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# 2016 Volcanic Activity in Alaska—Summary of Events and Response of the Alaska Volcano Observatory

Scientific Investigations Report 2020–5125

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

**Cover.** Aerial photograph of Pavlof Volcano taken at 20,000 feet showing the March 28, 2016, eruption. Photograph taken by the U.S. Coast Guard. Lieutenant Commander Nahshon Almandmoss was the Aircraft Commander. Petty Officer Austin Torres was the flight engineer. Photograph was taken from Coast Guard 1713, a HC-130H Hercules based at Air Station Kodiak.

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**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 | |
| metric tons per day (metric ton/d) | 1.1022 | tons per day (ton/d) |

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

$$°F = (1.8×°C) +32.$$

# Datum

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

Locations in latitude and longitude are presented in decimal degrees referenced to the WGS 1984 datum.

# Abbreviations

| | |
|---|---|
| AKDT | Alaska Daylight Time; UTC -8 hours |
| AKST | Alaska Standard Time; UTC -9 hours |
| AAWU | Alaska Aviation Weather Unit |
| ASL | above sea level |
| AVHRR | Advanced Very High-Resolution Radiometer |
| AVO | Alaska Volcano Observatory |
| EPA | U.S. Environmental Protection Agency |
| FAA | Federal Aviation Administration |
| FLIR | forward looking infrared |
| GPS | Global Positioning System |
| GVP | Smithsonian Institution Global Volcanism Program |
| IASI | Infrared Atmospheric Sounding Interferometer |
| NASA | National Aeronautics and Space Administration |
| NOAA | National Oceanic and Atmospheric Administration |
| NWS | National Weather Service |
| OMI | Ozone Mapping Instrument on NASA's Aura satellite |
| Pa | Pascal |
| PIREP | Pilot Weather Report |
| RSAM | real-time seismic amplitude measurement |
| SI | International System of Units |
| SIGMET | Significant Meteorological information statement, issued by NWS |
| SVERT | Sakhalin Volcanic Eruption Response Team |
| SWIR | Short Wave Infrared |
| UAFGI | University of Alaska, Fairbanks Geophysical Institute |
| USGS | U.S. Geological Survey |
| UTC | Coordinated Universal Time; same as Greenwich Mean Time |
| VAN | volcano activity notice |
| VONA | volcano observatory notice for aviation |
| WWLLN | World Wide Lightning Location Network at the University of Washington |

# 2016 Volcanic Activity in Alaska—Summary of Events and Response of the Alaska Volcano Observatory

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## Abstract

The Alaska Volcano Observatory responded to eruptions, volcanic unrest or suspected unrest, and seismic events at 15 volcanic centers in Alaska during 2016. The most notable volcanic activity consisted of eruptions at Pavlof and Bogoslof volcanoes. Both eruptions produced significant ash clouds that affected regional air travel. Mount Cleveland continued a pattern of dome growth followed by explosion, producing very short-lived ash clouds. An eruptive period at Shishaldin Volcano ended in 2016.

## Introduction

The Alaska Volcano Observatory (AVO) has a mandate to monitor, study, and warn of volcanic unrest at Alaskan volcanoes. This report summarizes notable volcanic activity in Alaska during 2016 (fig. 1; tables 1, 2) and briefly describes AVO's response to each. Information about all volcanoes at elevated alert status and events that prompted increased attention by AVO staff are included, even if no formal public notification ensued. Observations, images, and data typically not published elsewhere are included. In addition to the summarized volcano response activities, AVO conducted fieldwork for routine maintenance and ongoing projects, and also participated in fieldwork in the central and western Aleutian Islands as part of the Geodynamic Processes at Rifting and Subducting Margins program funded by the National Science Foundation in 2016.

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 2016.

Thirty-two of the fifty-four historically active volcanoes in Alaska were instrumented with a network of seismometers sufficiently reliable in their operation to detect and locate earthquakes as of December 31, 2016 (table 3). Included in this list is the Mount Cleveland seismograph network that requires a seismograph station in Nikolski, Alaska, 75 kilometers (km; 47 miles [mi]) from Mount Cleveland, to locate earthquakes. Information on AVO's Aviation Color Code and Volcano Alert Levels is in appendix 1.

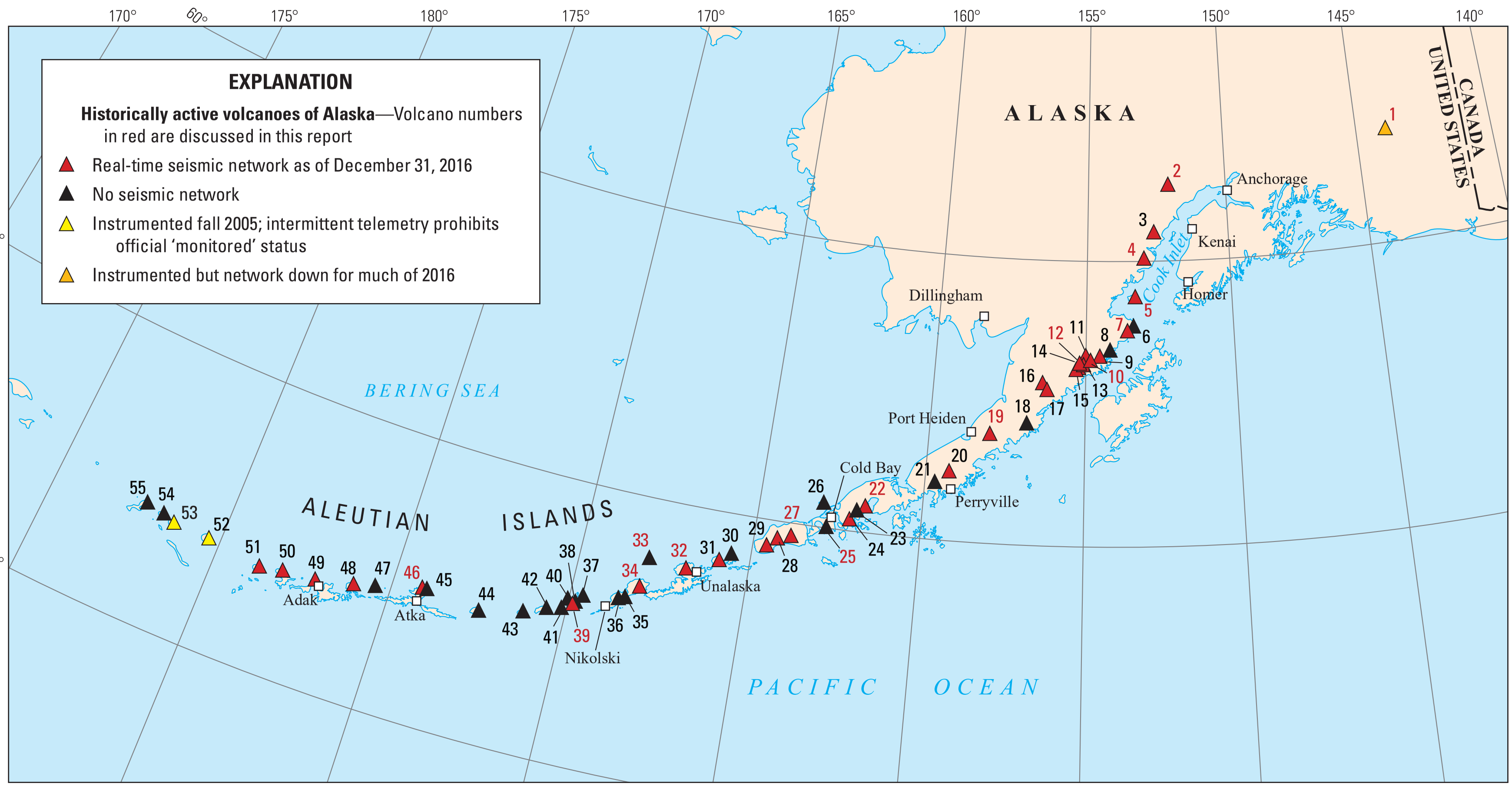
The AVO volcano-monitoring program includes daily analysis of satellite imagery (Advanced Very High Resolution Radiometer [AVHRR] and Moderate-resolution Imaging Spectroradiometer images, for example), web cameras, and seismicity; occasional overflights; airborne-gas measurements (annual airborne-gas measurements for the volcanoes in Cook Inlet and less frequent measurements for other volcanoes); compilation of pilot reports (PIREPs); and observations by local residents and mariners. AVO also receives real-time deformation data from permanent GPS stations at eight Alaskan volcanoes (Akutan, Augustine, Makushin, Okmok, Redoubt, Shishaldin, Spurr, and Westdahl). Periodic analysis of aerosols through the Ozone Mapping Instrument (OMI) on the National Aeronautics and Space Administration (NASA) Aura satellite (Lopez and others, 2013) and Interferometric Synthetic Aperture Radar imagery is used to monitor unrest at volcanoes in Alaska (for example, Lu, 2007). AVO is increasing the use of infrasound (atmospheric pressure waves) to detect explosions throughout the Aleutian arc (for example, Fee and others, 2010). AVO's response to the 2016–2017 eruption of Bogoslof volcano relied heavily on data from the World Wide Lightning Location Network at the University of Washington (WWLLN).

As part of AVO's longstanding close cooperation with volcano monitoring and reporting groups in the Russian Far East, earlier versions starting with Neal and others (2009) in this report series (table 4) included summaries of activity in

[1]Alaska Division of Geological & Geophysical Surveys.

[2]U.S. Geological Survey.

[3]University of Alaska, Fairbanks.




**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. Frosty Peak
26. Amak
27. Shishaldin
28. Fisher Caldera
29. Westdahl Peak
30. Gilbert
31. Akutan Peak
32. Makushin
33. Bogoslof Island
34. Okmok Caldera
35. Mount Recheshnoi
36. Vsevidof
37. Kagamil
38. Tana
39. Mount Cleveland
40. Carlisle
41. Herbert
42. Yunaska
43. Amukta
44. Seguam
45. Kliuchef (Atka)
46. Korovin
47. Kasatochi
48. Great Sitkin
49. Kanaga
50. Tanaga
51. Mount Gareloi
52. Semisopochnoi
53. Little Sitkin Island
54. Segula
55. Kiska

**Figure 1.** Map showing 54 historically active volcanoes in Alaska, their monitored status, and place names used in this report. Frosty Peak is included on this map but is not considered historically active. Following the established criteria and review of Cameron and Schaefer (2016), volcanoes are considered historically active if they had an eruption or period of intense deformation, or seismic, or fumarolic activity that is inferred to reflect the presence of magma at shallow levels beneath the volcano after 1741 when written records of volcanic activity began.

**Table 1.** Summary of 2016 monitoring highlights at volcanoes in Alaska, including actual eruptions, possible eruptions, and unusual increases in seismicity or fumarolic activity.

[Cross-referenced lists of volcanic activity by year and by volcano for this and all previous Alaska Volcano Observatory annual activity reports are presented in appendix tables 2.1 and 2.2. Location of volcanoes shown in figure 1]

| Volcano | Date of activity | Type of activity |
|---|---|---|
| Mount Wrangell | October | Report of summit ash deposit |
| Mount Spurr | Year-round | Earthquake swarms |
| Iliamna Volcano | March; May | Fumarolic activity; landslide |
| Augustine Volcano | February 2016–2017 | Seismic swarm |
| Mount Douglas | September–October | Seismic swarm |
| Katmai Group (Novarupta) | July; December | Resuspension of 1912 ash; deployment of particulate monitors |
| Aniakchak Crater | April | Nonvolcanic notable earthquake |
| Pavlof Volcano | March–July | Significant eruption |
| Frosty Peak | November | Avalanche |
| Shishaldin Volcano | January–March | Decreasing unrest |
| Makushin Volcano | February–December | Seismic swarms |
| Bogoslof Island | December | Significant eruption |
| Okmok Caldera | September | Seismic tremor |
| Mount Cleveland | Year-round | Continued low-level eruption |
| Korovin Volcano | February; April–August | Seismic tremor; fumarolic activity |

**Table 2.** Alaska volcanoes with Aviation Color Code and Volcano Alert Level changes in 2016.

[Description of Aviation Color Codes and Volcano Alert Levels is shown in appendix 1]

| Color Code | Date of change |
|---|---|
| Pavlof Volcano | |
| GREEN/NORMAL | January 1–March 27 |
| RED/WARNING | March 27–March 28 |
| ORANGE/WATCH | March 28–April 6 |
| YELLOW/ADVISORY | April 6–April 22 |
| GREEN/NORMAL | April 22–May 13 |
| ORANGE/WATCH | May 13–May 20 |
| YELLOW/ADVISORY | May 20–June 17 |
| GREEN/NORMAL | June 17–July 1 |
| YELLOW/ADVISORY | July 1–July 28 |
| ORANGE/WATCH | July 28–August 4 |
| YELLOW/ADVISORY | August 4–December 31 |
| Shishaldin Volcano | |
| YELLOW/ADVISORY | January 1–March 10 |
| GREEN/NORMAL | March 10–December 31 |
| Bogoslof Island | |
| UNASSIGNED | January 1–December 20 |
| RED/WARNING | December 20 |
| ORANGE/WATCH | December 20–December 21 |
| RED/WARNING | December 21 |
| ORANGE/WATCH | December 21–December 23 |
| RED/WARNING | December 23–December 24 |
| ORANGE/WATCH | December 24–December 26 |
| RED/WARNING | December 26–December 27 |
| ORANGE/WATCH | December 27–December 30 |
| RED/WARNING | December 30–December 31 |
| Mount Cleveland | |
| YELLOW/ADVISORY | January 1–April 16 |
| ORANGE/WATCH | April 16–April 29 |
| YELLOW/ADVISORY | April 29–May 5 |
| ORANGE/WATCH | May 5–June 3 |
| YELLOW/ADVISORY | June 3–October 24 |
| ORANGE/WATCH | October 24–November 4 |
| YELLOW/ADVISORY | November 4–December 31 |

**Table 3.** History of seismic monitoring of Alaska volcanoes through December 2016.

[First station installed refers to the date when 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. 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. Regularly issued written information statements began during the Redoubt Volcano eruption in 1989–90 and were expanded to include all Cook Inlet volcanoes in April 1991. The magnitude of completeness is the lowest magnitude earthquake that can confidently be located for activity at the volcanic center with an operational seismograph network. For more information on specific seismic network histories, readers are referred to the series of annual seismic summaries prepared by AVO (for example, Dixon and others, 2013). N/A not applicable]

| Approximate start date of seismic monitoring | Earthquakes located in 2016 | Magnitude of completeness[1] |
|---|---|---|
| **Mount Wrangell** | | |
| First station installed—July 2000<br>Network complete (4 stations)—**August 2001**<br>On monitored list in weekly update from November 2001–January 2012 | 0 | 0.9 |
| **Mount Spurr** | | |
| First station installed—August 1971<br>Network complete (17 stations)—**August 1989**<br>Added to monitored list in weekly update—April 1991 | 1,690 | 0.2 |
| **Redoubt Volcano** | | |
| First station installed—August 1971<br>Network complete (12 stations)—**August 1988**<br>Added to monitored list in weekly update—April 1991 | 170 | 0.1 |
| **Iliamna Volcano** | | |
| First station installed—September 1987<br>Network complete (7 stations)—**September 1994**<br>Added to monitored list in weekly update—April 1991 | 4 | −0.2 |
| **Augustine Volcano** | | |
| First station installed—October 1976<br>Network complete (12 stations)—**August 1978**<br>Added to monitored list in weekly update—April 1991 | 836 | 0.0 |
| **Fourpeaked Mountain** | | |
| First station installed—September 2006<br>Network complete (4 stations)—**October 2006**<br>On monitored list in weekly update —October 2006–November 2009; October 2011–February 2014 | 1 | 0.7 |
| **North Katmai area (Snowy Mountain)** | | |
| First station installed—August 1988<br>Network complete (5 stations)—**October 1998**<br>Added to monitored list in weekly update—December 1998 | 201 | 1.0 |
| **Central Katmai area (Mount Griggs, Mount Katmai, Novarupta, and Trident Volcano)** | | |
| First station installed—August 1988<br>Network complete (7 stations)—**July 1991**<br>Added to monitored list in weekly update—November 1996 | 302 | 0.6 |
| **South Katmai area (Mount Martin and Mount Mageik)** | | |
| First station installed—August 1988<br>Network complete (8 stations)—**July 1996**<br>Added to monitored list in weekly update—November 1996 | 139 | 0.4 |
| **Ukinrek Maars and Mount Peulik** | | |
| First station installed—March 2005<br>Network complete (7 stations)—**March 2005**<br>Added to monitored list in weekly update—April 2005 | 7 | 0.9 |

**Table 3.—Continued**

| Approximate start date of seismic monitoring | Earthquakes located in 2016 | Magnitude of completeness[1] |
|---|---|---|
| **Aniakchak Crater** | | |
| First station installed—July 1997<br>Network complete (6 stations)—**July 1997**<br>On monitored list in weekly update from November 1997–November 2009; September 2010–January 2014; returned on October 2015 | 36 | 1.4 |
| **Mount Veniaminof** | | |
| First station installed—February 2002<br>Network complete (9 stations)—**February 2002**<br>On monitored list in weekly update from September 2002–November 2009; returned October 2010 | 0 | 1.5 |
| **Pavlof Volcano** | | |
| First station installed—July 1996<br>Network complete (7 stations)—**July 1996**<br>Added to monitored list in weekly update—November 1996 | 11 | 1.0 |
| **Mount Dutton** | | |
| First station installed—July 1988<br>Network complete (5 stations)—**July 1996**<br>Added to monitored list in weekly update—November 1996 | 12 | 1.0 |
| **Shishaldin Volcano and Isanotski Peaks** | | |
| First station installed—July 1997<br>Network complete (7 stations)—**July 1997**<br>Shishaldin Volcano added to monitored list in weekly update—November 1997<br>Isanotski Peaks added to monitored list in weekly update—December 1998 | 41 | 0.6 |
| **Westdahl Peak and Fisher Caldera** | | |
| First station installed—August 1998<br>Network complete (6 stations)—**October 1998**<br>Added to monitored list in weekly update—December 1998 | 95 | 1.1 |
| **Akutan volcano** | | |
| First station installed—March 1996<br>Network complete (13 stations)—**July 1996**<br>Added to monitored list in weekly update—November 1996 | 235 | 0.4 |
| **Makushin Volcano** | | |
| First station installed—July 1996<br>Network complete (8 stations)—**July 1996**<br>Added to monitored list in weekly update—November 1996 | 702 | 0.5 |
| **Okmok volcano** | | |
| First station installed—January 2003<br>Network complete (13 stations)—**January 2003**<br>Added to monitored list in weekly update—January 2004 | 62 | 0.8 |
| **Mount Cleveland** | | |
| First station installed—August 2014<br>Network complete (2 stations)—N/A<br>Has not been added to the monitored list in the weekly update | 0 | 0.9 |
| **Korovin Volcano** | | |
| First station installed—July 2004<br>Network complete (7 stations)—**July 2004**<br>On monitored list in weekly update from December 2005–November 2009; October 2010–October 2011; returned March 2014 | 113 | 0.5 |

**Table 3.—Continued**

| Approximate start date of seismic monitoring | Earthquakes located in 2016 | Magnitude of completeness[1] |
|---|---|---|
| Great Sitkin Volcano | | |
| First station installed—September 1999<br>Network complete (6 stations)—**September 1999**<br>Added to monitored list in weekly update—December 1999 | 101 | 0.6 |
| Kanaga Volcano | | |
| First station installed—September 1999<br>Network complete (6 stations)—**September 1999**<br>Added to monitored list in weekly update—December 2000 | 133 | 1.2 |
| Tanaga Volcano | | |
| First station installed—August 2003<br>Network complete (6 stations)—**August 2003**<br>Added to monitored list in weekly update—June 2004 | 72 | 1.1 |
| Mount Gareloi | | |
| First station installed—August 2003<br>Network complete (6 stations)—**September 2003**<br>Added to monitored list in weekly update—June 2004 | 264 | 1.2 |
| Semisopochnoi Island (Mount Cerberus) | | |
| First station installed—September 2005<br>Network complete (6 stations)—**September 2005**<br>Has not been added to the monitored list in the weekly update | 57 | 0.5 |
| Little Sitkin Island | | |
| First station installed—September 2005<br>Network complete (4 stations)—**September 2005**<br>Has not been added to the monitored list in the weekly update | 32 | 0.0 |

[1]No magnitude of completion is calculated for Mount Cleveland owing to the lack of located seismicity.

**Table 4.** 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 4.—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 |

**Table 4.—Continued**

| Year | Citation | URL |
|---|---|---|
| 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 |
| 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, Alexandra, Wallace, K.L., 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, 61 p. | https://doi.org/10.3133/sir20205125 |

## 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.

## 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.

the Kamchatka Peninsula, Russia, and the Kurile Islands, a volcanic archipelago that extends southwest of Kamchatka. Beginning with the 2011 report (McGimsey and others, 2014), AVO no longer includes this information and refers interested readers to the websites of the Kamchatka and Sakhalin Volcanic Eruption Response Teams (http://www.kscnet.ru/ivs/kvert/index_eng.php and http://www.imgg.ru/?id_d=659) and to the Smithsonian Institution Global Volcanism Project (GVP; http://volcano.si.edu).

Thirty-two of the fifty-four historically active volcanoes in Alaska were instrumented with a network of seismometers sufficiently reliable in their operation to detect and locate earthquakes as of December 31, 2016 (table 3). Included in this list is the Mount Cleveland seismograph network that requires a seismograph station in Nikolski, Alaska, 75 kilometers (km; 47 miles [mi]) from Mount Cleveland, to locate earthquakes. Information on AVO's Aviation Color Code and Volcano Alert Levels is in appendix 1.

## Volcanic Activity in Alaska

Volcano descriptions are presented in geographic order from northeast to southwest along the Wrangell-Aleutian volcanic arc. Each entry has a title block with information about the volcano—its official name; unique GVP identifier; the latitude, longitude, and summit elevation; the global region; and an abbreviated summary highlighting the activity. Each summary is followed by detailed activity information, often with accompanying tables, images, and (or) figures, ending with a description of the volcano and summary of past volcanic activity. The event summary is derived from published material as well as AVO daily status reports, AVO weekly updates and special information releases, AVO email and online electronic logs, Miller and others (1998), and the Smithsonian Institution Global Volcanism Network Bulletins (available at http://www.volcano.si.edu/reports_bgvn.cfm). Beginning with the 2013 report, AVO's annual summary includes expanded information on seismicity and seismograph networks at Alaska volcanoes. Volcanic activity in past and present AVO summaries is 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 (presented in degrees and minutes rounded to the nearest minute) and summit elevations are taken from the AVO (World Geodetic System of 1984 datum) and may differ slightly from previously published compilations.

## Mount Wrangell


GVP# 315020
62.00° N., 144.01° W.
4,317 m (14,163 ft)

Copper River basin

**REPORT OF SUMMIT ASH DEPOSIT**

In late October 2016, AVO received a report transmitted from the north district interpreter of Wrangell-Saint Elias National Park describing a sighting of unusual or anomalous dark ash on the summit of Mount Wrangell (herein called Wrangell volcano to include Mount Wrangell and its surrounding volcanic features). The observer, a local, long-time resident of Chitina, Alaska, and seasonal ranger for the park, reported seeing a “pronounced dark area at the top of Wrangell which appears to be ash,” and she had not seen this before in decades. The view from Chitina is of the south-southwest flank of Mount Wrangell.

AVO seismologists analyzed data from the two weeks preceding the report and found no sign of unusual activity. Large earthquakes have been shown to disturb the shallow hydrothermal system at Wrangell volcano and cause extensive melting of the ice and snow in the summit crater (Benson and Motyka, 1978), but no such earthquake occurred in October.

