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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 and Geophysical Surveys. The Alaska Volcano Observatory is funded by the U.S. Geological Survey Volcano Hazards Program and the State of Alaska

2015 Volcanic Activity in Alaska: Summary of Events and Response of the Alaska Volcano Observatory

Scientific Investigations Report 2017–5104

U.S. Department of the Interior
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Cover: Photograph showing helicopter pilot preparing to pick up geochemists at the upper Geyser Bight geothermal area, Umnak Island, August 16, 2015. Photograph by John Lyons AVO/USGS. AVO database image: http://www.avo.alaska.edu/images/image.php?id=83891.

2015 Volcanic Activity in Alaska: Summary of Events and Response of the Alaska Volcano Observatory

By James P. Dixon, Cheryl E. Cameron, Alexandra M. Iezzi, and Kristi Wallace

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

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
square foot (ft^2)	0.09290	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)
foot per second (ft/s)	0.0003048	kilometer per second (km/s)
mile (mi)	1.609	kilometer (km)
square foot (ft^2)	929.0	square centimeter (cm^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
ton per day (ton/d)	0.9072	metric ton per day

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

$$°C = (°F-32)/1.8.$$

International System of Units to U.S. customary units

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)
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
kilometer per second (km/s)	3,281	foot per second (ft/s)
meter (m)	3,281	foot (ft)
metric ton per day	1.1022	ton per day (ton/d)
square centimeter (cm^2)	0.001076	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
square meter (m^2)	10.76	square foot (ft^2)

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

$$°F = (1.8×°C) +32.$$

Datum

Altitude and elevation as used in this report, refers 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 WGS 1984 datum.

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L).

2015 Volcanic Activity in Alaska: Summary of Events and Response of the Alaska Volcano Observatory

By James P. Dixon[1], Cheryl E. Cameron[2], Alexandra M. Iezzi[3], and Kristi Wallace[4]

Abstract

The Alaska Volcano Observatory (AVO) responded to eruptions, volcanic unrest or suspected unrest, and seismic events at 14 volcanic centers in Alaska during 2015. The most notable volcanic activity consisted of continuing intermittent ash eruptions from Cleveland and Shishaldin volcanoes in the Aleutian Islands. Two eruptive episodes, at Veniaminof and Pavlof, on the Alaska Peninsula ended in 2015. During 2015, AVO re-established the seismograph network at Aniakchak, installed six new broadband seismometers throughout the Aleutian Islands, and added a Multiple component Gas Analyzer System (MultiGAS) station on Augustine.

Introduction

The Alaska Volcano Observatory (AVO) has a mandate to monitor, study, and warn of volcanic unrest at Alaskan volcanoes. This report summarizes notable volcanic activity in Alaska during 2015 (fig. 1**;** tables 1 and 2) and briefly describes AVO's response. Information about all volcanoes at elevated alert status and events that prompted increased attention by AVO staff are included, even if no formal public notification ensued. Observations, images, and data typically not published elsewhere also are included. In addition to routine maintenance and fieldwork, AVO personnel were involved in extensive land-based and ship-based work in the central and western Aleutian Islands as part of the GeoPRISMS program funded by the National Science Foundation in 2015.

As of December 31, 2015, 33 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). Included in this list is the Cleveland seismograph network that requires a seismograph station in Nikolski, 75 km (47 mi) from Cleveland volcano, to locate earthquakes. Wrangell and Fourpeaked volcanoes are not considered to be seismically monitored due to network-wide outages that continued throughout 2015.

The AVO volcano-monitoring program includes daily analysis of satellite imagery (AVHRR, MODIS SAR images for example), web cameras, and seismicity; occasional overflights; airborne-gas measurements; compilation of pilot reports (PIREPs); and observations by local residents and mariners. AVO also receives real-time deformation data from permanent Global Positioning System (GPS) stations at eight Alaskan volcanoes (Akutan, Augustine, Makushin, Okmok, Redoubt, Shishaldin, Spurr, and Westdahl). Periodic analysis of the Ozone Mapping Instrument (OMI) on NASA's Aura satellite (Lopez and others, 2013) and Interferometric Synthetic Aperture Radar (InSAR) imagery also is used to monitor unrest at volcanoes in Alaska (for example, Lu, 2007). AVO is increasing the use of infrasound (atmospheric pressure waves) to detect explosions throughout the Aleutian arc (for example, Fee and others, 2010).

As part of AVO's longstanding close cooperation with volcano monitoring and reporting groups in the Russian Far East, earlier versions starting with Neal and others (2009) in this report series (table 4) included summaries of activity in Kamchatka and the Kurile Islands. 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 (KVERT) and Sakhalin (SVERT) Volcanic Eruption Response Teams (http://www.kscnet.ru/ivs/kvert/index_eng.php and http://www.imgg.ru/?id_d=659) and to the Smithsonian Institution Global Volcanism Project (GVP; http://volcano.si.edu).

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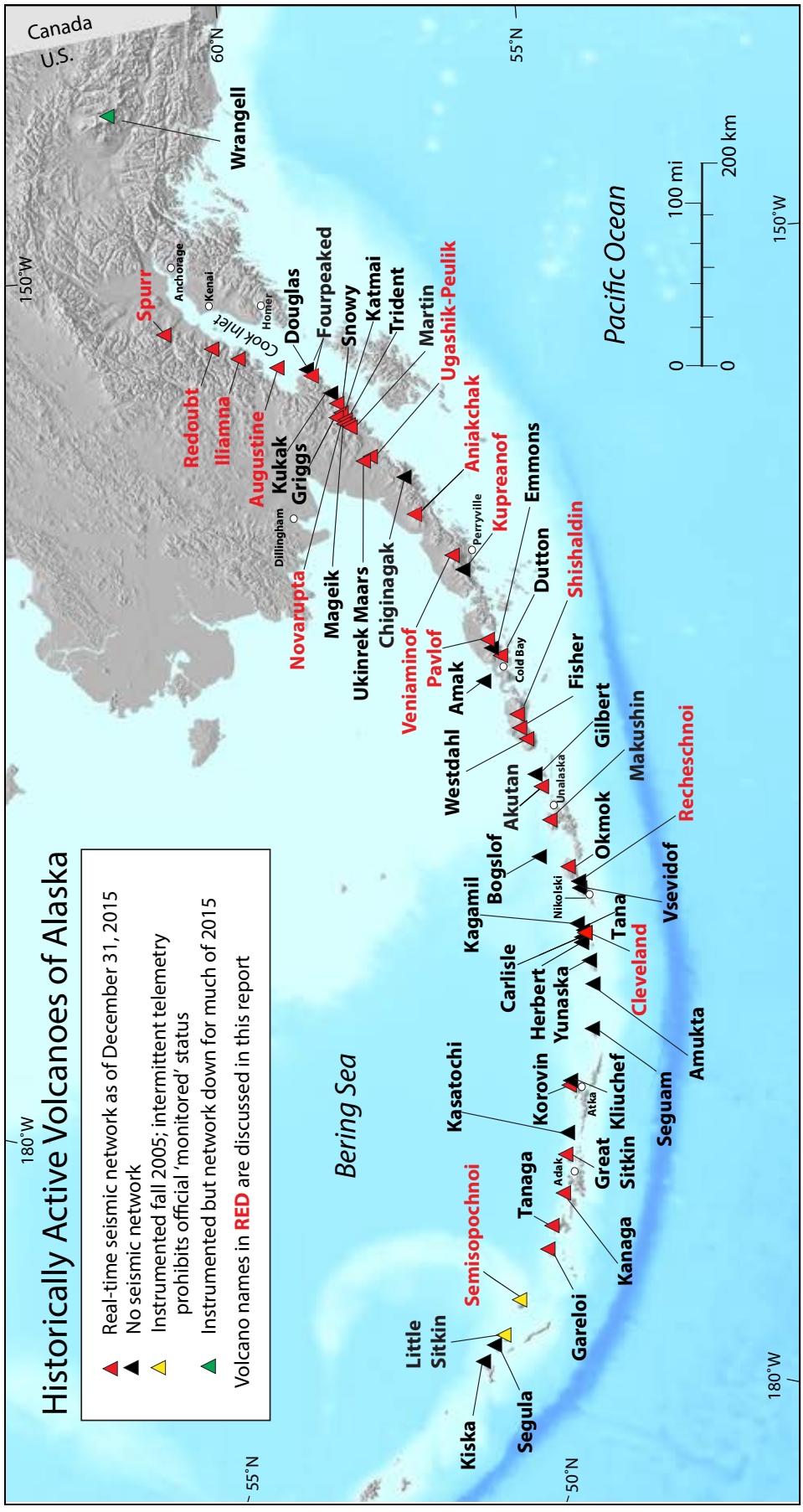

Figure 1. Map showing 52 historically active volcanoes in Alaska, their monitored status, and place names used in this report. Following the established criteria and review of Cameron and others (2008), volcanoes are considered historically active if they had an eruption or period of intense deformation, or seismic, or fumarolic activity that is inferred to reflect the presence of magma at shallow levels beneath the volcano post 1741 when written records of volcanic activity began.

Table 1. Summary of 2015 monitoring highlights at volcanoes in Alaska, including but not limited to actual eruptions, possible eruptions, unusual increases in seismicity or fumarolic activity and monitoring highlights.

[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 5 and 6. Locations of volcanoes are shown in figure 1]

Volcano	Date of activity	Type of activity
Spurr	October–December	Earthquake swarm
Redoubt	June	Snow, rock, and debris avalanche
Iliamna	July	Large tectonic earthquake
Augustine	Year-round	Steam plumes, rockfalls
Katmai	March, August–October	Resuspended 1912 ash
Ugashik-Peulik	March, July	Large tectonic earthquake, discolored water
Aniakchak	October	Added back in the monitored volcano list
Veniaminof	September–December	Seismic unrest
Kupreanof	April	Steam plume
Pavlof	January	End of 2014 eruption
Shishaldin	Year-round	Intermittent low-level eruption
Recheshnoi	Year-round	Continuation of increased seismicity
Cleveland	Year-round	Continued low-level eruption
Semisopochnoi	January–May	Earthquake swarm

Volcano descriptions are presented in geographic order from northeast to southwest along the Aleutian Arc. Each entry has a title block with information about the volcano—unique GVP identifier; the latitude, longitude, and summit elevation; the global region; and an abbreviated summary highlighting the activity. Each summary is followed by detailed activity information, often with accompanying tables, images, and (or) figures. Each volcano event summary ends with background information. The event summary is derived from published material as well as AVO daily status reports, AVO weekly updates and special information releases, AVO email and online electronic logs, Miller and others (1998), and the Smithsonian Institution Global Volcanism Network Bulletins (available at http://www.volcano.si.edu/reports_bgvn.cfm). Beginning with the 2013 report, AVO's annual summary includes expanded information on seismicity and seismograph networks at Alaska volcanoes. Volcanic activity in past and present AVO summaries are compiled by year (table 5) and by volcano (table 6).

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.

Table 2. Alaska volcanoes with Aviation Color Code and Volcano Alert Level changes in 2015.

[Description of Aviation Color Codes is shown in appendix 1. Volcanoes that are not showing signs of unrest and do not have a certified real-time seismograph network are not assigned a color code, 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**. The dates of January 1 and December 31 do not indicate a change in monitoring status and the color code is respectively carried over from 2014 and continued into 2016]

Color Code	Dates at this color in 2015
ANIAKCHAK	
UNASSIGNED	January 1 – October 23
GREEN/NORMAL	October 23 – December 31
VENIAMINOF	
GREEN/NORMAL	January 1 – October 1
YELLOW/ADVISORY	October 1 – December 11
GREEN/NORMAL	December 11 – December 31
PAVLOF	
YELLOW/ADVISORY	January 1 – January 15
GREEN/NORMAL	January 15 – December 31
SHISHALDIN	
ORANGE/WATCH	January 1 – Novemer 20
YELLOW/ADVISORY	November 20 – December 31
CLEVELAND	
YELLOW/ADVISORY	January 1 – May 28
UNASSIGNED	May 28 – June 17
YELLOW/ADVISORY	June 10 – July 21
ORANGE/WATCH	July 21 – October 14
YELLOW/ADVISORY	October 14 – December 31
SEMISOPOCHNOI	
UNASSIGNED	January 1 – March 25
YELLOW/ADVISORY	March 25 – May 28
UNASSIGNED	May 28 – December 31

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 are emphasized 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.

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 now considered to be post 1741, 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) concluded 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.

Table 3. History of seismic monitoring of Alaska volcanoes from August 1971 through December 2015.

[History of seismic monitoring. "First station installed" refers to the date when AVO first received real-time data from the station. This date can be many months following initial fieldwork at the volcano. Alaska Volcano Observatory (AVO) considers the seismograph network "complete" following installation and data transmission from a minimum of four seismograph 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 that began in 1991. The magnitude of completeness is the lowest magnitude earthquake that we are confident that all earthquakes equal to or larger has been located at the volcanic center based on data from 2002 to 2015. For more information on specific seismograph network histories, readers are referred to the series of annual seismic summaries prepared by AVO (for example, Dixon and others, 2013)]

Volcano	Approximate start date of seismic monitoring	Earthquakes located in 2015	Magnitude of completeness
Wrangell	First station installed – July 2000 Network complete (4 stations) – **August 2001** Added to monitored list in weekly update – November 2001 Removed from monitored list in weekly update – January 2012	0	0.9
Spurr	First station installed – August 1971 Network complete (17 stations) – **August 1989** Added to monitored list in weekly update – April 1991	519	0.2
Redoubt	First station installed – August 1971 Network complete (12 stations) – **August 1988** Added to monitored list in weekly update – April 1991	173	0.3
Iliamna	First station installed – September 1987 Network complete (7 stations) – **September 1994** Added to monitored list in weekly update – April 1991	8	-0.2
Augustine	First station installed – October 1976 Network complete (12 stations) – **August 1978** Added to monitored list in weekly update – April 1991	162	0.0
Fourpeaked	First station installed – September 2006 Network complete (4 stations) – **October 2006** Added to monitored list in weekly update – October 2006 Removed from monitored list in weekly update – November 2009	0	0.4
Katmai-North (Snowy)	First station installed – August 1988 Network complete (5 stations) – **October 1998** Added to monitored list in weekly update – December 1998	132	0.8
Katmai-Central (Griggs, Katmai, Novarupta, Trident)	First station installed – August 1988 Network complete (7 stations) – **July 1991** Added to monitored list in weekly update – November 1996	308	0.4
Katmai-South (Martin, Mageik)	First station installed – August 1988 Network complete (8 stations) – **July 1996** Added to monitored list in weekly update – November 1996	397	0.3
Ukinrek Maars/Peulik	First station installed – March 2005 Network complete (7 stations) – **March 2005** Added to monitored list in weekly update – April 2005	9	1.0
Aniakchak	First station installed – July 1997 Network complete (6 stations) – **July 1997** Added to monitored list in weekly update – November 1997 Removed from monitored list in weekly update – November 2009 Added back to monitored list in weekly update – October 2015	1	1.4

Table 3. History of seismic monitoring of Alaska volcanoes from August 1971 through December 2015.—Continued

Volcano	Approximate start date of seismic monitoring	Earthquakes located in 2015	Magnitude of completeness
Veniaminof	First station installed – February 2002 Network complete (9 stations) – **February 2002** Added to monitored list in weekly update – September 2002 Removed from monitored list in weekly update – November 2009	0	1.5
Pavlof	First station installed – July 1996 Network complete (7 stations) – **July 1996** Added to monitored list in weekly update – November 1996	18	1.0
Dutton	First station installed – July 1988 Network complete (5 stations) – **July 1996** Added to monitored list in weekly update – November 1996	1	1.0
Shishaldin (and Isantoski)	First station installed – July 1997 Network complete (7 stations) – **July 1997** Shishaldin added to list in weekly update – November 1997 Isantoski added to list in weekly update – December 1998	35	0.6
Westdahl (and Fisher)	First station installed – August 1998 Network complete (6 stations) – **October 1998** Added to monitored list in weekly update – December 1998	53	1.1
Akutan	First station installed – March 1996 Network complete (13 stations) – **July 1996** Added to monitored list in weekly update – November 1996	113	0.4
Makushin	First station installed – July 1996 Network complete (8 stations) – **July 1996** Added to monitored list in weekly update – November 1996	718	0.7
Okmok	First station installed – January 2003 Network complete (13 stations) – **January 2003** Added to monitored list in weekly update – January 2004	67	0.9
Cleveland	First station installed – August 2014 Network complete (2 stations) – N/A Not yet added to monitored list in weekly update	1	0.9
Korovin	First station installed – July 2004 Network complete (7 stations) – **July 2004** Added to monitored list in weekly update – December 2005	67	0.9
Great Sitkin	First station installed – September 1999 Network complete (6 stations) – **September 1999** Added to monitored list in weekly update – December 1999	108	1.2
Kanaga	First station installed – September 1999 Network complete (6 stations) – **September 1999** Added to monitored list in weekly update – December 2000	29	0.6
Tanaga	First station installed – August 2003 Network complete (6 stations) – **August 2003** Added to monitored list in weekly update – June 2004	68	1.2
Gareloi	First station installed – August 2003 Network complete (6 stations) – **September 2003** Added to monitored list in weekly update – June 2004	86	1.1
Semisopochnoi (Cerberus)	First station installed – September 2005 Network complete (6 stations) – **September 2005** Not yet added to monitored list in weekly update	20	1.2
Little Sitkin	First station installed – September 2005 Network complete (4 stations) – **September 2005** Not yet added to monitored list in weekly update	903	0.5

Table 4. Citations for Alaska Volcano Observatory Annual Summary reports, 1992–2014.

