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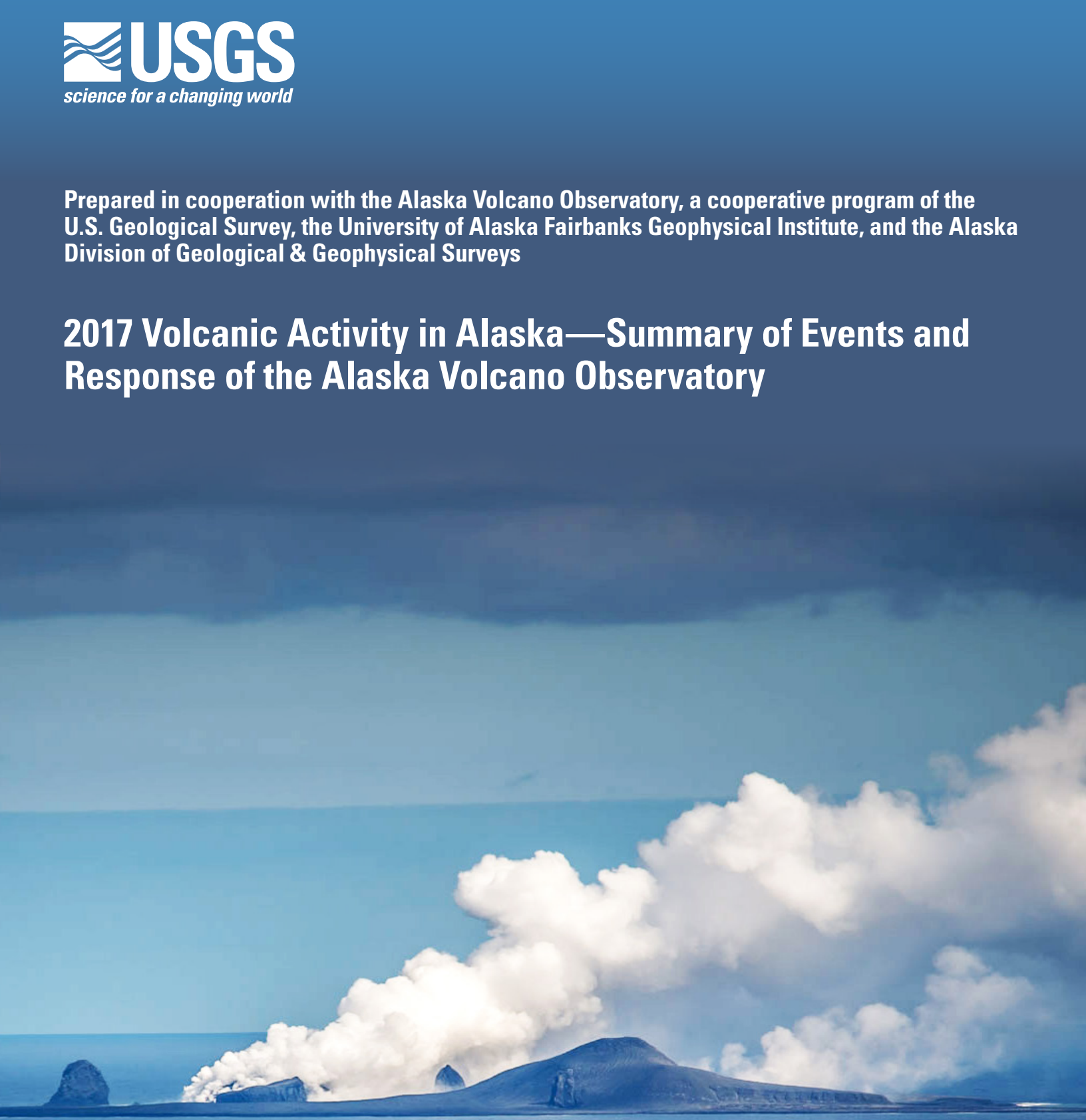
2017 Volcanic Activity in Alaska—Summary of Events and Response of the Alaska Volcano Observatory



Scientific Investigations Report 2020–5102

U.S. Department of the Interior
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Cover. Photograph of Bogoslof volcano showing a vigorous steam plume likely caused by interaction of a new, hot lava dome into seawater. Photograph by Dave Withrow, National Oceanic and Atmospheric Administration (NOAA), taken about 13 nautical miles from Bogoslof Island on August 26, 2017, aboard a NOAA twin otter (N56RF) aircraft while surveying harbor seals west of Dutch Harbor.

2017 Volcanic Activity in Alaska—Summary of Events and Response of the Alaska Volcano Observatory

By James P. Dixon, Cheryl E. Cameron, Alexandra M. Iezzi, John A. Power, Kristi Wallace, and Christopher F. Waythomas

Prepared in cooperation with the Alaska Volcano Observatory, a cooperative program of the U.S. Geological Survey, the University of Alaska Fairbanks Geophysical Institute, and the Alaska Division of Geological & Geophysical Surveys

Scientific Investigations Report 2020–5102

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

U.S. Department of the Interior
DAVID BERNHARDT, Secretary

U.S. Geological Survey
James F. Reilly II, Director

U.S. Geological Survey, Reston, Virginia: 2020

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
meter (m)	3.281	foot (ft)
kilometer (km)	3,281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Velocity	
kilometers per second (km/s)	3,281	feet per second (ft/s)
	Area	
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
cubic kilometer (km^3)	0.2399	cubic mile (mi^3)
	Mass flow	
Tons per day (ton/d)	0.9072	metric tons per day (metric ton/d)

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

$$°F = (1.8 \times °C) + 32.$$

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 decimal degrees referenced to the WGS 1984 datum.

Abbreviations

AKDT	Alaska Daylight Time; UTC -8 hours
AKST	Alaska Standard Time; UTC -9 hours
ASL	above sea level
AVO	Alaska Volcano Observatory
DLP	deep long-period
GPS	Global Positioning System
GVP	Smithsonian Institution Global Volcanism Program
InSAR	Interferometric Synthetic Aperture Radar
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
Pa	Pascal
PIREP	Pilot Weather Report
UAFGI	University of Alaska, Fairbanks Geophysical Institute
USGS	U.S. Geological Survey
UTC	Coordinated Universal Time; same as Greenwich Mean Time
VEI	Volcanic Explosivity Index
VTTS	Valley of Ten Thousand Smokes

2017 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] John A. Power,[1] Kristi L. Wallace,[1] and Christopher F. Waythomas[1]

Abstract

The Alaska Volcano Observatory responded to eruptions, significant and minor volcanic unrest, and seismic events at 16 volcanic centers in Alaska during 2017. The most notable volcanic activity consisted of a major eruption at Bogoslof Island, continuing intermittent dome growth and ash eruptions from Mount Cleveland, the end of the Pavlof Volcano eruption, volcanic unrest at Shishaldin Volcano, and significant earthquake activity at Tanaga and Great Sitkin Islands. This report also documents reports of degassing at Redoubt Volcano, Makushin Volcano, Mount Gareloi, and Kiska Volcano, anomalous seismicity at Mount Spurr, Augustine Volcano, Akutan Peak, and Makushin Volcano, landslides at Iliamna Volcano, resuspended ash from the 1912 Novarupta-Katmai eruption, and continuing inflation at Okmok Caldera.

Introduction

The Alaska Volcano Observatory (AVO) is responsible for monitoring, studying, and warning of hazards associated with volcanic unrest in Alaska (fig. 1). This report summarizes notable volcanic activity in Alaska during 2017 (tables 1 and 2) and briefly describes AVO's response. Information about all noteworthy episodes of volcanic unrest is included, even if no formal public notification was issued. Observations, images, and data that are typically not published elsewhere are included in this report. Descriptions of prominent eruptions are often a subject of stand-alone publications, and a series of papers describing the major eruption at Bogoslof Island has been recently published (Waythomas and others, 2019). Similar summaries of volcanic unrest and AVO's response have been published annually since 1992 (table 3).

The following descriptions of volcanic activity may use informal names for volcanoes. Many instances of the formal or official volcanic name do not coincide with the geographic or geologic extent of the volcano (for example, the Bogoslof volcano [informal name] comprises more islands than Bogoslof Island [formal name], the Global Positioning System [GPS] network at the Akutan volcano monitors more than Akutan Peak). Some volcanoes lack an official place name (for example, Alagogshak). The informal volcano names in use by the AVO are defined within the discussions of each volcano's activity during 2017.

The AVO volcano-monitoring program includes daily analysis of satellite imagery, web-camera imagery, and seismicity; occasional overflights; airborne and ground-based gas measurements; and a compilation of visual reports from aircraft pilots (PIREPs), observatory personnel, local residents, and mariners. AVO also receives real-time deformation data from permanent Global Positioning System stations at eight Alaskan volcanoes (Akutan, Augustine, Makushin, Okmok, Redoubt, Shishaldin, Spurr, and Westdahl). Periodic analysis of the Ozone Mapping Instrument on NASA's Aura satellite (Lopez and others, 2013) and Interferometric Synthetic Aperture Radar (InSAR) imagery (for example, Lee and others, 2010) augments AVO's ability to monitor unrest at volcanoes in Alaska. AVO increasingly monitors Alaska volcanoes using infrasound sensors that measure atmospheric pressure waves to detect explosions (for example, Fee and others, 2010).

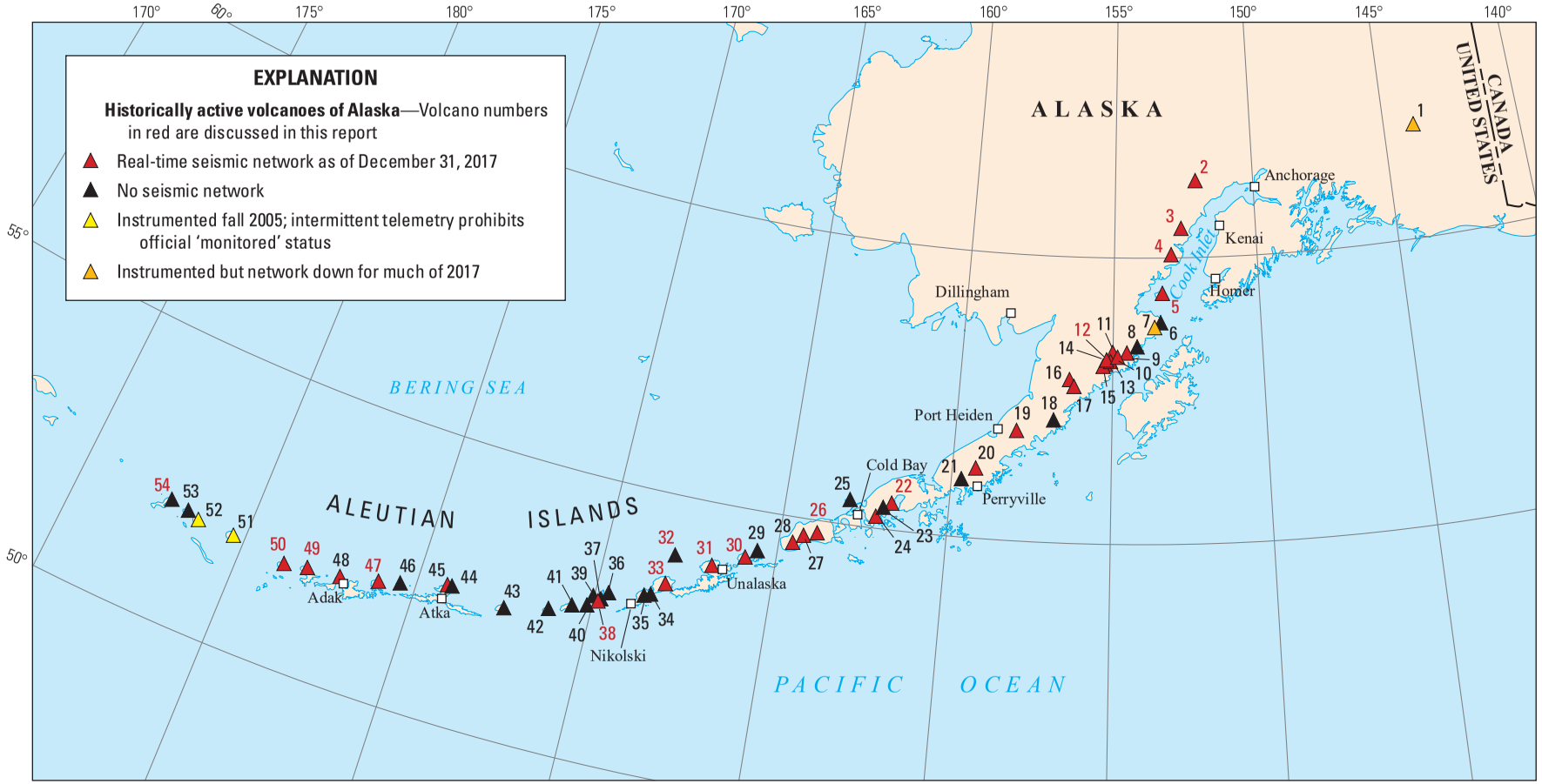
AVO scientists participate in a weekly duty, remote-sensing rotation, and they produce a daily report that consists of a summary of all observation at any volcano at an elevated Aviation Color Code and Volcano Alert Level. Descriptions of any anomalies seen in satellite imagery and web cameras at the remaining volcanic centers AVO monitors are also included. The observations are created and archived in an internal database structure to assist in retrieving past observations. A second rotation of scientists from AVO and the National Earthquake Information Center monitors the seismicity at volcanoes with seismometers. Three separate reports are compiled daily approximately 8 hours apart and are crafted within a relational database.

Thirty-four of the fifty-four historically active volcanoes in Alaska were instrumented with a network of seismometers as of December 31, 2017 (table 4). Excluded from the formal list are those volcanoes that have insufficient seismic instrumentation to calculate reliable earthquake hypocenters and magnitudes or where real-time telemetry is not reliable enough to produce a complete record of earthquake activity. At Mount Cleveland only two seismograph stations are in operation, which is below

[1]U.S. Geological Survey.

[2]Alaska Division of Geological & Geophysical Surveys.

[3]University of Alaska Fairbanks.



Alaska Albers Equal-Area Conic projection
Standard parallels 55° N. and 65° N.
Central meridian 154° W.
North American Datum of 1983

Volcanoes—Names in red are discussed in this report

1. Mount Wrangell
2. Mount Spurr
3. Redoubt
4. Iliamna
5. Augustine
6. Douglas
7. Fourpeaked Mountain
8. Kukak
9. Snowy Mountain
10. Mount Katmai
11. Mount Griggs
12. Novarupta
13. Trident
14. Mount Mageik
15. Mount Martin
16. Ukinrek Maars
17. Ugashik-Peulik
18. Chiginagak
19. Aniakchak Crater
20. Mount Veniaminof
21. Kupreanof
22. Pavlof
23. Emmons
24. Mount Dutton
25. Amak
26. Shishaldin
27. Fisher Caldera
28. Westdahl Peak
29. Gilbert
30. Akutan Peak
31. Makushin
32. Bogoslof Island
33. Okmok Caldera
34. Mount Recheshnoi
35. Vsevidof
36. Kagamil
37. Tana
38. Mount Cleveland
39. Carlisle
40. Herbert
41. Yunaska
42. Amukta
43. Seguam
44. Kliuchef (Atka)
45. Korovin
46. Kasatochi
47. Great Sitkin
48. Kanaga
49. Tanaga
50. Mount Gareloi
51. Semisopochnoi
52. Little Sitkin Island
53. Segula
54. Kiska

Figure 1. Map showing 54 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 (2018), volcanoes are considered historically active if they had an eruption or period of intense deformation, seismic, or fumarolic activity that is inferred to reflect the presence of magma at shallow levels beneath the volcano after 1741 when written records of Alaskan volcanic activity began.

Table 1. Summary of 2017 monitoring highlights at volcanoes in Alaska, including actual eruptions, possible eruptions, increases in seismicity, observations of fumarolic activity, and notable events.

[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 appendix tables 2.1 and 2.2. Location of volcanoes shown in figure 1]

Volcano	Date of activity	Type of activity
Mount Spurr	Year-round	Earthquake swarm
Redoubt Volcano	April	Degassing
Iliamna Volcano	April	Minor snow and debris flow
Augustine Volcano	Year-round	Seismic activity
Katmai Group (Novarupta)	June, November	Resuspension of 1912 ash
Pavlof Volcano	January; May–August	End of intermittent eruption; volcanic unrest
Shishaldin Volcano	December	Volcanic unrest
Akutan Peak	November	Earthquake swarm
Makushin Volcano	Year-round; November	Earthquake swarm; degassing
Bogoslof Island	Year-round	Significant eruption
Okmok Caldera	Year-round	Inflation
Mount Cleveland	Year-round	Low-level eruption
Great Sitkin Volcano	January; July	Earthquake swarm; explosion
Takawangha volcano (Tanaga Island)	January	Earthquake swarm
Mount Gareloi	March	Degassing
Kiska Volcano	November	Degassing

Table 2. Alaska volcanoes with Aviation Color Code and Volcano Alert Level changes in 2017.

[Dates are in 2017 unless otherwise indicated. Volcanoes with no elevated elevated alert level from Green and Normal throughout the year are not shown]

Color Code	Date of change
Pavlof Volcano	
YELLOW/ADVISORY	August 4, 2016–February 2
GREEN/NORMAL	February 2–June 7
YELLOW/ADVISORY	June 7–August 30
GREEN/NORMAL	August 30–December 31
Shishaldin Volcano	
GREEN/NORMAL	January 1–December 7
YELLOW/ADVISORY	December 6–December 31
Bogoslof Island	
RED/WARNING	January 1
ORANGE/WATCH	January 1–January 4
RED/WARNING	January 4–January 5
ORANGE/WATCH	January 5
RED/WARNING	January 5–January 6
ORANGE/WATCH	January 6–January 9
RED/WARNING	January 9–January 10
ORANGE/WATCH	January 10–January 18
RED/WARNING	January 18–January 19
ORANGE/WATCH	January 19–January 20
RED/WARNING	January 20–January 21
ORANGE/WATCH	January 21–January 22
RED/WARNING	January 22–January 23
ORANGE/WATCH	January 23–January 24
RED/WARNING	January 24–January 25
ORANGE/WATCH	January 25–January 26
RED/WARNING	January 26–January 27
ORANGE/WATCH	January 27
RED/WARNING	January 27–January 28
ORANGE/WATCH	January 28–January 31
RED/WARNING	January 31–February 1
ORANGE/WATCH	February 1–February 13
RED/WARNING	February 13
ORANGE/WATCH	February 13–February 17
RED/WARNING	February 17–February 19
ORANGE/WATCH	February 19–February 20
RED/WARNING	February 20–February 21
ORANGE/WATCH	February 21–March 8
RED/WARNING	March 8–March 9
ORANGE/WATCH	March 9–April 5
YELLOW/ADVISORY	April 5–April 16
ORANGE/WATCH	April 16–April 19
YELLOW/ADVISORY	April 19–May 17
ORANGE/WATCH	May 17
RED/WARNING	May 17

Table 2.—Continued

Color Code	Date of change
ORANGE/WATCH	May 17–May 28
RED/WARNING	May 28–May 29
ORANGE/WATCH	May 29–June 10
RED/WARNING	June 10
ORANGE/WATCH	June 10–13 June
RED/WARNING	13 June
ORANGE/WATCH	13 June–24 June
RED/WARNING	June 24
ORANGE/WATCH	June 24–27 June
RED/WARNING	June 27
ORANGE/WATCH	June 27–July 2
RED/WARNING	July 2–July 3
ORANGE/WATCH	July 3–July 5
RED/WARNING	July 5
ORANGE/WATCH	July 5–July 8
RED/WARNING	July 8–July 9
ORANGE/WATCH	July 9–July 10
RED/WARNING	July 10
ORANGE/WATCH	July 10–August 7
RED/WARNING	August 7–August 8
ORANGE/WATCH	August 8–September 27
YELLOW/ADVISORY	September 27–December 6
UNASSIGNED	December 6–December 31
Mount Cleveland	
YELLOW/ADVISORY	November 4, 2016–February 3
ORANGE/WATCH	February 3–March 8
YELLOW/ADVISORY	March 8–March 24
ORANGE/WATCH	March 24–April 5
YELLOW/ADVISORY	April 5–April 24
ORANGE/WATCH	April 24–June 26
YELLOW/ADVISORY	June 26–July 4
ORANGE/WATCH	July 4–December 12
YELLOW/ADVISORY	December 12–February 9, 2018
Great Sitkin Volcano	
GREEN/NORMAL	January 1–November 22
YELLOW/ADVISORY	November 22–December 31
Takawangha volcano	
GREEN/NORMAL	January 1–January 24
YELLOW/ADVISORY	January 24–February 8
GREEN/NORMAL	February 8–December 31

Table 3. Citations for Alaska Volcano Observatory annual summary reports, 1992–2016.

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://doi.org/10.3133/ofr9583
1993	Neal, C.A., McGimsey, R.G., and Doukas, M.P., 1996, 1993 volcanic activity in Alaska: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 96-0024, 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 95-0271, 18 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 96-0738, 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 97-0433, 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 99-0448, 42 p.	https://pubs.usgs.gov/of/1999/0448/
1998	McGimsey, R.G., Neal, C.A., and Girina, Olga, 2003, 1998 Volcanic activity in Alaska and Kamchatka: Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Open-File Report 03-0423, 35 p.	https://doi.org/10.3133/ofr03423

Table 3.—Continued

Year	Citation	URL
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 OpenFile Report OF 2004-1033, 49 p.	https://doi.org/10.3133/ofr20041033
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://doi.org/10.3133/ofr20041034
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://doi.org/10.3133/ofr20041453
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 OpenFile Report 2004-1058, 51 p.	https://doi.org/10.3133/ofr20041058
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 OpenFile Report 2005-1310, 58 p.	https://doi.org/10.3133/ofr20051310
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 OpenFile Report 2005-1308, 67 p.	https://doi.org/10.3133/ofr20051308
2005	McGimsey, R.G., Neal, C.A., Dixon, J.P., and 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://doi.org/10.3133/sir20075269
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://doi.org/10.3133/sir20085214
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://doi.org/10.3133/sir20105242
2008	Neal, C.A., McGimsey, R.G., Dixon, J.P., Cameron, C.E., Nuzhaev, A.A., and Chibisova, Marina, 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://doi.org/10.3133/sir20105243
2009	McGimsey, R.G., Neal, C.A., Girina, O.A., Chibisova, Marina, and Rybin, Alexander, 2014, 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://doi.org/10.3133/sir20135213
2010	Neal, C.A., Herrick, J., Girina, O.,A., Chibisova, M., Rybin, A., McGimsey, R.G., 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://doi.org/10.3133/sir20145034
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://doi.org/10.3133/sir20145159
2012	Herrick, J.A., Neal, C.A., Cameron, Cheryl, Dixon, Jim, 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, 80 p.	https://doi.org/10.3133/sir20145160
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://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 3.—Continued

Year	Citation	URL
2015	Dixon, J.P., Cameron, C.E., Iezzi, A.M., and Wallace, Kristi, 2017, 2015 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2017–5104, 81 p.	https://doi.org/10.3133/sir20175104
2016	Cameron, C.E., Dixon, J.P., Waythomas, C.F., Iezzi, A.M., Wallace, K., McGimsey, R.G., and Bull, K.F., 2020, 2016 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2020–5125, 63 p.	https://doi.org/10.3133/sir20205125
2017	Dixon, J.P., Cameron, C.E., Iezzi, A.M., Power, J.A., Wallace, K., Waythomas, C.F., 2020, 2017 Volcanic activity in Alaska—Summary of events and response of the Alaska Volcano Observatory: U.S. Geological Survey Scientific Investigations Report 2020–5102, 61 p.	https://doi.org/10.3133/sir20205102

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 the terms "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 a "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 after 1741, when written records of volcanic activity began. On the basis of a rigorous re-analysis of all accounts of volcanic activity in Alaska from many sources, Cameron and others (2018) concluded that 54 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.

minimum number of local seismograph stations to locate earthquakes. Little Sitkin and Semisopochnoi Islands are not considered monitored because the telemetry continues to be unreliable. Mount Wrangell and Fourpeaked Mountain volcanoes are not considered seismically monitored owing to network-wide outages that continued throughout 2017.

Volcanic Activity in Alaska

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 identifier assigned by the Smithsonian Institution Global Volcanism Program (GVP); latitude, longitude, and summit elevation; its geographical region; and an abbreviated summary of the 2017 activity. Each summary is followed by detailed activity information, often with accompanying tables, images, and (or) figures, ending with a description of the volcano and summary of past volcanic activity. The event summary is derived from published material such as Miller and others (1998) and the Smithsonian Institution Global Volcanism Network Bulletin (available at htpp://www.volcano.si.edu/reports_bgvn.cfn) as well as AVO daily status reports, AVO weekly updates, information releases, AVO email and online electronic logs. Beginning with the 2013 report, AVO's annual summary includes expanded information on seismicity at Alaska volcanoes. Volcanic activities in past and present AVO summaries are compiled by year (table 2.1) and by volcano (table 2.2).