On October 27, 2016, a clear weather day, local pilot Paul Claus flew around Mount Wrangell, including the summit area. He reported that conditions were perfect and that he did not see anything out of the ordinary. He suggested that the long run of great weather with lots of sunlight, no new snow, and melting of old snow, was likely responsible for making the dark areas of the summit (exposed cinders and ash) visibly stand out (figs. 2 and 3).

Wrangell volcano is a massive, glacier-covered shield volcano in the Wrangell-Saint Elias National Park and Preserve of eastern Alaska (fig. 4; Richter and others, 1995). Geothermally active areas occur on the east and west rims of the ice-filled 4 x 6 km (2.5 x 3.7 mi) summit crater, and high on the southwest flank, which is the source of nearly constant fumarolic emission (Benson and others, 2007). Resultant vapor plumes can be quite vigorous and sometimes reach hundreds of meters (thousands of feet) above ground level, occasionally entraining fine fragmental debris and producing localized deposits of dark material on the ice. This, in addition to wind redistribution of debris from the summit area, is often mistaken for eruptive activity. Since 1992, when AVO began compiling and publishing suspected volcanic activity, 10 reports of ash from Wrangell volcano have been documented (table 2.2). AVO relies on seismic data, local observers, pilots, and satellite images to report activity at the volcano. Except for vigorous steam and occasional phreatic ash emission, no historical magmatic eruptions are known to have occurred (Richter and others, 1995). A lava flow eruption reported in 1902 (Mendenhall, 1905) is considered an unconfirmed eruption report.

**Figure 2.** Aerial photograph showing exposed tephra deposits on the summit of Mount Wrangell. Photograph by Paul Claus, October 27, 2016, used with permission.

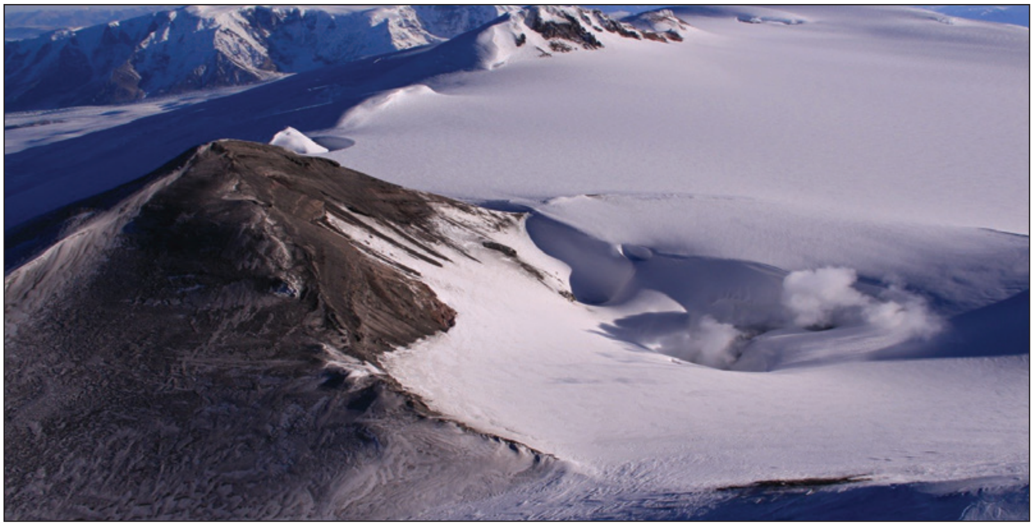


**Figure 3.** Aerial photograph of North Crater at the summit of Mount Wrangell. Active fumaroles are visible on the flanks of Mount Wrangell. Much of the North Crater stratocone is snow-free from warm weather, which exposed dark tephra deposits. This view is from the west looking over North Crater and across the summit caldera. Photograph by Paul Claus, October 27, 2016, used with permission.

**Figure 4.** Photograph showing the north-northwest flank of Mount Wrangell. All of the known active fumaroles on Wrangell are venting steam on this cold (–20 °F) afternoon of March 20, 2007. Photograph taken by Suzanne McCarthy from approximately Mile 18 of the Tok Highway, used with permission.

## Mount Spurr


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

Cook Inlet

**EARTHQUAKE SWARMS**

No volcanic activity was reported at Mount Spurr in 2016, but AVO located four distinct clusters and three less-distinct zones of seismic activity in the vicinity during the year. AVO refers to Mount Spurr and the surrounding features associated with its volcanism as “Spurr.” The four distinct clusters of seismic activity consisted of the typical Mount Spurr summit earthquakes that occurred throughout the year, earthquakes near Pothole Glacier (west of Mount Spurr) in late summer, an ongoing swarm of low-frequency earthquakes 10–15 km (6–9 mi) north of the summit (north Spurr earthquakes in fig. 5), and a cluster of earthquakes located 5 km (about 3 mi) east of the summit in May (east Spurr earthquakes in fig. 5). In addition to these areas of high activity, there are three, less-distinct zones of activity. These zones are 10 km (6.2 mi) south, 5 km (3 mi) west, and 20–30 km (12–18.5 mi) northeast of Mount Spurr and are in the area of the 1996 Strandline earthquake (Kilgore and others, 2011). The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively, throughout the year for Spurr.

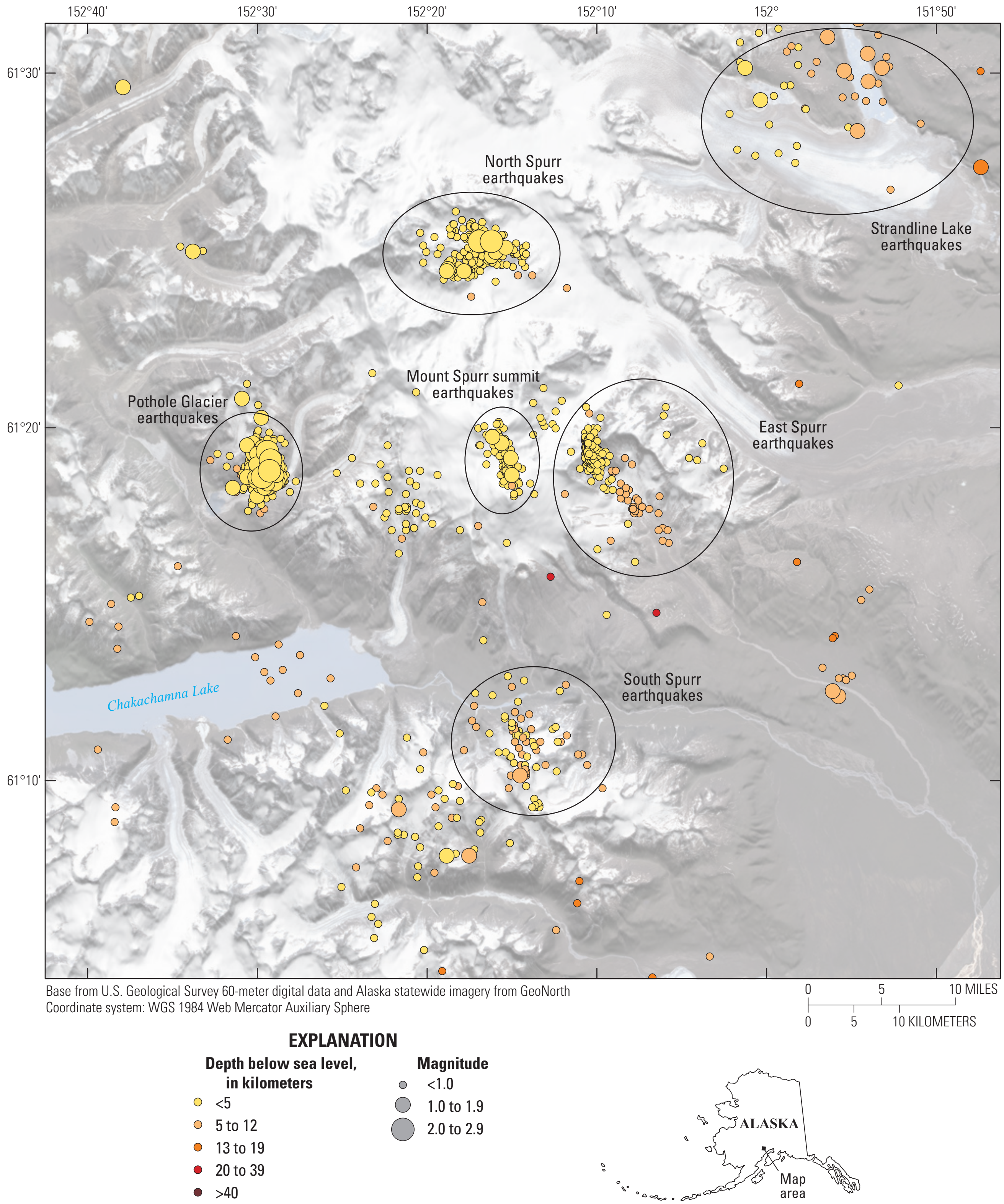



**Figure 5.** Epicentral map showing clusters of distinct and zones of less-distinct seismicity near Mount Spurr in 2016. The four clusters of distinct seismicity are the Mount Spurr summit earthquakes, Pothole Glacier earthquakes, north Spurr earthquakes, and east Spurr earthquakes The three zones of less-distinct seismicity are the south Spurr earthquakes, Strandline Lake earthquakes, and an unmarked group of events 5 kilometers (3 miles) west of Mount Spurr.

A cluster of distinct seismicity 5 km (3 mi) east of Mount Spurr contained nearly 600 highly similar earthquakes, in a region without a previous earthquake cluster (east Spurr earthquakes on fig. 5). These earthquakes were low-frequency, monotonic, and spatially centered on the edge of a glacier. Most occurred near the surface with a minor number located up to 10 km (6.2 mi) deep.

The Pothole Glacier earthquakes, like the east Spurr earthquake cluster, occurred in the vicinity of a glacier. This earthquake sequence began at the end of June and continued through July 2016. The earthquakes were shallow and were located at 2–5 km (1–3 mi) depth. High-frequency surface waves associated with these earthquakes confirmed a shallow source. This cluster was similar to previous earthquake swarms near the Pothole Glacier in 2003, 2010, 2012, and 2014, and consistently occurred during the spring or summer. A proposed model for this periodic earthquake sequence is that the Pothole Glacier could be slipping past an asperity along its bed. The morphology of Pothole Glacier moraine indicates that the glacier experiences pulsing behavior in its flow, with short episodes of fast motion every few years (Martin Truffer, University of Alaska Fairbanks Geophysical Institute, written commun., 2016). This proposed model is consistent with the observed pattern of seismicity. On September 2, AVO scientists observed a landslide on the north side of Pothole Glacier valley (fig. 6) that was a response to the same warm summer weather that is a suspected factor for the Pothole Glacier earthquake swarm.

The only ongoing cluster of earthquakes during 2016 is the continuation of activity first noticed in 2015 (north Mount Spurr earthquakes in fig. 5). Although earthquakes were located year-round, there were two periods of quiescence in April–June and September. Most earthquakes were located at 4 km (2.4 mi) depth and were classified as low frequency. The ongoing swarm continued into 2017 and was monitored by AVO seismologists.

Mount Spurr is a 3,374-m high (11,070-ft) stratovolcano located 125 km (80 mi) west of Anchorage (fig. 1). The summit of Mount Spurr is a largely ice-covered feature previously interpreted as a lava dome complex (Nye and Turner, 1990). Explosive historical eruptions occurred in 1953 and 1992 from Crater Peak, a satellite vent 3.5 km (2 mi) south of Mount Spurr's summit (Keith, 1995). Each of these eruptive phases produced ash falls on populated areas of south-central Alaska. No anomalous gas levels were noted in 2016 (Christoph Kern, U.S. Geological Survey [USGS], written commun., 2016).

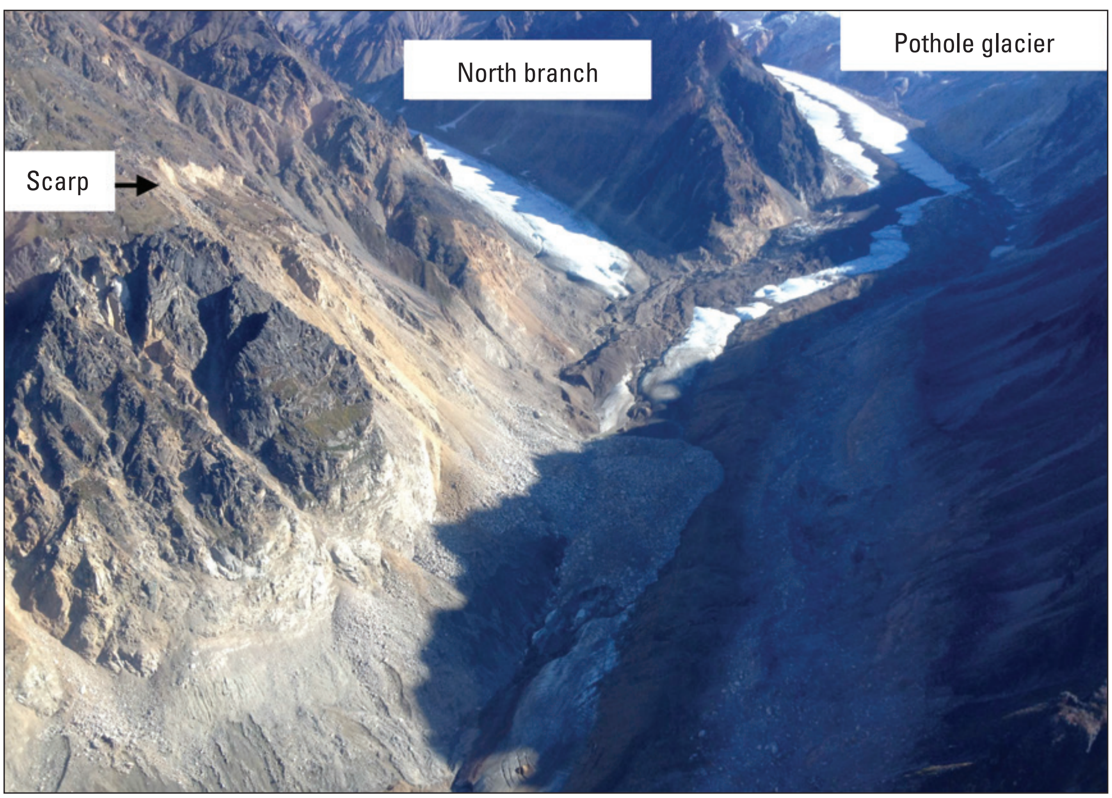



**Figure 6.** U.S. Geological Survey photograph looking east-northeast towards a landslide on the north side of the Pothole Glacier valley. Landslide may be related to an earlier earthquake swarm that occurred during the summer of 2016. Photograph taken by Matt Haney and Cyrus Read on September 2, 2016.

## Iliamna Volcano


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

Cook Inlet

**FUMAROLIC ACTIVITY; LANDSLIDE**

Members of the public noted typical amounts of steaming from the near-summit fumaroles at Iliamna Volcano, particularly in March 2016, and a large landslide occurred May 22. Iliamna remained at Aviation Color Code and Volcano Alert Level **GREEN** and **NORMAL**, respectively, throughout 2016.

Radio station KSRM in Soldotna, Alaska, contacted AVO on Saturday, March 12, stating that people on the Kenai Peninsula could see “quite a plume” coming from Iliamna Volcano. AVO noted no anomalous seismicity or evidence of increased steaming in satellite data. Web camera imagery showed white vapor and gas plumes rising from the volcano’s prominent and long-lived fumaroles. When Iliamna Volcano is backlit in the evening hours, as viewed from the Kenai Peninsula in spring and fall, its normal fumarolic plume often appears more prominent.

At 07:58 UTC May 22 (11:58 pm May 21 AKDT), AVO detected seismic and pressure sensor signals associated with a large avalanche on the flank of Iliamna Volcano. Seismic signals from the avalanche were detected on volcano monitoring networks throughout Cook Inlet and as far away as the Mount Katmai area, 250 km (155 mi) southwest. The event was also recorded on distant infrasound stations in Dillingham, Alaska, 326 km (202 mi) and Fairbanks, Alaska, 610 km (379 mi) southwest and northeast of Iliamna Volcano, respectively. AVO issued an Information Statement about the landslide on Sunday, May 22. The sizeable avalanche covered about 7.2 $km^2$ and extended down the east flank of the volcano (fig. 7; Dave Schneider, USGS, written commun., 2016)

Iliamna Volcano is a glaciated 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 and repeated, significant mass wasting of the steep, glacier-carved, and hydrothermally altered edifice (Waythomas and Miller, 1999). Fumaroles located at about 2,740 m (8,990 ft) ASL on the east flank produce nearly constant plumes of steam condensate and volcanic gas (Werner and others, 2011). In the past two decades, at least two magmatic intrusions have been documented (Roman and others, 2004; Prejean and others, 2012).

**Figure 7.** Photograph showing the May 22, 2016, landslide on the east flank of Iliamna Volcano. Photograph by Dennis Anderson, taken on May 23, 2016, and used with permission.

## Augustine Volcano

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

Cook Inlet

**SEISMIC SWARM**


Minor unrest occurred at Augustine Volcano in 2016 in the form of a seismic swarm that began in February and continued intermittently into 2017. This swarm was similar to precursory seismicity observed at Augustine Volcano before previous eruptions, prompting increased surveillance on the Augustine data streams. The unrest did not result in eruption, and the Aviation Color Code and Volcano Alert Level remained **GREEN** and **NORMAL**, respectively, throughout the year.

In 2016, there was a fivefold increase in the number of located earthquakes, totaling 836 for the year. The earthquakes were all located under the summit at shallow depths, 0–3 km (1–2 mi). Following a period of relative quiescence after the 2005–06 eruption, seismicity at Augustine Volcano increased slightly in 2012 when AVO located 54 earthquakes (fig. 8; Herrick and others, 2014). This activity continued to increase in 2013, 2014, and 2015 with 101, 127, and 162 earthquakes, respectively. The Augustine Volcano 2016 earthquake swarm began in February and continued at a high rate through the summer. A decrease in seismicity occurred during the fall and winter. Although the seismic activity looked much like precursory seismicity observed prior to the 1976, 1986, and 2005–06 eruptions, no eruption has yet ensued. No deformation or anomalous gas levels were noted in 2016.

On January 24, the magnitude 7.1 Iniskin earthquake occurred at 10:30 UTC (1:30 AM AKST), between Augustine and Iliamna Volcanoes, and was the result of tectonic plate motions. This earthquake's epicenter was about 27 km (17 mi) north of Augustine Volcano and 50 km (31 mi) south of Iliamna Volcano, at a depth of 122 km (76 mi). AVO did not detect any changes at either Augustine or Iliamna Volcano related to the earthquake.

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

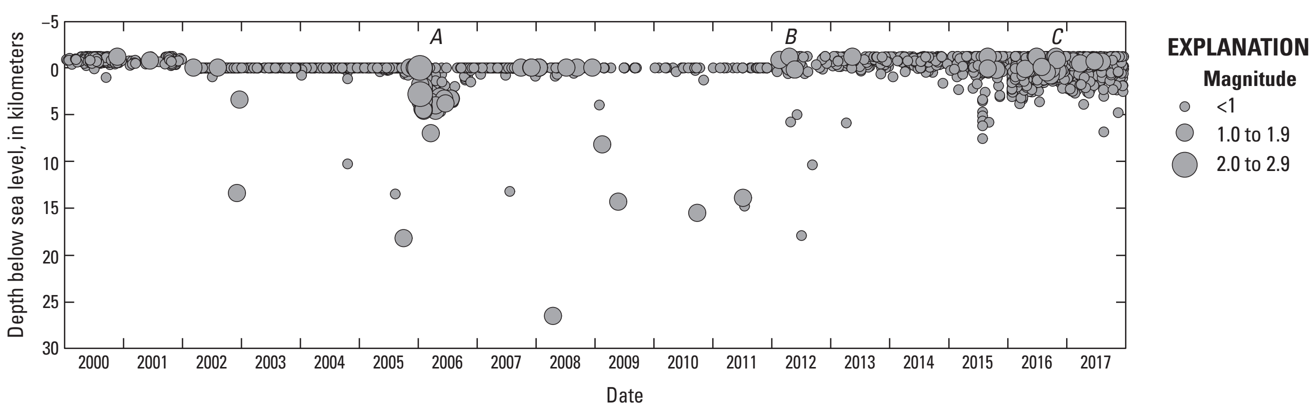



**Figure 8.** Graph showing seismicity at Augustine Volcano since 2000. The seismicity located at *A* represents 2005–2006 Augustine Volcano eruption. The seismicity at *B* is an artifact of the transition to the Advanced National Seismic System Quake Monitoring System in 2012, which resulted in any earthquake prior to 2012 with a depth above sea level (for example, within the mountain of Augustine Volcano) to be plotted at sea level. The seismicity at *C* is the start of the earthquake activity described in this report.

## Mount Douglas


GVP # 312270
58.8596° N., 153.5351° W.
2,140 m (7,021 ft)

Cook Inlet, Alaska Peninsula

**SEISMIC SWARM**

An increase in seismicity at unmonitored Mount Douglas was noted on September 27, 2016, by Alaska Earthquake Center (AEC) seismologists and was followed by a second swarm on October 15 (fig. 9). The activity near both Fourpeaked Mountain and Mount Douglas was characterized by numerous small earthquakes, most with local magnitudes ($M_L$) between 1 and 2, and spatially closer to Mount Douglas than Fourpeaked. A final short swarm occurred on November 18, similar to the activity in September and October. The Aviation Color Code and Volcano Alert Level remained at **UNASSIGNED** during the increased activity.

Mount Douglas is primarily ice-covered with active fumaroles that keep its small crater lake typically ice-free. Douglas has no known historical eruptions, and it lies in the northeast corner of Katmai National Park and Preserve on the Alaska Peninsula, 12 km (7.5 mi) northeast of Fourpeaked Mountain.

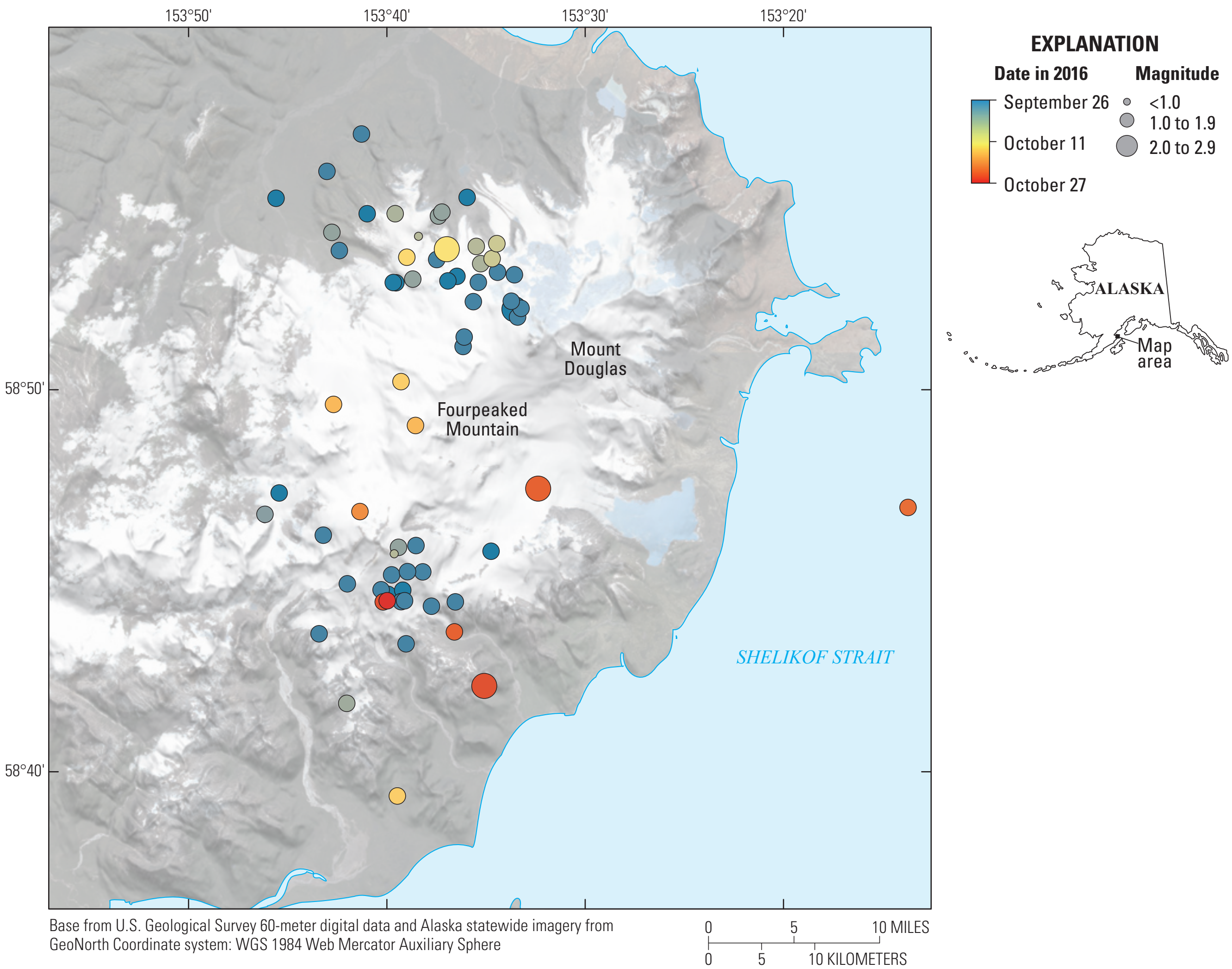



**Figure 9.** Map showing distribution of earthquakes near Mount Douglas. Earthquake symbols are scaled with local magnitude ($M_L$) and range from $M_L$ = 1.0 to 2.1. The color of the symbols refers to the date of the earthquakes between September 26 and October 27, 2016.