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.	https://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.	https://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, 19 p.	https://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.	https://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.	https://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.	https://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.	https://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.	https://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.	https://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, 53 p.	https://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.	https://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, 58 p.	https://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, 67 p.	https://pubs.usgs.gov/of/2005/1308/
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.	https://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.	https://pubs.usgs.gov/sir/2008/5214/

Table 4. Citations for Alaska Volcano Observatory Annual Summary reports, 1992–2014.—Continued

Year	Citation	URL
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.	https://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, 94 p.	https://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.	https://pubs.usgs.gov/sir/2013/5213/
2010	Neal, C.A., Herrick, J., Girina, O.A., Chibisova, M., Rybin, A., McGimsey, R., and Dixon, J., 2014, 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 2014-5034, 76 p.	https://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.	https://pubs.usgs.gov/sir/2014/5159/
2012	Herrick, J.A., Neal, C.A., Cameron, C.E., Dixon, J.P., 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.	https://pubs.usgs.gov/sir/2014/5160/
2013	Dixon, J.P., Cameron, Cheryl, McGimsey, R.G., Neal, C.A., and Waythomas, Chris, 2015, 2013 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2015–5110, 92 p.	https://dx.doi.org/10.3133/sir20155110
2014	Cameron, C.E., Dixon, J.P., Neal, C.A., Waythomas, C.F., Schaefer, J.R., and McGimsey, R.G., 2017, 2014 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2017–5077, 81 p.	https://doi.org/10.3133/sir20175077

Table 5. Compilation by year of volcanoes included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.

[Volcanoes are presented in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc and north to south along Kamchatka and the Kurile Islands. Prior to 1995 and after 2010, Alaska Volcano Observatory did not report on Russian volcanoes]

Volcanoes mentioned	
Alaskan	**Russian**
1992	
Spurr/Crater Peak	
Iliamna	
Redoubt	
Katmai Group (Mageik)	
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
Pavlof	Mutnovsky
Shishaldin	Alaid (Kurile Islands)
Westdahl	
Akutan	
Amukta	
Korovin (Atka)	
Kanaga	

Volcanoes mentioned	
Alaskan	**Russian**
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 5. Compilation by year of volcanoes included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.—Continued

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

Table 5. Compilation by year of volcanoes included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.—Continued

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

Volcanoes mentioned	
Alaskan	**Russian**
2014	
Spurr	
Redoubt	
Iliamna	
Fourpeaked	
Katmai Group (Katmai/ Novarupta, Martin)	
Chiginagak	
Aniakchak	
Veniaminof	
Pavlof	
Shishaldin	
Akutan	
Okmok	
Recheshonoi	
Cleveland	
Korovin	
Kanaga	
Semisopochnoi	
2015	
Spurr	
Redoubt	
Augustine	
Iliamna	
Katmai Group (Katmai, Novarupta)	
Ugashik-Peulik	
Aniakchak	
Veniaminof	
Kupreanof	
Pavlof	
Shishaldin	
Reshesnoi	
Cleveland	
Semisopochnoi	

Table 6. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.

[Volcanic centers are listed in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc. **Abbreviations:** CO_2, carbon dioxide; PIREP, pilot weather report]

Volcano	Year mentioned	Type of activity
Churchill	1993	Anomalous seismicity
Wrangell	1996	Steam plume
	1997	Steam plume
	1999	Steaming and phreatic ash emission
	2000	Steam plumes
	2002	Suspicious clouds, redistributed ash
	2003	Anomalous clouds
	2007	Triggered seismicity, vapor clouds, wind-blown ash
	2010	Anomalous clouds
	2012	Anomalous clouds
	2013	Redistributed ash, fumarolic activity
Sanford	1993	Reported steam plume likely from avalanche
	1994	Reported steam plume likely from avalanche
	1997	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	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
	2014	Earthquake swarm; outburst flood
	2015	Earthquake swarm
Redoubt	1992	Steam plume from still-cooling dome
	2003	Anomalous weather cloud
	2007	Possible steaming and increased thermal flux
	2008	Increased gas and thermal flux; debris flows
	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
	2014	Fumarolic plume
	2015	Snow, rock, and debris avalanche
Iliamna	1992	PIREP of large steam plume, media frenzy
	1994	Vigorous steam plume, avalanche
	1996	Intense seismicity related to magmatic intrusion
	1997	Anomalous seismic swarm; avalanche
	1999	Avalanche
	2003	Avalanche
	2005	Rock avalanche
	2012	Fumarolic plume, seismic swarms, avalanches
	2013	Avalanches
	2014	Avalanches
	2015	Large tectonic earthquake
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
	2013	Fumarolic plume
	2015	Steam plume, rockfalls

Table 6. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.—Continued

Volcano	Year mentioned	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	Anomalous cloud
Martin/Mageik/Trident	1994	Plume-like cloud
Martin	1995	Large steam plume
Martin/Mageik/Trident/Katmai	1996	Anomalous seismicity
Martin/Mageik/Snowy/Kukak	1997	PIREPS of ash and steam plumes
Snowy	2000	Steaming hole in glacier
Snowy/Kukak	2001	Steaming hole in glacier
Martin/Mageik	2002	Steam plume
Mageik	2003	Steaming, large cloud of resuspended ash
Martin	2004	Large steam plume
Martin	2005	Steam cloud, resuspended ash, new crater?
Martin	2006	Earthquake swarm
Martin	2010	Resuspended ash
Martin	2012	Elevated seismicity, fumarolic plumes
Katmai/Novarupta/Martin	2014	Resuspended 1912 ash; earthquake swarm, vapor plume
Katmai, Novarupta	2015	Resuspended 1912 ash
Becharof Lake	1998	Intense seismic swarm and inflationary episode
	2010	Earthquake swarm
Ugashik-Peulik	2013	Reported steaming, sulfur odors
	2015	Discolored water, large earthquake
Chiginagak	1997	Minor eruptive activity, new fumarole field
	1998	Continuation of increased fumarolic activity
	2000	Steam emissions from fumarole field
	2005	Heat to summit; acidic flood; cauldron develops
	2014	Fumarolic activity
Aniakchak	2005	Anomalous seismicity, thermal anomaly
	2008	Weather related noise on seismic stations
	2009	Anomalous seismicity
	2010	Low frequency earthquake swarms
	2010	Anomalous seismicity
	2011	Increased seismicity, possible tremor
	2012	Low-frequency earthquakes
	2013	Short seismic swarms
	2014	Seismographic network failure
Veniaminof	1993	Low-level eruption and lava flows
	1994	Strombolian eruption and lava flows
	1995	Strombolian eruptions
	1999	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
	2010	Sporadic seismicity, vapor plumes
	2013	Effusive eruption
	2014	End of 2013 eruption
	2015	Seismic unrest

Table 6. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.—Continued

Volcano	Year mentioned	Type of activity
Kupreanof	1994	PIREP of unusual steam plume
	2015	Steam plume
Pavlof	1996	Strombolian eruption
	1997	Strombolian eruption concludes
	1999	Summit snow melt, ash dustings, steam plumes
	2001	Steaming, possible ash, sulfur smell
	2005	Mis-located steam plume
	2007	Strombolian eruption, lava flows, lahars
	2013	Strombolian eruption
	2014	Two Strombolian eruptions
	2015	End of 2014 eruption
Hague (Emmons Lake Caldera)	2002	Increase in fumarolic activity in summit crater
	2003	Crater lake drains, refills, drains
	2005	Steam plume
Frosty	2001	Rock fall avalanches
Shishaldin	1993	Minor phreatic
	1994	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	Shallow seismicity; PIREP of possible eruption
	2003	Steam plumes
	2004	Small steam and ash plumes
	2005	Increased seismicity, steam plumes prompt PIREPS
	2008	Minor phreatic (?) ash emission and vigorous vapor plumes
	2009	Increased seismicity, small steam and ash plume, thermal anomalies
	2013	Increased seismicity, small steam plume
	2014	Low-level eruption
	2015	Intermittent low-level eruption
Westdahl	1992	Fissure eruption, lava fountains, ash clouds, lava flow
	1996	Suspicious weather cloud on satellite image
	2004	Seismic swarm
	2010	Increase in lower crustal seismicity
Akutan	1992	Steam/ash emissions
	1996	Intensive seismicity, ground cracking
	1998	Tremor-like seismicity
	2003	Anomalous steam plume
	2007	Triggered seismicity; inflation; anomalous steaming
	2013	Triggered seismicity, intermittent tremor
	2014	Earthquake swarm; uplift; probable magmatic inflation
Makushin	1993	Minor phreatic activity
	1994	PIREP of minor steam/ash
	1995	Steam plume
	2001	Increase in seismicity
	2008	Discolored seawater in Unalaska Bay
	2010	Seismicity, anomalous clouds reported
	2013	Inermittent tremor, small steam plume
Bogoslof	1992	Dome extrusion, ash and steam emissions

Table 6. Compilation by volcano for particular years included in an Alaska Volcano Observatory Annual Summaries, 1992–2015.—Continued

Volcano	Year mentioned	Type of activity
Okmok	1997	Strombolian eruption
	2001	Seismic swarm
	2008	Major phreatomagmatic eruption
	2009	Bursts of tremor, inflation
	2011	Inflation
	2013	Inflation, earthquake swarm
	2014	Inflation
Recheshnoi	2014	Increased seismicity
	2015	Continuation of increased seismicity
Vsevidof	1999	Sighting of ash after regional earthquake
Cleveland	1994	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	Intermittent explosions, small ash clouds, thermal anomalies
	2010	Explosions, small ash clouds, vapor plumes, thermal anomalies
	2011	Intermittent explosions, small ash clouds
	2012	Lava extrusion, explosions, small ash clouds
	2013	Lava extrusion, intermittent minor eruptions of steam and ash
	2014	Low-level eruption
	2015	Continued low-level eruption
Amukta	1996	Small eruption; ash emission
	1997	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	Audible rumbling, strong sulfur odor
Kliuchef	1995	Large steam plume, strong sulfur odor
Korovin	1996	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
Kasatochi	2005	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	Anomalous seismicity
	2002	Seismic swarm, tremor
	2013	Earthquake swarms
Kanaga	1993	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
	2014	Earthquake swarm
Gareloi	2013	Felt earthquakes
Tanaga	2005	Anomalous seismicity, including a period of tremor
Semisopochnoi	2014	Earthquake swarm; likely magmatic intrusion
	2015	Earthquake swarm

Volcanic Activity in Alaska, Northeast to Southwest Along Aleutian Arc

Mount Spurr

GVP # 313040
61.2989° N 152.2439° W
3,374 m (11,070 ft)

Cook Inlet

EARTHQUAKE SWARM

No volcanic activity was reported at Mount Spurr in 2015; the only activity noted was an earthquake swarm 12 km (6.5 mi) north of the summit. First noted in the AVO internal logs in mid-October, earthquakes in this area occurred sporadically for the previous 5 months with the rate increasing from 1–2 per week in July to several per day in October. The swarm peaked in November, with 47 earthquakes during the month (fig. 2). The rate of located earthquakes decreased by one-half in December and the swarm continued into 2016 at a much-reduced level of activity. The earthquakes in this cluster were shallow with 90 percent occurring between 3 and 5 km (1.6 to 2.7 mi) below sea level. The Aviation Color Code and Volcano Alert Level remained at **GREEN/NORMAL** through the year at Spurr.

Mount Spurr is a 3,374-m high (11,070-ft) ice- and snow-covered stratovolcano located 125 km (80 mi) west of Anchorage (fig. 3). Explosive historical eruptions occurred in 1953 and 1992 from Crater Peak, a satellite vent 3.5 km (2 mi) south of Mount Spurr's summit (Keith, 1995). Each of these eruptive phases produced ash falls on populated areas of south-central Alaska. The summit of Mount Spurr is a largely ice-covered feature previously interpreted as a lava dome complex (Nye and Turner, 1990). The last known significant eruption based on correlation of tephra deposits was about 5,200 years ago (Riehle, 1985).

Figure 2. On opposite page (p. 17). Annotated 24-hour webicorder display for seismic station BGL during the Mount Spurr earthquake swarm, November 9, 2015 UTC. Earthquakes with magnitudes of -0.2–1.4 are circled. The M=1.4 earthquake was the largest in the earthquake sequence. Seven earthquakes occurred on November 11, the only day with more located earthquakes in the swarm. Nine regional earthquakes not in the earthquake swarm are indicated by an "R." The earthquake at 02:05 UTC, located near Mount Spurr, was not part of the earthquake swarm. Calibration pulses occurred at 8:54 and 21:54 UTC. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id= 96871.

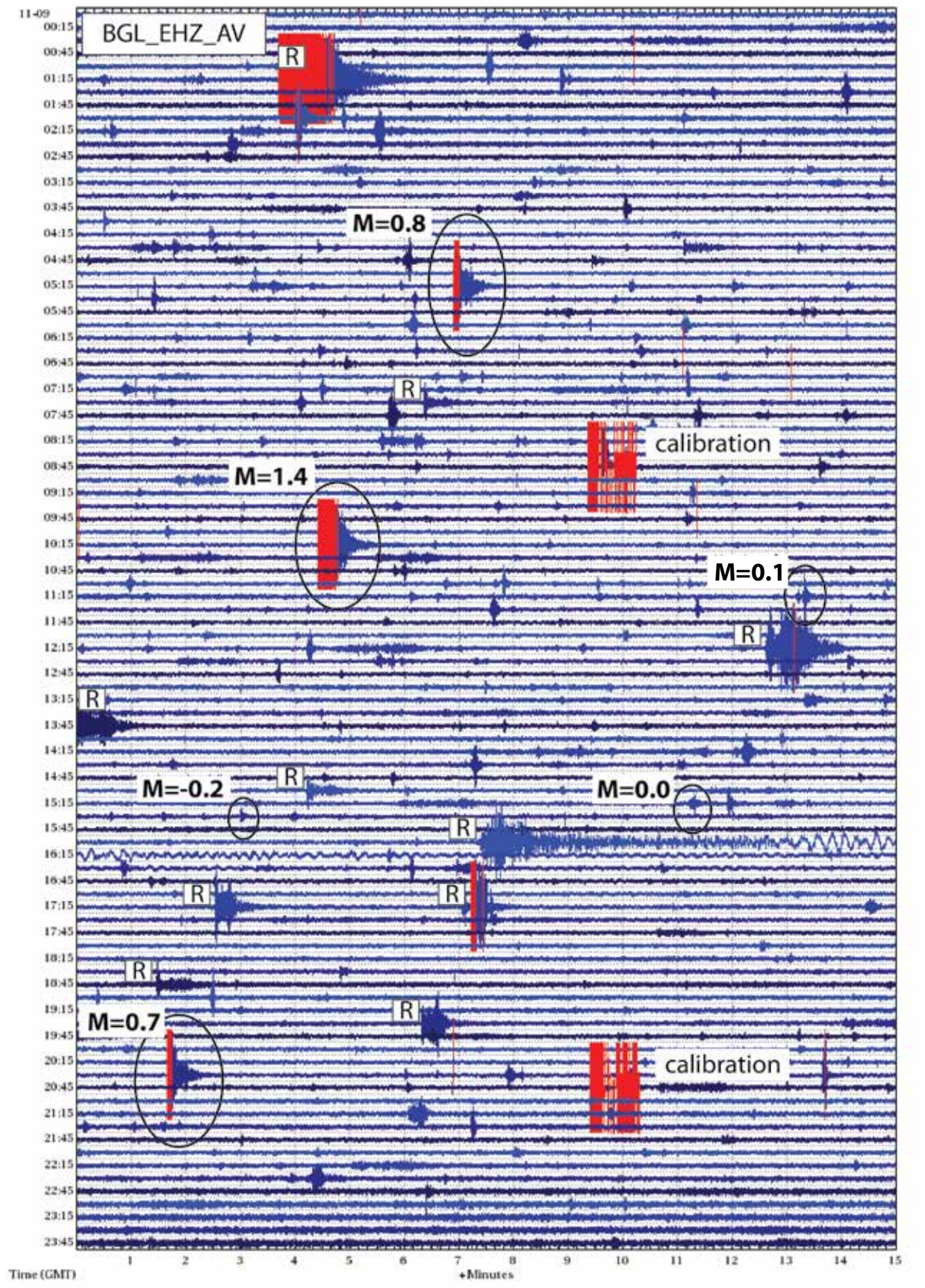

Figure 2.—Figure caption on opposite page (p. 16).

Figure 3. Oblique photograph of the summit of Mount Spurr. Photograph by Robert McGimsey, USGS/AVO, September 16, 2007. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=13620.

Redoubt Volcano

GVP # 313030
60.4852° N 152.7438° W
3,108 m (10,197 ft)

Cook Inlet

OUTBURST FLOOD/SNOW, ROCK, AND DEBRIS AVALANCHE

A significant amount of melt water was observed in late June, a suspected outburst flood from a subglacial meltwater reservoir in the Redoubt Volcano crater. Ground investigations determined the source of this outburst flood to be melt from a snow and debris avalanche, similar to those that routinely occur on Iliamna Volcano (fig. 4). A review of web camera views indicates this event occurred after June 28, and seismic evidence suggests a start at 03:54 UTC (19:54 AKDT) June 29. The source of the avalanche was a steep canyon wall immediately west of the 2009 dome. The avalanche is composed of multi-year snow and ice entrained with rock debris and fragmental products of the 2009 eruption. The Aviation Color Code and Volcano Alert Level were not changed due to this outburst flood and remained at **GREEN/NORMAL** through the year.

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 drainage and partially flooded the Drift River Oil Terminal facility. The 1966–68 eruption also produced lahars that flowed down the Drift River drainage. Ash clouds produced by the 1989–90 and 2009 eruptions affected air traffic and resulted in minor or trace amounts of ash on communities in south-central Alaska (Miller and Chouet, 1994; Schaefer, 2011).

