled nearly to the rim with tephra; the crater floor was marked by a 15 m (57 ft) diameter vent. New flowage deposits, including a lobe of lava (identified days later during reanalysis), extended down the upper northeastern, eastern, and southeastern flanks of the volcano. The lava flow lengthened over the next week, suggesting continued extrusion of lava from the summit vent. Details of the timing of lava extrusion with respect to explosions on May 6 remain unclear. Satellite images into June captured elevated temperatures in the summit area related to this activity (fig. 42).

Cleveland remained at Aviation Color Code and Volcano Alert Level **ORANGE/WATCH** until June 4, when AVO downgraded the status to **YELLOW/ADVISORY**. On July 26, analysis of a Landsat 8 image suggested new lava within the summit crater (fig. 43); it is possible extrusion of this lava occurred during a period of elevated temperatures and visible plume from the Cleveland summit during the prior week. AVO remained at **YELLOW/ADVISORY** and apparently this new lava never overtopped the crater rim, as it had in early May.

From early July through the end of 2013, AVO's infrasound and seismic networks detected a number of additional explosions and periods of infrasonic tremor at Cleveland (table 8). Most of these events did not have an accompanying ash signal in AVHRR satellite images, suggesting minor to no ash emissions during the events. It is entirely possible that very brief emissions of ash went unnoticed because of weather and gaps between satellite passes.

On December 28, a Cleveland explosion triggered the AVO infrasound alarms on both the Okmok and Akutan arrays at 21:29 UTC (12:29 AKST). Strongly elevated surface temperatures in the summit area appear in a satellite image 10 minutes prior to the explosion. Following a second explosion 2 days later, a small ash cloud was visible 73 km (45 mi) north of the volcano. Despite this activity, AVO remained at Aviation Color Code and Volcano Alert Level **YELLOW/ADVISORY** because these ash clouds were quite small, likely less than 20,000 ft ASL, and short-lived.

The 2013 activity at Cleveland is a continuation of the intermittent explosive and effusive activity that has occurred for much of the time since its last significant eruption in 2001 (Dean and others, 2004). Cleveland forms the western part of Chuginadak Island, an uninhabited island in the Islands of the Four Mountains Group (fig. 44) of the east-central Aleutians, about 73 km (45 mi) west of the community of Nikolski, and 1,500 km (940 mi) southwest of Anchorage. Historical eruptions have been characterized by short-lived ash explosions, lava fountaining, lava flows, and pyroclastic avalanches down the flanks. In February 2001, three explosive events produced ash clouds as high as 12 km (39,000 ft) ASL, a rubbly lava flow, and a hot avalanche that reached the sea (Dean and others, 2004). Geophysical instrumentation was installed on Cleveland in 2014 to augment a promising infrasound alarm technique to detect explosions at Cleveland in development since 2011 (De Angelis and others, 2012).

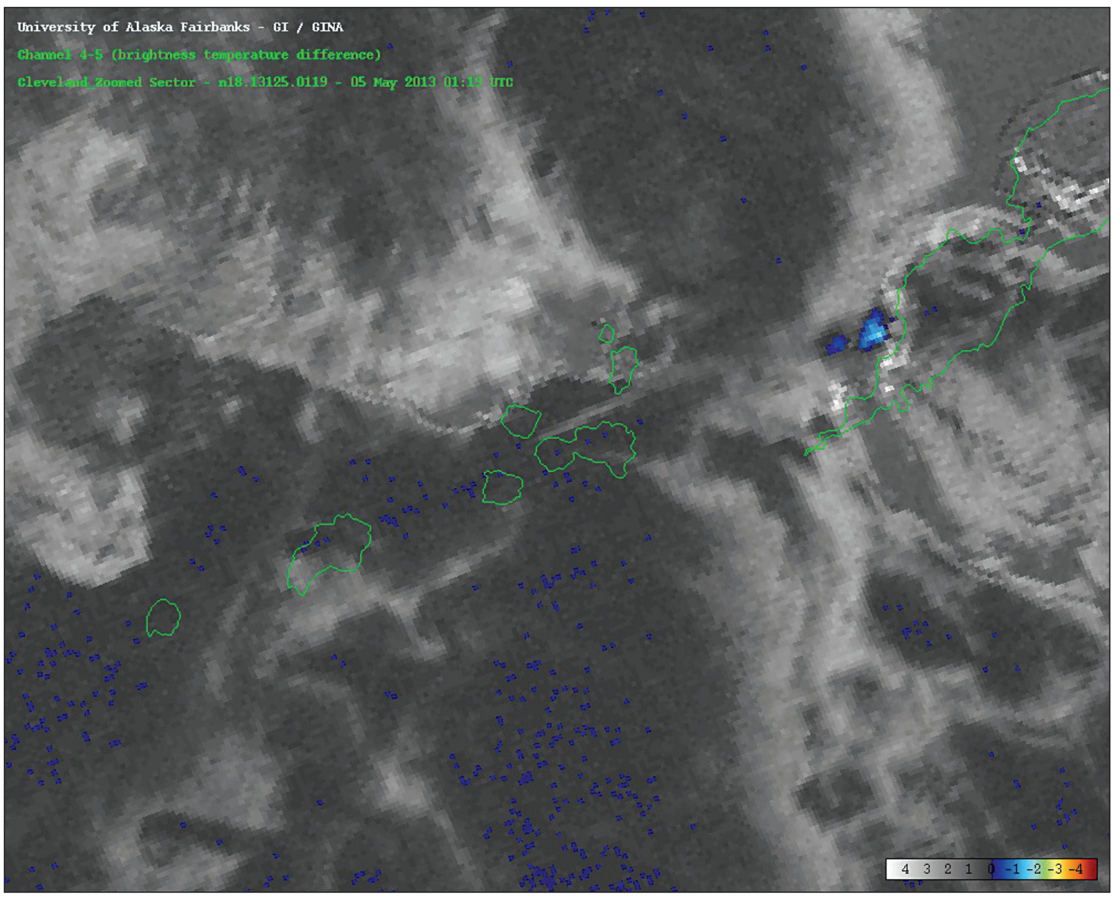

Figure 41. AVHRR brightness-temperature difference image of Cleveland Volcano ash cloud (blue region approaching the shoreline of southwest Umnak Island), 01:19 UTC, May 5 (05:19 AKDT, May 4), 2013. The coastline (green) is slightly offset from the actual image; a faint linear plume from Cleveland also is visible coming from the summit of the volcano. Image courtesy Peter Webley, UAFGI/AVO.