## Katmai Group (Novarupta)


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

Alaska Peninsula

**RESUSPENSION OF 1912 ASH; DEPLOYMENT OF PARTICULATE MONITORS**

Resuspension and transport of fine-grained volcanic ash deposited during the 1912 Novarupta-Katmai eruption has been frequently observed and documented over at least the last several decades (Hadley and others, 2004; McGimsey and others, 2005). Two episodes of ash resuspension were documented in 2016, and AVO helped deploy two air quality monitors to study and characterize the resuspended ash. The Aviation Color Code and Volcano Alert Level remained **GREEN** and **NORMAL**, respectively, for Mount Katmai and Novarupta during 2016.

The 1912 Novarupta-Katmai eruption produced approximately 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 today known as the Valley of Ten Thousand Smokes. Ash in this valley is as much as 200 m (660 ft) thick, and the valley remains almost entirely free of vegetation, even more than 100 years after the eruption. When the landscape is snow free, particularly when the ground has little moisture content, strong winds can pick up ash and create large ash clouds. During strong northwesterly winds, the ash can be resuspended and transported southeast across Shelikof Strait, Kodiak Island, and the Gulf of Alaska. These dust clouds are commonly identified as originating broadly from the Mount Katmai area rather than from a specific volcanic source and look identical to dispersing volcanic ash clouds in satellite imagery. They are often observed visually by individuals downwind and also in satellite imagery.

These dust clouds, primarily composed of volcanic ash, pose a hazard to aviation and a possible hazard to air quality for nearby communities. To better understand the ash fallout hazards from these events, AVO partnered with the Alaska Department of Environmental Conservation Air Quality Program to deploy two particulate monitors on Kodiak Island in late April 2016 (fig. 10). One monitor was located in the city of Kodiak, Alaska, on the east side of the island, and was operated by the US Coast Guard. The second monitor was located in Larsen Bay, on the west side of Kodiak Island and was operated by a local citizen. These monitors continuously measure particulate (≤10 microns in diameter) air quality, including during resuspension events, and are used to assess the hazards to public health. Particulate air quality standards

**Figure 10.** U.S. Geological Survey photograph showing Alaska Volcano Observatory (AVO) staff training US Coast Guard personnel on operation and maintenance of particulate monitor. AVO installed particulate monitors on Kodiak Island to study resuspended volcanic ash from the 1912 Novarupta-Katmai eruption and its possible health hazard. Photograph taken by Kristi Wallace, April 29, 2016.

are established by the U.S. Environmental Protection Agency (EPA) to protect public health (https://airnow.gov/index.cfm?action=aqibasics.aqi). In addition to deploying air quality monitors, AVO held trainings on ash collection in the communities of Kodiak and Larsen Bay with the goal of obtaining samples of particulate fallout during resuspension events. Study of these samples will help to confirm what these clouds are composed of and will help improve numerical models of ash resuspension and fallout.

High northwesterly winds on July 18, 2016, entrained and resuspended ash from the Novarupta and Mount Katmai area toward the southeast. The ash cloud was weakly visible in satellite imagery and was reported by a local pilot to be as high as 1,980 m (6,500 ft) ASL (fig. 11). The National Weather Service Alaska Aviation Weather Unit (NWS AAWU) issued a significant meteorological weather advisory (SIGMET) for aviators, and AVO issued an Information Statement. No reports of ashfall on Kodiak Island were received by AVO, and EPA air quality standards were not exceeded in Larsen Bay or Kodiak.

A two-day ash resuspension event occurred December 2–3, 2016. The cloud reached no higher than 1,800 m (6,000 ft) ASL and was identified in satellite imagery. Observers in Kodiak provided photographs of the approaching cloud (fig. 12). The NWS AAWU issued a SIGMET for aviators, and

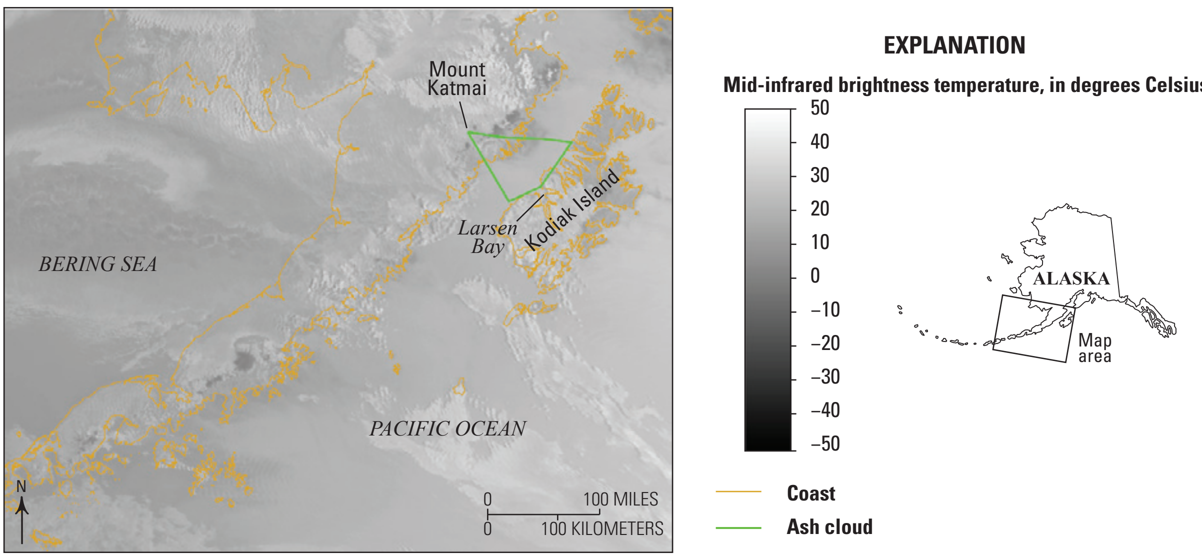



**Figure 11.** Satellite image showing a cloud of resuspended ash from the Mount Katmai area, extending southeast over Shelikof Strait to the east coast of Kodiak Island on July 18, 2016. Green outline defines the ash cloud at the time of the image. Landmass is outlined in yellow. Modified from the National Oceanic Atmospheric Administration Advanced Very High-Resolution Radiometer image originally annotated by Hans Scwhaiger, Alaska Volcano Observatory.

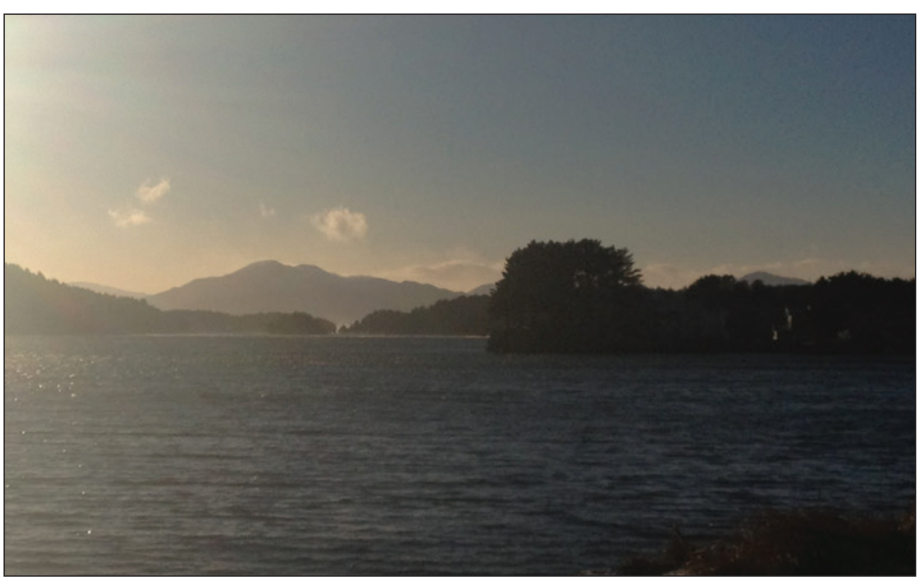


**Figure 12.** Photograph of brown haze from an approaching cloud of resuspended ash from the Mount Katmai area on December 2, 2016. Photograph by Stephen Bodnar used with permission.

AVO issued an Information Statement on December 2. The ash was weakly visible in satellite imagery on December 2 and 3, 2016 (fig. 13). Residents of Kodiak reported a fall of fine ash, and samples were collected and sent to AVO for confirmation and analysis. Air quality standards (24-hour standards) were not exceeded in Kodiak, but the event registered unhealthy levels (151–200 micrograms of particulate per cubic meter) on the Larsen Bay particulate monitor (fig. 14).

On December 31, 2016, hazy conditions were reported in Kodiak during southwesterly winds (fig. 15). A small sample of fallout from the cloud on the city of Kodiak was sent to AVO for confirmation of source material but was inconclusive. No ash cloud was observed in satellite imagery, and therefore, no action was taken by the NWS AAWU, and AVO did not issue a formal Information Statement, because the hazard was considered very low.

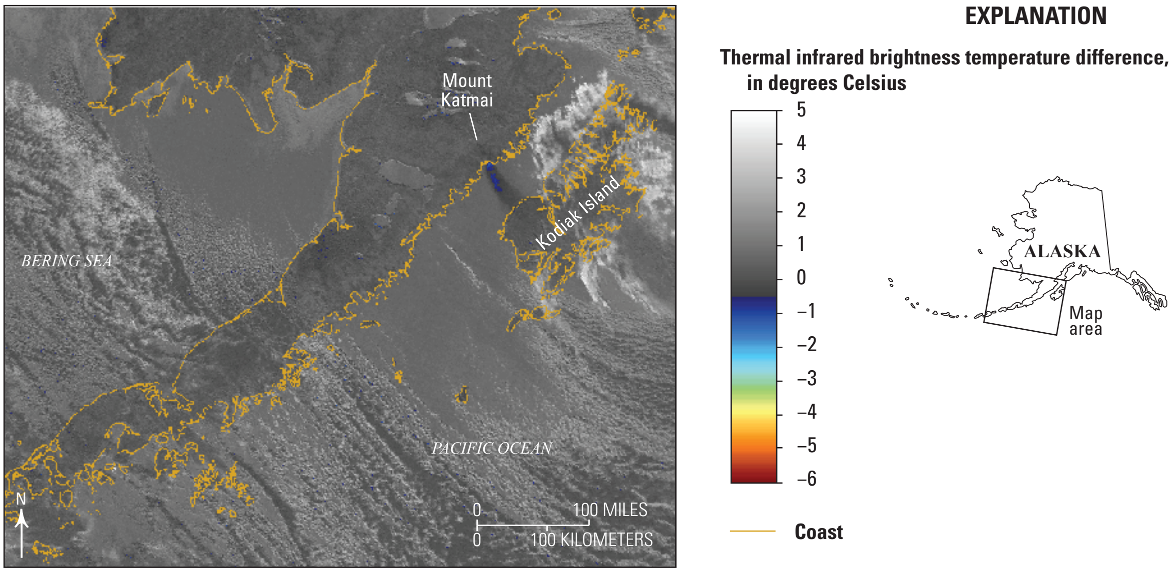



**Figure 13.** Satellite image showing resuspended ash from the 1912 Novarupta-Katmai eruption (blue area in upper right) carried southeast from the Mount Katmai area towards Kodiak Island. Modified from National Oceanic and Atmospheric Administration Advanced Very High-Resolution Radiometer image originally annotated by Janet Schaefer, Alaska Division of Geological & Geophysical Surveys, December 2, 2016.

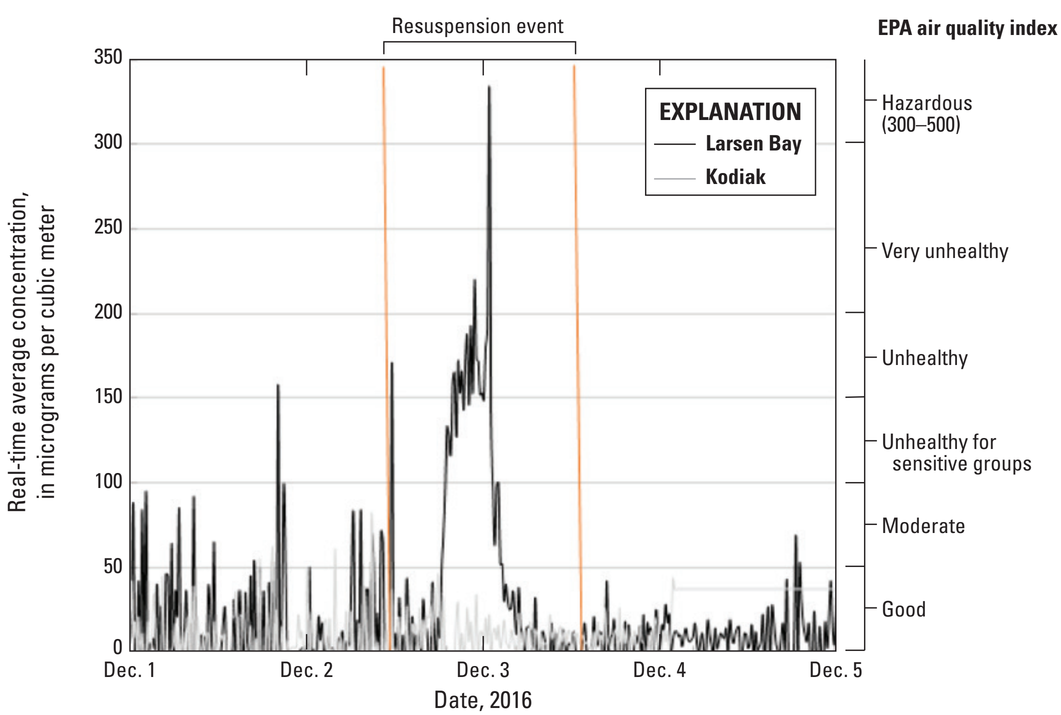



**Figure 14.** Graph showing particulate air quality data for Kodiak and Larsen Bay, Alaska on Kodiak Island during a resuspension event from the Mount Katmai and Novarupta area. The U.S. Environmental Protection Agency's (EPA) Air Quality Index values for human health are shown on the right. A spike in poor air quality was recorded in Larsen Bay on December 3, which likely corresponds to fallout from the resuspended cloud. Health hazard thresholds and categories taken from https://airnow.gov/index.cfm?action=aqibasics.aqi.

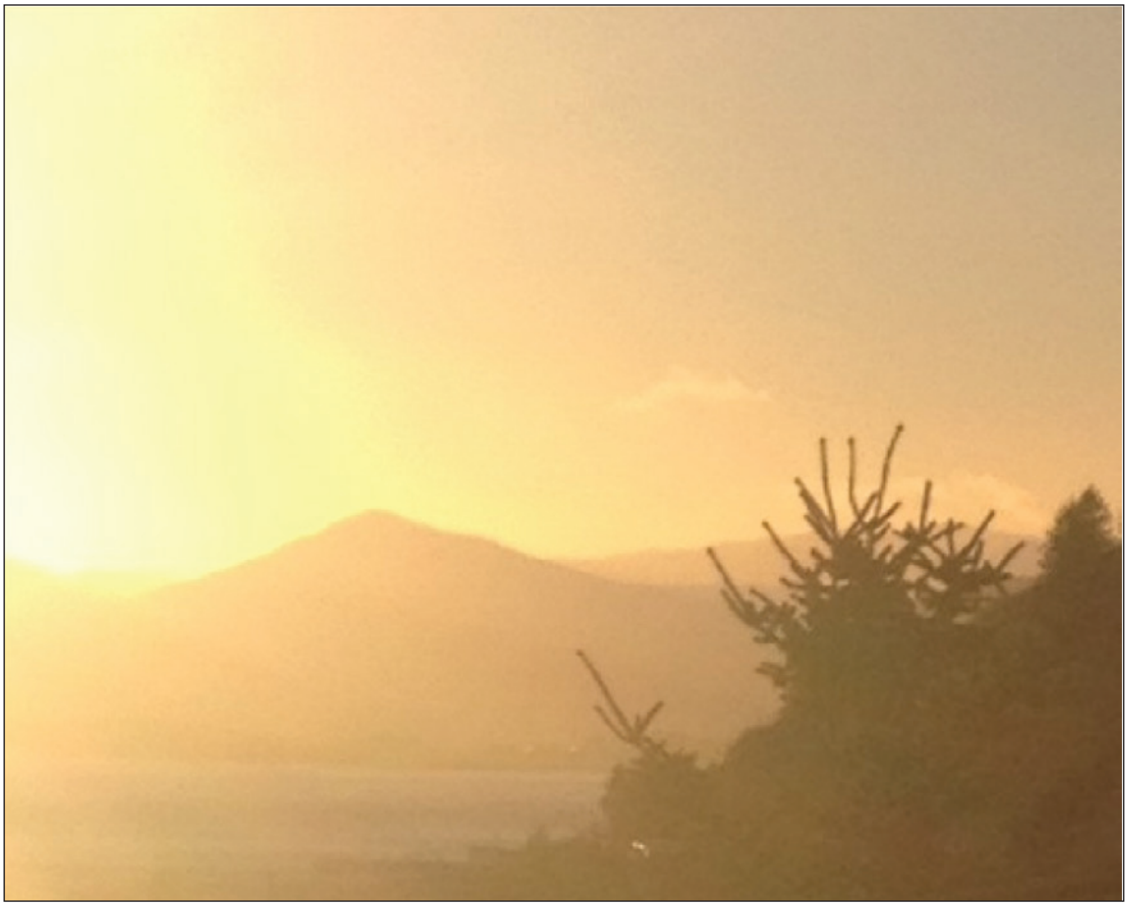


**Figure 15.** Photograph showing hazy conditions from an approaching dust cloud, resuspended from the Mount Katmai area on December 31, 2016. Photograph taken from Kodiak, Alaska, by Stephen Bodnar, used with permission.

## Aniakchak Crater


GVP# 312090
56.9058° N., 158.2090° W.
1,341 m (4,400 ft)

Alaska Peninsula

**SEISMIC SWARM**

Volcanic activity did not occur at Aniakchak volcano (an informal designation used by AVO to refer to the volcano that comprises Aniakchak Crater and the volcanic features in its vicinity) in 2016, but a magnitude 6.2 earthquake occurred 20 km east-southeast of Aniakchak caldera on April 2. This earthquake was followed by an energetic aftershock sequence, and most earthquakes were located in the upper 20 km of the crust. The earthquake and associated aftershock sequence were thrust events and nonvolcanic, although AVO seismologists closely monitored the activity in case a volcanic event was triggered by the regional earthquake sequence. The Aviation Color Code and Volcano Alert Level remained at **GREEN** and **NORMAL**, respectively.

Aniakchak volcano is a circular caldera 10 km (6.2 mi) in diameter and as deep as about 1 km (3,280 ft) from the rim to the caldera floor. The caldera formed during a catastrophic eruption of 75 $km^3$ (18 $mi^3$) of material about 3,400 years ago (Miller and Smith, 1987; Dreher and others, 2005; Bacon and others, 2014). Numerous lava domes, lava flows, and scoria cones occupy the interior of the caldera (Neal and others, 2000); the largest intracaldera cone is Vent Mountain, which is 2.5 km (1.5 mi) in diameter and 430 m (1,140 ft) above the floor of the caldera. The only historical eruption of Aniakchak volcano occurred in 1931 and was a powerful explosive event that covered a large part of the eastern Alaska Peninsula with ash (Nicholson and others, 2011).

## Pavlof Volcano


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

Alaska Peninsula

**SIGNIFICANT ERUPTION**

Pavlof Volcano erupted on March 27, 2016, about 500 days after the end of the previous eruption in 2014 (table 5). The March 27–28 eruption was a brief but intense eruptive event lasting about one day (fig. 16). This event generated minor ashfall at Nelson Lagoon 77 km (48 mi) northeast of Pavlof Volcano and trace ashfall at Port Heiden and Dillingham 263 km (164 mi) and 453 km (281 mi) northeast of Pavlof, respectively. More than a hundred flights were cancelled between March 27 and March 29 because of ash from the eruption. Two additional eruptive periods occurred in May and July 2016, but these events produced only small ash clouds and minor ash fallout confined to the upper flanks of the volcano. The March 28 eruption generated significant ash clouds reaching as high as 12.5 km (41,000 ft) ASL, and pyroclastic flows and lahars on the flanks of the volcano, one of which destroyed seismic station PV6 on the north flank of the volcano.

The first indication of unrest in 2016 began with a late morning telephone call on March 25 from National Weather Service personnel in Cold Bay, Alaska, who reported a steam plume rising from the summit of Pavlof Volcano (fig. 17). Although steam plumes at Pavlof are common, this particular plume was reported as more robust than usual. A review of web camera images from a Federal Aviation Administration (FAA) web camera in Cold Bay showed a prominent steam plume visible from 17:47 until 19:57 UTC (9:47 to 11:57 AKDT), when it became obscured by clouds. No unusual seismic activity was noted on March 25 or the following day on March 26.