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 (m) and feet (ft) above sea level (ASL). 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, in decimal degrees, and summit elevations, in meters and feet, are taken from the AVO database and may differ slightly from previously published compilations.

Table 4. History of seismic monitoring of Alaska volcanoes from August 1971 through December 2017.

[First station installed refers to the date when the Alaska Volcano Observatory (AVO) first received real-time data from a permanent station. This date can be many months after initial fieldwork at the volcano. AVO considers the seismic network "complete" (bolded date) after installation and data transmission from a minimum of four seismic stations. Typically, AVO seismologists monitor the seismicity at the volcanic center for at least 6 months to understand background rates of seismicity before formally declaring a volcano seismically monitored and adding it to the monitored list. The number of stations in parenthesis is the number of installed seismograph stations at the end of 2017. We note here the first mention and range of time, when applicable, of the seismic status of each monitored volcano in the AVO weekly update. The AVO weekly update has been regularly issued since the Redoubt Volcano eruption in 1989–90. The magnitude of completeness is the lowest magnitude earthquake that can confidently be located for activity at the volcanic center with an operational seismograph network. For more information on specific seismic network histories, readers are referred to the series of annual seismic summaries prepared by AVO (for example, Dixon and others, 2019). N/A, not applicable]

Approximate start date of seismic monitoring	Earthquakes located in 2017	Magnitude of completeness[1]
Mount Wrangell		
First station installed—July 2000 Network complete (4 stations)—**August 2001** On monitored list from November 2001–January 2012	16	0.9
Mount Spurr		
First station installed—August 1971 Network complete (17 stations)—**August 1989** Added to monitored list—April 1991	741	0.2
Redoubt Volcano		
First station installed—August 1971 Network complete (12 stations)—**August 1988** Added to monitored list—April 1991	196	0.4
Iliamna Volcano		
First station installed—September 1987 Network complete (8 stations)—**September 1994** Added to monitored list—April 1991	18	−0.2
Augustine Volcano		
First station installed—October 1976 Network complete (15 stations)—**August 1978** Added to monitored list—April 1991	367	0.1
Fourpeaked Mountains		
First station installed—September 2006 Network complete (4 stations)—**October 2006** On monitored list—October 2006–November 2009; October 2011–February 2014	33	0.7
North Katmai area (Snowy Mountain)		
First station installed—August 1988 Network complete (5 stations)—**October 1998** Added to monitored list—December 1998	138	0.8
Central Katmai area (Mount Griggs, Mount Katmai, Novarupta, and Trident Volcano)		
First station installed—August 1988 Network complete (8 stations)—**July 1991** Added to monitored list—November 1996	853	0.4
South Katmai area (Mount Martin and Mount Mageik)		
First station installed—August 1988 Network complete (8 stations)—**July 1996** Added to monitored list—November 1996	321	0.3
Ukinrek Maars and Mount Peulik		
First station installed—March 2005 Network complete (7 stations)—**August 2004** Added to monitored list—April 2005	7	0.9

Table 4.—Continued

Approximate start date of seismic monitoring	Earthquakes located in 2017	Magnitude of completeness[1]
Aniakchak Crater		
First station installed—July 1997 Network complete (6 stations)—**July 1997** On monitored list—November 1997–November 2009; September 2010–January 2014; returned October 2015	60	0.1
Mount Veniaminof		
First station installed—February 2002 Network complete (9 stations)—**February 2002** Added to monitored list—September 2002–November 2009; returned October 2010	33	1.1
Pavlof Volcano		
First station installed—July 1996 Network complete (7 stations)—**July 1996** Added to monitored list—November 1996	30	1.0
Mount Dutton		
First station installed—July 1988 Network complete (5 stations)—**July 1996** Added to monitored list—November 1996	1	1.0
Shishaldin Volcano and Isantoski Peaks		
First station installed—July 1997 Network complete (7 stations)—**July 1997** Shishaldin Volcano added to monitored list—November 1997 Isantoski Peaks added to monitored list—December 1998	32	0.6
Westdahl Peak and Fisher Caldera		
First station installed—August 1998 Network complete (6 stations)—**October 1998** Added to monitored list—December 1998	66	1.1
Akutan volcano		
First station installed—March 1996 Network complete (13 stations)—**July 1996** Added to monitored list—November 1996	220	0.3
Makushin Volcano		
First station installed—July 1996 Network complete (7 stations)—**July 1996** Added to monitored list—November 1996	857	0.5
Okmok volcano		
First station installed—January 2003 Network complete (13 stations)—**January 2003** Added to monitored list—January 2004	32	0.8
Mount Cleveland		
First station installed—August 2014 Network complete (2 stations)—N/A Has not been added to the monitored list.	0	-
Korovin Volcano		
First station installed—July 2004 Network complete (7 stations)—**July 2004** On monitored list—December 2005–November 2009; October 2010–October 2011; returned March 2014	114	0.5

Table 4.—Continued

Approximate start date of seismic monitoring	Earthquakes located in 2017	Magnitude of completeness[1]
Great Sitkin Volcano		
First station installed—September 1999 Network complete (6 stations)—**September 1999** Added to monitored list—December 1999	770	0.4
Kanaga Volcano		
First station installed—September 1999 Network complete (6 stations)—**September 1999** Added to monitored list—December 2000	57	1.2
Tanaga Volcano		
First station installed—August 2003 Network complete (6 stations)—**August 2003** Added to monitored list—June 2004	462	1.1
Mount Gareloi		
First station installed—August 2003 Network complete (6 stations)—**September 2003** Added to monitored list—June 2004	269	1.2
Semisopochnoi Island (Mount Cerberus)		
First station installed—September 2005 Network complete (6 stations)—**September 2005** Has not been added to the monitored list.	96	0.5
Little Sitkin Island		
First station installed—September 2005 Network complete (4 stations)—**September 2005** Has not been added to the monitored list.	39	0.0

Mount Spurr

GVP# 313040
61.2989° N., 152.2539° W.
3,374 m (11,070 ft)

Cook Inlet

EARTHQUAKE SWARM

No volcanic activity was reported at Mount Spurr in 2016, but five clusters of seismic activity in 2016 continued into 2017 (fig. 2), including an unusual earthquake sequence that started in 2015. AVO refers to Mount Spurr and the surrounding features associated with its volcanism as "Spurr." This cluster of low-frequency earthquakes (north Spurr earthquakes), was located 12 kilometers (km; 7 mi) north of Mount Spurr and continued to show activity throughout 2017. Although the character of the earthquakes is similar to glacial earthquakes, AVO has not determined a definite cause for this cluster of seismicity. The other four clusters (Mount Spurr summit, south Spurr, west Spurr, and the Strandline Lake earthquakes) are typical seismicity seen year-round in the vicinity of Mount Spurr (fig 2). An April 20 gas observation flight noted that the small plume emanating from the fumaroles in Spurr's summit crater contained detectable quantities of SO_2, H_2S, and HCl. The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL** throughout the year at Mount Spurr.

Mount Spurr is a 3,374 m high (11,070 ft) 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 in south-central Alaska. The summit of Mount Spurr is a primarily ice-covered feature previously interpreted as a lava dome complex (Nye and Turner, 1990). Multiple prehistoric (before 1700) eruptions at Mount Spurr have been identified (Riehle, 1985; Waythomas and Nye, 2002; Waythomas, 2007).

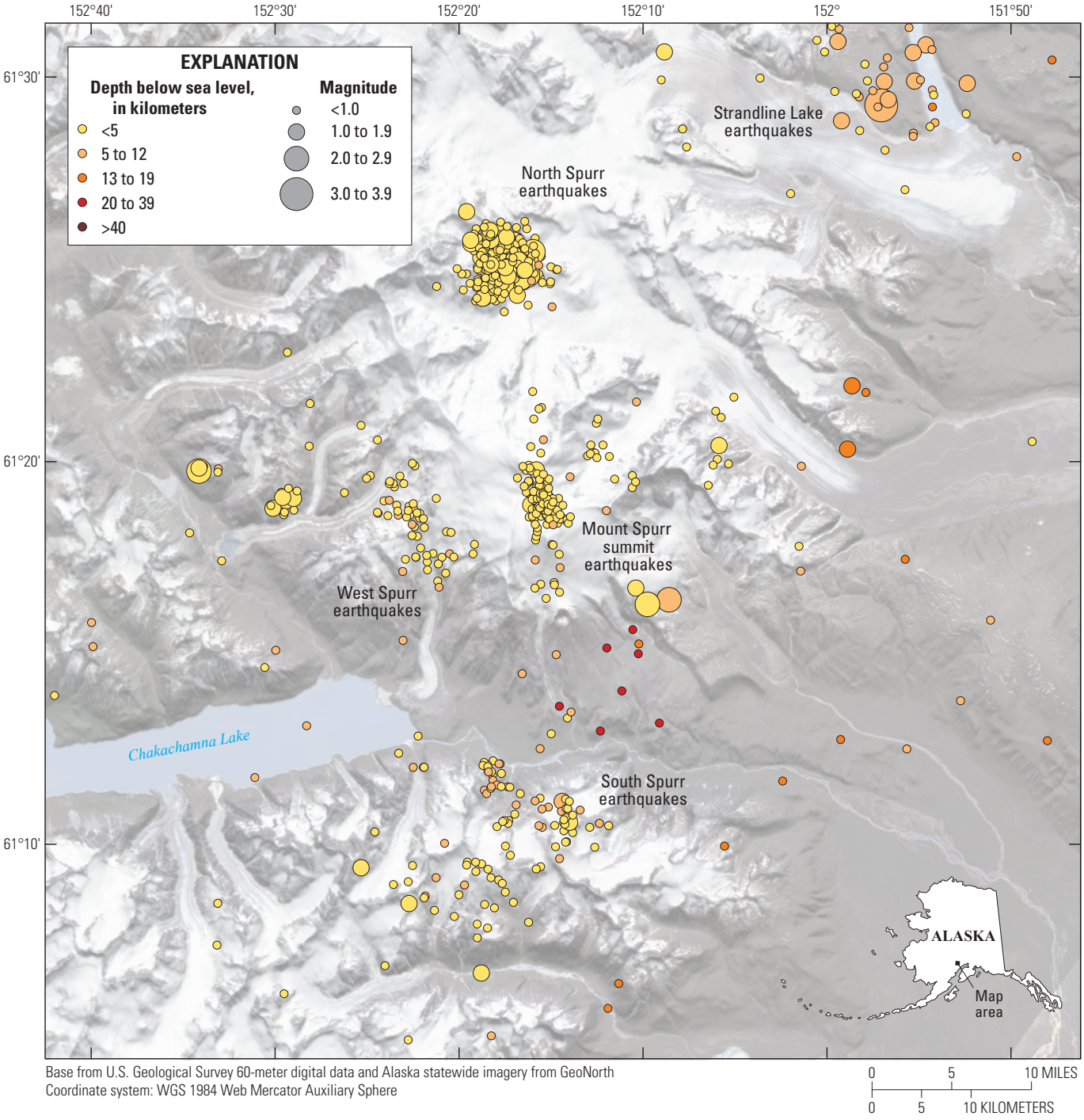


Figure 2. Epicentral map showing clusters of seismicity near Mount Spurr in 2017. The four clusters of distinct seismicity are the Mount Spurr summit earthquakes, north Spurr earthquakes, west Spurr earthquakes, south Spurr earthquakes, and the Strandline Lake earthquakes.

Figure 3. Aerial photograph of the summit of Mount Spurr on April 20, 2017. Photograph by Taryn Lopez, University of Alaska Fairbanks Geophysical Institute and Alaska Volcano Observatory.

Redoubt Volcano

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

Cook Inlet

GAS PLUME

AVO received a citizen observation of degassing from Redoubt Volcano on April 26, 2017. The report was of a heavy plume and (or) eruption, but checks of multiple datasets showed no anomalous activity. Meteorological conditions were favorable to accentuate on-going gas emission from the cooling 2009 lava dome, and thus no other action was taken by observatory personnel.

On April 20, 2017, a few days before the report of steaming, an observation and gas overflight by AVO observed a condensed plume that was emanating from the south end of the crater dome, and all gas species (SO_2, H_2S, HCl, and CO_2) were detected. The observations of the plume and its composition are consistent with expected background degassing. The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively, throughout the year.

Heavily ice-mantled Redoubt Volcano is located on the west side of Cook Inlet, 170 km (106 mi) southwest of Anchorage and 82 km (51 mi) west of Kenai, Alaska, within Lake Clark National Park and Preserve (fig. 4). Historical eruptions occurred in 1902, 1966–68, 1989–90, and 2009 (Waythomas and others, 1997; Schaefer, 2011; Bull and Buurman, 2013). The 1989–90 and 2009 eruptions produced mudflows 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).

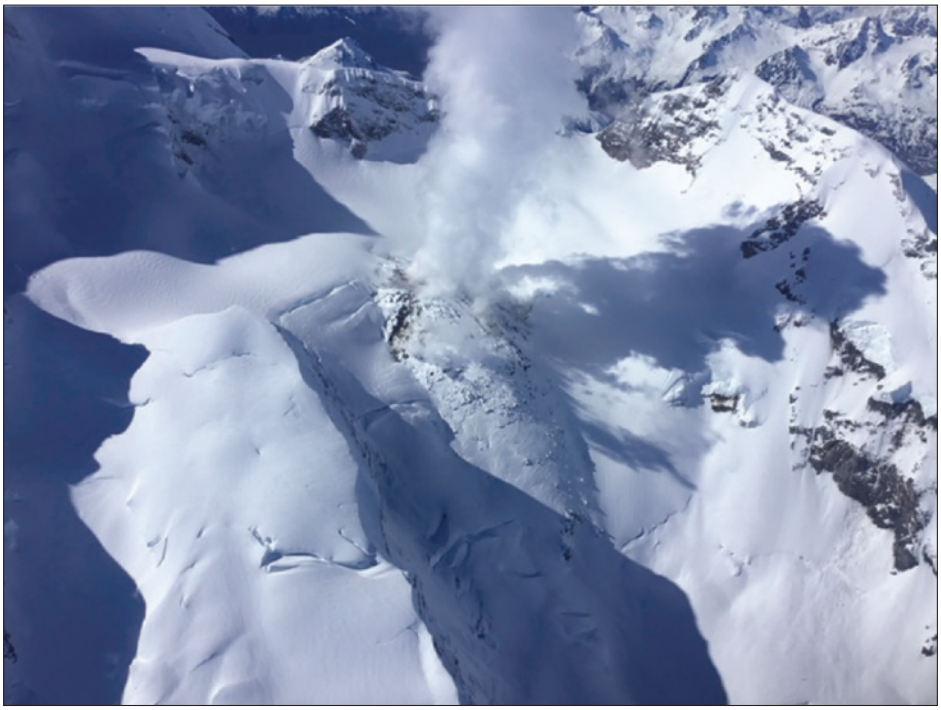


Figure 4. Aerial photograph of the 2009 lava dome on Redoubt Volcano on May 27, 2018, as viewed from the northwest. Photograph by Pat Madland.

Iliamna Volcano

GVP# 313020
60.0319° N., 153.0918° W.
3,053 m (10,016 ft)

Cook Inlet

MINOR SNOW AND DEBRIS FLOW

Avalanches are common on Iliamna Volcano, and although no large debris avalanches were noted in 2017, small debris flows were observed. In March, a pilot noticed a debris flow feature on the west side of Iliamna Volcano (fig. 5). A second flow feature was fortuitously imaged by an AVO web camera in mid-April. A review of web-camera images shows the debris flow began on April 12 during the warmest part of the day, with more material moving downslope over a period of 6 hours (fig. 6). During an April 20 gas overflight, AVO observed minor snow and debris avalanche deposits on all flanks of the volcano. Despite complications from a south wind, successful gas measurements were obtained from the fumarole fields on the southeast side of the volcano indicating typical background-level emissions. The Aviation Color Code and Volcano Alert Level at Iliamna Volcano remained at **GREEN** and **NORMAL**, respectively, throughout the year.

Iliamna Volcano is a glacier-carved stratovolcano located approximately 215 km (134 mi) southwest of Anchorage on the west 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) on the east flank (fig. 7) produce nearly constant plumes of steam and volcanic gas (Werner and others, 2011). In the past two decades, at least two magmatic intrusions without an eruption have occurred (Roman and others, 2004; Prejean and others, 2012).

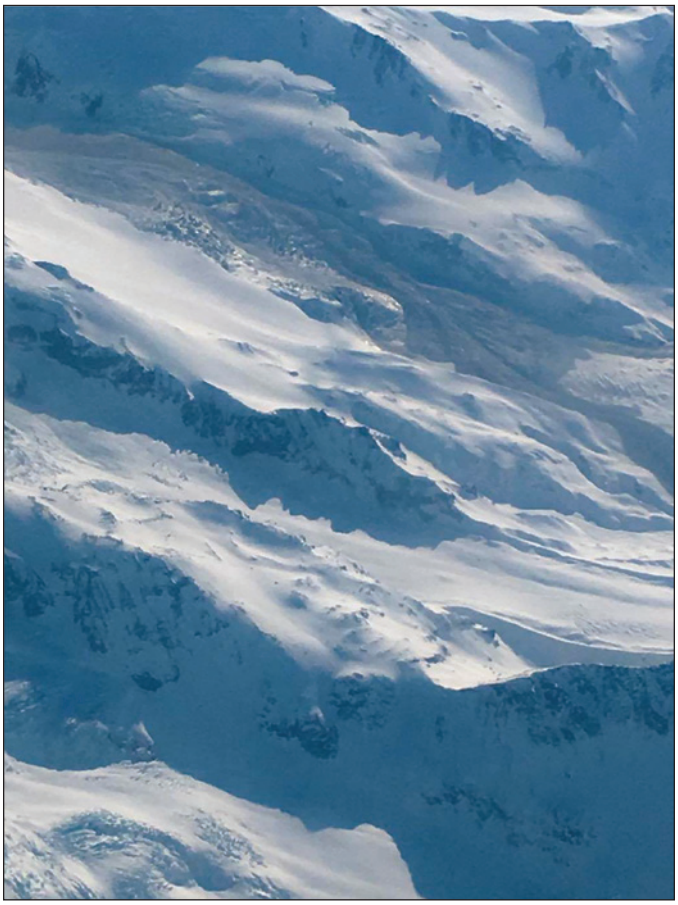


Figure 5. Photograph from March 17, 2017, of a debris flow on the west flank near the summit of Iliamna Volcano spotted by a citizen observer. Photograph by Gary Nielsen.

Figure 6. Alaska Volcano Observatory web-camera image from April 13, 2017, of a debris flow on the east side of Iliamna Volcano.

Figure 7. Aerial photograph of degassing from the two main fumarole fields on the east flank of Iliamna Volcano on April 20, 2017. Photograph by Taryn Lopez, University of Alaska Fairbanks Geophysical Institute and Alaska Volcano Observatory.

Augustine Volcano

GVP# 313010
59.3626° N., 153.4350° W.
1,260 m (4,134 ft)

Cook Inlet

SEISMIC ACTIVITY

The number of earthquakes located at Augustine Volcano in 2017 was abnormally high but was less than half (367) the number located in the previous year (836). The high level of seismicity was monitored closely and was determined not indicative of a pending eruption. A gas overflight in April was unable to make measurements of the plume, but on-ground measurements in July indicated that degassing activity remained at low levels. The Aviation Color Code and Volcano Alert Level at Augustine Volcano remained at **GREEN** and **NORMAL**, respectively, throughout the year.

Augustine Volcano, which forms the bulk of the 8 × 11 km (5 × 7 mi) Augustine Island in lower Cook Inlet, is one of the most visible and accessible volcanoes in Alaska (fig. 8). Augustine Volcano consists of a conical, central dome cluster and lava flow complex surrounded by a more gently sloping apron of fragmental deposits. Repeated sector collapses during the late Holocene have produced debris avalanches into Cook Inlet (Begét and Kienle, 1992), which makes Augustine Volcano a tsunami hazard to communities in south-central Alaska. Historical eruptions include significant activity in 1883, 1885, 1963–64, 1976, 1986, and 2005–06.

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 the last several decades (Hadley and others, 2004; McGimsey and others, 2005). When the landscape is snow-free, particularly when the ground has little moisture content, strong winds can pick up loose ash and create clouds of resuspended ash. These dust clouds are commonly identified as originating broadly from the Mount Katmai area rather than from a specific volcanic source and look similar to dispersing volcanic ash clouds in satellite imagery. Ash resuspension was observed once in early June and twice in November. In response AVO issued Information Statements for two of the three events corroborating formal hazard notifications issued by the National Weather Service (NWS). The Aviation Color Code and Volcano Alert Level remained **GREEN** and **NORMAL**, respectively, for all Katmai Group volcanoes during 2017.

On June 4, 2017, a National Oceanic and Atmospheric Administration (NOAA) and National Environmental Satellite, Data, and Information Service ash alert reported a possible resuspension event over the Valley of Ten Thousand Smokes (fig. 9). Atypical, easterly winds carried resuspended ash away

Figure 8. U.S. Geological Survey photograph of Augustine Island and Volcano. Photograph by Michelle Coombs on June 15, 2016.

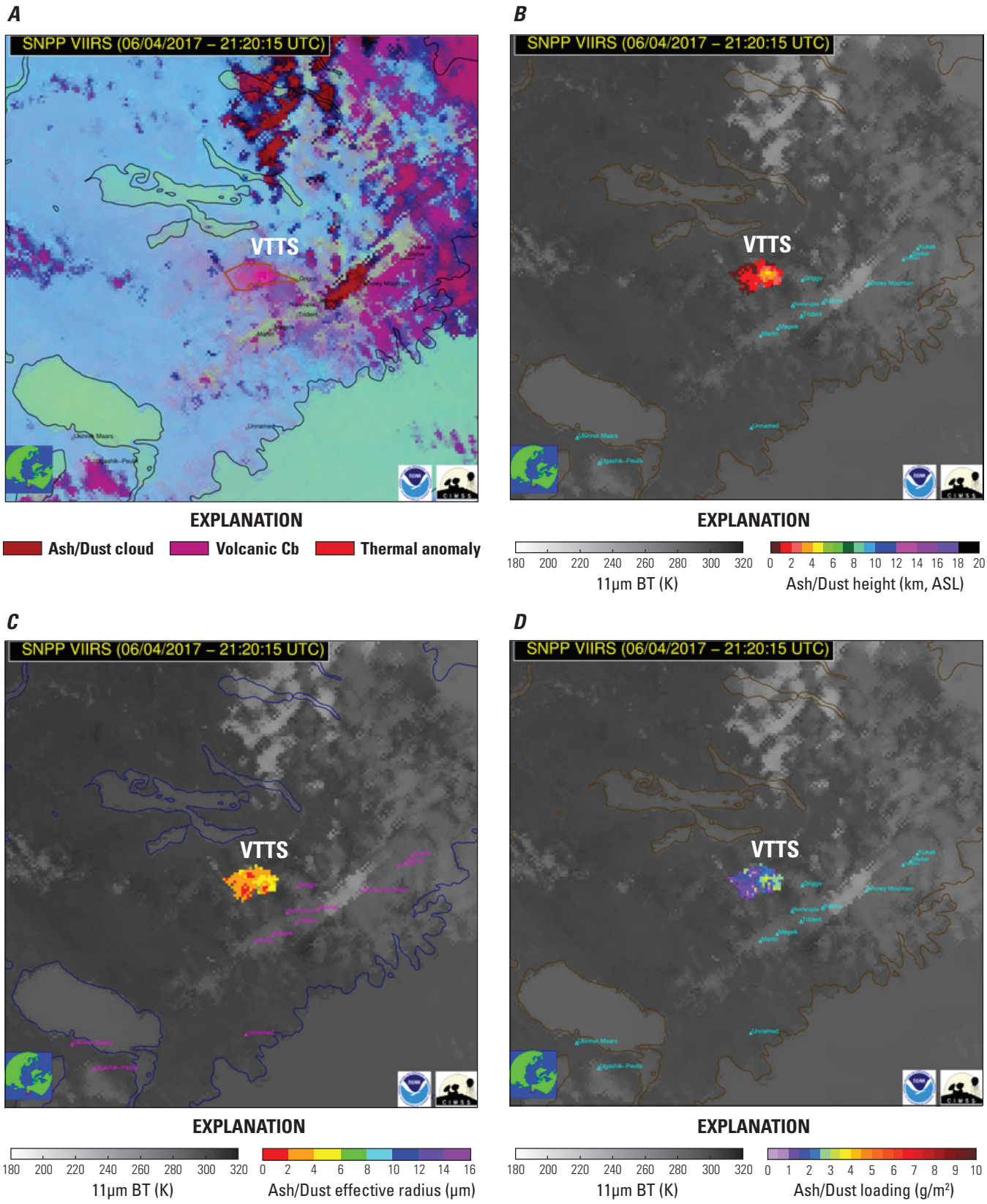


Figure 9. False color satellite images of June 4, 2017, ash resuspension event. *A*, False color satellite image (12–11 micrometers [µm], 11–3.9 µm, and 11 µm) showing the extent of the resuspended ash cloud (brown). *B*, Infrared (IR) Window image showing the ash and (or) dust cloud height in kilometers above sea level (km; ASL) overlain atop brightness temperature (BT) in degrees Kelvin (K). *C*, IR Window image showing the effective radius of the ash and (or) dust cloud in mm. *D*, IR Window image showing ash and (or) dust Loading in grams per square meters (g/m^2). VTTS shows the location of the Valley of Ten Thousand Smokes.

from population centers so that an AVO Information Statement was not issued. AVO alerted the NWS Alaska Aviation Weather Unit and documented the resuspension event and evaluation in the AVO internal logs.