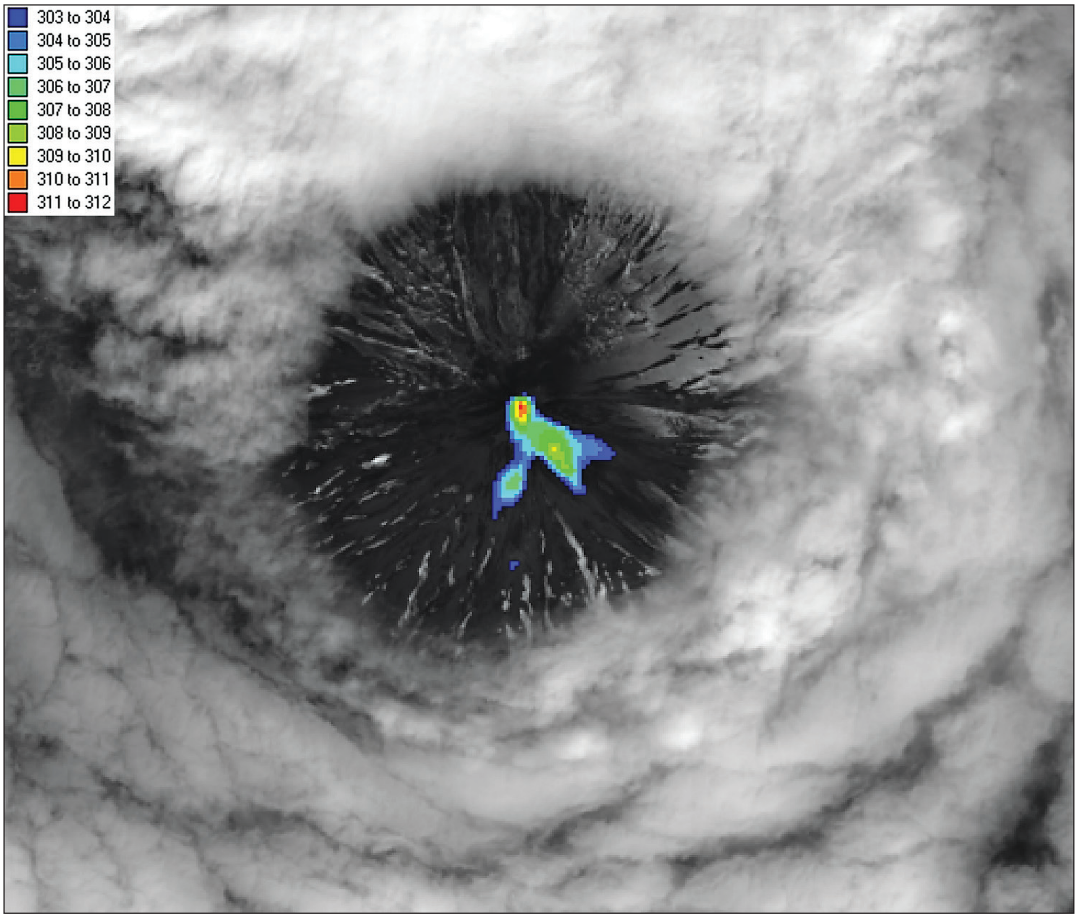

Figure 42. ASTER image of Cleveland summit showing elevated temperatures in the summit crater, atop and adjacent to May 6 lava flow lobe and other deposits related to early May activity. Temperature scale (colors in upper left corner of figure) is in degrees Celsius. Image courtesy Dave Schneider, USGS/AVO.

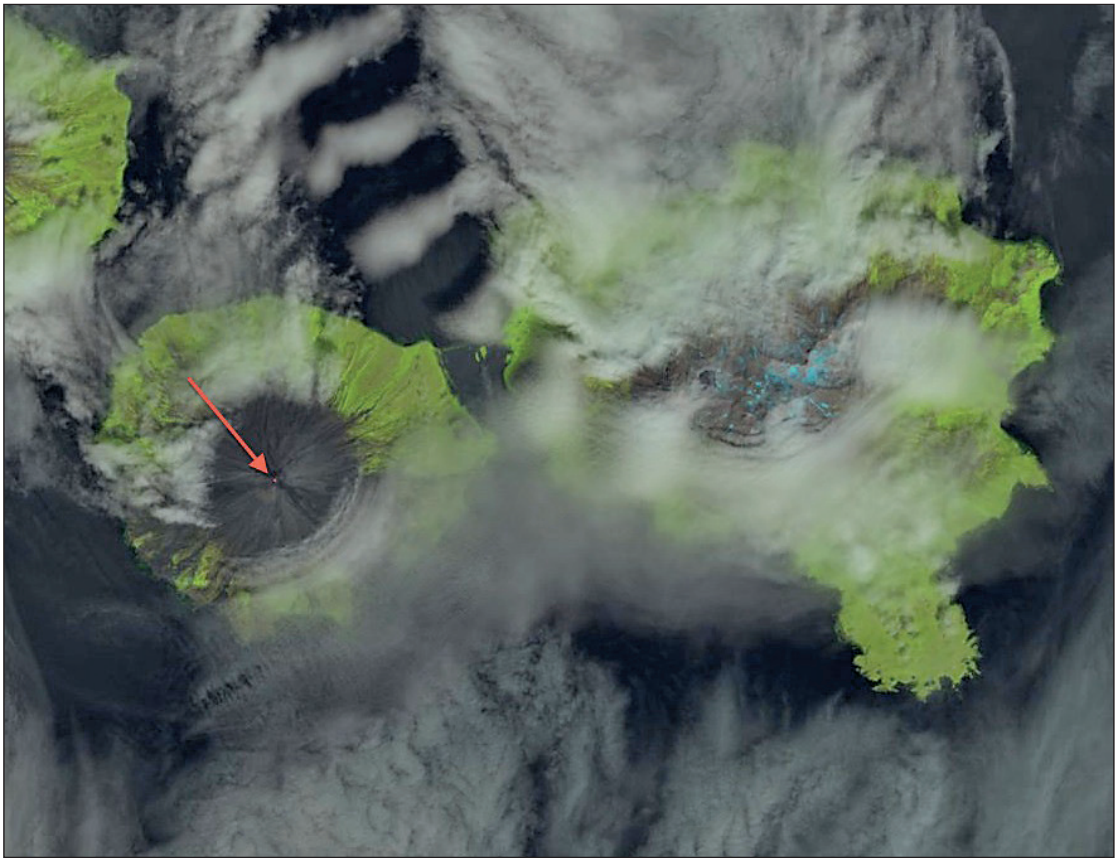

Figure 43. Landsat 8 image of Cleveland on July 26, 2013; note area of high temperature in summit crater (red arrow). Image courtesy Dave Schneider, USGS/AVO.