**Table 5.** Summary of activity and observations at Pavlof Volcano, 2016.

[Data based on chronology compiled by Kristi Wallace, U.S. Geological Survey, Alaska Volcano Observatory (AVO); Alex Iezzi University of Alaska Fairbanks Geophysical Institute and AVO; and other AVO staff. All dates are listed in month, day, and year format and in Universal Coordinated Time (UTC); certain observations are listed in both UTC and Alaska Daylight Time (AKDT) or Alaska Standard Time (AST); ASL, above sea level; FAA, Federal Aviation Administration; ft, feet; km, kilometer; NE, northeast; NWS, National Weather Service; RSAM, real-time seismic amplitude measurement; $SO_2$, sulfur dioxide; USCG, U.S. Coast Guard; VAN, Volcano Activity Notice; VONA, Volcano Observatory Notice for Aviation]

| Date (UTC) | Aviation Color Code/ Volcano Alert Level | Activity | Elevated surface temperatures | Ground, remote sensing observations | Seismic and infrasound observations | AVO operational response |
|---|---|---|---|---|---|---|
| 03/25/16 | GREEN/ NORMAL | More robust than usual steam plume reported in the morning | | Steam plume observed | | |
| 03/28/16 | RED/ WARNING | Pilot reported an ash cloud at about 6 km ASL and moving north (00:18 UTC) | High | Intense thermal anomalies and ash signals by 00:51 UTC | Retrospective analysis showed seismicity increase at about 23:53 UTC March 27, 2018, infrasound signals beginning at about 2:00 UTC March 28 | 1:12 UTC: elevated the Aviation Color Code to Red from Green at 1:12 UTC |
| 03/28/16 | RED/ WARNING | 4:05 UTC, pilot reported lava fountaining and flow feature on north flank | High | Ash cloud extended NE for about 180 km; lighting detected between 13:10-19:13 UTC | Tremor and RSAM increased from 00:00 UTC until 06:38 UTC (16:00 AKDT) March 28. RSAM values leveled off but continued to fluctuate until about 09:46 UTC March 28 (01:46 AKDT), when they increased to a peak value of 3200 and then began to decline in a saw tooth pattern. After 20:40 UTC (12:40 AKDT) the values fell to about pre-eruption levels | |

**Table 5.**—Continued

| Date (UTC) | Aviation Color Code/ Volcano Alert Level | Activity | Elevated surface temperatures | Ground, remote sensing observations | Seismic and infrasound observations | AVO operational response |
|---|---|---|---|---|---|---|
| 03/28/16 | RED/ WARNING | By 15:10 UTC, the Pavlof Volcano ash cloud was a continuous plume extending about 885 km over interior Alaska; lava fountaining continues | Incandescence visible in webcam images; ash cloud extending about 885 km seen in satellite imagery | | Ground coupled airwaves and strong seismicity continues | 16:34 UTC: Issued a VAN/ VONA and kept the color code at Red because of high tremor, lighting, and sustained ash emissions |
| 03/28/16 | RED/ WARNING | Seismicity decreases beginning about 20:24 UTC; trace ashfall in Nelson Lagoon, Port Heiden, and Dillingham, Alaska | | | | |
| 03/29/16 | ORANGE/ WATCH | Seismicity decreased, continuous ash emission no longer observed by 20:40 UTC | | Drifting ash cloud still present | Tremor remains slightly above background | 2:01 UTC: lowered the color code from Red to Orange |
| 04/6/16 | YELLOW/ ADVISORY | Eruptive activity ended | | No indication of ash or lava emission | | 19:42 UTC: lowered the color code from Orange to Yellow |
| 04/22/16 | GREEN/ NORMAL | Several weeks of a return to background seismicity and no activity detected in satellite data | | | | 20:20 UTC: lowered the color code from Yellow to Green |
| 05/13/16 | ORANGE/ WATCH | Elevated seismicity observed from about 18:35 UTC, likely indicating low-level eruption | Cloudy | Cloudy | Seismicity increased | 12:04 UTC: raised the color code to Orange from Green |
| 05/15/16 | ORANGE/ WATCH | Eruption continues; minor ash emission at 3:46 UTC (estimated plume height 1,500 to 3,000 m), and again beginning at 19:25, estimate plume height 4,500 to 5,500 m). | Weak | Ash emission seen in webcam on May 15 | Tremor remains slightly above background | |

**Table 5.**—Continued

| Date (UTC) | Aviation Color Code/ Volcano Alert Level | Activity | Elevated surface temperatures | Ground, remote sensing observations | Seismic and infrasound observations | AVO operational response |
|---|---|---|---|---|---|---|
| 05/17/16 | ORANGE/ WATCH | Pilot reports of ash clouds to 4600 m; $SO_2$ seen in satellite data. | High | Robust steaming, high temperatures, and $SO_2$ plume | Tremor and low frequency events | Notified FAA, NWS, and USCG to alert of possible ash emissions |
| 05/20/16 | YELLOW/ ADVISORY | No ash emissions since May 16 | | No evidence of eruption | No seismic signals associated with ash emission or lava effusion | 19:35 UTC: lowered color code from Orange to Yellow |
| 06/17/16 | GREEN/ NORMAL | Return to normal background state | | | | 19:01 UTC: lowered color code from Yellow to Green |
| 07/1/16 | YELLOW/ ADVISORY | Increased seismicity and gas emissions | | Minor steam emissions seen in webcam | Seismicity increased | 19:44 UTC: raised color code from Green to Yellow |
| 07/12/16 | YELLOW/ ADVISORY | Minor ash and steam emissions | Weak | Minor ash and steam emissions seen in webcam | Elevated seismicity continues | |
| 07/28/16 | ORANGE/ WATCH | Steam and ash plume to 3.6 km ASL | Weak | Steam and ash plume to 3.6 km ASL | Minor increase in seismicity | 23:00 UTC: raised color code from Yellow to Orange |
| 08/4/16 | YELLOW/ ADVISORY | No evidence of continued ash since August 31; low-level steam and gas emissions continue | | Occasional elevated surface temperatures | Slightly above background | 19:21 UTC: lowered color code from Orange to Yellow |

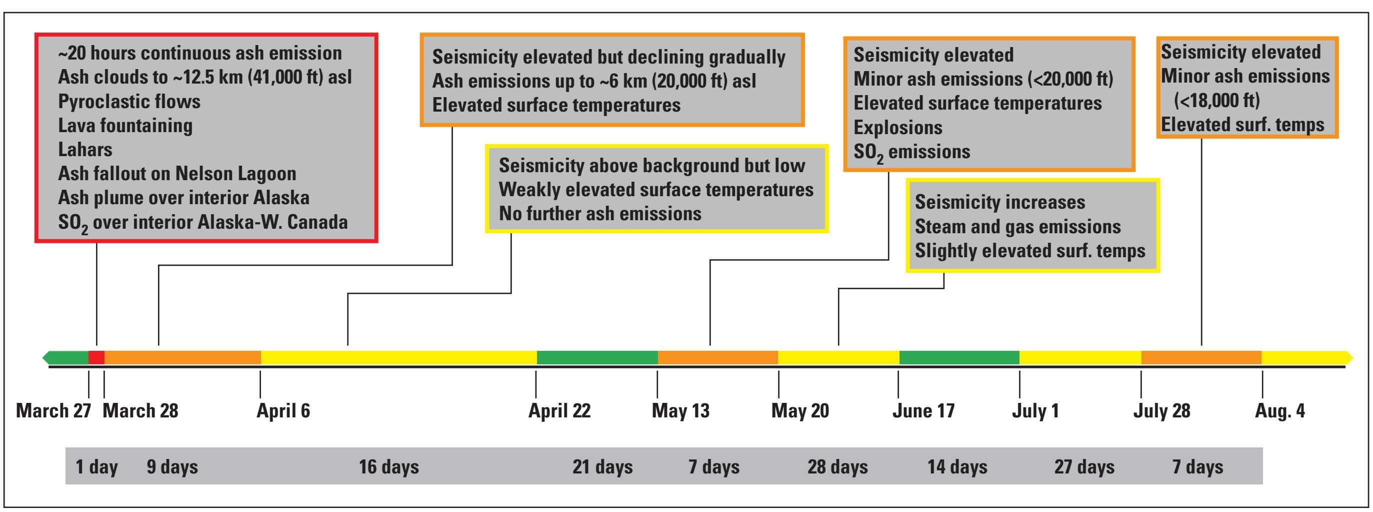



**Figure 16.** Chart showing the generalized chronology of eruptive activity at Pavlof Volcano in 2016. The time periods indicated at the bottom of the figure are the durations (in days) at each respective Aviation Color Code and Volcano Alert Level. ASL, above sea level; ft, feet; km, kilometers; $SO_2$, sulfur dioxide; surf, surface; W., western.

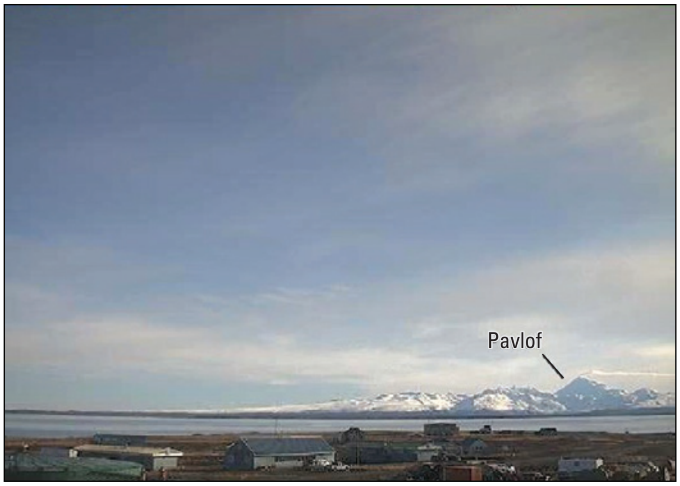



**Figure 17.** Web-camera image from the Federal Aviation Administration Cold Bay, Alaska, northeast camera, March 25, 2016, 18:57 Coordinated Universal Time (10:57 Alaska Daylight Time). Note prominent steam plume emanating from the summit of Pavlof Volcano. This was the first noteworthy sign of unrest preceding the March 27, 2016, eruption of Pavlof Volcano.

The volcano remained quiet throughout most of the day on Sunday, March 27, and a relatively clear satellite view of the volcano summit above the cloud deck at 22:33:15 UTC (14:33 AKDT) showed no evidence of any unrest. At 00:18 UTC, March 28 (16:18 AKDT), an ash cloud reaching about 6 km (20,000 ft) ASL and moving north was reported by a nearby pilot. At about 01:33 UTC March 28 (17:33 AKDT March 27), AVO received a pilot report of ash emissions from Pavlof Volcano reaching an altitude of about 9.1 km (30,000 ft) ASL and observations of lava at the surface. Retrospective analysis of seismic data indicated that seismicity began to increase from background levels at about 23:53 UTC (15:53 AKDT) denoted by an abrupt increase in real-time seismic amplitude measurement (RSAM) levels and the appearance of continuous tremor on all operating stations of the Pavlof Volcano network. The tremor and RSAM levels observed on station PS4A illustrate seismicity during the eruption (fig. 18). At about 00:00 UTC March 28 (16:00 AKDT) tremor and RSAM levels continued to increase until about 06:38 UTC March 28(22:38 AKDT) after which the RSAM values leveled off but continued to fluctuate. At approximately 09:46 UTC March 28 (01:46 AKDT) they increased toward a peak value of 3200 and then began to decline in a saw tooth pattern until 20:40 UTC (12:40 AKDT) when the values fell to about pre-eruption levels (fig. 18).

The abrupt increase in RSAM and tremor observed around 00:00 UTC March 28 (16:00 AKDT March 27) prompted AVO to raise the Aviation Color Code and the Volcano Alert Level to **RED** and **WARNING** at 01:12 UTC March 28 (17:12 AKDT), respectively. The rapid increase in seismicity is characteristic of several recent Pavlof Volcano eruptions, and it is not uncommon for the Aviation Color Code and the Volcano Alert Level to move from background status to the highest level with minimal precursory seismic activity.

At 04:05 UTC March 28 (20:05 AKDT March 27), AVO received a pilot report of lava fountaining near the summit and a flowage feature on the north flank of the volcano. According to the pilot, the flowage feature had apparently reached the Bering Sea coast. The pilot referred to the feature as a pyroclastic flow, and it is possible that pyroclastic flows produced

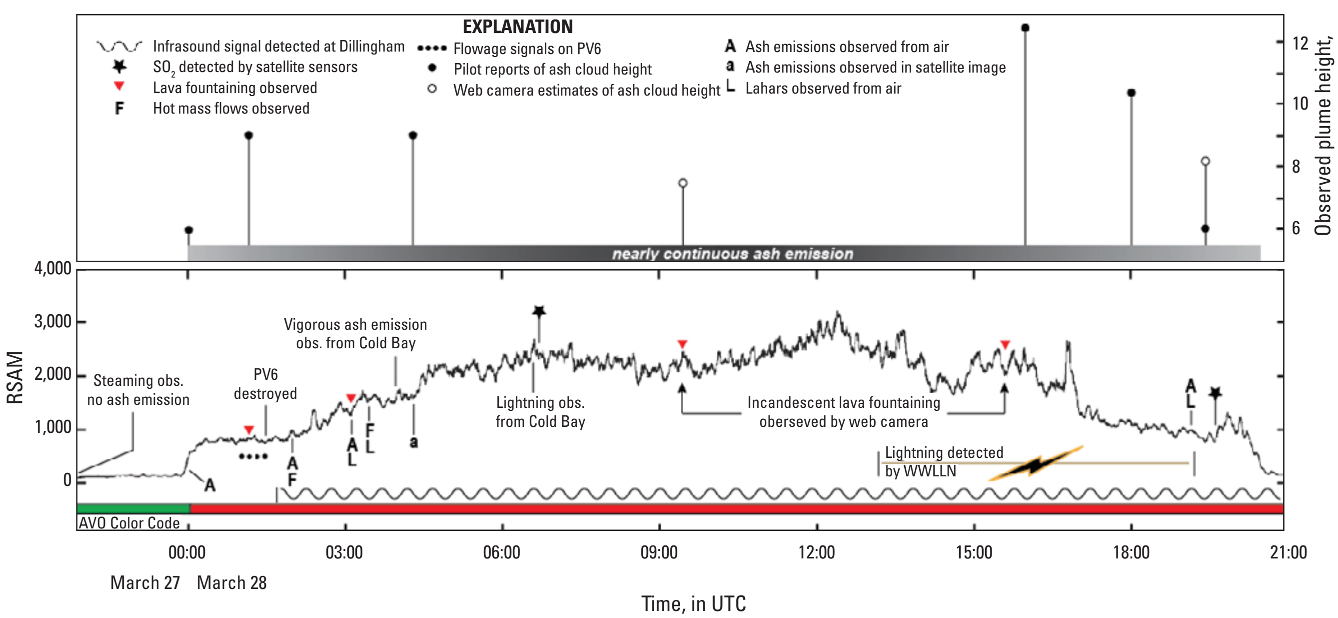



**Figure 18.** Real-time seismic amplitude measurement (RSAM) plot from seismic station PS4A showing changes in RSAM associated with the March 28 Coordinated Universal Time (UTC) eruptive period. Also shown are periods of significant ash emission, observed lava fountaining, and lightning detections. AVO, Alaska Volcano Observatory; RSAM, real-time seismic amplitude measurement; $SO_2$, sulfur dioxide; UTC, universal coordinated time; WWLLN, world wide lightning location network.

by collapse of the eruption column formed during the eruption. It is also possible that meltwater generated by the interaction of pyroclastic flows with snow and ice may have flowed well beyond the volcano to the north as lahars. The specific drainage containing the flow was not identified by the pilot, but lahars from previous historical eruptions have inundated both the Leontovich and Caribou River drainages on the north side of Pavlof Volcano.

Pyroclastic flows or hot granular mass flows associated with collapse of spatter accumulations on the upper part of the edifice likely destroyed seismic station PV6 on the lower north flank of the volcano (fig. 19). Flowage signals were evident at PV6 starting about 01:06 UTC March 28 (17:06 AKDT March 27), and the station stopped transmitting 12 minutes later at 01:18 UTC March 28 (17:18 AKDT March 27).

Satellite observations from 04:15 UTC March 28 (20:15 AKDT March 27) indicated that the ash cloud from the eruption extended 180 km (108 mi) northeast beyond the volcano over the Bering Sea (fig. 20). Ash cloud heights from pilot reports indicated a maximum altitude of about 9.1 km ASL (30,000 ft). By 15:10 UTC March 28 (07:10 AKDT), the Pavlof Volcano ash cloud formed a narrow, continuous plume that extended for about 885 km (550 mi) from the volcano over interior Alaska as detected in a Himawari-8 false color image (fig. 21).

Ash fallout on March 27–28 was reported in several communities northeast of Pavlof Volcano, including Nelson Lagoon, Port Heiden, and Dillingham, Alaska. In Nelson Lagoon 77 km (48 mi) northeast of Pavlof, 3–17 millimeters (mm; 0.125–0.66 inches) of dark ash fell, covering roofs and surfaces (fig. 22). Trace amounts of ash (<0.8 mm) were reported in Port Heiden and in Dillingham 263 km (164 mi) 453 km (281 mi) northeast of Pavlof Volcano, respectively.

The March 27–28 ash plume caused the cancellation of 41 Alaska Airlines flights to and from Barrow, Bethel, Anchorage, Fairbanks, Kotzebue, Nome, and Prudhoe Bay, Alaska, on Monday, March 28, 2016. Regional flights operated by Bering Air were cancelled on the morning of March 28, PenAir suspended service to Dutch Harbor, Alaska, in the afternoon, and Ravn reported numerous flight cancellations (FOX59, 2016). Flight cancellations continued on Tuesday, March 29, and Alaska Airlines reported 28 cancelled flights to Barrow, Bethel, Kotzebue, Nome, and Prudhoe Bay, representing about 57 percent of Alaska's flights to the most northern region it serves. Alaska Airlines additionally reported more than 6,200 travelers were affected on March 28 and 29 (Alaska Airlines, 2016).

Lightning in the vicinity of Pavlof Volcano was reported by the WWLLN, which consisted of 16 lightning flashes detected over a 6-hour period between 13:10–19:13 UTC

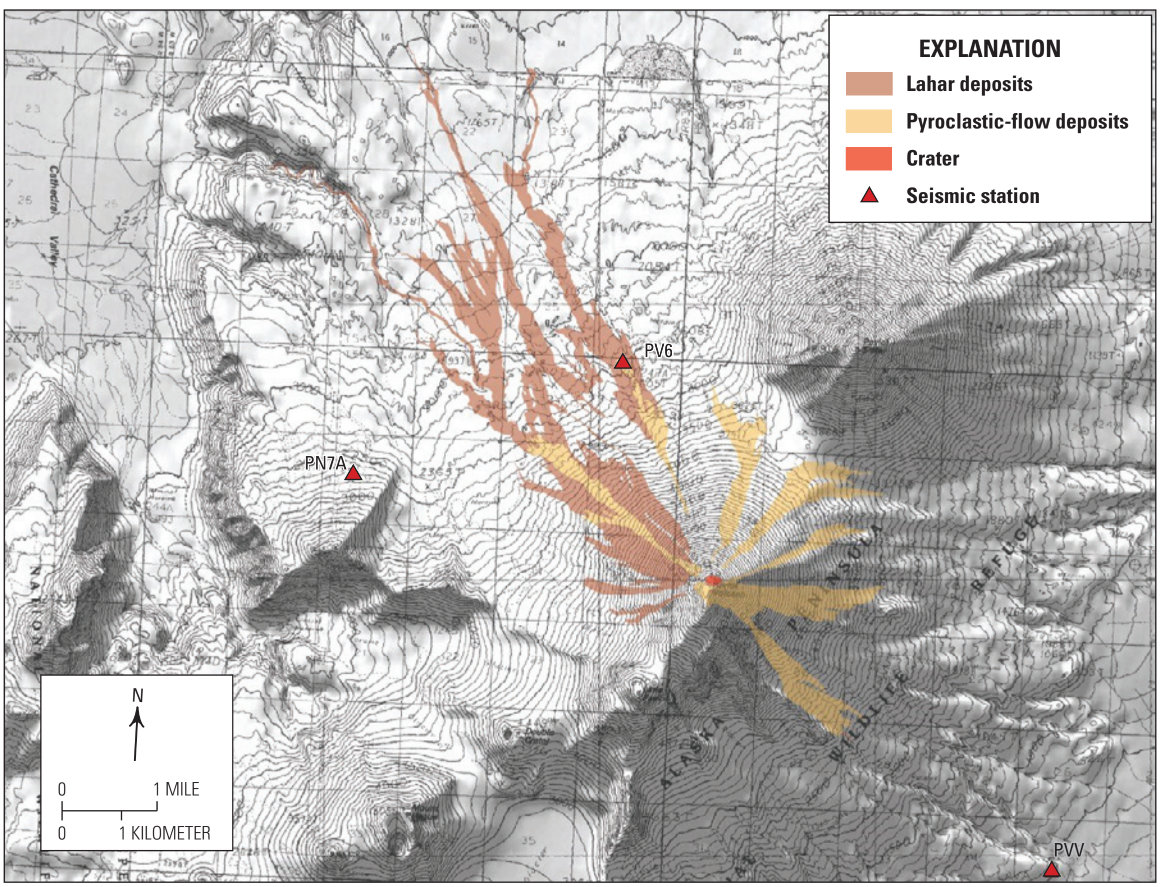



**Figure 19.** Map of Pavlof Volcano showing mass-flow deposits generated by the March 28 eruption. Deposits were identified and mapped on high resolution satellite images.

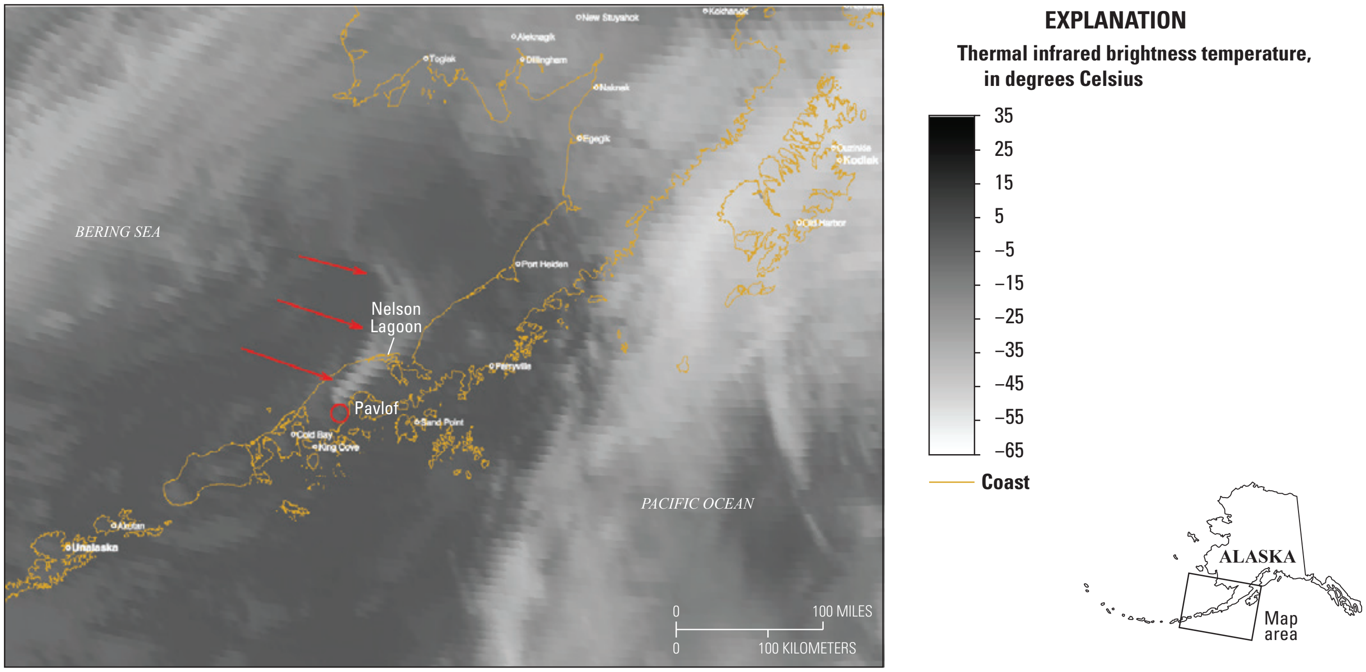



**Figure 20.** Geostationary operational environmental satellite thermal infrared image from 4:15 UTC March 28, 2016, showing extent of ash cloud (red arrows) from Pavlof Volcano.