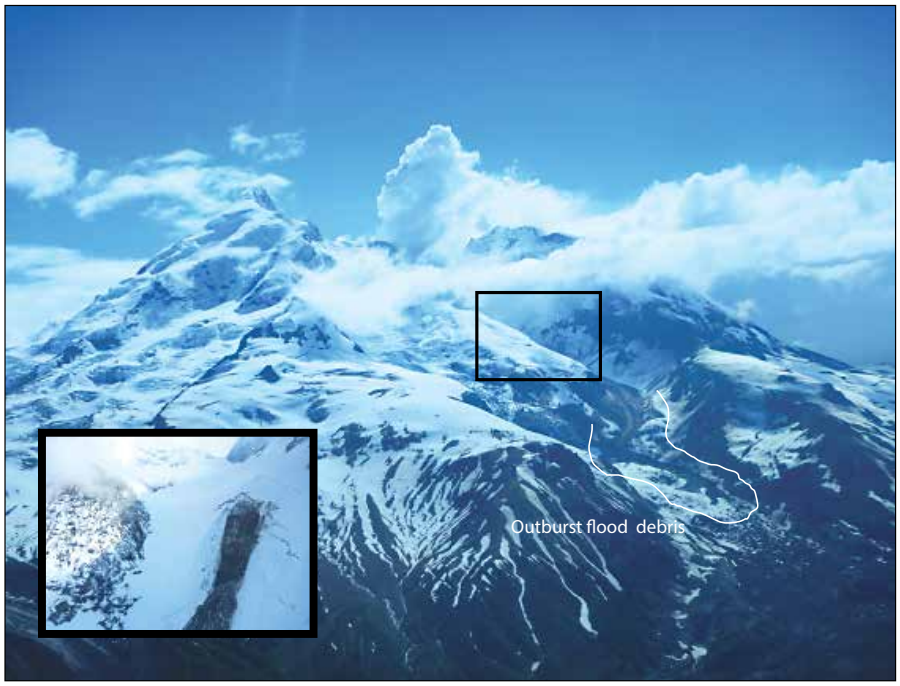

Figure 4. Outburst flood on Redoubt Volcano, which originated immediately outside the summit crater where crevassing and slab failure of the multi-year snowpack occur on a steep wall of the Drift Glacier canyon. The initial debris path lower on the glacier was light colored or grayish, but darkened to black as snow entrained in the debris melted, leaving a surface coat of debris. The inset photograph shows the source of the outburst flood (hidden by a ridge in the large photograph). In both photographs, low-level steaming can be seen from the dome at the summit of Redoubt Volcano. Photographs by Alex Iezzi, July 14, 2015. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=79711.

Iliamna Volcano

GVP # 313020
CAVW# 1103-02-
60°02′ N 153.05′ W
3,053 m (10,016 ft)

Cook Inlet

LARGE TECTONIC EARTHQUAKE

An information statement was issued by AVO on July 28 following a Mw=6.3 earthquake that occurred at 02:35 UTC (18:35 AKDT) near Iliamna Volcano. The event was tectonic in nature and was not a sign of volcanic unrest. The earthquake was located about 15 km (9 mi) south-southwest of Iliamna, at a depth of 119 km (74 mi) in the subducting (down-going) slab, as opposed to in the crust immediately below the volcano. Only three earthquakes within 10 km were located by the Alaska Earthquake Center in the month following the large earthquake. AVO installed a broadband seismograph station that was co-located with a short-period seismograph station in July. Iliamna remained at Aviation Color Code/Volcano Alert Level **GREEN/NORMAL** throughout 2015.

Iliamna Volcano is a glacier-carved stratovolcano located approximately 215 km (134 mi) southwest of Anchorage on the western side of 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) ASL on the eastern flank produce nearly constant plumes of steam condensate and volcanic gas (Werner and others, 2011). In the past two decades, at least two magmatic intrusions have occurred (Roman and others, 2004; Prejean and others, 2012).

Augustine Volcano

GVP # 313010

59.3626° N 153.4350° W
1,260 m (4,134 ft)

Cook Inlet

STEAM PLUMES, ROCKFALLS, INSTALLATION OF MULTIGAS STATION

Minor unrest occurred at Augustine Volcano in 2015 in the form of visible vapor plumes and rockfalls. In collaboration with Cascade Volcano Observatory (CVO), in June AVO installed a Multiple component Gas Analyzer System (MultiGAS) instrument at the summit of Augustine, designed to measure carbon dioxide (CO_2), sulfur dioxide (SO_2), and hydrogen sulfide (H_2S). The Aviation Color Code/Volcano Alert Level remained **GREEN/NORMAL** throughout the year.

Augustine has active fumaroles that often are visible under favorable atmospheric conditions. A gas measuring/sampling flight on April 3 detected low levels of water (H_2O), CO_2, SO_2, and H_2S, indicating that Augustine continues to degas at a low rate. The typical vapor plume at Augustine was often visible in web camera images during 2015, and was noted in satellite daily checks on January 25 and July 9. AVO received a PIREP of steam at Augustine on July 9.

Twenty-two instances of rockfalls occurred at Augustine in 2015 as identified by emergent signals recorded on Augustine seismograph stations: this was twice the number of rockfalls reported in 2014. These rockfalls were concentrated during the months of June, July, August, and October. Rockfall signals at Augustine typically have an emergent onset and appear first at summit stations AUP and AUSS (fig. 5).

On June 12 and 13, AVO and CVO scientists installed a new, permanent MultiGAS/ seismograph station near the summit of Augustine. The MultiGAS instrument (fig. 6) was designed and built at CVO, and includes sensors to intermittently measure CO_2 and H_2S. Data from these sensors are transmitted to AVO in near real time. A broadband seismograph station was installed near the MultiGas station at this time. Two months later another broadband seismograph station was added to the Augustine seismograph network.

Augustine Volcano is frequently active, close to populated areas, and is one of the most visible and accessible volcanoes in south-central Alaska. The volcano forms the bulk of Augustine Island, an 8 × 11 km (5 × 7 mi) island in lower Cook Inlet. Uplifted Jurassic and Cretaceous sedimentary rocks are exposed on the southern side of the island (Waitt and Begét, 2009). Augustine consists of a conical, central dome cluster and lava flow complex surrounded by a more gently sloping apron of fragmental deposits. The pre-2006 eruption elevation was 1,260 m (4,134 ft) ASL and the exact change to summit elevation has yet to be determined. Repeated sector collapses during the late Holocene have produced debris avalanches into Cook Inlet (Begét and Kienle, 1992). Historical eruptions include significant activity in 1883, 1885, 1963–64, 1976, 1986, and 2005–06.

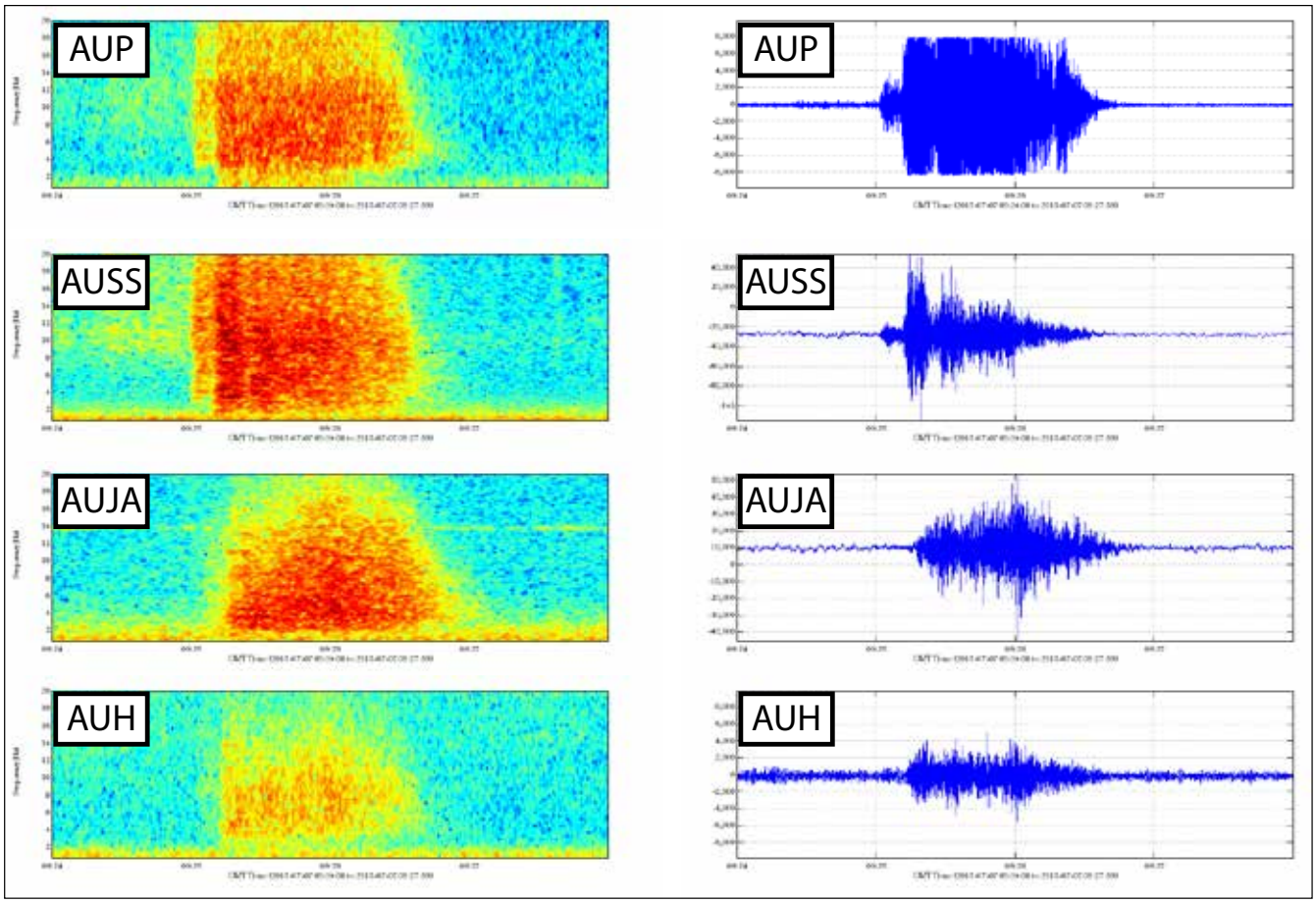

Figure 5. Spectrograms showing rockfall event at Augustine Volcano on July 7, 2015, 09:25 UTC (1:25 AKDT). The signals at four Augustine seismograph stations are shown with the rockfall first showing at summit stations AUP and AUSS and later at AUJA and AUH on the flank of the volcano. The frequency of the signal from 0 to 20 Hz is shown on the spectrograms on the right, and the waveforms with counts ± 10K for the short-period stations (AUP, AUH) and ± 45–65K for the broadband stations (AUJA, AUSS). The length of the signal in all images are approximately 4 seconds long. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=97611.

Figure 6. Joint MultiGAS/seismograph station AUSS installed on the summit of Augustine Volcano by AVO and CVO scientists on June 12 and 13, 2015. Photograph by Peter Kelly, USGS/CVO, June 13, 2015. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=79191.

Katmai Group (Novarupta)

GVP # 312180
58.2654° N 155.1591° W
841 m (2,759 ft)

Alaska Peninsula

RESUSPENSION OF 1912 ASH

Resuspension and transport of fine-grained volcanic ash deposited during the 1912 Novarupta-Katmai eruption has been frequently observed and documented over at least the last several decades (Hadley and others, 2004; McGimsey and others, 2005) and five episodes of resuspended ash were documented in 2015. The Aviation Color Code/Volcano Alert Level remained **GREEN/NORMAL** for Katmai and Novarupta during 2015.

The 1912 eruption of Novarupta deposited large quantities of ash in valleys of the Katmai area, and the landscape remains desolate and largely vegetation-free, even more than 100 years after the eruption. During times of no snow cover and strong northwesterly winds, the ash can be resuspended and transported southeast across Shelikof Strait, Kodiak Island, and the Gulf of Alaska. These events are commonly identified by the presence of ash clouds blowing from the Katmai area, and often are detected in satellite imagery, coupled with high winds and a lack of other volcanic signals (no thermal anomalies or elevated seismicity were detected at any of the Katmai group volcanoes).

High winds entrained and resuspended ash from Novarupta-Katmai 1912 on March 11, 2015, continuing into March 12, 2015. Alaska Airlines and Ravn Alaska cancelled flights into and out of Kodiak, due to high winds and ash. The ash was visible in satellite imagery, and strong winds were blowing from the Katmai area toward the southeast (fig. 7). The National Weather Service Alaska Aviation Weather Unit (NWS AAWU) issued a Special Weather Statement.

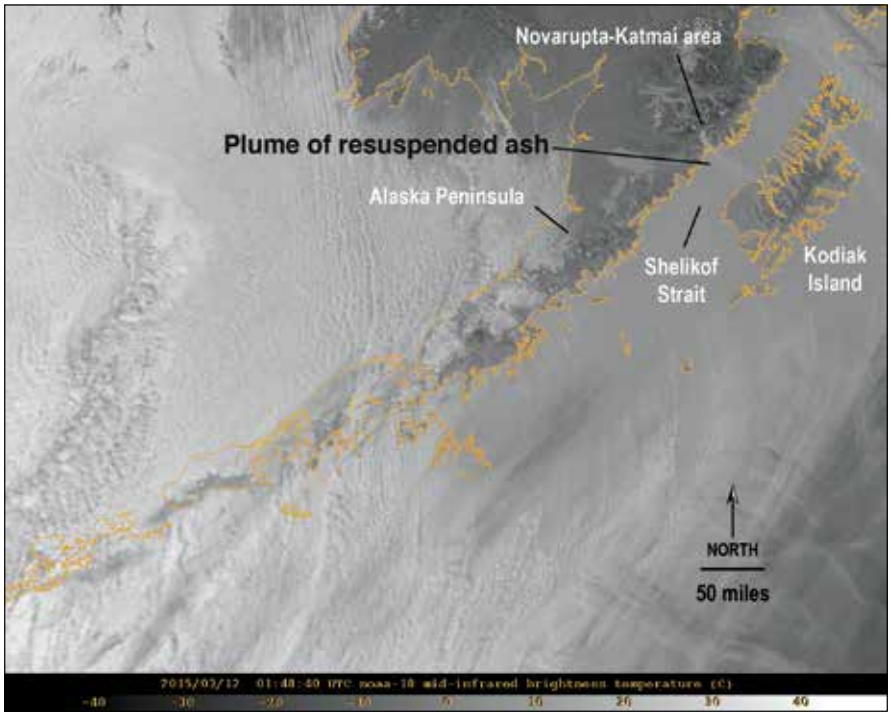

Figure 7. Satellite image showing a cloud of resuspended ash from the Katmai 1912 eruption extending southeast over Shelikof Strait from the Valley of Ten Thousand Smokes on March 11, 2015. Satellite image from NOAA AVHRR satellite. Image annotated by Christopher Waythomas, USGS/AVO. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=77351.

Four episodes of resuspended ash were observed during August through October. A multi-day ash resuspension event began on August 28, 2015, and continued through August 31, 2015. On August 30, the NWS issued a SIGnificant METeorological (SIGMET) information statement, and AVO mentioned the resuspended ash in its August 28 weekly update and issued a separate information statement on August 31. The ash was weakly visible in satellite imagery. Two ash resuspension events occurred in September—on September 23, with ash confined to altitudes less than 1,500 m (5,000 ft) ASL, and another on September 29–30. Residents of Kodiak reported a fall of fine ash on the night of September 29–30, mixed with sleet and snow. AVO issued information statements on both occasions. The final ash resuspension event of 2015 occurred on October 29–30, when strong winds in the Katmai area again entrained loose 1912 volcanic ash and carried it east over Shelikof Strait and Kodiak Island. AVO again issued an information statement regarding the event.

AVO installed two particulate monitors on Kodiak Island in 2015, designed to measure the amount and size of ash entrained during these resuspension events, study their effects, and help determine whether or not the remobilized ash presents a public health hazards. The instruments were first installed in September 2015, and were shut down for the winter (to prolong instrument life) in late November (fig. 8).

Figure 8. Alaska Volcano Observatory (AVO)-installed particulate monitors on Kodiak Island, to study resuspended 1912 volcanic ash and determine if the ash presents a health hazard to humans. In this image, AVO is training U.S. Coast Guard personnel on operation and maintenance of the monitor. Photograph by Kristi Wallace, USGS/AVO, September 8, 2015. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=80761.

Ugashik-Peulik

GVP # 312130

57.7503° N 156.3700° W
1,474 m (4,836 ft)

Alaska Peninsula

LARGE EARTHQUAKE AND DISCOLORED WATER

AVO responded to an M_L=4.1 earthquake at the Ugashik-Peulik volcanic center on March 26, and investigated discolored drainage water in July. The Aviation Color Code and Volcano Alert Level were not changed during this M_L=4.1 earthquake or the later observation of discolored water and remained at **GREEN/NORMAL** through the year.

On March 26 a M_L=4.1 earthquake and aftershocks occurred close to the west shore of Becharof Lake in the same area as the 1998 Becharof swarm (McGimsey and others, 1999), 35 km (19 mi) west-northwest of Ukinrek Maars and 47 km (25 mi) west-northwest of Peulik. The earthquake series was short-lived as 17 earthquakes, 10 greater than M_L=2.0, occurred within a 10-hour period, including the M_L=4.1 and a M_L=3.0 earthquake both of which occurred within the first 2 hours. These earthquakes formed a narrow east-west cluster 19 km (10 mi) in length at a depth of 7–9 km (3.7–4.9 mi). Nine additional earthquakes occurred in the same location in 2015—two in early March, five in mid-April, and two in late summer. The largest of these was a M_L=3.2 on April 21, 2015.

On July 15, an Alaska Department of Fish and Game (ADF&G) biologist reported that the water in Hot Springs Creek, flowing from Ugashik caldera into Ugashik Creek was "frothy and orange." The biologist also reported that salmon were not entering the stream where Ugashik Creek flows into Ugashik Lake as in past years (fig. 9). Two days after the report, two water samples were collected from Hot Springs Creek at locations shown in figure 9. Analysis (table 7) showed a pH (5.76 and 5.52) similar to previous water samples collected in June 2004 (pH=5.71) by Evans and other (2009) in a similar location. An aerial survey of the creek from the caldera to Upper Ugashik Lake detected no orange discoloration of the stream beyond the caldera. Outside the caldera, the stream was not running clear, but appeared heavily laden with sediment, rather than tinted orange as with waters inside the caldera. No unusual activity was observed and the discoloration likely was caused by a period of high runoff that intermixed the thermal waters with the clearer water in the stream causing a temporary flow of anomalously colored water that delayed the reported movement of salmon upstream by ADF&G biologists. No volcanic unrest was apparent.