Figure 44. International Space Station photograph of the Islands of the Four Mountains on November 15, 2013. Cleveland is at the center, its summit darkened with recent ejecta and melting by fumarolic activity. A very small white vapor plume rises from the summit crater. The young peaks of Carlise Volcano is to the northwest and Herbert to the southwest. The rugged, incised peak to the east of Cleveland is Tana Volcano on the eastern part of Chuginadak Island. Image courtesy of NASA. http://earthobservatory.nasa.gov/IOTD/view.php?id=82588&eocn=image&eoci=moreiotd.

Table 8. Summary of activity and observations at Cleveland Volcano in 2013.

[**Note:** An important reporting change occurred in May 2013 when AVO analysts stopped reporting the number of pixels with elevated temperatures seen in satellite images. Through May 2013, as a measure of elevated surface temperatures, "number of pixels" reported in parentheses are from an internal Alaska Volcano Observatory (AVO) database of daily satellite observations; this number is a very rough proxy for the intensity of elevated surface temperatures. After May 2013, the presence of elevated surface temperatures are noted with the phrase "Elevated temperatures." Absence of elevated temperature entries may simply mean clouds obscure the ground. **Abbreviations:** ASL, above sea level; AVHRR, Advanced Very High Radiometer; ft, foot; GOES, Geostationary Operational Environmental Satellite; km, kilometer; m, meter: mi, mile; MODIS, Moderate Resolution Imaging Spectroradiometer]

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
01-07-13	**YELLOW/ADVISORY**			White steam plume, no lava in crater.	
01-15-13	**YELLOW/ADVISORY**		AVHRR (2)	Possible steam plume detected in Web camera January 14.	
01-16-13	**YELLOW/ADVISORY**			Weak steam from summit crater.	
01-18-13	**YELLOW/ADVISORY**		AVHRR (3)		
01-22-13	**YELLOW/ADVISORY**		AVHRR (2)	No change at summit.	
01-23-13	**YELLOW/ADVISORY**		AVHRR (1)		
01-24-13	**YELLOW/ADVISORY**		AVHRR (2)		
01-25-13	**YELLOW/ADVISORY**		AVHRR (5)		
01-30-13	**YELLOW/ADVISORY**		AVHRR (1)	New summit dome approximately 100 m across; a report of this new lava did not reach AVO until February 6.	
01-31-13	**YELLOW/ADVISORY**		AVHRR (3) MODIS (1)		
02-01-13	**YELLOW/ADVISORY**		AVHRR (2) MODIS (2)		
02-02-13	**YELLOW/ADVISORY**		AVHRR (1)		
02-04-13	**YELLOW/ADVISORY**		AVHRR (3)		
02-05-13	**YELLOW/ADVISORY**		AVHRR (7) MODIS (2)		
02-06-13	**ORANGE/WATCH**	New lava in crater.	AVHRR (1)		
02-08-13	**ORANGE/WATCH**		AVHRR (3)		
02-09-13	**ORANGE/WATCH**			No significant change in the dome; small new extrusion about 25 m across sits atop the January 30 dome.	
02-10-13	**ORANGE/WATCH**		AVHRR (3)		
02-13-13	**ORANGE/WATCH**		AVHRR (3)		
02-15-13	**ORANGE/WATCH**		AVHRR (2)		
02-24-13	**ORANGE/WATCH**			No change, dome still intact.	
02-26-13	**ORANGE-WATCH**		AVHRR (1)		
03-04-13	**ORANGE/WATCH**			No change, dome still intact.	
03-08-13	**YELLOW/ADVISORY**	No activity since elevated temperatures on February 26.			

Table 8. Summary of activity and observations at Cleveland Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
03-11-13	YELLOW/ADVISORY		AVHRR (2)		
03-13-13	YELLOW/ADVISORY			Dome mostly unchanged. An approximate 10-m-diameter crater atop the dome is emitting a faint plume. There are also typical snow-free areas surrounding the rim of the summit crater.	
03-16-13	YELLOW/ADVISORY		AVHRR (1)		
04-08-13	YELLOW/ADVISORY		AVHRR (2) MODIS (1)		
04-13-13	YELLOW/ADVISORY		ASTER image shows elevated summit temperatures continue.		
04-14-13	YELLOW/ADVISORY		AVHRR (1)		
04-19-13	YELLOW/ADVISORY		AVHRR (1)		
04-20-13	YELLOW/ADVISORY			No change, dome still intact.	
04-22-13	YELLOW/ADVISORY		AVHRR (1) MODIS (1)		
04-26-13	YELLOW/ADVISORY		AVHRR (3)		
04-27-13	YELLOW/ADVISORY		AVHRR (2)		
04-28-13	YELLOW/ADVISORY		AVHRR (2)		
04-29-13	YELLOW/ADVISORY		AVHRR (1) MODIS (1)	No change, dome still intact.	
05-03-13	YELLOW/ADVISORY		AVHRR (1)		
05-04-13	ORANGE/WATCH	Explosion, elevated temperatures, small ash cloud, possibly continued low-level emissions.	AVHRR (3)	A detached ash cloud, likely below 20,000 ft ASL, was seen in multiple AVHRR images to the east and southeast of the volcano. At last sighting, it was 200 km to the southeast. Web camera images suggest continued low-level emissions.	Okmok seismic and infrasound networks record an explosion from Cleveland at approximately 13:00 UTC. This was followed by long-duration airwave signals that are interpreted as continuous low-level emissions of ash and gas (M. Haney, U.S. Geological Survey, written commun., 2013).
05-05-13	ORANGE/WATCH	Possible continuous, low-level ash emissions.	AVHRR (3) MODIS (3)	AVHRR image shows small detached ash cloud east of the volcano. A weak plume from the summit of the volcano persisted in MIR images. Elevated temperatures also seen in GOES imagery which is unusual for Cleveland. Residents of Nikolski hear a loud booming about 8:00 p.m. local time.	