Two ash resuspension events were detected in November, and the first was identified by a NOAA and Cooperative Institute for Meteorological Satellite Studies ash alert. On November 10, strong northwest winds over the Valley of Ten Thousand Smokes resuspended volcanic ash into a visible cloud and transported it eastward across Shelikof Strait and over Kodiak Island, where it was detected by the AVO particulate monitors at Larson Bay on the west coast of Kodiak Island. A similar sensor in the city of Kodiak, Alaska, on the east coast of Kodiak Island did not record any ash for this episode. AVO issued an Information Statement corroborating the hazard notifications issued by the NWS. By the evening of November 10, the resuspension event started to wane despite the surface winds continuing with gusts up to 20 meters per second (66 feet per second). A similar resuspension event occurred on November 13. The resuspended ash cloud extended 120 km (72 mi) to the southeast over the south end of Kodiak Island where no particulate monitors were installed. (fig. 10). AVO issued another Information Statement after the detection of this resuspension event.

The 1912 Novarupta-Katmai eruption was the largest of the 20th century, and produced about 17 cubic kilometers (km^3; 4 cubic miles [mi^3]) of ash deposits and 11 km^3 (2.6 mi^3) of pyroclastic material that filled nearby valleys, creating what is known today as the Valley of Ten Thousand Smokes (fig. 11) (Hildreth and Fierstein, 2012). Ash in this valley is as much as 200 m (660 ft) thick, and the valley remains almost entirely free of vegetation (Hildreth and Fierstein, 2012).

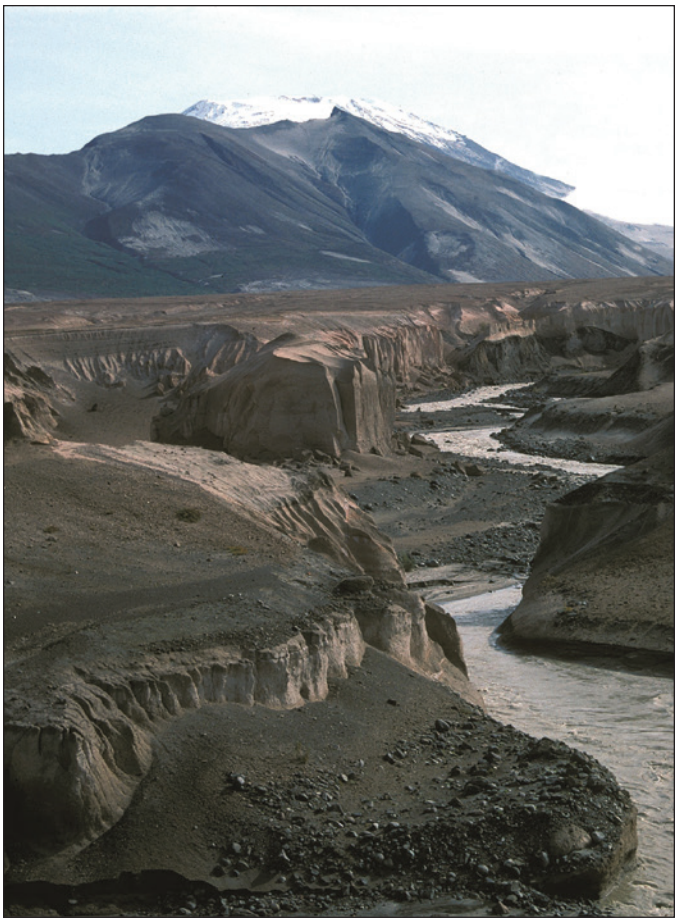


Figure 11. U.S. Geological photograph of River Lethe in Katmai National Park and Preserve, Valley of Ten Thousand Smokes, showing Mount Griggs in the background. The river has cut through the voluminous ash deposit from the 1912 Novarupta-Katmai eruption. Photograph taken by Jennifer Adleman, July 1997.

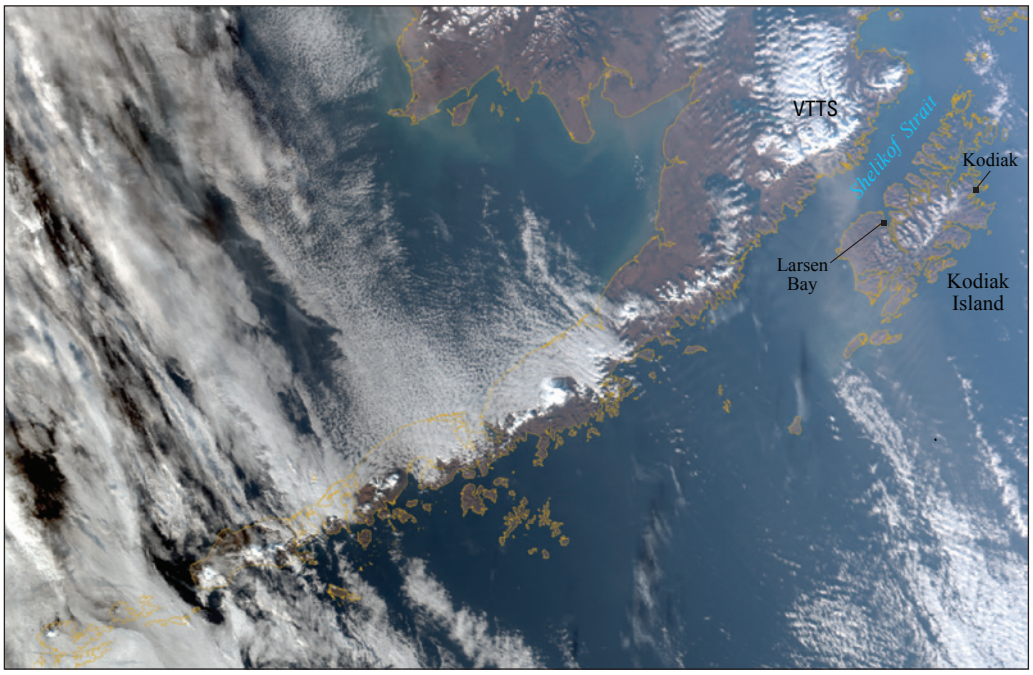


Figure 10. Satellite image of resuspension event on November 13, 2017. The resuspended ash is visible in the upper right of the image, extending from the Valley of Ten Thousand Smokes (VTTS) eastward to Kodiak Island.

Pavlof Volcano

GVP# 312030
55.4173° N., 161.8937° W.
2,518 m (8,261 ft)

Alaska Peninsula

END OF INTERMITTENT ERUPTION, VOLCANIC UNREST

Pavlof Volcano started 2017 at Aviation Color Code and Volcano Alert Level **YELLOW** and **ADVISORY**, respectively. By February, the level of unrest had returned to background levels with occasional small low-frequency earthquakes continuing to be observed in seismic data, which is consistent with an open degassing system. AVO lowered the Aviation Color Code to **GREEN** and the Alert Level to **NORMAL** on February 2, 2017.

Elevated surface temperatures and gas emissions were observed throughout the year. AVO personnel noted weakly elevated surface temperatures on five occasions in February–April, and at least three robust gas plumes were noted within the same period. AVO observed moderately elevated temperatures on May 10 (fig. 12). On May 28, a pilot report was issued describing a brown plume from Pavlof Volcano that reached an altitude of 3 km (10,000 ft). Seismic data showed no significant activity coincident with the report of the plume. In the first week of June, a persistent gas plume was observed in clear web-camera and satellite images, prompting increased attention to the Pavlof Volcano data streams. Bursts of strong low-frequency earthquake activity were observed beginning on June 6. This activity, along with subsequent short-duration tremor bursts and a pilot report of a plume reaching an altitude of 1,200 m (4,000 ft), AVO raised the Aviation Color Code to **YELLOW** and the Volcano Alert Level to **ADVISORY** on June 7.

Multiple observations of elevated surface temperatures and gas plumes were reported following the change in Volcano Alert Level at Pavlof Volcano. Sulfur dioxide (SO_2) was observed in satellite data on June 8 but was not observed in subsequent satellite imagery. Elevated seismicity declined after two days, and by the end of June 8 seismicity had returned to background levels. Four days later, on June 12 there was a short burst of activity, but no other anomalous seismicity occurred for the remainder of the month. A dark

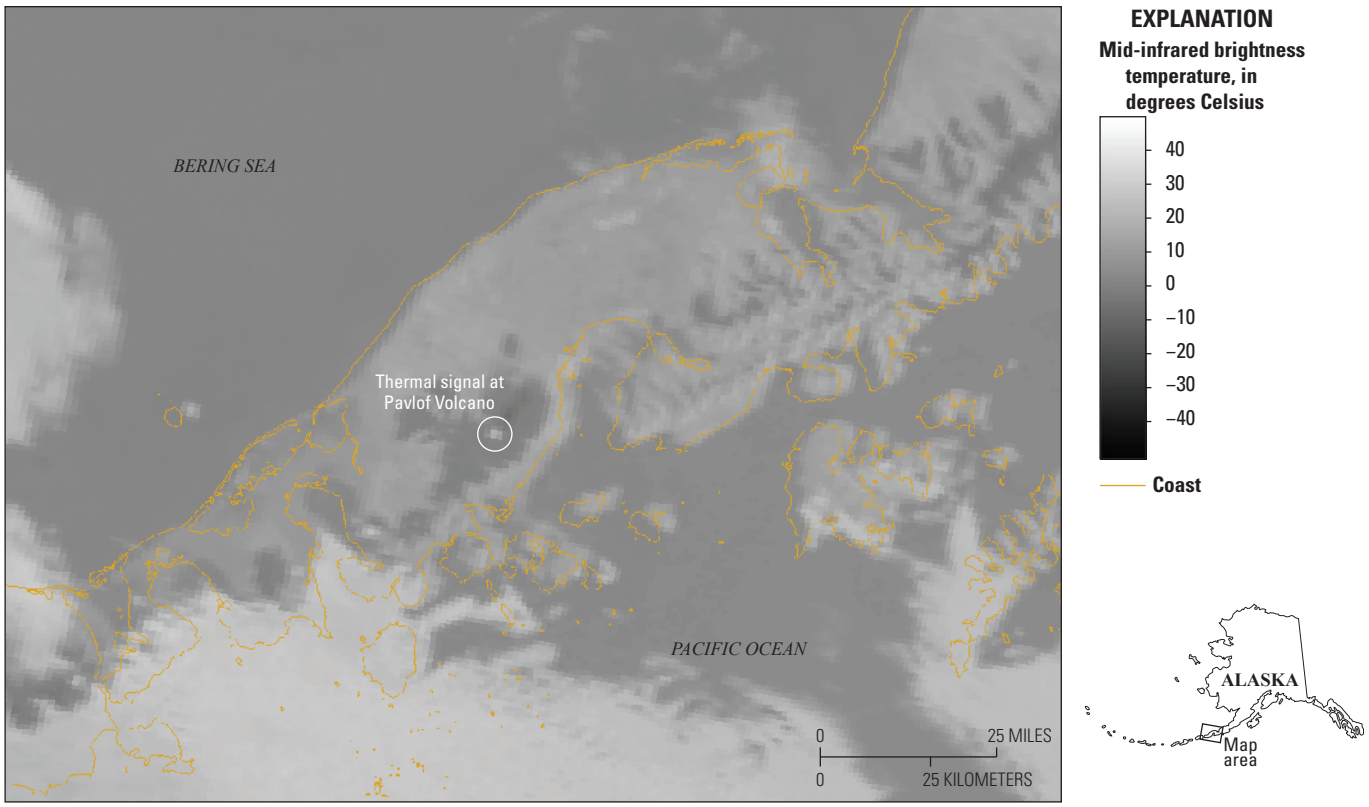


Figure 12. NOAA-18 mid-IR satellite image of moderate surface temperatures at Pavlof Volcano on May 11, 2017, 01:48 UTC (May 10, 2017, 17:48 AKDT).

grey plume was reported by a pilot on June 22 without any associated seismicity. Infrasound signals were not detected in June.

AVO continued to observe weakly elevated surface temperatures and gas plumes in July and August. Ground-based observations and gas measurements by AVO personnel, obtained on July 17–27, were consistent with degassing of shallow magma. Such degassing would not be detected by seismograph and infrasonic sensors, and only normal background activity was seen on these sensors in July and August. On August 30, in recognition of the decline in activity at Pavlof Volcano since mid-June, AVO reduced the Aviation Color Code to **GREEN** and the Volcano Alert Level to **NORMAL**. In the last five months of the year less than a half-dozen observations of suspected unrest were noted. None of these observations prompted a change in the Aviation Color Code and Volcano Alert Level for Pavlof Volcano, which remained at **GREEN** and **NORMAL**, respectively.

Pavlof Volcano is a stratovolcano located on the southwest end of the Alaska Peninsula, 950 km (590 mi) southwest of Anchorage (fig. 13). The first confirmed historical eruption was a Volcanic Explosivity Index 2 (VEI2) eruption in 1817 with 37 total VEI1–VEI3 eruptions noted in the last 200 years, making it the most frequently active volcano in the Aleutian arc (Cameron, 2005). During the previous 10 years there have been eruptive episodes at Pavlof Volcano in 2007, 2013, twice in 2014, and 2016.

Shishaldin Volcano

GVP# 311360
54.7554° N., 163.9711° W.
2,857 m (9,373 ft)

Unimak Islands, Fox Islands, Aleutian Islands

VOLCANIC UNREST

Shishaldin Volcano did not erupt in 2017, but volcanic unrest in December resulted in an elevated Aviation Color Code and Volcano Alert Level of **YELLOW** and **ADVISORY**, respectively, for much of the month. On April 20, AVO received a pilot report of an ash rich plume. Web-camera images confirmed the plume was composed of gas with no evidence of ash. Gas plumes are common at Shishaldin Volcano, and occasional reports of gas plumes and increased low-frequency seismic events were reported in AVO's internal logs for most of 2017.

In the last week of October, AVO noted elevated surface temperatures at the summit of Shishaldin Volcano. Throughout November, AVO observed increased low-frequency seismicity likely to be associated with small explosions. At the end of November, these explosions were being recorded on the infrasound array at Sand Point, Alaska, 230 km (140 mi) east of the volcano (fig. 14). In response to multiple signs of unrest, AVO

Figure 13. Photograph of 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.

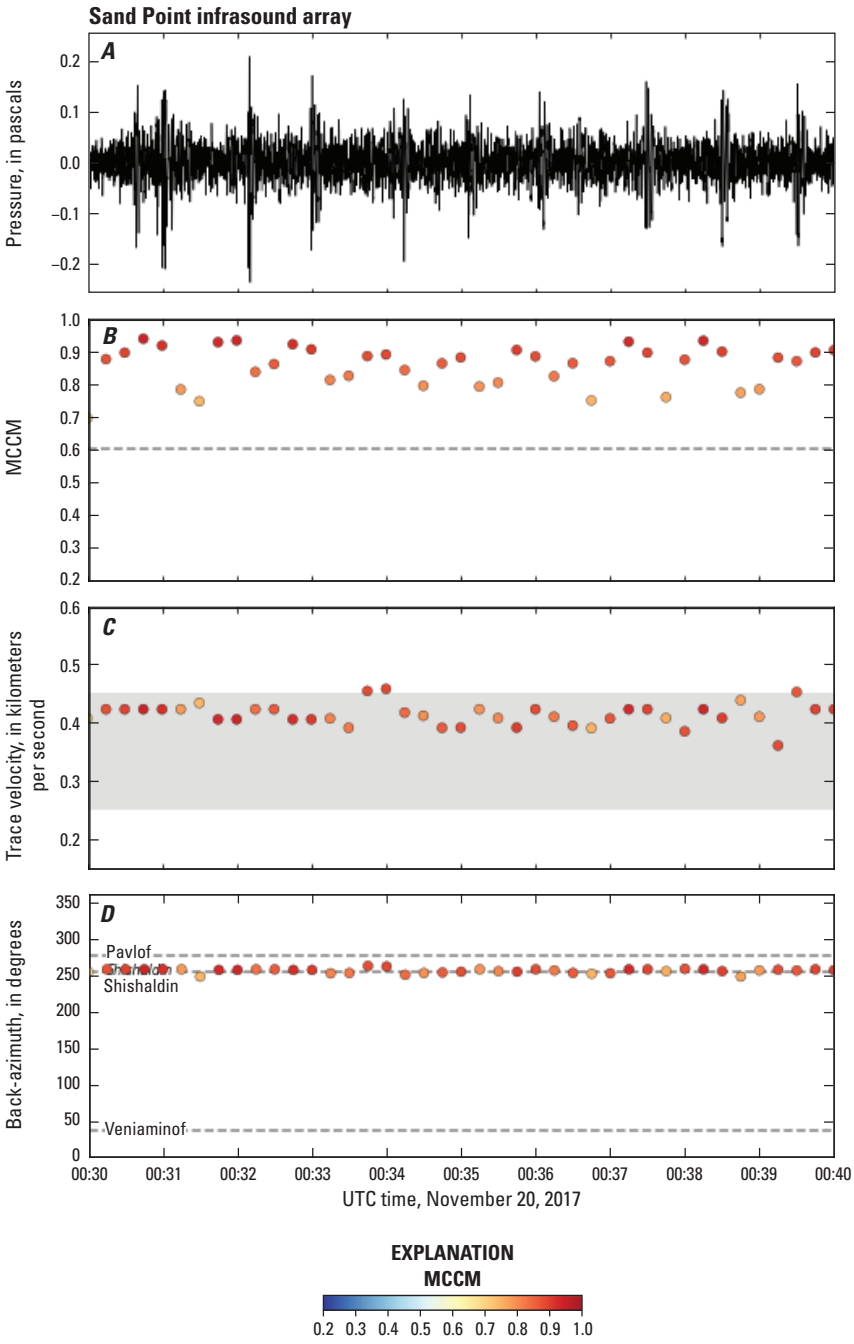


Figure 14. Graphs showing infrasound detection of Shishaldin Volcano on November 30, 2017, observed from the Sand Point, Alaska, infrasound array. *A*, A simple pressure (in pascals [Pa]) plot showing when the explosions occurred. *B*, F-statistic plot, which is an automated way of detecting explosion signals above the noise, the threshold is set at 6 and is indicated by a horizontal dashed line at 0.6 mean cross-correlation maximum (MCCM). F-statistic values are shown by dots shaded with the F-Statistic. *C*, Plot showing velocity of the signal across the array, in dots shaded with the F-Statistic. *D*, Plot showing azimuth of the signal with respect to the station. The azimuth is consistently near 250 degrees and is consistent with the location of Shishaldin Volcano. Dots are shown shaded with the F-statistic. Figure modified from image by John Lyons.

elevated the Aviation Color Code to **YELLOW** and Volcano Alert Level to **ADVISORY** on December 6. Observations of degassing and energetic small explosions continued through December.

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; fig. 15). A small summit crater typically emits a noticeable gas plume, occasionally with minor amounts of ash. Shishaldin is one of the most active volcanoes in the Aleutian volcanic arc (Cameron, 2005).

Figure 15. U.S. Geological Survey photograph of Shishaldin Volcano taken on August 7, 2018, by Matt Loewen.

Akutan Peak

GVP# 311320
54.1331° N., 165.9855° W.
1,303 m (4,275ft)

Akutan Island, Fox Islands, Aleutian Islands

EARTHQUAKE SWARM

From November 11 to November 13, a short earthquake swarm comprising three dozen earthquakes occurred off the coast of Akutan Island, approximately 12 km (7 mi) northwest of Akutan Peak (herein called Akutan volcano to include the volcano and its surrounding features beyond Akutan Peak; fig. 16). The swarm formed an elliptical cluster with the long axis pointed toward the volcano and dipping approximately 30 degrees down to the southeast. Earthquakes in the beginning of the sequence were located on the northwest end of Akutan Island, and later earthquakes migrated to the southeast. The magnitudes were small and were

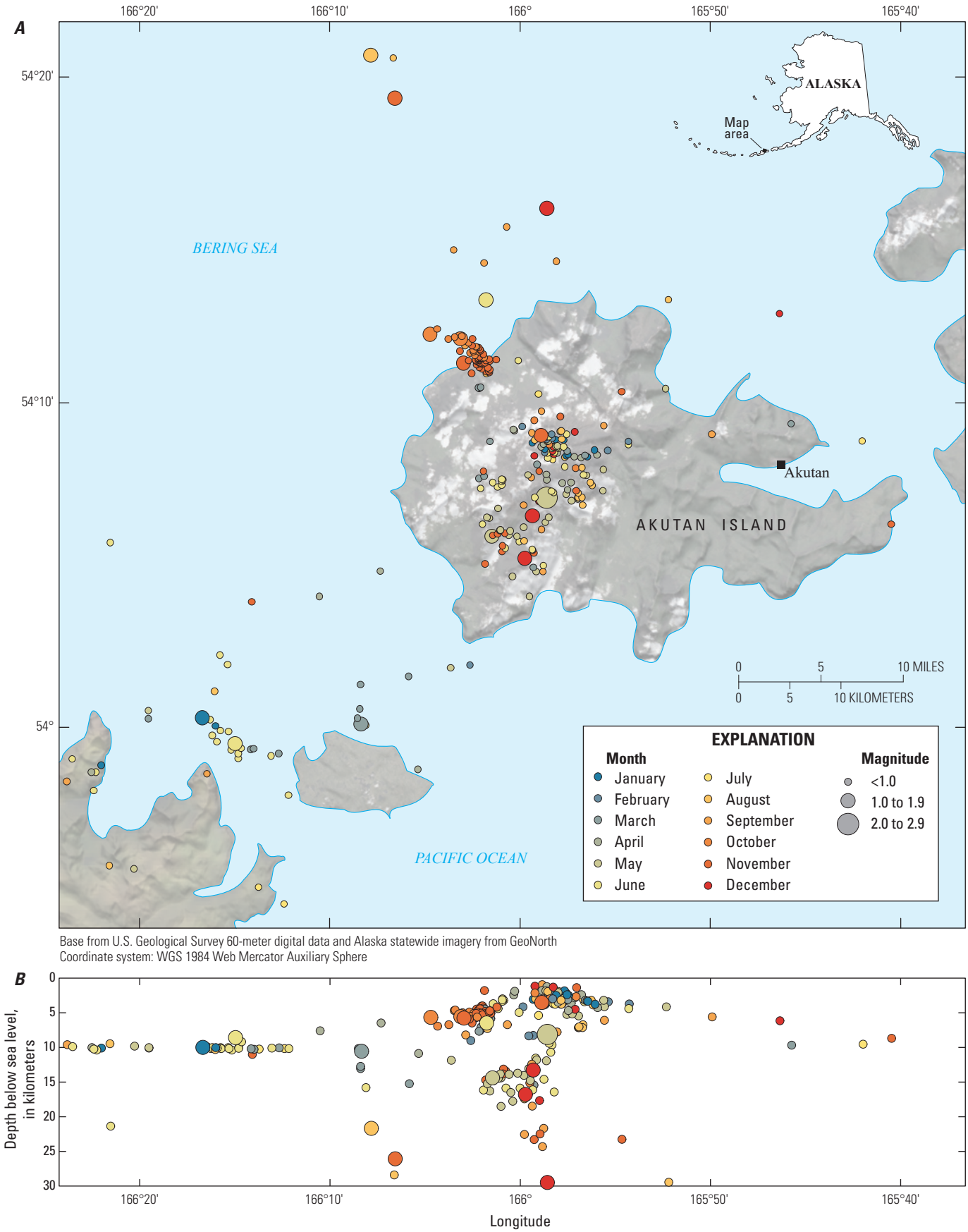


Figure 16. Map of (*A*) and graph (*B*) showing seismicity for Akutan Island in 2017. The November 11–13 swarm was located off the northwest coast of the island.

as much as M_L=1.3. No observed volcanic unrest at Akutan volcano followed the swarm. Tectonic earthquake swarms are commonplace in the Aleutian Islands, and typically an earthquake swarm indicative of an eruption will last longer than three days (Benoit and McNutt, 1996). The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively, throughout the year.