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. 10). 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 west side.

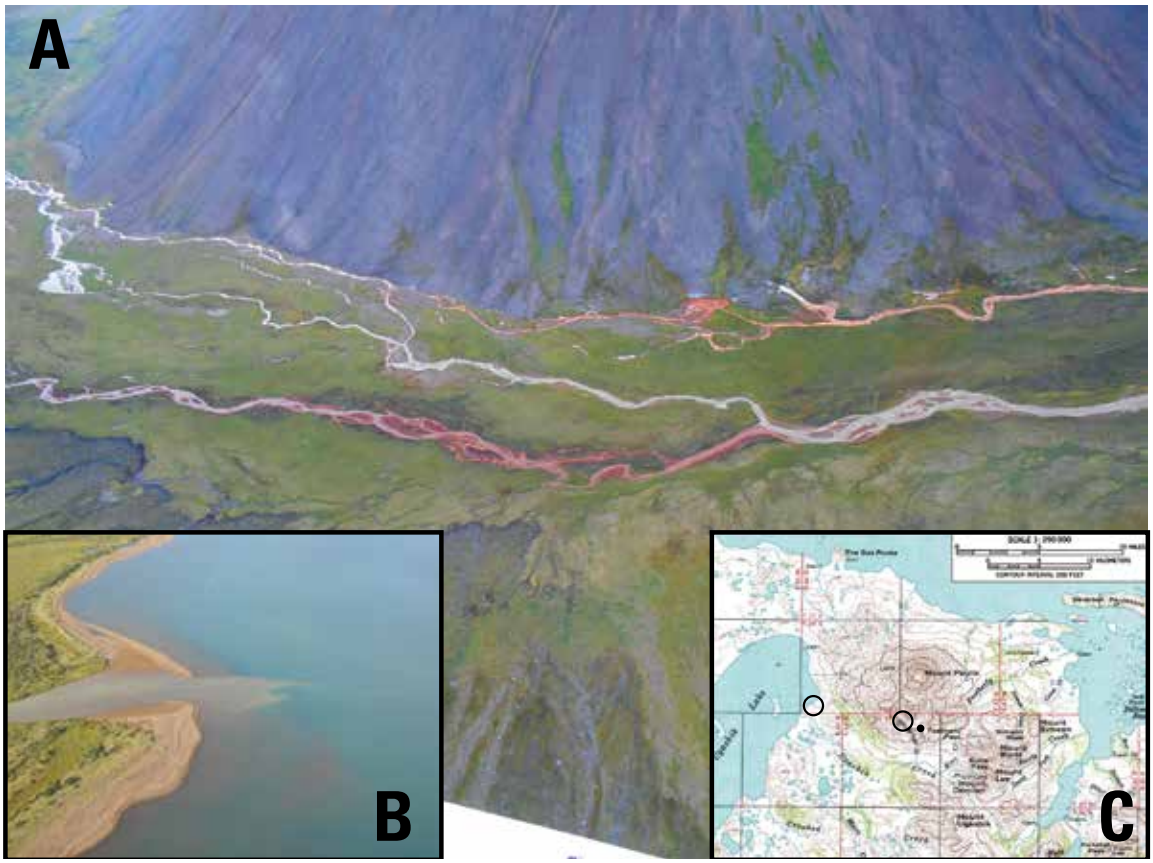

Figure 9. (A) Orange thermal waters emanating from springs at the base of the intracaldera stratocone within Ugashik caldera noted by biologists on July 15, 2015. Inset B shows the streamflow into Ugashik Lake and inset C shows the location of the water samples collected 2 days later. Dot indicates the water-sample location; circles indicate the location of the photographs. Photographs A and B by Kevin Payne, U.S. Fish and Wildlife Service, July 15, 2015. Inset C by Aaron Wech, USGS/AVO, July 17, 2015. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=79791, Inset B image URL: https://www.avo.alaska.edu/images/image.php?id=79771, Inset C database AVO image URL: https://www.avo.alaska.edu//images/image.php?id=667.

Figure 10. Aerial view, looking southwest, of Ugashik caldera adjacent to Peulik volcano. At least five lava domes (snow-covered in this view) currently occupy the floor of the 5-km (3-mi) diameter caldera. Photograph by M.E. Yount, USGS, April 11, 1984. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=431.

Table 7. Water chemistry samples collected in Ugashik caldera from Hot Springs Creek, July 17, 2015.

[Table is similar to table 1 in Evans and others (2009). Concentration of Cd, Co, CO_3, CR, CU, NI, NO_3, OH, PO_4 and Se, not included in the table, are below detection limits. Conductivity and total dissolved solids were not reported in Evans and others (2009), but are added here as the values are detectable and are non-zero numbers. Abbreviations: °C, degrees Celsius; µg/L, microgram per liter; mg/L, milligram per liter; µS/cm, microsiemens per centimeter; na, not applicable; <, less than]

Sample type	Sample No.	
	UGK 15-01	UGK 15-02
Temperature (°C)	8.6	10.1
pH	5.76	5.52
Conductivity (µS/cm)	304	257
Total dissolved solids	267	244
Major elements (mg/L)		
Sodium (Na)	37.7	32.3
Potassium (K)	2.71	2.41
Calcium (Ca)	12.7	11.3
Magnesium (Mg)	6.55	5.54
Silicon dioxide (SiO_2)	58	53
Boron (B)	0.914	0.595
Iron (Fe)	2.04	2.25
Bicarbonate (HCO_3)	113	112
Fluorine (F)	0.15	0.178
Chlorine (Cl)	27.6	18.3
Sulfate (SO_4)	4.37	5.65
Bromine (Br)	0.08	0.07
Nitrate (NO_3-N)	na	na
Trace elements (µg/L)		
Lithium (Li)	122	106
Manganese (Mn)	732	673
Zinc (Zn)	<5	<5
Aluminum (Al)	<5	<5
Lead (Pb)	na	na
Molybdenum (Mo)	<1	<1
Vanadium (V)	na	na
Barium (Ba)	8	7
Strontium (Sr)	148	120
Arsenic (As)	6	11
Rubidium (Rb)	11	<10
Cesium (Cs)	na	na
Uranium (U)	na	na
Isotopes		
δD	-89.64	-89.58
$\delta^{18}O$	-12.25	-12.29
$\delta^{13}C$-DIC	na	na
^{14}C-DIC	na	na

Aniakchak Volcano

GVP # 312090

56.9058° N 158.2090° W
1,341 m (4,400 ft)

Alaska Peninsula

STATION MAINTENANCE

Repairing the seismograph network at Aniakchak Volcano was a 2015 field season priority. AVO field staff re-established five of the six seismic monitoring instruments in the summer and resolved telemetry issues in August 2015. Stability of the network was monitored for more than 2 months; on October 23, Anicakchak was added back to the list of monitored volcanoes. With renewed seismic monitoring, the volcano moved from **UNASSIGNED** to Aviation Color Code **GREEN** and Volcano Alert Level **NORMAL**.

Aniakchak is a circular caldera 10 km (6.2 mi) in diameter and as deep as about 1 km (3,280 ft) from the rim to the caldera floor. 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, 2001); the largest intracaldera cone is Vent Mountain, 2.5 km (1.5 mi) in diameter and rising 430 m (1,140 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).

Mount Veniaminof

GVP # 312070

56.1979° N 159.3931° W
2,507 m (8,225 ft)

Alaska Peninsula

SEISMIC UNREST

Mount Veniaminof had a 2-month-long period of increased seismic unrest in 2015. At the end of September, seismicity at Mount Veniaminof increased in the form of volcanic tremor and small low-frequency earthquakes. This type of activity was a known precursor to previous eruptions, most recently in 2009 (McGimsey and others, 2014) and 2013 (Dixon and others, 2015). On October 1, after the activity persisted for 1 day, the Aviation Color Code and Volcano Alert Level were raised to **YELLOW/ADVISORY**. Throughout October and early November, clear views from the Federal Aviation Administration (FAA) Perryville northwest web camera occasionally showed minor steam plumes issuing from the intracaldera cone (fig. 11). The intermittent, short bursts of seismic tremor persisted into November, indicating continued unrest. At the end of November, the seismic unrest at Veniaminof decreased to near background levels. On December 11, the Aviation Color Code and Volcano Alert Level was lowered to **GREEN/NORMAL**.

Mount Veniaminof, an approximately 350-km^3 (84-mi^3) andesite and dacite 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 diameter (6.2-mi) 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 (about 984 ft) intracaldera cone. The last significant magmatic eruption prior to 2013 occurred in 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 by 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, 1985a). During the more significant historical eruptions, ash plumes reached about 7,800 m (about 26,000 ft) ASL and produced ash fallout within about 40 km (about 25 mi) of the volcano.

Figure 11. Steaming at Mount Veniaminof as viewed from Sandy Creek, 80 km (50 mi) west-southwest of the volcanic center. Photograph by Bill Stahl, ADDGS/AVO, October 14, 2015. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=83851.

Mount Kupreanof

GVP # 312060

59.3626° N 153.4350° W
1,895 m (6,217 ft)

Alaska Peninsula

STEAM PLUMES

A mariner report of "black smoke northwest of Ivanof Bay" was received at AVO on April 11, 2015. The probable source of the observation is Kupreanof Volcano where a known fumarolic field has persisted for decades (Yount and others, 1985b). Although reports from Kupreanof are uncommon, steaming from Kupreanof has been noted for at least the last 75 years and was last reported in the AVO annual summaries in 1994 (Neal and others, 1995). AVO took no further action on this isolated report.

Kupreanof is a deeply eroded stratovolcano with no known historical eruptions. Holocene debris avalanche deposits have been recognized; however, there is a vigorous fumarolic area marked by sulfur deposits at an elevation of 1,524 m (5,000 ft; fig. 12). Past steaming from Kupreanof has been noted in the literature as "eruption reports" (Global Volcanism Program, 1987). The nearest settlements are Perryville (45 km [28 mi] east-southeast) and Port Moller (48 km [30 mi] west).

Figure 12. Summit of Kupreanof Volcano showing the fumarolic field source of steaming in 1973. The summit of Kupreanof is the source of many steaming reports over the last 75 years. Deposits from the plume produce discoloring on the snow near the fumaroles. Photograph by Thomas P. Miller, USGS, July 1973. AVO database image URL: https://www.avo.alaska.edu/images/image.php?id=14001.

Pavlof Volcano

GVP# 312030

55.4173° N 161.8937° W
2,518 m (8,261 ft)

Alaska Peninsula

END OF INTERMITTENT LOW-LEVEL ERUPTION

Pavlof Volcano erupted twice in 2014, in May–June and November (Cameron and others, 2017). No further eruptive activity occurred after the November 2014 eruptive episode and the volcano gradually returned to normal background status. On January 15, 2015, AVO reduced the Aviation Color Code and Volcano Alert Level from **YELLOW/ADVISORY** to **GREEN/NORMAL**. Pavlof remained **GREEN/NORMAL** throughout the rest of 2015.

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. 13). The community of Cold Bay is located 60 km (37 mi) to the southwest of Pavlof. Based on the historical record, it is one of the most frequently active volcanoes in the Aleutian arc (Cameron, 2005). Eruptive activity typically is Strombolian lava fountaining throughout several weeks or months. The last eruption of Pavlof Volcano prior to the 2014 eruptions was in 2013 (Dixon and others, 2015).

Figure 13. Pavlof Volcano (right) on June 14, 2015, with Pavlof Sister (left) and Little Pavlof (right foreground). A large flow feature from the 2014 eruption on the north flank of Pavlof Volcano extends from the summit to the base of the volcano. Photograph by Barbara LaPenter, TetraTech, June 14, 2015, used with permission. AVO database image URL: https://avo.alaska.edu/images/image.php?id=79261.

Shishaldin Volcano

GVP# 311360

54.7554° N 163.9711° W
2,857 m (9,373 ft)

Unimak Islands, Fox Islands, Aleutian Islands

INTERMITTENT LOW-LEVEL ERUPTION, STEAM AND ASH PLUMES

The low-level eruption of Shishaldin Volcano that began January 30, 2014, continued throughout 2015 (fig. 14, table 8). The year began with an existing Aviation Color Code/Volcano Alert Level of **ORANGE/WATCH** set in place on March 30, 2014. The eruption in 2015 was mostly confined to the summit crater, producing intermittent lava within the summit crater, low-level steam plumes, and occasional dustings of ash and ballistics on the upper flanks of the volcano. During 2015, AVO collected Shishaldin information from the following data streams: the seismographic array on Unimak Island, infrasound arrays at Akutan and Dillingham, satellite imagery, a web camera on Isanotski Peak looking northwest to Shishaldin, mariner observations, and pilot reports.

Discrete low-frequency seismic events, tremor bursts, occasional volcano-tectonic earthquakes (VT), and ground-coupled airwaves occurred throughout the year. A strong tremor burst was recorded at 04:50 UTC July 27 (20:50 AKDT July 26), but was not correlated with any eruptive activity (fig. 15). Elevated surface temperatures (TA) typically occurred during periods of seismic tremor (table 8).

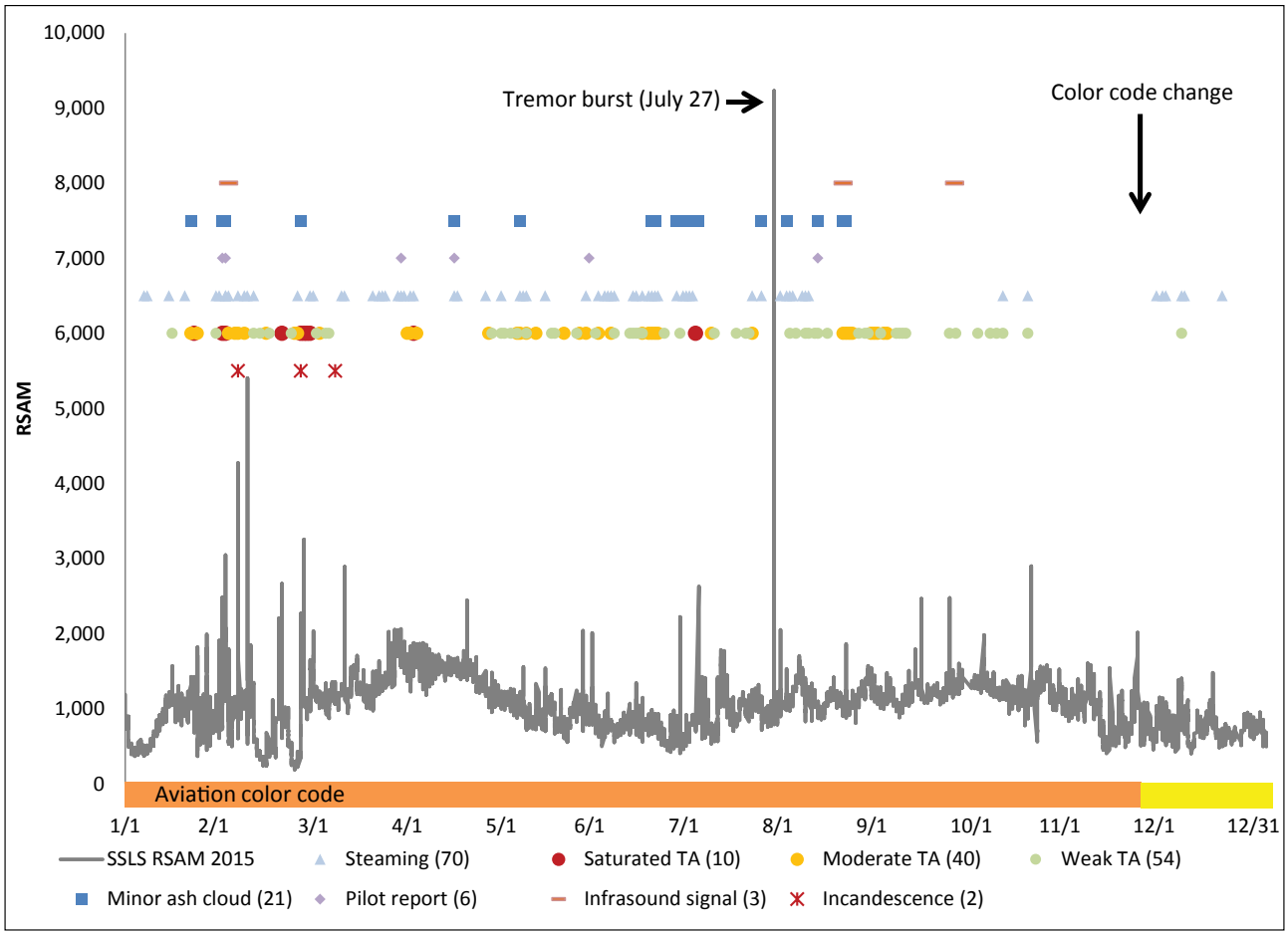

Figure 14. Chronology of 2015 Shishaldin Volcano activity. RSAM is the amplitude of the seismograph signal at station SSLS. TAs are thermal anomalies as observed in satellite imagery. Numbers in parentheses are the number of events recorded in 2015. Notable events in the 2015 activity are added. Modified from AVO database image URL: http://www.avo.alaska.edu/images/image.php?id=103401.

Table 8. Summary of activity and observations at Shishaldin Volcano in 2015.