Table 8. Summary of activity and observations at Cleveland Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
05-06-13	**ORANGE/WATCH**	Three explosions.	AVHRR (3)	The summit crater is nearly filled to the rim with fresh tephra deposits. A vent 15 m across is visible in the tephra field. New flowage deposits extend 2–4 km down the northeastern and eastern flanks of the volcano. A 100-m-wide lava flow lobe extends from the southeastern rim of the crater downslope about 600 m.	Explosions detected at 07:23, 16:00, and 20:30 UTC.
05-10-13	**ORANGE/WATCH**		AVHRR (1)MODIS (1)	Robust white vapor plume extending from the summit in MODIS image.	
05-11-13	**ORANGE/WATCH**		AVHRR (3)		
05-12-13	ORANGE/WATCH		AVHRR (3) MODIS (1)		
05-13-13	**ORANGE/WATCH**		AVHRR (3)		
05-14-13	**ORANGE/WATCH**		AVHRR (2)	Lava flow first seen at Cleveland on May 6 has advanced downslope another 700 m.	
05-15-13	**ORANGE/WATCH**		AVHRR (2) MODIS (1)	Both ASTER and MODIS satellite images showed an area of elevated temperature in the summit region.	
05-17-13	**ORANGE/WATCH**		AVHRR (3) MODIS (1)		
05-18-13	**ORANGE/WATCH**		AVHRR (1)		
05-19-13	**ORANGE/WATCH**		AVHRR (3)		
05-22-13	**ORANGE/WATCH**		AVHRR (3)		
05-27-13	**ORANGE/WATCH**		AVHRR (1)		
05-28-13	**ORANGE/WATCH**		AVHRR (1)		
05-29-13	**ORANGE/WATCH**			No changes in the summit area.	
06-04-13	**YELLOW/ADVISORY**	No activity since May 6.			
06-05-13	**YELLOW/ADVISORY**			No changes in the summit area.	
06-10-13	**YELLOW/ADVISORY**		Elevated temperature		
06-11-13	**YELLOW/ADVISORY**			No changes in the summit area.	
07-02-13	**YELLOW/ADVISORY**				
07-03-13	**YELLOW/ADVISORY**		Elevated temperature	Elevated temperatures persist as seen in short-wave infrared data from Landsat 8 on July 3. Noted after explosion of July 2.	
07-13-13	**YELLOW/ADVISORY**		Elevated temperature		
07-21-13	**YELLOW/ADVISORY**		Elevated temperature		
07-22-13	**YELLOW/ADVISORY**		Elevated temperature		

Table 8. Summary of activity and observations at Cleveland Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
07-24-13	YELLOW/ADVISORY		Elevated temperature		
07-25-13	YELLOW/ADVISORY	Possible degassing.	Elevated temperature	Plume seen in AVHRR satellite images from 07:22 a.m. AKDT (15:22 UTC) on July 24 until 5:24 p.m. AKDT (1:24 UTC) on July 25. No ash signal in brightness temperature view.	
07-26-13	YELLOW/ADVISORY	New lava flow in summit crater seen.		Landsat 8 image from July 26, 2013 shows likely lava in the summit crater; this may have been extruded on July 24, when there was a plume seen in AVHRR. Vapor plume in satellite image.	
07-27-13	YELLOW/ADVISORY		Elevated temperature		
07-28-13	YELLOW/ADVISORY		Elevated temperature		
08-03-13	YELLOW/ADVISORY		Elevated temperature		
08-23-13	YELLOW/ADVISORY		Elevated temperature		
08-29-13	YELLOW/ADVISORY		Elevated temperature	No changes over the past month.	
09-07-13	YELLOW/ADVISORY		Elevated temperature		
09-21-13	YELLOW/ADVISORY		Elevated temperature		
09-30-13	YELLOW/ADVISORY			No changes over the past month.	
10-02-13	YELLOW/ADVISORY	Explosion.		No sign of ash in partly cloudy satellite images or Web camera data.	Small explosion at Cleveland at 12:25 UTC triggered the Dillingham infrasound alarm. It was picked up on the Okmok infrasound network as well. Looks similar to previous small explosive events from Cleveland over the past couple years.
10-03-13	YELLOW/ADVISORY	Explosion.		No sign of ash in partly cloudy satellite images or Web camera data.	Explosion from Cleveland at 19:12 UTC. Alarm triggered on the Dillingham infrasound network. Seems larger than October 2 event but not as energetic as some events over the past couple years.
10-04-13	YELLOW/ADVISORY				Explosion at Cleveland around 01:23 UTC. It was picked up by the Dillingham alarm, but not on the Okmok or Akutan networks. Amplitude is smaller than yesterday’s event.
10-05-13	YELLOW/ADVISORY			No evidence of activity in satellite data.	Infrasonic tremor reported.
10-28-13	YELLOW/ADVISORY			No evidence of activity in satellite data.	
11-13-13	YELLOW/ADVISORY		Elevated temperature		
11-15-13	YELLOW/ADVISORY		Elevated temperature		

Table 8. Summary of activity and observations at Cleveland Volcano in 2013.—Continued

Date	Color code/ Alert level	Activity	Elevated surface temperatures, satellite sensor	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
11-16-13	YELLOW/ADVISORY		Elevated temperature	Very small steam plume seen in International Space Station Image ISS038-E-3612. Area around summit is bare of snow. Debris streaks downslope of summit high on cone.	
11-17-13	YELLOW/ADVISORY		Elevated temperature		
11-25-13	YELLOW/ADVISORY			No evidence of activity in satellite data.	
11-26-13	YELLOW/ADVISORY			White steam plume visible from summit crater.	Explosion at Cleveland at approximately 0431 UTC on November 26. The alarm was triggered on the Okmok infrasound array and confirmed on the Akutan infrasound array. This explosion looks more energetic than the most recent explosions and perhaps more similar to explosions in late 2011 and early 2012.
11-29-13	YELLOW/ADVISORY		Elevated temperature		
11-30-13	YELLOW/ADVISORY		Elevated temperature		
12-01-13	YELLOW/ADVISORY		Elevated temperature		
12-05-13	YELLOW/ADVISORY		Elevated temperature		
12-05-13	YELLOW/ADVISORY			A 30-m-wide pit is centered in the summit crater. A very small white plume fills the crater and extends a few hundred meters south.	
12-22-13	YELLOW/ADVISORY		Elevated temperature		
12-26-13	YELLOW/ADVISORY		Elevated temperature		
12-27-13	YELLOW/ADVISORY		Elevated temperature		
12-28-13	YELLOW/ADVISORY		Elevated temperature as high as 40°C) 10 minutes prior to explosion	MODIS satellite image at 21:19 UTC on December 28, shows a strong thermal anomaly in the mid-infrared.	Cleveland explosion appeared on the Okmok, Makushin, and Akutan networks. Infrasound alarm triggered on both the Okmok and Akutan arrays. Possibly weak ground-coupled signal on Westdahl. Origin time 21:29 UTC. The ground-coupled alarm triggered on two sets of four stations at Makushin.
12-29-13	YELLOW/ADVISORY		Elevated temperature, multiple images		
12-30-13	YELLOW/ADVISORY	Explosion, small ash cloud.		Detached ash cloud approximately 45 mi north of Cleveland in 06:28 UTC; AVHRR brightness-temperature difference image.	Explosion at 04:06 UTC first detected on the Okmok infrasound array. Similar amplitude and somewhat long duration (about 2 minutes) compared to typical Cleveland explosions. Also recorded on the Okmok and Makushin seismic networks, weakly on Dillingham array.