Akutan volcano is one of the most active volcanoes of the Aleutian volcanic arc and has erupted at least 31 times since 1790, most recently in 1992 (McGimsey and others, 1995). The volcano, which occupies the west half of Akutan Island, is a symmetrical stratocone with a 2-km- (1.2-mi-) diameter summit caldera (fig. 17). The caldera is breached to the northwest, and an intracaldera cinder cone has been the site of all historical eruptive activity (Richter and others, 1998; Waythomas and others, 1998). Akutan Island is home to the City of Akutan, Alaska,12 km (8 mi) east of Akutan volcano. It has one of the largest seafood-processing plants in the region, 11 km (6.6 mi) east of the volcano. In March 1996, two strong swarms of earthquakes occurred on the island, causing minor damage and prompting some residents and seafood-processing plant workers to leave the island (Lu and others, 2000). In response, a permanent seismic network was installed in summer 1996.

Makushin Volcano

GVP# 311310
53.8871° N., 166.9320° W.
1,800 m (5,906 ft)

Unimak Island, Fox Islands, Aleutian Islands

EARTHQUAKE SWARM, GAS PLUME

Earthquake swarms are common near Makushin Volcano, and in 2017 several such short earthquake swarms that did not result in eruptive activity occurred (fig. 18). The number of located earthquakes on Unalaska Island continued to increase in 2017, which is a trend that began in 2012. Located earthquakes totaled 236 in 2012, and the number of located earthquakes rose an average of 124 earthquakes per year to 857 in 2017. The increase in seismicity is unrelated to any changes in the seismograph network configuration because the depth and magnitude ranges are similar when the earthquakes located between 2012 and 2017 are compared to the earthquakes detected a decade earlier (fig. 19). AVO continues to monitor this seismicity closely because the cause of any single earthquake swarm may or may not be related to volcanism.

Figure 17. Aerial photograph of Akutan volcano taken by Vlad Karpayev on June 11, 2018.

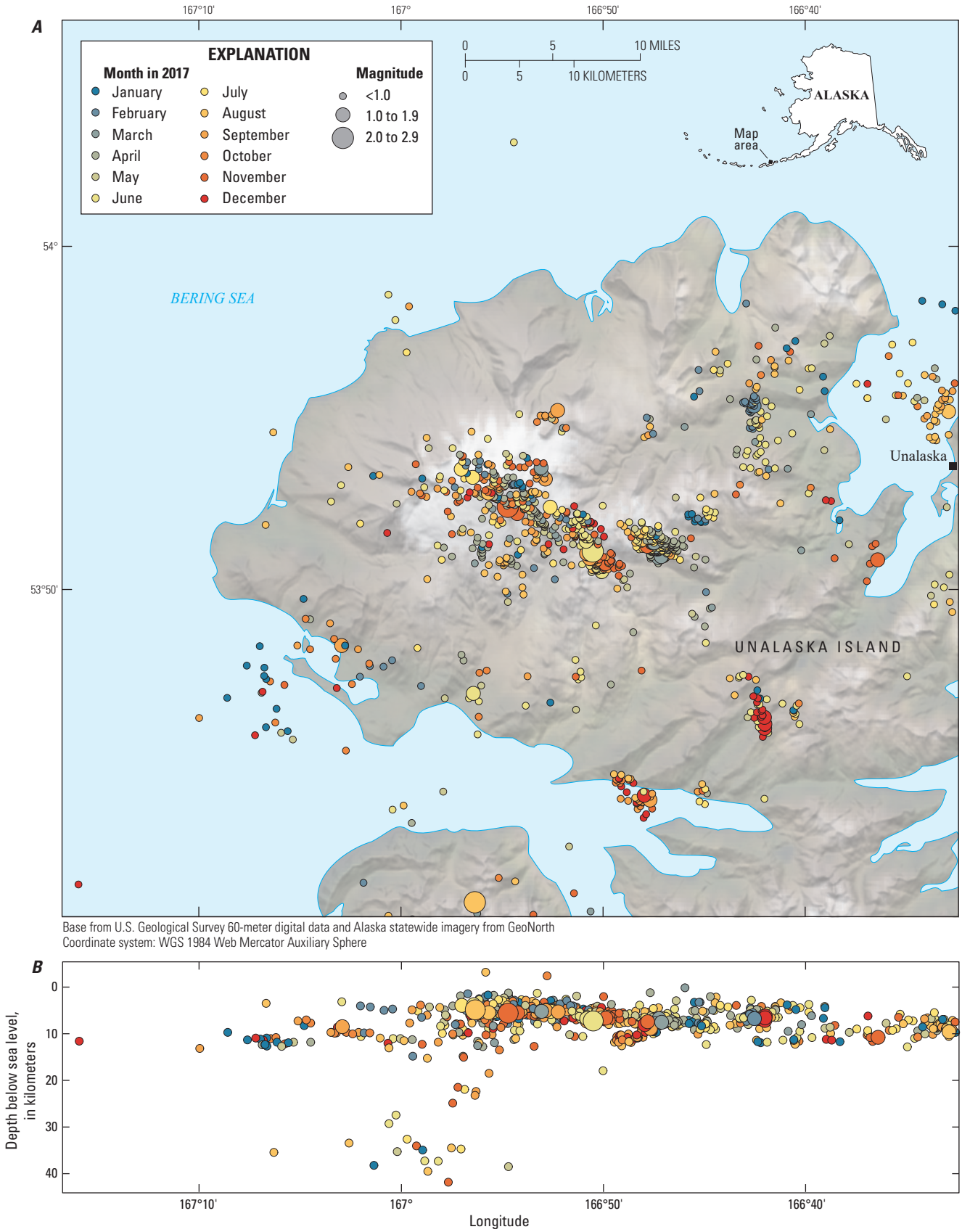


Figure 18. Map (*A*) and graph (*B*) showing seismicity on Unalaska Island in 2017.

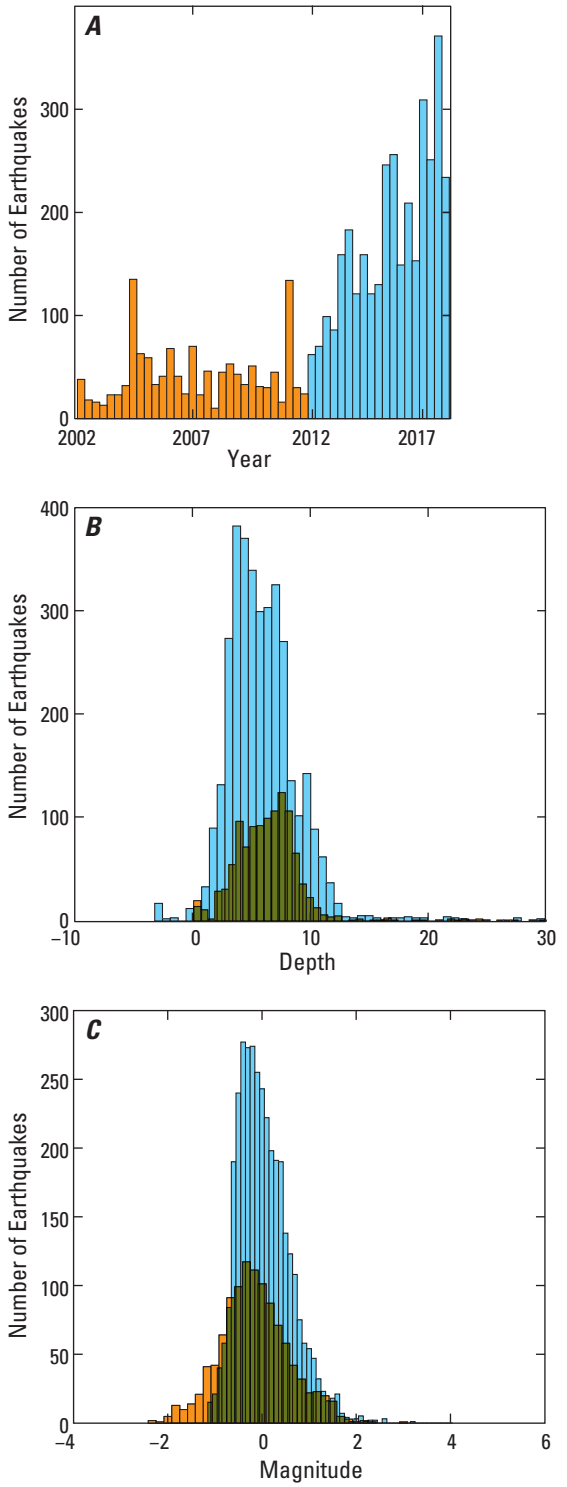


Figure 19. Bar graphs showing earthquake comparison at Makushin Volcano between 2002 and 2017. Earthquakes in the period 2002–11 are in orange. Earthquakes in the period 2012–2017 are in blue. *A*, Earthquakes in 2002–11 averaged 143 earthquakes per year. Earthquakes in 2012–17 averaged 559 earthquakes per year. Each bar represents about four months of data. *B*, Comparison of depths from earthquakes before 2012 and after. *C*, Comparison of magnitudes for earthquakes before 2012 and after.

In November, a citizen observer contacted AVO about an unusual brown haze over Unalaska Island that appeared on November 10 and tapered off over the next two days. AVO scientists searched for a volcanic cause. Nearby active volcanoes, Bogoslof and Cleveland, were quiet and wind patterns would not carry resuspension ash towards the observer. AVO believes the haze had a non-volcanic cause. The Aviation Color Code remained at **GREEN** and Volcano Alert Level **NORMAL** for Makushin Volcano throughout 2017.

Makushin Volcano is located on the eastern Aleutian island of Unalaska, about 25 km (15.5 mi) west of the city of Unalaska-Dutch Harbor, Alaska, an active fishing port (fig. 20). The volcano is a broad, truncated, and deeply glaciated stratovolcano with a 3 km (1.9 mi) wide summit caldera. Over the years as the ice cover has retreated, a small intracaldera cinder cone that hosts a turquoise-colored lake and abundant fumaroles has become a prominent feature near Makushin. The summit region is capped by a 40 square kilometers (km^2; about 15 square miles [mi^2]) icefield. Makushin Volcano is credited with 18 historical eruptions, the latest of which occurred on January 30, 1995, and consisted of a small summit explosion and ash plume that rose as high as 3,000 m (10,000 ft; McGimsey and Neal, 1996; McConnell and others, 1998; Begét and others, 2000).

Figure 20. Photograph of Makushin Volcano showing a gas plume rising from the summit region viewed from Dutch Harbor on December 25, 2017. Photograph by James Price.

Bogoslof Island

GVP# 311300
52.9272° N., 168.0344° W.
150 m (492 ft)

Fox Islands, Aleutian Islands

SIGNIFICANT ERUPTION

Eruptive activity at Bogoslof Island (herein called Bogoslof volcano to include the surface and submarine expressions of this volcanic system) began in December 2016, continued into 2017, and eventually ended in late August 2017. The last detected eruptive event during 2016–17 occurred on August 30, 2017, and a total of 70 eruptive events were documented between December 12, 2016, and August 30, 2017 (fig. 21; table 5). The 2016–17 eruptive period consisted of two main explosive phases. The first phase lasted from December 12, 2016, to March 13, 2017, and the second phase from May 17 to August 30, 2017. AVO monitored the 9-month long eruptive period using a combination of geophysical instruments and techniques, which included seismograph instruments on nearby Umnak and Unalaska Islands (fig. 22), infrasound sensors on Adak, Chuginadak, Umnak, and Unalaska Islands, lightning detection data from the Vaisala and World Wide Lightning Location networks, various satellite observations, and occasional eyewitness observations (Coombs and others, 2018). A special volume about the 2016–17 Bogoslof volcano eruption was published (Waythomas and others, 2019) and contains more details than can be presented here.

All eruptive events began at shallow (<150 m water depth) submarine vents. The vents either remained submerged throughout the duration of the eruptive event or became drier and emergent as eruptive activity proceeded and as water was displaced or isolated from the locus of eruptive activity. The explosive events that characterized the eruption lasted minutes to tens of minutes, which produced volcanic clouds that rose as high as 14 km (46,000 ft) and were often associated with abundant lightning, SO_2 emissions and occasional volcanic thunder (Haney and others, 2018). During December 2016 and January 2017, eruptive events occurred every 1 to 4 days. The rate of events declined in February 2017, and a short hiatus occurred from mid-March to mid-May. Explosive activity resumed on May 17, 2017, and continued intermittently in June, July, and August 2017.

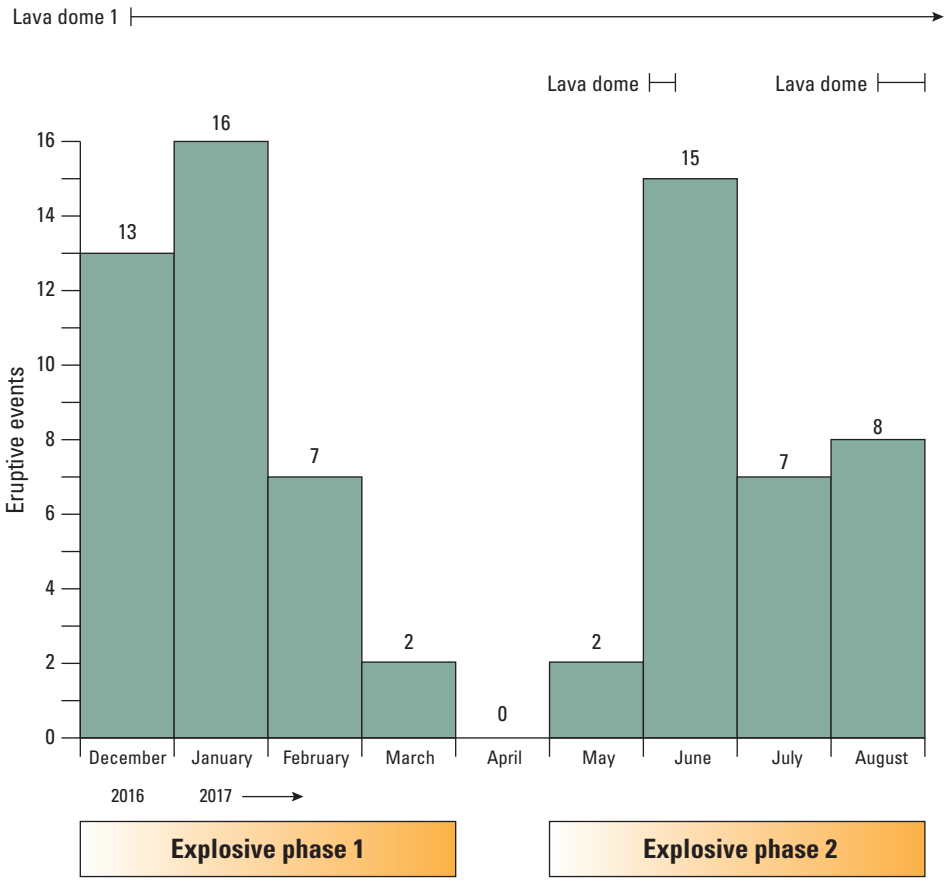


Figure 21. Bar graphs showing number of detected explosive events per month for the 2016–17 Bogoslof volcano. The timing of lava dome formations is also shown.

Table 5. Summary of significant events and Aviation Color Code and Volcanic Alert Level changes during the 2016–17 Bogoslof volcano eruption.

[Bogoslof volcano has no geophysical network. All mention of seismic and infrasound data is from networks located on Umnak and Unalaska Islands (about 40 and 60 km south and east of Bogoslof volcano, respectively). Table is based on chronology developed by Alaska Volcano Observatory (AVO) staff, especially Kristi Wallace, U.S. Geological Survey (USGS)-AVO, Dave Schneider, USGS-AVO, and David Fee, University of Alaska Fairbanks Geophysical Institute-AVO. All dates are listed in month, day, and year format and in Universal Coordinated Time (UTC); ASL, above sea level; ft, feet; km, kilometer; SO_2, sulfur dioxide]

Date (UTC)	Event Number	Aviation Color Code and Volcanic Alert Level	Type of unrest	Ground, remote sensing observations	Seismic and infrasound observations
12/12/16	1	UNASSIGNED	Uncertain; possible minor steam and ash emissions	Nothing apparent in satellite data	Infrasound detected
12/12/16	2	UNASSIGNED	Uncertain; possible minor steam and ash emissions	Nothing apparent in satellite data	Infrasound detected
12/14/16	3	UNASSIGNED	Steam and ash emissions, pyroclastic flows	Light colored volcanic cloud 2.6 km (8,530 ft) ASL observed in satellite data	Elevated seismicity detected
12/16/16	4	UNASSIGNED	Uncertain; steam and ash emissions	Volcanic cloud 6.1 km (20,000 ft) ASL, and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
12/19/16	5	UNASSIGNED	Uncertain; steam and ash emissions likely	SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
12/21/16	6	RED/WARNING	Steam and ash emissions, pyroclastic flows	Volcanic cloud 5 km (16,000 ft) ASL observed in satellite data and reported by pilots; SO_2 cloud and subaerial lava dome observed in satellite data	Elevated seismicity and infrasound detected
12/22/16	7	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 8.7 km (28,500 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
12/22/16	8	ORANGE/WATCH	Minor steam and ash emissions	Nothing apparent in satellite data	Infrasound detected
12/23/16	9	RED/WARNING	Minor steam and ash emissions	Nothing apparent in satellite data; lightning detected; mariner observed ash emissions and lava fountaining	Infrasound detected
12/26/16	10	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud to 8.5 km (28,000 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
12/29/16	11	ORANGE/WATCH	Minor steam and ash emissions	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
12/30/16	12	RED/WARNING	Steam and ash emissions	Volcanic cloud 5.1 km (16,700 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
12/31/16	13	RED/WARNING	Steam and ash emissions	SO_2 cloud observed in satellite data, lightning detected	Elevated seismicity and infrasound detected
01/02/17	14	ORANGE/WATCH	Uncertain; minor steam and ash emissions likely	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
01/04/17	15	RED/WARNING	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 8.7 km (28,545 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
01/05/17	16	RED/WARNING	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 11.8 km (38,715 ft) ASL observed in satellite data, reported by pilots and a mariner; SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
01/09/17	17	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 9.4 km (30,840 ft) ASL observed in satellite data and reported by pilots; lightning detected	Elevated seismicity and infrasound detected

Table 5.—Continued

Date (UTC)	Event Number	Aviation Color Code and Volcanic Alert Level	Type of unrest	Ground, remote sensing observations	Seismic and infrasound observations
01/12/17	18	ORANGE/WATCH	Minor steam and ash emissions	Small volcanic cloud 3.7 km (12,140 ft) ASL observed in satellite data and reported by a pilot	Elevated seismicity detected
01/12/17	19	ORANGE/WATCH	Minor steam and ash emissions	Small volcanic cloud 3.4 km (11,155 ft) ASL observed in satellite data and reported by pilots	Elevated seismicity detected
01/15/17	20	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows possible	SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
01/17/17	21	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows possible	SO_2 cloud observed.in satellite data	Elevated seismicity and infrasound detected
01/17/17	22	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows possible	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
01/18/17	23	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 8.5 km (27,885 ft) ASL observed in satellite data and reported by pilots; elevated surface temperatures, SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
01/20/17	24	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 7.5 km ASL observed in satellite data and reported by pilots; SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
01/22/17	25	RED/WARNING	Steam and ash emissions	Volcanic cloud 6.6 km (21,655 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Infrasound detected
01/24/17	26	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 7 km (22,965 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
01/26/17	27	RED/WARNING	Steam and ash emissions	Volcanic cloud 5.5 km (18,050 ft) ASL observed in satellite data and reported by pilots; SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
01/27/17	28	RED/WARNING	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 6–10 km (20,100–32,150 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
01/31/17	29	RED/WARNING	Steam and ash emissions, pyroclastic flows likely. Ballistic ejecta generated	Volcanic cloud 5.9 km (19,360 ft) ASL and SO_2 cloud observed in satellite data; lightning detected; trace ashfall reported at Dutch Harbor/Unalaska	Elevated seismicity and long-duration (400 minutes) infrasound detected
02/03/17	30	ORANGE/WATCH	Minor steam and ash emissions likely	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
02/04/17	31	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 4.6 km (15,100 ft) ASL observed in satellite data and reported by pilots; elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
02/13/17	32	ORANGE/WATCH	Possible minor steam and ash emissions	Volcanic cloud 5.9 km (19,350 ft) observed in in satellite data	Elevated seismicity detected
02/17/17	33	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 5.9 km (19,350 ft) ASL and SO_2 cloud observed in satellite data and reported by pilots; lightning detected	Elevated seismicity and infrasound detected

Table 5.—Continued

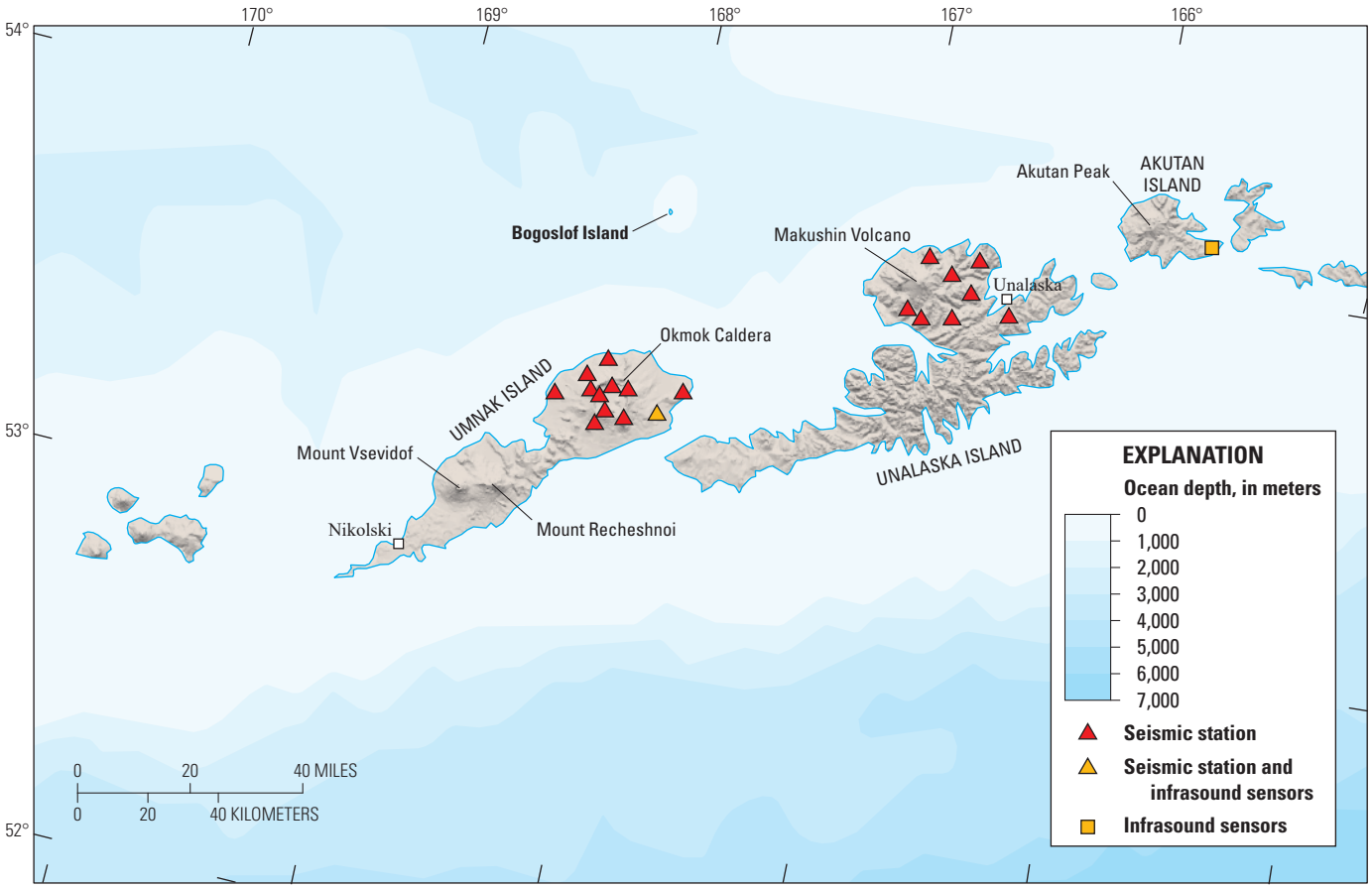
Date (UTC)	Event Number	Aviation Color Code and Volcanic Alert Level	Type of unrest	Ground, remote sensing observations	Seismic and infrasound observations
02/18/17	34	RED/WARNING	Minor steam and ash emissions likely	Volcanic cloud 6.5 km (21,325 ft) ASL observed in satellite data and a pilot report	Elevated seismicity and infrasound detected
02/18/17	35	RED/WARNING	Steam and ash emissions	Volcanic cloud 8.6 km (28,200 ft) ASL observed in satellite data and a pilot report. SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
02/20/17	36	RED/WARNING	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 6.1 km (20,000 ft) ASL observed in satellite data and pilot reports; SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
03/08/17	37	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 11–13 km (33,130–43,960 ft)ASL and SO_2 cloud observed in satellite data; lightning detected; trace amounts of ashfall on Unalaska Island	Elevated seismicity and infrasound detected
03/13/17	38	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 4.1 km (13,450 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
05/17/17	39	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 10 km (32,800 ft) ASL observed in satellite data and reported by pilots; elevated surface temperatures, SO_2 cloud and lightning detected.; trace amounts of ashfall on village of Nikolski	Elevated seismicity and infrasound detected
05/28/17	40	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 10.1 km (33,130 ft) ASL and SO_2 cloud observed in satellite data and pilot repots; lightning detected	Elevated seismicity and infrasound detected
06/01/17	41	ORANGE/WATCH	Minor steam and ash emissions likely	Volcanic cloud 7.3 km (23,950 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
06/05/17	42	ORANGE/WATCH	Possible minor steam and ash emissions	Elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
06/05/17	43	ORANGE/WATCH	Possible minor steam and ash emissions	Nothing apparent in satellite data; steam cloud observed by mariner	Elevated seismicity detected
06/06/17	44	ORANGE/WATCH	Possible minor steam and ash emissions	Possible minor steam and ash emissions	Elevated seismicity and infrasound detected
06/07/17	45	ORANGE/WATCH	Possible minor steam and ash emissions; subaerial lava dome extrusion	Small volcanic cloud 1.5 km (4,920 ft) ASL; subaerial lava dome and elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
06/08/17	46	ORANGE/WATCH	Possible minor steam and ash emissions	Elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
06/09/17	47	ORANGE/WATCH	Minor steam and ash emissions	Small volcanic cloud 3.2 km (10,500 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
06/10/17	48	RED/WARNING	Steam and ash emissions, pyroclastic flows likely. Ballistic ejecta generated	Volcanic cloud 9.5 km (31,1610 ft) ASL observed in satellite data; lightning detected	Elevated seismicity and infrasound detected
06/13/17	49	RED/WARNING	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud 3.8 km (12,470 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected

Table 5.—Continued

Date (UTC)	Event Number	Aviation Color Code and Volcanic Alert Level	Type of unrest	Ground, remote sensing observations	Seismic and infrasound observations
06/13/17	50	ORANGE/WATCH	Possible minor steam and ash emissions	Nothing apparent in satellite data	Slightly elevated seismicity and infrasound detected
06/24/17	51	RED/WARNING	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 11.9 km (39,00 ft) ASL observed in satellite data and reported by a pilot; elevated surface temperatures detected in satellite data; lightning detected	Elevated seismicity and infrasound detected
06/24/17	52	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud reported by a pilot.; elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
06/27/17	53	RED/WARNING	Steam and ash emissions	Volcanic cloud 8.6 km (28,215 ft) ASL and SO_2 cloud observed in satellite data	Elevated seismicity detected
06/27/17	54	ORANGE/WATCH	Steam and ash emissions	Volcanic cloud 8.1 km (26,575 ft) ASL observed in satellite data; lightning detected	Elevated seismicity detected
06/30/17	55	ORANGE/WATCH	Minor steam and ash emissions	Small volcanic cloud 3.8 km (12,470 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
07/02/17	56	RED/WARNING	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud 7.9 km (25,920 ft) ASL observed in satellite data and reported by pilots; SO_2 cloud detected in satellite data	Elevated seismicity and infrasound detected
07/05/17	57	RED/WARNING	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud 8.4 km ASL observed in satellite data and reported by pilots; lightning detected	Elevated seismicity and infrasound detected
07/05/17	58	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud 6.9 km (22,640 ft) ASL observed in satellite data	Elevated seismicity and infrasound detected
07/05/17	59	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows uncertain	Volcanic cloud 6.5 km (31,325 ft) ASL observed in satellite data	Elevated seismicity detected
07/10/17	60	RED/WARNING	Minor(?) steam and ash emissions, pyroclastic flows uncertain	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
07/10/17	61	ORANGE/WATCH	Minor steam and ash emissions possible	Volcanic cloud reported by a pilot; nothing apparent in satellite data	Elevated seismicity and infrasound detected
07/11/17	62	ORANGE/WATCH	Minor steam and ash emissions possible	Nothing apparent in satellite data	Elevated seismicity detected
08/07/17	63	RED/WARNING	Steam and ash emissions, pyroclastic flows likely	Volcanic cloud 10.8–12.7 km (35,430–41,670 ft) ASL observed in satellite data and a pilot report; SO_2 cloud and lightning detected	Elevated seismicity and infrasound detected
08/14/17	64	ORANGE/WATCH	Minor steam and ash emissions possible	Nothing apparent in satellite data	Elevated seismicity and infrasound detected
08/22/17	65	ORANGE/WATCH	Minor steam and ash emissions possible; subaerial lava dome extrusion	Lava dome and elevated surface temperatures observed in satellite data	Elevated seismicity and infrasound detected
08/27/17	66	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows possible	Volcanic cloud 9.2 km (30,180 ft) ASL and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected

Table 5.—Continued

Date (UTC)	Event Number	Aviation Color Code and Volcanic Alert Level	Type of unrest	Ground, remote sensing observations	Seismic and infrasound observations
08/27/17	67	ORANGE/WATCH	Minor steam and ash emissions	Volcanic cloud 8.7 km (28,540 ft) ASL observed in satellite data and a pilot report	Elevated seismicity and infrasound detected
08/28/17	68	ORANGE/WATCH	Minor steam and ash emissions possible	Elevated surface temperatures and SO_2 cloud observed in satellite data	Elevated seismicity and infrasound detected
08/28/17	69	ORANGE/WATCH	Minor steam and ash emissions possible	Volcanic cloud 6.7 km (21,980 ft) ASL observed in satellite data and a pilot report ; elevated surface temperatures and SO_2 cloud detected in satellite data	Elevated seismicity and infrasound detected
08/30/17	70	ORANGE/WATCH	Steam and ash emissions, pyroclastic flows likely. Ballistic ejecta generated	Elevated surface temperatures and SO_2 cloud observed in satellite data; lightning detected	Elevated seismicity and infrasound detected



Base from Natural Earth and U.S. Geological Survey digital data
Alaska Albers Equal-Area Conic projection
Standard parallels 55° N. and 65° N.
Central meridian 154° W.
North American Datum of 1983

Figure 22. Map of area around Bogoslof Island showing the location of seismograph and infrasound stations that were prominent in monitoring the 2016–17 Bogoslof volcano eruption.

A visit to Bogoslof Island by AVO personnel in August 2018 revealed a lava dome partially buried by pyroclastic debris, previously assumed to be a tephra cone associated with Surtseyan eruptive activity. A satellite image from December 21, 2016, showed a feature with positive relief in the general vicinity of the lava dome. Two lava domes were recognized in satellite data from June 5–10, and August 18–30, 2017. Both of the lava domes were destroyed by subsequent explosive activity on June 10 and August 30, 2017. No further explosive activity was detected by AVO after August 30, 2017. Above background surface temperatures associated with hot ground and water in the vent area were detected in satellite data for several months following the cessation of the eruption. On September 27, 2017, AVO lowered the Aviation Color Code and Volcano Alert Level to **YELLOW** and **ADVISORY**, respectively, and the volcano returned to a quiescent state by the end of 2017.

As a result of the eruption, Bogoslof Island experienced significant morphological changes and the size of the island grew from about 0.3 km^2 (0.1 mi^2) to about 1.9 km^2 (0.7 mi^2) by the end of the eruptive activity (fig. 23). Several tuff rings were constructed by pyroclastic flows and fallout of ballistic ejecta. The tuff rings often contained small intra-island lakes which were typically the sites of explosive activity and were measurably hot when visited in August 2018, a year after the eruption ended.

Most volcanic clouds produced by the eruptive activity in 2017 were light-colored gas, ice-, and ash-bearing plumes that resulted in minor ash fallout. Trace amounts of ash fell on Unalaska Island on January 31 and March 8 and on the village of Nikolski on May 16, 2017. Numerous flights were rerouted, delayed, or cancelled to avoid volcanic ash, especially during January (Coombs and others, 2019). For example, during the January 18 explosion, about 50 flights were affected (National

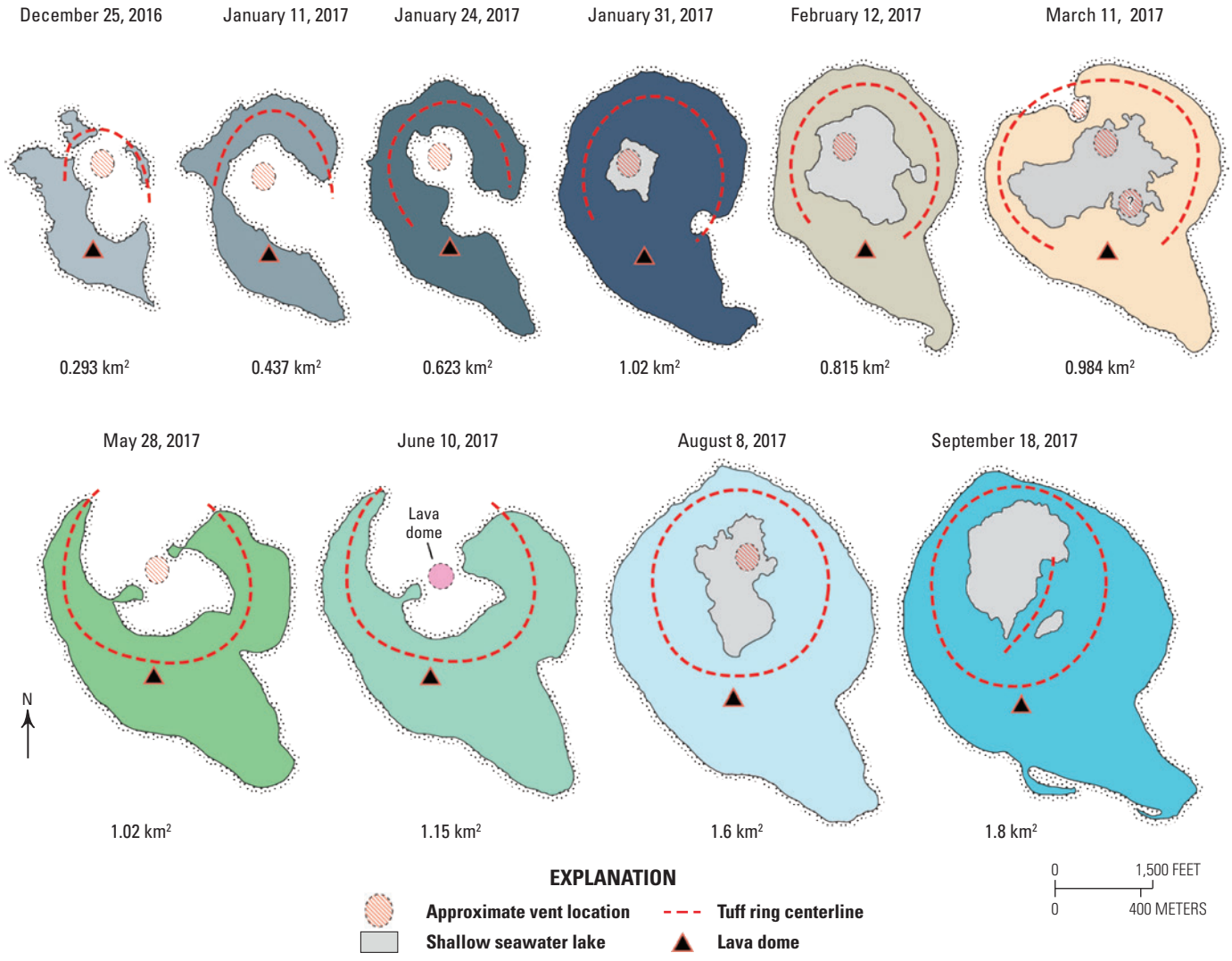


Figure 23. Diagrams showing the changes in the morphology of Bogoslof Island resulting from eruptive activity, December 25, 2016, to September 18, 2017.

Weather Service Central Weather Service Unit, written communication, 2017). Reduced freight capacity, because of flight cancellations owing to the Bogoslof volcano explosions, were noted in industry websites.

Bogoslof Island (fig. 24) is the largest of a cluster of small, low-lying islands making up the emergent summit of a large submarine stratovolcano. The highest point above sea level prior to the 2016–17 eruption was about 100 m (300 ft); however, the volcano is frequently altered by both eruptions and wave erosion and has undergone dramatic changes in historical time (Waythomas and Cameron, 2018). The two main islands currently above sea level are Fire Island and Bogoslof Island; both located about 98 km (61 mi) northwest of Unalaska-Dutch Harbor, Alaska, 123 km (76 mi) northeast of Nikolski, Alaska, and 149 km (93 mi) northeast of Akutan, Alaska. The volcano is situated slightly north (behind) of the main Aleutian volcanic front.

At least eight historical eruptions have been documented at Bogoslof volcano (Waythomas and Cameron, 2018). The most recent eruption prior to 2016–17 occurred in July 1992 and produced episodic steam and ash emissions including an ash cloud as high as 8 km (26,000 ft) ASL on July 20, followed by extrusion of a 150 m (500 ft) by 275 m (900 ft) lava dome on the north end of the island. Eruptions of the volcano are often characterized by multiple explosive, ash-producing events such as those observed in 2016–2017, as well as the growth of new lava domes.

Okmok Caldera

GVP# 311290
53.419° N., 168.132° W.
1,073 m (3,520 ft)

Fox Islands, Aleutian Islands

INFLATION

Gradual inflation at Okmok Caldera (herein called Okmok volcano to include associated volcanic features exterior to the caldera) was first noticed in September 2016 on GPS sensors and continued into 2017. In April, a north-trending inflation signal suggested a higher rate of inflation at Okmok volcano. Throughout the rest of 2017, the inflation signal continued, extending into 2018 without abatement and without evidence of an imminent eruption. The Aviation Color Code remained at **GREEN** and Volcano Alert Level **NORMAL** throughout 2017.

Okmok volcano occupies most of northeast Umnak Island (120 km [75 mi] southwest of Unalaska-Dutch Harbor, Alaska). It consists of younger lava flows and cones within two nested Quaternary calderas and numerous older flows and cones outside of the calderas, including Jag Peak and Mount Tulik (fig. 25). The volcano, built on a base of Tertiary volcanic rocks, consists of three rock series: (1) older flows

Figure 24. U.S. Geological Survey photograph of Bogoslof Island from the northwest on August 16, 2018, showing the domes above sea level. Features from left to right are: Castle Rock, degassing 2016–17 dome, 1926–27 dome (mostly obscured by gas plume), 1992 dome, and Fire Island. Photograph by Gabrielle Tepp.

Figure 25. Photograph of Okmok Caldera looking east from the caldera rim on July 16, 2018. Photograph by David Fee, University of Alaska Fairbanks Geophysical Institute-Alaska Volcano Observatory.

and pyroclastic beds of a pre-caldera shield complex, (2) pyroclastic deposits of two major caldera-forming eruptions, and (3) a post-caldera field of small cones and lava flows that includes historically active vents in the caldera (Byers, 1959; Larsen and others, 2007). Okmok volcano has had several eruptions in the past several hundred years, typically consisting of ash emissions that occasionally reach altitudes higher than 9 km (30,000 ft), but generally much lower. In the past 70 years, lava flows were emplaced on the caldera floor in 1945, 1958, and 1997 (Begét and others, 2005). The most recent eruption was a phreatomagmatic eruption during summer 2008 (Neal and others, 2011). Thermal springs and fumaroles occur in the Okmok Caldera and at Hot Springs Cove, 20 km (12 mi) to the southwest.

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

Mount Cleveland began the seventh straight year at an elevated Aviation Color Code and Volcano Alert Level in 2017. Activity consisted of intermittent elevated surface temperatures, degassing from the summit cone, and the extrusion of small lava domes punctuated by explosions (table 6). Mount Cleveland began 2017 with fewer but similarly sized explosions to those in previous years that transitioned into more frequent but smaller explosions towards the end of the year. The volcano is currently monitored with a small network of seismograph and infrasound sensors, a web camera, and satellite remote sensing, With these data streams available throughout the year for the first time, AVO is better able to characterize the ongoing activity at Mount Cleveland. Because of the low number of seismographic stations (2), AVO is unable to locate the types of earthquakes needed to assist in the prediction of an eruption at Mount Cleveland, and it is not formally listed as a seismically monitored volcano.

Mount Cleveland began 2017 at Aviation Color Code **YELLOW** and Volcano Alert Level **ADVISORY**. The last explosion in October 24, 2016, left a deep crater at the start of 2017. Activity in January consisted of intermittent gas plumes and elevated surface temperatures. By January 21, satellite imagery confirmed that a new lava dome partially occupied the summit crater. The dome measured 30 m (100 ft) in diameter on January 24, and by February 3 it was 70 m (230 ft) in diameter. The extrusion of this lava dome and potential for explosive activity prompted AVO to increase the Aviation Color Code to **ORANGE** and the Volcano Alert Level to **WATCH** on February 3. The dome ceased growing at 75 m (250 ft) in diameter around February 11 and remained unchanged into March, and weakly elevated surface temperatures and minor gas emissions were detected in satellite imagery and web-cameras during this time, consistent with cooling lava. After several weeks of inactivity, the Aviation Color Code and Volcano Alert Level was downgraded from **ORANGE** and **WATCH** to **YELLOW** and **ADVISORY**, respectively, on March 8.

The first explosion of 2017, which occurred on March 24 at 16:15 UTC (08:15 AKDT), removed the lava dome. The short-duration explosion showed characteristics similar to previous dome-related explosions with a very sharp onset followed by about 10 seconds of additional signal in infrasound data (fig 26). Cloud cover prevented the observation of ash cloud from this event. This explosion prompted the Aviation Color Code and Volcano Alert Level to be upgraded from **YELLOW** and **ADVISORY** to **ORANGE** and **WATCH**, respectively

On April 5, the Aviation Color Code and Volcano Alert Level was downgraded from **ORANGE** and **WATCH** to **YELLOW** and **ADVISORY**, respectively, because of inactivity since the explosion on March 24. Satellite imagery showed a new lava dome was extruded into the summit crater sometime before April 15 and by April 23 grew into a smooth 45-m- (150-ft-) diameter dome. The presence of a growing lava dome in the summit crater of Mount Cleveland prompted an Aviation Color Code and Volcano Alert Level upgrade to **ORANGE** and **WATCH**, respectively, on April 24. Extrusion of lava continued, and by April 28 three stacked domes had formed (fig. 27). The lowermost dome was 60 × 50 m (200 × 160 ft), the second dome 40 × 30 m (130 × 100 ft), and the newest and topmost dome was 15 m (50 ft) in diameter. The topmost circular dome continued to grow, and by May 2, it was greater than 20 m (65 ft) in diameter. Satellite imagery from May 8 showed no change in the size of the top dome, signifying that lava effusion had ceased at Mount Cleveland.

On May 17, 03:17 UTC (May 16, 19:17 AKDT), an automated infrasound alarm indicated an explosion. A continuous

Table 6. Summary of activity and observations at Mount Cleveland in 2017.

[This table is condensed from an extensive chronology that is maintained by Alex Iezzi, University of Alaska Fairbanks Geophysical Institute and Alaska Volcano Observatory, as the chronology editor. All dates are listed in month, day, and year format and in Universal Coordinated Time. Note: Absence of data in table below is marked by —, which may indicate no change in activity, possible cloud cover obscuring ground observations in satellite imagery, no observation recorded, or no seismic or infrasound detection observed.]

Date	Aviation color code and volcano alert level	Activity	Elevated surface temperatures	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
01/02/17	YELLOW/ADVISORY	—	Weak	—	—
01/04/17	YELLOW/ADVISORY	—	Moderate	—	—
01/06/17	YELLOW/ADVISORY	—	Weak	—	—
01/08/17	YELLOW/ADVISORY	—	Weak	—	—
01/09/17	YELLOW/ADVISORY	—	Weak	—	—
01/13/17	YELLOW/ADVISORY	—	—	Possible steam	—
01/14/17	YELLOW/ADVISORY	—	—	Robust steam plume	—
01/16/17	YELLOW/ADVISORY	—	—	Robust steam plume	—
01/17/17	YELLOW/ADVISORY	—	—	Steam plume	—
01/18/17	YELLOW/ADVISORY	—	—	Steam plume	—
01/19/17	YELLOW/ADVISORY	—	—	Steam plume	—
01/21/17	YELLOW/ADVISORY	—	—	Steam plume; new dome first appears	Few possibly local events
01/22/17	YELLOW/ADVISORY	—	—	—	One possibly local event
01/30/17	YELLOW/ADVISORY	—	—	—	One possibly local event
02/03/17	ORANGE/WATCH	New dome growth	—	New dome growth	—
02/06/17	ORANGE/WATCH	—	—	—	One possibly local event
02/07/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
02/09/17	ORANGE/WATCH	—	Unspecified	—	One possibly local event
02/11/17	ORANGE/WATCH	—	—	Dome growth ceased	One possibly local event
02/12/17	ORANGE/WATCH	—	—	—	Few possibly local events
02/17/17	ORANGE/WATCH	—	—	Possible steam	—
02/18/17	ORANGE/WATCH	—	—	Robust steam plume	—
02/19/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
02/21/17	ORANGE/WATCH	—	—	Possible steam	—
02/26/17	ORANGE/WATCH	—	Weak	—	—
02/28/17	ORANGE/WATCH	—	Weak	Minor steam	Few possibly local events
03/01/17	ORANGE/WATCH	—	Weak	Minor steam	—
03/02/17	ORANGE/WATCH	—	Weak	Minor steam	Micro swarm of regional events
03/03/17	ORANGE/WATCH	—	Weak	Minor steam	Few possibly local events
03/06/17	ORANGE/WATCH	—	Possible	Robust steam plume	—
03/08/17	YELLOW/ADVISORY	Decline in activity	—	Possible steam	—
03/09/17	YELLOW/ADVISORY	—	Possible	—	—
03/10/17	YELLOW/ADVISORY	—	—	Minor steam	—
03/11/17	YELLOW/ADVISORY	—	Weak	Minor steam	—
03/12/17	YELLOW/ADVISORY	—	Weak	—	—
03/13/17	YELLOW/ADVISORY	—	Possible	Minor steam	—
03/14/17	YELLOW/ADVISORY	—	Possible	Minor steam	—
03/16/17	YELLOW/ADVISORY	—	Weak	—	—
03/17/17	YELLOW/ADVISORY	—	Possible	—	—
03/18/17	YELLOW/ADVISORY	—	Weak	—	—
03/19/17	YELLOW/ADVISORY	—	Weak	—	—
03/20/17	YELLOW/ADVISORY	—	—	Minor steam	Few possibly local events
03/22/17	YELLOW/ADVISORY	—	Possible	Minor steam	—
03/23/17	YELLOW/ADVISORY	—	Unspecified	—	—

Table 6.—Continued

Date	Aviation color code and volcano alert level	Activity	Elevated surface temperatures	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
03/24/17	ORANGE/WATCH	Small explosion	—	No ash cloud observed; cloud deck at 30,000 ft; lava dome removed	Detected in infrasound and seismic data; very sharp onset with 10 seconds of jetting
03/27/17	ORANGE/WATCH	—	—	—	Few possibly local events
03/28/17	ORANGE/WATCH	—	Weak	—	—
04/03/17	ORANGE/WATCH	—	—	—	Few possibly local events
04/04/17	ORANGE/WATCH	—	—	—	Few possibly local events
04/05/17	YELLOW/ADVISORY	Decline in activity	—	—	Few possibly local events
04/06/17	YELLOW/ADVISORY	—	—	—	Increase in number of possibly local events
04/07/17	YELLOW/ADVISORY	—	—	—	Few possibly local events
04/09/17	YELLOW/ADVISORY	—	—	—	Few possibly local events
04/15/17	YELLOW/ADVISORY	—	—	Possible mound in summit crater <10 m in diameter	—
04/18/17	YELLOW/ADVISORY	—	Unspecified	—	—
04/23/17	YELLOW/ADVISORY	—	—	Mound grew into lava dome 45 m in diameter	—
04/24/17	ORANGE/WATCH	New dome growth	—	—	—
04/28/17	ORANGE/WATCH	—	—	Dome continued to grow	—
05/02/17	ORANGE/WATCH	—		Inflation of dome above vent	—
05/08/17	ORANGE/WATCH	—	—	No change to lava dome	—
05/17/17	ORANGE/WATCH	Explosion	—	Plume drifted 140 km SW; dome completely removed	Similar amplitude to previous explosion; detected by automated infrasound alarms
05/18/17	ORANGE/WATCH	—	—	Robust steam plume	—
05/20/17	ORANGE/WATCH	—	—	—	Few possibly local events
05/21/17	ORANGE/WATCH	—	—	Minor steam	—
05/22/17	ORANGE/WATCH	—	—	Minor steam	—
05/24/17	ORANGE/WATCH	—	—	Minor steam	—
05/26/17	ORANGE/WATCH	—	Possible	Minor steam; no change in dome-free crater	—
05/27/17	ORANGE/WATCH	—	—	Steam plume	Few possibly local events
05/29/17	ORANGE/WATCH	—	—	—	Few possibly local events
05/30/17	ORANGE/WATCH	—	—	—	Few possibly local events
05/31/17	ORANGE/WATCH	—	—	—	Few possibly local events
06/01/17	ORANGE/WATCH	—	—	Robust steam plume	Few possibly local events
06/02/17	ORANGE/WATCH	—	—	Robust steam plume	Few possibly local events
06/03/17	ORANGE/WATCH	—	—	—	Few possibly local events
06/04/17	ORANGE/WATCH	—	—	—	Few possibly local events
06/05/17	ORANGE/WATCH	—	—	Minor steam	Few possibly local events
06/06/17	ORANGE/WATCH	—	Possible	—	Small repeating low frequency events
06/07/17	ORANGE/WATCH	—	Unspecified	—	Small low frequency events continue to a lesser degree
06/08/17	ORANGE/WATCH	—	Unspecified	—	—
06/13/17	ORANGE/WATCH	—	Unspecified	—	—
06/16/17	ORANGE/WATCH	—	—	No change to dome-free crater	—
06/17/17	ORANGE/WATCH	—	—	Minor steam	—
06/19/17	ORANGE/WATCH	—	Weak	Possible steam	—