[Data based on chronology compiled by Kristi Wallace, U.S. Geological Survey, Alaska Volcano Observatory (USGS/AVO); and Alex Iezzi, University of Alaska Fairbanks Geophysical Institute and Alaska Volcano Observatory (UAFGI/AVO). **Abbreviations:** ASL, above sea level; PIREP, pilot weather report; VAN, Volcano Activity Notice. ft, foot; km, kilometer; m, meter: mi, mile]

Date/ Date range	Color code/ Alert level	Activity	Evidence, observations	AVO operational response
01-17-14 to 01-29-14	**GREEN/NORMAL**	Low-level steaming	Satellite data indicate persistent, low-level steam emissions from summit crater	
01-30-14 to 02-06-14	**YELLOW/ADVISORY**	Increased surface temperatures and steaming, airwave explosion signals	Satellite, Web camera, and seismic data, possible deformation signal	AVO issued a VAN, upgrading to **YELLOW/ADVISORY** on January 30, 2014
02-07-14 to 02-09-14	**YELLOW/ADVISORY**	Probable ice-rich volcanic cloud	Satellite data indicate ice-rich cloud, height about 7.6 km (25,000 ft) ASL	AVO increased watch schedule
02-10-14 to 02-13-14	**YELLOW/ADVISORY**	Elevated surface temperatures; faint intermittent tremor; steaming	Satellite, Web camera, and seismic data	
02-19-14 to 03-04-14	**YELLOW/ADVISORY**	Intermittent steaming and elevated surface temperature	Satellite data; clear Web camera views show steam from summit	AVO temporarily decreased watch schedule
03-04-14 to 03-25-14	**YELLOW/ADVISORY**	Steam plumes; elevated surface temperatures; airwave explosion signals; intermittent tremor	Satellite and Web camera data; seismic data; PIREP of small steam plume; possible tilt signal on March 18, 2014	
03-25-14 to 03-27-14	**YELLOW/ADVISORY**	Elevated surface temperatures consistent with new lava inside crater; airwave explosion signals; steaming	Satellite, Web camera, and seismic data	
03-28-14 to 03-29-14	**ORANGE/WATCH**	Elevated surface temperatures consistent with new lava inside crater; airwave explosion signals; steaming	Satellite, Web camera, and seismic data	AVO issued a VAN, upgrading to **ORANGE/WATCH** on March 28, 2014
03-30-14	**ORANGE/WATCH**	Probable minor ash emission	Darkening of crater rim photographed by mariner; photographs sent to AVO on April 1, 2014	
03-31-14 to 04-17-14	**ORANGE/WATCH**	Elevated surface temperatures; intermittent local earthquakes and airwaves; intermittent steam plumes	Satellite, Web camera, and seismic data	
04-17-14	**ORANGE/WATCH**	Increase in airwaves; steaming	Seismic and satellite data	

Table 8. Summary of activity and observations at Shishaldin Volcano in 2015.—Continued

Date/ Date range	Color code/ Alert level	Activity	Evidence, observations	AVO operational response
04-20-14 to 04-26-14	ORANGE/WATCH	Steaming; elevated surface temperatures; airwaves	Satellite, Web camera, and seismic data; PIREP of steam plume to 3.8 km (12,500 ft) ASL on April 26, 2014	
04-26-14 to 06-13-14	ORANGE/WATCH	Low-level eruptive activity; lava present in summit crater; explosion airwaves; intermittent tremor; intermittent steam plumes	Web camera showed ash on flanks on May 5; elevated surface temperatures in satellite data consistent with lava within the summit crater seen on May 13, 2014; Web camera steam plumes; seismic data; infrasound data from Akutan array	May 31, 2014, Pavlof eruption begins: AVO increases data checks for all volcanoes at elevated color codes
06-14-14	ORANGE/WATCH	Minor airborne ash; infrasound explosions	Minor airborne ash and dusting on snow seen in NASA EO-1 ALI image; infrasound signals	
06-15-14 to 07-04-2014	ORANGE/WATCH	Low-level eruptive activity; lava present in summit crater; intermittent small ash deposits; steam plume	Elevated surface temperatures in satellite data consistent with lava within the summit crater; Web camera steam plumes; June 27, 2014, PIREP of steam to 0.6 km (2,000 ft) above summit; mariner report of ash deposits on snow June 28, 2014; July 1, 2014, satellite data shows ash on southeastern side of edifice	
07-04-14 to 07-07-14	ORANGE/WATCH	Low-level eruptive activity; probable lava within summit crater; tremor signal	Elevated surface temperatures in satellite data; clear, non-consistent tremor in seismic data	
07-08-14 to 07-09-14	ORANGE/WATCH	Low-level eruptive activity; prominent steam plume; few local earthquakes	Elevated surface temperatures and steam plume in satellite data; seismic data	
07-09-14	ORANGE/WATCH	Increase in explosion airwaves	Seismic data; infrasound arrays at Dillingham and Akutan	
07-10-14 to 07-16-14	ORANGE/WATCH	Likely low-level eruptive activity; probable lava within summit crater; intermittent tremor; steaming	Elevated surface temperatures observed in satellite data; steaming in Web camera views; seismic data consistent with ongoing eruption in summit crater	
07-17-14 to 08-09-14	ORANGE/WATCH	Low-level eruptive activity; minor ash deposits; possible flowage features; steaming; intermittent tremor	Satellite data showing fresh deposits on flank July 17 and July 27, 2014; elevated surface temperatures in satellite data; Web camera and photographs of dark streaks on snow; steaming observed in Web camera; infrasonic tremor on August 8, 2014; intermittent tremor in seismic data	

Table 8. Summary of activity and observations at Shishaldin Volcano in 2015.—Continued

Date/ Date range	Color code/ Alert level	Activity	Evidence, observations	AVO operational response
08-10-14	**ORANGE/WATCH**	Visible incandescence in summit crater of Shishaldin	Photograph from AVO field personnel	
08-11-14 to 08-22-14	**ORANGE-WATCH**	Low-level eruptive activity; probable lava within summit crater; steaming	Elevated surface temperatures in satellite data; intermittent steaming (as high as 110 km [68 mi] from vent) in Web camera and satellite data; low seismicity	
08-23-14	**ORANGE/WATCH**	Steam and ash plume to 0.3 km (1,000 ft) above summit	PIREP	
08-24-14 to 09-22-14	**ORANGE/WATCH**	Likely low-level eruptive activity; steaming	Elevated surface temperatures in satellite imagery; intermittent steam plumes in Web camera; seismicity generally low, occasional airwaves	
09-23-14 to 09-30-14	**ORANGE/WATCH**	Likely low-level eruptive activity; steaming; infrasound explosions	Elevated surface temperatures in satellite imagery; intermittent steam plumes in Web camera and satellite imagery; infrasound tremor; seismicity generally low	
10-01-14 to 10-19-14	**ORANGE/WATCH**	Low-level eruptive activity; probable lava in summit crater; steaming	Strongly elevated surface temperatures consistent with lava extrusion in the summit crater seen in satellite imagery; intermittent infrasound tremor ground-coupled airwaves; seismicity slightly increased from previous period, including intermittent tremor and local earthquakes	
10-20-14 to 10-21-14	**ORANGE/WATCH**	Likely low-level eruptive activity continues; increased seismicity; explosion signals	Increase in low-frequency earthquakes and ground-coupled airwaves; elevated surface temperatures in satellite imagery	
10-22-14 to 10-24-14	**ORANGE/WATCH**	Likely low-level eruptive activity continues; low seismicity	Cloudy in satellite imagery and Web camera; slight decrease in seismicity	
10-25-14 to 11-03-14	**ORANGE/WATCH**	Increase in low-level eruptive activity; increased seismicity; small ash explosion	Increased tremor seen in seismic data; elevated surface temperatures consistent with lava in the crater seen in satellite imagery; explosions detected by infrasound; Web camera shows summit area darkened by ash and ballistics on October 26, 2014	AVO issued a VAN on October 28, 2014
11-04-14 to 11-19-14	**ORANGE/WATCH**	Likely low-level eruptive activity continues; seismicity decrease	Intermittent elevated surface temperatures seen in satellite data; mostly cloudy Web camera views; seismicity intermittent tremor	

Table 8. Summary of activity and observations at Shishaldin Volcano in 2015.—Continued

Date/ Date range	Color code/ Alert level	Activity	Evidence, observations	AVO operational response
11-20-14 to 11-23-14	**ORANGE/WATCH**	Likely low-level eruptive activity; seismicity increase	Number and size of earthquake events increased; elevated surface temperatures detected in satellite imagery	AVO increased watch schedule
11-24-14 to 11-26-14	**ORANGE/WATCH**	Probable increase in eruptive activity; lava in the summit crater; seismicity increase; infrasound explosions	Sharp increase in seismic activity at about 1:00 a.m. November 24, 2014; elevated surface temperatures consistent with lava in the summit crater seen in satellite imagery; explosions detected in infrasound data; steam plume evident in satellite imagery	AVO issued a VAN at 1:49 a.m. November 24, 2014
11-27-14 to 12-31-14	**ORANGE/WATCH**	Likely low-level eruptive activity continues; seismicity decrease	Elevated surface temperatures in satellite imagery; seismicity generally low; intermittent steaming seen in Web camera	AVO decreased watch schedule on December 10, 2014

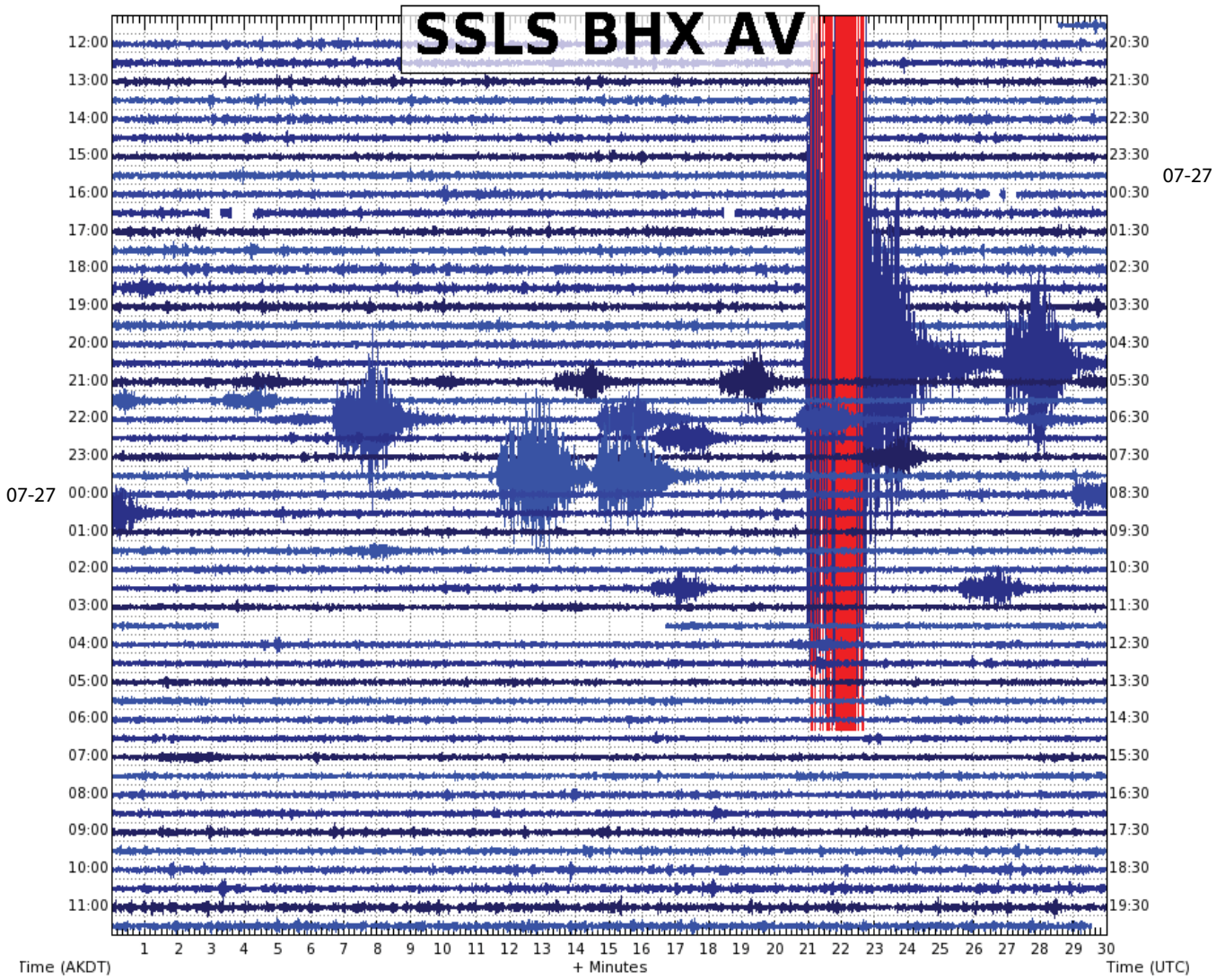

Figure 15. Filtered webicorder showing strong seismic tremor burst recorded July 27 at seismograph station SSLS. The seismic tremor burst corresponds to the spike on the RSAM (fig. 14). AVO database image URL: https://avo.alaska.edu/images/image.php?id=103391.

Web camera and satellite imagery of Shishaldin showed persistent, low-level steam plumes throughout most of the year including observations in every month except September when no steaming was noted (figs. 14, 16). Elevated surface temperatures observed in satellite imagery were detected throughout the year, but were notably stronger in January–April, becoming progressively weaker though December (figs. 14, 17). Consistent with strongly elevated surface temperatures and continuous seismicity in early 2015, incandescence within the summit crater was observed on February 2, February 26, and March 9, suggesting active lava at the surface of the volcano.

Minor, low-level ash emissions were observed on 21 occasions in web camera images (fig. 18), and were reported by both pilots and mariners between January and August. Typical ash clouds contained low concentrations of ash, evidenced by the light gray color and little to no ash signature in satellite imagery. The plumes typically extended a few to tens of kilometers downwind and lofted between a few to 1,000 m (less than 3,300 ft) above the vent, which is 3–4 km (9,400–12,000 ft) ASL.

Small infrasound signals were detected on the Dillingham (582 km/362 mi NE) and Akutan (135 km/84 mi SW) arrays in February, August, and September 2015, suggestive of an open vent, as opposed to a sealed vent where gases are trapped and might generate more energetic explosions. A research gas flight was flown in August 2015 to measure gases (CO_2, SO_2, and H_2S) being emitted from the volcano (fig. 19). At the same time, temporary ground-based gas monitoring equipment was deployed for 2 hours to measure gas in the plume (fig. 20). Results show that SO_2 emissions varied between 400–1,090 metric tons per day (440–1,200 tons per day) and carbon to sulfur (C/S) ratios were low, consistent with degassing of shallow magma through a partially open vent (Cindy Werner, USGS/AVO, written commun., 2015).

Figure 16. Typical low-level steaming from the summit of Shishaldin Volcano. Photograph was taken 72 km (45 mi) north-northwest of the volcano from a ship in the Bering Sea. Photograph by Levi Musselwhite, February 27, 2015, used with permission. AVO database image URL: https://avo.alaska.edu/images/image.php?id=77311.

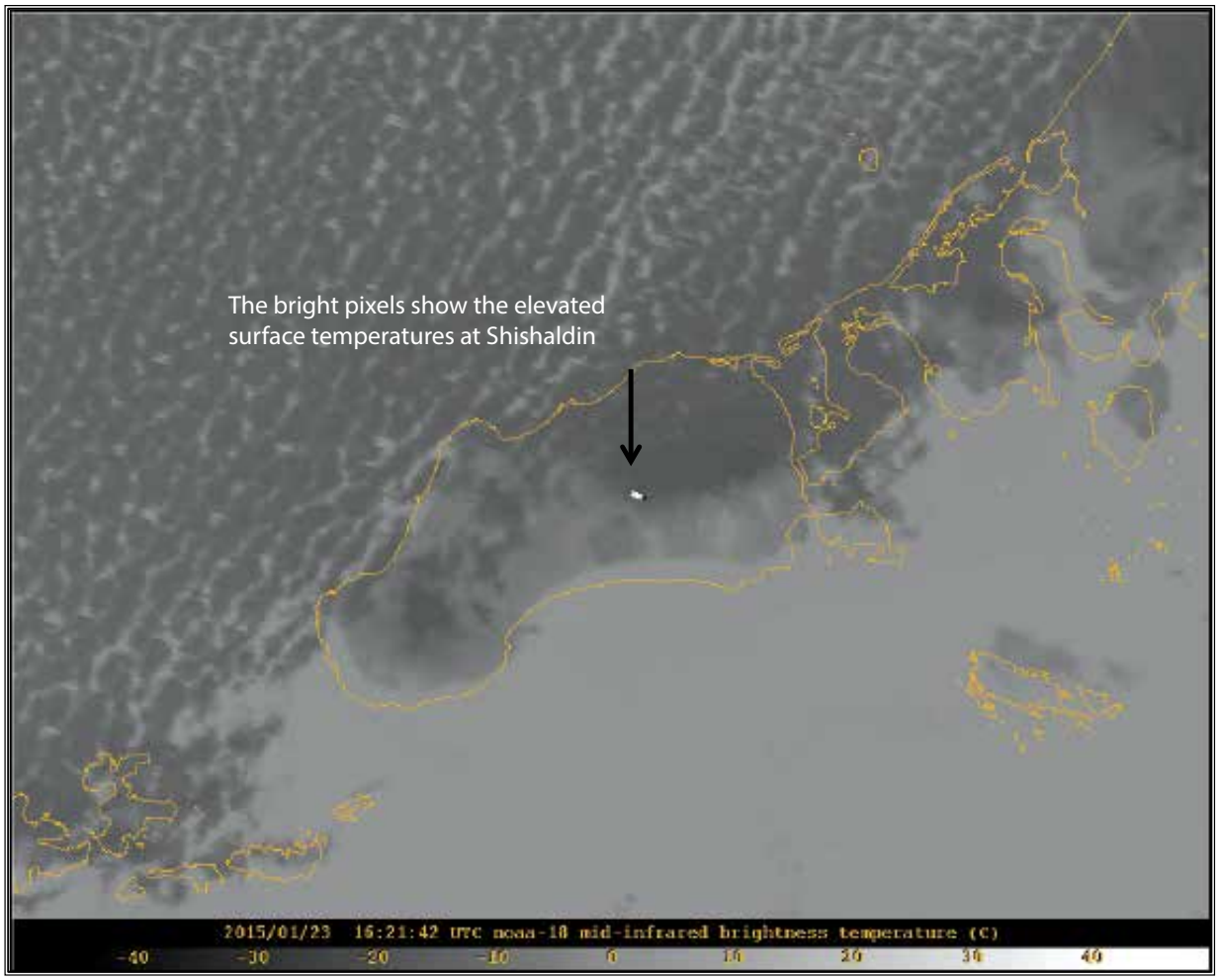

Figure 17. NOAA satellite mid-infrared image recording strongly elevated surface temperatures at Shishaldin on January 23, 2015. Modified from AVO database image URL: https://avo.alaska.edu/images/image.php?id=103381.