Table 9. Cleveland Volcano explosive events, December 25, 2011–December 31, 2013.

[Identification of events and catalog maintenance by Matt Haney, USGS/AVO. 2013 events discussed in this report are shown in **bold**]

Date	Time (UTC)	Infrasonic event No.
12-25-11	1213	1
12-25-11	1532	2
12-29-11	1312	3
03-08-12	0405	4
03-10-12	0150	5
03-13-12	2255	6
04-04-12	0912	7
04-07-12	0035	8
04-07-12	0526	9
04-13-12	16 04	10
04-13-12	19 01	11
04-19-12	12 38	12
05-04-12	18 54	13
05-05-12	09 20	14
06-04-12	10 08	15
06-19-12	22 04	16
06-26-12	11 19	17
07-12-12	05 52	18
08-04-12	16 38	19
08-17-12	08 48	20
08-20-12	02 55	21
11-10-12	20 25	22
05-04-13	**12 59**	**23**
05-06-13	**07 23**	**24**
05-06-13	**16 00**	**25**
05-06-13	**20 30**	**26**
10-02-13	**12 25**	**27**
10-03-13	**19 12**	**28**
10-04-13	**0123**	**29**
11-26-13	**0431**	**30**
12-28-13	**2129**	**31**

Korovin Volcano

GVP New # 311161

CAVW# 1101-161-

52°23'N 174°09'W
1,533 m (5,030 ft)

Andreanof Islands, Aleutian Islands

EARTHQUAKE SWARM, ISOLATED TREMOR

Starting on March 29, Korovin Volcano experienced a 2-week-long swarm of small earthquakes located 2–4 km (1.2–2.4 mi) northwest of the summit of Korovin. Earthquake activity peaked on April 10, with a rate of 10 earthquakes per hour, and the swarm ended by April 12 (fig. 45). Throughout 2013, AVO noted isolated tremor at Korovin. In comparison, this tremor released about one-third of the energy level of tremor associated with a 2006 period of unrest at Korovin. The Aviation Color Code and Volcano Alert Level remained **UNASSIGNED/UNASSIGNED** throughout the year.

Korovin volcano is a stratovolcano, 1,533 m (5,030 ft) high and almost 7 km (4.3 mi) in basal diameter, with two summit vents 0.6 km (0.4 mi) apart (Miller and others, 1998). The northwestern summit vent is a symmetric cone with a small crater. The southeastern summit vent is on the remnant of a cone with a steep-walled crater, about 1 km (0.6 mi) wide at the rim and at least several hundred meters deep. Intercalated lava flows and pyroclastic rocks comprise the upper part of the crater wall, but the bottom 100 m (330 ft) or so are nearly vertical and apparently consist entirely of lava flows. A turquoise-green lake fills the lower part of the crater; the color suggests the occurrence of solfataric activity (Sekora, 1973). Neighboring Kliuchef on the northern rim of the Atka Caldera is most likely a satellite vent of the earlier Atka volcano, as is Kliuchef, which is located on the northern rim of the Atka caldera. Korovin and Kliuchef are virtually undissected and thus are apparently of post-glacial age. Hot springs and fumaroles occur on the southern and western flanks of Mt. Kliuchef and near the head of a glacial valley 6 km (3.7 mi) southwest of Korovin volcano (Motyka and others, 1993).

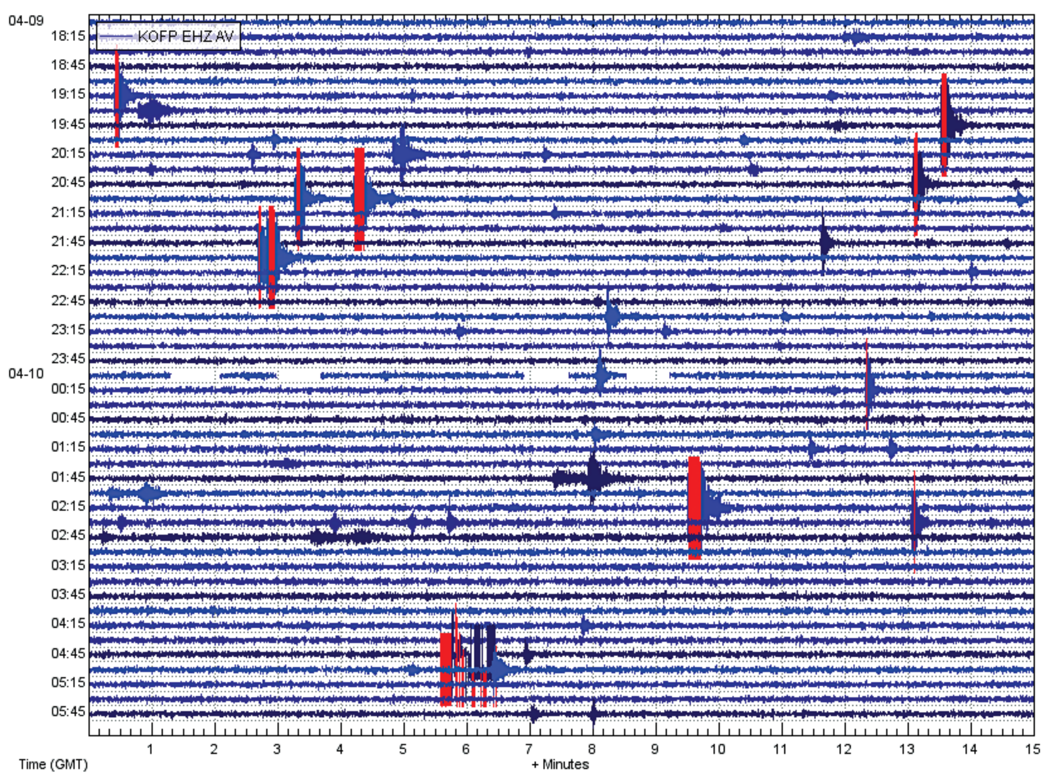

Figure 45. Seismograph station KOFP webicorder plot of the peak earthquake activity during the Kanaga earthquake swarm. Twenty-seven earthquakes were located in the 12 hours shown (18:00 UTC. April 9–06:00 UTC, April 10, 2013). Earthquakes greater than ML=1.2 are clipped with clipped values shown in red. The 24-hour calibration signal for KOFP is visible at 05:05 UTC on April 10.