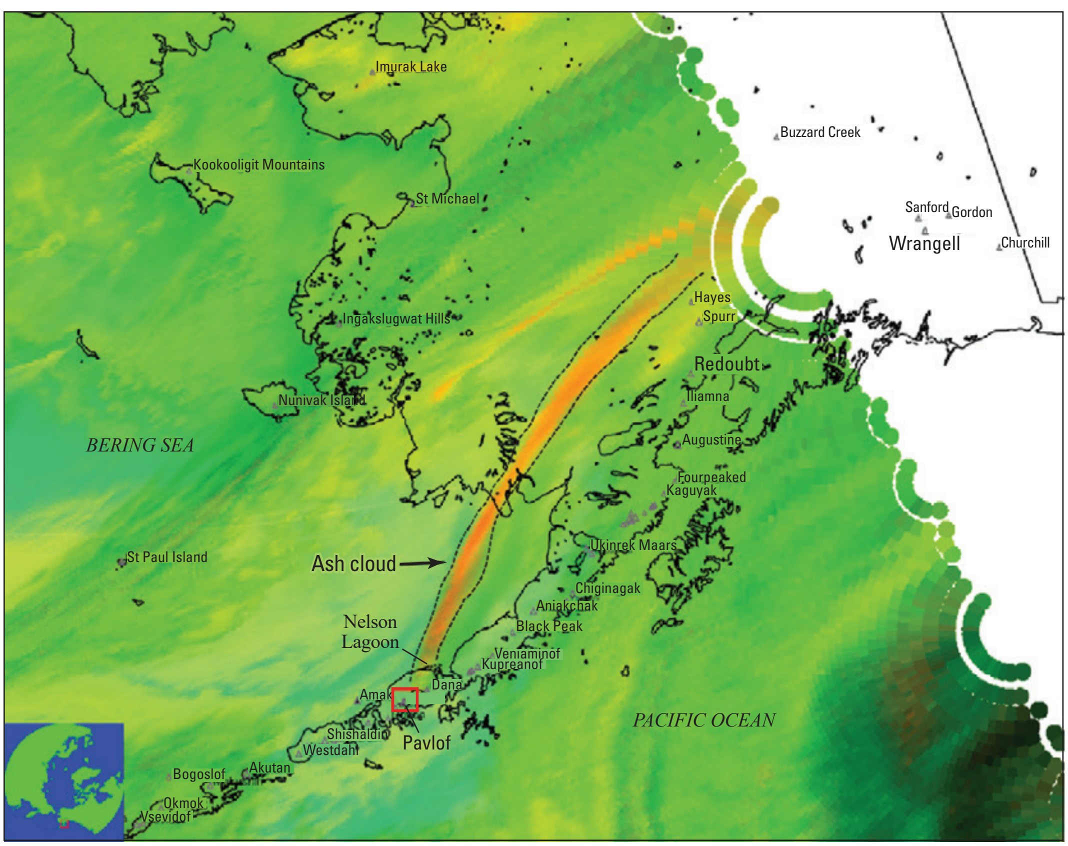



**Figure 21.** Himawari-8 false color satellite image from 15:10 UTC March 28, 2016, showing extent of Pavlof Volcano ash cloud (dashed outline) over interior Alaska.

(05:10–11:13 AKDT) on March 28. Sulfur dioxide ($SO_2$) emissions were detected by Infrared Atmospheric Sounding Interferometer (IASI) satellite sensors on the European Space Agency MetOp series of polar orbiting satellites on March 28 and 29. The $SO_2$ cloud extended over interior Alaska and northwestern Canada (fig. 23) and eventually reached the southern Hudson Bay area of central Canada. The cumulative $SO_2$ mass determined from the Ozone Mapping Profiler Suite (OMPS) satellite data obtained on 28 March was on the order of 20–30 kilotons (Simon Carn, Michigan Technological University, written commun., 2016).

The March 28 Pavlof eruption was clearly recorded by infrasound instruments 453 km (281 mi) to the northeast at Dillingham (fig. 18). An infrasound signal was first evident at about 02:00 UTC March 28 (18:00 AKDT March 27), which corresponds to an emission time at the vent of about 01:40 UTC March 28 (17:40 AKDT March 27). The magnitude of the infrasound signals gradually rose until about 04:30 UTC March 28 (20:30 AKDT March 27) and then stabilized at high levels for several hours before declining significantly with no clear signals detected at Dillingham after about 21:00 UTC (13:00 AKDT) March 28 (David Fee, University of Alaska Fairbanks Geophysical Institute, written commun., 2016).

By 20:40 UTC (12:40 AKDT) March 28, ash emissions were no longer evident in satellite data, and seismic activity had declined to nearly pre-eruption levels. AVO lowered the Aviation Color Code to **ORANGE** and the Volcano Alert Level to **WATCH** at 02:01 UTC (18:01 AKDT) March 29 because of the decline in robust eruptive activity.

**Figure 22.** Photograph showing minor ash fall deposits (dark brown coloration) on a deck in Nelson Lagoon, Alaska. Ash fall occurred on March 27–28, 2016. Photograph by Allan Brandell, March 30, 2016, used with permission.

After March 28, 2016, unrest at Pavlof Volcano gradually declined. By April 6, 2016, ash emissions were no longer detected, and only weakly elevated surface temperatures associated with cooling deposits were observed in satellite data. At this point, AVO lowered the Aviation Color Code to **YELLOW** and the Volcano Alert Level to **ADVISORY**. Unrest continued to decline throughout the month of April 2016, and on April 22 AVO lowered the Aviation Color Code to **GREEN** and the Volcano Alert Level to **NORMAL**.

Pavlof Volcano remained at background levels of unrest until May 13, 2016. At about 18:35 UTC (10:35 AKDT) May 13, seismic activity increased to levels commonly associated with low-level eruptive activity, suggesting that an eruption may have started. AVO responded by raising the Aviation Color Code to **ORANGE** and the Volcano Alert Level to **WATCH** at 20:04 UTC (12:04 AKDT) May 13. No volcanic activity was observed in satellite data or in web-camera views of the volcano on May 13. Minor ash emissions reaching as high as 6 km (20,000 ft) ASL were observed in images from the Cold Bay FAA web camera beginning around 03:46 UTC May 15 (19:46 AKDT May 14). Elevated surface temperatures were observed in satellite data on May 15, and $SO_2$ emissions were detected in Ozone Monitoring Instrument (OMI) satellite data at 23:28 UTC (15:28 AKDT) May 17. AVO received several pilot reports of ash clouds rising to about 4.6 km (15,000 ft) ASL on May 17. This brief period of low-level eruptive activity lasted only a few days, and on May 20 AVO lowered the Aviation Color Code to **YELLOW** and the Volcano Alert Level to **ADVISORY**. After a few more weeks of no activity, AVO moved the Aviation Color Code to **GREEN** and Volcano Alert Level to **NORMAL** on June 17.

The volcano remained quiet until July 1, 2016, when seismicity at the volcano began to increase, and minor steam emissions were observed in web-camera images. The increase in unrest prompted AVO to raise the Aviation Color Code to **YELLOW** and the Volcano Alert Level to **ADVISORY**.

Beginning around 21:00 UTC (13:00 AKDT) July 12 web-camera images showed minor ash emissions rising just above the roughly 2.6 km (8,500 ft) high summit vent and extending a few miles to the southwest. Clear satellite views of the volcano from about this same time showed no evidence of ash emissions or elevated surface temperatures, and there was no anomalous seismicity associated with this low-level activity. After July 12, Pavlof Volcano remained in a state of low-level unrest with occasional slightly elevated surface temperatures and minor steam and diffuse ash clouds observed. The Aviation Color Code remained **YELLOW** and the Volcanic Alert Level **ADVISORY**.

On July 28, minor eruptive activity was observed in web-camera and satellite images of Pavlof Volcano and was characterized by vigorous, steam-rich degassing and minor

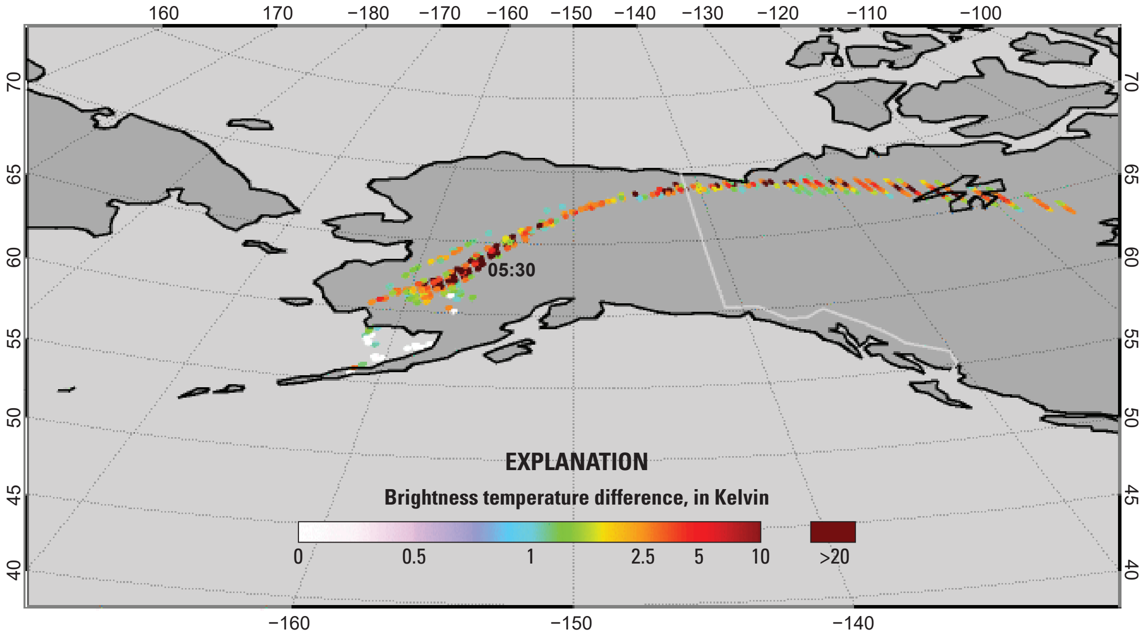



**Figure 23.** Map of the northern Pacific Ocean region showing sulfur dioxide ($SO_2$) brightness temperature, in Kelvin (K), derived from the Infrared Atmospheric Sounding Interferometer (IASI) on the European Space Agency MetOp series of polar orbiting satellites. Time of satellite overpass is 5:30 UTC. The colored area shows the detected extent of the $SO_2$ cloud from Pavlof Volcano on March 29, 2016. Image courtesy of the Support for Aviation Control Service program, Belgium Institute for Space Aeronomy.

ash emissions. Pilots also reported seeing ash emissions as high as 2.7–3.6 km (9,000–12,000 ft) ASL. These observations coincided with a minor increase in seismicity to levels high enough to warrant raising the Aviation Color Code to **ORANGE** and the Volcano Alert Level to **WATCH** at 19:55 UTC (11:55 AKDT) on July 28. Observations of minor steam and ash emissions as high as 2.4 km (8,000 ft) ASL were made by pilots on July 31. Only weakly elevated surface temperatures were observed on August 2, and by August 4 there was no further evidence of unrest at Pavlof Volcano. Thus, AVO reduced the Aviation Color Code to **YELLOW** and the Volcano Alert Level to **ADVISORY**.

Unrest at Pavlof Volcano remained slightly above background levels for about six months after early August 2016. Throughout this period, low-level steam and gas plumes from the summit and weakly elevated surface temperatures were observed occasionally when viewing conditions were favorable. The elevated surface temperatures were likely associated with still cooling pyroclastic deposits on the north flank of the volcano. By February 2017, unrest had declined to background levels although occasional, small, low-frequency events were observed in seismic data, consistent with an open, degassing system. AVO lowered the Aviation Color Code to **GREEN** and the Alert Level to **NORMAL** on February 2, 2017.

Pavlof Volcano is a symmetrical, conical-shaped stratovolcano located on the southwestern end of the Alaska Peninsula, about 950 km (590 mi) southwest of Anchorage, Alaska. The community of Cold Bay, Alaska, is located 60 km (37 mi) to the southwest of Pavlof Volcano. On the basis of historical record, it is one of the most frequently active volcanoes in the Aleutian arc (Cameron and others, 2018). Eruptive activity typically is Strombolian lava fountaining throughout several weeks or months. The last eruption of Pavlof Volcano prior to the 2016 eruptions was in 2014 (Waythomas and others, 2017).

## Frosty Peak


GVP# 312010
55.0673° N., 162.8354° W.
1,920 m (6,299 ft)

Alaska Peninsula

**AVALANCHE**

Eruptive activity and volcanic unrest were not observed at Frosty Peak in 2016, but residents 15 km (9 mi) to the northeast in Cold Bay, Alaska, reported an avalanche to AVO on November 12. Cold Bay resident Michael Livingston sent AVO photographs of the avalanche and rockfall taken by Happy Kremer (fig. 24). These images show that a small part of Frosty Peak's bedrock spire collapsed and formed a prominent linear debris avalanche track across the snow.

The Aviation Color Code and Volcanic Alert Level remained **UNASSIGNED**, because Frosty Peak is not seismically monitored by AVO and the avalanche was not initiated by volcanic activity. On November 14, AVO released an Information Statement about the event stating that, "The collapse is not due to volcanic activity and was likely the result of the failure of unstable, altered, and weakened rock that makes up the summit of the volcano. Similar rock, ice, and snow avalanches have occurred previously at Frosty, most recently in 2001 (McGimsey and others, 2004)."

Frosty Peak, located about 15 km (9 mi) southeast of Cold Bay, is a late Pleistocene to early Holocene stratovolcano that is now deeply incised by erosion (Wilson and Weber, 2001). A possibly Holocene debris-flow deposit rich in hydrothermally altered clasts, derived from the north crater of Frosty Peak, extends westward as much as 9 km and to within 1 km (0.6 mi) of the sea, and a Holocene ash flow has been identified (Wilson and Weber, 2001).

**Figure 24.** Photograph of Frosty Peak showing the 2016 avalanche. Photograph taken from Cold Bay, Alaska, by Happy Kremer, November 11, 2016, used with permission.

## Shishaldin Volcano


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

Unimak Islands, Fox Islands, Aleutian Islands

**DECREASING UNREST**

Shishaldin Volcano experienced intermittent, low-level eruption throughout 2015 (Dixon and others, 2017) and began January 2016 at Aviation Color Code **YELLOW** and Volcanic Alert Level **ADVISORY** with low-level tremor, detected airwaves from low-level explosive degassing, and the occasional observation of elevated surface temperatures at the summit. Moderately elevated surface temperatures were detected at Shishaldin Volcano in AVHRR satellite data on January 13, and airwaves were observed in seismic and infrasound data once on January 26. This activity then declined during the first two months of 2016. AVO lowered the Aviation Color Code and Volcanic Alert Level at Shishaldin from **YELLOW** and **ADVISORY** to **GREEN** and **NORMAL**, respectively, on March 10, stating that, “low-amplitude seismic tremor consistent with an open, degassing system continues to be seen in seismic data and is considered to be within the bounds of background activity for Shishaldin.”

Throughout the rest of the year, airwaves were occasionally observed in seismic data: February 8, 9, and 11–14; May 19; and October 3–5, 11, and 26. Shishaldin Volcano also continued its typical background-level activities, which consisted of intermittent steam plumes and weakly elevated surface temperatures throughout 2016 (fig. 25).

Shishaldin Volcano, located near the center of Unimak Island in the eastern Aleutian Islands, is a spectacular symmetric cone with a base diameter of approximately 16 km (10 mi). A small summit crater typically emits a noticeable steam plume occasionally containing minor amounts of ash. Shishaldin Volcano is one of the most active volcanoes in the Aleutian volcanic arc (Miller and others, 1998).

**Figure 25.** Aerial photograph of Shishaldin Volcano showing minor steam plume emanating from its small summit crater on July 1, 2016. Photograph by Tarek Wetzel, used with permission.

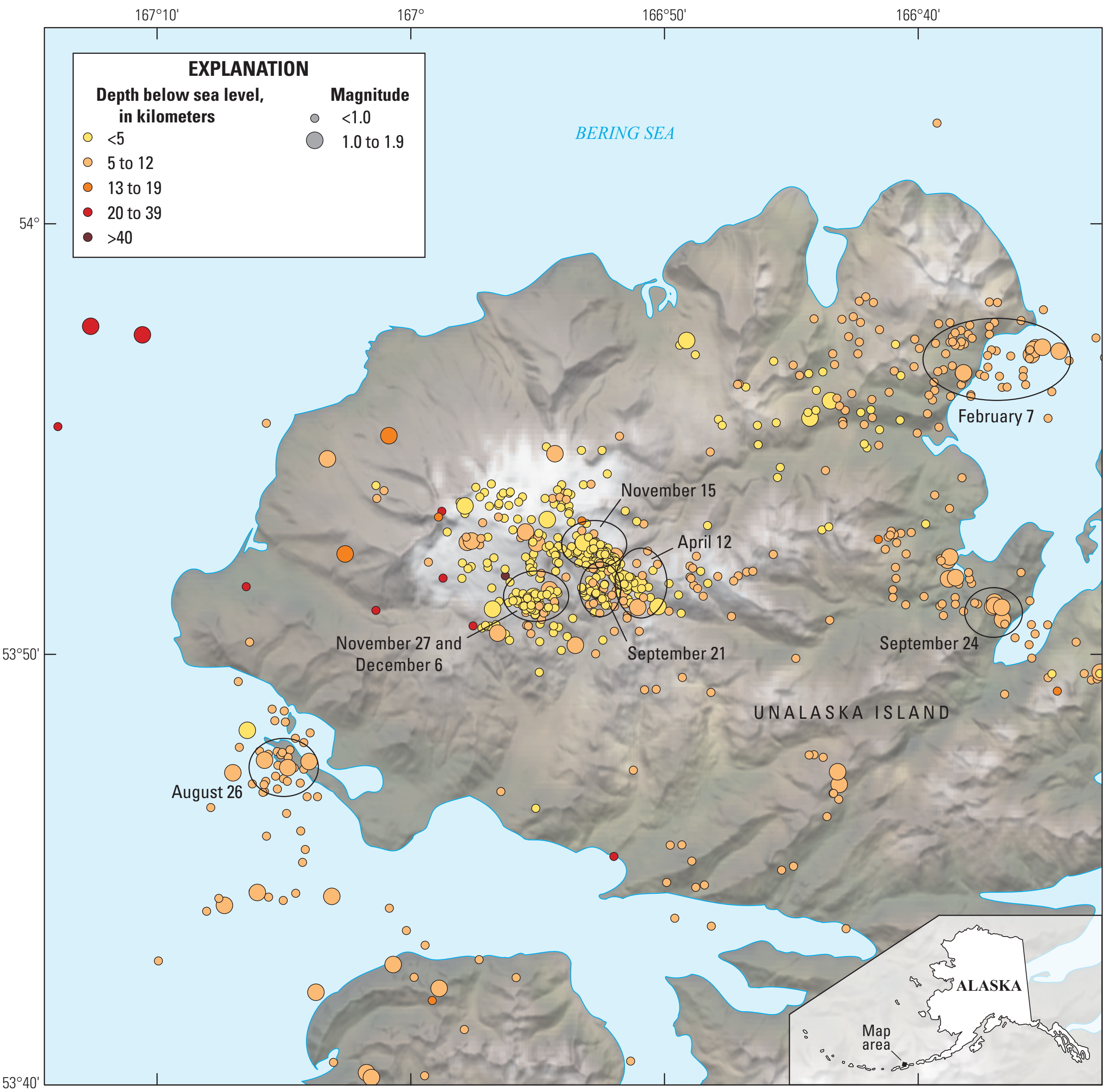
## Makushin Volcano


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

Fox Islands, Aleutian Islands

**SEISMIC SWARMS**

Earthquake swarms are common at Makushin Volcano, and nine short earthquake swarms occurred in 2016. Most swarms comprised fewer than two dozen earthquakes each. Prominent swarms occurred on February 7, April 12, August 26, September 21, September 24, November 15, November 27, and December 26 (fig. 26). During all of 2016, the Aviation Color Code and Volcanic Alert Level remained at **GREEN** and **NORMAL** respectively.




Base from U.S. Geological Survey 60-meter digital data and Alaska statewide imagery from GeoNorth
Coordinate system: WGS 1984 Web Mercator Auxiliary Sphere

0 5 10 MILES
0 5 10 KILOMETERS

**Figure 26.** Epicentral map showing the approximate locations of nine earthquake swarms (circled) on Makushin Volcano on February 7, April 12, August 26, September 21, September 24, November 15, November 27, and December 6, 2016.

Makushin Volcano is located on Unalaska Island in the eastern Aleutian Islands, about 25 km (15.5 mi) west of the city of Unalaska-Dutch Harbor, an active fishing port. The volcano is a broad, truncated, and deeply glaciated stratovolcano with a 3-km- (1.9 mi-) wide summit caldera. Over the years, as ice cover has retreated, a small intracaldera cinder cone that hosts a turquoise-colored lake and abundant fumaroles has become a prominent feature. The summit region is capped by a 40 $km^2$ (15 $mi^2$) 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) ASL (McGimsey and Neal, 1996; McConnell and others, 1998; Begét and others, 2000).

## Bogoslof Island


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

Fox Islands, Aleutian Islands

**SIGNIFICANT ERUPTION**

Bogoslof Island (herein called Bogoslof volcano to include the surface and submarine expression of this volcanic system) began erupting in mid-December 2016, and the eruption continued into 2017. The 2016 activity consisted of intermittent explosions lasting minutes to hours with the resulting volcanic clouds rising 2.6–8.7 km (8,500–28,500 ft) ASL. Throughout the eruption, island morphology was altered through the combined effects of pyroclastic debris emplacement and marine erosion of these unconsolidated volcanic deposits. AVO became aware of the eruption on December 21 from a pilot report of an ash plume (15:54 AKST December 20), and AVO raised the Aviation Color Code and Volcanic Alert Level to **RED** and **WARNING**, respectively (table 2; table 6). Retrospective analysis of seismic and satellite data suggests possible eruptive activity as early as December 12. The Aviation Color Code and Volcanic Alert Level at Bogoslof volcano alternated between **RED** and **WARNING** and **ORANGE** and **WATCH** between December 20 and December 31, respectively. Eruptive activity at Bogoslof volcano in 2017 is covered by the 2017 summary report (Dixon and others, 2020) and in a special volume about the 2016–17 Bogoslof volcano eruption (Waythomas and others, 2019), which contains more details than can be presented here.

Unlike many of the historically active volcanoes in Alaska, Bogoslof volcano lacks a local real-time geophysical monitoring network, and unrest is detected by geophysical instruments located at regional distances (beyond 40 km [25 mi]) from the volcano. Seismic activity in 2016 was detected by the AVO networks on Umnak and Unalaska Islands located 50 to 75 km (30–47 mi) south and east of the volcano, respectively. In addition, eruptive activity in 2016 was detected by infrasound equipment located on Umnak Island; Dillingham, Alaska, (445 km or 276 mi northeast of Bogoslof Island); Sand Point, Alaska (500 km or 310 mi northeast of Bogoslof Island); Akutan, Alaska (150 km or 93 mi northeast of Bogoslof); and Mount Cleveland (175 km or 109 mi southwest of Bogoslof Island). Volcanic lightning was associated with many of the volcano's ash clouds and was identified by lighting detection networks operated by WWLLN and by Vaisala monitoring systems. Volcanic $SO_2$ emissions from Bogoslof volcano were detected by various satellite-borne instruments. Additional observations from local observers on nearby islands, mariners, and pilots were useful in documenting the nature of eruptive activity in 2016 (Coombs and others, 2018). Explosive events at Bogoslof volcano during 2016 typically lasted only a few minutes to tens of minutes and resulted in ash clouds rising as high as 8.7 km (28,500 ft) ASL. At least 13 explosive events occurred at Bogoslof volcano during December 2016 (Coombs and others, 2018; Coombs and others, 2019).