Table 6.—Continued

Date	Aviation color code and volcano alert level	Activity	Elevated surface temperatures	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
06/20/17	ORANGE/WATCH	—	Unspecified	Plume	—
06/21/17	ORANGE/WATCH	—	Unspecified	—	—
06/22/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
06/26/17	YELLOW/ADVISORY	Decline in unrest	—	Minor steam	—
06/28/17	YELLOW/ADVISORY	—	—	—	Few possibly local events
06/29/17	YELLOW/ADVISORY	—	Weak	—	—
07/01/17	YELLOW/ADVISORY	—	—	Minor steam	—
07/02/17	YELLOW/ADVISORY	—	—	Minor steam	—
07/03/17	YELLOW/ADVISORY	—	Weak	Steam plume	—
07/04/17	ORANGE/WATCH	Explosion	—	No trace of a plume in satellite	10 minute duration detected by seismic and infrasound; burst of tremor before main explosion
07/07/17	ORANGE/WATCH	—	Unspecified	—	—
07/10/17	ORANGE/WATCH	—	—	Minor steam	—
07/14/17	ORANGE/WATCH	—	Unspecified	—	—
07/17/17	ORANGE/WATCH	—	—	New lava dome confirmed with diameter of 25 m	—
07/19/17	ORANGE/WATCH	—	Unspecified	—	—
07/20/17	ORANGE/WATCH	—	Unspecified	—	—
07/21/17	ORANGE/WATCH	—	Unspecified	Dome growth to 30 m diameter	—
07/22/17	ORANGE/WATCH	—	Unspecified	—	—
07/23/17	ORANGE/WATCH	—	Unspecified	—	—
07/24/17	ORANGE/WATCH	—	Weak	—	—
07/25/17	ORANGE/WATCH	—	—	Minor steam; dome growth to 40 × 45 m; dome inflation	—
07/26/17	ORANGE/WATCH	—	—	Minor steam	—
07/30/17	ORANGE/WATCH	—	Unspecified	Steam plume	—
07/31/17	ORANGE/WATCH	—	Moderate	Steam plume	—
08/01/17	ORANGE/WATCH	—	Strong	Dome growth to 50 × 45 m; dome inflation	—
08/06/17	ORANGE/WATCH	—	—	—	One possibly local event
08/07/17	ORANGE/WATCH	—	Unspecified	No change in dome	—
08/08/17	ORANGE/WATCH	—	Unspecified	—	—
08/09/17	ORANGE/WATCH	—	Moderate	—	—
08/10/17	ORANGE/WATCH	—	Unspecified	—	—
08/11/17	ORANGE/WATCH	—	Weak	—	—
08/13/17	ORANGE/WATCH	—	Weak	Minor steam	—
08/15/17	ORANGE/WATCH	—	Unspecified	—	—
08/17/17	ORANGE/WATCH	—	Weak	Summit overflight of lava dome	—
08/20/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
08/21/17	ORANGE/WATCH	—	Moderate	Minor steam	—
08/22/17	ORANGE/WATCH	Explosion	Moderate	Dome removed by explosion	Few possibly local events; explosion detected by seismic and infrasound
08/23/17	ORANGE/WATCH	—	—	—	Few possibly local events
08/23/17	ORANGE/WATCH	—	—	—	Few possibly local events
08/24/17	ORANGE/WATCH	—	—	—	Few possibly local events
08/25/17	ORANGE/WATCH	—	Unspecified	—	—

Table 6.—Continued

Date	Aviation color code and volcano alert level	Activity	Elevated surface temperatures	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
08/26/17	ORANGE/WATCH	—	Unspecified	—	—
08/27/17	ORANGE/WATCH	—	—	—	Few possibly local events
08/28/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
08/29/17	ORANGE/WATCH	—	—	Minor steam	—
08/30/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
08/31/17	ORANGE/WATCH	—	—	Minor steam	—
09/05/17	ORANGE/WATCH	—	Weak	—	—
09/10/17	ORANGE/WATCH	—	—	Minor steam	—
09/14/17	ORANGE/WATCH	—	Weak	Minor steam	—
09/17/17	ORANGE/WATCH	—	—	Minor steam	—
09/18/17	ORANGE/WATCH	—	—	Minor steam	One possibly local event
09/19/17	ORANGE/WATCH	—	—	—	One possibly local event
09/21/17	ORANGE/WATCH	—	—	—	Few possibly local events
09/23/17	ORANGE/WATCH	—	—	Minor steam	—
09/25/17	ORANGE/WATCH	—	—	—	Few possibly local events
09/26/17	ORANGE/WATCH	Explosion	—	Crater empty prior to explosion; ash cloud < 15,000 ft	2-minute-long explosion detected in seismic and infrasound data; few possibly local events
09/27/17	ORANGE/WATCH	—	—	—	One possibly local event
09/28/17	ORANGE/WATCH	Two very small explosions	Unspecified	—	Two very small explosions about 100 times smaller than one on 9/26/17
09/29/17	ORANGE/WATCH	—	—	—	Few possibly local events
09/30/17	ORANGE/WATCH	—	Unspecified	Minor steam	—
10/01/17	ORANGE/WATCH	Small explosion	Strong	New lava dome growing; no obvious new deposits	Small explosion; few possibly local events
10/02/17	ORANGE/WATCH	—	Strong	—	Few possibly local events
10/03/17	ORANGE/WATCH	—	—	—	Few possibly local events
10/06/17	ORANGE/WATCH	—	Strong	—	—
10/08/17	ORANGE/WATCH	—	Unspecified	—	—
10/11/17	ORANGE/WATCH	—	—	Lava dome growth to twice its area; now 115 × 95 m	—
10/15/17	ORANGE/WATCH	—	—	Lava dome growth to 100 × 125 m; dome inflation	—
10/16/17	ORANGE/WATCH	—	Moderate	Minor steam	—
10/19/17	ORANGE/WATCH	—	—	No major changes to lava dome	—
10/22/17	ORANGE/WATCH	—	Weak	Minor steam	—
10/23/17	ORANGE/WATCH	—	Moderate	Minor steam	—
10/24/17	ORANGE/WATCH	—	—	—	One possibly local event
10/27/17	ORANGE/WATCH	—	—	—	Three local long period earthquakes; no infrasound associated with events
10/28/17	ORANGE/WATCH	Explosion	—	—	30-second-long explosion detected by seismic and infrasound data
10/30/17	ORANGE/WATCH	Small explosion	—	—	Small explosion about 4 times smaller than one on 10/28/17
10/31/17	ORANGE/WATCH	—	Moderate	Recent explosions removed portion of central lava dome	—
11/03/17	ORANGE/WATCH	—	Strong	—	—

Table 6.—Continued

Date	Aviation color code and volcano alert level	Activity	Elevated surface temperatures	Ground, air, or other satellite observations	Seismic network and infrasound detection or other alarm triggers
11/05/17	ORANGE/WATCH	—	Weak	—	—
11/06/17	ORANGE/WATCH	—	Unspecified	—	—
11/07/17	ORANGE/WATCH	—	Moderate	—	—
11/08/17	ORANGE/WATCH	—	Unspecified	—	—
11/09/17	ORANGE/WATCH	—	Unspecified	—	—
11/11/17	ORANGE/WATCH	—	Unspecified	—	—
11/12/17	ORANGE/WATCH	Very small explosion	—	—	Very small explosion seen in local seismic and infrasound data
11/13/17	ORANGE/WATCH	—	Moderate	—	—
11/14/17	ORANGE/WATCH	Small explosion	Moderate	—	Small explosion detected with two local earthquakes 1 hour prior
11/16/17	ORANGE/WATCH	Small explosion	Weak	Possible small amount of ash emissions	Small explosion similar to size on 11/14/17
11/17/17	ORANGE/WATCH	—	—	—	Small earthquake swarm
11/30/17	ORANGE/WATCH	—	—	—	Few possibly local events
12/01/17	ORANGE/WATCH	—	—	—	Few possibly local events
12/03/17	ORANGE/WATCH	—	—	—	Few Possibly Local Events
12/04/17	ORANGE/WATCH	Small explosion	—	—	Small explosion only detected on closest station CLES
12/12/17	YELLOW/ADVISORY	Decline in activity	—	—	—
12/13/17	ORANGE/WATCH	Explosion	—	Ash cloud drifted east	Explosion detected by seismic and infrasound data
12/18/17	ORANGE/WATCH	Small explosion	—	—	Small explosion detected about four times smaller than event on 12/13/17
12/24/17	ORANGE/WATCH	—	—	—	Few possibly local events
12/25/17	ORANGE/WATCH	—	—	—	Few possibly local events
12/26/17	ORANGE/WATCH	—	Unspecified	—	Few possibly local events
12/29/17	ORANGE/WATCH	—	—	—	Few possibly local events
12/31/17	ORANGE/WATCH	—	Weak	—	—

broadband signal was recorded clearly in seismograph data and was also seen in infrasound data at stations CLES and CLCO for 10 minutes after the initial explosion. The extended infrasound signals were likely caused by jetting (continuous, vigorous gas emissions) after the destruction of the lava dome in the vent. The resulting ash plume drifted approximately 140 km (87 mi) to the southwest at an altitude of 4.6 km (15,000 ft) and was observed in visible Geostationary Operational Environmental Satellite imagery until nightfall. Satellite imagery just after the explosion showed that the dome was completely removed, and impact craters from ballistic dome fragments were formed on the upper flanks of the volcano. The Mount Cleveland summit crater was dome free through May 26.

On June 6, a series of repeating small low-frequency seismic events were recorded on seismograph station CLES, 3.5 km (2.1 mi) from the summit, but these events were not seen on nearby seismograph station CLCO, 15 km (9 mi) from the summit. The seismicity was consistent with lava dome growth, but poor viewing conditions prevented the confirmation of dome growth. On June 26, the Aviation Color Code and Volcano Alert Level was reduced from **ORANGE** and **WATCH** to **YELLOW** and **ADVISORY**, respectively, owing to the decline in activity.

On July 4, 11:19 UTC (03:19 AKDT), a moderate 10-minute eruption was detected by both seismograph and infrasound sensors, prompting the Aviation Color Code and Volcano Alert Level to be upgraded from **YELLOW** and **ADVISORY** to **ORANGE** and **WATCH**, respectively. This explosion differed from the previous explosion by being preceded by at least five low-frequency seismic events. Additionally, a burst of tremor was recorded 15 seconds prior to the onset of the main explosion (fig. 28).

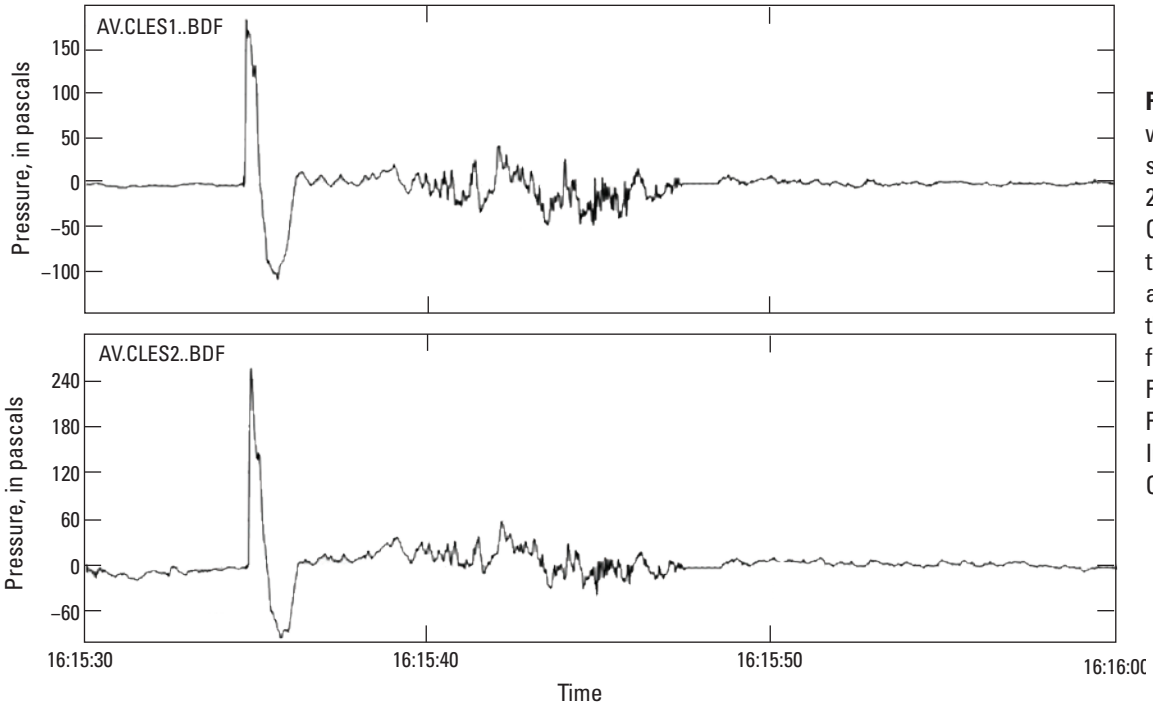


Figure 26. Infrasound waveform graphs showing the March 24, 2017, explosion of Mount Cleveland volcano at the station CLES located about 3.5 km (2.1 mi) from the summit. Modified from image by David Fee, University of Alaska Fairbanks Geophysical Institute-Alaska Volcano Observatory.

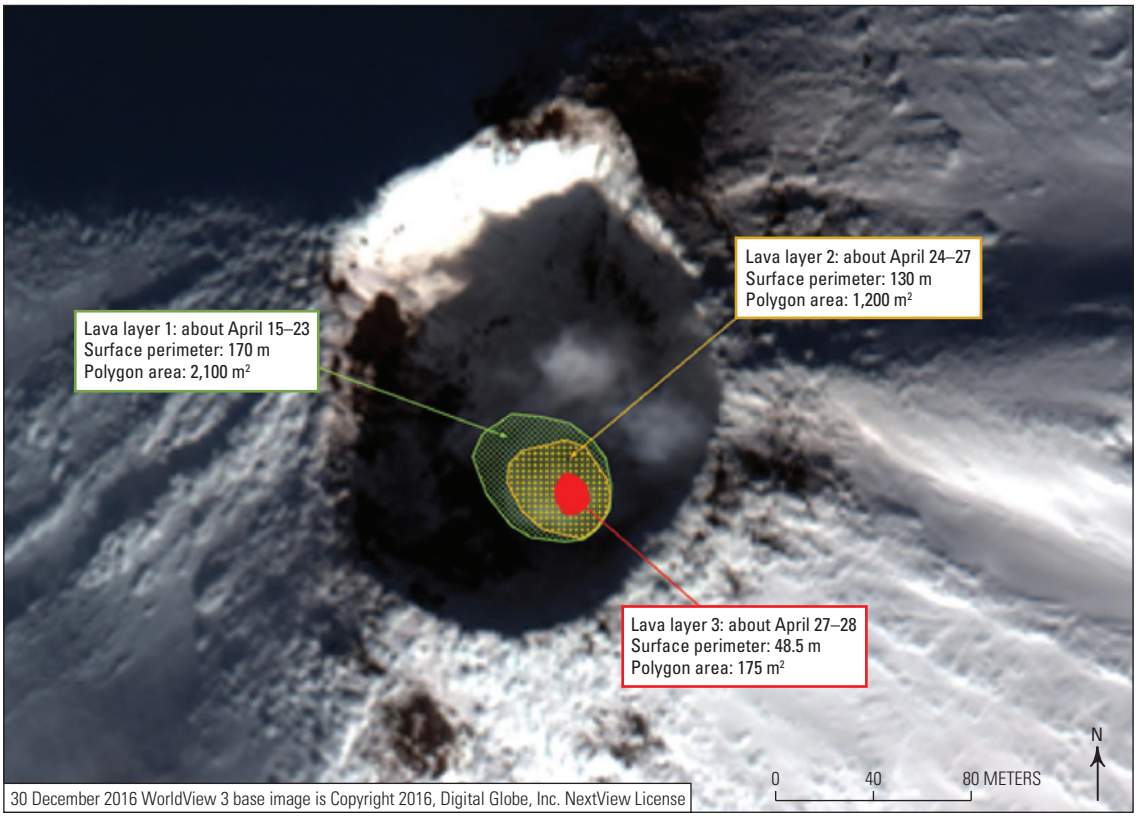


Figure 27. Worldview3 satellite base image and digital sketches of the three lava domes in Mount Cleveland's summit crater from April 15 to 28, 2017. Lava layer 1 represents the lowermost lava dome that formed about April 15–23. Lava layer 2 represents the second lava dome that formed about April 24–27. Lava layer 3 represents the topmost lava dome that formed about April 27–28. Modified from image by Rick Wessels, U.S. Geological Survey and Alaska Volcano Observatory.

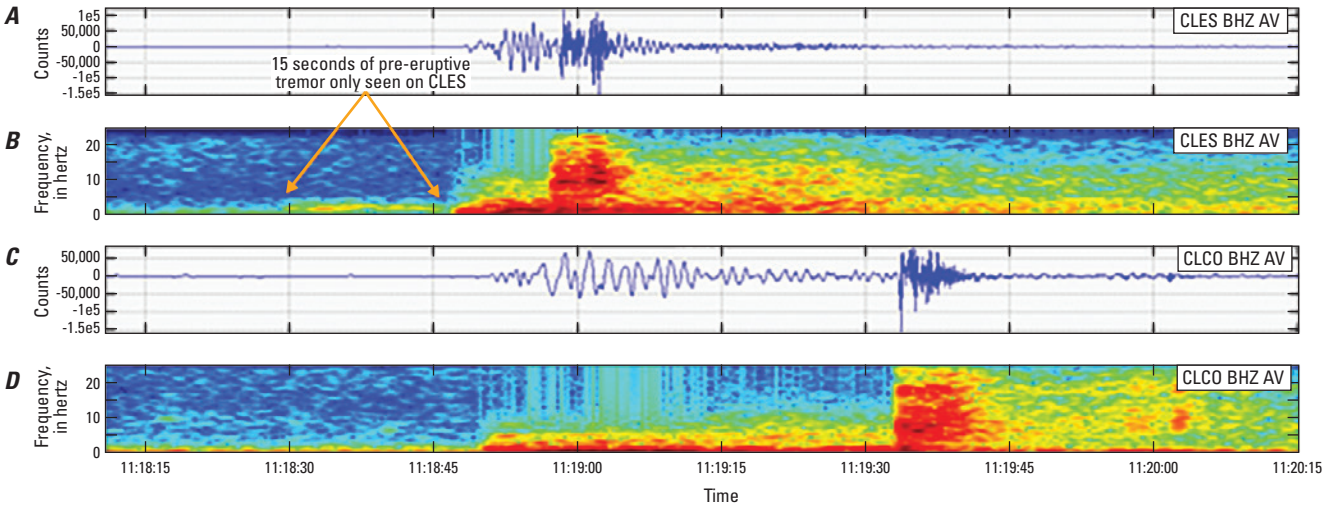


Figure 28. Seismic waveform (*A* and *C*) and spectrogram graphs (*B* and *D*) showing the July 4, 2017, explosion of Mount Cleveland. Arrows point to the 15-second duration of pre-eruptive tremor seen on station CLES. Stations CLES and CLCO are 3.5 km (2.1 mi) and 15.4 km (9.2 mi) away from Mount Cleveland, respectively. Modified from image by John Lyons, U.S. Geological Survey-Alaska Volcano Observatory.

Satellite data from July 17 show that a new 25-m- (80-ft-) diameter lava dome was emplaced in the summit crater. It grew to more than 50 m (160 ft) in diameter with increased vertical inflation by August 1. Satellite imagery on August 7 showed no change in the lava dome from the previous satellite images, signifying that lava effusion had ceased. This small lava dome was observed by an AVO field crew during an overflight of Mount Cleveland on August 17 (fig. 29).

The fourth explosion in 2017 occurred on August 22 at 18:43 UTC (10:43 AKDT). The oneminute explosion had no precursory activity and was detected by both seismograph and infrasound sensors. Satellite imagery suggested that this explosion, like the previous three eruptions, removed the existing lava dome. The crater remained empty for more than a month until another explosion occurred on September 26, 01:47 UTC (September 25, 17:47 AKDT). The initial blast lasted 3 seconds, but after a brief 15-second pause, a roughly 2-minute-long broadband signal was detected in both seismic and infrasound data suggesting an initial vulcanian blast that was followed by continuous emissions (fig. 30). An ash cloud was visible in a NOAA-19 satellite image south of Mount Cleveland for 30 minutes after the explosion.

Figure 29. Photograph of a small lava dome in the summit crater of Mount Cleveland volcano on August 17, 2017, taken by Janet Schaefer (Alaska Division of Geological & Geophysical Surveys and Alaska Volcano Observatory) during a summit overflight.

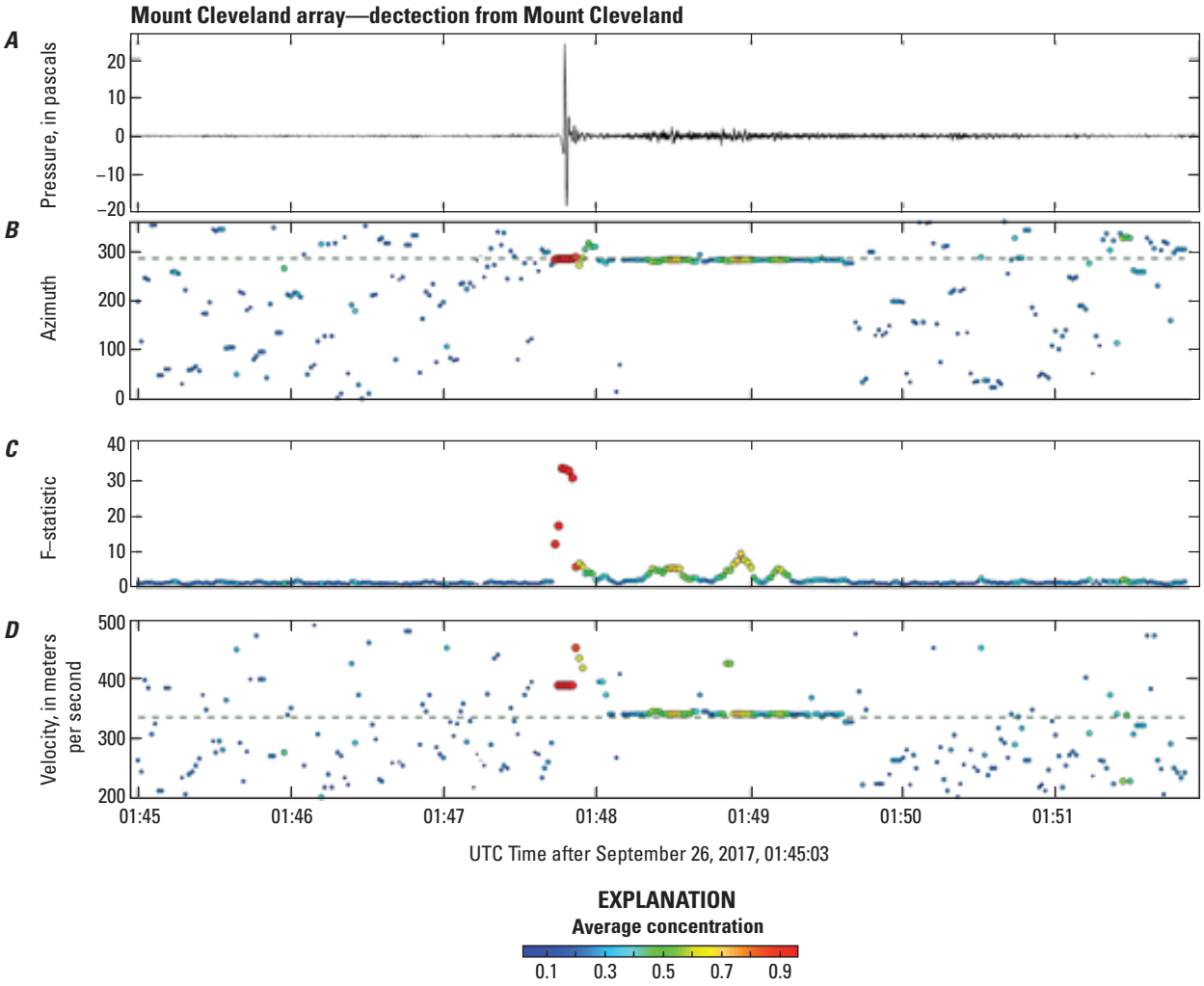


Figure 30. Several graphs of processed data from the station CLCO infrasound array for the September 26, 2017, Mount Cleveland explosion showing an initial blast followed by a brief pause and 2 minutes of jetting. *A*, Simple pressure plot showing when the explosion occurred. *B*, Plot showing the azimuth of the signal with respect to station CLCO. *C*, Plot showing the F-statistic, which is an algorithm for detecting explosion signals above the noise. *D*, Plot showing the velocity of the signal. Modified from image by John Lyons, U.S. Geological Survey and Alaska Volcano Observatory.