Great Sitkin Volcano

GVP New # 311120

CAVW# 1101-12-

52°04'N 176°07'W
1,740 m (5,709 ft)

Andreanof Islands, Aleutian Islands

EARTHQUAKE SWARMS, THERMAL ANOMALY

Two earthquake swarms were detected on seismic instrumentation at Great Sitkin Volcano during 2013, one in July and one in August. Both swarms consisted of about three dozen volcanic-tectonic earthquakes (fig. 46). Satellite data acquired September 3 showed a possible thermal feature, AVO determined that this was a signal from a known hot springs at the summit of Great Sitkin (fumarolic temperatures measured at 98 °C in 2005, Christina Neal, USGS/AVO, oral commun., 2013). The Aviation Color Code and Volcano Alert Level remained at **GREEN/NORMAL** throughout the year.

Great Sitkin Volcano is a basaltic-andesite volcano that comprises most of the northern one-half of Great Sitkin Island in the Andreanof Islands group in the central Aleutian Islands (Waythomas and others, 2003). The volcano consists of an older collapsed volcano and a younger parasitic cone with a 2–3 km (3–5 mi.) diameter summit crater. A steep-sided dome occupies the center of the crater. Great Sitkin erupted at least three times in the 20th century, most recently in 1974 when a lava dome formed in the crater accompanied by at least one ash cloud that reached about 3,000 m (10,000 ft) ASL (Miller and others, 1998). A poorly documented eruption occurred in 1945 also produced a lava dome that was partially destroyed by the 1974 eruption. Within the past 280 years, a large explosive eruption produced pyroclastic flows that partially filled a valley on the southwestern flank (Waythomas and Miller, 2003). Earthquake swarms accompanied by tremor also were recorded at Great Sitkin in 2001.

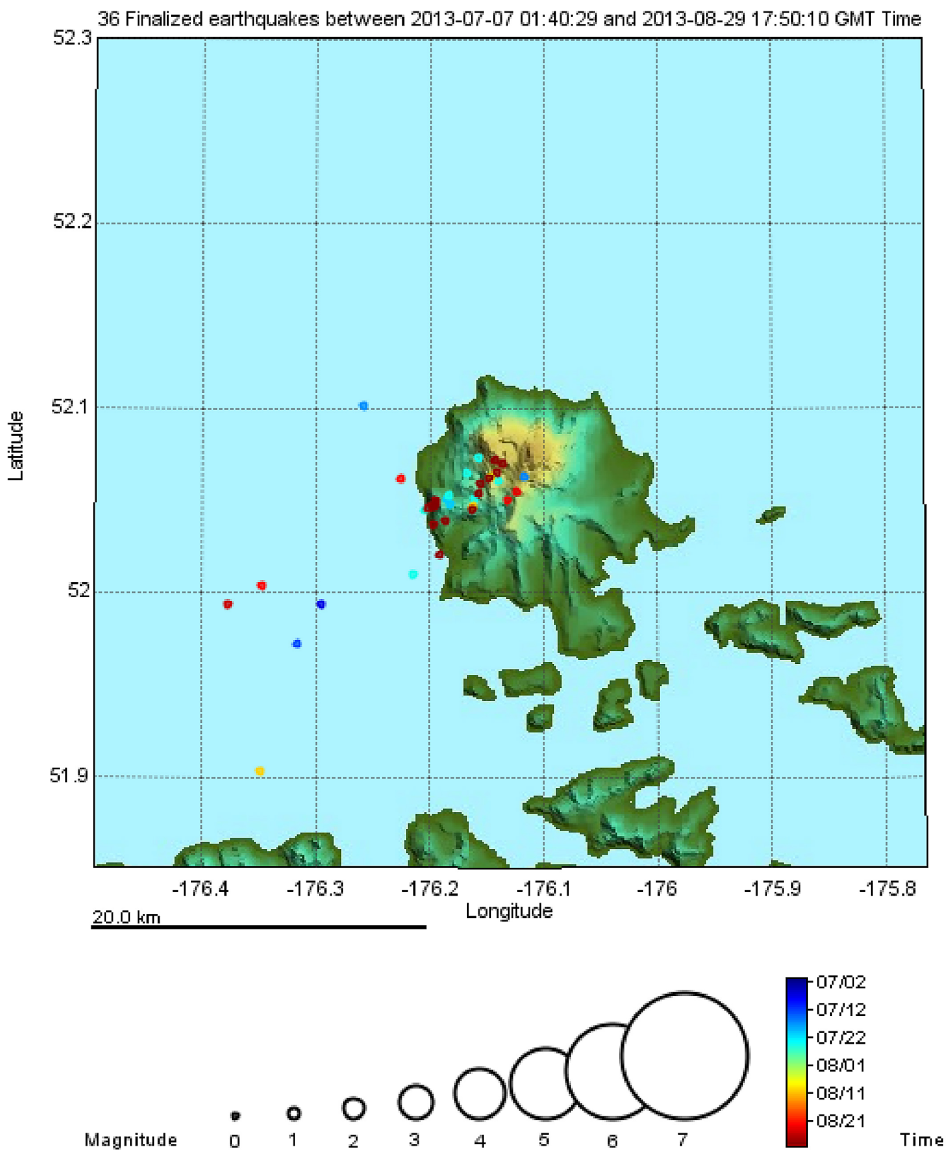

Figure 46. Map of two earthquake swarms located near Great Sitkin Volcano in July (light blue) and in August (dark red) 2013.