On November 20, citing a significant decrease in evidence of new lava in the crater since October 2015, AVO lowered the Aviation Color Code/Volcano Alert Level to **YELLOW/ADVISORY**. Low-level steaming and a single satellite image showing weakly elevated surface temperatures were noted in November and December 2015 and the year ended with no further change in Aviation Color Code/Volcano Alert Level.

Shishaldin Volcano, located near the center of Unimak Island in the eastern Aleutian Islands, is a spectacular symmetric cone with a base diameter of approximately 16 km (10 mi). A small summit crater typically emits a noticeable steam plume, occasionally with minor amounts of ash. Shishaldin is one of the most active volcanoes in the Aleutian volcanic arc (Cameron, 2005).

Figure 18. Shishaldin Volcano, backlit by the summer sunset, with steam and minor ash plume. View looking north, from a ship south of Shishaldin Volcano. Photograph courtesy of Allan and Kathy Lowe, May 7, 2015, used with permission. AVO database image URL: https://avo.alaska.edu/images/image.php?id=78791.

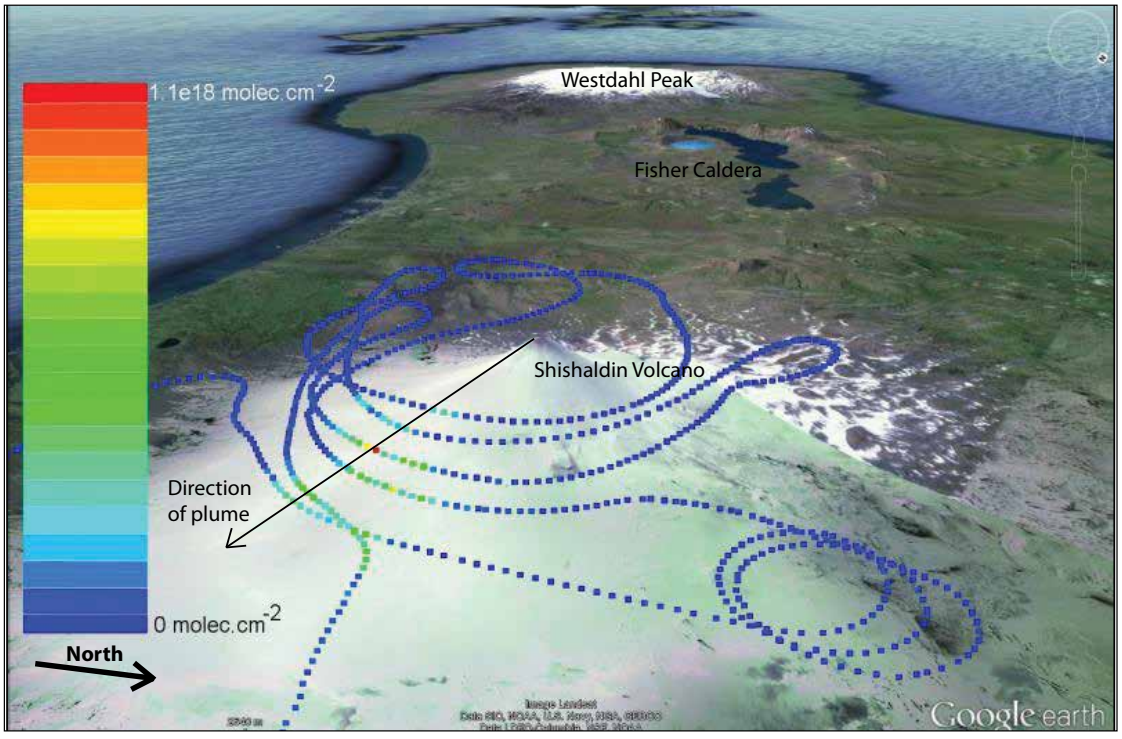

Figure 19. Satellite image showing aerial path of the flight measuring volcanic gases at Shishaldin Volcano, August 19, 2015. The gas plume is directed northeast as indicated by the gas-concentration color scale. Westdahl Peak is in the background, southwest of Shishaldin Volcano. Satellite image from Google, 2014. AVO image database URL: http://www.avo.alaska.edu/images/image.php?id=103311.

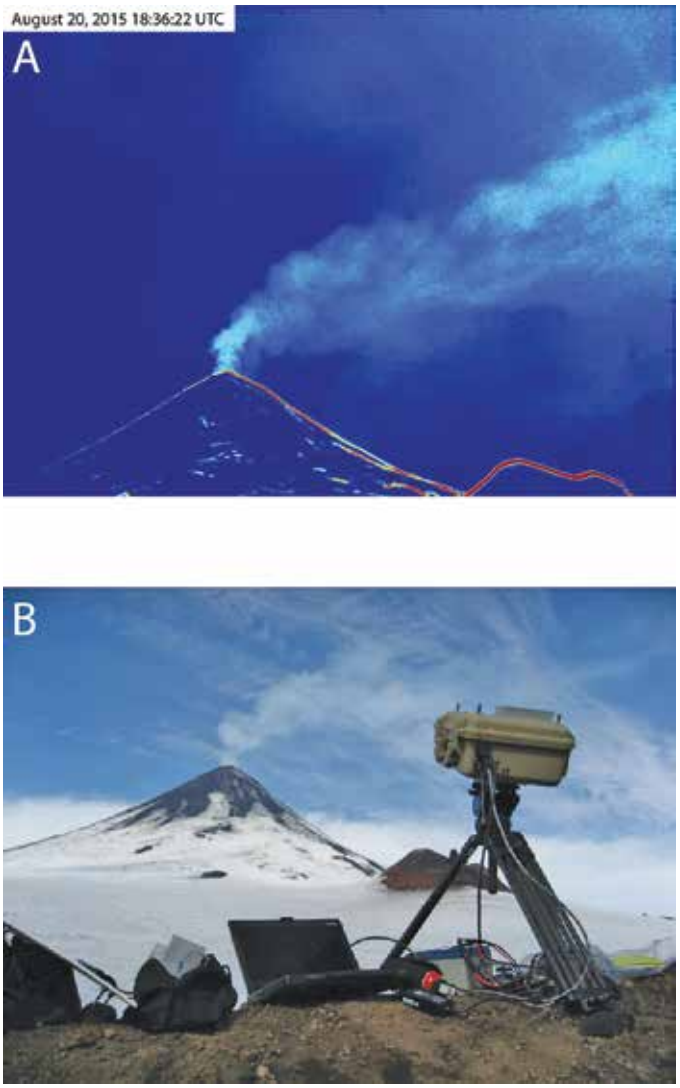

Figure 20. Temporary deployment of a ground-based ultraviolet SO_2 camera placed 5 km (3 mi) east of the summit vent of Shishaldin Volcano shown in B. (A) Ultraviolet image of the low-concentration SO_2 plume emitting from Shishaldin Volcano. (B) Temporary ground-based ultraviolet SO_2 camera. Photographs by Taryn Lopez, August 20, 2015. A: AVO database image URL: https://avo.alaska.edu/images/image.php?id=103321; B: AVO database image URL: https://avo.alaska.edu/images/image.php?id=103331.

Mount Recheshnoi

GVP# 311280

53.1536° N 168.5382° W
1,984 m (6.509 ft)

Umnak Island, Fox Islands, Aleutian Islands

CONTINUATION OF INCREASED SEISMICITY

The Geyser Bight Valley is a geothermal area (Nye and others, 1992; Motyka and others, 1993) southeast of Mount Recheshnoi (fig. 21). In 2007, the seismograph network on neighboring Okmok Caldera recorded a short earthquake swarm in October. Following a 5-year period of quiescence, seismic activity increased in the Geyser Bight area in 2013 and continued through July 2015. The vast majority of the earthquakes located in 2015 were at shallow depths, less than 7 km (4 mi) with earthquake magnitudes between M_L= 0.5 and M_L=1.5. Seven earthquakes were larger than M_L=2.0; the largest earthquake was a M_L=3.0 event on June 30. Because this sequence of earthquakes occurred well away from a historically active volcano, no change in the alert status was made at any neighboring volcanos.

Mount Recheshnoi is a Holocene-aged volcano located on the southern half of Umnak Island. A small neck connects the southern volcanoes of Umnak Island (Recheshnoi and the farther-south Vsevidof) with Okmok volcano, which occupies the northern half of Umnak Island. Mount Recheshnoi, a large stratovolcano, is heavily glaciated. Three Holocene andesite flows are on its eastern and western flanks, the youngest of which is about 3,000 years old (Black, 1975; Nye and others, 1992; Motyka and others, 1993). Recheshnoi also hosts one of only three known occurrences of high-silica rhyolite (dated to 0.135 Ma) in the Aleutian arc west of Novarupta (Nye and others, 1992; Motyka and others, 1993). A large zone of six hot thermal springs and small geysers is dispersed over an area of 4 km² (1.5 mi²). This geothermal area is one of the largest and hottest in Alaska (Nye and others, 1992).

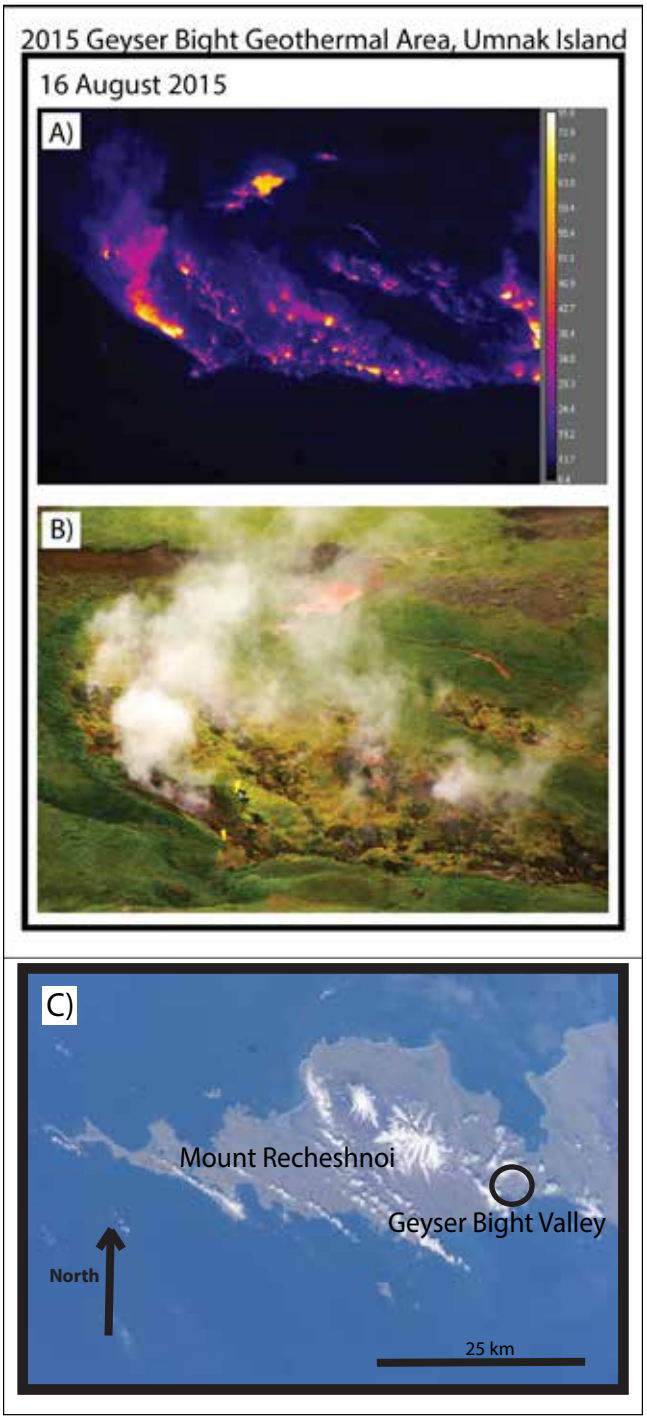

Figure 21. Upper Geyser Bight geothermal area on Umnak Island, Alaska, during 2015 geochemical sampling funded by the Deep Carbon Observatory. (A) Forward looking infrared (FLIR) image of the uppermost geothermal area showing intense fumarolic activity and boiling and near-boiling springs. (B) Same uppermost geothermal area in (A). The yellow-clad figures are gas geochemists from the Cascades Volcano Observatory sampling gases and waters from the geothermal features. (C) Index map showing the location of the Geyser Bight Valley on the western half of Umnak Island. Photographs by John Lyons, USGS/AVO, August 16, 2015. Oblique air photograph courtesy of the Image Science and Analysis Laboratory, NASA-Johnson Space Center. AVO database images URLs: http://avo.alaska.edu/images/image.php?id=83871; https://avo.alaska.edu/images/image.php?id=13946.

Mount Cleveland

GVP# 311240

52.8222° N 169.9450° W
1,730 m (5,676 ft)

Chuginadak Island, Fox Islands, Aleutian Islands

CONTINUED LOW-LEVEL ERUPTION

Volcanic activity at Mount Cleveland in 2015 was less robust than in previous years. The year commenced with the volcano at Aviation Color Code/Volcano Alert Level **YELLOW/ADVISORY** until a lull in activity prompted a return to **UNASSIGNED** status in late May. Renewed dome growth in June caused a return to **YELLOW/ADVISORY** status with an upgrade to **ORANGE/WATCH** in mid-July resulting from two notable explosions, intermittent thermal anomalies, and summit degassing. The Aviation Color Code/Volcano Alert Level was lowered to **YELLOW/ADVISORY** after a decrease of activity in October, and remained at this status through the end of the year (table 9).

Cleveland began the year at Aviation Color Code **YELLOW** and Volcano Alert Level **ADVISORY** and remained so for nearly 5 months. During this period, elevated temperatures were observed, as well as minor intermittent seismicity and steaming. At the volcano's summit, the dome emplaced after the November 6, 2014, explosion remained the same size through February 2015. Elevated surface temperatures were observed in clear satellite images (fig. 22). The diameter of the dome was about 45 m (150 ft) with an approximately 20 m (65 ft) depression that formed a shallow crater in the center. Incandescent fumaroles were detected on February 27 in cracks on the summit dome resulting from inflation of the dome. By March 27, satellite imagery confirmed growth of the dome to about 50 m (164 ft) in diameter (surface area 1,800 m^2 or 19,000 ft^2).

Figure 22. Perspective Landsat-8 satellite image of Mount Cleveland overlain with surface temperatures derived from shortwave-infrared (SWIR) data collected on January 5, 2015. Colors show the location of elevated surface temperatures, due to the presence of a small lava dome or plug, in the summit crater. Satellite image from Google, 2015. Image retrieved by Dave Schneider, USGS/AVO, January 5, 2015. AVO database image URL: https://avo.alaska.edu/images/image.php?id=72261.

Table 9. Summary of activity and observations at Mount Cleveland in 2015.

[This table is a summary of a more detailed eruption chronology for Cleveland volcano. **Color Code/Alert level** is the Aviation Color Code and Volcano Alert Level for the date or range of dates in the **Date/Date range** column. **Notable activity:** A notation of significant activity at the volcano. **Elevated surface temperature:** A qualitative strength of any thermal anomaly seen at the active vent of the volcano. **Remote sensing observations:** Web-camera and satellite images of the volcanic plume. **Geophysical observations:** Notable activity seen in the AVO seismograph and infrasound network to include sustained tremor, discrete low frequency earthquakes and volcano tectonic earthquakes. **Abbreviations:** ft, foot; m, meter]

Date/ Date range	Color code/ Alert level	Notable activity	Elevated surface temperature	Remote sensing observations	Geophysical observations
01-02-15 to 01-03-15	YELLOW/ADVISORY		Moderate		
01-05-15	YELLOW/ADVISORY		Weak		
01-07-15	YELLOW/ADVISORY			Dome remain at 45 m diameter with 20 m diameter depression	
01-09-15	YELLOW/ADVISORY		Weak		
01-24-15	YELLOW/ADVISORY		Moderate		Low-frequency activity
01-31-15 to 02-01-15	YELLOW/ADVISORY				Low-frequency activity
02-23-15	YELLOW/ADVISORY			Small plume	
02-25-15	YELLOW/ADVISORY		Moderate		
02-27-15	YELLOW/ADVISORY	Incandescent fumaroles		Incandescent fumaroles in cracks of lava dome	
02-28-15	YELLOW/ADVISORY			Plume (10,000 ft)	
03-02-15	YELLOW/ADVISORY	Dome growth		Dome inflation to 50 m; blocky surface	
03-08-15	YELLOW/ADVISORY			Dark area around summit	
03-12-15 and 03-23-15	YELLOW/ADVISORY			Minor Steam	
03-26-15	YELLOW/ADVISORY				Tremor signal
03-27-15	YELLOW/ADVISORY	Dome growth		Dome inflation	Low-frequency activity, tremor
03-29-15	YELLOW/ADVISORY			Small steam plume	Intermittent tremor
03-30-15	YELLOW/ADVISORY			Robust steam plume	
04-13-15	YELLOW/ADVISORY			Minor steam plume	
04-15-15	YELLOW/ADVISORY				Low-frequency activity
04-16-15	YELLOW/ADVISORY			Minor steam plume	
04-19-15 and 04-21-15	YELLOW/ADVISORY				Few local events
04-26-15	YELLOW/ADVISORY			Minor steam plume	
05-01-15	YELLOW/ADVISORY				Few local events
05-02-15	YELLOW/ADVISORY			Minor steam plume	

Table 9. Summary of activity and observations at Mount Cleveland in 2015.—Continued