The explosions later in 2017 were smaller and more frequent than those at the beginning of the year. Two small explosions occurred on September 28 at 13:19 and 13:58 UTC (05:19 and 05:58 AKDT, respectively) with amplitudes approximately 100 times smaller than the explosion 2 days prior. Another small explosion occurred on October 1, at 13:05 UTC (05:05 AKDT).

Satellite observations on October 1 showed a new lava dome greater than 70 m (230 ft) in diameter, and by October 15, the dome had doubled in area to cover 12,500 square meters (m^2;134,500 square feet [ft^2]) at a height of 15–20 m (50–65 ft). The dome continued to increase in both area and height through October 23. On October 28, a small, short-duration (30 sec) explosion occurred at 18:45 UTC (10:45 AKDT). A smaller explosion occurred on October 30 at 11:20 UTC (03:20 AKDT). Satellite imagery suggests that the October explosions removed a portion of the central vent from the dome. A small explosion occurred on November 12 at 09:56 UTC (00:56 AKST) followed by a similar-sized explosion on November 14 at 12:15 UTC (03:15 AKST). The latter event was preceded by two local earthquakes 1 hour prior to the explosion. Another small explosion occurred on November 16 at 22:44 UTC (13:44 AKST) that was similar to the previous events. Between November 17, 22:00 UTC (13:00 AKST) and November 18, 08:20 UTC (November 17, 23:20 AKST), a small volcanic-tectonic earthquake swarm occurred in the vicinity of Mount Cleveland, but its significance to the Mount Cleveland eruption sequence has yet to be determined. A small explosion occurred on December 4, 07:21 UTC (December 3, 22:21 AKST) that was seen just at the closest seismograph station to the summit (CLES).

Decreased activity following the December 4, 2017, explosion was interpreted as cessation of lava effusion at Mount Cleveland, which prompted AVO to change the Aviation Color Code and Volcano Alert Level from **ORANGE** and **WATCH** to **YELLOW** and **ADVISORY**, respectively, on December 12. However, less than a day later, another explosion occurred on December 13 at 13:20 UTC (04:20 AKST) necessitating that the Aviation Color Code and Volcano Alert Level to be returned to **ORANGE** and **WATCH**, respectively. The ash cloud from this eruptive event was visible in satellite imagery and drifted east at an altitude of 6.1 km (20,000 ft; fig. 31). The final explosion of 2017 occurred on December 18 at 03:17 UTC (December 17, 18:17 AKST), and like recent explosions was smaller than the explosions in early 2017. The Aviation Color Code and Volcano Alert Level remained at **ORANGE** and **WATCH**, respectively, for the remainder of the year.

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

Great Sitkin Volcano

GVP# 311120
52.0765° N., 176.1109° W.
1,740 m (5,709 ft)

Great Sitkin Island, Andreanof Islands, Aleutian Islands

EARTHQUAKE SWARM, EXPLOSION

Between late July 2016 and January 2018 Great Sitkin Volcano experienced increased earthquake activity, anomalous gas emissions from the summit crater, and two apparent small phreatic explosions that occurred on January 11 and July 22, 2017. These were the first two explosions detected at Great Sitkin Volcano since monitoring began in 1999. Earthquake hypocenters in 2017 were chiefly clustered beneath the summit crater and ranged in depth from the surface to 10 km, although some events were located at depths as great as 35 km. Earthquake magnitudes ranged from $M_L = -1.5$ to 2.83, although most events had magnitudes less than zero. The magnitude 2.8 occurred on September 29 at a depth of 1.5 km under the west flank of Great Sitkin Island (fig. 32).

On July 30, 2016, a marked increase in earthquake activity began at Great Sitkin Volcano that continued through early August. These earthquakes appeared to have initiated at depths of 15 to 18 km and then were followed within 12 hours by earthquakes with hypocenters shallower than 4 km (2.5 mi)

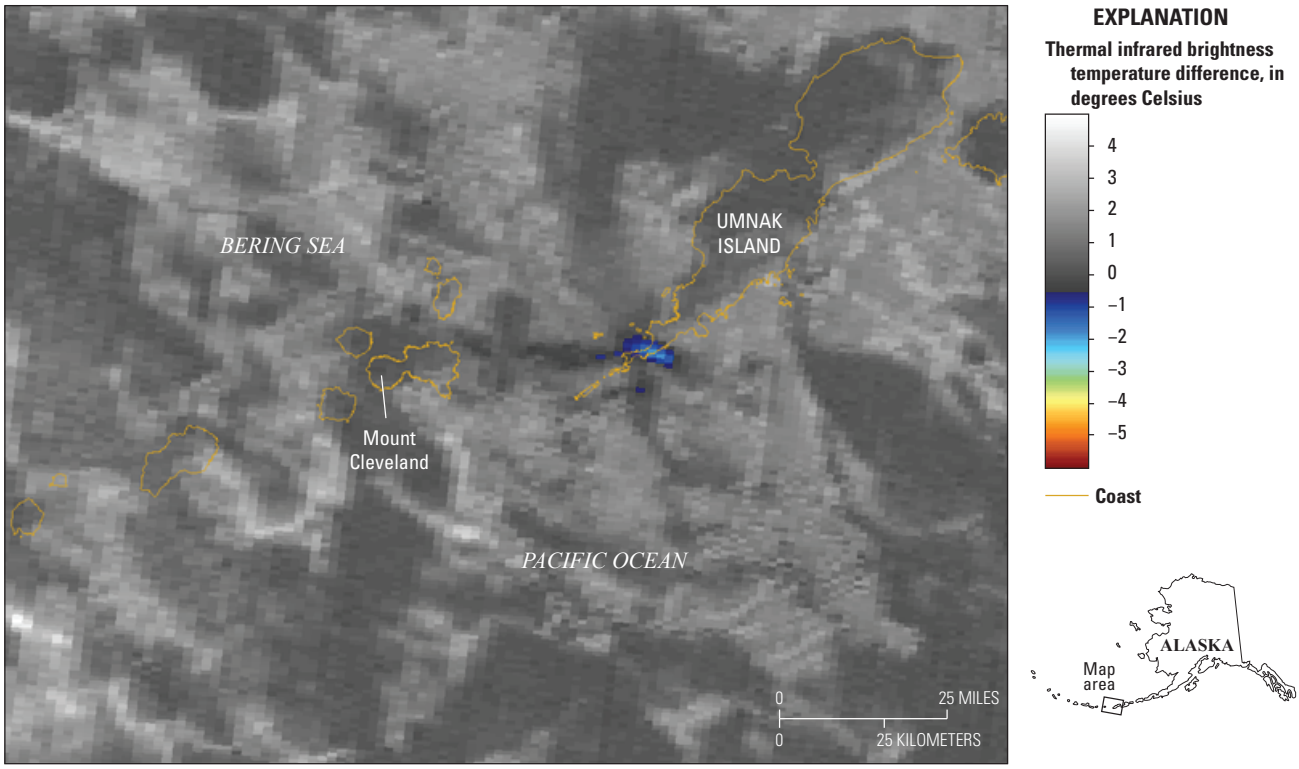


Figure 31. NOAA-19 thermal infrared brightness temperature difference image showing the December 13, 2017, eruption cloud drifting east (blue pixels) from Mount Cleveland. Modified from image by Tim Orr, U.S. Geological Survey and Alaska Volcano Observatory.

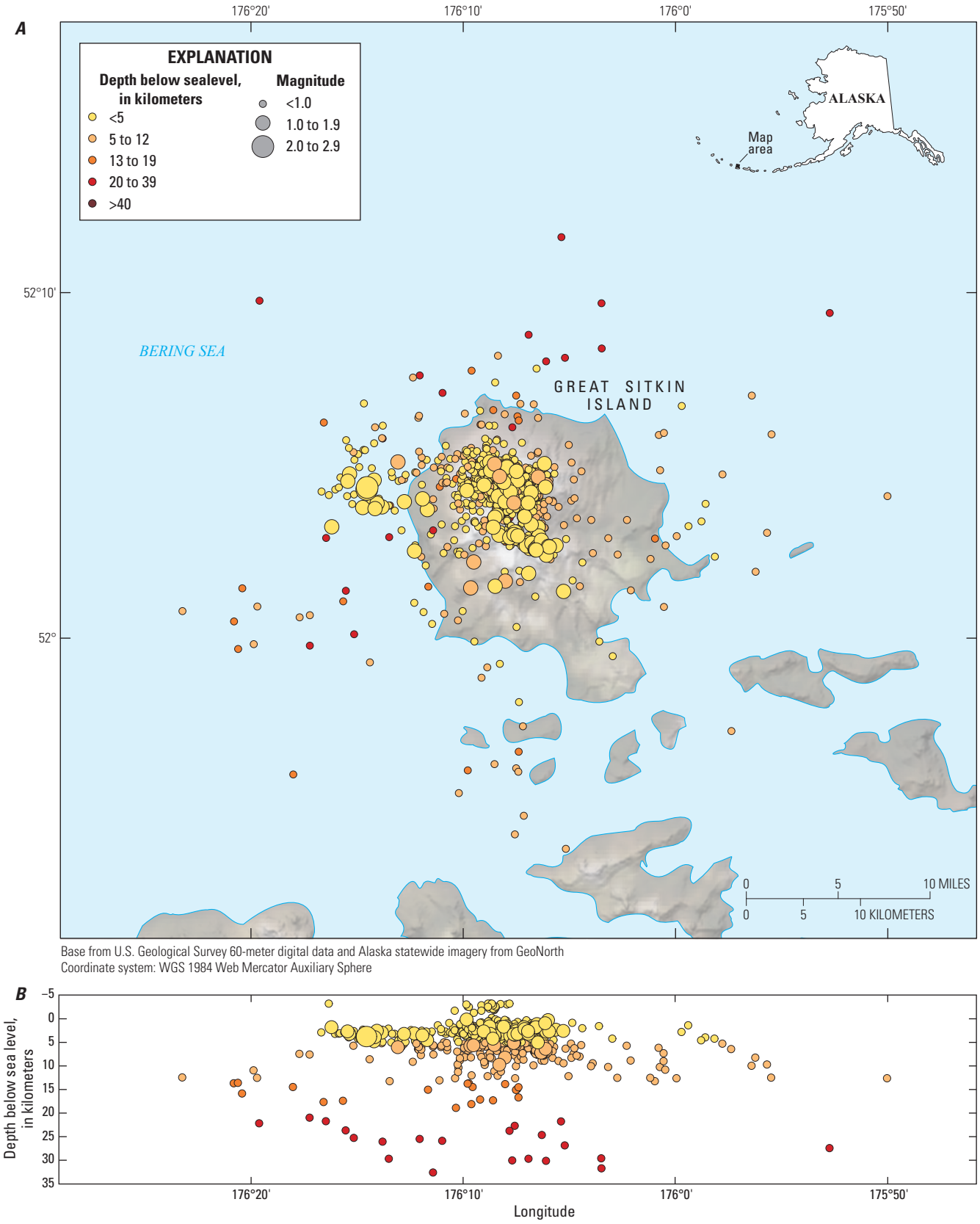


Figure 32. Map (*A*) and graph (*B*) of Great Sitkin Volcano showing earthquakes located in 2016 and 2017. The largest earthquake in this period, a M_L = 2.8 on September 29, 2017, occurred off the west flank of Great Sitkin Island.

depth (fig. 33). The deeper earthquakes on July 30 had a variety of waveform characteristics that range from broad-spectrum volcanic-tectonic earthquakes to low-frequency or long-period waveforms with extended codas suggesting that some were deep long-period (DLP) events (fig. 34). DLP earthquakes often indicate magma movement at depth and have been interpreted as recharge of shallow magma reservoirs (Power and others, 2004). After August 8, earthquake activity returned to background levels through the remainder of 2016.

On January 11, 2017, at 06:05 UTC (January 10, 21:05 AKST) a seismic signal with a high amplitude onset and an extended coda that contained numerous small earthquakes was observed only by stations on Great Sitkin Island (fig. 34). This event was interpreted as a small explosion despite the lack of confirming satellite imagery showing a gas or ash plume and detected associated infrasound signal. This event was followed by approximately 20 small ($M_L < 0.2$) locatable earthquakes beneath the northwest flank of Great Sitkin Volcano with depths ranging from the summit crater to 8.1 km (4.9 mi). After this small earthquake swarm, there was relative seismic quiescence until mid-March when small earthquakes resumed beneath the Great Sitkin Volcano summit crater at depths of 3 to 11 km (1.8 to 6.6 mi). This activity continued until late April (fig. 35).

In early June, shallow earthquake activity began a slow increase that continued until an explosive event at 00:17 UTC on July 22 (July 21, 16:17 AKDT). This event had an emergent onset, and the signal slowly increased until it clipped the maximum amplitude of the sensor after 6 minutes (fig. 36). Like the January explosion, this event did not produce a detectable ash plume visible in satellite imagery or a detectable infrasound signal. In response to increased unrest at Great Sitkin Volcano AVO issued an Information Statement describing the activity on July 27 but retained the Aviation Color Code and Volcano Alert Level at **GREEN** and **NORMAL**, respectively. After the July 22 explosion, seismicity remained elevated until mid-November (fig. 33).

On November 19, 2017, increased gas emissions from the volcano's summit crater was easily visible from the town of Adak, Alaska, and AVO received reports and photographs from concerned citizens, 42 km (26 mi) to the southwest (fig. 37). On November 22, after observations of increased degassing, AVO

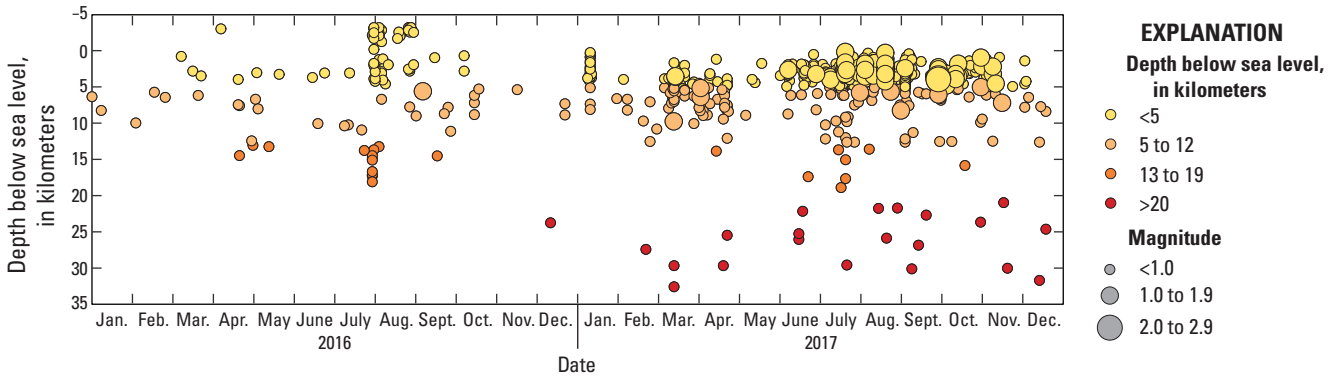


Figure 33. Plot showing earthquake focal depth versus time for January 1, 2016, through December 31, 2017, on Great Sitkin Volcano.

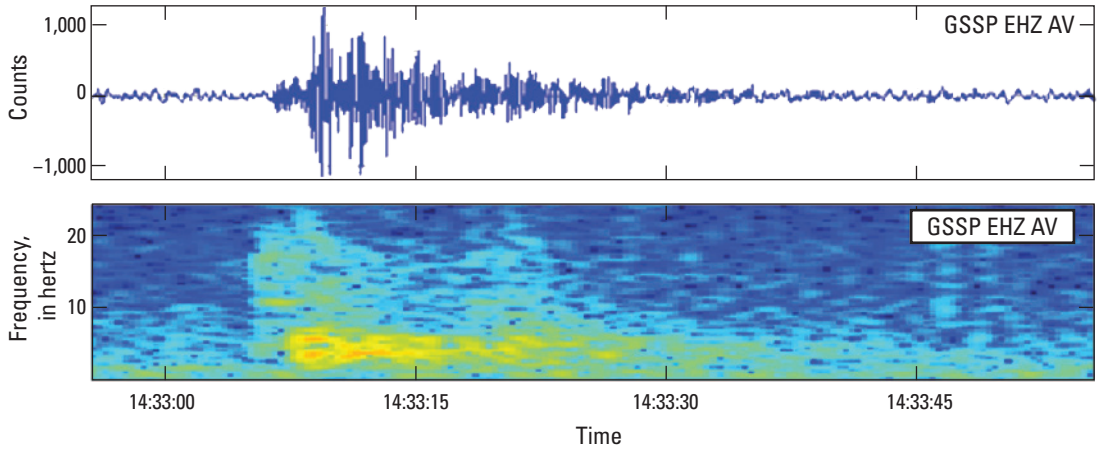


Figure 34. Waveform and spectrogram showing a magnitude –0.40 deep long-period event located under the north flank of Great Sitkin Volcano at 14:53 UTC on July 30, 2016, at a depth of 16.7 km.

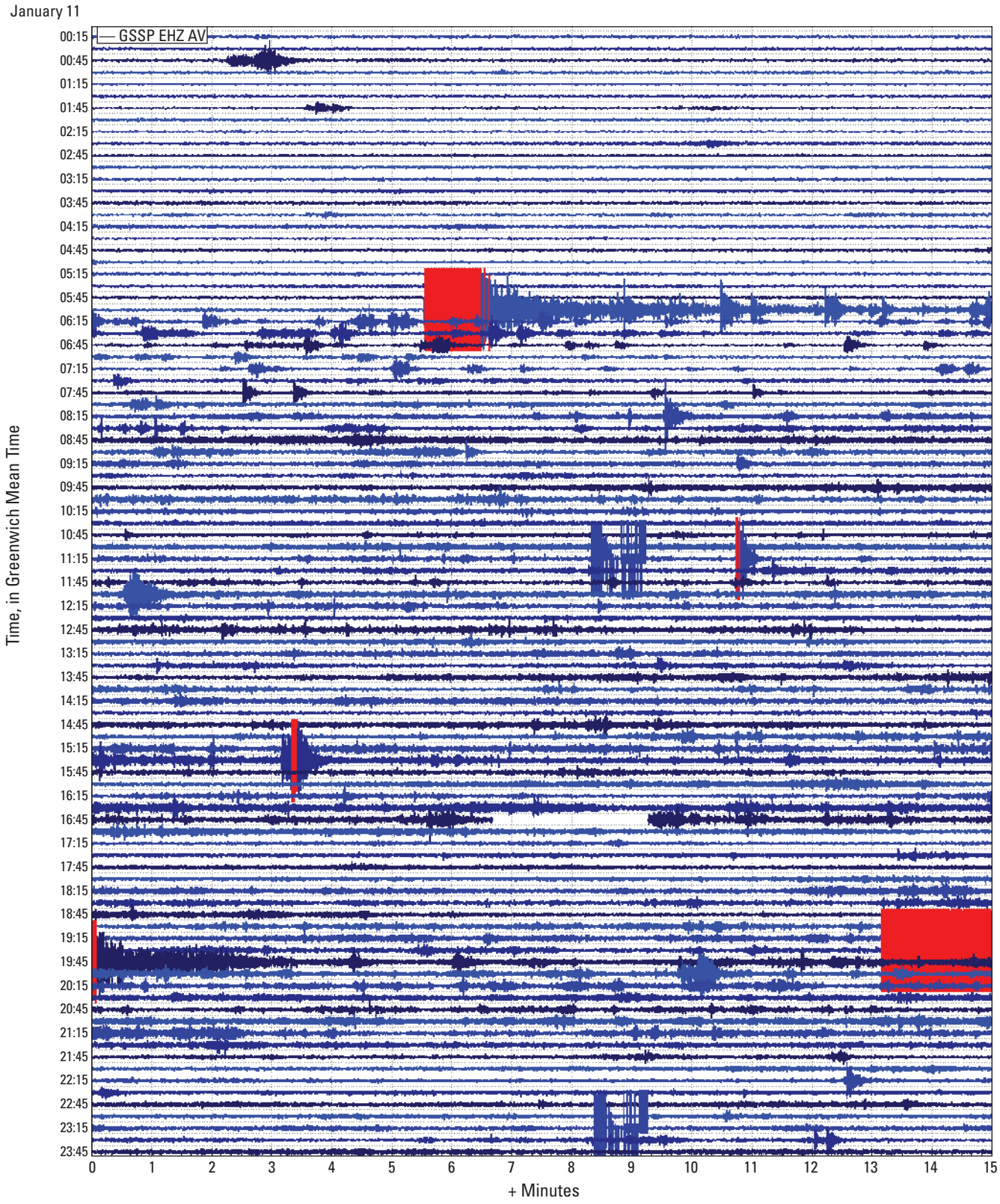


Figure 35. Seismogram of seismograph station GSSP on January 11, 2017. Suspected explosion occurs at 06:05 UTC (January 10, 221:05 AKST).

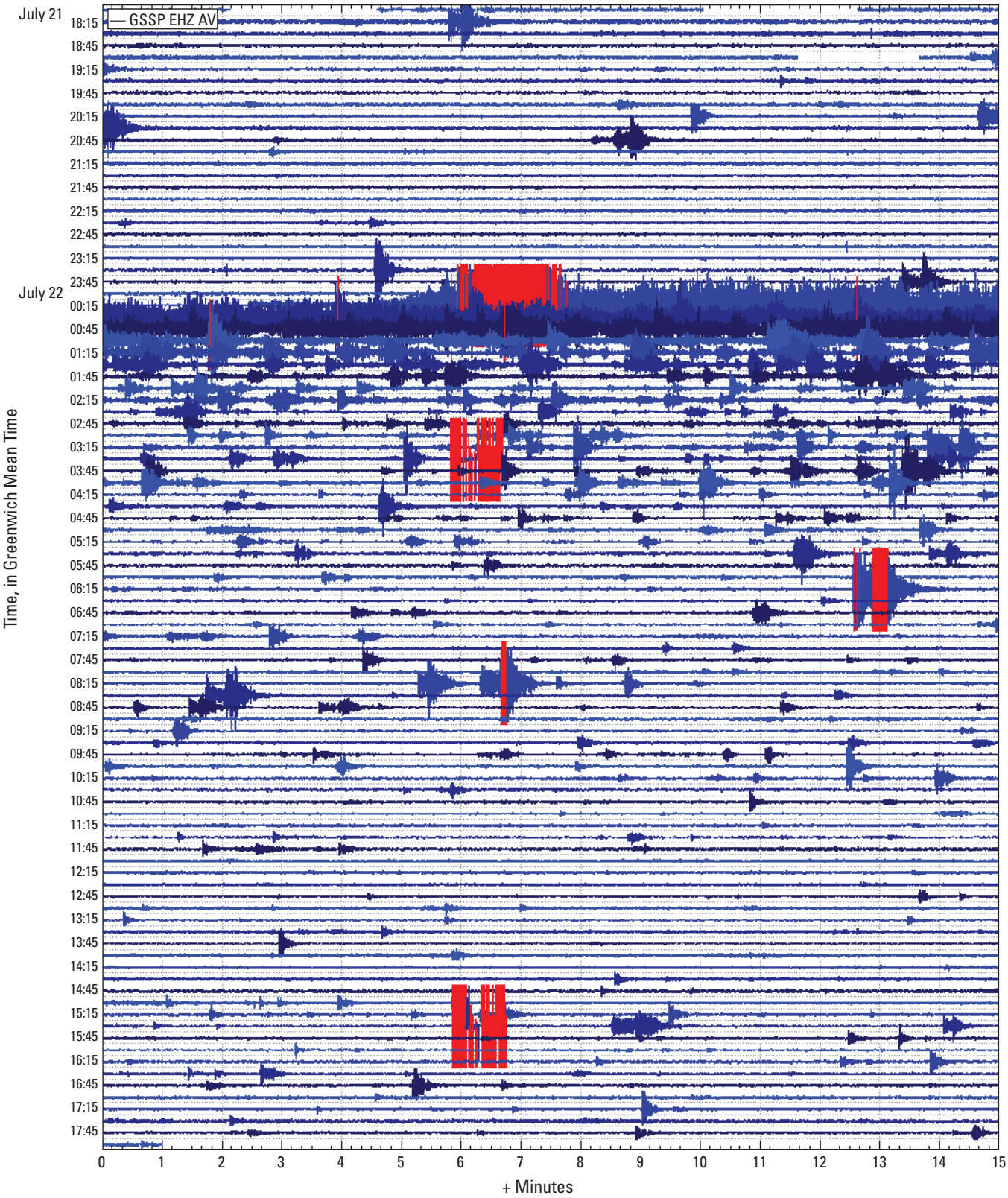


Figure 36. Seismogram of seismograph station GSSP showing 24-hours of data starting at 18:00 UTC (08:00 AKDT) on July 21, 2017. Suspected explosions begin at 00:17 UTC (July 22, 16:17 AKDT) and are followed by numerous small earthquakes.