Retrospective analysis of earthquake activity in the region indicated two earthquake sequences, one on September 28 and another starting on December 11. Many sporadic earthquakes occurred at Bogoslof volcano during a 6-month period preceding the onset of eruptive activity (Stephen Holtkamp, University of Alaska Fairbanks Geophysical Institute (UAFGI), written commun., 2017). At least eight earthquakes of magnitude 1.3–2.5 also occurred in this time frame near the volcano, but it is unclear given the seismic network configuration, if these earthquakes were related to precursory unrest at Bogoslof. The precursory phase of the eruption was also determined with retrospective data analysis: infrasound signals from December 12, followed by a Sentinel-2 satellite image from 22:29:29 UTC (13:29:29 AKST) December 14 that showed a billowy, white steam plume emanating from the central part of Bogoslof Island (fig. 27). On December 14, AVO received an email report from St. George, Alaska, 308 km (191 mi) north-northwest of Bogoslof Island, about an intermittent sulfur smell, likely corresponding to activity at Bogoslof volcano. Retrospective analysis of satellite data showed detectable $SO_2$ gas emissions from Bogoslof volcano on December 16 and 19.

On December 21, an explosive eruption of Bogoslof volcano was reported by several pilots who observed a lightly colored volcanic cloud at 00:54 UTC (15:54 AKST) December 20. Satellite data showed a discrete volcanic cloud just prior to 00:54 UTC (15:54 AKST) December 20 that detached and drifted to the south by 01:15 UTC (16:15 AKST) December 20. As a result of these observations, AVO raised the Aviation Color Code to **RED** and the Volcano Alert Level to **WARNING**.

Between the December 21 event and the end of the year, there were at least seven more explosive eruptions; two eruptions occurred on December 22, and one on December 23, 26, 29, 30, and 31, respectively (table 6). The December 2016 explosions sent ash clouds between 2.6 km (8,500 ft) and

**Table 6.** Summary of significant events and Aviation Color Code and Volcanic Alert Level changes during the 2016 portion of the 2016–2017 Bogoslof Island eruption.

[Table based on chronology developed by Alaska Volcano Observatory (AVO) staff, especially Kristi Wallace, U.S. Geologic 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); event numbers are determined and used as published in Coombs and others, 2019; ASL, above sea level; ft, feet; km, kilometer; sulfur dioxide, $SO_2$]

| Date (UTC) | Event Number | Aviation Color Code and Volcanic Alert Level | Type of Unrest | Ground, remote sensing observations | Seismic and infrasound observations[1] |
|---|---|---|---|---|---|
| 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, likely pyroclastic flows. | Lightly 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; uplift of the southern part of the island 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. |

[1]Bogoslof Island has no geophysical network and thus all mention of seismic and infrasound data are from networks located on Unimak and Unalaska Islands about 40 and 60 km south and east of Bogoslof Island, respectively.

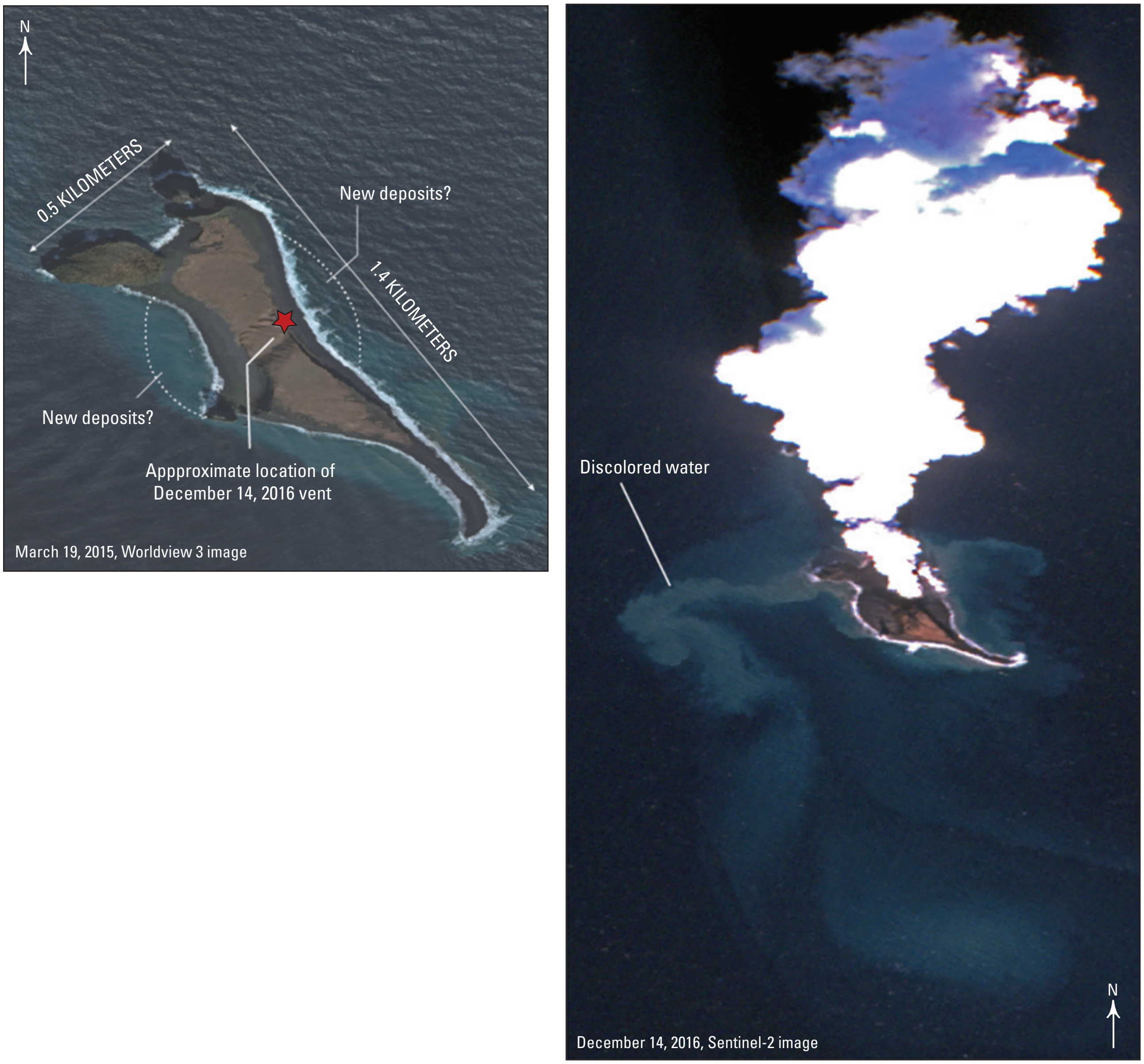



**Figure 27.** Composite images of Bogoslof Island taken on March 19, 2015, and December 14, 2016. The March 19, 2015, image shows the pre-eruption configuration of Bogoslof Island, and the approximate location of the vent is apparent in the December 14, 2016, Sentinel-2 image. Also shown are what appear to be new deposits on the east and west sides of the island. These apparent deposits and the robust volcanic cloud suggest that eruptive activity at Bogoslof Island was underway by December 14, 2016. Figure modified from image by Chris Waythomas, U.S. Geological Survey-Alaska Volcano Observatory.

9 km (28,500 ft) ASL and lasted between a few minutes to 3 hours. Figure 28 shows a satellite image of the volcanic cloud generated during the December 22 explosion. The U.S. Coast Guard cutter *Alex Haley* was able to witness the December 23 event (fig. 29) and provided rare, eyewitness images of this eruptive period. Figure 30 shows the volcanic cloud generated on December 26–27, which rose to about 8.5 km (28,000 ft).

During the month of December, AVO alternated the color code at Bogoslof volcano between **RED** and **ORANGE** multiple times, with five elevations to **RED** and four decreases to **ORANGE**. Although several explosions generated ash clouds visible in satellite imagery, ash clouds generated in 2016 did not have a significant impact because flights were diverted around the ash cloud, and ashfall did not affect

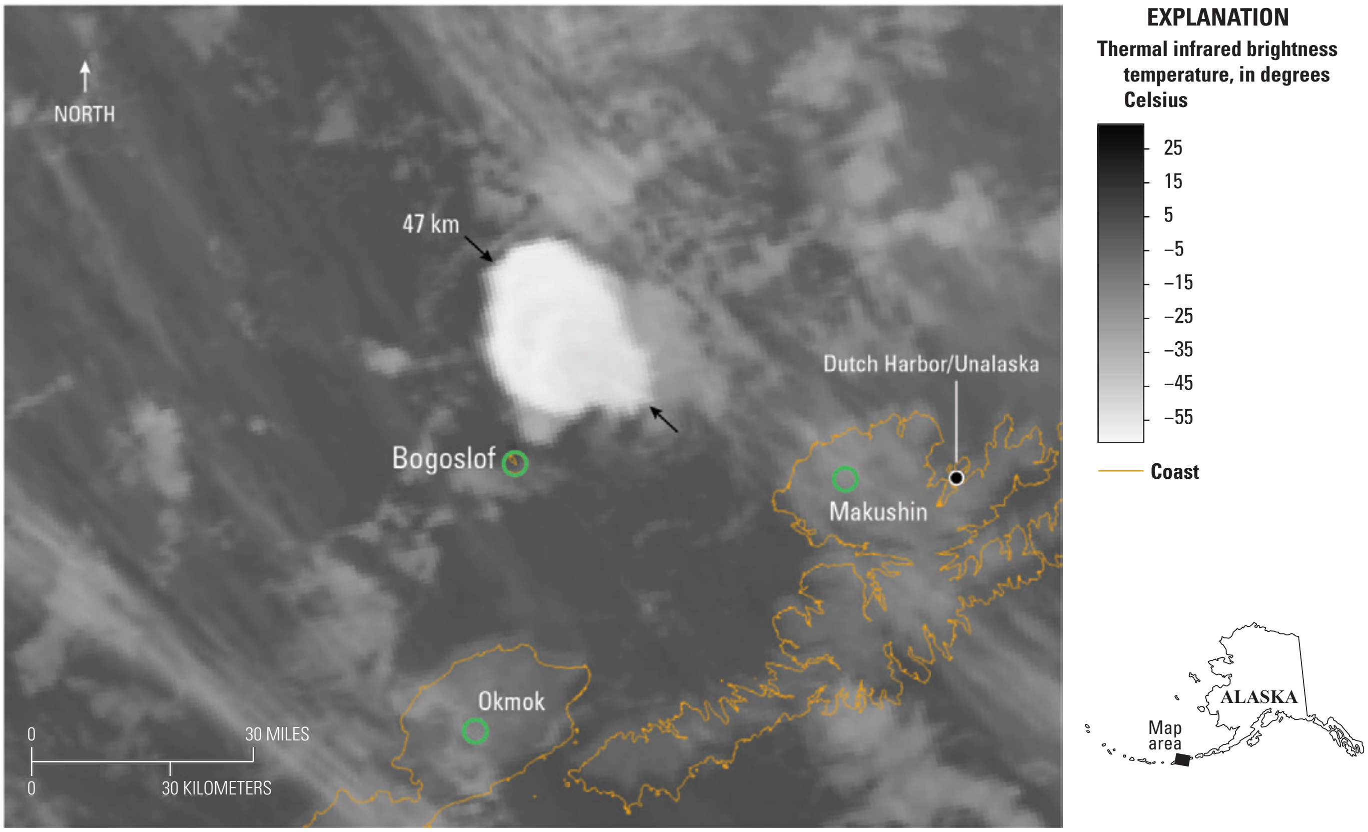



**Figure 28.** National Oceanic and Aviation Administration-19 Thermal Infrared image showing volcanic cloud erupted from Bogoslof Island at 01:48:39 UTC December 22, 2016 (16:48 AKST, December 21). The bright cloud reached a height of about 5 kilometers (km; 16,000 feet) ASL, a diameter of about 47 km, and probably contained significant amounts of water vapor and ice. Figure by Chris Waythomas, U.S. Geological Survey-Alaska Volcano Observatory.

**Figure 29.** Photograph of Bogoslof Island during the December 23, 2016, eruption showing lightning and the ejection of incandescent lava and fragmental material. Photograph taken on the morning of December 23, 2016, by the crew of the US Coast Guard (USCG) cutter *Alex Haley*. Photograph used with permission from the USCG.

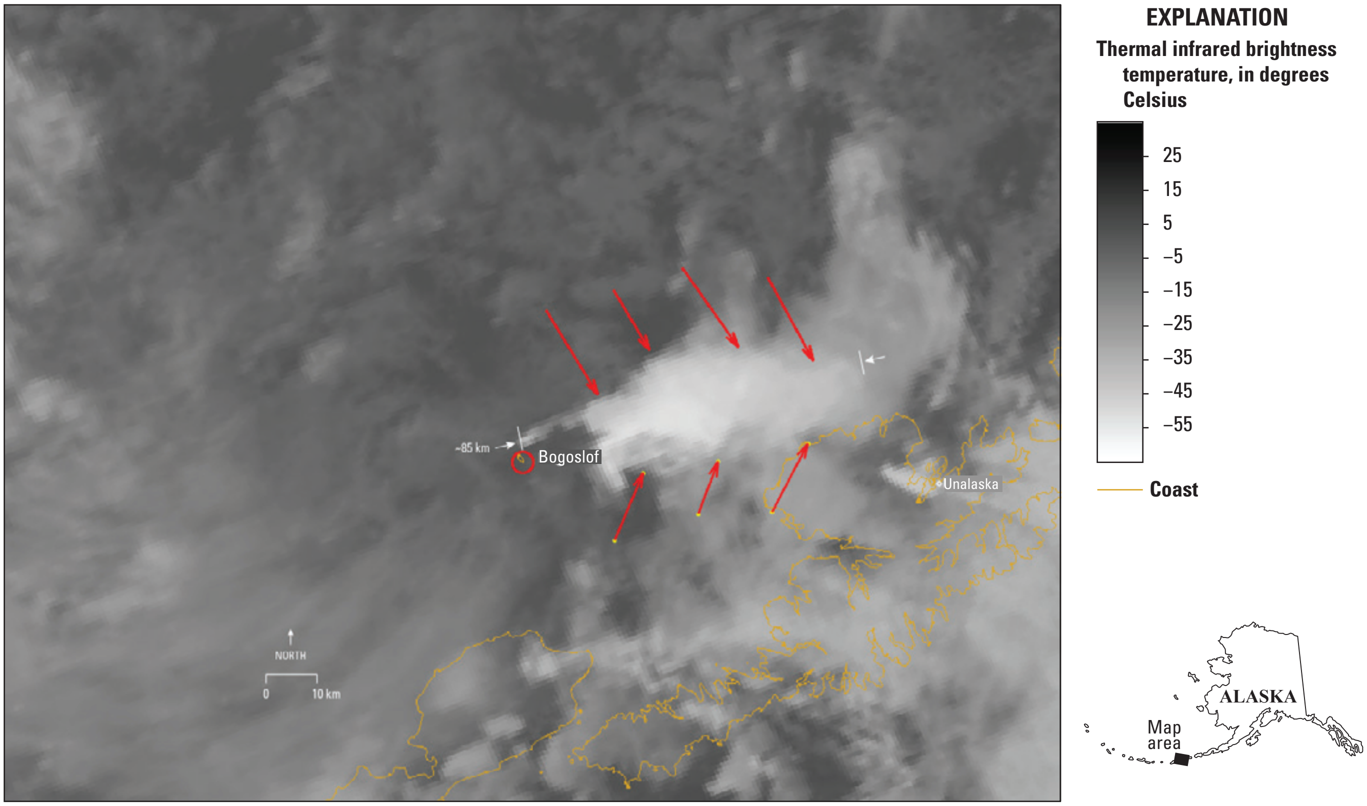



**Figure 30.** National Oceanic and Aviation Administration-19 Thermal Infrared image showing volcanic cloud (bordered by red arrows) erupted from Bogoslof Island at 00:50:26 UTC on December 27, 2016 (15:50 AKST December 26). Figure made by Dave Schneider, U.S. Geological Survey-Alaska Volcano Observatory.

any populated area. AVO lowered the Aviation Color Code to **ORANGE** and the Volcano Alert Level to **WATCH** at 19:32 UTC (10:32 AKST) January 1, 2017. Eruptive activity at Bogoslof volcano continued through August 2017, and it is described in Dixon and others (2017), Coombs and others (2018), a forthcoming special issue of the Bulletin of Volcanology, and other research journal articles.

Bogoslof Island is the largest of a cluster of small, low-lying islands that make up the emergent summit of a large submarine stratovolcano. The highest point above sea level prior to this 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. 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 of (behind) the main Aleutian volcanic front. Bogoslof volcano is within the U.S. Fish and Wildlife Service Aleutian Maritime National Wildlife Refuge and is habitat for marine mammals and seabirds.

At least eight historical eruptions have been documented at Bogoslof volcano (Waythomas and Cameron, 2018). The most recent prior to 2016 occurred from July 6 to 24, 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 new 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 2016–17, and 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

**SEISMIC TREMOR**

AVO seismologists noted seismic tremor at Okmok Caldera (herein called Okmok volcano to include associated volcanic features exterior to the caldera) in September 2016. This activity did not lead to significant unrest, and the Aviation Color Code and Volcano Alert Level remained **GREEN** and **NORMAL**, respectively. Tremor episodes began on September 19 and were frequently noted during the following week. Tremor episodes occurred at a rate of 5–10 per day and were detected on seismic stations within the caldera but not on those located outside the caldera. The locatable tremor episodes occurred in the east side of the caldera, and relative lag times suggested a source near Cone D. Although depths were not well constrained, they often seemed to be shallower than 5 km; however, occasional and more broadly occurring events seen across the network often had depths of greater than 25 km in the same region of the caldera (fig. 31).

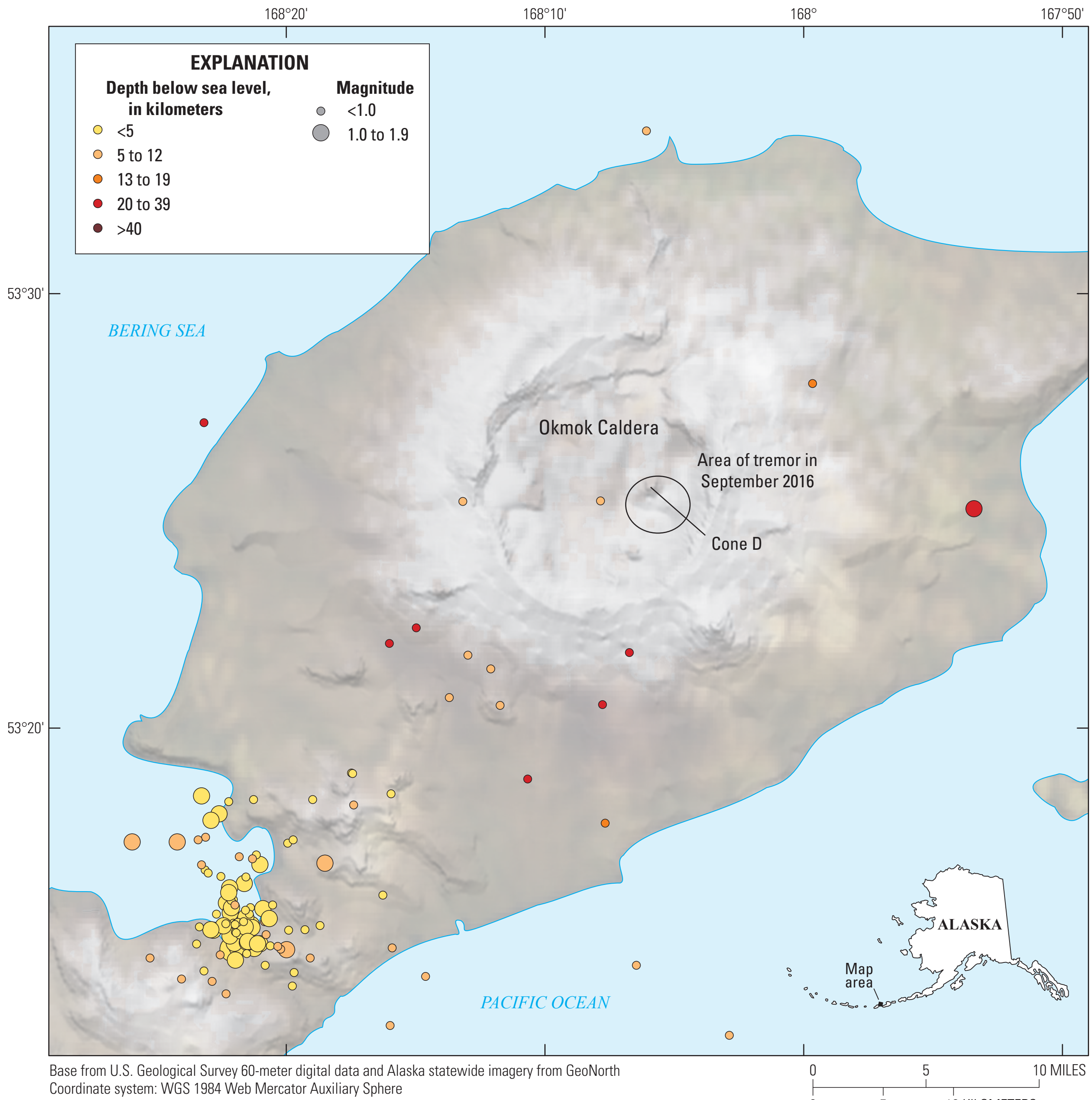



**Figure 31.** Epicentral map of northeast Umnak Island showing the 2016 seismicity at Okmok Caldera and the approximate location of the tremor (within the caldera on the east side).

Inflation coincident with the tremor was not initially noted with the GPS network, but re-evaluation found a westward motion on GPS sites OKCE and OKNC. This motion is not consistent with the typical inflation signal at Okmok volcano (Jeff Freymueller, University of Alaska Fairbanks Geophysical Institute, written commun., 2017). Seismic and infrasound alarms were crafted for the volcano to assist with monitoring, but no further activity ensued. Pulses of tremor were sporadically noted through October, and by early November the instances of tremor were no longer observed.

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. The volcano, built on a base of Tertiary volcanic rocks, consists of three rock series: (1) older flows and pyroclastic beds of a precaldera shield complex, (2) pyroclastic deposits of two major caldera-forming eruptions, and (3) a postcaldera 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 exceed 9,000 m (30,000 ft) ASL. 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 dramatic phreatomagmatic eruption over a 5-week period 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**

The past several years of activity at Mount Cleveland have been characterized by nearly continuous degassing, elevated surface temperatures, and short-lived ash-rich explosions that destroy small lava domes (Werner and others, 2017). Explosions typically do not yield ash clouds that exceed 4,500 m (15,000 ft) ASL. This behavior continued and included four explosions throughout 2016 (table 7). AVO observed intermittent elevated summit temperatures in satellite data and summit steaming in web-camera images throughout the year. Mount Cleveland is currently monitored with two seismic stations, local and regional infrasound stations, a web camera, and satellite remote sensing.

Mount Cleveland began 2016 at Aviation Color Code **YELLOW** and Volcano Alert Level **ADVISORY** after its August 7, 2015, explosion. A small lava dome emplaced after this explosion was still present at the beginning of 2016, and no changes to the dome were noted in the first few months of 2016 from satellite imagery. Minor steaming and weakly elevated surface temperatures were noted intermittently.