Date/ Date range	Color code/ Alert level	Notable activity	Elevated surface temperature	Remote sensing observations	Geophysical observations
05-15-15	YELLOW/ADVISORY				Few local events
05-24-15	YELLOW/ADVISORY			Minor steam plume	
05-28-15	UNASSIGNED				
06-04-15 and 06-12-15	UNASSIGNED				Few local events
06-17-15	YELLOW/ADVISORY	Dome growth		Lava dome growth to 55×85 m	
06-19-15	YELLOW/ADVISORY		Moderate		Few local events
06-27-15	YELLOW/ADVISORY			Minor steam plume	
06-29-15	YELLOW/ADVISORY	Fresh ash	Moderate	Fresh ash at summit	
07-04-15	YELLOW/ADVISORY		Moderate		
07-07-15	YELLOW/ADVISORY		Weak		
07-18-15	YELLOW/ADVISORY		Weak		Local volcano tectonic events
07-21-15	ORANGE/WATCH	Explosion; dome replaced by crater			Infrasound and ground-coupled airwave alarms triggered
07-23-15	ORANGE/WATCH		Moderate	Minor steam plume	
07-27-15	ORANGE/WATCH			Minor plume	Local event; M=6.9 tectonic earthquake
07-29-15	ORANGE/WATCH		Strong		
07-30-15	ORANGE/WATCH	Dome growth	Strong		
07-31-15	ORANGE/WATCH		Moderate		
08-01-15	ORANGE/WATCH	Small explosion	Moderate	Minor plume	Infrasound detection; 40 times smaller than previous event
08-02-15	ORANGE/WATCH		Weak	Minor plume	Weak event
08-03-15	ORANGE/WATCH		Weak	Minor steam plume	
08-04-15	ORANGE/WATCH	Fresh lava dome/pad	Weak	Summit overflight	Few local events
08-05-15	ORANGE/WATCH		Weak	Minor steam plume	Few local events
08-07-15	ORANGE/WATCH	Explosion			Infrasound signal shows explosion half the size of the July 21 expolsion. Few local events
08-09-15	ORANGE/WATCH				Few local events
08-10-15	ORANGE/WATCH			Minor steam plume	Local volcano tectonic earthquakes; few other events
08-13-15	ORANGE/WATCH				Small event
08-15-15	ORANGE/WATCH	Lava dome growth		Summit overflight	

Table 9. Summary of activity and observations at Mount Cleveland in 2015.—Continued

Date/ Date range	Color code/ Alert level	Notable activity	Elevated surface temperature	Remote sensing observations	Geophysical observations
08-18-15	ORANGE/WATCH		Moderate	Minor steam plume	Few local events
08-20-15	ORANGE/WATCH		Moderate		
08-21-15 to 08-22-15	ORANGE/WATCH			Minor steam plume	
08-23-15	ORANGE/WATCH		Weak		
08-24-15	ORANGE/WATCH		Moderate		
08-25-15 to 08-26-15	ORANGE/WATCH		Weak		
08-28-15	ORANGE/WATCH		Moderate		
08-29-15	ORANGE/WATCH	Earthquake swarm	Moderate		Earthquake swarm
08-30-15 to 09-01-15	ORANGE/WATCH				Few local events
09-05-15	ORANGE/WATCH		Weak–Moderate	Minor steam plume	
09-07-15	ORANGE/WATCH		Weak		Few local events
09-08-15 to 09-09-15	ORANGE/WATCH			Vigorous degassing	
09-12-15 to 09-13-15	ORANGE/WATCH		Moderate		
09-14-15 to 09-15-15	ORANGE/WATCH				Few local events
09-16-15	ORANGE/WATCH			Minor steam plume	Few local events
09-17-15 to 09-20-15	ORANGE/WATCH				Few local events
09-21-15 to 09-22-15	ORANGE/WATCH		Weak		
09-24-15	ORANGE/WATCH			Minor steam plume	
09-26-15	ORANGE/WATCH				Few local events
09-27-15	ORANGE/WATCH				Low-frequency activity
09-30-15	ORANGE/WATCH		Weak–Moderate		
10-01-15	ORANGE/WATCH			Minor steam plume	
10-04-15 and 10-06-15	ORANGE/WATCH				Few local events
10-09-15	ORANGE/WATCH			Minor steam plume	
10-14-15	YELLOW/ADVISORY				
10-15-15	YELLOW/ADVISORY		Weak		

Table 9. Summary of activity and observations at Mount Cleveland in 2015.—Continued

Date/ Date range	Color code/ Alert level	Notable activity	Elevated surface temperature	Remote sensing observations	Geophysical observations
10-24-15 to 10-25-15 and 10-27-15 to 10-29-15	YELLOW/ADVISORY			Minor steam plume	
10-31-15	YELLOW/ADVISORY		Weak		
11-08-15	YELLOW/ADVISORY				Small event
11-13-15	YELLOW/ADVISORY				Possible rockfalls
11-16-15	YELLOW/ADVISORY			Minor steam plume	Small event
11-18-15	YELLOW/ADVISORY				Small event
11-23-15	YELLOW/ADVISORY				Few local events
11-24-15	YELLOW/ADVISORY			Minor steam plume	Few local events
11-25-15 to 11-26-15 and 11-28-15	YELLOW/ADVISORY				Few local events
11-29-15 and 12-05-15	YELLOW/ADVISORY			Minor steam plume	
12-08-15	YELLOW/ADVISORY		Moderate		
12-17-15 and 12-18-17	YELLOW/ADVISORY				Few local events
12-20-15	YELLOW/ADVISORY		Weak		
12-22-15 and 12-23-15	YELLOW/ADVISORY				Few local events

After a sustained decline in eruptive activity over the span of a few weeks, Mount Cleveland was downgraded from Aviation Color Code/Volcano Alert Level **YELLOW/ADVISORY** to **UNASSIGNED** on May 28. Three weeks later, elevated surface temperatures returned, and a light dusting of ash visible on the upper flanks of Cleveland signified renewed activity. AVO increased the Aviation Color Code/Volcano Alert Level to **YELLOW/ADVISORY** on June 17 in response to this activity. Satellite imagery showed accelerated lava dome growth in the few days prior to raising the color code. The dome had increased to 55 × 85 m (180 × 280 ft) (outline area almost 3,900 m^2 or 42,000 ft^2).

On July 21, the Aviation Color Code/Volcano Alert Level was elevated from **YELLOW/ADVISORY** to **ORANGE/WATCH** when an explosion at 16:17 UTC (08:17 AKDT) of similar amplitude as the explosion on November 6, 2014, at Cleveland was detected by the Cleveland infrasound array and ground-coupled airwaves on the Okmok seismograph network (fig. 23). The explosion data, with no clear compression or rarefaction has been interpreted as a swelling and disruption of the conduit plug, followed by a more energetic 'uncorking' of the system (David Fee, UAFGI/AVO, written commun., 2015). This interpretation is similar to that for the previous explosion in November 2014. Satellite imagery showed that the lava dome was completely removed during this explosion and replaced by a small 40 m (130 ft) diameter crater. The hot summit vent surrounded by slightly cooler deposits likely from the July 21 explosion is shown in figure 24.

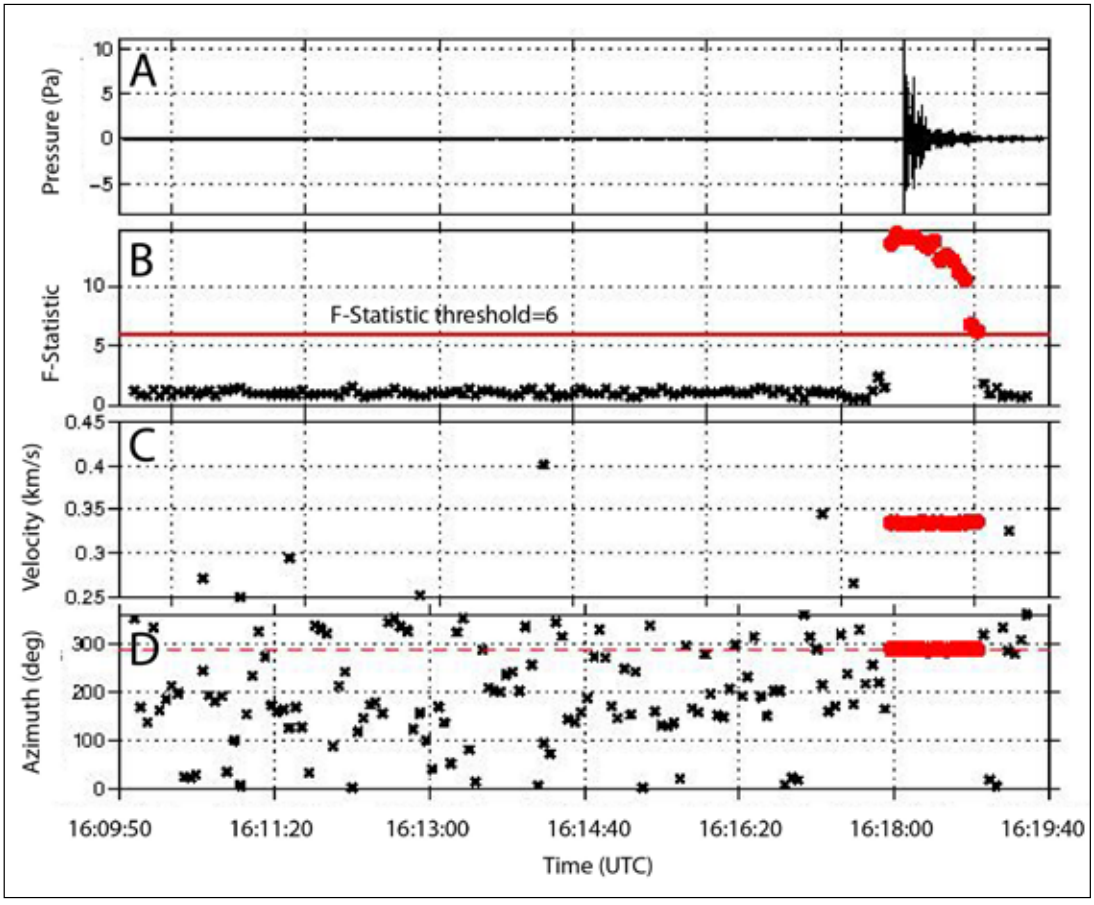

Figure 23. Data from the infrasound station near Mount Cleveland (CLCO) during the explosion on July 21, 2015, at 16:17 UTC (08:17 AKST). (A) A simple pressure (in pascals [Pa]) plot where the explosion can clearly be seen. (B) F-statistic, an automated way of detecting explosion signals above the noise; the threshold is set at 6 and is indicated by a horizontal line. Values below the threshold are indicated by crosses and values above the threshold are shown by dots. (C) Velocity of the signal, where dots show the values at the speed of sound (0.34 km/s or 1,100 ft/s) and crosses show values that are above or below the speed of sound. (D) Azimuth of the signal with respect to the station. The azimuth values with a constant azimuth, just below 300 degrees and consistent with the location of Mount Cleveland, are shown by dots. Values that do not show a sustained azimuth are shown by crosses. Image by David Fee, UAFGI/AVO. AVO database image URL: https://avo.alaska.edu/images/image.php?id=103341.

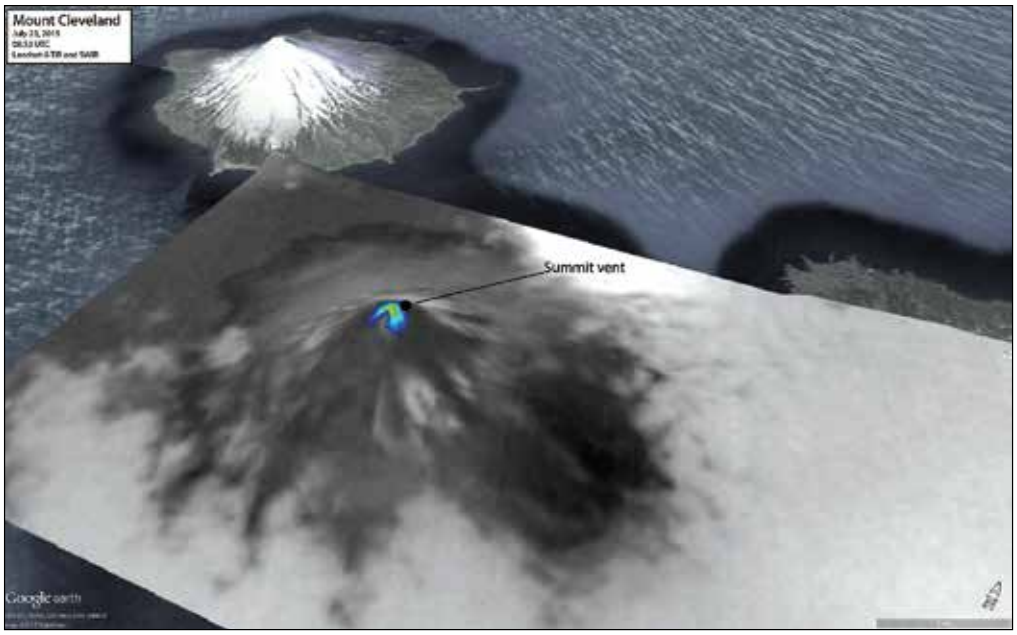

Figure 24. Landsat-8 satellite image of Mount Cleveland retrieved on July 23, 2015, at 08:53 UTC (00:53 AKDT) draped over topography. The grayscale base image is from thermal infrared (TIR) data and shows temperatures from cool (white) to warm (black). The color overlay displays surface temperature derived from short-wave infrared (SWIR) data and indicates high-temperature features at the summit. The hot summit vent is observed as a dot and surrounded by slightly cooler (but still hot) deposits likely from the July 21 explosion. Satellite image from Google earth, 2015. Image retrieved by Dave Schneider, USGS/AVO. AVO database image URL: https://avo.alaska.edu/images/image.php?id=79871.

On July 27 at 06:49 UTC (July 26 at 08:49 AKDT), a typical shallow subduction thrust earthquake of M=6.9 occurred about 80 km (50 mi) southeast from Cleveland. This earthquake was strictly tectonic and not related to the explosion at Cleveland, although many aftershocks were recorded on the Cleveland and neighboring seismograph networks.

On July 30, strongly elevated surface temperatures were noted, consistent with dome growth after the explosion of the prior week. Two days later, on August 1 at 11:28 UTC (03:28 AKDT), a small airwave signal (40 times smaller than the July 21 explosion) in the region of Cleveland was detected, but was not considered a major explosion. Elevated surface temperatures were consistently observed in satellite imagery and a small steam plume was visible in the web camera following this small explosion. On August 4, AVO personnel overflew the summit of the volcano and observed a fresh lava dome forming that had a hot core (about 550–600 °C). Only minor degassing was detected during the flight. Images from this overflight are shown in figures 25A and B.

A second explosion occurred on August 7 at 06:03 UTC (August 6, 22:03 AKDT) that was approximately one-half the amplitude of the July 21 explosion and much shorter in duration (1–2 seconds; fig. 26). As viewed from satellite imagery, the lava dome that had been growing steadily since July 21 was only partially removed along its southern margin. On August 15, another overflight of the summit by AVO personnel showed more robust degassing and a dome with extrusions of partially new lava (fig. 25; Werner and others, 2017). Satellite data from August 14 show that the 80 m (262 ft) diameter lava dome deflated in the center and a 25–30 m (82–98 ft) diameter area of incandescent fractures across the dome surface was observed.

August 29 marked the first notable earthquake swarm since the installation of a seismograph network on Cleveland in the summer of 2014 (fig. 27). The swarm began around 19:03 UTC (11:03 AKDT) and continued for several hours before diminishing. This earthquake swarm was concurrent with elevated surface temperatures; however, nothing of note was recorded in the infrasound data.

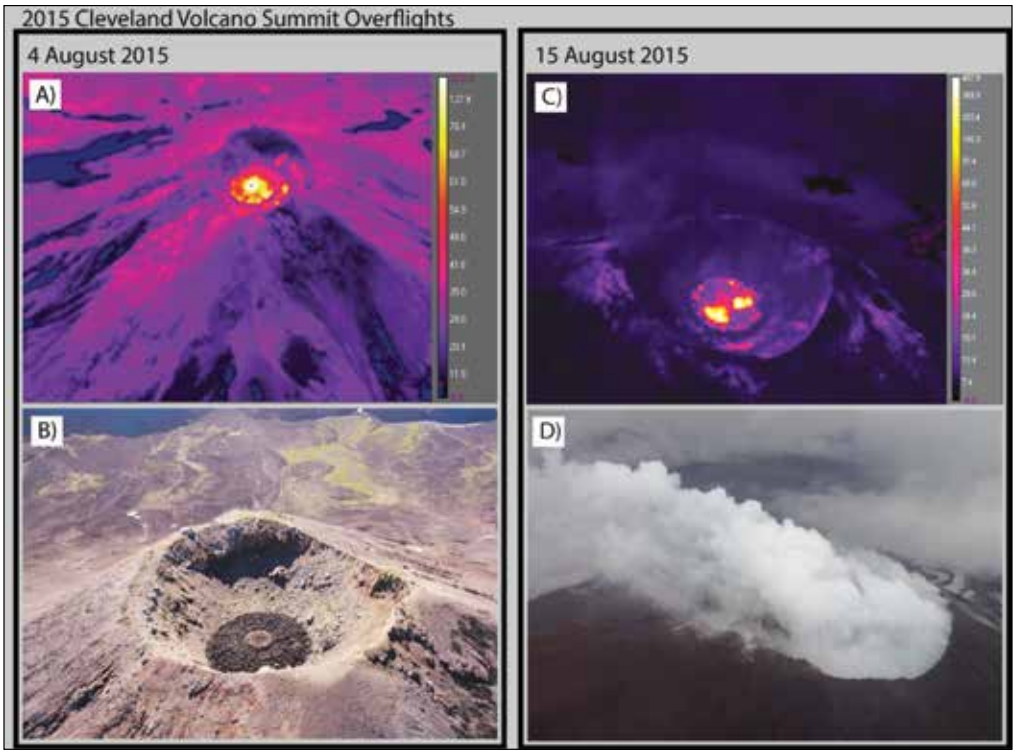

Figure 25. Summit of Mount Cleveland in August 2015. (A) Thermal images from August 4, 2015, show that the center of the newly formed lava dome is more than 500 °C. (B) August 4 image of the new lava dome, later partially destroyed on August 7. (C) Thermal image from the August 15 overflight showing hot extrusion on the partially new lava dome. (D) Vigorous degassing from the summit on August 15. Photograph A by John Lyons, USGS/AVO, August 4, 2015; photograph B by Joe Schmidt, Maritime Helicopters; August 4, 2015, used with permission; photograph C by John Lyons, USGS/AVO, August 15 2015; photograph D by Christoph Kern USGS/CVO, August 15, 2015. AVO database image URL: https://avo.alaska.edu/images/image.php?id=83841.