Figure 37. Photograph of Great Sitkin Volcano as seen from Adak, Alaska, 42 km (26 mi) to the southwest, showing gas plume from the summit crater on November 19, 2017. Photograph by Alain Beauparlant.

raised the Aviation Color Code to **YELLOW** and Volcano Alert Level to **ADVISORY**. Unrest characterized by increased crustal seismicity, degassing, and small explosive events continued into 2018. When the activity returned to background levels, the Aviation Color Code and Volcano Alert Level were lowered to **GREEN** and **NORMAL**, respectively, on January 18, 2018.

Great Sitkin Volcano is a basaltic-andesite volcano that constitutes most of the north half of Great Sitkin Island in the Andreanof Islands group of the central Aleutian Islands (Waythomas and others, 2003). The volcano consists of an older collapsed volcano and a younger parasitic cone with a 2–3-km- (1.2–1.8-mi-) diameter summit crater. A steep-sided dome occupies the center of the crater. Great Sitkin Volcano erupted at least three times in the 20th century and most recently with a small phreatic eruption in 2018. In 1974, a lava dome formed in the crater accompanied by at least one ash cloud that reached 3 km (10,000 ft; Miller and others, 1998). A poorly documented eruption in 1945 also produced a lava dome that was partially destroyed by the 1974 eruption. Within the past 280 years, a large explosive eruption produced pyroclastic flows that partially filled a valley on the southwest flank (Waythomas and Miller, 2003).

Takawangha Volcano

GVP# 311090
51.867° N., 178.027° W.
1,449 m (4,754 ft)

Tanaga Island, Andreanof Islands, Aleutian Islands

EARTHQUAKE SWARM

Tanaga Island, home to both Tanaga and Takawangha volcanoes, had an earthquake swarm in January 2017 that prompted additional monitoring by AVO staff. On January 23, an energetic earthquake swarm occurred 7 km (4 mi) east-southeast of Takawangha volcano near Gusty Bay (fig. 38), an area where three previous earthquake swarms have been recorded in October 2005, May 2008, and June 2009. AVO raised the Aviation Color Code to **YELLOW** and Volcano Alert Level to **ADVISORY** for Takawangha volcano as a precaution. During the first 24 hours of the earthquake swarm, the seismicity waxed and waned. On January 25, the seismicity began to decline until it approached background

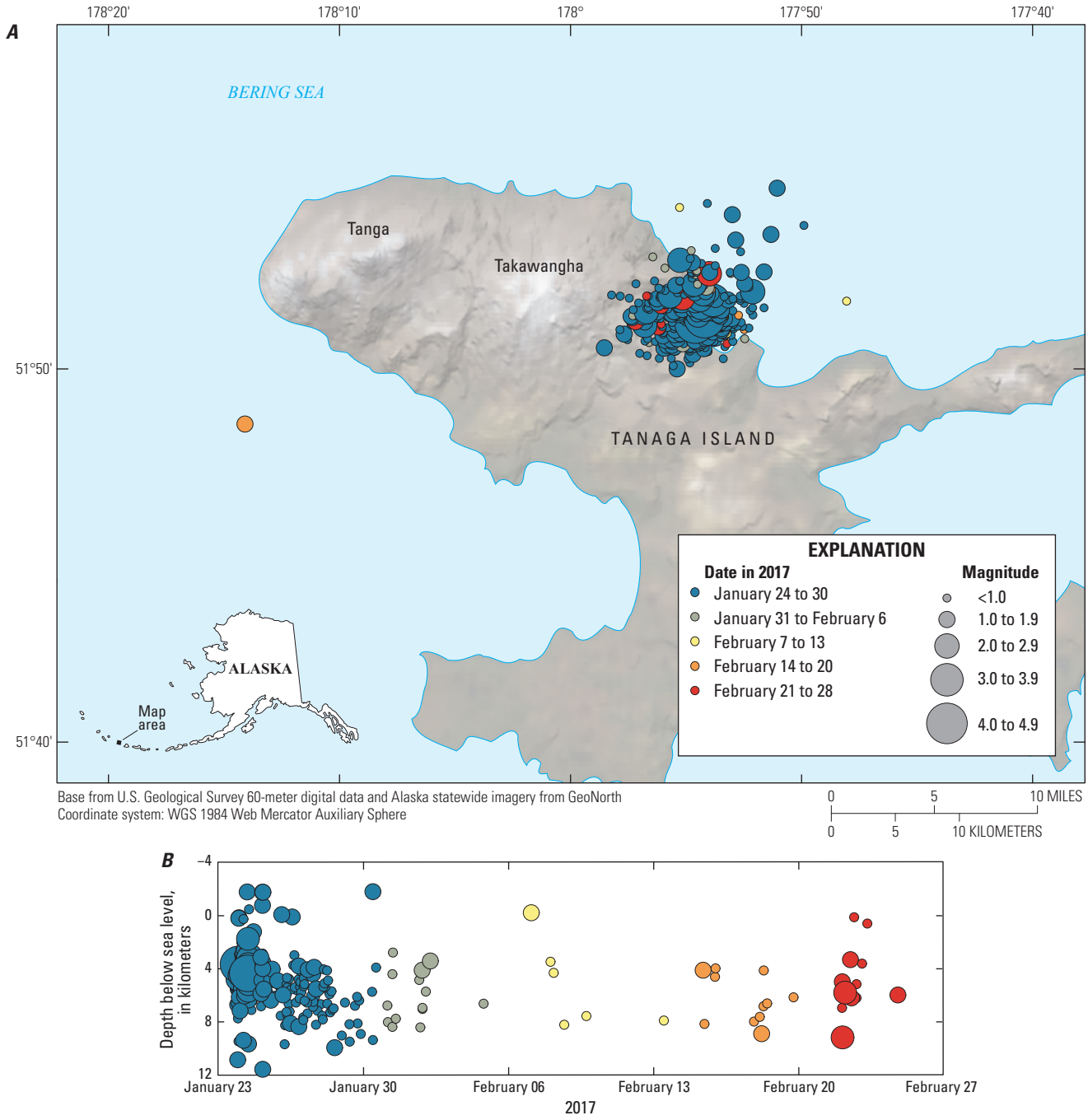


Figure 38. Map (*A*) and graph (*B*) earthquake of Tanaga Island showing earthquakes located from January 23 to February 28, 2017. Earthquake symbols are colored by date and size by magnitude.

levels by the end of the month. The earthquakes occurred in a spherical volume at depths between 2 and 8 km (1.2 and 4.8 mi), similar to the three previous swarms. There were four earthquakes of greater than M_L 3 in the nearly 400 earthquakes located in the brief swarm. On February 8, AVO reduced the Aviation Color Code and Volcano Alert Level to **GREEN** and **NORMAL**, respectively, where it remained for the rest of the year. Throughout February a small but significant number of earthquakes continued to be located in the Gusty Bay region. In March seismicity returned to background levels.

Takawangha volcano is a remote, 1,449 m (4,754 ft)-high stratovolcano located on the northeast part of Tanaga Island, roughly 95 km (59 miles) west of Adak, Alaska, in the Andreanof Islands (fig. 39). Takawangha volcano's summit is mostly ice-covered, except for five young craters that have erupted ash and lava flows in the last few thousand years. Parts

of the volcano's edifice are hydrothermally altered and may be unstable, which may cause localized debris avalanches from its flanks. Takawangha volcano lies across a topographic saddle from historically active Tanaga Volcano to the west. No historical eruptions are known from Takawangha; however, field work shows that recent eruptions have occurred, and it is possible that historical eruptions attributed to Tanaga may instead have come from Takawangha (Coombs and others, 2007).

Figure 39. U.S. Geological Survey photograph of Takawahgna volcano from the summit on the east side of Tanaga Volcano on August 28, 2003. Photograph by Michelle Coombs.

Mount Gareloi

GVP# 311070
51.789° N., 178.794° W.
1573 m (2,625 ft)

Gareloi Island, Andreanof Islands, Aleutian Islands

GAS PLUME

On March 28, 2017, a NASA scientist reported that that minor activity had been occurring at Mount Gareloi. An investigation of this observation concluded that there had been no change in the activity at Mount Gareloi but that a weather phenomenon interacted with persistent degassing to form the artifacts in the satellite images that the NASA scientist referenced in his report. The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively.

The amount of located seismicity at Mount Gareloi increased significantly in 2016 and remained elevated in 2017. A tectonic earthquake series 20–30 km (12–18 mi) southeast of Mount Gareloi began in 2016 and increased in activity in 2017. A second tectonic earthquake series, 10–15 km (6–9 mi) west of Mount Gareloi occurred only in 2016 and was nearly absent in 2017. The number of earthquakes on or near Gareloi Island was significantly greater in 2017 with the majority of these earthquakes occurring in a week-long period at the end of November. The ambient noise at the Gareloi Island seismograph stations was low during this time, and a number of small low-frequency earthquakes were located. Earthquakes similar to those in late November 2017 are often too small to be located due to the usually high seismic noise levels and have been detected frequently since the installation of the seismograph network. Independent signs of unrest were not observed coincident with the November swarm or at any time in 2017. The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively.

Mount Gareloi (fig. 40), which makes up most of Gareloi Island, is a stratovolcano 10 km (6 mi) by 8 km (4.8 mi) in diameter at its base that consists of two summits, separated by a narrow saddle (Miller and others, 1998). Both summits have been historically active (Coombs and others, 2012), and several prominent fumaroles are active at the south summit. Thirteen younger craters, from 80 to 1600 m (260 to 5250 ft) in diameter, are aligned along a south-southeast trending fissure that extends to the south summit. These craters formed during a major explosive eruption in 1929 that also produced four blocky lava flows and a blanket of grassy andesitic tuff that covers an area roughly 2.5 by 5 km (1.6 by 3.1 mi) on the volcano's southeast flank (Coats, 1959).

Figure 40. U.S. Geological Survey photograph looking northwest to Mount Gareloi in August 2013. Photograph by Christina Neal.

Kiska Volcano

GVP# 311020
52.103° N., 177.604° E.
1,220 m (4,003 ft)

Rat Islands, Aleutian Islands

GAS PLUME

On November 1, 2017, a commercial airline pilot reported minor smoke coming from the side of an undetermined volcano in the western Aleutian Islands (fig. 41). Descriptions and photos of the observation suggested that the activity was coming from fumaroles on the northwest flank of Kiska Volcano. This activity

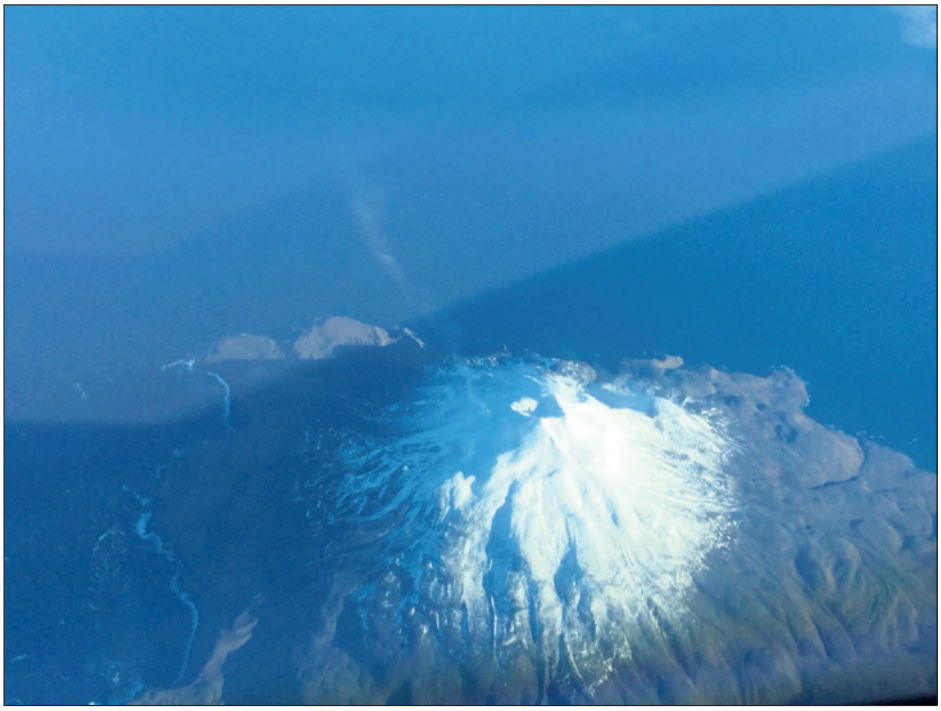


Figure 41. Photograph of Kiska Volcano showing gas plume from fumarolic field on the volcano's northwest flank on November 1, 2017. Photograph by Charles Krogsgaard.

is typical of that known to Kiska Volcano. This fumarole field is documented by AVO and other observers, and degassing has been noted on multiple occasions from this location for decades when scientists conducted field work on Kiska Island. The Aviation Color Code and Volcano Alert Level remained at **UNASSIGNED** throughout the year for Kiska Volcano.

Kiska Volcano is a stratovolcano, 8.5 by 6.4 km in diameter at its base, that is situated on the north end of Kiska Island (Miller and others 1998). A slightly elliptical crater, about 0.4 km in diameter and breached on the north, occupies the volcano summit. A 30-m- (100-ft-) high parasitic cinder cone originally formed in 1962 near sea level at Sirius Point, and an older parasitic cone, now leveled by marine erosion, formed at sea level 5.6 km (3.4 mi) southwest of the summit of Kiska Volcano. Kiska is underlain and flanked on the south by the remains of an older composite volcano (Marlow and others, 1973) that has been glacially eroded, but the older volcano shows no evidence of glacial dissection (Coats, 1961).

Acknowledgments

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Glossary of Selected Terms and Acronyms

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.

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

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.

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

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

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

intracaldera Refers to something within the caldera.

juvenile Volcanic material created from magma reaching the surface.

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.

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 gas-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.

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 mean a higher resolution.

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

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.

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.

Surtseyan eruption A type of phreatomagmatic eruption that often takes place in shallow water seas.

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

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

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).

Volcano 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.

Aviation Color Codes	
GREEN	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.
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 but poses limited hazards.
RED	Eruption is imminent with significant emission of volcanic ash into the atmosphere likely. **Or:** Eruption is underway or suspected with significant emission of volcanic ash into the atmosphere (ash-plume height specified, if possible).

Appendix 2. Compilation of volcanoes included in Alaska Volcano Observatory Annual Summaries by year, 1992–2017.

Table 2.1. Compilation of volcanoes included in Alaska Volcano Observatory Annual Summaries by year 1992–2017.

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

Volcanoes mentioned
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 Island)
Kanaga
1994
Sanford
Iliamna
Katmai Group (Martin, Mageik, and Trident)
Veniaminof
Kupreanof
Shishaldin
Makushin
Cleveland
Kanaga
1995
Katmai Group (Martin)
Veniaminof
Shishaldin
Makushin
Kliuchef (Atka Island)
Kanaga
1996
Wrangell
Iliamna
Katmai Group (Martin, Mageik, Trident, Katmai)
Pavlof
Shishaldin
Westdahl
Akutan
Amukta
Korovin (Atka)
Kanaga
1997
Wrangell
Sanford
Shrub Mud
Iliamna
Katmai Group (Martin, Mageik, Snowy, and Kukak)
Chiginagak
Pavlof
Shishaldin
Okmok
Cleveland
Amukta
1998
Shrub Mud
Augustine
Becharof Lake
Chiginagak
Shishaldin
Akutan
Korovin (Atka Island)
1999
Wrangell
Shrub Mud
Iliamna
Veniaminof
Pavlof
Shishaldin
Vsevidof
2000
Wrangell
Katmai Group (Snowy)
Chiginagak
Shishaldin
2001
Katmai Group (Snowy and Kukak)
Pavlof
Frosty
Shishaldin
Makushin
Okmok
Cleveland

Table 2.1.—Continued

Volcanoes mentioned
Great Sitkin
2002
Wrangell
Katmai Group (Martin and Mageik)
Veniaminof
Mount Hague (Emmons Lake Caldera)
Shishaldin
Great Sitkin
2003
Wrangell
Redoubt
Iliamna
Augustine
Katmai Group (Mageik)
Veniaminof
Pavlof
Mount Hague (Emmons Lake Caldera)
Shishaldin
Akutan
2004
Crillon (non-volcanic peak)
Spurr
Katmai Group (Martin)
Veniaminof
Shishaldin
Westdahl
2005
Spurr
Iliamna
Augustine
Katmai Group (Martin)
Chiginagak
Aniakchak
Veniaminof
Pavlof and Hague
Shishaldin
Cleveland
Korovin
Kasatochi
Tanaga
2006
Klawasi Mud
Spurr
Augustine
Fourpeaked
Katmai Group (Martin)
Veniaminof
Cleveland
Korovin
Kasatochi
2007
Redoubt
Augustine
Fourpeaked
Veniaminof
Pavlof
Akutan
Cleveland
Korovin
2008
Redoubt
Aniakchak
Veniaminof
Shishaldin
Okmok
Cleveland
Kasatochi
2009
Sanford
Redoubt
Fourpeaked
Aniakchak
Veniaminof
Shishaldin Volcano
Okmok
Cleveland
2010
Wrangell
Sanford
Redoubt
Fourpeaked
Katmai Group (Martin)
Becharof Lake
Aniakchak
Veniaminof
Westdahl
Makushin
Cleveland
Kasatochi
2011
Wrangell
Sanford
Redoubt
Fourpeaked
Aniakchak
Veniaminof
Makushin
Westdahl

Table 2.1.—Continued

Volcanoes mentioned
Cleveland
Kasatochi
2012
Wrangell
Spurr
Redoubt
Iliamna
Augustine
Fourpeaked
Katmai Group (Martin)
Aniakchak
Cleveland
Kanaga
Little Sitkin
2013
Wrangell
Redoubt
Iliamna
Augustine
Fourpeaked
Peulik
Aniakchak
Veniaminof
Pavlof
Shishaldin
Akutan
Makushin
Okmok
Cleveland
Korovin Volcano
Great Sitkin
Gareloi
2014
Spurr
Redoubt
Iliamna
Fourpeaked
Katmai Group (Katmai, Novarupta, and Martin)
Chiginagak
Aniakchak
Veniaminof
Pavlof
Shishaldin
Akutan
Okmok
Recheshnoi
Cleveland
Korovin
Kanaga
Semisopochnoi
2015
Spurr
Redoubt
Augustine
Iliamna
Katmai Group (Katmai, Novarupta)
Ugashik and Peulik
Aniakchak
Veniaminof
Kupreanof
Pavlof
Shishaldin
Recheshnoi
Cleveland
Semisopochnoi
2016
Wrangell
Spurr
Iliamna
Augustine
Fourpeaked
Katmai Group (Novarupta)
Aniakchak
Pavlof
Frosty
Shishaldin
Makushin
Bogoslof
Okmok
Cleveland
Korovin
2017
Spurr
Redoubt
Iliamna
Augustine
Katmai (Novarupta)
Pavlof
Shishaldin
Akutan
Makushin
Bogoslof
Okmok
Cleveland
Great Sitkin
Takawangha
Gareloi
Kiska

Table 2.2. Compilation by volcano for particular years included in Alaska Volcano Observatory Annual Summaries, 1992–2017.

[Volcanic centers are listed in geographical order from northeast to southwest along the Wrangell-Aleutian volcanic arc. Virgules are used when the exact source of activity is unknown. 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
	2016	Discolored summit
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
Klawasi Group (mud volcanoes)		
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	Suplinian 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
	2016	Earthquake swarm
	2017	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, ashfall
	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
	2017	Steaming
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

Table 2.2.—Continued

Volcano	Year Mentioned	Type of Activity
Iliamna—Continued	2003	Avalanche
	2005	Rock avalanche
	2012	Fumarolic plume, seismic swarms, avalanches
	2013	Avalanches
	2014	Avalanches
	2015	Large tectonic earthquake
	2016	Fumarolic activity; landslide
	2017	Minor snow and debris flow
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
	2016	Seismic swarm
	2017	Seismic 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
	2016	Seismic swarm
Katmai Group		
Mageik	1992	Anomalous cloud
Martin/Mageik/Trident	1994	Plume-like cloud
Martin	1995	Large steam plume
Martin/Mageik/Trident/ and Katmai	1996	Anomalous seismicity
Martin, Mageik, Snowy, and Kukak	1997	PIREPS of ash and steam plumes
Snowy	2000	Steaming hole in glacier
Snowy and Kukak	2001	Steaming hole in glacier
Martin and Mageik	2002	Steam plume
Mageik	2003	Steaming, large cloud of resuspended ash
Martin	2004	Large steam plume
	2005	Steam cloud, resuspended ash, new crater?
	2006	Earthquake swarm
	2010	Resuspended ash
	2012	Elevated seismicity, fumarolic plumes
Katmai, Novarupta, and Martin	2014	Resuspended 1912 ash; earthquake swarm, vapor plume
Katmai and Novarupta	2015	Resuspended 1912 ash
	2016	Resuspension of 1912 ash; deployment of particulate monitors
	2017	Resuspended 1912 ash
Becharof Lake	1998	Intense seismic swarm and inflationary episode
	2010	Earthquake swarm
Ugashik and 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

Table 2.2.—Continued

Volcano	Year Mentioned	Type of Activity
	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
	2011	Increased seismicity, possible tremor
	2012	Low-frequency earthquakes
	2013	Short seismic swarms
	2014	Seismographic network failure
	2016	Non-volcanic notable earthquake
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 eruptions
	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
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 eruptions, steam and ash plumes
	2015	End of 2014 eruptions
	2016	Significant eruption
	2017	End of intermittent eruption, volcanic unrest
Hague (Emmons Lake Caldera)	2002	Increase in fumarolic activity in summit crater
	2003	Crater lake drains, refills, drains
	2005	Steam plume
Frosty	2001	Rockfall avalanches
	2016	Avalanche
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

Table 2.2.—Continued

Volcano	Year Mentioned	Type of Activity
	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
	2016	Decreasing unrest
	2017	Volcanic unrest
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 emission
	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
	2017	Earthquake swarm
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	Intermittent tremor, small steam plume
	2016	Seismic swarms
	2017	Earthquake swarm, steaming
Bogoslof	1992	Dome extrusion, ash and steam emissions
	2016	Significant eruption
	2017	Significant eruption
Okmok	1997	Strombolian eruption
	2001	Seismic swarm
	2008	Major phreatomagmatic eruption
	2009	Bursts of tremor, inflation
	2011	Inflation
	2013	Inflation, earthquake swarm
	2014	Inflation
	2016	Seismic tremor
	2017	Inflation
Recheshnoi	2014	Increased seismicity
	2015	Continuation of increased fumarolic activity
Vsevidof	1999	Sighting of ash after regional earthquake

Table 2.2.—Continued

Volcano	Year Mentioned	Type of Activity
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
	2012	Intermittent explosions, small ash clouds
	2013	Lava extrusion, explosions, small ash clouds
	2014	Lava extrusion, intermittent minor eruptions of steam and ash
	2015	Continued low-level eruption
	2016	Continued low-level eruption
	2017	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 volcanic complex		
Kliuchef	1993	Audible rumbling, strong sulfur odor
	1995	Large steam plume, strong sulfur odor
Korovin	1996	PIREP of ash cloud, suspicious cloud on satellite image
	1998	Eruption; explosions and ashfall
	2005	Minor eruption, steam and ash
	2006	Seismic swarms, uplift, increased fumarolic activity
	2007	Seismic swarms; fumarolic activity
	2013	Earthquake swarms
	2016	Seismic tremor; fumarolic activity
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
	2017	Earthquake swarm, explosion
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 ashfall, new summit fissure
	2014	Earthquake swarm
Gareloi	2013	Felt earthquakes
	2017	Steaming
Tanaga	2005	Anomalous seismicity, including a period of tremor
Takawangha	2017	Earthquake swarm
Semisopochnoi	2014	Earthquake swarm; likely magmatic intrusion
	2015	Earthquake swarm
Kiska	2017	Steaming

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