**Table 7.** Summary of activity and observations at Mount Cleveland, 2016.

[Data based on chronology compiled by Kristi Wallace, U.S. Geological Survey/Alaska Volcano Observatory (AVO); Alex Iezzi University of Alaska Fairbanks Geophysical Institute/AVO; and other AVO staff. All dates are listed in month, day, and year format]

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 01/11/16 | YELLOW/ADVISORY | | Moderate | | Local Event |
| 01/14/16 | YELLOW/ADVISORY | | | | Mini Swarm |
| 01/15/16 | YELLOW/ADVISORY | | | | Mini Swarm Decreased |
| 01/16/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/17/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/18/16 | YELLOW/ADVISORY | | Weak | | Few Local Events |
| 01/19/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 01/20/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/21/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/22/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/23/16 | YELLOW/ADVISORY | | Weak | | Few Local Events |
| 01/24/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 01/27/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/02/16 | YELLOW/ADVISORY | | | | Increase in Local Events |

**Table 7.**—Continued

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 02/03/16 | YELLOW/ADVISORY | | | | Decrease in Local Events |
| 02/05/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/11/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/13/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/14/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/21/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/22/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/23/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/26/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 02/29/16 | YELLOW/ADVISORY | | Weak | | |
| 03/04/16 | YELLOW/ADVISORY | | Weak | | |
| 03/05/16 | YELLOW/ADVISORY | | | No Change to Summit Crater; Minor Steam | |
| 03/07/16 | YELLOW/ADVISORY | | Weak | | |
| 03/08/16 | YELLOW/ADVISORY | | Weak | | |
| 03/09/16 | YELLOW/ADVISORY | | Weak | Minor Steam | |
| 03/10/16 | YELLOW/ADVISORY | | | | Local Event |
| 03/14/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/15/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/16/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/17/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/18/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/19/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/20/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 03/22/16 | YELLOW/ADVISORY | | Weak | | |
| 03/26/16 | YELLOW/ADVISORY | | | | Local Event |
| 03/28/16 | YELLOW/ADVISORY | | | | Local Event |
| 03/29/16 | YELLOW/ADVISORY | | Moderate | | |
| 04/03/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 04/04/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 04/07/16 | YELLOW/ADVISORY | | | | Local Event |
| 04/08/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 04/16/16 | ORANGE/WATCH | Explosion | | | Infrasound and Seismic Alarms Triggered; Larger than Previous Events |
| 04/18/16 | ORANGE/WATCH | | | New Tephra Deposits; Flowage Deposits; Steam Plume | |

**Table 7.**—Continued

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 04/22/16 | ORANGE/WATCH | | | Lava Dome Gone; 35 m Diameter Vent Surrounded by Small Tephra Cone | |
| 04/23/16 | ORANGE/WATCH | | | | Few Local Events |
| 04/29/16 | YELLOW/ADVISORY | Decrease in Activity | | | |
| 05/02/16 | YELLOW/ADVISORY | | | No Change to Summit | |
| 05/03/16 | YELLOW/ADVISORY | | | | Local Earthquake |
| 05/04/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 05/05/16 | YELLOW/ADVISORY | | | 30 m Diameter Lava Dome Centered in Crater | |
| 05/06/16 | ORANGE/WATCH | Explosion; 55% Amplitude of 4/16 Explosion | | | Infrasound and Seismic Alarms Triggered |
| 05/08/16 | ORANGE/WATCH | | | False-color Satellite Image Showing Ash Deposits and Debris Flows | Few Local Events |
| 05/09/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/10/16 | ORANGE/WATCH | Explosion; 30% Amplitude of 5/6 Explosion | | | Infrasound and Seismic Alarms Triggered |
| 05/11/16 | ORANGE/WATCH | | | Small Dome Removed; New Flowage Deposits | |
| 05/12/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/13/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/14/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/15/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/16/16 | ORANGE/WATCH | | | Landsat-8 Image Showing Robust Steam and High Temperatures; Shallow Vent in Crater | Few Local Events |
| 05/17/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/18/16 | ORANGE/WATCH | | | New 50 m Diameter Dome Emplaced | Tremor Episodes |
| 05/21/16 | ORANGE/WATCH | | | Dome Enlarged to 60 m Diameter | |
| 05/23/16 | ORANGE/WATCH | | | No Additional Dome Growth | Local Event |
| 05/24/16 | ORANGE/WATCH | | Unknown | | |
| 05/25/16 | ORANGE/WATCH | | Unknown | | |
| 05/27/16 | ORANGE/WATCH | | | | Local Event |

**Table 7.**—Continued

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 05/28/16 | ORANGE/WATCH | | | | Small Local Seismic Swarm |
| 05/29/16 | ORANGE/WATCH | | | | Few Local Events |
| 05/31/16 | ORANGE/WATCH | | | | Few Local Events |
| 06/01/16 | ORANGE/WATCH | | | | Few Local Events |
| 06/03/16 | YELLOW/ADVISORY | Decrease in Activity | Weak | | |
| 06/04/16 | YELLOW/ADVISORY | | Moderate | | |
| 06/05/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 06/06/16 | YELLOW/ADVISORY | | Weak | | Local Event |
| 06/07/16 | YELLOW/ADVISORY | | | | Local Event |
| 06/13/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 06/17/16 | YELLOW/ADVISORY | | Weak | 20 m Diameter Vent in 50 m Diameter Dome | |
| 06/19/16 | YELLOW/ADVISORY | | Weak | | |
| 06/20/16 | YELLOW/ADVISORY | | Weak | | |
| 06/22/16 | YELLOW/ADVISORY | | Weak | | |
| 06/24/16 | YELLOW/ADVISORY | | Weak | No Change in Dome | |
| 06/26/16 | YELLOW/ADVISORY | | Weak | | |
| 06/27/16 | YELLOW/ADVISORY | | Weak | | Few Local Events |
| 06/28/16 | YELLOW/ADVISORY | | Weak | | Few Local Events |
| 06/29/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 06/30/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 07/01/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 07/02/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 07/03/16 | YELLOW/ADVISORY | | Weak | | Few Local Events |
| 07/04/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 07/10/16 | YELLOW/ADVISORY | | Moderate | | |
| 07/12/16 | YELLOW/ADVISORY | | Moderate | | |
| 07/14/16 | YELLOW/ADVISORY | | Weak | | |
| 07/22/16 | YELLOW/ADVISORY | | Weak | | |
| 07/23/16 | YELLOW/ADVISORY | | Weak | | |
| 07/26/16 | YELLOW/ADVISORY | | Unknown | Incandescence Observed; Field Crew Overflight | |
| 07/27/16 | YELLOW/ADVISORY | | Weak | | |
| 08/01/16 | YELLOW/ADVISORY | | Weak | | |
| 08/04/16 | YELLOW/ADVISORY | | Unknown | Minor Steam | |
| 08/05/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 08/08/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 08/09/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |

**Table 7.**—Continued

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 08/11/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 08/14/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 08/15/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 08/19/16 | YELLOW/ADVISORY | | Unknown | Minor Steam | |
| 08/23/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 08/24/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 08/25/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 08/26/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 08/27/16 | YELLOW/ADVISORY | | Unknown | | Few Local Events |
| 08/28/16 | YELLOW/ADVISORY | | Unknown | | Few Local Events |
| 08/29/16 | YELLOW/ADVISORY | | Unknown | Minor Steam | Few Local Events |
| 09/06/16 | YELLOW/ADVISORY | | Weak | | |
| 09/12/16 | YELLOW/ADVISORY | | Unknown | | |
| 09/23/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 09/27/16 | YELLOW/ADVISORY | | Unknown | | Few Local Events |
| 09/28/16 | YELLOW/ADVISORY | | Weak | | |
| 09/30/16 | YELLOW/ADVISORY | | | | Local Event |
| 10/03/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/05/16 | YELLOW/ADVISORY | | | | Local Event |
| 10/11/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 10/17/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/18/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/19/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/20/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 10/21/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 10/22/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/23/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 10/24/16 | ORANGE/WATCH | Explosion | Weak | | Infrasound and Seismic Alarms Triggered |
| 10/25/16 | ORANGE/WATCH | | Weak | Minor Steam; Possible Ash | |
| 10/27/16 | ORANGE/WATCH | | | Dome Removed By Explosion; Deep Crater Remains | |
| 11/04/16 | YELLOW/ADVISORY | Decrease in Activity | | | |
| 11/05/16 | YELLOW/ADVISORY | | Weak | Minor Steam | |
| 11/08/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 11/16/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 11/21/16 | YELLOW/ADVISORY | | | Minor Steam; Possible Ash | Few Local Events |

**Table 7.**—Continued

| Date | Aviation Color Code and Volcano Alert Level | Activity | Elevated surface temperatures | Evidence and observations | Seismic network and infrasound detection or other alarm triggers |
|---|---|---|---|---|---|
| 11/22/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 11/23/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 11/24/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 11/25/16 | YELLOW/ADVISORY | | | | Local Event |
| 11/26/16 | YELLOW/ADVISORY | | | | Local Event |
| 11/27/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 11/28/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 12/02/16 | YELLOW/ADVISORY | | | | Local Event |
| 12/08/16 | YELLOW/ADVISORY | | Weak | | |
| 12/10/16 | YELLOW/ADVISORY | | Weak | | |
| 12/12/16 | YELLOW/ADVISORY | | | Minor Steam | Few Local Events |
| 12/13/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 12/14/16 | YELLOW/ADVISORY | | | Minor Steam | Local Event |
| 12/15/16 | YELLOW/ADVISORY | | | | Local Event |
| 12/16/16 | YELLOW/ADVISORY | | | | Few Local Events |
| 12/21/16 | YELLOW/ADVISORY | | | Minor Steam | |
| 12/23/16 | YELLOW/ADVISORY | | | | Few Local Events |

The first explosion of 2016 occurred April 16 at 18:58 UTC (10:58 AKDT). In response, AVO raised the Aviation Color Code and Volcanic Alert Level to **ORANGE** and **WATCH**, respectively. This explosion was first detected by local infrasound sensors at seismograph stations CLES and CLCO, 3.5km (2.1 mi) and 15 km (9 mi) from the summit, respectively, and was the 40th explosion recorded at Mount Cleveland by AVO since December 25, 2011. Similar to most explosions at Mount Cleveland, the explosion had an impulsive onset and short duration (fig. 32). However, this explosion slightly differed from previous explosions by having a larger amplitude that exceeded the measurement scale of the local infrasound sensor CLES and was over 200 pascals at the CLCO infrasound sensor, 15 km (9 mi) away. The infrasound signal lasted more than 10 minutes at CLES, suggesting additional ash venting after the initial eruption. Retrospective analysis of geophysical data shows possible discrete precursory infrasound and seismicity beginning about 4 hours before the explosion (figs. 32, 33). Finally, there was a very long-period seismic signal at the time of the explosion. This is the first precursory and coeruptive seismicity noted by AVO at Mount Cleveland and the only instance in 2016.

Vigorous steaming continued at the summit for about a week after the April 16 explosion. On April 18, satellite imagery showed that the upper northeast flanks of Mount Cleveland were covered with new tephra and ballistic blocks from the April 16 explosion. Subsequent satellite imagery also showed the lava dome was completely removed, and a 35-m-diameter vent, surrounded by a smaller tephra cone was visible. Because of no further eruptive activity, AVO lowered the Aviation Color Code and Volcanic Alert Level to **YELLOW** and **ADVISORY**, respectively, on April 29.

A new, 30-m-diameter lava dome appeared in satellite imagery on May 5. Soon after this satellite observation, the second explosion of 2016 occurred on 2:43 UTC May 6 (18:43 AKDT May 5). The explosion was detected both by local and remote infrasound sensors, local seismic stations, and ground-coupled airwaves on the seismic networks

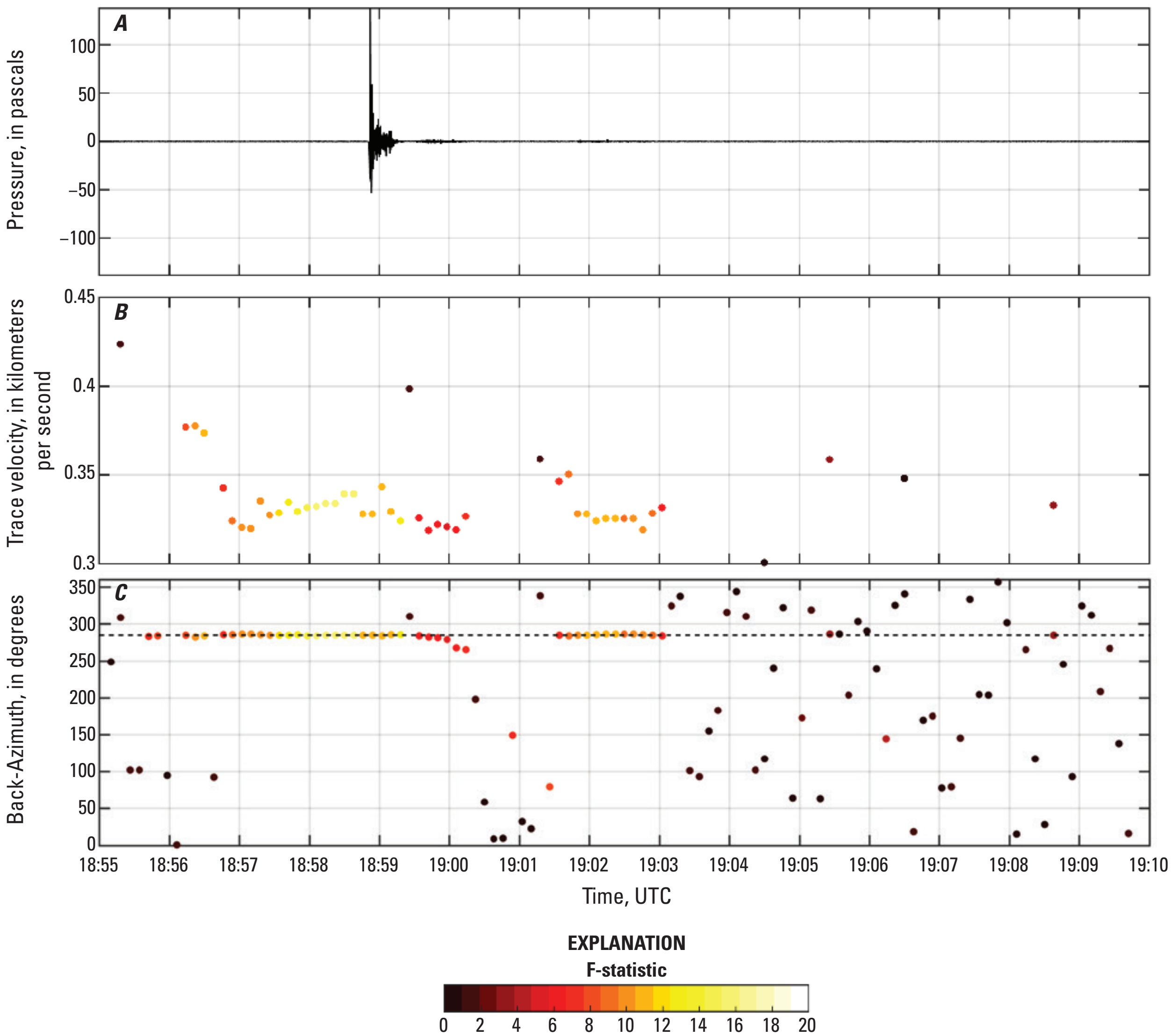



**Figure 32.** Graphs showing infrasound detection of the April 16, 2016, explosion of Mount Cleveland recorded by the CLCO infrasound sensor. *A*, A pressure plot, in pascals, showing when the explosion occurred. *B*, Velocity of the signal between the volcano and sensor, in kilometers per second. *C*, Azimuth of the signal with respect to the station. Colors of dots on *A* and *B* denote F-statistic, which is an automated way of detecting explosion signals above the noise. This explosion had some precursory infrasound and seismicity. Image by David Fee, University of Alaska Fairbanks Geophysical Institute and Alaska Volcano Observatory.

of nearby volcanoes. This explosion was about half the seismic amplitude of the April 16 event. Unlike the previous explosion, no obvious precursory seismicity was observed. AVO upgraded the Aviation Color Code and Volcano Alert Level to **ORANGE** and **WATCH** respectively the same day in response to this eruption. A few days later, on May 10, another small explosion (three times smaller in infrasound amplitude than the previous explosion) occurred at 15:32 UTC (07:32 AKDT). The infrasound signal showed multiple compressions, likely attributed to slow destruction of the dome. Satellite imagery on May 11 confirmed that the early May dome was completely removed, leaving behind a shallow vent. New flowage deposits extending in several directions from the summit crater were also noted. A Landsat-8 image from May 15 shows robust steaming and high temperatures in the summit crater (fig. 34).

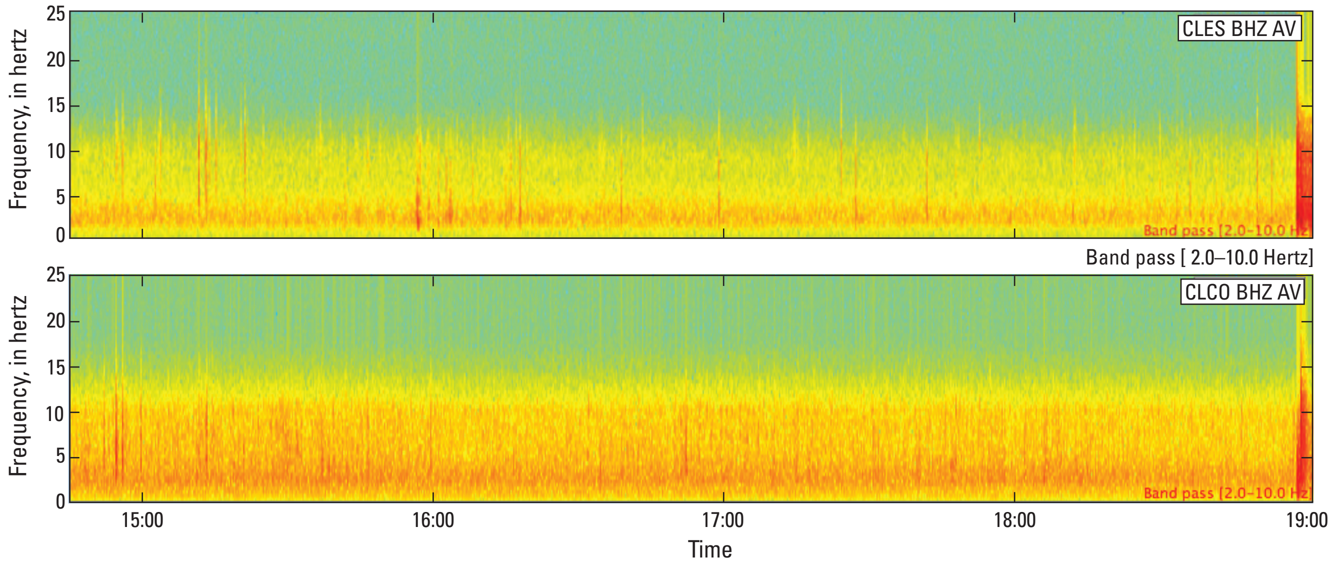



**Figure 33.** Spectrogram of seismic data, showing a series of small earthquakes recorded at CLES about 4 hours prior to the April 16, 2016, explosion of Mount Cleveland. This was the first precursory seismicity noted for any explosion at Mount Cleveland, and the only precursory activity for 2016. Data were band pass filtered between 2–10 hertz; however, earthquake energy reached as much as 20–25 hertz on CLES. Image by Aaron Wech, U.S. Geological Survey and Alaska Volcano Observatory.

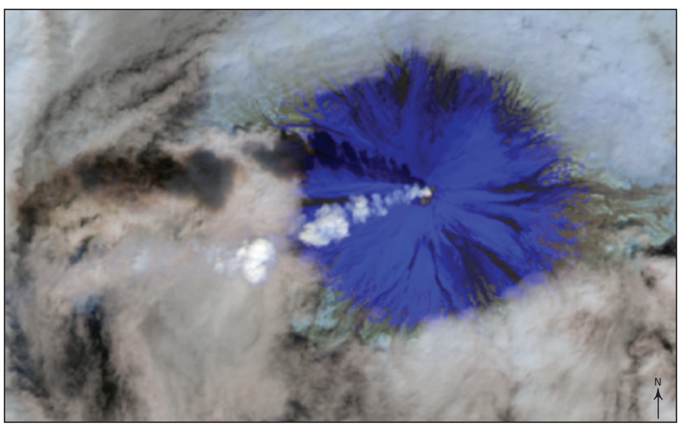



**Figure 34.** Satellite image of Landsat-8 data from May 15, 22:17 UTC showing robust steaming and high temperatures in the summit crater (satellite channels measuring shortwave infrared [SWIR]), which indicated continued unrest. Red=SWIR2, blue= SWIR1 and green = near infrared. High temperature features are visible in SWIR2 as red pixels. Robust steaming extends to the west and casts a shadow on the lower meteorological cloud deck. Bottom width of image is about 7 miles in length. Image by Dave Schneider, U.S. Geological Survey and Alaska Volcano Observatory.

Satellite views on May 18 showed a new, low-relief 50-m- (164-ft-) diameter lava dome centered in the summit crater. By May 21, the dome had grown to 60 m (197 ft) in diameter. Satellite images show recent eruptive deposits and the summit crater lava dome emplaced in mid-May (figs. 35, 36). Elevated surface temperatures continued after the explosion.

At 22:05 UTC May 28 (14:05 AKDT), a small local earthquake swarm began and continued for almost 6 hours but did not culminate in an explosion. With no major activity observed, the Aviation Color Code and Volcano Alert Level were downgraded from **ORANGE** and **WATCH** to **YELLOW** and **ADVISORY**, respectively, on June 3. Elevated surface temperatures and minor steaming continued intermittently, and a 20-m- (66-ft-) diameter vent formed in the center of the summit dome between June 8 and June 17.

An AVO field crew visited Mount Cleveland in late July to conduct network maintenance and collect gas samples of the plume. During a gas flight on July 26, a small dome, 46 m (151 ft) in diameter, with a crater in the center was observed (fig. 37). Forward looking infrared (FLIR) thermal camera images estimate the temperatures in the dome crater exceeded 600 °C, and incandescence was observed in the floor of the dome crater (fig. 38).

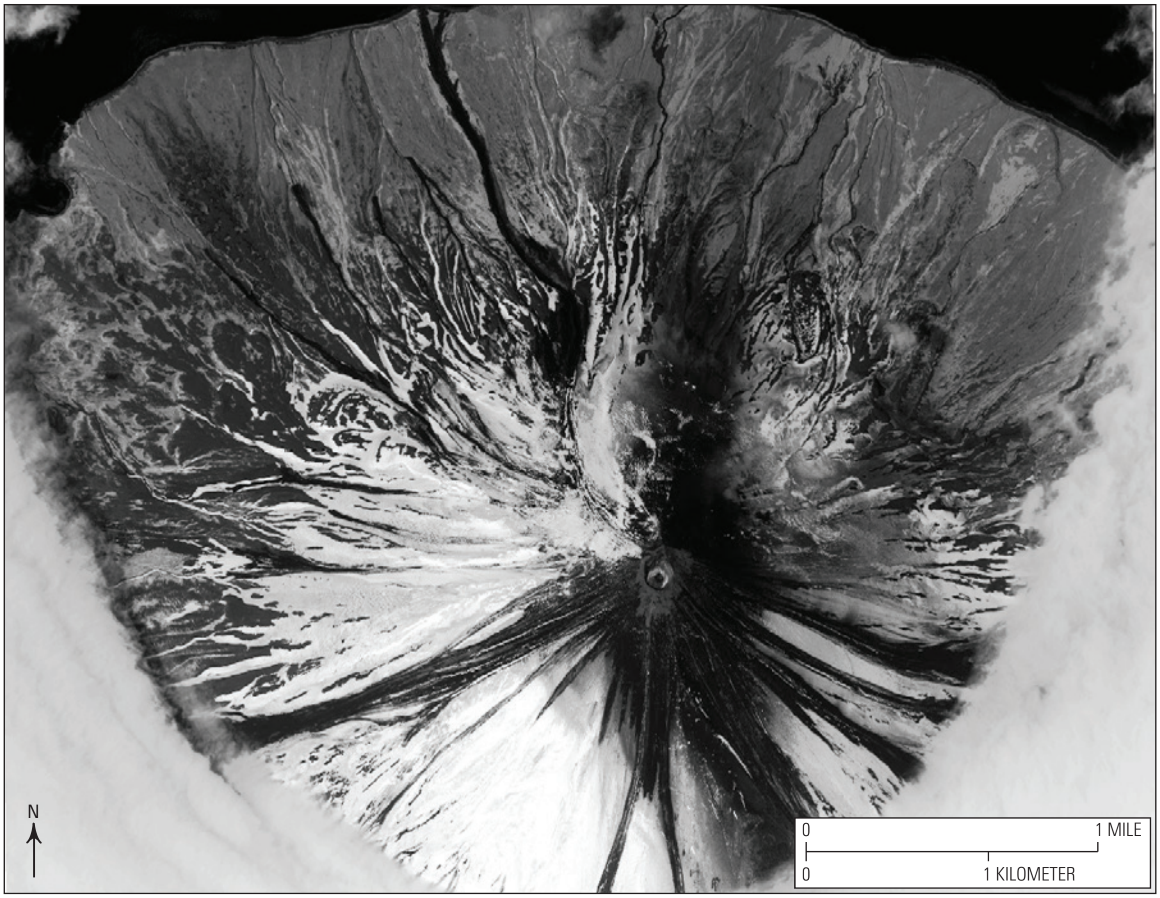



Image data copyright 2016 Digital Globe, NextView License

**Figure 35.** WorldView-1 satellite image from May 25, 2016, showing the recent eruptive deposits on Mount Cleveland's flanks and a lava dome within the summit crater. Image by Rick Wessels, U.S. Geological Survey and Alaska Volcano Observatory.