Elevated temperatures and minor steaming persisted for a few weeks following the two explosions. Strongly elevated temperatures decreased after July 30 and moderately elevated temperatures decreased regularly after that. This led to a lowering of the Aviation Color Code/Volcano Alert Level from **ORANGE/WATCH** to **YELLOW/ADVISORY** on October 14, and Cleveland remained at this level for the remainder of the year. Intermittent weakly elevated surface temperatures and minor steaming characterized the activity for the latter months of the year. A summary of the eruption between 2011 and 2015 is shown in figure 28.

Mount Cleveland volcano forms the western part of Chuginadak Island, an uninhabited island in the Islands of the Four Mountains group in the east-central Aleutians. Cleveland is located about 75 km (45 mi) west of the community of Nikolski and 1,500 km (940 mi) southwest of Anchorage. Short-lived ash explosions, lava fountains, lava flows, and pyroclastic avalanches down the flanks of the volcano have characterized historical eruptions. In February 2001, after 6 years of quiescence, three explosive events occurred at Cleveland that produced ash clouds as high as 12 km (39,000 ft) ASL (Dean and others, 2004), a rubbly lava flow, and hot avalanche that reached the sea. Intermittent explosive eruptions have occurred every year since 2001 with exceptional explosive activity in 2011–12.

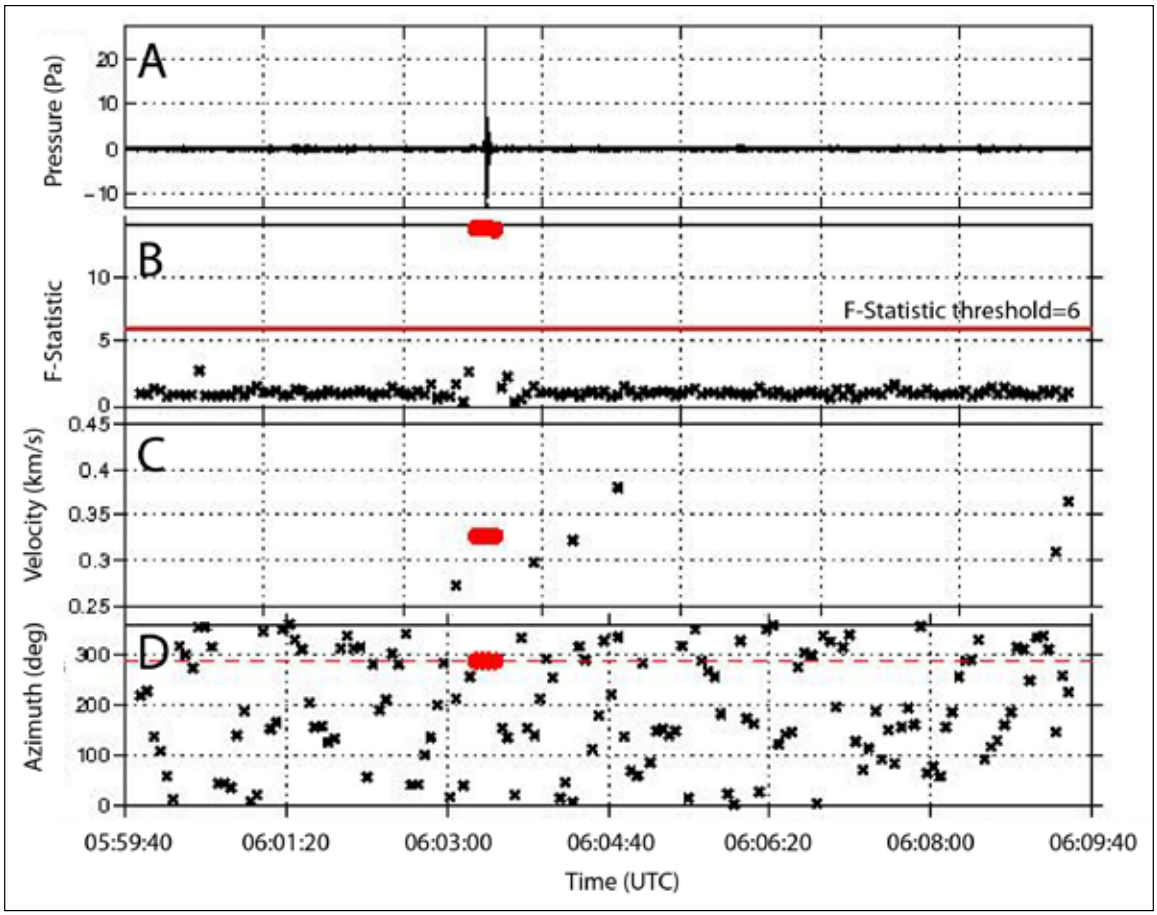

Figure 26. Data from the infrasound station near Mount Cleveland (CLCO) during the explosion on August 7, 2015, at 06:03 UTC (August 6, 22:03 AKDT). This explosion was about one-half the amplitude of the July 21 explosion and much shorter in duration. (A) A simple pressure (in pascals [pa]) plot where the explosion can clearly be seen. (B) F-statistic, which is an automated way of detecting explosion signals above the noise; the threshold is set at 6 and is indicated by a horizontal line. Values below the threshold are indicated by crosses and values above the threshold are shown by dots. (C) Velocity of the signal, where dots show the values at the speed of sound (0.34 km/s or 1,100 ft/s) and crosses show values that are above or below the speed of sound. (D) Azimuth of the signal with respect to the station. The azimuth values with a constant azimuth, just below 300 degrees and consistent with the location of Mount Cleveland, are shown by dots. Values that do not show a sustained azimuth are shown by crosses. Image courtesy of David Fee, UAFGI/AVO. AVO database image URL: https://avo.alaska.edu/images/image.php?id=103351.

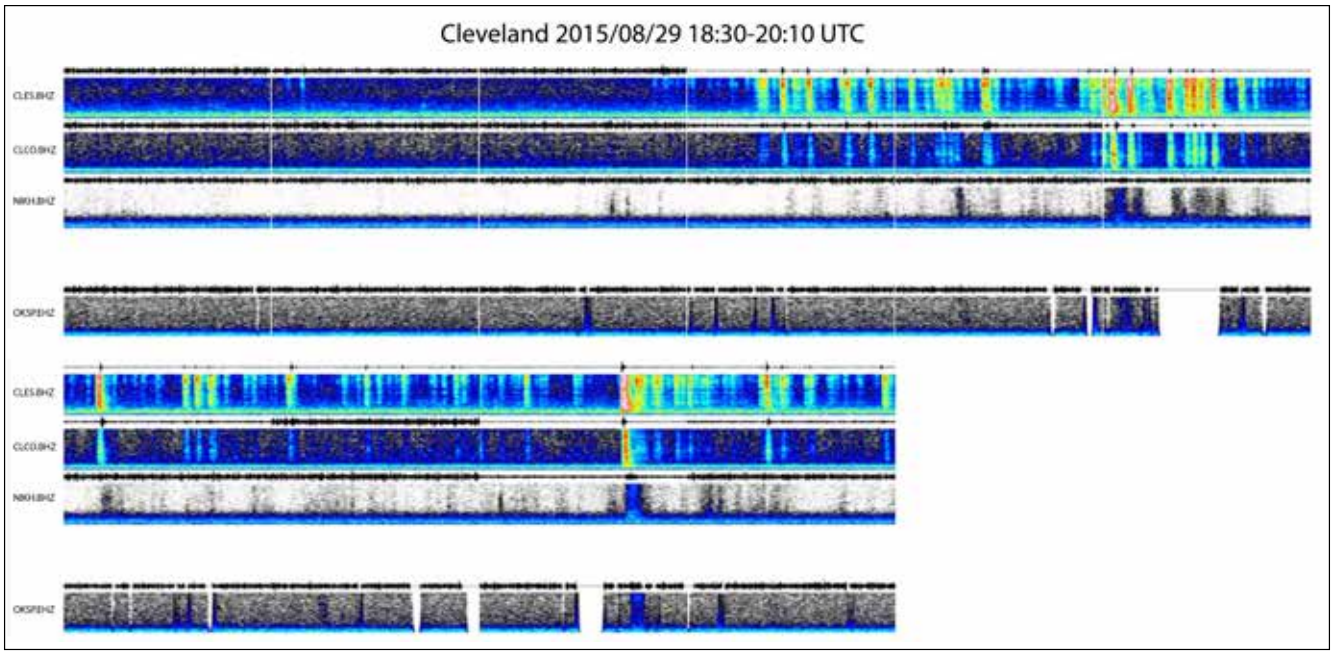

Figure 27. Spectrogram of four stations from 18:30 to 20:10 UTC (10:30-12:10 AKDT) August 29, 2015. The earthquake swarm at Mount Cleveland began around 19:03 UTC (11:03 AKDT) on August 29 recorded at CLES (strongest) and CLCO. The largest earthquakes in the swarm can be seen on NIKH (75 km from Cleveland) and OKSP (90 km from Cleveland). Figure by Aaron Wech, USGS/AVO. AVO database image URL: https://avo.alaska.edu/images/image.php?id=103361.

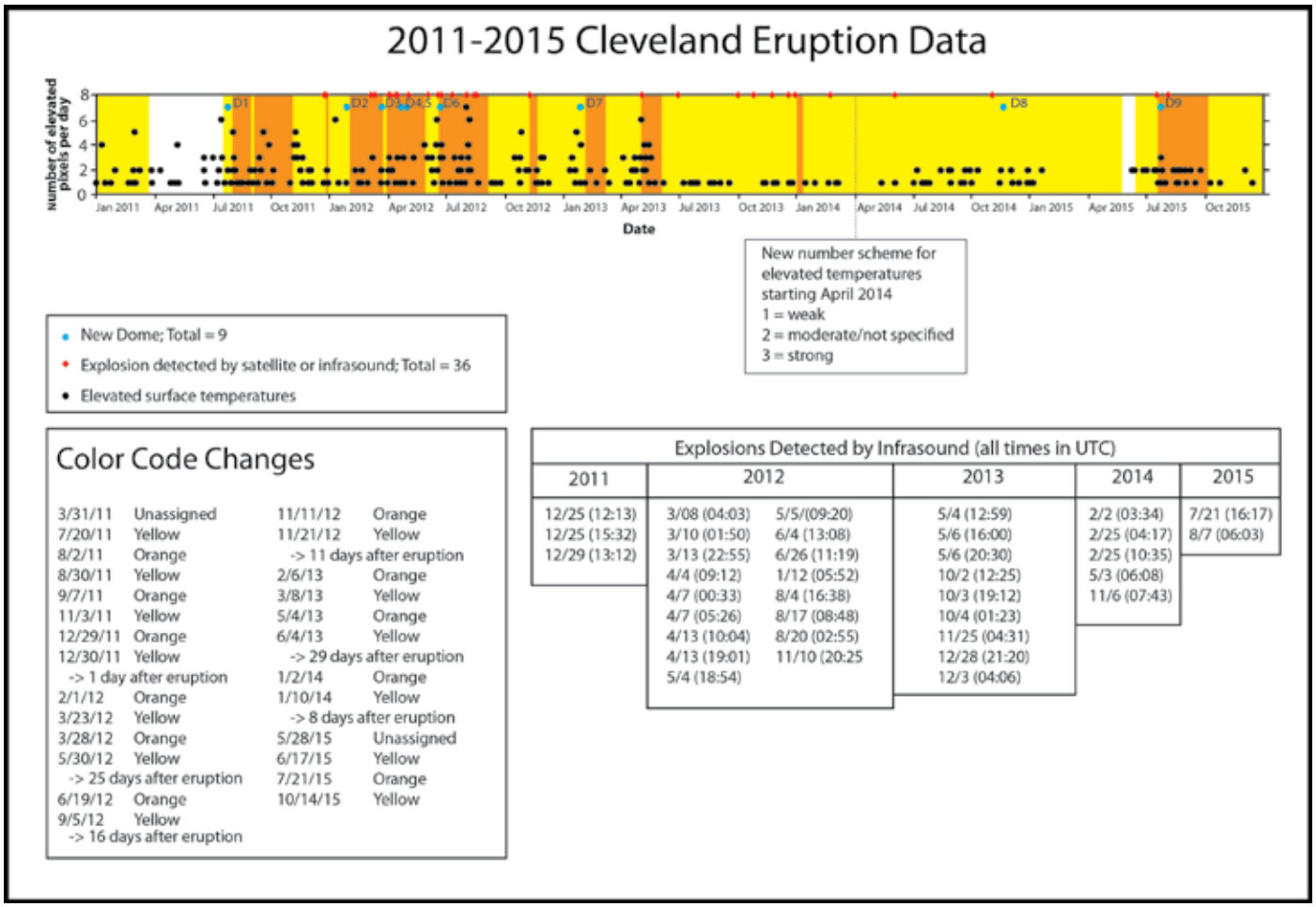

Figure 28. Eruptive history for 2011–15 indicating decreased activity at Mount Cleveland since 2012. The timeline colors indicate the Aviation Color Code/Volcano Alert Level: UNASSIGNED (white), YELLOW/ADVISORY, and ORANGE/WATCH. Explosions detected by infrasound with dates and times listed in "Explosions Detected" table were identified and cataloged by Matt Haney, USGS/AVO. From January 2011 through April 2014, the strength of surface temperatures was recorded by observing the number of elevated pixels per day. In April 2014, the reporting scheme changed to characterize the strength of thermal anomalies as weak, moderate, or highly elevated surface temperatures. Figure by Alex Iezzi, UAFGI/AVO, Kristi Wallace, USGS/AVO, and Elizabeth Redlinger, USGS/AVO. AVO database image URL: https://avo.alaska.edu/images/image.php?id=103371.

Semisopochnoi Island

GVP# 311060

551.9288° N 179.5977° E
800 m (2,625 ft)

Rat Islands, Aleutian Islands

EARTHQUAKE SWARM

An increase in seismicity at Semisopochnoi was recorded in January 2015, characterized by numerous small earthquakes, most with magnitudes less than M_L=1. The seismicity continued for several months and when tremor associated with the earthquake swarm appeared, AVO raised the Aviation Color Code/Volcano Alert Level from **UNASSIGNED** to **YELLOW/ADVISORY** on March 25, 2015. After a decline in the seismicity over a period of several months, the Aviation Color Code and Volcanic Alert Level were downgraded to **UNASSIGNED** on May 28. Throughout the earthquake swarm, no deformation or associated thermal anomalies were observed.

The volcanic vents on Semisopochnoi Island (figs. 1 and 29) are part of the largest young volcanic island in the western Aleutians. The volcanos are dominated by an 8-km (5-mi) diameter caldera that contains a small lake and numerous post-caldera cones and craters (Coats, 1959; Michelle Coombs, USGS/AVO, written commun., 2015). Warm springs downstream of the outlet of Fenner Lake attest to ongoing heat discharge through the caldera floor. The age of the caldera is not known with certainty, but likely is early Holocene; preliminary field evidence suggests that caldera-forming deposits are found on all quadrants of the island (Michelle Coombs USGS/AVO and Jessica Larsen, UAFGI/AVO, written commun., 2015). Radiocarbon dates on tephra from nearby Amchitka Island tentatively associated with the caldera-forming eruption suggest a maximum age of 6,920 radiocarbon years BP (Michelle Coombs, USGS/AVO, written commun., 2015). Since caldera formation, a number of post caldera vents scattered about the caldera floor and on the south flank have been active. The last known eruption at Semisopochnoi occurred in 1987, probably from Sugarloaf Peak on the south coast of the island, but details are scant (Reeder, 1990). Mount Cerberus, a three-peaked cone cluster in the southwest part of the caldera, is another prominent, young post-caldera landform.

Figure 29. Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image of Semispochnoi Island. AVO database image URL: https://avo.alaska.edu/images/image.php?id=761.

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Glossary of Selected Terms and Acronyms

AAWU Alaska Aviation Weather Unit.

AKDT "Alaska Daylight Time"; UTC -8 hours. Alaska Daylight time in 2015 ran from March 8 to November 1.

ADF&G State of Alaska Department of Fish and Game.

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.

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

AVO Alaska Volcano Observatory.

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

CVO Cascade Volcano Observatory.

FAA Federal Aviation Administration.

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

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.

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

GPS Global Positioning System.

GVP Smithsonian Institution Global Volcanism Program.

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

infrasound low-frequency sound waves, below the threshold of human hearing.

InSAR Interferometric Synthetic Aperture Radar.

intracaldera refers to something within the caldera.

juvenile volcanic material created from magma reaching the surface.

KVERT Kamchatkan Volcanic Eruption Response Team.

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

Landsat 8 an American earth observation satellite; the eighth in the Landsat program.

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

Low-frequency earthquakes earthquakes with dominant frequencies between 1 and 5 Hz.

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."

MultiGAS Multiple-component Gas Analyzer System

NASA National Aeronautics and Space Administration.

NOAA National Oceanic and Atmospheric 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.

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.

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

seismic swarm a flurry of closely spaced earthquakes or other ground shaking activity; often precedes an eruption.

SI International System of Units.

SIGMET SIGnificant METeorological information statement, issued by NWS.

Spatter cone a low, steep-sided cone of spatter built up on a fissure or vent.

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.

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

SWIR Short Wave Infrared.

TA elevated surface temperature.

tremor low-amplitude, continuous earthquake activity often associated with magma movement..

UAFGI University of Alaska Fairbanks Geophysical Institute.

USGS U.S. Geological Survey.

UTC "Coordinated Universal Time"; same as Greenwich Mean Time.

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

VT volcano-tectonic earthquake.

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].

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