Mount Gareloi

GVP New # 311070

CAVW# 1101-07-

51°47'N 178°48'W
1,573 m (5,161 ft)

Andreanof Islands, Aleutian Islands

FELT EARTHQUAKES, STEAMING FROM FUMAROLES

A U.S. Fish and Wildlife Service (USFWS) field crew felt tremors and observed steaming from a fumarolic area on Mount Gareloi during a field operation in the summer of 2013. The Aviation Color Code and Volcano Alert Level remained **GREEN/NORMAL** throughout the year.

In July and August, AVO duty personnel responded to observations from a USFWS crew conducting ornithology work on Gareloi Island. The initial reports were of “tremors of a magnitude that were noticeable to crews working outside, moving around.” A check of the seismicity showed no unusual activity. The background activity at Gareloi, since seismic station installation in 2003, has been constant low-level seismicity consisting of low-frequency earthquakes at a rate of one per minute. In light of the 2008 evacuation of a USFWS crew at Kasatochi and the subsequent eruption of Kasatochi (Waythomas and others, 2010), AVO closely monitored seismicity at Gareloi during the late summer. Despite close scrutiny, no changes were noted in the seismicity, nor were there further observations of felt events. Although the cause of the felt earthquakes was not determined, the felt reports were forwarded to AVO offices a week after a July 7 ML=5.5 earthquake and aftershock sequence south of Gareloi. The felt reports did not include event timing, and the most plausible explanation is that the USFW crew felt regional earthquakes and not volcano-related seismicity.

The USFW crew also noted “steam coming from the extensive fumarole area on the west peak” on July 30. Although this was a single observation, the field crew additionally commented that the weather on July 30 was unusually clear and allowed for the observation of steaming (fig. 47). Steaming at fumaroles on Gareloi is routinely seen, with observations of steaming in 2003 and 2005 (Michelle Coombs, USGS/AVO, written commun., 2005).

Mount Gareloi, which makes up most of Gareloi Island, is a stratovolcano 10 × 8 km (6.2 × 5.0 mi) in diameter at its base with two summits, separated by a narrow saddle (Miller and others, 1998). Two small glaciers extend northwest and southeast from the saddle. The northern, slightly higher peak is on the southern rim of a crater about 300 m (1,000 ft) across, which contains several active fumaroles. Thirteen younger craters, from 80 to 1,600 m (260 to 5,250 ft) in diameter, are aligned along a south-southeast trending fissure that extends from strandline to the southern summit. These craters formed during a major explosive eruption in 1929 that also produced four blocky lava flows and a blanket of grassy andesitic tuff that covers an area roughly 2.5 × 5 km (1.6 × 3.1 mi) on the volcano southeastern flank of the volcano (Coats, 1959; Coombs and others, 2012).

Figure 47. Photograph showing steaming from the fumaroles on Mount Gareloi on July 6, 2013. Photograph by Ian Jones, used with permission. AVO image database URL: http://www.avo.alaska.edu/images/image.php?id=57491.

Summary

2013 was a moderate year in terms of eruptions and unrest for the Alaska Volcano Observatory. The confirmed eruptive activity occurred at persistently active Mount Cleveland in the central Aleutians, a significant eruption at Pavlof Volcano on the Alaska Peninsula, and a minor eruption of Mount Veniaminof Volcano on the Alaska Peninsula. Other volcanoes in Alaska showed minor unrest in the form of unusual seismicity, notable fumarolic emissions, and suspicious clouds of likely non-volcanic origin.

Acknowledgments

This report represents work of the entire Alaska Volcano Observatory staff, colleagues from other U.S. Geological Survey Volcano Observatories, cooperating State and Federal agencies, and members of the public. Careful technical reviews by Hans Schwaiger and Tom Miller improved the content and presentation. We particularly thank Kristi Wallace, Elizabeth Redlinger, and others who contributed to maintaining the internal chronologies of activity at Cleveland, Veniaminof, and Pavlof volcanoes.

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Glossary of Selected Terms and Acronyms

AEIC Alaska Earthquake Information Center.

AKDT "Alaska Daylight Time"; UTC -8 hours. Alaska Daylight Time in 2013 ran from 10:00 UTC March 10 to 10:00 UTC November 3.

AKST "Alaska Standard Time"; UTC-9 hours.

andesite volcanic rock composed of about 53–63 percent silica (SiO_2, an essential constituent of most minerals found in rocks).

ash fine fragments (less than 2 millimeters across) of lava or rock formed in an explosive volcanic eruption.

ASL above sea level.

ASTER Advanced Spaceborne Thermal Emission and Reflection Radiometer.

AVHRR "Advanced Very High Resolution Radiometer"; AVHRR provides one form of satellite imagery.

AVO Alaska Volcano Observatory.

basalt general term for dark-colored igneous rock, usually extrusive, containing about 45–52 weight percent silica (SiO_2, an essential constituent of most minerals found in rocks).

bomb boulder-size chunk of partly solidified lava explosively ejected from a volcano.

caldera a large, roughly circular depression usually caused by volcanic collapse or explosion.

CAVW Smithsonian Institute's "Catalog of Active Volcanoes of the World" (Siebert and others, 2010).

cinder cone small, steep-sided conical hill built mainly of cinder, spatter, and volcanic bombs.

COSPEC "Correlation Spectrometer," a device for optically and remotely measuring sulfur-dioxide emissions.

earthquake family A group of earthquakes having similar waveforms at a fixed seismograph station that represent the same process at the same location

FAA Federal Aviation Administration.

fallout a general term for debris which falls to the Earth from an eruption cloud.

fault A fracture along which the blocks of the Earth's crust on either side have moved relative to one another parallel to the fracture.

fissure a roughly linear or sinuous crack or opening on a volcano; a type of vent which commonly produces lava fountains and flows.

FLIR "Forward Looking Infrared Radiometer," used to delineate objects of different temperature.

fumarole a small opening or vent from which hot gases are emitted.

GMT Greenwich Mean Time.

GOES Geostationary Operational Environmental Satellite.

GPS Global Positioning System.

GSFC Goddard Space Flight Center.

Holocene geologic epoch extending from the present to 10,000 years ago.

InSAR Interferometric Synthetic Aperture Radar.

intracaldera refers to something within the caldera.

ISS International Space Station.

KVERT Kamchatka Volcanic Eruption Response Team.

lapilli pyroclasts or volcanic fragments that are between 2 mm and 64 mm in diameter.

lahar A flow of a mixture of pyroclastic material and water.

lava molten rock that has reached the Earth's surface.