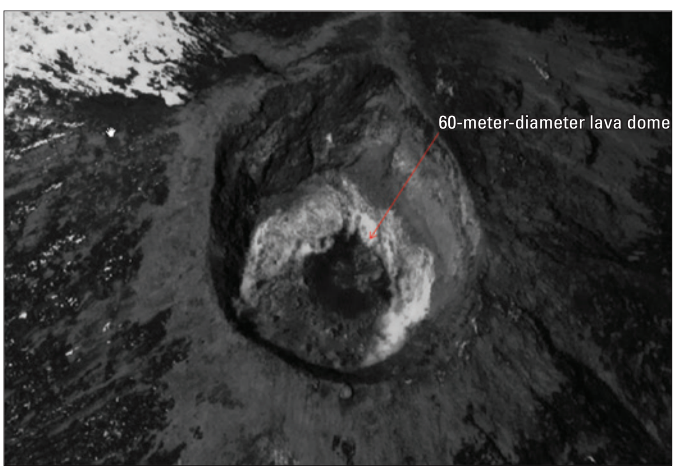



**Figure 36.** WorldView-1 satellite image from May 25, 2016, showing the mid-May lava dome within Mount Cleveland's summit crater. In this image, the dome is about 60 meters (about 200 feet) in diameter. Image by Rick Wessels, U.S. Geological Survey and Alaska Volcano Observatory.

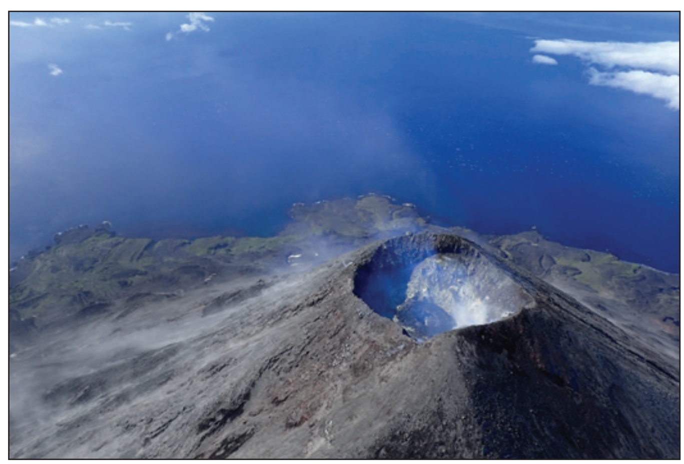


**Figure 37.** Photograph of Mount Cleveland from an Alaska Volcano Observatory overflight on July 26. A small dome with a crater in the center was observed in the center of the summit crater. Image by Cindy Werner, U.S. Geological Survey.

The final explosion of 2016 occurred at 21:10 UTC October 25 (13:10 AKDT). This explosion was detected by the local infrasound array and seismometers and was audible as far as Nikolski, Alaska, 74 km (44 mi) northeast of the volcano. AVO raised the Aviation Color Code and Volcano Alert Level to **ORANGE** and **WATCH,** respectively. Similar to previous explosions, most of the existing dome was removed, leaving a deep crater in its place. On November 4, the Aviation Color Code and Volcano Alert Level was lowered to **YELLOW** and **ADVISORY**, respectively, where it remained for the rest of the year despite intermittent observations of minor steaming and weakly elevated surface temperatures in the final two months of the year.

Mount Cleveland forms the western 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 and 1,500 km (940 mi) southwest of Anchorage. Short-lived ash explosions, lava fountains, lava flows, and pyroclastic avalanches down the flanks of the volcano have characterized historical eruptions. In February 2001, after 6 years of quiescence, three explosive events occurred at Mount Cleveland that produced ash clouds as high as 12 km (39,000 ft) ASL (Dean and others, 2004), a rubbly lava flow, and a hot avalanche that reached the sea. Intermittent explosive eruptions have occurred every year since 2001 with exceptional explosive activity in 2011–12.

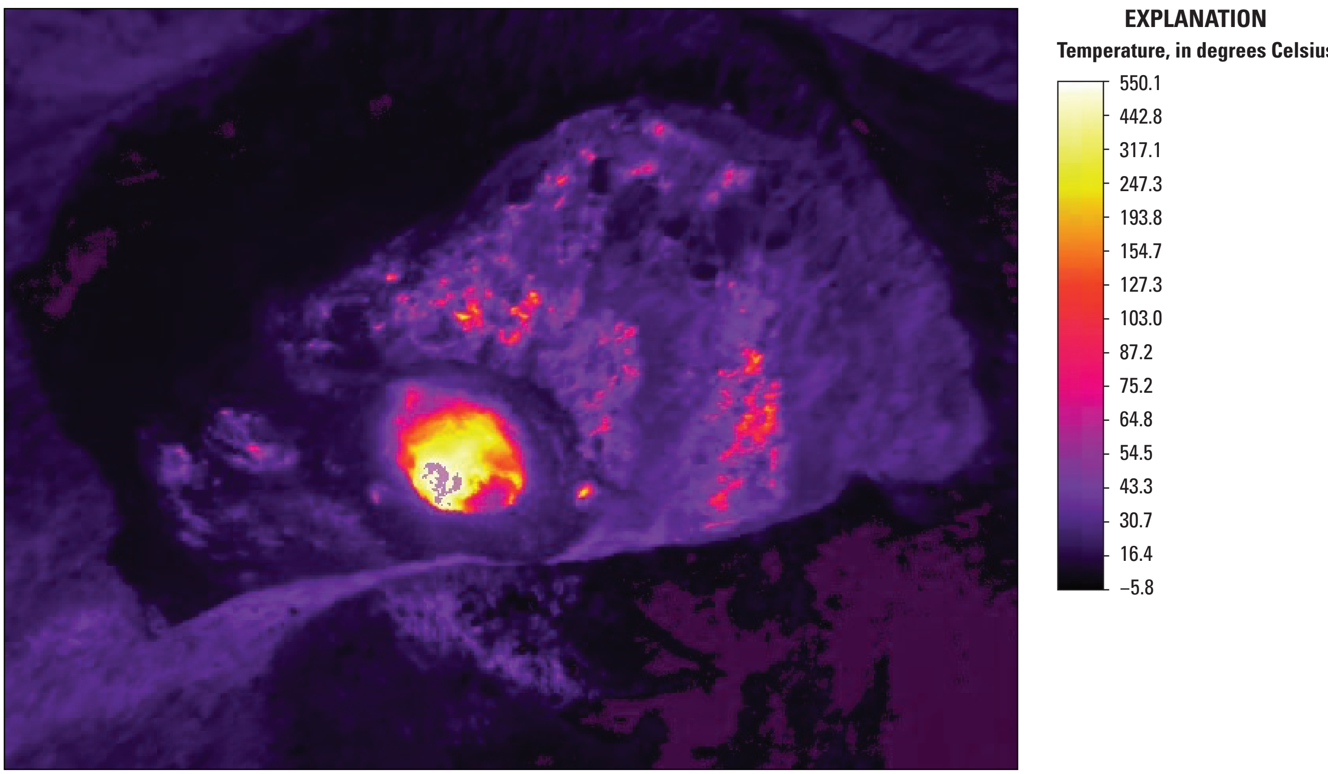



**Figure 38.** Forward looking infrared (FLIR) image of Mount Cleveland from an Alaska Volcano Observatory (AVO) overflight on July 26. A small dome with a crater in the center was observed in the center of the summit crater. On the basis of estimates of the summit crater rim diameter (Rick Wessels, U.S. Geological Survey [USGS], written commun., 2016), the diameter of the dome is about 46 meters (m) and the dome crater diameter is about 20 m. The FLIR image indicated temperatures in excess of 600 °C in the dome crater, and incandescence was observed in the floor of the dome crater. Image by John Lyons, USGS-AVO.

## Korovin Volcano


GVP# 311161
52.3793° N., 174.1548° W.
1,533 m (5,030 ft)

Andreanof Islands, Aleutian Islands

**SEISMIC TREMOR; FUMAROLIC ACTIVITY**

AVO received a report of steam coming from Korovin Volcano on February 2, 2016, from an Atka, Alaska, resident (fig. 39). A check on seismic data revealed no evidence of any increased activity, and the steaming source was from an area near the volcano with known fumarolic vents that often steam (Motyka and others, 1993). Thus, the February report is considered part of typical Korovin Volcano activity. From April through August, multiple tremor bursts were noted in the seismograph data (fig. 40), and April and May recorded more tremor bursts than the later months. AVO kept the Aviation Color Code and Volcano Alert Level **GREEN** and **NORMAL**, respectively, for Korovin Volcano but maintained increased awareness and data checks during periods of increased tremor.

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

**Figure 39.** Photograph of Korovin Volcano steaming on February 2, 2016, taken from Atka, Alaska. Photograph by Lucinda Nevzoroff, used with permission.

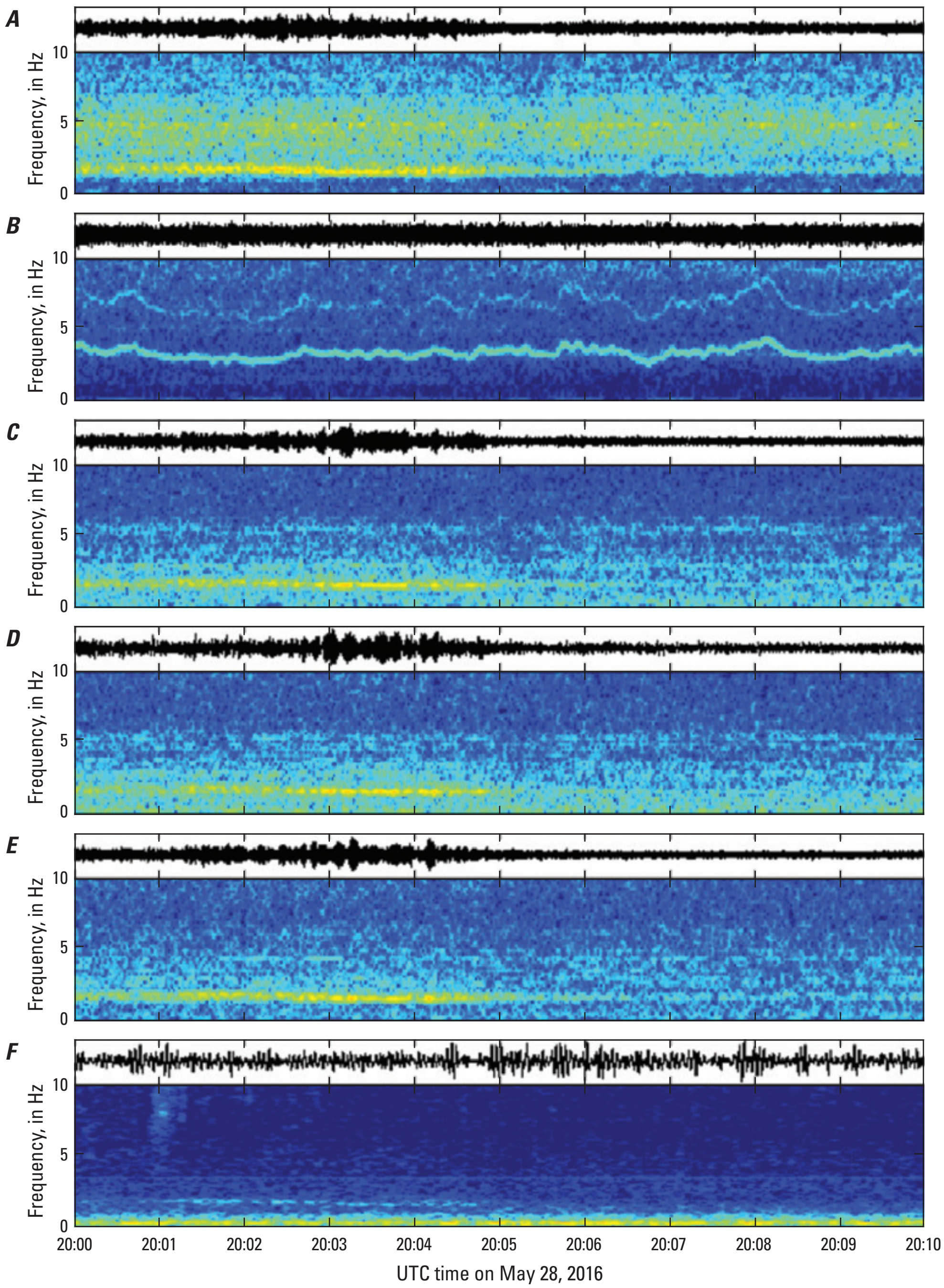



**Figure 40.** Spectrograms of the Korovin Volcano KONE (*A*), KOWE (*B*), KOKL (*C*), KOFP (*D*), KOSE (*E*), and ATKA (*F*) seismograph stations showing a typical tremor burst at the volcano.

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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.

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

**Holocene** geologic epoch that extends 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 groundwater as it comes in contact with hot volcanic rock or magma leading to a steam-driven explosion.

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

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

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

**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.

**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.

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

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

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

| Alert Levels | |
|---|---|
| **NORMAL** | Volcano is in typical background, noneruptive state.<br>**Or, after a change from a higher level:**<br>Volcanic activity has ceased, and volcano reverted to its noneruptive state. |
| **ADVISORY** | Volcano is exhibiting signs of elevated unrest above known background level.<br>**Or, after a change from a higher level:**<br>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.<br>**Or:**<br>Eruption is underway but poses limited hazards. |
| **WARNING** | Highly hazardous eruption is imminent, underway, or suspected. |

| Level of Concern Codes for Aviation | |
|---|---|
| **GREEN** | Volcano is in typical background, noneruptive state.<br>**Or, after a change from a higher level:**<br>Volcanic activity has ceased, and volcano reverted to its noneruptive state. |
| **YELLOW** | Volcano is exhibiting signs of elevated unrest above known background level.<br>**Or, after a change from a higher level:**<br>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.<br>**Or:**<br>Eruption is underway but poses limited hazards. |
| **RED** | Eruption is imminent with significant emission of volcanic ash into the atmosphere likely.<br>**Or:**<br>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, 1992–2016.

**Table 2.1.** Compilation of volcanoes included in Alaska Volcano Observatory Annual Summaries by year 1992–2016

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

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

**Table 2.1.**—Continued

| Volcanoes mentioned | |
|---|---|
| **Alaska** | **Russian** |
| Veniaminof | Karymsky |
| Pavlof | |
| Shishaldin | |
| Vsevidof | |
| **2000** | |
| Wrangell | Sheveluch |
| Katmai Group (Snowy) | Klyuchevskoy |
| Chiginagak | Bezymianny |
| Shishaldin | Karymsky |
| | Mutnovsky |
| **2001** | |
| Katmai Group (Snowy and Kukak) | Sheveluch |
| Pavlof | Klyuchevskoy |
| Frosty | Bezymianny |
| Shishaldin | Karymsky |
| Makushin | Avachinsky |
| Okmok | |
| Cleveland | |
| Great Sitkin | |
| **2002** | |
| Wrangell | Sheveluch |
| Katmai Group (Martin and Mageik) | Klyuchevskoy |
| Veniaminof | Bezymianny |
| Mount Hague (Emmons Lake Caldera) | Karymsky |
| Shishaldin | |
| Great Sitkin | |
| **2003** | |
| Wrangell | Sheveluch |
| Redoubt | Klyuchevskoy |
| Iliamna | Bezymianny |
| Augustine | Karymsky |
| Katmai Group (Mageik) | Alaid (Kurile Islands) |
| Veniaminof | Chikurachki (Kurile Islands) |
| Pavlof | |
| Mount Hague (Emmons Lake Caldera) | |
| Shishaldin | |
| Akutan | |
| **2004** | |
| Crillon (non-volcanic peak) | Sheveluch |

| Volcanoes mentioned | |
|---|---|
| **Alaska** | **Russian** |
| Spurr | Klyuchevskoy |
| Katmai Group (Martin) | Bezymianny |
| Veniaminof | Karymsky |
| Shishaldin | Chirinkotan (Kurile Islands) |
| Westdahl | |
| **2005** | |
| Spurr | Sheveluch |
| Iliamna | Klyuchevskoy |
| Augustine | Bezymianny |
| Katmai Group (Martin) | Karymsky |
| Chiginagak | Avachinsky |
| Aniakchak | Mutnovsky |
| Veniaminof | Ebeko (Kurile Islands) |
| Pavlof/Hague | Chikurachki (Kurile Islands) |
| Shishaldin | |
| Cleveland | |
| Korovin | |
| Kasatochi | |
| Tanaga | |
| **2006** | |
| Klawasi Mud | Sheveluch |
| Spurr | Klyuchevskoy |
| Augustine | Bezymianny |
| Fourpeaked | Karymsky |
| Katmai Group (Martin) | Ebeko (Kurile Islands) |
| Veniaminof | Severgin |
| Cleveland | Berga |
| Korovin | |
| Kasatochi | |
| **2007** | |
| Redoubt | Sheveluch |
| Augustine | Klyuchevskoy |
| Fourpeaked | Bezymianny |
| Veniaminof | Karymsky |
| Pavlof | Gorely and Mutnovsky |
| Akutan | Chikurachki (Kurile Islands) |
| Cleveland | Berga |
| Korovin | |
| **2008** | |
| Redoubt | Sheveluch |
| Aniakchak | Klyuchevskoy |
| Veniaminof | Bezymianny |

**Table 2.1.**—Continued

| Volcanoes mentioned | |
|---|---|
| **Alaska** | **Russian** |
| Shishaldin | Karymsky |
| Okmok | Koryaksky |
| Cleveland | Gorely and Mutnovsky |
| Kasatochi | Chikurachki (Kurile Islands) |
| | Tyatya |
| **2009** | |
| Sanford | Sheveluch |
| Redoubt | Klyuchevskoy |
| Fourpeaked | Bezymianny |
| Aniakchak | Kizimen |
| Veniaminof | Karymsky |
| Shishaldin Volcano | Koryaksky |
| Okmok | Gorely |
| Cleveland | Ebeko |
| | Sarychev |
| | Raikoke |
| **2010** | |
| Wrangell | Sheveluch |
| Sanford | Klyuchevskoy |
| Redoubt | Bezymianny |
| Fourpeaked | Kizimen |
| Katmai Group (Martin) | Karymsky |
| Becharof Lake | Gorely |
| Aniakchak | Ekarma |
| Veniaminof | |
| Westdahl | |
| Makushin | |
| Cleveland | |
| Kasatochi | |
| **2011** | |
| Wrangell | |
| Sanford | |
| Redoubt | |
| Fourpeaked | |
| Aniakchak | |
| Veniaminof | |
| Makushin | |
| Westdahl | |
| Cleveland | |
| Kasatochi | |
| **2012** | |
| Wrangell | |
| Spurr | |
| Redoubt | |
| Iliamna | |
| Augustine | |
| Fourpeaked | |
| Katmai Group (Martin) | |
| Aniakchak | |
| Cleveland | |
| Kanaga | |
| Little Sitkin | |
| **2013** | |
| Wrangell | |
| Redoubt | |
| 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 | |

**Table 2.1.**—Continued

| Volcanoes mentioned | |
|---|---|
| **Alaska** | **Russian** |
| Recheshnoi | |
| Cleveland | |
| Korovin | |
| Kanaga | |
| Semisopochnoi | |
| **2015** | |
| Spurr | |
| Redoubt | |
| Augustine | |
| Iliamna | |
| Katmai Group (Katmai, Novarupta) | |
| Ugashik-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 | |

**Table 2.2.** Compilation by volcano for particular years included in Alaska Volcano Observatory Annual Summaries, 1992–2016.

[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 |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| Klawasi Group (mud volcanoes) | | |
| Shrub Mud | 1997 | Eruption; energetic ejection of saline mud and CO2 |
| | 1998 | Eruption continues; ejection of saline mud and CO2 |
| | 1999 | Eruption continues; ejection of saline mud and CO2 |
| 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 swarms |
| 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 |
| Iliamna | 1992 | PIREP of large steam plume, media frenzy |
| | 1994 | Vigorous steam plume, avalanche |
| | 1996 | Intense seismicity related to magmatic intrusion |
| | 1997 | Anomalous seismic swarm; avalanche |
| | 1999 | Avalanche |
| | 2003 | Avalanche |
| | 2005 | Rock avalanche |
| | 2012 | Fumarolic plume, seismic swarms, avalanches |
| | 2013 | Avalanches |
| | 2014 | Avalanches |
| | 2015 | Large tectonic earthquake |
| | 2016 | Fumarolic activity; landslide |
| 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 |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| Augustine—Continued | 2015 | Steam plume, rockfalls |
| | 2016 | Seismic swarm |
| 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/Katmai | 1996 | Anomalous seismicity |
| Martin, Mageik, Snowy, and Kukak | 1997 | PIREPS of ash and steam plumes |
| Snowy | 2000 | Steaming hole in glacier |
| Snowy/Kukak | 2001 | Steaming hole in glacier |
| Martin/Mageik | 2002 | Steam plume |
| Mageik | 2003 | Steaming, large cloud of resuspended ash |
| Martin | 2004 | Large steam plume |
| | 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/Novarupta | 2015 | Resuspended 1912 ash |
| | 2016 | Resuspension of 1912 ash; deployment of particulate monitors |
| 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 |
| | 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 |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| Aniakchak—Continued | 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 |
| 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 |
| | 1998 | Minor eruptive activity; steam/ash |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| Shishaldin—Continued | 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 |
| 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 |
| 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 |
| Bogoslof | 1992 | Dome extrusion, ash and steam emissions |
| | 2016 | 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 |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| Recheshnoi | 2014 | Increased seismicity |
| | 2015 | Continuation of increased fumarolic activity |
| Vsevidof | 1999 | Sighting of ash after regional earthquake |
| Cleveland | 1994 | Possible steam/ash emission |
| | 1997 | Minor eruption, steam/ash |
| | 2001 | Eruption; gas/ash, lava/debris flows |
| | 2005 | Intermittent explosions |
| | 2006 | Intermittent explosions |
| | 2007 | Intermittent explosions, small ash clouds, ballistics |
| | 2008 | Intermittent explosions, small ash clouds |
| | 2009 | Intermittent explosions, small ash clouds, thermal anomalies |
| | 2010 | Explosions, small ash clouds, vapor plumes, thermal anomalies |
| | 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 |
| 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 |

**Table 2.2.**—Continued

| Volcano | Year Mentioned | Type of Activity |
|---|---|---|
| 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 |
| Tanaga | 2005 | Anomalous seismicity, including a period of tremor |
| Semisopochnoi | 2014 | Earthquake swarm; likely magmatic intrusion |
| | 2015 | Earthquake swarm |

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