M_L an earthquake magnitude scale based on the amplitude of ground motion as measured by a standard seismograph.

magma molten rock below the surface of the Earth.

MODIS Satellite-based "Moderate-resolution Imaging Spectroradiometer." .

NASA National Aeronautics and Space Administration.

NWS National Weather Service.

OMI Ozone Mapping Instrument on NASA's Aura satellite.

phreatic activity an explosive eruption caused by the sudden heating of ground water as it comes in contact with hot volcanic rock or magma leading to a steam-driven explosion.

phreatic ash fine fragments of volcanic rock expelled during phreatic activity; this ash usually is derived from existing rock and not from new magma.

PIREP "Pilot Weather Report"; a report of meteorological phenomena encountered by aircraft in flight.

pixel contraction of "picture element." A pixel is one of the many discrete rectangular elements that form a digital image or picture on a computer monitor or stored in memory. In a satellite image, resolution describes the size of a pixel in relation to area covered on the ground. More pixels per unit area on the ground means a higher resolution.

Pleistocene geologic epoch extending from about 2.6 million years ago to approximately 10,000 years before present.

PUFF a volcanic ash tracking model (Searcy and others, 1998).

pyroclast an individual particle ejected during a volcanic eruption; usually classified by size, for example, ash, lapilli.

RSAM Real-time Seismic Amplitude Measurement.

regional earthquake earthquake generated by fracture or slippage along a fault; not caused by volcanic activity.

SAR Synthetic Aperture Radar.

satellite cone a subsidiary volcanic vent located on the flank of a larger volcano.

seismic swarm a flurry of earthquakes; often precedes an eruption.

SI International System of Units.

SIGMET SIGnificant METeorological information statement, issued by NWS.

Stratovolcano Also called a stratocone or composite cone, a steep-sided volcano, usually conical in shape, built of interbedded lava flows and fragmental deposits from explosive eruptions.

Strombolian type of volcanic eruption characterized by intermittent bursts of fluid lava, usually basalt, from a vent or crater as gas bubbles rise through a conduit and burst at the surface.

SVA Suspect Volcanic Activity.

SVERT "Sakhalin Volcanic Eruption Response Team" monitors and reports on Kurile Island volcanoes.

tephra a general term covering all fragmental material expelled from a volcano (ash, bombs, cinders, etc.).

UAFGI University of Alaska Fairbanks Geophysical Institute.

UFWS United States Fish and Wildlife Service.

USGS United States Geological Survey.

UTC "Coordinated Universal Time"; same as Greenwich Mean Time (GMT).

VAN Volcanic Activity Notice.

vent an opening in the earth's surface through which magma erupts or volcanic gasses are emitted.

volcano-tectonic earthquakes earthquakes generated within or near a volcano from brittle rock failure resulting from strain induced by volcanic processes.

VT volcano-tectonic earthquake.

Vulcanian style of explosive eruption consisting of repeated, violent ejection of incandescent fragments of viscous lava, usually in the form of blocks, along with volcanic ash. Sometimes, Vulcanian eruptions involve water mixing with erupting magma.

Appendix 1. Volcano Alert Levels and Aviation Color Codes Used by United States Volcano Observatories

Alert levels address the overall activity at the volcano, not just the hazard to aviation. There may be situations where a volcano is producing lava flows that are dangerous on the ground and merit a WATCH or WARNING, however, the hazard to aviation is minimal. Alert levels announcements contain additional explanation of volcanic activity and expected hazards where possible. (Gardner and Guffanti, 2006).

Alert Levels	
NORMAL	Volcano is in typical background, noneruptive state. *Or, after a change from a higher level:* Volcanic activity has ceased and volcano reverted to its noneruptive state.
ADVISORY	Volcano is exhibiting signs of elevated unrest above known background level. *Or, after a change from a higher level:* Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
WATCH	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain. *Or:* Eruption is underway but poses limited hazards.
WARNING	Highly hazardous eruption is imminent, underway, or suspected.

Level of Concern Codes for Aviation	
GREEN	Volcano is in typical background, noneruptive state. *Or, after a change from a higher level:* Volcanic activity has ceased and volcano has returned to noneruptive background state.
YELLOW	Volcano is exhibiting signs of elevated unrest above known background level. *Or, after a change from a higher level:* Volcanic activity has decreased significantly but continues to be closely monitored for possible renewed increase.
ORANGE	Volcano is exhibiting heightened or escalating unrest with increased potential of eruption, timeframe uncertain. *Or:* Eruption is underway with no or minor ash emissions [ash-plume height specified, if possible].
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely. *Or:* Eruption is underway or suspected with significant emission of volcanic ash into the atmosphere [ash-plume height specified, if possible].

Appendix 2. Number of Earthquakes Located for Each Seismograph Subnetwork in 2013 within 20 Kilometers of the Volcanic Centers in Each Subnetwork

The totals for 2013 are separated into three event types—volcanic-tectonic (VT), low-frequency (LF), and other (all other possible event types). Magnitude of completeness (Mc) for AVO seismograph subnetworks for March 2002–December 2012.

Volcano subnetwork	Number of earthquakes		2013 event types			Magnitude of completeness
	2012	2013	Volcanic-tectonic	Low-frequency	All other	
Akutan	42	146	107	39	0	0.3
Aniakchak	40	48	11	37	0	1.4
Augustine	54	101	97	4	0	0.0
Dutton	12	11	11	0	0	1.0
Fourpeaked	123	71	71	0	0	0.4
Gareloi	16	10	10	0	0	1.2
Great Sitkin	24	79	73	6	0	0.6
Iliamna	738	444	340	104	0	0.4
Kanaga	52	147	136	11	0	1.2
Katmai Cluster	824	496	486	10	0	0.5
Korovin	22	186	173	12	0	0.7
Little Sitkin	1,050	3	2	0	1	0.0
Makushin	234	457	434	23	0	0.7
Okmok	33	55	25	30	0	0.9
Pavlof	4	9	2	7	0	1.0
Redoubt	154	189	137	52	0	0.3
Semisopochnoi	14	0	0	0	0	1.0
Shishaldin	64	3	3	0	0	0.6
Spurr	496	331	251	80	0	0.2
Tanaga	65	98	98	0	0	1.3
Ugashik-Peulik	59	17	13	4	0	0..3
Veniaminof	13	7	5	2	0	1.3
Westdahl	58	22	15	7	0	1.1
Wrangell	0	0	0	0	0	0.9
Totals	4,211	2,930	2,500	429	1	

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